



Optimizing the length of a singlering of the Total body J-PET

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Abstract:

Total-body PET has begun to be used in clinics, and to expand its applications in hospitals, reducing construction costs is imperative [1], [2]. We are developing a cost-effective total-body PET system utilizing plastic scintillators [2], [3]. The Total Body J-PET scanner comprises several rings, each consisting of 24 modules. A single module contains 32 plastic scintillators divided into two layers, which are read out on both ends by silicon photomultipliers (SiPMs). An additional wavelength shifter (WLS) layer is sandwiched between two plastic layers, which are read with SiPMs on one side.

One crucial aspect of having a cost-effective total-body PET system is optimizing the length of detector for total-body J-PET. We conducted tests on single detector units equipped with SiPMs connected to plastic scintillator strips at the axial ends. By utilizing a collimated beam of 511 keV photons from the Na-22 isotope, we characterized the detector performance, including amplitude, charge, rise time, fall time, and time resolution for various scintillator lengths. The comparison results of various scintillator lengths for optimizing the length of a single ring of the total-body J-PET is presented and discussed.

Total body J-PET:

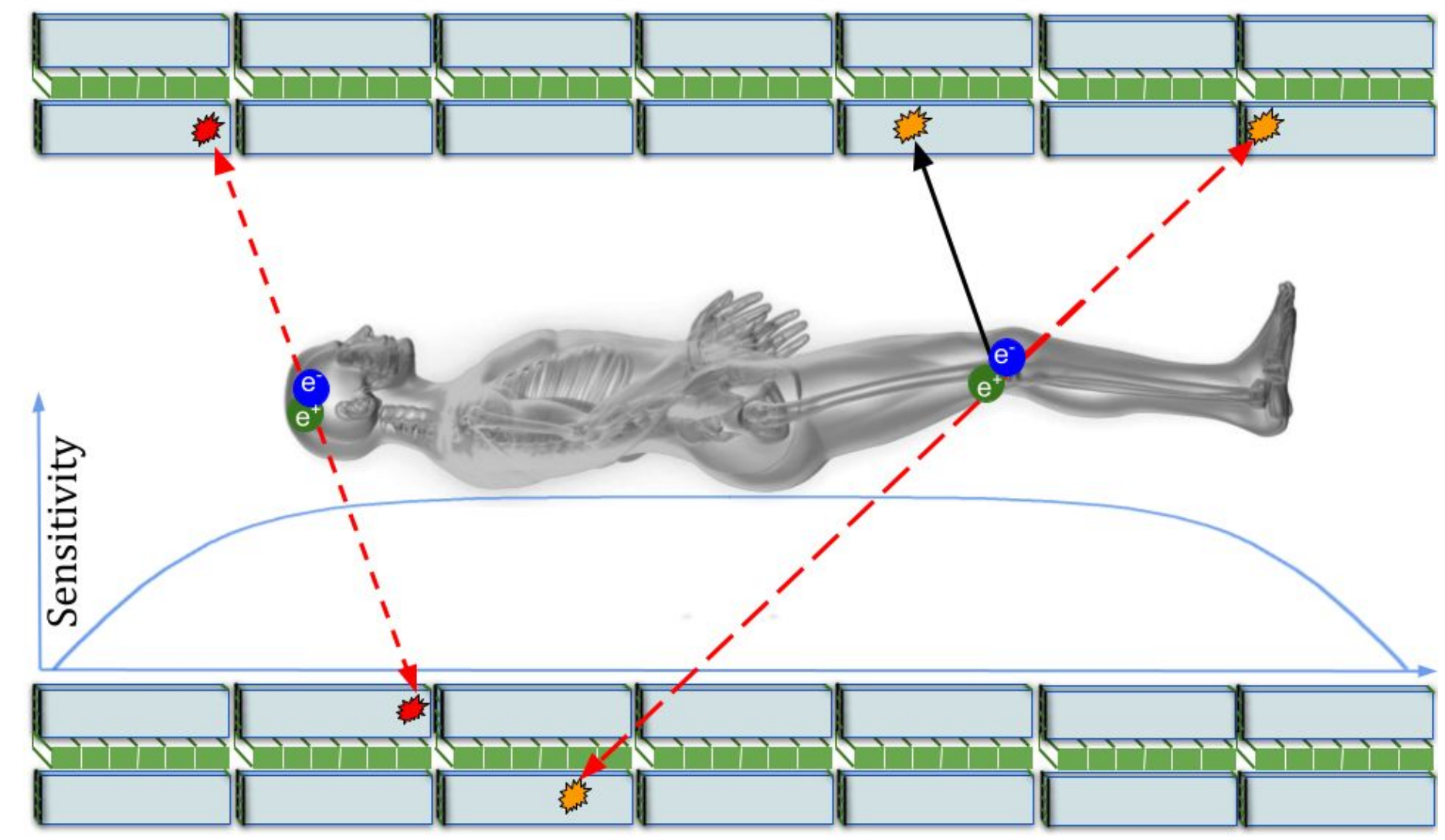


Figure 1. Example of the total body J-PET geometry consisting of several rings.

Experimental setup:

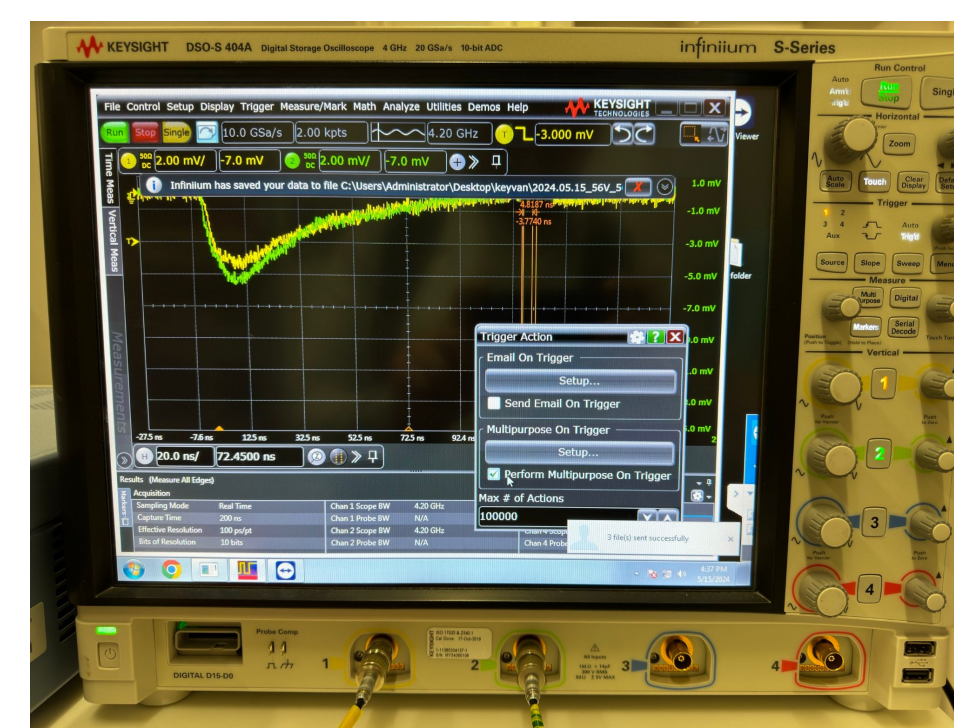
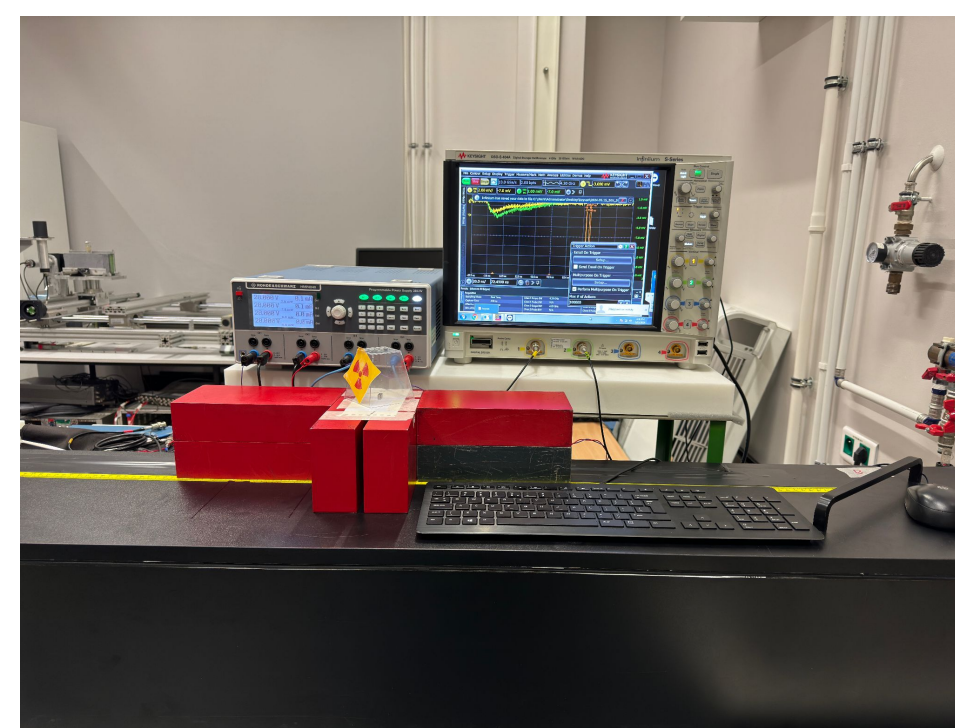
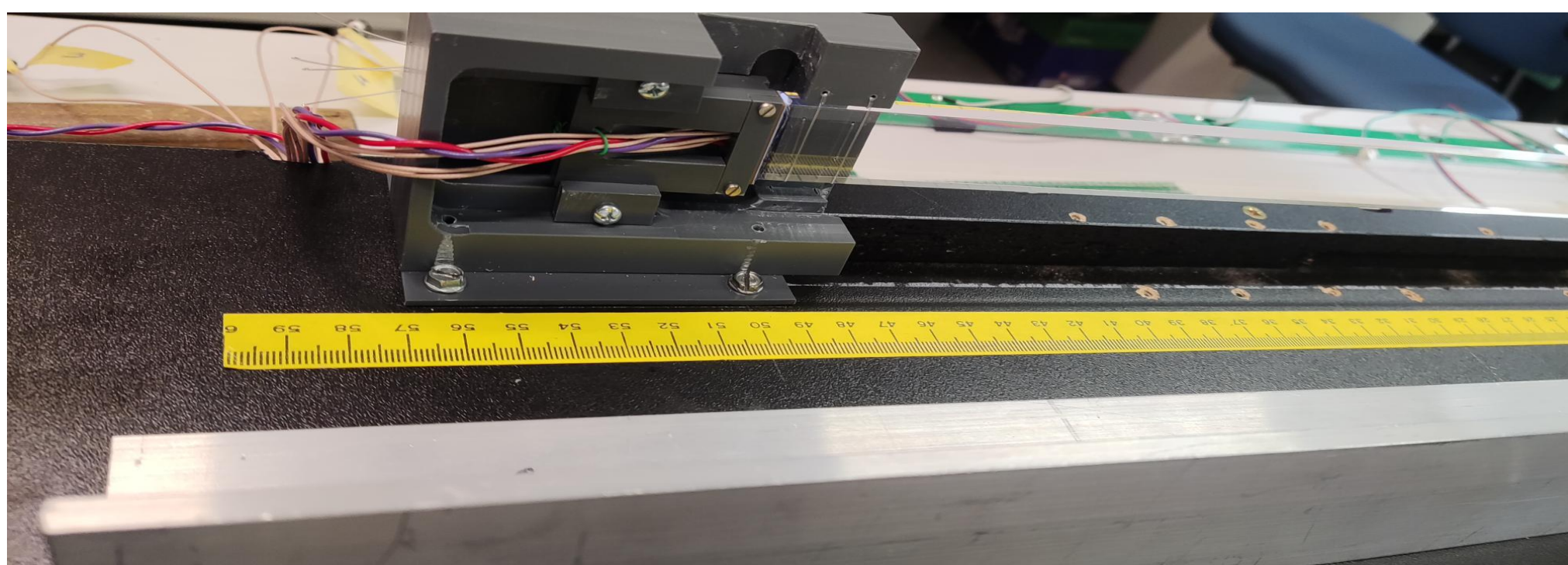


Figure 2. Schematic view of the experimental setup. (Left) SiPMs connected axially to both sides of the plastic scintillator. (Middle) Use lead blocks to collimate the beam of 511 keV photons from the Na-22 isotope. (Right) Example of the signal on the oscilloscope.

Scintillator Lengths: 100, 60, 33 and 5 cm.
Scan in the different position of the scintillators:
 $\pm 25\%$ of the length & center & ± 3.5 cm from the edge of the scintillators
SiPM: Hamamatsu S13361-6674
Breakdown voltage = 53 V
Over voltage = +3V
Scintillator: EJ-200
Source: Na

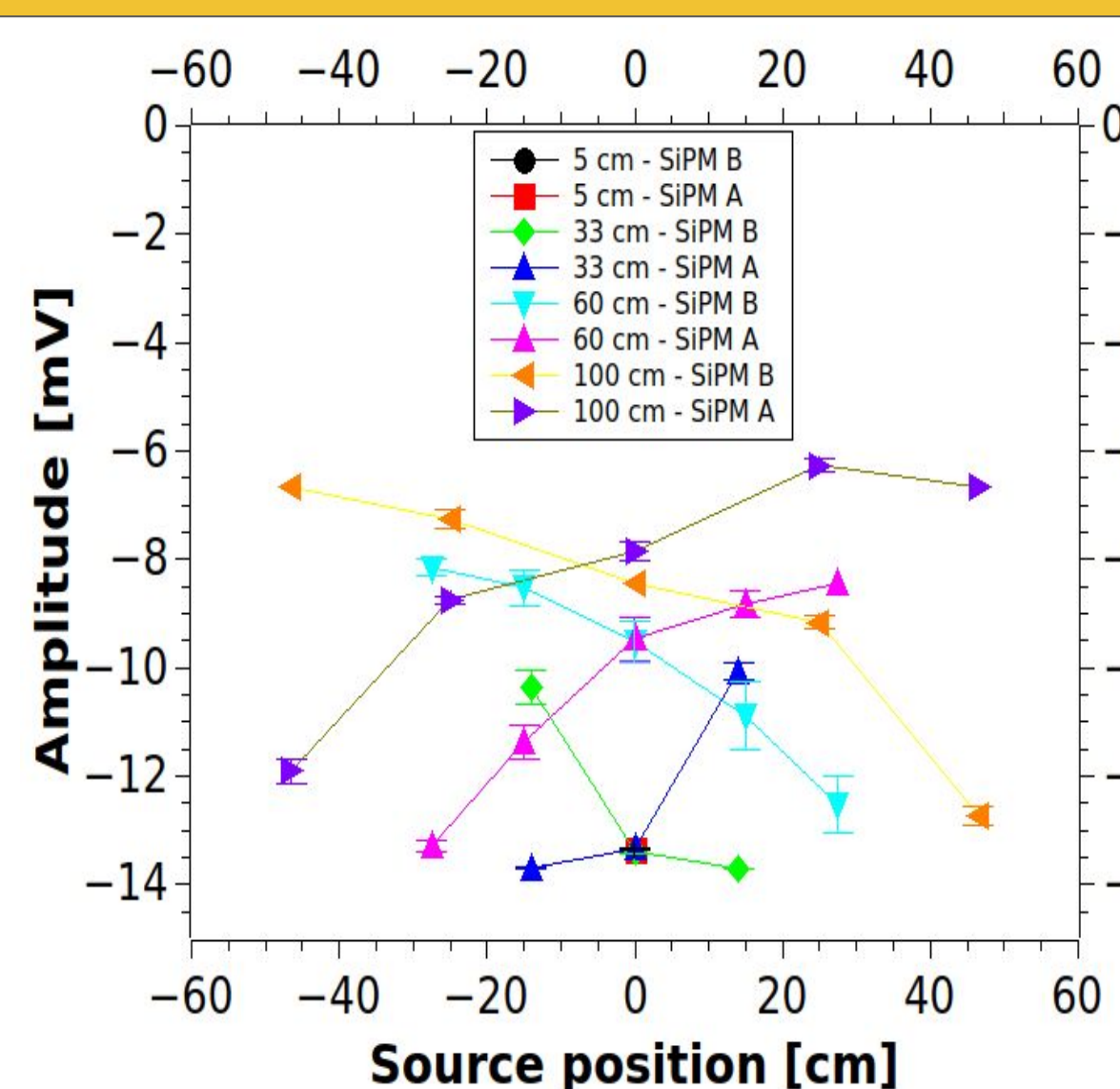
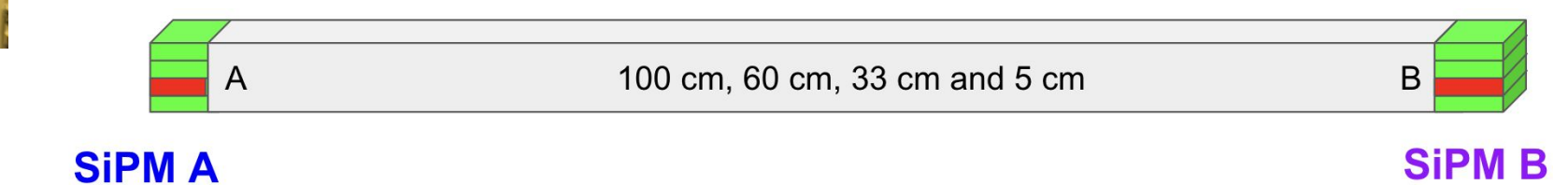


Figure 4. Amplitude from both SiPM based on different positions and lengths of the scintillator

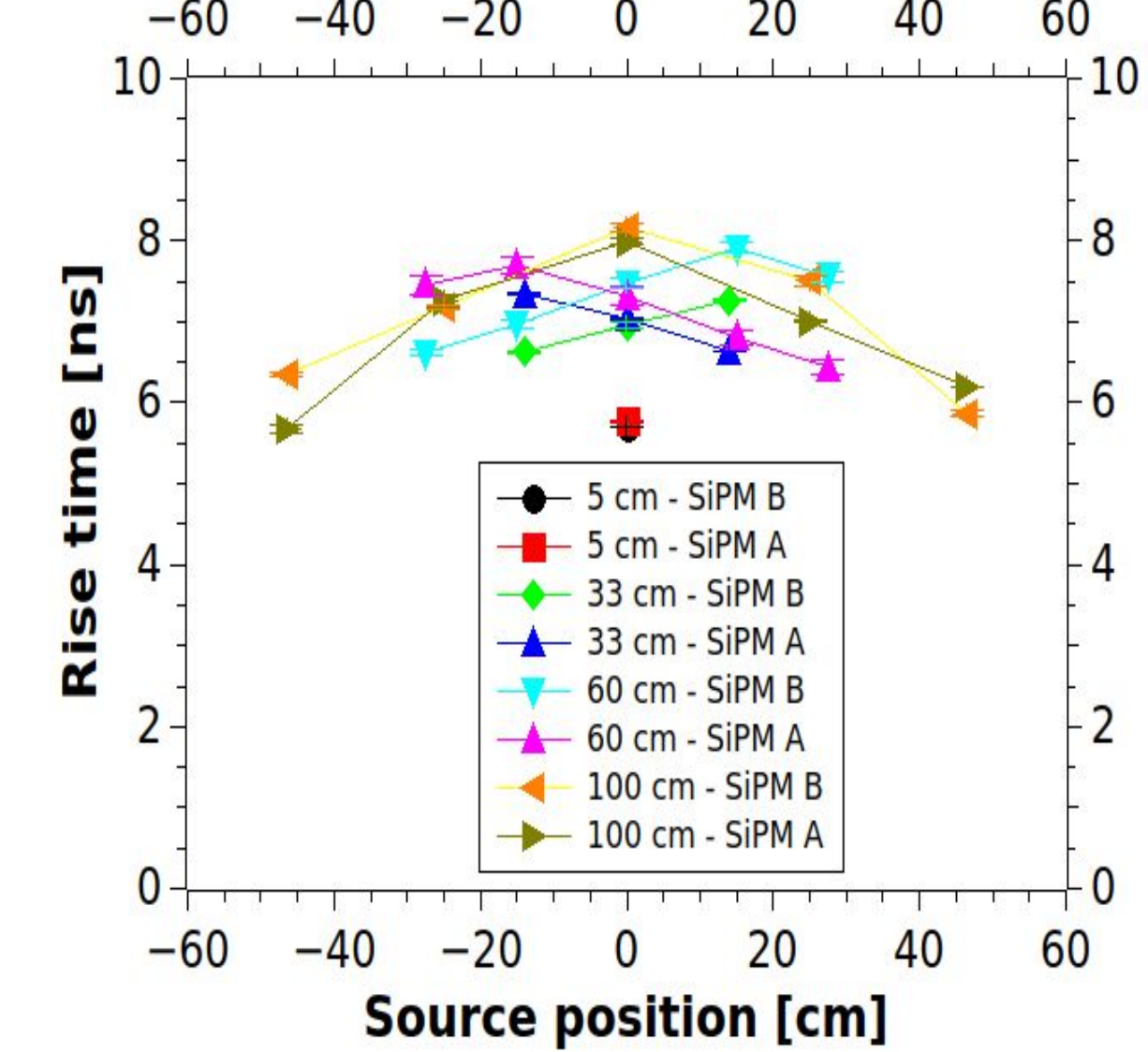


Figure 6. Rise time based on different positions and lengths of the scintillator

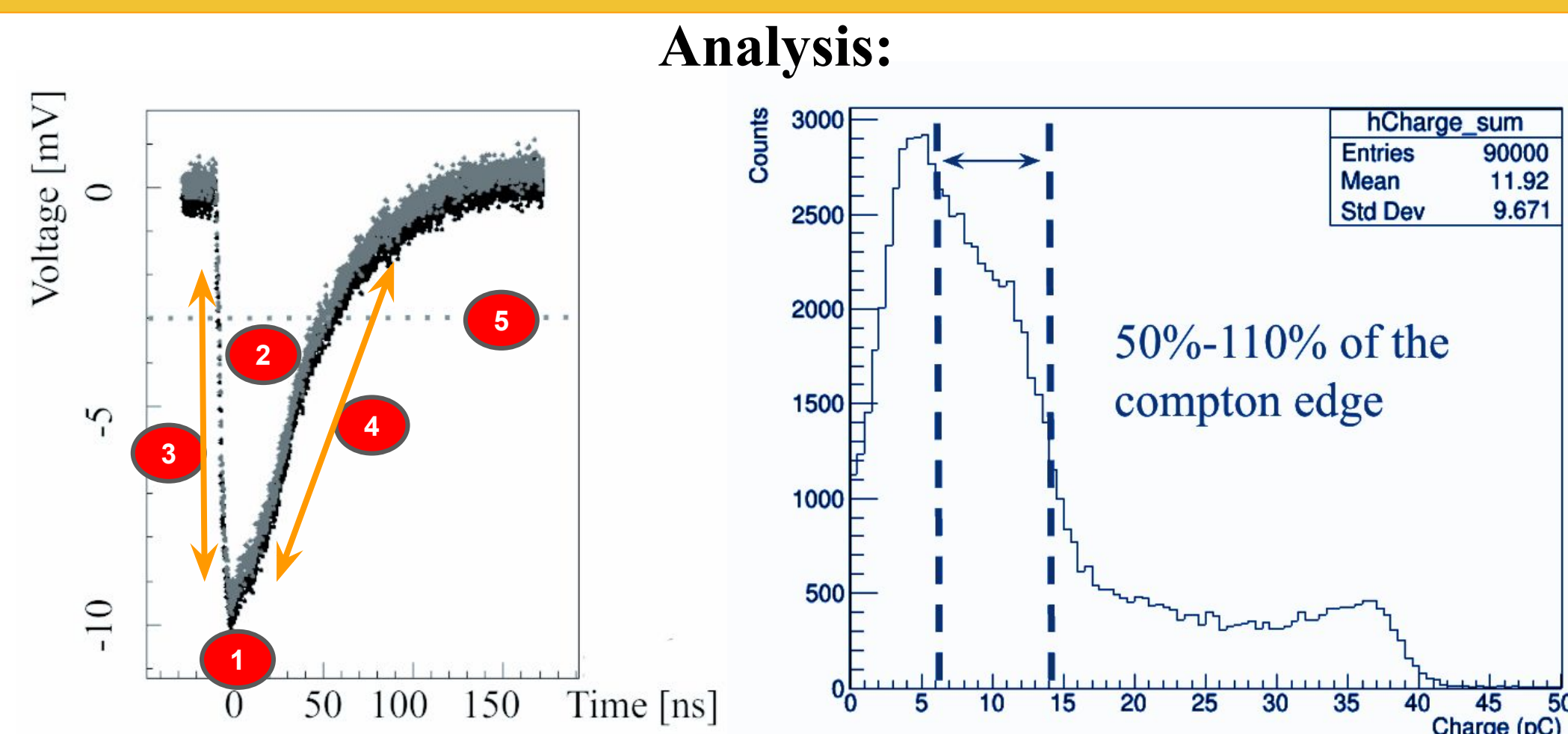


Figure 3. (Left) Sample of the one signal. (Right) raw charge sum spectra.
1- Amplitude (Minimum pick) 2- charge (area under the red signal) 3- Rise Time (based on 10-90% of amplitude) 4- Fall Time (based on 90-10% of amplitude) 5- Time difference (is the difference between the rising edge in constant threshold from both SiPMs)

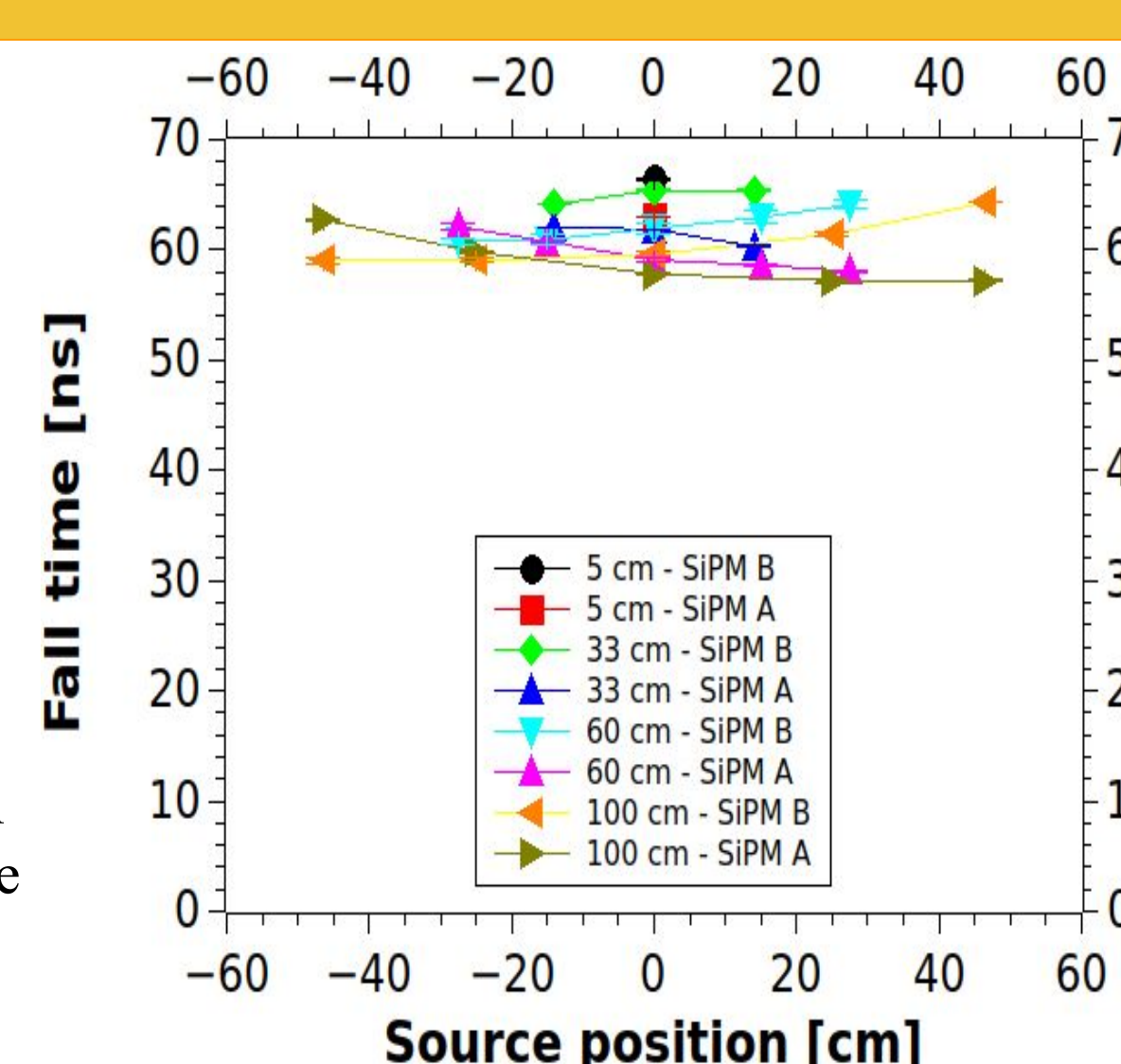


Figure 7. Fall time based on different positions and lengths of the scintillator

Figure 8. Sigma (TOF) based on different positions and lengths of the scintillator

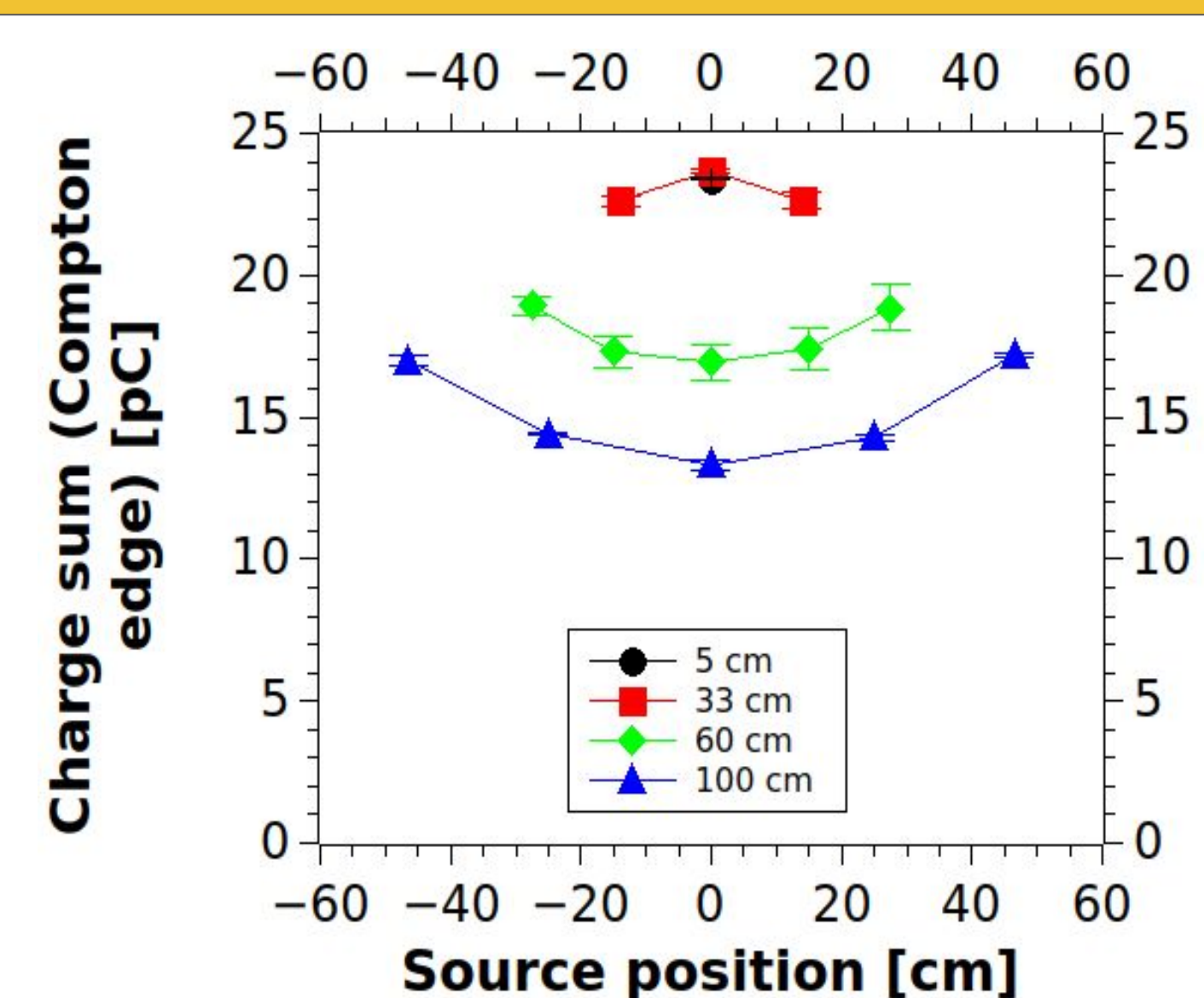


Figure 5. Charge sum based on different positions and lengths of the scintillator

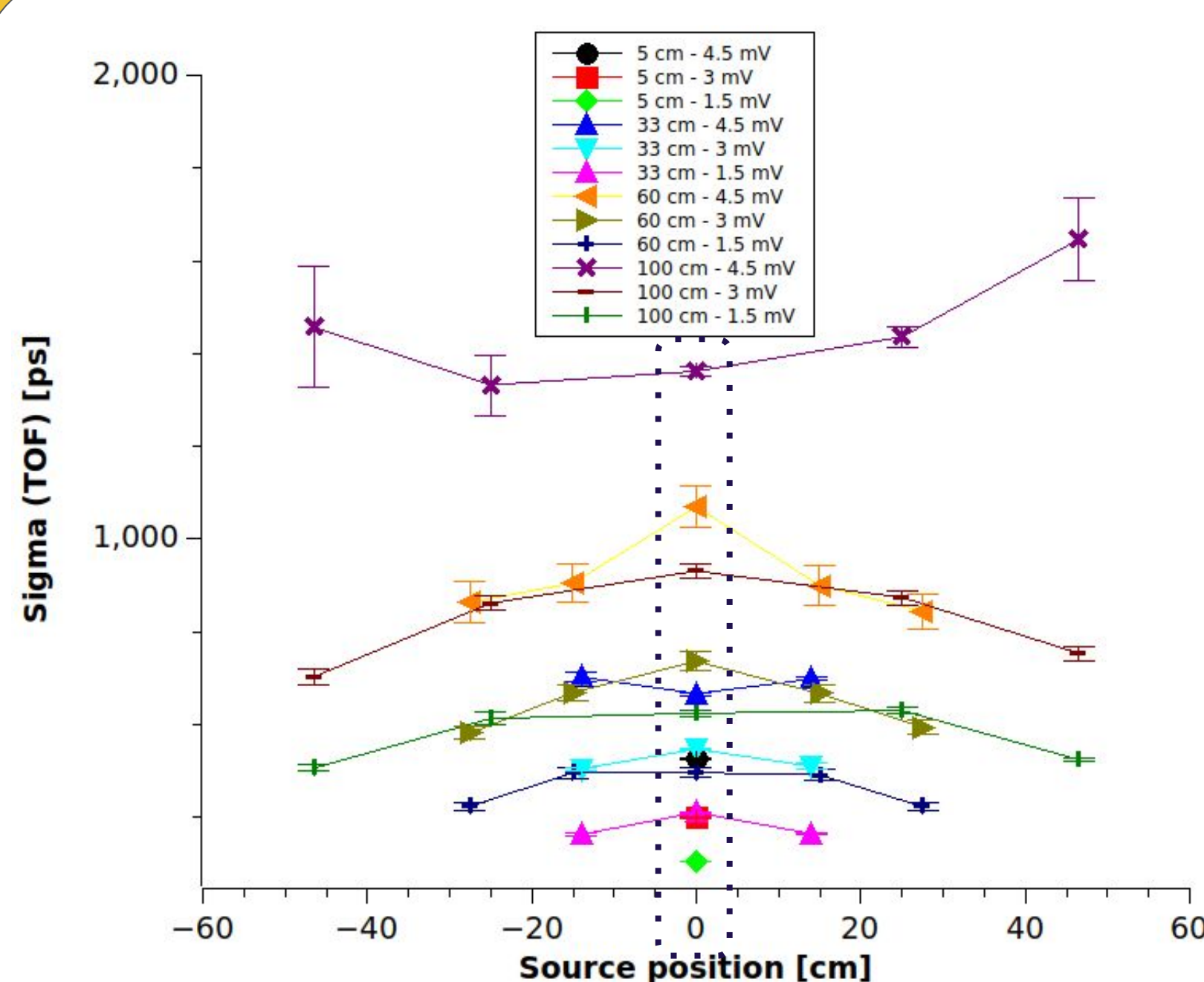
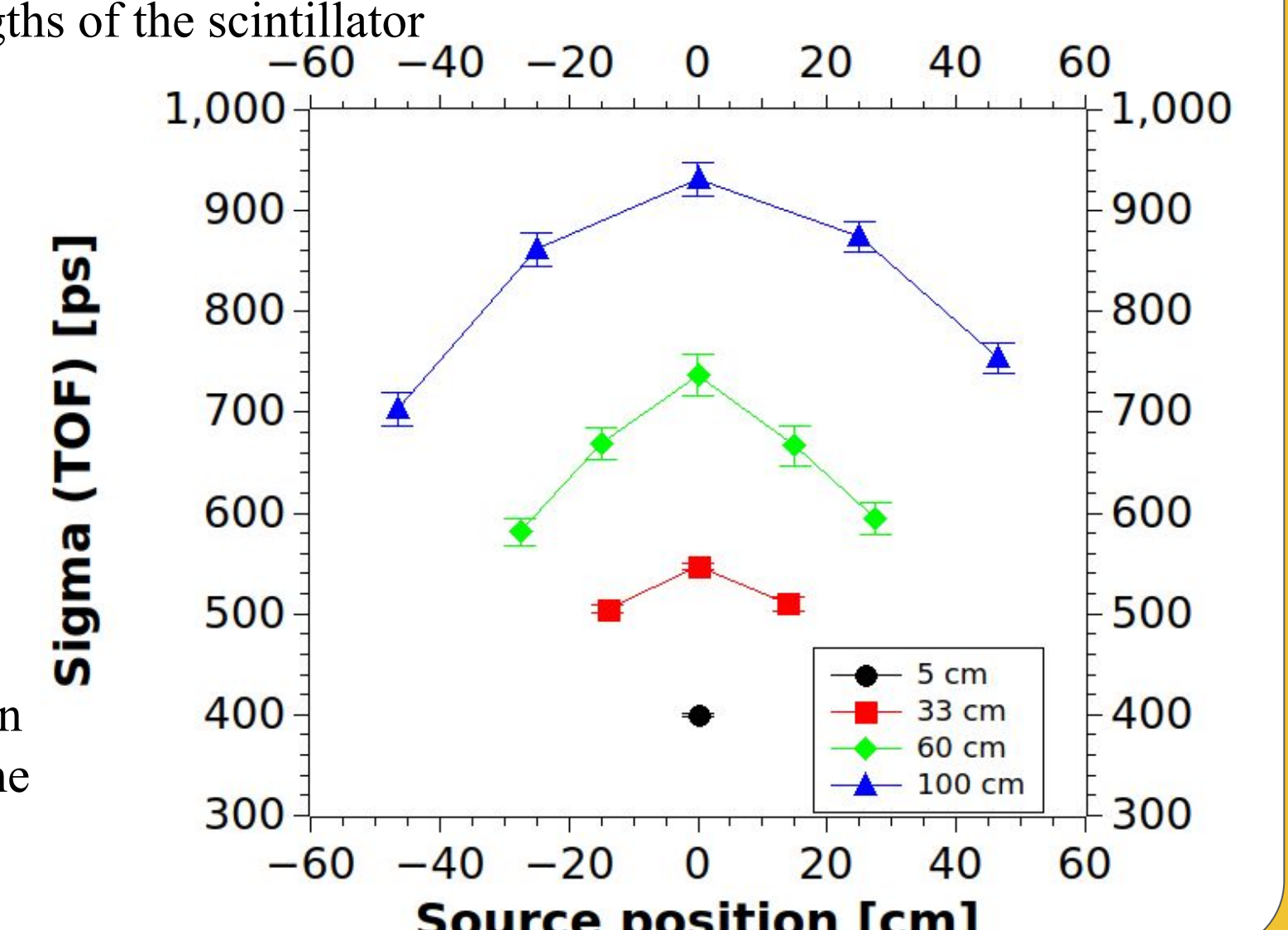


Figure 9. Sigma (TOF) based on different positions and lengths of the scintillator at various constant thresholds.

Time based on the Over Voltage:

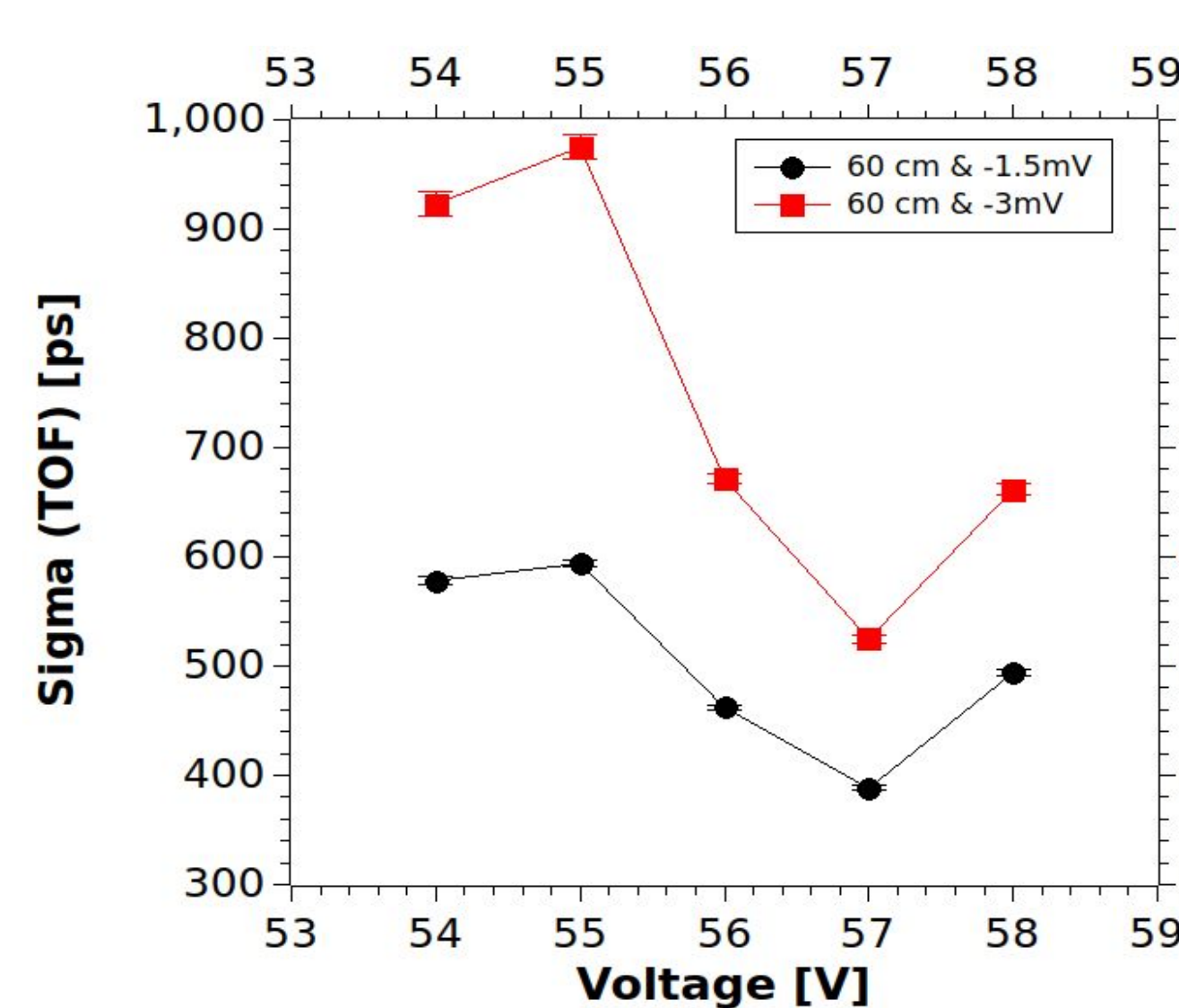
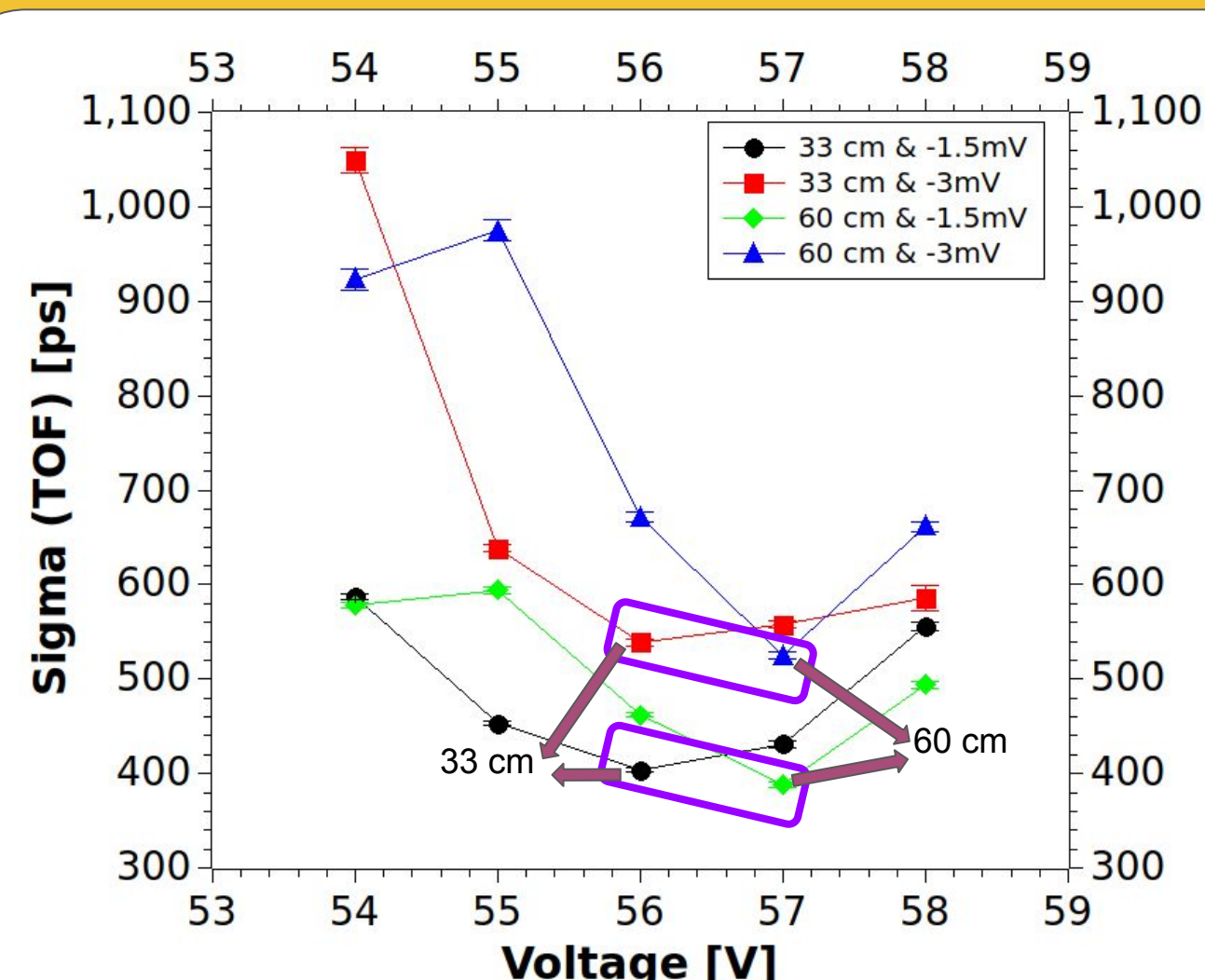
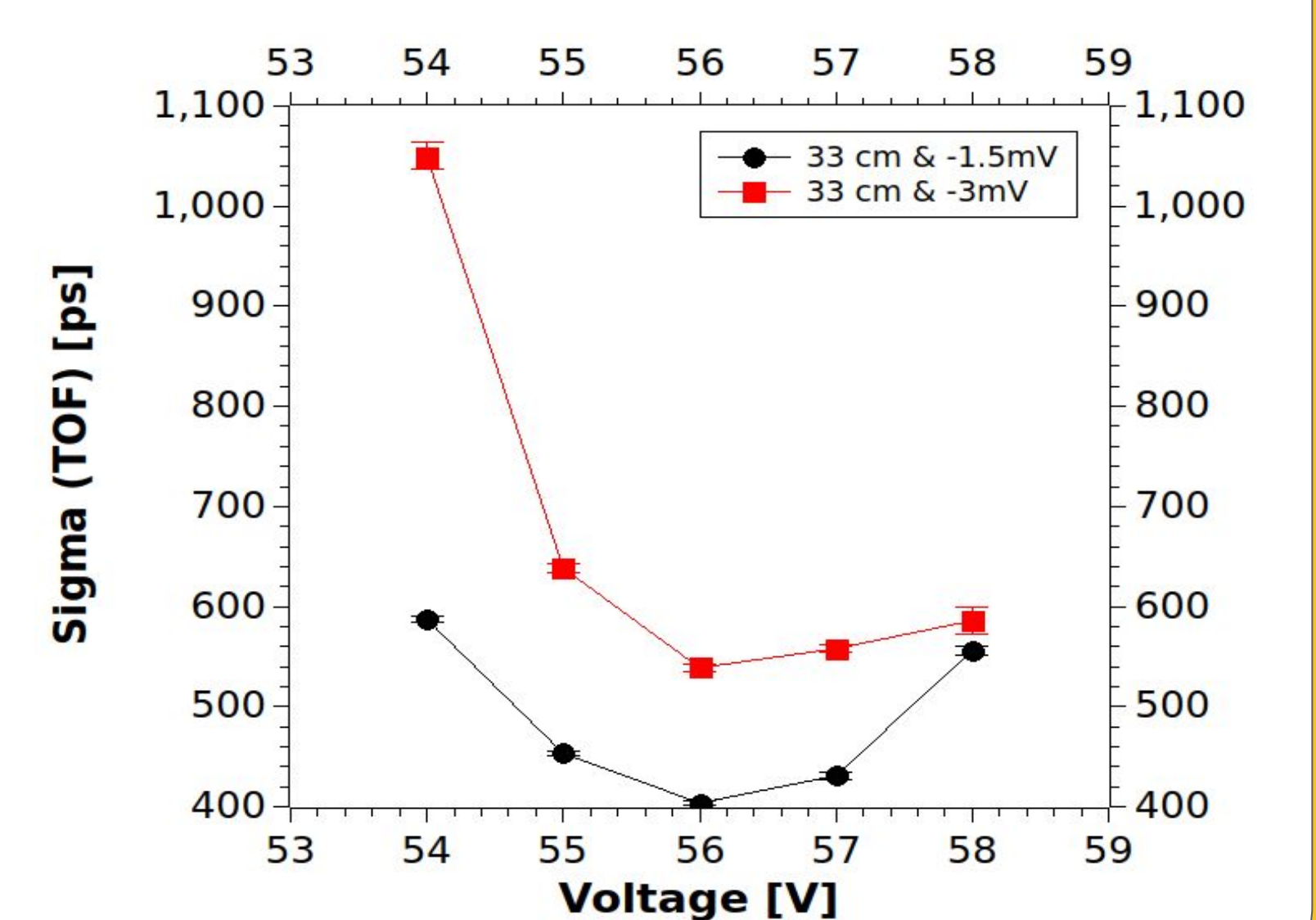


Figure 10. Sigma (TOF) at the center position of the scintillator with the length of 60 cm at various constant thresholds based on different voltages.

Figure 11. Sigma (TOF) at the center position of the scintillator with the length of 33 cm at various constant thresholds based on different voltages.



Conclusion

We characterized the SiPM performance for different lengths of the scintillator and observed that shorter scintillators provide better time resolution.

In the next step, we applied different over-voltages to scintillators with lengths of 60 cm and 33 cm. For the 33 cm scintillator, a +3V over-voltage resulted in better resolution, while for the 60 cm scintillator, a +4V over-voltage provided better resolution.

As shown, the 60 cm scintillator with a +4V over-voltage achieves better time resolution than the 33 cm scintillator with a +3V over-voltage.

Acknowledgment:

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References:

- [1]. S. Vandenberghe et al., "The potential of a medium-cost long axial FOV PET system for nuclear medicine departments", EJNMMI 50 (2023) 652-660.
- [2]. P. Moskal, E. Stępień, "Prospects and Clinical Perspectives of Total-Body PET Imaging Using Plastic Scintillators", PET Clinics 15 (2020) 439-452.
- [3]. P. Moskal et al., "Simulating NEMA characteristics of the modular total-body J-PET scanner—an economic total-body PET from plastic scintillators", Phys. Med. Biol. vol. 66, pp. 175015, 2021.