JETS IN DEEP INELASTIC ELECTROPRODUCTION

DECO Collaboration

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ABSTRACT

Results on jet structure of the hadronic final state in electron-proton scattering are presented. The kinematic range includes $1 < Q^2 < 6$ GeV^2 and $9 < W^2 < 16$ GeV^2. The correlation between the jet axis determined with sphericity or thrust and the direction of the virtual photon is measured. Comparison with data from e^+e^--annihilation is made. A method to estimate the intrinsic transverse momentum of the quark in the target proton is presented.

In the framework of the quark-parton model the fast final state hadrons from electron-proton scattering are interpreted as quark or diquark fragments. The hadronic final state is expected to exhibit a dominant two jet structure. In its center-of-mass system these jets are collinear. The extent to which the jet axis agree with the direction of the virtual photon will depend on the intrinsic transverse momentum of the quark in the target proton.

We present results on jet structure from an electron-proton scattering experiment performed in an 11.5 GeV electron beam at the Wilson Synchrotron Laboratory. The apparatus, the main part of which was a streamer chamber, is described in Ref. 1. The kinematic region is 1 GeV^2 < Q^2 < 6 GeV^2 and 9 GeV^2 < W^2 < 16 GeV^2 ($-Q^2$, W^2 are the squares of the invariant masses of the virtual photon and the final state hadrons respectively). To suppress contributions from diffractive processes, predominantly $ep \to ep\rho^0(\to\pi^+\pi^-)$, only events with more than three charged hadrons in the final state are accepted. The quantities used are sphericity[2,3,4]

$$S = \frac{3}{2} \min\left(\sum_i p_{i\perp}^2 \Big/ \sum p_i^2 \right) \tag{1}$$

and thrust[3,5]

$$T = \max\left(\sum_i |p_{i\parallel}| \Big/ \sum_i |p_i| \right). \tag{2}$$

Since in this experiment neutral hadrons were not detected the summations in formulae (1) and (2) run only over charged hadrons.

In Fig. 1 the distribution of $|\cos\Theta|$ is shown where Θ is the angle between the sphericity or thrust axis and the direction of the virtual photon in the center-of-mass system.

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The data exhibit a strong correlation between the jet axis and the photon direction as expected. For the Lorentz-transformation to the center-of-mass system the hadrons have to be identified as pions, kaons or protons. This is done on a statistical basis using parametrizations of hadron structure functions[6]. Even when all charged hadrons are treated as pions the results remain qualitatively the same.

In Fig. 2 $<p_\perp>$ and $<p_{||}>$ of all hadrons with respect to the directions of the virtual photon and the sphericity and thrust axis are presented as function of W' where $W' = W - m_N + m_\pi \approx W - 0.8$ GeV. For comparison the results from PLUTO[3] on $<p_\perp>$ and $<p_{||}>$ relative to the thrust axis are included. The use of W' instead of W for the ep data serves as a rough correction for the kinematic effect of the final baryon. Although the ranges of W and W' covered by the e^+e^- and ep data do not overlap the figure shows clearly that the ep data continue the trend defined by the e^+e^- data when the sphericity or thrust axes are used. This does not hold however when $p_\perp$ and $p_{||}$ are defined with respect to the virtual photon direction.

The deviations of the sphericity and thrust axes from the calculated direction of the virtual photon seen in Fig. 1 and Fig. 2 may be due to several causes: a) radiative effects, b) missing neutrals, c) non-identification of protons and kaons, d) the fact that the sphericity and thrust axes are only approximations to the real jet direction at finite energies, e) transverse momentum of the quark in the target proton. In order to eliminate the first three causes for the following investigation events were selected that satisfy a kinematic 4c fit e.g. for the reaction type $ep \to ep\pi^+\pi^+\pi^-\pi^-$. To disentangle the influences of the last two causes listed above a Monte Carlo model was developed. This model is based on Field and Feynman's parametrization of quark fragmentation[7] which was found to be in

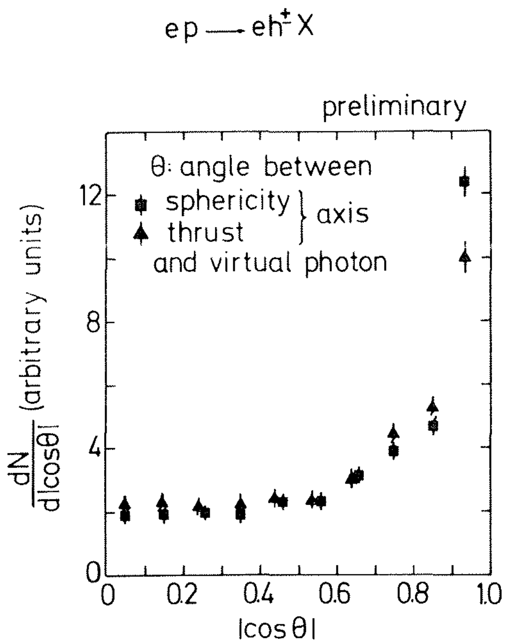

Fig. 1 The distribution of $|\cos\Theta|$ for events with more than three observed final state hadrons at $9 < W^2 < 16$ GeV^2 and $Q^2 > 1$ GeV^2.

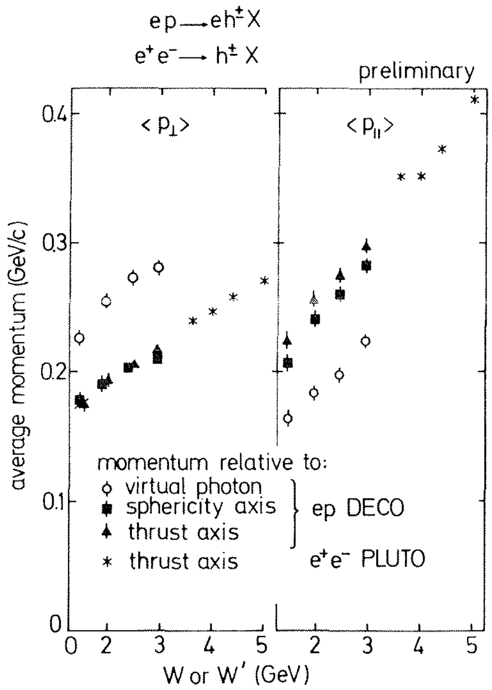

Fig.2 The average transverse and longitudinal momentum of all final state hadrons as a function of $W' = W - m_N + m_\pi$ for events with more than three observed hadrons. The PLUTO[3] data are shown as function of W.

good agreement with the pion fragmentation functions determined in this experiment[6]. It is assumed that the fragmentation of the diquark system is equal to that of the quark except for the fact that the first rank hadron is always a baryon. The quark and diquark jets with energy W/2 each and opposite directions are first calculated independently. Then the two jets are combined whereby in an iterative way the momenta of the hadrons are changed according to momentum and energy conservation[8].

Comparison between the experimental events and the results of the Monte Carlo model shows good agreement in the distributions of momenta, sphericity, $m_{\pi^+\pi^-}$, $m_{p\pi^+}$, $m_{p\pi^-}$, and $p_\perp^2$ with respect to the sphericity axis. This gives confidence that the model serves as a good description of the final hadronic system in our experiment.

On the other hand, the average angle between the direction of the parent quark and the jet axis in the Monte Carlo model comes out significantly smaller than the angle between the virtual photon direction and the jet axis in the real events. This suggests that the fragmenting quark did have a primordial transverse momentum distribution. Assuming this distribution to be of the form $\exp(-k_\perp^2/2\sigma^2)dk_\perp^2$, it is found that the most likely value for $\langle k_\perp \rangle_{quark}$ lies between 0.5 and 0.9 GeV/c (see Fig. 3).

In summary our investigation of jet structure of the hadronic final state in ep scattering provides further support for the quark-parton model. The data show a strong correlation between the direction of the virtual photon and the jet axis. The mean transverse and longitudinal momenta of the hadrons with respect to the jet axis in ep scattering and e^+e^- annihilation follow a common trend. The width of the angular distribution between virtual photon and jet direction is consistent with an intrinsic transverse momentum of the quark in the target proton of 0.7 ± 0.2 GeV/c.

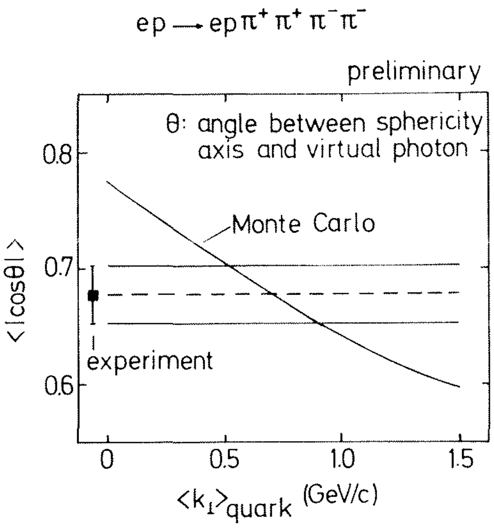

Fig.3 Comparison between the experimental result on <|cosΘ|> and a Monte Carlo model with varying intrinsic transverse momentum $k_\perp$ of the quark in the target proton.

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