FRIB Status and Scientific Program

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for the FRIB project team

October 2014

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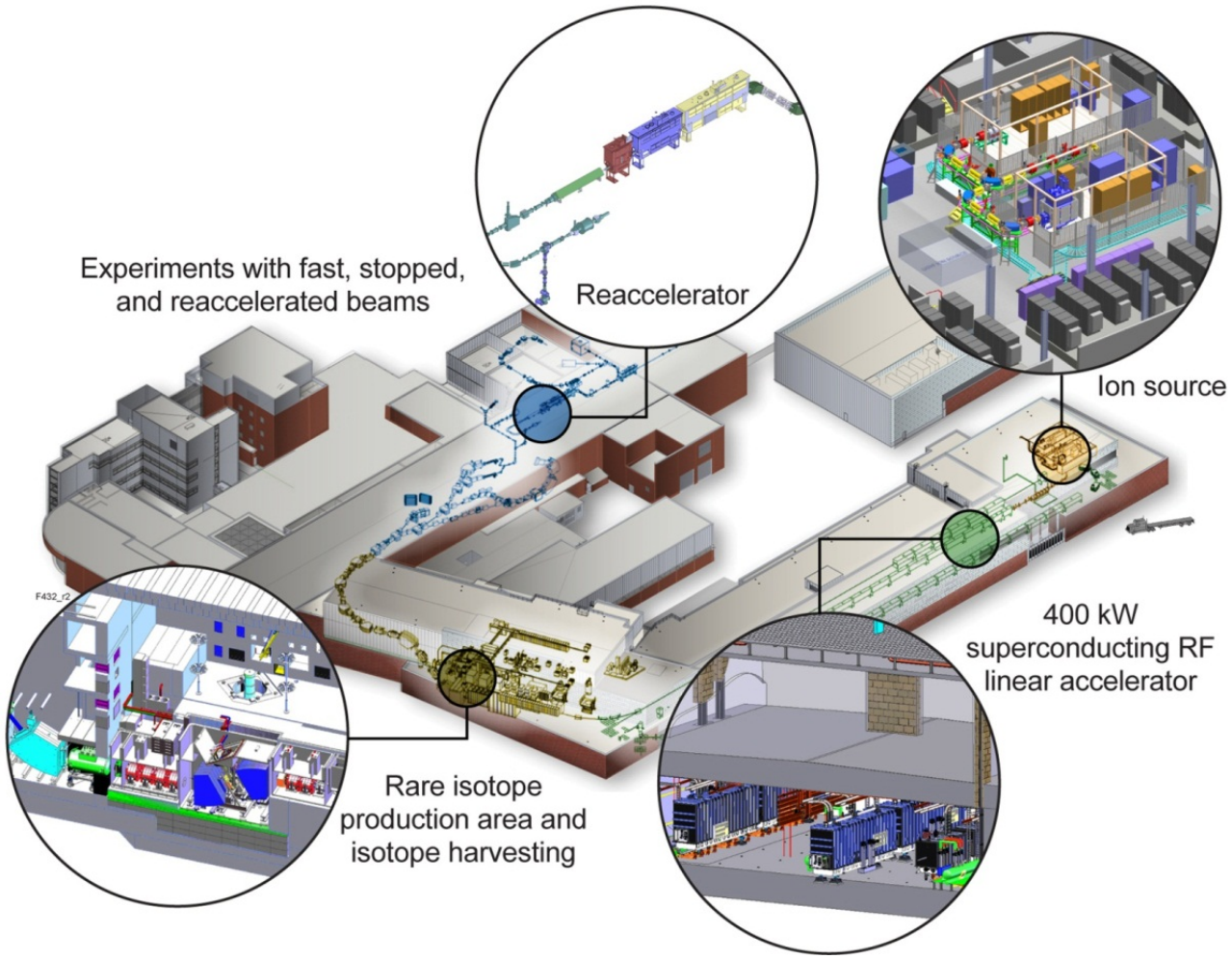
U.S. DEPARTMENT OF ENERGY | Office of Science

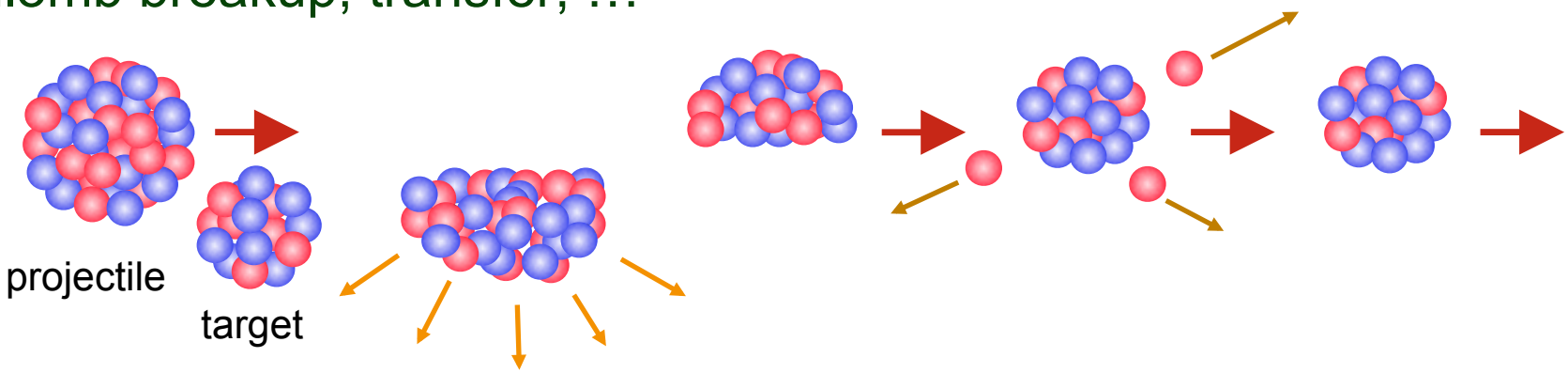
Major US Project – Facility for Rare Isotope Beams, FRIB

- Funded by the US DOE Office of Science
- Key Feature is 200 MeV/u 400kW beam power (5 x10^{13} ^{238}U/s)
- Separation of isotopes in-flight
- Science program requires range of energies: Fast, Stopped, and reaccelerated beams
- Upgradable to 400 MeV/u and multi-user



In-flight Isotope Production Scheme

- FRIB uses the same production scheme as the SuperFRS at FAIR
- Cartoon of nuclide production – projectile fragmentation, fission, Coulomb breakup, transfer, …



- To produce a potential drip-line nucleus like ^{122}Zr the production cross section (from ^{136}Xe) is estimated to be 2×10^{-18}
- Nevertheless with a ^{136}Xe beam of 8×10^{13} ion/s (12 pμA, 400 kW at 200 MeV/u) a few atoms per week can be made and studied (efficient >80% collection; sensitive 1 out of 10^{20})
- The availability of a wide range of new isotopes allows major advances in nuclear science.

Facility for Rare Isotope Beams: Program

Properties of atomic nuclei

- Develop a predictive model of nuclei and their interactions
- New isotopes provide key insights, e.g., changing magic numbers, 3N forces, improved density functional schemes, unique properties (halo)

Astrophysics: Nuclear processes in the cosmos

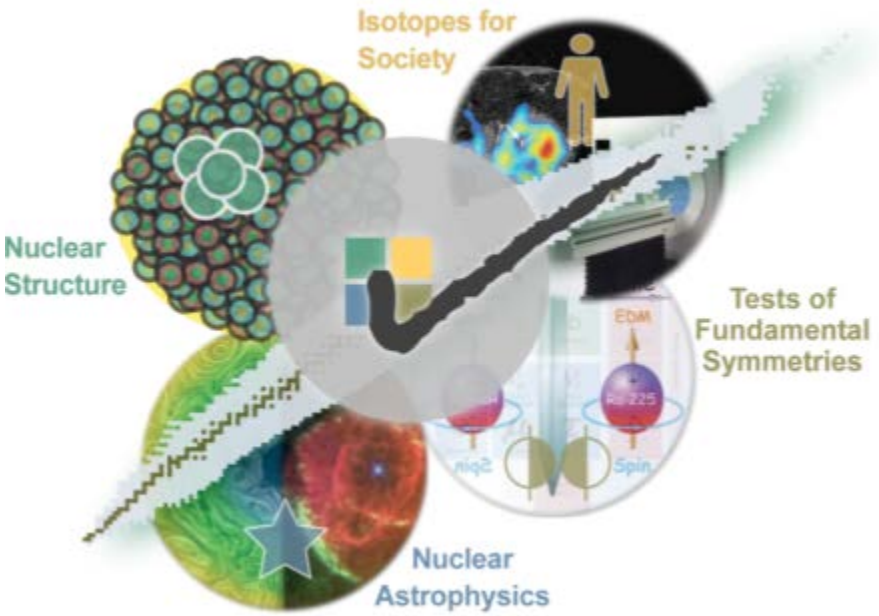
- Origin of the elements, chemical history
- Explosive environments: novae, supernovae, X-ray bursts …
- Properties of neutron stars

Fundamental Symmetries

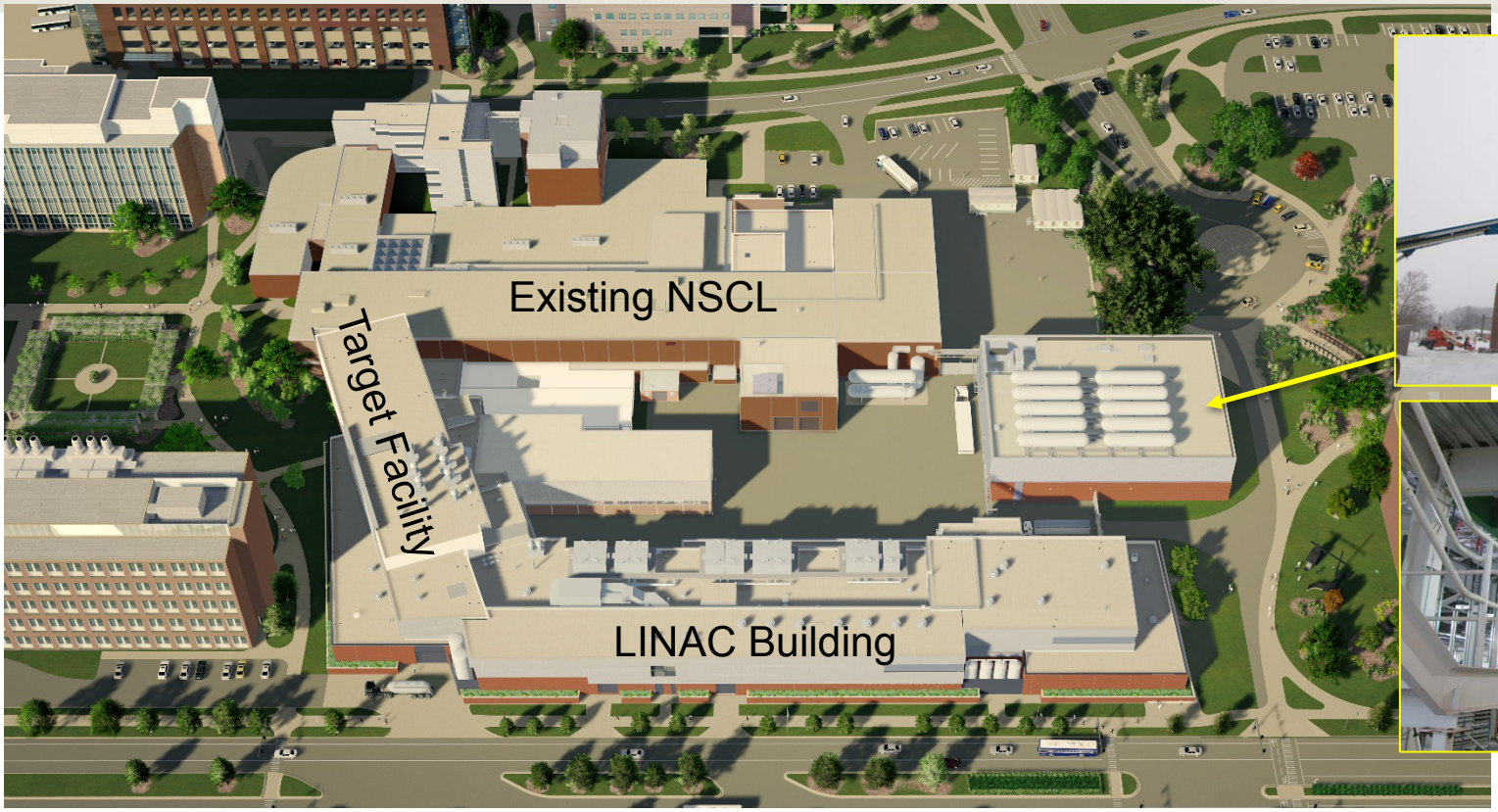
- Effects of symmetry violations are amplified in certain nuclei
- Example: Enhanced EDM searches

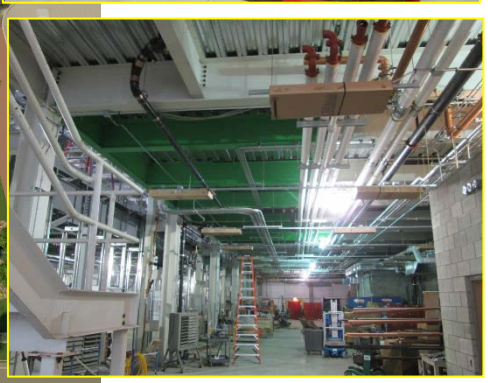
Societal applications and benefits

- Medicine, energy, material sciences, …



FRIB Facility Overview





FRIB Construction is Underway: Ground Breaking March 17, 2014

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

FRIB Civil Construction Progess

FRIB construction site on 13 October 2014 - web camera at www.frib.msu.edu

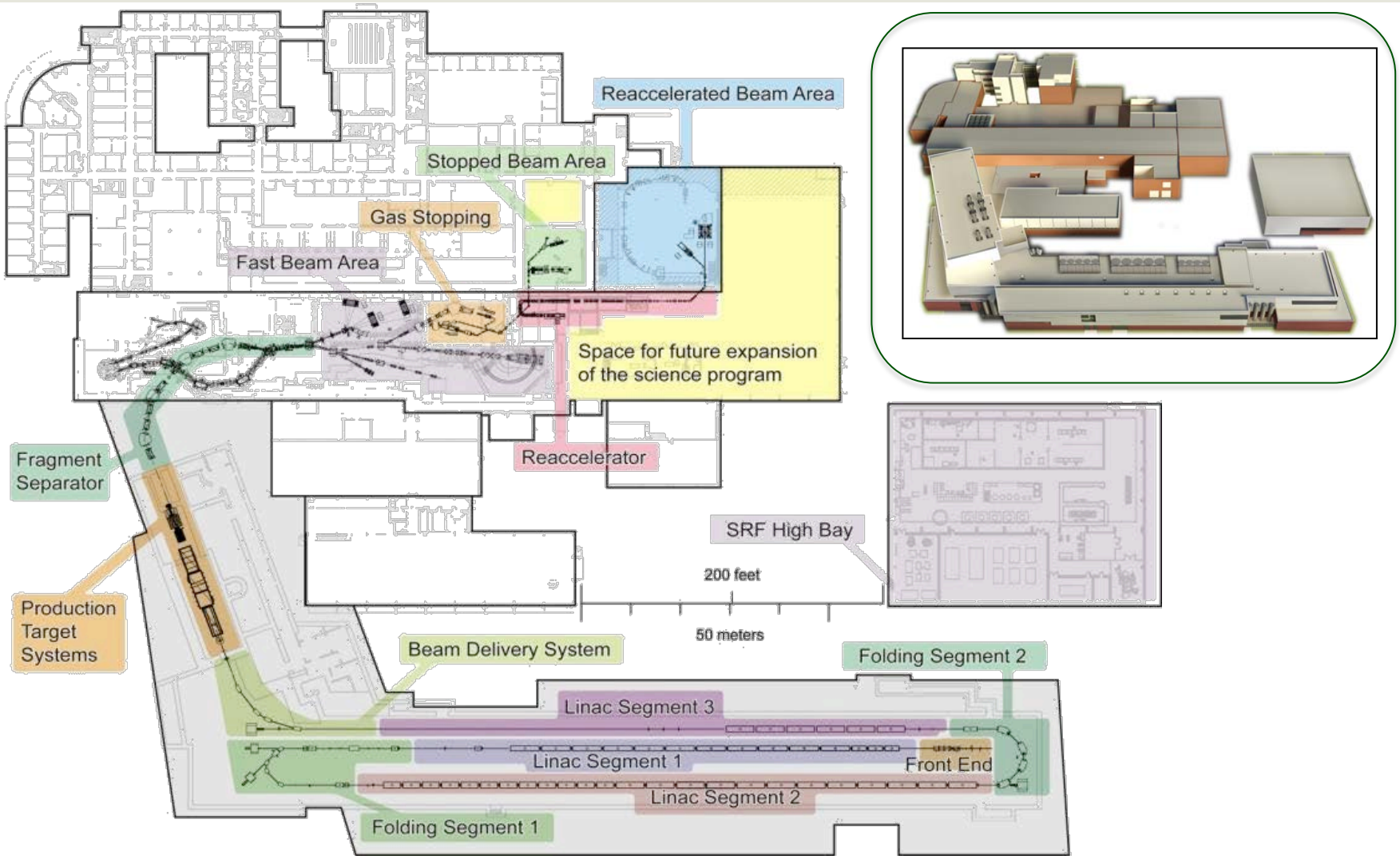
FRIB Civil Construction Underway

& 9 Weeks Ahead of Schedule

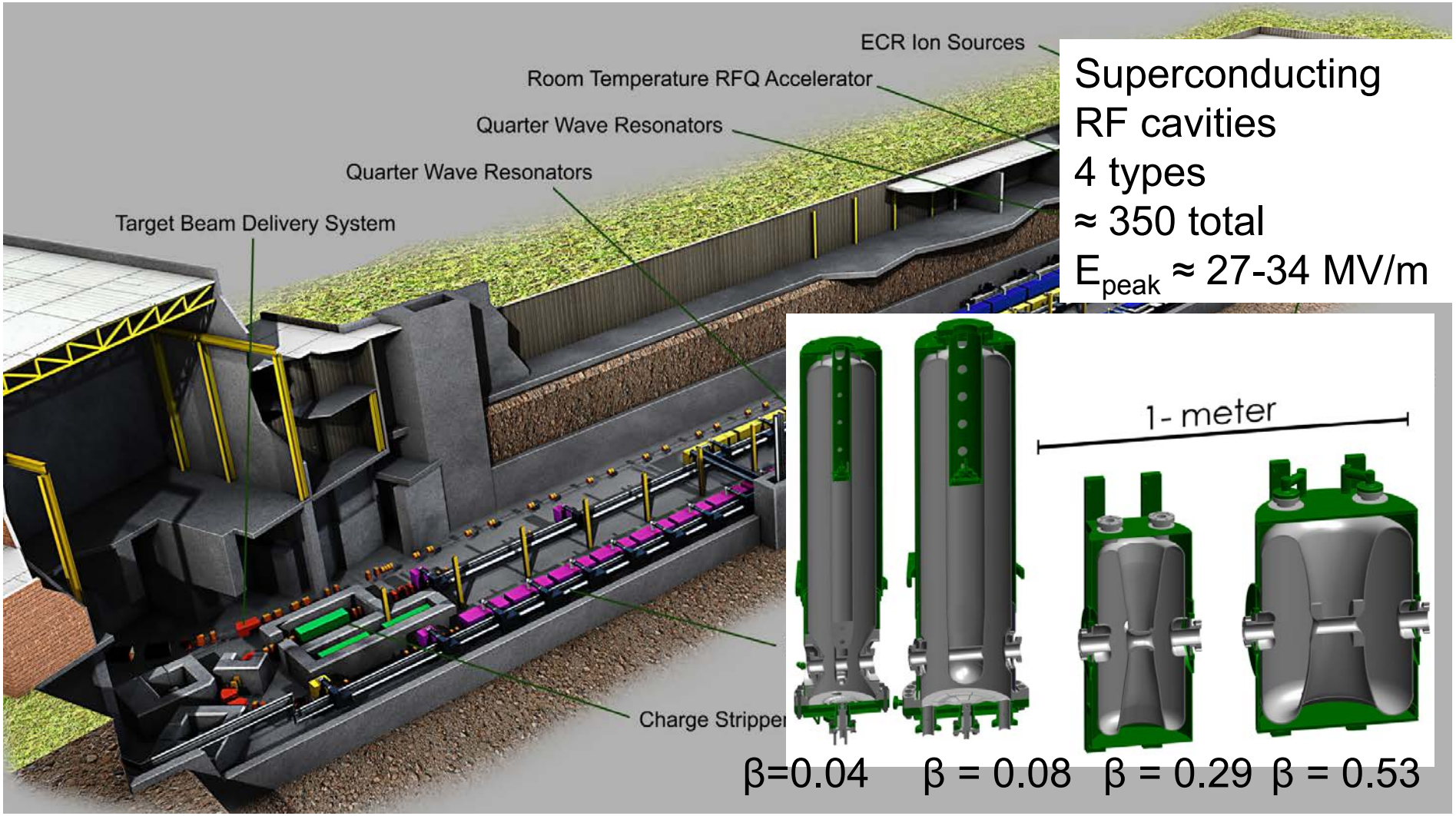
FRIB: Cost and Schedule

- FRIB project started 6/2009
- Total project cost $730 million
  - $635.5M Department of Energy
  - $94.5M Michigan State University and State of Michigan
- Civil construction started 3/2014
- Technical construction start 10/2014
  - Critical Decision CD-3b approved 8/2014
- CD-4 (DOE project completion) 6/2022
  - Project managed for early completion 12/2020
- NSCL will continue to operate as national user facility until shortly before FRIB completion – funded by NSF
  - Integration of NSCL facilities into FRIB within one year in 2019-2020

FRIB Facility Overview



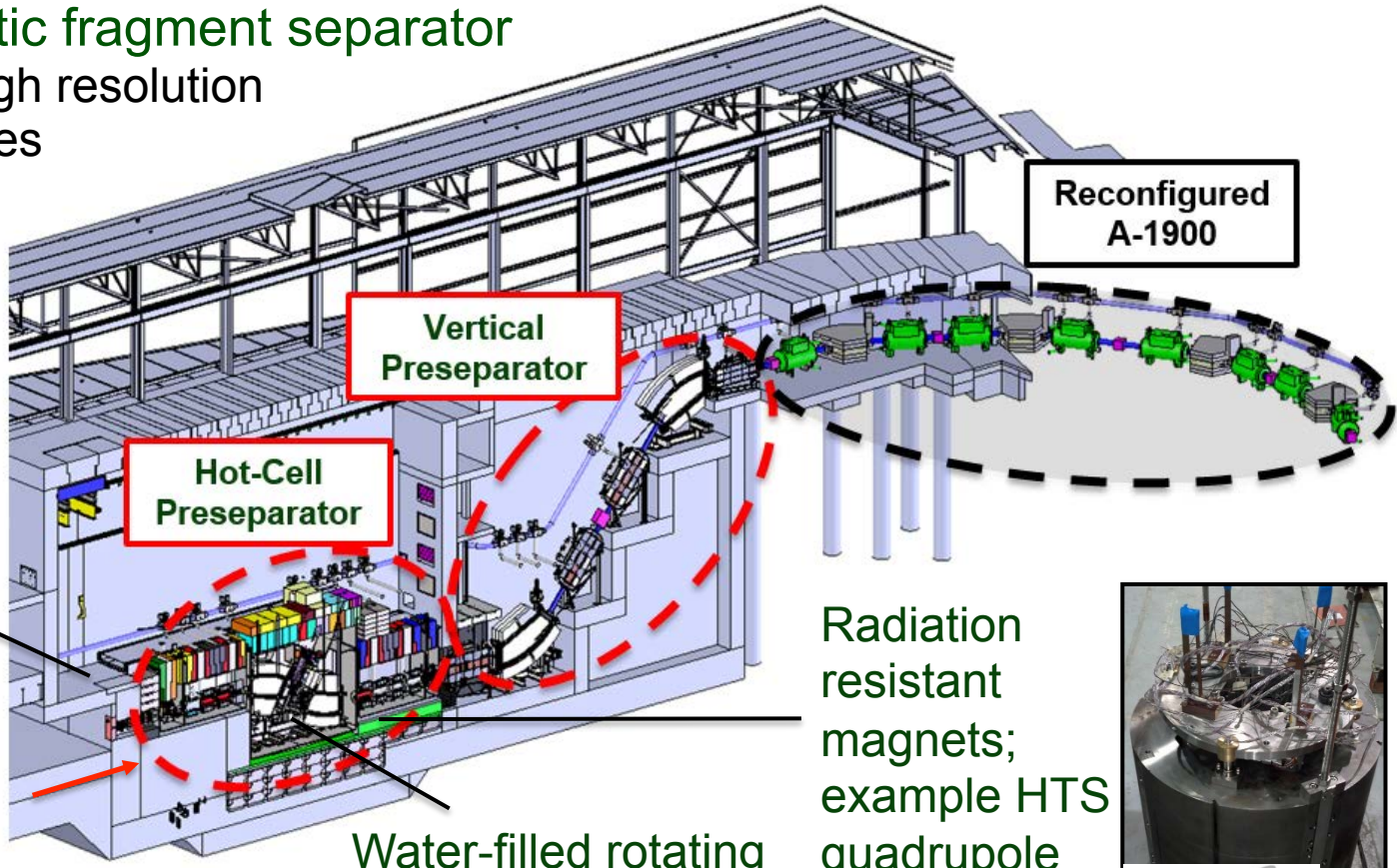
Driver Linear Accelerator



FRIB: Fragment Separator
Three Separation Stages

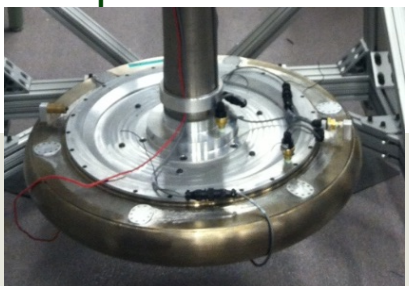
- Three stage magnetic fragment separator
  - High acceptance, high resolution multiple optical modes

Multi-slice rotating graphite target



Radiation resistant magnets; example HTS quadrupole

Water-filled rotating beam dump

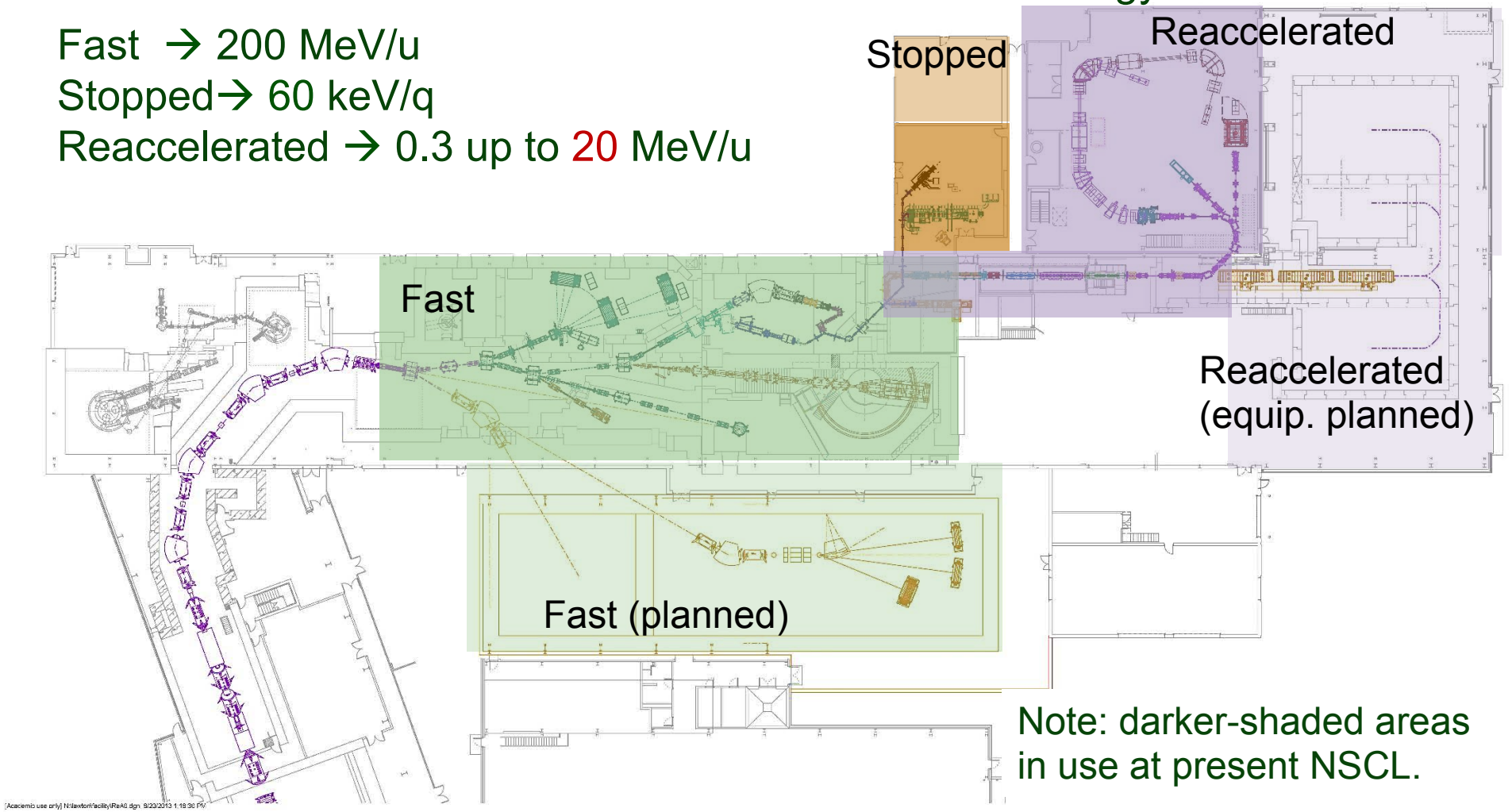


Final design substantially complete
Magnet fabrication to start in Nov/2014

Three Experimental Energy Regimes

Radioactive Ion Beams are needed/available in three energy domains:

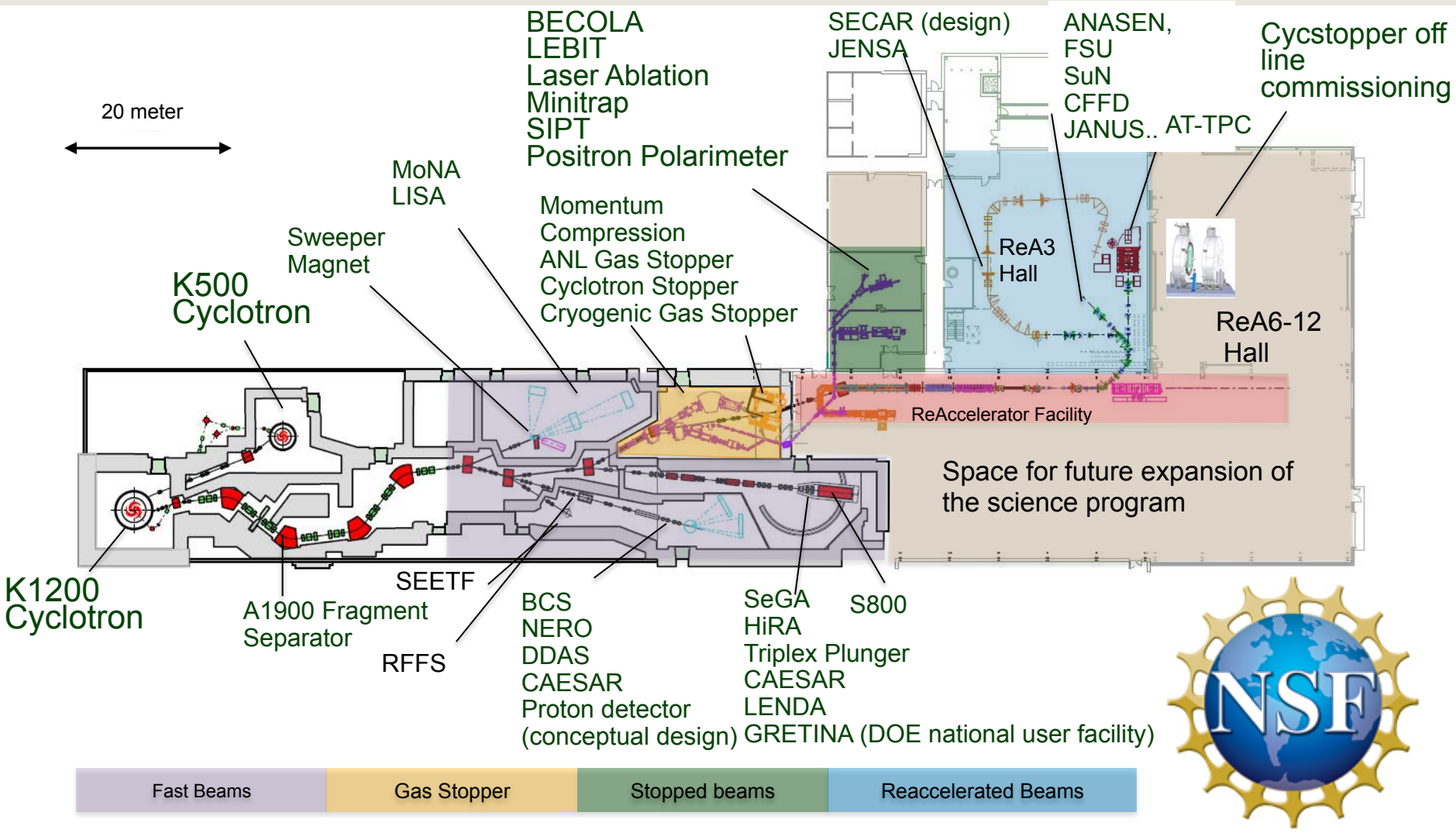
Fast → 200 MeV/u
Stopped→ 60 keV/q
Reaccelerated → 0.3 up to 20 MeV/u



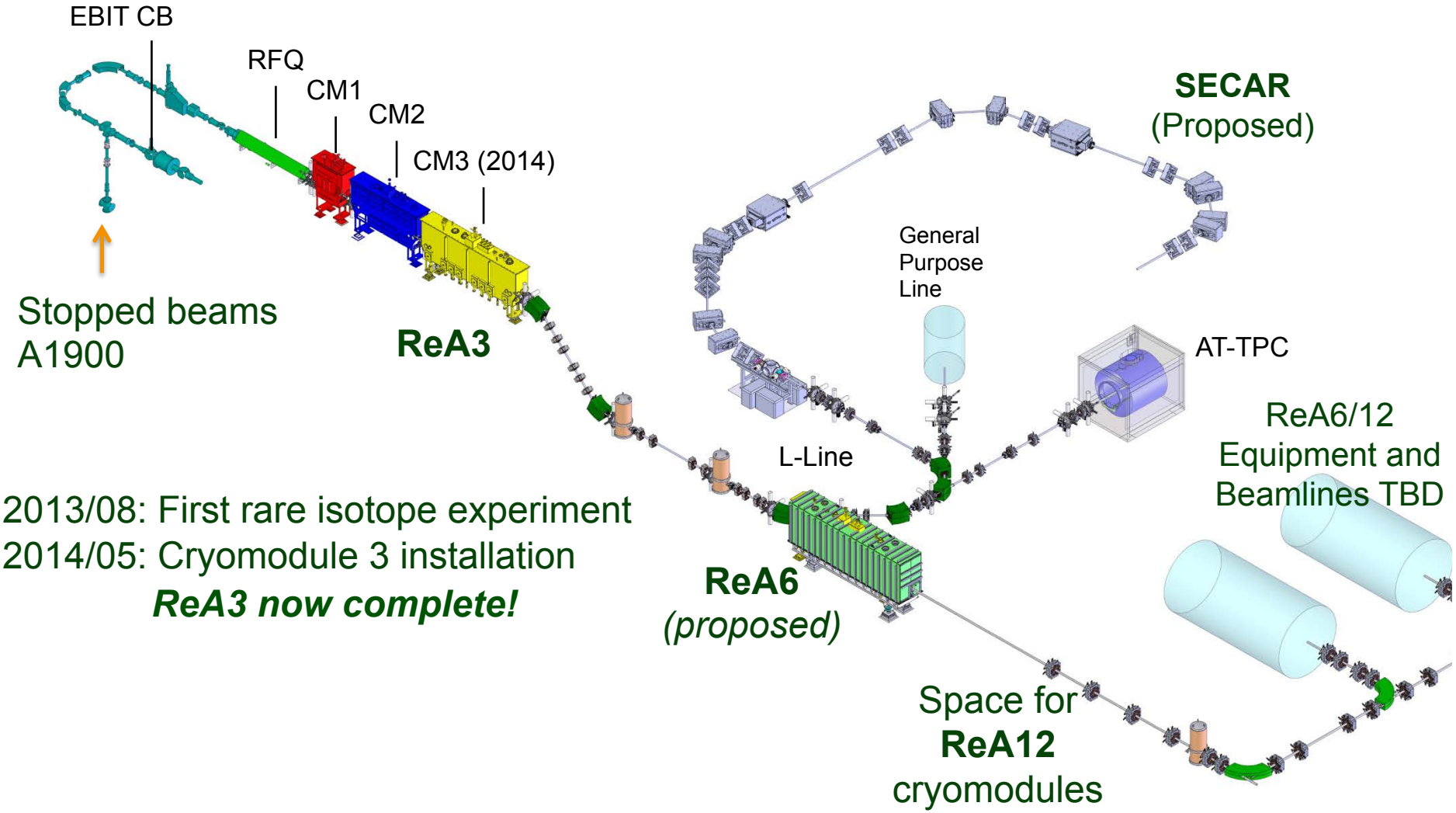
Note: darker-shaded areas in use at present NSCL.

Continued Science Opportunities at NSCL

with Fast, Stopped, Reaccelerated Beams



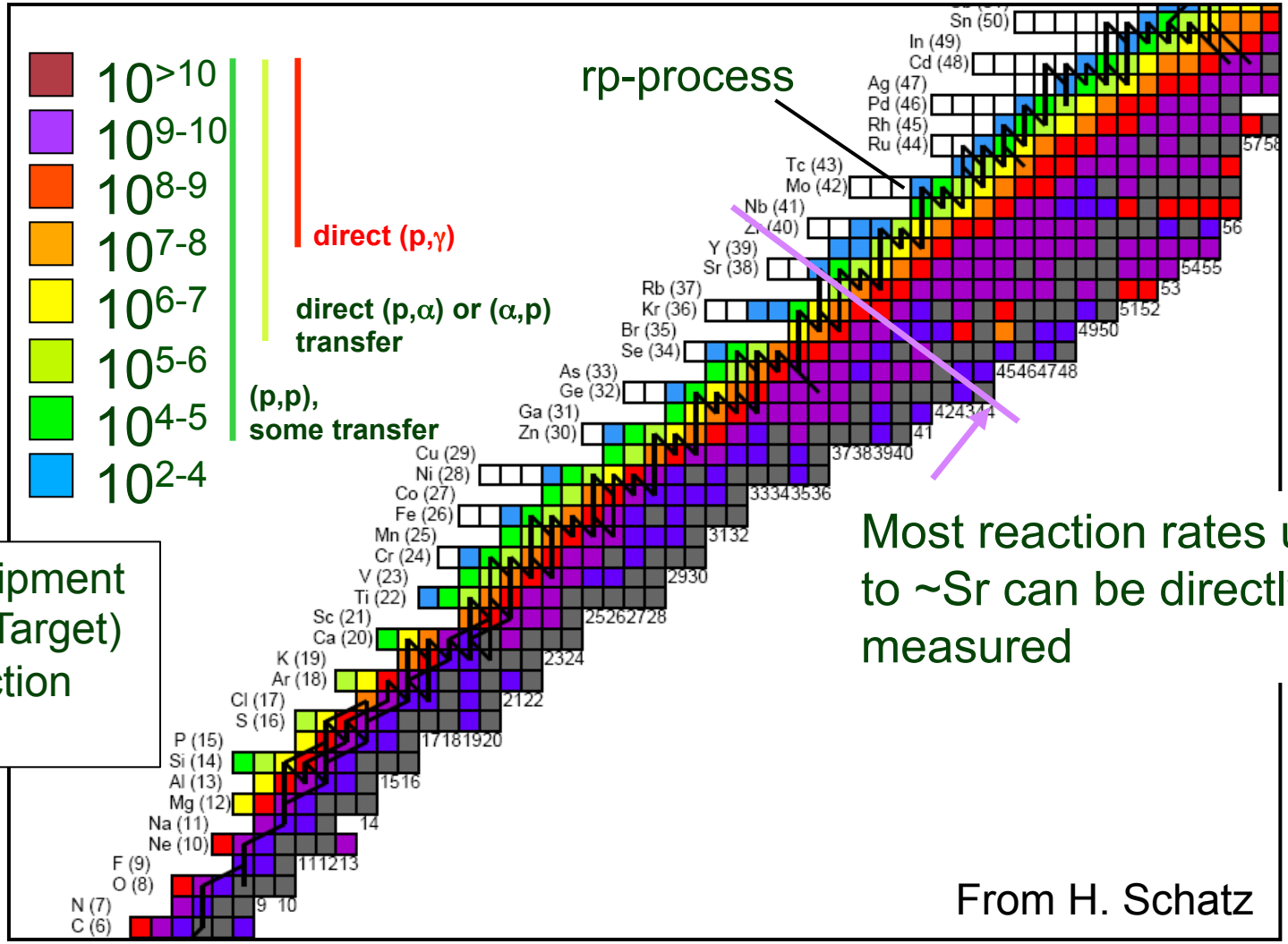
ReA3 the Re-accelerator at NSCL



2013/08: First rare isotope experiment
2014/05: Cryomodule 3 installation
ReA3 now complete!

FRIB: Possibilities for Novae and X-ray burst reaction rate studies

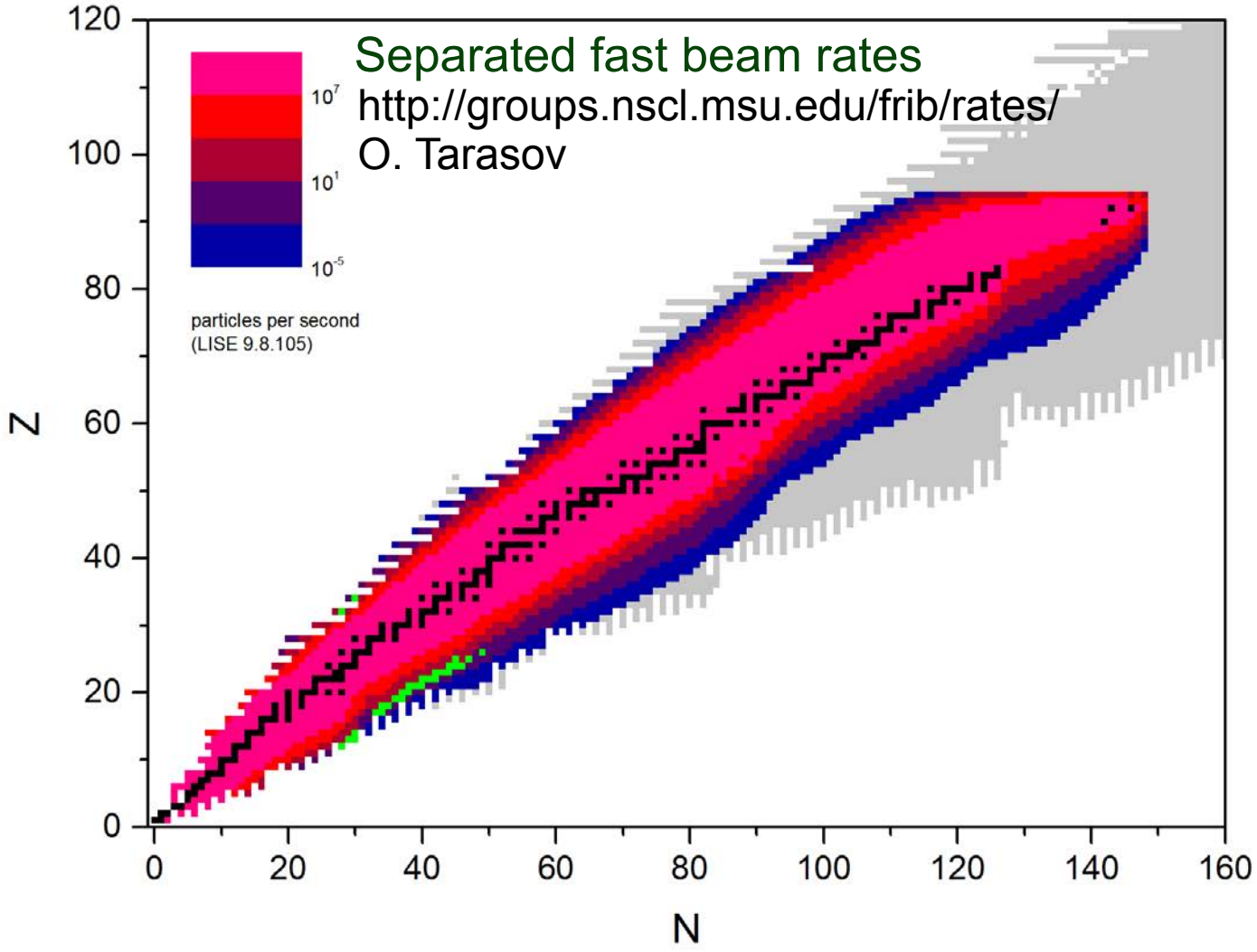
Predicted Reaccelerated beams rates



Specialized equipment (SECAR & gas Target) allow direct reaction studies

FRIB Projected Production Rates

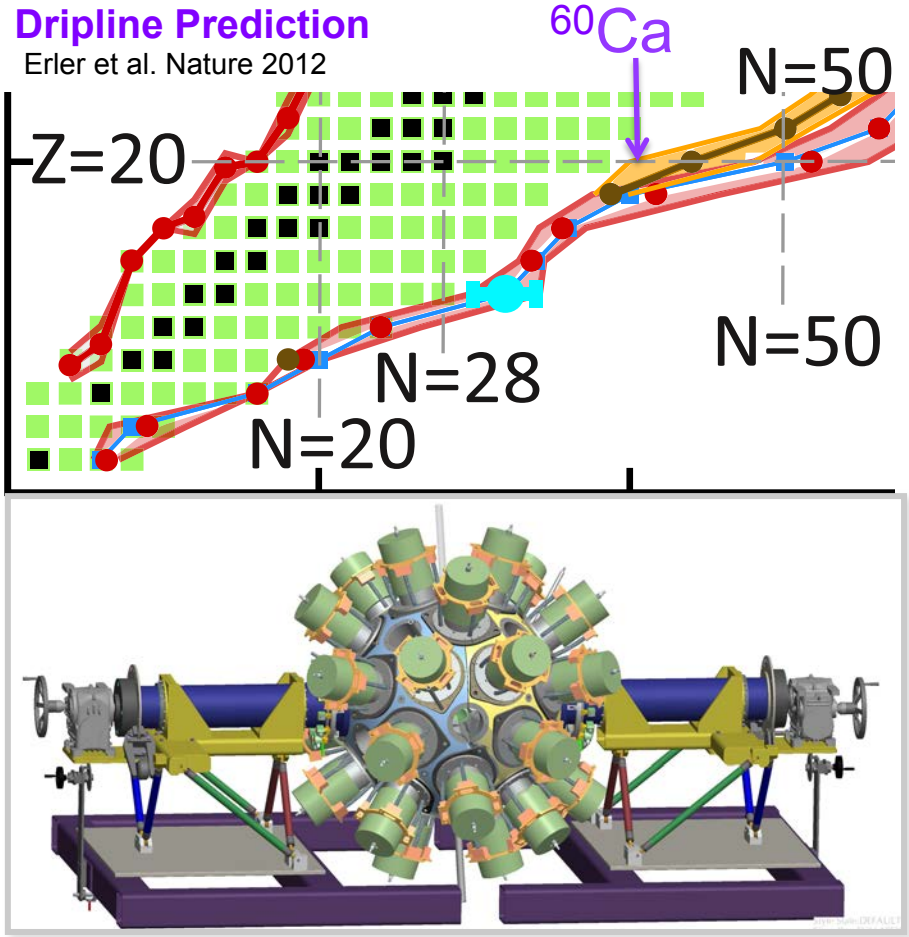
Similar yields for other new facilities – FAIR



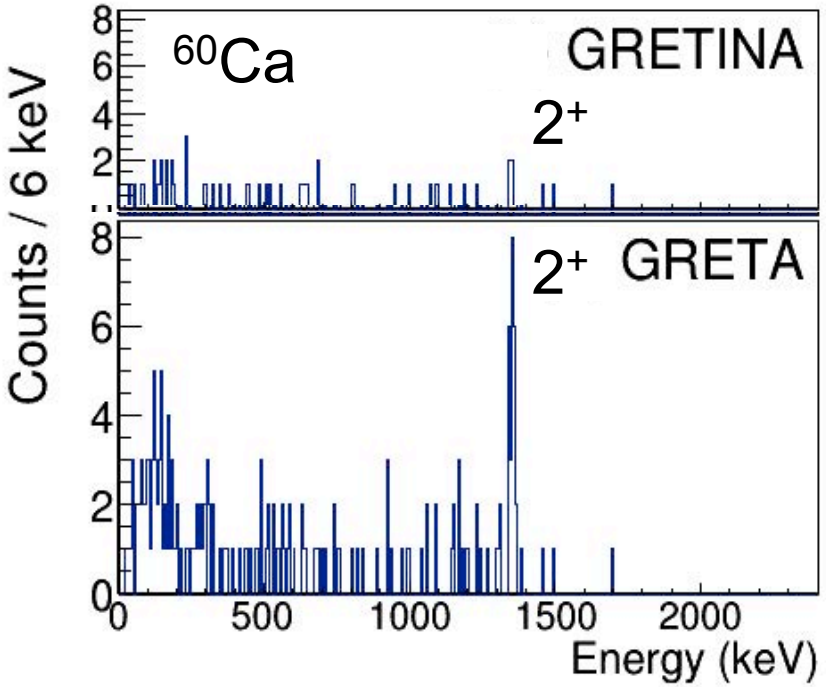
- Projected production yields for FRIB (EPAX3 – K. Summerer et al.)
- Blue region 1 particle per day.
- Studies along or near the drip line up to Z=40

T. Baumann

Key Experimental Equipment: GRETA at FRIB



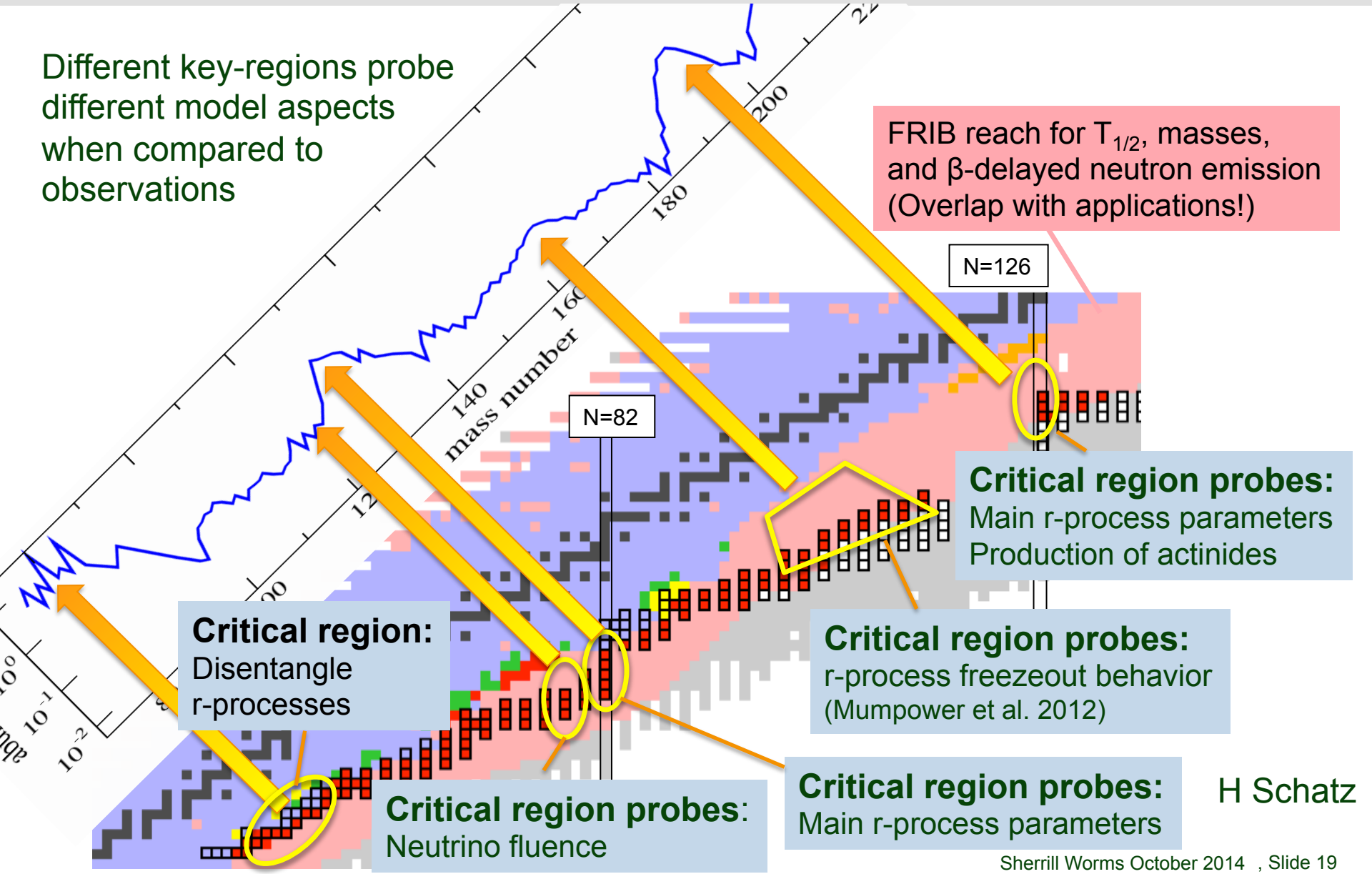
Simulated spectrum of ^{60}Ca populated in one-proton removal



4π Gamma Ray Energy Tracking Array GRETA with precise Doppler reconstruction of γ-rays emitted in flight

From H. Crawford

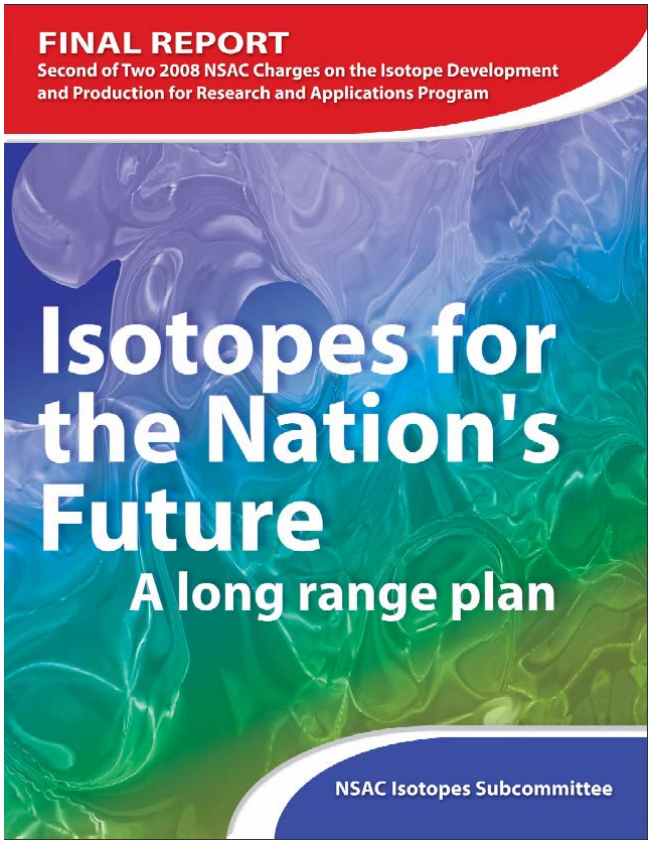
New Facilities will Enable the Needed Breakthrough in Nuclear Physics



FRIB Will Provide Isotopes Needed for the Nation's Future

"Most of the isotopes in use today in practical settings were developed as long as 50 years ago. With few exceptions (e.g., ^{82}Sr and ^{90}Y) there are no new products or services that use isotopes developed in the past 20 years. Without the availability of research isotopes, it is not possible to develop new science or new applications based on isotopes. This problem is extreme in the case of accelerator isotopes …"

Subcommittee Finding
Isotopes for the Nation's Future
NSAC Long Range Plan Study 2008



- Next generation rare isotope facilities can provide isotopes for applied science while serving forefront nuclear research
- FRIB is designed to provide fast access to a broad range of new isotopes for research

FRIB: Isotope Harvesting Opportunities
Make Best Use of Rare Isotopes Produced

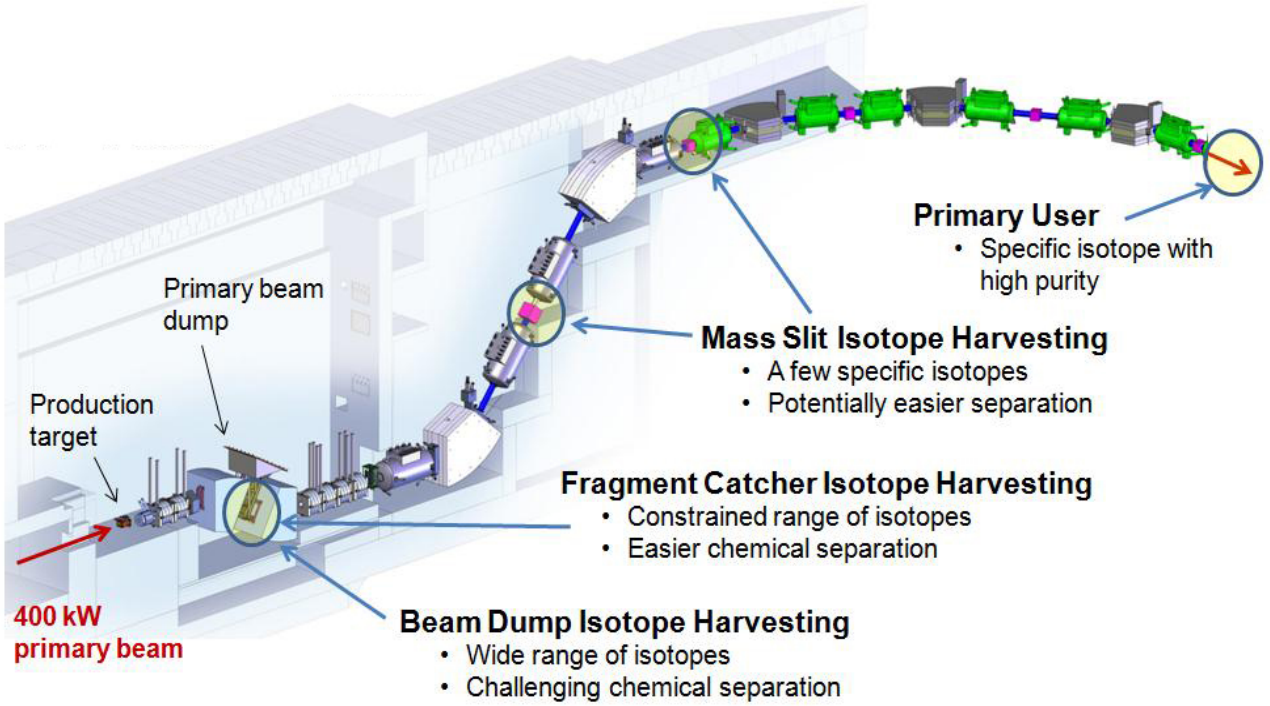
- Produce a rare isotope beam for a primary user
- At the same time up to 1000 other isotopes are produced that could be harvested and used for other experiments or applications

Workshop series on "Isotope Harvesting at FRIB",

1st, Santa Fe, NM, 2010

2nd, East Lansing, MI, 2012

3rd, St Louis, MO, 2014



Harvesting of isotopes for applications is not in the base design, but we are making efforts to add these capabilities.

Research Papers Based on ^{68}Ga

Nuclear and Radiochemistry Expertise

US National Academies Press (2012)

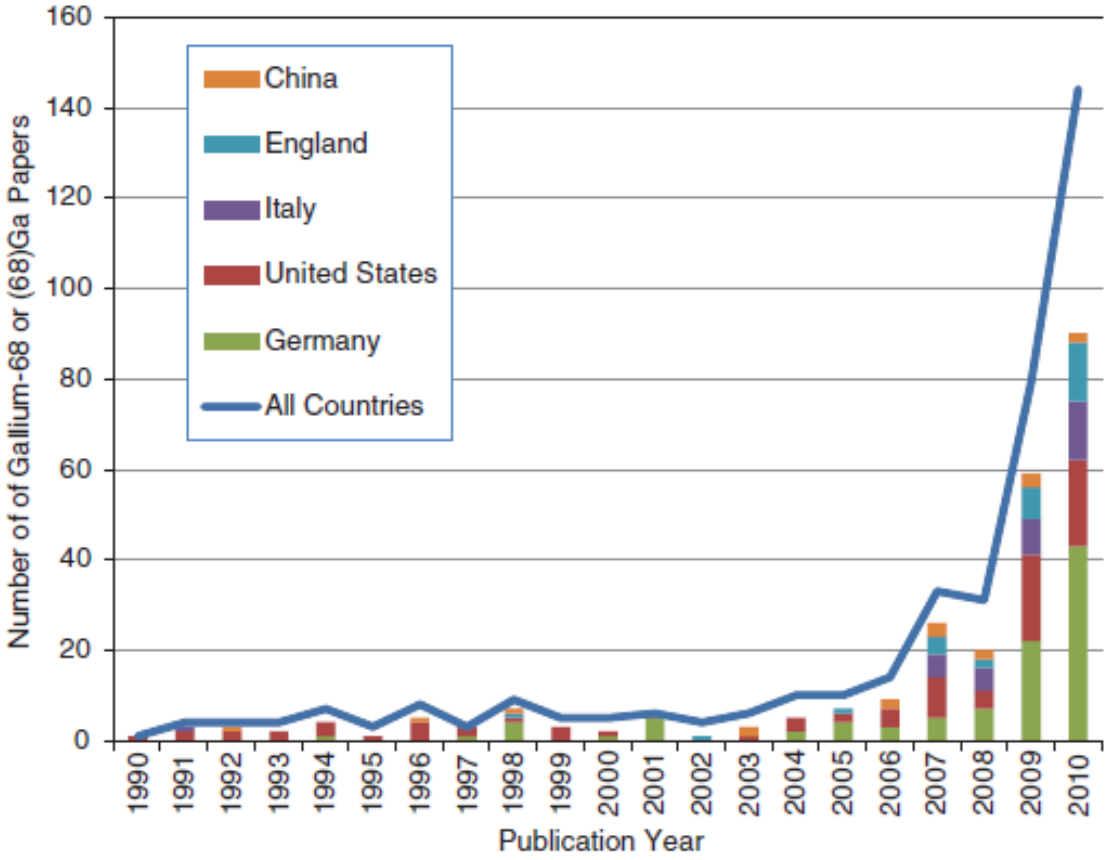


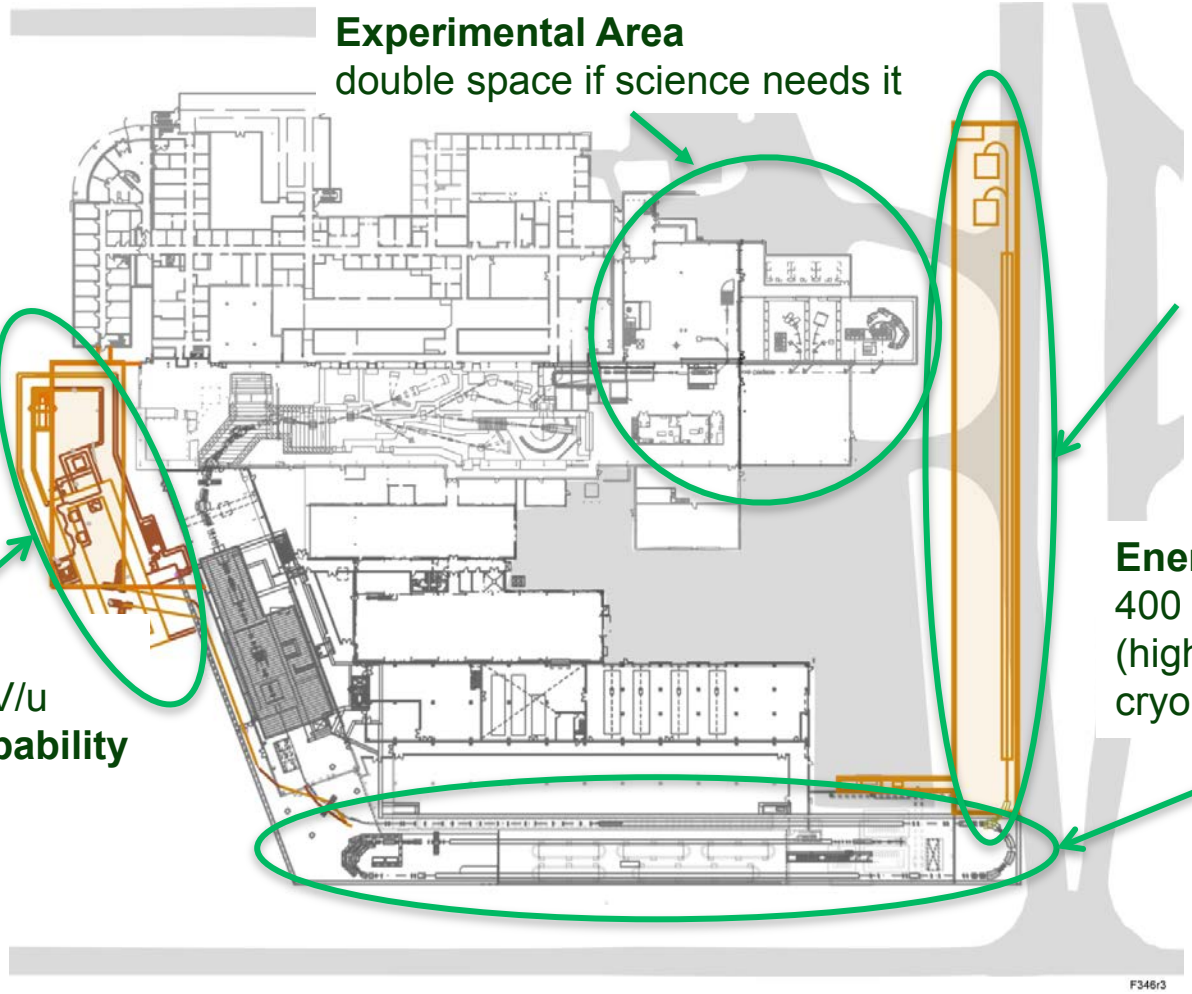
FIGURE 4-1 Keyword search of journal articles by country for nuclear medicine related keyword, 1978-2010. (A) fluorodeoxyglucose (FDG), (B) Fluorine-18 or (18)F, (C) Gallium-68 or (68)Gallium.
SOURCE: Web of Science keyword search, 2011.

FRIB Users Organization

www.fribusers.org

- Scientists have organized themselves in the project-independent FRIB Users Organization (FRIBUO)
  - Chartered organization with an elected executive committee
  - 1386 members (92 U.S. colleges and universities, 10 national laboratories, 51 countries) as of August 2014
  - 19 working groups on instruments
- Annual community meetings
- Science Advisory Committee
  - Review of equipment initiatives (February 2011)
  - Review of FRIB integrated design (March 2012)
  - Review of equipment priorities (October 2013)
  - Next meeting on equipment priorities (early 2015)

Science-driven Upgrade Options Remain

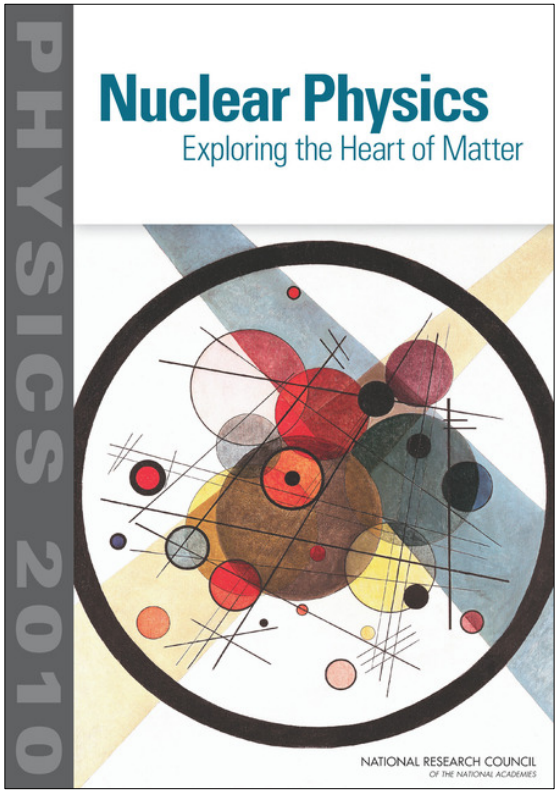


FRIB is Complementary to FAIR

- FRIB and FAIR address similar science goals but are highly complementary
- FRIB has a significant focus on lower-energy reactions with reaccelerated beams and experiments with trapped stopped beams
- FRIB production energy is 200 MeV/u at 400kW
- No storage rings are planned for FRIB
- FAIR has higher energy and cleaner separation for higher Z ions
- FAIR higher energy is an advantage for many reaction studies and mesonic atoms, delta production in exotic nuclei, …
- FAIR has more efficient collection of rare isotopes due to the higher production energy
- FAIR will be able to take advantage of secondary production (could be 100x gain in extreme cases)

Summary

- FRIB construction is underway and is scheduled for early completion in 2020
- NSCL will continue a vibrant science program (end in 2019)
- Broad science program
  - Physics of atomic nuclei
  - Nuclear Astrophysics
  - Fundamental Symmetries
  - Applications
- Existing and new equipment is planned for FRIB
- Complementary to the FAIR program



FRIB top Priority of US National Academies (2013)