

Towards Novel Medical Isotope Production at HF-ADNeF

Max Conroy

STFC Nuclear Physics Summer School 2024

15/8/24

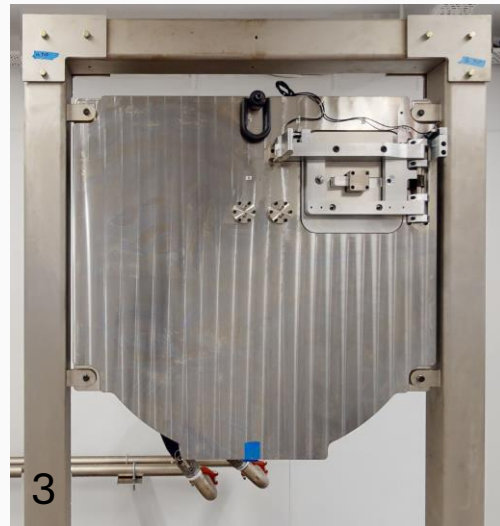
Contact: m.j.conroy@pgr.bham.ac.uk



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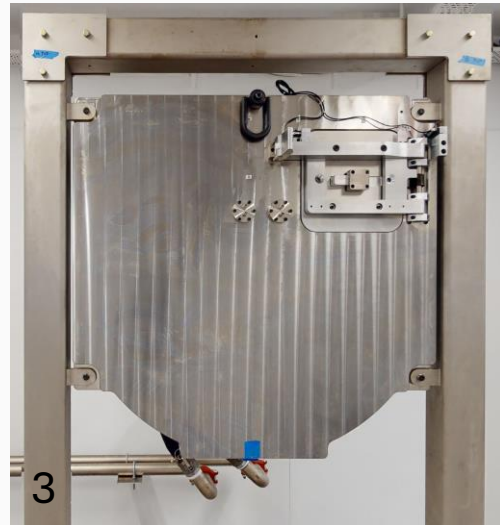


High Flux Accelerator-Driven Neutron Facility



- Bought from Neutron Therapeutics
- Hyperion type linear accelerator, up to 2.6 MeV protons at currents > 30 mA
- Proton beam incident upon lithium target, formed of 16 rotating water-cooled petals
- Neutrons produced via ${}^7\text{Li}(p,n){}^7\text{Be}$ reaction, mostly forwards focused.
- **Flux $> 10^{12}$ n cm 2 s $^{-1}$**

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Commissioned December 2023

Novel Medical Isotopes

- Many promising medical isotopes...

Lu 177		
7 m	160.4 d	6.6443 d
β^-	β^- 0.2 γ 208, 228..., m_1	β^- 0.5... γ 208, 113...
γ 1003, 89...	IT(116), e^- γ 414...	e^- , g σ 880
m_2	σ 417	

Ho 166	
1132.6 a	26.824 h
β^- 0.07, 1.3...	β^- 1.8, 1.9...
γ 184, 810, 712...	γ 81...
σ 10778	e^-

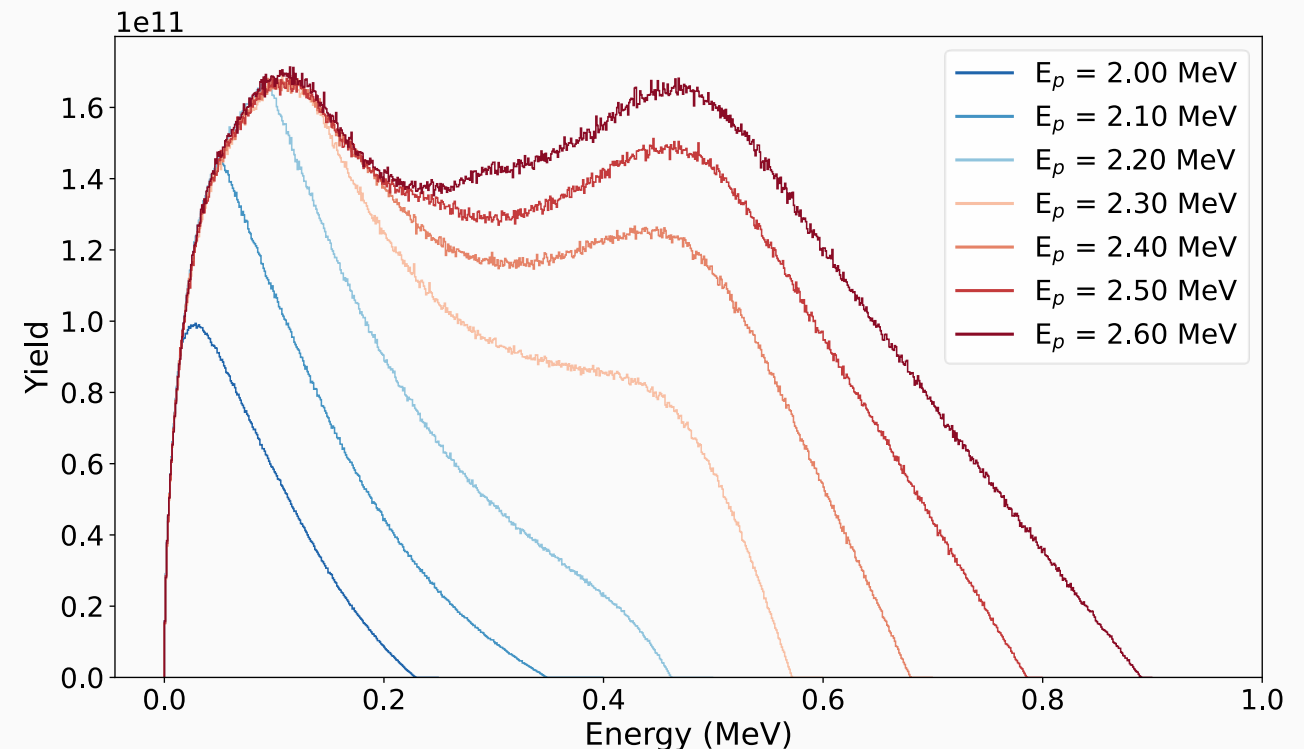
Tb 161
81.5 h
β^- 0.5, 0.6...
γ 26, 49, 75...
e^-

Ac 225
9.920 d
α 5.830, 5.793 5.732...
C 14
σ 12.0

- Conventionally produced in nuclear reactors (EU, Canada...)
- Is smaller scale, on-site production feasible?

OpenMC Simulation

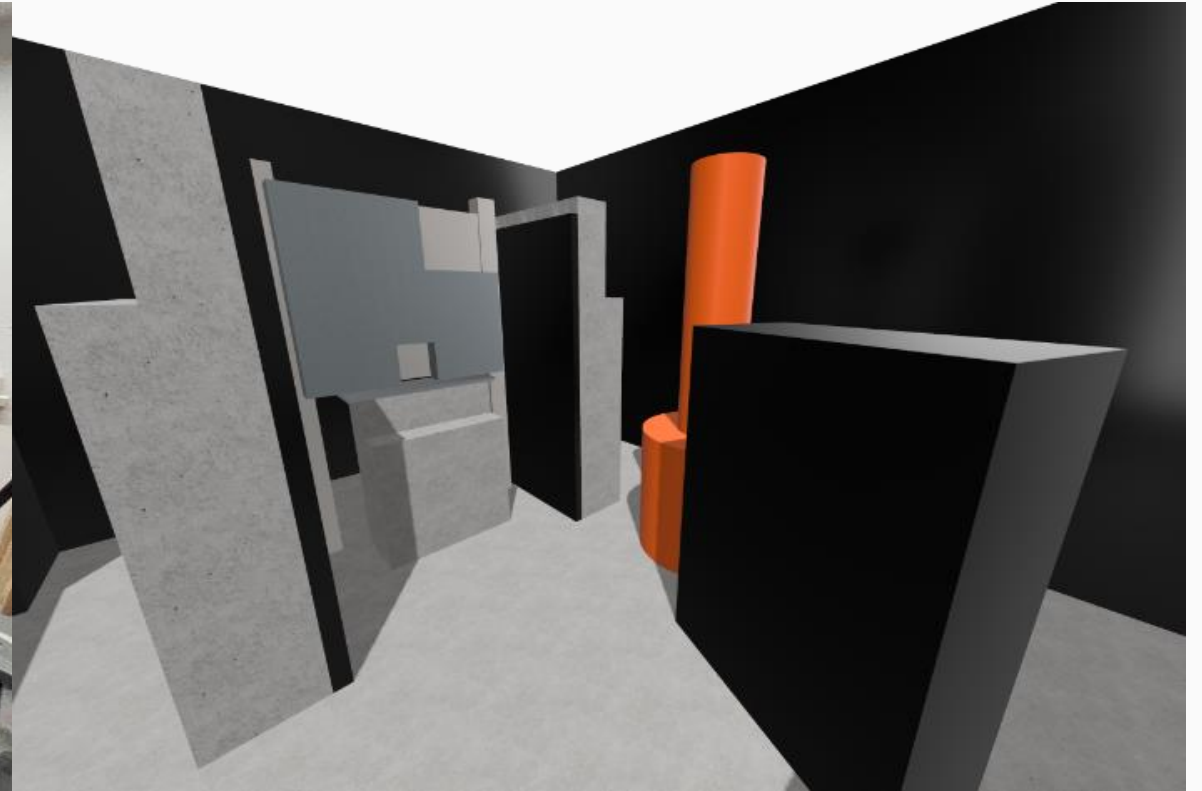
- OpenMC: neutral particle transport code (MCNP)
- Created a custom starting source term for simulations
 - Samples from measured differential cross section data¹
- Observe "double hump" energy spectrum for increasing E_p



¹ENDF/B-VIII.0

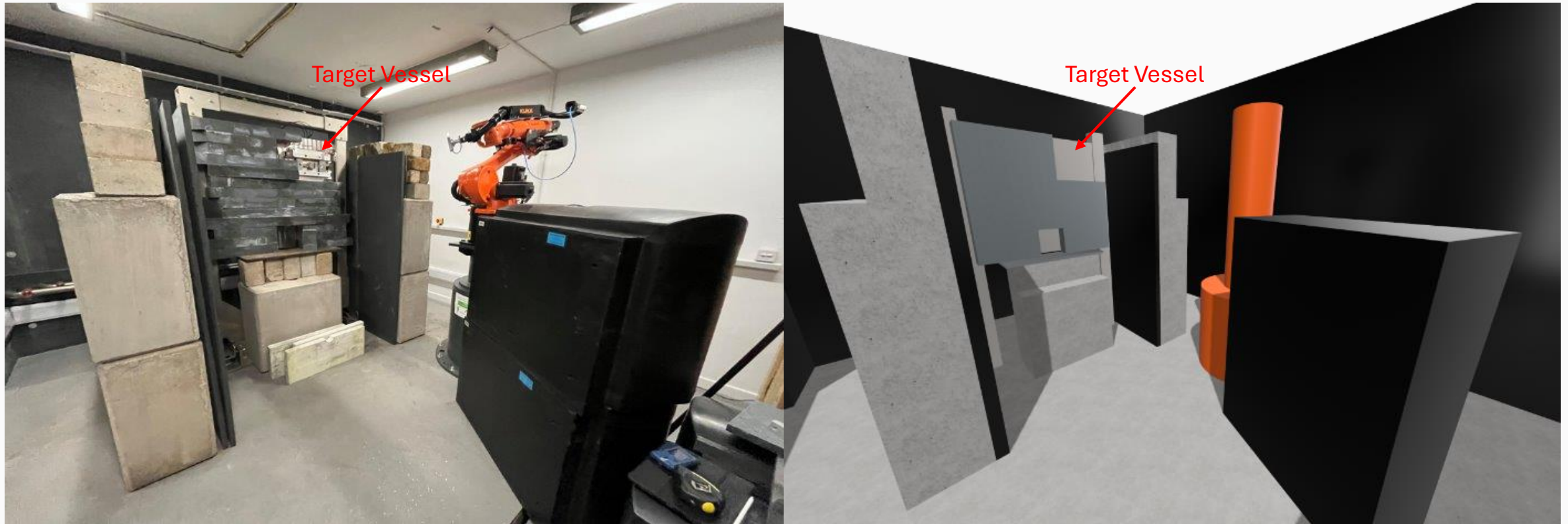
OpenMC Simulation

- 3D CAD of target and surroundings built in OpenMC



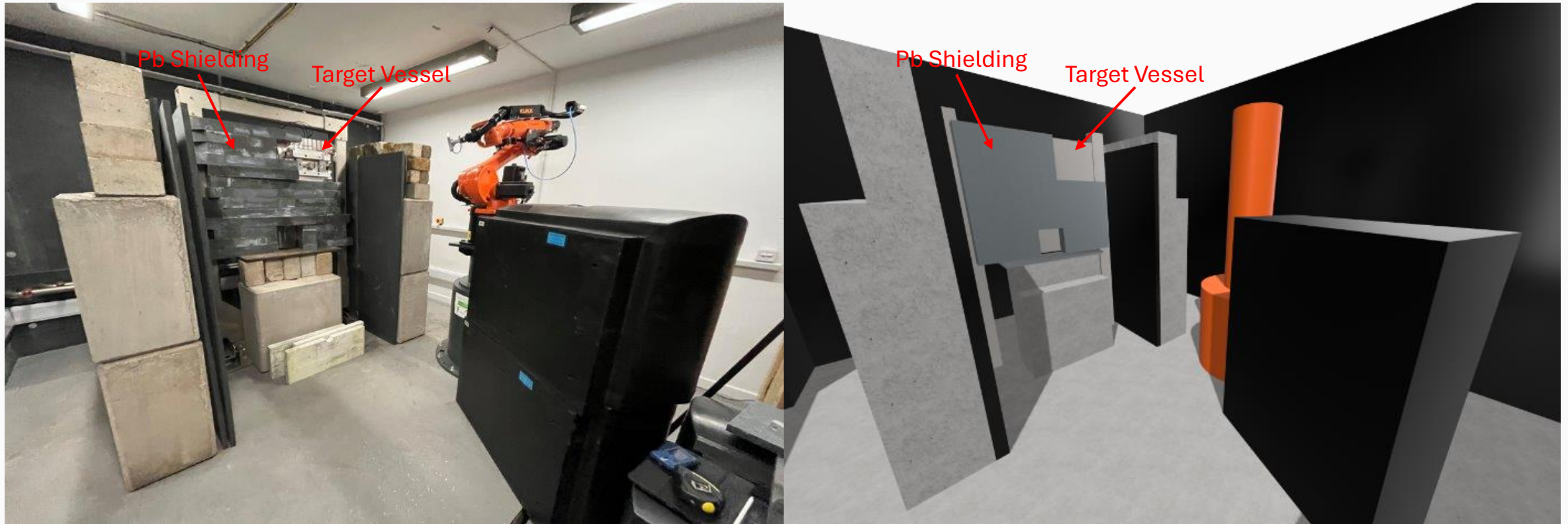
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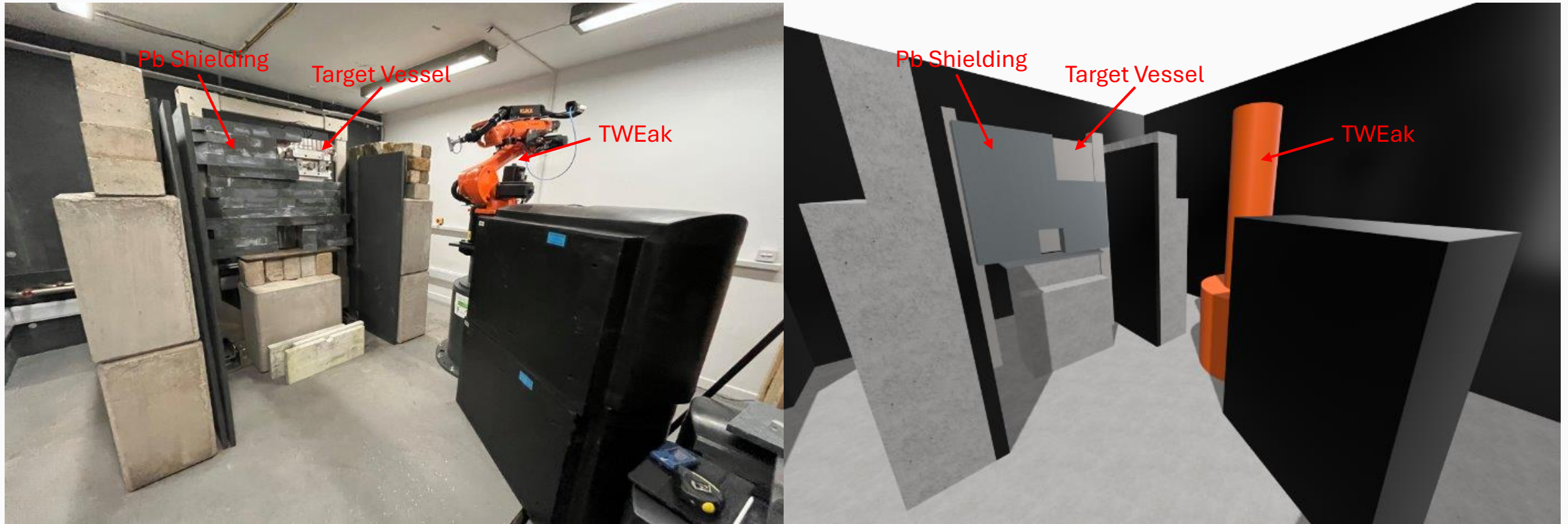
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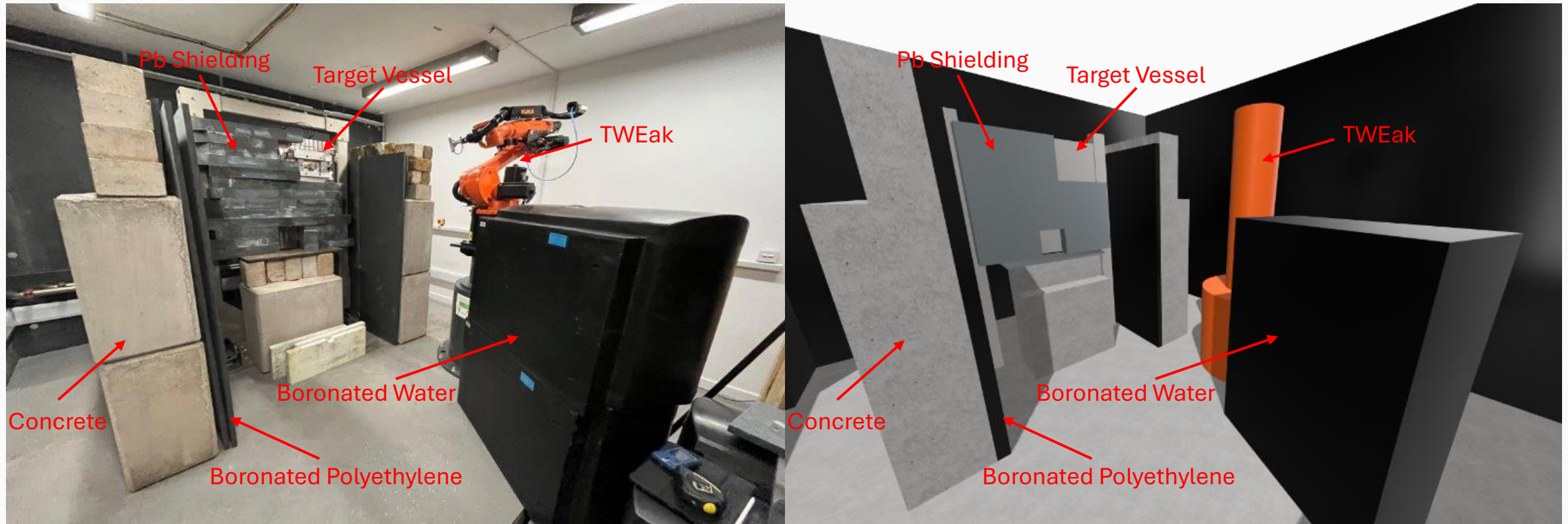
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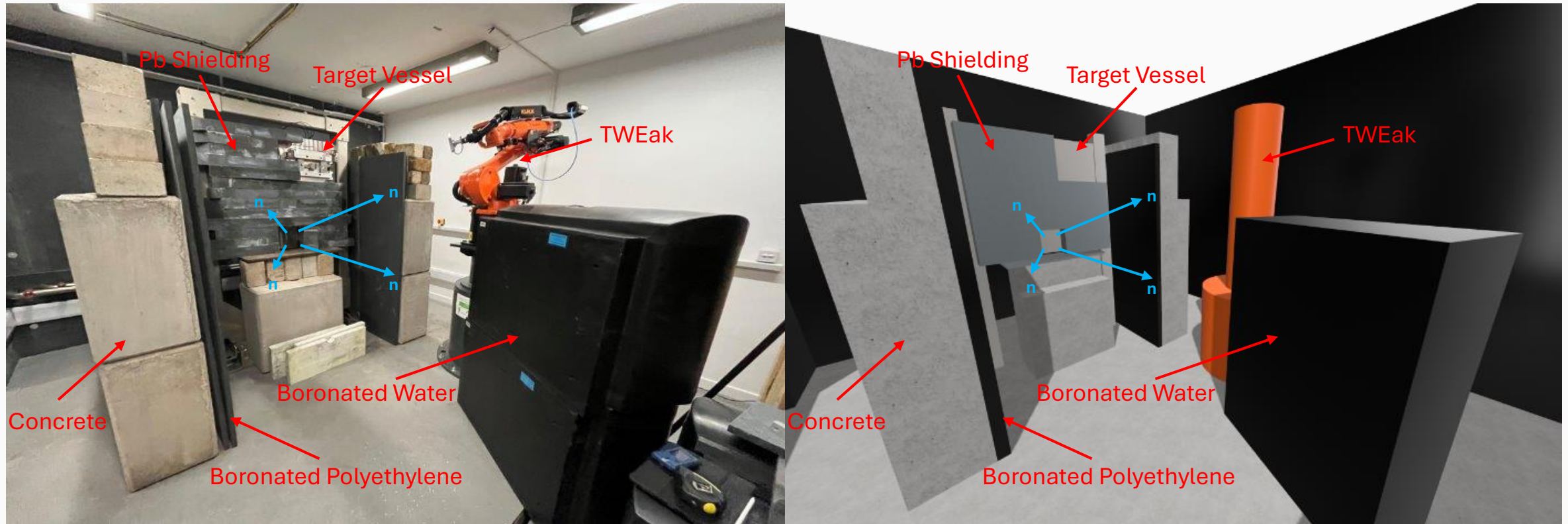
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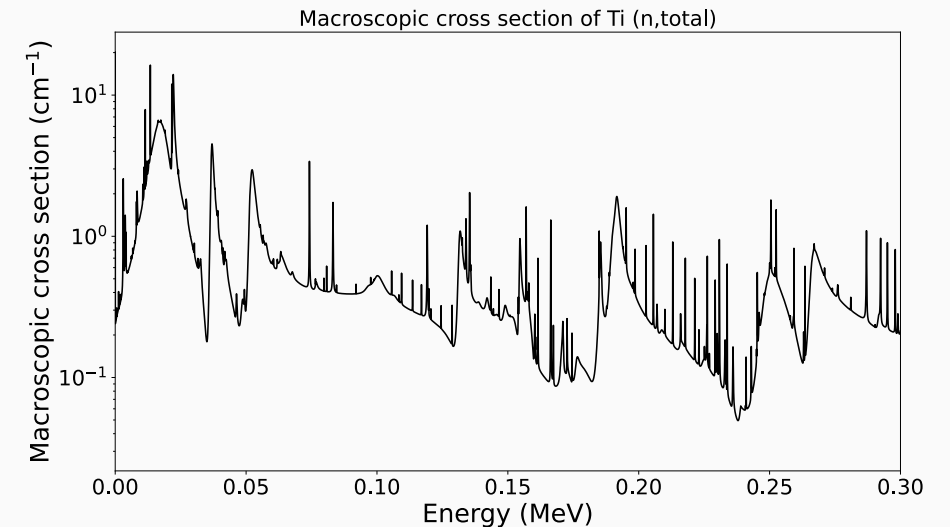
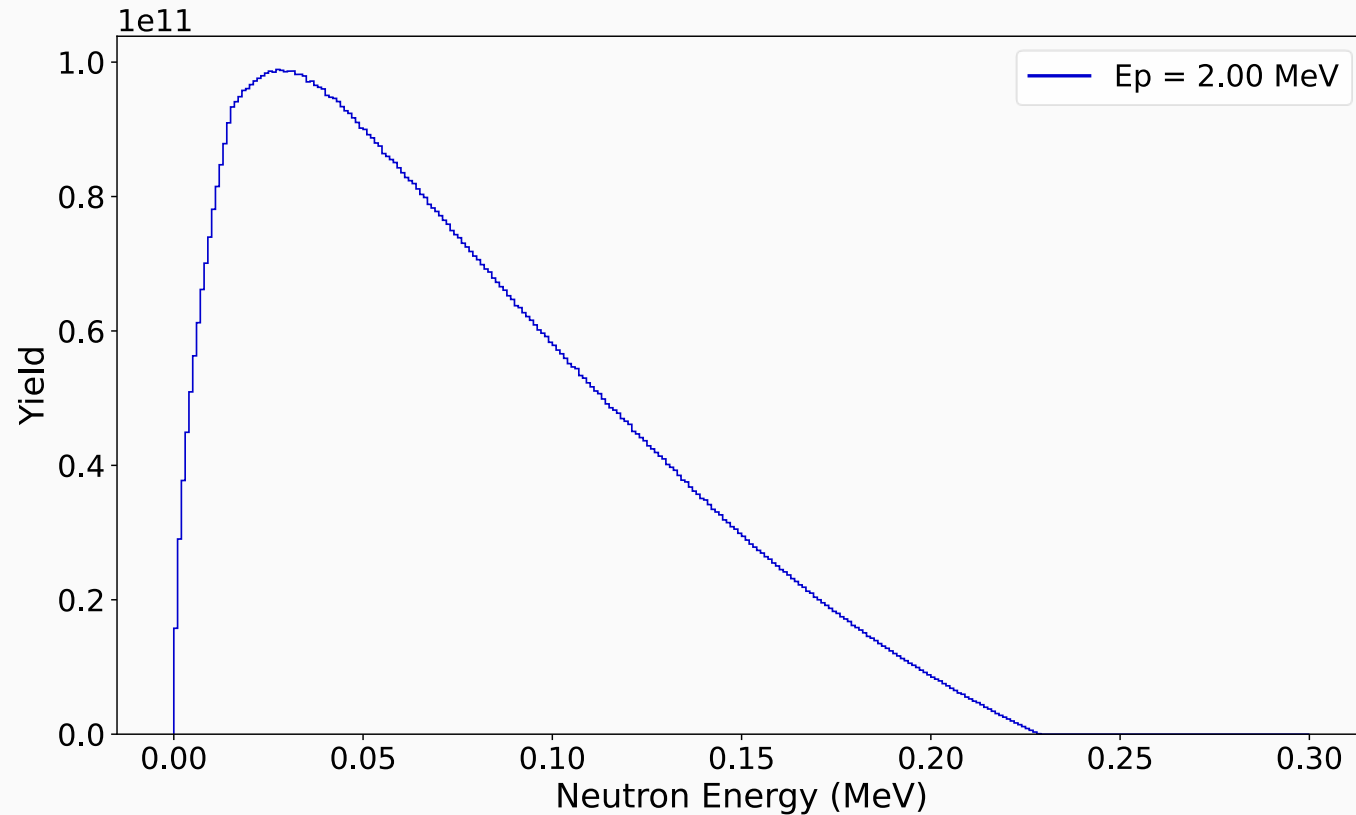
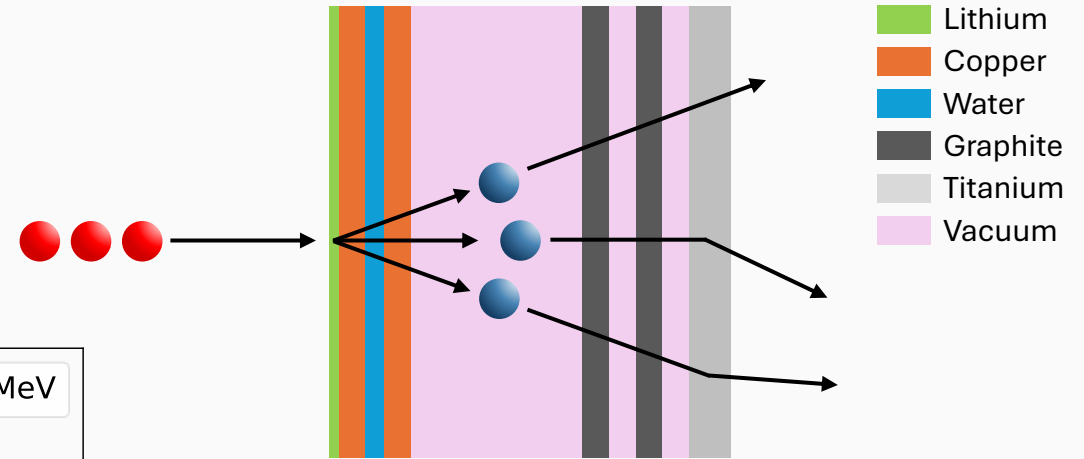
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OpenMC Simulations

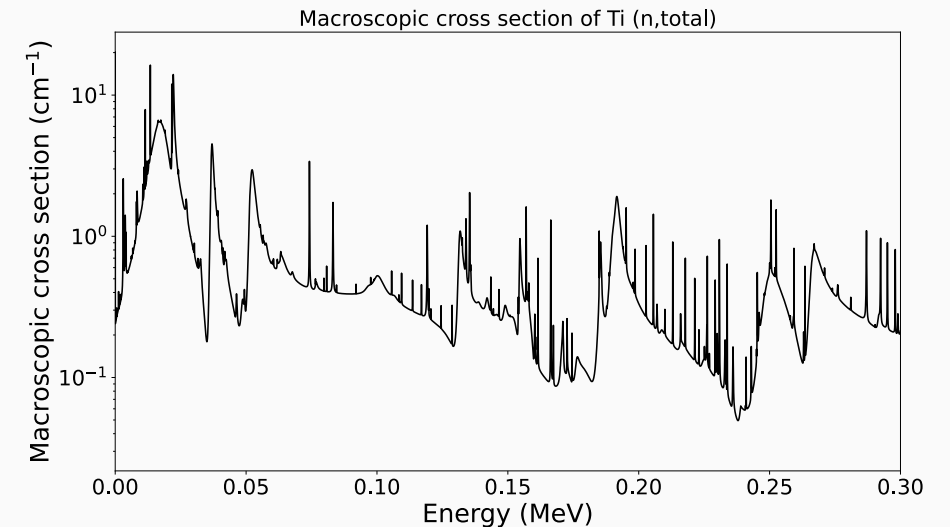
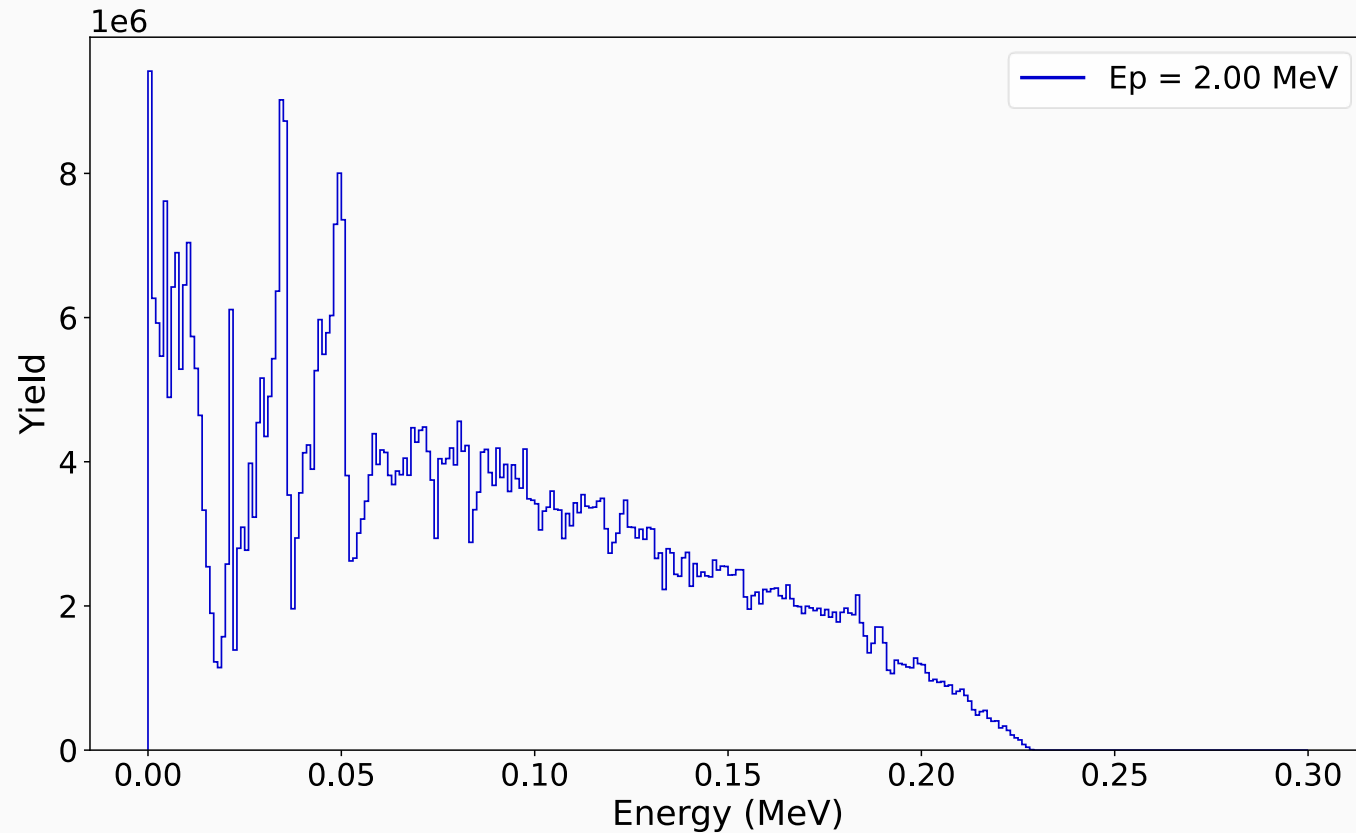
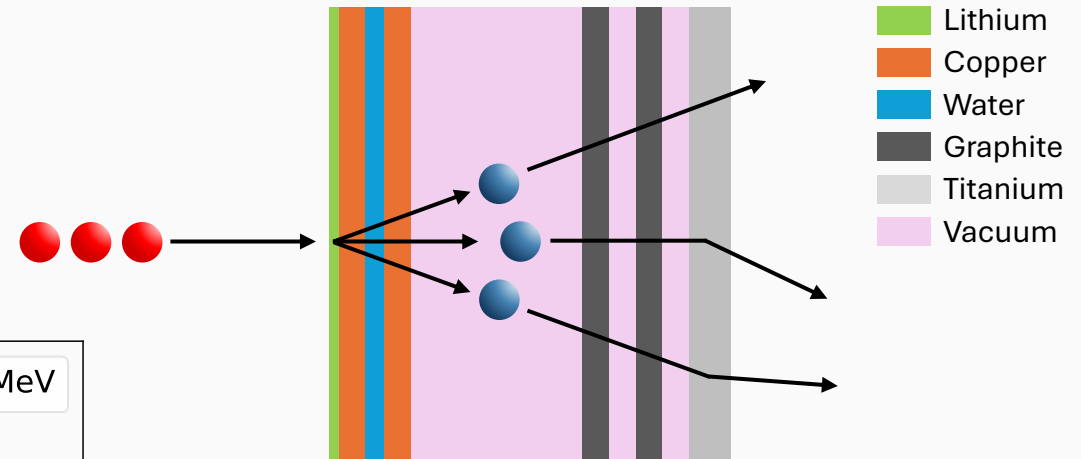
- Simulating neutrons in this geometry...



From XS-Plot.com (TENDL 2019 data)

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Use Case: ^{166}Ho Production

- Theragnostic isotope:
 - **Therapeutic** β^-
 - 80.6 keV γ for imaging (**diagnostic**)
- Currently used for treatment of liver metastasis²
- No method of production in the UK

Ho 166	
1132.6 a	26.824 h
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²Stella M et. Al. Cardiovasc Intervent Radiol. 2022 Nov;45(11):1634-1645

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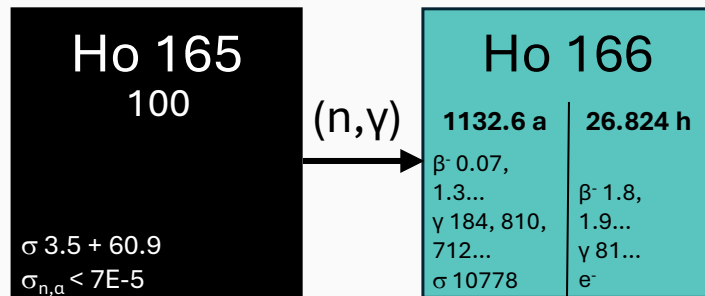
Experiment proposed by NNL and completed as a collaboration between NNL and UoB.

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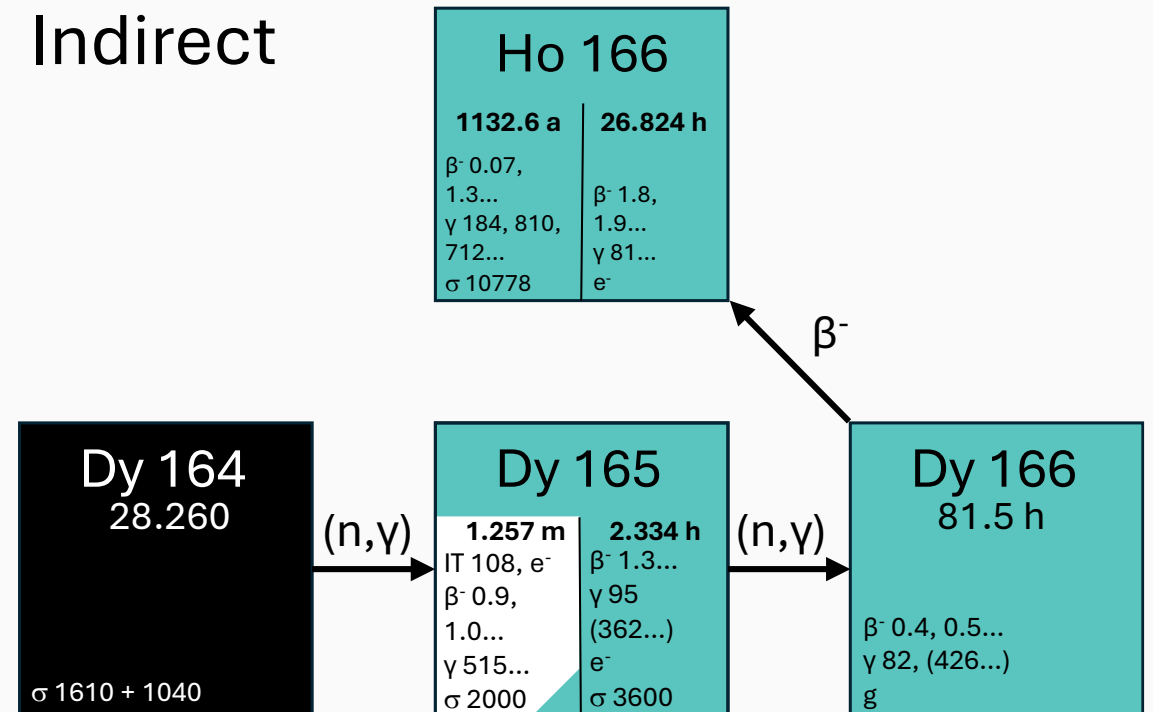
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Direct



High yield
Natural holmium is isotopically pure
Produces ^{166m}Ho (carrier-added)

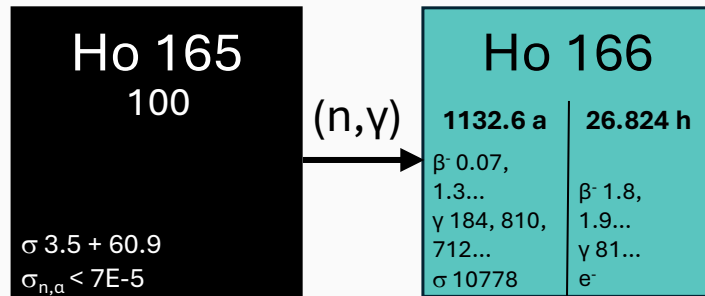
Indirect



Lower yield
Non-carrier-added

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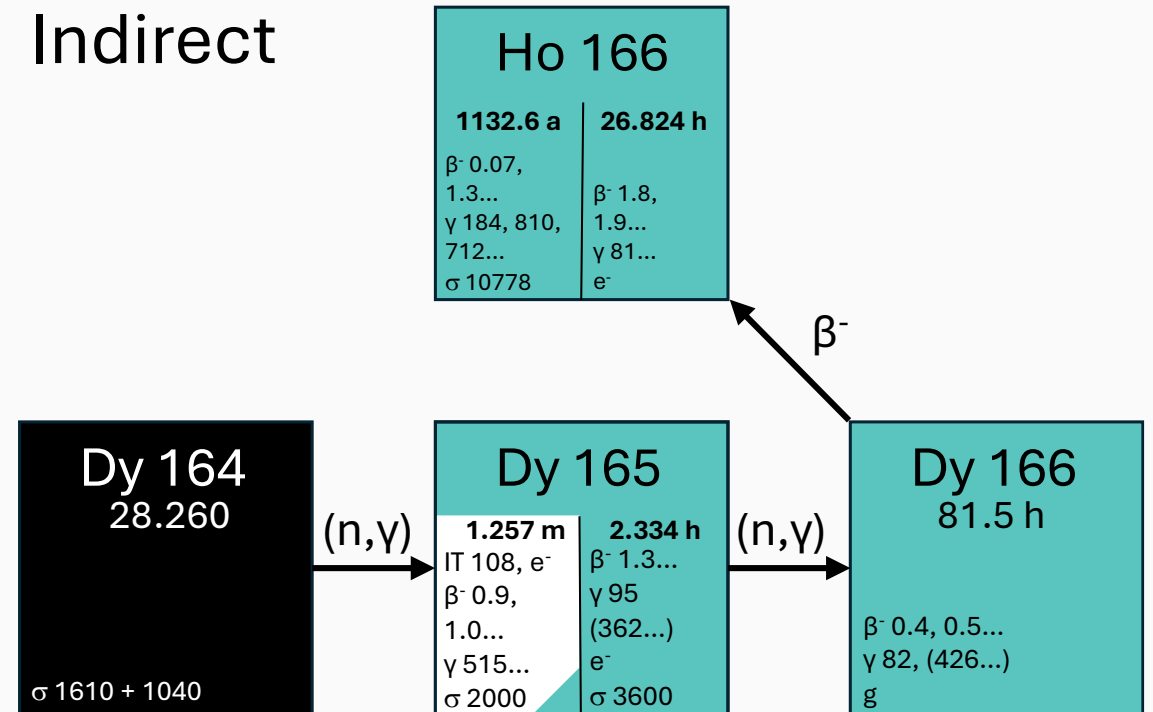
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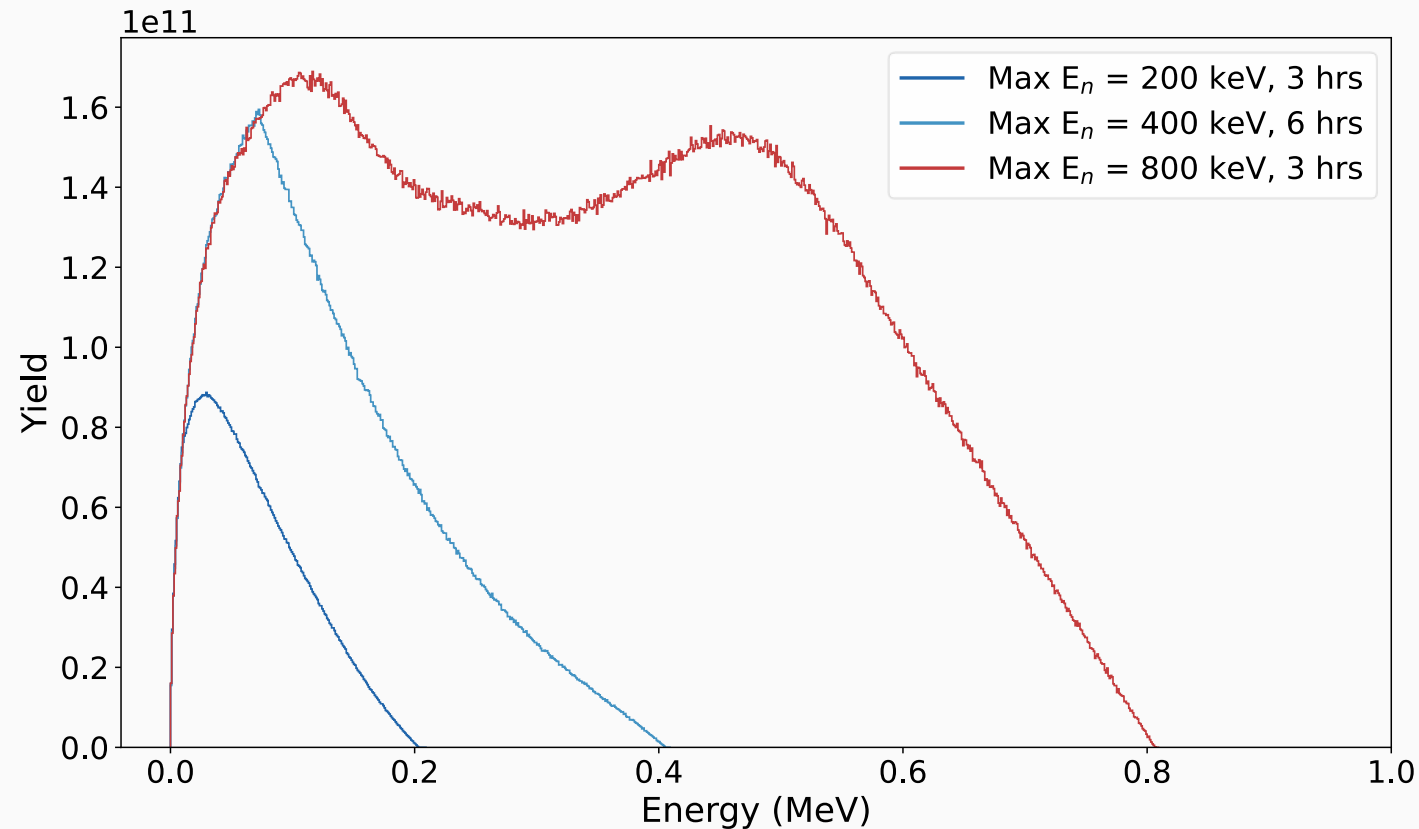


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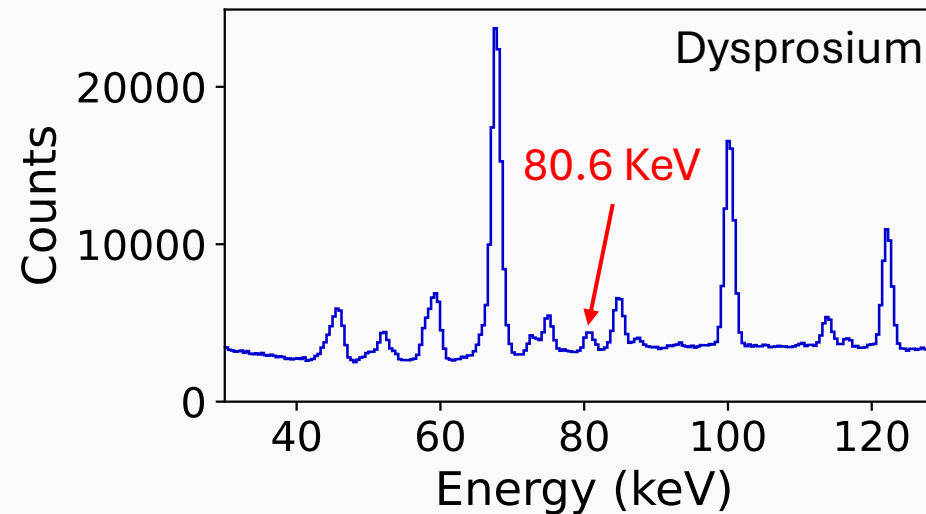
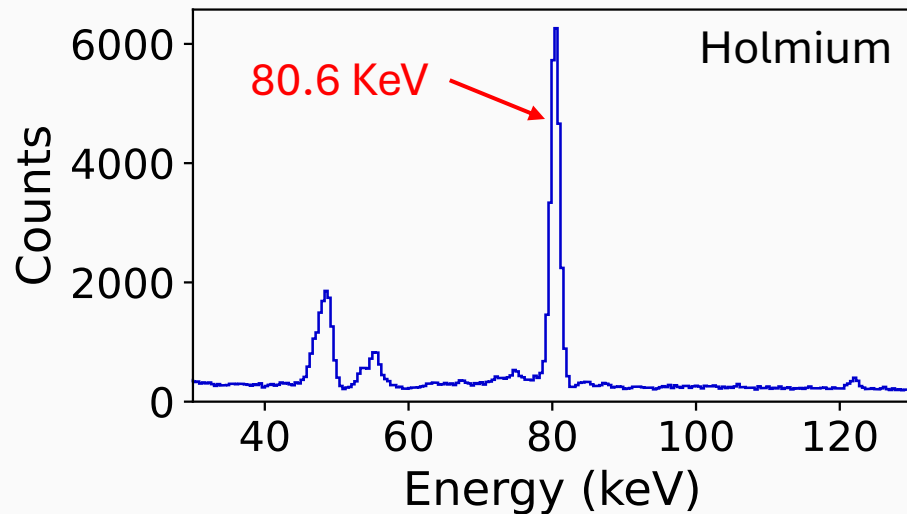
Irradiation at HF-ADNeF

- Three irradiation conditions:

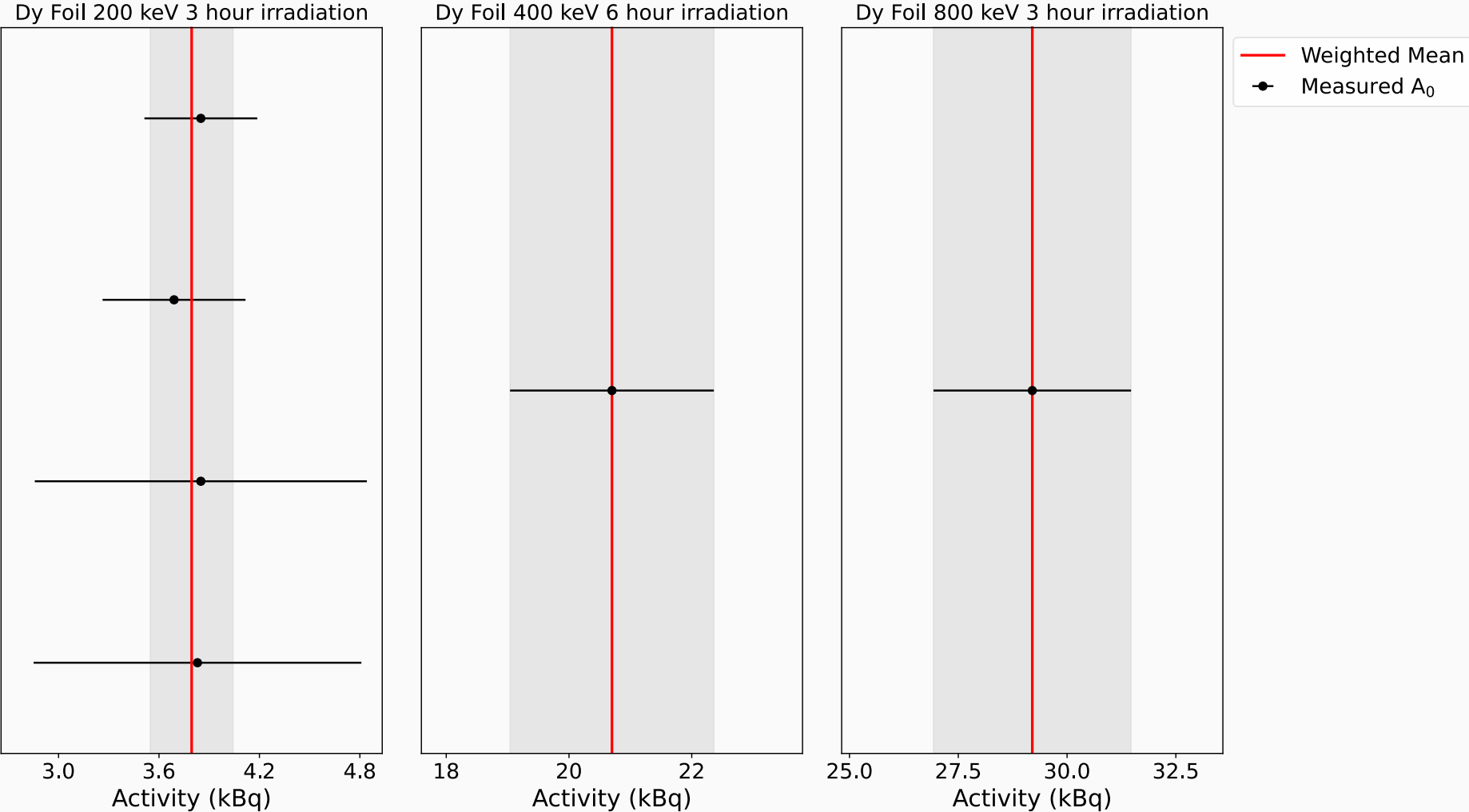


Gamma Spectroscopy

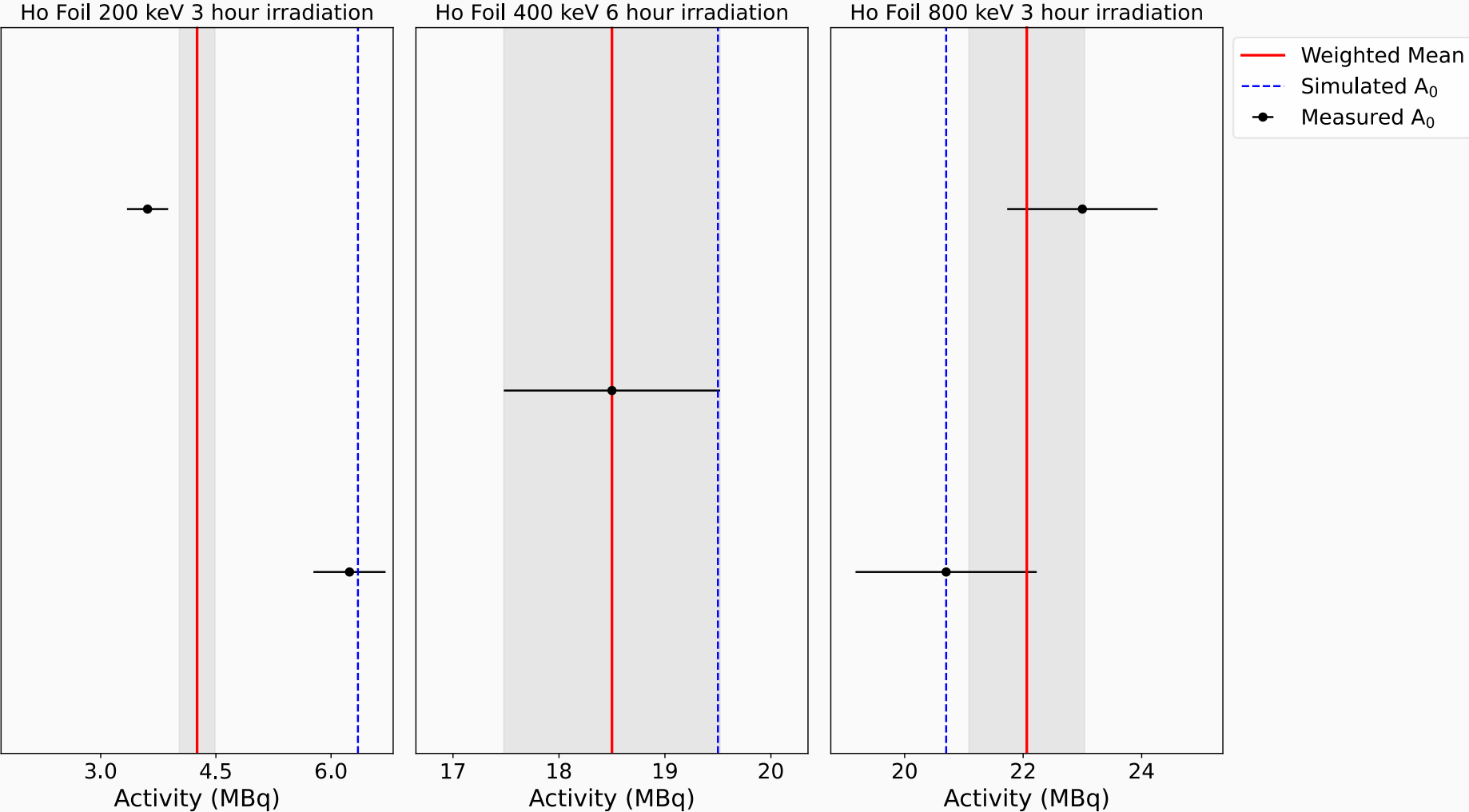
- Measured irradiated foils with HPGe
- Shielded from Pb X-rays with copper foils
- Geometric and self-attenuation correction of foils calculated with Monte Carlo



Experimental Results (Preliminary)



Experimental Results (Preliminary)



Conclusion and Future Work

- Developed a computational framework for testing radioisotope production at HF-ADNeF
- Experimentally produced ^{166}Ho and compared to simulation
- Aim to repeat experimental work with thin window HPGe
- Develop simulation to use OpenMC depletion module
- Simulate moderators and other additions for yield optimization
- Compare to other codes (Geant4, MCNP)
- Produce new isotopes!

Thank you to...

Dr Tony Price¹, Ms Bethany Slingsby², Dr Robert Mills², Professor Martin Freer¹,
Dr Luigi Capponi², Professor Tzany Kokalova¹, Professor Carl Wheldon¹,
Dr Jack Bishop¹

¹School of Physics and Astronomy, University of Birmingham, UK

²National Nuclear Laboratory, UK

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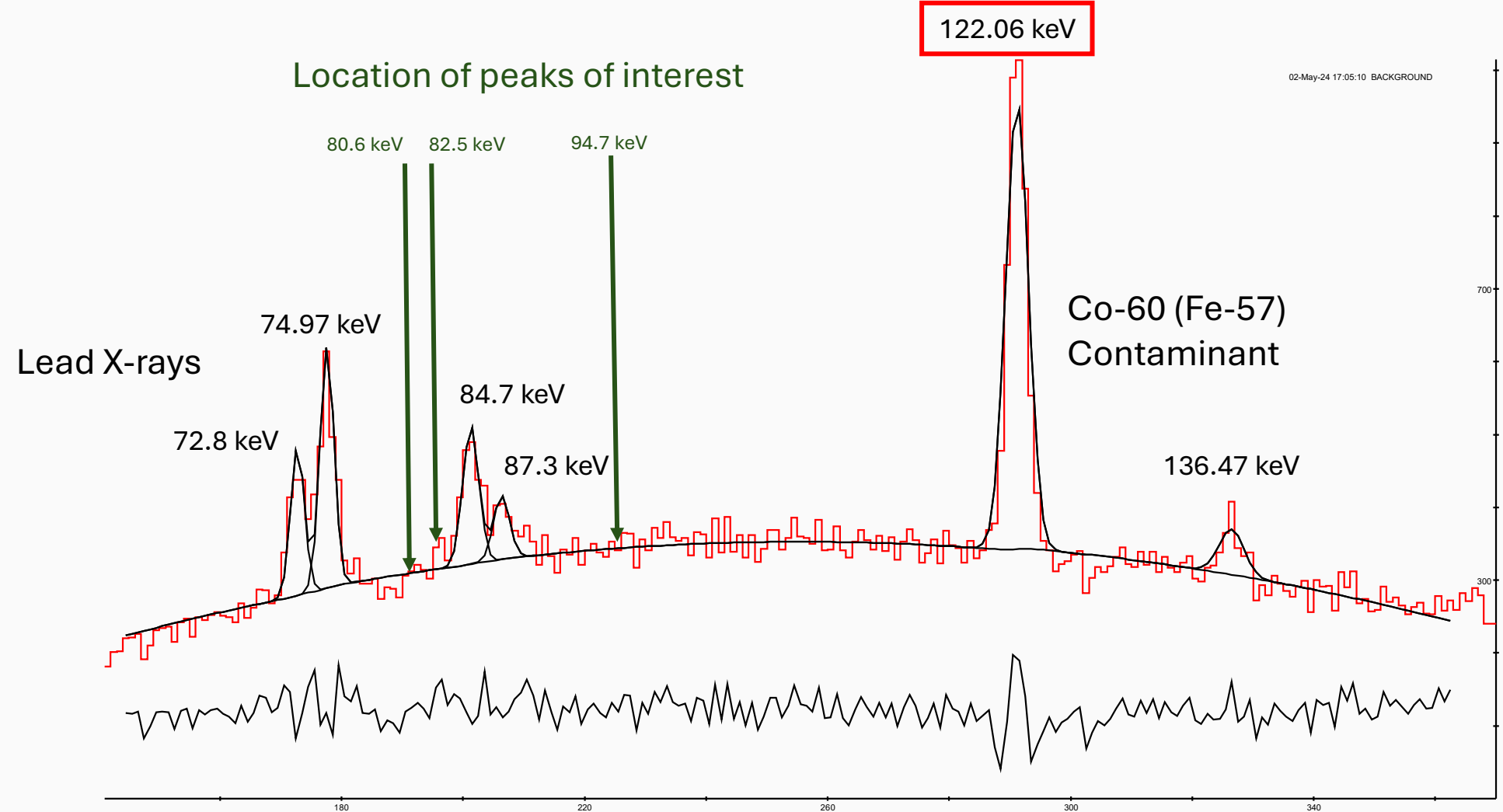


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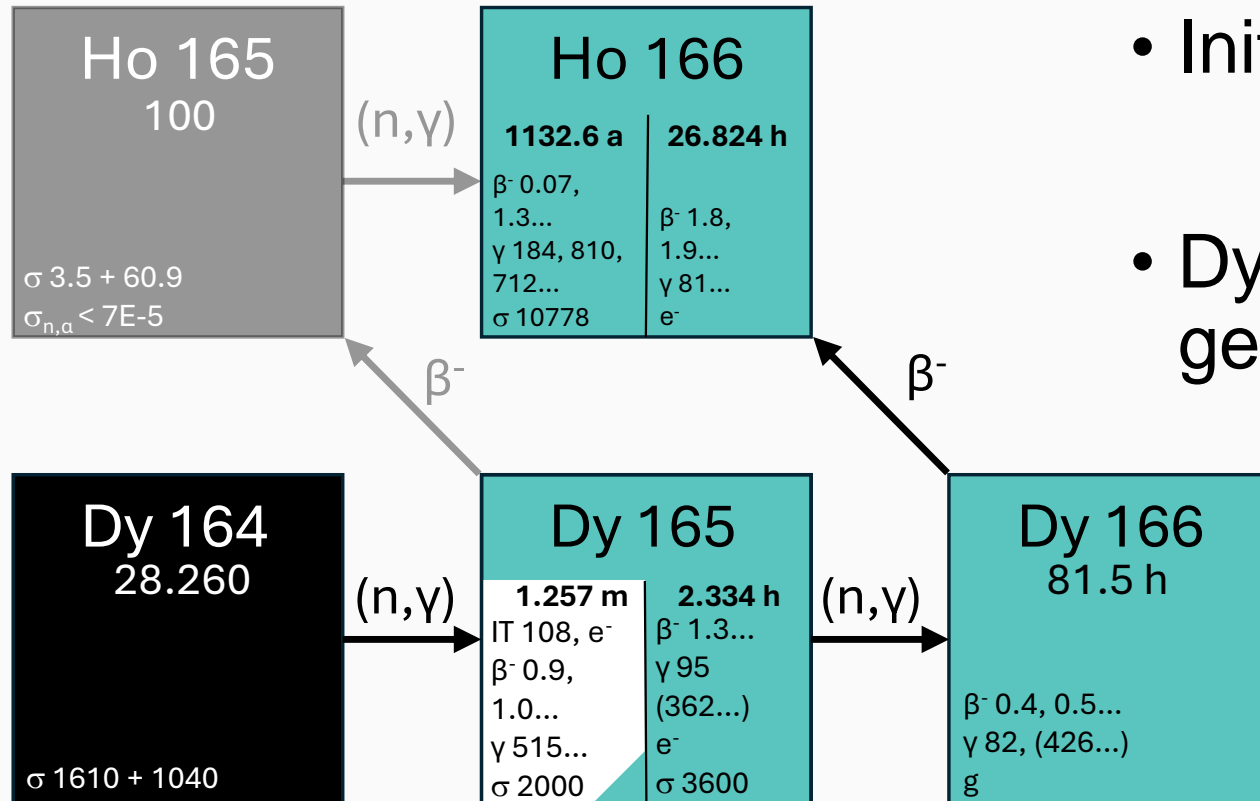


Background Impact

Affects Eu-152 efficiency measurement



Use Case: ^{166}Ho Production



- Initial chemical separation
- Dy-166 then becomes generator