HXS4BSM: Proposal on how to provide reference "Higgs" cross sections for BSM applications in a wide mass range

Introduction

Historically, the LHC-HXSWG has provided accurate and precise predictions (and a very successful set of corresponding plots) for the SM Higgs production cross sections at the LHC energies for the main channels and in a wide range of masses. The main motivation was, of course, that the mass of the SM Higgs was unknown. After discovery of a resonance at 125 GeV, such predictions have been still widely used to exclude the existence of a "SM Higgs" at different mass, something certainly welcome and necessary given that the properties of the 125 GeV resonance was still rather uncertain. After the extremely successful campaign of measurements at 7/8 TeV, evidence has accumulated that the resonance at 125 GeV is the scalar predicted by the SM. Search of New Physics in the context of possible extensions/deviations in the scalar sector has therefore moved in two main directions: one is the precise determination of the strength and structure of the Higgs interactions, the other is the search for additional scalars.

In this context, it is therefore necessary to critically reconsider the meaning and the usefulness of having precise and accurate SM-like predictions for masses different from 125 GeV. After discussions with the ATLAS/CMS experimental community, a need for reference cross sections for Higgs production in a wide range of masses (lighter than the SM Higgs and up to several TeVs) has emerged. The main motivations that have been identified are:

- Such predictions can be used as reference values in designing analyses and in easily (yet reliably) estimating the sensitivity and reach of generic scalar searches.
- They provide a "natural" and easy-to-communicate unit of measure when talking about the production of New Physics scalars: Ex: "In this model and point in parameter space the light scalar has 30 times larger cross sections than that of a SM-like Higgs of the same mass".
- They can be directly and "easily" employed in a model independent-way, i.e. for models that be easily related to the SM by a rescaling of the couplings.
- Other…

The motivations for providing reference "SM-like" cross sections being established the discussion has moved to what would be the most robust and useful way of making such predictions available. For example, especially in the case of heavy scalars, concerns about the inclusion of the SM width (in whatever scheme) in the computation of cross sections has been raised. For example, for a SM Higgs over 1 TeV, such effects become dominant, the width dependence very large, making the corresponding predictions not directly employable in cases where the heavy scalars would be relatively narrow. For smaller masses, 500 GeV<mH<1 TeV, the width effects are typically larger than the precision expected from TH, calling into question the usefulness of having very accurate predictions in the first place. Another important point is that of EW corrections, which in general cannot be "rescaled" in any BSM scenario. Other important aspects, which are model-dependent (such as interference with the backgrounds or non-trivial dependence of the predictions from SM coupling rescaling), need also to be addressed.

Proposal

We propose to provide "Reference Higgs Cross sections at the LHC for BSM applications" for the 7 main production channels (ggF, VBF, WH, ZH, bbH, ttH, tHj) processes with the following characteristics:

- **Mass Range: [10 GeV, 3 TeV] .**

  More precisely (units in GeV):

  10-> 150 in step of 5 (note: lower mass limit might depend on stability of the code at low Bjorken x. To be assessed.)

  150 -> 500 in steps of 10

  500 -> 3000 in steps of 50

- **Energies: 7/8/13/14 TeV**

- **Higgs Width = 0 .**

In other words, we require cross sections to be calculated for Higgs exactly on shell, no decay or convolution with the line shape should be performed. On the other hand, it would be useful to also provide simple codes that can convolve the Gamma=0 results with a user-defined line shape and in this case give examples of applications.

- **Separate EW corrections.**

Predictions should be given at the best accuracy available in QCD for that channel. EW corrections should be quoted (when possible) separately.

- **For relevant processes, and if possible, the contributions proportional to different Higgs couplings should be given separately, together with the corresponding uncertainties.**

Example: in ggF and bbH, the yt^2, yt*yb, yb^2 contributions should be given as the sum of three terms.

- **All other external parameters should be chosen as in the corresponding best SM predictions as well as the evaluation of the uncertainties.**

PDF's, alphaS, SM parameters, should all match those of the reference SM cross sections and the uncertainties should be evaluated following the same recipes.

- **SM width: At each mass point, the corresponding Higgs widths calculated in the SM with the same characteristics above should be provided.**

A complementary table with the "would-be" width of a SM Higgs of the corresponding mass should be given in a similar form.

- **Examples on how to use these predictions in specific cases are provided.**

For example: the EW singlet case or the 2HDM. Particular attention should be given to how to include a line shape (explicit examples should be given with different widths and schemes), how to include interference with the SM backgrounds (for example gg>H>VV and gg>VV, gg>H>tt and gg>tt, and so on).