PROCEEDINGS OF SCIENCE

Study of the $gg \to Hjj$ background to Weak Boson Fusion Higgs production

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We analyse some distributions relevant to the discrimination between Higgs production via weak-boson fusion and via gluon fusion. By using a matrix element calculation merged with the HERWIG parton shower, we find that, contrary to previous studies, higher order corrections preserve a set of correlations among the leading jets, characteristic of the two production processes.

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1. Introduction

Weak-boson fusion (WBF) will be an important channel for Higgs boson searches at the LHC and even more for the determination of its couplings to gauge bosons and fermions. The typical signature consists of the Higgs boson in association with two forward jets (tagging jets), separated by several units in rapidity. The requirement of sufficiently high p_T for these jets, in order to have high tagging efficiency and avoid contamination from the underlying event, translates in a large jet-jet invariant mass, of the order of 1 TeV. A relevant contribution to the same signature is given by Higgs production through gluon fusion with two additional jets.

While QCD production is an additional important contribution for searches, it has to be considered as an irreducible background for the electroweak Higgs coupling determination, since it depends only on the Yukawa couplings (essentially the $t\bar{t}H$ coupling). For these reasons it is important to analyse in some detail the features of the two different production processes for their separation.

In the literature several studies have already been performed: while WBF is known at QCD Next-to-Leading Order (NLO) accuracy [1], QCD Higgs production is known only at Leading Order (LO) in QCD, since it is a one-loop process at lowest order. In Refs. [2, 3, 4] the complete calculation has been performed and compared with the results obtained in the limit $m_t \to \infty$. The same approximation has been used in Ref. [5] to calculate the matrix elements with Higgs plus three final state hard partons in LO accuracy. Very recent is the calculation of virtual corrections to Higgs plus four parton processes [6], an essential ingredient for the calculation of NLO corrections to $pp \to H+2$ jets.

The partonic studies performed up to now [4, 5] pointed out two effective observables capable of discriminating between gluon fusion and WBF, and of signalling the occurence of anomalous Higgs-gauge bosons couplings [7]: the correlation in the azimuthal plane betwen the tagging jets and the central jet-veto. However, one may wonder if higher order QCD radiation effects could wash out the specific feature of each process. For instance a much weaker correlation between the tagging jets in Higgs + 2 jets production via gluon fusion has been found after showering and the hadronisation [8]. These results, though, cannot be directly compared with the ones obtained in Ref. [4], because the two tagging jets are generated by the parton shower and not by the matrix element. Thus it is not possible to distinguish the de-correlation due to showering and hadronisation from the correlation between the two jets due to the hard radiation, because the latter is included only in its soft/collinear approximation provided by the shower. However, it is possible to remedy to the shortcomings above by using a matrix-element Monte Carlo event generator, such as ALPGEN [9], interfaced to the parton shower for QCD higher order corrections. In this contribution some preliminary results obtained with this tool will be illustrated. A more detailed and exhaustive study will be presented elsewhere [10].

2. The calculation

The effective coupling ggH, in the limit $m_t \to \infty$, has been implemented in the ALPHA code [11] at the Lagrangian level [1]. In ALPGEN version 2.0 the process $pp \to H+N$ jets $(N<5)$ has been

[1]This approximation has been shown to be very good for m_H and $p_T^j < m_t$ in Refs. [2, 4].

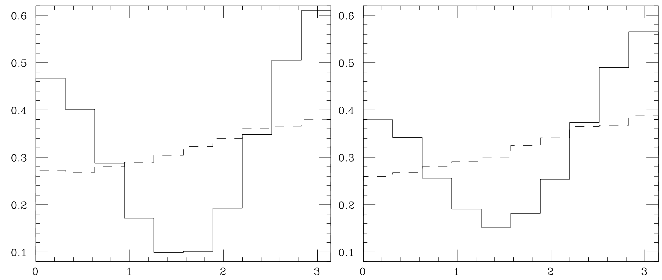

Figure 1: Left: $\frac{1}{\sigma}d\sigma/d\phi_{jj}$ distribution at LO partonic level for the process $pp \to H+2$ jets. Solid line refers to QCD Higgs production, dashed line to WBF. Right: $\frac{1}{\sigma}d\sigma/d\phi_{j_1 j_2}$ distribution with parton shower (j_1 and j_2 are the leading p_T jets) on top of $pp \to H+2$ jets generated events.

introduced (and interfaced to the parton shower for higher order QCD corrections and hadronisation) with exact LO QCD matrix elements for $p_1 p_2 \to H$ plus up to N additional partons, with p_1 and p_2 the initial state partons. The event selection and parameters adopted for the numerical simulations are the same as in Ref. [5], *i.e.*: $p^j_\perp \geq 20$ GeV, $|\eta_j| \leq 5$, $R_{jj} \geq 0.6$, $|\eta_{j1} - \eta_{j2}| \geq 4.2$, $\eta_{j1} \cdot \eta_{j2} \leq 0$, $M_{jj} \geq 600$ GeV, with $m_H = 120$ GeV and the PDF set CTEQ5L. The adopted factorisation and renormalisation scales (affecting much more QCD Higgs production than WBF) are: $\alpha_s^{2+N\text{jets}}(\mu_R) \to \alpha_s^2(M_H)\Pi_i \alpha_s(p_i^T)$ and $\mu_F = (\Pi_i p_i^T)^{(1/N)}$. After this parameter tuning we obtained perfect agreement between the `ALPGEN` predictions and the calculation of Ref.[5]. The jets are defined according to the routine `GETJET` [12], which uses a simplified version of the UA1 jet algorithm. The event selection for jets is the same as for partons. Four samples of unweighted events have been generated, for WBF and QCD Higgs production, each for two and three final state jets. These samples have been used as input for the `HERWIG` [13] parton shower to simulate higher order QCD corrections.

3. Results

In Fig. 1 we compare the predictions for the $\Delta\phi_{jj}$ azimuthal correlation distribution between the two tagging jets (solid line refers to gluon fusion, dashed line to WBF). The left panel reproduces the results of Ref. [4] at the parton level, *i.e.* the amplitude for WBF is only mildly dependent on the value of $\Delta\phi_{jj}$, while the amplitude for gluon fusion displays a characteristic dip for $\Delta\phi_{jj} = \pi/2$. Such a dip is manteined when we include higher order QCD corrections on top of matrix elements, even if less pronounced. As expected the additional radiation due to showering and hadronisation dilutes the correlation between jets but is still present, contrary to the findings of Ref. [8]. Also in the case of Higgs + 3 jets generated by `ALPGEN` plus parton shower, with the tagging jets defined as the two leading p_T jets, we obtain the same correlation pattern (we can not display the results for lack of space), which is thus not destroyed by additional hard radiation.

Another distiguishing feature of WBF is that to leading order no colour is exchanged in the t-channel and hence no gluon exchange is possible to $\mathcal{O}(\alpha_s)$ (except for a tiny contribution due to equal-flavour quark scattering). Gluon fusion Higgs + 2 jets production, instead, is dominated by gluon exchange in the t-channel. Therefore, like for other QCD backgrounds, the bremsstrahlung radiation is expected to occur everywehre in rapidity. In order to analyse that, in Ref. [5] the

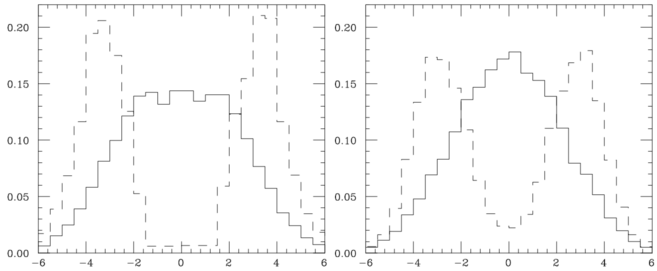

Figure 2: Left: $\frac{1}{\sigma}d\sigma/dy_{\rm rel}$ distribution ($y_{\rm rel} = y_3 - (y_1 + y_2)/2$) with parton shower on top of $pp \to H +$ 2 jets generated events; dashed WBF, solid QCD Higgs production. Right: the same as in the left pane, but with parton shower on top of $pp \to H + 3$ jets generated events.

distribution in rapidity of a third jet was considered in Higgs + 3 jets production, with a parton-level analysis. Here we analyse in Fig. 2 the same distribution, *i.e.* the rapidity of the third jet, measured with respect to the rapidity average of the tagging jets, starting with Higgs + 2 jets (left panel) or with Higgs + 3 jets matrix element events and adding parton shower radiation. While for WBF Fig. 2 confirms the parton-level analysis of Ref. [5], for gluon fusion we find that the third jet is much more likely to be emitted central in rapidity if we start directly with three hard partons in the matrix element. The plot on the left, where the third jet is given by the parton shower, is very similar to the partonic Higgs + 3 jets prediction.

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