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Higgs production through vector-boson fusion at the NLO matched with parton showers

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ABSTRACT

We present a study of Higgs hadroproduction through vector-boson fusion at the NLO in QCD matched with parton showers. We discuss the matching systematics affecting this process through a comparison of the aMC@NLO predictions with the POWHEG and the pure-NLO ones.

1. Introduction

The production of a Standard-Model (SM) Higgs boson (H^0) through the so-called vector-boson-fusion (VBF) mechanism features the second-largest cross section among the H^0 production channels in hadronic collisions and, although smaller than the gluon-fusion one by about one order of magnitude, it still provides useful complementary informations. After the discovery of a SM-Higgs-like particle [1,2], the emphasis is rapidly shifting towards the determination of its properties, and in this respect VBF may play an increasingly important role, owing to its sensitivity to various combinations of Higgs couplings [3], which can be studied by considering different decay channels. However, the very distinctive features of VBF, with two jets lying relatively close to the beam line and travelling in opposite directions, render it a challenging case, given that rather severe cuts have to be applied in order to reduce backgrounds (among which, in the coupling measurement perspective, one may count the contamination due to $gg \to H^0$). While the typical kinematic regions probed at the LHC do not pose problems for perturbative-QCD computations (as shown by the behaviour of the rather moderate NLO [4–6] and NNLO [7,8] corrections in parton-level results), the presence of two jets in a hadronically-enriched environment implies the necessity of using hadron-level simulations such as those generated with parton shower Monte Carlo's (PSMC's), in order to obtain more realistic predictions.

It has by now become a rather standard procedure that of matching NLO QCD results with PSMC's, by using either the MC@NLO [9] or the POWHEG [10,11] formalism. Because of the potential importance of shower and hadronisation effects and of the good behaviour of NLO corrections, VBF appears in fact to be an ideal application for matching techniques. However, this has been done so far only in the context of the POWHEG approach [12]; in this Letter, we amend this by presenting MC@NLO results obtained with the fully-automated aMC@NLO framework, and by comparing them extensively with those obtained with the code constructed in reference [12] and implemented in the publicly available POWHEG-Box framework [13]. The primary motivation for doing so is phenomenological. As is known, MC@NLO and POWHEG differ by terms of order $\mathcal{O}(\alpha_S^{b+2})$ [14], i.e. two orders larger than the Born's; furthermore, they differ by logarithmic orders beyond the leading even if matched to the same PSMC, owing to the fact that POWHEG generates the first emission with own Sudakov form factors, independent of those of the PSMC.[1] While these differences are typically small, consistently with their being beyond the nominal accuracy of the calculations, Higgs production in gluon fusion constitutes a striking counter-example, with the two approaches yielding significant discrepancies in the Higgs

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[1] The latter differences are actually logarithmically leading in the case of an angular-ordered PSMC which does not include a vetoed-truncated shower [10].

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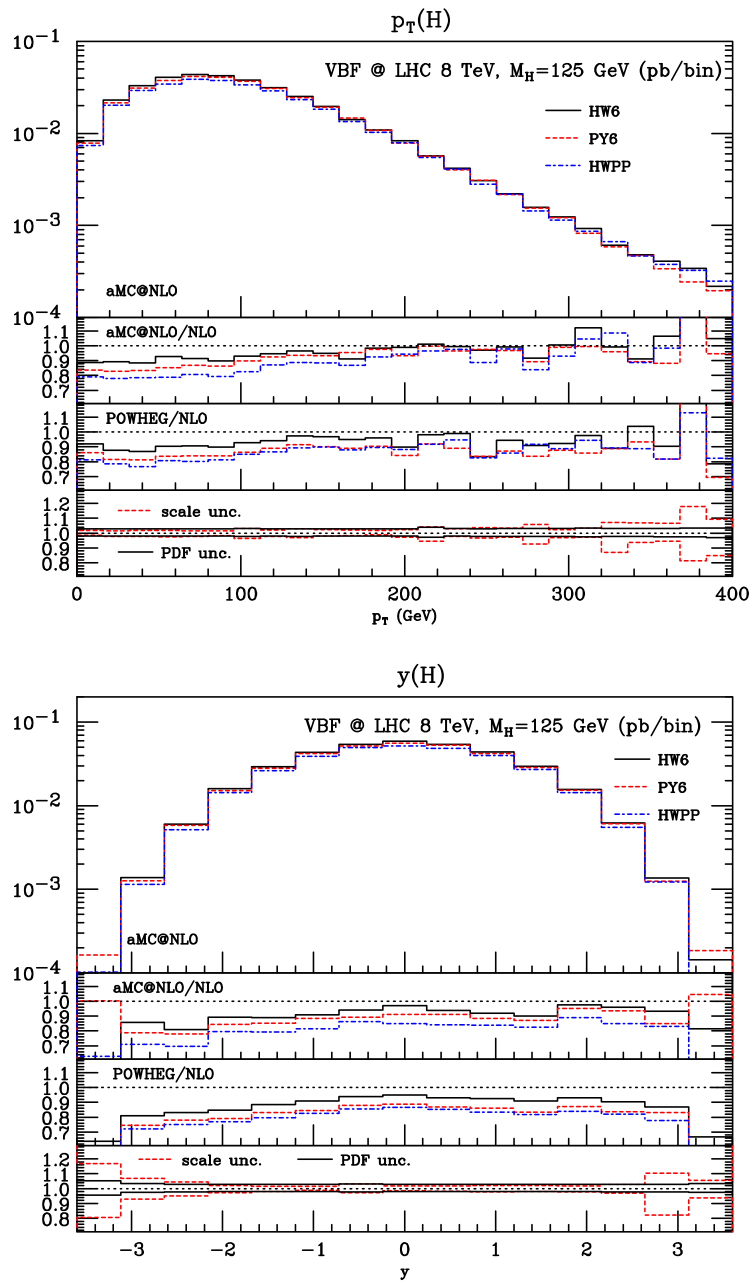

Fig. 1. Higgs boson transverse-momentum (top) and rapidity (bottom) distributions. Main frame: aMC@NLO matched with HERWIG6 (black solid), virtuality-ordered PYTHIA6 (red dashed) and HERWIG++ (blue dot-dashed). Upper (middle) inset: ratios of aMC@NLO (POWHEG) over the fixed-order NLO, with the same colour pattern as the main frame. Lower inset: scale (red-dashed) and PDF (black solid) uncertainties for aMC@NLO + HERWIG6. See text for further details.

transverse momentum,[2] and in the Higgs-hardest-jet rapidity difference. The latter observable in particular, being quite sensitive to the radiation pattern generated by the PSMC,[3] plus the internal Sudakov in the case of POWHEG, could have direct implications for VBF, given the importance of 'extra' radiation in this process. In general, the differences between the MC@NLO and POWHEG results should give one a fair idea of the NLO-matching systematics, a topic which, to the best of our knowledge, has not been studied in VBF Higgs production. A lesser motivation is technical, and is that of validating the aMC@NLO machinery with a further non-trivial process on top of those considered so far. We remind the reader that aMC@NLO is a generator that implements the matching of a generic NLO QCD computation with a PSMC according to the MC@NLO formalism; its defining feature is that all ingredients of such matching and computation are fully automated. The program is developed within the MADGRAPH 5 [16] framework and, as such, it does not necessitate of any coding by the user, the specification of the process and of its basic physics features (e.g. particle masses or phase-space cuts) being the only external informations required: the relevant computer codes are then generated on-the-fly, and the only practical limitation is represented by CPU availability. aMC@NLO is based on different building blocks, each devoted to the generation and evaluation of a specific contribution to an NLO-matched computation. MADFKS [17]

2 Before any tuning of the `hfact` parameter in POWHEG.

3 See Ref. [15] for a discussion on this point.