INELASTIC PROTON-PROTON SCATTERING AT 925 MEV

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This work was carried out as part of a programme undertaken by emulsion groups at the Universities of Belfast, Birmingham and Glasgow. The tracks of protons, with an energy of 925 ± 25 Mev, from the Birmingham synchrotron were followed in nuclear emulsions in order to search for elastic and inelastic scatterings from free protons, and for quasi-elastic scatterings from bound protons in emulsion nuclei. All events having two or four prongs were recorded.

The energetically possible reactions which could be distinguished are:

$$\begin{aligned} p + p \rightarrow\ & p + p \\ & d + \pi^+ \\ & p + n + \pi^+ \\ & p + p + \pi^0 \\ & p + p + \pi^+ + \pi^- \end{aligned}$$

It is possible to distinguish the first two processes by measurements of angles alone. For the other processes measurements of the energies of the particles are also required. The energies were determined by grain counting and, in favourable cases, by measurement of multiple scattering. The last three processes were distinguished by applying the principles of the conservation of energy and momentum.

Results

(*a*) *Cross-sections*

The cross-sections measured for the different reactions were as follows:

$p + p \rightarrow$	$p + p$	17 ± 3 mb.
	$d + \pi^+$	0.6 ± 0.4 mb.
	$p + n + \pi^+$	27 ± 3 mb.
	$p + p + \pi^0$	6 ± 2 mb.
	$p + p + \pi^+ + \pi^-$	< 0.2 mb.

The errors quoted are statistical standard deviations and take no account of systematic errors arising from incorrect identification of events or from scanning loss.

(*b*) *Differential distributions*

Poor statistics, arising from the small cross-sections, prevented an examination of the processes involving the production of deuterons or π^0 mesons. We therefore examined only the process $p + p \rightarrow p + n + \pi^+$ (92 events). In the figures shown below the histograms with broken lines represent events in which both measurements of grain density and multiple scattering were made on the tracks of π^+ mesons.

In this reaction all the distributions should be symmetric about 90° in the centre of momentum (c-) system, and were found to be so within the limits of statistical error. The distributions were therefore folded about this angle.

All angular distributions appeared to be isotropic in the c-system within the limits of statistical accuracy (fig. 1). A strong correlation was found, however, in the angles between π^+ meson and proton. This is shown in fig. 2.

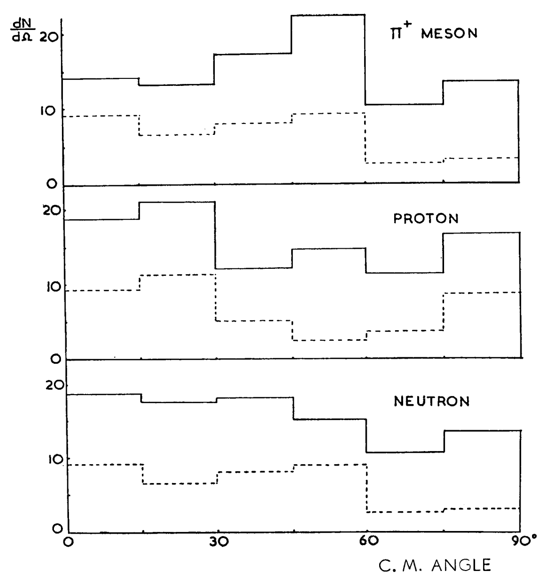

Fig. 1. Angular distributions in the c.m.s. for π^+ mesons, protons and neutrons from the reaction $p+p \rightarrow p+n+\pi^+$.

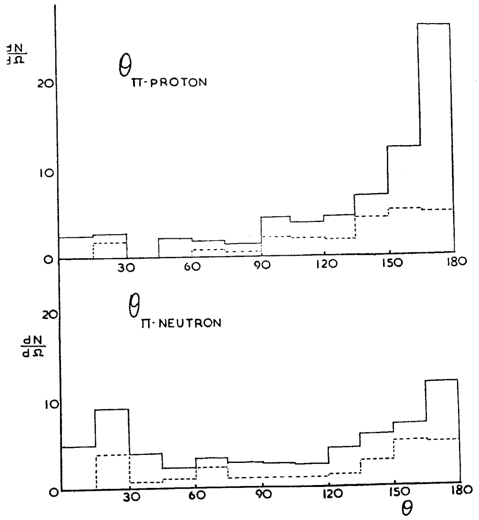

Fig. 2. Angular correlation between mesons and protons and between mesons and neutrons.

The measured momentum distribution are displayed in figs. 3 and 4. They are compared with those expected if the only consideration was the availability of momentum space. It can be seen that there are apparent deviations, especially in the case of the π^+ meson.

Interpretation

When the energy of the primary proton is 925 Mev, the energy available in the c-system is well above the threshold for the formation of a nucleon isobar with $T = {}^3/_2$, suggested by Peaslee.

In the table given below the measured cross-sections are compared with the predictions of the Fermi statistical theory and with a modification which assumes that all production procedes through the excited $T = {}^3/_2$ state.

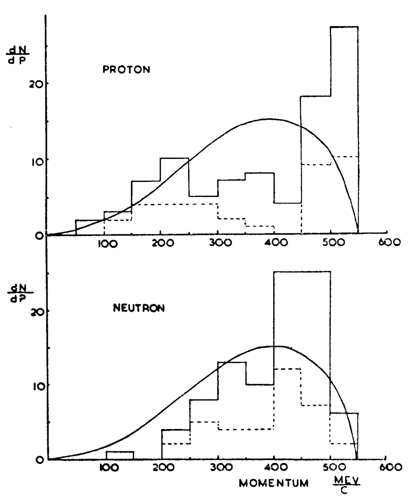

Fig. 3. Momentum distributions in the lab. system, compared with statistical theory, for protons and neutrons.

Product	Measured	Fermi theory	Modified theory
$p + p$	17 ± 3 mb	38 mb	16 mb
$p + n + \pi^+$	27 ± 3	7	26.7
$p + p + \pi^0$	6 ± 2	3	5.3
$p + p + \pi^+ + \pi^-$	< 0.2	0	0

It should be borne in mind, however, that to obtain the the figures in the last two columns drastic assumptions must be made. Furthermore the Fermi theory assumes that all the elastic scattering is of the compound—elastic type. The measured angular distributions suggest, however, that most of the elastic scattering at energies of $\sim$ 1 Gev is diffraction scattering.

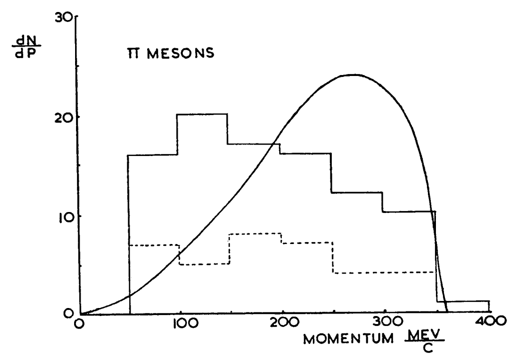

Fig. 4. As fig. 3, but for π mesons.

Our measured ratio for the yield of π^+ to π^0 mesons is 4.2 ± 1.0. The statistical theory of Fermi predicts ratios of 1, 3 and ∞, whilst the ratio is 5, if the assumption is made that meson production takes place only through the $T = {}^3/_2$ state.

The strong tendency for the π^+ meson and proton to emerge in opposite directions, shown in the angular correlation diagrams, and the peak at a high value in the neutron

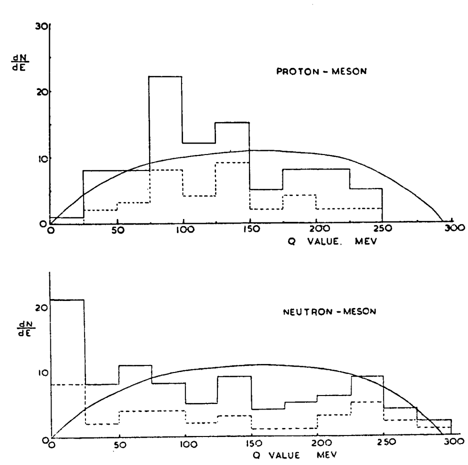

Fig. 5. Plots of Q-values between proton and meson and between neutron and meson.

momentum distribution supports the concept of a $T = {}^3/_2$ state. Nevertheless, if this state is formed it can be seen that other factors than those occuring in π proton scattering must influence it by considering Q-values for the π proton system. Assuming that the π^+ meson and proton result from the disintegration of an excited state it is possible to calculate the Q-value for the break-up. The Q-values for the events attributed to the production of π^+ mesons are shown in fig. 5. It can be seen that this distribution peaks at $\sim$ 100 Mev instead of at $\sim$ 160 Mev expected from π - p scattering.

Thus, whilst the experiment offers some support to the hypothesis that meson production takes place through a $T = {}^3/_2$ state, the theoretical predictions are not sufficiently unique for an experiment of this nature to provide strong confirmation of the existence of this state.