Status of Radioactive Ion Beams at the HRIBF

Transfer Reactions Workshop

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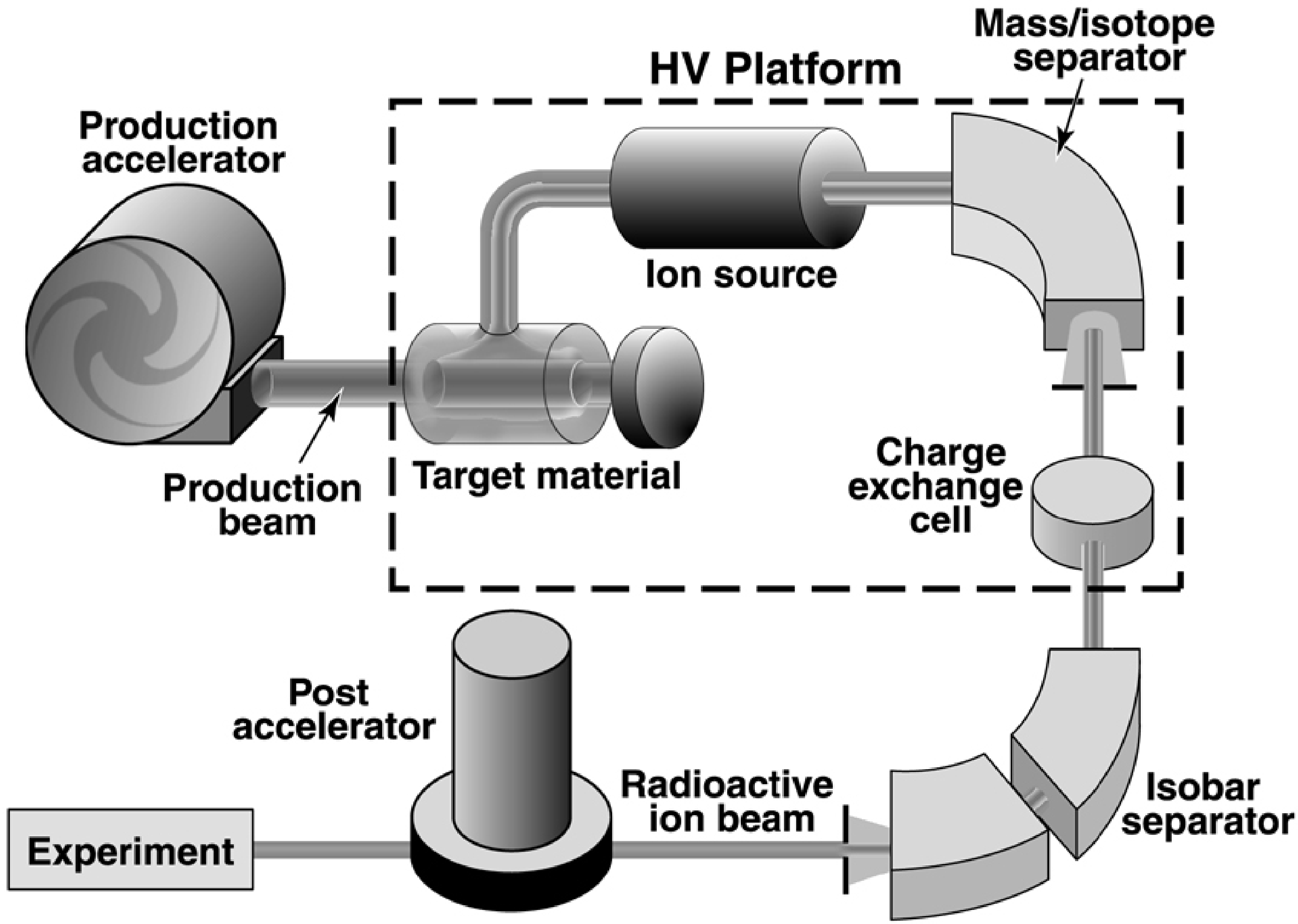
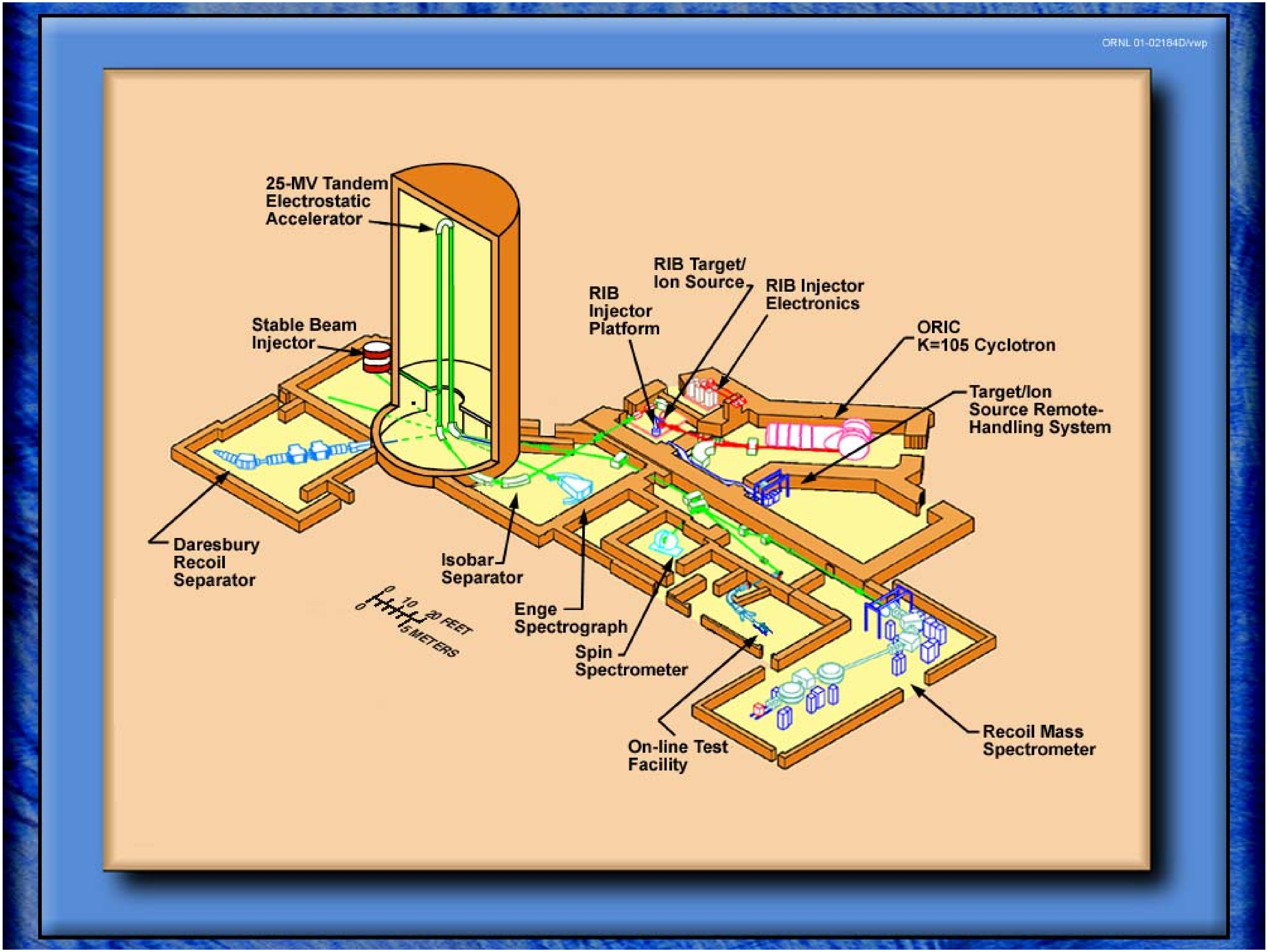
HRIBF, Oak Ridge, TN

Dan Stracener
Physics Division, ORNL

The HRIBF: an ISOL RIB facility





ORNL 01-02184D/vwp
25-MV Tandem Electrostatic Accelerator
RIB Target/ Ion Source
RIB Injector Electronics
RIB Injector Platform
Stable Beam Injector
ORIC K=105 Cyclotron
Target/Ion Source Remote-Handling System
Daresbury Recoil Separator
Isobar Separator
0 10 20 FEET
0 5 METERS
Enge Spectrograph
Spin Spectrometer
On-line Test Facility
Recoil Mass Spectrometer

Ion Sources used for RIB Production

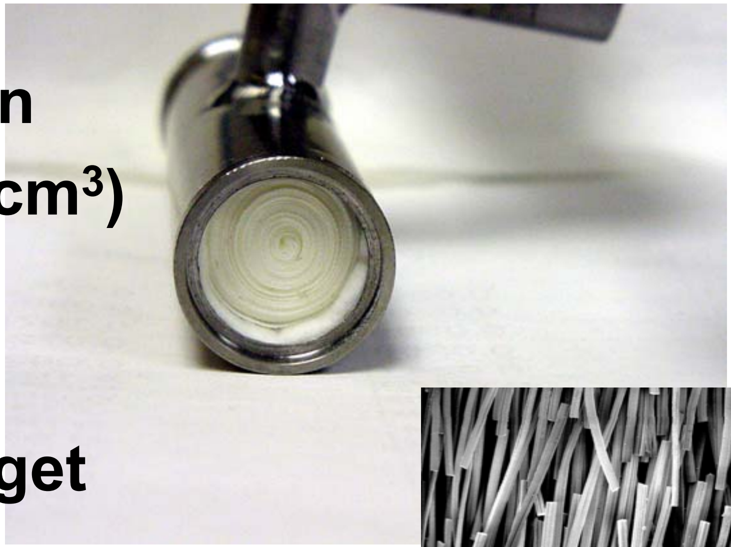
- **Electron Beam Plasma Ion Source**
  - High positive ionization efficiency for many elements
  - >1000 hrs (5000 μAh) mean lifetime in beam
- **Kinetic Ejection Negative Ion Source**
  - Used for production of $^{17,18}F$ beams
  - >1200 hrs (3000 μAh) mean lifetime in beam
- **Negative Surface Ionization (LaB_6 surface)**
  - Specific for Group VIIA elements
  - High efficiency and good emittance
- **Batch-mode Cs-sputter Negative Ion Source**
  - On-line production of long-lived nuclei (e.g. ^{56}Ni)

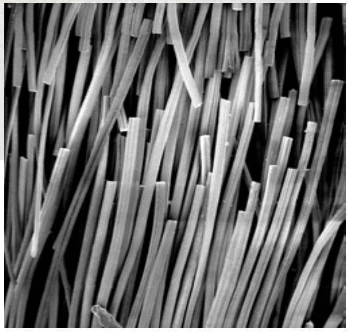
RIB Production Targets

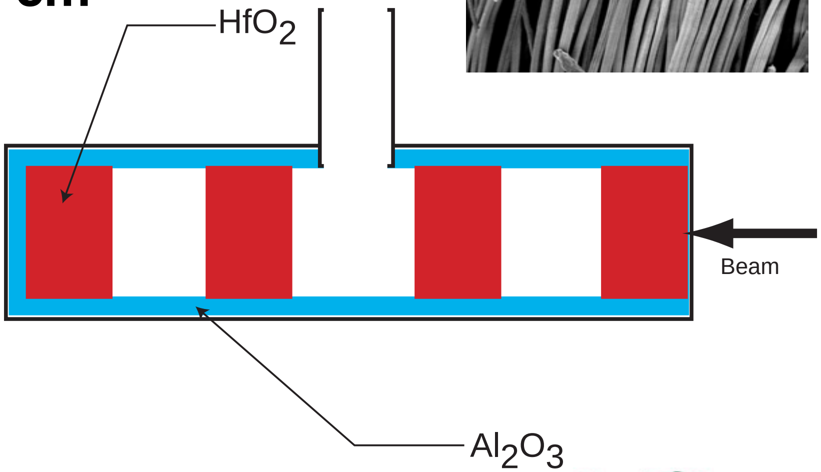
- **HfO$_2$ fibers** (production of ^{17}F and ^{18}F)
- **Uranium Carbide** (production of n-rich beams)
- **Molten metals**
  - Germanium for production of As and Ga isotopes
  - Nickel for production of Cu isotopes
- **Ni pellets** (production of ^{56}Ni via (p,p2n) reaction)
- **Silicon Carbide** (production of ^{25}Al and ^{26}Al)
  - Fibers (15 μm) and powder (1 μm)
- **Cerium Sulfide** (production of ^{33}Cl and ^{34}Cl)
  - Thin layers deposited on W-coated carbon matrix
- **Pd powders** (production of p-rich Ag isotopes)

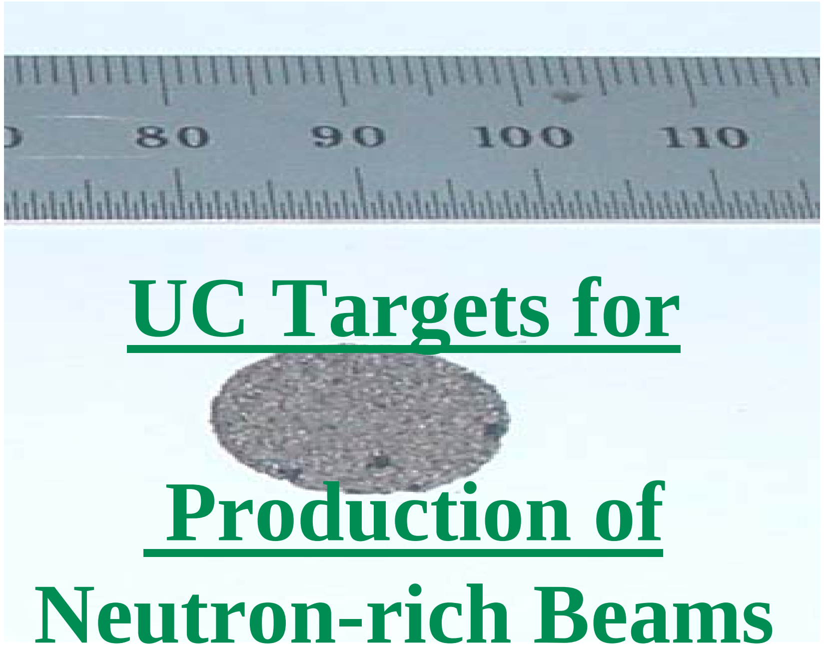
HfO_2 Fiber Target for Production of $^{17,18}F$ Beams

- Thin Fibers (5 μm) - fast diffusion
- High porosity (density is 1.15 g/cm^3)
- Refractory (m.p. is 2770 C)
- Free of volatile impurities
- 4 rolls of HfO_2 cloth used for target
  - 1.5 cm diameter x 1 cm thick each
  - Range of 42 MeV deuterons is 1.6 cm
- Al_2O_3 felt sheath
  - Provides aluminum vapor
  - Transported as AlF molecule

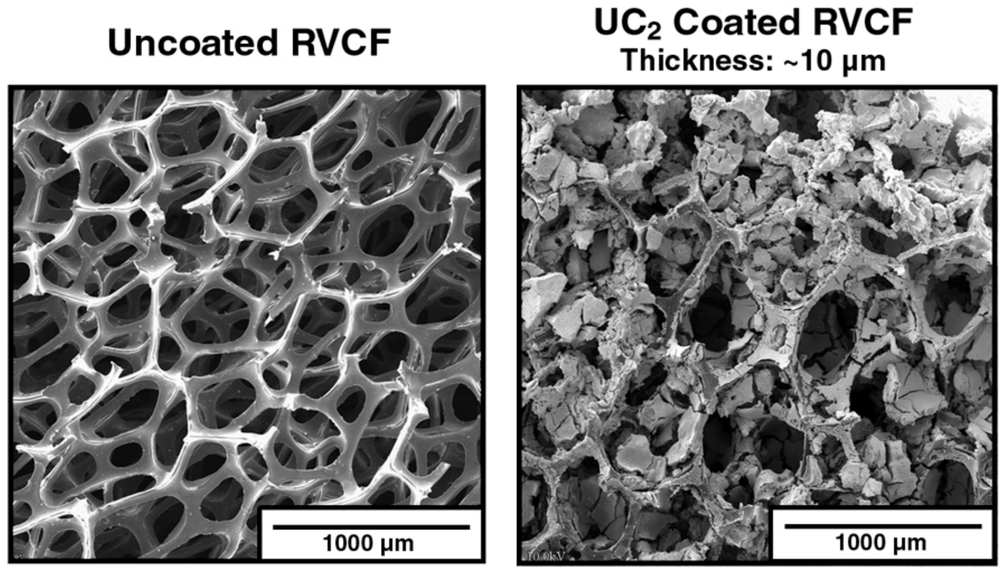




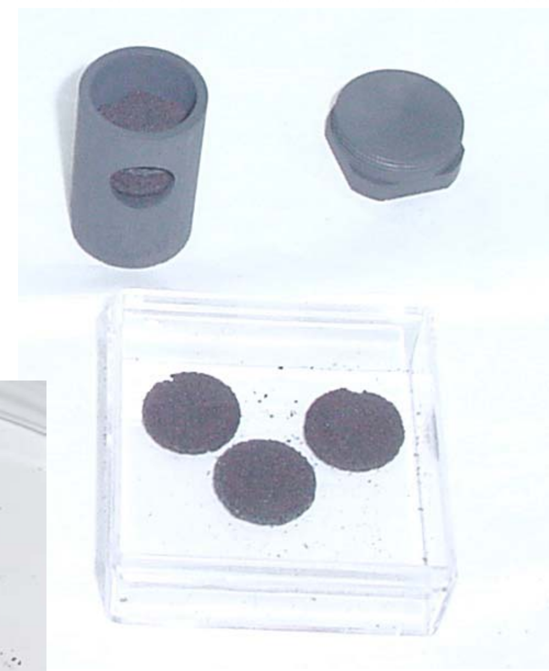


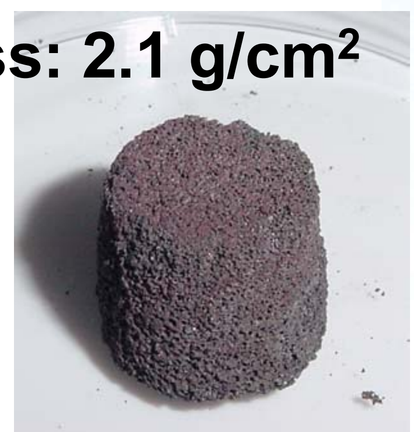


UC Targets for Production of Neutron-rich Beams

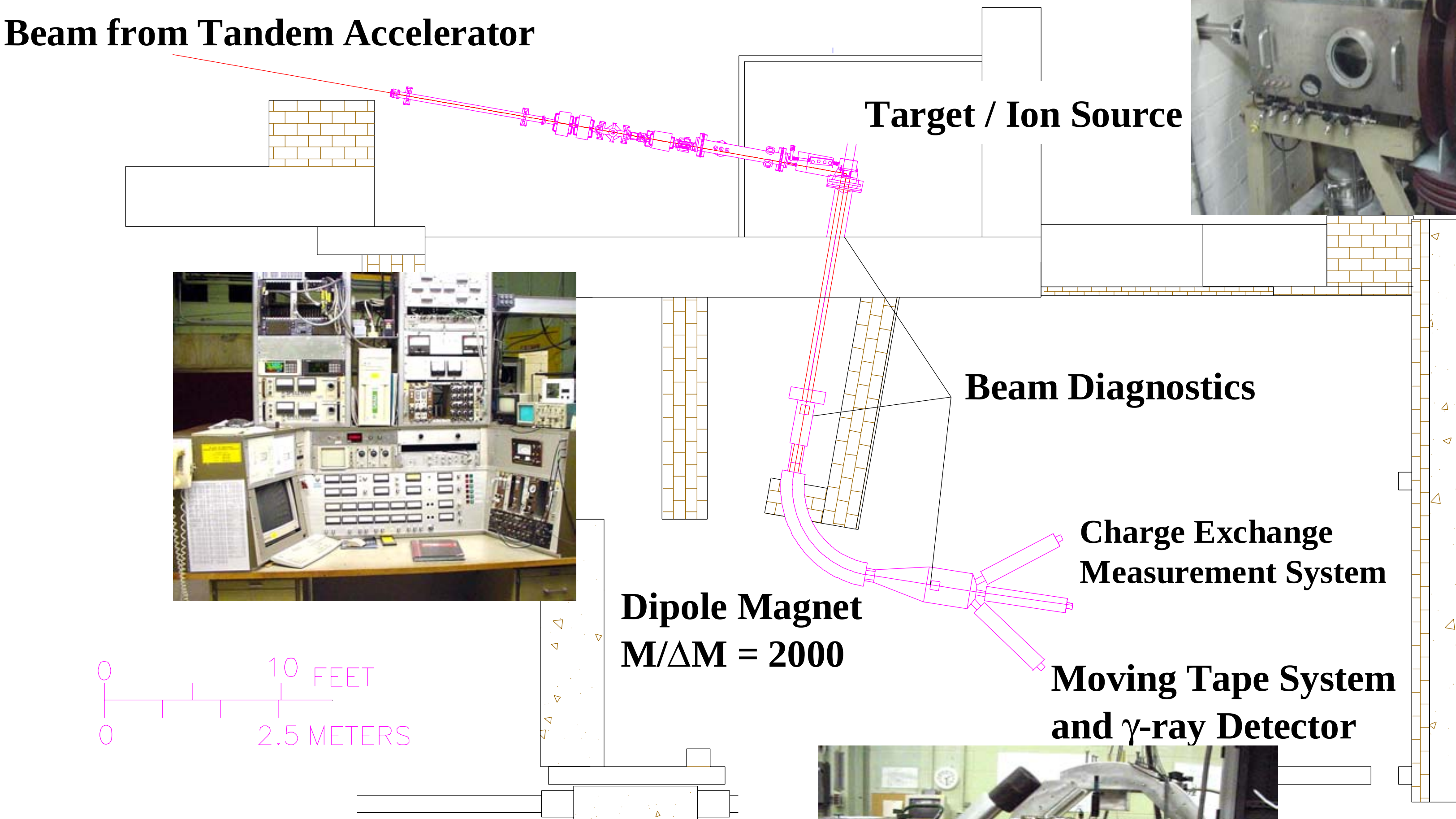


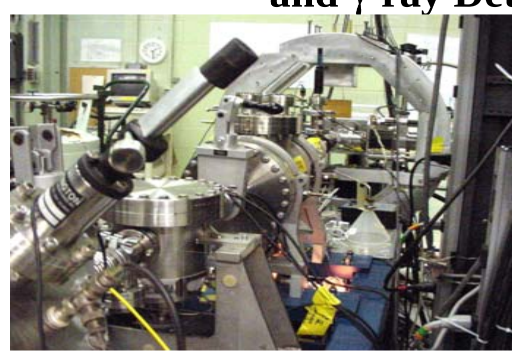
- **RVC fiber diameter: 60 μm**
- **Matrix density: 0.06 g/cm^3**
- **UC coating thickness: 8 - 10 mm**
- **Target density: 1.17 g/cm^3**
- **Uranium target thickness: 2.1 g/cm^2**
- **Mass ratio is U:C::6.6:1**
- **Atomic ratio is UC_3**





On-Line Target and Ion Source Testing Facility



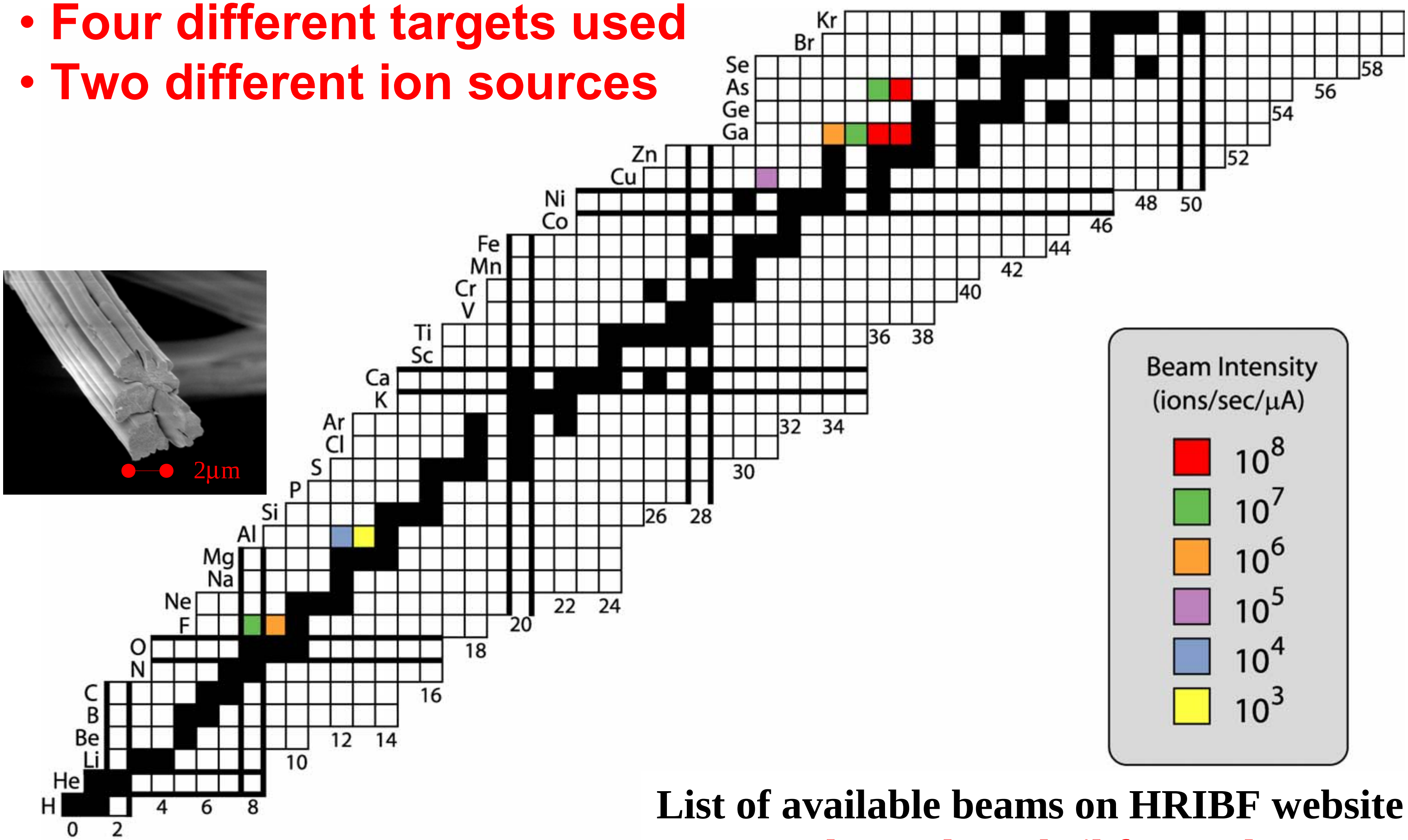


On-line Target and Ion Source Testing

- An independent, low intensity test facility is an important and unique capability
- Makes use of a pre-existing separator
- Measure characteristics of the targets and ion sources
  - release from the target
  - transport from target to ion source
  - ion source efficiency (especially at high target temperatures)
- Compatible with the RIB Injector Platform
  - mechanically identical
  - operational experience is transportable
  - results are scaleable (10 nA to 10 μA)
- Dual function as test facility and TIS quality assurance

Proton-rich Radioactive Ion Beams

- **Four different targets used**
- **Two different ion sources**

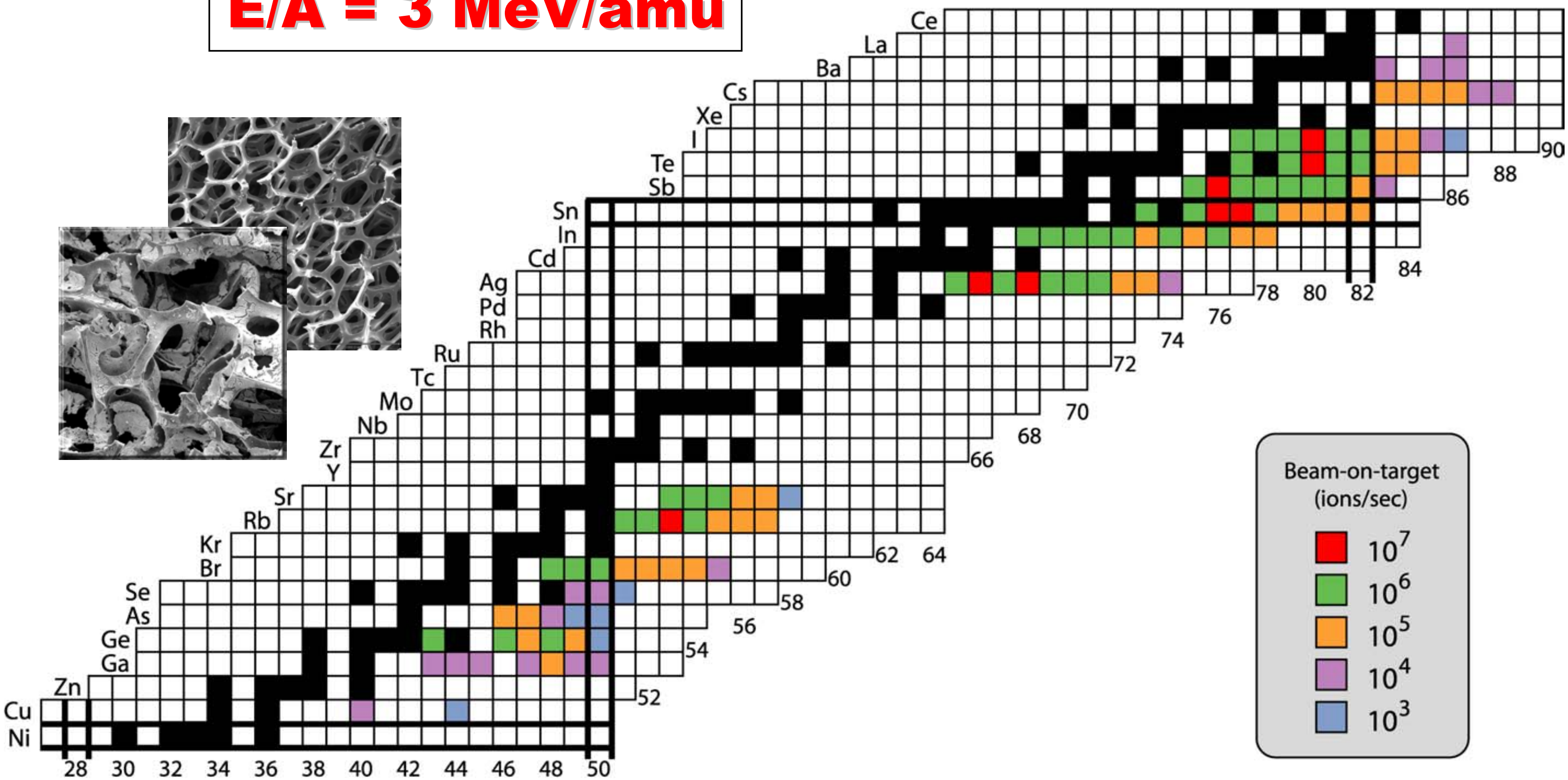


List of available beams on HRIBF website at www.phy.ornl.gov/hribf/users/beams/

Available Neutron-rich Radioactive Ion Beams

(over 100 beams with intensities ≥10^3 ions/sec)

E/A = 3 MeV/amu



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Accelerated proton-rich Radioactive Ion Beams

RIB	Energy Range	Highest Intensity	ORIC Current	Purity
	(MeV)	(pps on target)	(μA on target)	(%)
^{17}F	10-170	1.0×10^{7}	3	100
^{18}F	10-25	3.0×10^{5}	1	10
^{67}Ga*	160	2.5×10^{5}	5	> 90
^{69}As	160	2.0×10^{6}	5	~ 10
^{70}As*	140	2.0×10^{3}	0.01	$< 10^{-6}$

* These beams were used for commissioning runs

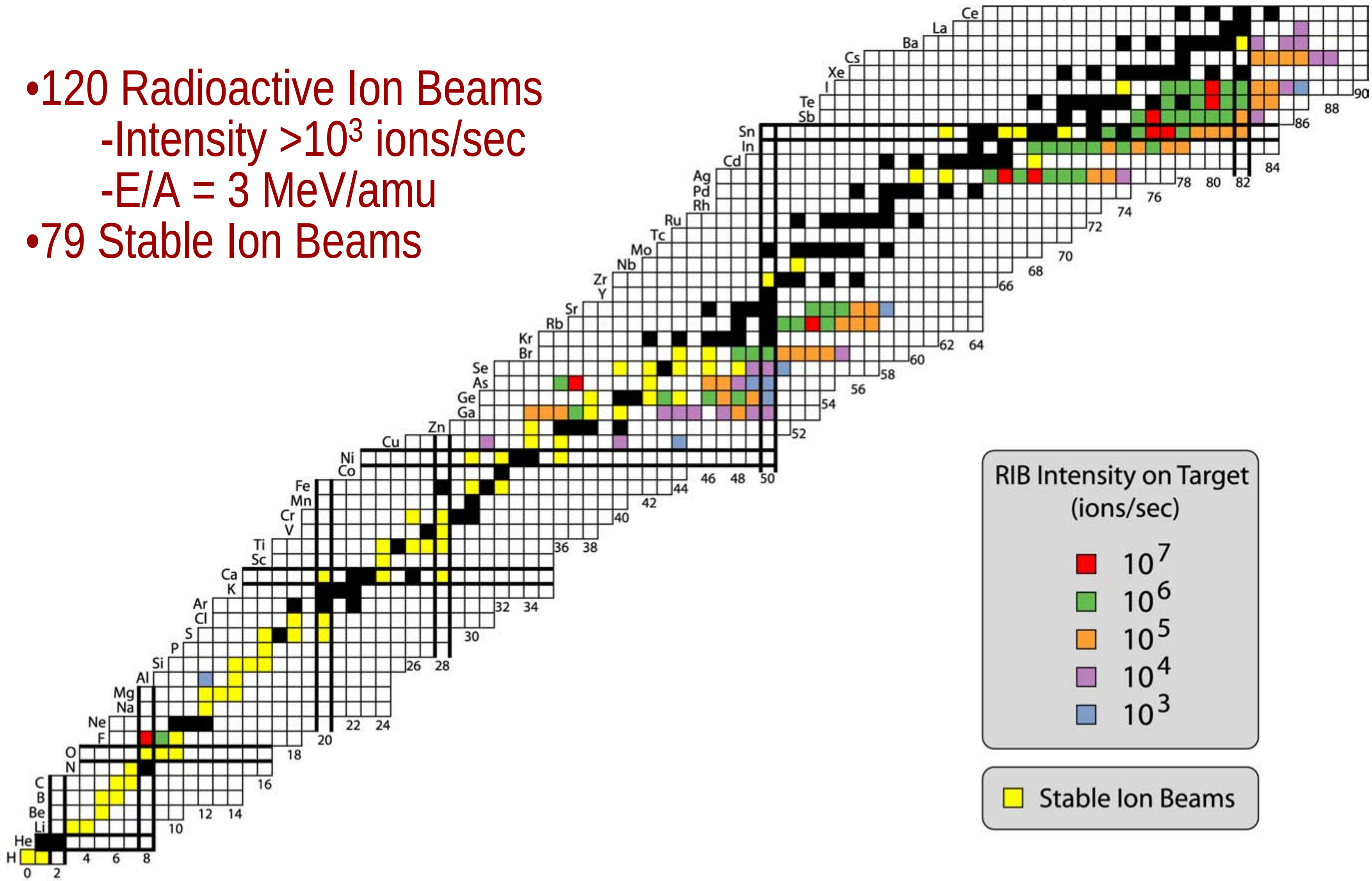
Accelerated n-rich Radioactive Ion Beams

RIB	Energy Range (MeV)	Highest Intensity (pps on target)	ORIC Current (μA on target)	Purity (%)
^{78}Ge	175	1.5×10^6	7	38
^{80}Ge	179	1.8×10^6	7	10
^{117}Ag*	460	1.2×10^6	9	95
^{118}Ag	455	1.5×10^6	11	90
^{126}Sn	378	1.0×10^7	5	50
^{128}Sn	384	2.5×10^6	5	20
^{132}Te	350-396	5.0×10^6	5	87
^{134}Te	396-560	2.4×10^6	7	70
^{136}Te	396	5.0×10^5	7	50

* Used for commissioning

Accelerated Ion Beams **Now Available** at the HRIBF

- 120 Radioactive Ion Beams
  - -Intensity >10^3 ions/sec
  - -E/A = 3 MeV/amu
- 79 Stable Ion Beams



Improving the n-rich RIB Yields

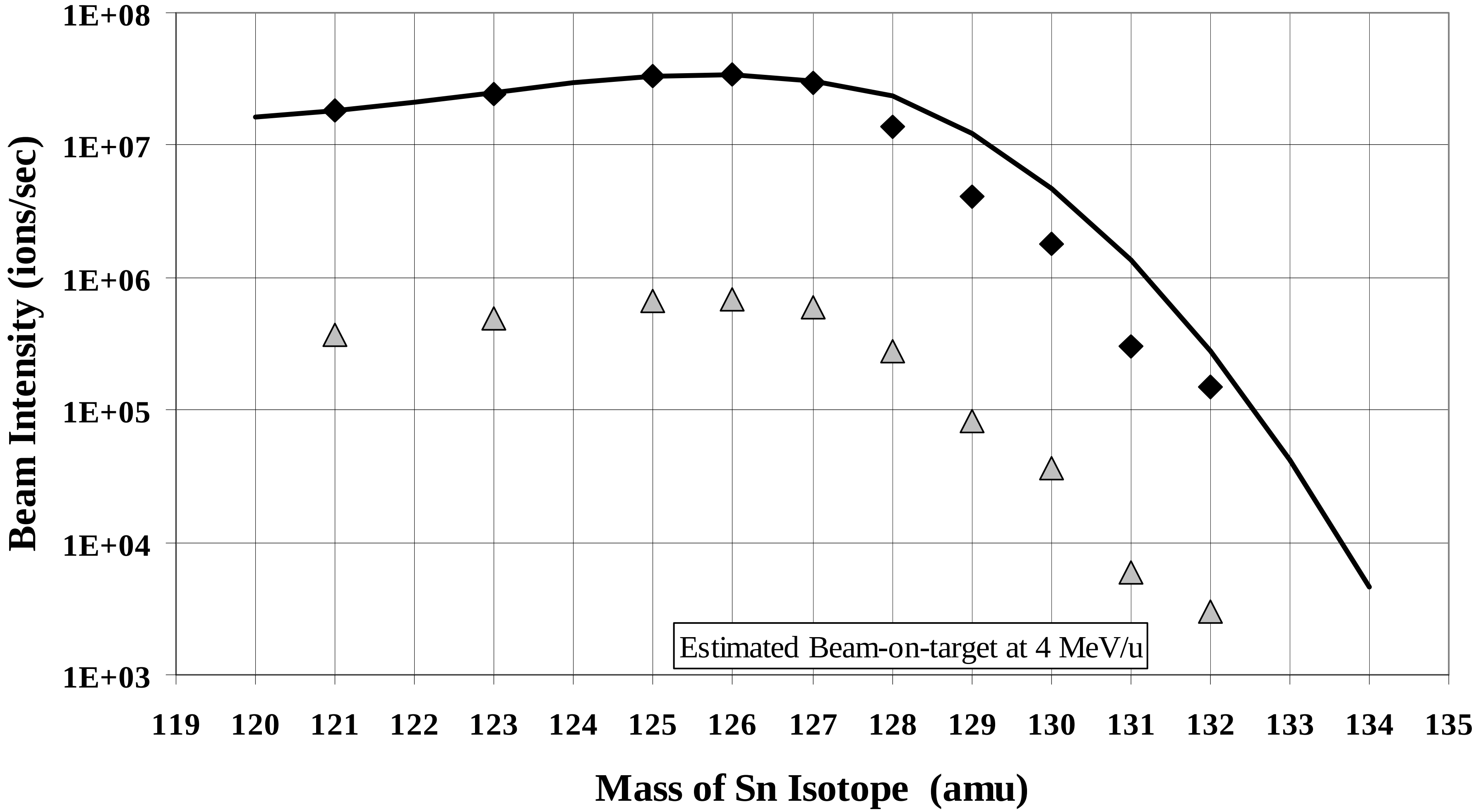
- **Beam purity**
  - ionization selectivity
  - chemistry in the target and ion source
  - lower emittance to improve isobar separation
  - selective charge exchange schemes
- **Beam intensity**
  - higher production rates
    - raster the beam across the target
    - more refractory targets
    - faster dissipation of heat from the target
  - more efficient transport of short-lived nuclei
  - ion sources with higher ionization efficiencies

Pure Sn Beams

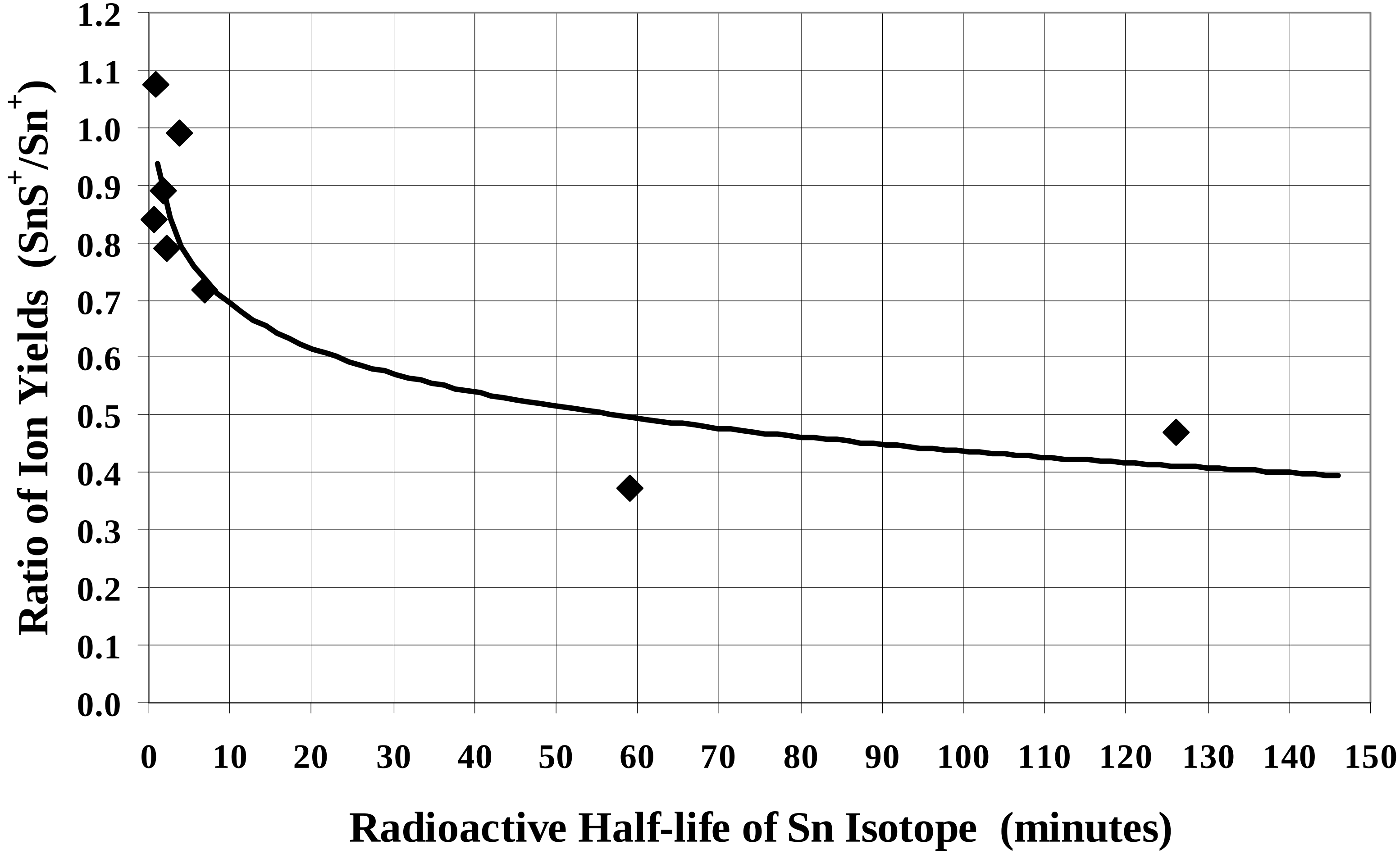
- Most of the neutron-rich Sn beams are contaminated
  - A=132 beam consists of 87% Te, 12% Sb, and 1% Sn
- Solution: extract from EBP ion source as SnS^+
- Sulfur is added to the UC target via H_2S gas
- No detectable TeS^+ or SbS^+ ions
- Convert SnS^+ to Sn^- in a Cs-vapor cell
- Energy spread is ~400 eV (molecular breakup)
- Selection process is unknown
  - do TeS and SbS dissociate due to high target temperature
  - do these molecules breakup during the ionization process
  - why don't the oxides behave in a similar manner
- Pure Ge beams are also available using this technique

Intensity of Sn^- beams injected into the Tandem (from SnS^+)

(the solid line is the production rate in the target, normalized to ^{127}Sn)



Ratios of positive ion yields for Sn isotopes (SnS^+ and Sn^+ from a UC target)



Pure Br and I Beams

- Release efficiency of Br and I from UC target is high
- Charge exchange efficiency in Cs-cell is low (0.8%)
- Solution: make negative ions directly using negative surface ionization from a hot LaB_6 surface
  - 15% efficiency for stable Br^- beams
- Br negative ion yields are 25 times greater than with EBPIS followed by charge exchange
- Yields are 10 times greater for iodine
- Expect at least 10^5 pps on target for ^{89}Br and ^{137}I (8 neutrons beyond last stable isotope)
- Br beams are pure (no Se or Rb observed)
- I beams are pure (no Sn, Sb, Te, or Cs)

Pure Rb Beams

- Rb release from target is quite fast
- Positive ion sources using surface ionization have high efficiencies for Rb (>90% ISOLDE)
- Ionizer is a hot Ta or W tubular surface
- Charge exchange efficiency in Cs-cell is 0.3%
- Sr is also ionized efficiently but at higher operating temperatures
- Should result in at least a factor of 10 increase over present yields with higher beam purity
- Expect to deliver to experiments at least 10^5 pps for Rb isotopes out to ^{94}Rb (7 neutrons beyond stability)

Other Targets and Beams in Development

- ^{25}Al from SiC
  - already tested fibers (15 μm dia.) and powder (1 μm dia.)
  - ^{25}Al yield in both cases was low (10^4 pps/μA from EBPIS)
  - thin layer of SiC deposited on low-density RVC matrix
- Optimize UC targets
  - vary the uranium density and matrix porosity
- ^{33}Cl from CeS
  - 1 μm dia. powder suspended in low-density matrix
  - LaB_6 surface ion source (negative)
- ^{26}Si and ^{27}Si from Al_2O_3 target
  - use technique developed for Sn and Ge (extract as SiS^+)
- Pd target for proton-rich Ag beams
  - complements the n-rich Ag beams from UC target
- ^{7}Be beams from a multi-sample Cs-sputter ion source

RIB Development Personnel

Ion Source Development

Gerald Alton
Hassina Bilheux*
Jean Bilheux*
Yuan Liu

Engineers

Darryl Dowling
Alan Tatum

*Graduate Student

RIB Operations & Development

Jim Beene
Jerry Hale
Paul Mueller
Dan Stracener

Technical Support

John Cole
Don Pierce
Charles Reed
Cecil Williams