π^--p INTERACTION AT 1.4 Bev

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The statistical theory of Fermi, taking into account the resonance interaction between a pion and a nucleon as well as the resonance interaction between two π mesons, is used to explain the experimental results of the π-p interaction at 1.4 Bev. The results obtained are compared with the corresponding results of the "isobaric" model of Sternheimer and Lindenbaum.[1]

AT the present time, there is a large amount of experimental data on the π^--p interaction in the energy range 1.0 to 1.4 Bev.[2-4] A theoretical interpretation of this interaction is possible with the help of Fermi's statistical theory, but, as pointed out by Sternheimer and Lindenbaum,[1] the predictions of Fermi's original theory deviate considerably from experiment. These authors therefore proposed the "isobaric" model, in which it is assumed that the π^--p interaction takes place via an intermediate "isobaric" state. It was shown that the results obtained using this model, within the limit of statistical errors, are in accordance with the experimental results near 1.0 Bev. However, for incident π mesons with energy close to 1.4 Bev, there is a noticeable difference from experimental results. In the present work, we show that the π^--p interaction in this domain can be interpreted with the help of the statistical theory of Fermi, taking into account the resonance interaction of π mesons with nucleons and the resonance interaction between two π mesons.

The resonance interaction between particles, within the framework of Fermi's statistical theory, was considered in accordance with the method proposed by Belen'kiĭ.[5] The resonance interaction of π mesons with nucleons was taken into account using the isobar — "quasi-particle" — with effective mass 1.32,* isotopic spin $T = 3/2$ and intrinsic spin $S = 3/2$ — which decays into a π meson and nucleon.[6] (In the following, this isobar is denoted by the symbol N'.) The resonance interaction between two π mesons was accounted for with the help of a "quasi-particle" with effective mass $\mu = 0.47$, isotopic spin $T = 0$ and intrinsic spin $S = 0$, which decays quickly into two π mesons (this "quasi-particle" is denoted by the symbol Π and it is called the "Π-particle").[7]

The statistical weights of the possible types of reactions in π^--p collisions at 1.4 Bev was calculated according to the formula given in Belen'kiĭ et al.,[6] are as follows: (N2 — process taking place with the formation of a nucleon and two π mesons; N'1 — process proceeding with the formation of an isobar and one π meson, which we can consider to be free and different from the π meson formed on the decay of the isobar; NΠ — process, in which a nucleon and a Π particle are formed, etc.).

N1	N2	N'1	NΠ	N3	N'2	NΠ1	N'Π	N4	Strange particles
12	18	18	7	5	8	8	2	0	22

Hence it is seen that the basic processes, determining the reactions (n + −) and (p − 0), are the two-particle processes NΠ and N'1. Moreover, the kinematic characteristics of each basic two-particle process is independent of the matrix element H_{if}. Therefore, the basic requirement of Fermi's statistical theory (independence of H_{if}) is known to be fulfilled for these processes.

Using the charge distribution in the final state of the π^--p collision mentioned in reference 7, we obtained the distribution of charge of the products according to the number of prongs:

two-prong collision	88 (94)
four-prong collision	12 (6),

It agrees, to within the statistical errors, with the experimental data (the numbers inside the parenthesis), obtained by Eisberg et al.[2] The statistical weight of the "strange" particles, although somewhat less than calculated according to the statistical theory with only isobars taken into account, is overestimated. Apparently, accounting for resonance interactions cannot reduce the statistical

*We always set $\hbar = c = M_{nuc} = 1$.

weight of "strange" particles down to the experimental value, making it necessary to introduce into the statistical theory supplementary assumptions regarding processes involving "strange" particle production (see, for example, reference 8).

In calculating the momentum distributions it is assumed that the isobar and the Π particle decay isotropically in their rest frames. Then, in the decay of the isobar (Π particle) the momentum spectrum of the meson is given by[6]

$$N(p)\,dp = p\,dp/2p_c\gamma V\sqrt{p^2+\mu^2},$$

$$\gamma\,|p_c - VE_c| \leqslant p \leqslant \gamma\,|p_c + VE_c|,$$

$$\gamma = (1-V^2)^{-1/2}; \qquad E_c = (p_c^2+\mu^2)^{1/2},$$

where p_c is the meson momentum at the decay of the isobar (Π particle) at rest; V is the velocity of the isobar (Π particle) in the center-of-mass frame of the meson plus nucleon. The momentum distributions of the mesons and nucleons in the reactions (n + −) and (p − 0) in the center-of-mass system is presented in Figs. 1 and 2. The momentum distribution of the nucleon at impinging pion energies of 1.4 Bev is well explained by our calculations as well as by calculations using the "isobaric" model,[1] while at 1.0 Bev it has in the 300 − 350 Mev domain,[3] a characteristic maximum which cannot be explained by the "isobaric" model, see Fig. 1. In our case, there exists a uniquely possible process, which can bring out a similar maximum, the NΠ process. However, calculations give this maximum shifted by 100 Mev towards the higher momenta (see Fig. 1). Consequently, to make the theoretically-obtained maximum agree with experiment, it is necessary to

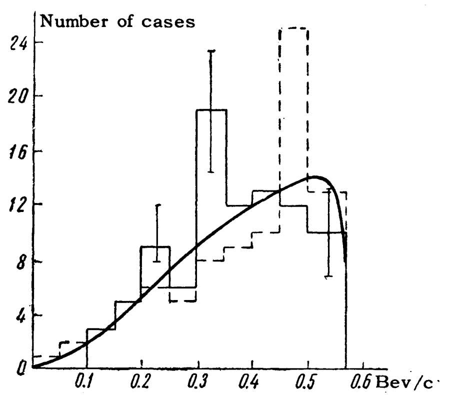

FIG. 1. Momentum distribution of nucleons in the reactions (n + −) and (p − 0) at 1.0 Bev. The continuous histogram is from experiment;[3] the dotted line represents the calculations of the statistical theory, taking resonance interactions into account; the continuous curve was calculated using the "isobar" model.[1]

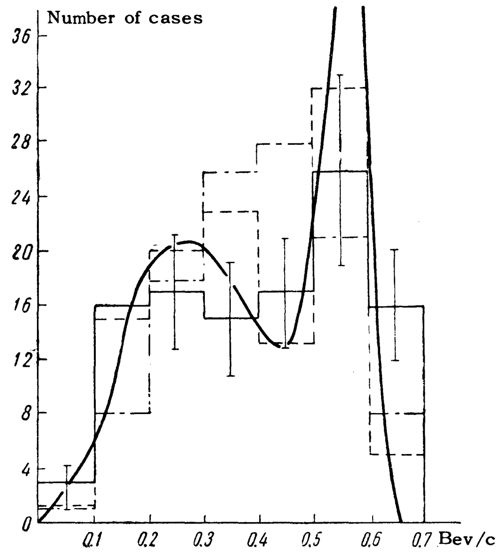

FIG. 2. Momentum distribution of all π-mesons in the reactions (n + −) and (p − 0) at 1.4 Bev. Continuous histogram – experiment,[2] dotted line – calculations using the statistical theory, taking resonance interactions into account (isobar and resonance π − π interaction), dash-dot line – calculated according to the statistical theory, taking only the isobar into account.[6] The continuous curve – calculated with the "isobaric" model.[1]

increase the mass of the Π particle to 0.69.* It is necessary to note here that because of the very crude way of determining the momentum of the nucleon in the paper of Walker et al.,[3] the errors in the mass of the Π particle determined by this method, can turn out to be very considerable. Therefore, in spite of some quantitative disagreement, the effect can be considered as indicating the existence of resonance π-π interaction.

Figure 2 shows the momentum distribution of the π mesons in the reactions (n + −) and (p − 0), in the center of mass system. The theoretical histograms are normalized to the number observed in the experiment. The large experimental error in determining the momentum of the π meson does not allow a unique comparison; nevertheless the character of the experimental results can be explained.

The maximum in the high-momentum domain appears to be due to the process N′1, while the maximum in the domain of low momenta appears to be due to π mesons from the decay of the isobar in this same process. It is natural that the patterns observed and calculated on the "isobaric" model of Sternheimer and Lindenbaum, which takes into account only the process N′1, are similar. However, the maximum in the region of high mo-

*An analogous idea was expressed by Goto.[9]

menta appears strongly overestimated and does not lie within experimental error.

In conclusion, it should be noted that the statistical theory, in which only the isobar is accounted for, gives a worse pion momentum distribution than ours, compared with experiment. Thus, a statistical theory that takes into account not only the isobar but also the resonance interaction of two pions is not contradicted by experimental data on the π^--p interaction at incident pion energies of 1.4 Bev, while the results obtained in this domain using the "isobaric" model begin to disagree with experiment.

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16