Characterizing the Behavior of HVSS for EOS

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Abstract

Neutrinos are some of the least understood Standard Model particles. Recently, many more experiments, such as DUNE, SNO+, and T2K, have been looking to dive deeper into these mysterious particles. The EOS experiment, housed at Lawrence Berkeley National Laboratory, hopes to provide an integrated test-bed to develop hybrid neutrino detectors and to support these efforts.

This research focused on the testing of the HVSS (High Voltage Splitter and Summer) prototype board (a part of the EOS experiment), aimed at developing detectors capable of detecting both Cherenkov and scintillation signals simultaneously to detect neutrinos. The study examined the timing characteristics, efficiency, accuracy, and sensitivity of the board in response to photon emissions from a scintillator material activated by a radioactive source.

The research investigated the triggering thresholds of the multi-channel board, which was crucial for triggering on realistic events. The setup utilized test pulses and background noise analysis to establish effective trigger thresholds for optimal signal detection. The study also explored hysteresis effects in the triggering system and investigated the correlation between the analog sum output and input pulse.

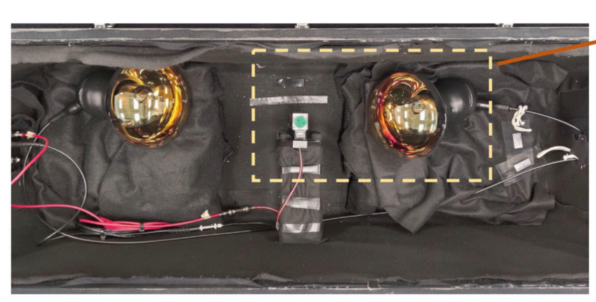
Through the testing process, the efficiency of PMT triggering was analyzed under various biasing voltages. The resulting data provided insights into the minimum analog sum signal required to trigger PMT responses consistently. The data also quantified the gain of the PMTs as a function of voltage, determining their performance characteristics in the single-photoelectron regime.

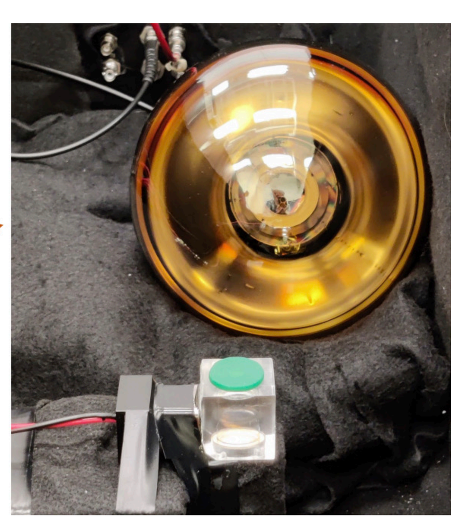
The findings from this research contributed to the ongoing development of the EOS experiment, offering valuable insights into the behavior and performance of the board and the PMTs in a complex experimental setup. The ability to detect both Cherenkov and scintillation signals has promising implications for future neutrino physics experiments, and the results of this study aided in refining the technology required for such endeavors.

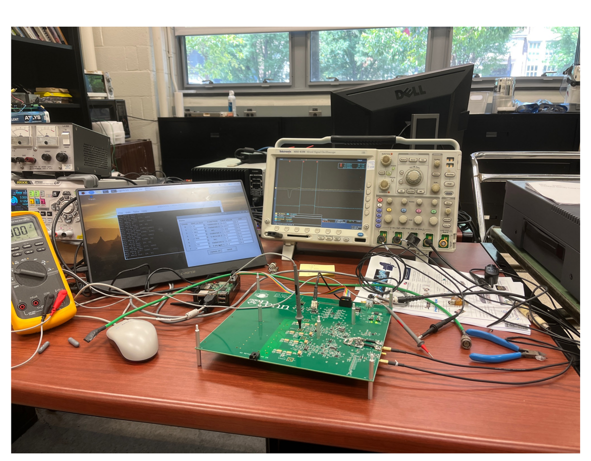
Materials and Methods

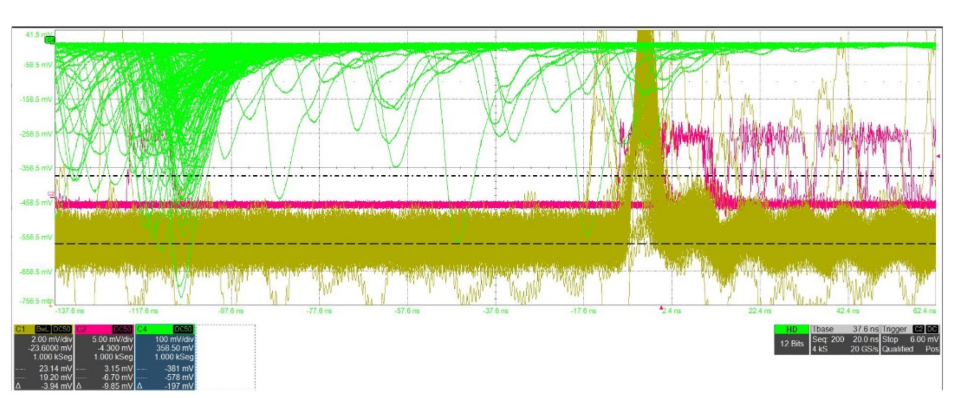
- The experimental setup involved a dark box containing two 8" PMT tubes placed approximately 2 feet away from a photon source.
- Additionally, a 1" PMT tube was positioned against a liquid scintillator with a Strontium-90 electron source, utilizing beta decay to produce low-energy electrons that generated scintillation photons upon interaction with a scintillation material.

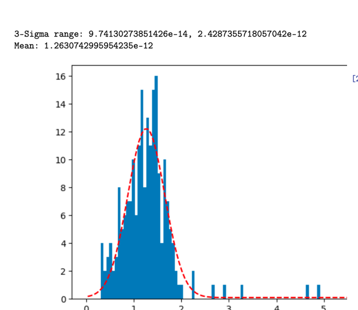
Inside the Box

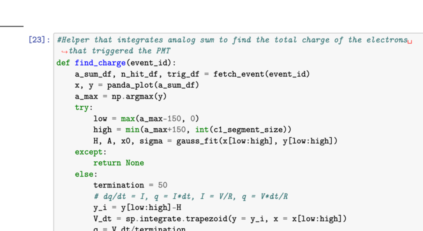










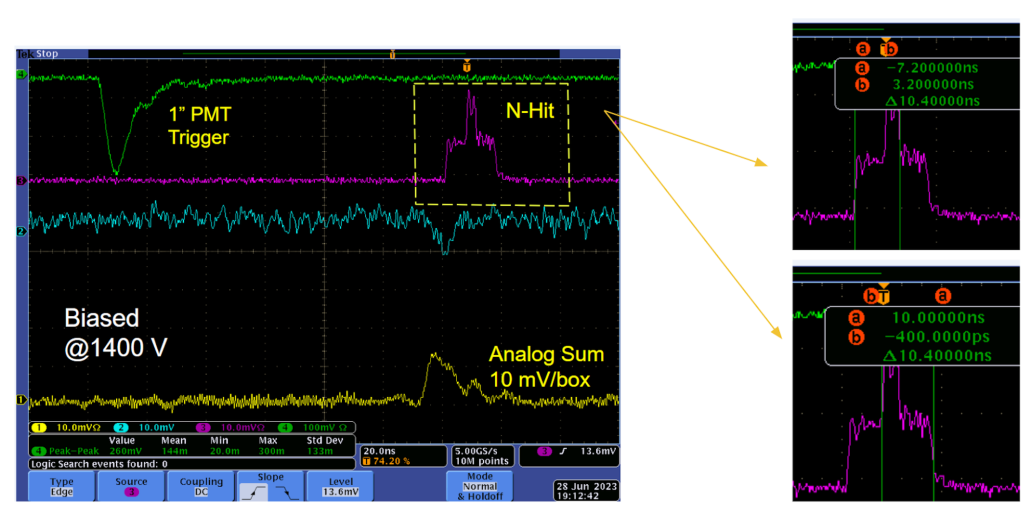


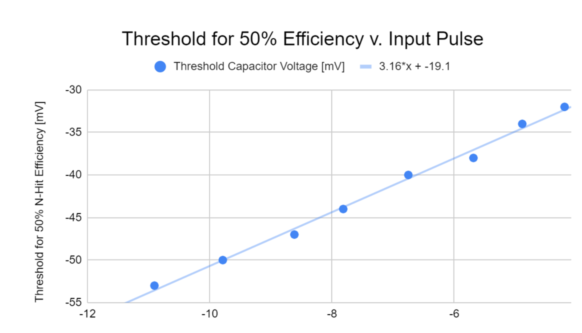
Objectives

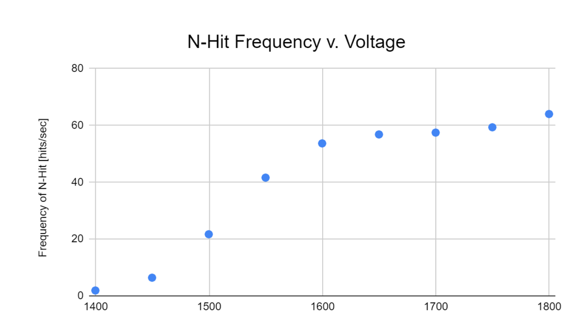
- Evaluate the performance and stability of the HVSS board in providing high voltage to the PMTs by monitoring voltage levels, current draw, and potential fluctuations.
- Study the relationship between analog sum signals and input pulse.
- Determine the optimal threshold settings within the HVSS board for triggering PMT responses.
- Analyze the frequency of N-Hit events triggered by the HVSS board across a range of biasing voltages.
- Investigate the minimum analog sum signal necessary to consistently trigger N-Hit responses.
- Characterize the hysteresis behavior of HVSS and assess its influence on triggering efficiency.

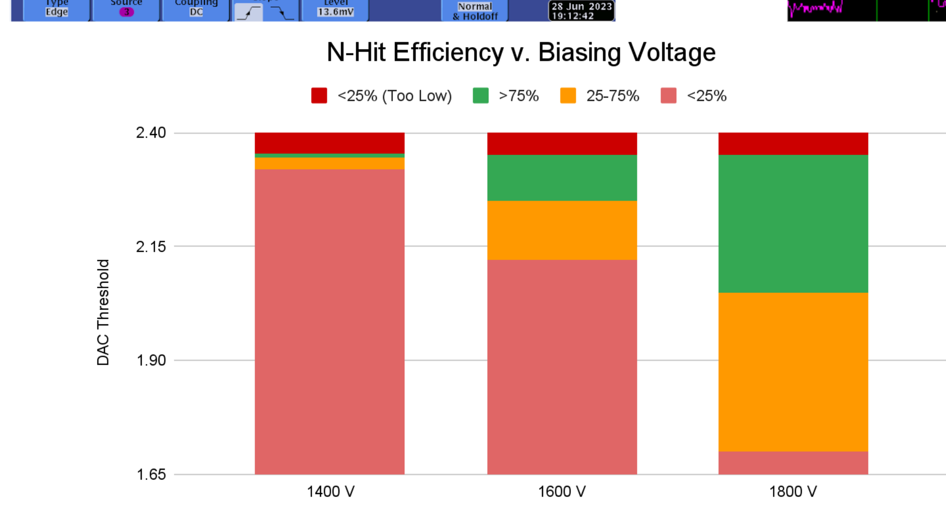
Results

- **Thresholds and Noise:** We were able to understand the 50% triggering thresholds for each channel, the effect of trace distance, and the minimum test pulse size we could detect.
- **HV and PMT Efficiency:** Efficiency and rate of N-Hit triggers were analyzed for different biasing voltages, revealing optimal operating conditions.
- **Hysteresis and Thresholds:** Optimal hysteresis was at 5.6kΩ and a DAC threshold of 2.3.
- **Analog Sum and Charge:** The relationship between analog sum and charge output from PMTs was established through Gaussian fitting and integration techniques and was determined to be linear.
- **PMT Gain:** The gain of the PMTs was determined by comparing high-voltage input to the current drawn. The observed current aligned well with the expected current, indicating no unaccounted impedance.
- **Handling:** The high-voltage parts of the board need to be handled carefully to avoid any oils being deposited, and conformal coating/Kapton tape would be ideal









A spark across a high voltage capacitor

Conclusions

- **Enhanced HVSS Board Performance:** Our examination of the HVSS board's behavior under varying conditions has unveiled insights that can potentially lead to the refinement and optimization of its performance. By addressing issues like voltage stability, triggering efficiency, cable impedance, and hysteresis effects, we've contributed to the overall reliability and accuracy of the EOS Experiment.
- **Informed Calibration and Data Analysis:** Our comprehensive analysis of PMT gains, threshold adjustments, and charge computations equips researchers with a deeper understanding of how different variables influence signal detection and event reconstruction. This knowledge serves as a valuable asset in calibrating the detector and interpreting experimental data accurately, thereby enhancing the precision of neutrino physics research.
- **Advancements in Hybrid Detection Technology:** The successful integration of Cherenkov and scintillation signals through this board and technologies like dichroicons hold promise not only for the EOS Experiment but for the broader field of particle detection. This advancement potentially opens the door to designing future detectors with enhanced sensitivity and discrimination capabilities, offering researchers a more refined tool to uncover the mysteries of neutrinos.
- **Interdisciplinary Collaboration:** Our research underscores the symbiotic relationship between particle physics and electrical engineering, showcasing the potential of interdisciplinary collaboration. The cross-pollination of expertise from these distinct fields has yielded insights and innovations that would have been challenging to achieve in isolation.

In summary, our exploration of the HVSS board and its implications within the EOS Experiment resonates with the spirit of discovery and collaboration that fuels scientific progress. By making advancements in detection, we contribute to a grander narrative of human curiosity and ambition, with the ultimate goal of unraveling the mysteries of neutrinos.

References

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