Study of Jet Shapes in Charm Photoproduction at HERA

Mária Martišíková
for the H1 Collaboration

DESY, Notkestrasse 85, 22603, Hamburg, Germany
E-mail: maria.martisikova@desy.de

Abstract. Jet shapes in charm photoproduction events in *ep* collisions at HERA are studied. The main goal is to distinguish jets initiated by quarks and gluons in order to shed light on the production mechanism of charm events.

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INTRODUCTION

Charm production in *ep* collisions at HERA is dominated by photon gluon fusion processes (fig. 1). In photoproduction in addition to direct photon processes (fig. 1a), resolved photon processes (fig. 1b-d) can contribute significantly. A key question is to which extent the charm production can be attributed to the so called c-excitation processes (fig. 1c-d). In perturbative QCD at LO only those processes produce a hard gluon in addition to a charm quark, while the direct photon and other resolved processes (fig. 1b) lead to the production of a $c\bar{c}$ pair. The aim of the present study is the distinction of the $c\bar{c}$ component from the cg events. Due to differences in the jet formation processes, gluon jets are expected to be broader than quark jets [1]. Such differences have been observed previously between jets initiated by light quarks and by gluons [2].

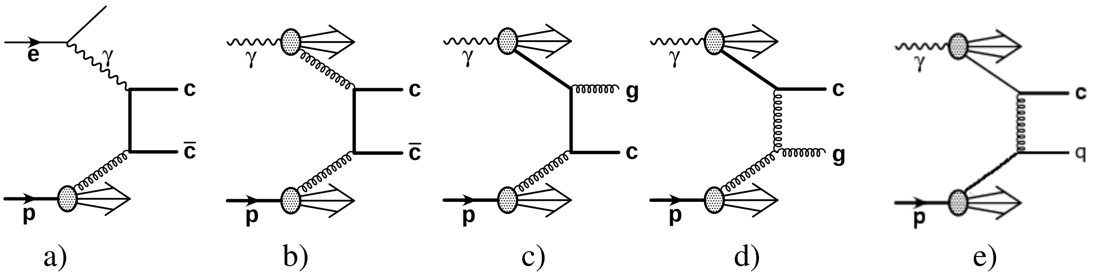

FIGURE 1. Charm quark production processes in leading order pQCD.

EXPERIMENTAL METHOD

The jet shapes are studied using the variable 'integrated jet shape' $\psi(r)$. It is defined as the fraction of the jet transverse momentum (with respect to the beam axis) deposited within a cone of the radius r around the jet axis relative to the transverse momentum of the jet, contained in a cone of radius R=1 (fig. 2)

$$\psi(r) = \frac{p_t^{cone}(r)}{p_t^{cone}(R)}$$

The radius is defined as $r = \sqrt{\Delta\eta^2 + \Delta\phi^2}$, where $\Delta\eta$ and $\Delta\phi$ are the distances of the particles to the jet axis in pseudorapidity η and azimuthal angle ϕ respectively. The mean $\langle\psi(r)\rangle$ over events is studied as a function of r/R.

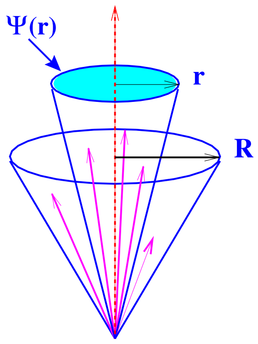

FIGURE2. Definition of $\psi(r)$

EVENT SELECTION

The analysis is based on the event sample selected for the recent determination of the beauty cross section [3]. The data were recorded in 1999 and 2000 at a center-of-mass energy of 318 GeV and correspond to an integrated luminosity of 48 pb^{-1}. The kinematic range is restricted to $Q^2 < 1$ GeV^2 and $0.2 < y < 0.8$. Massless jets are reconstructed by the inclusive k_t algorithm in the p_t recombination scheme using a combination of tracks and calorimeter energy deposits. The selection requires at least two jets with transverse momentum $p_t > 7(6)$ GeV, of which at least one contains a muon candidate. Muons are selected in the angular range $35^\circ < \theta(\mu) < 130^\circ$, with $p_t^\mu > 2.5$ GeV. In order to enrich the sample in charm events a cut on the transverse momentum of the muon track relative to the associated jet, $p_t^{rel} < 1$ GeV, is imposed. The final sample contains 800 events with a charm purity of about 75% . The remaining background due to b and light quark production is subtracted statistically, using the fractions as predicted by the inclusive PYTHIA Monte Carlo simulation, which were checked to describe the data.

For comparison a dijet event sample is selected which fulfills the same jet selection criteria as the charm sample except for the requirement of a high p_t muon. In this case the kinematic range is restricted to $Q^2 < 0.01$ GeV^2 and $0.3 < y < 0.65$. This event sample is dominated by the production of light quarks ($\sim 75\%$).

RESULTS OF THE JET SHAPE MEASUREMENTS

The fraction x_γ^{obs} of the photon energy entering the hard interaction is estimated using the observable

$$x_\gamma^{obs} = \frac{\sum_{Jet_1}(E-p_z) + \sum_{Jet_2}(E-p_z)}{\sum_{all\ \ hadrons}(E-p_z)}$$

For the direct process x_γ^{obs} approaches unity, in resolved processes x_γ^{obs} can be small.

The distributions of the averaged integrated jet shapes $\langle\psi(r)\rangle$ as functions of r/R are presented for two separate regions of x_γ^{obs}. Distributions for the charm sample are shown in fig. 3. Only the jet without muon is studied. The PYTHIA 6.1 predictions, using CTEQ5L and GRVG-LO the parton densities for proton and photon, respectively, are shown with the data. Direct and resolved photon processes are simulated, including excitation processes. The curves for the direct and resolved photon events are shown separately. The data are described well by the PYTHIA prediction at high x_γ^{obs}, but a disagreement is observed in the region of $x_\gamma^{obs} \leq 0.75$. In the PYTHIA simulation the rise of $\langle \psi(r) \rangle$ is softened due to the presence of gluon jets in the resolved photon sample. Such a slow rise is not observed in the data.

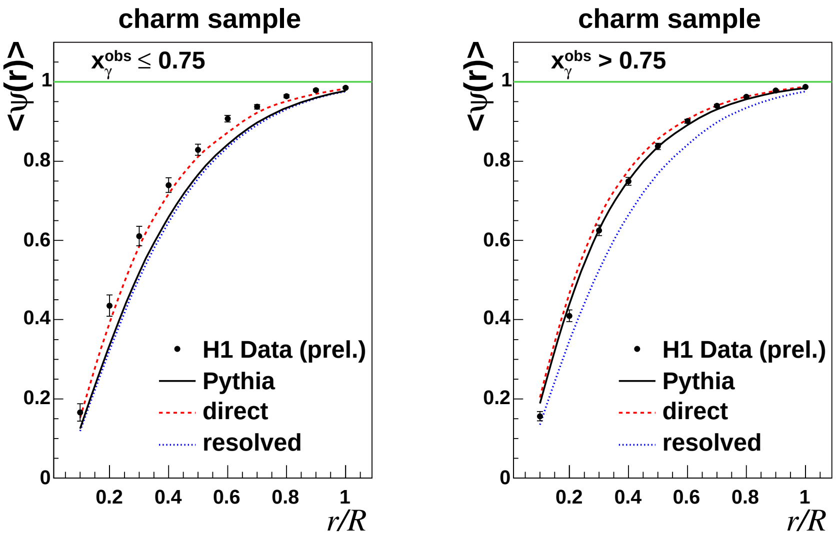

FIGURE 3. $\langle \psi(r) \rangle$ for the charm event sample in two different regions of x_γ^{obs}. The data are compared with the prediction from PYTHIA. The expected curves for direct and resolved photon processes are shown separately.

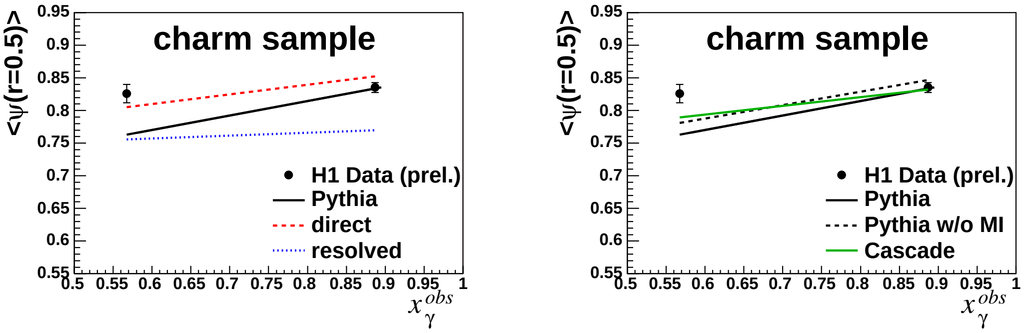

FIGURE 4. $\langle \psi(r/R = 0.5) \rangle$ as a function of x_γ^{obs} for the charm sample. The same points are compared with PYTHIA (left), CASCADE and PYTHIA without multiple interactions (right).

In fig. 4 the averaged integrated jet shape at a fixed value $r/R = 0.5$ is shown for the charm sample as a function of x_γ^{obs} and compared with different model calculations. PYTHIA describes the data at high x_γ^{obs}, while deviations are seen at low x_γ^{obs}. PYTHIA without multiple interactions (MI) is closer to the data at low x_γ^{obs}, while the description at high x_γ^{obs} is only marginally worse. The CASCADE 1.0 model using an unintegrated parton density (JS2001) describes the data well in the high x_γ^{obs} region and is closer to the data at low x_γ^{obs}.

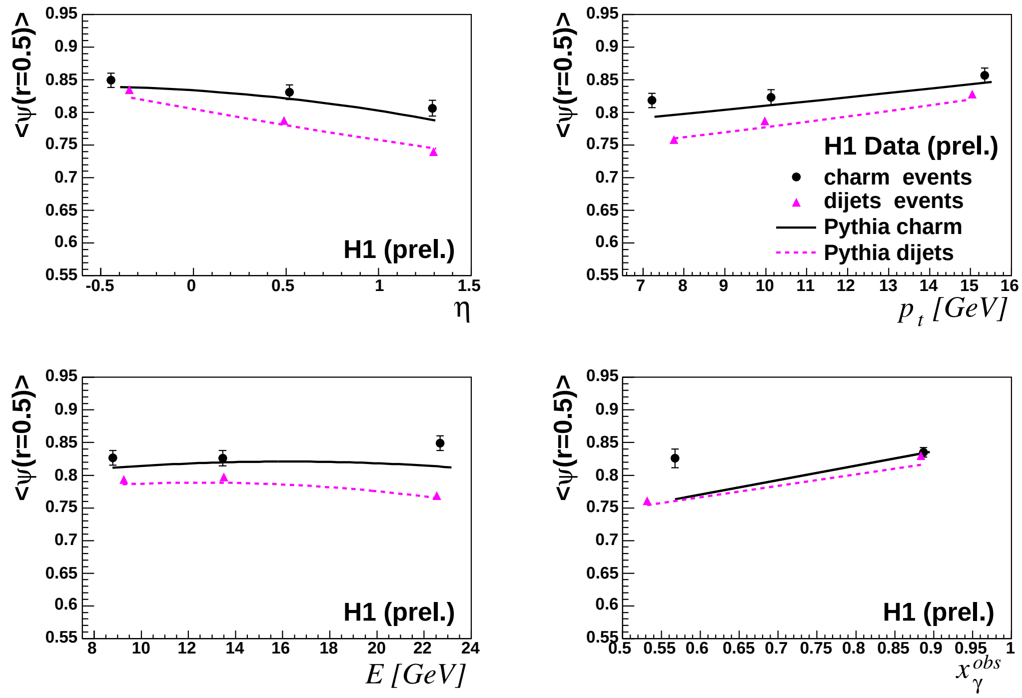

FIGURE 5. Differential distributions of $\langle\psi(r/R=0.5)\rangle$ as functions of the jet quantities η, p_t, E and x_γ^{obs} for the charm and dijet samples. The predictions from PYTHIA are shown for both data samples.

It was checked that variation of the background due to b quarks and light quarks or of the Peterson fragmentation parameter ε_c, did not change the distributions significantly.

In fig. 5 the jet shapes in charm events are directly compared to dijet events which are dominated by light quarks. For dijets both selected jets enter the distributions. PYTHIA describes the dijet data well everywhere.

CONCLUSIONS

Jet shapes are studied in a charm dijet photoproduction sample with the H1 detector at HERA. The resolved component in PYTHIA is dominated by charm excitation, where in addition to the charm quark jet a gluon initiated jet is expected, which is broader than the charm jet. In the charm data sample the jet shapes are however found to be similar in direct and resolved photon enriched samples. For comparison a light quark dominated dijet sample was studied. The jet shapes are in agreement with PYTHIA. The observed discrepancy between the charm data and PYTHIA indicates a lack of understanding of the charm production process in the resolved photon region.

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