



Discovery and Applications of Radio-Isotopes with the Facility for Rare Isotope Beams (FRIB)

Thomas Glasmacher, FRIB Laboratory Director
Michigan State University

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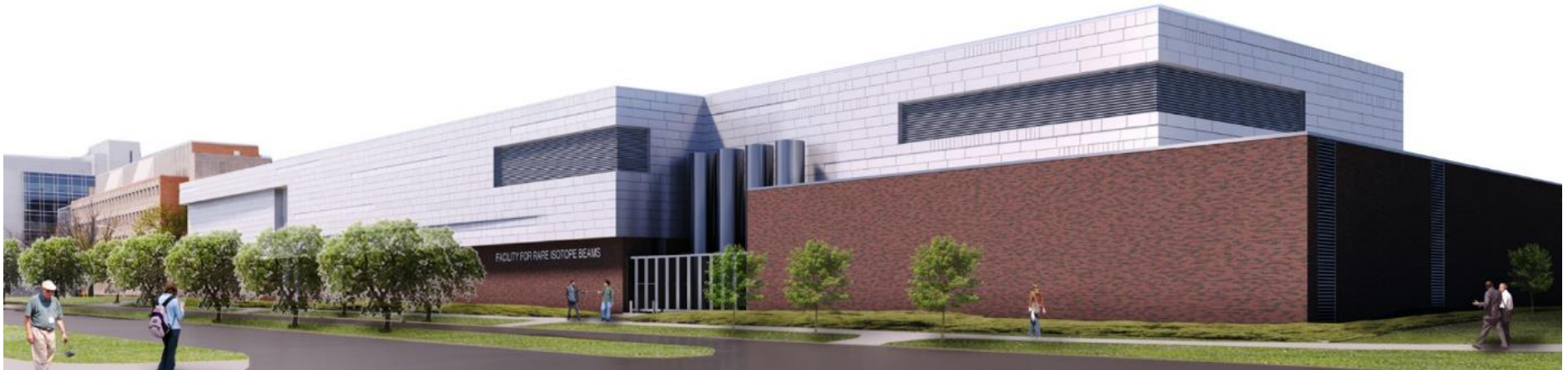


U.S. DEPARTMENT OF
ENERGY

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Science

Facility for Rare Isotope Beams Tracking to Early Completion in 2021

- FRIB is a DOE-SC scientific user facility for rare isotope research supporting the mission of the Office of Nuclear Physics in DOE-SC
- FRIB and DOE Isotope Program will partner to make available critical isotopes
- FRIB is based on a superconducting radio-frequency linear accelerator capable of accelerating all stable ions (hydrogen to uranium) to 200 MeV/nucleon at ultimately 400 kW power
- CD-4 date is June 2022, managing to early completion in 2021
- User program starts in early 2022



2021: Commissioned Entire Linac

^{86}Kr Beam Accelerated to end of FRIB Linac at 212 MeV/u Energy

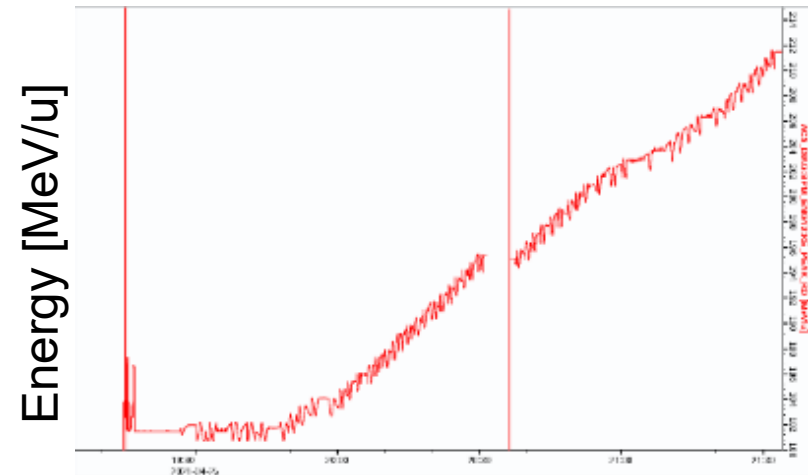
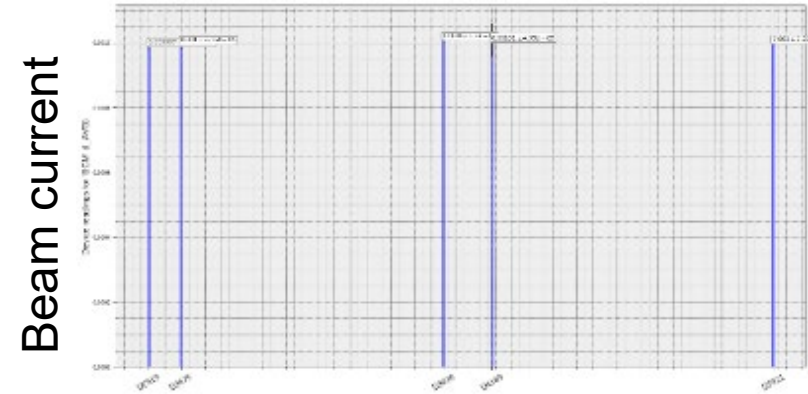
- Commissioned 46 cryomodules in 3 steps 2019-2021, 100% transmission upon beam permission without activating any correctors



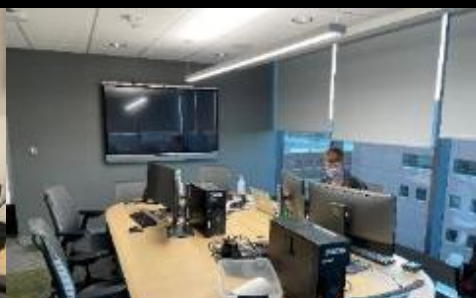
- Commissioning in five separate control rooms to comply COVID-19 workplace safeguards



AP control room



Cryo control room



BIM control room



RF control room

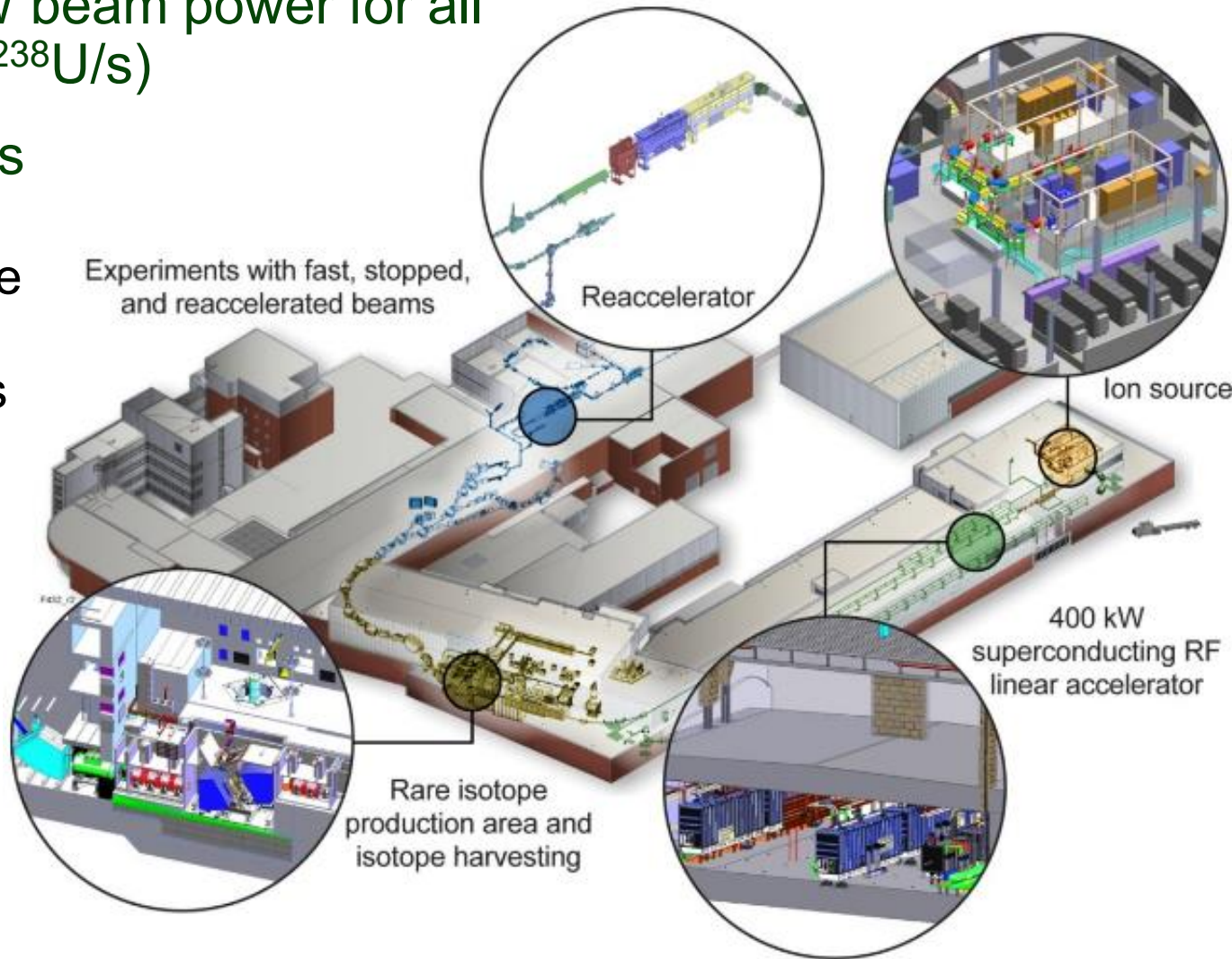


Main control room

FRIB Optimized for Science

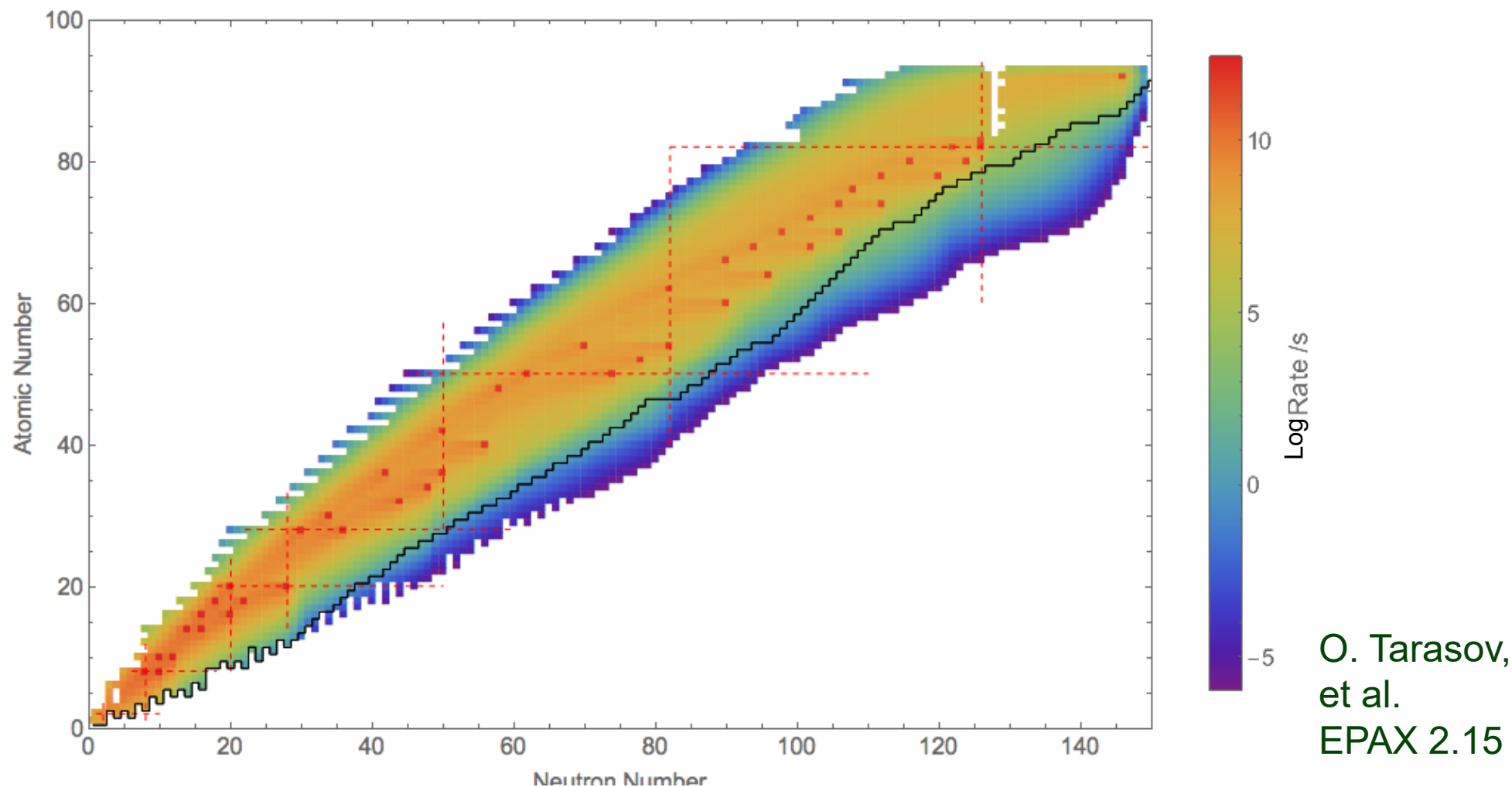
with Fast, Stopped and Reaccelerated Rare Isotope Beams

- Key feature is 400 kW beam power for all ions ($8\text{p}\mu\text{A}$ or $5 \times 10^{13} \text{ }^{238}\text{U/s}$)
- Separation of isotopes in-flight provides
 - Fast development time for any isotope
 - Beams of all elements and short half-lives
 - Fast, stopped, and reaccelerated beams
 - High selectivity
- Isotope harvesting capability from beam dump water

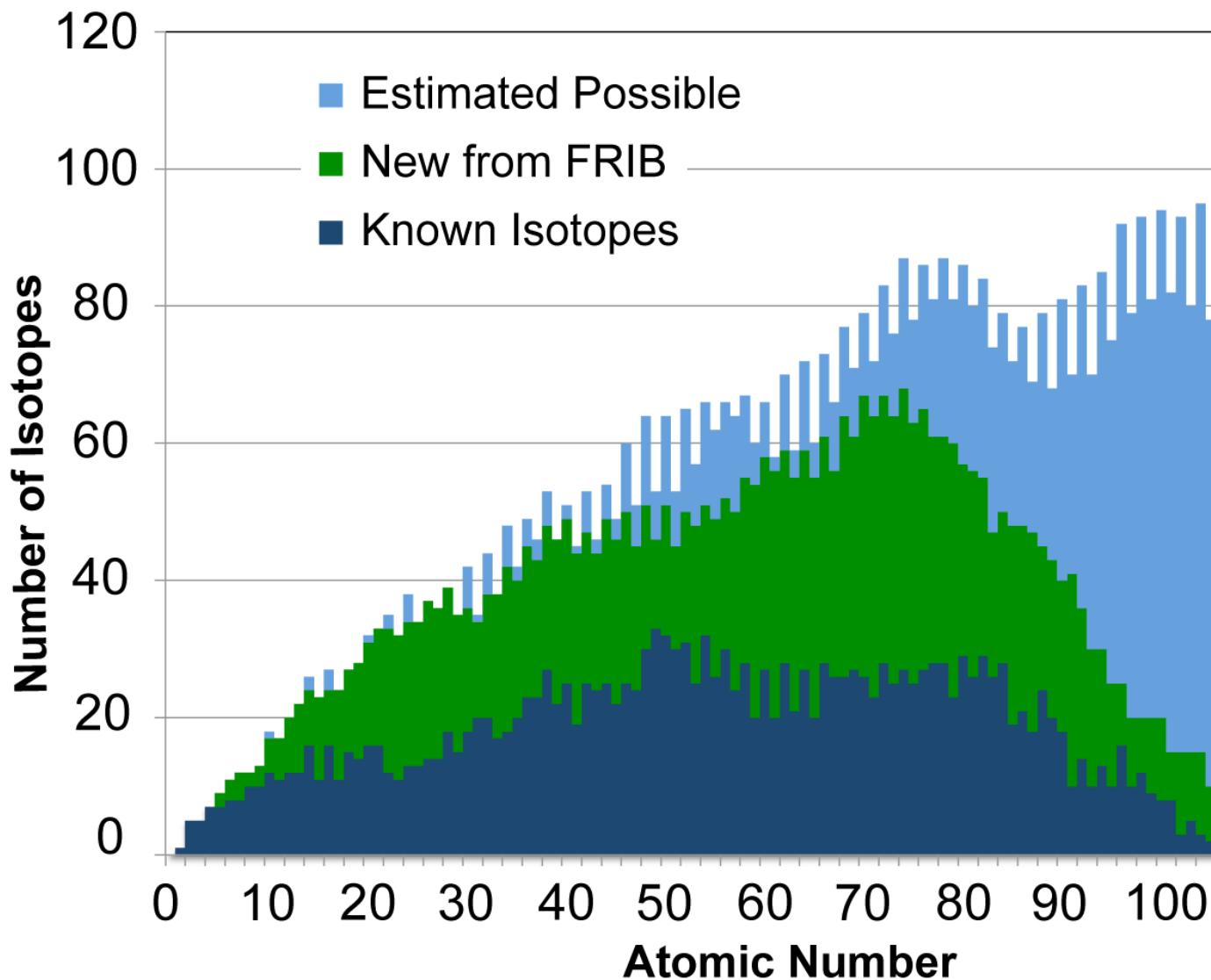


FRIB Estimated Beam Rates

<https://groups.nsl.msui.edu/frib/rates/fribrates.html>

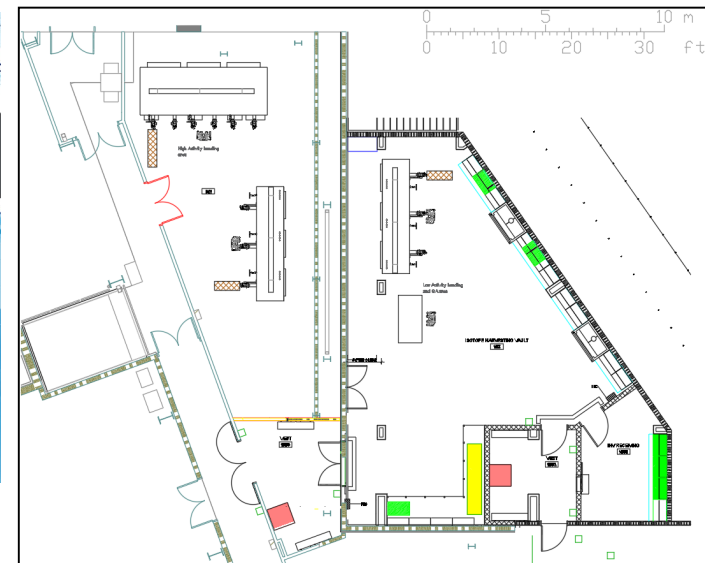
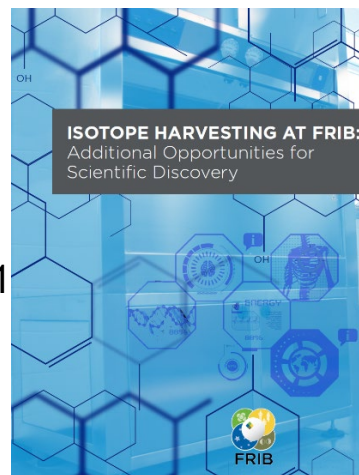
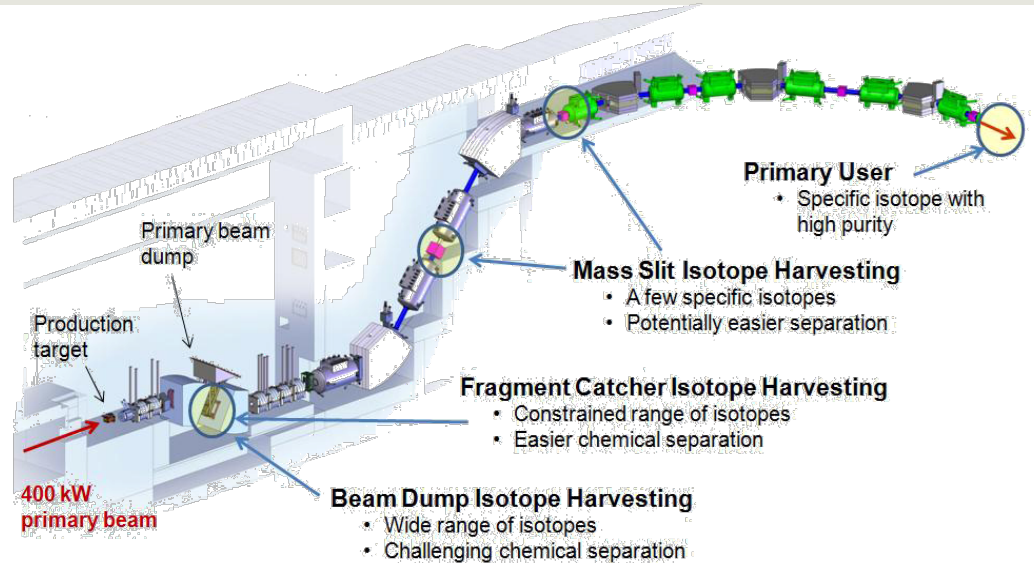


The Number of Isotopes Available at FRIB



Isotope Harvesting at FRIB

- Many rare isotopes are produced but only one isotope delivered to single user
 - Often 1000 other isotopes are produced that could be harvested and used for experiments or applications
- 2015 Long Range Plan (LPR) for DOE-NP Isotope Program recommends investment in infrastructure for isotope harvesting at FRIB
- FRIB had provisions for isotope harvesting incorporated in the design
 - Non-conventional utilities prepared for harvesting upgrade
 - Space for isotope handling included in MSU-funded HRS high-bay
- Isotope harvesting whitepaper published
 - J. Phys. G: Nucl. Part. Phys. **46** (2019) 100501
- DOE IP is supporting the addition of isotope harvesting to FRIB
 - PI: Greg Severin
 - 3-year design, construction, commissioning started in Sept 2020



Collaborating with National Laboratories and International Partners

- **ANL**
 - Liquid lithium stripper
 - Beam dynamics verification ; $\beta=0.29$ HWR processing and testing ; SRF tuner validation ; beam dump ; SRF components development
 - RF couplers for multi-gap buncher
- **BNL**
 - Plasma window & charge stripper, physics modeling, magnets
- **FNAL**
 - Diagnostics, SRF processing
- **JLab**
 - Cryoplant; cryodistribution design & prototyping
 - Cavity hydrogen degassing; e-traveler
 - HWR processing & certification
 - QWR and HWR cryomodule design and engineering support for production
- **LANL**
 - Proton ion source
- **LBNL**
 - ECR coldmass; beam dynamics
- **ORNL**
 - Remote handling, diagnostics; large-vessel vacuum, cryoplant controls
- **SLAC**
 - Cryogenics, SRF multipacting, physics modeling



- **RIKEN**
 - Helium gas charge stripper
- **TRIUMF**
 - Beam dynamics design, physics modeling SRF, QWR etching
- **INFN**
 - SRF technology
- **KEK**
 - SRF technology, SC solenoid prototyping
- **IMP**
 - Magnets
- **Budker Institute, INR Institute**
 - Diagnostics
- **Tsinghua Univ. & CAS**
 - RFQ
- **ESS**
 - Accelerator physics
- **DTRA**
 - RFQ power supply
- **CSNSM-JaNNUS**
 - Nuclear recoil damage to materials
- **RaDIATE**
 - Nuclear recoil damage to materials
- **GANIL**
 - Rare isotope physics, target development
- **GSI**
 - Rare isotope physics, fragment separators
- **U Notre Dame**
 - Recoil implantation testing of materials



Facility for Rare Isotope Beams
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Michigan State University

Summary

- FRIB Project is about 96% complete. FRIB Project is on schedule and on budget, and being managed to early completion in December 2021 and start of user operation in early 2022, CD-4 is in June 2022
 - 1,500 users are engaged and ready for science
- FRIB superconducting radio-frequency linear accelerator is commissioned and accelerated ions to above 200 MeV/nucleon
 - Power will be ramped up to 400 kW over five year
- FRIB will double the number of known isotopes
- Isotope harvesting capabilities built into FRIB and FRIB
- DOE Isotope Program partners to make available critical isotopes
 - Commensal harvesting from beam dump water
 - Isotope Harvesting Laboratory being implemented (2020-2023)
 - Greg Severin is the Principal Investigator
- FRIB would be possible without the help and collaboration of the DOE-SC National Laboratories and our international collaborators



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