Development of Prototype Simplified Neutron Scatter Camera for Nuclear Safeguards Applications

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Introduction and Motivation

- Neutron imaging systems can provide valuable spatial information about neutron sources in safeguards scenarios
- Many successful systems have been made, but most are large, expensive, or have complicated readout, making widespread adoption in the safeguards repertoire difficult
- This project seeks to build a simplified, less expensive prototype neutron scatter camera that can perform satisfactory source localization

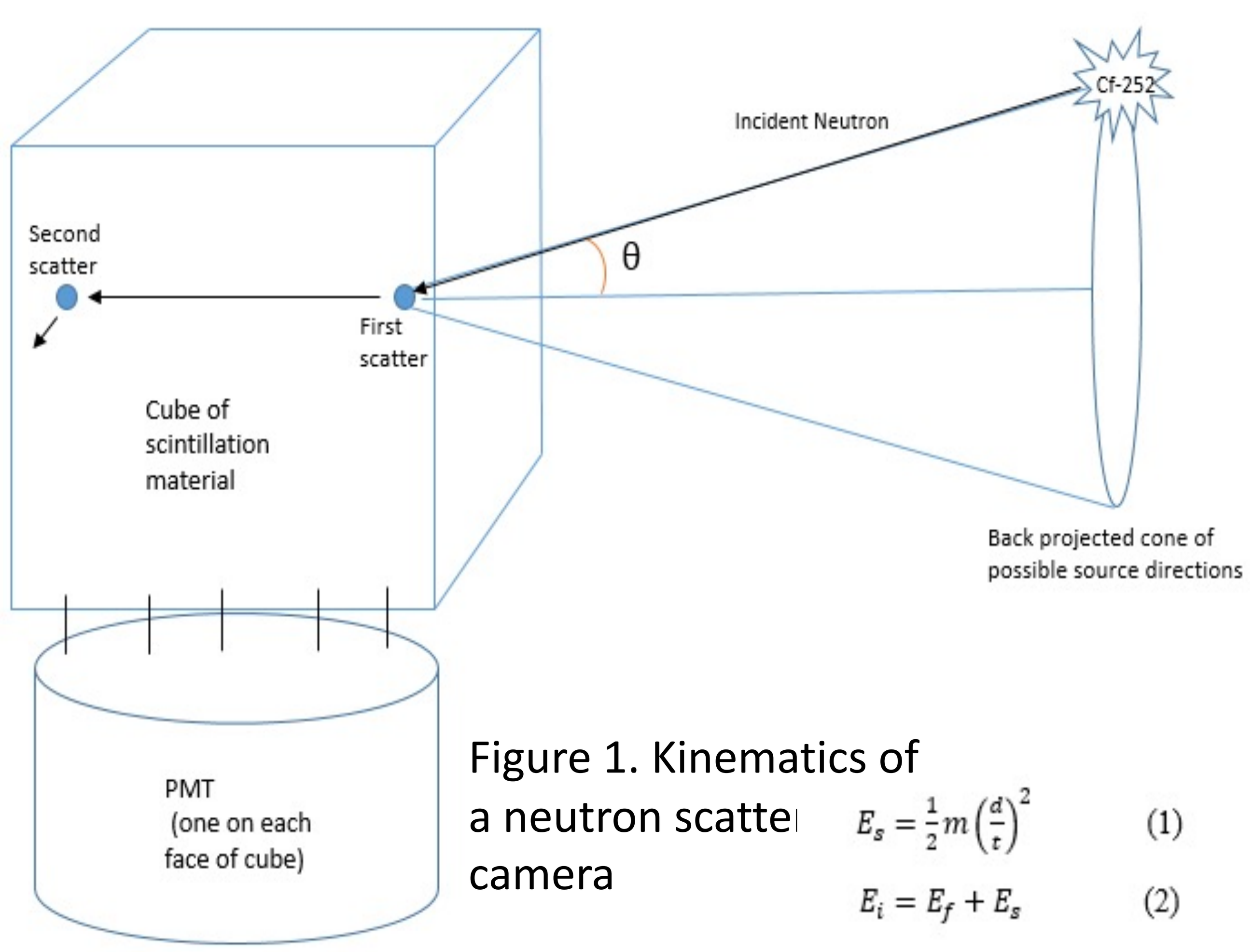

Figure 1. Kinematics of a neutron scatter camera

$$E_s = \frac{1}{2} m \left(\frac{d}{t}\right)^2 \quad (1)$$

$$E_i = E_f + E_s \quad (2)$$

$$\theta_n = \sin^{-1}\sqrt{E_f/E_i} \quad (3)$$

Mission Relevance

- An affordable, mobile neutron imaging system could be of use in managing nuclear materials, treaty verification, accident response, external reactor core monitoring, and security in smuggling or diversion scenarios.

Technical Approach and Results

- Prototype simulation performed using MCNPX-PoliMi
- Cube-shaped fast plastic scintillator EJ-230 chosen for good timing and relatively high light yield
- PMTs coupled to each of the 6 faces of the cube
- Positions of neutron scattering events within scintillator volume determined by analyzing the ratios of light arriving at photodetectors
- Measurements show ability to accurately localize neutron point sources through double pulse finding algorithm

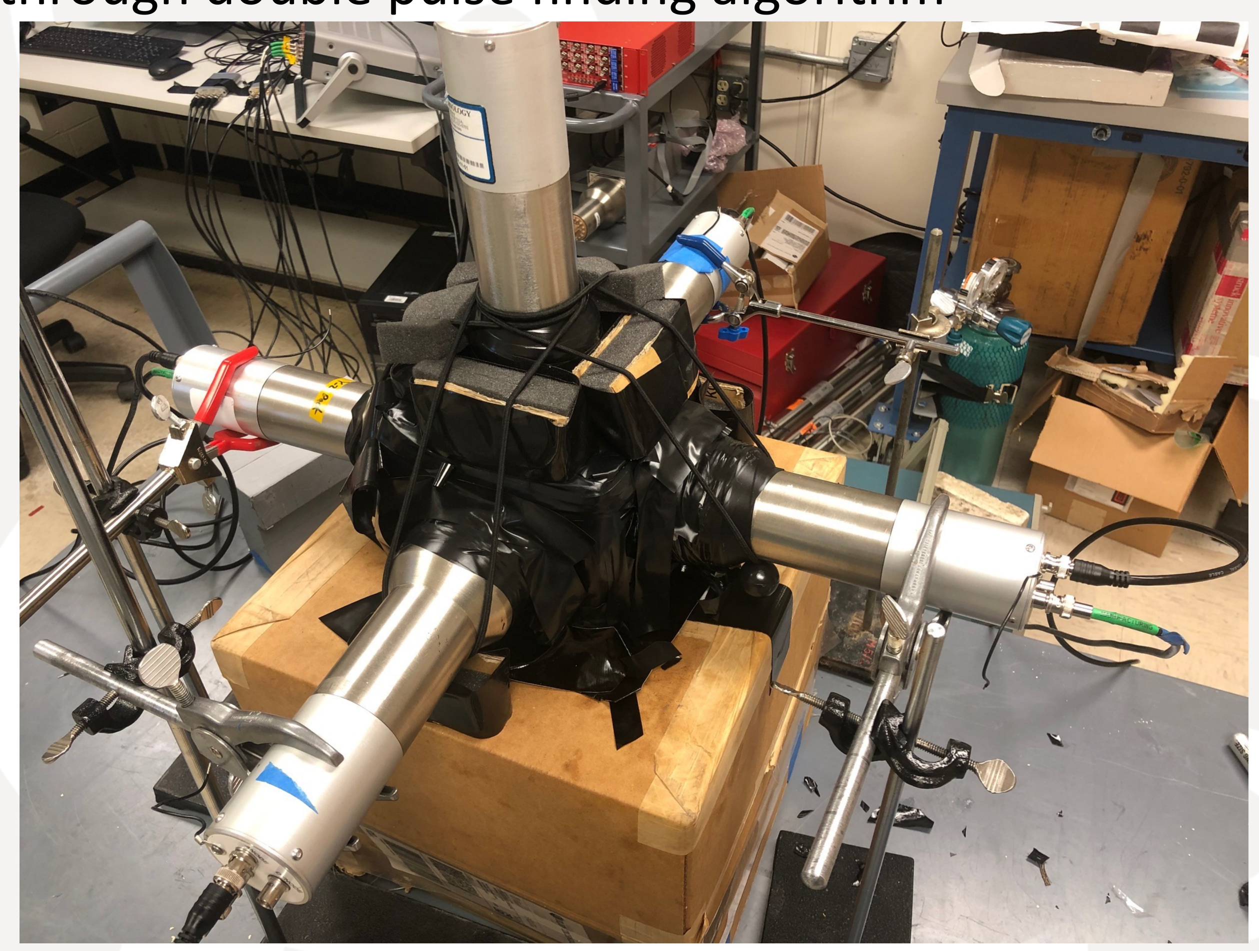

Figure 2. Prototype simplified neutron scatter camera using EJ230 fast plastic, six PMTs

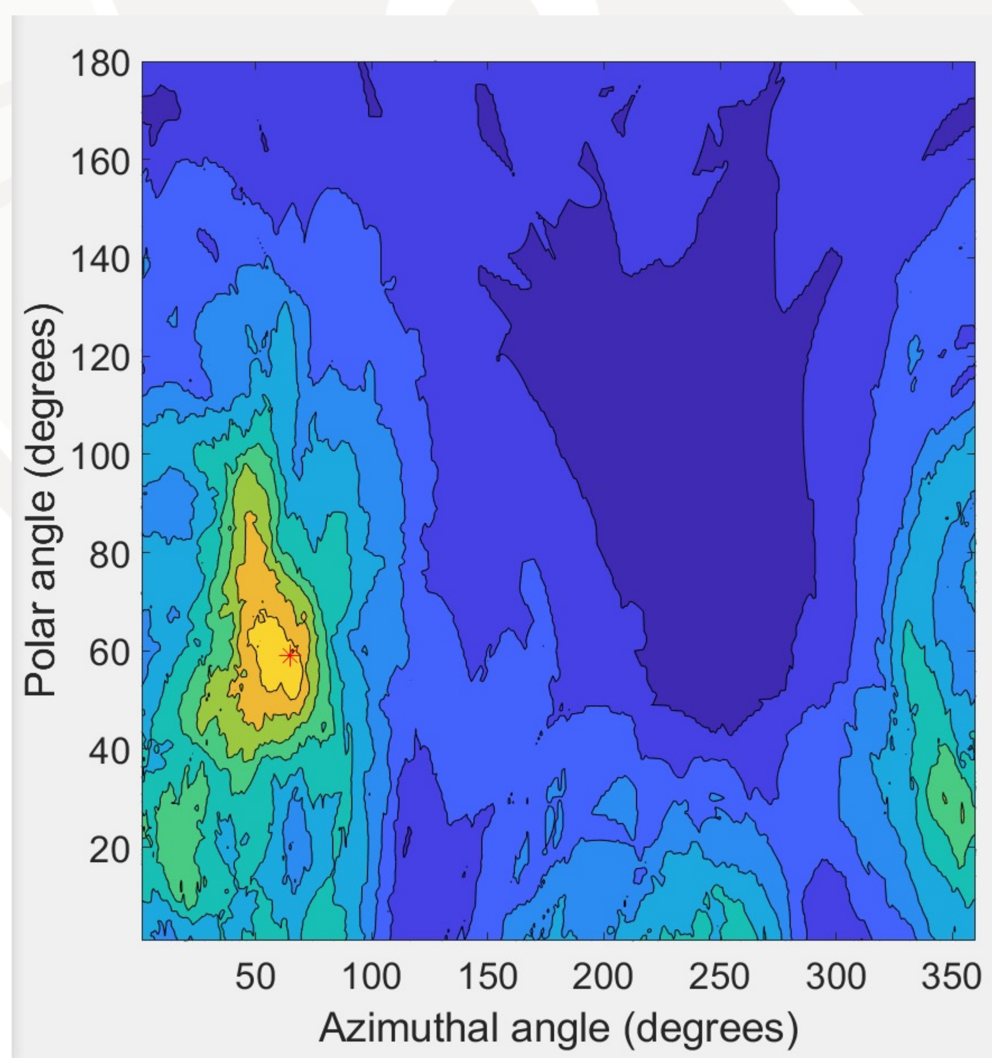

Figure 3. Neutron image of Cf-252 source located at (65, 59) using 60 cones

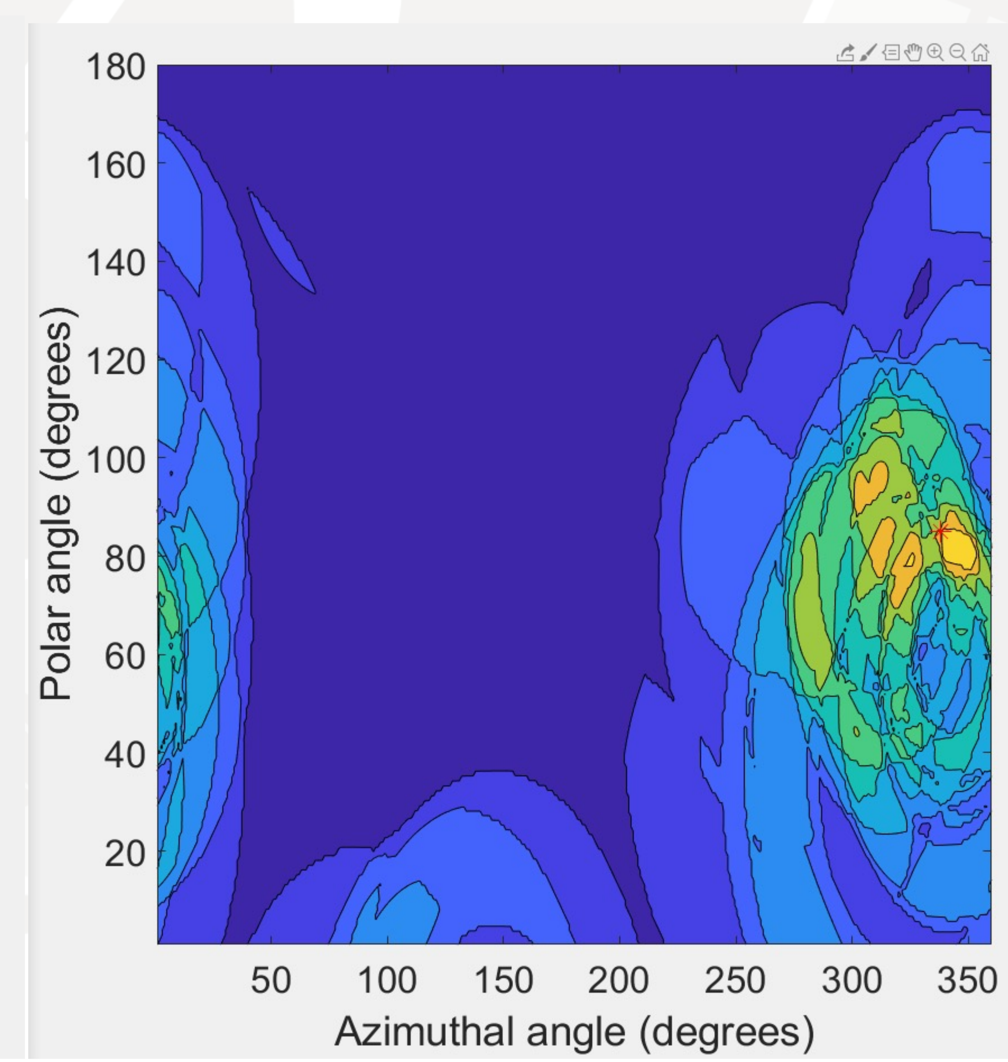

Figure 4. Neutron image of Cf-252 source located at (338, 85) using 16 cones

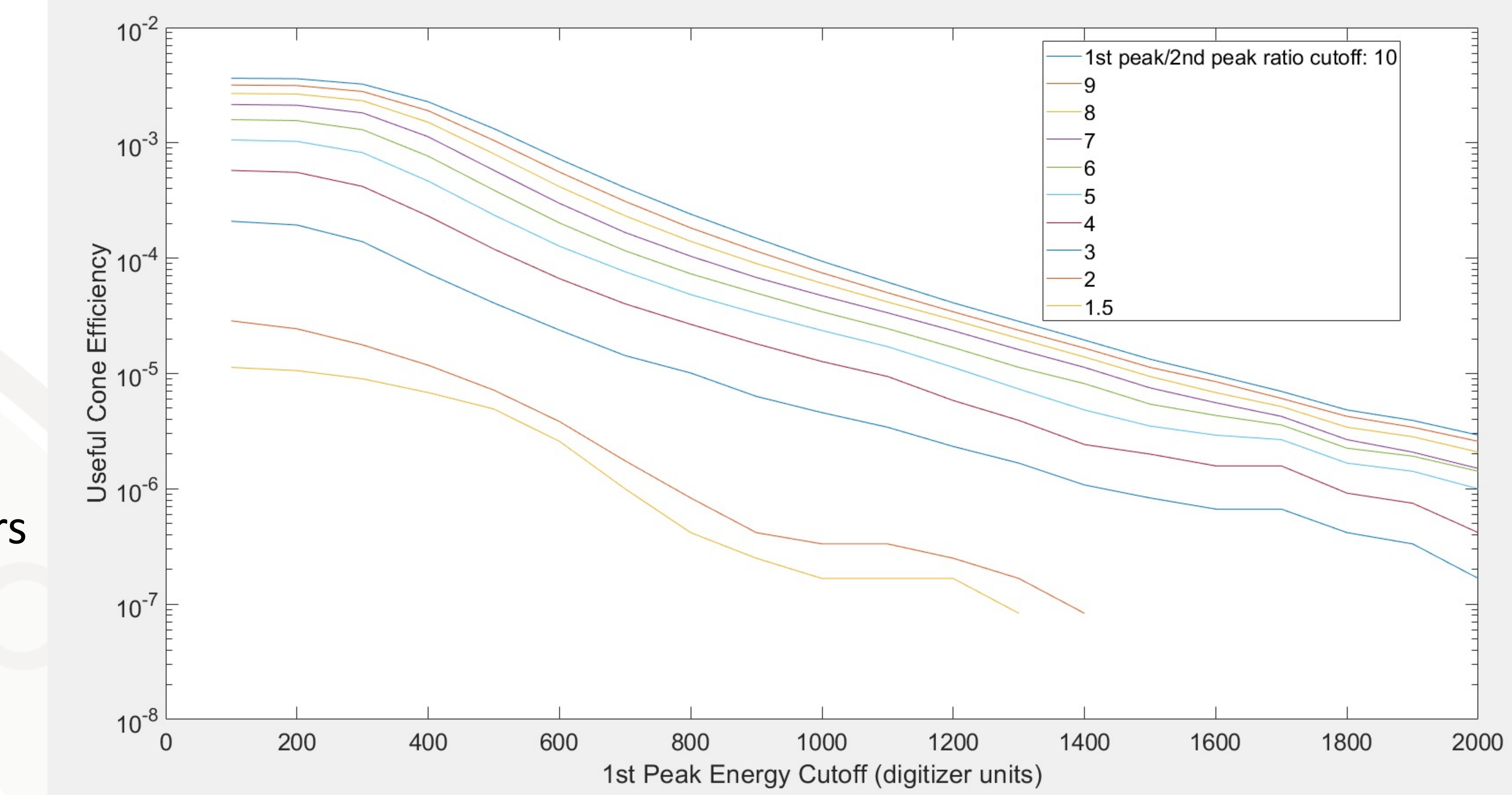

Figure 5. Back-projected cone efficiency for various 1st scatter to 2nd scatter ratios. In general, as this cutoff ration is lowered, the less likely second peaks are to be noise.

Conclusion

- Prototype neutron scatter camera capable of localizing neutron point sources using a single plastic scintillator volume and standard PMTs
- Best achievable angular resolutions: $\sigma_{azimuthal}$=27.1 σ_{polar}=16.5
- Timing resolution of PMT/EJ230 system: 0.8 ns
- Best results with "two step" imaging procedure: first step makes guess of source direction by using all pulses, second step generates images from cones going in the same general direction as initial guess

Next Steps

- Further quantify camera angular resolution for distributed and multiple sources
- Quantify measurement times necessary to produce useful images at different source strengths and standoff distances
- Explore alternative photomultipliers

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