MTV Student Virtual Research Symposium

Neutron Resonance Analysis of Fissile Material Using a D-T Neutron Generator (*an update*)

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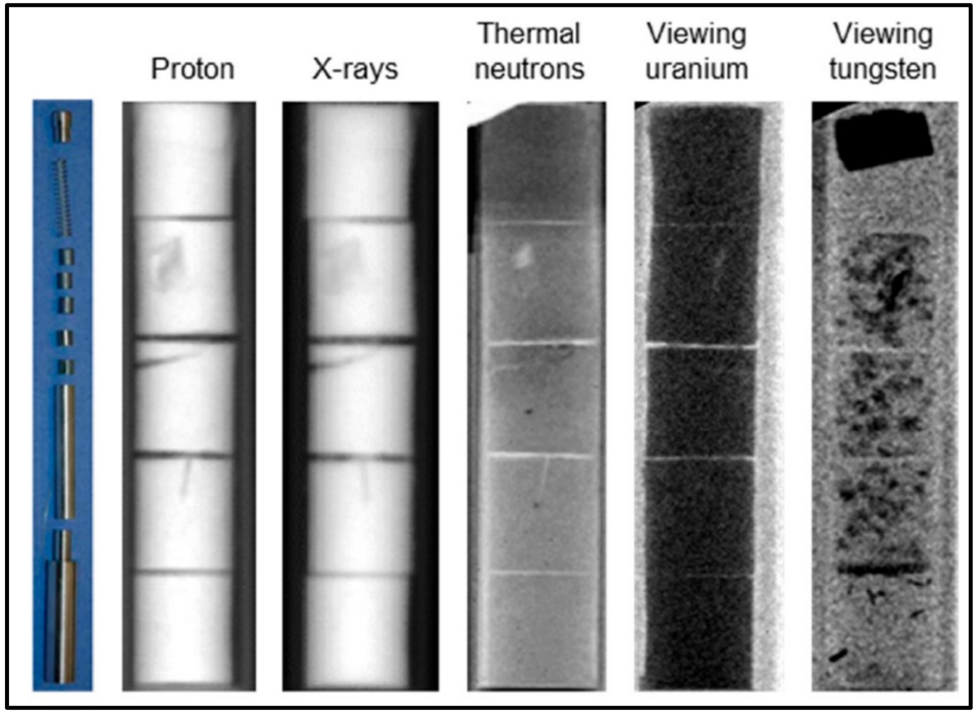
Motivation

- Verification of nuclear arms control treaty compliance requires on-site material identification and isotopic composition analysis
- X-ray imaging and most passive detection techniques are not suitable for analysis of mid- and high-Z materials (e.g. Fe, Pb, U, Pu)
- Epithermal neutron resonance imaging is a proven, isotopically sensitive technique with potential application for safeguards applications

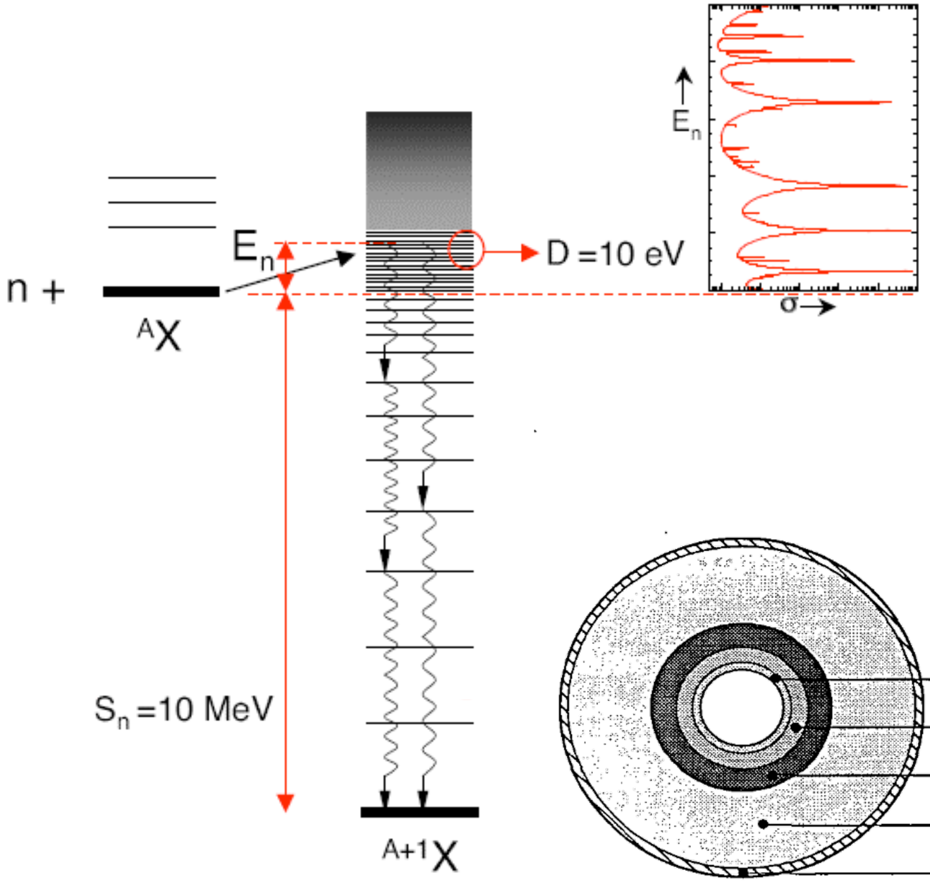
Mission Relevance

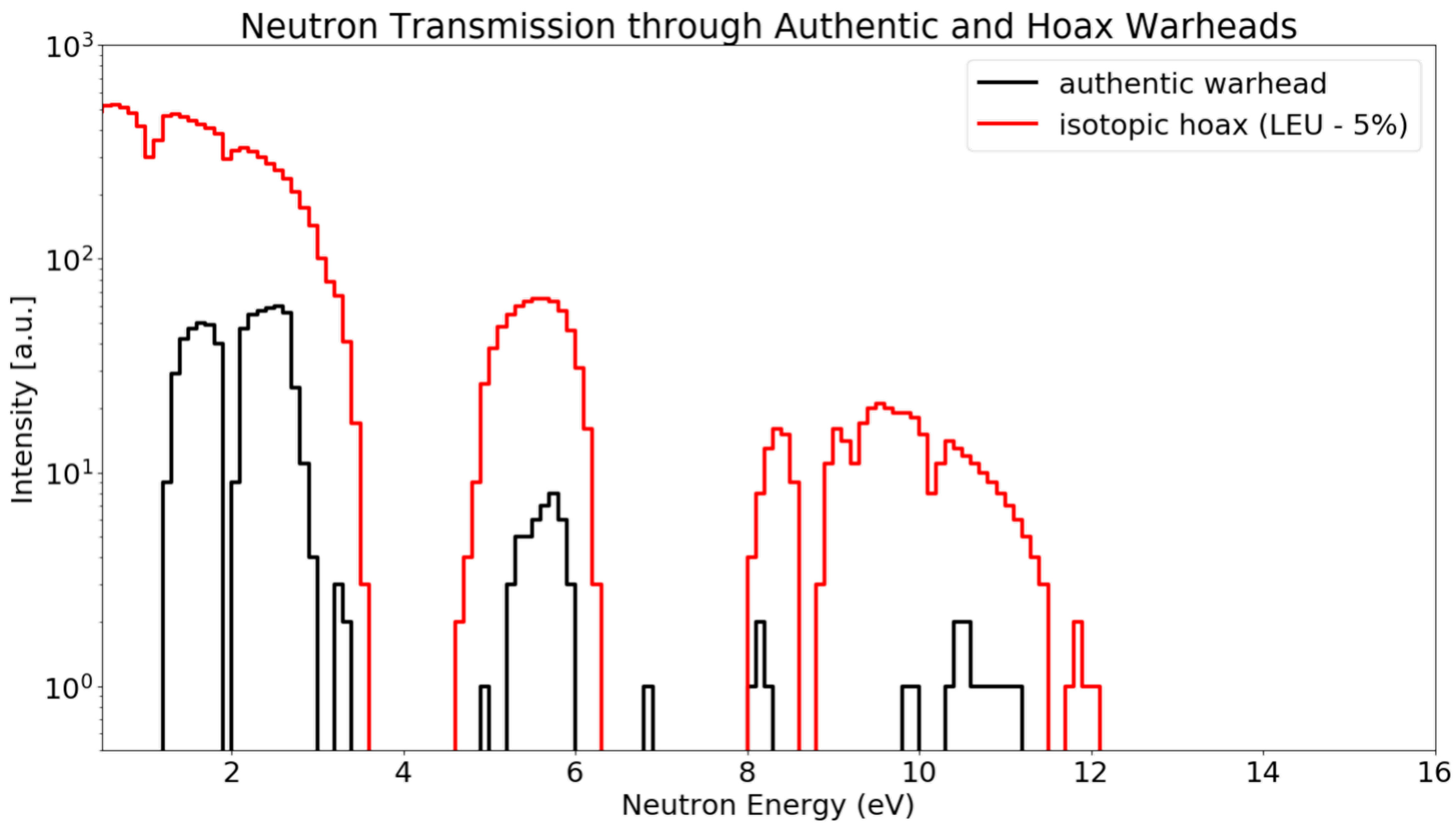
- Epithermal neutron resonance imaging has been demonstrated for imaging fresh and spent nuclear fuel for safeguards applications
- Extending the technique to a mobile capability will expand its utility to nuclear inspections
- Application in warhead verification method represents a novel use case to prevent potential noncompliance with international treaties

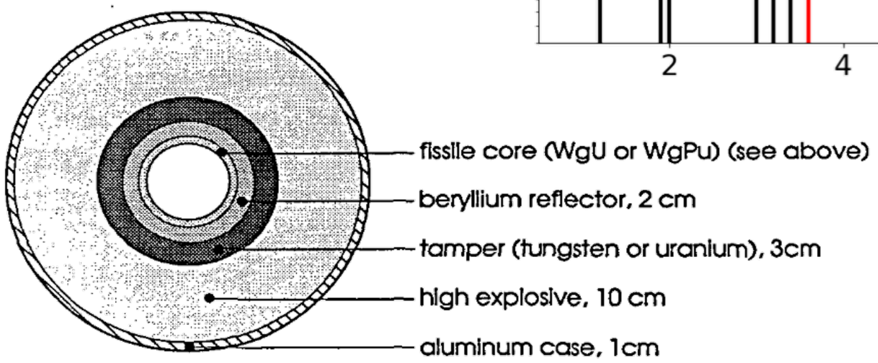


Nelson, R. O. et al. 2018. “Neutron Imaging at LANSCE -- From Cold to Ultrafast.” *Journal of Imaging* 4 (2): 45.

Background



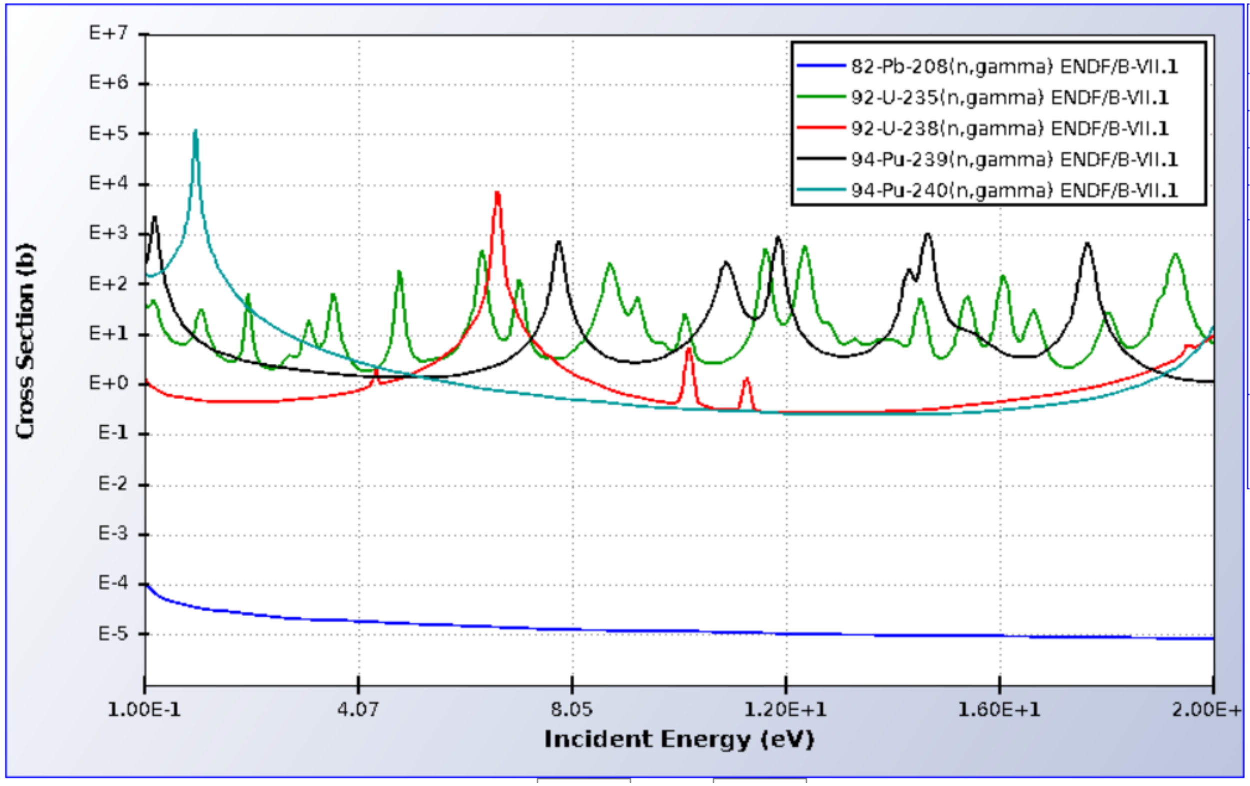




Sources: Neutron Resonance Spectroscopy, Frank Gunsing, 2005.
S. Fetter *et al*. 1990. "Detecting Nuclear Warheads." *Science & Global Security* 1 (3–4): 225–53.

Background

- Isotopic signatures for Special Nuclear Material (U-235, U-238, Pu-239, Pu-240)
- No epithermal resonances for common shielding materials (H, C, O, Al, Fe, Pb) – reasonable penetration
- **Induced nuclear reactions, *e.g.* (n, γ), can provide additional information for material identification**



Source: National Nuclear Data Center

Technical Workplan

- Geant4 simulations to optimize experimental setup, determine feasibility
- Laboratory setup of simplified apparatus using existent DT generator to validate experimental results
- Testing of different fissile materials and geometries at national laboratory (ideally using improved DT generator)
- Improvements to isotopic sensitivity and spatial resolution

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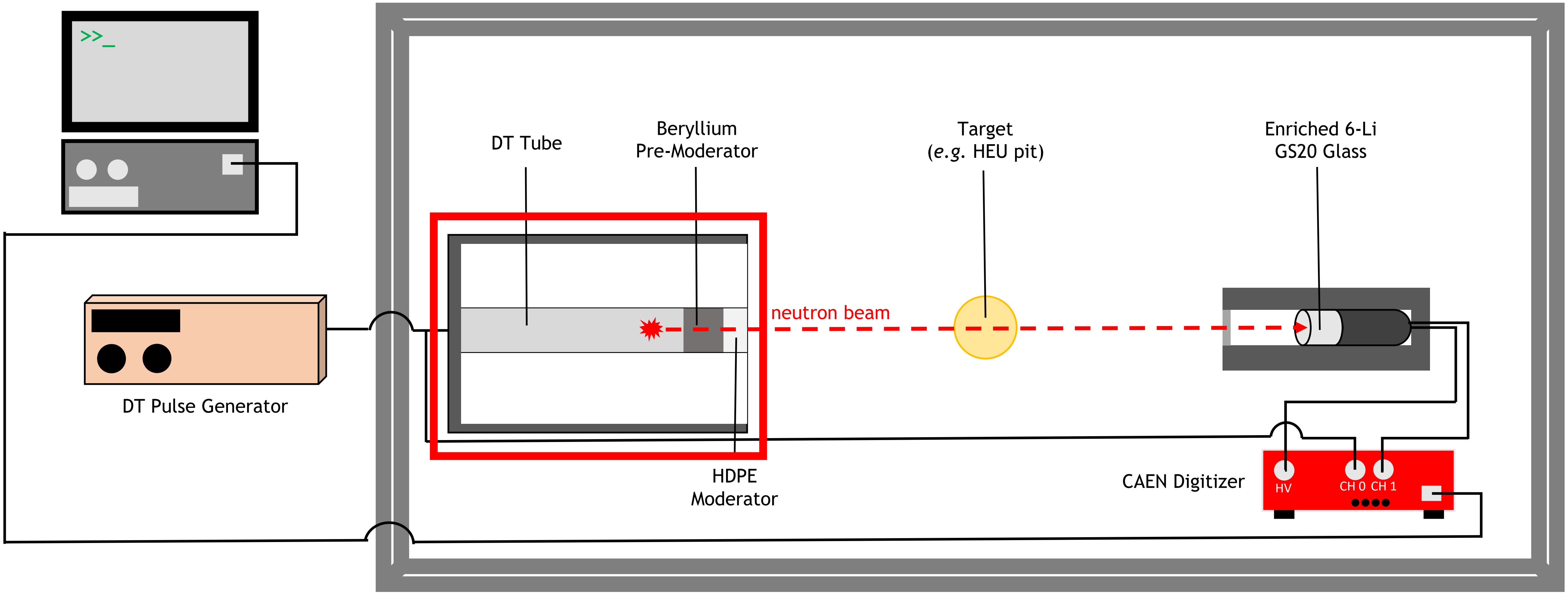
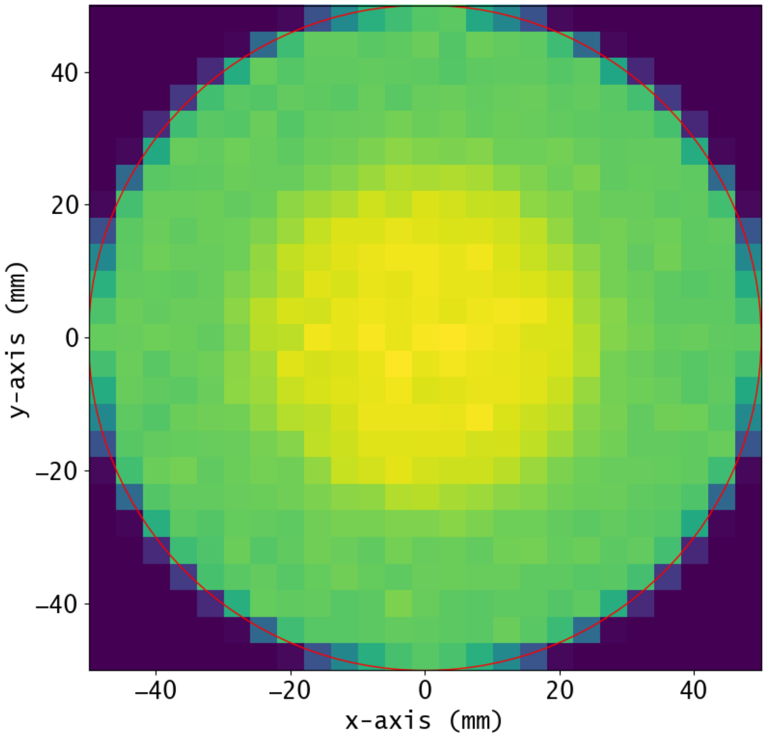
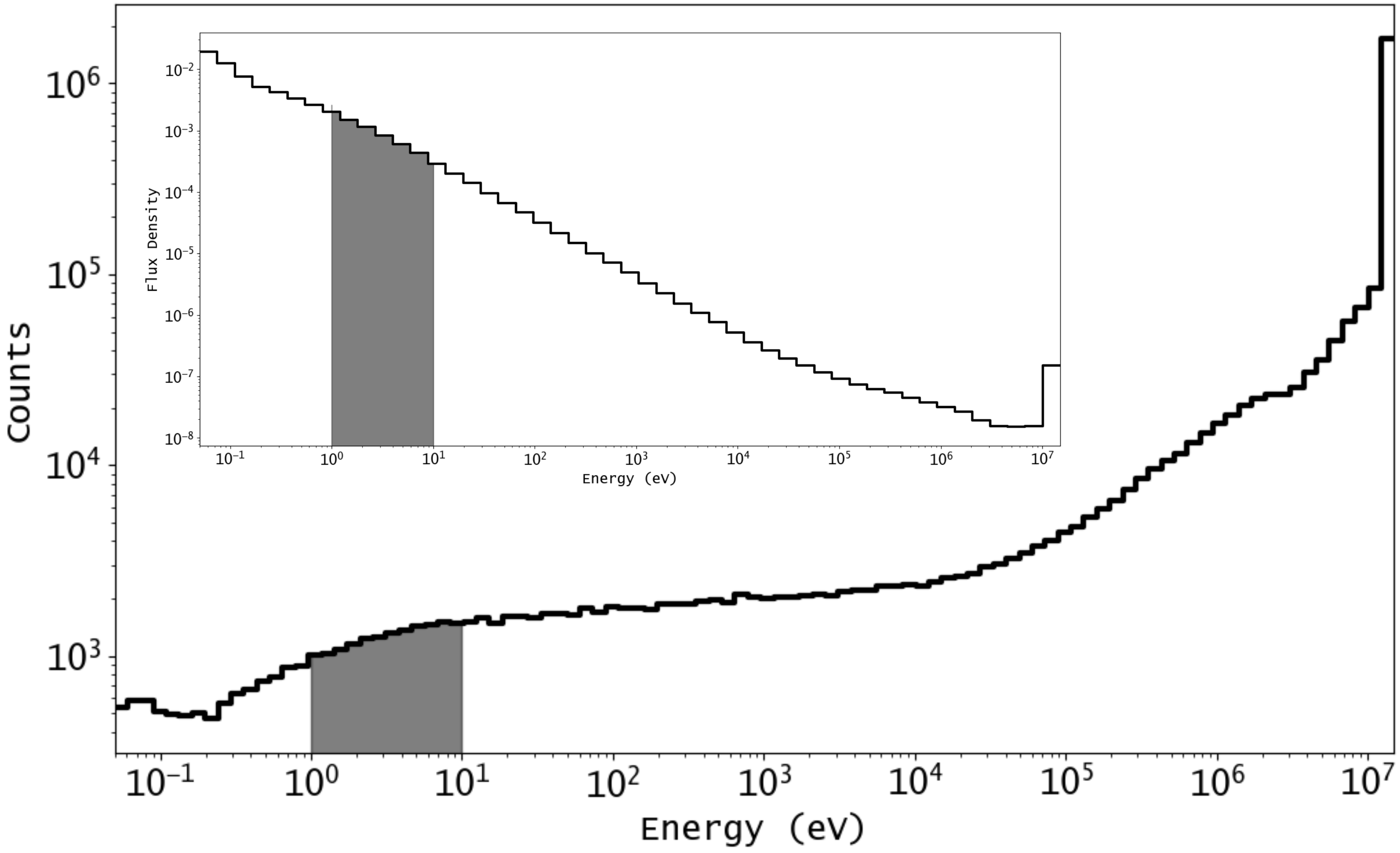
Experimental Setup



Epithermal neutron generation via ^{9}Be(n, 2n) reaction



Forward-directed neutron spectrum at surface of moderator assembly (2.5cm diameter DT target)



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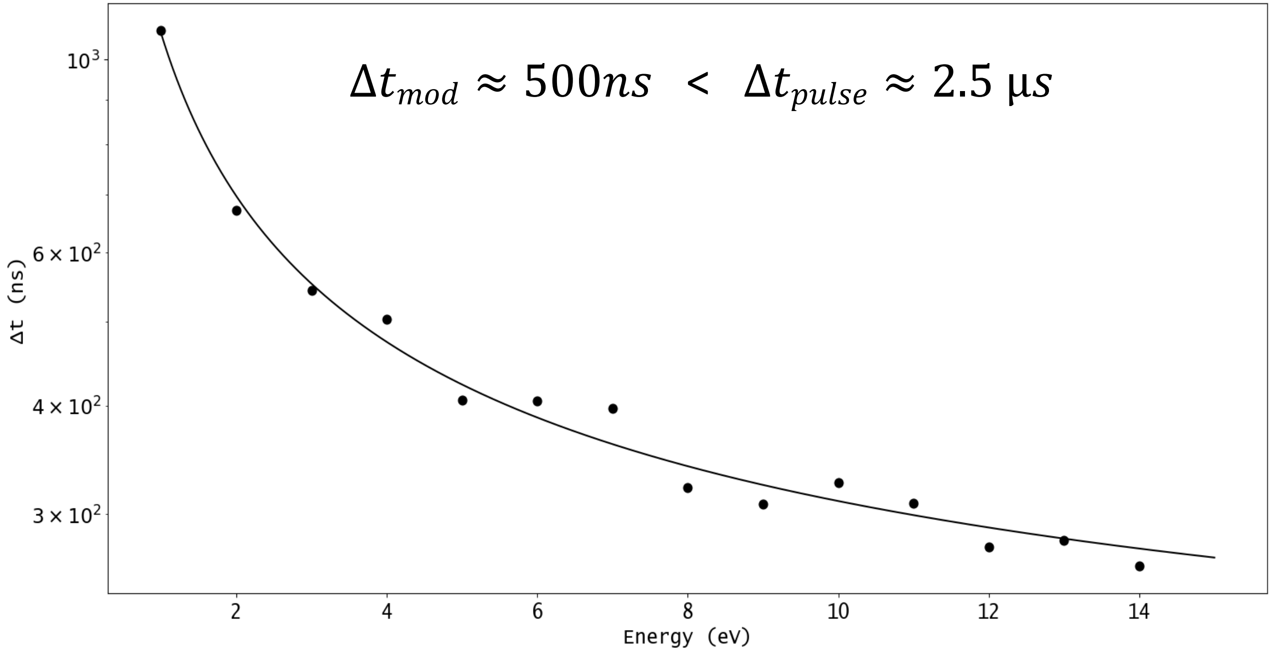

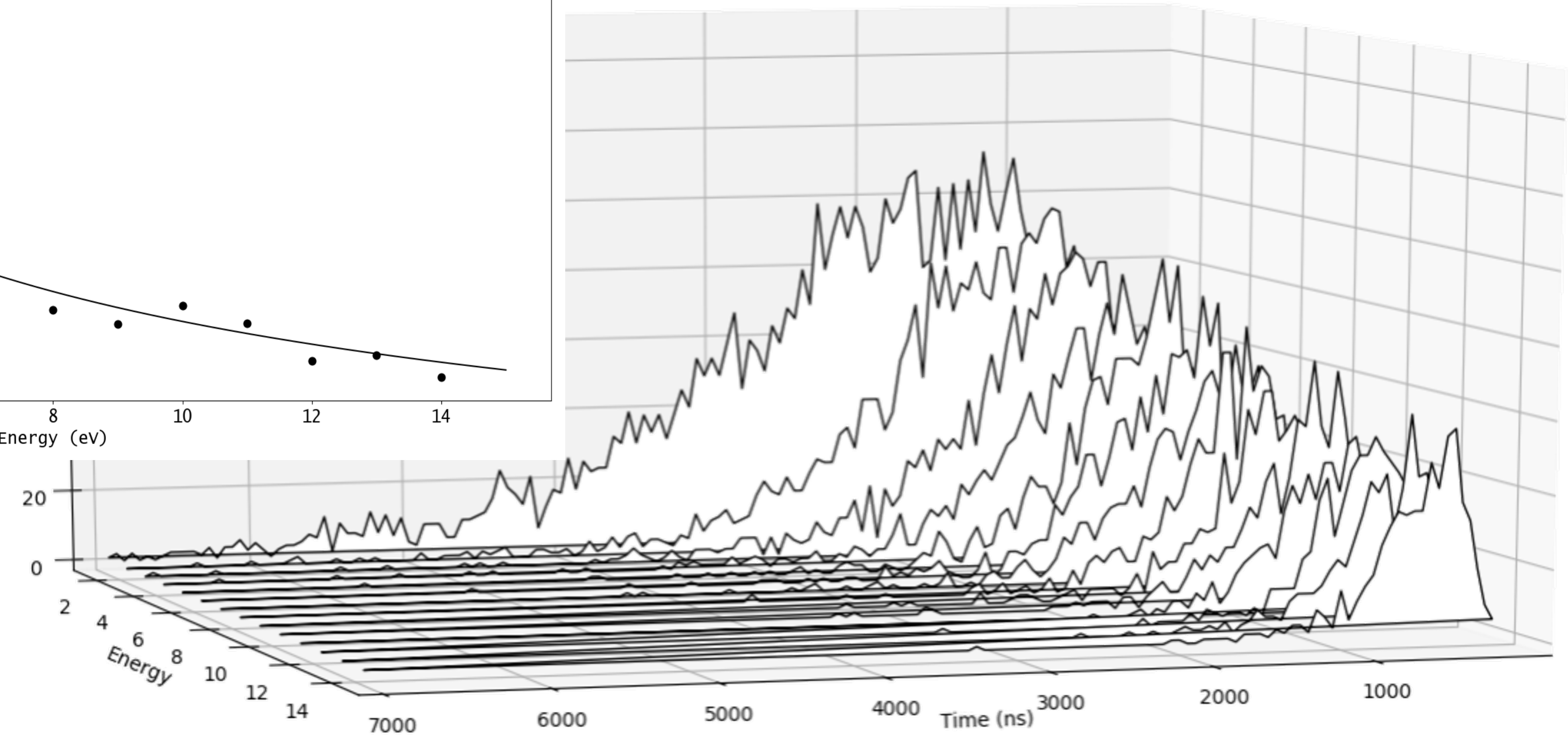

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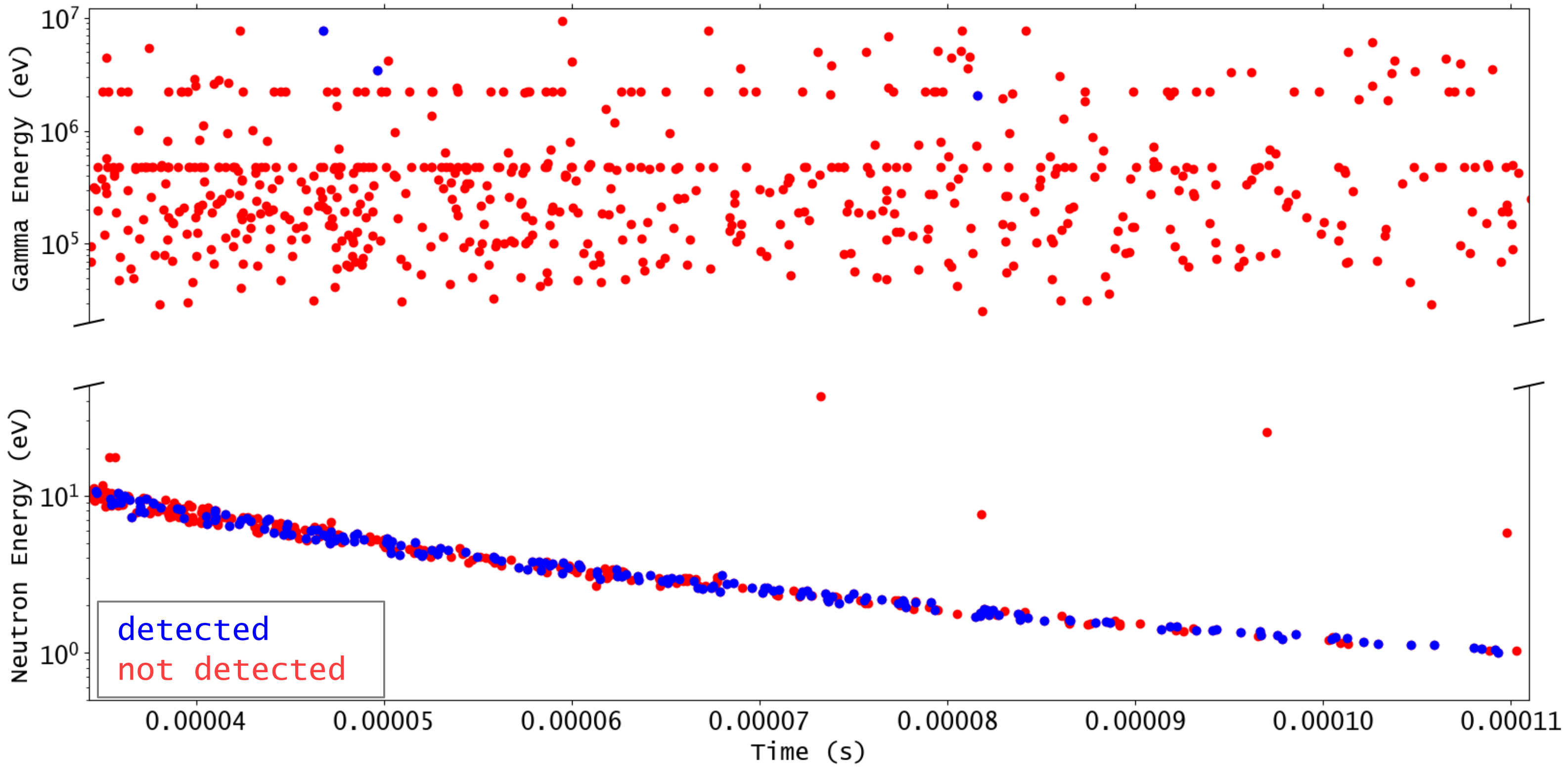
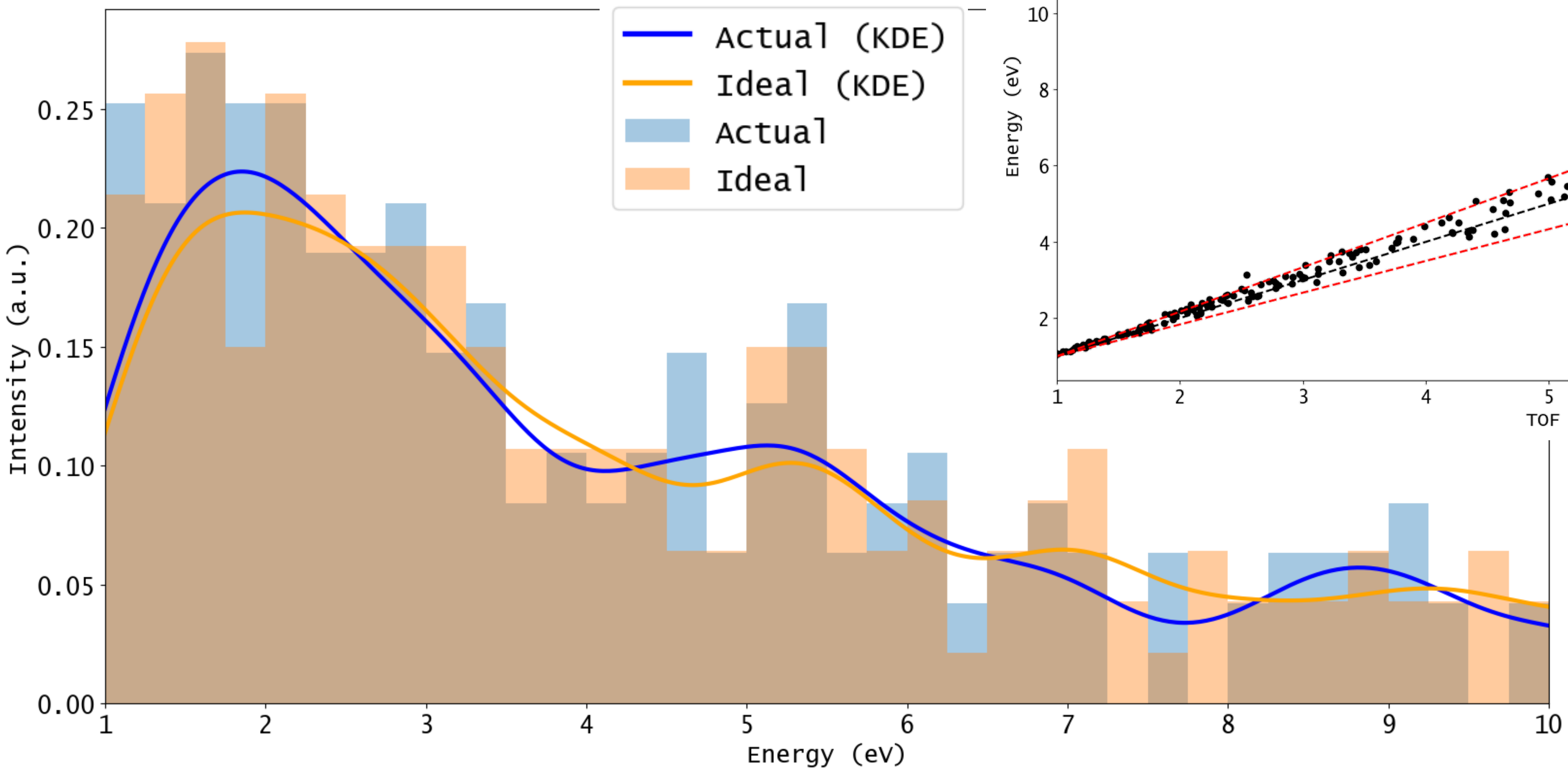
High-quality neutron beam with good gamma-neutron discrimination and acceptable epithermal neutron detection efficiency (~50%)

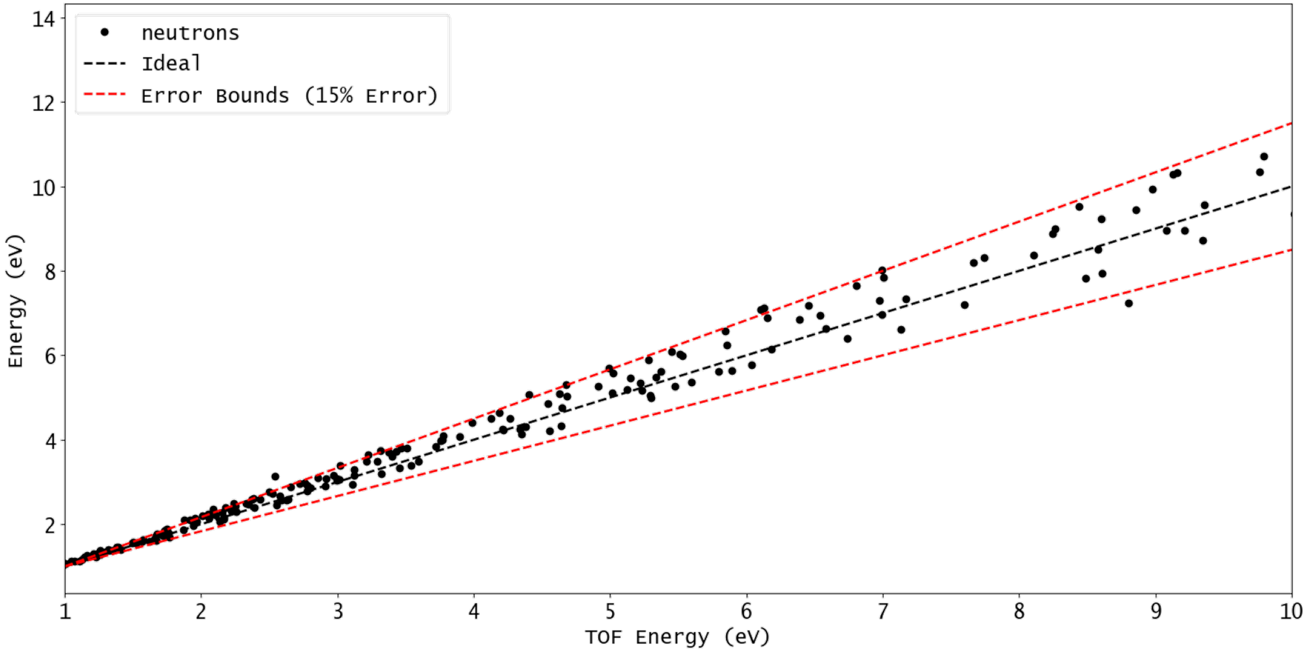


Simulated Neutrons (biased):	2.13e+08
Equivalent Run Time (s):	24.5
Epithermal Neutron Flux (n/cm^2/s):	3.53e-01
True Epithermal Neutrons Detected:	170/347
Avg. Accuracy in Energy (eV):	1.70e-01
Number of Gammas Above 1.0e+06:	116
Number of Gammas Detected:	3
Number of "thermal" gammas:	27
Number of wraparound gammas:	17
Number of thermal neutrons:	16
Number of wraparound neutrons:	0

4x improvement in epithermal neutron production compared to HDPE-only moderator!

High-quality neutron beam with accurate TOF energy reconstruction





Conclusion

- Beryllium pre-moderator increases epithermal neutron flux by factor of 4 compared to HDPE-only moderator
- 5 mm thick ^{6}Li glass scintillator improves n/γ discrimination compared to 1’’ glass with acceptable loss in neutron detection efficiency (~50%)
- I never thought I would miss working in a windowless, underground vault

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Next Steps

- Implement variance reduction techniques to reduce simulation time by order of magnitude
- Implement optical light production in Geant4 to better model neutron detector response in 6-Li glass scintillator
- (Eventually) Continue experiments at MIT using DT generator and test targets (*e.g.* 5mm W metal)
- Continue to explore possibility of incorporating detection of secondary reactions into isotopic composition analysis (*e.g*. neutron capture gamma spectroscopy)

MTV Impact

- Annual MTV workshops have been a great source of feedback, led to collaboration with Princeton (Rob Goldston, PPPL)
- Participated in the recent MCNP/PoliMi Workshop hosted by Dr. Clarke and Prof. Kiedrowski
- MTV coordinated a summer internship at Lawrence Livermore National Laboratory working on Dense Plasma Focus D-T neutron generator (Supervisor: Dr. Andrea Schmidt, Plasma Engineering Group)
- Potential further collaboration with PNNL and LLNL, future testing at DAF(?)

Acknowledgements

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