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Polarization of the Recoil Proton from the Neutral Photoproduction at 800 and 910 Mev

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The measurements on the polarization of the recoil protons from the process $\gamma+p\rightarrow\pi^0+p$ have been extended to higher γ-ray energies, at 90° in the center-of-mass system. We have found at 910 Mev a polarization, $P=-0.45\pm0.07$; at 800 Mev, $P=-0.42\pm0.10$. The rather high values of P agree with the hypothesis that the neutral photoproduction in the 500-1000 Mev range can be described by the well-known three resonant states, and strongly indicate that the second and third resonance have opposite parity. The probable quantum numbers are: $T=\frac{1}{2}$, $J=\frac{3}{2}$, D pion wave for the second resonance; $T=\frac{1}{2}$, $J=\frac{5}{2}$, F wave for the third resonance.

EXTENDING our earlier measurements[1] on the polarization of the recoil proton from the process $\gamma+p\rightarrow\pi^0+p$, we have measured the polarization at the γ-ray energy of 800 and 910 Mev, at 90° in the c.m. system (c.m.s.).

Figure 1 gives the general disposition of the experiment. The experimental technique is the same as described in our first paper.[1]

Basically we measure the left-to-right asymmetry in the scattering of the protons from the carbon scatterer C.

The counters 1, 2, 3, ⋯, 10 are plastic scintillation counters which detect the proton; the Čerenkov counter detects the γ rays from the π^0 meson decay. C indicates the carbon scatterer, and Cu the copper absorbers which define the range of the proton energy.

We counted at the same time four kinds of coincidences:

L=left: (Čer, 1, 2, 3, 4, −5);
(Čer, 1, 2, 3, 4, 5, −6)

R=right: (Čer, 1, 2, 7, 8, −9);
(Čer, 1, 2, 7, 8, 9, −10).

In this way we measured two different energy channels: the first sees protons of 214–258 Mev, corresponding to a center γ-ray energy of 800 Mev; the second sees protons of 258–302 Mev, corresponding to a center γ-ray energy of 910 Mev.

The protons were selected by discriminating against the pions by requiring coincidence of the Čerenkov counter as well as pulse-height discrimination in the counters 2, 3, and 7.

The corrections of the raw data for the empty-target contribution, for the accidentals and for the inelastic collisions of the protons in carbon,[2] have been made along the same lines as have been described in reference 1.

The correction of the asymmetry $\epsilon=(L-R)/(L+R)$ due to the inelastic collisions in C has been evaluated to be of about 12% at 910 Mev and 24% at 800 Mev.

A measurement at 910 Mev is more difficult than at 700–800 Mev, because of the lower cross section of photoproduction (a factor of ~1.6). Furthermore, the analyzing power of C becomes lower (by a factor of ~1.3), and the effect of the nuclear interactions in the absorbers is increased (by a factor of ~1.3).

The computation of the polarization from the corrected experimental asymmetry has been made by the application of the "Monte Carlo" method and the use of the FINAC electronic computer; the data used in this calculation have been the elastic scattering cross section of polarized protons by carbon, as published by Hafner[3] and Chamberlain.[4]

We have found at 910 Mev a polarization of the protons, $P=-(0.45\pm0.07)$; at 800 Mev a ploarization, $P=-(0.42\pm0.10)$.

The value at 800 Mev (which is affected by a larger correction than the measurement at 910 Mev) is in good agreement with our previous measurement at 800 Mev (see Fig. 2).[1,5–7]

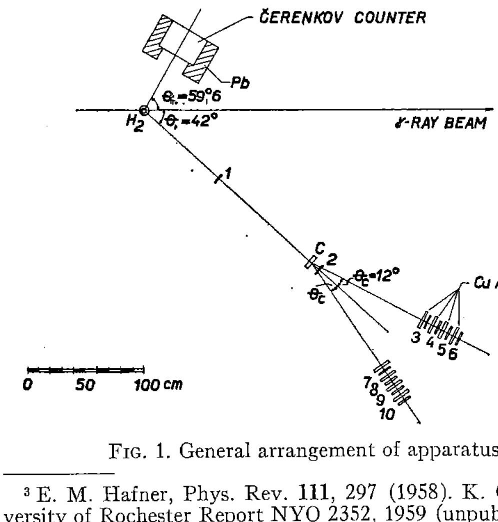

FIG. 1. General arrangement of apparatus.

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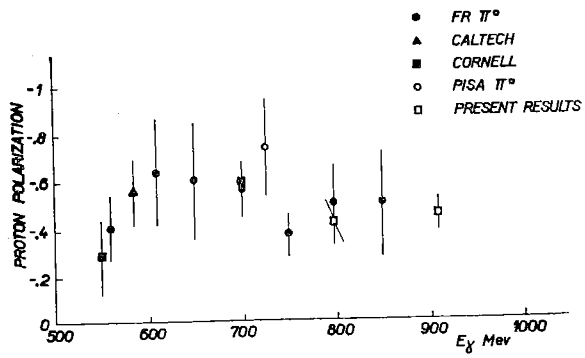

FIG. 2. The polarization of the recoil proton at 90° c.m. versus the gamma-ray energy. FR π^0 is reference 1, Caltech reference 5, Cornell reference 6, and Pisa π^0 reference 7.

A summary of the results of all the measurements of the polarization of the recoil proton at 90° c.m.s. versus the γ-ray energy is given in Fig. 2.

We may conclude, following our previous analysis,[1] that such a high value of the polarization up to 910 Mev agrees with the hypothesis that the neutral photoproduction in the 500–1000 Mev energy range can be described by three resonant states A, B, and C (the so called first, second, and third resonances) which have the quantum numbers listed in Table I.

Our new values of the polarization indicate the presence of at least two states of opposite parity at 910 Mev, in agreement with the assignment of the states B and C. More precisely, our experimental values agree with the polarization estimated by us on the assumption that only the states B and C are present, and that a single-level formula describes their amplitudes, with a width of $\sim$60 Mev for the second resonance. It is worth remembering that some preliminary measurements reported by Peierls[8] seemed to indicate only a small polarization at 900 Mev, causing some difficulty in the assignment of B and C.

The new results emphasize therefore our previous conclusions, which were reached on the basis of measurements at lower energies.

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TABLE I. The quantum numbers of the states A, B, and C under the hypothesis that the neutral photoproduction may be mainly explained by them (ABC model): j=multipole order; l_π=pion orbital momentum; J=total angular momentum; ω=parity; and T=isotopic spin.

Level	j	l_π	J	ω	T
A	1	P	$\frac{3}{2}$	+	$\frac{3}{2}$
B	1	D	$\frac{3}{2}$	−	$\frac{1}{2}$
C	2	F	$\frac{5}{2}$	+	$\frac{1}{2}$

The high value of the polarization at 910 Mev is in agreement with the asymmetry found around 90° c.m.s. in the angular distribution of the π^0's at 950 Mev.[9–12] At these energies, in fact, this asymmetry around 90° c.m. indicates that the two states must have opposite parity.

Furthermore, the recent measurements of the $\pi-p$ scattering[13] are in agreement with the conclusion that the second and third resonances are mainly due to $D_{\frac{3}{2}}$ and $F_{\frac{5}{2}}$ final states, respectively.

Notwithstanding these semiquantitative agreements, we must, however, emphasize that the ABC model is almost surely too simple; as a matter of fact the success in explaining the experimental data is likely due to their poor resolution and statistics.

The only certain fact at present, in agreement also with the discussion of other authors,[5] is that Table I is correct if three, and only three, resonant states are present.

These considerations emphasize the importance of further measurements of higher precision, so that a much more severe test of the present hypothesis may become possible.

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