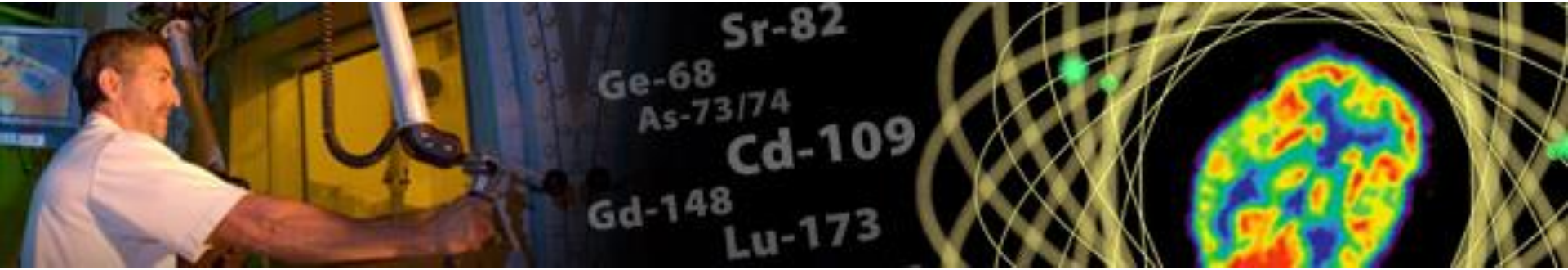
U.S. DEPARTMENT OF ENERGY

Isotope Program
U.S. Department of Energy

Isotope Production R&D: Research for Emerging Isotopes



7th Workshop on Isotope Federal Supply and Demand
January 12, 2021

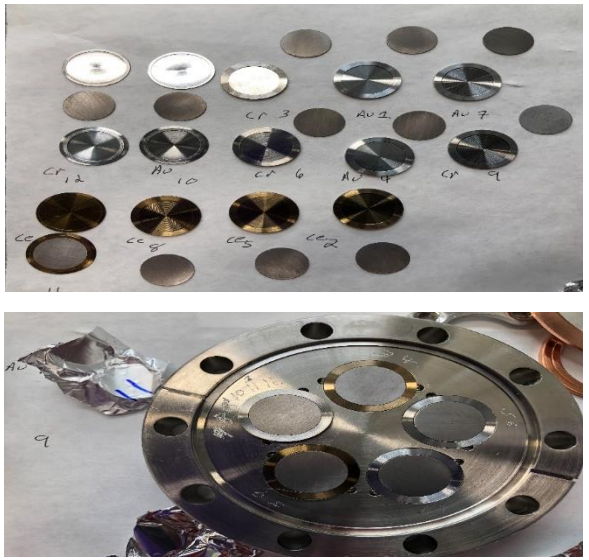
Dr. Ethan Balkin
Program Manager for Isotope R&D
Office Isotope R&D and Production, Office of Science, U.S. Department of Energy

DOE IP Supported R&D

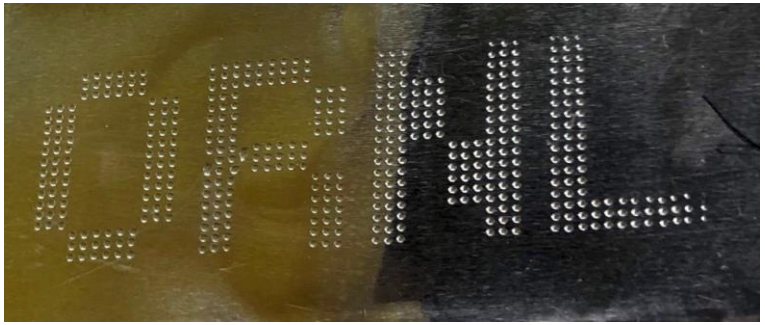
Transmutation and nuclear data (neutrons, charged particles, high energy gamma photons)

- Targetry (thermal hydraulics, materials, particle transport modeling)
- Processes for recovery and purification of radioisotopes; remote handling/automation
- Mass-separation for enriched stable isotopes and HSA radioactive isotopes
- Applications R&D **not** directly supported by DOE IP

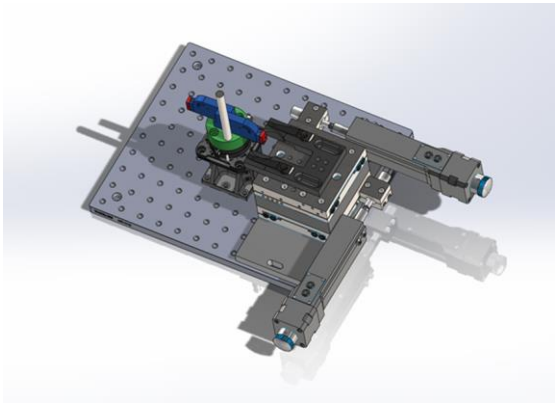
➢ Planned FOA to bridge the funding Valley of Death
➢ Transformative approaches to targetry to facilitate research and commercial isotope production
➢ SC QIS Research Initiative
➢ SC Fundamental Science to Transform Manufacturing Initiative
➢ New DOE IP Traineeship
➢ ***Other??? Community oriented R&D priorities***



Preparation of parts for initial thermal bonding studies to inform next-gen LANL target design (top) all parts with various coatings (bottom) materials packaged for shipment for thermal pressing

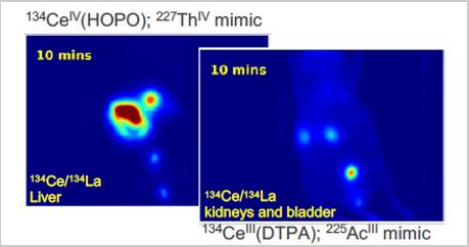


Inkjet printing of Targets: Successful Printing of Bitmap Patterns: 50 nL drops of water on aluminum

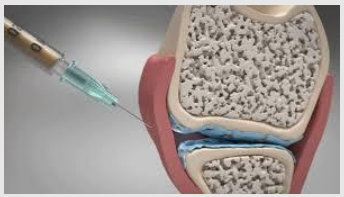


Custom Designed and Fabricated Biofluidix Printer

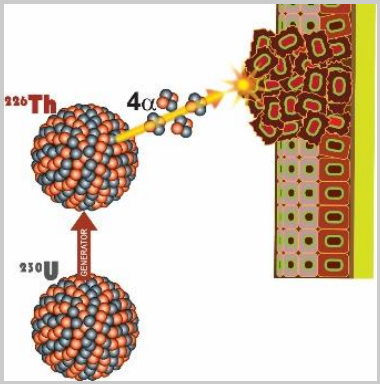
Emerging Imaging Isotopes

Isotope	Potential Use	Current R&D Scope
cerium-134 (Ce-134) 	PET imaging analogue for alpha-emitting isotopes	Scaling up yields and getting evaluations of product by user community
cobalt-55 (Co-55)	Longer half-life PET imaging agent often used to study slower biological processes (e.g. effects of stroke and TBI)	Scaling up yields and processing capacity
manganese-52 (Mn-52)	PET imaging agent – some unique brain applications	Scaling up yields and processing capacity
selenium-72/arsenic-72 (Se-72/As-72) generator	PET imaging agent	Increasing specific activity and developing a more robust generator
vanadium-48 (V-48)	PET imaging agent	Scaling up yields and processing capacity
yttrium-86 (Y-86)	PET imaging agent	Scaling up yields and processing capacity

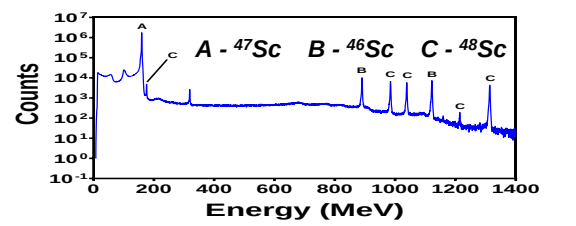
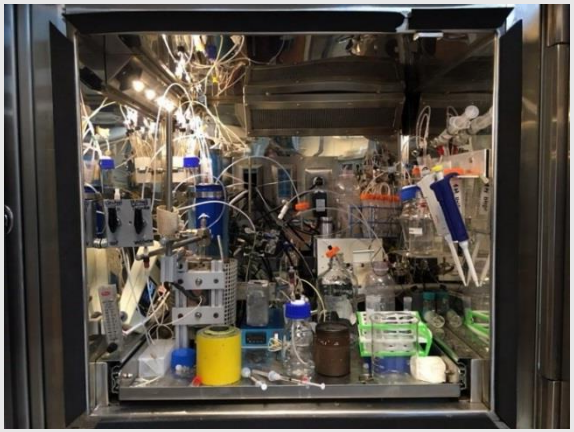
Emerging Therapeutic Isotopes

Isotope	Potential Use	Current R&D Scope
erbium-165 (Er-165)	Treatment of infectious processes as well as cancers using low-energy Auger and Coster-Kronig electrons.	Initial R&D including feasibility of production, assessment of yields and development of processing chemistry.
lead-212/bismuth-212 (Pb-212/Bi-212) generator 	Treatment of infectious processes as well as cancers using alpha particles.	Scaling up generator capacity and robustness to allow for the larger quantities needed in clinical trials.
terbium-161 (Tb-161)	Treatment of infectious processes as well as cancers as a β^- emitter.	Initial R&D including feasibility of production, assessment of yields and development of processing chemistry.
tin-117m (Sn-117m) 	Therapeutic isotope for various joint diseases using low-energy Auger and conversion electrons.	Scaling up batch yields and increasing specific activity to meet market demand

Emerging Therapeutic Isotopes

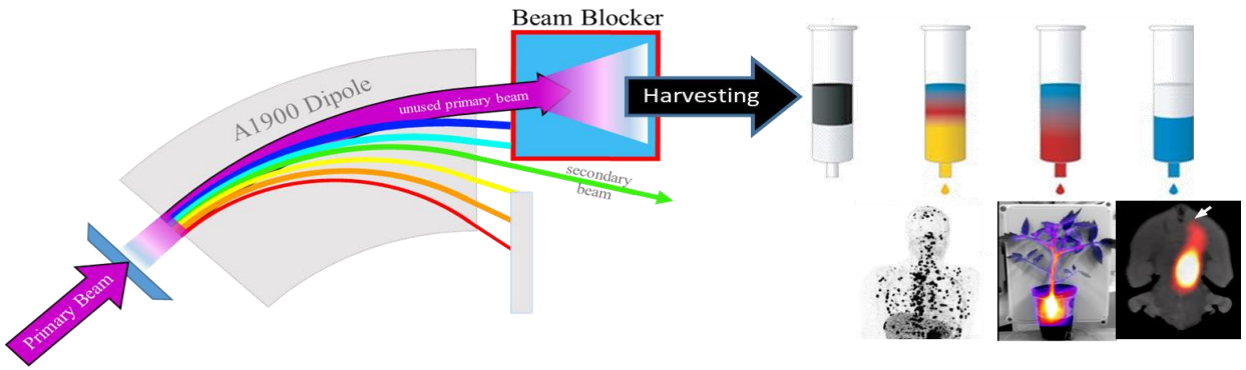
Isotope	Potential Use	Current R&D Scope
uranium-230/thorium-226 (U-230/Th-226) generator 	Treatment of infectious processes as well as cancers using alpha particles.	Scaling up batch yields and improving the processing chemistry. Additionally, the team is working to develop a robust generator and aims to have the isotope evaluated by the user community by late 2023.
iridium-192 (Ir-192) 	High dose-rate brachytherapy for treatment of tumors. Also used in industrial radiography to detect structural damage in metal parts	Preliminary target design complete. Working on initial production R&D (tests of production feasibility).

Emerging Theranostic Isotopes

Isotope	Potential Use	Current R&D Scope
Radioscandiums (Sc-43/44/47) 	Potential uses include imaging and therapy of infectious processes as well as cancers. Sc-43 and Sc-44 are PET imaging isotopes, while Sc-47 is a therapeutic β^- emitter.	Team is going through a down-selection to determine the most efficient means of production for each and scaling up yields as they go. Evaluations of product by user community will follow shortly
Radiobromines (Br-76/77) 	76 is a PET imaging isotope, while 77 offers the advantage of therapeutic low-energy Auger and Coster-Kronig electrons. Potential uses include imaging and therapy of infectious processes as well as cancers.	Scaling up yields, frequency, and processing capacity.

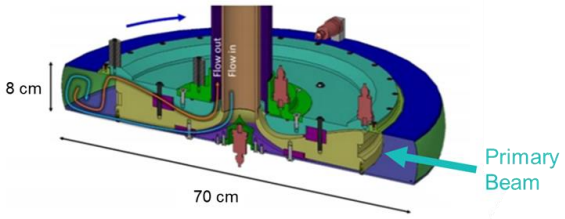
Isotope Harvesting at FRIB

New research effort will enable solid, liquid, and gas phase harvesting of radioisotopes from the Facility for Rare Isotope Beams at Michigan State University.



The isotope harvesting project will support the production of radioisotopes for a wide range of research applications.

Conceptual view of new hot cells for purifying and harvesting the radioisotopes from the FRIB beam dump system.



FRIB Beam dump: dissipates the FRIB beam energy and in the process radioisotopes are created in the cooling water.

Isotopes planned for initial harvesting R&D

Isotope	Use	Potentially Interested Agency
Rn-211	Rn/At generator	NIH, FDA
Pa-229	Searches for nuclear EDM	DOE, NSF
Ra-225	Searches for nuclear EDM & feedstock for Ac-225	DOE, NSF
Ca-47	Ca/Sc generator	NIH, FDA
Na-22	Co-produced with Ca-47	DOE, NNSA, NSF
Kr-76/77	Parents for Br-76/77	NIH, FDA
Se-72/73	As-72 PET emitter, As-73 for stockpile stewardship	NIH, FDA, NNSA

Restoring Stable Isotope Production/Enrichment

- Conducting R&D into EMIS technology to be able to separate heavier mass elements
- Exploring centrifuge development for light gasses
- Exploring alternative separations technologies
  - Plasma separation
  - Adaption of Laser induced separation (e.g. AVLIS at LLNL)
- Stable isotopes currently being explored are:
  - Mo-98 & 100, Si-28, Xe-129, Yb-176, and others.
- QIS initiative
  - Isotopes for QIS can be radioactive or stable. QIS specs can be extremely challenging.
  - R&D to develop new isotope enrichment technology is high risk and challenging, as are computations. Some isotopes can take years of research to learn how to produce and then years to actually produce.
    - Simulations, GC design and test stands

Stable Isotope Purification

Heavy Water

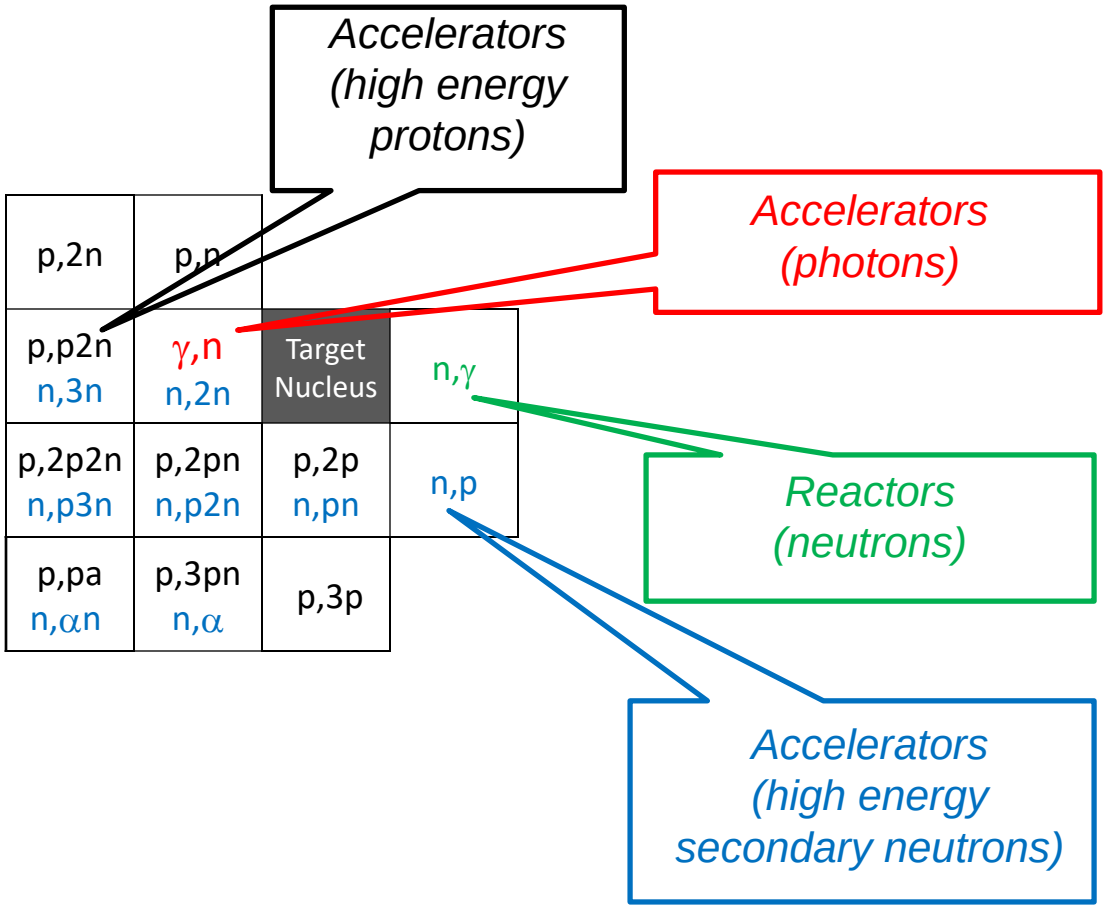
- Substantial quantity of D2O at SRS (~500,000 gallons)
  - Tritium contaminated (0.7-2.4 average Ci/liter)
  - 141,000 gallons clean except for tritium
  - 350,000 gallons also with chemical impurities
- SC pursuing cleanup options
- SC pursuing new production with National Energy Technology Laboratory (NETL)
  - Evaluating methane steam reformation/membrane separation process

Helium-3

- Recovered from NNSA tritium recycle and purification activities

Nuclear Data Needs

- **Cross sections for reactor production**
  - **Effective cross sections**
  - **Excitation functions**
- **Energy resolved cross sections for accelerator production with**
  - **High energy protons**
  - **High energy neutrons**
  - **Photons**



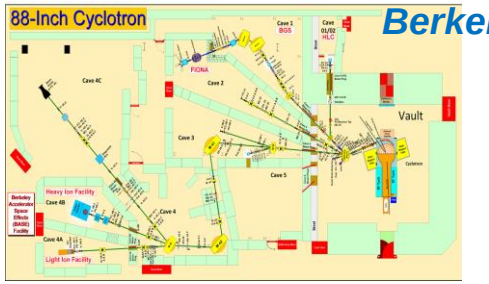
DOE IP Nuclear Data Initiative

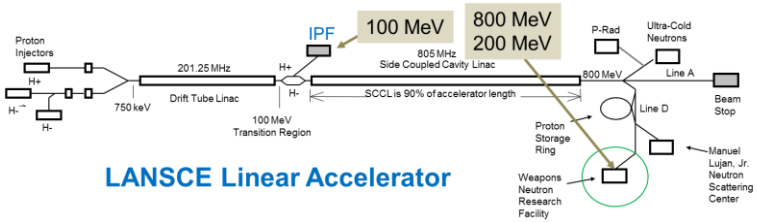
- **Expanding measurement capability to multiple facilities to better cover proton energy ranges up to 200 MeV**

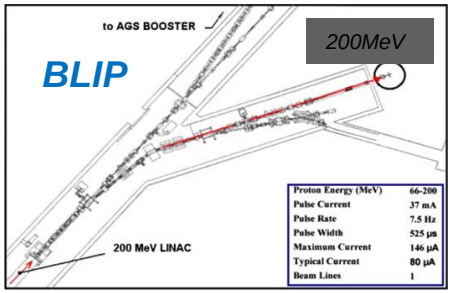
  - **Berkeley (<60 MeV) - includes Faraday cup style chamber for monitor reaction measurements**

  - **LANL – IPF (40-100 MeV) – includes new low beam current measurement capability for monitor reaction measurements (100 nA with 1% accuracy)**

  - **BNL – BLIP (100-200 MeV)**







Ongoing Measurements

- **High Energy Protons**
  - Th+p for production of therapy isotopes ^{225}Ac, ^{227}Th and ^{223}Ra
  - ^{nat}Sb,^{121}Sb+p for production of ^{119}Te/^{119}Sb, a promising Auger e-emitter for therapy
  - La+p for production of ^{134}Ce/^{134}La (PET analogues for ^{225}Ac and ^{227}Th)
  - Fe+p, Cu+p for production ^{52g}Mn, ^{54}Mn, ^{48}Cr, ^{55}Co, ^{58m}Co, ^{57}Ni
  - Nb+p for ^{93}Nb(p,4n)^{90}Mo as monitor reaction
  - As+p for production of ^{72}Se – generator for ^{72}As (PET imaging isotope of the ^{72}As/ ^{77}As theranostic pair)
- **High Energy Neutrons**
  - Production of ^{193m}Pt, ^{64}Cu/^{67}Cu, ^{47}Sc, ^{77}As via (n,p)
- **Photonuclear**
  - ^{48}Ti(γ,p)^{47}Sc, ^{196}Pt(γ,n)^{195m}Pt
- **Low energies**
  - ^{232}Th(p,x)^{229}Th for production of ^{229}Th/ ^{225}Ac
  - ^{238}U(p,xn) and ^{235}U(d,xn)$^{235\text{-}237}$Np for Production of ^{236g}Np

Workforce Development

- Workforce development is a priority in all funded R&D activities
- DOE IP participates in the annual DOE SC Early Career Research Program
- DOE IP supports travel bursaries for students and postdocs to attend conferences/symposia
- DOE IP supports the annual Nuclear and Radiochemistry Summer Schools at BNL and San Jose State Univ.
  - Collaborative effort w/ BES and NP-Low Energy Program
- New in 2020: Monthly Virtual Seminar Series – On the Horizon: Novel Isotopes & Future Leaders
- New in 2021: Isotope Traineeship – *Support for graduate traineeships in nuclear and radiochemistry, with an emphasis in isotope production.*
  - *Ensures the ongoing availability of the very specialized workforce necessary to produce radioactive and enriched stable isotopes, includes target processing and radionuclide purification using remote handling facilities such as hot-cells, glove-boxes, robotics and other forms of automation.*
  - *Envisioned as a rotation based program where applicants are exposed to multiple sites within the DOE IP.*

Summary

The DOE Isotope Program R&D Portfolio:

- **Is engaged in a variety of efforts aimed at advancing the field of isotope science to meet the needs of the user communities we serve**
- **Develops production techniques for isotopes not currently available**
- **Supplies a wide range of isotopes for research and commercial applications**
- **Is taking steps to increase production efficiency and capabilities**
- **Is actively engaged in growing the workforce**
- **Is prepared to make investments to conduct research and develop isotope production techniques for isotopes of interest to the community. Please provide your input!**

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The DOE Isotope Program's Virtual Seminar Series

On the Horizon: Novel Isotopes and Future Leaders

This presentation opportunities will allow junior scientists to showcase their research (completed or in-progress) to various Federal staff and members of the isotope community including DOE, National Laboratory researchers, and various institutes of higher education.

Talks for this session include:
"Exploring Eluent Effects on Late Actinide Separations"
"Production of 77Br and 76Br"

January 28th, 2021
4:00 PM – 5:00 PM (ET)/3:00 PM – 4:00 PM (CT)

Must register to attend – the link to the webinar will be provided once registration is complete

Register

Speakers for this session include:

Korey Carter- Korey graduated with a BS in Physics from Michigan State University in 2011 and received his PhD in Chemistry from The George Washington University in 2017, where he worked in the lab of Christopher Cahill studying halogen bonding in f-block hybrid materials. Since 2017, he has worked as a postdoctoral fellow in the group of Rebecca Abergel at Lawrence Berkeley National Laboratory, investigating fundamental bonding interactions in f- and d-block coordination complexes with specific applications in radiochemical separations, nuclear medicine, metal-ion decorporation, and nuclear waste stewardship. Beginning in January 2021, He will be joining the University of Iowa to start as an assistant professor in the department of chemistry where his group will use f-block coordination chemistry to address fundamental challenges in quantum information science, nuclear medicine, and separations chemistry.

Sean McGuinness- Sean received a Bachelor's degree in physics and mechanical engineering from Fairfield University. He is currently finishing his Ph.D. in nuclear physics with Professor Graham Peaslee at the University of Notre Dame. His work focuses on the production of medically-useful radionuclides via heavy-ion reactions.

Hosted by:

The Texas A&M University System
National Laboratories Office