# EXPERIMENTAL RESULTS ON $\Pi^+ + P$ SCATTERING IN THE ENERGY RANGE BETWEEN 70 AND 130 MEV

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**(presented by G. Quareni)**

The scattering of $\pi^+$ on protons in the energy range from 70 to 130 Mev has been studied using nuclear emulsion.

A stack of 20 G5 stripped emulsions, 600 $\mu$ thick, $7 \times 11$ cm² was exposed to a $(132 \pm 5)$ Mev $\pi^+$ beam of the Chicago synchrocyclotron. The beam was directed parallel to the emulsion surface and traversed the stack for a length of 11 cm., with a flux of $\sim$ 50,000 particles/cm².

The pion energy varied continuously in the emulsion. Area scanning was made over a length of 9 cm., corresponding to the energy interval from 70 to 130 Mev. Kinematical criteria were used to select the $\pi^+ + P$ events. The pion energy was deduced from measurement of the recoil-proton range. Details of the experimental technique have been reported in a previous paper [1].

So far, 1217 events have been found. In addition, 546 $\pi^+ + P$ scatterings have been found in the angular region $135° < \vartheta_{c.m.} < 180°$ and for the energy range from 90 to 130 Mev, using the scanning method described below. In back-scattering, the recoil-proton is projected forward, at a small angle, with respect to the direction of the incident pion. For the scanning, a cross section of the emulsion perpendicular to the beam direction is observed and all grey tracks crossing it and forming an angle with

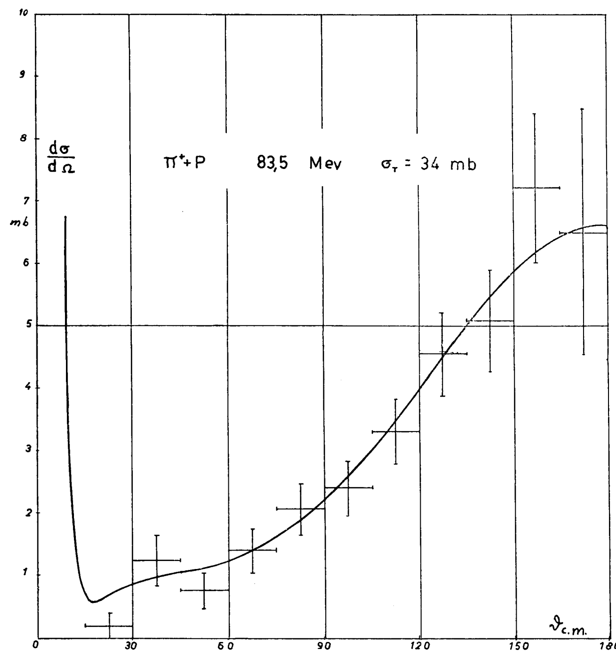


**Fig. 1.** Angular dependence in the centre of mass frame of $(\pi^+ + P)$ scattering cross-section at 83 Mev.

| Energy interval (Mev) | Number of events | $\bar{E}$ | $\sigma_T$ | $\alpha_3$ | $\alpha_{31}$ | $\alpha_{33}$ |
|---|---|---|---|---|---|---|
| 70-90 | 270 | 83,5 | 34 | $-10.8 \pm 2.5$ | $-2.8 \pm 1.3$ | $13.1 \pm 1.9$ |
| 90-110 | 621 | 100 | 58 | $-9.5 \pm 1.9$ | $-2.7 \pm 0.9$ | $22.0 \pm 1.6$ |
| 110-120 | 369 | 114 | 83 | $-10.1 \pm 3.5$ | $-2.4 \pm 2.5$ | $29.3 \pm 1.5$ |
| 120-130 | 502 | 124 | 106 | $-14.4 \pm 4.8$ | $-2.8 \pm 2.9$ | $34.4 \pm 1.8$ |

* G. Dascola, S. Mora and G. Todesco of the University of Parma have contributed to the determinations in the energy range of 90 - 110 Mev.
M. Della Corte and T. Fazzini of the University of Florence have contributed for the energy range 70 - 90 Mev.

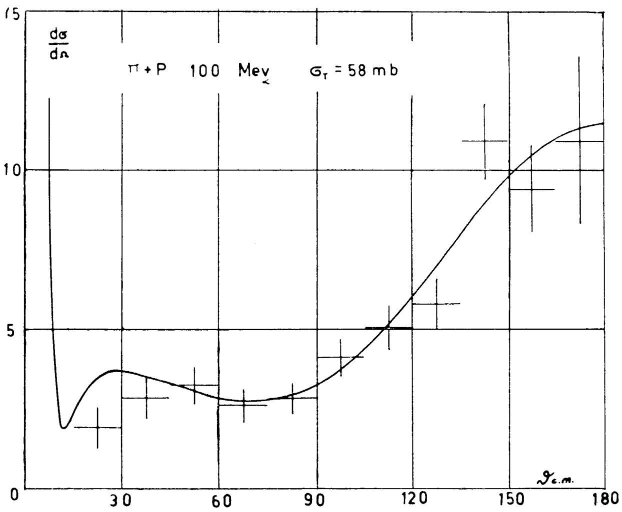


**Fig. 2.** Angular dependence in the centre of mass frame of ($\pi^+ + P$) scattering cross-section at 100 Mev.

the beam direction smaller than 30° are noted. Every track is followed in the opposite direction to the pion motion, until the track either leaves the emulsion or appears to emerge from an interaction. In this manner, many $\pi^+ + P$ events can be easily identified. The scanning rate is 3 events ($\vartheta_{c.m.} > 135°$) per scanner per day, while the rate of area scanning is 1 with no restriction on the angle, and 0,3 for $\vartheta_{c.m.} > 135°$.

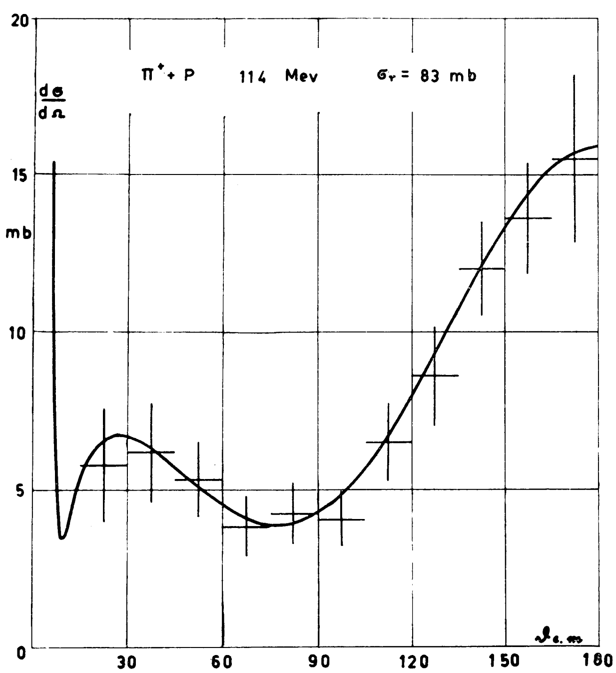


**Fig. 3.** Angular dependence in the centre of mass frame of ($\pi^+ + P$) scattering cross-section at 114 Mev.

Corrections must be applied to the observed frequencies, since the efficiency of the scanning depends, for geometrical reasons, on the scattering angle $\vartheta$. The energy and angular dependences of the corrected frequencies are in good agreement with the area scanning results.

All events were subdivided into four energy groups, as listed in the preceding Table.

In column 2 the numbers of the events are listed and in column 3 the average energies in each group as experimentally determined. Column 4 gives the total cross-sections as derived from the best fit of all the available counter and emulsion data. The cross-sections estimated on the basis of the number of events found in the present work is in satisfactory agreement with the values listed in the Table.

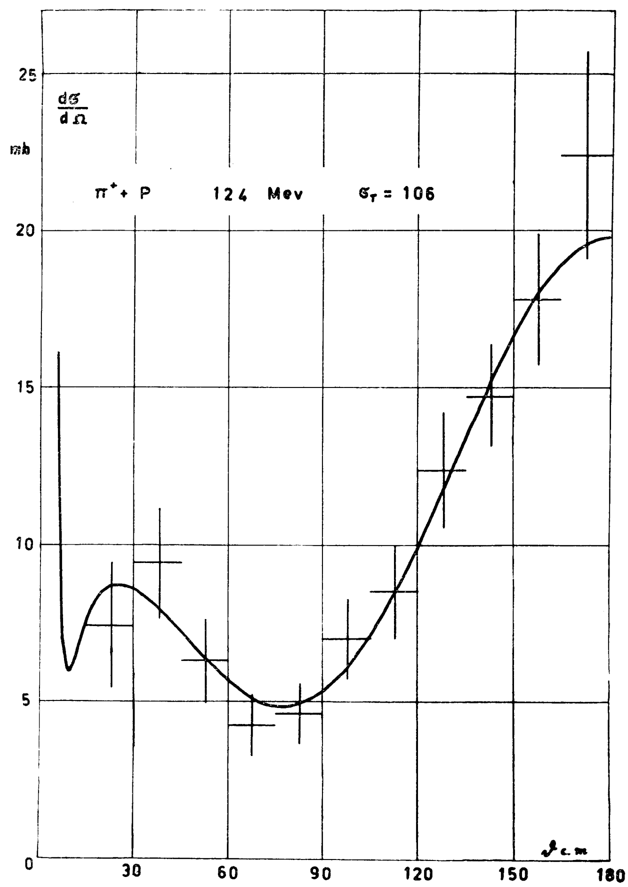


**Fig. 4.** Angular dependence in the centre of mass frame of ($\pi^+ + P$) scattering cross-section at 124 Mev.

The main source of uncertainty in our estimates arises from the inaccurate knowledge of the $H_2$ – content in the emulsion.

The angular dependence of the differential cross-section was determined at each energy. The results are plotted in figs. 1, 2, 3 and 4. The errors given are the standard ones.

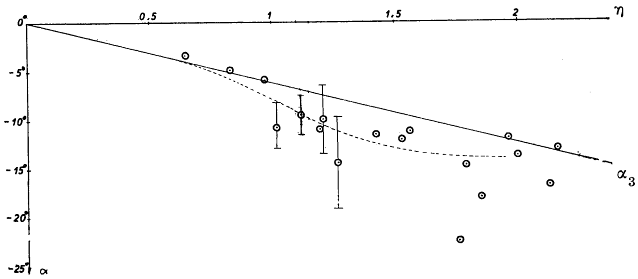


**Fig. 5.** Variation of $\alpha_3$ with pion momentum.

The experimental data were analysed in terms of partial waves, assuming that only S and P waves play a role. The effect of the Coulomb scattering was taken into account.

In columns 5, 6 and 7 are listed the phase shifts $\alpha_3$, $\alpha_{31}$, and $\alpha_{33}$, corresponding to the Fermi solution with destructive Coulomb interference.

The solid lines in the figures represent the least square fits of the experimental points with the assumptions specified above.

The results obtained lead to the following conclusions :

(*a*) All the phase shifts determined are in good agreement with the values obtained with different techniques.

(*b*) S and P waves with Coulomb interference describe very well the experimental results in the whole angular interval. Hence there is no need for introduction of waves of higher angular momentum.

(*c*) There is definite evidence that the Coulomb interference is destructive.

(*d*) The determination of $\alpha_3$ is still inadequate for definite conclusions about the energy dependence of this phase shift. However, a linear dependence does not seem to be compatible with the available data. Taking into account the results obtained from the mesic atoms, the photoproduction, the scattering of positive and negative pions, and basing the analysis on the charge independence, at low momenta, $\alpha_3$ may be represented by $\alpha_3 = 6{,}3^\circ \cdot \eta$. Our results seem to be in disagreement with the extrapolation of the behaviour in our energy region (Solid line in fig. 5). If we consider the higher energies also, there is an indication that the momentum dependence could be described by a slightly more complicated behaviour as shown by the dotted curve drawn in fig. 5.

(*e*) The phase shift $\alpha_{31}$ is small and negative in the whole energy range explored. The present data, added to the information previously available, give a fair description of the energy dependence of this phase shift (fig. 6).

(*f*) If the experimental values for $\alpha_{31}$ are inserted in Low's equation [2], one obtains for the $\pi$ nucleon coupling constant the value $f^2 = 0.11 \pm 0.02$. It is important to note that this agrees within the limits of error with the result $f^2 = 0.107 \pm 0.01$ obtained by a similar method from the experimental values of $\alpha_{33}$ [3]. The theoretical behaviour for these phase shifts is shown by the solid lines in fig. 6.

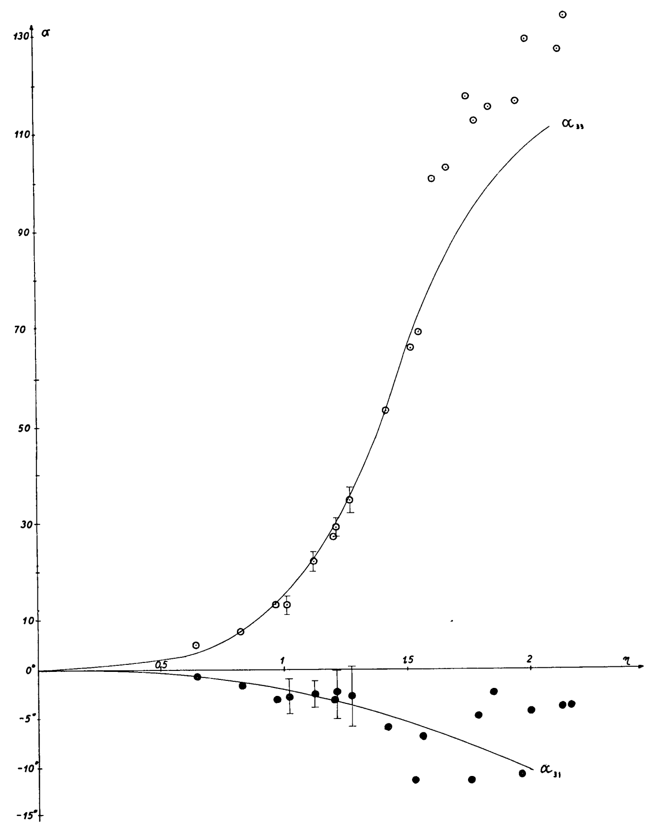


**Fig. 6.** Variation of $\alpha_{33}$ and $\alpha_{31}$ with pion momentum.

## LIST OF REFERENCES

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2. Low, F. E. Pion nucleon scattering and photo meson production. *In* Rochester Conference on high energy nuclear physics. 5th. Proceedings, p. 57-62, 1955.
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