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# Source Location Reconstruction Using a Compact Neutron Scatter Camera Constructed from Pillars of Plastic Scintillator


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## Motivation and Introduction

- Neutron scatter cameras use the kinematics of elastic neutron-proton scattering to estimate the incoming direction of neutrons
- The single volume scatter camera (SVSC) design can substantially increase detection efficiency relative to the usual, multi-volume scatter camera (MVSC) design
- Neutrons must scatter twice in the scintillator volume to reconstruct the incident neutron direction

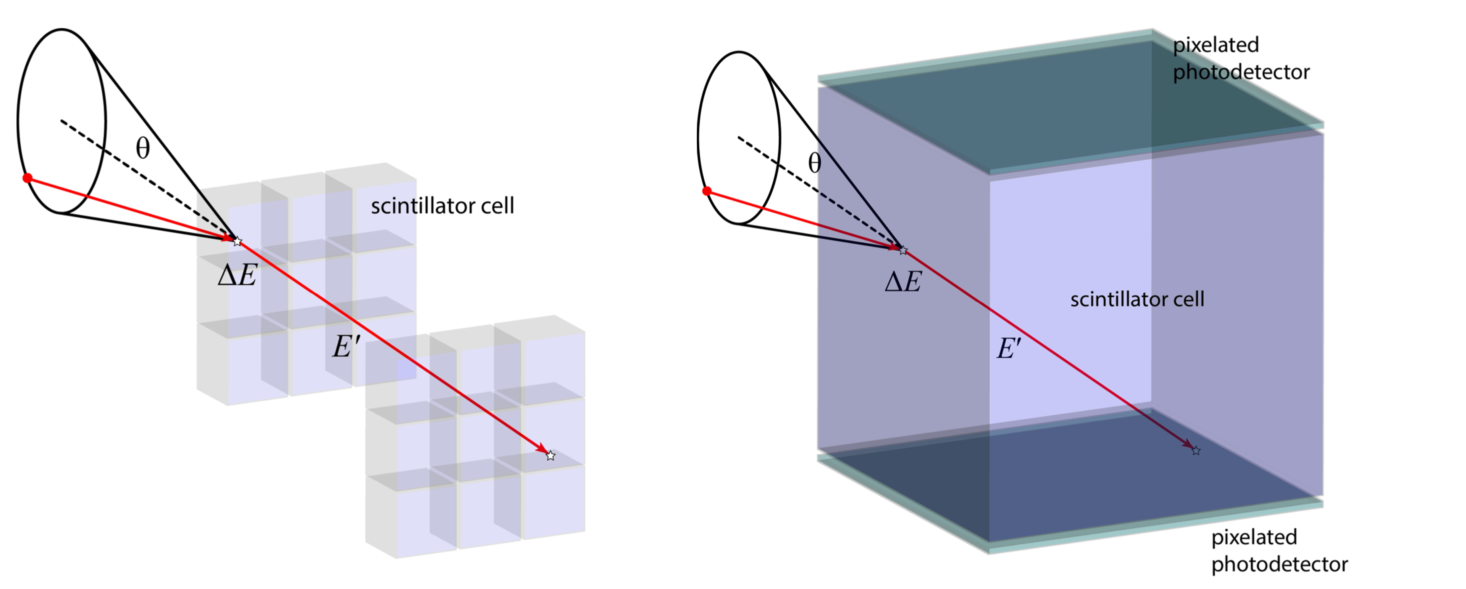


Figure 1. MVSC design with two planes of optically isolated scintillator cells vs. SVSC with one optically contiguous scintillator cell and pixelated photodetectors on two opposing faces

- An optically segmented single volume neutron scatter camera can be constructed from pillars of plastic scintillator (SVSC-PiPS)
  - This design reduces the number of pixels that need to be digitized to the 4 optical channels that emit scintillation light
  - It is also easily transportable (the sensitive volume is likely to be approximately 20 cm × 20 cm × 20 cm)

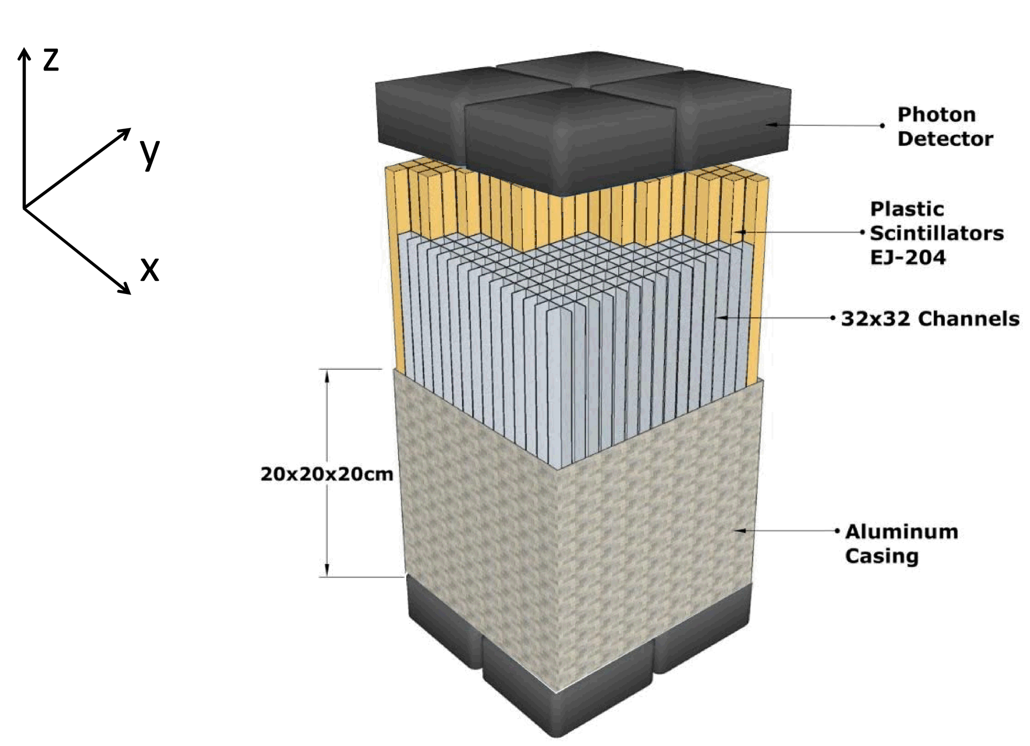


Figure 2. SVSC-PiPS design

## Channel Response Functions

- Using Geant4 for scintillation light transport, we obtained the channel response functions shown below

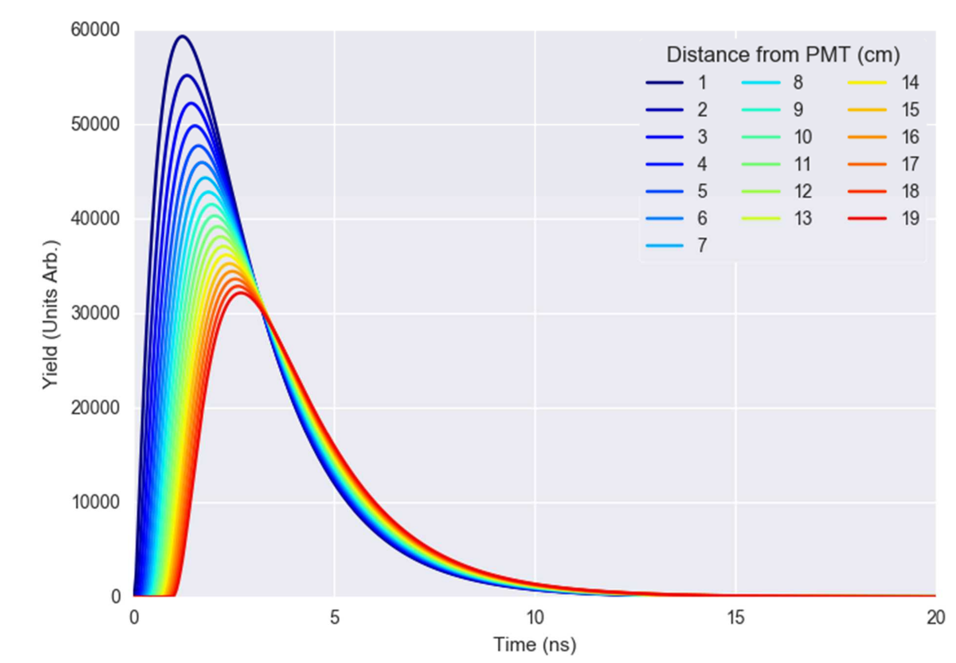


Figure 3. Channel response functions tabulated at 1 cm increments for a 1 cm x 1 cm x 20 cm EJ-204 pillar.

- We used maximum likelihood estimation (MLE) to estimate scintillation position within the pillar using the Geant4 models of channel photoelectron arrival vs. time and scintillation position

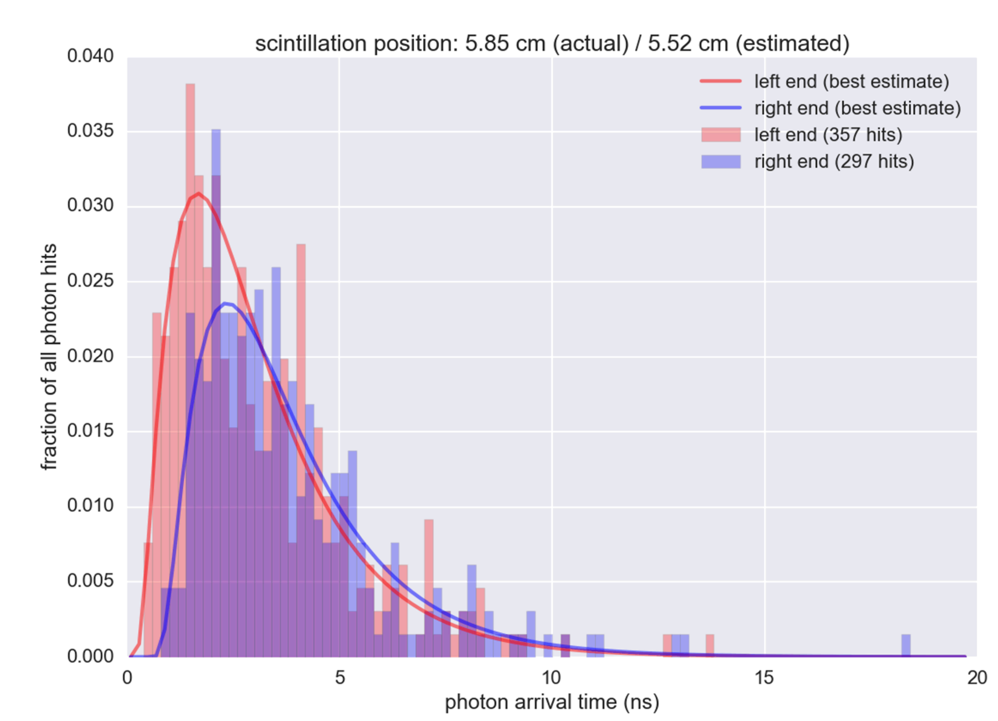


Figure 4. Simulated 2 MeV neutron-proton scattering event 5.85 cm along the pillar. Left photodetector response (at 0 cm) shown in red and right photodetector response (at 20 cm) shown in blue.

- Using estimated scintillation positions along the length of the pillar (z), and the center of the bar illuminated for the (x, y) position, we used MLE to reconstruct a cone of possible neutron source locations using (1)

$$\Psi = \tan^{-1}\sqrt{\frac{E_p}{E_n'}} \qquad (1)$$

## Reconstruction Results

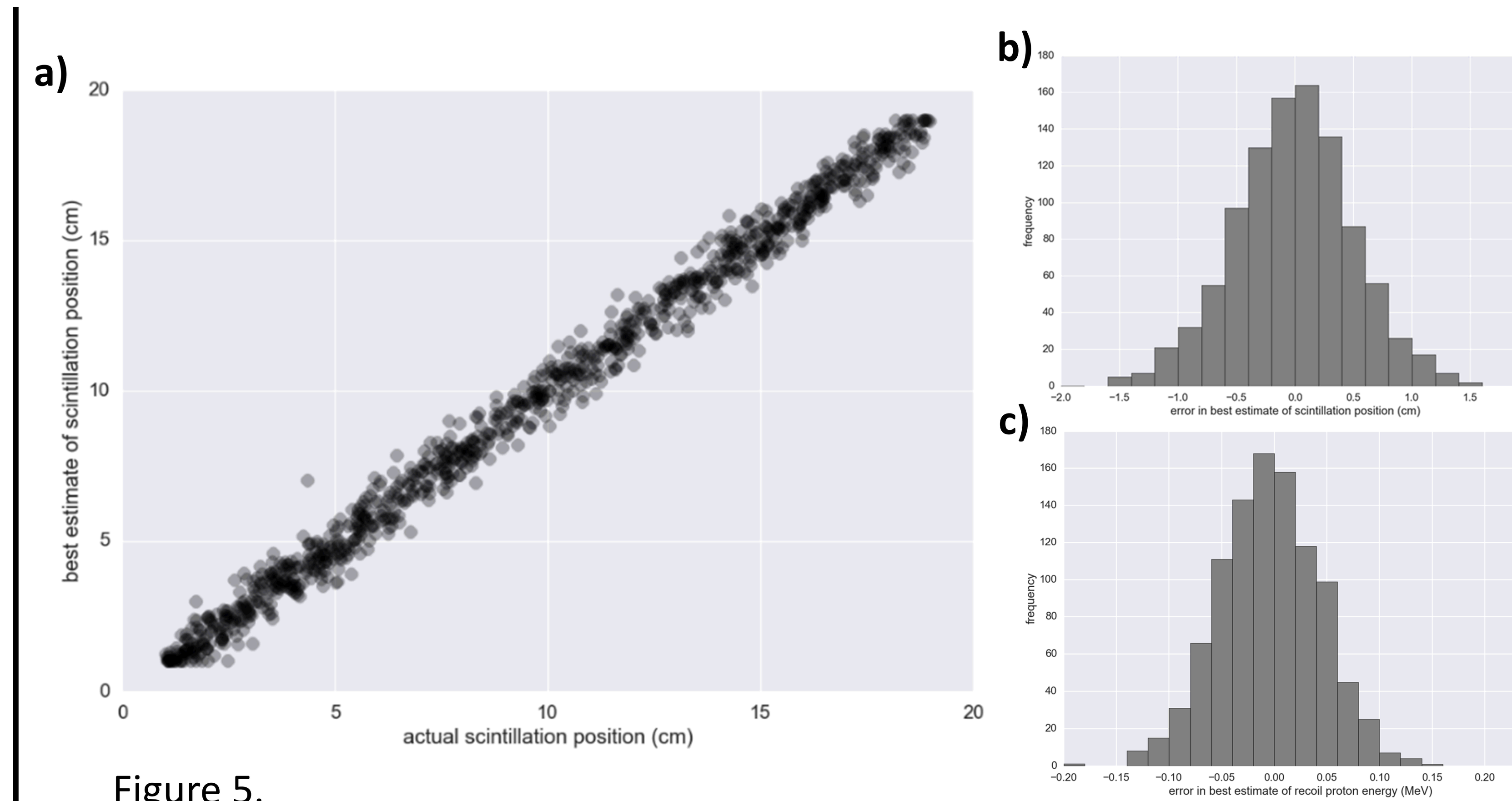


Figure 5.
a) Actual scintillation position vs. best estimate. Estimated position uncertainty is independent of scintillation position
b) Position estimate error histogram
c) Energy estimate error histogram

- **RMS errors of BFGS estimates for scintillation position (mm) and recoil proton energy (keV)**
  - 1 MeV recoil proton energy
    - 9 mm / 80 keV
  - 2 MeV recoil proton energy
    - 5 mm / 40 keV

- We simulated the SVSC's response to a point source of fission neutrons using MCNPX-PoliMi, we estimated the scintillation position using the preceding MLE analysis, and we back-projected the source direction

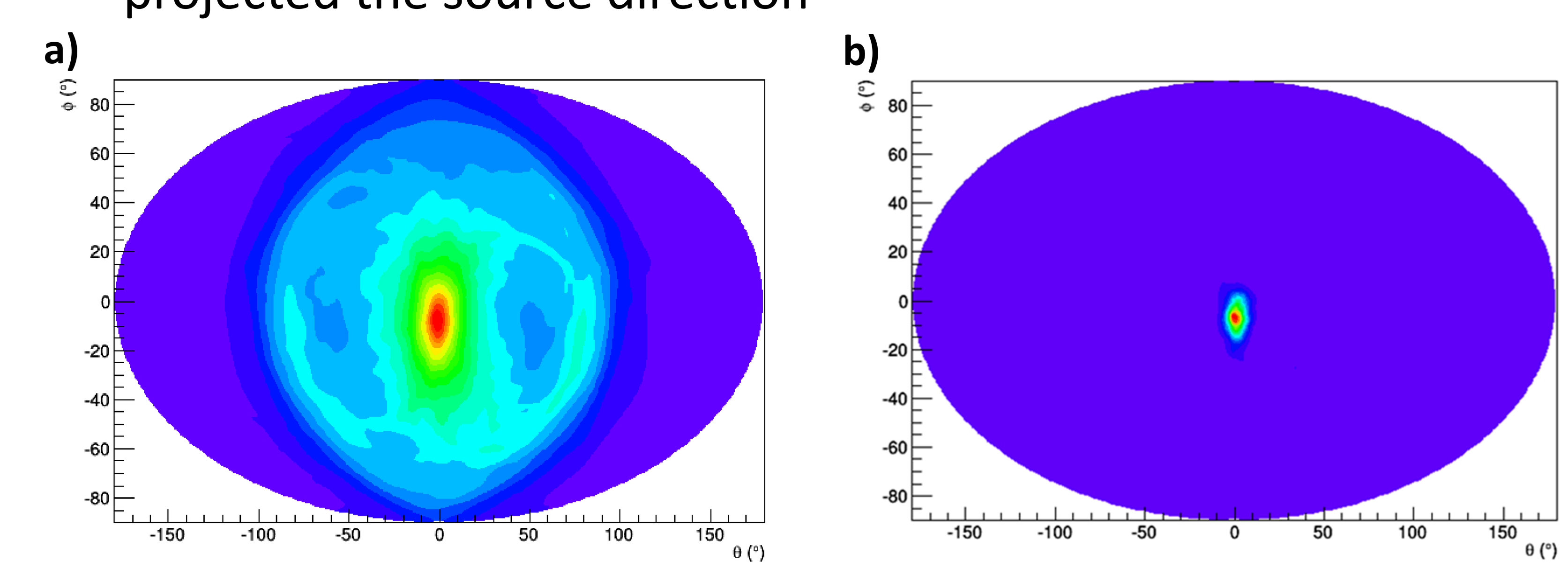


Figure 6. Cf-252 source located at (0°, 0°)
a) Back projection reconstruction
b) MLEM reconstruction

## Conclusions

- The SVSC-PiPS can estimate scintillation position within 5 mm RMS error
- It can estimate source direction within 5 degree RMS error


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