Vol. 33 (2002) ACTA PHYSICA POLONICA B No 11

DISCUSSION SESSION ON DIFFRACTIVE HIGGS PRODUCTION*

A. De Roeck

CERN, 1211 Geneva 23, Switzerland

and C. Royon

CEA, SPP, DAPNIA, CE-Saclay, 91191 Gif-sur-Yvette Cedex, France
SPP and University of Texas at Arlington, Arlington, USA

(Received August 19, 2002)

This note summarizes the discussion session on diffractive Higgs production at the DIS2002 workshop.

PACS numbers: 13.85.Hd, 14.80.Bn, 14.80.Cp

1. Introduction

One of the main goals of the Large Hadron Collider (LHC) under construction at CERN is the search for, discovery and measurement of the Higgs boson, the particle associated with the field that can provide a mechanism for electroweak symmetry breaking in the Standard Model. The mass of the Higgs boson is unknown but precise measurements of electroweak processes hint towards a value below 196 GeV (95% C.L.). Direct searches exclude a Higgs with a mass smaller than 114.1 GeV (95% C.L.). If Supersymmetry will turn out to be the mechanism that stabilizes the Standard Model at high energies, then the theoretically preferred region for the (lightest) Higgs mass is below 135 GeV.

Measuring a light Higgs at the LHC will not be an easy task [1], but rather a delicate trade-off between signal and background. *E.g.* inclusive Higgs production with the Higgs decaying into its most favorable mode, $b\bar{b}$, cannot be used to discover the Higgs due to the too high background of $b\bar{b}$ production. It, is therefore, important to explore more, in particular clean, processes which would allow to discover the Higgs boson.

* Presented at the X International Workshop on Deep Inelastic Scattering (DIS2002) Cracow, Poland, 30 April–4 May, 2002.

Recently, renewed attention has been drawn to diffractive Higgs production [2], being first discussed in [3]. Since then, several groups have studied the processes but there are substantial differences in the approaches used and results obtained. At the DIS02 meeting the most recent approaches were confronted in a discussion session. For simplicity we will distinguish here only two main categories: *exclusive* and *inclusive* production, see Fig. 1. For each of these there are several different models discussed. Furthermore, we will only discuss those diffractive channels where the incident protons survive the interaction and can be detected in *e.g.* Roman pot detectors, as these constitute the most interesting event classes. But all these processes do have contributions from channels where the protons dissociate, and which can be used in case one is only interested in the presence of a gap and not in measuring the scattered proton.

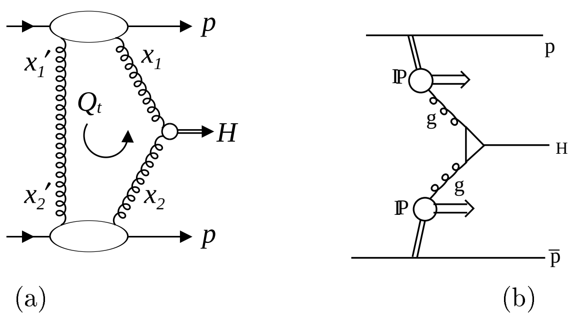

Fig. 1. Diagrams for (a) exclusive and (b) inclusive diffractive Higgs production.

2. Exclusive production

In the case of exclusive production (Fig. 1(a)), the final state is simple $pp \to p{+}H{+}p$. In such a configuration one can benefit from strong spin $J_Z = 0$ selection rules which essentially switches off the LO order QCD background production such as $b\bar{b}$ production, and thus reduce the background by several orders of magnitude.

The light Higgs production cross sections for exclusive production by the different calculations range from approximately 100 fb [3, 4] to 3 fb [5]. Much of the difference between the results comes from whether and how a so called gap survival probability is included in the calculation. The Tevatron diffractive data imposes the need of a gap survival probability of order 0.1 for most calculations of diffractive hard scattering processes.

The most detailed recent analysis of the exclusive channels is performed in [5] and they find a cross section of the order of 3 fb. They also estimate, within their approach, an uncertainty of a factor of two on this result [1]. In other words the exclusive Higgs production cross section could well be rather small, but still detectable at the LHC.

3. Inclusive processes

Several groups have also studied the inclusive production cross section (Fig. 1(b)). Here we distinguish a so called factorizable, non-factorizable and soft color interaction model. A compilation of different recent calculations for the cross sections is given in Table I.

TABLE I

Cross sections for inclusive Higgs production.

σ_H(fb)	Normalization	Ref.
320	$\times 3.8$	[8]
260–390	no rescaling	[6]
0.19–0.16		[9]

In the factorizable model [6], two pomerons are emitted with a structure function and flux factor as measured in deep inelastic data at HERA. The cross sections for both diffractive dijet and Higgs production are calculated for Tevatron and LHC energies. Diffractive dijets have been measured at CDF, so the prediction can be compared to the data. The authors find this prediction a factor 10 too large, and rescale the Higgs cross section with this gap survival probability accordingly. The cross sections for LHC in their paper are not rescaled. In [5] similar cross sections are calculated, and results similar results obtained, be it using actually different diagrams as explained in [1]

In the non-factorizable model [7, 8], two pomerons are emitted with a structure function as measured in deep inelastic data at HERA, but a soft flux factor ($\varepsilon = 0.08$ instead of ~ 0.2) is used, meant to absorb the factorization breaking seen between HERA and Tevatron hard diffractive measurements. Similarly the cross sections for both diffractive dijet and Higgs production are calculated for Tevatron and LHC energies. The dijet cross section is a found to be a factor 3.8 too small at the Tevatron, and the Higgs cross section is rescaled accordingly, also for the LHC results. The resulting numbers are similar to [6], but for the latter no gap suppression factor has been applied for the LHC predictions. If this is applied the result in [6] would be a factor 10–20 smaller than these results.

In [9] the authors use the soft color interaction (and also the general area law) model to predict Higgs production cross sections. This model can describe a variety of diffractive data at the Tevatron and HERA. It predicts a small cross section for diffractive Higgs production at the Tevatron.

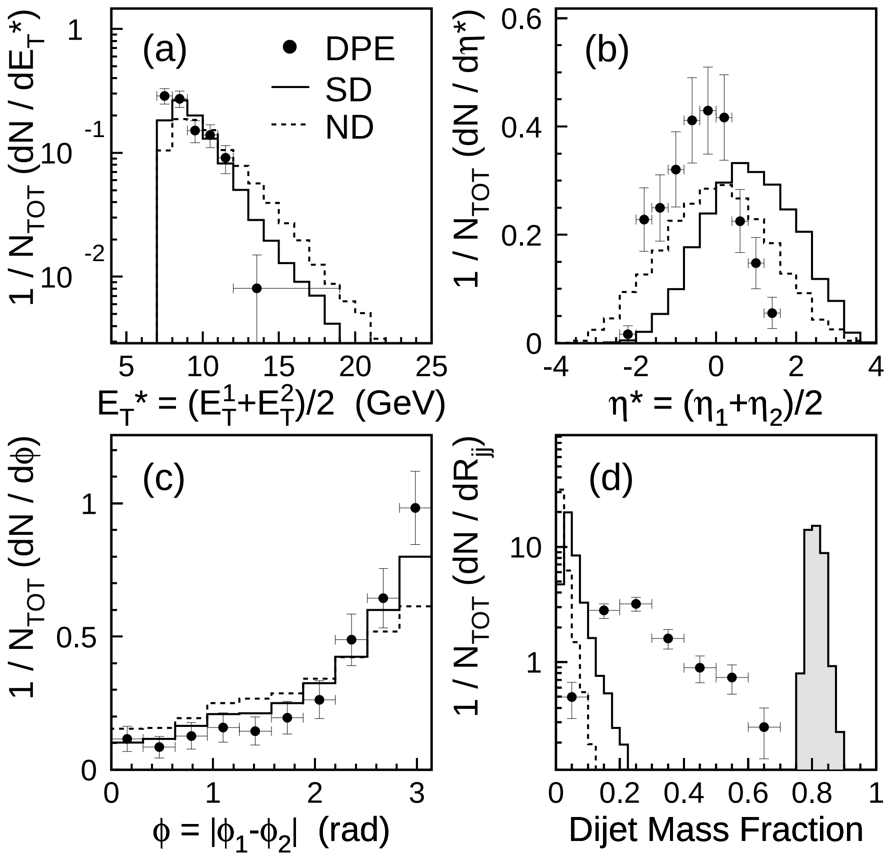

Fig. 2. Dijet quantities DPE events as measured by CDF. The bottom-right plot shows the dijet mass fraction.

4. Discussion

The following discussion developed at the meeting.

- Comparison between the different calculations, especially the exclusive channels: what is the origin of the differences in the models? How can we control the all important gap survival probability experimentally? For the pomeron processes, the difference in predictions is a factor 10 for those models that "use" emission of pomerons. It appears that this factor can be mostly explained by the different value ε used for the flux [10].

- What are the uncertainties on the calculations? By varying the parameters in the models for the cross section calculations (input structure functions *etc.*) one could get a handle on the spread within a given model. One author of [3] reported that the uncertainty can be easily as large as a factor 10. Recently in [1] the uncertainty was evaluated to be a factor two only for the calculations first presented in [5].

- How can one test these models? While now generally accepted that the diffractive Higgs production rates for the Tevatron are probably too small to be of use, there are several processes which can be exploited at this collider in the next years, *e.g.* diffractive dijet, di-photon, χ_c and possibly χ_b production. Di-photon production should be measurable in Run-II according to the predictions in [6]. Perhaps also vector meson production at HERA can play a role in discriminating the models.

  In particular diffractive dijet production is very interesting. CDF [11] has already measured double pomeron exchange (DPE) dijet production. Fig. 2 shows — among other distributions — the fraction of the energy of the dijets compared to the total energy in the central system. Clearly every inclusive model for Higgs production, when applied to predict Higgs and dijet production rates should describe the shape and normalization of this distribution. Note, however, that the CDF data are not corrected for detector smearing, and thus to reproduce these signals one needs an event generator and detector simulation which has the proper energy smearing.

  CDF also sets a limit on the cross section for exclusive dijet production *i.e.* where all visible energy enters in the two jets. They find that a most 5.1 events (3.7 nb) are compatible with this hypothesis. *E.g.* any model predicting a LARGER cross section than this can already be excluded.

- Concerning the debate of exclusive and inclusive production: What can one finally gain from the inclusive diffractive Higgs production with respect to inclusive Higgs production? In this case there will be no J_Z selection rule to suppress the background and one cannot use the relation $M_{pp} = M_H$, since there are always remnants around. Some initial ideas have been proposed in [8], but need to be substantiated with real hadronization and detector simulation. In particular inclusive production studies should make a full background calculations to show that the signal will be visible at the end.
  There were concerns expressed whether exclusive events at such large scales really happen in nature. Will there not always be some soft gluons around which spoil the exclusiveness? Di-photon production at the Tevatron would be a good testing ground to confirm that these events are produced at high energies.

5. Suggested homework

- The new Tevatron Run-II data will be of pivotal importance to settle some of these questions. We suggest that the following data be collected.

  Measure the DPE dijet spectra, preferably with double proton tagging to really constrain the M_{dijet}, and measure it for different E_{T} scales (such that one can test the ε value of the flux).

  Try to measure the exclusive di-photon or a χ states. These have the advantage over the dijets that it is easier to determine their "exclusiveness". The cross sections are, however, much lower, so here the Run-II luminosity will be needed.

- For the different models it would be useful to have the comparisons of the predictions with Fig. 2. Predictions for higher jet E_{T} cuts, such as 10 and 15 GeV would be useful for future comparisons with data and to demonstrate the cross section behavior with the scale in the model.

- For the different models it would be useful to have predictions for diphoton production rates, *e.g.* for photons with $E_{\mathrm{T}} > 7$ GeV, as in [6].

- A Monte Carlo generator for all these processes would be useful, to compare with experimental data, *e.g.* the dijet mass fraction.

The goal is to have these model numbers available by the Low-x meeting in September 2002 (Antwerpen/Belgium).

We thank all contributers to this session for their presentation and a lively discussion.

REFERENCES

[1] A. De Roeck *et al.*, `hep-ph/0207042`.

[2] M.G. Albrow, A. Rostovtsev, `hep-ph/0009336`.

[3] A. Bialas, P.V. Landshoff, *Phys. Lett.* **B256**, 540 (1990); A. Bialas, W. Szeremeta, *Phys. Lett.* **B296**, 191 (1992); A. Bialas, R. Janik, *Zeit. Phys.* **C62**, 487 (1994).

[4] A. Schafer, O. Nachtmann, R. Schöpf, *Phys. Lett.* **B249**, 331 (1990); J.D. Bjorken, *Phys. Rev.* **D47**, 101 (1993); J-R. Cudell, O.F. Hernandez, *Nucl. Phys.* **B471**, 471 (1996); H.J. Lu, J. Milana *Phys. Rev.* **D51**, 6107 (1995); D. Graudenz, G. Veneziano *Phys. Lett.* **B365**, 302 (1996); M. Heyssler, Z. Kunszt, W.J. Stirling, *Phys. Lett.* **B406**, 95 (1997); E.M. Levin, `hep-ph/9912403` and references therein.

[5] V.A. Khoze, A.D. Martin, M.G. Ryskin, *Eur. Phys. J.* **C14**, 525 (2000); V.A. Khoze, A.D. Martin, M.G. Ryskin, *Eur. Phys. J.* **C19**, 477 (2001); V.A. Khoze, `hep-ph/0105224`.

[6] B. Cox, J. Forshaw, B. Heinemann, `hep-ph/0110173`.

[7] M. Boonekamp, R. Peschanski, C. Royon, *Phys. Rev. Lett.* **87**, 251806 (2001). Some misprints are corrected in formulae (1) and (3) of Ref. [8].

[8] M. Boonekamp, A. De Roeck, R. Peschanski, C. Royon, `hep-ph/0205332`.

[9] R. Enberg, G. Ingelman, A. Kissavos, N. Timneanu, `hep-ph/0203267`.

[10] M. Boonekamp, *Acta Phys. Pol.* **B33**, 3485 (2002), this proceedings.

[11] T. Affolder *et al.*, CDF Collaboration, *Phys. Rev. Lett.* **85**, 4215 (2000).