

Inclusive Higgs production via double pomeron exchange

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ABSTRACT: We evaluate inclusive Higgs boson and dijet cross-sections at the Tevatron collider via double pomeron exchange. Such inclusive processes, normalized to the observed dijet rate observed at run I by the CDF collaboration, noticeably increase the predictions for Higgs production in diffractive events at the Tevatron Run II.

1. Theoretical framework

It has been shown [1, 2] that Higgs boson and dijet production via double pomeron exchange may be non negligible. Our aim is to give predictions based on inclusive Higgs boson and dijet production at the Tevatron collider via double pomeron exchange [3]. So far, the predictions have been based on exclusive production without accompanying radiation, which is indeed present, e.g. in double pomeron dijet production at the Tevatron [4].

In the following we use as a starting point the Bialas-Landshoff exclusive model for Higgs boson and heavy flavor jet production [1]. We modify it in order to take into account inclusive Higgs boson and dijet production [3].

Let us introduce the formulae for inclusive Higgs boson and dijet production cross-sections via double pomeron exchange.

$$d\sigma_H^{incl} = C_H \left(\frac{x_1^g x_2^g s}{M_H^2} \right)^{2\epsilon} \delta \left(\xi_1 \xi_2 - \frac{M_H^2}{x_1^g x_2^g s} \right) \prod_{i=1,2} \left\{ G_P(x_i^g, \mu) \frac{dx_i^g}{x_i^g} \frac{d\xi_i}{\xi_i} d^2 v_i \xi_i^{\alpha' v_i^2} \exp(-2\lambda v_i^2) \right\},$$

$$d\sigma_{JJ}^{incl} \sim \left(\frac{x_1^g x_2^g s}{M_{JJ}^2} \right)^{2\epsilon} F_{JJ} \prod_{i=1,2} \left\{ G_P(x_i^g, \mu) \frac{dx_i^g}{x_i^g} \frac{d\xi_i}{\xi_i} d^2 v_i d^2 k_i \xi_i^{\alpha' v_i^2} \exp(-2\lambda v_i^2) \right\}, \quad (1.1)$$

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where x_1^g, x_2^g define the fraction of the Pomerons' momentum carried by the gluons involved in the hard process, see Fig.1, and $G_P(x_{1,2}^g, \mu)$, are, up to a normalization, the gluon structure function in the Pomerons extracted from HERA experiments, see [5]. μ^2 is the hard scale (for simplicity kept fixed at 75 GeV^2 , the highest value studied at HERA; we neglect the small [5] contribution of quark initiated processes in the Pomeron). By construction of our model, the known formulae for *exclusive* channels in Ref.[1] (except $gg \rightarrow gg$, not included in [1]) are recovered by the substitution $G_P(x_i^g, \mu) \rightarrow \delta(x_i^g - 1)$.

The formulae (1.1) are written for a Higgs boson of mass M_H and two jets (of total mass M_{JJ}), respectively. The Pomeron trajectory is $\alpha(t) = 1 + \epsilon + \alpha' t$ ($\epsilon \sim .08, \alpha' \sim .25 \text{ GeV}^{-2}$), $\xi_{1,2}$ ($< .1$) are the Pomerons' fraction of longitudinal momentum, $v_{1,2}$, the 2-transverse momenta of the outgoing p, \bar{p} , $k_{1,2}$, those of the outgoing quark jets, $\lambda \sim 4 \text{ GeV}^{-2}$ the slope of the Pomeron $p\bar{p}$ coupling.

The dijet cross-section σ_{JJ} depends on the $gg \rightarrow \bar{Q}^f Q^f$ and $gg \rightarrow gg$ cross-sections [6].

The physical origin of our formulae (1.1) extended to the *inclusive* case is the following: Since the overall partonic configuration is produced initially by the long-range, soft double pomeron interaction, we assume that, up to a normalization, the *inclusive* cross-section is the convolution of the “hard” $partons \rightarrow Higgs\ boson, partons \rightarrow jets$ subprocesses by the Pomeron structure function into gluons, see Fig.1. The expected factorization breaking of hadroproduction will appear in the normalization through a renormalization of the Pomeron fluxes, which are not the same as in hard diffraction at HERA. Indeed, this ansatz remarkably reproduces the dijet mass fraction seen in experiment, see Fig.2.

2. Comparison with the CDF results

Let us compare our results with the measurements performed in the CDF experiment at Tevatron [4]. To this end, we interfaced our generator with SHW [7] a fast simulation of the D0 and CDF detectors. We chose as gluon content of the pomeron the result of the H1 “fit 1” performed in Ref. [5], up to a normalization of the flux determined by comparison with CDF results.

We first compare our results for the dijet mass fraction with the measurement of the CDF collaboration [4] in double pomeron events. As shown in Fig. 2, the dijet mass fraction spectrum is well reproduced. The CDF measurement could clearly not be described without radiation since the obtained dijet mass fraction would peak near one, up to detector resolution effects.

To be more detailed, a tagged antiproton with $0.035 \leq \xi_{\bar{p}} \leq 0.095$ and $|t| < 1 \text{ GeV}^2$ was required. This quantity is reconstructed using the roman pot detectors installed by the CDF collaboration. After the CDF cuts to tag an antiproton and the fast simulation of the detector, we obtain a cross section of 14.4 nb , to be compared with the CDF measurement of 43.6 nb . We thus scale up our cross-sections by a factor $43.6/14.4 \sim 3$.

3. Predictions for Higgs boson production

We can now give predictions for the Higgs boson production cross sections in double diffractive events, by scaling our results by the above determined factor . The results are given in Table 1, first column. We note the high values of the cross-sections, which predict¹ more than 10 events per fb^{-1} for a Higgs boson mass below 140 GeV.

After interfacing the generator with SHW [7], we can estimate the rates which could be observed in the experiments. The experimental resolution and acceptances of the roman pot detectors have been chosen to be similar to the D0 ones for dipole detectors, namely the t -resolution is $0.1\sqrt{t}$, t -acceptance $|t| \leq 0.5 \text{ GeV}^2$, ξ -resolution 0.2 %, and the ξ -acceptance 100% if $\xi > 0.04$, 0% if $\xi < 0.01$ and linear between 0 and 100% if $0.01 < \xi < 0.04$ [8]. The tagging efficiency (see column 2 of Table 1) is quite good if one uses dipole detector on each side. To be able to trigger these events, some activity inside the central detector will be required, and we give in Table 1, third column, the number of events after requiring at least two jets of $p_T > 30 \text{ GeV}$ ².

To enhance the signal to background ratio, it is possible to cut on the proton and antiproton tagged energy at 930 GeV, on the jet topologies (the jets coming from Higgs boson events are more central) and on the reconstructed mass distribution using the missing mass method [9] (see Fig.4 of reference [3]). We slightly modified the original method to partly take into account radiation and define $M_H = \sqrt{\xi_p \xi_{\bar{p}} s \frac{E_{jet1} + E_{jet2} + E_p + E_{\bar{p}}}{2E_{beam}}}$ where the E_{jeti} are the leading two jets energies, E_p and $E_{\bar{p}}$ the tagged p and \bar{p} energies. We notice that the missing mass method is not working so nicely when radiation is included. It is however still a competitive method to reduce background and reconstruct the Higgs boson mass³. Since we obtain quite high cross-sections, other Higgs boson decay channels with smaller branching ratios, like $H \rightarrow \tau^+ \tau^-$ (about 10% of Higgs boson decay, see table 1) or $H \rightarrow W^+ W^-$ are of very high interest since the expected background is very small. The background over signal ratio will be studied in more detail in Ref [3].

4. Acknowledgments

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¹The expected luminosity is between 20 and 25 fb^{-1} per experiment for run II.

²This allows us to enhance our signal/background ratio (the $b\bar{b}$ diffractive background without any cuts is estimated to be about $2.3 \cdot 10^7$ events per fb^{-1} , and becomes about $8.3 \cdot 10^4$ events after those p_T cuts), as shown in Fig.3 c,d. When we compare Fig.2 c,d, we also note that radiation is more important for dijet events than for Higgs boson events, since the distribution for dijet events is more shifted to the left after radiation than the Higgs boson one. Hence, the p_T cut is more efficient after radiation.

³Due to radiation effects which escape mostly into the beam pipe, the missing mass method cannot work as it stands and is modified by radiation. However, it will be very useful to perform constrained fits and to have different ways of reconstructing the Higgs boson mass.

$M_{Higgsboson}$	(1)	(2)	(3)	(4)	(5)
100	26.6	18.5	5.7	1.9	0.2
110	21.6	14.0	5.3	1.3	0.7
120	17.4	9.8	4.8	1.0	1.9
130	13.8	6.1	3.2	0.6	3.3
140	10.6	2.9	1.8	0.3	4.2
150	8.0	1.0	0.8	0.1	5.0
160	5.7	0.2	0.1	0.0	4.5
170	3.7	0.0	0.0	0.0	2.9

Table 1: Number of Higgs boson events for $1 fb^{-1}$. The first column gives the number of events at the generator level (all decay channels included), and the other columns after a fast simulation of the detector. The second column gives the number of events decaying into $b\bar{b}$ tagged in the dipole roman pot detectors (see text), the third one requiring additionally at least two jets of $p_T > 30 GeV$, the fourth one gives the number of reconstructed and tagged events when the Higgs boson decays into τ , and the fifth one when the Higgs boson decays into W^+W^- (in this channel, the background is found to be negligible).

References

- [1] J.D. Bjorken, *Phys.Rev.* **D47** (1993), A. Bialas and P.V. Landshoff, *Phys. Lett.* **B256** (1990) 540, A. Bialas and W. Szeremeta, *Phys. Lett.* **B296** (1992) 191, A. Bialas and R. Janik, *Zeit. für. Phys.* **C62** (1994) 487.
- [2] *Higgs boson*: J-R Cudell and O.F. Hernandez, *Nucl. Phys.* **B471** (1996) 471; E.M. Levin hep-ph/9912403 and referencies therein; V.A. Khoze, A.D. Martin and M.G. Ryskin, *Eur. Phys. J.* **C19** (2001) 477 and referencies therein.
Dijets: J. Pumplin, , *Phys. Rev.* **D52** (1995) 1477; A. Berera and J.C. Collins, *Nucl. Phys.* **B474** (1996) 183; A.D. Martin, M.G. Ryskin and V.A. Khoze, *Phys. Rev.* **D56** (1997) 5967; A. Berera, *Phys. Rev.* **D62** (2000) 015015;
Higgs boson and dijets: V.A. Khoze, A.D. Martin and M.G. Ryskin, hep-ph/0006005; V.A. Khoze, hep-ph/0105224 and referencies therein.
- [3] M. Boonekamp, R. Peschanski and C. Royon, accepted by *Phys. Rev. Lett.*
- [4] T. Affolder et al., CDF Coll. , *Phys. Rev. Lett.* **85** (2000) 4215.
- [5] C. Royon, L. Schoeffel, J.Bartels, H.Jung, R.Peschanski, *Phys. Rev* **D63** (2001) 074004.
- [6] B.L. Combridge and C.J. Maxwell, *Nucl. Phys.* **B239** (1984) 429.
- [7] *SHW, a fast simulation package for D0 and CDF detectors*, see www.physics.rutgers.edu/jconway/soft/shw/shw.html.
- [8] *Proposal for a Forward Proton Detector at D0*, D0 Collab. (1997), Proposal P-900 to Fermilab PAC.
- [9] M.G. Albrow and A. Rostovtsev, hep-ph/0009336.

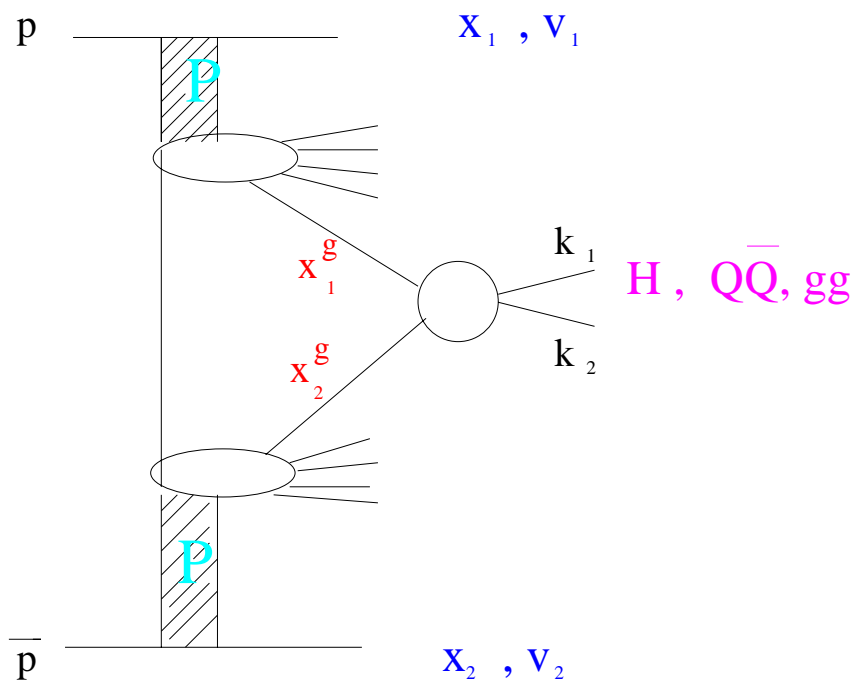


Figure 1: Inclusive production scheme. $x_i \equiv 1 - \xi_i, v_i$ are the longitudinal and transverse 2-momenta of the diffracted (anti)proton, x_i^g , the Pomeron fraction momentum brought by the gluons participating in the hard cross-section, k_i , the transverse 2-momenta of the outgoing jets in the central region from quarks, gluons or the $\bar{b}b$ decay products of the Higgs boson.

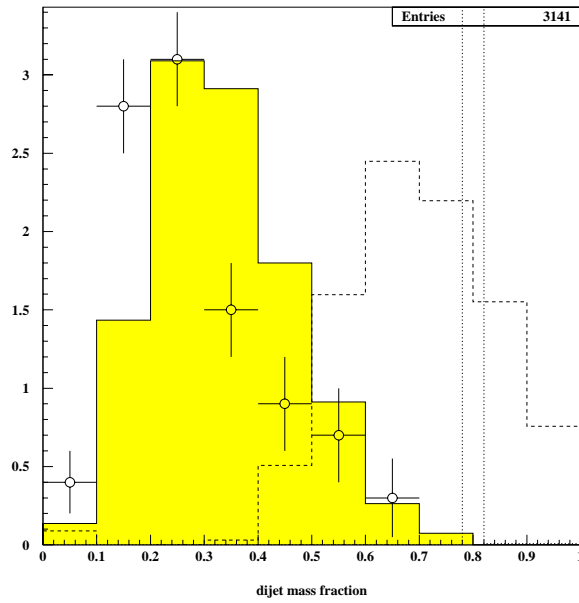


Figure 2: Comparison of the dijet mass fraction obtained in our model and CDF data (open circles). *With radiation:* The shaded distribution is the dijet distribution after radiation and simulation of the detector.

Without radiation: Dotted line: distribution at generator level; Dashed line: after simulation of the detector.