Recent Investigations Using the Neutron Scatter Camera

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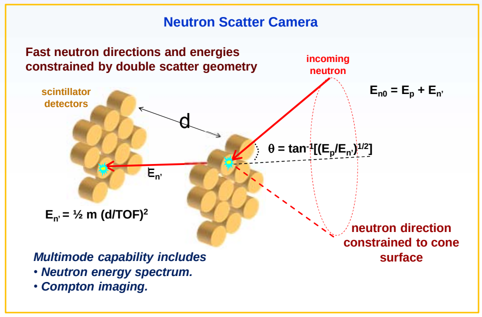
Introduction

The Neutron Scatter Camera

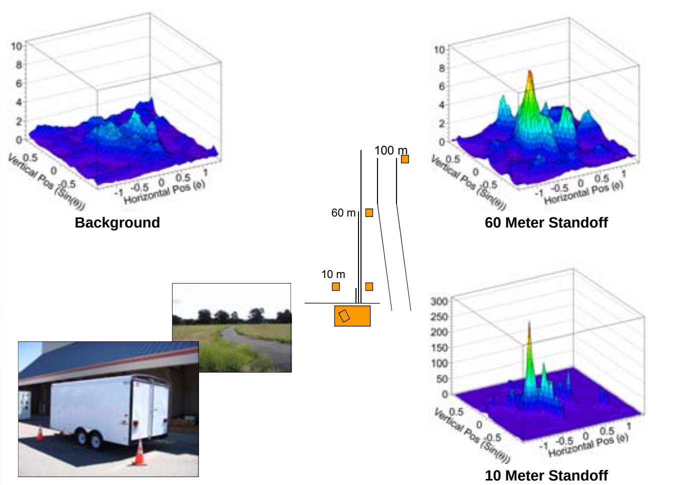
The Neutron Scatter Camera (NSC) is a mature fast neutron imaging and spectroscopy system based around liquid scintillator and double scatter events. This platform provides several advantages over other technologies including high background rejection, imaging, neutron/gamma discrimination, as well as neutron spectrometry. Recent results with the NSC will be discussed from several applications: long distance source detection, multiple extended source resolution through shielding, and spectroscopic measurements.

The NSC enables imaging of neutrons in much the same way as Compton cameras image gamma-rays. Instead of Compton scattering, we use conservation of energy and momentum from elastic scatters to recreate neutron events. We are able to determine the energy and direction of neutrons from proton-neutron collisions in scintillator, as well as the Time-of-Flight (TOF) between these events in two different cells. Discrimination between gamma and neutron events is done using pulse shape discrimination (PSD). If the flux is sufficiently above background, we can determine not only the angular location but also the energy spectrum of a source. When sufficient scattering events are recorded an image can be built up, thus making the detection system a neutron camera.



Standoff

Detection of SNM at large distances is of particular interest and difficulty for radiation detectors, due to low rates and correspondingly higher backgrounds. The NSC was recently fielded to explore ranged detection of a Cf-252 source (strength roughly corresponding to a IAEA significant source) between 20 and 100 meters away. The source was successfully identified at up to 60 meters away.



Background

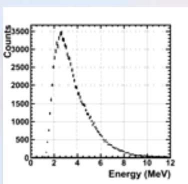
60 Meter Standoff

10 Meter Standoff

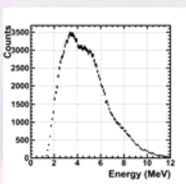
Spectroscopy

In addition to being a useful tool in determining source angular position, the Neutron Scatter Camera (NSC) simultaneously measures source neutron energy spectra. This faculty could play an important role in distinguishing various neutron sources, e.g. fission, (α,n) and (γ,n) reactions, cosmic ray, and D-D or D-T fusion concurrently with forming an image. We undertook this work with the specific goal of determining how the spectra measured by the NSC would compare to previously determined spectra. The ^{241}Am-Be radioactive source is widely used in many applications ranging from detector calibration to oil well logging. ^{241}Am-Be is therefore one of the most likely benign neutron sources encountered in cargo, and discerning it from fission spectrum neutron sources is of importance.

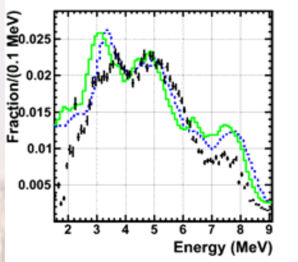
Neutron energy spectrum measurements are inherently limited by the NSC's energy resolution, which is dominated by the energy resolution of the liquid organic scintillator. However, they do show reasonable agreement with the expected spectra after an unfolding analysis to correct for resolution effects. These results show that the NSC can discern between source spectra, and that our MCNP-PoliMi model agrees with data reasonably well to help predict NSC energy response.



Raw ^{252}Cf neutron energy spectrum as measured by the NSC.



Raw ^{241}AmBe neutron energy spectrum as measured by the NSC.

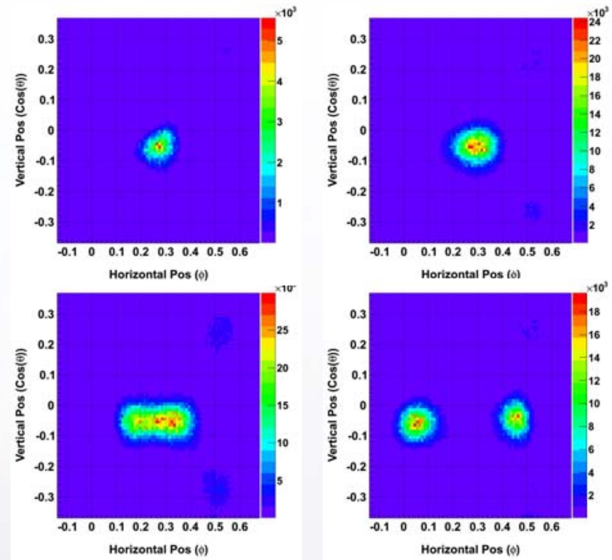


Comparison of unfolded ^{241}AmBe spectra (points) with the ISO 8529-1 standard (green solid line) and the measurement from Geiger (blue dashed line).

Extended Source Study

In the context of arms control treaty verification and related applications, spatially extended radiation sources are commonly encountered. It may be desirable to distinguish extended sources from point sources by their radiation signatures, which requires high-resolution imaging capabilities. Imaging detectors can be challenged by extended sources due to the decreased signal-to-noise ratio per pixel relative to a point source with the same overall activity. The NSC has been extensively tested in various configurations using point sources, but its response to extended sources was not well understood. In this study we emulated extended sources using time-integrated exposures to moving Cf-252 sources.

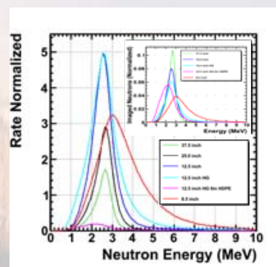
Although not developed and optimized for high-resolution imaging, the NSC was capable of reconstructing extended sources, and of distinguishing multiple extended sources at reasonable separation, as demonstrated in the figure below. It did not perform as well in distinguishing point from extended sources, and the limitations in the efficiency of double-scatter imaging as currently implemented are evident in the large integration times needed to produce these images.



MLEM reconstructed images of a single extended source (19.5 h, top left), two extended sources with small separation (22.4 h, top right), two extended sources with medium separation (47.4 h, bottom left), and two extended sources with large separation, (28.8 h, bottom right).

Energy Resolution with DD

In order to measure and understand the energy resolution of the NSC, we used a DD neutron generator to get a monoenergetic neutron flux in the fission energy range (~2.5 MeV). The energy resolution as well as the detection efficiency depend strongly on the plane separation. The figure shows the measured energy distribution for various plane separations, both normalized to equal time (main plot) for comparison of efficiency and normalized to equal areas(inset) for more easy direct comparison of the energy resolution. The (non-Gaussian) fractional energy resolution is on the order of 15-20% for medium plane spacing.



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