HIGGS BOSON PRODUCTION VIA DOUBLE POMERON EXCHANGE AT THE TEVATRON AND THE LHC*

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Double diffractive Higgs boson production is assessed in the picture of composite Pomeron collisions. It is shown how the introduction of Pomeron parton densities allows to describe some critical aspects of the existing data, and how these and future measurements of double diffractive dijet production will allow to constrain the non-perturbative parameters involved in the process.

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1. Introduction

Recent studies [1] suggest that an interesting channel to observe the Higgs boson is the Double Pomeron Exchange process (DPE). We present, in the following, our estimates obtained in the inclusive picture of double diffractive interactions. Our model and its consequences is outlined in the first section; the second section discusses its calibration on coming DPE dijet data.

2. Bialas–Landshoff model with composite $\mathbb{P}$

The starting points of our model are the predictions by Bialas, Landshoff, Szeremeta and Janik in the beginning of the 1990's [2], concerning Higgs boson and dijet production in exclusive $\mathbb{P}$–$\mathbb{P}$ collisions:

$$p + p \to p + H + p\,; \quad p + p \to p + \text{jet} + \text{jet} + p\,,$$

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where the pomerons are emitted in the t-channel (following a Regge trajectory $\alpha(t)$ as obtained from hadron-hadron total cross-sections [3]) and fuse into a Higgs boson or a jet pair. These processes are characterized by extremely clean final states, in which (as was realized later [4]) the central mass can be obtained with high precision from measurements of the outgoing protons momenta, promising significant enhancement of the Higgs signal over the dijet background. Further signal enhancement comes from the helicity constraints on the dijet final state, inducing light-quark suppression proportionally to their mass.

In our approach, the pomerons are seen as composite objects (with parton densities), so that the final state becomes:

$$pp \to p + X + H + Y + p\,; \;\; pp \to p + X + \mathrm{jet} + \mathrm{jet} + Y + p\,,$$

where now X and Y figure the remnants of the $\mathbb{P}$–$\mathbb{P}$ collision. We assume that the Pomeron formation remains a soft, long-timescale process which again follows the Regge trajectory used in the original model; and that perturbative QCD applies at the hard vertex, where we use the language of Pomeron parton densities.

Given the above, the differential cross-sections for inclusive Higgs boson and dijet production via DPE become:

$$\begin{aligned}
\sigma_H \;&\propto\; C_H \left(\frac{x_1^g x_2^g s}{M_H^2}\right)^{2\varepsilon} \delta_H \prod_{i=1,2} \left[G_P(x_i^g)\frac{\xi^{\alpha' v_i^2}}{1-\xi_i}F(v_i^2)\right],\\
\sigma_{JJ} \;&\propto\; C_{JJ} \left(\frac{x_1^g x_2^g s}{M_H^2}\right)^{2\varepsilon} \delta_{JJ}^2 \prod_{i=1,2} \left[G_P(x_i^g)\xi_i^{\alpha' v_i^2}F(v_i^2)\right] F_{JJ}.
\end{aligned}$$

The constants C_H, C_{JJ} are normalizations containing factors related to the hard matrix elements together with a common factor G^8 due to the non-perturbative coupling at the proton–Pomeron vertex. The x_i^g define the Pomeron momentum fraction carried by the gluons involved in the hard process, $G_P(x_i^g)$ are the corresponding structure functions (as extracted from the HERA experiments [5]; the hard scale μ^2 is taken to be 75 GeV^2), v_i are the transverse momenta of the outgoing protons, ξ_i are the proton momentum losses (required to be smaller than 10%) and η_i are the jet rapidities. $F(v_i^2) = \exp(-2v_i^2\lambda), \lambda \;=\; 2\mathrm{GeV}^{-2}$ is the proton form factor; F_{JJ} is the cross-section of the hard $gg \to q\bar{q}, gg$ processes; finally the Pomeron trajectory is $\alpha(t) = 1 + \varepsilon + \alpha' t$, with $\varepsilon = 0.08$ and $\alpha' = 0.25$ GeV^{-2} as obtained from hadron–hadron total cross-sections [3].

The consequences of our assumptions are threefold. We realize that there are a number of unknown factors (non-perturbative couplings, normalization of $G_P(x_i^g)$) which prevent us from giving absolute predictions for all processes, so that the model has to be calibrated on data. In particular, all normalization uncertainties disappear in the ratio σ_H/σ_{JJ}, which suggests that a reliable estimate of Higgs boson production rates can be obtained after normalizing our dijet prediction to the observed cross-section. Further, since the process is now inclusive, dijet production is again flavour-democratic. Finally, the presence of Pomeron remnants destroys the relation between the outgoing proton momenta and the central mass, so that new, more involved experimental methods have to be considered. These are discussed in [6].

Notice also the cross-section dependence on the Pomeron trajectory parameters ε and α'. Since the value of these parameters seems to depend on the physical environment (for instance, a Regge fit to diffractive HERA data leads to $\varepsilon = 0.2$ [5], a value which was also used in [7]), the possibility of estimating them from data (rather than taking $\varepsilon = 0.08$ for granted) is also considered.

3. Model calibration on data

The CDF Collaboration has published results on double diffractive dijet production [8], obtaining a measured cross-section of 43.6 nb ($\pm$ 50% systematic error). The prediction of our model (with parameters as explained above, and after reproducing the experimental cuts) is 11.5 nb. This leads to a scaling factor of 3.8, which at this point summarizes all unknown parameters.

An indicator of the "inclusiveness" of the process is given by the dijet mass fraction, defined as the ratio of the dijet mass measured in the central region, and the missing mass from the outgoing protons. This ratio should be 1 (up to experimental resolution effects) for exclusive events. We see in figure 1(left) that this picture is strongly disfavoured by the data. On the contrary, our model reproduces the distribution well, supporting the concept of a composite pomeron. Higgs boson production cross-sections obtained after inclusion of the scaling factor are displayed in figure 2.

We varied the ε-parameter from our standard value (ε =0.08) to an extreme value of $\varepsilon = 0.5$. As can be seen from the differential cross-section formulae, a higher ε-value will induce higher cross-section values, especially at low central mass. The importance of this effect (up to a factor 5–10) is displayed in figure 1(right). As a consequence, a more complete calibration procedure involves first determining the dynamical parameters (primarily ε, but also α') on differential cross-sections, compute total cross-sections with the newly determined parameters, and finally compare to the measured value to fix the unknown normalizations and extract the scaling factor. Of course, this study requires a much larger data sample than is available, and will be possible only after Run-II.

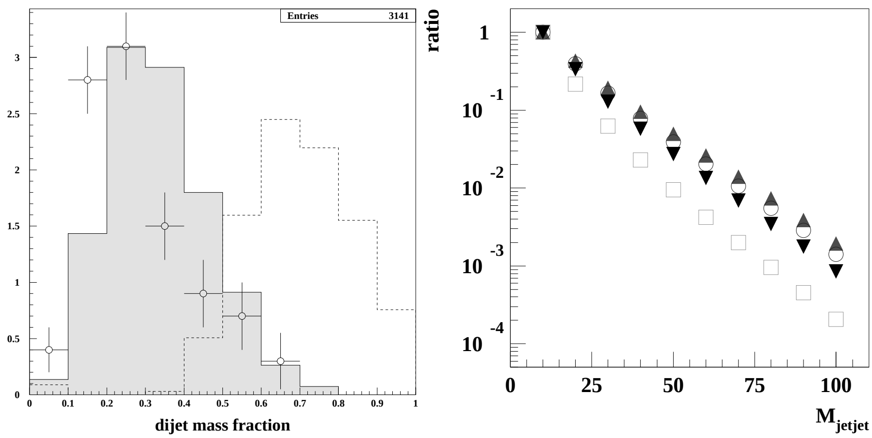

Fig. 1. (Left): dijet mass fraction distribution in the CDF data [8] (dots) and as predicted by the present model. (Right): comparison of $d\sigma_{JJ}/dM_{JJ}$ for different values of ε (ε =0.08, 0.15, 0.25, 0.5 for light triangles, circles, dark triangles and squares, respectively). All distributions are normalized to 1 at low mass.

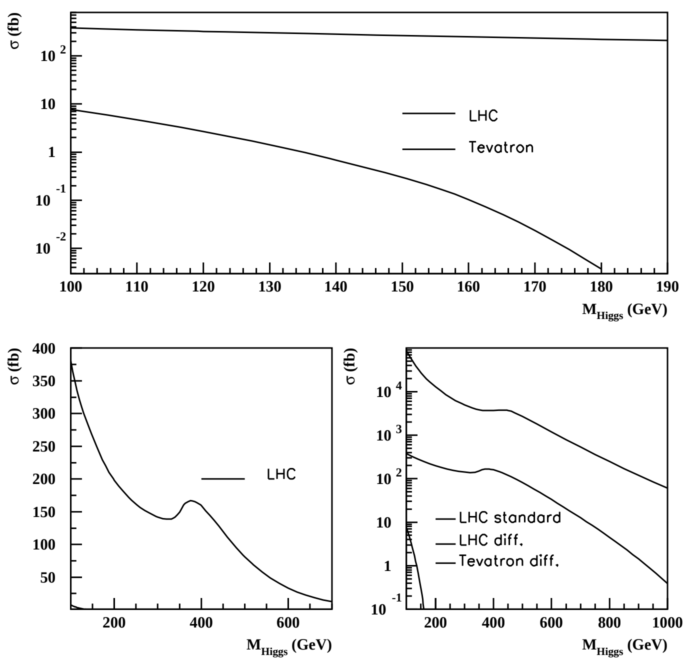

Fig. 2. Higgs boson production cross-section obtained after normalization of the dijet prediction.

4. Conclusions

The present model qualitatively describes the available and await to be put to further testing. The coming Run-II Tevatron data will constrain the parameters in Regge-like double-diffraction models, using differential dijet cross-sections. Assuming the usual value $\varepsilon = 0.08$, Higgs boson production will be small at the Tevatron (due to constraints on the maximum proton energy loss), and sizeable at LHC.

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