INSTITUTE OF NUCLEAR AND PARTICLE PHYSICS
DEPARTMENT OF PHYSICS & ASTRONOMY

Performance Evaluation of Photomultiplier Tubes (PMTs) for the CLAS12 Calorimeter in Hall B: A Comparative Analysis

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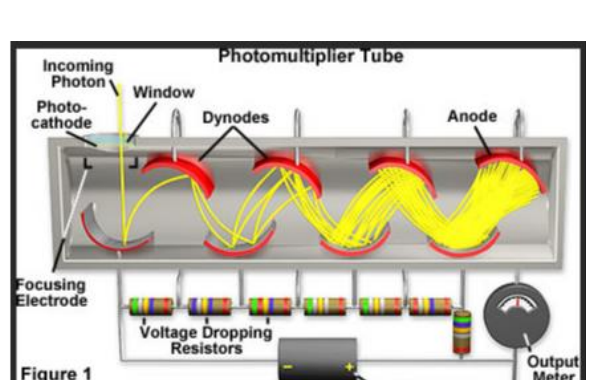
Summary:

This research project focused on verifying the accuracy of manufacturer tests and assessing the performance of Photomultiplier Tubes (PMTs) and voltage dividers for the CLAS 12 CEBAF Large Acceptance Spectrometer 12 GeV detector at Jefferson Lab. PMTs are crucial components that convert particle interactions into detectable signals. When particles interact with matter within the detector, they generate minuscule amounts of light. These faint light emissions are then captured by the PMTs. Herein lies the significance of the comprehensive testing conducted on 220 PMTs, grouped into sets of four. The evaluation encompassed a spectrum of voltage settings, ranging from 1500 to 1750 volts in 50-volt increments per run. In addition to the PMTs, the research also encompassed testing the dividers used in conjunction with the PMTs. By conducting comprehensive tests on both components, this study aimed to ensure accurate and efficient operation before integrating them into the detector. The obtained data will contribute to the enhancement of the CLAS12 detector's performance and further advances in high-energy nuclear physics research at Jefferson Lab.

What is a PMT

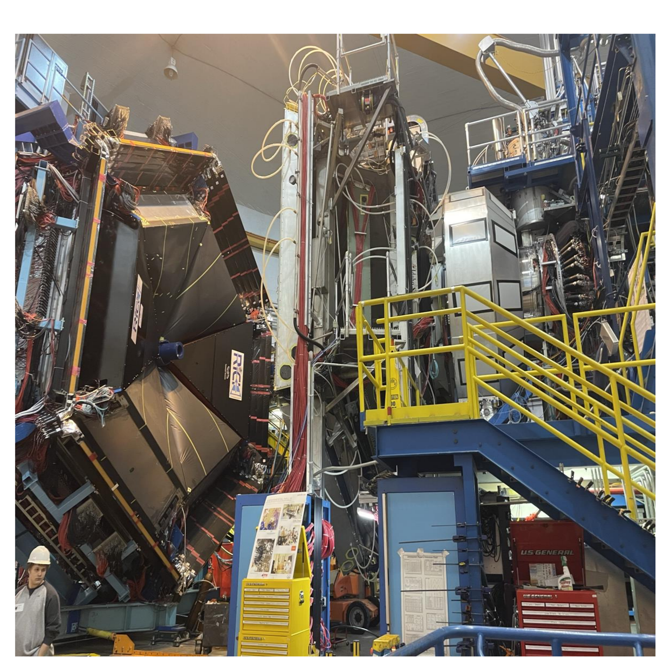
A PMT (Photo-Multiplier tube) is a highly sensitive device used to measure light in scientific and technical applications. It works by utilizing the photoelectric effect, where a photocathode emits electrons when exposed to photons. These emitted electrons are then accelerated towards a series of dynodes, undergoing multiplication through secondary emission. The amplified electrons pass through a voltage divider, a crucial component that distributes and adjusts the voltage between each of the pins on the PMT. Subsequently, the multiplied and divided electrons are collected by an anode, generating an amplified electrical signal proportional to the incident light intensity.



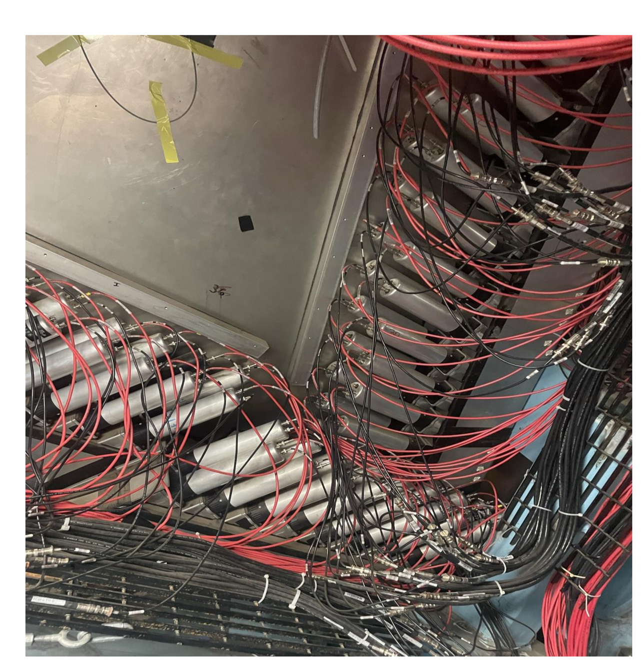
Method:

- Test Setup: Arrange a controlled testing environment, including a dark box, calibrated LED light source, and appropriate cabling.
- PMT and Divider Inspection: Visually inspect PMTs and dividers for any physical damage or abnormalities before testing.
- PMT-Divider Compatibility: Connect PMTs to voltage dividers, ensuring proper alignment and secure connections.
- Voltage Adjustment: Set the desired high voltage level within the recommended operating range to optimize PMT performance.
- Data Acquisition System Configuration: Connect the PMT output signals to a data acquisition system, ensuring accurate and reliable signal capture.
- Signal Validation: Run the data acquisition system to confirm the presence of PMT signals and check for any anomalies.
- HV and Signal Variation: Gradually increase the high voltage while monitoring the PMT signals to assess their response at different voltage levels. In addition to this it calibrates the PMTs with each other.
- Data Analysis: Analyze the collected data to identify any deviations or irregularities in PMT performance, allowing for the detection of faulty PMTs or optimal HV settings. Account for efficiency among set to see which PMTs work best.

CLAS12 detector in hall B :



Mounted PMTs on the calorimeter:



Conclusion:

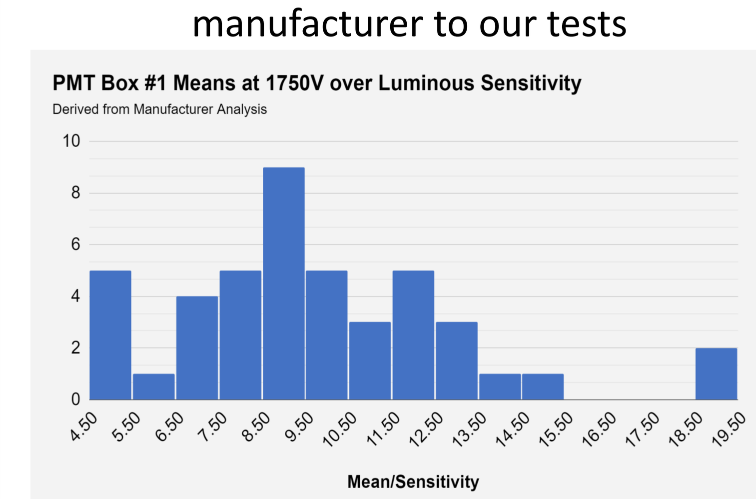
In conclusion, our analysis confirms that all photomultiplier tubes (PMTs) examined for the CLAS12 detector are in good condition, surpassing the performance of the previous models. The successful integration of these improved PMTs into the detector marks a significant advancement. Additionally, this project has provided me with invaluable learning experiences, including programming skills and proficiency in working with Linux. I am grateful for the knowledge gained and eagerly look forward to the exciting outcomes enabled by the CLAS12 detector.

Results:

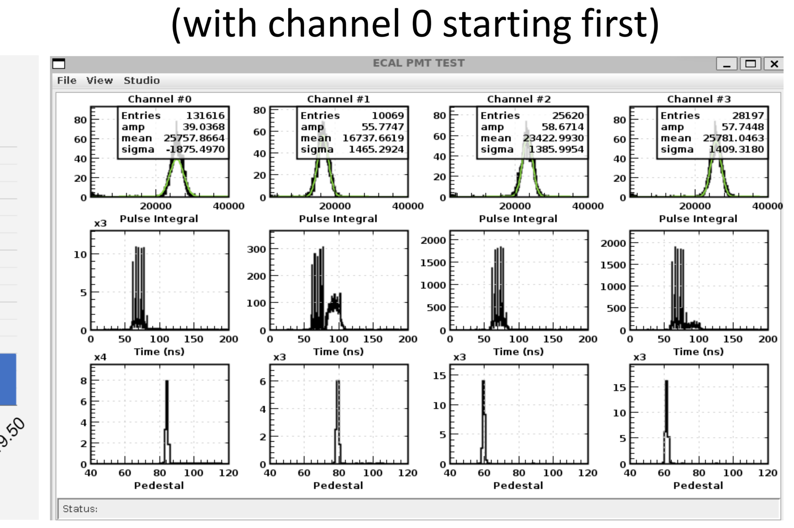
Data set from *run 696 taken at a voltage of 1750V (*the same as what the manufacturer tested the PMTs at. Which is more commonly referred to as luminous sensitivity) Doing this we can see the difference between what the manufacture said it tested at and our own: (they are in different units Manufacturer is in A/lm and our mean is in flash ADC counts which is a digital count derived from the signal samples taken by the fADC system.)

		1750V					
PMT No:	Channel:	Run	Mean	Error	*Manufacturer*	Dark Current	Mean/Manufacturer
FA0052	0	696	25938.09505	1.414214	2140	6.5	12.12060516
FA0053	1	696	23365.60312	37.977176	2440	7.2	9.57606685
FA0054	2	696	25745.72758	26.281185	3330	30	7.731449723
FA0059	3	696	16753.21298	20.138992	1290	5.4	12.9869868

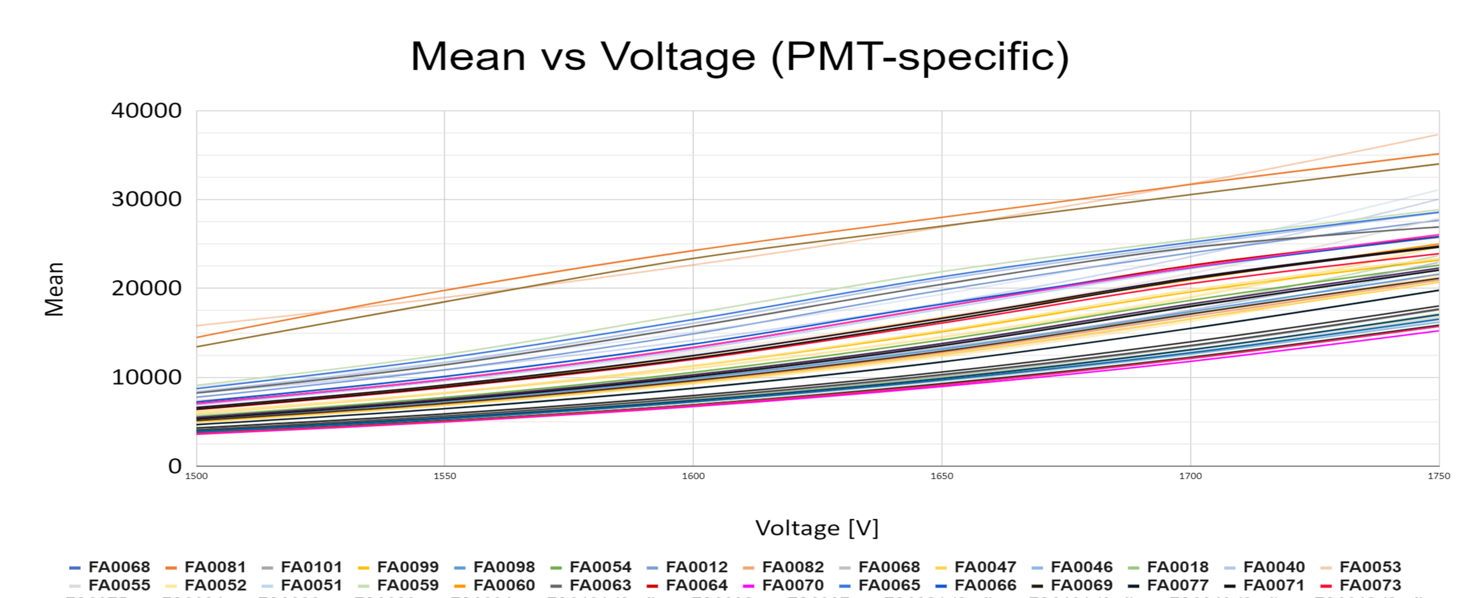
Box 1 chart showing the ratio of manufacturer to our tests



The form fit pulse integral graph *of run 696*: (with channel 0 starting first)



Box 1 chart for the mean vs the voltage:



PMT and PMT dividers

Future Implications:

The CLAS12 Hall B detector at Jefferson Lab in Newport News, Virginia, presents exciting opportunities for future research endeavors. Leveraging the wealth of existing data, the detector enables the exploration of various scientific avenues. Ongoing research with the detector includes:

- Particle Interaction Studies: Researchers can delve into detailed studies of particle interactions, examining their dynamics, properties, and underlying fundamental forces.
- Nucleon Structure and Quark Confinement: The CLAS12 detector allows for precise investigations of nucleon structure and the confinement of quarks within protons and neutrons, shedding light on the fundamental building blocks of matter.
- Hadronic Matter and QCD: Researchers can explore the behavior of hadronic matter under extreme conditions, investigating the transition from confined quarks to a deconfined state and contributing to the understanding of Quantum Chromodynamics (QCD).
- Dark Matter Detection and Characterization: The CLAS12 project also aims to contribute to the search for dark matter by conducting experiments that could potentially detect and characterize this elusive form of matter, providing valuable insights into its nature and properties.

Broader impact of PMTs:

- Medical equipment: PET (positron emission technology), X-ray image diagnostic equipment, Gamma cameras.
- Biotechnology: DNA sequencers flow cytometers.
- Oil well logging
- Environmental measurements: Dust counters, Laser radar (LIDAR), NOx and SOx analyzers.
- Aerospace applications: Ozone measurement and X-ray astronomy.

References:

- Burkert, V.D et al., (2020). The CLAS12 Spectrometer at Jefferson Laboratory. Nuclear Instruments and Methods in Physics Research, Section A 163419.
- Asryan, G et al., (2020). The CLAS12 forward electromagnetic calorimeter. Nuclear Instruments and Methods in Physics Research Section A, 959, 163425.
- Hamamatsu Photonics K.K. (n.d.). Photomultiplier Tubes Handbook: Basics and Applications (4th ed.).