Rare Isotope Beams in the Americas - Present and Next Generation Facilities

Georg Bollen

Michigan State University

Facility for Rare Isotope Beams

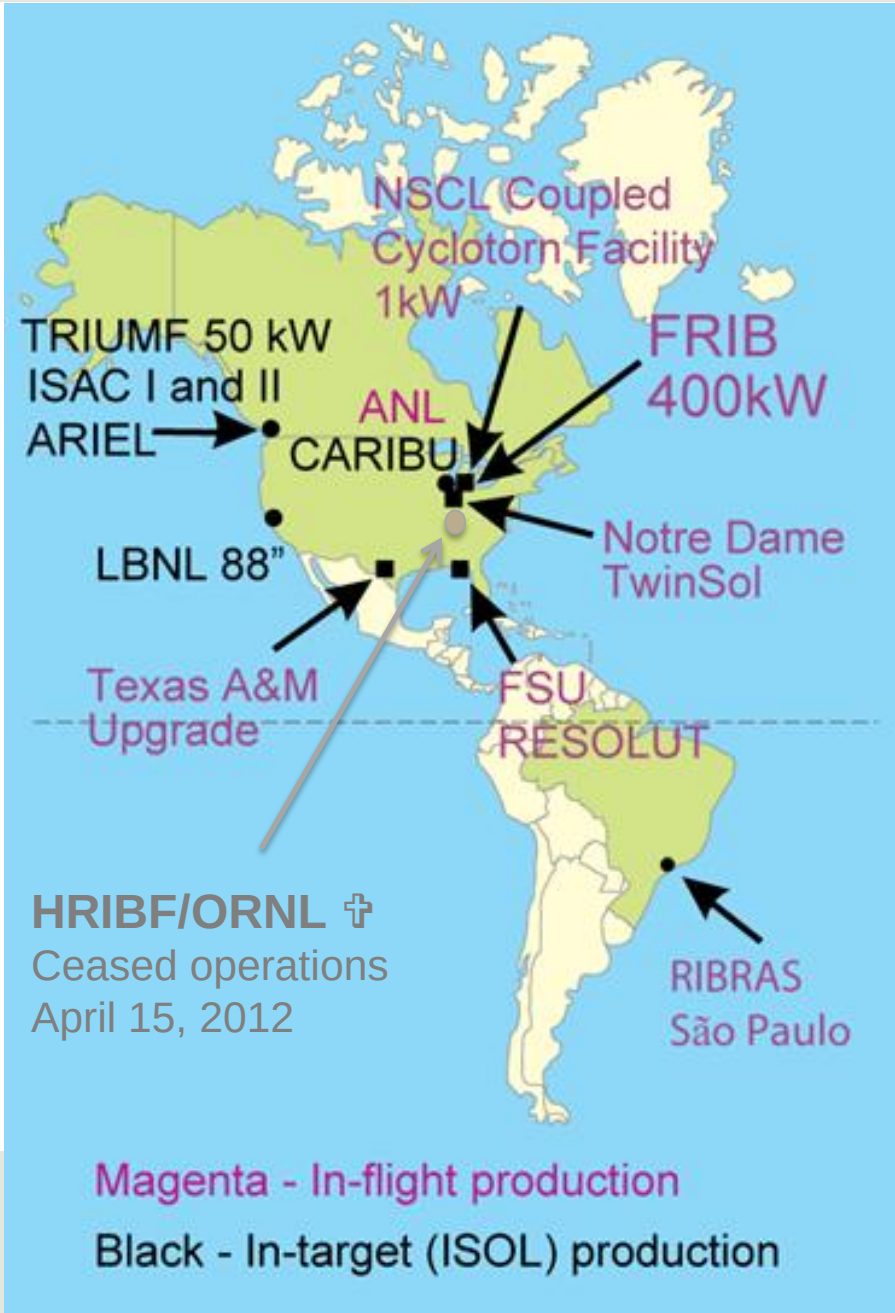
MICHIGAN STATE UNIVERSITY

FRIB

Rare Isotope Beams in the Americas
Present and Next Generation Facilities

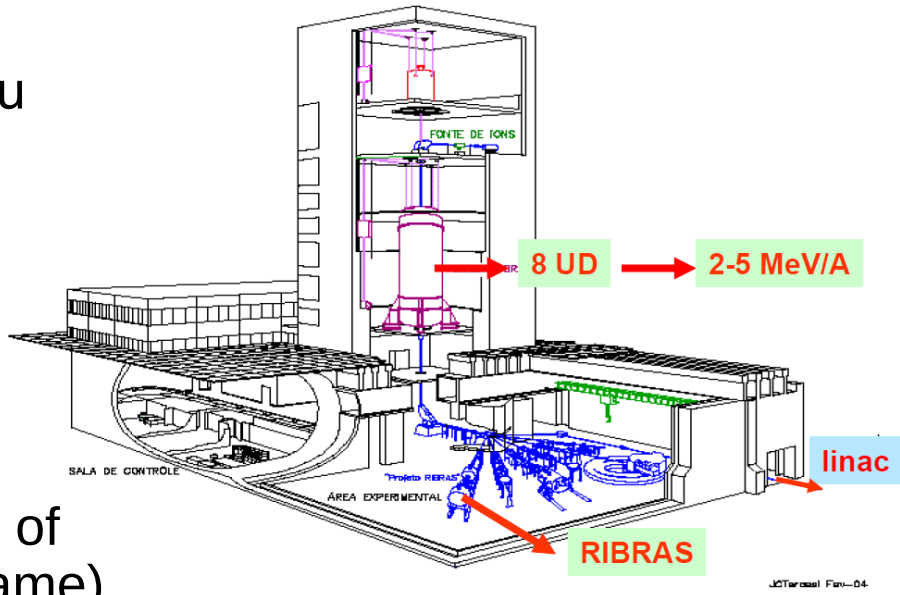
Outline

- University based facilities, local user facilities
- Major national user facilities
- Next generation facilities under construction
- Summary



RIBRAS at São Paulo Nuclear Physics Open Laboratory

- 8 UD tandem Pelletron accelerator
  - Continuous beams: p, d, Li, C, O, Si, …, Cu
  - Energies 2-5 MeV/A
- Under installation
  - 10 MeV/A superconducting LINAC
  - Will make RIBRAS unique
- RIBRAS Rare Isotope Beam Production
  - Dual-solenoid for production and separation of rare isotopes (similar to TwinSol at Notre Dame)
  - Seconday beams ^{8}Li, ^{6}He, ^{7}Be, ^{8}B, ^{10}B, … with rates of 10^{4}-10^{6} /s
- Experimental Program
  - Elastic scattering and transfer reactions, for example ^{6}He on ^{9}Be, ^{27}Al, ^{51}V and ^{120}Sn targets
- International user group



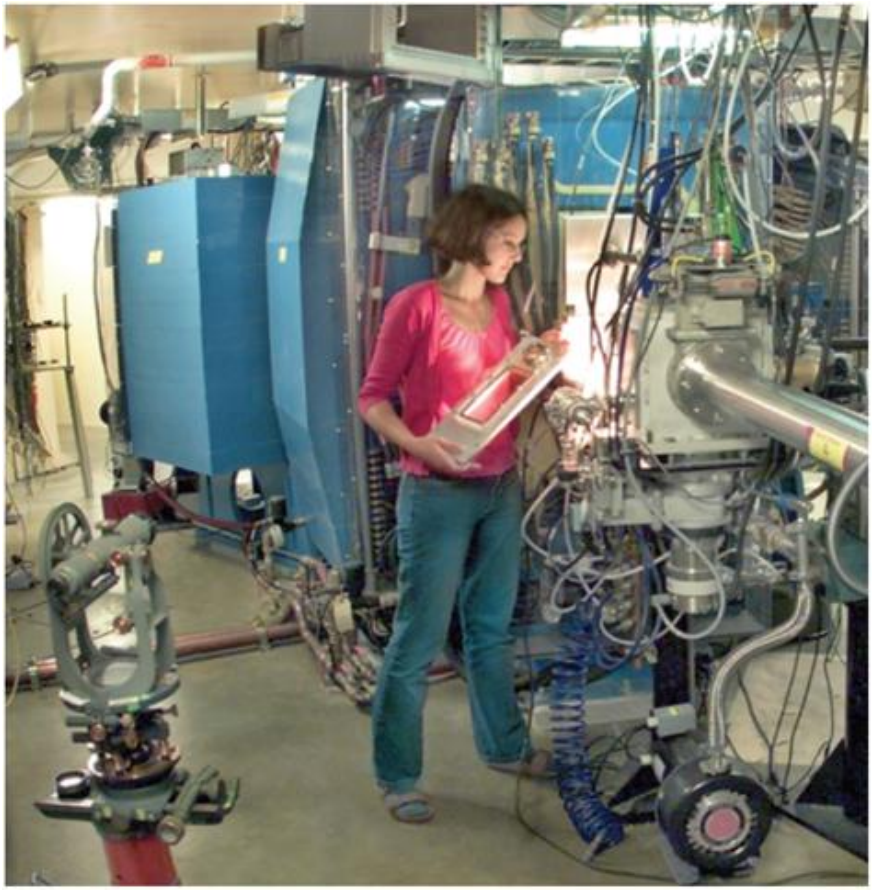
LBNL 88” Cyclotron

- Nuclear structure, astrophysics, heavy element studies, fundamental interactions, symmetries, and technology R&D

- **Berkeley Gas-filled Separator (BGS)**
  - » Workhorse for superheavy element synthesis and study
  - » Upgrade underway for direct mass number measurement for SHE
    - *Confirmation of present assignments.*
    - *Gas catcher after BGS combined with mass separator+ low-background counting station*

- Next-generation Gamma Ray Energy Tracking Array (GRETINA)
  - » Used for transactinide studies after BGS
  - » Now experiment campaign at NSCL
  - » Next - ATLAS

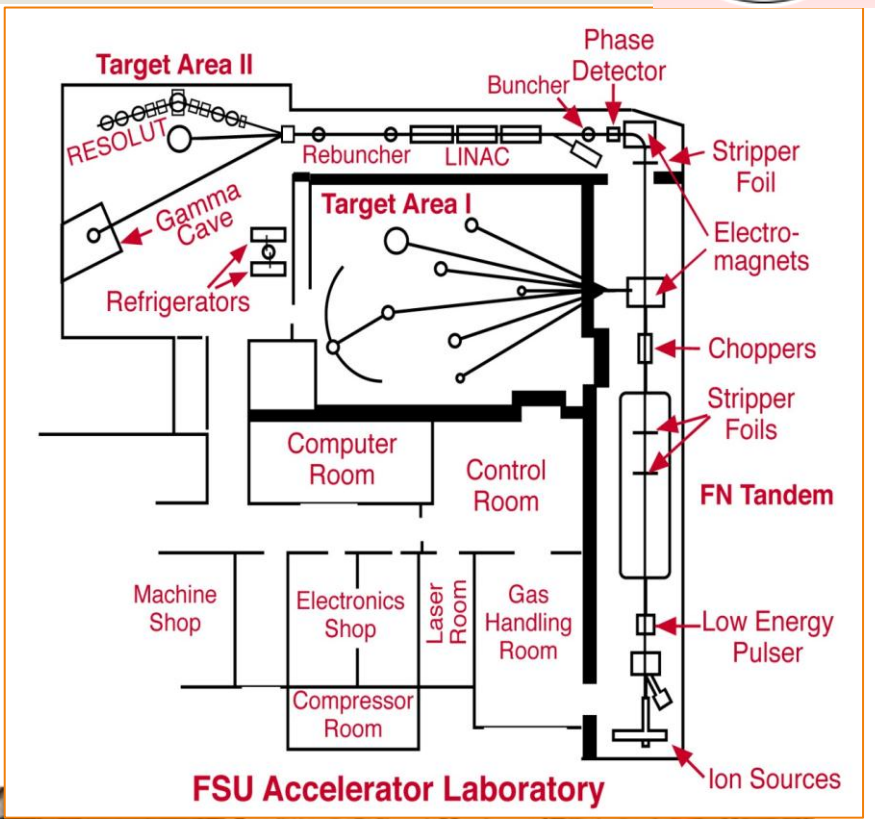
I.-Y. Lee

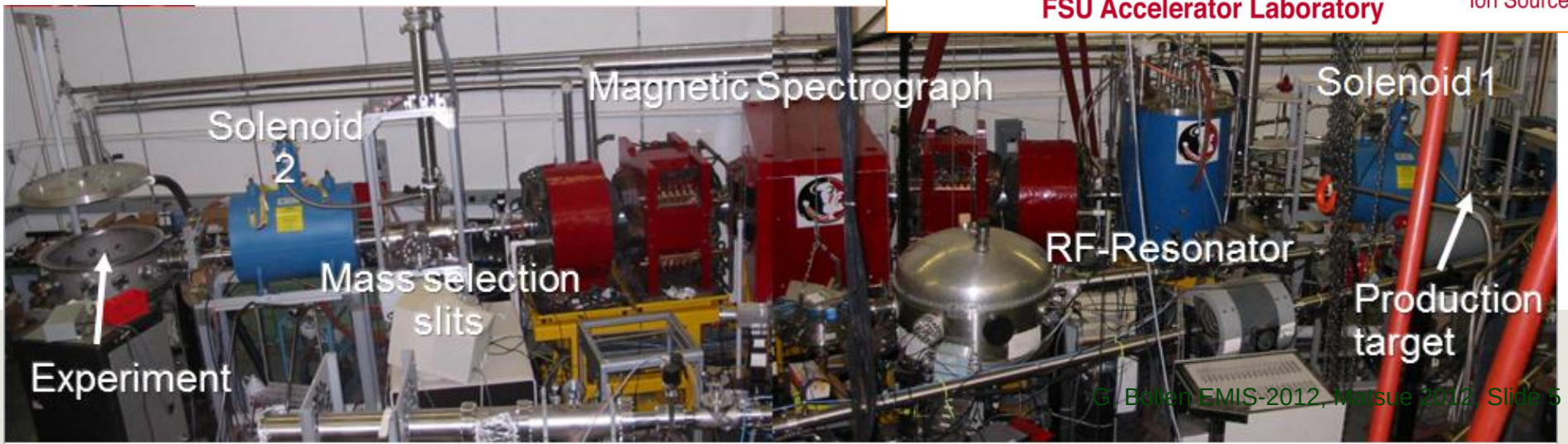


- VENUS
  - » 3rd generation ECR ion source as needed for FRIB

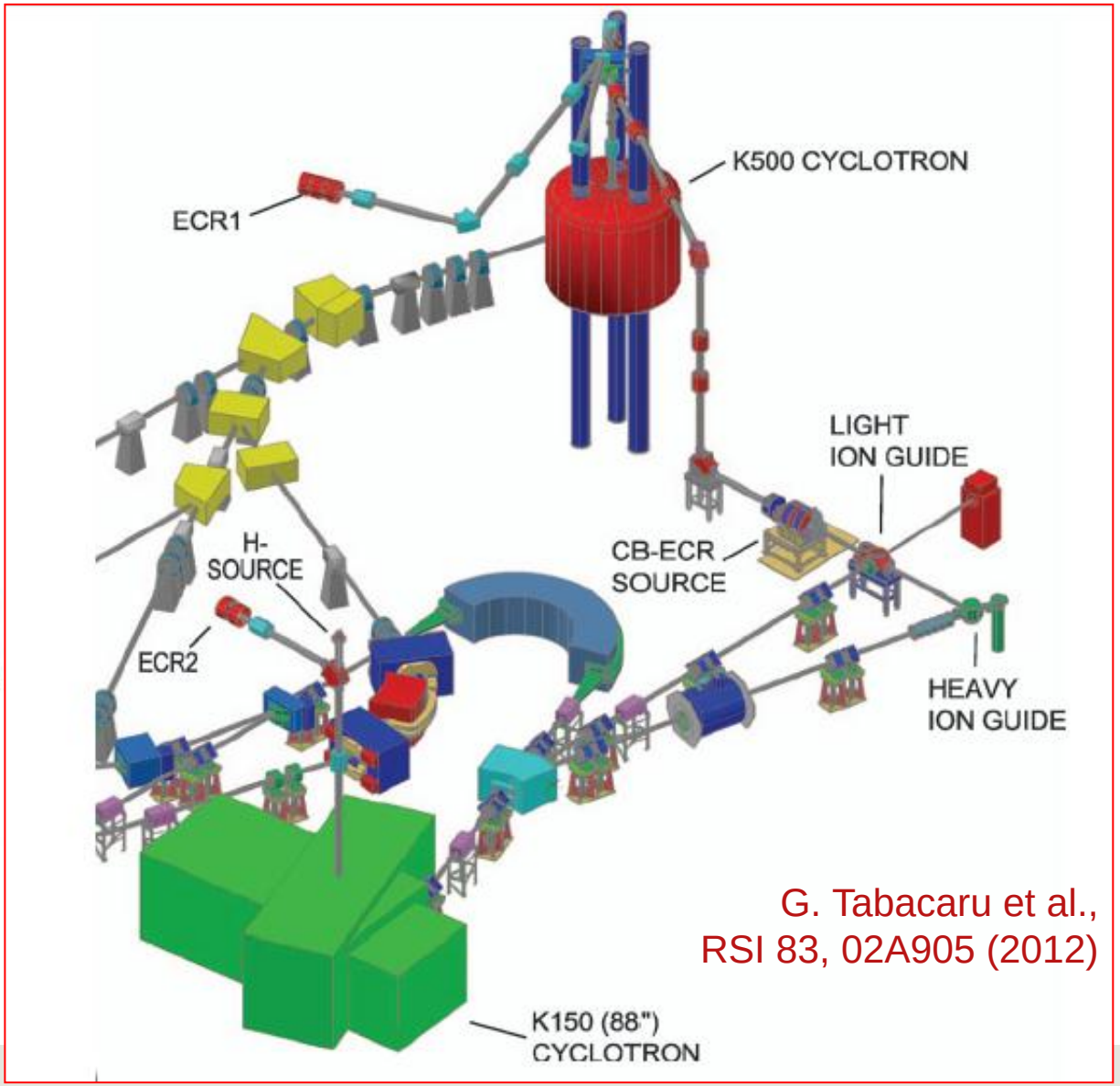
RESOLUT at the John D. Fox Accelerator Laboratory at FSU

- 8.5 MV Tandem + 8 MV Linac
  - ^{1}H 17 MeV/u ... ^{40}Ca: 5 MeV/u
- **RESOLUT** In-flight Radioactive Beam Facility
  - SC RF-Resonator combined with high acceptance magnetic spectrograph
  - Mass 6-30, 1-2 nucleons off stability
- Nuclear Structure, Nuclear Astrophysics with high-resolution γ-spectroscopy, reaction studies
- **ANASEN** – Active Target Detector System developed in collaboration with LSU
  - First experiments performed
  - Also planned to be used at ReA at NSCL





T-REX (TAMU Reaccelerated Exotics) at Texas A&M University Cyclotron Facility



G. Tabacaru et al.,
RSI 83, 02A905 (2012)

Upgrade

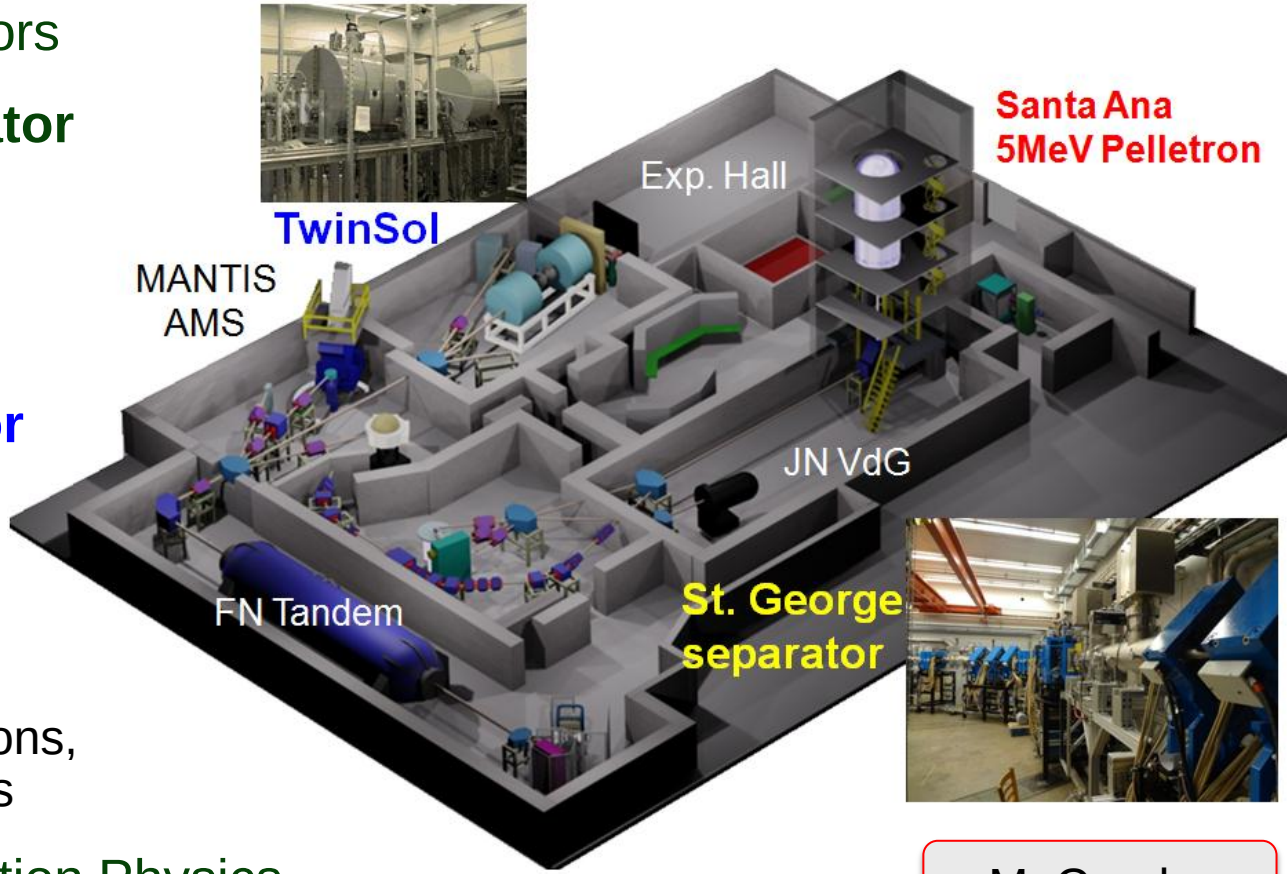
- K150 cyclotron as driver for production of radioactive species
  - high intensity stable isotope beams
- K500 cyclotron as post-accelerator
- Light-ion guide and heavy-ion guide
- ECR charge booster

New Experimental Developments

- Penning Trap for decay studies
- Heavy Element Chemistry in a gas catcher

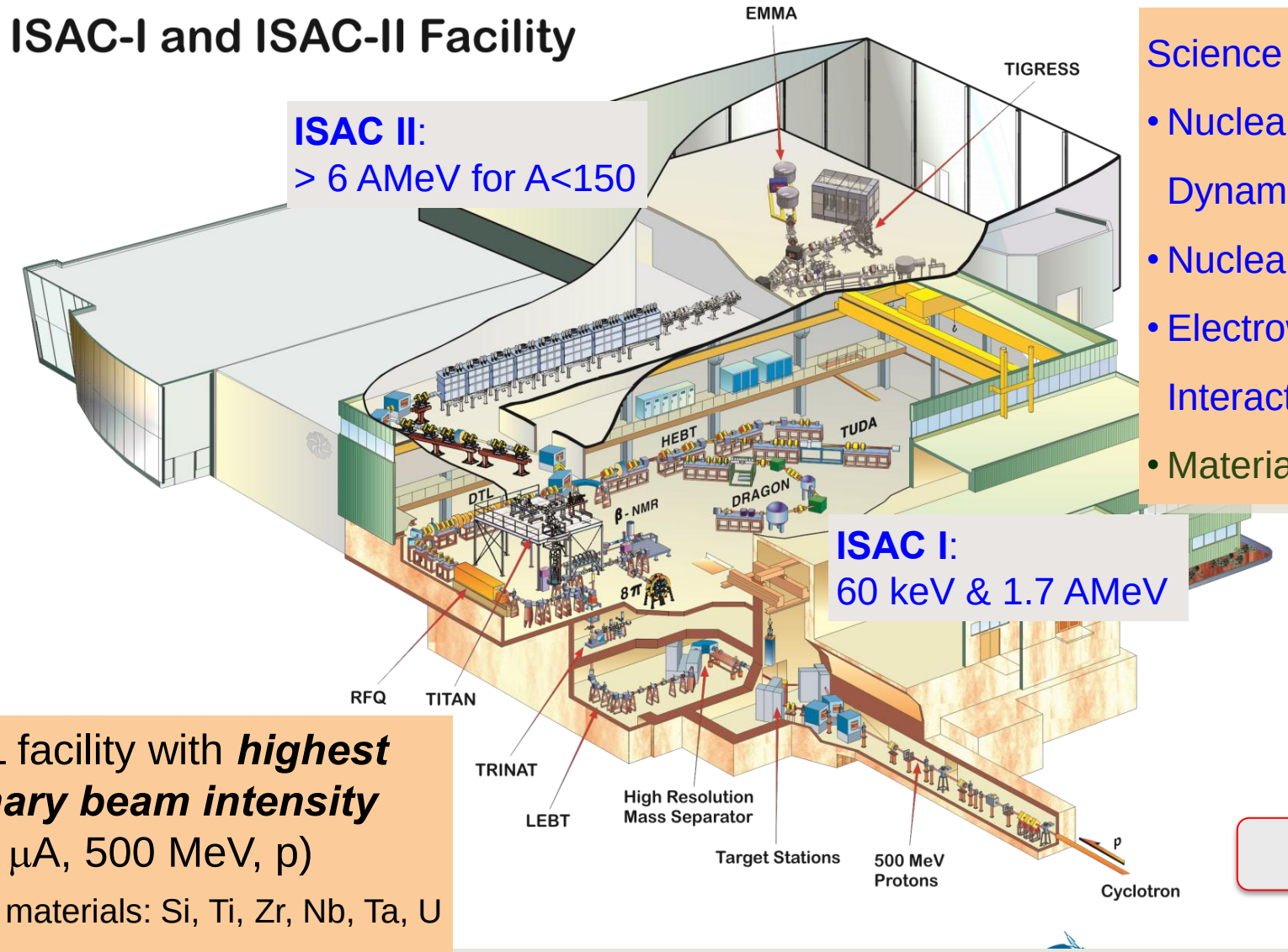
Nuclear Science Laboratory NSL at Notre Dame University

- 10MV FN Pelletron tandem and 1MV JN VdG accelerators
- **5 MV HI Pelletron accelerator (being installed)**
- **TWINSOL rare isotope beam facility**
- **St. George recoil separator**
  - Basis for SECAR design for ReA at NSCL/FRIB
- Nuclear Astrophysics
  - reactions for stellar burning, nova and X-ray burst explosions, neutron sources for s-process
- Nuclear Structure and Reaction Physics
  - Halo studies on light systems, lifetime measurements, nuclear structure near particle thresholds



M. Couder

ISAC Rare Isotope Beam Facility at TRIUMF



ISAC II:
> 6 AMeV for A<150

ISAC I:
60 keV & 1.7 AMeV

Science Programs

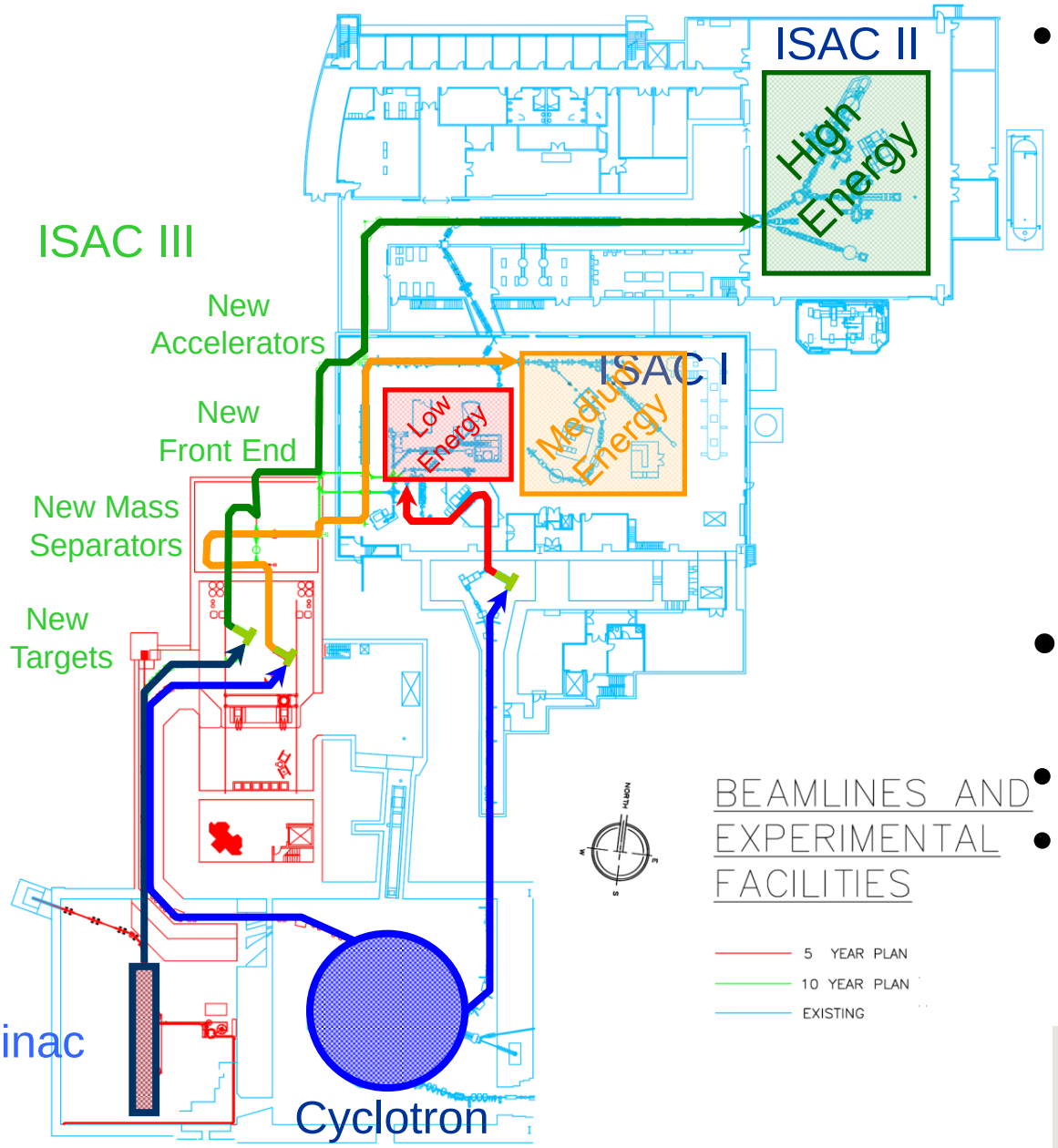
- Nuclear Structure & Dynamics
- Nuclear Astrophysics
- Electroweak Interaction Studies
- Material Science

ISOL facility with ***highest primary beam intensity*** (100 μA, 500 MeV, p)

target materials: Si, Ti, Zr, Nb, Ta, U

J. Lassen

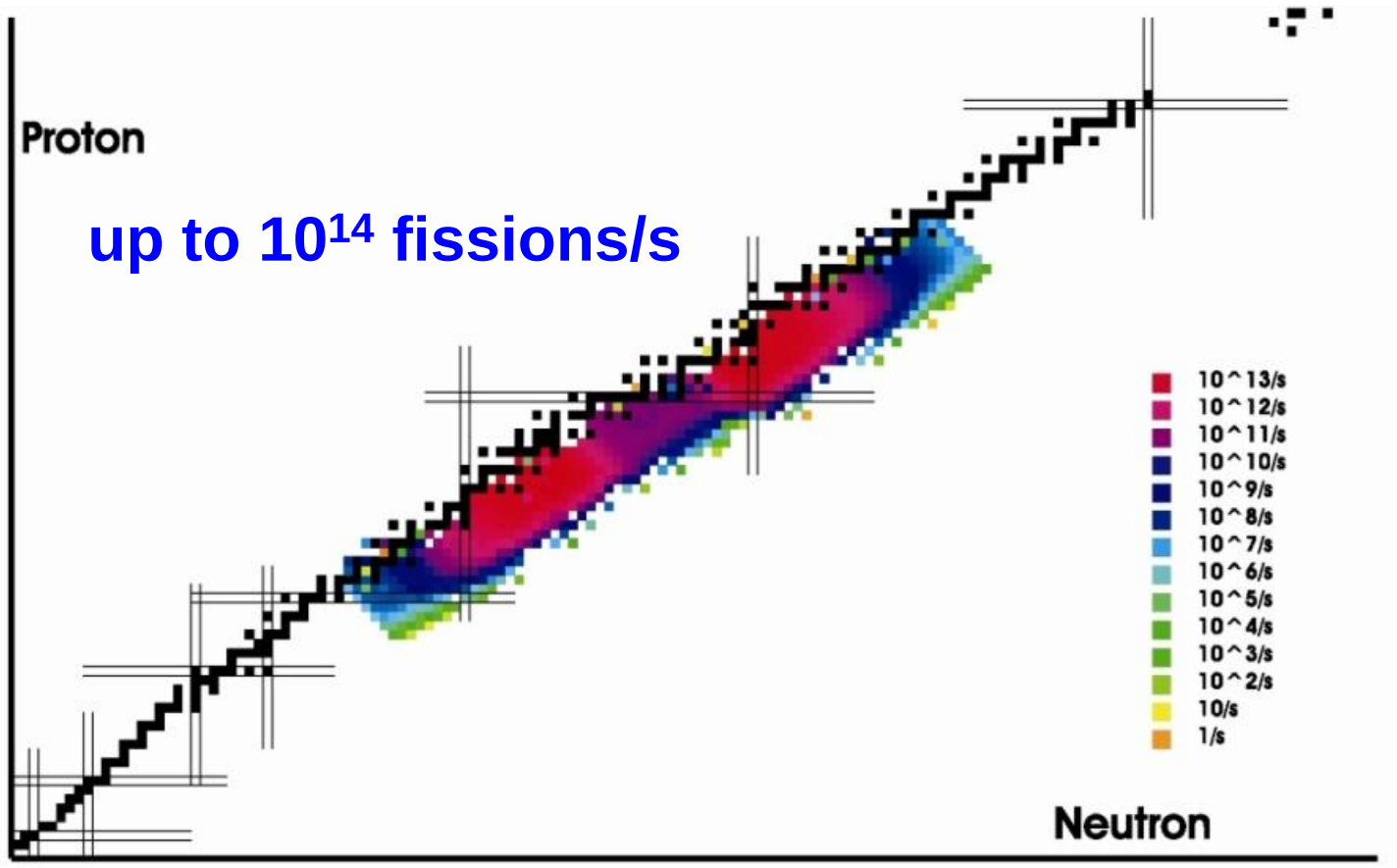
Advanced Rare Isotope Laboratory (ARIEL)



- New complementary **e-driver for photo-fission** to substantially expand the rare isotope beam program with:
  - 3simultaneous beams (more beam hours)
  - new beam species
  - increased beam development capabilities
- 50 MeV / 10 mA e-beam superconducting linac
- New proton beamline
- New target stations and front end

ARIEL Fission Yields

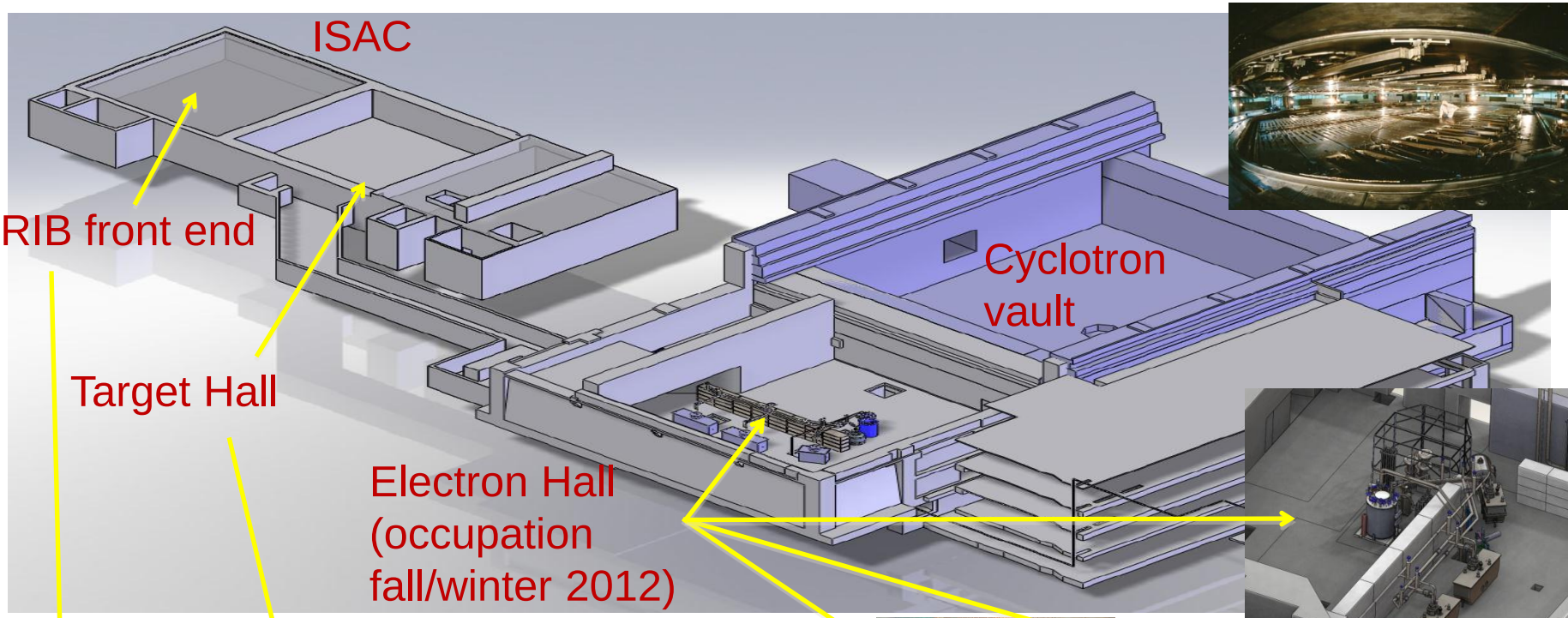
50 MeV 10 mA electrons onto converter & UC_x target.



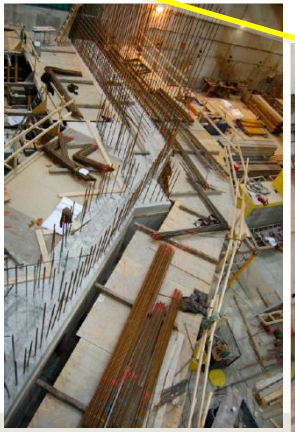
Target and ion source development needed to leverage the high fission yields

J. Lassen

ARIEL construction underway



tunnel breakthrough



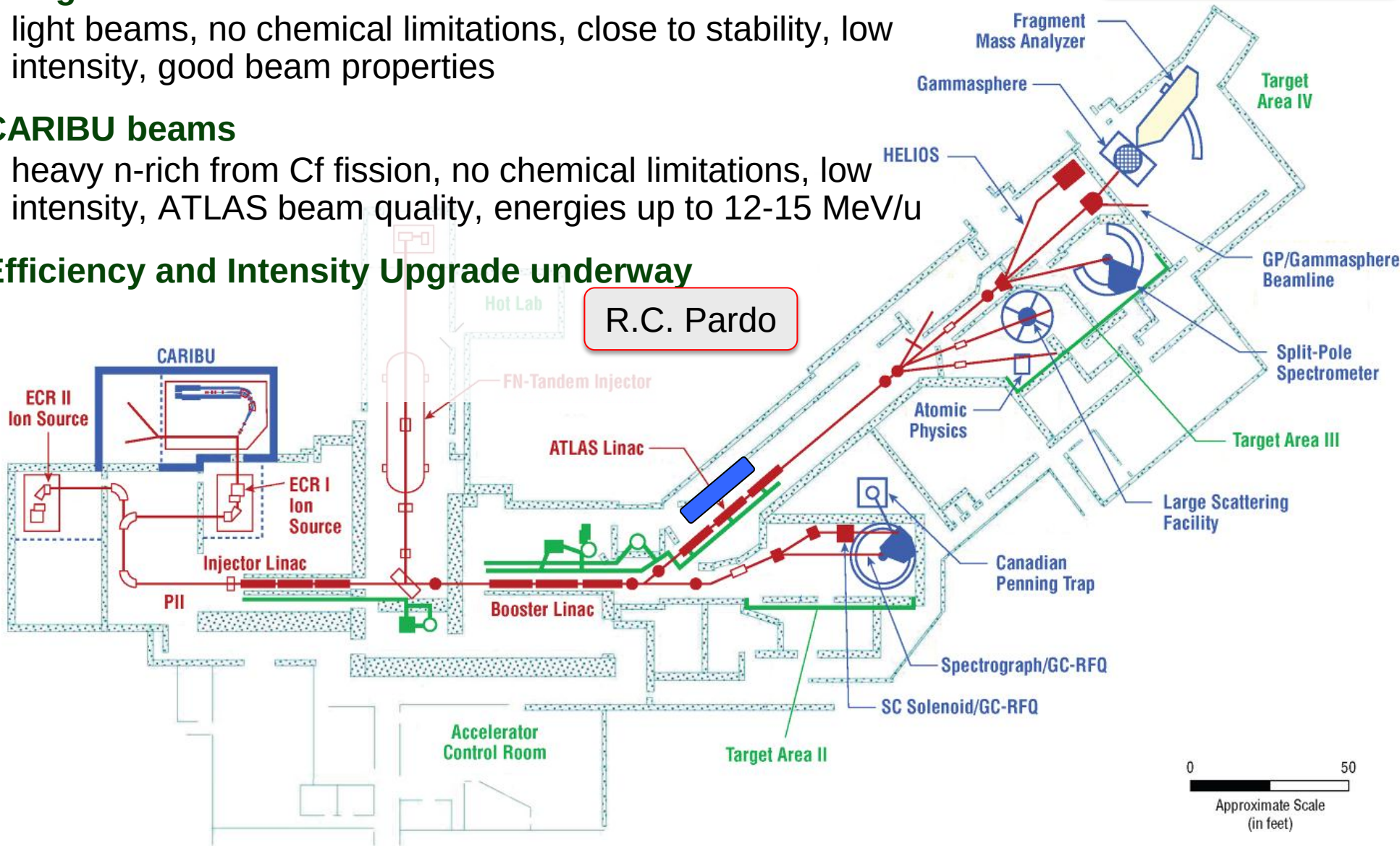
(occupation spring 2013)

ATLAS Facility at Argonne National Laboratory

- Stable beams at medium intensity and energy up to 10-20 MeV/u
- **In-flight radioactive beams**
  - light beams, no chemical limitations, close to stability, low intensity, good beam properties
- **CARIBU beams**
  - heavy n-rich from Cf fission, no chemical limitations, low intensity, ATLAS beam quality, energies up to 12-15 MeV/u
- **Efficiency and Intensity Upgrade underway**

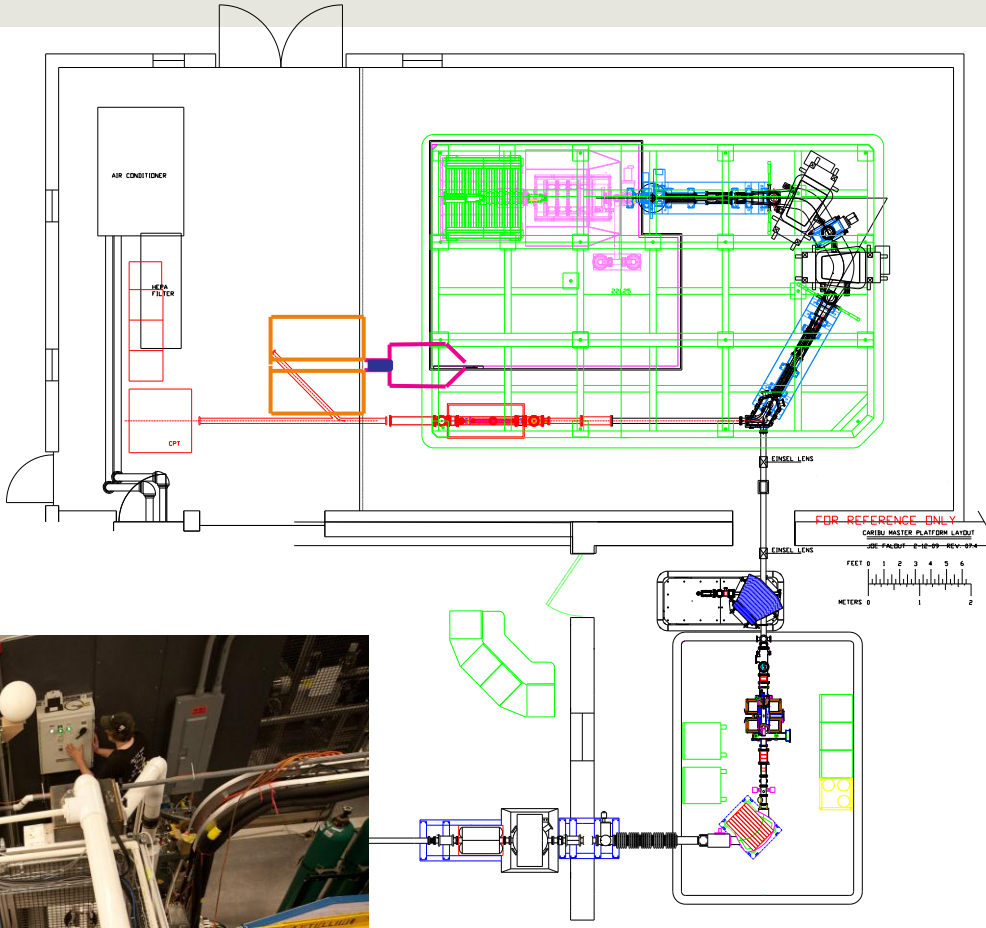
D. Seweryniak

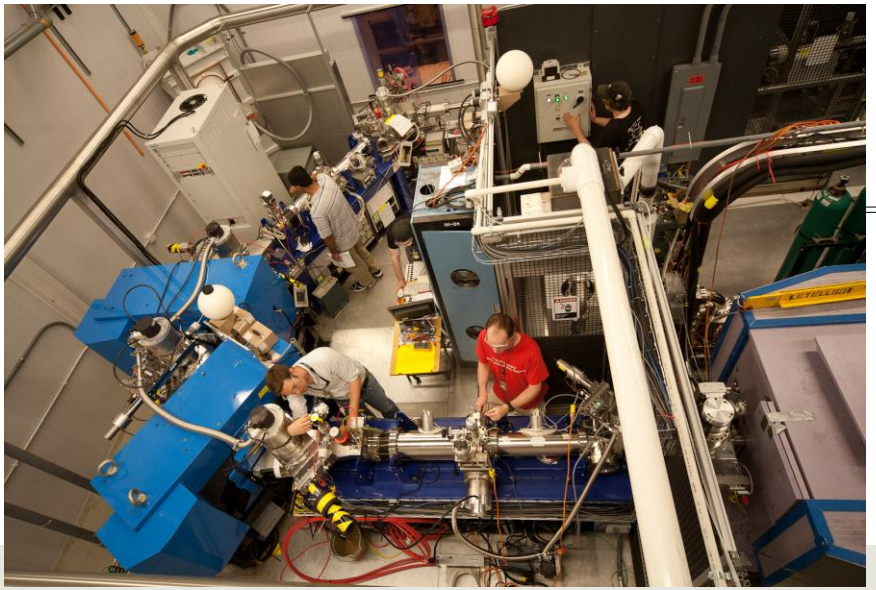
R.C. Pardo



CARIBU – Californium Rare Ion Breeder Upgrade
Neutron-rich beam source

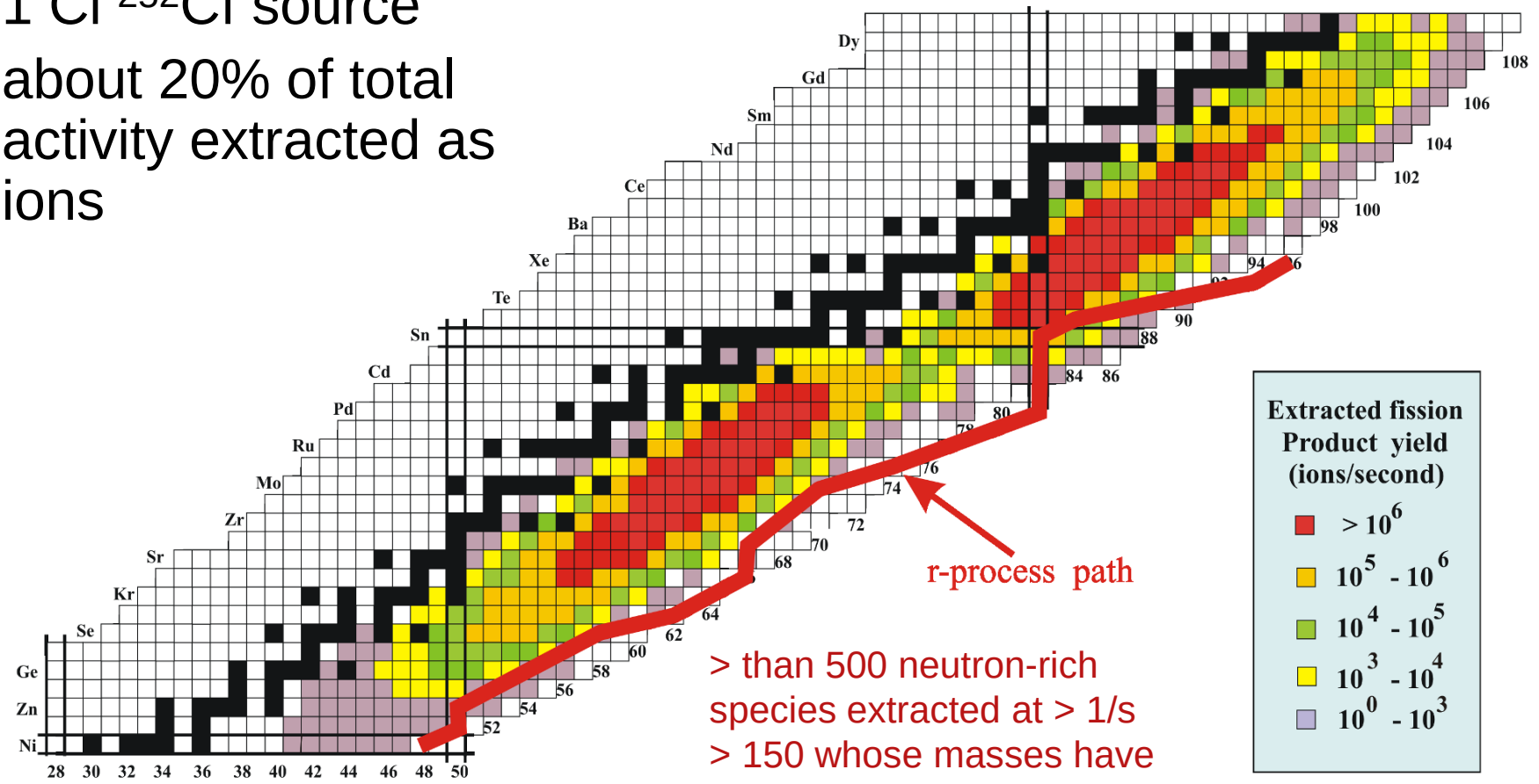
- **PRODUCTION**: ^{252}Cf source inside gas catcher
  - Thermalizes fission fragments
  - Extracts all species quickly
  - Forms low emittance beam
- **SELECTION**: Isobar separator
  - Purifies beam
- **DELIVERY**: beamlines and preparation
  - Switchyard
  - Low-energy buncher
  - Charge breeder
  - Post-accelerator ATLAS





CARIBU extracted beam rates (at 50 keV)

- 1 Ci ^{252}Cf source
- about 20% of total activity extracted as ions



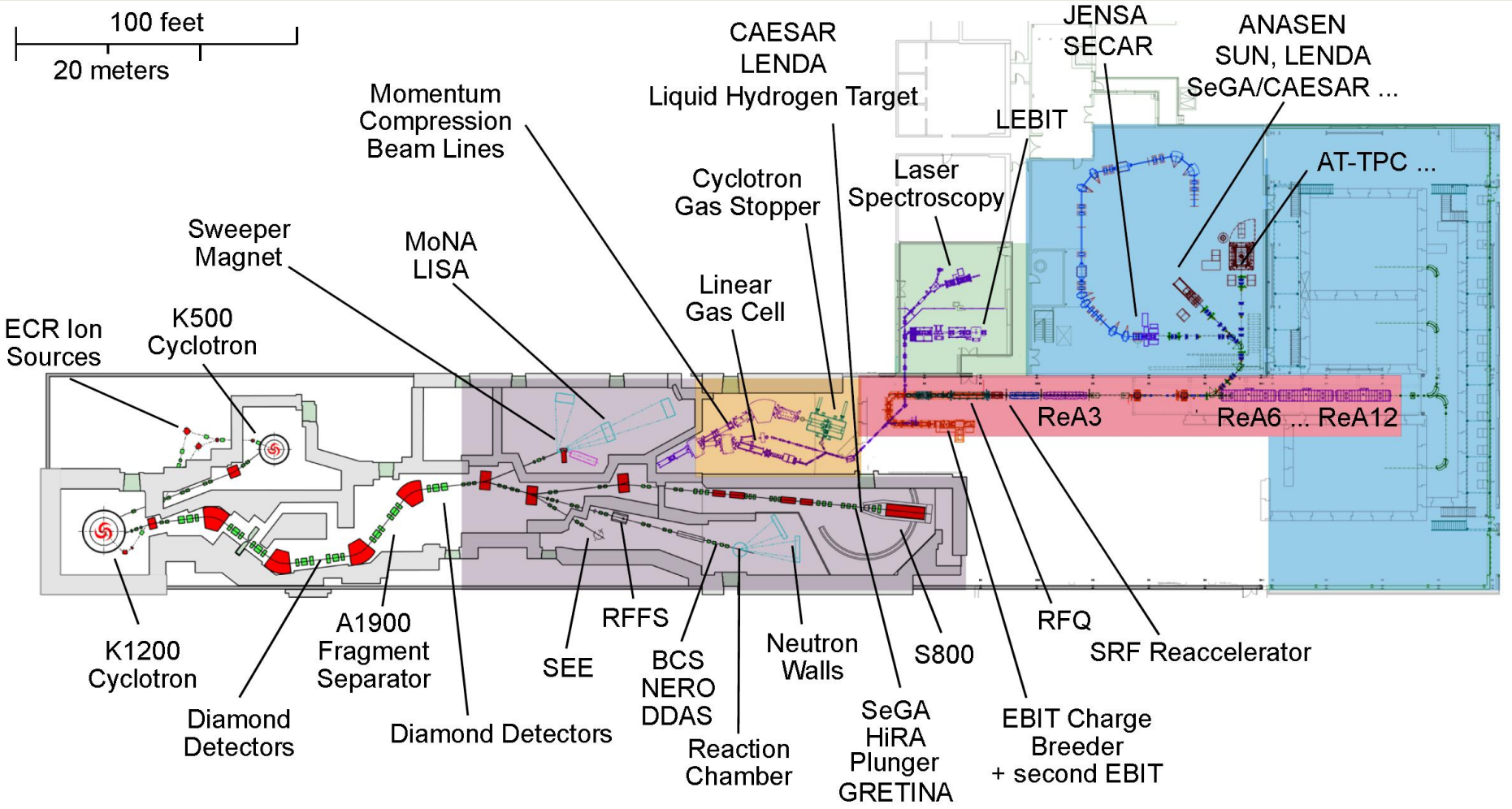
> than 500 neutron-rich species extracted at > 1/s
> 150 whose masses have never been measured

CPT Penning trap mass measurements underway
First Coulomb excitation experiments performed

NSCL and FRIB at MSU

- 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 US's flagship user facility for rare-isotope research; funded by the U.S. National Science Foundation

National Superconducting Cyclotron Laboratory



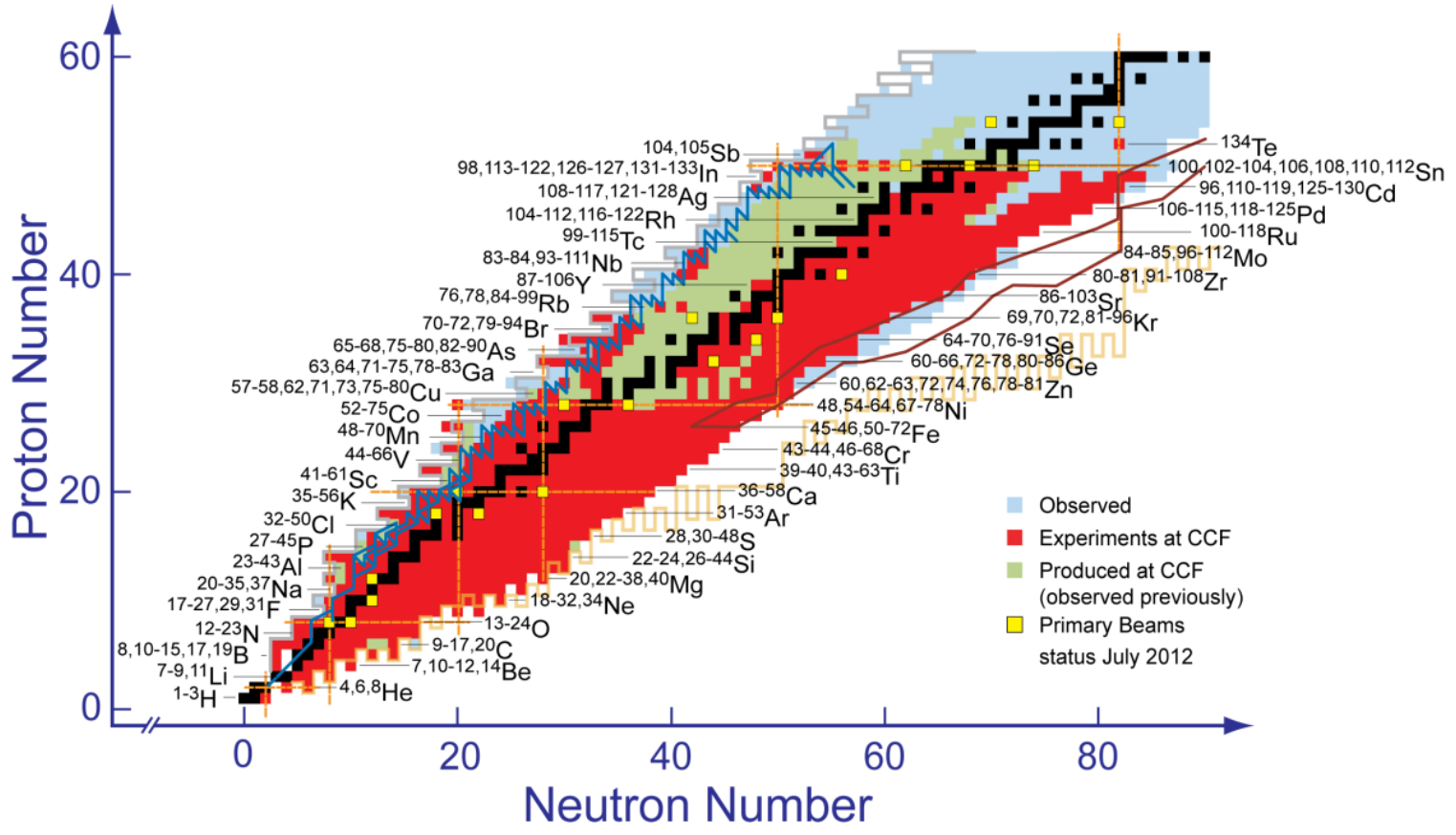
S. Schwarz
M. Brodeur

D. Leitner

ReA3 will be commissioned in 2013;
ReA6 will be completed by end of 2015

Rare Isotope Beams at NSCL
Enable Pre-FRIB Science

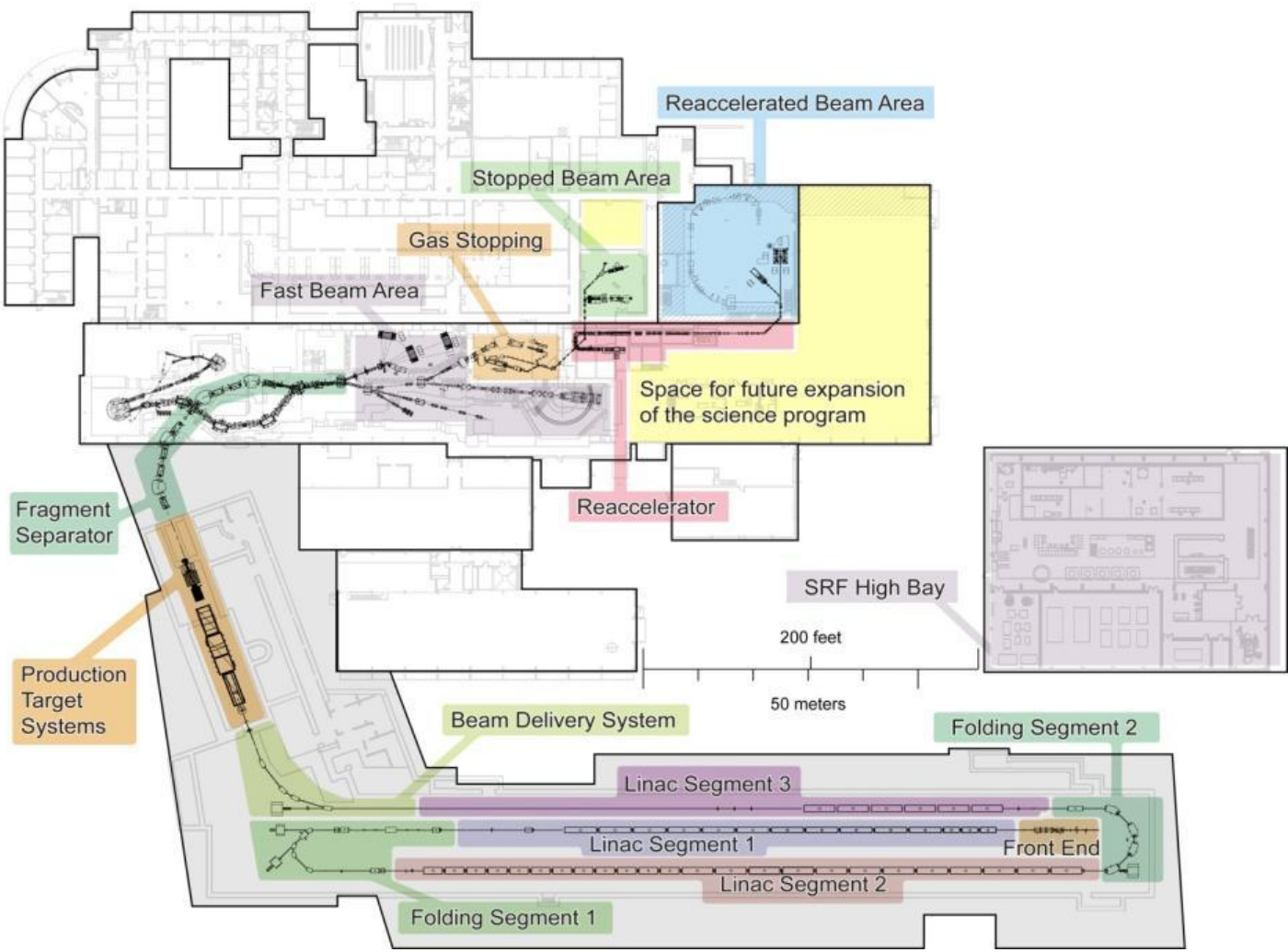
- More than 1000 RIBs have been made – more than 860 RIBs have been used in experiments



World-unique Opportunities with Fast, Stopped, (and soon) Reaccelerated Beams

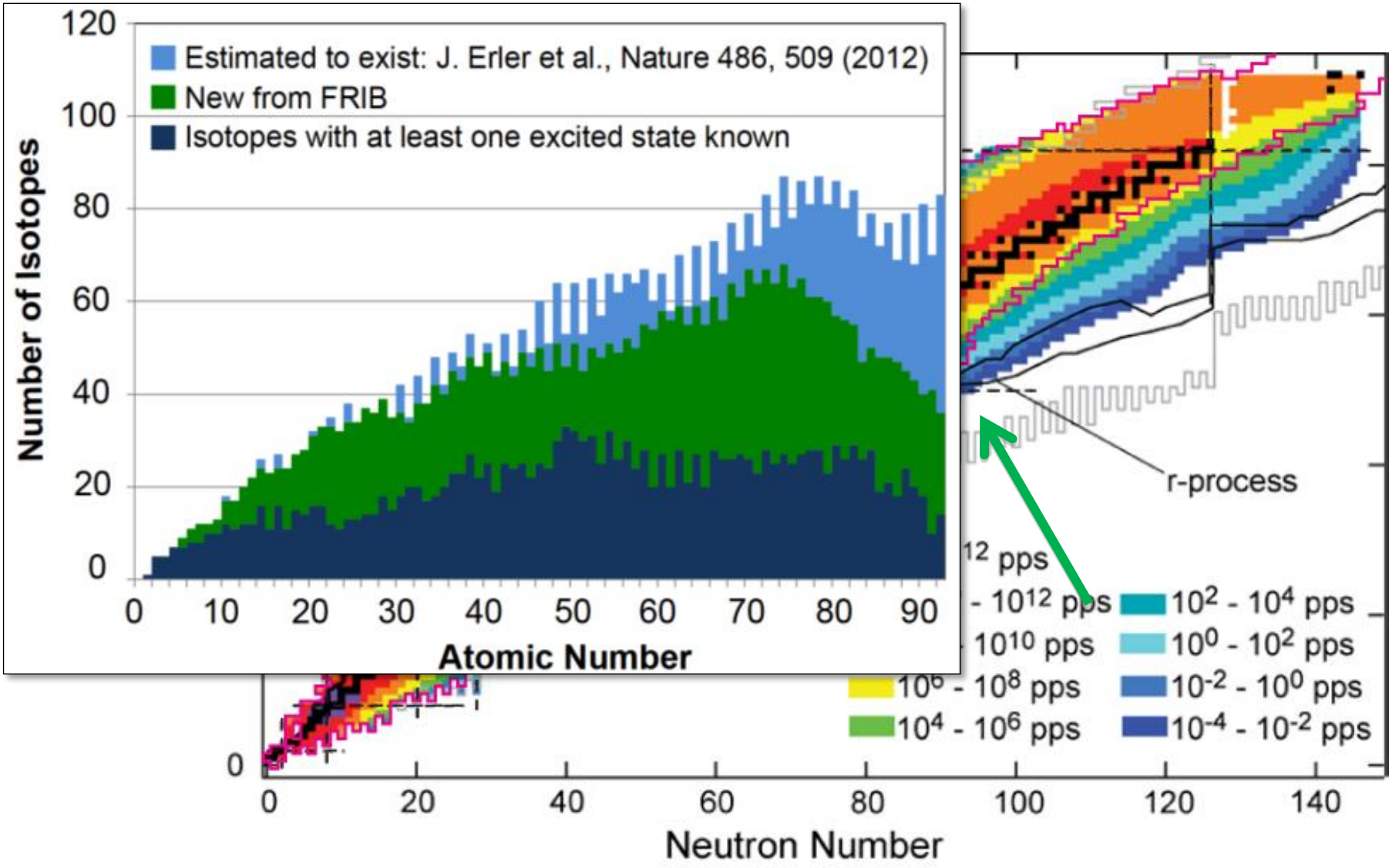
Facility for Rare Isotope Beams

- Rare isotope production via in-flight technique with primary beams up to 400 kW, 200 MeV/u uranium
- Fast, stopped and reaccelerated beam capability
- Upgrade options
  - 400 MeV/u for U
  - ISOL production – Multi-user capability



World-leading next-generation rare isotope beam facility

FRIB Beams Will Enable New Discoveries



The Path to FRIB

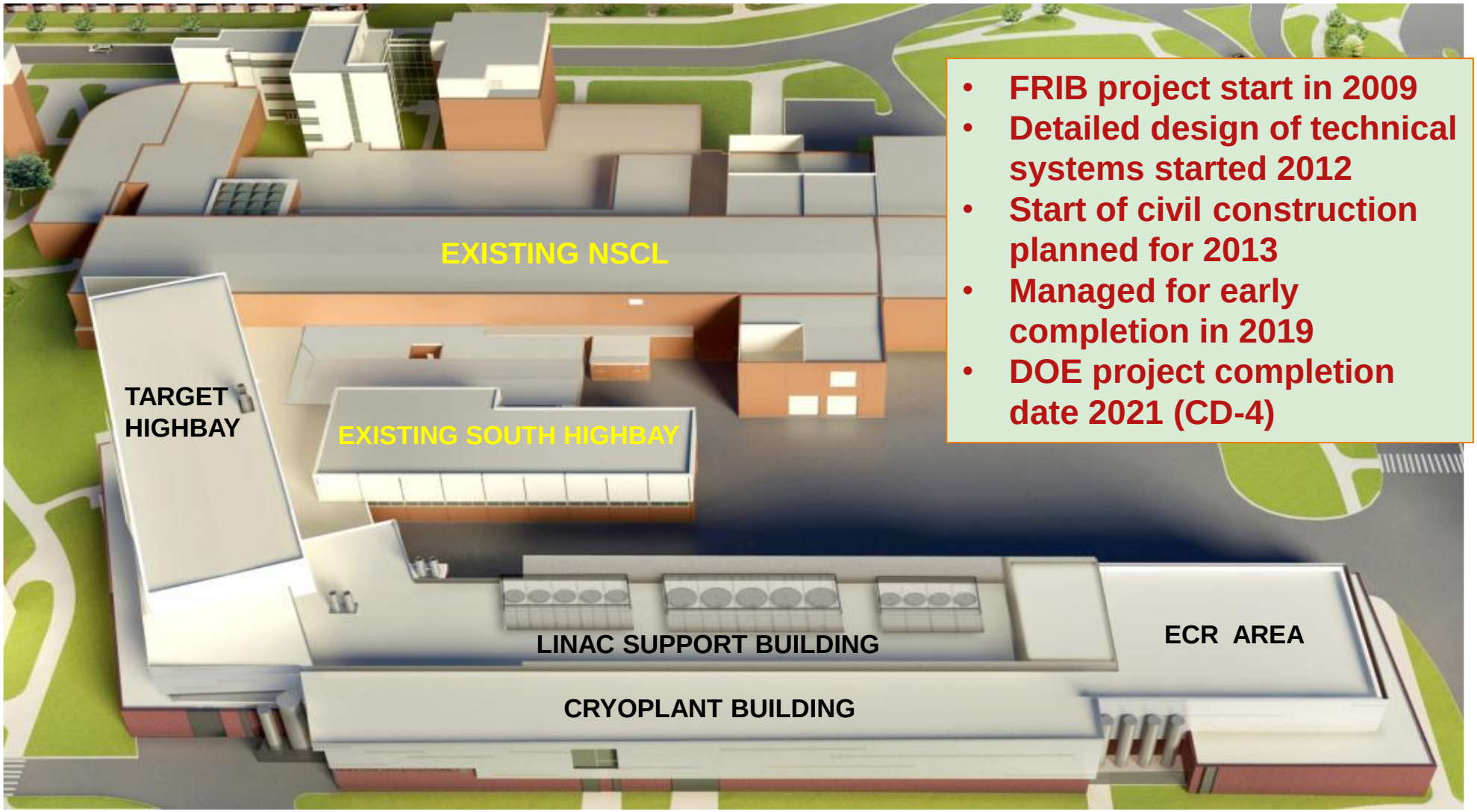
- FRIB being built under cooperative agreement between DOE and MSU
  - Total Project Cost $680M
  - Includes $94.5M contribution from MSU
- Technical scope of FRIB project
  - 400 kW heavy ion linac, 200 MeV/u for U
  - Target facility and fragment separator with 400 kW beam power capability

FRIB Project
Project Manager: T. Glasmacher
Accelerator Systems: J. Wei
Experimental Systems: G. Bollen
Conventional Facilities: B. Bull

FRIB/NSCL Laboratories
Director: C.K. Gelbke
Chief Scientist: B.M. Sherrill

- "External" contributions to FRIB laboratory
  - Beam stopping systems, beam lines, reaccelerator
  - Experimental areas and experimental equipment
- FRIB technical scope with be realized while NSCL continuous to operate as national user facility prior to integration into FRIB
  - Pre-FRIB science + minimum shutdown for transition to full FRIB facility

Facility for Rare Isotope Beams
Layouts Frozen, Civil Design Completed



- FRIB project start in 2009
- Detailed design of technical systems started 2012
- Start of civil construction planned for 2013
- Managed for early completion in 2019
- DOE project completion date 2021 (CD-4)

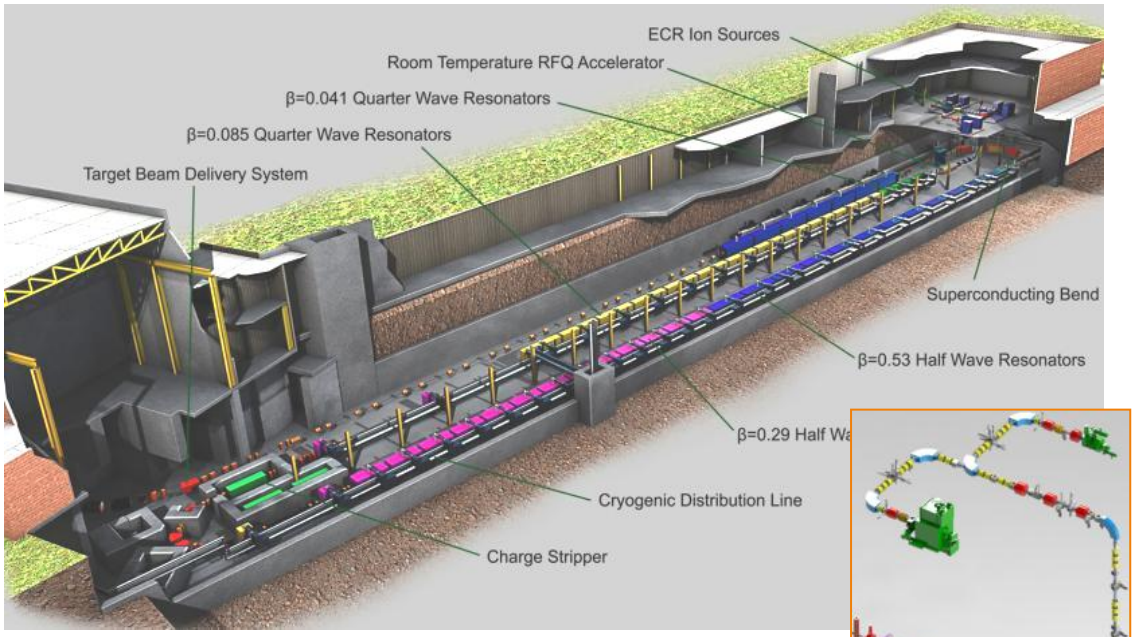
FRIB Site Preparation
Getting Ready for Civil Construction

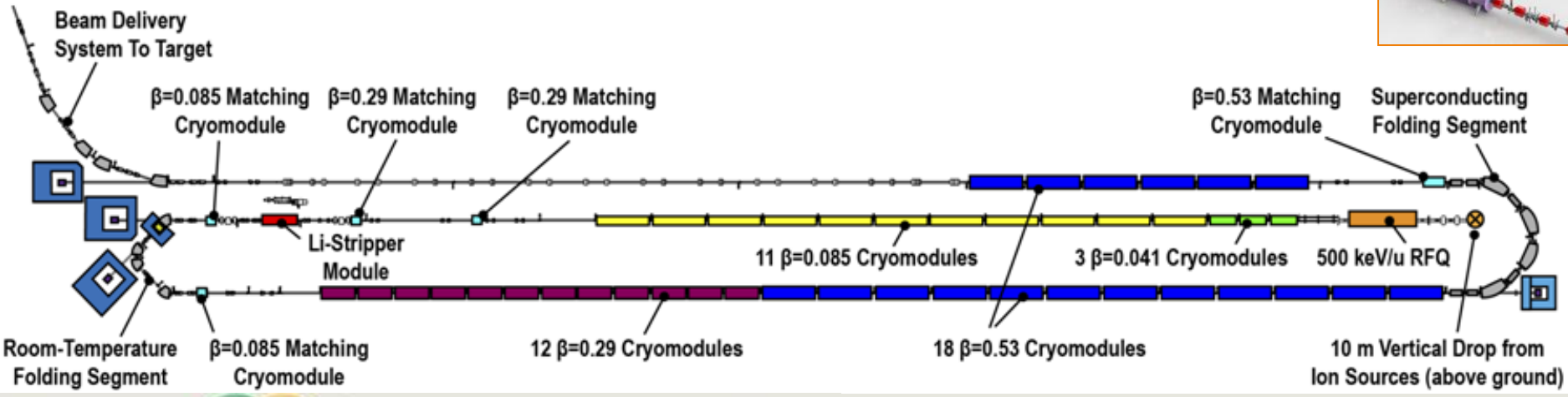
- FRIB site preparations on track for starting civil construction in 2013

Watch “movie” at
http://frib.msu.edu/

FRIB Accelerator Systems
SRF Driver Linac

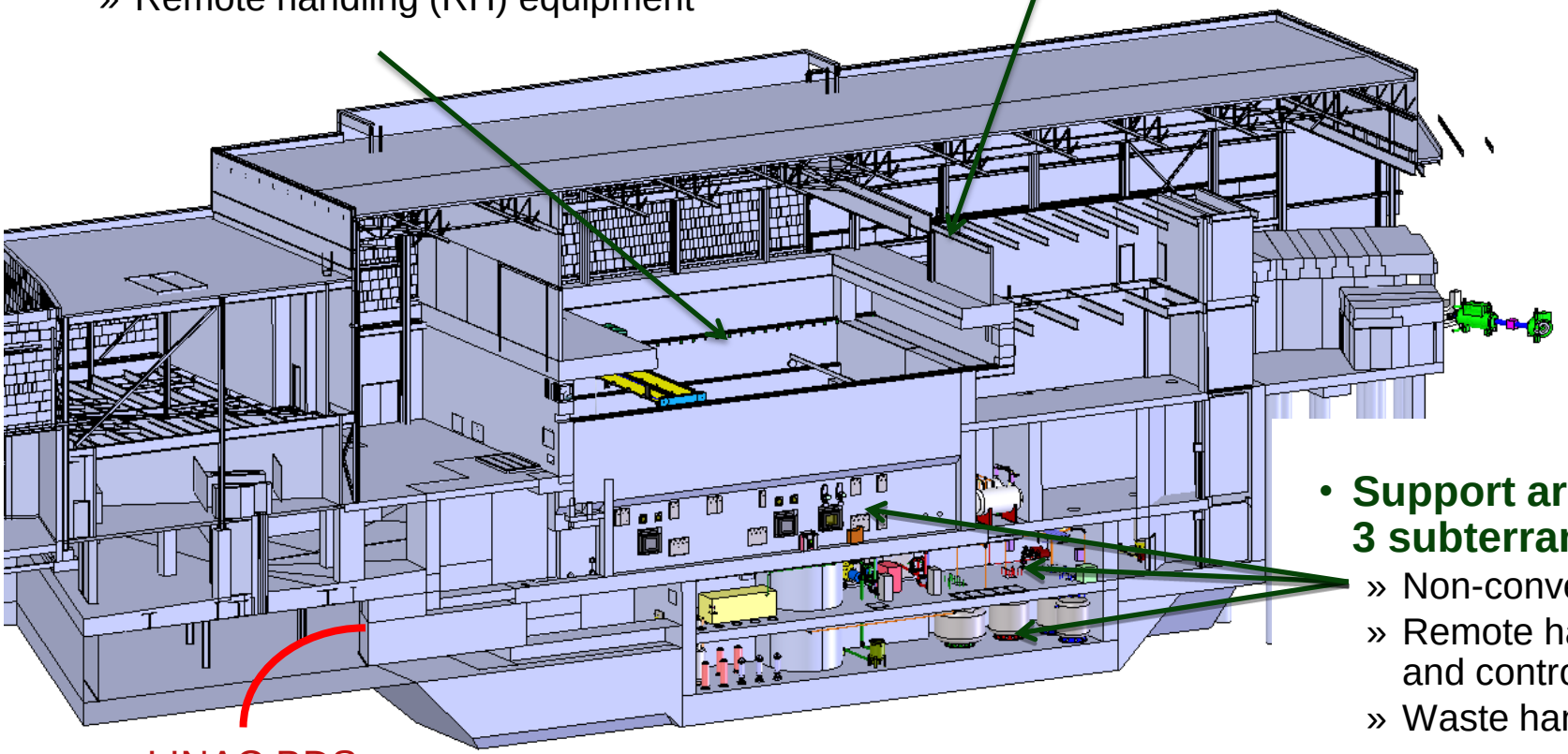
- Accelerate ion species up to ^{238}U with energies of no less than 200 MeV/u
- Provide beam power up to 400kW
- Energy upgrade to 400 MeV/u for uranium by filling vacant slots with 12 SRF cryomodules





FRIB Rare Isotope Production Facility

- **Target hot cell, subterranean**
  - » Production target
  - » Fragment preseparator
  - » Primary beam dump(s)
  - » Remote handling (RH) equipment
- **Target facility building high bay**
  - » Second and third stage of fragment separator



- **Support areas, 3 subterranean levels**
  - » Non-conventional utilities
  - » Remote handling gallery and control room
  - » Waste handling

Shielding design compatible with 400 MeV/u energy upgrade

FRIB Experimental Systems
Fragment Separator

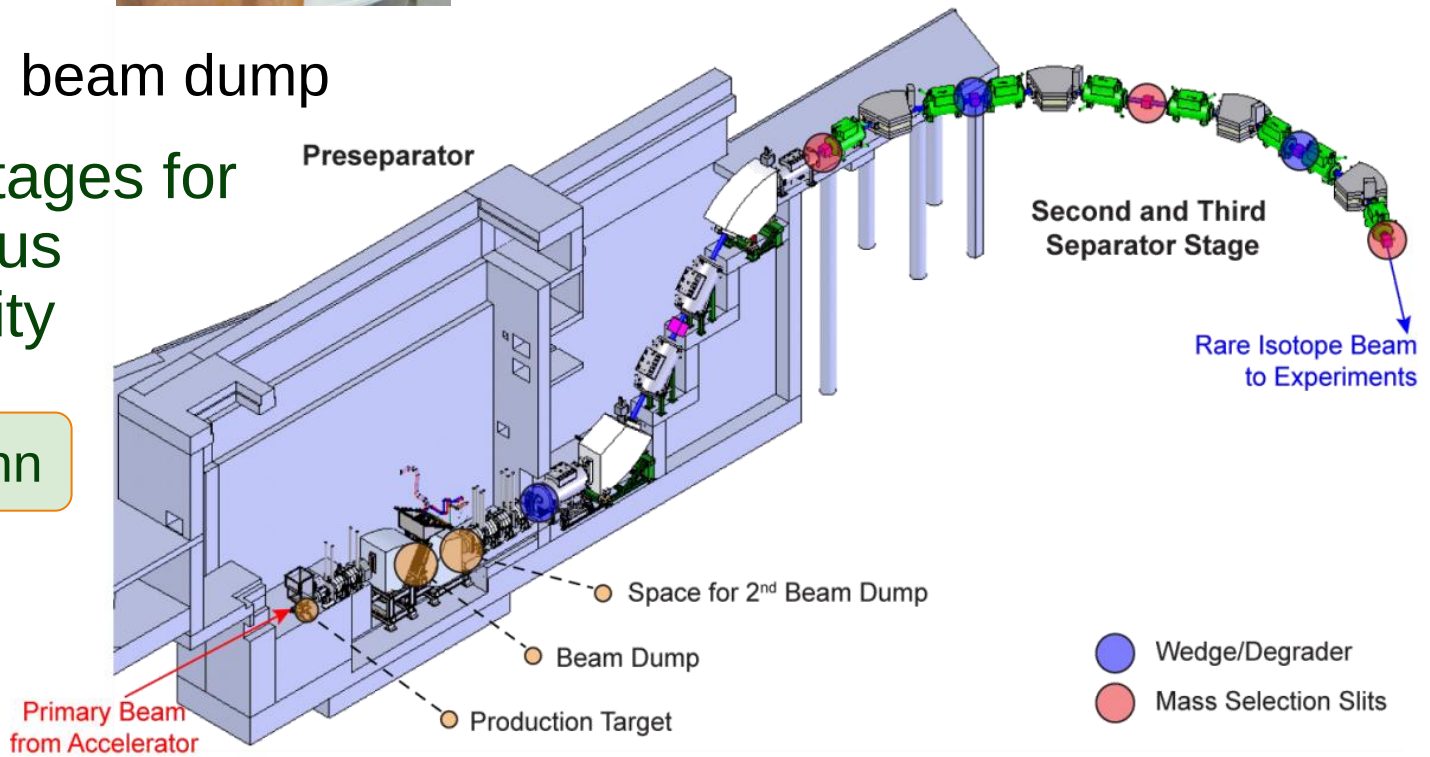
- Production of rare isotope beams with 400 kW beam power using light to heavy ions up to ^{238}U with energy ≥ 200 MeV/u
  - Rotating graphite target

F. Pellemoine

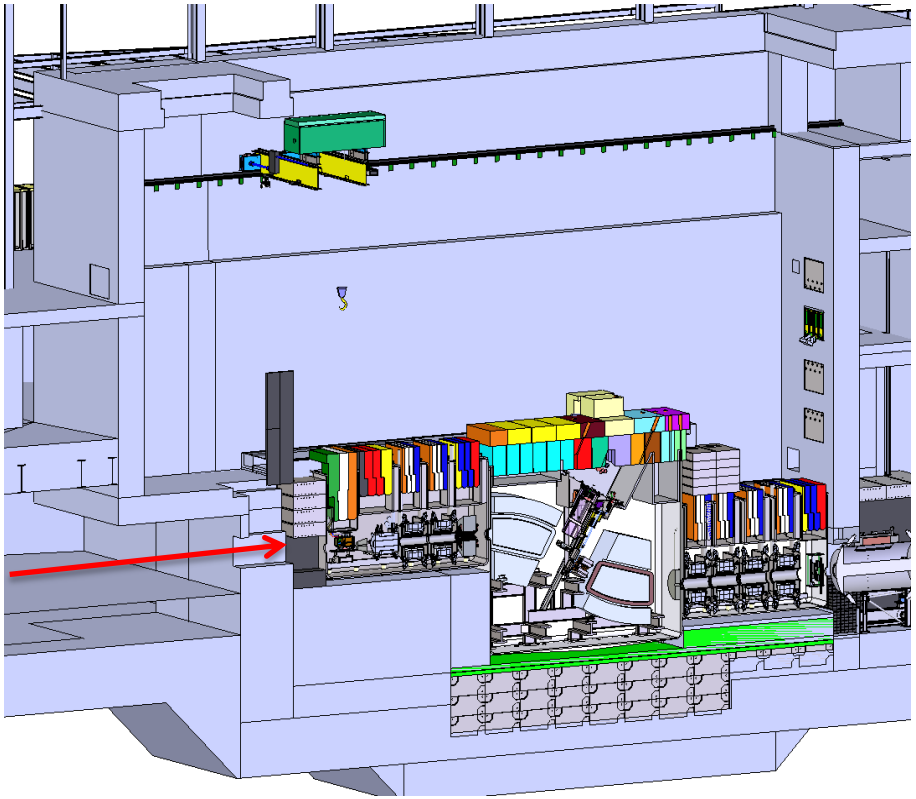
  - Water-filled rotating beam dump

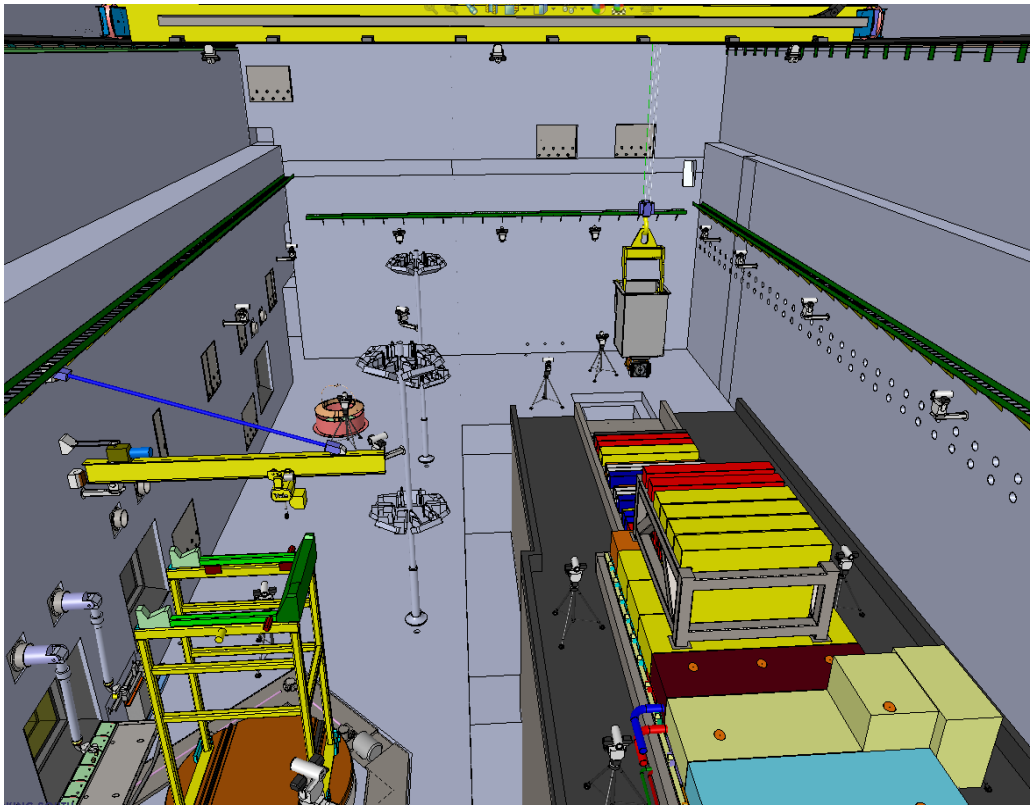
- Three separation stages for high beam purity plus operational versatility

M. Hausmann



Fragment Separator and Target Facility
Design Meets 400-kW Power Requirement





Remote Handling Integrated in Target Facility Design

- Hands-on access after beam-off
- Target change design goal <1 day

OAK RIDGE National Laboratory

FRIB Fragment Separator
Isotope harvesting provisions included in design

- Produce a rare isotope beam for a primary user, for example ^{200}W from a ^{238}U primary beam

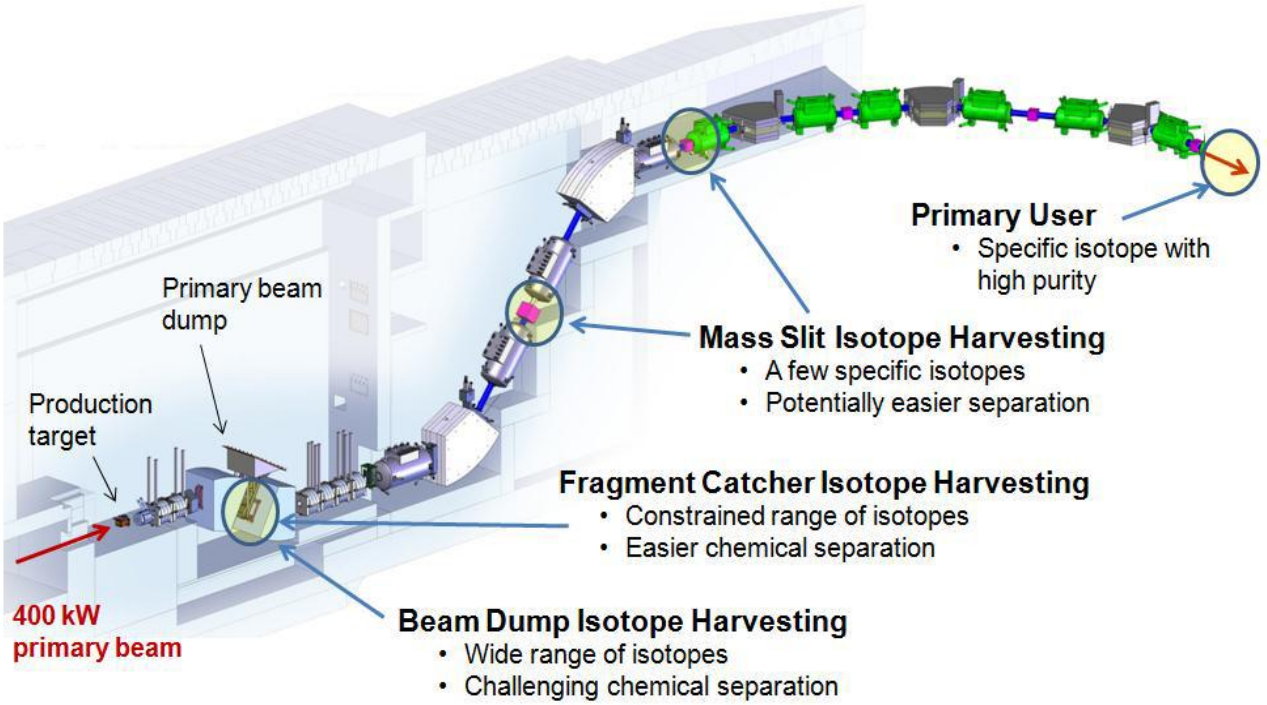
W. Mittig

- At the same time up to 1000 other isotopes are produced that could be harvested and used for other experiments or applications.
  - Catcher/ion source systems like PALIS@BIGRIPS
  - Harvesting from beam dump water loops

M. Wada

		^{238}U	^{136}Xe	^{86}Kr	^{48}Ca
Isotope	Half Life	Activity [mCi]			
^{28}Mg	0.87 d	7	36	190	2100
^{32}Si	132 y	0.1	0.4	2	25
^{44}Ti	60 y	0.1	0.8	5	0.9
^{48}V	16 d	80	385	2200	80
^{67}Cu	2.6 d	200	100	950	
^{85}Kr	10.8 y	50	2	1700	
^{211}Rn	14.6 h	230			
^{221}Rn	0.42 h	4			
^{223}Rn	0.39 h	1			
^{225}Rn	270 s	2			
^{225}Ac	10 d	170			

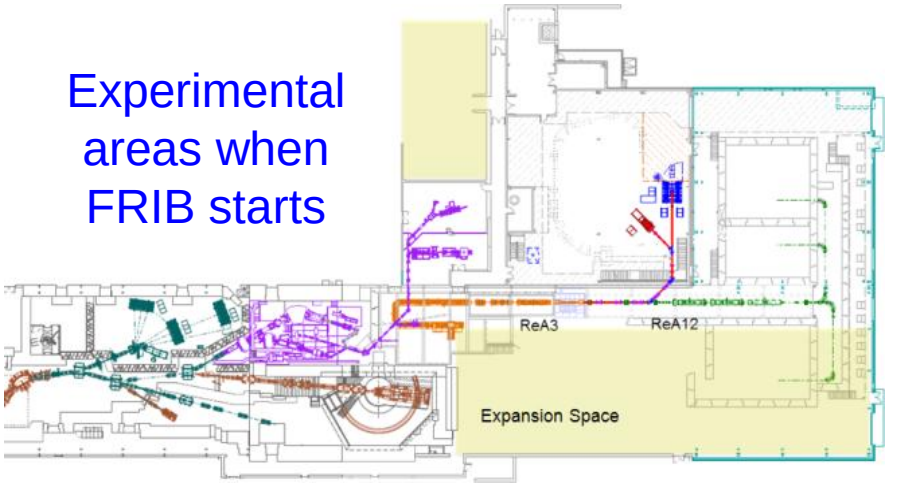
Isotope inventories in beam dump cooling loop after 1 year of operation



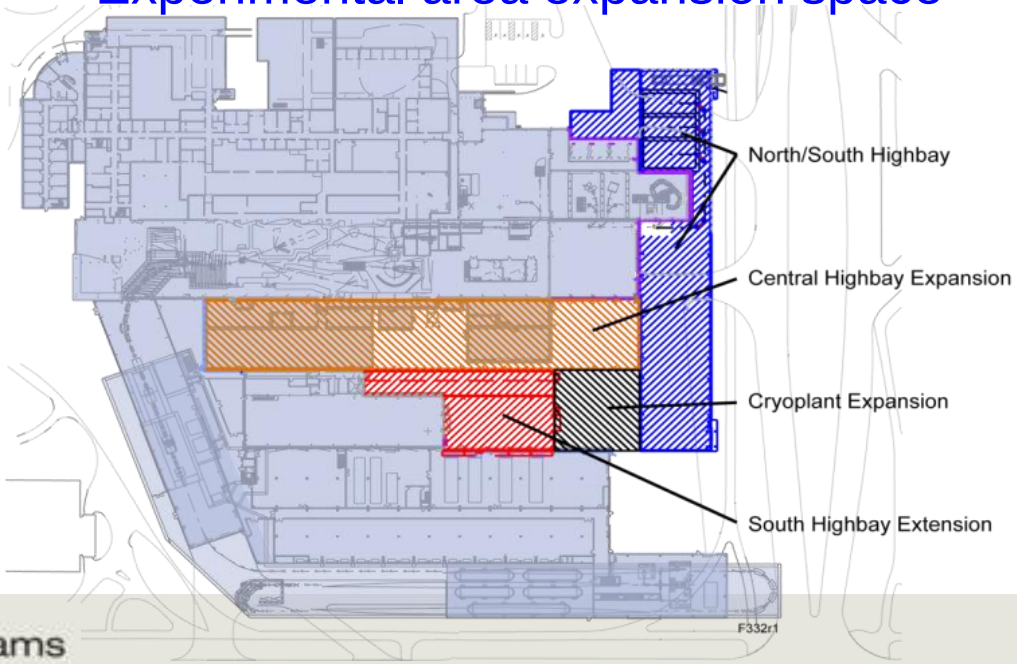
Experimental Areas and Equipment at FRIB

- Reconfigurable areas for fast, stopped and reaccelerated beam experiments
  - 47,000 sq ft when FRIB starts
  - Additional 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, SECAR, CAESAR, …
  - Equipment available in the community and movable (existing , under development, or planned)
    - » GRETINA, GRETA, ANASEN, CHICO, Nanoball, …

Experimental areas when FRIB starts



Experimental area expansion space



FRIB Users Organization
Over 1300 Users Ready for Science

- Users are organized as part of the independent FRIB Users Organization
  - FRIBUO has >1300 members (92 US Colleges and Universities, 10 National Laboratories, 58 countries) as of Dec 2012
  - Chartered organization with an elected executive committee
    FRIBUO has 20 working groups on experimental equipment


Low Energy Science Community Meeting, August 2012

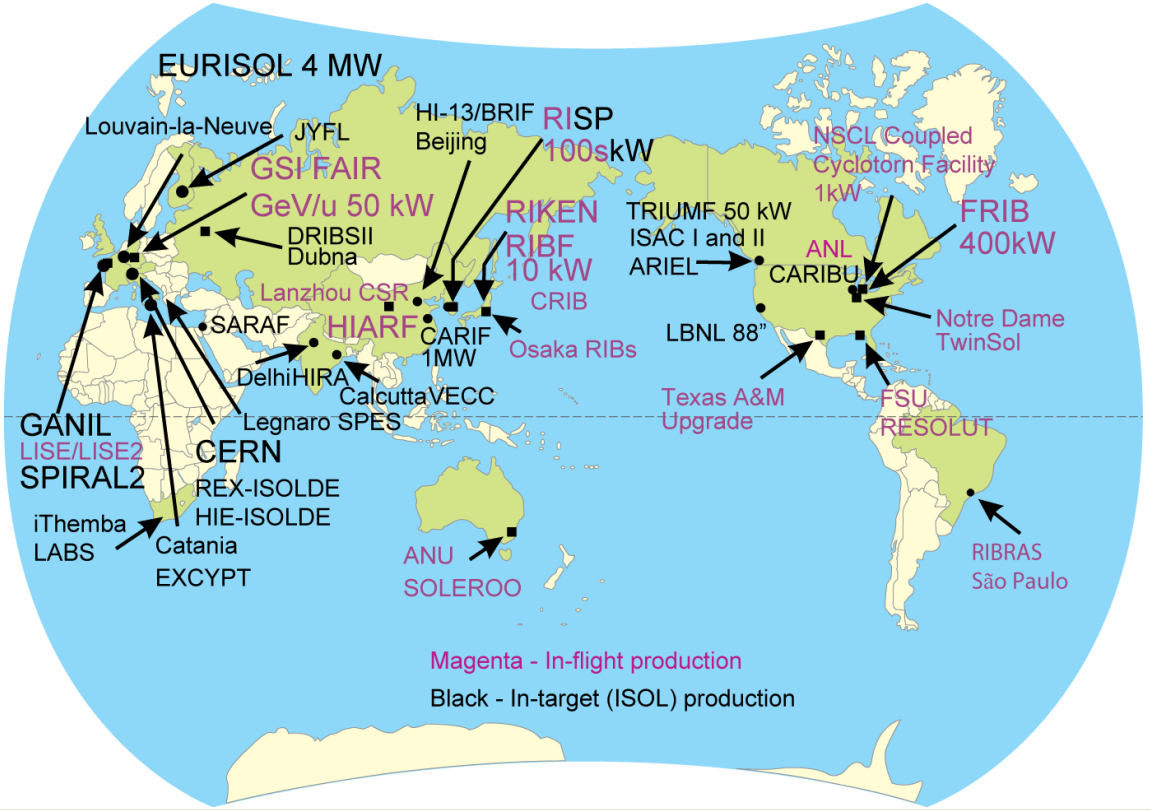

Joint Users Meeting, August 2011


FRIB Equipment Workshop, February 2010

FRIB Users Organization
FACILITY FOR RARE ISOTOPE BEAMS

Summary

- Rare Isotope Science in the Americas builds on strong user communities, world-class facilities based on ISOL and in-flight production, and a broad range of smaller facilities
- Rare Isotope Beam facilities in the Americas complement existing facilities wordlwide
- FRIB and ARIEL under construction will be word-leading facilities for Rare Isotope Science



Thanks for material to Alinka Lépine-Szily, Robert Janssens, Rainer Kruecken, Guy Savard, Ingo Wiedenhover