Comments

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Comment on diquark fragmentation

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We discuss diquark fragmentation and suggest that a spectator *uu* system in deep-inelastic lepton-nucleon scattering has a larger breakup probability than a *ud* system. The reason for this is argued to be that half of the leftover *ud* systems are in bound $(ud)_0$ diquark configurations, while no such bound *uu* diquarks exist.

Diquark fragmentation into baryons and mesons has been discussed recently by two groups.[1] They both reach the conclusion that diquark breakup must be taken into account in order to understand data from deep-inelastic lepton-nucleon scattering. These groups define a diquark as the two quarks left over in the nucleon fragmentation region when a quark has been knocked out by the projectile. In their models, no difference is made between *uu* and *ud* diquarks concerning their breakup probability. Consequently, the rate of mesons in the target fragmentation region is expected to be independent of the nature of the diquark.

When discussing diquark fragmentation it is, however, important to note that different authors seem to give widely different meanings to the word "diquark." In contrast to the definition mentioned above, several groups[2] treat diquarks as *bound* objects of two quarks, with the binding force possibly being due to the color-magnetic interaction as given by QCD. This interpretation suggests that diquarks with $S=I=0$, such as the $(ud)_0$, are less massive than their counterparts $(ud)_1$, $(uu)_1$, and $(dd)_1$ with $S=I=1$. Since one-gluon exchange results in a repulsive force in the spin-1 qq configurations, the latter are less likely to exist as bound objects.

We have recently analyzed,[3] together with Jändel, the role of diquarks in deep-inelastic lepton-nucleon scattering. Assuming that diquark form factors can account for the scaling violation in nucleon structure functions, we showed that the proton is mostly in a $u(ud)_0$ configuration. In fact, a detailed study[4] of the role of spin-1 diquarks gave the result that they most likely are "accidental." By this we mean that while the abundant $(ud)_0$ is a bound-state phenomenon, the small contribution from spin-1 diquarks could come from events where two quarks are close together in the nucleon by pure accident.

With this model of ours in mind we reserve the word diquark for the $(ud)_0$, and mean by *uu* and *ud* the systems that are left of a proton when, respectively, a *d* and a *u* quark are knocked out by the projectile.

To simplify the flavor dependence, we restrict the discussion to neutrino and antineutrino scattering on protons. In neutrino scattering, a *d* quark is knocked out, and a *uu* fragments in the backward hemisphere ($x_F < 0$), while for antineutrinos, a *u* quark is knocked out, and a *ud* is left. In our model, the *ud* could be either a $(ud)_0$ diquark, when the "isolated" *u* quark is hit, or a two-quark configuration similar to the *uu*, when the *u* quark in the $(ud)_0$ is knocked out. These possibilities occur with equal probabilities. The bound $(ud)_0$ should, however, have a *much lower breakup probability* than the *uu* or the other *ud* configuration when left to fragment in the target fragmentation region (see Fig. 1).

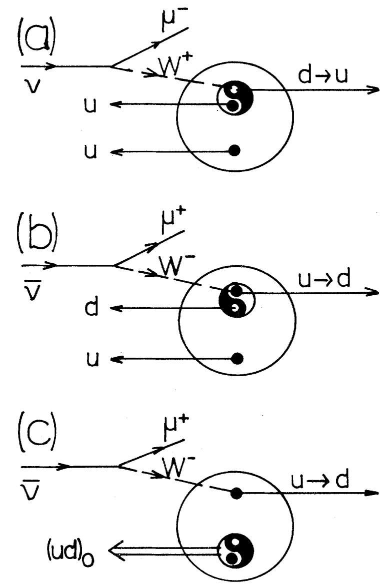

FIG. 1. Target fragmentation of a proton in deep-inelastic νp and $\bar{\nu}p$ scattering according to our diquark model of the nucleon structure (Refs. 3 and 4). We neglect the small fraction of events where a ν, or $\bar{\nu}$, knocks out a diquark in the current fragmentation region. (a) When a ν knocks out the *d* quark, the remaining *uu* system fragments into pions roughly like two independent *u* quarks. (b) When an $\bar{\nu}$ knocks out the *u* quark in the $(ud)_0$ diquark, the remaining *ud* system fragments into pions just like the *uu* system in (a). (c) When an $\bar{\nu}$ knocks out the "isolated" *u* quark, the remaining $(ud)_0$ diquark fragments roughly like *one* quark.

In order to discriminate between our picture of diquarks as bound objects and that of diquarks as nothing but the leftover quarks, we use the recent data on pion production in νp and $\bar{\nu} p$ collisions[5] to compute the suitable ratio $D_{uu}^{\pi}/D_{ud}^{\pi}$. Here D_{uu}^{π} is the fragmentation function to a charged backward pion when a d is knocked out by a ν, while D_{ud}^{π} is the same quantity when a u is knocked out by an $\bar{\nu}$. If a uu and a ud differ only in isospin this ratio must be equal to unity for all values of x_F. If, on the other hand, the ud is a bound $(ud)_0$ in every second event, the ratio $D_{uu}^{\pi}/D_{ud}^{\pi}$ should exceed one. This is so because a true diquark fragments into fewer mesons than do two quarks.

In a forthcoming work we will study the fragmentation of quarks and diquarks in detail. For the purpose of this Comment it suffices, however, to make the very rough estimate that a $(ud)_0$ diquark fragments into pions like *one* of the u quarks in the uu system. The pions are created in the color field of a backward-going constituent, and should not depend much on whether this is a colored quark or an anticolored diquark. The $(ud)_0$ is, on the average, twice as energetic as one of the u quarks in the uu pair, when counted in the c.m. system of the final hadrons. The effect of this excess energy for pion production is, however, compensated by the fact that the $(ud)_0$ has to give a leading (backward) baryon, since it (by definition) does not break up. There is no such requirement for an unbound uu system, and the baryon from a νp collision can therefore be softer, and leave more energy to the fragmentation into pions. Consequently, we expect a uu system to fragment like two quarks, while a ud fragments like two quarks only in half the events and approximately like one single quark in the other half. Summing up the contributions, we get

$$D_{uu}^{\pi}/D_{ud}^{\pi} \approx \frac{1\times 2}{(0.5\times 2)+(0.5\times 1)} = \frac{4}{3} ,$$

which could not be expected to be valid at $x_F \approx 0.5$ or above, i.e., close to the "mean" phase-space boundary of two independent quark jets and the "effective" boundary of the $(ud)_0$. There might also be complications at $x_F \approx 0$, where other than clean constituent effects might contribute.

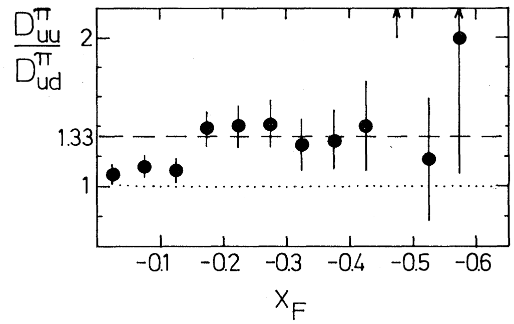

FIG. 2. Comparison of the expectation $D_{uu}^{\pi}/D_{ud}^{\pi} \approx \frac{4}{3}$ from our diquark model, as illustrated by Fig. 1, the expectation $D_{uu}^{\pi}/D_{ud}^{\pi} = 1$ from the model of Ref. 1, and the experimental data of Ref. 5. The momentum variable x_F is the scaled quantity $p_L^*/p_{L\,\max}^*$, where p_L^* is the pion longitudinal momentum in the center-of-mass system of all final-state hadrons.

The data[5] are plotted in Fig. 2 and compared with the two model results $D_{uu}^{\pi}/D_{ud}^{\pi} = 1$ for leftover diquarks[1] and $\frac{4}{3}$ for our model with a $(ud)_0$ diquark only. It can be seen that data favor our approach, but that more accurate results would be necessary to make this fairly clean probe of diquark effects more conclusive.

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[1] U. P. Sukhatme, K. E. Lassila, and R. Orava, Phys. Rev. D 25, 2975 (1982); A. Bartl, H. Fraas, and W. Majerotto, *ibid.* 26, 1061 (1982). See also M. Fontannaz, B. Pire, and D. Schiff, Phys. Lett. 77B, 315 (1978) for a similar view on diquarks.

[2] See, for instance, Z. Dziembowski, W. J. Metzger, and R. T. Van de Walle, Z. Phys. C 10, 231 (1981); P. V. Landshoff, rapporteur talk at the International Conference on High Energy Physics, Lisbon, 1981, Cambridge Report No. DAMTP 81/22, 1981 (unpublished); L. V. Laperashvili, Yad. Fiz. 35, 742 (1982) [Sov. J. Nucl. Phys. 35, 431 (1982)], and references therein.

[3] S. Fredriksson, M. Jändel, and T. Larsson, Z. Phys. C 14, 35 (1982).

[4] S. Fredriksson, M. Jändel, and T. Larsson, Z. Phys. C (to be published).

[5] P. Allen *et al.*, Nucl. Phys. B214, 369 (1983).