NAPAC'22 Program

07-Aug-22 08:00 – 12:00: SUXF — Project Management

SUXF1 Project Management and Accelerator Development (*S. Biedron*)

07-Aug-22 12:30 – 16:30: SUZF — Systems Engineering

SUZF1 Introduction to Systems Engineering Concepts (*S. Biedron*)

08-Aug-22 07:55 – 10:00: MOODE — Opening Plenary Session

MOODE1 Applications of Particle Accelerators (*M. Uesaka*)
MOODE2 Expanding the Boundaries of X-ray Lasers: LCLS Upgrades and Future (*G.R. Hays*)
MOODE3 Building a Global, Collaborative Accelerator Economy: Summary of the IPAC 2022 Industrial Session (*R. Geometrante*)
MOODE4 PW-Class Lasers for Accelerators - Overview and an Industry Perspective (*O.J. Chalus*)

08-Aug-22 10:30 – 12:30: MOYD — Colliders

MOYD1 Progress on the Electron-Ion Collider (*F.J. Willeke*)
MOYD2 Options for Future Colliders on Fermilab Site (*P.C. Bhat*)
MOYD3 EIC Transverse Emittance Growth due to Crab Cavity RF Noise: Estimates and Mitigation (*T. Mastoridis*)
MOYD4 Model Parameters Determination in EIC Strong-Strong Simulation (*D. Xu*)
MOYD5 Tolerances of Crab Dispersion at the Interaction Point in the Hadron Storage Ring of the Electron-Ion Collider (*Y. Luo*)
MOYD6 Chromatic Correction of the EIC Electron Ring Lattice (*Y. Cai*)

08-Aug-22 10:30 – 12:30: MOYE — Accelerator Technology

MOYE1 Role of People, Materials, and Manufacturing in the Future of Vacuum Electronics (*D. Gamzina*)
MOYE2 LCLS-II HE vCM Test Results: Newly Developed N-Doping Treatment and Plasma Processing (*B. Giaccone*)
MOYE3 Conduction Cooled Superconducting RF Cavity With Field Emission Cathode (*Y. Ji*)
MOYE4 Diagnoses and Repair of a Crack in the Drift Tube LINAC Accelerating Structure at LANSCE (*W.C. Barkley*)
MOYE5 In Situ Plasma Processing of Superconducting Cavities at JLab (*T. Powers*)
MOYE6 Spin-Polarized Electron Photoemission and Detection Studies (*A.C. Rodriguez Alicea*)

08-Aug-22 14:00 – 16:00: MOZD — Photon Sources and Electron Accelerators

MOZD1 Commissioning of LCLS-II (*Y. Ding*)
MOZD2 Single-Pass High-Efficiency THz FEL (*A.C. Fisher*)
MOZD3 Development of Two-Color Sub-Femtosecond Pump/Probe Techniques With X-Ray Free-Electron Lasers (*Z.H. Guo*)
MOZD4 Uncertainty Quantification of Beam Parameters in an LIA Inferred from Bayesian Analysis of Solenoid Scans (*M.A. Jaworski*)
MOZD5 An ERL-Based Compact X-Ray FEL (*F. Lin*)
MOZD6 Accelerator Physics Lessons From CBETA, the First Multi-Turn SRF ERL (*K.E. Deitrick*)

08-Aug-22 14:00 – 16:00: MOZE — Advanced Acceleration

MOZE1 Demonstration of High-Gradient in a Cryo-Cooled X-Band Structure (*M.H. Nasr*)
MOZE2 Results of Awake Run 1 and Plans for Run 2 Towards HEP Applications (*M. Bergamaschi*)
MOZE3 An X-band Short-Pulse Ultra-High Gradient Photoinjector (*G. Chen*)
MOZE4 Ceramic Enhanced Accelerator Structure Low Power Test and Designs of High Power and Beam Tests (*H. Xu*)
MOZE5 Simulation and Experimental Results of Dielectric Disk Accelerating Structures (*S. Weatherly*)
MOZE6 Fulfilling the Mission of Brookhaven ATF as a DOE Flagship User Facility in Accelerator Stewardship (*M.A. Palmer*)

08-Aug-22 16:30 – 18:00: MOPA — Poster Session

MOPA01 Realistic CAD-Based Geometries for Arbitrary Magnets With Beam Delivery Simulation (BDSIM) (*E. Ramoisiaux*)
MOPA02 Proton Therapy Beamline Activation of the IBA Proteus One Using BDSIM and FISPACT-II (*E. Ramoisiaux*)
MOPA03 Flexible Features of the Compact Storage Ring in the cSTART Project at Karlsruhe Institute of Technology (*A.I. Papash*)
MOPA04 Design and Development of Deflector Magnet System for High Power Electron Beam Accelerator (*S.H. Das*)
MOPA05 Status on OPAL and Future Directions Towards the Exascale Area (*A. Adelmann*)
MOPA06 A Quantum Mechanical Model of Qubits in Crystalline Beams (*A. Adelmann*)
MOPA07 Fast, Efficient and Flexible Particle Accelerator Optimisation Using Densely Connected and Invertible Neural Networks (*A. Adelmann*)
MOPA08 Methods for Beamline Optimization for High Intensity Muon Beams at PSI (*E.V. Valetov*)
MOPA09 Design of a 4D Emittance Diagnostic for Low-Energy Ion Beams (*T.R. Curtin*)
MOPA10 HPC Modeling of a High-Gradient C-Band Linac for Hard X-Ray Free-Electron Lasers (*T.B. Bolin*)
MOPA11 Active Noise Control Algorithm for Multiple Cavities (*M.I. Caskey*)
MOPA12 Commissioning of HOM Detectors in the First Cryomodule of the LCLS-II Linac (*J.A. Diaz Cruz*)
MOPA13 Design of a Surrogate Model for MUED at BNL Using VSim and HPC (*S.I. Sosa Guitron*)
MOPA14 A Wide Dynamic-Range Halo Monitor for 8-GeV Proton Beams at FNAL (*R. Ainsworth*)
MOPA15 Synchronous High-Frequency Distributed Readout for Edge Processing at the Fermilab Main Injector and Recycler (*J.R. Berlioz*)
MOPA16 Options for Future Colliders on Fermilab Site (*P.C. Bhat*)
MOPA17 Symplectic Particle Tracking in a Thick Nonlinear McMillan Lens for the Fermilab Integrable Optics Test Accelerator (IOTA) (*B.L. Cathey*)
MOPA18 Residual Dose and Environmental Monitoring for the Fermilab Main Injector Tunnel Using the Data Acquisition Logging Engine (Dale) (*N. Chelidze*)
MOPA19 The Effect of the Main Injector Ramp on the Recycler (*N. Chelidze*)
MOPA20 A Study on High Pressure Rinsing of 650 MHz Niobium Superconducting RF Cavity (*V. Chouhan*)
MOPA21 Effect of Electropolishing on Nitrogen Doped and Undoped Niobium Surfaces (*V. Chouhan*)
MOPA22 Study on Electropolishing Conditions for High and Low Beta 650 MHz Niobium SRF Cavity (*V. Chouhan*)
MOPA23 Tests of the Extended Range SRF Cavity Tuners for the LCLS-II HE Project (*C. Contreras-Martinez*)
MOPA24 LCLS-II and HE Cryomodule Microphonics at CMTF at Fermilab (*C. Contreras-Martinez*)
MOPA25 Lorentz Force Detuning Compensation With a Double Lever Tuner on a dressed ILC/1.3 GHz Cavity at Room Temperature (*C. Contreras-Martinez*)
MOPA26 Study of Different Material Piezoelectric Stroke Displacement With Respect to Temperature Using SRF Cavity (*C. Contreras-Martinez*)
MOPA27 Test of the Low Beta 650 MHz SRF Cavity Tuner for PIP-II at 2 K (*C. Contreras-Martinez*)
MOPA28 Semantic Regression for Disentangling Radiative Beam Losses in the Fermilab Main Injector and Recycler (*K.J. Hazelwood*)
MOPA29 Second Generation Fermilab Main Injector 8 GeV Beamline Collimation Preliminary Design (*K.J. Hazelwood*)
MOPA30 LCLS-II BCS Average Current Monitor (*N.M. Ludlow*)
MOPA31 Plasma Photocathode Based on Ionization of Neutral Gas Triggered by the Superposition of Laser and Plasma Wakefields (*N. Majernik*)
MOPA32 Transverse Beam Dynamics With Synergia III (*O. Mohsen*)
MOPA33 Waker Experiments at Fermilab Recycler Ring (*O. Mohsen*)
MOPA34 Noise in Intense Electron Bunches (*S. Nagaitsev*)
MOPA35 Studies of Injection Painting From the Fermilab SRF Linac in PIP-III Upgrade Scenarios (*D.V. Neuffer*)
MOPA36 Optimization of Superconducting Linac for Proton Improvement Plan-II (PIP-II) (*A. Pathak*)
MOPA38 Accelerated Lifetime Test of the SRF Cavity Tuner/Dressed Cavity System for the LCLS II He Project (*Y.M. Pischalnikov*)
MOPA39 2.6-GHz SRF Cavity Tuner for DarkPhoton Experiment (*Y.M. Pischalnikov*)
MOPA41 Linac Diagnostics for Machine Learning Applications (*R.V. Sharankova*)

MOPA42	Considerations Concerning the Use of HTS Conductor for Accelerator Dipoles with Inductions above 15 T (*M.A. Green*)
MOPA43	Dee Voltage Regulator for the 88-Inch Cyclotron (*M. Kireeff*)
MOPA44	Utilizing Python to Prepare the VENUS Ion Source for Machine Learning (*A. Kireeff*)
MOPA45	Vacuum Electron Devices in the 88-Inch Cyclotron (*M. Kireeff Covo*)
MOPA46	Cryogenic Dielectric Structure With GOhm/m Level Shunt Impedance (*R.A. Kostin*)
MOPA47	Progress Toward Commercial Epitaxy of Alkali Antimonide Photocathodes (*E.J. Montgomery*)
MOPA48	Laser-Plasma Interactions and THz Radiation in LWFA (*K.A. Wolfinger*)
MOPA49	Measurements and Simulations of a Ti:Sapphire Crystal at kHz Repetition Rates (*D.T. Abell*)
MOPA50	Integrated Photonics Structure Cathodes for Longitudinally Shaped Bunch Trains (*S.J. Coleman*)
MOPA51	Electron Beam Phase Space Reconstruction From a Gas Sheet Diagnostic (*N.M. Cook*)
MOPA52	Online Correction of Laser Focal Position Using FPGA-Based ML Models (*N.M. Cook*)
MOPA53	An Integrated Data Processing and Management Platform for X-Ray Light Source Operations (*N.M. Cook*)
MOPA54	Influence of Electron Transport Coefficients Models on Capillary Discharge Plasmas (*A. Diaw*)
MOPA55	Facilitating Machine Learning Collaborations Between Labs, Universities, and Industry (*J.P. Edelen*)
MOPA56	Identification of Superconducting Magnet Quenches with Machine Learning (*M.C. Kilpatrick*)
MOPA57	Online Models for X-Ray Beamlines (*B. Nash*)
MOPA58	An Algorithm for Suppression of Speckle Noise in Neutron Camera Images (*I.V. Pogorelov*)
MOPA59	Prediction of Gaseous Breakdown for Plasma Cleaning of RF Cavities (*S.A. Ahmed*)
MOPA60	HFSS Enables Multipaction Analysis of High Power RF/Microwave Components (*S.A. Ahmed*)
MOPA61	High-Power Solid State Switching for RFQ Linac Drive Chain (*E.L. Atkinson*)
MOPA62	High Quality Conformal Coatings on Accelerator Components via Novel Radial Magnetron With High-Power Impulse Magnetron Sputtering (*W.M. Huber*)
MOPA63	Multiphysics Simulation of the Thermal Response of a Nanofibrous Target in a High-Intensity Beam (*W.J. Asztalos*)
MOPA64	Circular Modes for Mitigating Space-Charge Effects and Enabling Flat Beams (*O. Gilanliogullari*)
MOPA66	Hadron Monitor Calibration System for NuMI (*N.L. Muldrow*)
MOPA67	Examining the Effects of Oxygen Doping on SRF Cavity Performance (*H. Hu*)
MOPA68	Adjoint Optimization of Circular Lattices (*T.M. Antonsen*)
MOPA69	Adjoint Optimization Applied to Flat to Round Transformers (*T.M. Antonsen*)
MOPA70	Film Dosimetry Characterization of the Research Linac at the University of Maryland (*A.S. Johnson*)
MOPA71	Demonstration of Flat/Round Transformations of Angular Momentum and Space Charge Dominated Electron Beams (*P.G. O'Shea*)
MOPA72	Preliminary Tests and Beam Dynamics Simulations of a Straight-Merger Beamline (*A.A. Al Marzouk*)
MOPA73	First-Principle Simulation of a Bunch Compressor for the Argonne Wakefield Accelerator (*A.A. Al Marzouk*)
MOPA74	Design of a W-Band Corrugated Waveguide for Structure Wakefield Acceleration (*B. Leung*)
MOPA75	ML Techniques in Slow Spill Regulation System for Mu2e (*A. Narayanan*)
MOPA76	Modeling of Sub-Thz Dielectric-Lined Waveguide (*C.L. Phillips*)
MOPA77	Microbunching Instability in Beam-Driven Structured Wakefield Accelerators (*W.H. Tan*)
MOPA78	Temporally Shaped Ultraviolet Pulses for Tailored Bunch Generation in Argonne Wakefield Accelerator (*T. Xu*)
MOPA79	Studying the Emission Characteristics of Field Emission Cathodes With Various Geometries (*M.R. Howard*)
MOPA80	Design Study for Non-Intercepting Gas-Sheet Profile Monitor at FRIB (*A. Lokey*)
MOPA81	Study of Nonlinear Dynamics in the 4-D Hénon Map Using the Square Matrix Method and Iterative Methods (*K.J. Anderson*)
MOPA82	AGS Experiment on Space Charge Driven Third Order Resonance (*M.A. Balcewicz*)
MOPA83	Automation of Superconducting Cavity and Superconducting Magnet Operation for FRIB (*W. Chang*)
MOPA84	Superconducting Cavity Commissioning for the FRIB Linac (*W. Chang*)
MOPA85	Design of a 185.7-MHz Superconducting RF Photoinjector Quarter-Wave Resonator for the LCLS-II-HE Low-Emittance Injector (*S.H. Kim*)
MOPA86	Conditioning of Low-Field Multipacting Barriers in Superconducting Quarter-Wave Resonators (*S.H. Kim*)
MOPA87	Design of the Cathode Stalk for the LCLS-II-HE Low Emittance Injector (*T. Konomi*)

MOPA88 FRIB and UEM LLRF Controller Upgrade (*S.R. Kunjir*)
MOPA89 RHIC Electron-Beam Cooling Analysis Using Principle Component and Autoencoder Analysis (*A.D. Tran*)
MOPA90 Relating Initial Distribution to Beam Loss on the Front End of the Heavy-Ion Linac Using Machine Learning (*A.D. Tran*)
MOPA91 Plasma Cleaning of Superconducting Quarter-Wave Resonators Using a Higher-Order Mode (*T. Xu*)
MOPA92 Brightness Mapping in RF Guns (*B.G. Sims*)

09-Aug-22 08:00 – 10:00: TUXD — Accelerator Applications
TUXD1 Radiation Concerns and Mitigation Schemes for Accelerator Facility Components (*F. Pellemoine*)
TUXD2 An E-Beam Irradiation Beamline at Jefferson Lab for 1,4-Dioxane and Per- and Polyfluoroalkyl Substances Remediation in Wastewater (*X. Li*)
TUXD3 Production Pathways for Medically Interesting Isotopes (*L. Rosado Del Rio*)
TUXD4 Laser-Plasma-Accelerator-Driven Electron Radiography on the OMEGA EP Laser (*G.M. Bruhaug*)
TUXD5 Development of Achromatic Imaging Capabilities for pRad at LANSCE (*M. Schanz*)
TUXD6 Dual Radiofrequency Cavity Based Monochromatization for High Resolution Electron Energy Loss Spectroscopy (*A.V. Kulkarni*)

09-Aug-22 08:00 – 10:00: TUXE — Tutorial
TUXE1 The Importance of Data, High-Performance Computing, and Artificial Intelligence/Machine Learning (*C.M. Sweeney*)

09-Aug-22 10:30 – 12:30: TUYD — Photon Sources and Electron Accelerators
TUYD1 High Voltage DC Gun for High Intensity Polarized Electron Source (*O.H. Rahman*)
TUYD2 Progress Towards Long-Lifetime, High-Current Polarized-Electron Sources (*J.P. Biswas*)
TUYD3 The Quest for the Perfect Cathode (*J. Smedley*)
TUYD4 Towards High Brightness from Plasmon-Enhanced Photoemitters (*C.M. Pierce*)
TUYD5 Epitaxial Alkali-Antimonide Photocathodes on Lattice-matched Substrates (*P. Saha*)
TUYD6 Commissioning of the ASU Cryocooled 200 kV DC Electron Gun (*G.S. Gevorkyan*)

09-Aug-22 10:30 – 12:30: TUYE — Computing and Data Science for Acc Sys
TUYE1 Coulomb Crystals in Storage Rings for Quantum Information Science (*K.A. Brown*)
TUYE2 Next Generation Computational Tools For The Modeling And Design Of Particle Accelerators At Exascale (*A. Huebl*)
TUYE3 An Open-Source Based Data Management and Processing Framework on a Central Server for Scientific Experimental Data (*A. Liu*)
TUYE4 Machine Learning for Anomaly Detection and Classification in Particle Accelerators (*I. Lobach*)
TUYE5 Multiobjective Optimization of the LCLS-II Photoinjector (*N.R. Neveu*)
TUYE6 High-Fidelity Simulations and Machine Learning for Accelerator Design and Optimization (*A. Adelmann*)

09-Aug-22 13:00 – 14:00: TUAE — Sustainability Brown Bag Luncheon
TUAE1 Sustainability Brown Bag Luncheon: Let's Get the Conversation Started (*M. Uesaka*)

09-Aug-22 13:00 – 16:00: TUZG — RadiaSoft Satellite Session
TUZG1 Magnets to ML to Light Sources: Designing from the Browser with Sirepo (*J.P. Edelen*)

09-Aug-22 14:00 – 16:00: TUZD — Colliders
TUZD1 The Electron/Positron Future Circular Collider (*F. Zimmermann*)
TUZD2 The International Effort Towards a Muon Collider (*D. Stratakis*)
TUZD3 Ultimate Limits of Future Colliders (*M. Bai*)
TUZD4 Plans for Future Energy Frontier Accelerators to Drive Particle Physics Discovery (*M. Turner*)
TUZD5 Experience and Challenges With Electron Cooling of Colliding Ion Beams in RHIC (*A.V. Fedotov*)
TUZD6 DarkSRF: Using Accelerator Technology to Search for a Dark Photon (*A.S. Romanenko*)

09-Aug-22 14:00 – 16:00: TUZE — Beam Dynamics

TUZE1 Experimental Phase-Space Tracking of a Single Electron in a Storage Ring (*A.L. Romanov*)
TUZE2 Nonlinear Optics from Off-Energy Closed Orbits (*D.K. Olsson*)
TUZE3 Optimizing the Discovery of Underlying Nonlinear Beam Dynamics (*L.A. Pocher*)
TUZE4 Particle-in-Cell Simulations of High Current Density Electron Beams in the Scorpius Linear Induction Accelerator (*S.E. Clark*)
TUZE5 Studies of Ion Beam Heating by Electron Beams (*S. Seletskiy*)
TUZE6 Studies of Ion Instability Using a Gas Injection System (*J.R. Calvey*)

09-Aug-22 16:30 – 18:00: TUPA — Poster Session

TUPA01 Calculation of Muon g-2 Beam Dynamics Corrections Using Nonlinear Normal Forms (*E.V. Valetov*)
TUPA02 Characterization of Octupole Elements for IOTA (*J.N. Wieland*)
TUPA04 Sheet Electron Probe for Beam Tomography (*V.G. Dudnikov*)
TUPA05 An H^- Injector for the ESS Storage Ring (*V.G. Dudnikov*)
TUPA06 RF Cathode Heating in Surface Plasma Negative Ion Sources (*V.G. Dudnikov*)
TUPA07 Improving of the Converter Surface Plasma Sources (*V.G. Dudnikov*)
TUPA09 Designing Accelerator-Driven Experiments for Accelerator-Driven Reactors (*R.P. Johnson*)
TUPA10 Development and In-Situ Testing of Novel Electrode and Insulating Materials for Molten Salts (*R.P. Johnson*)
TUPA11 Magnet System for a Compact Microtron Source (*S.A. Kahn*)
TUPA12 Innovative Magnetron Power Sources for Superconducting RF (SRF) Accelerators (*M.L. Neubauer*)
TUPA13 Affordable, Efficient Injection-Locked Magnetrons for Superconducting Cavities (*M. Popovic*)
TUPA14 Fast First-Order Spin Propagation for Spin Matching and Polarization Optimization With Bmad (*D. Sagan*)
TUPA15 Development of a CVD System for Next-Generation SRF Cavities (*G. Gaitan*)
TUPA16 Singularity-Free Exact Sector Bend Transport Equations (*D. Sagan*)
TUPA17 Beam-Based Alignment for Sextupole Families in the EIC (*D. Sagan*)
TUPA18 Promise and Challenges of a Method for 5x5 Sigma Matrix Measurement in a Transport Line (*M. Borland*)
TUPA19 Avoiding Combinatorial Explosion in Simulation of Multiple Magnet Errors in Swap-Out Safety Tracking for the Advanced Photon Source Upgrade (*M. Borland*)
TUPA20 Status of New Undulators for the APS Upgrade (*R.J. Dejus*)
TUPA21 Hydrodynamic and Beam Dynamic Simulations of Ultra-Low Emittance Whole Beam Dumps in the Advanced Photon Source Storage Ring (*J.C. Dooling*)
TUPA22 Measurements of Bunch Length in the Advanced Photon Source Booster Synchrotron (*J.C. Dooling*)
TUPA23 First Beam Results Using the 10-kW Harmonic Rf Solid-State Amplifier for the APS Particle Accumulator Ring (*K.C. Harkay*)
TUPA24 Robust Digital Twin Models from Experimental Data (*N. Kuklev*)
TUPA25 Differentiable Approach to Particle Tracking and Beam Optics Measurements (*N. Kuklev*)
TUPA26 Fringe Field Maps for Cartesian Dipoles With Longitudinal And/or Transverse Gradients (*R.R. Lindberg*)
TUPA27 Longitudinal Feedback Dynamics in Storage Rings With Small Synchrotron Tunes (*R.R. Lindberg*)
TUPA28 Update on the Development of a Low-Cost Button BPM Signal Detector at AWA (*S.Y. Kim*)
TUPA29 Machine Learning for Predicting Power Supply Trips in Storage Rings (*I. Lobach*)
TUPA30 Development of a Compact 2D Carbon Beam Scanner for Cancer Therapy (*B. Mustapha*)
TUPA31 Machine Learning to Support the ATLAS Linac Operations at Argonne (*B. Mustapha*)
TUPA32 Superconducting Undulator End Coils Configured as a Phase Shifter (*M.F. Qian*)
TUPA33 Magnetic Field Calculation of Superconducting Undulators for FEL Using Maxwell 3D (*Y. Shiroyanagi*)
TUPA34 Model-Based Calibration of Control Parameters at the Argonne Wakefield Accelerator (*I.P. Sugrue*)
TUPA35 APS Linac Hot-Spare RF Gun Operation and Beam Optimization (*Y. Sun*)
TUPA36 The Advanced Photon Source Linac Extension Area Beamline (*K.P. Wootton*)
TUPA37 A Distributed Beam Loss Monitor Based upon Activation of Oxygen in Deionised Cooling Water (*K.P. Wootton*)
TUPA38 Sublinear Intensity Response of Cerium-Doped Yttrium Aluminium Garnet Screen With Charge (*K.P. Wootton*)
TUPA39 A Miniature Adjustable Phase Undulator for a Compact X-Ray FEL (*J.Z. Xu*)

TUPA41 Applications of machine learning in photo-cathode injectors (*A. Aslam*)
TUPA42 LANSCE Modernization Project at LANL (*D.V. Gorelov*)
TUPA43 Novel RF Phase Detector for Accelerator Applications (*J.M. Potter*)
TUPA44 A Personal History of the Development of the LAMPF/LANSCE Accelerator (*J.M. Potter*)
TUPA45 A Laser-Neutralization Based Bunch Length Diagnostic for LANSCE (*H.L. Andrews*)
TUPA46 Mechanistic Simulations of Material Evolution Under Electric Fields (*S. Bagchi*)
TUPA47 Upgrade from ADCs with Centrally Scheduled Triggers to Continually Triggered Waveform Digitizers (*S.A. Baily*)
TUPA48 Effect of Lattice Misalignments on Beam Dynamics in LANSCE Linear Accelerator (*Y.K. Batygin*)
TUPA49 Ceramic Enhanced Accelerator Space Readiness (*M.R. Bradley*)
TUPA50 Minimizing Energy Spread from the Microbunching Instability in the Linac for an X-Ray Free Electron Laser (*L.D. Duffy*)
TUPA51 RF Power Detector Upgrade for the LANSCE DTL (*S.R. Gomez*)
TUPA52 Initial Results of the 201.25 MHz Coaxial Window Test Stand (*T.W. Hall*)
TUPA53 Modeling of Coherent Synchrotron Radiation Effects in High Brightness Beams via a Novel Particle-Mesh Method and Surrogate Models With Symplectic Neural Networks (*C.-K. Huang*)
TUPA54 Simulation Study of HOM Suppression for the C-Band Accelerating Structure (*D. Kim*)
TUPA55 Progress Toward Improving Accelerator Performance and Automating Operations With Advanced Analysis Software (*J.E. Koglin*)
TUPA56 Beam Coupling Impedances of Asymmetric Components of the Scorpius Induction Linac (*S.S. Kurennoy*)
TUPA57 EM and Beam Dynamics Modeling of the LANSCE Coupled-Cavity Linac (*S.S. Kurennoy*)
TUPA58 Iterative Tuning of the Beam Feedforward Controller for LANSCE LINAC Digital Low-Level RF Control System (*S. Kwon*)
TUPA59 RF System Upgrade for Low Energy DTL Cavity at LANSCE (*J.T.M. Lyles*)
TUPA60 A Compact FEL Design for THz Generation (*Q.R. Marksteiner*)
TUPA61 Alkali Antimonide Photocathode Thin Film Growth: from Sequential Deposition Towards Automated Process Control (*V.N. Pavlenko*)
TUPA62 LANSCE Control System's 50th Anniversary (*M. Pieck*)
TUPA63 The Beam Plasma Interactions Experiment (Beam PIE): Progress on a Sub-Orbital Active Experiment Using Pulsed Electron Beams (*C.D. Roper*)
TUPA64 Analysis of Resonant Converter Topology for High-Voltage Modulators (*M. Sanchez Barrueta*)
TUPA65 Machine Learning for the LANL Electromagnetic Isotope Separator (*A. Scheinker*)
TUPA67 Optimization of Harmonic Current Frequency Content for an Accelerated Beam Produced from a Gridded Gun (*J.M. Tinlin*)
TUPA68 Study of Different Ferrite Material for Inductive Insert in the Proton Storage Ring at LANSCE (*J. Upadhyay*)
TUPA69 Improving Cavity Phase Measurements at the Los Alamos Neutron Science Center (*P. Van Rooy*)
TUPA70 Ab Initio Cu Alloy Design for High-Gradient Accelerating Structures (*G.X. Wang*)
TUPA71 Safe Extremum Seeking for Real Time Optimization of Particle Accelerators (*A.B. Williams*)
TUPA72 Comparison Study of the First Bunch Compressor Schemes by a Conventional and a Double C-Chicane for MaRIE XFEL (*H. Xu*)
TUPA73 Design and Low Power Test of an Electron Bunching Enhancer Using Electrostatic Potential Depression (*H. Xu*)
TUPA74 Numerical Calculations of Wave Generation From a Bunched Electron Beam in Space (*H. Xu*)
TUPA75 High-Gradient Testing Results of the Benchmark a/λ=0.105 Cavity at CERF-NM (*M.R.A. Zuboraj*)
TUPA76 High Current Photoinjector Electron Source for Compact Short Wavelength FEL (*O. Camacho*)
TUPA77 X-Band Harmonic Longitudinal Phase Space Linearization at the PEGASUS Photoinjector (*P.E. Denham*)
TUPA78 Using a Tunable Light Source to Reduce Mean Transverse Energy of an Electron Beam (*D.A. Garcia*)
TUPA79 Temperature-Dependent Effects on RF Surface Resistivity (*G.E. Lawler*)
TUPA80 New Cryogenic Brightness-Optimized Radiofrequency Gun (CYBORG) (*G.E. Lawler*)
TUPA81 Design of a High-Power RF Breakdown Test for a Cryocooled C-Band Copper Structure (*G.E. Lawler*)
TUPA82 Transverse Stability in an Alternating Symmetry Planar Dielectric Wakefield Structure (*W.J. Lynn*)
TUPA83 Derivative-Free Optimization of Multipole Fits to Experimental Wakefield Data (*N. Majernik*)

TUPA84 Reconstructing Beam Parameters From Betatron Radiation Through Machine Learning and Maximum Likelihood Estimation (*N. Majernik*)
TUPA85 Multileaf Collimator for AWA's EEX Beamline (*N. Majernik*)
TUPA86 Simulations of Nanoblade Cathode Emissions With Image Charge Trapping for Yield and Brightness Analyses (*J.I. Mann*)
TUPA87 Simulations for the Space Plasma Experiments at the SAMURAI Lab (*N. Majernik*)
TUPA88 FAST-GREENS: a High Efficiency Free Electron Laser Driven by Superconducting RF Accelerator (*A.C. Fisher*)
TUPA89 Photon Spectrometers at FACET-II (*B. Naranjo*)
TUPA90 High-Throughput Injection-Acceleration of Electron Bunches From a Linear Accelerator to a Laser Wakefield Accelerator (*Y.P. Wu*)
TUPA91 Distributed Coupling Linac for Efficient Acceleration of High Charge Electron Bunches (*A. Dhar*)
TUPA92 Solid-State Driven X-band Linac for Electron Microscopy (*A. Dhar*)

09-Aug-22 18:00 – 20:00: TUADE — Entertaiment and Historical Talk
TUADE1 Los Alamos National Laboratory: Beyond Manhattan (*A.B. Carr*)

10-Aug-22 08:00 – 10:00: WEXD — Beam Dynamics
WEXD1 Advances in Beam Dynamics at Nuclear Physics Accelerator Facilities (*A.V. Sy*)
WEXD2 Storage Ring Tracking Using Generalized Gradient Representations of Full Magnetic Field Maps (*R.R. Lindberg*)
WEXD3 Map Tracking in Rings With Stochastic Radiation Emission Effects (*D. Sagan*)
WEXD4 OPAL for Self-Consistent Start-to-End Simulation of Undulator-Based Facilities (*A. Adelmann*)
WEXD5 Benchmarking Simulation for AWA Drive Linac and Emittance Exchange Beamline Using OPAL, GPT, and Impact-T (*S.Y. Kim*)
WEXD6 Electron Cloud Measurements in Fermilab Booster (*S.A.K. Wijethunga*)

10-Aug-22 08:00 – 10:00: WEXE — Tutorial 1
WEXE1 Accelerator Science and Technology via Inventive Principles of TRIZ (*A. Seryi*)

10-Aug-22 08:00 – 10:00: WEXF — Tutorial 2
WEXF1 Accelerator Computation: Fast, Cheap, and Easy (*J.R. Cary*)

10-Aug-22 10:30 – 12:30: WEYD — Advanced Acceleration
WEYD1 Ultrahigh Energy Electrons From Laser Wakefield Accelerators (*B.M. Hegelich*)
WEYD2 First Lasing of a Free-Electron Laser With a Compact Beam-Driven Plasma Accelerator (*S. Romeo*)
WEYD3 Positron Acceleration in Linear, Moderately Non-Linear and Non-Linear Plasma Wakefields (*J.W. Cao*)
WEYD4 Design and Fabrication of a Metamaterial Wakefield Accelerating Structure (*D.C. Merenich*)
WEYD5 Highly Spin-Polarized Multi-GeV Sub-Femtosecond Electron Beams Generated From Single-Species Plasma Photocathodes (*Z. Nie*)
WEYD6 Studies of a PIP-II Mu2e Experiment (*M.A. Cummings*)

10-Aug-22 10:30 – 12:30: WEYE — Hadron Accelerators
WEYE1 Next-Generation Accelerator Facilities at Fermilab: Megawatt Upgrade of the NuMI Neutrino Beam (*R.M. Zwaska*)
WEYE2 Upgrade of the FRIB ReAccelerator (*A.C.C. Villari*)
WEYE3 Improvements to the Recycler/Main Injector to Deliver 850 KW+ (*R. Ainsworth*)
WEYE4 Electron Cloud Simulations in the Fermilab Recycler (*A.P. Schreckenberger*)
WEYE5 Model/Measurement Comparison of the Transverse Phase Space Distribution of an RFQ-Generated Bunch at the SNS BTF (*K.J. Ruisard*)
WEYE6 Thermionic Source for Electron Cooling at IOTA (*M.K. Bossard*)

10-Aug-22 14:00 – 16:00: WEZD — Accelerator Technology
WEZD1 ARDAP's Perspective on Accelerator Technology Research and Development in the US (*B.E. Carlsten*)
WEZD2 Solid State Active Reset Induction Technology to Accelerate kA Electron Beam (*J. Ellsworth*)

WEZD3 Magnetron R&D Progress for High Efficiency CW RF Sources of Industrial Accelerators (*H. Wang*)
WEZD4 Using Off-Axis Undulator Radiation as a Longitudinal Electron-Beam Diagnostic (*Q.R. Marksteiner*)
WEZD5 Micro-Electromechanical Systems Based Multi-Beam Ion Accelerators (*Q. Ji*)
WEZD6 Manufacturing the Harmonic Kicker Cavity Prototype for the Electron-Ion Collider (*S.A. Overstreet*)

10-Aug-22 14:00 – 16:00: WEZE — Accelerator Applications

WEZE1 Current Status of Developing an Ultrafast Electron Microscope (*X. Yang*)
WEZE2 Ultrafast Electron Diffraction at Cornell Using Low Emittance Photocathodes (*J.M. Maxson*)
WEZE3 Compact, High-Power Superconducting Electron Linear Accelerators for MW Industrial Applications (*J.C.T. Thangaraj*)
WEZE4 First High-Gradient Results of UED/UEM SRF Gun at Cryogenics Temperatures (*R.A. Kostin*)
WEZE5 Magnetic Flux Expulsion in Superconducting Radio-Frequency Niobium Cavities Made From Cold Worked Niobium (*B.D. Khanal*)
WEZE6 Characterization of the Fields Inside the CO_2-Laser-Driven Wakefield Accelerators Using Relativistic Electron Beams (*I. Petrushina*)

10-Aug-22 16:30 – 18:00: WEPA — Wednesday Poster Session

WEPA01 Beam Dynamics Optimization of a Low Emittance Photoinjector Without Buncher Cavities (*F. Ji*)
WEPA02 Beam Dynamics Studies on a Low Emittance Injector for LCLS-II-HE (*F. Ji*)
WEPA03 Status of the SLAC/MSU SRF Gun Development Project (*J.W. Lewellen*)
WEPA04 Simulating 2D Transient Coherent Synchrotron Radiation in Julia (*W. Lou*)
WEPA06 Advancement of Strategic Accelerator Technologies: RF Sources (*J.W. Merrick*)
WEPA07 Characterization and Optimization of Accelerators Exhibiting Hysteresis Using Differentiable Physics Models (*R.J. Roussel*)
WEPA08 Design and Operation Experience of a Multi-collimator/YAG Screen Device on LCLS II Low Energy Beamline (*L. Xiao*)
WEPA09 A Parallel Automatic Simulation Tool for Cavity Shape Optimization (*L. Xiao*)
WEPA10 Determination of LCLS-II Gun-2 Prototype Dimensions (*L. Xiao*)
WEPA11 Unwrapping Image Data Using Adaptive Machine Learning (*E.H. Toler*)
WEPA12 Operational Experience of the New Booster Cryomodule at the Upgraded Injector Test Facility (*M.W. Bruker*)
WEPA13 New Results at JLab Describing Operating Lifetime of GaAs Photo-guns (*M.W. Bruker*)
WEPA14 Microbunching Gain Evaluation of the Strong Hadron Cooler Energy Recovery Linac of the Electron Ion Collider (*K.E. Deitrick*)
WEPA15 Exploring Nb_3Sn Magnet Technologies for the Second Interaction Region of the Electron-Ion Collider (*B.R. Gamage*)
WEPA16 A 500 kV Inverted Geometry Feedthrough for a High Voltage DC Electron Gun (*C. Hernandez-Garcia*)
WEPA17 Improved Electrostatic Design of the Jefferson Lab 300 kV DC Photogun and the Minimization of Beam Deflection (*M.A. Mamun*)
WEPA18 TE011 Cavity for Monitoring Magnetic Momentum of a Magnetized Beam (*M.A. Mamun*)
WEPA19 He Production Update at Jlab - Introducing an Enhanced Nitrogen Purge for Clean String Assembly (*P.D. Owen*)
WEPA20 High-Gradient Wien Spin Rotators at Jefferson Lab (*G.G. Palacios Serrano*)
WEPA21 Uncertainty Aware Anomaly Detection to Predict Errant Beam Pulses in the SNS Accelerator (*K. Rajput*)
WEPA22 Measuring the Electric Dipole Moment of the Electron in a Two-Energy Spin-Transparent Storage Ring (*R. Suleiman*)
WEPA23 SRF Cavity Instability Detection With Machine Learning at CEBAF (*D.L. Turner*)
WEPA24 pyJSPEC: A Python Module for IBS and Electron Cooling Simulation (*H. Zhang*)
WEPA25 Field Emission Mitigation in CEBAF SRF Cavities Using Deep Learning (*K. Ahammed*)
WEPA26 197-MHz Waveguide-Loaded Crab-Cavity Design for the Electron-Ion Collider (*S.U. De Silva*)
WEPA27 Effect of Duration of 120 C Baking on the Performance of Superconducting Radio Frequency Niobium Cavities (*B.D. Khanal*)
WEPA28 An E-Beam Irradiation Beamline at Jefferson Lab for 1,4-Dioxane and Per- and Polyfluoroalkyl Substances Remediation in Wastewater (*X. Li*)
WEPA29 Real-time Cavity Fault Prediction in CEBAF Using Deep Learning (*M. Rahman*)

WEPA30 Nb_3Sn Coating of a 2.6 GHz SRF Cavity by Sputter Deposition Technique (*M.S. Shakel*)
WEPA31 Lower Temperature Annealing of Vapor Diffused Nb_3Sn for Accelerator Cavities. (*J.K. Tiskumara*)
WEPA32 Spallation Neutron Source Cryogenic Moderator System Helium Gas Analysis System (*B. DeGraff*)
WEPA33 Laser Stripping for 1.3 GeV H^- Beam at the SNS (*T.V. Gorlov*)
WEPA34 Transverse Transfer Maps in the Hard-Edge Limit of Quadrupole and Bend Magnets Fringe Fields (*T.V. Gorlov*)
WEPA35 The Collimation System in the SNS HEBT (*F. Lin*)
WEPA36 Particle Tracking: Emittance Growth Rate Due to RF Phase Noise Induced in JLEIC Crab Cavies (*F. Lin*)
WEPA37 Benchmarking and Exploring Parameter Space of the 2-Phase Bubble Tracking Model for Liquid Mercury Target Simulation (*L. Lin*)
WEPA38 Progress on Machine Learning for the SNS High-Voltage Converter Modulators (*M.I. Radaideh*)
WEPA40 The L-CAPE Project at FNAL (*J.F. Strube*)
WEPA41 Maximizing Output of 3-MeV S-band Industrial Accelerator (*S. Proskin*)
WEPA42 A Modular X-ray Detector for Beamline Diagnostics at LANL (*P.M. Freeman*)
WEPA43 Self-Contained Linac Irradiator for the Sterile Insect Technique (SIT) (*A. Amirari*)
WEPA44 Compact Inter-Undulator Diagnostic Assembly for TESSA-515 (*T.J. Hodgetts*)
WEPA45 Practical Review on Beam Line Commissioning Procedures and Techniques for Scientific and Industrial Electron Accelerators (*M.O. Kravchenko*)
WEPA46 Test Results of a High-Gradient Low-Beta S-band Negative Harmonic Accelerating Structure (*A.C. Araujo Martinez*)
WEPA47 Optimization of Negative-Harmonic High-Gradient Accelerating Structure for Low-Beta Ions (*A.C. Araujo Martinez*)
WEPA48 Electromagnetic Design of a Compact RF Chopper for Heavy-Ion Beams Separation at FRIB (*A.C. Araujo Martinez*)
WEPA49 Ferrite-Free Circulator Based on Material Non-Lienarity (*A.I. Pronikov*)
WEPA50 Initial Development of a High-Voltage Pulse Generator for a Short-Pulse Stripline Kicker (*J. Prager*)
WEPA51 External Fast Electrically-Controlled Ferroelectric Tuner for CEBAF SRF Cavities (*A. Kanareykin*)
WEPA52 Demonstration of Twice-Reduced Lorentz-Force Detuning in SRF Cavity by Copper Cold Spraying (*R.A. Kostin*)
WEPA53 An Open Radiofrequency Accelerating Structure (*S.V. Kuzikov*)
WEPA54 Successful Experimental Demonstrations of the IDEAS-Halo Detector With Protons and Electrons at Various Energies (*A. Liu*)
WEPA55 Applications of Machine Automation With Robotics and Computer Vision in Cleanroom Assemblies (*A. Liu*)
WEPA56 Encapsulation of Photocathodes Using High Power Pulsed RF Sputtering of hBN (*A. Liu*)
WEPA57 Implementation of a Flux-Concentrator-Based Objective Lens for UED/UEM (*E.J. Montgomery*)
WEPA58 High-quality Diffraction Grade Diamond Substrates for X-ray optics (*I.V. Ponomarev*)
WEPA59 Simulation Studies of Ionization-Injection in High-Atomic-Number Gases (*A. Cheng*)
WEPA60 Machine Learning for Designing Flying Focus Optics (*G.J. Kim*)
WEPA61 Investigating the Transverse Trapping Condition in Beam-Induced Ionization Injection in Plasma Wakefield Accelerators (*Y. Yan*)
WEPA62 Design and Commissioning of the ASU CXLS RF System (*B.J. Cook*)
WEPA63 Extensions of the Complex (IQ) Baseband RF Cavity Model Including RF Source and Beam Interactions (*S.P. Jachim*)
WEPA64 Design and Commissioning of the ASU CXLS Machine Protection System (*S.P. Jachim*)
WEPA65 On-Chip Photonics Integrated Photocathodes (*A.H. Kachwala*)
WEPA66 Near-Threshold Photoemission from Graphene-Coated Cu Single Crystals (*C.J. Knill*)
WEPA67 Effects of Transverse Dependence of Kicks in Simulations of Microbunched Electron Cooling (*W.F. Bergan*)
WEPA68 Record Quantum Efficiency from Superlattice Photocathode for Spin Polarized Electron Beam Production (*J.P. Biswas*)
WEPA69 The Impact on the Vertical Beam Dynamics Due to the Noise in a Horizontal Crab Crossing Scheme (*Y. Hao*)
WEPA70 Tensor Decomposition for the Compression and Analysis of 10-kHz BPM Data (*Y. Hidaka*)
WEPA71 Unified Orbit Feedback at NSLS-II (*Y. Hidaka*)

WEPA72 Analysis of Beam-Induced Heating of the NSLS-II Ceramic Vacuum Chambers (*A. Khan*)
WEPA73 Numerical Studies of Short-range Wakefields at NSLS-II with GdfidL and ECHO3D (*A. Khan*)
WEPA74 Characterization of Fully Coupled Linear Optics With Turn-by-Turn Data (*Y. Li*)
WEPA75 6-D Element-by-Element Particle Tracking With Crab Cavity Phase Noise and Weak-Strong Beam-Beam Interaction for the Hadron Storage Ring of the Electron-Ion Collider (*Y. Luo*)
WEPA76 Radio Frequency System and Controls of the NSLS-II Injector LINAC for Multi-Bunch Beams (*H. Ma*)
WEPA77 A New PCB Rotating Coil at NSLS-II (*M. Musardo*)
WEPA78 Proton-Electron Focusing in EIC Ring Electron Cooler (*S. Seletskiy*)
WEPA79 Friction Force in Non-Magnetized Bunched Electron Coolers (*S. Seletskiy*)
WEPA80 Progress on a Convergence Map Based on Square Matrix for Nonlinear Lattice Optimization (*V.V. Smaluk*)
WEPA81 NSLS-II Timing-Resolved Machine Operation Plan (*G.M. Wang*)
WEPA82 Complex Bend Prototype Beamline Design (*G.M. Wang*)
WEPA83 Extended Soft-Gaussian Code for Beam-Beam Simulations (*D. Xu*)
WEPA84 Transverse Coupled-Bunch Instability Driven by the Resistive Wall Impedance at SuperKEKB (*A. Blednykh*)
WEPA85 Localized Beam Induced Heating Analysis of the EIC Vacuum Chamber Components (*M.P. Sangroula*)
WEPA87 Electron Beam-Ion Instability with Beam-Beam Interaction at the Electron-Ion Collider (*B. Podobedov*)
WEPA88 A Quasi-Optical Beam Position Monitor (*S.V. Kuzikov*)

10-Aug-22 18:00 – 20:30: WEADE — Celebration of Diversity, Equity, and Inclusion in the Accelerator Community
WEADE1 Integrating Diversity and Inclusion in the Workplace: Los Alamos National Laboratory's Strategies for Expanding Diversity and Fostering Inclusion and Belonging (*K.S. Haight*)

11-Aug-22 08:00 – 10:00: THXD — Beam Instrumentation and Controls
THXD1 Machine Learning for Improved Accelerator Health and Reliability (*Y.A. Yucesan*)
THXD2 6D Phase Space Diagnostics Based on Adaptive Tuning of the Latent Space of Encoder-Decoder Convolutional Neural Networks (*A. Scheinker*)
THXD3 Improved Multi-Dimensional Bunch Shape Monitor (*A.C. Araujo Martinez*)
THXD4 Online Accelerator Tuning with Adaptive Bayesian Optimization (*N. Kuklev*)
THXD5 Machine Learning-Based Tuning of Control Parameters for LLRF System of Superconducting Cavities (*J.A. Diaz Cruz*)
THXD6 A Quasi-Optical Beam Position Monitor (*S.V. Kuzikov*)

11-Aug-22 08:00 – 10:00: THXE — Tutorial
THXE1 Accelerators for Quantum Technologies (*A.S. Romanenko*)

11-Aug-22 10:30 – 12:30: THYD — Photon Sources and Electron Accelerators
THYD1 XFEL as a Low-Emittance Injector for a 4th-Generation Synchrotron Radiation Source (*T. Hara*)
THYD2 The Challenging Physics Regimes of High Current Electron Beams (*J.E. Coleman*)
THYD3 Update on the Status of the C-Band Research and Facilities at LANL (*E.I. Simakov*)
THYD4 Progress on the APS-U Injector Upgrade (*J.R. Calvey*)
THYD5 Emittance Measurements of Nanoblade-Enhanced High Field Cathode (*G.E. Lawler*)
THYD6 Arrival Time and Energy Jitter Effects on the Performance of X-ray Free Electron Laser Oscillator (*G. Tiwari*)

11-Aug-22 10:30 – 12:30: THYE — Accelerator Technology
THYE1 Overview of Superconducting Magnet Technologies (*S. Prestemon*)
THYE2 Development of Short-Period Nb_3Sn Superconducting Planar Undulators at the Advanced Photon Source (*I. Kesgin*)
THYE3 Superconducting Undulators and Cryomodules for X-ray Free-Electron Lasers (*D.C. Nguyen*)
THYE4 Development of an Ultra-Low Vibration Cryostat Based on a Closed-Cycle Cryocooler (*R.W. Roca*)
THYE5 Analysis of Low RRR SRF Cavities (*K. Howard*)

THYE6 First Demonstration of a ZrNb Alloyed Surface for Superconducting Radio-Frequency Cavities (*Z. Sun*)

11-Aug-22 14:00 – 16:00: THZD — Hadron Accelerators

THZD1 Instant Phase Setting in a Large Superconducting Linac (*A.S. Plastun*)
THZD2 Advances in the ATLAS Accelerator (*M.P. Kelly*)
THZD3 Design of 3-GeV High-Gradient Booster for Upgraded Proton Radiography at LANSCE (*Y.K. Batygin*)
THZD4 Accelerating Structures for High-Gradient Proton Radiography Booster at LANSCE (*S.S. Kurennoy*)
THZD5 Modelling H^- Injection and Painting in Vertical and Horizontal FFAs Using OPAL (*A. Adelmann*)
THZD6 An 8-GeV Linac for the Fermilab 2.5-MW Upgrade (*D.V. Neuffer*)

11-Aug-22 14:00 – 16:00: THZE — Beam Instrumentation and Controls

THZE1 Machine Learning-Based Longitudinal Phase Space Prediction of Particle Accelerators (*C. Emma*)
THZE2 Developing Control System Specifications and Requirements for the Electron Ion Collider (*A. Blednykh*)
THZE3 An Electrodeless Diamond Beam Monitor (*S.V. Kuzikov*)
THZE4 Gas Sheet Ionization Diagnostic for Transverse Profile Measurement (*N. Burger*)
THZE5 Recent Developments of the Soft X-ray Beam Position Monitor Project (*B. Podobedov*)
THZE6 A Time-Resolved Beam Halo Monitor for Accelerator Beam Diagnostics Using Diamond Detectors and High Speed Digitizers (*B. Rotter*)

11-Aug-22 17:00 – 18:00: THADE — Louis Costrell Awards Session

12-Aug-22 08:00 – 10:00: FRXD — Beam Dynamics

FRXD1 Demonstration of Optical Stochastic Cooling in an Electron Storage Ring (*J.D. Jarvis*)
FRXD2 Experimental Demonstration of Multi-Function Longitudinal Beam Phase-Space Manipulation via Double Emittance-Exchange (*J. Seok*)
FRXD3 Measurements of the Five-Dimensional Phase Space Distribution of a High-Intensity Ion Beam (*A.M. Hoover*)
FRXD4 Suppressing the Microbunching Instability at ATF using Laser Assisted Bunch Compression (*Q.R. Marksteiner*)
FRXD5 Nonlinearly Shaped Pulses at LCLS-II (*N.R. Neveu*)
FRXD6 Bunch Length Measurements at the CEBAF Injector at 130 kV (*S. Pokharel*)

12-Aug-22 08:00 – 10:00: FRXE — Tutorial

FRXE1 Bayesian Algorithms for Practical Accelerator Control and Adaptive Machine Learning for Time-Varying Systems (*A. Scheinker*)

12-Aug-22 10:30 – 12:30: FRCDE — Closing Session

FRCDE1 Accelerator Searches for Axions and Dark Matter (*R. van de Water*)
FRCDE2 Accelerator Production of Medical Radionuclides (*C.S. Cutler*)
FRCDE3 Radiation Effects in Microelectronics - Why We Need Particle Accelerators (*J.A. Pellish*)

SUXF — Project Management

SUXF1

Project Management and Accelerator Development

S. Biedron (Element Aero) L.M. Georgson Petrén (Roddare)

Accelerator laboratories belong to the largest research investments to be found regardless laboratory, research institute or country funding the initiatives. This impose a great responsibility on the researchers and engineers developing, building and updating research facilities. Accelerator development are important research projects and will affect many stakeholders regardless if it is a smaller upgrade of an RF system or development of a large scale FEL. Wet developing new systems project management is a core competence for every laboratory. Yet this is a knowledge area often ignored in favor skill development in areas closer to physics and technology. This can be a very expensive mistake as the value of proper project management cannot be underestimated. This half day training will give you insight in the basics of projects. What is a project and what does project management mean. And how can this be adopted in accelerator development.

 Chair: S. Biedron, Element Aero (Chicago, USA)

SUZF — Systems Engineering

SUZF1

Introduction to Systems Engineering Concepts

S. Biedron (Element Aero) L.M. Georgson Petrén (Roddare)

Systems engineering has long been employed in defense and non-defense industries but not commonly in particle accelerator systems. The common definition of Systems Engineering is as follows "It is a transdisciplinary and integrative approach to enable the successful realization, use, and retirement of engineered systems, using systems principles and concepts, and scientific, technological, and management methods." This overview introduces participants to the fundamental principles of systems engineering and their application to the development of complex systems. Systems engineering helps address engineering challenges as well as how systems engineering is essential to project management. The overview will help the participant learn the language of methods and processes commonplace in industry. We will define the following through examples: systems, the systems development lifecycle, and methods of systems engineering, beginning with the system requirements. One example will be exploring a novel particle accelerator through systems engineering methods.

Chair: S. Biedron, Element Aero (Chicago, USA)

MOODE — Opening Plenary Session

MOODE1

Applications of Particle Accelerators

M. Uesaka (JAEC)

Applications of particle accelerators amid global policies of carbon neutrality and economic security. are reviewed. Downsizing of high energy large scaled accelerators by advanced technologies enables a variety of medical and industrial uses. One of the highlights is upgrade of sustainable suplly chain of medical radioisotopes by the best mix of research reactors and accelerators. 99Mo/99mTc for diagnosis are going to be produced by low enriched U reactor and proton-cyclotron, electron rhodotron and electron linac. Moreover, the theranostics by 177Lu (beta) and 211At/225Ac (alpha) are going to be realized. Proton-cyclotron and electron linac are expected to produce them soon. This new affordable radiation therapy should play an important role in the IAEA project of Rays of Hopes. Next, proof-of-principle trails of on-site bridge inspection of the portable X-band (9.3 GHz) electron linac X-ray/neutron sources are under way. The technical guideline for the practical inspection is to be formed in a couple of years. Ultimate micro-accelerator for microbeam applications is dielectric laser accelerator, such as ACHIP project. Updated projects and results are also introduced.

MOODE2

Expanding the Boundaries of X-ray Lasers: LCLS Upgrades and Future

G.R. Hays (SLAC)

The Linac Coherent Light Source (LCLS) is currently in the midst of several major upgrades: LCLS-II, LCLS-II-HE, and MEC-U. These upgrades will augment the facility with a 4 GeV continuous-wave superconducting electron accelerator (LCLS-II) that is subsequently extended to 8 GeV (LCLS-II-HE), and a PW-class laser system coupled to the X-ray laser (MEC-U). The science motivation, expected performance, technological drivers, and status will be presented. Future capabilities, beyond those enabled with the ongoing upgrades, will also be discussed.

MOODE3

Building a Global, Collaborative Accelerator Economy: Summary of the IPAC 2022 Industrial Session

R. Geometrante (KYMA)

The 13th International Particular Accelerator Conference 2022 (IPAC22) was held this June as an in-person event in Bangkok, Thailand. What happened, and what's next? Great emphasis was given to its industrial session. Particle accelerators are at a crucial moment: innovation, ideas and know-how have to be shared between individuals both in lab-based- and university-based-STE (Science Technology and Engineering) and industry. Bridges have to be built to improve high technology products and to identify new products and markets. The Industrial Session discussed about novel ideas and concrete actions on how best to implement and apply impactful strategies that would help with integration and co-innovation between industry, laboratories and universities, with the clear and shared aim: building a global, collaborative accelerator economy.

MOODE4

PW-Class Lasers for Accelerators - Overview and an Industry Perspective

O.J. Chalus (THALES LAS France)

In this presentation, we will review the current experiments done by various research group over the world on Laser assisted particle acceleration (BELLA, DESY, Weizmann...). We will spend a bit of time on the description of the laser technologies used for this. What are the specifications required for such laser, their footprint and their future development.

MOYD — Colliders

Progress on the Electron-Ion Collider

MOYD1

F.J. Willeke (BNL) A. Seryi (JLab)

We will be reporting on the progress of the design and preparatory R&D for the Electron-Ion Collider.

Options for Future Colliders on Fermilab Site

MOYD2

P.C. Bhat, V.D. Shiltsev (Fermilab)

As part of the Snowmass'21 effort, the Fermilab Collider Group has considered several options of future colliders which would fit the FNAL site boundaries. Here we present the most feasible opportunities and discuss their energy reach, luminosity potential and physics case, technical and financial feasibility.

EIC Transverse Emittance Growth due to Crab Cavity RF Noise: Estimates and Mitigation

MOYD3

T. Mastoridis (CalPoly)

The Electron-Ion Collider (EIC) requires crab cavities to compensate for a 25 mrad crossing angle and achieve maximum luminosity. The crab cavity Radio Frequency (RF) system will inject low levels of noise to the crabbing field, generating transverse emittance growth and potentially limiting luminosity lifetime. In this work, we estimate the transverse emittance growth rate as a function of the Crab Cavity RF noise and quantify RF noise specifications for reasonable performance. Finally, we evaluate the possible mitigation of the RF noise induced emittance growth via a dedicated feedback system.

Model Parameters Determination in EIC Strong-Strong Simulation

MOYD4

D. Xu (BNL)

The ion beam is sensitive to numerical noise in the strong-strong simulation of the Electron-Ion Collider (EIC). This paper discusses the impact of model parameters — macro particles, transverse grids and longitudinal slices — on beam size evolution in PIC based strong-strong simulation. It will help us to understand the emittance growth in strong-strong simulation.

Tolerances of Crab Dispersion at the Interaction Point in the Hadron Storage Ring of the Electron-Ion Collider

MOYD5

Y. Luo, J.S. Berg, M. Blaskiewicz, C. Montag, V. Ptitsyn, F.J. Willeke, D. Xu (BNL) Y. Hao (FRIB) V.S. Morozov (ORNL RAD) J. Qiang (LBNL) T. Satogata (JLab)

The Electron Ion Collider (EIC) presently under construction at Brookhaven National Laboratory will collide polarized high energy electron beams with hadron beams with luminosity up to 10^{34} cm^{-2} s^{-1} in the center mass energy range of 20 to 140 GeV. Due to the detector solenoid in the interaction region, the design horizontal crabbing angle will be coupled to the vertical plane if uncompensated. In this article, we estimate the tolerance of crab dispersion at the interaction point in the EIC Hadron Storage Ring (HSR). Both strong-strong and weak-strong simulations are used. We found that there is a tight tolerance of vertical crabbing angle at the interaction point in the HSR.

Chromatic Correction of the EIC Electron Ring Lattice

MOYD6

Y. Cai (SLAC)

The lattice for the Electron Storage Ring of the Electron Ion Collider is discussed. At 18 GeV the rms energy spread approaches 0.001 making chromatic correction a priority. This is especially true with two interaction regions. The techniques used to find an adequate lattice will be discussed and the current design presented.

MOYE — Accelerator Technology

MOYE1

Role of People, Materials, and Manufacturing in the Future of Vacuum Electronics

D. Gamzina (SLAC) F. Casagrande (FRIB) C.E. Reece, R.A. Rimmer (JLab)

Our focus must shift to development of materials and manufacturing technologies to realize compact and affordable vacuum electronics that solve the world's most challenging problems. Nanocomposite scandate tungsten materials are developed to reproducibly produce an order of magnitude higher current density electron emission than what is commercially available today. The mechanics of material interaction with RF is characterized using newly developed in-situ RF-pump / X-ray probe diffraction technique allowing to measure temporal evolution of materials' microstructural state. Electron-beam melting-based copper additive manufacturing is developed for production of vacuum electronics opening opportunities to build on-demand complex components out of high-strength copper and its alloys. A new vacuum electronics company is founded offering rapid manufacturing of affordable millimeter wave power amplifiers based on vacuum-electronics technologies. Finally, the SAGE Journey program has been established to inspire 500 high school students to learn about particle accelerators and consider careers in science and engineering at the DOE National Laboratories.

MOYE2

LCLS-II HE vCM Test Results: Newly Developed N-Doping Treatment and Plasma Processing

B. Giaccone (Fermilab)

This talk presents the results of the LCLS-II HE verification cryomodule (vCM), which aimed at verifing that the cryomodule is capable to meet the project specification (Q_0=2.7·10^{10} at 19 MV/m) with the newly developed nitrogen doping treatment. The test also carried out detailed studies on multipacting processing optimization and Q-factor quench degradation. Plasma processing was also carried out in four out of eight cavities in the cryomodule, showing its effectiveness in eliminating multipacting. These studies will be discussed.

MOYE3

Conduction Cooled Superconducting RF Cavity With Field Emission Cathode

Y. Ji, R. Dhuley, C.J. Edwards, J.C.T. Thangaraj (Fermilab) D. Mihalcea, O. Mohsen, P. Piot (Northern Illinois University)

To achieve Ampere-class electron beam accelerator the pulse delivery rate need to be much higher than the typical photo injector repetition rate of the order of a few kilohertz. We propose here an injector which can generate electron bunches at the same rate as the operating RF frequency. A conduction-cooled superconducting radio frequency (SRF) cavity operating in the CW mode and housing a field emission element at its region of high axial electric field can be a viable method of generating high-repetition-rate electron bunches. In this paper, we report the development and experiments on a conduction-cooled Nb_3Sn cavity with a niobium rod intended as a field emitter. The initial experiments demonstrate ~0.4 MV/m average accelerating gradient, which is equivalent of peak gradient of 1.8~MV/m. The measured RF cavity quality factor is 1.4×10^8 slightly above our goal. The achieved field gradient is limited by the relatively low input RF power and by the poor coupling between the external power supply and the RF cavity. With ideal coupling the field gradient can be as high as 0.6~MV/m still below our goal of 1~MV/m.

MOYE4

Diagnoses and Repair of a Crack in the Drift Tube LINAC Accelerating Structure at LANSCE

W.C. Barkley, D.A. Bingham, M.J. Borden, J.A. Burkhart, D.J. Evans, J.T.M. Lyles, J.P. Montross, J.F. O'Hara, B.J. Roller, M. Sanchez Barrueta (LANL)

Many were perplexed at the inability of Module 3 at LANSCE to operate at peak power and duty factor while running production beam. During the 2018 production run, the DTL began to intermittently break down, leading to a series of root cause investigations. These analyses included eliminating the usual suspects: vacuum leak, debris in tank, driveline window, power coupler, etc. The throttling back of repetition rate from 120 to 60 Hz allowed continued production with a diminished beam, one that reduced neutron flux to three experimental areas. During the annual shutdown in 2019, a more thorough investigation involving the use of x-ray detection, high-resolution cameras and IR detection through site glass windows was performed. After a tenacious search, a 30 cm long crack was discovered in a weld at one of the ion pump port grates. Inaccessibility for welding from the outside and in a confined space, non-intrusive repairs were tried first but were unsuccessful. Ultimately, an expert welder entered the tank to weld the crack under unfamiliar welding conditions. This paper describes the diagnoses, non-intrusive solutions and ultimate repair of the crack in the accelerating structure.

In Situ Plasma Processing of Superconducting Cavities at JLab

T. Powers, N.C. Brock, T.D. Ganey (JLab)

MOYE5

Jefferson Lab has an ongoing R&D program in plasma processing which is close to going into production processing in the CEBAF accelerator. Plasma processing is a common technique for removing hydrocarbons from surfaces, which increases the work function and reduces the secondary emission coefficient. Unlike helium processing which relies on ion bombardment of the field emitters, plasma processing uses free oxygen produced in the plasma to break down the hydrocarbons on the surface of the cavity. The initial focus of the effort was processing C100 cavities by injecting RF power into the HOM coupler ports. Results from processing cryomodule in the cryomodule test bunker as well as vertical test results will be presented. We plan to start processing cryomodules in the CEBAF tunnel within the next year. The goal will be to improve the operational gradients and the energy margin of the linacs. This work will describe the systems and methods used at JLAB for processing cavities using an argon oxygen gas mixture. Before and after plasma processing results will also be presented.

Spin-Polarized Electron Photoemission and Detection Studies

A.C. Rodriguez Alicea, R. Palai (University of Puerto Rico, Rio Piedras Campus)
O. Chubenko, S.S. Karkare (Arizona State University) L. Cultrera (BNL)

MOYE6

As of today, photocathodes based on Gallium Arsenide (GaAs) are the only option available for electron guns to produce spin polarized electron beams. Quantum Efficiency (QE) and Electron Spin Polarization (ESP) strongly depend on the experimental conditions, like photon energy, and also on temperature. To understand the relevance of a number of physical parameters on the electron emission, we are attempting at developing a framework where ab-initio numerical simulations of electronic band structures can be used to provide inputs to Monte Carlo simulations of photoelectron beam transport and emission. By validation with experimental measurements, we aim at building the basis on which future investigations will be able to study new materials that could outperform GaAs-based photocathodes. At the same time, we are commissioning a new experimental setup capable of characterizing the photoemission properties of GaAs and other candidate materials.

MOZD — Photon Sources and Electron Accelerators

MOZD1

Commissioning of LCLS-II

Y. Ding (SLAC)

The LCLS-II is a CW FEL based on a 4 GeV SRF linac. Commissioning of the CW Electron Gun and SRF linac was begun during the winter of 2022 with expectations of 1st light during Summer 2022. Results will be presented.

MOZD2

Single-Pass High-Efficiency THz FEL

A.C. Fisher, P. Musumeci (UCLA)

The THz gap is a region of the electromagnetic spectrum where high average and peak power radiation sources are scarce while at the same time scientific and industrial applications are growing in demand. Free-electron laser coupling in a magnetic undulator is one of the best options for radiation generation in this frequency range, but slippage effects require the use of relatively long and low current electron bunches to drive the THz FEL, limiting amplification gain and output peak power. Here we use a circular waveguide in a 0.96 m strongly tapered helical undulator to match the radiation and e-beam velocities, allowing resonant energy extraction from an ultrashort 200 pC 5.5 MeV electron beam over an extended distance. E-beam energy measurements, supported by energy and spectral measurement of the THz FEL radiation, indicate an average energy efficiency of $\sim$ 10%, with some particles losing $>$ 20% of their initial kinetic energy.

MOZD3

Development of Two-Color Sub-Femtosecond Pump/Probe Techniques With X-Ray Free-Electron Lasers

Z.H. Guo, P.L. Franz (Stanford University) D.B. Cesar, J.P. Cryan, T.D.C. Driver, J.P. Duris, Z. Huang, K. Larsen, S. Li, A. Marinelli, J.T. O'Neal, R. Robles, N.S. Sudar, A.L. Wang, Z. Zhang (SLAC)

We report the generation of GW-level attosecond pump/probe pulse pairs with tunable sub-femtosecond delays at the Linac Coherent Light Source (LCLS). The attosecond 370 eV pump pulse is first generated via the Enhanced Self-Amplified Spontaneous Emission (ESASE) method, then the attosecond 740 eV probe pulse is produced by re-amplifying the electron beam microbunching after the magnetic chicane. Due to the harmonic amplification, the minimal delay between pump-probe pulse pairs (limited by slippage between the light field and the electron bunch) can be shorter than 1 femtosecond. We use the angular streaking technique to measure temporal delays between pump/probe pulse pairs at multiple beamline configurations. When the delay chicane is turned off, the averaged delay is increased by $\sim$150 attoseconds by adding one undulator module for probe pulses. Long delays can be set up by turning the delay chicane on. These experimental results are in agreement with start-to-end XFEL simulations. Looking toward future experiments, our sub-femtosecond pump/probe technique can be applied to observe electronic charge dynamics in molecular systems.

MOZD4

Uncertainty Quantification of Beam Parameters in an LIA Inferred from Bayesian Analysis of Solenoid Scans

M.A. Jaworski, D.C. Moir, S. Szustkowski (LANL)

Linear induction accelerators (LIAs), such as DARHT at Los Alamos National Laboratory, make use of the beam envelope equation to simulate the beam and design experiments. Accepted practice is to infer beam parameters using the solenoid scan technique with optical transition radiation (OTR) beam profiles. These scans are then analyzed with an envelope equation solver to find a solution consistent with the data and machine parameters (beam energy, current, magnetic field, and geometry). The most common code for this purpose with flash-radiography LIAs is XTR [1]. The code assumes the machine parameters are perfectly known and that beam profiles will follow a normal distribution about the best fit and solves by minimizing the Chi-square metric. We construct a Bayesian model of the beam parameters allowing machine parameters, such as solenoid position and strength, to vary within reasonable uncertainty bounds. Machine parameters such as geometry are allowed to vary and the impact on the inferred beam parameters is quantified. Posterior likelihood functions are constructed using Markov-chain Monte Carlo methods to further examine the validity of the normal distribution assumption.

MOZD5

An ERL-Based Compact X-Ray FEL

F. Lin, V.S. Morozov (ORNL RAD)

We propose to develop an energy-recovery-linac (ERL)-based X-ray free-electron laser (FEL). Taking advantage of the demonstrated high-efficiency energy recovery of the beam power in the ERL, the proposed concept offers the following benefits: i) recirculating the electron beam through high-gradient SRF cavities shortens the linac, ii) energy recovery in the SRF linac saves the klystron power and reduces the beam dump power, iii) the high average beam power produces a high average photon brightness. In addition, such a concept has the capability of optimized high-brightness CW X-ray FEL performance at different energies with simultaneous multipole sources. In this paper, we will present the preliminary results on the study of feasibility, optics design, and parameter optimization.

MOZD6

Accelerator Physics Lessons From CBETA, the First Multi-Turn SRF ERL

G.H. Hoffstaetter (Cornell University (CLASSE), Cornell Laboratory for Accelerator-Based Sciences and Education) , K.E. Deitrick (JLab)

The Cornell-BNL ERL Test Accelerator (CBETA) has been designed, constructed, and commissioned in a collaboration between Cornell and BNL. It focuses on energy-saving measures in accelerators, including permanent magnets, energy recovery, and superconductors; it has thus been referred to as a green accelerator. CBETA has become the world's first Energy Recovery Linac (ERL) that accelerates through multiple turns and then recovers the energy in SRF cavities though multiple decelerating turns. The energy is then available to accelerate more beam. It has also become the first accelerator that operates 7 beams in the same large-energy aperture Fixed Field Alternating-gradient (FFA) lattice. The FFA is constructed of permanent combined function magnets and transports energies of 42, 78, 114, and 150 MeV simultaneously. Accelerator physics lessons from the commissioning period will be described and applications of such an accelerator from hadron cooling to EUV lithography and from nuclear physics to a compact Compton source will be discussed.

MOZE — Advanced Acceleration

MOZE1

Demonstration of High-Gradient in a Cryo-Cooled X-Band Structure

M.H. Nasr (SLAC)

We show experimental results demonstrating the first operation of an X-band structure at high-gradient (>100 MeV/m). Results also show a breakdown rate two orders of magnitude lower than at room temperature.

MOZE2

Results of Awake Run 1 and Plans for Run 2 Towards HEP Applications

M. Bergamaschi (CERN)

We summarize the experimental results obtained during Run 1 with a plasma wakefield accelerator driven by a 400 GeV proton bunch. We then outline experimental plans for Run 2 aimed at demonstrating that high energy (~10 GeV) electron bunch can be accelerated to sufficient quality for mid-term application to high-energy physics (HEP).

MOZE3

An X-band Short-Pulse Ultra-High Gradient Photoinjector

G. Chen, D.S. Doran, C.-J. Jing, S.Y. Kim, W. Liu, W. Liu, P. Piot, J.G. Power, C. Whiteford, E.E. Wisniewski (ANL) C.-J. Jing, E.W. Knight, S.V. Kuzikov (Euclid TechLabs) C.-J. Jing (Euclid Beamlabs) P. Piot, W.H. Tan (Northern Illinois University)

A short pulse high gradient RF gun has been recently tested at Argonne Wakefield Accelerator (AWA) facility. The carried-out test showed that the 1.5-cell gun was able to inject 3 MeV, up to 100 pC bunches at room temperature being fed by 9 ns up to 300 MW 11.7 GHz pulses. The cathode field was as high as ~400 MV/m. So high field is aimed to mitigate repealing Coulomb forces substantially. The gun was equipped with a downstream linac to be fed from the same power extractor as the gun itself. Here we report results of recent experiments carried out at AWA.

MOZE4

Ceramic Enhanced Accelerator Structure Low Power Test and Designs of High Power and Beam Tests

H. Xu, M.R. Bradley, L.D. Duffy, M.A. Holloway, J. Upadhyay (LANL)

A ceramic enhanced accelerator structure (CEAS) uses a concentric ceramic ring placed inside a metallic pillbox cavity to significantly increase the shunt impedance of the cavity. Single cell standing wave CEAS cavities are designed, built, and tested at low power at 5.1 GHz. The results indicate 30% increase in shunt impedance compared to that of a purely metallic pillbox cavity. A beam test setup has been designed to use a single cell CEAS cavity to modulate a 30-keV direct-current (DC) electron beam at an accelerating gradient of 1 to 2 MV/m to verify the beam acceleration capability of the CEAS concept and to study the potential charging effect on the ceramic component during the operation. Another single cell standing wave CEAS cavity has been designed for high power test at 5.7 GHz for the high accelerating gradient capability.

MOZE5

Simulation and Experimental Results of Dielectric Disk Accelerating Structures

S. Weatherly (Illinois Institute of Technology)

A method of decreasing the required footprint of linear electron accelerators and to improve their energy efficiency is utilizing short RF pulses (~9 ns) with Dielectric Disk Accelerators (DDA). A DDA is an accelerating structure that utilizes dielectric disks in its design to improve the shunt impedance. Two DDA structures have been designed and tested at the Argonne Wakefield Accelerator. A single cell clamped DDA structure recently achieved an accelerating gradient of 102 MV/m. A multicell clamped DDA structure has been designed and is being fabricated. Simulation results for this new structure show a 108 MV/m accelerating gradient with 400 MW of input power with a high shunt impedance and group velocity. Engineering designs have been improved from the single cell structure to ensure consistent clamping over the entire structure.

Fulfilling the Mission of Brookhaven ATF as a DOE Flagship User Facility in Accelerator Stewardship

I. Pogorelsky, M. Babzien, M.G. Fedurin, R. Kupfer, M.A. Palmer, M.N. Polyanskiy (BNL)
N. Vafaei-Najafabadi (Stony Brook University)

Over last three decades, BNL Accelerator Test Facility (ATF) pioneered the concept of a proposal-based user facility for lasers and electron beam-driven advanced accelerator research (AAR). This has made ATF an internationally recognized destination for researchers who benefit from access to unique scientific capabilities not otherwise available to individual institutions and businesses. Operating as an Office of Science National User Facility and a flagship DOE facility in Accelerator R&D Stewardship, ATF pursues an ambitious upgrade plan for its lasers and electron beam infrastructure to enable experiments at the forefront of the AAR. In this talk, we will present our path towards attaining a novel multi-terawatt sub-picosecond regime with a long-wave IR 9-um laser. Future enhancements to the electron beam and near-IR laser capabilities will also be presented. The combination of linac- and laser-driven e-beams will empower a unique state-of-the-art science program. This includes integrated multi-beam research in laser wakefield accelerators, such as the two-color ionization injection, with the promise of an all-optical scheme for generating collider-quality electrons beams.

MOPA — Poster Session

MOPA01

Realistic CAD-Based Geometries for Arbitrary Magnets With Beam Delivery Simulation (BDSIM)

E. Ramoisiaux, R. Dantinne, E. Gnacadja, C. Hernalsteens, S. Musibau, B. Ndihokubwayo, N. Pauly, R. Tesse, M. Vanwelde (ULB) S.T. Boogert, L.J. Nevay, W. Shields (Royal Holloway, University of London) C. Hernalsteens (CERN)

Monte Carlo simulations are required to evaluate beam losses and secondary radiation accurately in particle accelerators and beamlines. Detailed CAD geometries are critical to account for a realistic distribution of material masses but increase the model complexity and often lead to code duplication. Beam Delivery Simulation (BDSIM) and the Python package pyg4ometry enable handling such accelerator models within a single, simplified workflow to run complete simulations of primary and secondary particle tracking and interactions with matter using Geant4 routines. Additional capabilities have been developed to model arbitrary bent magnets by associating externally modeled geometries to the magnet poles, yoke, and beampipe. Individual field descriptions can be associated with the yoke and vacuum pipe separately to provide fine-grained control of the magnet model. The implementation of these new features is described in detail and applied to the modeling of the CERN Proton Synchrotron (PS) combined function magnets.

MOPA02

Proton Therapy Beamline Activation of the IBA Proteus One Using BDSIM and FISPACT-II

E. Ramoisiaux, E. Gnacadja, C. Hernalsteens, N. Pauly, R. Tesse, M. Vanwelde (ULB) C. Hernalsteens (CERN)

A known drawback of cyclotron-based proton therapy system is the generation of large fluxes of secondary particles as the beam interacts with the beamline elements, the energy degrader being the dominant source. Compact systems exacerbate these challenges for concrete shielding and beamline element activation. Our implementation of the Rigorous Two-Step method uses Beam Delivery Simulation (BDSIM), for primary and secondary transport and neutron fluence scoring based on Geant4 and FISPACT-II for time-dependent nuclear inventory and solving the rate equation. This approach is applied to the Ion Beam Applications (IBA) Proteus®ONE (P1) system, where a complete model has been built, validated, and used for shielding activation simulations. We detail first simulations of the activation on quadrupole magnets in high-fluence locations downstream of the degrader. Results show the evolution of the long-lived nuclide concentrations for short and long timescales throughout the facility lifetime for a typical operation scenario.

MOPA03

Flexible Features of the Compact Storage Ring in the cSTART Project at Karlsruhe Institute of Technology

A.I. Papash, E. Bründermann, D. El Khechen, B. Haerer, A.-S. Mueller, R. Ruprecht, M. Schwarz (KIT)

Within the cSTART project (compact storage ring for accelerator research and technology), a Very Large Acceptance compact Storage Ring (VLA-cSR) will be realized at the Institute for Beam Physics and Technology (IBPT) of the Karlsruhe Institute of Technology (KIT). A modified geometry of a compact storage ring operating at 50 MeV energy range has been studied and main features of the new model are described here. The new design, based on 45^o bending magnets, is suitable to store a wide momentum spread beam as well as ultra-short electron bunches in the sub-ps range injected from the plasma cell as well as from the Ferninfrarot Linac-Und Test Experiment (FLUTE). The DBA lattice of the VLA-cSR with different settings and relaxed parameters, split elements and higher order optics of tolerable strength allows to improve the dynamic aperture and momentum acceptance to an acceptable level. This contribution discusses the lattice features in detail, expected lifetime, injection, tolerances and different possible operation schemes of the ring.

MOPA04

Design and Development of Deflector Magnet System for High Power Electron Beam Accelerator

S.H. Das, A.S. Dhavale, A. Mitra, R.N. Rajan, N.T. Thakur, A. Waghmare (BARC)

The Electron Beam Waste Water Treatment (EBWWT) system at Electron Beam Centre, BARC has high power accelerator for textile waste water irradiation. The high power accelerated electron beam in an accelerator is scanned over a large area to distribute its energy and utilize the beam for applications. The scanning topology used in EBWWT is two dimensional scanning over a 50 μm thick titanium foil window with an area of 1500 mm x 100 mm. In case the X-scan magnet fails, the beam will fall on titanium foil at a spot till the scan magnet failure is detected and AC source to the accelerator is switched off. Even after switching off the source voltage, stored energy in the HV system will be dumped in the titanium foil, thus raising its local temperature and deteriorating the vacuum, which may lead to rupture of the foil. To

prevent this, a deflector magnet has been designed and developed to deflect the beam as soon as possible after scan magnet failure. The beam is deflected towards scan horn sidewalls (material SS).

Status on OPAL and Future Directions Towards the Exascale Area

MOPA05

A. Adelmann, A. Albà, A. Gsell, J. Snuverink (PSI) P. Calvo (CIEMAT) M. Frey (University of St Andrews) N.R. Neveu (SLAC) D. Winklehner (MIT)

OPAL (Object Oriented Parallel Accelerator Library) is a C++ based massively parallel open source program for tracking charged particles in large scale accelerator structures and beam lines, including 3D space charge, particle-matter-gas interaction, and 3D undulator radiation. The meticulous parallel architecture allows large and difficult problems, including one-to-one simulations with high resolution and no macro particles, to be tackled in a reasonable amount of timet. The current code state as well as the most recent physics advancements and upgrades are discussed, including the unique feature of a sampler for creating massive labeled data sets with tens of thousands of cores for machine learning. We also demonstrate scalability of our core algorithms up to 4600 GPUs and 32'000 CPUs, as part of our effort to make OPAL exascale ready.

A Quantum Mechanical Model of Qubits in Crystalline Beams

MOPA06

A. Adelmann (PSI)

In straightforward but realistic accelerator setups, the numerical evolution of an ion electron structure is shown. In order to conduct a qualitative analysis of the potential applications of such states in quantum sensing and storage ring quantum computing, the Julia-based framework can examine the fidelity of quantum states in a system based on crystalline ion beams. An expansion of the ion's electron structure into plane waves enables high flexibility in terms of the Hamiltonians and physics effects that can be explored. The implementation of the components is validated on well-known analytical quantum harmonic oscillator solutions.

Fast, Efficient and Flexible Particle Accelerator Optimisation Using Densely Connected and Invertible Neural Networks

MOPA07

A. Adelmann (PSI)

Due to the enormous number of factors involved and the underlying non-linear dynamics, identifying optimal operation points for these complicated devices is a difficult process. We present two families of data-driven surrogate models based on fully connected and invertible deep neural networks that can be used in place of costly physics computer models. For two fundamentally distinct types of particle accelerators, these models are used in multi-objective optimizations to discover Pareto optimal operation points. Our method decreases the time to solution for multi-objective accelerator optimization by a factor of up to 640 and lowers the computational cost by up to 98 percent [1]. The architecture presented here should pave the way for future multi-objective particle accelerator online and real-time optimization.

Methods for Beamline Optimization for High Intensity Muon Beams at PSI

MOPA08

E.V. Valetov (PSI)

We perform beamline design optimization for the High Intensity Muon Beams (HIMB) project at the Paul Scherrer Institute (PSI), which will deliver muon beams at the unprecedented rate of 10^{10} muons/s to next-generation intensity frontier particle physics and material science experiments. For optimization of the design and operational parameters to maximize the beamline transmission, we use the asynchronous Bayesian optimization package DeepHyper and a custom build of G4beamline with variance reduction and measured cross sections. We minimize the beam spot size at the final foci using a COSY INFINITY model with differential-algebraic system knobs, where we minimize the respective transfer map elements using the Levenberg-Marquardt and simulated annealing optimizers. We obtained a transmission of $1.34{\cdot}10^{10}$ muons/s in a G4beamline model of HIMB's MUH2 beamline into the experimental area.

Design of a 4D Emittance Diagnostic for Low-Energy Ion Beams

MOPA09

T.R. Curtin, M.S. Curtin (Ion Linac Systems, Inc.)

Characterization of ion beams from an ion injector consisting of an electron-cyclotron-resonance (ECR) source in combination with a low-energy-beam-transport (LEBT) typically exhibits a complex four-dimensional transverse phase-space distribution. The importance of measuring the ion beam correlations following extraction and transport of the low-energy beam is critical to enabling optimization of beam transmission through downstream accelerating structures. A design for a transverse, four-dimensional emittance meter for low-energy protons from the Ion Linac Systems (ILS) ECR-LEBT ion injector is provided.

MOPA10

HPC Modeling of a High-Gradient C-Band Linac for Hard X-Ray Free-Electron Lasers

T.B. Bolin (UNM-ECE) S. Biedron (UNM-ME)

The production of soft to hard x-rays (up to 25 keV) at XFEL (x-ray free-electron laser) facilities has enabled new developments in a multitude of disciplines. There is great potential for new scientific discovery at higher energies (42+ keV), such as those that can be provided by MaRIE (Matter-Radiation Interactions in Extremes) at Los Alamos National Laboratory. These instruments can require a large amount of cost-escalating real estate: The FEL driver is typically an electron beam linear accelerator (LINAC) and the need for higher electron beam energies to produce higher energy X-rays dictates that the linac becomes longer. State of art accelerating technology is required to reduce the linac length by reducing the size of the cavities, which in turn provides for a high acceleration gradient. High-frequency S, C, and X band operation is necessary for compact accelerating structures. Here we use the Argonne Leadership Computing Facility (ALCF) to run simulations for XFEL high-gradient LINAC design in the C-band (4 to 8 GHz). We investigate two different traveling wave (TW) geometries optimized for high-gradient operation as modeled at the ALCF using VSim software.

MOPA11

Active Noise Control Algorithm for Multiple Cavities

M.I. Caskey, J.A. Diaz Cruz (UNM-ECE) S. Biedron (Element Aero)

Presently, the use of super conducting radio frequency (SRF) cavities with high intrinsic quality factors has proven ideal in situations involving low beam loading, as a high intrinsic quality factor allows for increased energy efficiency. As such, this technology has the potential to benefit new research into light source linacs and energy recovery linacs. However, due to the narrow bandwidth attributed to large quality factors, the use of these SRF cavities requires more power to mitigate the effects of vibrations within the cavity and maintain a fixed frequency. In a paper by Banerjee et al., it was proposed that the current practice of actively suppressing such vibrations using fast tuners may be improved through the implementation of a newly formulated active noise control algorithm. It is the aim of this research to use mathematical modeling techniques for the purpose of defining the functional parameters of the algorithm theorized in the paper.

MOPA12

Commissioning of HOM Detectors in the First Cryomodule of the LCLS-II Linac

J.A. Diaz Cruz (UNM-ECE) B.T. Jacobson, N.R. Neveu, J.P. Sikora (SLAC)

Long-range wakefields (LRWs) may cause emittance dilution effects. LWRs are especially unwanted at facilities with low emittance beams like the LCLS-II at SLAC. Dipolar higher-order modes (HOMs) are a set of LRWs that are excited by off-axis beams. The HOM detectors were built to measure the beam-induced HOM signals for TESLA-type superconducting RF (SRF) cavities; they were tested at the Fermilab Accelerator Science and Technology (FAST) facility and are now installed at SLAC. The HOM detectors were designed to investigate long-range wakefield effects on the beam. This paper presents the initial results of HOM measurements at the first cryomodule (CM) of the LCLS-II linac and describes the relevant hardware and setup of the experiment.

MOPA13

Design of a Surrogate Model for MUED at BNL Using VSim and HPC

S.I. Sosa Guitron, S. Biedron, T.B. Bolin, M.A. Fazio (UNM-ECE) S. Biedron (Element Aero) S. Biedron (UNM-ME)

The MeV Ultrafast Electron Diffraction (MUED) system at Brookhaven National Laboratory presents a unique capability for material science. As part of the plan to make this a true user facility, we are exploring machine development approaches based on tools like Machine Learning, we are designing a surrogate model of the MUED beamline to support control tasks of the instrument. We use VSim to model the beam dynamics of the RF gun and Elegant to transport the beam through the rest of the beamline. We use High Performance Computing resources from Argonne Leadership Computing Facility to generate the data for the surrogate modeling based on the original simulation as well as training of the model.

A Wide Dynamic-Range Halo Monitor for 8-GeV Proton Beams at FNAL

MOPA14

Y. Hashimoto, T.M. Mitsuhashi, C. Ohmori, T. Sasaki, M. Tejima, T. Toyama, M. Uota (KEK) , R. Ainsworth (Fermilab) H. Sakai (Mitsubishi Electric System & Service Co., Ltd) Y. Sato (J-PARC, KEK & JAEA)

Eliminating harmful beam halos is the most important technique for high-intensity proton accelerators. Therefore, beam halo diagnosis is indispensable and becomes more and more important. At J-PARC, a wide dynamic range monitor was installed in the beam transport line in 2012. The device is a two-dimensional beam profile monitor [*, **], and it has a dynamic range of approximately six digits of magnitude by using Optical Transition Radiation and fluorescence screens. The FNAL accelerator complex has been upgrading through increased beam intensity and beam quality. A new beam halo diagnostic device is required in the beam transport line between the booster and recycler. It will be manufactured in a collaboration between J-PARC and FNAL as a part of the U.S.-Japan Science and Technology Cooperation Program in High Energy Physics. We are redesigning the monitor to satisfy FNAL specifications for beam energy, intensity, and size. The equipment will be manufactured at J-PARC and then shipped to FNAL in 2024. In this report, the design of the device will be described.

Synchronous High-Frequency Distributed Readout for Edge Processing at the Fermilab Main Injector and Recycler

MOPA15

J.R. Berlioz, M.R. Austin, K.J. Hazelwood, M.A. Ibrahim, G. Pradhan, A.L. Saewert, B.A. Schupbach, R.M. Thurman-Keup (Fermilab)

Much of the instrumentation hardware of the Fermilab Main Injector and Recycler accelerators is original to their 1990s construction. Current and proposed projects are demanding more data from this older hardware. One such project, Real-time Edge AI for Distributed Systems (READS), requires high-frequency synchronized beam loss monitor (BLM) readings, with low latency from around the 2+ mile Main Injector complex. Significant work has been done to develop new hardware to intercept and broadcast over Ethernet the required BLM readings without needing to upgrade or alter the existing operational BLM system. This paper will detail the work done to create such a novel system.

Options for Future Colliders on Fermilab Site

MOPA16

S.A. Belomestnykh, P.C. Bhat, V.D. Shiltsev (Fermilab)

As part of the Snowmass'21 effort, the Fermilab Collider Group has considered several options of future colliders which would fit the FNAL site boundaries. Here we present the most feasible opportunities and discuss their energy reach, luminosity potential and physics case, technical and financial feasibility.

Symplectic Particle Tracking in a Thick Nonlinear McMillan Lens for the Fermilab Integrable Optics Test Accelerator (IOTA)

MOPA17

B.L. Cathey, G. Stancari, T. Zolkin (Fermilab)

The McMillan system is a novel method to increase the tune spread of a beam without decreasing its dynamic aperture due to the system's integrability. While the ideal system is based on an infinitely thin kick, the physical design requires a thick electron lens, including a solenoid. Particle transport through the lens is difficult to simulate due to the nature of the force on the circulating beam. This paper demonstrates accurate simulation of a thick McMillan lens in a solenoid using symplectic integrators derived from Yoshida's method.

Residual Dose and Environmental Monitoring for the Fermilab Main Injector Tunnel Using the Data Acquisition Logging Engine (Dale)

MOPA18

N. Chelidze, R. Ainsworth, B.C. Brown, D. Capista, K.J. Hazelwood, D.K. Morris, M.J. Murphy (Fermilab)

The Recycler and the Main Injector are part of the Fermilab Accelerator complex used to deliver proton beam to the different experiments. It is very important to control and minimize losses in both machines during operation, to reduce personnel dose from residual activation and to preserve component lifetime. To minimize losses, we need to identify the loss points and adjust the components accordingly. The Data Acquisition Loss Engine (DALE) platform has been developed within the Main Injector department and upgraded throughout the years. DALE is used to survey the entire enclosure for residual dose rates and environmental readings when unrestricted access to the enclosure is possible. Currently DALE has two radiation meters, which are aligned along each machine, so loss points can be identified for both at the same time. DALE attaches to the enclosure carts and is continuously in motion monitoring dose rates and other environmental readings. In this paper we will describe

how DALE is used to provide radiation maps of the residual dose rates in the enclosure. We will also compare the loss points with the Beam Loss monitor data.

MOPA19

The Effect of the Main Injector Ramp on the Recycler

N. Chelidze, R. Ainsworth, K.J. Hazelwood (Fermilab)

The Recycler and Main Injector are part of the Fermilab Accelerator complex used to deliver a high power proton beam. Both machines share the same enclosure with the Recycler mounted 6 ft above the Main Injector. The Main Injector accelerates beam from 8 GeV to 120 GeV. While the majority of the Recycler has mu metal shielding, the effect of the Main Injector ramp is still significant and can affect both the tunes and the orbit. In this paper, we detail the size of these effects.

MOPA20

A Study on High Pressure Rinsing of 650 MHz Niobium Superconducting RF Cavity

V. Chouhan, F. Furuta, M. Martinello, T.J. Ring, G. Wu (Fermilab)

High pressure water rinsing (HPR) is applied as a final cleaning process to niobium superconducting RF cavities before assembling them in a cryomodule. We conducted a systematic study on HPR of 650 MHz cavities to mitigate field emission issue observed during cryogenic RF tests of the cavities. This detailed HPR study was performed to understand the effect of HPR parameters on surface cleaning efficiency. The cleaning efficiency was tested by rinsing contaminated electropolished Nb samples under different HPR conditions and by analyzing the rinsed surfaces. Water spray patterns obtained from different types of nozzles were also characterized and wall-pressure, a pressure applied by the water spray on the cavity wall, profiles were obtained for the 650 MHz cavity. Based on the results obtained from the study, a spray head containing several nozzles was designed with an aim to improve the cavity wall cleaning efficiency.

MOPA21

Effect of Electropolishing on Nitrogen Doped and Undoped Niobium Surfaces

V. Chouhan, F. Furuta, M. Martinello, T.J. Ring, G. Wu (Fermilab)

The cold electropolishing (EP) shows a better performance of a nitrogen-doped (N-doped) niobium (Nb) superconducting RF cavity. In order to understand the effect of temperature on N-doped and undoped surfaces, a systematic EP study was conducted with small samples in a beaker, 1-cell Nb coupon cavity, and 9-cell Nb cavity. The Nb samples and cavities were electropolished at different temperatures ranging from a very low temperature below 0^{o}C to standard high temperature ranging between 25^{o}C to 32^{o}C. In both, sample- and cavity-EP, Nb surface temperature was controlled and monitored. This paper shows detailed information on the N-doped and undoped Nb surfaces electropolished at different temperatures.

MOPA22

Study on Electropolishing Conditions for High and Low Beta 650 MHz Niobium SRF Cavity

V. Chouhan, D.J. Bice, F. Furuta, M. Martinello, M.K. Ng, H. Park, T.J. Ring, G. Wu (Fermilab) B.M. Guilfoyle, M.P. Kelly, T. Reid (ANL)

The PIP II accelerator will include different types of niobium SRF cavities including 650 MHz elliptical low (0.61) and high (0.92) cavities. The elliptical cavity surface is processed with the electropolishing (EP) method. The elliptical cavities especially the low 650 MHz cavities showed a rough equator surface after the EP process was applied. This work was focused to study the effect of different EP parameters, including cathode surface area, temperature and voltage, and optimize them to improve the cavity surface.

MOPA23

Tests of the Extended Range SRF Cavity Tuners for the LCLS-II HE Project

C. Contreras-Martinez, T.T. Arkan, A.T. Cravatta, B.D. Hartsell, J.A. Kaluzny, T.N. Khabiboulline, Y.M. Pischalnikov, S. Posen, G.V. Romanov, J.C. Yun (Fermilab)

The LCLS-II HE superconducting linac will produce multi-energy beams by supporting multiple undulator lines simultaneously. This will be achieved by using the cavity SRF tuner in the off-frequency detune method. This off-frequency operation method was tested in the verification cryomodule (vCM) and CM 1 at Fermilab at 2 K. In both cases the tuners were able to achieve a frequency shift of -465 kHz. This study will discuss cavity frequency during each step as it is being assembled in the cryomodule string and finally when it is being tested at 2 K. Tracking the cavity frequency helped in enabling the tuners to reach this large frequency shift. The specific procedure of tuner setting during assembly will be presented.

LCLS-II and HE Cryomodule Microphonics at CMTF at Fermilab

MOPA24

C. Contreras-Martinez, B.E. Chase, A.T. Cravatta, J.A. Einstein-Curtis, E.R. Harms, J.P. Holzbauer, S. Posen (Fermilab) L.R. Doolittle (LBNL)

Vibration induced by microphonics causes the cavity to detune. This study discusses the microphonics of 16 cryomodules, 14 for LCLS-II and 2 for LCLS-II HE tested at CMTF. The peak detuning, as well as the RMS detuning for each cryomodule, will be discussed. For each cryomodule, the data was taken with enough soaking time to prevent any thermalization effects which can show up in the detuning. Each data capture taken was 30 minutes or longer and sampled at 1 kHz.

Lorentz Force Detuning Compensation With a Double Lever Tuner on a dressed ILC/1.3 GHz Cavity at Room Temperature

MOPA25

C. Contreras-Martinez, Y.M. Pischalnikov, J.C. Yun (Fermilab)

Pulsed SRF linacs with high accelerating gradients experience large frequency shifts caused by Lorentz force detuning (LFD). A piezoelectric actuator with a resonance control algorithm can maintain the cavity frequency at the nominal level thus reducing the RF power. This study uses a double lever tuner with a piezoelectric actuator for compensation and another piezoelectric actuator to simulate the effects of the Lorentz force pulse. A double lever tuner has an advantage by increasing the stiffness of the cavity-tuner system thus reducing the effects of LFD. The tests are conducted at room temperature and with a dressed 1.3 GHz 9-cell cavity.

Study of Different Material Piezoelectric Stroke Displacement With Respect to Temperature Using SRF Cavity

MOPA26

C. Contreras-Martinez, Y.M. Pischalnikov, J.C. Yun (Fermilab)

Piezoelectric actuators are used for resonance control in superconducting linacs. The level of frequency compensation depends on the piezoelectric stroke displacement. In this study, the stroke displacement will be measured with an SRF cavity by measuring the frequency shift with respect to the voltage applied. The entire system was submerged in liquid helium. This study characterizes two PZT piezoelectric actuators, P-844K075 and P-844K093, and a lithium niobate P-844B0005 piezoelectric actuator. All these actuators were developed at Physik Instrumente. The piezoelectric displacement was measured at different temperatures.

Test of the Low Beta 650 MHz SRF Cavity Tuner for PIP-II at 2 K

MOPA27

C. Contreras-Martinez, S.K. Chandrasekaran, S. Cheban, G.V. Eremeev, I.V. Gonin, T.N. Khabiboulline, Y.M. Pischalnikov, O.V. Prokofiev, A.I. Sukhanov, J.C. Yun (Fermilab)

The PIP-II linac will include thirty-six β =0.61 and twenty-four β =0.92 650 MHz 5 cell elliptical SRF cavities. Each cavity will be equipped with a tuning system consisting of a double lever slow tuner for coarse frequency tuning and a piezoelectric actuator for fine frequency tuning. The same tuner will be used for both the β =0.61 and β =0.92 cavities. Results of testing the cavity-tuner system for the β =0.61 will be presented for the first time. The mechanical modes of the cavity-tuner system were measured via transfer function with the piezo. Lastly, the cavity's microphonics in the test stand was measured and will be discussed.

Semantic Regression for Disentangling Radiative Beam Losses in the Fermilab Main Injector and Recycler

MOPA28

M. Thieme, H. Liu, S. Memik, R. Shi (Northwestern University) M.R. Austin, K.J. Hazelwood, M.A. Ibrahim, V.P. Nagaslaev, A. Narayanan, D.J. Nicklaus, A.L. Saewert, B.A. Schupbach, K. Seiya, R.M. Thurman-Keup, N.V. Tran (Fermilab)

Fermilab's Main Injector enclosure houses two accelerators: the Main Injector (MI) and the Recycler (RR). In periods of joint operation, radiative beam losses from MI and RR overlap on the enclosure's beam loss monitoring (BLM) system, making it difficult to attribute those losses to a single machine. Incorrect diagnoses result in unnecessary downtime that incur both financial and experimental cost. In this work, we introduce a novel neural approach for automatically disentangling each machine's contributions to those measured losses. Using a continuous adaptation of the popular UNet architecture in conjunction with a novel data augmentation scheme, our model accurately infers the machine of origin on a per-BLM basis in periods of joint and independent operation. Crucially, by extracting beam loss information at varying receptive fields, the method is capable of learning both local and global machine signatures and producing high quality inferences using only raw BLM measurements.

MOPA29

Second Generation Fermilab Main Injector 8 GeV Beamline Collimation Preliminary Design

K.J. Hazelwood, P. Adamson, B.C. Brown, D. Capista, R.M. Donahue, B.L. Klein, N.V. Mokhov, V.S. Pronskikh, V.I. Sidorov, M.C. Vincent (Fermilab)

The current Fermilab Main Injector 8 GeV beamline transverse collimation system was installed in 2006. Since then, proton beam intensities and rates have increased significantly. With the promise of even greater beam intensities and a faster rep rate when the PIP-II upgrade completes later this decade, the current collimation system will be insufficient. Over the past 18 months, multiple collimation designs have been investigated, some more traditional and others novel. A preliminary design review was conducted and a design chosen. Work is underway to finalize the chosen design, prototype some of its novel components and procure parts for installation Summer 2023.

MOPA30

LCLS-II BCS Average Current Monitor

N.M. Ludlow (SLAC)

LCLS-II is a 4th generation light source at the SLAC National Accelerator Laboratory. LCLS-II will accelerate a 30 µA electron beam with a 1 MHz bunch rate with a new superconducting Continuous Waveform (CW) RF accelerator. The Average Current Monitor (ACM) is part of the Beam Containment System (BCS) for the LCLS-II accelerator. The Beam Containment System is a safety system that provides paths to safely shut the accelerator beam off under a variety of conditions. The Average Current Monitor is a beam diagnostic within the BCS that is used to verify that the accelerator is producing the appropriate current level and to limit beam power to allowed values to protect the machine and beam dumps. The average beam current is obtained by measuring the power level induced by the beam in a low Q cavity. By knowing the Q, the beta, and the coupling of the cavity, the instantaneous charge can be calculated, then integrating the instantaneous charge over one millisecond will yield the average current. This paper will discuss progress in the checkout process of the ACM LLRF hardware leading to LCLS-II commissioning.

MOPA31

Plasma Photocathode Based on Ionization of Neutral Gas Triggered by the Superposition of Laser and Plasma Wakefields

P. Manwani, Y. Kang, N. Majernik, J.B. Rosenzweig (UCLA) D.L. Bruhwiler (RadiaSoft LLC) T. Heinemann (DESY) T. Heinemann, B. Hidding (USTRAT/SUPA) M.D. Litos (Colorado University at Boulder)

Optically triggered ionization in plasma wakefields offers a lot of possibilities to study the injection behavior based on the spatiotemporal location of the laser with respect to the beam plasma structure. The injection position can be carefully optimized considering the overlap of the laser and plasma wakefields leading to the production of beams with varied sets of parameters. This allows for precision timing since injection is essentially locked to the wake and considerations on laser pulse limitations since laser fields are supplemented by the strong electric fields created by the collective separation of the plasma species. The possible witness beam parameters resulting from such an interaction are discussed in this paper using particle-in-cell (PIC) simulations with an emphasis on the parameters achievable at the FACET-II facility.

MOPA32

Transverse Beam Dynamics With Synergia III

O. Mohsen, R. Ainsworth, A.V. Burov, E.G. Stern (Fermilab)

Seeing and possibly breaking the beam intensity limitations require a better understanding of beam instabilities. To be reliable, such understanding requires good simulations tools. In this work, we carry out simulations of single bunch transverse instabilities of proton beams under the presence of space charge and different types of impedance. Specifically, we use Synergia III as our simulation tool and benchmark its results with the relevant theoretical models.

MOPA33

Waker Experiments at Fermilab Recycler Ring

O. Mohsen, R. Ainsworth, A.V. Burov (Fermilab)

Attaining high-intensity hadron beams is often limited due to the transverse collective instabilities, whose understanding is thus required to see and possibly extend the intensity limitations. To explore such instabilities, a novel artificial wake system, the waker, has been built and tested at the Fermilab Recycler Ring (RR). In this report, we show recent upgrades of the waker. Also, we present experimental studies of instabilities at various space charge and wake parameters.

Noise in Intense Electron Bunches

MOPA34

S. Nagaitsev, D.R. Broemmelsiek, J.D. Jarvis, A.H. Lumpkin, J. Ruan, G.W. Saewert, R.M. Thurman-Keup (Fermilab) Z. Huang, G. Stupakov (SLAC) Y.K. Kim (University of Chicago)

We report on our investigations into density fluctuations in electron bunches. Noise and density fluctuations in relativistic electron bunches, accelerated in a linac, are of critical importance to various Coherent Electron Cooling (CEC) concepts as well as to free-electron lasers (FELs). For CEC, the beam noise results in additional diffusion that counteracts cooling. In SASE FELs, a microwave instability starts from the initial noise in the beam and eventually leads to the beam microbunching yielding coherent radiation, and the initial noise in the FEL bandwidth plays a useful role. In seeded FELs, in contrast, such noise interferes with the seed signal, so that reducing noise at the initial seed wavelength would lower the seed laser power requirement. Our research goals are (1) to measure the electron beam density noise level in a 0.5 to 10 um wavelength range, (2) to predict the beam noise level in order to compare with the measurements, and (3) to find mechanisms that affect the beam noise to control its level in a predictable manner. In this presentation we will describe our progress to date as well as our future experimental plans at Fermilab's FAST electron linac.

Studies of Injection Painting From the Fermilab SRF Linac in PIP-III Upgrade Scenarios

MOPA35

D.V. Neuffer, J.S. Eldred (Fermilab)

In high-intensity Fermilab upgrade scenarios, H^- charge-exchange injection over many turns must be used to accumulate protons in a storage ring or accelerator. The technique of injecting the linac beam onto a carbon foil to accumulate beam in a larger phase space beam (injection "painting") is discussed and developed. Manipulation of the injection parameters to minimize the number of foil hits and degree of foil heating, while optimizing the phase space in the storage ring, is discussed. Parameters for 0.8, 2.0, and 8 GeV Linac injection are discussed.

Optimization of Superconducting Linac for Proton Improvement Plan-II (PIP-II)

MOPA36

A. Pathak, E. Pozdeyev (Fermilab)

PIP-II is an essential upgrade of the Fermilab complex that will enable the world's most intense high-energy beam of neutrinos for the international Deep Underground Neutrino Experiment at LBNF and support a broad physics program at Fermilab. Ultimately, the PIP-II superconducting linac will be capable of accelerating the H^- CW beam to 800 MeV with an average power of 1.6 MW. To operate the linac with such high power, beam losses and beam emittance growth must be tightly controlled. In this paper, we present the results of global optimization of the Linac options towards a robust and efficient physics design for the superconducting section of the PIP-II linac. We also investigate the impact of the nonlinear field of the dipole correctors on the beam quality and derive the requirement on the field quality using statistical analysis. Finally, we assess the need to correct the quadrupole focusing produced by Half Wave, and Single Spoke accelerating cavities. We assess the feasibility of controlling the beam coupling in the machine by changing the polarity of the field of Linac focusing solenoids

Accelerated Lifetime Test of the SRF Cavity Tuner/Dressed Cavity System for the LCLS II He Project

MOPA38

Y.M. Pischalnikov, T.T. Arkan, C. Contreras-Martinez, B.D. Hartsell, J.A. Kaluzny, Y.M. Orlov, R.V. Pilipenko, J.C. Yun (Fermilab) W. Lahmadi (Wahid Lahmadi)

The off-frequency detune method is being considered for application in the LCLS-II-HE superconducting linac to produce multi-energy electron beams for supporting multiple undulator lines simultaneously. Design of the tuner has been changed to deliver roughly 3 times larger frequency tuning range. Working requirements for off-frequency operation (OFO) state that cavities be tuned at least twice a month. This specification requires the increase of the tuner longevity by 30 times compared with LCLS-II demands. Accelerated longevity tests of the LCLS-II HE dressed cavity with tuner were conducted at FNAL's HTS. Detail analysis of wearing and impacts on performances of the tuner's piezo and stepper motor actuators will be presented. Additionally, results of longevity testing of the dressed cavity bellow, when cooled down to 2 K and compressed by 2.6 mm for roughly 2000 cycles, will be presented.

MOPA39

2.6-GHz SRF Cavity Tuner for DarkPhoton Experiment

Y.M. Pischalnikov, C. Contreras-Martinez, I.V. Gonin, T.N. Khabiboulline, O.S. Melnychuk, R.V. Pilipenko, S. Posen, O.V. Pronitchev, J.C. Yun (Fermilab)

There are several experiments ongoing at FNAL that require frequency tuning of bare (undressed) SRF cavities when they are cooled down and operated inside dilution refrigerator. One of these experiments is for the search of dark photons using a 2.6-GHz SRF cavity. The limited heat capacity of a dilution refrigerator prevents using a stepper motor for an SRF cavity tuner. The tuner for the 2.6 GHz SRF cavity will be equipped with encapsulated piezo actuators that will deliver long and short-range frequency tuning. Design of the tuner and results of the testing cavity/tuner system at ambient environment and at $T = 2\,\mathrm{K}$ will be presented.

MOPA41

Linac Diagnostics for Machine Learning Applications

R.V. Sharankova, K. Seiya, M.E. Wesley (Fermilab) M.W. Mwaniki (IIT)

The Fermilab Linac delivers 400 MeV H^- beam to the rest of the accelerator chain. Providing stable intensity, energy, and emittance is key since it directly affects downstream machines. To operate high current beam, accelerators must minimize uncontrolled particle loss; this is generally accomplished by minimizing beam emittance. Ambient temperature and humidity variations are known to affect resonance frequency of the accelerating cavities which induces emittance growth. In addition, the energy and phase space distribution of particles emerging from the ion source are subject to fluctuations. To counter these effects we are working on implementing dynamic longitudinal parameter optimization based on Machine Learning (ML). As an input for the ML model, signals from beam diagnostic have to be well understand and reliable. We have been revisiting diagnostics in the linac. In this presentation we discuss the status of the diagnostics and beam studies as well as the status and plans for ML-based optimization.

MOPA42

Considerations Concerning the Use of HTS Conductor for Accelerator Dipoles with Inductions above 15 T

M.A. Green (LBNL)

The use of high temperature superconductors for accelerator dipole has been discussed for about twenty years and maybe a little more. Conductors that can potentially be used for accelerator magnets have been available for about fifteen years. These conductors are REBCO tape conductors, which can be wound into coils with no reaction after winding, and BISSCO cable conductors, which require reaction after winding and insulation after reaction in a process similar to Nb_3Sn cables. Both conductors are expensive and the process after reacting is expensive. Some unknown factors that remain: Will either conductor degrade in current carrying capacity with repeated cycling like Nb_3Sn cables do? The other two issues are problems for both types of HTS conductors and they are; 1) quench protection in the event of a normal region run-away and 2) dealing with the superconducting magnetization inherent with HTS cables and tapes. This paper will discuss the last two issues and maybe will provide a partial solution to these problems.

MOPA43

Dee Voltage Regulator for the 88-Inch Cyclotron

M. Kireeff, P. Bloemhard, T. Hassan, L. Phair (LBNL)

A new broadband Dee voltage regulator was designed and built for the 88-Inch Cyclotron at Lawrence Berkeley National Laboratory. The previous regulator was obsolete, consequently, it was difficult to troubleshoot and repair. Additionally, during operation, it displayed problems of distortion and stability at certain frequencies. The new regulator uses off-the-shelf components that can detect and disable the RF during sparking events, protecting the RF driver system. Furthermore, it improves the tuning of the cyclotron and allows consistency in operation.

MOPA44

Utilizing Python to Prepare the VENUS Ion Source for Machine Learning

A. Kireeff, L. Phair, M.J. Regis, M. Salathe, D.S. Todd (LBNL)

The fully superconducting electron cyclotron resonance (ECR) ion source VENUS is one of the world's two highest-performing ECR ion sources, and a copy of this source will soon be used to produce ion beams at FRIB. The tuning and optimization of ECR ion sources is time consuming, and there are few detailed theoretical models to guide this work. To aid in this process, we are working toward utilizing machine learning to both efficiently optimize VENUS and reliably maintain its stability for long campaigns. We have created a Python library to interface with the programmable logic controller (PLC) in order to operate VENUS and collect and store source and beam data. We will discuss the design

and safety considerations that went into creating this library, the implementation of the library, and some of the capabilities it enables.

Vacuum Electron Devices in the 88-Inch Cyclotron

MOPA45

M. Kireeff Covo, J.Y. Benitez, P. Bloemhard, J.P. Garcia, B. Ninemire, L. Phair, D.S. Todd, D.Z. Xie (LBNL)

The 88-Inch Cyclotron at Lawrence Berkeley National Laboratory is a sector-focused cyclotron that has light- and heavy-ion capabilities and supports a local research program in nuclear science and is the home of the Berkeley Accelerator Space Effects Facility, which studies effects of radiation on microelectronics, optics, materials, and cells. The cyclotron utilizes several vacuum electron devices (VEDs) in different systems, mainly to convey plasma heating, high power RF generation, and high-voltage and current DC power generation. VEDs have been proven reliable, robust, and radiation resistant. They also have wide range, good response against transients, and stable operation with load mismatch during system tuning, instabilities, or breakdowns. The paper will describe applications of these devices in the 88-Inch Cyclotron

Cryogenic Dielectric Structure With GOhm/m Level Shunt Impedance

MOPA46

R.A. Kostin, C. Jing (Euclid Beamlabs)

Shunt impedance is one of the most important parameters characterizing particle acceleration efficiency. It is well known that RF losses are reduced at cryogenic temperatures. For example, a record high shunt impedance of 350 MOhm/m was demonstrated recently for all metal X-band structure, which is more than 2 times higher than at room temperature. However, hybrid dielectric structures can achieve even higher values due to the fact that losses in dielectric materials reduced much more than in pure copper. In this paper we will cover potential designs of dielectric structures which can achieve twice as high shunt impedance at cryogenic temperatures than all metal structures. Mechanical design suggestions and thermal simulations will be also provided.

Progress Toward Commercial Epitaxy of Alkali Antimonide Photocathodes

MOPA47

E.J. Montgomery, C.-J. Jing, S. Poddar (Euclid Beamlabs) O. Chubenko, G.S. Gevorkyan, S.S. Karkare, P. Saha (Arizona State University) H.A. Padmore (LBNL)

Photoemitted electron beams unavoidably exhibit nonzero transverse momenta. Ultra-low transverse emittance must be achieved for higher-performance free electron lasers (FEL), colliders, and ultrafast electron diffraction/microscopy (UED/UEM). For high rep rate and high peak current, good quantum efficiency (QE) is needed to avoid laser-induced non-linearities or heating. Copper enables 100 pC bunches at ϵ=0.4 µm. Advances towards ϵ=0.1 µm require ultra-low emittance semiconductors. We report efforts towards epitaxial growth of cesium antimonide and commercial production capability at Euclid Techlabs. Future work will emphasize repeatability and deposition parameters, and in-gun emittance measurement at cryogenic temperatures is planned.

Laser-Plasma Interactions and THz Radiation in LWFA

MOPA48

K.A. Wolfinger, M.D. Litos (Colorado University at Boulder) J.R. Cary (Tech-X) J.R. Cary, V. Lee, G.R. Werner (CIPS)

Numerical simulations of laser-plasma interactions in laser wakefield acceleration (LWFA) demonstrate the generation of axially polarized electromagnetic pulses (EMPs). These EMPs radiate away energy with a characteristic frequency determined by the plasma frequency, in the THz range for typical LWFA experiments. This is confirmed by full 2D electromagnetic particle-in-cell (PIC) simulations, which are replicated by a ponderomotively-driven reduced model that captures the EMP generation essentials. For a pulse length matched to the plasma wavelength, we compare the laser pulse's fractional energy losses to the wakefield and the EMP. As the pulse's transverse width becomes smaller than its length, both the fractional energy losses to the EMP and the electromagnetic components of the wakefield increase.

MOPA49

Measurements and Simulations of a Ti:Sapphire Crystal at kHz Repetition Rates

D.T. Abell, D.L. Bruhwiler, P. Moeller, R. Nagler, B. Nash, I.V. Pogorelov (RadiaSoft LLC) Q. Chen, C.G.R. Geddes, C. Toth, J. van Tilborg (LBNL) N.B. Goldring (STATE33 Inc.)

Next-generation multi-TeraWatt-scale femtosecond laser systems will operate at kHz-scale repetition rates. We present recent measurements of single-pass propagation of an infrared seed pulse through a single Ti:Sapphire crystal, pumped at 1 kHz rate. Measurements are made with and without thermal effects (pumping). By adjusting the relative timing of the pump and seed pulses, we measure the seed pulse evolution with and without laser amplification. The open source finite-element code FEniCS [1] is used to simulate thermal transport within the crystal, inferring the expected quadratic radial variation of the near-axis index of refraction. Python representations of the longitudinally-integrated seed laser wavefront are instantiated from wavefront sensor diagnostic data. The open source SRW code [2] is used to propagate the wavefront through the crystal, including thermal focusing and laser amplification. The simulation results are compared with experimental data and with published analytic models.

MOPA50

Integrated Photonics Structure Cathodes for Longitudinally Shaped Bunch Trains

S.J. Coleman, D.T. Abell, C.C. Hall (RadiaSoft LLC) R. Kapadia (University of Southern California) S.S. Karkare (Arizona State University) P. Piot, J.F. Power (ANL)

Compact, high-gradient structure wakefield accelerators can operate at improved efficiency using shaped electron beams, such as a high transformer ratio beam shape, to drive the wakes. These shapes have generally come from a photocathode gun followed by a transverse mask to imprint a desired shape on the transverse distribution, and then an emittance exchanger (EEX) to convert that transverse shape into a longitudinal distribution. This process discards some large fraction of the beam, limiting wall-plug efficiency as well as leaving a solid object in the path of the beam. In this paper, we present a proposed method of using integrated photonics structures to control the emission pattern on the cathode surface. This transverse pattern is then converted into a longitudinal pattern at the end of an EEX. This removes the need for the mask, preserving the total charge produced at the cathode surface. We present simulations of an experimental set-up to demonstrate this concept at the Argonne Wakefield Accelerator.

MOPA51

Electron Beam Phase Space Reconstruction From a Gas Sheet Diagnostic

N.M. Cook, A. Diaw, C.C. Hall (RadiaSoft LLC) G. Andonian (RadiaBeam) N.P. Norvell (UCSC) M. Yadav (The University of Liverpool)

Next generation particle accelerators demand increasingly high brightness beams for applications ranging from colliders to free electron lasers to studies of nonperturbative QED. These rigorous requirements on bunch charge and shape introduce diagnostic challenges for effectively measuring beam parameters at interaction points. We report on the simulation and training of a non-destructive beam diagnostic capable of characterizing high intensity charged particle beams. The diagnostic consists of a tailored neutral gas curtain, electrostatic microscope, and high sensitivity camera. An incident electron beam ionizes the gas curtain, while the electrostatic microscope transports generated ions to an imaging screen. Simulations of the ionization and transport process are performed using the Warp code. Then, a neural network is trained to provide accurate estimates of the initial electron beam parameters. We present initial results for a range of beam and gas curtain parameters and comment on extensibility to other beam intensity regimes.

MOPA52

Online Correction of Laser Focal Position Using FPGA-Based ML Models

N.M. Cook, S.J. Coleman, J.P. Edelen, J.A. Einstein-Curtis (RadiaSoft LLC) S.K. Barber, C.E. Berger, J. van Tilborg (LBNL)

Ultrafast lasers play an increasingly critical role in the generation, manipulation, and acceleration of electron beams for High Energy Physics applications. Laser plasma accelerators enable order of magnitude improvements in accelerating gradient and promise compact tunable GeV electron beam sources, while novel photocathode systems permit fundamental advances in electron beam manipulation for accelerator and radiation applications Advances in fast feedback systems are required to stabilize laser performance at kHz repetition rate operation against environmental fluctuations. A field programmable gate array (FPGA) based digital control system, coupled with responsive optics, can provide rapid and precise stabilization of ultrafast lasers. A collaboration between RadiaSoft and the Lawrence Berkeley National Laboratory BELLA Center to develop, test, and deploy these systems across a range of beamlines operating at >1 Hz repetition rate, including 1 kHz systems, was created.

An Integrated Data Processing and Management Platform for X-Ray Light Source Operations

MOPA53

N.M. Cook, E.G. Carlin, R. Nagler, B. Nash (RadiaSoft LLC) A.M. Barbour, M.S. Rakitin, L. Wiegart (BNL)

The design, execution, and analysis of light source experiments requires the use of increasingly complex simulation, controls and data management tools. Existing workflows require significant specialization to account for beamline-specific operations and pre-processing steps in order to collect and prepare data for more sophisticated analysis. Recent efforts to address these needs at the National Synchrotron Light Source II (NSLS-II) have resulted in the creation of the Bluesky data collection framework, an open-source library providing for experimental control and scientific data collection via high level abstraction of experimental procedures, instrument readouts, and data analysis. We present a prototype data management interface that couples with Bluesky to support guided simulation, measurement, and rapid processing operations. Initial demonstrations illustrate application to coherent X-ray scattering beamlines at the NSLS-II. We then discuss extensions of this interface to permit analysis operations across distributed computing resources, including the use of the Sirepo scientific framework, as well as Jupyter notebooks running on remote computing clusters.

Influence of Electron Transport Coefficients Models on Capillary Discharge Plasmas

MOPA54

A. Diaw, S.J. Coleman, N.M. Cook, J.P. Edelen (RadiaSoft LLC) E.C. Hansen, P. Tzeferacos (Flash Center for Computational Science)

Magnetohydrodynamics (MHD) is a fluid dynamics model of long-wavelength and low-frequency plasma behavior, accounting for thermal conduction and radiative energy loss. MHD can be applied to a wide range of plasma phenomena and problems in capillary discharge waveguides dynamics. Typical MHD simulations are highly sensitive to the microscopic closure models, such as transport properties. As part of an effort to understand and quantify uncertainties in modeling and designing next-generation plasma accelerators, we study the impact of electron heating and thermal conduction on capillary waveguide performance. First, we implement three different transport models into the FLASH code (i) Davies et al., (ii) Spitzer, and (iii) Epperlein-Haines (EH). Second, we perform 2D high-resolution MHD simulations using an argon-filled capillary discharge waveguide. We demonstrate that the EH model significantly overestimates the electron temperature inside the channel while predicting a lower azimuthal magnetic field. Moreover, the Spitzer model, often used in MHD simulations for plasma-based accelerators, predicts a significantly higher electron temperature than the other models suggest.

Facilitating Machine Learning Collaborations Between Labs, Universities, and Industry

MOPA55

J.P. Edelen, D.T. Abell, D.L. Bruhwiler, S.J. Coleman, N.M. Cook, A. Diaw, J.A. Einstein-Curtis, C.C. Hall, M.C. Kilpatrick, B. Nash, I.V. Pogorelov (RadiaSoft LLC) K.A. Brown (BNL) S. Calder (ORNL RAD) A.L. Edelen (SLAC) C.M. Hoffmann (ORNL) P. Piot (Northern Illinois University) C. Tennant (JLab)

The phrase "Machine Learning for Accelerators" has become ubiquitous in community reports, papers, proposals, and presentations. This quickly evolving landscape continues to grow in both the breadth and depth of applications including, physics modeling, anomaly detection, controls, diagnostics, and analysis. Consequently, laboratories, universities, and companies across the globe have established dedicated ML and data-science groups and collaborations aiming to address this burgeoning array of accelerator technology problems. However, the compartmentalization of both small and large collaborations coupled with a funding environment that supports specific application spaces has limited the ability for the field to advance in a highly efficient manner. A paradigm shift is needed to better leverage community resources and to take the next step towards advancing machine learning technology. This talk will discuss how direct and open collaboration between labs, universities, and industry can fuel the next wave of ML advancements and accelerate their adoption in the field.

Identification of Superconducting Magnet Quenches with Machine Learning

MOPA56

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Superconducting magnet technology is one of the cornerstones of large particle accelerator facilities. A challenge with operating these systems is the possibility for the magnets to quench. The ability to predict quenches and take preventative action in advance, would no doubt decrease the likelihood of a catastrophic failure and increase the lifetime operability of particle accelerators. We are in development of a machine learning workflow for the deployment of quench detection and prediction systems that can be integrated with real time systems and accelerator operations. In collaboration with Brookhaven National Laboratory, our methods for algorithm development will utilize magnet data from singular test stands and those that are in operation at the Relativistic Heavy Ion Collider to allow for a robust identification of magnet quenches. We aim to reduce the false positive identification of magnet quenches and identify precursors to prospective quench events in magnet data.

MOPA57

Online Models for X-Ray Beamlines

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X-ray beamlines transport synchrotron radiation from the magnetic source to the sample at a synchrotron light source. Alignment of elements such as mirrors and gratings are often done manually and can be quite time consuming. The use of photon beam models during operations is not common in the same way that they are used to great benefit for particle beams in accelerators. Linear and non-linear optics including the effects of coherence may be computed from source properties and augmented with measurements. In collaboration with NSLS-II, we are developing software tools and methods to include the model of the x-ray beam as it passes on its way to the sample. We are integrating the Blue-Sky beamline control toolkit with the Sirepo interface to several x-ray optics codes. Further, we are developing a simplified linear optics approach based on a Gauss-Schell model and linear canonical transforms as well as developing Machine Learning models for use directly from diagnostics data. We present progress on applying these ideas on NSLS-II beamlines and give a future outlook on this rather large and open domain for technological development.

MOPA58

An Algorithm for Suppression of Speckle Noise in Neutron Camera Images

I.V. Pogorelov, J.P. Edelen (RadiaSoft LLC)

Neutron camera images from beamlines at neutron scattering facilities, such as those at Oak Ridge National Laboratory, are contaminated by speckle noise. Denoised images are useful for, among other things, training various machine learning models developed to assist in automated sample positioning during experiments. Peculiar statistical properties of the speckle noise render conventional denoising techniques ineffective. We prototyped a customized denoising algorithm, based on a particular way of computing an inscribed envelope of the signal (image), that performed well on real-life neutron camera image data.

MOPA59

Prediction of Gaseous Breakdown for Plasma Cleaning of RF Cavities

S.A. Ahmed (Ansys, Inc.)

The quest for a high accelerating gradient in superconducting radio frequency cavity attracted scientists to adopt the plasma cleaning technology. Generating an efficient plasma inside a complex cavity structure for a desired frequency, gas types, and pressure for a given temperature is a challenge. The onset of discharge can be obtained from the well-known Paschen curve. Setting up an experiment is expensive and time-consuming, which may lead to a significant delay in the project. A high-fidelity computer simulation, modeling an arbitrary geometry and tracking the Paschen curve in a complex electromagnetic environment is therefore necessary. Ansys HFSS through its Finite Element Mesh (FEM) for the full-wave EM simulations combined with the electron impact ionization of gases enables the successful prediction of plasma breakdown for an arbitrary configuration for a wide frequency band and variety of gases. A comprehensive study will be demonstrated at the conference.

MOPA60

HFSS Enables Multipaction Analysis of High Power RF/Microwave Components

S.A. Ahmed (Ansys, Inc.)

The radiofrequency (RF) components in particle accelerators operated under a vacuum and driven by high RF power may be prone to electron multipaction — an RF triggered electron resonance phenomenon causing malfunction or complete breakdown. Therefore, exploring the design challenges of vacuum RF windows, cavities, and other devices for the electron multipaction becomes necessary. Setting up an experiment to mitigate the failure of RF devices is expensive and time-consuming, which may cause a significant delay in the project. Therefore, a high-fidelity computer simulation modeling the arbitrary geometry and tracking the particles (electrons) in a complex electromagnetic environment is desirable. Ansys HFSS through Finite Element Mesh (FEM) for the full-wave RF simulation combined with the particle-in-cell (PIC) technique for tracking particles in EM fields; enables the engineers/physicist successful prediction of system failure against the electron multipaction. This paper will demonstrate the workflow of the HFSS multipaction analysis.

High-Power Solid State Switching for RFQ Linac Drive Chain

MOPA61

E.L. Atkinson, T.J. Houlahan, B.E. Jurczyk, R.A. Stubbers (Starfire Industries LLC)

In this work, we present operational and performance data for a solid state switching circuit that delivers pulsed power at up to 12 kV and 100 A. This circuit, which is comprised of a series configuration of IGBT-based subcircuits, is suitable for driving the high-power vacuum-tube amplifiers that are typically used in RF accelerator systems. Each subcircuit can switch up to 3 kV, and the subcircuits can be stacked in series to extend the overall voltage capabilities of the switch. The circuit is designed to prevent overvoltaging any single transistor during switching transients or faults, regardless of the number of series subcircuits. Further, the circuit also includes the capability for rapid arc detection and suppression. We have demonstrated switching up to 100 A at 12 kV and for pulse repetition frequencies and durations in the range of 1-200 Hz and 10-50 μs, respectively. Additionally, we have demonstrated that the arc suppression circuitry reliably limits arcs at 10-12 kV with a quench time of ~1 μs and with a total energy of <0.2 J, minimizing the grid erosion in the vacuum tube during an arc. Performance data will be presented and discussed.

High Quality Conformal Coatings on Accelerator Components via Novel Radial Magnetron With High-Power Impulse Magnetron Sputtering

MOPA62

W.M. Huber, I. Haehnlein, T.J. Houlahan, B.E. Jurczyk, A.S. Morrice, R.A. Stubbers (Starfire Industries LLC)

In this work, we present two configurations of a novel radial magnetron design that are suitable for coating the complex inner surfaces of a variety of modern particle accelerator components. These devices have been used in conjunction with high-power impulse magnetron sputtering (HiPIMS) to deposit copper and niobium films onto the inner surfaces of bellows assemblies, waveguides, and SRF cavities. These films, with thicknesses of up to 3 μm and 40 μm for niobium and copper, respectively, have been shown to be conformal, adherent, and conductive. In the case of copper, the post-bake RRR values of the resulting films are well within the range specified for electroplating of the LCLS-II bellows and CEBAF waveguide assemblies. In addition to requiring no chemical processing beyond a detergent rinse and solvent degrease, this magnetron design exhibits over 80% target material utilization. Further, in the case of niobium, an enhancement in RRR over that of the bulk (target) material has been observed.

Multiphysics Simulation of the Thermal Response of a Nanofibrous Target in a High-Intensity Beam

MOPA63

W.J. Asztalos (IIT) S.K. Bidhar, F. Pellemoine (Fermilab) P. Rath (IIT Bhubaneswar)

Nanofibrous structures are of high interest to the fields of engineering and material science, and investigation of their properties as well as discovery of novel applications for them both constitute lively areas of research. A very promising application of nanofiber mats lies in the field of accelerator technology: beam targets made from nanofiber mats offer a solution to the problem of advancing the "intensity frontier" — the limit on the beam intensities that can be realized in fixed target experiments and neutrino production facilities. However, testing has shown that the survivability of these nanofiber targets depends strongly on their manufacturing parameters, such as the packing density of fibers. Higher density mats developed a hole in their center and became rigid following beam exposure, with the exact cause of the failure unclear. Lower density mats, on the other hand, were undamaged and retained their flexibility. In this work, we will use multiphysics simulations to perform a thermal study on how nanofiber targets react to high intensity beams, so that the dependency of the nanofiber targets' lifetime on its construction parameters can be better understood.

Circular Modes for Mitigating Space-Charge Effects and Enabling Flat Beams

MOPA64

O. Gilanliogullari (IIT) B. Mustapha (ANL) P. Snopok (Illinois Institute of Technology)

Flat beams are preferred in high-intensity accelerators and high-energy colliders due to one of the transverse plane emittances being smaller, which enhances luminosity and beam brightness. However, flat beams are devastating at low energies due to space charge forces which are significantly enhanced in one plane. The same is true, although to a lesser degree, for non-symmetric elliptical beams. In order to mitigate this effect, circular mode beam optics can be used. In this paper, we show that circular mode beams dilute space charge effects at lower energies, and can be transformed to flat beams later on.

MOPA66

Hadron Monitor Calibration System for NuMI

N.L. Muldrow (IIT) P. Snopok (Illinois Institute of Technology) K. Yonehara (Fermilab)

NuMI (Neutrinos at Main Injector) beamline at Fermi National Accelerator Laboratory provides neutrinos to various neutrino experiments. The hadron monitor consisting of a 5 by 5 array of ionization chambers is part of the diagnostics for the beamline. In order to calibrate the hadron monitor, a gamma source is needed. We present the status and progress of the development of the calibration system for the hadron monitor. The system based on Raspberry Pi controlled CNC system, motors, and position sensors would allow us to place the gamma source precisely to calibrate the signal gain of individual pixels. The ultimate outcome of the study is a prototype of the calibration system.

MOPA67

Examining the Effects of Oxygen Doping on SRF Cavity Performance

H. Hu, Y.K. Kim (University of Chicago) D. Bafia (Fermilab)

Superconducting radio frequency (SRF) cavities are resonators with extremely low surface resistance that enable accelerating cavities to have extremely high quality factors (Q_0). High Q_0 decreases the capital required to keep the accelerators cold by reducing power loss. The performance of SRF cavities is largely governed by the surface composition of the first 100 nm of the cavity surface. Impurities such as oxygen and nitrogen have been observed to yield high Q_0, but their precise roles are still being studied. Here, we compare the performance of cavities doped with nitrogen and oxygen in terms of surface composition and heating behavior with field. Understanding how these impurities affects the performance of these cavities allows us to have further insight into the underlying mechanisms that enable these surface treatments to yield high Q_0 performance.

MOPA68

Adjoint Optimization of Circular Lattices

T.M. Antonsen, L. Dovlatyan, A.K. Einarsson, I. Haber, P.G. O'Shea, P.G. O'Shea (UMD)

Design of circular lattices involves optimizing figures of merit (FoMs) characterizing the beam properties subject to the constraint that the beam distribution function be approximately periodic in trips around the lattice. We are developing an algorithm that accomplishes this with minimal computational effort. The algorithm takes advantage of recent developments in adjoint techniques [1] that allow the derivatives of the FoM with respect to the many parameters describing the lattice to be evaluated. The present description of the accelerator is based on the 10 second moments of the beam distribution function in the transverse phase space. However, extensions to kinetic descriptions will be discussed. Our algorithm, which we name "Adjoint with a Chaser", works as three separate minimizations run concurrently. These three working together force the beam into a periodic state, while varying parameters to minimize an FoM. Examples relevant to the Maryland lattice UMER will be presented.

MOPA69

Adjoint Optimization Applied to Flat to Round Transformers

T.M. Antonsen, B.L. Beaudoin, S. Bernal, L. Dovlatyan, I. Haber, P.G. O'Shea, D.F. Sutter (UMD)

We present the numerical optimization, using adjoint techniques, of Flat-to-Round (FTR) transformers operating in the strong self-field limit. FTRs transform an unmagnetized beam that has a high aspect ratio, elliptical spatial cross section, to a round beam in a solenoidal magnetic field. In its simplest form the flat to round conversion is accomplished with a triplet of quadrupoles, and a solenoid. FTR transformers have multiple applications in beam physics research, including manipulating electron beams to cool co-propagating hadron beams. Parameters that can be varied to optimize the FTR conversion are the positions and strengths of the four magnet elements, including the orientations and axial profiles of the quadrupoles and the axial profile and strength of the solenoid's magnetic field. The adjoint method we employ [1] allows for optimization of the lattice with a minimum computational effort including self-fields. The present model is based on a moment description of the beam. However, the generalization to a particle description will be presented. The optimized designs presented here will be tested in experiments under construction at the University of Maryland.

MOPA70

Film Dosimetry Characterization of the Research Linac at the University of Maryland

A.S. Johnson, L.T. Gilde, M.K. Hottinger, T.W. Koeth (UMD)

A heavily modified Varian linac was installed as part of the University of Maryland Radiation Facilities in the early 1980s. The electron linac was initially used for materials testing and pulsed radiolysis. Overtime, diagnostics such as a spectrometer magnet and scintillator screens have been removed, limiting the ability to describe the electron beam. The beamline is currently configured with a thin titanium window to allow the electrons to escape the vacuum region

and interact with samples in air. A calibrated film dosimetry system was used to characterize the transverse beam dimensions and uniformity in air. The results of these experimental measurements will be described in this paper.

Demonstration of Flat/Round Transformations of Angular Momentum and Space-Charge Dominated Electron Beams

MOPA71

P.G. O'Shea, T.M. Antonsen, B.L. Beaudoin, S. Bernal, L. Dovlatyan, I. Haber, L.A. Pocher, D.F. Sutter (UMD)

We describe an experiment under development to demonstrate Derbenev's flat-to-round (FTR) [1] and round-to flat (RTF) optical transformations, designed to match electron beams from a high energy storage ring into and out of a solenoidal cooling channel. We are using a modified, existing linear transport system with a design optimized by applying a computationally-efficient adjoint numerical optimization technique being developed by our group for general application to beam optical systems [2]. We are exploring the optimization of FTR/RTFs using a system of moment equations using adjoint techniques. We will first explore cases of low space charge followed by further examples with significant space charge, comparing simulations to beam measurements and reoptimizing the design as needed to test alternative experimental configurations. Our goal is to experimentally test the Derbenev scheme, which has not been done in its entirety, and to carry out a rigorous, experimental validation of the adjoint techniques.

Preliminary Tests and Beam Dynamics Simulations of a Straight-Merger Beamline

MOPA72

A.A. Al Marzouk, P. Piot, T. Xu (Northern Illinois University) S.V. Benson (JLab) P. Piot, J.G. Power, E.E. Wisniewski (ANL)

Beamlines capable of merging beams with different energies are critical to many applications related to advanced accelerator concepts and energy-recovery linacs (ERLs). In an ERL, a low-energy "fresh" bright bunch is generally injected into a superconducting linac for acceleration using the fields established by a decelerated "spent" beam traveling on the same axis. A straight-merger system composed of a selecting cavity with a superimposed dipole magnet was proposed and recently test at AWA. This paper reports on the experimental results obtained so far along with detailed beam dynamics investigations of the merger concept and its ability to conserve the beam brightness associated with the fresh bunch.

First-Principle Simulation of a Bunch Compressor for the Argonne Wakefield Accelerator

MOPA73

A.A. Al Marzouk, P. Piot (Northern Illinois University) P. Piot (ANL)

Increasing the 5D brightness is critical to a number of applications related to light sources and advanced accelerator concepts. This paper investigates the implementation of a bunch compressor chicane for the Argonne Wakefield Accelerator (AWA) to increase the peak current and enable high electric field in wakefield accelerators. The simulations are based on the LW3D program [1]. account for collective (including radiative) effects, and perform for a range of bunch charges.

Design of a W-Band Corrugated Waveguide for Structure Wakefield Acceleration

MOPA74

B. Leung, X. Lu, C.L. Phillips, P. Piot (Northern Illinois University) D.S. Doran, X. Lu, P. Piot, J.G. Power (ANL)

Current research on structure wakefield acceleration aims to develop radio-frequency structures that can produce high gradients, with work in the sub-terahertz regime being particularly interesting because of the potential to create more compact and economical accelerators. Metallic corrugated waveguides at sub-terahertz frequencies are one such structure. We have designed a W-band corrugated waveguide for a collinear wakefield acceleration experiment at the Argonne Wakefield Accelerator (AWA). Using the CST Studio Suite, we have optimized the structure for the maximum achievable gradient in the wakefield from a nominal AWA electron bunch at 65 MeV. Simulation results from different solvers of CST were benchmarked with each other, with analytical models, and with another simulation code, ECHO. We are investigating the mechanical design, suitable fabrication technologies, and the possibility to apply advanced bunch shaping techniques to improve the structure performance.

MOPA75

ML Techniques in Slow Spill Regulation System for Mu2e

A. Narayanan (Northern Illinois University)

A third-integer resonant slow extraction system is being developed for the Fermilab's Delivery Ring to deliver protons to the Mu2e experiment. During a slow extraction process, the beam on target is liable to experience small intensity variations due to many factors. Owing to the experiment's strict requirements in the quality of the spill, a Spill Regulation System (SRS) is currently under design. The SRS primarily consists of three components - slow regulation, fast regulation, and harmonic content tracker. In this presentation, we shall present the investigations of using Machine Learning (ML) in the fast regulation system, including further optimizations of PID controller gains for the fast regulation, prospects of an ML agent completely replacing the PID controller using supervised learning schemes such as Long Short-Term Memory (LSTM) and Gated Recurrent Unit (GRU) ML models, the simulated impact and limitation of beam pipe's B-field screening bandwidth on both PID and ML regulation of the spill. We also present here nascent results of Reinforcement Learning efforts, including continuous-action actor-critic methods and soft actor-critic methods, to regulate the spill rate.

MOPA76

Modeling of Sub-Thz Dielectric-Lined Waveguide

C.L. Phillips (Northern Illinois University)

Dielectric-lined waveguides have been extensively studied to potentially support high-gradient acceleration in beam-driven dielectric wakefield acceleration (DWFA) and for beam manipulations. In this paper, we investigate the wakefield generated by a relativistic bunch passing through a dielectric waveguide with different transverse sections. We specifically consider the case of a structure consisting of two dielectric slabs, a rectangular and square structure. Numerical simulations performed with the fine-difference time-domain of the WARPX program reveal some interesting features of the transverse wake and a possible experiment at the Argonne Wakefield Accelerator is simulated using start-to-end simulations combining OPAL with WARPX.

MOPA77

Microbunching Instability in Beam-Driven Structured Wakefield Accelerators

W.H. Tan, P. Piot (Northern Illinois University) P. Piot (ANL)

The development of beam-driven collinear structured wakefield acceleration relies on throughout understanding of the dynamics of the drive beam for sustainable extraction of its energy. We report on the long term simulation studies made possible with the advancement of computational modeling in accelerator physics. We show that apart from the beam-breakup instability due to misalignment, the variation of transverse focusing also induces microbunching instability that deteriorates the drive beam. Simulation examples are shown using electromagnetic code WarpX.

MOPA78

Temporally Shaped Ultraviolet Pulses for Tailored Bunch Generation in Argonne Wakefield Accelerator

T. Xu, P. Piot (Northern Illinois University) S. Carbajo (UCLA) S. Carbajo, R.A. Lemons (SLAC) P. Piot, J.G. Power (ANL)

Photocathode laser shaping is an appealing technique to generate tailored electron bunches due to its versatility and simplicity. Most photocathodes require photon energies exceeding the nominal photon energy produced by the lasing medium. A common setup consists of an infrared (IR) laser system with a 3x frequency conversion to the ultraviolet (UV). In this work, we present the numerical modeling of a temporal shaping technique capable of producing electron bunches with linearly-ramped current profiles for application to collinear wakefield accelerators. Specifically, we show that controlling higher-order dispersion terms associated with the IR pulse provides some control over the UV temporal shape. Possible optics configurations are discussed and beam-dynamics simulation of an electron-bunch shaping experiment at the Argonne Wakefield Accelerator described.

MOPA79

Studying the Emission Characteristics of Field Emission Cathodes With Various Geometries

M.R. Howard, S.M. Lidia (FRIB) J.E. Coleman (LANL)

The cathode test stand (CTS) at LANL is designed to hold off voltages of up to 500kV and can supply pulse durations up to 2.6 μs. Using this test stand, we are able to test both field emission and photocathodes with different geometries and materials at various pulse lengths and PFN voltages. Currently, the test stand is used to evaluate field emission using a velvet cathode over various pulse lengths. The CTS employs various diagnostic tools, including E-dots, B-dots, and a scintillator coupled with a pepperpot mask in order to measure the extracted voltage, current, beam distribution, and transverse emittance. Xenos [1] has been used to create and simulate diode geometries that permits study to optimize various beam parameters. These geometries include changing the size and recess of the cathode as well as implementing a Pierce geometry. Here, we will discuss comparisons for various simulated cathodes and how changes in geometry impact given beam parameters.

Design Study for Non-Intercepting Gas-Sheet Profile Monitor at FRIB

MOPA80

A. Lokey, S.M. Lidia (FRIB)

Non-invasive profile monitors offer a significant advantage for continuous, online monitoring of transverse beam profile and tuning of beam parameters during operation. This is due to both the non-destructive nature of the measurement and the unique feature that some monitors have of being able to determine both transverse profiles in one measurement [1]. One method of interest for making this measurement is the use of a thin gas curtain, which intercepts the beam and generates both ions and photons, which can be collected at a detector situated perpendicular to the gas sheet. This study will investigate the requirements for developing such a measurement device for use at the Facility for Rare Isotope Beams (FRIB), which produces high-intensity, multi charge state, heavy ion beams. Included will be an initial design specifications and an analysis of alternatives between ionization and beam-induced fluorescence measurement techniques for acquiring signal from the gas sheet.

Study of Nonlinear Dynamics in the 4-D Hénon Map Using the Square Matrix Method and Iterative Methods

MOPA81

K.J. Anderson, Y. Hao (FRIB) L.H. Yu (BNL)

The Hénon Map represents a linear lattice with a single sextopole kick. This map has been extensively studied due to it's chaotic behavior. The case for the two dimensional phase space has recently been revisited using ideas from KAM theory to create an iterative process that transforms nonlinear perturbed trajectories into rigid rotations [1]. The convergence of this method relates to the resonance structure and can be used as an indicator of the dynamic aperture. The studies of this method have been extended to the four dimensional phase space case which introduces coupling between the transverse coordinates.

AGS Experiment on Space Charge Driven Third Order Resonance

MOPA82

M.A. Balcewicz, Y. Hao (FRIB) Y. Hao, H. Huang (BNL)

Resonance line crossings at significant space charge tune shifts can exhibit various phenomena due to periodic resonance crossing from synchrotron motion [1] and manifests as halo generation and bunch shortening along with the more mundane emittance growth and beam loss. An injection experiment is conducted at the AGS using the fast wall current monitor and eIPM to probe third order resonances to better characterize the resonance crossing over a 4 ms time scale. This experiment shows good agreement with previous experiments, save for lack of bunch shortening, likely due to relative resonance strength. A study to correct AGS eIPM errors is also performed to validate solutions emittance measurements.

Automation of Superconducting Cavity and Superconducting Magnet Operation for FRIB

MOPA83

W. Chang, Y. Choi, X.-J. Du, W. Hartung, S.H. Kim, T. Konomi, S.R. Kunjir, H. Nguyen, J.T. Popielarski, K. Saito, T. Xu, S. Zhao (FRIB)

The superconducting (SC) driver linac for the Facility for Rare Isotope Beams (FRIB) is a heavy-ion accelerator that accelerate ions to 200 MeV per nucleon. The linac has 46 cryomodules that contain 324 SC cavities and 69 SC solenoid packages. For linac operation with high availability and high reliability, automation is essential for such tasks as fast device turn-on/off, fast recovery from trips, and real-time monitoring of operational performance. We have implemented several automation algorithms, including one-button turn-on/off of SC cavities and SC magnets; automated degaussing of SC solenoids; mitigation of field emission-induced multipacting during recovery from cavity trips; and real-time monitoring of the cavity field level calibration. The design, development, and operating experience with automation will be presented.

MOPA84

Superconducting Cavity Commissioning for the FRIB Linac

W. Chang, W. Hartung, S.H. Kim, T. Konomi, S.R. Kunjir, J.T. Popielarski, K. Saito, T. Xu, S. Zhao (FRIB)

The superconducting driver linac for the Facility for Rare Isotope Beams (FRIB) is a heavy ion accelerator that has 46 cryomodules with 324 superconducting (SC) cavities that accelerate ions to 200 MeV per nucleon. Linac commissioning was done in multiple phases, in parallel with technical installation. Ion beam have now been accelerated to the design energy through the full linac; rare isotopes were first produced in December 2021; and the first user experiment was completed in May 2022. All cryomodules were successfully commissioned. Cryomodule commissioning included establishing the desired cavity fields, measuring field emission X-rays, optimizing the tuner control loops, measuring the cavity dynamic heat load, and confirming the low-level RF control (amplitude and phase stability). Results on cryomodule commissioning and cryomodule performance will be presented.

MOPA85

Design of a 185.7-MHz Superconducting RF Photoinjector Quarter-Wave Resonator for the LCLS-II-HE Low-Emittance Injector

S.H. Kim, W. Hartung, S.J. Miller, J.T. Popielarski, T. Xu (FRIB) C. Adolphsen, L. Ge, F. Ji, J.W. Lewellen, L. Xiao (SLAC) M.P. Kelly, T.B. Petersen (ANL)

A 185.7-MHz superconducting quarter-wave resonator (QWR) was designed for the low emittance injector of the Linac Coherent Light Source high energy upgrade (LCLS-II-HE). The cavity was designed to minimize the risk of cathode efficiency degradation due to multipacting or field emission and to operate with a high RF electric field at the cathode for low electron-beam emittance. Cavity design features include: (1) shaping of the cavity wall to reduce the strength of the low-field coaxial multipacting barrier; (2) four ports for electropolishing and high-pressure water rinsing; and (3) a fundamental power coupler (FPC) port located away from the accelerating gap. The design is oriented toward minimizing the risk of particulate contamination and avoid harmful dipole components in the RF field. The ANL 162-MHz FPC design for PIP-II is being adapted for the gun cavity. We will present the RF design of the cavity integrated with the FPC.

MOPA86

Conditioning of Low-Field Multipacting Barriers in Superconducting Quarter-Wave Resonators

S.H. Kim, W. Chang, W. Hartung, J.T. Popielarski, T. Xu (FRIB)

Multipacting (MP) barriers are typically observed at very low RF amplitude, at a field 2 to 3 orders of magnitude below the operating gradient, in low-frequency (<~100 MHz), quarter-wave resonators (QWRs). Such barriers may be troublesome, as RF conditioning with a fundamental power coupler (FPC) of typical coupling strength (external Q = 10^6 to 10^7) is generally difficult. For the FRIB β = 0.085 QWRs (80.5 MHz), the low barrier is observed at an accelerating gradient (E_{acc}) of ~10 kV/m; the operating E_{acc} is 5.6 MV/m. Theoretical and simulation studies suggested that the conditioning is difficult due to the relatively low RF power dissipated into multipacting rather than being a problem of the low barrier being stronger than other barriers. We developed a single-stub coaxial FPC matching element for external adjustment of the external Q by one order of magnitude. The matching element provided a significant reduction in the time to condition the low barrier. We will present theoretical and simulation studies of the low MP barrier and experimental results on MP conditioning with the single-stub FPC matching element.

MOPA87

Design of the Cathode Stalk for the LCLS-II-HE Low Emittance Injector

T. Konomi, W. Hartung, S.H. Kim, S.J. Miller, D.G. Morris, J.T. Popielarski, K. Saito, A. Taylor, T. Xu (FRIB) C. Adolphsen, J.W. Lewellen (SLAC) S. Gatzmaga, P. Murcek, R. Xiang (HZDR) M.P. Kelly, T.B. Petersen (ANL)

Superconducting radio-frequency (SRF) electron guns are attractive for delivery of beams at a high bunch repetition rate with a high accelerating field. An SRF gun is the most suitable injector for the high-energy upgrade of the Linac Coherent Light Source (LCLS-II-HE), which will produce high-energy X-rays at high repetition rate. An SRF gun is being developed for LCLS-II-HE as a collaborative effort by FRIB, HZDR, ANL, and SLAC. The cavity operating frequency is 185.7 MHz, and the target accelerating field at the photocathode is 30 MV/m. The photocathode is replaceable. The cathode is held by a fixture ('cathode stalk') that is designed for thermal isolation and particle-free cathode exchange. The stalk must allow for precise alignment of the cathode position, cryogenic or room-temperature cathode operating temperature, and DC bias to inhibit multipacting. We are planning a test of the stalk to confirm that the design meets the requirements for RF power dissipation and biasing. In this presentation, we will describe the cathode stalk design and RF/DC stalk test plan.

FRIB and UEM LLRF Controller Upgrade

MOPA88

S.R. Kunjir, E. Bernal, D.G. Morris, S. Zhao (FRIB)

The Facility for Rare Isotope Beams (FRIB) is developing a 644 MHz superconducting cavity (SC) for a future upgrade project. The current low level radio frequency (LLRF) controller at FRIB is not able to operate at 644 MHz. The Ultrafast Electron Microscope (UEM) laboratory within the Department of Physics at Michigan State University designed an LLRF controller based on analog RF components to operate a 1.013 GHz room temperature (RT) cavity. With requirements for improved stability, performance and user controls there was a need to upgrade the analog LLRF controller. The FRIB RF group designed, developed and fabricated a new digital LLRF controller, with high-speed serial interface between system on chip field programmable gate array and fast data converters and capable of high frequency direct sampling, to meet the requirements of 644 MHz SC cavity and 1.013 GHz UEM RT cavity. This paper gives an overview of the upgraded digital LLRF controller, its features, improvements and preliminary test results.

RHIC Electron-Beam Cooling Analysis Using Principle Component and Autoencoder Analysis

MOPA89

A.D. Tran, Y. Hao (FRIB) X. Gu (BNL)

Principal component analysis and autoencoder analysis were used to analyze the experimental data of RHIC operation with low energy RHIC electron cooling (LEReC). This is unsupervised learning which includes electron beam set- tings and observable during operation. Both analyses were used to gauge the dimensional reducibility of the data and to understand which features are important to beam cooling.

Relating Initial Distribution to Beam Loss on the Front End of the Heavy-Ion Linac Using Machine Learning

MOPA90

A.D. Tran, Y. Hao (FRIB) J.L. Martinez Marin, B. Mustapha (ANL)

This work demonstrates using a Neural Network and a Gaussian Process to model the ATLAS front-end. Various neural network architectures were created and trained on the machine settings and outputs to model the phase space projections. The model was then trained on a dataset, with non-linear distortion, to gauge the transferability of the model from simulation to machine.

Plasma Cleaning of Superconducting Quarter-Wave Resonators Using a Higher-Order Mode

MOPA91

W. Hartung, W. Chang, K. Elliott, S.H. Kim, T. Konomi, J.T. Popielarski, K. Saito, T. Xu (FRIB)

The Facility for Rare Isotope Beams (FRIB) is a superconducting ion linac with acceleration provided by 104 quarter-wave resonators (QWRs) and 220 half-wave resonators (HWRs); FRIB user operations began in May 2022. Plasma cleaning is being developed as a method to mitigate possible future degradation of QWR or HWR performance: in-situ plasma cleaning represents an alternative to removal and disassembly of cryomodules for refurbishment of each cavity via repeat etching and rinsing. Initial measurements were done on a QWR and an HWR with room-temperature-matched input couplers to drive the plasma via the fundamental mode. Subsequent plasma cleaning tests were done on two additional FRIB QWRs using the fundamental power coupler (FPC) to drive the plasma. When using the FPC, a higher-order mode (HOM) at 5 times the accelerating mode frequency was used to drive the plasma. Use of the HOM allowed for less mismatch at the FPC and hence lower field in the coupler relative to the cavity. A neon-oxygen gas mixture was used for plasma generation. Before and after cold tests showed a significant reduction in field emission X-rays after plasma cleaning. Results will be presented.

Brightness Mapping in RF Guns

MOPA92

B.G. Sims, S.V. Baryshev (Michigan State University)

High brightness and high charge are two counter processes; maintaining both is difficult with current technologies. The Low Emittance Injector (LEI) for LCLS-II-HE is the most recent example of the necessity of high charge and high brightness systems. The LEI has the goal of 100 pC per bunch and 0.1 µm emittance, together leading to a brightness of the order of 10^{15} A/m^2 rad^2 using a gradient as low as 10 to 30 MV/m. Thus, managing space charge effects is key to the LEI's success. In this work, the effects of transverse and longitudinal bunch forming and their corresponding effects on brightness are explored. This parametrization study is conducted by varying the area that electrons are sourced from and the pulse length to optimize the brightness to benefit from ~0 meV MTE. The intrinsic, space charge, RF, and other dynamics emittance components were evaluated and mapped for highest brightness for the LCLS-II-HE LEI. A counterexample of a 1.3 GHz quarter-wave 100 MV/m gun of the Argonne Cathode Teststand is presented. These examples allow us to emphasize important nuances for optimizing the brightness in low gradient SRF guns against high and ultrahigh gradient copper guns.

TUXD — Accelerator Applications

TUXD1

Radiation Concerns and Mitigation Schemes for Accelerator Facility Components

F. Pellemoine (Fermilab)

Major accelerator facilities are limited in beam power not by their accelerators but by the beam intercepting device survivability. In some cases, the target must endure high power pulsed beam, leading to high cycle thermal shocks. Most of the time, the increased beam power creates significant challenges such as corrosion and radiation damage that causes harmful effects on the material and degrades their mechanical and thermal properties during irradiation. This can eventually lead to the failure of the material and drastically reduced lifetime of targets and beam intercepting devices. In order to operate reliable beam-intercepting devices in the framework of energy and intensity increase projects of the future, it is essential to develop a strong R&D program and have synergy with various expertise. Based on those strong R&D programs, several ways exist to mitigate radiation damage in material in order to increase lifetime of targets in accelerators. After presenting the high-power target challenges facing next generation accelerators with few examples of international facilities, I will provide few ways to mitigate radiation damages in target material.

TUXD2

An E-Beam Irradiation Beamline at Jefferson Lab for 1,4-Dioxane and Per- and Polyfluoroalkyl Substances Remediation in Wastewater

X. Li, H. Baumgart (ODU) G. Ciovati, M.D. McCaughan, M. Poelker, S. Wang (JLab)
F.E. Hannon (Phase Space Tech)

The Upgraded Injector Test Facility (UITF) at Jefferson Lab, providing a beam energy up to 10 MeV, is suitable for wastewater remediation research. To investigate the degradation of 1,4-dioxane and per- and polyfluoroalkyl substances (PFAS), widespread in wastewater and potential to be regulated in near future [1], a beamline for electron-beam irradiation has been designed, installed and successfully commissioned at the UITF. A solenoid with a peak axial magnetic field of up to 0.28 T and a raster were used to obtain a Gaussian beam profile with a transverse standard deviation of ~15 mm. It was applied to irradiate 1,4-dioxane sample filled in the target cell that was designed to let the entire sample receive significant irradiation doses. The dose distribution and absorbed dose, few studied in the existing publications, are necessary measures for the degradation mechanism investigation and have been innovatively achieved in this work using simulations, which were calibrated with opti-chromic dosimeter rods directly exposed to the electron beam. This approach provides an important way for investigating the environmental remediation impact of electron-beam irradiation.

TUXD3

Production Pathways for Medically Interesting Isotopes

L. Rosado Del Rio (University of Puerto Rico, Rio Piedras Campus) L.F. Dabill (Coe College) A. Hutton (JLab)

Radioisotopes are commonly used in nuclear medicine for treating cancer and new, more effective treatment options are always desired. As a result, there is a national need for new radioisotopes and ways to produce them. A computer program was created that evaluates the daughters for all known reactions of projectiles (gamma rays, protons or neutrons) with every stable target isotope by comparing the cross-sections for each reaction at a desired energy, and outputs a list of the potential daughter isotopes that are most likely to be generated. The program then evaluates the decay chains of these daughters to provide a list of the possible decay chains that contain the radioisotope of interest. By knowing the daughter production and decay chain for each isotope, it is possible to go from the desired radioisotope to the stable isotope that can be used as a target for its production. This project would facilitate the search for new pathways to creating useful theranostic isotopes.

TUXD4

Laser-Plasma-Accelerator-Driven Electron Radiography on the OMEGA EP Laser

G.M. Bruhaug, G.W. Collins, H.G. Rinderknecht, J.R. Rygg, J.L. Shaw, M.S. Wei (LLE)
M.S. Freeman, F.E. Merrill, L.P. Neukirch, C. Wilde (LANL)

Contact and projection electron radiography using a laser-plasma electron accelerator driven by the OMEGA EP laser are shown for static and laser-driven targets. Radiography analysis techniques are shown and attempts to optimize the electron source for radiography are discussed. Future work plans to add chicanes and magnetic optics are outlined and their impact discussed.

Chair: R. Geometrante, KYMA (Trieste, Italy)

Development of Achromatic Imaging Capabilities for pRad at LANSCE

TUXD5

M. Schanz, J.C. Allison, M.S. Freeman, F.G. Mariam, C.L. Morris, L.P. Neukirch, Z. Tang (LANL) E.V. Valetov (MSU)

Proton radiography is a powerful diagnostics technique that is capable of resolving ultra-fast processes on the ns scale in dense matter with micrometer spatial resolution. This unique performance is realized by the use of a chromatic imaging system, which consists of four quadrupole lenses [1]. Chromatic imaging systems have a mono-energetic focal length. That means, if a target with areas of different energy losses is to be investigated, it is only possible to focus on one proton energy leaving other areas of interest blurred. A simple method of focusing multiple energies at once and thus increasing the depth-of-field is the use of multiple detector stations along the beam axis. Proton images captured at downstream detector positions can be combined into a single image using a method called 'focus stacking'. A complete cancellation of the position- and energy dependent 2nd order chromatic aberrations that mostly affect the current image quality of pRad [2] is only possible by using an achromatic imaging system. Following the proposals in early design studies at LANSCE [3] a new prototype achromatic system is currently being developed for a 25 MeV S-band electron accelerator.

Dual Radiofrequency Cavity Based Monochromatization for High Resolution Electron Energy Loss Spectroscopy

TUXD6

A.V. Kulkarni, P.E. Denham, A. Kogar, P. Musumeci (UCLA)

Reducing the energy spread of electron beams can enable breakthrough advances in electron energy loss spectroscopic investigations of solid state samples where characteristic excitations typically have energy scales on the order of meV. In conventional electron sources the energy spread is limited by the emission process and typically on the order of a fraction of an eV. State-of-the-art energy resolution can only be achieved after significant losses in the monochromatization process. Here we propose to take advantage of photoemission from ultrashort laser pulses (~40 fs) so that after a longitudinal phase space manipulation that trades pulse duration for energy spread, the energy spread can be reduced by more than one order of magnitude. The scheme uses two RF cavities to accomplish this goal and can be implemented on a relatively short (~ 1m) beamline. Analytical predictions and results of 3D self consistent beam dynamics simulations are presented to support the findings.

TUXE — Tutorial

TUXE1

The Importance of Data, High-Performance Computing, and Artificial Intelligence/Machine Learning

C.M. Sweeney (LANL) A.L. Edelen (SLAC) D. Martin (ANL)

As existing accelerator facilities are upgraded and new facilities come online, data volumes and velocity are increasing even with shorter data collection times. High-performance computing (HPC) systems doing simulation, data analytics and artificial intelligence/machine learning (AI/ML) are playing a major role in pre-experiment planning, design of experiments, real-time beam line and experiment analysis and control, and post-run data processing. Simulation and AI incorporated into experimental data analysis workflows are making efficient use of expensive facilities and accelerating scientific discoveries. HPC is experiencing its own growth, with exascale computers and AI acceleration coming online at several supercomputer centers. AI/ML is in the midst of rapid growth of techniques and expansion into new application areas. This session will focus on current and emerging technologies in HPC, experimental workflows, and AI/ML techniques to help you incorporate them into your own research. Dr. D. Martin will provide "HPC Overview" followed by "Workflows" by Dr. C. Sweeney. "AI and ML" by Dr. A. Edelen will be followed by community discussions and questions from the audience.

Chair: C.M. Sweeney, LANL (Los Alamos, New Mexico, USA)

TUYD — Photon Sources and Electron Accelerators

High Voltage DC Gun for High Intensity Polarized Electron Source

TUYD1

O.H. Rahman (BNL)

At Brookhaven National Lab, we have constructed a high intensity polarized electron gun with an inverted electrode geometry and large cathode area. The DC gun showed stable operation at 300 KV with bunch charge up to 16 nC. It also incorporates new technologies such as an active cathode cooling system, a biased anode, and a unique high voltage cable with a semiconductor jacket. Lifetime tests with a biased anode has showed exceptional performance. This gun exceeds EIC polarized gun requirements — high voltage, bunch charge, average current and charge lifetime — with ease. In this talk, we report on the design and performance of the gun including high voltage performance and cathode lifetime tests.

Progress Towards Long-Lifetime, High-Current Polarized-Electron Sources

TUYD2

J.P. Biswas (Stony Brook University) **J.P. Biswas**, M. Gaowei, W. Liu, O.H. Rahman, J.T. Sadowski, X. Tong, E. Wang (BNL)

We describe new activation techniques, developed using Cs-Te and Cs-O-Te as a activation layers, to achieve Negative Electron Affinity (NEA) surfaces of GaAs. X-Ray photoelectron spectroscopic and Low Energy Electron Microscopic studies have been performed on these surfaces. The results indicate that both layers achieve NEA of GaAs and lead to longer charge lifetime compared to traditional Cs-O/GaAs photocathodes.

The Quest for the Perfect Cathode

TUYD3

J.W. Lewellen, J. Smedley, T. Vecchione (SLAC) D. Filippetto (LBNL) S.S. Karkare (Arizona State University) J.M. Maxson (Cornell University (CLASSE), Cornell Laboratory for Accelerator-Based Sciences and Education) P. Musumeci (UCLA)

The next generation of free electron lasers will be the first to see the performance of the laser strongly dependent on the materials properties of the photocathode. A new injector proposed for the LCLS-II HE is an example of this revolution, with the goal of increasing the photon energy achievable by LCLS-II to over 20 keV. We must now ask, what is the optimal cathode, temperature, and laser combination to enable this injector? There are many competing requirements. The cathode must be robust enough to operate in a superconducting injector, and must not cause contamination of the injector. It must achieve sufficient charge at high repetition rate, while minimizing the emittance. The wavelength chosen must minimize mean transverse energy while maintaining tolerable levels of multiphoton emission. The cathode must be capable of operating at high (~30 MV/m) gradient, which puts limits on both surface roughness and field emission. This presentation will discuss the trade space for such a cathode/laser combination, and detail a new collaborative program among a variety of institutions to investigate it.

Towards High Brightness from Plasmon-Enhanced Photoemitters

TUYD4

C.M. Pierce, I.V. Bazarov, J.M. Maxson (Cornell University (CLASSE), Cornell Laboratory for Accelerator-Based Sciences and Education) S. Cabrini, D.B. Durham, D. Filippetto, F. Riminucci (LBNL) A. Minor (UC Berkeley)

Plasmonic cathodes, whose nanoscale features may locally enhance optical energy from the driving laser trapped at the vacuum interface, have emerged as a promising technology for improving the brightness of metal cathodes. A six orders of magnitude improvement [1] in the non-linear yield of metals has been experimentally demonstrated through this type of nanopatterning. Further, nanoscale lens structures may focus light below its free space wavelength offering multiphoton photoemission from a region near 10 times smaller [2] than that achievable in typical photoinjectors. In this proceeding, we report on our efforts to characterize the brightness of two plasmonic cathode concepts: a spiral lens and a nanogroove array. We demonstrate an ability to engineer and fabricate nanoscale patterned cathodes by comparing their optical properties with those computed with a finite difference time domain code. Our photoemission measurements are compared with particle tracking simulations that account for the effect of the optical nearfield on the just-emitted electrons. Finally, prospects of this technology for the control and acceleration of charged particle beams are discussed.

Chair: Y. Sun, ANL (Lemont, Illinois, USA)

TUYD5

Epitaxial Alkali-Antimonide Photocathodes on Lattice-matched Substrates

P. Saha, S.S. Karkare (Arizona State University) E. Echeverria, A. Galdi, J.M. Maxson, C.A. Pennington (Cornell University (CLASSE), Cornell Laboratory for Accelerator-Based Sciences and Education) E.J. Montgomery, S. Poddar (Euclid Beamlabs)

Alkali-antimonides photocathodes, characterized by high quantum efficiency (QE) and low mean transverse energy (MTE) in the visible range of spectrum, are excellent candidates for electron sources to drive X-ray Free Electron Lasers (XFEL) and Ultrafast Electron Diffraction (UED). A key figure of merit for these applications is the electron beam brightness, which is inversely proportional to MTE. MTE can be limited by nanoscale surface roughness. Recently, we have demonstrated physically and chemically smooth Cs_3Sb cathodes on Strontium Titanate (STO) substrates grown via co-deposition technique. Such flat cathodes could result from a more ordered growth. In this paper, we present RHEED data of co-deposited Cs_3Sb cathodes on STO. Efforts to achieve epitaxial growth of Cs_3Sb on STO are then demonstrated via RHEED. We find that films grown epitaxially on substrates like STO and SiC (previously used to achieve single crystalline Cs_3Sb) exhibit QE higher than the polycrystalline Cs_3Sb cathodes, by an order of magnitude below photoemission threshold. Given the larger QE, lower laser fluence could be used to extract high charge densities, thereby leading to enhanced beam brightness.

TUYD6

Commissioning of the ASU Cryocooled 200 kV DC Electron Gun

G.S. Gevorkyan, T.J. Hanks, A.H. Kachwala, S.S. Karkare, C.J. Knill, C.A. Sarabia Cardenas (Arizona State University)

We present the first results of the commissioning of the 200 kV DC electron gun with a cryogenically cooled cathode at Arizona State University. The gun is specifically designed for studying a wide variety of novel cathode materials including single crystalline and epitaxially grown materials at 30 K temperatures to obtain the lowest possible intrinsic emittance of UED and XFEL applications [1]. We will present the measurements of the cryogenic performance of the gun and the first high voltage commissioning results.

TUYE — Computing and Data Science for Acc Sys

Coulomb Crystals in Storage Rings for Quantum Information Science

TUYE1

K.A. Brown (BNL)

Quantum information science is a growing field that promises to take computing into a new age of higher performance and larger scale computing as well as being capable of solving problems classical computers are incapable of solving. The outstanding issue in practical quantum computing today is scaling up the system while maintaining interconnectivity of the qubits and low error rates in qubit operations to be able to implement error correction and fault-tolerant operations. Trapped ion qubits offer long coherence times that allow error correction. However, error correction algorithms require large numbers of qubits to work properly. We can potentially create many thousands (or more) of qubits with long coherence states in a storage ring. For example, a circular radio-frequency quadrupole, which acts as a large circular ion trap and could enable larger scale quantum computing. Such a Storage Ring Quantum Computer (SRQC) would be a scalable and fault tolerant quantum information system, composed of qubits with very long coherence lifetimes.

Next Generation Computational Tools For The Modeling And Design Of Particle Accelerators At Exascale

TUYE2

A. Huebl (LBNL)

Particle accelerators, among the largest, most complex devices, demand increasingly sophisticated computational tools for the design and optimization of the next generation of accelerators that will meet the challenges of increasing energy, intensity, accuracy, compactness, complexity and efficiency. It is key that contemporary software take advantage of the latest advances in computer hardware and scientific software engineering practices, delivering speed, reproducibility and feature composability for the aforementioned challenges. We will describe the software stack that is being developed at the heart of the Beam pLasma Accelerator Simulation Toolkit (BLAST) by LBNL and collaborators. We first describe how the US DOE Exascale Computing Project (ECP) application WarpX [1-3] will exploit the power of GPUs and its performance on Exascale supercomputers for the modeling of laser-plasma acceleration. We then describe how we are leveraging the ECP experience to develop a new generation ecosystem of codes that, combined with machine learning, will deliver from ultrafast to ultraprecise modeling for future accelerator design and operations, even enabling virtual twins of accelerators.

An Open-Source Based Data Management and Processing Framework on a Central Server for Scientific Experimental Data

TUYE3

A. Liu, W. Si (Euclid TechLabs)

The ever-expanding size of accelerator operation and experimental data including those generated by electron microscopes and beamline facilities renders most proprietary software inefficient at managing data. The Findability, Accessibility, Interoperability, and Reuse (FAIR) principles of digital assets require a convenient platform for users to share and manage data on. An open-source data framework for storing raw data and metadata, hosting databases, and providing a platform for data processing and visualization is highly desirable. In this paper, we present an open-source, infrastructure-independent data management software framework, named by Euclid-NexusLIMS, to archive, register, record, visualize and process experimental data. The software was targeted initially for electron microscopes, but can be widely applied to all scientific experimental data.

Machine Learning for Anomaly Detection and Classification in Particle Accelerators

TUYE4

I. Lobach, M. Borland, K.C. Harkay, N. Kuklev, Y. Sun (ANL)

We explore the possibility of using a Machine Learning (ML) algorithm to identify the source of occasional poor performance of the Particle Accumulator Ring (PAR) and the Linac-To-PAR (LTP) transport line, which are parts of the injector complex of the Advanced Photon Source (APS) at Argonne National Lab. The cause of reduced injection or extraction efficiencies may be as simple as one parameter being out of range. Still, it may take an expert considerable time to notice it, whereas a well-trained ML model can point at it instantly. In addition, a machine expert might not be immediately available when a problem occurs. Therefore, we began by focusing on such single-parameter anomalies. The training data were generated by creating controlled perturbations of several parameters of PAR and LTP one-by-one, while continuously logging all available process variables. Then, several ML classifiers were trained to recognize certain signatures in the logged data and link them to the sources of poor machine performance. Possible applications of autoencoders and variational autoencoders for unsupervised anomaly detection and for anomaly clustering were considered as well.

TUYE5

Multiobjective Optimization of the LCLS-II Photoinjector

N.R. Neveu (SLAC) P.L. Franz (Stanford University) S.T.P. Hudson, J.M. Larson (ANL)

Genetic algorithms and particle swarm optimization are currently the most widely used optimization algorithms in the accelerator physics community. These algorithms can take many evaluations to find optimal solutions for one machine prototype. In this work, the LCLS-II photoinjector is optimized with three optimization algorithms: a genetic algorithm, a surrogate based algorithm, and a multi-start scalarization method. All three algorithms were able to optimize the photoinjector, with various trade-offs for each method discussed here.

TUYE6

High-Fidelity Simulations and Machine Learning for Accelerator Design and Optimization

D. Winklehner (MIT) , A. Adelmann (PSI)

Computation has become a critically important tool for particle accelerator design and optimization. Thanks to massively parallel codes running on high-performance clusters, we can now accurately predict emergent properties of particle ensembles and non-linear collective effects, and use machine learning (ML) for analysis and to create "virtual twins" of accelerator systems. Here, we will present the IsoDAR experiment in neutrino physics as an example. For it, we have developed a compact and cost-effective cyclotron-based driver to produce very high-intensity beams. The system will be able to deliver cw proton currents of 10 mA on target in the energy regime around 60 MeV. 10 mA is a factor of 10 higher than commercially available machines. This increase in current is possible due to longitudinal-radial coupling through space charge, an effect dubbed "vortex motion". We will discuss the high-fidelity OPAL simulations performed to simulate this effect in the IsoDAR cyclotron and predict beam losses due to halo formation. We will present uncertainty quantification for this design and we will show our study to optimize the IsoDAR injector RFQ using ML.

TUAE — Sustainability Brown Bag Luncheon

Sustainability Brown Bag Luncheon: Let's Get the Conversation Started

M. Uesaka (JAEC) S.V. Milton (Tau Systems)

This lunch's purpose is to continue the discussion of how accelerators can be more green as well as how accelerators and peripheral technologies can help with sustainability at all levels as well as with clean energy. After a short opening conversation between the two discussion leaders to provoke ideas, they will guide additional dialogue generated through audience engagement to extend through the duration of the conference and beyond.

TUZG — RadiaSoft Satellite Session

TUZG1

Magnets to ML to Light Sources: Designing from the Browser with Sirepo

J.P. Edelen, B. Nash (RadiaSoft LLC) R.J. Roussel (SLAC)

Join us for an afternoon intensive with the Sirepo CAE & Design platform! Experts will present their work and lead tutorials using Sirepo's apps and tools for magnet design, ML techniques in control systems, and X-ray beamline modeling. Bring your own laptop and pre-register to use the free gateway at Sirepo.com for practical exercises. Dr. Edelen will provide a tutorial on how to design dipoles and undulators using parameterized magnets. Dr. Roussel will demonstrate combining the classical Preisach model of hysteresis with ML techniques to efficiently create non-parametric, high-fidelity models of arbitrary systems exhibiting hysteresis. Also shown will be how using these joint hysteresis-beam models allows users to overcome optimization performance limitations when hysteresis effects are ignored. Dr. Nash will review the capabilities of Shadow and SRW within Sirepo, discuss additional optics tools in the interface including brightness and linear optics, demonstrate translation between the two codes, and show how to continue your simulation work in a python based Jupyter notebook.

 Chair: J.P. Edelen, RadiaSoft LLC (Boulder, Colorado, USA)

TUZD — Colliders

The Electron/Positron Future Circular Collider

TUZD1

F. Zimmermann (CERN)

The electron/positron Future Circular Collider (FCC) is a 90-km electron/positron collider aimed at studying the Z0, W+ and W- bosons, the Higgs, and t-tbar with very high luminosity. After encouragement from the European Strategy on Particle Physics, the FCC Collaboration has begun a design study to understand the detailed implementation of such a collider. The design study will be completed at the end of 2025 and presented to the expected follow-on European Strategy for Particle Physics.

The International Effort Towards a Muon Collider

TUZD2

D. Stratakis (Fermilab) D. Schulte (CERN)

The recently formed International Muon Collider Collaboration aims to complete the R&D and design work required to deliver a Conceptual Design Report for a multi-TeV muon collider facility within the next decade. An overview of the planned research program, identifying the most challenging R&D questions, a discussion of the design approach, and the potential of such a machine for high energy physics research will be presented.

Ultimate Limits of Future Colliders

TUZD3

V.D. Shiltsev (Fermilab) , M. Bai (SLAC)

With seven operational colliders in the world and two under construction, the international particle physics community not only actively explores options for the next facilities for detailed studies of the Higgs/electroweak physics and beyond-the-LHC energy frontier, but seeks a clear picture of the limits of the colliding beams method. We evaluate the limits on energy, luminosity, and social affordability of the future facilities and ultimate colliders &mdash& linear and circular, proton, electron-positron, and muon, based on traditional as well as on advanced accelerator technologies.

Plans for Future Energy Frontier Accelerators to Drive Particle Physics Discovery

TUZD4

M. Turner (LBNL) M.A. Palmer (BNL) N. Pastrone (INFN-Torino) J.Y. Tang (IHEP) A. Valishev (Fermilab)

The U.S. Particle Physics Community Planning Exercise, "Snowmass 2021", is nearing completion. This process provides input for the Particle Physics Project Prioritization Panel (P5), which will develop a ~10 year scientific vision for the future of the U.S. high energy physics program. High energy particle colliders are the most promising tools to test the Standard Model and have been on the discovery forefront for the past 50 years. A future collider may also enable exploration of e.g., new particles and interactions, physics beyond the SM and dark matter. Several future multi-TeV collider concepts were considered during Snowmass. A range of issues were discussed, including: their physics reach, their level of maturity, the potential machine routes, timelines, R&D requirements, and common issues for these very high energy machines such as energy efficiency and cost. We will compare future collider concepts (1-100 TeV center-of-mass energy range (or beyond)) based on their physics potential, technology R&D required, and potential timelines. The aim is to explore possible strategies towards a next-generation multi-TeV collider to enable discoveries at the energy frontier.

Experience and Challenges With Electron Cooling of Colliding Ion Beams in RHIC

TUZD5

A.V. Fedotov, X. Gu, D. Kayran, J. Kewisch, S. Seletskiy (BNL)

Electron cooling of ion beams employing rf-accelerated electron bunches was successfully used for the RHIC physics program in 2020 and 2021 and was essential in achieving the required luminosity goals. This presentation will summarize experience and challenges with electron cooling of colliding ion beams in RHIC. We also outline ongoing studies using rf-based electron cooler LEReC.

Chair: M.A. Palmer, BNL (Upton, New York, USA)

DarkSRF: Using Accelerator Technology to Search for a Dark Photon

S. Posen, A.S. Romanenko (Fermilab)

Superconducting radio frequency (SRF) cavities have long been used to accelerate beams of charged particles. But their extremely high quality factors $>10^{10}$ make them useful in high sensitivity searches for physics beyond the standard model. DarkSRF is a 'light-shining-through-the-wall' (LSW) experiment in which two SRF cavities are tuned to the same frequency and only one is powered. RF power appearing in the unpowered cavity could be a sign of conversion of photons from the powered cavity into dark photons, and then conversion back into photons. In this contribution, we overview the concept, experimental apparatus, and first results.

TUZE — Beam Dynamics

Experimental Phase-Space Tracking of a Single Electron in a Storage Ring

TUZE1

A.L. Romanov (Fermilab)

This talk would present the results of the first ever experimental tracking of the betatron and synchrotron phases for a single electron in the Fermilab IOTA ring. The reported technology makes it is possible to fully track a single electron in a storage ring, which requires tracking of amplitudes and phases for both, slow synchrotron and fast betatron oscillations.

Nonlinear Optics from Off-Energy Closed Orbits

TUZE2

D.K. Olsson (MAX IV Laboratory, Lund University)

Among several techniques used to characterize and correct the non-linear optics of a storage ring, NOECO (Non-linear optics from Off-Energy Closed Orbits) is the natural expansion of the well-known scheme LOCO for quadrupoles. This approach is based on measuring an orbit response matrix at an off-nominal energy and it is valid for chromatic sextupoles. In this contribution the method [1] will be presented as deployed for the MAX IV 3 GeV ring.

Optimizing the Discovery of Underlying Nonlinear Beam Dynamics

TUZE3

L.A. Pocher, T.M. Antonsen, L. Dovlatyan, I. Haber, P.G. O'Shea (UMD)

One of the DOE-HEP Grand Challenges identified by Nagaitsev et al. relates to the use of virtual particle accelerators for beam prediction and optimization. Useful virtual accelerators rely on efficient and effective methodologies grounded in theory, simulation, and experiment. This paper uses an algorithm called Sparse Identification of Nonlinear Dynamical systems (SINDy), which has not previously been applied to beam physics. We believe the SINDy methodology promises to simplify the optimization of accelerator design and commissioning, particularly where space charge is important. We show how SINDy can be used to discover and identify the underlying differential equation system governing the beam moment evolution. We compare discovered differential equations to theoretical predictions and results from the PIC code WARP modeling. We then integrate the discovered differential system forward in time and compare the results to data analyzed in prior work using a Machine Learning paradigm called Reservoir Computing. Finally, we propose extending our methodology, SINDy for Virtual Accelerators (SINDyVA), to the broader community's computational and real experiments.

Particle-in-Cell Simulations of High Current Density Electron Beams in the Scorpius Linear Induction Accelerator

TUZE4

S.E. Clark, Y.-J. Chen, J. Ellsworth, A.T. Fetterman, C.N. Melton, W.D. Stem (LLNL)

Particle-in-cell (PIC) simulations of a high current density ($I > 1$ kA), and highly relativistic electron beam ($E \sim$ 2-20 MeV) in the Scorpius Linear Induction Accelerator (LIA) are presented. The simulation set consists of a 3D electrostatic/magnetostatic simulation coupled to a 2D XY slice solver that propagates the beam through the proposed accelerator lattice for Scorpius, a next-generation flash X-ray radiography source. These simulations focus on the growth of azimuthal modes in the beam (e.g. Diocotron instability) that arise when physical ring distributions manifest in the beam either due to electron optics or solenoidal focusing and transport. The saturation mechanism appears to lead to the generation of halo particles and conversion down to lower mode numbers as the width of the ring distribution increases. The mode growth and saturation can contribute to the generation of hot spots on the target as well possible azimuthal asymmetries in the radiograph. Simulation results are compared to linear theory and tuning parameters are investigated to mitigate the growth of azimuthal modes in the Scorpius electron beam.

Studies of Ion Beam Heating by Electron Beams

TUZE5

S. Seletskiy, A.V. Fedotov, D. Kayran (BNL)

Presence of an electron beam created by either electron coolers or electron lenses in an ion storage ring is associated with an unwanted emittance growth (heating) of the ion bunches. In this paper we report experimental studies of the electron-ion heating in the Low Energy RHIC electron Cooler (LEReC).

Studies of Ion Instability Using a Gas Injection System

J.R. Calvey, M. Borland, L. Emery, P.S. Kallakuri (ANL)

Ion trapping occurs when a negatively charged beam ionizes residual gas inside an accelerator vacuum chamber, and the resulting ions become trapped in the beam potential. Trapped ions can cause a variety of undesirable effects, including coherent instability and incoherent emittance growth. Because of the challenging emittance and stability requirements of next generation light sources, ion trapping is a serious concern. To study this effect at the present APS, a gas injection system was designed and installed at two different locations in the ring. The system creates a controlled and localized pressure bump of nitrogen gas, so the resulting ion instability can be studied. Measurements were taken under a wide variety of beam conditions, using a spectrum analyzer, pinhole camera, and bunch-by-bunch feedback system. The feedback system was also used to perform grow-damp measurements, allowing us to measure the growth rate of individual unstable modes. This paper will present some of the results of these experiments. Simulations using the IONEFFECTS element in the particle tracking code elegant will also be presented.

TUPA — Poster Session

Calculation of Muon g-2 Beam Dynamics Corrections Using Nonlinear Normal Forms

TUPA01

E.V. Valetov, M. Berz (MSU)

Muon g-2 storage ring experiments, such as the Muon g-2 Experiment at Fermilab and the Muon g-2 /EDM Experiment at J-PARC, require calculations of beam dynamics corrections for muons not being in the mid-plane, for their oscillations, and for electric fields. These corrections can be calculated by binning the density distribution of muons in the phase space, computing the average corrections for a representative particle from each bin, and obtaining the weighted average of the corrections over the phase space. However, with five phase space variables, the number of bins becomes very large. Also, each representative muon needs to be tracked for many turns. We propose an efficient and rigorous method to calculate all beam dynamics corrections with an effective dimensionality reduction by two using nonlinear normal forms, where particles uniformly sample points on circles in the normal form phase space. This allows a simple uniform averaging of all corrections over the two azimuthal directions in the normal form coordinates from the one-turn spin-orbital transfer map. Overall, this is expected to increase the accuracy by reducing the computational expense by 3 to 5 orders of magnitude.

Characterization of Octupole Elements for IOTA

TUPA02

J.N. Wieland (MSU)

The Integrable Optics Test Accelerator (IOTA) is a research storage ring constructed and operated to demonstrate the advantages of nonlinear integrable lattices. One of the nonlinear lattice configurations with one integral of motion is based on a string of short octupoles. The results of the individual magnet's characterizations, which were necessary to determine their multipole composition and magnetic centers, are presented. This information was used to select and align the best subset of octupoles for the IOTA run 4. The method and results of the beam-based measurements of the string alignment are presented. The relative positions of the individual octupoles were measured using closed-orbit responses.

Sheet Electron Probe for Beam Tomography

TUPA04

V.G. Dudnikov, G. Dudnikova (Muons, Inc)

We propose a new approach to electron beam tomography: we will generate a pulsed sheet of electrons. As the ion beam bunches pass through the sheet, they cause distortions in the distribution of sheet electrons arriving at a luminescent screen with a CCD device on the other side of the beam; these sheet electrons are interpreted to give a continuous measurement of the beam profile. The apparatus to generate the sheet beam is a strip cathode, which, compared to the scanning electron beam probe, is smaller, has simpler design and less expensive manufacturing, has better magnetic shielding, has higher sensitivity and higher resolution, has better accuracy of measurement, and has better time resolution.

An H^- Injector for the ESS Storage Ring

TUPA05

V.G. Dudnikov (Muons, Inc)

H^- charge exchange (stripping) injection into the European Spallation neutron Source (ESS) Storage Ring requires a 90 mA H^- ion source that delivers 2.9 ms pulses at 14 Hz repetition rate (duty factor ~4%) that can be extended to 28 Hz (df 8%). This can be achieved with a magnetron surface plasma H^- source (SPS) with active cathode and anode cooling. The Brookhaven National Laboratory (BNL) magnetron SPS can produce an H^- beam current of 100 mA with about 2 kW discharge power and can operate up to 0.7 % duty factor (average power 14 W) without active cooling. We describe how active cathode and anode cooling can be applied to the BNL source to increase the average discharge power up to 140 W (df 8%) to satisfy the needs of the ESS. We also describe the use of a short electrostatic LEBT as is used at the Oak Ridge National Laboratory Spallation Neutron Source to improve the beam delivery to the RFQ.

RF Cathode Heating in Surface Plasma Negative Ion Sources

TUPA06

V.G. Dudnikov (Muons, Inc)

Life time of cathode in LANSCE converter surface plasma negative ion source can be increased by using an RF cathode heating. With RF cathode heating, it could be used cathode wire of larger diameter as d=3-4 mm. Skin depth of cooper at frequency 4 MHz is d=0.0321 mm. Specific Resistivity of copper R=1.68 10^{-6} Ω cm. Specific Resistivity of Tungsten at 200 K is 79 10^{-6} Ω cm, 47 times larger than for copper. Skin depth for tungsten should be $47^{1/2} = 7$

times larger for tungsten dT=0.225 mm. For wire with diameter D=3 mm, perimeter S=3.14xD=9.42 mm. Conductive area is SxdT=2.4 mm^2. Resistivity of tungsten wire 790 10^{-6}/2.4=329 10^{-6} Ω/mm. Resistivity of L=250 mm Tungsten wire is R=329 10^{-6} L=82.291 10^{-6} =0.082 Ohm. Power P=RI2; I2=P/R=10^3 W/0.082=12195 A^2. I=12195$^{1/2}$ = 110 A. It could be used cathode wire of larger diameter as d=3 mm and can significantly increase life time. For heating can be used RF generator with frequency f=4 MHZ with power > 2 kW and matching network with a separating transformer for possibility to apply a discharge voltage. With surface heating could not be formed hat spot.

TUPA07

Improving of the Converter Surface Plasma Sources

V.G. Dudnikov (Muons, Inc) G. Dudnikova (UMD)

A LV SPS with a biased converter was developed for the Los Alamos linac. A large gas-discharge chamber with a multipole magnetic wall and 2 heated cathodes supports a discharge generating plasma. A converter with a diameter of 5 cm and a potential of up to -300 V bombarded by positive ions and emits secondary negative ions, accelerates them and focuses in an emission aperture with a diameter of 6.4 mm. From this SPS, up to 18 mA of H^- ions is extracted at a duty cycle of up to 10%. For dependence of an extracted H^- beam current on the discharge current is typical a strong saturation through H^- destruction in thick layer of discharge plasma and gas. The H^- beam intensity and H^- generation efficiency can be improved by decrease of plasma layer thickness between converter surface and emission aperture. It is possible to improve beam characteristics by small modification of this converted SPS. It is proposed to used a thin Penning discharge in front of the converter. Magnetic field for Penning discharge is created by permanent magnets. Decrease of plasma end gas between converter and emission aperture can decrease H^- beam loss and increase an extracted beam intensity up to 2 times.

TUPA(

Designing Accelerator-Driven Experiments for Accelerator-Driven Reactors

R.P. Johnson, R.J. Abrams, M.A. Cummings, J.D. Lobo, T.J. Roberts (Muons, Inc)

Experiments for Mu*STAR, an accelerator-driven subcritical molten salt reactor, is discussed.

TUPA10

Development and In-Situ Testing of Novel Electrode and Insulating Materials for Molten Salts

R.P. Johnson, J.D. Lobo (Muons, Inc)

A design of a thermodynamic reference electrode probe was developed and requirements for the membrane, sensor body, and conducting electrodes were investigated. Materials were selected, procured, and tested in chloride molten salt at high temperatures. A novel radiofrequency spectroscopic technique was conceived.

TUPA11

Magnet System for a Compact Microtron Source

S.A. Kahn, R.J. Abrams, M.A. Cummings, R.P. Johnson, G.M. Kazakevich (Muons, Inc)

A microtron can be an effective intense electron source. It can use less RF power than a linac to produce a similar energy because the beam will pass through the RF cavity several times. To produce a high-quality low-emittance beam with a microtron requires a magnetic system with a field uniformity $\delta B|/|B<0.001$. Field quality for a compact microtron with fewer turns is more difficult to achieve. In this study we describe the magnet for a compact S-band microtron that will achieve the necessary field requirements. The shaping of the magnet poles and shimming of the magnet iron at the outer extent of the poles will be employed to provide field uniformity.

TUPA12

Innovative Magnetron Power Sources for Superconducting RF (SRF) Accelerators

M.L. Neubauer, G.M. Kazakevich, M. Popovic (Muons, Inc)

The construction, replacement, and operating costs for klystron power sources now used for superconducting RF (SRF) accelerators are high. In their most cost-effective configuration, one high-power klystron drives several SRF cavities that have separate requirements for phase and amplitude control, requiring additional phase and amplitude control devices for each cavity. Magnetron RF power sources can cost much less and operate at much higher efficiency than klystrons, but they do not have the phase and amplitude controls or lifetime needed to drive SRF cavities in particle accelerators used by DOE NP. In this project, Muons, Inc. will work with an industrial partner to develop fast and flexible manufacturing techniques to allow many ideas to be tested for construction variations that enable new phase and amplitude injection locking control methods, longer lifetime, and inexpensive refurbishing resulting in the lowest possible life-cycle costs.

Affordable, Efficient Injection-Locked Magnetrons for Superconducting Cavities

TUPA13

M. Popovic, S.A. Kahn, G.M. Kazakevich (Muons, Inc)

Existing magnetrons that are typically used to study methods of control or lifetime improvements for SRF accelerators are built for much different applications such kitchen microwave ovens (1kW, 2.45 GHz) or industrial heating (100 kW, 915 MHz). In this project, Muons, Inc. will work with an industrial partner to develop fast and flexible manufacturing techniques to allow many ideas to be tested for construction variations that enable new phase and amplitude injection locking control methods, longer lifetime, and inexpensive refurbishing resulting in the lowest possible life-cycle costs. In Phase II magnetron sources will be tested on SRF cavities to accelerate an electron beam at JLab. A magnetron operating at 650 MHz will be constructed and tested with our novel patented subcritical voltage operation methods to drive an SRF cavity. The choice of 650 MHz is an optimal frequency for magnetron efficiency. The critical areas of magnetron manufacturing and design affecting life-cycle costs that will be modeled for improvement include: Q_{ext}, filaments, magnetic field, vane design, and novel control of outgassing.

Fast First-Order Spin Propagation for Spin Matching and Polarization Optimization With Bmad

TUPA14

J.M. Asimow, J.A. Crittenden, G.H. Hoffstaetter, D. Sagan, M.G. Signorelli (Cornell University (CLASSE), Cornell Laboratory for Accelerator-Based Sciences and Education)

Accurate spin tracking is essential for the simulation and propagation of polarized beams, in which a majority of the particles' spin point in the same direction. Bmad, an open-sourced library for the simulation of charged particle dynamics, traditionally tracks spin via integrating through each element of a lattice. While exceptionally accurate, this method has the drawback of being slow; at best, the runtime is proportional to the length of the element. By solving the spin transport equation for simple magnet elements, Bmad can reduce this algorithm to constant runtime while maintaining high accuracy. This method, known as "Sprint," enables quicker spin matching and prototyping of lattice designs via Bmad.

Development of a CVD System for Next-Generation SRF Cavities

TUPA15

G. Gaitan, A.T. Holic, M. Liepe, J. Sears, Z. Sun (Cornell University (CLASSE), Cornell Laboratory for Accelerator-Based Sciences and Education) M. Liepe, J. Sears (Cornell University)

Next-generation, thin-film surfaces employing Nb_3Sn, NbN, NbTiN, and other compound superconductors are destined to allow reaching superior RF performance levels in SRF cavities. Optimized, advanced deposition processes are required to enable high-quality films of such materials on large and complex-shaped cavities. For this purpose, Cornell University is developing a remote plasma-enhanced chemical vapor deposition (CVD) system that facilitates coating on complicated geometries with a high deposition rate. This system is based on a high-temperature tube furnace with a clean vacuum and furnace loading system. The use of plasma alongside reacting precursors will significantly reduce the required processing temperature and promote precursor decomposition. The system can also be used for annealing cavities after the CVD process to improve the surface layer. The safety of the system is an important concern, as various chlorine compounds are used in the CVD of Nb_3Sn. Due to the corrosive potential of the chloride used in the CVD system, special care needs to be given to the gas flow system and we are working on an integrated control system for the whole system.

Singularity-Free Exact Sector Bend Transport Equations

TUPA16

D. Sagan (Cornell University (CLASSE), Cornell Laboratory for Accelerator-Based Sciences and Education)

Exact transport equations for a pure sector bend (a bend with a dipole field and nothing else) have been derived and formulated to avoid singularities when evaluated. These equations have been implemented in the Bmad software toolkit for charged-particle simulations.

Beam-Based Alignment for Sextupole Families in the EIC

TUPA17

J.C. Wang, G.H. Hoffstaetter, D. Sagan (Cornell University (CLASSE), Cornell Laboratory for Accelerator-Based Sciences and Education) C. Montag (BNL)

To steer the closed orbit in a storage ring through the center of its quadrupoles, it is important to accurately know the quadrupole centers relative to nearby beam position monitors. Usually this is achieved by beam-based alignment (BBA). Assuming the quadrupole strength can be changed individually, one finds the BPM reading where changing a quadrupole's strength does not alter the closed orbit. Since most quadrupoles are powered in series, they can only be varied independently if costly power supplies are added. For the EIC electron storage ring (ESR), we investigate whether sextupole BBA can be used instead. Individually powered sextupole BBA techniques already exist, but most sextupoles are powered in families and cannot be individually changed. We therefore developed a method where a localized bump changes the beam excursion in a single sextupole of a family, turning off all families that also have sextupoles in the bump. The bump amplitude at which the sextupole does not cause a closed orbit kick determines the sextupole's alignment. This study was made to investigate the precision to which this method can be utilized.

TUPA18

Promise and Challenges of a Method for 5x5 Sigma Matrix Measurement in a Transport Line

M. Borland, V. Sajaev, K.P. Wootton (ANL)

The Advanced Photon Source (APS) is upgrading the storage ring to a design that requires on-axis injection. Matching between the incoming beam and the ring is important to ensure high injection efficiency. Toward this end, we have developed and tested a method for measuring all sigma matrix elements except those related to the time coordinate. We report on challenges inherent in this technique, based on simulation and real-world trials.

TUPA19

Avoiding Combinatorial Explosion in Simulation of Multiple Magnet Errors in Swap-Out Safety Tracking for the Advanced Photon Source Upgrade

M. Borland, R. Soliday (ANL)

The Advanced Photon Source (APS) is upgrading the storage ring to a hybrid seven-bend-achromat design with reverse bends, providing a natural emittance of 41 pm at 6 GeV. The small dynamic acceptance entails operation in on-axis swap-out mode. Careful consideration is required of the safety implications of injection with shutters open. Tracking studies require simulation of multiple simultaneous magnet errors, some combinations of which may introduce potentially dangerous conditions. A naive grid scan of possible errors, while potentially very complete, would be prohibitively time-consuming. We describe a different approach using biased sampling of particle distributions from successive scans. We also describe other aspects of the simulations, such as use of 3D field maps and a highly detailed aperture model.

TUPA20

Status of New Undulators for the APS Upgrade

R.J. Dejus, J.E. Ackley, E.A. Anliker, G.C. Avellar, S.J. Bettenhausen, K.D. Boerste, A.T. Donnelly, E. Gubbels, Q.B. Hasse, Y. Ivanyushenkov, W.G. Jansma, M. Kasa, E.R. Moog, Y. Piao, M.F. Qian, M. Ramanathan, Y. Shiroyanagi, J.M. TerHAAR, I. Vasserman, N.R. Weir, J.Z. Xu (ANL)

The Advanced Photon Source Upgrade (APS-U) project is developing a multi-bend achromat (MBA) lattice at 6.0-GeV beam energy to replace the existing APS storage ring lattice operating at 7.0 GeV. A major part of the project is to design, fabricate, and install optimized insertion devices (IDs) for 35 beamlines. We have developed four new period lengths for new hybrid permanent magnet undulators (HPMUs) and plan to reuse 23 existing undulators with four more different period lengths. For the superconducting undulators (SCUs) we have developed two new short period lengths for eight new SCUs with three different magnet lengths. The SCUs will be installed in the upgraded storage ring in both inline and canted configurations. Large challenges were anticipated at the start of the project to be able to meet tight mechanical fabrication tolerances for many new components and to tune undulators to tight magnetic field requirements on schedule to be ready for storage ring installation prior to beam commissioning. We will provide a status update, including measurements results to date, and report on tools and techniques used to meet those demands.

TUPA21

Hydrodynamic and Beam Dynamic Simulations of Ultra-Low Emittance Whole Beam Dumps in the Advanced Photon Source Storage Ring

J.C. Dooling, M. Borland, A.M. Grannan, C.J. Graziani, Y. Lee, R.R. Lindberg, G. Navrotski (ANL) N.M. Cook (RadiaSoft LLC) D.W. Lee (UCSC)

The Advanced Photon Source Upgrade will use a multi-bend achromatic lattice to reduce vertical and horizontal beam emittances by one- and two-orders of magnitude respectively; in addition operating current will double. The resulting electron beam will be capable of depositing more than 150 MGy on machine protection collimators creating high-energy-density conditions. Work is underway to couple the beam dynamics code Elegant with the particle-matter interaction program MARS and the magneto-hydrodynamics code FLASH to model the effects of whole beam dumps on the collimators. Loss distributions from Elegant are input to MARS which provide dose maps to FLASH. We also examine the propagation of downstream shower components after the beam interacts with the collimator. Electrons and positrons are tracked to determine locations of beam loss. Beam dump experiments conducted in the APS storage-ring, generated dose levels as high as 30 MGy resulting in severe damage to the collimator surfaces with melting in the bulk. The deformed collimator surface may lead to beam deposition in unexpected locations. A fan-out kicker is planned to mitigate the effects of whole beam dumps on the collimators.

Measurements of Bunch Length in the Advanced Photon Source Booster Synchrotron

TUPA22

J.C. Dooling, W. Berg, J.R. Calvey, K.C. Harkay, K.P. Wootton (ANL)

A bunch duration monitor (BDM) was installed at the end of a synchrotron light monitor (SLM) port in the Advanced Photon Source (APS) booster synchrotron. The BDM is based on a fast Hamamatsu metal-semiconductor-metal detector with nominal rise and fall times of 30 ps. Bunch length data is especially important as the bunch charge will be raised from 3 nC, used in the existing machine, to as much as 18 nC for APS-Upgrade operation. During preliminary high-charge studies, the SLM image is observed to move over a period of minutes while the BDM signal intensity varies; the motion is likely due to thermal loading of the in-tunnel synchrotron light mirror. Work is underway to stabilize the position using a simple feedback system and motorized mirror mount, as well as a new synchrotron light mirror assembly with improved thermal load handling. The feedback system will maintain optical alignment on the BDM at an optimum position based on the SLM centroid location. The optical layout and feedback system will be presented along with preliminary bunch length data.

First Beam Results Using the 10-kW Harmonic Rf Solid-State Amplifier for the APS Particle Accumulator Ring

TUPA23

K.C. Harkay, T.G. Berenc, J.R. Calvey, J.C. Dooling, H. Shang, T.L. Smith, Y. Sun, U. Wienands (ANL)

The Advanced Photon Source (APS) particle accumulator ring (PAR) was designed to accumulate linac pulses into a single bunch using a fundamental radio frequency (rf) system, and longitudinally compress the beam using a harmonic rf system prior to injection into the booster. The APS Upgrade injectors will need to supply full-current bunch replacement with high single-bunch charge for swap-out injection in the new storage ring. Significant bunch lengthening is observed in the PAR at high charge, which negatively affects beam capture in the booster. Predictions showed that the bunch length could be compressed to better match the booster acceptance using a combination of higher beam energy and higher harmonic gap voltage. A new 10-kW harmonic rf solid-state amplifier (SSA) was installed in 2021 to raise the gap voltage and improve bunch compression. The SSA has been operating reliably. Initial results show that the charge-dependent bunch lengthening in PAR with higher gap voltage agrees qualitatively with predictions. A tool was written to automate bunch length data acquisition. Future plans to increase the beam energy, which makes the SSA more effective, will also be summarized.

Robust Digital Twin Models from Experimental Data

TUPA24

N. Kuklev, H. Shang, Y. Sun (ANL)

Recently, machine learning tools have been proposed for accelerator optimization, anomaly detection, and other purposes. Due to limited beam time, majority of their testing and debugging is performed on simulated data. In some machines, simulations have poor agreement with experimental results. We explore development of digital twin (surrogate) models purely from or augmented by experimental data, which can then be used to improve experimental ML tool performance. Our main contribution are methods to compensate for deficiencies in experimental data — limited parameter space, sparse sampling, noise, and imbalance in terms of parameter and objective distributions. We propose and benchmark label density smoothing, feature density smoothing, synthetic minority over-sampling, adaptive regularization, and other approaches. Applicability to both tree-based (random/gradient-boosted forests) and neural-network based architectures is studied. We also describe a distributed hyperparameter tuning approach to pick best methods for specific datasets. Our results show significant improvement in accuracy as compared to standard surrogate models, with little to no performance degradation.

Differentiable Approach to Particle Tracking and Beam Optics Measurements

TUPA25

N. Kuklev (ANL)

Particle accelerators require extensive optimization of linear and nonlinear parameters. Due to complexity of analytic treatments, numerical optimizations are often used. Lack of gradient information limits optimization method choices to derivative-free ones such as simplex or genetic algorithms. We explore a reformulation of beam optics and particle tracking that preserves gradient information by making use of automatic differentiation tools from PyTorch machine learning library. Standard computations (matrix multiplication, symplectic integrators) are converted to a graph of tensor operations forming a nonlinear map, and backpropagation is used to find parameter gradients with respect to objectives.

To confirm validity, code output is compared to analytic and finite difference results. Using gradient information, we show improved convergence speed in optics matching and orbit correction. We also demonstrate use of differentiable models with probabilistic programming for Bayesian inference of magnet parameters, phase space density, and beam optics. Optics results are benchmarked against LOCO analysis, and practical advantages of knowing parameter posterior distributions discussed.

TUPA26

Fringe Field Maps for Cartesian Dipoles With Longitudinal And/or Transverse Gradients

R.R. Lindberg, M. Borland (ANL)

Fringe fields effects in dipoles can give rise to important linear and nonlinear contributions. This paper describes how to extend the classic results of Brown [1] and the more recent calculations of Hwang and Lee [2] to Cartesian dipoles with transverse and/or longitudinal gradients. We do this by 1) introducing a more general definition of the fringe field that can be applied to longitudinal gradient dipoles, 2) allowing for quadrupole and/or sextupole content in the magnet body, and 3) showing how to employ the resulting fringe field maps as a symplectic transformation of the coordinates. We compare our calculation results with tracking for longitudinal and transverse gradient dipoles planned for the APS-U.

TUPA27

Longitudinal Feedback Dynamics in Storage Rings With Small Synchrotron Tunes

R.R. Lindberg (ANL)

We analyze the dynamics of multibunch longitudinal instabilities including bunch-by-bunch feedback under the assumption that the synchrotron tune is small. We find that increasing the feedback response does not always guarantee stability, even in the ideal case with no noise. As an example, we show that if the growth rate of a cavity-driven mode is of the order of the synchrotron frequency, then there are parameter regions for which the instability cannot be controlled by feedback irrespective of its gain. We verify these calculations with tracking simulations relevant to the APS-U, and find that the dynamics do not depend upon whether the longitudinal feedback relies on phase-sensing or energy-sensing technology. Hence, this choice should be dictated by measurement accuracy and noise considerations.

TUPA28

Update on the Development of a Low-Cost Button BPM Signal Detector at AWA

W. Liu, G. Chen, D.S. Doran, S.Y. Kim, X. Lu, P. Piot, J.G. Power, C. Whiteford, E.E. Wisniewski (ANL) E.E. Wisniewski (IIT)

A single-pulse, high dynamic range, cost-effective BPM signal detector has been on the most wanted list of the Argonne Wakefield Accelerator (AWA) Test Facility for many years. The unique capabilities of the AWA beamline require BPM instrumentation with an unprecedented dynamic range, thus a cost-effective solution could be challenging to design and prototype. With the help of a better circuit model for a button BPM signal source, we are able to do the circuit simulations with more realistic input signals and make predictions much closer to realities. Our most recent design and prototype results are shared in this paper.

TUPA29

Machine Learning for Predicting Power Supply Trips in Storage Rings

I. Lobach, M. Borland, L. Emery, G.I. Fystro, Y. Sun (ANL) J.P. Edelen (RadiaSoft LLC)

In the Advanced Photon Source (APS) storage ring at Argonne National Lab, trips in the magnet power supplies (PS) result in a complete electron beam loss a few times a year. Several PS parameters are constantly logged in APS. In this contribution, we investigate the historical data for the last 10 years to find precursors for the PS trips that could provide an advance notice for future trips and allow some preventive action by the ring operator or the maintenance team. Various unsupervised anomaly detection models can be trained on the vast amounts of available reference data — the data that ended with an intentional beam dump. We find that such models can sometimes detect trip precursors in PS currents, voltages, and in the temperatures of magnets, capacitors and transistors (components of PS). We also explore the possibility of using the water flow data (used in magnet and PS cooling) for predicting PS trips, as sometimes an insufficient cooling water flow can lead to rising magnet and PS temperatures and, therefore, to a trip.

TUPA30

Development of a Compact 2D Carbon Beam Scanner for Cancer Therapy

B. Mustapha, A. Barcikowski, J.A. Nolen (ANL) V.P. Derenchuk (ProNova Solutions)

A novel trapezoidal coil 2D carbon beam scanner has been designed, and a prototype has been successfully developed and tested. The field performance of the magnet has been characterized and it is in excellent agreement with the simulations. A better than 1% field uniformity in both planes has been achieved within the useful aperture of the magnet. This represents a significant improvement over the prior art of the elephant-ear scanner design. A comparison of the two designs and the results from the new trapezoidal-coil design will be presented and discussed. Higher power and online beam testing are planned in the near future.

Machine Learning to Support the ATLAS Linac Operations at Argonne

TUPA31

B. Mustapha, B.R. Blomberg, K.J. Bunnell, J.L. Martinez Marin, D. Stanton (ANL)

The use of artificial intelligence can significantly reduce the time needed to tune the ATLAS heavy ion linac. After establishing automatic data collection procedures and analyzing the data, we have developed and tested machine learning models to tune and control the machine. Models based on Bayesian optimization (BO) and reinforcement learning (RL) will be presented and their performance compared and discussed. RL and BO are well-known AI techniques, often used for control systems. The results will be presented for a subsection of ATLAS that contains complex elements such as the radiofrequency quadrupole. The models will be later generalized to the whole ATLAS linac, and similar models can be developed for any accelerator with a modern control system.

Superconducting Undulator End Coils Configured as a Phase Shifter

TUPA32

M.F. Qian (ANL)

Dipole correctors and phase shifters are usually needed in the interspace of a permanent magnet (PM)-based undulator array for purposes of beam steering and phase matching when the field strength is changing. Unlike the PM-based undulators, the superconducting undulator (SCU) can change its end field with the help of varying currents in the end coils. By setting the end coil currents the beam-steering and the phase-matching could be realized, thus eliminating the need for standalone correctors and phase shifters, saving the interspace as well as reducing the mechanical complexity of an undulator array. We developed a procedure for determining the SCU end coil currents and verified it by numerical simulations. The procedure as well as the simulation results are described in this paper.

Magnetic Field Calculation of Superconducting Undulators for FEL Using Maxwell 3D

TUPA33

Y. Shiroyanagi, Y. Ivanyushenkov, M. Kasa (ANL)

An ANL-SLAC collaboration is working on design of a planar superconducting undulator (SCU) demonstrator for FEL. As a part of this project, a SCU magnet prototype is planned to be built and tested. A planar SCU magnet consisting of two 0.5-m-long segments is being designed. Although OPERA is a standard tool for magnetic field calculation, ANSYS Maxwell 3D can also be used for a large and complex geometry. An ANSYS calculated magnetic field was benchmarked with the measured field profile of existing SCUs. This paper presents calculation of magnetic field and field integrals of 0.5-m-long (one segment) and ~1.5-m-long (two segments) magnetic structures with end corrections.

Model-Based Calibration of Control Parameters at the Argonne Wakefield Accelerator

TUPA34

I.P. Sugrue, B. Mustapha, P. Piot, J.G. Power (ANL) N. Krislock (Northern Illinois University)

Particle accelerators utilize a large number of control parameters to generate and manipulate beams. Digital models and simulations are often used to find the best operating parameters to achieve a set of given beam parameters. Unfortunately, the optimized physics parameters cannot precisely be set in the control system due to, e.g., calibration uncertainties. We developed a data-driven physics-informed surrogate model using neural networks to replace digital models relying on beam-dynamics simulations. This surrogate model can then be used to perform quick diagnostics of the Argonne Wakefield accelerator in real time using nonlinear least-squares methods to find the most likely operating parameters given a measured beam distribution.

APS Linac Hot-Spare RF Gun Operation and Beam Optimization

TUPA35

Y. Sun, M. Borland, G.I. Fystro, N. Kuklev, I. Lobach, H. Shang (ANL) X. Huang (SLAC)

A hot-spare thermionic RF gun (RG1) beamline was installed at the front end of the APS linac over 20 years ago. It served as a back-up electron source for the APS storage ring X-ray user operation. In recent years, it has been a challenge for RG1 to function as a viable backup. The RF gun had experienced arcs at nominal RF power levels, beam out of the gun was unstable, and beam transmission efficiency from the gun in the linac and further down to the APS injector ring was poor. In this paper, we report our journey to recover the RG1 beam operation, including an RF gun restoration process, RG1 beamline element debugging, additional metal shield installation for the current monitor ceramic gap, and beam optimization for optimal injection efficiency.

TUPA36

The Advanced Photon Source Linac Extension Area Beamline

K.P. Wootton, W. Berg, J.M. Byrd, J.C. Dooling, G.I. Fystro, A.H. Lumpkin, Y. Sun, A. Zholents (ANL) C.C. Hall (RadiaSoft LLC)

The Linac Extension Area at the Advanced Photon Source is a flexible beamline area for testing accelerator components and techniques. Driven by the Advanced Photon Source electron linac equipped with a photocathode RF electron gun, the Linac Extension Area houses a 12 m long beamline. The beamline is furnished with YAG screens, BPMs and a magnetic spectrometer to assist with characterization of beam emittance and energy spread. A 1.4 m long insertion in the middle of the beamline is provided for the installation of a device under test. The beamline is expected to be available soon for testing accelerator components and techniques using round and flat electron beams over an energy range 150 to 450 MeV. In the present work, we describe this beamline and summarize the main beam parameters.

TUPA37

A Distributed Beam Loss Monitor Based upon Activation of Oxygen in Deionised Cooling Water

K.P. Wootton (ANL)

We propose a novel beam loss detection scheme whereby activation of deionised cooling water is used to observe elevated radiation around the APS storage ring. This is based on radioactivation of oxygen within deionised cooling water by gamma rays above 10 MeV and neutrons above 15 MeV. Losses would be detected using a gamma ray detector monitoring process water flow out of the accelerator enclosure. We anticipate that this could be used to provide a segmented, distributed loss monitor system covering the accelerator components closest to locations where radiation is generated.

TUPA38

Sublinear Intensity Response of Cerium-Doped Yttrium Aluminium Garnet Screen With Charge

K.P. Wootton, A.H. Lumpkin (ANL)

Swap-out injection to the Advanced Photon Source Upgrade storage ring necessitates the injection of ~17 nC electron bunches at 6 GeV. To aid with machine tune-up and to measure the beam size, diagnostic imaging screens are envisaged at several locations in the beam transport line from the booster synchrotron to the storage ring. As such, it is important to determine whether the response of these screens to charge is linear. In the present work, we examine the effect of sublinear intensity quenching of a Cerium-doped Yttrium-Aluminium-Garnet scintillator screen. A 1.3 megapixel FLIR BlackFly monochrome digital camera was used to image the beam at the scintillator. At 7 GeV beam energy, over the charge densities investigated (<10 fC um^{-2}), reduction of the image intensity due to quenching of the scintillator is observed to produce approximately a 10 % effect on intensity.

TUPA39

A Miniature Adjustable Phase Undulator for a Compact X-Ray FEL

J.Z. Xu, M.F. Qian, A. Zholents (ANL)

The design of an adjustable phase undulator (APU) with cross section fitting dimensions of 5 inches by 5 inches is presented. The undulator employs a permanent magnet assembly with a < 10-mm period and yields a maximum undulator parameter K > 1. This K affords ~ 20% photon energy tunability in each individual x-ray FEL of a compact x-ray FEL facility, being designed at Argonne National Laboratory, without the need to vary the electron beam energy [1]. The design of a compact array of APUs is presented.

TUPA41

Applications of machine learning in photo-cathode injectors

A. Aslam (UNM-ECE) S. Biedron (Element Aero)

To configure a photoinjector to reproduce a given electron bunch with the desired characteristics, it is necessary to adjust the operating parameters with high precision. More or less, the fine tunability of the laser parameters are of extreme importance as we try to model further applications of the photoinjector. The laser pulse incident on the photocathode critically affects the electron bunch 3D phase space. Parameters such as the laser pulse transverse shape, total energy, and temporal profile must be controlled independently, any laser pulse variation over both short and long-time scales also requires correction. The ability to produce arbitrary laser intensity distributions enables better control of electron bunch transverse and longitudinal emittance by affecting the space-charge forces throughout the bunch. In an accelerator employing a photoinjector, electron optics in the beamline downstream are used to transport, manipulate, and characterize the electron bunch. The adjustment of the electron optics to achieve a desired electron bunch at the interaction point is a much better understood problem than laser adjustment, so this research emphasizes laser shaping.

LANSCE Modernization Project at LANL

TUPA42

D.V. Gorelov, J. Barraza, Y.K. Batygin, D.A.D. Dimitrov, I. Draganic, E. Henestroza, S.S. Kurennoy (LANL)

In the framework of LANSCE Accelerator Modernization Project preliminary research, during evaluation of critical technology elements it was found that the proposed RFQ design had not yet been demonstrated experimentally worldwide. Such an RFQ should combine the ability of traditional light ion RFQs (i.e., [1]) and the flexibility of acceleration of pre-bunched beams, like RFQs for heavy ions [2]. The proposed RFQ should be able to accelerate H^+ and H^- beams with 35-mA beam current from 100 keV to 3 MeV and at the same time preserve the prescribed macro-bunch beam time structure required by experiments. New algorithms for RFQ geometry generation have been proposed, and optimization algorithms are being developed at LANL. LAMP demonstration plans also include development of a new set of electrodes for the existing RFQ at our Test Stand that will allow us to demonstrate the critical technology ahead of time in a laboratory experimental setup with low duty factor and low energy.

Novel RF Phase Detector for Accelerator Applications

TUPA43

J.M. Potter (JP Accelerator Works)

A novel phase detector has been developed that is suitable for use in an rf phase locked loop for locking an rf source to an rf accelerator structure or phase locking the accelerator structure to a fixed or adjustable frequency rf source. It is also useful for fast phase feedback to control the phase of an accelerator rf field. The principle is applicable to a wide range of frequencies and amplitudes. The phase is uniquely and unambiguously determined over 360^o, eliminating the need for external phase shifters or phase references. The operation of this phase detector is described in detail. An application is described that uses a DDS-based LLRF source as the rf input to a high-power rf system.

A Personal History of the Development of the LAMPF/LANSCE Accelerator

TUPA44

J.M. Potter (JP Accelerator Works)

The LAMPF/LANSCE accelerator has now been operational for 50 years. I arrived as a LASL employee in Group P11 in April 1964 at the beginning stages of its development. I participated in the development of the resonant coupling principle [1] and went on to develop tuning procedures for the 805-MHz coupled cavity linac (CCL) structures and the post-stabilized drift tube linac (DTL) [2]. The resonant coupling principle is now well established as the basis for rf linear accelerators worldwide. I will discuss the development and building of the accelerator from my viewpoint as a member of a large, dedicated team of physicists, engineers, technicians, and support personnel.

A Laser-Neutralization Based Bunch Length Diagnostic for LANSCE

TUPA45

H.L. Andrews, J.L. Medina, C.G. Miera, C.E. Taylor, R.T. Thornton (LANL)

For high power ion accelerators such as the machine at the heart of the Los Alamos Neutron Science Center (LANSCE), beam "tails" and "halo" can pose significant problems. Such small fractions of the beam current are easy to lose and difficult to measure, yet can contain enough charge to generate significant radiation; thus, halo and tails can pose a direct threat to instrumentation through radiation, and impact maintenance due to activation. At LANSCE, we are in the installation phase of building a laser-neutralization based bunch length diagnostic. The proposed diagnostic will have high temporal resolution, very high dynamic range, allow for the detection of bunch tails, and will be minimally invasive so it can be operated during routine accelerator operation. We present our design and progress to date.

Mechanistic Simulations of Material Evolution Under Electric Fields

TUPA46

S. Bagchi, D. Perez (LANL)

High-gradients are inevitably encountered in technologies ranging from accelerators to miniaturized electronic devices. It is now well understood that material functionality under extreme fields can heavily depend on the coupling between electro-thermal loading and microstructural deformation, but the fundamental mechanisms underpinning this coupling remain poorly understood. While they are difficult to explicitly access experimentally, relevant nanoscale deformation mechanisms can in principle be directly probed by atomistic simulations. We include electric-field-induced Lorentz forces using a charge-equilibration molecular dynamics framework that allows for the dynamical evolution of atomic charges. Using this tool, we explore the joint effect of electric-fields-induced stresses and thermo-mechanical stresses on the plastic deformation of fcc metals. We explore the motion and multiplication of dislocations in both the bulk and at free surfaces, and discuss the various regimes of electric fields and pulsed heating as they couple with the plastic deformation and surface diffusion. These results inform possible mechanisms of breakdown precursor formation in accelerating structures.

TUPA47

Upgrade from ADCs with Centrally Scheduled Triggers to Continually Triggered Waveform Digitizers

S.A. Baily, B.C. Atencio, A.J. Braido, C.D. Hatch, J.O. Hill, S.M. Johnson, L.S. Kennel, M. Pieck, L.E. Walker, H.A. Watkins, E.E. Westbrook, K. Xu, D.D. Zimmermann (LANL)

The LANSCE control system includes many data channels that are timed and flavored, i.e., users can specify the type of beam and time within the beam pulse at which data is reported. RICE, the original LANSCE control system, accomplished this by queuing up triggers and scheduling ADC readouts with custom hardware based on requests. This year we upgraded this system to a new EPICS system that includes waveform digitizers that collect data from every cycle. An appropriate subset of the data is then returned to each client. This is made possible by improvements to EPICS software, a COTS VPX FPGA card that runs EPICS on a soft-core processor, and a COTS PMC waveform digitizer. This year we upgraded over 1200 waveform channels from RICE to the new TDAQ (Timed/flavored Data Acquisition) system.

TUPA48

Effect of Lattice Misalignments on Beam Dynamics in LANSCE Linear Accelerator

Y.K. Batygin, S.S. Kurennoy (LANL)

Accelerator channel misalignments can significantly affect beam parameters in long linear accelerators. Measurements of misalignments of the LANSCE linac lattice elements was performed by the Mechanical Design Engineering Group of the Los Alamos Accelerator Operations and Technology Division. In order to determine effect of misalignment on beam parameters in LANSCE linac, the start-to-end simulations of LANSCE accelerator were performed using Beampath and CST codes including measured displacements of quadrupoles and accelerating tanks. Simulations were done for both H^+ and H^- beams with various beam flavors. Effect of misalignments was compared with those due to beam space charge and distortion of RF field along the channel. Paper presents results of simulation and comparison with experimental data of beam emittance growth along the machine.

TUPA49

Ceramic Enhanced Accelerator Space Readiness

M.R. Bradley (LANL)

An experimental design for an accelerator cavity uses a ceramic ring insert instead of the solid metal conventionally used to form a microwave cavity. Constructing the cavity in this manner results in a power efficiency greater than that of conventional accelerator designs. Increased power efficiency naturally lends itself to several applications including use in space where power is in a limited supply. A major drawback of the ceramic enhanced cavity design is that ceramic is significantly less durable than its conventional metal counterpart. Durability as well as power efficiency is a critical requirement of space bound experiments. In order to prepare this accelerator design for space flight this project increases the thickness of the ceramic ring in order to improve its structural strength. This increase of thickness is paired with a change in the inner diameter of the copper shell containing the ceramic in order to allow for larger ceramic thicknesses without sacrificing the enhanced properties of the accelerator cavity. The electromagnetic modeling program CST is used to model both the ceramic insert and the copper shell to determine dimensions with desirable properties.

TUPA50

Minimizing Energy Spread from the Microbunching Instability in the Linac for an X-Ray Free Electron Laser

L.D. Duffy, P.M. Anisimov, Q.R. Marksteiner, H. Xu (LANL)

X-ray free electron lasers require a small energy spread and well-bunched beam to lase. However, compression of an electron bunch during linac transport is compromised by the microbunching instability, which distorts the current profile of the bunch and increases the beam energy spread. Bunch compression is typically done in two stages. We study the optimal location for the second bunch compressor in a C-band linac, to both achieve the desired compression factor and minimize the energy spread from the microbunching instability, using both theoretical calculations and simulations with the Elegant code.

RF Power Detector Upgrade for the LANSCE DTL

TUPA51

S.R. Gomez, J.T.M. Lyles, M. Sanchez Barrueta, G.M. Sandoval, Jr. (LANL) R.D. Summers (Compa Industries, Inc.)

The Radio Frequency (RF) Power detector is used to perform pulsed RF power measurements of input and output signals for the different amplifier stages feeding the LANSCE DTL (Drift Tube Linac). It uses an ADL5511 envelope detector to produce a DC (Direct Current) signal where the voltage is proportional to the input RF voltage. The voltage is then sampled by a 12-bit analog to digital converter (ADC) and the equivalent power is computed and scaled to the actual input or output power it represents via a PIC18F87J93 microcontroller. The power detector needs to be programmed and calibrated to account for differences between devices and to accurately represent all power stages of the amplifiers. Since 2015, the program in this device has been largely unchanged and it now relies on outdated systems to keep it running. Updates to the program have been made to expand on its original capabilities and allow for continued operation and production of these devices.

Initial Results of the 201.25 MHz Coaxial Window Test Stand

TUPA52

T.W. Hall, J.T.M. Lyles, A. Poudel, A.S. Waghmare (LANL)

We have recently commissioned an RF window test stand for the Drift Tube Linear Accelerator (DTL) portion of the Los Alamos Neutron Science Center (LANSCE). The window test stand consists of two RF windows that create a vacuum chamber which allows the windows to be tested to the peak power levels used in the DTL. Initial results clearly indicated multipactoring due to the increase of pressure at specific regions of peak forward power levels. Temperature measured at various azimuthal locations on both windows showed increased multipactor heating on the downstream window versus the upstream window. We present the effect of the titanium nitride coating that is presently applied to windows on both multipactor and window temperature. These results are discussed with respect to their impact on the LANSCE DTL performance.

Modeling of Coherent Synchrotron Radiation Effects in High Brightness Beams via a Novel Particle-Mesh Method and Surrogate Models With Symplectic Neural Networks

TUPA53

C.-K. Huang, B.E. Carlsten, G.A. Dilts, J. Domine, R. Garimella, T.J. Kwan, F.Y. Li, H.N. Rakotoarivelo, R.W. Robey, B. Shen, Q. Tang (LANL)

A novel self-consistent beam dynamics code is developed based on a Lagrangian method for the calculation of the particles' radiation near-fields using wavefront/wavelet meshes via the Green's function of the Maxwell equations. These fields are then interpolated onto a moving mesh for dynamic update of the beam. This method allows radiation co-propagation and self-consistent interaction with the beam in 2D/3D simulations at greatly reduced numerical errors. Multiple levels of parallelisms are inherent in this method and implemented in our code CoSyR [1] using MPI, multi-threading, and GPUs. Our simulations reveal the slice emittance growth in a bend and the interplay between the longitudinal and transverse dynamics that occurs in a complex manner not captured in the 1D longitudinal static-state coherent synchrotron radiation model. Finally, we show that surrogate models with symplectic neural networks can be trained from these simulations with significant time-savings for the modeling of nonlinear beam dynamics effects.

Simulation Study of HOM Suppression for the C-Band Accelerating Structure

TUPA54

D. Kim, E.I. Simakov (LANL) Z. Li (SLAC)

High-gradient cryo-cooled C-band normal-conducting radio-frequency (NCRF) accelerating structures are proposed to be employed for the future multi-TeV energy range linear collider. A cold copper distributed coupling structure offers many degrees of freedom for optimization of individual cavities to achieve high RF efficiency of acceleration and high accelerating gradient. We use the ACE3P code (Omega3P and ACD tools) to investigate in detail the higher order mode (HOM) spectrum of the C-band distributed coupling accelerator structure with particular focus on dipole modes. First, we compute the wall loss Q-factors, shunt impedance, and wakefield transverse kick factors for the modes in the frequency range up to 40 GHz. Next, for the proposed HOM suppression design we compute the product of the Q-factors and the transverse kick factors for the major HOM with and without damping loads. We compare the results of ACE3P simulations to CST simulations.

TUPA55

Progress Toward Improving Accelerator Performance and Automating Operations With Advanced Analysis Software

J.E. Koglin, J.E. Coleman, M. McKerns, D. Ronquillo, A. Scheinker, K.L. Van Buren, A.B. Williams (LANL) E.H. Toler (Courant Institute of Mathematical Sciences, New York University)

The penetrating radiography provided by the Dual Axis Radiographic Hydrodynamic Test (DARHT) facility is a key capability in executing a core mission of the Los Alamos National Laboratory (LANL). A new suite of software is being developed in the Python programming language to support operations of the of two DARHT linear induction accelerators (LIAs). Historical data, built as hdf5 data structures for over a decade of operations, are being used to develop automated failure and anomaly detection software and train machine learning models to assist in beam tuning. Adaptive machine learning (AML) that incorporate physics-based models are being designed to use non-invasive diagnostic measurements to address the challenge of time variation in accelerator performance and target density evolution. AML methods are also being developed for experiments that use invasive diagnostics to understand the accelerator behavior at key locations, the results of which will be fed back into the accelerator models. The status and future outlook for these developments will be reported, including how Jupyter notebooks are being used to rapidly deploy these advances as highly-interactive web applications.

TUPA56

Beam Coupling Impedances of Asymmetric Components of the Scorpius Induction Linac

S.S. Kurennoy (LANL)

The transverse beam coupling impedance of induction linacs must be minimized to avoid beam breakdown instability. The vacuum chamber of the Scorpius linac contains complicated asymmetric elements. We present calculations of the transverse impedance for three asymmetric discontinuities: (1) a pumping section between accelerating cells, which contains vacuum plenum, pumping grid, and bellows; (2) a fast flapper valve; and (3) a debris blocker at the end of the linac. The dipole transverse impedance is calculated with CST Studio using both wakefield solver and eigen solver.

TUPA57

EM and Beam Dynamics Modeling of the LANSCE Coupled-Cavity Linac

S.S. Kurennoy, Y.K. Batygin, D.V. Gorelov (LANL)

The 800-MeV proton linac at LANSCE consists of a drift-tube linac, which brings the beam to 100 MeV, followed by a coupled-cavity linac (CCL) consisting of 44 modules. Each CCL module contains multiple tanks, and it is fed by a single 805-MHz klystron. CCL tanks are multi-cell blocks of identical re-entrant side-coupled cavities, which are followed by drifts with magnetic quadrupole doublets. Bridge couplers — special cavities displaced from the beam axis — electromagnetically couple CCL tanks over such drifts. We have developed 3D CST models of CCL tanks. Their electromagnetic analysis is performed using MicroWave Studio. Beam dynamics is modeled with Particle Studio for bunch trains with realistic beam distributions using the CST calculated RF fields and quadrupole magnetic fields to determine the output beam parameters. Beam dynamics results are crosschecked with other multi-particle codes.

TUPA58

Iterative Tuning of the Beam Feedforward Controller for LANSCE LINAC Digital Low-Level RF Control System

S. Kwon, A.T. Archuleta, L.J. Castellano, M.S. Prokop, C. Rose, P.A. Torrez, P. Van Rooy (LANL)

The Los Alamos Neutron Science Center (LANSCE) proton accelerator supports multiple experimental areas and accelerates several beam particle species, each having its own peak current value, repetition rate, and required chopping profiles. New digital low-level RF (LLRF) systems have been designed and deployed on 26 of the 44 805-MHz coupled cavity linac (CCL) sections of the linear accelerator, replacing the 50-year-old analog cavity-field control systems. For the beam loading compensation, a beam feedforward controller is implemented. The tuning method does not need an a priori plant model but only needs data collected in previous experimental runs. The controller tuning and gain/phase updates are performed between each of the RF pulses on the host server. Once the tuning calculations are performed, the controller gain and phase are downloaded from the host to the controller in the FPGA, and updated feedforward gain and phase adjustments are applied to each subsequent RF pulse.

RF System Upgrade for Low Energy DTL Cavity at LANSCE

TUPA59

J.T.M. Lyles, R.E. Bratton, T.W. Hall, M. Sanchez Barrueta (LANL)

The Los Alamos Neutron Science Center (LANSCE) 100-MeV Drift Tube Linac (DTL) uses four accelerating cavities. In May of 2021, a new RF amplifier system was commissioned to drive the first 4-MeV cavity. It had been powered for 30 years with a triode vacuum tube RF amplifier driven by a tetrode, along with four more vacuum tubes for anode high-voltage modulation. The new amplifier system uses one tetrode amplifier driven by a 20-kW solid state amplifier (SSA) to generate 400 kWp at 201.25 MHz. The tetrode amplifier is protected for reflected power from the DTL by a coaxial circulator. The new installation includes cRio controls and a fast protection and monitoring system capable of reacting to faults within 10 μs. A new digital low-level RF (LLRF) system has been installed that integrates I/Q signal processing, PI feedback, and feedforward controls for beam loading compensation. Issues with LLRF stability were initially encountered due to interaction from thermal-related RF phase changes. After these issues were solved, the final outcome has been a reliable new RF system to complete the overall upgrade of the LANSCE DTL RF power plant.

A Compact FEL Design for THz Generation

TUPA60

M.R.A. Zuboraj, Q.R. Marksteiner (LANL)

Our motivation is to develop a table-top high power (10 to 100 W) THz (1.75×10^{12} Hz) source for national security applications. This source can be targeted to many security related needs such as detection of concealed weapons, explosives, biohazards, drugs, cargo inspection and THz radars. The project aims at developing a portable high-power THz source that consists of a compact accelerator-based Free Electron Laser (FEL) system. For miniaturization, this project explored different seeding methods to compress the beam before lasing in the undulator magnets. It was found that the most effective way to seed an FEL with THz power was to use a Quantum Cascade Laser (QCL). A space-based accelerator structure developed at LANL along with QCL seeding was found to be appropriate for meter long FEL machine that would generate 10 W of THz power at 1.75 THz. Here we will discuss the straw-man design for this system, and propose a scaled down demonstration experiment that can be done using existing equipment at LANL.

Alkali Antimonide Photocathode Thin Film Growth: from Sequential Deposition Towards Automated Process Control

TUPA61

V.N. Pavlenko (LANL)

Photocathodes generating electron beams with the mean transverse energy (MTE) of ~10 meV or even lower may soon become practical due to recent advances in accelerator technology. Alkali antimonide films grown by traditional (sequential) method will not be able to satisfy such stringent requirements due to their significant physical and chemical roughness. Co-deposition technique was shown to yield much smoother films. However, there are no co-deposition recipes that could be shared between different thin film growth facilities, and reproducibility even within a given facility is admittedly poor. We argue that the poor reproducibility is due to the lack of control of the film growth parameters, which results in unintended changes of stoichiometric composition. We show that photoemissive properties of cesium antimonide are related to its stoichiometric composition in a specific way that allows to implement feedback-based process control. Such process control effectively maintains nearly constant stoichiometry of the film via small real-time adjustments to the ratio of the incident fluxes. We discuss the impact of the method on the development of recipe standards and quality control.

LANSCE Control System's 50th Anniversary

TUPA62

M. Pieck, C.D. Hatch, H.A. Watkins, E.E. Westbrook (LANL)

After being in service almost exactly 50 years, the LANSCE (Los Alamos Neutron Science Center) control system has achieved a major milestone: replacing its original and reliable RICE (Remote Instrumentation and Control Equipment) with a modern customized control system. The RICE upgrade that started around the year 2000 was challenging because of its technology (late 1960's), number of channels (>10,000), and unique characteristics (all-modules data takes, timed/flavored data takes). We discuss motivations, technological challenges, and new systems providing cutting edge instrumentation and controls capabilities. The boundary condition, as usual, was that we had to implement these changes on a running accelerator.

TUPA63

The Beam Plasma Interactions Experiment (Beam PIE): Progress on a Sub-Orbital Active Experiment Using Pulsed Electron Beams

C.D. Roper, R.J. Aragonez, B.E. Carlsten, R.C. Clanton, A.S. Guider, R.L. Hemphill, M.A. Holloway, J.W. Lewellen, Q.R. Marksteiner, M.A. Mealy, D. Patrick, G.D. Reeves (LANL)

In the past, electron beam experiments wee used to study spacecraft-plasma coupling, spacecraft charging, and wave generation. Studies of wave-generation and wave-particle interactions using electron beams were of particular interest in the early days of active space experiments. In the last few years new advances in space technology, diagnostics, and accelerator technologies have enabled a paradigm shift for a new generation of active space experiments. This technology shift provides an opportunity to expand knowledge of wave and wave-particle interactions, which play a critical role in some of the most important dynamics in space and astrophysical plasmas. A Los Alamos National Laboratory and NASA Goddard Spaceflight Center joint collaboration will demonstrate the first advanced linear electron accelerator instrumentation for use in future space experiments. We present progress on this experiment, called the Beam Plasma Interactions Experiment (Beam PIE). Beam PIE is a sounding rocket experiment that will use an electron beam to quantitatively understand and characterize how energetic electron beams in space couple to plasmas to stimulate whistler-mode and R-X-mode radiation.

TUPA64

Analysis of Resonant Converter Topology for High-Voltage Modulators

M. Sanchez Barrueta, J.T.M. Lyles (LANL)

At the Los Alamos Neutron Science Center (LANSCE), we are considering various topologies to replace obsolete charging supplies and capacitor banks that provide high-voltage direct-current (DC) power to the 44, 805-MHz klystron modulators that drive the LANSCE Coupled Cavity Linac (CCL). Among the possible replacement topologies is the High Voltage Converter Modulator (HVCM), originally designed at LANSCE for use at the Spallation Neutron Source (SNS), to be used as a pulsed high-voltage power supply for klystron-based RF transmitters. The HVCM topology uses high frequency transformers with resonant LC networks for efficient energy conversion and a frequency dependent gain, which permits the use of frequency modulation as a control variable to afford pulse flattening and excellent regulation as demonstrated at SNS. A mathematical analysis is presented that links the converter resonant tank components to the frequency dependent output behavior of the converter modulator.

TUPA65

Machine Learning for the LANL Electromagnetic Isotope Separator

A. Scheinker, K.W. Dudeck, C.P. Leibman (LANL)

The Los Alamos National Laboratory electromagnetic isotope separator (EMIS) utilizes a Freeman ion source to generate beams of various elements which are accelerated to 40 keV and passed through a 75-degree bend using a large dipole magnet with a radius of 1.2 m. The isotope mass differences translate directly to a spread in momentum, dp, relative to the design momentum p0. Momentum spread is converted to spread in the horizontal arrival location dx at a target chamber by the dispersion of the dipole magnet: dx = D(s)dp/p0. By placing a thin slit leading to a collection chamber at a location xc specific isotope mass is isolated by adjusting the dipole magnet strength or the beam energy. The arriving beam current at xc is associated with average isotope atomic mass, giving an isotope mass spectrum I(m) measured in mA. Although the EMIS is a compact system (5 m) setting up and automatically running at an optimal isotope separation profile I(m) profile is challenging due to time-variation of the complex source as well as un-modeled disturbances. We present preliminary results of developing adaptive machine learning-based tools for the EMIS beam and for the accelerator components.

TUPA67

Optimization of Harmonic Current Frequency Content for an Accelerated Beam Produced from a Gridded Gun

J.M. Tinlin, B.E. Carlsten, E.I. Simakov (LANL)

This poster will present a study of the harmonic-current frequency content of RF accelerator beams whose injection frequency differs from the operating frequency of the accelerator. Specifically, we explored the harmonic current content of a beam produced in a gridded gun that operates at one frequency and then injected into an accelerator that operates at a different frequency. The study was conducted using Los Alamos National Laboratory's simulation packages SUPERFISH and PARMELA. SUPERFISH was used to model RF accelerator cavities and the fields in the gridded gun, while PARMELA was used to track individual particles as they traveled through the gun and accelerator. The data outputted by PARMELA was processed in custom Python scripts to provide necessary analysis such as calculation of

the harmonic-current frequency content, optimization, and visualization. Being able to control the harmonic-current content of a beam is important for efficient coupling of two accelerators operating at different frequencies, as well as allowing the beam to couple to RF components in beamlines, such as diagnostics and structures, that were originally designed for different accelerator frequencies.

Study of Different Ferrite Material for Inductive Insert in the Proton Storage Ring at LANSCE

TUPA68

J. Upadhyay, A.M. Alexander, E. Henestroza, E.-C. Huang, J.T.M. Lyles, C.E. Taylor (LANL)

Inductive inserts are used in the proton storage ring (PSR) at Los Alamos National Science Center to reduce beam instabilities. These ferrite inserts are great for reducing the beam instabilities in present production beam bunches. Studies are being conducted for the storage of shorter beams with the same or more intensity. This leads to more beam instability. We are studying the different ferrite material properties and their frequency dependence to map out the parameter space where, with the help of these inserts, we can produce the beam without the instability. ELEGANT simulations of the beam in the proton storage ring with different ferrite material properties in current inserts will be presented, and the status of the study will be shown.

Improving Cavity Phase Measurements at the Los Alamos Neutron Science Center

TUPA69

P. Van Rooy, A.T. Archuleta, L.J. Castellano, S. Kwon, M.S. Prokop, P.A. Torrez (LANL)

Control stability of the phase and amplitude in the cavity is a significant contributor to beam performance. The ability to measure phase and amplitude of pulsed RF systems at accuracies of $\pm$ 0.1 degrees and $\pm$ 0.1 percent required for our systems is difficult, and custom-designed circuitry is required. The digital low-level RF upgrade at the Los Alamos Neutron Science Center is continuing to progress with improved cavity phase measurements. The previous generation of the cavity phase and amplitude measurement system has a phase ambiguity, which requires repeated calibrations to ascertain the correct phase direction. The new phase measurement system removes the ambiguity and the need for field calibration while improving the range and precision of the cavity phase measurements. In addition, the new digital low-level RF systems is designed to upgrade the legacy system without significant mechanical, electrical, or cabling changes. Performance data for the new phase measurement system is presented.

Ab Initio Cu Alloy Design for High-Gradient Accelerating Structures

TUPA70

G.X. Wang, D. Perez, E.I. Simakov (LANL)

Increasing the operational gradient of normal-conducting accelerator structures is key to reducing the length and cost of accelerator facilities, and enabling compact portable accelerators for many applications in industry, medicine and biology, energy and environment, and national security. The RF breakdown is a major factor limiting achievable accelerating gradients. Previous experiments have demonstrated that CuAg alloys can significantly suppress the breakdown probability as compared to pure Cu. However, there is currently no comprehensive theoretical approach that can predict the performance of different Cu alloys for high-gradient applications. This presentation will report a Figure-of-Merit (FOM) based on the tradeoff between solid solution strengthening and the additional thermal stress induced by RF pulse heating to characterize the high-gradient performance of Cu alloys. The FOM allows us to perform high-throughput ab-initio screening for a large number of binary Cu alloys. Several alloys, such as CuAg, CuCd, CuHg, CuAu, CuIn, and CuMg, are identified for the design of future high-gradient normal-conducting accelerating structures.

Safe Extremum Seeking for Real Time Optimization of Particle Accelerators

TUPA71

A.B. Williams, A. Scheinker (LANL)

In this work we present a form of real time optimization, based on classical extremum seeking (ES), which is aware of constraints arising from a need for safety. The algorithm optimizes an objective function over a set of tuning parameters, while ensuring an unknown safety function remains greater than a specified value over the course of tuning. We show experimentally how our safe ES algorithm is able to deal with the constrained problem through the use of an additional term inspired by a solution to a quadratic program. We use the Kapchinsky-Vladimirsky envelope equation as the model of the beam, and consider the magnet strengths as the tuning parameters. The objective consists of the sum of errors in transverse beam size at the endpoint of the beamline. We also consider the safety of the system as the amount of beam loss, and use a naive model of beam loss as a function of the integral of the transverse size of the beam. The performance of our algorithm on this simulation provides a proof of concept and demonstrates potential usefulness in accelerator applications.

TUPA72

Comparison Study of the First Bunch Compressor Schemes by a Conventional and a Double C-Chicane for MaRIE XFEL

H. Xu, P.M. Anisimov, L.D. Duffy, Q.R. Marksteiner (LANL)

We report our comparison study on the first stage electron bunch compression schemes at 750 MeV using a conventional and a double C-chicane for the X-ray free electron laser (XFEL) under development for the Matter-Radiation Interactions in Extremes (MaRIE) initiative at Los Alamos National Laboratory. Compared to the performance of the conventional C-chicane bunch compressor, the double C-chicane scheme exhibits the capability of utilizing the transverse momentum shift induced by the coherent synchrotron radiation in the second C-chicane to compensate that generated in the first C-chicane, resulting in a compressed electron bunch with minimized transverse momentum shift along the beam. It is also found that the double C-chicane scheme can be designed to significantly better preserve the beam emittance in the course of the bunch compression. This is particularly beneficial for the MaRIE XFEL whose lasing performance critically depends on the preservation of the ultralow beam emittance.

TUPA73

Design and Low Power Test of an Electron Bunching Enhancer Using Electrostatic Potential Depression

H. Xu, B.E. Carlsten, Q.R. Marksteiner (LANL) B.L. Beaudoin, T.W. Koeth, A. Ting (UMD)

We present our experimental design and low power test results of a structure for the proof-of-principle demonstration of fast increase of the first harmonic current content in a bunched electron beam, using the technique of electrostatic potential depression (EPD). A primarily bunched electron beam from an inductive output tube (IOT) at 710 MHz first enters an idler cavity, where the longitudinal slope of the beam energy distribution is reversed. The beam then transits through an EPD section implemented by a short beam pipe with a negative high voltage bias, inside which the rate of increase of the first harmonic current is significantly enhanced. An output cavity measures the harmonic current developed inside the beam downstream of the EPD section. Low power test results of the idler and the output cavities agree with the theoretical design.

TUPA74

Numerical Calculations of Wave Generation From a Bunched Electron Beam in Space

H. Xu, G.L. Delzanno, L.D. Duffy, Q.R. Marksteiner (LANL)

We present our numerical approach and preliminary results of the calculations of whistler and X-mode wave generation by a bunched electron beam in space. The artificial generation of whistler and X-mode plasma waves in space is among the candidate techniques to accomplish the radiation belt remediation (RBR), in an effort to precipitate energetic electrons towards the atmosphere to reduce their threat to low-Earth orbit satellites. Free-space propagation of an electron pulse in a constant background magnetic field was simulated with the CST particle-in-cell (PIC) solver, with the temporal evolution of the beam recorded. The SpectralPlasmaSolver (SPS) was then modified to use the recorded electron pulse propagation to calculate the real-time plasma waves generated by the beam. SPS simulation results of the wave generation for the upcoming Beam-PIE experiment as well as an ideal bunched electron beam are shown.

TUPA75

High-Gradient Testing Results of the Benchmark a/λ=0.105 Cavity at CERF-NM

M.R.A. Zuboraj, D.V. Gorelov, T.W. Hall, M.E. Middendorf, E.I. Simakov, T. Tajima (LANL)

This presentation will report initial results of high gradient testing of two C-band accelerating cavities fabricated at Los Alamos National Laboratory (LANL). At LANL, we commissioned a C-band Engineering Research Facility of New Mexico (CERF-NM) which has unique capability of conditioning and testing accelerating cavities for operation at surface electric fields at the excess of 300 MV/m, powered by a 50 MW, 5.712 GHz Canon klystron. Recently, we fabricated and tested two benchmark copper cavities at CERF-NM. These cavities establish a benchmark for high gradient performance at C-band and the same geometry will be used to provide direct comparison between high gradient performance of cavities fabricated of different alloys and by different fabrication methods. The cavities consist of three cells with one high gradient central cell and two coupling cells on the sides. The ratio of the radius of the coupling iris to the wavelength is a/λ=0.105. This poster will report high gradient test results such as breakdown rates as function of peak surface electric and magnetic fields and pulse heating.

High Current Photoinjector Electron Source for Compact Short Wavelength FEL

TUPA76

O. Camacho, N. Majernik, J.B. Rosenzweig (UCLA)

FEL X-ray sources have proven invaluable instruments in advancing fundamental research in physics, chemistry, biology, and materials science. Recent interest in shifting the current research paradigm by compactifying these devices to a scale feasible for university laboratories calls for simultaneous order-of-magnitude refinement of peak current, energy spread, and emittance. We consider an ultra high-field C-band RF photoinjector design with coupled standing- and traveling-wave cavities to focus the beam in three dimensions, and achieve sub-micron transverse emittance and peak currents in the hundreds of amperes prior to acceleration. The beam produced is of sufficient quality to drive FEL lasing in the deep UV regime without the need for external magnetic compression, significantly reducing the requisite beamline footprint and total cost. The distribution of and variation in the output distribution are analyzed, along with tolerance of the device to beamline errors.

X-Band Harmonic Longitudinal Phase Space Linearization at the PEGASUS Photoinjector

TUPA77

P.E. Denham (UCLA)

RF photoinjectors are ideal sources for high speed electron microscopes because they yield bright, pulsed beams, potentially delivering excellent spatio-temporal resolution (10 nm - 10 ps). Ultrafast time-resolved microscopes ideally rely on electron beams with duration on the picosecond time scale — pulses of this character sample RF-nonlinearities that lead to energy-time correlations which significantly degrade energy spread. Cavities of a higher harmonic than the RF source can be used to compensate for these RF-nonlinearities. Start to end simulations suggest that this type of compensation can reduce energy spread to 10^{-5}. This work is an experimental study of x-band harmonic linearization of a beam's longitudinal phase space at the PEGASUS facility, with the goal of a relative energy spread of less than 10^{-4}. We present an implemented optical setup that minimizes the betatron contribution at the spectrometer screen. The design utilizes a pinhole and quadrupole optics before and in the dispersion section, enabling energy resolution down to 10^{-5}.

Using a Tunable Light Source to Reduce Mean Transverse Energy of an Electron Beam

TUPA78

D.A. Garcia (UCLA)

The production of a bright electron beam from a photoinjector is an important step in advancing accelerator physics. When an electron beam is created at the photocathode, the thermal energy of the electrons gives the beam a transverse energy spread that we call the mean transverse energy (MTE). A simple way to increase the brightness of an electron bunch is to reduce the MTE at the photocathode. We look to reduce the MTE of an electron beam by using a tunable light source in the UV to match the photon energy to the work function of a copper photocathode. Using an 800 nm Ti:Sapphire laser with 45 fs pulses, we create white light by focusing IR light onto silica glass and create 400 nm blue light by SHG and mix the white and blue in a BBO crystal to create tunable UV light. Our experiment will take place in a 30 kV DC electron gun where we will report measurements of emittance as we vary laser wavelength.

Temperature-Dependent Effects on RF Surface Resistivity

TUPA79

G.E. Lawler, A. Fukasawa, N. Majernik, J.R. Parsons, J.B. Rosenzweig, Y. Sakai (UCLA)
F. Bosco (Sapienza University of Rome)

Several promising concepts for future linacs are dependent on high-gradient cavities enabled by reduced breakdown rates from normal conducting cryogenic operation. The physical phenomena associated with the reduced breakdown rates are complex and necessitate continued basic physics experiments and theory to understand. We use techniques developed for previous X-band and S-band low-power surface resistivity measurement by way of temperature-dependent quality factor measurements to study C-band cavities. Data comparing the difference between surface resistivity at cryogenic temperatures first as a function of machining process will be compared and future experiments using various copper silver alloys will be presented.

New Cryogenic Brightness-Optimized Radiofrequency Gun (CYBORG)

TUPA80

G.E. Lawler, O. Camacho, A. Fukasawa, N. Majernik, P. Manwani, J.B. Rosenzweig, Y. Sakai, M. Yadav (UCLA) F. Bosco (Sapienza University of Rome) Z. Li (SLAC)

Xray free electron laser (XFEL) facilities in their current form are large, costly to maintain, and inaccessible due to their minimal supply and high demand. It is then advantageous to consider miniaturizing XFELs through a variety of means. We hope to increase beam brightness from the photoinjector via high gradient operation (>120 MV/m) and cryogenic temperature operation at the cathode (<77K). To this end we have designed and fabricated our new CrYogenic Brightness-Optimized Radiofrequency Gun (CYBGORG). The photogun is 0.5 cell so much less complicated than our eventual 1.6 cell photoinjector. It will serve as a prototype and test bed for cathode studies in a new cryogenic and very high gradient regime. We present here the fabricated structure, progress towards commissioning, and beamline simulations.

TUPA81

Design of a High-Power RF Breakdown Test for a Cryocooled C-Band Copper Structure

G.E. Lawler, A. Fukasawa, J.R. Parsons, J.B. Rosenzweig (UCLA) Z. Li, S.G. Tantawi (SLAC) A. Mostacci, B. Spataro (LNF-INFN) E.I. Simakov, T. Tajima (LANL)

High-gradient RF structures capable of maintaining gradients in excess of 250 MV/m are critical in several concepts for future electron accelerators. Concepts such as the ultra-compact free electron laser (UC-XFEL) and the Cool Copper Collider (C3) plan to obtain these gradients through the cryogenic operation (<77K) of normal conducting copper cavities. Breakdown rates, the most significant gradient limitation, are significantly reduced at these low temperatures, but the precise physics is complex and involves many interacting effects. High-power RF breakdown measurements at cryogenic temperatures are needed at the less explored C-band frequency (5.712 GHz), which is of great interest for the aforementioned concepts. On behalf of a large collaboration of UCLA, SLAC, LANL, and INFN, the first C-band cryogenic breakdown measurements will be made using a LANL RF test infrastructure. The 2-cell geometry designed for testing will be modifications of the distributed coupled reentrant design used to efficiently power the cells while staying below the limiting values of peak surface electric and magnetic fields.

TUPA82

Transverse Stability in an Alternating Symmetry Planar Dielectric Wakefield Structure

W.J. Lynn, G. Andonian, N. Majernik, S.M. OTool, J.B. Rosenzweig (UCLA)

Dielectric Wakefield Acceleration (DWA) is a promising technique for realizing the next generation of linear colliders. It provides access to significantly higher accelerating gradients than traditional radio-frequency cavities. One impediment to realizing a DWA-powered accelerator is the issue of the transverse stability of the beams within the dielectric structure due to short-range wakefields. These short-range wakefields have a tendency to induce a phenomenon known as single-bunch beam breakup, which acts as its name implies and destroys the relevant beam. We attempt to solve this issue by leveraging the quadrupole mode excited in a planar dielectric structure and then alternating the orientation of said structure to turn an unstable system into a stable one. We examine this issue computationally to determine the limits of stability and based on those simulations describe a future experimental realization of this strategy.

TUPA83

Derivative-Free Optimization of Multipole Fits to Experimental Wakefield Data

N. Majernik, G. Andonian, W.J. Lynn, J.B. Rosenzweig (UCLA) P. Piot, T. Xu (Northern Illinois University)

A method to deduce the transverse self-wakefields acting on a beam, based only on screen images, is introduced. By employing derivative-free optimization, the relatively high-dimensional parameter space can be efficiently explored to determine the multipole components up to the desired order. This technique complements simulations, which are able to directly infer the wakefield composition. It is applied to representative simulation results as a benchmark and also applied to experimental data on skew wake observations from dielectric slab structures.

TUPA84

Reconstructing Beam Parameters From Betatron Radiation Through Machine Learning and Maximum Likelihood Estimation

S. Zhang, N. Majernik, B. Naranjo, M.H. Oruganti, J.B. Rosenzweig, M. Yadav (UCLA) O. Apsimon, C.P. Welsch, M. Yadav (The University of Liverpool)

In plasma wakefield acceleration, a dense drive beam generates a linear focusing force that causes electrons inside the witness beam to undergo harmonic transverse betatron oscillations, giving rise to betatron radiation. Because information about the properties of the beam is encoded in the betatron radiation, measurements of the radiation such as those recorded by the UCLA-built Compton spectrometer can be used to reconstruct beam parameters. Two possible methods of extracting information about beam parameters from measurements of radiation are machine learning (ML), which is increasingly being implemented for different fields of beam diagnostics, and a statistical technique known as maximum likelihood estimation (MLE). We assess the ability of both machine learning and MLE methods to accurately extract beam parameters from measurements of betatron radiation.

Multileaf Collimator for AWA's EEX Beamline

TUPA85

N. Majernik, G. Andonian, C.D. Lorch, J.B. Rosenzweig (UCLA) D.S. Doran, J.G. Power, E.E. Wisniewski (ANL)

By shaping the transverse profile of a particle beam prior to an emittance exchange (EEX) beamline, drive and witness beams with variable current profiles and bunch spacing can be produced. Presently at AWA, this transverse shaping is accomplished with individually laser-cut tungsten masks, making the refinement of beam profiles a slow process. In contrast, a multileaf collimator (MLC) is a device that can selectively mask the profile of a beam using many independently actuated leaves. Since an MLC permits real-time adjustment of the beam shape, its use as a beam mask would permit much faster optimization in a manner highly synergistic with machine learning. Beam dynamics simulations have shown that such an approach is functionally equivalent to that offered by the laser cut masks. In this work, the construction and commissioning of a 40-leaf, UHV compatible MLC is discussed.

Simulations of Nanoblade Cathode Emissions With Image Charge Trapping for Yield and Brightness Analyses

TUPA86

J.I. Mann, G.E. Lawler, J.B. Rosenzweig, B. Wang (UCLA) T. Arias, J.K. Nangoi (Cornell University) S.S. Karkare (Arizona State University)

Laser-induced field emission from nanostructures as a means to create high brightness electron beams has been a continually growing topic of study. Experiments using nanoblade emitters have achieved peak fields upwards of 40 GV/m according to semi-classical analyses, begging further theoretical investigation. A recent paper has provided analytical reductions of the common semi-infinite Jellium system for pulsed incident lasers. We utilize these results to further understand the physics underlying electron rescattering-type emissions. We numerically evaluate this analytical solution to efficiently produce spectra and yield curves. The effect of space-charge trapping at emission may be simply included by directly modifying these spectra. Additionally, we use a self-consistent 1-D time-dependent Schrödinger equation with an image charge potential to study the same system as a more exact, but computationally costly, approach. With these results we may finally investigate the mean transverse energy and beam brightness at the cathode in these extreme regimes.

Simulations for the Space Plasma Experiments at the SAMURAI Lab

TUPA87

P. Manwani, H.S. Ancelin, A. Fukasawa, G.E. Lawler, N. Majernik, B. Naranjo, J.B. Rosenzweig, Y. Sakai, O. Williams (UCLA) G. Andonian (RadiaBeam)

Plasma wakefield acceleration using the electron linear accelerator test facility, SAMURAI, can be used to study the Jovian electron spectrum due to the high energy spread of the beam after the plasma interaction. The SAMURAI RF facility which is currently being constructed and commissioned at UCLA, is is capable of producing beams with 10 MeV energy, 2 nC charge, and 200 fsec bunch lengths with a 4 um emittance. Particle-in-cell (PIC) simulations are used to study the beam spectrum that would be generated from plasma interaction. Experimental methods and diagnostics are discussed in this paper.

FAST-GREENS: a High Efficiency Free Electron Laser Driven by Superconducting RF Accelerator

TUPA88

P. Musumeci, P.E. Denham, A.C. Fisher, J. Jin (UCLA) R.B. Agustsson, T.J. Hodgetts, A.Y. Murokh (RadiaBeam) L. Amoudry (Université Paris-Saclay, CNRS/IN2P3, IJCLab) D.R. Broemmelsiek, S. Nagaitsev, J.K. Santucci, G. Stancari, A. Valishev (Fermilab) A.H. Lumpkin, A. Zholents (ANL)

In this paper we will describe the status of the FAST-GREENS experimental program where a 4 m-long strongly tapered helical undulator with a seeded pre-buncher is used in the high gain TESSA regime to convert a significant fraction (up to 10%) of energy from the 240 MeV electron beam from the FAST linac to coherent 515 nm radiation. We will also discuss the longer term plans for the setup where by embedding the undulator in an optical cavity matched with the high repetition rate from the superconducting accelerator (3.9 MHz), a very high average power laser source can be obtained. Eventually, the laser pulses can be redirected onto the relativistic electrons to generate by inverse Compton scattering a very high flux of circularly polarized gamma rays for polarized positron production.

TUPA89

Photon Spectrometers at FACET-II

B. Naranjo, G. Andonian, A. Fukasawa, N. Majernik, J.B. Rosenzweig, Y. Sakai, O. Williams, M. Yadav (UCLA) D.W. Storey (SLAC)

In the experiments planned for the Facility for Advanced Accelerator Experimental Tests (FACET-II) at SLAC National Accelerator Laboratory, a pulsed electron beam of energy 10 GeV interacts with a variety of targets, including plasmas, solid targets, and high-intensity electromagnetic fields. A key physics diagnostic is the resulting downstream radiation, for which we are developing both a Compton spectrometer and a pair spectrometer. In both cases, photons incident on a converter target yield charged particles which subsequently are magnetically analyzed. The Compton spectrometer, optimized for the lower range of photon energies resulting from betatron radiation, can simultaneously resolve both angular and spectral information on a shot-by-shot basis. The pair spectrometer, optimized for a wide photon energy range of 10 MeV through 10 GeV, also on a single-shot basis, is particularly suited for strong-field QED (SFQED) studies. We review the design of these spectrometers and present an update of their construction and testing.

TUPA90

High-Throughput Injection-Acceleration of Electron Bunches From a Linear Accelerator to a Laser Wakefield Accelerator

Y.P. Wu, C. Joshi, W.B. Mori, Z. Nie (UCLA) Y.C. Du, Y. Fang, J.F. Hua, F. Li, S. Liu, W. Lu, C.H. Pai, B. Peng, C.J. Zhang, J. Zhang (TUB) Z. Zhou (CAEP/IAE)

Plasma-based accelerators can accelerate electrons or positrons with extremely high gradients. For their use as next-generation light sources and colliders, beams with good stability, high quality and controllable polarization are required. The accelerated electrons can be either internally injected from the background plasma or externally injected from conventional accelerators. Despite significant progress, the beam properties obtained with the internal injection scheme fall short of simultaneously reaching these requirements. In contrast, such high-property beams are routinely generated from conventional accelerators. Therefore, it is important to demonstrate the injection from a conventional accelerator into a plasma-based machine followed by further beam acceleration. Here we report the demonstration of external injection from a conventional linear accelerator into a laser wakefield accelerator and subsequent acceleration without any significant loss of charge, which is achieved by properly shaping and matching the beam into the plasma structure. The experimental results, combined with 3D PIC simulations, also indicate low degradation in the beam quality.

TUPA91

Distributed Coupling Linac for Efficient Acceleration of High Charge Electron Bunches

A. Dhar, M. Bai, A.A. Haase, Z. Li, E.A. Nanni, M.A.K. Othman, A.V. Sy, S.G. Tantawi, G.R. White (SLAC)

The Electron Ion Collider requires a pre-injector linac to accelerate large electron bunches from 4 MeV up to 400 MeV over 35 m [1]. Currently this linac is being designed with 3 m long traveling wave structures, which provide a gradient of 16 MV/m. We propose the use of a 1 m distributed coupling design as a potential alternative and future upgrade path to this design. Distributed coupling allows power to be fed into each cavity directly via a waveguide manifold, avoiding on-axis coupling [2]. A distributed coupling structure at S-band was designed to optimize for shunt impedance and large aperture size. This design provides greater efficiency, thereby lowering the number of klystrons required to power the full linac. In addition, particle tracking analysis shows that this linac maintains lower emittance as bunch charge increases to 14 nC and wakefields become more prevalent. We present the design of this distributed coupling structure, as well as a progress report on structure manufacturing and characterization.

TUPA92

Solid-State Driven X-band Linac for Electron Microscopy

A. Dhar, E.A. Nanni, M.A.K. Othman, A.V. Sy, S.G. Tantawi (SLAC)

Current transmission electron microscopes (TEM) accelerate electrons to 200-300 keV using DC electron guns with a nanoamp of current and very low emittance. However, at higher voltages these DC sources rapidly grow in size, oftentimes several meters tall for 1 MeV microscopes [1]. Replacing these electron guns with a compact linac powered by solid-state sources could dramatically lower cost while maintaining beam quality, thereby increasing accessibility. Utilizing compact high shunt impedance X-band structures ensures that each RF cycle contains at most a few electrons, preserving beam coherence. CW operation of the RF linac is possible with distributed solid-state architectures [2] which power each cavity directly with solid-state amplifiers which can now provide up to 100W of power at X-band frequencies. We present an initial design and tests for a prototype low-cost CW RF linac for high-throughput electron diffraction producing 200 keV electrons with a standing-wave architecture where each cell is individually powered by a solid-state transistor. This design also provides an upgrade path for future compact MeV-scale sources on the order of 1 meter in size.

TUADE — Entertaiment and Historical Talk

TUADE1

Los Alamos National Laboratory: Beyond Manhattan

A.B. Carr (LANL)

Many know the story of the Manhattan Project, and the crucial role played by Oppenheimer's Laboratory at Los Alamos in the design, construction and deployment of the world's first nuclear weapons. But what happened to the Laboratory after the war? Why did it remain in existence, and how did it evolve over the years? Alan Carr will discuss how Los Alamos National Laboratory has changed through the decades, and conclude by giving a quick survey of the modern institution on the eve of its 80th anniversary.

Chair: W.L. Peterson, LANL (Los Alamos, New Mexico, USA)

WEXD — Beam Dynamics

WEXD1

Advances in Beam Dynamics at Nuclear Physics Accelerator Facilities

A.V. Sy (JLab)

Beam dynamics of particle accelerators is a rich subfield that enables accelerators to be used in pursuit of fundamental topics in particle physics in increasingly complex ways. The field is constantly evolving as new and advanced accelerators push the limits of energy, luminosity, and accelerated species. This talk will cover some recent beam dynamics developments for future operation of DOE nuclear physics user facilities, including upgrade options for Jefferson Lab's 12 GeV CEBAF.

WEXD2

Storage Ring Tracking Using Generalized Gradient Representations of Full Magnetic Field Maps

R.R. Lindberg, M. Borland (ANL)

We have developed a set of tools to simulate particle dynamics in the full magnetic field using the generalized gradients representation. Generalized gradients provide accurate and analytic representations of the magnetic field that allow for symplectic tracking [1]. We describe the tools that convert magnetic field data into generalized gradients representations suitable for tracking in Elegant, and discuss recent results based upon tracking with the full field representations for all magnets in the APS-U storage ring.

WEXD3

Map Tracking in Rings With Stochastic Radiation Emission Effects

D. Sagan, G.H. Hoffstaetter (Cornell University (CLASSE), Cornell Laboratory for Accelerator-Based Sciences and Education)

Particle tracking is an important and widely used simulation tool since it is the only reliable technique that can accurately and reliably probe the nonlinear effects that can develop in particle beams over many turns. Charged particle motion in accelerators is not deterministic when radiation effects are relevant. To accurately model these, both deterministic and stochastic effects have to be included. Routinely, particle tracking in accelerators is done either by tracking element-by-element which is slow, or by using a transfer map. While one can include the appropriate stochastic terms into element-by-element tracking, this is generally not done when tracking using transfer maps. Presented here is an algorithm for including stochastic radiation in a truncated Taylor series transfer map. Generating such maps has been implemented in the PTC code which is interfaced to the Bmad toolkit. We derive the stochastic distribution that has to be applied to appropriately characterize the traversed accelerator section. Comparisons of map tracking with element-by-element tracking demonstrate the utility of this approach.

WEXD4

OPAL for Self-Consistent Start-to-End Simulation of Undulator-Based Facilities

A. Adelmann, A. Albà (PSI) A. Fallahi (ETH Zurich, Photonics Laboratory)

The Object Oriented Parallel Accelerator Library (OPAL), a parallel open source tool for charged-particle optics is augmented with a new flavor OPAL-FEL. With OPAL-FEL we solve the electromagnetic potential equations in free-space for radiating particles propagating along an undulator using an FDTD/PIC scheme. We present results of two benchmark [1] studies where OPAL-FEL simulations are compared to experimental results. Both experiments are about electron beamlines where the longitudinal phase space is modulated with a short magnetic wiggler. To our knowledge, this is the only beam dynamics model that allows a start-to-end simulation of FELs, in a fully 3D fashion including radiation.

WEXD5

Benchmarking Simulation for AWA Drive Linac and Emittance Exchange Beamline Using OPAL, GPT, and Impact-T

S.Y. Kim, G. Chen, D.S. Doran, G. Ha, W. Liu, J.G. Power, E.E. Wisniewski (ANL)
E.A. Frame, P. Piot (Northern Illinois University)

In Argonne Wakefield Accelerator (AWA) facility, particle-tracking simulations have been critical to guiding beam-dynamic experiments, e.g., for various beam manipulations using an available emittance-exchange beamline (EEX). The unique beamline available at AWA provide a test case to perform in-depth comparison between different particle-tracking program including collective effects such as space charge force and coherent synchrotron radiation. In this study, using AWA electron injector and emittance exchange beamline, we will compare the simulations results obtained by GPT, OPAL, and Impact-T code. We will specifically report on convergence test as a function of parameters that controls the underlying algorithms.

Chair: J.M. Byrd, ANL (Lemont, Illinois, USA)

Electron Cloud Measurements in Fermilab Booster

S.A.K. Wijethunga, J.S. Eldred, J.S. Eldred, E. Pozdeyev, C.-Y. Tan (Fermilab)

Fermilab Booster synchrotron requires an intensity upgrade from 4.5×10^{12} to 6.5×10^{12} protons per pulse as a part of the Fermilab's Proton Improvement Project-II (PIP-II). One of the factors which may limit the high-intensity performance is the fast transverse instabilities caused by electron cloud effects. According to the experience in the Recycler, the electron cloud gradually builds up over multiple turns in the gradient dipole magnets and can reach final intensities orders of magnitude greater than in a pure dipole. Since the Booster synchrotron also incorporates gradient dipole magnets, it is important to discover any existence of an electron cloud. And if it does, its effects on the PIP-II era Booster and its mitigating techniques. As the first step, the presence or absence of the electron cloud was investigated using the clearing bunch technique. This paper presents experimental details and observations of the bunch-by-bunch tune shifts of beams with various bunch train structures at low and high intensities.

WEXE — Tutorial 1

WEXE1

Accelerator Science and Technology via Inventive Principles of TRIZ

A. Seryi (JLab)

A swift overview of modern areas of accelerator physics and technology presented via and connected through inventive principles of TRIZ, the industrial methodology of inventiveness. A wide range of topics, such as synchrotron radiation, electron cooling, plasma acceleration, are introduced via easy-to-follow back-of-the-envelope derivations. These are connected via canonical yet adjusted for science TRIZ inventive principles and laws, illustrated by numerous inventions such as fiber lasers, tune jumps, inverted guns, and others. This short tutorial introduces a new approach which amalgamates science and industrial inventiveness, enhances creativity, and boosts innovations towards developing the next generations of accelerators and their applications.

WEXF — Tutorial 2

WEXF1

Accelerator Computation: Fast, Cheap, and Easy

J.R. Cary (Tech-X)

Computation has seen dramatically increased speed over the past decade, with the rise of device (GPU) computing. To make this increased computing capability more widely available, there is a need to move it to the cloud, where elastic and cheap resources are available. To make this capability more accessible, there is a need for easily used codes, usable after minimal training. This talk presents an approach to all three of these goals, showing that accelerator computations can be made fast, cheap, and easy.

WEYD — Advanced Acceleration

WEYD1

Ultrahigh Energy Electrons From Laser Wakefield Accelerators

B.M. Hegelich (The University of Texas at Austin)

We report peak electron energies well in excess of 10 GeV from a laser wakefield accelerator. Proof-of-principle experiment have been performed at the Texas Petawatt laser using a 10 cm long gas cell filled with helium gas and seeded by metallic nanoparticles. Greater than 10 GeV electron energies have been observed repeatedly in multiple independent experiments. This results fulfill a major milestones in DOE's Advanced Accelerator Strategy Report from 2016 and open up the potential of laser wakefield accelerators as high energy machines or as drivers for laser-driven XFELs. Compared with other wakefield acceleration schemes, our scheme is straightforward since it requires only a gas cell and a source of nanoparticles for electron injection. No external guiding or heating mechanisms are employed. The nanoparticle-assisted laser wakefield acceleration can control all the electron beam parameters: charge, energy spread, energy, emittance, and the number of bunches in the beam. Bunch charges are on the order of a few nanocoulomb for the whole beam and in the 100s pC range in the high energy part, an order of magnitude increase over previous results at greater than 5 GeV.

WEYD2

First Lasing of a Free-Electron Laser With a Compact Beam-Driven Plasma Accelerator

S. Romeo, M. Galletti, R. Pompili (LNF-INFN)

Plasma-based technology promises a revolution in the field of particle accelerators by pushing beams to GeV energies within centimeter distances and enabling the realization of ultra-compact facilities for user applications like Free-Electron Lasers (FEL). Here we report the first experimental evidence of FEL lasing by a compact (3 cm) particle beam-driven plasma accelerator. FEL radiation is observed in the infrared range with typical exponential growth of its intensity over six consecutive undulators. This achievement is based on the technique we recently developed for energy spread control during acceleration in plasma, generating electron bunches with high-quality, comparable with state-of-the-art accelerators. This proof-of-principle experiment represents an important milestone in the use of plasma-based accelerators contributing to the development of next-generation compact machines for user-oriented applications.

WEYD3

Positron Acceleration in Linear, Moderately Non-Linear and Non-Linear Plasma Wakefields

J.W. Cao, E. Adli (University of Oslo) S. Corde (LOA) S.J. Gessner (SLAC)

Accelerating particles to high energies with high efficiency and beam quality is crucial in developing accelerator technologies. The plasma acceleration technique, providing unprecedented high gradients, is considered as a promising future technology. While important progress has been made in plasma-based electron acceleration in recent years, identifying a reliable acceleration technique for the positron counterpart would pave the way to a linear collider for high-energy physics applications. In this talk, we present a study* that demonstrates a trade-off between efficiency and beam quality in the presence of a positron load in plasma. We show a primary step and highlight the importance of comparing across the different regimes with coherent numerical simulations. Such comparisons provide insight to advantages and weaknesses of each regime based on consistent parameters and criteria. The results show that the moderately non-linear regime can achieve high efficiency and good beam quality simultaneously, while the non-linear regime using a donut-shaped electron driver is more suitable for high-charge, high-gradient acceleration, at the cost of a degraded efficiency and beam quality.

WEYD4

Design and Fabrication of a Metamaterial Wakefield Accelerating Structure

D.C. Merenich, X. Lu (Northern Illinois University) X. Lu, J.G. Power, D.S. Scott (ANL)

Metamaterials (MTMs) are engineered materials that can show exotic electromagnetic properties such as simultaneously negative permittivity and permeability. MTMs are promising candidates for structure-based wakefield acceleration structures, which can mitigate the impact of radio frequency (RF) breakdown, thus achieving a high gradient. Previous experiments carried out at the Argonne Wakefield Accelerator (AWA) successfully demonstrated MTM structures as efficient power extraction and transfer structures (PETS) from a high-charge drive beam. Here we present the design, fabrication, and cold test of an X-band MTM accelerator structure for acceleration of the witness beam in the two-beam acceleration scheme. The MTM structure design was performed using the CST Studio Suite, with the unit cell and the complete multi-cell periodic structure both optimized for high gradient. Cold test of the fabricated structure shows good agreement with simulation results. Future work includes a beam test at AWA to study the short-pulse RF breakdown physics in the MTM structure, as an important component towards a future compact linear collider based on two-beam acceleration.

Highly Spin-Polarized Multi-GeV Sub-Femtosecond Electron Beams Generated from Single-Species Plasma Photocathodes

WEYD5

Z. Nie, C. Joshi, F. Li, K.A. Marsh, D. Matteo, W.B. Mori, N. Nambu, F.S. Tsung, Y.P. Wu, C. Zhang (UCLA) W. An (BNU) F. Morales, S. Patchkovskii, O. Smirnova (MBI)

High-gradient and high-efficiency acceleration in plasma-based accelerators has been demonstrated, showing its potential as the building block for a future collider operating at the energy frontier of particle physics. However, generating and accelerating the required spin-polarized beams in such a collider using plasma-based accelerators has been a long-standing challenge. Here we show that the passage of a highly relativistic, high-current electron beam through a single-species (ytterbium) vapor excites a nonlinear plasma wake by primarily ionizing the two outer 6s electrons. Further photoionization of the resultant Yb^{2+} ions by a circularly polarized laser injects the 4f14 electrons into this wake generating a highly spin-polarized beam. Combining time-dependent Schrodinger equation simulations with particle-in-cell simulations, we show that a sub-femtosecond, high-current (4 kA) electron beam with up to 56% net spin polarization can be generated and accelerated to 15 GeV in just 41 cm. This relatively simple scheme solves the perplexing problem of producing spin-polarized relativistic electrons in plasma-based accelerators.

Studies of a PIP-II Mu2e Experiment

WEYD6

M.A. Cummings, R.J. Abrams, R.P. Johnson, T.J. Roberts (Muons, Inc)

We propose a design of an upgraded Mu2e experiment for the future Fermilab PIP-II era based on the muon collider front end. The consensus is that such an upgrade should provide a factor of 10 increase in the rate of stopping muons in the experimental target. The current Mu2e design is optimized for 8 kW of protons at 8 GeV. The PIP-II upgrade project is a 250-meter-long CW linac capable of accelerating a 2-mA proton beam to a kinetic energy of 800 MeV (total power 1.6 MW). This would significantly improve the Fermilab proton source to enable next-generation intensity frontier experiments. But using this 800 MeV beam poses challenges to the Mu2E experiment. Bright muon beams generated from sources designed for muon collider and neutrino factory facilities have been shown to generate two orders of magnitude more muons per proton than the current Mu2e production target and solenoid. In contrast to the current Mu2e, the muon collider design has forward-production of muons from the target.

WEYE — Hadron Accelerators

WEYE1

Next-Generation Accelerator Facilities at Fermilab: Megawatt Upgrade of the NuMI Neutrino Beam

R.M. Zwaska, J.S. Eldred (Fermilab)

Fermilab is actively designing its next generation of proton accelerators (presently titled PIU - Proton Intensity Upgrade) to produce 2.4 MW of 120 GeV beam to the Long Baseline Neutrino Facility (LBNF), and deliver Megawatt scale beams to a suite of other particle physics experiments researching neutrinos, muons, dark matter, and other particle physics phenomena. These new accelerators will employ state-of-the-art superconducting RF, and rings that will accumulate, compress, and possibly accelerate beam to experiments with a rapid cycling synchrotron. The new accelerators at Fermilab will build off the under construction PIP-II Project - a unique CW superconducting H^- Linac. The approach will utilize much of the the existing accelerator complex (Recycler, Delivery Ring, and Main Injector) at higher intensity, and retire the original linac and Booster synchrotron. The PIU will use the major next experiments now under construction (LBNF and Mu2e). Novel beam formatting and delivery techniques may be developed for the next round of experiments. Additionally, R&D presently underway in beam dynamics, RF, and targetry may contribute to the capability of new accelerator facilities.

WEYE2

Upgrade of the FRIB ReAccelerator

A.C.C. Villari (FRIB)

The ReAccelerator was upgraded from 3 MeV/u to 6 MeV/u for ions with charge over mass equal to 1/4. This upgrade included a new ion source to produce stable and long living rare isotopes in a batch mode, a new room-temperature rebuncher after the first section of acceleration, a new $\beta = 0.085$ quarter-wave-resonator cryomodule and two new beamlines in a brand-new experimental vault. This talk will describe the upgrade, initial operation and all beams obtained and successfully used in the first experiments.

WEYE3

Improvements to the Recycler/Main Injector to Deliver 850 KW+

R. Ainsworth, P. Adamson, D. Capista, N. Chelidze, K.J. Hazelwood, I. Kourbanis, O. Mohsen, D.K. Morris, M.J. Murphy, M. Wren, M. Xiao (Fermilab) C.E. Gonzalez-Ortiz (MSU)

The Main Injector is used to deliver a 120 GeV high power proton beam for Neutrino experiments. The design power of 700 kW was reached in early 2017 but further improvements have seen a new sustained peak power of 893 kW. Two of the main improvements include the shortening of the Main Injector ramp length as well optimizing the slip-stacking procedure performed in the Recycler to reduce the amount of uncaptured beam making its way into the Main Injector. These improvements will be discussed in this paper as well future upgrades to reach higher beam powers.

WEYE4

Electron Cloud Simulations in the Fermilab Recycler

A.P. Schreckenberger (University of Illinois at Urbana-Champaign) R. Ainsworth (Fermilab)

We present a simulation study to characterize the stability region of the Fermilab Recycler Ring in the context of secondary emission yield (SEY). Interactions between electrons and beampipe material can produce electron clouds that jeopardize beam stability in certain focusing configurations. Such an instability was documented in the Recycler, and the work presented here reflects improvements to better understand that finding. We incorporated the Furman-Pivi Model into the PyECLOUD analysis, and we determined the instability threshold for various bunch lengths, beam intensities, SEY magnitudes, and model parameters.

WEYE5

Model/Measurement Comparison of the Transverse Phase Space Distribution of an RFQ-Generated Bunch at the SNS BTF

K.J. Ruisard, A.V. Aleksandrov, S.M. Cousineau, A.M. Hoover, A.P. Zhukov (ORNL)

The research program at the SNS Beam Test Facility is focused on resolving observed model/measurement discrepancies that preclude accurate loss prediction in high-power linacs. The current program of study is focused on deploying direct 6D measurements to reconstruct a realistic model of the initial beam distribution at the RFQ output. This detailed characterization also provides an opportunity for benchmark of RFQ simulations. Here we compare PARMTEQ predictions against 5D-resolved (x, x', y, y', dE) phase space measurements of the BTF H^- bunch, focusing on the

 Chair: D. Li, LBNL (Berkeley, California, USA) transverse distribution. This work is an extension of [1], which focused on the longitudinal phase space. Improved transverse resolution in 5D measurement is achieved using the approach described in [2].

Thermionic Source for Electron Cooling at IOTA

M.K. Bossard, Y.K. Kim (University of Chicago) N. Banerjee (Enrico Fermi Institute, University of Chicago)

We are planning a new electron cooling experiment at the Integrable Optics Test Accelerator (IOTA) at Fermilab for cooling ~2.5 MeV protons in the presence of intense space-charge. Here we present the simulations and design of a thermionic electron source for cooling at IOTA. We particularly discuss parameters of the thermionic source electrodes, as well as the simulation results. We also present a new electron source test-stand at the University of Chicago, which will be used to test the new thermionic electron source, as well as other electron sources. In addition, we discuss results from analyzing the test stand operations with a currently existing electron source. Furthermore, we present future steps for the test stand as well as production and commissioning of the thermionic source at IOTA.

WEZD — Accelerator Technology

WEZD1

ARDAP's Perspective on Accelerator Technology Research and Development in the US

B.E. Carlsten (LANL)

The current state and future prospects for the U.S. accelerator technology ecosystem will be discussed, along with the role of the new Office of Accelerator R&D and Production.

WEZD2

Solid State Active Reset Induction Technology to Accelerate kA Electron Beam

J. Ellsworth (LLNL)

We will discuss Solid State Active reset technology and how it can be applied to kiloampere electron beams.

WEZD3

Magnetron R&D Progress for High Efficiency CW RF Sources of Industrial Accelerators

H. Wang, K. Jordan, R.M. Nelson, S.A. Overstreet, R.A. Rimmer (JLab) J.N. Blum (VCU) B.R.L. Coriton, C.P. Moeller, K.A. Thackston (GA) J.L. Vega (The College of William and Mary) G. Ziemyte (UKY)

After the demonstration of using high efficiency magnetron power to combine and to drive a radio frequency accelerator at 2450 MHz in CW mode [1], we have tested an industrial grade cooking magnetron transmitter at 915 MHz with a 75 kW CW power delivered to a water load with and without an injection signal. We will report the initial result of these high power tests. Also the performance updates of injection locking bandwidth and the power combining efficiency by using a magic-Tee combiner at the 2450 MHz magnetron test stands will be presented. Their application to industrial accelerators will be discussed.

WEZD4

Using Off-Axis Undulator Radiation as a Longitudinal Electron-Beam Diagnostic

Q.R. Marksteiner, H.L. Andrews, J.E. Coleman, W.P. Romero, N.A. Yampolsky, M.R.A. Zuboraj (LANL) S.K. Barber, R.D. Ryne, J. van Tilborg (LBNL) C. Emma (SLAC) B. Ostler (University of Chicago)

A novel diagnostic has been developed that uses off-axis undulator radiation to characterize the longitudinal bunch profile of an electron beam. The diagnostic uses a small, ~0.1-m long undulator with mirrors that focus the undulator radiation onto an array of pyrometers. The mirrors both focus the radiation onto the pyrometer and remove the chirping effect that comes from the finite length of the undulator. Numerical and analytical models have been developed to calculate the radiation for a given bunch length, and a phase retrieval algorithm has been developed to extract the bunch profile from measured data. The diagnostic has been installed at the BELLA laser-plasma wakefield accelerator, and will be used to characterize the bunch length there. The concept and relevant results will be presented.

WEZD5

Micro-Electromechanical Systems Based Multi-Beam Ion Accelerators

Q. Ji, A. Amsellem, A. Persaud, Z. Qin, P.A. Seidl, N. Valverde (LBNL) K. Afridi, V. Gund, Y. Hou, A. Lal, D. Ni (Cornell University) S.M. Lund (FRIB)

We report on the development of multi-beam radio frequency (RF) linear ion accelerators that are formed from stacks of low-cost printed circuit boards. An array of 112 beamlets is formed using MEMS techniques in 4" wafers. The peak argon ion current accelerated in the 112-beamlet column to date is 0.5 mA [1]. We have accelerated ions in stacks of 32 wafers to an energy of 100 keV. The measured energy gain in each RF gap reached 6.5 keV on average, resulting in an effective acceleration gradient of 0.4 MV/m. We will describe how this approach to multi-beam RF ion acceleration can scale to high beam power for applications in material processing and nuclear materials development.

WEZD6

Manufacturing the Harmonic Kicker Cavity Prototype for the Electron-Ion Collider

S.A. Overstreet, M.W. Bruker, G.A. Grose, J. Guo, J. Henry, G.-T. Park, R.A. Rimmer, H. Wang, R.S. Williams (JLab)

High-bunch-frequency beam-separation schemes, such as the injection scheme proposed for the Rapid Cycling Synchrotron at the Electron-Ion Collider, demand rise and fall times an order of magnitude below what can realistically be accomplished with a stripline kicker. Nanosecond-time-scale kick waveforms can instead be obtained by Fourier synthesis in a harmonically resonant quarter-wave radio-frequency cavity which is optimized for high shunt impedance. Originally developed for the

JLEIC Circulator Cooler Ring, a hypothetical 11-pass ring driven by an energy-recovery linac at Jefferson Lab, our high-power prototype of such a harmonic kicker cavity, which operates at five modes at the same time, will demonstrate the viability of this concept with a beam test at Jefferson Lab. As the geometry of the cavity, tight mechanical tolerances, and number of ports complicate the design and manufacturing process, special care must be given to the order of the manufacturing steps. We present our experiences with the manufacturing of the present design, lessons learned, and first commissioning results from the prototype.

WEZE — Accelerator Applications

WEZE1

Current Status of Developing an Ultrafast Electron Microscope

X. Yang, T.V. Shaftan, V.V. Smaluk, Y. Zhu (BNL) P. Musumeci (UCLA) W. Wan (ShanghaiTech University)

Recent studies of ultrafast electron microscopy (UEM) techniques show the use of short bunches of relativistic electrons are promising for the development of a new instrument for imaging samples of various materials. Compared to conventional electron microscopes, the main advantage of UEMs with the electron energy of a few MeV is the possibility to study thick samples. We will discuss the progress of UEM design to date, the principal challenges on the way to a high resolution, and possible methods for their mitigation including the design of low-aberration magnetic optics, RF and mechanical subsystems with high stability, and precise collimation of electrons scattered in the samples.

WEZE2

Ultrafast Electron Diffraction at Cornell Using Low Emittance Photocathodes

J.M. Maxson (Cornell University (CLASSE), Cornell Laboratory for Accelerator-Based Sciences and Education)

A new system for ultrafast electron diffraction has been commissioned at Cornell which uses alkali antimonides photocathode in a 200 keV DC gun. Utilizing a tunable wavelength ultrafast laser source, it is the first photogun to use near-photoemission-threshold drive laser wavelengths in operation, which provides for very low emittance initial conditions. Emittance is preserved in the space charge regime via emittance compensation in conjunction with multipole correction out to sextupole order. The end result is beam quality that provides the ability to study much smaller material samples (down to a few microns across) or to resolve fine features in diffraction space; these are demonstrated via proof of principle experiments.

WEZE3

Compact, High-Power Superconducting Electron Linear Accelerators for MW Industrial Applications

J.C.T. Thangaraj, R. Dhuley (Fermilab)

Fermilab has developed a novel concept for an industrial electron linac using Nb_3Sn coating technology and conduction cooling. We will show the range of multi-cavity linac designs targeted toward various applications. We will also discuss technology development status with results on conduction cooling of SRF cavities based on cryocoolers, which removes the need for liquid Helium, thus making SRF technology accessible to industrial applications. These conduction-cooled linacs can generate electron beam energies up to 10 MeV in continuous-wave operation and can reach higher power (>=1 MW) by combing several modules. Compact and light enough to mount on mobile platforms, our machine is anticipated to enable new in-situ environmental remediation applications such as waste-water treatment for urban areas, X-ray medical device sterilization, and innovative pavement applications. We also show cost-economics and key R&D areas that much be addressed for a practical machine.

WEZE4

First High-Gradient Results of UED/UEM SRF Gun at Cryogenics Temperatures

R.A. Kostin, C. Jing (Euclid Beamlabs) D.J. Bice, T.N. Khabiboulline, S. Posen (Fermilab)

Benefiting from the rapid progress on RF photogun technologies in the past two decades, the development of MeV range ultrafast electron diffraction/microscopy (UED and UEM) has been identified as an enabling instrumentation. UEM or UED use low power electron beams with modest energies of a few MeV to study ultrafast phenomena in a variety of novel and exotic materials. SRF photoguns become a promising candidate to produce highly stable electrons for UEM/UED applications because of the ultrahigh shot-to-shot stability compared to room temperature RF photoguns. SRF technology was prohibitively expensive for industrial use until two recent advancements: Nb_3Sn and conduction cooling. The use of Nb_3Sn allows to operate SRF cavities at higher temperatures (4K) with low power dissipation which is within the reach of commercially available closed-cycle cryocoolers. Euclid is developing a continuous wave (CW), 1.5-cell, MeV-scale SRF conduction cooled photogun operating at 1.3 GHz. In this paper, we present first high gradient results of the gun conducted in liquid helium.

Chair: H.L. Andrews, LANL (Los Alamos, New Mexico, USA)

Magnetic Flux Expulsion in Superconducting Radio-Frequency Niobium Cavities Made From Cold Worked Niobium

WEZE5

B.D. Khanal, G. Ciovati (ODU) S. Balachandran, P.J. Lee (NHMFL) S. Chetri (ASC) P. Dhakal (JLab)

Trapped residual magnetic field during the cool down of superconducting radio frequency (SRF) cavities is one of the primary sources of RF residual losses leading to lower quality factor. Historically, SRF cavities have been fabricated from high purity fine grain niobium with grain size ~50 to 100 μm as well as large grain with grain size of the order of few centimeters. Non-uniform recrystallization of fine-grain Nb cavities after the post fabrication heat treatment leads to higher flux trapping during the cool down, and hence the lower quality factor. We fabricated two 1.3 GHz single cell cavities from cold-worked niobium from different vendors and processed along with cavities made from SRF grade Nb. The flux expulsion and flux trapping sensitivity were measured after successive heat treatments in the range 800 to 1000°C. The flux expulsion from cold-worked fine-grain Nb cavities improves after 800°C/3h heat treatments and it becomes similar to that of standard fine-grain Nb cavities when the heat treatment temperature is higher than 900°C.

Characterization of the Fields Inside the CO_2-Laser-Driven Wakefield Accelerators Using Relativistic Electron Beams

WEZE6

I. Petrushina (SUNY SB) M. Babzien, M.G. Fedurin, K. Kusche, M.A. Palmer, I. Pogorelsky, M.N. Polyanskiy (BNL) M. Downer, R. Zgadzaj (The University of Texas at Austin) A.S. Gaikwad, V. Litvinenko, N. Vafaei-Najafabadi (Stony Brook University) C. Joshi, W.B. Mori, C. Zhang (UCLA) R. Kupfer (LLNL) V. Samulyak (SBU)

The CO_2 laser at the Accelerator Test Facility of Brookhaven National Laboratory is a unique source generating 2-ps-long, multi-TW pulses in the mid-IR regime. This rapidly evolving system opens an opportunity for the generation of large bubbles in low-density plasmas ($\sim 10^{16}$ cm^{-3}) that are ideal for acceleration of externally injected electron beams. A new generation of diagnostic tools is needed to characterize the fields inside such structures and to improve the means of external injection. In recent years, the electron beam probing technique has shown to be successful in direct visualization of the plasma wakefields. Here we present a new method utilizing the electron beam probing and Transmission Electron Microscopy (TEM) grids that will allow us to selectively illuminate different portions of the wake and to characterize the electric field strength within the wake based on the location of the focal point of the probe beamlets. The analytical evaluation of the approach and supporting simulation results will be presented and discussed.

WEPA — Wednesday Poster Session

WEPA01

Beam Dynamics Optimization of a Low Emittance Photoinjector Without Buncher Cavities

J. Qiang (LBNL) , F. Ji, T.O. Raubenheimer (SLAC)

The photoinjector plays an important role in generating high brightness low emittance electron beam for x-ray free electron laser applications. In this paper, we report on beam dynamics optimization study of a low emittance photoinjector based on a proposed superconducting gun without including any buncher cavities. Multi-objective optimization with self-consistent beam dynamics simulations was employed to attain the optimal Pareto front.

WEPA02

Beam Dynamics Studies on a Low Emittance Injector for LCLS-II-HE

F. Ji, C. Adolphsen, R. Coy, L. Ge, C.E. Mayes, T.O. Raubenheimer, M.C. Ross, X.J. Wang, L. Xiao, F. Zhou (SLAC) S.T. Littleton (Stanford University)

The SLAC High Energy upgrade of LCLS-II (LCLS-II-HE) will double the beam energy to 8 GeV, increasing the XFEL photon energy reach to about 13 keV. The energy reach can be extended to 20 keV if the beam emittance can be halved, which requires a higher gradient electron gun with a lower intrinsic emittance photocathode. To this end, the Low Emittance Injector (LEI) will be built that will run parallel to the existing LCLS-II Injector. The LEI design will be based on a state-of-the-art SRF gun with a 30 MV/m cathode gradient. The main goal is to produce transverse beam emittances of 0.1 mm-mrad for 100 pC bunch charges. This paper describes the beam dynamics studies on the design of the LEI including the simulations and multi-objective genetic algorithm (MOGA) optimizations. Performance with different injector layouts, cathode gradients, bunch charges and cathode mean transverse energies (MTEs) will be presented.

WEPA03

Status of the SLAC/MSU SRF Gun Development Project

J.W. Lewellen, C. Adolphsen, R. Coy, L. Ge, F. Ji, M.J. Murphy, L. Xiao (SLAC) A. Arnold, S. Gatzmaga, P. Murcek, R. Xiang (HZDR) Y. Choi, C. Compton, X.-J. Du, D.B. Greene, W. Hartung, S.H. Kim, T. Konomi, S.J. Miller, D.G. Morris, M.S. Patil, J.T. Popielarski, L. Popielarski, K. Saito, T. Xu (FRIB) M.P. Kelly, T.B. Petersen (ANL)

The LCLS-II-HE project at SLAC is intended to increase the photon energy reach of the LCLS-II FEL to at least 20 keV. In addition to upgrading the undulator system, and increasing the electron beam energy to 8 GeV, the project will also construct a low-emittance injector (LEI) in a new tunnel. To achieve the LEI emittance goals, a low-MTE photocathode will be required, as will on-cathode electric fields up to 50% higher than those achievable in the current LCLS-II photoinjector. The beam source for the LEI will be based around a superconducting quarterwave cavity resonant at 185.7 MHz. A prototype gun is currently being designed and fabricated at the Facility for Rare Isotope Beams (FRIB) at Michigan State University. This paper presents the performance goals for the new gun design, an overview of the prototype development effort, current status, and future plans including fabrication of a "production" gun for the LEI.

WEPA04

Simulating 2D Transient Coherent Synchrotron Radiation in Julia

W. Lou, Y. Cai, C.E. Mayes (SLAC)

Coherent Synchrotron Radiation (CSR) in bending magnets poses a limit for electron beams to reach high brightness in novel accelerators. While the longitudinal wakefield has been well studied in the one-dimensional CSR theory and implemented in various simulation codes, transverse wakefields have received less attention. Following the recently developed two and three-dimensional CSR theory, we developed software packages in Python and Julia to simulate the 2D CSR effects. The Python packages, PyCSR2D and PyCSR3D, utilize parallel processing in CPU to compute the steady-state CSR wakes. The Julia package, CSR2D.jl, additionally computes the 2D transient CSR wakes with GPU compatibility. We applied these codes to simulate the 2D CSR effects in the LCLS-II and FACET-II particle accelerators at the SLAC National Accelerator Laboratory.

WEPA06

Advancement of Strategic Accelerator Technologies: RF Sources

J.W. Merrick (SLAC) R.B. Agustsson (RadiaBeam) M. Liepe (Cornell University)

Particle accelerators are now practical tools for advancing other industries such as pharmaceuticals, national security, and materials research; however, accelerator technologies in the United States have floundered due to inconsistent demand and high development costs this has had detrimental effects for the development and supply of high-power RF sources for accelerators. Lack of domestic production capacity for RF sources has even forced the US to procure key parts for large scientific projects from abroad. This business plan seeks to address market failures that have led to this

point and provide a strategy for incentivizing investments in supporting domestic accelerator RF source technologies. By utilizing feedback from a wide variety of stake holders in private industry and public institutions; we seek to create effective partnerships that will lead to a sustainable domestic accelerator economy. This report examines methods of leveraging emerging markets and contracting structures that can use HPRF source technologies while minimizing required public funding by creating methods of strategic partnering that will lower the development risk and barriers to entry for industry.

Characterization and Optimization of Accelerators Exhibiting Hysteresis Using Differentiable Physics Models

WEPA07

R.J. Roussel, A.L. Edelen, D.F. Ratner (SLAC) K. Dubey (University of Chicago) J.P. Gonzalez Aguilera (Enrico Fermi Institute, University of Chicago) N. Kuklev (ANL)

Future improvements in accelerator performance are predicated on increasingly accurate online modeling of accelerators. Hysteresis effects in magnetic, mechanical, and material components of accelerators is often neglected in both online accelerator models and control algorithms, even though reproducibility errors from systems exhibiting hysteresis are no longer negligible in high precision accelerators. To maximize accelerator performance, these effects must be considered. In this work, we combine the classical Preisach model of hysteresis with machine learning techniques to efficiently and accurately model arbitrary systems exhibiting hysteresis. We demonstrate that our technique accurately predicts hysteresis effects in physical accelerator magnets. Furthermore, combining these hysteresis models with Bayesian statistical models of beam response allows us to overcome optimization performance limitations when hysteresis effects are ignored. We also experimentally demonstrate how these methods can be used in-situ, allowing characterization of hysteresis in accelerator magnets without directly measuring the magnets themselves, using the beam response.

Design and Operation Experience of a Multi-collimator/YAG Screen Device on LCLS II Low Energy Beamline

WEPA08

X. Liu, C. Adolphsen, M. Santana-Leitner, L. Xiao, F. Zhou (SLAC)

During the commissioning of the normal conducting VHF RF gun of LCLS II, it was observed that field emission (dark current) of roughly 2 μA level was present under normal operation of the gun. While the dark current of this level is deemed manageable with existing beamline configurations, it is desired in precaution to add a collimator on the low energy beamline to block the dark current, being concerned that the dark current situation might worsen with time. Since no spare longitudinal space is available, the new device takes place of the existing YAG screen. The new device is made of a 15 mm thick copper plate, with four round apertures of 6, 8, 10, and 12 mm radius respectively. At the end of the collimator plate, features are made for clamping two YAG screens and mounting their corresponding mirrors for beam/halo profile imaging. The collimator plate is electrically insulated from the chamber so that it can also be used for measuring the dark current. A motor-driven UHV compatible linear translator shifts the device between positions. Besides design details, related thermal, beam dynamics, and radiation analyses as well as operation experience will be presented.

A Parallel Automatic Simulation Tool for Cavity Shape Optimization

WEPA09

L. Ge, Z. Li, C.-K. Ng, L. Xiao (SLAC) M. Beall, B.R. Downie, O. Klaas (Simmetrix Inc.)

We present a parallel automatic shape optimization workflow for designing accelerator cavities. The newly developed 3D parallel optimization tool Opt3P based on discrete adjoint methods is used to determine the optimal accelerator cavity shape with the desired spectral response. Initial and updated models, meshes, and design velocities of design parameters for defining the cavity shape are generated with Simmetrix tools for mesh generation (MeshSim), geometry modification and query (GeomSim), and user interface tools (SimModeler). Two shape optimization examples using this automatic simulation workflow will be presented here. One is the TESLA cavity with higher-order-mode (HOM) couplers and the other is a superconducting rf (SRF) gun. The objective for the TESLA cavity is to minimize HOM damping factors and for the SRF gun to minimize the surface electric and magnetic fields while maintaining its operating mode frequency at a prescribed value. The results demonstrate that the automatic simulation tool allows an efficient shape optimization procedure with minimal manual operations. All simulations were performed on the NERSC supercomputer Cori system for solution speedup.

WEPA10

Determination of LCLS-II Gun-2 Prototype Dimensions

L. Xiao, C. Adolphsen, E.N. Jongewaard, X. Liu, F. Zhou (SLAC)

The LCLS-II spare gun (Gun-2) design is largely based on the existing LCLS-II gun (Gun-1), in which there is significant captured dark current (DC) that originates on the high field copper surface near the cathode plug gap opening. To help suppress DC, the Gun-2 cathode and anode noses and the cathode plug opening are elliptically shaped to minimize the peak surface field for a given cathode gradient. Stainless steel (SS) cathode and anode inserts are used in Gun-2 to further reduce dark current. The RF simulations were performed using a model that includes all the 3D features. The thermal and structural analyses were done to investigate the effects of the air pressure and RF heating. The multi-physics simulation results provided the information needed to compute the overall frequency change from the basic 2D model to the nominal frequency during operation. The Gun-2 cathode-to-anode gap distance will be made 1 mm longer than the nominal gap with the expectation that less than 1 mm will be machined off to meet the target frequency. In this paper, the Gun-2 frequency correction calculations are presented, and the cathode-to-anode gap determination is discussed.

WEPA11

Unwrapping Image Data Using Adaptive Machine Learning

E.H. Toler (Courant Institute of Mathematical Sciences, New York University) J.E. Coleman, J.E. Koglin, M. McKerns, H.E. Morris, A. Scheinker, A.B. Williams (LANL)

Adaptive machine learning (AML) methods have been developed to process a series of 532-nm laser interferometer and shadowgraph measurements, which capture the density evolution of materials that were rapidly heated with an intense relativistic electron beam. A physics-based model of the density evolution was built based on hydrodynamic simulations. We also applied AML techniques to unwrap the phase shifts in the interferometer images. Through a combination of forward processing the density evolution model and inversion of the measurements, we spatially resolve the density and velocity of the expanding target material and place bounds on the temperature. We report initial results of this AML technique applied to several different target materials. The toolset that we have developed will be deployed as an interactive analysis tool to provide rapid feedback during future experiments. This analysis and modeling approach will also be used to guide the development of the system and experimental approach to future measurements.

WEPA12

Operational Experience of the New Booster Cryomodule at the Upgraded Injector Test Facility

M.W. Bruker, R. Bachimanchi, J.M. Grames, M.D. McCaughan, J. Musson, T.E. Plawski, M. Poelker, T. Powers, H. Wang, Y.W. Wang (JLab)

Since the early 1990s, the injector of the CEBAF accelerator at Jefferson Lab has relied on a normal-conducting RF graded-beta capture section to boost the kinetic energy of the electron beam from 100 keV to 600 keV for subsequent acceleration using a cryomodule housing two superconducting 5-cell cavities similar to those used throughout the accelerator. To simplify the injector design and improve the beam quality, the normal-conducting RF capture section and the cryomodule will be replaced with a new booster cryomodule employing a superconducting, β=0.6, 2- cell-cavity capture section and a single β=0.97 7-cell cavity. The Upgraded Injector Test Facility at Jefferson Lab is currently hosting the new cryomodule to evaluate its performance with beam before installation at CEBAF. Though presently limited to 100 nA CW current due to radiation shielding limitations, our measurements demonstrate the viability of the new booster cryomodule. Apart from showcasing the experimental applications, we present insight into the microphonics and instrumentation issues arising from the operation of such a machine located above ground in a busy building.

WEPA13

New Results at JLab Describing Operating Lifetime of GaAs Photo-guns

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Polarized electrons from GaAs photocathodes have been key to some of the highest impact results of the JLab/CEBAF science program over the past 30 years. During this time, various studies have given insight into improving the operational lifetime of these photocathodes in DC high voltage photo-guns, notably while using lasers with spatial Gaussian profiles typically 0.5 to 1 mm FWHM and with cathode voltages typically 100 to 130 kV. In this contribution, we report new results in three areas related to improving operating lifetime of GaAs photo-guns. First, new simulation results are presented describing the anticipated benefit of increasing the operating lifetime by increasing the area of the laser illumination well beyond 1 mm FWHM. Second, new experimental results are presented describing the behavior of operating lifetime on the accelerating gap voltage of the photo-gun up to 180 kV. Third, new calculations are presented offering an explanation which conforms to the experimental observations for the continual improvement in operating lifetime as quantum efficiency worsens, both with bulk and strained-superlattice GaAs/GaAsP photocathodes.

Microbunching Gain Evaluation of the Strong Hadron Cooler Energy Recovery Linac of the Electron Ion Collider

WEPA14

K.E. Deitrick (JLab)

The planned Electron Ion Collider (EIC) has an Energy Recovery Linac (ERL) that provides strong hadron cooling (SHC) in order to control the beam quality of the hadrons. In this paper, I evaluate the anticipated microbunching gain of the current SHC ERL design.

Exploring Nb_3Sn Magnet Technologies for the Second Interaction Region of the Electron-Ion Collider

WEPA15

B.R. Gamage (JLab)

Efficient realization of the scientific potential of the Electron Ion Collider (EIC) calls for a future second Interaction Region (2nd IR) and detector to be added in the RHIC IR8 region after the EIC project completion. The second IR and detector are needed to independently cross-check the results of the first detector, and to provide measurements with complementary acceptance. The available space in the existing RHIC IR8 and maximum fields achievable with NbTi superconducting magnet technology impose constraints on the second IR performance. Since commissioning of the 2nd IR is envisioned a few years after the first IR, this longer time frame will allow more R&D for Nb_3Sn magnet technology, and thus there could be a potential choice of technologies for the 2nd IR magnets. Presently we are exploring potential 2nd IR performance benefits, such as luminosity and acceptance, and the technical risks associated with the use of Nb_3Sn magnets. In this paper, we present the current progress of this work.

A 500 kV Inverted Geometry Feedthrough for a High Voltage DC Electron Gun

WEPA16

C. Hernandez-Garcia, D.B. Bullard, J.M. Grames, G.G. Palacios Serrano, M. Poelker (JLab)

The Continuous Electron Beam Accelerator Facility injector at Jefferson Lab (JLab) utilizes an inverted-geometry ceramic insulator photogun operating at 130 kV direct current to generate spin-polarized electron beams for high-energy nuclear physics experiments. A second photogun delivers 180 keV beam for commissioning a SRF booster in a testbed accelerator, and a larger version delivers 300 keV magnetized beam in a test stand beam line. This contribution reports on the development of an unprecedented inverted-insulator with cable connector for reliably applying 500 kV DC to a future polarized beam photogun, to be designed for operating at 350 kV without field emission. Such a photogun design could then be used for generating a polarized electron beam to drive a spin-polarized positron source as a demonstrator for high energy nuclear physics at JLab. There are no commercial cable connectors that fit the large inverted insulators required for that voltage range. Our proposed concept is based on a modified epoxy receptacle with intervening SF6 layer and a test electrode in a vacuum vessel.

Improved Electrostatic Design of the Jefferson Lab 300 kV DC Photogun and the Minimization of Beam Deflection

WEPA17

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An electron beam with high bunch charge and high repetition rate is required for electron cooling of the ion beam to achieve the high luminosity required for the proposed electron-ion colliders. An improved design of the 300 kV DC high voltage photogun at Jefferson Lab was incorporated toward overcoming the beam loss and space charge current limitation experienced in the original design. To reach the bunch charge goal of $\sim$ few nC within 75 ps bunches, the existing DC high voltage photogun electrodes and anode-cathode gap were modified to increase the longitudinal electric field (Ez) at the photocathode. The anode-cathode gap was reduced to increase the Ez at the photocathode, and the anode aperture was spatially shifted with respect to the beamline longitudinal axis to minimize the beam deflection introduced by the geometric asymmetry of the inverted insulator photogun. The electrostatic design and beam dynamics simulations were performed to determine the required modification. Beam-based measurement from the modified gun confirmed the reduction of the beam deflection, which is presented in this contribution.

WEPA18

TE011 Cavity for Monitoring Magnetic Momentum of a Magnetized Beam

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Future Electron-Ion Colliders rely on cooling of the ion beam to achieve the high luminosity requirement. A bunched beam cooler uses a magnetized electron beam from the injector for which a non-invasive measurement of the magnetic momentum is highly desired. The electric field of a passive copper rf cavity in TE011 mode has only an azimuthal component. TE011 mode in an ideal pillbox cavity will have energy exchanging interaction with the azimuthal motion of a particle, which makes it an ideal candidate as a magnetic momentum monitor. This contribution presents beam-based preliminary test results from a 2994-MHz TE011 pillbox cavity with 3-mm wall thickness.

WEPA19

He Production Update at Jlab - Introducing an Enhanced Nitrogen Purge for Clean String Assembly

P.D. Owen (JLab)

A major limitation to cryomodule performance is field emission caused by particulates within the superconducting cavities. To reduce contamination of the inner surfaces during assembly in a cleanroom, the whole string can be connected to a purge system, which maintains a constant overpressure of dry, clean nitrogen gas. Following successes of similar systems at XFEL and Fermilab, Jefferson Lab followed this example for the production of LCLS-II HE cryomodules. Implementing this system required new procedures, infrastructure, and hardware, as well as significant testing of the system before production began. This paper will summarize the implemented controls and procedures, including lessons learned from Fermilab, as well as the results of mock-up tests. Based on the latter, the system was used to assemble the first article string in April 2022, and was also used during a rework required due to issues with cold FPC ceramics two months later. The benefits of using a purge system with regards to procedure, time savings, and added flexibility for potential rework have already proven to provide a significant improvement for the production of LCLS-II-HE cryomodules at Jefferson Lab.

WEPA20

High-Gradient Wien Spin Rotators at Jefferson Lab

G.G. Palacios Serrano, P.A. Adderley, D.B. Bullard, J.M. Grames, C. Hernandez-Garcia, M. Poelker (JLab)

Nuclear physics experiments performed in the Continuous Electron Beam Accelerator Facility (CEBAF) at Jefferson Laboratory (JLab) require spin manipulation of electron beams. Two Wien spin rotators in the injector keV region are essential at CEBAF to establish longitudinal polarization at the end station target, and to flip the polarization direction by 180^{o} to rule out false asymmetries. In a Wien filter, the homogeneous and independent electric and magnetic fields, along with the velocity vectors of the electrons that traverse it, form a mutually orthogonal system. The magnitude of the electrostatic field, established by biasing two highly-polished electrodes, defines the desired spin angle at the target yet deviates the beam trajectory due to the Lorentz force. The beam trajectory in the injector is then reestablished by adjusting the magnetic field, induced by an electromagnet encasing the device vacuum chamber. This contribution describes the evolution design and high voltage testing of Wien filters for spin manipulation at increased beam energies in the keV injector region, required by high precision parity violation experiments like Moller.

WEPA21

Uncertainty Aware Anomaly Detection to Predict Errant Beam Pulses in the SNS Accelerator

K. Rajput, T.C. Jeske, M. Schram (JLab) W. Blokland, P. Ramuhalli, A.P. Zhukov (ORNL) C.C. Peters, Y.A. Yucesan (ORNL RAD)

In order to improve the day-to-day particle accelerators operations and maximize the delivery of the science, new analytical techniques are being explored for anomaly detection, classification, and prognostications. We describe the application of an uncertainty aware machine learning (ML) method using Siamese neural network model to predict upcoming errant beam pulses. Predicting errant beam pulses reduces downtime and can prevent potential damage to the accelerator. The uncertainty aware machine learning model was developed to be able to classify abnormal pulses not seen before. Additionally, we developed a gradient class activation mapping technique for our model to identify relevant regions within a pulse that makes it anomalous and for clustering fault types. We describe the accelerator operation, related ML research, the prediction performance required to abort beam while maintaining operations, the monitoring device and its data, the uncertainty aware Siamese method with its results, and fault type clustering results.

Measuring the Electric Dipole Moment of the Electron in a Two-Energy Spin-Transparent Storage Ring

WEPA22

R. Suleiman, Y.S. Derbenev (JLab) V.S. Morozov (ORNL RAD)

We will present a new design of a two-energy storage ring for low energy (0.2 to 2 MeV) polarized electron bunches [1]. The new design is based on the transparent spin methodology that cancels the spin precession due to the magnetic dipole moment at any energy while allowing for spin precession induced by the fundamental physics of interest to accumulate. Counter-rotating electron beams of multiple bunches, with different polarizations (longitudinal and radial) and with both positive and negative helicities, provide adequate control of systematic effects. The buildup of the vertical component of beam polarization can be measured using standard Mott polarimetry that is optimal at low electron energy. These rings can be used to measure the permanent electric dipole moment of the electron, relevant to CP violation and matter-antimatter asymmetry in the universe, and to search for dark energy and ultra-light dark matter.

SRF Cavity Instability Detection With Machine Learning at CEBAF

WEPA23

D.L. Turner, R. Bachimanchi, A. Carpenter, J. Latshaw, C. Tennant, L.S. Vidyaratne (JLab)

During the operation of CEBAF, one or more unstable superconducting radio-frequency (SRF) cavities often cause beam loss trips while the unstable cavities themselves do not necessarily trip off. Identifying an unstable cavity out of the hundreds of cavities installed at CEBAF is difficult and time-consuming. The present RF controls for the legacy cavities report at only 1 Hz, which is too slow to detect fast transient instabilities. A fast data acquisition system for the legacy SRF cavities is being developed which samples and reports at 5 kHz to allow for detection of transients. A prototype chassis has been installed and tested in CEBAF. An autoencoder based machine learning model is being developed to identify anomalous SRF cavity behavior. The model is presently being trained on the slow (1 Hz) data that is currently available, and a separate model will be developed and trained using the fast (5 kHz) DAQ data once it becomes available. This paper will discuss the present status of the new fast data acquisition system and results of testing the prototype chassis. This paper will also detail the initial performance metrics of the autoencoder model.

pyJSPEC: A Python Module for IBS and Electron Cooling Simulation

WEPA24

H. Zhang, S.V. Benson, M.W. Bruker, Y. Zhang (JLab)

The intrabeam scattering is an important collective effect that can deteriorate the property of a high-intensity beam and electron cooling is a method to mitigate the IBS effect. JSPEC (JLab Simulation Package on Electron Cooling) is an open-source C++ program developed at Jefferson Lab, which simulates the evolution of the ion beam under the IBS and/or the electron cooling effect. The Python wrapper of the C++ code, pyJSPEC, for Python 3.x environment has been recently developed and released. It allows the users to run JSPEC simulations in a Python environment. It also makes it possible for JSPEC to collaborate with other accelerator and beam modeling programs as well as plentiful python tools in data visualization, optimization, machine learning, etc. In this paper, we will introduce the features of pyJSPEC and demonstrate how to use it with sample codes and numerical results.

Field Emission Mitigation in CEBAF SRF Cavities Using Deep Learning

WEPA25

K. Ahammed, J. Li (ODU) A. Carpenter, R. Suleiman, C. Tennant, L.S. Vidyaratne (JLab)

The Continuous Electron Beam Accelerator Facility (CEBAF) operates hundreds of superconducting radio frequency (SRF) cavities in its two main linear accelerators. Field emission can occur when the cavities are set to high operating RF gradients and is an ongoing operational challenge. This is especially true in newer, higher gradient SRF cavities. Field emission results in damage to accelerator hardware, generates high levels of neutron and gamma radiation, and has deleterious effects on CEBAF operations. So, field emission reduction is imperative for the reliable, high gradient operation of CEBAF that is required by experimenters. Here we explore the use of deep learning architectures via multilayer perceptron to simultaneously model radiation measurements at multiple detectors in response to arbitrary gradient distributions. These models are trained on collected data and could be used to minimize the radiation production through gradient redistribution. This work builds on previous efforts in developing machine learning (ML) models, and is able to produce similar model performance as our previous ML model without requiring knowledge of the field emission onset for each cavity.

WEPA26

197-MHz Waveguide-Loaded Crab-Cavity Design for the Electron-Ion Collider

S.U. De Silva, J.R. Delayen (ODU)

The Electron-Ion Collider requires several crabbing systems at both hadron storage ring and electron storage rings in order to reach the desired luminosity goal. The 197-MHz crab-cavity system is one of the critical rf systems of the collider. The crab cavity based on the rf-dipole design explores the option of waveguide load damping in suppressing the higher-order modes and to meet the tight impedance specifications. The cavity is designed with compact dogbone waveguides with transitions to rectangular waveguides and waveguide loads. This paper presents the compact 197-MHz crab-cavity design with waveguide damping and other ancillaries.

WEPA27

Effect of Duration of 120 C Baking on the Performance of Superconducting Radio-Frequency Niobium Cavities

B.D. Khanal, G. Ciovati (ODU) P. Dhakal (JLab)

Over the last decade much attention was given in increasing the quality factor of superconducting radio frequency (SRF) cavities by impurity doping. Prior to the era of doping, the final cavity processing technique to achieve the high accelerating gradient includes the "in situ" low temperature baking of SRF cavities at temperature $\sim 120^{o}$C for several hours. Here, we present the results of a series of measurements on 1.3 GHz TESLA shape single-cell cavities with successive low temperature baking at 120^{o}C up to 96 hours. The experimental data were analyzed with available theory of superconductivity to elucidate the effect of the duration of low temperature baking on the superconducting properties of cavity materials as well as the RF performance. In addition, the RF loss related to the trapping of residual magnetic field refereed as flux trapping sensitivity was measured with respect to the duration of 120^{o}C bake.

WEPA28

An E-Beam Irradiation Beamline at Jefferson Lab for 1,4-Dioxane and Per- and Polyfluoroalkyl Substances Remediation in Wastewater

X. Li, H. Baumgart, G. Ciovati (ODU) G. Ciovati, M.D. McCaughan, M. Poelker, S. Wang (JLab) F.E. Hannon (Phase Space Tech)

The Upgraded Injector Test Facility (UITF) at Jefferson Lab, providing a beam energy up to 10 MeV, is suitable for wastewater remediation research. To investigate the degradation of 1,4-dioxane and per- and polyfluoroalkyl substances (PFASs), widespread in wastewater and potentially regulated in the near future, a beamline for electron-beam irradiation has been designed, installed, and successfully commissioned at the UITF. A solenoid with peak axial magnetic field of up to 0.28 T and a raster were used to obtain a Gaussian beam profile with a transverse standard deviation of $\sim$15 mm. It was applied to irradiate a 1,4-dioxane sample filled in the target cell that was designed to let the entire sample receive significant irradiation doses. Few dose distribution and absorbed dose studies exist in existing publications, but they are necessary measures for the degradation mechanism investigation. These measures have been innovatively achieved in this work using simulations that were calibrated with optichromic dosimeter rods directly exposed to the electron beam. This approach provides an important way to investigate the environmental remediation impact of electron-beam irradiation.

WEPA29

Real-time Cavity Fault Prediction in CEBAF Using Deep Learning

M. Rahman, K.M. Iftekharuddin (ODU) A. Carpenter, C. Tennant, L.S. Vidyaratne (JLab)

Data-driven prediction of future faults is a major research area for many industrial applications. In this work, we present a new procedure of real-time fault prediction for superconducting radio-frequency (SRF) cavities at the Continuous Electron Beam Accelerator Facility (CEBAF) using deep learning. CEBAF has been afflicted by frequent downtime caused by SRF cavity faults. We perform fault prediction using pre-fault RF signals from C100-type cryomodules. Using the pre-fault signal information, the new algorithm predicts the type of cavity fault before the actual onset. The early prediction may enable potential mitigation strategies to prevent the fault. In our work, we apply a two-stage fault prediction pipeline. In the first stage, a model distinguishes between faulty and normal signals using a U-Net deep learning architecture. In the second stage of the network, signals flagged as faulty by the first model are classified into one of seven fault types based on learned signatures in the data. Initial results show that our model can successfully predict most fault types 200 ms before onset. We will discuss reasons for poor model performance on specific fault types.

Nb_3Sn Coating of a 2.6 GHz SRF Cavity by Sputter Deposition Technique

WEPA30

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Nb_3Sn is of interest as a coating for SRF cavities due to its higher transition temperature Tc ~18.3 K and superheating field Hsh ~400 mT, both are twice that of Nb. Nb_3Sn coated cavities can achieve high-quality factors at 4 K and can replace the bulk Nb cavities operated at 2 K. A cylindrical magnetron sputtering system was built, commissioned, and used to deposit Nb_3Sn on the inner surface of a 2.6 GHz single-cell Nb cavity. With two identical cylindrical magnetrons, this system can coat a cavity with high symmetry and uniform thickness. Using Nb-Sn multilayer sequential sputtering followed by annealing at 950°C for 3 hours, polycrystalline Nb_3Sn films were first deposited at the equivalent positions of the cavity's beam tubes and equator. The film's composition, crystal structure, and morphology were characterized by energy dispersive spectroscopy, X-ray diffraction, and atomic force microscopy. The Tc of the films was measured by the four-point probe method and was 17.61 to 17.76 K. Based on these studies, ~1.2 micron thick Nb_3Sn was deposited inside a 2.6 GHz Nb cavity. We will discuss first results from samples and cavity coatings, and the status of the coating system.

Lower Temperature Annealing of Vapor Diffused Nb_3Sn for Accelerator Cavities.

WEPA31

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Nb_3Sn is a next generation superconducting material used in the accelerator cavities with higher critical temperature and superheating field (both twice than that of Nb) promising superior performance, cost reduction, and higher operating temperature compared to Nb. The Sn vapor diffusion method is the most preferred and successful technique so far to coat niobium cavities with Nb_3Sn. Among the well-known post coating treatments to improve the quality of the coating, higher temperature annealing without Sn is known to degrade Nb_3Sn because of Sn loss. But there are only limited available research studies on studying the post-coating annealing at low temperatures. Low temperatures around 800°C - 1000°C may improve the material and surface properties of vapor diffused Nb_3Sn. This paper discusses the detailed material study on characterizing Nb_3Sn coated samples after post annealing at lower temperature between 850°C and 950°C and assess the RF performances after applying the tailored annealing profile to a SRF cavity.

Spallation Neutron Source Cryogenic Moderator System Helium Gas Analysis System

WEPA32

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The Spallation Neutron Source (SNS) at Oak Ridge National Laboratory (ORNL) operates the Cryogenic Moderator System (CMS). The CMS comprises a 20-K helium refrigerator and three helium to hydrogen heat exchangers in support of hydrogen cooled spallation moderation vessels. This system uses vessels filled with activated carbon as the final major component to remove oil vapor from the compressed helium in the cryogenic cold box. SNS uses a LINDE multi-component gas analyzer to detect the presence of contaminants in the warm helium flow upstream of the cold box including aerosolized oil vapor. The design challenges of installing and operating this analyzer on the CMS system due to normal system operating pressures will be discussed. The design, fabrication, installation, commissioning, and initial results of this system operation will be presented. Future upgrades to the analyzer system will also be discussed.

Laser Stripping for 1.3 GeV H^- Beam at the SNS

WEPA33

T.V. Gorlov, A.V. Aleksandrov, S.M. Cousineau, Y. Liu, A.R. Oguz (ORNL) M.J. Kay (UTK)

A realistic full duty factor laser stripping charge exchange injection scheme for future 1.3 GeV beam at the SNS is considered. Different schemes of laser stripping involving combinations of photoexcitation, photoionization and magnetic field stripping are calculated. The laser power and magnetic field strength needed for different approaches are estimated and compared. The most practical scheme of laser stripping is selected for development.

Transverse Transfer Maps in the Hard-Edge Limit of Quadrupole and Bend Magnets Fringe Fields

WEPA34

T.V. Gorlov (ORNL)

Beam dynamics of charged particles in the fringe field of a quadrupole and a dipole magnet is considered. An effective method for solving symplectic Lie map exp(:f:) in such cases has been developed. A precise analytic solution for nonlinear transverse beam dynamics in a quadrupole magnet with hard-edge fringe field has been obtained. The method of Lie map calculation considered here can be applied for other magnets and for soft edge type of fringe field.

WEPA35

The Collimation System in the SNS HEBT

F. Lin (ORNL RAD)

The collimation systems in the High Energy Beam Transport (HEBT) in the Spallation Neutron Source (SNS) are utilized to reduce the probability of uncontrolled beam loss and to protect the transfer line itself and the accelerator systems downstream. They cover the collimation in all dimensions: four transverse collimators (two in each horizontal and vertical plane) and one momentum collimator. In each collimation system, the upstream scraper foils strip the H^- to H^+, and the H^+ will be dumped in the downstream collector collimators. We revisit the existing collimation systems in the HEBT and explore the collimation efficiency using the measured particle distributions through the laser wire scan. In this paper, we report the study results and propose possible solutions to improve the collimation efficiency.

WEPA36

Particle Tracking: Emittance Growth Rate Due to RF Phase Noise Induced in JLEIC Crab Cavies

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For Electron-Ion Collider (EIC), the crab crossing scheme provides a head-on beam-beam collision for beams with a nonzero crossing angle. The crab cavities in the scheme can reduce the loss of luminosity at the interaction point. Some of the key parameters of the crabbing system are the tolerances to the crab cavity synchronization and their phase and amplitude noise. The constraints on these tolerances come from the maximum acceptable emittance growth rate and the maximum acceptable luminosity reduction. T. Mastoridis et al found that the transverse emittance growth is dominated by the crab cavity phase noise and derived the relationship between rf phase noise and the transverse emittance growth rate. Similar to EIC, Jefferson Lab Electron-Ion Collider (JLEIC) design provides a crab crossing scheme, for monitoring the emittance's variations due to the crab cavities' phase noise, we implemented both Bmad and Elegant particle tracking codes to simulate a beam behavior in ion ring of JLEIC. We also did the bench marking between the simulations with the analytic solutions. The contribution to the emittance growth due to the rf phase noise in crab cavities was addressed in our study.

WEPA37

Benchmarking and Exploring Parameter Space of the 2-Phase Bubble Tracking Model for Liquid Mercury Target Simulation

L. Lin, M.I. Radaideh, H. Tran, D.E. Winder (ORNL)

High intensity proton pulses strike the Spallation Neutron Source (SNS)'s mercury target to provide bright neutron beams. These strikes deposit extensive energy into the mercury and its steel vessel. Prediction of the resultant loading on the target is difficult when helium gas is intentionally injected into the mercury to reduce the loading and to mitigate the pitting damage on the vessel. A 2-phase material model that incorporates the Rayleigh-Plesset (R-P) model is expected to address this complex multi-physics dynamics problem by including the bubble dynamics in the liquid mercury. We present a study comparing the measured target strains in the SNS target station with the simulation results of the solid mechanics simulation framework. We investigate a wide range of various physical model parameters, including the number of bubble families, bubble size distribution, viscosity, surface tension, etc. to understand their impact on simulation accuracy. Our initial findings reveal that using 8-10 bubble families in the model renders a simulation strain envelope that covers the experimental ones. Further optimization studies are planned to predict the strain response more accurately.

WEPA38

Progress on Machine Learning for the SNS High-Voltage Converter Modulators

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The High-Voltage Converter Modulators (HVCM) used to power the klystrons in the Spallation Neutron Source (SNS) linac were selected as one area to explore machine learning due to reliability issues in the past and the availability of large sets of archived waveforms. Progress in the past two years has resulted in generating a significant amount of simulated and measured data for training neural network models such as recurrent neural networks, convolutional neural networks, and variational autoencoders. Applications in anomaly detection, fault classification, and prognostics of capacitor degradation were pursued in collaboration with the Jefferson Laboratory, and early promising results were achieved. This paper will discuss the progress to date and present results from these efforts.

The L-CAPE Project at FNAL

WEPA40

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The LINAC controls system at FNAL records data asynchronously from several thousand devices. In the case of unplanned downtime, operations are mostly reactive, investigating the cause of the outage and documenting it with operator-defined labels. Advance knowledge of an impending downtime as well as its duration could prompt downstream systems to take a prescribed action such as going to standby, potentially leading to large energy savings. The goals of the LINAC Condition Anomaly Prediction of Emergence (L-CAPE) project are to (1) apply data analytics to improve the information that is available to operators in the control room, (2) use machine learning to automate the prompt labeling of outages, and (3) discover patterns in the data that could lead to a prediction of outages and their duration. We present an overview of the challenges in dealing with data from over 2500 devices, our approach to developing an ML-based automated outage labeling system, and the progress toward our goals. Our work is a steppingstone for developing a model that combines a global view of the LINAC with the ability to adapt to changing operating conditions.

Maximizing Output of 3-MeV S-band Industrial Accelerator

WEPA41

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Earlier, we have reported on a record-breaking 3-MeV Accelerator Beam Centerline (ABC) built in 2017-2018. An upgraded version of this 3-MeV S-band ABC has been developed at Varex Imaging as a key component for one of the most popular X-ray industrial linear accelerator systems, commonly used for security and NDT applications. Being significantly strained by excessive backstreaming, increasing of the ABC output is a challenging task. We describe these challenges and highlight high power test results. The triode gun and structure design improvements allowed us to raise stable output up to 530 Rad/min/1m at 3 MeV and up to 220 Rad/min/1m at 4.5 MeV with a widely available 2.5-MW/2.7-kW magnetron, while maintaining the spot size at 2 mm.

A Modular X-ray Detector for Beamline Diagnostics at LANL

WEPA42

P.M. Freeman (UCSB)

An X-ray detector is being developed for diagnostic measurement and monitoring of the Drift Tube LINAC (DTL) at the Los Alamos Neutron Science Center (LANSCE) at Los Alamos National Lab. The detector will consist of a row of x-ray spectrometers adjacent to the DTL that will measure the spectrum of X-rays resulting from bremsstrahlung of electrons created in vacuum by the RF. Each spectrometer will monitor a specific gap between drift tubes, and will consist of an array of scintillating crystals coupled to SiPMs read out with custom-built electronics. The spectrometer is designed with one LYSO and three NaI crystals. The LYSO provides a tagged gamma source with three peaks that are used for calibration of the NaI. A prototype of the spectrometer was tested at the LANSCE DTL to validate the feasibility of measuring gamma spectra and performing self-calibration in situ. A summary of test results with the LANSCE prototype will be presented, along with a detector system design that aims to be modular and inexpensive across all modules in the DTL. Plans for future development will be presented as well.

Self-Contained Linac Irradiator for the Sterile Insect Technique (SIT)

WEPA43

A. Amirari, R.D. Berry, S.V. Kutsaev (RadiaBeam)

A 3-MeV X-band linac has been developed employing a cost-effective split structure design in order to replace radioactive isotope irradiators currently used for the Sterile Insect Technique (SIT) and other applications. The penetration of a Co-60 irradiator can be matched with Bremsstrahlung produced by a 3-MeV electron beam. The use of electron accelerators eliminates security risks and hazards inherent with radioactive sources. We present the current state of this X-band split structure linac and the rest of the irradiator system.

WEPA44

Compact Inter-Undulator Diagnostic Assembly for TESSA-515

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Beamline space is a very expensive and highly sought-after commodity, which makes the creation of compact diagnostics extremely valuable. The FAST- GREENS experimental program consists of four helical undulators in the high gain TESSA regime with an inter-undulator gap of only 17 cm. Within this short distance, we needed to fit two focusing quadrupoles, a variable strength phase shifter, and a transverse profile monitor consisting of a YAG-OTR combination for co-aligning the electron beam and laser. By making the quadrupoles tunable with a variable gradient, in combination with vertical displacement, we can match the beam transversely. The two quadrupoles in conjunction with the electromagnetic dipole also serve as a phase shifter. This paper will discuss the mechanical design of this break section and its components.

WEPA45

Practical Review on Beam Line Commissioning Procedures and Techniques for Scientific and Industrial Electron Accelerators

M.O. Kravchenko, A. Amirari, D.I. Gavryushkin, S.V. Kutsaev, M. Ruelas (RadiaBeam)

Accelerator science has a constant demand requiring improved electron beam quality for both scientific and industrial applications. Examples of parameters on existing systems that affect overall beam quality include: vacuum stability, component level alignment, RF phase matching, electron injection parameters, etc. A proper beam commissioning process allows the characterization of initial parameters that tune system setup appropriately in order to improve net beam quality and becomes a valuable source of data to guide system operation. Here we will discuss methods and possible obstacles during the commissioning process of accelerator systems experienced at RadiaBeam. This includes a description of the diagnostic equipment that may be used to commission a beam line such as: current transformers, faraday cups, profile monitors and pyro detectors. The interpretation of raw data from the diagnostics in terms of usefulness for further adjustments and improvements on the beam line as shown in current work. Simulations and empirical comparisons are also presented as examples for commissioning procedures within the aspect of expectations and actual results.

WEPA46

Test Results of a High-Gradient Low-Beta S-band Negative Harmonic Accelerating Structure

S.V. Kutsaev, R.B. Agustsson, A.C. Araujo Martinez, O. Chimalpopoca, A.Yu. Smirnov (RadiaBeam) D.A. Meyer, B. Mustapha, A. Nassiri, T.L. Smith, Y. Yang (ANL)

We report the high-gradient tests results of a novel traveling wave accelerating structure for β = 0.3 based on a novel approach of operating at the first negative spatial harmonic. Accelerating gradients of 50 MV/m and peak electric fields of 160 MV/m were achieved in a single structure consisting of 15 coupled cells during tests at the advanced photon source. This work was performed by RadiaBeam, in collaboration with the Argonne National Laboratory, as a part of a Research and Development Program for the development of an ultrahigh gradient linear accelerator, the Advanced Compact Carbon Ion Linac (ACCIL), for hadron therapy.

WEPA47

Optimization of Negative-Harmonic High-Gradient Accelerating Structure for Low-Beta Ions

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High gradient accelerating structures for low-velocity particles are essential components for novel compact hadron therapy machines. Modern hadron therapy projects, such as ACCIL, proposed by ANL, include the capability of image-guided therapy, with a beam scanning system operating at up to 1000 Hz rate. Therefore, it is essential that the accelerator can provide beams with similar rates. In this paper, we report the development of a 15-cell S-band 40 MV/m magnetically-coupled accelerating structure for $\beta \sim 0.3$ ions that are synchronized with the first negative harmonic. We have optimized the geometry of the structure, improving its shunt impedance by $\sim$ 50%, while maintaining the peak surface fields below the recommended limits. The structure is designed to operate with an input power of ~5 MW at 2856 MHz via SLED pulse compressor, delivering a 550 ns beam pulse at 1000 Hz repetition rate. We will present and discuss the optimization of the RF design, as well as the thermal and mechanical analysis performed for the structure.

Electromagnetic Design of a Compact RF Chopper for Heavy-Ion Beams Separation at FRIB

WEPA48

A.C. Araujo Martinez, R.B. Agustsson, Y.C. Chen, S.V. Kutsaev (RadiaBeam) A.S. Plastun, X. Rao (FRIB)

Rare isotope beams are produced at FRIB via fragmentation of a primary heavy ion beam in a thin target. The isotope beam of interest is contaminated with other fragments, which must be filtered out to ensure the delivery of rare isotopes with desired rates and purities. One of the stages for the fragment separation will be an RF deflecting cavity, providing the time-of-flight separation. However, to avoid neighboring bunches overlapping with each other and with the contaminants, it is necessary to increase the inter-bunch distance by a factor of four, corresponding to a 20.125 MHz rate. To solve this problem, we have developed an RF chopper system for the 500 keV/u primary heavy-ion beams. The system consists of a deflecting quarter wave resonator (QWR) cavity operating at 60.375 MHz, two dipole steering magnets, and a beam dump. In this paper, we present and discuss the optimization of the electromagnetic design of the QWR cavity and magnets, as well as some aspects, related to beam dynamics and conceptual engineering design.

Ferrite-Free Circulator Based on Material Non-Lienarity

WEPA49

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There are many reasons to eliminate ferrites in microwave circulator systems, which can lead to a major improvement in the circulator's performance and accuracy of their applications. In order to do this, we propose to exploit optical non-linearities, realized via an asymmetric Fano resonance coupled to the Lorentzian resonance. This approach allows to surpass the fundamental restriction of non-linearity and forward transmission, where one of these properties must be sacrificed in favor of the other. At the same time to allow this device to work in the regime with reflected power present, we propose to utilize an approach based on time variation of the resonant frequencies of three resonators connected in a way to form a 3-port system. In this paper, we present the current design and experimental progress of such development.

Initial Development of a High-Voltage Pulse Generator for a Short-Pulse Stripline Kicker

WEPA50

J. Prager, K.E. Miller, K. Muggli, C. Schmidt, H. Yeager (EHT)

The future Electron Ion Collider, to be located at Brookhaven National Laboratory (BNL), will require a new short-pulse stripline kicker for the 150 MeV energy recovery LINAC. The pulse generator must produce ±50 kV pulses with widths less than 38 ns into a 50^{o} kicker load and with low jitter. The power system must be highly reliable and robust to potential faults. Eagle Harbor Technologies (EHT), Inc. is leveraging our previous experience developing inductive adders to produce a high-voltage pulse generator that can meet the needs of the BNL kickers. In this program, EHT designed a single inductive adder stage and demonstrated the challenging pulse characteristics including fast rise and fall times, low jitter, and flattop stability while operating at the full current (1 kA). EHT will present the development status and output waveforms.

External Fast Electrically-Controlled Ferroelectric Tuner for CEBAF SRF Cavities

WEPA51

A. Kanareykin, C.-J. Jing, E.W. Knight, S.V. Kuzikov, Y. Zhao (Euclid TechLabs) C. Hovater, T. Powers, R.A. Rimmer (JLab)

In the world's first, CERN recently tested Euclid's prototype ferroelectric tuner with a super-conducting cavity, and successfully demonstrated its microphonics compensation [1]. This is a significant step forward in the development of an entirely new class of tuners that will allow fast (100 ns) electronic control of cavity frequencies. For many applications, this could reduce significantly RF power consumption of accelerators. With this presentation, we will demonstrate Euclid's fast ferroelectric tuning technology in RF power configurations that combine the RF power source (klystron) and the fast active tuner at the same cavity port. This new technology is being applied to CEBAF's C100 cryomodules. We considered a magic-T configuration that will allow its use with a single RF port connected to the cavity. The low-level RF electronics of the C100 tuner was modified, and an algorithm for the FRT application was developed. With a simplified FRT prototype, the tuning range under biasing voltage required for the C100 microphonics compensation was demonstrated experimentally.

WEPA52

Demonstration of Twice-Reduced Lorentz-Force Detuning in SRF Cavity by Copper Cold Spraying

R.A. Kostin, C.-J. Jing, A. Kanareykin (Euclid TechLabs) G. Ciovati (JLab)

Superconducting RF (SRF) cavities usually are made from thin-walled high RRR Niobium and are susceptible to Lorentz Force Detuning (LFD) ' cavity deformation phenomena by RF fields. In this paper, we present high gradient cryogenic results of an SRF cavity with two times reduced LFD achieved by copper cold spray reinforcement without sacrificing cavity flexibility for tuning. Finite-element model was developed first to find the best geometry for LFD reduction, which incorporated coupled RF, structural and thermal modules, and is also presented.

WEPA53

An Open Radiofrequency Accelerating Structure

S.V. Kuzikov (Euclid TechLabs)

We report an open multi-cell accelerating structure. Being integrated with a set of open-end waveguides, this structure can supress high-order modes (HOMs). All the accelerating cells are connected at the side to rectangular cross-section waveguides which strongly coupled with free space or absorbers. Due to the anti-phased contribution of the cell pairs, the operating mode does not leak out, and has as high quality factor as for a closed accelerating structure. However, the compensation does not occur for spurious high-order modes. This operating principle also allows for strong coupling between the cells of the structure, which is why high homogeneity of the accelerating fields can be provided along the structure. We discuss the obtained simulation results and possible applications for high-current accelerators and RF photoinjectors.

WEPA54

Successful Experimental Demonstrations of the IDEAS-Halo Detector With Protons and Electrons at Various Energies

A. Liu, J.R. Callahan, S.M. Milller, W. Si (Euclid TechLabs)

Euclid Techlabs has been designing and testing a cost-effective iris diaphragm beam halo/profile detector, which can be easily configured to work with various primary beam energies and sites. Besides working as a measurement device, it can also work as a controllable beam scraper/collimator. This novel iris diaphragm detector utilizes the current signal produced by the beam charge deposition on the moveable conductive iris blades, to accurately measure the beam distribution from the outlier to the beam core. Although the detector was designed primarily for electron beams, simulations have indicated that it can work with proton beams at various energies. In this paper, we discuss the recent experiments of our iris diaphragm e-beam apparatus series (IDEAS)-halo detector with medium and high energy protons and low to medium energy electrons at a few beam facilities in the U.S.

WEPA55

Applications of Machine Automation With Robotics and Computer Vision in Cleanroom Assemblies

A. Liu, J.R. Callahan, S.M. Milller, W. Si (Euclid TechLabs)

The modern linear particle accelerators use superconducting radio frequency (SRF) cavities for achieving extremely high-quality factors (Q) and higher beam stability. The assembly process of the system, although with a much more stringent cleanness requirement, is very similar to the ultrahigh vacuum (UHV) system operation procedure. Humans, who are conventionally the operators in this procedure, can only avoid contaminating the system by wearing proper sterile personal protection equipment to avoid direct skin contact with the systems, or dropping lint or dander. However, humans unavoidably make unintentional mistakes that can contaminate the environment - cross contamination of the coverall suits during wearing, slippage of masks or goggles, damaged gloves, and so forth. Besides, humans are limited when operating heavy weights, which may lead to incorrect procedures, or even worse, injury. In this paper, we present our recent work on a viable and cost-effective machine automation composed of a robotic arm and computer vision algorithms to dominate the assembly process in a cleanroom environment, for example for SRF string assemblies, and more.

Encapsulation of Photocathodes Using High Power Pulsed RF Sputtering of hBN

WEPA56

A. Liu, J.R. Callahan, S. Poddar (Euclid TechLabs) J.P. Biswas, M. Gaowei, J.T. Sadowski (BNL)

Photocathodes of various materials are used in photoinjectors for generating photoelectron beams. Of particular interest are the alkali antimonides because of their ultra-high quantum efficiency (QE) and relatively low requirements for growth, and metallic materials such as Cu and Mg which have lower QE but are easier to maintain and have longer lifetime. The biggest challenge of using the alkali antimonide photocathode is that it has an extremely stringent requirement on vacuum and is destroyed rapidly by residual air in the system, while exposure of Mg and Cu in air also impacts the photocathode performance because of the oxidation. The photocathode can be protected against harmful gas molecules by using one or two monolayers of a 2D material such as graphene or hexagonal boron nitride (hBN). Furthermore, hBN monolayers even have the potential to improve the QE of the photocathode when working as the encapsulation thin-film. In this paper, we will discuss the feasibility of coating a photocathode with hBN by high power pulsed RF sputtering by using metallic photocathodes as examples, and compare the performance with encapsulated photocathodes with transferred hBN thin-films.

Implementation of a Flux-Concentrator-Based Objective Lens for UED/UEM

WEPA57

E.J. Montgomery, C.-J. Jing, E.W. Knight, Y. Zhao (Euclid TechLabs) S. Ross (Euclid Beamlabs)

Euclid Techlabs has been working to develop a novel miniature pulsed Tesla-class solenoid lens system for MeV UED/UEM applications. In the past several months, we have performed bench testing of the final Flux Concentrator (FC) based Objective Lens. We have fabricated a fully non-magnetic stainless steel sample chamber. It has been integrated with the FC lens. Meanwhile, field stability using a new 2 kA 10 Hz pulser and an upgraded chiller is the 10^{-4} range. Temperature fluctuation is not the limiting factor for field amplitude stability. Peak axial field is 1.83 T. Transverse fields are zero within the alignment error of the 3-axis Hall probe (<0.5% of axial). Timing jitter is about ± 0.4 µs. This is three orders of magnitude shorter than the duration of the pulse and should have negligible impact on field stability shot to shot. The final assembly is planned to undergo testing at BNL in 2022.

High-quality Diffraction Grade Diamond Substrates for X-ray optics

WEPA58

I.V. Ponomarev (Euclid TechLabs) A. Kanareykin (Euclid Beamlabs)

Next-generation of synchrotron and Free-Electron Laser X-ray sources will increase the peak power by several orders of magnitude. In these conditions, X-ray intensity will become too severe for the existing materials. Diamond is the most promising, if not only candidate, due to its high thermal conductivity, small thermal expansion, and low X-ray absorption. Unfortunately, the availability of large size, high-crystallinity, and low-defect density diamond substrates is very limited. Presently, there are no suppliers of high-quality diamonds with low defect concentrations in the United States to support this rapidly developing field of diamond X-ray optics applications for the next generation sources. We developed the modified High-Pressure High-Temperature (HPHT) temperature gradient growth technology that allows growing the highest crystalline quality large diamond crystals, with dislocation density less than 10 cm^{-2}.

Simulation Studies of Ionization-Injection in High-Atomic-Number Gases

WEPA59

A. Cheng, V. Samulyak (SBU) M. Downer, R. Zgadzaj (The University of Texas at Austin) R. Kupfer (LLNL) N. Vafaei-Najafabadi (Stony Brook University)

To study methods of controlled injection, experiment (BNL-ATF AE88) has been conducted for two-color ionization injected laser wakefield accelerator with a long wave infrared drive laser and a transverse, tightly focused, near infrared injection laser, using Krypton as a target gas. A numerical model for the laser driven multi-level ionization of high-Z gases has been implemented in the electromagnetic PIC code SPACE to help understanding the experimental results. By using analytical solution for the ionization evolution, the algorithm improves the accuracy and resolves the discrepancy between the main code time step and the characteristic time scale of ionization processes. A locally reduced system of differential equations was used to improve the efficiency of the multi-level ionization problem. The experimental results indicated improvement in the divergence of electron bunch accelerated when using the injection laser. The corresponding simulations provided more information on the increase of the amount of charge in the electron bunch from the two-color ionization injection and the evolution of wake at the laser-plasma interaction location.

WEPA60

Machine Learning for Designing Flying Focus Optics

G.J. Kim (Stony Brook University)

Meter-scale plasma channels are an essential component for plasma wakefield accelerators. One method for generating such a channel is ionization via a laser pulse using a method known as flying focus. Flying focus is based on the application of a hyper-chromatic (diffractive) lens to a chirped laser. In this manner, a traveling ionization wave with arbitrary velocity can be generated. The spatial characteristics of the plasma channel are dictated by the phase imprinted on the laser by the lens. Our approach to determining the phase of this optic is through machine learning. Our algorithm will receive the desired laser intensity profile and will use the method of "gradient descent" to return an optic (or phase plate) that would produce the inputted behavior. Gradient descent is an iterative approach that optimizes a cost function in a problem with no analytical solution, which makes it the suitable approach for this problem. This poster will describe the first steps toward this goal, which consist of deploying this method on a ray tracing problem that optimizes the surface of the optic to create an optimal focal spot.

WEPA61

Investigating the Transverse Trapping Condition in Beam-Induced Ionization Injection in Plasma Wakefield Accelerators

Y. Yan, N. Vafaei-Najafabadi, X. Zhang (Stony Brook University)

Plasma wakefield accelerators (PWFAs) have demonstrated acceleration gradients of tens of GeV per meter. To get an accelerated beam with low energy spread, the acceleration field has to be uniform along the beam. This is possible if the injected beam has a trapezoidal density profile [1]. Thus, the method called Beam-Induced Ionization Injection (B-III) is proposed to shape the density distribution of the injected beam. In this method, the drive beam field increases as its slice envelope oscillates to its minimum value due to the betatron oscillation and releases impurity plasma electrons that are then injected. Controlling those ionized electrons requires an understanding of their trapping mechanism. In this work, we will present our research based on the injection of the ultrashort, femtosecond electron beams using B-III. We will track the ionized electrons using our eTrack code based on the PIC simulation fieldmaps. We will show that a critical transverse trapping condition has to be satisfied for the trapping of electrons ionized by the drive beam.

WEPA62

Design and Commissioning of the ASU CXLS RF System

B.J. Cook, G.I. Babic, J.R.S. Falconer, W.S. Graves, M.R. Holl, S.P. Jachim, R.E. Larsen (Arizona State University)

The Compact X-ray Light Source (CXLS) uses inverse Compton scattering of a high intensity laser off a bright, relativistic electron beam to produce hard x-rays. The accelerator consists of a photoinjector and three standing-wave linac sections, which are powered by two 6-MW klystrons operating at 9.3 GHz with a repetition rate of 1 kHz. This paper presents the design and commissioning of the CXLS RF systems consisting of both high-power RF structures and low-power diagnostics. The high-power RF system is comprised of two solid state amplifier and klystron modulator sets, various directional couplers, and three phase shifter power dividers. The low-level system consists of a master oscillator and laser phase lock, IQ modulators, IQ demodulators, and downconverters. We present measurements of the low-level and high-power RF phase and amplitude stability showing RMS timing jitter in the tens of femtoseconds and amplitude jitter below 0.1% at high power.

WEPA63

Extensions of the Complex (IQ) Baseband RF Cavity Model Including RF Source and Beam Interactions

S.P. Jachim, B.J. Cook, J.R.S. Falconer (Arizona State University)

This paper extends prior work describing a complex envelope (i.e., baseband) dynamic model of excited accelerator RF cavities, including the effects of frequency detuning, beam loading, reflections, multiple drive ports, and parasitic modes. This model is presented here in closed-form transfer function and state-variable realizations, which may be more appropriate for analytic purposes. Several example simulations illustrate the detailed insight into RF system behavior afforded by this model.

Design and Commissioning of the ASU CXLS Machine Protection System

WEPA64

S.P. Jachim, B.J. Cook, J.R.S. Falconer, A.J. Gardeck, W.S. Graves, M.R. Holl, R.S. Rednour, D.M. Smith, J.V. Vela (Arizona State University)

To protect against fault conditions in the high-power RF transport and accelerating structures of the Arizona State University (ASU) Compact X-Ray Light Source (CXLS), the Machine Protection System (MPS) extinguishes the 6.5-MW RF energy sources within approximately 50 ns of the fault event. In addition, each fault is localized and reported remotely via USB for operational and maintenance purposes. This paper outlines the requirements, design, and performance of the MPS applied on the CXLS.

On-Chip Photonics Integrated Photocathodes

WEPA65

A.H. Kachwala, O. Chubenko, S.S. Karkare (Arizona State University) R. Ahsan (USC) H.U. Chae, R. Kapadia (University of Southern California)

Photonics integrated photocathodes can result in advanced electron sources for various accelerator applications. In such photocathodes, light can be directed using waveguides and other photonic components on the substrate underneath a photoemissive film to generate electron emission from specific locations at sub-micron scales and at specific times at 100-femtosecond scales along with triggering novel photoemission mechanisms resulting in brighter electron beams and enabling unprecedented spatio-temporal shaping of the emitted electrons. In this work we have demonstrated photoemission confined in the transverse direction using a nanofabricated Si_3N_4 waveguide underneath a 40-nm thick cesiated GaAs photoemissive film, thus demonstrating a proof of principle feasibility of such photonics integrated photocathodes. This work paves the way to integrate the advances in the field of photonics and nanofabrication with photocathodes to develop better electron sources.

Near-Threshold Photoemission from Graphene-Coated Cu Single Crystals

WEPA66

C.J. Knill, S.S. Karkare (Arizona State University) H. Ago, K. Kawahara (Global Innovation Center, Kyushu University) E. Batista, N.A. Moody, G.X. Wang, H. Yamaguchi, P. Yang (LANL)

The brightness of electron beams emitted from photocathodes plays a key role in the performance of x-ray free electron lasers (XFELs) and ultrafast electron diffraction (UED) experiments. In order to achieve the maximum beam brightness, the electrons need to be emitted from photocathodes with the smallest possible mean transverse energy (MTE). Recent studies have looked at the effect that a graphene coating has on the quantum efficiency (QE) of the cathode [1]. However, there have not yet been any investigations into the effect that a graphene coating has on the MTE. Here we report on MTE and QE measurements of a graphene coated Cu(110) single crystal cathode at room and cryogenic temperatures. At room temperature, a minimum MTE of 25 meV was measured at 295 nm. This MTE remained stable at 25 meV over several days. At 77 K, the minimum MTE of 9 meV was measured at 290 nm. We perform density functional theory (DFT) calculations to look at the effects of a graphene coating on a Cu(111) surface state. These calculations show that the graphene coating reduces the radius of the surface state, allowing for emission from a lower transverse energy state in comparison to bare Cu(111).

Effects of Transverse Dependence of Kicks in Simulations of Microbunched Electron Cooling

WEPA67

W.F. Bergan (BNL) G. Stupakov (SLAC)

Microbunched electron cooling (MBEC) is a cooling scheme in which a beam of hadrons to be cooled induces energy perturbations in a beam of electrons. These electron energy perturbations are amplified and turned into density modulations, which in turn provide energy kicks to the hadrons, tending to cool them. For simplification, previous work has modelled the electron-hadron interactions using a disc-disc model, assuming that the inter-particle kicks depend only on the longitudinal distances between individual hadrons and electrons. In reality, these kicks will also have a transverse dependence, which will impact the cooling process. We incorporate this transverse kick dependence into our simulations of the cooling process, allowing us to better understand the physics and provide improved design goals for the MBEC cooler for the Electron-Ion Collider.

Record Quantum Efficiency from Superlattice Photocathode for Spin-Polarized Electron-Beam Production

WEPA68

J.P. Biswas, L. Cultrera, W. Liu, J. Skarita, E. Wang (BNL) S.D. Hawkins, J.F. Klem, S.R. Lee (Sandia National Laboratories)

Electron sources producing highly spin-polarized electron beams are currently possible only with photocathodes based on GaAs and other III-V semiconductors. GaAs/GaAsP superlattice (SL) photocathodes with a distributed Bragg reflector (DBR) represent the state of the art for the production of spin-polarized electrons. We present results on a SL-DBR GaAs/GaAsP structure designed to leverage strain compensation to achieve simultaneously high QE and spin polarization. These photocathode structures were grown using molecular beam epitaxy and achieved quantum efficiencies exceeding 15% and electron spin polarization of about 75% when illuminated with near bandgap photon energies.

WEPA69

The Impact on the Vertical Beam Dynamics Due to the Noise in a Horizontal Crab Crossing Scheme

Y. Hao (BNL) Y. Luo (Brookhaven National Laboratory (BNL), Electron-Ion Collider)

The crab crossing scheme has been adopted by several colliders to boost the performance. The lower RF control noise of the crab cavities has been identified as one of the significant sources that impact the transverse beam quality in the crabbing plane. However, through beam-beam interaction and other coupling sources, the effect may also affect the other non-crabbing plane. In this paper, we report the simulation observations of the beam dynamics in the non-crabbing plane in presence of the phase noise in the crab cavity.

WEPA70

Tensor Decomposition for the Compression and Analysis of 10-kHz BPM Data

J. Choi, Y. Hidaka, Y. Hu, G.M. Wang (BNL)

In the NSLS-II storage ring during user operation, fast-acquisition (FA) 10-kHz BPM data are collected, and their spectral properties are analyzed. Various periodograms and spectral peaks are being provided every minute, and they are very useful in identifying any changes in the orbit. Unfortunately, because of the large amount of data, only several numbers are being continually archived for later study, and the full raw data are saved only by hand when needed. We are developing methods utilizing tensor decomposition techniques to save and analyze the FA data; this paper reports the current status of this project.

WEPA71

Unified Orbit Feedback at NSLS-II

Y. Hidaka, R.M. Smith, Y. Tian, G.M. Wang (BNL)

We have developed an orbit correction/feedback program to unify the existing orbit-related feedback systems for stable beam operation at NSLS-II. Until recently only a handful of beamlines have been benefiting from the long-term orbit stability provided by a local bump agent program. To expand this to all the beamlines as well as to correct more frequently, a new slow orbit feedback program called unified orbit feedback (UOFB) was written from scratch. This program works with the fast orbit feedback transparently, while accumulated fast corrector strength is continuously shifted to the slow correctors, and RF frequency is adjusted for circumference change. The UOFB can keep three different types of local bumps to the target offsets/angles for days: those for insertion device (ID) sources with only ID RF beam position monitors (BPMs); those with mixtures of ID RF BPMs and X-ray BPMs; and those for bending magnet sources with arc BPMs between which orbit correctors, dipoles, and quadrupoles exist. Furthermore, this feedback can accommodate beamline user requests to enable/disable the feedback loop for their beamline and change bump target setpoints without turning itself off.

WEPA72

Analysis of Beam-Induced Heating of the NSLS-II Ceramic Vacuum Chambers

G. Bassi, C. Hetzel, A. Khan, B.N. Kosciuk, M. Seegitz, V.V. Smaluk, R.J. Todd (BNL)
A. Blednykh (Brookhaven National Laboratory (BNL), Electron-Ion Collider)

We discuss impedance calculations and related heating issues of the titanium-coated NSLS-II kicker ceramic chambers, with the titanium coating thickness estimated from in situ measurements of the end-to-end resistance of each chamber. Power densities are calculated on the titanium coating to allow for thermal analysis with the code ANSYS and comparison with heating measurements. The impedance analysis is performed using a realistic model of the ceramic complex permittivity, and special consideration is given to the impedance calculation in the limit of zero titanium coating thickness.

WEPA73

Numerical Studies of Short-range Wakefields at NSLS-II with GdfidL and ECHO3D

A. Khan, M. Seegitz, V.V. Smaluk, R.J. Todd (BNL) A. Blednykh (Brookhaven National Laboratory (BNL), Electron-Ion Collider)

The beam intensity in future low-emittance light sources with small gap wigglers and undulators is limited by the effects of short-range wakefields, especially by the beam-induced heating of the vacuum chamber components. We have cross-checked two electromagnetic solvers, GdfidL and ECHO3D, by simulation of the short-range wakefields in the NSLS-II flange absorber and in the taper transition of an in-vacuum undulator to test the consistency and precision of the wakefield models.

Characterization of Fully Coupled Linear Optics With Turn-by-Turn Data

WEPA74

Y. Li, R.S. Rainer, V.V. Smaluk (BNL)

In the future diffraction-limited light source rings, fully coupled linear optics to generate round beams is preferable. While machine tune approaching to linear difference resonances, small random errors, such as quadrupole rolls, can result in fully coupled optics. Consequently, some uncertainty exists in such optics due to random errors distributions. Given beam position monitors turn-by-turn readings, the harmonic analysis method was used to characterize the coupled Ripken Twiss parameters.

6-D Element-by-Element Particle Tracking With Crab Cavity Phase Noise and Weak-Strong Beam-Beam Interaction for the Hadron Storage Ring of the Electron-Ion Collider

WEPA75

Y. Luo, J.S. Berg, M. Blaskiewicz, C. Montag, V. Ptitsyn, F.J. Willeke, D. Xu (BNL) Y. Hao (FRIB) H. Huang (ODU) V.S. Morozov (ORNL RAD) J. Qiang (LBNL) T. Satogata (JLab)

The Electron Ion Collider (EIC) presently under construction at Brookhaven National Laboratory will collide polarized high energy electron beams with hadron beams with luminosity up to 10^{34} cm^{-2} s^{-1} in the center mass energy range of 20 to 140 GeV. Crab cavities are used to compensate the geometric luminosity due to a large crossing angle in the EIC. However, it was found that the phase noise in crab cavities will generate a significant emittance growth for hadron beams and its tolerance from analytical calculation is very small for the Hadron Storage Ring (HSR) of the EIC. In this paper, we report on 6-D symplectic particle tracking to estimate the proton emittance growth rate, especially in the vertical plane, for the HSR with weak-strong beam-beam and other machine or lattice errors.

Radio Frequency System and Controls of the NSLS-II Injector LINAC for Multi-Bunch Beams

WEPA76

H. Ma (BNL)

The Multi-Bunch Mode (MBM) beam injection operation of the NSLS-II LINAC imposes some special requirements on its radio frequency system (RF), one of which is the fast beam loading compensation functionality in its digital RF control. The latter in turn requires that the high-power RF klystrons operate in a near-linear mode. Requirements like those had a significant impact on the original design and planning of the RF system, and the same requirements continue to guide the current RF system upgrades.

A New PCB Rotating Coil at NSLS-II

WEPA77

M. Musardo, J. Avronsart, F.A. DePaola, L. Doom, R. Faussete, F.C. Lincoln, S.K. Sharma, T. Tanabe (BNL) D. Assell, J. DiMarco (Fermilab) A. Banerjee (SBU) C.L. Doose, A.K. Jain (ANL)

Several R&D projects are underway at NSLS-II towards an upgrade of its storage ring with a new lattice that will use high field magnets with small bores of 16-22 mm. A large fraction of the high field magnets are expected to be of permanent magnet technology that will require precise magnetic measurements and field harmonics corrections. A new magnetic measurement bench has been built based on a printed circuit board (PCB) coil of 12 mm diameter and 270 mm active length. This PCB coil has the capabil-ity of measuring field quality to a level of 10 ppm of the main field up to the 15th harmonic with a sensitivity between 0.01 m2 and 0.02 m2 at the reference radius of 5 mm. This paper will describe the main features of the rotating coil bench and discuss the measurement results of a permanent-magnet Halbach quadrupole of 12.7 mm bore diameter.

Proton-Electron Focusing in EIC Ring Electron Cooler

WEPA78

S. Seletskiy, A.V. Fedotov, D. Kayran, J. Kewisch (BNL)

The Electron Ion Collider (EIC) requires a cooling of protons at the top energy. The Ring Electron Cooler (REC) is a suitable option for such a cooling. In this paper we consider an effect of a proton-electron space charge (SC) focusing on the quality of the electron beam in the REC. We show that, with properly adjusted parameters of the Ring Electron Cooler, the SC focusing in the REC cooling section does not significantly affect the cooler performance.

WEPA79

Friction Force in Non-Magnetized Bunched Electron Coolers

S. Seletskiy, A.V. Fedotov (BNL)

Recent success of Low Energy RHIC Electron Cooler (LEReC) opened a road for development of high energy electron coolers based on non-magnetized electron bunches accelerated by RF cavities. The electron bunches in such coolers can have an asymmetric velocity distribution with arbitrary ratios between horizontal, vertical, and longitudinal velocity spreads. In this paper we revisit formulas of friction force in non-magnetized cooling and derive both the expressions useful for the quick numerical simulations and the analytic formulas for several limiting cases.

WEPA80

Progress on a Convergence Map Based on Square Matrix for Nonlinear Lattice Optimization

L.H. Yu, Y. Hao, Y. Hidaka, F. Plassard, V.V. Smaluk (BNL) Y. Hao (FRIB)

We report progress on applying the square matrix method to obtain in high speed a "convergence map", which is similar but different from a frequency map. We give an example of applying the method to optimize a nonlinear lattice for the NSLS-II upgrade. The convergence map is obtained by solving the nonlinear dynamical equation by iteration of the perturbation method and studying the convergence. The map provides information about the stability border of the dynamical aperture. We compare the map with the frequency map from tracking. The result in our example of nonlinear optimization of the NSLS-II lattice shows the new method may be applied in nonlinear lattice optimization, taking advantage of the high speed (about 30~300 times faster) to explore x, y, and the off-momentum phase space.

WEPA81

NSLS-II Timing-Resolved Machine Operation Plan

G.M. Wang, B. Bacha, G. Bassi, G.L. Carr, Y. Hidaka, Y. Hu, Y. Li, D. Padrazo Jr, R.S. Rainer, J. Rose, T.V. Shaftan, V.V. Smaluk, Y. Tian (BNL)

NSLS-II is a 3-GeV third-generation synchrotron light source at Brookhaven National Lab. The storage ring has been in routine operations for over six years and hosts 28 operating beamlines. The storage ring performance has continuously improved, including 500-mA with limited insertion devices closed due to RF power limitation, and routine 400-mA top off operation with 90% uniform filling pattern. Recently, we are exploring different operation modes, uniform multi single-bunch mode, and camshaft mode with a high single-bunch charge, to support timing-resolved user experiments. In this paper, we summarize the user requirements on the beam parameters and the progress of accelerator studies.

WEPA82

Complex Bend Prototype Beamline Design

G.M. Wang, F.A. DePaola, L. Doom, R. Gambella, B.N. Kosciuk, D. Padrazo Jr, T.V. Shaftan, S.K. Sharma, V.V. Smaluk, R.J. Todd (BNL)

Modern synchrotron light sources are competing intensively to increase X-ray brightness and, eventually, approach the diffraction limit, which sets the final goal of lattice emittance. Recently, we propose a new optics solution aimed at reaching low emittance, using a lattice element "Complex Bend". The Complex Bend is a sequence of dipole poles interleaved with strong alternate focusing so as to maintain the beta-function and dispersion oscillating at low values. By integrating this element in the NSLS-IIU upgrade, the designed lattice emittance is around 30 pm-rad. To prove the feasibility of this new design, we have planned the key element prototype test in the beam line with 200-MeV beam energy. Currently, we have finished the design and fabricated the prototype complex bend, with gradient at 140 T/m. In this paper, we will report the test beamline design and test plan.

WEPA83

Extended Soft-Gaussian Code for Beam-Beam Simulations

D. Xu (BNL)

Large ion beam emittance growth is observed in strong-strong beam-beam simulations for the Electron-Ion Collider (EIC). As we know, the Particle-In-Cell (PIC) solver is subject to numerical noises. As an alternative approach, an extended soft-Gaussian code is developed with help of Hermite polynomials in this paper. The correlation between the horizontal and the vertical coordinates of macro-particles is considered. The 3rd order center moments are also included in the beam-beam force. This code could be used as a cross check tool of PIC based strong-strong simulation.

Transverse Coupled-Bunch Instability Driven by the Resistive Wall Impedance at SuperKEKB

WEPA84

D. Zhou, T. Ishibashi, M. Tobiyama (KEK) G. Bassi (BNL) , A. Blednykh (Brookhaven National Laboratory (BNL), Electron-Ion Collider)

The growth time of transverse coupled-bunch instability (TCBI) in the vertical direction was measured at SuperKEKB rings. Resistive wall (RW) impedance is the primary source of driving TCBI. As a collider, special vacuum chambers are remarkable sources of RW impedance in addition to RW impedance from regular chambers. Such chambers include collimators where the chamber gap is very small and interaction region where the vertical beta functions are very large. The classical theory of TCBI based on uniform filling patterns is used to estimate the growth time. The recently developed general approach with arbitrary multibunch configurations [1] is also applied. The theoretical results are found to agree with the measurements.

Localized Beam Induced Heating Analysis of the EIC Vacuum Chamber Components

WEPA85

M.P. Sangroula, D.M. Gassner, C.J. Liaw, C. Liu, P. Thieberger (BNL) J.R. Bellon, A. Blednykh, C. Hetzel, S. Verdu-Andres (Brookhaven National Laboratory (BNL), Electron-Ion Collider)

The Electron-Ion Collider (EIC), to be built at Brookhaven National Laboratory (BNL), is designed to provide a high electron-proton luminosity of 10^{34} cm^{-2} s^{-1}. One of the challenging tasks for the Electron Storage Ring (ESR) is to operate at an average beam current of 2.5 A within 1160 bunches with a $\sim$ 7 mm bunch length. The Hadron Storage Ring (HSR) will accumulate an average current of 0.69 A within 290 bunches with a 60 mm bunch length. Both rings require the impedance budget simulations. The intense e-beam in the ESR can lead to the overheating of vacuum chamber components due to localized metallic losses. This paper focuses on the beam-induced heating analysis of the ESR vacuum components including bellows, gate-valve, and BPM. To perform thermal analysis, the resistive loss on individual components is calculated with CST and then fed to ANSYS to determine the temperature distribution on the vacuum components. Preliminary results suggest that active water cooling will be required for most of the ESR vacuum components. Similar impedance optimization work is performed for the HSR vacuum components. The impedance analysis of the HSR stripline injection kicker is presented.

Electron Beam-Ion Instability with Beam-Beam Interaction at the Electron-Ion Collider

WEPA87

B. Podobedov (Brookhaven National Laboratory (BNL), Electron-Ion Collider)
M. Blaskiewicz (BNL)

Collective beam dynamics in the Electron-Ion Collider will be significantly affected by the beam-beam interaction. For the transverse instabilities of the electron beam, such as the beam-ion instability or the TMCI, the beam-beam interaction is expected to provide a significant stabilizing influence, mainly due to the induced tune spread. Here we present detailed tracking simulations of the instability with Elegant and Fast Beam-Ion codes, comparisons between the two codes, as well as with the analytical predictions.

A Quasi-Optical Beam Position Monitor

WEPA88

S.V. Kuzikov (Euclid TechLabs)

There is a strong demand for non-destructive electron Beam Position Monitors (BPMs) for non-perturbative diagnostics of the electron beam position. Challenges are related to the shortness of the electron beam and the noisy chamber environment that are typical for modern RF-driven and plasma-driven accelerators. We propose using a pair of identical high-quality quasi-optical resonators attached to opposite sides of the beam pipe. The resonators can introduce Photonic Band Gap (BPM) structures. These open resonators sustain very low numbers of high-quality modes. We intend to operate at the lowest mode among the others that are capable of being excited by the bunches. The mentioned mode has a coupling coefficient with the beam that depends on the distance between the bunch and the coupling hole. The lower this distance, the higher the coupling. Therefore, comparing the pick-up signals of both resonators with an oscilloscope, we can determine the beam position.

WEADE — Celebration of Diversity, Equity, and Inclusion in the Accelerator Community

Integrating Diversity and Inclusion in the Workplace: Los Alamos National Laboratory's Strategies for Expanding Diversity and Fostering Inclusion and Belonging

K.S. Haight (LANL)

Diversity fuels an innovative, agile and principled workforce that is essential to solving problems of global importance. Diversity of thought, experience, and perspective leads to better problem solving and promotes creativity. But diversity in the workplace does not organically grow without conscientious attention. Like growing a tree requires water, sun and fresh air, growing a diverse workforce requires awareness, strategy and reflection. Los Alamos National Laboratory's approach to expanding diversity employs awareness, strategic action-oriented programs, and consistent reflection and rerouting to build a workforce that reflects the nation and world we are tasked to protect. But expanding diversity is meaningless without also fostering inclusion and belonging. Hear about successes and areas for further redirection from Los Alamos's EEO and Affirmative Action Officer. Hear about the diversity of our Accelerator community and how this sector of our workforce compares to the broader community. And hear how the voices of our workforce are shaping our programs and initiatives to ensure that every unique voice, every idea and opinion, are welcome and respected.

Chair: E.I. Simakov, LANL (Los Alamos, New Mexico, USA)

THXD — Beam Instrumentation and Controls

Machine Learning for Improved Accelerator Health and Reliability

THXD1

Y.A. Yucesan (ORNL RAD)

This talk will summarize the effort by the community in using machine learning for improved accelerator operations. This talk will also discuss efforts to implement a machine learning framework to improve accelerator reliability at the Spallation Neutron Source. It will describe new prognostics algorithms for detecting beam faults, classification of the fault sources, and efforts to integrate the algorithms into operations. it will also describe additional efforts to utilize ML for health and predictive prognostics on critical accelerator hardware and targets.

D Phase Space Diagnostics Based on Adaptive Tuning of the Latent Space of Encoder-Decoder Convolutional Neural Networks

THXD2

A. Scheinker (LANL)

We present a general approach to 6D phase space diagnostics for charged particle beams based on adaptively tuning the low-dimensional latent space of generative encoder-decoder convolutional neural networks (CNN). Our approach first trains the CNN based on supervised learning to learn the correlations and physics constrains within a given accelerator system. The input of the CNN is a high dimensional collection of 2D phase space projections of the beam at the accelerator entrance together with a vector of accelerator parameters such as magnet and RF settings. The inputs are squeezed down to a low-dimensional latent space from which we generate the output in the form of projections of the beam's 6D phase space at various accelerator locations. After training the CNN is applied in an unsupervised adaptive manner by comparing a subset of the output predictions to available measurements with the error guiding feedback directly in the low-dimensional latent space. We show that our approach is robust to unseen time-variation of the input beam and accelerator parameters and a study of the robustness of the method to go beyond the span of the training data.

Improved Multi-Dimensional Bunch Shape Monitor

THXD3

S.V. Kutsaev, R.B. Agustsson, A.C. Araujo Martinez, A. Moro, K.V. Taletski (RadiaBeam)
A.V. Aleksandrov (ORNL)

RadiaBeam is developing the Bunch Shape Monitor (BSM) with improved performance that incorporates three major innovations. First, the collection efficiency is improved by adding a focusing field between the wire and the entrance slit. Second, an improvement of the measurement speed is achieved by sampling longitudinal profiles of multiple energy slices simultaneously. Finally, the design is augmented with both a movable wire and a microwave deflecting cavity to add functionality and enable measuring the transverse profile as a wire scanner. In this paper we present the design of the BSM and its sub-systems as well as the initial test results of the new focusing system at SNS beamline.

Online Accelerator Tuning with Adaptive Bayesian Optimization

THXD4

N. Kuklev, M. Borland, G.I. Fystro, H. Shang, Y. Sun (ANL)

Particle accelerators require continuous adjustment to maintain beam quality. At the Advanced Photon Source (APS) this is accomplished using a mix of operator-controlled and automated tools. To improve the latter, we explored the use of machine learning (ML) at the APS injector complex. The core approach we chose was single and multi-objective Bayesian optimization (BO), which is well suited for sparse data tasks. To enable long-term online use, we modified BO into adaptive Bayesian optimization (ABO) though auxiliary models of device drift, physics-informed quality weights, time-biased data subsampling, digital twin retraining, and other approaches. The ABO allowed for compensation of changes in inputs and objectives without discarding previous data. Benchmarks showed better ABO performance in several simulated and experimental cases. To integrate ABO into the operational workflow, we developed a Python command line utility, pysddsoptimize, that is compatible with existing Tcl/Tk tools and the SDDS data format. This allowed for fast implementation, debugging, and benchmarking. Our results are an encouraging step for the wider adoption of ML at APS.

Chair: J.C. Dooling, ANL (Lemont, Illinois, USA)

THXD5

Machine Learning-Based Tuning of Control Parameters for LLRF System of Superconducting Cavities

J.A. Diaz Cruz, S. Biedron (UNM-ECE) **J.A. Diaz Cruz** (SLAC)

The multiple systems involved in the operation of particle accelerators use diverse control systems to reach the desired operating point for the machine. Each system needs to tune several control parameters to achieve the required performance. Traditional Low-Level RF systems are implanted as proportional-integral feedback loops, whose gains need to be optimized. In this paper, we explore Machine Learning as a tool to improve a traditional LLRF controller by tuning its gains using a Neural Network. We present the data production scheme and a control parameter optimization using a Neural Network and compare the performance of the enhanced ML controller with the traditional one. For this, we use a cavity emulator and the LCLS-II LLRF system. The NN training is performed using the THETA supercomputer.

THXD6

A Quasi-Optical Beam Position Monitor

S.V. Kuzikov (Euclid TechLabs)

There is a strong demand for non-destructive electron Beam Position Monitors (BPMs) for non-perturbative diagnostics of the electron beam position. Challenges are related to the shortness of the electron beam and the noisy chamber environment that are typical for modern RF-driven and plasma-driven accelerators. We propose using a pair of identical high-quality quasi-optical resonators attached to opposite sides of the beam pipe. The resonators can introduce Photonic Band Gap (BPM) structures. These open resonators sustain very low numbers of high-quality modes. We intend to operate at the lowest mode among the others that are capable of being excited by the bunches. The mentioned mode has a coupling coefficient with the beam that depends on the distance between the bunch and the coupling hole. The lower this distance, the higher the coupling. Therefore, comparing the pick-up signals of both resonators with an oscilloscope, we can determine the beam position.

THXE — Tutorial

Accelerators for Quantum Technologies

THXE1

A.S. Romanenko (Fermilab) K.A. Brown (BNL) S. Sosa (ODU)

Dr. A. Romanenko will present "SRF-based accelerator technologies for Quantum" followed by "Large Ion Traps for Quantum Information Systems" presented by Dr. K. Brown. "Examples of AI/ML enabled by HPCs in design applied to a QIS" presentation by Dr. S. Sosa will be followed by panel discussion and audience questions.

THYD — Photon Sources and Electron Accelerators

THYD1

XFEL as a Low-Emittance Injector for a 4th-Generation Synchrotron Radiation Source

T. Hara (RIKEN SPring-8 Center)

Low-emittance beam injection is required for the future SPring-8-II due to its small injection beam aperture. To meet this requirement, the SACLA linac has been used as a low-emittance injector since 2020 [1]. In order to perform the beam injection in parallel with XFEL operation, three accelerators are virtually constructed in a control system for the two XFEL beamlines and the beam injection, and thus the accelerator parameters can be independently tuned. Since the reference clock frequencies of the two accelerators are not related by an integer multiple, a new timing system was developed that achieves 3.8 ps (rms) synchronization. To maintain bunch purity better than 10^{-8}, which is routinely requested at SPring-8, an electron sweeper and an RF knock-out system are introduced for the SACLA injector and the SPring-8 storage ring. Although 0.1 nm-rad emittance of SACLA is increased by an order of magnitude at a transport line mainly due to quantum excitation of synchrotron radiation, it is still small enough for SPring-8-II. By shutting down an old dedicated injector complex, energy consumption has been significantly reduced, and it contributes to create a low-carbon society.

THYD2

The Challenging Physics Regimes of High Current Electron Beams

J.E. Coleman (LANL)

Electrons with intense space charge produce truly challenging physics regimes every step of the way. Hollow electron beams produced in the injector with thin enhanced edges are subject to the diocotron instability or a velocity shear, which is related to the Kelvin Helmholtz instability. Misaligned focusing elements and non-uniform current densities lead to non-linear transport effects in accelerator transport. Electrons focused to intensities $>10^5$ J/cm^2 or ne ~ 10^{19} m^{-3} can produce hot, Te > 1 eV, solid density plasmas that expand slowly over several hundred nanoseconds. The subsequent temperature and density gradients that are produced can generate magnetic fields. Example measurements and calculations of each of these phenomena are presented.

THYD3

Update on the Status of the C-Band Research and Facilities at LANL

E.I. Simakov, A.M. Alexander, D.V. Gorelov, T.W. Hall, M.E. Middendorf, T. Tajima, M.R.A. Zuboraj (LANL)

We will report on the status of C-band Engineering Research Facility in New Mexico (CERF-NM). Modern applications such as X-ray sources require accelerators with optimized cost of construction and operation, naturally calling for high-gradient acceleration. At LANL we commissioned a high gradient test stand powered by a 50 MW, 5.712 GHz Canon klystron. The test stand is capable of conditioning accelerating cavities for operation at surface electric fields in excess of 300 MV/m. CERF-NM is the first high gradient C-band test facility in the United States. CERF-NM was fully commissioned in 2021. In the last year, multiple C-band high gradient cavities and components were tested at CERF-NM. We studied high gradient limitations of these cavities, and mapped breakdown probabilities as functions of the peak surface fields. Currently we work to implement several updates to the test stand including the ability to autonomously operate at high gradient for the round-the-clock high gradient conditioning. Adding capability to operate at cryogenic temperatures is considered. We will also discuss LANL's plans for C-band capability development.

THYD4

Progress on the APS-U Injector Upgrade

J.R. Calvey, T. Fors, K.C. Harkay, U. Wienands (ANL)

For the APS-Upgrade, it was decided to leave the present APS injector chain in place and make individual improvements where needed. The main challenges faced by the injectors are delivering a high charge bunch (up to 16 nC in a single shot) to the storage ring, operating the booster synchrotron and storage ring at different rf frequencies, and maintaining good charge stability during APS-U operations. This paper will summarize recent progress on the injector upgrade. Topics include bucket targeting with the new injection/extraction timing system (IETS), modeling of high charge longitudinal instability in the PAR, and measurements of charge stability for different modes of operation.

Chair: N.A. Moody, LANL (Los Alamos, New Mexico, USA)

Emittance Measurements of Nanoblade-Enhanced High Field Cathode

THYD5

G.E. Lawler, J.I. Mann, N. Montanez, J.B. Rosenzweig (UCLA)

High brightness cathodes are increasingly a focus for accelerator applications ranging from free electron lasers to ultrafast electron diffraction. There is further an increasing interest in fabrication and control of the cathode surface to better control the emission characteristics and improve beam brightness. One method we can consider is based on well-known silicon nanofabrication techniques, which we use to create patterned cathode surfaces. The sharp edges produced lead to field emission increases and high brightness emission. We have demonstrated that a beam can be successfully extracted with a low emittance, and we have reconstructed a portion of the energy spectrum. Due to the simplicity of extended geometries in nanofabrication, our beam possesses a uniquely high aspect ratio in its transverse cross section. We can begin to consider modifications for emittance exchange beamlines and, having shown the patterning principle is sound, we can consider additional patterns such as hollow beams.

Arrival Time and Energy Jitter Effects on the Performance of X-ray Free Electron Laser Oscillator

THYD6

G. Tiwari (BNL) K.-J. Kim, R.R. Lindberg (ANL) K.-J. Kim (University of Chicago)

We report on the effects of electron beam arrival time and energy jitter on the power level and the fluctuations of the output of an X-ray FEL oscillator (XFELO). For this study, we apply the FEL driven paraxial resonator model of XFELO along with an analytical reflectivity profile to mimic the phase shift and spectral filtering effects of Bragg-crystals in the XFELO. The thresholds for acceptable timing jitters and energy jitters are determined in terms of the fluctuations of power output at the steady-state. We explore potential ways to mitigate the power output fluctuations in the presence of unavoidable electron beam jitters.

THYE — Accelerator Technology

THYE1

Overview of Superconducting Magnet Technologies

S. Prestemon (LBNL) K. Amm (BNL) L.D. Cooley (NHMFL)

Very high field superconducting magnets represent a critical technology for future accelerators, high field user magnets, and energy applications such as magnetic fusion and wind turbines. In addition, an overview of the record High Ramping Rates in HTS Based Super-conducting Accelerator Magnet will be given.

THYE2

Development of Short-Period Nb_3Sn Superconducting Planar Undulators at the Advanced Photon Source

I. Kesgin (ANL)

Superconducting technology has enabled the development of short-period undulators for higher-brightness X-rays at synchrotron light sources. Superconducting undulators (SCUs) hold great promise for XFELs as well. All operational devices are currently Nb Ti-based. Nb_3Sn has the potential to further enhance the performance of SCUs. This paper will describe the technical challenges and progress to date of this technology.

THYE3

Superconducting Undulators and Cryomodules for X-ray Free-Electron Lasers

D.C. Nguyen, G.J. Bouchard, B.M. Dunham, G.L. Gassner, Z. Huang, E.M. Kraft, P. Krejcik, M.A. Montironi, H.-D. Nuhn, T.O. Raubenheimer, Z.R. Wolf, Z. Zhang (SLAC) J.M. Byrd, J.D. Fuerst, E. Gluskin, Y. Ivanyushenkov, M. Kasa, E.R. Moog, M.F. Qian, Y. Shiroyanagi (ANL)

We present connectable designs of superconducting undulators (SCU) and cryomodules (CM) based on previous SCU and CM designs at Argonne National Lab. The new SCU and CM designs will allow us to connect one CM to the next to form a contiguous line of SCUs with no breaks between the cryomodules. The SCU design will have correctors and phase shifters integrated into the main SCU magnet core, as well as external corrector magnets for trajectory corrections. There will also be a cryogenic magnetic quadrupole and a cold RF beam position monitor (BPM) integrated in the SCU CM. In addition to providing the usual FODO transverse focusing, the quadrupole and BPM will be used for the beam-based alignment technique that is critical for X-ray FEL operation. In this paper, we will present the conceptual design of the new SCU CM as well as results of FEL simulations using the SCUs as afterburners for the LCLS hard X-ray undulators.

THYE4

Development of an Ultra-Low Vibration Cryostat Based on a Closed-Cycle Cryocooler

R.W. Roca, Y. Torun (Illinois Institute of Technology) E.W. Knight, R.A. Kostin, Y. Zhao (Euclid TechLabs)

Low temperature and low vibration cryostats are useful in a variety of applications such as x-ray diffraction, quantum computing, x-ray monochromators and cryo-TEMs. In this project, we explore an ultra-low vibration cryostat with the cooling provided by a closed cycle cryocooler. Closed-cycle cryocoolers inevitably introduce vibrations into the system, and in this project, flexible copper braiding was used to decouple vibrations and provide cooling at the same time. In order to develop the cryostat, capacity map of a two stage Sumitomo cryocooler was measured as well as vibration transmission through different copper braids using an IR interferometer. This paper covers the capacity map and vibration measurements in the first prototype.

THYE5

Analysis of Low RRR SRF Cavities

K. Howard, Y.K. Kim (University of Chicago) D. Bafia, A. Grassellino (Fermilab)

Recent findings in the superconducting radio-frequency (SRF) community have shown that introducing certain impurities into high-purity niobium can improve quality factors and accelerating gradients. Success has been found in nitrogen-doping, infusion of the native oxide into the niobium surface, and thin films of alternate superconductors atop a niobium bulk cavity. We question why some impurities improve RF performance while others hinder it. The purpose of this study is to characterize the impurity profile of niobium with a low residual resistance ratio (RRR) and correlate these impurities with the RF performance of low RRR cavities so that the mechanism of recent impurity-based improvements can be better understood and improved upon. Additionally, we performed surface treatments, low temperature baking and nitrogen-doping, on low RRR cavities to evaluate how the intentional addition of more impurities to the RF layer affects performance. We have found that low RRR cavities experience low temperature-dependent BCS resistance behavior more prominently than their high RRR counterparts. The results of this study have the potential to unlock a new understanding on SRF materials.

First Demonstration of a ZrNb Alloyed Surface for Superconducting Radio-Frequency Cavities

Z. Sun, M. Liepe, T.E. Oseroff (Cornell University (CLASSE), Cornell Laboratory for Accelerator-Based Sciences and Education)

Surface design of the RF surface is a promising path to next-generation SRF cavities. Here, we report a new strategy based on ZrNb surface alloying. Material development via an electrochemical process will be detailed. RF performance evaluated in the Cornell sample host cavity will be discussed. Cornell demonstrates that ZrNb alloying is a viable new technology to improve the performance of SRF cavities.

THZD — Hadron Accelerators

THZD1

Instant Phase Setting in a Large Superconducting Linac

A.S. Plastun, P.N. Ostroumov (FRIB)

The instant phase setting reduces the time needed to setup 324 accelerating cavities of the FRIB linac from 20 hours to 10 minutes. This technique uses a 1D computer model of the linac to predict the cavity phases. The model has been accurately calibrated using the data of the 360-degree phase scans - a common procedure for phasing of linear accelerators. The model was validated by comparison with another phase scan results. The predictions applied to the linac are then verified by multiple time-of-flight energy measurements and the response of the beam position/phase monitors (BPMs) to an intentional energy and phase mismatch. The presented approach not just reduces the time and the effort required to tune the FRIB accelerator for new experiments every couple of weeks, but it also provides an easy recovery from cavity fault scenarios. It is beneficial for user facilities requiring high beam availability, as well as for radioactive ion beam accelerators, where quick time-of-flight energy measurement via the BPMs is not possible due to the low intensities of these beams.

THZD2

Advances in the ATLAS Accelerator

M.P. Kelly, C. Dickerson, B.M. Guilfoyle, M.R. Hendricks, M. Kedzie, T.B. Petersen, T. Reid (ANL)

The ATLAS Superconducting Linac at Argonne National Laboratory is a leading facility for nuclear reaction and structure studies, providing ion beams over the full mass range to a community of users from the US and abroad. The technology of ATLAS has been continuously upgraded since commissioning in 1978 and has remained at the forefront of superconducting linac development, especially for low-beta Linacs, for more than four decades. We present an overview of the present state ATLAS superconducting technology, the latest approaches for superconducting cavity cryomodules commissioned within the last 10 years and the outlook and potential impact of transformative new technologies to low-beta ion accelerators.

THZD3

Design of 3-GeV High-Gradient Booster for Upgraded Proton Radiography at LANSCE

Y.K. Batygin, S.S. Kurennoy (LANL)

Increasing the proton beam energy from the present 800 MeV to 3 GeV will improve the resolution of the Proton Radiography Facility at the Los Alamos Neutron Science Center (LANSCE) by a factor of 10. It will bridge the gap between the existing facilities, which covers large length scales for thick objects, and future high-brightness light sources, which can provide the finest resolution. Proton radiography requires a sequence of short beam pulses (~20 x 80 ns) separated by intervals of variable duration, from about 300 ns to 1 to 2 μs. To achieve the required parameters, the high gradient 3-GeV booster is proposed. The booster consists of 1.4 GHz buncher, two accelerators based on 2.8 GHz and 5.6 GHz high-gradient accelerating structures and 1.4 GHz debuncher. Utilization of buncher-accelerator-debuncher scheme allows us to combine high-gradient acceleration with significant reduction of beam momentum spread. Paper discusses details of linac design and expected beam parameters.

THZD4

Accelerating Structures for High-Gradient Proton Radiography Booster at LANSCE

S.S. Kurennoy, Y.K. Batygin, E.R. Olivas (LANL)

Increasing energy of proton beam at LANSCE from 800 MeV to 3 GeV improves radiography resolution ~10 times. We proposed accomplishing such an energy boost with a compact cost-effective linac based on normal conducting high-gradient (HG) RF accelerating structures. Such an unusual proton linac is feasible for proton radiography (pRad), which operates with short RF pulses. For a compact pRad booster at LANSCE, we have developed a multi-stage design: a short L-band section to capture and compress the 800-MeV proton beam followed by the main HG linac based on S- and C-band cavities, and finally, by an L-band de-buncher [1]. Here we present details of development, including EM and thermal-stress analysis, of proton HG structures with distributed RF coupling for the pRad booster. A simple two-cell structure with distributed coupling is being fabricated and will be tested at the LANL C-band RF Test Stand.

Modelling H⁻ Injection and Painting in Vertical and Horizontal FFAs Using OPAL

THZD5

C.T. Rogers (STFC/RAL/ISIS) , A. Adelmann (PSI)

H^- phase space painting using charge-exchange has been used in synchrotrons to inject and accumulate high intensity bunches of protons, but has never been used in Fixed Field Accelerators (FFAs). In H^- charge-exchange injection, H^- ions pass through a thin foil where the electrons are stripped from the ion leaving a proton. In combination with an appropriate dipole, well-separated H^- ion and proton beams converge at the foil in this non-Liouvillean process. This can be combined with painting of the phase space, where the position of the injected beam is manipulated with respect to the circulating protons in order to inject beams having a specific profile in phase-space. In this paper the simulation of such injection is studied, performed using the latest improvements in the OPAL code. Injection into a small test ring that is under development as part of the ISIS upgrade program is considered.

An 8-GeV Linac for the Fermilab 2.5-MW Upgrade

THZD6

D.V. Neuffer, S.A. Belomestnykh, D.E. Johnson, S. Posen, E. Pozdeyev, V.S. Pronskikh, A. Saini, N. Solyak, V.P. Yakovlev (Fermilab) H. Padamsee (Cornell University (CLASSE), Cornell Laboratory for Accelerator-Based Sciences and Education)

Increasing the Main Injector (MI) beam power above ~1.2 MW requires replacement of the 8-GeV Booster by a higher intensity alternative. In the Project X era, rapid-cycling synchrotron (RCS) and linac solutions were considered for this purpose. In this paper, we consider the linac version that produces 8 GeV H^- beam for injection into the Recycler Ring (RR) or Main Injector (MI). The linac takes ~1-GeV beam from the PIP-II Linac and accelerates it to ~2 GeV in a 650-MHz SRF linac, followed by a 8-GeV pulsed linac using 1300 MHz cryomodules. The linac components incorporate recent improvements in SRF technology. Research needed to implement the high power SRF Linac is described.

THZE — Beam Instrumentation and Controls

THZE1

Machine Learning-Based Longitudinal Phase Space Prediction of Particle Accelerators

C. Emma (SLAC)

The author would report on the application of machine learning (ML) methods for predicting the longitudinal phase space (LPS) distribution of particle accelerators. The approach consists of training a ML-based virtual diagnostic to predict the LPS using only nondestructive linac and e-beam measurements as inputs.

THZE2

Developing Control System Specifications and Requirements for the Electron Ion Collider

A. Blednykh, D.M. Gassner (Brookhaven National Laboratory (BNL), Electron-Ion Collider) E.C. Aschenauer, M. Blaskiewicz, K.A. Drees, T. Hayes, J.P. Jamilkowski, S. Nemesure, V. Schoefer, K.S. Smith, F.J. Willeke (BNL) L.R. Dalesio (EPIC Consulting)

An Accelerator Research facility is a unique science and engineering challenge in that the requirements for developing a robust, optimized science facility are limited by engineering and cost limitations. Each facility is planned to achieve some science goal within a given schedule and budget and is then expected to operate for three decades. In three decades, the mechanical systems and the industrial IO to control them is not likely to change. In that same time, electronics will go through some 4 generations of change. The software that integrates the systems and provides tools for operations, automation, data analysis and machine studies will have many new standards. To help understand the process of designing and planning such a facility, we explain the specifications and requirements for the Electron Ion Collider (EIC) from both a physics and engineering perspective.

THZE3

An Electrodeless Diamond Beam Monitor

S.V. Kuzikov, P.V. Avrakhov, C.-J. Jing, E.W. Knight, Y. Zhao (Euclid TechLabs) C.-J. Jing, J.G. Power, D.S. Scott, E.E. Wisniewski (ANL) C.-J. Jing (Euclid Beamlabs)

Being a wide-band semiconductor, diamond can be used to measure the flux of passing particles based on a particle-induced conductivity effect. We recently demonstrated a diamond electrodeless electron beam halo monitor. That monitor was based on a thin piece of diamond (blade) placed in an open high-quality microwave resonator. The blade partially intercepted the beam. By measuring the change in RF properties of the resonator, one could infer the beam parameters. At Argonne Wakefield Accelerator we have tested 1D and 2D monitors. To enhance the sensitivity of our diamond sensor, we proposed applying a bias voltage to the diamond which can sustain the avalanche of free carriers. In experiment carried out with 120 kV, $\sim$1 μA beam we showed that the response signal for the avalanche monitor biased with up to 5 kV voltage can be up to 100 times larger in comparison with the signal of the same non-biased device.

THZE4

Gas Sheet Ionization Diagnostic for Transverse Profile Measurement

N. Burger, G. Andonian, T.J. Hodgetts, A.-L.M.S. Lamure (RadiaBeam) N.M. Cook, A. Diaw (RadiaSoft LLC) P.E. Denham, P. Musumeci, A. Ody, J.K. Penney (UCLA) N.P. Norvell (UCSC) C.P. Welsch, M. Yadav (The University of Liverpool) C.P. Welsch (Cockcroft Institute)

Transverse profile diagnostics for high-intensity beams require solutions that are non-intercepting and single-shot. In this paper, we describe a gas-sheet ionization diagnostic that employs a precision-shaped, neutral gas jet. As the high-intensity beam passes through the gas sheet, neutral particles are ionized. The ionization products are transported and imaged on a detector. A neural-network based reconstruction algorithm, trained on simulation data, then outputs the initial transverse conditions of the beam prior to ionization. The diagnostic is also adaptable to image the photons from recombination. Preliminary tests at low energy are presented to characterize the working principle of the instrument, including comparisons to existing diagnostics. The results are parametrized as a function of beam charge, spot size, and bunch length.

THZE5

Recent Developments of the Soft X-ray Beam Position Monitor Project

B. Podobedov, D.M. Bacescu, C. Eng, S. Hulbert, C. Mazzoli, C.S. Nelson (BNL) D. Donetski, K. Kucharczyk, J. Liu, R. Lutchman (Stony Brook University)

A novel soft X-ray BPM (sXBPM) for high-power white beams of undulator radiation is being developed through a joint effort of BNL/ NSLS-II and Stony Brook University. In our approach, custom-made multi-pixel GaAs detector arrays are placed into the outer portions of the x-ray beam, and the beam position is inferred from the pixel photocurrents. In this paper, we present a brief overview and the most recent developments in our project. To date, the mechanical design of the system is completed

and most of the vacuum and mechanical components have been installed into the 23-ID canted undulator beamline first optical enclosure. The remainder of the system, including the detector arrays, are being installed during the upcoming NSLS-II machine shutdown. The GaAs detectors have been designed, fabricated, and tested in the visible range with a high-power Ar-ion laser as well as in the soft and hard x-ray regions at two NSLS-II beamlines.

A Time-Resolved Beam Halo Monitor for Accelerator Beam Diagnostics Using Diamond Detectors and High Speed Digitizers

I.S. Mostafanezhad, K.T. Flood, L.M. Macchiarulo, B. Rotter (Nalu Scientific, LLC) J. Bohon (LBNL) E.M. Muller (BNL) J. Smedley (LANL) J. Smedley (SLAC)

We will describe the development and prospects for the Time-Resolved Beam Halo Monitor (TR-BHM) along with results from initial beam tests. The TR-BHM is a detector system for measuring and characterizing the spatial and temporal structure of particle halos accompanying accelerated particle bunches utilizing diamond strip detectors read out by system-on-chip (SoC) high-speed waveform digitizers developed by Nalu Scientific LLC (NSL). It will provide a powerful non-destructive in-situ beam diagnostic detector for real-time measurements and control of beam parameters for the next generation of light sources. The theory, detection methodology, and instrumentation will be discussed, as well as measurement results from full-system x-ray beam calibration tests and preparations for an upcoming prototype installation at FACET.

FRXD — Beam Dynamics

FRXD1

Demonstration of Optical Stochastic Cooling in an Electron Storage Ring

J.D. Jarvis, D.R. Broemmelsiek, K. Carlson, D.R. Edstrom, V.A. Lebedev, S. Nagaitsev, H. Piekarz, A.L. Romanov, J. Ruan, J.K. Santucci, G. Stancari, A. Valishev (Fermilab) S. Chattopadhyay, A.J. Dick, P. Piot (Northern Illinois University) I. Lobach (University of Chicago)

Optical stochastic cooling (OSC), proposed nearly thirty years ago, replaces the conventional microwave elements of stochastic cooling (SC) with optical-frequency analogs, such as undulators, optical lenses and optical amplifiers. Here we discuss the first experimental observation of OSC, which was performed at the Fermi National Accelerator Laboratory's Integrable Optics Test Accelerator (IOTA) with 100-MeV electrons and a radiation wavelength of 950 nm. The experiment employed a non-amplified configuration of OSC and achieved a longitudinal damping rate close to one order of magnitude larger than the beam's natural damping due to synchrotron radiation. The integrated system demonstrated sub-femtosecond stability and a bandwidth of ~20 THz, a factor of ~2000-times higher than conventional microwave SC systems. Coupling to the transverse planes enabled simultaneous cooling of the beam in all degrees of freedom. This first demonstration of SC at optical frequencies serves as a foundation for more advanced experiments with high-gain optical amplification and advances opportunities for future operational OSC systems at colliders and other accelerator facilities.

FRXD2

Experimental Demonstration of Multi-Function Longitudinal Beam Phase-Space Manipulation via Double Emittance-Exchange

J. Seok (ANL) **J. Seok** (UNIST)

Beam manipulation in the longitudinal direction is not straightforward due to the speed and duration of the bunch. Longitudinal manipulation usually require dedicated radio-frequency (RF) cavities and anisochronous beamlines (e.g., chicane) to control beam's time-energy correlation (called chirp). In this talk, a new method using a double emittance exchange (DEEX) beamline was demonstrated for the first time at the Argonne Wakefield Accelerator Facility. It allows control of the longitudinal phase space using relatively simple transverse manipulation techniques. This method enables various longitudinal manipulations such as tunable bunch compression, longitudinal chirp control, and nonlinearity compensation in a remarkably flexible manner. We report proof-of-principle experiment results demonstrating three key functions of the DEEX bunch compressor.

FRXD3

Measurements of the Five-Dimensional Phase Space Distribution of a High-Intensity Ion Beam

A.M. Hoover, A.V. Aleksandrov, S.M. Cousineau, K.J. Ruisard, A.P. Zhukov (ORNL)

No simulation of intense beam transport has accurately reproduced measurements at the level of beam halo. One potential explanation of this discrepancy is a lack of knowledge of the initial distribution of particles in six-dimensional (6D) phase space. A direct 6D measurement of an ion beam was recently performed at the Spallation Neutron Source (SNS) Beam Test Facility (BTF), revealing nonlinear transverse-longitudinal correlations in the beam core that affect downstream evolution. Unfortunately, direct 6D measurements are limited in resolution and dynamic range; here, we discuss the use of three slits and one screen to measure a 5D projection of the 6D phase space distribution, overcoming these limitations at the cost of one dimension. We examine the measured 5D distribution before and after transport through the BTF and compare to particle-in-cell simulations. We also discuss the possibility of reconstructing the 6D distribution from 5D and 4D projections.

FRXD4

Suppressing the Microbunching Instability at ATF using Laser Assisted Bunch Compression

Q.R. Marksteiner, P.M. Anisimov, B.E. Carlsten, G. Latour, E.I. Simakov, H. Xu (LANL)

The microbunching instability in linear accelerators can significantly increase the energy spread of an electron beam. The instability can be suppressed by artificially increasing the random energy spread of an electron beam, but this leads to unacceptably high energy spreads for future XFEL systems. One possibility of suppressing this instability is to use laser assisted bunch compression (LABC) instead of the second chicane in an XFEL system, thereby eliminating the cascaded chicane effect that magnifies the microbunching instability. An experiment is proposed at ATF to test this concept, and numerical simulations of the experiment are shown.

Nonlinearly Shaped Pulses at LCLS-II

FRXD5

N.R. Neveu, S. Carbajo, Y. Ding, J.P. Duris, R.A. Lemons, A. Marinelli, J. Tang (SLAC)

With the goal of improving emittance and longitudinal phase space of the electron beam, we consider nonlinear shaping of the temporal laser profile at the cathode. The operational Ultraviolet (UV) optics installed at the LCLS and LCLS-II currently produce Gaussian shaped pulses. Our simulations show the potential to reduce emittance and increase peak brightness when comparing nonlinear UV laser shapes on the cathode to baseline Gaussian pulses at the cathode.

Bunch Length Measurements at the CEBAF Injector at 130 kV

FRXD6

S. Pokharel, G.A. Krafft (ODU) M.W. Bruker, J.M. Grames, A.S. Hofler, R. Kazimi, G.A. Krafft, S. Zhang (JLab)

In this work, we investigated the evolution in bunch length of beams through the CEBAF injector for low to high charge per bunch. Using the General Particle Tracer (GPT), we have simulated the beams through the beamline of the CEBAF injector and analyzed the beam to get the bunch lengths at the location of chopper. We performed these simulations with the existing injector using a 130 kV gun voltage. Finally, we describe measurements to validate these simulations. The measurements have been done using chopper scanning technique for two injector laser drive frequency modes: one with 500 MHz, and another with 250 MHz.

FRXE — Tutorial

Bayesian Algorithms for Practical Accelerator Control and Adaptive Machine Learning for Time-Varying Systems

A. Scheinker (LANL) R.J. Roussel (SLAC)

Particle accelerators are complicated machines with thousands of coupled time varying components. The electromagnetic fields of accelerator devices such as magnets and RF cavities drift and are uncertain due to external disturbances, vibrations, temperature changes, and hysteresis. Accelerated charged particle beams are complex objects with 6D phase space dynamics governed by collective effects such as space charge forces, coherent synchrotron radiation, and whose initial phase space distributions change in unexpected and difficult to measure ways. This two-part tutorial presents recent developments in Bayesian methods and adaptive machine learning (ML) techniques for accelerators. Part 1: We introduce Bayesian control algorithms, and we describe how these algorithms can be customized to solve practical accelerator specific problems, including online characterization and optimization. Part 2: We give an overview of adaptive ML (AML) combining adaptive model-independent feedback within physics-informed ML architectures to make ML tools robust to time-variation (distribution shift) and to enable their use further beyond the span of the training data without relying on re-training.

FRCDE — Closing Session

Accelerator Searches for Axions and Dark Matter

FRCDE1

R. van de Water (LANL)

This talk will give an overview of the theory and the accelerator and detector techniques used for dark sector searches. As an example, the talk will then focus on a recent and local experiment, the Coherent CAPTAIN-Mills (CCM), which has begun running at the LANSCE Lujan center. In a three year run CCM will search for sub-GeV dark matter with sensitivities that probe early Universe relic density limits. It will also probe for Axion Like Particles (ALP's) parameter space un-tested by previous experiments and cosmological constraints, and test new interpretation of the legendary LSND and MiniBooNE excesses. CCM will operate at the Lujan Center at LANSCE which is a 100-kW neutron and stopped pion source that delivers an 800-MeV proton beam onto a tungsten target at 20 Hz with a pulse width of 290 ns. The 10 ton liquid argon CCM detector is placed 23 m from the target and is instrumented with 200 fast nano-second 8" PMT's that can detect scattering events in time with the beam from as low as 10 keV thresholds up to 200 MeV. Initial data results will be shown demonstrating the power of the new experiment.

Accelerator Production of Medical Radionuclides

FRCDE2

C.S. Cutler, D. Kim, D. Medvedev (BNL)

Since 1931 major advances have enabled the production of small compact cyclotrons to be installed at hospitals and pharmacies enabling the supply of short-lived radionuclides around the world. This and the development of the generator allowed for remote access to radionuclides and the expansion of nuclear medicine. In the 1970's and 80's major accelerator facilities operating at 100 MeV and higher were installed in many of the national labs and used for production of radionuclides at energies and currents not available on the small compact machines. These high energy accelerators have played an important role in supplying Radionuclides such as Sr-82 used in Sr/Rb generators for cardiac imaging and Ac-225 for cancer therapy. They continue to be advanced to further production yields by installing beam rastering systems that have allowed higher intensities and thus higher production yields. As well as adding mass separation techniques that enable novel radionuclides to be produced in quality suitable for use. These enhanced accelerator capabilities and the production of these novel radionuclides will be presented.

Radiation Effects in Microelectronics - Why We Need Particle Accelerators

FRCDE3

J.A. Pellish (NASA Goddard Space Flight Center)

We have seen anomalies due to radiation effects in electronic devices since the mid-1970s. We group radiation effects into different categories: one of which is single-event effects (SEE). SEE are any measurable or observable change in state or performance of a microelectronic device, component, subsystem, or system resulting from a single energetic-particle strike. Today, SEE dominate radiation risks for many ground- and space-based systems. Engineers require knowledge of SEE susceptibility for devices and systems since it impacts both availability and reliability. Design teams frequently use particle accelerators to simulate ionizing radiation environments. The rapid growth of systems operating in harsh radiation environments has pushed accelerator facility access constraints to the breaking point. Investments in new radiation effects testing infrastructure have begun. Meanwhile, there remain unanswered questions about accelerator facility workforce and potential business model impacts on existing ecosystems. We must maintain existing facility access as while building out new capabilities, or risk unacceptable impacts to product development and space system operations.

Chair: S.V. Milton, Tau Systems (Chicago, USA)

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