Microchannel Plate Characterization for use in a Single Volume Neutron Scatter Camera

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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 incident neutron direction

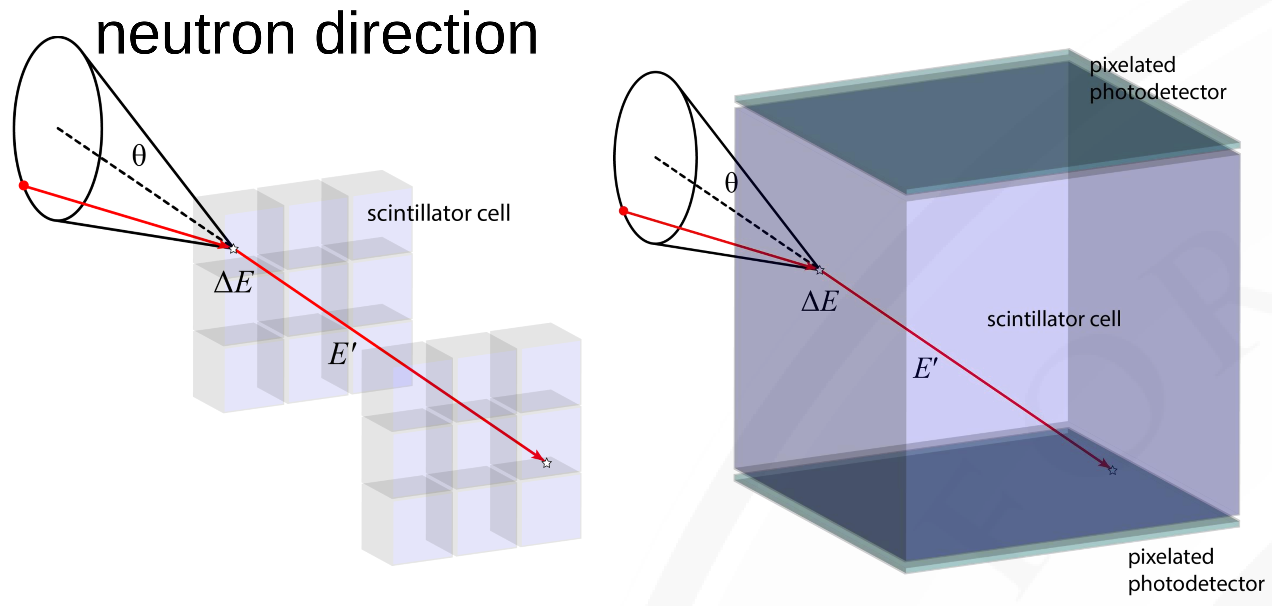

Figure 1. MVSC design with two planes of optically isolated scintillator cells vs. SVSC with one optically contiguous scintillator cell and pixelated photodetectors on two opposing faces

- We need to estimate the number and time of arrival of each photoelectron(PE) present in each pixel of the microchannel plate (MCP) for every scintillation event
- PE arrival time used for scintillation position reconstruction

Hardware

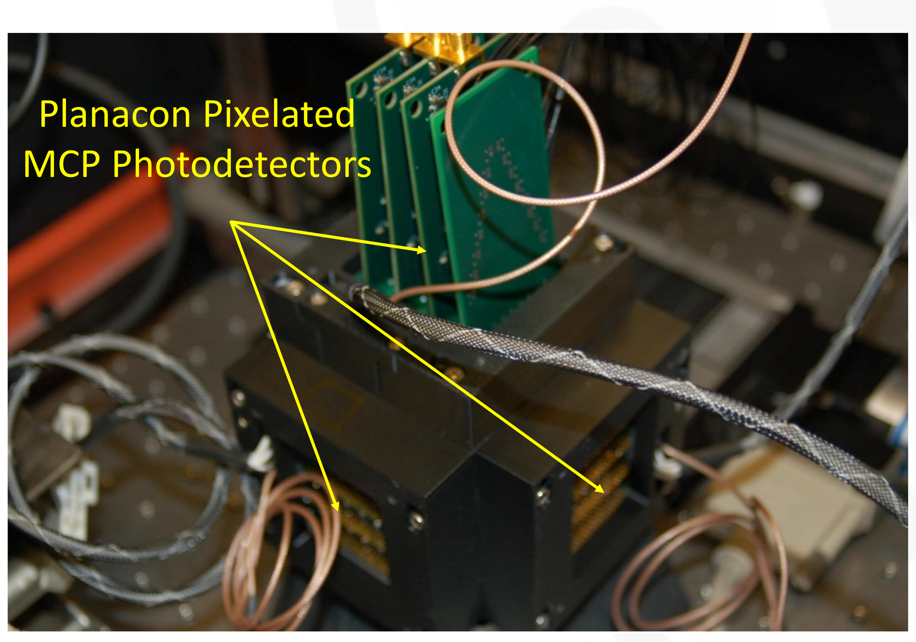

Figure 2. SVSC housing with 3 pixelated Planacon photodetectors surrounding the scintillator inside. Digitization triggered off of dynode signal from Planacon.

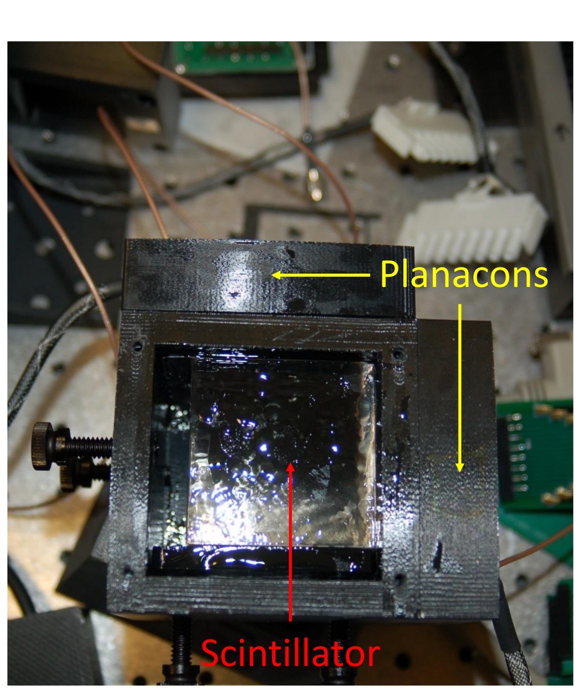

Figure 3. Inside of SVSC with top photodetector removed

Single Photoelectron Characterization

- The manufacturing process of MCPs causes variations in quantum efficiency, gain, and noise across the face of the MCP

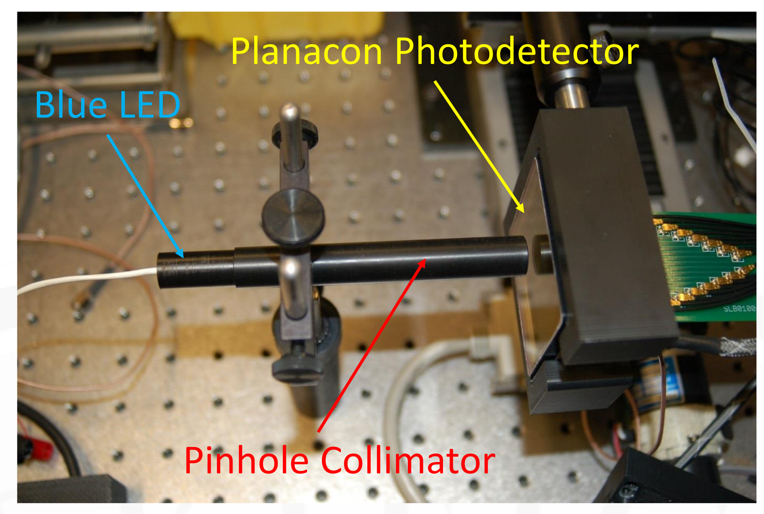

Figure 4. Blue LED characterization using a pinhole collimator on each pixel of the photodetector

- We used a blue LED to rasterize over each pixel to obtain a single photoelectron peak, gain, relative occupancy, threshold, and average single PE waveform for each pixel

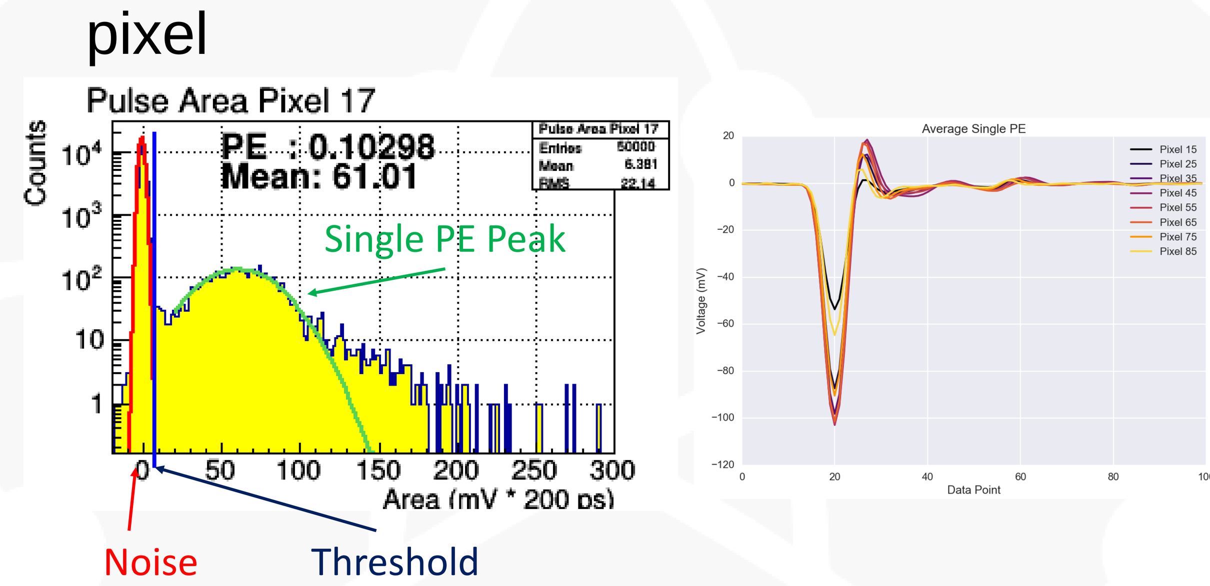

Figure 5. (Left) Gaussian fitted noise peak in red. Threshold set at 5σ above noise Gaussian mean. Gaussian fit applied to single PE region to estimate pixel gain. (Right) Average single PE waveforms for a row of pixels of the MCP

Waveform Filtering

- Large waveforms cause crosstalk from the dynode of the MCP
- Bessel band-stop filter used to reduce noise peak in power density spectrum

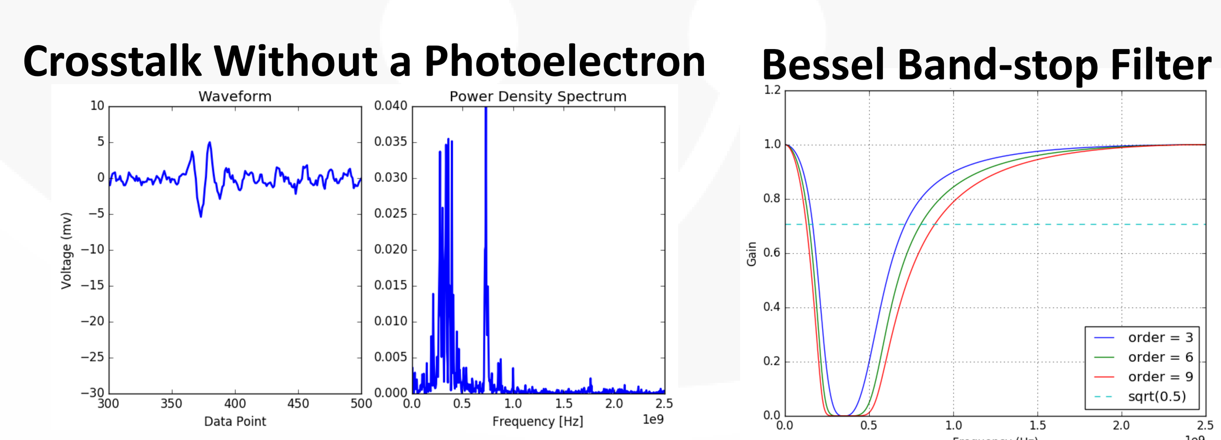

Figure 6. (Left) Common shape of crosstalk on a channel with corresponding power density spectrum. (Right) Bessel band-stop filter applied to all waveforms to remove cross talk effects

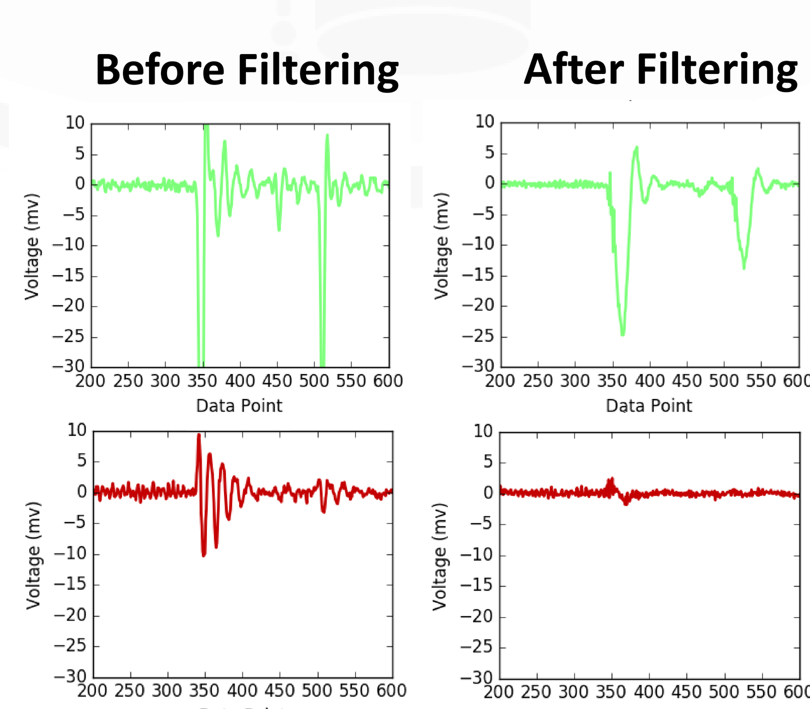

Figure 7. Two waveforms before and after the Bessel band-stop filter is applied. Large reduction in oscillations from the filter.

How Does Filtering Affect Characterization

- Less than 1% difference in gain, relative occupancy, width of single PE peak, and area of average single PE waveform for every pixel after filtering
- Average single PE waveform shape changes

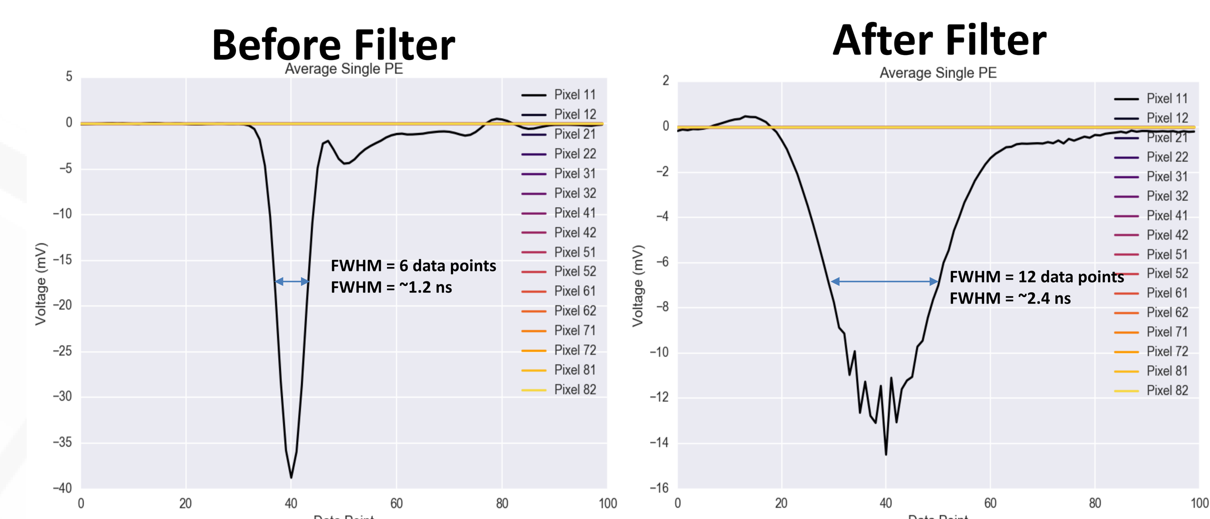

Figure 8. Average single photoelectron waveform before and after filtering for pixel 11. Large reduction in waveform amplitude. Filtering also increases FWHM. Area of each waveform stays approximately the same.

MLEM Waveform Fitting

- We used the average single PE waveform to determine how many photoelectrons were present for each scintillation event using MLEM
- We allowed the average waveform area to fluctuate ±2σ to match single PE peak region from characterization
- Estimates number of photoelectrons and timing information for each pixel

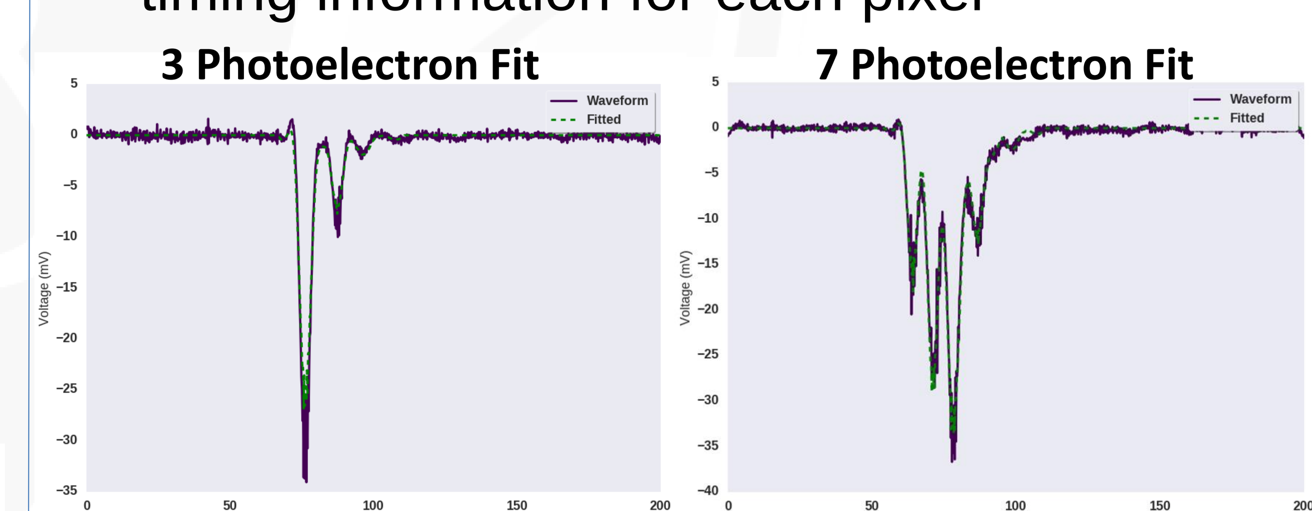

Figure 9. Multiple PE fits compared to the Bessel band-stop filtered waveform

- Measurement performed using an EJ-232Q plastic disc on the face of the Planacon
- Characterization data for each pixel used for determining number of PEs and timing

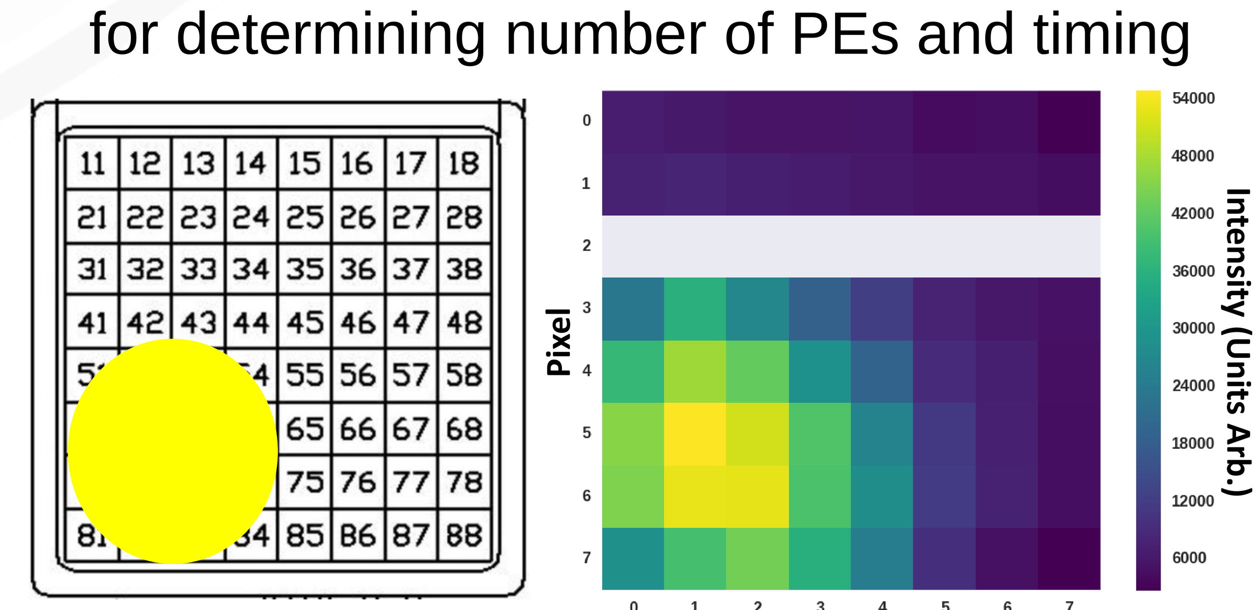

Figure 10. Cf-252 source used for scintillation. (Left) EJ-232Q disc position on the face of the Planacon. (Right) Time integrated Planacon response using waveform MLEM fitting corrected for relative pixel occupancy. Missing row used to digitize dynodes.

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