Minutes of the LHC HXSWG BSM meeting, Friday 22. 3. 2013

The main topic of this meeting was to discuss how ATLAS and CMS can explore the best way searches to the generic two Higgs doublet models (2HDM). As the parameter space is large, some simplifications/benchmarks are desirable.

ATLAS presented recently an analysis where a direct search for H is done, while all the other Higgs masses are assumed to be large. The free parameters remain: mH, tan β, α. Exclusion limits were presented on the mH – cos α plane for given tan β assuming type I or type II 2HDM with the condition that the lightest CP-even Higgs boson is identified with the boson at ~125 GeV. For this analysis, the SM Higgs MCs were rescaled with 2HDM couplings (see below for the description of the tools). In this approach one needs to be careful how the SM kinematics gets modified, especially from the bbH contribution. This is more of an issue at high tan β, the ATLAS analysis applied b-tag veto to minimise this problem. In general, a more quantitative assessment of possible biases could be done with an MSSM bbH MC sample. Top and bottom loop contributions can affect the HpT as well, though this should be a smaller effect, it would be nice to estimate this in the future. Currently, the H width is taken in the narrow width approximation. Since the h@125 GeV couplings to the W/Z are SM-like, the H width should be small, however it can be broadened above 250 GeV by H→hh (needs to be quantified).

Further constraints on the 2HDM parameter space could be set by taking into account the diphoton decay rate of the observed boson at ~125 GeV.

The main available tools for a search of H in the 2HDM scenario are SusHi and 2HDMC.

2HDMC [CPC **181** (2010) 189] is a general-purpose calculator for the two-Higgs doublet model and can be used to calculate all 2HDM BRs and width for any parameter at tree level for the CP-conserving scenario. Off-shell effects (e.g. h(125)→ZZ→4l, H±→tb) are not yet fully included in the program, however this is being implemented.

SusHi [CPC **184** (2013) 1605] is a program for the calculation of Higgs production in gluon fusion and bottom-quark annihilation in the MSSM (and SM). If the squark and gluino couplings are switched off, SusHi can be used to calculate general 2HDM cross sections. The program provides exact NLO QCD corrections and NNLO QCD corrections in the heavy top quark limit which are valid for mH < 2 mt. EW corrections are not applicable in the 2HDM scenario and have to be turned off.

The VBF and VH productions in the 2HDM can be estimated with the VBF@NNLO and VH@NNLO programs running at the NLO level and then rescale the cross section using the 2HDMC program.

Full higher-order **EW corrections** are not available in the 2HDM for any of these production modes. For now, the recommendation is to use only an uncertainty for the missing EW corrections. For the gluon-fusion production this could be the EW contribution from the light-quarks only which can be calculated with SusHi. For the other production modes the uncertainty can be taken as the magnitude of the SM EW corrections (until a better recommendation is found).

Further suggestions of **2HDM benchmark choices**: take mh~125 GeV as an input and scan over values of |cos (α-β)| vs tan β for benchmark choices of λ, λA and λF (linear

combinations of the Higgs self-couplings). While |cos (α-β)| should range from 0 to 0.5 (corresponding to a very rough SM-like h), tan β could be taken as 0.5 < tan β < 50. An alternative would be a 3 parameter scan over cos (α-β)|, tan β and mH and choose benchmark values for λA and λF. Different parameterisations can be mapped to each other with the 2HDMC code.

There was a short discussion on the null hypothesis for the experimental searches. The overall agreement was that for the moment this could be the SM, while the 2HDM scenario is the test hypothesis.

ToDo items for the nearer future:

- *Extend consideration to type III/IV benchmark models and charged Higgs searches, as well as to the scenario where the boson at 125 GeV is the heavier Higgs H*
- *Provide cross section / BR tables linked from the LHC HXSWG (Nikos Rompotis started to work on this already)*
- *Could ask the authors of VBF@NNLO and VH@NNLO to include the 2HDM couplings in a more formal way*
- *Discuss further the best way how to implement or access the uncertainties due to the missing higher-order EW corrections*
- *Quantify width effects at higher masses due to H→hh decays*
- *Quantify kinematic biases compared to the SM expectation in different regions of the parameter space*
- *Consider the contributions of additional new degrees of freedom (scalars, fermions, vectors) to the H production*