POLARIMETRY OF SHORT PULSE GAMMA-RAYS AND POSITIONS

M. Fukuda, T.Hirose, I.Sakai, Tokyo Metropolitan University, Hachioji-shi, Tokyo, Japan
T.Aoki, M.Washio, Waseda University, Shinjyuku-ku, Tokyo, Japan
T.Iimura, Seikei University, Musashino-shi, Tokyo, Japan
Y.Kurihara, T.Okugi, T.Omori, J.Urakawa, KEK, tukuba-shi, Ibaraki, Japan

Abstract

We have made a basic study of a polarized positron source for the next generation linear collider, JLC[1][2]. This is based on a new idea that polarized positrons are pair-created from polarized γ-rays produced through Compton scattering of circularly polarized laser lights o relativistic electron beams[3][4]. Since a pulse duration of γ-rays thus produced is extremely short i.e. 20 psec, the polarization of γ-rays cannot be determined by an ordinary method in which one measures an individual scattering process of a γ-ray on an electron in a magnetized iron. Using the simulation code GEANT [5], we find that the intensity of γ-rays penetrating through a magnetized iron depends on the relative spin direction of γ-rays and electrons. We will report a design of a polarimeter both for polarized γ-rays and positrons based on simulation studies.

1 INTRODUCTION

A proposed idea producing high polarized positrons is illustrated in Fig. 1. We have measured back scattered γ-rays and pair created positrons using a laser light with the wave length of 532 nm, i.e. second harmonic of Nd:YAG and an electron beam of 1.28 GeV at KEK-ATF[6][7][8].

Because the pulse duration of γ-rays produced by this method is very short, i.e. 20psec, it is difficult to determine the polarization of γ-rays by ordinary method. Hence, we make use of a phenomena that transmission of circularly polarized γ-rays through a magnetized iron depends on a direction and a magnitude of a magnetic field.

This paper describes a basic concept of the polarimetry and technical aspects for a design of the polarimeter.

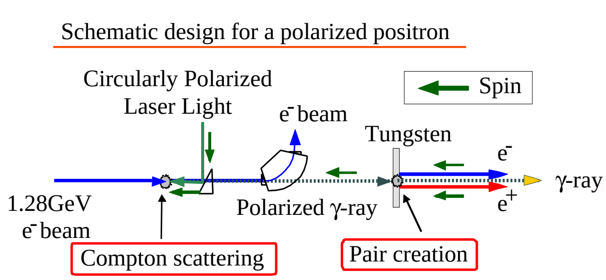

Figure 1: Schematic illustration of a polarized positron generation

2 METHOD OF POLARIZATION MEASUREMENT

2.1 Source of polarized γ-rays and positrons

Circularly polarized γ-rays are generated through Compton scattering of circularly polarized laser light ($\lambda = 532nm$) on electron beams of 1.28 GeV. The polarized positrons arc produced from pair creation caused by these γ-rays passing through thin tungsten target. The differential cross sections are shown in Fig. 2 (a) separately for left- and right-handed γ-rays

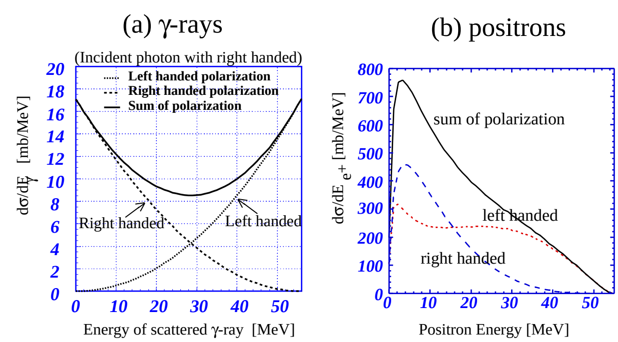

Figure 2: The di eren tial cross section of γ-rays (a) and positrons (b)

generated by a right handed laser lights. Fig. 2 (b) shows the cross sections of positrons with the left- and right-handed helicity.

These graphs show that higher energy parts of γ-rays and positrons have a larger magnitude of polarization. For example, it is possible to obtain 70% polarization by selecting positrons with the energy higher than 24 MeV.

2.2 Principle of polarization measurement

A spin of the free electrons in a magnetized iron aligns parallely to directions on of magnetic fields applied. It is well known that transmission of circularly polarized γ-rays depends on a relative direction of the polarization and the magnetic field.

When mono-energetic γ-rays enter into a magnetized iron with a saturated magnetic field (about

2.2[T]), the transmission rate and asymmetry for circularly polarized γ-rays are calculated for iron targets with thickness of 7cm and 15cm as shown in Fig. 3. Here the electron polarization in the iron is assumed

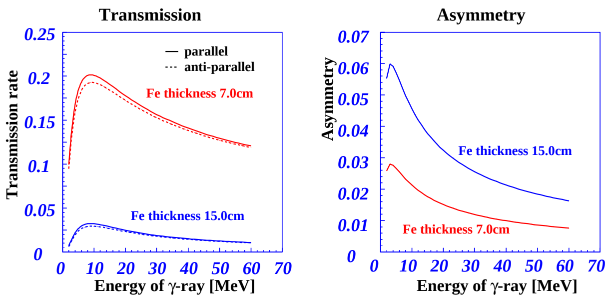

Figure 3: The transmission rate and the asymmetry in terms of incident γ-rays energy

as 7.7 %, because only two free electrons out of 26 electrons can flip along the magnetic field direction. The asymmetry is calculated by the formula, $A = \frac{N_{\uparrow\uparrow} - N_{\uparrow\downarrow}}{N_{\uparrow\uparrow} + N_{\uparrow\downarrow}}$, and an error is given by $\frac{1}{\sqrt{N_{\uparrow\uparrow} + N_{\uparrow\downarrow}}}$, where $N_{\uparrow\uparrow}$ ($N_{\uparrow\downarrow}$) represents the spin direction of a γ-ray on parallel (anti-parallel) with that of an electron.

As shown in Fig. 3, the asymmetry varies with the thickness of a iron target and a γ-rays energy.

3 POLARIMETER

3.1 Concept of polarimeter

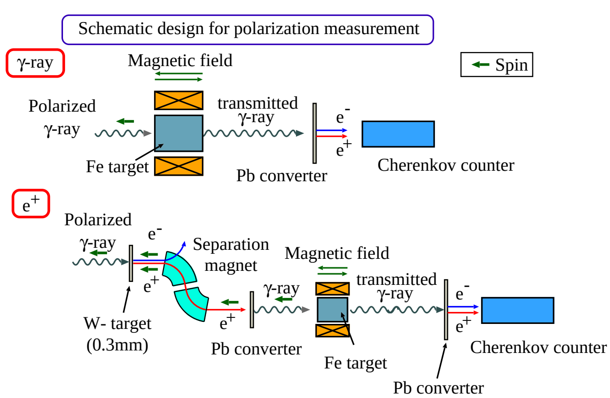

Figure 4: Schematic view for polarization measurement

Advantages of this method is that we can determine an average polarization of γ-rays confined in one bunch by counting a number of transmitted γ-rays through a magnetized iron leading to a higher polarization can be effectively extracted γ-rays in a higher energy region using a Cerenkov counter with a relevant threshold.

The positron polarization can be measured in the similar manner once a positron is converted into a γ-ray. Schematic views of the polarimeters are depicted in Fig. 4

As shown in Fig. 3, the asymmetry of γ-rays depends upon the thickness of irons and γ-rays energies. Fig. 5 (a) indicates dependences of the asymmetry on thickness of the magnetized iron for γ-rays with a energy higher than 20, 30, and 40 MeV. Fig. 5 (b) shows a number of γ-rays required to measure the asymmetry with a precision of 3σ, i.e. $\Delta A/A = 1/3$. We

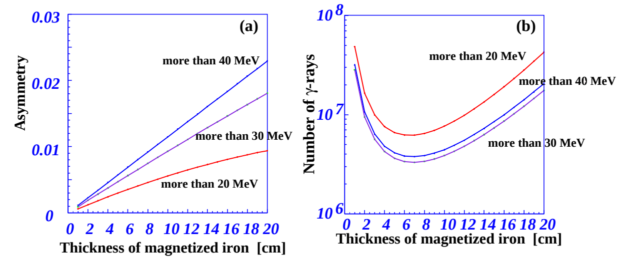

Figure 5: (a) the average asymmetry of γ-rays as a function of energy threshold, (b) the number of γ-rays required to measure this asymmetry with precision of 3σ when being vary the thickness of magnetized iron.

choose the thickness of 15cm, because the thicker iron have the larger asymmetry and is not very sensitive to systematic errors.

Fig. 6 shows the magnetized iron target designed by POISSON [9] and the magnitude of a electron polarization. The design principle is to achieve a flat region of magnetic fields as widely as possible along the z-direction

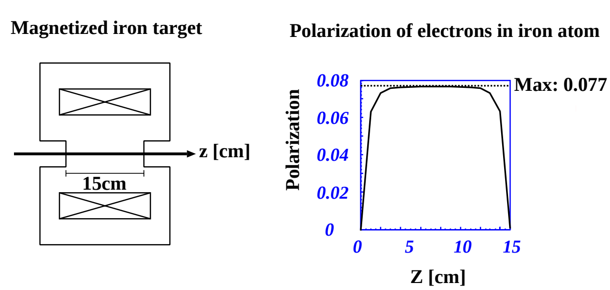

Figure 6: Cross section of a magnetized iron target and the polarizations of electrons along the depth of the magnet.

3.2 Detector

In order to detect higher energy regions of γ-rays, we chose an air Cerenkov counter with the threshold of 22 MeV.

To determine the polarization, it is important to detect only γ-rays transmitting through the magnetized iron without being subject to Compton scattering. Actually via backgrounds are caused from interactions of γ-rays and electrons in the iron target. As these γ-rays and electrons are emitted into wide angular regions, we can effectively detect transmitted γ-rays by setting a detector in a narrow forward area. Using the simulation code GEANT, a distance between the detector with a size of 10cm × 10cm and the magnetized iron are fixed as 3m where 96% of particles entering the detector are transmitted γ-rays.

Transmitted γ-rays are converted into charged particles ($e^{\pm}$) in a Pb sheet with a thickness of 2.8 mm placed at the entrance of the Cerenkov detector.

3.3 Predicted asymmetry

Fig. 7(a) shows a cross section of the Cerenkov counter. The asymmetry calculated by GEANT is shown in Fig. 7 (b) as a function of energy thresholds. When the

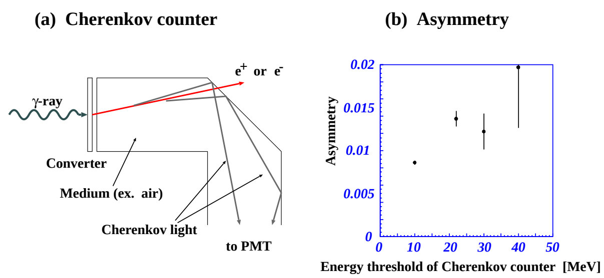

Figure 7: Cerenkov counter (a) and predicted asymmetry of Cerenkov photons (b). In this, it assumed that the converter is the lead with thickness of 0.28cm and the length of medium is 25cm.

energy threshold of a detector is 22 MeV, the asymmetry is 1.3%. In a similar manner, we have studied the asymmetry for positrons to design a polarimeter as illustrated in Fig. 4.

4 SUMMARY

On the basis of extensive studies using the Monte-Carlo simulation program GEANT, it is crified that we will be able to determine the polarization of γ-rays by measuring transmission of γ-rays through a magnetized iron. It is of importance to use a Cerenkov counter to extract high energy γ-rays with higher polarization.

In this fall, it is scheduled to carry out the polarization measurement of Compton γ-rays, using air Cerenkov counter. To measure predicted asymmetry(1.3%) with the precision of 3σ, the measurement time of 14 minutes is required when that numbers of γ-rays per pulse is 1.0×10^6 and the repetition of pulse is 1.56 Hz.

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