PROCEEDINGS OF SCIENCE

Charm fragmentation at HERA

Juraj Bracinik∗†
Max-Planck Institut for Physics, Germany
E-mail: bracinik@mppmu.mpg.de

Recent data on charm fragmentation, collected and analyzed by the H1 and ZEUS collaborations, are reviewed and compared with a results from e^+e^- experiments. The measured fragmentation ratios and fragmentation fractions are in agreement with those measured in e^+e^-, thus supporting the assumption of universality. Results on the structure of charm jets are presented. The normalized differential cross section of D^*-mesons as a function of fragmentation sensitive observables has been measured and used to extract fragmentation function parameters.

International Europhysics Conference on High Energy Physics
July 21st - 27th 2005
Lisboa, Portugal

∗Speaker.
†for H1 and ZEUS collaborations

1. Introduction

In perturbative QCD (pQCD), the cross section for inclusive production of a heavy hadron H can be expressed as a convolution of two terms:

$$\sigma(p) = \int dz\, dp_{\mathrm{part}}\; \sigma(p_{\mathrm{part}}) D_{\mathrm{H}}^{\mathrm{part}}(\mathrm{z}) \delta(p - \mathrm{z} p_{\mathrm{part}}) \tag{1.1}$$

where $\sigma(p_{\mathrm{part}})$ is the perturbative part of the cross section for the production of a parton and $D_{\mathrm{H}}^{\mathrm{part}}(\mathrm{z})$ is the corresponding fragmentation function. The latter contains a nonperturbative, uncalculable part. The factorization theorem, if applicable, predicts that $D_{\mathrm{H}}^{\mathrm{part}}(\mathrm{z})$ is universal, i.e. both its shape and normalization are independent of the hard subprocess and the scale at which the parton, e.g. heavy quark was produced. This assumption of universality needs to be verified by experiment.

2. The measurement of charm fragmentation fractions and ratios at HERA

In order to study the probabilities of a heavy quark to hadronize into various heavy hadrons, two types of observables are used. The fragmentation fraction for a given charmed hadron is defined as the ratio of the total production cross section for the given hadron to that for the charm quark. Fragmentation ratios are used to highlight certain aspects of the hadronization process. Their exact definitions can be found in references [1 – 3]. In their definitions, only cross sections of directly produced states are used.

The ZEUS collaboration has measured the fragmentation fractions and ratios of D^+, D^0, D_S^+, D^{*+} and Λ_c states[1] both in deep-inelastic scattering (DIS) and photoproduction [2, 3]. These states were measured by reconstruction of invariant mass and number of events was determined, after subtracting reflections, in a fit to signal and background. The measured cross sections are given for the visible phase space, defined for photoproduction as $Q^2 < 1$ GeV^2, 130 <W< 300 GeV, $p_t(D,\Lambda) > 3.8$ GeV, $|\eta(D,\Lambda)| < 1.6$ and for DIS as $1.5 < Q^2 < 1000$ GeV^2, $0.02 < y < 0.7$, $p_t(D,\Lambda) > 3$ GeV and $|\eta(D,\Lambda)| < 1.6$. The data samples analyzed correspond to a luminosity of 79 pb^{-1}(photoproduction) and 82 pb^{-1} (DIS). The charm quark production cross section in the visible range, needed to calculate the fragmentation fractions was calculated from the measured cross sections of Ds and Λ_c.

The H1 collaboration has used a different experimental procedure to measure fragmentation ratios and fractions of D^+, D^0, D_S^+ and D^{*+}in DIS, profiting from its central silicon tracker [1]. In order to improve the signal/background ratio, cuts on secondary vertex parameters were used. The number of visible charmed meson states was then determined from a fit to the invariant mass distribution. The measurement was done in the kinematic region $2 < Q^2 < 100$ GeV ^{2}, $0.05 < y < 0.7$, $p_t(D) > 2.5$ GeV and $|\eta(D)| < 1.5$. The analyzed data sample corresponds to a luminosity of 47 pb^{-1}. A QCD-based model was used to extrapolate the measured cross sections to the full phase space and to predict the total charm quark cross section. The fragmentation ratios were then calculated from the measured fragmentation fractions.

Although H1 and ZEUS have used different experimental procedures, the results are compatible with each other and with results from e^+e^- experiments (with competitive errors) and thus support the assumption of universality (for example see Fig.1 left).

[1]together with their charge conjugate states

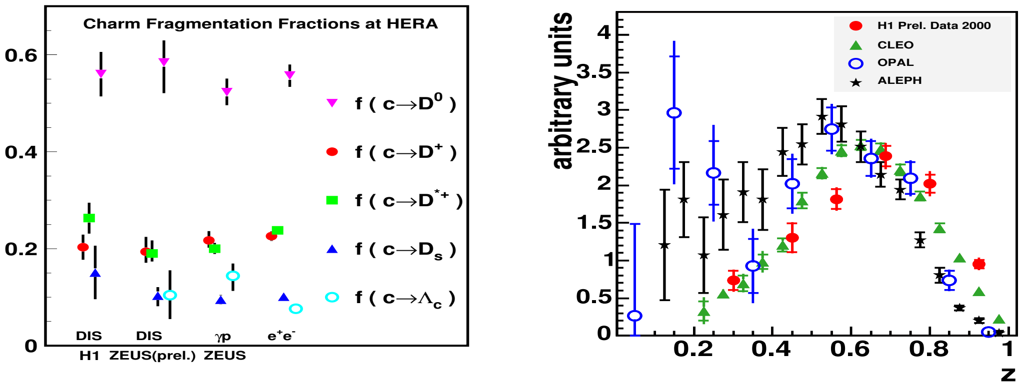

Figure 1: The fragmentation fractions for charmed hadrons (see Sec.2) (left), the differential cross section of D^*-meson as a function of z (hemisphere method) compared with data from e^+e^- (right).

3. Structure of charm jets in DIS

The H1 collaboration investigated the structure of charm jets in DIS in the phase space region $2 < Q^2 < 100$ GeV ^{2}, $0.05 < y_e < 0.7$ [4]. The charm jet was tagged by a D^*-meson in the kinematic range $p_t(D^*) > 1.5$ GeV , $|\eta(D^*)| < 1.5$, and it was found in the laboratory frame using inclusive $k_\perp$ algorithmus. This D^*-Jet fulfills the requirements $p_{t\,\mathrm{jet}} > 1.5$ GeV and $|\eta_{\mathrm{jet}}| < 1.5$. In addition to jet shapes and subjet multiplicity, the "gluon" subjet angle α_G was studied. The latter is designed to be sensitive to the angular distribution of gluons belonging to D^*-Jet. Therefore the jet finder was rerun on the particles of the D^*-Jet. The jet resolution parameter was varied until exactly two subjets were found. α_G is defined as the angle between the axis of the D^*-Jet and the subjet which does not contain the D^*-meson.

According to pQCD, gluon emission off a heavy quark is influenced by the quark mass. Gluon emission in the direction of the heavy quark momentum is suppressed, the so-called the dead cone effect. For small angles α of radiated gluons with respect to the initial quark direction pQCD predicts $d\sigma/d\alpha \approx K\alpha^3/(\alpha^2+\alpha_0^2)^2$, where $\alpha_0 = m_\mathrm{Q}/E_\mathrm{Q}$ is the size of dead cone. The product $\alpha_0 E_Q$ is expected to be independent of the quark energy.

The measured distribution of α_G in bins of jet energy was fitted by the angular distribution as predicted by pQCD, keeping α_0 as a free parameter. The product of α_0 and E_{jet} does not depend on the jet energy, its value being consistent with the charm quark mass. The same analysis has been repeated with two samples of fake D^* jets, produced predominantly by light quarks. For these samples $\alpha_0 E_{\mathrm{jet}}$ does not depend on the energy of the jet either [4] , the value is lower than for the charm tagged sample. However, with current level of experimental uncertainties no conclusion about the presence of the dead cone effect can be drawn .

4. The measurement of D^* fragmentation function in DIS

As can be seen from equation 1.1, the fragmentation function $D_\mathrm{H}^{\mathrm{part}}(\mathrm{z})$ cannot be measured directly, as all observables contain its convolution with hard matrix elements. However, some observables are more sensitive to $D_\mathrm{H}^{part}(\mathrm{z})$ than others. In ep collisions, in contrast to e^+e^-, the choice of preferred observable is less obvious. The H1 collaboration has measured the differential cross section of D^*-mesons as a function of two scaling variables. In the case of the so-called 'jet method', the momentum of the charmed quark is approximated by the momentum of the reconstructed D^*-Jet. In the case of the 'hemisphere method', the momentum of the charm quark is approximated by the momentum of a suitably defined hemisphere in the photon-proton center-of-mass frame [5], analoguous to the beam-momentum in e^+e^- collisions.

The analysis covers the kinematic region $2 < Q^2 < 100$ GeV^2, $0.05 < y < 0.7$, with $p_t(D^*) >$ 1.5 GeV and $|\eta(D^*)| < 1.5$. In case of the jet method, $p_t(D^*_{\text{jet}}) > 3$ GeV was required.

The normalized differential cross section of D^*-meson as a function of z from the hemisphere method is expected to be comparable to the results from e^+e^- experiments, and it is therefore compared with selected results as shown in Fig.1 right. Although the shapes are similar, systematic differences beyond experimental errors can be seen. These may be due to different definitions of z, different underlying hard subprocesses, or they may indicate violation of universality. Dedicated phenomenological analysis and more precise *ep* data are needed to clarify these questions.

The preliminary measurements of differential cross sections were used to extract parameters for the Peterson and Kartvelishvili parametrizations of non-perturbative fragmentation functions in the framework of the leading order+parton shower model of RAPGAP/PYTHIA. The parameters extracted using the jet and hemisphere method differ ($< 3\sigma$), signalling a potentially improper description of the hadronic final state by the model, including the choice of fragm. function parametrization. H1 therefore quotes a range of $4.0 < \alpha < 6.8$ for the Kartvelishvili and of $0.014 < \varepsilon < 0.036$ for the Peterson parametrization.

5. Acknowledgements

I would like to thank to Günter Grindhammer, Zuzana Rúriková and Roberval Walsh for usefull discussions on the subject.

References

[1] A. Aktas *et al.* [H1 Collaboration], *Inclusive Production of D^+, D^0, D_s^+ and D^*+ Mesons in Deep Inelastic Scattering at HERA*, Eur. Phys. J. C **38** (2005) 447 [hep-ex/0408149]

[2] S. Chekanov *et al.* [ZEUS Collaboration] *Measurement of charm fragmentation ratios and fractions in photoproduction at HERA*, Eur. Phys. J. C **44** (2005) 351 [hep-ex/0508019]

[3] S. Chekanov *et al.* [ZEUS Collaboration] *Measurement of charm fragmentation fractions and ratios in deep inelastic scattering at HERA*, contributed paper to XXIInd International Symposium on Lepton-Photon Interactions at High Energy, June 2005, Uppsala, Sweden.

[4] A. Aktas *et al.* [H1 Collaboration], *The Structure of Charm Jets in Deep-Inelastic Scattering*, contributed paper to XXIInd International Symposium on Lepton-Photon Interactions at High Energy, June 2005, Uppsala, Sweden.

[5] A. Aktas *et al.* [H1 Collaboration], *Determination of the Charm Fragmentation Function in Deep-Inelastic Scattering at HERA*, contributed paper to XXIInd International Symposium on Lepton-Photon Interactions at High Energy, June 2005, Uppsala, Sweden.