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MCNP-PoliMi Simulation of a Small Form Factor Neutron Scatter Camera Backpack

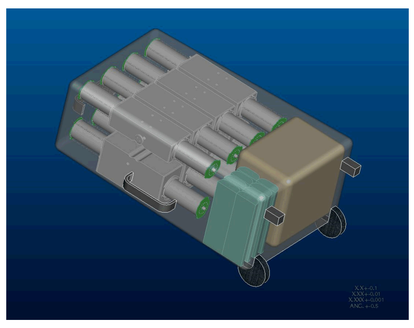
Mark Gerling[1], Scott Kiff[1] and Nicholas Mascarenhas[2]

1: Sandia National Laboratories, 7011 East Ave, Livermore, CA 94550
2: IAEA, Vienna International Centre, PO Box 100, A1400 Vienna, Austria

Introduction

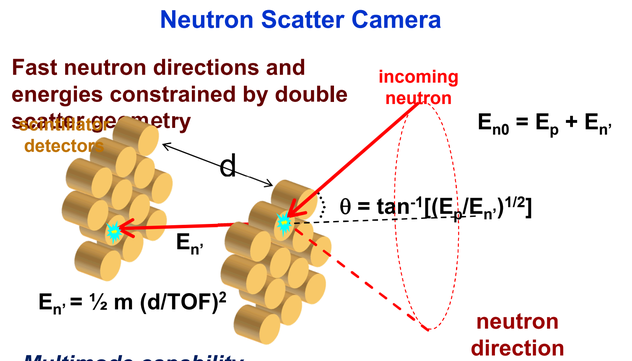
Sandia is investigating a backpack-mounted fast neutron imaging system to improve sensitivity to SNM and provide localization capabilities in search applications. The proposed system is based upon the Neutron Scatter Camera, a large, segmented dual-mode imaging system (neutrons and gamma rays) optimized for large-area search applications.

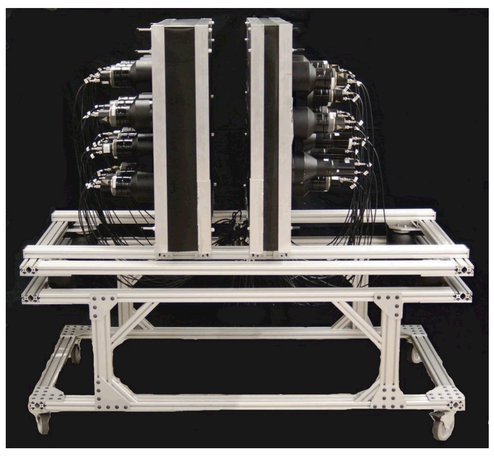
Shrinking the Neutron Scatter Camera to a small form factor is not trivial, as changes in detection segment size and spacing can have large effects on imaging performance. We modeled the camera in several small form factors, comparing performance in imaging resolution and reconstructed event rate. We also performed several photomultiplier and cell geometry tests in an effort to parameterize the performance of smaller form factors. We show that the camera can be optimized for small backpack sized operations while maintaining acceptable performance, through MCNP-PoliMi simulations.



Imaging Concept

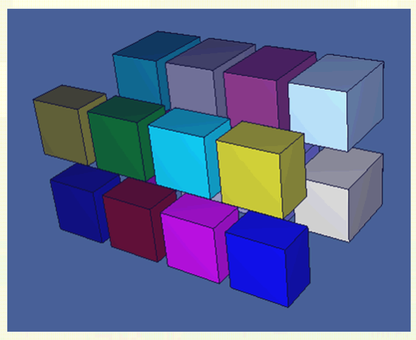
The Neutron Scatter Camera uses the physics of double elastic-scatter events to calculate an image from neutron source distributions. This study takes the previously developed Neutron Scatter Camera, which has historically relied on a large volume of EJ-309 scintillator for increased sensitivity and large spacing between segments for good imaging resolution, and attempts to reduce it to single man portable mass of less than 50 pounds.

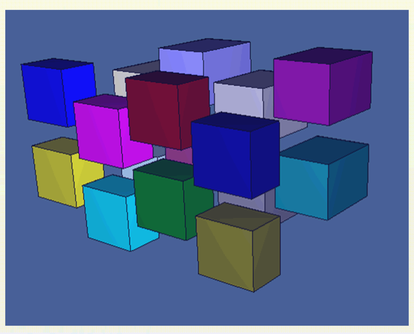




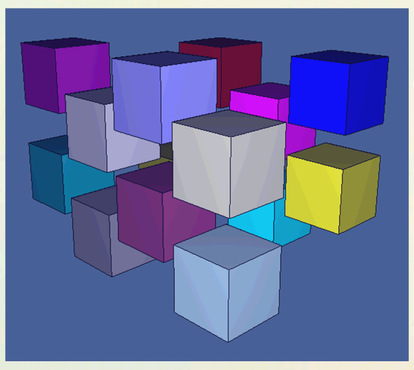
Detector Design and Geometry

- Initial design: Two planes of 8 detector elements, for a total of 16 detectors. Front plane cells measured 3x3x2 inches while rear plane cells measured 3x3x4 inches. Detectors were packed in rectangular planes 5 to 8 inches apart. An example is shown to the right:

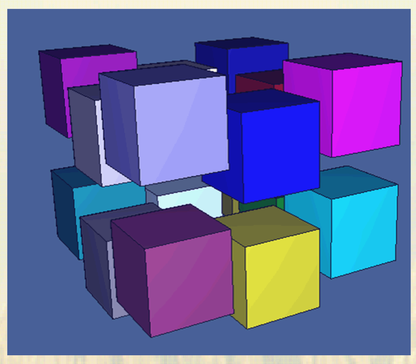




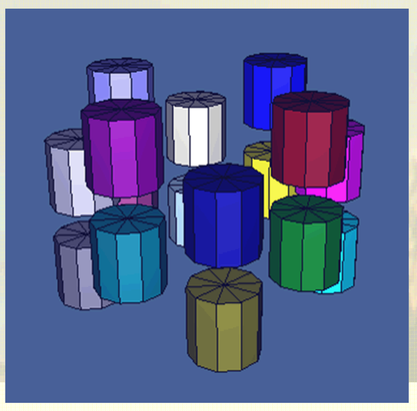
- The design was subsequently improved with the addition of variations between pairs of detectors in the Z (vertical). This improves source imaging in the vertical.



- Modeling was done to verify making cell depth a uniform 3 inches for both planes. Given an unknown source location, imaging and rates do not suffer greatly and a more uniform sensitivity can be gained by not biasing cell thickness. This geometry change is ideal if the source location and direction is not known in a search application.



- Further refinement for search application involves removing plane dependence and making a more circular geometry.

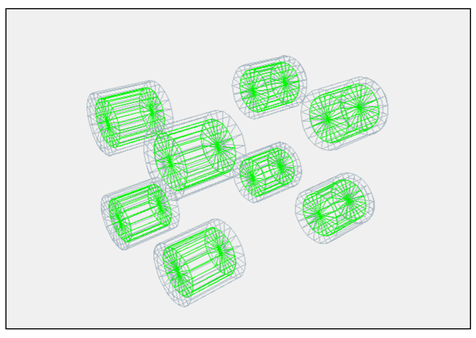


- Current testing has revealed that cylindrical cells perform better than the cubic cells modeled, and the simulation models have been modified to reflect this fact. The diagram on the left shows the latest model simulated with MCNP-PoliMi.

MCNP-PoliMi

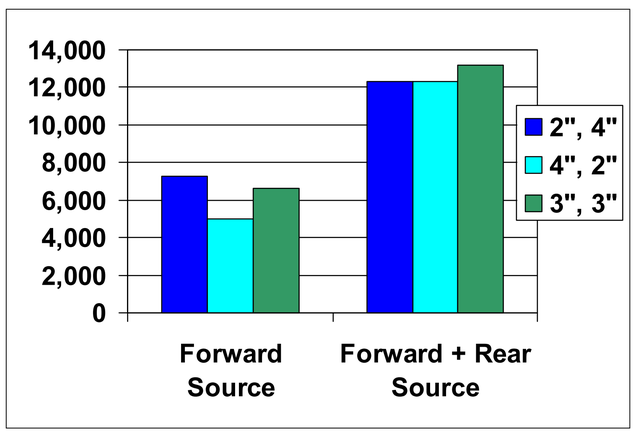
MCNP-PoliMi models of the previous 32 cell Neutron Scatter Camera were utilized as a baseline for comparison to more compact cameras. The simulations concentrated on shorter distances between planes and reduced cell sizes in an effort to reduce the total size and volume of the Neutron Scatter Camera. Importance was placed on maintaining imaging capabilities through optimizations of double scatter probability for these new geometries.

Initial benchmarking utilized an 8-cell design which was both assembled and tested and simulated in MCNP-PoliMi. The test system was composed of 2” by 2” cylindrical cells. The results of this study led to our decision to move to larger cell sizes.

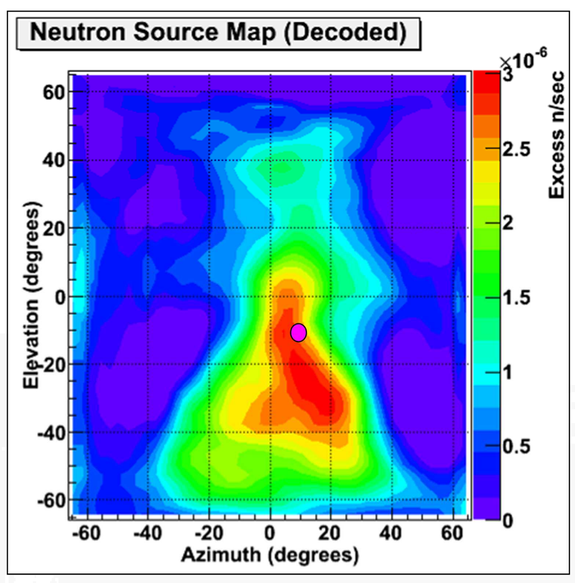


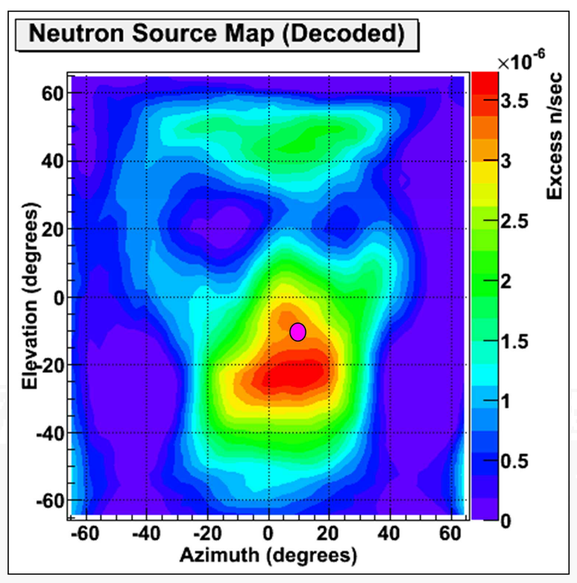
After initial characterization of the test cells, more advanced geometries were simulated from the “detector design and geometry” section. Primary characterization metrics included doubles rates and image quality. The effect of two equal thickness planes vs. a thinner front plane was also explored.

With a known forward source, the optimized 2” + 4” setup outperforms a uniform 3” + 3” configuration. However, without a known source location, there is an overall gain in efficiency moving to a uniform 3” thickness on both front and rear cells. There is also not a large degradation of image quality.



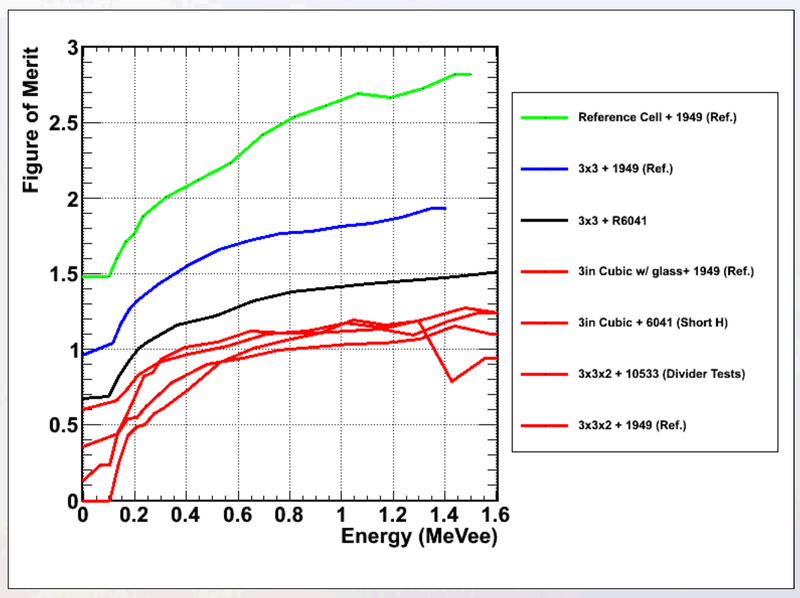
Simulations of these geometries were analyzed for image quality. A few images of the cubic geometry with a variety of source positions are included below.





System Testing and Initial Results

Testing has been conducted with both a small 8 cell test system as well as a variety of photomultiplier options and individual cell geometries. Discrepancies between cubic and cylindrical cells have led us to believe that cubic cells have considerably poorer pulse height discrimination (PSD), an important characteristic for distinguishing between gammas and neutrons. We have also shown that 2” x 2” cylindrical cells have superior PSD to alternate geometries, but not enough scintillator to make a practical cell volume for the proposed system. We are currently looking into alternate cell geometries including a 3” x 3” cylindrical cell design.



Conclusions and Future Work

Further investigations into cell design and final detector geometry are being conducted in MCNP-PoliMi as well as physical cell testing. Focus for the project has been shifted to a “man portable” system, which does not necessarily need to conform to a backpack size, thus relaxing some system requirements.

ACKNOWLEDGEMENTS

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