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DIQUARKS ROLE IN LARGE-$p_\perp$ DEUTERON AND H-DIHYPERON PRODUCTION IN HARD NUCLEON COLLISIONS

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To construct the strong interaction theory that has to solve the problems of dynamic structure hadrons and nuclei the study of light-nucleus production processes in elementary particle collisions may give a valuable information. From this point of view, the data on production of light nuclei (deutons, antideutons, tritons, etc.) in pp -collisions[1,2] and in e^+e^--annihilation[3] are rather attractive.

Extremely interesting results were obtained in first experiments aimed at studying large-$p_\perp$ ($0.5 \leq p_\perp \leq 3.7$ GeV/c; $\vartheta_{cM} \simeq 90^\circ$)deuteron production in pp-collisions at 70 GeV energy[2] carried out by Sulyaev's group in IHEP (Serpukhov). The fact that such friable system as the deuteron is formed in hard hadronic collisions in a rather big amount is already astonishing itself. But the most intriguing and unexpected thing turns out to be that the ratio of deuteron and proton productions is independent of $p_\perp$ (Fig. 1)!

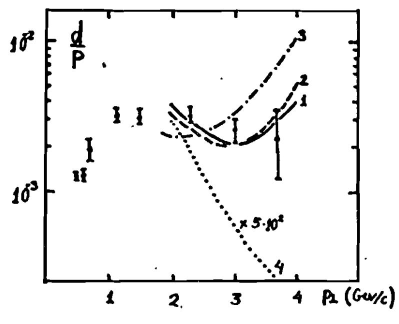
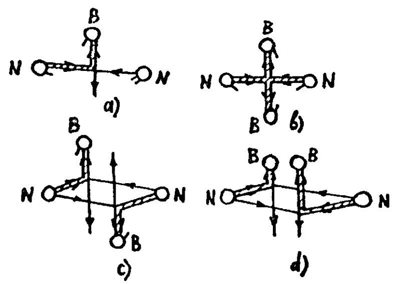


Fig. 1. The ratio of deuteron and proton productions in pp-collisions at $\vartheta_{cM} = 90^\circ$. ● - Sulyaev's group data[2]. Calculated at $\sqrt{s}$ = 11.5 GeV curves: 1 - with $\varkappa \sim 1/P^3$; 2 - with $\varkappa \sim 1/P^2$; 3 - with $\varkappa$ = const ; 4 - the predicted curves at 23.4 GeV.

In the same work[2] it is shown that the obtained data do not contradict the fusion mechanism of large-$p_\perp$ protons and neutrons produced in equal amount in pp -collisions. It is clear that a physical understanding is needed of the mechanism of nucleon pair production in one direction with close momenta which then form observed deuteron.

We propose a mechanism based on the diquark nucleon model[4-8] in which a scalar (ud)-diquark plays a dominant role, as well as on the model of simultaneous double collision of two pairs of constituents of colliding hadrons[9].

Our treatment is the following. In the $pp \to pX$ process quark-diquark (Fig.2a) and diquark-diquark (Fig. 2b) subprocesses are dominant[8,11]. In the $pp \to ppX$ symmetric proton-pair production process diquark-diquark scattering (Fig. 2b) is also important[8], though there is also a contribution from a process when a simultaneous double collision of colliding proton quarks and diquarks occurs (as is shown in Fig. 2c). It is easily seen, that the diagram shown in Fig. 2d is a contribution to the production of a nucleon-pair in one direction, i.e. the simultaneous double quark-diquark collision results in two (ud)-diquarks emitted in the same direction which form nucleons with similar momenta.



F i g. 2. The subprocesses diagrams giving contributions to the $B = N$, Λ^0 -baryon production in hard NN -collision: a) the quark-diquark subprocess; b) the diquark-diquark subprocess; c),d) the double quark-diquark collisions.

The cross section of production of such nucleon pairs with equal momenta has the following form:

$$\frac{E_p E_n d\sigma}{d^3p_p d^3p_n} \equiv \sigma_{pn} = W^2 \cdot K \cdot \int dx_1 dx_2 dy_1 dy_2 dz_1 dz_2 \, G(x_1,x_2)\, G(y_1,y_2) \frac{\hat{s}_1}{\pi}\frac{d\sigma}{d\hat{t}_1} \times$$
$$\times \delta(\hat{s}_1+\hat{t}_1+\hat{u}_1) f^2(Q_1^2) \frac{\hat{s}_2}{\pi}\frac{d\sigma}{d\hat{t}_2} \delta(\hat{s}_2+\hat{t}_2+\hat{u}_2) f^2(Q_2^2) \frac{D^p(z_1)}{z_1^2} \frac{D^n(z_2)}{z_2^2}, \qquad (1)$$

$$f(Q^2) = \frac{1}{1+Q^2/M^2}, \quad Q^2 = 2\frac{\hat{s}\hat{t}\hat{u}}{\hat{s}^2+\hat{t}^2+\hat{u}^2}, \quad \frac{d\sigma}{d\hat{t}} = -\frac{2300 \text{ mb}\cdot\text{GeV}^6}{\hat{s}\hat{t}^3},$$

where W is the probability of (ud)-diquark being in a proton; $G(x_1,x_2)$ is two-parton quark and diquark distribution function:

$$G(x_1,x_2) = 6x_1x_2\,\delta(1-x_1-x_2),$$

then[8]

$$G_d(x) = \int_0^1 dx' \, G(x,x') = 6x(1-x),$$

for simplicity we consider the quark and diquark with the total proton momentum; K is the coefficient characterising a double collision probability depending in general on the nucleon sizes, energy, etc.[9,10]; for further estimations we choose $K(\sqrt{s} = 11.5$ GeV$) = 1$ mb^{-1} and $K(\sqrt{s} = 23.4$ GeV$) = 0.25$ mb^{-1}. The choice of parametrisations of the functions and $M^2 = 12(\text{GeV}/c)^2$, $W = 0.70$ parameters in (1) is dictated by a good description of the data on large-$p_\perp$ proton and symmetric proton pair production in pp-collisions in the range from IHEP (Serpukhov) $\sqrt{s} = 11.5$ GeV energy to ISR CERN $\sqrt{s} = 62$ GeV energy[8].

Nowadays, the process of nucleon fusion to deuteron is unknown. One usually considers that the production cross section of a deuteron having p momentum out of a pair of nucleons is described by an approximate formula[12,13]:

$$\sigma_d(P) = \varkappa(P)\cdot\sigma_{pn}(P), \qquad (2)$$

where σ_d, σ_{pn} are invariant inclusive cross sections of deuteron and proton-neutron pair production, respectively; $\varkappa(p)$ is the fusion coefficient. The experimental information of $\varkappa(p)$ momentum dependence for $p < 2$ GeV/c obtained from hadron-nucleus interaction is somewhat contradictive[13], but the data for $p > 2$ GeV/c indicate a strong dependence on P: $1/p^n$, $n \gtrsim 3$[14] (though, perhaps, the mechanisms of fast deuteron production in proton-nucleus and proton-proton collisions are different).

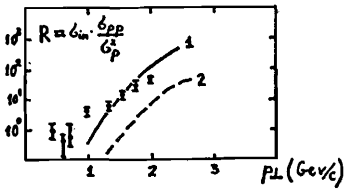
On the other hand, assuming $\sigma_p = \sigma_n$, formula (2) can be rewritten as follows/2/ :

$$\sigma_d(p) = \varkappa(p)\cdot R(P/2)\cdot\frac{1}{\sigma_{in}}\sigma_p^2(P/2), \qquad (3)$$

where $R(P)$ is the correlation coefficient:

$$R(p) = \sigma_{in}\frac{\sigma_{pn}(P)}{\sigma_p(P)\cdot\sigma_n(P)}, \qquad (4)$$

as soon as a pair of nucleons is formed independently, $R = 1$. For symmetric proton pairs ($\vartheta_{cm} = 90^\circ$, azimuthal angle $\varphi = 180^\circ$) in pp-collisions the correlation coefficient $R \sim 1$ at $p_\perp \lesssim 1$ GeV/c and exponentially increases at $p_\perp \gtrsim 1$ GeV/c /15/(Fig. 3), as one should expect, at single hard scattering of constituents, diquarks[8], and



F i g. 3. The correlation coefficient $R = \sigma_{in} \cdot \sigma pp/\sigma_p^2$ of proton pairs at $\sqrt{S}$ =11.5 GeV, $\vartheta_{cm} = 90^0$. ● - Sulyaev's group data [15] for symmetric proton pairs. Curves: 1 - φ = 180° (symmetric pairs); 2 - $\varphi \neq 180^0$.

subprotons[15,16]. In a double quark-diquark collision mechanism the correlation coefficient R for nonsymmetric pairs of protons with equal $p_\perp$($\vartheta_{cm} = 90^0$, $\varphi \neq 180^0$) also increases beginning from $p_\perp \simeq 1.5$ GeV/c (Fig. 3). At the same time the data[2] indicate that $\varkappa(P) \cdot R(P) \simeq$ const. It means that $\varkappa(P)$ sharply falls down with momentum increasing ($\sim 1/R(P/2)$) at $P \gtrsim 3$ GeV/c.

The d/p -ratio predicted at $p_\perp = 2$ GeV/c for $\sqrt{S}$ = 23.4 GeV is about 2.5 orders smaller than the d/p -ratio at $\sqrt{S}$ = 11.5 GeV (note that the d/p - ratio is falling down ($\sqrt{S}$ = 23.4 GeV) with $p_\perp$ increasing like P/π^+ -ratio ($\sqrt{S}$ = 23.4 GeV)).

Concerning the mechanisms of large-$p_\perp$ deuteron production via subprotons (in CIM[15,16]) or triple quark collision[9], it is obvious that such mechanisms give a strong d/p -ratio falling down with $p_\perp$ increasing at any energy.

For a complete understanding of deuteron production peculiarites the measurement of correlation coefficient for nonsymmetric pairs of protons ($\varphi \neq 180^0$; $\vartheta_{cm} = 90^0$) in pp-collisions is necessary. In the double quark-diquark collision mechanism one has to expect the correlation coefficient to be independent of the azimuthal angle φ outside $\varphi \approx 180^0$ region.

An absolute value of such a proton pair correlation coefficient would give knowledge about double quark-diquark collision process probabilities, as well as about two-parton quark-diquark distribution function having a more information than a conventional one-parton distribution function.

It is interesting that our mechanism of large - $p_\perp$ deuteron production in pp-collisions can be almost an ideal source for H-dihyperons (B = 2, S = -2, Q = 0)[17]. The account of strangeness suppression leads to the factor $\beta = 0.1 \div 0.3$ in the H/d = $\beta \cdot \varkappa_H / \varkappa_d$ production ratio. But the $\varkappa_H$ "fusion" coefficient for the H-dihyperon can be greater than $\varkappa_d$, because the H-dihyperon is a more bounded system (the six-quark state[17,18]) than the friable deuteron.

Actuality of the H-dihyperon search comes from the fact that some models predict the H-dihyperon stability with respect to strong decays[17-19] with lifetime $\tau \sim 10^{-8}$s[20].

There are also first indications to experimental detection of the H-dihyperon in proton-nuclei interactions[21].

SUMMARY

The proposed mechanism of simultaneous double quark-diquark collision can describe main features of large-$p_\perp$ deuteron production in pp-collisions at $\sqrt{S}$= 11.5 GeV (IHEP, Serpukhov[2]). The predictions are made for the energy $\sqrt{S}$ = 23.4 GeV.

The test of the proposed deuteron production mechanism demands the measurement of the cross section of large equal $p_\perp$ proton pair production at $\varphi \neq 180^0$. It gives information about the double quark-diquark collision role for such nucleon pair production.

The possibility of the H-dihyperon production in pp-collisions in the framework of the double quark-diquark collision mechanism is noted.

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