ELASTIC BACK SCATTERING OF 2.8-Bev/c π^- *MESONS ON NEUTRONS*

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Cases of quasielastic π^-n-scattering into the back hemisphere in the laboratory system of coordinates were looked for in a 17-liter freon chamber. The cross section for this process evaluated per F nucleus has turned out to be < 0.1 mb. Recalculated for free nucleons the total cross section for the elastic π^-n-scattering process is less than 0.02 mb in the range of angles 140 — 180° in the center-of-mass system. Comparison of this result with theoretical estimates of the contribution to the scattering of the diagram with one virtual nucleon indicates that it is compensated by more complicated diagrams.

INTRODUCTION

ELASTIC scattering of π mesons by nucleons can be regarded as the result of simpler processes: of scattering by virtual π (or K) mesons in the "meson cloud" associated with the nucleon, of scattering by the nucleon "core" and, finally, as a result of penetration deep into the "core." For the process of elastic scattering of π^+-mesons by protons this may be written in the form of a symbolic equation for Feynman diagrams (Fig. 1).

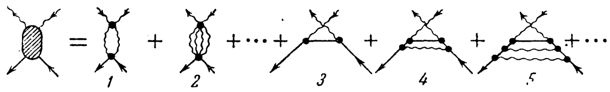

FIG. 1

Diagrams 1 and 2 lead to forward scattering for incident mesons of high energy. I. Ya. Pomeranchuk has noted a characteristic feature of the behavior of diagram 3 which, in contrast to diagrams of the form 1 or 2, should give at high energies a nonvanishing contribution to the back scattering of π^+ mesons. In the case of the scattering of π^- mesons by protons diagram 3 cannot occur in virtue of the law of conservation of charge. The analogous diagram of Fig. 2 with one virtual nucleon yields forward scattering at high energies. The angular distribution of π^+ mesons arising as a result of scattering described by diagram 3 has a maximum near 180° in the center-of-mass system (c.m.s.) with the width of the angular distribution being $\sim M/E$, where M is the nucleon mass and E is the energy of the incident meson in the c.m.s. An estimate of the cross section for the process with one virtual nucleon made by I. Ya. Pomeranchuk suggests the value $d\sigma/d\Omega(180°) \approx g^2k/4m^2 \approx 0.5$ mb. Here $\hbar = c = 1$, $g = 14$ is the meson-nucleon interaction constant, while $k \sim 1/40$ is an undetermined coefficient associated with the renormalization of the vertex parts and of the propagator in diagram 3. However, the contribution of diagram 3 can be compensated by the diagrams of the form 4, 5 etc. if they play a significant role in the scattering process.

EXPERIMENTAL ARRANGEMENT

At the present time there are no experimental data on the differential cross sections for the scattering of high-energy (several Bev) π^+ mesons by hydrogen. However, π^+p scattering is identical with π^-n scattering, data on which can be obtained if from the process of the interaction of mesons with nuclei we separate out the quasielastic π^-n scattering. On the other hand, a differential cross section for π^-n scattering in the backward direction ~ 0.5 mb/sr corresponding to an angular distribution of half-width 30 — 60° in the c.m.s. for incident mesons of energy of the order of several Bev leads to a total cross section ~ 1 mb.

A process with such a relatively large cross section can be studied well in a bubble chamber. Therefore, we have examined stereo-photographs obtained in the case of the interaction with matter of a beam of π^- mesons of momentum 2.8 Bev/c in a 17-liter freon bubble chamber [1] 50 cm long. The momentum spread of the beam is given by

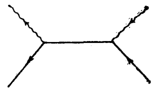

FIG. 2

$\Delta p/p = 10\%$. The working freon mixture (CF_3Cl and CF_2Cl_2) contains sufficiently light nuclei (the average atomic weight corresponds to a fluorine nucleus) and at the same time has a sufficiently high density (1.12 g/cm^3) and a sufficiently low value of the characteristic avalanche length (21.5 cm). This latter circumstance is particularly important, since the main background process has turned out to be the process involving the creation of π^0 mesons which were effectively recorded in the freon chamber by means of the decay γ quanta.

An incident meson momentum of 2.8 Bev/c in the laboratory system (l.s.) corresponds to a momentum of 1.05 Bev/c in the c.m.s. of the colliding meson and nucleon. Consequently, a sufficiently broad distribution of π^- mesons emerging in the backward direction ought to be observed. In the course of our work cases of scattering into the back hemisphere were recorded which corresponded in the c.m.s. to scattering in the angular interval 140 — 180°. The elastically back-scattered mesons must have momenta between 390 and 680 Mev/c and ranges greater than the length of the chamber.

The chamber was operated without a magnetic field. However, this is not particularly significant, since identification of elastic scattering by means of the correlation between the angle of scattering and the momentum of the π meson is in any case made difficult by the following circumstances: the relatively small change in the meson momentum as the scattering angle change from 90 to 180° in the l.s.; the 10% uncertainty in the momenta of the mesons in the beam; the uncertainty arising due to the Fermi motion of the nucleons in the target nucleus.

EXPERIMENTAL RESULTS

Three or four independent observers have examined ~ 2500 frames. These frames had recorded 36,000 meson traversals which gave rise to ~ 11,000 interactions with the working volume of the chamber, and this corresponds to a cross section of ~ 300 mb per average nucleus of the working mixture (F). Altogether there were recorded 14 single-prong events with one relativistic particle of momentum greater than 200 Mev/c emerging into the back hemisphere in the l.s. We have rejected the cases when the track ended in the chamber and when the ionization was twice the relativistic ionization. The efficiency of recording such events in the course of scanning the film is of the order of unity.

In ten of the recorded cases electron-positron pairs produced by the conversion of γ quanta appeared to radiate from the point of interaction (in one case there were four pairs, in two cases there were two pairs, and in seven cases there was one pair). It is natural to assume that the observed events are the result of an interaction involving the emission from a nucleus of one charged meson in the backward direction and of one or several π^0 mesons. The efficiency of recording a γ quantum within the chamber varies within the range from 0.6 to 0.23 depending on the spot at which the quantum was formed and on the scattering angle. There exists a certain probability of failing to record the π^0 mesons produced. This probability varies from ~ 10 to ~ 40%, depending on the angular distributions and on the multiplicity of production of π^0 mesons. Thus, events which are not accompanied by electron-positron pairs can also be included among the cases of multiple meson production. It is also possible that one of four cases is due to the reaction with the creation of a K^0 meson and its subsequent decay into two π^0 mesons, since in the chamber not far from the point of interaction there have been found three pairs radiating from a single point which is not associated with other interactions.

If, nevertheless, we assume that these four events are due to the elastic scattering of π^- mesons in the backward direction by the quasi-free neutrons in the nuclei, then the upper limit for the total cross section for scattering into the back hemisphere in the l.s. is $\sigma_n < 0.1$ mb per fluorine nucleus.

DISCUSSION OF RESULTS

On the basis of the experimental data obtained it is possible to make an estimate of the cross section for the process of elastic scattering of π^- mesons by a free neutron giving $\sigma < 0.1/n\eta$ mb ≈ 0.02 mb, where $n = 10$ is the number of neutrons in the fluorine nucleus, while $\eta \approx 0.5$ is a coefficient which takes into account the screening of nucleons in nuclei.

The choice of the value $\eta \approx 0.5$ may be justified in the following manner. Earlier Ballam et al [2] studied the elastic π^-n cross section at an energy of 460 Mev in a propane bubble chamber. A comparison was made of the angular distributions of π^- mesons scattered by neutrons contained in a carbon nucleus, and of π^+ mesons elastically scattered by hydrogen. It was shown that the data agreed well among themselves if we assume $\eta = 0.55$. The F nucleus is somewhat heavier than a C nucleus, so that one might expect that the coefficient η is smaller, but does not differ appreciably from the value of η for C. An estimate made on the basis of data on small angle quasi-elastic scattering of 2.8 Bev/c π^- mesons by neutrons contained in the nuclei of which freon is composed shows that $\eta \approx 0.5$. Since the coefficient η is practically constant as the meson energy changes by almost an order of magnitude, it may be supposed that η will also not change in the case of back-scattering of mesons. Estimates of η made on the basis of the optical model also suggest a value ~ 0.5.

Thus, the cross section for back-scattering of π^--mesons by neutrons is smaller by more than an order of magnitude than the value estimated by means of diagram 3.

Moreover, as I. Ya. Pomeranchuk has noted, it is less than the value $\pi\lambda\!\!\!^-{}^2/4\pi \approx 0.1$ mb ($\lambda\!\!\!^- = 1.9 \times 10^{-14}$ cm is the π-meson wavelength in the c.m.s.) which, generally speaking, should be expected for the contribution of just the S wave to the total cross section of elastic πN-scattering (in the present case independently of the sign of the meson charge) in the angular range studied (approximately 1 steradian in the c.m.s.). This means that the phases corresponding to low values of l are small, or else are such that the corresponding terms interfere and mutually cancel. The latter remark should be interpreted as an indication of the necessity for obtaining experimental data over a wider angular interval and with greater statistical accuracy rather than as a final result.

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[1] Blinov, Lomanov, Meshkovskii, Shalamov, and Shebanov, PTÉ (Instruments and Experimental Technique) **1**, 35 (1958).

[2] Ballam, Hang, Scanreet, and Walker, Nuovo cimento **14**, 240 (1959).

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