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Energy Calibration of STB-Tagger II by Using e^+e^- Pair Production

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The energy calibration of a bremsstrahlung tagging system STB-Tagger II was carried out by using a dipole magnet $\mathcal{R}$TAGX. The tagged photon energy was determined by a momentum analysis of e^+e^- pairs converted from bremsstrahlung photons at two energies of STB circulating electrons. The relative relation was obtained between the tagged photon energy for 920 MeV circulating electrons and that for 1200 MeV electrons. In this report, We present the method and the result of the energy calibration.

§1. Introduction

A tagged photon beamline has been constructed in the GeV-γ experimental hall at Laboratory of Nuclear Science (LNS), Tohoku University [1]. We insert a radiator made of a carbon fiber, 11 μm in diameter, into circulating electrons in the Stretcher-Booster (STB) ring to generate a high energy photon beam. The electrons strike the radiator just upstream from the bending magnet BM5 of the STB ring, and produce bremsstrahlung photons which are used as a beam. Recoiled electrons are analyzed by the BM5 and detected with a tagging system called STB Tagger II, which consists of 116 telescopes of two-layer scintillating fibers [2]. The energy E_γ of a produced photon is determined by the energy of the recoiled electron E_e and that of the circulating electron E_0 as

$$E_\gamma = E_0 - E_e$$

because the energy transferred to the nucleus is negligibly small. Thus E_e has to be measured precisely to provide a definite E_γ. However, there are some elements having slightly unknown factors in the STB Tagger II. The map of the magnetic flux in BM5 is not determined completely. The position and direction of the recoiled electron emitting a bremsstrahlung photon are not known precisely at the radiator. And the exact position of STB Tagger II is not well known. Therefore the energy calibration is required for STB Tagger II. To determine E_e, E_γ has to be given conversely, which has so far been made with two methods.

1. Missing mass M_X analysis for the $\gamma + p \to \pi^0 + X$ process [3], and
2. Direct Measurement of E_γ with a lead glass Cherenkov counter [4].

In the former method, however, there is an uncertainty in the vertex point of the π^0 decay, and the energy and position resolutions for incident photons are not good enough for this purpose. In the latter case, the energy response of the lead glass Cherenkov counter is not precisely investigated. These two methods did not work very well.

The tagged photon energy E_γ can be obtained by measuring momenta of the e^+e^- pair converted from the incident photon. E_γ is given as a sum of the e^+ and e^- energies E_{e^+} and E_{e^-}, namely

$$E_\gamma = E_{e^+} + E_{e^-}. \tag{1}$$

We have performed meson photoproduction experiments with an electro-magnetic calorimeter SCISSORS II to study nucleon resonances, using a tagged photon beam. Two circulating-electron energies of 920 and 1200 MeV have been selected to cover the incident photon energy from 600 to 1150 MeV. We can make a consistency check for STB Tagger II by comparing the overlap energy region measured under these different conditions of the electron energy. In this measurement, therefore, a dipole magnet $\mathcal{R}$TAGX [5] is operated at a fixed current to analyze the momentum of the e^+ and e^-, regardless of the electron energy.

§2. Experiment

We used the $\mathcal{R}$TAGX magnet for the momentum analysis of e^+e^- pairs. A 20 μm thick Au foil was placed in front of $\mathcal{R}$TAGX to produce e^+e^- pairs from the tagged photons. Electrons/positrons having different momenta were bent with different curvature by $\mathcal{R}$TAGX , and were detected with two scintillating fiber hodoscopes located behind $\mathcal{R}$TAGX. Each scintillating fiber measures 3×3 mm^2 in cross section, and 16 fibers are arranged in a hodoscope. One hodoscope was placed 1850 mm downstream from the center of $\mathcal{R}$TAGX and at $-46.6°$ with respect to the beam axis. The other hodoscope was movable so as to detect various energy electrons. Figure 1 shows the experimental setup for this energy calibration.

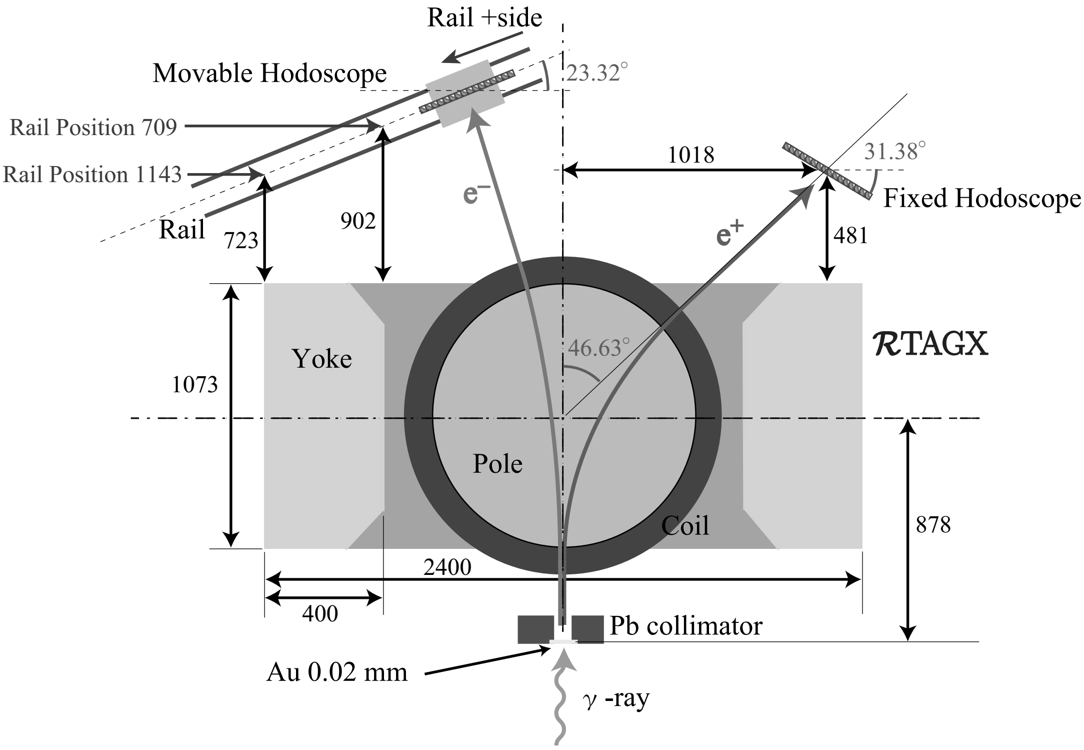

Fig.1. Experimental setup for the energy calibration of STB-Tagger II. The e^+e^- pairs are generated in the interaction of incident photons with a Au foil, and are detected by a fixed scintillating fiber hodoscope and a movable one.

A triple coincidence signal from STB-Tagger II and two scintillating fiber hodoscopes was used to form a trigger for the data acquisition:

$$(\text{trigger}) = (\text{tagger}) \otimes (\text{fixed hodoscope}) \otimes (\text{movable hodoscope}).$$

We measured the energy of each tagged photon defined with STB Tagger II using this trigger by detecting an e^+e^- pair generated from the tagged photon. The experiment was performed for two different electron energies of 920 and 1200 MeV.

§3. Data Analysis

A pair of e^+ and e^- were detected with the fixed and movable hodoscopes, respectively. Energies of e^+ and e^- were determined from the position of responding fibers in these hodoscopes. Here, the flight path of e^+/e^- with a given energy was calculated by utilizing the field map of $\mathcal{R}$TAGX, where the energy loss of e^+/e^- was taken into account in the Au foil and the air. The magnetic flux of $\mathcal{R}$TAGX is described elsewhere [6, 7]. Figure 2 shows the e^+/e^- energy as a function of the bending angle determined by a responding fiber.

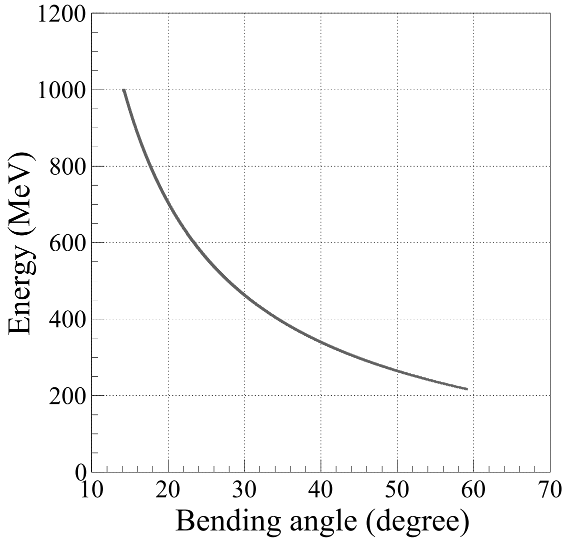

Fig.2. The e^+/e^- energy as a function of the bending angle.

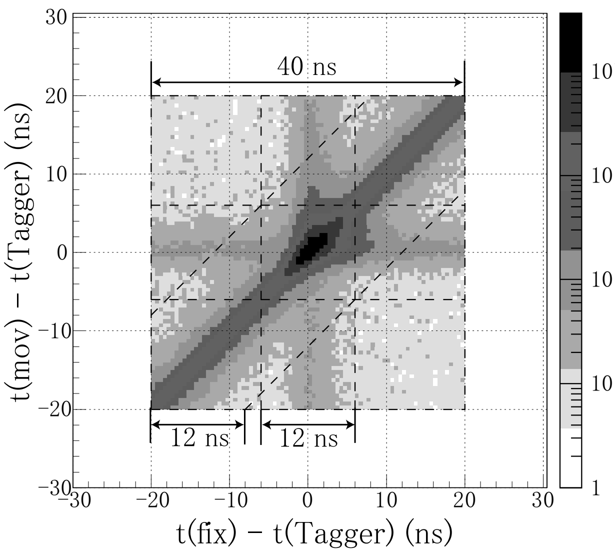

Fig.3. Timing Correlation between the movable and the fixed hodoscope.

Since the intensity of the bremsstrahlung photons was more than 10 MHz, there was a large fraction of accidental coincidence events. To estimate the number of true coincidence events, we made a two-dimensional plot of the timing signals from the movable and fixed hodoscopes. Figure 3 shows the timing correlation between the movable and fixed hodoscopes. The total area of the two-dimensional plot is divided into 16 regions by broken lines, the center region is the prompt area, and the other regions correspond to background events. The background events in the prompt area were subtracted with the method of two-dimensional side band subtraction. This method is described elsewhere [8, 11].

The energy of a tagged photon can be obtained with a sum of the e^+ and e^- energies as expressed in Eq. (1). Figure 4 shows e^+e^- energy sum distributions corresponding to tagger channel, 1, 70 and

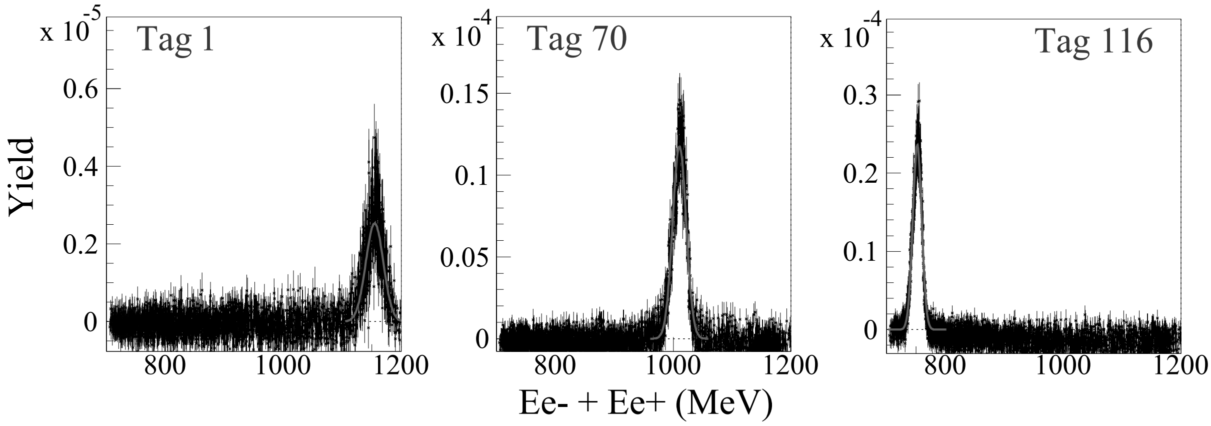

Fig.4. Energy sum distributions of e^+ and e^- converted from the tagged photons corresponding to tagger channel, 1, 70 and 116. Each curve is a Gaussian function fitted to the data.

116 after the background subtraction of accidental coincidence events. The centroid of the e^+e^- energy sum is determined by fitting a Gaussian function to the data.

§4. Tagged Photon Energy

The energy of photons tagged with STB Tagger II was calibrated by measuring the energies of e^+e^- pairs. STB-Tagger II covers the tagged photon energy range from 579 to 890 MeV for 920 MeV circulating electrons, and 752 to 1155 MeV for 1200 MeV electrons. Since the $\mathcal{R}$TAGX coils carried a fixed current, the tagged photon energy for 920 MeV electrons was determined relatively to that for 1200 MeV electrons. In Fig. 5, the measured photon energies are plotted as a function of the telescope number in STB Tagger II.

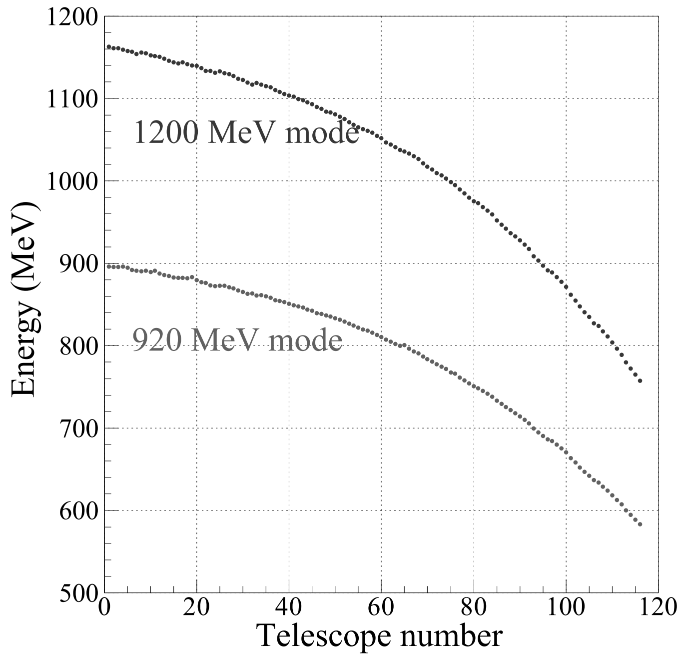

Fig.5. Relation between the photon energy and the telescope number in STB Tagger II at two circulating-electron energies of 920 and 1200 MeV.

We made another calibration by measuring the threshold energy of the $\gamma + p \rightarrow \eta + p$ reaction. This calibration identified the tagging telescope corresponding to the incident photon having the η production threshold energy. The threshold photon energy in the $\gamma + p \rightarrow \eta + p$ reaction can be calculated precisely, that is $E_\gamma = 707.25$ MeV. We compared the η threshold energy with the tagged photon energy corresponding to the η threshold point by the momentum analysis for e^+e^- pairs. It turned out that the tagged photon energy determined by the momentum analysis was 0.63% larger than the threshold energy [9]. This difference was mainly caused by an overall normalization uncertainty in the magnetic field of $\mathcal{R}$TAGX. Thus the normalization uncertainty was resolved [10]. The geometrical errors arise from a position measurement uncertainty of the fixed and movable hodoscopes, a setup uncertainty of the movable hodoscope location, and a position uncertainty of the incident photon beam [11]. The total uncertainty of the tagged photon energy is 0.3%.

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