Higgs production cross sections across a wide range of masses: use cases and plans

A cross-group discussion

The 17th Workshop of the LHC Higgs Working Group,
Online only, 9-11 November 2020

HXS4BSM: "Higgs" cross sections for BSM applications

https://twiki.cern.ch/twiki/bin/view/LHCPhysics/LHCHXSWG#BSM_Higgs

BSM Higgs

- Recommended values on SM-like Higgs XS for ggF, VBF, WH, ZH, ttH bbH and tH at 7 TeV (CERN Report 4)
- Recommended values on SM-like Higgs XS for ggF, VBF, WH, ZH, ttH bbH and tH at 8 TeV (CERN Report 4)
- Recommended values on SM-like Higgs XS for ggF, VBF, WH, ZH, ttH bbH and tH at 13 TeV (CERN Report 4)
- Recommended values on SM-like Higgs XS for ggF, VBF, WH, ZH, ttH bbH and tH at 14 TeV (CERN Report 4)

- MSSM neutral Higgs: XS scans of the m_A-tanβ plane

"SM-like" cross-section predictions for a scalar with mass varying between 10 GeV and 2-5 TeV

BUT… we already have a SM-like Higgs with M_H=125 GeV,
an additional scalar is not going to have SM-like couplings!

What are these numbers for?

The HXS4BSM manifesto (November 2015):

https://twiki.cern.ch/twiki/pub/LHCPhysics/LHCHXSWGCrossSectionsCalc/HXS4BSM_v0.5.pdf

- 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 [can] be easily related to the SM by a rescaling of the couplings.

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The proposal (November 2015):

- Full mass scan should be provided for major Higgs production processes:

  1. Major process: ggF, VBF, WH (also separate W^+H and W^-H), ZH (also $gg \to ZH$)
  2. Associated Higgs with heavy quark: ttH, bbH
  3. Associated Higgs with single top-quark: tH ($bq \to tHq'$, $bg \to WtH$, $qq \to btH$)

- Higgs width should be set to zero (NWA).
- Separate electroweak correction should be provided.
- For relevant processes, and if possible, the contributions proportional to different Higgs couplings should be given separately, together with the corresponding uncertainties.
- All other external parameters should be chosen as in the corresponding best SM predictions as well as the evaluation of the uncertainties.
- SM width: At each mass point, the corresponding Higgs widths calculated in the SM with the same characteristics above should be provided.
- Examples on how to use these predictions in specific cases are provided.

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The large width of a heavy SM Higgs is due to its coupling to gauge bosons; an additional scalar would not be SM-like

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E.g., in a THDM top & bottom contributions to gluon fusion are rescaled differently

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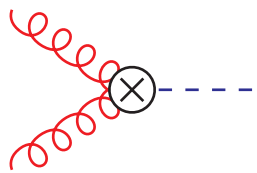
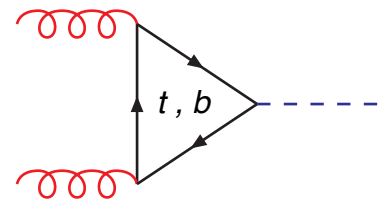
Two sets of numbers for gluon fusion [NOTE: only for 13 TeV]

“Point-like”



NNNLO QCD

“Quark-loop induced”



NLO QCD (top+bottom)
NNLO + NNLL QCD (heavy-top limit)
NLO EW correction

	Point-like effective					Quark-loop induced						
m_S or m_H (GeV)	Cross Section (pb)	+Theory %	-Theory %	TH Gaussian %	±(PDF+α_s) %	Cross Section (pb)	+QCD Scale %	-QCD Scale %	±(PDF+α_s) %	±PDF %	±α_s %	1+δ_{EW}
10.00	1.900E+03	+17.8	-21.3	±12.3	±12.2	6.996E+03	+49.9	-38.9	±8.0	±7.5	±2.7	0
15.00	1.203E+03	+11.6	-15.0	±8.7	±6.7	4.275E+03	+34.8	-29.2	±5.9	±5.1	±2.9	0
20.00	8.458E+02	+8.8	-11.8	±6.8	±5.4	2.085E+03	+25.7	-22.5	±4.8	±3.7	±3.0	0
25.00	6.322E+02	+7.1	-10.0	±5.8	±4.9	1.146E+03	+20.8	-18.2	±4.3	±3.1	±3.0	0
30.00	4.923E+02	+6.1	-8.8	±5.1	±4.6	7.103E+02	+18.5	-15.6	±4.2	±2.8	±3.1	0
35.00	3.949E+02	+5.5	-7.8	±4.5	±4.3	4.846E+02	+16.3	-13.9	±4.0	±2.6	±3.1	0
40.00	3.240E+02	+4.8	-7.3	±4.2	±4.2	3.555E+02	+14.8	-12.9	±3.9	±2.4	±3.1	0
45.00	2.706E+02	+4.3	-6.7	±3.9	±4.0	2.751E+02	+13.5	-12.1	±3.8	±2.3	±3.0	0
50.00	2.294E+02	+3.7	-6.0	±3.5	±4.0	2.214E+02	+12.5	-11.6	±3.7	±2.2	±3.0	0
55.00	1.968E+02	+3.5	-5.7	±3.3	±3.8	1.835E+02	+11.7	-11.1	±3.7	±2.2	±2.9	0
60.00	1.706E+02	+3.2	-5.4	±3.1	±3.7	1.555E+02	+11.1	-10.7	±3.6	±2.1	±2.9	0
65.00	1.492E+02	+3.1	-5.2	±3.0	±3.7	1.341E+02	+10.5	-10.3	±3.5	±2.1	±2.9	0

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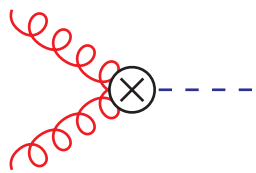

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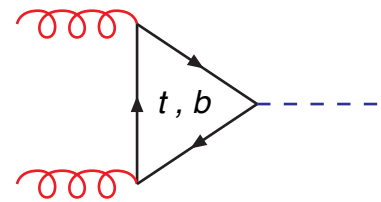

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NLO EW correction

m_S or m_H (GeV)	Cross Section (pb)
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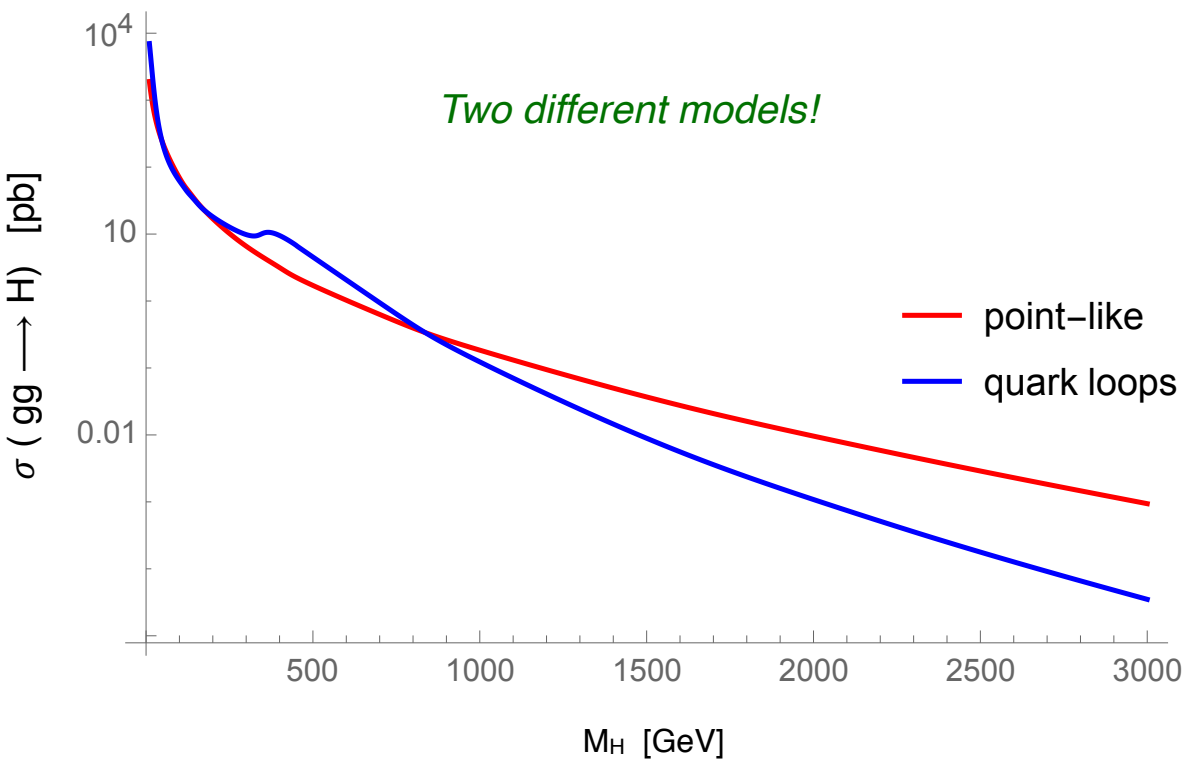
40.00	3.240E+02
45.00	2.706E+02
50.00	2.294E+02
55.00	1.968E+02
60.00	1.706E+02
65.00	1.492E+02



PDF+α_s) %	±PDF %	±α_s %	1+δ_{EW}
±8.0	±7.5	±2.7	0
±5.9	±5.1	±2.9	0
±4.8	±3.7	±3.0	0
±4.3	±3.1	±3.0	0
±4.2	±2.8	±3.1	0
±4.0	±2.6	±3.1	0
±3.9	±2.4	±3.1	0
±3.8	±2.3	±3.0	0
±3.7	±2.2	±3.0	0
±3.7	±2.2	±2.9	0
±3.6	±2.1	±2.9	0
±3.5	±2.1	±2.9	0

Open for discussion

- These results are five years old. Can/should they be updated to state of the art? Also, some of the tables stop at $M_H = 2$ TeV and might need to be extended.

- Is there a more-convenient way to provide these results? (e.g., K-factors)

- Which set of gluon-fusion numbers should be used in each analysis?
  NOTE: this exemplifies how the assumptions on the underlying UV model can have a larger impact on the prediction than the inclusion of additional corrections

- Should these numbers be used also in the interpretation of searches for BSM decays of the 125-GeV Higgs? Or should one use the state-of-the-art results? Small differences arise due e.g. to NWA approximation. Are they relevant? [recent example: a Higgs produced in VBF and decaying to gamma+invisible]

- Is there coordination on these issues between (and within) the collaborations?