

Commissioning of the Pair Spectrometer of the GlueX experiment

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Abstract. The main goal of the pair spectrometer of the GlueX experiment at Jefferson Lab is to determine the photon beam flux and to measure beam polarization. We present the design of the pair spectrometer and the performance results during first commissioning runs of the GlueX experiment.

1. Introduction

The GlueX is the new experiment in the experimental Hall D at Thomas Jefferson Accelerator Facility, whose main goal is to search for mesons with exotic quantum numbers using a beam of linearly polarized photons [1]. The photon beam is produced by a 12 GeV electron beam incident on a thin (20 – 50 μm) diamond radiator. Linearly polarized photons originate in the coherent radiation process from the diamond crystal lattice and result in sharp monochromatic peaks in the photon energy spectrum [2]. The energy of the beam photon can be determined by detecting the post-radiated electron in the broad band tagging hodoscope (TAGH) and tagger microscope (TAGM) detectors. In order to increase the fraction of linearly polarized photons, the beam is passed through a collimator with the typical diameter of 3.5 – 5 mm. Collimated photons are sent to the GlueX liquid hydrogen target.

The photon beam flux and the spectrum of the collimated photon beam is measured by the pair spectrometer [3], which is positioned in front of the GlueX detector. The energy of a beam photon and, therefore the beam energy spectrum, can be reconstructed by measuring the momentum of the $e^{\pm}$ pair produced in a thin ($\sim 10^{-3}$ radiation lengths) converter. The electron and positron are deflected in a dipole magnet with the magnetic field of 1.8 T and are subsequently detected in two layers of scintillator detectors: the high-granularity hodoscope and 16 coarse counters. The hodoscope and coarse counters are organized in two arms to register the electron and positron and are positioned symmetrically with respect to the beamline. Each arm covers the $e^{\pm}$ energy range between 3 GeV and 6.25 GeV. The high-granularity hodoscope is used to provide precise measurements of the photon energy. It consists of thin scintillator tiles with the thickness of 1 mm and 2 mm. The light from each tile is collected using wavelength shifting fibers and is detected by a Hamamatsu silicon



photomultiplier (SiPM) with a sensitive area of $3 \times 3 \text{ mm}^2$ [3-4]. The amount of light collected from a tile corresponds to about 60 – 90 SiPM pixels. The coarse scintillator counters are used to produce a trigger by requiring a coincidence of hits in the two detector arms. They also provide time measurements, which is required to identify the electron beam bunch for which the interaction occurred. The light from the scintillator counters is detected by Hamamatsu R6427-01 PMT's.

2. Performance of the pair spectrometer

The pair spectrometer was successfully operated during the first GlueX commissioning runs in the fall of 2015 and spring 2016. In the beginning, the accelerator was operated using a 6 GeV electron beam, which is a factor of two smaller than the designed energy. Later, the beam energy was increased to 12 GeV.

The detection efficiency of the pair spectrometer hodoscope was measured by reconstructing $e^\pm$ pairs. One lepton was required to be fully reconstructed, i.e., to have coincidence of hits in both the coarse counter and corresponding hodoscope counters. The other lepton was required to have a hit in the coarse counter. The efficiency is determined by searching for associated hits in the hodoscope. The hodoscope efficiency measured for several groups of scintillator tiles is presented in figure 1. Each group corresponds to the projection of the coarse counter. The average efficiency is found to be larger than 95%. Some gaps between the tiles accounts for some inefficiency.

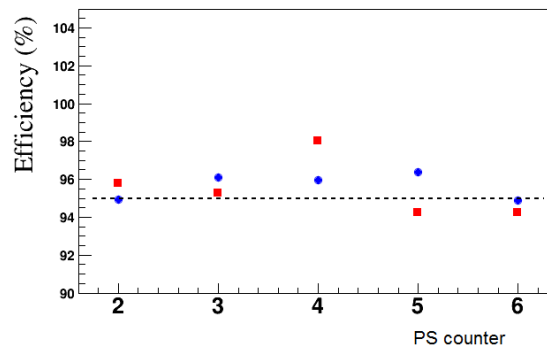


Figure 1. Average efficiency of the pair spectrometer hodoscope for several groups of tiles. Each group corresponds to the projection of the coarse PS counter. Circles and boxes correspond to two arms of the spectrometer.

The energy resolution of the pair spectrometer hodoscope was estimated using a broad-band tagging hodoscope (TAGH), which is used to measure energy of tagged electrons. Each TAGH counter corresponds to the specific energy range of beam photons. The energy resolution of the TAGH counters is better than that of the PS and ranges between 4 – 8 MeV. The energy spread in the PS hodoscope measured for each TAGH counter is presented in figure 2. The electron beam energy for this run period corresponded to 6 GeV. The photon beam energy of the first TAGH counter corresponds to about 5.8 GeV. The hole in the middle of the distribution represents the region where TAGH counters were not installed for this run period. The energy resolution was found to be slightly larger (by a few MeV) than that predicted by the detector simulation but is expected to be improved after the PS hodoscope energy calibration.

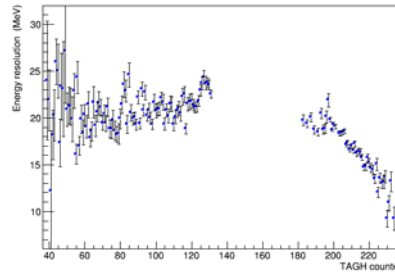


Figure 2. Energy spread of the pair spectrometer hodoscope measured for each TAGH counter.

The photon beam spectrum measured with the pair spectrometer is presented in figure 3. The left plot corresponds to runs with an amorphous radiator. The spectrum shape was found to be in a good agreement with predictions of the GlueX detector simulation of incoherent bremsstrahlung radiation. The energy spectrum measured with the diamond radiator is shown on the right plot of figure 3. Peaks in this plot correspond to coherent radiation from the diamond crystal lattice resulting in the production of linearly polarized photons. These spectra took into account pair spectrometer acceptance corrections. The acceptance was determined at small luminosity by measuring the photon flux using an electromagnetic calorimeter inserted to the photon beam.

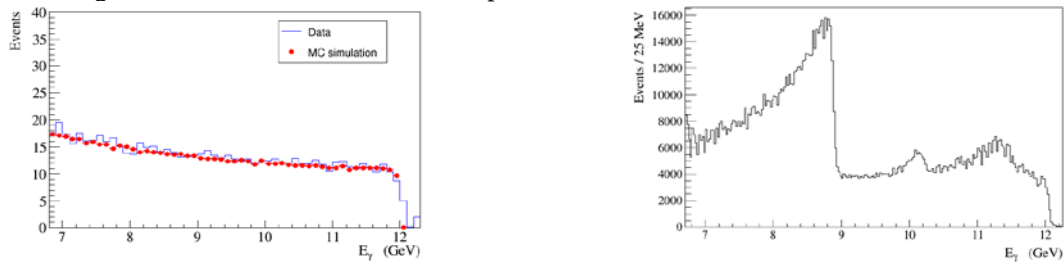


Figure 3. Energy spectra of beam photons measured with the PS hodoscope during commissioning runs with an amorphous radiator (left) and a diamond radiator (right). Circles represent predictions from the GlueX detector Monte Carlo simulation.

Measurements of time from the PS coarse counters were performed using an F1 time-to-digital converter (TDC) designed at Jefferson Lab. The bin width of the F1 TDC corresponds to about 58 ps. We measured the time resolution of the counters with respect to the RF signal, which is associated with the beam bunch crossing rate. A prescaled RF signal was sent as a reference to one of the TDC channels. The time walk corrected difference $t(\text{RF}) - t(\text{PS})$ in units of TDC bins is presented in figure 4. The time resolution measured with coarse counters was found to be better than 150 ps, which is sufficient to separate beam bunches. The light yield corresponds to more than 900 photo electrons detected with the PMT (figure 4).

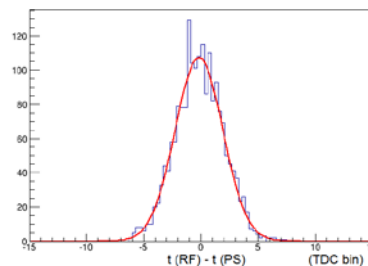


Figure 4. Time resolution of the pair spectrometer coarse counters measured with respect to the RF signal.

Acknowledgments

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References

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