Facility For Rare Isotope Beams

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U.S. DEPARTMENT OF ENERGY

Office of Science

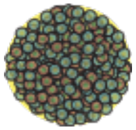
This lecture

- Motivation for FRIB: Why are rare isotopes important to study?
- How can one produce rare isotopes?
- How does FRIB do it?
- Some project details and status

NSCL/FRIB Overview

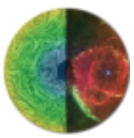
- FRIB will be the world's premier rare isotope user facility, a national user facility for the U.S. Department of Energy Office of Science
- Until FRIB is operational, NSCL is the nation's flagship user facility for rare isotope research; funded by the U.S. National Science Foundation

FRIB Enables Scientists to Make Discoveries



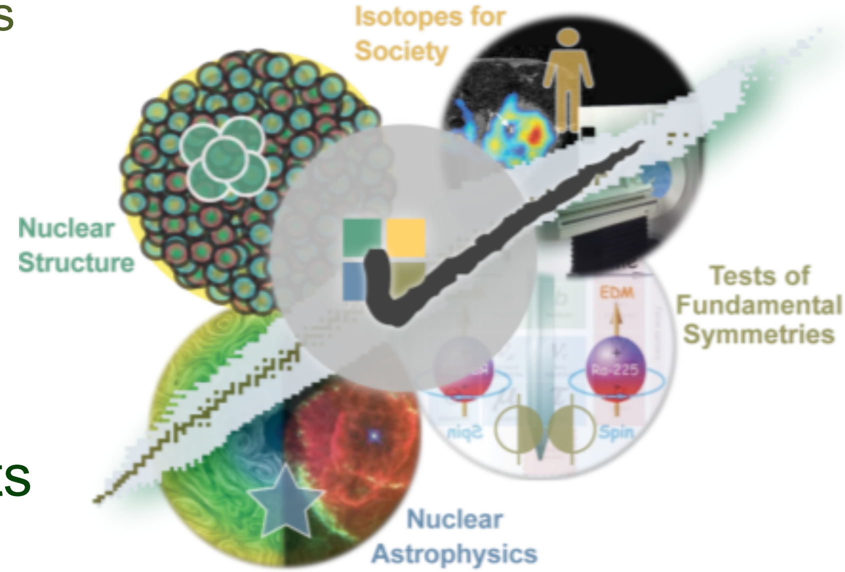
Properties of atomic nuclei

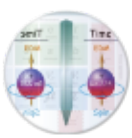
- Develop a predictive model of nuclei and their interactions
- Many-body quantum problem: intellectual overlap to mesoscopic science, quantum dots, atomic clusters, etc.



Astrophysics: What happens inside stars?

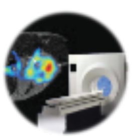
- Origin of the elements in the cosmos
- Explosive environments: novae, supernovae, X-ray bursts …
- Properties of neutron stars





Tests of laws of nature

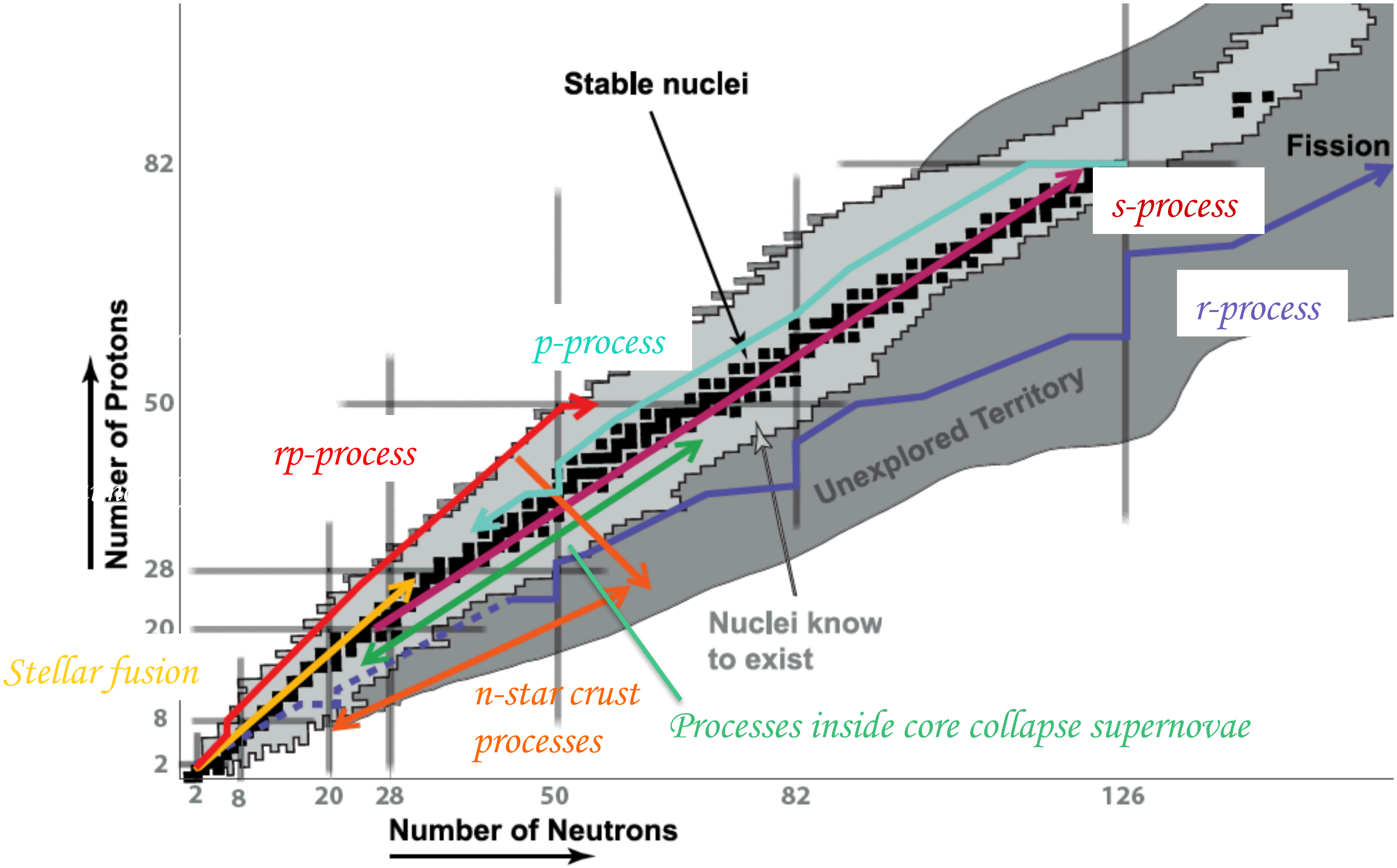
- Effects of symmetry violations are amplified in certain nuclei



Societal applications and benefits

- Medicine, energy, material sciences, national security

Nuclear processes in the cosmos



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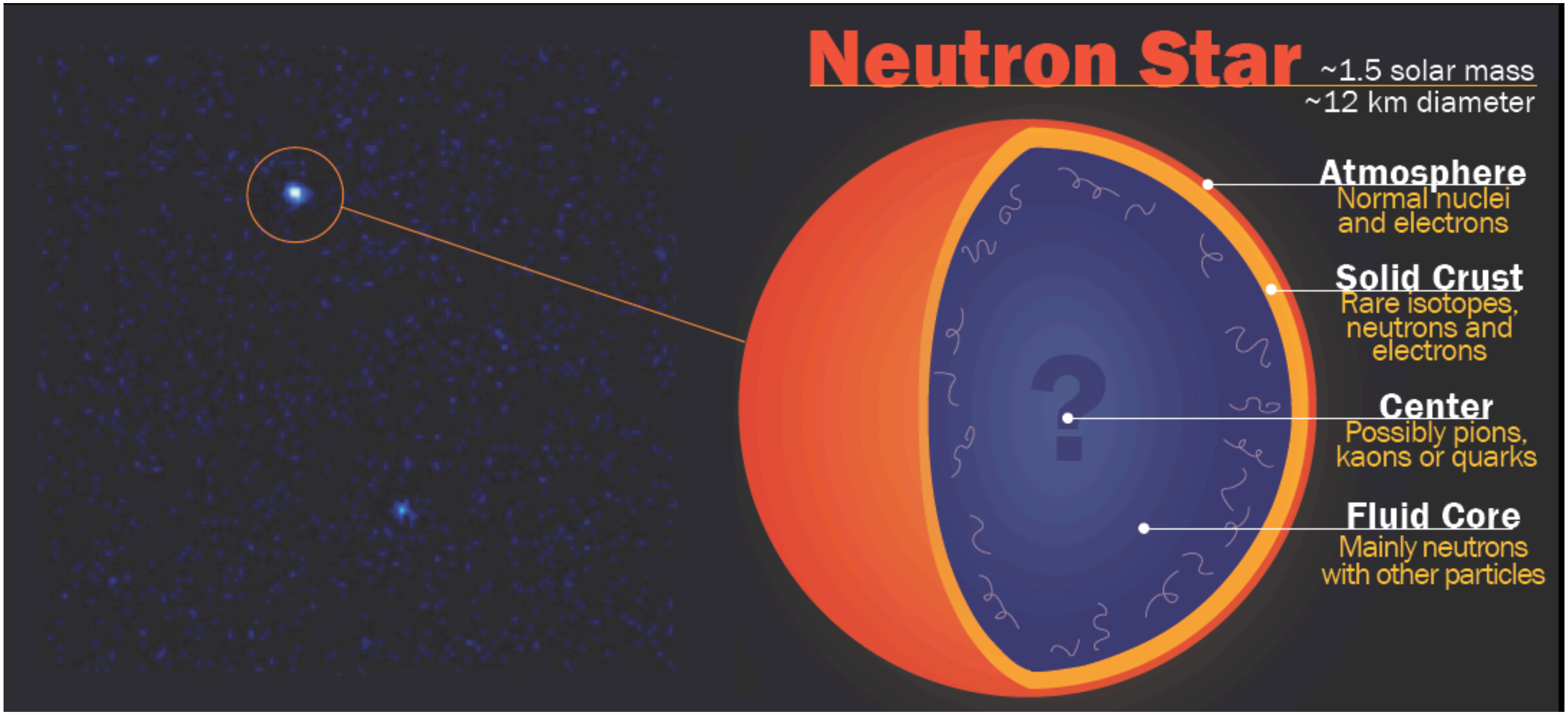
Neutron stars – wrapped in rare isotopes

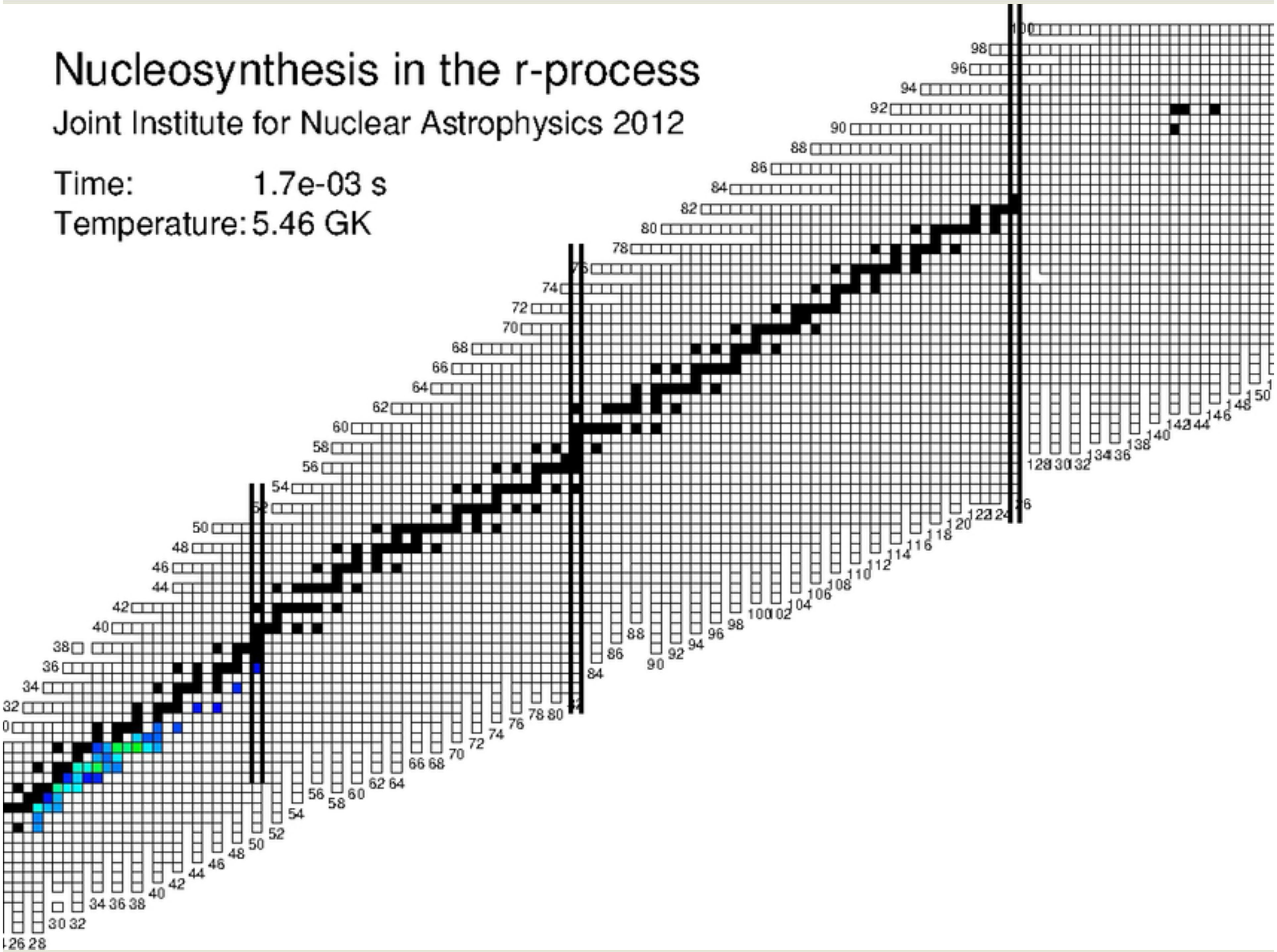


Nucleosynthesis in the r-process

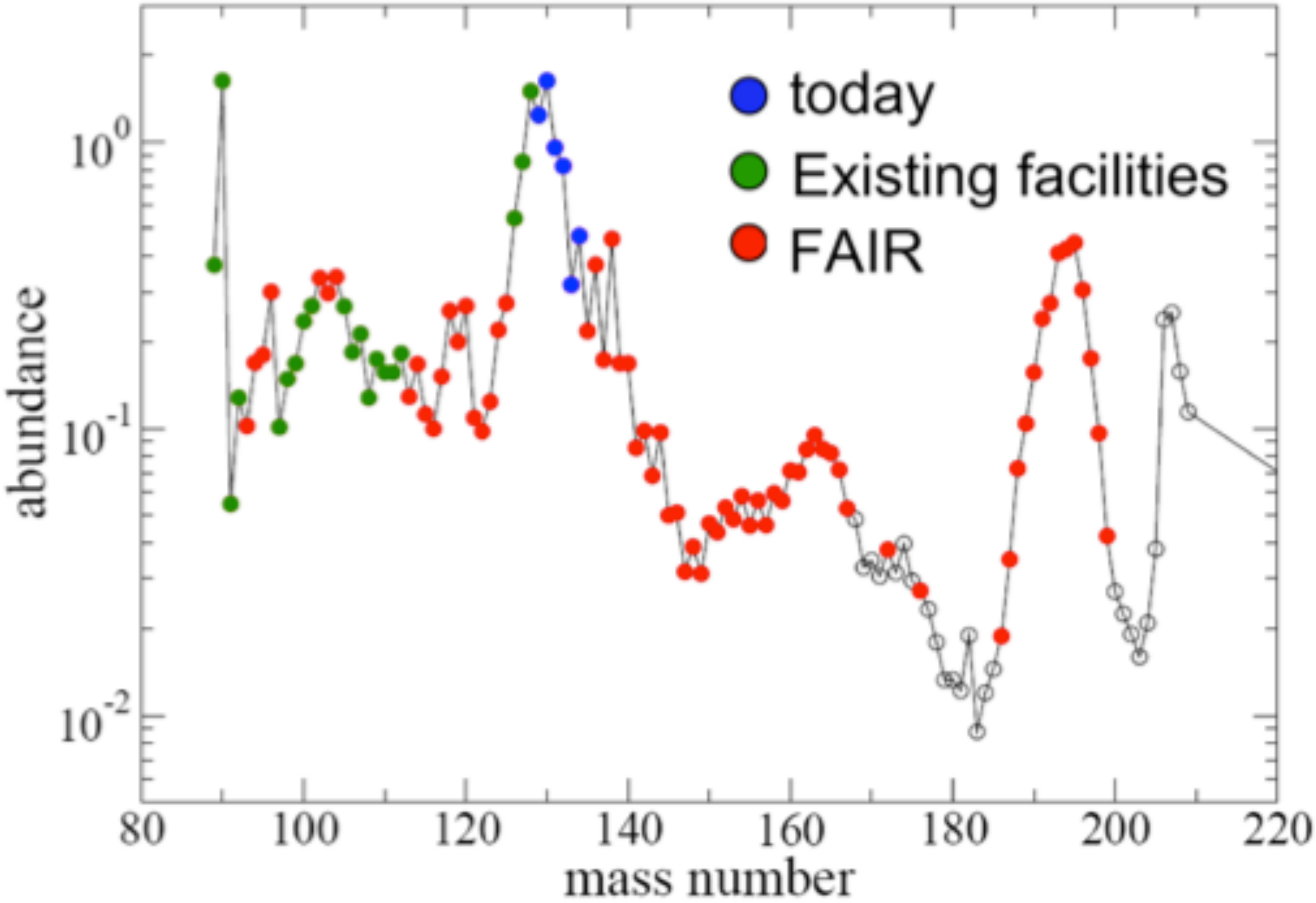
Joint Institute for Nuclear Astrophysics 2012

Time: 1.7e-03 s

Temperature: 5.46 GK



Reliable r-process abundances

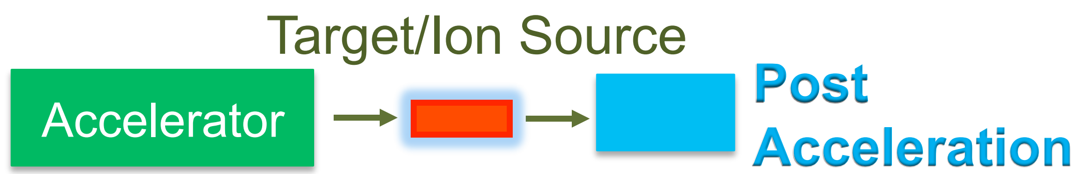


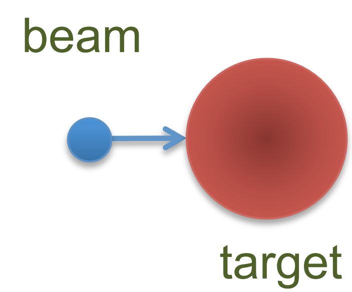
Question

How can one produce rare isotopes?

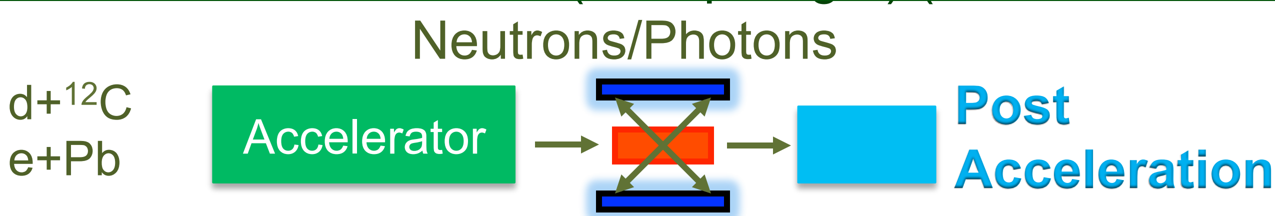
Rare Isotope Production Techniques: Uniqueness of FRIB

- Target spallation and fragmentation by light ions (ISOLDE/HRIBF/TRIUMF)

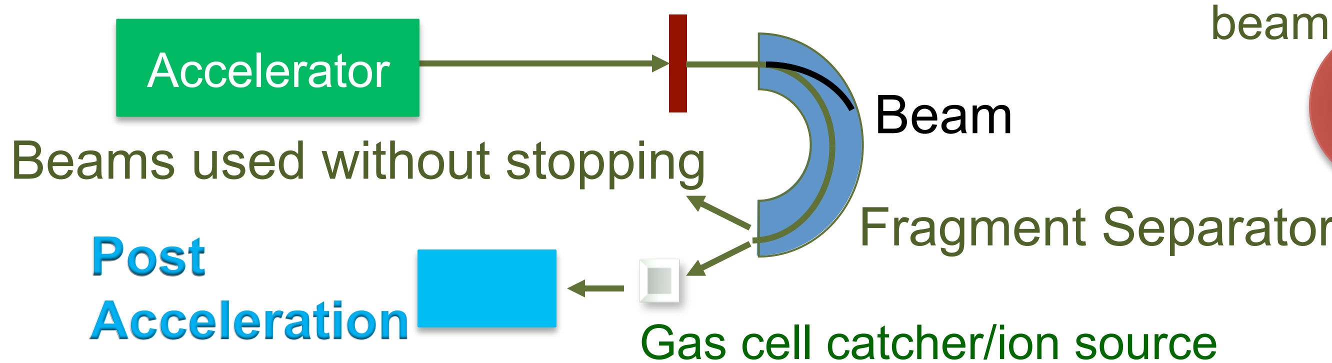




- Neutron induced fission (2-step target) (SPIRAL2/TRIUMF)



- In-flight Separation following projectile fragmentation/fission (RIKEN,FAIR,FRIB)



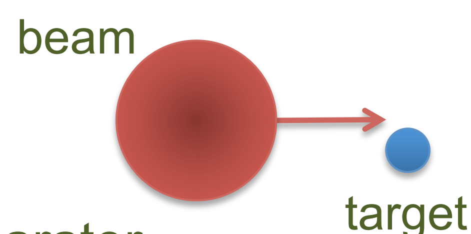
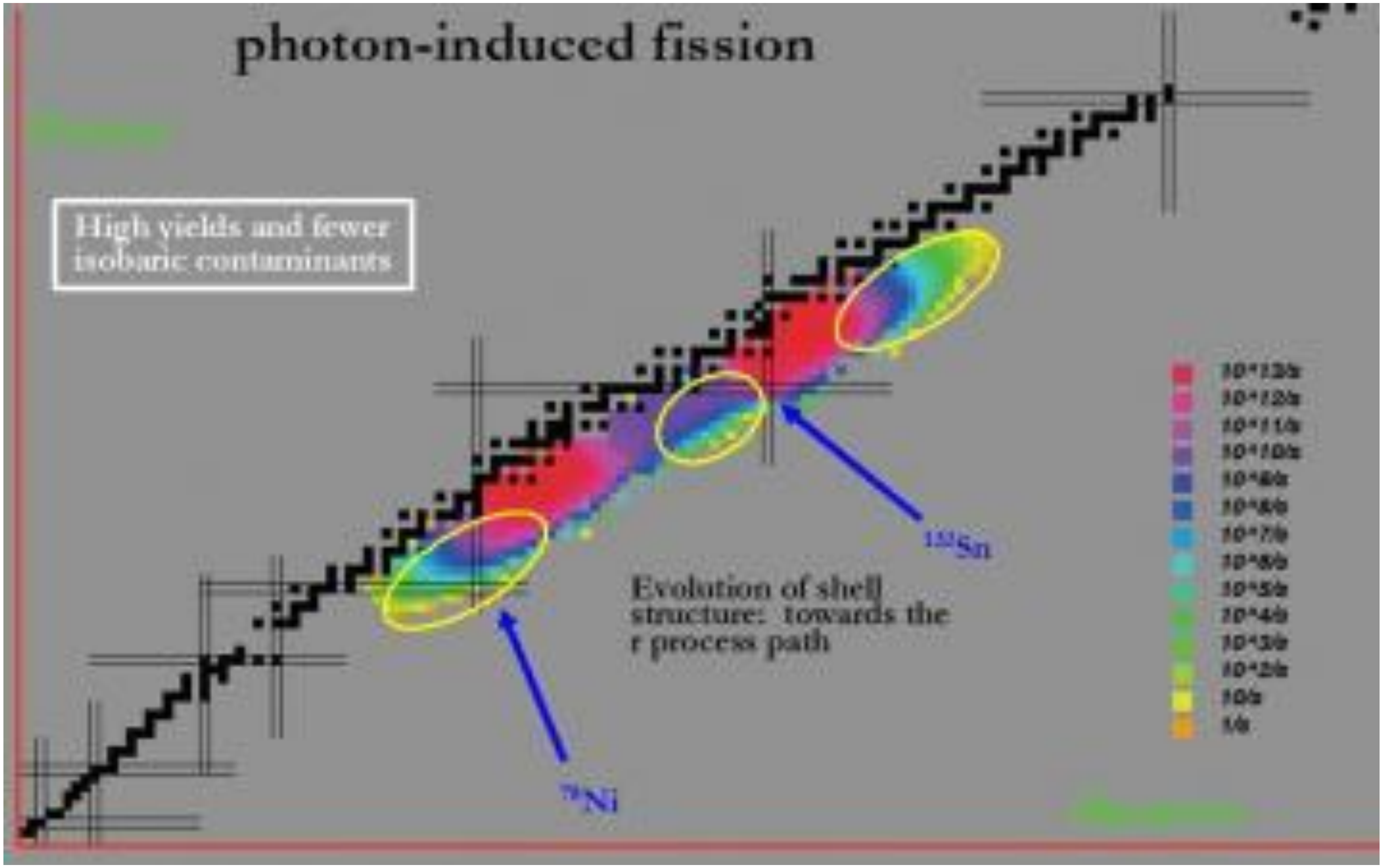
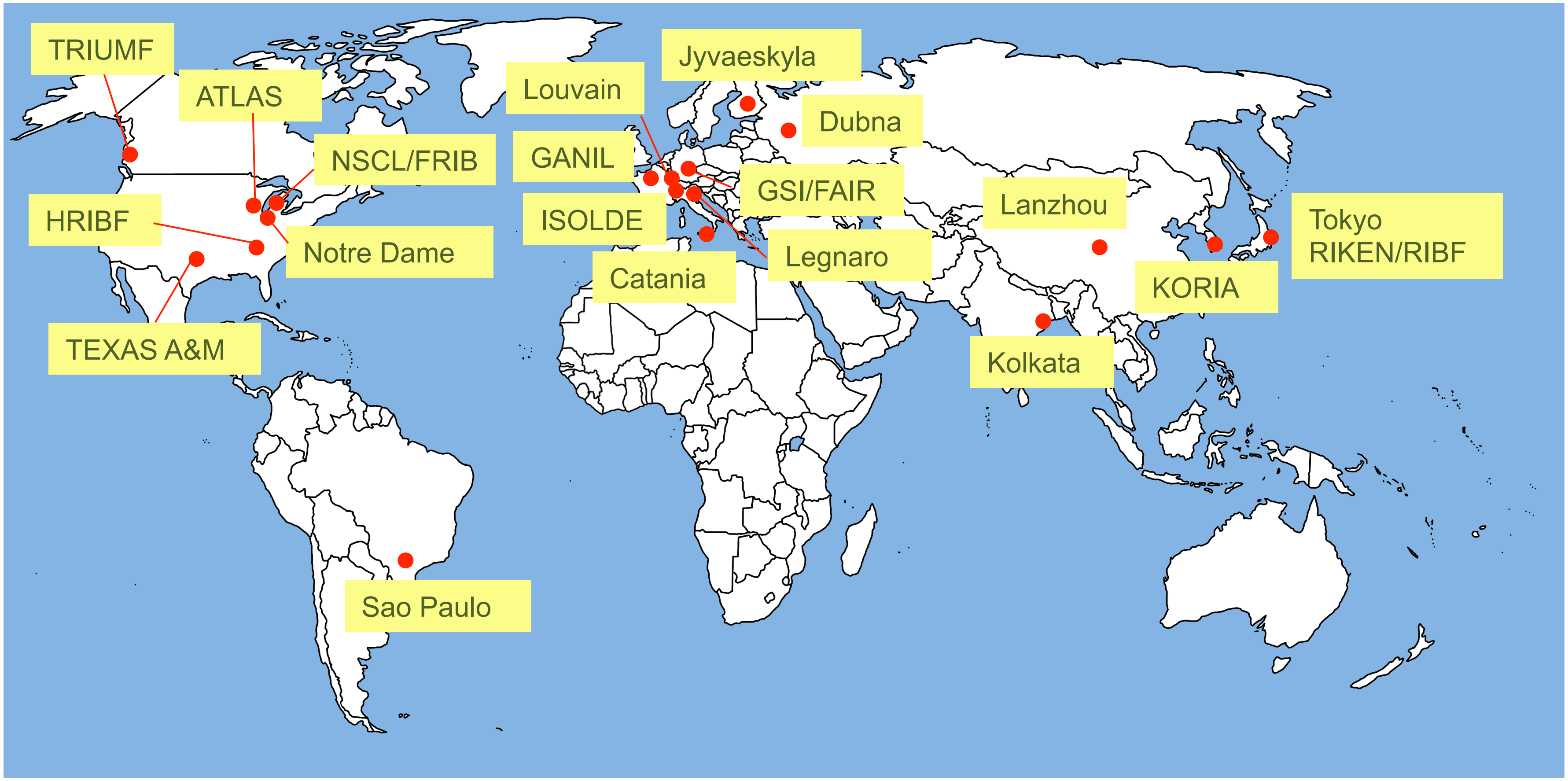


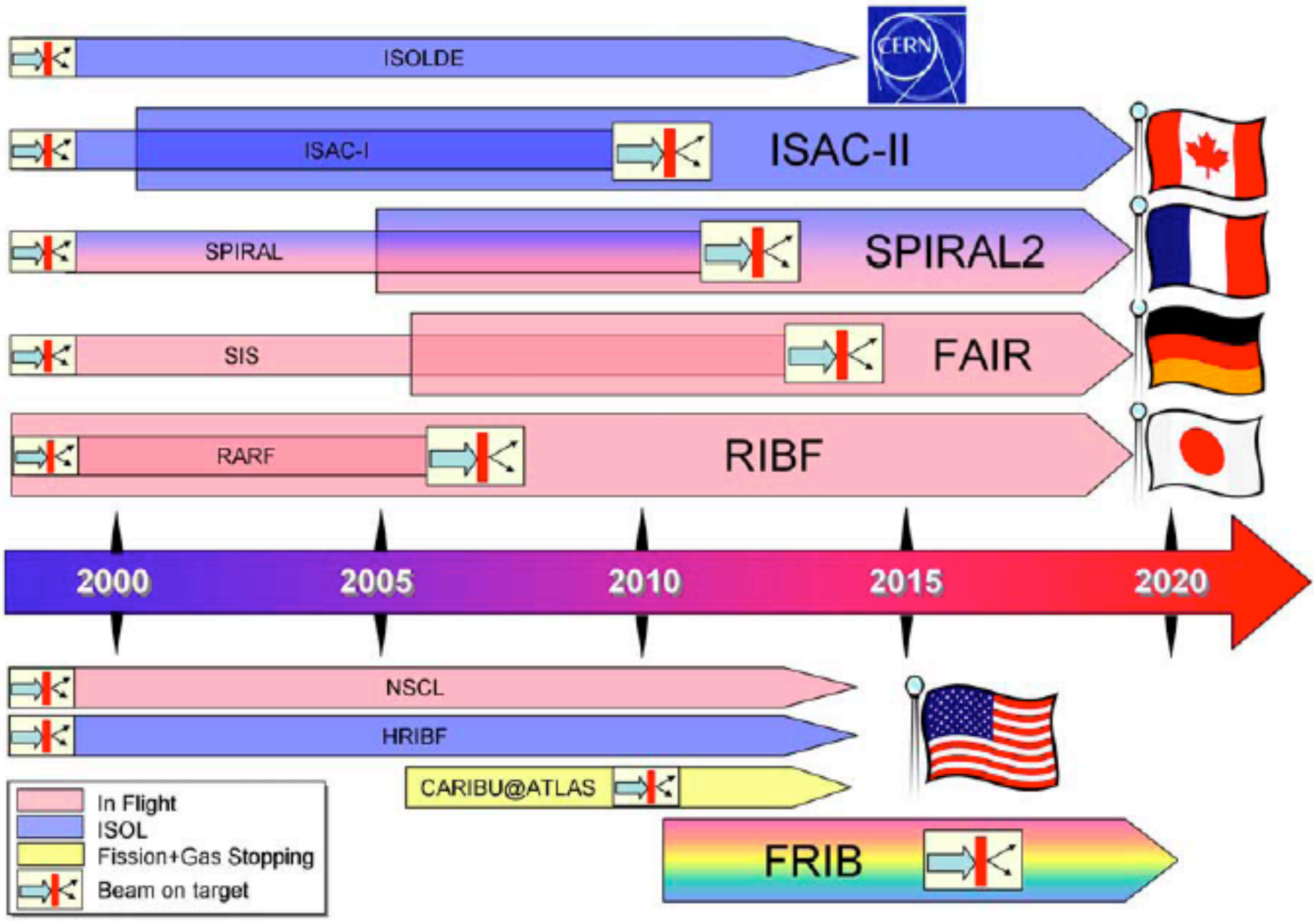
Photo fission yields



Rare Isotope Facilities Around the World

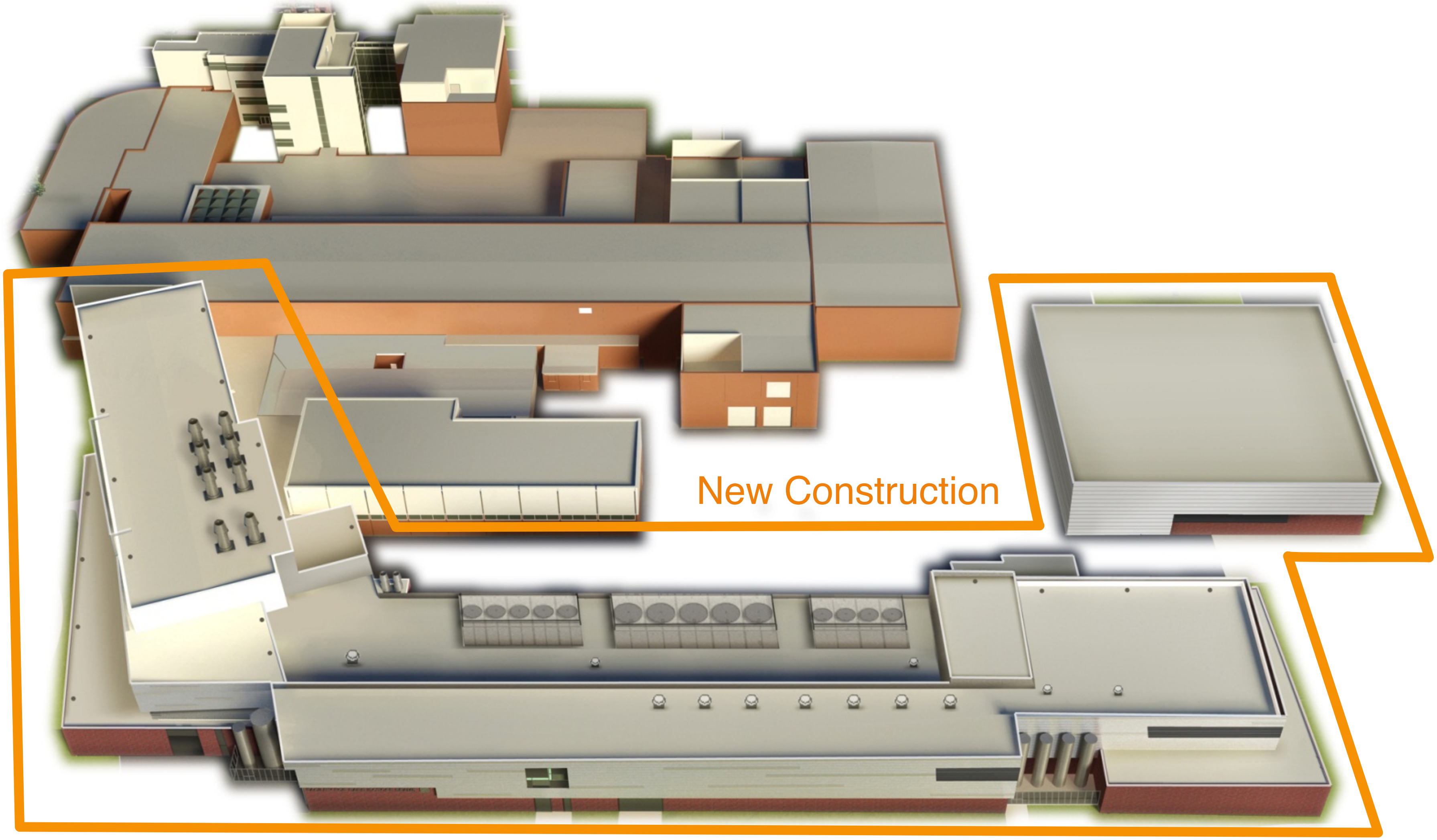


Timelines for major facilities

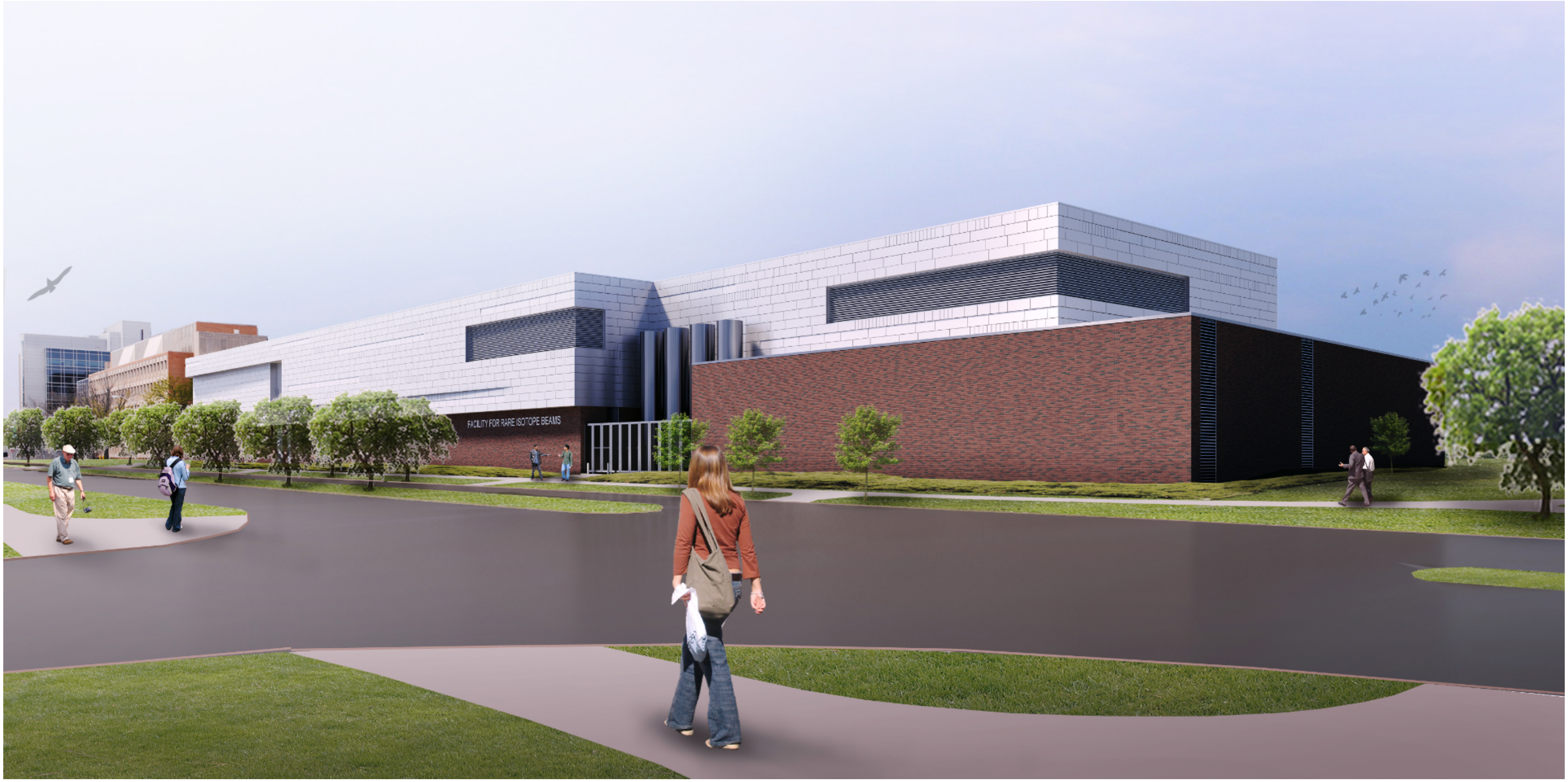


Rare Isotope Assessment Committee, NRC/NAS study 2006

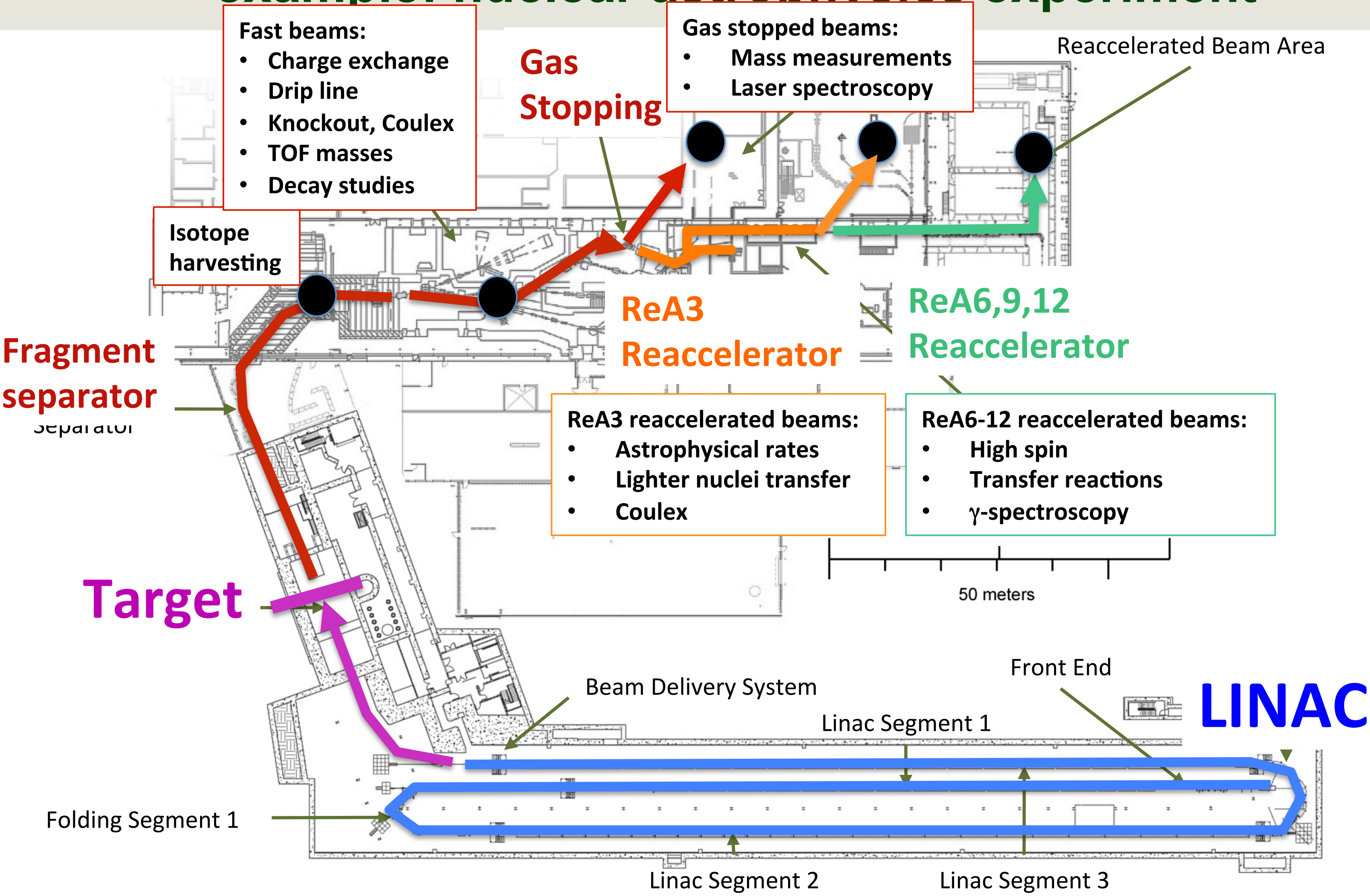
Final Civil Design is Complete



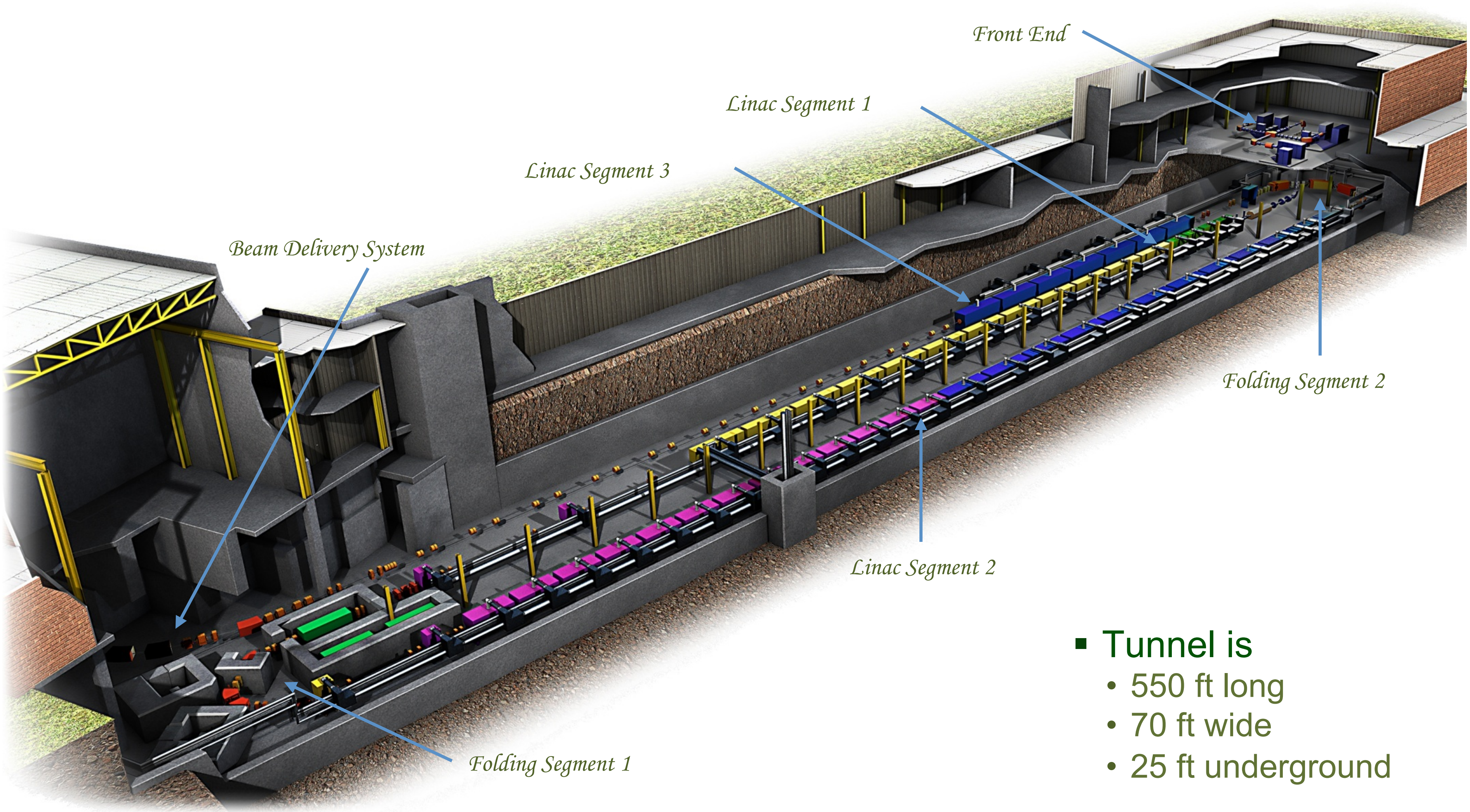
Rendered Perspective
Southeast View



FRIB Layout
example: nuclear astrophysics experiment



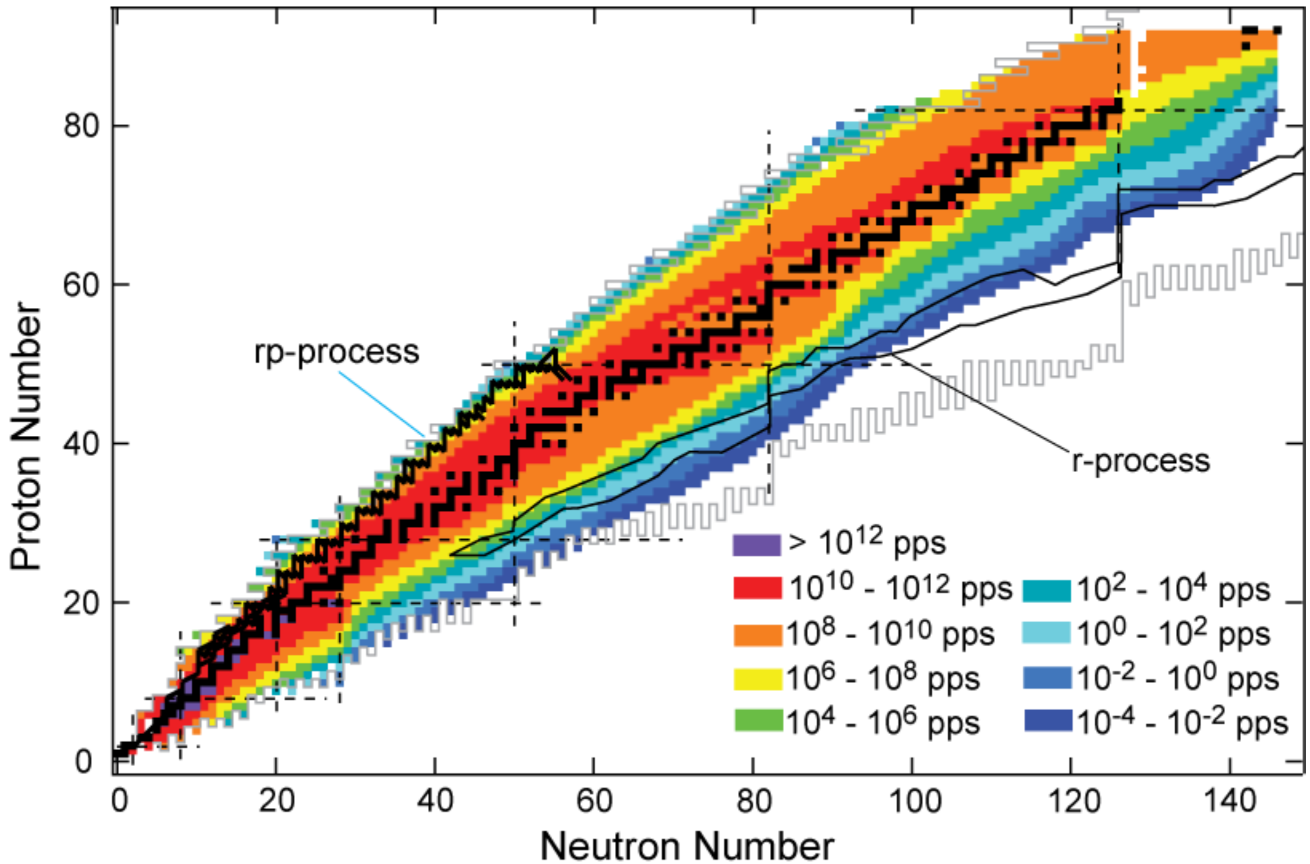
Driver Linear Accelerator



- Tunnel is
  - 550 ft long
  - 70 ft wide
  - 25 ft underground

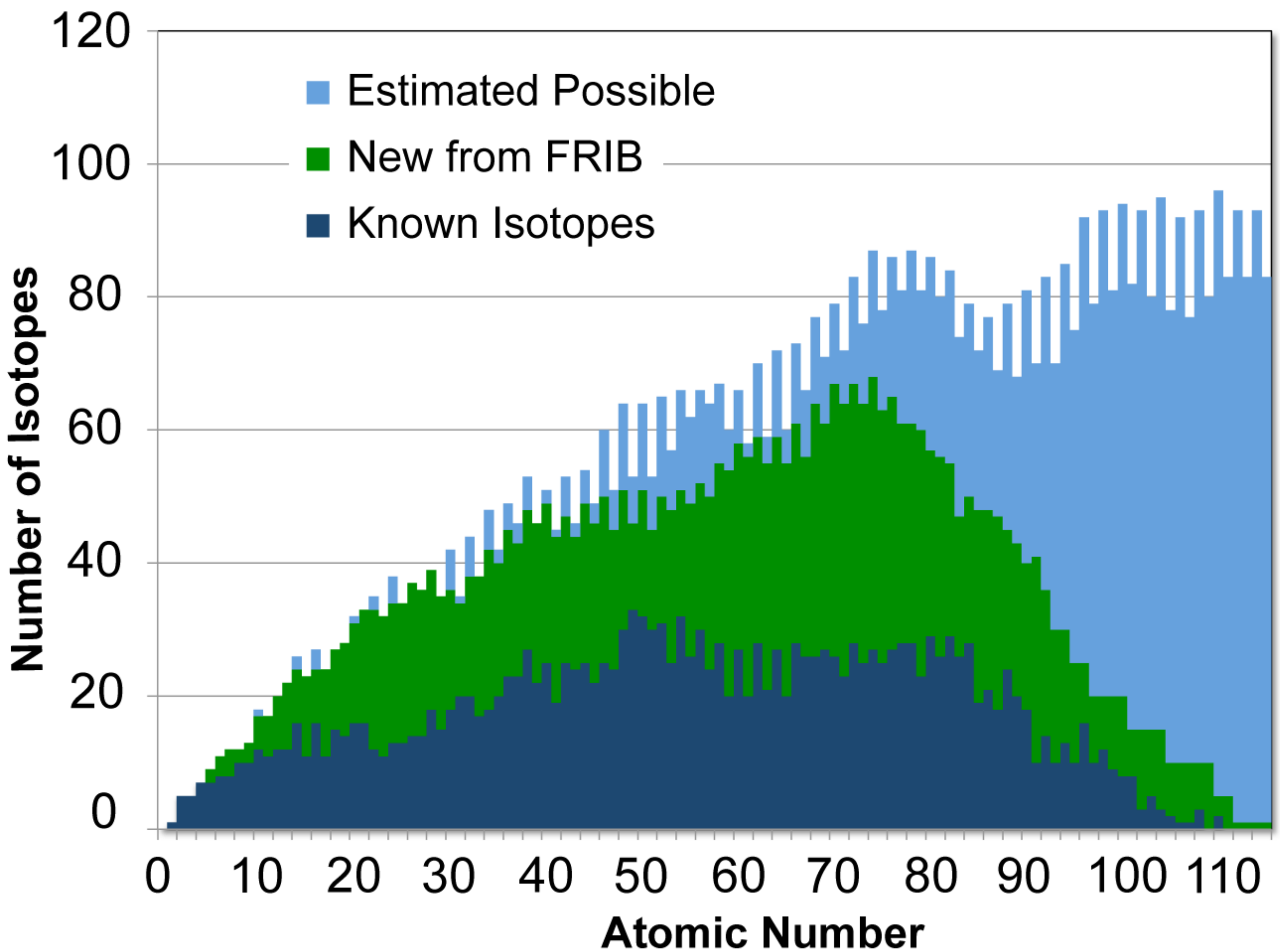
The Reach of FRIB

- FRIB is estimated to produce more than 1000 NEW isotopes at useful rates (4500 available for study; compared to 1900 now)
- Exciting prospects for study of nuclei along the drip line to A=120(compared to A=24)
- Production of most of the key nuclei for astrophysical modeling
- Theory is key to making the right measurements and interpreting them



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

The Reach of FRIB



Estimated Possible: Erler, Birge, Kortelainen, Nazarewicz, Olsen, Stoitsov, to be published

Based on a study of EDF parameters

Known – isotopes with at least one excited state known

Up to Z=90 FRIB will be able to make >80% of all possible isotopes

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
- Final technical design underway, to be completed in 2014
- CD-3b review in June 2014
- Managing to early completion in 2020
  - 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 $265M

Everybody is working hard
Ground Breaking March 17, 2014

Civil Construction Has Begun

- Civil construction began March, 2014
- New SRF Highbay (right side of picture) nearing completion

FRIB CONSTRUCTION SITE - 30 MARCH 2014

Web cams at frib.msu.edu

Over 1300 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)
  - FRIBUO has 1350 members (92 U.S. colleges and universities, 10 national laboratories, 55 countries) as of 27 August 2013
  - Chartered organization with an elected executive committee
  - FRIBUO has 19 working groups on experimental equipment
- Science Advisory Committee
  - Review of equipment initiatives (February 2011)
  - Review of FRIB integrated design (March 2012)
  - Review of equipment working group progress (October 2013)

August 2013
Low-Energy
Community Meeting
274 participants

fribusers.org

Join at fribusers.org (and fribastro.org)

Why is it called FRIB ???

URBAN DICTIONARY

1. frib 17 up, 6 down

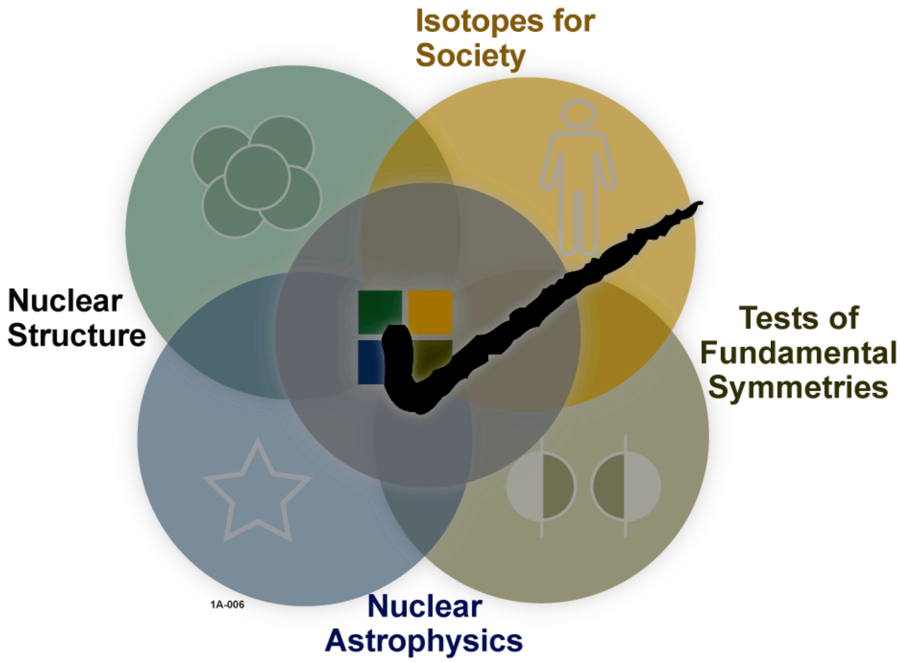
birf spelled backwards

2. frib 4 up, 12 down

A word that can be used to describe happiness, joy etc. Commonly replaces 'wow', 'cool' or 'great'.

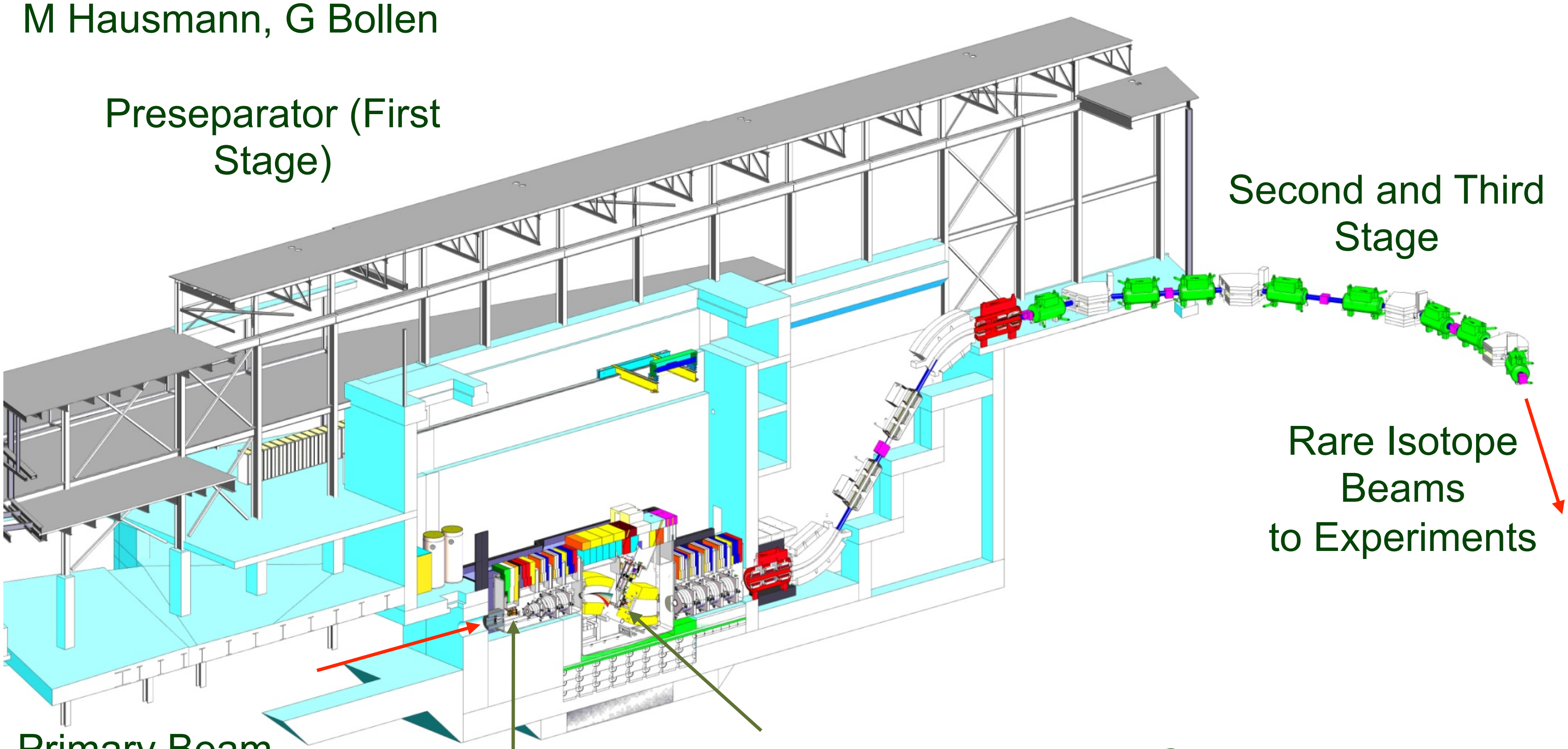
Summary

- FRIB will allow production of a wide range of isotopes
  - Extend our searches for the limits to nuclear stability
  - Answer key questions on the nature of the universe (chemical history, mechanisms of stellar explosions)
  - Opportunities for the tests of fundamental symmetries
  - Potential for important societal applications
- The unique features of FRIB
  - High power linear accelerator 400 kW
  - In-flight production and separation providing stopped and reaccelerated beams of elements difficulty to get from ISOL techniques



Isotope Production Area
Target and Fragment Separator

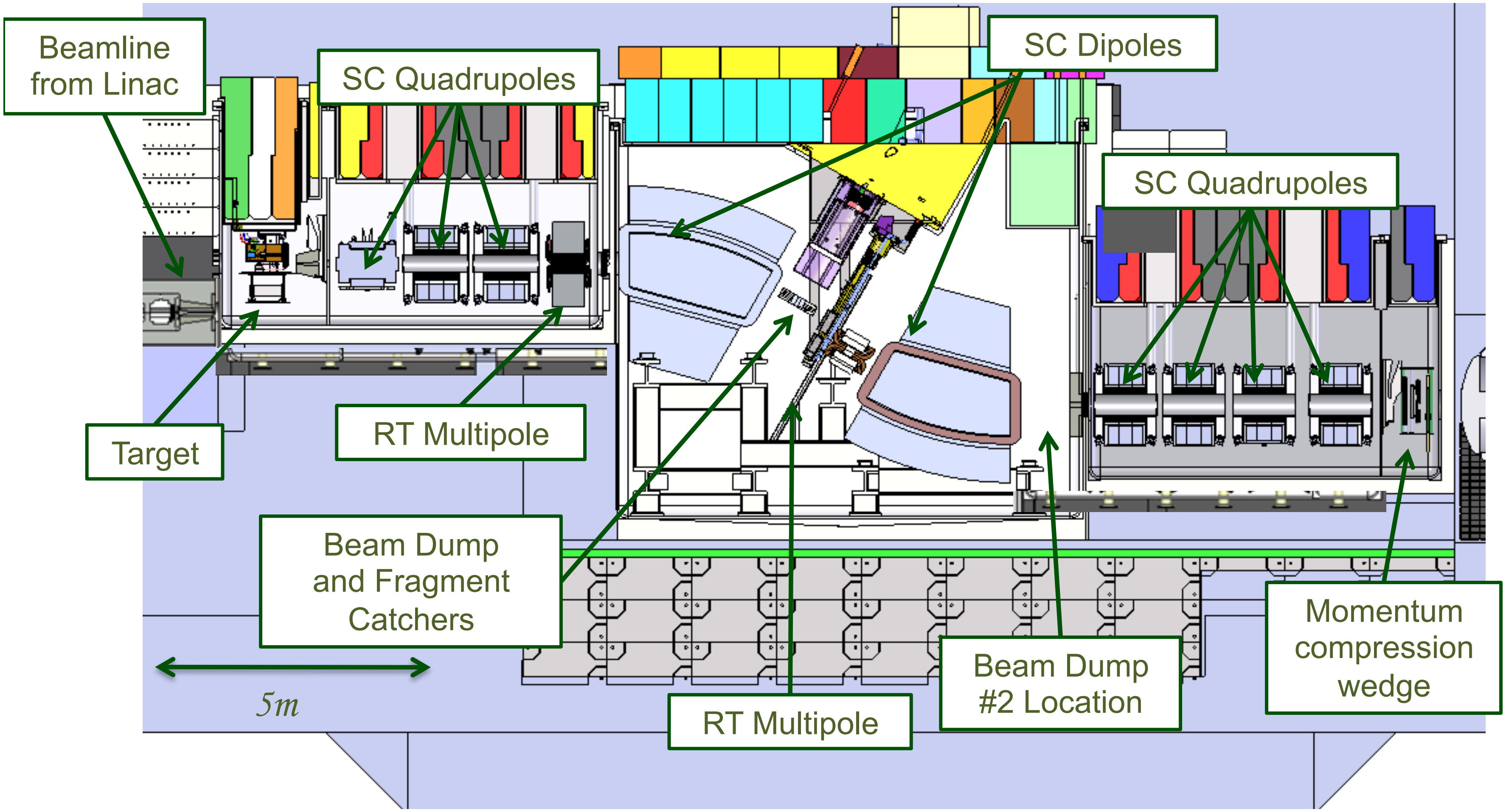
M Hausmann, G Bollen



Separator Length
96 m

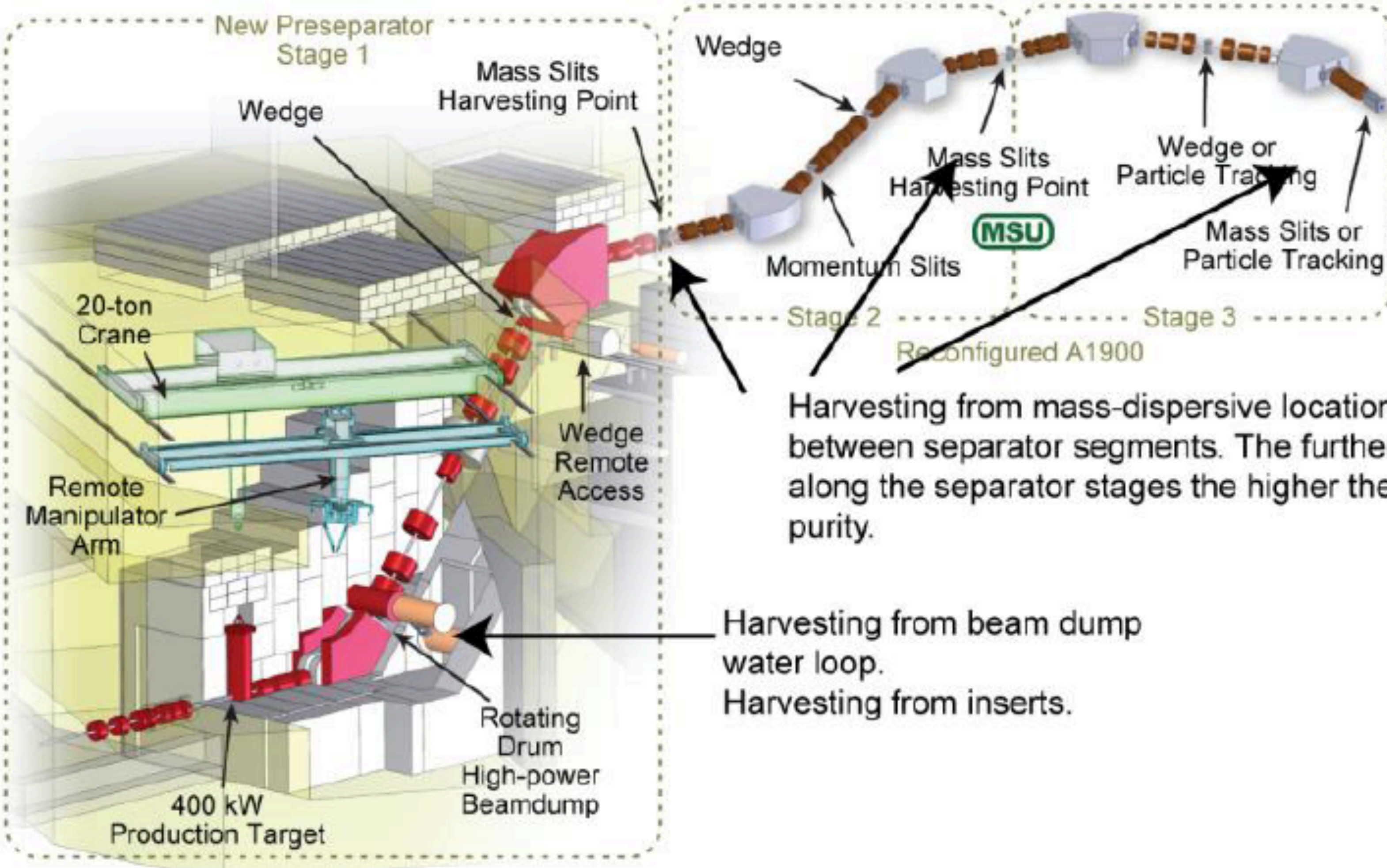
FRIB Preseparator
400 kW Beam Power Requirement

G Bollen



- Challenges: beam power densities, radiation damage, activation, …

Isotope harvesting points



Harvesting from mass-dispersive locations between separator segments. The further along the separator stages the higher the purity.

Harvesting from beam dump water loop.
Harvesting from inserts.

Gas Stopper

- R&D Program lead by ANL and MSU
- Technical Specifications
  - 3 complementary stopping stations and 2 momentum compression lines specifically optimized
  - **Two Linear gas stoppers** (ANL, MSU)
    - » L = 1.5 m, p < 300 mbar
    - » I < 10^8/s, $T^{1/2}$ > 100ms
  - **Cyclotron gas stopper** for light and medium heavy isotopes (NSF Funded)
    - » B_{max} = 2.3T, r_{inj} = 0.95, p_{He} = 50-250 mbar
    - » I > 10^8/s, $T_{1/2}$ < 50ms
  - **Solid stopper** for special elements and high beam rates
    - » Example: ^{15}O, I >10^{10}/s