



U.S. DEPARTMENT OF
ENERGY

Office of
Science

Status of R&D on New Isotope Production Approaches

5th Workshop on Isotope Federal Supply and Demand
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■ Core R&D

- Maintains core scientific expertise at stewarded labs and universities in isotope production and processing
- Supports R&D using unique capabilities and expertise to support IP mission
- Supports R&D to optimize ongoing isotope production at Labs and Universities
- Supports R&D to develop new production and processing techniques
- Facilitates responsiveness to requests for isotopes
- Important to recruiting and retention of workforce at our key facilities

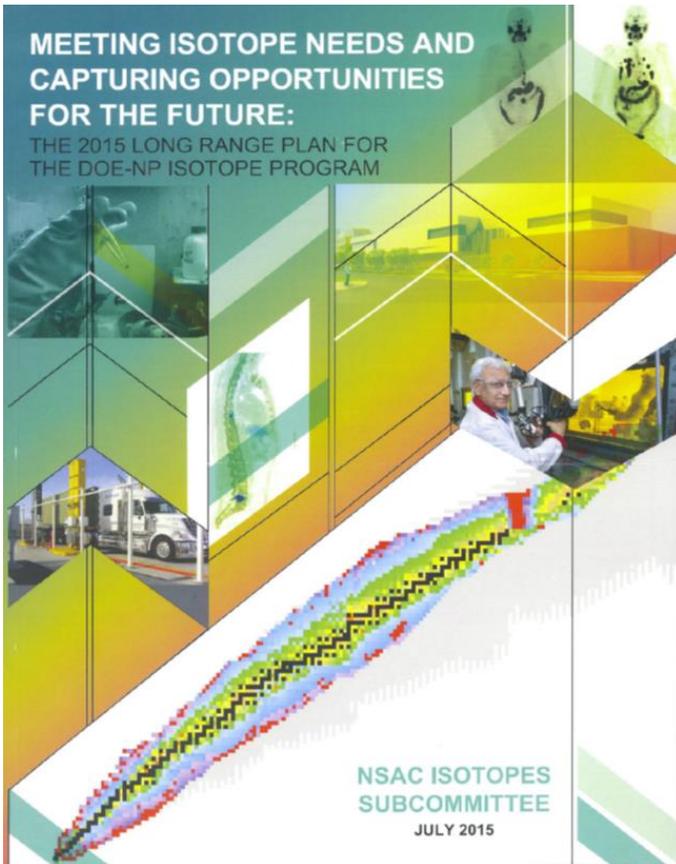
■ Competitive R&D

- Eligible to all labs and academic institutions
- Proposals are peer-reviewed – strong competition
- Targeted to demands identified by community (such as federal surveys)
- Helps us identify interests, opportunities and needs in the broader community
- Helps enable development of future workforce

■ SBIR/STTR for small businesses



- **Recommends a significant increase of R&D funding to optimize program (See Chapters 3 and 4)**
 - Continue support for R&D on the production of alpha-emitting radioisotopes
 - Support R&D into the production of high specific activity theragnostic radioisotopes
 - Continue support for R&D on the use of electron accelerators for isotope production
 - Support for R&D on production of isotopes important to basic research, national security, other applied research
 - Support R&D on the development of irradiation materials for targets exposed to extreme environments
 - Infrastructure development including facility upgrades, harvesting of isotopes at FRIB, automation, high capacity stable isotope enrichment, radioisotope separator
 - Investments in workforce development should continue to be a priority



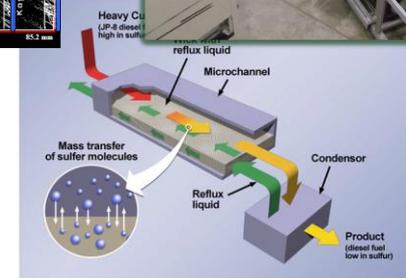
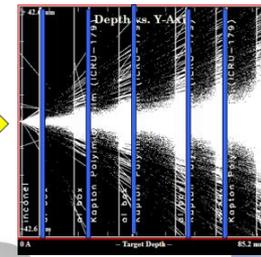
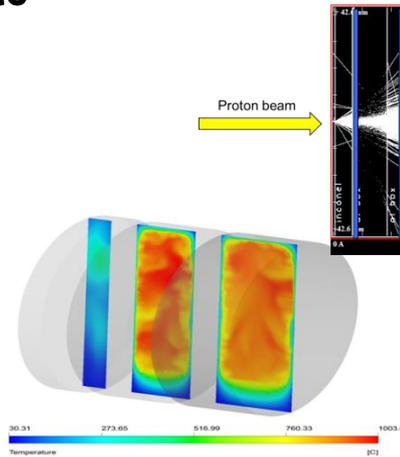
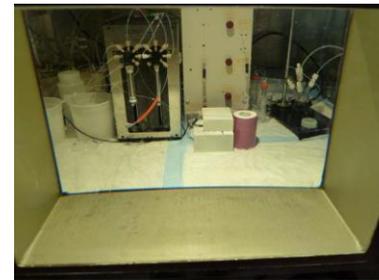
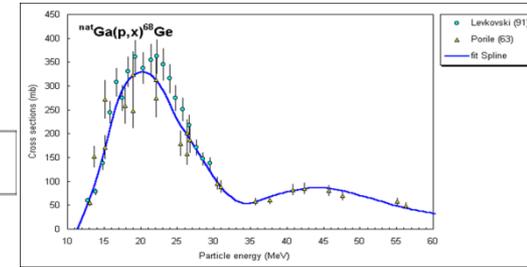
Key Areas of Research

- **Transmutation (neutrons, charged particles, high energy gamma photons)**
- **Targetry (thermal hydraulics, materials, nuclear data, particle transport modeling)**
- **Mass-separation for enriched stable isotopes and HSA radioactive isotopes**
- **Processes for recovery and purification of radioisotopes; remote handling/automation**
- **Application research NOT generally supported by the DOE Isotope Program**

n = neutron
 p = proton (H)
 d = deuteron (^2H); [pn]
 t = triton (^3H); [p2n]
 ^3He = [2pn]
 α = alpha particle (^4He); [2p2n]

	$\alpha, 3n$	$\alpha, 2n$		
		$^3\text{He}, n$		
	p,2n	p,n	d,n	t,n
			$^3\text{He}, np$	α, np
				$^3\text{He}, p$
		p,pn	Original Nucleus Z,N	d,p
		n,2n		n, γ
				t,np
	p, α	n,t	n,np	n,p
		d, α	p,2p	
		n,nd	n,d	t, ^3He
		n, α	n, ^3He	
		n,n ^3He	n,pd	

Z ↑ N →



- **Funding Opportunity Announcements (\$30.2M supporting 46 research projects)**

- Held biannually for academic and national laboratories
- Evaluation of proposals done under rigorous peer review
- Funding decisions strongly guided by community needs

**DE-PS02-09ER09-14
FY09/FY10**

**DE-FOA-0000447
FY11/FY12**

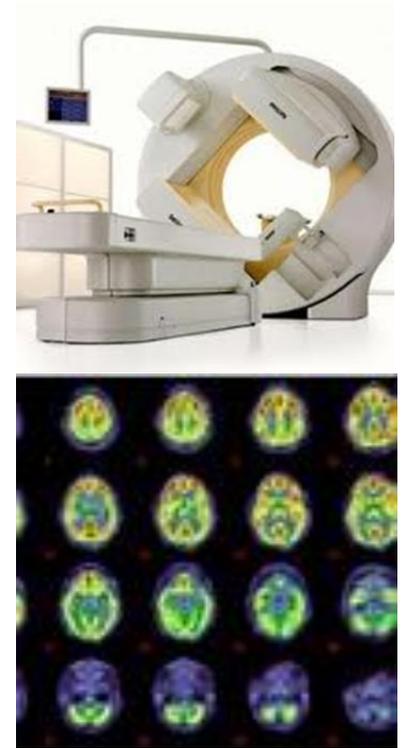
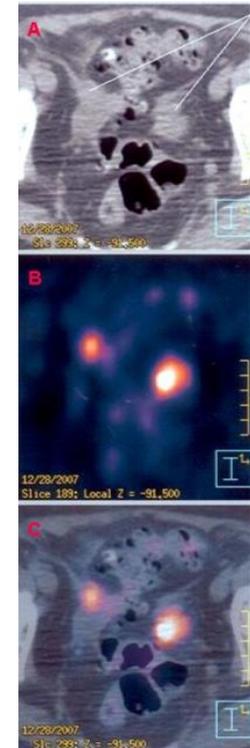
**DE-FOA-0000743
FY13/FY14**

**DE-FOA-0001099
FY15/FY16**

- **DE-FOA-0001588 FY17/FY18**

- ~\$3.5M per year
- 6 -10 new awards

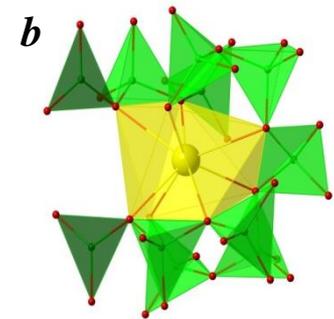
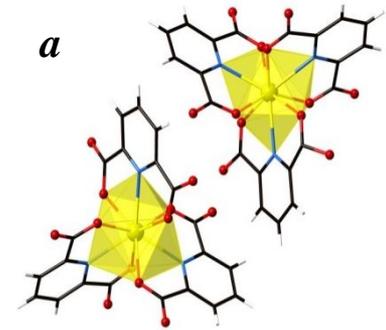
- **Alpha emitters for targeted therapy**
 - Ac-225/Bi-213, At-211, Rn-211, Ac-227/Th-227/Ra-223, Ra-224/Pb-212, U-230/Th-226
- **Beta and Auger electron emitters**
 - Sc-47, Cu-67, As-77, Re-186, W-188/Re-188, HSA Sm-153, Rh-105, Ru-106, Lu-177, Ho-166, Pm-149, and other radiolanthanides, Te-119/Sb-119, Pt-193m, Pt-195m
- **PET isotopes**
 - Sr-82, Se-72/As-72, Ti-44/Sc-44, Sc-47, Cu-64, Zr-89, Mn-52, Nb-90
- **SPECT and planar gamma imaging**
 - Direct Tc-99m production, Cu-67
- **Theragnostic isotopes**
 - Y-86/Y-90, As-72/As-76 or As-77, Cu-64/Cu-67, Cu-67, Sc-44/Sc-47, Sn-117m, Pt-193m
- **Bimodal imaging**
 - PET/CT (Ga-68)
 - PET/MRI (Mn-52)



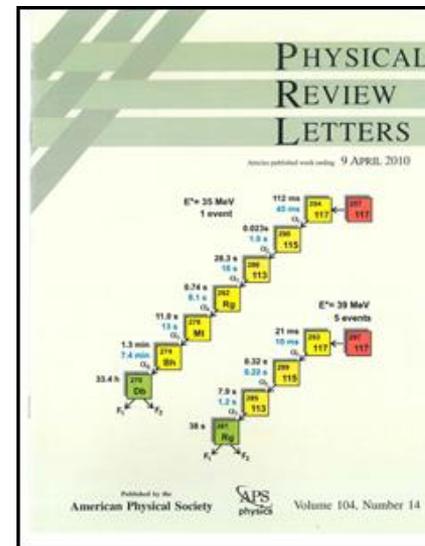
- **Np-236/Pu-236 for nuclear forensics**
 - Mass spectroscopy isotope dilution standards
 - Collaborative effort between LANL and U. Washington
 - Accelerator production on uranium targets
- **Actinides for Heavy Element Chemistry, Super Heavy Element Discovery, and Forensics**
 - Am-243, Pu-244, Cm-248, Cf-249/Cf-251, Bk-249
Es-253/Es-254, Fm-257
U-238, Np-236, Np-237, Pu-239/Pu-240/Pu-242
 - Harvested from legacy materials and/or co-produced in production of Cf-252
 - “Experimental Validation of the Optimization of Transcurium Isotope Production Model”
- **Environmental Tracers**
 - Si-32 for oceanographic research
 - As-73 for environmental toxicology
- **Isotopes for Nuclear Physics Research**
 - Ho-163 and Al-26 for astrophysics
 - Ge-76 for neutrino research



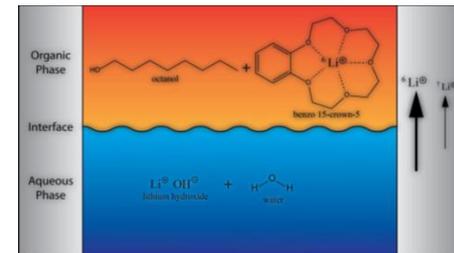
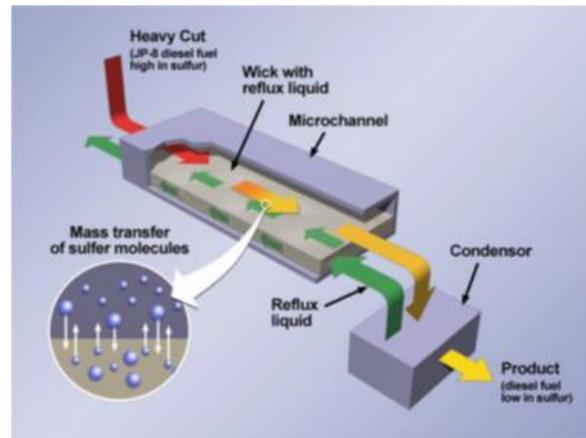
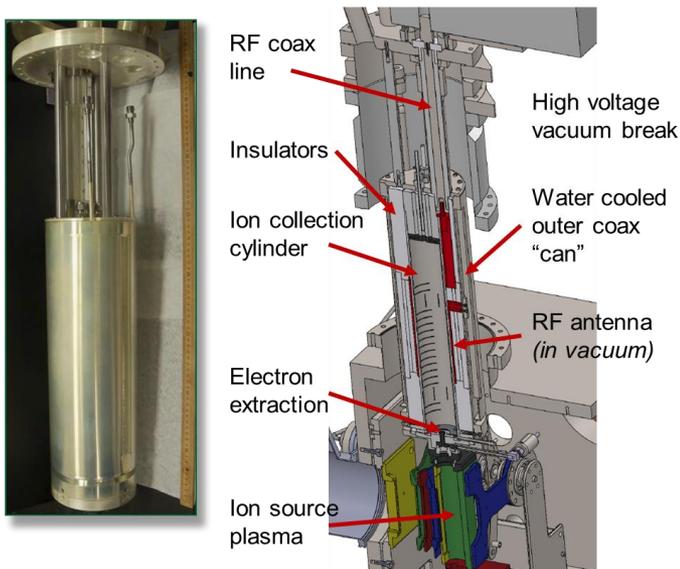
$Bk[B_6O_8(OH)_5]$



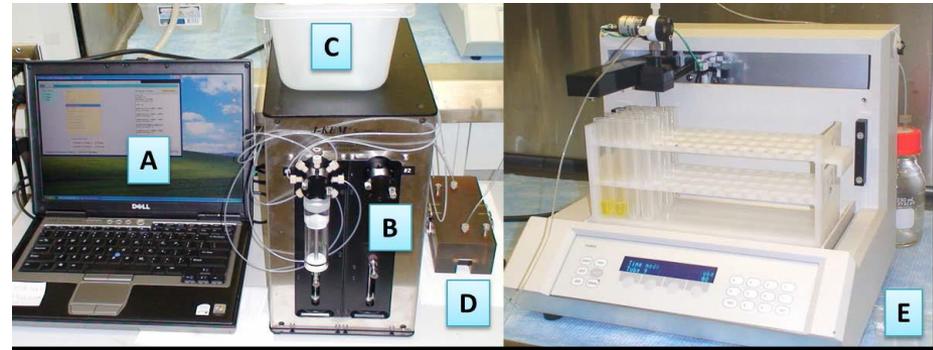
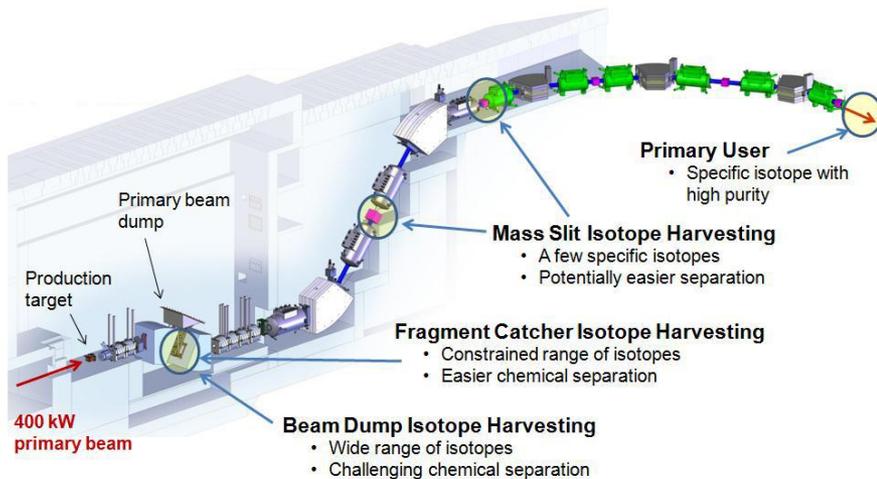
$^{249}Bk(DPA)_3$



- R&D for new production technology
 - Development of 100 mA ion source for electromagnetic stable isotope enrichment— ongoing (Grimm presentation)
 - Microchannel distillation for Ge-76 enrichment – NDBB
 - Environmentally friendly Li-7 production based upon crown-ether solvent extraction and/or chromatography – R&D to support ability to meet specifications for industry



- New technologies for chemical separations of lanthanides and actinides for isotope production
- Automation of isotope recovery and purification technologies
- Radioisotope production using photo-transmutation reactions in electron accelerators
- Production of radioisotopes using high energy neutrons
- Selective gaseous extraction of valuable fission isotopes from low-enriched uranium targets – refer to NNSA Mo-99
- Harvesting isotopes from the Facility for Rare Isotope Beams



FRIB Isotope Harvesting Strategies

- Core research funding at Laboratories supports students and post-docs
- Training components in funding)
 - MURR/LANL/BNL
 - Penn State University
 - University of Washington/PNNL
 - Hope College/Washington University
 - Texas A&M University
- Summer Schools in Nuclear Chemistry and Radiochemistry
- Workforce Development for Teachers and Scientists,
<http://science.energy.gov/wdts/>
 - DOE Office of Science Graduate Student Research (SCGSR) Program
 - SULI Program (Science Undergraduate Laboratory Internships)
- OSC Early Career Research Program
 - <http://science.energy.gov/early-career/>



- **The R&D program is successful**
 - Significant publishable advances toward new or improved production capability
 - Numerous students and postdocs have been engaged in the work supported by the program
 - The existence of the R&D program increases the ability to recruit and retain a skilled and vibrant workforce
- **R&D is a priority for the Isotope Program**
 - NSACI LRP Recommendations
 - We recommend a significant increase of funding for Research and Development
- **IP is prepared to conduct R&D on isotope production relevant to your mission**