SOME REMARKS ON LOW ENERGY PION PHENOMENA

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It would appear that in the last two years the anomalies that once existed in the relationship between pion photoproduction and scattering via the Panofsky ratio have gradually dissolved to the point that there exists a reasonable agreement within the field. The purpose of the present note is to show that when the experimental data are re-analysed according to better theoretical prescriptions there emerge certain small but not insignificant discrepancies in the data.

Following the suggestion of Baldin [1] we have analysed the reactions

$$\gamma + p \longrightarrow n + \pi^+, \tag{1}$$

$$\gamma + n \longrightarrow p + \pi^-, \tag{2}$$

in such a way that there should be good agreement with the predictions of the Chew-Goldberger-Low-Nambu and Robinson (C. G. L. N. R.) theory [2]. The basis of the method is that the comparison is made in a region of the kinematic variables such that the momentum transfer is fixed and equal to that occurring at the threshold of the reactions (1) and (2). In this way it is possible to eliminate the contribution under the dispersion integrals of the unobservable energy region. It has been shown that this is an important qualification [3] as the $\pi - \pi$ interaction can produce appreciable contributions to the amplitudes.

1 - PHOTOPRODUCTION DATA -

The cross-section for the process (1) can be written in the form

$$\frac{d\sigma}{d\Omega} = \eta\,\omega \left[1 + \frac{\mu}{M}\nu\right]^{-2} |T^+|^2,$$

in the notation employed by Bernardini [4] ; we require that the momentum transfer at any photon energy ν should be equal to that at threshold, i.e. we require [5].

$$\nu\,(\omega - \cos\vartheta) = 0.93.$$

We have analysed the available experimental data and extracted $|T^+|^2$ at the appropriate value of ϑ at each given ν [6], the result of this is shown in figure 1. It should be noted that the data of Beneventano et al. have been increased in absolute magnitude by 10 % to take account of a recent recalibration at Illinois [13]. Plotted also is the prediction of the C. G. L. N. R. theory with values of f^2 and ω_0^* as shown. A good agreement both in absolute magnitude and energy dependence is obtained from threshold up to the $\left(\frac{3}{2}\,\frac{3}{2}\right)$ resonance at 300 MeV. A suggestion of a bump in the experimental data occurs at around 215 MeV where there is a $\sim (30 \pm 10)\%$ absolute discrepancy with the theory. It is difficult to conclude whether this is due to a systematic experimental error (the experimental evidence relies entirely on one experiment) or to a true "resonance" occurring in the production amplitude. It is clear that new experimental data are highly desirable to verify or otherwise the existence of this phenomenon.

It may be relevant to note at this stage that recent Russian work [11] on the angular distribution of this reaction at 185 MeV is in disagreement with the experimental data of Beneventano et al. by about $(35 \pm 10)\%$ at backward angles. It must therefore be concluded, that the possibility of an experimental error of this magnitude cannot be completely ruled out.

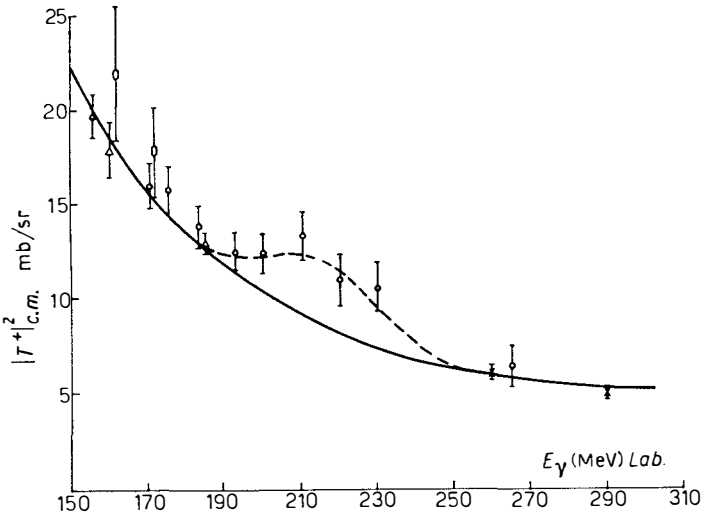

Figure 1 - Beneventano et al. [7] ; Leiss et al. [8] ; Knapp et al. [9] ; Walker et al. [10] ; Adamovich et al. [11] ; Barbara et al. [12] : -
——— C. G. L. N. R. with $f^2 = 0.081$ and $\omega_0 = 2.08$,
– – – – – – Best fit (Eye).

Fig. 1 The extrapolation of the experimental data to threshold would appear to be unambiguous and gives a value for $|T^+|^2$ of 22.0 μb/sr with an estimated accuracy of ±5 %.

2 - π^-/π^+ RATIO -

The photoproduction of charged pions from deuterium has been studied extensively by several investigators. We have used the experimental results of Beneventano et al. [7], Hogg and Bellamy [14], Sands et al. [15] and Rutherglen and Walker [16] which appear to constitute a reasonably self consistent set of data. Best fits by eye, as the proper analytic variation is unknown, were made to this data in the entire angular region and the values of ratio were extracted at the required values of ϑ. The variation of the π^-/π^+ ratio as a function of γ-ray energy is shown plotted in figure 2. The uncertainties shown are reasonable limits allowed by the fits to the experimental data. Also shown in figure 2 is the C. G. L. N. R. prediction evaluated under the same conditions as before. The corrections for final state interactions, both nuclear and Coulomb, have been calculated by Baldin [17] and their

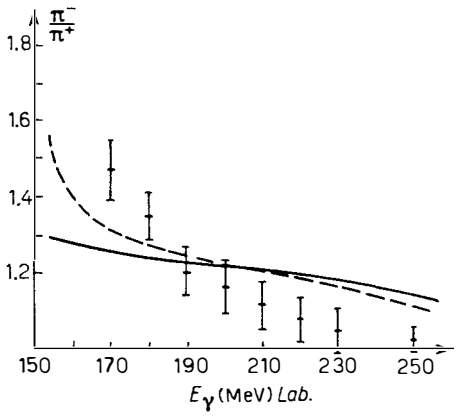

Figure 2 -
——— C. G. L. N. R. theory ;
– – – – – Corrected for final state effects.

effect on the C.G.L.N.R. theory is shown by the dashed line. The agreement is seen to be approximate and nowhere within the range investigated does the discrepancy exceed 13 %. The predicted energy variation of the ratio does seem to be in discord with that found experimentally. As the basic theory should be good to about 5 % and the final state interactions' correction takes account of effects which produce a $\geqslant 10$ % correction then it is just possible, although rather unlikely, that the experimental data can be properly described within the framework of the present theory.

It has been shown [3] that the π-π interaction gives an important contribution to the π^-/π^+ ratio. Therefore, it would seem desirable to adjust the parameters in the π-π contribution so that a good fit to the experimental data is obtained in this region of kinematic variables where the evaluation of the C.G.L.N.R. theory is thought to be reasonable, and not at a fixed angle in the c.m. system which is the procedure which has previously been followed.

It is clear from figure 2 that it is difficult to extrapolate the experimental data to threshold in a rigorous way. However, it would appear that a value 15 % to 20 % higher than that of 1.30 predicted by the C.G.L.N.R. theory, is not unreasonable.

3 - PANOFSKY RATIO AND S-WAVE SCATTERING LENGTHS -

Within the last year or two the Panofsky ratio has been remeasured with great accuracy by several groups and reported at the 1960 Rochester Conference. The mean value of all the data is

$$P = (1.53 \pm 1)\,\%.$$

Finally, the S-wave scattering lengths appear to have been treated in the most complete fashion by Hamilton and Woolcock [19] who obtain :

$$a_1 - a_3 = 0.259 \pm 0.006$$

4 - CONCLUSION -

When we use the above values of P, $a_3 - a_1$, and $|T^+|^2$ to calculate the π^-/π^+ ratio we obtain the value 1.34 ± 0.11. This value has to be compared with the threshold value of the π^-/π^+ ratio which we have already discussed. It is clearly in adequate agreement with the C.G.L.N.R. predictions. However, there is room for improvement in the agreement of this threshold value with that obtained from the rest of the experimental data.

In conclusion, we may say that although the description of low energy pion phenomena has reached a relatively satisfactory state, with reasonable internal consistency being displayed, there still exist certain discrepancies which remain to be clarified.

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[5] At the Rochester Conference 1960, BALDIN reported a similar comparison with experimental data but it appears that he used π^0-meson kinematics in the case of π^+-meson photoproduction. Secondly, his comparison did not include the interesting energy region where there appears to be a "resonance".

[6] Where experimental data are reported at values of the kinematic variables other than those required here we have only accepted these data when the difference in differential cross-section between the two conditions is less than 1 % under the assumption of a reasonable angular distribution.

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