A triplet polarimeter for use in the Jefferson Lab GlueX Experiment

*Brianna Thorpe, M. Dugger, B.G. Ritchie, Arizona State University, Tempe AZ 85287-1504 **

Abstract: The GlueX experiment in Hall D at Jefferson Lab will utilize a polarized photon beam to help identify exotic meson states. Knowledge of the degree of polarization of the photon beam is critical for identifying those states. The use of the triplet production process (pair creation off atomic electrons) could allow for determination of polarization with high precision. A newly-constructed polarimeter will be described, preliminary results of the detector's response to alpha and electron sources will be presented, and estimates of potential performance with the Jefferson Lab Hall D photon beam will be discussed.

Motivation

Jefferson Laboratory's GlueX detector is designed to search for exotic mesons. The detector uses a ~9 GeV photon beam created by the coherent bremsstrahlung of 12 GeV electrons incident on an oriented diamond crystal. To accomplish the goals of the GlueX experiment, the degree of photon beam polarization has to be known to within 0.04. This presentation describes a polarimeter based on the triplet photoproduction process.

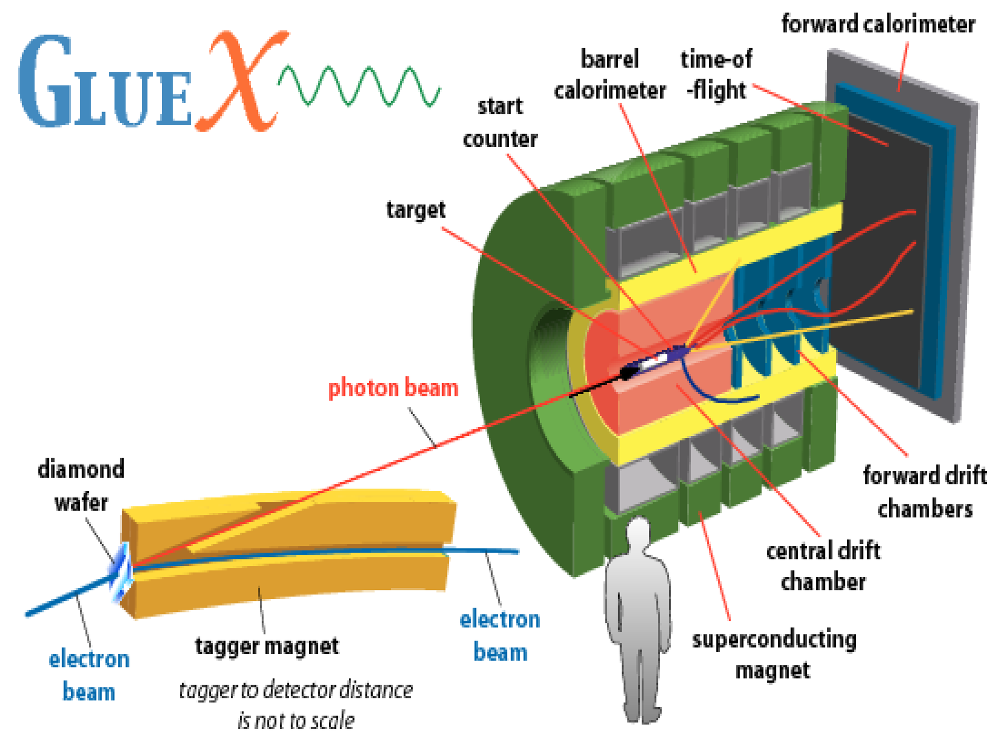


Figure 1: Sketch of the tagger and GlueX detector.

Triplet production and event generation

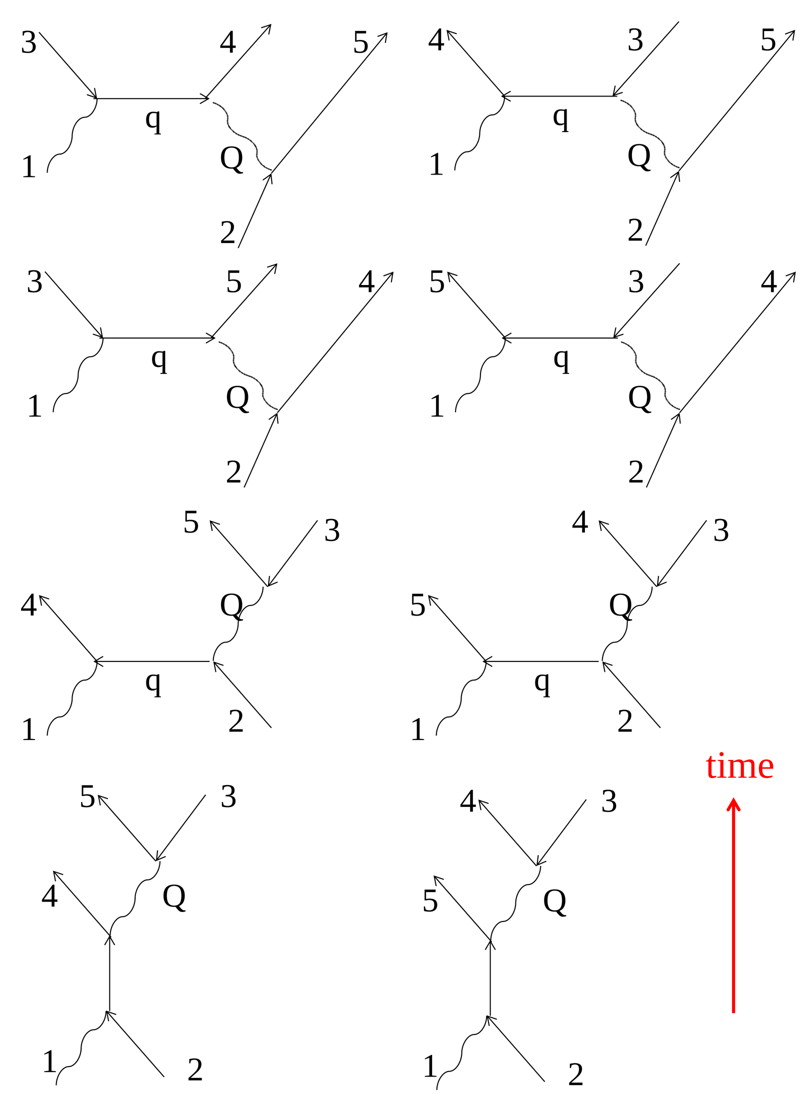


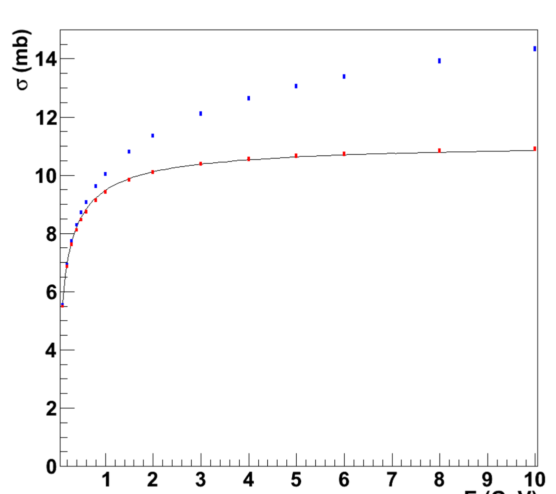
Figure 2: Diagrams included in event generator.

Triplet photoproduction: In this process, a polarized photon beam interacts with an atomic electron's electric field, resulting in the production of an electron and positron pair, with the atomic electron recoiling from the atom. Any transverse momentum of the electron-positron pair is compensated for by the recoil electron, which is slow-moving , and thus can attain large polar angles. The angular distribution of the recoil electrons gives information on the beam polarization.

For polarized photons $\sigma = \sigma_0[1 + P\Sigma\cos(2\varphi)]$, where σ_0 is the unpolarized cross section, P is the photon beam polarization, Σ is the beam asymmetry and φ is the azimuthal angle of the recoil electron. For GlueX, the photoproduced pair will be detected by a pair spectrometer upstream from the main detector. The device described here detects the recoil electron.

Event Generation: The event generator includes all of the tree level diagrams shown in figure 2. The event generator also included the screening correction provided in the paper by Maximon and Gimm.† Unpolarized cross section results from the event generator, with and without screening corrections, are compared to values from the NIST in figure 3.

† L. C. Maximon, H. A. Gimm Phys. Rev. A. 23, 1, (1981).



- **Black line**: Total cross section from NIST
- **Blue points**: Total cross section from event generator without screening correction
- **Red points**: Total cross section from event generator with screening corrections included

[1] L. C. Maximon, H. A. Gimm Phys. Rev. A. 23, 1, (1981).

Figure 3: Comparison of generator to NIST.

Hardware

Detector: The polarimeter uses an S3, double sided silicon strip detector, purchased from Micron Semiconductor. The detector has 32 azimuthal sectors on the ohmic side and 24 concentric rings on the junction side, resulting in 768 resolvable angular regions. The S3 has an outer active diameter of 70 mm and inner active diameter of 22 mm. The thickness of the silicon is 1034 microns and is fully depleted using a bias potential of 165 V. Figure 4 shows a picture of the detector mounted on a plate that can be inserted into the vacuum chamber.

Measuring the recoil distribution: The S3 will detect the recoil electrons produced when photons strike a thin beryllium foil 35 mm upstream of the S3. The photoproduced pair is detected in the pair spectrometer before the GlueX detector .

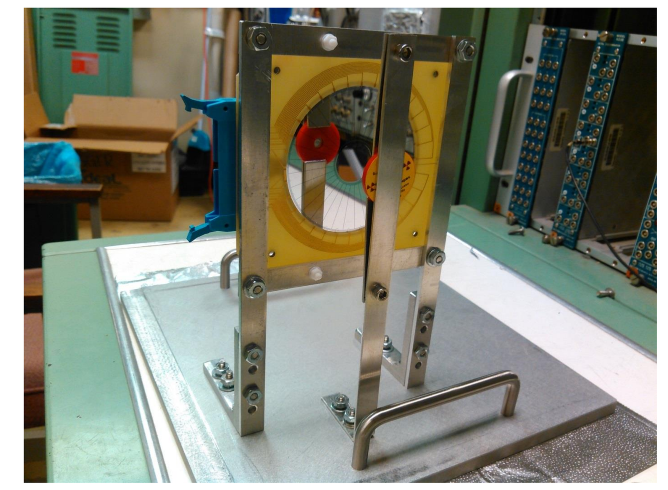


Figure 4: Micron S3 detector (sector side shown) mounted on the removable plate. The red disk is a Po210 source (used for testing).

Vacuum chamber: The vacuum chamber is a standard size purchased from Curt J. Lesker Company and has an inner volume of one cubic foot (12'x12'x12') with the number and type of flanges customized for the application, along with a removable plate and brackets. The interior of the chamber with the detector installed can be found in figure 5.

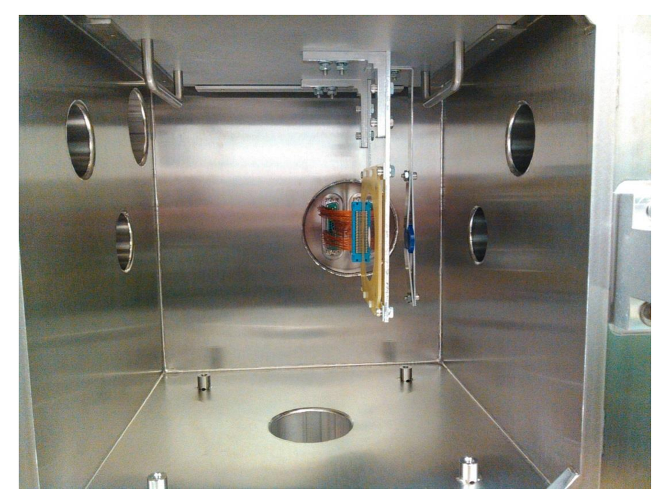


Figure 5: S3 detector inside chamber.

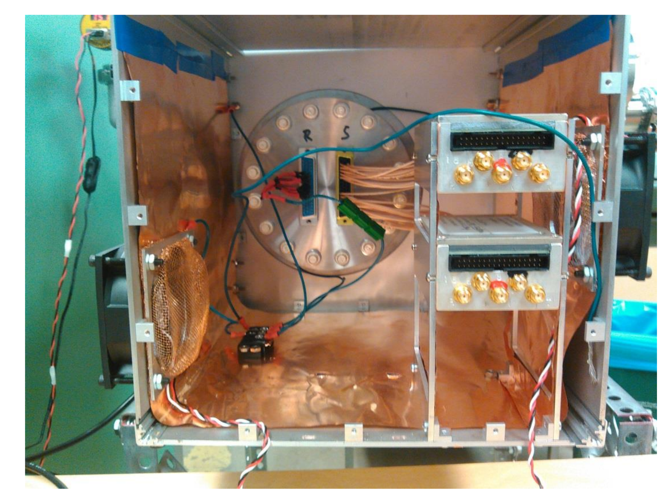


Figure 6: Preamps in preamp enclosure.

Preamps and enclosure: The preamps where purchased from Swan Research and have an effective sensitivity for our application of ~100 mV/MeV. A picture of the preamps inside the preamp enclosure can be found in figure 6.

Distribution box: A power and signal distribution box is attached to the backend of the preamp enclosure (see figure 7).

Positioning system: The positioning system consists of a stepper motor that moves a geared rack that is connected to a converters tray (home for beryllium foils) and can be seen in figure 8.

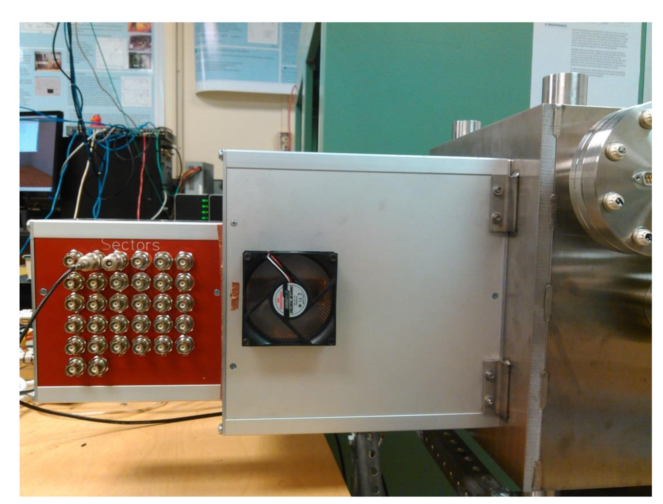


Figure 7: Distribution box (red) attached to preamp enclosure (with fan). Box to far right is the vacuum chamber.

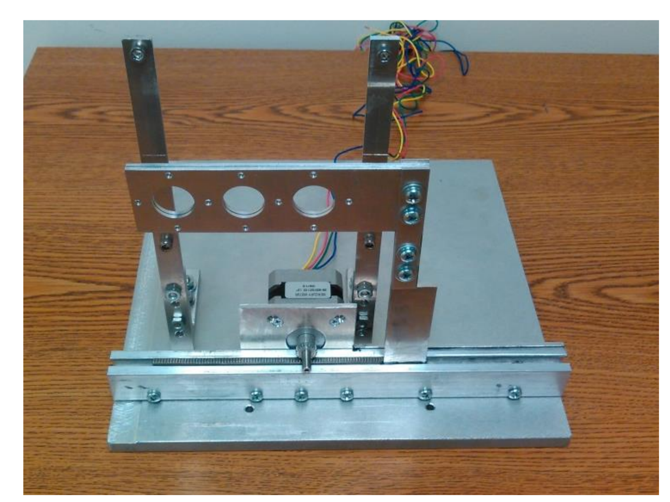


Figure 8: Positioning system (without S3 detector attached).

Detector response

The polarimeter was tested using various sources. For the initial test we used an alpha source (Po210). An oscilloscope snapshot using the alpha source can be seen in figure 9, where the voltage per division is 100 mV and the time per division is 10 µs. Once the detector was checked using the alpha source, we moved on to the beta source (Cs137). An oscilloscope snapshot using the beta source can be found in figure 10, where the voltage per division was set to 20 mV and the time per division was 50 ns.

An initial analysis yielded a resolution (standard deviation) of the detector and preamps of 12 keV, and is well within the resolution required for the device to function as a polarimeter.

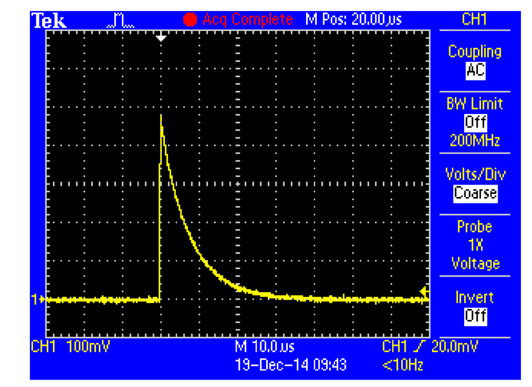


Figure 9: O-scope snapshot Po210 source.

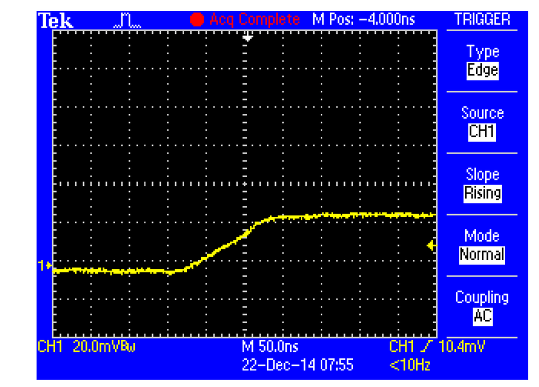


Figure 10: O-scope snapshot Cs137 source.

Simulation of analyzing power

Simulation: The generated events included the triplet production process described previously, along with the expected pair production off of the nucleon, and were processed through a full detector simulation of the triplet polarimeter using the GEANT4 library. An occupancy plot of the detected energy deposition versus azimuthal angle can be seen in figure 11, where the red line at 200 keV shows the threshold that were placed on the events that were further analyzed. For all events the incident photon polarization was set to 100%.

Analyzing power: The events that pass the energy threshold shown in figure 11 were processed to produce a weighted counts versus azimuthal angle plot that was fit to the function $A(1+B\cos(2\varphi))$, where A and B were parameters of the fit. The parameter B gives the analyzing power of the polarimeter. Figure 12 shows the result of the fit for a 35 µm beryllium converter. The analyzing power was found to be 19%.

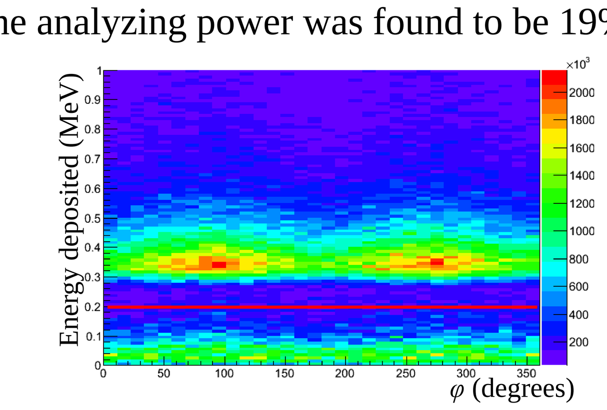


Figure 11: Energy versus φ

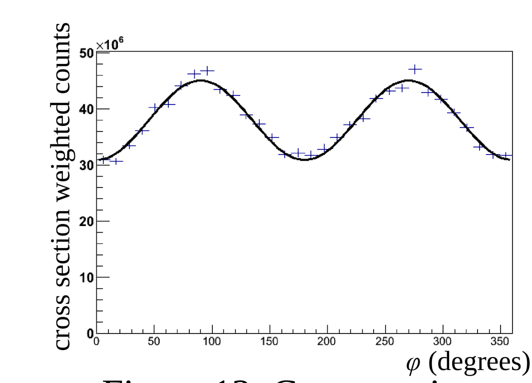


Figure 12: Cross section weighted counts versus φ

Installation

After the construction and testing of the polarimeter was completed, the device was taken apart and shipped to Jefferson Lab. The polarimeter has undergone initial vacuum tests and has been reconstructed to the extent that it had been at ASU. In the near future, fast ADC modules will be connected to the preamplifiers and the positioning system will be fully installed. We expect that the device will be placed in the beamline of Hall-D and data taken with a polarized photon beam later this year.

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