題目：TITLE

POLARIMETRY OF SHORT PULSE GAMMA-RAYS AND POSITIONS

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梗概：SYNOPSIS

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 \(\gamma\)-rays produced through Compton scattering of circularly polarized laser lights on relativistic electron beams[3][4]. Since a pulse duration of \(\gamma\)-rays thus produced is extremely short i.e. 20 psec, the polarization of \(\gamma\)-rays cannot be determined by an ordinary method in which one measures an individual scattering process of a \(\gamma\)-ray on an electron in a magnetized iron. Using the simulation code GEANT [5], we find that the intensity of \(\gamma\)-rays penetrating through a magnetized iron depends on the relative spin direction of \(\gamma\)-rays and electrons. We will report a design of a polarimeter both for polarized \(\gamma\)-rays and positrons based on simulation studies.

Submitted to APAC2001

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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 on 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 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. 20 psec, 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.

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 (λ = 532 nm) on electron beams of 1.28 GeV. The polarized positrons are 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 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 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, \( A = \frac{N_{↑↑} - N_{↓↓}}{N_{↑↑} + N_{↓↓}} \), and an error is given by \( \frac{1}{\sqrt{N_{↑↑} + N_{↓↓}}} \), where \( N_{↑↑} \) (\( N_{↓↓} \)) 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

![Schematic design for polarization measurement](image)

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 iron and γ-rays energies. Fig. 5 (a) indicates dependences of the asymmetry on thickness of the magnetized iron for γ-rays with an 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 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.

![Magnetized iron target](image)

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 $\gamma$-rays by setting a detector in a narrow forward area. Using the simulation code GEANT, a distance between the detector with a size of $10\text{cm} \times 10\text{cm}$ and the magnetized iron are fixed as $3\text{m}$ where $96\%$ of particles entering the detector are transmitted $\gamma$-rays.

Transmitted $\gamma$-rays are converted into charged particles ($e^\pm$) in a Pb sheet with a thickness of $2.8\text{mm}$ 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 energy threshold of a detector is $22\text{MeV}$, 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.

![Cerenkov counter and predicted asymmetry](image)

**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 $0.28\text{cm}$ and the length of medium is $25\text{cm}$.

### 4 SUMMARY

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

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

### 5 ACKNOWLEDGEMENTS

We would like to acknowledge all members of the ATF group for the operation of the ATF-damping ring. This research was partially supported by a Research Fund of KEK for Cooperative Developments, a Grant-in-Aid for Scientific Research (B)11554010, (A)11694092, (C)10640294 and a research program of US-Japan Cooperation in the Field of High-Energy Physics.

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[9] User’s guide for the POISSON/SUPERFISH group of codes, LA-UR-87-115