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DIFFRACTIVE HIGGS PRODUCTION AT THE LHC

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We use a Monte Carlo implementation of recently developped models of double diffractive Higgs production to assess the sensitivity of the LHC experiments.

1 Theoretical framework

The first proposed model for $pp \to p + H + p$, the Bialas-Landshoff (BL) [1] model, is based on a summation of two-gluon exchange Feynman graphs coupled to Higgs production by the top quark loop. The non-perturbative character of diffraction at the proton vertices relies on the introduction of "non-perturbative" gluon propagators which are modeled on the description of soft total cross-sections within the additive constituent quark model.

The other popular model for exclusive DPE has been developed by Khoze, Martin, Ryskin (KMR) [2]. It relies on a purely perturbative, factorized QCD mechanism applied to 2-gluon exchange among the protons, without reference to a reggeized Pomeron, and convoluted with the hard sub-processes $gg \to gg, q\bar{q}, H$. The main ingredients of this model are the so-called unintegrated off-forward gluon distributions in the proton.

The survival probability has not been applied in the original computations by Bialas et al, and the dijet cross-sections are found to exceed the CDF experimental bound [4]. It has however recently been shown, using the Good-Walker and Glauber formalisms, that the double Pomeron exchange contribution to central diffractive production of heavy objects has to be corrected for absorption, in a form determined by the elastic scattering between the incident protons [3].

More details about the theoretical model and its phenomenological applications can be found in Ref. [5] and [6]. In the following, we use the BL model for exclusive Higgs production recently implemented in a Monte-Carlo generator [5]. It has been shown that it gives results close to the KMR model.

2 Experimental context

The analysis is based on a fast simulation of the CMS detector at the LHC (Similar results would be obtained using the ATLAS simulation). The calorimetric coverage of the CMS experiment ranges up to a pseudorapidity of $|\eta| \sim 5$. The region devoted to precision measurements lies within $|\eta| \leq 3$, with a typical resolution on jet energy measurement of $\sim 50\%/\sqrt{E}$, where E is in GeV, and a granularity in pseudorapidity and azimuth of $\Delta\eta \times \Delta\Phi \sim 0.1 \times 0.1$.

In addition to the central CMS detector, the existence of roman pot detectors allowing to tag diffractively produced protons, located on both p sides is assumed [7]. The ξ acceptance and resolution have been derived for each device using a complete simulation of the LHC beam parameters. The combined ξ acceptance is $\sim 100\%$ for ξ ranging from 0.002 to 0.1, where ξ is the proton fractional momentum loss. The acceptance limit of the device closest to the interaction point is $\xi > \xi_{min}$ =0.02.

In exclusive double pomeron exchange, the mass of the central heavy object is given by $M^2 = \xi_1 \xi_2 s$ [8] where ξ_1 and ξ_2 are the proton fractional momentum losses measured in the roman pot detectors.

3 Existence of exclusive events

The question arises if exclusive events exist or not since they have never been observed so far. The DØ and CDF experiments at the Tevatron (and the LHC experiments) are ideal places to look for exclusive events in dijet or χ_C channels for instance [4] where exclusive events are expected to occur at high dijet mass fraction. So far, no evidence of the existence of exclusive events has been found. A nice way to show the existence of such events would be to study the correlation between the gap size measured in both p and $\bar{p}$ directions and the value of $log 1/\xi$ measured using roman pot detectors, which can be performed in the DØ experiment. The gap size between the pomeron remnant and the protons detected in roman pot detector is of the order of $log 1/\xi$ for usual diffractive events (the measurement giving a slightly smaller value to be in the acceptance of the forward detectors) while exclusive events show a much higher value for the rapidity gap since the gap occurs between the jets (or the χ_C) and the proton detected in roman pot detectors (in other words, there is no pomeron remnant). Fig. 1 shows the correlation between the gap size and $log 1/\xi$ at generator level for standard diffractive events and exclusive ones [9] [a]. Another observable leading to the same conclusion would be the correlation between ξ computed using roman pot detectors and using only the central detector.

4 Triggering on diffractive Higgs bosons

Some more details about triggering on diffractively produced Higgs bosons can be found in Ref. [5].

At low luminosity ($\sim 10^{33}$ cm^{-2} s^{-1}) during the first years of the LHC), it is possible to require a rapidity gap in the forward region of the calorimeter between the proton and the jets since the full available energy is used to produce the Higgs boson in exclusive events. This requirement can be performed at the first level of the trigger, requiring at the same time the presence of two high p_T jets in the main detector.

Triggering on diffractively produced Higgs at high luminosity is not easy since the total dijet cross-section at the LHC is orders of magnitude too large to allow

[a] To distinguish between pure exclusive and quasi-exclusive events, other observables such as the ratio of the cross sections of double diffractive production of diphoton and dilepton are needed [6].

triggering on the jets themselves, so benefit must be taken from the specifities of DPE.

If the needed ξ acceptance can be obtained for detectors close enough to the interaction point, requiring two detected protons at the first level trigger eliminates all non-diffractive dijet events and solves the problem. The maximum allowed distance is about 200m, a number given by the time needed for a proton to fly from the interaction point to the forward detector, for the detector signal to travel back, and for the trigger decision to be made, within the allowed first level trigger latency. This latency is of order 3 μs for the LHC detectors. If one requires a proton tag on each side at the first level of the trigger, this induces a cut on the Higgs mass to be greater than about 280 GeV.

If one wants to trigger on lower Higgs masses, the trigger is much more complicated. The first level trigger rate requiring two jets with $p_T > 40$ and 30 GeV, and a dijet mass greater than 80 GeV, is 1.1 kHz at low luminosity and 11 kHz at high luminosity. It is possible to reduce this rate at Level 1 by taking into account the fact that diffractive jets are more collimated or show less QCD radiation than usual jets [9].

5 Sensitivity on standard model Higgs production

This section summarizes the cuts applied in the analysis. As said before, both diffracted protons are required to be detected in roman pot detectors. The central mass is reconstructed using the measurement of ξ_1 and ξ_2 given by the forward detectors, giving $M_{miss} = (\xi_1 \xi_2 s)^{1/2}$.

The other cuts are based on detecting well measured, high p_T $b\bar{b}$ events. We first require the presence of two jets with $p_{T1} > 45$ GeV, $p_{T2} > 30$ GeV. The difference in azimuth between the two jets should be $170 < \Delta\Phi < 190$ degrees, asking the jets to be back-to-back. Both jets are required to be central, $|\eta| < 2.5$, with the difference in rapidity of both jets satisfying $|\Delta\eta| < 0.8$. We also apply a cut on the ratio of the dijet mass to the total mass of all jets measured in the calorimeters, $M_{JJ}/M_{all} > 0.75$. An additional cut requires a positive b tagging of the jets, eliminating all non-b dijet background, with the efficiency on b-quark dijets quoted above.

The ratio of the dijet mass to the missing mass should verify $M_{JJ}/(\xi_1 \xi_2 s)^{1/2} > 0.8$. This cut requires that all the available Pomeron-Pomeron collision energy is used to produce the Higgs boson.

6 Results

Results are given in Fig. 2 for a Higgs mass of 120 GeV, in terms of the signal to background ratio S/B, as a function of the Higgs boson mass resolution.

In order to obtain an S/B of 3 (resp. 1, 0.5), a mass resolution of about 0.3 GeV (resp. 1.2, 2.3 GeV) is needed. The forward detector design of [7] claims a resolution of about 2.-2.5 GeV, which leads to a S/B of about 0.4-0.6. Improvements in this design would increase the S/B ratio as indicated on the figure. As usual, this number is enhanced by a large factor if one considers supersymmetric Higgs boson production with favorable Higgs or squark field mixing parameters.

Our result can be compared to the phenomenological result of [10], where experimental issues were addressed within the KMR framework. For a missing mass resolution of ∼1 GeV, we have obtained S/B∼1, where the KMR collaboration finds S/B∼3. In [10], the background is integrated over a mass window of 1 GeV, assuming that 100% of the signal lies inside this window. This is the case only if the mass resolution is significantly smaller than 1 GeV, and typically of order 250-300 MeV. So assuming the result of [10] is given for a gaussian mass resolution of 1 GeV either underestimates the background by a factor ∼3, or overestimates the signal by the same factor. Taking this factor into account, and once again assuming that trigger rates and contamination by inclusive DPE can be kept under control, brings the KMR estimate to agree with our Monte-Carlo simulation.

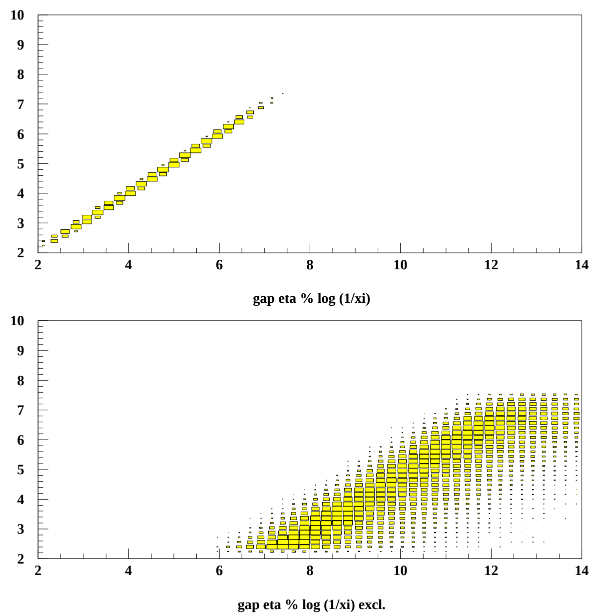

Figure 1. Correlation between the gap size (horizontal axis) and the value of $log 1/\xi$ measured using tagged protons for inclusive (upper plot) and exclusive (lower plot) diffractive events.

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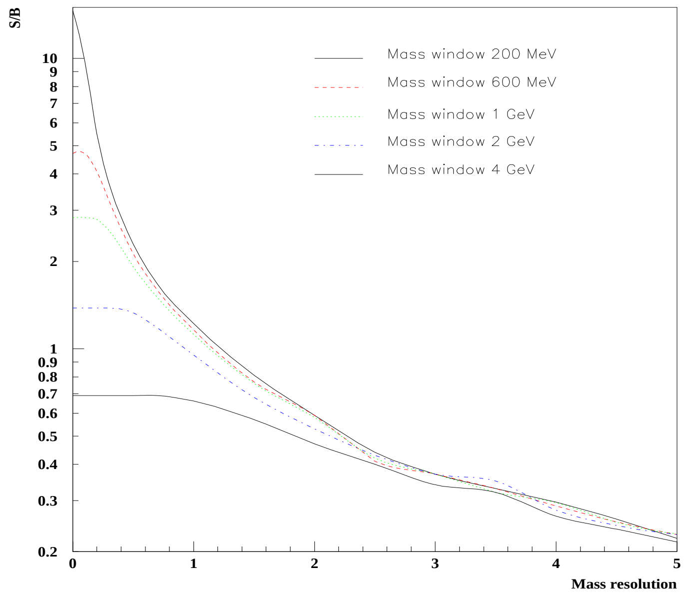

Figure 2. Standard Model Higgs boson signal to background ratio as a function of the resolution on the missing mass, in GeV. This figure assumes a Higgs boson mass of 120 GeV.

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