



Facility for Rare Isotope Beams under Construction

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MICHIGAN STATE
UNIVERSITY

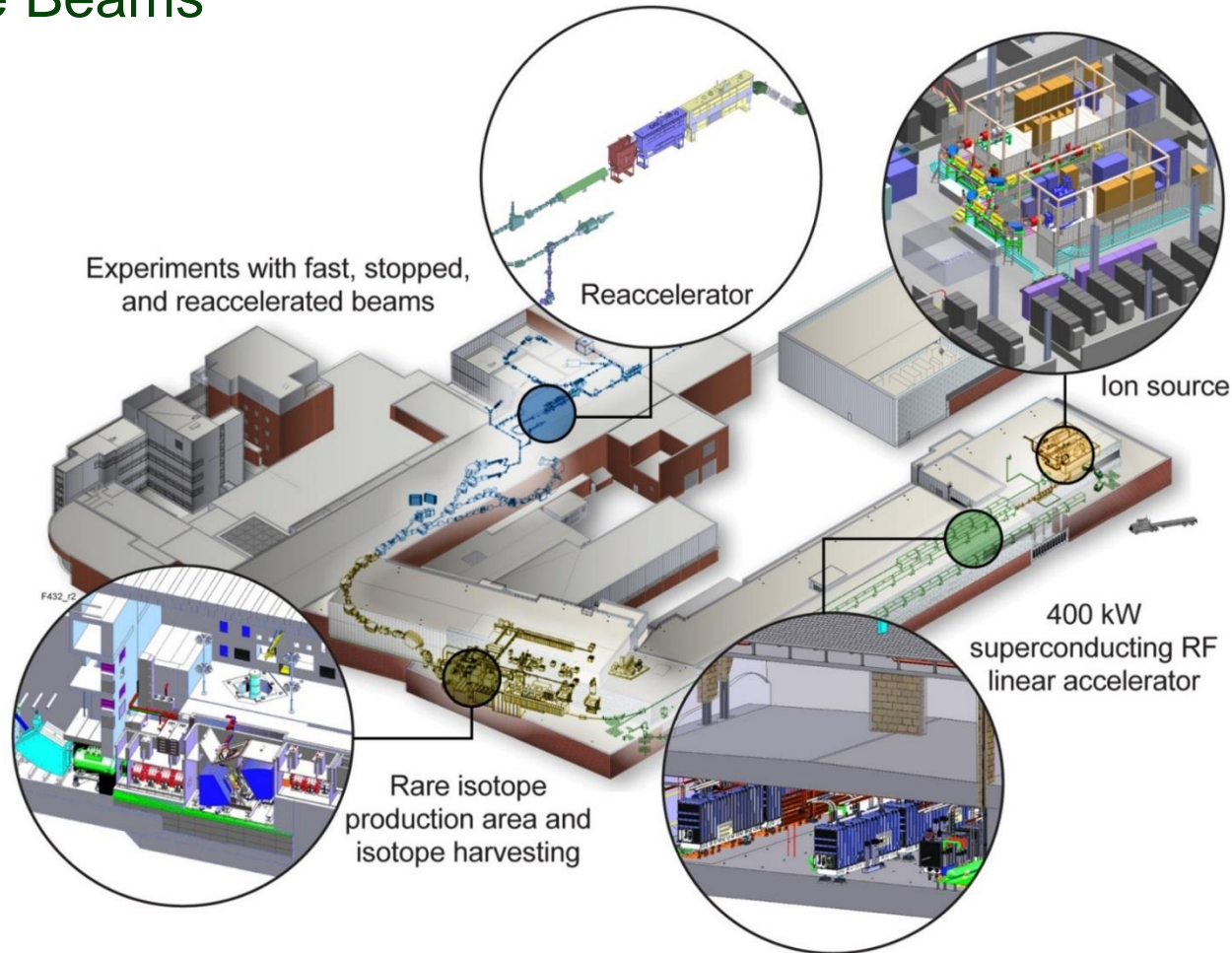


U.S. DEPARTMENT OF
ENERGY

Office of
Science

Outline

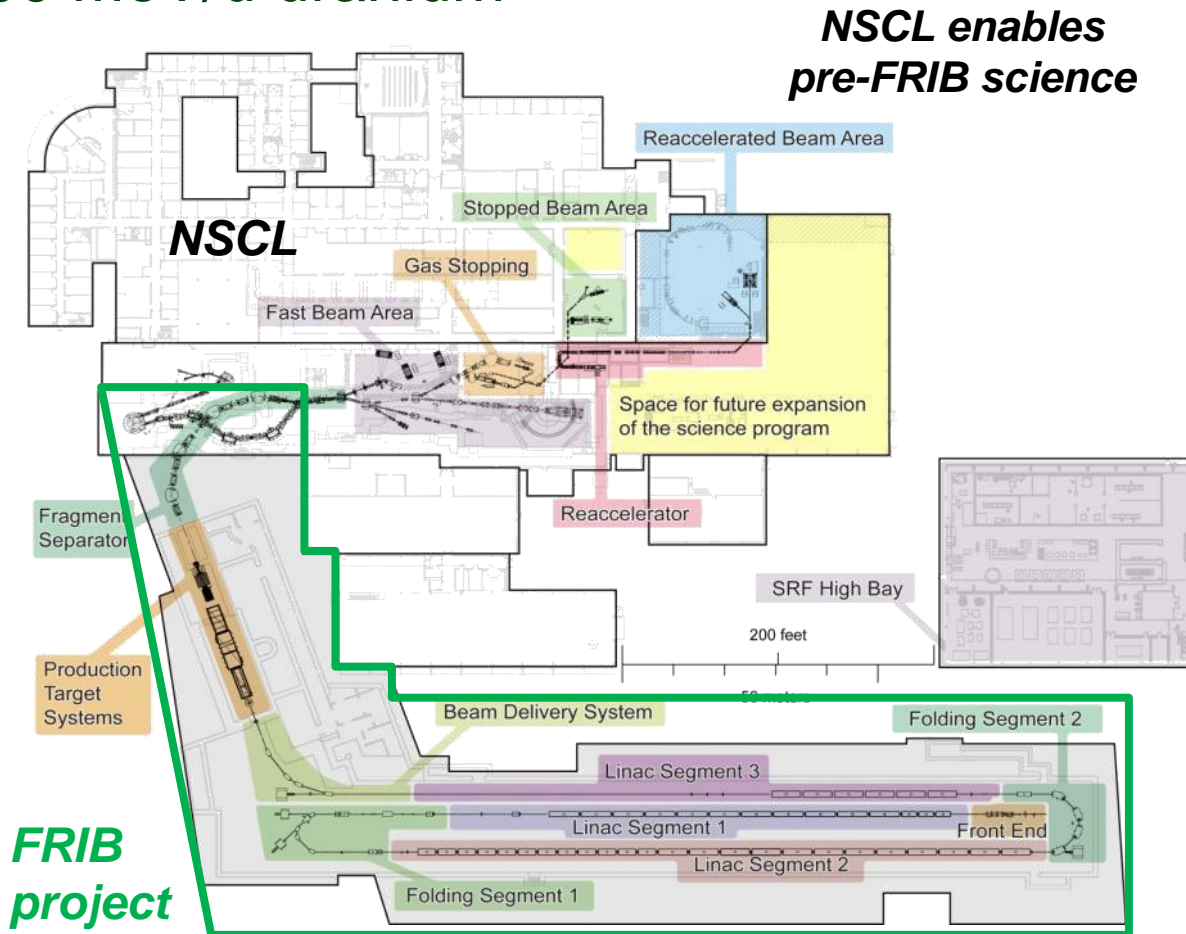
- Facility for Rare Isotope Beams Overview and Science
- FRIB Project Status
- NSCL Integration
- FRIB Users
- Summary



FRIB - Facility for Rare Isotope Beams

World-leading Next-generation Rare Isotope Beam Facility

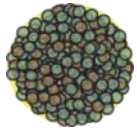
- Rare isotope production via in-flight technique with primary beams up to 400 kW, 200 MeV/u uranium
- Fast, stopped, and re-accelerated beam capability
- Upgrade options
 - 400 MeV/u for uranium
 - ISOL production – multi-user capability



FRIB project start 6/2009
 Civil construction started 3/2014
 Technical construction started 10/2014
 Managed to early completion 12/2020
 CD-4 (project completion) 6/2022

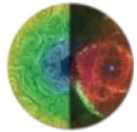
Total project cost \$730 million

FRIB – Four Science Themes



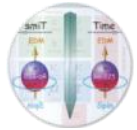
Properties of nuclei

- Develop a predictive model of nuclei and their interactions
- Many-body quantum problem: intellectual overlap to mesoscopic science, quantum dots, atomic clusters, etc.



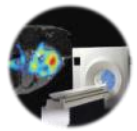
Astrophysical processes

- Origin of the elements in the cosmos
- Explosive environments: novae, supernovae, X-ray bursts ...
- Properties of neutron stars



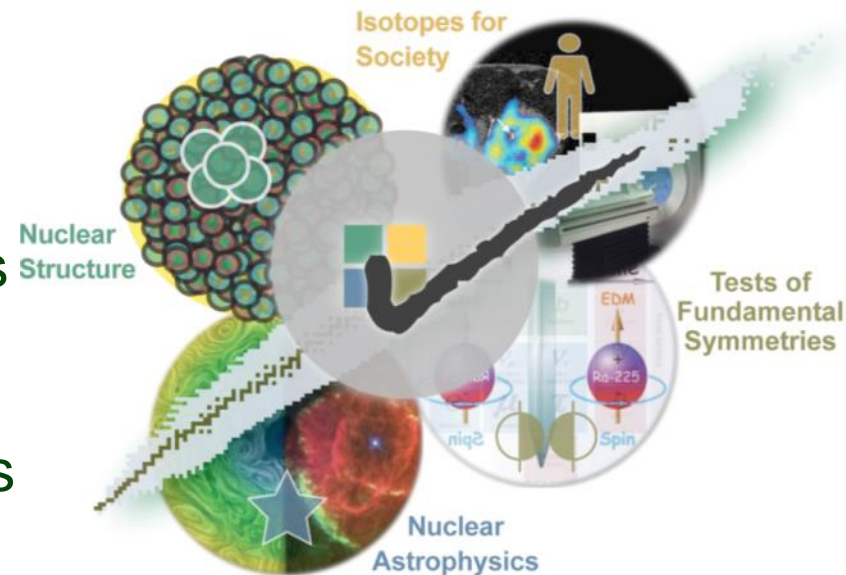
Tests of fundamental symmetries

- Effects of symmetry violations are amplified in certain nuclei



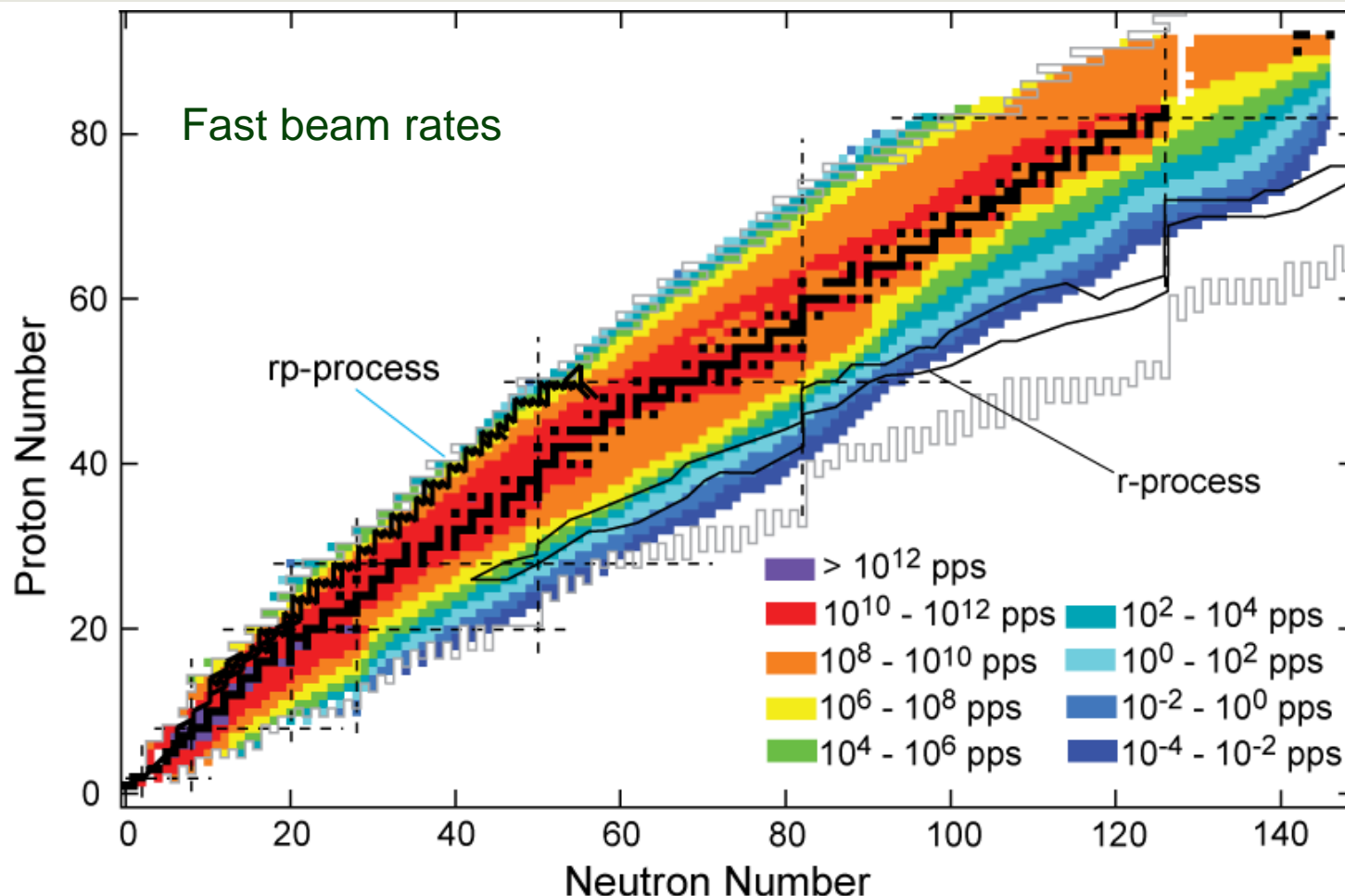
Societal applications and benefits

- Bio-medicine, energy, material sciences, national security



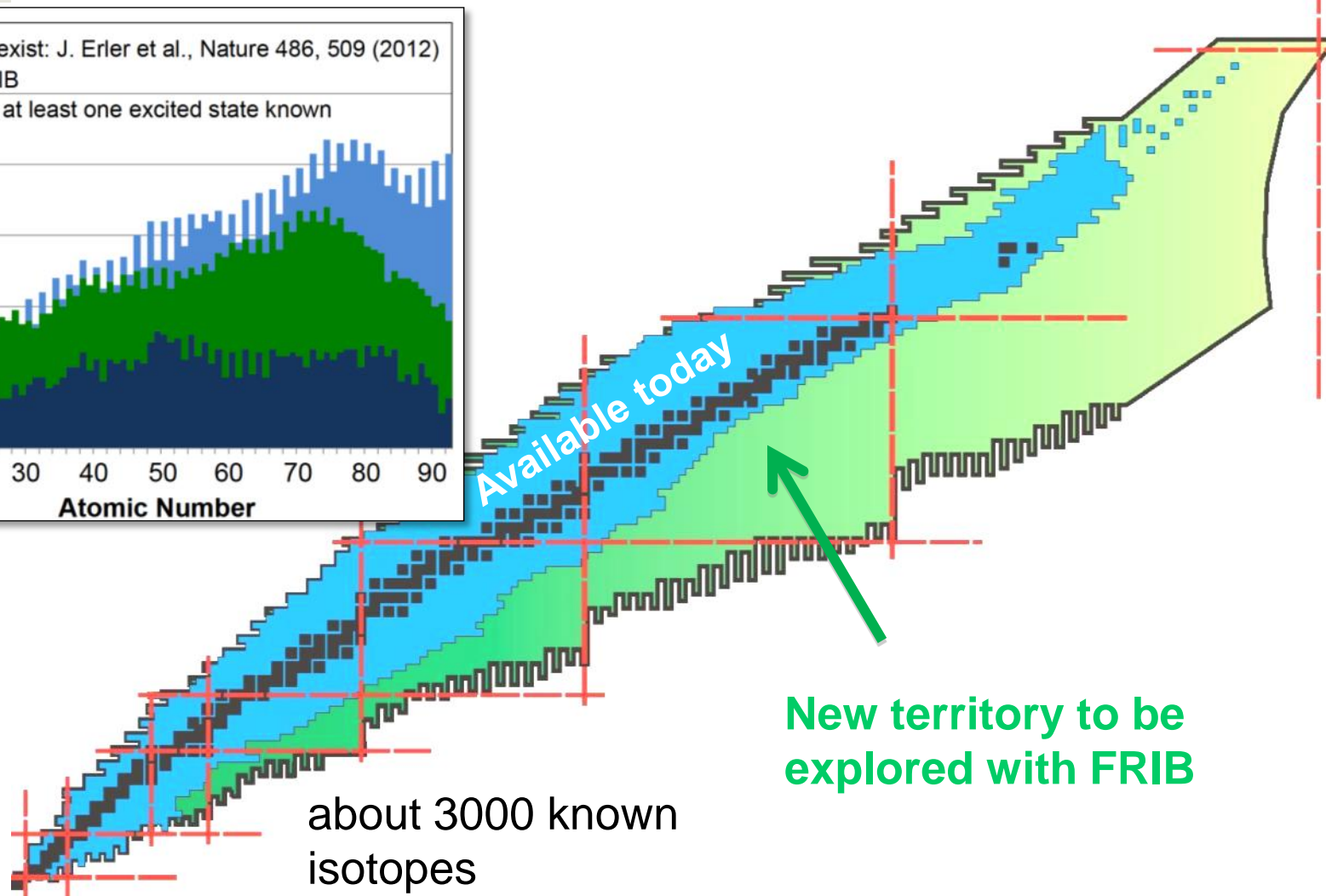
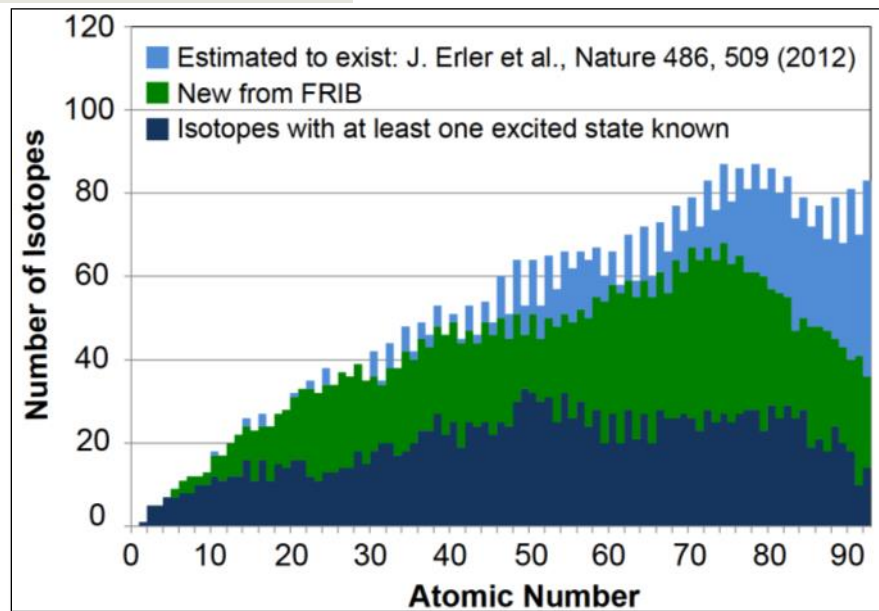
FRIB Rare Isotope Beam Rates

High Beam Rates to Maximize Science Reach



Rates are available at <http://groups.nsl.msu.edu/frib/rates/>

FRIB Beams Will Enable New Discoveries



FRIB Civil Construction Underway Began 3 March 2014

6/2014

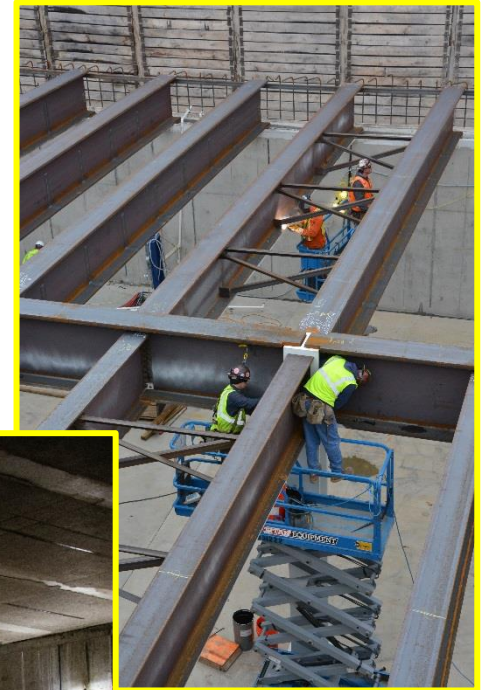


Web cameras at www.frib.msu.edu

FRIB Civil Construction Underway

9 Weeks Ahead of Schedule

July 2014



Dec 2014

Linac tunnel

East end lid complete

FRIB Civil Construction Underway

9 Weeks Ahead of Schedule



Target facility



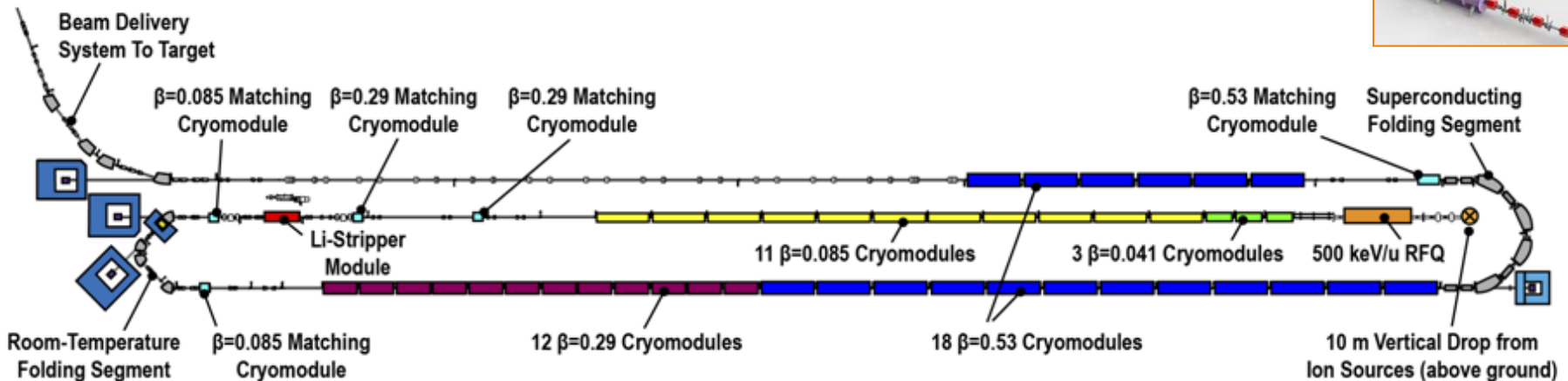
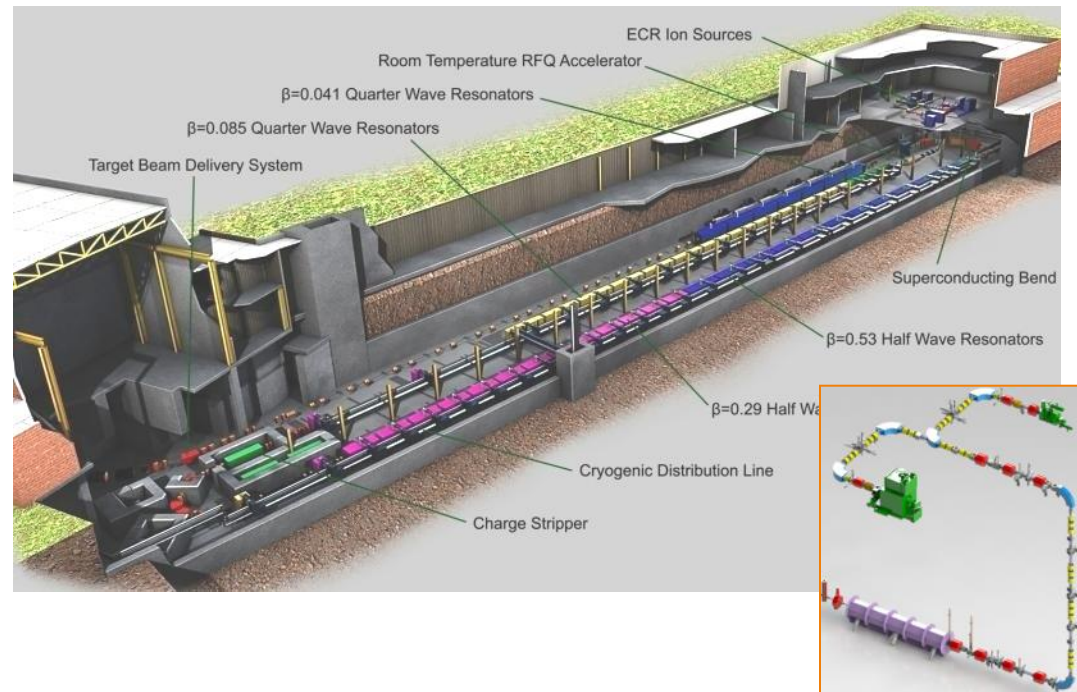
FRIB Construction Underway



FRIB Accelerator Systems

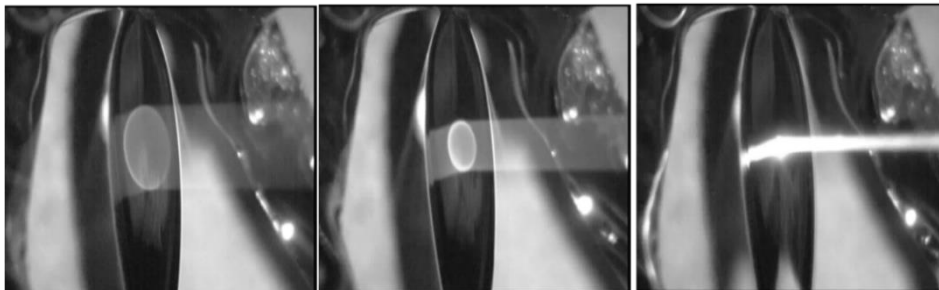
Superconducting RF Driver Linac

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



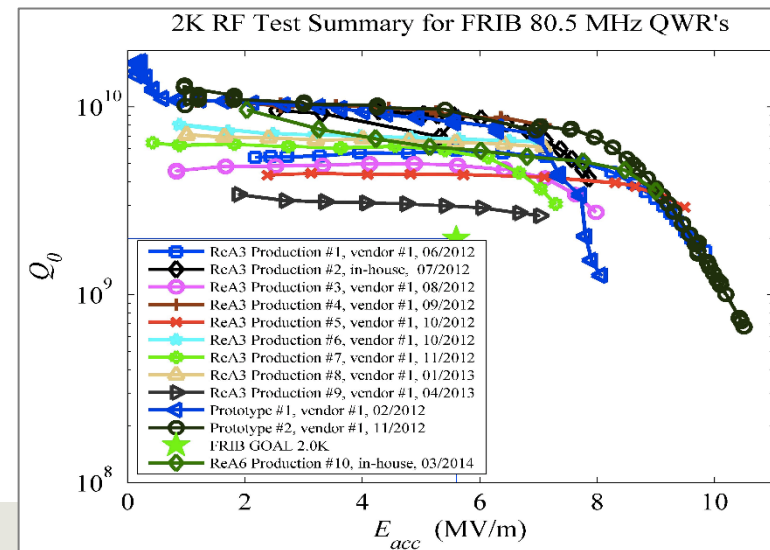
FRIB Accelerator Systems

- Cavity preproduction and cryomodule prototyping underway
 - Cavities exceed FRIB performance goals
- Charge stripping is technical challenge
 - Liquid lithium charge stripping scheme validated

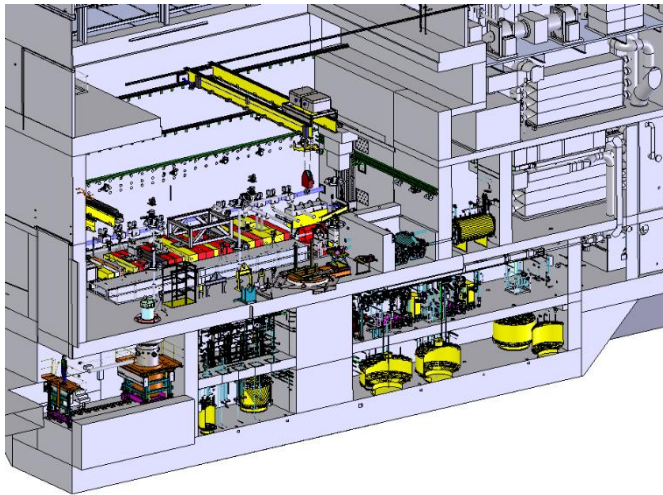
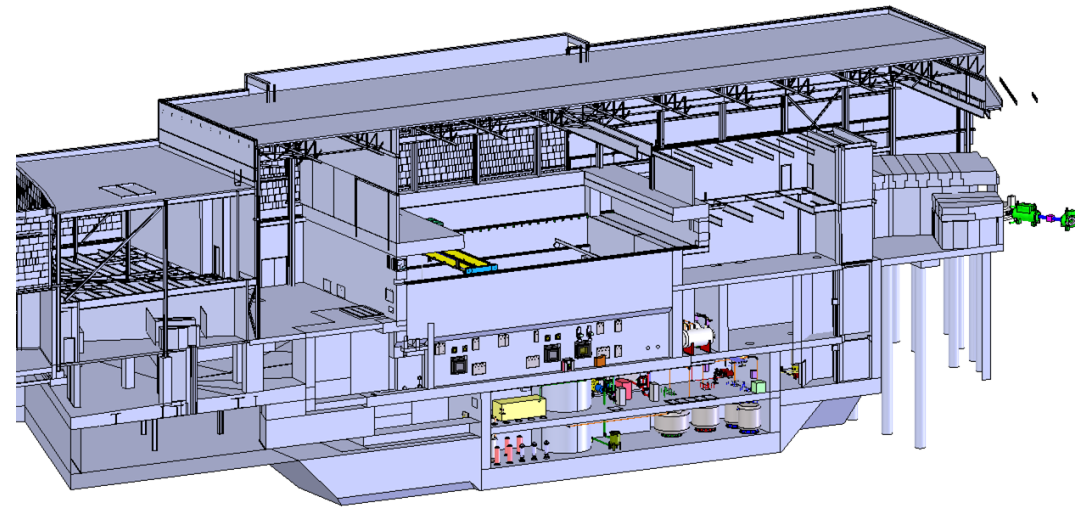


Argonne
NATIONAL LABORATORY

Los Alamos
NATIONAL LABORATORY
EST. 1943



FRIB Rare Isotope Production Facility Designed for 400 kW Operation



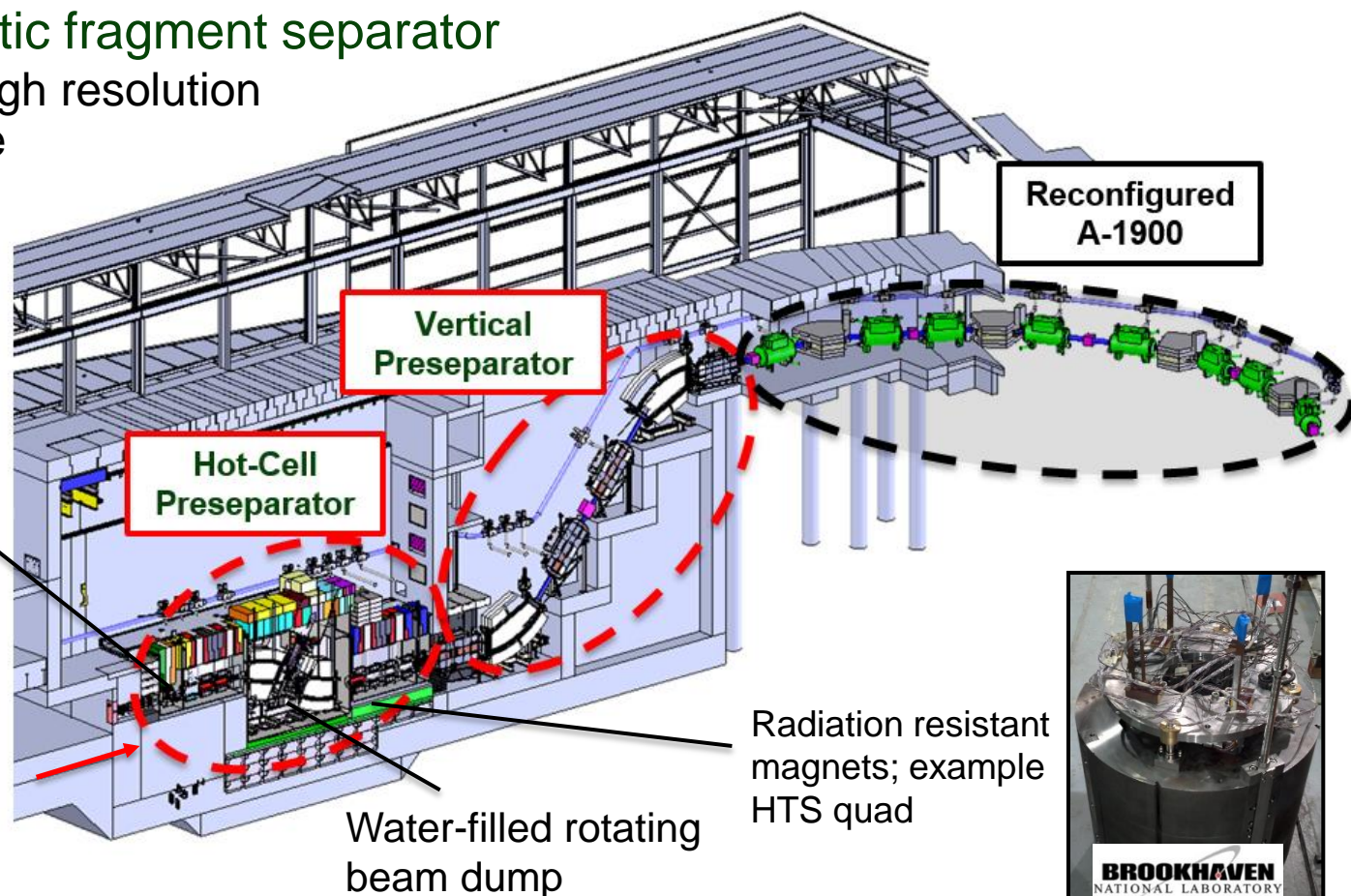
- Accommodates first part of fragment separator with target and beam dump
- Remote-handling of activated components (target change within 24 h)
- Non-conventional utilities



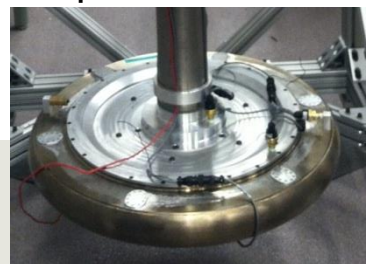
FRIB Fragment Separator Three Separation Stages

- Three stage magnetic fragment separator
 - High acceptance, high resolution to maximize science

Multi-slice rotating graphite target



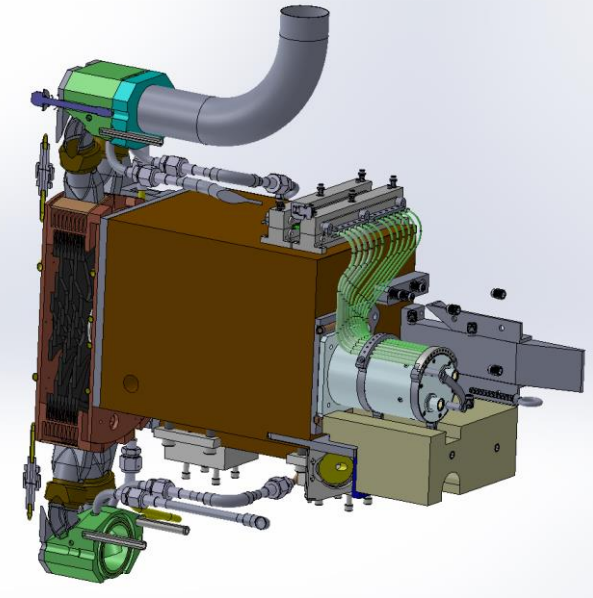
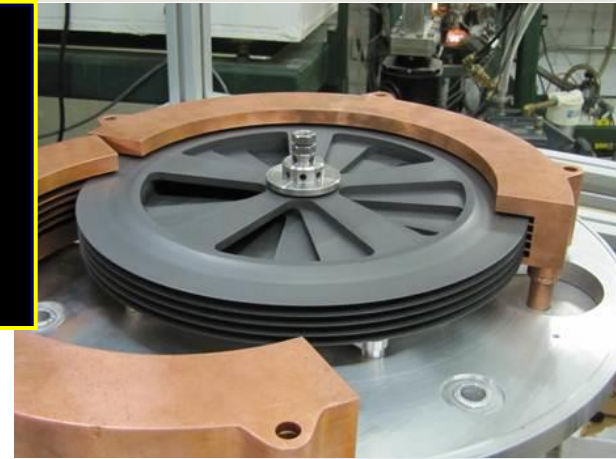
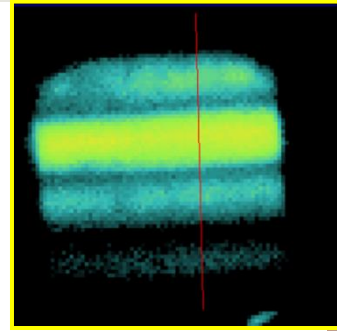
Final design substantially complete
Magnet fabrication to start early 2015



High-power Production Target

High-power Density Challenge Being Met

- Production Target
 - 100 kW beam power loss
 - 1 mm beam spot → 60 MW/cm³ for ²³⁸U
 - Desired lifetime of 2 weeks
- Multi-slice rotating graphite target
 - 5000 rpm, 30 cm diameter
 - T_{max} = 1900 C, P_{max}/slice = 10 kW
- Target concept successfully validated
 - High power electron beam tests at BINP
 - Graphite heavy ion irradiation studies at GSI



Confirmed with additional material tests

Isotope Harvesting Opportunity at FRIB

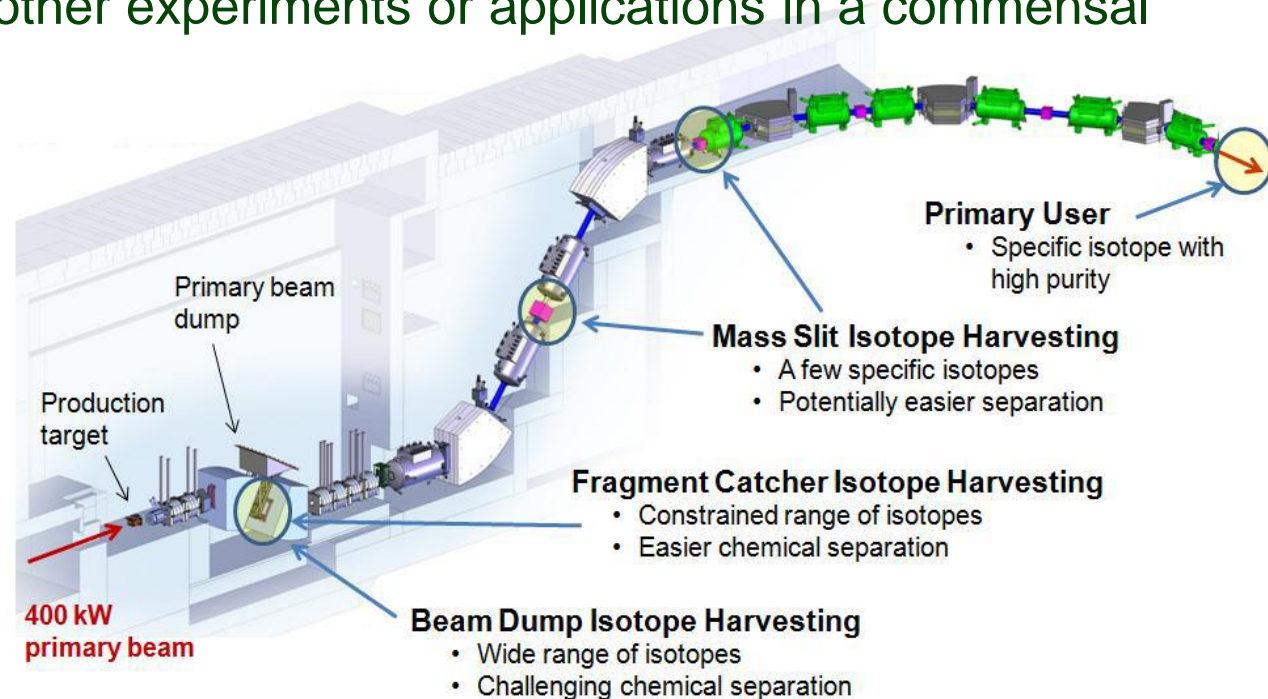
Make Best Use of Rare Isotopes Produced

- Produce a rare isotope beam for a primary user, for example ^{200}W from a ^{238}U primary beam
- At the same time up to 1000 other isotopes are produced that could be harvested and used for other experiments or applications in a commensal mode of operation

1st workshop on “Isotope Harvesting at FRIB”, Santa Fe, 2010

2nd workshop on “Isotope Harvesting at FRIB”, East Lansing, 2012

3rd workshop on “Isotope Harvesting at FRIB”, St Louis, 2014



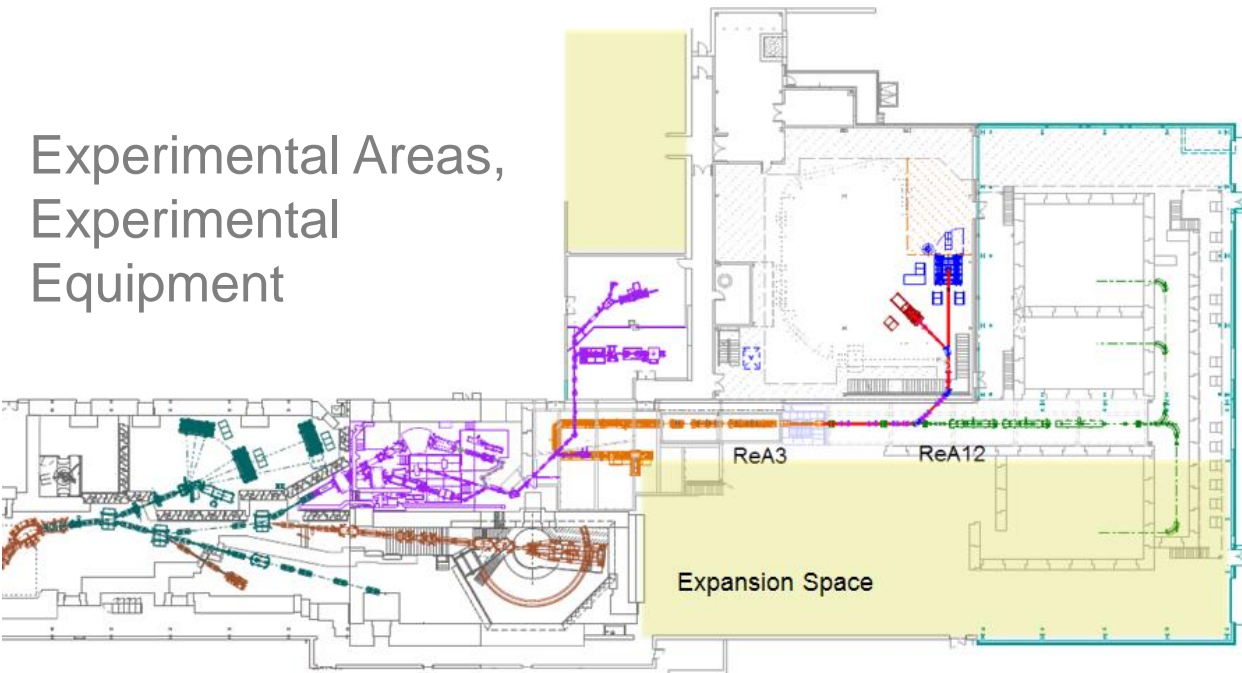
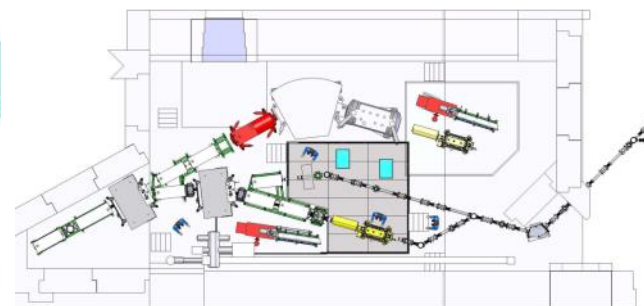
FRIB has provisions for isotope harvesting incorporated in the design

NSCL Enables pre-FRIB Science

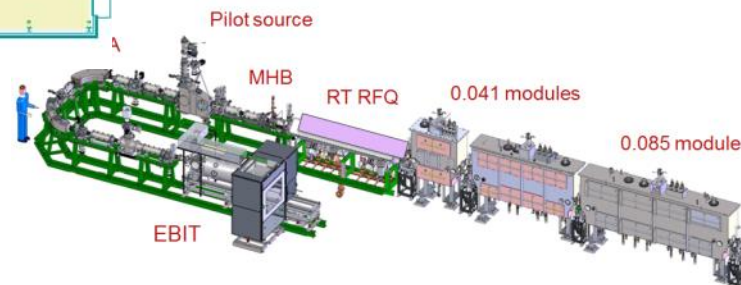
Fast, Stopped, and Reaccelerated Beams

Experimental Areas,
Experimental
Equipment

Beam Stopping



Reacceleration



New Equipment Development Geared Towards FRIB

Stopped Beams

■ Multifaceted approach

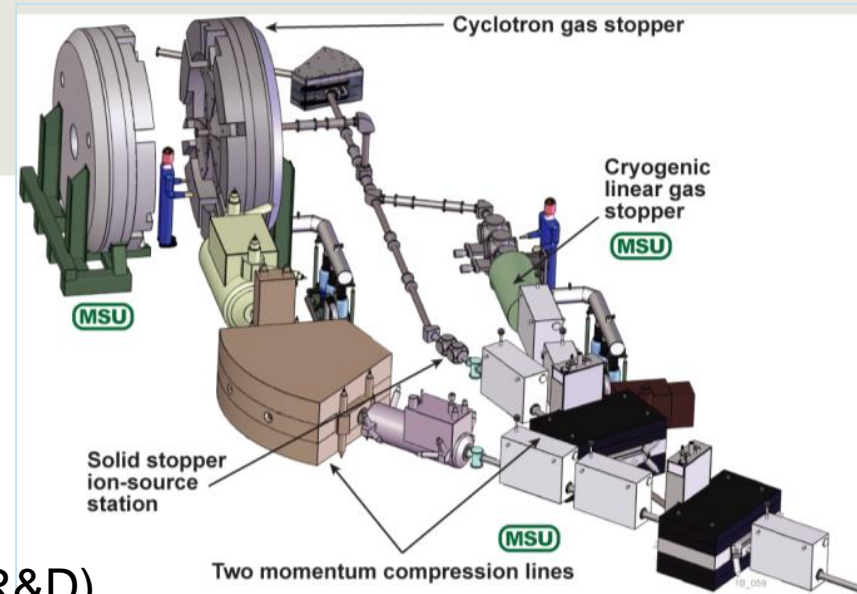
- Linear gas stopper (heavier ion beams)
- Cyclotron gas stopper (lighter ion beams)
- Solid stopper (certain elements, highest intensity)

■ Beam stopping developments

- Linear gas catcher (ANL) operational (FRIB R&D)
- Cyclotron gas stopper construction advanced (NSF + MSU funded)
- Advanced Cryogenic Gas Stopper underway (NSF funded)

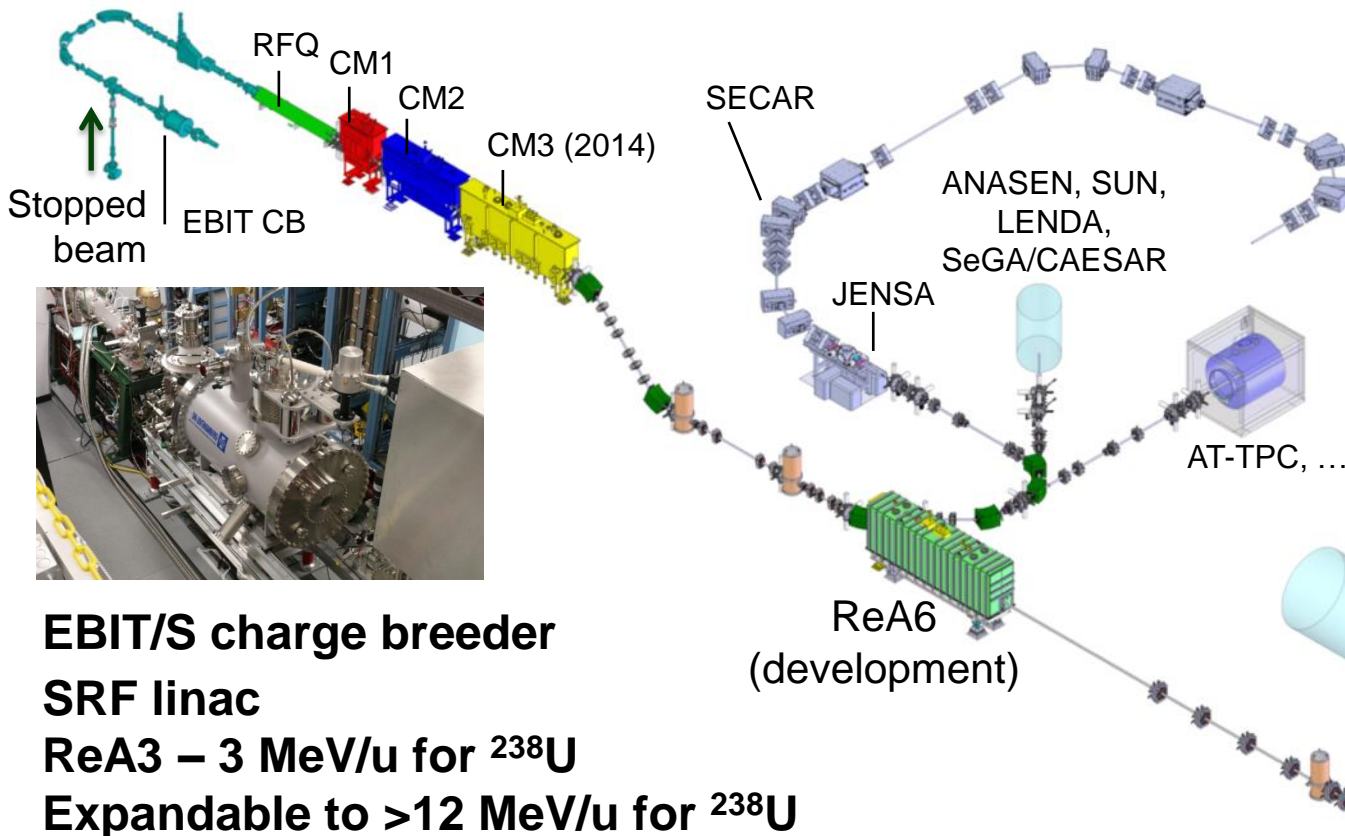
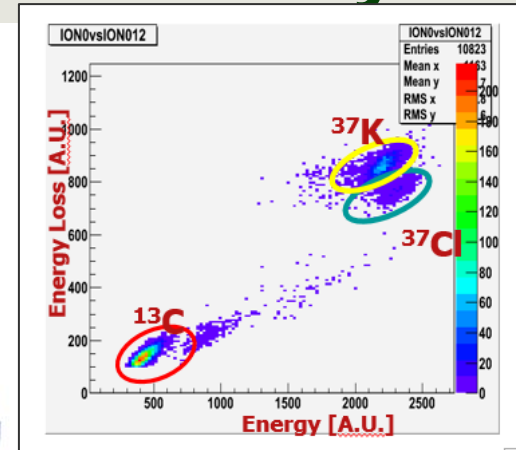
■ Experiments

- LEBIT
- BECOLA
- Double-arm positron polarimeter (under construction)

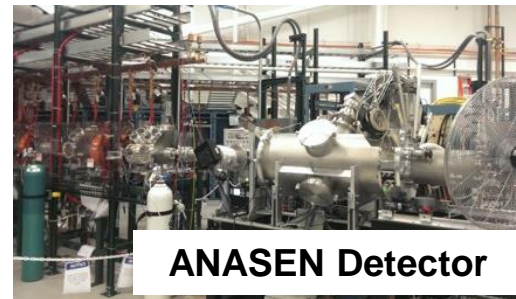


Reaccelerated Beams at NSCL and FRIB with ReA Facility

First radioactive beam experiment with ReA3 August 2013

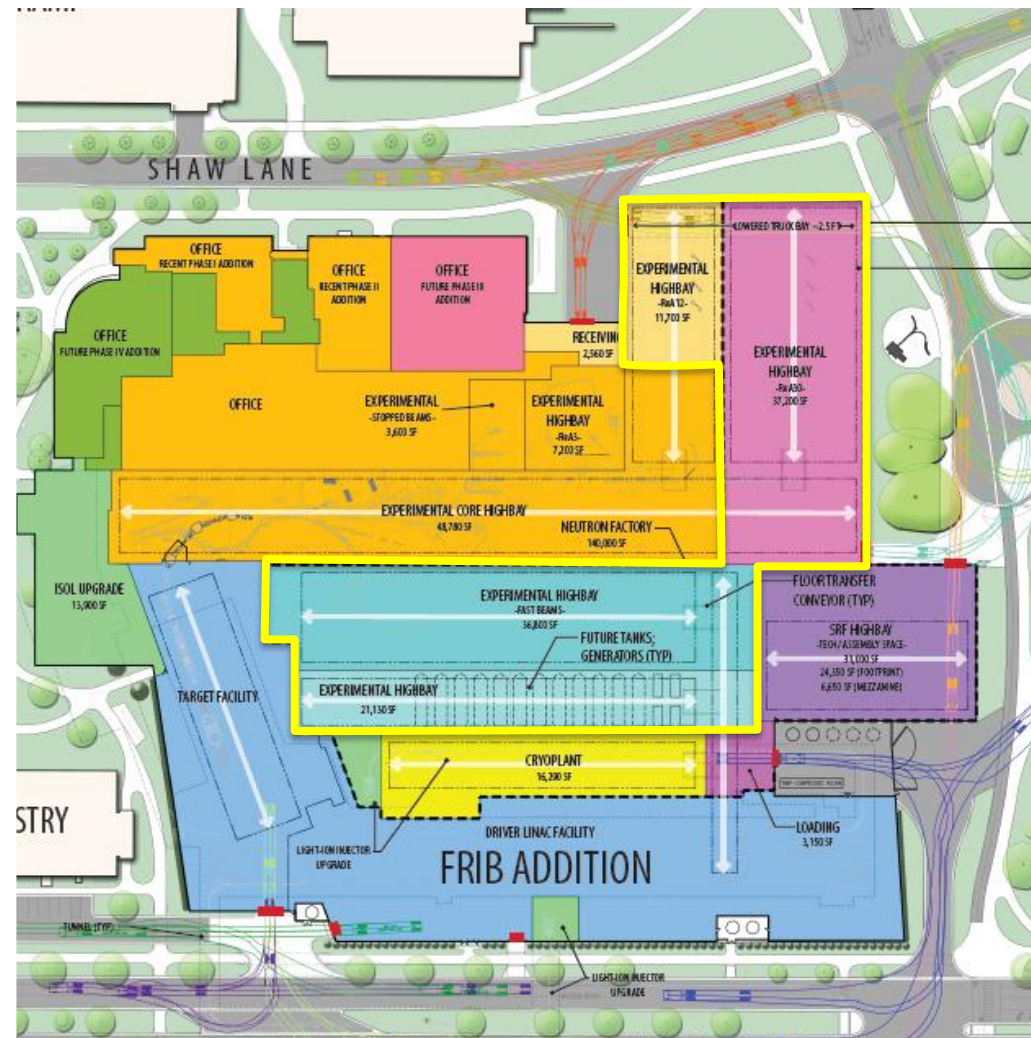


EBIT/S charge breeder
 SRF linac
 ReA3 – 3 MeV/u for ^{238}U
 Expandable to >12 MeV/u for ^{238}U



Experimental Area Expansion and New Experimental Equipment

- 47,000 sq ft operational when FRIB starts, upgrade space of more than 60,000 sq ft
- Experimental Equipment
 - Equipment at NSCL (existing or under development): S800, SeGA, MoNA, MoNA-LISA, LENDA, NSCL-BCS, LEBIT, BECOLA, AT-TPC, CAESAR, SUN, ...
 - Equipment available in the community and movable (existing, under development, or planned): GRETINA, ANASEN, CHICO, Nanoball, ORRUBA, JANUS, ...
 - Science driven new equipment developed by FRIB user community: SECAR, GRETA, HRS, ReA12 recoil separator, ...



Over 1300 Users Engaged and Ready for Science

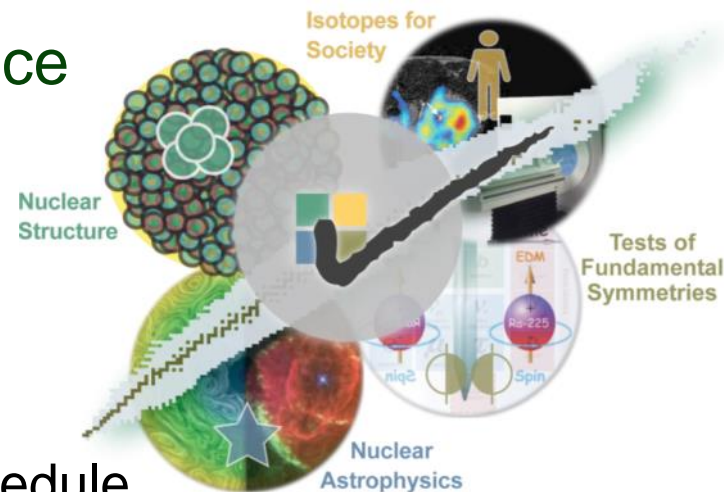
- Users are organized as part of the independent FRIB Users Organization (FRIBUO)
www.fribusers.org
- FRIBUO has 1350 members (92 U.S. colleges and universities, 10 national laboratories, 55 countries) as of April 2014
- FRIBUO has 19 working groups on experimental equipment
- Low Energy Nuclear Physics Town Meeting and Nuclear Astrophysics Town Meeting, 21-23 August 2014, Texas A&M University
 - Preparing input for next Nuclear Physics Long Range Plan
 - Joint first resolution



The highest priority In low-energy nuclear physics and nuclear astrophysics is the timely completion of the Facility for Rare Isotope Beams and the initiation of its full science program

Summary

- **FRIB to become a world-leading next-generation facility for rare isotope science**
 - Highest-power heavy ion linac worldwide
 - High-performance fragment separator
 - Fast, stopped, and reaccelerated beams
 - Provisions for isotope harvesting
- **FRIB project makes excellent progress**
 - Civil construction underway and ahead of schedule
 - Technical construction started
- **NSCL enables pre-FRIB science**
 - Well tested and optimized experimental equipment when FRIB starts
- **Strong, growing, and committed FRIB user group in place**



FRIB Team and Collaborators

▪ FRIB Project

- FRIB Project Leader: T. Glasmacher
- Accelerator Systems: J. Wei
- Experimental Systems: G. Bollen
- Conventional Facilities: B. Bull
- + **FRIB staff**

▪ Collaborating Institutions

- Argonne National Laboratory
- Brookhaven National Laboratory
- Fermilab
- Jefferson Laboratory
- Lawrence Berkeley National Laboratory
- Oak Ridge National Laboratory
- Stanford National Accelerator Lab.

▪ FRIB Laboratory

- FRIB Laboratory Director: K. Gelbke
- FRIB Chief Scientist: W. Nazarewicz
- Associate Laboratory Director for Users: B. Sherrill

- Budker Inst. of Nuclear Physics (Russia)
- GANIL (France)
- GSI (Germany)
- INFN Legnaro (Italy)
- KEK (Japan)
- RIKEN (Japan)
- Sandia
- Soreq (Israel)
- Tsinghua University & CAS (China)
- TRIUMF (Canada)

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