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ON THE QUARK-PARTON FRAGMENTATION FUNCTIONS *

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ABSTRACT

The quark parton model for inclusive pion production in the parton fragmentation region is compared with experimental data.

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The quark-parton model together with the assumption of short-range correlations in rapidity space gives a specific description for the distribution of hadrons produced either in current-hadron collisions or in electron-positron annihilation [1, 2, 3, 4]. We want to present here a first test of the validity of this model. We will first extract the quark-parton density functions from deep inelastic lepton-hadron collisions. As a second step we extract the parton fragmentation functions from data on $e^- + p \to e^- + \pi^{\pm}$ + anything at a fixed value of $x(=1/\omega)$[5]. Combining these two pieces of information we can calculate the π^+/π^- ratio at fixed ν for increasing Q^2 and compare with experimental results from SLAC[6].

QUARK-PARTON DENSITY FUNCTIONS: Information on the quark-parton density functions can best be obtained from deep inelastic neutrino collisions. The fact that the total antineutrino-nucleon cross section is close to 1/3 of the total neutrino-nucleon cross section indicates that away from the diffraction region ($x = 1/\omega \to 0$) anti-neutron and anti-proton type quarks can be neglected [7, 8, 9, 10]. There is as yet no such clear indication that strange quarks can also be neglected away from the diffractive region, however, it would be very surprising if this were not the case. Hence, excluding the small x region, only $u(x)$ (proton-type quarks) and $d(x)$ (neutron-type quarks) are expected to be appreciable. These two functions can then be extracted from the deep inelastic electron proton and electron neutron structure functions.

QUARK-PARTON FRAGMENTATION FUNCTIONS: The fragmentation function describing the decay of a parton p into a π plus anything will be denoted $D_p^{\pi}(z)$ where z is the fraction of the momentum of the parton p in the current parton Breit frame. The quark-parton model then gives the following expressions for the $\pi^{\pm}$ distributions $N_{ep}^{\pi^{\pm}}(x, z)$ $\left(= \frac{1}{\sigma}\int \frac{d\sigma}{dz\, d^2p}\, d^2p\right)$ in electron proton scattering in the parton fragmentation region (again excluding the small x region):

$$f_1^{ep}(x)\, N_{ep}^{\pi^+}(x, z) \cong \frac{4}{9}\, u(x)\, D_u^{\pi^+}(z) + \frac{1}{9}\, d(x)\, D_d^{\pi^+}(z) \qquad (1)$$

$$f_1^{ep}(x)\, N_{ep}^{\pi^-}(x,z) = \frac{4}{9}\, u(x)\, D_d^{\pi^+}(z) + \frac{1}{9}\, d(x)\, D_u^{\pi^+}(z) \qquad (2)$$

Experimentally, scaling in the variable z seems to have been seen in the region $0.2 < z < 0.7$. We therefore have limited our analysis to this domain. Since the experiment was done at $x = 0.24$, we inserted the values $u(x=0.24)$ and $d(x = 0.24)$ obtained from ep and en scattering. For $N_{ep}^{\pi^+}(x=0.24, z)$ we took a simple exponential fit which passes through most of the data points for z between 0.2 and 0.7. For $N_{ep}^{\pi^-}(x = 0.24, z)$ the data are more uncertain and, as a first approximation, we took one half of the π^+ distribution. This provides us with a rough qualitative fit to the data. The resulting curves we obtain for $D_u^{\pi^+}(z)$ and $D_d^{\pi^+}(z)$ are shown in figure 1.

PREDICTIONS: The power of equations (1) and (2) lies in the separation of the x dependence from the z dependence. Once $N_{ep}^{\pi}(x,z)$ is known for one particular value of x, we can calculate it for all values of x excluding the small x region. In figures 2 and 3 we show the results of such a calculation for $x = 0.5$ and $x = 0.8$. A notable feature of the predictions is the strong decrease in $N_{ep}^{\pi}(x,z)$ as x increases towards 1. This is a non-trivial result because in the closely related process of pion production in neutrino-proton collisions $N^{\pi}_{\nu p}(x,z)$ is predicted to be independent of x !

TEST: As a test we have compared the π^+/π^- ratio for fixed ν and increasing Q^2 with experimental data from SLAC[6]. Because this involves an extrapolation in x, this is clearly a check on the factorization property in eqs. (1) and (2) ! The calculated curve corresponds to $\nu = 9$ GeV and z between 0.3 and 0.7 while the experimental points correspond to $4 < \nu < 14$ and z between 0.3 and 1. Because u(x) and d(x) are smooth functions in x, it is not expected that the averaging in ν will have a large effect. As can be seen by inspecting figure 4 there is no inconsistency between the calculated curve and the data although the experimental points have higher values of z included (which leads to a bigger asymmetry) and the wide range in ν brings in events with low x values (not described by equations (1) and (2)).

In conclusion we may say that the quark-parton model is at present certainly not inconsistent with existing data.

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FIGURE CAPTIONS

Fig. 1. Curves for $D_u(z)$ and $D_d(z)$.

Fig. 2. Prediction for the inclusive distribution $e^- + p \rightarrow e^- + \pi^+ +$ anything for x = 0.5 and x = 0.8.

Fig. 3. Prediction for the inclusive distribution $e^- + p \rightarrow e^- + \pi^- +$ anything for x = 0.5 and x = 0.8.

Fig. 4. Comparison between the calculated π^+/π^- asymmetry (full curve) and data points from SLAC[6].

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