Applied Physics Capstone Final Report

High Voltage Control, Data Acquisition and Analysis Software for Jefferson Lab's Super BigBite Spectrometer CDet Detector

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Introduction

Thomas Jefferson National Accelerator Facility (Jlab) has had several experiments to measure the ratio of the proton elastic form factors. High precision measurements were made up to a Q^2 of 9 GeV^2. With the 12GeV beam upgrade at Jlab, the GEp(5) experiment will attempt to measure the ratio of the proton elastic form factors up to 14 GeV^2 . The Super BigBite Spectrometer (SBS) in Jlab's Hall A will perform this experiment by using the recoil polarization technique. The ratio of the form factors is related to the measurement of the polarization components of the recoil proton and electron from an elastic scattering [1]. Part of the SBS is the Coordinate Detector (CDet), which will be in the electron arm of the detector to improve the position measurement of the electrons before the electromagnetic calorimeter [2]. Good position resolution is critical in separating elastic scattered events from the inelastic background. The new CDet is composed of two planes of plastic scintillator hodoscopes. Each plane has 12 modules of 14 individual scintillator bars. The scintillator light produced by incident electrons is collected by wavelength-shifting fibers and detected by multi-anode PhotoMultiplier Tubes (PMT). Each PMT is supplied with high voltage and has 14 output channels that are fed into 1877S Time-to-Digital Converters (TDC) and Analog-to-Digital Converters (ADC) [4]. A high speed pipelined data acquisition system (DAQ) collects the TDC and ADC data, and produces a CODA data file to be analyzed by the Hall A analyzer. This project involves two principle components. The first is developing acquisition and physics analysis code which will allow a comparison of the test data to Monte Carlo simulations. Primarily, this will involve calibrating the energy and timing response of the detector. Second, it will be necessary to have a user-friendly system to monitor and control the detector's HV system. This will be accomplished through a GUI that interfaces with a time-dependent database of HV values.

Theory

High voltage is supplied to the PMTs from a LeCroy-1458 crate. Each mainframe crate has 10 HV modules with 12 channels each. The mainframe is connected to a portserver over an ethernet network using telnet protocol. The user computer then talks to the mainframe via the portserver. A simple graphical control system called hvs exists from previous Jlab experiments. The user can ssh into the high voltage controller and run the hvs bash script that starts the initialization of the high voltage mainframe and runs all of the java classes for the control system GUI. The HVMainMenu class generates the GUI and handles all of the visualization. The MainMenu talks to the mainframe through HVClient which looks at a list file for its host name and other information. This information is used to initialize the HVframe, HVchannel, and HVmodule objects, which store the location and identification for all of the crates, modules, and channels. The HVMonitor class talks to the client and reads data changes from the channels to the MainMenu. When the MainMenu is ran, the GUI is generated and a map configuration file can be loaded. This configuration file stores the channel location and naming information that will be displayevid in the GUI. From the MainMenu the HVMapTable can be generated, which, as seen in Figure2, indicates the status of each high voltage channel. Similarly, the HVMapMonitor displays the measured voltages, set voltages, and current draw for each channel, as seen in Figure3.

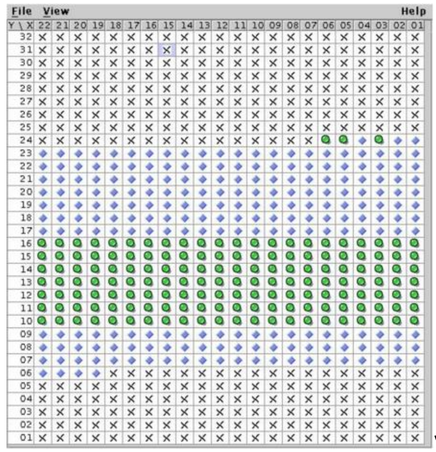

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Figure 1: The old HVTable display

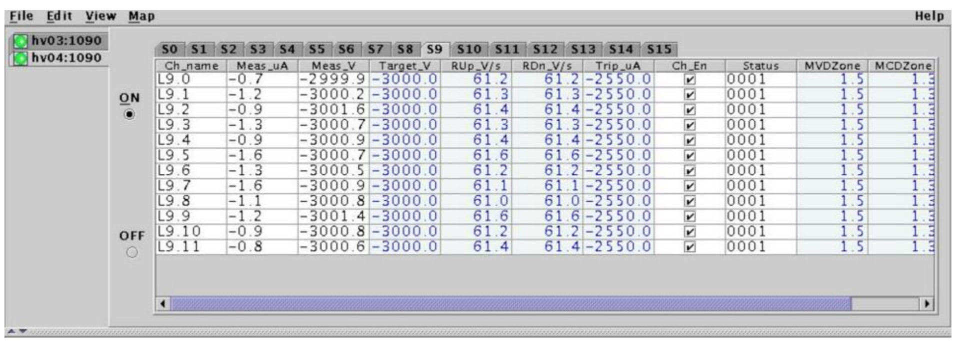


Figure 2: The old HVMap display

Once the detector is has high voltage, data can start being collected through CODA, the online data acquisition software. Using msqld, the mSQL daemon, a CODA database is created. CODA must be configured and connected to the readout controller using a tool called Cedit. To begin collecting data start the database, run CODA, load the newly created configuration, and start a run in the GUI. When the run is finished a CODA file is created that stores the run data in hexadecimal words. The analyzer code has to be able to decode the hexadecimal data words and create a ROOT tree of the raw ADC and TDC data to be further analyzed. Once a ROOT tree is created, a ROOT macro, which is a piece of C-like code, is written to generate histograms of interesting physics results to compare to Monte Carlo data.

Methods

The first main aspect of the project is developing a user-friendly system to monitor and control the detector's HV system. This was accomplished through a GUI that interfaces with a time-dependent database of HV values. To make the monitoring system easier to visually understand, HVmap configuration and HVMapTable had to be made to resemble the detector geometry. A gif image was made that shows the arrangement of the detector modules and the PMT channels coming from each side. The gif was placed in the middle of the MapTable GUI and the HV channels changed in the configuration file to align on each side of the detector next to the corresponding PMT, as seen in Figure4.

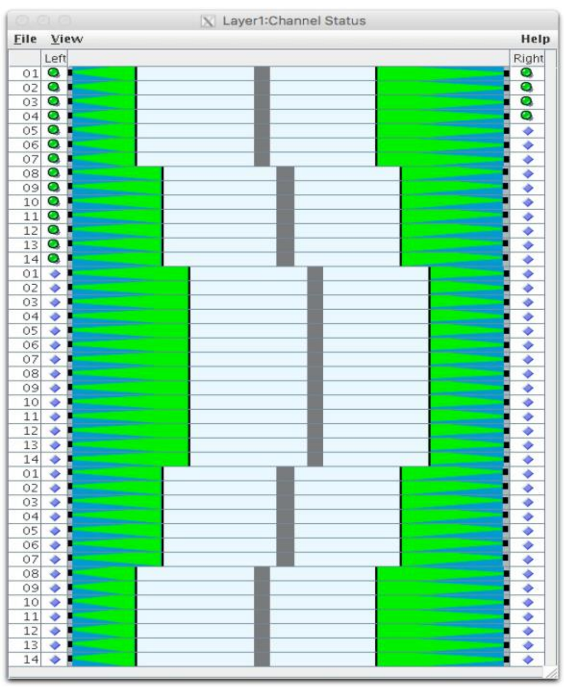


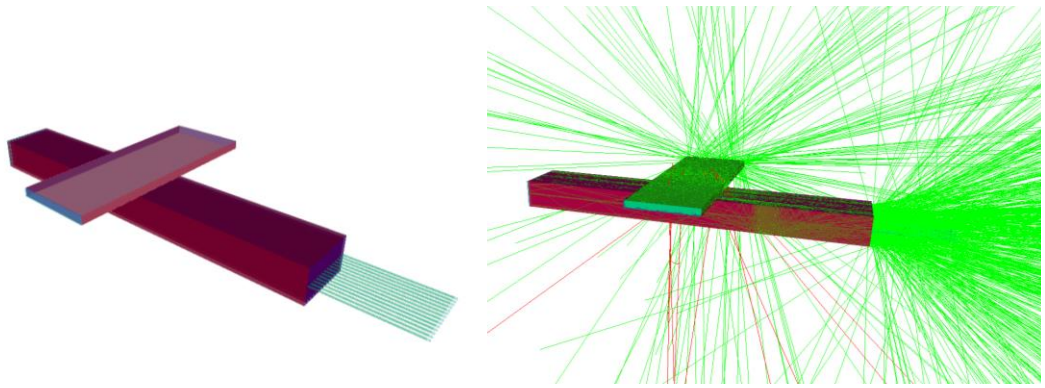
Figure 3: The New HVTable display

Now, when the user runs hvs, they can easily toggle between the Table view and Monitor view for each module, and see the status of each channel.

The second main aspect is developing acquisition and physics analysis code which will allow a comparison of the detector's cosmic ray test data to Monte Carlo simulations. For the analyzer to know which PMT and pixel each signal is coming from, a mapping class needs to be written to map each channel to an ADC and TDC location. A mapping class already existed that hardcoded each pixel number of one module to the ADC and TDC channels. The class was changed to read all the channel information directly from a text file, making it more general for the entire detector.

After the Analyzer creates a Root tree, a macro, plot.C, was written to further analyze the raw data. The macro looks event by event and plots the timing resolution, ADC distribution, multiplicity, and overall rate of the cosmic rays for each PMT and pixel. To get access to the ADC and TDC data in the ROOT tree, the macro has to set branch addresses to each branch in the tree. To plot raw values, the macro simply runs a loop over all the events in that branch and stores the variable in a histogram object. The axes, scale, and binning values of each histogram has to be set to best view and understand the variable being analyzed. A canvas object must be created for each histogram to be drawn on. All of the drawing and histogram manipulating methods are already built into ROOT, and just simply must be called.

A similar macro also reads in another ROOT tree from a Geant4 simulation and produce the similar histograms for comparison to the test data. The Geant4 simulation creates a bar with the same properties of scintillator, such as scintillation yield and index of refraction. Fourteen optical fibers are layered in the bar for each pixel on the PMT. The bar is wrapped around with a mirror surface with the same reflectivity of the Mylar film being used in the detector. Muons are generated from the side of the bar with the energy and angular distribution of cosmic rays. Geant keeps track of each event in steps, recording the position and energy of each primary and secondary particles produced. The simulation counts the amount of optical photons collected on the PMT surface which can be used to compare to ADC and multiplicity data.



Geant4 simulation of scintillator bars with cosmic rays producing optical photons

Data and Conclusions

The first plots to look at are the raw ADC spectra, as seen in Figures 4. Another plot produced that helps give an understanding of the detector's performance is the multiplicity plots seen in Figure7. The multiplicity histograms show that many of the events produce signals in several channels, up to 10. It seems unlikely that so many cosmic rays would come in at an incident angle that would trigger that many layers. The simulation data will be helpful in trying to understand where this high multiplicity is coming from. One concern was that there is crosstalk between pixels, resulting in high multiplicity events. When a Gaussian noise background was added and cuts made for an energy threshold of 5.0 MeV, the simulation multiplicity shifted slightly, as seen in Figure 5, resembling the experimental data. This threshold lets us know what voltage threshold to apply to the detector Future work could be to develop the simulation to account for energy deposition in pixels adjacent to the primary pixel to account for this crosstalk.

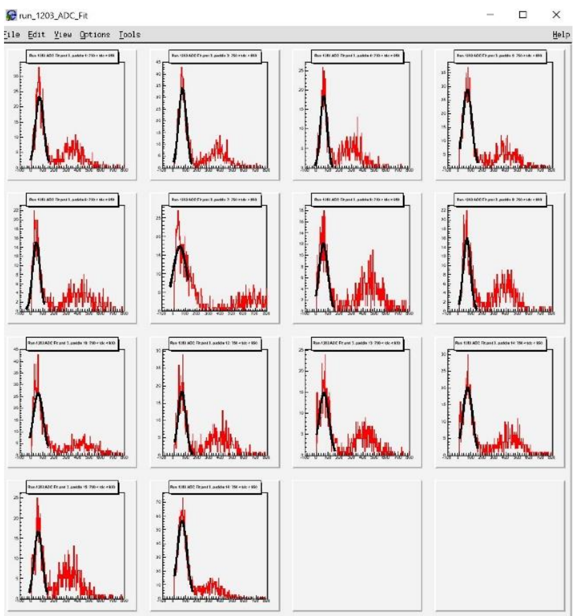


Figure 4 Fitted ADC histograms

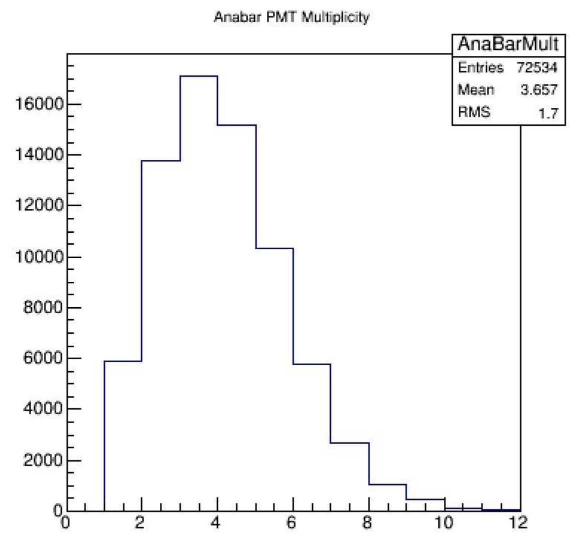


Figure 5 Simulation Multiplicity with threshold of 5.0Mev

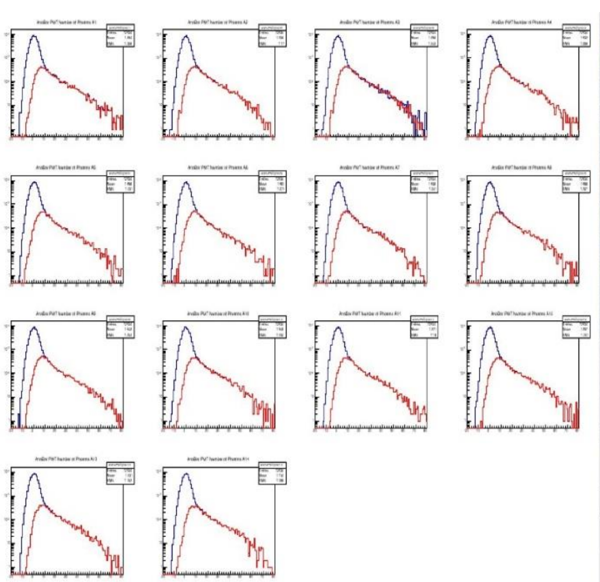


Figure 6: Simulation number of Photons

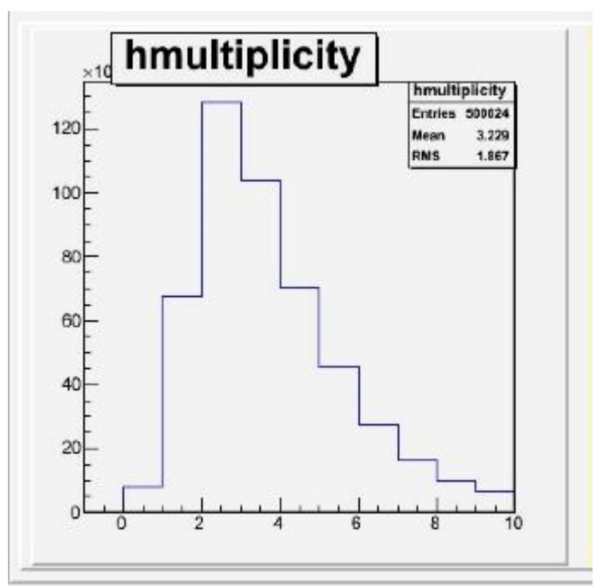
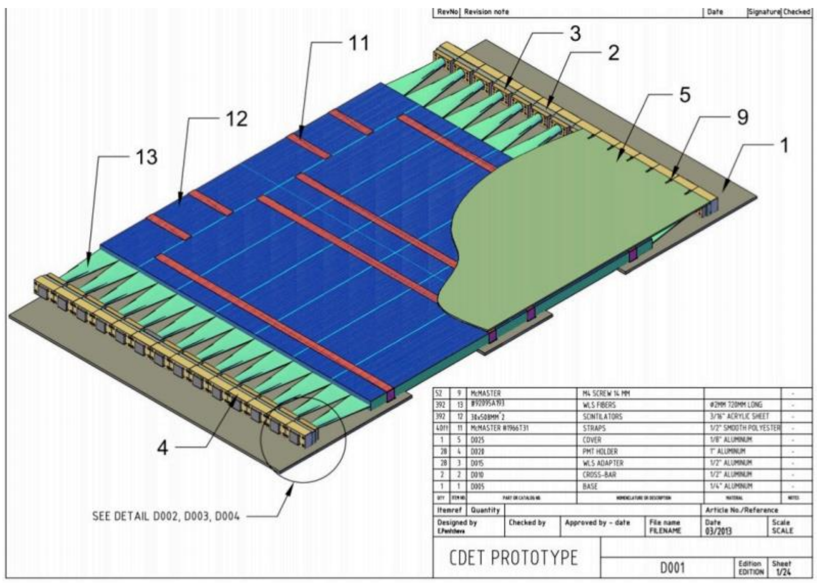


Figure 7 Multiplicity histogram

Appendix



Cdet prototype design

Layer	Module	L/R	PMT	ADCSLOT	ADCCHAN	TDCSLOT	TDCCHAN	PIXEL1	PIXEL2
1	1	2	1	20	0	14	0	4	5
1	1	2	2	20	16	14	16	4	8
1	1	2	3	20	32	14	32	2	11
1	1	2	4	20	48	14	48	1	13
1	1	2	5	21	0	14	64	4	14
1	1	2	6	23	32	14	80	3	13
1	1	2	7	23	48	15	0	4	16
1	1	2	8	21	48	15	16	13	16
1	1	2	9	22	0	15	32	4	16
1	1	2	10	22	16	15	48	13	16
1	1	2	11	22	32	15	64	13	16
1	1	2	12	22	48	15	80	13	16
1	1	2	13	23	0	16	0	5	16
1	1	2	14	23	16	16	16	13	16

1Database of channel locations in ADC and TDC

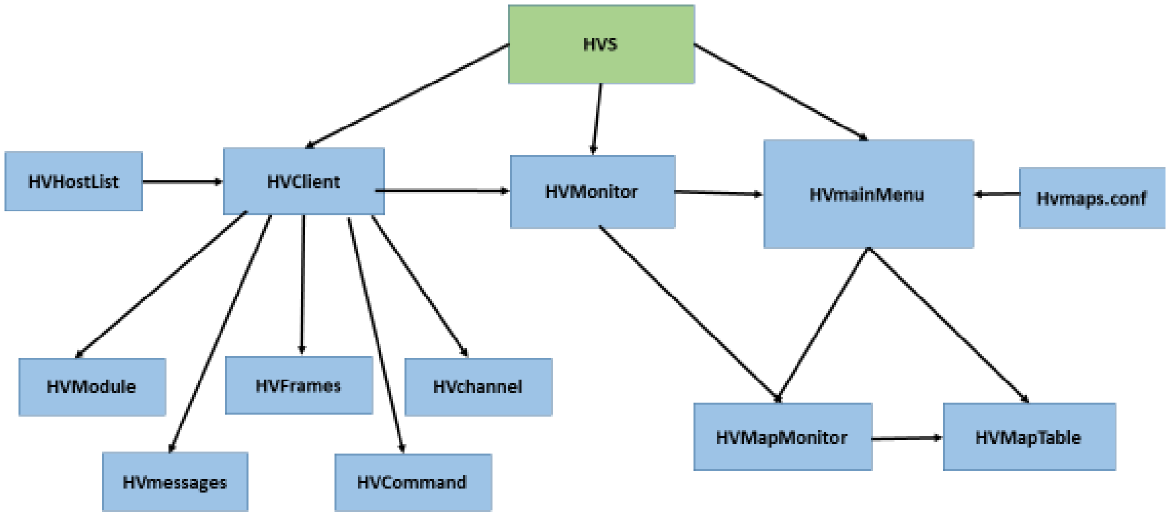


Figure 2: Flowchart for the high voltage control system code

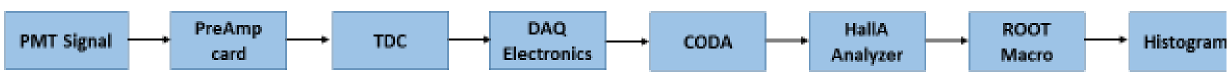


Figure 3:Flowchart for Cdet DAQ system and analysis

Bibliography

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