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Title: A comparative study of Higgs boson production from vector-boson fusion

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Referee report

The manuscript presents a detailed study of Higgs production via the vector-boson fusion (VBF) process. This process is particular interesting due to its intricate relation to the electroweak symmetry breaking mechanism. In particular, the upcoming experimental measurements will be able to probe more exclusive regions of phase space where new physics might occur. In that regard, a solid theoretical understanding of the process at hand is required. This is what the authors of the manuscript aim at in this work. After describing the tools that they use in the first part, they do an extensive study of the VBF process with respect to other Higgs-boson production mechanisms. A particular emphasis is put on regions with a Higgs boson with a high transverse momentum. Among other aspects, the authors study the dependence on the jet radius, the influence of cuts on the Higgs-boson transverse momentum, the effects of vetoes. The second part is devoted to a more detailed study of the cone size in different phase-space regions. Finally, the last part provides a quick comparison of different theoretical predictions.

This manuscript contains a lot of interesting information that are relevant for present and future studies of VBF at the LHC. In particular, such theory inputs are particularly valuable for upcoming high-luminosity phases of the LHC. This means that the manuscript should eventually be published in JHEP. Nonetheless, the manuscript in its present form does not yet fulfil the JHEP standards for publication.

The main criticism is that the different parts of the document are rather unbalanced in their quality and quantity. In particular, part III is very long, hard to read, and it is not clear what the main findings are. It gives the impression that it is essentially a collection of results (some very interesting, some trivial) without a clear structure. In that regard, I would strongly encourage the authors to introduce subsections and highlight clearly what is new (and interesting in their view) and what is already known. This would help the reader to get a clear picture of the findings in this work as well as following the line of thoughts of the authors. On the other hand, section IV is much easier to follow. Finally, section V is very short and a bit superficial. In particular, the authors compare different predictions without really analysing the results and their potential implications. Also, insight on why some differences appear is lacking. In general, it should be made clearer what in the present manuscript is new and goes beyond current knowledge.

Below, I have listed further points that the author should take into account:

Everywhere

1. Several plots mention "Les Houches 2019". Does it mean that some of these results have been already presented in the report of Les Houches 2019? If yes, this should be made clearer (probably in the introduction).

Section I

1. While not completely overlapping with the present study, some interesting references are missing. For example, arXiv: 1802.09955 and 1805.04446 are complimentary to it and should be cited. In general, I would encourage the authors to present a more detailed review of the theoretical status of VBF at the LHC in the introduction.

Section II

1. It is correct that PDF4LHC15_30 NNLO is used for all predictions (even at NLO)? This should be made explicit.

2. The description of the Powheg predictions around Eq. (5) is a bit unclear and clarifications should be provided. In particular, it is not clear how this prediction differs from a complete NLO QCD+PS prediction. Does it differ by the virtual corrections to the decay only? If possible, an estimate of the approximation would be useful. Also, while Eq. (5) is correct when integrating over the whole phase space, it is not true in

the presence of cuts (especially close to resonances). Some comments on it would also be welcome.

Section III

1. "The gluon-gluon fusion contributions are shown in both the Higgs effective theory (HEFT) and approximate Standard Model, using the reweighting technique described in Sec. II A. " Sec. II A. is not really illuminating on what is actually done there. This should be defined a bit more precisely and in particular how the two predictions differ. Also, why are both computations for ggF not provided in Table 1 (as on Fig. 3) for example? Note that the labelling is not consistent between the plots and the table.

2. A particular emphasis is put on the distinctions between VBF production with respect to VH. Such a distinction is actually unphysical as both production mechanism are actually undistinguishable (as they interfere) and posses the same physics content. The authors should explain why they want to treat VH as a background as, a priori, no distinction is required.

3. In the footnote of page 2, it is indicated that ttH is not relevant for this study. On the other hand, it is shown on Fig.2 which is a bit contradictory. In particular, the implementation of cuts for ttH is not clear. From the caption, it is says "all hadronic", probably meaning a 4j+2j_b final state. In this case, how is implemented the event selection for this process? Are the bottom jets counted as jets? Also, more information on how this process is computed (given it is presented) should be given in the text (and not only in the caption).

4. How the EW corrections are implemented for each process is unclear. Some references are given in the caption of Fig. 2 but it would be more useful to have more details in the text instead.

5. Concerning Fig.2, the event selection should also be mentioned in the text (and not only in the caption).

6. On page 11, "The fractional cross section distributions for the Higgs boson production processes are shown in the top panel of Fig. 10 as a function of Δy_{jj} using the two leading jets (i.e. the ones with largest pT) for the three different Higgs boson pT cuts." I believe it should be $\Delta y_{jj}^{\min}$ according to what is shown on the plot. This should also be made clearer in the text.

7. Several times, the authors use the word "original" to describe a jet without defining it explicitely. From the context, one somehow understands that this is a "Born" jet but such a definition is highly ambiguous in particular at higher order. More information should be provided.

Section IV

1. This section focus on the study of jet-radius. To my knowledge, such a study has been performed for the first time in arXiv: 1703.05676 (which is not cited). The authors should include this reference and explain how their study goes beyond the known results.

2. "In a previous study, we [...]". I think that "some of us" would be more appropriate.

Section V

1. A table with the cross section should be added as it present more information (and therefore help reproducibility of the work presented). This information should be available to the authors without extra runs.

2. In arXiv: 1803.07943, a comparison of theoretical predictions for VBS is also performed. Given the similarities between VBF and VBS, it would be interesting to qualitatively compare the present findings with the ones presented there. In particular, it seems that the agreement between fixed-order predictions and parton-shower ones is better in VBF than in VBS. Also, the spread of NLO+PS predictions seems to be larger for VBS than for VBF. The authors should comment on this.

3. On the plots, the "Matching & PS scheme variation" band should also be provided on the inset showing the ratio to NNLO (for example in Fig. 21, it is not visible in the absolute plots).

4. In addition, the 7-scale variation should also be added on the same inset (probably for the NNLO predictions). It would put the differences observed in perspective.

5. One can see noticeable differences between the various NLO+PS predictions in essentially all the observables. The authors should comments on this and explain how these differences could be explained (if possible).

6. From this study and given that the predictions do not agree very well in some phase-space regions, what are the implications for experimental analysis? Should the experimental measurements should stay away from these regions? Or are these differences negligible given the experimental precision even at high-luminosity LHC?

7. The definition of d_{23} and d_{34} is not given anywhere. This should be corrected.

8. The "Matching & PS scheme variation" band seems to increase for more exclusive cuts (for example on Fig. 22). Is it true? If yes, the author should comment on it.

Section VI

1. "Precise theoretical predictions for both signal and background processes are of utmost importance in order to harness the full statistical power of LHC event samples and have therefore been computed up to N3LO accuracy." I believe that this statement is not correct as all processes meant here are not known up to N3LO (QCD) accuracy. This should be corrected.

2. "In this manuscript we have presented a detailed comparison of the two types of calculations, i.e. NLOPS and NNLO [..]." I think this is also not correct. To my view, Section V does not qualify (yet?) for a "detailed" study.

3. "This paper follows a study with a similar spirit carried out with dijet, Z-boson + jet and Higgs boson + jet production at the LHC." Please provide the references.