Study of dijet production in events with a leading proton at HERA

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1 Introduction

In the study of ep interactions it is customary to distinguish two kinematic regions: the deep inelastic scattering (DIS) and the photoproduction region. The DIS regime is defined by the condition $Q^2 \gg m_p^2$.
Diffractive events in deep inelastic scattering (DIS) are characterized by the presence of a fast forward proton (only slightly deflected and having lost a few percent of its initial energy) and a large rapidity gap (an angular region, without hadronic activity, between the scattered proton and the hadronic final state).
This report presents the measurement of the distribution of the squared four-momentum transfer at the proton vertex, t, in diffractive deep inelastic positron-proton scattering events in which the hadronic final state consists of at least two jets.

2 Experimental set-up

The results presented in this report correspond to 32.6 pb^{-1} of data taken with the ZEUS detector during the year 2000, when positrons of 27.6 GeV collided with protons of 920 GeV, giving a centre-of-mass energy of 318 GeV. A longitudinal wiew of the ZEUS detector is shown in fig. 1.
DIS events were identified using information from the uranium-scintillator calorimeter (CAL), the central tracking detector (CTD), the small angle rear tracking detector (SRTD) and the rear part of the hadron-electron separator (RHES). Diffractive events were selected by requiring the detection of a proton in the Leading Proton Spectrometer (LPS). The latter has been designed to detect protons scattered at small angles in the forward direction carrying a substantial part of the proton momentum. These particles escape in the beam pipe, undetected by the main ZEUS detector. The LPS was a system of silicon microstrip detectors that could be inserted very close (typically a few mm) to the proton beam. The detectors were grouped in six stations, S1 to S6, placed along the beam-line in the direction of the proton beam, between 23.8 and 90.0

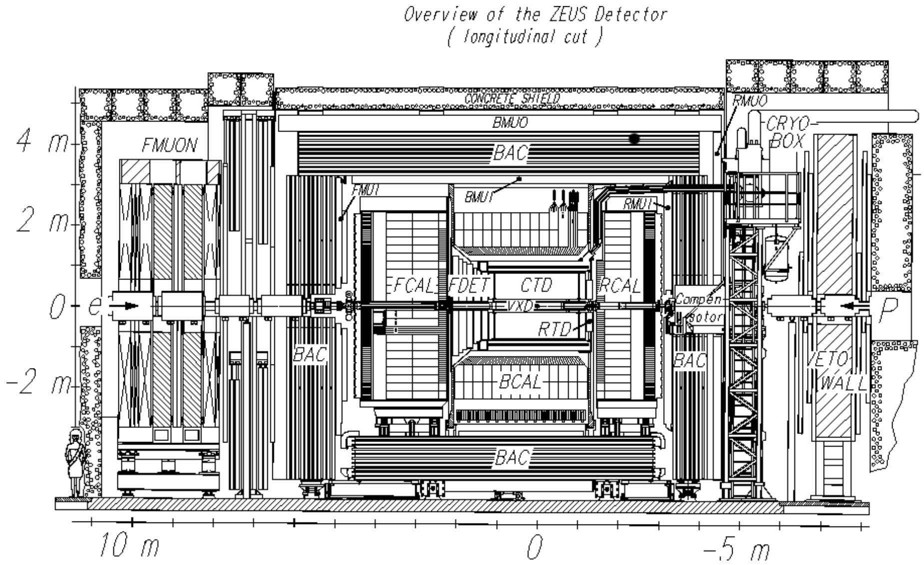

Figure 1: The ZEUS detector

m from the interaction point. The particle deflection induced by the magnets of the proton beam-line allowed a momentum analysis of the scattered proton. For the present measurement, only the stations S4, S5 and S6 were used.

3 Kinematics

Dijet production in diffractive DIS ($ep \to e + p + j1 + j2 + X'$) is characterised by the simultaneous presence of a scattered positron, e, measured in the CAL, a scattered proton, p, detected in the LPS, and the two jets j1 + j2 produced in the hard scattering along with the rest of the hadronic system X'.
The variables typical of a DIS event are:

- $s = (P+k)^2$, the squared ep centre-of-mass energy, where P and k indicate the incoming proton and the incoming positron momenta, respectively;
- $Q^2 = -q^2 = (k - k')^2$, the virtuality of the exchanged photon γ^*, where k' is the four-momentum of the scattered positron;
- $W^2 = (P + q)^2$, the centre-of-mass energy squared of the $\gamma^* p$ system.

Variables used to select diffractive events are:

- M_X, the invariant mass of the photon dissociative system;
- $t = (P - P')^2$, the four-momentum transfer squared at the proton vertex, where P' is the four-momentum of the scattered proton;
- $x_{\mathbb{P}} = (P - P') \cdot p/(P \cdot q)$, the momentum fraction lost by the proton;
- $\beta = Q^2/(2(P-P') \cdot q)$, the fractional momentum of the diffractive exchange carried by the struck parton.

Variables involved in the dijet measurement are:

- $z_{I\!P} = (q \cdot v)/(q \cdot (P - P'))$, the fractional momentum of the diffractive exchange carried by the parton participating in the hard process, where v is the four-momentum of the parton originating from the diffractive exchange;

- $x_\gamma = (P \cdot u)/(P \cdot q)$, the fractional momentum of the virtual photon participating in the hard process, where u is the four-momentum of the parton originating from the virtual photon.

4 Event reconstruction and data selection

4.1 DIS selection

The reconstruction of the scattered positron variables was carried out by combining the information from CAL, SRTD and HES. In order to select a DIS sample the following requirements were applied:

- the energy of the scattered positron had to be greater than 10 GeV in order to select a well reconstructed DIS candidate;

- the vertex of the event had to be in the range $|Z_{vtx}| \leq 50$ cm; this cut excludes events which have the vertex far from the nominal interaction point and would have a high probability of being non-ep background. Events without a measured vertex were rejected.

- the quantity $\sigma = \sum(E_i - pz_i)$ (where the sum runs over the scattered positron and all the EFOs) was required to be $45 \leq \sigma \leq 65$ GeV. EFOs are Energy Flow Objects reconstructed from calorimeter and tracking information. This cut suppresses strongly the photoproduction background which is characterized by values of σ significantly lower than 55 GeV.

The Q^2 and W variables were determined using the double-angle method. Events were accepted if $100 \leq W \leq 250$ GeV and $5 \leq Q^2 \leq 100$ GeV^2.

4.2 Jet selection

Jets were reconstructed from EFOs in the $\gamma^* p$ rest frame using the k_T clustering algorithm. The dijet sample was defined by selecting events with at least two jets which fulfill the following requirements:

- $E^*_{T,j1} \geq 5$ GeV and $E^*_{T,j2} \geq 4$ GeV where E^*_T is the jet transverse energy and the labels j1 and j2 refer to the jets with the highest and the second highest transverse energy, respectively;

- $-3.5 \leq \eta^*_{jet} \leq 0$, where η^*_{jet} is the pseudorapidity of the jets in the $\gamma^* p$ rest frame;

- the pseudorapidity of the selected jets, boosted to the laboratory frame, had to lie in the range $\mid \eta^{LAB}_{jet} \mid \leq 2$.

4.3 Diffractive selection

The following requirements were used to select the scattered proton measured in the LPS:

- only events with $p_x \leq 0$ where used; for the present sample, the LPS acceptance for $p_x \geq 0$ was very low and not well understood;
- the candidate proton was tracked along the beam-line and was rejected if, at any point, the distance of approach to the beam-pipe was less than 0.2 cm. It was also rejected if the x position of the track impact point at station S4 (upper part) was smaller than -30 mm. These cuts were made in order to select well reconstructed protons;
- $E + pz = (E + pz)_{CAL} + 2p_{z,LPS} \leq 1860$ GeV. Beam-halo background is caused by scattered protons, with energy close to that of the beam, originating from the interaction of a beam proton with the residual gas in the beam-pipe or with the beam collimators. A beam-halo proton may overlap with a standard non-diffractive DIS event. In this case, the proton measured in the LPS is uncorrelated with the activity in the central ZEUS detector. This background was suppressed by the requirement that the sum of the energy and the longitudinal component of the total momentum measured in the CAL and the LPS be less than the kinematical limit of twice the incoming proton energy;
- $x_{\mathbb{P}} \leq 0.03$, where $x_{\mathbb{P}}$ is the reconstructed value of $x_{\mathbb{P}}$ defined as: $x_{\mathbb{P}} = (Q^2 + M_x^2)/(Q^2 + W^2)$. The mass of the diffractive system, M_X, was reconstructed from the EFOs;
- $0.95 \leq x_L \leq 1.03$, where x_L is the fraction of the initial proton momentum carried by the scattered proton;
- the variable t was required to be in the range $0.09 \leq |t| \leq 0.55$ GeV^2.

The number of data events remaining after all cuts was 28.

5 Monte Carlo simulation and acceptance

A Monte Carlo simulation was used to correct data for acceptance and detector effects. The ZEUS detector response was simulated with a program based on GEANT 3.13. Events generated with RAPGAP were passed through the detector simulation, subjected to the same trigger requirements as the data, and processed by the same reconstruction and offline programs.
A comparison of data (points) and MC (histograms) is shown in figures 2, 3 and 4 for DIS, jet and diffractive variables, respectively. For the comparison, MC histograms were normalised to the number of data events.
The actual simulation only considered events with dijets from light quarks. A needed improvement is to include in the simulation events with dijets from charm quarks and events with resolved photons.
The resulting acceptance was on average around 1%, due to the low geometrical acceptance of the LPS.

6 Results

The t distribution, corrected for acceptance, has been measured in four bins of t, as shown in fig. 6. The value of the slope parameter b, obtained from a fit with the function $\frac{dN}{dt} = Ae^{-b|t|}$, is $b = 7.43 \pm 1.32$ GeV^{-2}.

References

[1] ZEUS Coll., S. Chekanov et al., *Accepted by Eur. Phys. J.* **C**, DESY-07-126.

[2] M. Ruspa, Ph. D. Thesis, Universita ' degli studi di Torino, (2001)

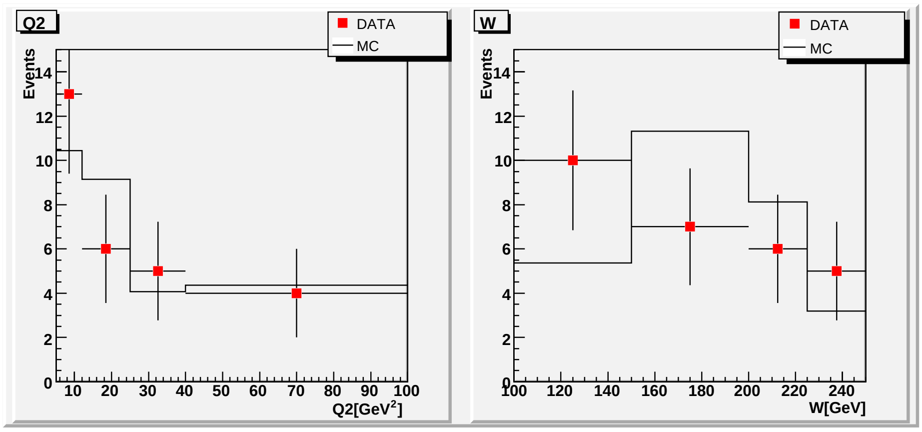

Figure 2: Data (points) and MC (histogram) comparison for Q^2 and W

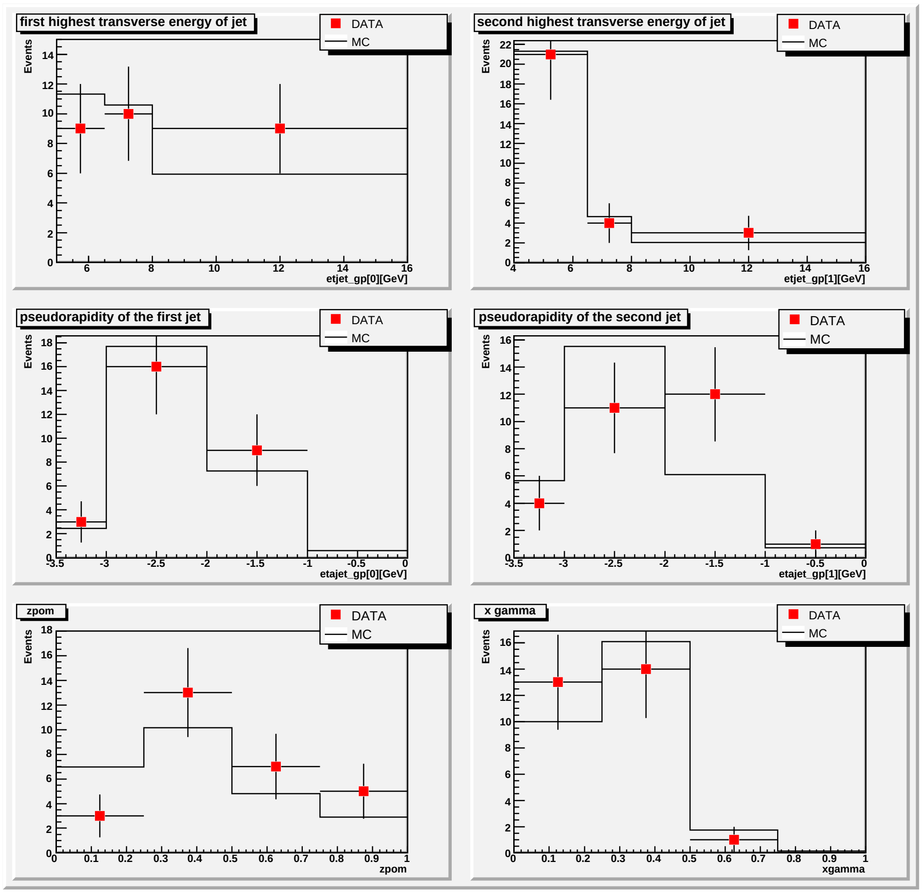

Figure 3: Data (points) and MC (histogram) comparison for the transverse energy of the first and the second jet, for the pseudorapidity of the two jets in the $\gamma^* p$ frame, and for $z_{I\!P}$ and x_γ

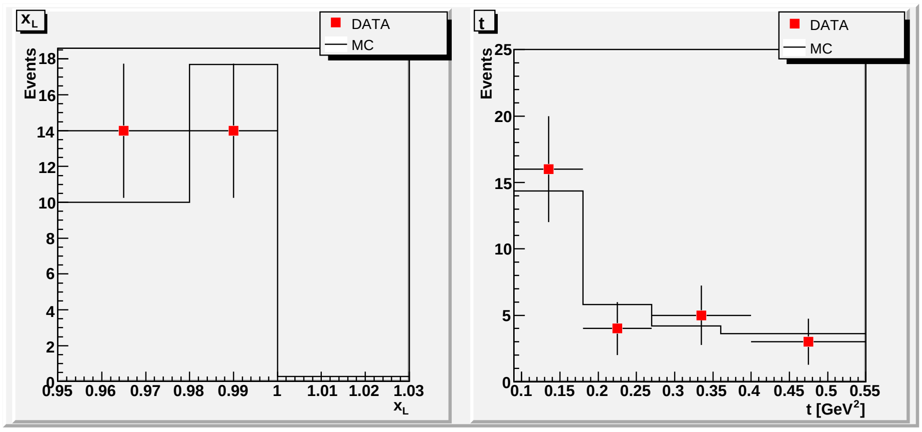

Figure 4: Data (points) and MC (histogram) comparison for x_L and t

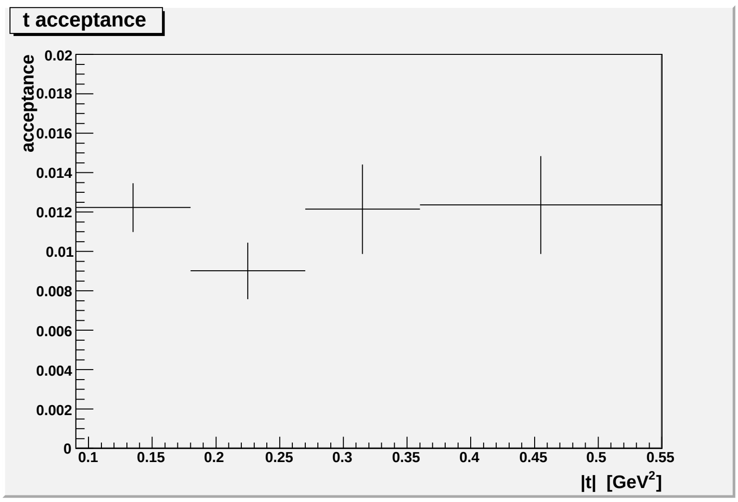

Figure 5: Acceptance as function of t

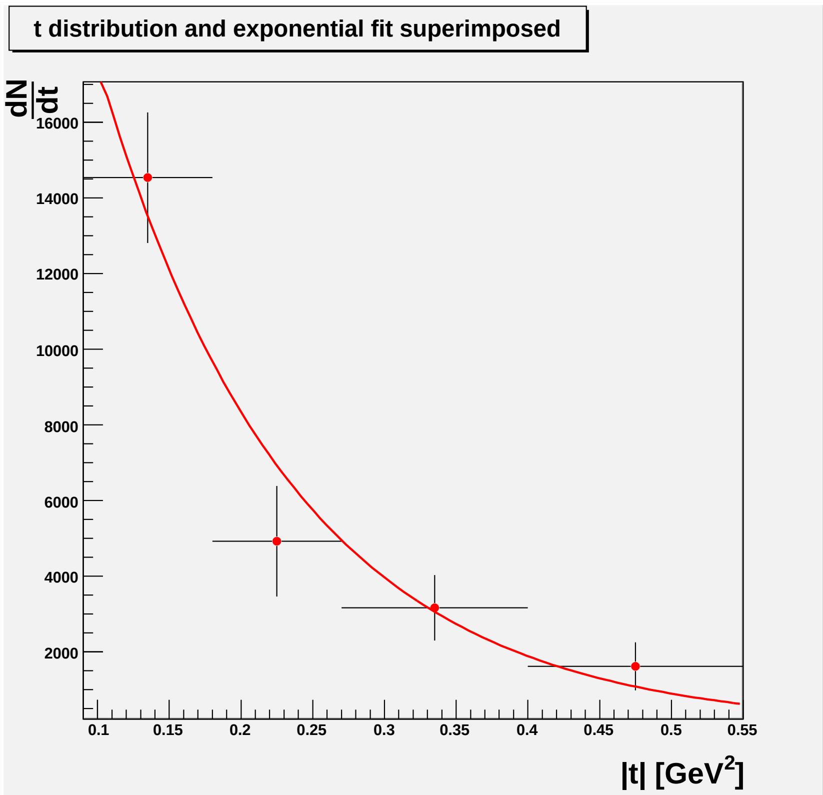

Figure 6: t distribution with the exponential fit superimposed