A proposal for a new photon detector to measure the direction of the photon

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Abstract

We propose an experiment to test a new photon detector which can measure the direction of the photon. This measurement is important to suppress the background from $K_L \rightarrow \pi^0\pi^0$ in the $K_L \rightarrow \pi^0\nu\bar{\nu}$ experiment.

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1 Purpose of the experiment

1.1 Motivation

The purpose of this experiment is to test a new photon detector which can measure the direction of the photon using the shower shape. The angle measurement will play an important role in $K_L \to \pi^0 \nu \bar{\nu}$ experiment to reduce backgrounds. One of the most serious backgrounds is $K_L \to \pi^0 \pi^0$ where two of the photons are not detected. These can be separated into two categories. "Even pair" background events are caused by missing two photons originating from the same π^0. "Odd pair" background events are caused by missing two photons originating from different π^0. In the latter case, the reconstructed vertex, obtained by assuming that the two detected photons came from the same π^0, is different from the real vertex.

Therefore, if we can measure the direction of the photon, we can reject "odd pair" background events whose γ angle is inconsistent from the reconstructed vertex.

2 Experiment

2.1 Detector

We are planning to test a new shashlik-type photon calorimeter as shown in Figure 1. The calorimeter module consists of 100 layers of 1.0mm-thick lead and 5.0mm-thick plastic scintillator plates. The size of each module is 8cm*8cm*40cm ($19X_0$). Scintillation light is read out by 64 wavelength shifting fibers which are arranged at 1cm interval. We will make two modules where each fiber are read out by a 64ch Multi anode PMT made by Hamamatsu. We will make other six modules which are read out by normal 2inch PMTs.

The modules with 64ch Multi anode PMT are divided into three sections in depth($3.8X_0$, $5.7X_0$, $19.0X_0$ from the front). The energy deposit profile in each section is read out by fibers designated for each section, as shown in Figure 2. In this figure, the fibers labeled "1", "2", and "3" read out only the 1st, 2nd, and 3rd sections, respectively.

2.2 The strategy to measure the direction of the photon

The strategy to measure the direction of the photon is shown in Figure 3. We will measure the transverse peak position of the deposit energy in each section. By fitting the peak position vs the depth of the block, we can measure the direction of the photon.

Figure 4 shows the reconstructed angle as a function of the incident angle, studied by using GEANT. The resolution of the reconstructed angle, which is shown by the error bars, is about 5 degrees for 1 GeV incident photon.

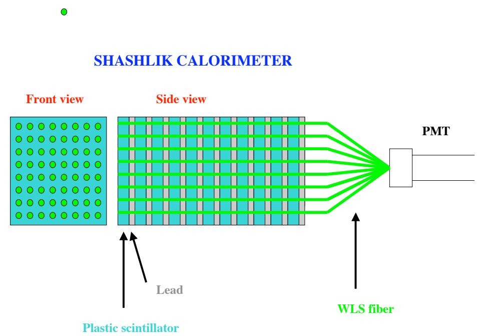

Figure 1: SHASHLIK CALORIMETER

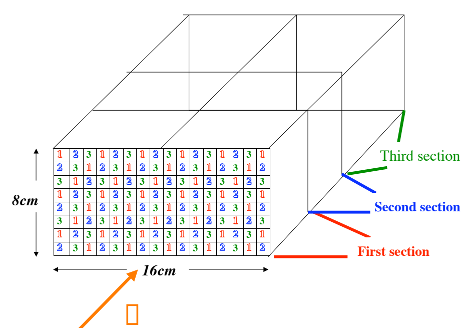

Figure 2: The modules with 64ch PMT

2.3 Tagged photon beam

We will use the backward-Compton scattered photons produced by laser at the BL33LEP beam line. The energy of photons, E_γ, is calculated by measuring the energy of the scattered electron with the existing tagging counters placed at the inner side of the storage ring:

$$E_\gamma\text{=8(GeV)-}E_{tag}$$

The tagging counters consist of 2 hodoscope planes with 10 plastic scintillators each as shown in Figure 5. The tagging counters can measure the energy of photons between 1.5GeV and 2.4GeV in about 200MeV bins.

We will place an active collimator with 1cm^ϕ hole or 3mm^ϕ hole in front of the photon detector.

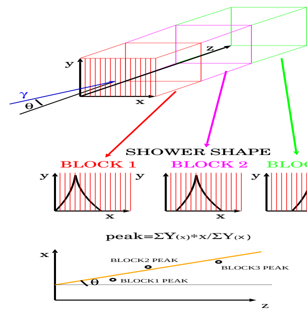

Figure 3: The strategy to measure the angle of the photon

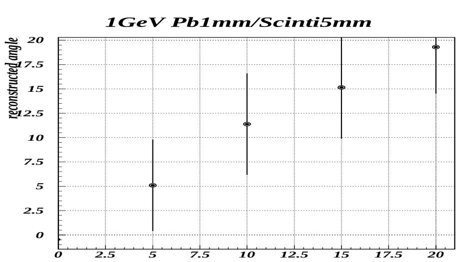

Figure 4: The reconstructed angle of the photons is shown as a function of the incident angle. The error bar indicate the resolution of the reconstructed angle.

2.4 Experiment

We plan to make the following two measurements. In both cases the detector will be placed between the Drift Chamber and TOF counters in the LEPS beam line, as shown in Figure 6.

2.4.1 Angle resolution measurement

We will stack 9 modules, as shown in Figure 7. The two modules in the second layer are read out by 64ch Multi anode PMTs in order to measure the angle resolution of our shashlik-type calorimeter. We plan to take photons at 6 incident angles (0, 5, 10, 15, 20, and 25 degrees) and at 4 incident positions.

2.4.2 Shower profile measurement

In order to measure a detailed shower profile at different depths, we plan to make another measurements, as shown in Figure 8. We will use a short module which consists of 5 layers of lead and scintillator plates ($1X_0$). This is read out by a 64ch multi anode PMT. In front of this short module, we will place a counter to locate the conversion depth, and dummy lead/plastic blocks. By varying the number of dummy lead/plastic blocks, we will measure the shower profile at $2X_0$, $3X_0$,........, $9X_0$,$11X_0$, $13X_0$,$15X_0$, $17X_0$, and $19X_0$ depths.

3 Estimation of the beam time request

We request 9 shifts in total for this experiment. The 4 shifts are for setting up counters, logic circuits and tuning the beam.

The remaining 5 shifts are for data taking. For each detector configuration, we plan to collect 50000 events. It takes about 200 sec (3 minutes) assuming that we can collect 250 events/sec[1]. We assumed that it takes 15 minutes to change the detector configuration. We plan to take 6 different angles (0, 5, 10,15, 20, and 25 degrees) at 4 positions for the angle resolution measurement, and 14 different depths at 7 different angle for the shower profile measurement. Therefore, the data taking takes $(4+14)\times6\times(3+15)min\times1.2=$ 38.88 hours(5 shifts) where the 1.2 is a safe factor.

4 Equipment

Detector

- Shashlik-type calorimeter (9 modules) and 1 short module
- active collimator

[1] Typical data size is 150word(300bytes). We assumed that the dead time is 1.5msec and the trigger rate is 400Hz.

- rotating table to support the detectors

Equipment for the front-end

- CAMAC crates
- CAMAC crate controllers
- FERA ADCs (LeCroy 4300B$\times$9)
- NIM modules
- delay cables

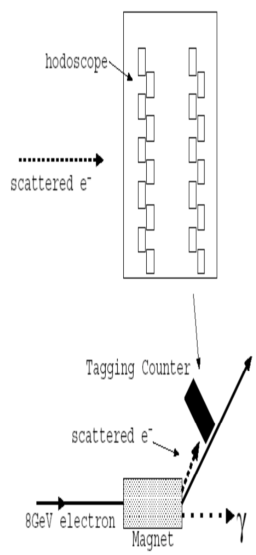

Figure 5: A brief sketch of tagging counter

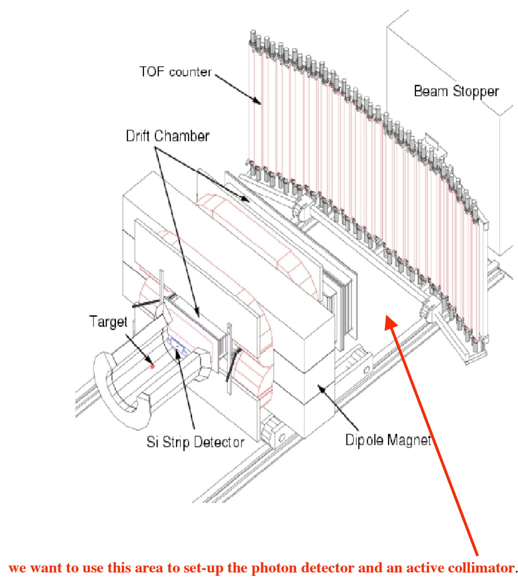

Figure 6: A brief skech of detector location

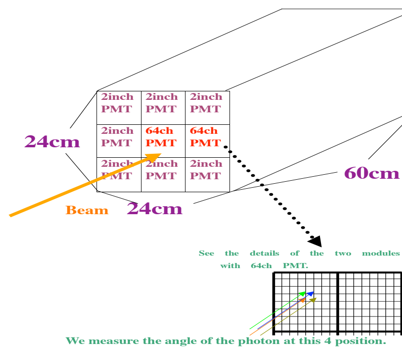

Figure 7: Angle resolution measurement

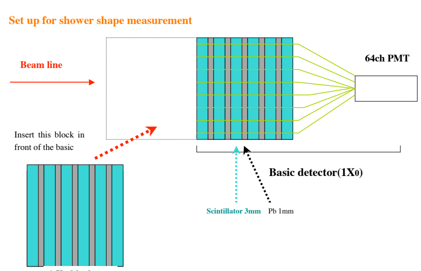

Figure 8: Shower Profile Measurement