The First Search for Neutrino Induced Nuclear Fission

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The νFission Process

ago but has no experimental confirmation. Neutrino Induced Nuclear Fission (νFission) was predicted over 53 years.[1]

The process proceeds in 2 steps:

(1) $$\nu_e + {}^{232}\text{Th} \rightarrow e^- + {}^{232}\text{Pa}^*$$

(2) $$^{232}\text{Pa}^* \rightarrow \text{FF}_1 + \text{FF}_2 + xn + y\gamma$$

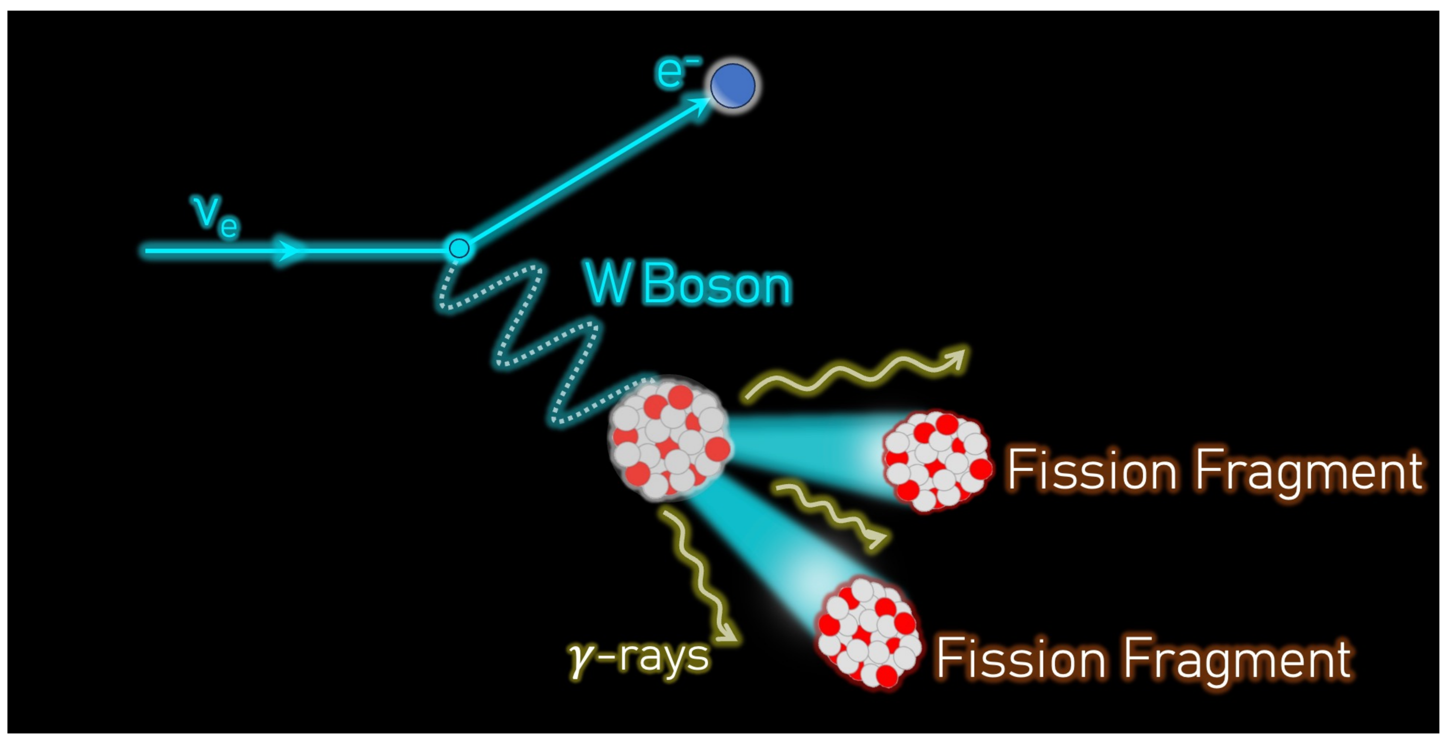


Fig 1: Illustration of the nuFission Process induced by an electron neutrino

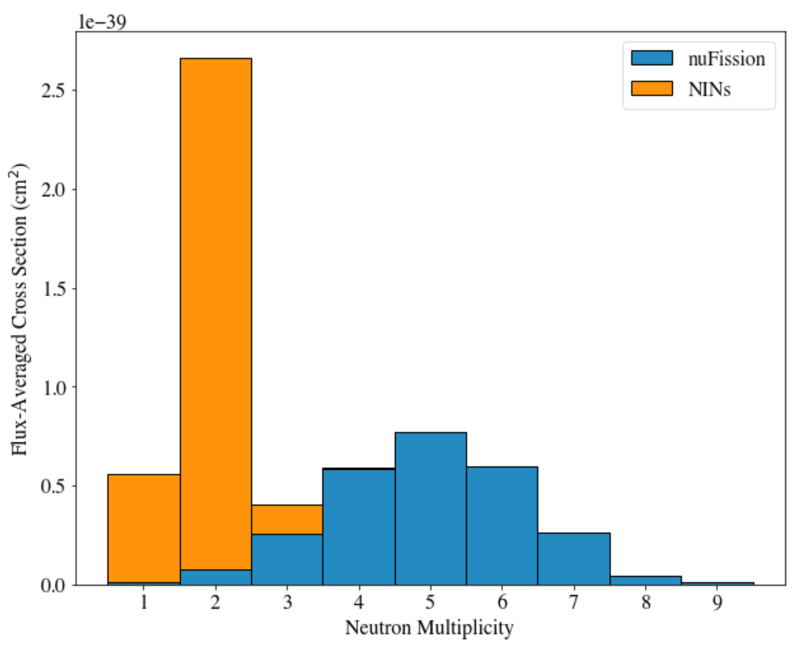


Fig 2: Neutron Multiplicity for NuFission on Thorium with a Decay-at-Rest Neutrino Source

The chosen signal is the prompt fission neutrons because:

1. They have a high average multiplicity
2. They are capable of escaping from a thick target such as thorium metal

The Neutrino Source

This experiment is conducted at Oak Ridge National Laboratory's Spallation Neutron Source, which in addition to being the world's most intense pulse neutron source, is a powerful Decay-at-Rest neutrino source.

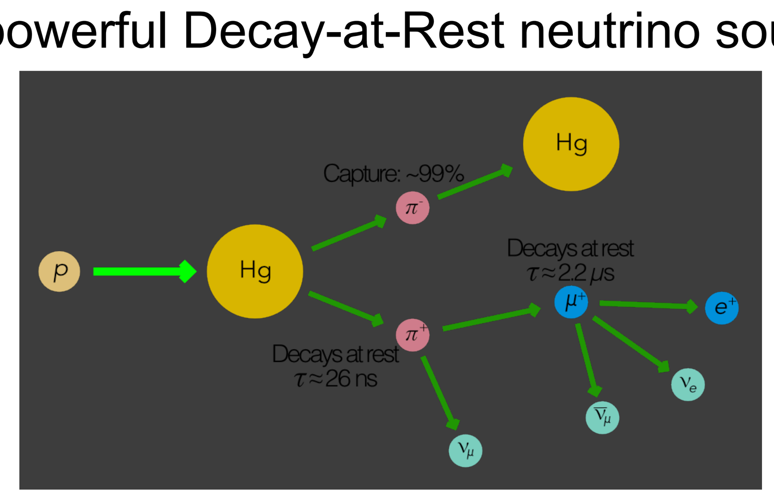


Fig 3: The neutrino production scheme for the SNS

- 1/3 of the neutrinos emitted from the SNS are electron neutrinos
- Average energy of ~30 MeV
- Pulse at 60 Hz

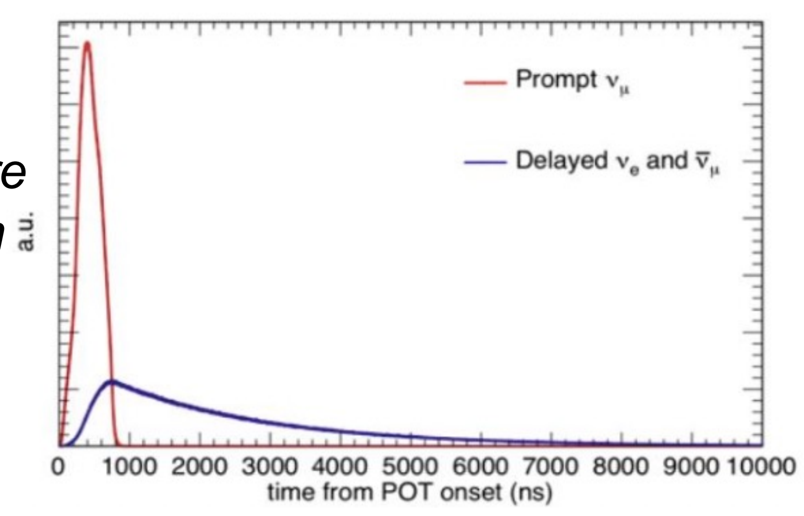


Fig 4: The Timing structure of the SNS neutrino beam broken into prompt and delayed components[2]

References:

1. V. I. Andryushin, et al ZhETF Pis Red, **13.** No 10, 1971
2. Akimov et al, Phys Rev D., **106,** 032003, 2022

The NuThor Detector

Fig 5: The NuThor detector in "Neutrino Alley" at the Spallation Neutron Source

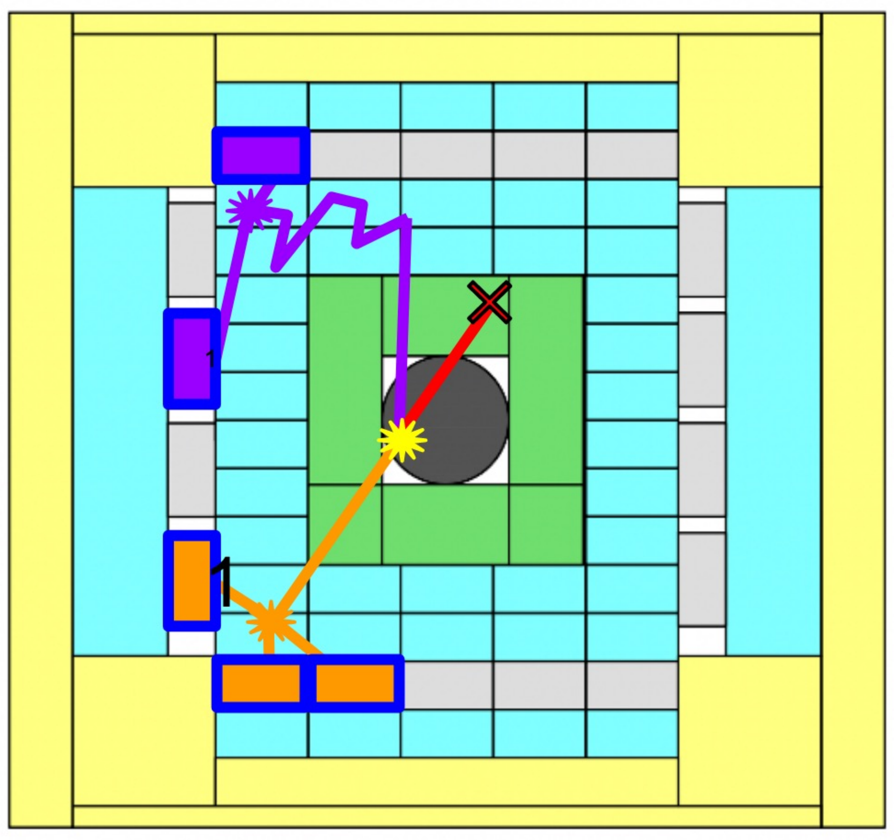


Fig 6: Cross section view of the inner workings of the NuThor detector.
Dark Grey = Thorium, Green = Lead, Cyan = Gd-Water, light gray = NaI, yellow = Borated Polyethylene

The NuThor detector is a dedicated nuFission instrument in the COHERENT detector suite. 52 kgs of thorium metal is exposed to the SNS neutrino flux. 800 kgs of lead shielding is stacked immediately around the thorium. Surrounding this Inner Core of thorium and lead is a Neutron Multiplicity Meter

The Neutron Multiplicity Meter:

- Water Bricks doped with Gadolinium Nitrate
- 36 NaI[Tl Scintillators
- Borated Polyethylene neutron shielding

3,000 beam hours of data collected as of now.
More to come with the SNS proton power upgrade this summer

Signal Expectations

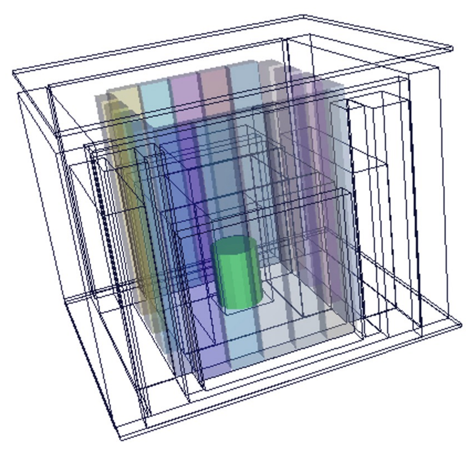


Fig 7: MCNP NuThor Geometry

Signal: The neutron signal is simulated with MCNP and run through a post-processing scheme that closely mimic the data acquisition process.

Background: A primary background to this work is the steady-state radioactivity of thorium target itself. The background gamma rays look topologically different from the signal events and are differentiated using a rudimentary Boosted Decision Tree classification model

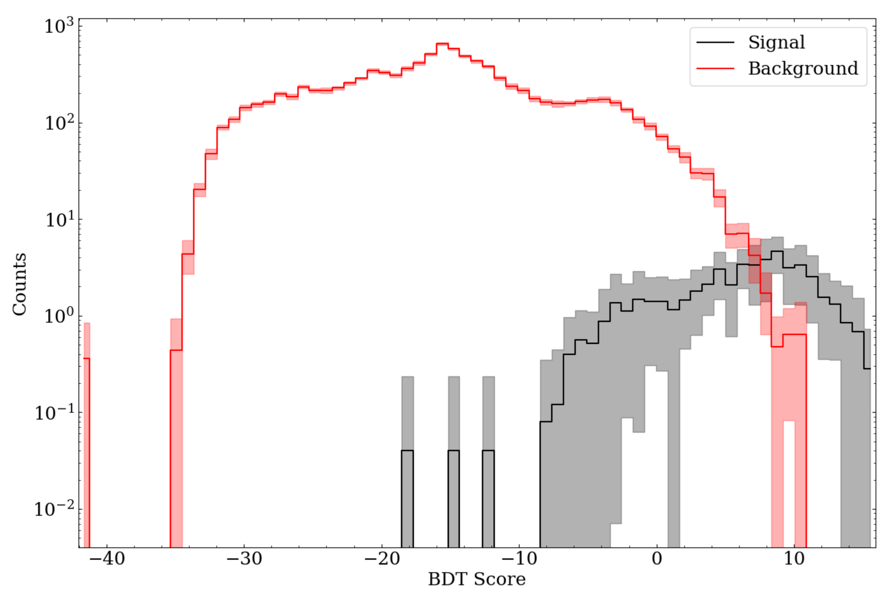
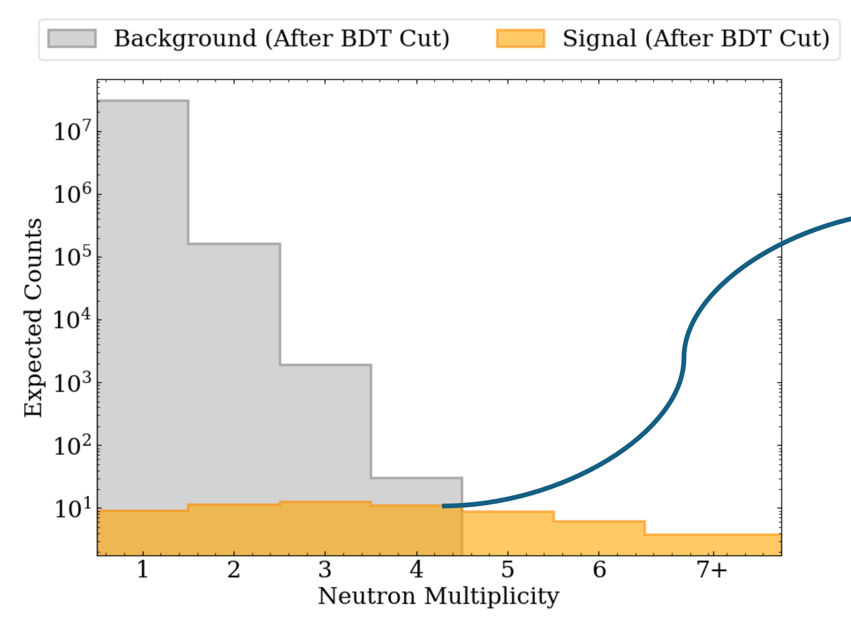


Fig 7: The signal and background likelihood scores output from the BDT classifier model



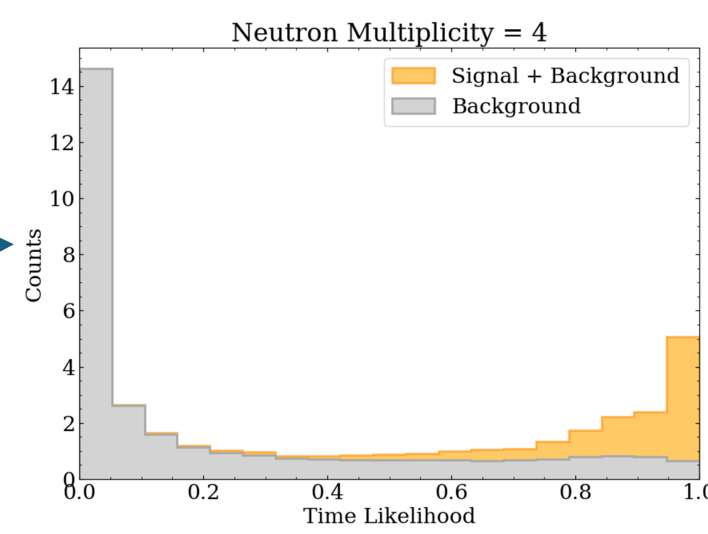


Fig 8: A time likelihood classification for Neutron Multiplicity = 4 Bin

Fig 9: The Neutron Multiplicity Distributions of Signal Neutrons (simulated) and steady-state backgrounds (data) after the BDT Cut