Commissioning of a Coordinate Detector for the Hall A Super BigBite Spectrometer

Ralph Marinaro

Mentor: Dr. Peter Monaghan (JLab, CNU), Supervisor: Dr. Bogdan Wojtsekhowski (JLab)

Abstract: The Super BigBite Spectrometer (SBS) will be supplemented by the Coordinate Detector (CDet) to provide particle position and trajectory data. CDet uses scintillating paddles that interact with particles to collect light events in separate channels. This allows experimenters to know where particles pass through the detector. The focus of this project is to develop the commissioning process and determine the efficiency and crosstalk percentages of each channel in CDet at different high voltage (HV) settings before installation of CDet in Hall A. Using cosmic rays, a half-module data acquisition system (DAQ) collects ADC and TDC data so that crosstalk and efficiency percentages for each channel can be calculated. After application of all cuts to remove unwanted events, the crosstalk and efficiency percentages are determined for every channel in the first module of CDet at the selected HV settings. Using the ADC value, crosstalk, and efficiency data, the optimal HV settings for each PMT in Module 1 can be determined and Module 1 can be proven ready for use in experimentation. This process will be applied to all six of CDet's modules before final installation for experimental use in Jefferson Lab's Hall A.

Coordinate Detector

The Coordinate Detector is a scintillator detector which will form part of the charged particle tracking system for the Super BigBite Spectrometer (SBS). This will be used in experiments for SBS in Experimental Hall A at Jefferson Lab to measure nucleon structure functions.

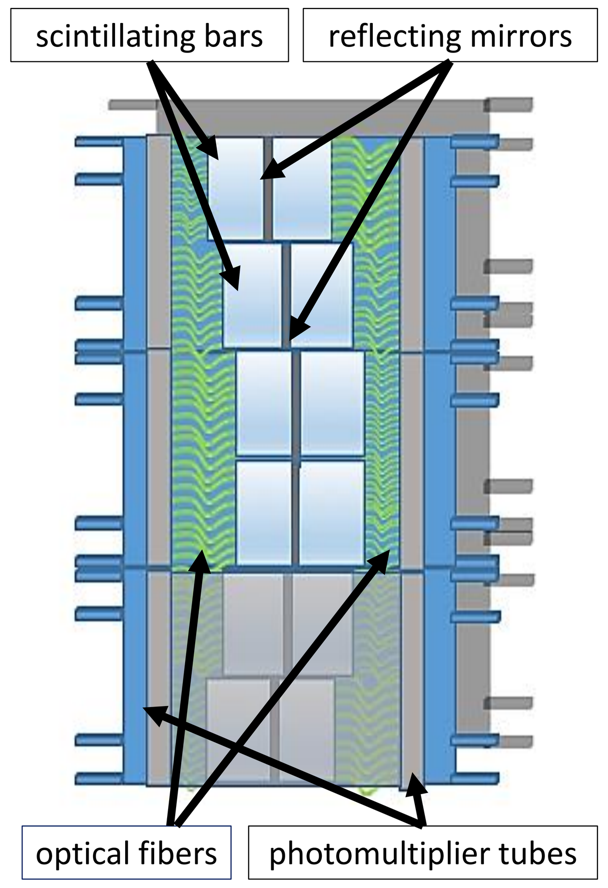


Fig. 1: Schematic of CDet

The detector consists of six modules stacked in two layers of three modules each (Fig. 1). Each module consists of 28 bars and each bar consists of 14 scintillator paddles. This means in total the detector has 2352 channels and each one is individually read out in the DAQ. For every scintillator paddle there is a matching optical fiber which is inserted horizontally through the paddle's center. When a charged particle goes through the paddle, it causes a small amount of light to be emitted from the material. The photons generated are then collected by the optical fiber in each paddle. All of the paddles are individually wrapped in shiny, reflective mylar to aid collection of the emitted light by the optical fibers.

Groups of 14 optical fibers in scintillating bars are connected to the photomultiplier tubes (PMTs). The light collected by each optical fiber is detected by a PMT. The PMT uses the photoelectric effect to turn detected light into charge signals, which are collected into a data file by the half-module DAQ.

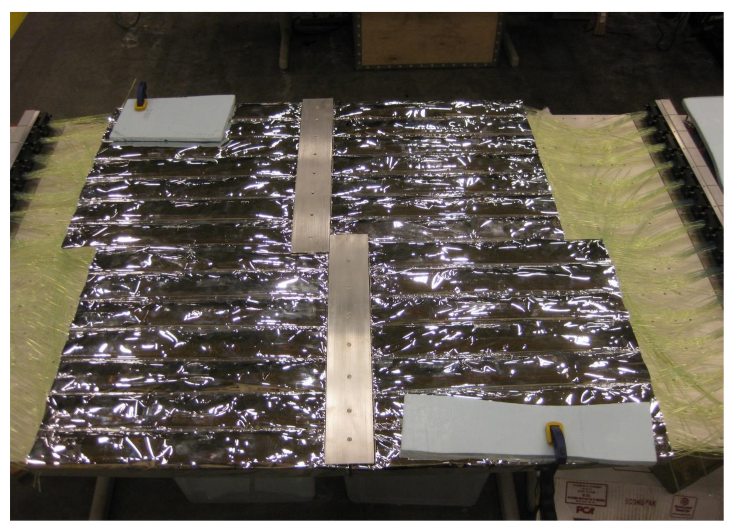


Fig. 2: Inside of Module

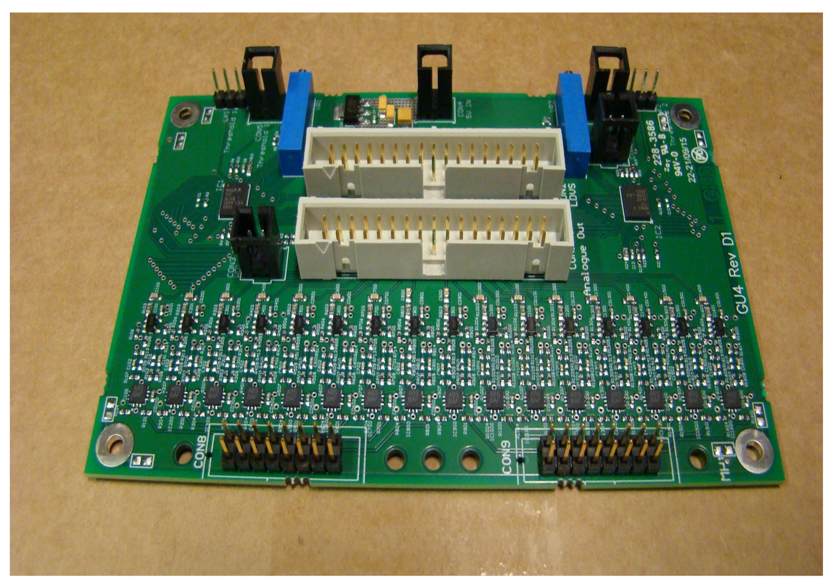
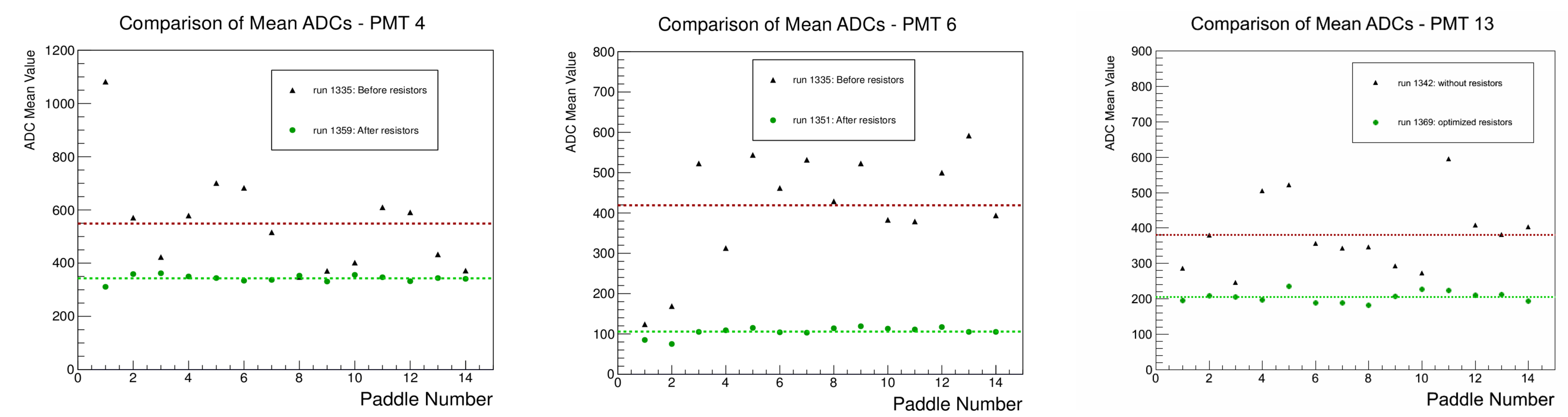


Fig. 3: NINO Card

For each PMT in the detector there is a corresponding NINO card. A NINO card (Fig. 3) is an amplifier-discriminator card which takes in the charge signals from the PMT and turns them into corresponding analogue (ADC) and logic (TDC) signals. These signals are read into data files by the DAQ.

Commissioning Process

The signal wires from the PMT are attached to the NINO card via a small circuit board. A pair of resistors for each channel are placed on the board in order to siphon off some of the charge. This means all of the channels can have their signal amplitude normalized in the resulting ADC spectrum. This charge normalization is shown for all 14 channels from three PMTs in the graphs below. The values for each resistor were determined by calculating a reduction coefficient between the ADC signal values for each channel in the PMT and the lowest ADC signal value in that PMT.



In this detector, each bar of fourteen paddles is read out by a single PMT. Each PMT has sixteen pixels and is called a multi-anode PMT. The sixteen optical fibers are connected to a collar which rests on the face of the PMT. Crosstalk is the parasitic, artificial correlation of events between channels in the PMT which generates incorrect data events that did not really occur.

A crosstalk event occurs when a signal in one channel is also registered in another channel due to capacitive coupling within the PMT. A multichannel oscilloscope was used to observe crosstalk events, as seen in Fig. 4 and Fig. 5. The crosstalk events in one pixel were observed by triggering on other channels within the PMT. A crosstalk event is characterized as having a bipolar signal pulse which results in a low or close to zero ADC signal value. Most crosstalk events also have a shorter TDC width between the leading and trailing edges of the signal.

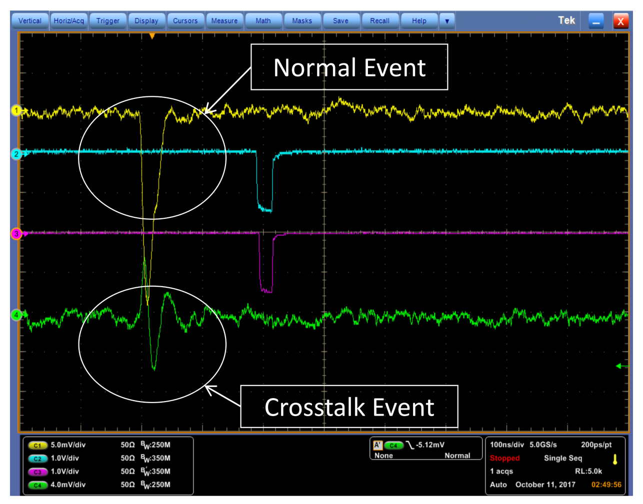
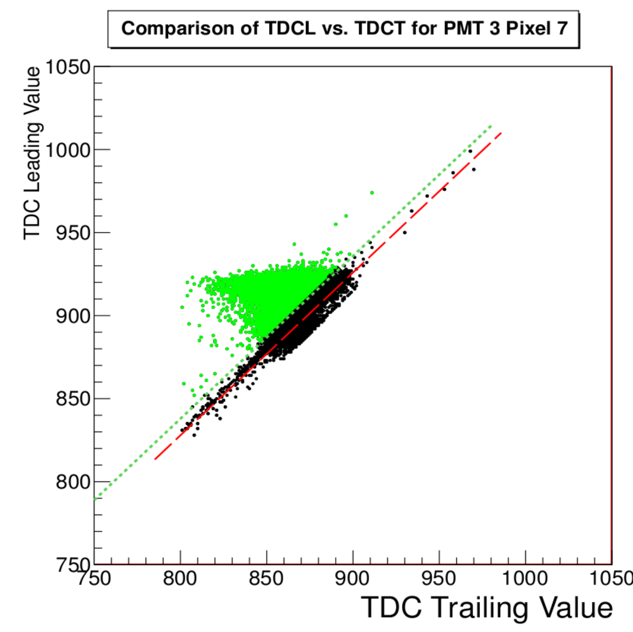
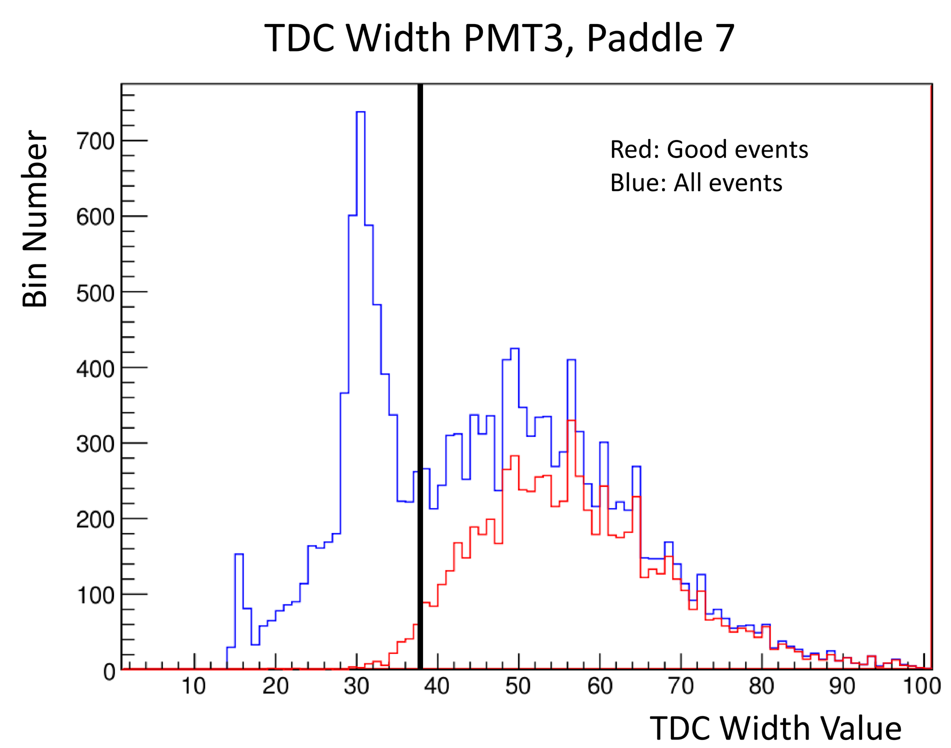


Fig. 4: Oscilloscope Comparison

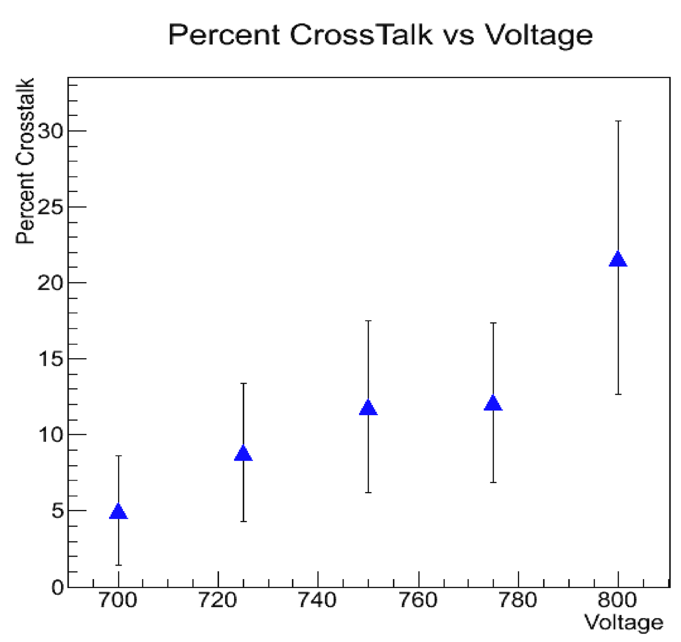
Fig. 5: TDC Width Observation

Using the short TDC widths which characterize a crosstalk event, a TDC width cut can be used to analytically reduce crosstalk percentages for every channel at every high voltage value. A linear fit (red) is made to the outlying TDC values. The fit is shifted to a larger TDC width (green) removing all events below. This TDC width is compared to the TDC width spectrum (below) to see how well the cut removes unwanted crosstalk data (blue).





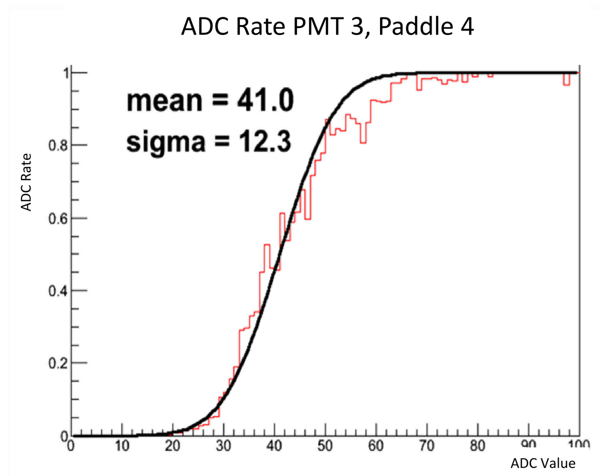
Supplemental crosstalk cuts are also placed on the TDC of every other channel in the same PMT as the channel being analyzed. These cuts remove some crosstalk, but the TDC width cut is most effective at removing crosstalk.

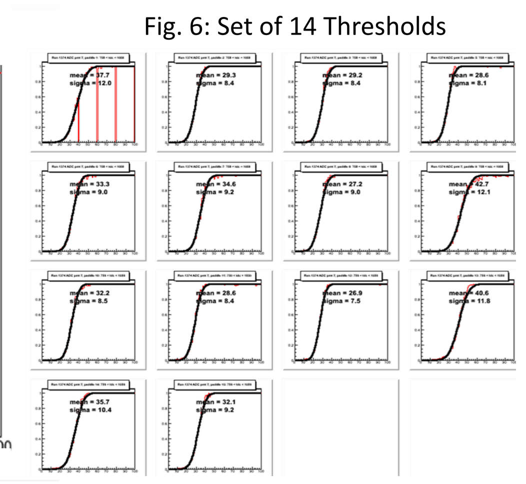


The percent crosstalk for each PMT was also observed at different high voltage levels. The amount of crosstalk increases with the high voltage, and the ADC signal values also increase. An optimal high voltage value has low crosstalk and a sufficient ADC value.

Efficiency Analysis

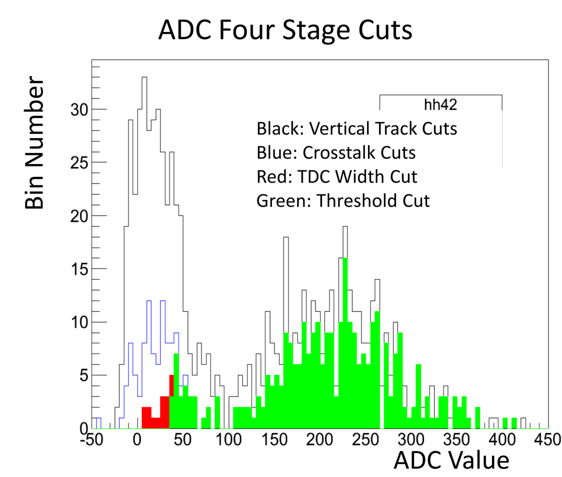
The ADC threshold value for each channel is calculated to be fifty percent of the ADC rate for the channel being analyzed. These threshold cuts are used to calculate the efficency percentages.

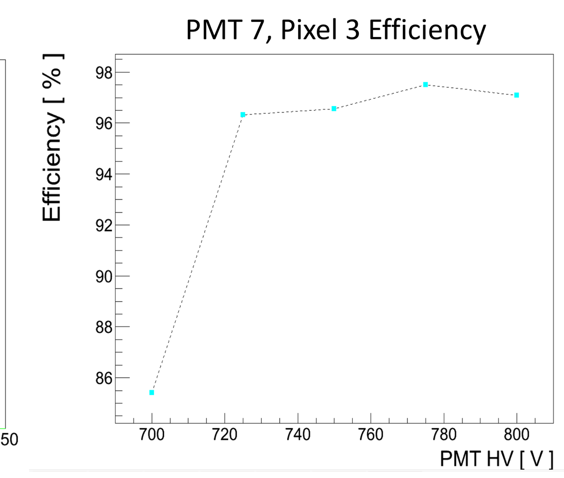




A good event is defined as being a cosmic ray that passes straight, or vertically through the paddle and is not a crosstalk event. Cuts are placed on the ADC and TDC data in four stages. The first stage defines a vertical cosmic ray track in the analyzed channel. The second stage is crosstalk cuts on all other channels in the PMT other than the channel being analyzed. The TDC width cut is the third stage to remove a large portion of the crosstalk remaining.

The remaining data is defined as good events. The efficency percentage for each channel is the number of good events above the ADC threshold cut divided by the number of total good events. This ADC threshold cut is the fourth stage of cuts to calculate efficiency.





Conclusion

The efficiency and crosstalk percentages calculated at the optimal HV values for Module 1 of CDet can be determined acceptable through the commissioning process. Using the efficiency, crosstalk, and ADC value data, the optimal high voltage settings for each PMT in Module 1 of CDet can be determined and Module 1 can be proven ready for use in experimentation to supplement the SBS detector system. This commissioning process will be applied to all six of CDet's modules before CDet's final installation in Jefferson Lab's Hall A.

Acknowledgements

Dr. Bogdan Wojtsekhowski (JLab)
Dr. Peter Monaghan (JLab, CNU)
Dr. Edward Brash (JLab, CNU)
Dr. John Annand (UOG)
Katie Whitcomb (CNU)

U.S. DEPARTMENT OF ENERGY
Office of Science