Solid-Phase Isotope Harvesting of ^{88}Zr from a Radioactive Ion Beam Facility

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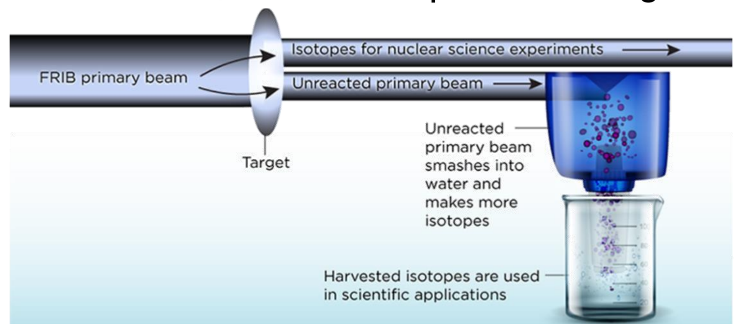
Abstract

- The Facility for Rare Isotope Beams (FRIB) produces high-purity radioactive ion beams for nuclear science experiments
- During the beam purification process, byproduct radionuclides will accumulate along the beamline
- Collecting, purifying, and using these radionuclides is called isotope harvesting
- Preliminary isotope harvesting efforts on the aqueous collection of ^{24}Na, $^{47}Ca/^{47}Sc$, ^{48}V, ^{62}Zn, ^{67}Cu, and ^{88}Zr have been performed
- In this work, the viability of isotope harvesting using solid collection of ^{88}Zr was examined where ^{88}Zr beam was stopped in a series of collectors comprised of Al, Cu, W, and Au
- ^{88}Zr was radiochemically recovered from the collectors with yields exceeding 80% and decontamination factors on the order of 10^5
- For elements of interest that readily hydrolyze in near-neutral pH aqueous conditions, such as Zr, harvesting through solid-phase collection has been shown to result in higher recovery yields compared to aqueous harvesting

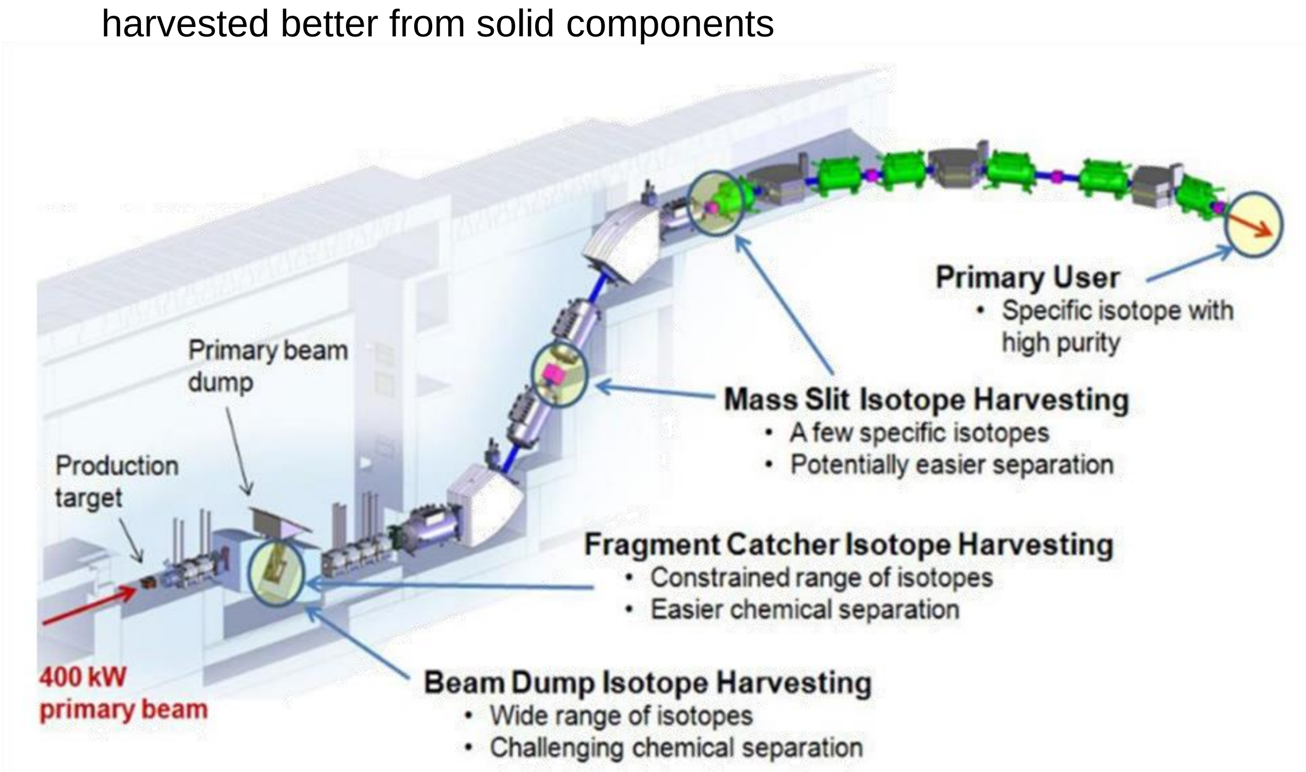
Introduction

- FRIB will accelerate beams of nuclides up to uranium for nuclear science research
- A large variety of isotopes will accumulate from normal operation
- Byproduct isotopes can be purified for other uses, called isotope harvesting
- Many exotic radionuclides will become available for use in applications such as:
  - Fundamental nuclear physics
  - Nuclear medicine
  - Astrophysics



FRIB, *Michigan State University*, 2022

- Up to 90% of unreacted primary beam deposits into aqueous beam dump when in use
- Radionuclides will accumulate at various points that can allow for harvesting
- Radionuclides that have difficult aqueous chemistry may be harvested better from solid components



Morrissey, D. J. Isotope Harvesting Opportunity at the Facility for Rare Isotope Beams. *Research at Michigan State University*

- ^{88}Zr
- Stockpile stewardship
- Strong gamma emission
- Suitable half-life
- Characteristic group IV chemistry

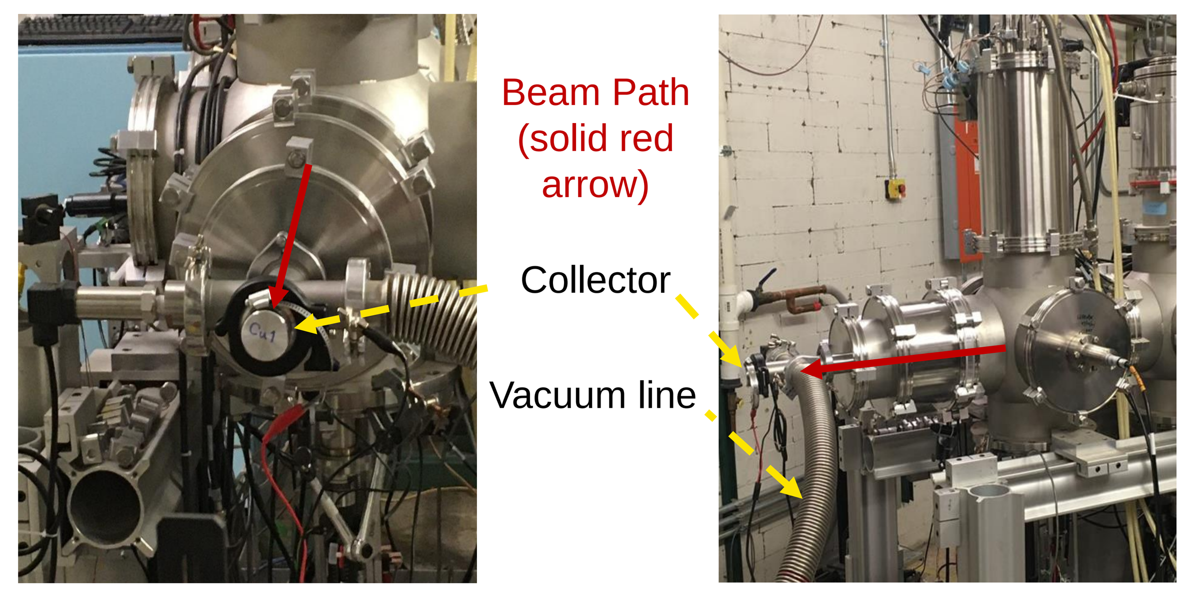
^{86}Zr 16.5 hours ε= 100%	^{87}Zr 1.68 hours ε= 100%	^{88}Zr 83.4 days ε= 100%	^{89}Zr 78.41 hours ε= 100%	^{90}Zr Stable 51.45%
	^{86}Y 14.74 hours ε= 100%	^{87}Y 79.8 hours ε= 100%	^{88}Y 106.6 days ε= 100%	^{89}Y Stable 100%

Z
N

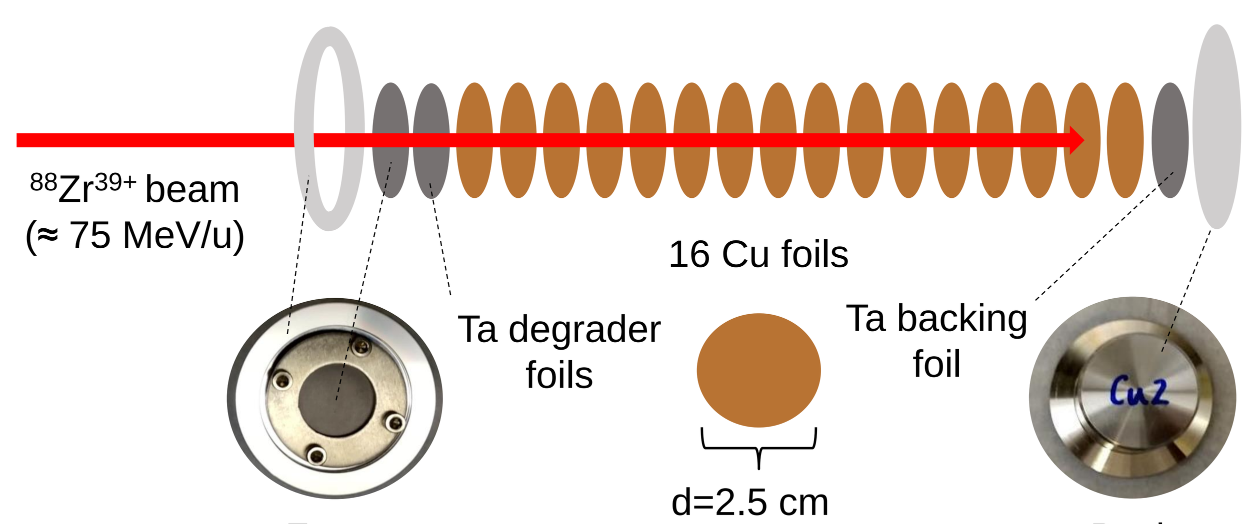
LLNL-POST-837635

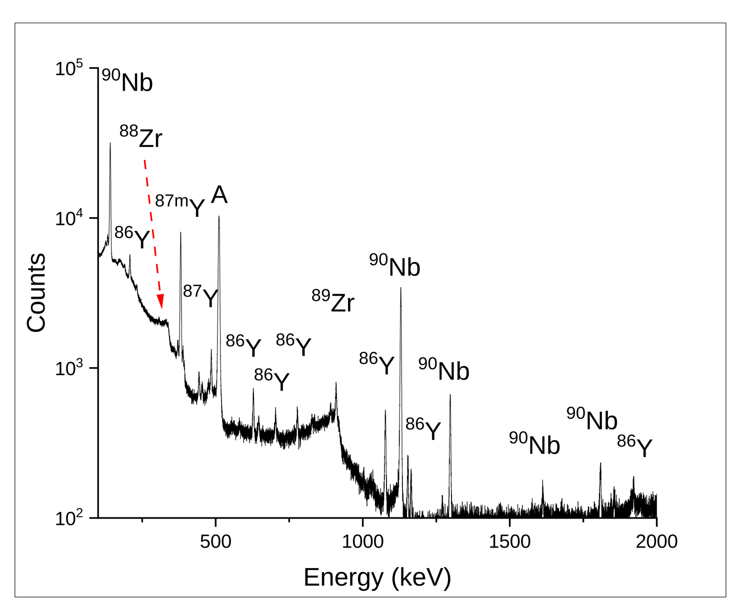
^{88}Zr Beamtime

1. ^{88}Zr beam generated from fragmentation of a stable 140 MeV/u ^{92}Mo beam
2. ^{88}Zr implanted into targets containing Al, Cu, W, and Au foil stacks
3. Foils analyzed with HPGe detector
4. Radiochemical separations performed on foils to isolate ^{88}Zr and ^{88}Y

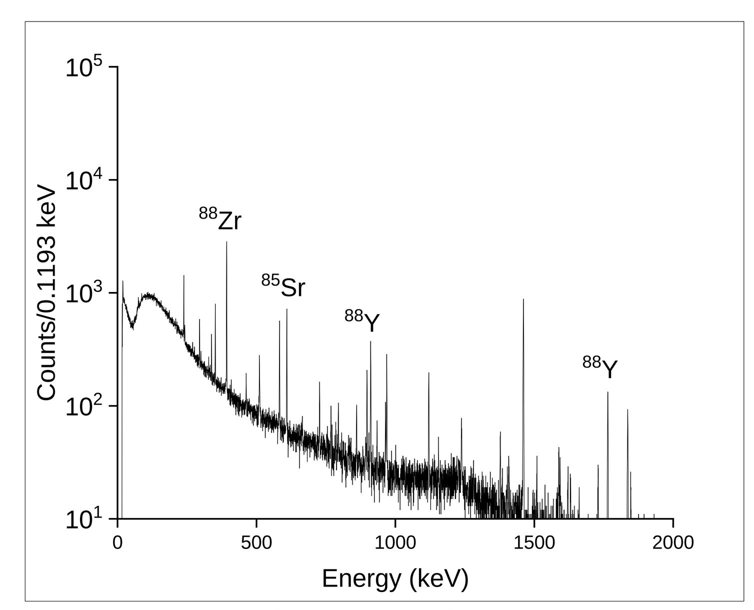


Front view Side view



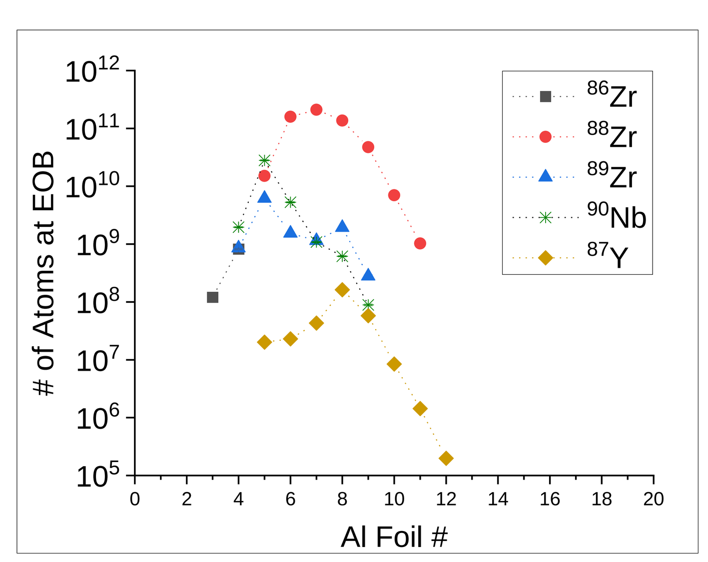


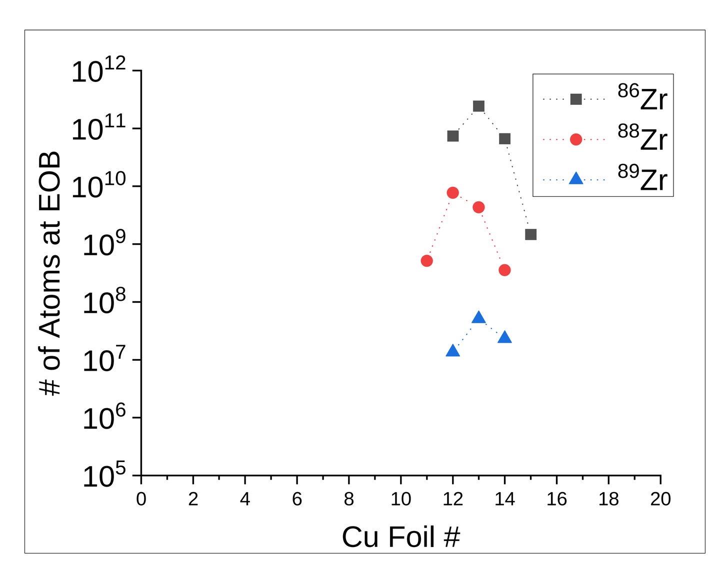
Cu collector spectrum <30 minutes after EOB



Only ^{85}Sr, ^{88}Zr, and ^{88}Y detectable 1 month after EOB

Collector	Activity at EOB (µCi)	Number of ^{88}Zr atoms at EOB	Integrated beam on target time (hours)	Average particle rate of ^{88}Zr (pps)
Al	1.55	5.94×10^{11}	7.78	2.12×10^7
Cu	1.04	4.02×10^{11}	6.15	1.82×10^7

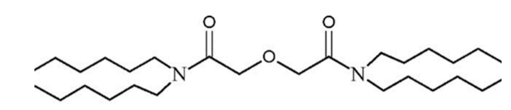




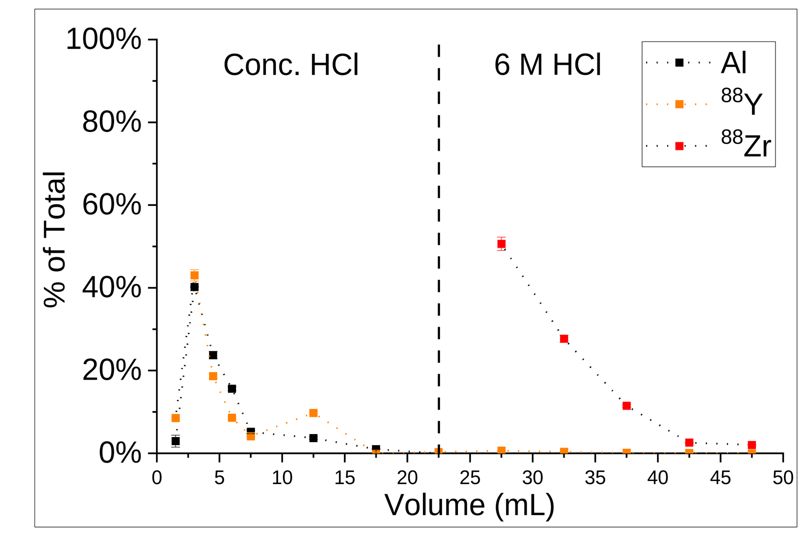
^{88}Zr and co-produced radionuclides distribution in both foil stacks

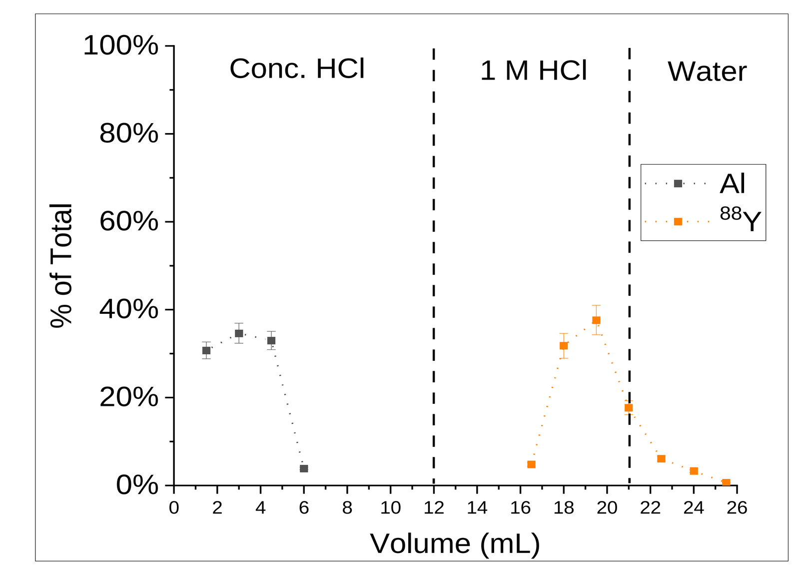
Harvesting ^{88}Zr from Al

1. Al foil with ^{88}Zr dissolved in HCl and HNO_3
2. Al reconstitution and precipitation
3. Anion exchange column to separate Al and ^{88}Zr
4. TODGA column to separate Al and ^{88}Y



TODGA

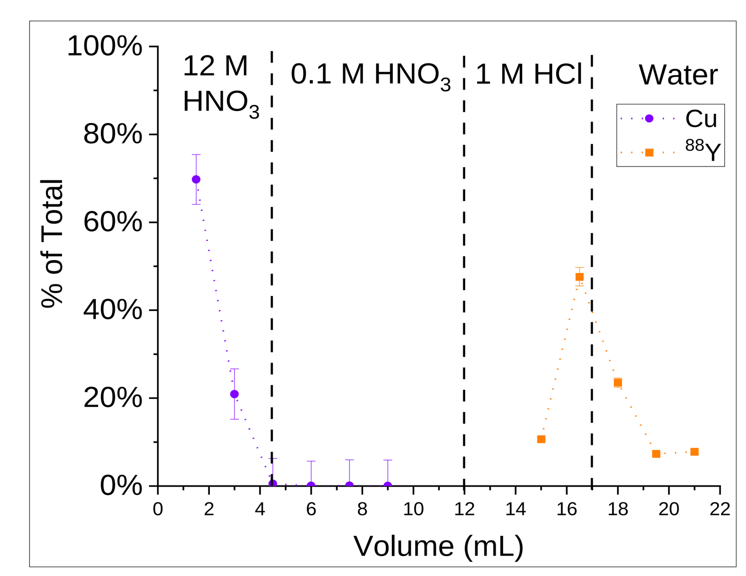


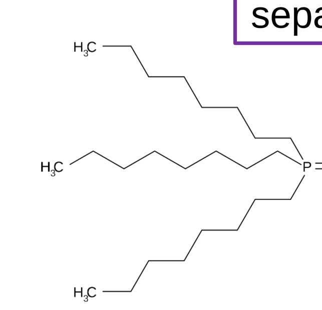


- ^{88}Zr Recovery= (86.6 ± 5.4)%
- Average DF= 2.2×10^5

Harvesting ^{88}Zr from Cu

1. Cu foil with ^{88}Zr dissolved in HNO_3
2. TOPO in n-dodecane solvent extraction of ^{88}Zr
3. ^{88}Zr in organic layer washed
4. ^{88}Zr back extracted in 1 M HCl
5. TODGA column to separate Cu and ^{88}Y





TOPO

- ^{88}Zr Recovery= (88.4 ± 5.4)%
- Average DF= 3.0×10^5

Conclusion

- 87% ± 5% ^{88}Zr recovered from Al and Cu
- >3x increase in ^{88}Zr recovery compared to aqueous harvesting efforts
- 92 ± 4% ^{88}Y recovered from Al and Cu
- Another tool for harvesting from decommissioned parts from RIB facilities

Future Work

- Harvesting methodologies for ^{88}Zr will be adapted to a microfluidics liquid-liquid extraction system for rapid Zr isotope harvesting
- Valuable, short-lived isotopes of Zr, such as ^{86}Zr or ^{89}Zr, can be harvested from FRIB, but will require rapid separation methods

Acknowledgments

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