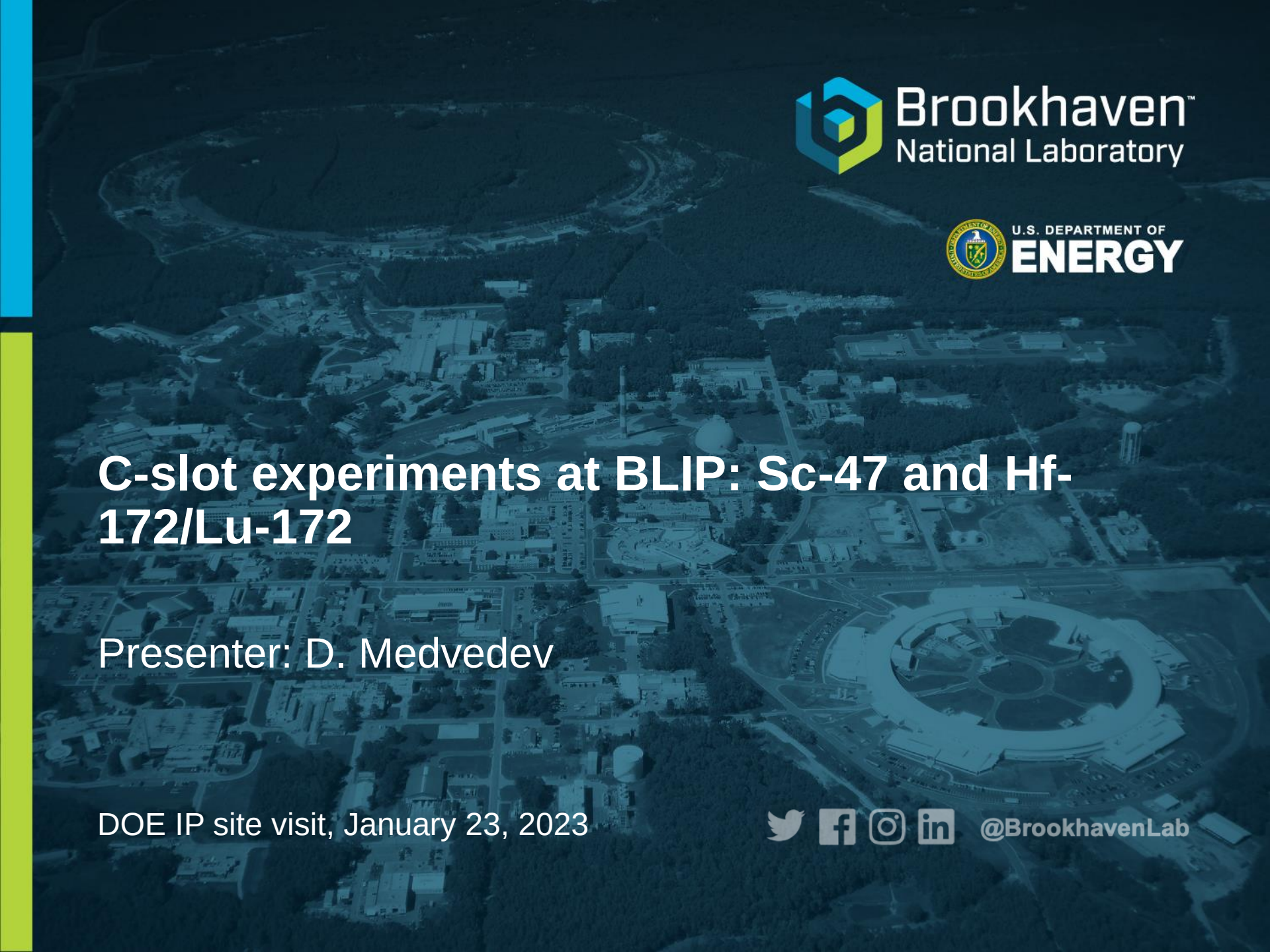

C-slot experiments at BLIP: Sc-47 and Hf-172/Lu-172

Presenter: D. Medvedev

DOE IP site visit, January 23, 2023

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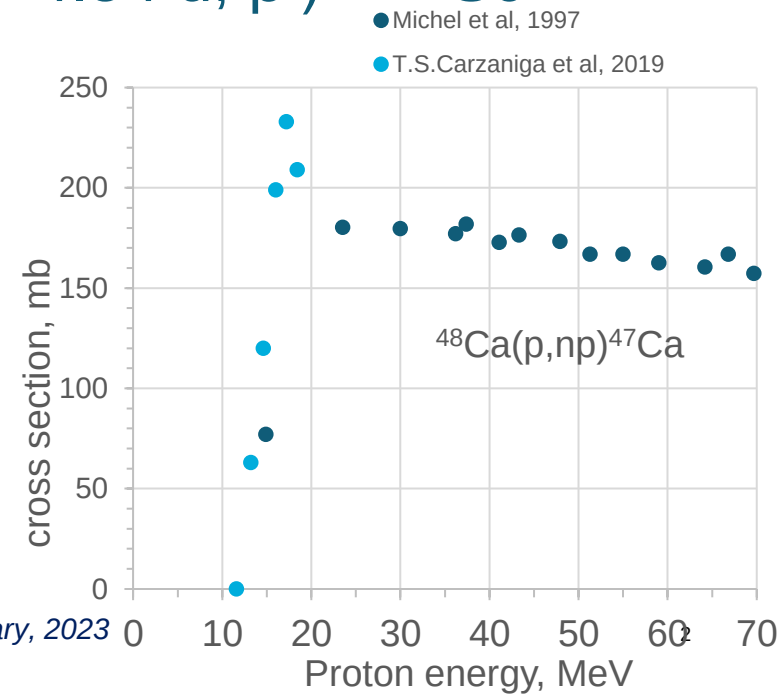
Nuclear properties and production route

Sc-47 - radiotherapeutic beta emitter

- Theranostic pair for PET isotope Sc-44
- $T_{1/2}$=3.35 days, mean β^- energy 162.0 keV, Eγ=159.4 (68.3%)

Production route $^{48}Ca(p,np)^{47}Ca$ ($T_{1/2}$=4.54 d, β^-) $\rightarrow ^{47}Sc$

- ^{48}Ca abundance – 0.187%
- Medium to low energy reaction
- Irradiate at C-slot, below 23 MeV
- Production by decay
- Use $^{nat}CaCl_2$ target
- Projected Ca-47 yield ~ 8 mCi



Irradiation at BLIP behind Ga_4Ni – energy budget

2020	Energy: 116.5 MeV	rastered beam	165	uA	Ga4Ni and CaCl2			
				thickness				
layer number	Layer	Material	density	inches	mm	Ei	Eout	E deposited, MeV
1	Be window	Berillium	1.85	0.012	0.305	116.38	116.08	0.30
2	AlBeMet window	AlBeMet	2.10	0.012	0.305	116.08	115.74	0.34
3	Beamline window	stainless steel	7.99	0.031	0.787	115.74	112.87	2.87
4	water gap	water	1.00	0.106	2.692	112.87	111.06	1.82
5	BOX front window	stainless steel	7.99	0.020	0.508	111.06	109.14	1.92
6	water gap	water	1.00	0.200	5.080	109.14	105.59	3.55
7	Aluminum slab	Aluminum	2.70	0.754	19.160	105.59	73.69	31.90
8	water gap	water	1.00	0.200	5.080	73.69	68.87	4.83
9	can window	Re coated Nb	8.43	0.015	0.381	68.87	66.86	2.01
10	Ga4Ni target	Ga4Ni	6.33	0.180	4.561	66.04	39.82	26.23
11	can window	Re coated NB	8.43	0.015	0.381	38.78	36.17	2.61
12	water gap	water	1.00	0.200	5.080	36.17	27.11	9.06
13	can window	inconel	8.43	0.012	0.305	27.11	23.47	3.64
14	CaCl2 target	CaCl2	2.15	0.196	4.979	23.47	0.00	23.47
15	can window	inconel	8.43	0.012	0.305	0.00	0.00	0.00
16	water gap	water	1.00	0.200	5.080	0.00	0.00	0.00
17	ss window	ss	8.00	0.029	0.737	0.00	0.00	0.00
18	vacuum	vacuum	0.00	0.596	15.138	0.00	0.00	0.00
19	ss window	ss	8.00	0.029	0.737	0.00	0.00	0.00
20	water gap	water	1.00	0.200	5.080	0.00	0.00	0.00
21	ss slab	ss	8.00	0.058	1.473	0.00	0.00	0.00
22	water gap	water	1.000	0.200	5.080	0.000	0.000	0.00

Chemical processing

Rick Darienzo

Strategy:

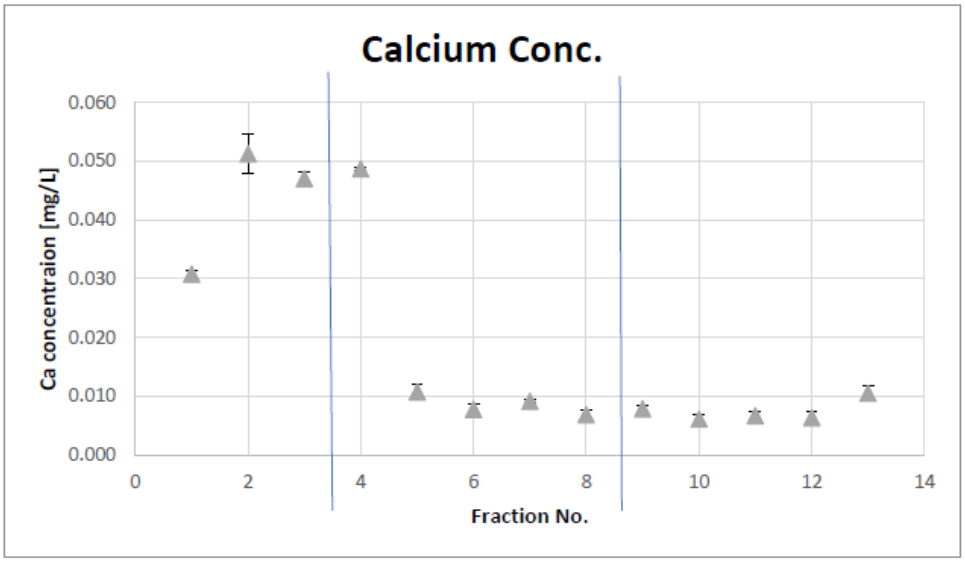
- Separate scandium fraction (Sc-47, Sc-46 Sc-44) as soon as possible after EOB
- Allow for Sc-47 to grow in from Ca-47
- Separate scandium fraction (now Sc-47 only)

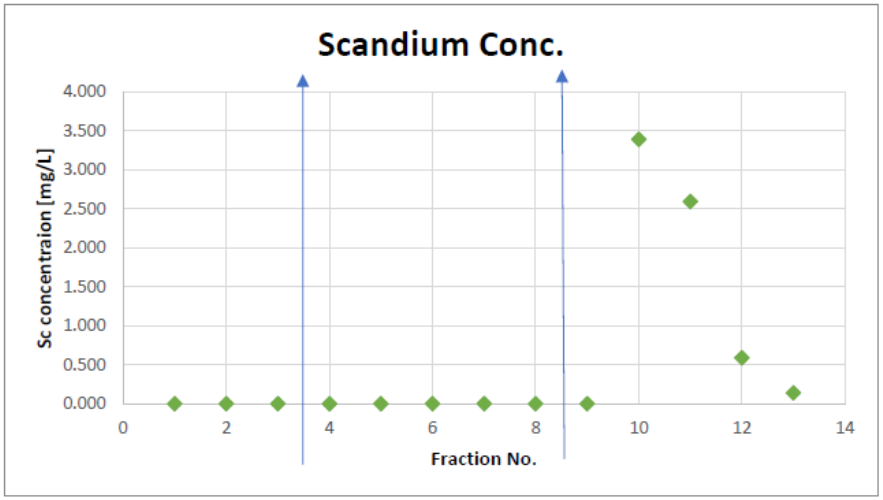
Approach

- Dissolve $CaCl_2$ target in 3 M HCl
- Use DGA column to separate scandium fraction from $CaCl_2$
- Wash in 3 N HCl and elution of Sc in 0.1 N HCl

DGA elution profile

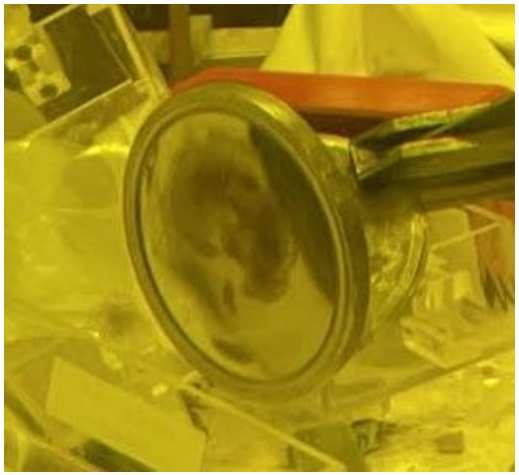
Rick Darienzo





Irradiation campaigns

- March 2021
  - 22.17 g $CaCl_2$ target, 122.2 μA, 93.6 h on target, 10:1 rastered beam
  - Target transferred to TPL and processed, 2.77 mCi of Ca-47 at EOB
- June 2021
  - 20.66 g $CaCl_2$ target, 122.9 μA, 94.7 h, 10:1 rastered beam
  - Target failed during irradiation



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Summary

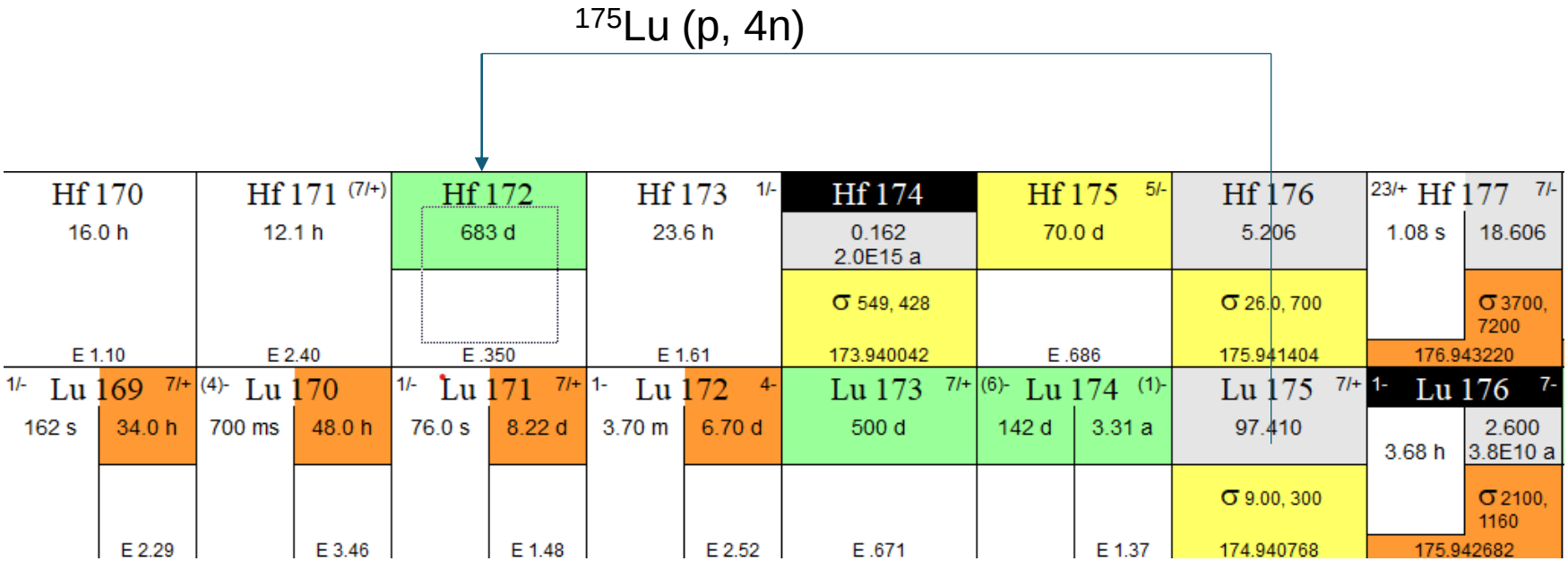
- First generation of $CaCl_2$ targets has been designed and irradiated in the c-slot at BLIP
- The concentration of useful nuclei in ^{nat}Ca is low – the method is more suitable for small cyclotron using ^{48}Ca
- Separation using DGA resin has proven to be applicable
- In the case of large targets there is a need for rapid separation due to relatively short half-life of Ca-47

Hf-172/Lu-172 production

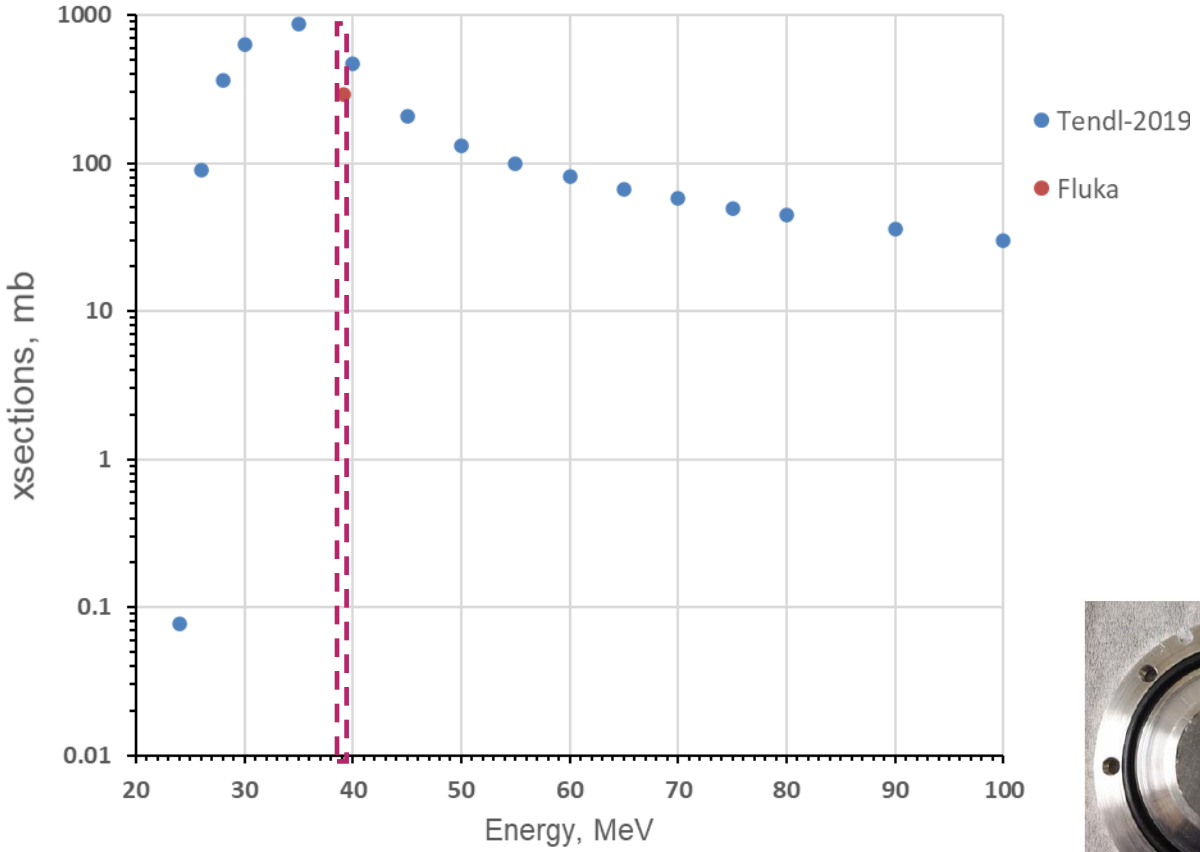
Rationale

- Lu-172 ($T_{1/2}$=6.70 d) is an isotope suitable for studies based on Perturbed Angular Correlation (PAC)
- PAC is used to study structure of chelator - radiometal complexes
- “Based in the angular correlation between two γ-rays, which is perturbed by the hyperfine interaction of the nuclear electric quadrupole moment (*Q*) with the electric field gradient (EFG) or the nuclear magnetic moment with an extranuclear magnetic field. PAC gives information serving as a “fingerprint” of the local structure.”

Production from natural Lu



Lu-175(p,4n) cross section data



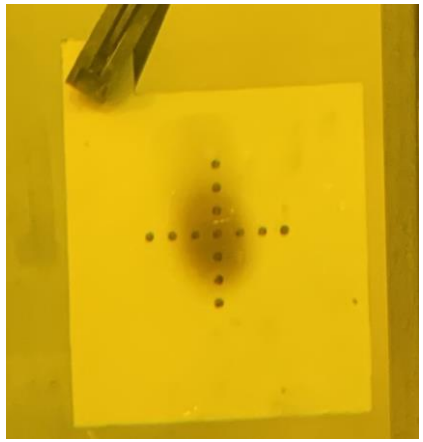
Target material

- Lutetium foil
- 0.025 cm thick, 2.5 cm diameter
- Isolated in a bolted capsule for irradiation
- Opened at BLIP in a hot cell

Energy propagation table

2022	Energy: 66 MeV	small raster 5 mm					1 μA		
				thickness					
layer number	Layer	Material	density	inches	mm	Ei	Eout	E deposited, MeV	Total power, W
1	Be window	Berillium	1.85	0.012	0.305	66.00	65.54	0.46	25.09
2	AlBeMet window	AlBeMet	2.10	0.012	0.305	65.54	65.01	0.53	28.67
3	Beamline window	stainless steel	7.99	0.031	0.787	65.01	60.57	4.44	242.13
4	water gap	water	1.00	0.106	2.692	60.57	57.62	2.95	160.65
5	BOX front window	stainless steel	7.99	0.508	12.903	57.62	54.48	3.14	171.23
6	water gap	water	1.00	0.100	2.54	54.48	51.44	3.04	165.51
7	Aluminum degrader	Aluminum	7.99	0.056	1.42	51.44	47.72	3.71	202.28
8	water gap	water	1.00	0.200	5.08	47.72	40.74	6.98	380.43
9	Bolted target window	Aluminum	2.70	0.020	0.508	40.74	39.17	1.57	85.38
10	Lutetium foil	Lu	9.70	0.010	0.254	39.17	37.34	1.84	100.08
11	Bolted target back wind	Aluminum	2.70	0.170	4.32	37.34	32.55	4.79	260.68
12	Water pocket	water	1.00	0.298	7.57	32.55	20.84	11.71	637.93
13	water gap	water	1.00	0.100	2.54	20.84	16.56	4.28	233.06
14	Aluminum degrader	Aluminum	2.70	1.736	44.10	16.56	stop	16.56	902.32
15	water gap	water	1.00	0.100	2.54	0.00	0.00	0.00	0.00
16	Aluminum degrader	Aluminum	2.70	0.056	1.42	0.00	0.00	0.00	0.00
17	water gap	water	1.00	0.000	0	0.00	0.00	0.00	0.00

Irradiation experiments



- June 2022
  - 1.58 g (d×h=28.56×0.2624 mm^2) Lu foil (Goodfellow®)
  - Energy: incident 66 MeV, 39.2 MeV on the foil
  - Beam current: 0.48 μA focused beam, 10 μA-h
  - Irradiated over 3 days for a total of 21.05 h
  - Dissolved and processed at RRPL

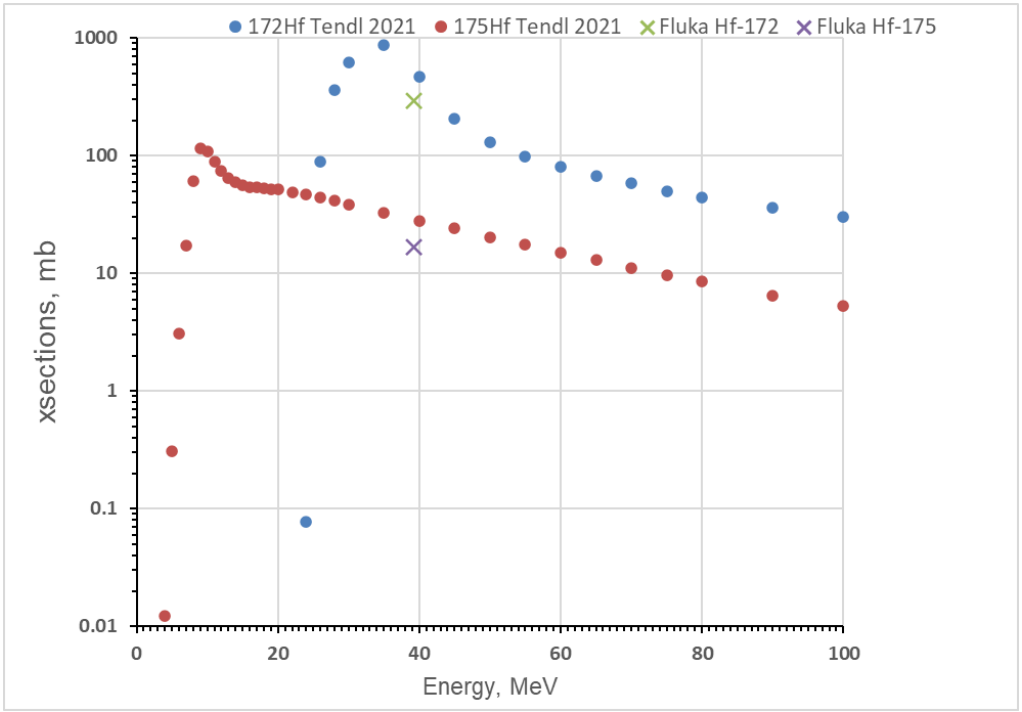
- January 2023
  - Lu foil similar in size, same material
  - Energy: incident 117 MeV, 34.9 MeV on the foil
  - Beam current: 2.69 μA focused beam, 62.9 μA-h
  - Irradiated for 23 hours
  - Added Cu, Ni, Al foil for beam monitoring
  - Shipped to MSU (Greg Severin/Samridhi Satija)

Dissolution and chemical processing

Samridhi Satija
MSU graduate student

Irradiation yield (measured vs. Fluka)

- Hf-172 - 10.78 vs 17.8 µCi
- Hf-175 – 12.51 vs 9.85 µCi



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Separation using Ln resin

Samridhi Satija
MSU graduate student

Strategy: adsorbing Hf, while allowing Lu to pass through

- Bed volume about 3 ml (900 mg)
- Loading and rinse in 7M HCl
- Elution of I

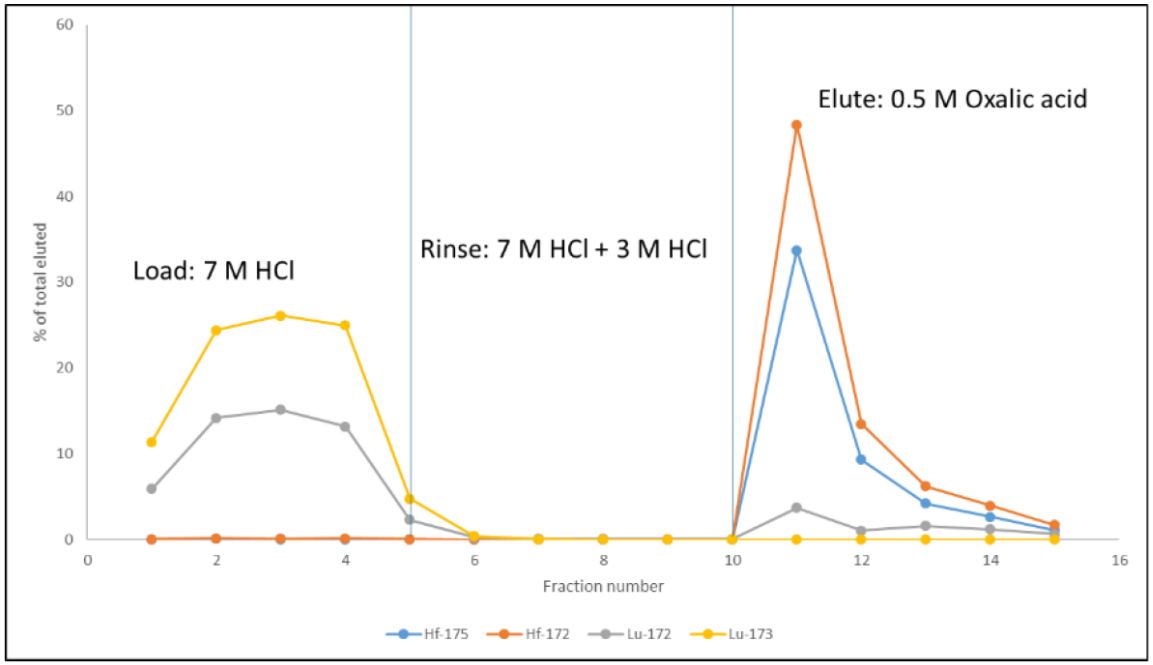

Figure 6: Elution profile for the radiochemical separation on the LN resin, with % of the activity eluted for each radioisotope. Each fraction is 13 mL and the activity is not decay corrected.

Summary

- Second irradiation of Lu foil was carried out in January 2023. The foil was shipped to MSU for processing
- The foil will be processed using developed methodology on Ln column
- Radiolabeling studies will be completed at MSU
- Beam characterization will be completed at BNL