PERIPHERAL EFFECTS OF 16 GeV/c NEGATIVE PIONS AND THE π–π CROSS SECTION

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(presented by D. R. O. Morrison)

INTRODUCTION

After Cocconi *et al.* [1] had discovered, with counters, the production of almost elastic, or quasi-elastic protons in high energy proton-proton interactions, we studied the corresponding events in a hydrogen bubble chamber [2]. A mechanism for this process, suggested independently by Amati and Prentki, and by Drell and Hiida [3], was that the incident proton was diffraction scattered by a virtual pion of the target proton. It then seemed interesting to study the same process with incoming pions as this could then be interpreted as the diffraction scattering of pions on virtual pions and so would give information on the pion-pion cross section. The same suggestion was made by Drell and Hiida [3]. This process is similar to the diffraction disintegration of Good and Walker [4].

Measurements were made on two prong events produced by 16 GeV/c negative pions in the CERN 32 cm hydrogen bubble chamber. The two prong events were chosen as the quasi-elastic events were expected to come from the reactions

$$\pi^- + p \;\rightarrow\; \pi^- + p + \pi^0 \qquad (1)$$

$$\rightarrow\; \pi^- + \pi^+ + n \qquad (2)$$

Using kinematical and ionisation (mean gap length) criteria, the elastic events were identified and separated. In this paper only the inelastic events are discussed.

RESULTS AND DISCUSSION

With the two-prong events measured there was no way of proving that there was definitely only one missing neutral particle. However the C.M. angular

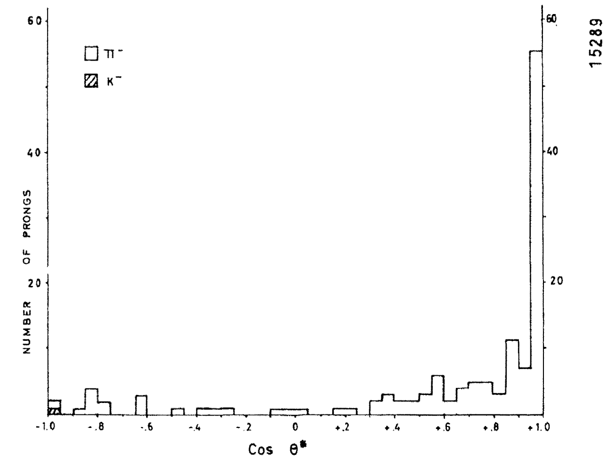

Fig. 1 C.M. angular distribution of two prong inelastic events in 16 GeV/c π^--p interactions. Negative prongs.

distribution of the negative tracks shown in Fig. 1 does indicate that the two-prong events do correspond to an unusual type.

The next problem was to plot the results so that the basic reaction mechanism may be more clearly understood. Here we plot for each prong, a point on a diagram where the x-axis is the C.M. longitudinal momentum, p_L^* and the y-axis is the transverse momentum p_T. The kinematical limit of this plot is a semi-circle on which prongs from elastic events would lie. The two end points of the plot with $p_T = 0$, $p_L^* = \pm 2.7$ GeV/c corresponds to the initial condition of the incident and target particle. Such a diagram is shown in Fig. 2 for the positive prongs. It may be noted that the transverse momentum is always small and a projection on the y-axis would show the distribution. In Fig. 3 the projection on the x-axis is shown. Instead of saying that the protons are emitted backwards in the C.M. system, we can say that they

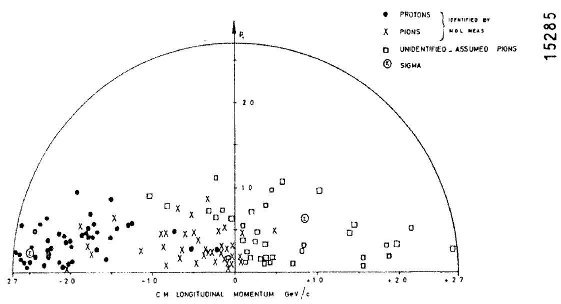

Fig. 2 C.M. longitudinal momentum distribution of inelastic two prong events in 16 GeV/c π^{-}-p interactions. Positive prongs.

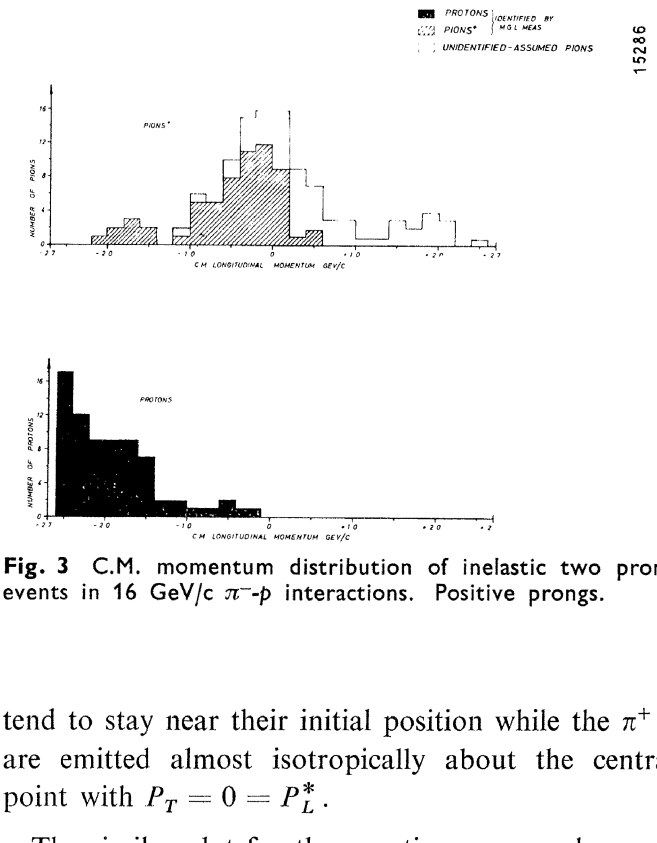

Fig. 3 C.M. momentum distribution of inelastic two prong events in 16 GeV/c π^{-}-p interactions. Positive prongs.

tend to stay near their initial position while the π^{+}'s are emitted almost isotropically about the central point with $P_T = 0 = P_L^*$.

The similar plot for the negative prongs, shown in Fig. 4, is interesting as it demonstrates that there are a large number of π^- particles which retain most of their initial momentum. In addition there is a group of π^- particles which are emitted near the central point, but this group is shifted in the forward C.M. direction. If we assume this group is the counterpart of the π^+ group, then the π^-'s may be divided into two groups, an approximately central one and a forward group which overlap near p_L^* values of 1.3 or 1.4 GeV/c.

To find out which positive particles correspond to this forward group of π^-'s, in Fig. 5 is plotted a scatter diagram of the p_L^* for the negative prong against the

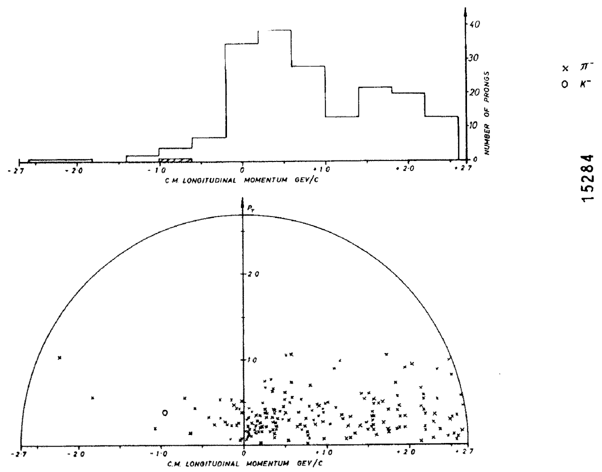

Fig. 4 C.M. momentum distributions of inelastic two prong events in 16 GeV/c π^{-}-p interactions. Negative prongs.

P_L^* for the positive (since, as can be seen from Fig. 2 and 4, the transverse momentum is relatively unimportant). The main point about Fig. 5 is that it is markedly unsymmetric. In particular there is a group of events where the negative pions continue in their initial direction while the positive prong goes backwards in the C.M. system. In this group of events it would appear as if the π^- had suffered a diffraction scattering since the π^- maintain both their charge and most of their initial momentum.

This is an experimental result. The problem is that there are now two interpretations: The first is that given in the Introduction where we consider the events are due to diffraction scattering of the incident pion

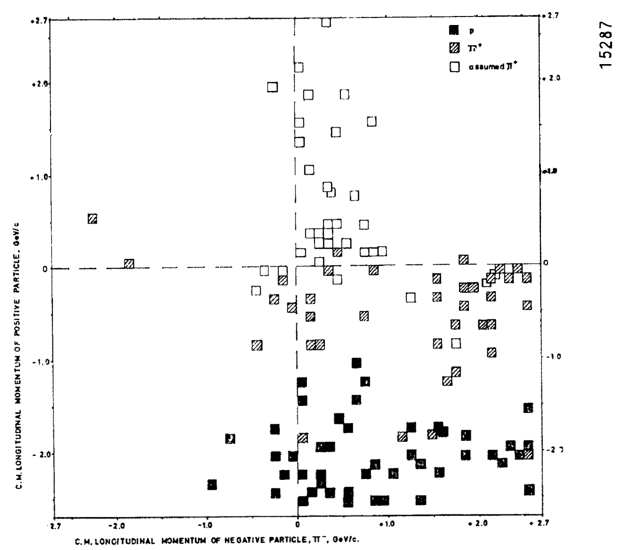

Fig. 5 Longitudinal momentum of negative particle versus longitudinal momentum of positive particle in C.M. system for inelastic two prong interactions of 16 GeV/c π^{-}-p.

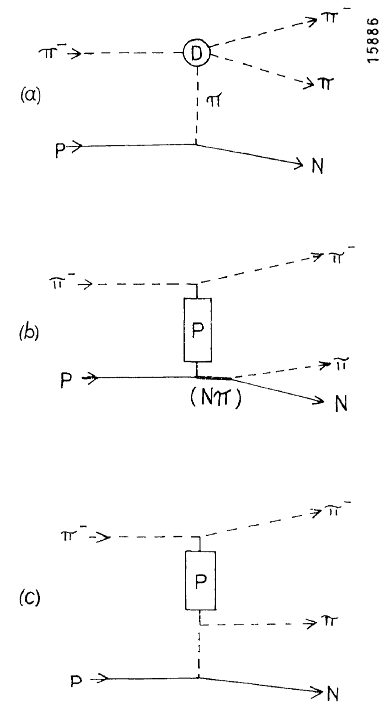

Fig. 6

on a virtual pion so that this is based on a one pion exchange model. The second is derived from the Regge pole approach and we may consider that a Pomeranchuk pole whose quantum numbers are all zero, is exchanged.

If we assume the first interpretation, for which the Feynman graph is given in Fig. 6a, then the virtual pion exchanged can be a π^0 or π^+ meson so that the positive prong is a proton or π^+ respectively. As the coupling constant at the bottom vertex is $(2)^{\frac{1}{2}}$ greater for an exchanged π^+ meson, we would expect twice as many π^+ as protons produced and as can be seen from Fig. 5 the experimental ratio of about 27/16 is consistant with this. From the total cross section of 2mb for these events Drell and Hiida [3] deduced the elastic $\pi - \pi$ cross section at the top vertex in Fig. 6a (using the known cross section at the bottom vertex and assuming that the shape of the $\pi - \pi$ diffraction peak is similar to that for πN and pp scattering). Then assuming that the scattering amplitude is purely imaginary so that the optical theorem may be used with the equality sign, they derived a total $\pi - \pi$ cross section of 16 mb. This may be compared with the value predicted by Gell-Mann [5] and by Gribov and Pomeranchuk [6] from the relation

$$\sigma_{\pi\pi} = (\sigma_{\pi N})^2/\sigma_{NN} = (26)^2/40 = 17 \text{ mb}. \qquad (3)$$

The Regge pole interpretation may be presented by the Feynman graph of Fig. 6b, where a Pomeranchuk pole is exchanged and where a $(N\pi)$ system is created. Since the Pomeranchuk pole has $T = 0$, the $(N\pi)$ state must have isotopic spin of 1/2 (on the one pion exchange model if there is a final state interaction to give $(N\pi)$, it also must have $T = 1/2$). It is possible to use the idea of diffraction scattering on a virtual pion while using the Regge pole approach if we greatly extend the concept of the " ladder " graphs of Amati *et al.* [7] and consider the Feynman graph shown in Fig. 6c which can be considered equivalent to Fig. 6a if we imagine the mechanism of exchange of the Pomeranchuk pole to be buried in the top vertex labelled " D ". If there is a strong final state interaction between the created pion (not the π^-) and the nucleon, then Fig. 6c has no meaning. The question is then, if the final state interactions are not too large, are the correlations between the particles small? If they are, Fig. 6a or 6c are relevant and the calculation by Drell and Hiida of the $\pi - \pi$ total cross section has some meaning.

It is of interest to ask how near is the recoil proton to the elastic limit and to compare this with the corresponding proton-proton single pion production [2]. For the sake of comparison with counter work we consider the " mirror " system [8] in which the π^- is at rest and the proton is the incoming particle. This proton would then have the same velocity as a 16 GeV/c pion and hence would have a total lab. energy of

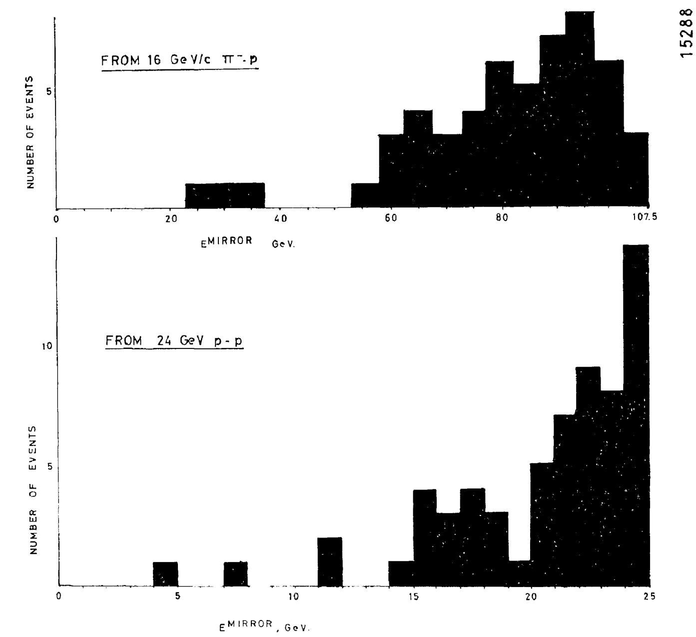

Fig. 7 Calculated mirror energy for " recoil " proton.

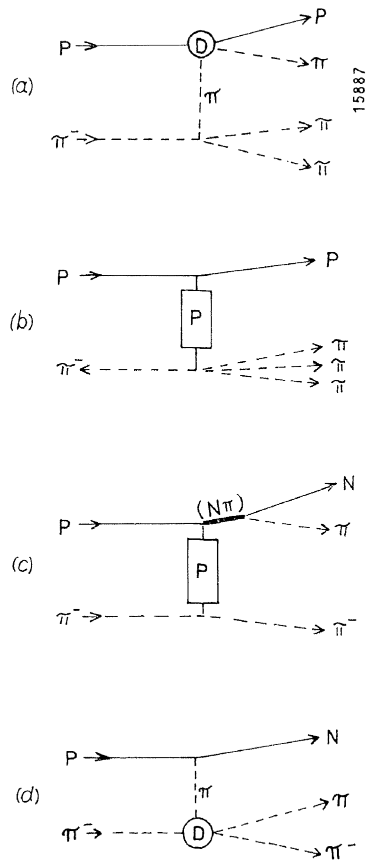

Fig. 8

107.5 GeV. The energy distribution of the " mirror " protons for $\pi-p$ and $p-p$ events is shown in Fig. 7. As the experimental resolution is about one-fifth of the intervals used, the difference in position of the peaks in the two graphs is significant, that is, in $\pi-p$ events the proton is further from the elastic limit than in $p-p$ events. This may be explained by considering the Feynman graphs of Fig. 8 where from the necessity of having an even number of pions at a pion vertex it follows that in Fig. 8a and 8b double and not single, pion production must occur; also in Fig. 8c and 8d since the nucleon N and pion are both emitted forward in the C.M.S., hence the nucleon is in general far from the elastic limit of 107.5 GeV.

CONCLUSIONS

It is shown that in high energy $\pi^{-}-p$ interactions there exists a class of events where the incident pion appears to be diffraction scattered. These may be interpreted as diffraction scattering on a virtual pion or in terms of the exchange of a Pomeranchuk pole. With the former explanation a total $\pi-\pi$ cross section of 16 mb can be deduced. A comparison is made between this process in $\pi-p$ and $p-p$ interactions.

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DISCUSSION

FENYVES: I would like to give some additional evidence from emulsion work for the diffraction scattering of the incident pion of 7 GeV on a virtual pion. For two prong events we have plotted the angular distribution for π^--mesons in the hypothetical $\pi-\pi$ system and find that π^- mesons are strongly collimated forward in the reaction of the type given by Dr. Morrison, so it seems that the π^-'s maintain the same direction in the $\pi-\pi$ system as their initial direction. A backward collimation of the mixture of π^+ mesons is observed in interactions of the type $\pi^-+p\to n+\pi^++\pi^-+$neutrals, and maybe explained by the production of π^+ mesons at the $\pi-N$ vertex.

HERZ: I should like to say that at Milan we have also looked at the angular distributions of the secondary pions in the $\pi-\pi$ centre-of-mass system. We find that the π^+'s are emitted approximately isotropically, and that the π^- show a narrow forward peak, superimposed on an otherwise isotropic distribution.