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POSITIVE PION PHOTOPRODUCTION WITH COHERENT BREMSSTRAHLUNG

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Results of a measurement of the asymmetry ratio $A = (\sigma_\perp - \sigma_\parallel)/(\sigma_\perp + \sigma_\parallel)$ with linearly polarized photons are reported here. The quantities $\sigma_\perp(\sigma_\parallel)$ are defined as the differential cross section for the photoproduction of positive pions by photons with the electric vector perpendicular (parallel) to the production plane.

The source of polarized photons was the coherent bremsstrahlung beam developed and described by Barbiellini et al. [1]. Electrons accelerated to an energy of 1 GeV by the synchrotron of the Laboratori Nazionali di Frascati interacted with a suitably alligned single crystal diamond target and produced a bremsstrahlung beam having the intensity and polarization characteristics shown in fig. 1.

The position of the intensity and polarization peaks is varied by changing the angle of the [110] crystal axis with respect to the incident electron direction. In practice two crystals were used as radiators for photons polarized perpendicularly and parallel to the (γ, π) plane. The intensity spectrum from each crystal was measured in great detail by means of an electron pair spectrometer. The two spectra were not indentical, possibly because of slight initial alignment differences or inherent characteristics of the crystals. However, the origin of the difference is of no immediate concern because the pion counting rates were normalized to the measured number of photons within the energy interval producing single π^+ events.

The beam polarization was not measured directly at the conditions of this experiment. How-

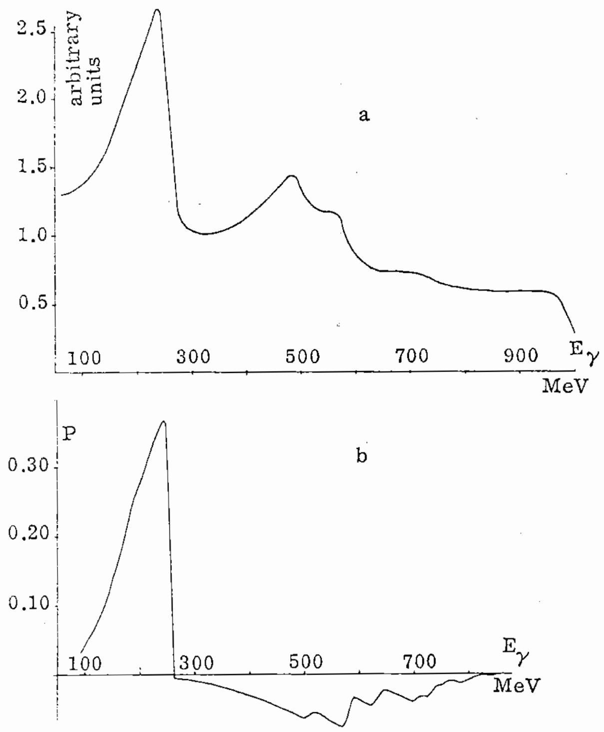

Fig. 1. (a) Coherent bremsstrahlung number-energy photon spectrum. This spectrum is not corrected for the pair spectrometer resolution. (b) Theoretical polarization-energy spectrum.

ever, a measurement of the relative polarization of 150 MeV photons as a function of crystal alignment was consistent with a Born approximation model of coherent bremsstrahlung [2]. This accord plus the good agreement between the theoretical and experimental values of the intensity lent credence to our accepting the calculated values of the polarization.

Events from the reaction $\gamma + p \rightarrow \pi^+ + n$ were identified by observing a selected momentum interval in a strong focusing magnetic spectrometer using conventional counter techniques to select the pions.

The most important backgrounds, π^+ of the correct momentum produced from multi-pion reactions and the decay muons of higher momentum pions, originate in higher energy processes. These must necessarily be present because the coherent bremsstrahlung spectrum contains photons of all energies up to that of the incident electrons. This contamination was estimated as follows. With all the spectrometer conditions fixed, the total pion yield was measured as a function of the alignment of the crystal with resp to the incident electron beam. That is, the position of the principal intensity peak was varied wi respect to the fixed spectrometer acceptance. While the peak position is being varied the higher energy region remains fairly constant. Hence, the total yield of events was the sum of a rapidly varying number of single π^+ events from the coherent region plus a slowly varying contribution from the higher energy region. A theoretical yield curve was calculated for the single π^+ events. The experimental and theoretical yields had the same general shape, differing only by a constant background. From a comparison of the two it was possible to estimate what background should be subtracted from the experimental curv and hence what fraction of the total events are single π^+.

In this experiment the background was always less than 11%. In as much as the higher energy photons have very little polarization, it was assumed that the background was the same for both the perpendicular and parallel crystal orientations.

Measurements have been made at five angles between 45° and 145° in the c.m. As the momentum acceptance of the spectrometer is $\Delta p/p$ = = 0.25, pion events originating from the photon interval $190 \leqslant h\nu \leqslant 255$ MeV were observed for a single magnet current setting. A counter system placed in the focal plane divided the total momentum acceptance into several bands.

During a given block of runs measurements were carried out over a period of several hours for each fixed laboratory angle and crystal orientation. At each angle the measurements were alternated several times between $\sigma_\perp$ and $\sigma_\parallel$. Within a block of runs the absolute counting rates were reproducible. From one block of runs to another (an interval of one or two months) the absolute counting rates did show some variation but the asymmetries were reproducible.

The quantities $\sigma_\perp$ and $\sigma_\parallel$ are related to the observed counting rates $\sigma_\perp$ and $\sigma_\parallel$ as follows:

$$\frac{(C_\perp - B_\perp) - (C_\parallel - B_\parallel)}{(C_\perp - B_\perp) + (C_\parallel - B_\parallel)} = P\left(\frac{\sigma_\perp - \sigma_\parallel}{\sigma_\perp + \sigma_\parallel}\right)$$

where $C_\perp(C_\parallel)$ is the observed counting rate normalized to the number of photons in the interval producing single π^+ events, when the photons are polarized perpendicular (parallel) to the (γ, π) plane.

P is the beam polarization defined as

$$P = \frac{N_\perp - N_\parallel}{N_\perp + N_\parallel}$$

Table 1

$\theta_{c.m.}$ \ E_γ	210 ± 12		225 ± 12		240 ± 16	
	A	P	A	P	A	P
45°	0.332 ± 0.043	0.293 ± 0.010	0.277 ± 0.032	0.329 ± 0.010		
71°	0.102 ± 0.040	0.293 ± 0.010	0.176 ± 0.025	0.329 ± 0.010		
88°	0.108 ± 0.036	0.293 ± 0.010	0.140 ± 0.025	0.329 ± 0.010		
120°	0.124 ± 0.066	0.274 ± 0.010	0.034 ± 0.046	0.308 ± 0.010	0.049 ± 0.035	0.329 ± 0.015
135°	0.057 ± 0.053	0.274 ± 0.010	-(0.033 ± 0.044)	0.308 ± 0.010	0.039 ± 0.032	0.329 ± 0.015

where $N_\perp(N_\parallel)$ is the relative number of photons having their electric vector perpendicular (parallel) to the (γ, π) plane.

$B_\perp(B_\parallel)$ is the background, i.e. events other than single π^+.

Part of the background, e.g. most of the empty target events, some of the muons, will satisfy

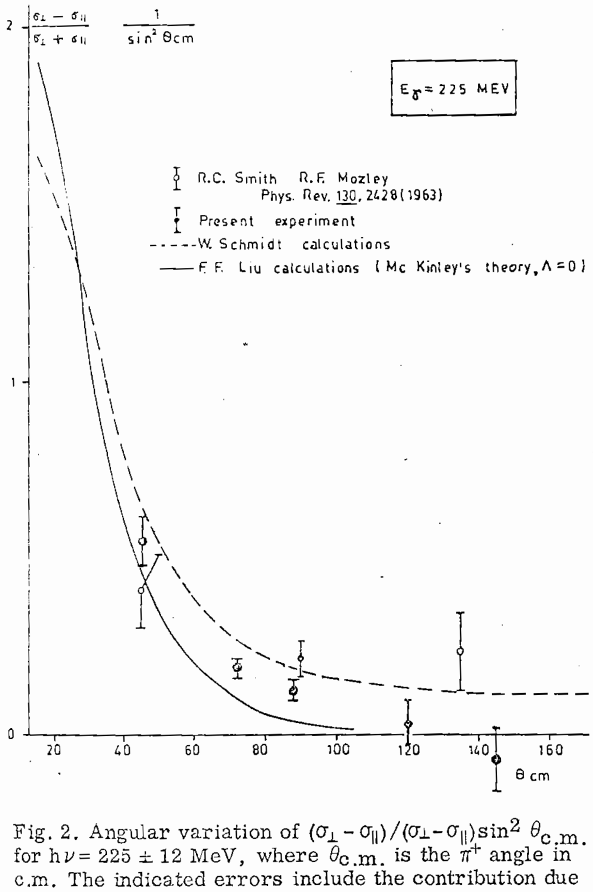

Fig. 2. Angular variation of $(\sigma_\perp - \sigma_\parallel)/(\sigma_\perp - \sigma_\parallel)\sin^2\theta_{c.m.}$ for $h\nu = 225 \pm 12$ MeV, where $\theta_{c.m.}$ is the π^+ angle in c.m. The indicated errors include the contribution due to the present uncertainty of the theoretical evaluation of the beam polarization.

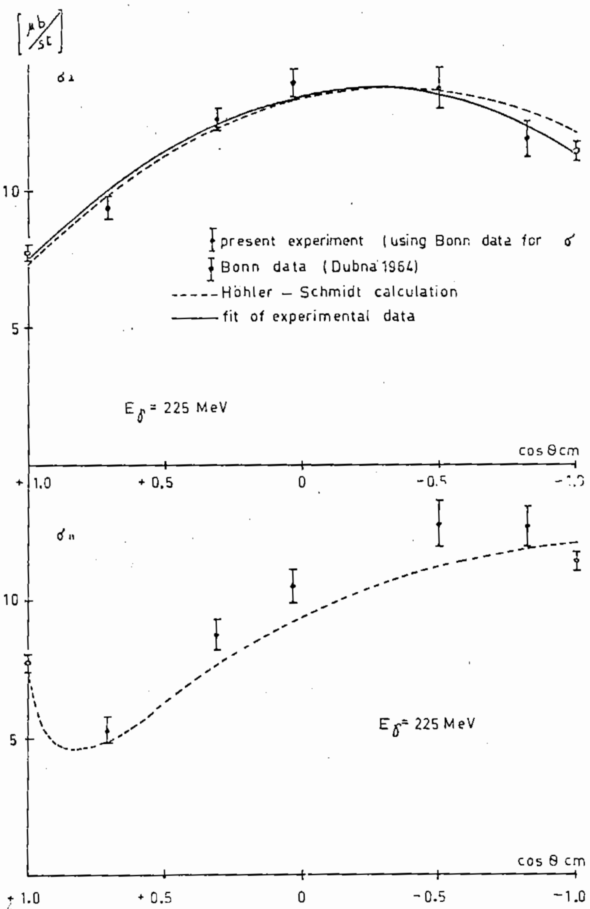

Fig. 3. Angular variation of $\sigma_\perp$ and $\sigma_\parallel$, for $\nu = 225 \pm 12$ MeV. The dotted lines give the theoretical prediction by Höhler and Schmidt [4]. A second order polynominal in cos $\theta_{c.m.}$ is used to fit the experimental data of $\sigma_\perp$ (solid line). We also report the data for $\sigma_\perp$ and $\sigma_\parallel$ at 0° and 180° obtained by a Moravcsik fit of Bonn data [7], exploiting the fact that $A = 0$ for these angles.

the condition $B_{\perp}/C_{\perp} = B_{\parallel}/C_{\parallel}$. In this case no error is introduced when the background is neglected.

However, as explained above, the multi-pion and muon contributions come largely from an unpolarized region so that the background is more nearly of the type $B_{\perp} = B_{\parallel} = B$. Hence:

$$\frac{C_{\perp} - C_{\parallel}}{C_{\perp} + C_{\parallel} - 2B} = P\left\{\frac{\sigma_{\perp} - \sigma_{\parallel}}{\sigma_{\perp} + \sigma_{\parallel}}\right\} = PA \ .$$

As $B/C_{\perp} \ll 1$ a relative error in B results in a much smaller relative error in PA.

The experimental results after background corrections are shown in table 1. The quantity P is the mean value of the polarization obtained from a Born approximation calculation of coherent bremsstrahlung taking into account the experimental resolution.

The results for A at $h\nu = 225 \pm 12$ MeV are shown in fig. 2 together with some previous results of Smith and Mozley [3], a theoretical curve by Schmidt and Hohler [4], and a calculation by Liu [5], based on the theory of McKinley [6].

In fig. 3 we report the angular dependence, for $h\nu = 225$ MeV, of $\sigma_{\perp}$ and $\sigma_{\parallel}$, obtained by our measurements of the asymmetry ratio A and the Bonn data [7], for the unpolarized cross section (σ), according to the relations:

$$\sigma_{\perp} = (1 + A)\sigma \ , \qquad \sigma_{\parallel} = (1 - A)\sigma \ .$$

A second order polynomial in $\cos \theta_{\mathrm{c.m.}}$ seems to be a good fit of $\sigma_{\perp}$ at $E_{\gamma} = 225$ MeV (see fig. 3). This means that we have no contribution of waves higher than P in $\sigma_{\perp}$ at this energy.

A more detailed account of the experiment a a discussion of the results will be published.

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References

1. G. Barbiellini, G. Bologna, G. Diambrini and G. P. Murtas, Phys. Rev. Letters 8 (1962) 112.
2. G. Barbiellini, G. Bologna, G. Diambrini and G. P. Murtas, Phys. Rev. Letters 9 (1962) 396.
3. R. C. Smith and R. F. Mozley, Phys. Rev. 130 (1963) 2429.
4. W. Schmidt, private communication.
5. F. F. Liu, private communication.
6. J. M. McKinley, Technical Report No. 38, Phys. Dept. Univ. of Illinois, Champaign-Urbana Ill. (unpublished.
7. D. Freitag, W. J. Schwille and R. J. Wedemeyer, Dubna Conference (1964).

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ERRATA

B. Maglić and G. Gosta, A method for the search for unstable particles using Jacobian peaks in angular distribution, Physics Letters 18 (1965) p. 185.

The name of the second author should read G. Costa.

B. J. Verhaar and L. D. Tolsma, Simple picture of reverse rotation of gamma-ray angular pattern in inelastic alpha-particle scattering Physics Letters 17 (1965) p. 55.

In fig. 3 the right-hand diagram should be omitted. The caption applies to the left-hand diagram.

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