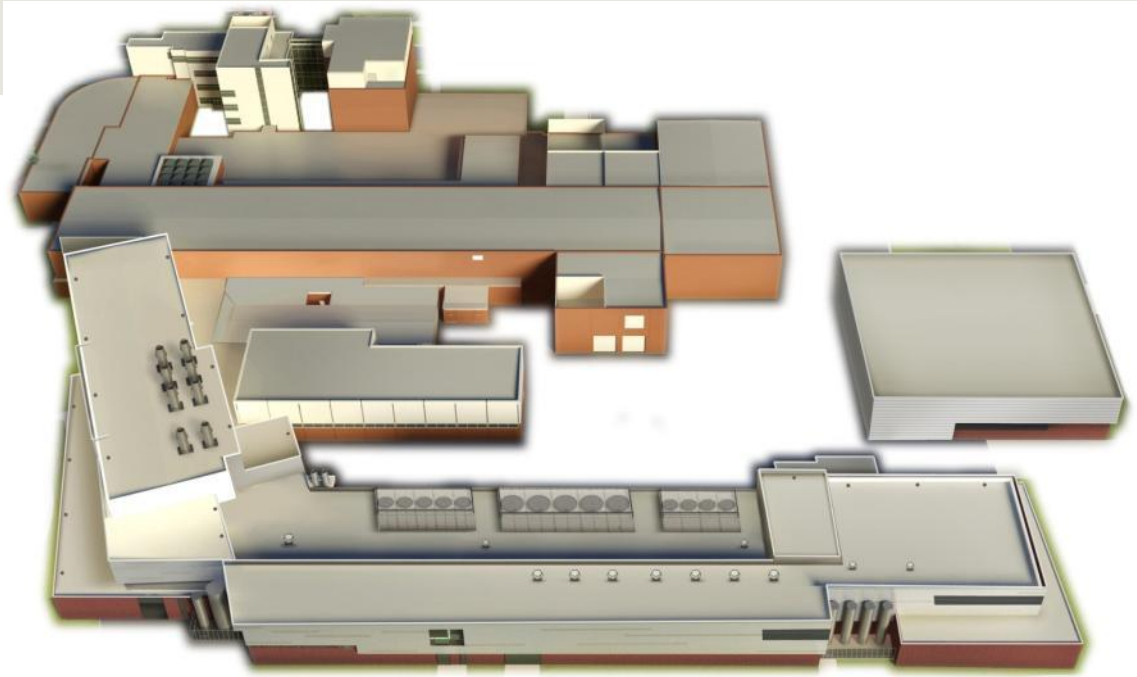


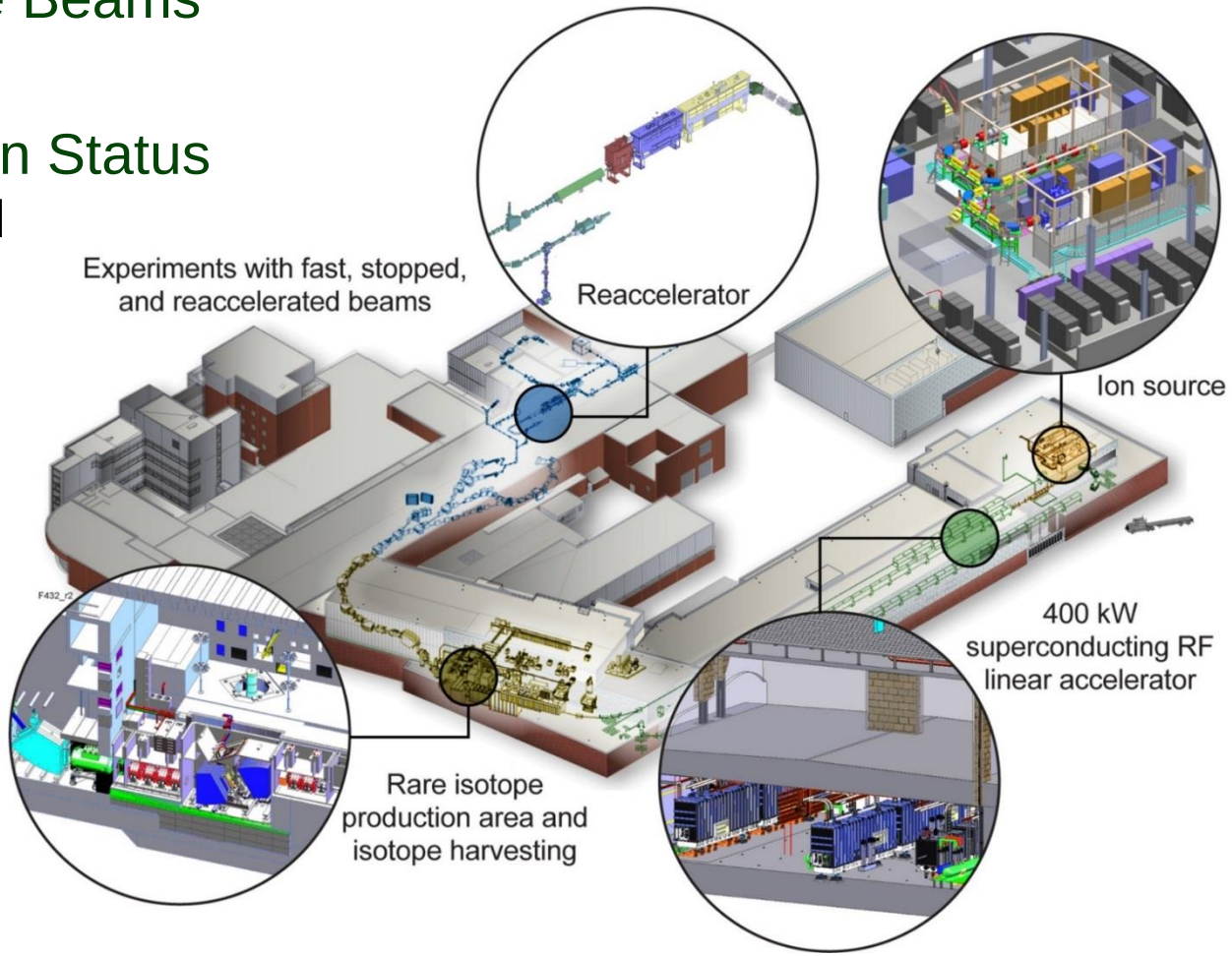
The Facility for Rare Isotope Beams

Chris Wrede
Michigan State University & NSCL
CGS15, Dresden, August 26th, 2014

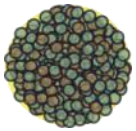
FRIB Facility for Rare Isotope Beams
U.S. Department of Energy Office of Science
Michigan State University
MICHIGAN STATE UNIVERSITY
U.S. DEPARTMENT OF ENERGY | Office of Science

Outline

- Facility for Rare Isotope Beams Science and Overview
- FRIB Project and Design Status
  - Civil construction started
  - Technical Construction to start soon
- NSCL and Integration
  - Beam stopping & reacceleration
  - Experimental areas and equipment
- FRIB Users
- Summary

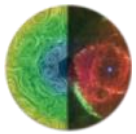


FRIB – Four Science Themes



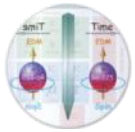
Properties of nuclei

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



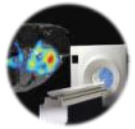
Astrophysical processes

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



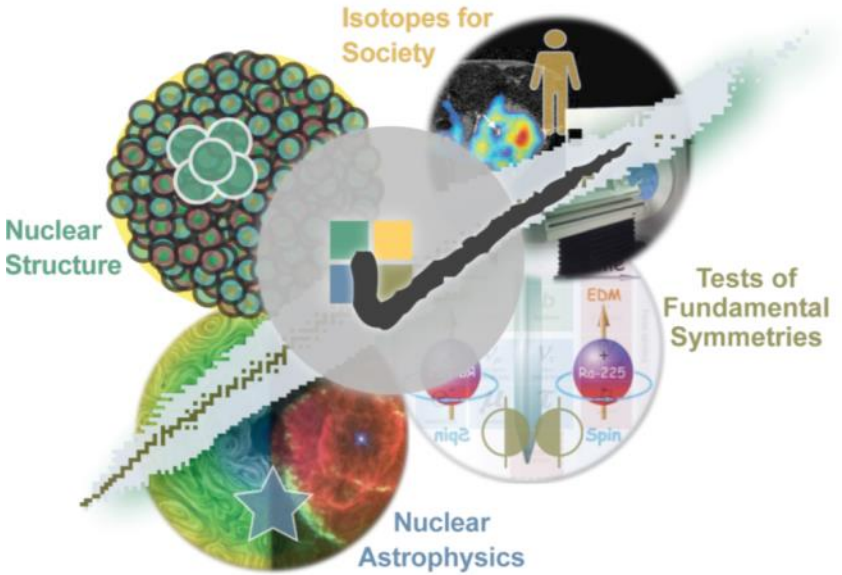
Tests of fundamental symmetries

- Effects of symmetry violations are amplified in certain nuclei



Societal applications and benefits

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



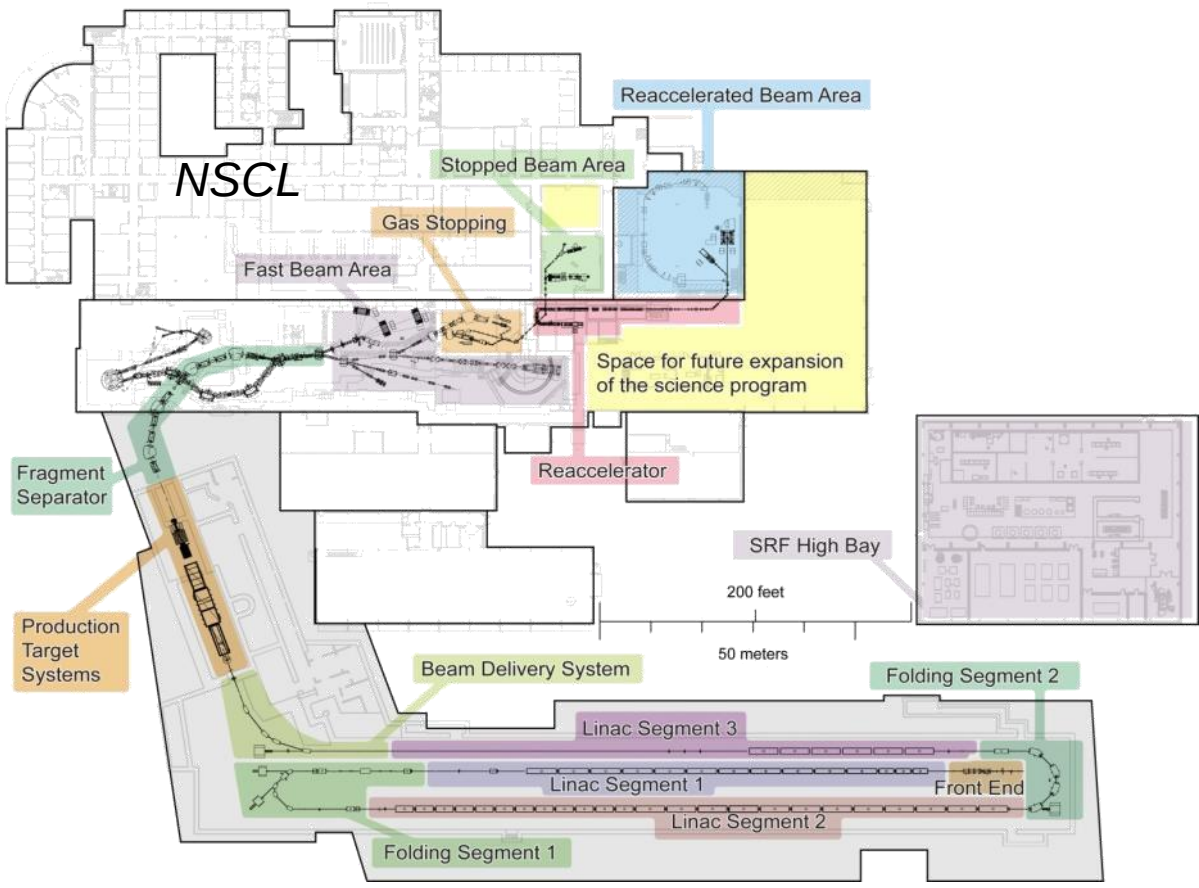
FRIB - Facility for Rare Isotope Beams

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

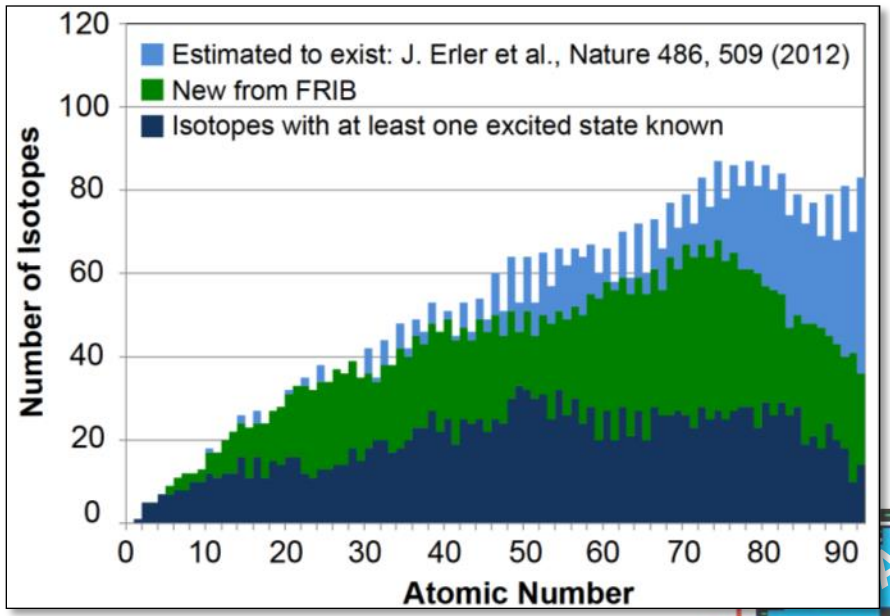
FRIB project start 6/2009
Civil construction started 3/2014
Technical construction to start 10/2014
Managed to early completion 12/2020
CD-4 (project completion) 6/2022

Total project cost $730 million



NSCL enables pre-FRIB science

FRIB Beams Will Enable New Discoveries

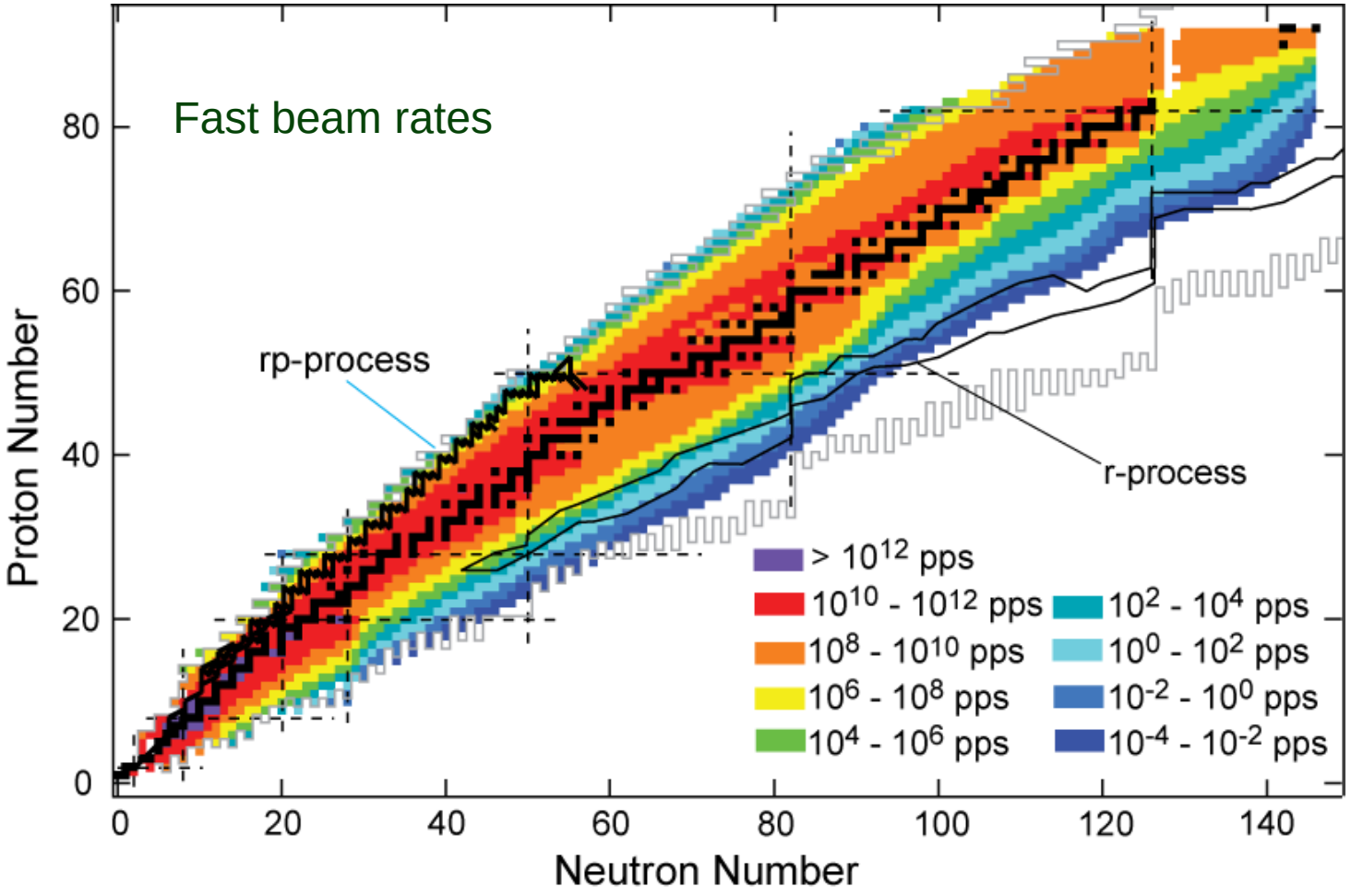


Available today

New territory to be explored with FRIB

about 3000 known isotopes

FRIB Rare Isotope Beam Rates
High Beam Rates to Maximize Science Reach



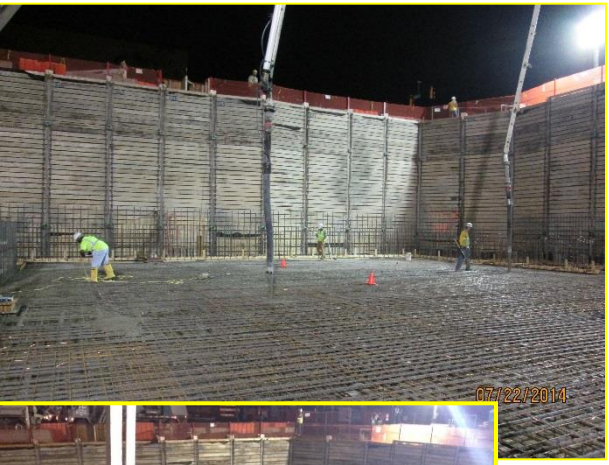
Rates are available at http://groups.nscl.msu.edu/frib/rates/

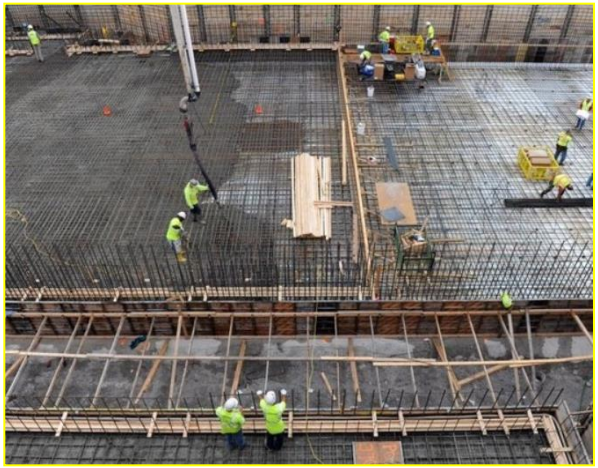
FRIB Civil Construction Underway Began 3 March 2014

FRIB construction site on 13 August 2014 -- Web cameras at www.frib.msu.edu

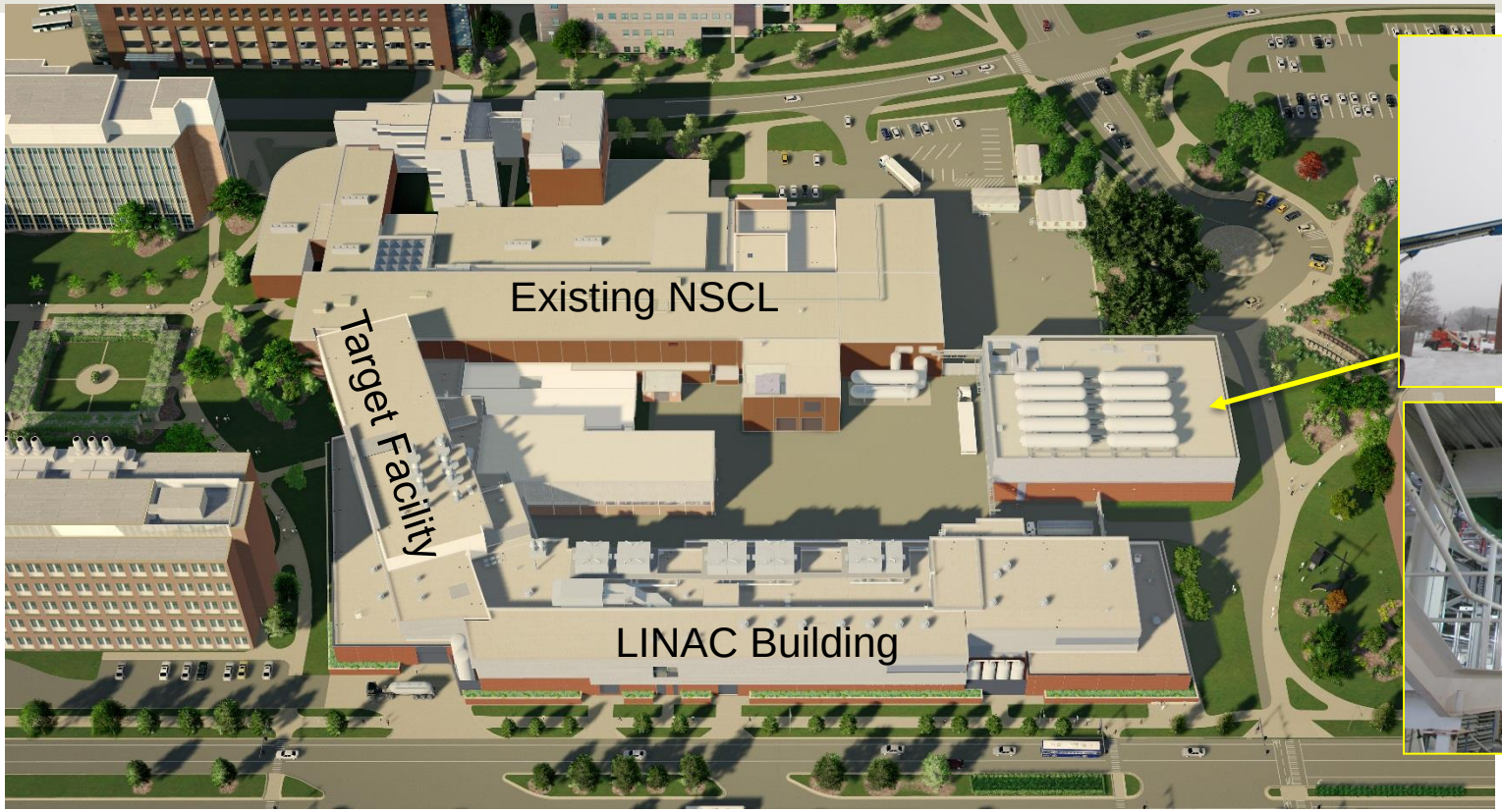
First Big Concrete Pour July 23

140 concrete trucks, 1400 cubic yards



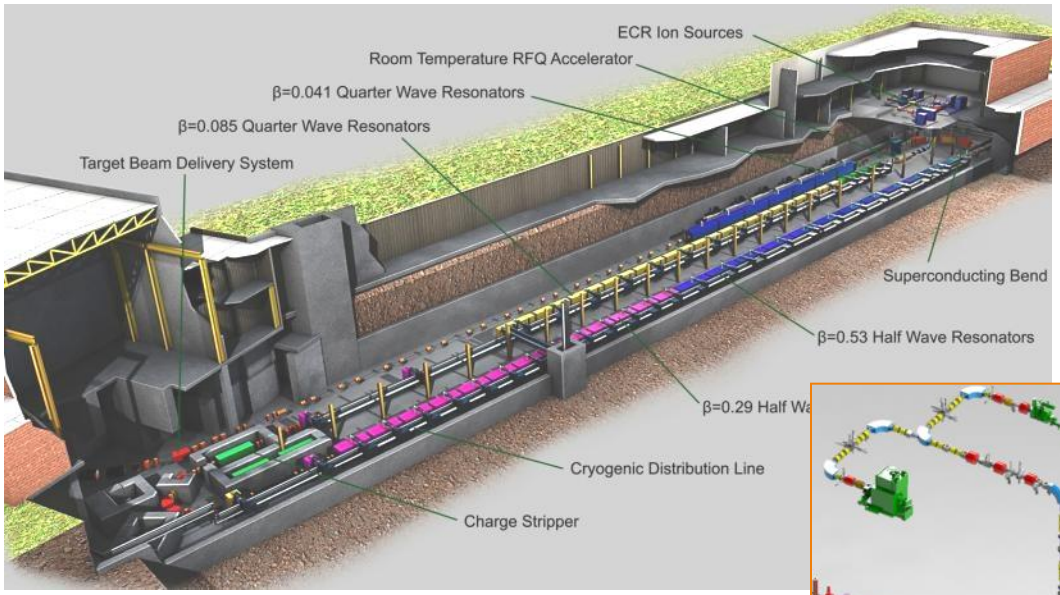


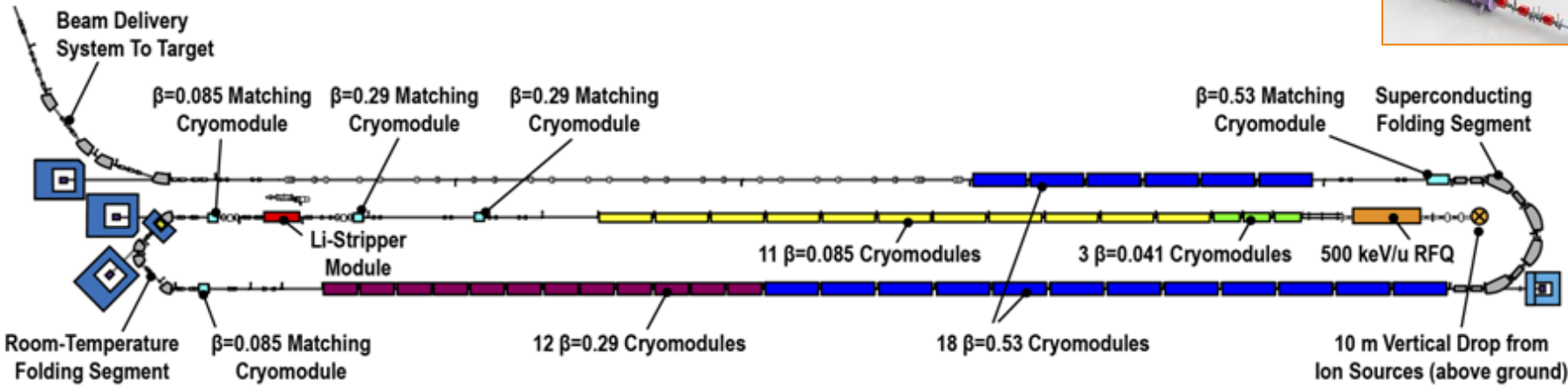
FRIB Construction Underway



FRIB Accelerator Systems
Superconducting RF Driver Linac

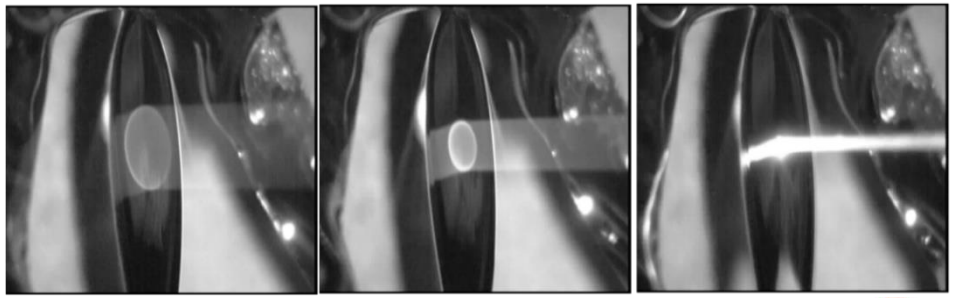
- Accelerate ion species up to ^{238}U with energies of no less than 200 MeV/u
- Provide beam power up to 400 kW
- Energy upgrade to 400 MeV/u for uranium by filling vacant slots with 12 SRF cryomodules





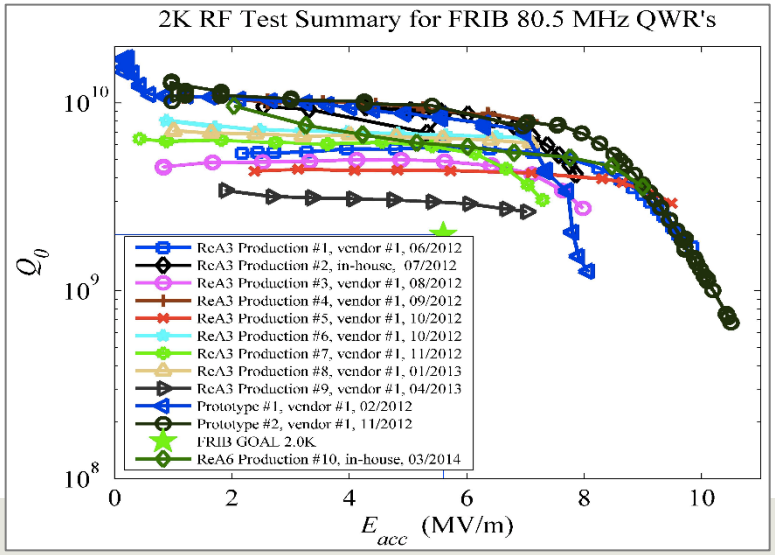
FRIB Accelerator Systems

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



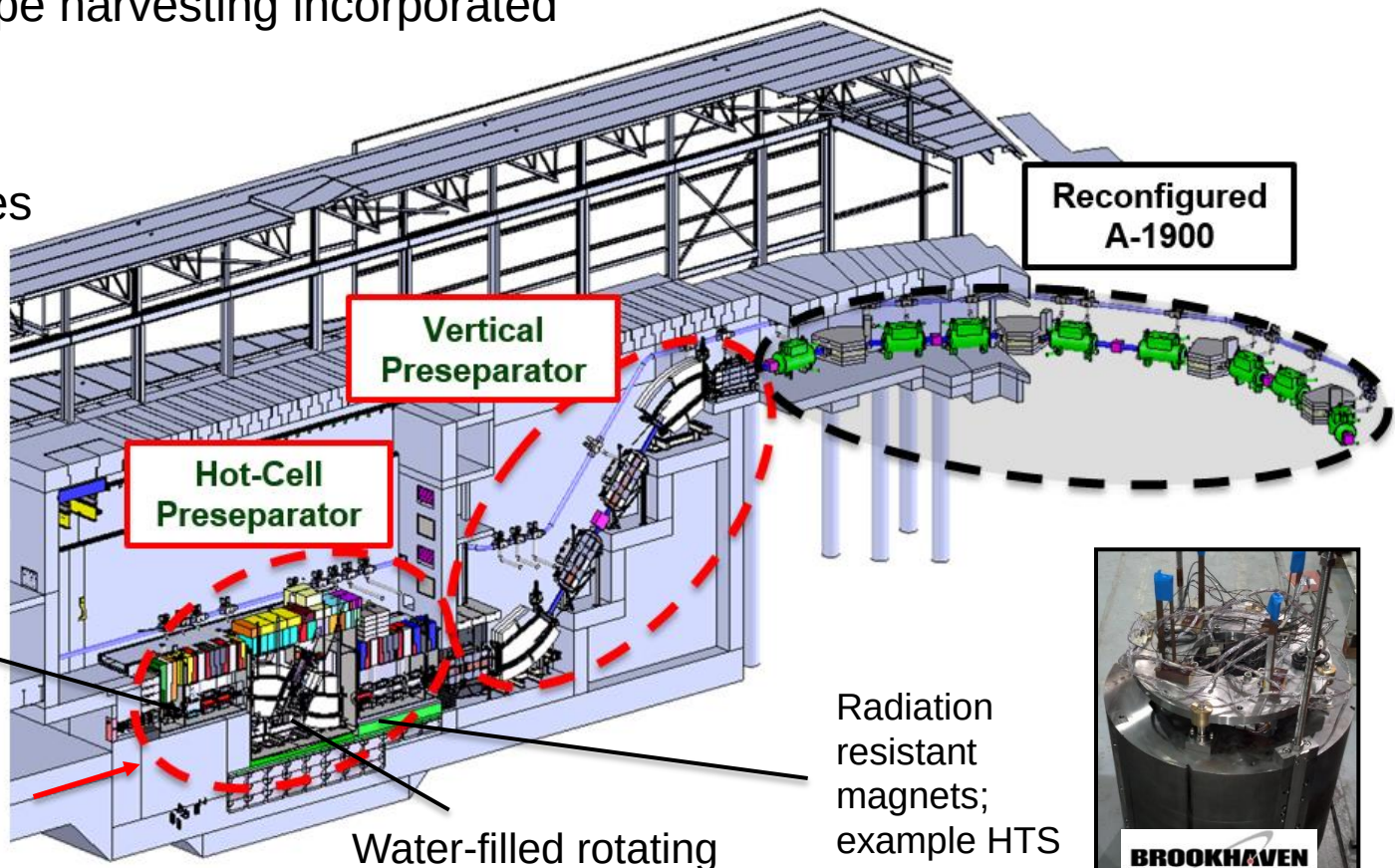
Argonne NATIONAL LABORATORY

Los Alamos NATIONAL LABORATORY EST.1943



FRIB Production Target & Fragment Separator

- Three stage magnetic fragment separator
  - High acceptance, high resolution to maximize science
  - Provisions for isotope harvesting incorporated in the design
- Challenges
  - High power densities
  - High radiation

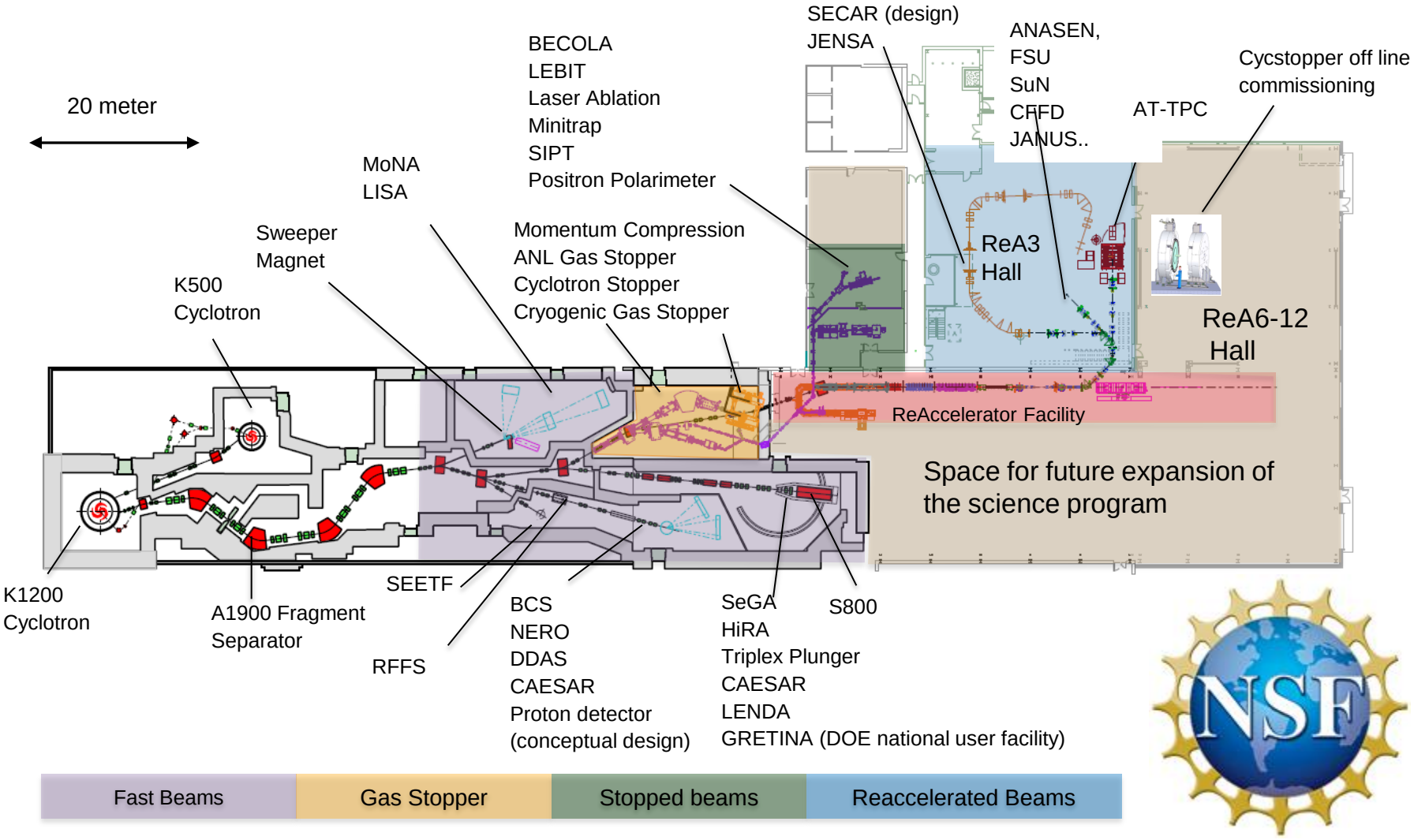


Multi-slice rotating graphite target

Water-filled rotating beam dump

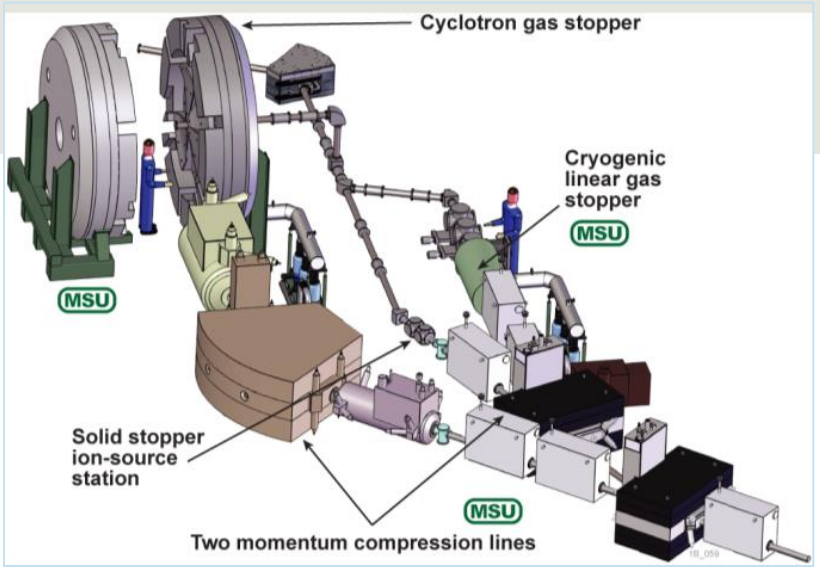
Radiation resistant magnets; example HTS quad

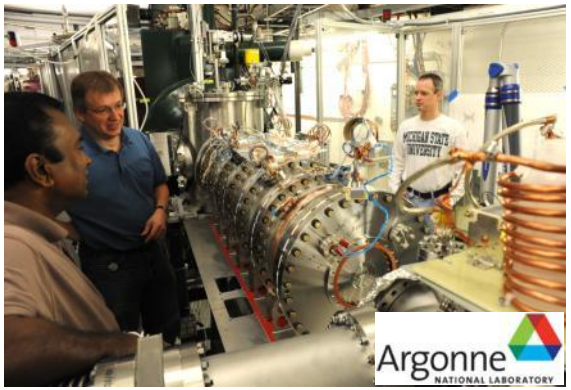
Early Science Opportunities at NSCL
with Fast, Stopped, Reaccelerated Beams



Stopped Beams at NSCL and FRIB

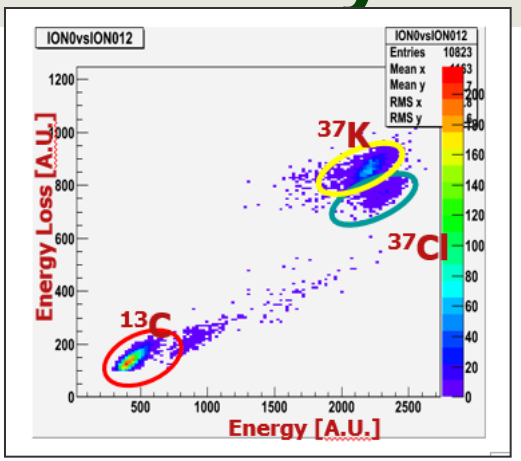
- Multifaceted approach
  - Linear gas stopper (heavier ion beams)
  - Cyclotron gas stopper (lighter ion beams)
  - Solid stopper (certain elements, highest intensity)
- Beam Stopping developments
  - Linear gas catcher (ANL) operational
  - Cyclotron gas stopper construction advanced (NSF + MSU funded)
  - Advanced Cryogenic Gas Stopper underway (NSF funding imminent)

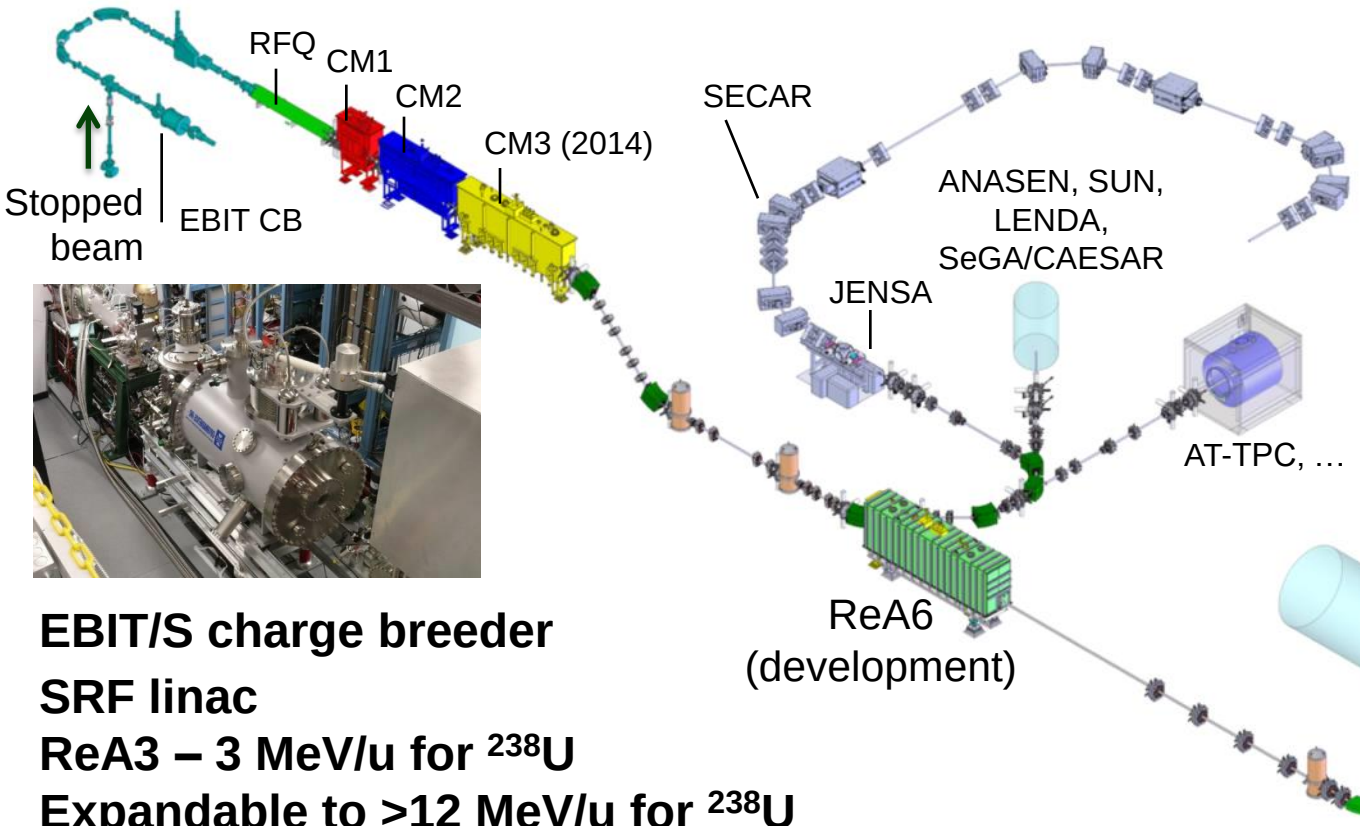


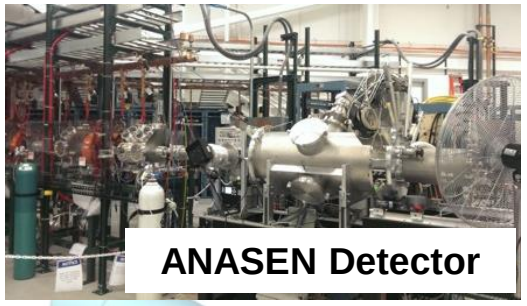


Reaccelerated Beams at NSCL and FRIB with ReA Facility

First radioactive beam experiment with ReA3 August 2013







EBIT/S charge breeder

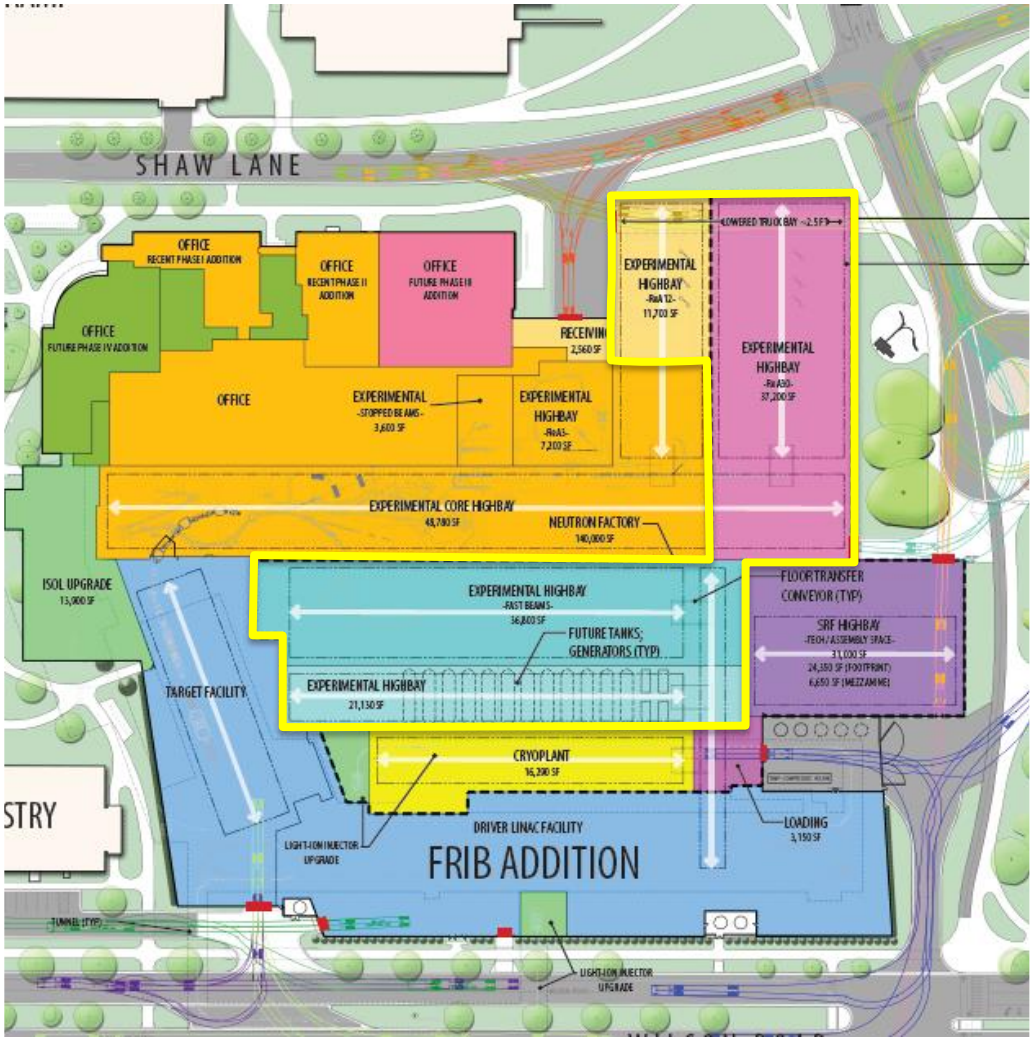
SRF linac

ReA3 – 3 MeV/u for ^{238}U

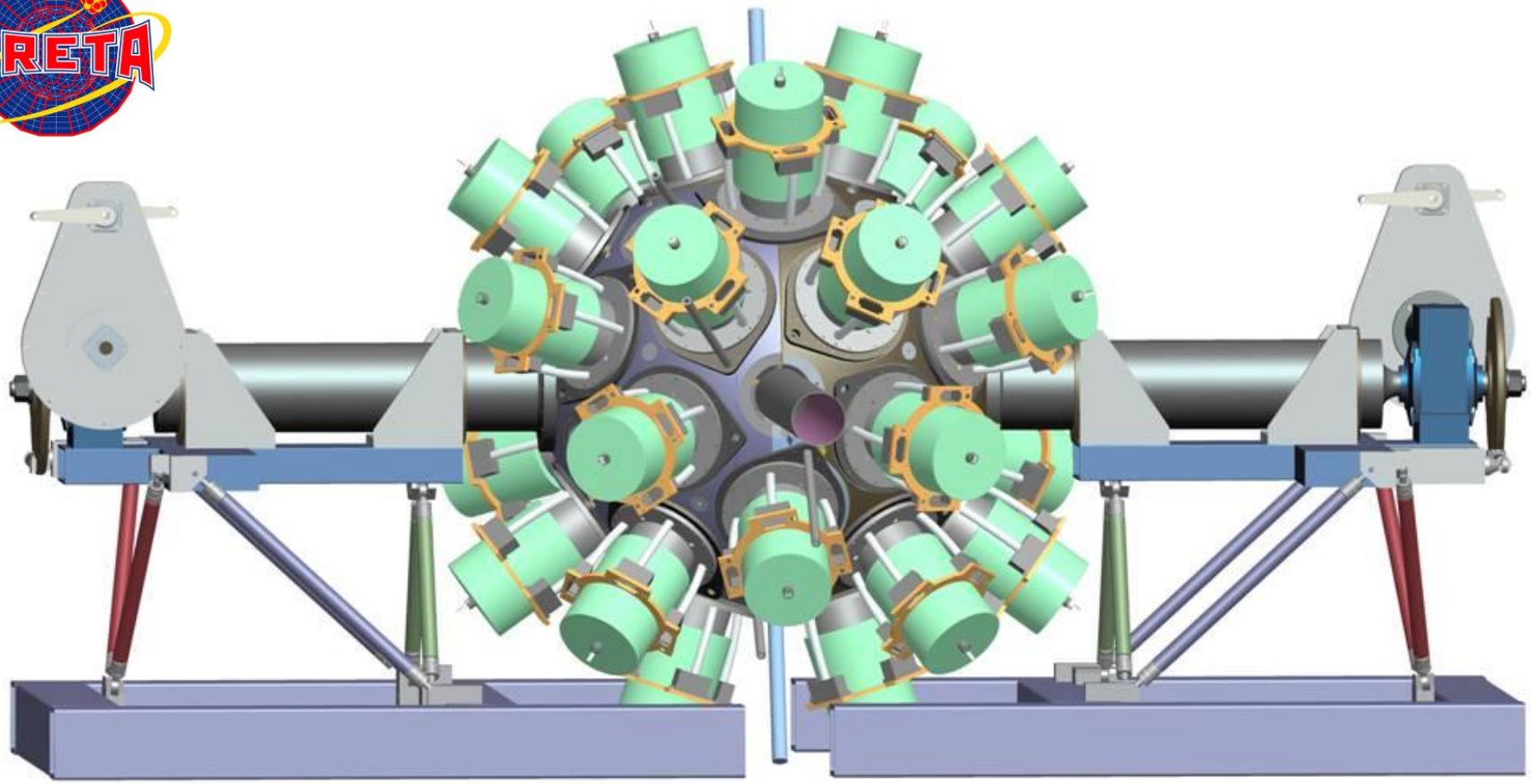
Expandable to >12 MeV/u for ^{238}U

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, ISLA, …



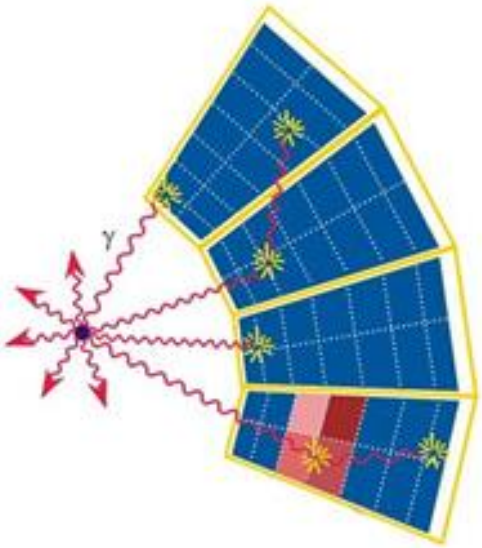
GRETA
The Gamma Ray Energy Tracking Array

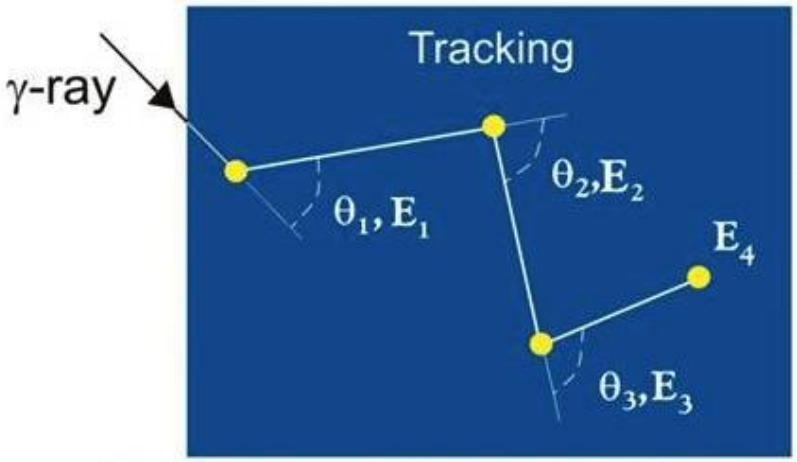


www.physics.fsu.edu/GRETINA.org/

www.lecmeeting.org/whitepapers.html

GRETA





- **Efficiency (~40%) - 30 HPGe quad-modules**

  Summing of scattered gamma rays:
  no solid angle lost to suppressors.
  4π coverage.
  Angular distributions/correlations.
  High-energy efficiency.

- **Position resolution (2 mm)**

  Position of 1st interaction.
  Excellent Doppler reconstruction.
  Effective energy resolution.

- **Peak-to-background (~ 55%)**

  Tracking.
  Rejection of Compton events, maintaining good spectral quality.

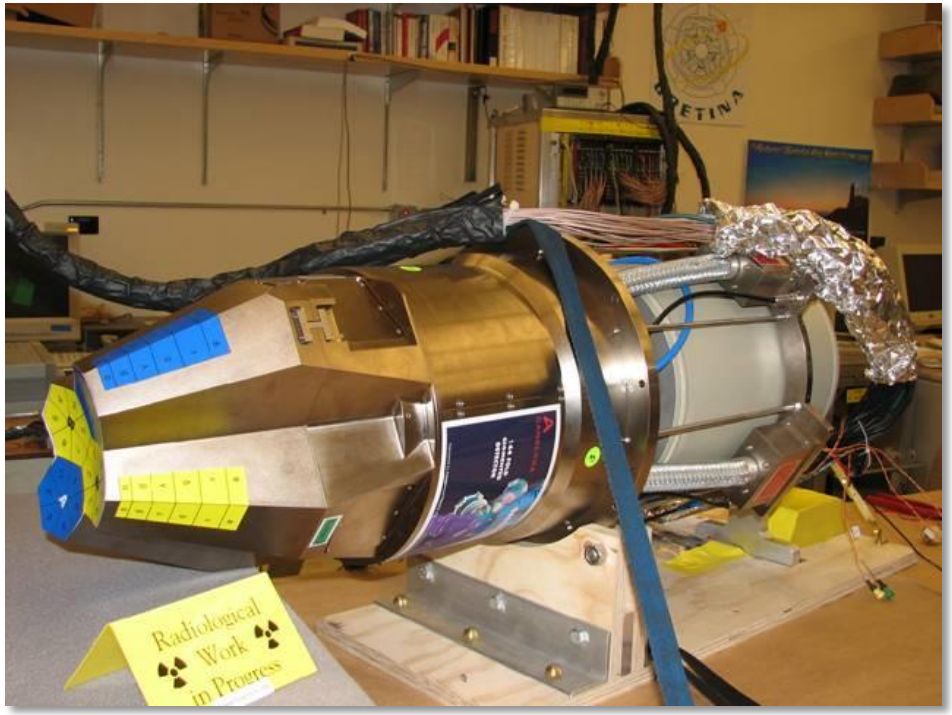
- **Polarization**

  Angular distribution of the 1st scattering.

- **Counting rate**

  Many segments.

Gretina / GRETA quad detectors

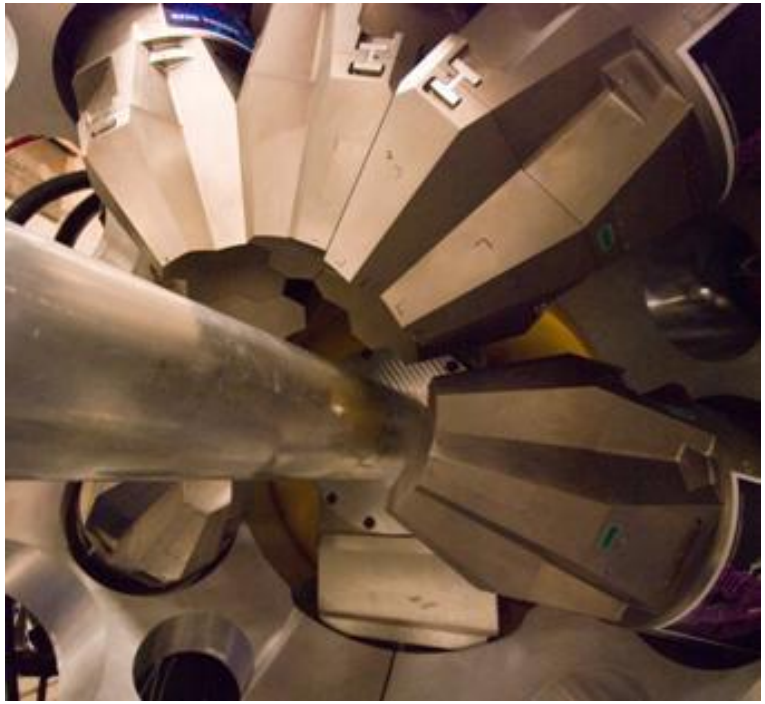


Gretina: 1π predecessor to GRETA

Commissioned at Berkeley

Successful campaign at NSCL (2012/13)

Currently running at ANL/ATLAS

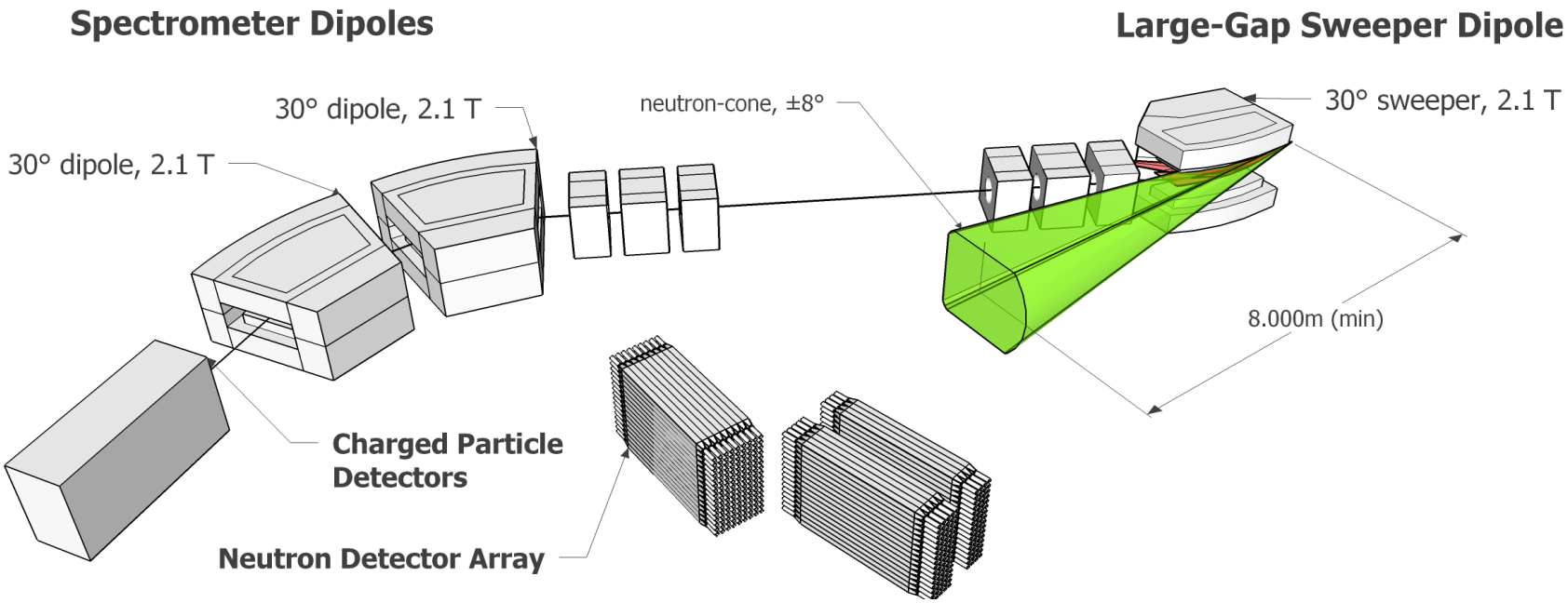


4 crystals per module

36 segments per crystal

148 signal channels per module

HRS
High-Rigidity Spectrometer



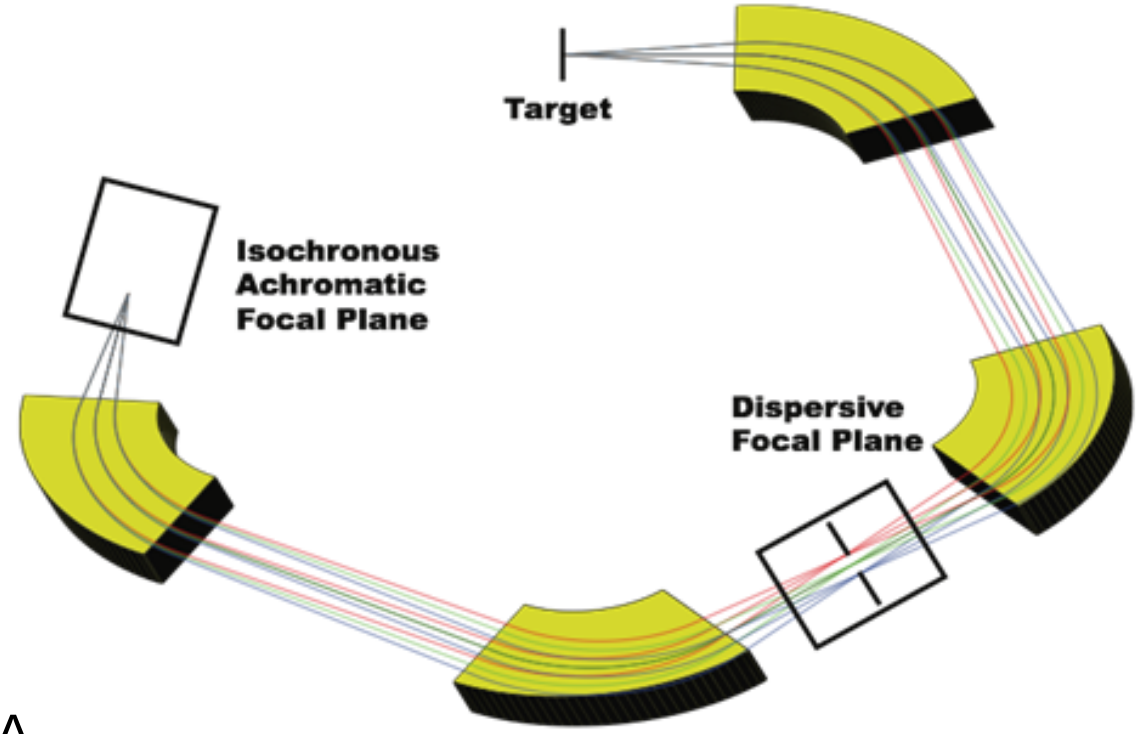
Primary design parameters

Maximum Magnetic Rigidity	8 Tm
Acceptance	10 msr
Momentum acceptance	10%
Momentum resolution	1 in 5000
Ion-optical features	Image after sweeper stage for removing beam
Dispersion	7 cm/%
Sweeper	30° bending angle, B_{max} = 2.1 T, gap size: 60 cm
Spectrometer Dipoles	2x30° bending angle, B_{max} = 2.1 T, gap size: 12 cm
Quadrupoles	based on FSQ7/8 design for FRIB separator, ~50cm maximum bore

- For fast RIBs (~170-200 MeV/u)
- Detectors surrounding target for:
  - γ rays (eg. GRETA)
  - charged-particles (eg. HiRA)
  - neutrons (eg. LENDA, VANDLE)
  - …

ISLA
Isochronous Separator with Large Acceptance

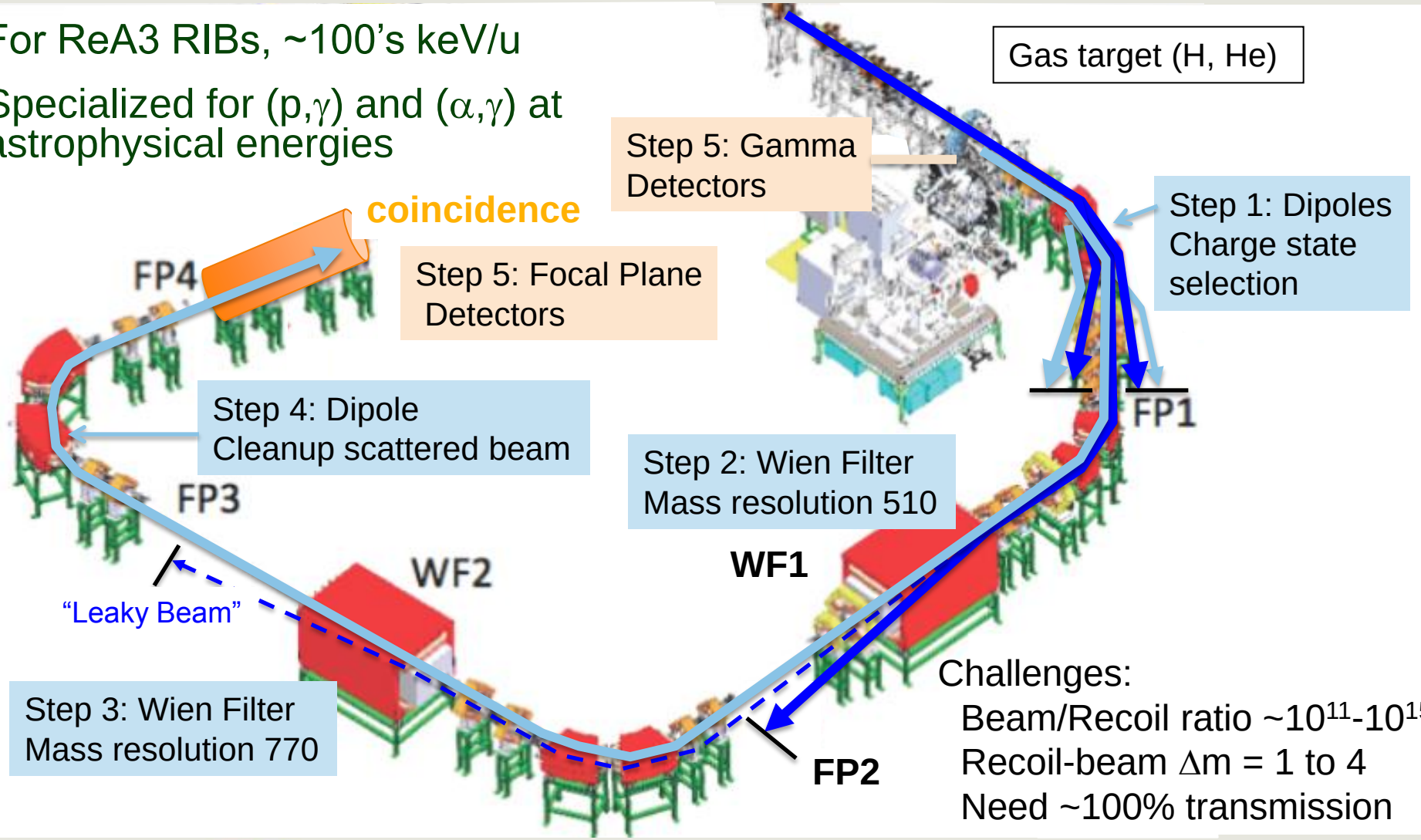
- For ReA12 RIBs: ~10 MeV/u
- Selected design (July 2014)
- M/Q resolving power > 1000
- Large acceptance
  - 64 msr
  - +/-10% momentum



- Flexible M/Q spectrometer
  - Space about target for GRETA
  - Incoming beam swinger allows operation off zero degrees
  - Small focal plane (implantation)
  - Low energy RF kicker allows physical separation of products by M/Q
  - First half could be used in a VAMOS-like mode
  - Could be operated in gas-filled mode

SECAR
SEparator for CApture Reactions

- For ReA3 RIBs, ~100's keV/u
- Specialized for (p,γ) and (α,γ) at astrophysical energies



Challenges:
- Beam/Recoil ratio ~10^{11}-10^{15}
- Recoil-beam Δm = 1 to 4
- Need ~100% transmission

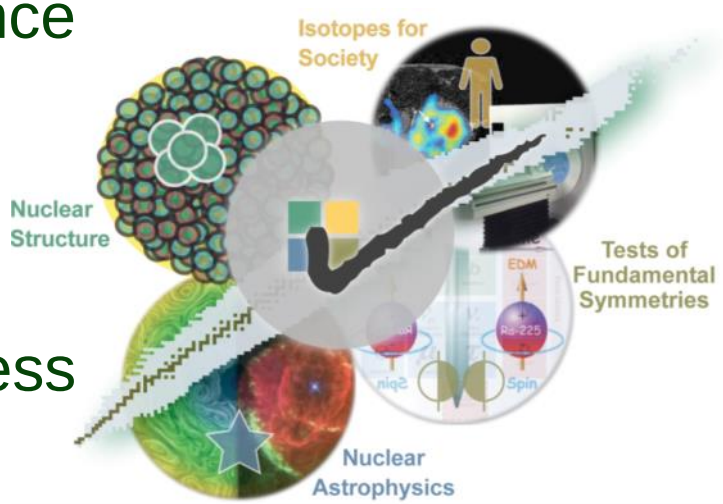
Over 1300 Users Engaged and Ready for Science

- Users are organized as part of the independent FRIB Users Organization (FRIBUO) www.fribusers.org
- FRIBUO has 1386 members (92 U.S. colleges and universities, 10 national laboratories, 55 countries) as of April 2014
- FRIBUO has 19 working groups on experimental equipment
- 21-23 August 2014, Low Energy Nuclear Physics and Nuclear Astrophysics Town Meetings, Texas A&M University

August 2013 Low-Energy Community Meeting 274 participants

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 is making excellent progress
  - Civil construction started
  - Technical construction starts this fall



- NSCL enables pre-FRIB science
  - Well tested and optimized experimental equipment when FRIB starts
- Several major new-equipment initiatives
  - GRETA, HRS, ISLA, SECAR, …
- Strong and growing FRIB user group in place

Thank you for your attention!

- Thanks for providing material:
  Matt Amthor, Georg Bollen, Thomas Glasmacher, Augusto Machiavelli, Wolfgang Mittig, Hendrik Schatz, Michael Smith, Remco Zegers