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R. Querzoli, G. Salvini, A. Silverman(o): THE POLARIZATION OF THE RECOIL PROTON IN THE PHOTOPRODUCTION OF π^0 MESONS FROM HYDROGEN

Introduction

The present research has been stimulated from the proposal of Sakurai(1) of measuring the polarization of the recoil proton in the reaction $\gamma + p \rightarrow \pi^0 + p$, in order to decide on the relative parity of the second resonance: $P_{3/2\,,\;1/2}$ according to Wilson; $D_{3/2\,,\;1/2}$ according to Peierls.

The Sakurai model is only an oversemplified one as it was pointed out by many authors (2,3), and as a matter of fact one cannot expect from the experiment on the polarization an unambiguous reply. Notwithstanding, we consider of preminent importance the knowledge of the polarization at different energies and angles in this fundamental 2-body process.

(o) At present at the Cornell University

(1) J.J. Sakurai, Phis. Rev. Letters 1, 258 (1958)

(2) Pellegrini and G. Stoppini, unpublished results

(3) G. Bernardini, invited report at the Kiev Conference (1959) L.F. Landovitz and L. Marshall Phis. Rev. Letters 3, 190 (1959)

Experimental disposition

The polarization of the recoil protons has been measured at different photon energies and at a center-of-mass angle of 90° observing the left-right asimmetry in the scattering of the protons on Carbon. In fig. 1 our experimental disposition is shown.

The photon beam of the Frascati electrosynchrotron is incident upon a liquid hydrogen target 6 cm in diameter. The protons emitted with an angle 42±2.5 degrees in the laboratory are incident upon a carbon scatterer C, and scatterings at small angles (~ 15°, see later) both to the left and right are measured.

The π^0's are revealed by a lead glass Cerenkov Counter; the protons are revealed by the counters 1⊢10. All of the proton counters are plastic scintillators.

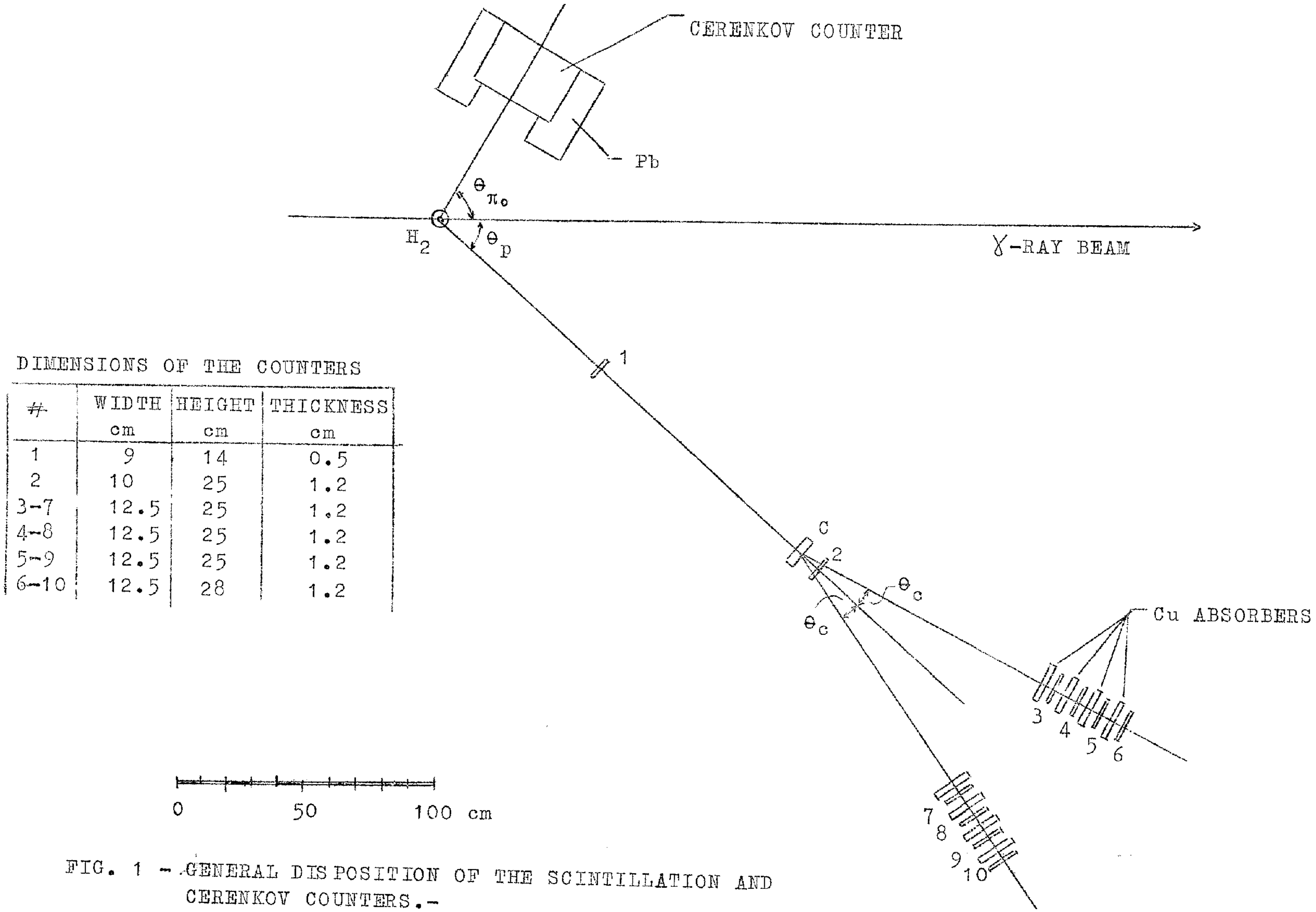
The range of the protons is determined by the copper abserbers between the counters; the discrimination between protons and pions is made by discrimination of the pulse size in counters 3, 7 (photographic records of the pulse size were periodically taken). The following coincidences and anticoincidences were taken:

A) Cer + 2 + 3 + 4 + 5 - 6 high energy channel (left)
B) Cer + 2 + 3 + 4 - 5 low energy channel (left)
C) Cer + 1 + 2 + 3 + 4 + 5 - 6 high energy channel (left)
D) Cer + 1 + 2 + 3 + 4 - 5 low energy channel (left)

and the corresponding ones at the right.

We have been therefore measuring protons in two different energy intervals at the same time. The measurements A, B were taken (about 50% of the time) when counter 1 had not yet been installed.

Both telescopes left and right were mounted on an aluminum and brass 2-arm frame whose angle θ_c (see fig.1)



DIMENSIONS OF THE COUNTERS

#	WIDTH cm	HEIGHT cm	THICKNESS cm
1	9	14	0.5
2	10	25	1.2
3-7	12.5	25	1.2
4-8	12.5	25	1.2
5-9	12.5	25	1.2
6-10	12.5	28	1.2

FIG. 1 - GENERAL DISPOSITION OF THE SCINTILLATION AND CERENKOV COUNTERS.-

could be changed and reobtained with at least .06 degrees precision.

The angle of the L and R telescopes was changed with the proton energy, as well as the carbon C thickness. A synthesis of our measurements is given in tables I, II.

Let's briefly summarize the possible sources of errors and the corrections for them:

- Delayed coincidences were regularly measured to subtract the accidentals. The effect was less than 10% in any condition.
- Background from target and air was regularly measured without H. The effect was generally less than 5%.
- Counter 1 avoids that a neutron coming from H gives rise to a detectable proton in the carbon C. The correction for this effect in the measurements without counter 1 is rather small.
- Inequalities in efficiency, discrimination, geometry in the two telescopes are of course very dangerous. The two telescopes were periodically compared by alternately moving them in line with the carbon scatterer and the hydrogen target, and thus counting unscatterd protons. This disposition gave a cross section of the $\gamma + p \rightarrow \pi^0 + p$ reaction in agreement with previous experiments. For the same reason we also measured the protons scattered at small angles (3° - 6°) to the left and to the right with each telescope; the asymmetries should be in this case very small.

  All these checks together guarantee the equality of the two telescopes.

Table I, (II). Columns meaning: 1: central energy of the γ's; 2: energy of the synchrotron; 3: γ energy width; 4: proton C.M. angle; 5: kinetic energy of the proton; 6: Carbon thichness; 7: Carbon scattering angle; 8: counter 1 present or not; 9 (10): frequency of the left (Right) telescope; 11: ratio right to left; 12: asymmetry (R/L-1); 13: the same corrected (see text)

1	2	3	4	5	6	7	8	9	10	11	12	13
E_γ	Em	ΔE_γ	0pcm	T	C (g cm^2)	0c	#1	Left	Right	R/L unc	ε unc	ε
500	650	70	90.7±5.2	129-155	3.7	16.5°	yes	7.6±0.50	11.4±0.8	1.5±0.14	0.20±0.07	0.25±0.09
700	830	95	91.4±5.2	180-216	8.08	14°	no	16.9±1.4	32.4±2.5	1.92±.22	0.33±.07	0.42± .10
							yes	19.0±1.7	38.4±2.4	2.02±.22		
750	870	110	91.7±5.2	195-238	8.08	14°	no	18.8±1.5	29.4±2.1	1.69±.19	0.26±.09	0.30± .12
800	930	118	92.2±5.2	214-258	8.08	14°	yes	10.7±1.1	20.0±1.0	1.87±.21	.30±.09	0.37± .13
850	990	130	92.5±5.2	236-276	8.08	14°	no	7.6±0.8	12.9±1.0	1.7±.22	.26±.10	0.32± .14

Table II.

1	2	3	4	5	6	7	8	9	10	11	12	13
475	650	75	90.7±5.2	93-129	3.7	16.5°	yes	42.5±1.8	43.9±1.6	1.03±.06	0±0.03	---
610	830	84	90.9±5.2	144-180	8.08	14°	no	40.1±4.4	62.7±3	1.56±.19	0.25±0.07	0.42±0.18
							yes	26.1±3.3	47.9±3.2	1.84±.28		
650	870	90	91.1±5.2	162-195	8.08	14°	no	28.8±2.1	47.5±2.6	1.65±.15	0.25±0.07	0.41±0.17
700	930	92	91.4±5.2	180-214	8.08	14°	yes	18.1±1.4	35.2±1.4	1.95±.17	0.32±0.08	0.50±0.19
750	990	110	91.7±5.2	192-236	8.08	14°	no	26.0±1.5	40.0±1.7	1.52±.11	0.21±0.05	0.31±0.1

Results

Our results are summarized in tables I and II. Table I refers to the high energy channel and table II refers to the low energy channel. E is the central energy of the photons producing the protons in the considered channel. E_m is the maximum energy of the bremsstrahlung beam: ΔE_γ is the energy interval of the photons which include 75% of the registered protons. θ_{pcm} is the center of mass angle of the emitted proton. T is the kinetic energy interval of the measured protons. C is the thickness of the Carbon target. θ_c is the scattering angle of the protons in the carbon. Column 8 specifics if the measurement was taken with or without counter 1; columns 9 and 10 give the intensity of the scattered protons at the left and at the right per 10^{13} equivalent quanta. Column 11 gives the ratio among the counting rates to the left and the right uncorrected for inelastic collisions. Column 12 gives the uncorrected asymmetry $\varepsilon = \frac{R-L}{R+L}$.

These numbers have to be corrected for the inelastic collisions of the protons in Carbon. In fact the polarization is obtained by using the Carbon as a polarization analyzer, and the analyzing power of the Carbon has been established in synchrocyclotron experiments through the study of the elastic collisions of protons in Carbon. It is important to correct for the possible inelastic collisions in Carbon, in order to get the correct value of column 13, that is the right-left asymmetry for elastic and quasi elastic collisions. The comparison between the two channels taken at the same time allows an estimate of the inelastic contribute. This is due to the higher percentage in the low energy channel of those protons that had an inelastic collision in Carbon and still remained in the detectable range of energies.

The estimate of the inelastic contribute has been made by the two channel method and by using the measurements at different energies of the inelastic collisions of protons in Carbon(4).

In fig. 2 the asymmetries for different photon energies are reported. To obtain the polarization of the protons from ε we have to average on the analysing power of the Carbon in the range of scattering angles selected with our geometry at each measurements, and on the flux of protons at each point of the Carbon. The flux of protons on the Carbon was measured by a small 2 x 25 cmq counter in three different positions in front of the Carbon, with the telescope in line with the Carbon and the H target. The asymmetry in the flux of protons on Carbon is rather small in our geometry, being always less than 15%.

Using these measurements and the data of analyzing power of Carbon in the literature we obtained the polarization of protons through a Montecarlo calculation, in a way not very different from the method used by Stein(5).

As well known, polarization is obtained from the relation: $\varepsilon = P P_c$
where P is the polarization of the protons we are investigating, and P_c is the Carbon analysing power, that is the asymmetry corresponding to a complete polarization of the emitted protor.

This method has been finished until now only for two energies, and the corresponding polarization is given in table III. The numbers in parenthesis are an estimate of the polarization by interpolation of the present results,

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(4) H. Tyren, J. Maris, Nuclear Phys. 3, 52 (1957)

(5) O. Chamberlain and cow. Phys. Rev. 102, 1659 (1956)
P.C. Stein, Phys. Rev. Lett. 2, 473 (1959)

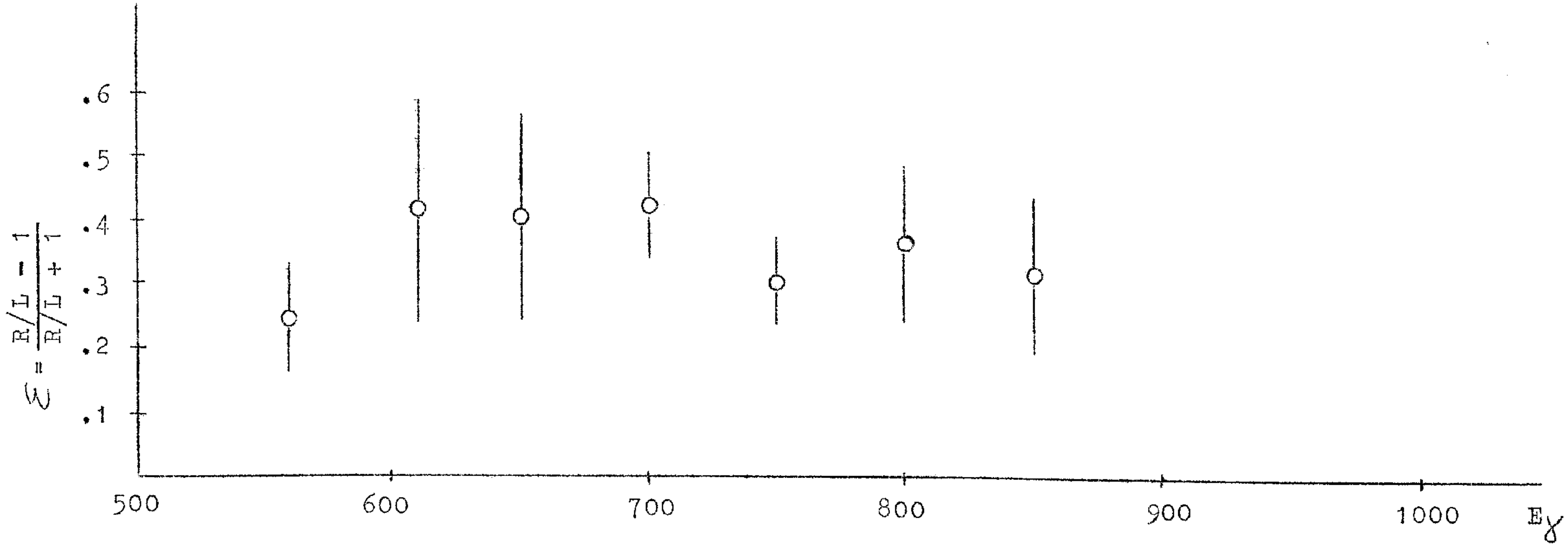

FIG. 2 - THE ASIMMETRY ε VERSUS THE ENERGY OF THE PHOTONS (THE INTENSITY IS ALWAYS LOWER AT THE TELESCOPE CLOSER TO THE γ-RAY BEAM).-

Table III. The polarization of the protons at different energies. The Montecarlo calculation is still in progress, and therefore the numbers now given may change somewhat.

Column 1: Central energy of the γ rays

Column 2: The asymmetry $\varepsilon = \frac{R/L - 1}{R/L + 1}$

Column 3: The polarization of the protons emitted in the process $\gamma + p \rightarrow \pi^0 + p$

E_γ	ε	P
560	0.25 ± 0.09	0.4 ± 0.14
610	0.42 ± 0.18	0.65 ± 0.23
650	0.41 ± 0.17	0.6 ± 0.25
700	0.43 ± 0.09	0.57 ± 0.12
750	0.31 ± 0.07	0.38 ± 0.09
800	0.37 ± 0.13	0.5 ± 0.17
850	0.32 ± 0.14	0.5 ± 0.22

and will be precisely fixed as soon as the Montecarlo calculation will be finished.

Discussion of the results

Our results give the following indications:

a) The polarization remains rather high in the energy interval 550↦850 MeV.

b) There is not an appreciable change of polarization of the protons around and after the second resonance.

Point a) is in agreement with the hypothesis that the first and the second resonance have opposite parities. In fact, an high interference is indicated by the high polarization and this favours the attribution of a $D_{3/2,\ 1/2}$ level to the secondo resonance; it also agrees with the results of Stein(5).

Point b) seems to us rather interesting, even if difficult to be interpreted: the polarization does not seem to be affected by the change of the cross section and of the phasis at the second resonance.

Some authors(3) have pointed out that polarization could arise from the second-third resonance interference. In this case the high polarization in the 700-850 MeV region could indicate that the parity of the third resonance is opposite to that of the D-wave second resonance. The present research is in progress at higher energies also for this purpose(6).

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(6) It would be of course very helpful to study the dependence of the polarization P on ϑpcm, to distinguish different multipolo channels on the basis of the different $\cos\vartheta$ behaviour of P. This task meets some experimental dif

It is clear from our measurements that in the energy interval we explored there is no region which can be described by a single state: in such a region the polarization should be $\sim$ zero.