Laboratori Nazionali di Frascati

LNF-65/58

P. Gorenstein, M. Grilli, P. Spillantini, M. Nigro, E. Schiavuta and V. Valente : POSITIVE PION PHOTOPRODUCTION WITH COHERENT BREMSSTRAHLUNG.

Estratto da: Proceedings of the Intern. Symp. on Electron and Photon Interactions at High Energies, Hamburg (Deutsches Phys. Gesellschaft, 1965), vol. II, p. 222.

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Positive Pion Photoproduction with Coherent Bremsstrahlung

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We have used linearly polarized photons from the Frascati Synchrotron to measure the asymmetry ratio:

$$A = \frac{d\sigma_\perp - d\sigma_\parallel}{d\sigma_\perp + d\sigma_\parallel} = \frac{1}{P}\,\frac{C_+ - C_-}{C_+ + C_-} \qquad (1)$$

for the process:

$$\gamma + p = n + \pi^+ \qquad (2)$$

in the energy range $200 < E\gamma < 250$ MeV.

The quantities in (1) are respectively:

$d\sigma_\perp$ ($d\sigma_\parallel$) = differential cross section of reaction (2) by photons having the electric vector perpendicular (parallel) to the production plane.

$P = \frac{N_\perp - N_\parallel}{N_\perp + N_\parallel}$ = polarization of γ-beam; where $N_\perp$ ($N_\parallel$) are the number of incident photons with the electric vector perpendicular (parallel) to the reaction plane.

C_+ (C_-) = pion counting rate when P is positive (negative).

Simoultaneous measurements were made for three values of the photon energy (210 ± 11; 225 ± 12; 240 ± 13 MeV) and for five angles at each energy [1].

Polarized photons were produced by the coherent bremsstrahlung of 1 GeV electrons in a single diamond crystal in the manner developed and described by G. Barbiellini, G. Bologna, G. Diambrini and G. P. Murtas [1]. The resulting beam is a spectrum containing photons of all energies up to the incident electron energy but having a substantial enhancement compared to the usual bremsstrahlung spectrum, in a certain energy interval which is accompanied by a polarization of the photon's electric vector (Fig. 1). The photons producing single pion events within our interval of acceptance were calculated as having an average polarization of about 32%.

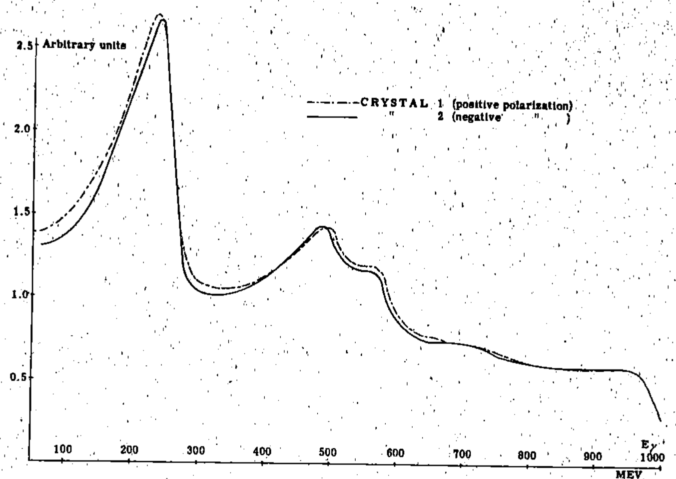

Fig. 1. An example of the coherent bremsstrahlung spectra from the diamond crystals used in this experiment. The two diamond crystals I and II were oriented with respect to the direction of the primary electron in order to give positive or negative polarization respectively (see text for the definition of the beam polarization)

A sketch of the apparatus is reported in Fig. 2.

The pions from process (2) were identified by observing a selected momentum band, in a strong-focusing magnetic spectrometer, using conventional counter techniques to identify the pions.

For a fixed set of spectrometer conditions measurements of pion yield were carried out alternately (several times in a given block of runs) for two diamond crystals, which were oriented to produce, respectively, $P \gtrless 0$. This procedure of alternating several times the measurements between C_+ and C_- was used in order to reduce systematic errors. The asymmetry ratios A measured each time were reproducible. The photon intensity spectrum of each crystal

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[1] We now report for 240 MeV only the data for $\theta_{CM} = 120°$ and 145° as the other data, for this energy, need forther analysis (which is in progress)

was determined in great detail, simoultaneously with the π^+ measurements by means of a pair spectrometer (Fig. 2). An example of such a spectrum is reported in Fig. 1. During all the running time the reproducibility of these spectra resulted to be better than (0.3)% and found to be in agreement with the calculated values. This fact makes possible to normalize all our measurements C_+ and C_- to an equal number of incident photons in the accepted energy band.

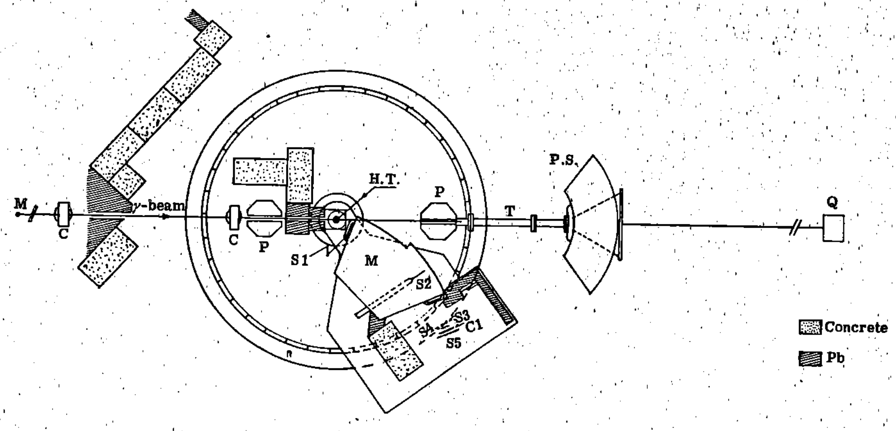

Fig. 2. Experimental apparatus: H. T. = Hydrogen Target; M = Strong-focusing magnet; $S_1 \ldots S_5$ = Counter's telescope for the identification of the pions; (S_1, S_2, S_3, S_4, S_5 = plastic scintillators C_1 = plexiglass Cerenkov); P. S. = Pair Spectrometer; Q Quantameter (Wilson's type)

The polarization of beam (P) has not been measured directly. The uncertainty of the theoretical evaluation of P is estimated to be less than ± 5%. An improved theoretical evaluation of the polarization is being carried out by G. Bologna [2] and an experimental determination of it (for $E\gamma$ = 150 – 225 MeV) now in progress [3].

In addition to π^+ originating from the process $\gamma + p \rightarrow \pi^+ + n$ there was a contamination from multi-pion processes involving higher energy photons. This background contribution was determined by making measurements of the pion yield as a function of the position of the intensity enhancement in the photon spectrum.

Our results for A are collected in Table 1. The errors reported are the statistical errors only.

The results for A, at $E\gamma$ = 210 and 225 MeV, are compared (Fig. 3a, b), when possible, with some previous results by Smith and Mozley [4], with the calculations of Schmidt [5] [Höhler - Schmidt Theory [6]] and with a calculation of F. F. Liu [7] based on the theory of McKinley [8].

Our values of $A/\text{sen}^2\, \theta_{CM}$ seem to be generally lower than those predicted by W. Schmidt.

Our data agree with those by Smith and Mozley [4]. It is interesting to note that the two experiments have used a completely different technique to obtain the polarization of photon beam.

Table 1 — Asymmetry ratios $A = \frac{\sigma_\perp - \sigma_\parallel}{\sigma_\perp + \sigma_\parallel}$

θ_{cm}		$E\gamma$	
	210 MeV	225 MeV	240 MeV
45°	.333 ± .042	.270 ± .030	
72°	.102 ± .037	.171 ± .025	
88°	.109 ± .032	.136 ± .022	
120°	.145 ± .068	.036 ± 0.42	.050 ± .035
145°	.062 ± .060	−.029 ± .040	.038 ± .032

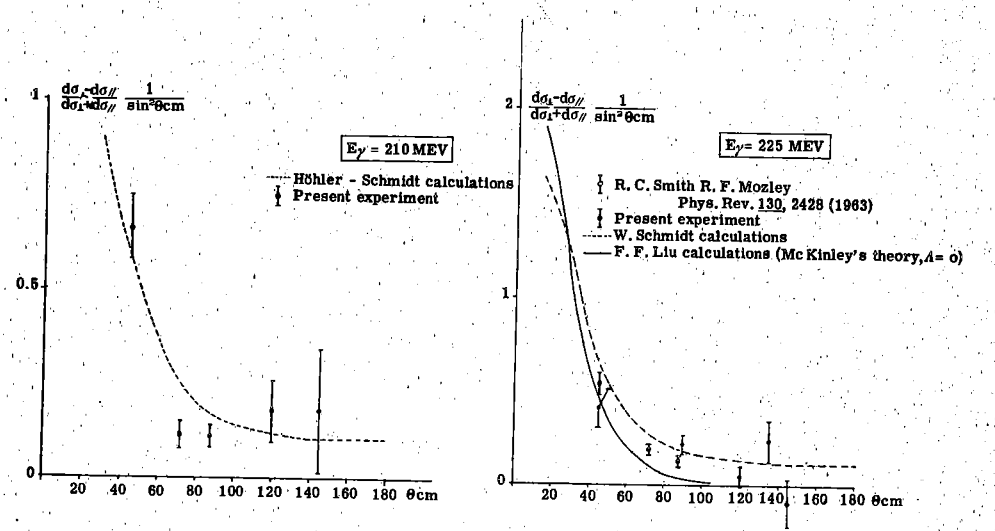

Fig. 3. Asymmetry ratios A (divided by sen² θ_{CM}) as a function of the (θ_{CM}) centre of mass angle of the π^+ (Fig. 3a: $E\gamma = 210$ MeV; Fig. 3b: $E\gamma = 225$ MeV). The data are compared with the Höhler-Schmidt theory 5,6 and McKinley theorey 7,8 . For the McKinley theory we report the case for $\Lambda = 0$. Λ is the $\gamma\pi\varrho$ coupling constant

From our measurements of the asymmetry ratio A, using the Bonn data [9] for the unpolarized cross section $d\sigma/d\Omega$ of process (2), we obtain the $(d\sigma_\perp/d\Omega)$:

$$\frac{d\sigma_\perp}{d\Omega} = \frac{d\sigma}{d\Omega}(1 + A) \tag{3}$$

This last cross section is particularly interesting because it has no contributions from higher partial waves, coming from the "photoelectric term". For this reason we have tried to fit the $\frac{d\sigma_\perp}{d\Omega}$ with a second order polyonomial in $\cos\theta_{CM}$:

$$\frac{d\sigma_\perp}{d\Omega} = A + B\cos\theta_{CM} + C\cos^2\theta_{CM} \qquad (4)$$

At present we give the $(d\sigma_\perp/d\Omega)$ only at $E_\gamma = 225$ MeV because there are no sufficient data of $(d\sigma/d\Omega)$ at $E_\gamma = 210$ MeV and of the asymmetry ratio A at $E_\gamma = 240$ MeV.

A second order polynomial in $\cos\theta_{CM}$ seems to be a good fit of $d\sigma_\perp/d\Omega$ at $E_\gamma = 225$ MeV (see Fig. 4). This means that we have no contribution of waves higher than p in $d\sigma_\perp/d\Omega$ at this energy.

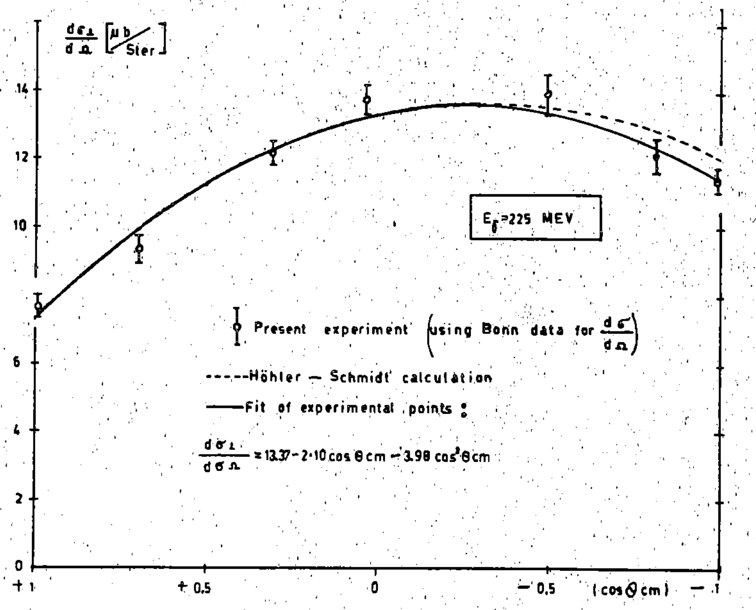

Fig. 4. $d\sigma_\perp/d\Omega$ (see text) as a function of θ_{CM}. The data for $\theta_{CM} = 0°$ and 180° are obtained with a Moravcsik fit of the Bonn data (telescope data) 9

Moreover, as we can see from Fig. 4, the measured $d\sigma_\perp/d\Omega$ agrees very well with the prediction of Höhler-Schmidt theory. This fact and the disagreement between the prevision of this theory and the measured asymmetry ratios A seem to indicate that the failure of the theoretical predictions is localized in the calculations of $d\sigma_\parallel/d\Omega$.

We are, at present, extending our measurements at higher energies, until $E_\gamma \sim 400$ MeV.

A detailed account of the experiment together with a full discussion of the data presented here will be shortly published.

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Photoproduction of π^+ on Proton at 0° in the Energy Range 300 to 600 MeV

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I. Introduction

Photoproduction of π^+ on proton in the energy range of the first resonance has been extensively studied [1,2,3,4]. The points at higher energies are scarcer [5,6,7] but precise.

Essentially two different attempts towards a theoretical interpretation of photoproduction above 350 MeV were made. One is the isobaric model of Gourdin and Salin [9]. The other one is based on the inclusion of pion-nucleon scattering experimental results in dispersion theory by Höhler and his group [10].

Amongst the photoproduction experiments, the 0° measurements are of special interest because the dispersion relations take a particularly simple form. From the other hand, the invariant amplitudes take also a simpler form at 0° because the direct interaction term disappears.

Unfortunately, it is very difficult to measure photoproduction at 0°. No data, up to now, had been taken in the region 300–550 MeV.

II. Principle of the measurement

We have undertaken the measurement of 0° π^+ photoproduction between 300 and 600 MeV. At 0° each π^+ is accompanied by a number of positrons of the order of 10^5 (the exact ratio depending on the experimental conditions) of the same momentum produced by electromagnetic pair creation.