MEASUREMENT OF HADRON MEAN FREE PATH FOR THE PARTICLE-PRODUCING COLLISIONS IN NUCLEAR MATTER

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ABSTRACT

It is not obvious a priori that the cross-section for a process in hadron collisions with free nucleons is the same as that for the process in hadron collisions with nucleons inside a target nucleus. The question arises: "What is the cross-section for a process in a hadron collision with nucleon inside the atomic nucleus ?". The answer to it must be found in experiments. The mean free path for particle-producing collisions of pions in nuclear matter is determined experimentally using pion-xenon nucleus collisions at 3.5 GeV/c momentum. Relation between the mean free path in question λ_i in nucleons/fm^2 and the cross-section σ_i in units of fm^2/nucleon for collisions of the hadron with free nucleon is: $\lambda_i = k / \sigma_i$, where $k = 3.00 \pm 0.26$.

1. Introduction

One of the main concepts which is useful in hadron-nucleus collision analysis is that of the mean free path λ ; it always has a subscript denoting a particular process. Usually, the mean free path λ fm for a process is related to the cross-section σ fm^2/nucleon for such a process in collisions of the hadron with free nucleon as:

$$\lambda = \frac{1}{\rho\sigma} \qquad (1)$$

where ρ in nucleons/fm^3 is the mean nucleon density in the target nucleus along λ. Relation (1) can be expressed as

$$\lambda = \frac{1}{\sigma} \qquad (2)$$

when λ is in nucleons/fm^2. It is convenient to express λ

in units of nucleons/S where $S = \pi D_o^2 \approx 10\ fm^2$ and D_o is the diameter of the nucleon.

The subject matter in this paper is to determine experimentally the mean free path λ_i nucleons/S for the particle-producing hadron-nucleon collisions in nuclear matter.

2. Method

Two experimental findings provide the basis for experimental determination of the hadron mean free path for the particle-producing collisions in nuclear matter: a) The discovery of hadron-nucleus collisions in which incident hadron is stopped or deflected only in accompaniment by intensive nucleon emission from the target nucleus without causing the particle production; the emitted nucleons are with kinetic energies from about 20 up to about 400 MeV, Strugalski Z. and Pluta J. (1974), Strugalski Z., Pawlak T., Pluta J. (1982). b) The discovery of definite relation between the intensity of the emitted nucleons and the thickness of the nuclear matter layer involved in any-type collision events - when particles are produced or not, Strugalski Z. (1984 a).

We can consider a sample of hadron-nucleus collisions as a result of interaction of a beam of hadrons with a lense-shaped "slab" of nuclear matter, Strugalski Z. (1984 b). In fact, in any collision event the target nucleus is destroyed, but in any of the collisions a hadron collides with identical nucleus.

Let us consider a hadron flux I_o incident on a layer of nuclear matter of the thickness dt. The differential intensity loss dI due to interactions is given by the relation $dI = -I_o \sigma \rho\, dt$, and so $I = I_o \exp(-\sigma \rho t) = I_o \exp(-t/\lambda)$. The mean free path λ in fm can be replaced by λ in nucleons/S, where $S \approx 10\ fm^2$; the thickness t in fm can be replaced by t in nucleons/S as well, and

$$I = I_o \exp(-t/\lambda) \qquad (3)$$

The thickness of the nuclear matter layer t in nucleons/S, involved in any type collision, is given from the relation between this thickness and the number n_p of the protons emitted in the event, Strugalski Z. (1984 a), as:

$$n_p = t \cdot S \cdot \frac{Z}{A} \qquad (4)$$

In measurements of the mean free path λ in nucleons/S the quantity I_o is simply the number of hadron-nucleus collisions analysed, the quantity I equals the number of events without causing an effect - the particle production, for example; all the quantities I_o, I, and t are measurable ones. Then, λ can be estimated simply from relation

(3).

For determination of the λ -s, the collision events observed in the 26 and 180 litre xenon bubble chambers , Kanarek T.I. et al. (1959), Kuznetsov E.V. et al. (1970), exposed to beams of pions were used.

3. Experiment

The smaller chamber was exposed to the positively charged pions with 2.34 GeV/c momentum from the synchrophasotron of the Joint Institute for Nuclear Research at Dubna. The bigger chamber was exposed to negatively charged pions with 3.5 GeV/c momentum from the accelerator of the Institute of Experimental and Theoretical Physics in Moscow.

In photograph scanning, any-type collision events were selected, a total information about the outcome in any of collisions was obtained, as it concerns the emitted nucleons and produced pions of any electric charge, including neutral pions, Strugalski Z., Pawlak T., Pluta J. (1982), Strugalski Z. et al. (1983).

4. Results

We measured the mean free path λ_i in nucleons/S for the particle-producing collisions, and the mean free path λ_d in nucleons/S for collisions without particle production when the incident hadrons were deflected through the deflection angles larger than $\Theta_{\pi} \geqslant 30$ degrees, Strugalski Z. (1983). We obtained for the particle-producing mean free path $\lambda_i = 12.4 \pm 1.7$ nucleons/S and for the mean free path $\lambda_d = 12.8 \pm 1.5$ nucleons/S.

We found that the formula for dtermination of λ_i from σ_i taken from elementary hadron-nucleon collisions should be, instead of formula (2):

$$\lambda_i = \frac{k}{\sigma_i} \qquad (5)$$

where λ_i and σ_i are in nucleons/S and S/nucleon correspondingly. $k = 3.0 \pm 0.26$.

5. Conclusions

The mean free path λ_i for particle-producing hadron collisions in nuclear matter, determined by means of formula (2), does not correspond to the mean free path determined experimentally.

This path λ_i , for particle-producing collisions, and the path λ_d, for the deflections through angles larger than 30 degrees, are practically the same.

But, the deflections through large angles are from collisions of incident hadron with hard constituents of the nucleons, Strugalski Z. (1982). The observed equality between λ_i and λ_d may mean that particles are produced when collisions occur with the hard constituent of the nucleon.

The inequality of values of the quantity λ_i evaluated from formula (2) and determined experimentally using the method presented above may be regarded as an appearance of a nucleon structure in hadron-nucleus collisions, Strugalski Z. (1984 c).

References

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