Radioactive ion beam production

2 methods:

- Isotope Separation On-Line (ISOL) method

  ISAC-TRIUMF in Canada
  REX-ISOLDE at CERN
  SPIRAL2 at GANIL in France
  SPES in Italy
  EURISOL facility (under construction)

- In-flight projectile fragmentation

  FRIB facility at MSU (under construction)
  RIBF at RIKEN near Tokyo (Japan)
  FAIR at GSI (Germany)

ISOL method

basic principle:
proton or light ion beams hit thick target to produce radioisotopes.

a) use spallation reaction: heavy nucleus emits large number of nucleons after being hit by high-energy particle; reaction product is highly radioactive
b) use proton-induced fission of U (or spontaneous fission of ^{252}Cf)

Target is heated to high temperature; the produced radioisotopes are extracted via gaseous diffusion, mass separated, and then post-accelerated in heavy-ion accelerator.

advantage:
potential for high-intensity RIB beams, excellent beam quality

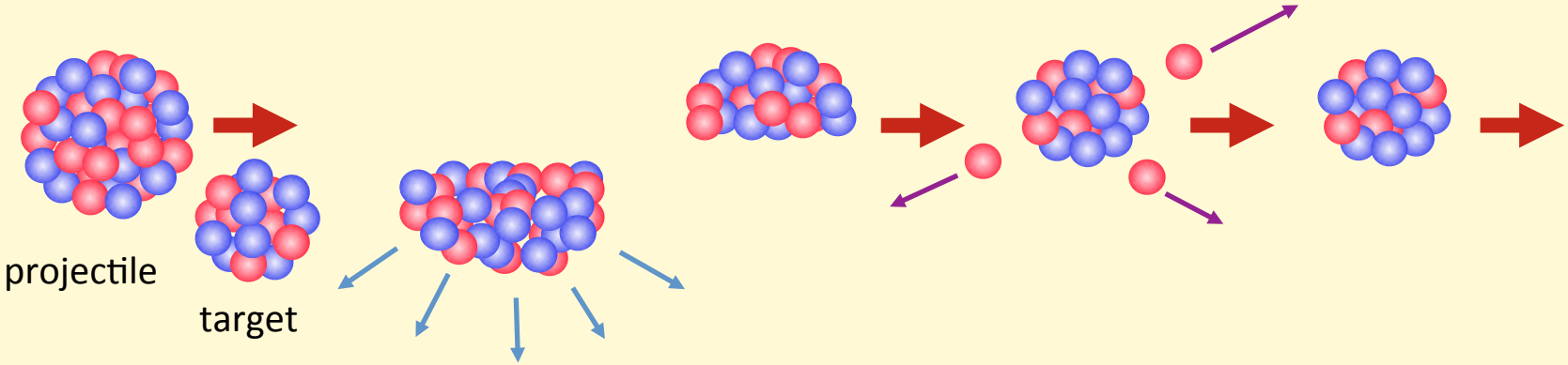
In-flight projectile fragmentation method

basic principle:
collision of two nuclei at relativistic energies produces highly unstable reaction fragments (radioactive) which are then slowed down by collisions in a gas cell.

advantage:
allows for production of short-lived RIBs

FRIB Isotope Production Scheme

- projectile fragmentation or fission (Coulomb breakup, transfer, …)



Radioactive Ion Beam (RIB) facilities in other countries

- RIBF at RIKEN (major new facility near Tokyo, Japan)
- FAIR (major new facility at GSI Darmstadt, Germany)
- SPIRAL2 at GANIL (major upgrade in France)
- ISOLDE upgrade (CERN, Switzerland)
- ISAC at TRIUMF (nuclear astrophysics facility, Vancouver, Canada)
- Radioactive Ion Beam Line (RIBLL) in Lanzhou, China

Status of GANIL/SPIRAL2 facility

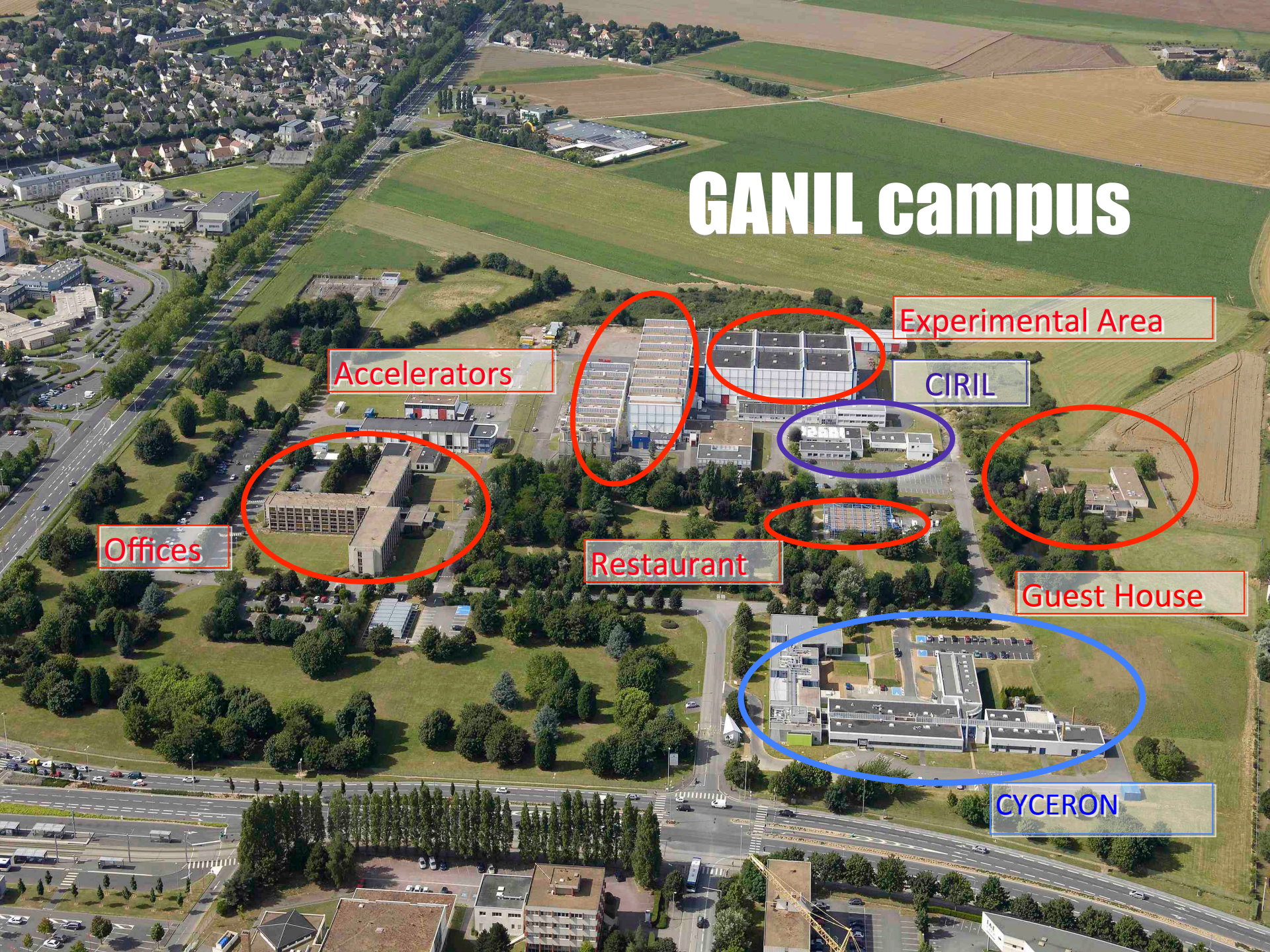
M. Lewitowicz
GANIL, CEA/DSM-CNRS/IN2P3, Caen, France

on behalf of GANIL, SPIRAL2 Project Group
&
Physics Collaborations

See also related NN2012 talks of:

Michael Bender, Abdou Chbihi, Fanny Farget, Francesca Gulminelli, Wolfram Korten, Paola Marini, Marie-France Rivet & Cedric Simenel

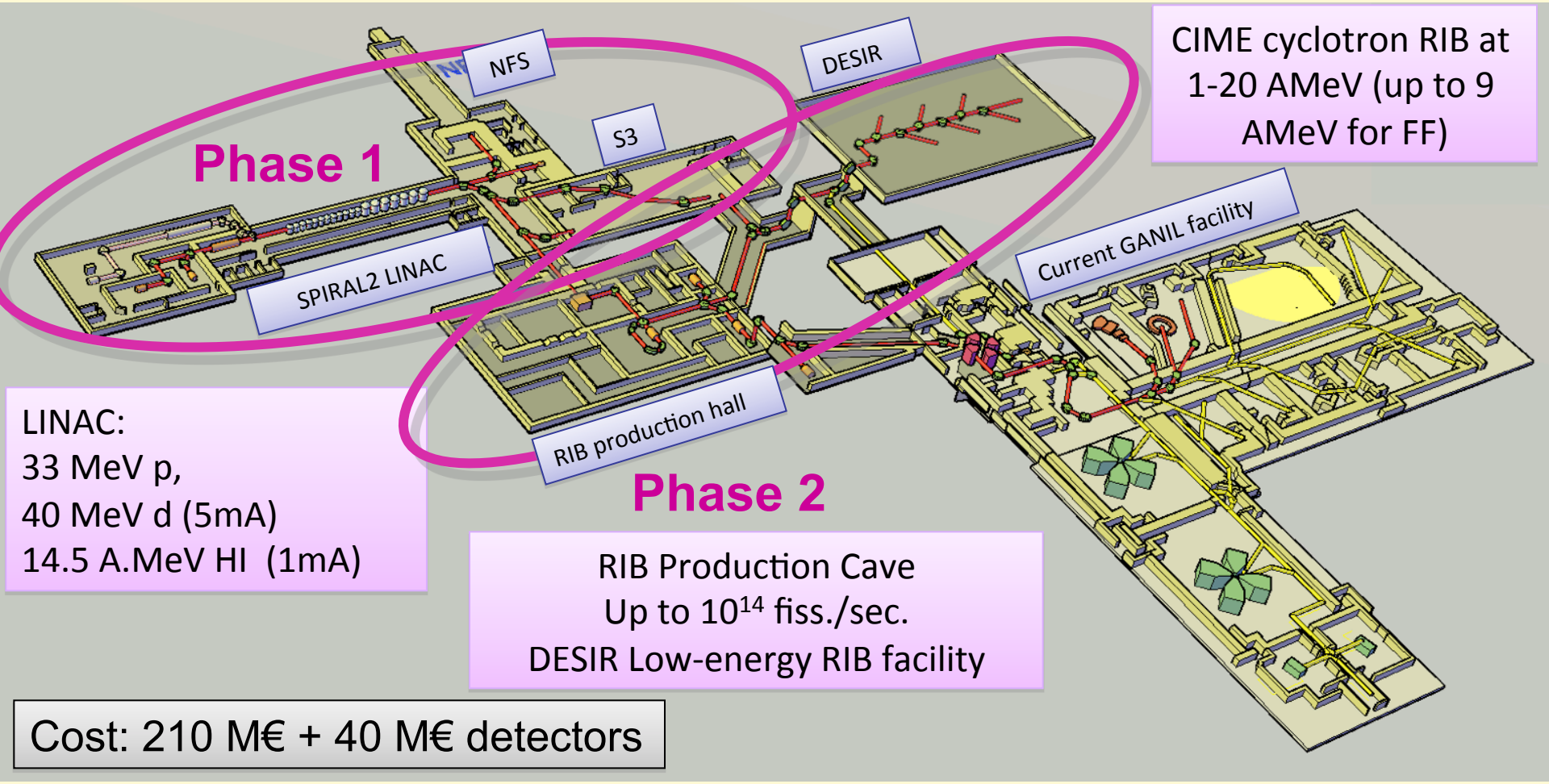
www.ganil-spiral2.eu


GANIL campus
Experimental Area
Accelerators
CIRIL
Offices
Restaurant
Guest House
CYCERON

SPIRAL2 under construction

Phase 1: High intensity stable beams + Experimental rooms (S^3 + NFS)

Phase 2: High-intensity low-energy (DESIR) & post-accelerated Radioactive Ion Beam facility



CIME cyclotron RIB at 1-20 AMeV (up to 9 AMeV for FF)

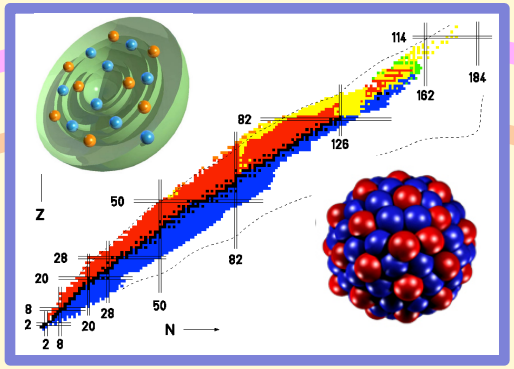
LINAC:
33 MeV p,
40 MeV d (5mA)
14.5 A.MeV HI (1mA)

RIB Production Cave
Up to 10^{14} fiss./sec.
DESIR Low-energy RIB facility

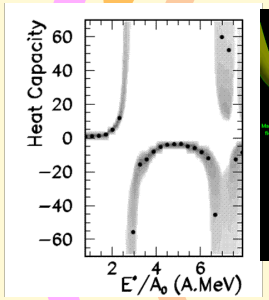
Cost: 210 M€ + 40 M€ detectors

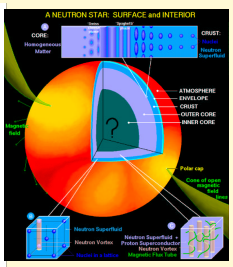
GANIL/SPIRAL2
Science

Nuclear structure

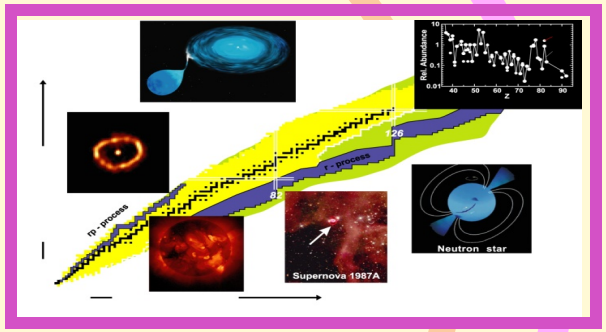


EOS
Liquid-gas phase
Isospin dependence

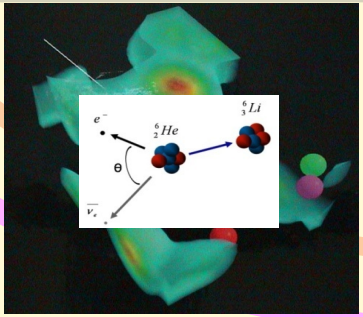




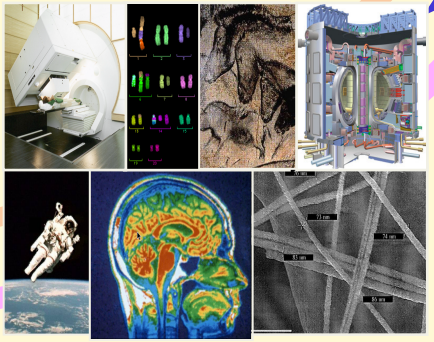
Nuclear Astrophysics



Fundamental Interactions



Multi-disciplinary research & Applications



Present and future of the RIKEN RI Beam Factory (RIBF)

-- the new facility: 5 years since the first beam from the new facility

T. Motobayashi
(RIKEN Nishina Center)

"fast"* RI beams by **projectile fragmentation and projectile fission**
Nuclei farther from the stability valley, hoping ……..

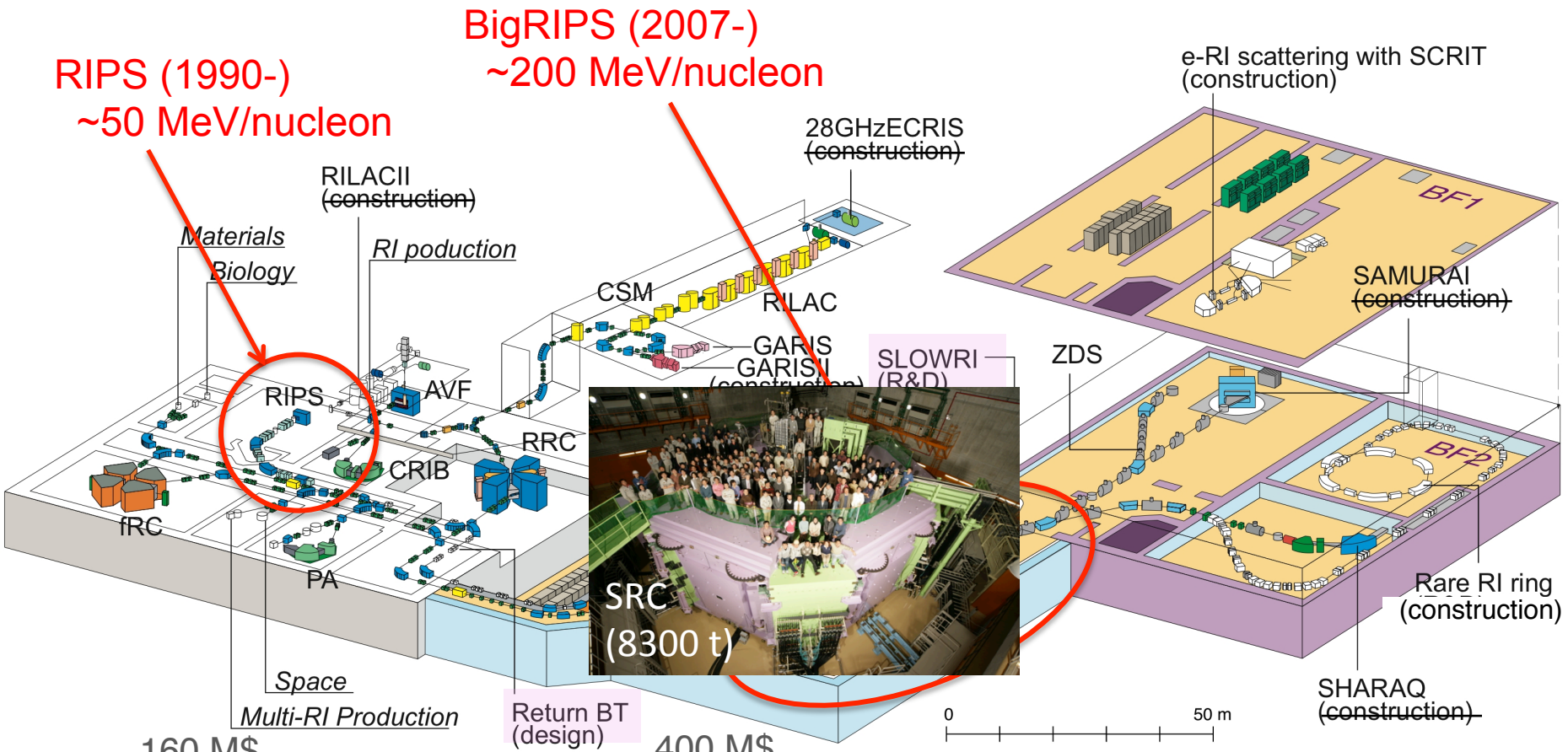
5 years of the new facility
- improvement of primary beams (intensity and stability)
- extension in the nuclear chart
- highlights
- construction of experimental devices

Near-term future
Possible upgrades

* $v/c \sim 0.3$-0.6

RIKEN NiSHiNA CENTER

RIBF – a new generation RIB facility in operation
with world highest capability of producing exotic nuclei in coming years!



160 M$
135 MeV/nucleon
for light nuclei (1986-)

400 M$
345 MeV/nucleon
up to U (2006-)

experimental
equipment

Radioactive Ion Beam (RIB) facilities in the U.S.

- Argonne Tandem Linac Accelerator System (ATLAS) at Argonne National Lab
- National Superconducting Cyclotron Lab (NSCL) at Michigan State University
- Facility for Rare Isotope Beams (FRIB), under construction at Michigan State University

CARIBU: A new facility for the study of neutron-rich isotopes

Guy Savard
Argonne National Laboratory
&
University of Chicago

11th International Conference on nucleus-nucleus collisions
June 1 2012, San Antonio, Texas

CARIBU upgrade at ATLAS (Argonne National Lab)

http://www.phy.anl.gov/atlas/caribu/Cf252_upgrade_proposal_final_Rev4.pdf

CARIBU = CAlifornium Rare Ion Breeder Upgrade

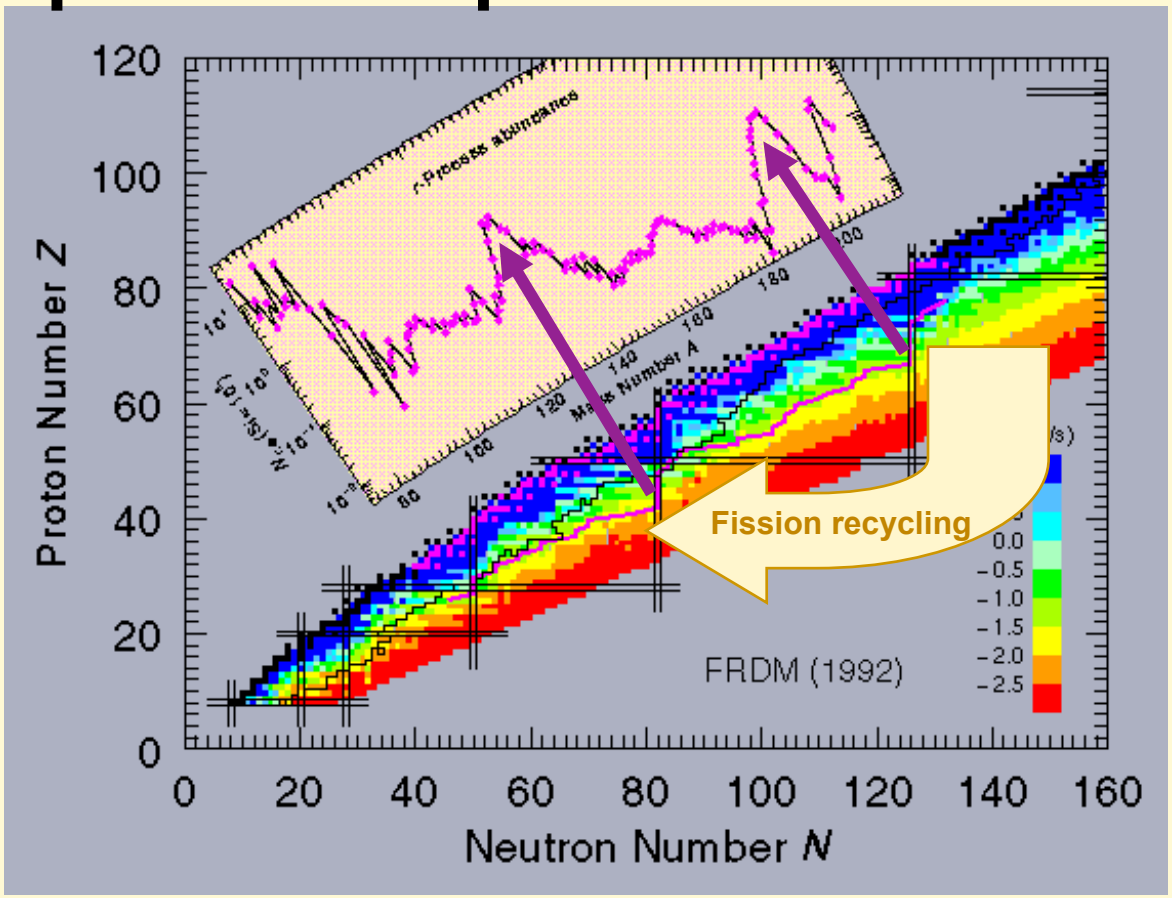
Basic idea:

Uses a 1 Curie ^{252}Cf spontaneous fission source. The charge and mass distribution is very broad (see next slide). Use these fission fragments for accelerated RIBs.

The r-process path

r-process:

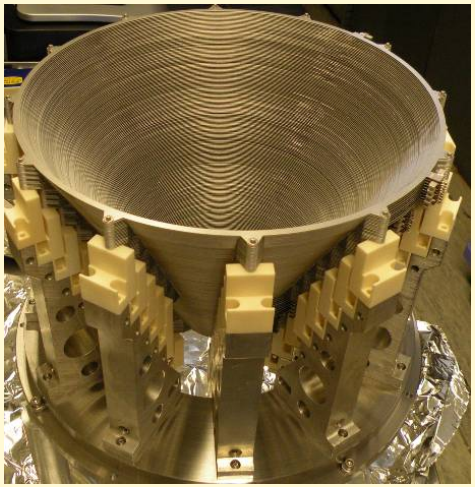
- Process known to exist
- Exact site unknown
- Path critically depends on nuclear properties of neutron-rich nuclei:
  - mass
  - lifetime
  - β-delayed neutrons
  - fissionability

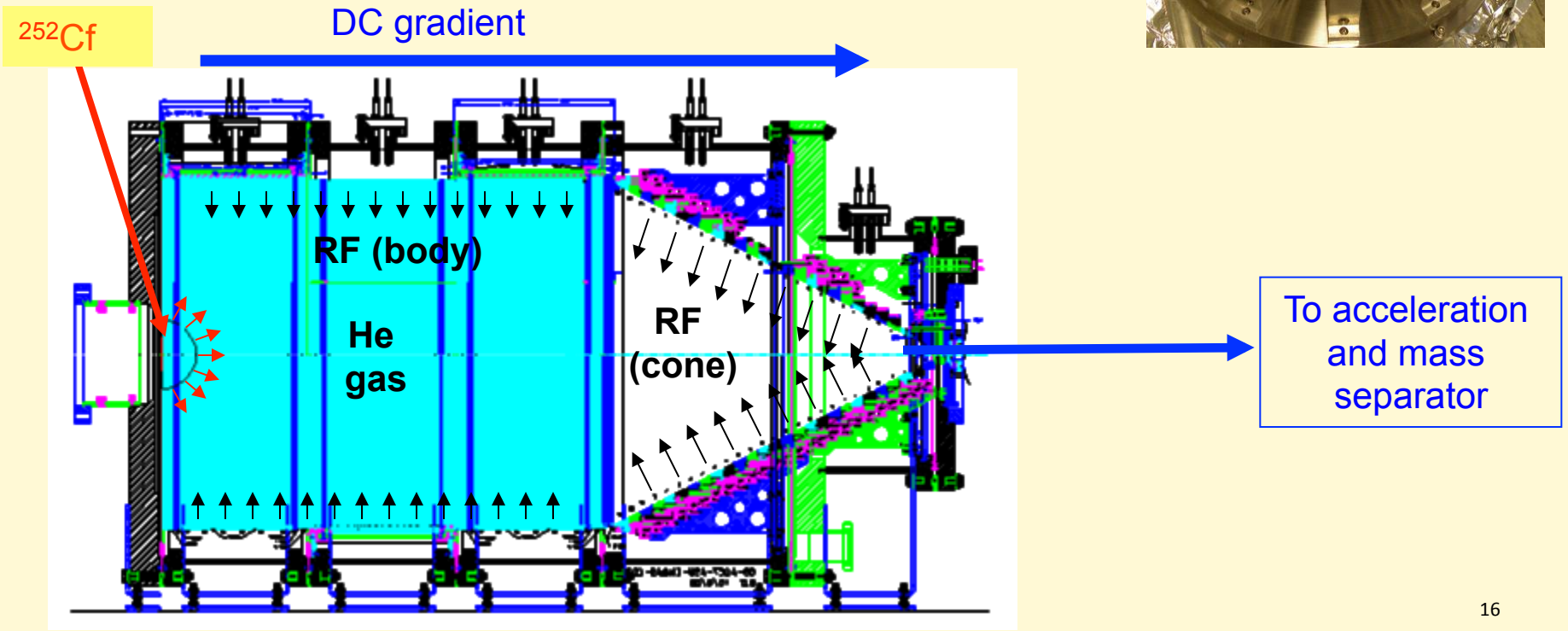


Efficient techniques exist to obtain this information but the required beams are missing in most of this region of the chart of nuclides.

CARIBU gas catcher: transforms fission recoils into a beam with good optical properties

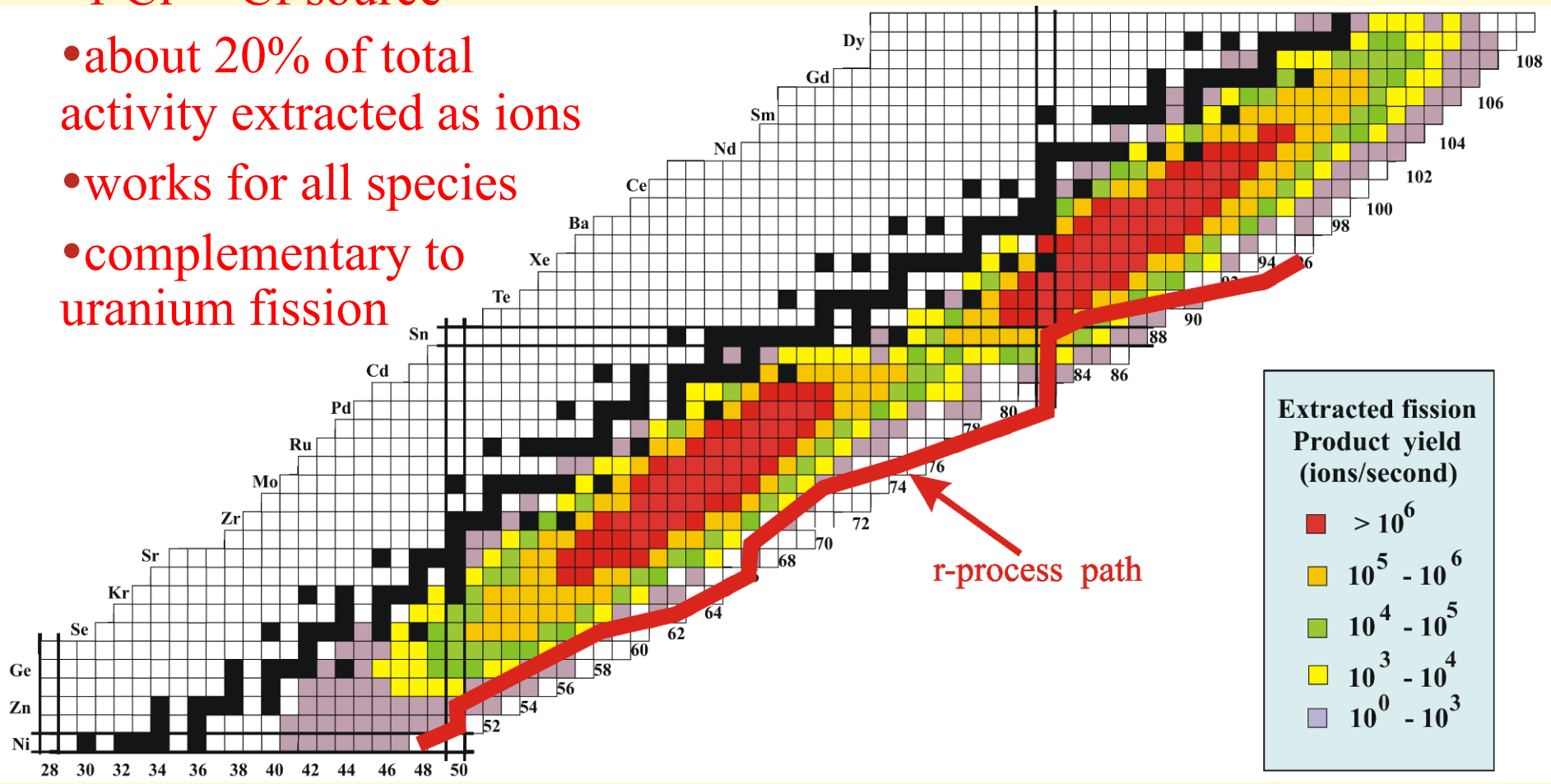
- **Based on smaller devices developed at ANL**
  - **Radioactive recoils stop in sub-ppb level impurity Helium gas**
  - **Radioactive ion transport by RF field + DC field + gas flow**
  - **Stainless steel and ceramics construction (1.2 m length, 50 cm inner diameter)**
  - **Fast and essentially universally applicable**
  - **Extraction in 2 RFQ sections with µRFQs for differential pumping**



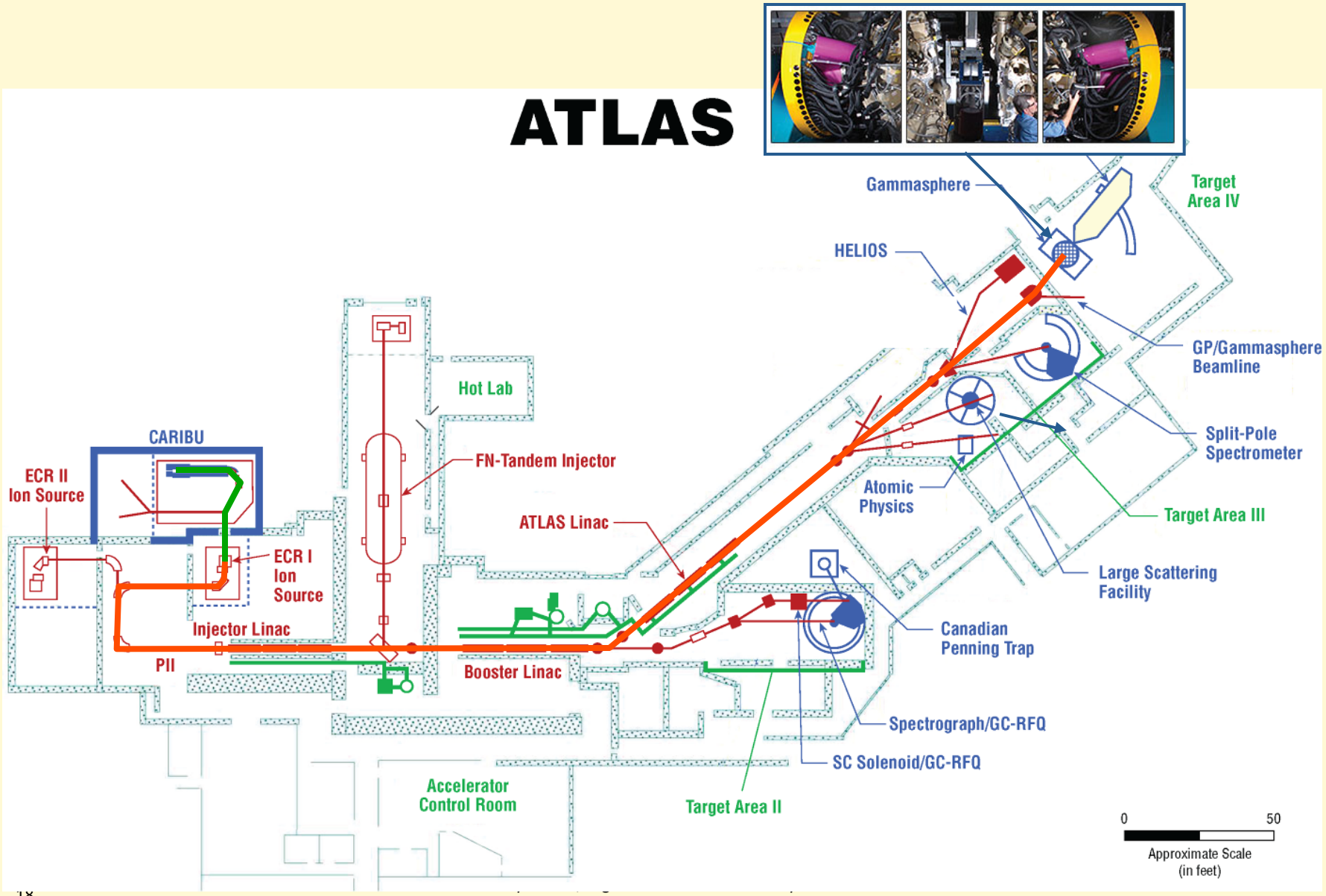


Extracted isotope yield at low energy (50 keV)

- 1 Ci ^{252}Cf source
- about 20% of total activity extracted as ions
- works for all species
- complementary to uranium fission



CARIBU beams reaccelerated to Gammasphere



Status

- CARIBU facility is operational
  - First RIB facility based on a gas catcher … it works
  - Over 70 different neutron-rich radioactive isotope species have been extracted and used for experiments in the last year
  - Low-energy program in full swing with experiments approved by PAC last January taking data
  - Reaccelerated beam program initiated at low intensity

- "1 Ci" source will replace the current 50 mCi source this summer. Combined with RFQ installation this fall, will yield gains of 10 to 40 in intensity for low-energy and reaccelerated beams.

PAC in fall 2012 will accept proposals for reaccelerated neutron-rich beams at energies between 3-15 MeV/u

Facility for Rare Isotope Beams (FRIB)

Features:

- two ECR (= electron cyclotron resonance) ion sources
- superconducting heavy-ion driver linear accelerator
  - uranium beams up to 200 MeV/nucleon
  - proton beams up to 600 MeV/nucleon
- one in-flight production target
- space to add up to two ISOL targets
- radioactive ion beam linear post-accelerator

Facility for Rare Isotope Beams: Status and Capabilities

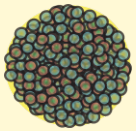
Brad Sherrill
for the FRIB Laboratory and Project Team
1 June 2012

MICHIGAN STATE UNIVERSITY

U.S. DEPARTMENT OF ENERGY | Office of Science

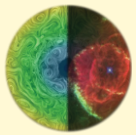
This material is based upon work supported by the U.S. Department of Energy Office of Science under Cooperative Agreement DE-SC0000661.
Michigan State University designs and establishes FRIB as a DOE Office of Science National User Facility in support of the mission of the Office of Nuclear Physics.

Introduction: FRIB Scientific Program



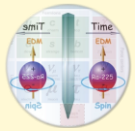
Properties of nuclei

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



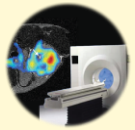
Astrophysical processes

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



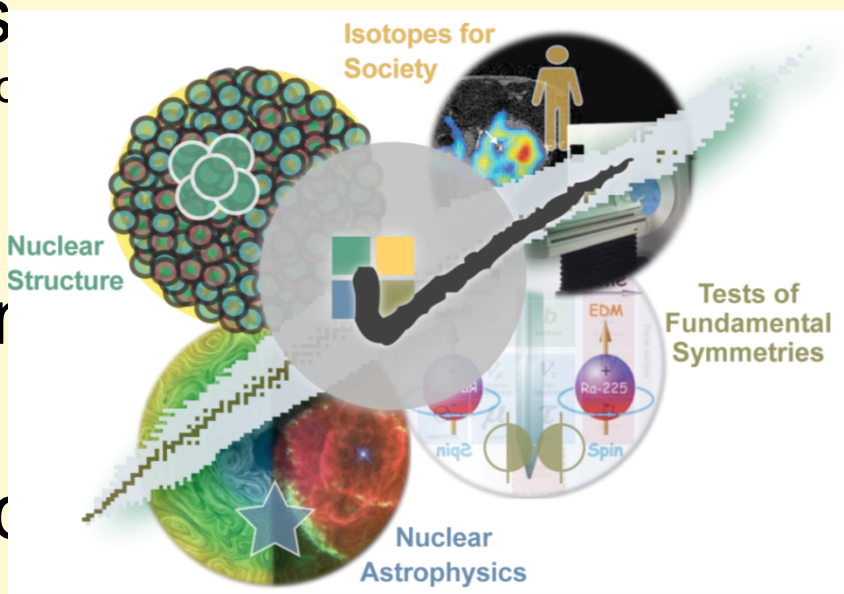
Tests of fundamental sy

- Effects of symmetry violations are amplified in certain nuclei

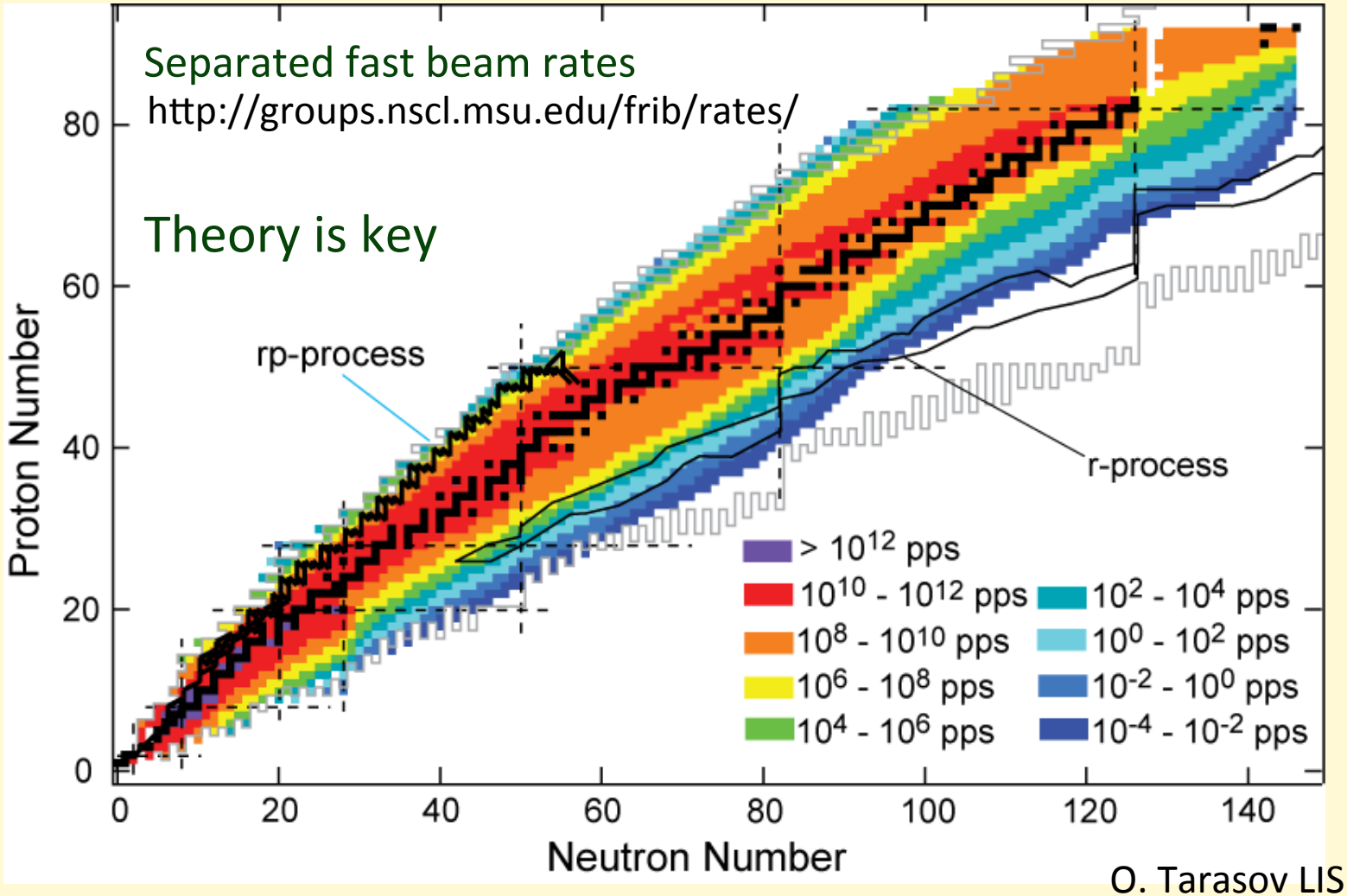


Societal applications an

- Bio-medicine, energy, material sciences, national security

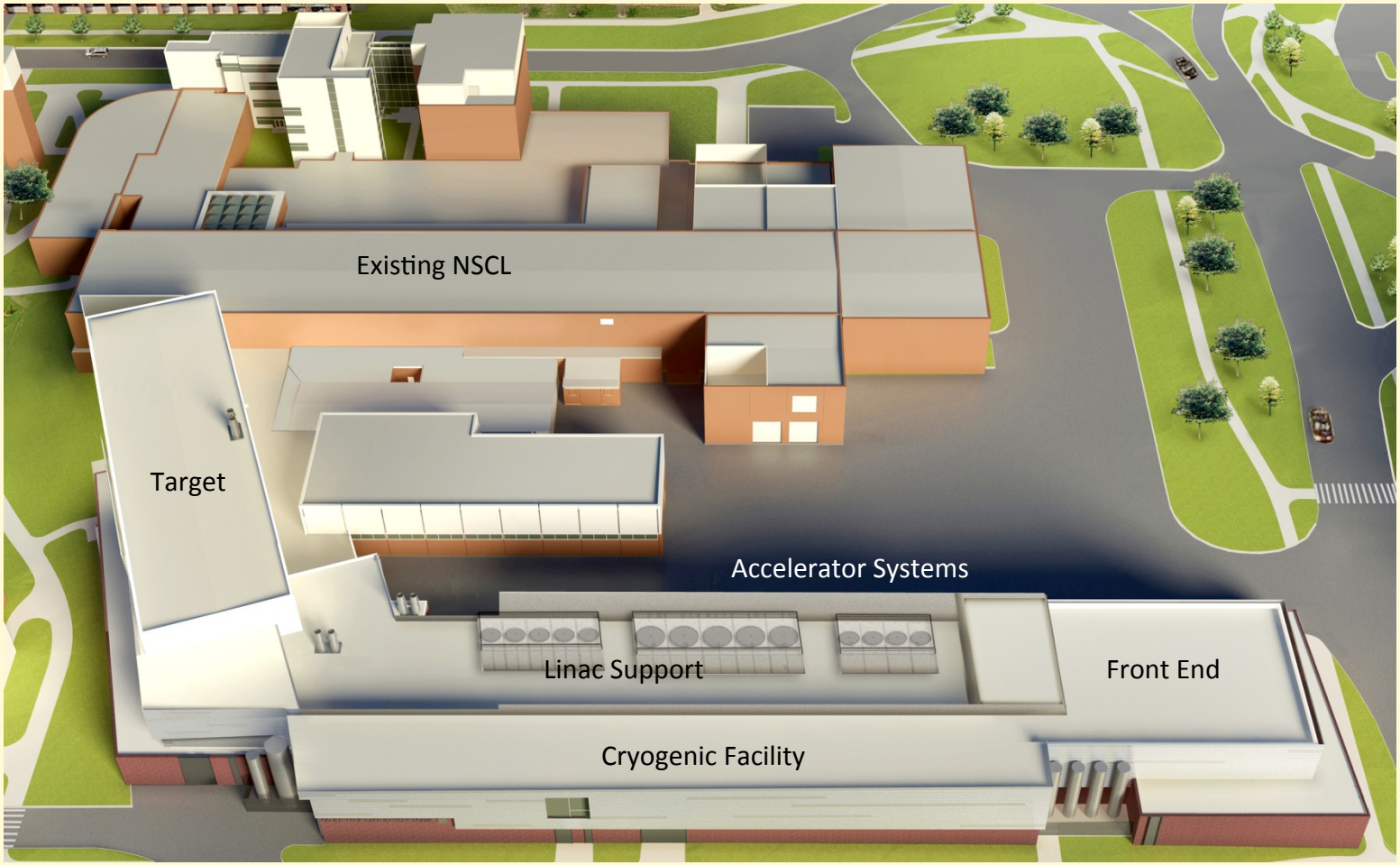


The Reach of FRIB

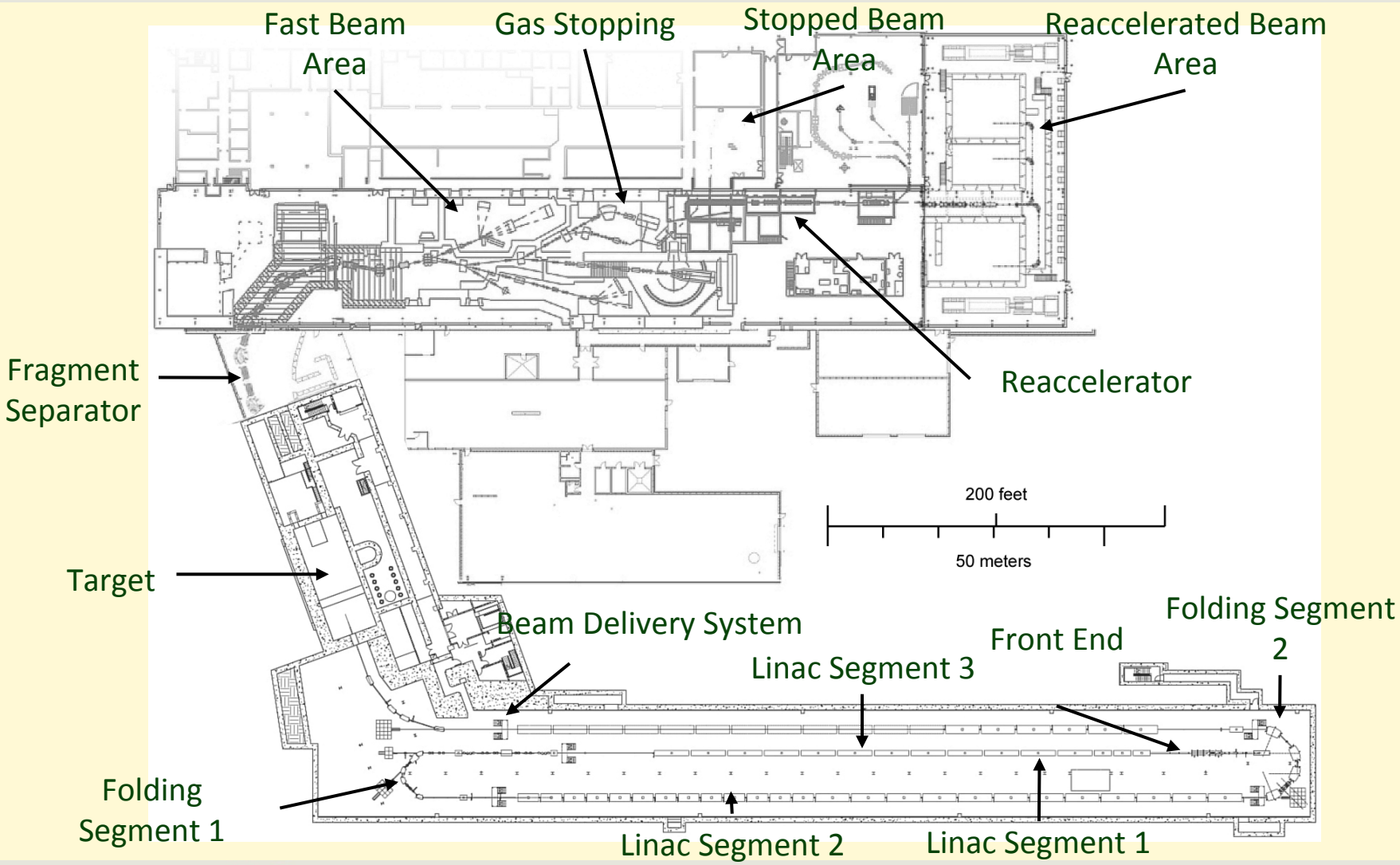


O. Tarasov LISE++

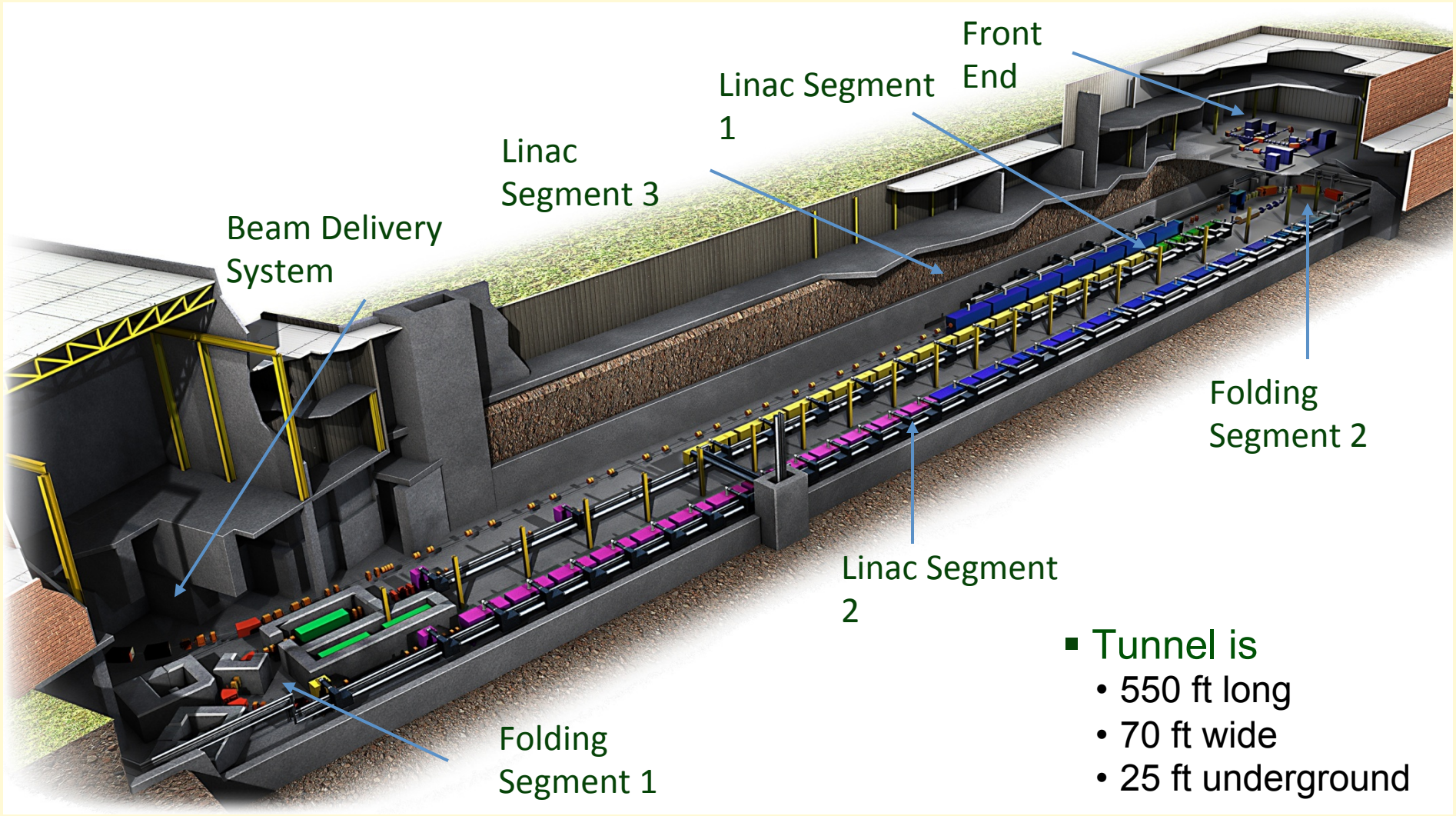
Overview of the FRIB Facility



FRIB Layout


Fast Beam Area
Gas Stopping
Stopped Beam Area
Reaccelerated Beam Area
Fragment Separator
Reaccelerator
200 feet
50 meters
Target
Beam Delivery System
Front End
Folding Segment 2
Linac Segment 3
Folding Segment 1
Linac Segment 2
Linac Segment 1

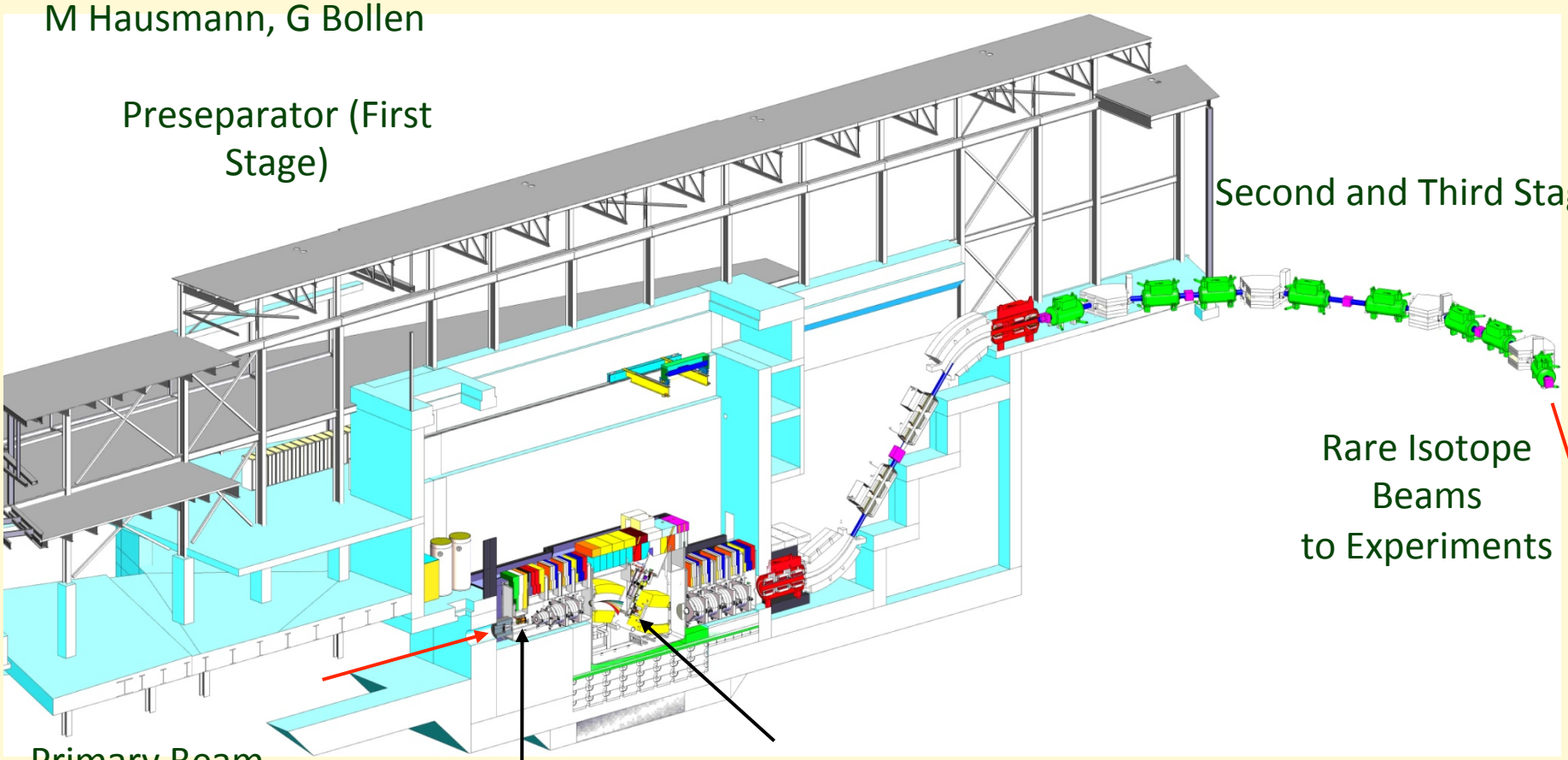
Driver Linear Accelerator



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

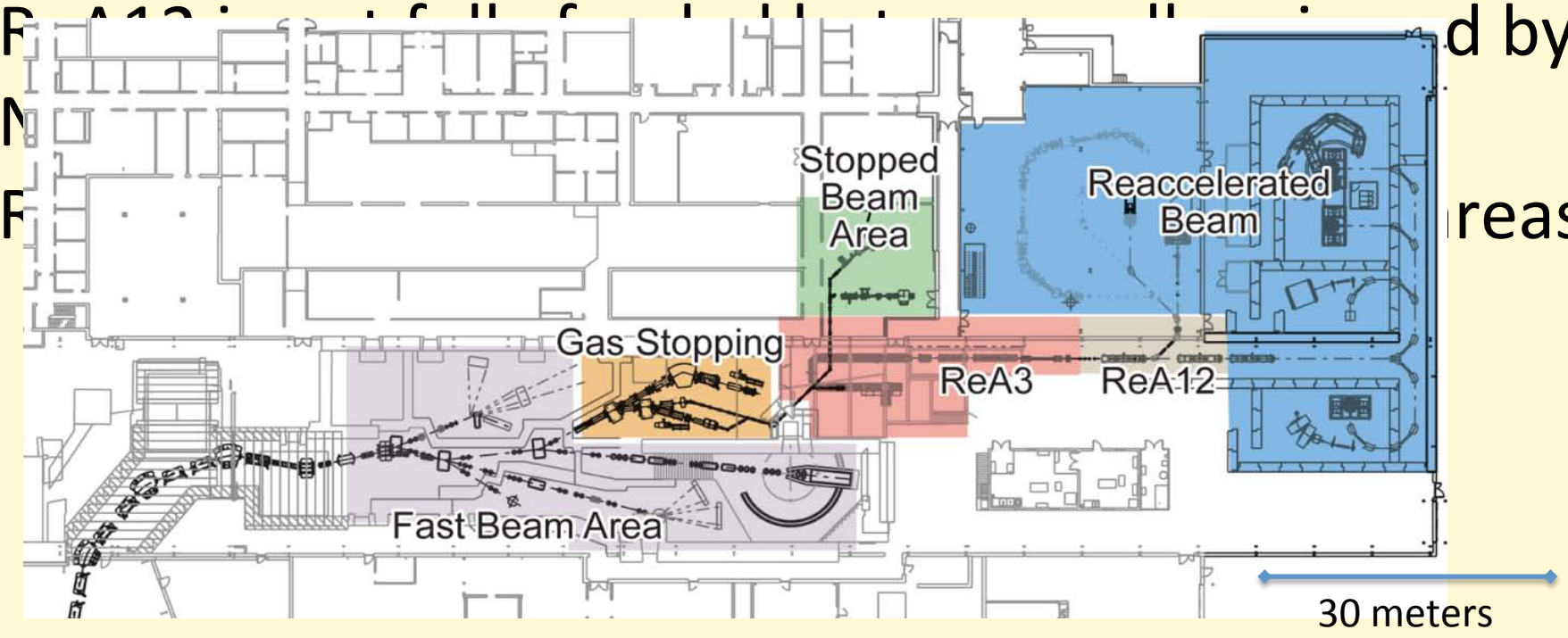
Isotope Production Area
Target and Fragment Separator

M Hausmann, G Bollen



Overview FRIB Reaccelerators, and Experimental Stations

- Fast, stopped, and reaccelerated beam capabilities (unique)
- ReA12 experimental hall is ready for occupancy
- R d by N
- F reas



Major new gamma ray detectors in the U.S.

GRETA = Gamma Ray Energy Tracking Array
GRETINA = smaller version of GRETA
GRETINA consists of 28 highly segmented hyper-pure germanium crystals.
Each crystal is segmented into 36 electrically isolated elements.

Gretina Website http://grfs1.lbl.gov/