STUDY OF EFFECTIVE MASS BETWEEN π^+ AND π^- IN TWO PRONG STARS WITH AND WITHOUT π^0, PRODUCED BY π^- OF 6 GeV/c

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(presented by F. Muller)

We have studied the mass distribution of the $\pi^+\pi^-$ group in the reactions

$$\pi^- + p \rightarrow \pi^+ + \pi^- + N$$
$$\pi^- + p \rightarrow \pi^+ + \pi^- + N + n\pi_0$$

for a π^- incident momentum of 6 GeV/c. The short radiation length of the mixture used allowed a quite satisfactory separation between the two interaction types.

Experimental arrangement

Photographs taken in the heavy liquid bubble chamber BP_3 of the Ecole Polytechnique [1)]

π^- momentum	$6.1 \pm 4\%$ GeV/c
liquid used-mass composition	C_3H_8 68.2%
	CF_3Br 31.8%
Density	0.55 g/cm^3
Radiation length	52 cm

Method

The hydrogen-like two prong interactions, for which the positive prong is either a π^+ or an energetic proton, have been selected.

These interactions may be divided into two classes:

Events for which the π^0 production is indicated by the materialisation of at least one γ-ray 57%

Events without visible γ-ray 43%

The missing mass (Mm) spectra for the two classes are different enough to allow a more complete separation into the following two sets (Fig. 1):

Events " without π^0 " No γ
$0 < \text{Mm} < 1800$ MeV

The remaining contamination of events with π^0 is about 17%

Events " with π^0 " At least one visible γ (75%)
or $\text{Mm} > 1800$ (25%)

The mean number of neutral pions produced in this last class is 1.7.

Results

The mass spectrum of $\pi^+\pi^-$ without π^0 (Fig. 2a) presents very few low mass events and a very well

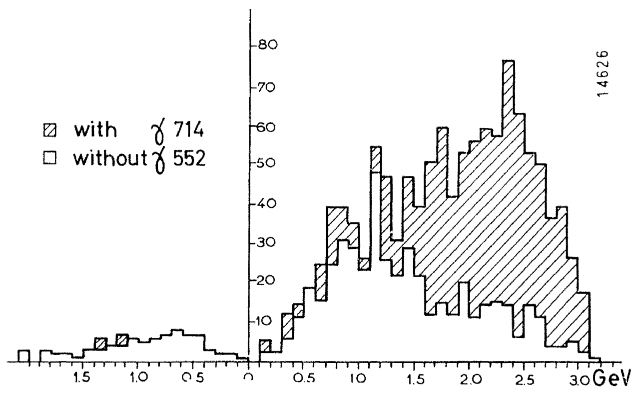

Fig. 1 Missing mass distribution.

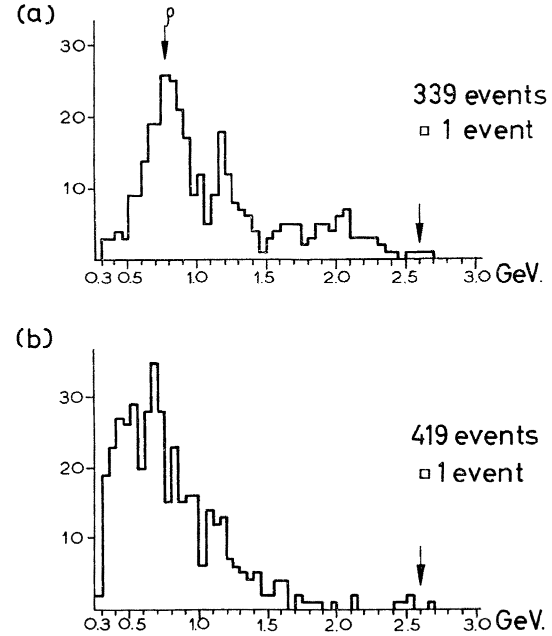

Fig. 2 $\pi^+\pi^-$ mass distribution (a) without additional π^0 (total sample) (b) with additional π^0 (half sample).

marked peak at the ρ mass. It has also at about 1200 MeV a clear peak, whose interpretation is not clear yet.

The momentum transfers Δ between the incident π^- and the $\pi^+\pi^-$ group are concentrated below 1 GeV and their distribution presents a marked peak at about $2m_\pi$ (Fig. 3). The shaded part of the spectrum corresponds to the events of the ρ region.

The mass spectrum of $\pi^+\pi^-$ without π^0 is quite different from the preceding (Fig. 2b). The number of low mass events is very large and the ρ does not appear clearly.

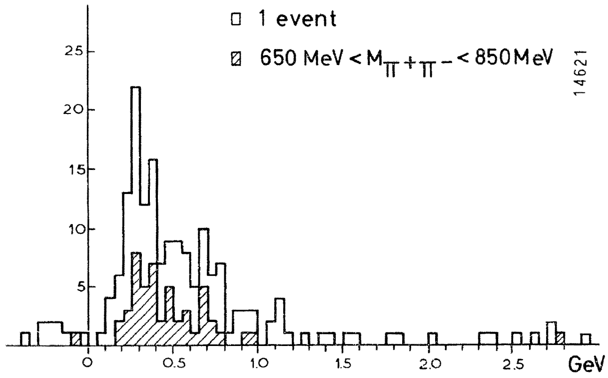

Fig. 3 Momentum transfer distribution for events without additional π^0 (179 events).

LIST OF REFERENCES

1. M. Bloch, A. Lagarrigue, P. Rançon, A. Rousset, Rev. of Sci. Inst., *32*, 1302 (1961).

DISCUSSION

JONES: I wonder what the mass resolution in the ϱ peak is?

MULLER: The mean error on the mass measurement around this region is of the order of 70 MeV. So that the total width of the ϱ peak is about 90.

PEYROU: I have not quite understood if the ϱ you find comes from events in which most of the energy of the incident particle was in the $\pi^+\pi^-$ or in events in which possible π^0's have taken a great part of the energy or do both occur?

MULLER: Most of our ϱ's are produced at high momentum transfers, at high missing masses and at small laboratory energy of the two $\pi^+\pi^-$ that we see. There is a correlation between the three variables.

PEYROU: If you consider events in which momentum is conserved by the visible particles, do you get more ϱ production or more, what you call, Morrison-like events?

MULLER: In the graph with t less than 0.5 $(\mathrm{GeV}/c)^2$ we found 28ϱ, only one third of the total number of ϱ and in the distribution of events with $E_+ + E_- > 7$ GeV we find 3ϱ's — in both cases with a background such that the ϱ does not stick ou much. We have made the mass plot of the (proton—π^-) system, but it was completely flat within the statistics. As for the simplest Feynman diagram with a ϱ from the top vertex and a neutron from the bottom vertex, it does not hold because there are more π^0's emitted which have large energy. The recoil proton momentum distribution is consistent with the peripheral model. So if you want to use the peripheral model, then you would have to add the extra π^0's at the upper vertex. So I cannot say that the peripheral model works or does not work.

DRELL: I should like to go to the board and make a comment separating and comparing these processes. This is a comment which will come up also for the talks of Morrison and Caldwell and it might help to differentiate between the different processes that have been discussed. There is one type of process in multi-GeV pion-nucleon scattering where π^- scattering from a proton produces a ϱ. This is a region where you have a mass produced of some 700 or 800 MeV with quantum numbers different from the pions, in particular with different charge and G conjugation and therefore the Pomeranchuk trajectory could not be responsible for this. In this one region of events, the only trajectory or the only particle exchange that could be responsible for this with low momentum transfer would be the pion. Of other candidates that could produce the ϱ, we may think of the omega, but the omega is neutral and therefore cannot carry the charge; the ϱ has the wrong quantum numbers because it is essentially two pions joining a pion and that cannot make two pions.

That leaves essentially only a charged pion. Now there may be some realm for the one pion exchange to be dominant in a low momentum transfer collision and the following experimental talks will be relevant to this question. For the ϱ°, the total energy on the two particles must be almost all the incident energy and must be shared more or less equally.

COCCONI: Is this not true only for low energy incoming pions?

DRELL: No, that is not so and we will wait for Caldwell's talk. The criterion for the one pion exchange here is that it produces two pions $\omega_1+\omega_2$ whose energy is of the order of the incident energy, but whose total mass, or four-momentum, $(\bar{p}_1+\bar{p}_2)^2$ has to be very much smaller because it has to be of the order of (mass of the $\varrho)^2$. Now there is another range of processes which you can look at and are being popularly called the Morrison events because he first saw them, in pion-nucleon collisions. These are ones in which a charged π^--meson comes up and a very high energy π^- containing most of the energy is seen to emerge. The minute you have isolated such an event you go into an entirely different kinematic region from ϱ production, because the second pion which is produced, has low energy and therefore the total mass of the π—π system is extremely large. So now you are looking at a two pion final system with a very large mass, produced again with a very low momentum transfer. Now the question is what is this production mechanism—what particle is exchanged between (a) and (b) in Fig. A? Now, starting backwards in time we would say

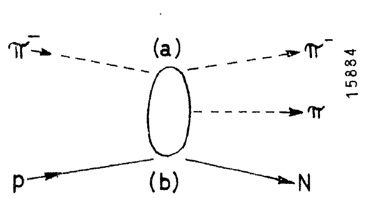

Fig. A

from the Regge point of view we can have a Pomeranchuk trajectory exchanged between (a) and (b) if the low energy π meson is considered to emerge in the bottom half of the diagram from (b). If this is the slow pion-case, I see, standing on my side, that there are no quantum numbers exchanged between (a) and (b) in this channel and therefore the popular Pomeranchuk trajectory can dominate. That would be a way of saying that there is diffraction scattering and down at (b) you excite a nucleon isobar which decays to the pion and nucleon.

COCCONI: $T = ½$.

DRELL: That is right. Because you have exchanged no quantum numbers you can form a nucleon isobar only with $T = ½$, either the second or the third resonance as was discussed in the Taylor *et al.* experiments. Now the question is, can one do more than make a phenomenological statement like this? Can one compute the cross-sections? So we go back twelve months to a calculation that Hiida and I did which is not entirely orthogonal to this. It is a very special part of this contribution, because we considered the following diagram, Fig. B. Incident at (a) is the high energy π^- or it would be the

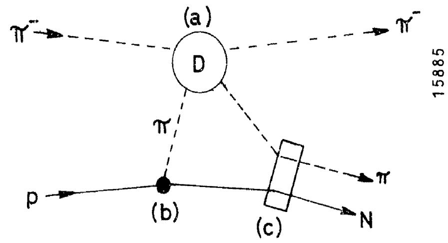

Fig. B

proton in the Taylor experiments, which diffraction scatters from a peripheral pion " Almost standing still " in the cloud of the nucleon. The total energy at (a) is still high, and for a low momentum transfer collision, we inserted a diffraction scattering amplitude at (a) and found a bump in the π^- energy spectrum. Now it may be that we are being too simple minded, that in fact the low energy recoil pion, as opposed to the high energy one that has been observed, has a strong final state interaction down at (c) which cannot be neglected. Then we just draw a big box around all of (a), (b) and (c) and say we have a special mechanism of the Pomeranchuk exchange. The crucial question is: is this a big final state interaction or not? If it is, we have a bad starting point with the peripheral one pion exchange calculation. If it isn't, we have a fairly sensible starting point. And this is a question which, in my mind, is answered partially by the experiments of Taylor *et al.* who showed that you have two bumps, for both isobars, whereas only one peak is found without the final state interaction, and is not quite fixed in energy, moving around too much. The second answer to the question has to come from a calculation of this final state interaction at (c). There is one in progress now and I just can't give an answer to-day because the man who is doing it is fighting with the computing machine. But we hope soon to know whether or not the final state interaction at (c) introduces a two-bump structure without substantially changing the magnitude of the calculated cross section.