DIFRACTIVE PRODUCTION OF THE HIGGS BOSON

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Diffractive production of the Higgs boson at hadron colliders is discussed in the light of the observed rate of hard diffractive dijet events at the Tevatron. The Higgs predictions of models successful for dijets are compared. LHC seems promising for a diffractive light Higgs boson and its mass determination. Hard diffractive dijets, diphotons and dileptons at the Tevatron (Run II) will be necessary to remove the remaining large uncertainties on cross-sections and signals.

1 Diffractive vs. Standard Higgs Production

Standard Higgs boson production comes mainly from gluon-gluon fusion via the top quark loop, where the gluons are in the wave function of the incoming hadrons. The branching ratios are in \(b\bar{b}, \tau^+\tau^-\), and \(\gamma\gamma\), for the lower part of the Higgs boson mass spectrum to be explored and \(W^+W^-\), \(Z^0Z^0\), for masses above 160 GeV. The main problem to be faced by the Higgs boson hunt for low masses is that \(b\bar{b}\) has an enormous QCD background, \(\tau^+\tau^-\), a difficult signature of decay modes and \(\gamma\gamma\), a small rate. While standard Higgs boson production is obviously the priority channel, it is thus useful to investigate other channels, with smaller cross-sections but possibly cleaner signals.

Diffractive Higgs boson production provides such an opportunity. Higgs boson production in the central rapidity region is mediated through color singlet exchanges leading to diffraction of the incoming hadrons at both vertices. Hence it is \(a\ priori\) possible to expect a single Higgs boson produced with large rapidity gaps separation with the diffracted hadrons (protons and/or antiprotons). Moreover, such diffractive processes can be selected by tagging initial hadrons using roman pot detectors, resulting in a pure signal: a Higgs boson and nothing else.

Of course, this hope had to be supported by an estimate of the cross-sections, which started with Ref.[1]. The difficulty with diffractive production is that it involves a mixture of perturba-
Figure 1: *Dijet mass fraction*. The data are from Ref.[2]. *Left:* (shaded) Gluons off the Pomeron (from model [3]); (white) “Exclusive” mode, before (column) or after (histogram) detector simulation. *Right:* (shaded) Gluons off the proton.

tive and non-perturbative aspects of QCD which is far from a complete understanding. This has been reflected in the large dispersion of predictions for the diffractive Higgs boson production cross-sections during the 10 past years, preventing reliable predictions for collider experiments.

2 “Calibration”: Hard diffractive dijets at Tevatron

The recent information allowing a progress in the determination of the cross-sections and the simulation of diffractive Higgs boson production came indirectly from the production of hard dijets observed at Tevatron. In the familiar configuration “Gap-Dijet-Gap”, it has been possible to register about 100 dijet events with suitable cuts allowing to characterize them as created *via* double color singlet (the so-called DPE: “Double Pomeron Exchange”).

Let us introduce the appropriate kinematic variables, namely: $\xi_1(\xi_2)$: the $p(\bar{p})$ fractional momentum loss (momentum fraction carried by the Pomeron at each vertex); $\Delta \eta_i \sim \log 1/\xi_i$: the rapidity gaps; $M^2 = s\xi_1\xi_2$: The total (dijets plus soft hadronic radiation) diffractive mass produced; $M^2_{J\bar{J}}$: the dijet mass; $M^2_{J\bar{J}}/s\xi_1\xi_2$: The dijet mass fraction.

Interestingly enough (see Fig.1) the dijet mass fraction spectrum indicates the existence of a soft hadronic radiation accompanying the dijet system. Hence, the dijet diffractive production is neither essentially “exclusive” (with just two jets) nor “soft” (with a large gluon radiation coming from the incident particles). It can be called “inclusive”. Only a few models and a more restrictive range of predictions have been able to take into account this peculiar experimental feature, and to describe the observed kinematical spectra and event rates.

Among the list of models having been proposed for hard diffractive production in the central region, only four (types of) models seem to survive the compatibility constraints with dijet production. Following the schemes of Fig.2, one has:

1. the non factorizable Pomeron model[3];
2. the factorizable Pomeron model[4];
3. The soft color interaction model[5].
4. The exclusive model[6];

The models (1,2) describe hard dijet diffraction *via* the exchange of color singlets (Double Pomeron exchange). The “inclusive” dijet mass ratio are well described (see *e.g.* model (1), Fig.1) by the hadronic radiation associated with the Pomeron structure functions determined in hard diffraction processes at HERA. In model (2), the known HERA/Tevatron factorization breaking is due to the rapidity gap survival, while in model (1), it is due to the soft gluon propagator as in [1], leading to different event rate predictions. In the model (3), it is also
described in the same way as diffraction at HERA, but using the soft color interaction formalism. Let us note the remaining “exclusive” model (4), which event rate is sufficiently damped by the gap survival probability to stay below the present experimental limit for the exclusive cross-section. We shall focus on the discussion of Higgs boson production on the predictions of these four models which are able to describe or at least be compatible with the present data.

### 3 Predictions for the Tevatron and LHC

Considering the four selected models, it is possible to check (or determine) their overall normalization to the dijet event rate. Hence, by assuming a safe extrapolation to the Higgs boson cross-sections, one gets a range of predictions for the Tevatron (run II) and the LHC which is summarized on Table 1.

The first line of Table 1 is for the Tevatron with a typical low Higgs mass. We see that all models predict too few events to be observable. On the contrary, three of the four models predict a significant cross-section (w.r.t. the expected luminosity) at the LHC, even in the presence of a small gap suppression factor (GSP). The soft color interaction model prediction (3), however, is still low, which is a incentive for further tests of the models. For completeness, the model predictions for a larger Higgs mass are given in the last line of the table.

Table 1 shows that the “inclusive” cross-sections are predicted in Pomeron models to be 10 to 100 times larger at LHC than the “exclusive” ones. It could even be possible that the

| Model Predictions for Diffractive Higgs Boson Cross-Sections (in femtobarns) | (1) | (2) | (3) | (4) |
|---|---|---|---|---|
| H~115 GeV, TeV. \(\mathcal{L} \sim 1 fb^{-1}\) | 1.7 | 0.029 | \(10^{-4}\) | .03 |
| H ~115 GeV, LHC \(\times = GSP \sim (.1 \rightarrow .03)\) | 169 | 379\(\times\) | 0.19 | 1.4 |
| H ~160 GeV, LHC | 123 | 145\(\times\) | - | .55 |
Figure 3: Higgs mass reconstruction, from [7]. With a Higgs mass of 120 GeV, the simulated Higgs mass reconstruction is displayed with a cut of 20, 50, 100, 500 GeV on total Pomeron remnants’ energy.

exclusive mode could be completely hidden by the inclusive one. However, the “inclusive” mode is hindered by the accompanying hadrons, the so-called Pomeron remnants. Indeed, this radiation may obscure the Higgs boson signal and e.g. the mass determination. In a recent publication 7, it was proposed to trigger on the Pomeron remnants, in order to improve the signal. In some sense, the idea is to find a compromise between the much higher cross-sections of the inclusive mode and the clean signal of the exclusive one. the improvement of the Higgs boson mass determination with the trigger on Pomeron remnants is shown in Fig.3.

The present uncertainties on cross-sections and signals remain quite large. They are mainly due to the diffractive cuts, the jet energy scale and the questions about the soft correction factors. Hopefully, stringent tests and discrimination of models will be provided by the high statistics of hard DPE dijets, diphotons and dileptons expected from the Run II. The lepton over photon rate will be able to distinguish between Pomeron and non-Pomeron models and the dijet mass differential spectrum, between factorizable and non-factorizable models 3.

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