



# Facility for Rare Isotope Beams Status

Frederique Pellemoine

RaDIATE Collaboration Meeting

CERN - December 17-21, 2018

**MICHIGAN STATE**  
**UNIVERSITY**



U.S. DEPARTMENT OF  
**ENERGY**

Office of  
Science

# FRIB - Facility for Rare Isotope Beams

## World-leading Next-generation Rare Isotope Beam Facility

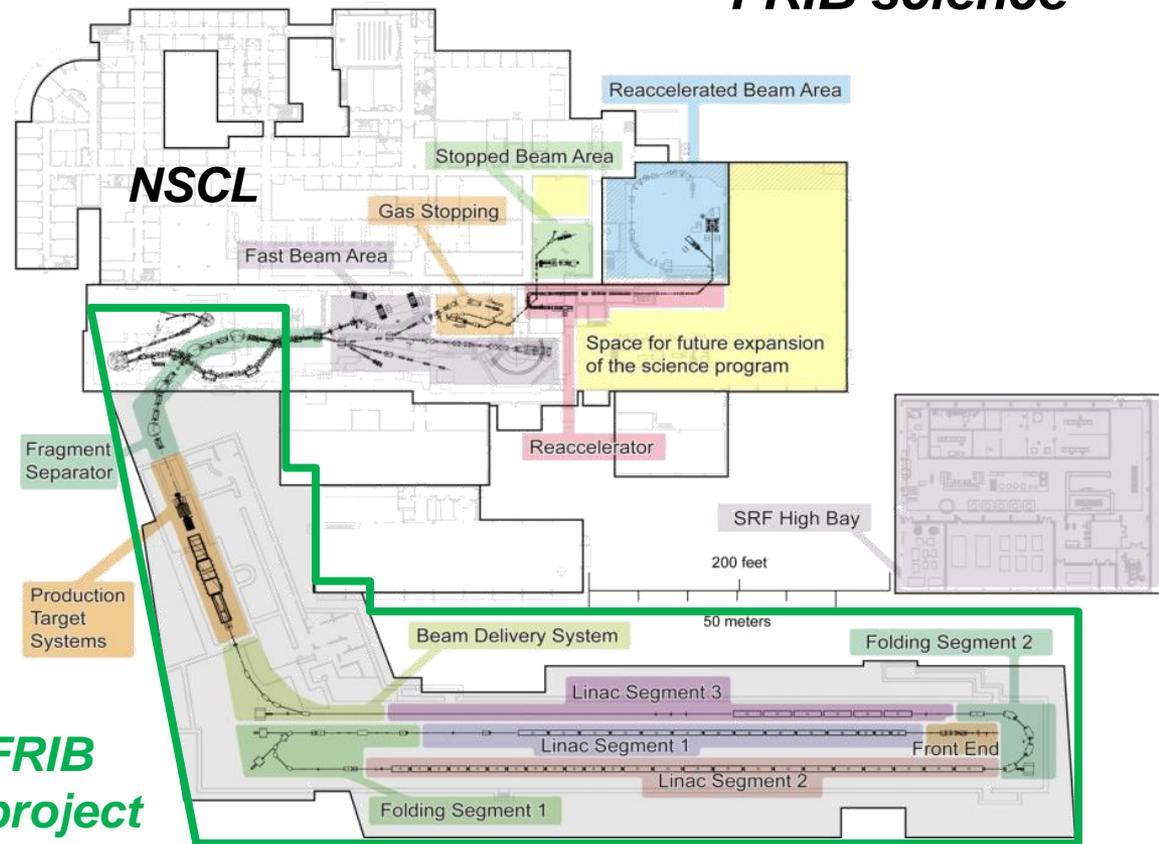
- Rare isotope production via in-flight technique with primary beams up to 400 kW, 200 MeV/u uranium
- Fast, stopped, and re-accelerated beam capability
- Upgrade options
  - 400 MeV/u for uranium
  - ISOL production

***NSCL enables pre-FRIB science***

Funded by DOE–SC Office of Nuclear Physics with contributions and cost share from Michigan State University

- Project started in 2009
- Civil construction and technical construction started in 2014
- First section of accelerator commissioned in 2018
- [CD-4 \(project completion\) 6/2022](#)
- Project managed to early completion in 2021

***FRIB project***



# Michigan State University, East Lansing

## Home of Future FRIB

- Founded in 1855
- 12,000 employees
- 50,000 students
- 5200 acre campus

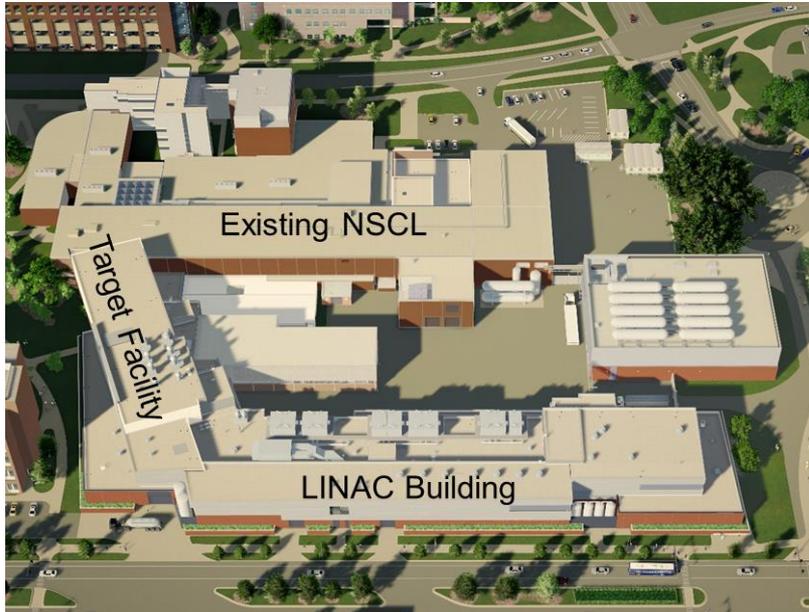
Present National Superconducting Cyclotron Laboratory (NSCL) and Facility for Rare Isotope Beams (FRIB) under construction

1 mile



**Facility for Rare Isotope Beams**  
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# FRIB Civil Construction Complete



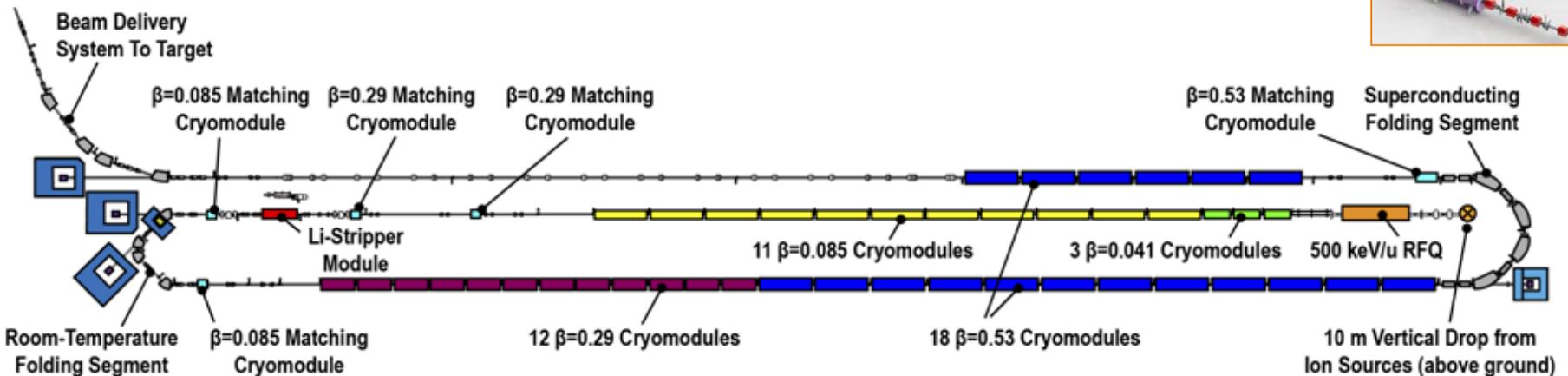
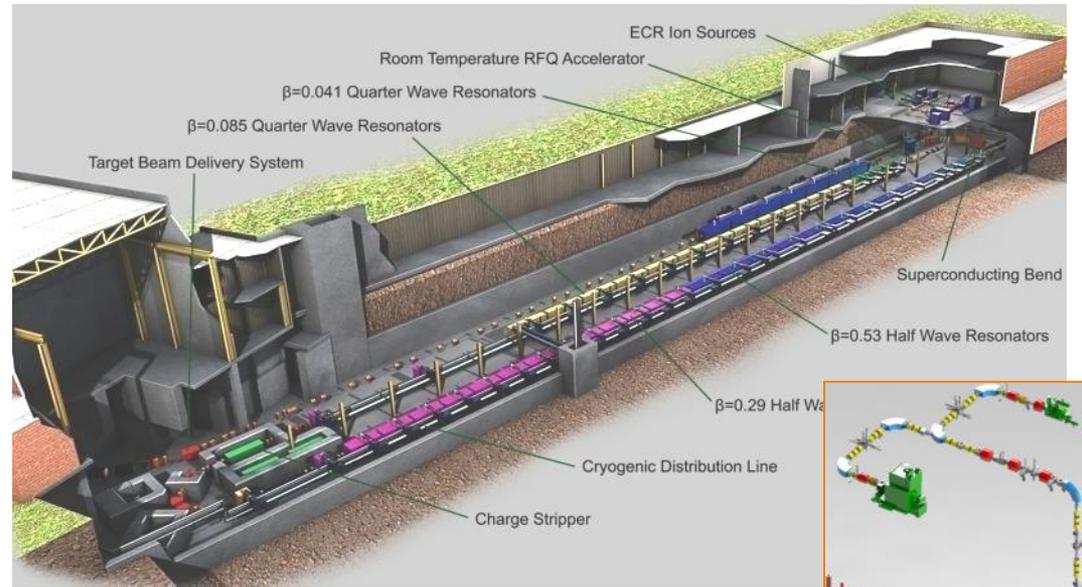
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# FRIB Accelerator Systems

## Superconducting RF Driver Linac

- Accelerate ion species up to  $^{238}\text{U}$  with energies of no less than 200 MeV/u
- Provide beam power up to 400kW
- Energy upgrade to 400 MeV/u for  $^{238}\text{U}$  by filling vacant slots with 12 SRF cryomodules



# Linac Cryomodule Installation 50% Complete

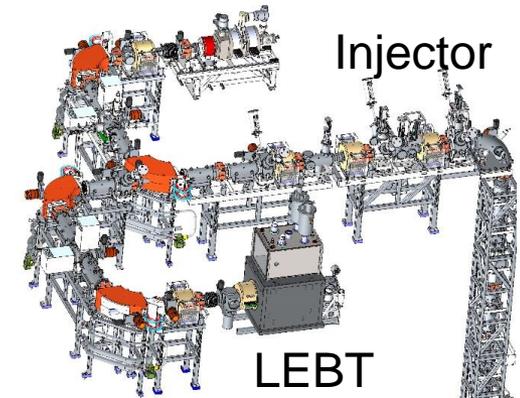
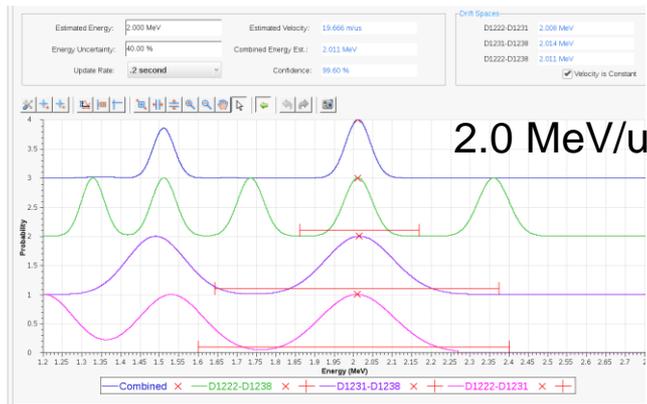
- 26 of 46 FRIB cryomodules installed in tunnel location



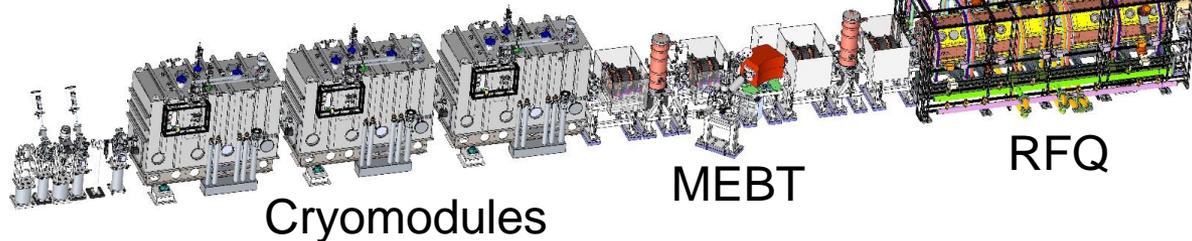
# Beam Commissioned Through First Three Cryomodules in July 2018

- Argon beam acceleration up to 2.3 MeV/u
- High power beam studies
  - 33  $\mu\text{A}$   $\text{Ar}^{9+}$  accelerated to 1.5 MeV/u with 30% duty factor
    - Accelerated 66 W Beam

Time of flight measurement using beam position monitors



Diagnostics



Cryomodules

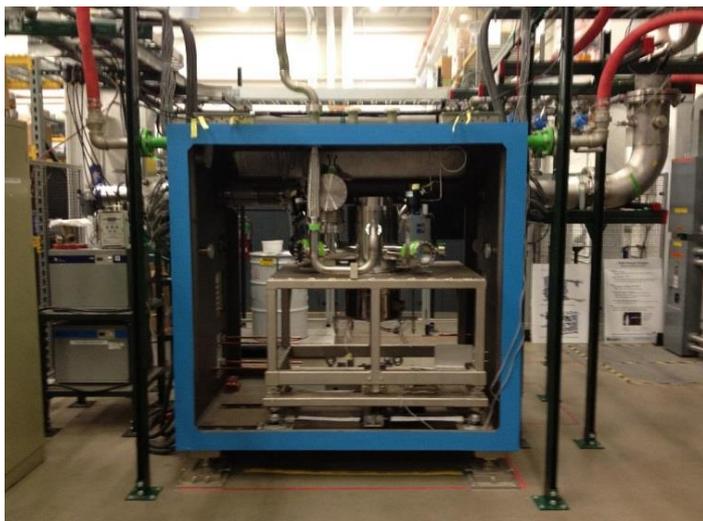
MEBT

RFQ

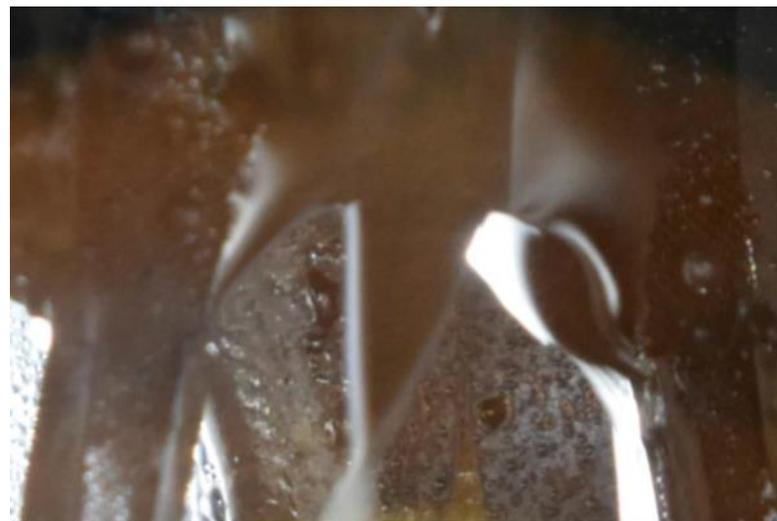
# Power Density Challenges Being Met

## Example: Charge Stripping of Intense Heavy Ion Beams

- High specific power loss of heavy ions in matter
  - Solid stripper not an option (10 MW/cm<sup>3</sup> power density)
  - Fast liquid metal film, plasma stripper are options
- Liquid Lithium Film Charge Stripper
  - Liquid lithium film (10 mm thick), Film established
    - » 50 Hour Continuous Operations Completed

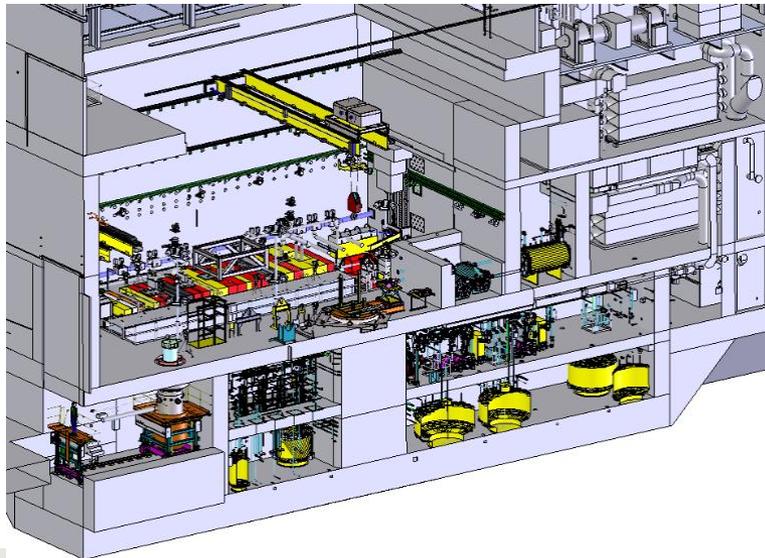
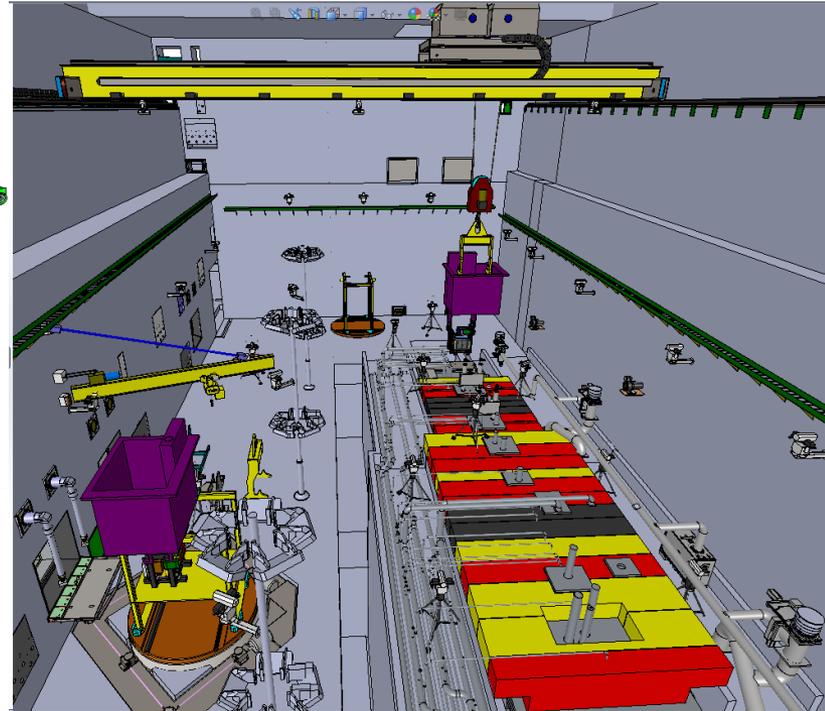
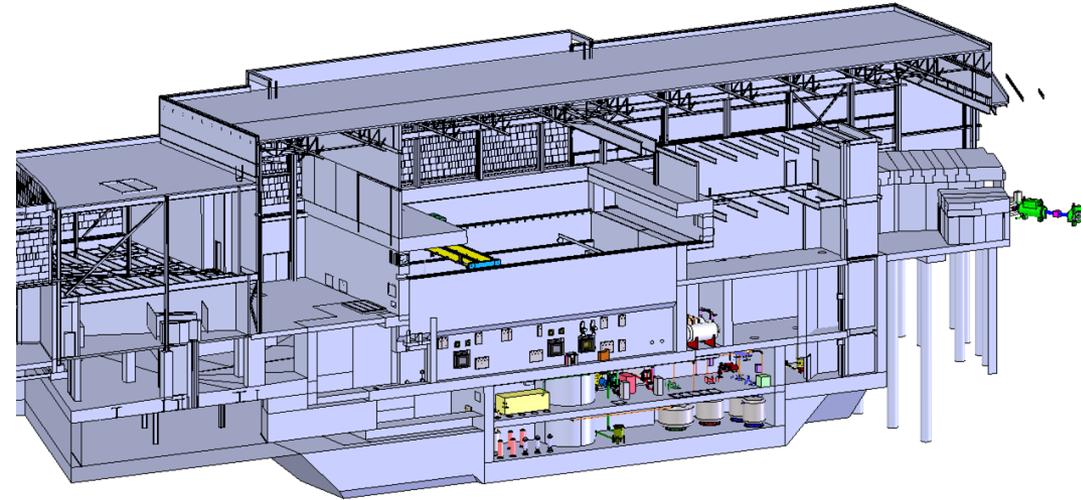


FRIB liquid lithium charge stripper device assembled



Established liquid lithium film (seen from the chamber view port)

# FRIB Rare Isotope Production Facility Designed for 400 kW Operation



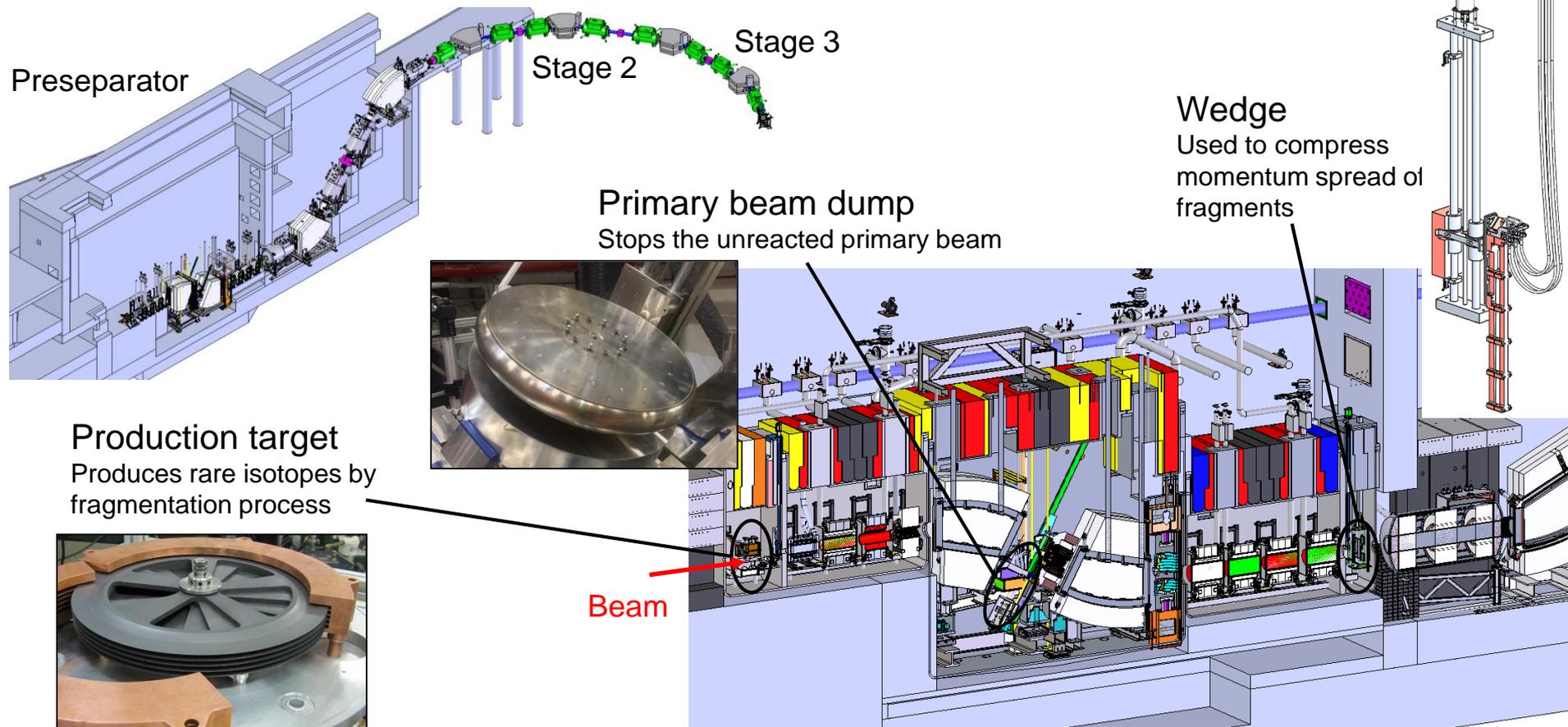
- Accommodates first part of fragment separator with target and beam dump
- Remote-handling of activated components (target change within 24 h)
- Non-conventional utilities



# Fragment Separator Overview

## Produce and Separate Rare Isotopes

- Three stage fragment separator for production and delivery of rare isotope
- Primary beam power of 400 kW and beam energies of  $\geq 200$  MeV/u

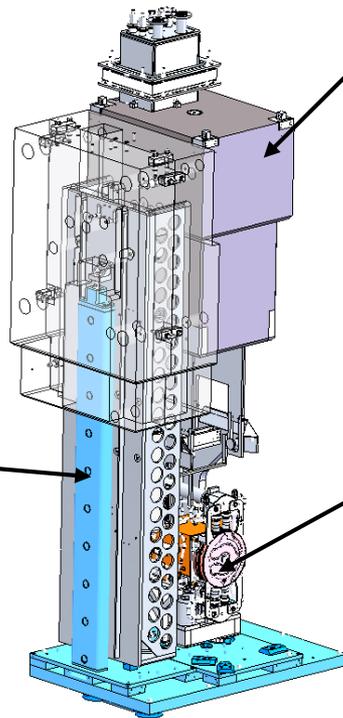


# High-power Target Ready for Installation in May 2019

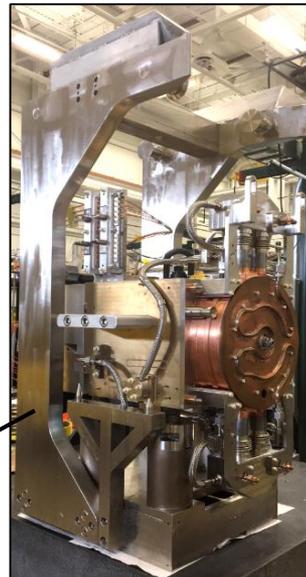
- Multi-slice rotating graphite target
  - High power capability up to 100 kW
  - >2 weeks lifetime
  - Remote replacement and maintenance
  - 5000 rpm, 30 cm diameter
  - $T_{\max} = 1900\text{ C}$ ,  $P_{\max/\text{slice}} = 10\text{ kW}$
- Target assembly near complete



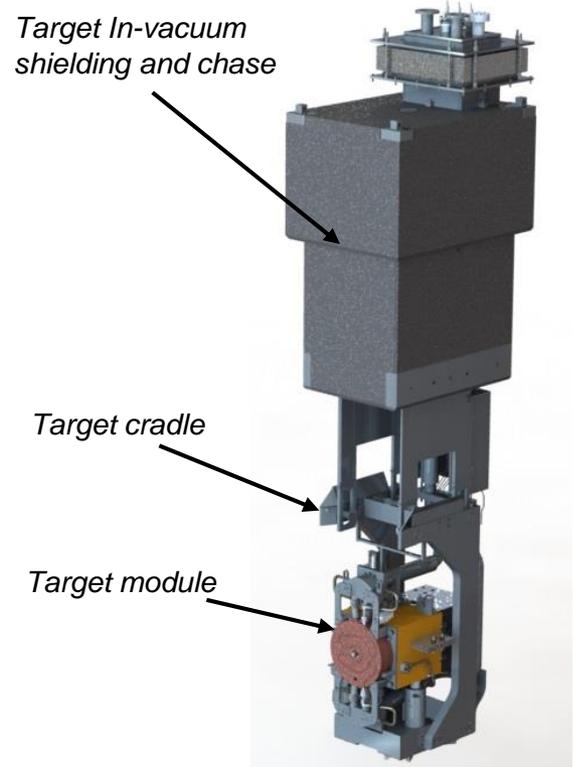
Thermal Imaging System mounted on the target vessel mounting frame



Target In-vacuum shielding and chase



Target mounted on cradle



Target cradle

Target module



Target disk module (prototype)

# High Power Beam Dump On Track for Completion in July 2019

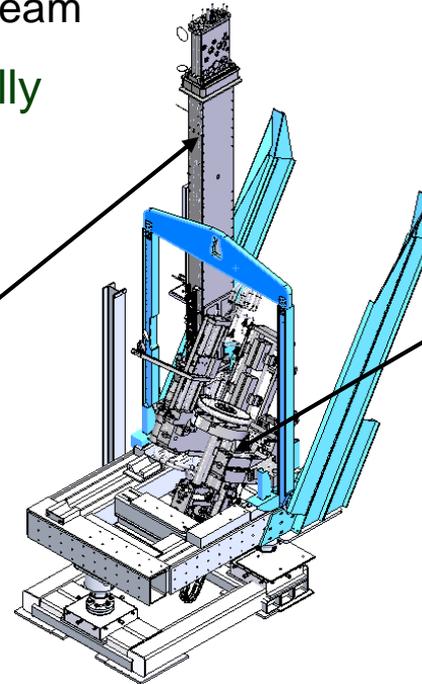
- Water-filled thin-walled rotating drum
  - Using water to stop the primary beam and absorb beam power
  - High power capability up to 325 kW
  - 1 year (5500 h) lifetime desirable
  - Remote replacement and maintenance
  - 600 rpm, 70 cm diameter
  - $T_{\max} = 150\text{ C}$ ,  $P_{\text{shell}} = 70\text{ kW}$  for full power of U beam
- Baseline design is 1-mm thick conventionally machined drum
  - Ultimately 0.5 mm wall thickness will be required
- Beam dump assembly near complete



Titanium beam dump drum with 1-mm shell



Utility chase shell

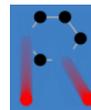


Beam dump module mounted on integration frame

# Beam Dump Material Testing and Studies

## Minimal Material Studies for Drum Lifetime Assessment

- Irradiated samples are at Pacific Northwest National Laboratory waiting for Post Irradiation Examination (PIE)



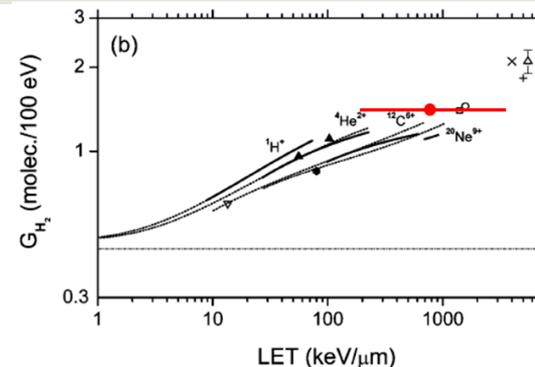
- Proposal for Rapid Turnaround Experiments (RTEs) from Nuclear Science User Facilities submitted

- Short beam-induced corrosion test (3½ hours) at NSCL in February 2018 with  $^{40}\text{Ca}$  beam at 140 MeV/A

- Gas production rate estimated for the beam dump water loop validated by experiment

- 3D-printed drum is considered but is not planned for early operations

- Collaborators at MSU support developments for future beam dump drum fabrication via 3-D printing
- 3D printed market develops fast



*G* factor (gas production): NSCL result compared to results from Meesungnoen, J.; Jay-Gerin, J. P. J. *Phys. Chem. A.*, **2005**, 109, 6406–6419

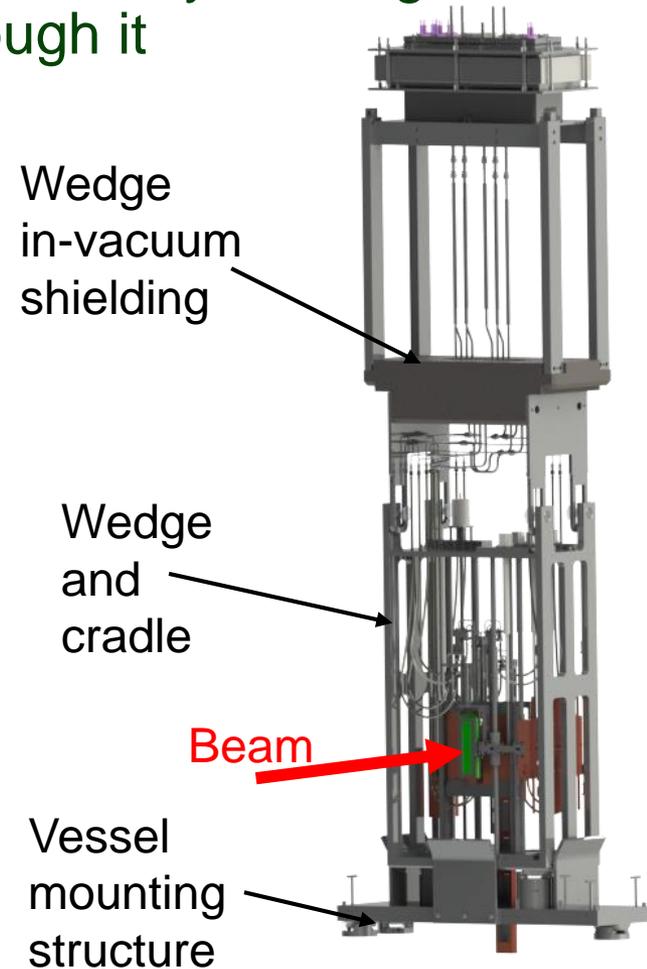
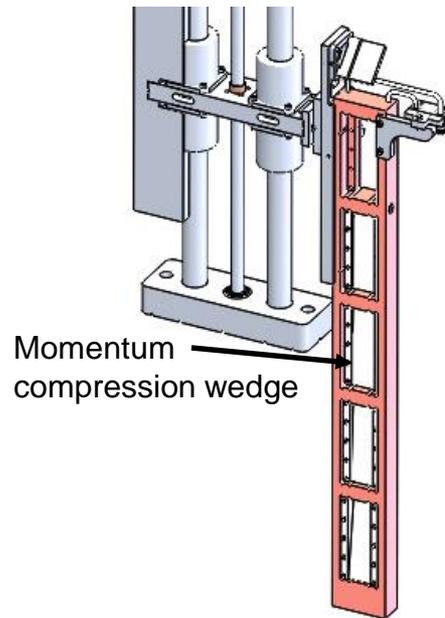


3D printed object with similar size than FRIB beam dump

# Wedge Assembly

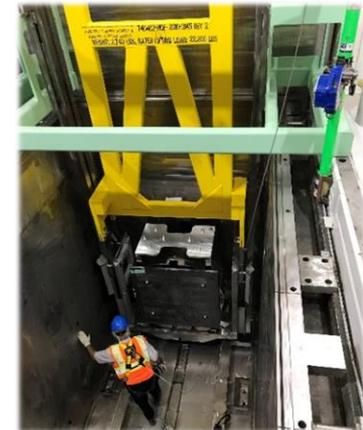
## Complete in August 2019

- Used to compress momentum spread of fragments by slowing down a momentum-dispersed beam ions passing through it
- Momentum compression wedge based on wedge-shaped degraders
- No significant technical challenge
- Design near complete



# Radiation-resistant Magnets - Fabrication on Track

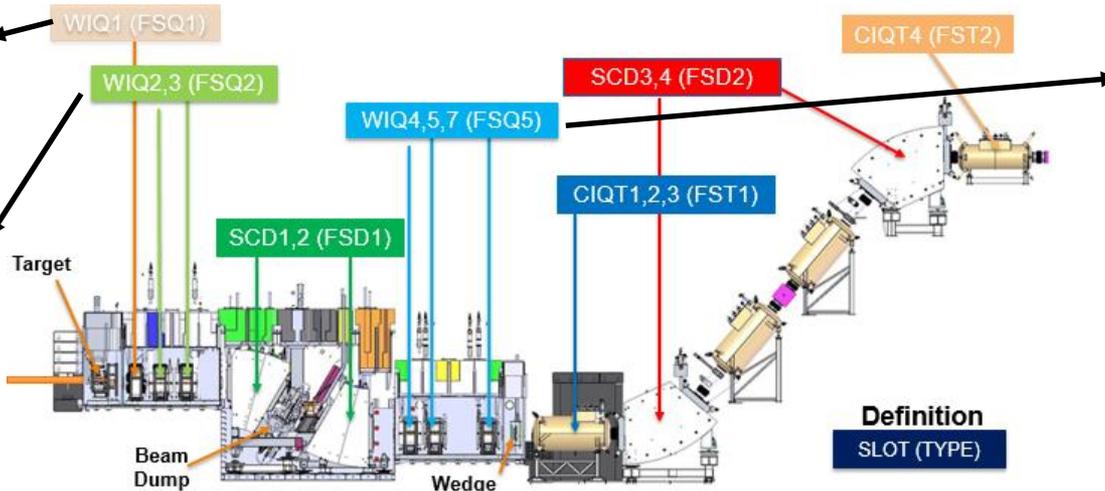
- Magnets close to the production target must survive in high radiation environment  $\Rightarrow$  warm iron quads required
- Magnets placed in large vacuum vessels and need to fit within the space allowed



First FSQ5-S1 installed in the wedge vacuum vessel



Room-temperature quadrupole fabrication at vendor on track



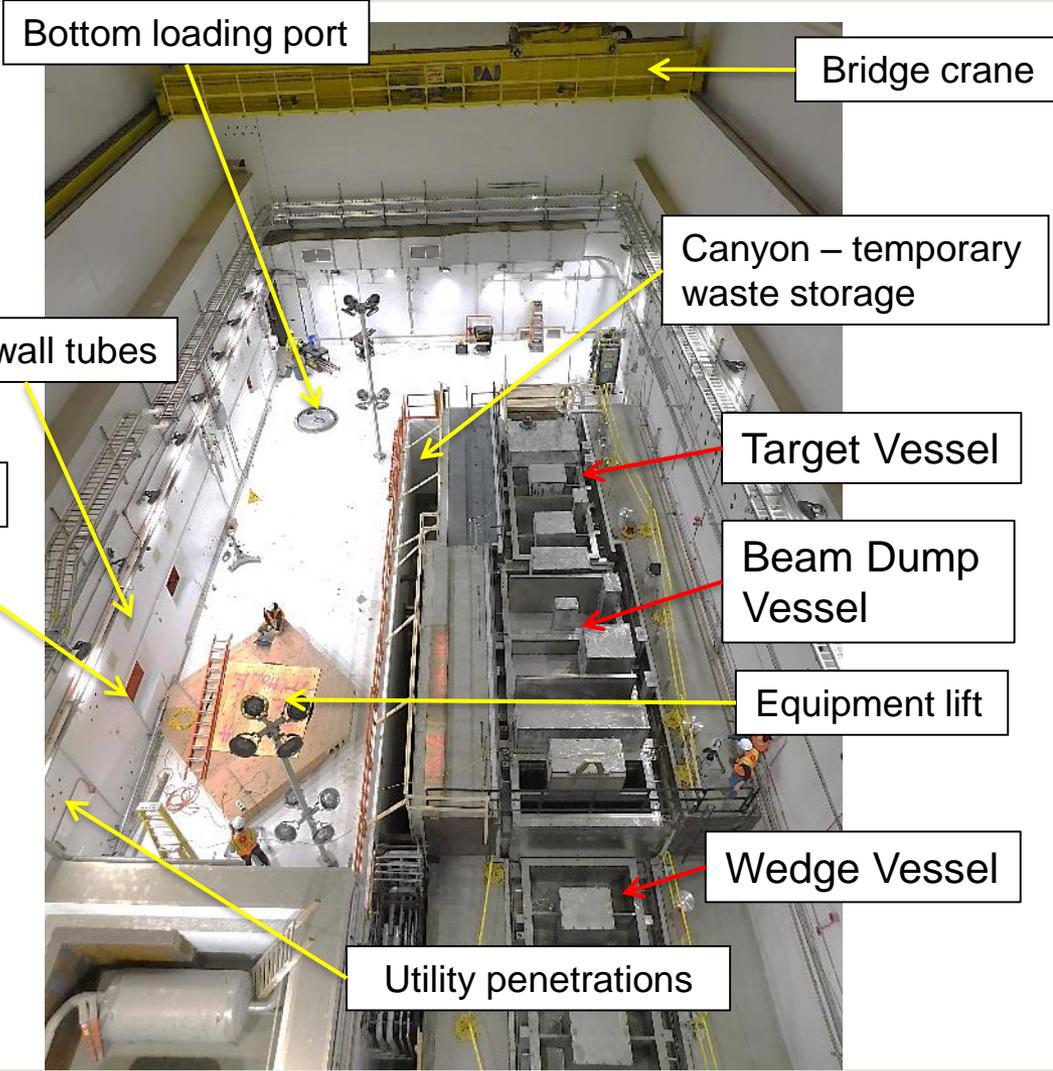
# Installation of Equipment in Target Hall

- Large vacuum vessels installed
- Remote-handling systems installed
- Non conventional Utilities piping installed
- First magnet installed



*Non-Conventional Utilities piping in target hall*

Shield window frame



Bottom loading port

Bridge crane

Canyon – temporary waste storage

MSM wall tubes

Target Vessel

Beam Dump Vessel

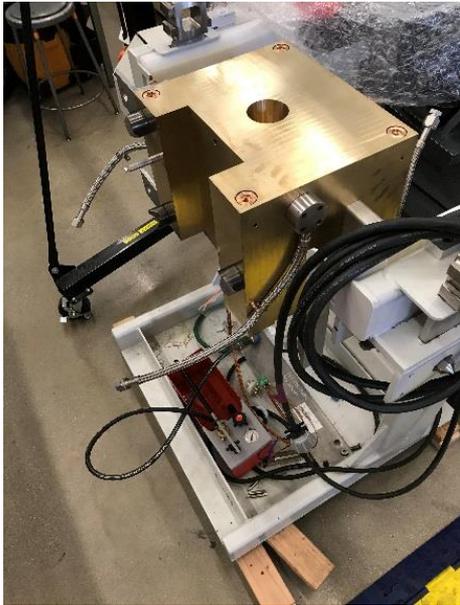
Equipment lift

Wedge Vessel

Utility penetrations

# Remote Handling Systems Used for Component Installation

- Remote-handling tooling used for handling of vacuum vessels lids and for magnet installation



Target rotation stand delivered to support module assembly



Beam dump workstand delivered



Vessel seal retainer lifter



FSQ5-magnet yoke in cradle placed in WIQ4 position using complete set of remote handling tooling

# Conclusion - Path forward

- **FRIB technical construction 85% complete**
  - Accelerated first beam with cryomodules
  - Established film in lithium charge stripper
  - Target facility ready for equipment installation
  - First warm iron quadrupole magnet installed in large vacuum vessels
  - Production target and beam dump assemblies near complete
- **FRIB project on track for early completion in 2021**



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Thank you for your attention



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