DIFFRACTIVE HIGGS BOSON PRODUCTION AT TEVATRON AND LHC

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We discuss the different models of central diffractive production of the Higgs boson at the Tevatron and the LHC. We also describe how the models can be tested using diffractive production data being taken at the Tevatron. We finally discuss the advantages of using diffractive events to reconstruct the mass of the Higgs boson especially at the LHC.

1 Inclusive Higgs production

Factorisable inclusive Higgs production. The factorisable inclusive Higgs and dijet production cross sections have been presented in Ref. [1]. In this model, the diffractive gluon density is taken from the H1 measurement [2] at HERA and is used to compute the diffractive dijet, diphoton or Higgs boson cross sections, by convoluting this parton density with the standard hard subprocess (diquark or Higgs boson production via a top loop). In this model, factorisation breaking between HERA and Tevatron is assumed to give a factor 0.1 in normalisation for the Higgs or dijet production cross sections at the Tevatron. Since this number is not known at LHC energies, no factor has been applied for the Higgs boson production cross sections at the LHC. The cross section is found to be very low at the Tevatron and quite high at the LHC, provided the survival gap probability is not too small (see Ref. [3]).

Non factorisable inclusive Higgs production. The non factorisable inclusive Higgs, dijet, diphoton and dilepton production cross sections have been presented in Ref. [4]. The main difference with the previous model is that the usual soft hadron-hadron cross section is assumed to produce the hard scattering, and this cross section is then convoluted with the partonic densities in the pomeron taken from the H1 experiment (see the third item of Ref. [4] to get a detailed description of the theoretical framework of this model).

A soft gluon is present between the two protons which implies in this model a natural factorisation breaking between the Tevatron and HERA. The pomeron intercept is thus the soft one in this model ($\epsilon = 0.08$) whereas a hard value of the pomeron intercept is used in the previous model ($\epsilon = 0.2$).

This model has been interfaced with PYTHIA for hadronisation. The generator has also been interfaced to a fast simulation of the DØ and CDF detectors, which allowed to scale the prediction to the CDF Run I measurement [5], namely $\sigma \sim 43.6 \pm 4.4$ (stat.) $\pm$ 21.6 (syst.) nb when the antiproton is tagged in the roman pot detectors in the following kinematical domain in ξ and t of the proton and the antiproton ($0.035 \leq \xi_{\bar{P}} \leq 0.095$, $|t| < 1$ GeV^2, $0.01 \leq \xi_p \leq 0.03$).

The results concerning the Higgs boson cross sections at the Tevatron and the LHC are given in Fig. 1. We note that the cross sections at the Tevatron are quite low like in the previous model and quite large at the LHC. In this model, there is no need to apply a survival gap probability since the cross section has been rescaled to the CDF measurement. It is however important to note that the scaling factor might be different at the LHC while the same factor between the Tevatron and the LHC has been assumed.

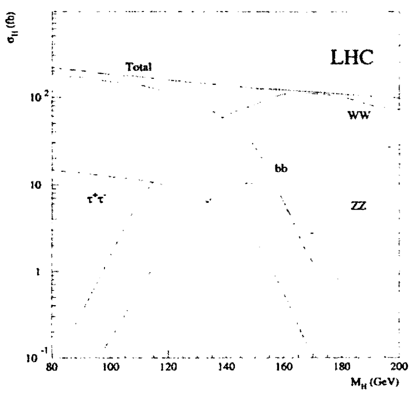

Figure 1: Higgs boson production cross-section at the LHC. Various decay channels are plotted as a function of the mass of the Higgs boson.

One assumption concerning both models was to take the gluon and quark densities in the pomeron measured at HERA, in the H1 experiment [2] to compute the Higgs boson production cross section. In Ref [6] is shown the recent determination of the gluon density inside the pomeron made by the H1 collaboration using the most recent diffractive structure function data. The result is compared to the CDF gluon density determination and both results show largely different normalisations but similar shapes. This justifies a priori to take a constant normalisation factor difference between HERA and the Tevatron, while keeping the same gluon density. More precise measurements at the Tevatron being performed using the CDF roman pot detectors or the new implemented Forward Proton Detector from DØ will be needed and available soon to test further this hypothesis.

Tests of the models at the Tevatron and differences between the factorisable and non factorisable models. Even if the diffractive Higgs boson production cross sections are too low at the Tevatron, important tests of the models concerning dijet, diphoton and dilepton production can be done, which will allow to make more precise predictions for the LHC. All models give predictions for these cross sections and we give in Fig. 2 [4] the predictions for the non factorisable inclusive model. All these measurements will be performed soon by the CDF and DØ experiments and will perform good tests of the model [7].

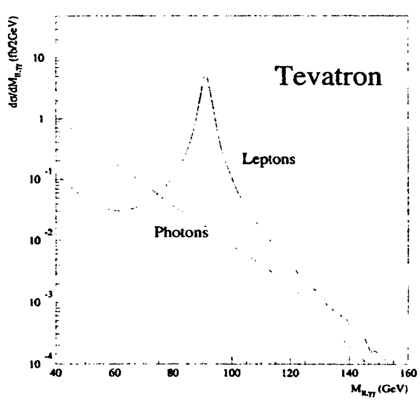

Figure 2: Differential diphoton and dilepton production cross-sections (fb) at the Tevatron. The dilepton cross-section corresponds to a single lepton flavour. The transverse energy of the central particles satisfies $E_T > 10$ GeV, and their rapidity is limited to $|y| < 4$.

2 Exclusive diffractive Higgs boson production

In this kind of models [8] a direct perturbative calculation is performed using the gluon density in the proton. This leads to very clean events where the protons are scattered at very small angle in the beam pipe (and can be tagged in roman pot detectors or microstations) and the Higgs boson which decays centrally in the main detector, and nothing else. The problem is that one needs to suppress totally QCD radiation. The price to pay to get this kind of events is an exponential Sudakov form factor to suppress QCD radiation which leads to a low cross section. One may wonder if these events exist (no soft gluon can be emitted after interaction), which can be tested at the Tevatron [9]. The diffractive Higgs boson cross section for this process (see [8, 3])is extremely small for the Tevatron and quite large enough for the LHC provided that the gap survival probability is not too small (1.4 fb for a Higgs of 120 GeV at the LHC).

At the Tevatron, it is important to check if the exclusive events exist or not and to measure their production cross section since they have never been observed yet. These events would be the ideal ones for the LHC. So far, the CDF collaboration looked at these events in the dijet channel and put a limit of 3.7 nb on their production cross section [9]. The difficulty is to distinguish these exclusive events from *quasi-exclusive* events produced in inclusive events. Namely, it is possible to produce events inclusively where most of the energy in the pomeron is used to produce dijets, diphotons, dileptons or Higgs bosons, or in other words, where pomeron remnants show very little energies. These " quasi-exclusive" events will be very similar to the exclusive ones and it is thus important to see how one can distinguish between them, and see if exclusive events exist or not. One way to distinguish between them would be to measure the ratio of the diffractive diphoton to dilepton cross sections at the Tevatron. In inclusive models, this ratio is determined by the quark and gluon distributions inside the Pomeron, and the presence of the Z pole in the dilepton cross-section. In exclusive models, it is only possible to produce diphoton diffractively but no dilepton. The diphoton cross section obtained for a mass fraction higher than 0.85-0.9 is of the order of 2 fb for both the exclusive and inclusive cross sections, and the ratio of the diphoton to dilepton cross section measured at the Tevatron is expected to show an enhancement and a change of slope as a function of the diphoton/dilepton mass if exclusive events exist. This will be a very clean test of the existence of exclusive events. Another possible test will be to measure the χ_b or χ_c central diffractive production cross section.

3 Higgs mass reconstruction using diffractive events

Higgs mass reconstruction in the case of exclusive events. Exclusive Higgs events are diffractive events where all the energy (basically all diffractive mass) is used to produce the Higgs boson. Kinematically, it is very easy to reconstruct the Higgs mass if one is able to measure the ξ of both scattered protons detected in roman pot detectors [10]: $M_{Higgs} = \sqrt{\xi_{p1}\xi_{p2}S}$. The mass reconstructed using roman pot detectors with a resolution in ξ of 0.2% , and in t of 10% $\sqrt{t}$ leads to a perfect Higgs mass reconstruction with a resolution better than 2%. This resolution allows a very good signal over background separation.

Higgs mass reconstruction in the case of inclusive events. In the case of inclusive events, the previous method to reconstruct the mass of the Higgs boson will not work so nicely since the total energy is used not only to produce the Higgs boson, but also lost in the pomeron remnants. The natural idea is to cut on the energy of the pomeron remnants to be able to get quasi-exclusive events where not much of the available energy is lost in pomeron remnants. The CMS collaboration [11] will be able to tag particles up to a rapidity of 7.5. In Fig. 3, we give the resolution obtained on the Higgs mass reconstruction if one is able to cut on the energy of the pomeron remnant (in these plots, we assume that we are able to tag the remnants up to a rapidity of 7.5, and the resolution of these detectors to be $100\%/\sqrt{E}$). The resolution of the Higgs mass is found to be about 2.1, 4.0, 4.6 and 6.6 GeV if one requires the remnant energies below a rapidity of 7.5 to be respectively less than 20, 50, 100 and 500 GeV at the LHC. Of course this method will work only during the first three years at the LHC when the luminosity will be low because of pile-up events. Of special interest are the cases when the Higgs boson decays into τ because of the low diffractive background.

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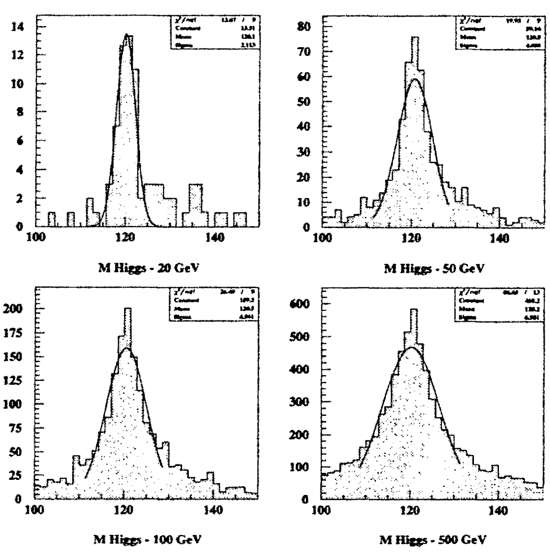

Figure 3: Higgs mass reconstruction for inclusive events using roman pot detectors, and central detectors up to a rapidity of 7.5 for a Higgs mass of 120 GeV at the LHC.

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