Capabilities at the National Superconducting Cyclotron Laboratory

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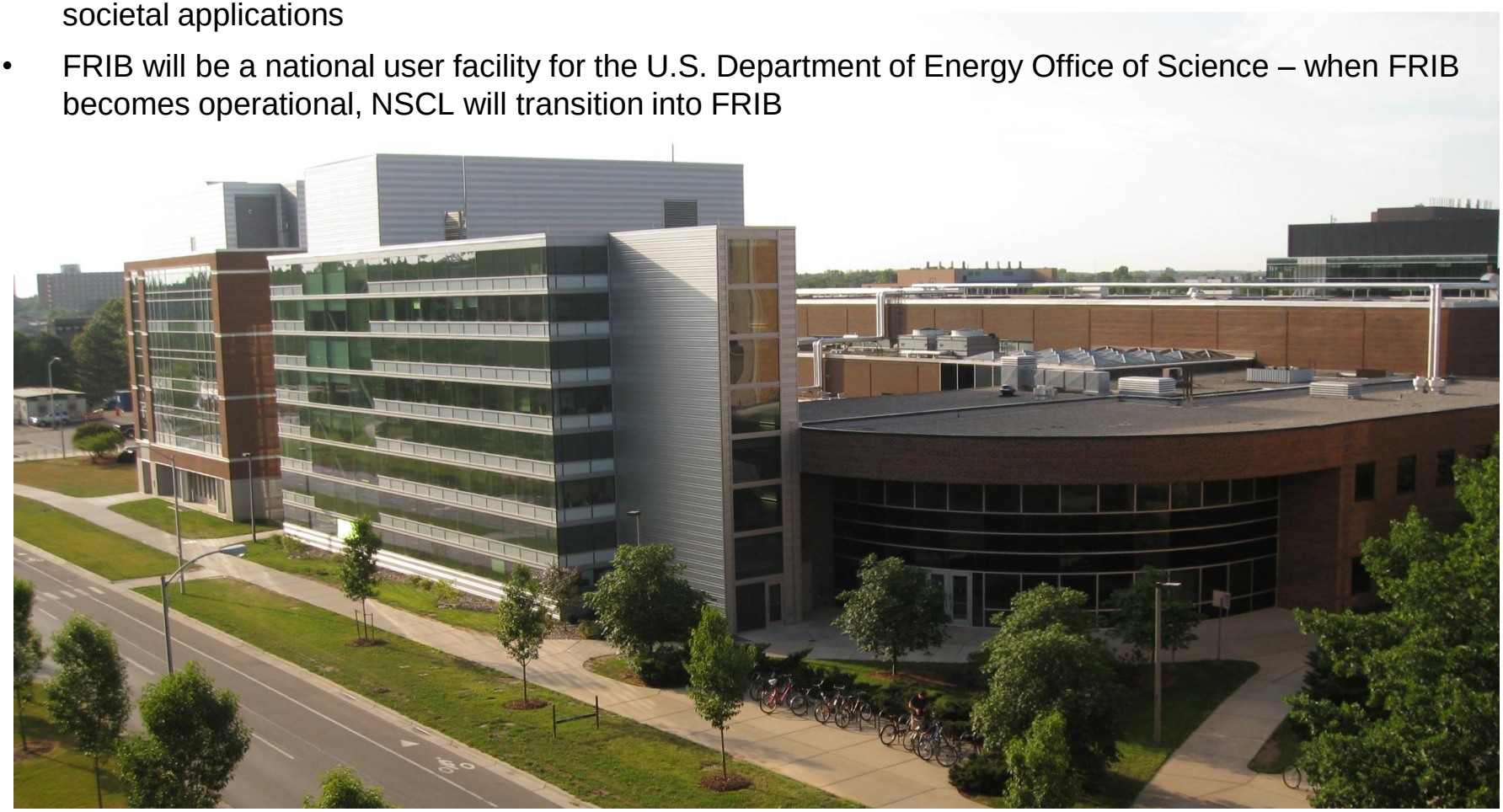
NDNCA workshop, May 26-29, 2015

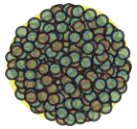
NSCL and FRIB Laboratory

- NSCL is funded by the U.S. National Science Foundation to operate a flagship user facility for rare isotope research and education in nuclear science, nuclear astrophysics, accelerator physics, and societal applications
- FRIB will be a national user facility for the U.S. Department of Energy Office of Science – when FRIB becomes operational, NSCL will transition into FRIB



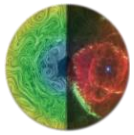
>500 employees, incl. 40 faculty, ~70 graduate and ~100 undergraduate students

Research Focus



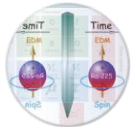
How does subatomic matter organize itself and what phenomena emerge?

- –At and Beyond the Nucleon Driplines
- –Shell evolution, Level Schemes & Collectivity
- –Nuclear Wave Functions through Direct Reactions
- –Reaction Dynamics & Nuclear Equation of State



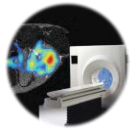
How did visible matter come into being and how does it evolve?

- –Origin of the Elements
- –Novae, Supernovae, X-ray bursts
- –Neutron Stars and Nuclear Equation of State



Are the fundamental interactions that are basic to the structure of matter fully understood?

- –CVC Hypothesis, Search for New Interactions & Couplings, EDM
- –Mass Measurements, IMME
- –Precise Measurements of Nuclear Radii & Moments



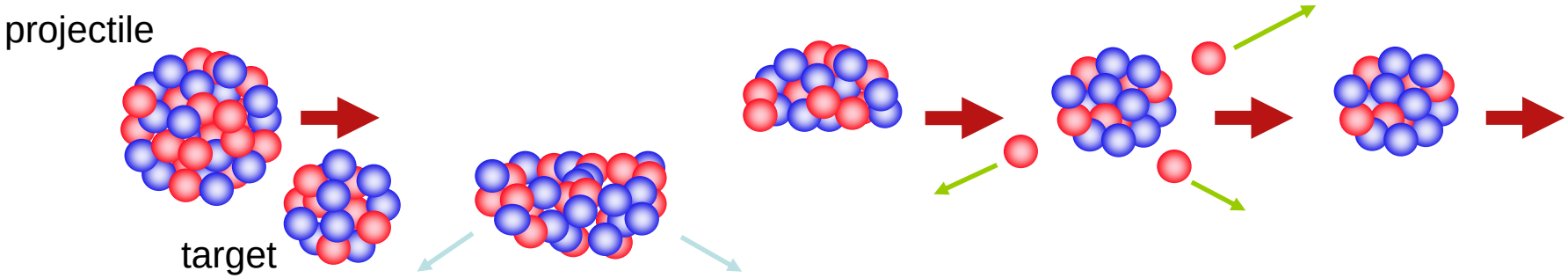
How can the knowledge and technological progress provided by nuclear physics best be used to benefit society?

- –Materials under extreme conditions
- –Detectors and Data for National Security
- –Isotope harvesting

Accelerator Physics

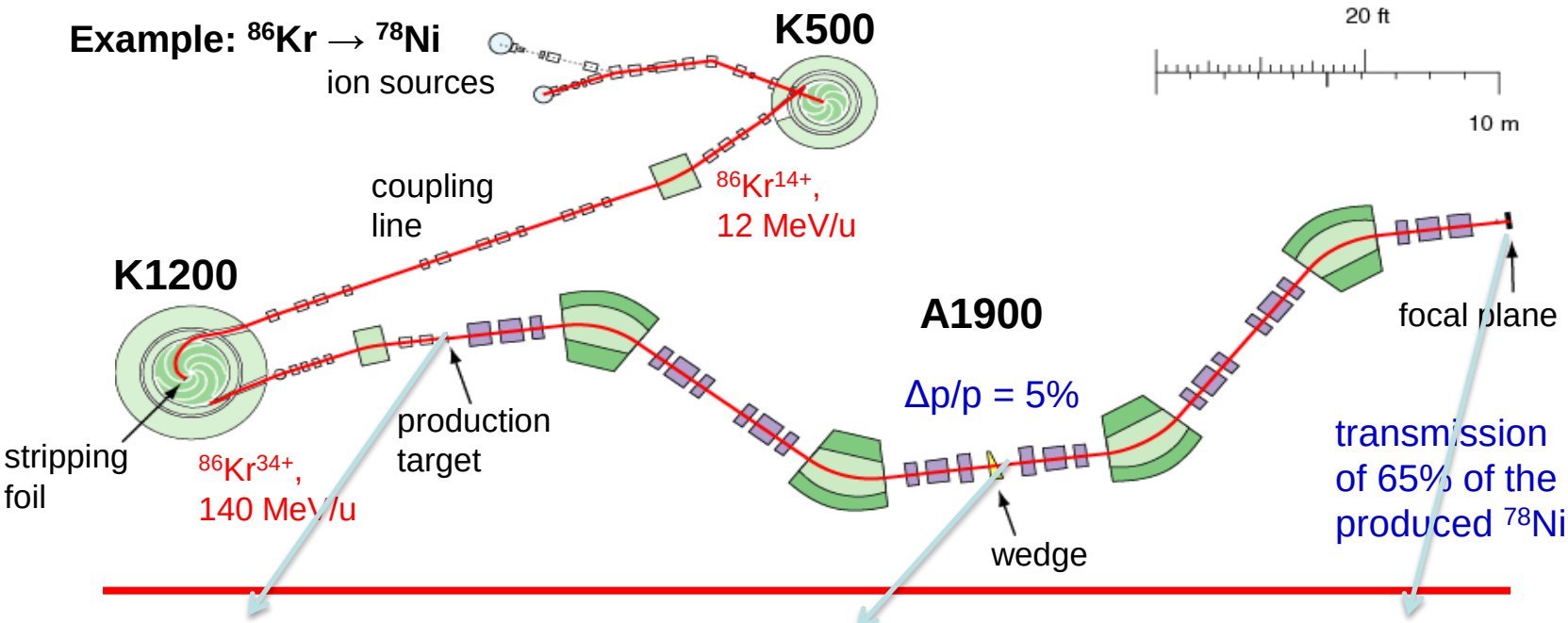
- – Accelerator Physics and Projects
- – Superconducting RF

Fragmentation

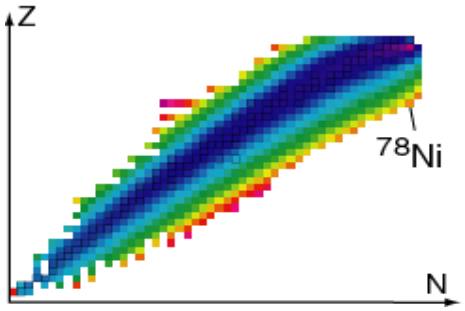


- Primary Beams include various isotopes of O, Ne, Mg, Ar, Ca, Ni, Ge, Se, Kr, Zr, Sn, Xe, Pb, Bi, U
- Primary beam energies vary between 45 MeV/nucleon (^{238}U) to 170 MeV/nucleon (^{20}Ne, ^{24}Mg)
- Intensities ranges between 0.1 pnA (^{238}U) to 175 pnA (^{16}O).
- http://www.nscl.msu.edu/users/beams.html
- Production target is typically Be.

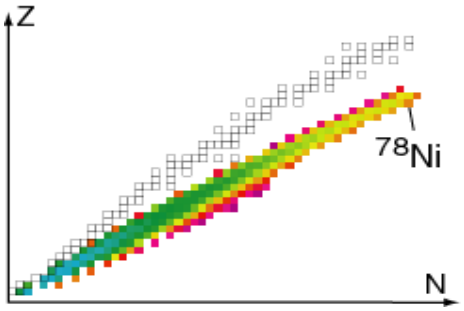
Isolating a Specific Fragmentation Product



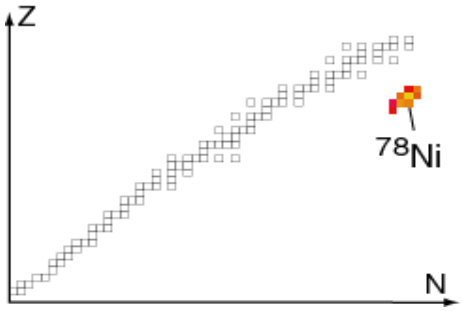
fragment yield after target



fragment yield after wedge

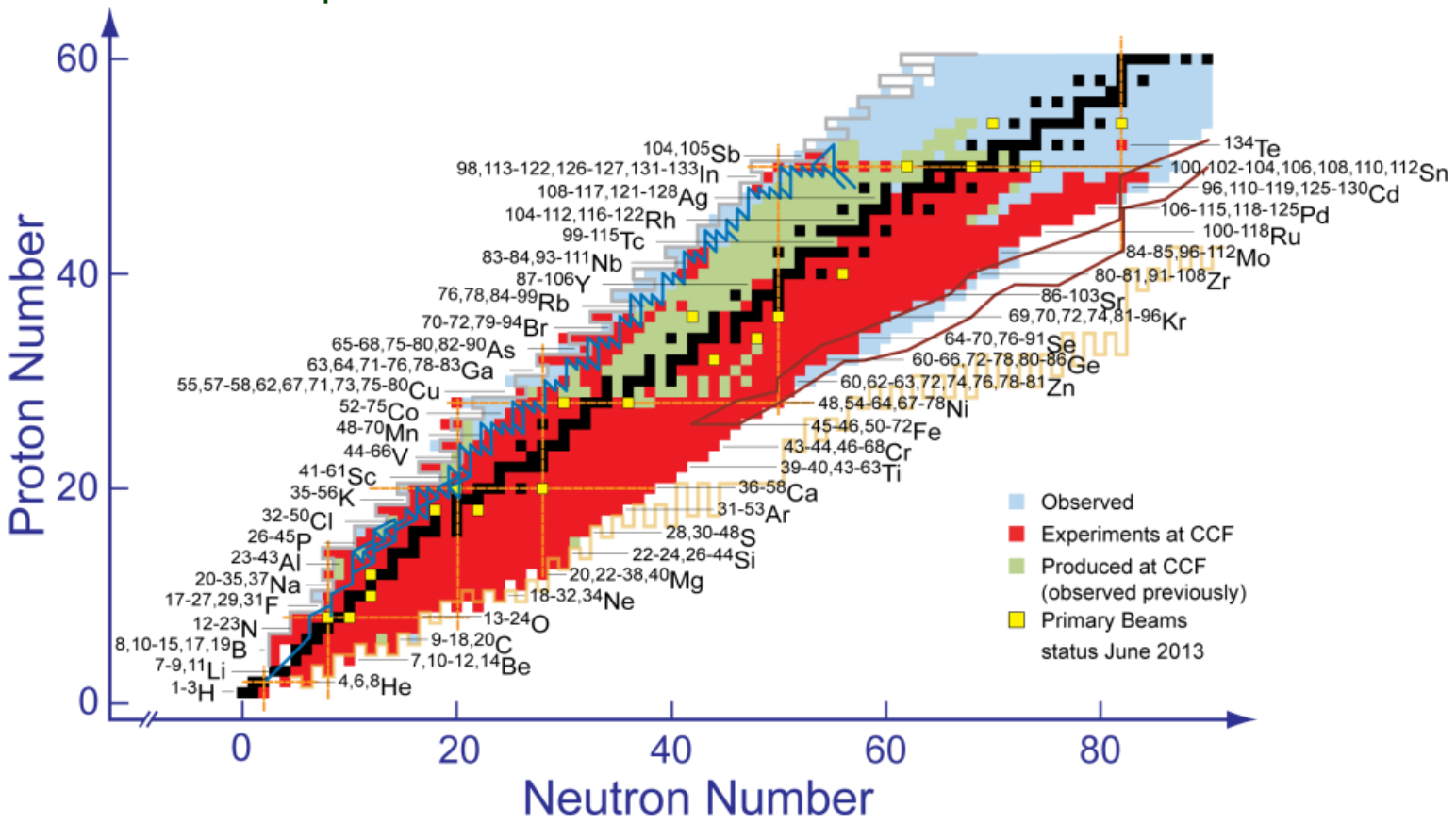


fragment yield at focal plane

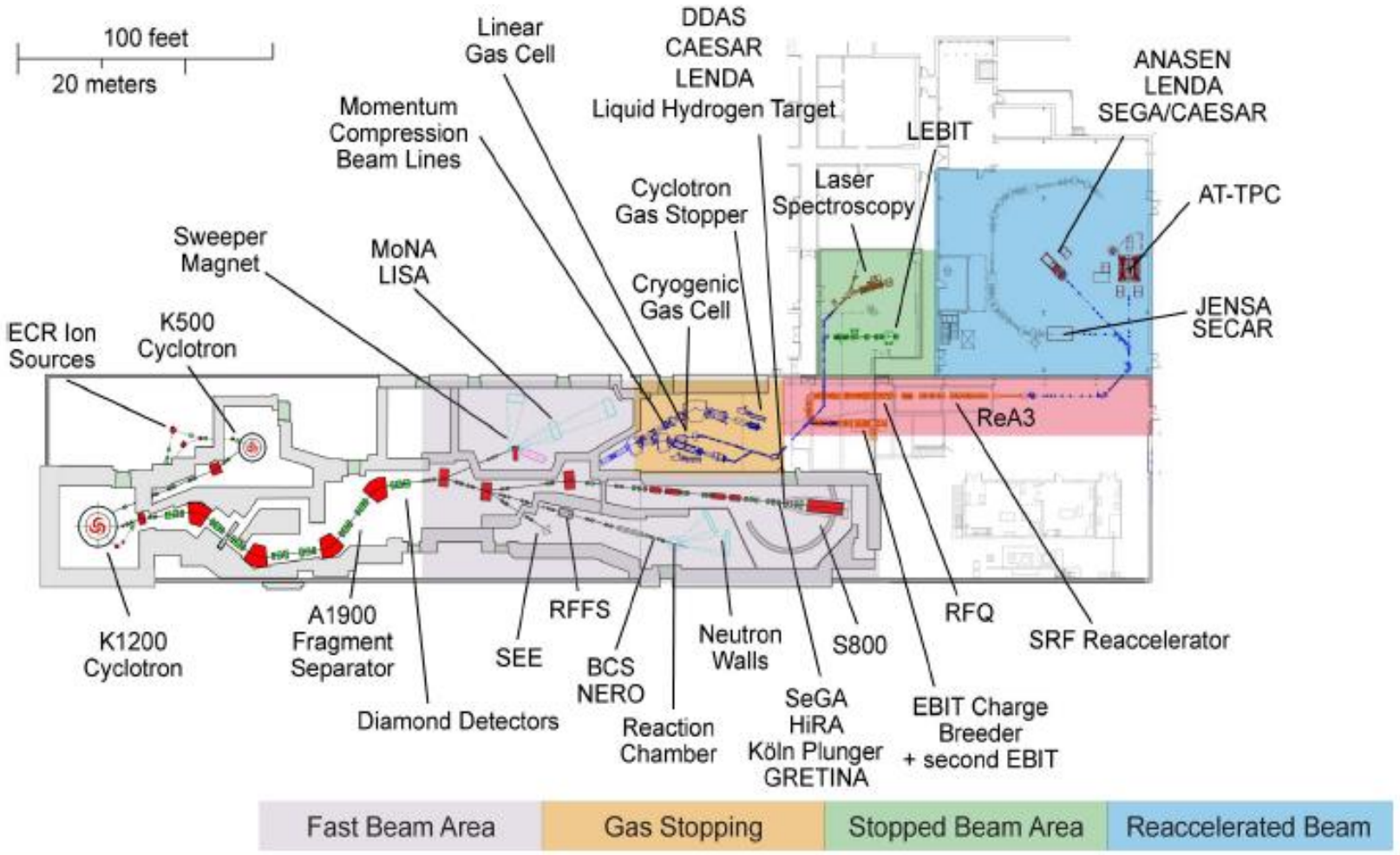


In-flight Separation Offers a Wide Variety of Rare Isotopes

- At the CCF more than 1000 RIBs have been produced and more than 870 RIBs have been used in experiments.
- LISE for beam rate predictions.



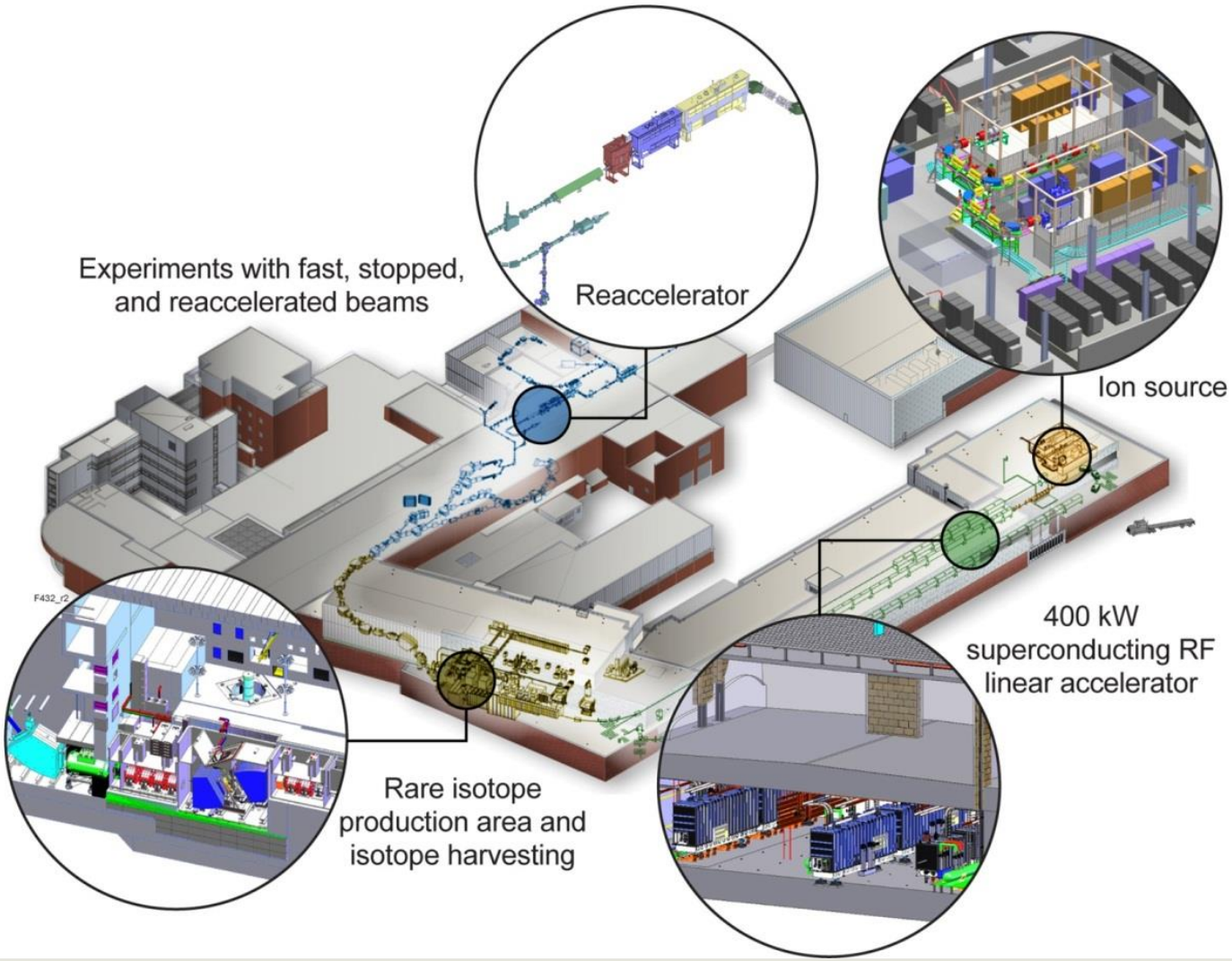
Fast, Stopped, And Reaccelerated Beams of Rare Isotopes



Beamtime Allocation through PAC

- Spokesperson (or designated back-up) is official point of contact
  - Certifies that all collaborators agreed to be part of proposal team
  - Responsible for experiment and dissemination of information to collaboration
- All proposals are confidential until approved
- Each proposal is screened by NSCL staff for technical and safety issues
  - Comments are communicated to spokesperson for optional response
  - Comments and response are forwarded to reviewers
- Each submitted proposal is assigned a principal and back-up reviewer
  - Spokesperson and reviewers are encouraged to talk to clarify questions that may arise prior to (or during) PAC meeting
  - No oral presentations
- Director normally accepts PAC recommendation and transmits written PAC statement with note of concurrence to spokesperson
  - PAC approval is valid for 2 (+1) years

Facility for Rare Isotope Beams, FRIB

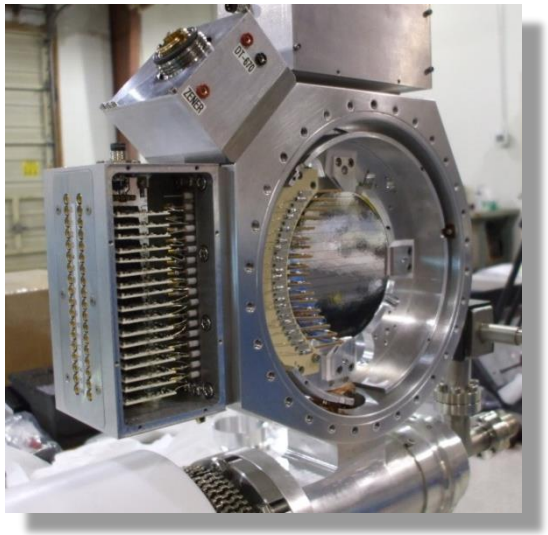


FRIB now

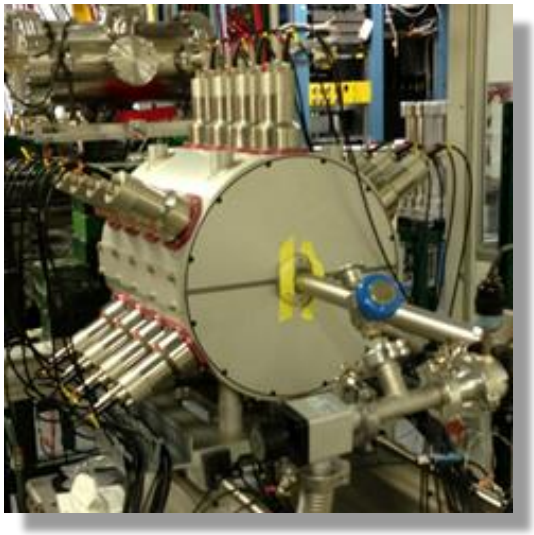
FRIB construction site on 27 May, 2015 - web camera at www.frib.msu.edu

Two Examples of NSCL capabilities

- Beta-decay:
  - Measure half-lives, delayed neutron branching ratios, low-energy excited states.
  - Possible extensions to masses and average electron energies.

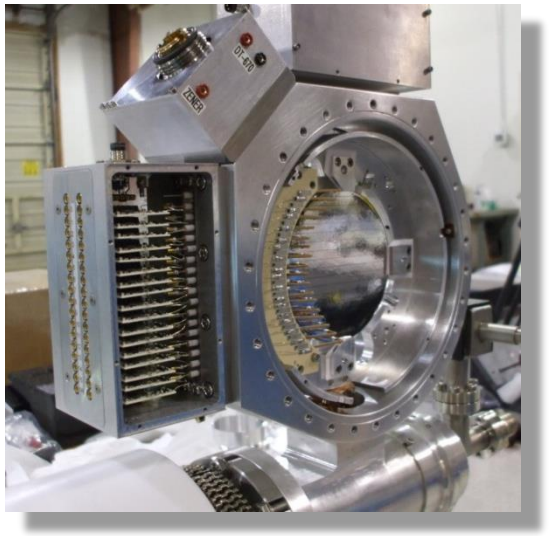


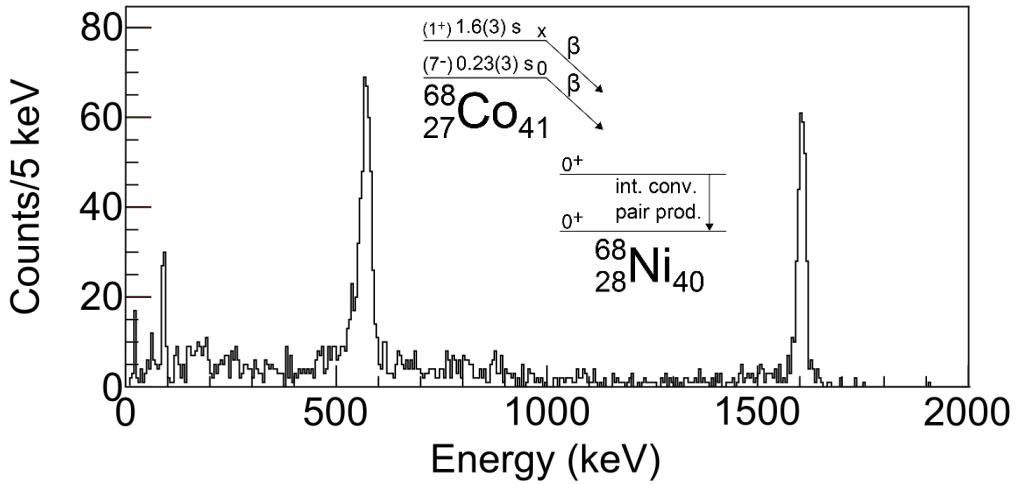
- Neutron capture:
  - Infer neutron capture rates of short-lived isotopes from beta decay
  - Use total absorption spectroscopy to measure gamma-ray cascades.



Beta-Decay Spectroscopy

- Half-life
  - Measure arrival time and position of ions correlate to subsequent beta decay.
- Beta-delay neutron branching ratios
  - Measure delayed neutrons in coincidence with beta-decay electron.
  - Ion-by-ion counting of total number of parent nuclei.
- Unique decay modes
  - Electron conversion of isomeric states

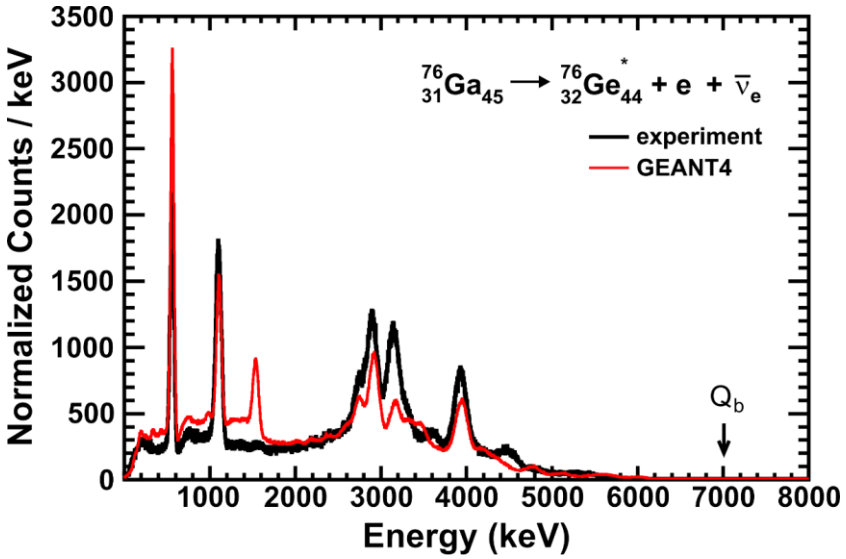


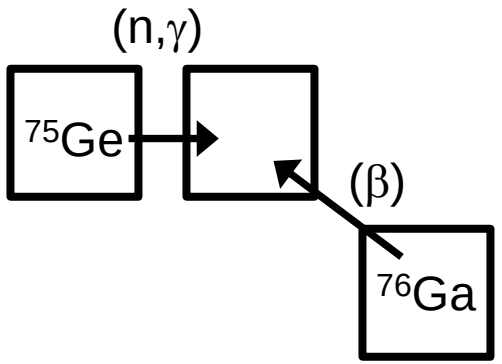


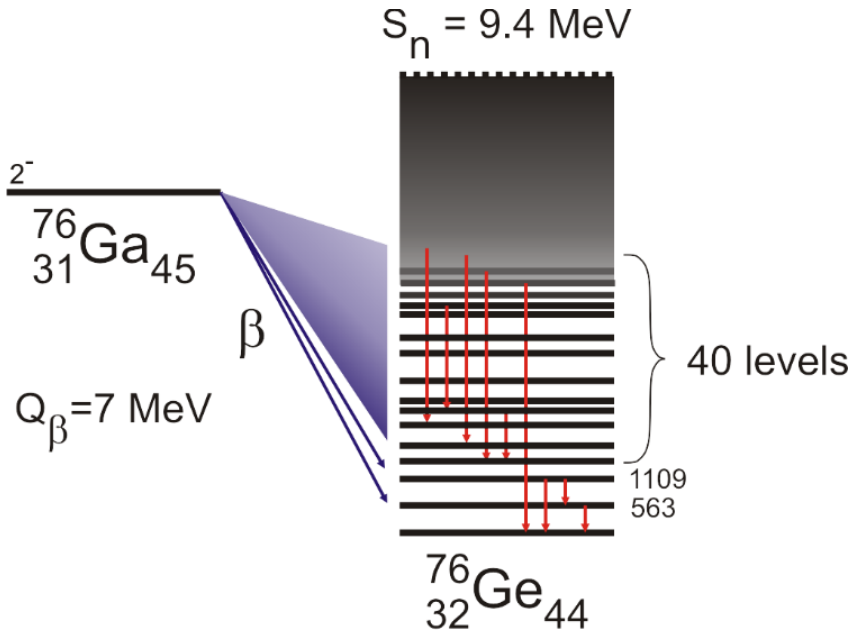
S. Suchyta *et al.*, PRC, **89**, 021301(R) (2014)

TAGS: ^{76}Ga

- Applied technique to beta decay of ^{76}Ga.
- Infer neutron capture cross section of ^{75}Ge.
  - Determine level densities and gamma-ray strength functions

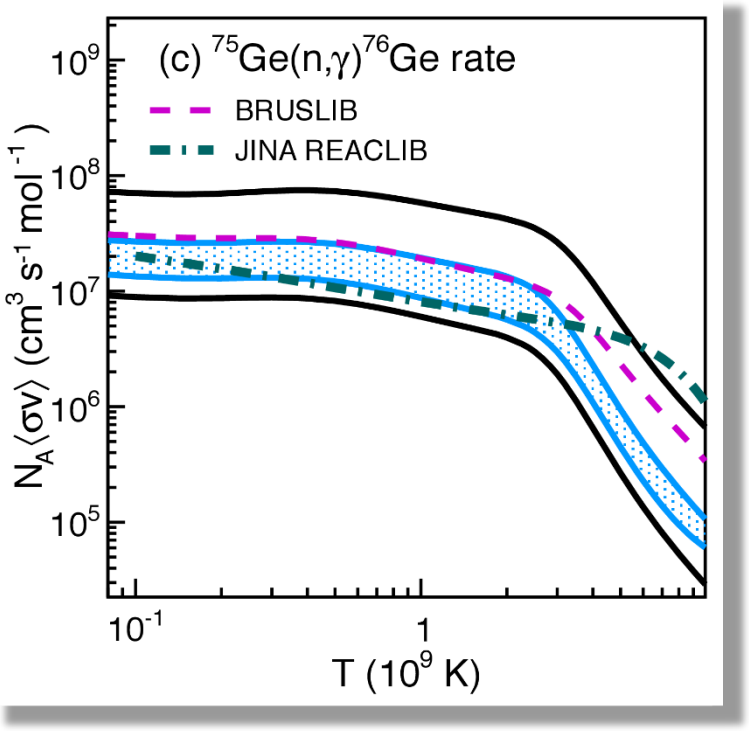




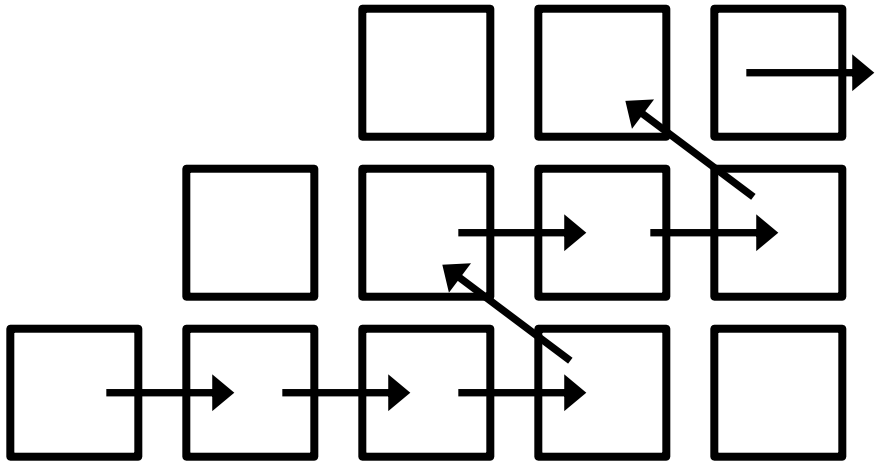


$^{75}Ge(n,\gamma)$

- Infer neutron capture cross section of ^{75}Ge.

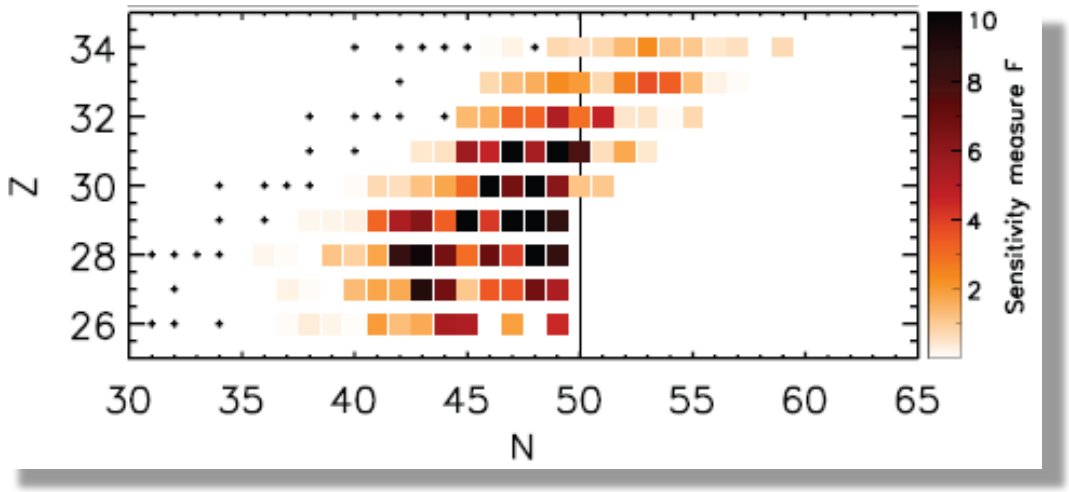


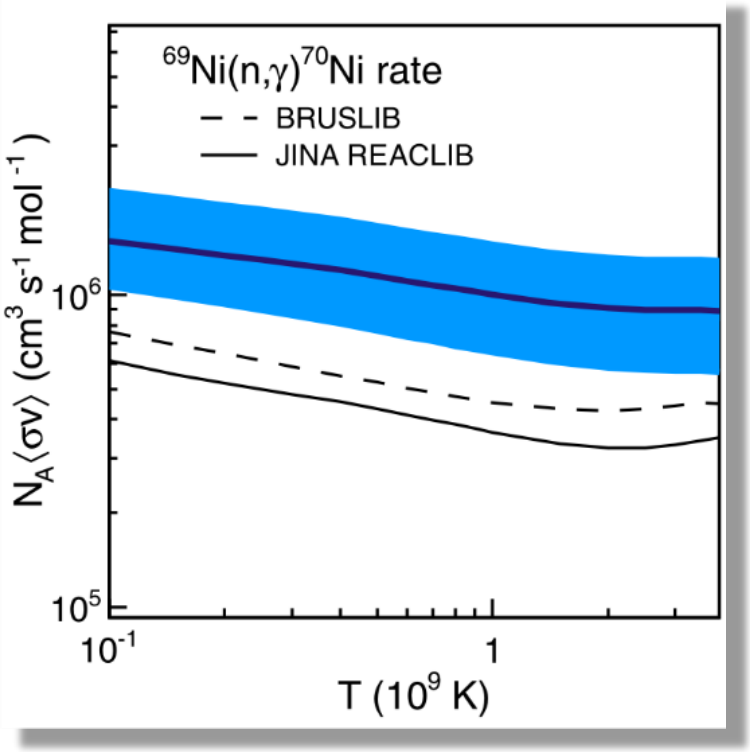
Astrophysics: r-process



Schematic r-process

- Neutron capture rates influence r-process abundances.
- Theoretical models can vary by orders of magnitude.





R. Surman *et al.*, AIP Advances, **4**, 041008 (2014)

Conclusions

- Broad science program at NSCL
  - Physics of atomic nuclei
  - Nuclear astrophysics
  - Fundamental symmetries
  - Applications
- Wide range of experiment equipment to carry out science program.
- Unique combination of a large range of isotopes available over fast, thermal, and reaccelerated energies coupled with state-of-art equipment.
- Two examples demonstrating capabilities for decay spectroscopy.
  - Half-lives, delayed neutron-branching ratios, electron conversion, neutron capture