Upgrade of SuN++ with the SuNFLOWER Detector Array

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INTRODUCTION

The Summing NaI detector, developed at Michigan State University, is a segmented array of NaI crystals and photomultiplier tubes [1], used for direct measurement of β-decay strength distributions and indirect neutron capture reaction constraints through the β-Oslo method [2]. An upgrade to this detector, SuN++ (shown in Figure 1), uses smaller NaI crystals and CeBr crystals for better segmentation and energy resolution [3].

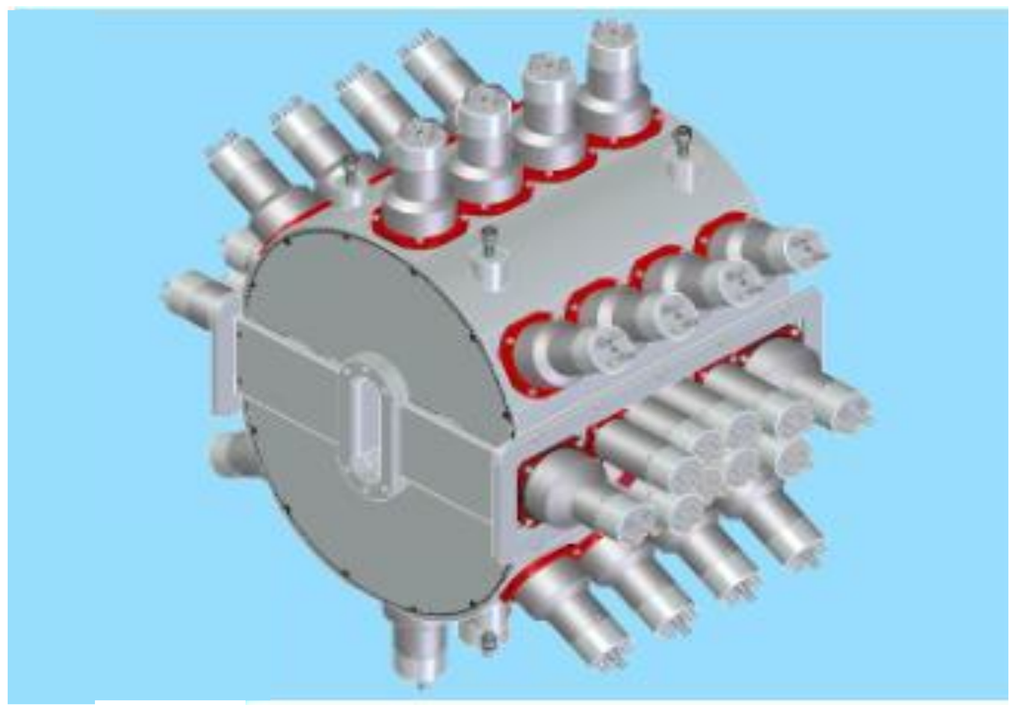

Figure 1: The Summing NaI++ (SuN++) detector, developed at Michigan State University. The SuN++ PMTs corresponding to NaI and CeBr crystals are shown in the middle segment of the detector.

SuN++, used in conjunction with the tape station, SuNTAN [4], and fiber scintillator detector can be used as a charged particle detector used to isolate events of interest from high energy background. To improve on this system, the upgrade SuNFLOWER (shown in Figure 2) was introduced to replace the fiber scintillator detector.

UPGRADE OF THE FIBER DETECTOR: SuNFLOWER

This upgrade will further increase segmentation as compared to the fiber scintillator detector. SuNFLOWER will consist of an array of plastic scintillators, the light output from which will be read in by silicon photomultipliers (SiPM). This setup was chosen due to space constraints between the beam line and the SuN++ detectors.

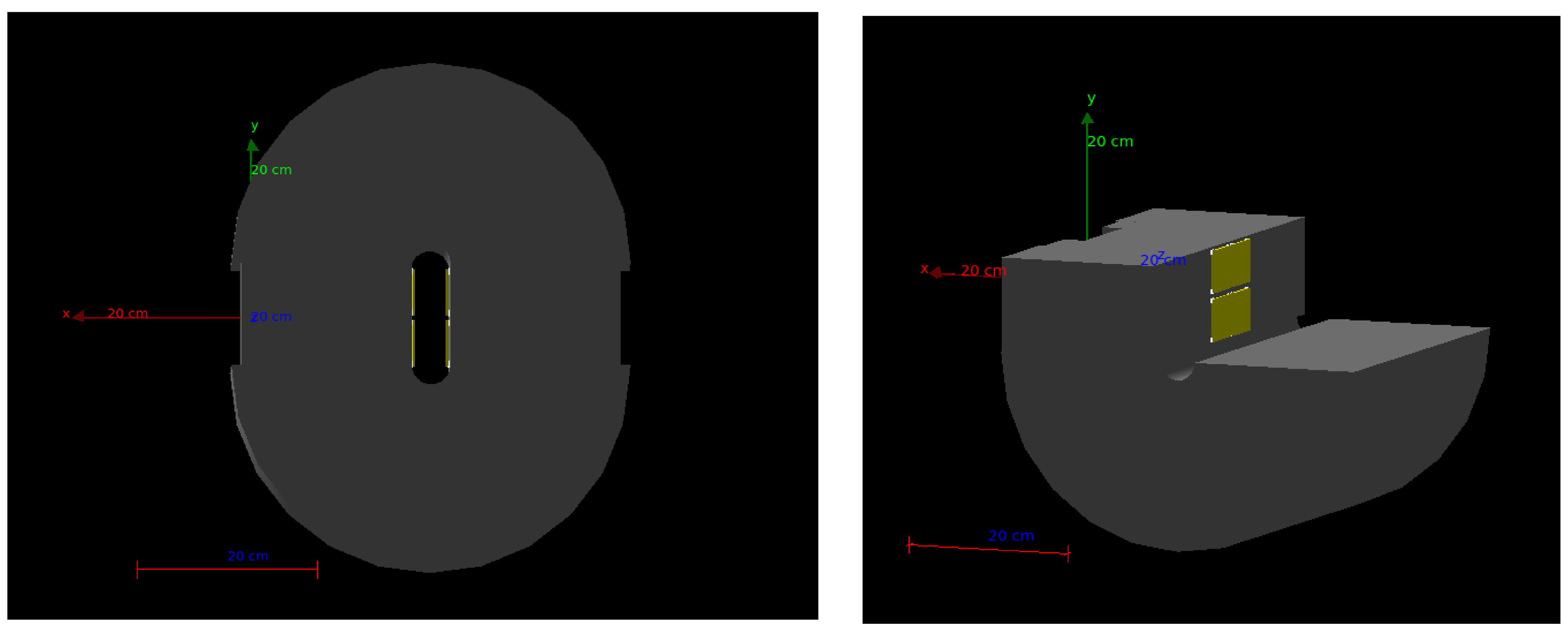

Figure 2: A schematic of SuN++, including the SuNFLOWER array in yellow. The figure on the left looks along the beam line. The figure on the right is slightly off beam axis and has the right SuN++ segments and top SuN segments removed for better visibility of SuNFLOWER.

In this configuration, the SuNFLOWER array is placed in front of the CeBr crystals. While the detectors will be placed inside the beam line, the beam pipe has been left off this visualization for clarity.

SuNFLOWER- Experimental Method

To test the SuNFLOWER array to determine the best SiPM configuration, it was necessary to test the spatial resolution of the array with only two SiPMs, as shown in Figure 3. This was accomplished with a ^{90}Sr source, moved in 1 cm increments around the plastic scintillator. Energy plots showing spatial resolution are shown in Figures 4 and 5.

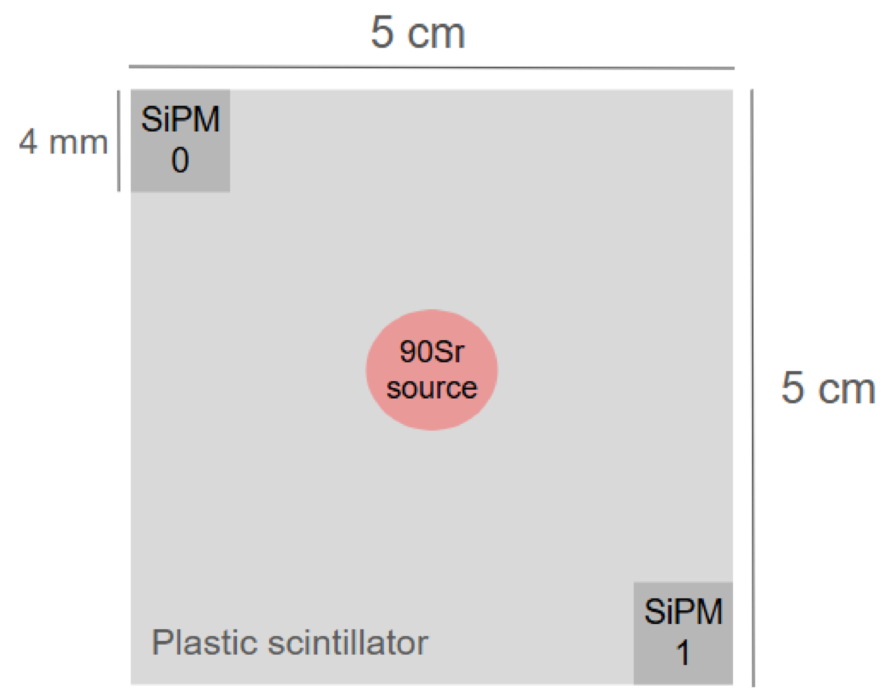

Figure 3: A schematic of the setup used to characterize behavior of two SiPMs. Not drawn to scale.

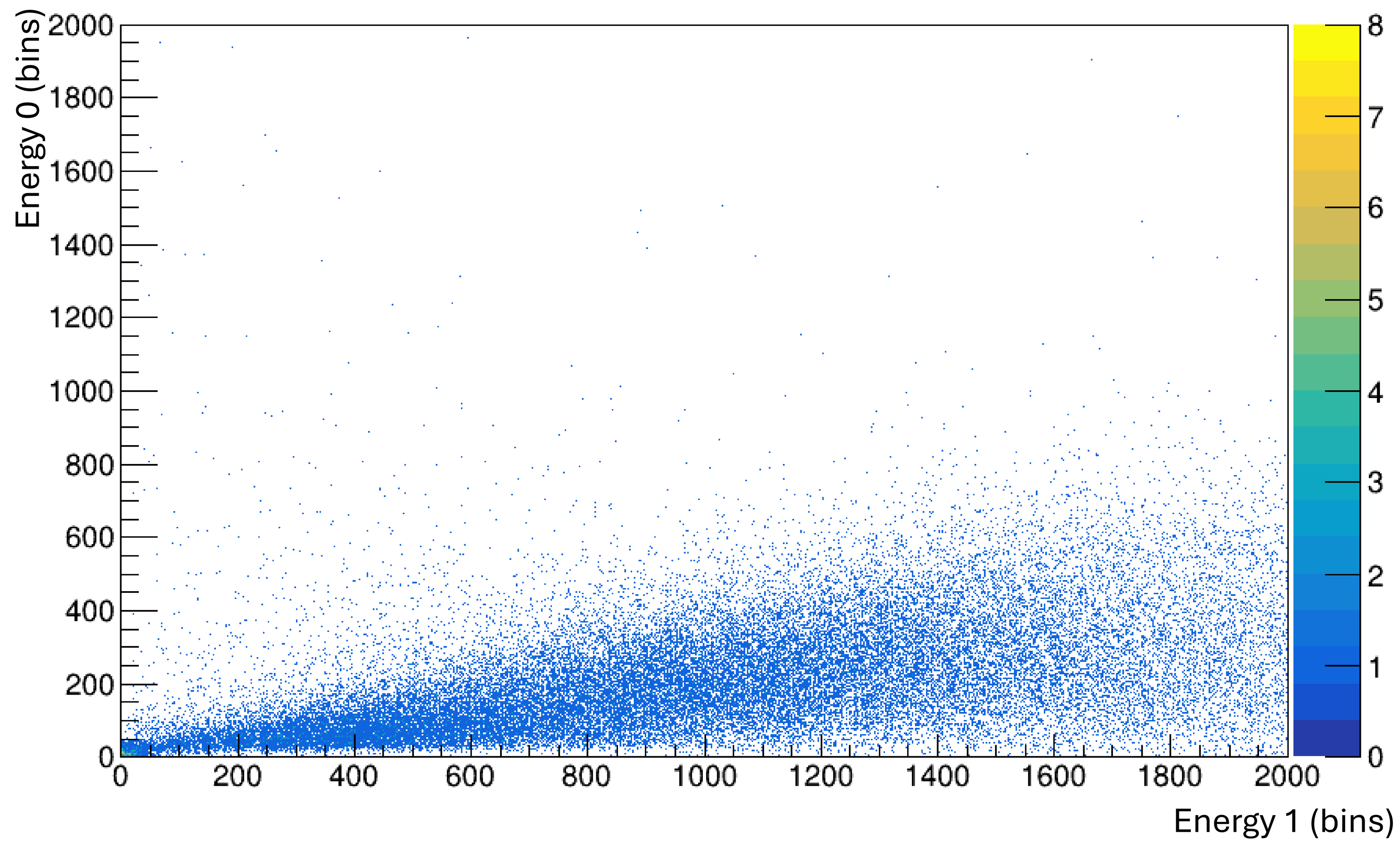

Figure 4: A two dimensional energy histogram with the ^{90}Sr source placed directly on top of SiPM one, conditional on both SiPMs seeing an event.

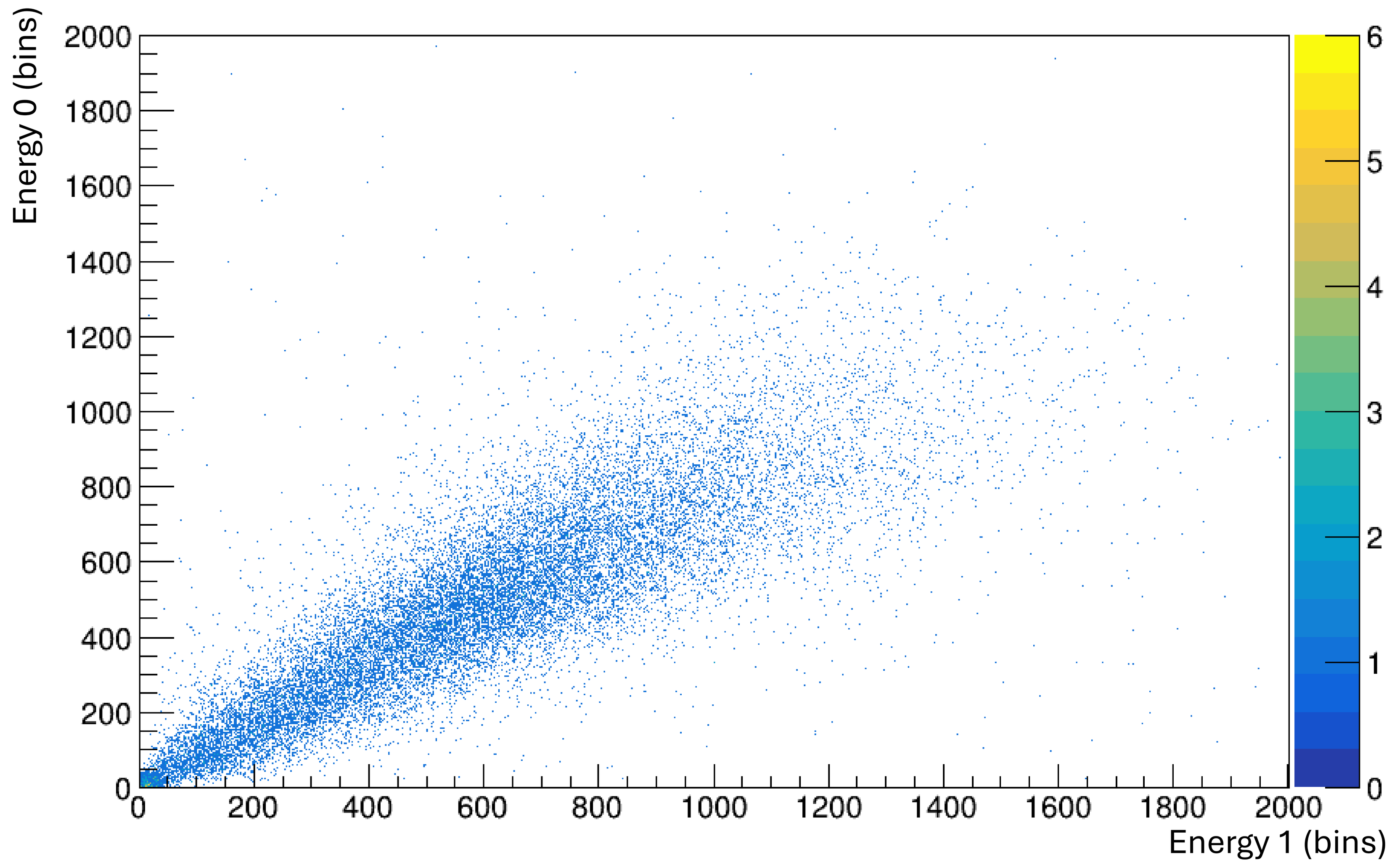

Figure 5: A two dimensional histogram with the ^{90}Sr source placed directly between SiPM zero and SiPM one, conditional on both SiPMs seeing an event.

NEXT STEPS

The next steps in developing this detector array are as follows:

- Characterizing the SuN++ detector efficiency in Geant4, using a ^{60}Co and ^{137}Cs source input file.
- Developing a 4 SiPM array to replace the 2 SiPM array. This increase in the number of SiPMs on each scintillator will improve the detection of charged particles, and is necessary to prevent loss of data if a charged particle interacts in an area without a SiPM nearby.
- Further testing will be necessary to characterize SiPM behavior as well as to determine what pixelation is necessary.

References:

[1] Simon, A. et al., NIM A, 703 (2013).

[2] Lyons, S. et al., Physical Review C, 100 (2019).

[3] E. K. Ronning et al., in preparation (2025).

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FRIB FACILITY FOR RARE ISOTOPE BEAMS

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