Stilbene Cube Characterization for a Mini Neutron Scatter Camera

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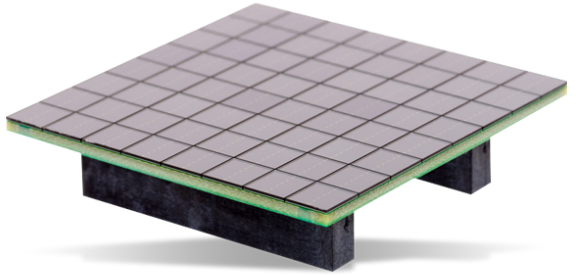
Introduction and Motivation

- Neutrons are emitted passively from special nuclear material (SNM) or when SNM is actively interrogated.
- Neutrons are not significantly present in background radiation.
- Detection and localization of neutron sources is valuable in determining the presence of SNM.
- To localize neutron sources: need small and portable system.
  - Emergency response
- Mini neutron scatter camera utilizing silicon photomultipliers (SiPM) can yield this capability.

Mini Neutron Scatter Camera

- Silicon photo multipliers (SiPM):
  - Compact
  - Low voltage
  - No shielding required
  - Comparable timing and PSD to photo multiplier tubes (PMTs)

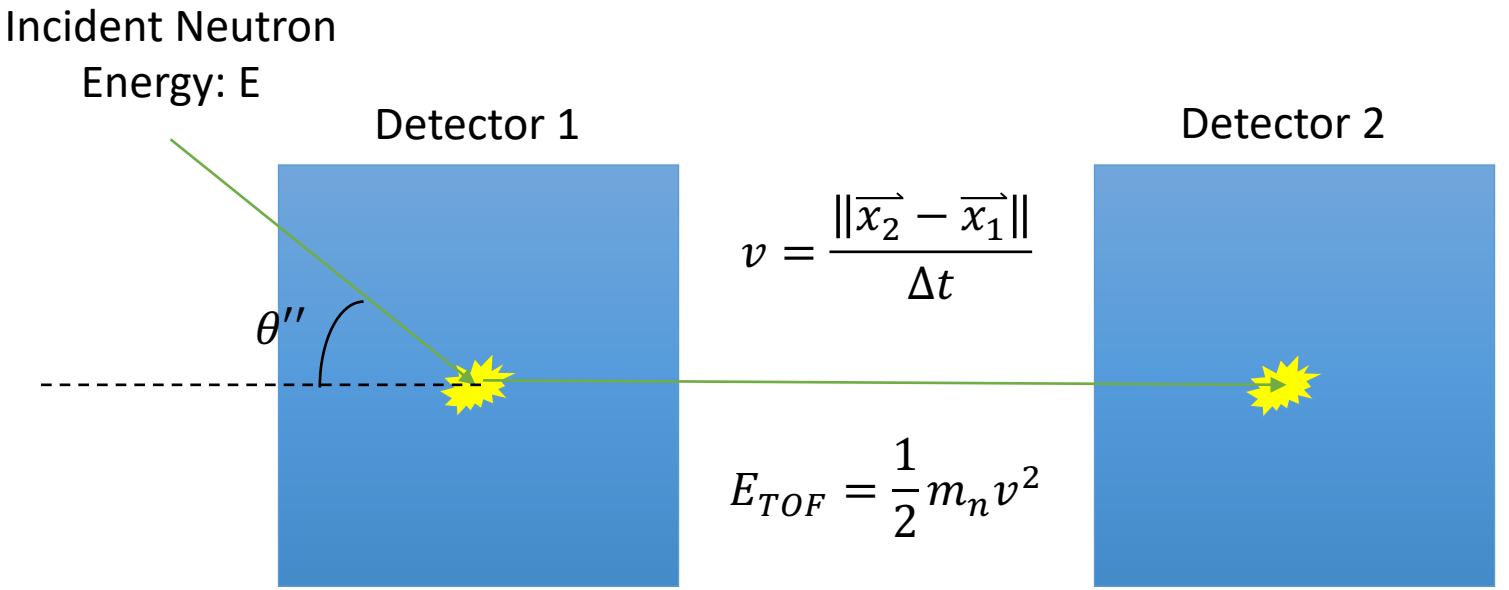
J-series SensL SiPM array



- Stilbene cubes:
  - Timing properties
  - PSD capabilities
  - Light output

Inrad Optics stilbene crystal

Technical Background



From this information we can find: $E = E_{TOF} + E_1$ and α = $cos^2(\theta'') = \frac{E_{TOF}}{E}$

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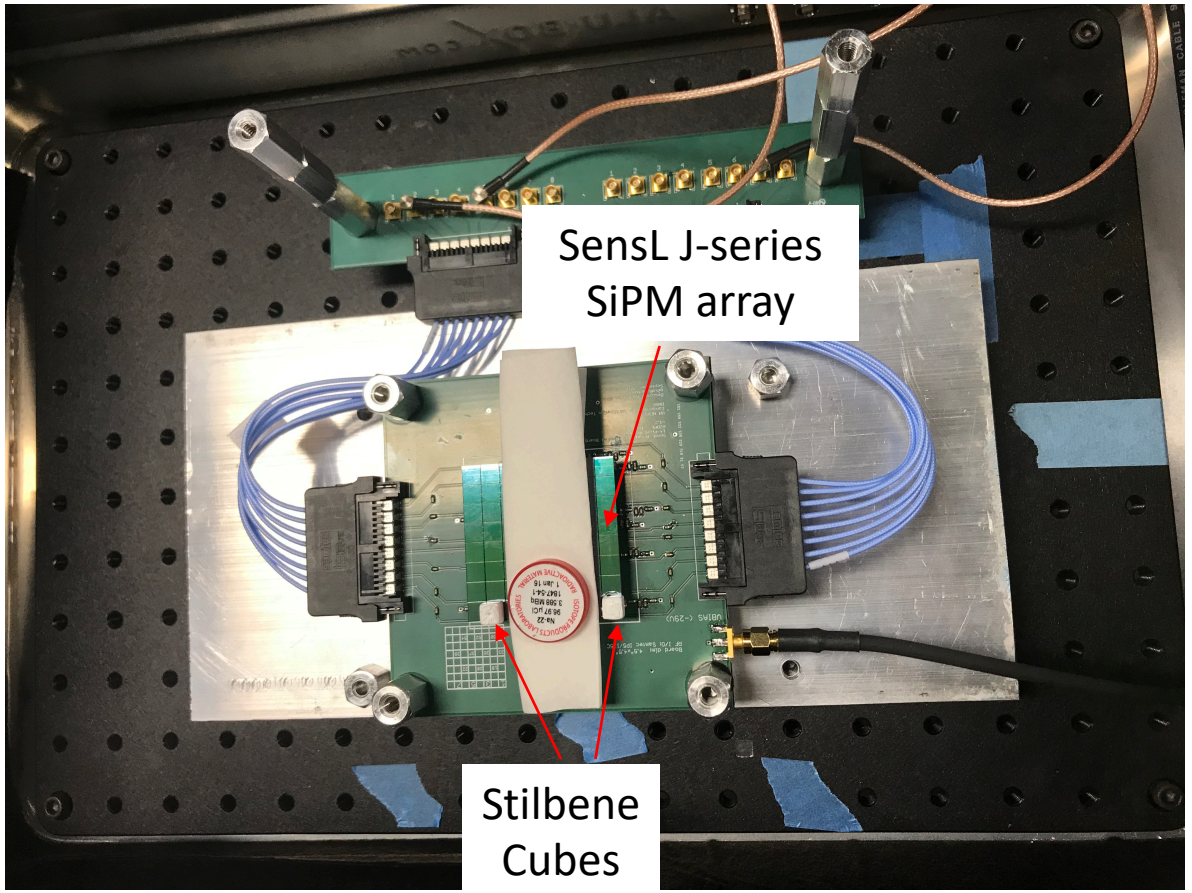
Characterization for the Mini Neutron Scatter Camera

- Calibration from pulse integral to gamma-ray light output
- Discriminate between neutron and gamma-ray interactions – PSD
- Time resolution
- Know energy resolution of our detector
- Know the neutron light output

Laboratory Measurements

- ^{137}Cs – Calibrate gamma-ray light output
- ^{252}Cf – Pulse shape discrimination (PSD)
  - PSD optimization
- ^{22}Na – Coincident measurement
  - Necessary to measure time resolution

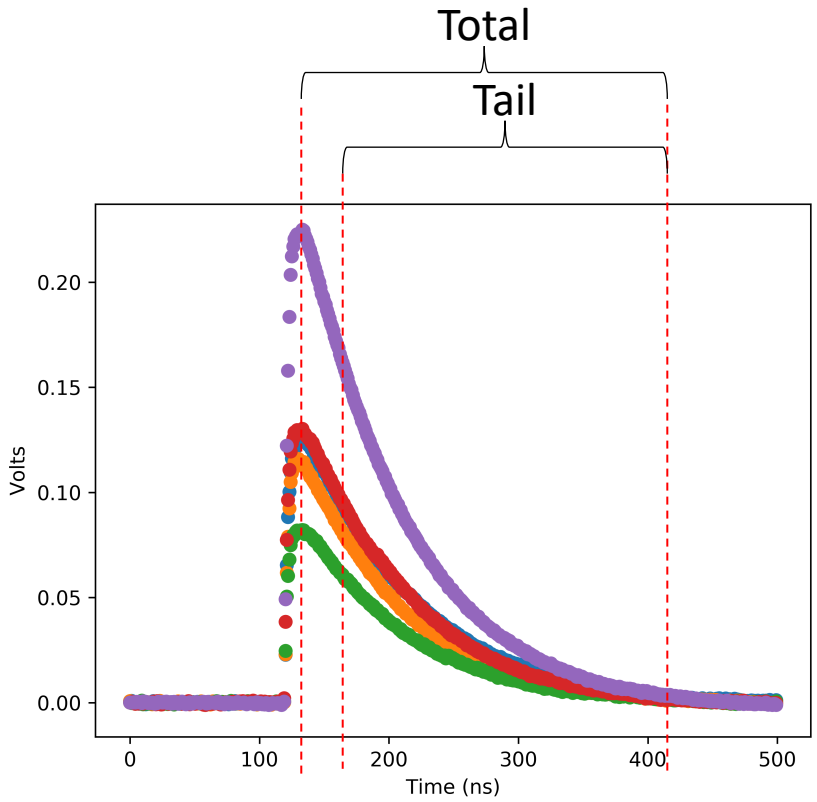
^{22}Na measurement experimental setup

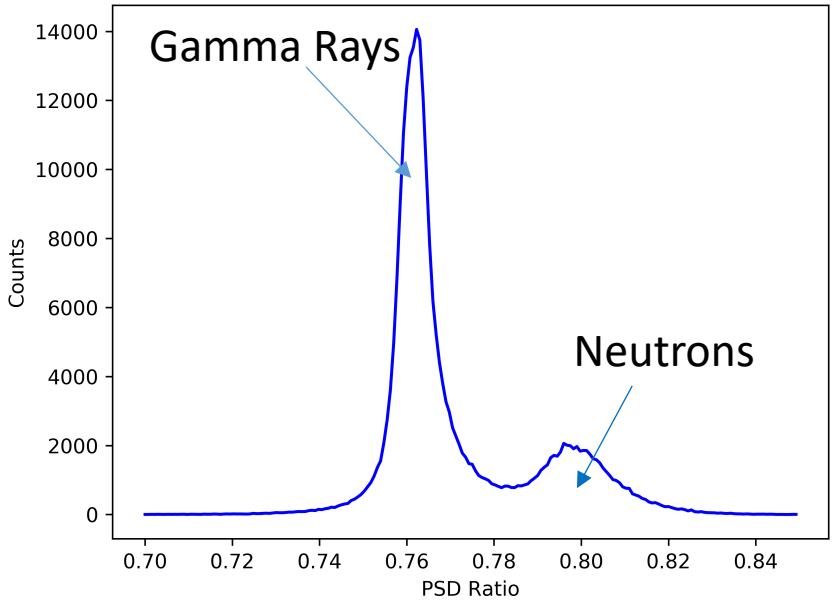


Results: ^{252}Cf Measurement

- Pulse shape discrimination (PSD) optimization
  - $PSD\ Ratio = \frac{Tail}{Total}$

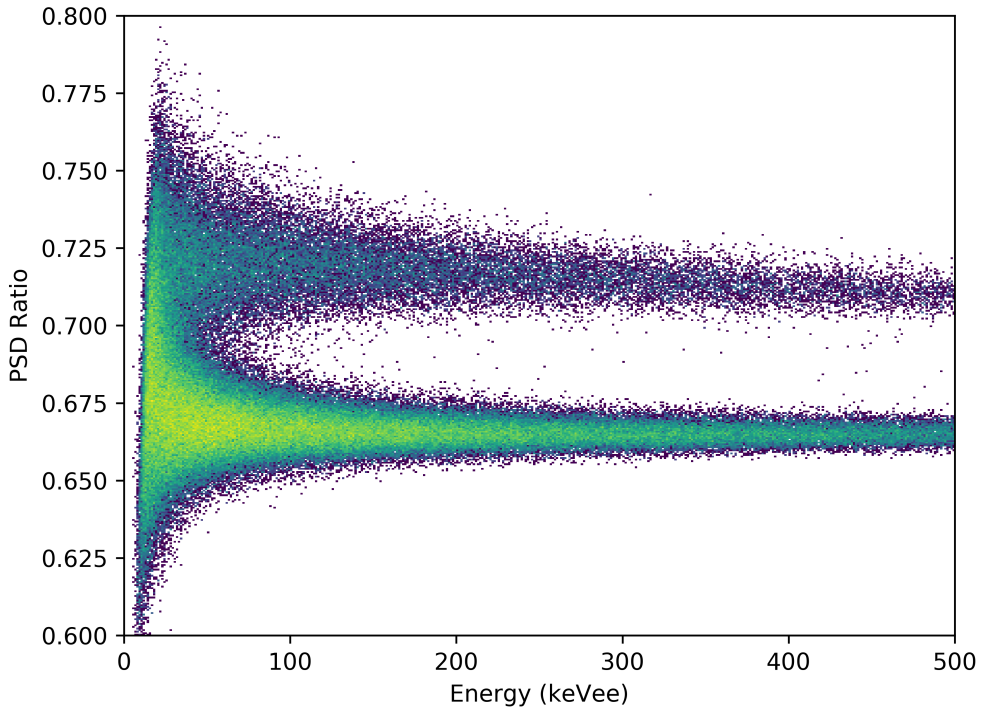
$$\mathrm{FOM} = \frac{\mu_n - \mu_\gamma}{FWHM_n + FWHM_\gamma}$$



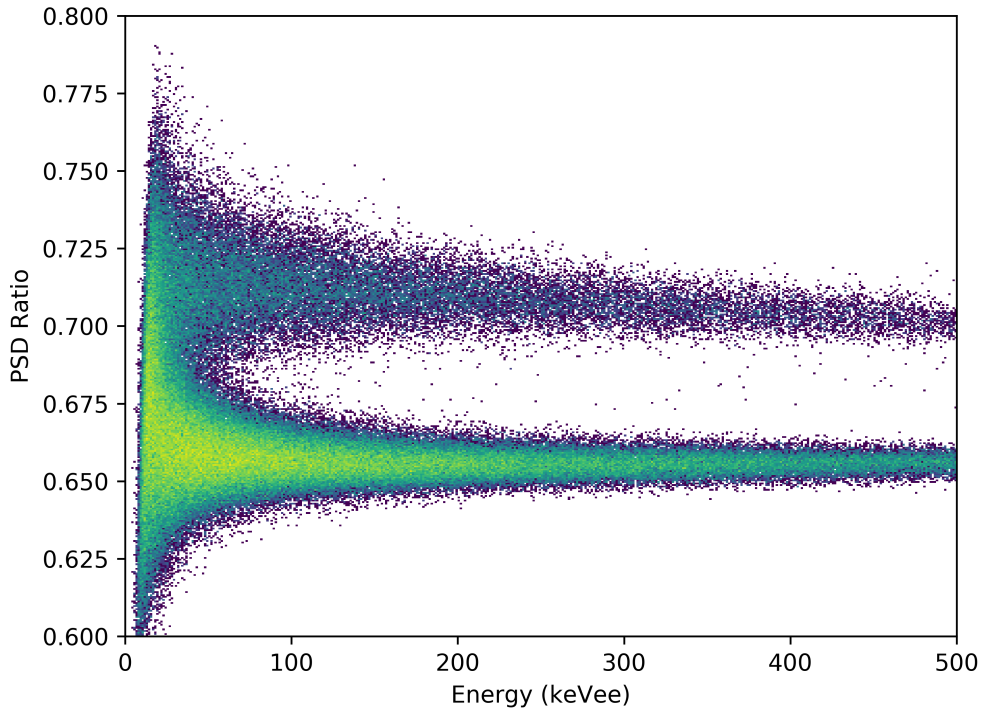


Results: ^{252}Cf Measurement

^{252}Cf optimized PSD ratios: cube 1



^{252}Cf optimized PSD ratios: cube 2



Results: ^{252}Cf Measurement

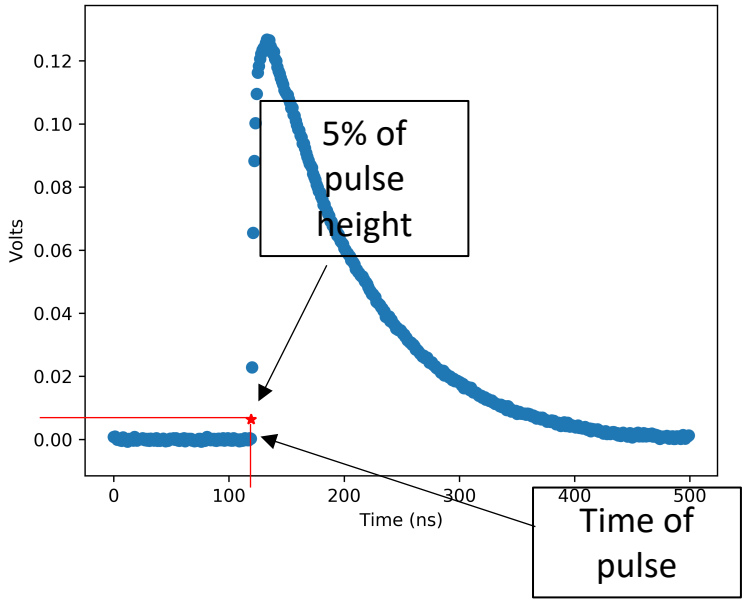
Energy (keVee)	FOM Cube 1	FOM Cube 2
50 – 100	1.14	1.18
100 – 150	1.71	1.66

Tail: 60 ns past maximum to 400 ns
Total: maximum to 400 ns

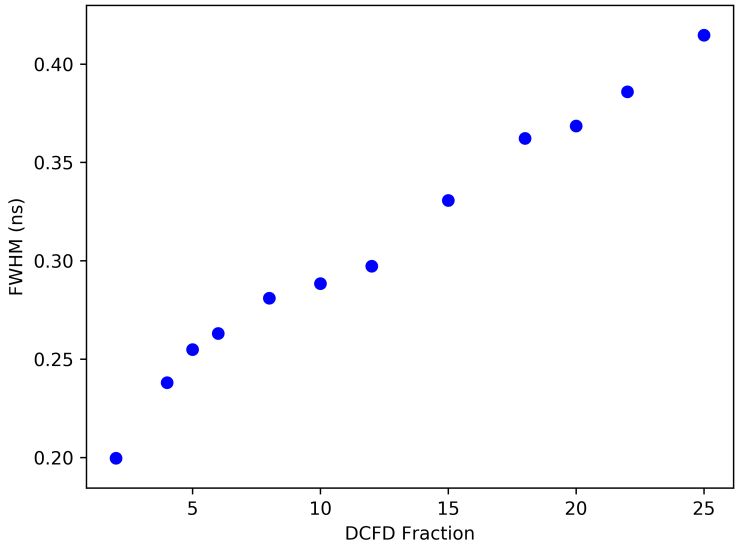
Results: ^{22}Na Measurement

- Digital constant fraction discrimination (DCFD) optimization

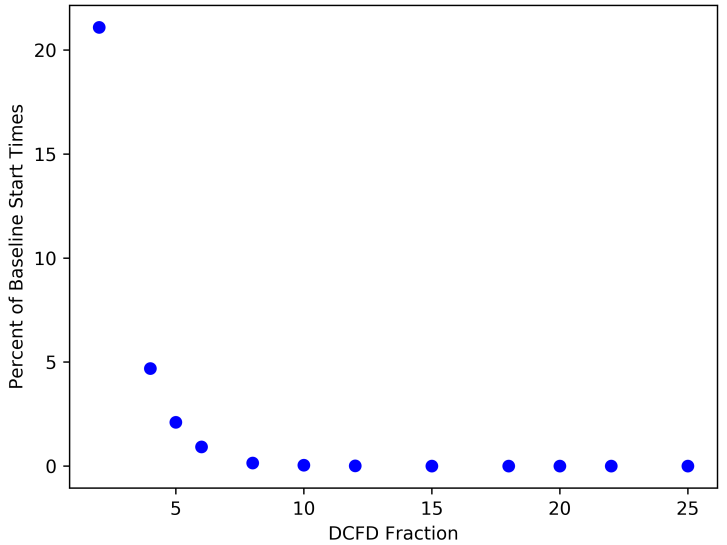
Raw pulse from the ^{22}Na measurement.



FWHM as a function of the DCFD fraction.

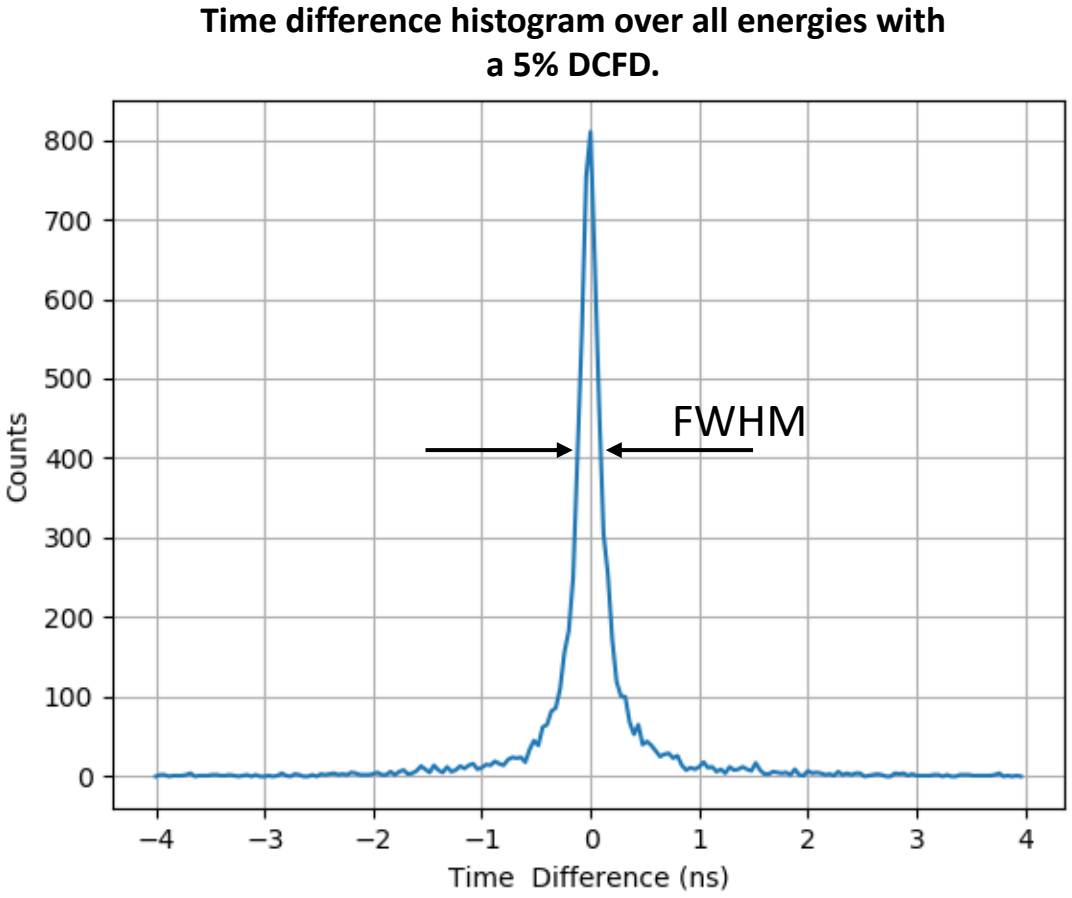


Percentage of bad start times as a function of the DCFD fraction.



Results: ^{22}Na Measurement

- 250 ps FWHM over all energies
- Gate on Compton edge (240 to 390 keVee) : 160 ps FWHM



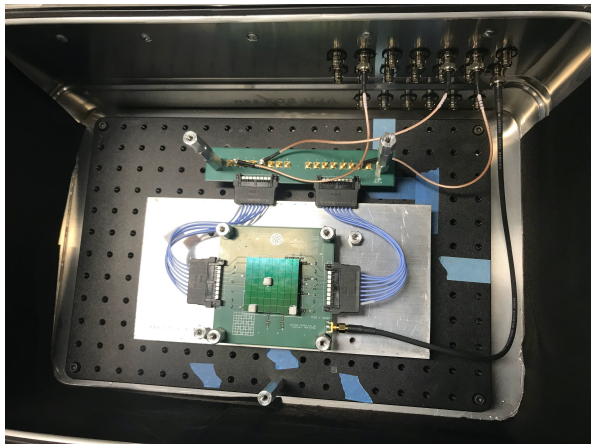
MTV Impact

- Opportunities for participation in workshops and conferences.
- Work with national laboratories:
  - Collaboration with Sandia National Laboratory.
  - Internship at Los Alamos National Laboratory this summer.

Conclusion

- Based on this characterization we have found excellent PSD and timing resolution.
- This PSD and timing resolution is sufficient to successfully image neutrons.
- A mini neutron scatter camera is a viable technology.

The experimental setup of three stilbene cubes coupled to a J-series SiPM array.



Next Steps

- Additional laboratory measurements
  - Energy resolution
  - Neutron light output
- Simulations of the mini neutron scatter camera
  - 8 stilbene cubes

Acknowledgements

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