Detector Characterization for a Parity-Violation Experiment

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Abstract

The G0 experiment at Jefferson Lab uses parity-violating elastic electron scattering to extract the strange quark contribution to the charge and magnetization distributions within the proton. The backward-angle phase of the experiment will begin acquiring data in December 2005. In this phase of the experiment, the trajectories of recoiling electrons will be reconstructed with plastic scintillator detectors. Aerogel threshold Cherenkov counters will be used for particle identification. Owing to the small asmmetries that must be measured in parity-violating experiments, the detectors function at a high rate and with high efficiency. Each detector must therefore be calibrated in terms of light yield and timing resolution. Cosmic rays were used for this purpose, simulating the response to high energy electrons. Results of the calibration process will be presented.

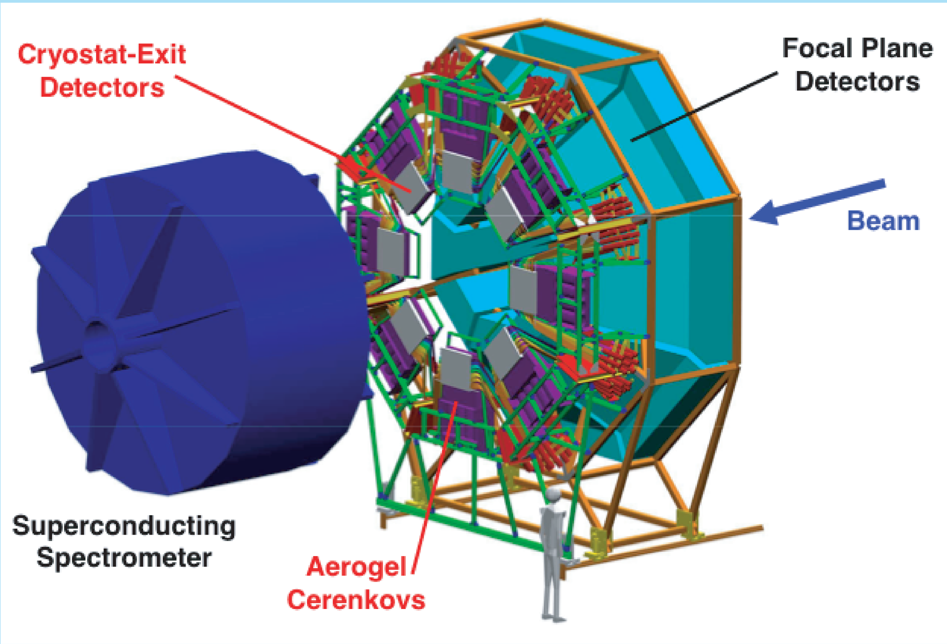
Parity Violation

Parity transformation is equivilant to mirror reflection. The electromagnetic and strong interactions are said to conserve parity, or more precisely, to be invariant under the parity transformation. Oppositly, the weak interaction is said to violate parity. In collision experiments involving electron beams, parity transformation is equivilant to reversing the helicity of the beam. Since electrons interact with matter through the electromagnetic and weak forces, helicity reversal will produce detectable scattering asymmetries. This effect can be utilized by running the scattering experiment with the beam helicity in both the regular and reversed states, and measuring the resulting asymmetries.

The G0 Experiment

The aim of the G0 experiment at Jefferson Lab is to study the quark substructure of the proton. Specifically, G0 uses parity violating elastic electron scattering to extract the strange quark contribution to the charge and magnetization distributions within the proton. In the experiment, the electron beam provided by Jefferson Lab is incident on a liquid helium target. Scattered particles are collected by a large-acceptance spectrometer toroid, and are detected in plastic scintillation and aerogel threshold Cherenkov counters.

Owing to different sensitivities to the strange quark, G0 will be carried out in two phases. The initial stage, completed in early 2004, detected protons at forward angles of scatter. Contrary to this, the second stage of G0 will detect electrons recoiling at backward angles, and will commence in December of 2005.



G0 Backward Angle Configuration

Aerogel Threshold Cherenkov Counter [1]

Backward Angle Detectors

When G0 begins running in the backward angle phase, three types of particles will be detected at large angles of scatter; elastic electrons, inelastic electrons, and negative pions. Since the elastic scattered electrons contain information about the strange quark, G0 seeks to detect only the events produced by these particles. Detectors must therefore serve to distinguish between particles types.

In order to isolate the elastic events from the inelastic, G0 implements trajectory reconstruction. Two sets of plastic scintillation counters are used for this purpose. The set located nearest the superconducting magnet consists of 9 counters. These are the Cryostat-Exit Detectors (CEDs). The Focal Plane Detectors (FPDs) are formed by 16 scintillation counters, and are located behind the CEDs. The combination of CED and FPD can then be used to reconstruct the trajectory of any given event. Since inelastic electrons scatter at greater angles in the magnetic field, the CED/FPD combinations triggered by these particles will differ from those of the elastic electrons.

Aerogel threshold Cherenkov counters are then used to differentiate between the electrons and pions. Within Cherenkov counters, only particles with sufficient velocity will stimulate photon emission. That is, when $v > c/n$. Since the pions produced in the inelastic collisions recoil with velocities below this threshold level, they will not stimulate Cherenkov light.

left to right: CEDs unwrapped [3], *CEDs, & FPDs.*

Detectors Testing

The asymmetries that G0 aims to quantify in the backward-angle phase are very small. For this reason, the detectors used in the experiment must function at a high rate and with high efficiency. Each detector must therefore be characterized in terms of timing resolution and light yield before the experiment begins. In the case of the CEDs and Cherenkov counters, cosmic rays were used for this purpose, simulating the response to high energy electrons. These methods are outlined below.

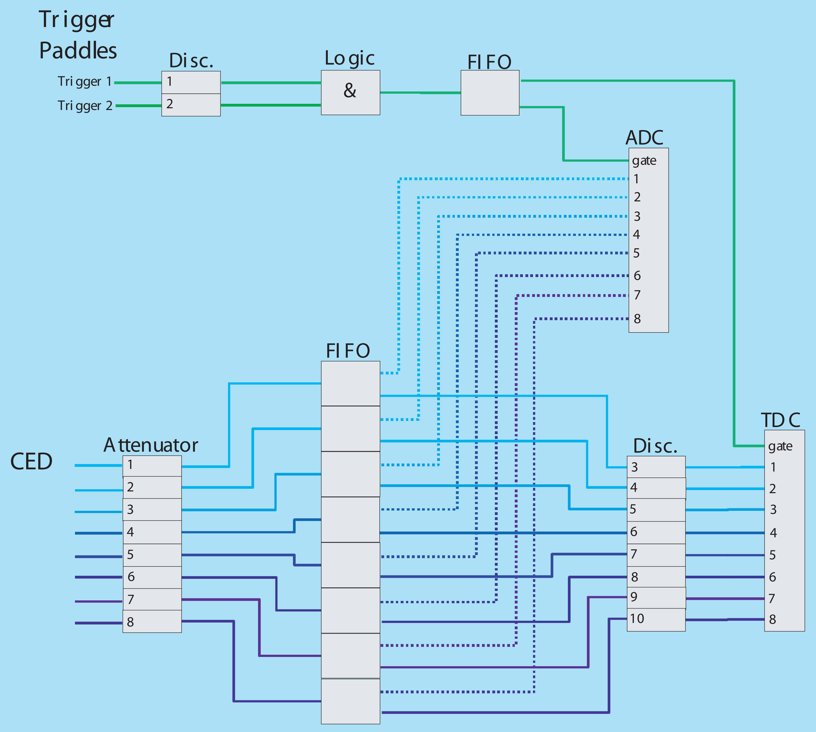


Figure 1: CED Cosmic Test

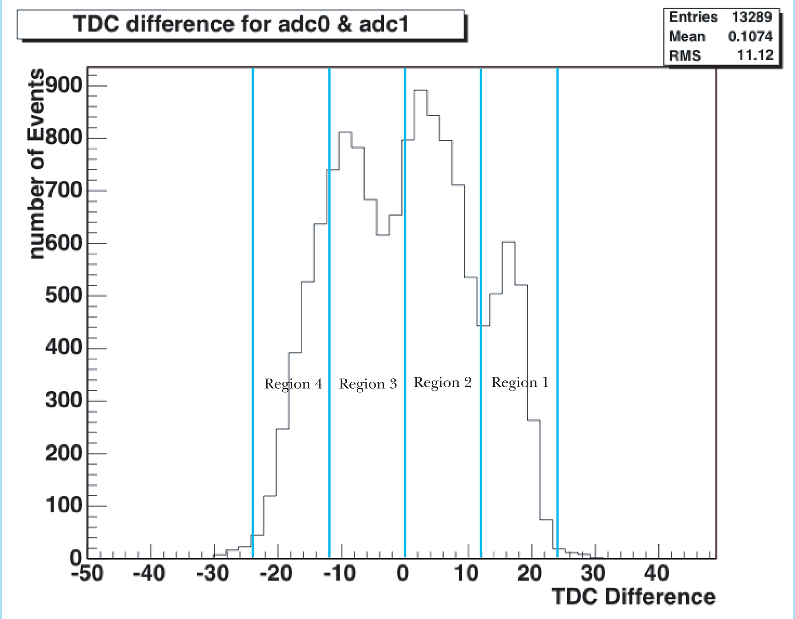


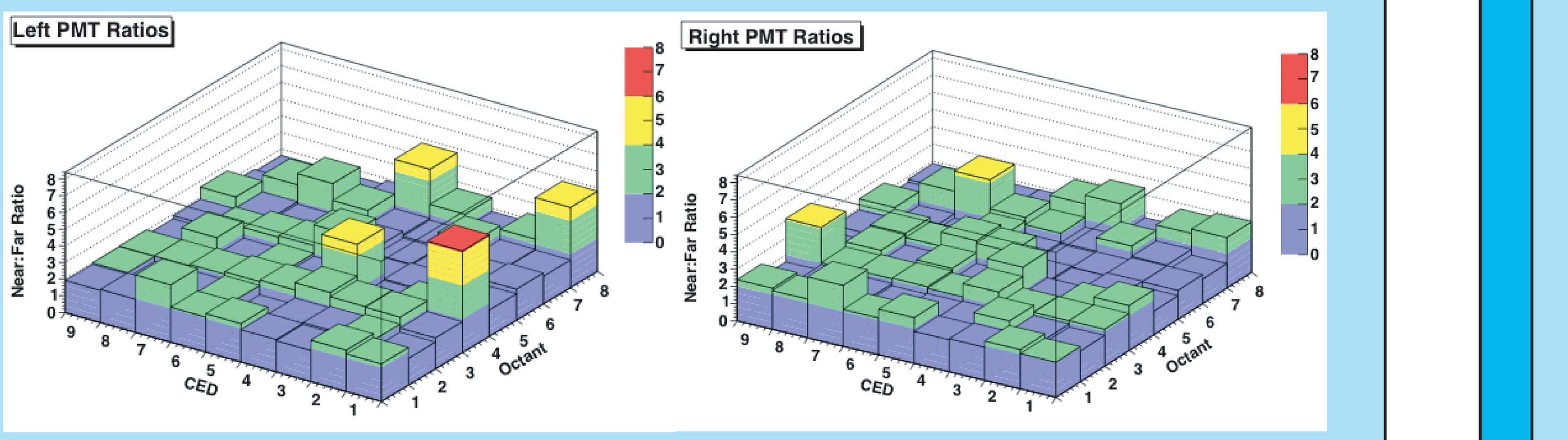
Figure 2: TDC Difference between left and Right PMT

CED Calibration

In the CED calibration process, large panels of scintillator, called trigger paddles, are placed on either side of the CED. When a cosmic event is detected in both paddles, the Data Aquisition System, or DAQ, begins timing until an event is detected in the CED (refer to Figure 1 on the left).

For the DAQ to register these events, the light produced within the scintillator must be converted to an elecronic signal. This is accomplished by photomultiplier tubes, or PMTs, which produce a characteristic number of photoelectrons for every photon. Each CED is equipted with two such PMTs; left and right. The electronic signals from these PMTs are then sent through a discriminator. This allows the DAQ to isolate events above a specified threshold level, and eliminate false signals occuring as a result of noise within the PMTs.

Time to digital convertors (TDCs) then transform the recorded response time of the left and right PMTs into digital signals that can be analyzed by the computer. The difference in response time between the two signals is then used to indicate the event location within the CED. Events are grouped according to their location in one of four regions, and the number

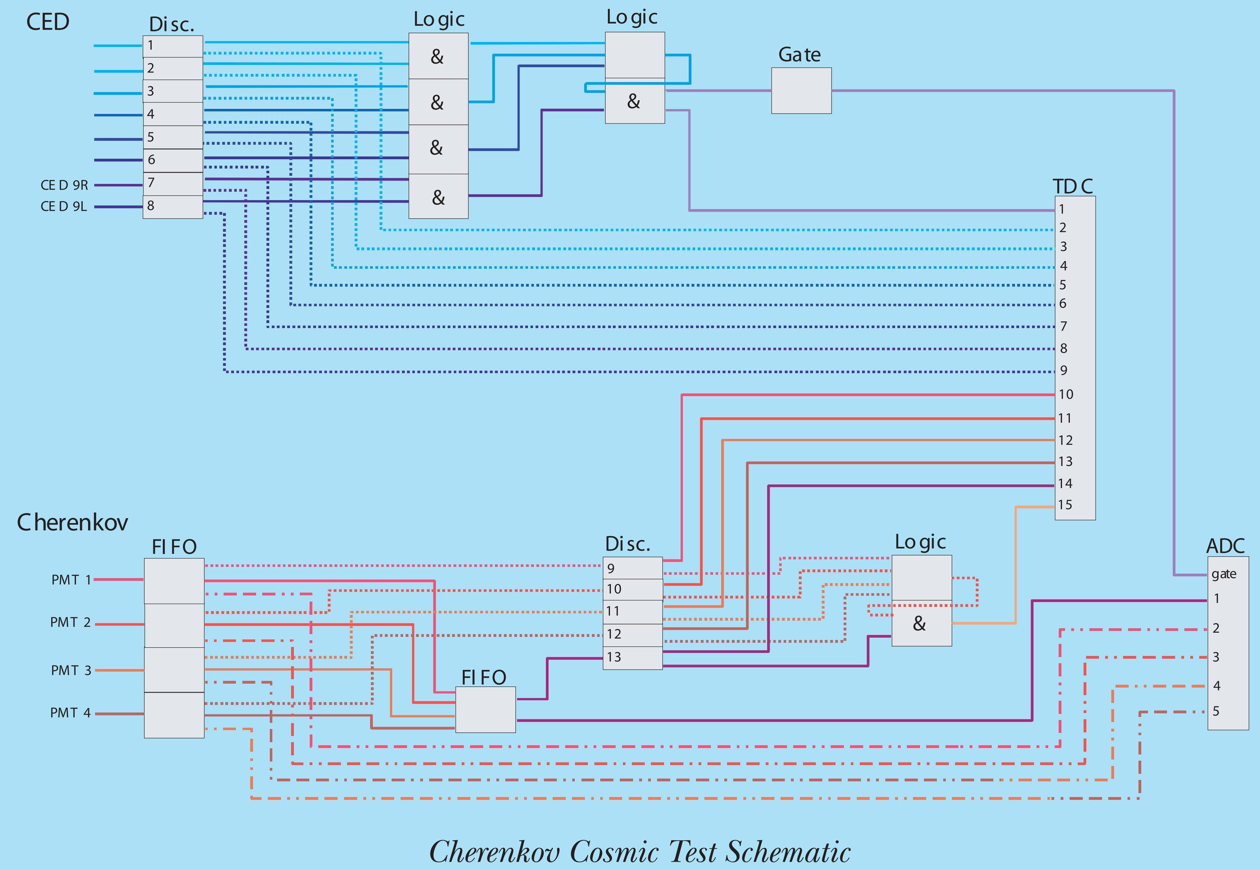


CED Photomultiplier Tubes in Efficiency [3]

of photoelectrons produced by each region is calculated. The photoelectron yield is then used to indicate the efficiency of the CED. Refering to Figure 2, CEDs of high transmission will produce compariable numbers of photoelectrons in all 4 regions. As in the above figure, inefficencent CEDs can also be identified by taking the ratio of the yield in the region nearest the PMT, as compared to that in the region farthest from the PMT. Smaller ratios indicate high transmission within the CED (blue and green levels), whereas large ratios indicate poor transmission (yellow and red levels). Using this method of indicting inefficiencies, it was possible this summer to identify one such CED.

Cherenkov Calibration

Calibration of the aerogel threshold Cherenkv counters will follow similar steps as in the CED calibration, but with notable differences in apparatus. As in the schematic below, the Cherenkov calibration does not install additional trigger paddles to initiate timing devices, but instead uses the previously tested CEDs as triggers. The advantage being that the trajectory of the incident cosmic event can be reconstructed. Differences in the Cherenkov PMT response time will then be determined, as will the light yield of each PMT.



Cherenkov Cosmic Test Schematic

Conclusion

Using the methods outlined above, all the CEDs to be istalled in the apparatus for the G0 experiment have been calibrated. The light yield and efficiency of each was determined, and used to isolate detectors of low efficiency. These will be removed, and their replecaments tested. The Cherenkov calibration is currently underway. Both processes are necessary to ensure the peformance of the detectors when the experiment runs in December.

References

[1] L. Lee, *North American Aerogel Cherenkovs*, G0 Report G0-05-008, 2005
[2] L. Lee, *Backangle Support, Scintillators, Lightguides*, G0 Report G0-03-098, 2003,
[3] M. Gericke, presentation at July 2005 Collabortion meeting