The First Search Neutrino-Induced Nuclear Fission

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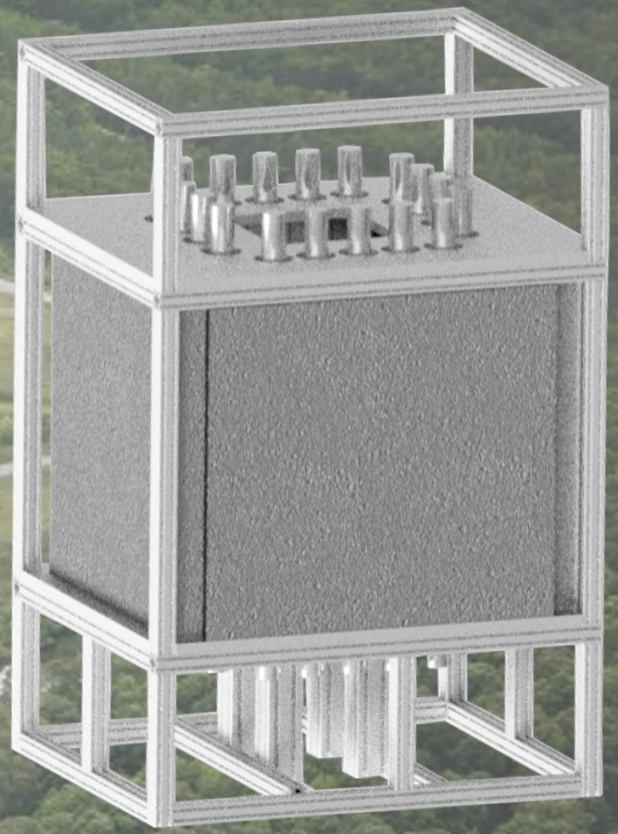
Duke University
Triangle Universities Nuclear Lab



NUTHOR

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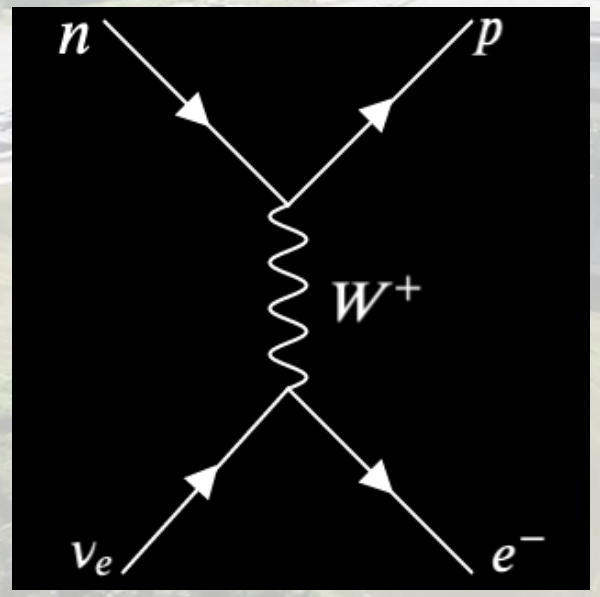
Introduction and Motivation

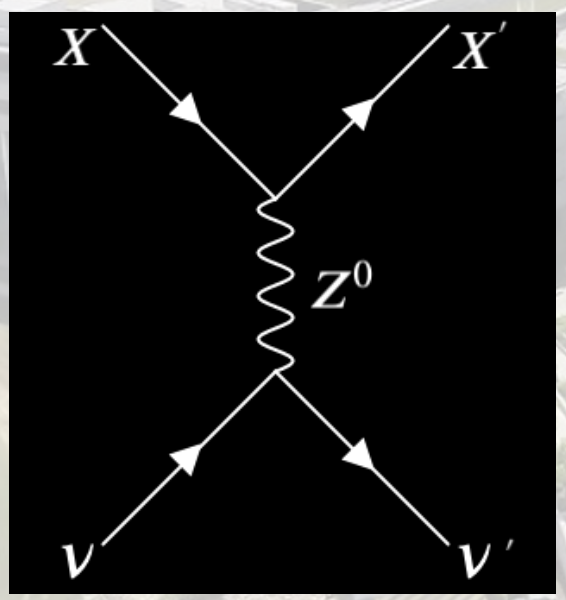
Predicted at least 52 years ago

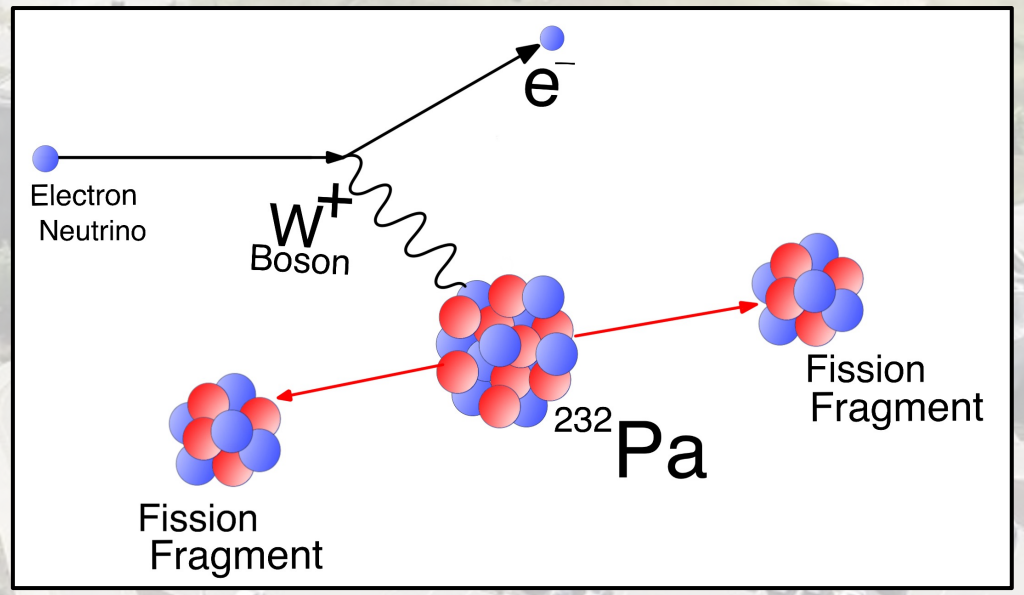
Currently, no experimental confirmation

This experiment is the first experimental initiative towards this process

May constitute a new tool in the toolkit for reactor monitoring, supernova detection, and/or R-Process nucleosynthesis modeling



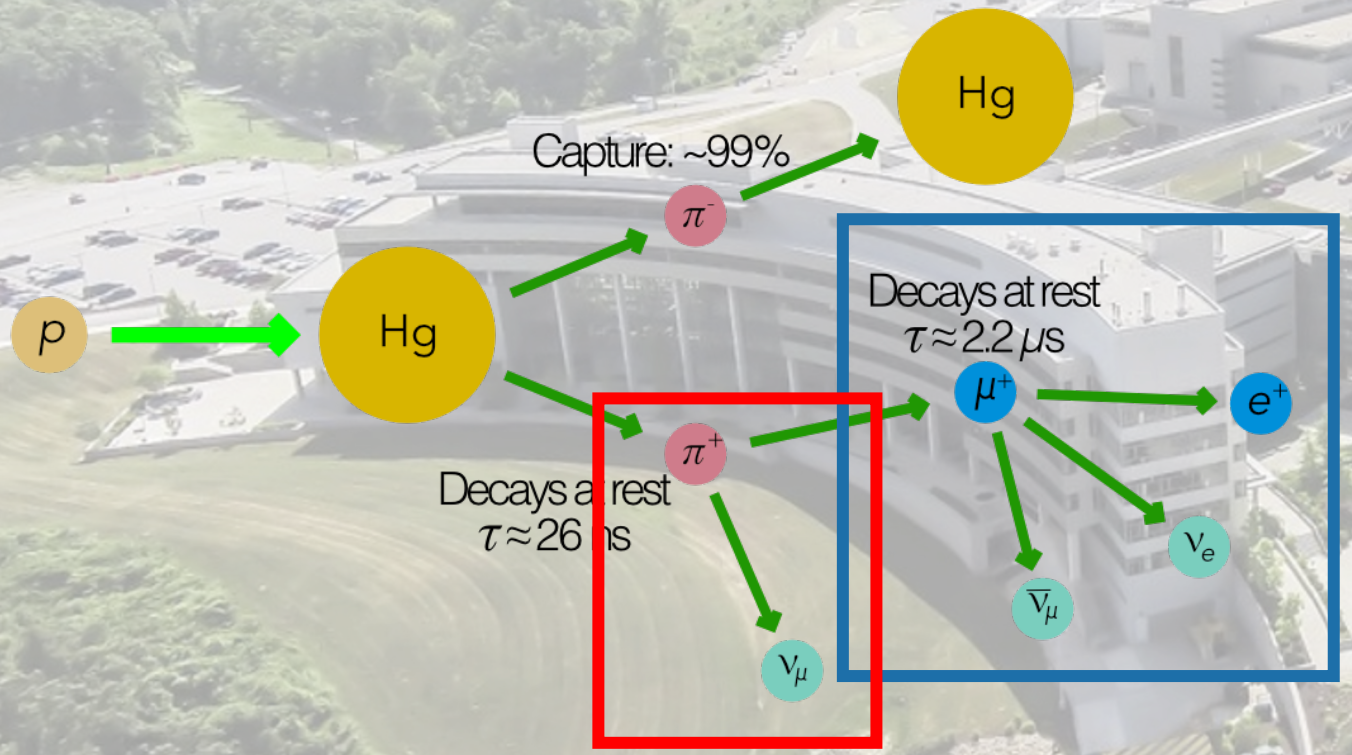


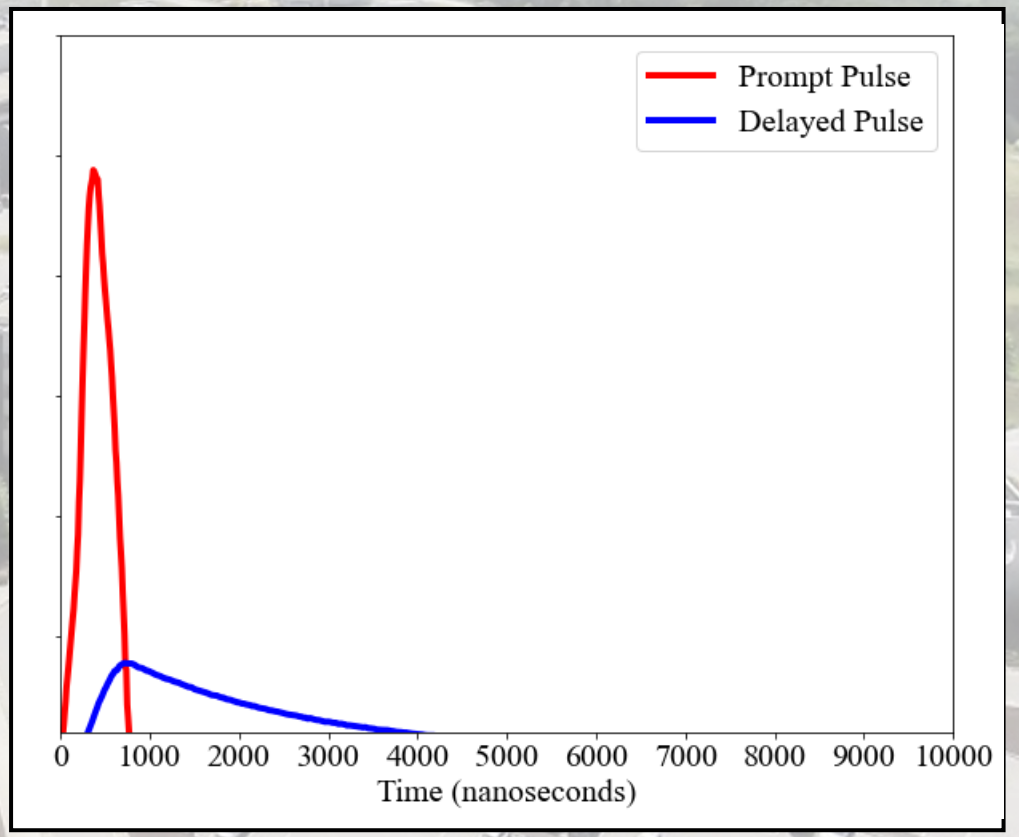


Experiment Site – Oak Ridge National Lab

Spallation Neutron Source

- Pulsed at 60 Hz for excellent background suppression





Fission Material Selection

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

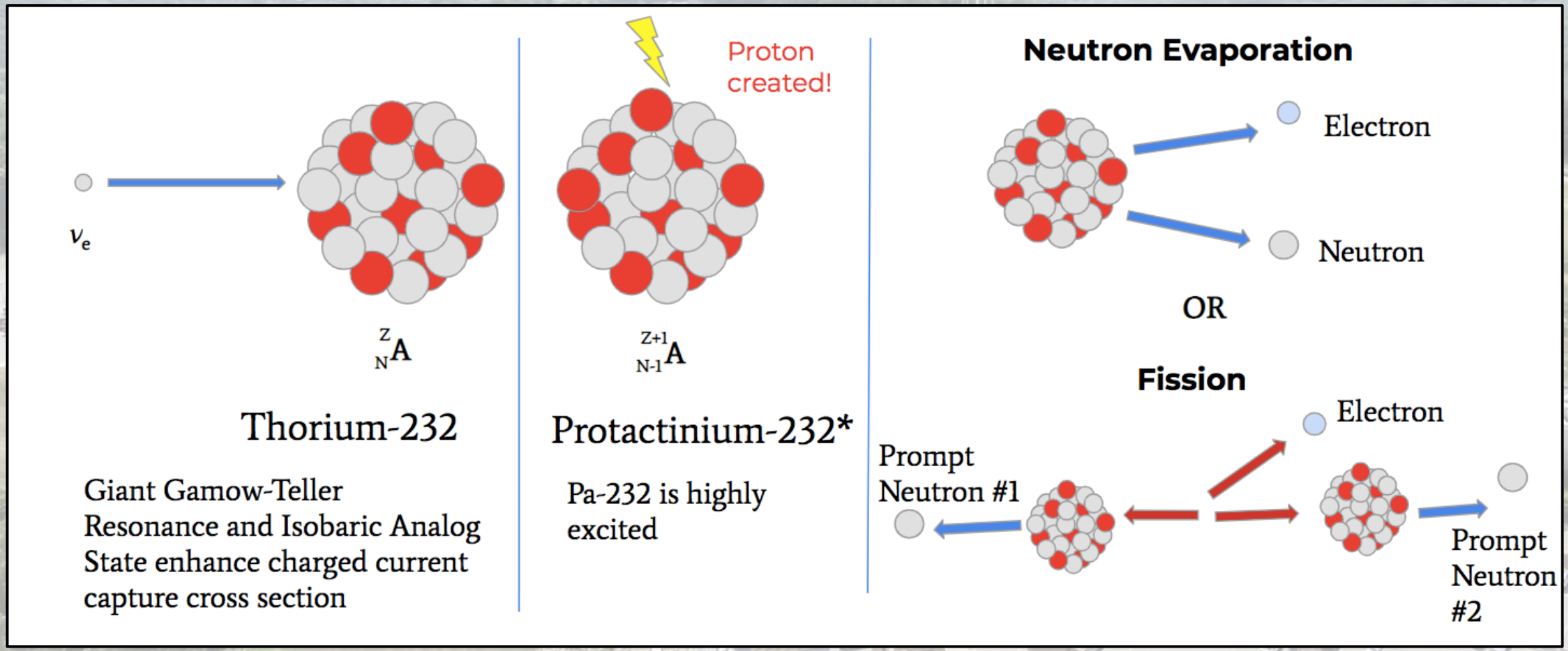
89	90	91	92	93	94	95	96	97	98	99	100	101	102	103
Ac	Th	Pa	U	Np	Pu	Am	Cm	Bk	Cf	Es	Fm	Md	No	Lr
Actinium (227)	Thorium 232.0377	Protactinium 231.03588	Uranium 238.02891	Neptunium (237)	Plutonium (244)	Americium (243)	Curium (247)	Berkelium (247)	Californium (251)	Einsteinium (252)	Fermium (257)	Mendelevium (258)	Nobelium (259)	Lawrencium (266)

Thorium & Uranium are the most practical candidates

BUT

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

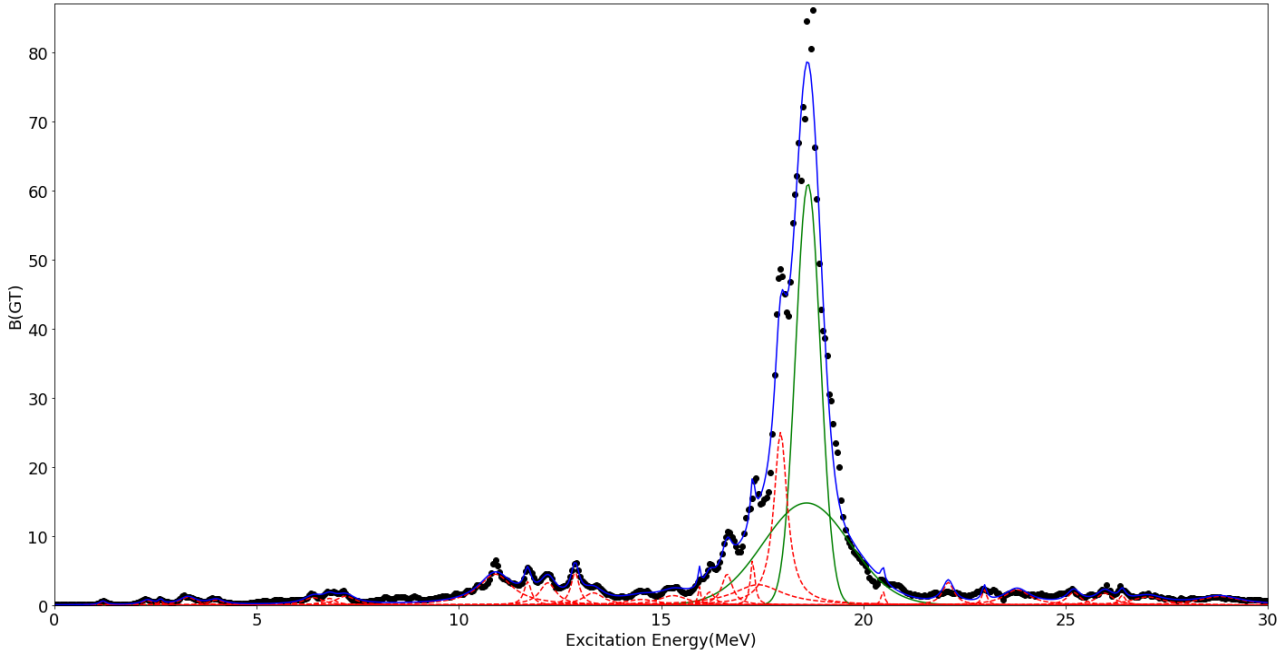
Statistical Decay



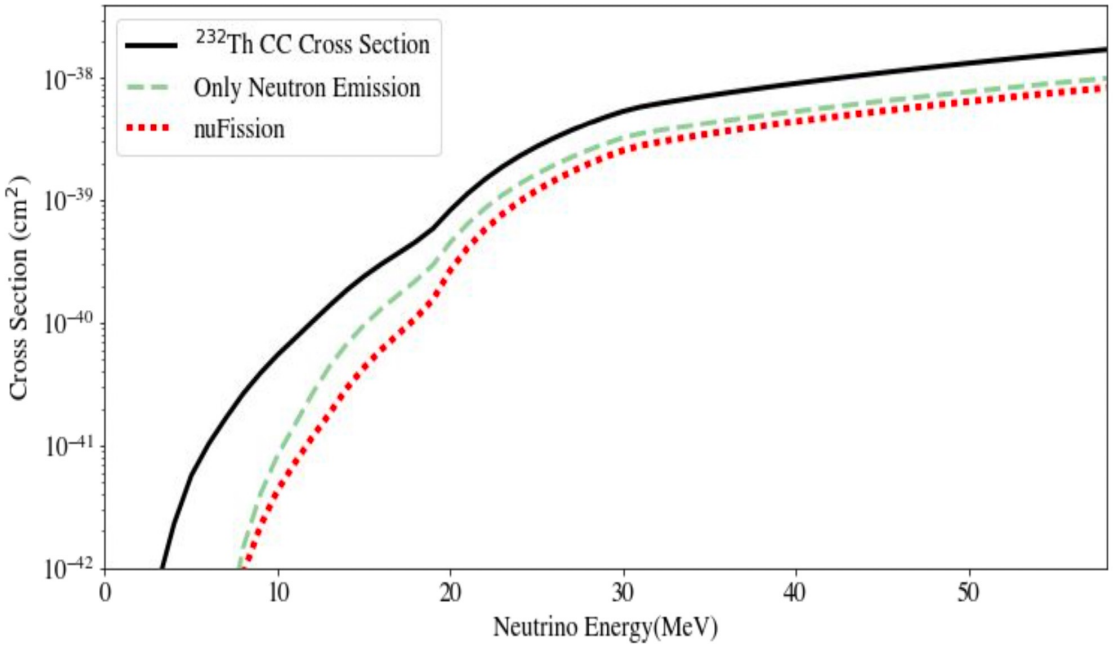
Thorium NuFission Signal

First needed the charged-current neutrino cross section for Thorium

Beta-Strength Function for Allowed Transitions

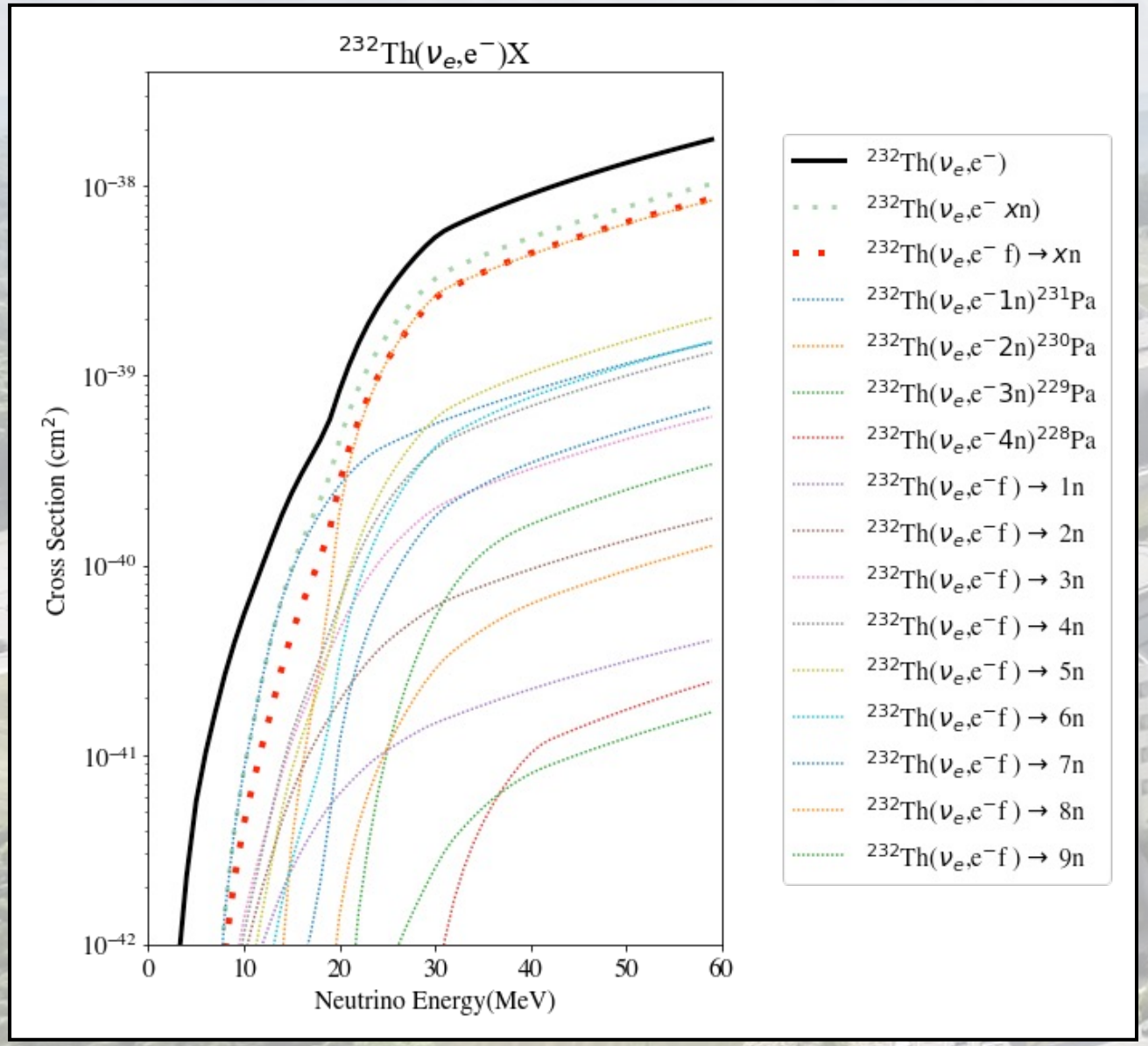


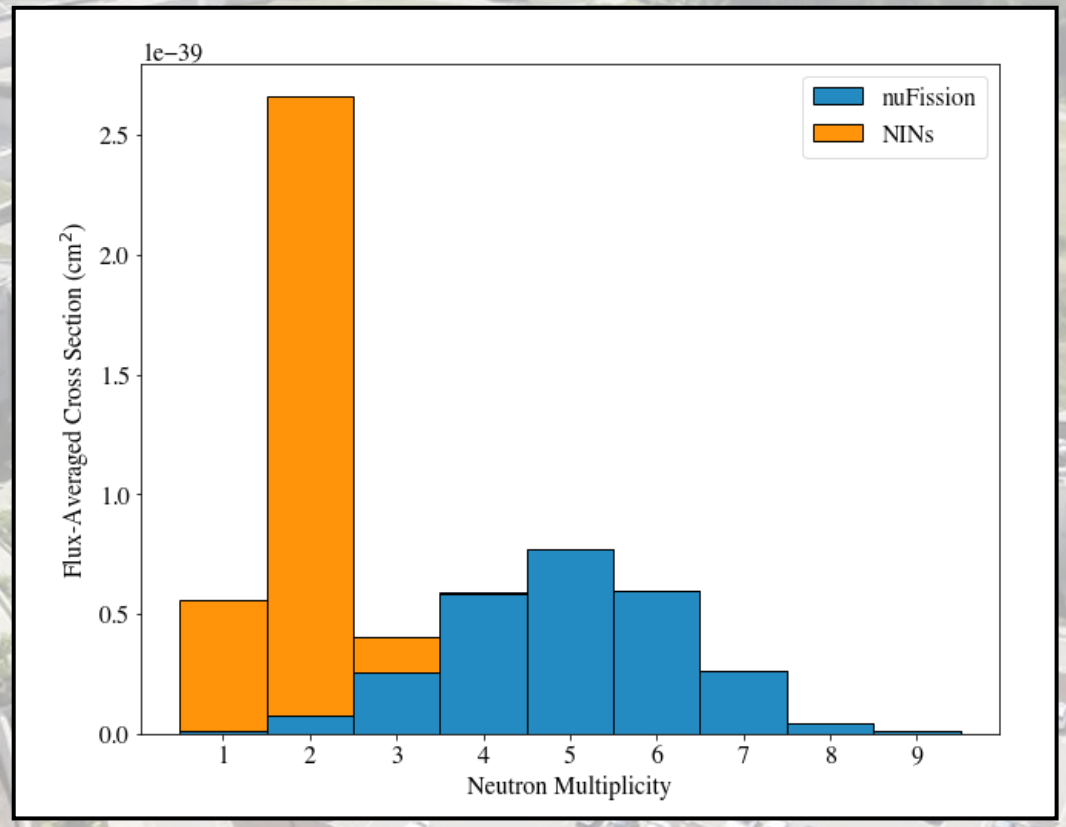
Charged-Current Cross Section on Thorium



CC Event Estimate: **~2 CC Events per** kgs Th-232 per SNS year - nuFission Estimate: **~1 nuFissions** per kgs Th-232 per SNS year

Fission Neutron Signal





NuThor Detector Built & Deployed

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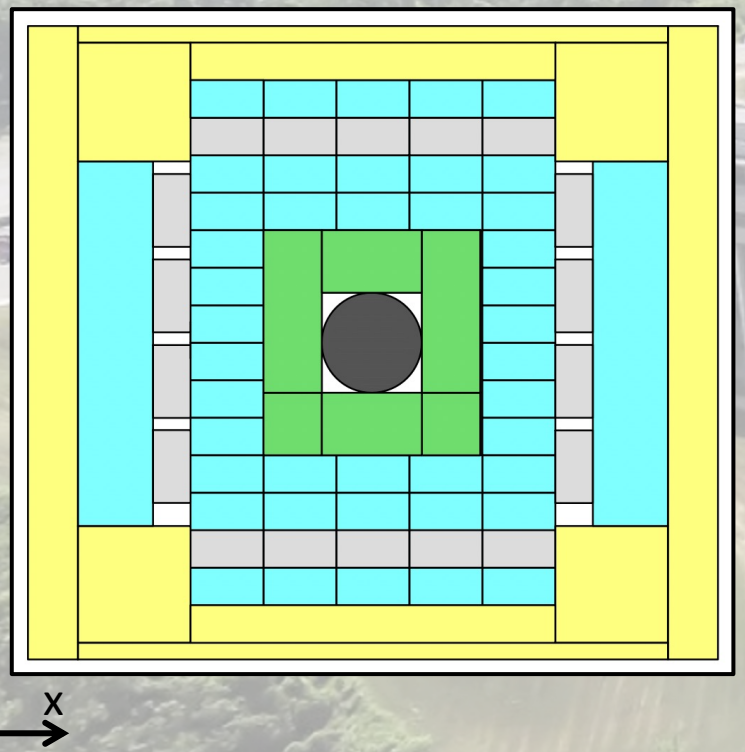

52.0 Kilograms of ^{232}Th Metal Core
Over 2,000 Beam Hours of data taken

Th-232 Metal	
Lead	
Gd-Water	
NaI[Tl]	
Bor. Poly.	

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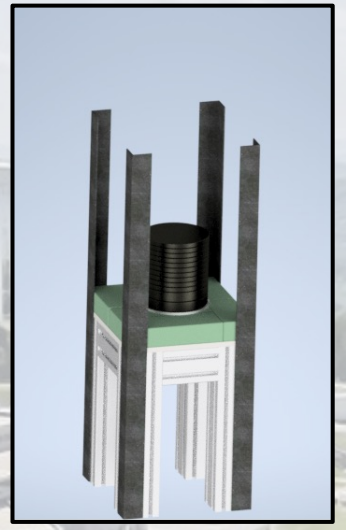
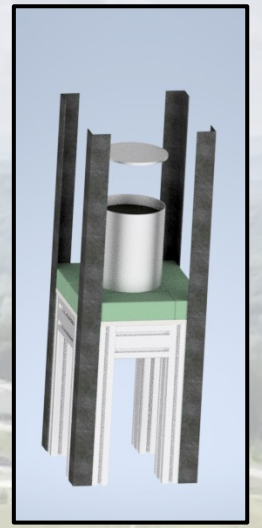
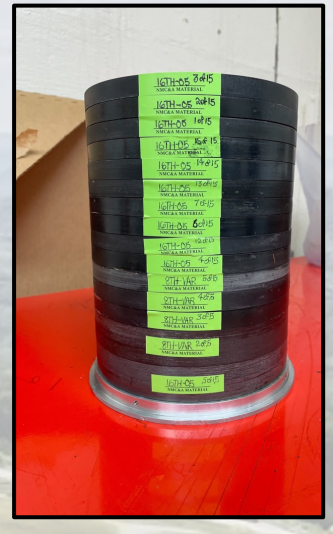
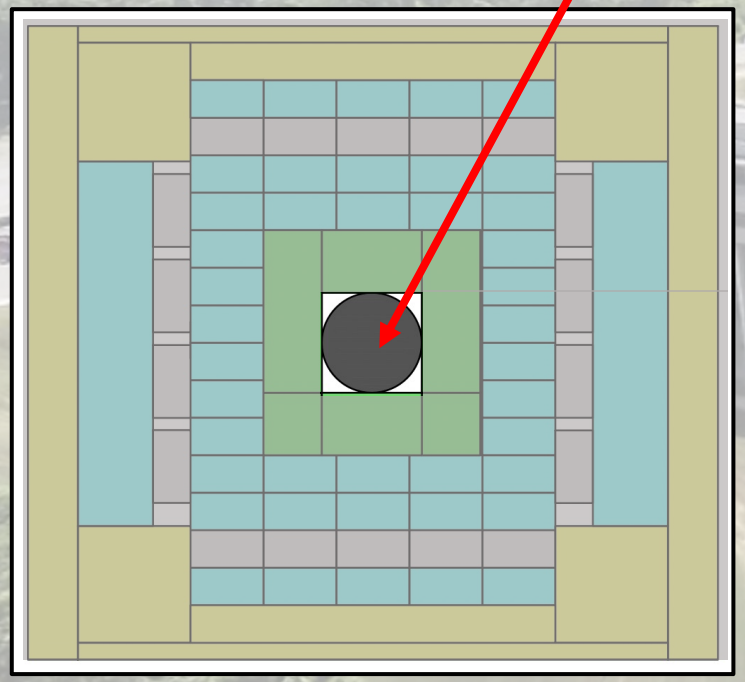
NuThor Detector Built & Deployed







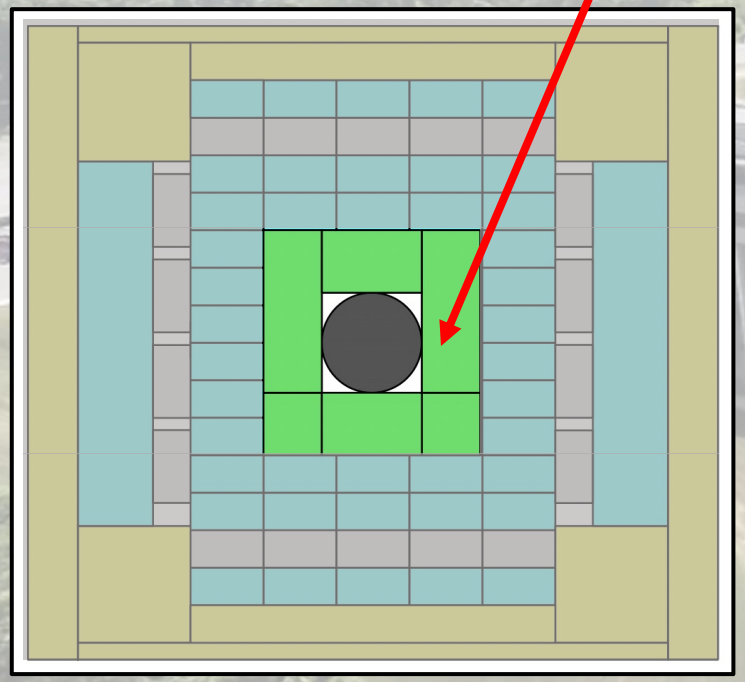
Thorium Plates



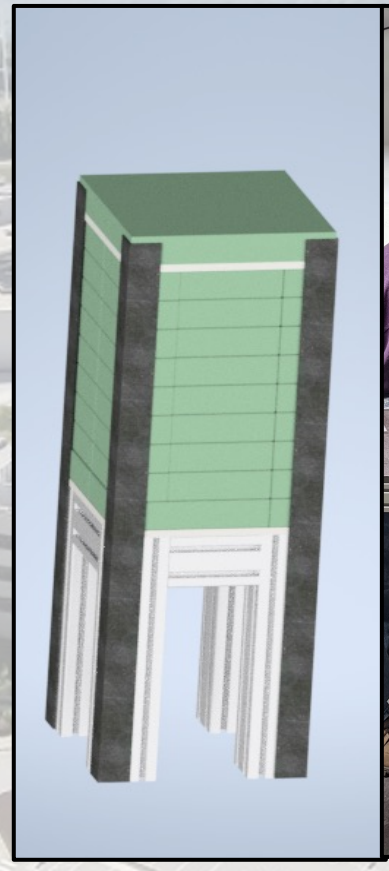
Th-232 Metal	
Lead	
Gd-Water	
NaI[Tl]	
Bor. Poly.	

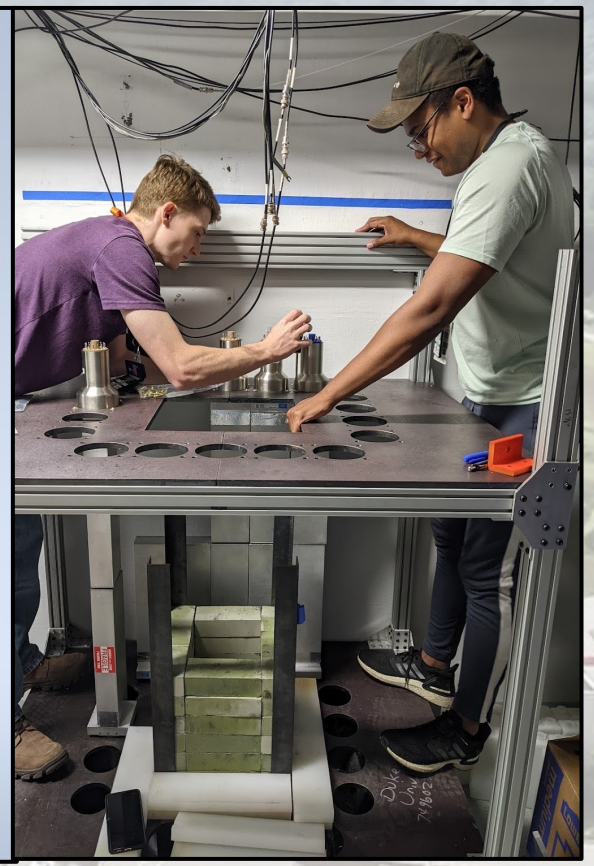
NuThor Detector Built & Deployed

Inner Lead Shielding



Th-232 Metal	
Lead	
Gd-Water	
NaI[Tl]	
Bor. Poly.	





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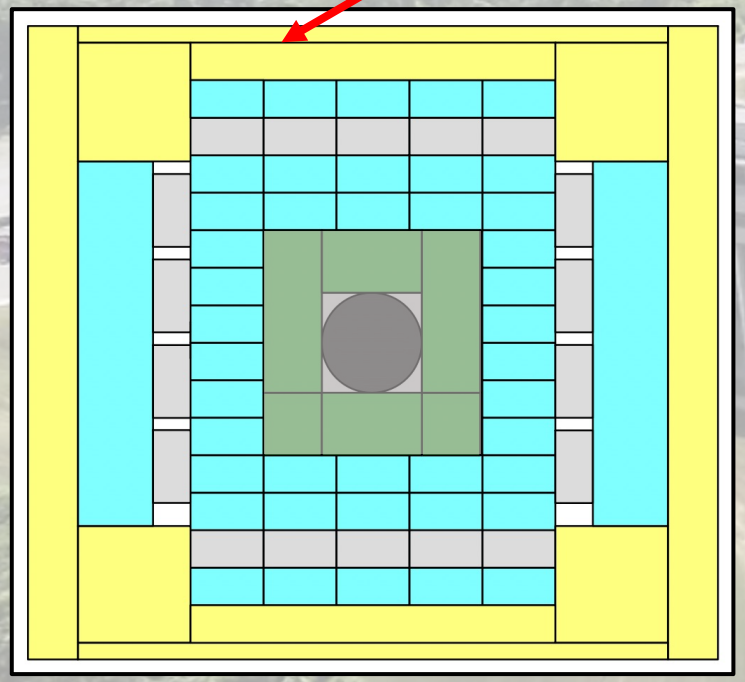
Neutron Multiplicity Meter



Th-232 Metal	
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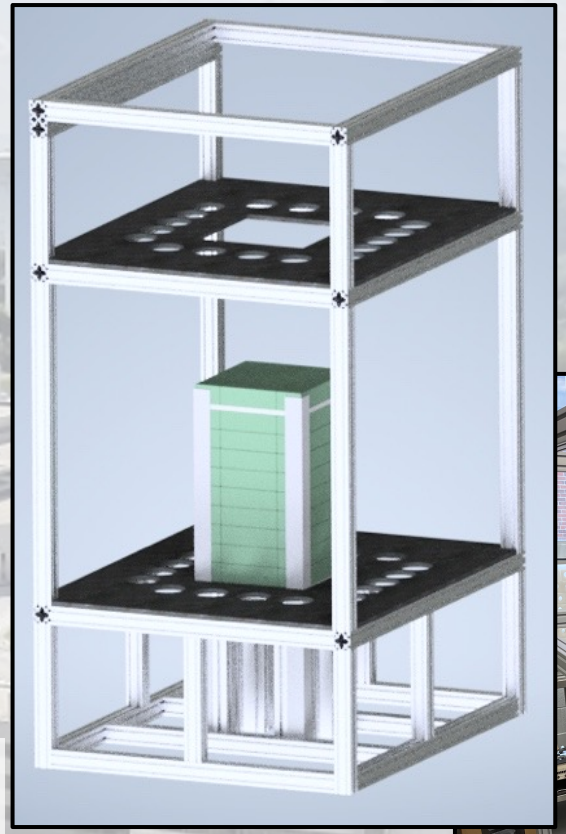
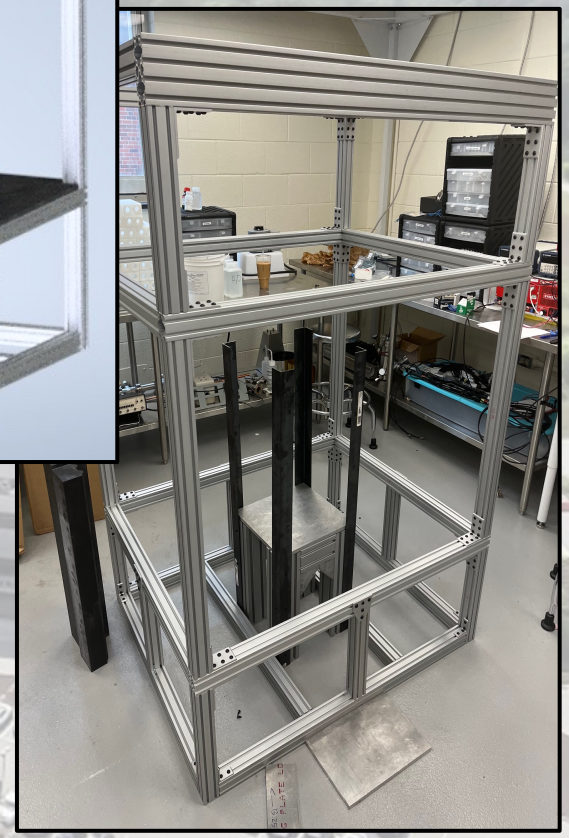
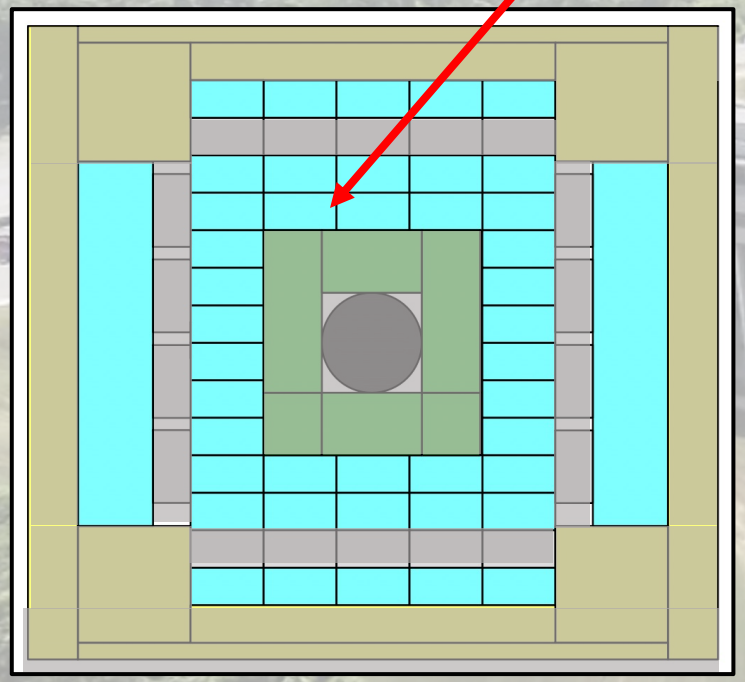
Gd-Water	
NaI[Tl]	
Bor. Poly.	



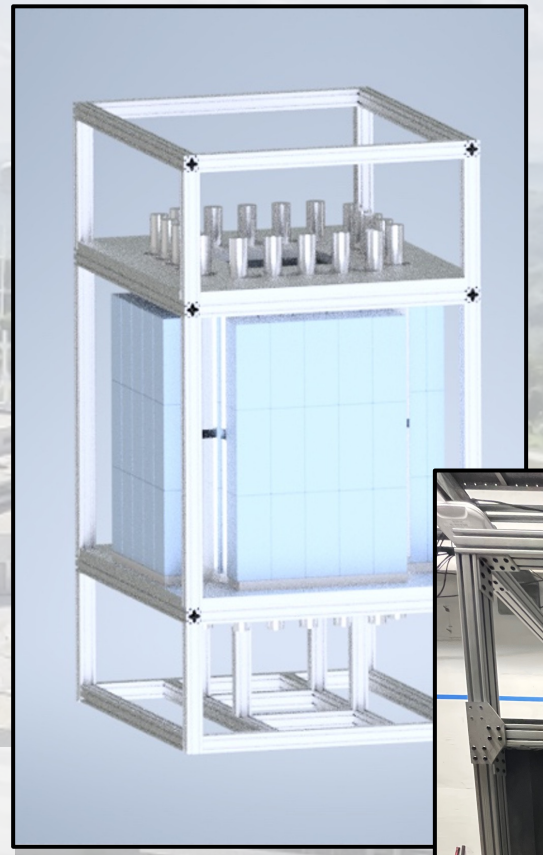


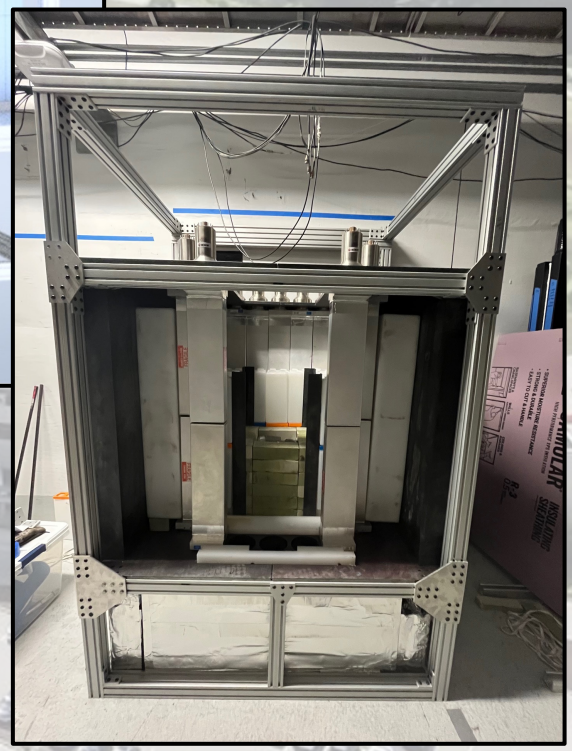
NuThor Detector Built & Deployed

Gadolinium-Doped Water Bricks



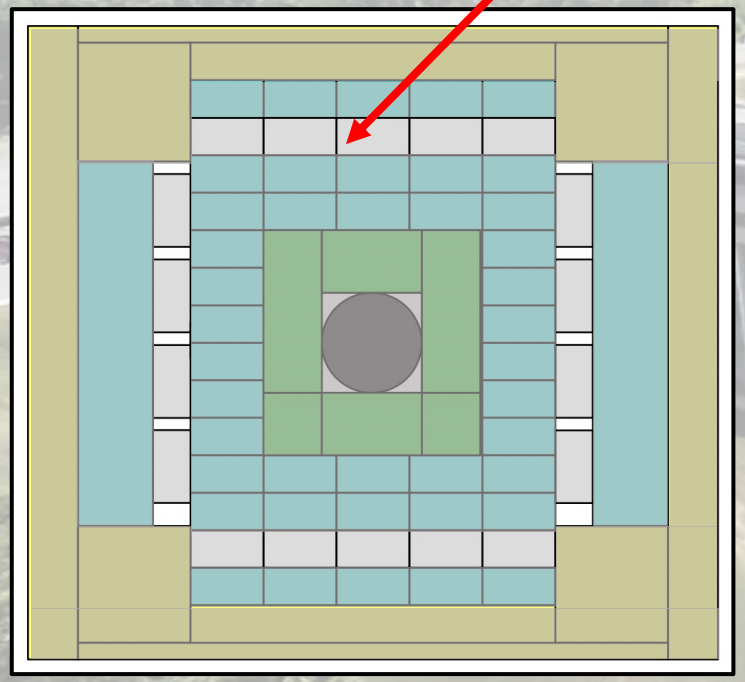
Th-232 Metal	
Lead	
Gd-Water	
NaI[Tl]	
Bor. Poly.	





NuThor Detector Built & Deployed

36 NaI[Tl] Scintillator Crystals



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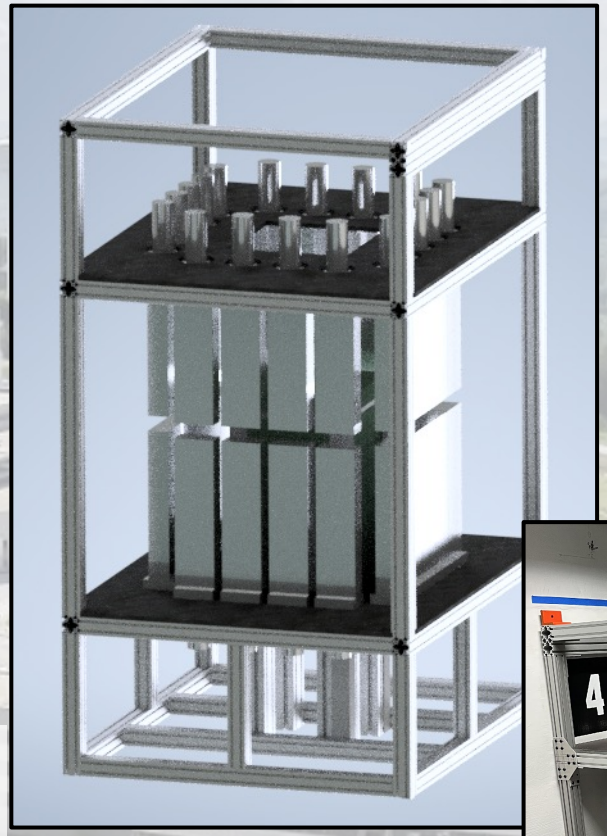

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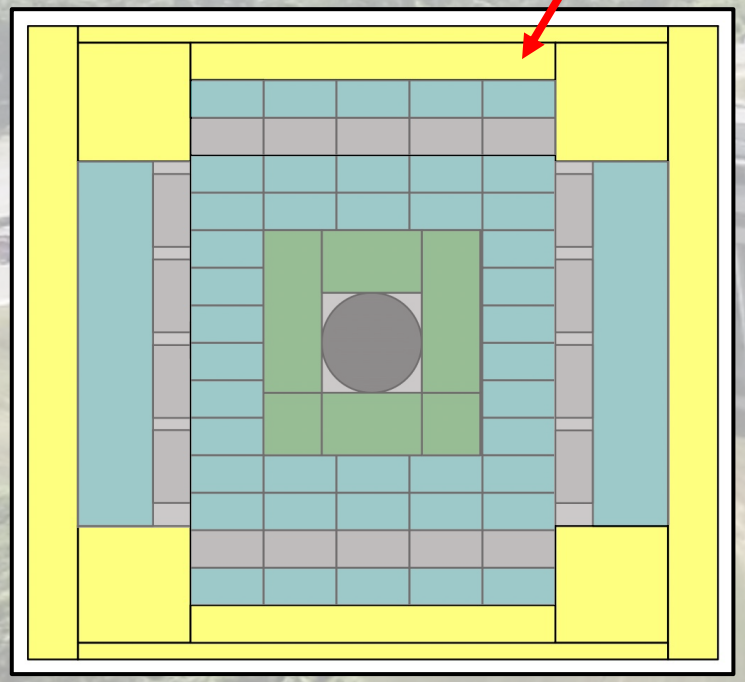
NuThor Detector Built & Deployed

Borated Polyethylene



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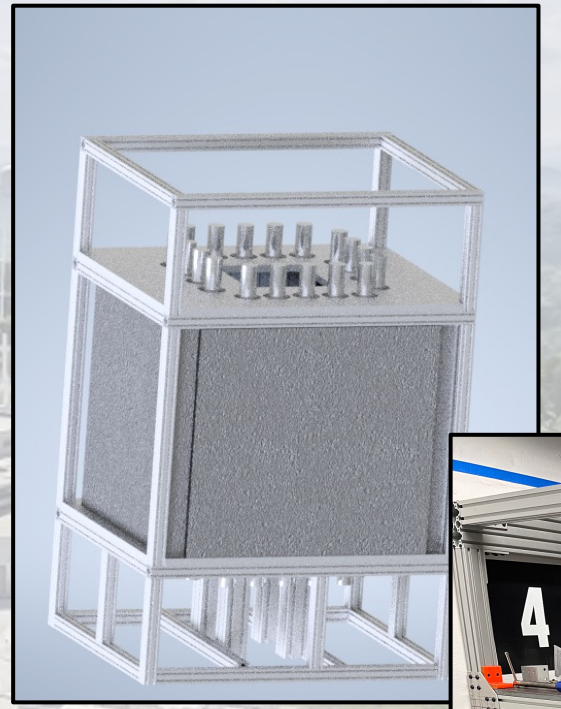

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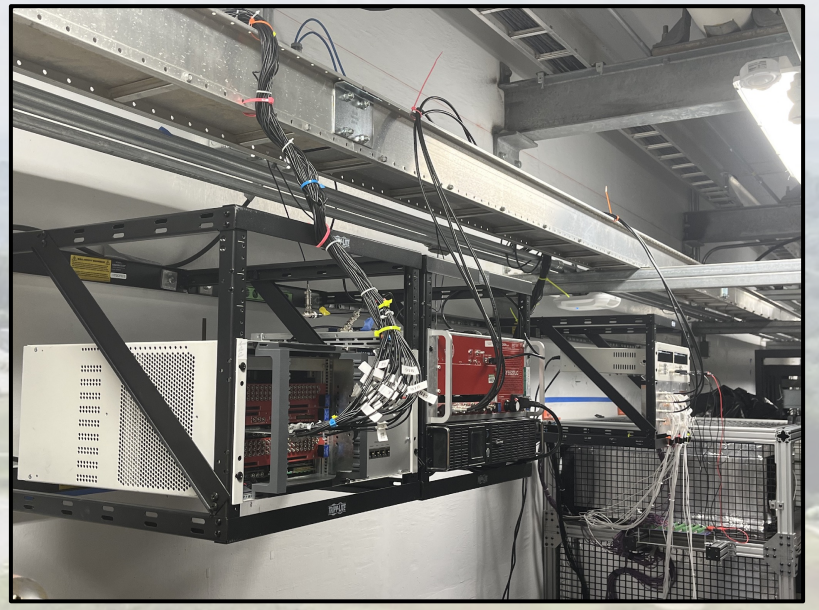
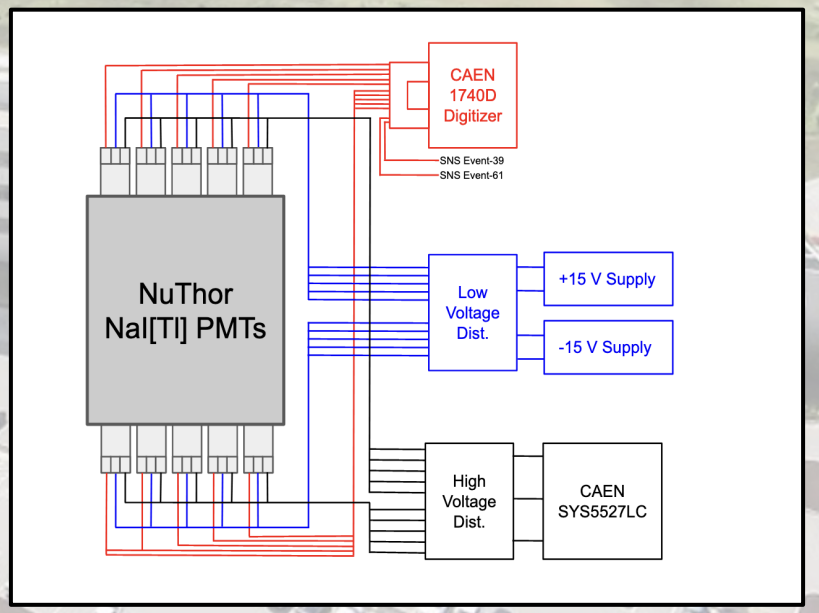
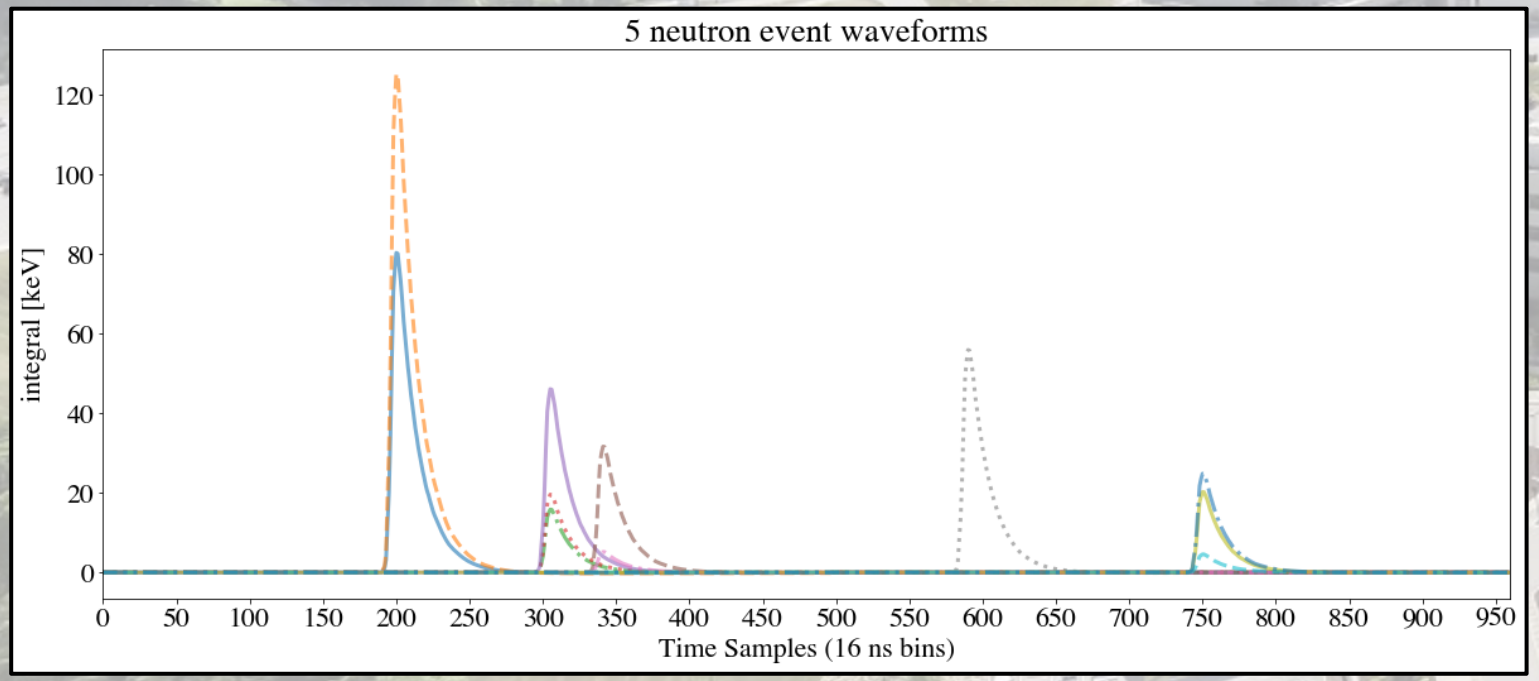
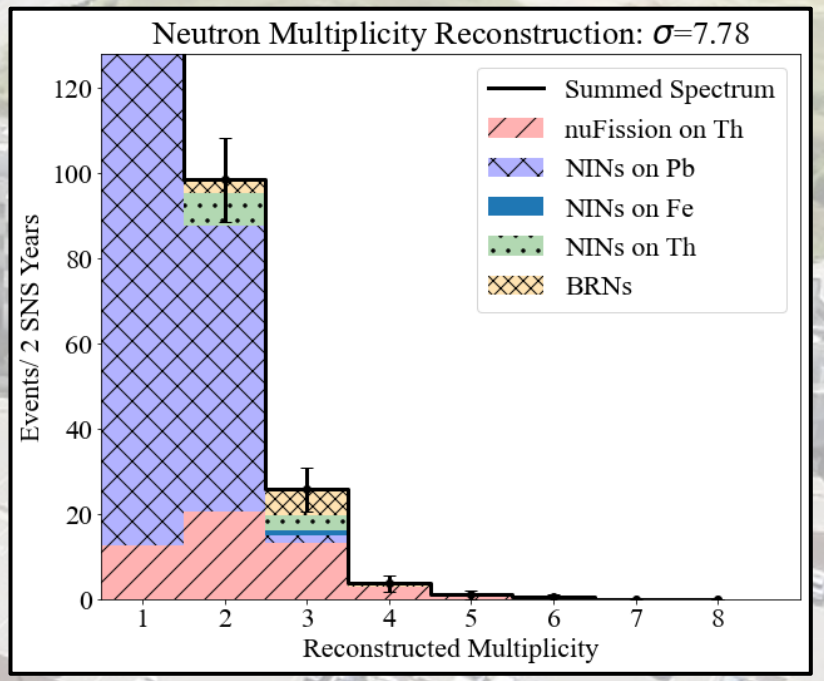
Early Data Analysis

Zero-threshold, external trigger on SNS Timing Signals






5 neutron event waveforms
integral [keV]
Time Samples (16 ns bins)
0
20
40
60
80
100
120
0
50
100
150
200
250
300
350
400
450
500
550
600
650
700
750
800
850
900
950


Neutron Multiplicity Reconstruction: σ=7.78
Summed Spectrum
nuFission on Th
NINs on Pb
NINs on Fe
NINs on Th
BRNs
Events/ 2 SNS Years
Reconstructed Multiplicity
0
20
40
60
80
100
120
1
2
3
4
5
6
7
8

Physics Event Topology

Expected Impact

- This would be the very first experimental confirmation of the new way to split the atom
- This would simultaneously be the first experimental confirmation of neutrino-induced neutron emission
- Could potentially be a novel method of detecting reactor neutrinos