

DIFFRACTIVE HIGGS PRODUCTION: SOFT COLOUR INTERACTIONS PERSPECTIVE*

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We briefly present the soft colour interaction models which are successful in reproducing a multitude of diffractive hard scattering data, and give predictions for diffractive Higgs production at the Tevatron and LHC. Only a few diffractive Higgs events may be produced at the Tevatron, but we predict a substantial rate at the LHC.

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Higgs production in diffractive hard scattering has been argued to be useful for Higgs discovery because of the lower hadronic background activity in events with one or two rapidity gaps and leading protons. This especially holds for Higgs production in so-called Double Pomeron Exchange (DPE) events, where the two beam protons survive the collision, keeping a large fraction of the beam momentum, and where there is a central system containing a Higgs. Another possibility is exclusive Higgs production, $p\bar{p} \rightarrow p\bar{p}H$, where the central system is just a Higgs boson, and a missing mass method [1] can be applied.

Existing predictions [2] of the cross sections for these processes vary by several orders of magnitude, so the central question is whether the cross section is large enough. In contrast to other models used for estimating the diffractive Higgs cross section, our models have proven very successful in reproducing experimental data on diffractive hard scattering processes both from the ep collider HERA and from $p\bar{p}$ collisions at the Tevatron [3]. This puts us in a better position to answer the question whether the diffractive Higgs channel is a feasible one at the Tevatron and at LHC [4].

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The Soft Colour Interaction (SCI) model [5] and the Generalised Area Law (GAL) model [6] were developed under the assumption that soft colour exchanges give variations in the topology of the confining colour string-fields such that different final states could emerge after hadronisation, *e.g.* with and without rapidity gaps or leading protons.

Both models are implemented in the Lund Monte Carlo programs LEPTO [7] for deep inelastic scattering and PYTHIA [8] for hadron-hadron collisions. The hard parton level interactions are given by standard perturbative matrix elements and parton showers, which are not altered by the softer non-perturbative effects. The SCI model then applies an explicit mechanism where colour-anticolour (corresponding to non-perturbative gluons) can be exchanged between the emerging partons and hadron remnants. The GAL model, similar in spirit, is formulated in terms of interactions between the strings. The soft colour exchanges between partons or strings change the colour topology resulting in another string configuration (Fig. 1). The probability for such an exchange is taken to be a constant phenomenological parameter in the SCI case, while for GAL the probability for two strings to interact is dynamically varying, favouring “shorter” strings and suppressing ‘longer’ ones. The only parameter entering the models has its value determined from the HERA rapidity gap data and then is kept fixed.

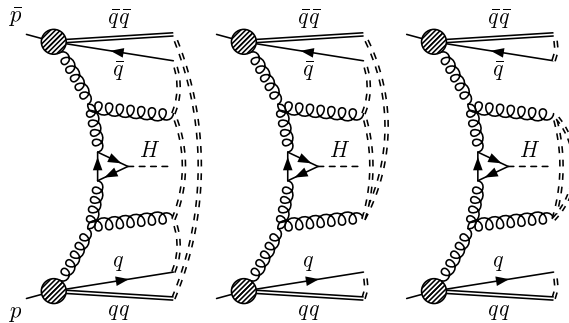


Fig. 1. Higgs production in $p\bar{p}$ collisions with string topologies (double-dashed lines) before and after soft colour interactions in the SCI or GAL model, resulting in events with one or two rapidity gaps (leading particles).

The SCI and GAL models give different diffractive hard scattering processes by simply choosing different hard scattering subprocesses in PYTHIA. Rapidity gap events containing a W , a dijet system or bottom quarks are found to be in agreement with Tevatron data [3]. Diffractive events with a leading proton, or two leading protons [9], are also well described [3]. In particular, the cross sections for dijets in DPE events obtained from the models agree with the CDF data [9], as do more exclusive quantities, such as the

dijet mass fraction (see Fig. 2). Let us emphasise that the dynamics of this process is similar to the DPE Higgs process, and this has been advocated as a testing ground for different models aiming at describing diffractive Higgs.

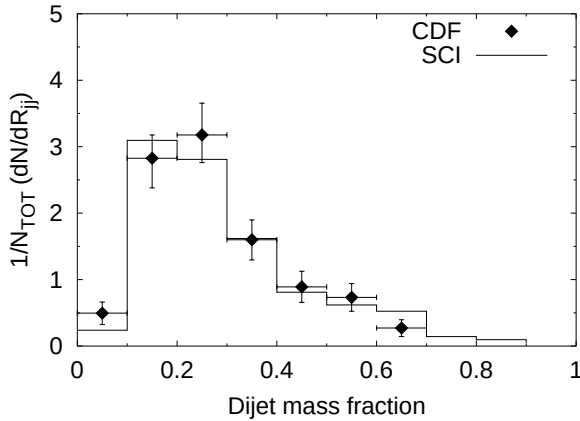


Fig. 2. Distribution of the dijet mass fraction (ratio of dijet mass to total central system mass) in DPE events at the Tevatron, CDF data [9] compared to SCI model.

The predictive power of the models has also been tested, since we were able to predict correct ratios for production of J/ψ associated with gaps at the Tevatron [3]. It is remarkable how through the same soft colour mechanism, two different soft phenomena arise in the same event, namely a rapidity gap and turning a colour octet $c\bar{c}$ pair into a colour singlet producing J/ψ . Furthermore, our predicted ratios for diffractive Z production [3] seem to be in very good agreement with those recently found by DØ [10].

The properties of the Higgs boson in the Standard Model are fixed, except for its mass. The present lower limit is 114.1 GeV and χ^2 fits to high precision electroweak data favours $m_H < 212$ GeV [11]. The latest LEP data give an indication ($\sim 2.1\sigma$) of a Higgs with a mass of 115.6 GeV [12].

Higgs production at the Tevatron and the LHC can proceed through many subprocesses, which are included in PYTHIA version 6 [8]. The dominant one is $gg \rightarrow H$, which accounts for 50% and 70% of the cross section (for $115 < m_H < 200$ GeV) at the Tevatron and LHC, respectively. In this process, see Fig. 1, the gluons couple to a quark loop with dominant contribution from top due to its large coupling to the Higgs. Other production channels are also considered. The overall cross sections are obtained by folding the subprocess cross sections with the parton density distributions.

After the standard parton showers in PYTHIA, SCI or GAL is applied, giving a total sample of Higgs events, with varying hadronic final states. Single Diffractive (SD) Higgs events are selected using one of two crite-

ria: (1) a leading (anti)proton with $x_F > 0.9$ or (2) a rapidity gap in $2.4 < |\eta| < 5.9$ as used by the CDF collaboration. Applying the conditions in both hemispheres results in a sample of DPE Higgs events. The resulting cross sections and relative rates are shown in Table I. The results have an uncertainty of about a factor two related to details of the hadron remnant treatment and choice of parton density parameterisation.

TABLE I

Cross sections at the Tevatron and LHC for Higgs in Single Diffractive (SD) and DPE events, using leading proton or rapidity gap definitions, as well as relative rates (SD/all and DPE/SD) and number of events, obtained from the soft colour exchange models SCI and GAL.

$m_H = 115 \text{ GeV}$	Tevatron $\sqrt{s} = 1.96 \text{ TeV}$ $\mathcal{L} = 20 \text{ fb}^{-1}$		LHC $\sqrt{s} = 14 \text{ TeV}$ $\mathcal{L} = 30 \text{ fb}^{-1}$	
$\sigma[\text{fb}] \text{ Higgs-total}$	600		27000	
	SCI	GAL	SCI	GAL
Higgs in single diffraction:				
$\sigma [\text{fb}] \text{ leading-}p$	1.2	1.2	190	160
$\sigma [\text{fb}] \text{ gap}$	2.4	3.6	27	27
$R [\%] \text{ leading-}p$	0.2	0.2	0.7	0.6
$R [\%] \text{ gap}$	0.4	0.6	0.1	0.1
$\# H + \text{leading-}p$	24	24	5700	4800
$\hookrightarrow \# H \rightarrow \gamma\gamma$	0.024	0.024	6	5
Higgs in DPE:				
$\sigma [\text{fb}] \text{ leading-}p\text{'s}$	1.2×10^{-4}	2.4×10^{-4}	0.19	0.16
$\sigma [\text{fb}] \text{ gaps}$	2.4×10^{-3}	7.2×10^{-3}	2.7×10^{-4}	5.4×10^{-3}
$R [\%] \text{ leading-}p\text{'s}$	0.01	0.02	0.1	0.1
$R [\%] \text{ gaps}$	0.1	0.2	0.001	0.02
$\# H + \text{leading-}p\text{'s}$	0.0024	0.0048	6	5

The cross sections at the Tevatron are quite low in view of the luminosity to be achieved in Run II. Higgs in DPE events are far below an observable rate. For $m_H = 115 \text{ GeV}$, only tens of single diffractive Higgs events are predicted. Only the most abundant decay channel, $H \rightarrow b\bar{b}$, can then be of use and a very efficient b -quark tagging and Higgs reconstruction is required. The conclusion for the Tevatron is thus that the advantage of a simplified reconstruction of the Higgs in the cleaner diffractive events is not really usable in practice due to a too small number of diffractive Higgs events being produced.

In contrast, the high energy and luminosity available at the LHC facilitate a study of single diffractive Higgs production, where also the striking $H \rightarrow \gamma\gamma$ decay should be observed. Also a few DPE Higgs events may be observed. The quality of a diffractive event changes, however, at LHC energies. Besides the production of a hard subsystem and one or two leading protons, the energy is still enough for populating forward detector rapidity regions with particles. As seen in Fig. 3, the multiplicity of particles is considerably higher at the LHC, compared to the Tevatron. The requirement of a “clean” diffractive Higgs event with a large rapidity gap in an observable region cannot be achieved without paying the price of a lower cross section. Requiring gaps instead of leading protons gives a substantial reduction in the cross section, as seen in Table I. Note that the high luminosity mode of LHC cannot be used, since the resulting pile-up of events would destroy the rapidity gaps.

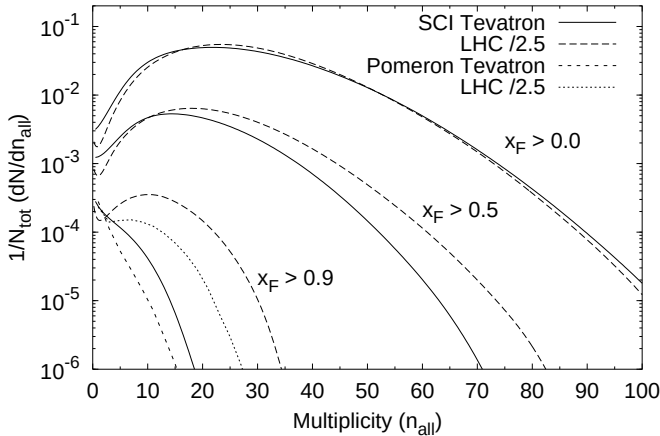


Fig. 3. Multiplicity (for LHC divided by 2.5) in the region $2.4 < |\eta| < 5.9$ in the hemisphere of a leading proton with the indicated minimum x_F , for Higgs events from the SCI and the Pomeron models.

In conclusion, the soft colour interactions models predict a rate of diffractive Higgs events at the Tevatron which is too low to be useful. However, LHC should facilitate studies of Higgs in single diffraction and the observation of some DPE events with a Higgs boson.

REFERENCES

- [1] M.G. Albrow, A. Rostovtsev, [hep-ph/0009336](#).
- [2] A. Bialas, P.V. Landshoff, *Phys. Lett.* **B256**, 540 (1991); H.J. Lu, J. Milana, *Phys. Rev.* **D51**, 6107 (1995); D. Graudenz, G. Veneziano, *Phys. Lett.* **B365**, 302 (1996); J.R. Cudell, O.F. Hernandez, *Nucl. Phys.* **B471**, 471 (1996); M. Heyssler, Z. Kunszt, W.J. Stirling, *Phys. Lett.* **B406**, 95 (1997); V.A. Khoze, A.D. Martin, M.G. Ryskin, *Eur. Phys. J.* **C14**, 525 (2000); M. Boonekamp, R. Peschanski, C. Royon, *Phys. Rev. Lett.* **87**, 251806 (2001); B. Cox, J. Forshaw, B. Heinemann, *Phys. Lett.* **B540**, 263 (2002).
- [3] R. Enberg *et al.*, *Phys. Rev.* **D64**, 114015 (2001).
- [4] R. Enberg, G. Ingelman, A. Kissavos, N. Timneanu, [hep-ph/0203267](#).
- [5] A. Edin *et al.*, *Phys. Lett.* **B366**, 371 (1996); *Z. Phys.* **C75**, 57 (1997).
- [6] J. Rathsmann, *Phys. Lett.* **B452**, 364 (1999).
- [7] G. Ingelman *et al.*, *Comput. Phys. Commun.* **101**, 108 (1997).
- [8] T. Sjöstrand *et al.*, *Comput. Phys. Commun.* **135**, 238 (2001).
- [9] T. Affolder *et al.* (CDF Collaboration), *Phys. Rev. Lett.* **85**, 4215 (2000).
- [10] V. Šimák, *Acta. Phys. Pol.* **B33**, 3451 (2002), these proceedings.
- [11] D. Abbaneo *et al.*, CERN-EP-2000-016, Jan 2000.
- [12] LEP Higgs Working Group, [hep-ex/0107029](#).