DIFFRACTION AT HERA AND IMPLICATIONS FOR TEVATRON AND LHC

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We describe new QCD fits to diffractive cross sections measured at HERA and we use the parton densities derived from these fits to predict the shape of the dijet mass fraction in double Pomeron exchange at the Tevatron. We discuss the existence of exclusive events in this dijet channel and some prospects are given for the LHC.

1 Diffraction at HERA

One of the most important experimental results from the DESY *ep* collider HERA is the observation of a significant fraction (around 15%) of diffractive events in deep inelastic scattering (DIS) with large rapidity gap between the scattered proton, which remains intact, and the rest of the final system [1]. In the standard QCD description of DIS, such events are not expected in such an abundance since large gaps are exponentially suppressed due to color strings formed between the proton remnant and scattered partons. For diffractive events, however, a color neutral cluster of partons fragments independently of the scattered proton. The theoretical description of diffractive events is a real challenge since it must combine perturbative QCD effect of hard scattering with nonperturbative phenomenon of rapidity gap formation.

There are various interpretations of this phenomenon, but a very appealing one relies upon a partonic interpretation of the structure of the Pomeron [2]. It is defined in the presence of a hard scale, the photon virtuality Q^2 or jet transverse momentum, which allows to apply perturbative QCD. Soft diffraction, when such a scale is missing, is outside the scope of the model but can be described in the context of Regge pole phenomenology. This phenomenology, however, turns out to be quite useful in the description of a soft part of hard diffraction, responsible for the rapidity gap formation. In fact, it is possible to nicely describe the diffractive cross-section data from HERA by a QCD DGLAP evolution of parton distributions in the Pomeron combined with a Regge parametrisation of flux factors describing the probability of finding a Pomeron state in the proton [1]. It follows exactly the same procedure than for standard DIS except that the diffractive distributions are related to the Pomeron, whose flux factor is factorised and parametrised as a function of $x_{\mathbb{P}}$, the momentum fraction lost by the proton.

Sets of diffractive parton distribution functions (dPDFs) are shown in figure 1. In the infinite momentum frame, the dPDFs have an interpretation of conditional probabilities to find a parton in the proton with the momentum fraction $x = \beta x_{\mathbb{P}}$, where β denotes the fraction of the particular parton in the Pomeron. The gluons dominate the diffractive exchange and carry approximately 70 % of the momentum. While the quark densities are found to be relatively close for H1 and ZEUS experiments, the gluon density differs by more than a factor 2. New preliminary data from ZEUS reduce this discrepancy.

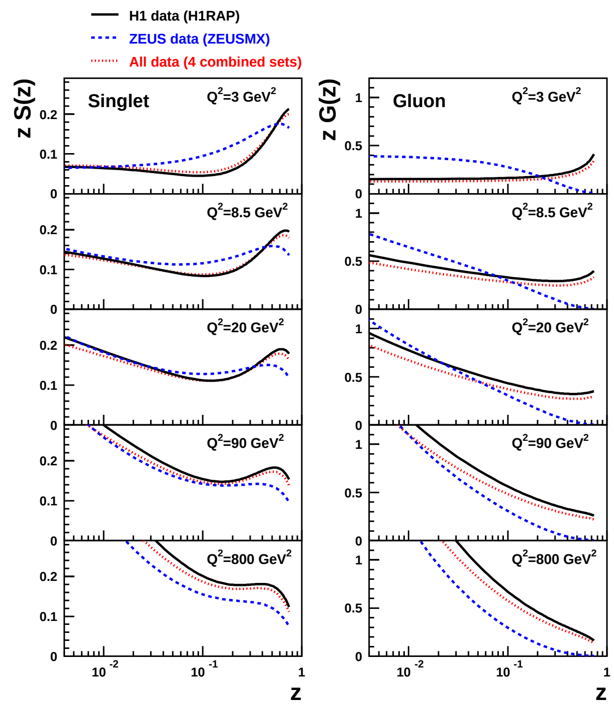

Figure 1: Singlet and gluon distributions of the Pomeron as a function of z, the fractional momentum of the Pomeron carried by the struck parton, derived from QCD fits on H1RAP data alone, ZEUSMX data alone or the four data sets together. The parton densities are normalised to represent $x_{\mathbb{P}}$ times the true parton densities multiplied by the flux factor at $x_{\mathbb{P}} = 0.003$.

In the following, we will use the QCD fits to the H1 data to compare with the dijet mass fractions measured by the CDF collaboration in double Pomeron exchange and we discuss the possible evidence for exclusive events in this context.

2 Diffraction at Tevatron and LHC

The difference between diffraction at HERA and at the Tevatron is that diffraction at the Tevatron can occur not only on either p or $\bar{p}$ side as at HERA, but also on both sides. The former case is called single diffraction whereas the other one double Pomeron exchange. In the same way as we have defined the kinematical variables $x_{\mathbb{P}}$ and β at HERA, we define $\xi_{1,2}$ as the proton fractional momentum loss (or as the p or $\bar{p}$ momentum fraction carried by the Pomeron), and $\beta_{1,2}$, the fraction of the Pomeron momentum carried by the interacting parton. The produced diffractive mass is equal to $M^2 = s\xi_1$ for single diffractive events and to $M^2 = s\xi_1\xi_2$ for double Pomeron exchange, where $\sqrt{s}$ is the energy of the reaction in the center of mass frame. The size of the rapidity gap is of the order of $\Delta\eta \sim \log 1/\xi_{1,2}$.

It has been shown that the dPDFs of HERA can not be used directly to make predictions at the Tevatron. Indeed, factorisation does not hold and a gap survival probability of a few % has to be considered. It corresponds to the probability that there is no soft additional interaction or in other words that the event remains diffractive. Knowing the presence of this essential factor, we can discuss the case of the double Pomeron exchange at the Tevatron. A schematic view of non diffractive, inclusive double Pomeron exchange and exclusive diffractive events at the Tevatron or the LHC is displayed in figure 2. The upper left plot shows the "standard" non diffractive events where the Higgs boson, the dijet or diphotons are produced directly by a coupling to the proton associated with proton remnants. The bottom plot displays the standard diffractive double Pomeron exchange (DPE) where the protons remain intact after

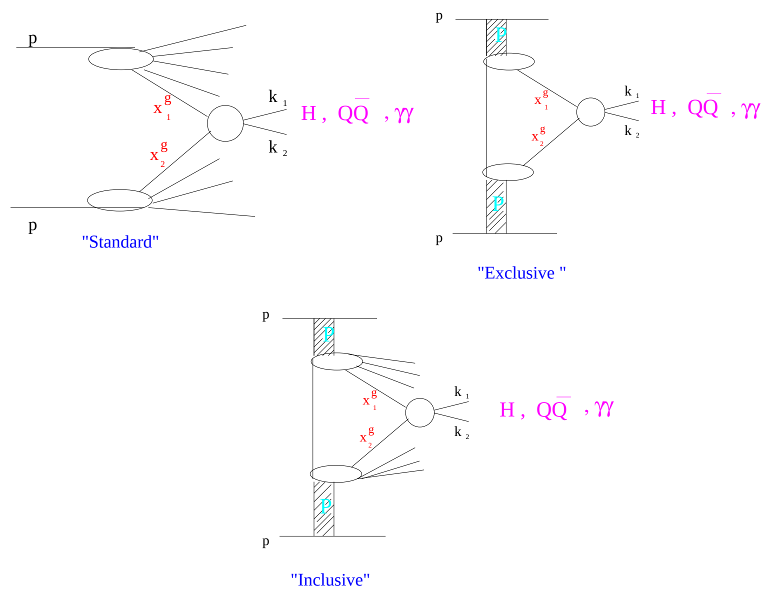

Figure 2: *Scheme of non diffractive, inclusive double Pomeron exchange and exclusive events at the Tevatron or LHC*

interaction and the total available energy is used to produce the heavy object and the Pomeron remnants. There may be a third class of processes displayed in the upper right figure, namely the exclusive diffractive production. Exclusive events allow a precise reconstruction of the mass and kinematical properties of the central object using the central detector or even more precisely using very forward detectors installed far downstream from the interaction point[3]. As mentioned above, the mass of the produced object can be computed using roman pot detectors and tagged protons, $M = \sqrt{s\xi_1\xi_2}$, where $\xi_{1,2}$ represent the fractions of energy losses for both protons. We see immediately the advantage of those processes : we can benefit from the good roman pot resolution on $\xi_{1,2}$ to get a good resolution on mass. Therefore, it is possible to measure the mass and the kinematical properties of the produced object and use this information to increase the signal over background ratio by reducing the mass window of measurement[3].

If such exclusive processes exist in DPE, the most appealing is certainly the Higgs boson production through this channel at the LHC[3]. It cannot be observed at the Tevatron due to the low production cross section, but one can use present measurements at the Tevatron to investigate any evidence for the existence of exclusive production in DPE.

3 Dijet mass fraction at the Tevatron

The CDF collaboration has measured the so-called dijet mass fraction (DMF) in dijet events when the antiproton is tagged in the roman pot detectors and when there is a rapidity gap on the proton side to ensure that the event corresponds to a double Pomeron exchange[3]. The measured observable R_{JJ} is defined as the ratio of the mass carried by the two jets divided by the total diffractive mass. The DMF turns out to be a very appropriate observable for identifying the exclusive production, which would manifest itself as an excess of the events towards $R_{JJ} \sim 1$. Indeed, for exclusive events, the dijet mass is essentially equal to the mass of the central system because no Pomeron remnant is present. Then, for exclusive events, the DMF is 1 at generator level and can be smeared out towards lower values taking into account the detector resolutions. The advantage of DMF is that one can focus on the shape of the distribution. The observation of exclusive events does not rely on the overall normalization which might be strongly dependent on the detector simulation and acceptance of the roman pot detector. Results are shown in figure 3 with Monte-Carlo expectations calculated using DPEMC [4]. Indeed, we see a clear deficit of events towards high values of the DMF, where exclusive events are supposed to occur. In figure 3, a specific model describing exclusive events [5] is also added to the inclusive prediction and we obtain a good agreement between data and the sum of MC expectations [4]. It is a first evidence that exclusive events could contribute at the Tevatron [3,6].

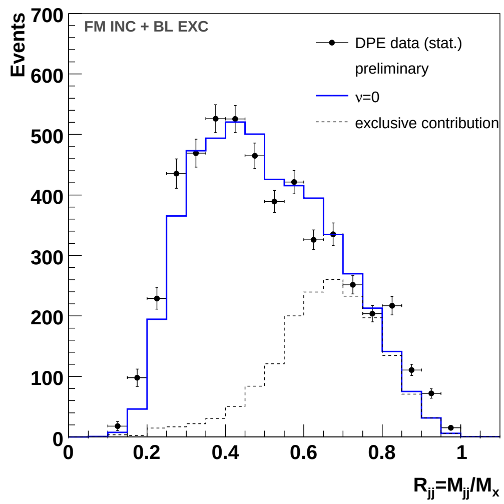

Figure 3: Dijet mass fraction for jets $p_T > 10\,\mathrm{GeV}$. The data are compared to the sum of inclusive and exclusive predictions. The dPDFs derived from H1 data have been used together with the survival gap probability measured with single diffractive events at Tevatron.

4 Conclusions

We have discussed a first evidence for the existence of exlusive events in double Pomeron exchange at the Tevatron. If such events can be also observed at the LHC, it would be possible to produce a Higgs boson as well as of a dijet system regarding the cross section values accessible at the LHC. First, a direct precise determination of the gluon density in the Pomeron through the measurement of the diffractive dijet cross section at the Tevatron and the LHC would be necessary if one wants to prove the existence of exclusive events in the dijet channel. In particular, a Tevatron or LHC diffractive gluon density could be extracted including *de facto* the survival gap probability. Then, the great benefit of exclusive events concerns the precise reconstruction of the mass of the central object, using roman pot detectors installed far downstream from the interaction point [3]. It gives the opportunity to work with a favorable signal/background ratio compared to standard Higgs searches with a mass below 150 GeV.

References

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