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MINER – A Mobile Imager of Neutrons for Emergency Responders

Mark D. Gerling, John E. M. Goldsmith, and Jim S. Brennan

***Abstract*–Our research group has been developing a fast neutron imaging platform to enhance the capabilities of emergency responders in the localization and characterization of special nuclear material. This mobile imager of neutrons for emergency responders (MINER) is a compact neutron scatter camera optimized to provide omni-directional (4-Pi) imaging with only a ~twofold decrease in sensitivity compared to our much larger neutron scatter cameras. The system performance is tuned for fission energy neutron imaging and spectroscopy, and it also can function as a Compton camera for gamma imaging. Results will be presented relating to detector response as well as several measurement campaigns at external facilities.**

I. Introduction

THE neutron scatter camera concept has been under development at Sandia for almost a decade. The technique relies on detecting neutron-proton recoils from a neutron source in two separate cells and measuring the time between those interactions. This results in an energy and time-of-flight measurement which we are then able to use to locate the direction and energy spectrum of the neutron source. While lower efficiency than other single-scatter detection methods, several advantages are gained by the double-scatter configuration of MINER which we will present here, as well as results from several measurements at external sites.

II. Portability

Mobility was a primary design consideration for this project, initially even aiming for a backpack form factor. This requirement was later relaxed, resulting in the current configuration and an overall higher sensitivity. MINER currently weights near 40 kg, while sacrificing only ~2x the sensitivity of the much larger Neutron Scatter Camera, and combines that with lower power electronics as well. For comparison, the previous generation neutron scatter camera weighed in at ~160 kg for the camera and frame, with an additional ~270 kg for the electronics rack, for a total weight of ~330 kg. A relative comparison is shown in Figure 1.

For convenience of transport, MINER has a Pelican case which it can be packed in/out of in under 10 minutes and contains all equipment necessary to operate (Figure 2). Battery operation can also be accomplished for several hours using a car battery and the power distribution box.

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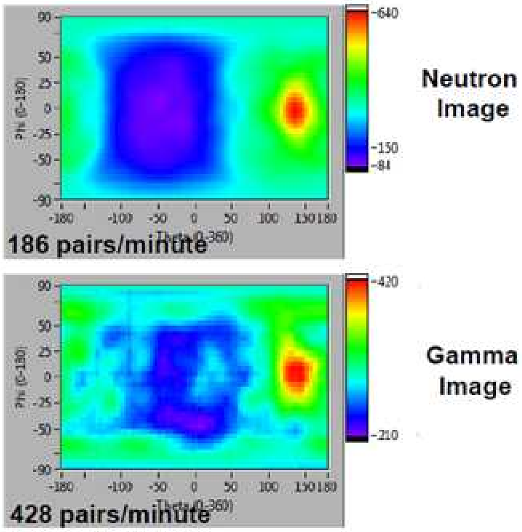
All authors are with Sandia National Laboratories, Livermore, CA 94550 USA. (e-mail: mgerlin@sandia.gov and jgold@sandia.gov).

Figure 1: MINER (left) next to the larger neutron scatter camera and associated electronics rack. The digitizer and power distribution boxes can be seen on the side of MINER. Relative sizes approximate.

Figure 2: MINER packed in Pelican case for travel.

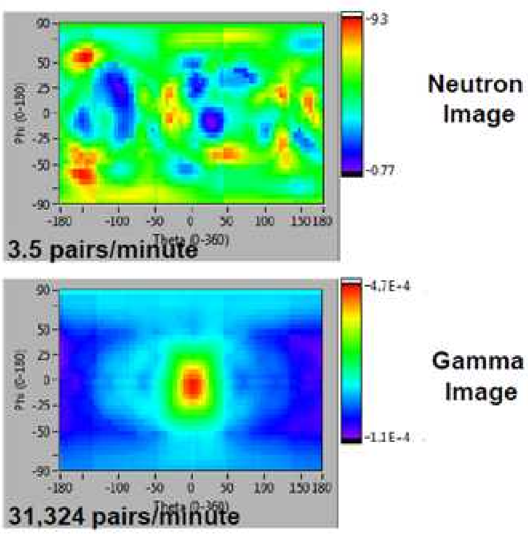
III. Neutron-Gamma Discrimination

The double-scatter and time-of-flight requirement for imaging provides an extra opportunity to discriminate based on pulse-shape, which gives MINER a high degree of gamma rejection in neutron imaging. These rejected events can also often be used to generate gamma images through approximating the total gamma energy (since it is not captured in liquid scintillator). Below in Figure 3 through Figure 5 we present an example of this for imaging a neutron source and a strong gamma source both separately and together with some spatial separation. The background rate was ~1.5 neutron pairs/minute in this location.



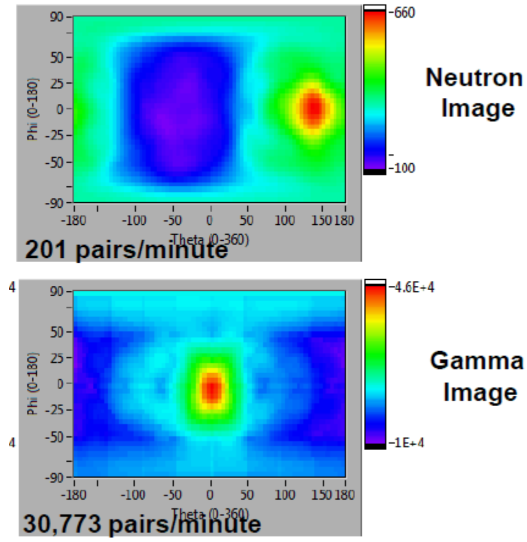
Cf

Figure 3: Cf-252 source only, 135 degrees, with correlated gammas also imaged.



Eu

Figure 4: Eu gamma source only, 0 degrees. No neutron image.



Cf + Eu

Figure 5: Both Cf-252 and Eu sources, imaged in their respective locations. In this case the Eu gammas overwhelm and obscure the gammas from Cf-252.

IV. Imaging and Monitoring

While imaging can be useful for search scenarios, it can also be used to monitor known SNM for movement. In the following experiment a weak Pu neutron source was imaged through 12" of concrete. Due to the very small quantity and low rates, these images were produced in 450 minutes, while no shielding images of the same source at 5 meters took 120 minutes. These results are included in Figure 6 through Figure 9.

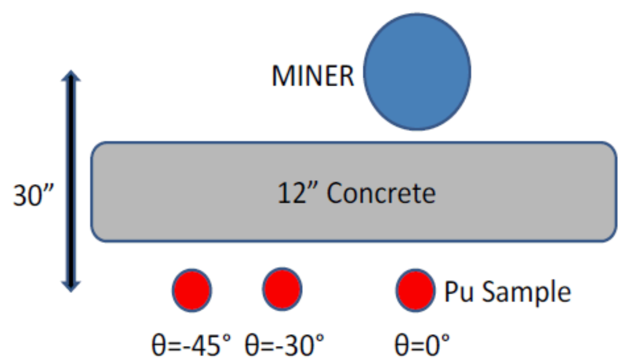


Figure 6: Diagram of test setup.

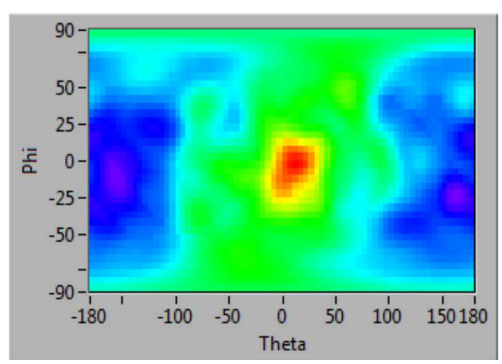


Figure 7: Pu imaged at 0 degrees in 450 minutes.

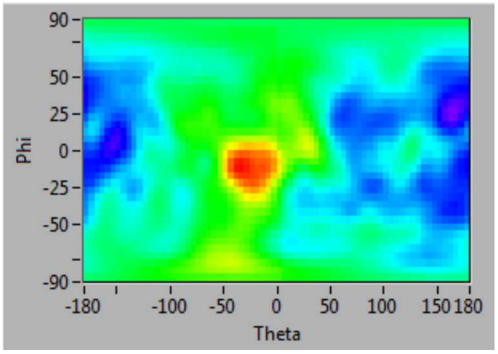


Figure 8: Pu imaged at -30 degrees in 450 minutes

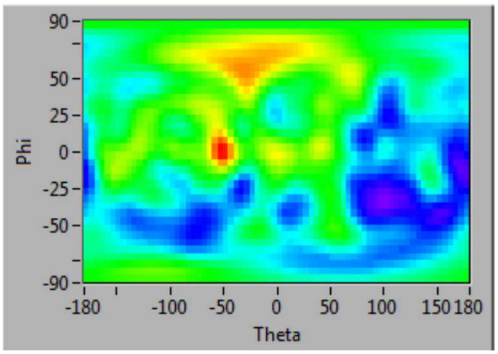


Figure 9: Pu imaged at -45 degrees in 450 minutes

V. SPECTROSCOPY

Energy measurements made at the Idaho National Laboratory Zero Power Physics Reactor facility demonstrate the capabilities of the system to make neutron spectrum measurements. Plutonium oxides and metals were measured, as well as Cf-252. These are compared to Cf-252 and AmBe measured at Sandia National Laboratories in California (Figure 10). Additionally, we explored the effects of shielding (both HDPE and lead) on the Cf-252 spectrum in Figure 11. One important note is that these spectra include the system response, and do not represent the true source spectrum.

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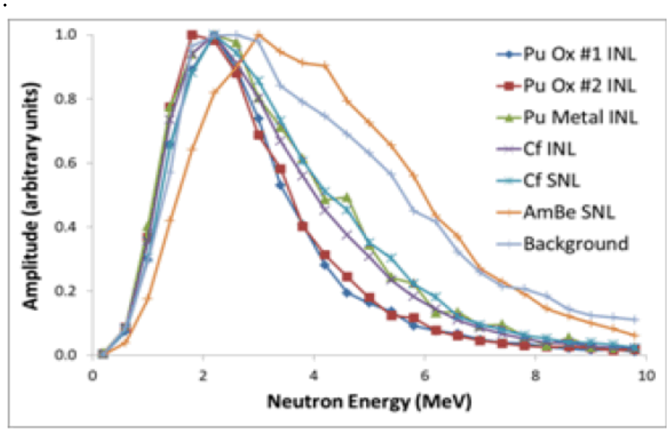

Figure 10: Spectrum comparison between different forms of plutonium compared to Cf-252 and AmBe.

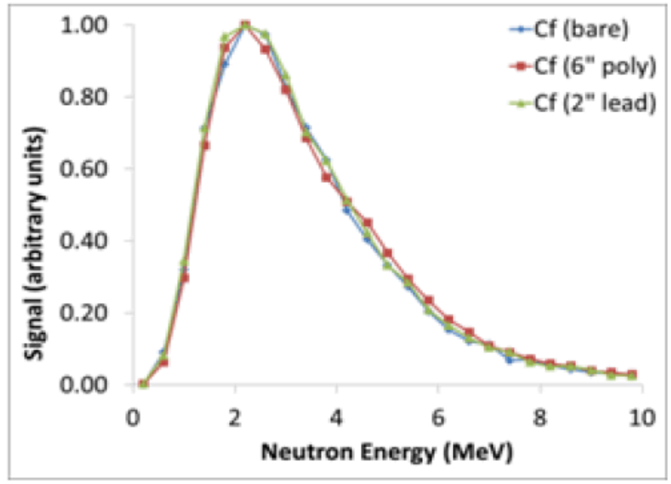

Figure 11: Cf-252 neutron energy spectrum with and without HDPE/lead shielding.

VI. HIGH-RISE SEARCH AND IDENTIFICATION

MINER also demonstrated imaging sources at a distance in a high-rise experiment. Here, the system was able to image Cf-252 at a distance of 28 meters between buildings both unshielded and with a moderate 4" of HDPE. This measurement also provided a unique opportunity to measure an example of an asymmetrical neutron background due to building shielding. Further, spectroscopy was utilized at these distances to discriminate between Cf-252 and AmBe. These results are presented in Figure 12 through Figure 15.

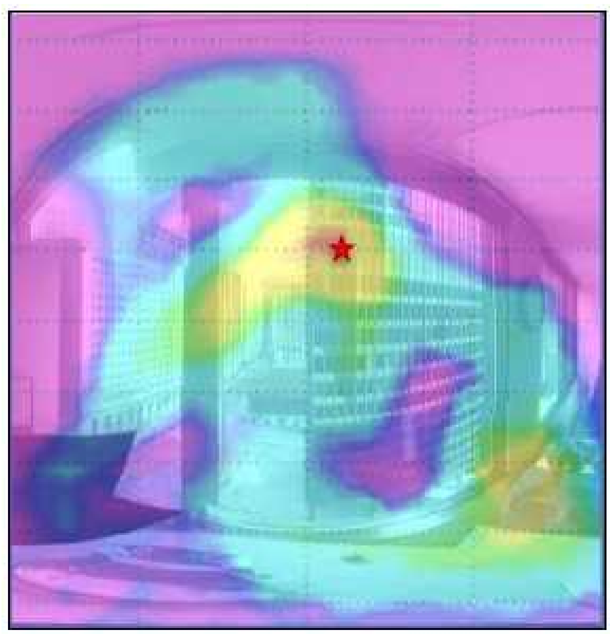

Figure 12: Cf-252 unshielded at 28 meters, 30 minutes.

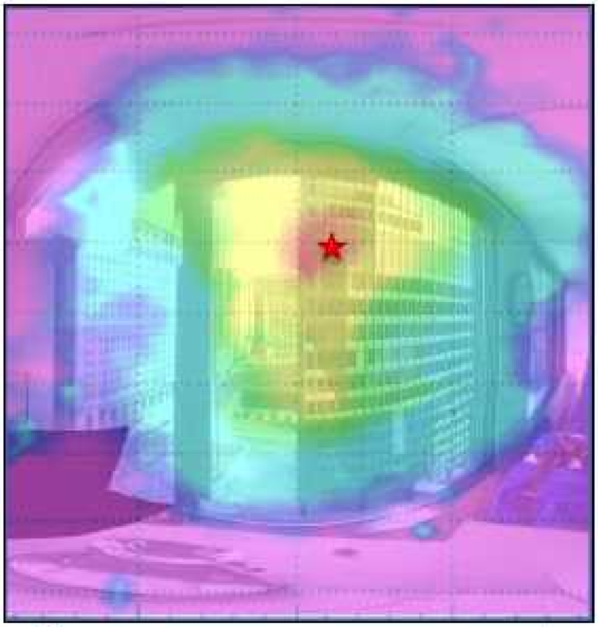

Figure 13: Cf-252 behind 4" HDPE, 28 meters in 618 minutes.

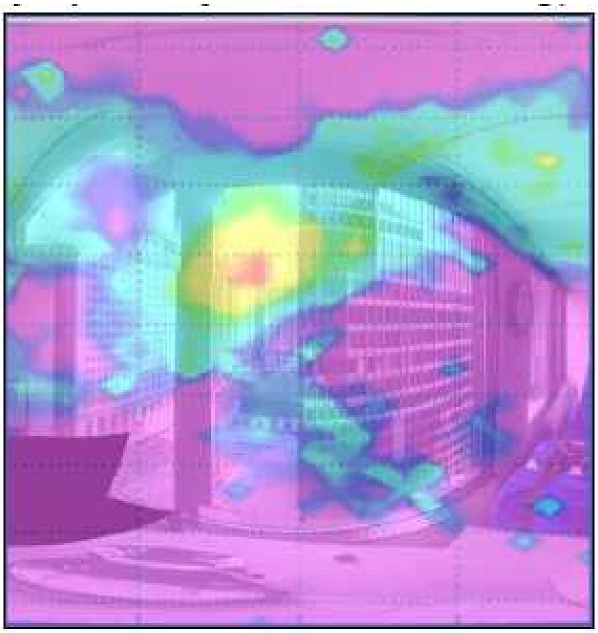

Figure 14: 10 hour background measurement of the open sky.

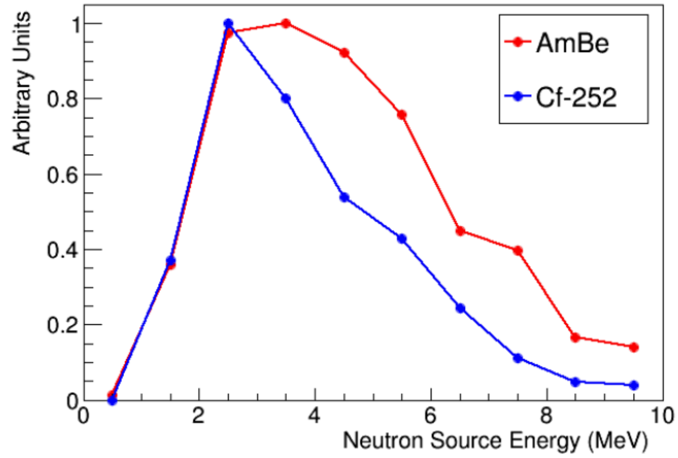

Figure 15: Cf-252 and AmBe spectrum, measured from 28 meters in several hours.

VII. Conclusions

MINER is a capable system which has had the opportunity to participate in several demonstrations to show many of its capabilities and versatility. The portability of the system allows it to be rapidly deployed in a large variety of environments, and it provides a unique combination of source localization and diagnostics.

Further investigations with the system are warranted for multiplication measurements, as well as more quantitative analysis of detection significance.

Acknowledgment

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