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BARYON-ANTIBARYON ANGULAR CORRELATIONS IN QUARK JETS*

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ABSTRACT

The azimuthal angular distribution of baryon-antibaryon pairs in a quark jet is calculated and compared with experimental data in e^+e^- annihilation.

The study of baryon production[1] in high-energetic quark jets is important because it gives more insight into the mechanism of quark hadronization. Many phenomenological models of quark fragmentation describe baryon production by the creation of a diquark-antidiquark pair in the color field[2],[3],[4]. An interesting and important consequence of such a picture is the prediction of correlations between the baryon and the antibaryon which must also be produced. Two experimental groups at PETRA have already measured such baryon-antibaryon correlations[5],[6]. They looked for the distribution of $p - \bar{p}$ pairs in azimuthal angle ϕ, where, more precisely, ϕ is the angle between the transverse momenta of p and $\bar{p}$ when all particle momenta are projected onto a plane perpendicular to the jet axis. If the diquark mechanism dominates one would expect most $p - \bar{p}$ pairs be near $\phi = 180^o$.

A calculation of this azimuthal angular distribution of baryon-antibaryon pairs has been done by H. Fraas, H. R. Gerhold, W. Majerotto and myself[7]. The basic assumption entering is that the transverse momenta of the created diquark and antidiquark are locally compensated. As the diquark is most probably not just a pointlike object one has to allow also for "break-up." We do this by assigning a probability p_3 that the first particle emitted from the diquark is a meson, and a probability p_4 that the first particle emitted is a baryon, with $p_3 + p_4 = 1$ (see also Ref. 4 for the definition of p_3 and p_4).

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If there were no diquark break-up (i.e. $p_3 = 0$), then the baryon and the antibaryon would be produced as neighbors in rank and would have the strongest correlation. Let us call $W_0(\phi)$ the azimuthal angular distribution of baryon-antibaryon pairs obtained in this case. If, on the other hand, at least one meson is emitted in rank between the baryon and the antibaryon, then this correlation is completely lost and the azimuthal angular distribution of the pairs is flat. Since the first case occurs with probability $p_4 = 1 - p_3$, in general we obtain for the baryon-antibaryon angular distribution

$$W(\phi) = (1 - p_3)\, W_0(\phi) + p_3\, \frac{1}{2\pi} \tag{1}$$

when the normalization convention $\int_0^{2\pi} W(\phi)\, d\phi = 1$ is used. The form of Eq. (1) remains valid even if the baryon and the antibaryon are decay products of resonances. Resonance decay can change at most the shape of the function $W_0(\phi)$. Moreover, Eq. (1) is independent of the flavor of the initial quark as well as of the baryon and antibaryon. The only approximation made is that multiple baryon production is neglected. This is fulfilled to good accuracy for presently available energies.

The function $W_0(\phi)$ entering Eq. (1) has been calculated in Ref. 7. Assuming a Gaussian distribution for the transverse momentum dependence for the quark and the diquark, where the parameters σ_q, σ_d may be different, one obtains

$$W_0(\phi) = \frac{\alpha(\alpha+2)}{2\pi(\alpha+1)^2} \sum_{n=0}^{\infty} \frac{[\Gamma(\frac{1}{2}\, n + 1)]^2}{n!} \left(-\frac{2\cos\phi}{\alpha+1}\right)^n \tag{2}$$

with $\alpha = (\sigma_q/\sigma_d)^2$. It is interesting to notice that this is the only parameter on which $W_0(\phi)$ depends. In Fig. 1 $W_0(\phi)$ is shown as it follows from Eq. (2) for $n_{\max} = 20$, for $\alpha = 1$ and $\alpha = (0.35/0.5)^2 = 0.49$. Also shown in Fig. 1 is $W_0(\phi)$ resulting from a Monte Carlo calculation including resonance decay, for $\alpha = 1$. From the agreement with the expression (2) one can conclude that resonance decay is not very important for the shape of $W_0(\phi)$. This can be understood because the baryon resulting from a resonance decay gets most of the momentum.

We tried to compare in Fig. 2 our results with the data on the $p - \bar{p}$ angular distribution obtained by the JADE[5] and the TASSO collaboration[6]. The JADE data [Fig. 2(a)] seem to indicate some $p - \bar{p}$ correlation with $p_3 \simeq 0.5$ being reasonable. The TASSO data[6] [Fig. 2(b)] have better statistics showing a ϕ distribution of the $p - \bar{p}$ pairs which is practically flat. According to Eq. (1) one

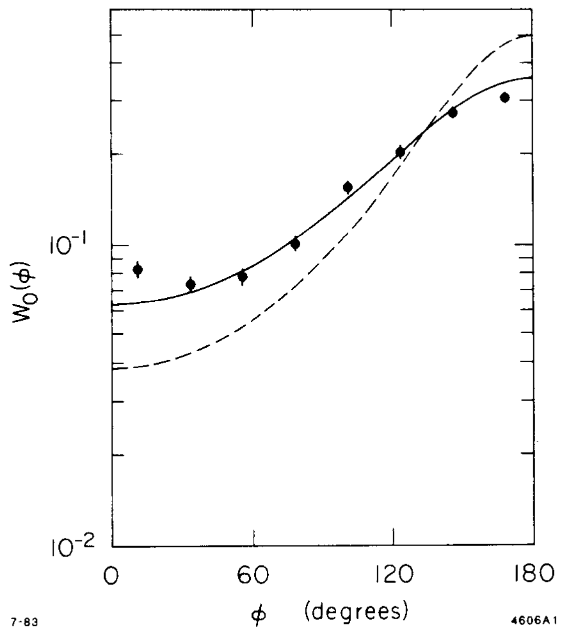

Fig. 1. $W_0(\phi)$ versus ϕ following from Eq. (2) for $n_{\max} = 20$, solid lines: $\alpha = (\sigma_q/\sigma_d)^2 = 1$, dotted lines: $\alpha = (0.35/0.5)^2$. ϕ Monte Carlo result for $W_0(\phi)$ for $\alpha = 1$ (resonance decay included).

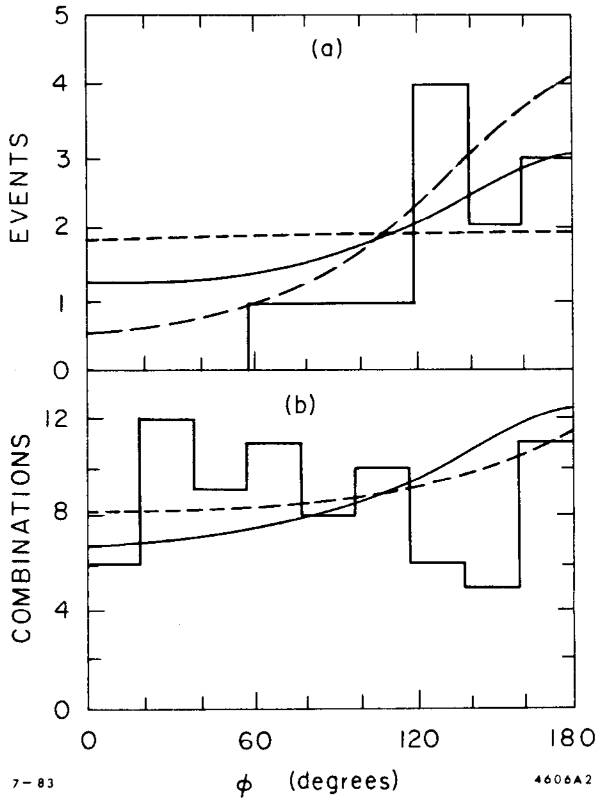

Fig. 2. Comparison of $W(\phi)$ following from Eqs. (1) and (2) ($\alpha = 1$) with experiment. (a) Data from Ref. 5, (——) $p_3 = 0.5$, (— — —) $p_3 = 0$, (- - -) $p_3 = 1$. (b) Data from Ref. 6, solid line: $p_3 = 0.5$, dashed line: prediction of the model of Ref. 3.

would be inclined to infer from this a large amount of diquark splitting, i.e. $0.5 \lesssim p_3 \lesssim 1$. The TASSO group, however, has compared its results also with the prediction of the LUND model[3] which also gives a rather flat ϕ distribution for the $p - \bar{p}$ pairs although in this model there is no diquark splitting at all (corresponding to $p_3 = 0$ in our notation). The reason for this behavior[8] lies in the manner gluon fragmentation is treated within the LUND model. In this model hadronization takes place along the color flux lines which will be distorted when a hard gluon is emitted. The Lorentz transformation necessary to go from the CMS of each string piece to the laboratory frame affects mostly the slow baryons. As the TASSO group applies a cut $|p| \leq 1.2$ GeV/c to the p and $\bar{p}$ momenta, the correlation between the p and the $\bar{p}$ becomes to a large extent washed out[8].

In order to study the nature of the diquark by means of Eqs. (1) and (2) one, therefore, needs baryon-antibaryon events in "thin" jets, i.e. quark jets which are not affected by gluon radiation. Knowing more about baryon production in quark jets one could then again consider three-jet events, obtaining in this way more detailed information about gluon fragmentation. If in a good sample of clean two-jet events the ϕ distribution of baryon-antibaryon pairs still turns out to be flat one might have to abandon the notion of the diquark at all.

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