ISOL TASK FORCE UPDATE TO NSAC

Hermann Grunder, Jefferson Lab
Richard Boyd, Ohio State University

April 30, 1999

ISOL PRESENTATION TO NSAC

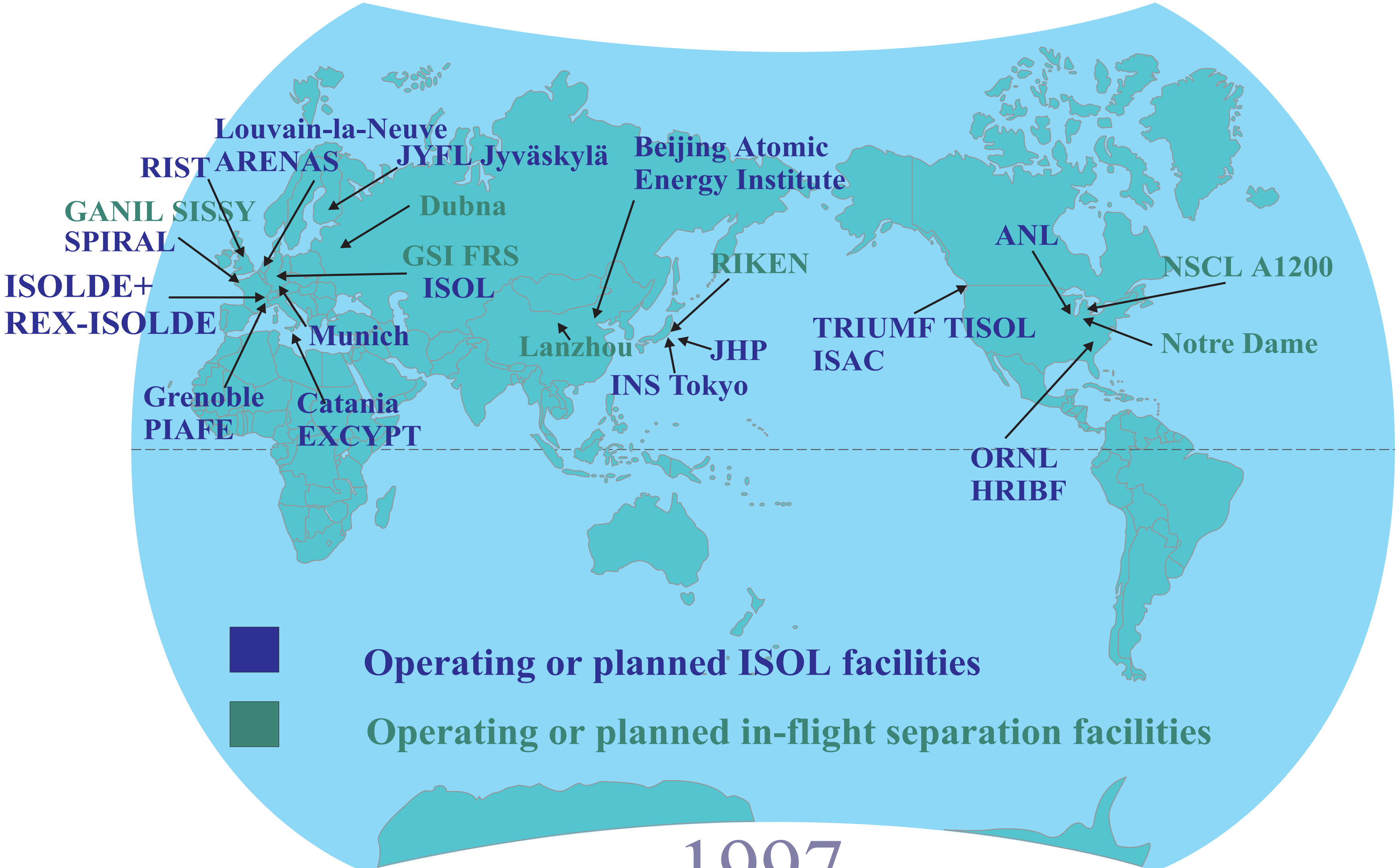
1996 DOE/NSAC Long Range Plan

"The scientific opportunities made available by world-class radioactive beams are extremely compelling and merit very high priority. The U.S. is well-positioned for a leadership role in this important area; accordingly

- We strongly recommend the immediate upgrade of the MSU facility to provide intense beams of radioactive nuclei via fragmentation.

- We strongly recommend development of a cost-effective plan for a next generation ISOL-type facility and its construction when RHIC construction is substantially complete."

World Wide Radioactive Beam Facilities



1997

April 30, 1999

ISOL PRESENTATION TO NSAC

Charge to the Task Force

- On the basis of the scientific case provided by the November 1997 white paper "Scientific Opportunities with an Advanced ISOL Facility"
  - Assess the technical opportunities
  - Identify R&D needs
- Not a review of proposals
- April update to NSAC (today)
- Report in October 1999

Membership

- Jim Beene - ORNL
- Dick Boyd - Ohio St.
- Rick Casten - Yale
- Konrad Gelbke - MSU, NSAC
- Hermann Grunder - JLab, Chair
- Stan Kowalski - MIT
- Claude Lyneis - LBNL
- Jay Marx- LBNL
- Jerry Nolen - ANL
- Helge Ravn - CERN
- Paul Schmor - TRIUMF
- Brad Sherrill - MSU

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Consultants

- Juha Äystö - University of Jyväskylä
- Roger Bennett - Rutherford Lab
- Joe Bisognano - DOE
- Chip Britt - DOE
- Marik Dombsky - TRIUMF
- Charlie Landram - LLNL
- I-Y Lee - LBNL
- Guy Savard - ANL
- Will Talbert - Amparo
- Antonio Villari - GANIL
- Michiharu Wada - RIKEN
- Hermann Wollnik - U Giessen

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SCIENTIFIC MOTIVATION FOR THE PROPOSED ISOL RADIOACTIVE ION BEAM FACILITY

- Throughout the decades over which experiments in Nuclear Physics have been performed, we've been constrained to those nuclei very close to stability.

- NATURE, HOWEVER, HAS NEVER BEEN SO CONSTRAINED!

- It is hoped the PROPOSED (later, PREMIER) ISOL RADIOACTIVE ION BEAM FACILITY (PIRIBF) WILL CORRECT THIS IMBALANCE.

- ISOL = Isotope Separator On Line: the radioactive ion beam is produced, then stopped, then reaccelerated.

- RHIC is being built to study the conditions that haven't existed since the Big Bang.

- PIRIBF is proposed to study nuclei that haven't existed in our Galaxy since the last supernova.

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PHYSICS WITH RADIOACTIVE ION BEAMS

- THE PIRIBF MUST BE ABLE TO PRODUCE USEFUL BEAMS OF VERY SHORT-LIVED NUCLEI WITH HIGHER INTENSITY, FARTHER FROM STABILITY, THAN ANY OTHER FACILITY, EITHER EXISTING OR BEING CONSTRUCTED.

- GENERAL FEATURES
  - Many types of experiments exist; I_{BEAM} defines what can be done.
  - Far from stability, low I_{BEAM} is expected, but large detectors can compensate.
  - Even I_{BEAM} = 1 nucleus sec^{-1}, especially at neutron-rich side, might be very important.

- PROPERTIES
  - With PIRIBF, Production/stopping/ acceleration takes ~ 1 ms.
  - High beam quality can be achieved, since the post accelerator starts with thermalized ions.

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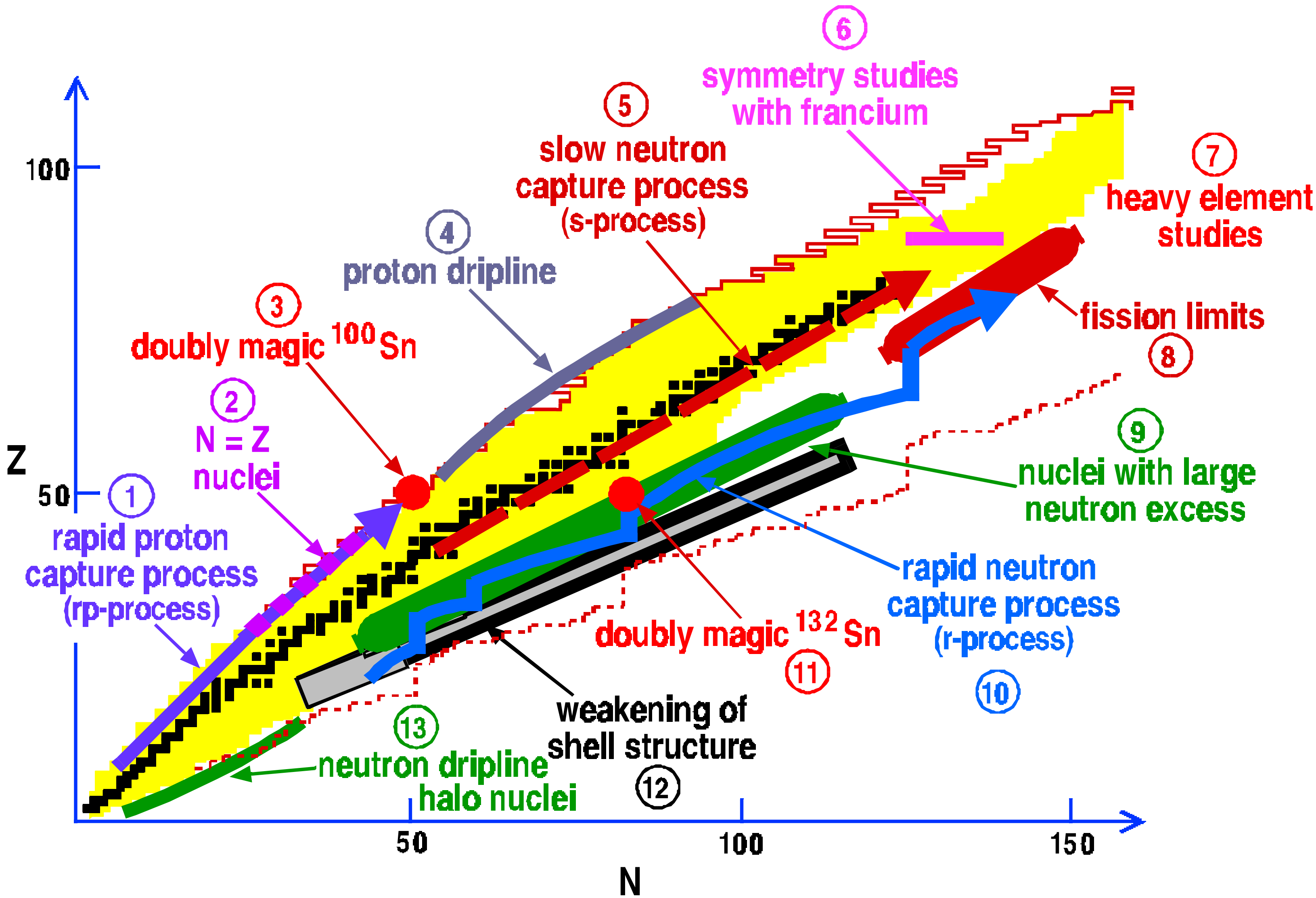

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MASS A < 20 u REGION

- NUCLEAR PHYSICS:
  - Nuclear Structure
  - Neutron Halos

- NUCLEAR ASTROPHYSICS
  - ♦ Hot CNO Cycle
  - Solar Neutrino Reactions

- These are all currently under intense study at RIB labs around the world; they should be in the "refinement" stage by the time the PIRIBF exists.

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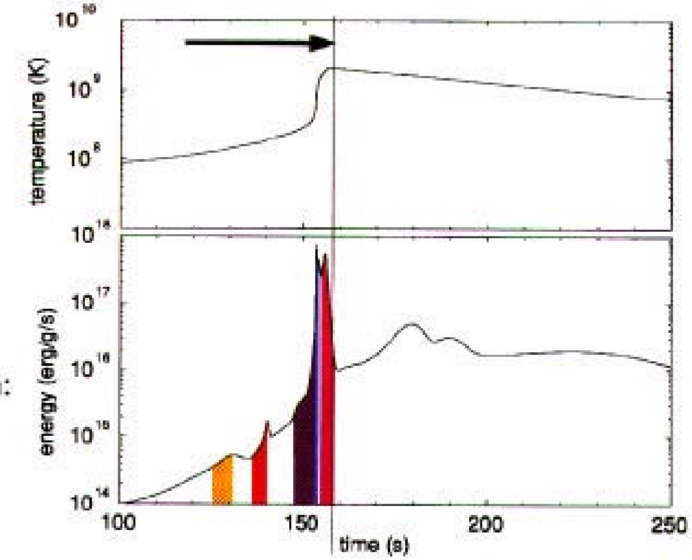
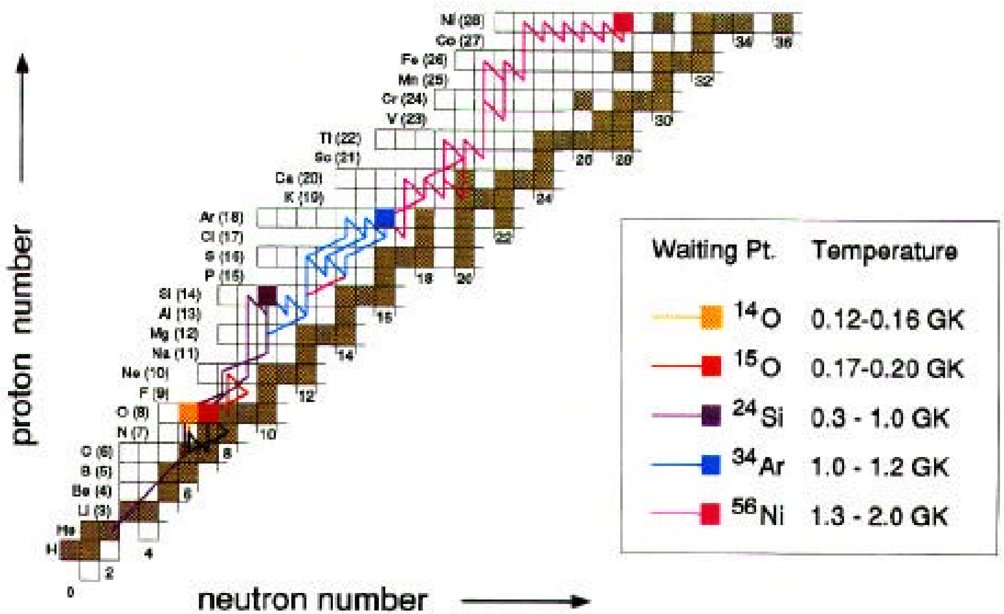
- temperature:
- energy production:





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MASS A = 21-60 u REGION

NUCLEAR PHYSICS

- **Nuclear Structure: Evolution of shell structure with neutron number (both p-**
  and n-rich sides, and through stability)
- ♦ **Neutron halos (n-rich side)**
- **The locations of the proton and neutron drip lines**
- **Nuclei beyond the drip lines (both p- and n-rich sides)**

NUCLEAR ASTROPHYSICS

- ♦ **rp-Process (p-rich side)**
- **Big bang nucleosynthesis (n-rich side)**
- **Much work of this *type* is being done, but key issues involving nuclei far from stability will remain for the PIRIBF.**

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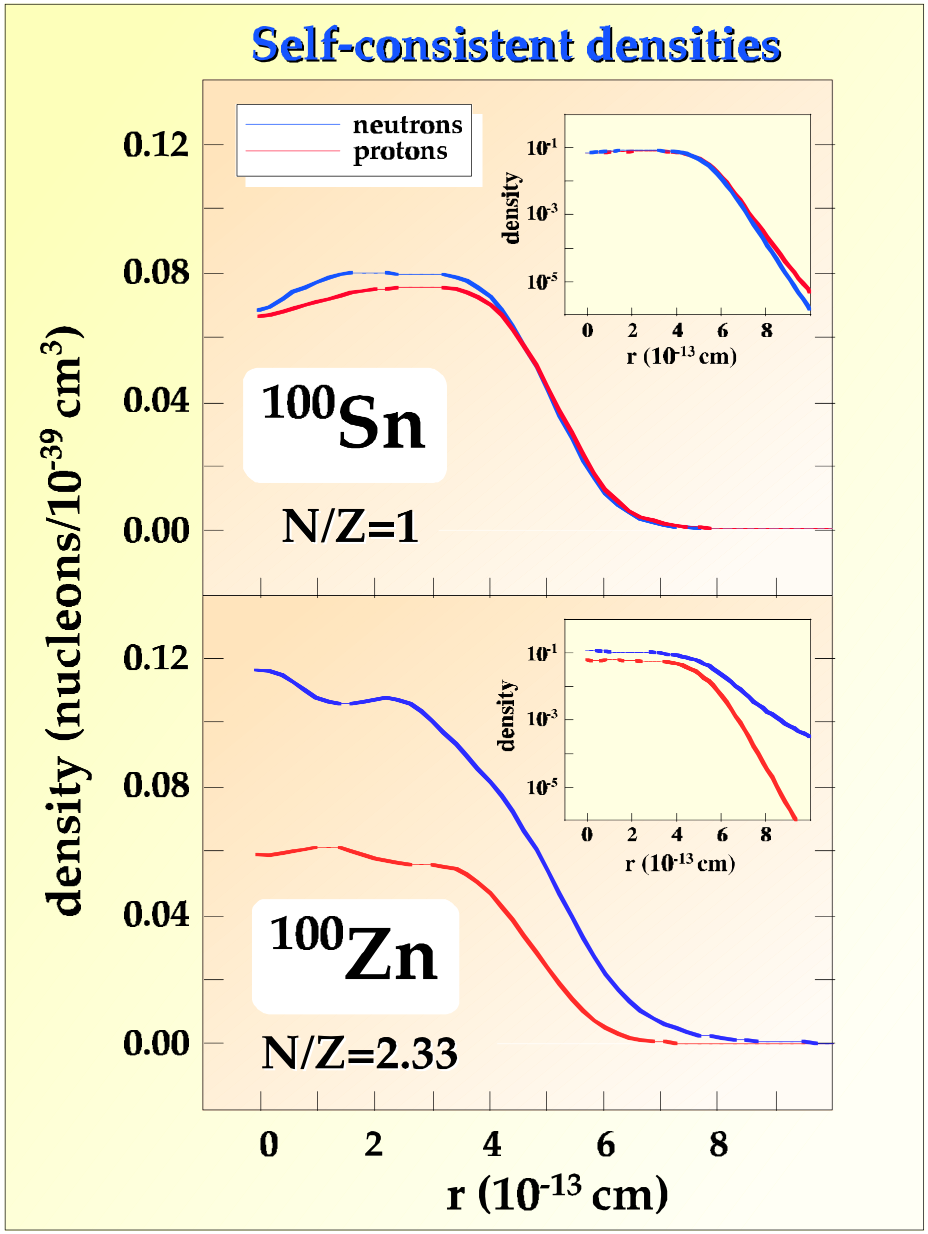

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MASS 61 < A < 120 u REGION

NUCLEAR PHYSICS

- **Evolution of structure with neutron number**
  - **Onset of deformation (p & n-rich sides)**
  - ♦ **Quenching of shell closures (n-rich side)**
  - **Nucleonic Cooper pairs (p-rich side) ^{100}Sn (and ^{132}Sn)^{48}Ni, ^{56}Ni, ^{68}Ni, ^{78}Ni, and beyond!**

NUCLEAR ASTROPHYSICS

- **Higher mass rp-process (p-rich side)**
  - **"Termination" point?**
  - **Two-proton captures**
  - **Repetitive rp-process; synthesis of ^{92,94}Mo)**
  - **Lower mass r-process (*very* n-rich side)**

FUNDAMENTAL SYMMETRIES

♦ **$0^+ \rightarrow 0^+$ β-decays and the CKM matrix (N = Z nuclei)**

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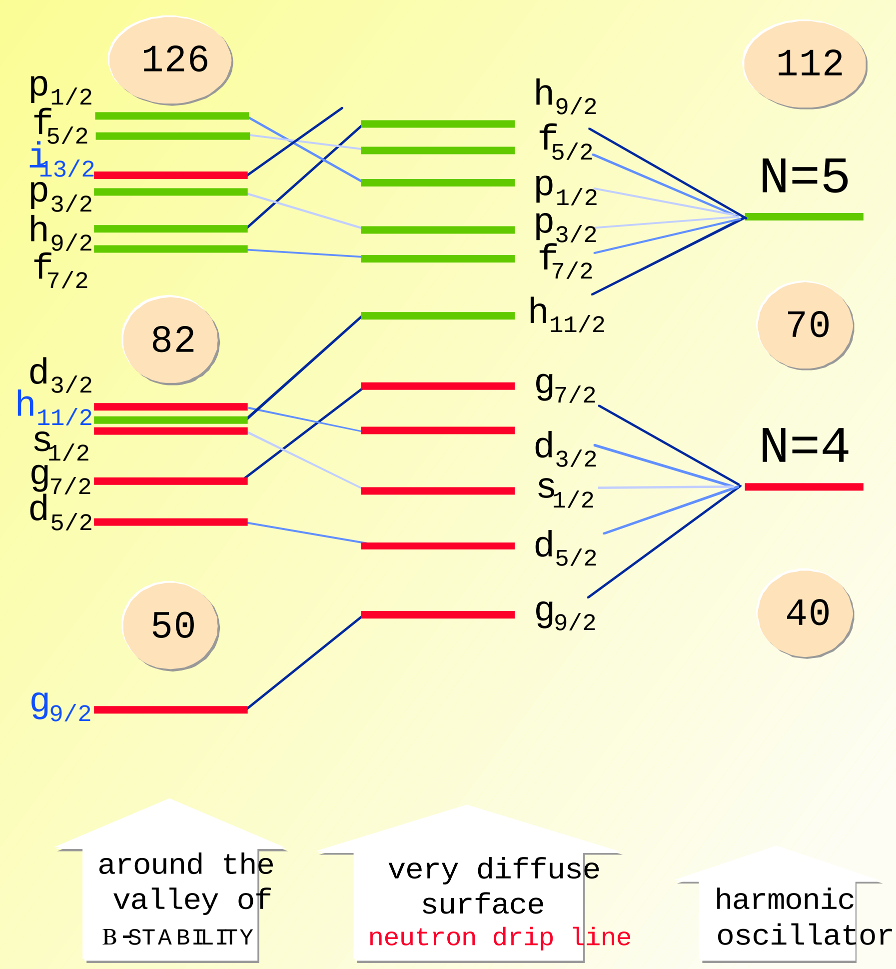
Nuclear Shell Structure



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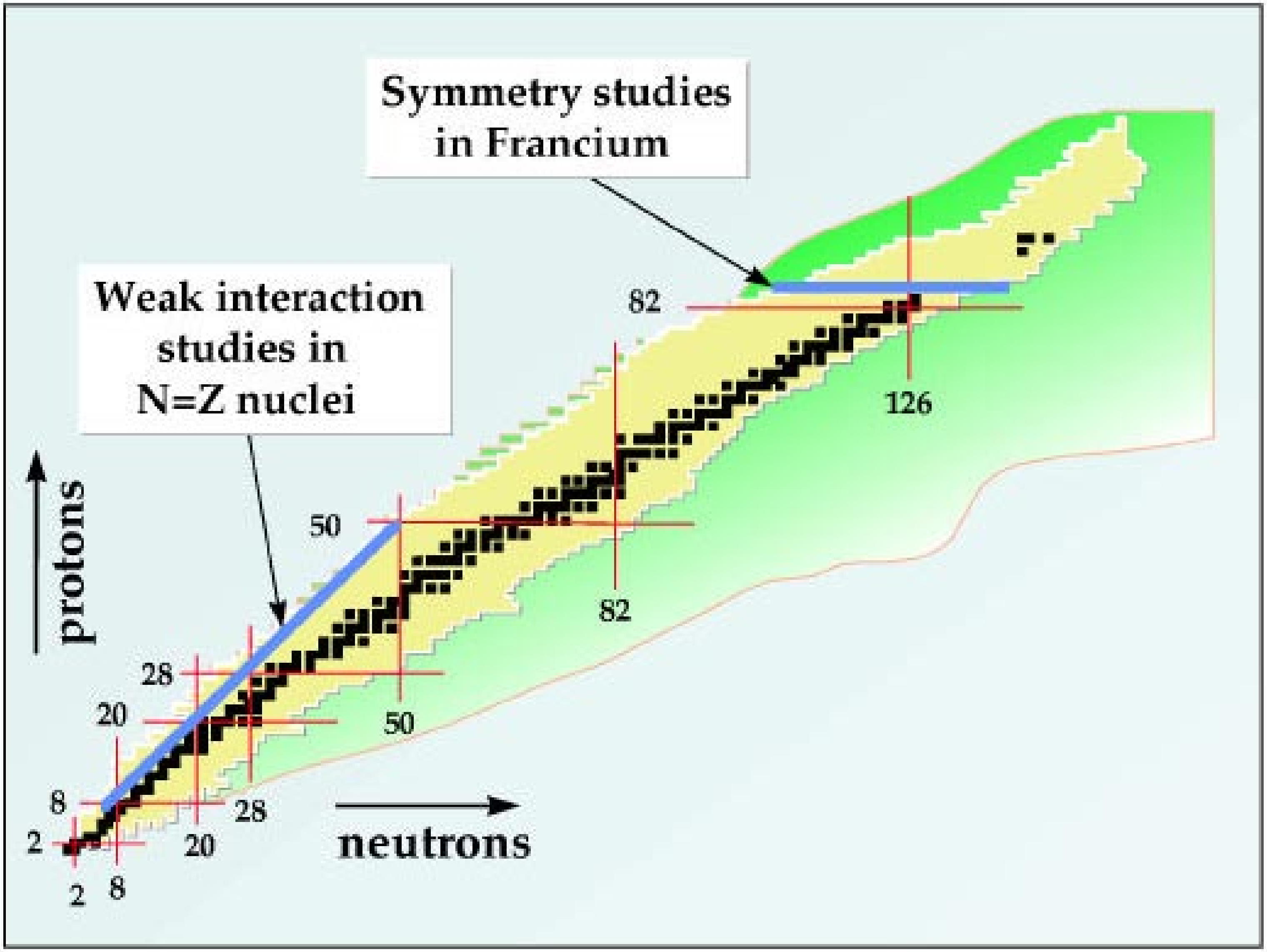

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MASS 121 u < A REGION

Nuclear Structure

- **Evolution of structure with N in *long* chains, p-rich to n-rich, through stability**
  - **Onset of deformation**
  - **Quenching of shell closures**
  - ♦ **Utilize N_pN_n approach**

Nuclear Astrophysics

- **r-process (n-rich side)**
  - **Study (n,γ) ↔ (γ,n) equilibrium**
  - ♦ **Half-lives at closed shells**
  - **Half-lives of isomers**

Fundamental Symmetries

- **Parity and time-reversal violations in Fr (p- and n-rich)**

Superheavies

- **Production via n-rich RIB on n-rich target?**

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CHALLENGES OF RADIOACTIVE BEAM EXPERIMENTS

1. **BEAM IS RADIOACTIVE**

- **$\rightarrow$ High Background**
- **Must control beam losses**
- **Detectors must have high count rate capability**

2. **BEAMS WILL BE LOW INTENSITY AND CROSS SECTIONS MAY BE SMALL**

- **$\rightarrow$ Low reaction rate**
- **Detectors must have high efficiency**
- **Detectors must have high selectivity--coincidences**

3. **EXPERIMENTS ARE OFTEN DONE IN INVERSE KINEMATICS**

- **$\rightarrow$ Large kinematic (Doppler) broadening**
- **Detectors must have high granularity**

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- Unanimous view of the Task Force:
  - The US Nuclear Physics Community can and needs to make a major contribution.

- What machine would be the best possible, limited only by Nature and the state of technology?

  - Paradigm shift
    - What does the best possible (final) machine look like?

→ – Uranium beam, 1 pμA ~ 200–400 MeV/u

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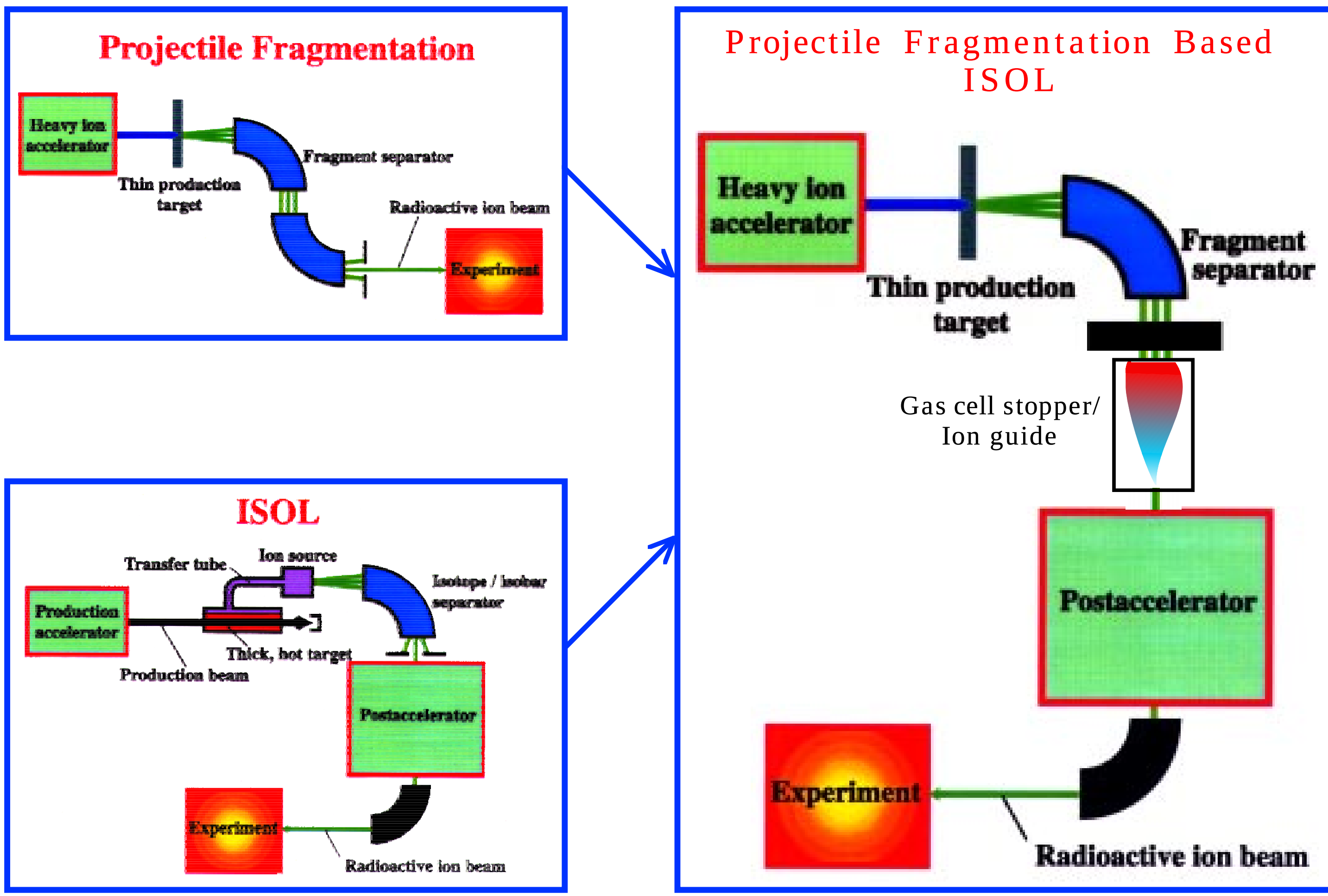
ANL-P-22,533

Projectile Fragmentation Based ISOL Concept with a Multiple Beam (Heavy Ion) Driver

- Fast Extraction Times (~msec)
- Chemical independence
- Isobar separation



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- Recognition:
  - Greatest scientific value and technical challenge is short-lived species (τ < 100 ms).
  - Next challenge is extraction efficiency for non-chemically-inert elements.

- Given the proper driver, projectile fragmentation into a gas catcher is the unique best method.
  - It directly bypasses the above difficulties.

- Exploiting this method extends the reach of this facility
  - 2–5 isotopes farther in neutron-rich direction
  - 1–2 isotopes farther in proton -rich direction

- The fundamentals of the technologies needed have been demonstrated–no showstoppers, but serious R&D must be undertaken.

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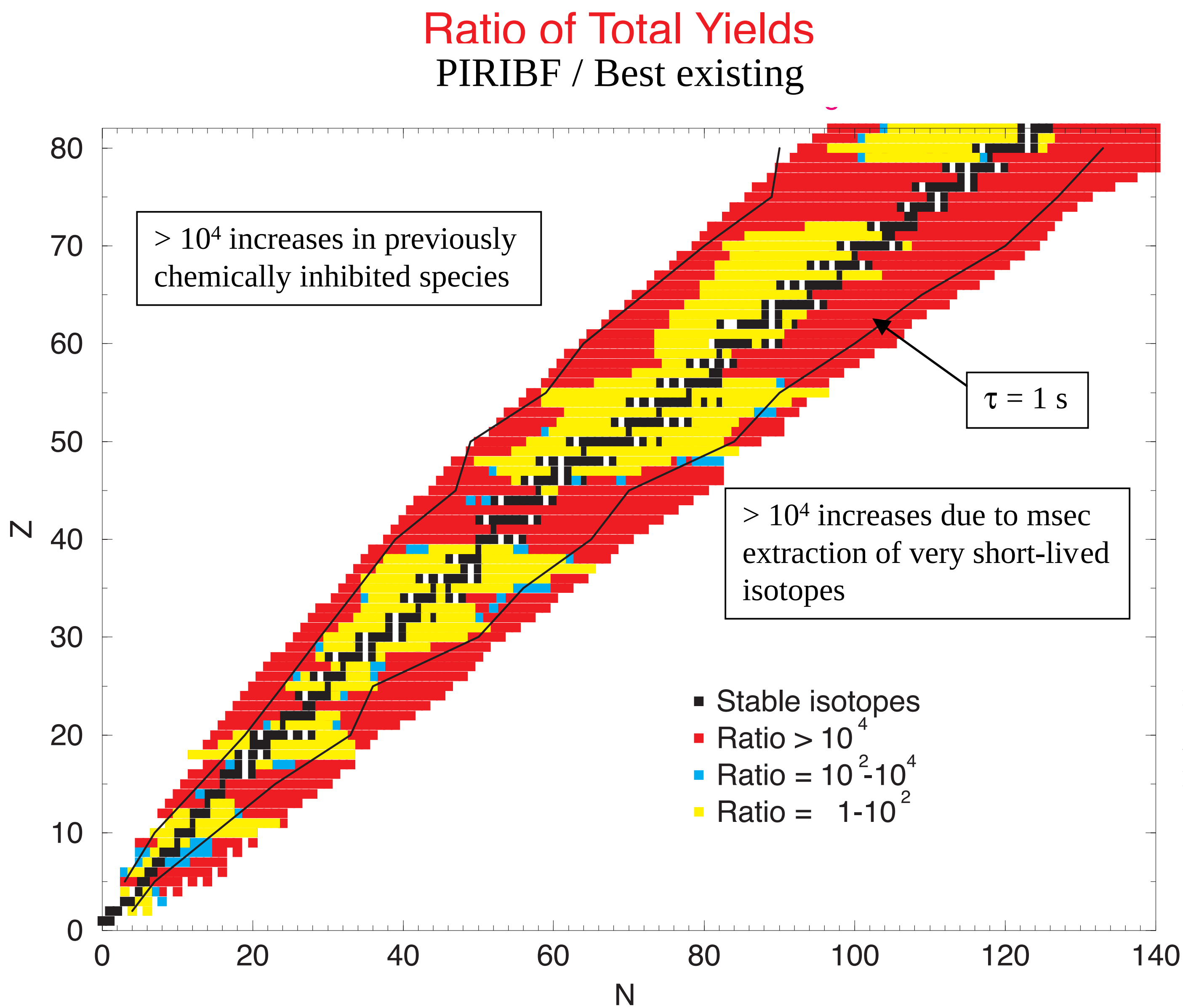

Includes extrapolation from ISOLDE to ISAC-2 as "existing".

Figure courtesy of ANL

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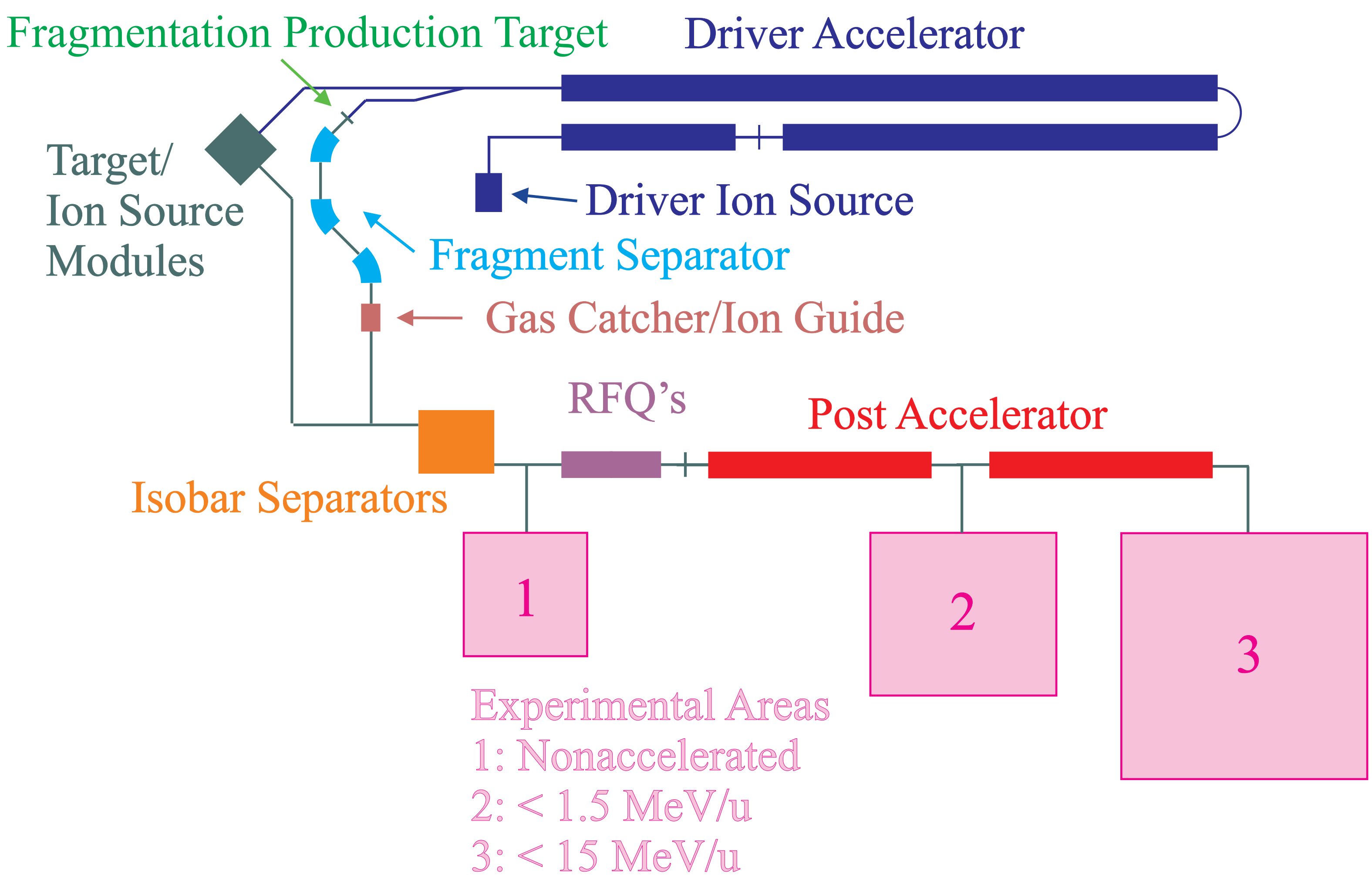
Simplified Schematic Layout of a PIRIB Facility



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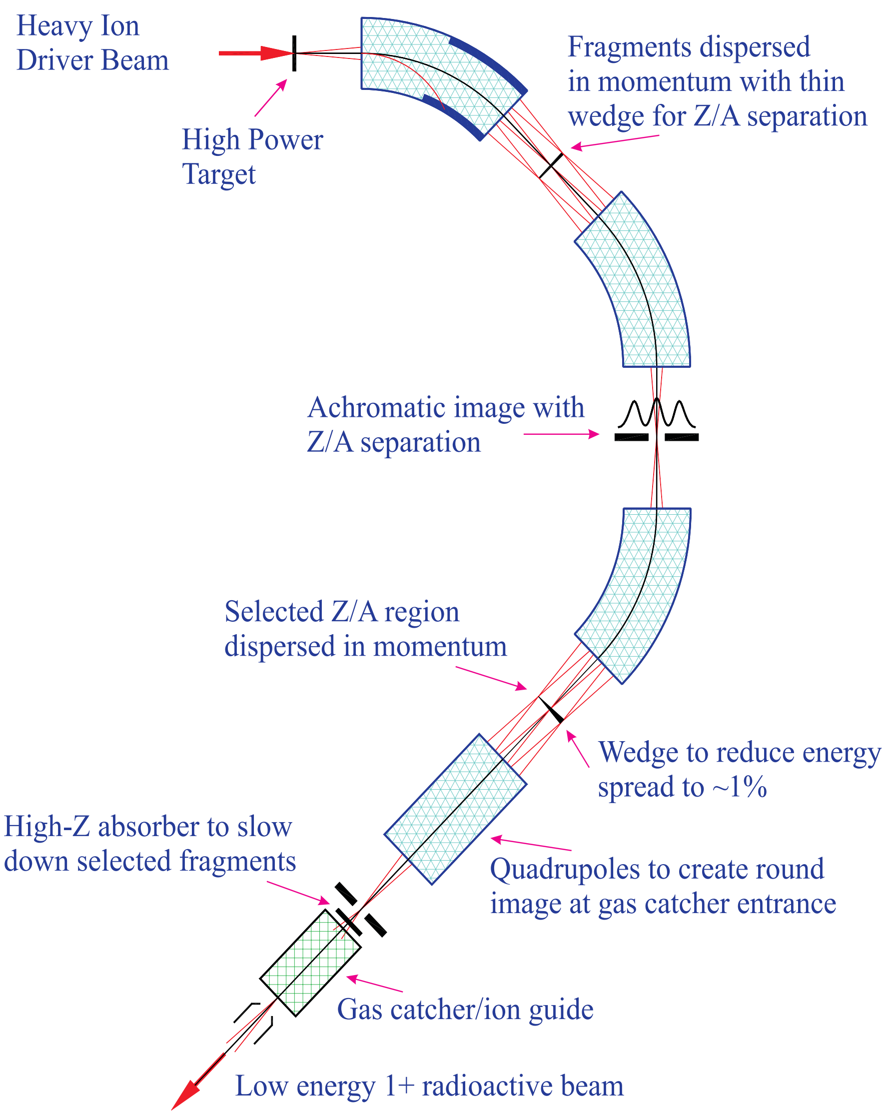
Schematic Layout of Fragment Separator and Gas Catcher



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Yields for Proposed ISOL Radioactive Ion Beam Facility

From a Muitibeam Driver, Mass Separated Intensities (ions/s)

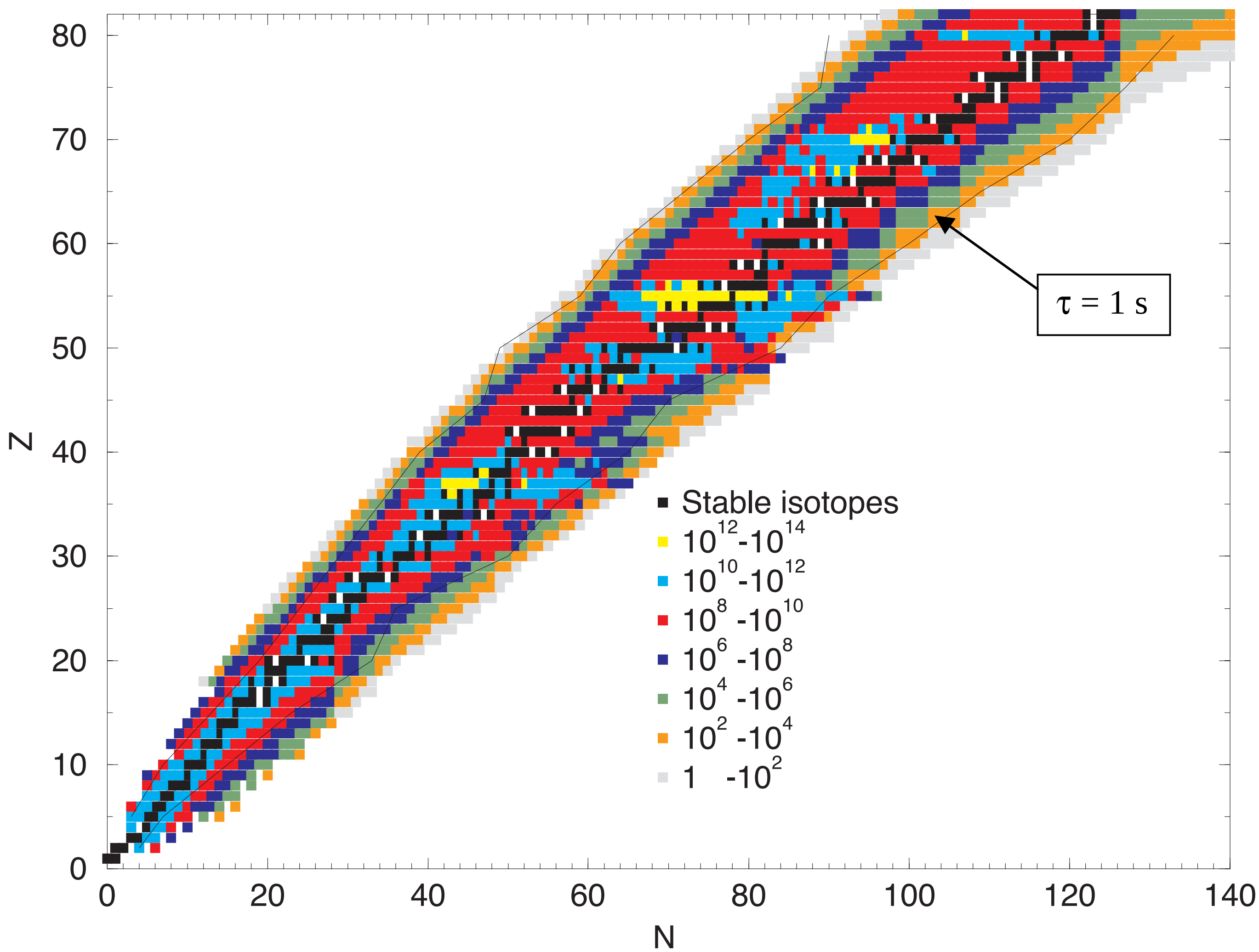

Figure courtesy of ANL

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R&D Topics (exclusive of Accelerator R&D)

- Targets
  - spot size (< 5mm) for heavy-ion fragmentation targets
  - release efficiency for light-ion drivers
  - power handling capability
- Gas stopping
  - capture efficiency
  - transport properties of the gas catcher as a function of beam intensity (plasma formation). Where does it break down?
  - molecular species analysis in the gas catcher and its affect on yields (chemistry)
  - [Present European effort ~30 FTE (EXOTRAPS), Japanese ~ 5 FTE]
- Laser ion sources
- Fragment separator
  - how large an acceptance is realistic?
  - is it possible to extract multiple beams?
- Production cross section measurements (there are many unknowns)
  - GSI - learn from experiments presently underway
  - CERN - (motivated by Rubia's energy amplifier) may be some new measurements
- Detector instrumentation
  - Subject of recent workshop
  - Stoke active community participation in existing ISOL efforts
- Continue building the technical experience base

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Accelerator R&D

- Driver
  - High charge state ion source
    - Up to Uranium at 1 pμA
  - Superconducting low-beta structures
    - Push the gradient for maximum efficiency
  - Prepare concept, preliminary design
    - Consider construction phasing options
- Post accelerator
  - Transverse focusing [350 T-m required?]

Prepare a CDR

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Summary

- Exciting physics outlined in the white paper
- A “final” facility can be envisioned
  - Phasing options to be determined
- No technical showstoppers
  - R&D essential
- Next steps
  - Develop concept, preliminary design, Conceptual Design Report
- Final Report of Task Force, October 1999