QCD-EFFECTS IN JET PROFILES IN μ-p SCATTERING

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ABSTRACT

QCD-effects in jets produced in μ-p deep inelastic scattering (DIS) have been investigated. Data is found to follow the QCD-predictions including contributions from soft gluon emission. Evidence is obtained that data favour a string-alike fragmentation over an independent jet model.

1. INTRODUCTION

Besides e^+e^- collisions, deep inelastic μ-p scattering (DIS) is an appropriate process to study QCD-modifications of the simple Quark-Parton-Model predictions. The interaction of the virtual photon with the constituents of the target nucleon results in a forward quark jet and a backward target jet. The direction of the virtual photon, the momentum transfer Q^2 and the energy transfer $\nu = k_\mu - k_{\mu'}$ can be well determined from the kinematics of the muon. The total hadronic energy W is related to Q^2 and x_{Bj} by

$$W^2 = M^2 + Q^2 \left(\frac{1}{x} - 1\right)$$

and ranges from about 4 GeV to 24 GeV in this experiment.

QCD effects can be studied using single particle distributions (e.g. z, x_F, p_t, particle and energy-flows) as well as event shape variables (like Thrust, Oblateness, Spericity). For example, the Q^2-dependence of the differential multiplicity (1) of charged hadrons and the increase of $\langle pt \rangle$ relative to the virtual photon direction (2) with W are effects predicted by QCD.

The results presented are based on an analysis of 30000 μ-p events from a hydrogen target using the 280 GeV μ-beam and the EMC double magnet spectrometer. The apparatus (3) consists of a forward spectrometer to measure the scattered muon and fast hadrons and a vertex spectrometer part including a streamer chamber. Tracks are measured in a momentum range between .2 and 280 GeV/c, this corresponds to a nearly 4π acceptance in the CMS.

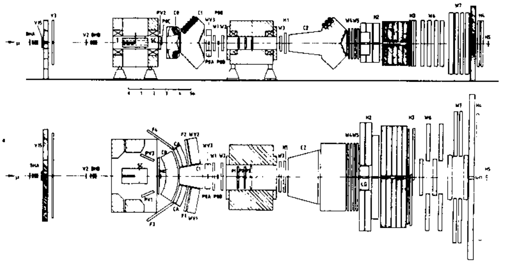

Fig.1 Plan view and side view of the spectrometer (vertex and forward). BH are beam hodoscopes, V's veto hodoscopes. H's scintillator hodoscopes, P's–P0's–PV's proportional chambers, W's driftchambers, C's Cherenkov counters, LG lead glass detector, SC streamerchamber

In μ-p DIS, the following diagrams contribute to additional p_t for forward going hadrons.

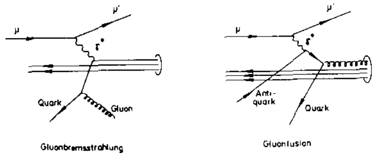

Fig. 2 Lowest order α_s processes in μ-p

These QCD-effects have to be isolated from other sources of p_t, such as transverse motion of the quarks inside the nucleon (primordial k_t), the fragmentation itself and the decay of unstable particles.

Contributions from fragmentation and from k_t do not explicitly depend on W and are expected to be roughly forward/backward symmetric, whereas hard QCD-effects as well as effects from the emission of soft gluons (as in the Lund 4.3-model) increase with W and occur only in the forward jet. (4)

2. JET PROFILES IN μ-p SCATTERING

A possibility to separate QCD-effects in jets from purely kinematic W-effects is the analysis of jet-profiles which are defined as:

$$\frac{d\varepsilon}{d\lambda} = \frac{1}{N_{ev}} \sum \frac{\Delta\varepsilon'}{\Delta\lambda} \qquad \varepsilon^i = \frac{E_i^{charged}}{E_{jet}}$$

$$E_{jet} = \sum_i E_i^{charged} \qquad \text{(summation: } x_F < 0 \text{ backward jet}$$

$$x_F > 0 \text{ forward jet)}$$

$$\lambda = \frac{x_F}{p_t} = \frac{\cot\Theta}{W/2}$$

Scaling of jet profiles (e.g. being independent of jet energy) was found to be valid at low energy pp-reactions (5) and in neutrino-p scattering (6).

Using charged particles only, EMC data has been analysed in 4 W-intervals and is compared to various model predictions.

W1: 4 - 8 GeV W2: 8 - 12 GeV W3: 12 - 16 GeV W4: 16 - 20 GeV

As is shown in Fig. 3, the independent jet model without QCD shows very good scaling, except for the first bin. The ratios of jet-profiles at different energies, which are defined as:

$$\mathrm{Wik}\ (\lambda) = \frac{d\varepsilon/d\lambda\ (\mathrm{Wi})}{d\varepsilon/d\lambda\ (\mathrm{Wk})}$$

are very close to unity both for the backward and the forward jet (Fig. 5a). However, data jet profiles do not show this scaling behaviour in the forward jet (Fig. 4).

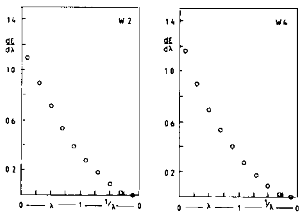

Fig. 3: Jet profiles (IJ, forward, no QCD), W2 and W4

Ratios of energy-profiles as expected from the Lund model are compared to data in Fig. 5b. While the backward jet ratios essentially remain flat (also with QCD included), the forward jet shows sizeable deviations increasing with W. They are due to hard QCD as well as to multiple emission of soft gluons, both effects being almost equally large.

In contrast to the independent jet model, there are scaling deviations present already in the Lund-model without QCD (Fig. 5b, dotted line). In fact this behaviour is expected as a "string-effect" due to a "crosstalk" between the backward and the forward jet, it depends (for the forward jet) on the transverse mass of the backward going particles (baryons from the target remnant) and contributes to the scaling deviations in the string model (7). By definition, there is no "crosstalk" in the independent jet fragmentation. Good agreement of data and Monte-Carlo can only be obtained using the Lund-fragmentation with full QCD.

3. THE RADIATION PROFILE FUNCTION

A radiation profile function parametrizing the jet profile has been suggested (5) and was tested at low energies and in Monte Carlo calculations for e^+e^- annihilation (8).

$$\rho(\lambda) = \frac{M}{|1 + M^2\lambda^2|^{3/2}}$$

The parameter M corresponds to the average transverse mass in the central rapidity plateau. To test the validity of $\rho(\lambda)$ in μ-p scattering a LSQ fit of M to the data (see Fig. 4) and various Monte Carlo models is summarized in Fig. 6. The resulting M reflects the "broadness" of the jets with fragmentation effects (limited p_t) being eliminated. In general, ρ is found to describe the jet profile for the forward jet satisfactorily, the backward jet, however shows sizeable deviations. For the Lund-model with QCD and the "string-effect" included, the increase of M with W roughly agrees with the data and is much stronger than in the independent jet model.

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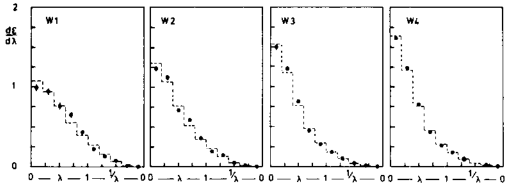
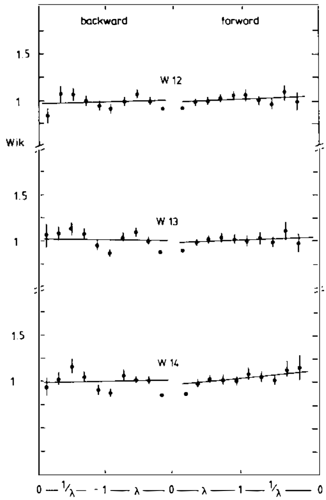


Fig. 4: Forward jet profiles for different W-intervals
(data and fit)



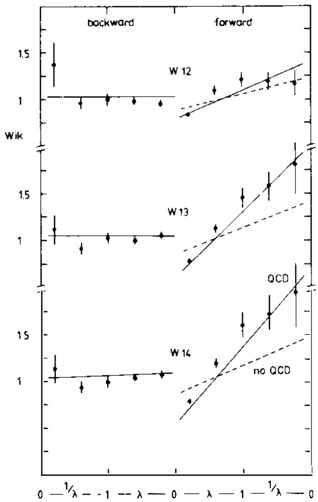


Fig. 5a Fig. 5b

Ratios of jet profiles for IJ model without QCD (5a) and the Lund-model with QCD compared to data (5b)

Fig. 6: Fitted M-values for data and Lund-model