Neutron Portal Monitor for Security Applications

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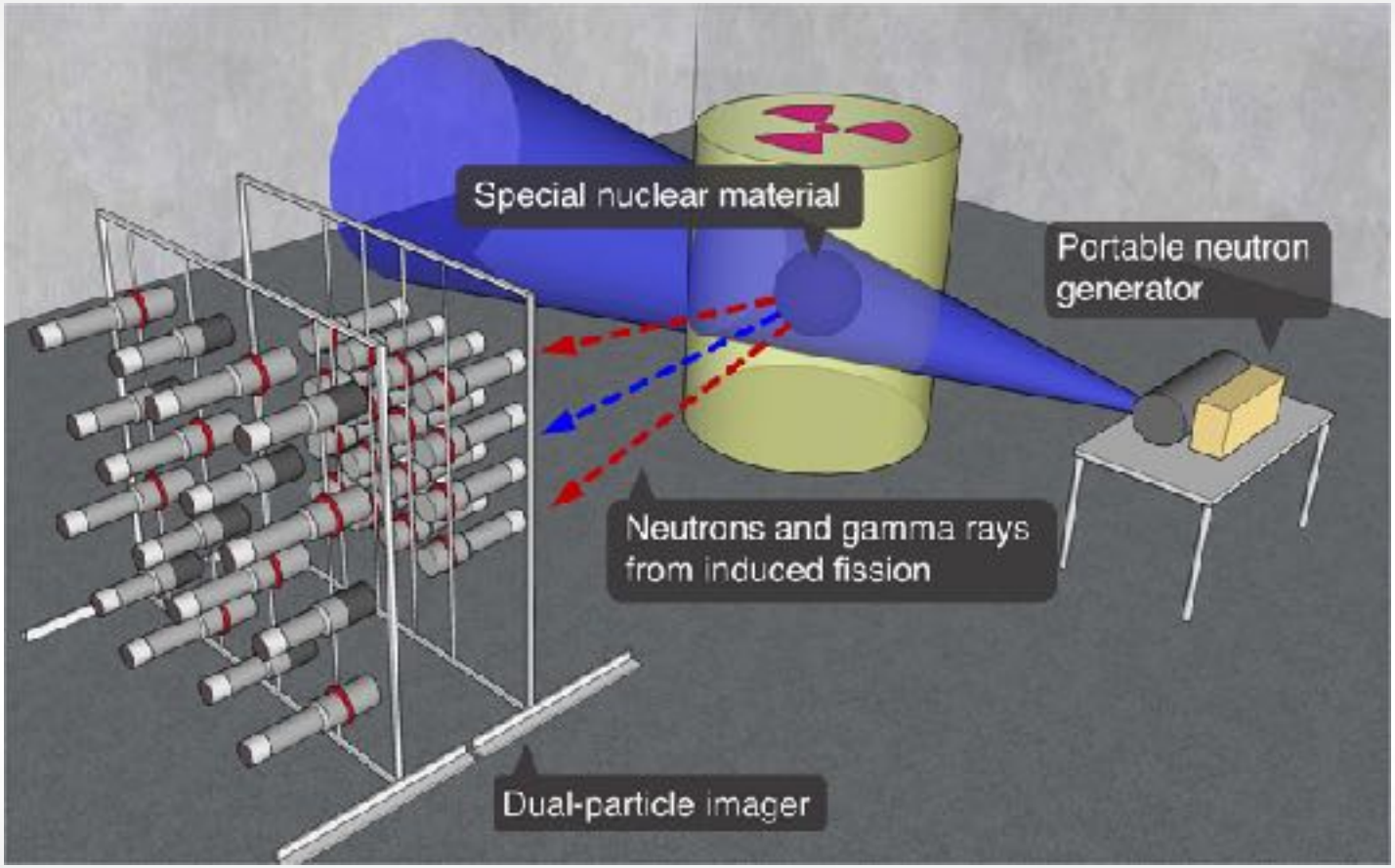
Portal Monitors

- Gamma detection
- Thermal Neutron detection
- Fast Neutron detection

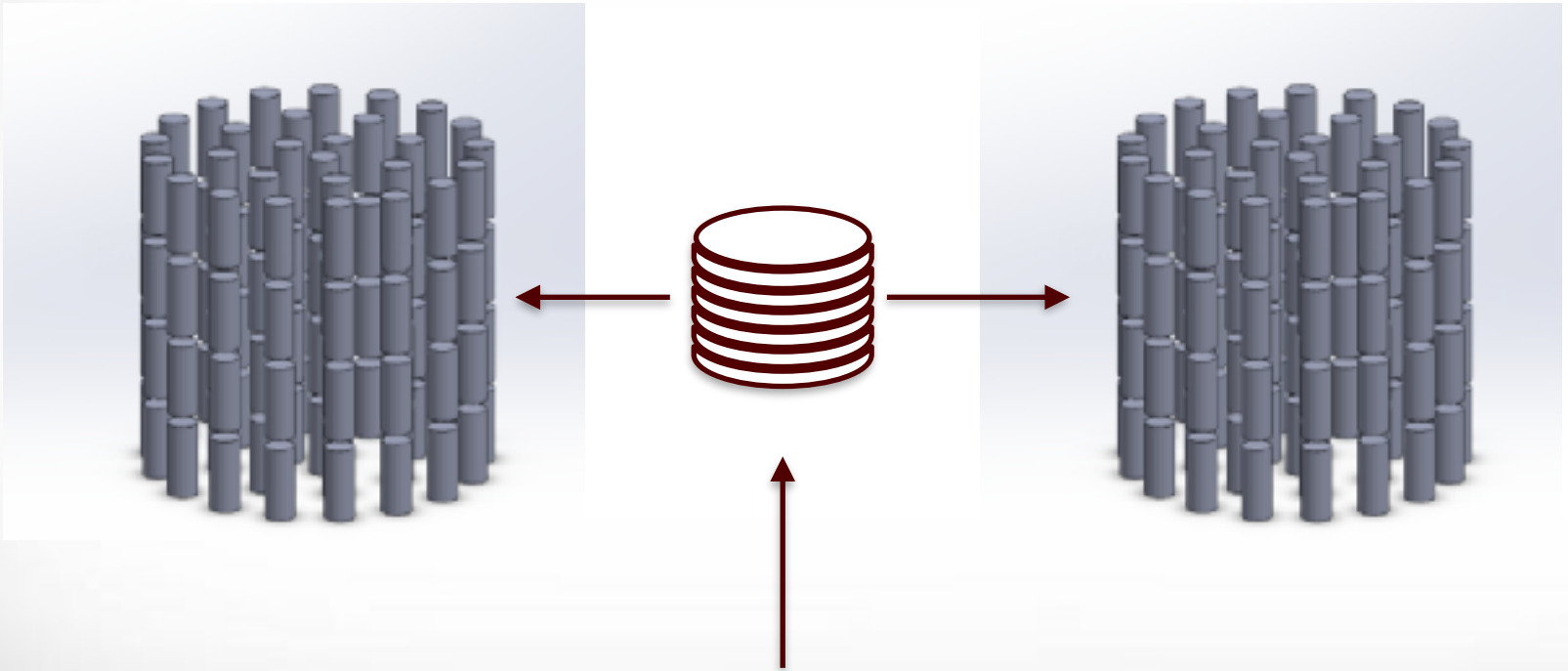
Highly Enriched Uranium (HEU) is a challenge:
neutron flux is extremely low,
γ-rays have low energy - easily shielded

Active neutron imaging scheme



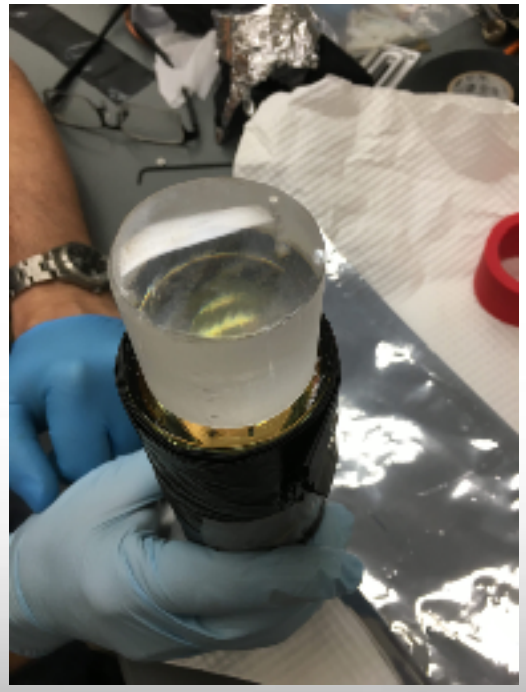
M. Himel, et. al., Sci. Rep. 7, 7997 (2017)

General scheme

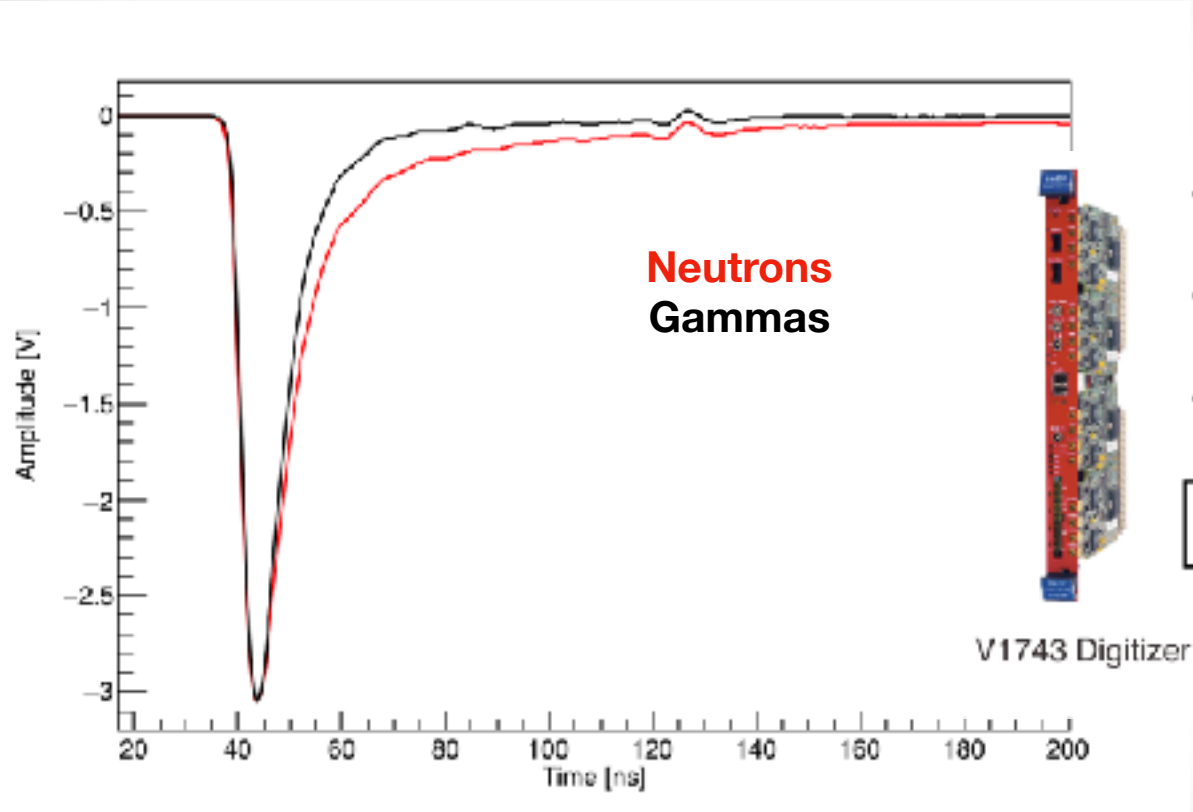


P - terphenyl ($C_{18}H_{14}$)

- Very bright - 27,000 photons / MeVee
- Fast - Decay time 3.7 ns
- Perfect pulse shape discrimination

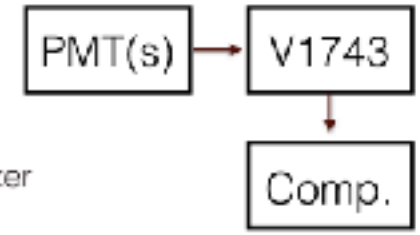


PSD for p-terphenyl



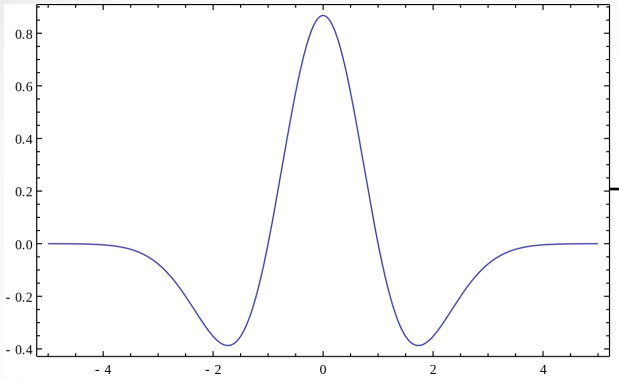
V1743 Digitizer

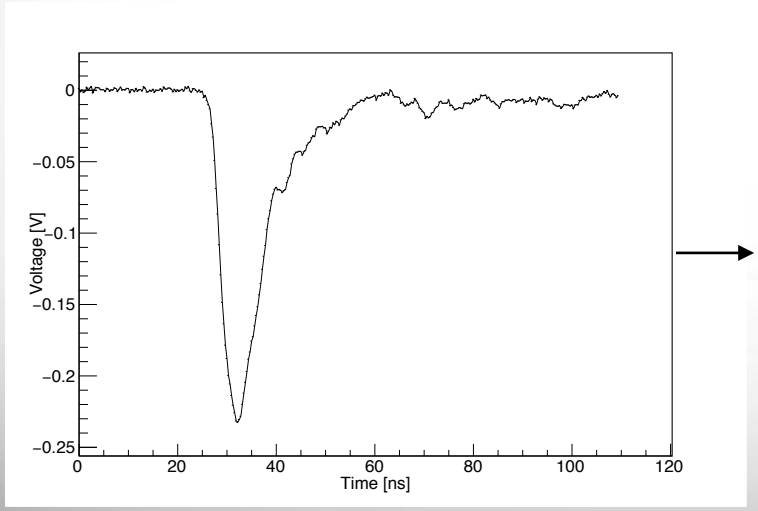
- Digitizes signal into waveforms
- Sampling Rate: 0.4, 0.8, 1.6, 3.2 GS/s
- Dynamic Range: -2.5 V



Best PSD found was the use of Wavelet Analysis

"Mother Wavelet" (Ricker, etc.)





Signal

FFT

FFT

Mul.

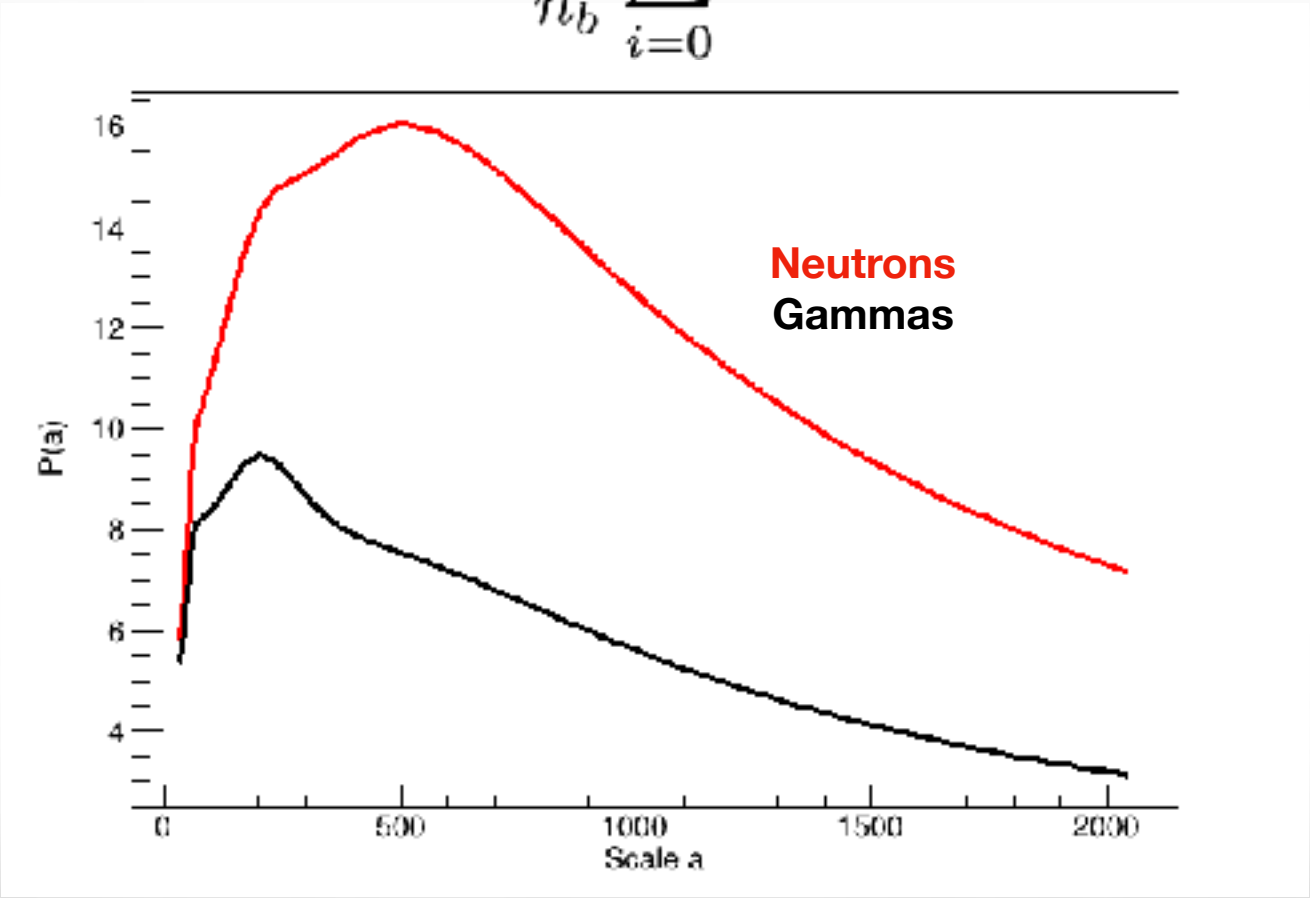
IFFT

II

$$W_f(a,b) = \int_{-\infty}^{\infty} f(t)\frac{1}{\sqrt{a}}\phi^*\left(\frac{t-b}{b}\right)dt$$

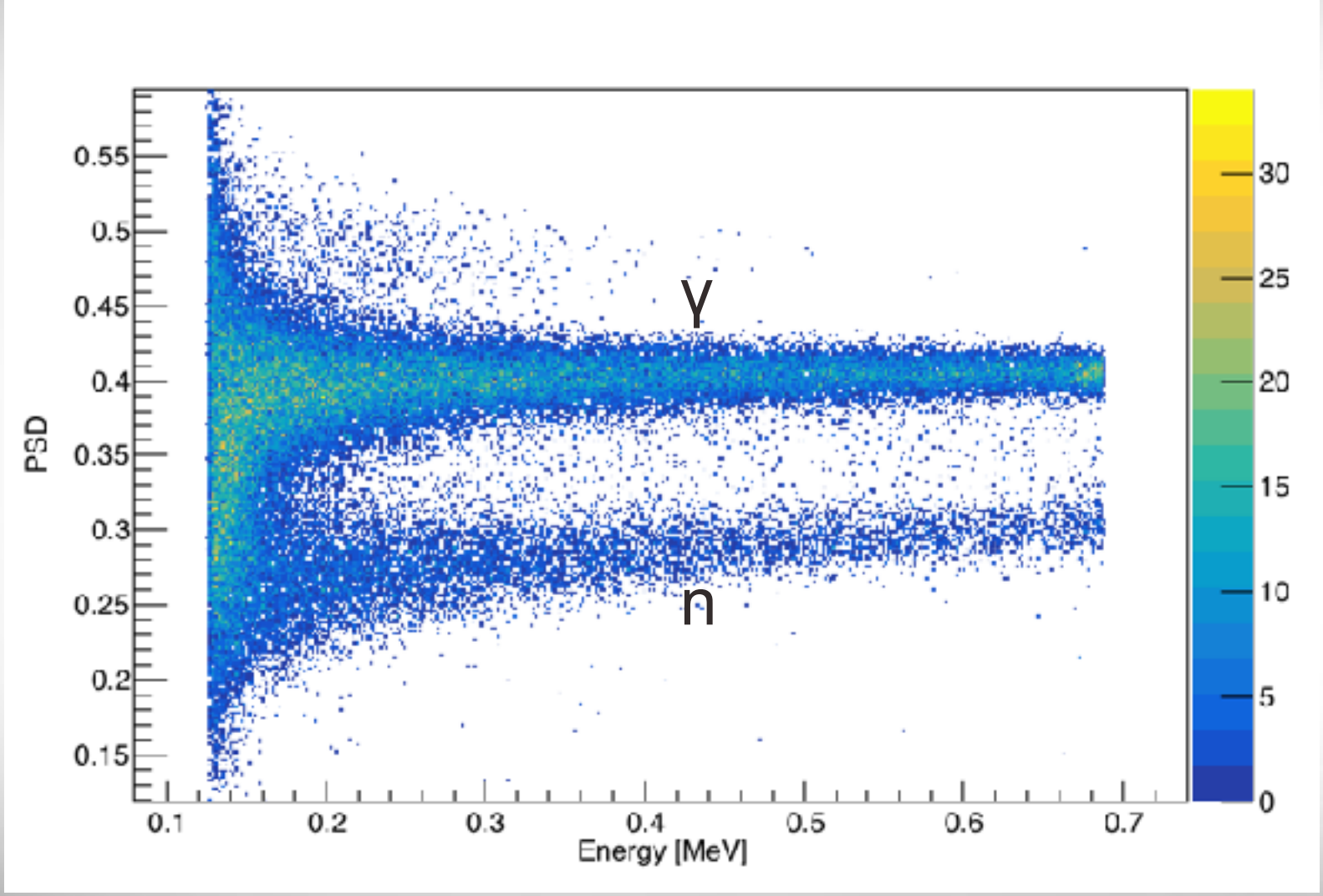
Best PSD found was the use of Wavelet Analysis

Power Spectrum $$P(a) = \frac{1}{n_b} \sum_{i=0}^{n_b} |W_\psi(a, b_i)|^2$$



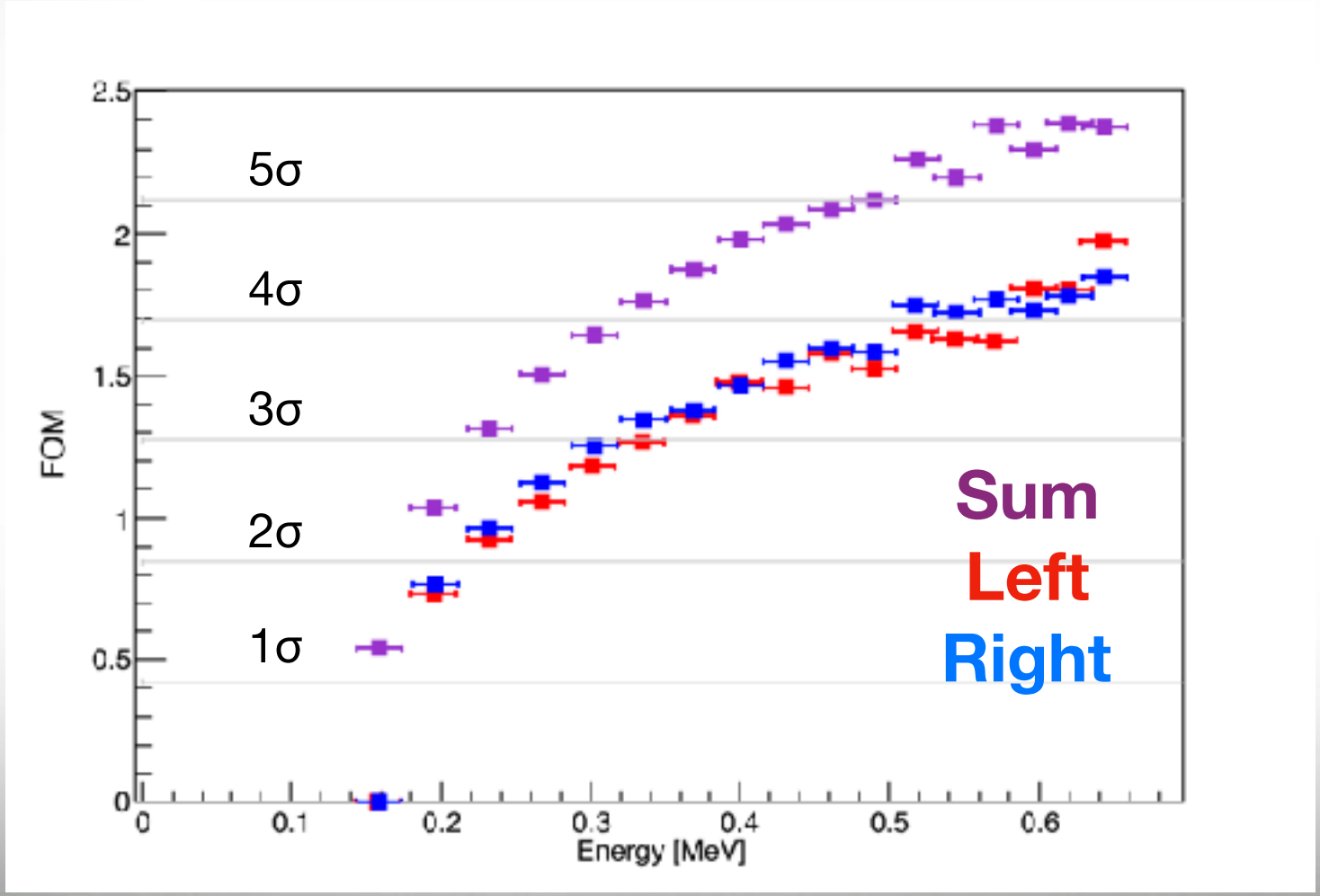
Power Spectrum vs Scale for 600 keV recoil neutron energy and gamma (gamma at same amplitude)

PSD spectrum



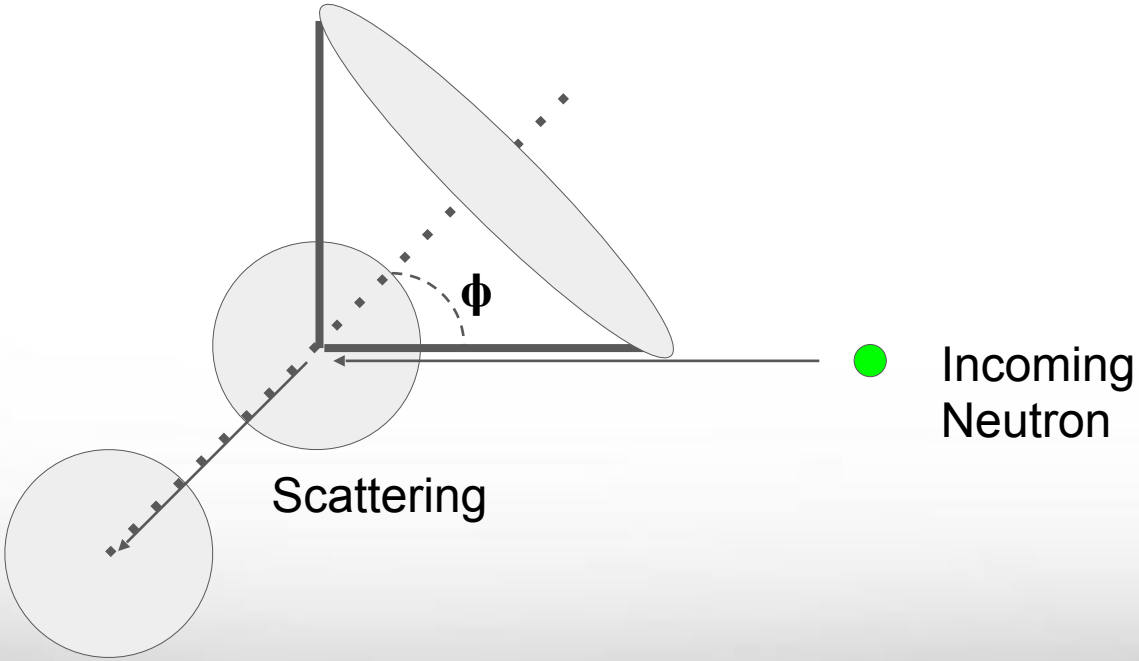
PSD Figure of Merit

$$\mathrm{FOM} = \frac{\mu_n - \mu_\gamma}{2.36(\sigma_n + \sigma_\gamma)}$$



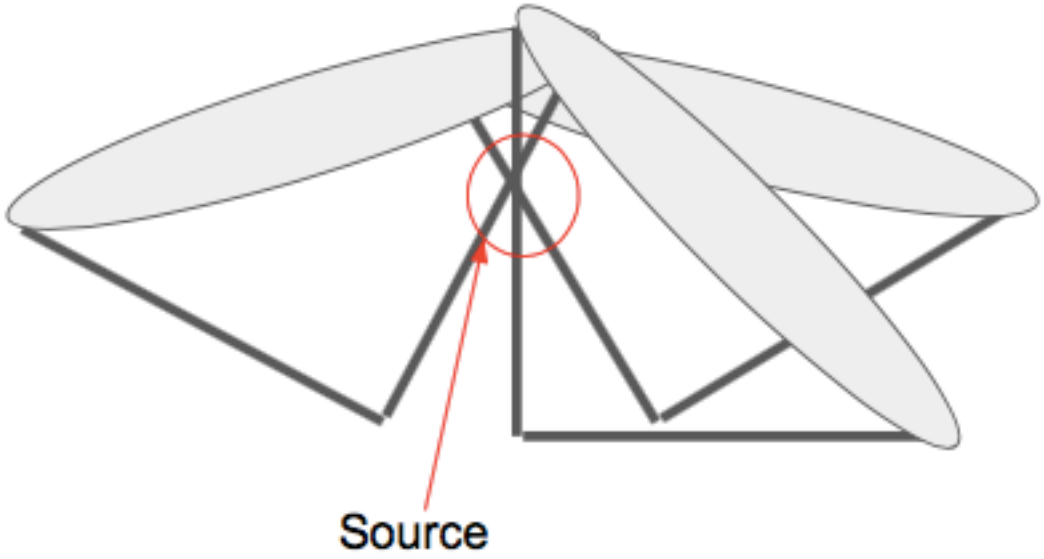
Double Hit Neutron Tracking

- Vertex localization for the first and second hit
- Time between the hits
- Energy deposited by the neutron

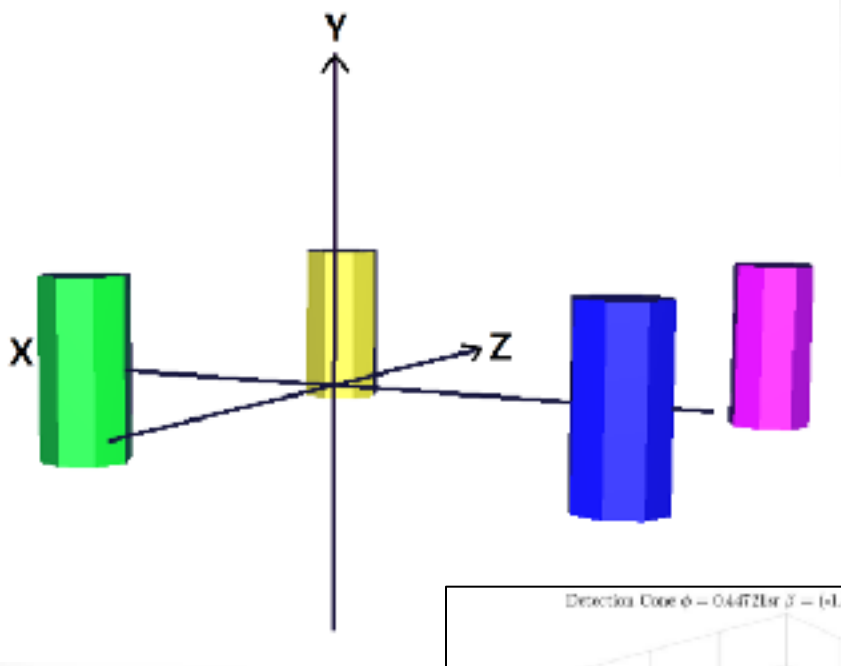


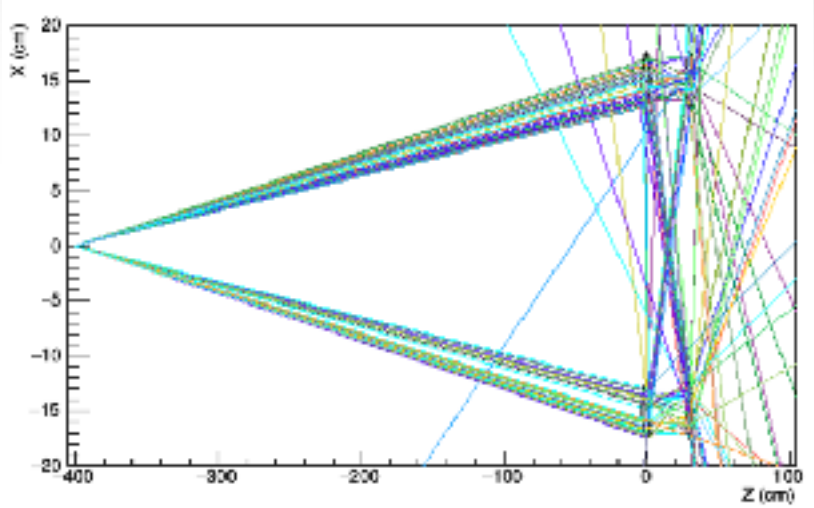
Double Hit Neutron Tracking

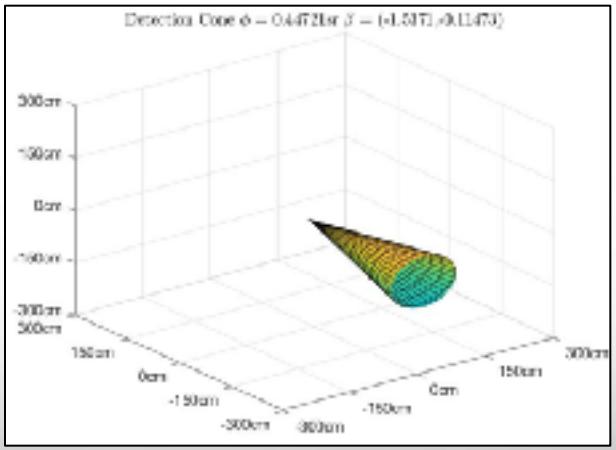
If several cones intersect a particular region of space, there is likely a source there.



MCNP Symulation

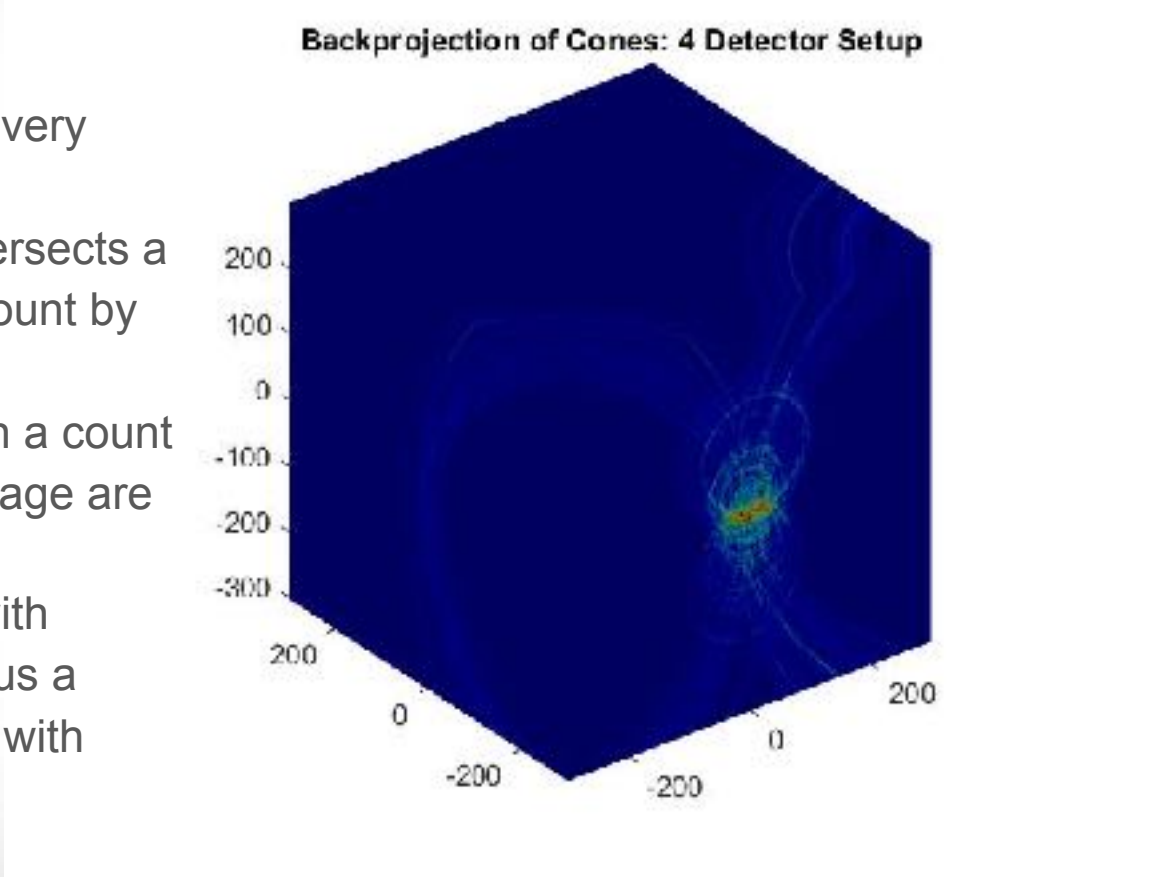




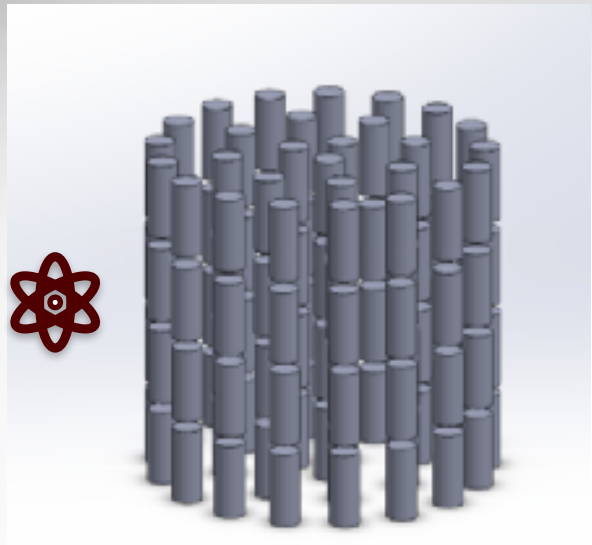


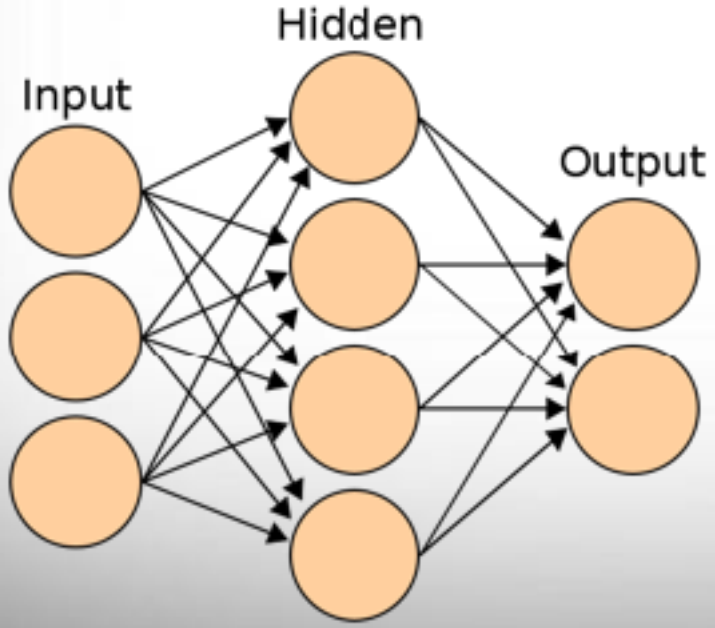
Intersecting cones reconstruction

- Associate a counter with every voxel
- Whenever a new cone intersects a given voxel, increase its count by one
- At the end, any voxels with a count much higher than the average are likely near a source
- The presence of a voxel with unusually high count tells us a source is present to begin with



Neural Network source recognition

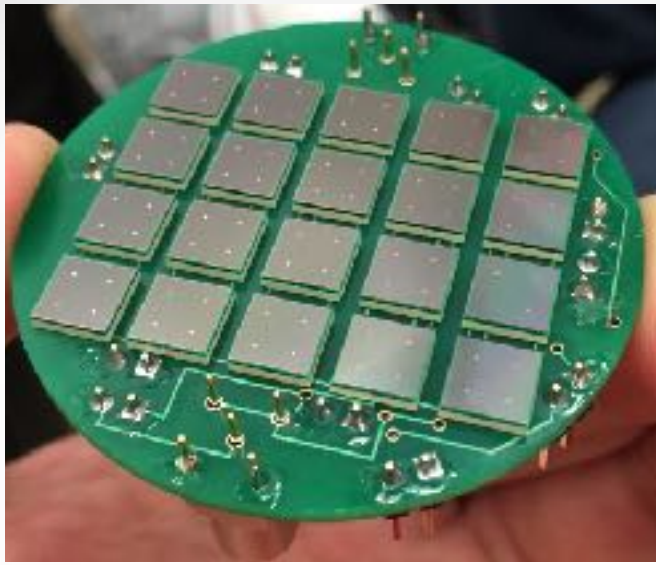


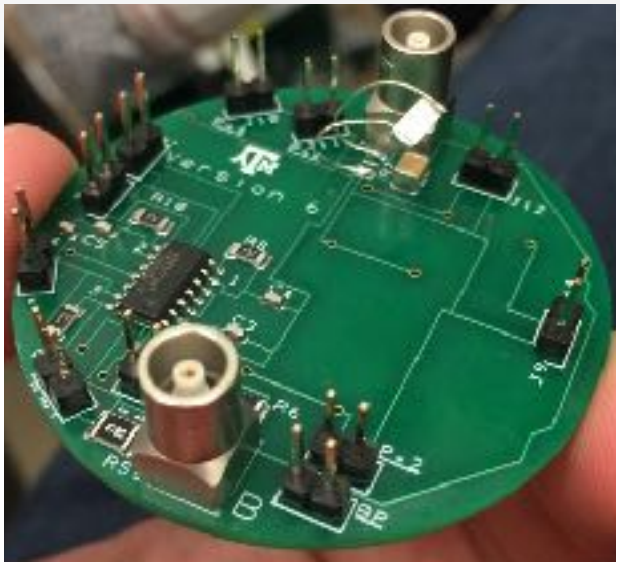


# of double hits per sample - 2,000
Training samples - 10,000
Test samples - 10,000

SNR	Accuracy
10%	99%
7%	96.2%
5%	93.5%
3%	84%

SiPM readout

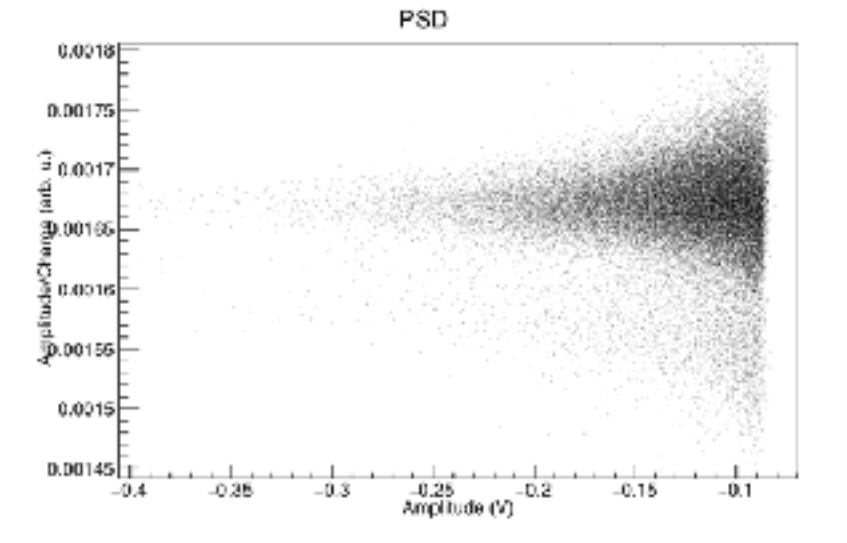


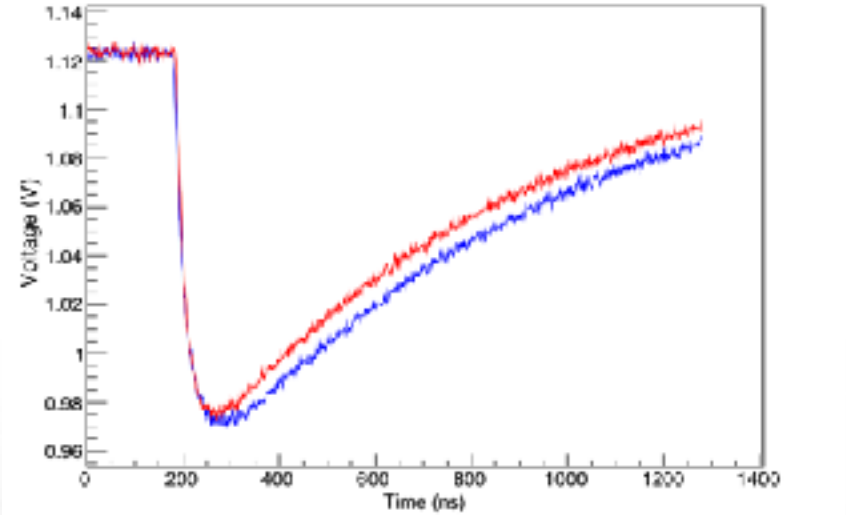


- 4x5 matrix of 20 multiplexed Hamamatsu SiPMs
- Simple circuit with no active elements

SiPM readout

- Using the raw signal from the SiPMs
- The right plot shows one waveform from each band in the left plot





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