Readout Electronics of SiPMs Coupled to Stilbene in a Fast-Neutron Multiplicity Counter

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Introduction

Abstract

An application of silicon photomultipliers (SiPMs) as a replacement to photomultiplier tubes in a fast-neutron multiplicity counter is being explored. Silicon photomultipliers are smaller, less sensitive to magnetic fields, and require lower voltage when compared to photomultiplier tubes.

Custom printed circuit boards have been produced to readout signals from arrays of SiPMs coupled to organic scintillators, specifically stilbene crystal.

Detector configurations with SiPMs coupled to stilbene have previously shown comparable pulse-shape discrimination capabilities to PMT based systems [1].

Fig. 1: 4-pixel SiPM array coupled to Ø2" × 2" stilbene in 3D-printed assembly

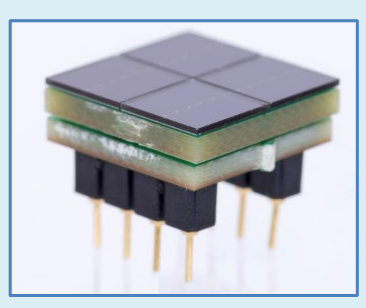

Fig. 2: SensL ArrayJ—4P-EVB SiPM Array

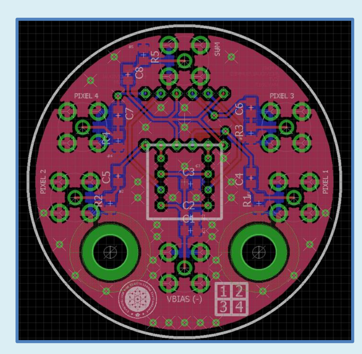

Fig. 3: 4-Pixel Passive SiPM Readout PCB in CadSoft Eagle

Passive Array Readout

- Apply bias to SiPM array cathode and readout individual or summed anode signal
- Preserve accuracy of signal shape and timing
- Optional AC coupling
- PSD capabilities of assembly were evaluated

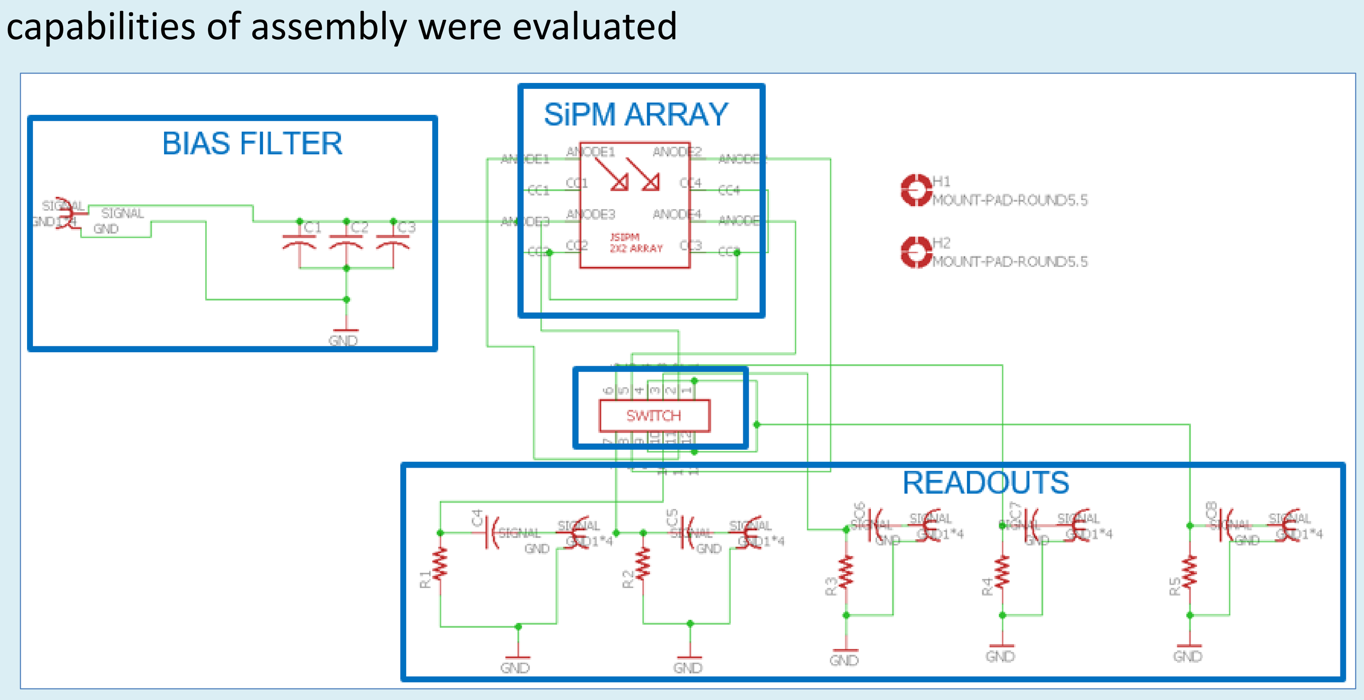

Fig. 4: Neutron back-projection technique

Methods

Setup

- Inrad Ø2" × 2" stilbene crystals wrapped in PTFE tape and coupled to 4P-SiPM array
- Encased in custom 3D-printed plastic enclosure made in SolidWorks
- Assembly placed in dark box
- Array reverse-biased at 29V with desktop power supply
- Signals digitized using CAEN DT5730 at 500 MSa/s
- 95-µCi Cs-137 662 keV gamma ray source used for calibration
- Cf-252 spontaneous fission source used for PSD evaluation

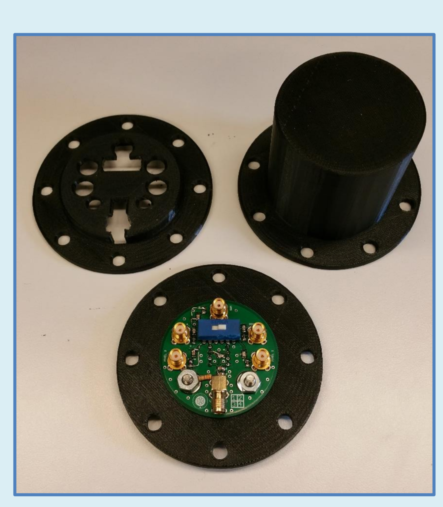

Fig. 5: 3D-printed enclosure

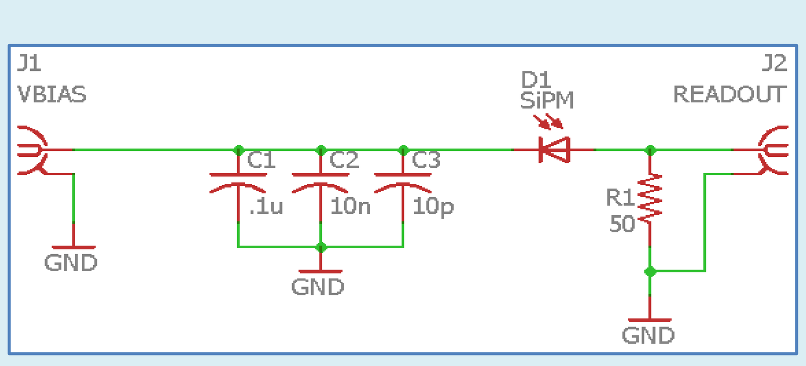

Fig. 6: Simplified single pixel readout circuit

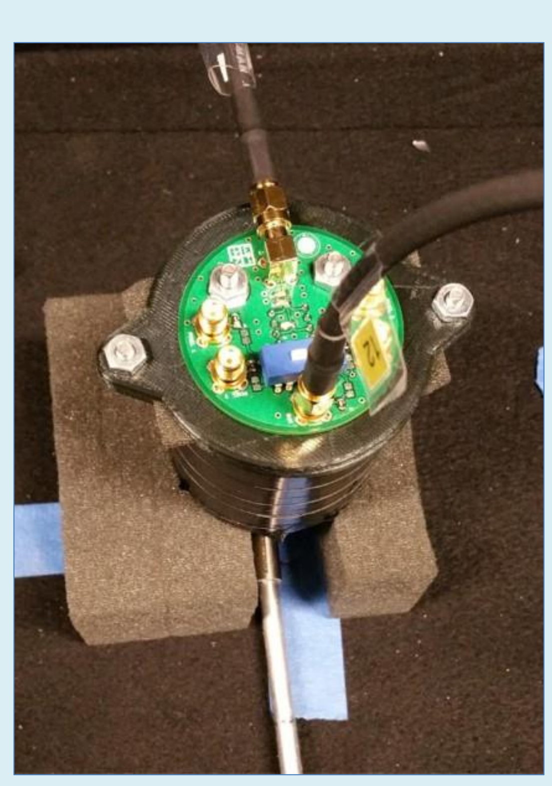

Fig. 7: Experimental setup with Cf-252

Results

- **Analogous pixel response:**
- Individual pixel and summed response
- 95-µCi Cs-137 source
- Observed uniform individual pixel response
- Compton edge picked as 80% of Compton peak

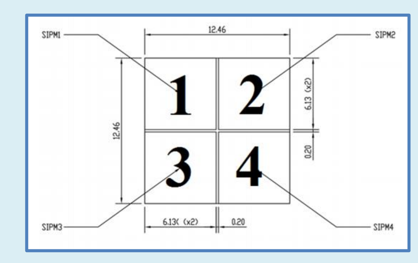

Fig. 8: Pixel numbering scheme

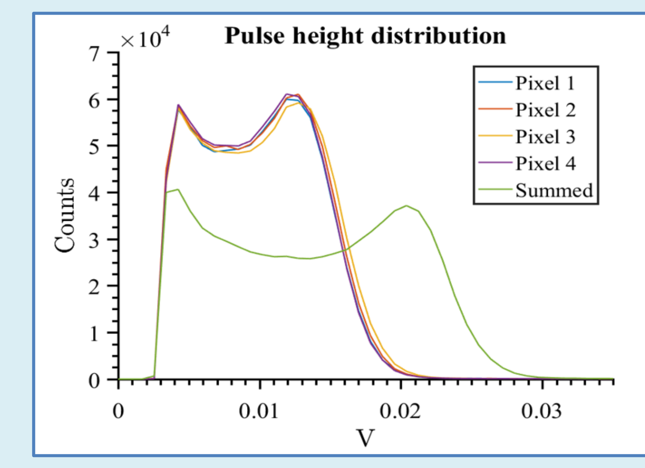

Fig. 9: Pulse height distribution

- **Pulse-shape discrimination:**
- Summed pixel response to Cf-252 source
- Energy calibrated using Cs-137
- Unoptimized PSD parameters
- DC coupled – slow pulses
- Pileup

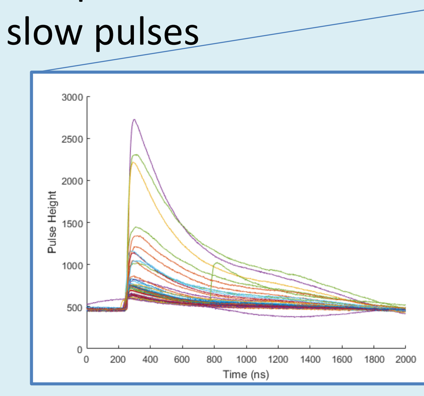

Fig. 10: Pulses from DC-coupled readout

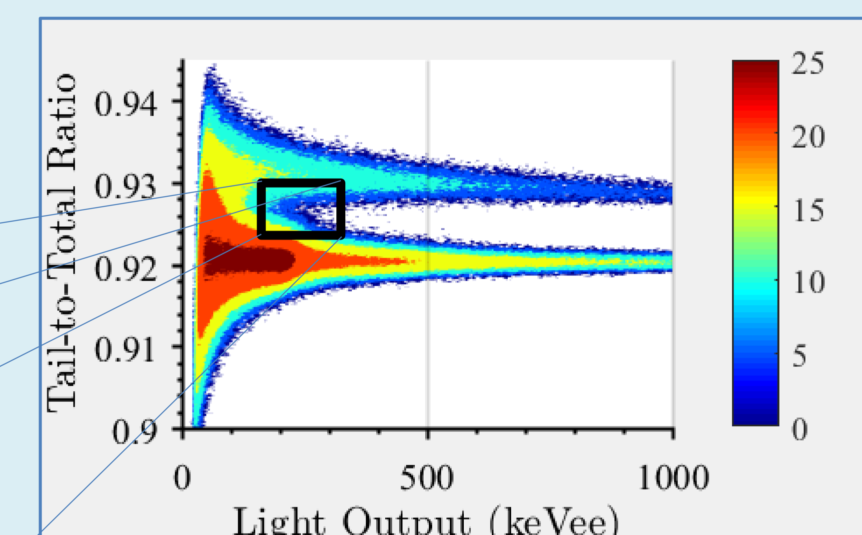

Fig. 11: Tail-to-total vs. light output

- Quantifying PSD performance – figure-of-merit
- Gaussian fit of each particle distribution for an energy bin

$$FOM = \frac{\delta}{FWHM_\gamma + FWHM_n}$$

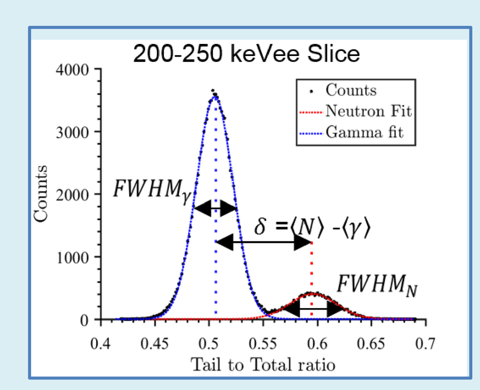

Fig. 12: FOM calculation

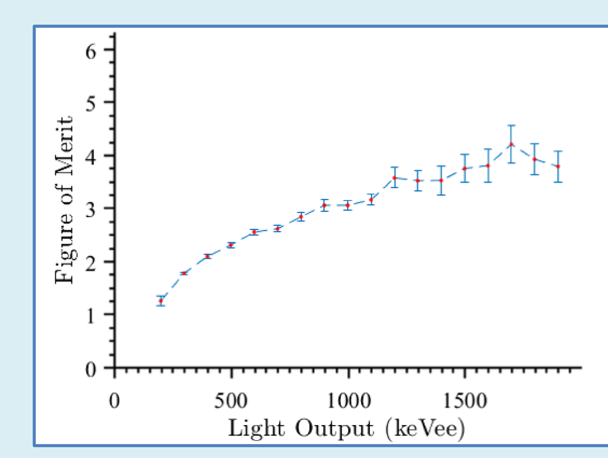

Fig. 13: Pulse integral FOM by slice

Active Acquisition

- Desire larger pulses, with shorter tails to reduce pileup – AC couple and amplify readout
- Simulated frequency response of transimpedance amplifier (TIA) circuit for various feedback and AC coupling designs
- Band-pass: attenuate noise while amplifying signal

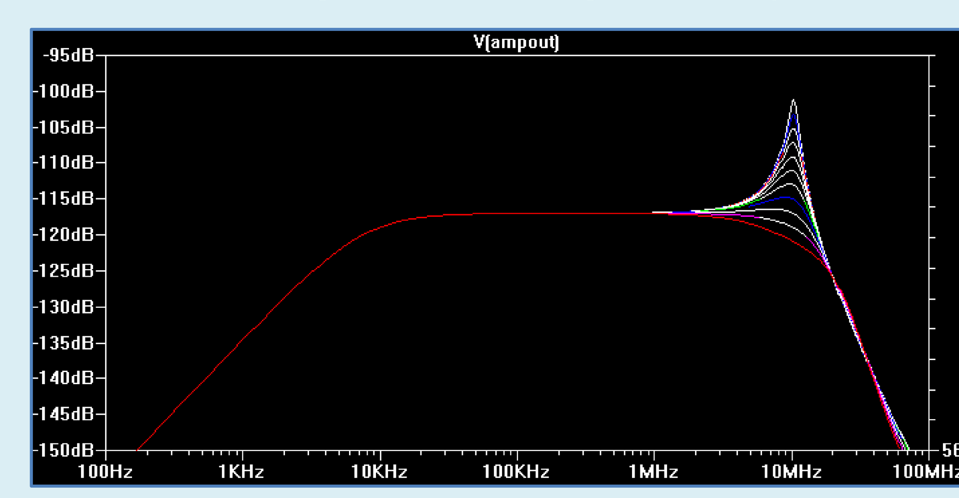

Fig. 12: Active circuit Bode plot

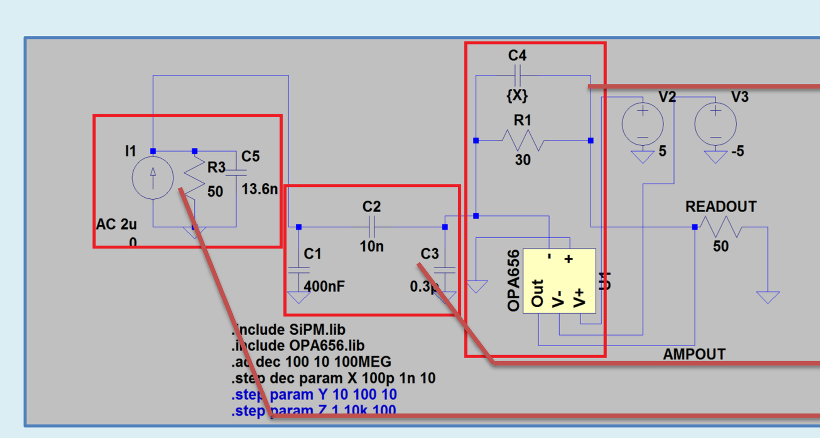

Fig. 13: Active circuit simulated in LTspice IV

- Additional bias required for TIA
- Eventual addition of thermistor to account for SiPM thermal sensitivity

Conclusions

- Signal response is uniform across the SiPM array active area
- Pulse pileup is an issue with DC readout and affects PSD
- Implementing AC coupling and active readout will reduce pileup issue

Further Work

- Evaluate PSD capabilities of passive AC coupled configuration
- Implement active circuit design with transimpedance amplifier
- Examine effects on pulse-shape discrimination
- Replace PMTs in FNMC with SiPM arrays
- Explore temperature sensitivity of detector assembly and implement thermistor in design

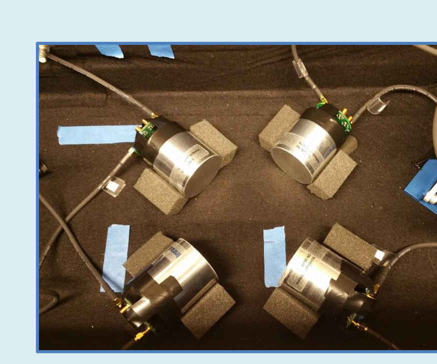

Fig. 14: Several assemblies in a well configuration

References

[1] M. Ruch, M. Flaska, S. Pozzi, "Pulse shape discrimination performance of stilbene coupled to low-noise silicon photomultipliers", NIMA, Volume 793, 1 September 2015, Pages 1–5

This work was funded in-part by the Consortium for Verification Technology under Department of Energy National Nuclear Security Administration award number DE-NA0002534

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