Final States in Diffractive DIS from ZEUS

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Hadronic final states are analyzed for diffractive deep inelastic scattering $ep \to eXp$, in which the virtual photon dissociates into a hadronic final state of mass $4 < M_X < 35$ GeV and the scattered proton, carrying more than 95% of the initial proton momentum, is detected in the Leading Proton Spectrometer. The event shape variables, thrust and sphericity, are studied as a function of the invariant mass M_X and the measurements are compared to models of diffractive deep inelastic scattering as well as to measurements performed in e^+e^- collisions. Characteristics of the final states are further investigated in terms of energy flow and transverse energy flow in the center of mass of the system

1. INTRODUCTION

Diffractive deep inelastic scattering (DIS) processes are most commonly ascribed to the t-channel exchange of a color singlet object with the quantum numbers of the vacuum, called the "Pomeron" ($I\!P$) [1,2]. The diffractive DIS process $ep \to e'p'X$, where X represents the observed multihadronic final state with an invariant mass M_X, is characterized by the presence of a fast forward scattered proton (p'). Here an analysis is presented based on events selected by the presence of the diffractively scattered proton in the leading proton spectrometer (LPS) of the ZEUS detector [3]. The hadronic final state of mass M_X is analyzed in its center of mass system (cms), which in models based on the pomeron exchange picture is equivalent to the cms of the virtual photon and the pomeron, here called the $\gamma^* I\!P$ cms.

The event shape variables thrust T and sphericity S provide information on the topology of the hadronic final state which is related to the hadronic structure of the Pomeron [4]. The thrust can be calculated as

$$T = \max_{\boldsymbol{n}} \frac{\sum_i |\boldsymbol{n} \cdot \boldsymbol{p}_i|}{\sum_i |\boldsymbol{p}_i|}, \quad (1)$$

where $\boldsymbol{p_i}$ represents the momentum of the observed hadronic final state particle and the unit vector $\boldsymbol{n}$ gives the orientation of the thrust axis. The sphericity S of the event is defined as

$$S = \frac{3}{2}(\lambda_2 + \lambda_3), \quad (2)$$

where λ_2 and λ_3 are the largest eigenvalues of the sphericity tensor [5],

For isotropic events, the sphericity S approaches 1 and the thrust T becomes 0.5, while for very collimated two-jet events S is about 0 and T is about 1.

For additional information of the structure of an event, the energy and transverse energy flow distributions have been investigated.

2. KINEMATICS AND EVENT SELECTION

The relevant kinematic variables in diffractive DIS events are described in Fig. 1. The results presented here are based on data taken with the ZEUS experiment in 1997, when the proton and positron beam energies were 820 GeV and 27.5 GeV, respectively. The integrated LPS luminosity was approximately 15 pb^{-1}. The selection of DIS events is described in [7]. The following kinematic range was defined for this analysis: $4 < Q^2 < 90\,\mathrm{GeV}^2$, $4 < M_X < 35\,\mathrm{GeV}$ and $0.0003 < x_{I\!P} < 0.03$.

3. MONTE CARLO MODELS

- The RAPGAP [6] program assumes a partonic substructure of the $I\!P$ in terms of quark and gluon densities. The following version was used: RAPGAP 2.06v51, with leading $I\!P$ + subleading reggeon exchange and parton densities in the $I\!P$ according to the results of H1 fit 2 [8]. Two fragmentation modes were used, ARIADNE (color dipole model) and MEPS (parton shower).

- The MC generator RIDI (RIDI 2.0) simulates the diffractive dissociation of virtual photons in *ep* interactions following the approach of Ryskin [9].

For thrust and sphericity RAPGAP(ARIADNE) is used to correct for detector effects and smearing. Typical correction factors are in the range from 2% to 10%. Since none of the models gives a reasonable description of the energy flow distributions, an unfolding error due to an alternative correction with RAPGAP(MEPS) was included in these results. Typical correction factors in this case are about 10%.

4. RESULTS AND CONCLUSIONS

In Fig. 2, we compare the event shape variables thrust and sphericity for diffractive DIS with results obtained in e^+e^- experiments [10] at center-of-mass energies of $\sqrt{s} = M_X$. We find, within the errors, about the same slope and absolute value, thus confirming our previous results [4]. The comparison of our data on thrust to the H1 results shows a discrepancy, with H1 seeing less-collimated events. One should note here that H1 uses a different event selection (*large rapidity gap* [11]) for their diffractive sample. It can also be seen, that the RAPGAP(ARIADNE)-model gives the best prediction for thrust and sphericity. On the other hand the same generator interfaced to MEPS fails completely, showing that fragmentation is a very important issue in this measurement. We further studied subsamples of our data, slicing the phase space: $x_{I\!P} < 0.01$ or $x_{I\!P} > 0.01$, $W > 100$ GeV, $Q^2 < 10$ GeV^2 or $Q^2 > 10$ GeV^2. We found no dependence of thrust and sphericity on any of these variables within this kinematic range.

In the energy and transverse energy flow distributions a two jet structure developing with increasing mass M_X (see Figs. 3 and 4) can be seen. The energy flow measurement (Fig. 3) is also in general agreement with the H1 results. In the higher mass bins the distributions show a slight enhancement with respect to the γ^* side.

In summary, the thrust and sphericity measurments agree with e^+e^- results and the RAPGAP(ARIADNE) model. For the energy and transverse energy flow measurement all Monte-Carlo models fail to give a good description of the data.

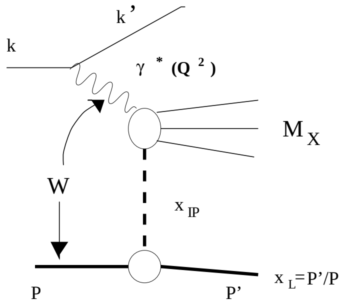

Figure 1. Schematic diagram of diffractive DIS events with relevant kinematic variables. $x_{I\!P}$ is reconstructed as $x_{I\!P} = \frac{M_X^2+Q^2}{W^2+Q^2}$.

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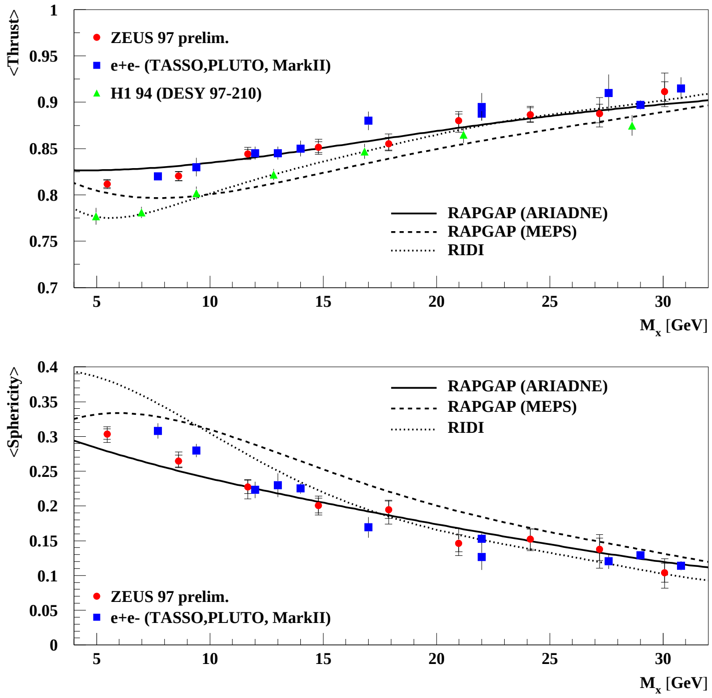

Figure 2. Average thrust and sphericity as a function of M_X. Error bars include systematic and statistical uncertainties.

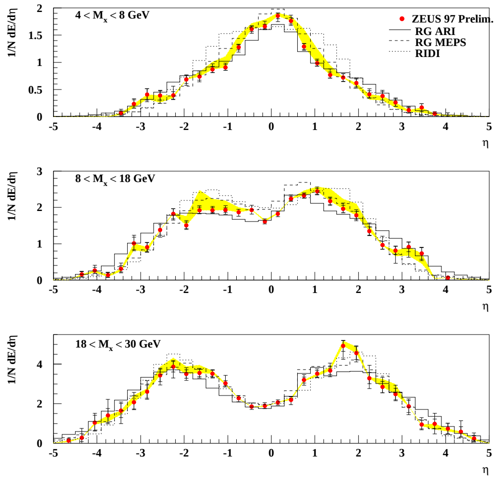

Figure 3. Energy flow in the $\gamma^* I\!P$ system as a function of pseudorapidity η ($\eta > 0$ is the γ^* direction). The shaded band gives the correction uncertainty using different models.

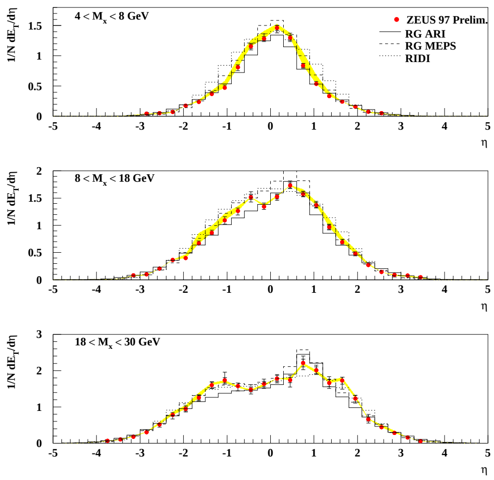

Figure 4. Transverse energy flow in the $\gamma^* I\!P$ system as a function of pseudorapidity η. The shaded band gives the correction uncertainty using different models.