Facility for Rare Isotope Beams

and

‘he r-process

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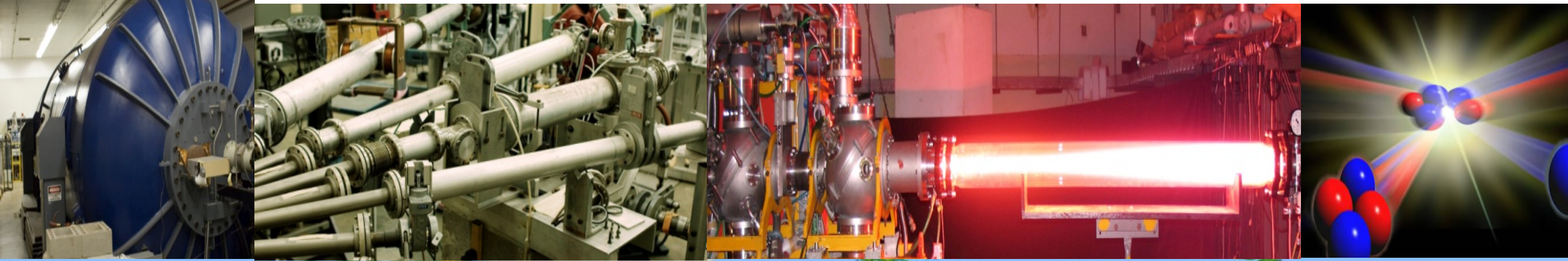
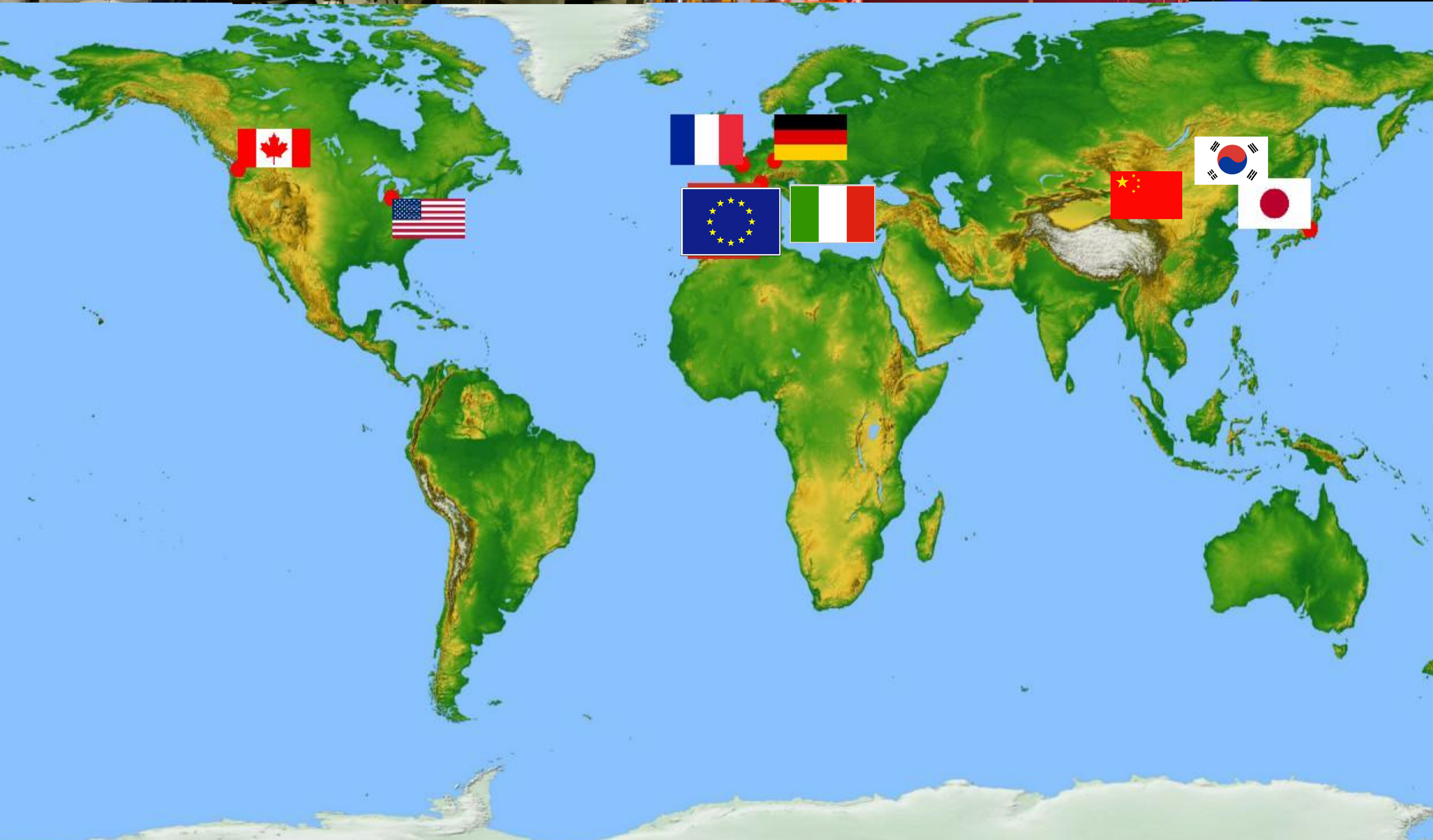
J I N A

SPES Project

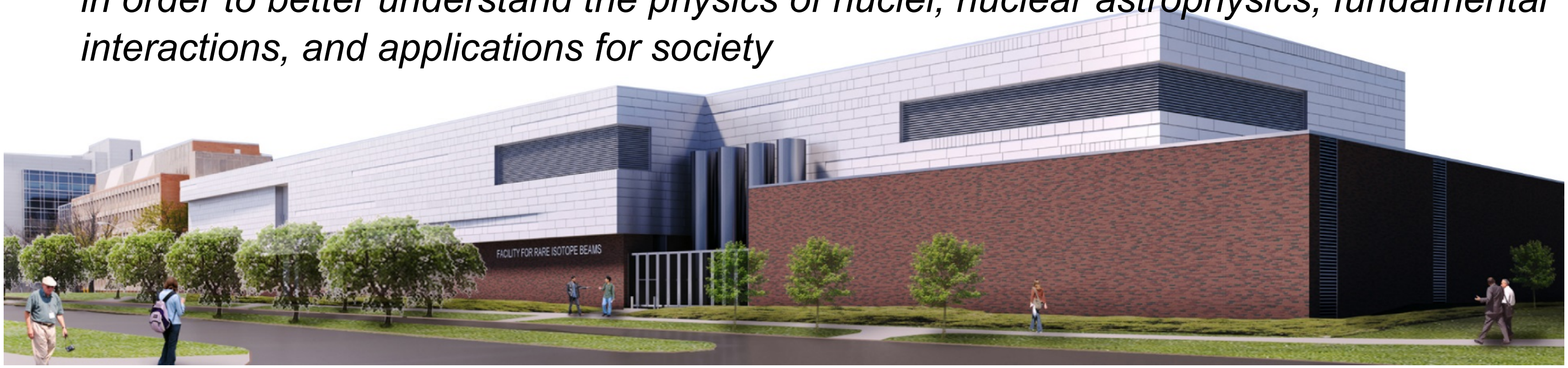
November 13, 2015
Caserta

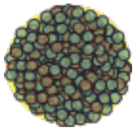
Facility for Rare Isotope Beams: FRIB

- FRIB will be a $730 million national user facility funded by the Department of Energy Office of Science (DOE-SC), Michigan State University, and the State of Michigan
- FRIB Project completion date is June 2022, managing to an early completion in December 2020
- FRIB will serve as a DOE-SC national user facility for world-class rare isotope research supporting the mission of the Office of Nuclear Physics in DOE-SC

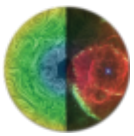
FRIB will enable scientists to make discoveries about the properties of these rare isotopes in order to better understand the physics of nuclei, nuclear astrophysics, fundamental interactions, and applications for society



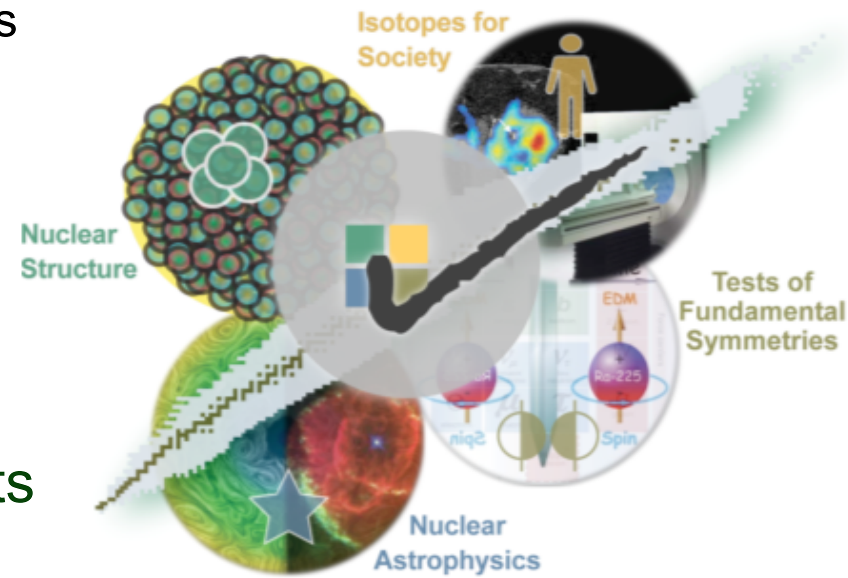
FRIB Will Enable Scientists to Make Discoveries

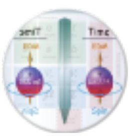


Properties of atomic nuclei
- Develop a predictive model of nuclei and their interactions
- Many-body quantum problem: intellectual overlap to mesoscopic science, quantum dots, atomic clusters, etc.

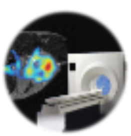


Astrophysics: What happens inside stars?
- Origin of the elements in the cosmos
- Explosive environments: novae, supernovae, X-ray bursts …
- Properties of neutron stars





Tests of laws of nature
- Effects of symmetry violations are amplified in certain nuclei



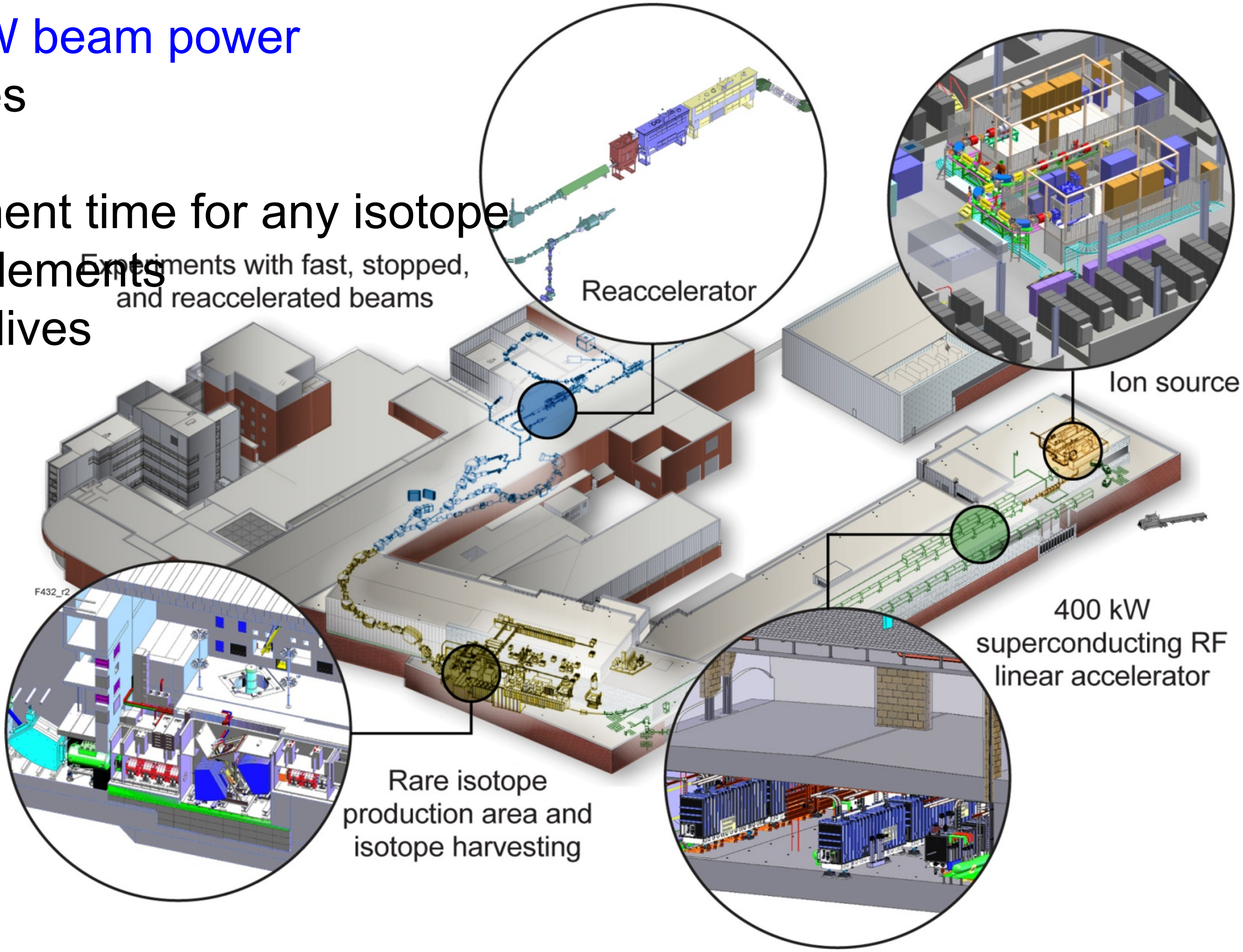
Societal applications and benefits
- Medicine, energy, material sciences, national security

Optimized for Science with Fast, Stopped and Reaccelerated Rare Isotope Beams

Key feature is 400 kW beam power

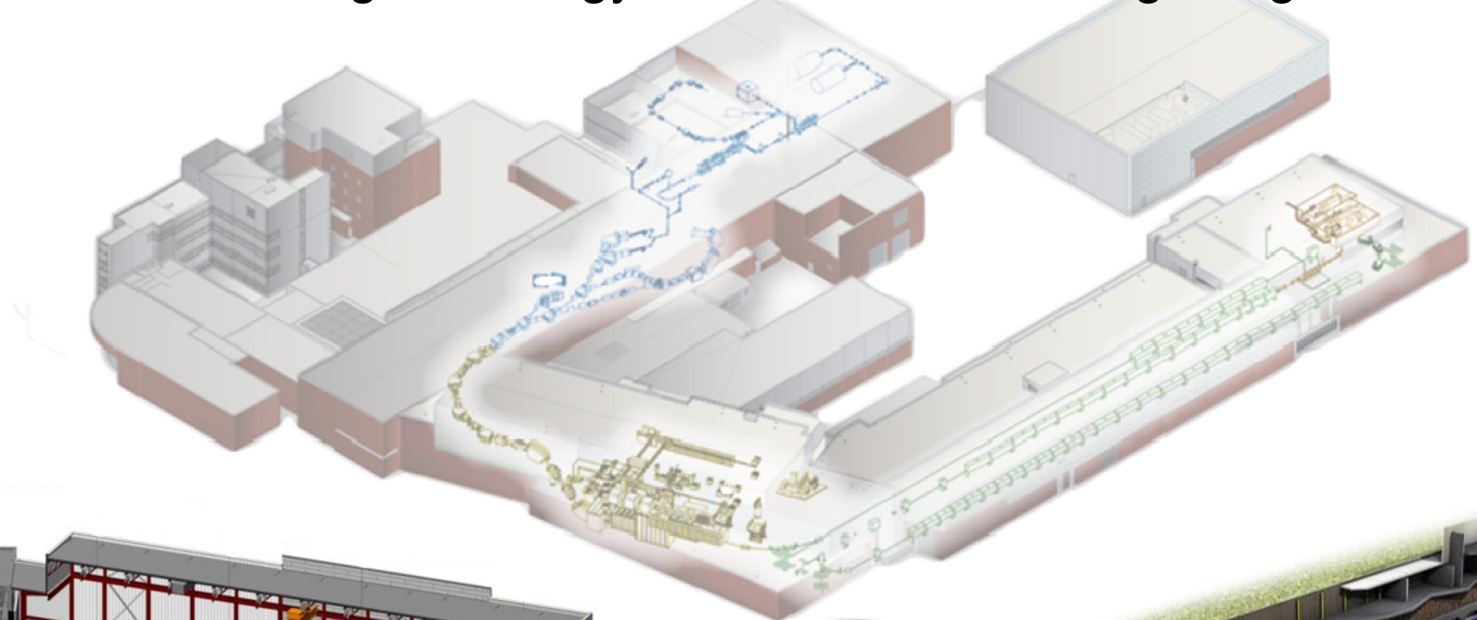
Separation of isotopes in-flight

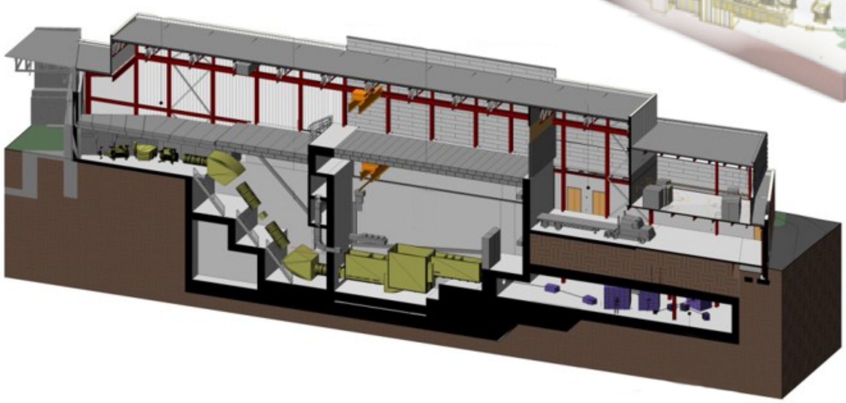
- Fast development time for any isotope
- Suited for all elements and short half-lives

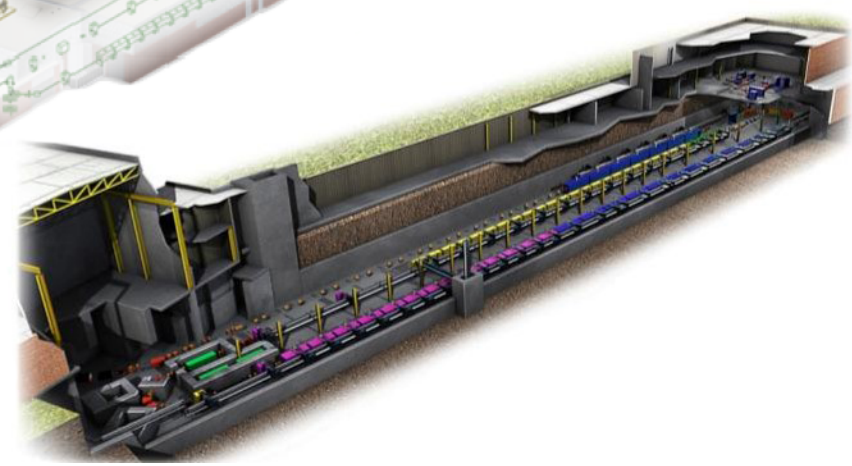


Integrated Design Includes Options for Science-Driven Upgrades

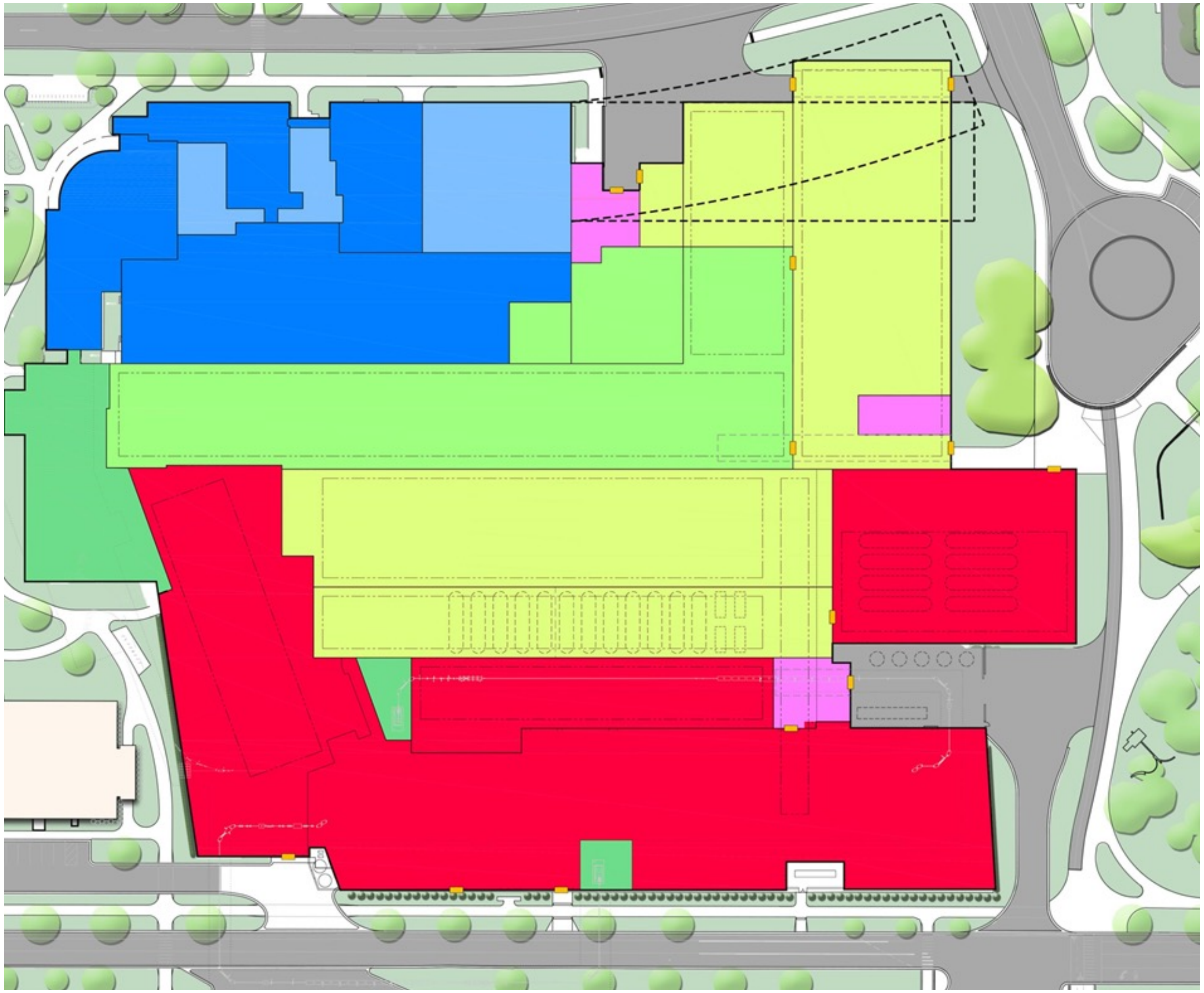
Possibilities include higher beam energy, isotope harvesting, multi-user operation, ISOL, higher-energy reacceleration, storage rings, …







Site Master Plan Includes Space for Science-Driven Upgrades



- Higher beam energy
- Isotope harvesting
- Multi-user operation,
- ISOL
- Higher-energy reacceleration
- Storage rings, …

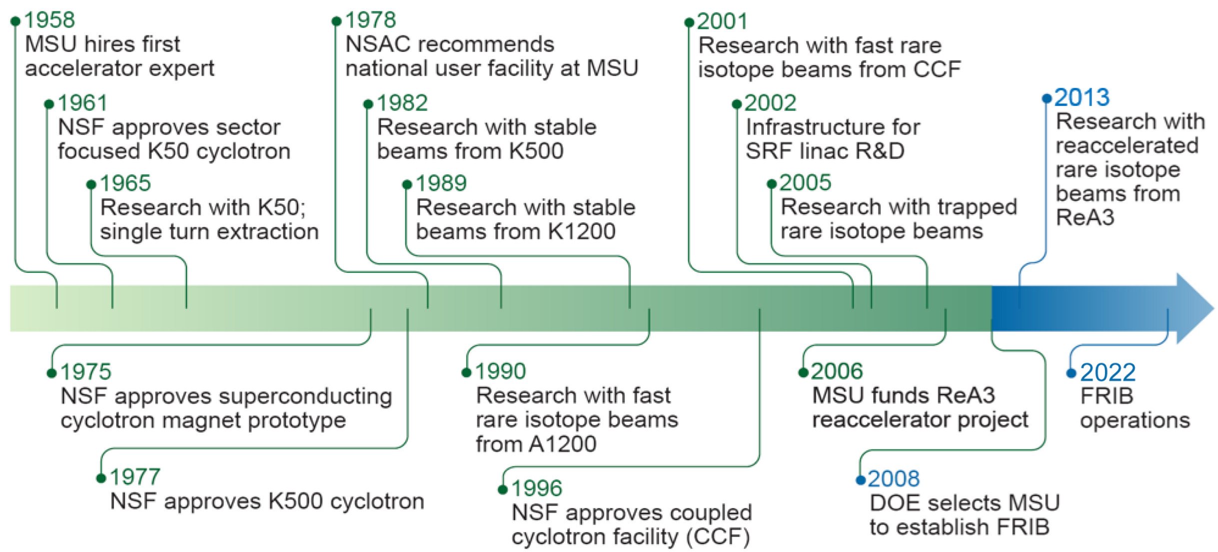
Legend

- Blue: existing offices
- Light green: Existing NSCL
- Red: FRIB
- Yellow: Additional experimental space

Final Civil Design

MSU and FRIB

- MSU has a 50-year history in accelerator-based science
- MSU has the leading rare isotope research group in the country
- MSU won FRIB in an open competition in 2008
- FRIB project is well-managed
- FRIB civil construction began in March 2014
- FRIB technical construction started in October 2014



FRIB Construction is Underway: Ground Breaking March 17, 2014

FRIB construction site 17 March 2014 – www.frib.msu.edu

Civil Construction Moving Forward

- Civil construction began in March 2014

FRIB construction site – May 2015; Accelerator tunnel complete and surface bulding going up

Web cams at frib.msu.edu

Civil Construction Eight Weeks Ahead of Baseline Schedule

FRIB construction site – October 2015
Web cameras at www.frib.msu.edu

Conventional Facilities Progress

View of tunnel lid re-steel looking east

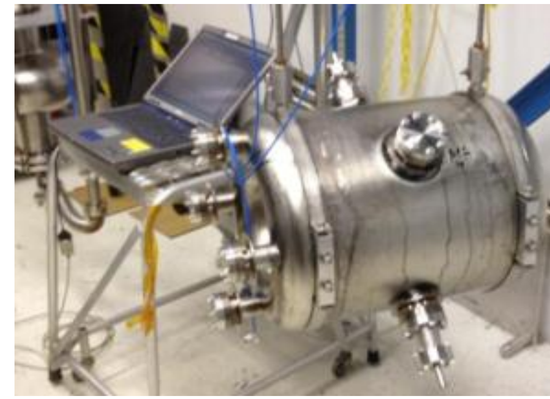
- Tunnel is
  - 570 feet long
  - 70 feet wide
  - 32 feet underground

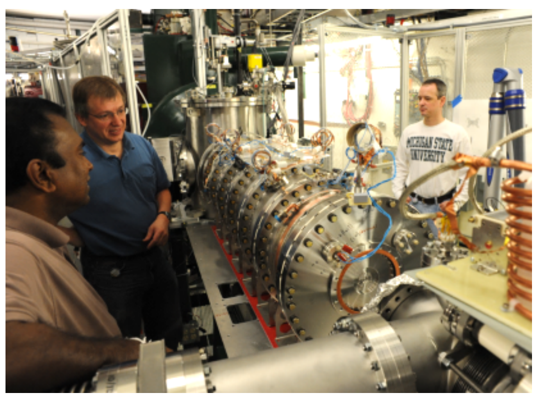
Linac tunnel facing east

Technical Construction Started Oct 2014

- Technical construction started in October 2014



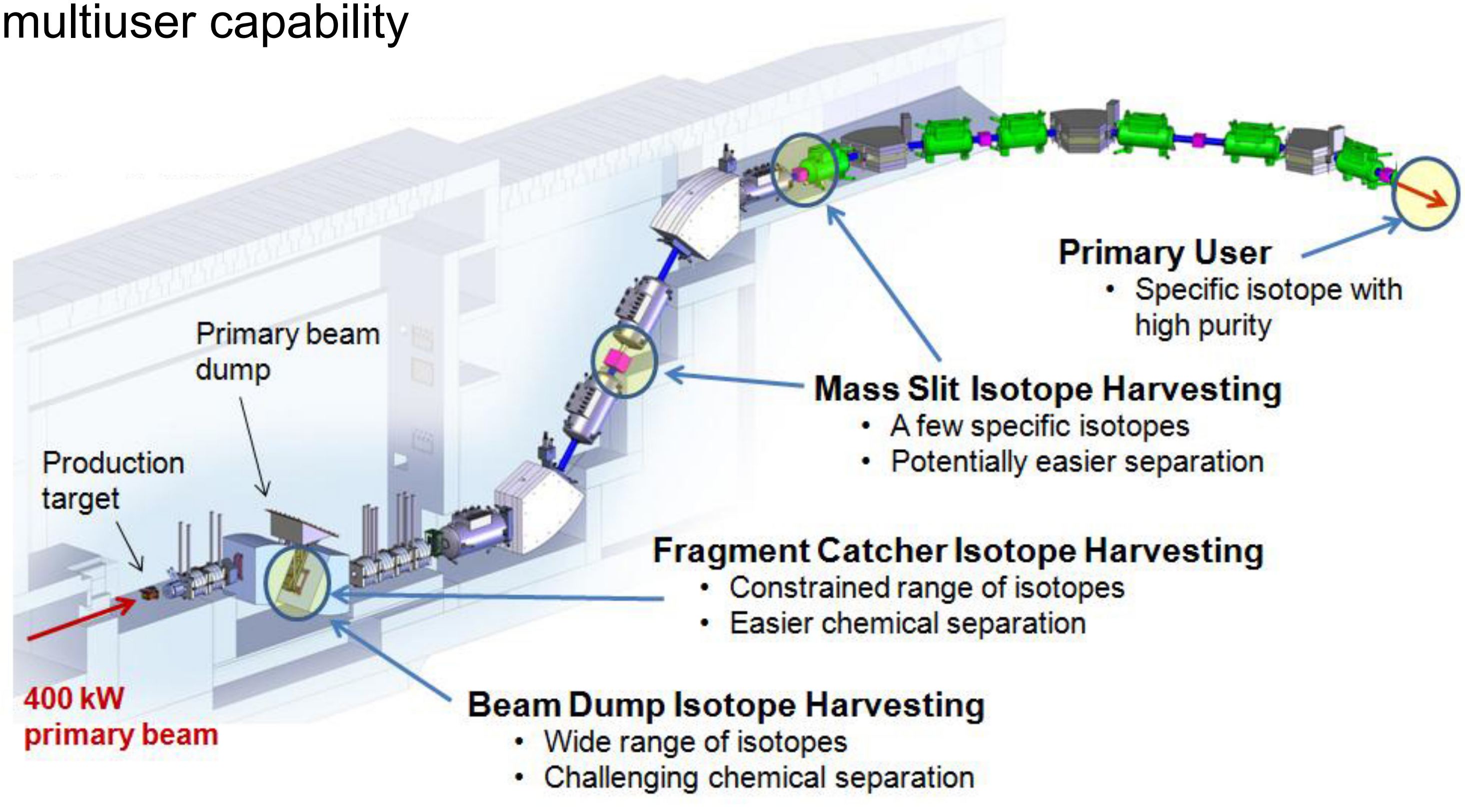



FRIB Project is on Schedule and Budget

- Project started in June 2009
  - Michigan State University selected to design and establish FRIB after rigorous merit-review process
  - Cooperative Agreement signed by DOE and MSU in June 2009
- Conceptual design completed; CD-1 approved in September 2010
- Preliminary technical design, final civil design, and R&D complete
- CD-2/3a approved in August 2013
  - Project baseline and start of civil construction upon further notice from the DOE-SC
- Civil construction began March 3, 2014
- CD-3b review in June 2014
- Technical construction started in October 2014
- Managing to early completion in FY2021
  - CD-4 (project completion) is 2022
- Cost to DOE - $635.5 million
  - Total project cost of $730M includes $94.5M cost share from MSU
  - Value of MSU contributions above cost share exceeds $300M

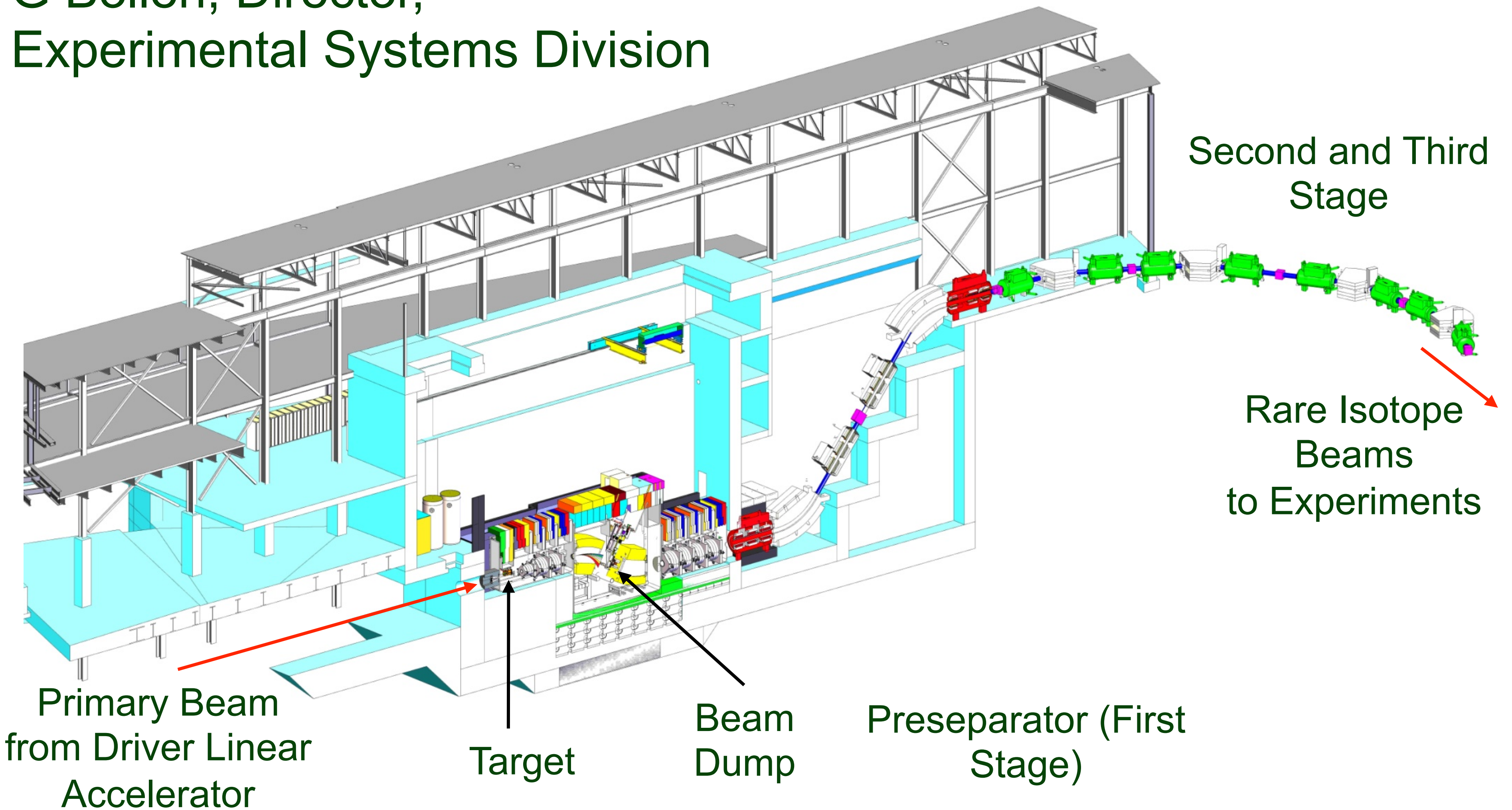
FRIB Design Foresees Opportunities for Harvesting and Commensal Use of Beams

- Isotope harvesting is not in baseline design, provisions to add later are in design
- 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 nuclear science or applications in commensal mode - providing multiuser capability



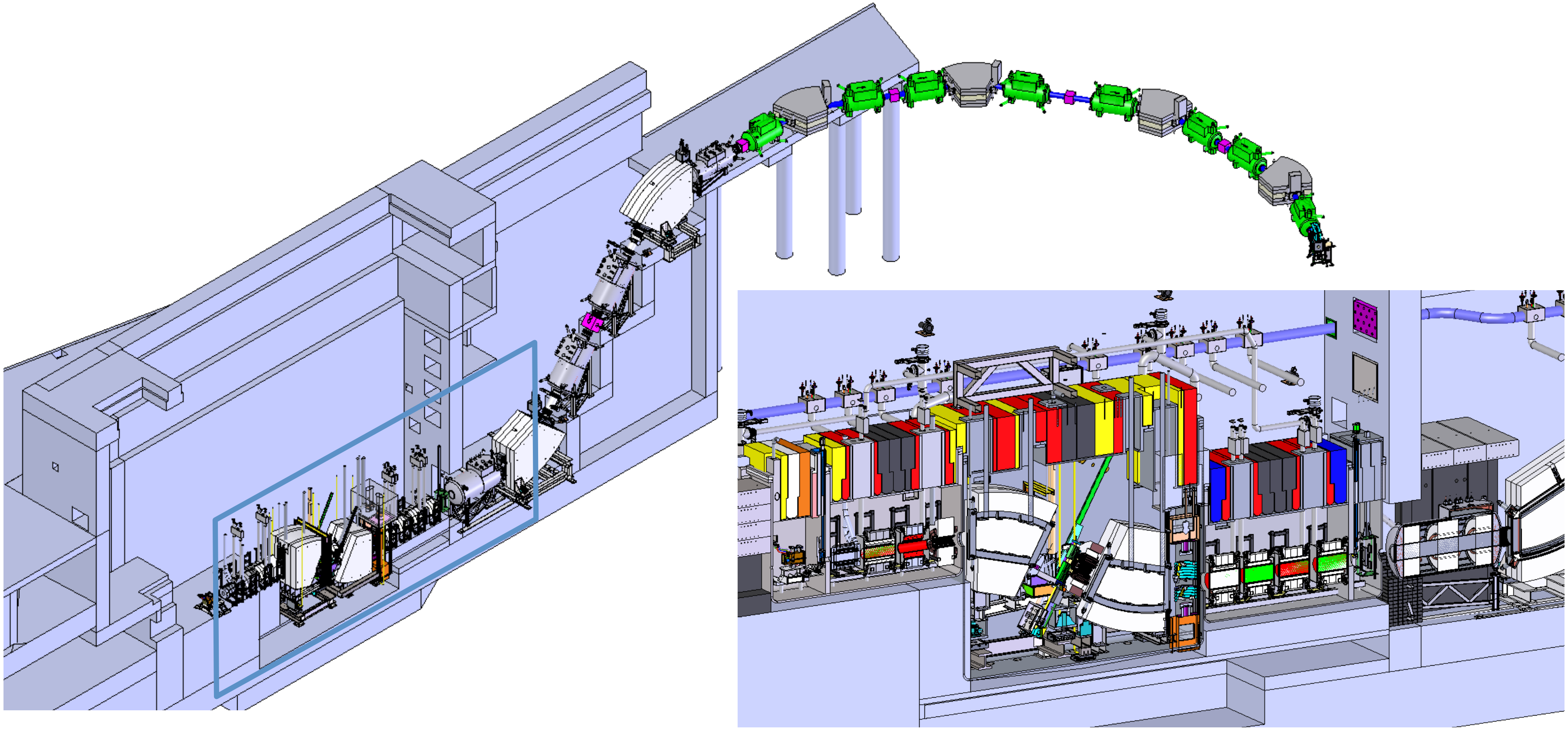
Isotope Production Area
Target and Fragment Separator

G Bollen, Director,
Experimental Systems Division



Fragment Separator

- Three-stage fragment separator for production and delivery of rare isotope with high rates and high purities to maximize FRIB science reach
- Primary beam power of 400 kW and beam energies of ≥ 200 MeV/u



Over 1400 Users Engaged and Ready for Science

FRIB Users Organization
FACILITY FOR RARE ISOTOPE BEAMS

- Users are organized as part of the independent FRIB Users Organization (FRIBUO) www.fribusers.org
  - Chartered organization with an elected executive committee
  - 1,418 members (92 U.S. colleges and universities, 10 national laboratories, 51 countries) as of February 2015
  - **19 working groups on instruments**
  - 21-23 August 2014, Low Energy Community Meeting, Texas A&M University

  "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."

  www.lecmeeting.org/preambleAndResolutionsTAMU2014.pdf
- Science Advisory Committee
  - Review of equipment priorities (2-3 March 2015)

  "FRIB will cover a wide range of topics at the forefront of nuclear science"

  "Significant scientific opportunities will be realized with the addition of several classes of experimental equipment"

The Physics Division of Oak Ridge National Laboratory (ORNL) and the University of Tennessee - Knoxville (UTK) will host a collaboration meeting for those who wish to work on the **Facility for Rare Isotope Beams (FRIB) Decay Station**. The meeting will take place on the ORNL campus at the Joint Institute for Nuclear Physics and Applications on January 21-22, 2016.

The purpose of the meeting is to coordinate and plan for the construction of the FRIB decay station. The outcome of the collaboration meeting will be a white paper detailing the science case and implementation plan. We welcome individuals intending to use, build, or support elements of the decay station to present their ideas and address the following:

1. Science arguments in support of the device(s)
2. Description, sketches, and/or designs of equipment
3. Any simulations or other measures of expected performance
4. Any necessary beam parameters, locations, etc.
5. Any necessary signals expected to be supplied by the facility
6. Identify any potential infrastructure impacts to the facility or requests of the facility
7. Electronics required (will it all be “digital” or something else)
8. Data analysis and data storage capability requirements

Collaborations Around the World

- ANL
  - Liquid lithium stripper
  - Beam dynamics verification; β=0.29 HWR design; SRF tuner validation
- BNL
  - Plasma window & charge stripper, physics modeling, database
- FNAL
  - Diagnostics, SRF processing
- JLab
  - Cryoplant; cryodistribution design & prototyping
  - Cavity hydrogen degassing; cryomodule design
- LANL
  - Proton ion source for Li test
- LBNL
  - ECR coldmass; beam dynamics**
- ORNL
  - Diagnostics, controls
- SLAC
  - Cryogenics**, SRF multipacting**, physics modeling**

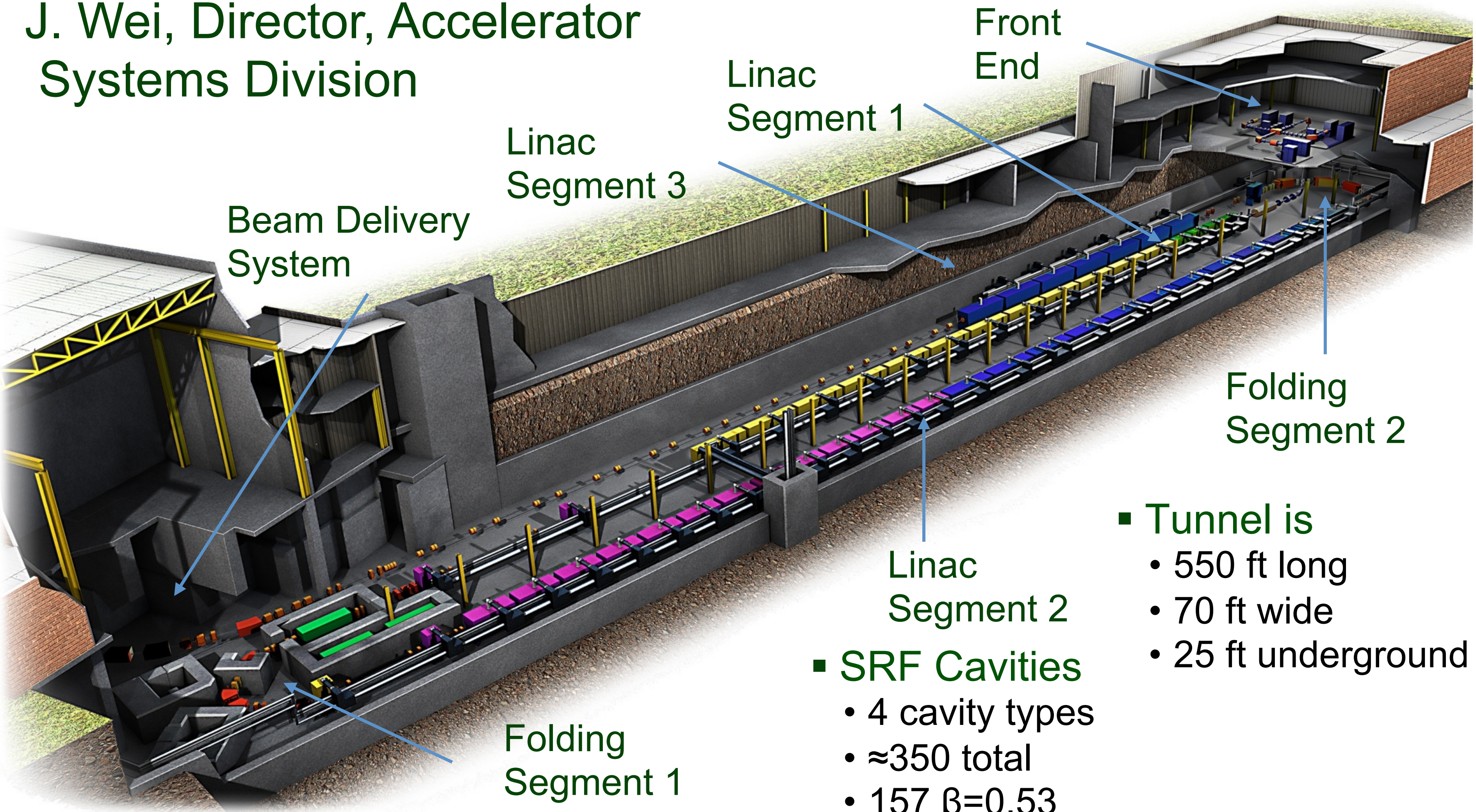
- RIKEN (Japan)
  - Helium gas charge stripper
- TRIUMF (Canada)
  - Beam dynamics design, physics modeling **
  - SRF, QWR etching*
- GSI (Germany)
  - Materials
- INFN (Italy)
  - SRF technology
- KEK (Japan)
  - SRF technology, SC solenoid prototyping
- IMP (China)
  - Magnets
- Budker Institute, INR Institute (Russia)
  - Diagnostics
- Tsinghua Univ. & CAS (China)
  - RFQ
- ESS (Sweden)
  - Accelerator Physics*

* Under discussion or in preparation

** Completed

FRIB Driver Linear Accelerator

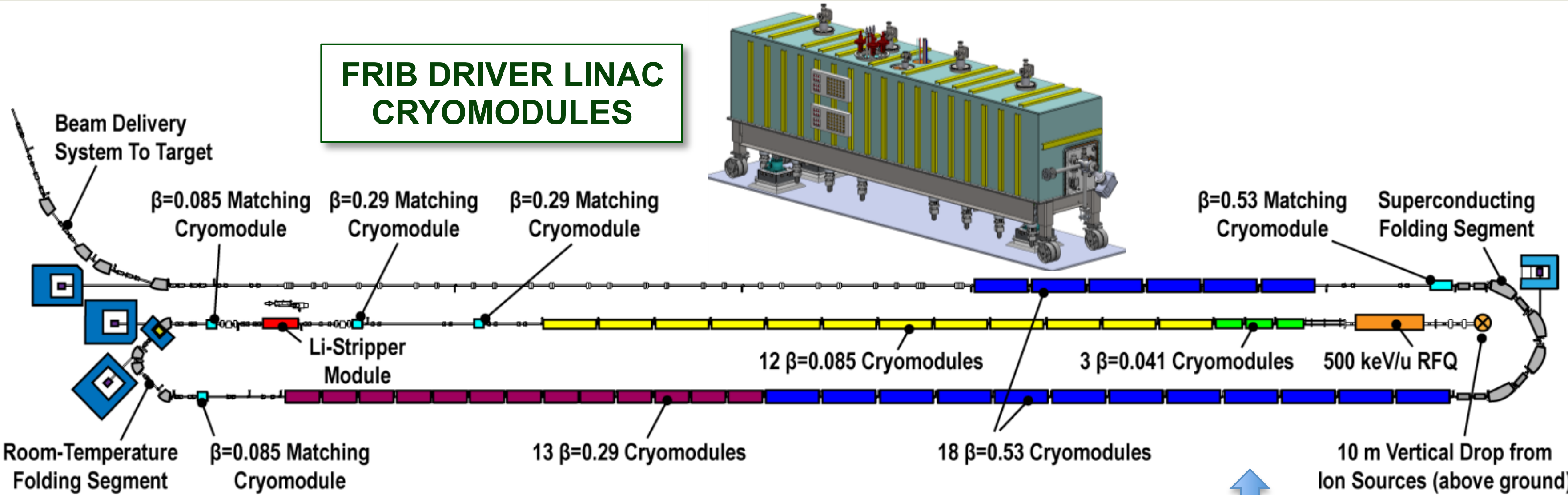
J. Wei, Director, Accelerator Systems Division



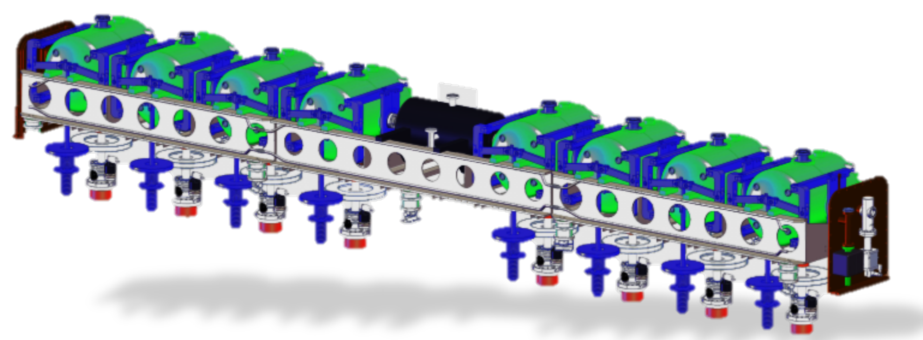
- SRF Cavities
  - 4 cavity types
  - ≈350 total
  - 157 β=0.53
- Tunnel is
  - 550 ft long
  - 70 ft wide
  - 25 ft underground

Develop and Mass-produce Four Different Types of Cavities, Cold Masses, and Cryomodules for FRIB Linac

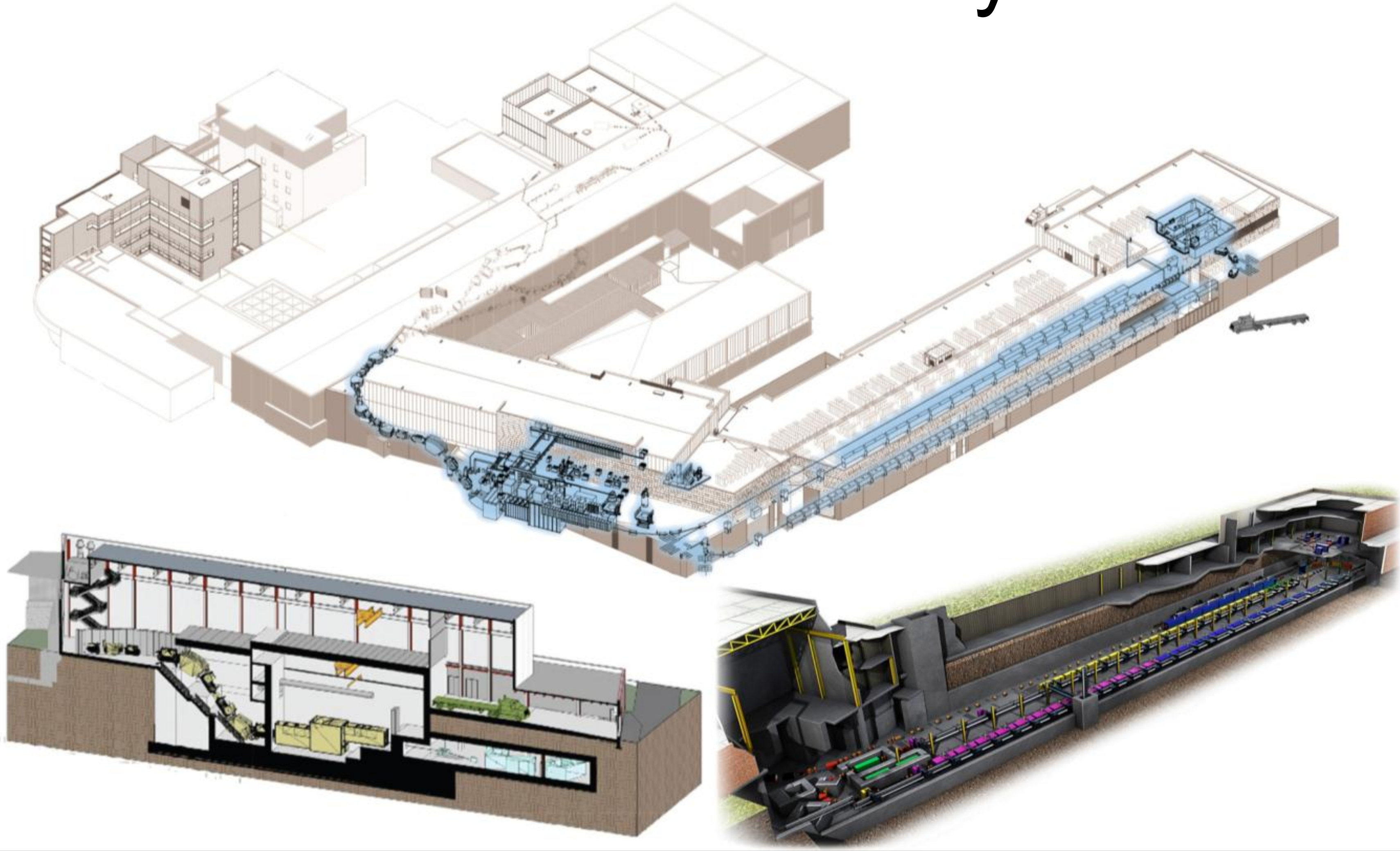
FRIB DRIVER LINAC CRYOMODULES



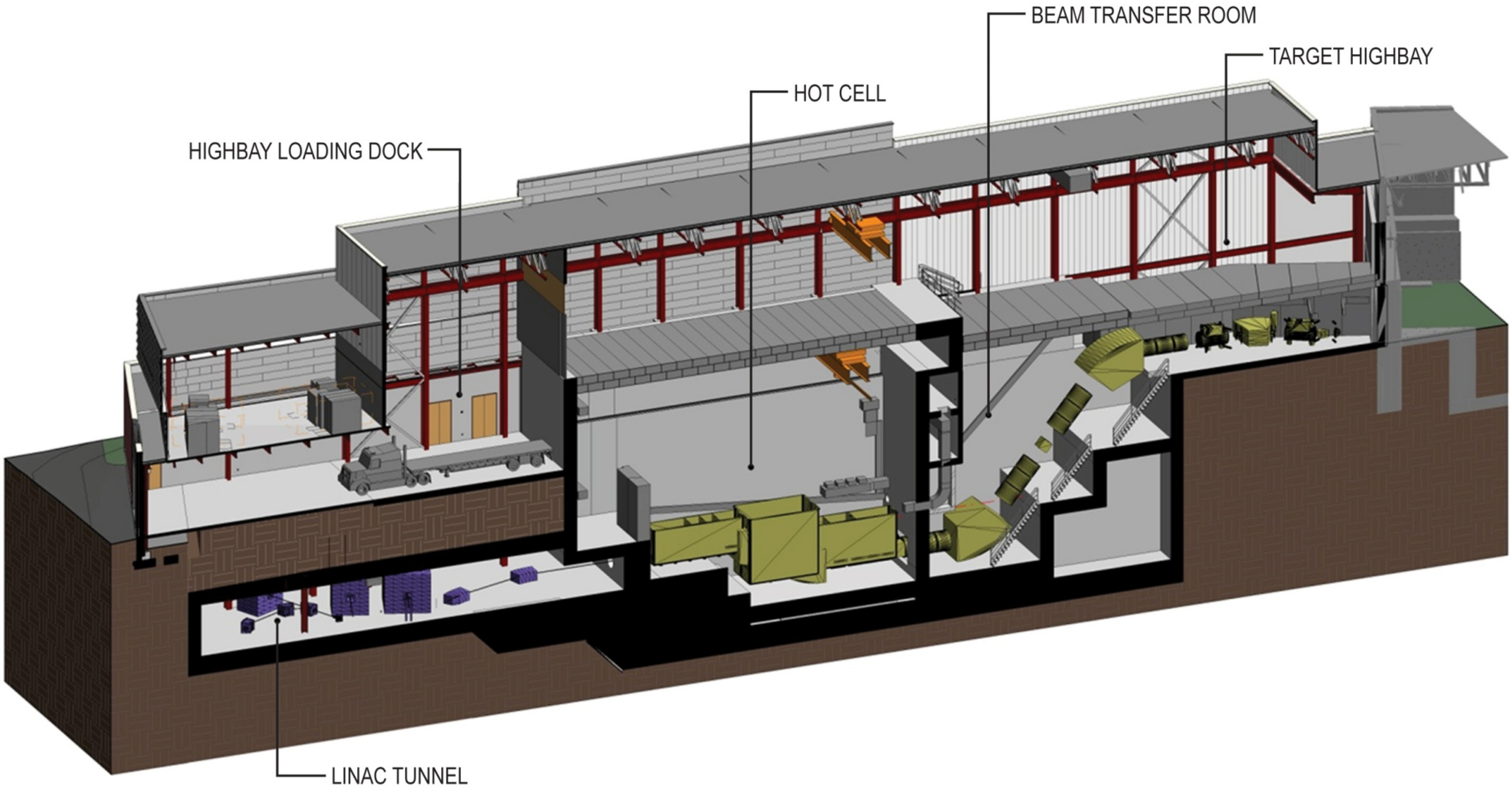
CAVITY DEVELOPMENT & PRODUCTION → **COLD MASS ASSEMBLY**



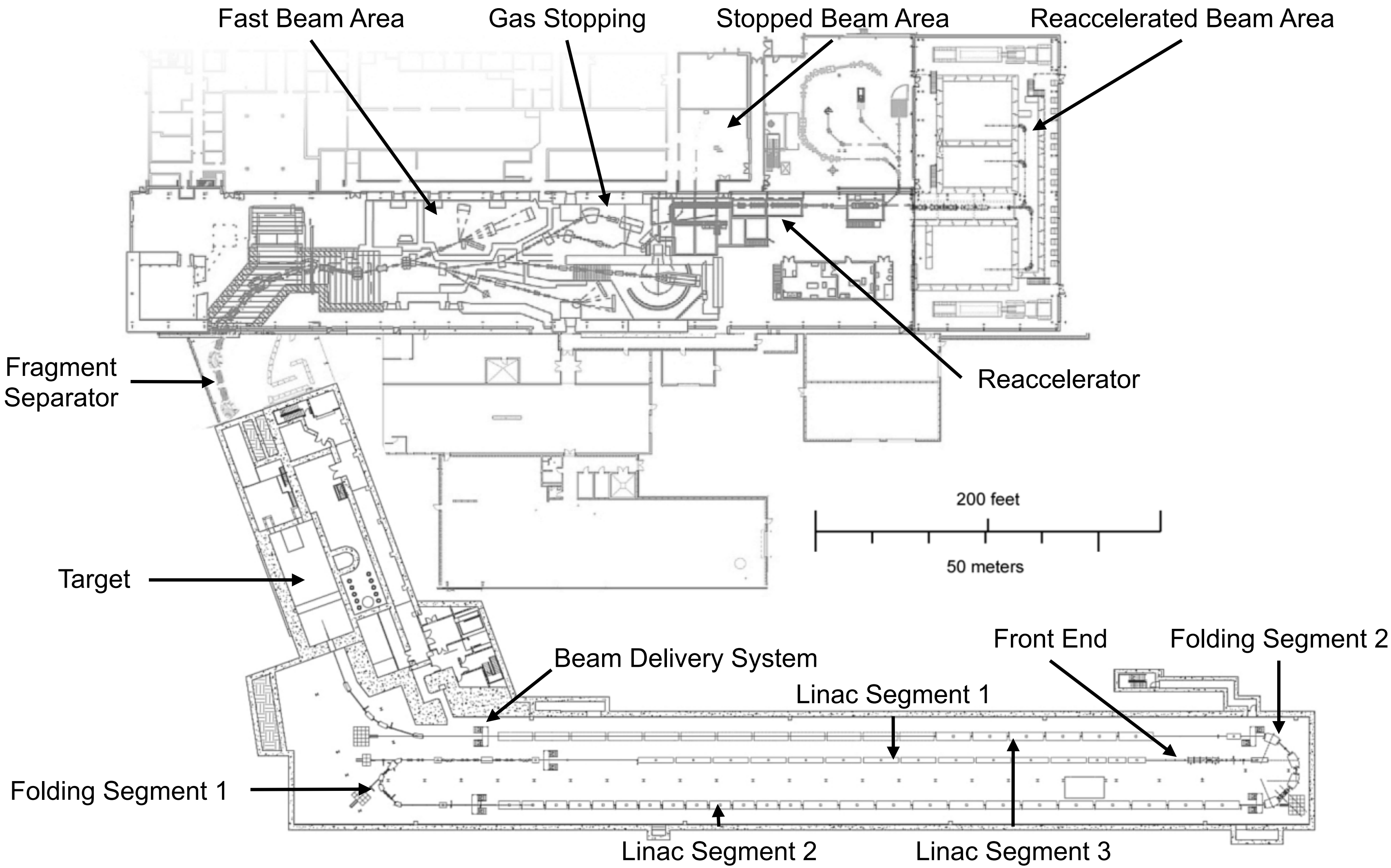
World's Most Powerful Rare Isotope Research Facility



Production Target Systems

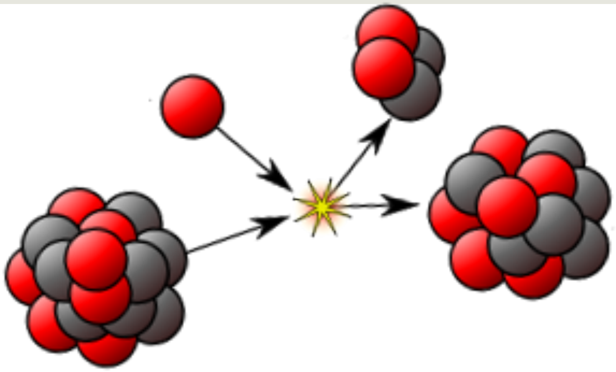


Layout of Accelerator and Experimental Areas

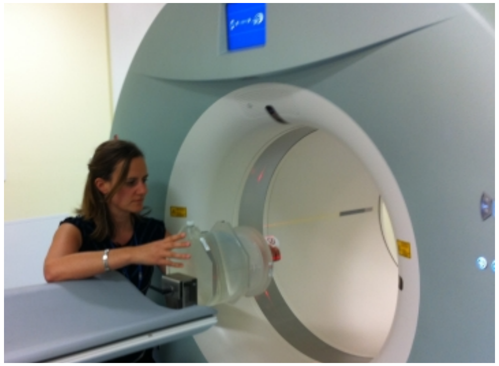


Big Questions for Nuclear Science

- Why do atoms exist?
- A basic tenant of chemistry is that atoms and mass are not created or destroyed. Where do atoms come from?
- What are atoms made of?
- What are new and novel ways to use isotopes to solve societies problems?

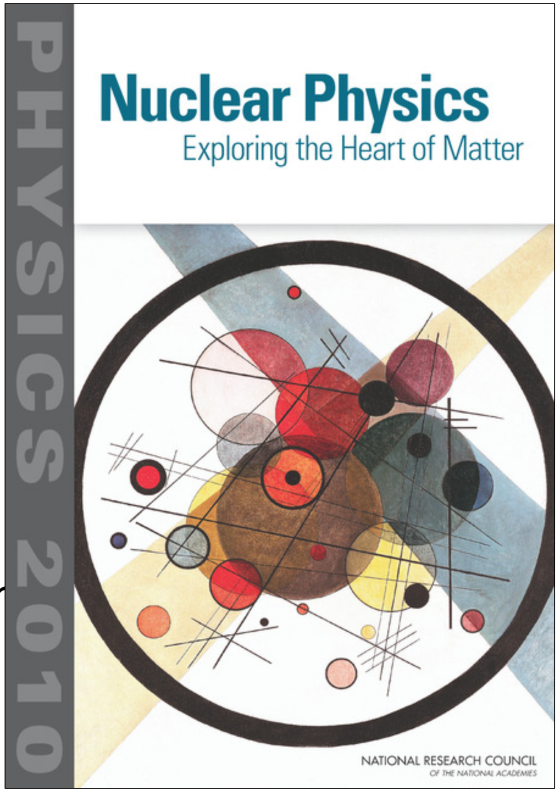


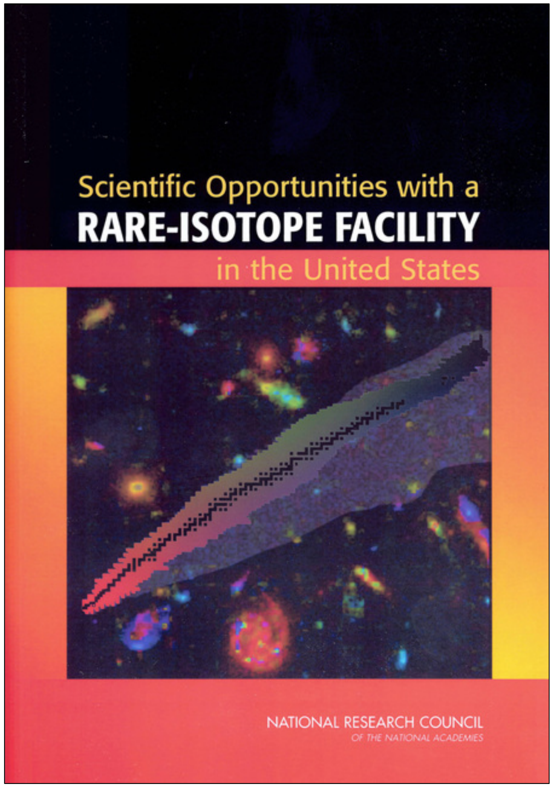
Answers to these questions require study of rare isotopes. Until about 20 years ago scientists had little or no capability to do that. The new Facility for Rare Isotope Beams, FRIB, will finally provide access to the most important ones.



Endorsement of FRIB Science by National Research Council of the National Academies

- National Research Council Decadal Study on Nuclear Physics Report
  - Nuclear Physics: Exploring the Heart of Matter (2013)
- National Academies Rare Isotope Science Assessment Committee Report (RISAC)
  - Scientific Opportunities with a Rare-Isotope Facility in the United States (2007)





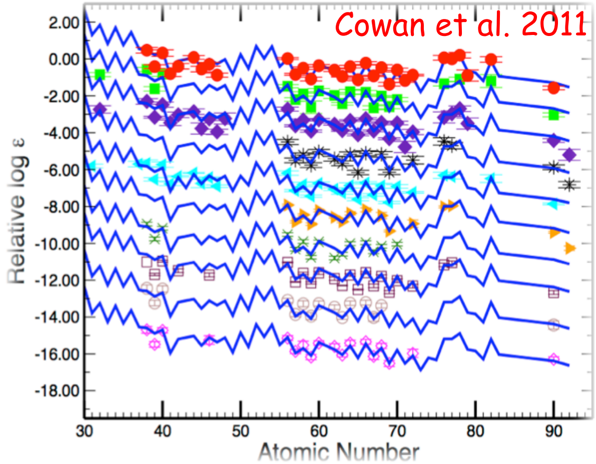
Rare Isotopes for Society

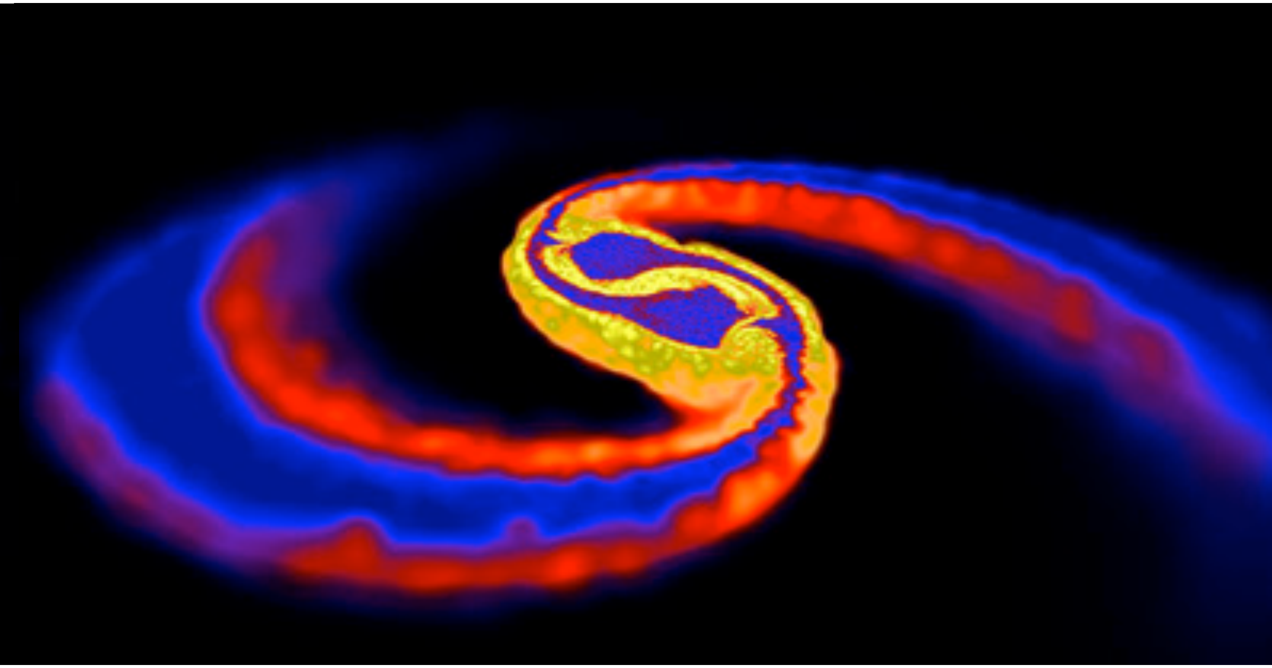
- Workforce
  - Development of talent for technical, medical, security, and industrial fields
- Homeland security and defense
  - Detectors at borders and throughout the country to detect nuclear material and components
  - Nuclear scanning techniques to screen cargo and luggage
  - Nuclear forensic methods to track and trace nuclear material
- Medical applications
  - Isotopes for medical research
  - Medical imaging and treatment of cancer and tumors
- Energy
  - Reliable calculation of fission and energy generation
  - Allow mechanisms of radiation damage to be studied in detail
  - Sensitive probes for the development of new materials, e.g. lithium-film batteries

Nuclear Science Research and Innovation

- Innovation boosts the national economy and provides an improved quality of life for society.
- Examples of innovations made possible by nuclear science research
  - Radiocarbon dating
  - Medical CT scanners and MRI imaging
  - Modern oil and gas exploration
  - Disease-resistant crops and food preservation
  - Radiation detectors at airports
  - Modern computer processors

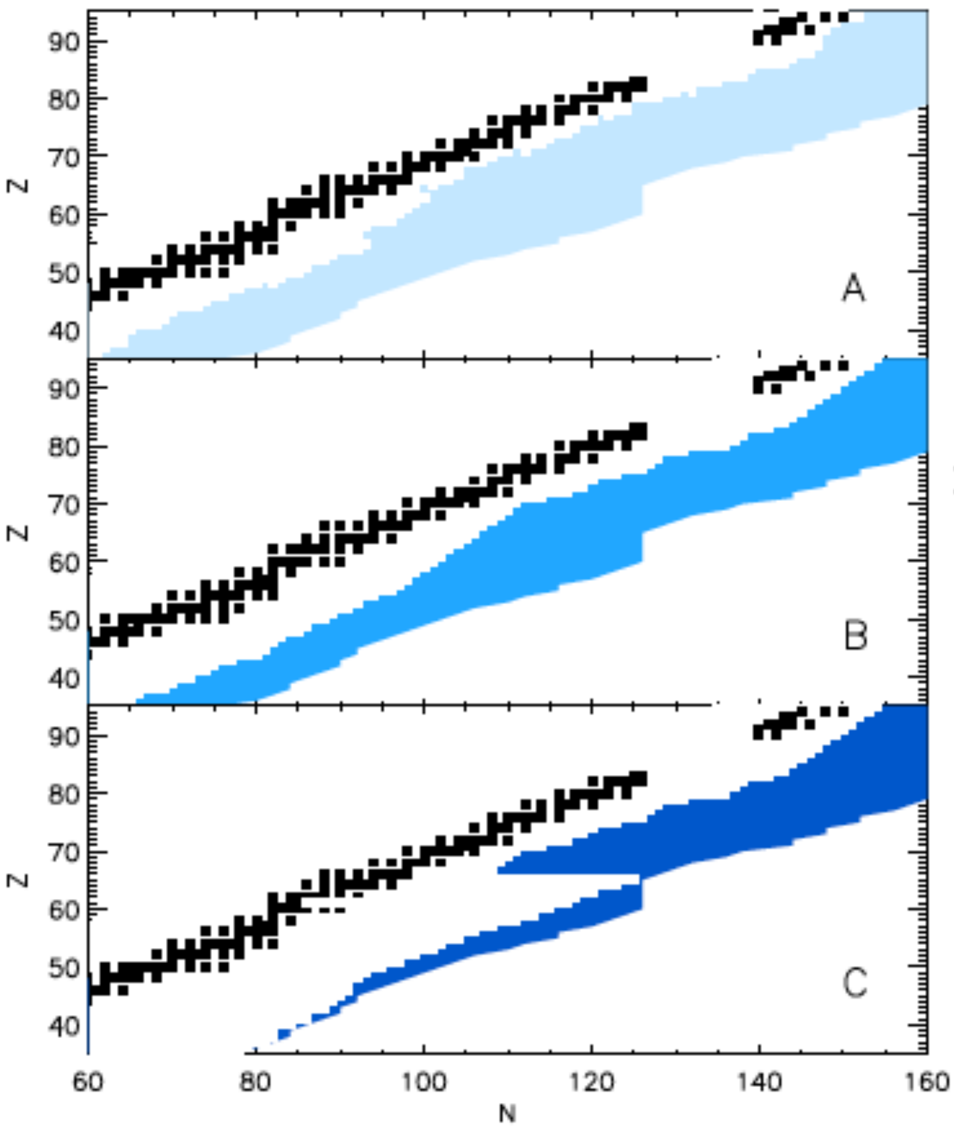
r-process

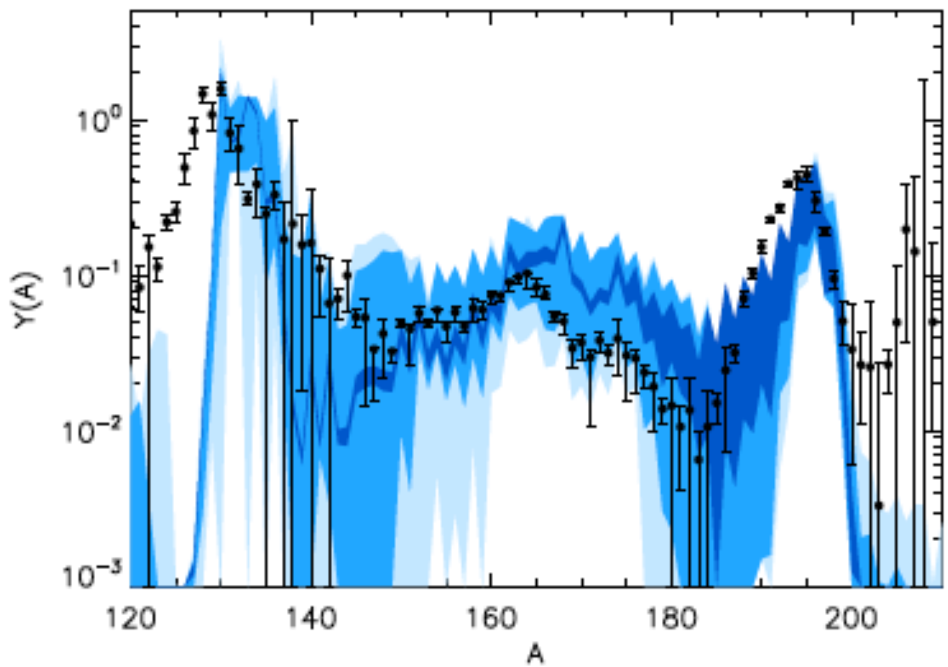




Temperature, density as a function of time, initial compositions, neutrons

Surman, Mumpower, Aprahamian, Mazurian Lakes, 2015





Thank you