SAND2013-8113P

Annual Report

MINER – A Mobile Imager of Neutrons for Emergency Responders (Formerly BING: A Backpack Imaging Neutron and Gamma Spectrometer for Emergency Responders)

SL11-Backpack-NImager-PD03

Lab: Sandia National Laboratories

Project PI: John Goldsmith

Primary Author: John Goldsmith

Contributors: Mark Gerling, Jim Brennan, Scott Kiff, John Steele, Nick Mascarenhas

Date: September 30, 2013

MINER – A Mobile Imager of Neutrons for Emergency Responders (Formerly BING: A Backpack Imaging Neutron and Gamma Spectrometer for Emergency Responders)

SL11-Backpack-NImager-PD03

We are developing a mobile 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 based on the Neutron Scatter Camera, a large segmented imaging system that was optimized for large-area search applications. Due to the reduced size and power requirements of a man-portable system, MINER has been engineered to fit a much smaller form factor. It provides omnidirectional (4π) imaging, with only a ~twofold decrease in sensitivity compared to the much larger neutron scatter cameras. The system was designed to optimize its performance for neutron imaging and spectroscopy, but it does also function as a Compton camera for gamma imaging.

The detector head is housed in a 36” high, 15” diameter cylinder, and the detector electronics consist of a single sixteen-channel digitizer and a laptop computer (Fig. 1). The entire system (including detection electronics and the laptop computer) is transported in a 43”x27”x20” Pelican case (Fig. 1). It can be set up in about fifteen minutes, and has characterized SNM objects during field campaigns at the Nevada National Security Site Baker facility and the INL (Idaho National Laboratory) Zero Power Physics Reactor facility.

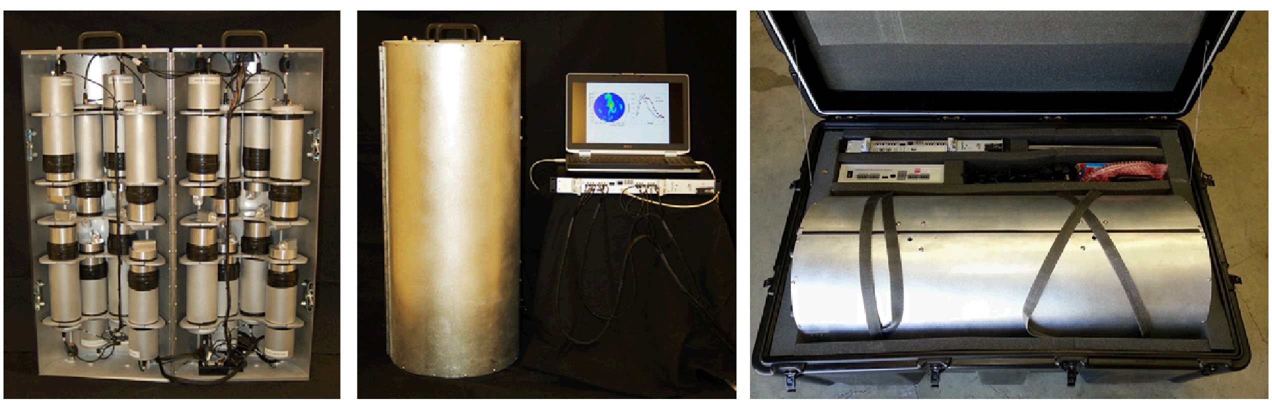

Figure 1. Left: detector head opened up. Center: operational configuration of system. Right: system packed up in its shipping case.

During the INL field campaign, we had the opportunity to conduct measurements on three plutonium-containing objects (a metal sphere and two cans that contain plutonium oxide) in a variety of configurations, and with and without various combinations of poly moderator and stainless steel shielding around the objects. Fig. 2 presents representative neutron and gamma images of the shielded plutonium sphere. Roughly half an hour was needed to generate a good gamma image, but the neutron signature of the object was sufficiently strong that its direction relative to the detector could be determined within the first minute.

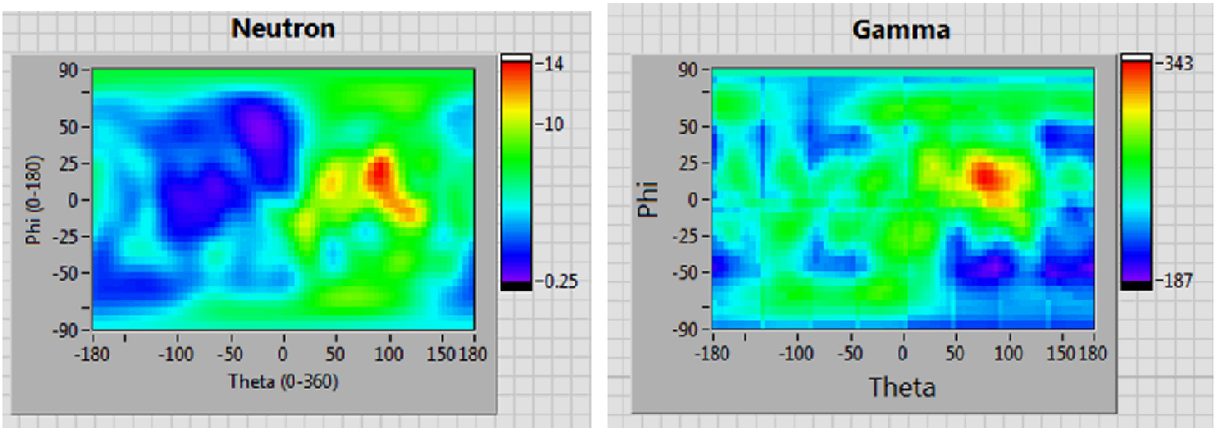

Figure 2. One-minute measurement (neutron) and thirty-minute measurement (gamma) of the plutonium sphere surrounded by 3.5" of poly and 2" of stainless steel, located 2 m from the detector at a relative angle (theta) of 90°

MINER also measures neutron energy spectra without requiring any unfolding or deconvolution procedures. For each neutron double-scatter event, the energy of the incident neutron is calculated as the sum of the energy deposited in the first liquid scintillator cell and the kinetic energy of the scattered neutron, the latter determined by its velocity as measured by the time of flight between the two cells. The instrument does introduce some distortions in the spectra, but these effects do not vary from measurement to measurement. We therefore have good confidence in our ability to detect changes in spectra from sources measured under the same conditions. Fig. 3 displays spectra recorded at INL for the three plutonium sources, plus the Cf source, a Cf source at Sandia, and an AmBe source at Sandia.

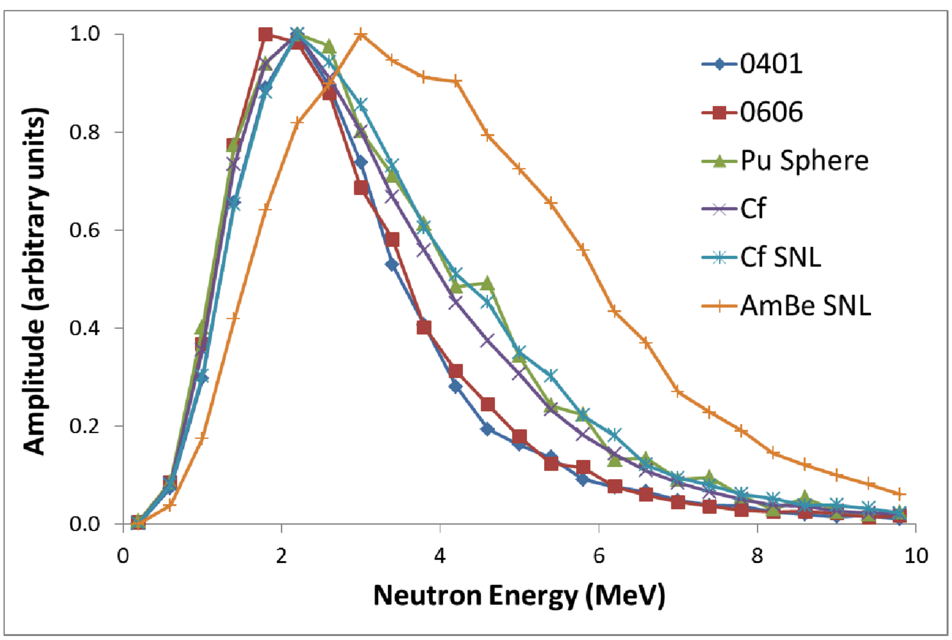

Figure 3. Peak-normalized neutron energy spectra for the indicated sources (0401 and 0606 are the two plutonium oxide samples); "SNL" refers to measurements performed at Sandia. The spectra have not been corrected for energy variations in the instrument response.

As expected, the AmBe spectrum has significantly more high-neutron-energy content than the fission sources. Also as expected, the spectrum measured from the bare Pu sphere is very similar to the Cf spectrum (a second Cf spectrum measured at Sandia is displayed to indicate the spectral reproducibility; other Cf spectra measured at INL and Sandia show similar agreement). The spectra from the two plutonium oxide objects are very similar to each other, but, somewhat unexpectedly, are significantly different than the Pu sphere or Cf spectra. Measurements made at Sandia of a bare Cf source and the same source surrounded by 4' of poly show much less variation in spectral shape. We are therefore left with the intriguing possibility that neutron spectra can not only distinguish between fission and AmBe sources, but also possibly between metallic and plutonium oxide. The cause of this difference (if it is real) and its use for this application requires additional study.

The precise timing and pulse-shape-discrimination capabilities of the MINER system may lend themselves to additional diagnostic capabilities. As an example, placing a small ^{252}Cf source at the center and measuring the time delay between a gamma and a correlated neutron, we can plot the deposited neutron energy as a function of the gamma-neutron detection time difference (plot on the left in Fig. 4). Any events "above and to the right" of the observed signals will be an indication of source multiplication from induced fission, thus indicating the presence of SNM. This is the basis of the time-correlated pulse-height method, which is simulated in the plot on the right in Fig. 4.

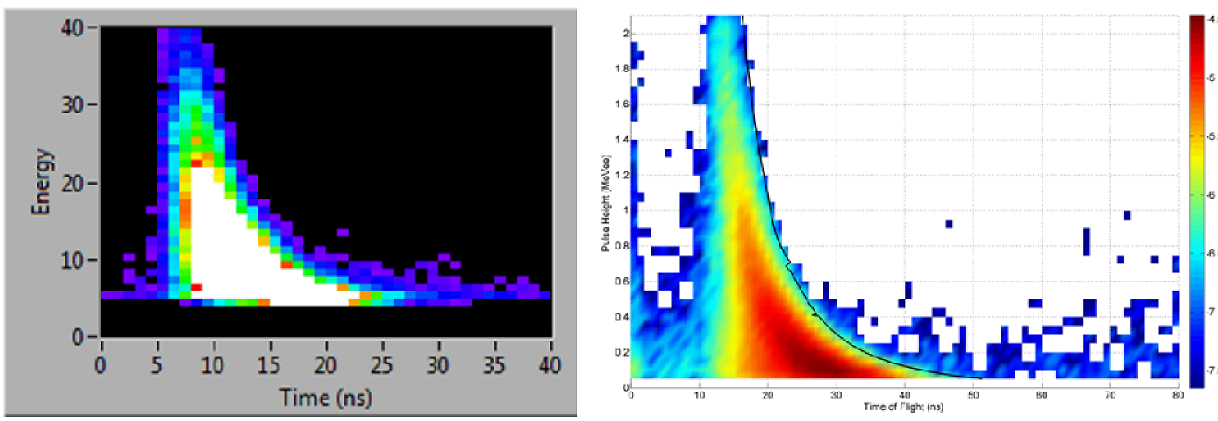

Figure 4. Measurement (left) and simulation (right) of the time-correlated pulse-height method for measuring source multiplication

The combination of omnidirectional imaging of neutrons and gammas, neutron spectroscopy, and fission source multiplication characterization make MINER a powerful tool for emergency responders. We continue to explore and refine the capabilities of the system for this and other applications.

Sandia National Laboratories is a multi-program laboratory managed and operated by Sandia Corporation, a wholly owned subsidiary of Lockheed Martin Corporation, for the U.S. Department of Energy's National Nuclear Security Administration under contract DE-AC04-94AL85000.