Simulation Study of SiPM Sensitivity to Rayleigh Scattering Measurement in the TallBo Chamber

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Experimental Setup

TallBo is a cryostat which will be used in experiments to analyze and reduce uncertainty in the optical properties of liquid argon. Knowing these properties is essential to obtaining accurate data from experiments that use liquid argon detectors, such as DUNE.

In preparation for the TallBo experiment, we develop and run photon simulations on this geometry. This allows us to identify the best places to put our 12 SiPM light sensors for the experiments and provides us with some baseline results to compare.

- Standalone Geant4 for simulation
- GDML for geometry
- Specifiable LAr level, scattering length, and absorption length within geometry file
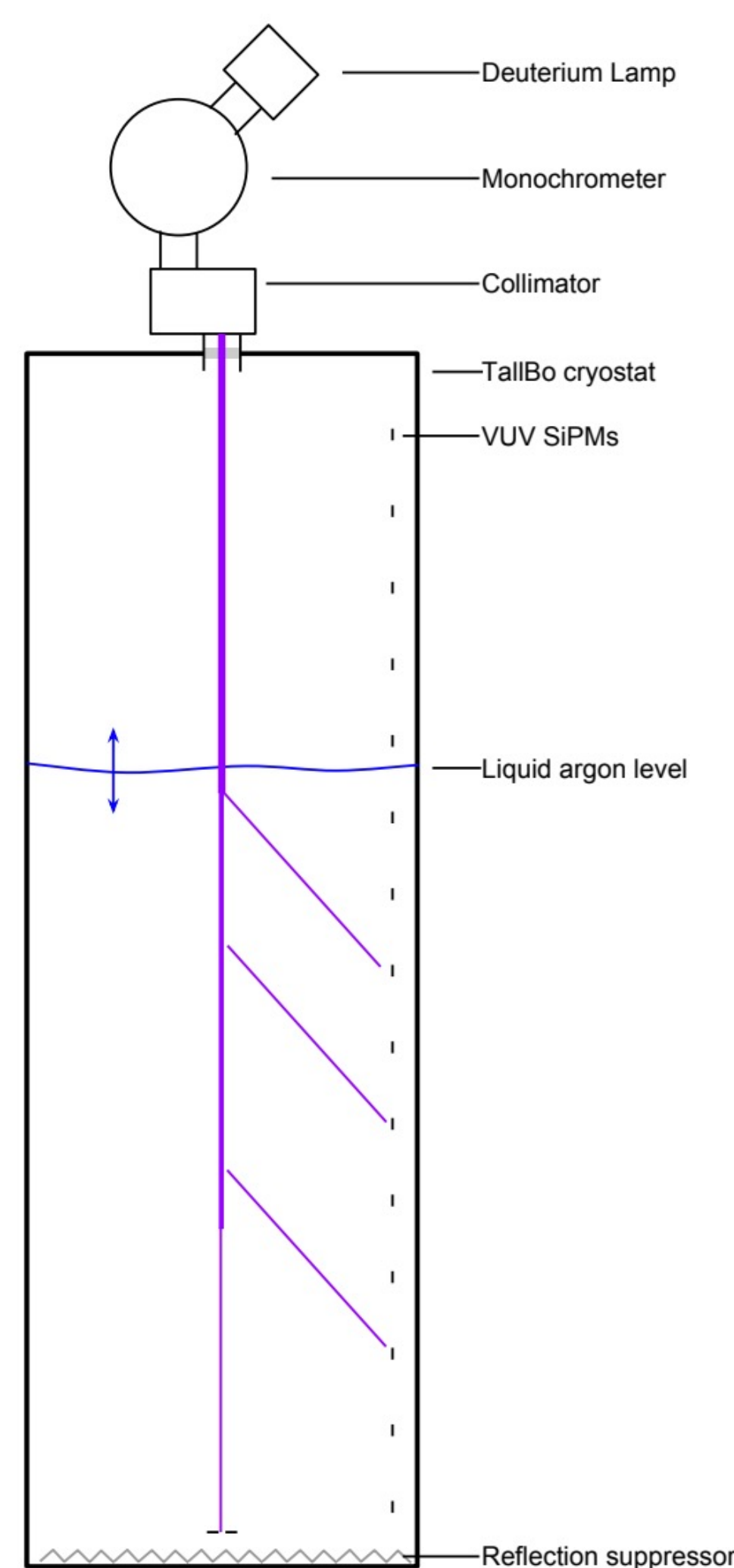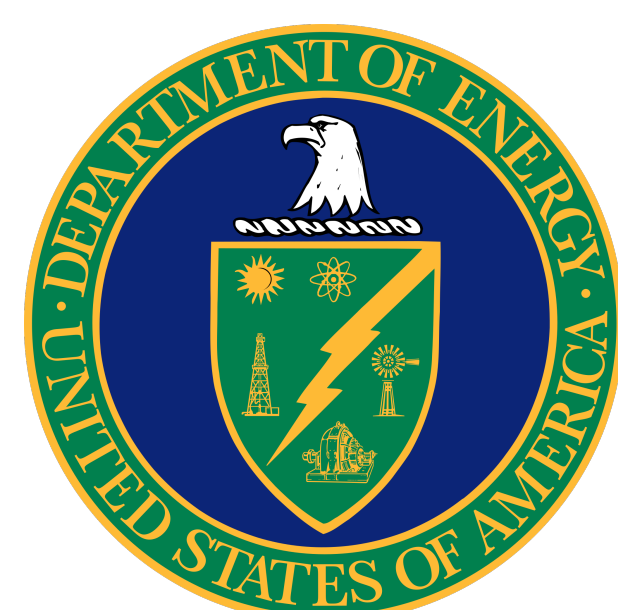- 101 possible SiPMs (0-48 on bottom, 49-100 along the sides)

Figure 1: A schematic of the TallBo cryostat geometry. The shapes on the top of the cylinder are part of the light source, whereas the cylinder itself is to be filled with liquid argon and is the volume to be simulated in this project.

Simulation Validation

We ran several benchmark simulations to validate that the results follow what we expect. First, we looked at how the LAr fill level affects the number of photon hits on the SiPM directly underneath the light source.
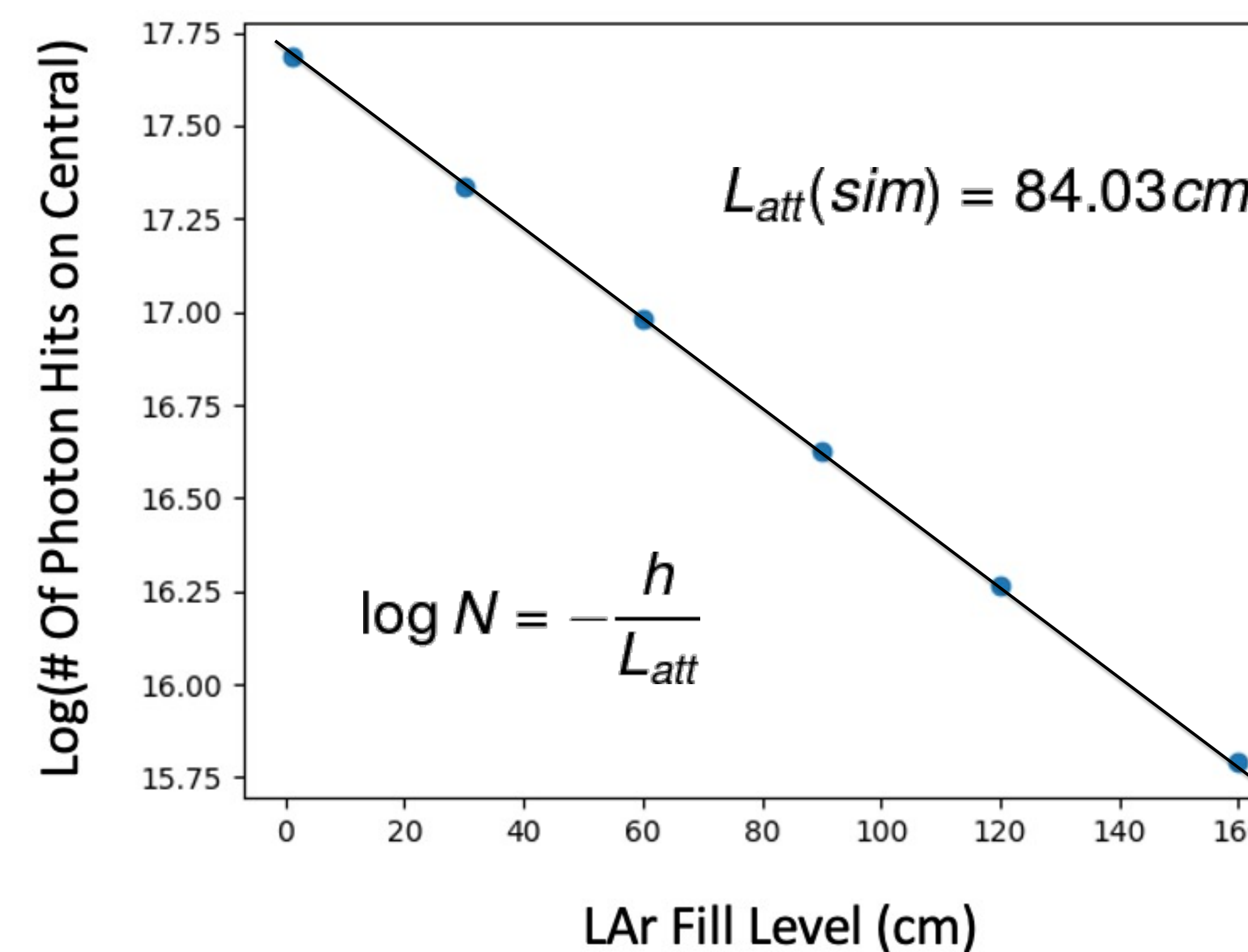

$$L_{att}(sim) = 84.03\,cm$$

$$\log N = -\frac{h}{L_{att}}$$

Figure 2: A log-scale plot of LAr fill level (max 180 cm) vs. the number of photons hits on the central SIPM. A total of 5e7 photons were made during the simulation. The line of best fit of this data can be used to determine the attenuation length predicted by the simulation using the Beer-Lambert Law.

The attenuation length can also be calculated manually using our configured scattering and absorption lengths. We can compare this to the result from the simulated data to validate our simulation.

$$\frac{1}{L_{att}} = \frac{1}{L_{scatt}} + \frac{1}{L_{abs}} = \frac{1}{90\,cm} + \frac{1}{1000\,cm} \qquad L_{att} = 83.33\,cm$$

Scattering Length Sensitivity

Analyzing SIPM sensitivity to scattering length changes is one of the main goals of our simulation, as it indicates good positions to place the sensors.
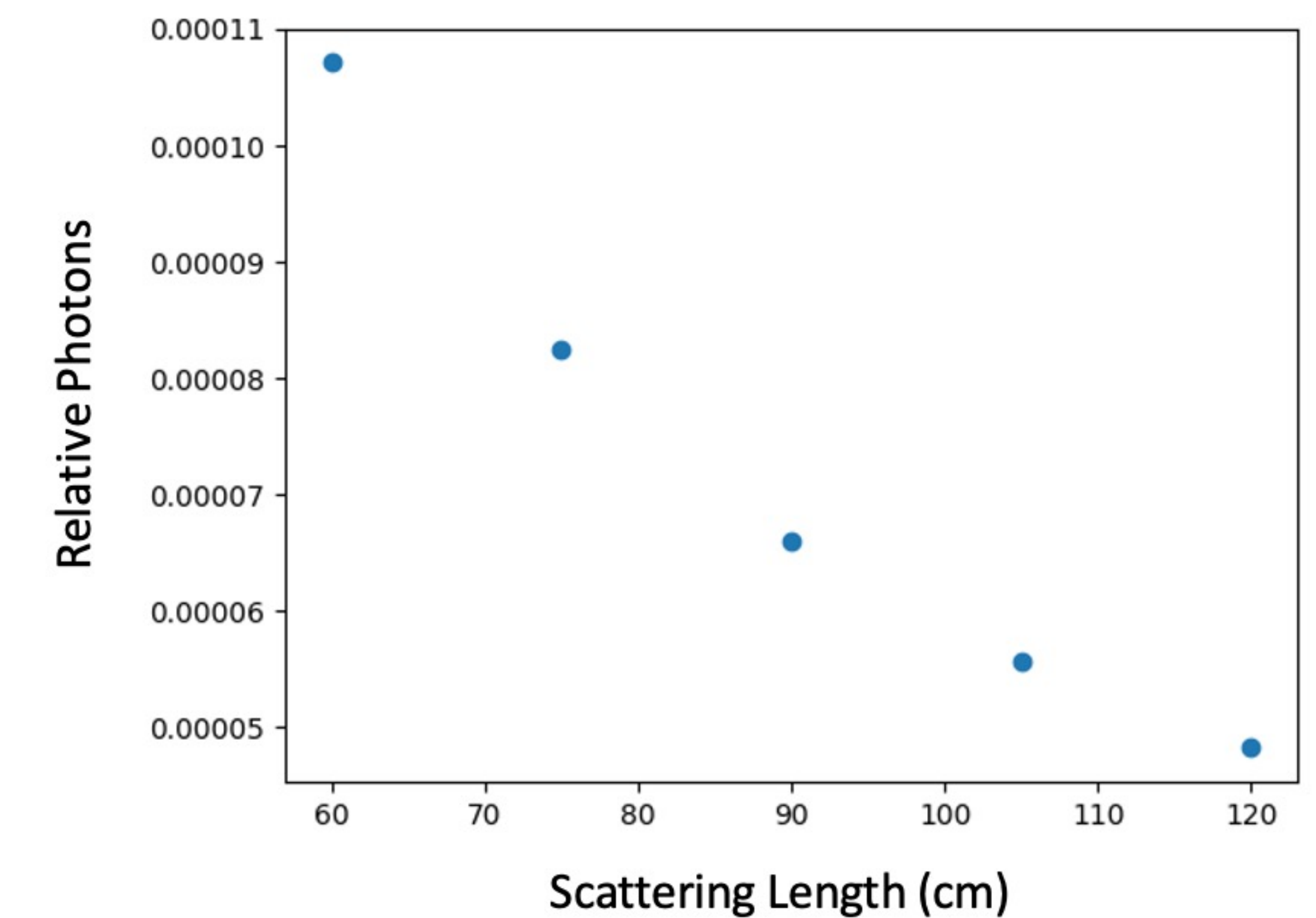

Figure 3: A plot of the relative photon hits vs. scattering length on one of the SIPMs. 5 simulations were run in total, each with a different scattering length (60, 75, 90, 105, 120 cm).

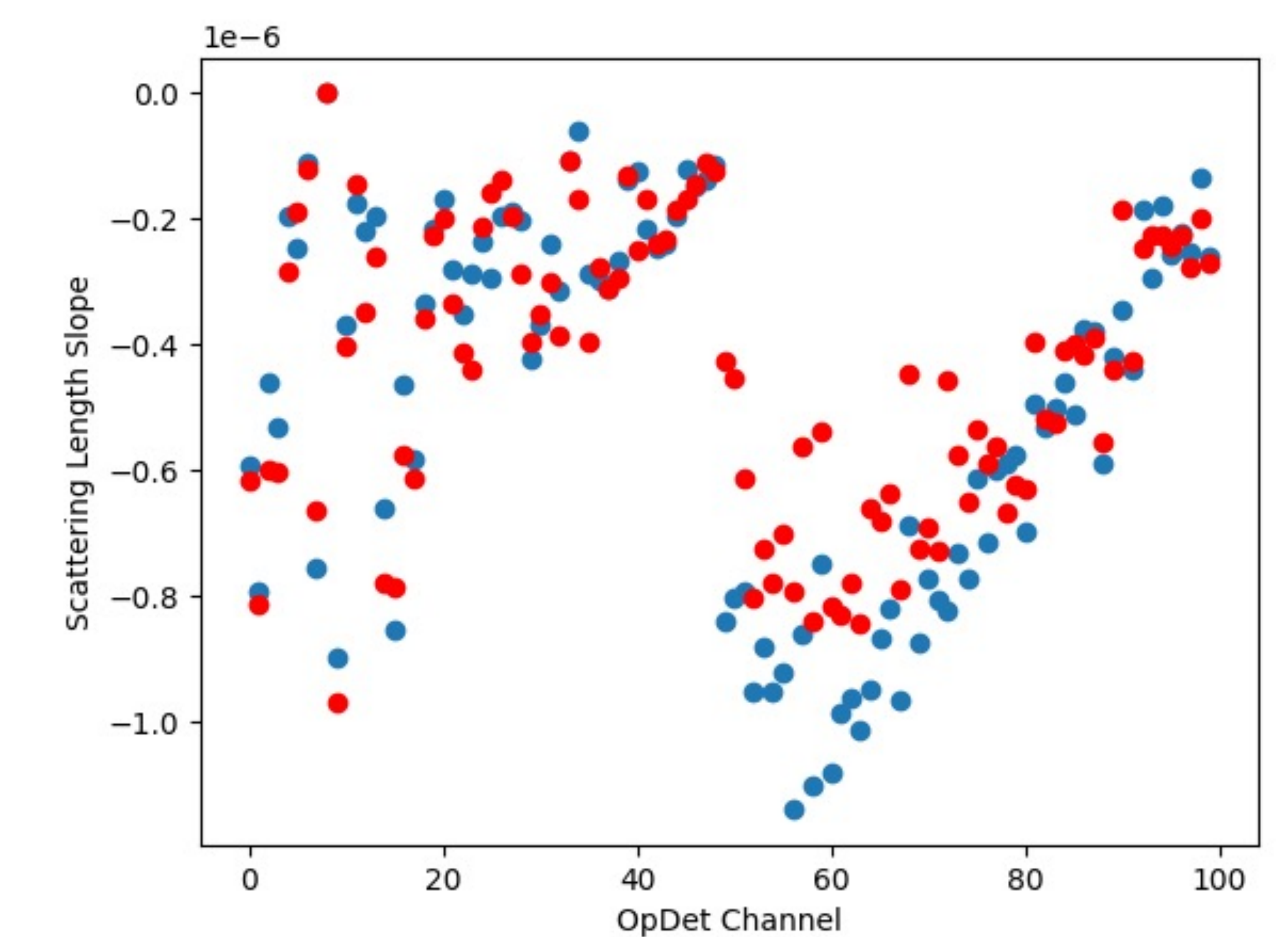The slope of the above plot would then be the sensitivity of that SIPM to scattering length.

Figure 4: A plot of the scattering length sensitivity (slope) for each SIPM. The blue points represent sensitivities calculated using runs where only the scattering length changes. For the red points, we also change the absorption length so that the attenuation length remains constant.
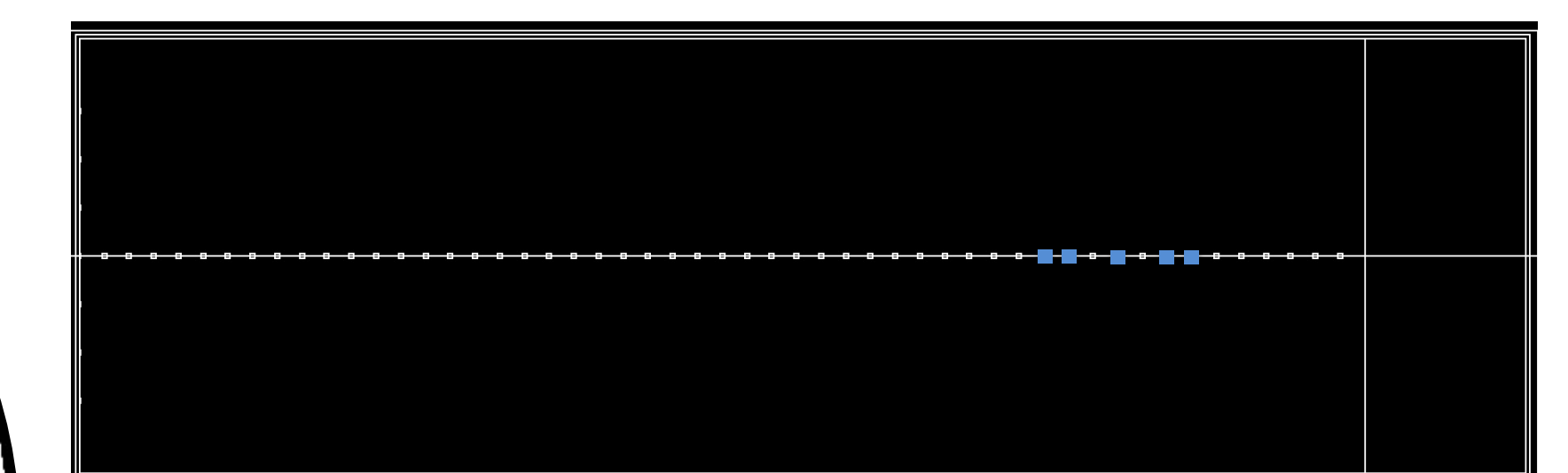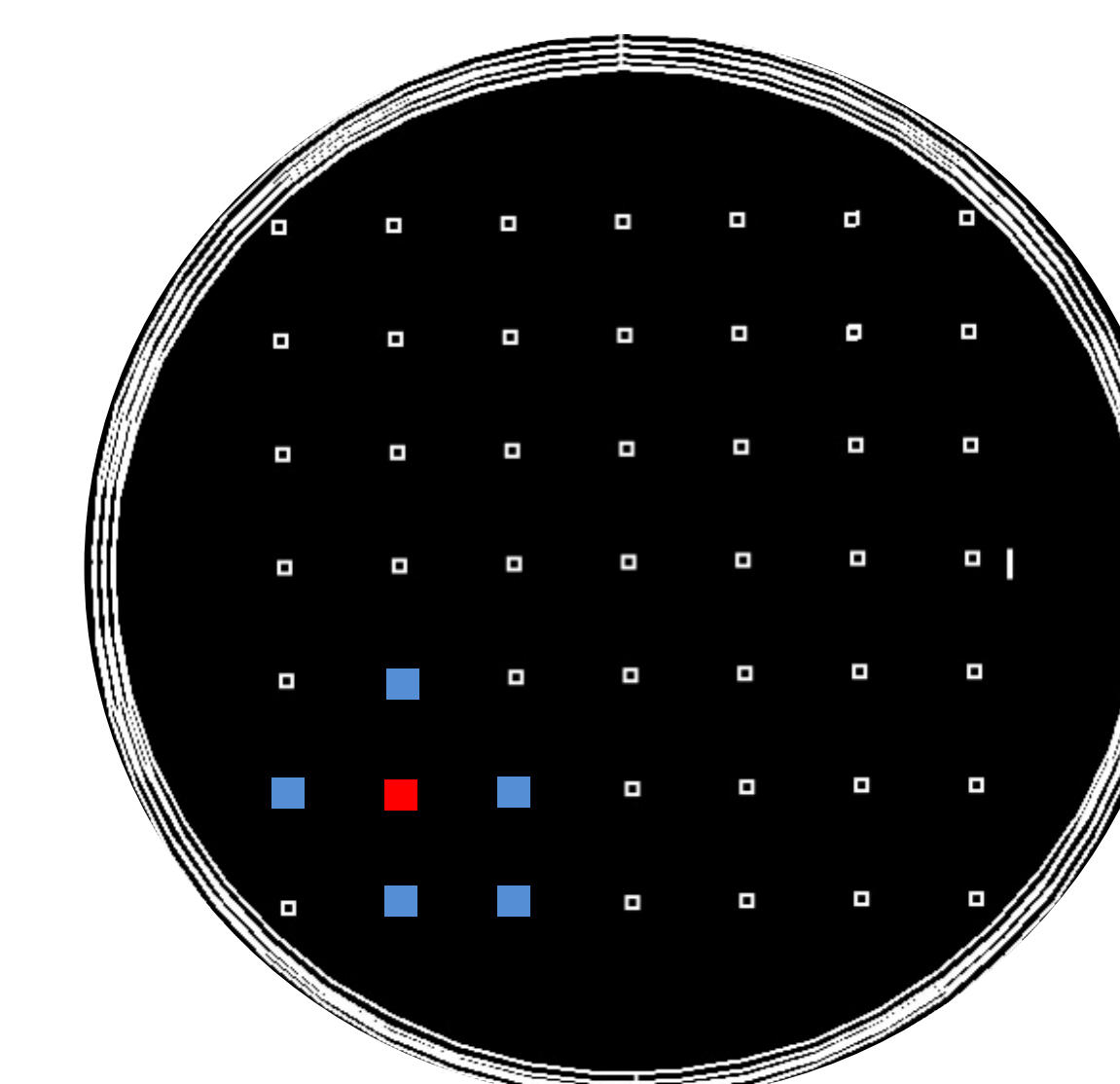

Figure 5: Diagrams of the bottom/side SiPM arrays in our geometry. The red marker indicates the central SiPM directly under the light source, whereas the blue markers indicate the most sensitive bottom/side SiPMs according to Figure 4.

Acknowledgements

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