625

ВН

ЛАБОРАТОРИЯ ВЫСОКИХ ЭНЕРГИЙ

ОБЪЕДИНЕННЫЙ ИНСТИТУТ ЯДЕРНЫХ ИССЛЕДОВАНИЙ

V.A. Nikitin, E.N. Tzyganov

D–625

AN ESTIMATION OF THE UPPER LIMIT OF THE CHARGE EXCHANGE CROSS SECTION IN (p – n) INTERACTION AT 8.5 BEV

Дубна 1961

V.A. Nikitin, E.N. Tzyganov

D–625

AN ESTIMATION OF THE UPPER LIMIT OF THE CHARGE EXCHANGE CROSS SECTION IN (p – n) INTERACTION AT 8.5 BEV

Abstract

The upper limit of the cross section for elastic charge exchange proton-neutron scattering has been found to be $\sigma_{ex} \leqslant 0.46 \pm 0.15$ mb at 8.5 BeV by using the emulsions.

According to the statistical theory the cross section for charge exchange $(p-n)$ scattering must be small at high energies (as well as the cross section for any possible inelastic channel in nucleon interaction): $\sigma_{ex} \approx 2.10^{-4} \sigma_{in}$ at an energy of 10 BeV/1/, σ_{in} is the cross section for all inelastic processes. However, it is not excluded, that the charge exchange is somehow distinguished out of all other channels. Another reason which accounts for the interest in the charge exchange scattering is that the ratio σ_{ex}/σ_{el} (σ_{el} is the elastic scattering cross section) depends, in the framework of the isotopic invariance, on the contribution of the one-meson interaction scheme to elastic nucleon-nucleon scattering. So, if elastic ($N-N$) scattering takes place only due to the one meson interaction, then the above said ratio is equal to 4.

In this paper an attempt is made to estimate the upper limit of the charge exchange cross section in proton scattering on the neutrons bound in the emulsion nuclei at a proton energy of 8.5 BeV.

Experimental Arrangement and Results

An emulsion stack 10 x 10 x 2 cm^3 has been irradiated by a 8.5 BeV proton beam. The beam was directed perpendicular to the emulsion pellicles. The advantage of this method for observing the events of type of elastic $(p-p)$ scattering and the charge exchange $p + n \rightarrow n + p$ was described in /2/. The emulsion was area-scanned. All the two-prong and one-prong stars having a black and grey ray were selected for the processing. (This corresponds to the proton energy up to ~300 MeV). Among the two-prong stars there were elastic proton scatterings on hydrogen and quasi-elastic $(p-p)$ scatterings, i.e., scatterings of protons on protons bound in the emulsion nuclei. Among the one-prong stars there must be charge exchange reactions $p + n \rightarrow n + p$ (if such a reaction occurs)*.

If the number of quasi-free protons and neutrons is the same, then the charge exchange cross section is

$$\sigma_{ex} = \frac{N_{ex}}{N_{квази\,(p-p)}} \sigma_{el} \cdot k \qquad (1)$$

N is the number of the corresponding events distinguished after the processing, k is the relative recording efficiency of two - and one - prong stars, This value will be overestimated, or underestimated depending upon the criteria according to which the charge exchange events and quasi-elastic scatterings were selected.

---

* This reaction may be also considered as elastic proton-neutron scattering in the backward direction in the c.m.s.

The selection criteria were the following.

1. The identification of the charge exchange events : a) all the stars without the recoil nucleus were selected; b) the prong in the one-prong star is considered to be the recoil proton generated after the charge exchange of a neutron. Here the emission angle and the momentum of the recoil proton will be connected. If the binding energy of neutrons in a nucleus and their distribution by the momenta is known, on the plane angle-momentum it is possible to construct a region which the points corresponding to the charge exchange reaction hit. The density of the points outside this region is a characteristic of the background.

2. The identification of quasi-elastic $(p-p)$ scatterings.

This is reduced to the calculation (for the two-prong stars without the recoil nucleus and the β-decay electron) of the momentum of the target-proton, i.e., the proton bound in a nucleus. This momentum is calculated as a difference of the observed momentum of the recoil proton and the transferred momentum. The magnitude of the first momentum is measured by its path (range) (or the ionization) in the emulsion, the magnitude of the second one - by the scattering angle of the primary proton. This angle is measured with an accuracy of 0.2°. Then the distribution of the number of events by the momentum of the target proton is plotted $\frac{dN}{dp}(p)$ where p is the calculated momentum of the target proton, $\frac{dN}{dp}$ is the number of events with the given p.

This function has a vivid maximum in the neighbourhood of the point $p = 0$ which corresponds to the quasi-elastic $(p-p)$ scattering (Fig. 1). The width of the maximum consists of the magnitude of the mean momentum of the target proton inside the nucleus and of the inaccuracy in the measurements. The value of the function $\frac{dN}{dp}$ for large p characterizes the background. In our case it was found to be $\sim$ 10%. To estimate the background we tried to identify the 'quasi-elastic events' of three-prong stars, neglecting, at the same time, one of the prongs. It turned out, that the probability of identifying the 'quasi-elastic events' from a three-prong star is 10 times less than from the two-prong one. This shows that the quasi-elastic events can be identified suficiently reliably in the above-mentioned way.

One can see from what has been said that the two-prong stars are subject to more strict selection criteria than the one-prong ones. Therefore, expression (1) yields the upper limit for the charge exchange cross section. We have obtained $\sigma_{ex} \lesssim 0.46 \pm 0.15$* mb.

The statistical material on the basis of which this value has been obtained was as follows. 8.1 cm^3 of emulsion has been scanned. 1859 two-prong stars have been recorded, out of which 466 quasi-elastic $(p-p)$ scatterings have been identified. As for one-prong stars, their number was found to be 55. After the

* The error indicated is a statistical one. An essential assumption we have made should be emphasized: the transferred momentum during charge exchange is not much less than the transferred momentum in elastic scattering. If it is not so, then on the bound neutron the charge exchange cannot be observed at all.

processing there remained 20. The scanning efficiency for the two-prong stars was $\sim 92\%$, and for the one-prong stars $\sim 75\%$. It was found by the results of the secondary scanning of all the area (two-fold scanning). The cross section of $\sigma_{el} = 8{,}7$ mb has been taken from /2/.

Conclusions

1. The ratio is $\frac{\sigma_{ex}}{\sigma_{el}} \leqslant 0.07$. This implies that the contribution of the one-meson scattering to the cross section for the elastic nucleon interaction does not exceed 2%.*

2. Under some assumptions one can succeed in estimating the maximum difference in the total cross sections for ($p-p$) and ($p-n$) interactions $\Delta_{tot} = \sigma_{pp} - \sigma_{pn}$. Indeed, according to the isotopic invariance there is a relationship between the amplitudes of the corresponding elastic processes

$$\mathcal{A}_{pp}^{(3),(0)} - \mathcal{A}_{pn}^{(3),(0)} = \mathcal{A}_{ex}^{(3),(0)} .$$

The indices '3' and '0' designate that this relationship holds for the triplet and singlet nucleon states (here we speak about ordinary spin). By using the relations

$$\frac{k}{4\pi} \, \mathrm{Im}\, \mathcal{A} = \sigma_{tot} \; ; \quad \sigma_{ex}(\theta) \geqslant \left[\mathrm{Im}\, \mathcal{A}_{ex}(\theta) \right]^2$$

we get

$$\Delta_{tot} \leqslant \frac{4\pi}{k} \left[\frac{3}{4} \sqrt{\sigma_{ex}^{(3)}(0)} + \frac{1}{4} \sqrt{\sigma_{ex}^{(0)}(0)} \right]. \qquad (2)$$

Here $\sigma_{ex}^{(3)}(0)$, $\sigma_{ex}^{(0)}(0)$ are the differential charge exchange cross sections at 0° in the triplet and singlet nucleon states. These cross sections are connected with the cross section $\sigma_{ex}(0)$ measured by means of an unpolarized target and of an unpolarized beam i.e. $\frac{3}{4} \sigma_{ex}^{(3)}(0) + \frac{1}{4} \sigma_{ex}^{(0)}(0) = \sigma_{ex}(0)$. Therefore, the expression in the square bracket of formula (2) assumes the maximum value $\sqrt{\sigma_{ex}(0)}$, when $\sigma_{ex}^{(3)}(0) = \sigma_{ex}^{(0)}(0)$, and the minimum value $\frac{1}{2}\sqrt{\sigma_{ex}(0)}$ when $\sigma_{ex}^{(0)} = 0$. Thus, the measurement of Δ_{tot} and of the differential charge exchange cross section at 0° yields some information about the spin interaction. Since the data on the value $\sigma_{ex}(0)$ are not available we have to make use of a simpler formula

$$\Delta_{tot} \leqslant \frac{4\pi}{k} \sqrt{\sigma_{ex} \frac{\sigma_{el}(0)}{\sigma_{el}}} \qquad (3)$$

---

* We do not take into account a possible interference of the one-meson and many-meson interactions.

($\sigma_{el}(0)$ is the differential cross section for elastic ($p-p$) scattering at 0°) which is valid under the following assumptions : a) the cross sections are independent of the spin nucleon state; b) the differential cross sections for elastic ($p-p$) scattering and charge exchange ($p-n$) scattering are alike. According to the data of [2], $\sigma_{el}(0) \approx 160$ mb/ster. Therefore $\Delta_{tot} \leq 11$ mb. If the amplitude of elastic ($p-p$)- scattering is assumed to be purely imaginary, then (3) takes on the form

$$\Delta_{tot} \leq \sqrt{\sigma_{ex} \frac{\sigma_{pp\,tot}}{\sigma_{el\,pp}}} \,. \qquad (4)$$

From (4) follows $\Delta_{tot} \leq 9$ mb, what does not contradict the available experimental data[3].

3) The obtained limit for the charge exchange cross section is too high to check the prediction of the statistical theory.

4) Evidently, that the estimate of the charge exchange cross section may serve as an estimate for elastic ($p-n$) scattering in the backward direction in the c.m.s.

The authors are grateful to M.I. Podgoretsky, V.G. Grishin and V.N. Streltzov for advice and discussions.

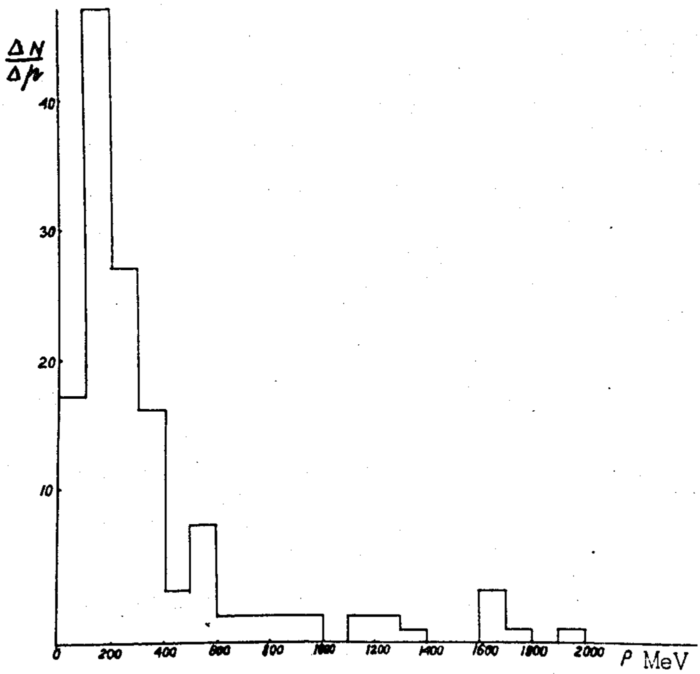

Fig. 1.

Distribution of the two-prong stars, having neither the recoil nucleus, nor the electron of the β- decay, by the momenta of the target proton.

References.

1. Д.И.Блохинцев, В.С.Барашенков, Б.М.Барбашов. Структура нуклона. Preprint ОИЯИ, Р-317.
2. П.К.Марков, Э.Н.Цыганов, М.Г.Шафранова, Б.А.Шахбазян. ЖЭТФ, т.38, 1471 /1960/.
3. Proc.Ann.Intern.Conf. on H.E. Physics at Rochester (1960).

Received by Publishing Department on October 27, 1960.