Search for exclusive events using the dijet mass fraction

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Abstract
We use new HERA QCD fits to predict the shape of a dijet mass fraction R_{JJ} at the Tevatron, investigate the presence of exclusive signal in CDF dijet mass fraction measurement, and look for its appearance in the dijet channel at the LHC.

Exclusive diffractive production of heavy mass objects is an interesting part of the physics program at the LHC. The fact that all energy lost by scattered protons is used to create a desired object (Higgs boson, dijets, diphotons, etc.) in the central rapidity region, yields highly accurate reconstruction of its mass (e.g. Higgs mass precision can reach $\sigma(M) \sim 1\,\text{GeV}$ [1]). The energy flowing into diffractive system can be precisely computed using missing momenta of scattered protons measured by proton taggers placed in the LHC tunnel.

But the exclusive production rate is so far not confidently known. The CDF collaboration advocated a presence of exclusive signal in the dijet production, analyzing the dijet mass fraction R_{jj} distribution [2]. It was an indirect measurement since the exclusive contribution was obtained by subtracting the inclusive diffractive contribution (where the energy lost by protons is used not only for producing the heavy object but also for pomeron remnants) from the measured signal. The inclusive contribution was calculated with the knowledge of diffractive PDFs as measured at HERA.

However, looking at newer QCD fits of HERA data presented in Ref. [3] one notices significant differences from the PDFs used in CDF analysis, mainly in the gluon distribution function. Its normalization has changed by a factor of 2 plus it turned out that the QCD fits poorly constrain the gluon density at large β, where β denotes the momentum fraction of a pomeron carried into the hard interaction by an interacting parton. This is quantitatively expressed as follows: multiplying the gluon density by a factor $(1-\beta)^{\nu}$, the uncertainty on the gluon translates to the uncertainty on the parameter ν as $\nu = 0.0 \pm 0.6$. It is important to see whether this uncertainty on the gluon distribution function cannot imitate the exclusive signal in the dijet mass fraction measurement.

1 Search for the exclusive signal at the Tevatron

In the CDF measurement [2], one requests two jets with p_T greater than certain threshold $p_T^{min} = 10, 25\,\text{GeV}$ and defines the dijet mass fraction distribution R_{jj} as a ratio of the invariant dijet mass to the total diffractive energy in the event. We compared the data with two models for

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inclusive diffraction, namely Factorized (FM) [4] and BPR [5] model. In the first case, diffractive cross section almost exactly factorizes to the flux factor and the parton distribution function; the only factorization breaking comes through the survival probability factor which is about 0.1 for the Tevatron energies and is predicted to be 0.03 for the LHC. Pomeron parameters are obtained from the fits at HERA. BPR model, on the other hand, is viewed as an exchange of two non-perturbative pomerons with soft pomeron parameters as extracted by the Donnachie and Landshoff [6].

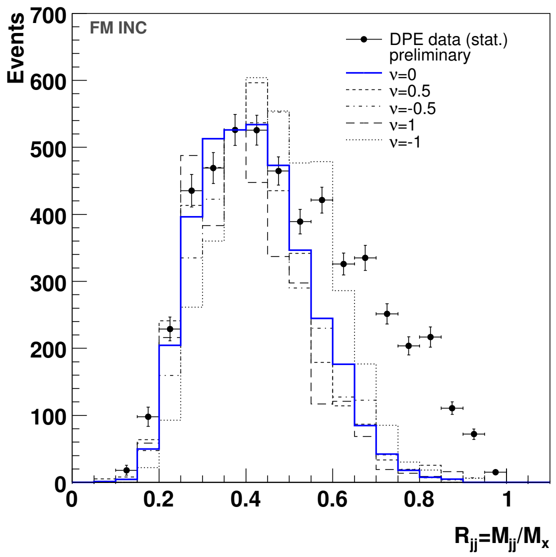

Fig. 1: Dijet mass fraction for jets $p_T > 10\,\text{GeV}$ predicted by Factorized model for inclusive diffraction. The uncertainty of the gluon density at high β is obtained by multiplying the gluon distribution by $(1-\beta)^{\nu}$ for different values of $\nu = -1, -0.5, 0, 0.5, 1$ (non-solid lines).

In Fig. 1, one can see the comparison of the CDF dijet mass fraction data with $p_T^{min} = 10\,\text{GeV}$ with the Factorized model for inclusive diffraction using the new parton densities [3]. The blue curve denotes the calculation performed with official PDFs whereas the other distributions correspond to gluon density variations at high β for $\nu = -1, -0.5, 0, 0.5, 1$. We note that even taking into account the gluon uncertainties, one is unable to explain the tail of the R_{jj} distribution and even though the data statistics is limited for a dijets with p_T above 25 GeV, the conclusion holds also. BPR model gives similar results; inclusive contribution by itself is insufficient to describe the data.

Therefore, the exclusive R_{jj} distribution predicted by Khoze-Martin-Ryskin (KMR) [7] exclusive model was added on top of the inclusive one, performing a fit of the two contributions to the data. The model is based on the direct coupling of perturbative gluons to the protons. As seen in Fig. 2, one can describe the measured CDF data well by superimposing FM and KMR model. It is worth mentioning that the relative normalizations between the inclusive and the exclusive contributions obtained from the fit for $p_T^{min} = 10\,\text{GeV}$ and $p_T^{min} = 25\,\text{GeV}$ jets

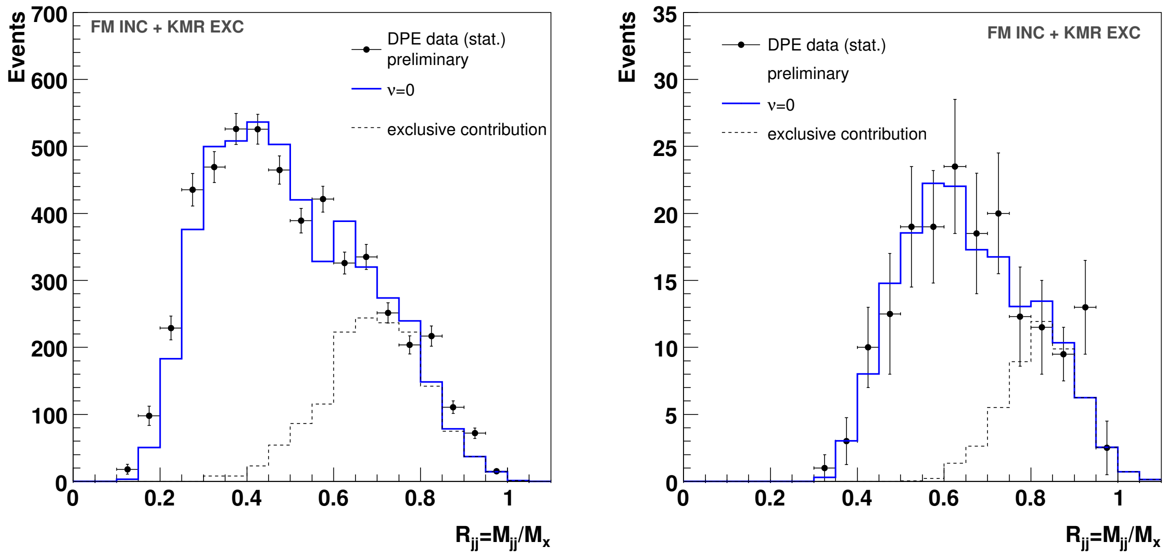

Fig. 2: Dijet mass fraction for jets $p_T > 10\,\mathrm{GeV}$ (left) and $p_T > 25\,\mathrm{GeV}$ (left). Inclusive contribution (FM) and exclusive contribution (KMR) are superimposed. We notice that the exclusive contribution allows to describe the tails at high R_{jj}.

where consistent with each other. This allowed us to determine the relative normalization from the Tevatron measurement and to apply it when making predictions of R_{jj} for the LHC. Let us note that the other existing model for exclusive diffraction, the Bialas-Landshoff model (BL), is disfavoured by the CDF data because it predicts to slow decrease of an exclusive dijet production cross section as a function of the jet p_T [8].

Beside the pomeron inspired models, we also investigated a prediction of the Soft color interaction model (SCI) [9] which succesfully described number of HERA and Tevatron measurements [10]. The model interprets diffraction as a consequence of a special color rearrangement in the final state controlled by just one probabilistic parameter. For low $p_T^{min} = 10\,\mathrm{GeV}$ jet threshold, one needs to add exclusive production to describe the data similarly as in the case of pomeron inspired models, whereas for $p_T^{min} = 25\,\mathrm{GeV}$ the need of an additional contribution to reproduce the data is not so evident. However, it is important to stress that the SCI signal comes from the single diffraction events mainly and thus producing two protons in the final state within this framework is almost impossible. Consequently, the SCI model fails to describe other characteristics of the measurement like jet rapidity distributions and is therefore in disagreement with CDF dijet data [8].

2 Dijet mass fraction at the LHC

Having fixed the relative normalization between the inclusive and exclusive production, we made a prediction of dijet mass fraction at the LHC environment. The prediction of R_{jj} for jets with p_T above 400 GeV is shown in Fig. 3 (left). The exclusive contribution manifests itself as a

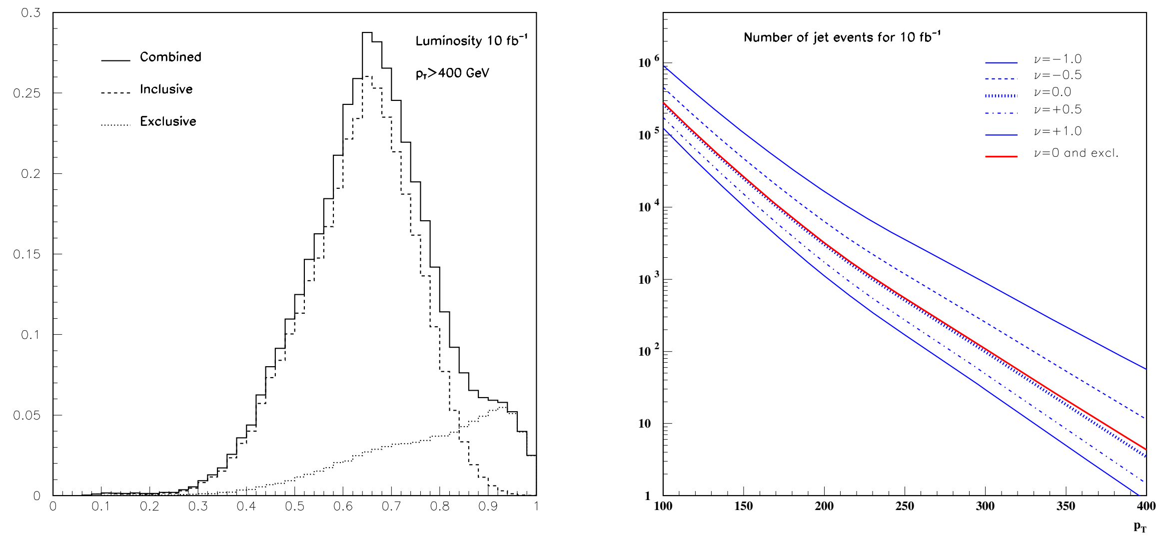

Fig. 3: Left:dijet mass fraction at the LHC for jets $p_T > 400$ GeV. Inclusive contribution (FM) and exclusive contribution (KMR) are superimposed. The exclusive signal appears at high R_{jj}. Right: number of jet events as a function of a jet threshold. The gluon uncertainty in the calculation can overshadow the signal due to the exclusive events.

peak toward high R_{jj}. Precise prediction of the dijet mass fraction distribution depends on many peculiarities, e.g. parameters of the pomeron flux, pomeron structure function, or survival probability factor. One of the important factors is the gluon density in the pomeron. Its tail at high β can significantly influence the number of dijet diffractive events as demonstrated in Fig. 3 (right). The signal due to the exclusive production could be mimicked by the uncertainty on the gluon. It is therefore desirable to perform QCD fits at the LHC to extract the pomeron parton densities precisely in order to be able to distinguish the exclusive exclusive signal.

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