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It is of considerable interest for the study of elementary particle physics to perform experiments with beams of linearly polarized photons(1). These experiments require an accurate knowledge of the degree of polarization of the beam. If the beam is produced in the conventional manner, which uses the natural polarization of the bremsstrahlung perpendicular to the plane of emission, the polarization can in principle be evaluated from the geometry of the beam itself(2).

A second method, with could produce beams of higher intensity, is based on the fact that the bremsstrahlung coherently produced on a single-crystal target can, under certain conditions, be strongly linearly polarized(3,4). The polarization of a beam produced by this method cannot be evaluated a priori with confidence and must therefore be measured in some way.

The measurement of linear polarization requires the observation of azimuthal asymmetries in processes initiated by the γ rays.

The only method presently well understood is based on pair production. The difficulty here is that at high energy pair production is restricted to a narrow forward cone and the expected asymmetries are quite small, of the order of 20 - 30% even for fully polarized beam and under the best conditions.

The use of processes involving strong interacting particles is in general unsatisfactory as one then requires some information on the details of the interaction. An exception seems to be the elastic photoproduction of a neutral pion on He^4 (or in general on a spin 0 nucleus):

$$\gamma + He^4 \rightarrow \pi^0 + He^4 \tag{1}$$

This process is particularly simple as only the photon, among the particles involved, has spin different from zero. The only vector quantities here are the photon polarization vector $\underset{\sim}{\varepsilon}$, its momentum $\underset{\sim}{k}$, and the momentum of the emitted pion $\underset{\sim}{k'}$. The amplitude for the process will therefore be proportional to the only pseudoscalar quantity:

$$\mathcal{M} = \mathcal{Q} \cdot [\underset{\sim}{\varepsilon} \cdot (\underset{\sim}{k} \times \underset{\sim}{k'})] \tag{2}$$

$\mathcal{Q}$ can depend on the photon energy and on the angle of emission of the pion. The cross-section for a beam of linear polarization $\underset{\sim}{P}$ is then:

$$\left(\frac{d\sigma}{d\Omega}\right)_P = \left[(1-|\underset{\sim}{P}|) + 2|\underset{\sim}{P}|\sin^2\varphi\right]\left(\frac{d\sigma}{d\Omega}\right)_{P=0} \tag{3}$$

where the azimuth φ is defined as the angle between the plane of emission ($\underset{\sim}{k}$, $\underset{\sim}{k'}$) and the plane of polarization ($\underset{\sim}{k}$, $\underset{\sim}{P}$).

For a fully polarized beam ($|\underset{\sim}{P}| = 1$) the azimuthal distribution is simply $\sin^2\varphi$. The analyzing power of this process is therefore equal to that of a Nicol prism for visible light.

The ratio of the cross-sections at 90° from $\underset{\sim}{P}$ and parallel to $\underset{\sim}{P}$ is:

$$\frac{d\sigma_\perp}{d\sigma_\parallel} = (1+|\underset{\sim}{P}|)/(1-|\underset{\sim}{P}|) \tag{4}$$

This ratio is already 1.5 for a 20% polarization and increases very steeply. In this method statistics is not a problem; one should, however, be able to discriminate against such processes as

$$\gamma + He^4 \rightarrow n + He^3 + \pi^0 \qquad (5)$$

$$\gamma + He^4 \rightarrow \pi^0 + \pi^0 + He^4 \qquad (6)$$

whose azimuthal distribution cannot be evaluated at present with confidence[5].

The method proposed here has rather unique properties, especially for photons of high energy; the difficulties of the method based on pair production increase rapidly with energy, and also increasing is our ignorance of the details of other processes involving strong interacting particles[6].

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References

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(4) Experiments with a beam produced in this manner are now in progress at Frascati (G. Bologna, G. Barbiellini, G. Diambrini and G. Murtas)

See also: J. De Wire, Laboratori Nazionali di Frascati, nota interna n° 87 (unpublished)

(5) Near the threshold for process (6) the relative angular momentum of the two pions will be l = 0 (the next permitted value is l = 2); under these conditions the azimuthal distribution of the α recoil is again uniquely determined. It is in fact $\cos^2 \phi$ for complete polarization so that contributions of (6) can mask the asymmetry in (1).

(6) For γ-ray energies below the pion threshold there exist particular photo disintegration reactions with well-defined analyzing power for the photon polarization.