

Theoretical description of Higgs production and decay

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Introduction

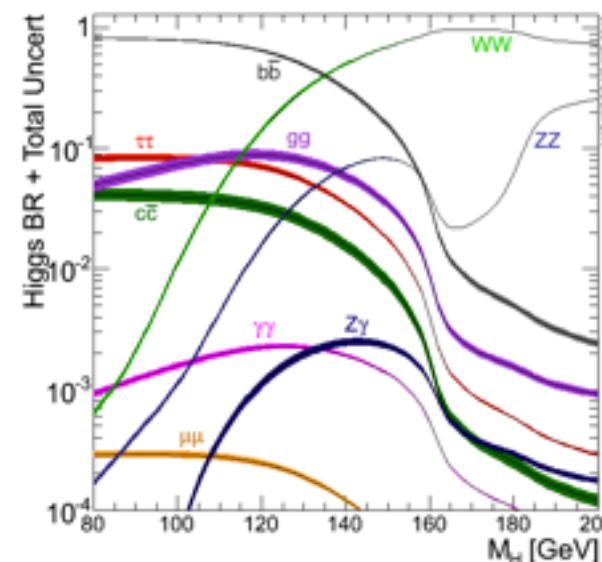
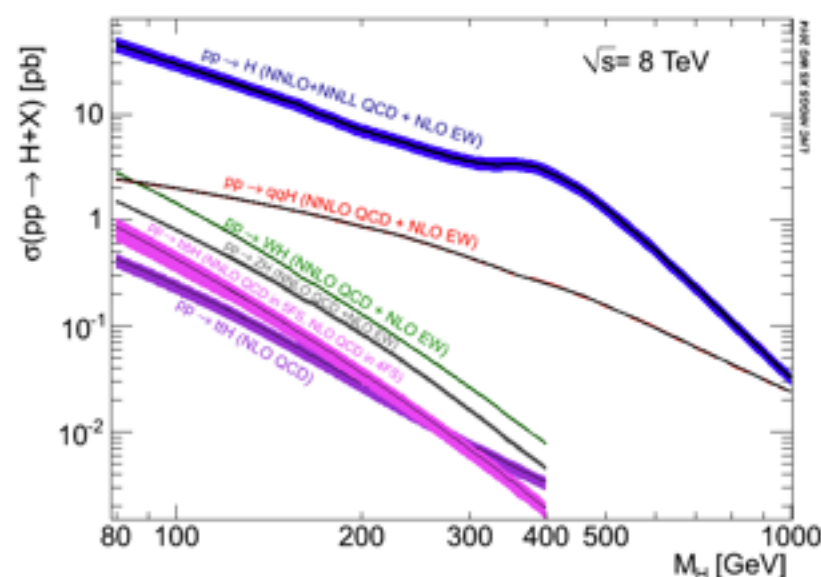
The number of Higgs-related events is given by the product of the Higgs boson production cross section in a particular channel and the Higgs boson decay rate to a particular final state.

$$N_Y \sim \sum_X \sigma^X(pp \rightarrow H) \text{Br}(H \rightarrow Y)$$

The production is dominated by the gluon fusion; weak boson fusion comes distant second; we will focus on those channels in what follows.

Decays of the Higgs boson are understood very well for all practical (LHC) purposes. The total width is dominated by Higgs decays to b quark pairs. This partial decay rate is known through four loops in QCD (residual scale uncertainty is less than a percent) and the uncertainty related to the input value of the b-quark mass is small.

Other channels either do not carry significant QCD uncertainties at the first place ($H \rightarrow VV$) or QCD effects are very well known ($H \rightarrow gg$, $H \rightarrow \gamma\gamma$). One loop electroweak corrections are known to all major decay channels.



$$\Gamma_H \sim \Gamma(H \rightarrow b\bar{b})$$

$$\Gamma(H \rightarrow b\bar{b}) \sim m_b^2$$

$$m_b = (4.18 \pm 0.03) \text{ GeV}$$

$$\Delta\Gamma_H/\Gamma_H \sim \mathcal{O}(1.4\%)$$

Perhaps a rather conservative uncertainty estimate.

Framework

To obtain high-precision predictions for Higgs boson production at colliders, we use the general QCD factorization framework, [studied and verified](#) at the Tevatron and the Run I LHC.

$$d\sigma = \int dx_1 dx_2 f_i(x_1) f_j(x_2) d\sigma_{ij}(x_1, x_2) F_J (1 + \mathcal{O}(\Lambda_{\text{QCD}}/Q))$$

Until very recently, [theory uncertainties on partonic cross sections and parton luminosity were close to 10 percent each](#). The [non-perturbative corrections](#) are expected to be just a few percent for the Higgs-related observables [but we do not have detailed understanding of these effects](#).

The major focus now is on improving perturbative predictions for partonic cross sections and on having trustworthy parton distribution functions.

[Perturbative description of partonic cross sections](#) is an important and (very) active field of research. The level of sophistication that has been reached in connection with the description of Higgs-related processes at the LHC is without a precedent. Indeed,

- 1) [all major Higgs production and decay channels are currently known through \(at least\) NLO QCD \(many through NNLO\), and through NLO electroweak.](#)
- 2) [Many associated Higgs production processes with high jet multiplicity are also known at least through NLO QCD.](#)
- 3) [Matching/merging of NLO QCD \(and NNLO QCD for simple cases\) results with parton showers is available thanks to MC@NLO, Powheg, Sherpa etc..](#)

Outline

Although NLO QCD computations for high-multiplicity processes, as well as matching and merging are very important topics, they are also relatively well-established by now. I'll not talk about them here.

Instead, I want to spend most of my time talking about three recent results that may have a potential to significantly affect the way we think about the possibility to do precision Higgs physics at hadron colliders. They include:

1) the N^3 LO QCD calculation of the inclusive Higgs boson production in gluon fusion;

Anastasiou, Duhr, Dulat, Furlan, Herzog, Mistlberger etc.

2) the NNLO QCD calculation of the fiducial cross sections for the production of a Higgs boson and a jet at the LHC;

Boughezal, Caola, K.M., Petriello, Schulze

Boughezal, Focke, Giele, Liu, Petriello

Chen, Gehrmann, Glover, Jacqueir

3) the NNLO QCD calculation of the fiducial cross section for Higgs production in weak boson fusion at the LHC.

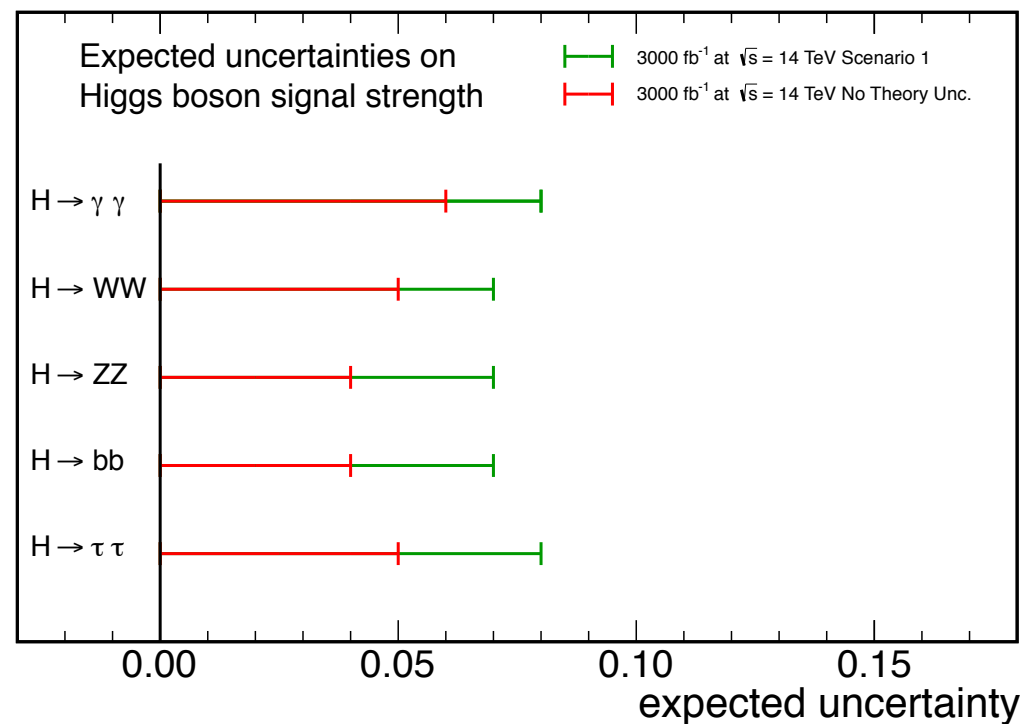
Cacciari, Dreyer, Kalberg, Salam, Zanderighi

I have chosen these results since they give us a new perspective on the ultimate precision achievable on the theory side in the exploration of Higgs boson physics at the LHC. Another important lesson that these results seem to teach us is that -- beyond a certain level -- fixed order results are indispensable and can not be substituted by their approximate estimates, including the resummations.

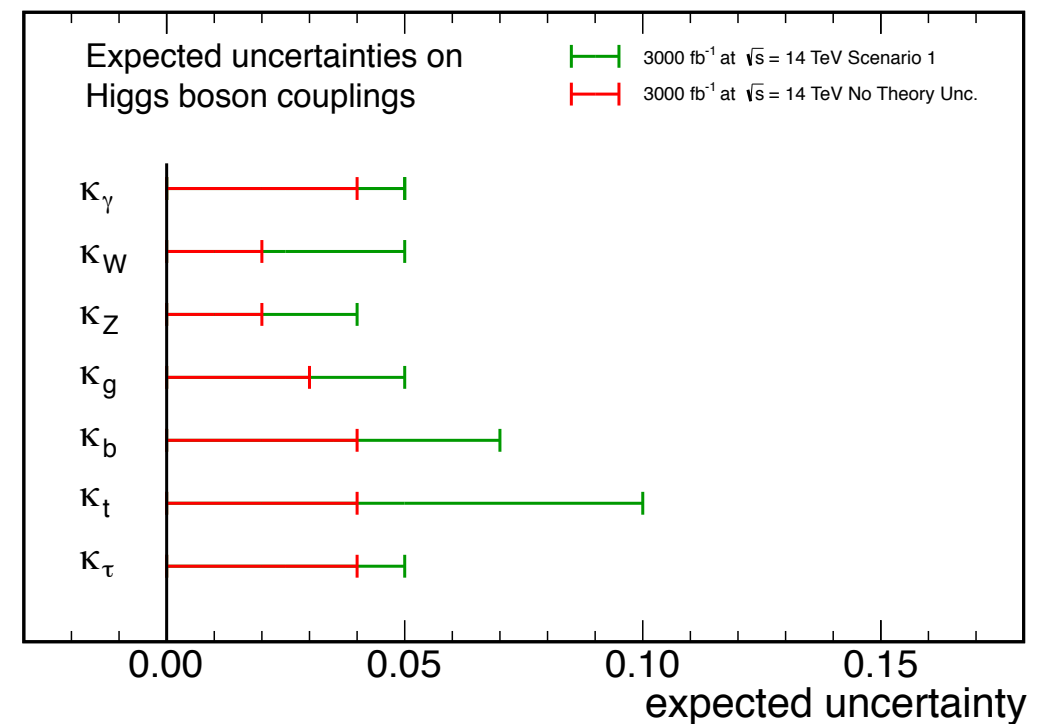
Theoretical precision and 3000/fb expectations

H+0 jet	N ³ LO	O(3-5 %)	10 pb	fully inclusive
H+1 jet	N ² LO	O(7%)	7 pb	fully exclusive; Higgs decays, infinite mass limit
H+2 jet	NLO	O(20%)	1.5 pb	matched/merged
H+3 jet	NLO	O(20%)	0.4 pb	matched/merged/almost
WBF	N ² LO	O(1%)	1.5 pb	exclusive, no VBF cuts
WBF	N ² LO	O(5%)	0.2 pb	exclusive, VBF cuts
ZH, WH	N ² LO	O(2-3%)	O(1) pb	decays to bottom quarks
ttH	NLO	O(5%)	0.2pb	decays, off-shell effects

CMS Projection



CMS Projection

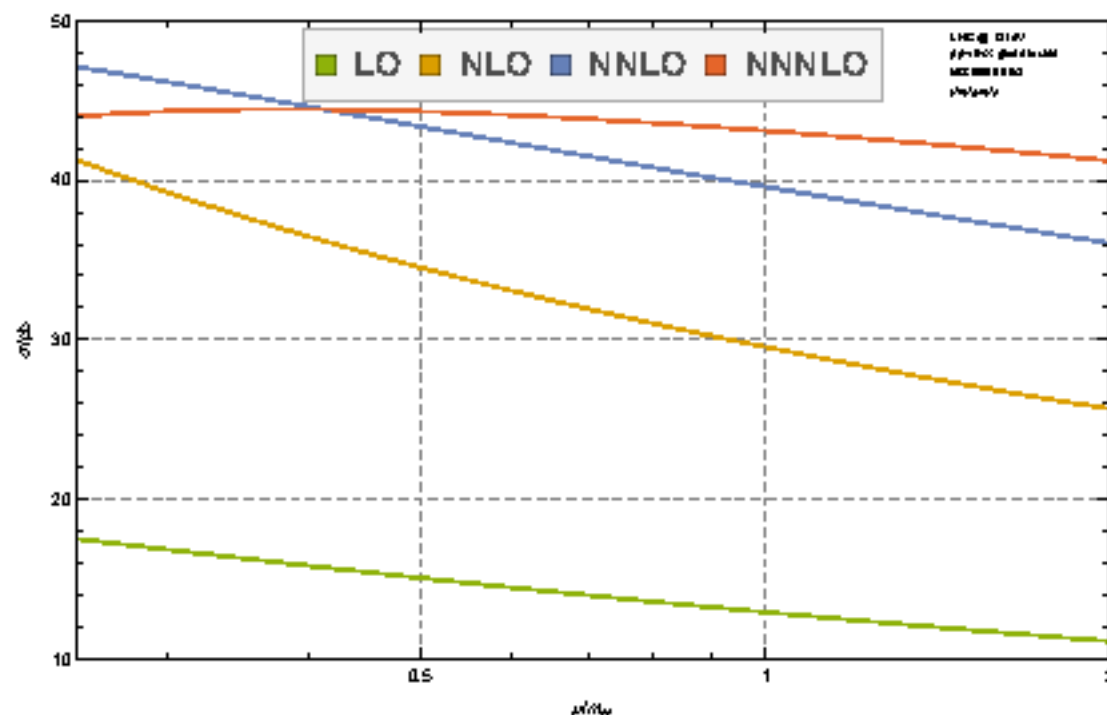
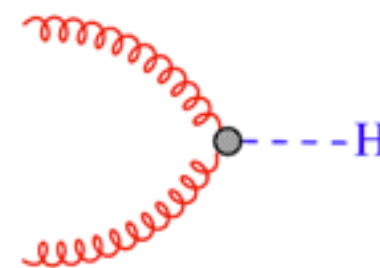
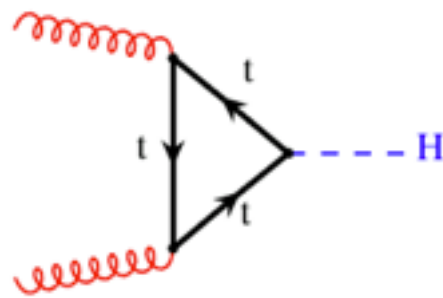


Theoretical precision on major Higgs production cross sections, that we already have, seems to match the experimental precision achievable with 3000/fb. [A new situation, thanks to the recent theoretical results.](#)

Higgs boson production in gluon fusion

Gluon fusion is the dominant production mechanism at the LHC. The production rate is known to be affected by large $O(100\%)$ QCD radiative corrections. These corrections are currently known to **three loop order** (N^3LO) in the infinite top mass limit.

This is **extremely non-trivial** computation whose success is the consequence of the ingenuity of its authors, powerful computational technologies developed recently and tremendous capability of modern computing facilities.



Scale uncertainty of the gluon fusion cross section

σ/pb	2 TeV	7 TeV	8 TeV	13 TeV	14 TeV
$\mu = \frac{m_H}{2}$	$0.99^{+0.43\%}_{-4.65\%}$	$15.31^{+0.31\%}_{-3.08\%}$	$19.47^{+0.32\%}_{-2.99\%}$	$44.31^{+0.31\%}_{-2.64\%}$	$49.87^{+0.32\%}_{-2.61\%}$
$\mu = m_H$	$0.94^{+4.87\%}_{-7.35\%}$	$14.84^{+3.18\%}_{-5.27\%}$	$18.90^{+3.08\%}_{-5.02\%}$	$43.14^{+2.71\%}_{-4.45\%}$	$48.57^{+2.68\%}_{-4.24\%}$

Anastasiou, Duhr, Dulat, Furlan, Herzog, Gehrmann, Mistlberger etc.

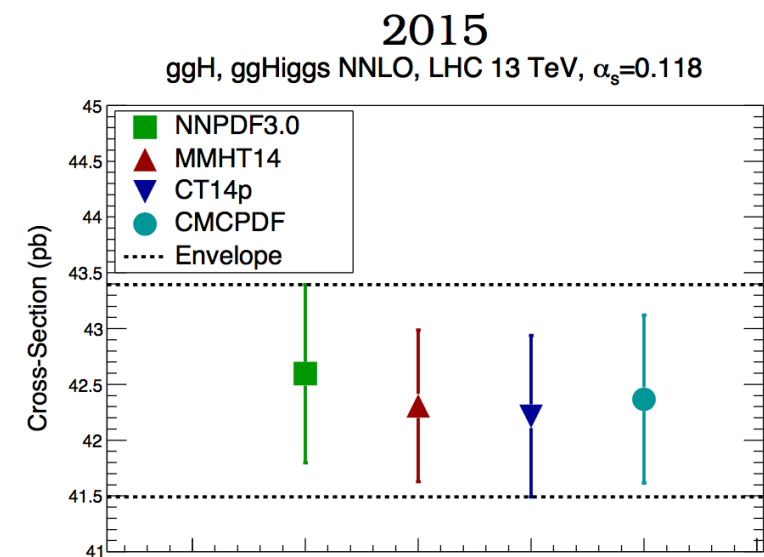
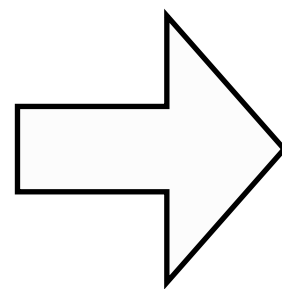
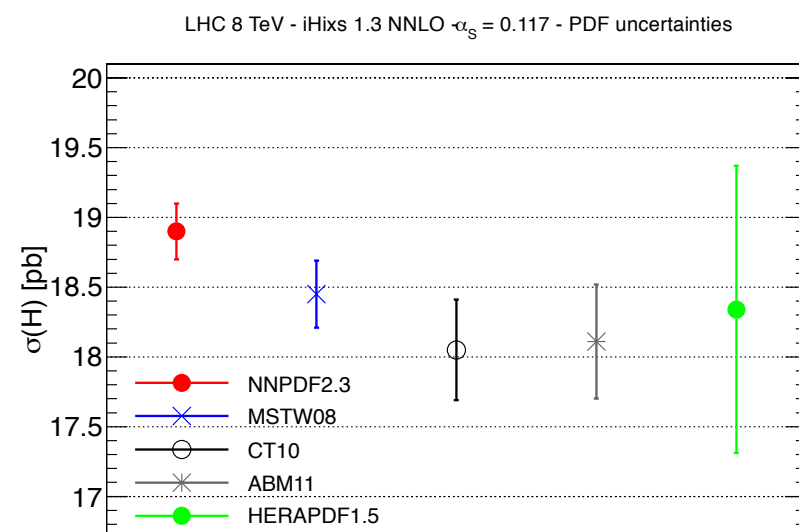
The perturbative series for $gg \rightarrow H$ cross section appear to converge. This is no small feat as the corrections start at $O(100\%)$ at NLO, are still $O(20\%)$ at NNLO, but decrease to just $O(4\%)$ at N^3LO . The residual scale dependence uncertainty is just about 3%.

Higgs boson production in gluon fusion

Suppose we want to use this very high perturbative precision, to claim that Higgs production cross sections and couplings can be measured with a few percent accuracy at the LHC, we should consider other effects that are, potentially, of a similar magnitude and, unfortunately, there are plenty of them.

We need to control parton distribution functions, effects of finite top and bottom quark masses, electroweak corrections, interferences with backgrounds, acceptances and non-perturbative corrections.

As an example, consider the parton distribution functions. Until very recently, the discrepancies between PDF sets from different collaborations were quite substantial; the most recent PDF releases seem to show a more coherent outcome. Not clear why this happened; slow evolution towards convergence....



Another important issue is the error that we make by neglecting N^3 LO PDFs in computing N^3 LO cross section. There seems to be an argument by Forte et al., that the error is tiny, but we do not know how to bound this error from above.

Higgs boson production in gluon fusion

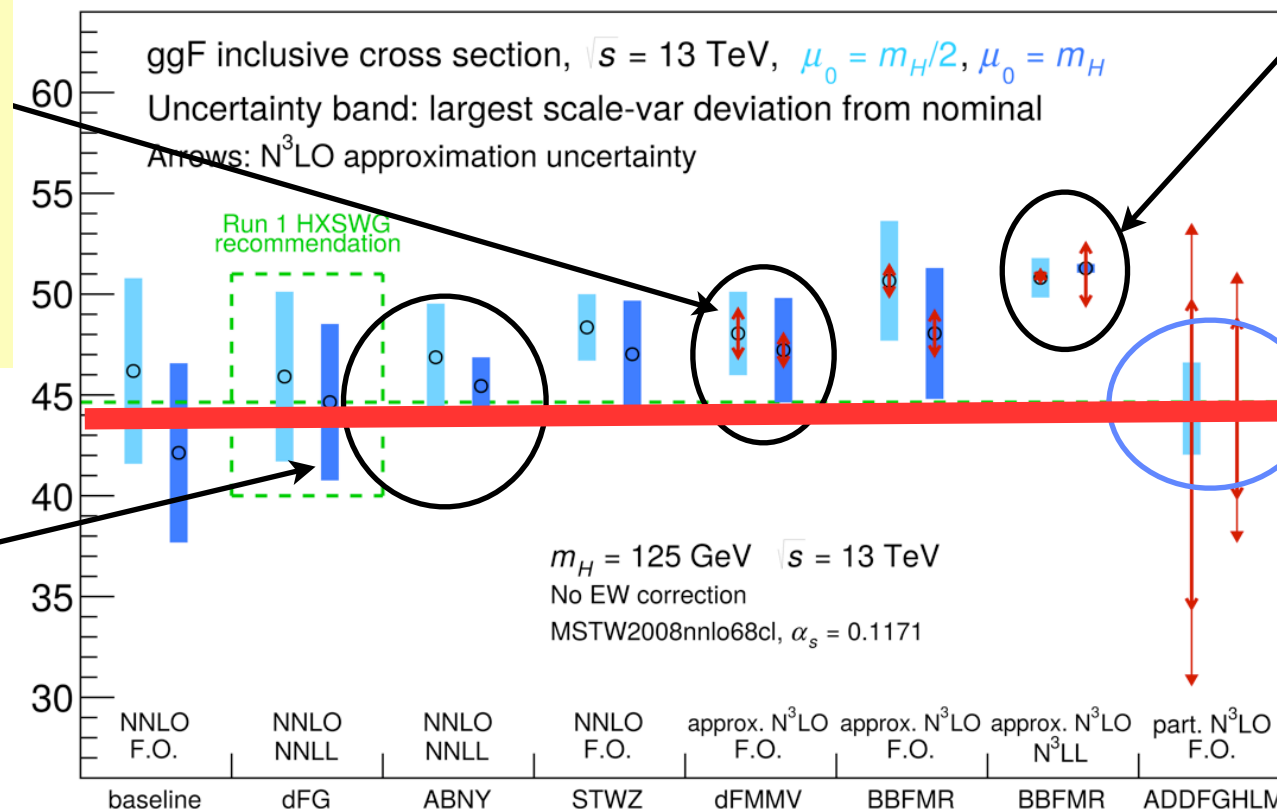
Estimates of N³LO Higgs production cross sections were attempted before an exact calculation became available, using the various approximations. The HXSWG has assembled various predictions for the Higgs cross section made before the N³LO result became available.

The picture below should tell us about the success or failure of these predictions. But it does not, it seems that not quite the same things are being compared on this plot.

More generally, it is important to understand how well approximate methods capture results of fixed-order perturbative computations since it will teach us to what extent approximate predictions for Higgs boson production cross sections, as well as for other processes, are reliable

The authors of this result claim the same increase of the cross-section relative to NNLO as the exact N3LO computation shows. Yet, the results on that plot look very different.

Good agreement with N3LO; obviously larger errors.



It would be important to understand why this point is so much higher than everybody else and why the claimed precision is so high.

N3LO result

Taken from the HXWG summary

Acceptances

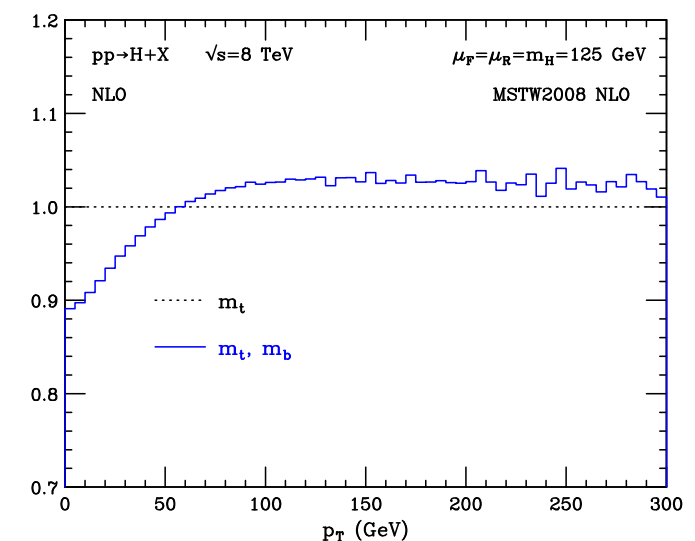
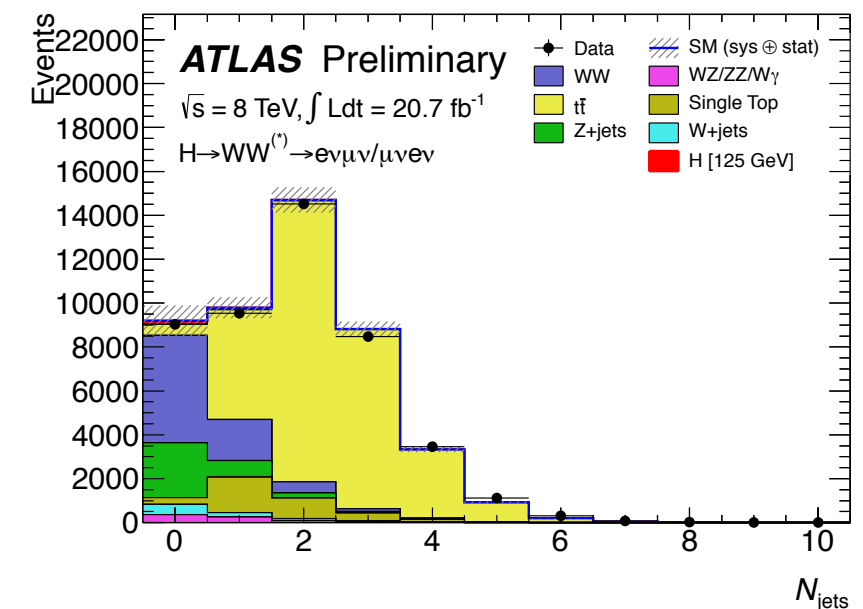
A very important aspect of precision Higgs physics is precise knowledge of **acceptances**. This is simply the statement that measurements are performed in phase-spaces defined through the kinematic cuts and that inclusive cross sections are simply not measurable.

Often, acceptances are computed by the experimental collaborations using parton shower event generators or, at most, NLO computations. The question is --- if this is really sufficient if we aim at a few percent precision on the Higgs cross sections / couplings.

In case of the Higgs production, the important aspect of fiducial volume definition is the **jet-binning**; it implies that 0-jet, 1-jet and 2-jet cross sections are measured; the inclusive cross section is then reconstructed by putting all these cross sections together.

A smaller -- but still relevant issue -- is the dependence of radiative corrections on other details of the fiducial volume definition, including kinematics of Higgs decay products. We will see in what follows that proper estimates of these effects are required.

Finally, a related issue is the modeling of the Higgs boson transverse momentum distribution. Here, we have some interesting theoretical issues to sort out.

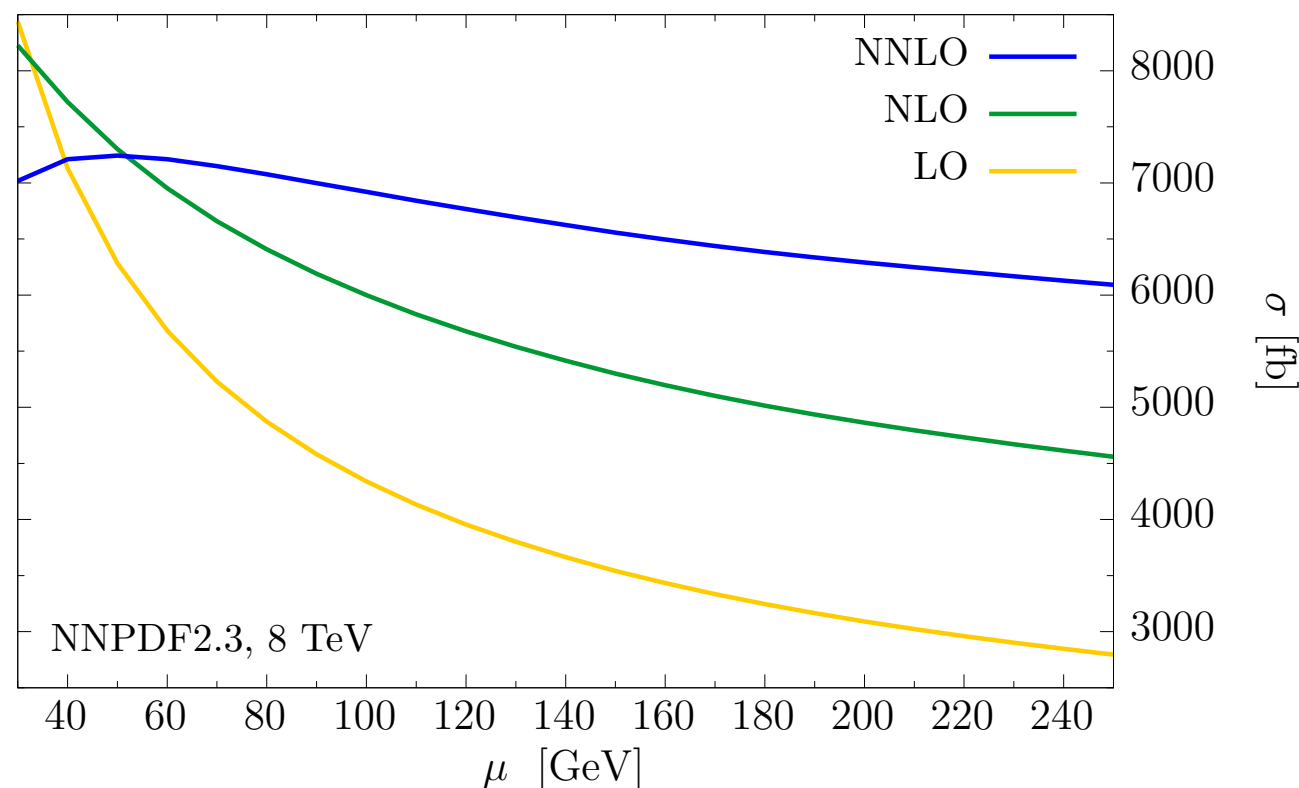


Grazzini, Sarksyan

H+jet @ NNLO

A “fiducial partner” of the total Higgs production cross section at N³LO is the H+j cross section at NNLO QCD. The NNLO QCD corrections to H+jet production at the LHC were computed recently (in an approximation of an infinitely large top quark mass).

The NNLO QCD corrections increase the H+jet production cross section by O(20%) and significantly reduce the scale dependence uncertainty. This is similar to corrections to the inclusive Higgs production cross section although corrections to H+jet are slightly smaller.



$$\sigma_{\text{LO}} = 3.9^{+1.7}_{-1.1} \text{ pb}$$

$$\sigma_{\text{NLO}} = 5.6^{+1.3}_{-1.1} \text{ pb}$$

$$\sigma_{\text{NNLO}} = 6.7^{+0.5}_{-0.6} \text{ pb}$$

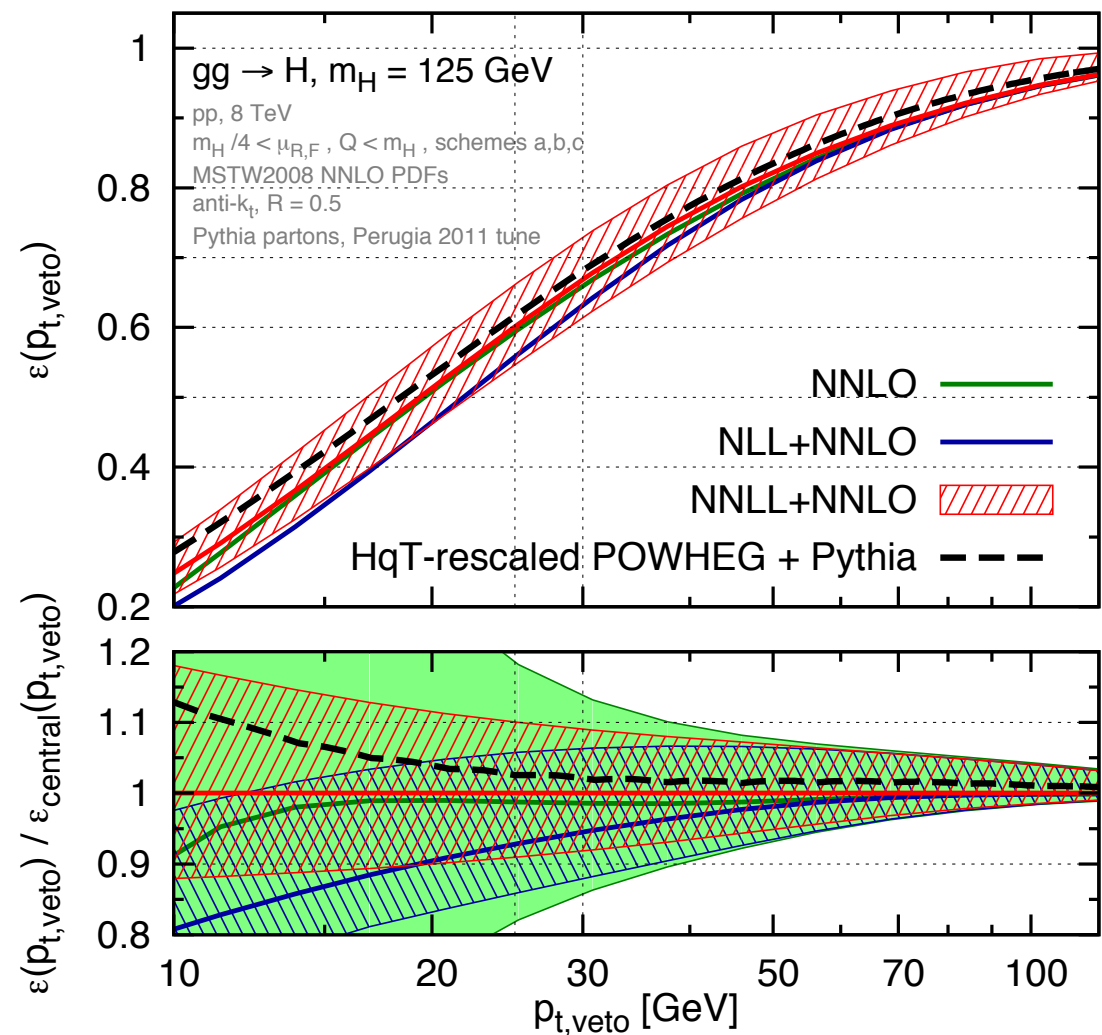
The cross sections for the anti- k_t algorithm with the jet transverse momentum cut of 30 GeV at the 8 TeV LHC.

R. Boughezal, F. Caola, K.M., F. Petriello, M. Schulze

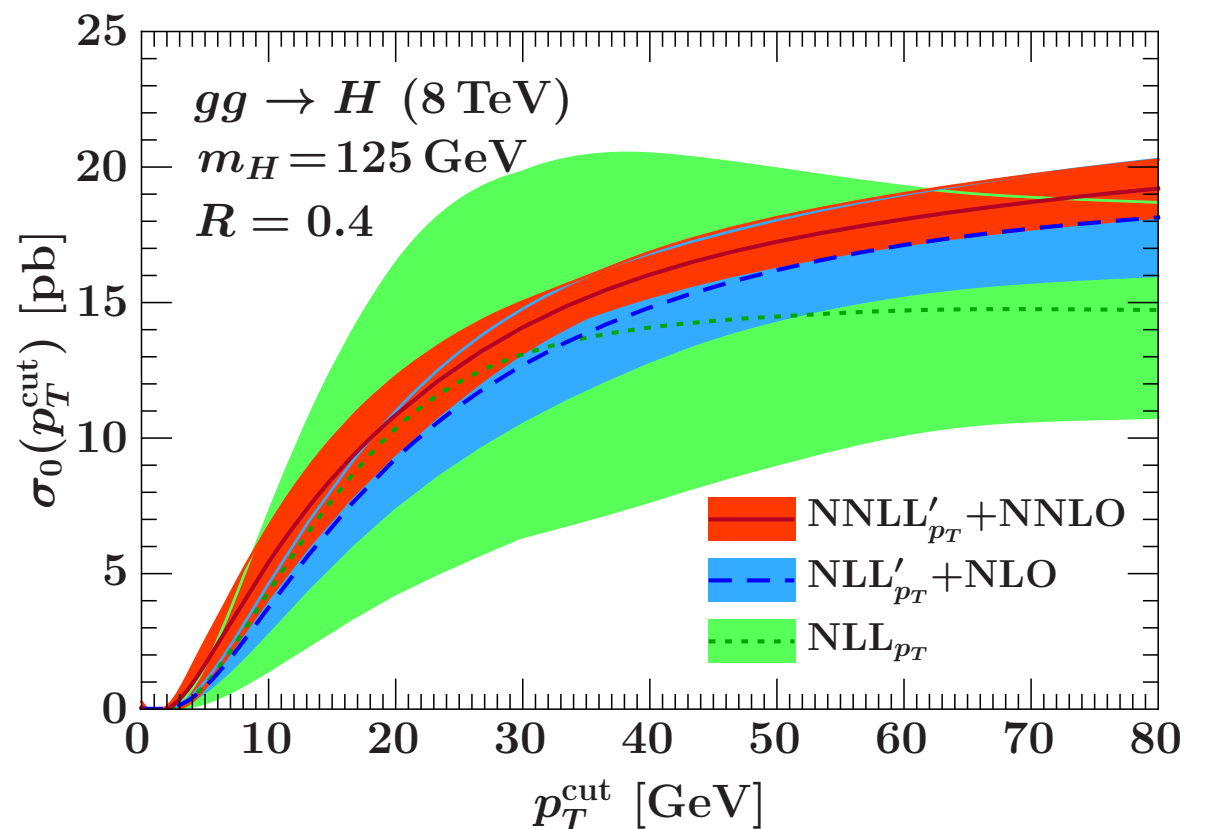
Using these results and the N³LO computation of the Higgs total cross section, one can find the fraction of Higgs boson events without detectable QCD radiation.

Jet veto acceptances

This is achieved by subtracting inclusive H+j production cross section from the inclusive Higgs production cross section in matching orders of pQCD; the result is the Higgs production cross section with zero jets. Until very recently -- such analysis was restricted to NNLO, this year an opportunity appeared to extend it to N³LO in perturbative QCD.



$$\epsilon_{p_{t,veto}} = \frac{[\Sigma_0 + \Sigma_1 + \Sigma_2 + \Sigma_3](p_{t,veto})}{\sigma_0 + \sigma_1 + \sigma_2 + \sigma_3}$$



Re-summation of many different potentially enhanced terms (logarithms of the transverse momentum cut and the jet radius) were performed by many groups. Matching to fixed order results is supposed to have a major impact.

Banfi, Zanderighi, Salam; Tackmann, Zuberi, Walsh; Becher, Neubert

Fiducial cross sections

The results of N³LO computation for inclusive Higgs production, NNLO for the H +j production as well as advances with re-summations of jet-radius logarithms allow one to improve on existing predictions for 0-jet and 1-jet bin cross sections.

For the 13 TeV LHC, using NNPDF2.3, anti-k_T, R=0.5, $\mu_0=m_H/2$, $Q_{\text{res}} = m_H/2$ and accounting for top and bottom mass effects, one finds the following results:

	LHC 13 TeV	$\epsilon^{\text{N}^3\text{LO}+\text{NNLL}+\text{LL}_R}$	$\Sigma_{0\text{-jet}}^{\text{N}^3\text{LO}+\text{NNLL}+\text{LL}_R}$ [pb]	$\Sigma_{0\text{-jet}}^{\text{N}^3\text{LO}}$	$\Sigma_{0\text{-jet}}^{\text{NNLO}+\text{NNLL}}$
0-jet bin	$p_{t,\text{veto}} = 25 \text{ GeV}$	$0.539^{+0.017}_{-0.008}$	$24.7^{+0.8}_{-1.0}$	$24.3^{+0.5}_{-1.0}$	$24.6^{+2.6}_{-3.8}$
	$p_{t,\text{veto}} = 30 \text{ GeV}$	$0.608^{+0.016}_{-0.007}$	$27.9^{+0.7}_{-1.1}$	$27.5^{+0.5}_{-1.1}$	$27.7^{+2.9}_{-4.0}$
	LHC 13 TeV	$\Sigma_{\geq 1\text{-jet}}^{\text{NNLO}+\text{NNLL}+\text{LL}_R}$ [pb]	$\Sigma_{\geq 1\text{-jet}}^{\text{NNLO}}$ [pb]		
$\geq 1\text{-jet bin}$	$p_{t,\text{min}} = 25 \text{ GeV}$	$21.2^{+0.4}_{-1.1}$	$21.6^{+0.5}_{-1.0}$		
	$p_{t,\text{min}} = 30 \text{ GeV}$	$18.0^{+0.3}_{-1.0}$	$18.4^{+0.4}_{-0.8}$		

- No breakdown of fixed order perturbation theory for $p_T \sim 25\text{-}30 \text{ GeV}$;
- Reliable error estimate from lower orders ; residual errors O(3-5) percent for the two jet bins;
- Re-summed results change fixed-order results within the error bars of the former/latter. There seems to be little difference between re-summed and fixed order results. However, let us consider a different scale.

A. Banfi, F. Caola, F. Dreyer, P. Monni, G.Salam, G. Zanderighi, F. Dulat

Fiducial cross sections

It turns out that for the scale choice $\mu_0=m_H$, the importance of fixed order results is much more pronounced. For the 13 TeV LHC, using NNPDF2.3, anti- k_T , $R=0.5$, $\mu_0=m_H$, $Q_{\text{res}} = m_H/2$ and accounting for top and bottom mass effects, one finds the following results:

A. Banfi, F. Caola, F. Dreyer, P. Monni, G.Salam, G. Zanderighi, F. Dulat

	LHC 13 TeV	$\epsilon^{\text{N}^3\text{LO}+\text{NNLL}+\text{LL}_R}$	$\Sigma_{0\text{-jet}}^{\text{N}^3\text{LO}+\text{NNLL}+\text{LL}_R}$ [pb]	$\Sigma_{0\text{-jet}}^{\text{N}^3\text{LO}}$	$\Sigma_{0\text{-jet}}^{\text{NNLO}+\text{NNLL}}$
0-jet bin	$p_{t,\text{veto}} = 25 \text{ GeV}$	$0.541^{+0.013}_{-0.023}$	$24.0^{+1.0}_{-1.7}$	$24.0^{+1.2}_{-2.3}$	$23.1^{+2.8}_{-4.0}$
	$p_{t,\text{veto}} = 30 \text{ GeV}$	$0.612^{+0.013}_{-0.023}$	$27.2^{+1.1}_{-1.9}$	$27.1^{+1.2}_{-2.2}$	$25.9^{+3.1}_{-4.2}$

	LHC 13 TeV	$\Sigma_{\geq 1\text{-jet}}^{\text{NNLO}+\text{NNLL}+\text{LL}_R}$ [pb]	$\Sigma_{\geq 1\text{-jet}}^{\text{NNLO}}$ [pb]
$\geq 1\text{-jet bin}$	$p_{t,\text{min}} = 25 \text{ GeV}$	$20.4^{+1.2}_{-1.3}$	$20.5^{+2.0}_{-1.5}$
	$p_{t,\text{min}} = 30 \text{ GeV}$	$17.2^{+1.2}_{-1.1}$	$17.3^{+1.7}_{-1.2}$

The NNLO + NNLL central value is clearly below the N^3LO central value; the impact of resummations on the final result is marginal.

Although it is interesting to see how physics results are built up at different scales, it is important to emphasize that final results for efficiencies and jet-binned cross sections are largely (3%) independent of the central scale choice once fixed order results are properly accounted for.

H+jet @ NNLO : Higgs decay and fiducial results

Jet vetoes provide one (important) aspect of the fiducial volume definition. The other is that Higgs boson decay products are observed experimentally and their kinematics is affected by radiative effects. It is straightforward to account for this, since the Higgs boson is a scalar particle and no spin correlations are involved.

What makes this calculation even more interesting is that there are measurements of the ATLAS and CMS collaborations at the 8 TeV LHC that can be directly compared to the results of the fiducial volume calculation (results are shown for infinitely heavy top quark).

Atlas cuts on photons and jets

$$\text{anti} - k_t, \quad \Delta R = 0.4, \quad p_{j\perp} = 30 \text{ GeV}, \quad \text{abs}(y_j) < 4.4 \\ p_{\perp, \gamma_1} > 43.75 \text{ GeV}, \quad p_{\perp, \gamma_2} = 31.25 \text{ GeV}, \quad \Delta R_{\gamma j} > 0.4$$

$$\sigma_{1j, \text{ATLAS}}^{\text{fid}} = 21.5 \pm 5.3(\text{stat}) \pm 2.3(\text{syst}) \pm 0.6 \text{ lum fb}$$

$$\sigma_{\text{LO}}^{\text{fid}} = 5.43_{-1.5}^{+2.32} \text{ fb} \quad \sigma_{\text{NLO}}^{\text{fid}} = 7.98_{-1.46}^{+1.76} \text{ fb} \quad \sigma_{\text{NNLO}}^{\text{fid}} = 9.46_{-0.84}^{+0.56} \text{ fb}$$

F. Caola, K.M., M. Schulze

The difference between the ATLAS H+j measurements and the SM prediction is close to two standard deviations; the ratio of central values is larger than in the inclusive case.

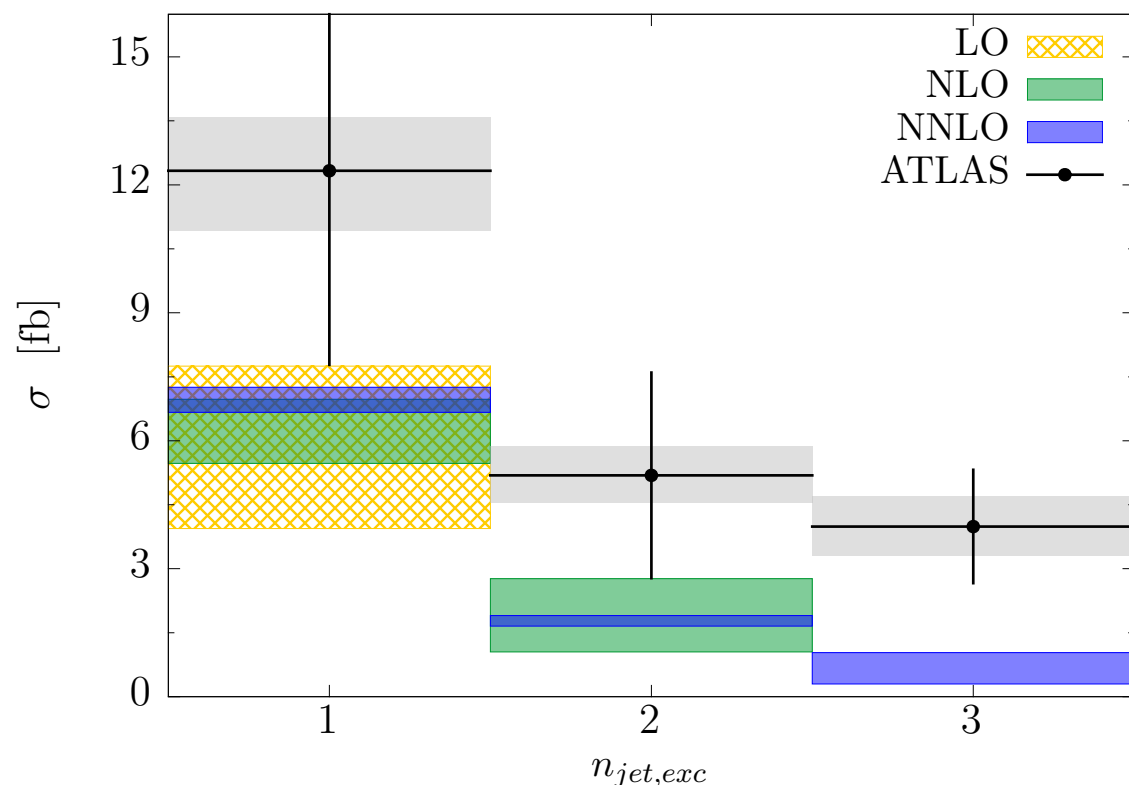
Acceptances show O(few) percent changes at NLO and then stabilize:

$$A_{\text{LO}} = 0.594(4), \quad A_{\text{NLO}} = 0.614(3), \quad A_{\text{NNLO}} = 0.614(4).$$

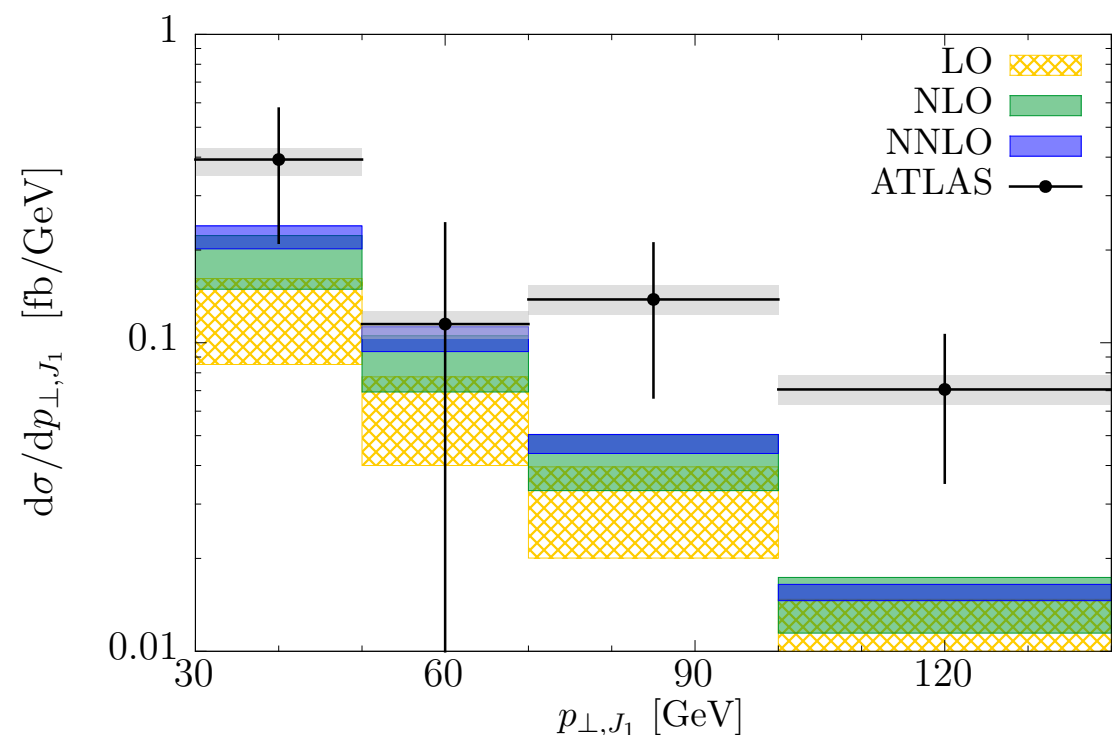
H+jet @ NNLO: fiducial results

Once Higgs boson decays are included on the theory side, any fiducial cross section or distribution can be obtained. To make the long story short, I only show a few plots where comparison with the results of the ATLAS data is performed.

Data is always higher than the theory prediction; shapes of jet transverse momentum distribution are also different. Although these discrepancies are not statistically significant, they are peculiar. The existence of precise theory predictions should serve as a motivation for refined experimental analyses, this time at 13 TeV.



Exclusive jet cross sections



Transverse momentum distribution of a leading jet

F. Caola, K.M., M. Schulze

Mass effects in Higgs production in gluon fusion

An interesting problem appears when we try to understand the Higgs boson transverse momentum distribution. From the two Figures below we see that the inclusion of the bottom quark contribution changes the quality of the theoretical prediction quite dramatically for moderate values of the transverse momenta.

The reason for this are the enhanced Sudakov-like effects that appear in the bottom quark loop. These effects are unusual since they involve the soft fermion line and the helicity flip.

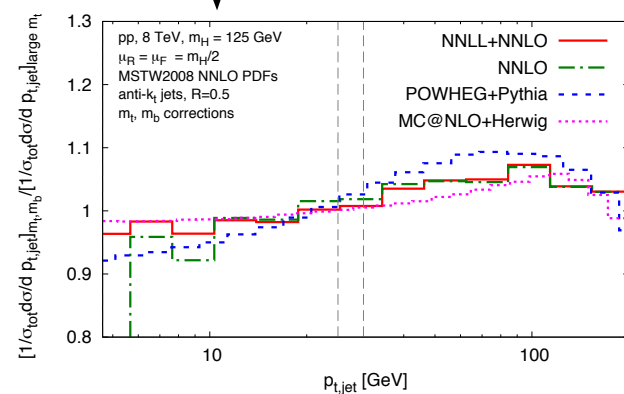
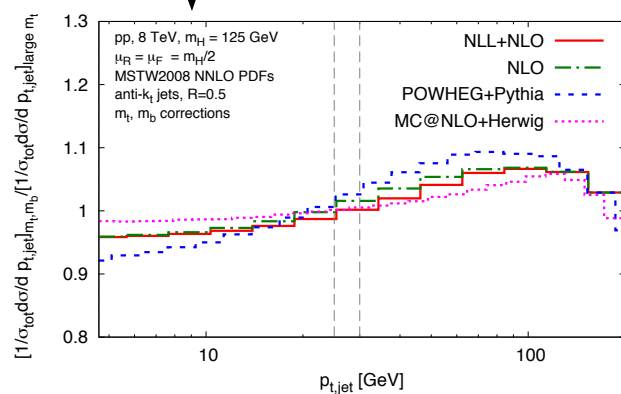
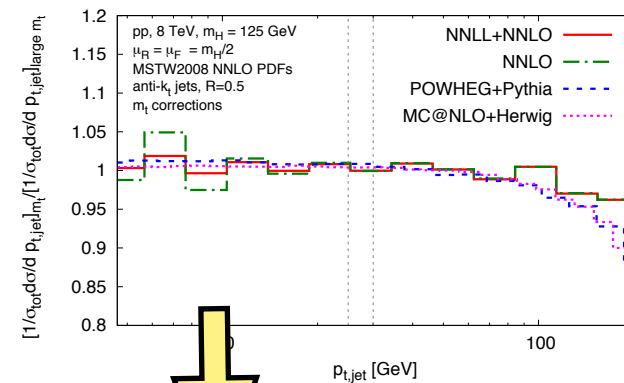
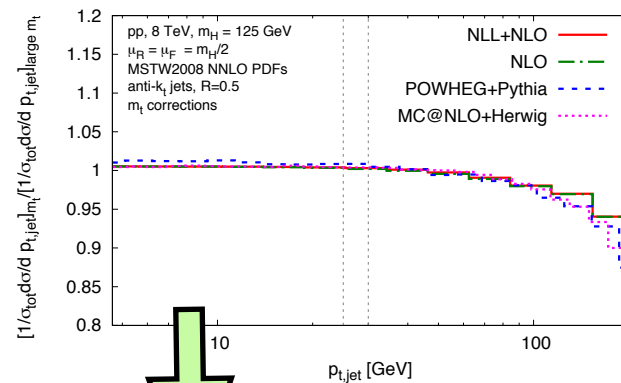
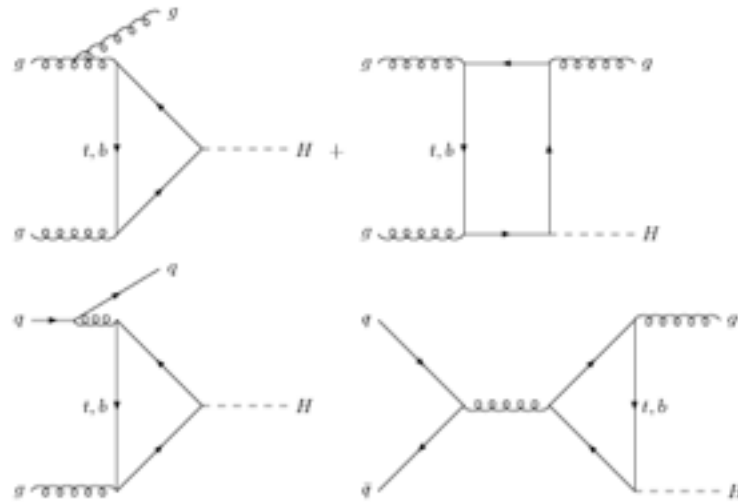
$$m_b^2 \ll p_\perp^2 \ll s, m_H^2$$

$$\mathcal{M}_{+++} = -g_s \sqrt{2} f^{a_1 a_2 a_3} \frac{g_s^2 g_y m}{16\pi^2} \frac{\langle 12 \rangle^2}{[12] \langle 23 \rangle \langle 13 \rangle} A_{+++}$$

$$\mathcal{M}_{++-} = g_s \sqrt{2} f^{a_1 a_2 a_3} \frac{g_s^2 g_y m}{16\pi^2} \frac{\langle 12 \rangle}{[23][13]} A_{++-}$$

$$A_{++\pm} = \ln^2 \frac{s}{m_b^2} \mp \frac{1}{2} \ln^2 \frac{p_\perp^2}{m^2}$$

It is not clear how to treat these terms properly in the context of parton showers/re-summations. Two different ways of dealing with them (exponentiation vs. plain NLO) leads to about 2% differences in jet veto efficiencies.



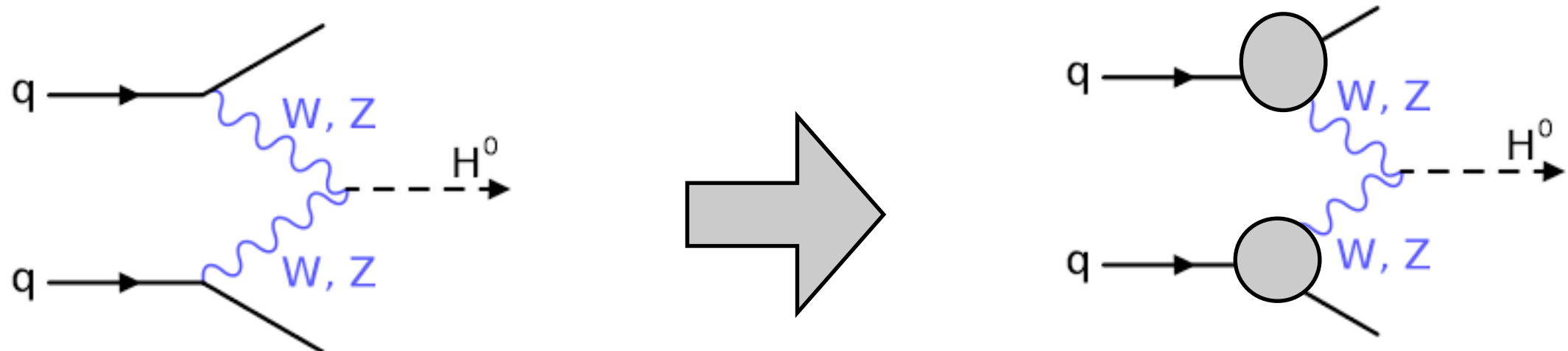
Banfi, Monni, Zanderighi

Higgs boson production in weak boson fusion

The Higgs boson production in weak boson fusion is an interesting process for a variety of reasons, including the direct access to HVV ($V = Z, W$) coupling etc.

Due to color conservation, computations of NLO QCD corrections are simple -- the upper and lower qqV vertices receive QCD corrections but the two blocks do not talk to each other. As the consequence, one can view the structure of QCD corrections -- [to the total inclusive cross section](#) --- as the "Deep Inelastic Scattering squared" and use the DIS building blocks - [the structure functions](#) - to calculate the corrections. For NLO QCD, this observation is not essential but it is useful for NNLO since those results for the coefficients functions are available.

The QCD corrections obtained in this approach are small ($O(5\%)$ NLO, $O(3\%)$ NNLO) ; it then seemed natural to assume that this size of QCD corrections will be indicative for the fiducial cross sections.



Bolzoni, Maltoni, Moch, Zaro

Higgs boson production in weak boson fusion

However, this assumption turns out to be incorrect and, in fact, one can get larger $O(6-10\%)$ corrections for fiducial (VBF cuts) cross sections and kinematic distributions. Often, the shape of those corrections seems rather different from both the NLO and/or parton shower predictions. The message -- again -- seems to be that fixed order computations are required beyond certain level of precision; approximate results may indicate their magnitude but not much beyond that.

WBF cuts

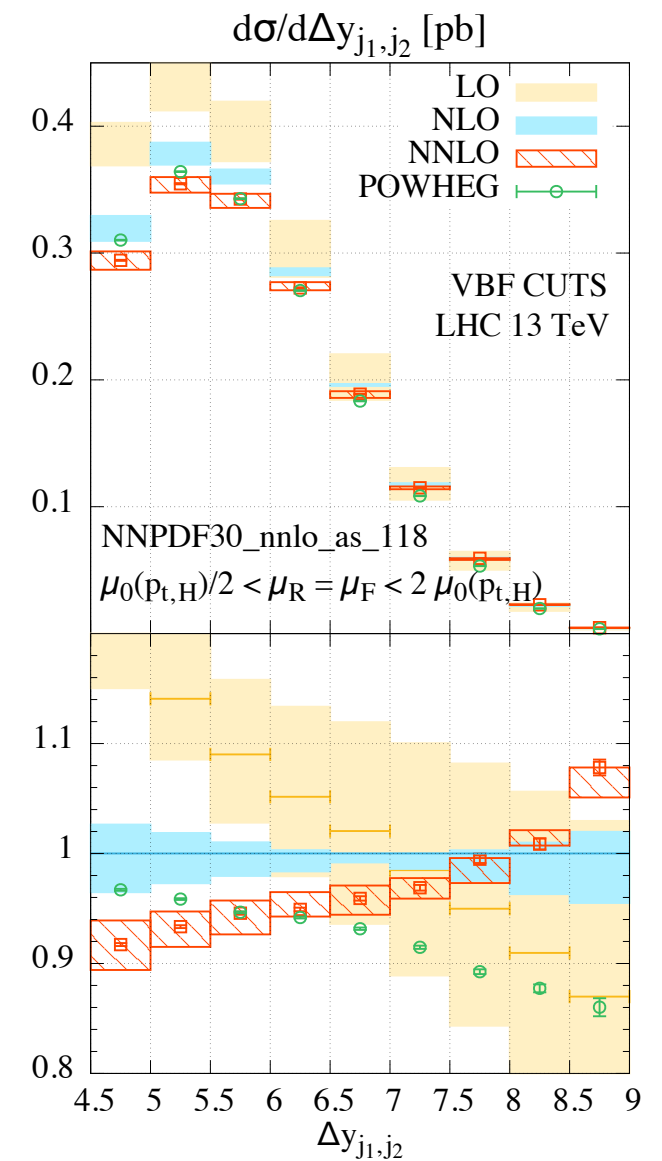
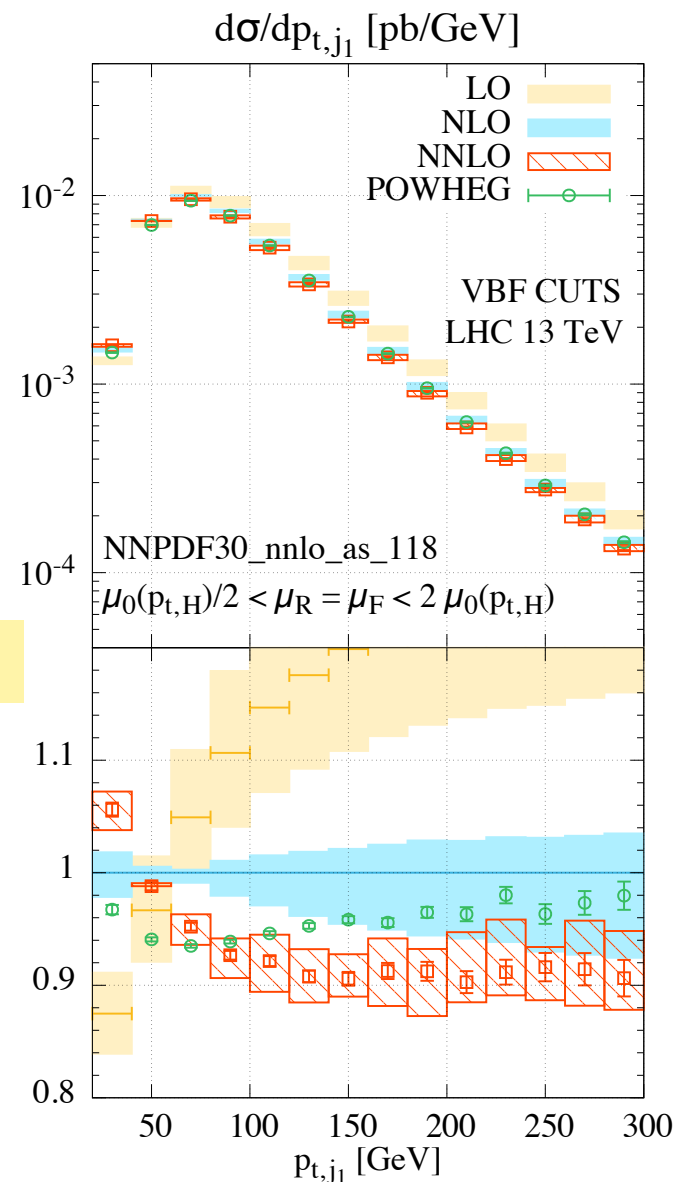
$$p_{\perp}^{j_{1,2}} > 25 \text{ GeV}, \quad |y_{j_{1,2}}| < 4.5,$$

$$\Delta y_{j_1, j_2} = 4.5, \quad m_{j_1, j_2} > 600 \text{ GeV},$$

$$y_{j_1} y_{j_2} < 0, \quad \Delta R > 0.4$$

Cross sections with and without WBF cuts

	$\sigma^{\text{nocuts}} [\text{pb}]$	$\sigma^{\text{VBF cuts}} [\text{pb}]$
LO	$4.032^{+0.057}_{-0.069}$	$0.957^{+0.066}_{-0.059}$
NLO	$3.929^{+0.024}_{-0.023}$	$0.876^{+0.008}_{-0.018}$
NNLO	$3.888^{+0.016}_{-0.012}$	$0.826^{+0.013}_{-0.014}$



Cacciari, Dreyer, Kalberg, Salam, Zanderighi

Higgs boson production: what's next?

H+0 jet	N ³ LO	O(3-5 %)	10 pb	fully inclusive
H+1 jet	N ² LO	O(7%)	7 pb	fully exclusive; Higgs decays, infinite mass limit
H+2 jet	NLO	O(20%)	1.5 pb	matched/merged
H+3 jet	NLO	O(20%)	0.4 pb	matched/merged/almost
WBF	N ² LO	O(1%)	1.5 pb	exclusive, no VBF cuts
WBF	N ² LO	O(5%)	0.2 pb	exclusive, VBF cuts
ZH, WH	N ² LO	O(2-3%)	O(1) pb	decays to bottom quarks
ttH	NLO	O(5%)	0.2pb	decays, off-shell effects

Theoretical precision on Higgs production cross sections that is achieved thanks to recent developments in the field is impressive; perhaps, it was not quite expected to be so rapid. The important question is then -- what is the next big thing?

A better understanding of how to treat (internal) mass effects in Higgs production, will help to improve the theoretical description of a variety of things (top quark mass effects in H+j and the off-shell Higgs; Higgs pair production at NLO QCD; ZH production in gluon fusion through the massive top quark loop) etc.

Extending the NNLO techniques to higher multiplicities is desirable (e.g. H+2j as a background to weak boson fusion etc.).

Conclusion

Availability of precise predictions for Higgs production and decay processes in the Standard Model is a crucial element of the research program aimed at detailed studies of Higgs boson properties at the LHC.

We have seen an impressive progress in this field in the past year (!) (inclusive Higgs $N^3\text{LO}$, H+jet at NNLO, Higgs in WBF at NNLO).

NNLO predictions for fiducial cross sections and kinematic distributions are becoming available; this will make extraction of the Higgs coupling constants much more accurate than previously anticipated.

These fixed order predictions can be compared to various approximations invented to estimate expected magnitude of radiative corrections. It appears (c.f. $N^3\text{LO}$, H+j and H@WBF) that approximate methods do not provide satisfactory estimates although more studies are needed for definite conclusions.

The impressive progress with fixed order computations (as well as with merging and matching) should enable us to verify -- or disprove -- the Standard Model nature of the Higgs boson at the LHC in a convincing and reliable way.