ON THE ANALYSIS OF INELASTIC PROTON-NEUTRON COLLISIONS AT AN ENERGY OF 20 GeV

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Abstract

Full Text

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Academician of the Academy of Sciences of the Kazakh SSR Zh. S. TAKIBAEV,
E. G. BOOS,
R. A. TURSUNOV

ON THE ANALYSIS OF INELASTIC PROTON-NEUTRON COLLISIONS AT AN ENERGY OF 20 GeV

After the selection of events of the coherent type (1), 148 three-prong interactions of protons with momentum 19.8 GeV/c with quasi-free neutrons of Ilford G-5 emulsion nuclei were chosen for analysis. The selection of nucleon–nucleon events and the identification of secondary particles were carried out using the methodological requirements described in papers (2, 3).

Fig. 1. Angular distribution of protons in the c.m.s. The curve shows results obtained from work (4)

Figure 1 presents the angular distribution of secondary protons in the center-of-mass system of the colliding nucleons. The distribution is sharply collimated in the direction of the collision axis—93% of all particles are contained in the interval $0.8 < |\cos\theta^*| < 1.0$—and is asymmetric. This form of the angular distribution is well explained by a one-meson-exchange model with excitation of only one of the colliding nucleons, or without excitation of the nucleons but with an intermediate $\pi\pi$ interaction (4).

The asymmetry coefficient η of the distribution shown in Fig. 1 is equal to -0.20 ± 0.07 ($\eta = (\bar{N}_\mathrm{f} - \bar{N}_\mathrm{b})/(\bar{N}_\mathrm{f} + \bar{N}_\mathrm{b})$, where $\bar{N}_\mathrm{f}$ and $\bar{N}_\mathrm{b}$ are the numbers of protons flying in the c.m.s. into the forward and backward hemispheres), which may indicate a significant role of nucleon charge exchange at the energy under consideration.

The presently available values of the asymmetry coefficients of the angular distribution of protons, obtained for pn interactions at an energy of 9 GeV, differ

Fig. 2. Momentum spectrum of secondary protons in the c.m.s.

Figure 2: Fig. 2. Momentum spectrum of secondary protons in the c.m.s.

in sign: -0.32 ± 0.12 in work ([5]) for

events with three charged particles in the final state* and 0.26 ± 0.05, according to the data of work (7). An explanation of the effect observed in works (5, 6) was given, within the one-meson approximation, in works (4, 6), on the basis of the assumption that diagrams with excitation of only one of the colliding nucleons make an important contribution. The value of η obtained by us indicates a substantial role of this diagram also at higher energy.

Fig. 2. Momentum spectrum of secondary protons in the c.m.s. **1**—corresponds to the results of calculations by statistical theory (8), **2**—by the one-meson model (4)

The total angular distribution of all secondary charged particles is symmetric within the limits of measurement errors. The mean number per interaction is 0.90 ± 0.07 for protons, 1.87 ± 0.16 for π-mesons, and 0.23 ± 0.06 for K-mesons.

The momentum spectrum of secondary protons is presented in Fig. 2. The same figure also gives the results of calculations by Hagedorn according to the statistical theory at an energy of 25 GeV (8) (curve 1) and by Usik and Kuchin at an energy of 20 GeV (4) (curve 2). It is clearly seen that each of the indicated theoretical models describes only part of the broad experimental distribution with a maximum in the region $(0.4 \div 0.8)$ GeV/c. The appearance of this maximum, with the sharp collimation of the angular distribution of protons, appears to be a very interesting feature of the elementary act.

Figure 3 gives the dependence of the fraction of energy lost by the nucleon,

$$k^* = (M\gamma_c - \varepsilon^*)/M(\gamma_c - 1)$$

(M is the nucleon mass, γ_c is the Lorentz factor of the c.m.s., ε^* is the nucleon energy in this system), on the emission angle in the c.m.s., θ^*. A weak correlation is observed between the fraction of energy lost by the nucleon and its emission angle over a wide range of values of k^*. The mean value over all interactions is $\langle k^* \rangle = 0.66 \pm 0.03$.

Separately, 33 interactions with 2 identified protons were considered, in which it was possible to determine the value of the inelasticity coefficient

$$k_{\mathrm{n}}^* = (2M\gamma_c - \varepsilon_1^* - \varepsilon_2^*)/2M(\gamma_c - 1)$$

($\langle k_{\mathrm{n}}^* \rangle = 0.67 \pm 0.18$). The distribution of the quantity k_{n}^* is uniform and has no features; moreover, all the considered values of the inelasticity coefficient fall practically in the interval 0.4–1.0.

The data presented above indicate that nucleons deviate little from their initial direction of motion even with relatively large energy losses.

Figure 4 presents the distribution of protons according to the value of the four-dimensional momentum Δ^2. The curve in Fig. 4 corresponds to the results of calculations by the peripheral model (4). Two distinct maxima stand out in the distribution, the second of them ($1.2 < \Delta^2 < 2.4$), which is not described by the curve, being due mainly to protons flying in the c.m.s. into the backward hemisphere.

* In work (6) it is shown that the sign and magnitude of the asymmetry, within the limits of errors, do not depend on multiplicity, and for all pn interactions $\eta = -0.32 \pm 0.10$.

The difference between the distributions of protons with $\vartheta^* > 90^\circ$ and $\vartheta^* < 90^\circ$ cannot be regarded as random at the 5% significance level. The observed discrepancy may be connected with the influence of a charge-exchange process accompanied by the formation of a heavy nucleon resonance. Estimates show that the mass of such a resonance should be about 5 GeV; however, this question requires further, very critical study.

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Fig. 3

Fig. 4

Fig. 3. Dependence of k^* on the proton emission angle in the c.m.s.

Fig. 4. Distribution of protons with respect to the quantity Δ^2. The hatched part corresponds to protons with $\vartheta^* > 90^\circ$. The curve is taken from Ref. ([4])

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Institute of Nuclear Physics
Academy of Sciences of the Kazakh SSR

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Note: Figure translations are in progress. See original paper for figures.