INL/CON-23-75959-Revision-3

Isotope Production Education and Research via a Systematic Study of Photo-nuclear Reaction Yields and Excitation Functions

July 2024

Edna S Cardenas, Michael A Reichenberger, Douglas P. Wells, Van Romero, Dan S. Dale, Tony Forest

Changing the World's Energy Future

Idaho National Laboratory

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Isotope Production Education and Research via a Systematic Study of Photonuclear Reaction Yields and Excitation Functions

DOE Office of Science Funded Project

Collaborators:
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Dan Dale, Tony Forest (ISU)

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U.S. Department of Energy's Office of Nuclear Energy

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Background and Early Isotope Uses

- Isotope production research accelerated after World War II.
- Atomic Energy Commission (1946) enabled development of isotopes for peaceful purposes. [1]
- Isotope production flourished:
  - Biological tracers
    - Radiocarbon was used to determine the chemical reactions that take place in photosynthesis. [2]
  - Cancer therapy and diagnosis
    - Radioactive phosphorus was used to treat leukemia. [3]
- Concern over dual role:
  - Regulatory agency
  - Isotope supplier
  - Nuclear Regulatory Commission
  - Energy Research and Development Administration

Isotope Production within the Department of Energy

- In 1977 the Department of Energy was established. [4]
  - Supplies of Isotopes grew.
- In the 1990s, research and development significantly declined as did the career pathway into the industry. [5]
- In 2009, DOE established an isotope subcommittee to:
  - identify and prioritize research opportunities using isotopes,
  - recommend a long-term strategic plan for isotope production. [6]

Isotope Subcommittee Recommendations

- 2009 recommendations included [6]:
  - "…enhance the capabilities of the isotope program in the production and supply of isotopes generated from reactors, accelerators, and separators."
  - "Investing in workforce development in a multipronged approach, reaching out to students, post-doctoral fellows, and faculty through professional training, curriculum development, and meeting/workshop participation."
- 2015 recommendations included [7]:
  - using electron linear accelerators as a "unique potential source of isotopes",
  - reiterated the need for "investments in workforce development to educate and train the next generation of nuclear scientists …"

Reaching a New Energy Sciences Workforce (RENEW)

- Established by 2022 to grow the workforce.
- Provides training to students from historically underrepresented institutions.
- Expose students to careers they may have not initially considered.

Research and Education Program

- Collaboration between researchers from the New Mexico Institute of Mining and Technology, Idaho State University, and Idaho National Laboratory.
- Program offers:
  - Courses in nuclear science from both universities,
  - Hands-on laboratory training,
  - Photonuclear isotope production experiments using electron linear accelerators,
  - Summer internships at INL.
- Goal of supporting 15 undergraduate and 15 graduate students over the 5-year program.

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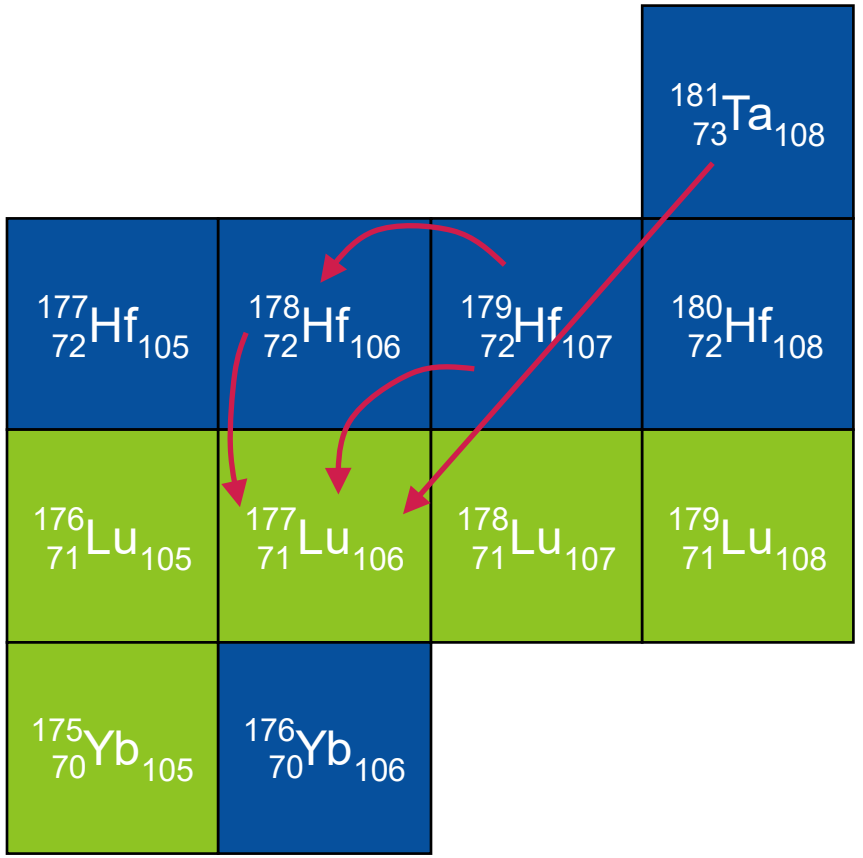
Program Research

- Study many isotopes listed in the “Meeting Isotope Needs and Capturing Opportunities for the Future: The 2015 Long Range Plan for the DOE-NP Isotope Program”.
  - Short half-life theragnostic isotopes that are impractical to obtain from foreign suppliers.
  - Isotopes used in nuclear security applications.
  - Research and develop new uses and applications.

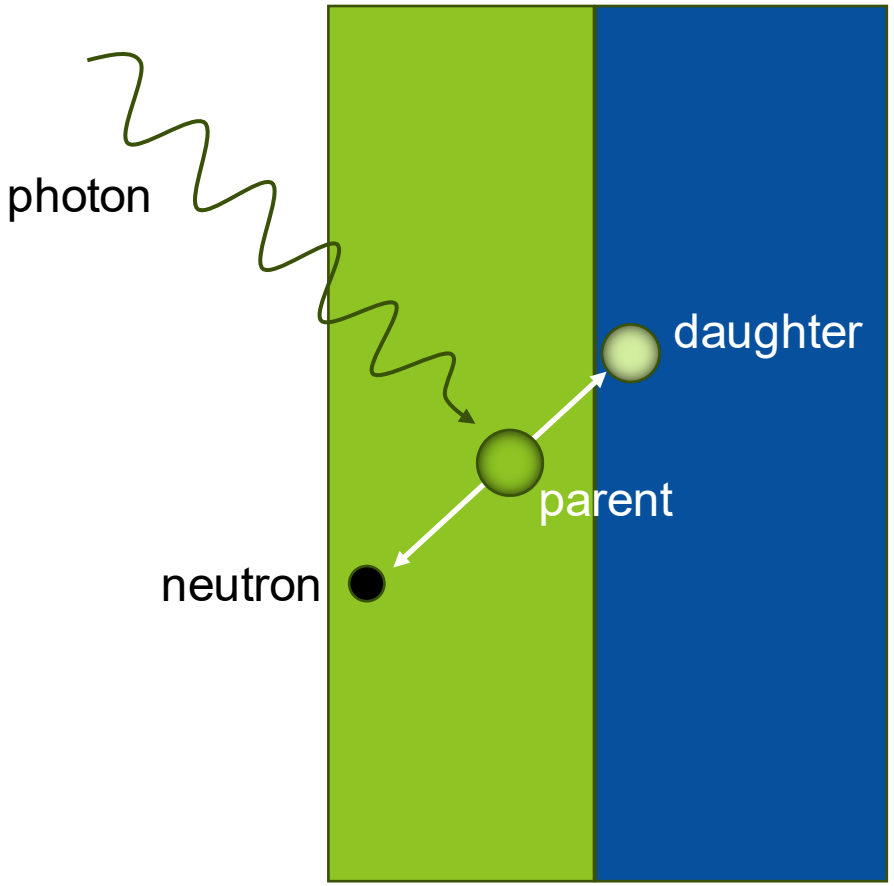
Photonuclear Reactions using LINACS

- Advantages to using LINACs over nuclear reactors:
  - Lower capital and decommissioning costs.
  - Lower volume of radioactive waste.
  - Waste is less hazardous.
  - No nuclear weapons proliferation risk.
- Performing measurements of bremsstrahlung-weighted yields for reactions, including:
  - (γ, α), (γ, p), (γ, n), and (γ, np).



Kinematic Recoil Experiments

- Investigating kinematic recoil to address the longstanding isotope separation challenge in (γ, n) reactions.
  - Increases the specific activity by using “catcher” materials.



Recent Experiments

Utilized LINACs at the Idaho Accelerator Center to produce:

- ^{177}Lu, a therapeutic isotope to treat inoperable cancer.
  - ^{178}Hf(γ,p) & ^{179}Hf(γ,np)
- ^{90}Sr, a power source for spacecrafts & radiotherapy for melanoma.
  - ^{94}Zr(γ,α) & ^{92}Zr(γ,np)
- ^{47}Sc, diagnosis and treatment of cancers.
  - ^{51}V(γ,α)

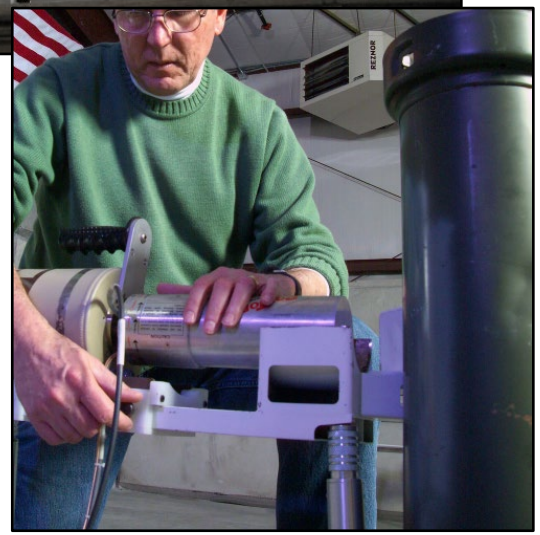
INL Internship Projects

- *Coincidence Radiation Detection Systems for Detection, Assay and Background Reduction*
  - The project would focus on improving detector sensitivities by setting up a beta-gamma or alpha-gamma coincidence system for the detection & quantification of specific isotopes.
- *INL Gas Lab Isotope Production and Assay*
  - Participate in the production of radioxenon and its separation from photonuclear-produced iodine. The student will build and test a gas manifold using radioactive and non-radioactive samples.
- *Photonuclear Isotope Production of ^{135}Xe*
  - The student will perform radiation transport modeling, aid in sample construction and preparation, setup experiment at the IAC, and help with gamma spectroscopy.
- *X-Ray Imaging and Tomography*
  - The student will have the option to work on several projects related to x-ray imaging and tomography including data analysis, segmentation, and image rendering.
- *Positron Annihilation Spectroscopy*
  - The student will aid in gamma spectroscopy, data analysis, and design improvements to a sample chamber in the positron annihilation program at INL's Materials and Fuels Complex.

Tours for Students at INL Facilities

Students will go on facility tours throughout the summer.

- Advanced Test Reactor- study the effects on fuels & materials from intense neutron and gamma radiation.
  - Produce ^{238}Pu (power source for NASA's deep space exploration missions) & ^{60}Co (treatment of cancers)
- Portable Isotopic Neutron Spectroscopy System (PINS)
  - Neutron-based nondestructive assessment to identify chemicals in containers.



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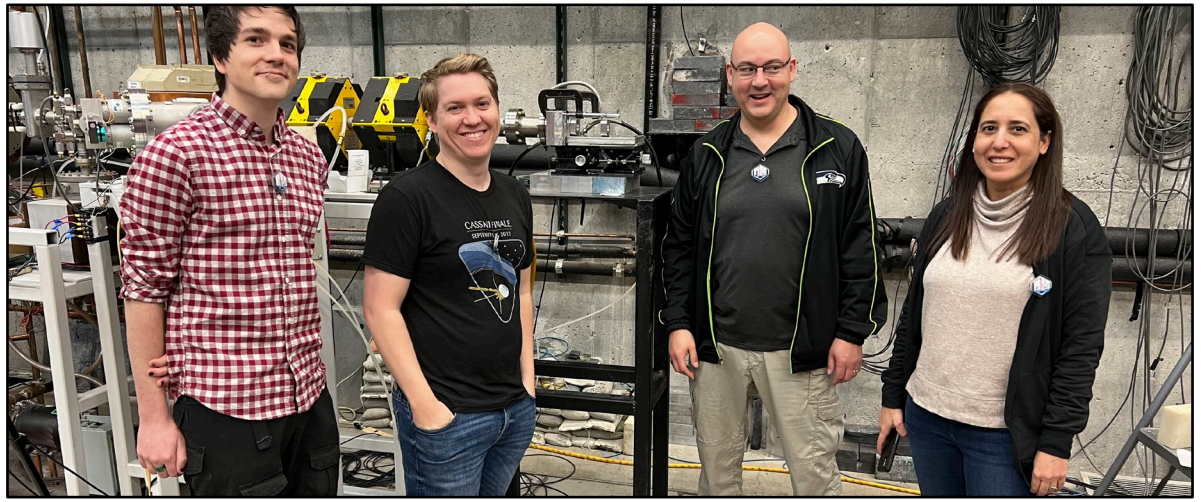

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