DOUBLE CHARGE EXCHANGE OF π MESONS

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In the interaction of π mesons with nuclei, collisions whereby a positively charged meson transforms into a negative one or vice versa are possible. The meson charge then changes by two units. Such processes have not been studied experimentally. The investigation of these processes, however, is highly interesting since it may provide new information on the interaction of charged and neutral mesons with nuclei. Furthermore, the possibility of using double charge exchange processes of mesons for the study of the structure of the nucleus and for the formation of new light nuclei is of great current interest.

To observe double charge exchange of π^+ mesons, an emulsion chamber was bombarded with 80 MeV π^+ mesons [1]. The developed emulsion layers were scanned for stopped π^- mesons. The tracks of the recorded π^- mesons were extended in the chamber up to their emergence from the stars formed in the emulsion. Stars having a primary track

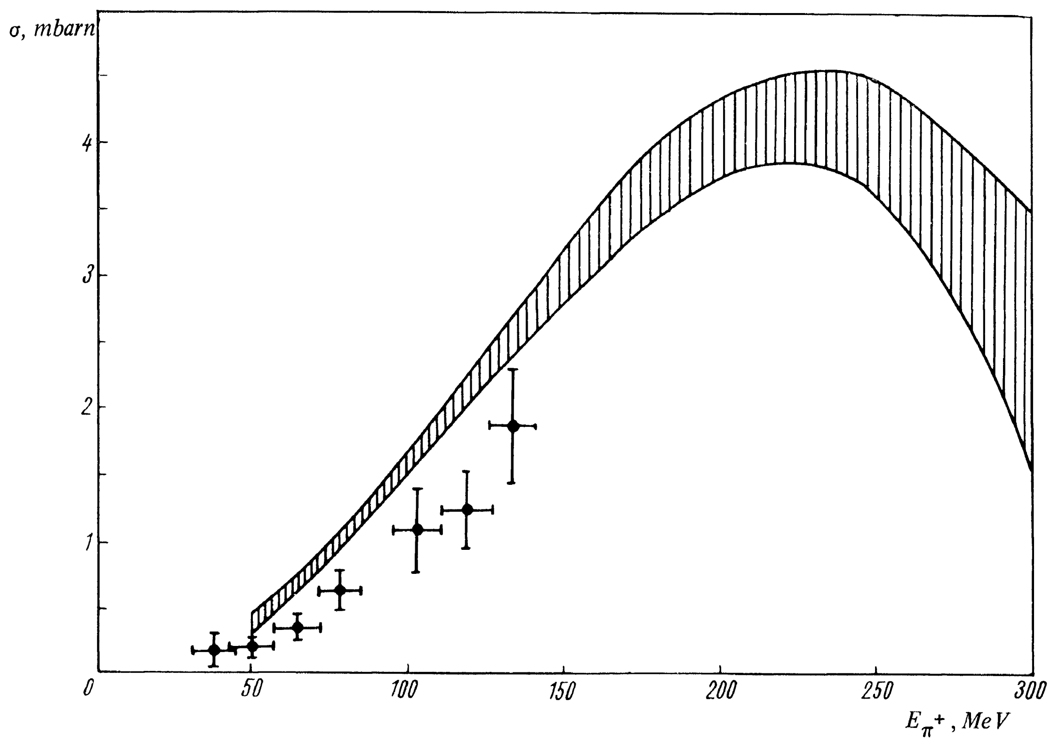

Fig. 1. Energy dependence of the total cross section for double charge exchange of π^+ mesons on photoemulsion nuclei (the shaded area corresponds to a calculation by the Monte Carlo method).

were selected. An examination of 15 layers showed that 31 such stars were recorded. It was found that all the primary tracks in these stars do not differ according to ionization density (to within 10%) or direction (± 3°) from the tracks of beam π^+ mesons. These events cannot be due to an impurity of π^- mesons in the beam.

Thus, in this study we recorded the double charge exchange of π^+ mesons on nuclei in the photoemulsion. This exchange may take place according to the scheme:

$$\pi^+ + n \longrightarrow \pi^0 + p$$
$$\hookrightarrow \pi^0 + n \longrightarrow \pi^- + p \qquad (1)$$

or

$$\pi^+ + (2n) \longrightarrow \pi^- + (2p). \qquad (2)$$

All cases recorded belonged to the primary meson energy range from 30 to 80 MeV. Not a single event was found in the 0 – 30 MeV energy range. The cross section for double charge exchange of π^+ mesons in the 30 – 80 MeV energy range was found equal to $(5 \pm 1) \cdot 10^{-28}$ cm^2.

An examination of all the layers of this chamber revealed 79 events. In addition, searches were carried out for double charge exchange events in an emulsion chamber irradiated by 140 MeV π^+ mesons. Altogether 230 events were recorded in both chambers.

On the basis of these events the cross section for double charge exchange of π^+ mesons was determined for seven energy intervals of the primary mesons. Fig. 1 gives the energy dependence of the total cross section for double charge exchange on nuclei in the photoemulsion. As can be seen the magnitude of the total cross section increases with energy.

Fig. 2 presents the energy distribution of secondary π^- mesons (the histogram is based on 100 cases in which the primary meson energy was 60 – 100 MeV). It follows from

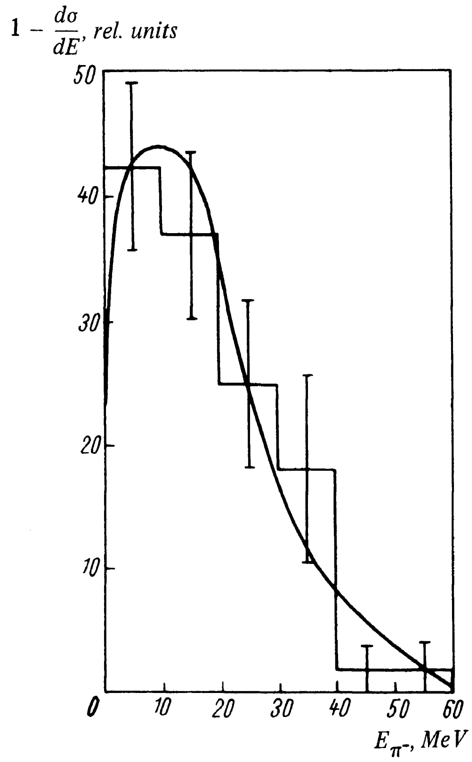

Fig. 2. Energy distribution of secondary π^- mesons from the double charge exchange reaction for a primary π^+ meson energy of 60 – 100 MeV. The spectrum contains 100 events (the solid curve is based on a calculation by the Monte Carlo method).

the energy distribution of the secondary mesons that in double charge exchange a π meson gives up a considerable part of its kinetic energy to the nucleus. This result is understandable if it is assumed that the reaction proceeds in two stages by the scheme (1). Under this assumption we tried to simulate the double charge exchange of a π meson in a nucleus by the Monte Carlo method. In the calculations the nuclear model was taken to be a uniform Fermi gas which fills a sphere of radius $R = r_0 A^{1/3}$. The calculations were made separately for the light and heavy nuclei constituting the photoemulsion, and the results were then averaged. In this way the probability of double charge exchange of π^+ mesons on nuclei in the photoemulsion for different energies in the interval from 50 to 300 MeV was calculated. At the same time the probabilities of inelastic scattering and of meson formation were determined. The values obtained for the double charge exchange cross sections are given in Fig. 1.

A comparison shows that the calculated cross sections satisfactorily agree with the experimental results for $r_0 = 1.10^{-13}$ cm. For energies above 140 MeV the calculation predicts a further increase in the cross section for double charge exchange up to a maximum value at approximately 200 MeV. This maximum is a reflection of resonance scattering of π mesons on free nucleons.

The energy distribution of the secondary π^- mesons was calculated for 80 MeV (Fig. 2). This also agrees with the experimental results.

Thus we may note that with the help of a comparatively simple nuclear model and the data on the interaction of π mesons with free nucleons, it is possible to describe the characteristic features of the double charge exchange reaction of mesons, if the latter is assumed to proceed in two stages according to the scheme (1). Further experiments were directed toward studying double charge exchange of π^- mesons. The emulsion chamber was irradiated by 87 MeV π^- mesons. The search for double charge exchange events was carried out as in [1]. Till now 27 cases of double charge exchange of π^- mesons on nuclei in the photoemulsion have been recorded. All events belong to the primary meson energy interval of 40 – 87 MeV. The cross section of double charge exchange of π^- mesons in this energy interval was estimated from these events to be $(0.09 \pm 0.003) \cdot 10^{-27}$ cm^2.

REFERENCES

1. Batusov Yu. A. et al. JETP, **46**, 817 (1964).