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Indications of hard diquarks in e^+e^- annihilation

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It is suggested that very small spin-0 diquarks are directly produced in e^+e^- annihilation and then fragment into leading baryons and other hadrons. The most influential diquark is the charmed diquark (uc), due to its high charge. It gives a sizable contribution to the hadronic R factor and to the two-jet angular distribution in the energy region $W = 4$—8 GeV. At these energies, a careful study of Λ production would provide the best additional test of the model.

I. INTRODUCTION

Recently, we have suggested in several publications[1–5] that diquarks are responsible for many interesting trends in high-energy data. In this paper we continue the analysis along these lines by investigating the role of diquark-antidiquark $(D\bar{D})$ production in e^+e^- annihilation. We then refer to those $D\bar{D}$ pairs that are directly produced by the virtual photon, in contrast to the "vacuum" pairs created in the color field of a produced quark-antiquark $(q\bar{q})$ pair. The latter case has been studied by us earlier.[3]

Obviously, the direct process $e^+e^- \to D\bar{D}$, followed by the D and $\bar{D}$ fragmenting into hadrons, can be of importance only if the diquarks are pointlike enough to compete with the dominating quark process $e^+e^- \to q\bar{q}$. In most theoretical analyses of e^+e^- annihilation such $D\bar{D}$ pairs are neglected, either because they are supposed not to exist at all, or because the diquarks are considered so large that they are suppressed by very small form factors. There are, however, a few suggestions in the literature that directly produced diquarks might give measurable effects,[6–9] but no effort has been made to probe their relative importance or sizes by analyzing the data.

Such an analysis can be made in a fairly straightforward way, however. As an input for predictions we will use only the particular diquark model that we derived earlier when analyzing the data on deep-inelastic lepton-nucleon scattering.[1,2] This will result in a reproduction of the data on the hadronic R factor, $\sigma(e^+e^- \to \text{hadrons})/\sigma(e^+e^- \to \mu^+\mu^-)$, as well as predictions for the two-jet angular distribution and the baryon yields; all as functions of the total e^+e^- collision energy W. We will not make any attempt to get a better fit to data by adding perturbative QCD corrections. Instead we follow the philosophy discussed in Ref. 5. There we noted that data from, for instance, deep-inelastic lepton-nucleon scattering can be reproduced both with perturbative QCD effects only and with nonperturbative diquark effects only, and hence with any mixture of the two. Any admixture of diquark effects would therefore mean that there is a lower "need" for a gluonic correction, and hence that the strong coupling constant is lower than the values extracted from conventional perturbative QCD fits to those data. Consequently, it seems most straightforward to take the diquark concept to its limits by neglecting perturbative QCD corrections to the processes under study. By concentrating, in addition, on the features where diquarks would give particularly clear signatures that would be hard to understand as coming from gluons, one will (we hope) be able to find out whether diquarks exist or not as dynamical objects.

II. THE DIQUARK MODEL

The main assumption in our diquark model is one of simplicity, namely, that genuine diquarks, i.e., dynamically bound two-quark states, appear only as spin-0 objects, which are quite small.

Our fits[1,2] to the data on deep-inelastic lepton-nucleon scattering showed that the dominant diquark in nucleons is the $(ud)_0$ with spin and isospin 0 and SU(3) color representation $\underline{3}^*$. Spin-1 configurations of two quarks give non-negligible contributions due to the high electric charge of a uu pair. Such two-quark systems turn out, however, to be so rare, heavy, and large that we guess they are accidental in nucleons, i.e., they do not appear as bound objects. Instead they couple to the incoming photon only "by accident" when the single quark happens to be so close to one of the quarks in the genuine diquark that the photon cannot dissolve the unbound two-quark system. Hence, spin-1 diquarks do not appear in e^+e^- reactions.

The $(ud)_0$ seems to have an electromagnetic form factor of the type

$$F_{(ud)_0}(Q^2) = (1 + Q^2/M^2)^{-1} \quad \text{for spacelike } Q^2 > 0 \; , \qquad (1)$$

with $M^2 \approx 10$ GeV^2, corresponding to a very small diquark.

When probing this model further by confronting it with data on diquark fragmentation in neutrino-proton scattering, two of us found[4] that the $(ud)_0$ does not seem to break up when fragmenting into hadrons. We therefore assume that a spin-0 diquark always ends up inside a baryon (neglecting possible diquark-antidiquark bound states).

In our earlier study[3] of the influence of spin-0 $D\bar{D}$ pairs created in the color field of a fragmenting quark we found a best-fit value of only 225 MeV for the $(ud)_0$ mass and of 450 MeV for the $(us)_0$ and $(ds)_0$ masses. These are the values needed to explain the yield of slow baryons in e^+e^- annihilation. The 225 MeV also happens to be the value needed for reproducing the proton mass in the MIT bag model if the proton is treated as a bag with a massless u quark and a massive $(ud)_0$ diquark.

Before studying directly produced $D\bar{D}$ pairs, we can summarize the assumptions of importance for e^+e^- annihilation:

(i) The only diquarks of relevance are those with spin 0 and color $\underline{3}^*$. We neglect, for simplicity, the possibility of orbital or color excitations.

(ii) The scalar diquarks stay together and end up in baryons. Directly produced diquarks therefore give rise to leading baryons.

(iii) The size of the $(ud)_0$ corresponds to a size parameter of about 10 GeV^2 in the spacelike elastic form factor.

When extending the model to the direct process $e^+e^- \to D\bar{D}$, there is one feature that will dominate the predictions, namely, the appearance of heavier spin-0 diquarks at high energies. The diquarks are, in order of increasing mass, the $(ud)_0$, $(us)_0$, $(ds)_0$, $(uc)_0$, $(dc)_0$, $(sc)_0$, $(ub)_0$, $(db)_0$, $(sb)_0$, and $(cb)_0$.

The cross section for producing a certain $D\bar{D}$ pair in $e^+e^- \to D_i\bar{D}_i$ can be determined from the charge (squared), mass, and timelike form factor of the diquark D_i. As far as the charges are concerned, it is obvious that the charmed diquark $(uc)_0$ with $e_D{}^2 = 16e^2/9$ is of a particular interest.

To estimate the diquark masses, we start with the 225 MeV mentioned above for the $(ud)_0$. Then we assume that the heavier ones can be computed by just adding the quark mass differences when one or more of the quarks in the $(ud)_0$ are changed into a heavier quark. For the quark masses we take the values

$$m_u = m_d = 0\ ,\quad m_s = 225\ \text{MeV}\ ,\quad m_c = 1.5\ \text{GeV}\ ,$$

and (2)

$$m_b = 4.5\ \text{GeV}\ .$$

This leads to the diquark masses given in Table I. Our final results do not depend much on the detailed diquark masses.

The crucial point for computing the diquark contribution to e^+e^- annihilation is naturally the timelike form factor of the heavier diquarks. The only independent piece of information we have is the empirical relation (1) for the spacelike form factor. It is not possible to continue this relation in a unique way to the timelike region $W^2 = -Q^2 > 0$, since we do not know the exact dynamics in the diquark system. As long as there are no resonances in the $D\bar{D}$ system the form factor should fulfill $F(W^2) \le 1$, and then naturally $F(W^2) \to 0$ as $W \to \infty$.

There are reasons to believe that the falloff in $F(W^2)$ with rising W would be somewhat slower than that of $F(Q^2)$ with rising Q^2 in the spacelike region. First, this is true at intermediate W values for the straightforward analytic continuation of the expression in (1). Then one might argue that the mass parameter $M^2 = 10$ GeV^2 does not reflect the size of a "naked" $(ud)_0$ diquark, but rather of a $(ud)_0$ that is disturbed by the third quark in the nucleon. The $(ud)_0$ would then be even smaller in e^+e^- reactions than inside the nucleon. We try to take these points into account by using the simplest possible expression for the form factor of the diquark D_i:

TABLE I. The quark and diquark parameters used in Eqs. (4), (9), and (10). The particular choices are motivated in the text. Isospin symmetry has been assumed. The charge is in units of e.

Quarks and diquarks	Mass m_i (GeV)	Parameter $M_i{}^2$ (GeV^2)	(Charge)^2 summed
u,d	0		$\frac{5}{9}$
s	0.225		$\frac{1}{9}$
c	1.500		$\frac{4}{9}$
b	4.500		$\frac{1}{9}$
$(ud)_0$	0.225	10	$\frac{1}{9}$
$(us)_0,(ds)_0$	0.450	40	$\frac{5}{9}$
$(uc)_0,(dc)_0$	1.725	40	$\frac{17}{9}$
$(sc)_0$	1.950	$150-\infty$	$\frac{1}{9}$
$(ub)_0,(db)_0$	4.725	40	$\frac{5}{9}$
$(sb)_0$	4.950	$150-\infty$	$\frac{4}{9}$
$(cb)_0$	6.275	$150-\infty$	$\frac{1}{9}$

$$F_i(W^2) = \begin{cases} 1 \ \text{at}\ 4m_i{}^2 < W^2 \le M_i{}^2\ , \\ M_i{}^2/W^2 \ \text{at}\ M_i{}^2 < W^2\ . \end{cases} \tag{3}$$

Taking $M_i^2 = 10$ GeV^2 for the $(ud)_0$, it remains to find the $M_i{}^2$ values for the heavier diquarks. The $M_i{}^2$ is obviously related to the rms radius of the diquark through

$$M_i{}^2 \propto \langle r^2 \rangle_i{}^{-1}\ . \tag{4}$$

Finally, we make the simplifying assumption that this radius is inversely proportional to the reduced mass of the two-quark system, just like in a nonrelativistic Coulomb system. Hence,

$$(\langle r^2 \rangle_i)^{1/2} \propto \mu^{-1}\ , \tag{5}$$

where

$$\mu = m_{q1} m_{q2}/(m_{q1} + m_{q2})\ , \tag{6}$$

and m_{q1} and m_{q2} are the masses of the two quarks in the diquark. Equations (5) and (6) do not apply to massless quarks. By giving the u and d quarks some small masses $(\ll m_s)$ we can, however, get the simple result

$$M_{us}{}^2 = M_{ds}{}^2 = M_{uc}{}^2 = M_{dc}{}^2 = M_{ub}{}^2 = M_{db}{}^2 = 40\ \text{GeV}^2\ . \tag{7}$$

This corresponds to the well-known result that a light-heavy two-particle Coulomb system has half the Bohr radius of a light-light system. Still, the reference to a nonrelativistic Coulomb system is naturally vague, and one could therefore regard Eq. (7) as nothing but a reasonable guess. As it will turn out, the only M^2 to be probed by the data is the $M_{uc}{}^2 (= M_{dc}{}^2)$ due to the high charge of the $(uc)_0$.

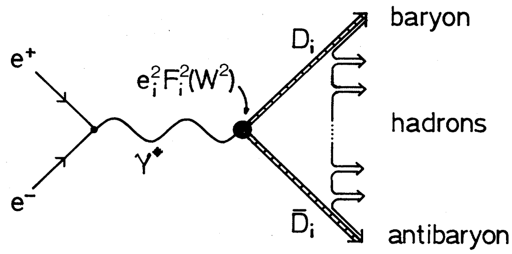

FIG. 1. The process $e^+e^- \to D_i\bar{D}_i$ in the one-photon approximation, followed by the diquark-antidiquark pair fragmenting into final-state hadrons. The photon-diquark coupling is determined by the diquark charge and timelike form factor.

With practically massless u and d quarks, all the diquarks that are not given in Eq. (7) will have higher M^2 values. There are no reasons to believe, though, that the $(sc)_0$, $(sb)_0$, and $(cb)_0$ diquarks are pointlike at, for instance, DESY PETRA energies $W \lesssim 40$ GeV, and we will therefore present results for a range of M^2 values for these diquarks. The parameters of the model are collected in Table I.

III. THE HADRONIC R FACTOR

Now we are ready to analyze the consequences of the diquark diagram in Fig. 1. The theoretical derivation of the cross section, in the one-photon approximation, for the process $e^+e^- \to D\bar{D}$ with scalar, pointlike D and $\bar{D}$ can be found in, for instance, Ref. 6. The contribution from the pair $D_i\bar{D}_i$ to the ratio

$$R = \sigma(e^+e^- \to \text{hadrons})/\sigma(e^+e^- \to \mu^+\mu^-) \tag{8}$$

then reads, for extended scalars,

$$\Delta R_{D_i} = \tfrac{3}{4} e_i^2 \left[1 - \frac{4m_i^2}{W^2}\right]^{3/2} F_i^2(W^2) \,. \tag{9}$$

Here the factor 3 comes from summing over colors, the $\frac{1}{4}$ from the spin 0 and the $(1-4m_i^2/W^2)^{3/2}$ from the kinematic threshold effect. The corresponding formula for the quark process $e^+e^- \to q_i\bar{q}_i$ is

$$\Delta R_{q_i} = 3e_i^2 \left[1 - \frac{4m_i^2}{W^2}\right]^{1/2} \left[1 + \frac{2m_i^2}{W^2}\right] . \tag{10}$$

The muon mass has been neglected in (9) and (10).

In Fig. 2 we plot R as the added contributions from (9) and (10) for the parameter values given in Table I. It can be seen that the agreement with data[10] is quite good. There are obviously three rather distinct regions in the energy W, and we discuss them separately below.

(i) The region $W \lesssim 3.5$ GeV. Here there are only light diquarks, which are not very influential. In addition, the data are not so accurate, and the fit is therefore less conclusive.

(ii) The region $3.5 \lesssim W \lesssim 15$ GeV. This is where the charmed diquarks appear and are predicted to contribute significantly to R, which explains the broad bump at $5 \lesssim W \lesssim 8$ GeV in the data of Ref. 11. Various other explanations of this structure were considered in Ref. 12, but none of those was found to be plausible. It should be noted, though, that Ref. 13 quotes some conflicting, but unpublished, data[14] as evidence against a bump in R. The difference between Refs. 11 and 14 is hard to analyze, since both data sets have been subject to several substantial systematic corrections, some of which are model dependent.

(iii) The region $W \gtrsim 15$ GeV. Here the quark contribu-

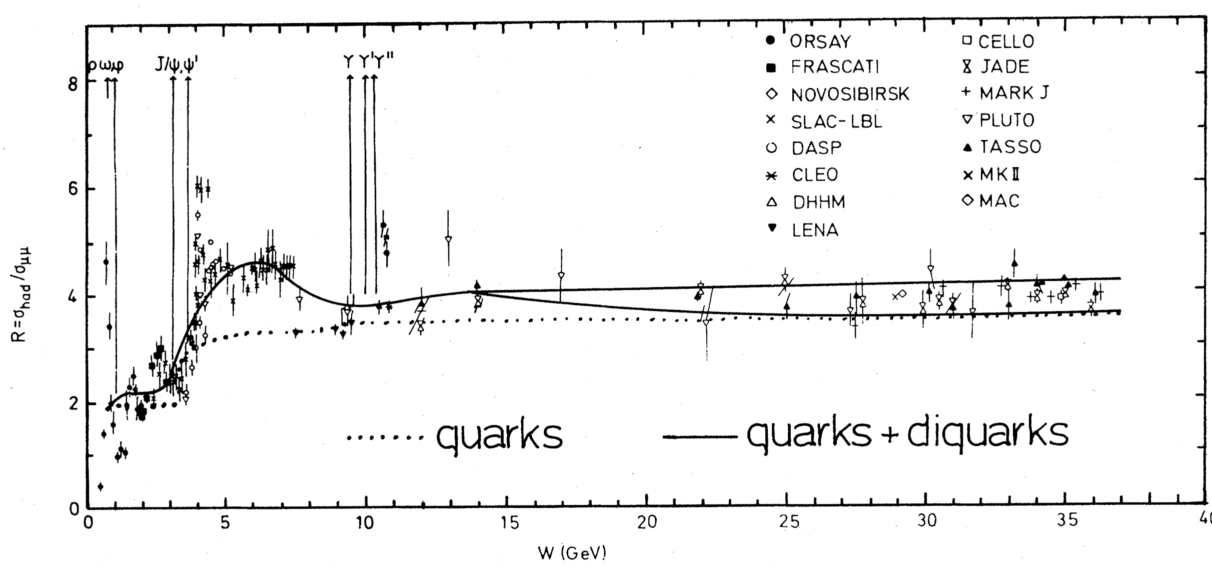

FIG. 2. The hadronic R factor defined by Eq. (8). The data points are taken from the collection in Ref. 10. The dotted line shows the contribution from quark-antiquark pairs, and the full lines display the added cross sections for quark-antiquark and diquark-antidiquark pairs; all according to Eqs. (9) and (10) with quark and diquark parameters taken from Table I. The two lines at energies $W > 14$ GeV show the range in R values consistent with the uncertainty in size parameters for the heaviest diquarks, as given in Table I. However, as argued in the text, data on, for instance, the two-jet thrust axis angular distribution give indirect support to the lower curve, representing a suppression of $D\bar{D}$ events at high W values.

tion underestimates the data with about 7% on the average. The error bars are, however, of the same order. It is therefore not meaningful to fit the "tail" of the almost pointlike diquark distributions to the data in this W region. On one hand, one could get a ΔR of around 10% by assuming that the $(sb)_0$ and $(cb)_0$ are pointlike all the way up to the highest energies, but it is, on the other hand, more likely that this excess in R is due to the events that show a three-jet structure. Presumably, the $D\bar{D}$ events can therefore be neglected at $W \gtrsim 15$ GeV. This naturally also applies to possible diquarks with the top quark.

IV. THE TWO-JET ANGULAR DISTRIBUTION

With the help of Eqs. (9) and (10) it is easy to compute the angular distribution of hadronic events as fitted to a two-jet structure. Taking θ as the cms angle between the beam and jet directions, the scalar diquark jets in $e^+e^- \to D\bar{D}$ are distributed like $1-\cos^2\theta$, while the quark jets from $e^+e^- \to q\bar{q}$ follow the familiar $1+\cos^2\theta$ distribution (neglecting a small 1-$\cos^2\theta$ contribution just above the $q\bar{q}$ thresholds).

When fitting the data to a two-jet (thrust axis) angle distribution of the form

$$f_{2\,\text{jet}}(\theta) \propto 1+\alpha\cos^2\theta \;, \tag{11}$$

our model therefore predicts that the parameter α is related to the contribution from diquarks to the total hadronic cross section through the relation

$$\alpha = -3+4[1+\sigma(e^+e^- \to D\bar{D})/\sigma(e^+e^- \to \text{hadrons})]^{-1} \;. \tag{12}$$

We compute α from Eqs. (9) and (10) and display the result in Fig. 3 for W values below 15 GeV, together with the experimental results at 4.8—7.4 GeV (Refs. 11 and 15), 9—10 GeV (Ref. 16), and 10.5 GeV (Ref. 17). The error bars show statistical uncertainties only. The data points illustrated by unfilled circles at $W \leq 7.4$ GeV have been extracted by us from the data of Refs. 11 and 15.

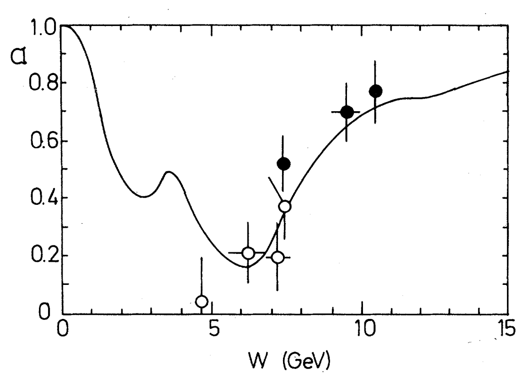

FIG. 3. The jet (thrust axis) angular distribution in two-jet events, when parametrized as $1+\alpha\cos^2\theta$. The filled data points are from Ref. 15 (7.4 GeV), Ref. 16 (9—10 GeV), and Ref. 17 (10.5 GeV), the unfilled ones from our analysis of the data of Refs. 11 and 15, as explained in the text. The curve shows the expectation from quark and diquark reactions through Eq. (12). Quark reactions alone would lead to $\alpha=1$ (neglecting kinematic mass corrections and gluon processes).

We have simply averaged the data[15] on the charged-hadron $\alpha(x)$ over $x = 2p_{\text{had}}/W$ with the help of the data[11] on $d\sigma/dx$. We have not considered the smearing effect of quark and diquark fragmentation on the hadronic angular distribution. The filled circle at 7.4 GeV shows the result of a jet analysis with polarized beams in Ref. 15. That value should not be mixed up with the result "$\alpha = 0.97 \pm 0.14$" presented in Ref. 15, which is achieved after a jet-model Monte Carlo simulation of $\alpha(x)$. Then 0.97 ± 0.14 is the limit of $\alpha(x)$ as $x \to 1$. This represents the angular distribution of the partons that give rise to the fastest hadrons. These partons cannot be diquarks though, since a diquark always gives a massive baryon. At 7.4 GeV this rest mass effect limits x to values below around 0.75.

It is interesting to note that no significant deviation from $\alpha=1$ has been found above 15 GeV.[10] This seems inconsistent with the 10% admixture of diquarks needed for a best fit to R with two-jet diquark events only. Therefore we assume that all directly produced scalar $D\bar{D}$ pairs can be neglected beyond $W \approx 15$ GeV and that three-jet events are responsible for the 7% excess in R over the $q\bar{q}$ contribution. In a forthcoming publication we will discuss in detail a model for three-jet events suggested by us in Ref. 5. There we pointed out that if there is a substantial number of events like $e^+e^- \to D\bar{D}$, there should also be events with *unbound* two-quark systems in $e^+e^- \to qq\bar{D}$ and $e^+e^- \to \bar{q}\bar{q}D$. Such three-jet events would have some very distinct signatures and therefore deserve an analysis of their own. For the purpose of this work it suffices to note that a qq or $\bar{q}\bar{q}$ pair should have $J=1$ and a high effective mass in order to explain why these events survive at high energies but still do not give a $1-\cos^2\theta$ contribution when analyzed as two-jet events.

V. BARYON PRODUCTION

The yields and momentum spectra of produced baryons are ideal measures of the influence of diquarks in hadron-hadron, lepton-hadron, and e^+e^- reactions. The quark recombination model of Ref. 18, where three independent quarks join to form a baryon, can explain only a minor fraction of the baryon yields. In the improved quark-recombination scheme of Ref. 19 it has, however, been found that the size of the baryon yields is quite compatible with experimental observations. Detailed comparison with the data is, however, not possible due to the assumed flavor SU(3) symmetry of this approach. Many models contain, therefore, the assumption that baryons are created only when a $D\bar{D}$ pair appears during the fragmentation of a q or a $\bar{q}$. Such baryons are produced on the 8% level all over phase space. As mentioned earlier, the data here can be understood within our model[3] with the help of light $(ud)_0$, $(us)_0$, and $(ds)_0$ diquarks, and their antidiquarks, while the heavier diquarks are strongly suppressed. The contribution from the directly produced $D\bar{D}$ pairs, which are quite important in our approach, has some strikingly different properties, however.

In Ref. 8, Meyer tested a scheme for baryon production, which in our language would correspond to pointlike direct diquarks produced in 7.5% of the hadronic e^+e^-

reactions. Without specifying the possible quantum numbers or couplings of such diquarks, Meyer concluded that data on baryon production at 30—34 GeV e^+e^- energy are not accurate enough to establish such a 7.5% contribution. If our diquark parameters, as given in Table I, are correct, it would, however, be wiser to test this idea with accurate baryon data at energies of 4—8 GeV. A glance at Fig. 2 shows that here we expect up to 30% of the hadronic events to contain a baryon-antibaryon pair that has been created from a direct $D\bar{D}$ pair.

It is not possible to measure separately the contribution from direct diquarks, since they mix at all angles and momenta with the ones created from the color fields. Nevertheless, these two contributions to the yields of baryons have very different detailed features. We list these properties below.

(i) The number of baryons per event from vacuum $D\bar{D}$ pairs is roughly proportional to the number of produced pions all over phase space. Baryons from direct $D\bar{D}$ pairs appear, however, according to Eq. (9).

(ii) The quantum-number dependence is quite different in the two components. This is most apparent for charmed baryons. Charmed diquarks are too heavy to be created during the quark fragmentation, and therefore appear only as directly produced objects. The Λ_c, for example, could therefore be composed either of a direct c quark and a $(ud)_0$ diquark from the vacuum, or of a direct $(uc)_0$ or $(dc)_0$ and a d or u quark from the vacuum. In both cases the Λ_c is the leading particle in the jet, but the angle and W dependence of the two components will be very different.

(iii) The angle dependence is, in accordance with the previous discussion, roughly $1+\cos^2\theta$ for baryons from quark jets, but $1-\cos^2\theta$ from diquark jets.

(iv) The baryon-antibaryon correlation is also radically different in the two components. Vacuum $D\bar{D}$ pairs are created in the vacuum with little internal energy, and therefore come out in baryon-antibaryon pairs that are close in phase space. A direct $D\bar{D}$ pair, however, carries the full initial energy, and gives rise to a baryon and an antibaryon that are correlated back-to-back in angle.

(v) The baryon momentum distribution is more shifted toward high momenta for the direct component as compared to the indirect one, since a direct diquark always gives a leading baryon, while a vacuum diquark is slower on the average.

Detailed numerical predictions for the average number and momentum distribution of various baryons are outside the scope of this work, since they would require further assumptions about how quarks and diquarks fragment into hadrons. As has been demonstrated clearly enough in the literature, already the treatment of quark fragmentation requires quite complex Monte Carlo computer programs with numerous adjustable parameters. In addition, one would have to take into account that different baryons are detected by completely different techniques, with different sensitivities for, especially, the fast baryons that are of interest for probing the influence of the direct diquarks. The best case seems to be Λ production, because a large fraction of the Λ's should come from the crucial Λ_c decay.[20] The admixture of such decay products among the directly produced Λ's is, however, poorly known. Therefore, we list a few particularly clear *qualitative* trends that we expect in Λ production. These trends would, if confirmed, be practically impossible to understand in terms of vacuum $D\bar{D}$ pairs alone, and naturally also in terms of quark and gluon processes alone. The entries below are the same as in the previous list of properties.

(i), (ii) The number of Λ's per event should rise monotonously with W due to the vacuum $D\bar{D}$ pairs and the increase in phase space, but should on top of that have a clear structure in the energy region 4—8 GeV due to the decay of Λ_c's from direct diquarks. Such direct Λ_c's are expected to be about ten times as many at $W\approx 6$ GeV as from vacuum diquarks, which in turn implies that the mean number of Λ's per event is expected to be *several times* higher at 6 GeV than at somewhat higher energies.[21]

(iii) The angle distribution of Λ's at $W\approx 6$ GeV will consequently be dominated by the $1-\cos^2\theta$ component, so that the yield of Λ's will *increase* with outgoing angle and have a maximum at 90°. This feature will be particularly clear if measured for fast Λ's.

(iv) The $\Lambda-\bar{\Lambda}$ correlation at $W\approx 6$ GeV is expected to be dominated by the back-to-back effect in the direct $D\bar{D}$ pair. The distribution in the $\Lambda\bar{\Lambda}$ opening angle, $\theta_{\Lambda\bar{\Lambda}}$, will have a rather broad peak at $\theta_{\Lambda\bar{\Lambda}}=180°$ though, since the decays of the original back-to-back Λ_c and $\bar{\Lambda}_c$ lead to a smearing in the outgoing Λ and $\bar{\Lambda}$ directions.

(v) The Λ momentum distribution will be more extended toward higher momenta at $W\approx 6$ GeV than at other energies and than for other produced particles (such as pions).

It should be noted that current data on Λ production except those of Ref. 21, are taken at $W \gg 6$ GeV and therefore of no use for testing these predictions.

VI. CONCLUSIONS

We have shown that the present data from e^+e^- annihilation into hadrons leave room for the existence of very small spin-0 diquarks that can be produced directly from the virtual photon. When treated as elementary objects with a spatial extension described by a form factor, they are predicted to leave traces in several different connections. The main effect will be in the energy region $W=4$—8 GeV and come from the charmed diquarks $(uc)_0$, $(dc)_0$, and $(sc)_0$. Since they are expected to appear in baryons like the Λ_c (and Ξ_c), which decay frequently into Λ, the most crucial experimental test of the existence of small scalar diquarks would be to measure as many properties as possible of Λ production at $W\approx 6$ GeV.

Most of the trends predicted in the preceding paragraphs would, if confirmed, be hard to understand in terms of perturbative gluonic reactions, and would support the view that there are important nonperturbative effects in the form of diquark formation. That would naturally also have far-reaching consequences for the interpretation of other data within perturbative and nonperturbative QCD schemes.

ACKNOWLEDGMENT

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