Neutrino-Induced Nuclear Fission

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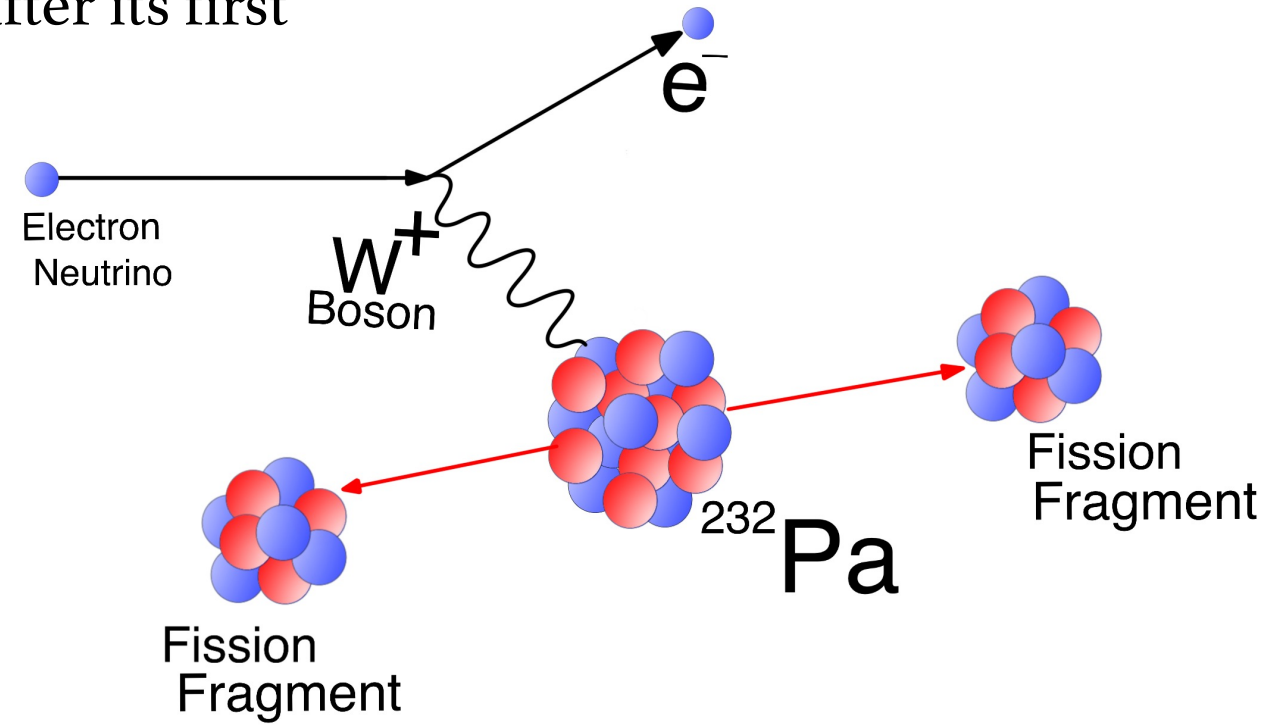
Tyler Johnson
Duke University
Triangle Universities Nuclear Lab

Introduction and Motivation

This experiment would be the first observation of Neutrino-Induced Nuclear Fission or NuFission at least 50 years after its first prediction

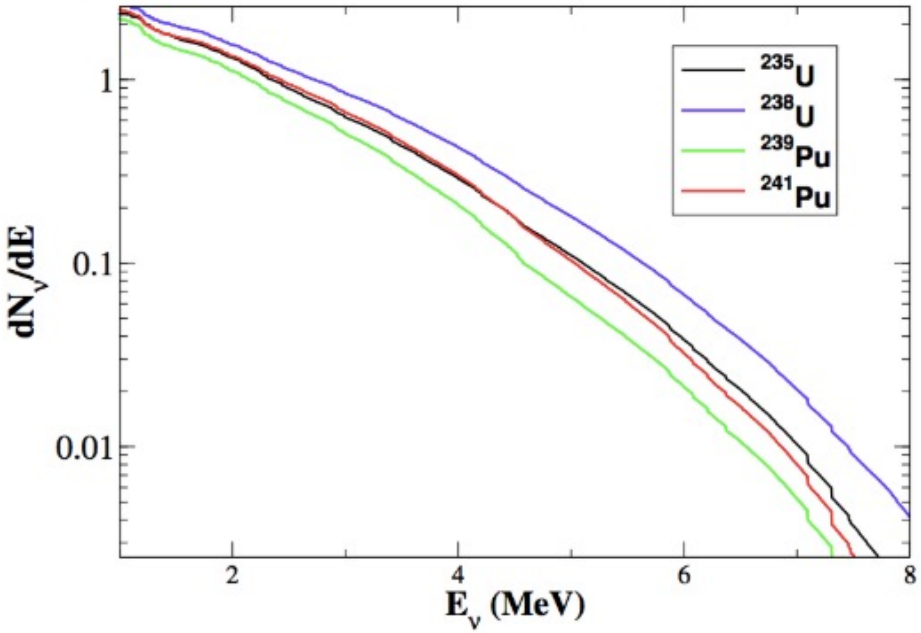
Neutrino-Induced Nuclear Fission may constitute a novel reactor monitoring approach with a dramatic 200 MeV signal of a nuclear fission



Mission Relevance

A NuFission-based neutrino detector would be a simple, compact apparatus that chiefly relies on neutron counting rather than a complex event topology

Fission outputs ~200 MeV so the Event is dramatic and unambiguous

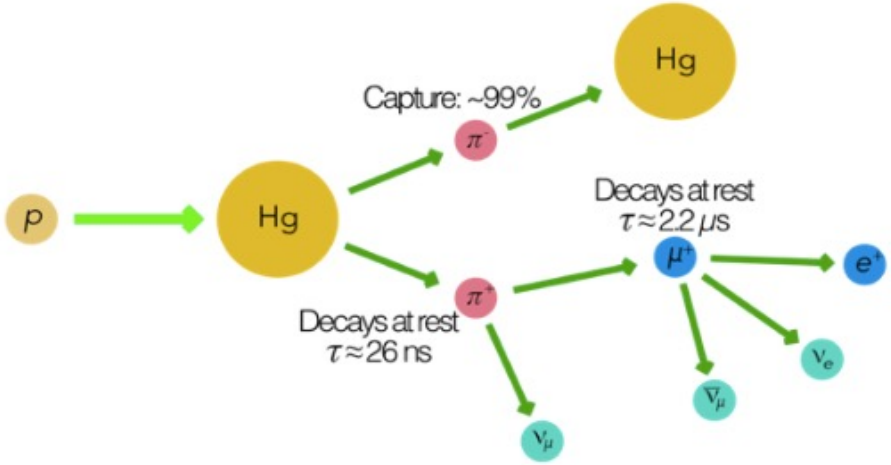


Source: A. Hayes, P. Vogel, *Reactor Neutrino Spectra*

Experiment Site – Oak Ridge National Lab

Spallation Neutron Source

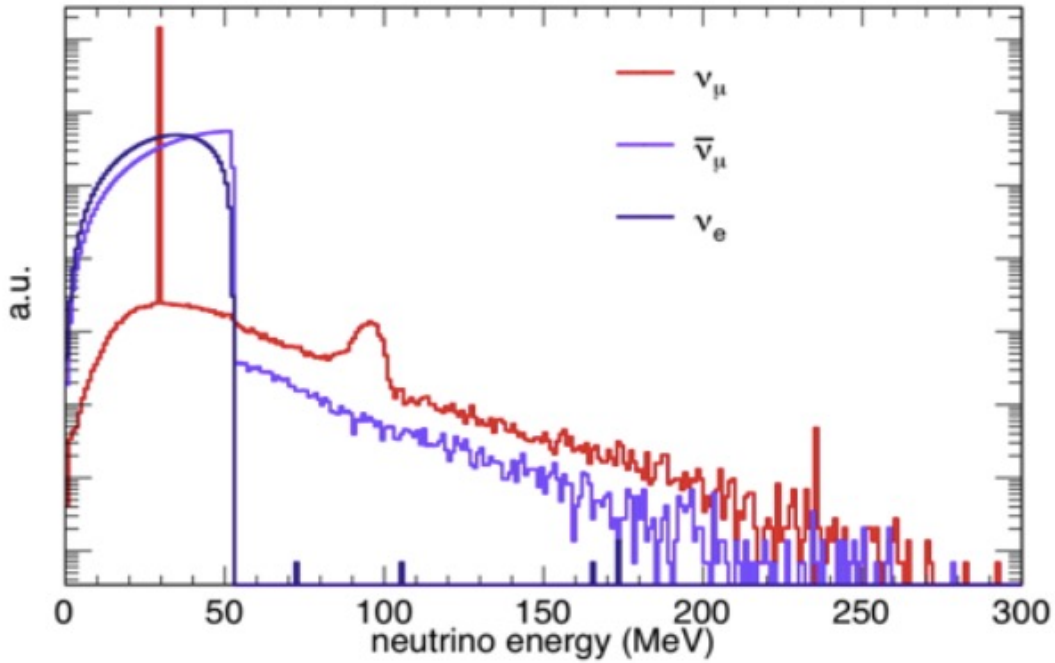
Pion Decay-at-Rest Neutrino Source

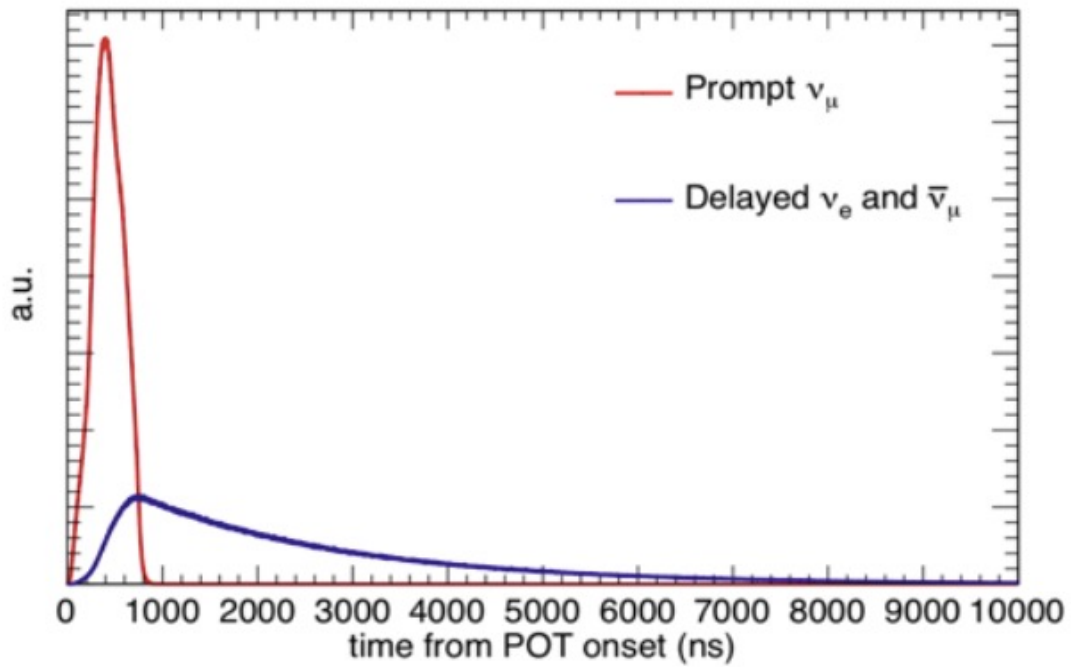


ν flux 4.3×10^7 **ν** cm^{-2} s^{-1} at 20 m

60 Hz Pulse

No electron antineutrinos





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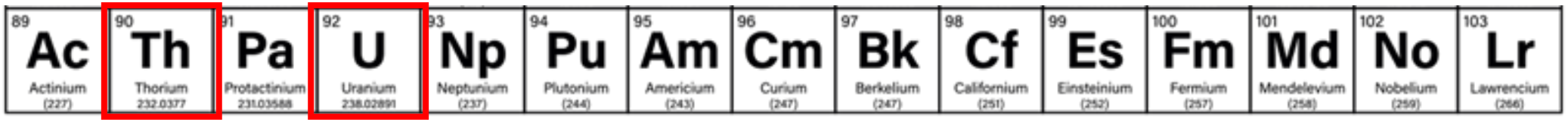
Fission Material Selection

There are several fissionable nuclei to choose from but few are available in large quantities



Thorium & Uranium are the most practical candidates

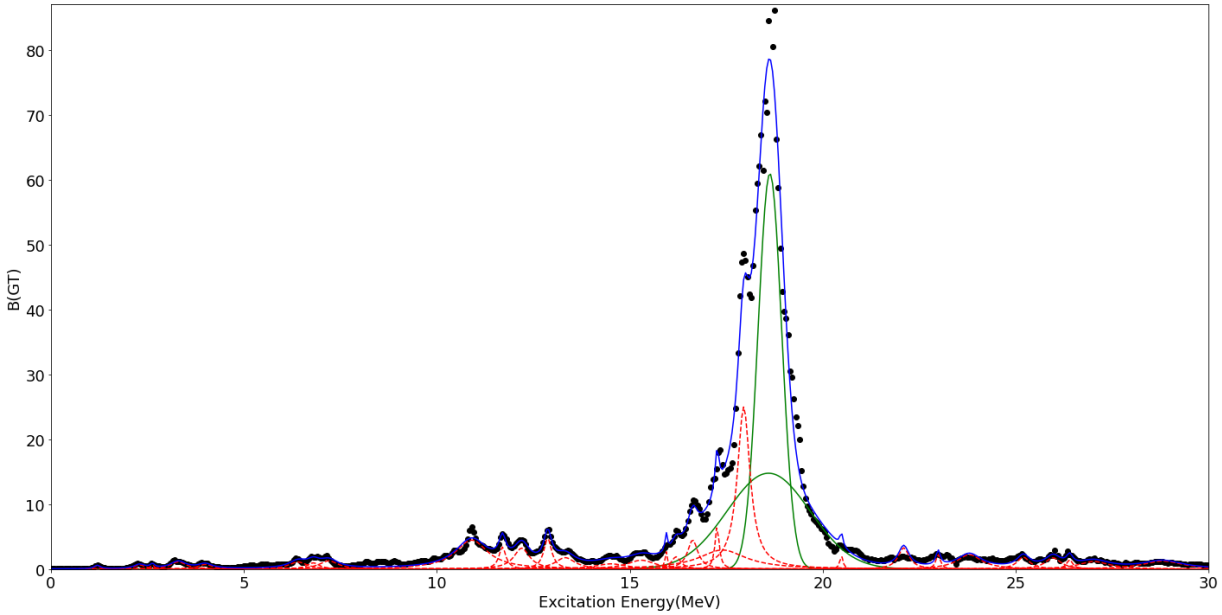
BUT

Thorium has a spontaneous fission rate 5 orders of magnitude less than uranium

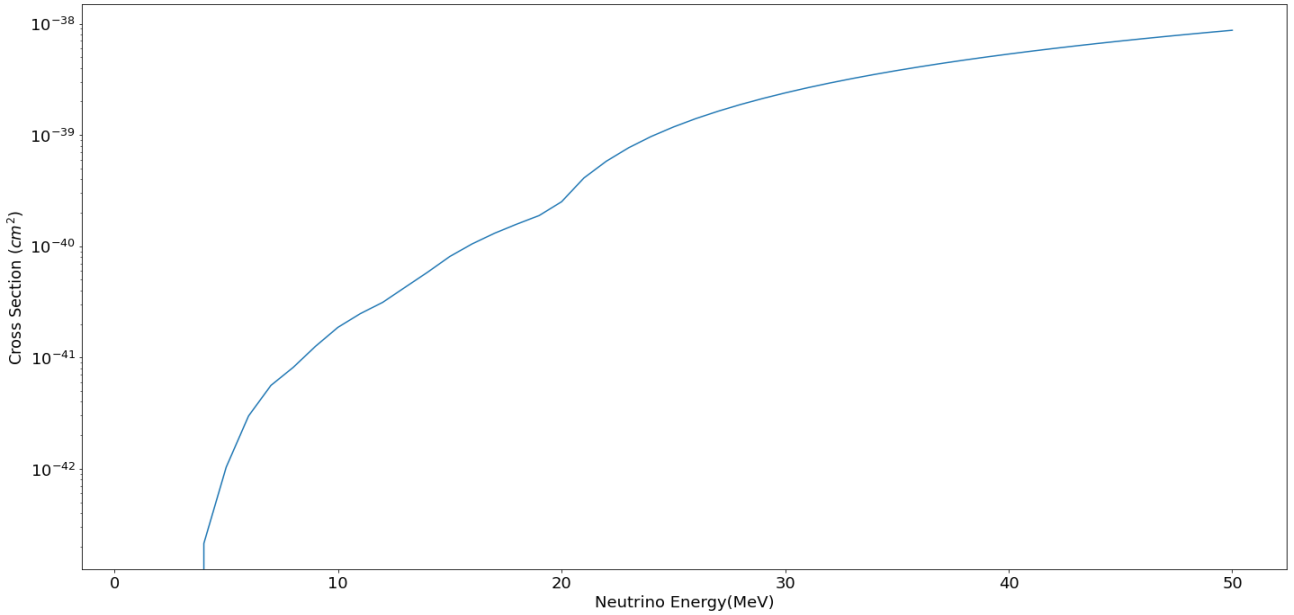
Thorium NuFission Signal

First needed the charged-current neutrino cross section for Thorium

Beta-Strength Function for Allowed Transitions

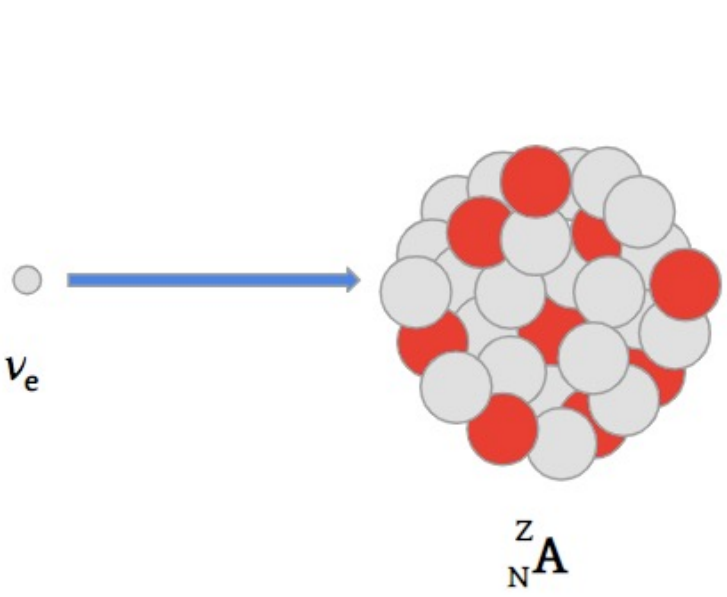


Charged-Current Cross Section on Thorium



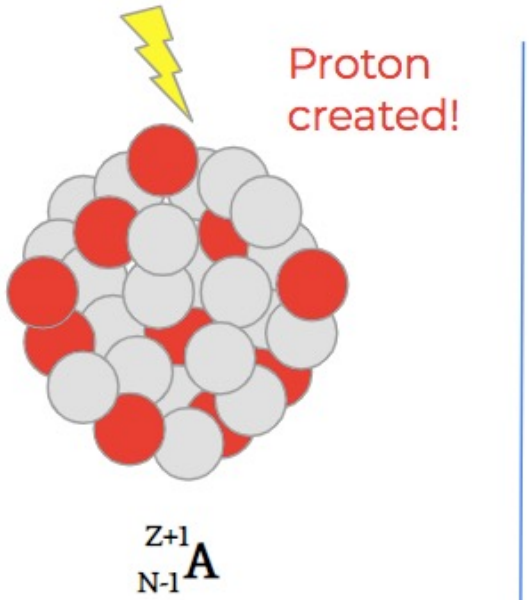
CC Event Estimate: **~195/SNS year** for 68 kgs Th-232
nuFission Event Estimate: **~60/SNS year** for 68 kgs Th-232

Statistical Decay



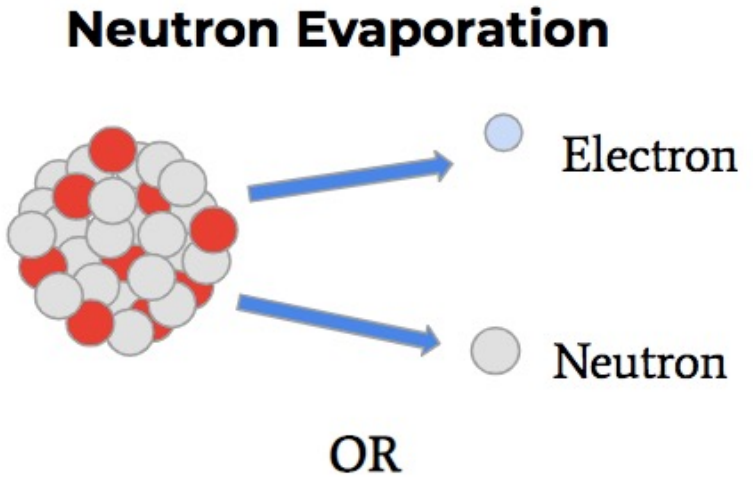
Thorium-232

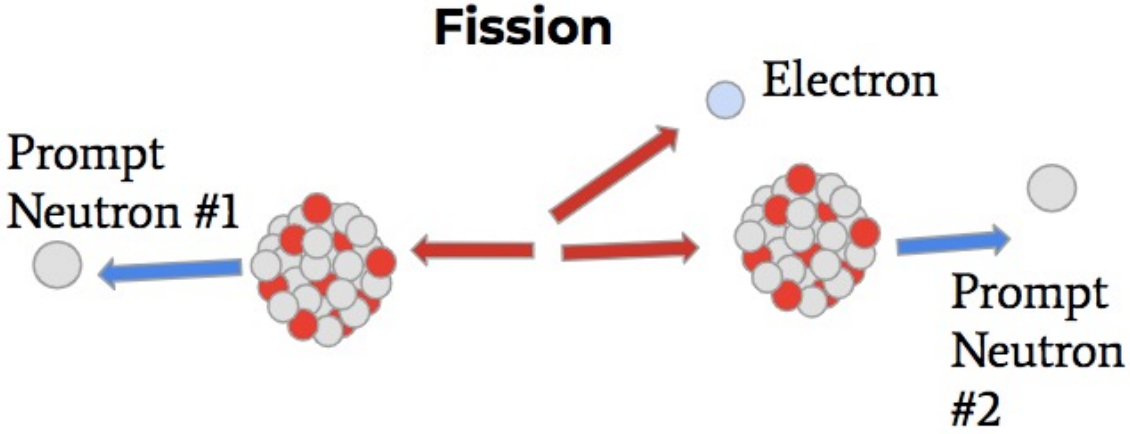
Giant Gamow-Teller Resonance and Isobaric Analog State enhance charged current capture cross section



Protactinium-232*

Pa-232 is highly excited

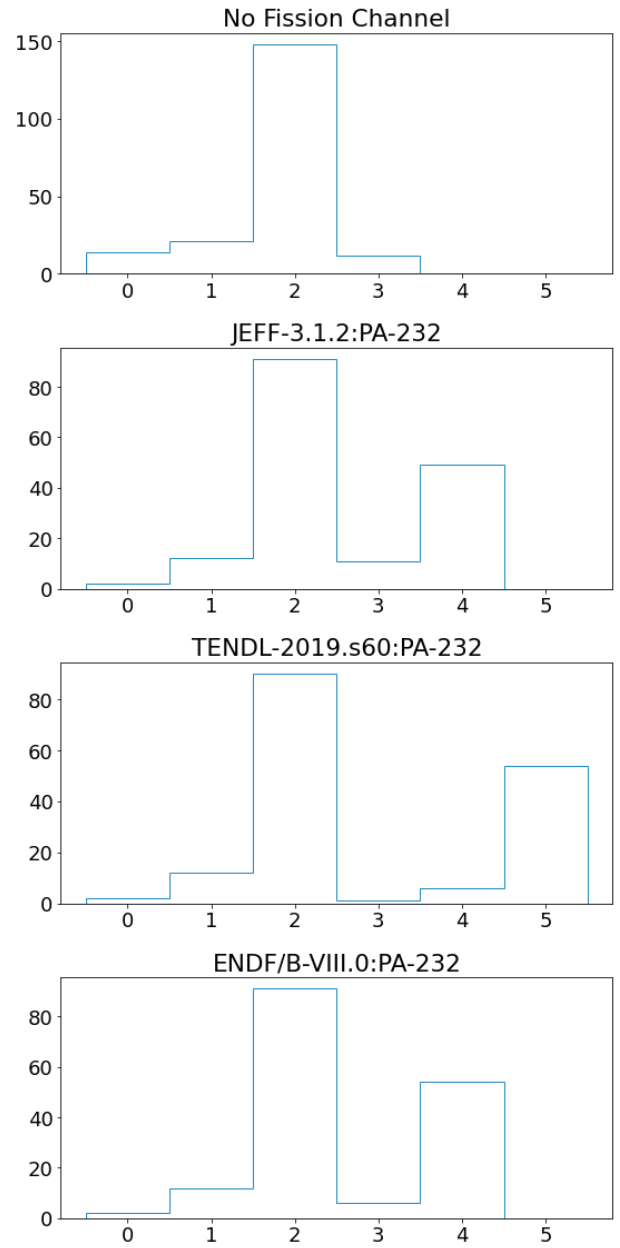




Fission Neutron Signal

Thus far, the most practical NuFission signal is <u>3+ prompt neutron detections coincident with the SNS beam pulse</u>

Neutrino-Induced Neutron Emission has a lower average neutron multiplicity (v = 1.8) so an excess of 3+ neutron detectors would suggest the occurrence (or non-occurrence) of nuFission

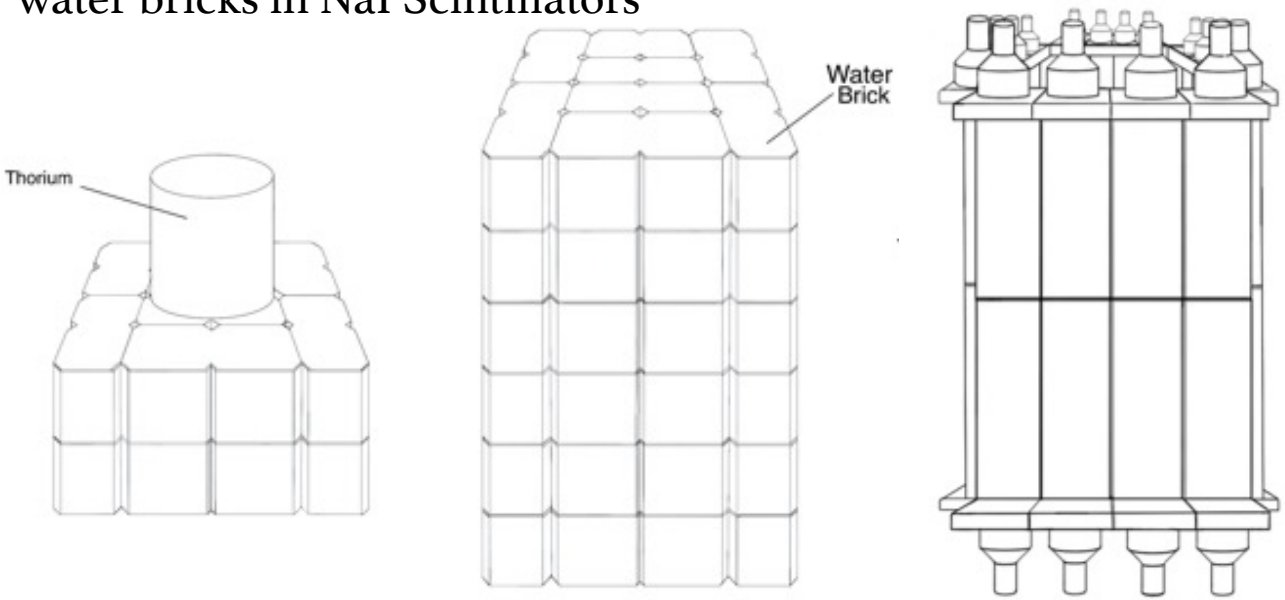


Detector Design

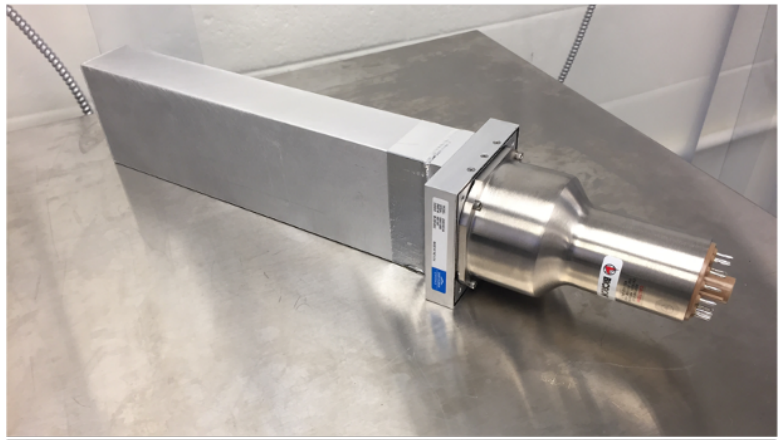
Hermetically seal the thorium metal inside a neutron capture apparatus

We plan to dissolve Gadolinium Nitrate powder into water, fill run-of-the-mill polypropylene water bricks with the mixture, then stack them all around the Thorium

Neutron-captures on Gd emit 8 MeV in gamma rays so we will wrap the Gd-water bricks in NaI Scintillators



We have many NaI crystals at the ready



Expected Impact

This would be the very first experimental confirmation of this new way to split the atom

Additionally, nuFission may help explain certain astrophysics phenomena like the abundance peak around A=90 resulting from R-Process nucleosynthesis

Could potentially be a novel method of detecting reactor neutrinos

MTV Impact

- The deployment site for the nuFission detector is Oak Ridge National Laboratory (specifically the Spallation Neutron Source) so this work will deepen the relationships between Duke, MTV, and Oak Ridge

Conclusion

Because the design portion of this initiative nearly complete and the Barbeau Group already possesses the majority of the materials needed for construction, we believe the building and deployment of the nuFission detector will be relatively quick

We lost some ground during COVID, but we believe it's probable to accomplish a deployment to the SNS fairly soon to begin the data taking campaign

Acknowledgements

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