ISOL Task Force Report to NSAC

Hermann Grunder, Jefferson Lab

November 22, 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."

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
- Final Report

ISOL Task Force

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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- Activities and meeting topics
  - In 1998:
    - October 30, Santa Fe—organization
    - November 16, ANL—context, required beam specifications, key issues
    - December 14–16, ANL/Oak Ridge/Knoxville—site visits, beam specifications
  - In 1999:
    - January 23–24, JLab—physics, experimental equipment, target challenges
    - February 21–22, TRIUMF—site visit, radiation, yields
    - March 25–26, Atlanta—yields, IGISOL method, vision shift
    - April 23, Washington, D.C.—interim report to NSAC
    - June 24–25, MSU—system capability, driver specifications
    - August 11–13, ANL—driver workshop
    - September 21, Washington, D.C.—driver performance and cost analysis
    - October 5, Chicago—report refinement

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Driver Working Group

Gerald Alton—Oak Ridge National Laboratory
Joe Bisognano—DOE, Jefferson Lab
Jean Delayen—Jefferson Lab
Stanley Kowalski—Massachusetts Institute of Technology
Y. Y. Lee—Brookhaven National Laboratory
Christoph Leemann—Jefferson Lab, *chair*
Claude Lyneis—Lawrence Berkeley National Laboratory
Jerry Nolen—Argonne National Laboratory
Charles Reece—Jefferson Lab
Ken Shepard—Argonne National Laboratory
Brad Sherrill—Michigan State University
John Staples—Lawrence Berkeley National Laboratory
Richard York—Michigan State University
Bill Weng— Brookhaven National Laboratory

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Consultants

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Tony Chargin*—Lawrence Livermore National Laboratory
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Geoff Pile*— Argonne National Laboratory, APS
Claus Rode*—Jefferson Lab
Guy Savard—Argonne National Laboratory
Bill Schneider*—Jefferson Lab
Will Talbert—Amparo
John Vincent*— Michigan State University
Antonio Villari—GANIL
Michiharu Wada—RIKEN
Hermann Wollnik—University of Giessen

* Member of driver costing team

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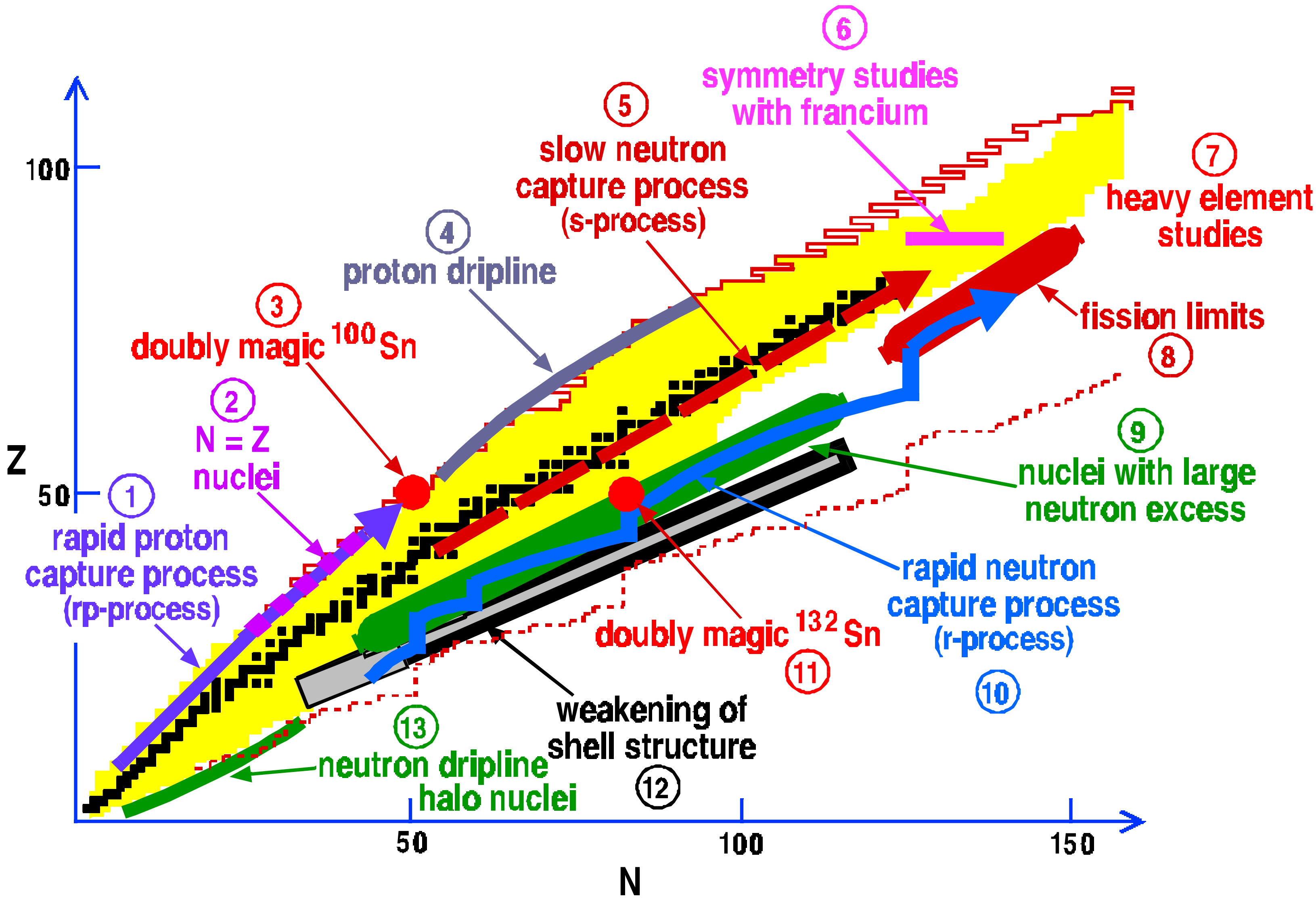

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- Unanimous view of the Task Force:
  - The US Nuclear Physics Community can and needs to make a major contribution.

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

  - **One with great flexibility: RIA**
    - Driver beam is selectable: p – U
      - Capable of 1 pμA, 400 MeV/u uranium
    - Target styles are varied
      - Classic ISOL, two-step ISOL, isobar-separated IGISOL
    - Detector end stations are versatile

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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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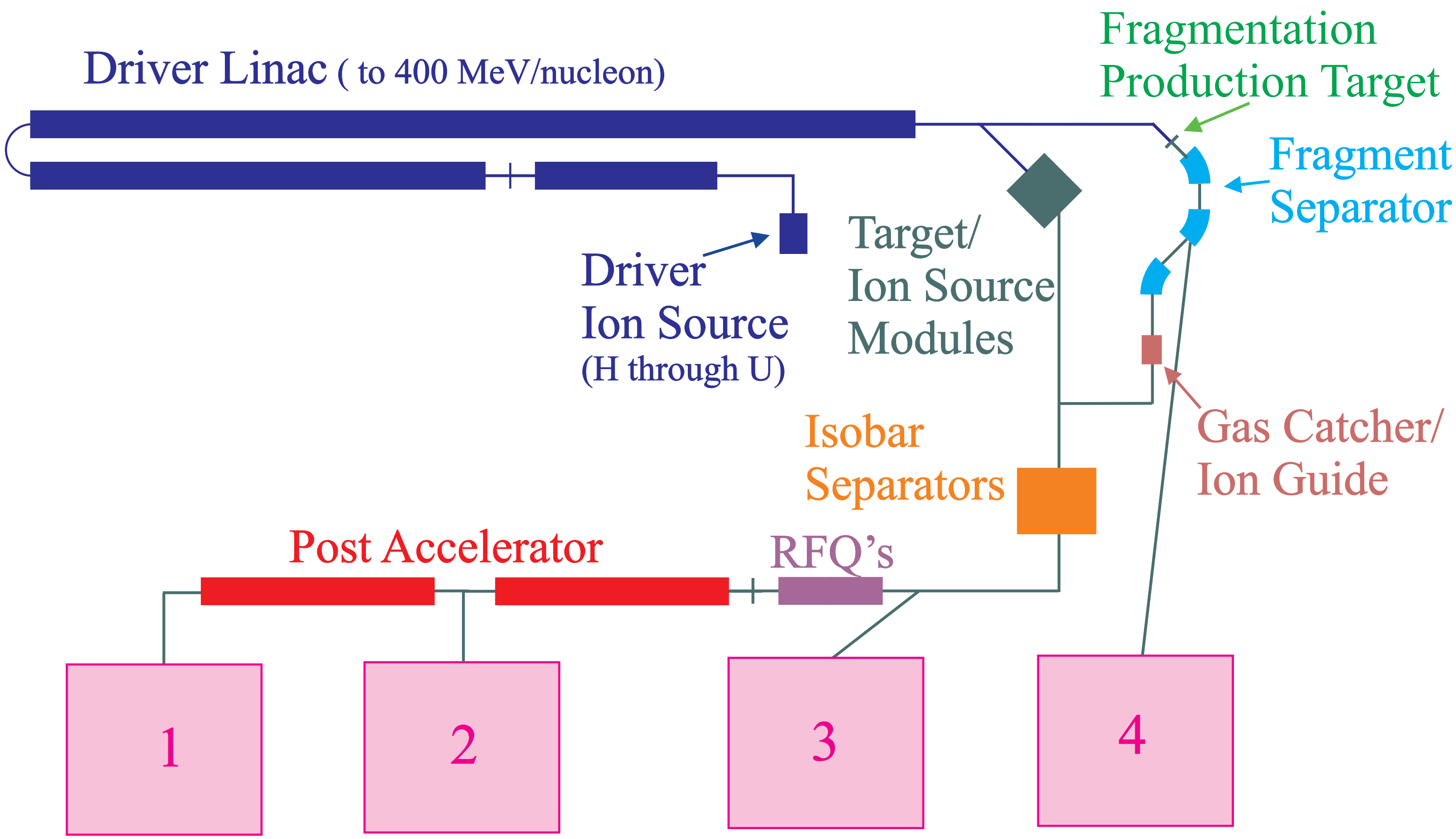
Simplified Schematic Layout of the Rare Isotope Accelerator (RIA) Facility



Experimental Areas:
1: < 12 MeV/u   2: < 1.5 MeV/u   3: Nonaccelerated   4: In-flight fragments

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Isotopic Yields for RIA

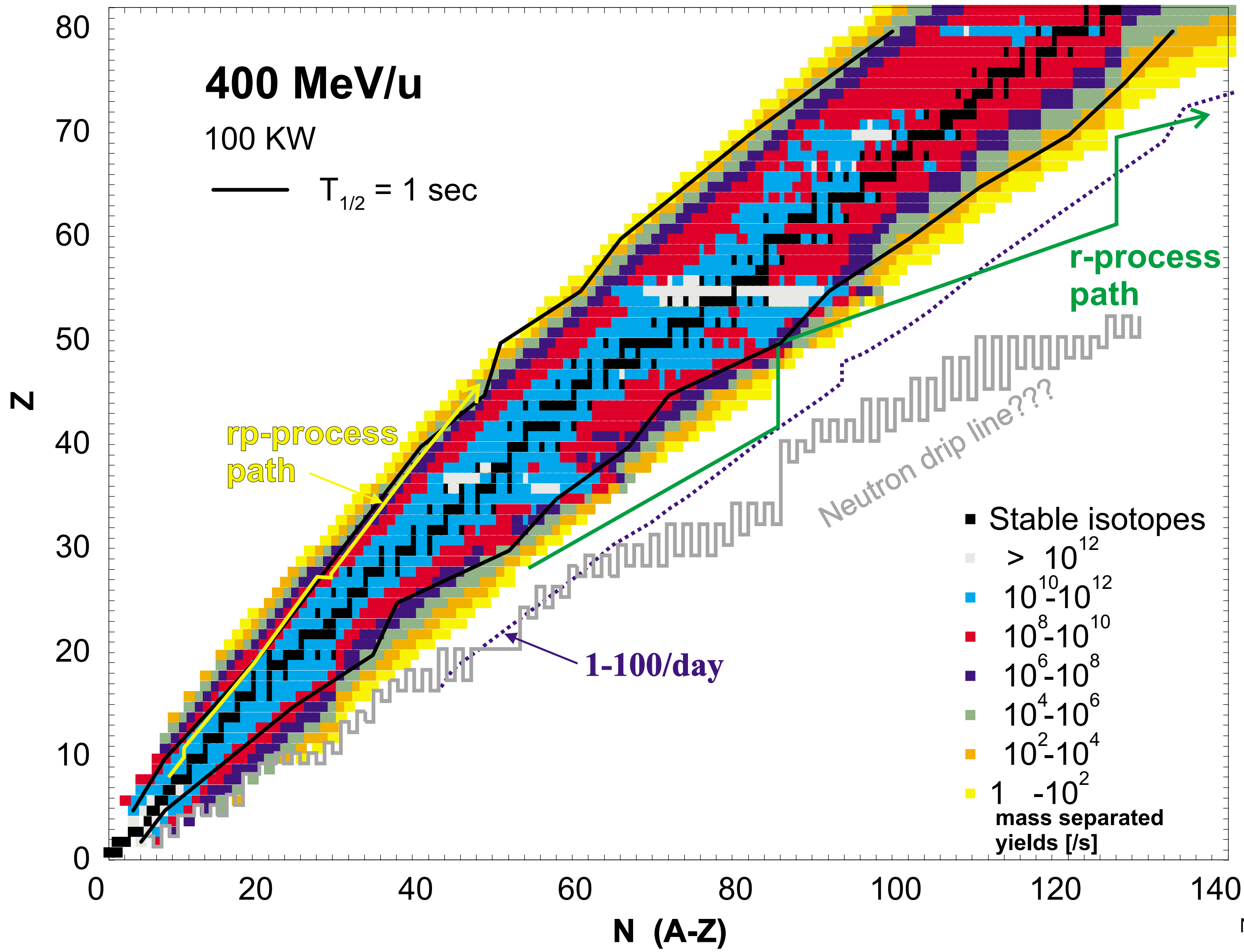

Figure courtesy of ANL

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Driver Accelerator System Description

- The focused RIA Driver Working Group studied various design schemes and found:
    - The RIA driver requirements can be most effectively met in a linac design by employing state-of-the-art accelerator technology, including electron cyclotron resonance (ECR) sources, radio-frequency quadrupoles (RFQ), interdigital H-type (IH) structures, SRF accelerating cavities, and superconducting (SC) solenoids.
    - 400 kW beam power could be available for most beams immediately, and for the heaviest ions following appropriate ion-source development.
    - The rf and cryogenic systems will meet the requirements for reliability.
    - Modest accelerator system design studies have already yielded significant cost-reduction steps.
    - Because of high leverage on civil construction design and costs, there may be significant advantage to completion of nominal cryomodule design (implying key element prototyping) early in the planning process.

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Accelerating Elements of the Benchmark RIA Driver Linac

Section	Element	Beta = *v/c*	Frequency (MHz)	Temp. (K)	# Elements	Voltage (MV)
Source	***ECR***	***(Ions up to uranium at 30+)***				
Injector	RFQ	0.004–0.017	58.3	293	1	1.2
Injector	IH	0.017–0.05	58.3	293	4	9
Injector	4-gap	0.05–0.09	58.3	4.5	24	21
Injector	2-gap	0.09–0.16	116.6	4.5	57	71
1st Stripper	***Stripper***	***(Lithium film or carbon wheel)***				
Midsection	2-gap	0.16–0.3	175	4.5	72	111
Midsection	2-gap	0.3–0.4	350	4.5	96	150
2nd Stripper	***Stripper***	***(Carbon wheel)***				
Endsection	6-cell	0.4–0.54	700	2	60	261
Endsection	6-cell	0.54–0.8	700	2	96	684

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Projected Driver Output Beams

A/Z	*I* source (pμA)	Q_{inject}	Q_{strip1}	Q_{strip2}	*I* out (pμA)	Beam Energy (MeV/u) 1st Strip	2nd Strip	Output	Power (kW)
1/1	548	1	1	1	548	51	228	731	400
3/2	218	2	2	2	218	40	173	612	400
2/1	379	1	1	1	379	33	140	528	400
18/8	54	6	8	8	45	26	125	491	400
40/8	24	11	18	18	20	22	125	494	400
86/36	10	17	35*	36	8.5	18	113	460	336
136/54	5	25	50*	54*	3.4	17	104	445	206
238/92	1.5	30	74.5*	90*	1.0	12	87	403	100

* Indicates multiple charge states.

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R&D Topics

- Gas stopping
  - capture efficiency
  - transport properties of the gas catcher as a function of beam intensity (plasma formation).
  - molecular species analysis in the gas catcher and its affect on yields (chemistry)
- Fragment separator
  - momentum compression
  - use of radiation-hardened materials
- Targets
  - release efficiency for light-ion drivers
  - liquid lithium
  - power handling capability
- Prototyping superconducting structures
  - push the gradient for maximum efficiency
  - develop optimum rf control scheme
- High-charge-state ECR ion source
  - up to uranium at 2 pμA
- Detector instrumentation
  - subject of recent workshop

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Recommendations

- The RIA facility can be built based on modest extrapolations of existing technologies. No technical showstoppers exist, and only a relatively modest amount of R&D must be completed before a comprehensive conceptual design can be prepared. With construction beginning in FY 2002, the facility could be ready to begin operations in FY 2007. In support of this goal, the Task Force recommends:

  1. The design and construction of a Rare-Isotope Accelerator (RIA) facility that provides unprecedented beams of a diverse assortment of nuclei. The scientific potential of the RIA facility will be maximized by integrating multiple techniques for producing and separating, then accelerating and utilizing, these rare isotopes. RIA will be based on a highly flexible superconducting linac driver capable of providing 100 kW, 400 MeV/nucleon beams of any stable isotope from hydrogen to uranium.

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Recommendations (cont.)

2. That an additional important opportunity be provided: fast in-flight separated beams of rare isotopes. This will extend the scientific reach of the RIA facility. We recommend that the RIA design accommodate this capability, and that the capability be implemented at the earliest possible time.

3. Complete preconstruction R&D on key elements of the sources, targets, driver linac, and experimental equipment. Specific systems where R&D will provide opportunities for cost reduction and enhanced performance are identified later in the report. Significant efforts from several national laboratories will be needed to complete the preconstruction R&D, to develop a comprehensive conceptual design report (CDR), and to construct RIA.

4. Timely commissioning of a CDR to prepare the project for construction start in FY2002. Strong coordinating leadership is required. It will be vital for DOE to ensure continuity of the CDR team in the construction of RIA.

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Recommendations (cont.)

5. In addition, the Task Force notes that in the next phase, the diverse user community must increasingly participate in the evolution and execution of RIA planning to ensure a successful RIA facility that best serves forefront research.

Specifically, a preconceptual design report should be undertaken by competent particpants from universities and national laboratories under qualified leadership, leaving the site open.

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Summary

- Exciting physics has been outlined
  - "Scientific Opportunities with an Advanced ISOL Facility" (November 1997 white paper)

- A world-leading facility can be constructed for $500 million

- No technical showstoppers
  - R&D essential

- Next step
  - Develop Preconceptual Design Report