HIAT 2025 Abstracts

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SUP: Sunday Student Poster Session
22 June 2025 16:00 - 18:00

SUP01/MOP01

Computation model for space charge effect for bunched beam in collider rings
Helena Alamprese, Yue Hao (Facility for Rare Isotope Beams).

In the last two decades, numerical and experimental studies have extensively explored the impact of the space charge on bunched beams in both linear accelerators and storage rings. However, fully accounting for space charge effects over the entire accelerator is computationally intensive, especially in storage rings, where simulations must track beam dynamics over many turns and extended time periods. In many cases, space charge forces cannot be neglected, motivating the development of an alternative computational model. Here, we explore the space charge induced nonlinear dynamics using a model that approximates the Coulomb force by concentrating its effects at discrete locations along the accelerator. This approach enables efficient analyses of the full six-dimensional phase space evolution under space charge effects. Future work will apply this model to further investigate the interplay between space charge and beam-beam interactions in colliders, as well as to assess long-term stability criteria in ring accelerators.

SUP03/MOP03

Ion beam techniques for analysis the materials using 1.7 MV tandem accelerator
Gajigatte Umapathy, Dinakar Kanjilal, Sundeep Chopra, Sunil Ojha (Inter-University Accelerator Centre).

The 1.7 MV (5SDH-2) tandem accelerator at the Inter-University Accelerator Centre (IUAC) has been playing a major role in advancing research activities in materials science and nuclear physics experiments using various advanced ionbeam characterization techniques. In this work, I present the IBA technique studies such as (a) RBS Analysis of Au and Au/Ag Thin Films for investigating the effects of low energy ion irradiation (8 keV Ni, 10 keV Ar, and 400 keV Ar) for applications in Surface-Enhanced Raman Scattering (SERS) and other technological applications, (b) RBS of Nat/28Si on Au Backing For in-beam γ-ray spectroscopy experiments for detailed compositional analysis and target integrity, (c) Depth Profiling in 4H-SiC by utilizing RBS Channeling to assess disorder and strain induced by Si ion implantation and its recovery post-thermal annealing (d) Hydrogen Detection in α-Fe2O3 Analysis by ERDA techniques to study the reversible hydrogen control of and ferromagnetic anisotropy, highlighting the material's potential for novel magnetic storage technologies, will be discussed.

SUP04/MOP04

Monte Carlo simulation analysis for radiation damage on Glidcop Al-15 caused by 17-20 MeV/u heavy ions in FRIB

Ethan Fletcher, Alexander Plastun, Steven Lidia, Takuji Kanemura (Facility for Rare Isotope Beams), Eiichi Wakai (High Energy Accelerator Research Organization), Patrick Hurh (Fermi National Accelerator Laboratory).

The Facility for Rare Isotope Beams (FRIB) SRF linear heavy-ion accelerator is designed to accelerate all ions up to uranium to a maximum beam power of 400 kW. Several beam intercepting devices (BIDs) are essential to the successful operation of the accelerator, including a low power charge selector (LPCS) made of copper containing 0.15% precipitated aluminum oxide by weight called Glidcop Al-15. As FRIB ramps up the primary beam power beyond the current 20 kW level, the charge selector must withstand higher radiation damage rates, typically measured in displacements per atom (dpa). Significant beam induced radiation damage including significant deformation, like swelling, blistering, and cracking has been observed on a recently removed LPCS. We also observed physical features up to about 5.5 mm wide and appear to be deeper than the projected range of any ions. This paper presents the results of Monte Carlo simulations carried out using the Particle and Heavy Ion Transport code System (PHITS), quantifying the total damage dose and ion concentration, etc. Simulating an accurate irradiation history is essential to determining the scope of post irradiation examination (PIE) work.

SUP05/MOP16

Developing a next-generation MR-ToF device for the Facility for Rare Isotope Beams

Christian Ireland, Franziska Maria Maier, Ryan Ringle (Facility for Rare Isotope Beams), Erich Leistenschneider (University of British Columbia & TRIUMF).

Multi-reflection time-of-flight (MR-ToF) devices have arisen as indispensable tools at radioactive ion beam (RIB) facilities. These electrostatic ion beam traps act as highly-selective mass separators providing purified ion beams to subsequent experiments as well as high-precision mass spectrometers enabling mass measurements of short-lived nuclei. Efforts are ongoing to push the limits of these devices, enabling higher resolving power and/or ion throughput. State-of-the-art devices operate with a few keV of beam energy, however simulations detail the need to pursue higher energies [*]. To this end, a high-voltage MR-ToF device has been designed for the Facility for Rare Isotope Beams (FRIB) enabling both high mass resolving power and high ion throughput. Such a device will enable precision mass measurements of short-lived ions as well as the delivery of pure high-intensity beams to subsequent experiments in the stopped and reaccelerated beam areas at FRIB.

[*] F. M. Maier et al., NIMA 1056, 168545 (2023)

SUP06/MOP18

Extending JuTrack's capabilities to the FRIB accelerator to enhance online modeling

Christian Ratcliff, Jinyu Wan, Kei Fukushima, Yue Hao (Facility for Rare Isotope Beams).

JuTrack is a Julia-based accelerator modeling and tracking package that utilizes compiler-level automatic differentiation (AD) to enable fast and accurate derivative calculations. While JuTrack provides a solid foundation for beam dynamics simulations, its capabilities must be extended to support the Facility for Rare Isotopes (FRIB) linac. This includes modeling heavy-ion linac accelerator components such as the liquid-lithium charge stripper, which facilitates efficient acceleration by remove electrons from heavy isotopes, and incorporating multi-charge state acceleration tracking, which allows for charge-dependent beam dynamics. These extensions address challenges such as the beam matching and optimization of multi charge state through various accelerating structures and beam-material interaction modeling while maintaining the auto differentiation capability. This work focuses on adapting JuTrack to incorporate these elements, enhancing its online modeling abilities. We present modifications to JuTrack's framework and demonstrate their performance in FRIB simulations.

SUP07/WEP22

Beam dynamics design of the superconductiong section of a 100 mA superconducting linac

Man Yi, Zhijun Wang, Shuhui Liu (Institute of Modern Physics, Chinese Academy of Sciences).

Beam loss is a critical challenge in the physics design of high power superconducting proton linacs. The challenge is even more acute in linacs that feature high peak intensity and low energy, which has strong space charge effect and RF nonlinear force. In this paper, we study how to achieve a high transmission rate for beam halo particles, commonly a major source of beam loss, via beam halo matching and acceptance optimization. We employ this method of beam loss reduction to improve the physics design of a high power 100mA superconducting linac which has potential applications in high brightness neutron production.

SUP08/MOP27

Physical design and optimization of an E × B chopper based on permanent magnets

Duanyang Jia, Weilong Chen, Yuan He, Zhijun Wang (Institute of Modern Physics, Chinese Academy of Sciences).

Chopper systems are typically used to provide beam time structure and ensure the safety of accelerator operations by deflecting the beam away. To meet the strict beam stopping time requirements of the China Initiative Accelerator Driven System (CiADS), an E × B chopper design has been developed based on a permanent magnet and an electrostatic deflection plate. In this paper, the physical design of the chopper system is detailed, and each component of the chopper is optimized through simulation analysis. Finally, the feasibility of the chopper system is validated through multi-particle simulations and error analysis.

SUP10/THA02

Phase space tomography at ATLAS using maximum entropy tomography

Anthony Tran (Facility for Rare Isotope Beams), Brahim Mustapha (Argonne National Laboratory), Yue Hao (Facility for Rare Isotope Beams).

We use one-dimensional measurements to reconstruct the four-dimensional phase space of an ion beam at the Argonne Tandem Linac Accelerator System (ATLAS) using maximum entropy tomography. This was accomplished with a novel algorithm that directly reconstructs 4D from 1D. The results were compared against a quadrupole scan measurement of the phase space. Finally, an error analysis method employing statistical analysis was used to estimate the errors.

SUP12/TUP02

Investigation of mechanical stability of silicon carbide in aluminium oxide under high temperature and 800 keV Ar ion irradiation

Gajigatte Umapathy (Inter-University Accelerator Centre), Santanu Ghosh (Indian Institute of Technology Delhi).

The SiC acts as the primary barrier against the release of fission products in the TRISO-type fuel. For the present generation, SMR technology A highly explored area for optimizing commercial nuclear fuel efficiency is managing the Kr/Xe fission gas budget, as these gases act as time limiters due to thermal fission gas swelling or nucleating high swelling behaviour (HSB) structures' expansion. In this study, we investigate irradiation stability of SiC(TiO2) Al2O3 composit. Alumina is recognized for its role in enhancing adhesion under high-temperature conditions, while TiO_2 functions as a binding agent within the matrix. The sample $(Al_2O_3)x(TiO_2)ySiCz$, where the concentration x=y=0-10,z=1-x+y was prepared by the additive method using pure powders pressed into pellets, followed by dual-step sintering for 10 and 14 hours at 1000°C and 1400°C, respectively. The samples were irradiated with a 800 keV Ar^+ beam at doses ranging from 1e15 to 1e17 atoms/cm^2. The crystal structure, morphology, and physical properties were studied in pre- and post-irradiation conditions using characterization techniques such as RBS, FESEM, XRD, TEM, and nano-indentation.

SUP13/TUP03

Numerical modeling to predict ignition thresholds for plasma processing of superconducting radio-frequency cavities

Zachary Hosek, Patrick Tutt, Ting Xu, Walter Hartung (Facility for Rare Isotope Beams).

Laboratories such as Oak Ridge, Fermilab, and Jefferson Laboratory have been developing plasma cleaning techniques for superconducting radio-frequency (SRF) cavities. These techniques show promise as an in-situ method of mitigating degradation in cavity performance via removal of surface hydrocarbon contamination. Plasma cleaning studies for SRF cavities in the driver linac at the Facility for Rare Isotope Beams (FRIB) began in 2020. Both neon-oxygen and argon-oxygen plasmas have been found to be effective in improving FRIB accelerating cavities. The ignition threshold RF electric field can be predicted for a diffusion-dominated plasma using the solution to the diffusion equation for a given cavity

shape; a numerical solution is needed for realistic cavity shapes. Predictions for several cavity shapes will be presented and compared to available plasma ignition threshold measurements.

SUP14/TUP12

Research on compensation of a rf cavity failure in a superconducting linac by reinforcement learning algorithm

Tielong Wang, Yuan He, Zhijun Wang (Institute of Modern Physics, Chinese Academy of Sciences).

High reliability is a major challenge of high-current linear accelerators. This is particularly problematic for Accelerator Driven Systems (ADS) such as the China initiative Accelerator Driven System (CiADS). In order to achieve rapid beam recovery, it is necessary to adjust and compensate the cavities adjacent to the failed cavity. In this study, we employ the Proximal Policy Optimization (PPO) algorithm, a reinforcement learning technique, to train a compensation model within a simulated environment of the CiADS superconducting HWR010 section. Compared to previous methods utilizing genetic algorithms, the reinforcement learning approach demonstrates superior performance in delivering more stable and consistent results.

SUP15/WEP20

Multi-q beam studies at FRIB: simulations and measurements

Alec Gonzalez, Alexander Plastun, Kei Fukushima, Peter Ostroumov, Tomofumi Maruta (Facility for Rare Isotope Beams).

The Facility for Rare Isotope Beams (FRIB) linear accelerator is capable of simultaneously transporting and accelerating multiple-charge-state heavy-ion beams. Accurate transverse and longitudinal matching of these beams is a challenging problem, particularly in achromatic bending segments of the linac. To solve it, we employ both macroparticle tracking and linear optics codes. The simulation models are being developed, cross-checked, and validated by beam measurements. The studies are focused on the beam size, envelope matching, charge state separation, and the response of the beam position. The results of the studies with the 16.5 MeV/u five-charge-state uranium beam will be presented.

SUP16/TUP14

Avoiding beam instabilities and resonances with circular modes

Onur Gilanliogullari (Illinois Institute of Technology), Brahim Mustapha (Argonne National Laboratory), Pavel Snopok (Illinois Institute of Technology).

Beam instabilities and resonances affect the transverse dynamics in particle accelerators and, when encountered, can trigger emittance growth and beam loss. Resonance lines originate from nonlinear elements and effects in the lattice,and impose strict constraints on the choice of working points and narrow the available tune space. Circular modes—intrinsically coupled, flat-round eigenmodes—provide an alternative beam motion and dynamics. In this study we derive the third-order sextupole resonance

conditions in the coupled (normal-mode) parametrization and show that, with circular-mode lattice design and beam operation, most of these resonance lines are naturally suppressed thanks to the mode's inherent flatness.

SUP17/MOP02

Simulation of improved injection kicker waveforms in the SNS accumulator ring

Luis Garabito Ruiz (Facility for Rare Isotope Beams), Austin Hoover, Nicholas Evans (Oak Ridge National Laboratory), Steven Lund (Facility for Rare Isotope Beams).

Recent empirical tuning of the Spallation Neutron Source injection system has produced new injection kicker settings, new time-varying waveforms for each of the eight injection magnets forming a closed four-bump in each plane, for the proton accumulator ring. These new settings deliver beam parameters consistent with target requirements for beam size and peak density, and identical RMS beam sizes at upstream diagnostics. However, beam halo has been reduced from previous settings providing the same RMS size, as evidenced by a significant temperature reduction on halo-monitoring thermocouples surrounding the proton beam window that separates the accelerator vacuum from the helium-filled target environment. In this work we use PyORBIT, a PIC code developed at Oak Ridge National Laboratory, to simulate the injection process for the previous settings, and the newly identified working point to gain insight into the likely source of the halo reduction and investigate further improvements to injection tuning.

SUP18/MOP13

Beam dynamics design for alternating phase focusing proton linac for a compact accelerator based neutron source

Mina Abbaslou, Robert Laxdal, Marco Marchetto, Philipp Kolb, Tobias Junginger, Oliver Kester (TRIUMF), Drew Marquardt (University of Windsor).

A prototype Canadian compact accelerator-driven neutron source (PC-CANS) is proposed for installation at the University of Windsor. The source is based on a high-intensity compact proton RF accelerator that delivers an average current of 10 mA of protons at 10 MeV to the target. The accelerator consists of a short radio frequency quadrupole (RFQ), followed by an efficient drift tube Linac (DTL) structure. Different variants of DTL were investigated for our studies including the Alvarez TM010 structure and various H-mode structures using both negative synchronous phase and KONUS beam dynamics all at 352.2MHz. For completeness an alternate phase focusing (APF) design was also included in the study. Details of the beam dynamics of a high intensity proton APF Linac are presented in this paper.

SUP20/MOP07

Control of microphonics for a superconducting radio-frequency photo-injector cryomodule

Kaela Villafania, Jacob Brown, Sang-Hoon Kim, Ting Xu, Wei Chang (Facility for Rare Isotope Beams).

A superconducting radio-frequency photo-injector cryomodule is being developed for the high-energy upgrade of the Linac Coherent Light Source (LCLS-II-HE). This effort is a collaboration between the Facility for Rare Isotope Beams at Michigan State University (MSU), Argonne National Laboratory, Helmholtz-Zentrum Dresden-Rossendorf, and SLAC National Accelerator Laboratory. The cryomodule features a 185.7 MHz superconducting quarter-wave resonator (QWR) designed to operate with an RF electric field of 30 MV/m at the photo-cathode. Mechanical vibrations must be controlled for operation with stable amplitude and phase. The first prototype cryomodule was cold-tested at MSU with a QWR, fundamental power coupler, tuner, and cathode stalk. In the cold test, we observed microphonics that made it difficult to control the RF phase at high gradient. The cryogenic circuit was identified as a likely culprit. This paper presents our studies of microphonics during the cryomodule cold test and follow-up investigations at room temperature. Our findings provided valuable feedback for modifications to the cryogenic circuit and a successful second cold test of the cryomodule.

SUP22/TUP27

Assessment of magnetic quadrupole pick-up structure at FRIB

Carlos Sarabia-Cardenas, Peter Ostroumov, Steven Lidia (Facility for Rare Isotope Beams).

A magnetic quadrupole pick-up structure is being assessed for creation and future use at The Facility for Rare Isotope Beams (FRIB) at Michigan State University (MSU). The geometric design makes use of magnetic loops that couple with the radial magnetic field of a beam, allowing for rejection of the common mode of the beam, while leaving the dipole signal as the dominant signal and enhancing the quadruple signal of the beam. Of interest is examining the response due to the multiple charge state heavy ion beams that FRIB produces and the ability to resolve the differing charge states. Presented here is the optimization of the device for the FRIB beamline.

SUP24/WEC02

The beam dynamics case of Beam-Beam Wire Compensators for the HL-LHC era

Philippe Belanger (University of British Columbia & TRIUMF), Dobrin Kaltchev, Rick Baartman (TRIUMF), Guido Sterbini (European Organization for Nuclear Research).

Beam-beam long-range interactions are known to be a strong source of non-linearities in hadron colliders, undermining the performance of the LHC during proton-proton collisions. In order to enhance the luminosity production of the machine and increase the tolerance of the working point after the High Luminosity upgrade of the LHC (HL-LHC), dedicated correctors such as beam-beam wire compensators can be used. In this paper, the beam dynamics of this compensation problem is studied in details, ultimately showing that the linearity of the machine can be significantly improved throughout the beam core ---

and up to several sigmas --- leading to an improvement of the Dynamic Aperture (DA) of the machine. This conclusion is shown to be supported by analytic calculations, dynamic aperture simulation studies, as well as experimental results presented in earlier work. Both nominal and pacman bunches are shown to benefit from the compensation. In the proposed approach, wire compensators can be positioned according to the collimation settings, simplifying their practical implementation in the machine for the HL-LHC era.

SUP25/WEP19

Study of ponderomotive instability in the FRIB beta=0.53 half-wave resonator

Jacob Brown, Sang-Hoon Kim, Shen Zhao, Ting Xu, Wei Chang (Facility for Rare Isotope Beams).

Superconducting radio-frequency niobium cavities are susceptible to deformations caused by external or internal forces, leading to shifts in the cavity resonant frequency. One source of deformation comes from the radiation pressure of the cavity fields, producing the so-called Lorentz force detuning effect. This effect can couple to the cavity mechanical modes in generator driven mode, leading to ponderomotive instability. In the FRIB 322 MHz, β=0.53 Half-wave Resonators (HWR), the instability appeared when the cavity was detuned, with thresholds depending on low-level RF control parameters, such as closed loop gain, as well as accelerating gradient. Using a measured Lorentz Transfer Function, Simulink simulations were conducted to predict the instability thresholds, which were then compared with the experimental results. We will discuss how these thresholds can be broadened to enable stable operation at higher gradients.

SUP26/WEP05

Minimization of residual resistance with ultra-low background magnetic field in 644 MHz medium-velocity nitrogen-doped superconducting elliptical cavities for FRIB400

Sean Moskaitis, Peter Ostroumov, Sang-Hoon Kim, Yoo Lim Cheon (Facility for Rare Isotope Beams).

Advancements in superconducting cavity surface treatment have increased residual resistance sensitivity to the trapped magnetic flux primarily caused by background magnetic field. A fast cooldown was implemented in 1.3 GHz TESLA cavities to improve flux expulsion. The larger size of 644 MHz medium-velocity 5-cell elliptical cavities for the FRIB energy upgrade (FRIB400) introduces challenges in reaching cavity temperature gradients needed for effective flux expulsion during fast cooldown, which risks additional trapped magnetic flux due to thermoelectric currents. Therefore, we are investigating feasibility of a slow cooldown with minimal background magnetic field. To determine allowable background magnetic field, we measured the residual resistance sensitivity to trapped magnetic flux in a 1-cell nitrogen-doped (N-doped) FRIB400 R&D cavity. We also optimized a magnetic shield design to reach ultra-low (<1 mG) background magnetic field at cryogenic temperatures and measured its field attenuation. We will present the measured magnetic permeability of two materials at cryogenic temperatures and discuss their feasibility to meet operation requirements in future FRIB400 cryomodules.

SUP27/WEP24

Variable wedge for FRIB ARIS

Zhuoqun Wu, Marc Hausmann, Xing Rao (Facility for Rare Isotope Beams), Bradley Sherrill (Michigan State University).

At the Facility for Rare Isotope Beams (FRIB) Advanced Rare Isotope Separator (ARIS)*, wedges filter rare isotopes and produce beams of specified isotopes for experiments. Proper wedges (with the right thickness, angle, and density variation) efficiently collect and purify rare isotope beams by selectively slowing desired beams and contaminants via atomic interactions while maintaining achromaticity.

Currently, wedges are designed, fabricated, and swapped for each experiment based on LISE++ analysis. While effective, this process requires significant preparation time, and the single-wedge operation allows no adjustments for calculation, material, or fabrication errors.

To enhance ARIS, a variable wedge system is being developed. It consists of four degraders: two with quadratic cross sections forming an angle-tunable wedge** and two linear-shaped pieces adjusting thickness. By modifying their positions, the system achieves angle variation of 1–20 mrad and thickness variation of 0.5–20 mm.

This paper presents the system's principle, design, performance estimation, and simulation results, demonstrating improved efficiency, higher isotope yield, and reduced FRIB operation costs.

* M. Hausmann, A.M. Aaron, A.M. Amthor, et al., "Design of the Advanced Rare Isotope Separator ARIS at FRIB," Nucl. Instrum. Methods Phys. Res. B, Vol. 317, Part B, 2013, pp. 349-353, ISSN 0168-583X.
** J. Hwang, S. Michimasa, S. Ota, et al., "Angle-tunable wedge degrader for an energy-degrading RI beamline," PTEP 2019 (2019) 4, 043D02, DOI: 10.1093/ptep/ptz028.

SUP28/WEP06

Image mapping for multiple charge state beams using a beam induced fluorescence profile monitor

Aubrey Lokey (Facility for Rare Isotope Beams).

Work continues on a minimally invasive, nitrogen fluorescence gas sheet at the Facility for Rare Isotope Beams (FRIB). A low density gas sheet may be used to observe the 2D transverse beam profile of high intensity, multiple charge state beams with minimal interference. Spatially and temporally correlated profiles are of particular interest in locations where there is significant charge state spread, such as the FRIB linac folding segments. A low-density gas sheet measurement system offers advantages for gas handling in nitrogen sensitive areas, however signal intensity is significantly lower than techniques using higher density gas sheets and jets. This work discusses measurement considerations for photon distributions generated by several spatially separated interaction points and design considerations for a high-sensitivity optics system for handling the expected low signal intensity.

SUP30/WEB04
WEP12

Enhancing ALPI-PIAVE performance at INFN-LNL with advanced optimization algorithms

Ysabella Kassandra Ong, Andrea Pisent, Damiano Bortolato, Enrico Fagotti, Luca Bellan, Maurizio Montis, Michele Comunian (Istituto Nazionale di Fisica Nucleare).

The ALPI-PIAVE heavy-ion accelerator complex at INFN-LNL requires precise tuning to achieve optimal performance, particularly given its complex beam dynamics and high-dimensional parameter space. Although the facility is designed for 60% transmission, actual transmission rates are significantly lower, around 15–20%, highlighting the need for improved optimization strategies. In this work, we compare advanced optimization techniques, specifically Bayesian Optimization (BO) and Trust Region Bayesian Optimization (TuRBO), to enhance the efficiency, reliability, and adaptability of ALPI-PIAVE operations. Since Bayesian optimization algorithms are sensitive to accelerator parameter drifts, we integrated Particle Swarm Optimization (PSO) to improve robustness. Additionally, we conducted controlled instability tests to evaluate performance under dynamic conditions. The results of these experiments and their implications for real-time accelerator tuning are presented in this paper.

MOO - Opening
23 June 2025 09:10 - 09:30

/ 09:10

Opening Ceremony
Peter Ostroumov (Facility for Rare Isotope Beams).

/ 09:20

Welcome and introduction of FRIB
Thomas Glasmacher (Facility for Rare Isotope Beams).

MOX: Invited Talks
23 June 2025 09:30 - 10:30

MOX01 / 09:30

FRIB operations: first three years
Jie Wei, Adam Fila, Adam Powers, Alec Gonzalez, Alexander Dombos, Alexander Plastun, Alexandra Gade, Andreas Stolz, Andrei Ganshyn, Ben Arend, Brandon Ewert, Brandon Kortum, Bryan Tousignant, Caleb Alleman, Chinh Nguyen, Chris Compton, Cody Knowles, Daid Kahl, Dan Morris, Daniel Barofsky, Danlu Zhang, Devin Jager, Douglas McNanney, Duane Newhart, Eiichi Wakai, Elaine Kwan, Ethan Metzgar, Fabio Casagrande, Felix Marti, Frank Ferrell, Genevieve West, Georg Bollen, Geunhyeong Lee, Gregory Timko, Guillaume Machicoane, Haoyu Cheng, Hiroyuki Ao, Hsiao-Chaun Hseuh, Igor Nesterenko, Jeongseog Song, Jill Berryman, Jinyu Wan, John Curtin, John LeTourneau, John Priller, John Wenstrom, Junseong Kim, Junwei Guo, Kei Fukushima, Kelly Davidson, Kenji Saito, Kent Holland, Kyle Elliott, Laura Popielarski, Ling Wang, Marc Hausmann, Marc Reaume, Marco Cortesi, Martin Mugerian, Masanori Ikegami, Mathew Wright, Mauricio Portillo, Michael LaVere, Michael Larmann, Mohit Patil, Nathan Bultman, Nathan Joseph, Niranjan Kulkarni, Nusair Hasan, Pedro Nariyoshi, Peter Cole, Peter Manwiller, Peter Ostroumov, Qiang Zhao, Remco G.T. Zegers, Roben Walker, Ryoto Iwai, Salvatore Di Carlo, Samuel Miller, Sang-hoon Kim, Scott Cogan, Sergio Rodriguez Esparza, Shelly Jones, Shen Zhao, Shumpei Noji, Sierra Rogers, Steven Beher, Steven Lidia, Takuji Kanemura, Tanner Lange, Taro Konomi, Thomas Ginter, Thomas Glasmacher, Thomas Larter, Ting Xu, Tomofumi Maruta, Tong Zhang, Venkatarao Ganni, Walter Hartung, Wei Chang, Xiaoji Du, Xing Rao, Xiuli Wang, Yoonhyuck Choi, Yue Hao, ZhiYong Li (Facility for Rare Isotope Beams), Alberto Facco (Facility for Rare Isotope Beams; Istituto Nazionale di Fisica Nucleare, Laboratori Nazionali di Legnaro), Bradley Sherrill, Mallory Smith, Mathias Steiner, Oleg Tarasov (Michigan State University), Patrick Hurh (Fermi National Accelerator Laboratory), Robert Laxdal (TRIUMF; Facility for Rare Isotope Beams), Soren Prestemon, Tengming Shen (Lawrence Berkeley National Laboratory), Yoichi Momozaki (Facility for Rare Isotope Beams; Argonne National

Laboratory).

During the first three years since May 2022, FRIB has been operating safely meeting expectations of both scientific and industrial users with high machine availability, while ramping up the beam power to 20 kW for heavy ions including uranium. The paper summarizes the operational experience and challenges, accelerator improvement projects, expansions in user stations, accelerator R&D and workforce growth programs, and preparation for facility upgrades*.

*J. Wei et al., Technological developments and accelerator improvements for the FRIB beam power ramp-up, JINST, 19, T05011 (2024)

MOX02 / 10:00

GANIL, The French National Ion Accelerator: operation of today and the upcoming projects for the next 20 years

Hanna Franberg Delahaye (Grand Accélérateur Nat. d'Ions Lourds).

GANIL provides stable beam accelerator installations with the cyclotron facility and the SPIRAL2-LINAC facility, both coupled with access to production of radioactive ion beams in the various low and high-energy experimental areas.

The SPIRAL2SC-LINAC were initially designed for production of radioactive beams for experimental physics research. The project will complete the construction, adding several target stations, for production of fission fragments as well as Multi-Nucleon Transfer or fusion evaporation reactions. The on going project also study an additional electrondriver (40MeVelectrons) to avoid any bottleneck issues in stable beam availability.The exotic beams produced are then to be transported to any of GANIL's experimental areas,spanning from low energy areas (30-60keV)to high energies areas (5-10MeV/u)or (50-70MeV/u)by the addition of a new postaccelerator.GANIL will then offer a complete range of stable and exotic beams for the different research opportunities in a large variety of intensity and energies to communities for fundamental research as well as applied and industrial research.

MOY: Invited Talks

23 June 2025 10:50 - 11:50

MOY01 / 10:50

Progress and status of high intensity heavy ion accelerator facility (HIAF) in China

Jiancheng Yang , Liangting Sun (Institute of Modern Physics, Chinese Academy of Sciences).

HIAF (High Intensity heavy ion Accelerator Facility) is a new large-scale facility for nuclear physics research in China. HIAF consists of a superconducting linac, a high-energy synchrotron booster, a high-energy radioactive isotope beam line, an experimental storage ring, and a few experimental setups. Able to produce unprecedented intense ion beams from hydrogen to uranium, HIAF will also promote heavy-ion applications in medicine, life science, space science, and material science. The HIAF project began in Dec 2018 and is proceeding on schedule. After extensive R&D work in the past several years, we achieved a

major breakthrough in fast cycle acceleration through innovative technologies. Civil engineering and infrastructure were completed in Jun 2024, and most of the mass production and fabrication have been completed. We are currently installing equipment in phases. The ion source SECR will provide first beam in Aug 2024. The low energy CW ion beam of iLinac and the high energy pulsed ion beam from BRing are expected at the end of 2024. The Day One Experiment in SRing will be at the end of 2025. The progress and present status of the project will be given in the presentation.

MOY02 / 11:20

Operation status of the RAON facility

Hyung Jin Kim, Yeonsei Chung (Institute for Basic Science).

The RAON (Rare isotope Accelerator complex for ON-Line experiments) is a rare isotope accelerator facility in Korea focused on fundamental science research by generating and accelerating RIBs (Rare Isotope Beams). Recently, a low-energy linear accelerator, comprising an injector system and a superconducting linear accelerator, was successfully commissioned. Additionally, RIBs produced by the ISOL (Isotope Separator On-Line) system were successfully reaccelerated using this low-energy linear accelerator. This presentation will provide an update on the operation status of the RAON facility, including the beam commissioning results of the low-energy linac.

MOB: Contributed Talks

23 June 2025 11:50 - 12:30

MOB01 / 11:50

First RIB production with SPES Exotic Beam Facility at INFN-LNL

Alberto Andrighetto, Alberto Monetti, Alessio Galatà, Andrea Pisent, Antonio Palmieri, Carlo Baltador, Carlo Roncolato, Carmelo Sebastiano Gallo, Damiano Bortolato, Daniela Benini, Daniele Scarpa, Dimitris Zafiropoulos, Enrico Fagotti, Francesco Grespan, Giorgio Keppel, Giovanni Bisoffi, Juan Esposito, Lisa Centofante, Loris Antoniazzi, Luca Bellan, Luca de Ruvo, Luigi Ferrari, M. Francesca Moisio, Marco Miglioranza, Maria Luisa Allegrini, Mario Maggiore, Massimo Rossignoli, Mattia Manzolaro, Maurizio Montis, Michele Ballan, Michele Comunian, Paolo Modanese, Piergiorgio Antonini, Stefano Corradetti, Tommaso Marchi, Ysabella Kassandra Ong (Istituto Nazionale di Fisica Nucleare), Giordano Lilli (Istituto Nazionale di Fisica Nucleare, Laboratori Nazionali di Legnaro).

SPES (Selective Production of Exotic Species) is the INFN facility for the production and post-acceleration of exotic nuclei for forefront research in nuclear physics and for the production of radioisotopes for medical applications. The primary proton beam, extracted by a commercial cyclotron, irradiates targets like SiC, TiC or UCx where the ISOL technique is used to produce and extract exotic nuclei. Those are ionized, selected and either transported to low energy experiments or cooled with an RFQ cooler, purified from isobars contaminants through a High-Resolution Mass Separator, sent to a charge breeder to increase charge state, injected into a RFQ accelerator and accelerated into ALPI superconducting Linac to finally reach the experimental stations. The primary beamline

have been fully commissioned and the first radioactive beams have been produced and transported to low energy experiments while the re-accelerator is under installation. A description of the entire facility as well as its commissioning status is given.

MOB03/12:10
MOP11

Design and fabrication of FRIB normal conducting cavities

Xing Rao, Alexander Plastun, Nathan Bultman, Peter Ostroumov, Samuel Miller (Facility for Rare Isotope Beams).

The FRIB (Facility for Rare Isotope Beams) CW linac is based on 326 superconducting cavities, a normal conducting RFQ, and eight normal conducting bunching cavities. Five unique designs were developed for a 40.25-MHz Multi-Harmonic buncher (MHB), 80.5-MHz quarter-wave cavity MEBT bunchers, 161-MHz H-type cavity bunchers, 322-MHz H-type bunchers, and a quarter-wave 161-MHz buncher for a ReAccelerator.

The cavities are made of high-purity copper using high-temperature furnace brazing. They are equipped with motorized tuners for real-time frequency control. An efficient water cooling is provided for CW operation. We have developed and applied a multi-step brazing technique to achieve high dimensional accuracy, reliable RF contacts, and accommodate large stainless steel-to-copper joints.

The paper will cover the main parameters for each type of bunchers, their design/fabrication, cooling design, RF contact design/effectiveness, tuning process, brazing design and fabrication challenges, coupler design, copper-to-stainless steel transitions, etc. The operation status of these bunchers will also be discussed.

MOB02/withdrawn

Re-accelerated and in-flight radioactive ion beams at the TAMU Cyclotron Institute

Brian Roeder (Texas A&M University Cyclotron Institute), Fred Abegglen, Gabriel Tabacaru, George Kim (Texas A&M University), Sherry Yennello (Texas A&M University Cyclotron Institute).

In-flight radioactive ion beams with Mass A<60 have been available for over 30 years at the Cyclotron Institute at Texas A&M University. Recently, stopped and re-accelerated radioactive ion beams are becoming available. The re-accelerated beams are produced, stopped and extracted with the IGISOL technique, and then transported with an ion guide to a charge-breeding ECR source. Once the ions are charge-bred, the highly charged ions are re-accelerated with the TAMU K500 cyclotron with energies up to 20 MeV/u. So far, beams of 112In, 105Cd, 105In, 89Nb and 89Zr have been produced.

Results from the beam development experiments for the re-accelerated radioactive ions beams at TAMU will be presented, with details about how the beams are produced, re-accelerated and identified after acceleration. Future prospects for lighter mass radioactive ion beams and possible upgrades to our in-flight radioactive ion beam facilities will also be discussed.

MOZ: Invited Talks
23 June 2025 14:00 - 15:00

MOZ01 / 14:00

nuCARIBU commissioning and initial operation

Clayton Dickerson, Daniel Santiago-Gonzalez, Guy Savard, Jake McLain, Richard Vondrasek (Argonne National Laboratory), David Du, Vasile Sabaiduc, Vladimir Ryjkov (Best Cyclotron Systems Inc.).

nuCARIBU will fundamentally change the way neutron-rich, heavy (A>100) radioactive ion beams (RIB) are created at ATLAS. Protons from a 6 MeV, 0.5 mA cyclotron will bombard a 7Li target to generate neutrons via the p-7Li reaction. These neutrons will be thermalized in a moderator and then captured in an actinide foil, e.g. 235U. Heavy fission fragments resulting from the neutron capture reactions will be formed into ion beams in an existing gas catcher and separator system. This new production mechanism will replace the current source of radioactive ions, a thin plating of spontaneously fissioning 252Cf. nuCARIBU is expected to increase the overall intensity of n-rich ions, and improve the consistency and reliability of RIB at ATLAS. The cyclotron has demonstrated full beam production, and the results of initial proton extraction tests agree well with simulations. This paper will present the results of the cyclotron commissioning, neutron production, and initial radioactive beam production.

MOZ02 / 14:20

RIBs production at IJCLab

Enrique Minaya Ramirez (Université Paris-Saclay, CNRS/IN2P3, IJCLab).

Description of process, specifications, neutron-rich radionuclides production, RILIS (Ga, Ag, etc.), perspectives, experimental set-ups of the facility (RIALTO). Option: news of ISOL-France community.

MOZ03 / 14:40

High power targetry devices at FRIB: challenges, status and plan

Takuji Kanemura (Facility for Rare Isotope Beams).

High-intensity heavy-ion accelerators have unique challenges in beam intercepting devices that originate from extremely high energy loss per distance traveled by heavy ions traversing materials. These challenges often prohibit such accelerators from achieving higher beam power and thus determine the accelerator performance. In this paper, challenges in the operation and development of beam intercepting devices (strippers, charge selection systems, high-power fragmentation targets, and beam dumps) at FRIB, and status and plan of those devices are discussed.

MOC: Contributed Talks
23 June 2025 15:00 - 16:00

MOC01 / 15:00

Commissioning of the S3 Spectrometer : advances, challenges and outlook

Marc-Hervé Stodel (Grand Accélérateur Nat. d'Ions Lourds), Antoine Drouart, Martial Authier (Commissariat à l'Energie Atomique), Bertrand Jacquot, Christelle Stodel, Franck Esnault, Hervé Savajols, Muhammad Aburas, Romuald Levallois, Thierry Lefrou (Grand Accélérateur Nat. d'Ions Lourds), Franck Lutton, Gilles Olivier (Université Paris-Saclay, CNRS/IN2P3, IJCLab).

The linear accelerator of the SPIRAL2 facility at GANIL delivers both light ions to study nuclear reactions with neutrons in the Neutron for Science (NFS) experimental hall, and heavier ions to produce exotic nuclei, like heavy and super heavy nuclei, in the Super Separator Spectrometer (S3).

By combining electromagnetic components and thanks to their very large aperture, S3 is a powerful tool to purify most of the elements of interest produced in the target from the primary intense ion beam, and retrieving them up to the focal plane to analyse them.

The search for very rare events in nuclear reactions requires advanced technics that are not standard in our laboratories, which in S3 are fulfilled by the 7 iron-free superconducting multipoles triplets, the large gap of the electric dipole, the high performance movable beam dump and the fully instrumented target station.

This presentation will introduce the advanced beam optic scheme, cover the current challenges encountered in qualifying the S3 spectrometer's main components, and more generally give an overview of the on-going commissioning of this new scientific facility at GANIL.

MOC02 / 15:20

Design considerations for a proton linac for a compact accelerator based neutron source for Canada

Mina Abbaslou, Robert Laxdal, Marco Marchetto, Philipp Kolb, Tobias Junginger, Oliver Kester (TRIUMF), Drew Marquardt (University of Windsor).

A prototype Canadian compact accelerator-driven neutron source (PC-CANS) is proposed for installation at the University of Windsor. The source will utilize a high-intensity compact proton RF linear accelerator, delivering a peak current of 20 mA with a 5% duty factor of protons at 10 MeV to the target. The accelerator comprises a short radio-frequency quadrupole (RFQ) to 3 MeV, followed by a drift tube Linac (DTL) structure accelerating to 10 MeV. Various room temperature DTL variants, including Alvarez, and H-mode variants using APF, KONUS, and standard beam dynamics are considered at a frequency of 352.2 MHz, in addition to a superconducting HWR variant at 176.1 MHz.

This paper compares the beam dynamics of the various structures including RFQ variants at the two frequencies. Comparisons include beam transmission, longitudinal and transverse emittance growth, Linac length, RF power and longitudinal and transverse phase acceptance.

Beam dynamics simulations were conducted using the PARMTEQ, LANA, PARMILA, and Trace-3D codes.

This work contributes to the development of high power proton Linacs by providing a comparison in performance over several Linac structures.

MOC03 / 15:40

A second fast tape station for CERN-ISOLDE

Isabel Frank, Line Le, Mia Au, Sebastian Rothe, Simon Stegemann (European Organization for Nuclear Research).

CERN-ISOLDE is a research facility for the production of radioactive ion beams, delivering more than 1000 isotopes of over 74 elements for experiments in a wide range of research fields. Radioactive nuclei are generated by proton-induced reactions in a target and ion source unit, then ionized and extracted as radioactive ion beams. For the qualitative and quantitative analysis of the beams as well as for target development a fast tape station (FTS) is used for decay spectroscopy of short-lived isotopes. Since the FTS is located in the central beam line, it is not possible for users to use the beam during these measurements, thus being competitive to the experiments. To fulfill the high demand for new beams, higher beam purity and intensity, and more resistant targets, beam and target development is necessary. To facilitate simultaneous operation and development, a second and improved FTS in currently being commissioned. Installed in a dedicated beam line, it will be connected directly to one target station, enabling beam and target development without affecting operation in the central beam line and allowing beam delivery to experiments scheduled at the other target station.

MOP: Monday Poster Session

23 June 2025 16:20 - 18:00

MOP01 / SUP01

Computation model for space charge effect for bunched beam in collider rings

Helena Alamprese, Yue Hao (Facility for Rare Isotope Beams).

In the last two decades, numerical and experimental studies have extensively explored the impact of the space charge on bunched beams in both linear accelerators and storage rings. However, fully accounting for space charge effects over the entire accelerator is computationally intensive, especially in storage rings, where simulations must track beam dynamics over many turns and extended time periods. In many cases, space charge forces cannot be neglected, motivating the development of an alternative computational model. Here, we explore the space charge induced nonlinear dynamics using a model that approximates the Coulomb force by concentrating its effects at discrete locations along the accelerator. This approach enables efficient analyses of the full six-dimensional phase space evolution under space charge effects. Future work will apply this model to further investigate the interplay between space charge and beam-beam interactions in colliders, as well as to assess long-term stability criteria in ring accelerators.

MOP02/SUP17

Simulation of improved injection kicker waveforms in the SNS accumulator ring

Luis Garabito Ruiz (Facility for Rare Isotope Beams), Austin Hoover, Nicholas Evans (Oak Ridge National Laboratory), Steven Lund (Facility for Rare Isotope Beams).

Recent empirical tuning of the Spallation Neutron Source injection system has produced new injection kicker settings, new time-varying waveforms for each of the eight injection magnets forming a closed four-bump in each plane, for the proton accumulator ring. These new settings deliver beam parameters consistent with target requirements for beam size and peak density, and identical RMS beam sizes at upstream diagnostics. However, beam halo has been reduced from previous settings providing the same RMS size, as evidenced by a significant temperature reduction on halo-monitoring thermocouples surrounding the proton beam window that separates the accelerator vacuum from the helium-filled target environment. In this work we use PyORBIT, a PIC code developed at Oak Ridge National Laboratory, to simulate the injection process for the previous settings, and the newly identified working point to gain insight into the likely source of the halo reduction and investigate further improvements to injection tuning.

MOP03/SUP03

Ion beam techniques for analysis the materials using 1.7 MV tandem accelerator

Gajigatte Umapathy, Dinakar Kanjilal, Sundeep Chopra, Sunil Ojha (Inter-University Accelerator Centre).

The 1.7 MV (5SDH-2) tandem accelerator at the Inter-University Accelerator Centre (IUAC) has been playing a major role in advancing research activities in materials science and nuclear physics experiments using various advanced ionbeam characterization techniques. In this work, I present the IBA technique studies such as (a) RBS Analysis of Au and Au/Ag Thin Films for investigating the effects of low energy ion irradiation (8 keV Ni, 10 keV Ar, and 400 keV Ar) for applications in Surface-Enhanced Raman Scattering (SERS) and other technological applications, (b) RBS of Nat/28Si on Au Backing For in-beam γ-ray spectroscopy experiments for detailed compositional analysis and target integrity, (c) Depth Profiling in 4H-SiC by utilizing RBS Channeling to assess disorder and strain induced by Si ion implantation and its recovery post-thermal annealing (d) Hydrogen Detection in α-Fe2O3 Analysis by ERDA techniques to study the reversible hydrogen control of and ferromagnetic anisotropy, highlighting the material's potential for novel magnetic storage technologies, will be discussed.

MOP04/SUP04

Monte Carlo simulation analysis for radiation damage on Glidcop Al-15 caused by 17-20 MeV/u heavy ions in FRIB

Ethan Fletcher, Alexander Plastun, Steven Lidia, Takuji Kanemura (Facility for Rare Isotope Beams), Eiichi Wakai (High Energy Accelerator Research Organization), Patrick Hurh (Fermi National Accelerator Laboratory).

The Facility for Rare Isotope Beams (FRIB) SRF linear heavy-ion accelerator is designed to accelerate all ions up to uranium to a maximum beam power of 400 kW. Several beam

intercepting devices (BIDs) are essential to the successful operation of the accelerator, including a low power charge selector (LPCS) made of copper containing 0.15% precipitated aluminum oxide by weight called Glidcop Al-15. As FRIB ramps up the primary beam power beyond the current 20 kW level, the charge selector must withstand higher radiation damage rates, typically measured in displacements per atom (dpa). Significant beam induced radiation damage including significant deformation, like swelling, blistering, and cracking has been observed on a recently removed LPCS. We also observed physical features up to about 5.5 mm wide and appear to be deeper than the projected range of any ions. This paper presents the results of Monte Carlo simulations carried out using the Particle and Heavy Ion Transport code System (PHITS), quantifying the total damage dose and ion concentration, etc. Simulating an accurate irradiation history is essential to determining the scope of post irradiation examination (PIE) work.

MOP05

Thermal-hydraulic analysis of a 20kW beam power water-cooled mini-channel beam dump at Facility for Rare Isotope Beam

Raul Quispe-Abad, Jeongseog Song, Marc Reaume, Mohit Patil, Nathan Bultman, Samuel Miller, Takuji Kanemura (Facility for Rare Isotope Beams).

The Facility for Rare Isotope Beams (FRIB) is a high-power heavy-ion accelerator, completed in April 2022, designed to accelerate heavy ions to energies exceeding 200 MeV per nucleon (MeV/u). These ions collide with a rotating graphite target, while the residual beam is absorbed by a water-cooled static beam dump positioned at a 6-degree angle to the beam path. The current beam dump consists of a machined C18150 copper alloy block, explosion-bonded to AL2219 alloy with precision-machined cooling grooves. Cooling water is supplied through 3D-printed Aluminum 6061 inlet and outlet components, facilitating heat dissipation from the beam stopper. This paper examines the thermal-hydraulic performance of the Mini-Channel Beam Dump (MCBD) under both nominal and off-nominal conditions. The MCBD is designed to handle operational beam power up to 20 kW, with planned optimizations to support a power ramp-up to 30 kW.

MOP06

From design to beam delivery: a 200 MHz linear injector for heavy-ion cancer therapy

Chaopeng Wang (Lanzhou Ion Therapy Co., Ltd.), Jian Shi, Wenjie Yang (Institute of Modern Physics, Chinese Academy of Sciences).

This paper presents the design and performance of a linear injector for heavy-ion cancer therapy,utilizing 200 MHz radio frequency quadrupole (RFQ) accelerator combined with two alternating phase focusing (APF) structures.This simplifies the accelerator structure, enhances beam quality,and ensures high acceleration gradients,making it a pivotal advancement in compact and cost-effective heavy-ion therapy systems.The proposed configuration aims to deliver high-intensity ion beams with enhanced energy efficiency for clinical applications.The system achieves a remarkable output max beam current of 0.2 mA with energy of 7 MeV/u to the downstream synchro-tron for precision cancer therapy.And now the design and fabrication to beam commissioning has been completed, with

experimental results confirming that the system meets all predefined specifications.Beam tuning results demonstrate that the injector reliably delivers beams meeting the target specifications a peak current of 0.2 mA and energy of 7 MeV/u.These achievements validate the technical robustness of the proposed configuration and mark a pivotal advancement in the deployment of heavy-ion accelerators for clinical cancer treatment

MOP07/SUP20

Control of microphonics for a superconducting radio-frequency photo-injector cryomodule

Kaela Villafania, Jacob Brown, Sang-Hoon Kim, Ting Xu, Wei Chang (Facility for Rare Isotope Beams).

A superconducting radio-frequency photo-injector cryomodule is being developed for the high-energy upgrade of the Linac Coherent Light Source (LCLS-II-HE). This effort is a collaboration between the Facility for Rare Isotope Beams at Michigan State University (MSU), Argonne National Laboratory, Helmholtz-Zentrum Dresden-Rossendorf, and SLAC National Accelerator Laboratory. The cryomodule features a 185.7 MHz superconducting quarter-wave resonator (QWR) designed to operate with an RF electric field of 30 MV/m at the photo-cathode. Mechanical vibrations must be controlled for operation with stable amplitude and phase. The first prototype cryomodule was cold-tested at MSU with a QWR, fundamental power coupler, tuner, and cathode stalk. In the cold test, we observed microphonics that made it difficult to control the RF phase at high gradient. The cryogenic circuit was identified as a likely culprit. This paper presents our studies of microphonics during the cryomodule cold test and follow-up investigations at room temperature. Our findings provided valuable feedback for modifications to the cryogenic circuit and a successful second cold test of the cryomodule.

MOP08

Thermal analysis of the FRIB400 energy upgrade cavity fundamental power coupler

Blake Gower, Sang-Hoon Kim, Ting Xu (Facility for Rare Isotope Beams).

The Facility for Rare Isotope Beams (FRIB) energy upgrade to 400 MeV/u or higher will be accomplished with the addition of 11 cryomodules containing beta = 0.65 elliptical cavities to the FRIB linear accelerator (linac). The fundamental power coupler (FPC) is a continuous wave (CW) coaxial design delivering 15 kW of forward power at 644 MHz with an accelerating gradient of 17.5 MV/m and an external Q range of 7.7e6 to 3.4e7 corresponding to a 5 mm bellows stroke in either direction from its neutral position. The FPC design includes both warm and cold radiofrequency (RF) windows. The cold RF window is encompassed by a cooling jacket supplied with helium at 55 K. This provides conductive cooling to the central antenna from the outer conductor, across the ceramic portion, to the inner conductor, with the aim of minimizing heat input to the liquid helium at 2 K surrounding the superconducting niobium cavity. A coupled self-consistent RF-thermal analysis of the FPC operating with FRIB parameters and materials is presented here.

MOP09

Minimally-invasive real-time beam current approximation for light ion beams using existing beam profile monitors in ATLAS

David Novak, Clayton Dickerson, Daniel Stanton, Jake McLain, Kenneth Bunnell (Argonne National Laboratory), Daniel Santiago-Gonzalez (Louisiana State University).

Since its beginning ATLAS has had both Faraday Cups to measure beam current, and Beam Profile Monitors (BPM) to trace the beam profile. However only the Faraday Cups are used to perform objective beam measurements during tuning and delivery, because cups block the beam during measurements. ATLAS has approximately 41 BPMs which utilize a helically wound wire that continuously sweeps the Y and X profile but does not block beam. The output of these BPMs is sent through a series of multiplexers to an oscilloscope in the control room where operators can see the Y-X sweeps in real-time, as well as capture the waveform on-demand. To make the BPMs more useful for everyday beamline operations, a tighter coupling of the BPMs to the control system is required. The first step is to continuously capture the BPM signal by the control system. Once continuous capture is implemented, software tools to store, analyze, and display key metrics from the BPMs are required to make use of the data. The system would primarily be used as a minimally-invasive approximation of continuous real-time beam current monitor, capable of measuring light ions.

MOP10

Testing of high-capacity Sumitomo cryocooler

Paul Davis, Gary Zinkann, Michael Kelly (Argonne National Laboratory).

Commercially available cryocoolers typically provide about 2 Watts of cooling at 4.5 K. The ANL Physics Division accelerator group has been testing a new two stage Gifford-McMahon/Joule-Thomson (GM-JT) cryocooler from Sumitomo Heavy Industries. In tests at both RadiaBeam and Argonne the measured cooling capacity is approximately 9.5 Watts at 4.5 K. The cryocooler has also been used to condense helium at approximately 4.3 K at a rate of about 0.4 L/hr into a small helium container. We report here on the experimental hardware used to perform these measurements and discuss the data. The device appears to be an excellent complement to new low-loss Nb3Sn cavities under development at ANL and elsewhere. We comment on this application and the outlook for future uses of the device in ATLAS and elsewhere.

MOP11/MOB03

Design and fabrication of FRIB normal conducting cavities

Xing Rao, Alexander Plastun, Nathan Bultman, Peter Ostroumov, Samuel Miller (Facility for Rare Isotope Beams).

The FRIB (Facility for Rare Isotope Beams) CW linac is based on 326 superconducting cavities, a normal conducting RFQ, and eight normal conducting bunching cavities. Five unique designs were developed for a 40.25-MHz Multi-Harmonic buncher (MHB), 80.5-MHz quarter-wave cavity MEBT bunchers, 161-MHz H-type cavity bunchers, 322-MHz H-type bunchers, and a quarter-wave 161-MHz buncher for a ReAccelerator.

The cavities are made of high-purity copper using high-temperature furnace brazing. They are equipped with motorized tuners for real-time frequency control. An efficient water cooling is provided for CW operation. We have developed and applied a multi-step brazing technique to achieve high dimensional accuracy, reliable RF contacts, and accommodate large stainless steel-to-copper joints.

The paper will cover the main parameters for each type of bunchers, their design/fabrication, cooling design, RF contact design/effectiveness, tuning process, brazing design and fabrication challenges, coupler design, copper-to-stainless steel transitions, etc. The operation status of these bunchers will also be discussed.

MOP12

Modularized SiC MOSFET-based accelerator-grade pulsed power supply design

Tianrun Yang (Institute of Modern Physics, Chinese Academy of Sciences).

This paper proposes a modular all-SiC design for accelerator pulsed power systems. A unipolar frequency-doubled hybrid SPWM modulation strategy is developed for the front-end PWM rectifier, eliminating zero-crossing distortion (verified by Fourier analysis) and achieving 2.8% THD. A hybrid analog-digital control architecture combines analog control (front-stage rectification and phase-shifted full-bridge) for dynamic response with digital H-bridge control for algorithm flexibility. The comprehensive soft-switching scheme integrates: 1) front-stage resistor-relay coordination, 2) intermediate-stage LC-resonant ZVS, and 3) digital ramp-controlled commutation. An optimized SiC MOSFET driver circuit with active clamping and RC snubber suppresses voltage spikes by 43% while balancing switching dynamics. This multi-level integration enhances modularity through component consolidation and thermal optimization, achieving 96.2% peak efficiency and 30% power density improvement. The design establishes a technical foundation for high-repetition-frequency, high-power applications.

MOP13/SUP18

Beam dynamics design for alternating phase focusing proton linac for a compact accelerator based neutron source

Mina Abbaslou, Robert Laxdal, Marco Marchetto, Philipp Kolb, Tobias Junginger, Oliver Kester (TRIUMF), Drew Marquardt (University of Windsor).

A prototype Canadian compact accelerator-driven neutron source (PC-CANS) is proposed for installation at the University of Windsor. The source is based on a high-intensity compact proton RF accelerator that delivers an average current of 10 mA of protons at 10 MeV to the target. The accelerator consists of a short radio frequency quadrupole (RFQ), followed by an efficient drift tube Linac (DTL) structure. Different variants of DTL were investigated for our studies including the Alvarez TM010 structure and various H-mode structures using both negative synchronous phase and KONUS beam dynamics all at 352.2MHz. For completeness an alternate phase focusing (APF) design was also included in the study. Details of the beam dynamics of a high intensity proton APF Linac are presented in this paper.

MOP14

Mechanical vibration study of low-energy superconducting linear accelerator (SCL3) in RAON

Myung Ook Hyun, Hyojae Jang, Jaehee Shin, Oh Ryong Choi, Youngkwon Kim (Institute for Basic Science).

Recently, the Institute for Rare Isotope Science (IRIS, previously RISP) in the Institute for Basic Science (IBS), Daejeon, South Korea, finished the first beam commissioning for operating of low-energy superconducting linear accelerator (SCL3). SCL3 is composed of two types of cavity, quarter wave resonator (QWR) which has 81.25MHz RF frequency and half wave resonator (HWR) which has 162.5MHz RF frequency. During operation, RF control was very complicated due to many issues including mechanical vibrations coming from vacuum pump, cryogenic valve, or undefined source. In this paper, we will discuss the SCL3 mechanical vibration data measured by a laser doppler vibrometer (LDV). In addition, the mechanical vibration of SCL3 cryogenic components such as transfer lines and supports will be also described.

MOP16/SUP05

Developing a next-generation MR-ToF device for the Facility for Rare Isotope Beams

Christian Ireland, Franziska Maria Maier, Ryan Ringle (Facility for Rare Isotope Beams), Erich Leistenschneider (University of British Columbia & TRIUMF).

Multi-reflection time-of-flight (MR-ToF) devices have arisen as indispensable tools at radioactive ion beam (RIB) facilities. These electrostatic ion beam traps act as highly-selective mass separators providing purified ion beams to subsequent experiments as well as high-precision mass spectrometers enabling mass measurements of short-lived nuclei. Efforts are ongoing to push the limits of these devices, enabling higher resolving power and/or ion throughput. State-of-the-art devices operate with a few keV of beam energy, however simulations detail the need to pursue higher energies [*]. To this end, a high-voltage MR-ToF device has been designed for the Facility for Rare Isotope Beams (FRIB) enabling both high mass resolving power and high ion throughput. Such a device will enable precision mass measurements of short-lived ions as well as the delivery of pure high-intensity beams to subsequent experiments in the stopped and reaccelerated beam areas at FRIB.

[*] F. M. Maier et al., NIMA 1056, 168545 (2023)

MOP17

Energization, mapping, alignment of a 28 GHz superconducting ECR magnet

Xiaoji Du, Danlu Zhang, Hai Nguyen, Hengkang Zheng, John Wenstrom, Junseong Kim, Junwei Guo, Ting Xu, Yamen Al-Mahmoud, Yoonhyuck Choi (Facility for Rare Isotope Beams), Diego Arbelaez, Soren Prestemon, Tengming Shen, Yang Ye (Lawrence Berkeley National Laboratory), Guillaume Machicoane (Michigan State University).

To meet the beam power requirements of 400 KW for heavy ions at the Facility for Rare Isotope Beams (FRIB), the Electron Cyclotron Resonance (ECR) Ion Source needs to operate at a full 28 GHz radio frequency. The ECR magnet is required to generate a corresponding

stable high magnetic field, which is a superposition of the solenoid field and the radial sextupole field. A precise alignment between the magnet and the plasma chamber is required to reduce the differences in the six weak field positions on the chamber wall, thereby reducing local overheating. In this study, a 3D magnetic model was developed to analyze the electromagnetic (EM) performance of the magnet. This paper also introduced a tailored mapper designed to scan the 3D field map of the magnet. From the high harmonic analysis results, the misalignment between the magnetic center and the beamline was calculated, and the subsequent position adjustment was made with the support link control. The azimuthal angle and axial position of the six weak field were estimated at various operating scenarios, providing guidance to improve the design of the plasma chamber for high-power ECR beam operation.

MOP18/SUP06

Extending JuTrack's capabilities to the FRIB accelerator to enhance online modeling
Christian Ratcliff, Jinyu Wan, Kei Fukushima, Yue Hao (Facility for Rare Isotope Beams).

JuTrack is a Julia-based accelerator modeling and tracking package that utilizes compiler-level automatic differentiation (AD) to enable fast and accurate derivative calculations. While JuTrack provides a solid foundation for beam dynamics simulations, its capabilities must be extended to support the Facility for Rare Isotopes (FRIB) linac. This includes modeling heavy-ion linac accelerator components such as the liquid-lithium charge stripper, which facilitates efficient acceleration by remove electrons from heavy isotopes, and incorporating multi-charge state acceleration tracking, which allows for charge-dependent beam dynamics. These extensions address challenges such as the beam matching and optimization of multi charge state through various accelerating structures and beam-material interaction modeling while maintaining the auto differentiation capability. This work focuses on adapting JuTrack to incorporate these elements, enhancing its online modeling abilities. We present modifications to JuTrack's framework and demonstrate their performance in FRIB simulations.

MOP19

Budget-friendly defense against radiation-induced camera damage
Evan Daykin, Douglas McNanney, Steven Lidia (Facility for Rare Isotope Beams).

Cameras observing scintillating viewers provide a valuable tool for tuning heavy ion beams. The close placement of these cameras near intense stray neutron and ion radiation, particularly at elements intercepting the primary beam, presents a unique reliability challenge. Commercial solutions are sparse, expensive, and sometimes tightly regulated. We present common failure modes observed at FRIB and propose solutions to extend the lifespan of unspecialized industrial cameras using consumer-grade hardware and open-source software.

MOP21

Physics applications in support of FRIB beam tuning and operations

Tong Zhang, Alexander Plastun, Kei Fukushima, Kilean Hwang, Peter Ostroumov, Tomofumi Maruta (Facility for Rare Isotope Beams), Qiang Zhao (Michigan State University).

Physics application software plays a crucial role in the tuning and operation of the FRIB accelerator. Development began long before the initial commissioning, and with real beam operations, numerous new applications have been created and refined through collaboration between engineers and physicists. These efforts have significantly enhanced beam tuning efficiency and delivery for experiments. This paper provides an overview of the current state of software development, highlights key applications, and outlines the roadmap for future advancements.

MOP22

Emittance calculation automation via "Pepper Pot" image processing

Alexander Grabenhofer (Argonne National Laboratory).

An approach to ion beam emittance calculation using code to automate the calibration, capture, and processing of beam images from the ATLAS Pepper Pot system. System calibration and emittance calculations are performed using code designed to minimize user interaction (single button operation) and maximize accuracy by clean processing (noise filtering and automated adaptable beam spot recognition).

MOP27/SUP08

Physical design and optimization of an E × B chopper based on permanent magnets

Duanyang Jia, Weilong Chen, Yuan He, Zhijun Wang (Institute of Modern Physics, Chinese Academy of Sciences).

Chopper systems are typically used to provide beam time structure and ensure the safety of accelerator operations by deflecting the beam away. To meet the strict beam stopping time requirements of the China Initiative Accelerator Driven System (CiADS), an E × B chopper design has been developed based on a permanent magnet and an electrostatic deflection plate. In this paper, the physical design of the chopper system is detailed, and each component of the chopper is optimized through simulation analysis. Finally, the feasibility of the chopper system is validated through multi-particle simulations and error analysis.

MOP28

Rare-Isotope production with the ARIS separator system at FRIB

Mallory Smith, Bradley Sherrill, Elaine Kwan, Mathias Steiner, Mauricio Portillo, Oleg Tarasov (Michigan State University), Alexander Dombos, Daid Kahl, Holly Matthews, Isaiah Richardson, Kei Fukushima, Marc Hausmann, Marco Cortesi, Scott Cogan, Steven Lidia (Facility for Rare Isotope Beams), Salvatore Di Carlo (European Organization for Nuclear Research).

The Facility for Rare Isotope Beams signifies a major advancement in rare isotope beams for research. Delivering heavy and exotic rare isotope beams is accomplished with the Advanced Rare Isotope Separator (ARIS), which creates, purifies and transports radioactive beams. These secondary beams can range from hydrogen to uranium. Every RIB is carefully planned, produced and characterized by ARIS's system of diagnostics, detectors and data acquisition (DAQ). ARIS detectors can measure the time of flight, energy loss, charge, gamma-rays and position of the species in the beam, allowing the identity, rate, purity, energy and emittance of each rare isotope to be accurately quantified. The needs of each experiment drive the requirement for tuning, to achieve the desired RIB properties for diverse experiments. In this presentation, the current ARIS system of scintillators, PPACs (parallel plate avalanche counters), silicon and gamma-ray detectors, and associated DAQ will be discussed. Furthermore, the ARIS detector system will undergo upgrades to support the main LINAC upgrades from the current 20kW, and these upcoming challenges and changes to detectors and DAQ will be included as well.

MOP29

Updated magnetic rigidity calibration of ARIS

Alexander Dombos (Facility for Rare Isotope Beams), Bradley Sherrill, Mallory Smith, Mathias Steiner, Oleg Tarasov (Michigan State University), Daid Kahl, Elaine Kwan, Kei Fukushima, Marc Hausmann, Mauricio Portillo (Facility for Rare Isotope Beams).

The Facility for Rare Isotopes Beams (FRIB) enables groundbreaking research in nuclear physics, astrophysics, and fundamental interactions, as well as the societal applications of this work. Critical to the science program at FRIB is the Advanced Rare Isotope Separator (ARIS), which separates, identifies, and purifies fragments produced via projectile fragmentation and fission using a variety of beamline elements, including eight superconducting dipole magnets. An accurate magnetic rigidity calibration of these dipole magnets is crucial for obtaining peak fragment yields with optimal transport conditions in minimal time and informing simulations of fragment separator experiments. This work reports on the use of the FRIB linear accelerator to provide a U-238 beam of known energy, with accuracy of 0.1%. Charge states of the beam, formed in a thin foil can then be used to calibrate the ARIS dipole field vs bend radius over a range of rigidities. Due to saturation of the iron in the dipoles, the field vs bend radius curve is not linear and deviates significantly once the central field is above 1.5 T. Details of the procedure and results will be presented.

Operational experience and improvements of the ATLAS in-flight system

Ben Blomberg, Calem Hoffman, Clayton Dickerson, Matthew Hendricks (Argonne National Laboratory).

In 2018, the Argonne Tandem Linac Accelerator System (ATLAS) expanded its ability to produce and select radioactive in-flight beams through transfer reactions with the addition of a magnetic chicane for beam momentum selection referred to as the Radioactive Ion Separator or RAISOR. The ATLAS in-flight system consists of a production target positioned immediately upstream of RAISOR, followed by an RF sweeper to further refine beam purity. In this contribution, we present our experience operating the ATLAS in-flight system, operational and facility improvements, current limitations, and upgrade plans.

TUX: Invited Talks
24 June 2025 08:30 - 10:30

TUX01 / 08:30

Future challenges for CERN's ion injector complex
Maciej Slupecki (European Organization for Nuclear Research).

The ion injector complex at CERN supplies ions for collisions at the Large Hadron Collider (LHC) and for fixed-target physics programmes at the Super Proton Synchrotron (SPS) and Proton Synchrotron (PS). In recent years, there has been growing interest in experiments with lighter ions than lead within the ion-physics community. The NA61/SHINE collaboration has requested beams of oxygen, magnesium, and boron for Run 4 (2030-2033), while the HEARTS++ project proposal aims to enable switching between four ion species, with each transition occurring within 15 minutes. Additionally, LHC experiments are considering lighter-than-lead ion beams for Run 5 (2036-2041), pending an assessment of which particle species collisions offer higher nucleon-nucleon luminosity. Consolidating these future scenarios demands an evaluation of the light-ion performance of the present injector complex. This contribution discusses the challenges of the present injector complex in view of light-ion operation and a proposed ion complex upgrade to address future needs.

TUX02 / 09:00

Automated beam tuning of the TRIUMF ISAC facility
Olivier Shelbaya, Paul Jung, Oliver Kester, Omar Hassan, Rick Baartman, Spencer Kiy (TRIUMF).

Modern heavy ion accelerators have become more complex, with greater variability in energy, isotope selection, and A/q ratios. In response, TRIUMF has launched a program focused on automating beam tuning and delivery across its accelerator complex. This initiative includes high-level applications, model-based tuning of the accelerator, and the integration of machine learning tools. For example, Bayesian optimization is used to correct beam orbits within the TRIUMF accelerators. This presentation will provide an overview of the program's progress and highlight some exciting new results achieved over the past two years.

TUX03 / 09:30

Maintaining optimal beam brightness and luminosity using machine learning
Weijian Lin (Brookhaven National Laboratory).

While human operators are very good at finding the optimal conditions that maximize the luminosity in RHIC, maintaining those conditions can be a demanding task. There is also no metric that can measurably determine if those optimal conditions are truly optimal, given the degrees of freedom are very high and there are multiple and competing objectives. In this talk we will describe how we use machine learning and improved physics models to build

systems for optimizing the beam brightness during injection at the BNL Booster and AGS synchrotrons and efforts to maintain maximum luminosity in RHIC.

TUX04 / 09:50

Recent developments of machine-learning-based techniques in RIKEN RI Beam Factory

Takahiro Nishi, Yasuyuki Morita (RIKEN Nishina Center).

Recent developments of machine-learning-based techniques in RIKEN RI Beam Factory The RIKEN RI Beam Factory (RIBF) is a heavy ion accelerator facility consisting of four ECR ion sources, two linacs, five cyclotrons, and a superconducting fragment separator. For the efficient operation of this facility, developments of beam diagnostics and beam tuning methods using machine learning have been initiated. This presentation will focus on the following two topics. The first is the prediction of the beam intensity from the ECR ion sources. By using plasma images as input to the machine learning model, the beam intensity has been successfully estimated for short-term test datasets. The second is the development of a parameter optimization system based on Bayesian Optimization for high intensity heavy ion beams. We successfully optimized primary 36+Kr beam at 30 enA while monitoring 34+Kr by trackers in a spectrometer. Future prospects for the application of machine learning at RIBF, including these methods, will be discussed.

TUX05 / 10:10

Boost of ALPI superconducting linac performances using AI techniques

Luca Bellan, Alessio Galatà, Andrea Pisent, Carmelo Sebastiano Gallo, Damiano Bortolato, Davide Marcato, Enrico Fagotti, Enrico Munaron, Fabio Gelain, Francesco Grespan, Giovanni Savarese, Iandrimalala Rakotobe Andriamaro, Lisa Centofante, Loris Antoniazzi, Marco Roetta, Maurizio Montis, Mauro Giacchini, Michele Comunian, Osvaldo Carletto, Ysabella Kassandra Ong (Istituto Nazionale di Fisica Nucleare).

The heavy ion superconductive linac ALPI has been operating at the Legnaro National Laboratories since its completion in the 1990s. As the first generation in Europe, it featured several innovative techniques and design weaknesses, such as very small transverse and longitudinal acceptances. This led to long setting times and low transmission rates of 35%, compared to 93% obtained using simulations. Additionally, the machine experienced instabilities, requiring frequent accelerator retuning. From 2011 to 2024, an extensive beam dynamics studies program was conducted, culminating in the introduction of Artificial Intelligence techniques in 2022-2024. These techniques made it possible to accelerate the accelerator setup, counteract instabilities and reach the nominal transmission of the linac, about 85%, in June 2024, 32 years after its construction. This paper presents the AI techniques involved, the studies performed, and how they impact routine operations.

TUY: Invited Talks
24 June 2025 10:50 - 12:00

TUY01 / 10:50

Recirculating and energy recovery ion linear accelerators
Ji Qiang, Qing Ji (Lawrence Berkeley National Laboratory).

High intensity ion accelerators are a key technology for high energy physics, nuclear physics, defense, industry, and other applications. Recirculating linacs are a promising approach to achieve high-power machines by combining CW operation (like a linac) with re-use of costly superconducting cavities (like a rapid cycling synchrotron). This has the promise to reduce both the accelerator footprint and cost. We present the initial design of recirculating linacs for high-power ion acceleration with a focus on beam physics related design challenges as well as the unique requirements for accelerator magnet technology.

TUY02 / 11:20

Operation status of China Accelerator Facility for Superheavy Elements (CAFe2)
Weilong Chen (Institute of Modern Physics, Chinese Academy of Sciences).

China Accelerator Facility for Superheavy Elements (CAFe2) is a state-of-the-art scientific facility dedicated to the synthesis and investigation of superheavy nuclei and elements. It features a continuous wave RFQ, a fully superconducting linac that comprises twenty three half-wave resonator cavities housed within four cryostats, and an experimental terminal. The linac is designed to achieve an energy of 6.5 MeV/u for ion species with an A/Q ratio approximately equal to 3.5. CAFe2 evolved from its predecessor, CAFe, which was initially a proton demo linac for accelerator driven systems. Following its upgrade in 2021, CAFe2 has accumulated over 10000 hours of operation time, providing heavy ion beams for superheavy element experiments at beam currents exceeding 10 upA. This talk will review the operation of CAFe2 and highlight the efforts to enhance the stability and tuning efficiency of high-intensity heavy ion beams.

TUY03 / 11:40

Nb3Sn superconducting cavity developments for heavy-ion beams
Michael Kelly, Troy Petersen (Argonne National Laboratory).

Niobium-tin has been identified as the most promising next-generation superconducting material for accelerator cavities. This is due to the higher critical temperature (Tc = 18 K) of Nb3Sn compared to niobium (TC = 9.2 K), which leads to greatly reduced RF losses in the cavity during 4.5 K operation. This allows two important changes during cavity and cryomodule design. First, the higher Tc leads to negligible BCS losses when operated at 4.5 K, which allows for a higher frequency to be used, translating to significantly smaller cavities and cryomodules. Second, the reduced dissipated power lowers the required cryogenic cooling capacity, meaning that cavities can feasibly be operated on 5-10 W cryocoolers instead of a centralized helium refrigeration plant. These plants and distribution systems are costly and complex, requiring skilled technicians for operation and

maintenance. These fundamental changes present an opportunity for a paradigm shift in how low-beta linacs are designed and operated.

TUB: Contributed Talks
24 June 2025 12:00 - 12:20

TUB01 / 12:00

A single-slice rotating graphite target at FRIB

Jeongseog Song, Daniel Cole, Daniel Jaeha Lee, Geunhyeong Lee, Jie Wei, Justin Simon, Marc Reaume, Michael Larmann, Mohit Patil, Nathan Bultman, Nicholas Jockheck, Raul Quispe-Abad, Samuel Miller, Takuji Kanemura (Facility for Rare Isotope Beams), Mathias Steiner, Mauricio Portillo (Michigan State University).

The FRIB accelerator, constructed and commissioned in 2022, serves as a leading facility for producing rare isotope beams and exploring elements beyond the limits of stability. These beams are produced by reactions between stable primary beams and a graphite production target. Meanwhile, approximately 20–40% of the primary beam power is deposited in the target, necessitating efficient heat dissipation. Currently, FRIB operates at a primary beam power of 15 kW. To enhance thermal dissipation efficiency, a single-slice rotating graphite target with a diameter of approximately 30 cm is employed. This paper presents an overview of the current status of the production target system and ongoing R&D efforts to enhance its performance and durability under high-power beam conditions.

TUZ: Invited Talks
24 June 2025 14:00 - 14:40

TUZ01 / 14:00

In relation to a sustainable approach considering the design and operation of accelerators

Maud Baylac (Centre National de la Recherche Scientifique), Achille Stocchi (Laboratoire de Physique des 2 Infinis Irène Joliot-Curie, Centre National de la Recherche Scientifique), Cristian Pira (Istituto Nazionale di Fisica Nucleare), Jens Knobloch (University of Siegen), Jorgen D'Hondt (Laboratoire de Physique Subatomique et de Cosmologie, Centre National de la Recherche Scientifique).

Particle accelerators are essential instruments for research infrastructures and for a variety of applications, accounting for 40,000 machines worldwide. In a context of sustainability, minimizing the energy consumption of accelerators is an unavoidable challenge.

Funded by the EU (HORIZON-INFRA-2023-TECH-01-01 under GA n°101131435), the iSAS project (Innovate for Sustainable Accelerating Systems) was launched in 2024. It aims to innovate on core technologies of SRF accelerating systems to minimize energy consumption. It will enhance collaborations in the field to broaden and expedite these

technologies. It is complementary to other programs developping energy-efficient magnets or RF sources and reusing the waste heat produced.

The iSAS project concentrates on SRF accelerating systems with the largest leverage for energy savings. The developped technologies aim to optimize: - ferro-electric fast reactive tuners, - low lever radio frequency control system, - coatings of Nb3Sn on Cu cavities, - couplers (fundamental, higher order modes) and beam line absorbers.

iSAS aims to perform R&D on these technologies and to promote their implementation towards industry, by raising their TRL levels.

TUZ02 / 14:20

Primary beam development for FRIB experiments
Tomofumi Maruta (Facility for Rare Isotope Beams).

In this presentation, discussion of primary beam tuning procedures based on physics applications. Recent updates of the beam tuning applications to minimize the accelerator setup time. Discussion of beam tuning steps for the development of low-loss accelerator tune.

TUC: Contributed Talks
24 June 2025 14:40 - 16:00

TUC01 / 14:40

Commissioning and operation of LEAF with high intensity heavy ion beams
Yao Yang, Yuhan Zhai (Institute of Modern Physics, Chinese Academy of Sciences).

The low-energy, high-intensity, high-charge-state heavy ion accelerator facility LEAF (Low Energy Accelerator Facility) has recently been fully completed at IMP. LEAF aims to prototype the room temperature front end of the High Intensity Heavy Ion Accelerator Facility (HIAF), and to operate as a standalone facility to conduct research in multiple physics disciplines using high-intensity, low-energy heavy ion beams. Capable of accelerating high-intensity ion beams of M/q=2~7 to 0.3~0.7 MeV/u, LEAF comprises a high-performance highly charged superconducting ECR ion source, a high-voltage platform, a low-energy beam transport (LEBT), a 4-vane 81.25 MHz RFQ, a medium-energy beam transport (MEBT), a 81.25 MHz IH structure DTL and several experimental terminals. First constructed in 2018, the facility had logged 13,000 hours of on-target beam time by March 2024. Recently, with the high-performance ECR ion source in operation, >1.0 emA O6+ and >0.2 emA Bi35+ have been successfully accelerated with an efficiency of 80%~85%. This talk will describe the design LEAF and its features as a multidisciplinary heavy ion platform, and discuss the commissioning of high-intensity heavy ion beams.

TUC02 / 15:00

Beam commissioning of the RAON heavy ion accelerator

Dong-O Jeon, Hyung Jin Kim, Ji-Ho Jang, Yujung Ahn (Institute for Basic Science).

Beam commissioning of the SCL3 (low energy SCL) with Argon stable ion beam was conducted in 2024. Various beam physics studies were conducted including the tomographic reconstruction of the beam phase space in the LEBT, SCL3. Excellent agreement with the Allison scanner emittance data was observed. Argon stable ion beam was provided for the users. In addition sodium rare isotope beam from the ISOL was accelerated using the SCL3.

TUC03 / 15:20

Development of plasma processing for superconducting half-wave resonators

Walter Hartung, Kyle Elliott, Patrick Tutt, Sang-Hoon Kim, Taro Konomi, Ting Xu, Wei Chang (Facility for Rare Isotope Beams).

Several groups have demonstrated that plasma processing can help to mitigate degradation of the performance of superconducting radio-frequency cavities, making plasma processing a promising alternative to removal of cryomodules from the accelerator for refurbishment. Studies of plasma processing for quarter-wave resonators (QWRs) and half-wave resonators (HWRs) are underway at FRIB, where a total of 324 such resonators are presently in operation. Challenges for this effort include the high FPC mismatch at room temperature, the limited view of the cavity interior, and the absence of higher-order mode (HOM) couplers. A plasma processing trial on a QWR cryomodule, driving the plasma with HOMs via the fundamental power coupler (FPC) was done in January 2024. In parallel with QWR development, plasma processing tests are being done on HWRs, so far driving the plasma with the fundamental mode via a custom antenna or the FPC. Before-and-after cold tests suggest that plasma processing has good potential for reduction of field emission in HWRs.

TUC04 / 15:40

Demonstration of the first 1 GHz Niobium-Tin quarter-wave cavity

Yang Zhou, Berardino Guilfoyle, Mark Kedzie, Michael Kelly, Paul Davis, Thomas Reid, Troy Petersen (Argonne National Laboratory), Brad Tennis, Grigory Eremeev, Sam Posen (Fermi National Accelerator Laboratory), Edward Spranza (RadiaBeam Technologies), Ronald Agustsson (RadiaBeam Technologies, United States).

Niobium-Tin (Nb3Sn) is a promising alternative to pure niobium for low-beta ion accelerators due to low RF losses even at high frequencies. At 4.5K, the expected Bardeen-Cooper-Schrieffer resistance of Nb3Sn is a few nano-Ohms at 1GHz, with two orders of magnitude improvement compared to pure niobium. The low Nb3Sn RF losses allow the use of higher frequency, much smaller cavities while maintaining 4.5K operation that is compatible with cryocoolers. This work aims to demonstrate the feasibility of coating a high-frequency 1GHz, compact quarter-wave cavity. The development of this cavity has the potential to transform low-beta ion accelerators through size reductions and by enabling the replacement of large helium cryoplants with small plug-in cryocoolers. We have designed,

built, and tested a 1GHz Nb3Sn coated quarter-wave cavity. Nb3Sn coating has been performed once by vapor diffusion at Fermilab. Cryogenic cold tests show a quality factor of ~1E9 at low accelerating electric fields or ~7 times higher than the theoretical limit for pure niobium at 1GHz. This first coating does not yet meet our quality factor or gradient goals; however, we plan to continue to develop this cavity.

TUP: Tuesday Poster Session
24 June 2025 16:20 - 18:00

TUP01

Optimization of a mini-channel beam dump for FRIB operation
Samuel Miller (Facility for Rare Isotope Beams), Drew Winder (Oak Ridge National Laboratory), Jeongseog Song, Marc Reaume, Mohit Patil, Nathan Bultman, Raul Quispe-Abad, Takuji Kanemura (Facility for Rare Isotope Beams).

The Facility for Rare Isotope Beams (FRIB) is a high-power heavy ion accelerator facility at Michigan State University that completed in 2022. Its driver linac is designed to accelerate all stable ions to energies above 200 MeV/u with beam power of up to 400 kW. Currently, FRIB is operating between 10 to 20 kW, delivering multiple primary beam species. The beam dump absorbs approximately 75% of the primary beam power. The existing beam dump head can accommodate up to 20 kW operation, with a planned transition to an optimized mini-channel beam dump design with capability up to 30 kW and beyond. Presented here is an overview of the mini-channel beam dump head design optimization and supporting analysis.

TUP02/SUP12

Investigation of mechanical stability of silicon carbide in aluminium oxide under high temperature and 800 keV Ar ion irradiation
Gajigatte Umapathy (Inter-University Accelerator Centre), Santanu Ghosh (Indian Institute of Technology Delhi).

The SiC acts as the primary barrier against the release of fission products in the TRISO-type fuel. For the present generation, SMR technology A highly explored area for optimizing commercial nuclear fuel efficiency is managing the Kr/Xe fission gas budget, as these gases act as time limiters due to thermal fission gas swelling or nucleating high swelling behaviour (HSB) structures' expansion. In this study, we investigate irradiation stability of SiC(TiO2) Al2O3 composit. Alumina is recognized for its role in enhancing adhesion under high-temperature conditions, while TiO_2 functions as a binding agent within the matrix. The sample $(Al_2O_3)x(TiO_2)ySiCz$, where the concentration x=y=0-10,z=1-x+y was prepared by the additive method using pure powders pressed into pellets, followed by dual-step sintering for 10 and 14 hours at 1000°C and 1400°C, respectively. The samples were irradiated with a 800 keV Ar^+ beam at doses ranging from 1e15 to 1e17 atoms/cm^2. The crystal structure, morphology, and physical properties were studied in pre- and post-irradiation conditions using characterization techniques such as RBS, FESEM, XRD, TEM, and nano-indentation.

TUP03

Study on synergistic irradiation effects of nuclear materials based on cocktail ion beam technology

Yuhan Zhai, Hongwei Zhao, Liangting Sun, Yao Yang (Institute of Modern Physics, Chinese Academy of Sciences).

Cocktail beams, composed of multiple ion species with tailored energy and composition, have emerged as a transformative tool for simulating the synergistic irradiation effects experienced by structural materials in advanced nuclear reactors. This study demonstrates the development of cocktail ion beams at the Low Energy high-intensity heavy ion Accelerator Facility (LEAF), leveraging a fourth-generation superconducting ECR ion source (FECR) and energy modulation systems to generate high-intensity, low-energy-spread beams. Key innovations include a drift tube linac (DTL) and rebunchers, enabling precise energy tuning to align ion penetration depths. To validate the radiation-induced damage characteristics of mixed-ion beams, irradiation responses of monocrystalline copper were systematically compared across different irradiation modalities. The analysis reveals that simultaneous cocktail beam exposure induces markedly distinct microstructural evolution compared to sequential irradiation (e.g., Fe→He or He→Fe) and single-ion (e.g., Fe or He) irradiation protocols under equivalent displacement damage conditions.

TUP04

Design and experimental thermal validation of the mini-channel beam dump for FRIB

Jeongseog Song, Geunhyeong Lee, Jie Wei, Marc Reaume, Mohit Patil, Nathan Bultman, Raul Quispe-Abad, Samuel Miller, Takuji Kanemura (Facility for Rare Isotope Beams).

The FRIB, a leading experimental nuclear physics facility, produces high-intensity beams of proton- and neutron-rich nuclei. FRIB provides high-yield, high-purity rare isotope beams via primary beams interactions with a graphite target. After the target, the unreacted primary beam should be absorbed by a beam dump. To support operations at 20 kW, an intermediate beam dump system, called the minichannel beam dump (MCBD), has been developed and implemented. This system features a static structure oriented at a 6° angle, reducing power density by 10 times. The MCBD is fabricated as a bimetal using an Al-Cu alloy, with a high-thermal-conductivity copper absorber for enhanced heat dissipation and 2 mm × 7 mm aluminum cooling channels that prevent copper oxidation and significantly improve cooling efficiency. The thermal performance of the MCBD was validated through experimental testing using a 17 keV e-beam at the Applied Research Laboratory, showing measured temperatures matching ANSYS simulation within 10% uncertainty. These results indicate that the MCBD can reliably support FRIB operations at 20 kW or higher, ensuring effective heat dissipation under high-power conditions.

TUP05

Application of ASME BPVC Section VIII, Division-2, design by analysis requirement to FRIB static beam dump

Mohit Patil (Facility for Rare Isotope Beams), Drew Winder (Oak Ridge National Laboratory), Jeongseog Song, Marc Reaume, Nathan Bultman, Raul Quispe-Abad, Samuel Miller, Takuji Kanemura (Facility for Rare Isotope Beams).

The Facility for Rare Isotope Beams (FRIB) at Michigan State University is a high-power heavy-ion accelerator, completed in 2022. Its driver linac is designed to accelerate all stable ions to energies exceeding 200 MeV/u, with a maximum beam power of 400 kW. Currently, FRIB operates at beam powers between 10 and 20 kW, delivering multiple primary beam species. Approximately 75% of the primary beam power is absorbed by the beam dump. The existing mini-channel beam dump (MCBD) absorber is designed to handle up to 20 kW, with plans for an optimized beam dump capable of supporting 30 kW and beyond. This paper presents the design-by-analysis procedures outlined in ASME Boiler and Pressure Vessel Code that have been applied to the MCBD design.

TUP06

Monte-Carlo simulation of vacuum system for advanced charge selector

Xiuli Wang, Alexander Plastun, Takuji Kanemura (Facility for Rare Isotope Beams).

To intercept unwanted charge states from stripped beams with higher power densities, an advanced charge selector is currently under development at the Facility for Rare Isotope Beams (FRIB). This upgraded charge selector is designed to intercept beam spots that have a power of up to 5 kW and an rms size as small as 0.7 mm × 1.25 mm. To enhance heat dissipation and mitigate thermal stress, rotating graphite wheels are employed as the beam-intercepting medium.

An essential aspect of this design is the development of a robust vacuum system to ensure reliable and efficient operation while minimize beam losses in downstream sections. The high graphite temperature, maintained over 1000 °C for radiation damage annealing, raised concerns about gas load. To aid the vacuum system design, vacuum simulations were carried out using a Monte Carlo-based simulation code, MolFlow. The sublimation of graphite, outgassing from the vacuum chamber's inner wall and the effect of pumping speed on vacuum performance are considered. The results demonstrate that the proposed vacuum system can maintain a pressure under 1×10^{-7} mbar, ensuring adequate vacuum conditions for beam operations.

TUP07

Upgrade of RF beam sweeper for purifying rare isotope beams at the ATLAS Facility

Aurora Cecilia Araujo Martinez (RadiaBeam Technologies, United States), Albert Barcikowski, Brahim Mustapha (Argonne National Laboratory), Alexander Smirnov, Christopher Oberempt, Ronald Agustsson, Sergey Kutsaev (RadiaBeam Technologies, United States).

The RF beam sweeper is a crucial component for radioactive ion beam production, which enhances the purity of in-flight produced rare isotope beams by introducing a time-

of-flight separation. The current sweeper operates at ATLAS's subharmonic frequency of 6 MHz using 1-meter-long electrode plates and a maximum deflecting voltage of 55 kV, which is sufficient for the separation of certain beams. However, the new capabilities, enabled by the recently commissioned in-flight radioactive beam separator RAISOR demand higher voltages and higher frequency operation. To address these needs, we are developing an advanced RF sweeper capable of switching between 6 MHz and 12 MHz, depending on the beam, with a maximum deflecting voltage of 150 kV. The design is based on a resonant circuit with electrode plates and an adjustable coil, along with a sliding contact switch for frequency switching. This talk presents the sweeper design and fabrication progress.

TUP08/SUP13

Numerical modeling to predict ignition thresholds for plasma processing of superconducting radio-frequency cavities

Zachary Hosek, Patrick Tutt, Ting Xu, Walter Hartung (Facility for Rare Isotope Beams).

Laboratories such as Oak Ridge, Fermilab, and Jefferson Laboratory have been developing plasma cleaning techniques for superconducting radio-frequency (SRF) cavities. These techniques show promise as an in-situ method of mitigating degradation in cavity performance via removal of surface hydrocarbon contamination. Plasma cleaning studies for SRF cavities in the driver linac at the Facility for Rare Isotope Beams (FRIB) began in 2020. Both neon-oxygen and argon-oxygen plasmas have been found to be effective in improving FRIB accelerating cavities. The ignition threshold RF electric field can be predicted for a diffusion-dominated plasma using the solution to the diffusion equation for a given cavity shape; a numerical solution is needed for realistic cavity shapes. Predictions for several cavity shapes will be presented and compared to available plasma ignition threshold measurements.

TUP09

Development of automatic beam tuning system using Bayesian optimization for high intensity heavy ion beams at RIBF

Takahiro Nishi, Akito Uchiyama, Hiroki Fujii, Naoki Fukuda, Toshiyuki Sumikama, Yasuyuki Morita, Yohei SHIMIZU (RIKEN Nishina Center).

In general, accelerator facilities are controlled by a huge number of parameters. The RIKEN RI Beam Factory (RIBF), a heavy-ion accelerator complex consisting of several cyclotrons and Linacs, is controlled or influenced by more than 600 parameters, including environmental factors. To optimize these parameters more efficiently and accurately, we are attempting to implement Bayesian optimization (BO). Given the importance of space charge effects and beam loading, it is desirable to adjust parameters at high beam intensity, making it crucial to develop an optimization system capable of handling high-intensity heavy ion beams.

We have been working on developing indices suitable for high-intensity beams and exploring methods for optimization while maintaining operational safety. So far we developed a technique that enables the simultaneous measurement of beam transmission and spot shape on the target by tracking charge-converted particles after passing through

the target. Additionally, we are investigating the use of line BO with a safety function to ensure safe beam optimization. Currently, we are preparing for simulations and tests using beam line.

TUP10

The ATLAS AI-ML Dashboard

Adwaith Ravichandran, Brahim Mustapha (Argonne National Laboratory).

We have developed a browser-based user interface for AI-ML applications at Argonne's ATLAS ion linac facility. The new interface is named the "ATLAS AI-ML Dashboard", it is based on the web application package, Dash, and customized to easily include any ATLAS beamline and select from several beam tuning options and optimization algorithms. The interface is being introduced to the operators and their feedback will be used to further improve its capabilities. Among the features that are being added is the extraction of the initial beam parameters, from pepper-pots and quad scans, to use as input for the optimization procedure. In addition to presenting the main features of the ATLAS AI-ML interface, we will also present the first online experience of the operators.

TUP11

Application of ML tools for extraction of Q-terms and transverse beam matching

Kilean Hwang, Alexander Plastun, Kei Fukushima, Peter Ostroumov, Tomofumi Maruta, Tong Zhang (Facility for Rare Isotope Beams), Qiang Zhao (Michigan State University).

Data inaccuracies make training an accurate Beam Quadrupole Moment at BPM (BPMQ) model challenging. Similarly, reconstructing Courant-Snyder (CS) parameters from BPMQ predictions is difficult due to BPMQ model limitations. Increasing the number of BPMQ predictions helps mitigate overfitting in CS inference caused by inaccurate BPMQ predictions. We present Bayesian Active Learning (BAL) to acquire measurements strategically, improving CS parameter inference despite model limitations.

TUP12/SUP14

Research on compensation of a rf cavity failure in a superconducting linac by reinforcement learning algorithm

Tielong Wang, Yuan He, Zhijun Wang (Institute of Modern Physics, Chinese Academy of Sciences).

High reliability is a major challenge of high-current linear accelerators. This is particularly problematic for Accelerator Driven Systems (ADS) such as the China initiative Accelerator Driven System (CiADS). In order to achieve rapid beam recovery, it is necessary to adjust and compensate the cavities adjacent to the failed cavity. In this study, we employ the Proximal Policy Optimization (PPO) algorithm, a reinforcement learning technique, to train a compensation model within a simulated environment of the CiADS superconducting HWR010 section. Compared to previous methods utilizing genetic algorithms, the reinforcement learning approach demonstrates superior performance in delivering more stable and consistent results.

TUP13

FRIB multi-gap buncher conditioning up to 30 kW

Hiroyuki Ao, Dan Morris, Eleazar Gutierrez, Shen Zhao, Xing Rao (Facility for Rare Isotope Beams).

The Facility for Rare Isotope Beams has begun operations for scientific users since May 2022. To reduce beam loss in the driver linac, we plan to operate two multi-gap bunchers (MGBs) at a higher accelerating voltage. This paper presents progress and lessons learned from the early-stage operations of the MGBs, as well as a summary of the phased high-power conditioning, which progressed from an RF power of 18 kW to 26.5 kW, and then to 30 kW. Both MGBs were successfully conditioned during maintenance periods. After approximately 100 hours of conditioning, MGB1 operated without any trips in the last 12 hours, and MGB2 experienced only three trips during the same period.

TUP14/SUP16

Avoiding beam instabilities and resonances with circular modes

Onur Gilanliogullari (Illinois Institute of Technology), Brahim Mustapha (Argonne National Laboratory), Pavel Snopok (Illinois Institute of Technology).

Beam instabilities and resonances affect the transverse dynamics in particle accelerators and, when encountered, can trigger emittance growth and beam loss. Resonance lines originate from nonlinear elements and effects in the lattice,and impose strict constraints on the choice of working points and narrow the available tune space. Circular modes—intrinsically coupled, flat-round eigenmodes—provide an alternative beam motion and dynamics. In this study we derive the third-order sextupole resonance conditions in the coupled (normal-mode) parametrization and show that, with circular-mode lattice design and beam operation, most of these resonance lines are naturally suppressed thanks to the mode's inherent flatness.

TUP16

Development of High Temperature Ovens (HTOs) for solid ion beam production at Facility for Rare Isotope Beams (FRIB)

Haoyu Cheng, Alexander Plastun, Joseph Backlas, Junwei Guo, Miao Hu, Xing Rao (Facility for Rare Isotope Beams), Guillaume Machicoane, Larry Tobos, Randall Rencsok (Michigan State University).

Inductive ovens are integral to electron cyclotron resonance (ECR) ion sources, facilitating the generation of high-intensity solid ion beams. At the Facility for Rare Isotope Beams (FRIB), specialized inductive High Temperature Oven (HTO) has been developed to ensure the reliable production of solid ion beams for the High-Power ECR (HPECR) ion source. These HTOs have successfully supported the operation of various solid ion beams, including Silicon, Nickel, and Uranium. In alignment with the FRIB beam power ramp-up objectives, future requirements include increased beam currents and prolonged operational durations for heavier species. To optimize HTO performance in response to these evolving demands, a series of design improvements have been implemented, drawing on insights from previous operational experience. These improvements are intended to enhance both

operational stability and beam consistency. The detailed improved design, Ansys® simulation results, and testing results will be presented and discussed.

TUP17

Upgrading the magnetic field profile of the Texas A&M 14.5 GHz electron cyclotron resonance ion source

H.I. Park, D.P. May, F.P. Abbeglen, G.C. Tabacaru, S.L. Molitor (Texas A&M University).

An upgrade of the magnetic field profile of the Texas A&M 14.5 GHz electron cyclotron resonance ion source (ECRIS) is in progress, guided by well-established magnetic-field scaling rules for ECRIS. On the injection end, a new lower-carbon steel plug with a modified design has already been installed to increase the axial magnetic field at the injection end of the plasma chamber. Now, detailed calculations, using the permanent-magnet code PANDIRA, have been performed to optimize the radial magnetic field of the hexapole. A new aluminum plasma chamber will soon be constructed with more reliable cooling. Finally, six new NdFeB permanent-magnet bars will be installed in the new chamber before the final replacement of the old plasma-chamber-hexapole assembly. Together, these modifications are expected to significantly improve the performance of the ion source by achieving better plasma confinement and by enhancing beam stability, eventually leading to an increase in high-charge-state ion production.

TUP18

Computational analysis of MP activation and suppression in 325 MHz FPC

Heejin Do (Institute for Basic Science).

A 325 MHz RF Fundamental Power Coupler (FPC) designed to operate under 20 kW CW in the high energy SC Linac of the RAON. One of the most important consideration in the FPC EM design is to reduce and eliminate a multipacting (MP) activation in both TW mode and SW mode. Prior to the MP reduction design, the MP bands of the FPC was computed with CST Particle Studio. It was confirmed that third or higher order of MP bands were activated within the operating range on the surface condition of the coupler. Therefore, designs to suppress MP are needed. To eliminate MP, a DC voltage was applied to center conductor of the FPC. Detailed the simulation modeling and computational analysis results where MP was effectively suppressed for both modes are presented.

TUP19

The 120 kW solid state amplifier system for the FRIB RFQ

Eleazar Gutierrez, Dan Morris, Enrique Bernal, Shen Zhao (Facility for Rare Isotope Beams).

The Facility for Rare Isotope Beams (FRIB) radio frequency quadrupole (RFQ) runs in continuous wave mode at 80.5 MHz with an input power up to 120 kW. The current tetrode amplifier had some failures and was greatly improved during commissioning and early operations. However, some potential failures may cause long repair time and compromise overall system availability. In comparison, the solid state amplifiers have shorter repair time due to the modular design and absence of high voltage. Currently FRIB is commissioning the 120 kW solid state amplifier system. It uses the same 2 kW 80.5 MHz modules as those used

in FRIB linear segment 1. This allows the sharing of spares as well as reducing the effort for developing new controls and maintenance procedures. Each of the eight racks includes six amplifier modules and can output 15 kW power into a matched load. The system uses 3 dB quadrature hybrid couplers in a 3-stage corporate power combining scheme to achieve 120 kW. The paper will detail the design and commissioning of this system.

TUP20

An energy recovery ion linear accelerator
Ji Qiang (Lawrence Berkeley National Laboratory).

High-power proton/ion linear accelerators have important applications in both scientific research and industry. However, operation of such accelerators with megawatt-level beam power is expensive and limits the broad availability of those facilities. In this study, we propose a novel energy recovery ion linear accelerator in which the final high-energy GeV-level ion beam is reused to give its energy back to the RF fields in the accelerator. This substantially reduces the power consumption of the linear accelerator and also avoids the need for a high-power beam dump.

TUP21

Study on properties of NEG deposited on the titanium alloy lined vacuum chamber
Changchun Li, Cheng Luo, Jun Meng (Institute of Modern Physics, Chinese Academy of Sciences).

A ramping rate of 12 T/s is designed for the dipole magnet of BRing at HIAF. To reduce eddy current effects, a titanium alloy lined chamber with a 0.3 mm titanium alloy inner liner by 3D printing and an ultra-thin stainless steel outer wall has been adopted. To reduce the internal pressure and enhance the beam lifetime, a film of TiZrV is coated on the chamber.

The ultimate vacuum of the titanium alloy-lined vacuum chamber is tested, which indicates that after coating with TiZrV, the pressure at the middle of the chamber reduced, effectively reducing the pressure in the central region. The life of the TiZrV film was studied by repeated activation and venting cycles under two conditions of N2 and air filling. With N2 filling, after 15 activation cycles, the vacuum in the middle of the chamber showed no significant change. However, with air filling, after 7 activation cycles, the vacuum in the middle degraded, indicating a decline in the pumping performance of the TiZrV film. Air exposure significantly impacts the life of the film, necessitating that TiZrV films be protected with N2 in applications and minimizing exposure time.

TUP22

Study on the performance of titanium alloy-lined thin-walled vacuum chamber
Cheng Luo, Changchun Li (Institute of Modern Physics, Chinese Academy of Sciences).

HIAF-BRing, the main synchrotron accelerator of the High Intensity Heavy-Ion Accelerator Facility, requires an average pressure lower than 1×10^{-9} Pa and the magnetic field increase rate of no less than 12 T/s to fulfill radioactive beam physics and high energy density physics experiments. To reduce the eddy current effect and the gap size of dipoles, a titanium alloy-lined thin-walled vacuum chamber with a wall thickness of 0.3 mm is

proposed by IMP, which has been developed from the initial ceramic-lined vacuum chamber. By mechanical loading testing, when the internal stress of titanium alloy rings made by 3D selective laser melting (SLM) reaches 639 MPa, it is still within the elastic deformation range, in fact, the yield strength of the 3D printed titanium alloy material is 912 MPa. In order to reduce the pressure gradient inside the thin-walled vacuum chamber caused by the surface outgassing of the rings, TiZrV thin fflms have been deposited on the rings by planar target magnetron sputtering. Through TiZrV deposited on the rings, the pressure at the middle of the thin-walled vacuum chamber has been dropped from 1.5×10^{-9} Pa to 1.0×10^{-9} Pa.

TUP23

Design and operational experience of FRIB magnet and electrostatic power supplies

Kent Holland, Alex Kohler, Lam Nguyen, Ryan Bliton (Facility for Rare Isotope Beams).

This paper will present design principles, procurement strategies, installation and testing plans, and availability data from commissioning and operation of over 1500 magnet and electrostatic power supplies at the Facility of Rare Isotope Beams (FRIB). This paper introduces the types of power supplies required for the FRIB which range in size from electrostatic high voltage power supplies less than 1 Watt to 150 kW magnet power supplies. The power supplies range in complexity from simple single quadrant units to four-quadrant pulsed electrostatic high voltage units to units requiring complex auxiliary equipment. Stability requirements of these power supplies range from 10 ppm for some sensitive experimental equipment to 3000 ppm for some multipole magnets.

TUP24

Feasibility study of plasma processing in the FRIB400 energy upgrade multi-cell elliptical superconducting cavity

Yoo Lim Cheon, Patrick Tutt, Sang-hoon Kim, Ting Xu, Walter Hartung (Facility for Rare Isotope Beams).

A 5-cell elliptical superconducting radio-frequency (SRF) cavity (644 MHz, beta = 0.65) is being developed at Michigan State University for the proposed FRIB driver linac energy upgrade (FRIB400). The cavity is not equipped with higher-order mode (HOM) couplers and the fundamental power coupler (FPC) coupling strength is relatively weak (loaded bandwidth = 32 Hz) due to CW operation, so a key challenge is to perform effective cavity plasma processing while avoiding plasma ignition in the FPC region; FPC ignition could otherwise lead to copper sputtering onto the niobium cavity surfaces or damage to the FPC ceramic window. In this study, we examined the feasibility of plasma processing by driving HOMs through the FPC. With a combination of TE111 passband modes, we were able to sustain plasma in each of the 5 cells without FPC ignition. We will present measurements of the plasma density as a function of drive mode, input RF power, drive RF frequency shift, and gas pressure, and will discuss an optimized cleaning recipe for future FRIB400 cryomodules.

TUP25

Sub-milliamp current control from switched-mode power supply in ATLAS nuCARIBU ion source.

David Novak, Clayton Dickerson, Kenneth Bunnell (Argonne National Laboratory), Daniel Santiago-Gonzalez, Shiv Kumar (Argonne Tandem Linac Accelerator System, Argonne National Laboratory).

The Argonne Tandem Linac Accelerator System (ATLAS) has been a National User Facility since 1985. Since the commissioning of the Californium Rare Isotope Breeder Unit (CARIBU) in 2012, it has used 2 bespoke water-cooled linear power supplies to allow for milliamp control of the isobar separator magnets, which allows for milligauss control of the magnets. During the upgrade to nuCARIBU, the aging linear power supplies were replaced with off-the-shelf (OTS) switched mode power supplies (SMPS). The benefit of the SMPS is higher efficiency and since they are air-cooled, no load on the water cooling system, while the detriment is the decrease in resolution of the current control. To overcome this limitation, a device was constructed that allows control of a sub-milliamp constant current sink, which is placed in parallel to the magnet. This arrangement allows the control system to "leak" a precise amount of current away from the magnet, effectively giving sub-milliamp control of the current going into the magnet.

TUP27/SUP22

Assessment of magnetic quadrupole pick-up structure at FRIB

Carlos Sarabia-Cardenas, Peter Ostroumov, Steven Lidia (Facility for Rare Isotope Beams).

A magnetic quadrupole pick-up structure is being assessed for creation and future use at The Facility for Rare Isotope Beams (FRIB) at Michigan State University (MSU). The geometric design makes use of magnetic loops that couple with the radial magnetic field of a beam, allowing for rejection of the common mode of the beam, while leaving the dipole signal as the dominant signal and enhancing the quadruple signal of the beam. Of interest is examining the response due to the multiple charge state heavy ion beams that FRIB produces and the ability to resolve the differing charge states. Presented here is the optimization of the device for the FRIB beamline.

TUP29

FRIB chopper monitor system calibration process

Joseph Hartford, Enrique Bernal, Masanori Ikegami, ZhiYong Li (Facility for Rare Isotope Beams).

At FRIB, a chopper in the low energy beamline is used for beam power control as well as machine protection through beam mitigation. An FPGA based monitoring system was developed to govern the chopper's operation and ensure that it is functioning properly. This chopper monitoring system conducts checks of the incoming chopper control signal, the high voltage being applied to the chopper plates, and the current flow to and from the plates as the voltage is applied and removed. A curve fitting, or calibration, is required to convert from a digital value to a user readable physical quantity, and vice-versa for the input of acceptable threshold settings for machine protection purposes. As the chopper is

functionally a capacitor, the current flow, as high voltage is applied or removed, will vary with level of HV applied and with any change in the capacitive load. This reality makes calibration of the chopper current readings difficult, and an analytical approach was adopted to overcome these difficulties and ensure satisfactory functioning of the monitoring system. This analytical process and a subsequent calibration of the chopper monitor will be discussed in detail in this paper.

TUP30

Superconducting multipole triplets magnets commissioning for the S3 spectrometer at GANIL

Franck Esnault, Antoine Wagret-Quatromme, Bertrand Haize, Frédéric Carville, Hervé Savajols, Marc-Hervé Stodel, Muhammad Aburas, Thierry Lefrou (Grand Accélérateur Nat. d'Ions Lourds), Franck Lutton (Université Paris-Saclay, CNRS/IN2P3, IJCLab), Guillaume Dilasser (Université Paris-Saclay), Guillem Tocabens (Commissariat à l'Énergie Atomique et aux Énergies Alternatives), Martial Authier (Commissariat à l'Energie Atomique).

The “Super Separator Spectrometer” project S3 is under technical commissioning at the GANIL facility (Caen-France). It is a new research installation designed for fundamental physics experiments with high intensity radioactive heavy ions beams produced by the SPIRAL2 linear accelerator. This spectrometer will open new horizons for nuclear physics. The S3 spectrometer is made of seven Superconducting Multipole Triplets (SMT) to guide and focalize the beam and select the particles of interest.

This paper presents SMTs technology and their magnetic, electrical and cryogenic operating characteristics as well as their technical commissioning for the S3 project.

WEX: Invited Talks
25 June 2025 08:30 - 10:20

WEX01 / 08:30

Status of High Performance ECR ion sources: achievements and perspectives
Liangting Sun (Institute of Modern Physics, Chinese Academy of Sciences).

Production of 0.5~1.0 emA highly charged heavy ion beams has been requested by worldwide next generation heavy ion facilities, but remains big challenge to the community. Regarded as the most powerful machine to produce high intensity heavy ion beams, ECR ion sources have been used by most of the heavy ion accelerator facilities in the world, which have also greatly boosted their continuous development over the years. Even after more than 50 years since the first prototype ECR ion source was demonstrated, it still retains its vitality in terms of extracted ion beam intensities and charge states. This paper will present the latest progresses of worldwide high performance ECR ion sources. The main contents will focus on new ion source development, high performance operation, new technology research and the perspectives on high beam intensity operation for heavy ion accelerators.

WEX02 / 09:00

Design of past, present and future superconducting magnets for ECR ion source
Yang Ye, Paolo Ferracin (Lawrence Berkeley National Laboratory).

Superconducting magnets are required for electron cyclotron resonance ion sources (ECRIS) to achieve a high charge state and high intensity heavy-ion beam. Several different designs have been, or are being explored to take full advantage of the high current carrying capabilities of superconducting materials. This talk provide an overview of these different designs, mainly based on sextupole-in-solenoid and solenoid-in-sextupole lay-outs, developed in various laboratories worldwide, as well as the innovative close-loop coil design (MARS) currently under fabrication at LBNL. A comparison between expected performance of the different ECR superconducting magnets will be given, and an outlook towards the possibility of implementing new more advanced superconducting materials will be discussed.

WEX03 / 09:20

Production and charge breeding for post-acceleration of the first RI beam from RAON ISOL facility
Kyounghun Yoo, Dong-Joon Park, Jae-Won Jeong, Jin-Ho Lee, Seongjin Heo, Takashi Hashimoto, Wonjoo Hwang, Yeong Heum Yeon, Young-Ho Park (Institute for Basic Science).

In March 2023, the first rare isotope beam (RIB) was successfully extracted from the Isotope Separation On-Line (ISOL) at the RAON heavy-ion accelerator facility. Surface-ionized beams of lithium (Li), sodium (Na), and aluminum (Al), produced by bombarding a silicon carbide (SiC) target with a 70 MeV proton beam, were delivered to the RIB separation and transport system. The production efficiency of Na isotopes from the SiC target was generally satisfactory, and a short-lived isotope, 24mNa (t1/2 = 20 ms), was successfully

measured. The performance of the ISOL RIB separation and transport system was validated through on-line experiments with both stable and radioactive sodium beams. The preparation of highly charged ions, meeting the injection requirements for the SCL3 post-accelerator (energies of 10 keV/u and an A/q ratio of < 6), was achieved using the Electron Beam Ion Source (EBIS). The ISOL RIB, 25Na5+, was successfully charge-bred and transported to the post-accelerator. This presentation will discuss the production, charge breeding, and post-acceleration of RAON's first RI beam.

WEX04 / 09:40

Demonstration of closed shell breeding of cesium with an EBIS

Richard Vondrasek (Argonne National Laboratory).

The Argonne National Laboratory electron beam ion source serves as a charge breeder for the Californium Rare Isotope Breeder Upgrade (CARIBU). The source accepts radioactive beams of 1+ or 2+ ions and raises them to a charge state sufficient for post-acceleration in the ATLAS linac. The efficiency of this process impacts the length of each experiment and hence the type and number of experiments which can be run in each program cycle. Recent efforts to improve the charge breeding efficiency have focused on utilizing the closed shell breeding technique for the mid-mass species typical of CARIBU. Charge breeding investigations with stable cesium have demonstrated an absolute efficiency of 72% for Cs27+ and a total device efficiency of 93%.

WEX05 / 10:00

Measurement of forward-directed neutrons generated by an inverse kinematic reaction using incident 7Li3+ beam

Toshiro Sakabe (Brookhaven National Laboratory), Alexander Smushkin, Benedikt Schmitz, Jonas Kohl, Philipp Zitzmann (Technical University of Darmstadt), Antonino Cannavó, Masahiro Okamura, Shunsuke Ikeda, Takeshi Kanesue (Brookhaven National Laboratory), Giovanni Ceccio (Czech Academy of Sciences), Kazumasa Takahashi (Department of Energy Sciences), Madhawa Horana Gamage (Columbia University).

In this work, we show our current status in the development of an accelerator-based neutron source based on an incident ion-beam of several tens of mA lithium, which realizes the inverse kinematic reaction between lithium-7 and proton: p(7Li,n)7Be. This neutron source is expected to generate forward-directed neutrons. Understanding the neutron distribution and flux is essential for neutron applications. The present study aims to clarify the neutron distribution and flux in the p(7Li,n)7Be case. Generated neutrons were measured to aid in designing the neutron source. Lithium beams from Tandem van de Graaf accelerators at BNL and HZDR were used to irradiate hydrogen-rich targets, such as polypropylene films, to induce the reaction. Liquid scintillators (BC-501) were located around the target to cover different angles, including the forward direction, to investigate neutron angular distribution and fluxes. The results confirmed a significant concentration of measurement signals in the forward direction throughout the experiments. The differentiation between neutrons and gamma rays using a pulse shape discrimination method is underway. Further details will be presented.

WEY: Invited Talks
25 June 2025 10:50 - 11:30

WEY01 / 10:50

High current heavy ion acceleration: 55 mA of Al11+ achieved
Madhawa Horana Gamage (Columbia University), Masahiro Okamura, Antonino Cannavó, Sergey Kondrashev, Shunsuke Ikeda, Takeshi Kanesue (Brookhaven National Laboratory), Giovanni Ceccio (Czech Academy of Sciences), Guy Garty (Columbia University), Kazumasa Takahashi (Department of Energy Sciences).

We are studying a high charge state ion beam provider based on a laser ion source using the direct plasma injection scheme (DPIS). Recently, we achieved 55 mA of Al11+ beam accelerated by an RFQ linear accelerator. This is a very high value compared to the beam intensities achieved so far for heavy-ion beams captured and accelerated by RF accelerators. This increase in beam current is largely due to our understanding of the ion-extraction conditions at the entrance of the RFQ. The optimal extraction structure was investigated. No breakdown was observed between the RFQ and the ion source. Details of the experiment and future plans will be presented. In addition, the test results of the newly developed RFQ electrode will be reported. This electrode is designed to capture more ions. It is also the first four-rod RFQ with a variable B concept.

WEY02 / 11:10

High intensity Ti-50 beam production for superheavy element research
Damon Todd (Lawrence Berkeley National Laboratory).

Elements 115-118 were discovered by bombarding transuranic targets with high-current Ca-48 beams, but a lack of heavier targets prevents extending the periodic table using calcium. The recent production of two atoms of element 116 by LBNL researchers using Ti-50 opens a new pathway for the discovery of elements beyond 118. The 88" Cyclotron's acceleration and delivery of the puA Ti-50 beams used to create these particles will be discussed. In particular, we will present the novel inductive oven used to provide a stable stream of titanium vapor to LBNL's superconducting ECR ion source VENUS, extract >100 uA Ti12+, and minimize consumption of this expensive, low-abundance isotope.

WEB: Contributed Talks
25 June 2025 11:30 - 12:30

Note: sequence of presentations for Session WEB: WEB01, WEB04, WEB03. (WEB02 will not be presented).

WEB01 / 11:30

New generation Bunch Shape Monitor for ion linacs

Aurora Cecilia Araujo Martinez, Adam Moro, Alexander Smirnov, Ronald Agustsson, Sergey Kutsaev (RadiaBeam Technologies, United States), Alexander Aleksandrov (Oak Ridge National Laboratory).

Measuring longitudinal beam parameters is essential for the operation and development of high-intensity linear accelerators, but it remains a significant challenge for ion beams at non-relativistic energies. The Bunch Shape Monitor (BSM) is a diagnostic device that uses secondary electrons emitted from a wire inserted into the beam, which retains the temporal charge distribution of the primary beam. The existing BSM models suffer from low electron collection efficiency and are limited to one-dimensional measurements of the longitudinal phase coordinate. To address these limitations, RadiaBeam has developed a next-generation BSM with enhanced performance. Key upgrades include a focusing field between the wire and entrance slit to improve electron collection efficiency, an upgraded microwave deflector for greater beam linearity, and a movable mechanism enabling simultaneous transverse profile and longitudinal measurements. In this talk, we present the design, fabrication, and testing of the new BSM prototype, along with the future improvements driven by the experimental feedback.

WEB04 /11:50
WEP12/SUP30

Enhancing ALPI-PIAVE performance at INFN-LNL with advanced optimization algorithms

Ysabella Kassandra Ong, Andrea Pisent, Damiano Bortolato, Enrico Fagotti, Luca Bellan, Maurizio Montis, Michele Comunian (Istituto Nazionale di Fisica Nucleare).

The ALPI-PIAVE heavy-ion accelerator complex at INFN-LNL requires precise tuning to achieve optimal performance, particularly given its complex beam dynamics and high-dimensional parameter space. Although the facility is designed for 60% transmission, actual transmission rates are significantly lower, around 15–20%, highlighting the need for improved optimization strategies. In this work, we compare advanced optimization techniques, specifically Bayesian Optimization (BO) and Trust Region Bayesian Optimization (TuRBO), to enhance the efficiency, reliability, and adaptability of ALPI-PIAVE operations. Since Bayesian optimization algorithms are sensitive to accelerator parameter drifts, we integrated Particle Swarm Optimization (PSO) to improve robustness. Additionally, we conducted controlled instability tests to evaluate performance under dynamic conditions. The results of these experiments and their implications for real-time accelerator tuning are presented in this paper.

WEB03 / 12:10

A scintillator-based monitor for real-time, high-resolution imaging and analysis of high-intensity to single-particle ion beams

Peter Friedman (Integrated Sensors, LLC), Claudio Ferretti, Daniel Levin, Nicholas Ristow (University of Michigan), Thomas Ginter (Facility for Rare Isotope Beams).

We have developed a scintillator-based beam monitor (SBM) for real-time beam analysis over a wide range of isotopes, energies and intensities. It has attracted particular attention at facilities where single-particle and fast beam imaging and tuning are at a premium. Two types of proprietary scintillators are used: 1) a semi-crystalline polymer material (PM) with a thickness of ~1 to 200 microns, yielding stronger signals per unit thickness than tested PVT-based plastic scintillators; 2) a hybrid material (HM) of ~100-400 microns thick, yielding order-of-magnitude larger signals per unit thickness than single crystal CsI(Tl), producing sharp beam images with minimal internal reflections. These scintillators are non-hygroscopic with HM being especially radiation damage resistant. An SBM prototype was staged at FRIB with a 2.7 MeV/u ion-beam of Kr-86 demonstrating real-time beam profiles and rate analysis from single-particles to >10^5 pps with ~20 micron spatial resolution. A commercialized second-generation SBM product was installed and successfully tested on the ReA3-SECAR FRIB beamline using a 4.5 MeV/u beam of mixed and "pure" Cl-35 and N-14 ions over a range from 10-10^7 pps.

WEB02 / withdrawn

Overview and progress of the HIAF beam diagnostics system

Junxia Wu (Institute of Modern Physics, Chinese Academy of Sciences).

The heavy ion accelerator facility (HIAF) under construction in China produces various stable and radioactive intense beams with energies ranging from MeV/u to GeV/u. It is a next-generation, storage-ring-based heavy-ion research facility, focusing on interdisciplinary studies in nuclear physics, nuclear astrophysics, atomic physics, and heavy ions applications for society. The construction of HIAF started in December of 2018 and the machine commission is scheduled in 2025. Presently the installation of all beam instruments has been finished and the instruments commissioning is going on. An overview of the whole beam instruments will be given.

WEZ: Invited Talks

25 June 2025 14:00 - 14:40

WEZ01 / 14:00

Single-bunch extraction at the 88-Inch Cyclotron

Michel Kireeff Covo (Lawrence Berkeley National Laboratory).

The extraction system of the 88-Inch Cyclotron at Lawrence Berkeley National Laboratory has been modified to enable single-bunch extraction. This is achieved by increasing the voltage of the first deflector to oversteer the beam, halting extraction, and then selectively switching it off using a high-voltage chopper to synchronize the deflector's

operational voltage with the transit time of a single bunch, enabling its extraction. A pre-chopper positioned before the cyclotron limits the beam available for acceleration, minimizing activation and sputtering damage from discarded bunches. This cost-effective technique is crucial for time-sensitive experiments and provides precise control over dose delivery, broadening the cyclotron's range of applications. Future efforts will focus on increasing extraction frequency by optimizing the deflector electronics for faster recovery times, and exploring sequential switching of two deflectors to reduce the required oversteering voltage.

WEZ02 / 14:20

Advances in transverse beam halo characterization and implications for HL-LHC

Milica Rakic (École Polytechnique Fédérale de Lausanne), Pascal Hermes, Stefano Redaelli (European Organization for Nuclear Research).

Measurements of the transverse beam halo in the LHC showed that it contains a non-negligible portion of the total stored beam energy, with implications for both collimation system performance and overall machine protection. As the HL-LHC era, with a significant increase in stored beam energy approaches, the understanding and modelling of the beam halo distribution becomes even more important. This applies particularly for the risk quantification in view of new failure scenarios.

This contribution summarizes the recent progress in beam halo measurement, new findings from refined analysis methods, an overview of the employment of key measurement techniques, and advancements in experiments aiming to quantify the origin of beam halo. We describe the latest halo models and how they affect the performance of potential active halo control mechanisms in simulations. These developments form a critical input to HL-LHC machine protection strategies.

WEC: Contributed Talks

25 June 2025 14:40 - 16:00

WEC01 / 14:40

Study on high-current beam extraction methods of a q/A=1/2 K100 compact cyclotron for multi-disciplinary utilization

Jong-Won Kim (Institute for Basic Science).

High-current beam extraction from a compact cyclotron is limited by extraction efficiency since slight beam losses at the extraction can cause severe radio activation. In fact, high-current compact cyclotron for positive ions has not been developed. We have designed a high-current q/A=1/2 K100 compact cyclotron to accelerate H2+, D+ for medical isotope and neutron production, and light heavy ions such as 14N7+, 36Ar18+ for space radiation test and radiobiology. The beam energy is 25 MeV/u and proton current expected to be over 2 mA. Extraction efficiency of over 99.5 % is required at a beam power of 50 kW to allow hands-on maintenance. According to optics simulation a single-turn extraction can be achieved using electrostatic deflector with the help of orbital precession induced by 1st harmonic field. The radial gain with four RF dees at 100 kV is ~10 mm by acceleration and

enlarged by precession. In addition, we explored a magnetic extraction method (self-extraction) with a groove locally reducing the sector magnet. Charge-stripping extraction was studied for H2+ beam to enable energy variability. Finally, a layout of the facility is envisioned for multi- disciplinary utilization.

WEC02 / 15:00
SUP24

The beam dynamics case of Beam-Beam Wire Compensators for the HL-LHC era
Philippe Belanger (University of British Columbia & TRIUMF), Dobrin Kaltchev, Rick Baartman (TRIUMF), Guido Sterbini (European Organization for Nuclear Research).

Beam-beam long-range interactions are known to be a strong source of non-linearities in hadron colliders, undermining the performance of the LHC during proton-proton collisions. In order to enhance the luminosity production of the machine and increase the tolerance of the working point after the High Luminosity upgrade of the LHC (HL-LHC), dedicated correctors such as beam-beam wire compensators can be used. In this paper, the beam dynamics of this compensation problem is studied in details, ultimately showing that the linearity of the machine can be significantly improved throughout the beam core --- and up to several sigmas --- leading to an improvement of the Dynamic Aperture (DA) of the machine. This conclusion is shown to be supported by analytic calculations, dynamic aperture simulation studies, as well as experimental results presented in earlier work. Both nominal and pacman bunches are shown to benefit from the compensation. In the proposed approach, wire compensators can be positioned according to the collimation settings, simplifying their practical implementation in the machine for the HL-LHC era.

WEC03 / 15:20

A multi-voltage FEBIAD ion source for the study of molecular properties
Alexander Schmidt, Bernard Crepieux, Justus Berbalk, Katerina Chrysalidis, Line Le, Mathieu Bovigny, Mia Au, Sebastian Rothe, Stefano Mazari (European Organization for Nuclear Research), Maximilian Mario Schütt (GSI Helmholtz Centre for Heavy Ion Research), Santiago Ramos Garces (Belgian Nuclear Research Centre), Yazareth Peña Rodríguez (Universidad Nacional Autónoma de México).

Radioactive ion beam facilities produce and extract isotopes and species of interest by employing a variety of target materials and ion sources. The forced electron beam induced arc discharge (FEBIAD) type plasma ion source * ** is the principal choice for volatile species such as noble gases and molecules and is also used in case surface or resonant laser ionization is insufficient.

In its standard configuration, the electron energy is defined by the potential difference between the grounded cathode and the floated anode cavity. At CERN-ISOLDE, a special multi-voltage FEBIAD ion source has been prototyped, which isolates the electron acceleration grid from the main anode cavity body and decouples the cathode potential from the ground. This separation allows to tune the electron energy and potential shape within the anode, with the goal of studying properties such as ionization and dissociation energies of radioactive molecules.

The influence of the multi-voltage assembly on the electron energy and electric field was characterized by simulations. Their results served as a reference for measurements on stable molecules, which were carried out at the ISOLDE Offline 2 separator.

* L. Penescu et al., Rev. Sci. Instrum, 2010, 81(2)
** Y. Martinez Palenzuela et al., Nucl. Instrum. Methods Phys. Res. B, 2018, 431(59)

WEC04 / 15:40

Design and operation of Extended EBIS at Brookhaven National Laboratory

Edward Beebe (Brookhaven National Laboratory).

Extended EBIS (EEBIS) was commissioned during Spring 2023 as an intensity upgrade to RhicEBIS. Notable features include extended trap regions, a highly efficient gas injection cell and partitioned ultra high vacuum regions.

EEBIS has delivered high charge state ions to the NASA space radiation laboratory during its first year of operation, after a brief commissioning period. Intensity of 12 pulse, 5Hz Au32+ ion beams were not sufficient to provide Au ions for the RHIC accelerator program during the first year of operation.

Modification to the EEBIS upstream drift electrode structure have been made to decrease HV arcing within the short trap region. In addition, the electron gun barium oxide cathode has been replaced with the previously employed RhicEBIS iridium cerium cathode type, in order to provide more robust electron beams at high electron beam duty factors used for injection scheme for the RHIC accelerator.

Recommissioning of the EEBIS will begin in Mid March 2025 with ion beams expected to be available to the AGS booster ring by the end of April 2025.

WEP: Wednesday Poster Session

25 June 2025 16:20 - 18:00

WEP01

Design of a compact synchrotron for HiTS 400s, a hybrid ion therapy system

Tenghui Rui (Tsinghua University), Jian Shi, Lizhen Ma (Institute of Modern Physics, Chinese Academy of Sciences), Xiaopeng Jiang (Tsinghua University).

The synchrotron in the Hybrid Ion Therapy System (HiTS 400s) is designed to provide a compact, high-performance accelerator for multi-ion radiotherapy, with a circumference of under 35 meters. This paper presents the design and development of the synchrotron, focusing on key aspects such as lattice optimization, multi-turn injection, third-order resonance slow extraction, and space charge effects. The synchrotron employs a compact lattice that balances a reduced footprint with sufficient dynamic aperture. A multi-turn injection scheme is implemented to maximize beam intensity and enable multi-ion injection. The third-order resonance extraction system is optimized to ensure a stable and uniform extracted beam suitable for clinical dose delivery. Additionally, space charge effects are analyzed to assess their impact on beam dynamics. The results demonstrate the

feasibility of achieving both compact size and high beam quality, paving the way for future advances in ion beam radiotherapy systems.

WEP02

The development of superconducting magnets for a compact heavy ion therapy facility

Wenjie Yang, Jian Shi, Lizhen Ma, Xinlong Zhu, Peng Li (Institute of Modern Physics, Chinese Academy of Sciences).

A compact heavy ion therapy facility, currently under construction by Lanzhou Ion Therapy Co., Ltd. in China, is set to utilize advanced superconducting magnets. This facility features a superconducting synchrotron accelerator with a circumference of less than 35 meters, complemented by a superconducting rotating gantry. The synchrotron accelerator is equipped with eight 45-degree superconducting dipole magnets, each designed to maintain a good field region of at least 100 mm, a central magnetic field of no less than 3 T, a ramping rate of 1 T/s, and exceptional magnetic field uniformity exceeding 3E-4. In the rotating gantry, superconducting magnets are configured in a combined dipole-quadrupole arrangement, in which a 45-degree bending dipole magnet is integrated at both ends with two 20-degree quadrupole magnets. The rotating gantry consists of six sets of these combined dipole-quadrupole superconducting magnets. This article focuses on the design of these magnets and the preliminary test results.

WEP03

Mitigating the thermal challenges in carbon stripper: test bench simulation to enhance the device stability

Basil Abdelmegied, Felix Marti, Takuji Kanemura (Facility for Rare Isotope Beams).

The Facility for Rare Isotope Beams (FRIB) LINAC utilizes two stripper media: liquid lithium and carbon, the beam energy is 17-20 MeV/u. Thermal stress management in carbon strippers is crucial for improving the performance and durability of components. This study focuses on simulating the beam heating with a 460 nm laser beam as a heating source to evaluate its effect on a carbon foil and to guide design updates for use with high power heavy ion beams. The first objective is to measure the carbon foil's emissivity under controlled conditions, which is crucial for understanding thermal behavior and energy transfer. The laser beam has a predetermined intensity to accurately determine the foil's emissivity. Proposed design updates include replacing existing components with more durable metal gears, bearings, coating the inner walls with high-emissivity paint to improve thermal efficiency, and integrating a proximity sensor to monitor the rotational speed of the drive gear. These modifications are expected to optimize the measurements, which will consequently help improving the performance of the Carbon Stripper and ensure the longevity of the system under high-temperature conditions.

WEP04

Evidence of fission gas bubble in high burn-up structures in nuclear target

Gajigatte Umapathy, Pankaj Kumar (Inter-University Accelerator Centre), Santanu Ghosh (Indian Institute of Technology Delhi), Dinakar Kanjilal, Sundeep Chopra, Sunil Ojha (Inter-University Accelerator Centre).

The MeV-range energetic ions beyond Coulomb's barrier of a target-beam combination lead to nuclear reactions, subsequently evaporation's leave or submerge the target materials. This is through extreme high temperature referring as high burn up structure (HBS). The Erbium (Er) is used as burnable, neutron absorber with nuclear fuel matrix. Its quite interesting to observe pure Er under reaction environment. In this study, I present the evidence of HBS of

1. Elongated and vermicularinter-granular bubbles in Te.
2. Clustered spherical inter-granular bubbles and fuel cracks in Er and Tm.
3. Carbonaceous deposits on Sn.

via SEM observation. The RBS, EDS and XRD characterization results of these nuclear targets will also be presented.The details of the experiments are in Table 1 with reference list.

WEP05/SUP26

Minimization of residual resistance with ultra-low background magnetic field in 644 MHz medium-velocity nitrogen-doped superconducting elliptical cavities for FRIB400

Sean Moskaitis, Peter Ostroumov, Sang-Hoon Kim, Yoo Lim Cheon (Facility for Rare Isotope Beams).

Advancements in superconducting cavity surface treatment have increased residual resistance sensitivity to the trapped magnetic flux primarily caused by background magnetic field. A fast cooldown was implemented in 1.3 GHz TESLA cavities to improve flux expulsion. The larger size of 644 MHz medium-velocity 5-cell elliptical cavities for the FRIB energy upgrade (FRIB400) introduces challenges in reaching cavity temperature gradients needed for effective flux expulsion during fast cooldown, which risks additional trapped magnetic flux due to thermoelectric currents. Therefore, we are investigating feasibility of a slow cooldown with minimal background magnetic field. To determine allowable background magnetic field, we measured the residual resistance sensitivity to trapped magnetic flux in a 1-cell nitrogen-doped (N-doped) FRIB400 R&D cavity. We also optimized a magnetic shield design to reach ultra-low (<1 mG) background magnetic field at cryogenic temperatures and measured its field attenuation. We will present the measured magnetic permeability of two materials at cryogenic temperatures and discuss their feasibility to meet operation requirements in future FRIB400 cryomodules.

WEP06/SUP28

Image mapping for multiple charge state beams using a beam induced fluorescence profile monitor

Aubrey Lokey (Facility for Rare Isotope Beams).

Work continues on a minimally invasive, nitrogen fluorescence gas sheet at the Facility for Rare Isotope Beams (FRIB). A low density gas sheet may be used to observe the 2D

transverse beam profile of high intensity, multiple charge state beams with minimal interference. Spatially and temporally correlated profiles are of particular interest in locations where there is significant charge state spread, such as the FRIB linac folding segments. A low-density gas sheet measurement system offers advantages for gas handling in nitrogen sensitive areas, however signal intensity is significantly lower than techniques using higher density gas sheets and jets. This work discusses measurement considerations for photon distributions generated by several spatially separated interaction points and design considerations for a high-sensitivity optics system for handling the expected low signal intensity.

WEP07

Beam loss detection and mitigation at FRIB

Scott Cogan, Alexander Plastun, Douglas McNanney, Peter Ostroumov, Shen Zhao, Steven Lidia, Takuji Kanemura, Tomofumi Maruta (Facility for Rare Isotope Beams), Qiang Zhao (Michigan State University).

This work presents an overview of beam loss detection and mitigation at the Facility for Rare Isotope Beams (FRIB). A diverse array of loss monitoring systems—including ion chambers, neutron detectors, halo rings, fast thermometry, and differential beam current monitors (BCM)—are deployed to detect losses ranging from large events that risk machine damage to low-level losses that result in undesirable machine activation. To ensure protection, hundreds of detector thresholds with varying time responses are precisely configured for each beam mode, ion species, and energy. The Threshold Configuration Tool (TCT), a sophisticated software solution, optimizes these thresholds to safeguard the machine while minimizing false trips. Additionally, FRIB's high-power beam employs a novel self-healing liquid lithium film charge stripper, which introduces beam energy fluctuations and occasional gaps in the film, leading to downstream losses. Fast and slow feedback systems stabilize the post-stripper beam energy, effectively reducing these losses. This work will discuss how FRIB experiences running at 10kW beam power influenced the evolution of our systems and tools.

WEP08

Beam intensity prediction for ECR ion source using machine learning

Yasuyuki Morita (RIKEN Nishina Center), Ayumi Kasagi (Rikkyo University), Keita Kamakura (Saitama University), Naoya Oka (National Institute of Information and Communications Technology), Takahiro Nishi (RIKEN Nishina Center).

Long-term beam stability is one of the important issues in supplying heavy ion beams using an Electron Cyclotron Resonance Ion Source (ECRIS). When the beam intensity decreases in long-term operation, we should tune the ECRIS parameters to restore the original beam intensity. Continuous measurement of the beam intensity using a Faraday cup is impractical while the beam is in use. We have had to rely on an unreliable method of monitoring the total drain current to estimate the beam intensity during the beamtime. To resolve this issue, we propose a new method for predicting the beam intensity using machine learning. Our approach uses plasma images, captured through the beam

extraction electrode, in addition to the operating parameters as input for the machine learning model. In short-term test datasets, our model has successfully predicted the beam intensity. In addition, ablation studies have shown that plasma images are essential for beam intensity prediction. This presentation will detail the prediction model and its results on the test data.

WEP09

JuTrack, a Julia-based tool for accelerator modeling and tracking with auto-differentiation

Jinyu Wan, Christian Ratcliff, Helena Alamprese, Yue Hao (Facility for Rare Isotope Beams), Ji Qiang (Lawrence Berkeley National Laboratory).

JuTrack is a novel accelerator modeling and tracking package developed in the Julia programming language. Taking advantage of compiler-level automatic differentiation (AD), JuTrack allows rapid and accurate derivative calculations for arbitrary differentiable functions. This paper introduces the core capabilities of JuTrack, including lattice modeling and particle tracking, and demonstrates how AD-derived derivatives enhance the efficiency of beam physics studies through several practical examples.

WEP10

Machine-Learning-Assisted Rapid Beam Energy Change at the ATLAS Heavy Ion Linac

Adwaith Ravichandran, Brahim Mustapha (Argonne National Laboratory).

Studying nuclear reactions to develop new medical isotopes requires the measurement of production cross sections at varying beam energies. To do this efficiently, the energy needs to be changed rapidly to avoid wasting precious beam time. Such data is also needed to improve the accuracy of nuclear reaction codes. We present recent experimental results, employing machine learning methods, for rapid tuning of an 16O beam following a manual energy change from 106 MeV to 71 MeV. ML tuning optimization was first performed for the 106 MeV beam, then the energy was changed to 71 MeV and the settings scaled by the ratio of magnetic rigidities. A second ML optimization was then carried out for the 71 MeV beam to maximize transmission. The energy switch and re-tuning procedure took less than 15 minutes. The collected data is then used to validate the same procedure in a virtual model of ATLAS running the TRACK simulation code. The validated model is used to emulate a prospective experimental run with energy change included as part of the machine learning procedure by incorporating the tuning of accelerating elements and subsequent transport lines to change the beam energy over a wider range

WEP11

Design improvements of a minichannel beam dump wing through AI-driven Genetic Algorithms

Geunhyeong Lee, Jeongseog Song, Mohit Patil, Nathan Bultman, Raul Quispe-Abad, Takuji Kanemura (Facility for Rare Isotope Beams).

At the FRIB (Facility for Rare Isotope Beams), a minichannel beam dump with 2 mm x 7mm water passages can dissipate about 20 kW of heat through high-velocity flow. Its

central region features a 6°-tilted CuCrZr absorber plate with an explosion-bonded 2219 Al cooling channel for efficient convection. The wing-section surface, angled from 6° to 90° next to the absorber plate, experiences higher heat fluxes and maximum temperatures, becoming more severe as the beam size increases. Optimizing the beam dump's geometry is therefore essential to accommodate variable beam sizes and absorb higher beam power. Even small angle changes in the surface orientation significantly affect the heat distribution, which raises the temperature of the CuCrZr plate and complicates global optimization in a limited space. To address this, a Genetic Algorithm (GA) explores a wide range of designs to prevent premature convergence, while a Soft Actor-Critic (SAC) method fine-tunes the details. A 2D finite volume method is employed to reduce the computational load. By merging the GA's broad search with SAC's adaptive refinement, the design can withstand higher heat loads under diverse beam conditions.

WEP12 /WEB04 SUP30

Enhancing ALPI-PIAVE performance at INFN-LNL with advanced optimization algorithms

Ysabella Kassandra Ong, Andrea Pisent, Damiano Bortolato, Enrico Fagotti, Luca Bellan, Maurizio Montis, Michele Comunian (Istituto Nazionale di Fisica Nucleare).

The ALPI-PIAVE heavy-ion accelerator complex at INFN-LNL requires precise tuning to achieve optimal performance, particularly given its complex beam dynamics and high-dimensional parameter space. Although the facility is designed for 60% transmission, actual transmission rates are significantly lower, around 15–20%, highlighting the need for improved optimization strategies. In this work, we compare advanced optimization techniques, specifically Bayesian Optimization (BO) and Trust Region Bayesian Optimization (TuRBO), to enhance the efficiency, reliability, and adaptability of ALPI-PIAVE operations. Since Bayesian optimization algorithms are sensitive to accelerator parameter drifts, we integrated Particle Swarm Optimization (PSO) to improve robustness. Additionally, we conducted controlled instability tests to evaluate performance under dynamic conditions. The results of these experiments and their implications for real-time accelerator tuning are presented in this paper.

WEP13

Operation and development of FRIB 28 GHz ECR ion source

Junwei Guo, Dan Morris, Eleazar Gutierrez, Haoyu Cheng, John Brandon, Joseph Backlas, Shen Zhao, Ting Xu, Tomofumi Maruta, Xiaoji Du, Xing Rao, Yoonhyuck Choi (Facility for Rare Isotope Beams), Diego Arbelaez, Paolo Ferracin, Soren Prestemon, Tengming Shen, Yang Ye (Lawrence Berkeley National Laboratory), Guillaume Machicoane, Larry Tobos, Randall Rencsok (Michigan State University).

HPECR (High-Power superconducting electron cyclotron resonance ion source) has been in routine operation at 18 GHz for FRIB (Facility for Rare Isotope Beams) since Jan. 2023. It has delivered various species of heavy ion beams for user experiments such as 28Si11+, 48Ca10+, 58Ni17+, 124Xe26+ and 238U35+ etc., and the total beam time so far has

exceeded 3600 hours. To meet the FRIB beam power ramp-up demand, a 28 GHz/10 kW gyrotron microwave transmitter has been installed and tested, with the source commissioning is currently in progress. In this contribution, a review of the operation of the HPECR ion source at FRIB will be presented. Typical performances, operation status, as well as the future development plans will be discussed.

WEP14

Beam diagnostics in ARIS to investigate wedge defect at FRIB

Daid Kahl, Alexander Dombos, Kei Fukushima, Marc Hausmann, Xing Rao (Facility for Rare Isotope Beams), Bradley Sherrill, Elaine Kwan, Mallory Smith, Mathias Steiner, Mauricio Portillo, Oleg Tarasov (Michigan State University).

The Facility for Rare Isotope Beams (FRIB), operating at Michigan State University since 2022, produces a variety of nuclear species via fragmentation or fission. Heavy ions are accelerated by the FRIB LINAC to energies of >170 MeV/u which impinge on mm-thick graphite targets to make the RIs in-flight. The resulting cocktail of ions are separated and purified with the Advanced Rare Isotope Separator (ARIS). Magnetic separation of isotopes with the same A/Z ratio is performed with an achromatic energy degrader or wedge. As the first stage of ARIS involves a momentum compression of k=3, the pre-separator wedge geometric cross section is more complex than a simple isosceles triangle, having a parabolic shape to reduce aberrations. Wedge inhomogeneities from imperfect machining or within the material itself (e.g., bubbles, density variations) can adversely affect the beam's phase space, resulting in a larger beam spot size and lower transmission. Here we report a comparison of different wedge materials using standard beam diagnostics from viewers and position-sensitive detectors. Particular attention is paid to the calibration procedure for parallel plate avalanche counters (PPACs).

WEP15

Design and installation of the RAON In-Flight Fragment Separator

Taeksu Shin, Chong Cheoul Yun, Do Dyun Kim, Eun Hee Kim, Jang Youl Kim, Sukjin Choi (Institute for Basic Science).

The In-Flight (IF) fragment separator, a central component of the Rare Isotope Accelerator complex for ON-line experiments (RAON), has been installed to facilitate the production and separation of rare isotope beams at high energies. Designed as a next-generation system, the RAON IF separator features a two-stage configuration with large momentum (±3%) and angular acceptances (±40 mrad horizontal, ±50 mrad vertical), and a maximum magnetic rigidity of 7.5 Tm. The system comprises a production target, beam dump, magnet assembly, and a detector suite for particle identification. Both the production target and beam dump are constructed from graphite and are capable of withstanding beam powers up to 80 kW. The magnet system integrates high-temperature superconducting (HTS) magnets (6 quadrupoles, 1 sextupole), low-temperature superconducting (LTS) magnets (13 quadrupole triplets), and resistive magnets (8 dipoles, 1 sextupole), enabling high-efficiency transmission and separation of exotic nuclei. Particle identification using a Bρ–ToF–ΔE

technique is implemented at key focal planes. An overview of the RAON IF separator's design, components, and operational readiness will be presented.

WEP17

Processing technology of FSQ1 radiation-resistant quadrupole magnet

Junjie Yao (Lanzhou Ion Therapy Co., Ltd.).

The FSQ1 quadrupole magnet in the Facility for Rare Isotope Beams (FRIB) at Michigan State University (MSU) is a core magnetic component designed for ultra-high vacuum (UHV) and radiation environments. This magnet adopts an innovative split-type structural design, the iron core uses DT4 material with a modular pole-yoke split structure for precision assembly, while incorporate a vacuum chamber into the core to seal the coil in vacuum environment. Key technical improvements for the extreme operating conditions including optimized thermal conduction paths at the pole-yoke interface and vacuum pipe-coil assembly to enhance thermal management, applying nickel plating on the iron core surface to reduce the outgassing rate of the material to meet the UHV requirements, utilizing five-axis CNC precision machining to control pole accuracy, innovating vacuum epoxy potting of coils to reduce insulation layer bubbles. Experiments confirms that the magnet meets FRIB's stringent requirements for UHV maintenance, radiation resistance, and long-term operational stability.

WEP18

A Phenomenological Model of the Fundamental Power Coupler for a Superconducting Resonator

Ran Huang, Yuan He (Institute of Modern Physics, Chinese Academy of Sciences).

A phenomenological model of the RF Behavior of the superconducting cavity fundamental power coupler is proposed in this paper by analyzing the simulation results of a transient beam loading process in an extreme over-coupled superconducting cavity. With this phenomenological model, the calculation of the transient reflected power from a superconducting cavity under beam loading can be mathematically simplified to algebraic operations without solving the differential equation governing the transient beam loading process and maintaining the calculation accuracy. Moreover, the simple and vivid physical picture provided by this phenomenological model can facilitate understanding intuitively the incredible surge in the time evolution of the reflected power from a superconducting cavity in certain beam loading processes. The validity of the phenomenological model has been carefully examined in various beam loading processes and cavity conditions, while the method based on this phenomenological model has been utilized in the transient RF analysis of the superconducting cavity system of the CAFe Linac and achieved satisfying results.

Study of ponderomotive instability in the FRIB beta=0.53 half-wave resonator

Jacob Brown, Sang-Hoon Kim, Shen Zhao, Ting Xu, Wei Chang (Facility for Rare Isotope Beams).

Superconducting radio-frequency niobium cavities are susceptible to deformations caused by external or internal forces, leading to shifts in the cavity resonant frequency. One source of deformation comes from the radiation pressure of the cavity fields, producing the so-called Lorentz force detuning effect. This effect can couple to the cavity mechanical modes in generator driven mode, leading to ponderomotive instability. In the FRIB 322 MHz, β=0.53 Half-wave Resonators (HWR), the instability appeared when the cavity was detuned, with thresholds depending on low-level RF control parameters, such as closed loop gain, as well as accelerating gradient. Using a measured Lorentz Transfer Function, Simulink simulations were conducted to predict the instability thresholds, which were then compared with the experimental results. We will discuss how these thresholds can be broadened to enable stable operation at higher gradients.

Multi-q beam studies at FRIB: simulations and measurements

Alec Gonzalez, Alexander Plastun, Kei Fukushima, Peter Ostroumov, Tomofumi Maruta (Facility for Rare Isotope Beams).

The Facility for Rare Isotope Beams (FRIB) linear accelerator is capable of simultaneously transporting and accelerating multiple-charge-state heavy-ion beams. Accurate transverse and longitudinal matching of these beams is a challenging problem, particularly in achromatic bending segments of the linac. To solve it, we employ both macroparticle tracking and linear optics codes. The simulation models are being developed, cross-checked, and validated by beam measurements. The studies are focused on the beam size, envelope matching, charge state separation, and the response of the beam position. The results of the studies with the 16.5 MeV/u five-charge-state uranium beam will be presented.

Production and tuning of heavy ion beams for FSEE experiments

Qiang Zhao (Michigan State University), Alexander Plastun, Kei Fukushima, Kilean Hwang, Peter Ostroumov, Steven Lidia, Tomofumi Maruta, Tong Zhang (Facility for Rare Isotope Beams), Guillaume Machicoane (Michigan State University).

FSEE has been established at the Facility for Rare Isotope Beams (FRIB) to provide heavy ion beams for testing Single Event Effects (SEE). It shares the existing FRIB front-end and the first segment of superconducting linac with a dedicated beam line and an end-user station. Highly charged ions in cocktails are produced with Electron Cyclotron Resonance ion sources. Beam species are then selected and injected into a cw Radio Frequency Quadrupole with an external buncher followed by a cw superconducting linac consisting of 100 quarter-wave resonators that can output continuously up to 20 MeV/u for heaviest ions and 40 MeV/u for light ions. The 17-meter FSEE line starts with a dipole followed by scattering

foils and a unique optical lattice consisting of 4 quadrupoles and 2 octupoles to obtain a uniform beam with size up to 20cm by 20cm. With 7 ions at 16 energies, FSEE has been providing an extensive range of beam parameters for users since its commissioning in 2021. We will present the design, development, and operation of the FSEE facility, discuss the beam tuning and characterization of beam parameters with sets of diagnostics and physics applications including Machine Learning.

WEP22/SUP07

Beam dynamics design of the superconductiong section of a 100 mA superconducting linac

Man Yi, Zhijun Wang, Shuhui Liu (Institute of Modern Physics, Chinese Academy of Sciences).

Beam loss is a critical challenge in the physics design of high power superconducting proton linacs. The challenge is even more acute in linacs that feature high peak intensity and low energy, which has strong space charge effect and RF nonlinear force. In this paper, we study how to achieve a high transmission rate for beam halo particles, commonly a major source of beam loss, via beam halo matching and acceptance optimization. We employ this method of beam loss reduction to improve the physics design of a high power 100mA superconducting linac which has potential applications in high brightness neutron production.

WEP23

Modular accelerator pulse power supply design based on SiC MOSFET

Tianrun Yang (Institute of Modern Physics, Chinese Academy of Sciences).

An all-sic modular design scheme for accelerator pulse power system is presented in this paper. A monopole frequency doubling hybrid SPWM modulation strategy is developed for the analysis of the front-end PWM rectifier. Zero cross distortion is eliminated by Fourier verification, and 2.8% THD is achieved. The hybrid control architecture combines the dynamic response of analog control (pre-stage rectification and intermediate-stage phase-shifted full bridge) with the algorithmic flexibility of post-stage H-bridge digital control. The comprehensive soft switch integrates pre-stage resistance-relay coordination, intermediate-stage LC-resonant ZVS, and digital ramp control for post-stage operation. The optimized SiC MOSFET driver circuit, with active clamping and RC buffers, suppressed 43% of voltage spikes while balancing the switching dynamics. This multi-layer power supply design realizes the application of high repetition frequency and high power.

WEP24/SUP27

Variable wedge for FRIB ARIS

Zhuoqun Wu, Marc Hausmann, Xing Rao (Facility for Rare Isotope Beams), Bradley Sherrill (Michigan State University).

At the Facility for Rare Isotope Beams (FRIB) Advanced Rare Isotope Separator (ARIS)*, wedges filter rare isotopes and produce beams of specified isotopes for experiments. Proper wedges (with the right thickness, angle, and density variation) efficiently collect and purify

rare isotope beams by selectively slowing desired beams and contaminants via atomic interactions while maintaining achromaticity.

Currently, wedges are designed, fabricated, and swapped for each experiment based on LISE++ analysis. While effective, this process requires significant preparation time, and the single-wedge operation allows no adjustments for calculation, material, or fabrication errors.

To enhance ARIS, a variable wedge system is being developed. It consists of four degraders: two with quadratic cross sections forming an angle-tunable wedge** and two linear-shaped pieces adjusting thickness. By modifying their positions, the system achieves angle variation of 1–20 mrad and thickness variation of 0.5–20 mm.

This paper presents the system's principle, design, performance estimation, and simulation results, demonstrating improved efficiency, higher isotope yield, and reduced FRIB operation costs.

* M. Hausmann, A.M. Aaron, A.M. Amthor, et al., "Design of the Advanced Rare Isotope Separator ARIS at FRIB," Nucl. Instrum. Methods Phys. Res. B, Vol. 317, Part B, 2013, pp. 349-353, ISSN 0168-583X.
** J. Hwang, S. Michimasa, S. Ota, et al., "Angle-tunable wedge degrader for an energy-degrading RI beamline," PTEP 2019 (2019) 4, 043D02, DOI: 10.1093/ptep/ptz028.

WEP27

Development for iLinac of HIAF Project at IMP

Yue Tao (Advanced Energy Science and Technology Guangdong Laboratory), Weilong Chen, Zhijun Wang (Institute of Modern Physics, Chinese Academy of Sciences).

The Superconducting Ion Linac (iLinac) of High Intensity Heavy-ion Accelerator Facility (HIAF) is composed of an ECR ion source, low energy beam transport line (LEBT), 81.25MHz radio frequency quadrupole (RFQ) accelerator, medium energy beam transport line (MEBT) and superconducting section composed by Quarter Wave Resonators (QWR007) and Half Wave Resonators (HWR015). The 238U35+ beam is accelerated by the RFQ accelerator from 0.014 MeV/u to 0.8 MeV/u and then to 17 MeV/u by 96th SC cavities. The room-temperature front end of the iLINAC has been assembled and successfully produced a beam at present. Three cryostats have been installed in the tunnel.

WEP29

The CYREN project: Refurbishment of the GANIL cyclotrons facility

Pascal Anger, Pierre-Emmanuel Bernaudin (Grand Accélérateur Nat. d'Ions Lourds).

For over 40 years, the GANIL facility has been supplying stable beams (carbon to uranium, 60 keV/A to 95 MeV/A) from a set of 4 cyclotrons and producing low- and high-energy radioactive ion beams for fundamental, applied and industrial research.

Since 2010, due to the SPIRAL2 construction and compliance projects following the first obligatory safety review since the French safety decree, the cyclotrons maintenance and refurbishment were reduced to a bare minimum, and as a consequence the failure rate increased over the years.

The outlined exceptional scientific program from the users at the facility is requesting GANIL to guarantee the operation over the next 20 years or more. Therefore an ambitious renovation program, the CYREN (Cyclotrons Renovation) project, was launched in 2024.

This article will cover the progress of this project. Detailing the challenges, partly due to the diversity of the different installations with theirs unique equipment's. The project covers everything from the 5 cyclotrons, beam lines, the associated experimental caves, building infrastructures, technical utilities and the safety, security and radiation protection systems.

WEP30 / 16:40

Radiation effects beamline developments at the Facility for Rare Isotope Beams

Steven Lidia, Alexander Plastun, Andreas Stolz, Douglas McNanney, Kei Fukushima, Kilean Hwang, Peter Ostroumov, Sang-Hoon Kim, Scott Cogan, Sergio Rodriguez Esparza, Shen Zhao, Tomofumi Maruta, Xing Rao (Facility for Rare Isotope Beams), Francisco Figueiredo (Brazilian Synchrotron Light Laboratory), Guillaume Machicoane, Qiang Zhao, Randall Rencsok (Michigan State University).

A new capability for heavy-ion single-event effects (SEE) testing in electronics systems has been implemented on the Facility for Rare Isotope Beams (FRIB) linear accelerator, providing beams to users in the ~10 – 40 MeV/nucleon range. We discuss the design and implementation of the FRIB SEE (FSEE) beamline and user interfaces including descriptions of: (i) the beamline optical lattice and layout; (ii) establishment and changing of linac tunes to support testing requirements; (iii) ion source development to support fast and frequent beam changes; and (iv) dosimetry instrumentation and user support infrastructure. We review operational experience and include discussion of ongoing development efforts in dosimetry and facility capabilities to deliver high-flux, short-pulse heavy ion beams. Development of the K500 cyclotron into a dedicated facility, and options for a high energy beamline are introduced.

THX: Invited Talks
26 June 2025 08:30 - 09:30

THX01 / 08:30

Mimicking the radiation environment of interplanetary space in the Lab & the BNL proposed High Energy Effects Test facility

Trevor Olsen (Brookhaven National Laboratory).

Heavy ion accelerators facilities, such as BNL's NASA Space Radiation Laboratory (NSRL), mimic the radiation environment in space by delivering proton and heavy ion beams over a range of beam energies. The focus of the research at NSRL has largely been on the NASA radiobiology program. In recent years researchers working on microelectronics for space have been using the facility. However, these new users have different demands from the traditional beam requirements for radiobiology and require significant amounts of beam time (thousands of hours). In this talk we describe the needs of space application experimenters and how the proposed High Energy Effects Test facility meets these challenges.

THX02 / 08:50

Recent developments in low and medium energy ion beam facilities for radiation effects testing

Steven Lidia (Facility for Rare Isotope Beams), Dannie Steski (Brookhaven National Laboratory), Henry Clark (Texas A&M University), Larry Phair (Lawrence Berkeley National Laboratory), Peter Linardakis, Thomas McGoram (Research School of Physics and Engineering).

Ion beam facilities that operate in the 0.01 to 50 MeV/u energy range are useful materials development and electronic testing of semiconductor components. Currently used accelerator architectures include tandem linacs, cyclotrons, and RF linacs which provide a wide set of testing parameters in terms of ion species, beam energy, spatiotemporal format, and flux. We report on the current status and planned facility developments at the tandem (ANU, BNL), cyclotron (LBNL, MSU, TAMU), and RF linac (MSU) facilities. Trends in use cases and anticipated demand to support various research communities are discussed.

THX03 / 09:10

High energy ion implantation at BNL

Charles Carlson, Dannie Steski (Brookhaven National Laboratory), Thomas Kubley (University of Michigan–Ann Arbor).

Silicon carbide (SiC) has several properties such as wide band gap and high voltage breakdown, that give it a significant advantage over silicon for the next generation of medium and high frequency applications. To fully realize these advantages, requires deep ion implantation (~>6 μm). Unfortunately, the energy of conventional ion implanters limits the implantation depth in SiC to approximately 1 μm. Brookhaven National Laboratory (BNL) has developed a system that uses the 15 MV MP-class Tandem Van de Graaffs to implant ions in

SiC to a depth >15 µm. By changing the ion beam energy in discrete steps, the overlapping implantations can build a uniform implantation profile from the maximum implantation depth to the surface. To implant ions near the surface of the SiC wafer requires the use of an energy absorber to degrade the ion energy from 10's of MeV to a few keV. BNL has built a system to demonstrate the feasibility of this approach. The BNL system is described, and the results of high energy implantation for high voltage SiC devices are presented. Future improvements to the system are also discussed.

THA: Contributed Talks

26 June 2025 09:30 - 10:30

THA01 / 09:30

Vacuum system for Super-FRS at FAIR: radiation-tolerant design and remote handling solutions

Neeraj Kurichiyanil, Andreas Kraemer, Christos Karagiannis, Helmut Weick, Sivaji Purushotaman (GSI Helmholtz Centre for Heavy Ion Research).

The Super-FRS at FAIR, a large-acceptance superconducting fragment separator, will produce heavy-ion fragments in a shielded target area and direct the beams to three experimental branches. Its vacuum systems must endure high levels of prompt and residual radiation, with irradiated components handled remotely during maintenance. Beyond supporting diverse experimental scenarios, challenges include significant outgassing, no bake-out capability, unconventional seals, and conductance limits. In the high-radiation target and pre-separator zones, specially designed inflatable metallic and elastomer seals enable remote handling of parts. Insertable plugs with beam diagnostics, collimator slits, degraders, and other components use self-sealing mechanisms. Radiation and accessibility constrain pump and diagnostic choices. This contribution outlines the vacuum design for the Super-FRS beamline and discusses specialized solutions implemented to achieve and maintain the required vacuum levels and ensure system maintainability over time.

THA02 / 09:50
SUP10

Phase space tomography at ATLAS using maximum entropy tomography

Anthony Tran (Facility for Rare Isotope Beams), Brahim Mustapha (Argonne National Laboratory), Yue Hao (Facility for Rare Isotope Beams).

We use one-dimensional measurements to reconstruct the four-dimensional phase space of an ion beam at the Argonne Tandem Linac Accelerator System (ATLAS) using maximum entropy tomography. This was accomplished with a novel algorithm that directly reconstructs 4D from 1D. The results were compared against a quadrupole scan measurement of the phase space. Finally, an error analysis method employing statistical analysis was used to estimate the errors.

THA03 / 10:10

Six-dimensional beam matching with linear accelerator structures

Yuri Batygin (Los Alamos National Laboratory).

Beam matching is a common accelerator design and operation technique to minimize beam losses. Although widely used, a full theoretical understanding of beam matching in 6D remains elusive. In this paper, we present an analytical treatment of 6D beam matching of a high-intensity beam in RF structures. We start within the framework of a linear model and apply the averaging method to a set of 3D beam envelope equations. Accordingly, we obtain a matched solution that is comprised of smoothed envelopes and periodic terms, describing envelope oscillations with the period of the focusing structure. We then consider the nonlinear regime, where the beam size is comparable with the separatrix size. Starting with a Hamiltonian analysis in 6D phase space, we attain a self-consistent beam profile, showing that it significantly differs from the commonly used ellipsoidal shape. Subsequently, we analyze the special case of equilibrium with equal space charge depression between all degrees of freedom. A comparison of beam dynamics for equipartitioned, equal space charge depression, and equal emittances beams is given. Finally, we present experimental results on beam matching in the LANSCE linac.

THY: Invited Talks

26 June 2025 10:50 - 12:10

THY01 / 10:50

NEWGAIN project at GANIL: construction of the new heavy ion injector for the superconducting LINAC

Frederic Chautard (Grand Accélérateur Nat. d'Ions Lourds).

A new project, NEWGAIN (NEW GAnil Injector), is under construction at GANIL, and aims to build a second injector for heavier beams with A/q up to 7, as an extension of the SPIRAL2 accelerator. With this upgrade, SPIRAL2 will provide high intensity beams, from proton to uranium, thus increasing GANIL international competitiveness both in fundamental science and associated applications.

The presentation will provide an update on the progress of the construction phase and the main milestones achieved and to come. The layout and the main technical components of the new injector, based on 2 ECR ion sources (one of them existing), two LEBT, one RFQ and a MEBT section to transport the beam into the present MEBT connected to the LINAC will be presented.

THY02 / 11:10

Demonstration of cavity field mapping by falling drops of liquid

Xiaonan Du (GSI Helmholtz Centre for Heavy Ion Research).

Experimental mapping of the electric field of a cavity is usually through bead-pull measurements. These require quite long times to align the bead and are generally restricted to the beam axis. Here, the bead has been replaced by drops of liquid falling through the

cavity. Together with efficient compression and noise reduction techniques, the method allows for fast and precise measurements. The launching position of the droplets is controlled by a motor driver, thus allowing for automated 3d-field mapping around the axis. Results from mapping a 36 MHz buncher cavity are presented.

THY03 / 11:30

Operation of a pulsed gas stripper during regular user beam time at GSI
Peter Gerhard, Michael Maier (GSI Helmholtz Centre for Heavy Ion Research).

The charge state spectrum of heavy ions like uranium stripped at 1.4 MeV/u using nitrogen can be narrowed significantly by applying pulsed injection of hydrogen into a dedicated interaction chamber. Pulsing reduces the load of the pumping system to an acceptable amount. Such a set-up is under construction at GSI/Germany. Time-resolved investigations of the build-up of the stripping target have been carried out. Recently, a prototype set-up has been operated during six months of user beam time, mainly with nitrogen but also with hydrogen. A number of ion species has been stripped in the course of the beam time, and a considerable amount of data on stripping efficiencies have been measured using both gases. The contribution summarizes the challenges related to establish such a set-up and the results being obtained so far.

THY04 / 11:50

RF power limits of 4-rod RFQs
Holger Podlech (Goethe University Frankfurt).

There is a long tradition at the Institute of Applied Physics at Frankfurt University of new developments for 4-rod. In the past years the RF-power front8ier of 4-Rod RFQs has been explored resulting in prototype tests that pushed the power dissipation in cw-mode into the regime of 4-Vane RFQs. For instance, during performance tests of a 6 stem prototype it could be demonstrated that a 4-Rod RFQ at high frequencies could reach up to 120 kW per meter. In this tests the input power and the electrode voltage was observed using gamma spectroscopy. An overview of activities at the IAP on this topic will be provided.

THW – Student Award Session
26 June 2025 12:10 – 12:30

FRX: Invited Talks
27 June 2025 08:30 - 08:50

FRX01 / 08:30

A charge stripper ring for RIBF
Hiroshi Imao (RIKEN Nishina Center).

For the upgrade of the RIKEN RI Beam Factory (RIBF) to increase the intensity of heavy ion beams, especially for the heaviest uranium beams the charge conversion efficiency of the two charge strippers (He gas and rotating graphite sheet disk strippers) is not sufficient and represents a serious bottleneck for the intensity upgrade. A new device called Charge Stripper Rings (CSRs) has been proposed and is being designed as an effective way to dramatically increase charge conversion efficiency beyond the 50% level, which is 10 times the current level. The design and development status of CSRs will be discussed.

FRA: Contributed Talks
27 June 2025 08:50 - 10:30

Note: sequence of presentations for Session FRA: FRA05, FRA01, FRA02, FRA03, FRA04.

FRA05 / 08:50

Reaccelerating long-lived radioisotopes at FRIB
Ana Henriques (Facility for Rare Isotope Beams), Alain Lapierre, Antonio Villari, Qiang Zhao, Samuel Nash (Michigan State University), Chandana Sumithrarachchi, Christopher Izzo, Hyock-Jun Son, Stefan Schwarz, Xiangcheng Chen (Facility for Rare Isotope Beams), Fernanda Garcia (SLAC National Accelerator Laboratory).

The ReAccelerator at FRIB successfully ran its first stand-alone beam in May 2021. Several technical upgrades were implemented to expand its scientific capabilities, including a new BMIS source, a room-temperature rebuncher, and the ReA6 accelerator with its corresponding experimental vault.

Following the successful commissioning of these upgrades, over 25 beams were delivered to experiments, including six long-lived radioisotopes: Be-7, Be-10, Al-26, Si-32, Ni-56, and As-73. However, isobaric contamination posed challenges for beam delivery, requiring various strategies to improve beam purity.

In this contribution, we outline the key steps that led to the success of the stand-alone program, including a description of the upgrades, approaches and results to mitigating isobaric contamination, and planned future improvements.

FRA01 / 09:10

Rare isotope beam tuning in FRIB

Kei Fukushima, Alexander Dombos, Daid Kahl, Marc Hausmann, Peter Ostroumov (Facility for Rare Isotope Beams), Bradley Sherrill, Elaine Kwan, Mallory Smith, Mathias Steiner, Mauricio Portillo (Michigan State University).

The Facility for Rare Isotope Beams (FRIB) provides rare-isotope beams for user experiments in nuclear physics, nuclear astrophysics, fundamental symmetries, etc. A superconducting driver-linac accelerates heavy-ion beams onto the production target, and the Advanced Rare Isotope Separator (ARIS) collects and purifies the rare isotope fragments of interest. Subsequently, the transfer hall beamlines deliver isotopes to user setups at experiment stations. The isotope beam condition from ARIS strongly depends on the fragment of interest. Therefore, the beamline settings are optimized for each experiment based on various users' requirements on the fly. Two new beamlines in the transfer hall were commissioned in 2025, bringing the total number of available end stations to five. Since the first user experiments in 2022, ongoing beam tests and operations have continued to improve operational efficiency and user satisfaction. Results and findings of beam tuning obtained from the commissioning and recent operations will be reported.

FRA02 / 09:30

Rare-isotope production optics of ARIS preseparator

Mauricio Portillo (Michigan State University), Alexander Dombos, Daid Kahl, Elaine Kwan, Evan Daykin, Igor Nesterenko, Jeongseog Song, Kei Fukushima, Marc Hausmann, Peter Ostroumov, Samuel Miller, Scott Cogan, Steven Lidia, Ting Xu, Tong Zhang, Xiaoji Du, Xing Rao, Yoonhyuck Choi (Facility for Rare Isotope Beams), Bradley Sherrill, Mallory Smith, Mathias Steiner, Oleg Tarasov (Michigan State University).

The Advance Rare Isotope Separator (ARIS) at FRIB provides in-flight purification of rare-isotope beams (RIB) generated by fragmentation or fission on a target. Beams of stable ions from a driver linac impinge on a graphite target that is thin enough such that products maintain velocities close to that of the incident beam. The incident primary beam impinge on-target at about 200 MeV/u (for uranium and higher for lighter species). The energy may be lower than the maximum allowed, depending on the requirements of the experiment.

Using multi-charge state acceleration, the linac has most recently provided up to 20 kW on-target with a long-term goal of reaching 400 kW. Specialized magnets, collimators and other components have been designed into the separator in order to withstand the harsh conditions and allow maintenance. The optics properties at the beam dump are important since the power density must be kept low enough to avoid failure of the material. We describe the various optics modes that have been developed for safe operations and maximizing the beam power allowed for RIB production.

FRA03 / 09:50

Particle identification using trajectory reconstruction with the ARIS separator system at the Facility for Rare Isotope Beams, FRIB

Elaine Kwan, Alexander Dombos, Daid Kahl, Kei Fukushima, Marc Hausmann, Shane Watters (Facility for Rare Isotope Beams), Bradley Sherrill, Mallory Smith, Mathias Steiner, Mauricio Portillo, Oleg Tarasov (Michigan State University).

The production of radioactive beams is crucial to understand structure of atomic nuclei away from stability. The operation of FRIB will ultimately provide access to previously unreachable unstable nuclei. Radioactive beams produced at FRIB can be selected and purified using the Advanced Rare Isotope Separator (ARIS) for further study by users. Ions are identified based on the energy loss, magnetic rigidity, gamma rays, time of flight, total energy in a suite of detectors. The transport of cocktail beams to the end of ARIS can impact the path length and the measured flight time. This can lead to uncertainty in the particle identification and worse timing resolution can occur if not corrected for. Characterizing the ion optics with position-sensitive detectors allows for corrections to the flight path of the ions. This in conjunction with the use of transfer matrices allows for the particle's trajectory to be reconstructed and thus correct for the variation in the measured time of flight. These corrections are crucial for enhancing charge-state identification, especially in a high-resolution optics mode. The impact of applying a trajectory reconstruction method will be presented.

FRA04 / 10:10

The SPES-ISOLPHARM beamline for the production of medical radionuclides at INFN-LNL

Alberto Arzenton (Univ. degli Studi di Padova), Alberto Andrighetto, Massimo Martello, Stefano Corradetti, aurora leso (Istituto Nazionale di Fisica Nucleare), Daiyuan Chen (Univ. degli Studi di Padova), Davide Serafini, Emilio Mariotti (University of Siena), Giulia S. Valli, Marcello lunardon, Sandra Moretto (University of Padua).

The ISOLPHARM project, headed by the Legnaro National Laboratories of the Italian National Institute for Nuclear Physics (INFN-LNL), has the aim of developing innovative radiopharmaceuticals based on the radionuclides produced at the SPES Isotope Separation On-Line (ISOL) facility. Regarding the infrastructure, in late 2024 a key milestone of SPES was achieved: the production of the first radioactive ion beam by irradiating a silicon carbide target with an intermediate-energy proton beam. Moreover, the ISOLPHARM implantation station for radionuclide delivery to users, IRIS, is currently being installed online. Since its beginning in 2014, ISOLPHARM has built a broad network of universities, hospitals and research centers. The beta emitter silver-111, in particular, obtainable using uranium carbide targets, has aroused a great interest in the collaboration as a theranostic candidate for targeted radionuclide therapy; a dedicated experimental campaign performed the first in-vitro tests and in-vivo imaging in 2024. This contribution will provide an overview on the status of the beamline and on the main results achieved by the preclinical experiments involving silver-111.

Note: abstract for FRA05 is included at the beginning of Session FRA.

FRB: Contributed Talks
27 June 2025 10:50 - 11:30

FRB01 / 10:50

A virtual machine model for the ATLAS ion linac at Argonne

Brahim Mustapha, Adwaith Ravichandran (Argonne National Laboratory).

A virtual machine model that seamlessly integrates with the online accelerator system would highly benefit the operators to test and evaluate beam tuning scenarios and apply them online. As part of this effort, the code TRACK is wrapped with control system architectures and a custom-made graphic user interface based on the Dash web application package. Customizability and task visualization are prioritized based on end user feedback. More important is how well the model agrees with the real machine. A recent effort to account for beam steering and misalignment effects has reduced the error between simulation and measurements from ~ 50% to ~ 10%. More work to reduce this error and further close the gap is currently underway. The concurrent execution of simulation with experiment for troubleshooting and parallel optimizations to quickly determine ideal element settings for the desired beam parameters are some of the features to be highlighted. Previously published AI-ML capabilities are incorporated to this extent. Simulation-based surrogate models benchmarked against collected data are being developed to speed up the process and reproduce the operating conditions in a timely manner.

FRB02 / 11:10

Development of compact accelerator based neutron sources for Canada, the PC-CANS project

Oliver Kester (TRIUMF), Drew Marquardt (University of Windsor), Mina Abbaslou, Robert Laxdal (TRIUMF).

Neutron scattering has proven to be one of the most powerful methods for the investigation of structure and dynamics of condensed matter on atomic length and time scales. The neutron science community faces a decline of sources for neutrons with research reactors shutting down and even with new spallation neutron sources coming online. In an effort to address this challenge, the global neutron community is responding by taking advantage of recent advances in accelerator technology to develop compact accelerator-based neutron sources (CANS). The Canadian community embarks on a prototype Canadian CANS (PC-CANS) development to perform the first step towards a national Canadian CANS facility of a next generation CANS. The technical development towards this new concept in context on activities in North America will be presented.

FRY: Closing
27 June 2025 11:30 - 12:30

FRY01 / 11:30

Recent nuclear science highlights from heavy-ion accelerator facilities
Alexandra Gade (Facility for Rare Isotope Beams).

This presentation will highlight the variety of scientific challenges that can be addressed in the field of nuclear physics with experiments enabled at heavy-ion accelerator facilities. The breadth of the discovery potential will be illustrated with recent examples from nuclear science laboratories around the world, with a focus on the exploration of rare isotopes.

FRY02 / 12:00

Closing Ceremony
Peter Ostroumov (Facility for Rare Isotope Beams).