NRTA technique for isotopic identification using an isotopic neutron source

MTV Workshop, 2022

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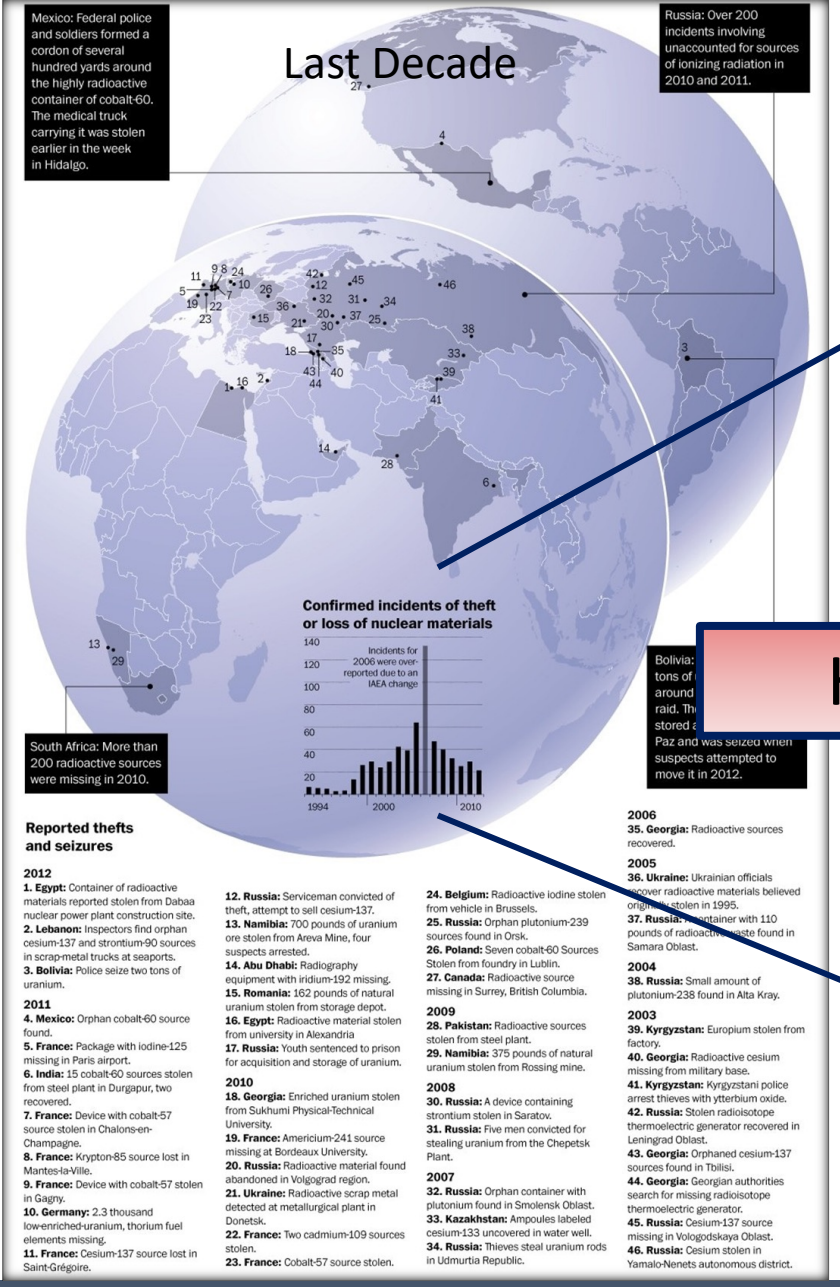
Introduction

An orphaned radioactive source (Picture Courtesy : PNRI and IAEA)

- Nuclear material does go missing
- IAEA: Illicit trafficking of nuclear materials pose a threat

Source: IAEA Incident and Trafficking Database (ITDB) 2020 Fact Sheet



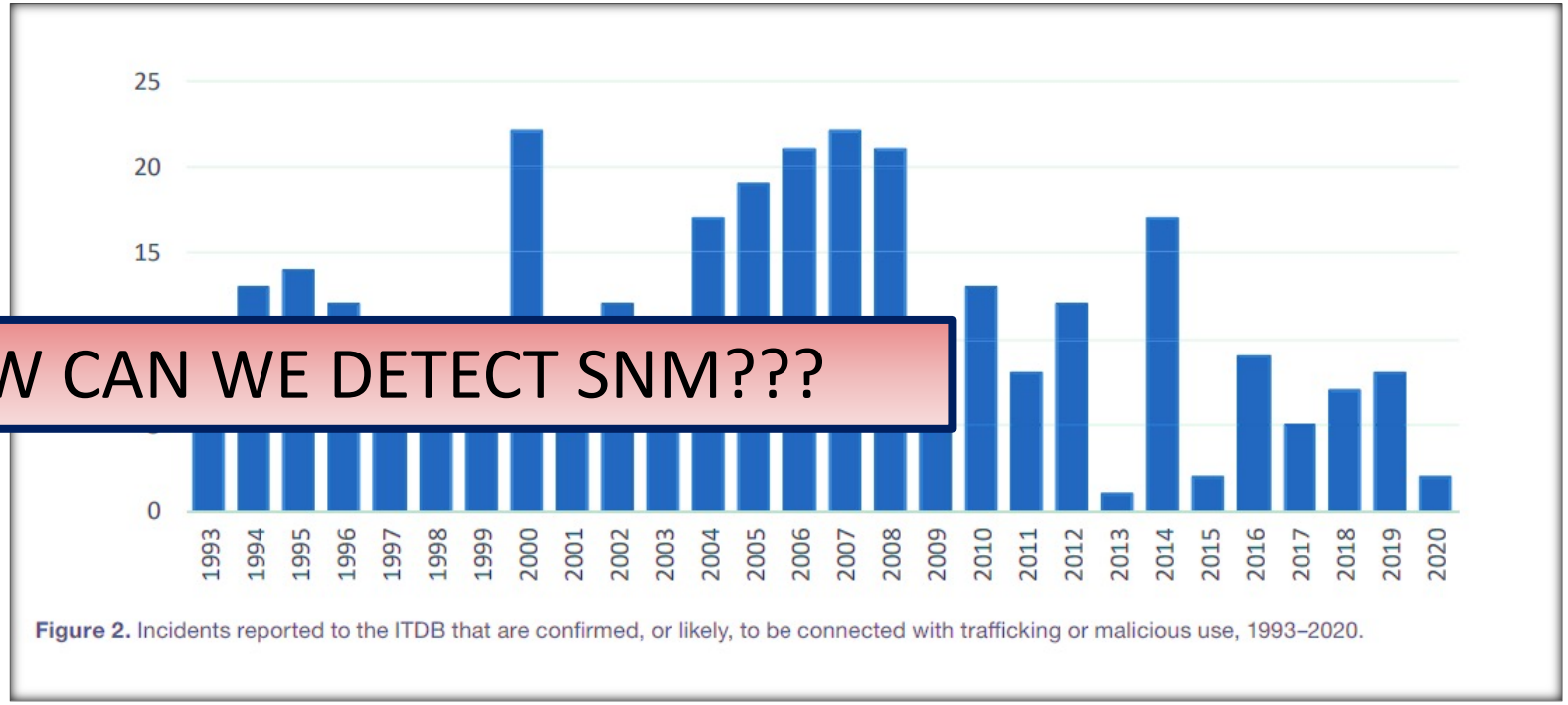


Figure 2. Incidents reported to the ITDB that are confirmed, or likely, to be connected with trafficking or malicious use, 1993–2020.

HOW CAN WE DETECT SNM???

Between 1993 and 2020, the IAEA reported 12 incidents connected with trafficking or malicious use of high enriched uranium, 3 of plutonium and 5 of PuBe sources.

Source: IAEA Incident and Trafficking Database (ITDB) 2020 Fact Sheet

HOW CAN WE DETECT CONCEALED SNM???

FIG. 23. Packaging of HEU seized in Bulgaria, May 1999. Source: Lawrence Livermore National Laboratory, http://www.llnl.gov/str/March05/Hutcheon.html.

.2 incidents connected with
ranium, 3 of plutonium and

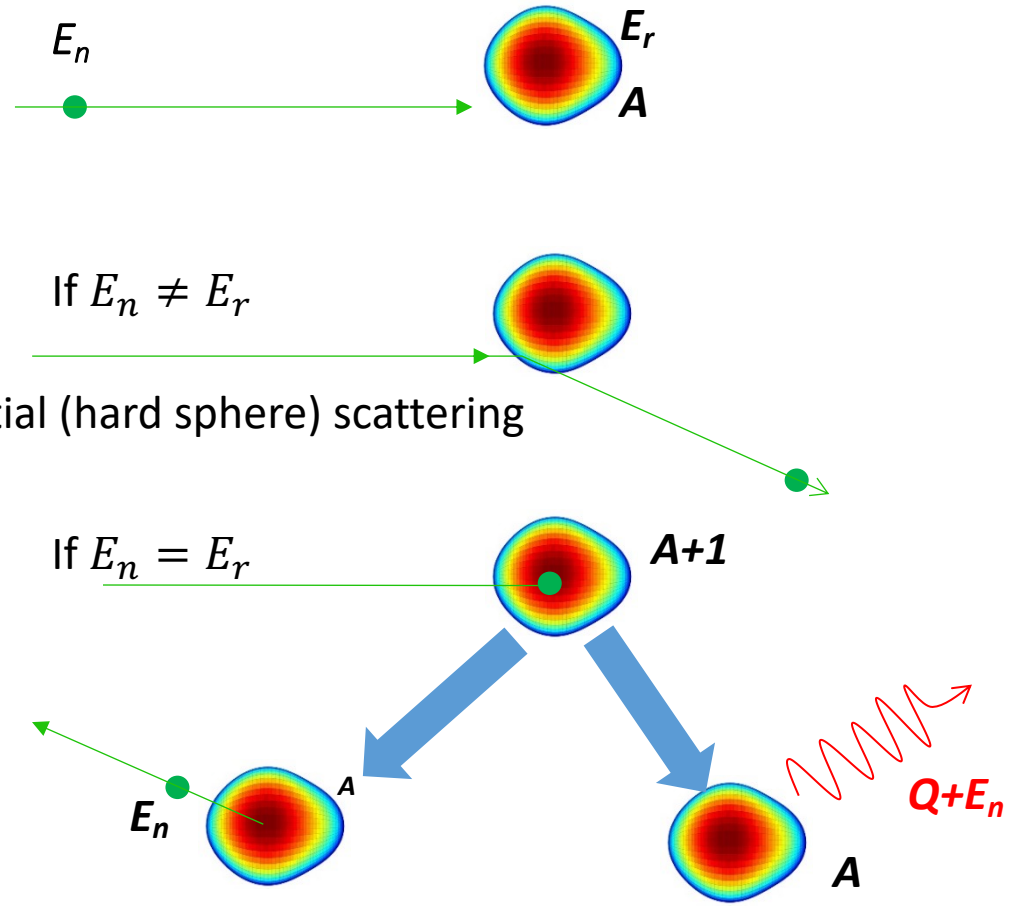
Mission Relevance

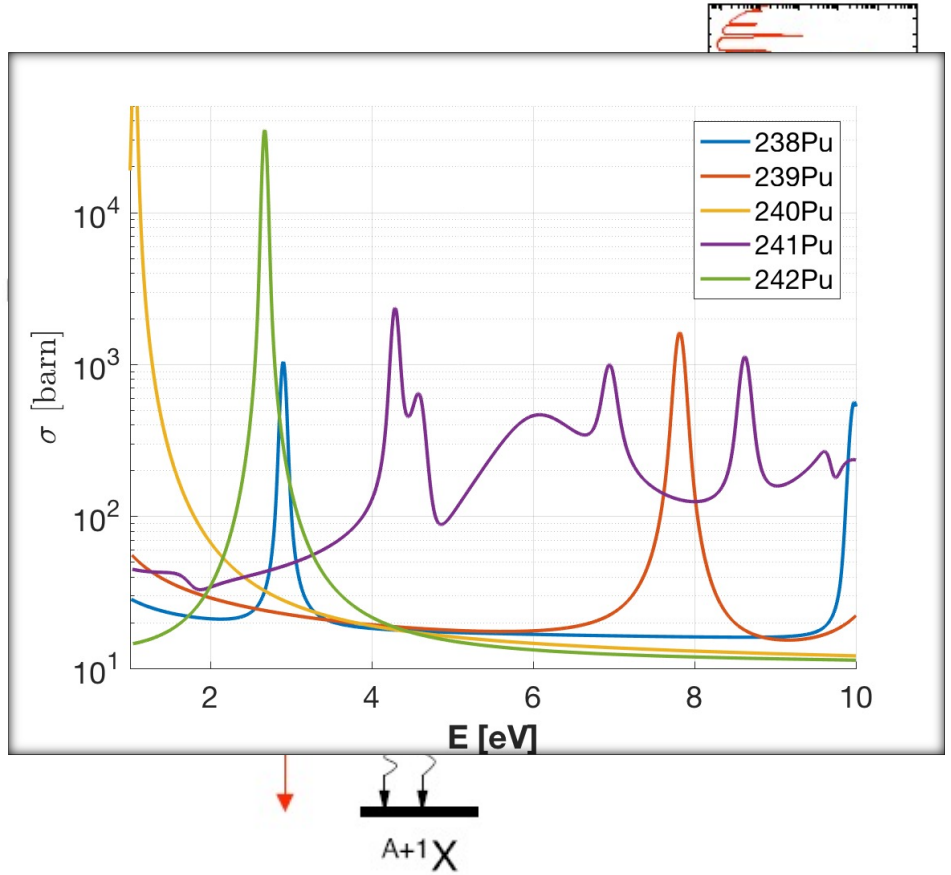
- Technological advancements and development of compact, mobile, on-site facility having elemental detection and isotopic analysis capabilities
- *NNSA Mission*
  - *Website:* https://www.energy.gov/nnsa/missions/nonproliferation

  Preventing nuclear weapons proliferation and reducing the threat of nuclear and radiological terrorism around the world are key U.S national security strategic objectives that require constant vigilance.

  NNSA's Office of Defense Nuclear Nonproliferation works globally to prevent state and non-state actors from developing nuclear weapons or acquiring weapons-usable nuclear or radiological materials, equipment, technology, and expertise.

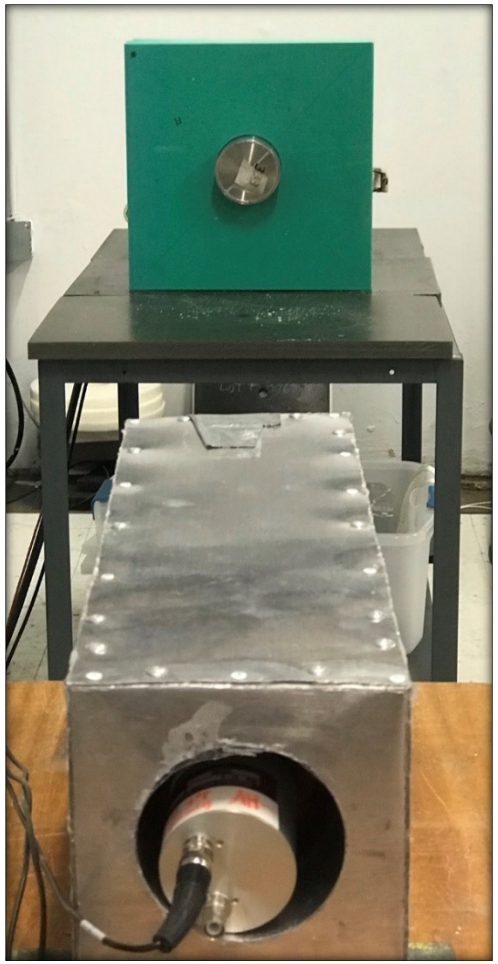
Approach: Use Resonances as Unique Fingerprint of Nuclear Structure

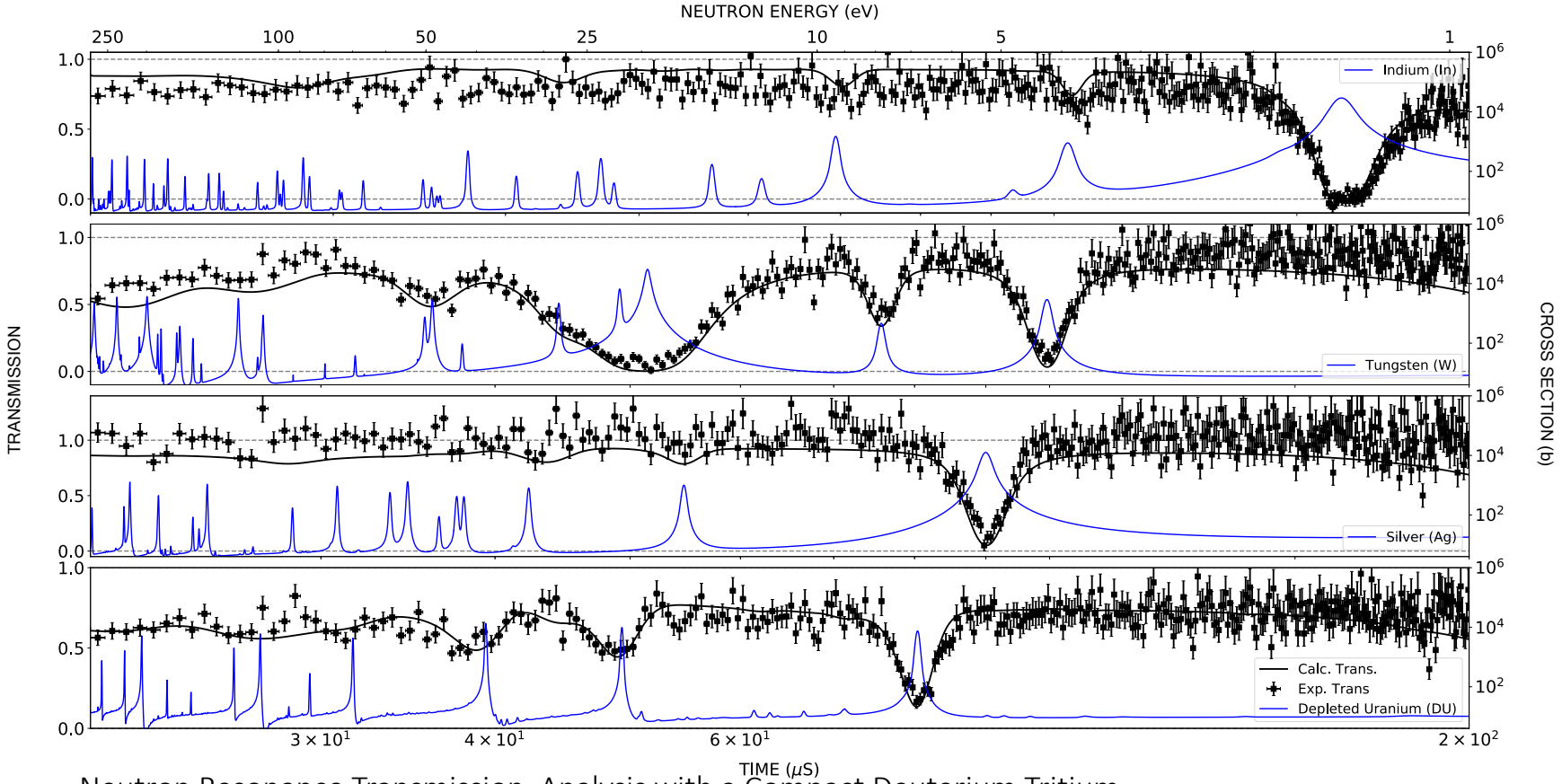




Neutron Resonance Spectroscopy, Frank Gunsing, 2005.

Towards a compact, on-site material identification and isotopic analysis facility: NRTA – DT Generator Setup



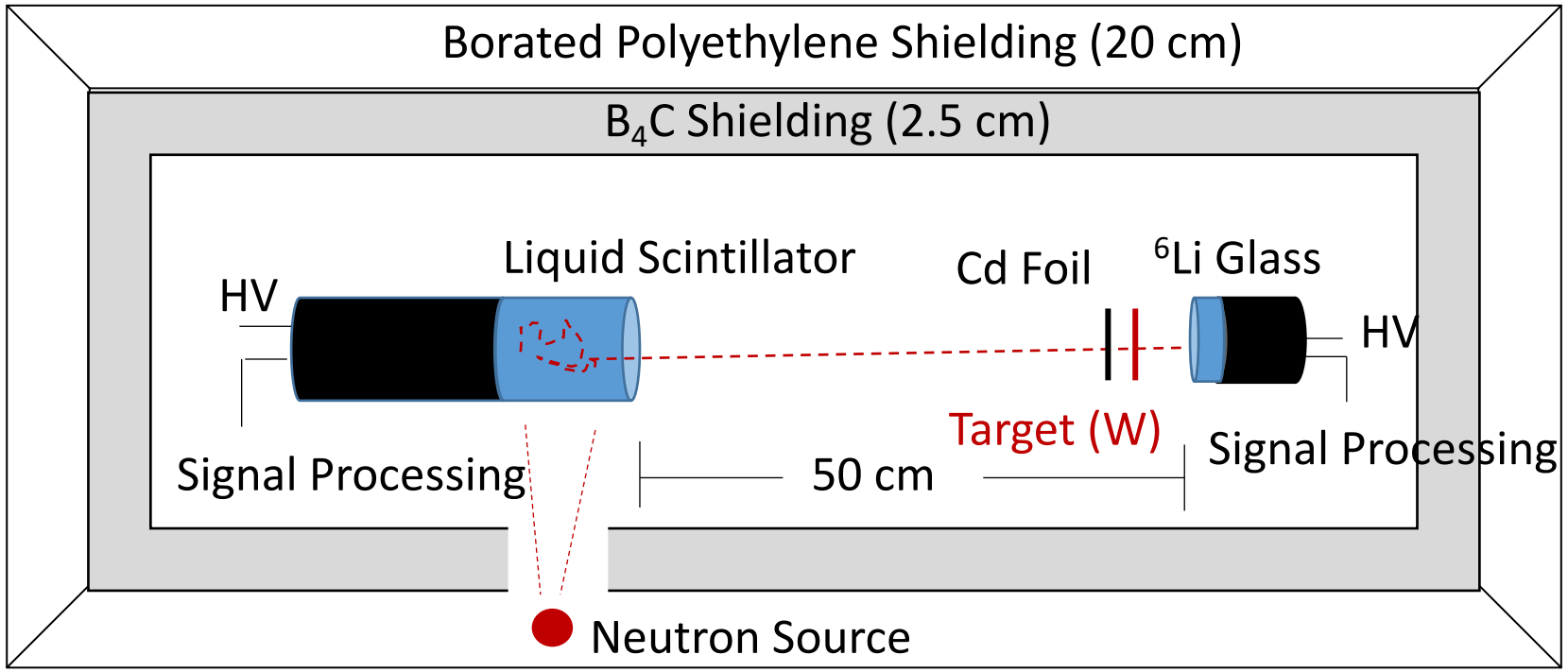


Neutron Resonance Transmission Analysis with a Compact Deuterium Tritium Neutron Generator

Ethan A. Klein *et al.*, https://arxiv.org/abs/2012.03937

(Ethan Klein's Presentation)

Towards a compact, on-site material identification and isotopic analysis facility: NRTA – Isotopic Neutron Source Setup



Coincidence measurement b/w two detectors

Neutron source : AmBe

Source activity : 10^4 n/s

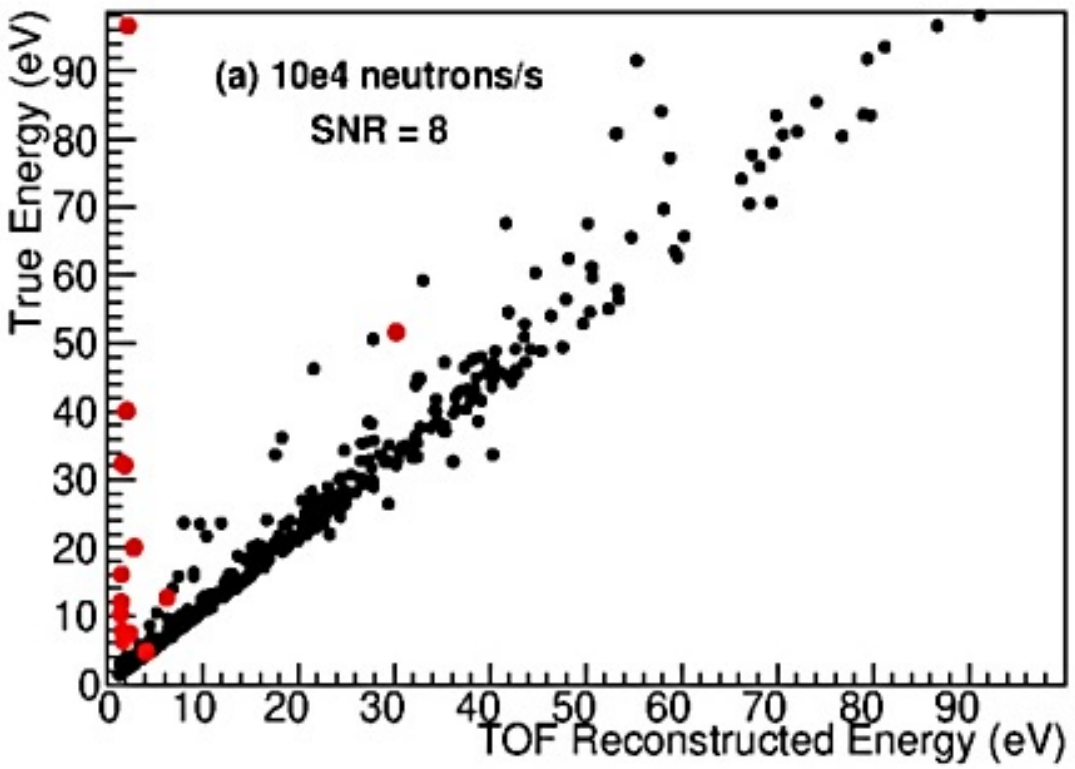
TOF distance : 50 cm

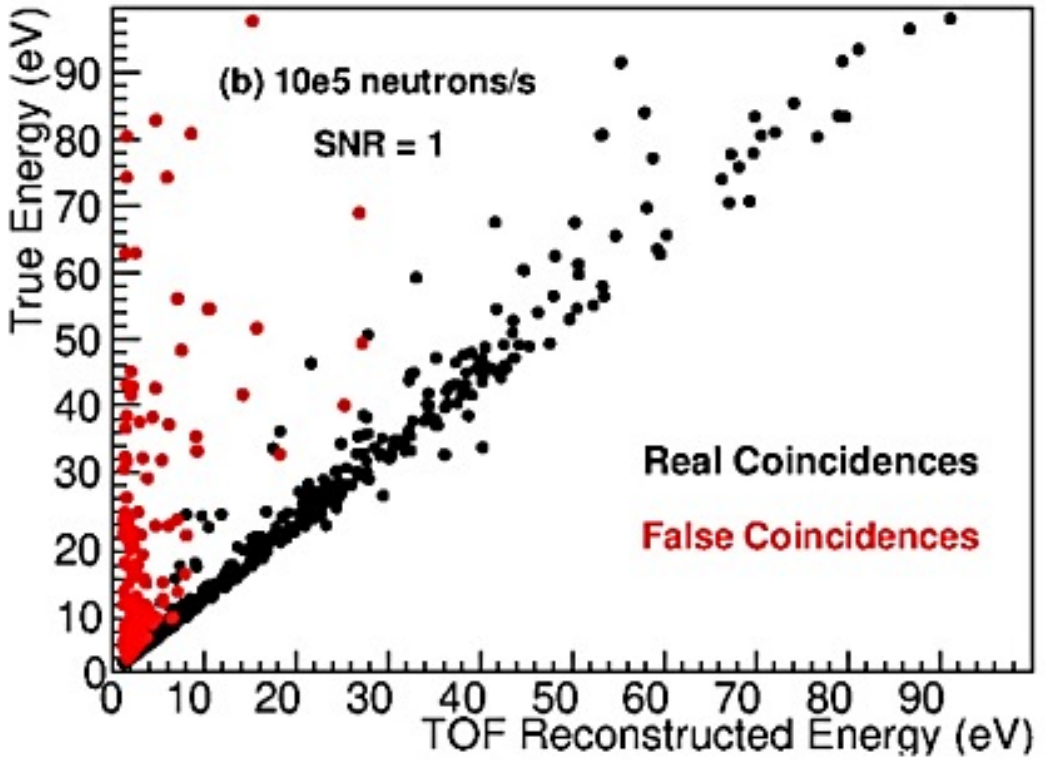
Det 1 is a liquid scintillator: Fast neutron detection, TOF start + moderator

Det 2 is a ^{6}Li-doped GS20 glass detector : TOF end + thermal neutron detection

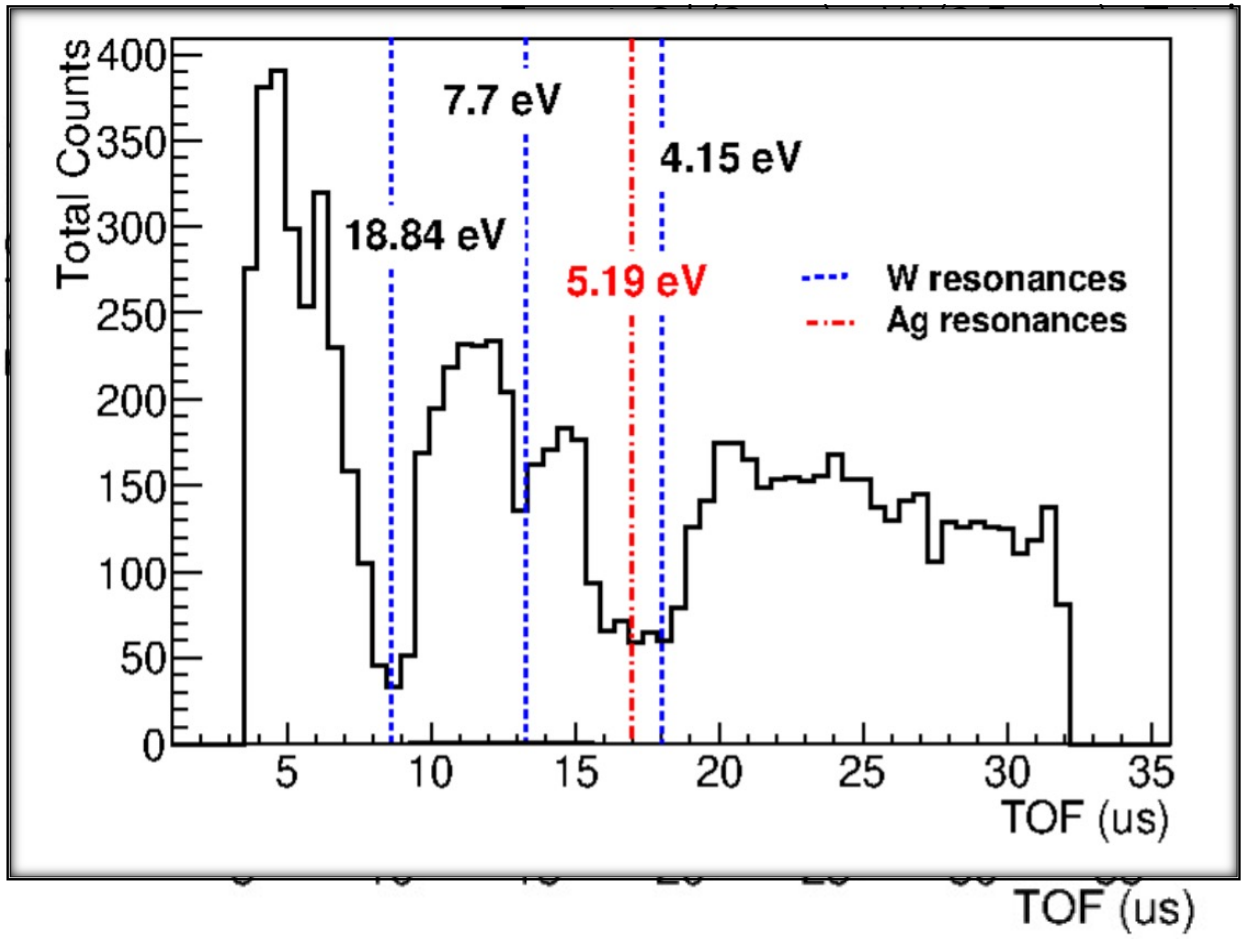
Simulation Results: Energy Reconstruction

Target: Cd (3mm) , **Total No. of Particles Simulated** : 10^9





Simulation Results: Source Activity



No. of Particles Simulated : 10^9

Target: Cd (3mm) + W (3.5 mm) + Ag (0.25 mm)

Total No. of Particles Simulated : 10^9

Source Activity : 10^4 nps

Comparison of neutron transmission spectrum for a W target with two different

Resolution is dominated by the spread in the moderation time

At TOF ~ 31 us → 1 eV, a spread of 7 us in moderation time is expected

At TOF ~ 8 us → 20 eV, a spread of 3 us is predicted

TOF Setup

Neutron Source

AmBe Source

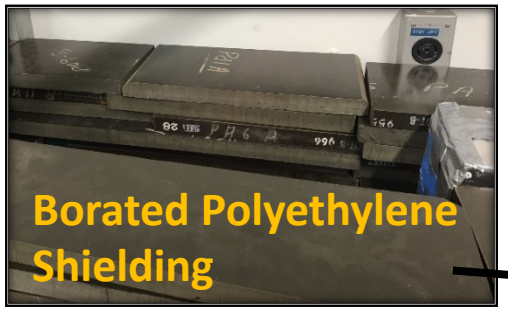
$^{241}Am \rightarrow {}^{237}Np + {}^{4}He + \gamma$

$^{4}He + {}^{9}Be \rightarrow {}^{12}C + n + \gamma$

Activity: ~ 10e+06 n/s

Energy: < 11 MeV

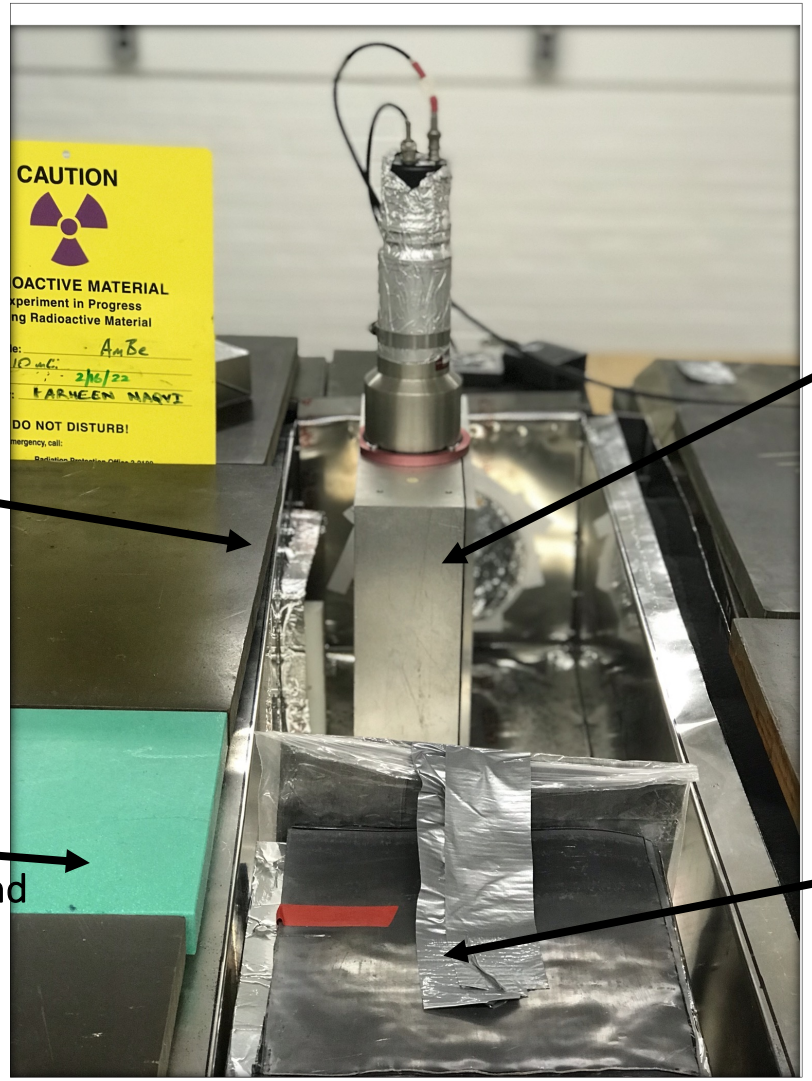
Shielding



Outer layer of Borated sand

Polyethylene (20 cm) for fast neutrons

Slow Neutrons: Inner layer of 1-2" B_4C



Moderation

Active moderation

Liquid scintillator (3" X 8" X 8")

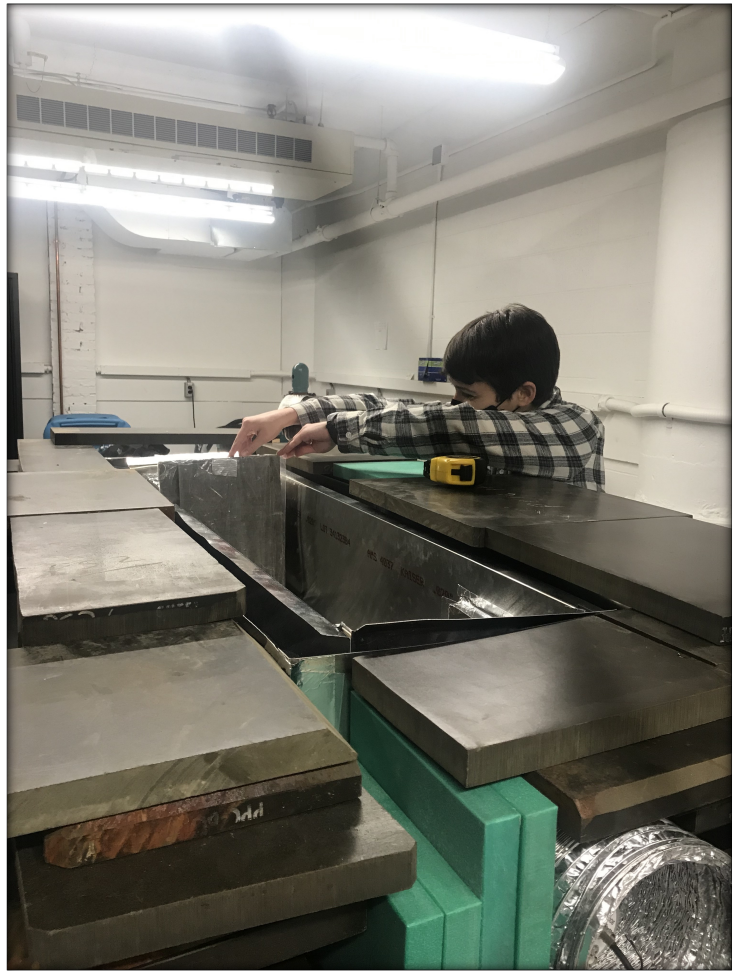
Detection

1 disk of 1cm thick,

^{6}Li doped- Ce activated GS20 glass

Manufactured by Scintacor Inc.

Experimental Results



Thanks to Peninah Levine – Grad Student

- ✓ Designing and machining the boxes
- ✓ Setting up Borated Poly
- ✓ Testing the neutron and liquid scintillator detectors
- ✓ Optimizing the setup for minimum background
- ▪ Data collection - ongoing

Target: Cd (3mm) + Ag (0.25mm) ,
Data Collected for 24 hours

MTV Impact

- Workshops
  - The upcoming MTV workshop on MCNP will be useful as an introduction to the code.
  - Presenting and discussing the work at MTV workshops has often led to new ideas and improvement in the setup.

Conclusions and Next Steps

- Potential for mobile NRTA measurement with simpler setup and isotopic neutron sources !

ISIS Neutron Source ~$1bln

~$20k

- Limited Neutron flux.
- Limited Resolution due to moderation times.
- False coincidences limit the source activity resulting in long measurement times.

Next Steps

- TOF resolution might improve using a Cf source, E < 1 MeV neutrons – thinner moderator – less time spent in moderation.
- Proof of concept through experiments.

Acknowledgements

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