FRAGMENTATION IN DIFFRACTIVE DEEP INELASTIC SCATTERING AT HERA

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Fragmentation measurements are presented for diffractive and non-diffractive deep inelastic ep scattering data in the Breit frame of reference. The average charged multiplicity in the current hemisphere, $< n >$, is shown to compare well with DIS at low β and with e^+e^- at high β. The evolution of the peak and width of the current hemisphere fragmentation functions for charged particles is studied as a function of photon virtuality, Q, and is found to agree with results obtained in non-diffractive deep inelastic scattering.

1 Introduction

Previous studies[1,2,3,4] of Deep Inelastic ep Scattering (DIS) in the Breit frame of reference[5] have established the universality of hadronic fragmentation properties and their energy dependence for quarks ejected from a proton and for quarks produced from the vacuum in e^+e^-annihilation experiments.

This paper summarises results[6] that further tests concepts of this universality by examining the fragmentation properties of quarks thrown out of the pomeron in diffractive DIS (DIFF) scattering when probed with the same highly virtual boson as used in non-diffractive DIS (DIS) scattering.

A particularly suitable frame of reference in which to study quark fragmentation in ep scattering is the Breit Frame. In this frame and within the naive quark-parton model (QPM) the purely space-like virtual photon has longitudinal momentum $-Q$ and collides elastically and head-on with a quark of longitudinal momentum $Q/2$. The struck quark is scattered with an equal but opposite momentum while the proton remnant fragments into the opposite hemisphere. Particles emerging from the interaction are assigned to the current region (and associated with the struck quark) if they have negative longitudinal momenta. The energy scale for the current region, set by the virtual photon, is given by $Q/2$, and is independent of the nature (diffractive or non-diffractive) of the event.

2 Fragmentation Functions

The ratio of the momentum of a given charged hadron, $p_h^{\pm}$, to the energy scale ($Q/2$) of the current hemisphere of the Breit frame is $x_p = p_h^{\pm}/(Q/2)$.

It has been shown [1] to be directly comparable to $x_p = p_h^{\pm}/(E^*/2)$ for one hemisphere of an e^+e^- experiment where $\sqrt{s_{ee}} = E^* = Q$. Using $\xi = \ln\left(\frac{1}{x_p}\right)$, the fragmentation function may be defined as

$$D^{\pm}(\xi) = \left(\frac{1}{N}\right) \times dn^{\pm}_{tracks}/d\xi \tag{1}$$

The Modified Leading Log Approximation (MLLA)[7] coupled together with Local Parton Hadron Duality (LPHD) predicts that in the region of the peak of the hadronic ξ distribution, the shape is approximately Gaussian. The MLLA also gives a prediction for the energy behaviour of the peak position and width of this Gaussian (the first and second moments of the fragmentation function respectively) in the so-called limiting spectrum approximation;

$$\xi_{peak} = 0.5U + c_2\sqrt{U} + O(1) \tag{2}$$

$$\xi_{width} = \sqrt{\frac{U^{3/2}}{2c_1}}. \tag{3}$$

Here $U = \ln(Q/\Lambda_{eff})$, where Λ_{eff} is an effective scale parameter, c_1 and c_2 are constants dependent on the number of excited flavours and colours in QCD, and $O(1)$ is a slowly varying function of energy containing all QCD diagrams beyond leading order. This term is assumed to be constant in this analysis.

Figure 1 summarises the energy evolution of the fragmentation function. The solid (dashed) line is the simultaneous fit to the peak position and width of the MLLA parameterisation for DIS (DIFF) events. These give $\Lambda_{eff} = 0.21 \pm 0.04$ (0.19 ± 0.03) and $O(1) = -0.42 \pm 0.12$ (-0.49 ± 0.12).

Both DIS and DIFF distributions and parameters are compatible with each other, and with previous DIS and e^+e^- experiments thus lending further support to the concept of quark fragmentation universality.

3 Average Charged Multiplicity

The area under the fragmentation function is the averaged charged multiplicity, $<n>$, also known as the zeroth moment of the fragmentation function. Figure 2 compares the average charged multiplicity in the current region between DIS and DIFF data and a comparison is made with MEAR[8] Monte-Carlo for DIS events and with RAPGAP[9] for DIFF events using the resolved

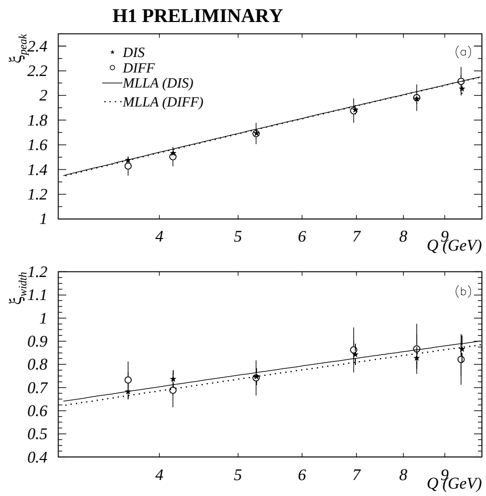

Figure 1. The energy evolution of the (a) peak position and (b) width of the fragmentation function for both DIS and DIFF selections. The solid (dashed) line is the simultaneous fit of the MLLA parameterisation to the DIS (DIFF) data.

$I\!P$ model and the fit 2 parameterisation from H1[10]. The DIFF selection is split into high and low β samples and shown together with a parameterisation[11] of e^+e^- results for a single hemisphere, where contributions from K^0 and Λ decays have been subtracted, to be comparable with this data.

The observation of a significant shortfall of $<n>$ for DIS data compared with that of e^+e^- was explained [1] by LO QCD processes present in *ep* but not in e^+e^- interactions. Such higher order QCD processes lead to a depopulation of tracks in the current region (or even an empty current region). This effect is also observed for the low β DIFF selection which is expected to be dominated by $q\overline{q}g$ production. The high β DIFF selection which is expected to be dominated by $q\overline{q}$ production, compares well with the e^+e^- parameterisation. Both selections are reasonable well described by the RAPGAP Monte-Carlo.

4 Conclusions

The universality of quark fragmentation has been supported by comparing spectra for quarks originating from the pomeron with those from quarks from the proton and from quarks produced from the vacuum in e^+e^- annihilation

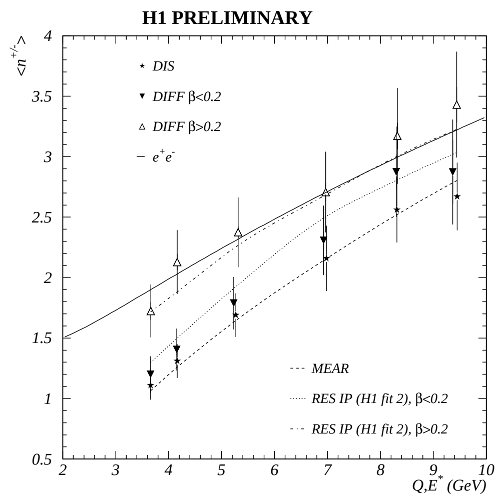

Figure 2. The average charged multiplicities as a function of the energy scale Q. The error is dominated by a correlated systematic error of about $\sim 7\%$ associated with the energy uncertainty of the scattered electron in the SpaCal. The solid curve is a fit to many e^+e^- results as a function of the centre of mass energy E^*($E^* = Q$), the dashed line a prediction for the MEAR Monte-Carlo for DIS events and the dotted and dashed-dotted lines comes from RAPGAP using the resolved $I\!\!P$ model and the fit 2 parameterisation from H1.

experiments.

The β dependence of diffractive DIS data is consistent with the expectation for final states of $q\overline{q}g$ at low β and for $q\overline{q}$ at high β but is also reproduced in models where there is no explicit modelling of these final state configurations, strongly suggesting that these effects are a result of restricting the phase space that is implicit in making a selection of β.

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