PEP-171

A PULSED LASER POLARIZATION MONITOR FOR PEP

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Abstract

Back scattered circularly polarized laser photons are considered as a monitor for electron beam polarization. The up-down asymmetry of up to 10 percent can be measured using a wire ionization chamber with submillimeter resolution. With a pulsed laser backgrounds are not expected to be large.

The back-scattering of laser photons off high energy electron beams is well documented (1) and has been a highly successful technique for bubble chamber experiments at SLAC. It has been suggested that spin-dependent terms in Compton scattering provides a good tool for measuring electron beam polarizations (2).

Measuring beam polarizations at PEP presents a number of technical problems. Perhaps the most serious of these problems is the presence of synchrotron radiation and beam bremsstrahlung photons in the direction of the back-scattered laser photons. A second problem arises from the extreme sensitivity of the photon spatial distribution to electron orbit changes in the PEP lattice, caused for example by external mechanical or magnetic perturbations. The purpose of this note is to suggest that these difficulties can be overcome by using a pulsed ruby laser similar to the one operated at SLAC over a period of several years. With such a laser, up to 2 joules of energy per pulse can be obtained, yielding 7×10^{18} photons into a 30 nsec (FWHM) pulse. The yield of back-scattered photons from a single pulse interacting with a single electron bunch is estimated to be approximately 10^7 quanta with an average energy of 2 GeV/photon. This represents a signal which greately exceeds levels estimated for background processes.

A) Spin Dependent Compton Scattering

The analysis of spin-dependent terms in Compton scattering is found in the work of Lipps and Tolhoek (3). If we assume that final state particle polarizations are unobserved, only circularly polarized photons lead to effects that are sensitive to the electron beam polarization. For transversely polarized electrons and circularly polarized photons, the cross section has the form

$$\frac{d^2\sigma}{d\rho\, d\phi} = \sigma_0(\rho) \mp P_e P_\gamma \cos\phi \, \sigma_1(\rho)$$

where ρ is the fractional energy of the scattered photon

$$(\rho = E_\gamma / E_{max})$$

and ϕ is the azimuthal angle ($\phi = 0$ for photons in the plane in which the electron direction and spin vectors lie). An up-down asymmetry arises from the $\cos\phi$ term. This asymmetry is proportional to $P_e P_\gamma$. Measurement of this asymmetry, and knowledge of σ_0 and σ_1 allow one to extract $P_e P_\gamma$.

Back-scattered laser photons transform into a narrow forward cone in the lab. For a photons which scatters at 90 degrees in the electron rest frame, the corresponding lab angle is

$$\sin\theta = 1/\gamma \quad = .034 \text{ millirad at PEP}.$$

For a detector placed 80 meters from the laser-beam interaction point, the back-scattered photons fall in a circle of radius .3 cm. Ninety-nine percent of the back-scattered photons fall in a circle of radius 3.2 cm. Angular divergences of the electron beam in the vertical direction exceed .034 millirad at most points in the PEP lattice. By choosing an interaction point where the angular divergences in the vertical direction are minimized and by focussing the laser beam to a point, it appears possible to resolve the intrinsic Compton angular distribution. However this point needs more study in detail.

Figure 1 shows the dependence of σ_0 and σ_1 on ρ.

B) The Yield of Photons

For a beam of photons passing through a beam of electrons, the number of photons scattered can be approximated by

$$Y = \frac{2 n_1 n_2 \sigma \ell}{a c \tau}$$

where n_1, n_2 are the number of photons and electrons,
σ is the effective cross section = 470 millibarns
l is the length of the interaction area = 500 cm.
a is the area of the larger of the two beams = .5 cm
c is the velocity of light = 3×10^{10} cm/sec
τ is the length of the longer pulse duration = 30 nsec.

For $n_1 = 7 \times 10^{18}$ and $n_2 = 10^{12}$ one obtains

$$Y = .7 \times 10^7 \text{ photons per pulse.}$$

C) An Ionization Detector

Measurement of an up-down asymmetry requires a device of good spatial resolution to observe the asymmetry variation over a few millimeters. An argon-filled detector consisting of fine wires spaced .02 mm (.008") apart has sufficient resolution. A lead converter in front of the detector converts photons into e pairs. The ions in the gas are collected on the wires. The charge from each wire is amplified and digitized for analysis. A sketch of the detector shows the idea:

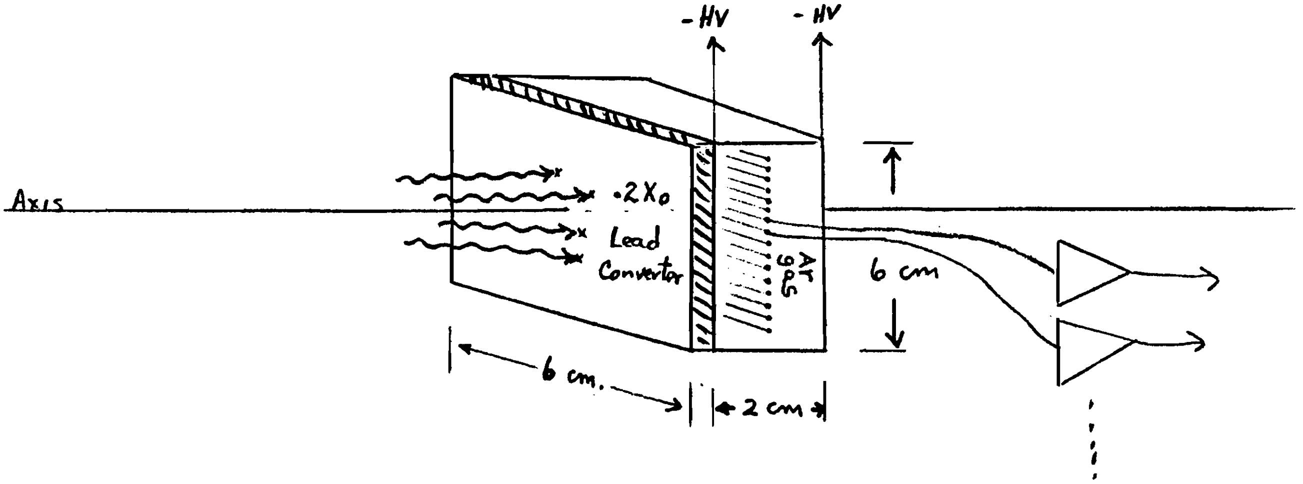

Figure 2 shows the distribution of charge projected onto the vertical axis . For a 2 cm. gap in the ionization chamber, approximately 100 pC. per pulse will be collected from all of the wires. Figure 3 shows the up-down asymmetry to be expected for 100% polarization $P_e P_\gamma$. Note that the asymmetry used here,

$$A = \frac{\sigma(y)-\sigma(-y)}{\sigma(y)+\sigma(-y)}$$

,where y is the vertical displacement from the spot center , is independent of the total flux, so that it should be insensitive to the pulse-to-pulse amplitude fluctuations.

D) Backgrounds

Backgrounds to the back-scattered laser photons come from beam bremsstrahlung and synchrotron radiation. The first is negligible if the detector is gated to look at only one passage of the electron beam. Synchrotron radiation is estimated to be 2.6 megawatts around the entire ring, per beam. A single e^- bunch, into a detector which subtends only 1 millirad of the arc, contributes 2 joules per turn, or 2×10^6 GeV/pulse/turn. Attenuation of synchrotron radiation in .1 X_0 of lead achieves a reduction by a factor of approximately 100 in the synchrotron radiation seen by a detector, while high energy photons are attenuated by 7%. With a high-Z absorber placed upstream of the detector,the synchrotron radiation can be suppressed to a level below 1 % of the signal from the back-scattered laser photons.

E) Conclusions

Backgrounds to detecting laser back-scattered photons can best be handled by using a pulsed ruby laser. Yields up to $.7 \times 10^7$ GeV per pulse should be achievable into a detector with an aperture of a few centimeters on a side. A magnet to sweep away spray from synchrotron radiation does not seem to be needed. Background photons from synchrotron radiation can be attenuated to a negligible level. For transversely polarized electrons and circularly polarized photons, up-down asymmetries of 10 % can be reached. For a detector placed 80 meters from the laser beam interaction point, the maximum asymmetry occurs at about 2 millimeters above and below the 0 degrees back-scatter point. An ionization detector consisting of finely spaced wires and argon gas is suggested as a means of resolving the spatial distribution of the flux of the back-scattered photons.

REFERENCES

1. J. J. Murray and P. R. Klein, SLAC-TN-67-19, June 1967; also C. K. Sinclair , J. J. Murray, P. R. Klein, M. Rabin, IEEE Trans. on Nuclear Science <u>16</u> , No. 3, 1065 (1969). Earlier references are given in these reports.
2. C. Y. Prescott, SLAC-TN-73-1, January 1973.
3. F. Lipps and H. A. Tolhoek, Physica <u>20</u>, 85,395 (1954). In equation 2.7,pg 397, the factor $k \cos \theta$ should be $k_o \cos \theta$. See also S. Gasiorowicz, Elementary Particle Physics (J. Wiley and Sons, New York, 1967), Chapter 10.

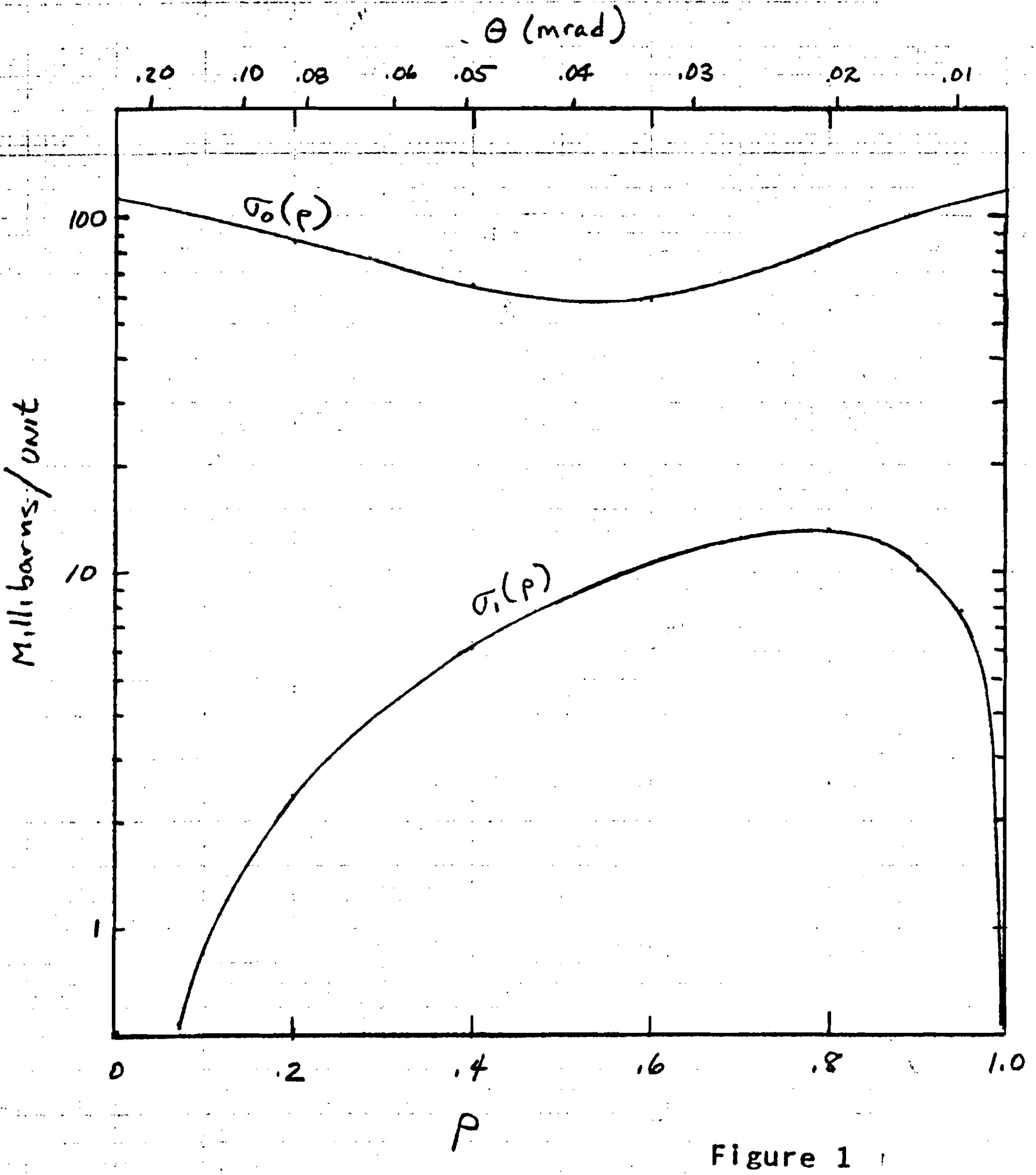
θ (mrad)
.20
.10
.08
.06
.05
.04
.03
.02
.01
Millibarns/unit
100
10
1
$\sigma_0(\rho)$
$\sigma_1(\rho)$
0
.2
.4
.6
.8
1.0
ρ

Figure 1

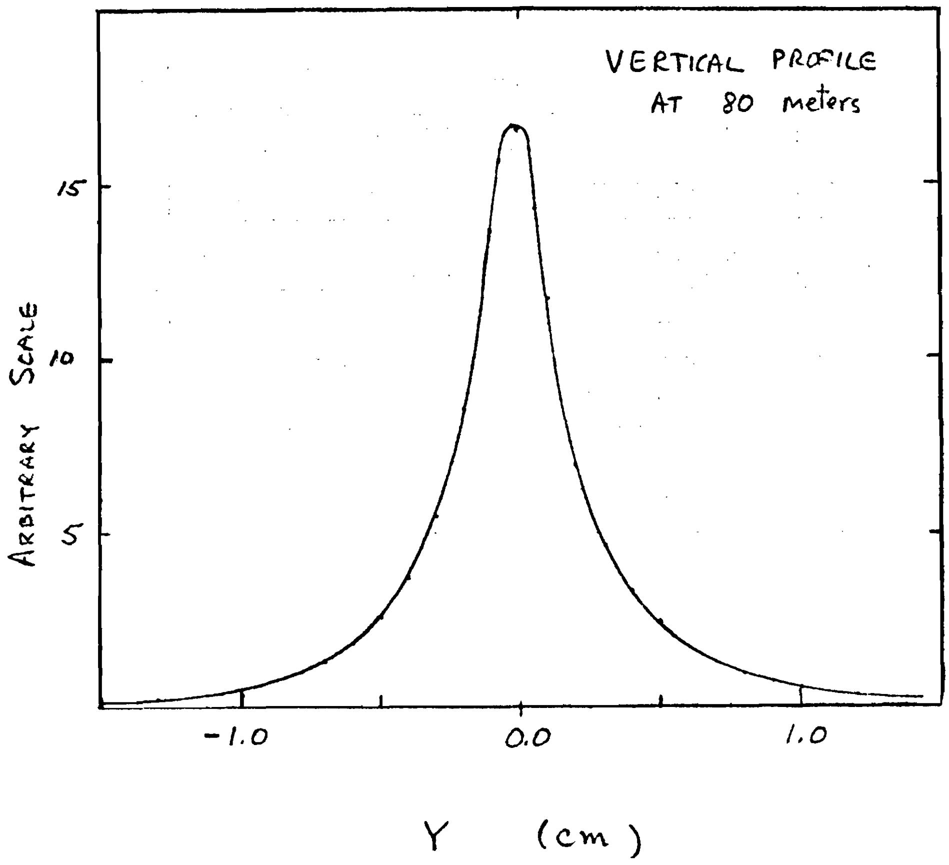

Figure 2

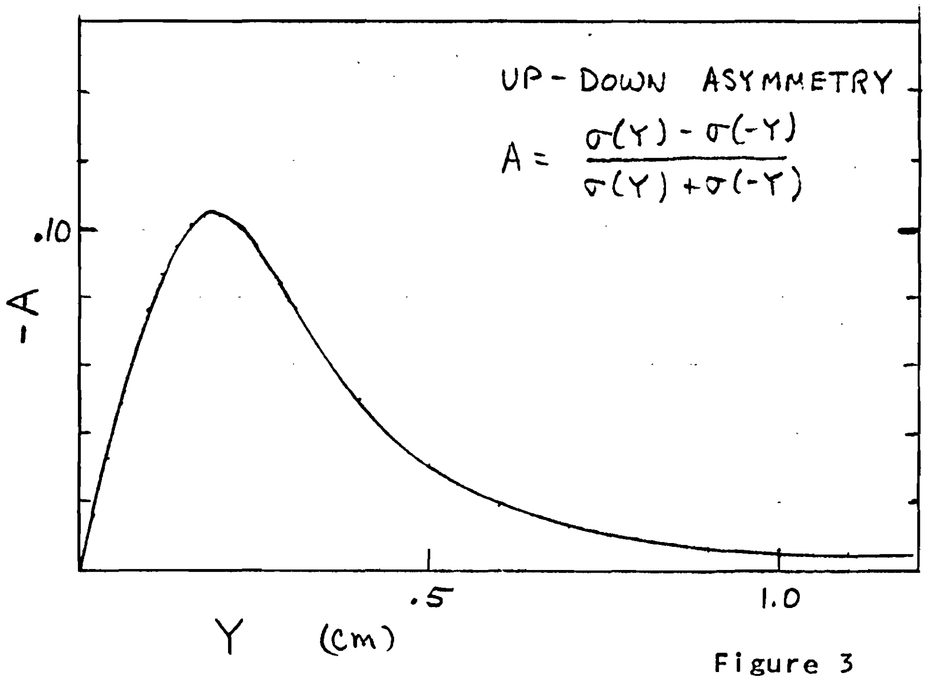

Figure 3