New results in ep hadronic final states from diffractive scattering and leading baryon production

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Abstract
We present preliminary results from both the H1 and ZEUS experiments at HERA for four different hadronic final state analyses in the area of leading baryon and diffractive processes. These measurements are used to aid our understanding of the interactions through color singlet exchange.

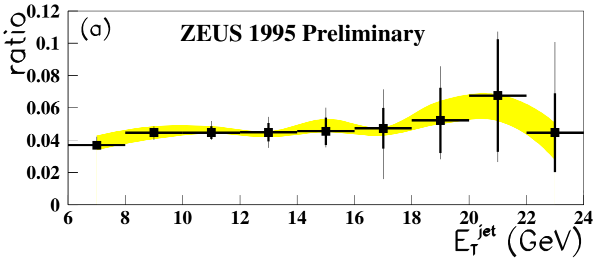
1. Introduction

Since the early days of hadron-hadron scattering, a significant part of the cross section has been seen to come from soft, color-singlet exchange. A phenomenological description was created in which the cross section could be described in terms of two asymptotic *Regge* trajectories known as the Reggeon (IR) and the Pomeron (IP).

When HERA first turned on, it was quite striking to learn that approximately 10% of the total cross section was made up again of a color singlet exchange process. This implied that HERA could provide an environment for careful study of this process. In this paper, four different processes are presented which have been recently analyzed at the H1 and ZEUS experiments in an attempt to better understand the nature of these color-singlet exchanges.

2. Di-Jets Events with Leading Neutrons

This first measurement deals mainly in the kinematical region in which the reggeon trajectory is dominant. To test our expectation that the Regge phenomenology implies a single exchanged particle, the tagged di-jet final state offers a good environment. A tagged neutron provides a clean forward signature of the proton system, while the di-jet provides a hard scale in the final state. The 1995 data from ZEUS[1] support the expectation of factorization in such a process, by looking at the ratio of events with a tagged neutron to those without (Fig. 1). This ratio remains constant, independent of the transverse energy of the jets. In addition, the neutron energy spectrum is independent of the exchanged photon momentum.



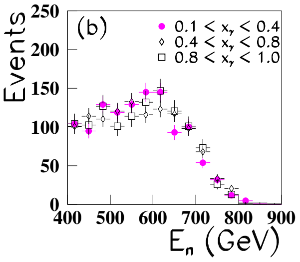
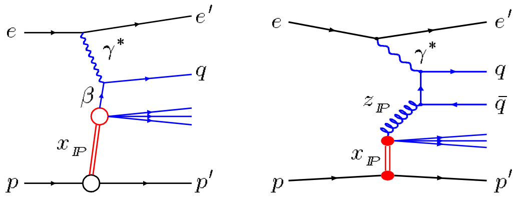


Figure 1. (a) the ratio of tagged to untagged neutron events are shown relative to the transverse energy of the jets. (b) the event rate as a function of the energy of the tagged neutron for three bins in photon momentum.

With these results supporting the idea that this is a factorizable process, we can look further at the nature of the exchanged reggeon. Since we know that we have a tagged neutron in the final state, the naïve expectation would hold that the incoming proton is reduced to a neutron (tagged) and a π^+. The Regge exchange is therefore expected to be primarily pion dominated. To further study this, the ZEUS data have been compared to different Monte Carlo models of pion flux and pion structure functions. The data show good sensitivity to the different pion flux models and are most consistent with the one-pion-exchange models. However, the data are not sufficient to distinguish between the different pion structure function predictions.

3. Event Shape Analysis of Diffractive Events with Leading Proton

Attempts to understand the underlying structure of diffractive events have led to many different modes of final state analyses. In this analysis, the diffractive events are characterized by the detection of a leading proton in the Leading Proton Spectrometer (LPS) at ZEUS. With the detection of a leading proton and the scattered electron, the nature of the exchange is very well constrained to that part of the cross-section dominated by the pomeron trajectory. With that in mind, the nature or possible structure of the pomeron can be analyzed by looking at the event shape of all additional hadronic products. Naïvely, one can understand the usefulness of this technique by considering the following two diagrams:



Since the virtual photon from the electron can couple to a quark but not to a gluon, a quark dominated pomeron will not require any additional sub-process and will therefore be dominated by a 2-jet topology (the struck quark and the pomeron remnant). However, in the case of a gluon dominated pomeron, the interaction would be primarily governed by the familiar photon-gluon fusion diagram which would then have a 3-jet topology (quark jet, anti-quark jet, and pomeron remnant).

Recent results [1] have been released by the ZEUS collaboration (Fig. 2) to update their previous measurements [2] of the *thrust* (the back-to-back nature of the event) and *sphericity* (uniform distribution of the event). It is interesting to note that the new results from ZEUS are now in better agreement with previous e^+e^- data while showing a mild deviation from the previously published H1 results [3]. This agreement with e^+e^- measurements gives the impression that a more quark-like object is being probed. Further comparisons have also been presented in the particle production rates relative to the incoming photon direction (x_F). These are all in good agreement with the previous H1 data.

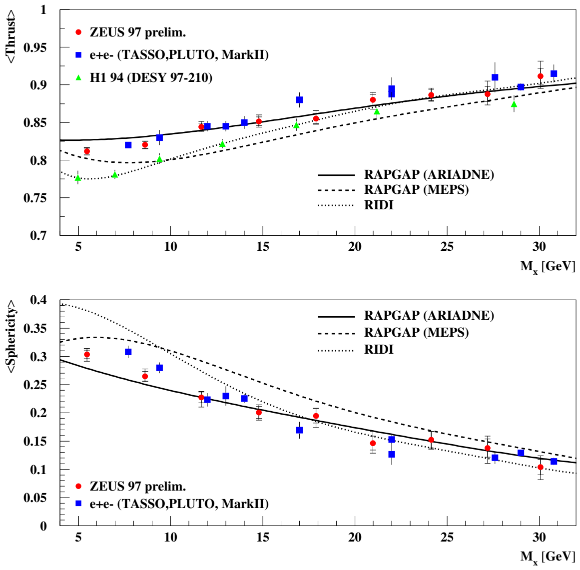


Figure 2. Thrust and Sphericity measurements from ZEUS compared with the previously published data of H1 and other e^+e^- experiments.

4. Diffractive D* Production

Another method for better understanding the quark/gluon nature of the exchanged particle in a diffractive process is by the use of a hard scale. Both the H1 and ZEUS collaborations have recent results for the diffractive production of open charm[1]. The additional mass scale of the charm production allows one to restrict the contributing processes. The dominant process is the familiar photon-gluon fusion, implying good sensitivity to the gluon content of the pomeron. In addition, predictions exist for the production of open charm in models for which diffraction is governed by soft color interactions or perturbative 2 gluon exchange, rather than the resolved pomeron picture.

Both H1 and ZEUS have provided differential cross section measurements for the decay mode $D^* \to K\pi\pi$. In addition, ZEUS has analyzed the $D^* \to K3\pi\pi$ decay mode. All distributions show a consistent shape with predictions. This confirms the expectation that the cross section is dominated by low Q^2 and low $z_{I\!P}$ events. However, the overall normalization of the cross section is more problematic. The ZEUS data are in agreement with the magnitude predicted by most models. The H1 data, however, are approximately a factor of 3 lower than the resolved pomeron predictions and a factor of 2 lower than those from soft color interactions.

This discrepancy is also born out in the calculated total cross sections. H1 presents a preliminary result for the total ep cross section as measured in the $D^* \to K\pi\pi$ channel of 154 ± 40 (stat) ± 35 (sys) pb, while ZEUS presents, for the same channel, 379 ± 66 (stat) ${}^{+99}_{-140}$ (sys) pb. ZEUS also presents the total ep cross section as measured from the $D^* \to K3\pi\pi$ channel, at slightly different kinematics, as 526 ± 110 (stat) ${}^{+200}_{-240}$ (sys) pb. Both ZEUS results are consistent with the same overall D^* production rate.

5. Diffractive Di-Jet Production

Since the disparate D^* results might suggest a breakdown of the resolved pomeron models, it is useful to examine other hard scale processes which might aid our understanding of this process. It has been frequently suggested that most of the existing inclusive results can also be well described by perturbative 2-gluon exchange or by classical soft color field interaction models. By examining differential distributions of diffractive events with a di-jet in the final state, H1 expects to see good sensitivity to some of these different models.

The most striking thing to come out of this analysis[1] can be seen in the $z_{\mathbb{P}}$ distribution (Fig. 3) where the di-jet production is dominated by events in which only a small fraction ($z_{\mathbb{P}}$) of the visible hadronic final state is collected in the two leading jets. This stands in direct contradiction to the expectations of the perturbative 2-gluon models which, at the parton level and in lowest order, expect to be concentrated near $z_{\mathbb{P}} = 1$. In addition, it is quite interesting to note the very good agreement between the di-jet data and the predictions from the resolved pomeron Monte Carlo calculations based on the fits to inclusive $F_2^{D(3)}$ data. This implies that the large gluon contribution, which was inferred by H1[4] from the inclusive data, is in surprisingly good agreement with the di-jet process, which is expected to have a much higher sensitivity to gluons than to quarks. One can see from the breakdown shown in Fig. 3 the relatively large gluon contribution in the Monte Carlo prediction, and it's good agreement with the overall shape of the di-jet production. The deviations at low $z_{\mathbb{P}}$ might be an additional hint of resolved photon contributions which are expected at these energies.

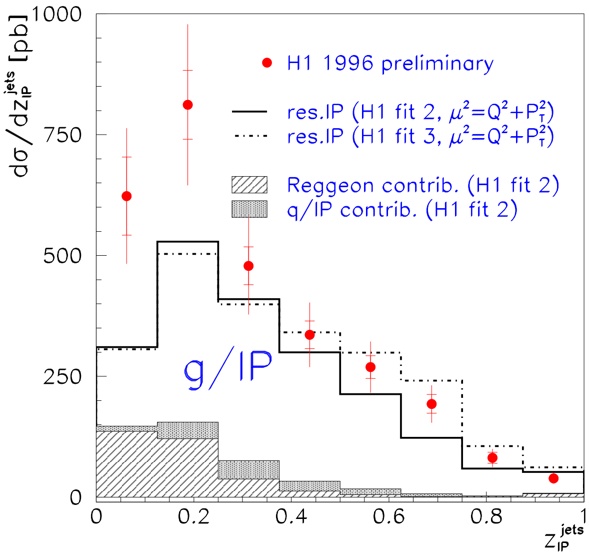


Figure 3. Diffractive di-jet production as a function of $z_{\mathbb{P}}$. The data are compared to Monte Carlo predictions based on the resolved pomeron models using fits to the inclusive $F_2^{D(3)}$ data. These fits contain a large ($\sim 80\%$) gluon content of the pomeron. Fit 2 refers to a rather flat distribution, in $z_{\mathbb{P}}$, of gluons, while fit 3 refers to a gluon distribution that is peaked at $z_{\mathbb{P}} = 1$.

6. Conclusions

As has been shown, HERA is providing a very good laboratory for the continued investigation of the nature of color singlet exchange. Further measurements of exclusive final states are allowing the investigation and further comprehension of our current set of phenomenology. The current data from H1 and ZEUS are in global agreement with two very interesting exceptions: the recent update of the ZEUS event shape measurements in which the thrust measurements appear more quark-like, consistent with the e^+e^- data, and the H1 D^* results which show an overall normalization that is a factor of 3 lower than expectations. These are interesting discrepancies which are being thoroughly investigated. However, it is striking to realize that the vast majority of the data is still in good agreement with the original conclusions from the inclusive $F_2^{D(3)}$ measurements: that the pomeron appears to be a gluon dominated composite object. Many questions remain, however, and we look forward to the improved statistics and additional exclusive channels that will be available with future data.

References

[1] Contributed Papers to EPS-HEP 99 **3-40**, **3-42**, **3-37**, **3-47**, **3-50**
[2] ZEUS Collab., *Phys. Lett.* **B421** (1998) 368.
[3] H1 Collab., *Phys. Lett.* **B428** (1998) 206.
[4] H1 Collab., *Z. Phys.* **C76** (1997) 613.