Available online at www.sciencedirect.com
ScienceDirect
Nuclear Instruments and Methods in Physics Research A 579 (2007) 973–978
NUCLEAR INSTRUMENTS & METHODS IN PHYSICS RESEARCH Section A
www.elsevier.com/locate/nima

Experimental study of photon beam polarimetry based on nuclear e^+e^- pair production in an amorphous target

F. Adamyan[a], A. Aganyants[a], H. Hakobyan[a], J. Manukyan[a], R. Oganezov[a], L. Sargsyan[a], A. Sirunyan[a,*], H. Vartapetian[a], R.T. Jones[b]

[a] *Yerevan Physics Institute, 2 Alikhanian Brothers str., EPD, 375036 Yerevan, Armenia*
[b] *University of Connecticut, Storrs, CT, USA*

Received 30 November 2006; received in revised form 11 June 2007; accepted 13 June 2007
Available online 26 June 2007

Abstract

The degree of linear polarization of a coherent bremsstrahlung (CB) was measured using an azimuthal asymmetry of incoherent e^+e^- pair production. The measurement was carried out in the γ-2 photon beam line of the Yerevan synchrotron, using a 2.55 GeV electron beam and a diamond radiator oriented to position the primary coherent peak in the interval 0.9–1.1 GeV. The polarization at the peak was measured to be 0.56 ± 0.06, in good agreement with the value computed from CB spectral shape analysis.

PACS: 14.70.Bh; 24.70.+s; 78.70.−g

Keywords: Analyzing power; Polarimeter; Linear polarization; Bremsstrahlung

1. Introduction

Direct methods for determining the linear polarization of a coherent bremsstrahlung (CB) photon beam are based upon the azimuthal dependence of the pair conversion process. These include using an oriented crystal as the pair converter and measuring the conversion rate as a function of crystal azimuthal orientation [1], and measuring the azimuthal asymmetry of e^+e^- pairs from nuclear pair production [2] or of the recoil electron from triplet production [3] in an amorphous target. Alternatively, the polarization may be computed from the basic CB process for an ideal beam and crystal, and then corrected for real experimental conditions based on analyzing the shape of the CB beam energy spectrum [4,5]. The latter method is of great practical utility to experiments using CB beams because the beam spectrum is measured more easily than is the polarization.

In a recent article [6], a CB polarimeter is described which exploits the azimuthal dependence of incoherent e^+e^- nuclear pair production within narrow ranges in both polar $\Delta\theta$ and azimuthal $\Delta\varphi$ angles [7]. Monte Carlo simulations of this polarimeter operating in the energy range $E_\gamma = 0.9$–1.1 GeV have shown that it is capable of measuring beam polarization at the level of $\sigma_p = 0.02$ if symmetric e^+e^- pairs are selected. This polarimeter has recently been constructed and installed on the γ-2 beam line of the YERPHI electron synchrotron. In this paper we present results from experimental measurements carried out with this polarimeter in a CB beam with maximal energy $E_\gamma = 2.55$ GeV.

2. Method of polarization measurement

Direct determination of photon beam polarization involves the measurement of the asymmetry in the scattering rates for some process between the two orthogonal states of the beam, and its interpretation as the product of the beam polarization and the analyzing power.

*Corresponding author. Tel.: +374 10 342747; fax: +374 1 355524.
E-mail address: sirunian@mail.yerphi.am (A. Sirunyan).

0168-9002/$ - see front matter © 2007 Elsevier B.V. All rights reserved.
doi:10.1016/j.nima.2007.06.024

The analyzing power or azimuthal asymmetry of incoherent e^+e^- pair production is defined as

$$A = \frac{\sigma_{\parallel} - \sigma_{\perp}}{\sigma_{\parallel} + \sigma_{\perp}} \tag{1}$$

where $\sigma_{\parallel}$ and $\sigma_{\perp}$ are the differential cross-sections for pairs with their production plane parallel and perpendicular to the plane of photon polarization, respectively.

These cross-sections are computed using the analytical expressions found in Ref. [8], where the degree of linear polarization is described in the terms of the Stokes parameter ξ_3. The values $\xi_3 = +1, -1$ correspond to 100% linear polarization ($P_\gamma = 1$) for the polarization orientation perpendicular (+1) and parallel (−1) to the production plane. An experimental measurement of asymmetry necessarily includes a finite aperture around the parallel and perpendicular directions. This is taken into account using a Monte Carlo simulation that incorporates the details of the setup. The simulation is used to produce the asymmetry A_{MC} that would result if the polarization of the beam were 100%.

The CB photon beam linear polarization ($P_\gamma < 1$) is extracted from the measured asymmetry as

$$P_\gamma = A_{\mathrm{exp}}/A_{\mathrm{MC}} \tag{2}$$

where A_{exp} is the experimental asymmetry and A_{MC} is the Monte Carlo simulation result from Eq. (1), calculated for $P_\gamma = 1$. The simulation includes a detailed model of pair production using differential cross-sections with accurate atomic form factors [6,9] and incorporating the detailed geometry and magnetic fields of the beam line and PS-6 polarimeter. The use of Eq. (2) implicitly assumes that measuring the counting rate difference in A_{exp} involves only switching the state of the beam polarization axis, and that all other beam conditions such as the energy spectrum and especially the absolute degree of linear polarization remain unchanged during the measurement. The precision of P_γ depends on the statistical and systematic uncertainties on the values of both A_{exp} and A_{MC}. Controlling systematic errors depend both upon the ability to limit variations in the beam operating conditions during the measurement of A_{exp} and upon the ability of the simulation to estimate the sensitivity to any residual variations which may bias the measurement.

3. Layout of the experimental setup

A sketch of the experimental setup in the γ-2 beam line is shown in Fig. 1. The beam of linearly polarized photons [10], generated by 2.55 GeV electrons incident on a diamond crystal (height 8 mm, width 2 mm, thickness 0.072 mm), is collimated and cleaned by the set of collimators K_1, K_2 and sweeping magnets SM_1, SM_2 to an angular divergence half-angle of 0.12 mrad. It then passes through a 10 μm Mylar converter (C_1) located at the entrance to the PS-30 pair spectrometer. The pair spectrometer measures the CB intensity spectrum simultaneously in 30 energy bins with energy resolution $\delta E_\gamma / E_\gamma = 0.02$ [11]. The integral intensity of the photon beam is measured by the Wilson quantameter (Q) located at the end of the beam line. The polarimeter PS-6 includes a 20 μm aluminum converter (C_2), a vertical slit collimator (K_3) and the PS-6 dipole spectrometer. The slit K_3 and PS-6 hodoscopes are located 15.8 and 19.9 m downstream of the C_2 converter, respectively. These distances are sufficient to allow the particles in pairs to be separated far enough to define a reasonably sharp boundary in the angular acceptance. The vertical slit K_3 is made of lead 6 cm thick, 2.6 cm wide and 8 cm high and installed in the beam vacuum pipe to the entrance of the dipole magnet. It provides azimuthal selection of e^+e^- pairs by passing only those whose pair-production plane is close to the vertical within range $\Delta\varphi = \pm 35^\circ$. After the pairs have been dispersed in the dipole field of the spectrometer, they are detected in scintillating counters arranged to form six telescopes, with three channels on each side of the beam. Each telescope consists of one small scintillator in front which defines the energy channel for that telescope, overlapped with a larger counter located 60 cm behind it. As shown in Fig. 2, the telescopes are on either side of the beam, numbered $N_1 - N_3$ in order of decreasing energy. The front scintillators for channels N_1 and N_3 are 2.5 cm

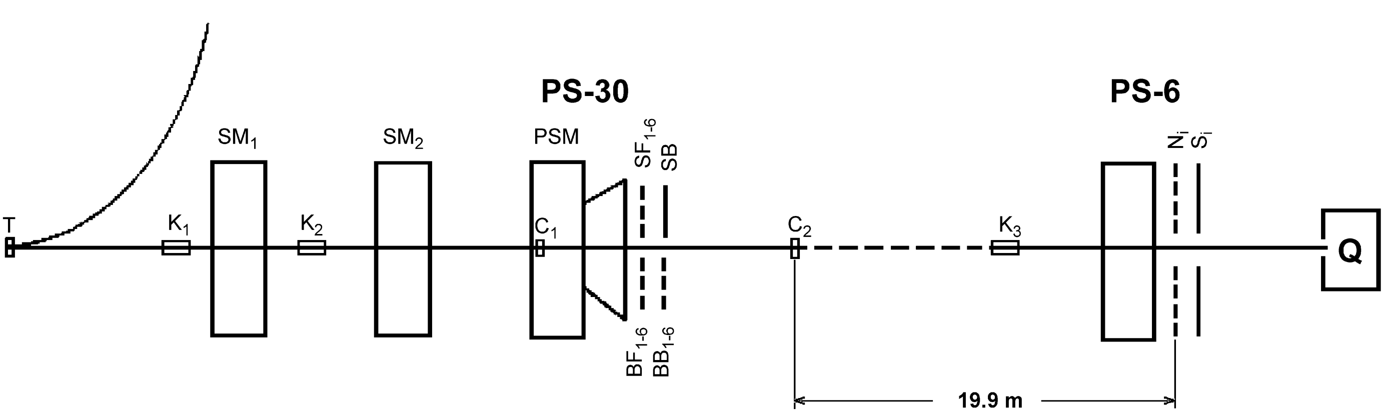

Fig. 1. Layout of the experimental setup, from the bremsstrahlung radiator (T) to the beam stop quantameter (Q). The two pair spectrometers PS-30 and PS-6 are the primary instruments used in this experiment.