

New developments in neutron measurements for safeguards

- A fast-neutron multiplicity counter (FNMC) based on stilbene and EJ-309 was developed for neutron coincidence and multiplicity counting [1]
 - Sensitive to fast neutrons → no moderation required
 - Low accidentals count rate
 - Partially retain the energy of interacting neutrons
- Silicon photomultipliers (SiPMs) could replace PMTs for crystal readout
 - Fast timing
 - Retain pulse-shape discrimination [2]
 - More compact form factor of the device

Selected detector configuration

The use of the light guide for a crystal-SiPM area ratio of 14x increased the overall detection efficiency of approximately 5%, compared to a direct coupling. This modest efficiency improvement hardly justifies the additional design complexity due to adding a light guide to the assembly.

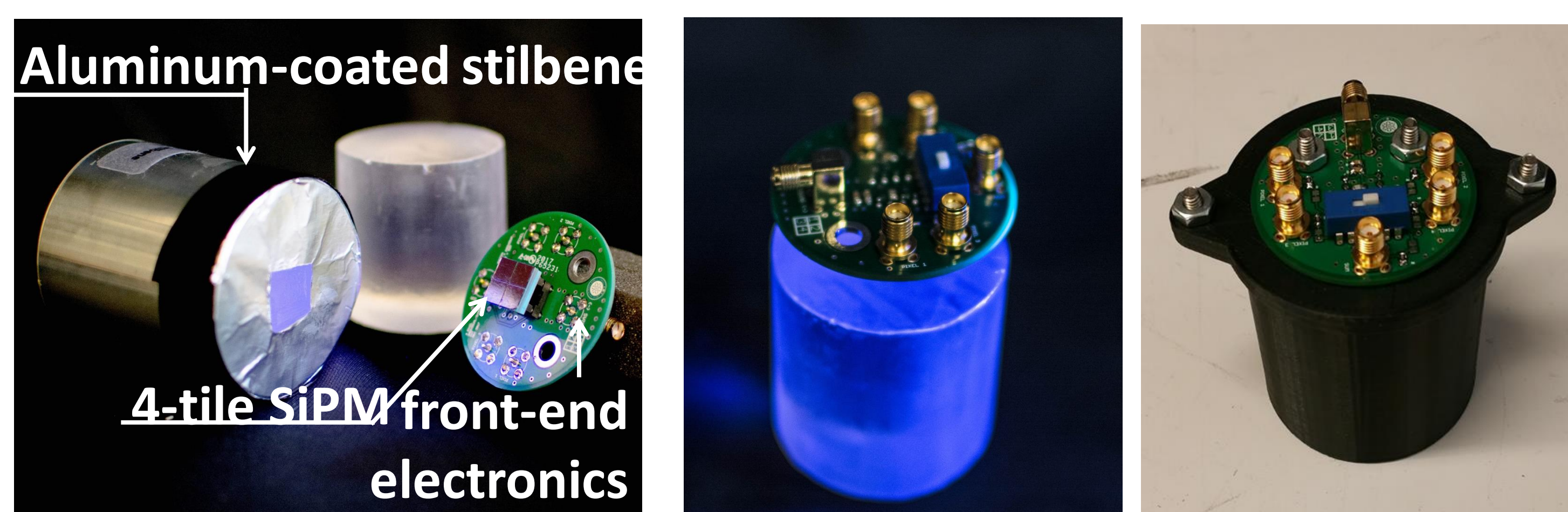


Figure 3. Final configuration of 25.4 mm Ø x 25.4 mm L stilbene crystal coupled to a 4-tile (ArrayJ-60035-4P-EVB) SiPM.

SiPM readout electronics

The current readout architecture is passive.

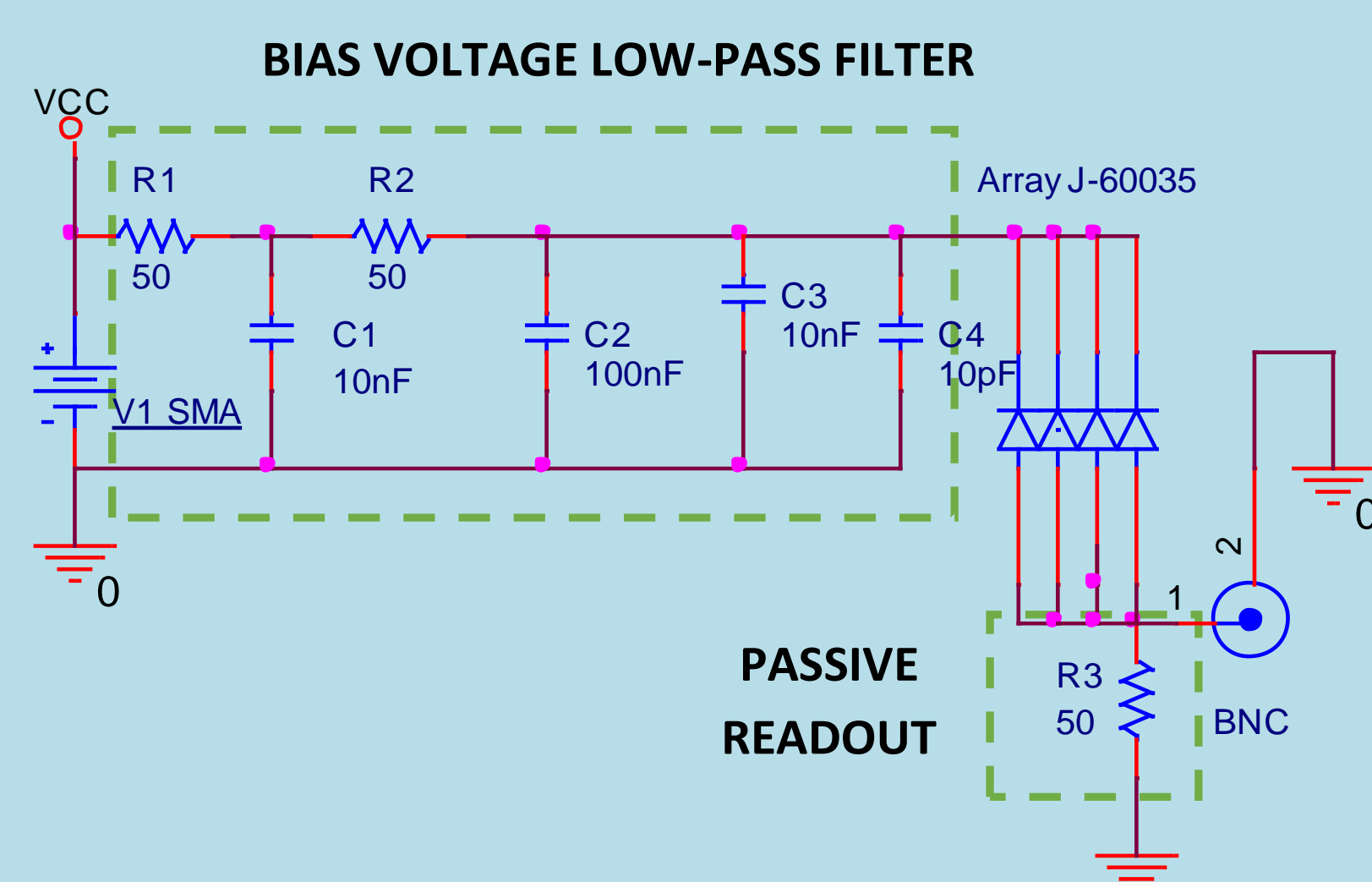


Figure 4. Schematics of the passive readout circuits. All resistor values are in Ohm.

The schematic in Fig. 4 was edited to include AC coupling, which is required to minimize pulse pile-up.

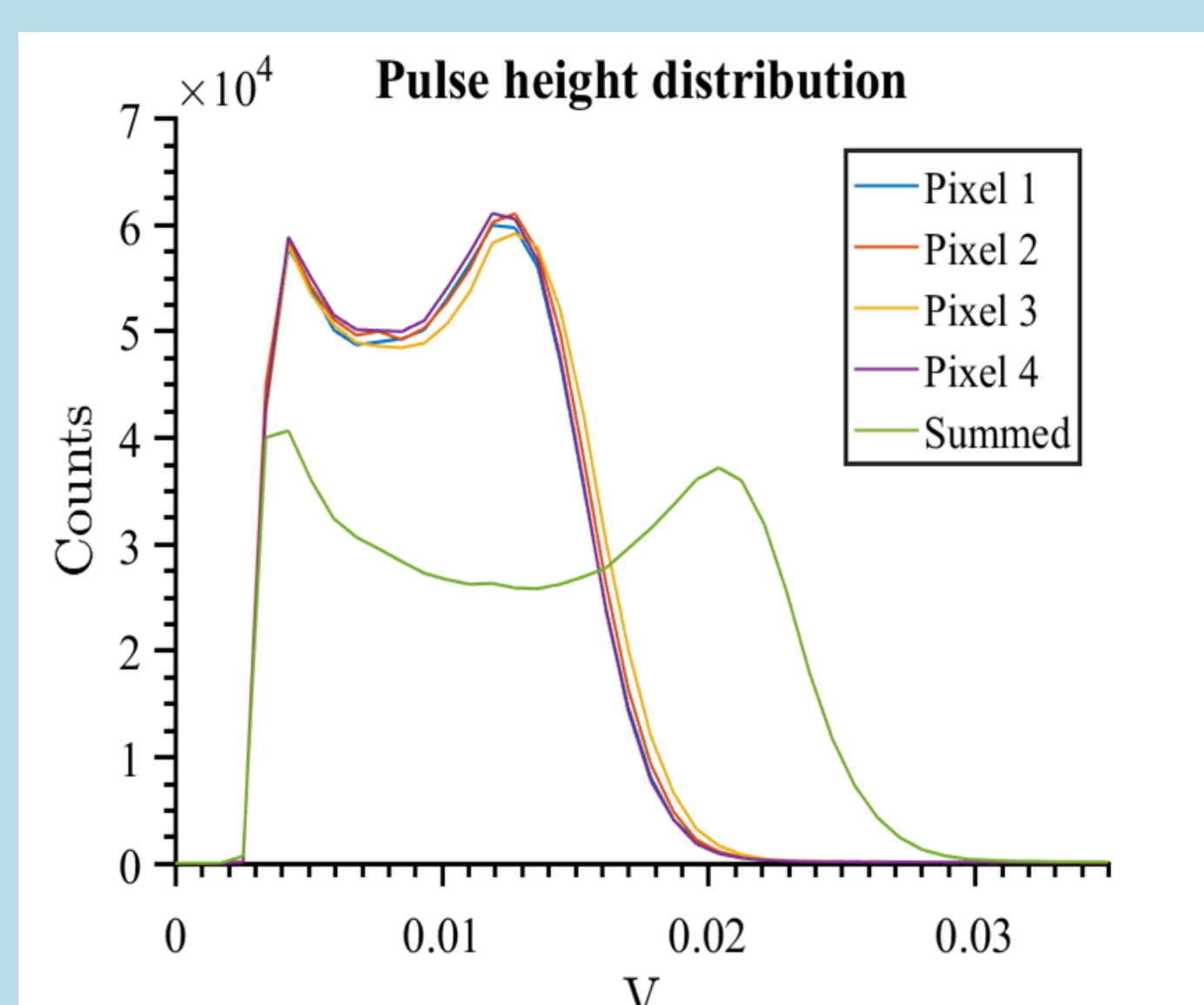
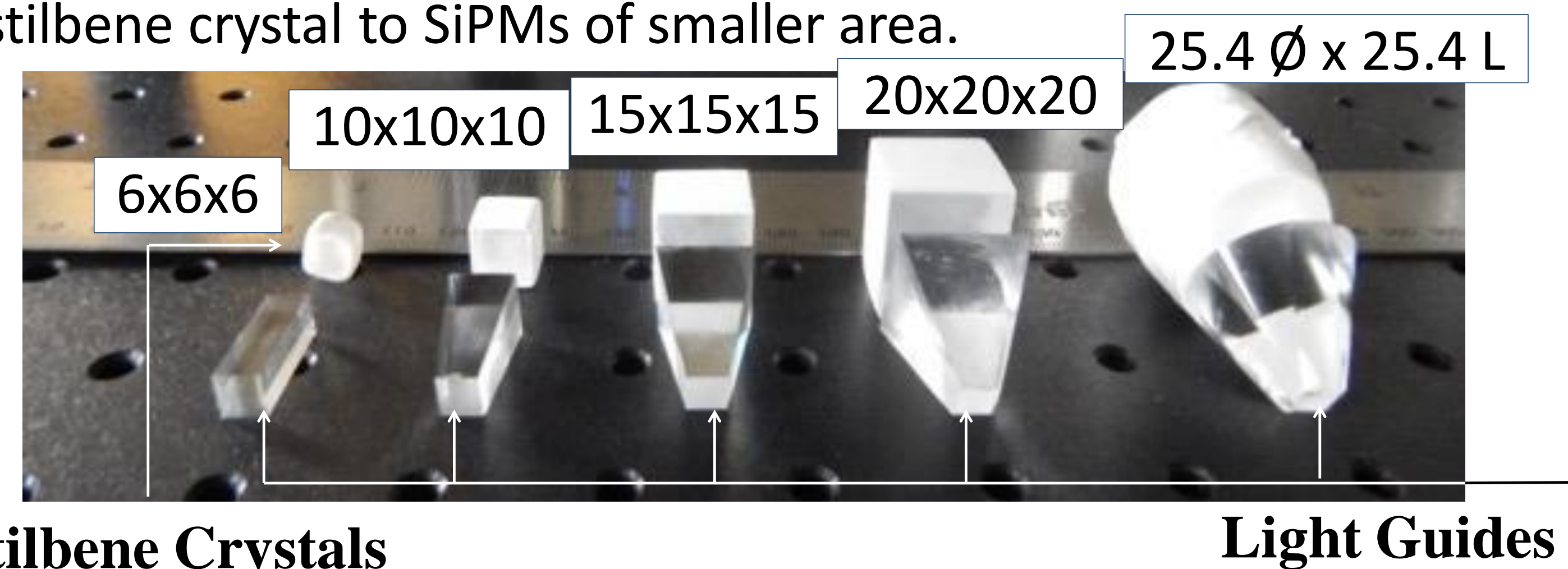


Figure 5. Pulse height distribution of a 91-μCi Cs-137 source.

The response to a Cs-137 source by the single SiPMs is comparable → no single bias per SiPM needed.

SiPM-stilbene coupling light guides

We investigated the use of PMMA UVT light guides to couple stilbene crystal to SiPMs of smaller area.



Stilbene Crystals

Light Guides

Figure 1. Stilbene crystals (top row) and light guides. The SiPM area was 6mm x 6 mm. All dimensions are in mm.

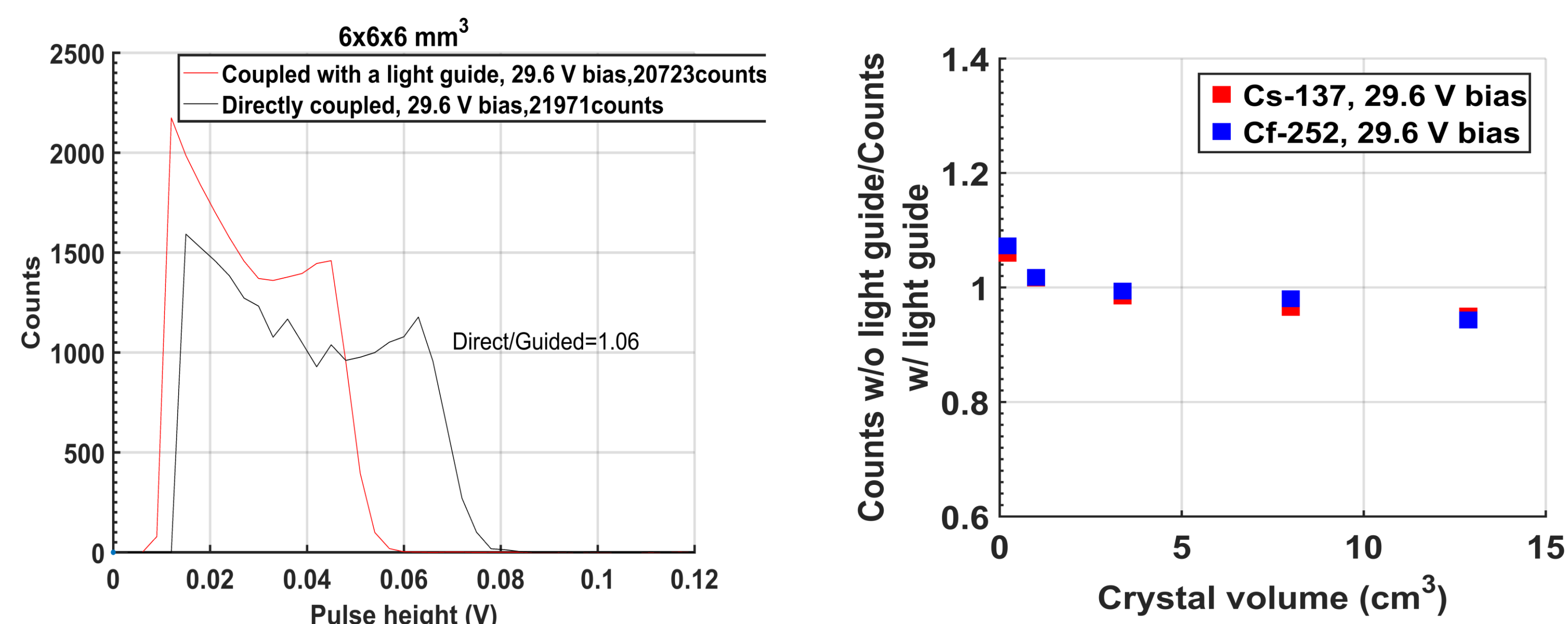


Figure 2. Pulse height distribution with and without a light guide for Cs-137 (left) and ratio of the counts with and without a light guide as a function of crystal volume for a Cs-137 and a Cf-252 source (right).

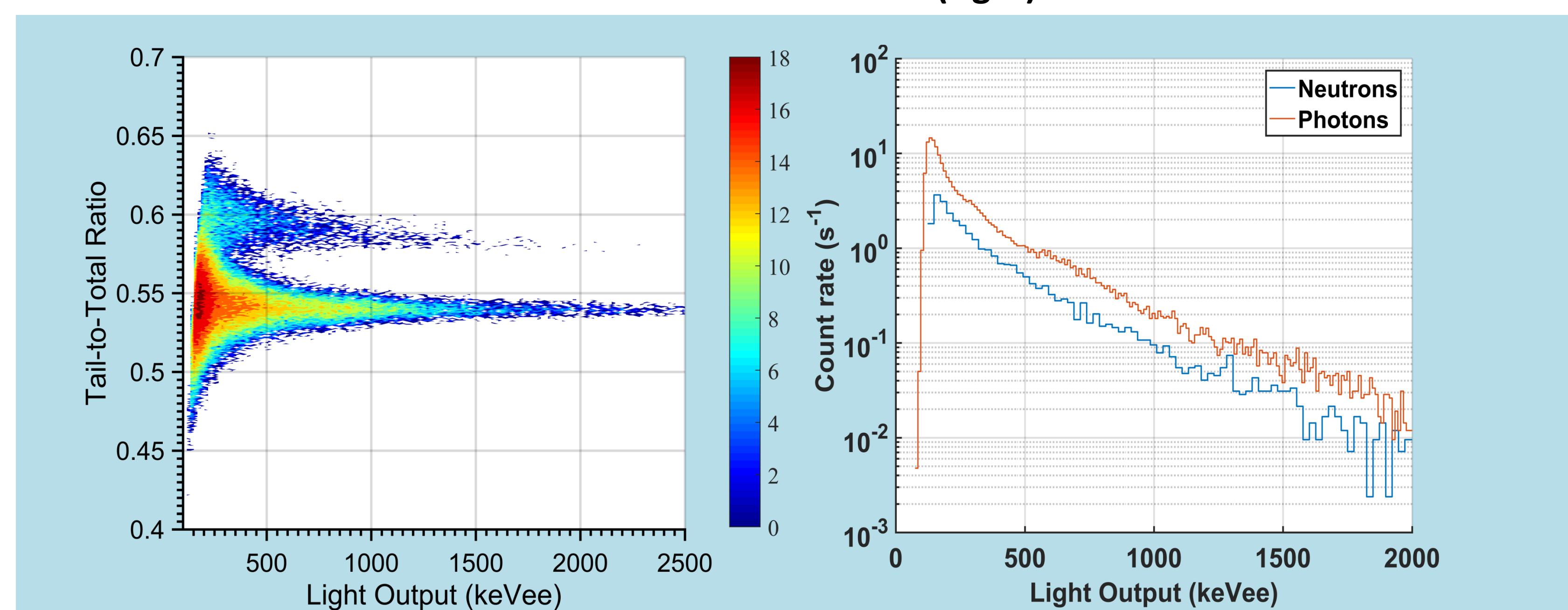


Figure 6. Scatter density plot of tail-total ratio as a function of pulse integral for Cf-252 pulses (left) and pulse height distributions of a Cf-252 source using a 5.08 cm diameter by 5.08 cm length cylindrical stilbene crystal directly coupled to a 12 mm x 12 mm active area SiPM.

Testing of an FNMC based on SiPM readout

Position of a 30 μCi Cf-252 source

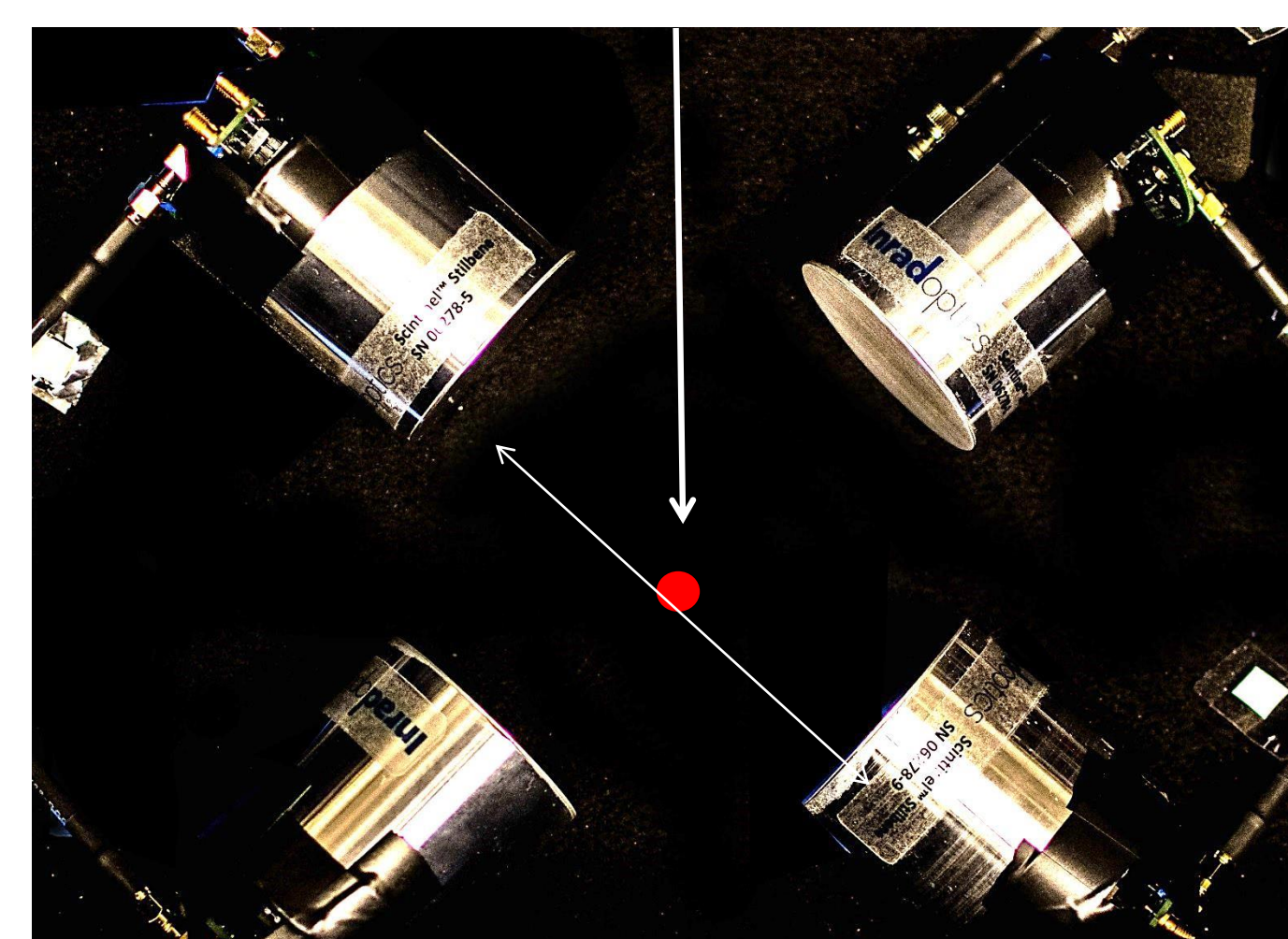


Figure 7. Proof-of-concept of time-correlated measurement using the developed detector units (left) and cross-correlated neutron counts (well radius of 15 cm, 3h measurement time).

References

- [1] A. Di Fulvio *et al.*, "Passive assay of plutonium metal plates using a fast-neutron multiplicity counter," *NIMA*, vol. 855, pp. 92–101, 2017.
- [2] M. L. Ruch, J. Nguyen, M. Flaska, and S. A. Pozzi, "Time Resolution of Stilbene Coupled to Silicon Photomultipliers for use in a Handheld Dual Particle Scatter Camera," in *2015 IEEE Nuclear Science Symposium and Medical Imaging Conference (NSS/MIC)*, 2015.