Report from H→ WW* → lνlν Subgroup

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on Behalf of H→ WW* → lνlν Group
at BNL Higgs XS May 4-6 Workshop

Common Cuts

https://twiki.cern.ch/twiki/bin/view/LHCPhysics/WW

Common Cuts have been modified slightly to include JET:

1) ptl1/l2 > 20, |etal1/l2|<2.5
2) MET > 30
3) mll>12
4) pt_jet_max < 30 for |eta|<3 with Anti KT jet of cone size 0.5

Analysis Needs & Discussions

Typical data analysis:

a) **MC samples**
   - **Pre-selection efficiency if pre-selections are applied**
   - **Total Cross-section and its uncertainty from a MC sample, which should be common for all experiments**

b) **Cuts**
   a) **Acceptances, data analysis and experiment dependent**
   b) **Uncertainties of acceptance (common errors and un-correlated errors, need to separate them to combine results from different experiments)**

Discussions: few discussions and workings are going on, Frank Krauss on Higgs differential Cross-sections and H→WW* subgroup about acceptance uncertainties

Approach 1

https://indico.cern.ch/conferenceDisplay.py?confId=135791

Study Higgs → WW*/ZZ* differential cross-sections with cuts

a) **Comparison at/with fixed order (ME level):**
   - PDFs (CTEQ6 and MRST2008 NLO and NNLO)
   - Scales
   - MC models (POWHEG-Box, Sherpa, Herwig++, NNLO+Resummation)
   - cuts

b) **Comparison after showing**
   - Including MC@NLO (+Herwig)
   - α_s effects

c) **Underlying events**

d) **Question: how about pileup effects?**

Useful from theoretical point view, not clear how to use them in data analysis (most likely cuts will not be same as data analysis. More details and studies see Thur. session

Approach 2 for H→ WW* → lvlv

- Total cross-section and its uncertainty from LHC Higgs Cross-section yellow book
- Common Guide on Acceptance Uncertainties for experiments and Study Common Errors from:
  - PDFs, scale and α_s
  - Common cuts, such as jet veto
  - MC models
  - Underline events and pileup, may need detector related event generation or full simulation

Similar studies need to be done from data analysis group on effects from cuts, underline and pileup events

A Proposal

Experiments are sensitive to cross sections within detector acceptance:

$$\sigma_{\text{vis}} = \sigma_{\text{tot}} \times A \times f$$

- Take the total cross sections and their uncertainties from the CERN Yellow Report;
- Estimate acceptance (except that on jet veto/bin) uncertainties from scale, PDF+as, … using appropriate MC programs, and assume they are independent;
- Estimate jet veto/bin (scale) uncertainties separately and take into account potential correlations with those on the total cross sections

  For gg→H, f_0 is largely anti-correlated, f_1 and f_2 are largely correlated with the total cross section

- Take differences between NLO MC generators as a systematic

F0, f1 and f2 are fraction of 0, 1 and 2 jets

ggF H Cross-sections & Errors

https://twiki.cern.ch/twiki/bin/view/LHCPhysics/CERNYellowReportPageAt7TeV

m_H (GeV)	Cross Section (pb)	+error %	- error %	+scale %	-scale %	+(PDF+α_s) %	-(PDF+α_s) %
90	29.47	22.9	-15.6	14.8	-8.7	8.1	-6.9
95	26.58	21.9	-15.9	13.9	-9.0	8.0	-6.9
100	24.02	21.2	-15.6	13.3	-8.6	7.9	-7.0
105	21.78	20.8	-15.5	12.8	-8.5	7.9	-7.1
110	19.84	20.4	-15.3	12.5	-8.2	7.9	-7.1
115	18.13	20.0	-15.3	12.1	-8.1	7.9	-7.2
120	16.63	19.7	-15.1	11.9	-7.9	7.8	-7.2
125	15.31	19.5	-15.1	11.7	-7.8	7.8	-7.3
130	14.12	19.2	-15.1	11.3	-7.7	7.8	-7.4
135	13.08	18.9	-15.0	11.1	-7.6	7.8	-7.5
140	12.13	18.8	-14.9	11.0	-7.4	7.8	-7.5
145	11.27	18.7	-14.9	10.9	-7.4	7.8	-7.6
150	10.50	18.7	-14.9	10.9	-7.2	7.8	-7.7
155	9.795	18.5	-15.0	10.8	-7.3	7.7	-7.7
160	9.080	18.6	-15.0	10.9	-7.2	7.7	-7.8
165	8.319	18.1	-14.7	10.4	-6.9	7.7	-7.9
170	7.729	17.9	-14.9	10.2	-7.0	7.7	-8.0
175	7.211	17.9	-14.8	10.2	-6.8	7.7	-8.0

Questions:
For H→ WW → lvlv do we need to add additional systematic errors from H→ WW* branching ratio and W→lv branching ratio?

Scale and PDF Uncertainties

Relative change in the 0-jet fraction:

- **QCD scale: ~5% (pT>30 GeV)**

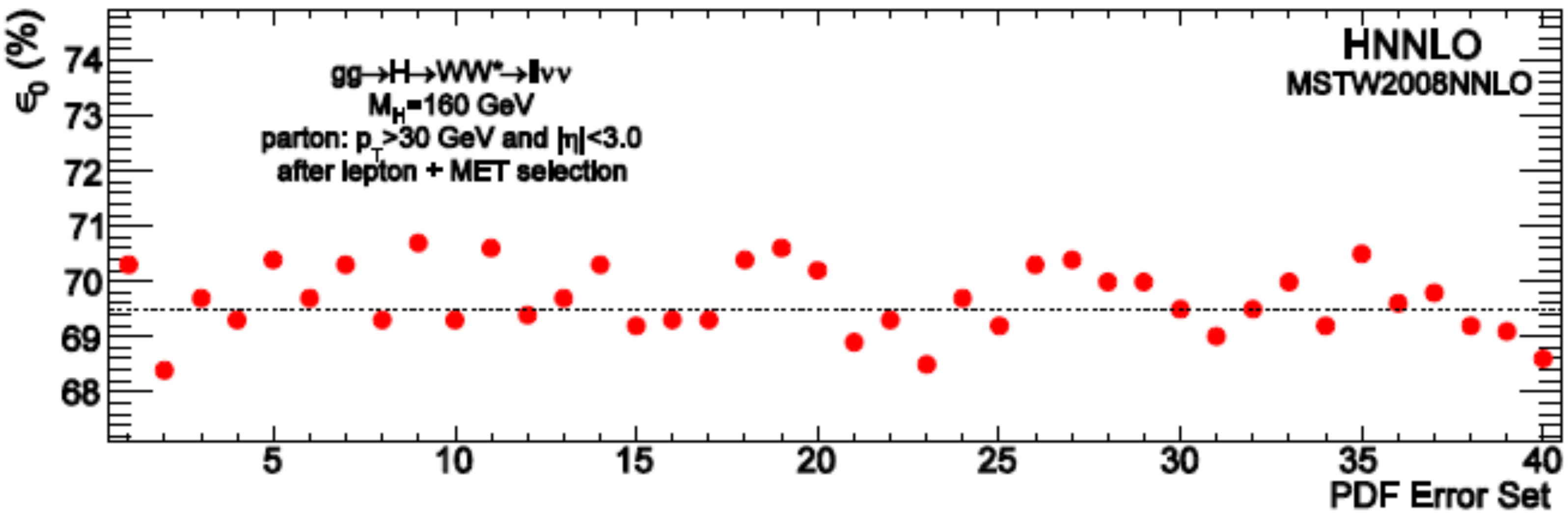
  from μ_F and μ_R variations by x2 around their central value M_H

- **PDF: ~3%**

  from 40 MSTW2008 90%CL error sets following $\Delta\varepsilon = \frac{1}{2}\sqrt{\sum_{i=1}^{20}\left(\varepsilon_i^+ - \varepsilon_i^-\right)^2}$

Scale variations

μ_F/M_H	μ_R/M_H	ϵ_0 (%)
0.5	0.5	66.2
0.5	1.0	68.2
0.5	2.0	70.9
1.0	0.5	66.8
1.0	1.0	69.5
1.0	2.0	72.1
2.0	0.5	67.2
2.0	1.0	69.4
2.0	2.0	72.6



Uncertainties Continued...

- α_S: ~2% variation

  from ±90% CL α_S MSTW2008 fits

- For the joint ATLAS/CMS selection, the combined scale, PDF and as uncertainties are:

  0-jet fraction: ~6%

  1-jet fraction: ~7%

  2-jet fraction: ~35%

- For ATLAS selection (pT>20 GeV and $|\eta|<4.5$), the combined uncertainties are

  0-jet fraction: ~10%

  1-jet fraction: ~6%

  2-jet fraction: ~35%

Strong anti-correlations between 0- and 2-jet fractions

ggF Jet Bin Correlation

Basic parton level selection using HNNLO

Two leptons with pT>20 GeV and |η|<2.5;
MissingEt > 30 GeV (pT of the two neutrino system);
Event veto if jets with pT>30 GeV and |η|<3.0

	$(\mu_F/m_H,\ \mu_R/m_H)$								
	(0.5, 0.5)	(0.5, 1.0)	(0.5, 2.0)	(1.0, 0.5)	(1.0, 1.0)	(1.0, 2.0)	(2.0, 0.5)	(2.0, 1.0)	(2.0, 2.0)
	Cross sections in 0, 1 and 2-jet bin								
σ_0	30.1	28.5	26.6	30.1	28.6	26.8	30.3	28.6	27.0
σ_1	11.5	10.2	8.86	11.6	10.2	8.77	11.7	10.1	8.60
σ_2	3.95	2.64	1.84	3.57	2.39	1.66	3.24	2.17	1.51
	Fractions in 0, 1 and 2-jet bin								
f_0	66.1	68.9	71.4	66.5	69.5	72.0	67.0	70.0	72.8
f_1	25.2	24.7	23.7	25.6	24.7	23.6	25.9	24.7	23.2
f_2	8.69	6.40	4.92	7.88	5.80	4.45	7.17	5.31	4.06

f_j correlation matrix

$$\begin{pmatrix} 1.00 & -0.95 & -0.98 \\ -0.95 & 1.00 & 0.88 \\ -0.98 & 0.88 & 1.00 \end{pmatrix}$$

σ_{tot} and f_j correlation:

0-jet=-0.99, 1-jet=0.96, 2-jet=0.95

Higgs $q_T(p_T)$ reweighting

- The QCD correction of the $gg \to H$ process is up to NLL(Resummation)+NLO(Fixed order) for both McAtNLO(+Herwig) and PowHeg(+Pythia) generators.
- The HqT program provides Higgs p_T distributions up to NNLL+NNLO.

  http://theory.fi.infn.it/grazzini/codes.html
- We are using HqT to reweight Higgs p_T distributions from NLL+NLO to NNLL+NNLO.
- Since the transverse momentum(q_T or p_T) of the Higgs is related to the jet activity. Reweighting the Higgs p_T will change jet multiplicities.
- Three mass points ($m_H = 130, 160, 400$ GeV) are studied in this talk for comparisons between McAtNlo and PowHeg.
- All studies are based on the parton level truth information without QED radiation corrections for leptons.

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https://indico.cern.ch/getFile.py/access?contribId=0&resId=0&materialId=slides&confId=135791

Impact on the acceptance

- Study the impact of the Higgs p_T reweighting on the acceptance
- The acceptance requirement consists of several cuts sequentially applied on kinematics of leptons, E_T^{miss} and the jet multiplicity.
  - $p_T^{\ell,1} > 20$ GeV , $p_T^{\ell,2} > 15$ GeV and $|\eta^{\ell}| < 2.5$
  - $E_T^{miss} > 30$ GeV
  - 0, 1 and 2 Jets with $p_T^{jet} > 25$ GeV and $|\eta^{jet}| < 4.5$

Cut Acc. Eff.	McAtNlo m_H = 130 GeV w.o RWT	McAtNlo m_H = 130 GeV with RWT	McAtNlo m_H = 130 GeV diff.(%)	PowHeg m_H = 130 GeV w.o RWT	PowHeg m_H = 130 GeV with RWT	PowHeg m_H = 130 GeV diff.(%)	McAtNlo m_H = 160 GeV w.o RWT	McAtNlo m_H = 160 GeV with RWT	McAtNlo m_H = 160 GeV diff.(%)	PowHeg m_H = 160 GeV w.o RWT	PowHeg m_H = 160 GeV with RWT	PowHeg m_H = 160 GeV diff.(%)
Lepton cut	0.484	0.482	-0.30	0.522	0.509	-2.50	0.714	0.714	-0.11	0.741	0.738	-0.45
E_T^{miss} cut	0.387	0.385	-0.33	0.414	0.405	-2.07	0.634	0.634	-0.08	0.657	0.656	-0.11
Zero Jet	0.246	0.251	2.22	0.216	0.253	17.14	0.371	0.382	2.82	0.326	0.380	16.59
One Jet	0.106	0.103	-3.24	0.134	0.115	-13.85	0.197	0.191	-3.03	0.220	0.202	-8.21
Two Jet	0.027	0.025	-5.99	0.045	0.029	-35.95	0.052	0.049	-5.20	0.079	0.057	-28.43

- The reweighting changes the zero jet acceptance by 2-3% for McAtNlo and 17% for PowHeg with
- The major correction is on the jet multiplicity, as it is highly related to the Higgs p_T
- After the Higgs p_T reweighting, the McAtNlo and PowHeg acceptance agrees well!

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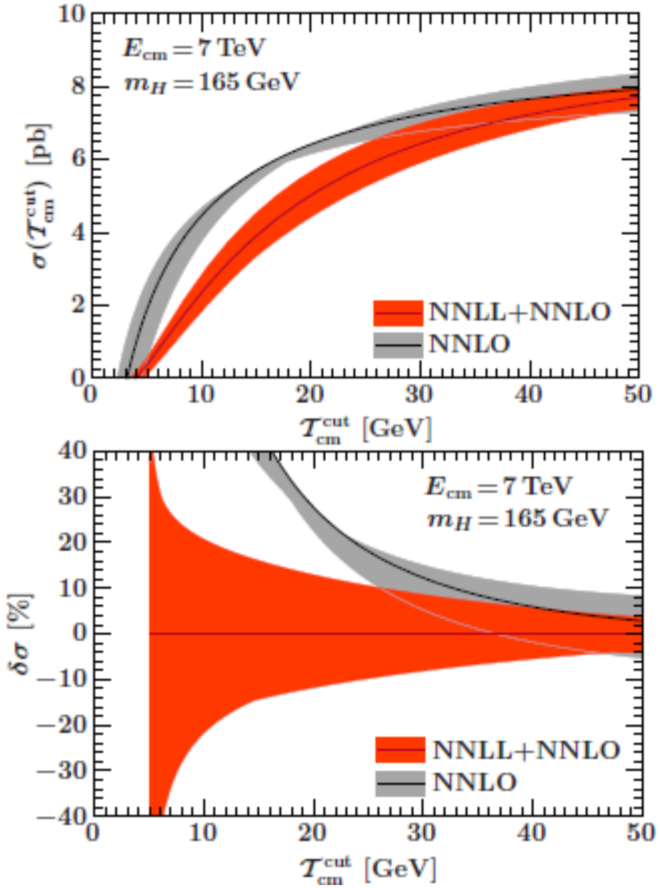
Few Outstanding Issues

Jet Veto

https://indico.cern.ch/conferenceDisplay.py?confId=128018

Higgs Production with a Jet Veto at NNLL+NNLO by Frank Tackmann (MIT) https://indico.cern.ch/getFile.py/access?contribId=0&resId=0&materialId=slides&confId=128018

Results at Small $\mathcal{T}_{\rm cm}^{\rm cut}$ (0-Jet Region)

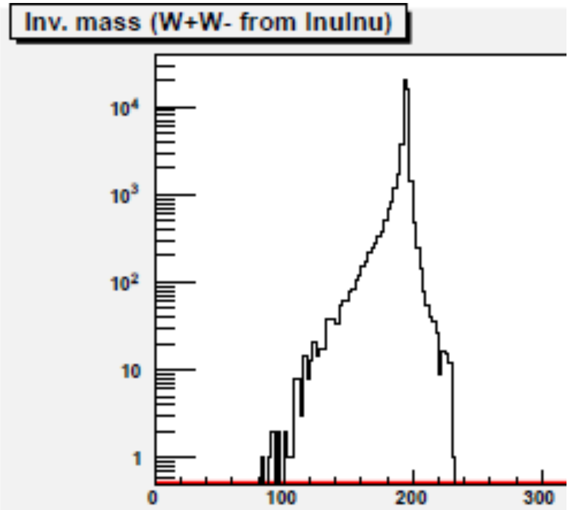


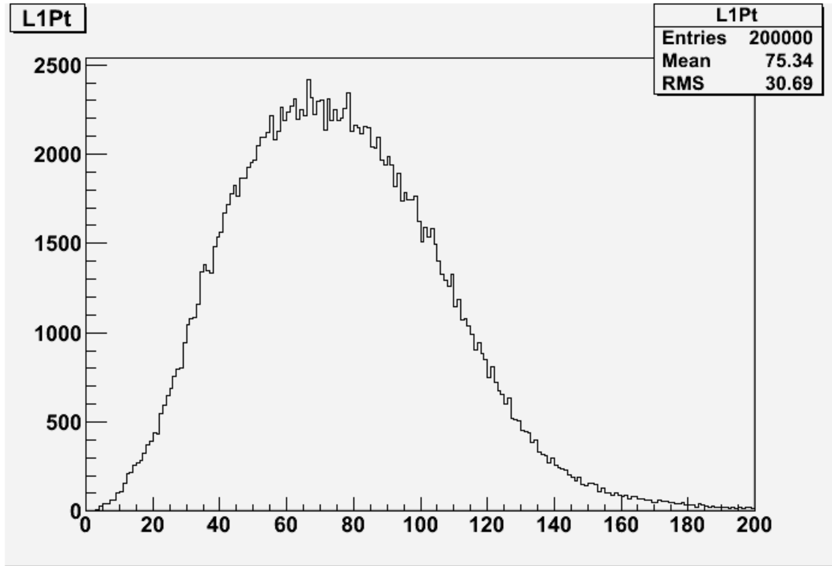
Compare NNLL+NNLO to NNLO only

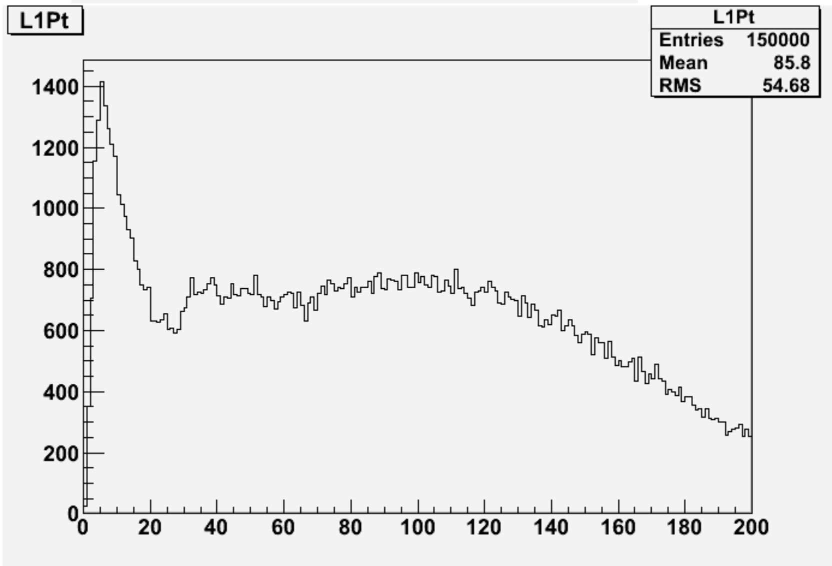
- NNLO alone is not reliable for small $\mathcal{T}_{\rm cm}^{\rm cut}$
- Jet-veto logarithms are important: Central value including NNLL lower than NNLO (partly accounted for by parton shower)
- Scale uncertainty at NNLL+NNLO is $10 - 20\%$

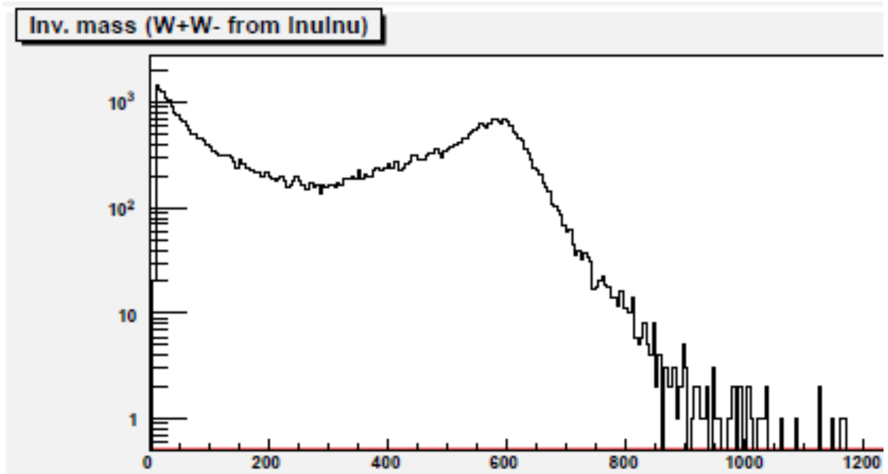
From Hao's studies by reweighting, the NNLL effects on MC@NLO are small on jet veto, around 17% for POWHEG. Here the effects are hugh at low beam thrust. Final conclusion is necessary

Fixed Higgs Width on MC@NLO



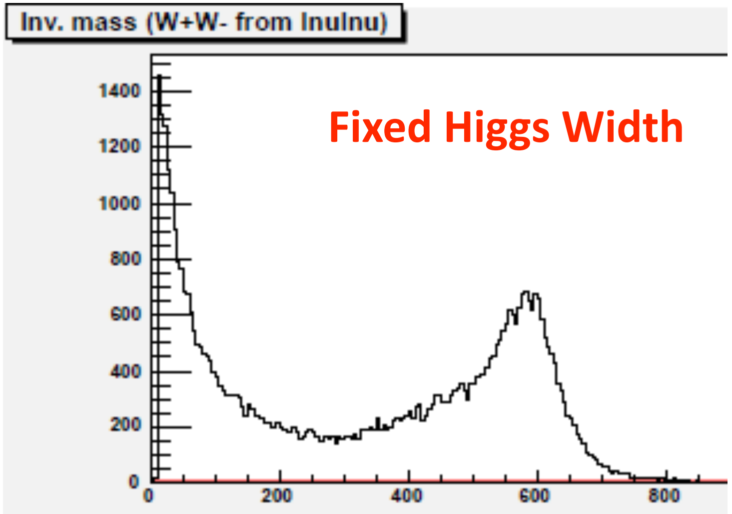


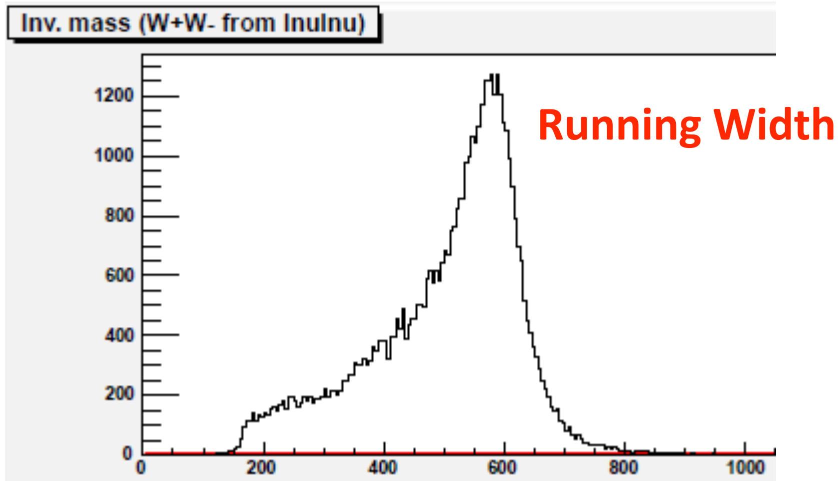




Abnormal Higgs Mass and lepton Pt show up for Higgs > 300GeV
The higgs-mass distribution in standalone Herwig is (fastly) going to zero when the higgs mass approaches zero due to the use of the "running" width

Introduce Running Width by Stefano





The Higgs mass distribution is reasonable, but the total cross-section reduced a lot!

600GeV Higgs cross-sections:
XS (pb-1) with running Higgs width : 0.1215
XS(pb-1) with fixed Higgs width : 0.1948
XS(pb-1) LHC Higgs-XS book : 0.1827

with H -> WW branching ratio 0.558 from LHC Higgs-XS yellow book

Comments by Stefano Frixione

You cannot compare the running with the fixed-width scenario. If you remember the distribution in M_H with a fixed width, there was a steep rise at low M_H, whose contribution to the total rate is not negligible. It's not correct to multiply a total rate
obtained with a fixed width times BR(H->WW): what you have used is a constant, and therefore you completely miss the fact that at low M_H there must not be any contribution to the WW channel. This is the reason why the implementation of the running width includes automatically the branching ratios: the latter must *NOT* be considered a constant, but a function of the M_H mass.

In other words, you have two options:
1. You are interested in the total rate. You run with a fixed width.
2. You are interested in a specific channel (eg WW); you run with a running width.

For high mass Higgs cross-section, debating is still going on from theoretical point view