Standard Model Higgs Physics

Massimiliano Grazzini
University of Zurich

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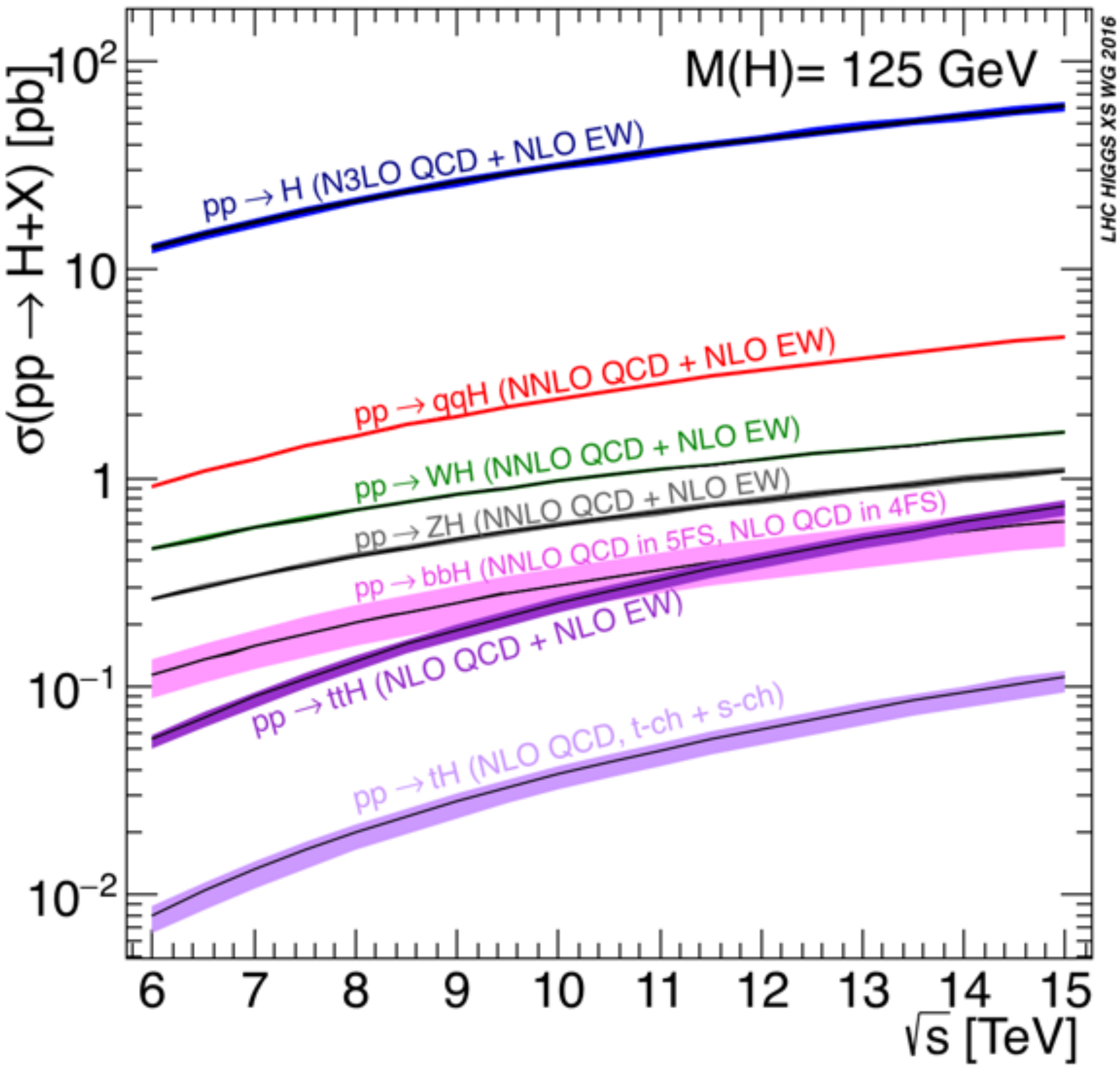
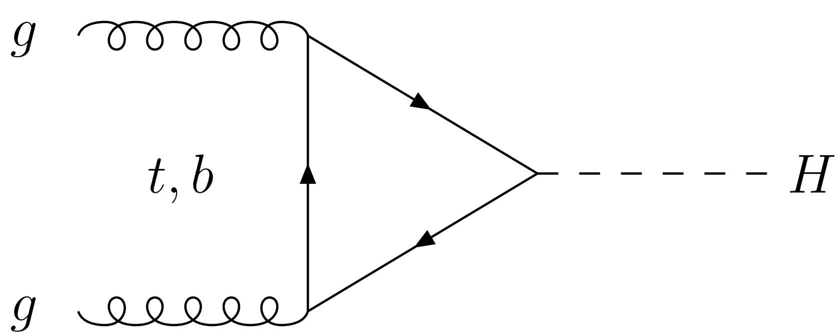
Outline

- gluon fusion
  - Inclusive cross section
  - H+jet(s) and jet-vetoed cross section
  - Transverse-momentum spectrum
- VH, VBF, ttH
- Higgs decays
- Off-Shell/Interference
- Double Higgs production
- Summary

Production channels



gg→H

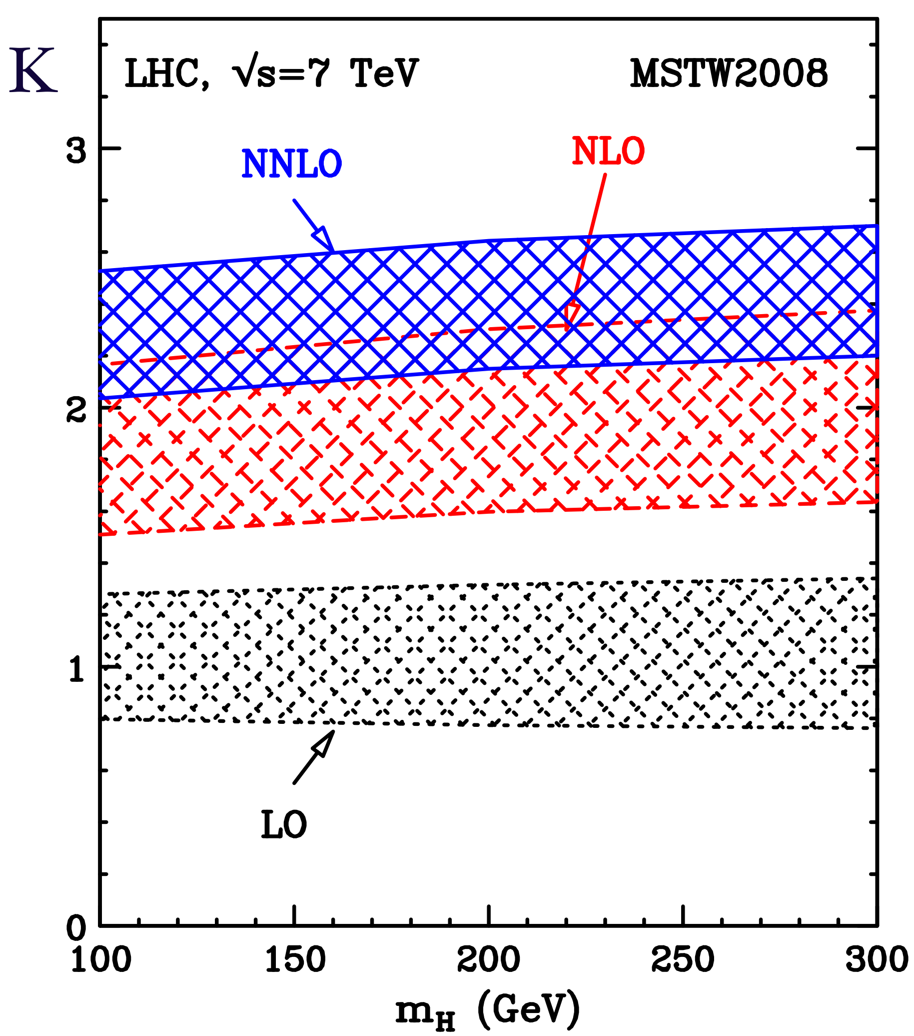


The Higgs coupling is proportional to the quark mass → top-loop dominates

$O(\alpha_S^2)$ process already at Born level

QCD corrections to the total rate computed 25 years ago and found to be large → O(100 %) effect !

A. Djouadi, D. Graudenz, M. Spira, P. Zerwas (1991)



Next-to-next-to leading order (NNLO) corrections computed in the large-m_{top} limit (+25 % at the LHC, +30 % at the Tevatron)

R.Harlander, W.B. Kilgore (2001)
C. Anastasiou, K. Melnikov (2002)
V. Ravindran, J. Smith, W.L.Van Neerven (2003)

Soft-gluon effects included

S.Catani, D de Florian, P.Nason,MG (2003)

scale uncertainty computed with $m_H/2 < \mu_F, \mu_R < 2\, m_H$ and $1/2 < \mu_F/\mu_R < 2$

gg→H

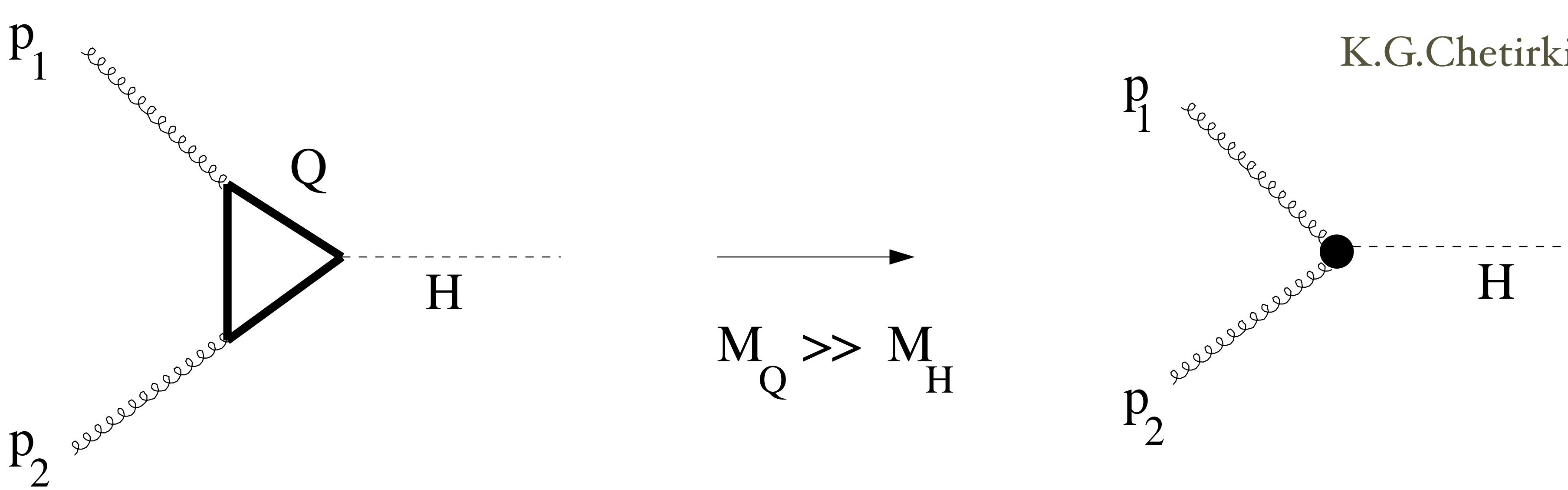
For a light Higgs it is possible to use an effective lagrangian approach obtained when $m_{top} \to \infty$

J.Ellis, M.K.Gaillard, D.V.Nanopoulos (1976)
M.Voloshin, V.Zakharov, M.Shifman (1979)

$$\mathcal{L}_{eff} = -\frac{1}{4}\left[1 - \frac{\alpha_S}{3\pi}\frac{H}{v}(1+\Delta)\right] \mathrm{Tr}\, G_{\mu\nu}G^{\mu\nu}$$

Known to $\mathcal{O}(\alpha_S^3)$

K.G.Chetirkin, M.Steinhauser, B.A.Kniehl (1997)



Effective vertex: one loop less !

The subleading terms in large-m_{top} limit at NNLO have been evaluated

S.Marzani et al. (2008)
R.Harlander et al. (2009,2010)
M.Steinhauser et al. (2009)

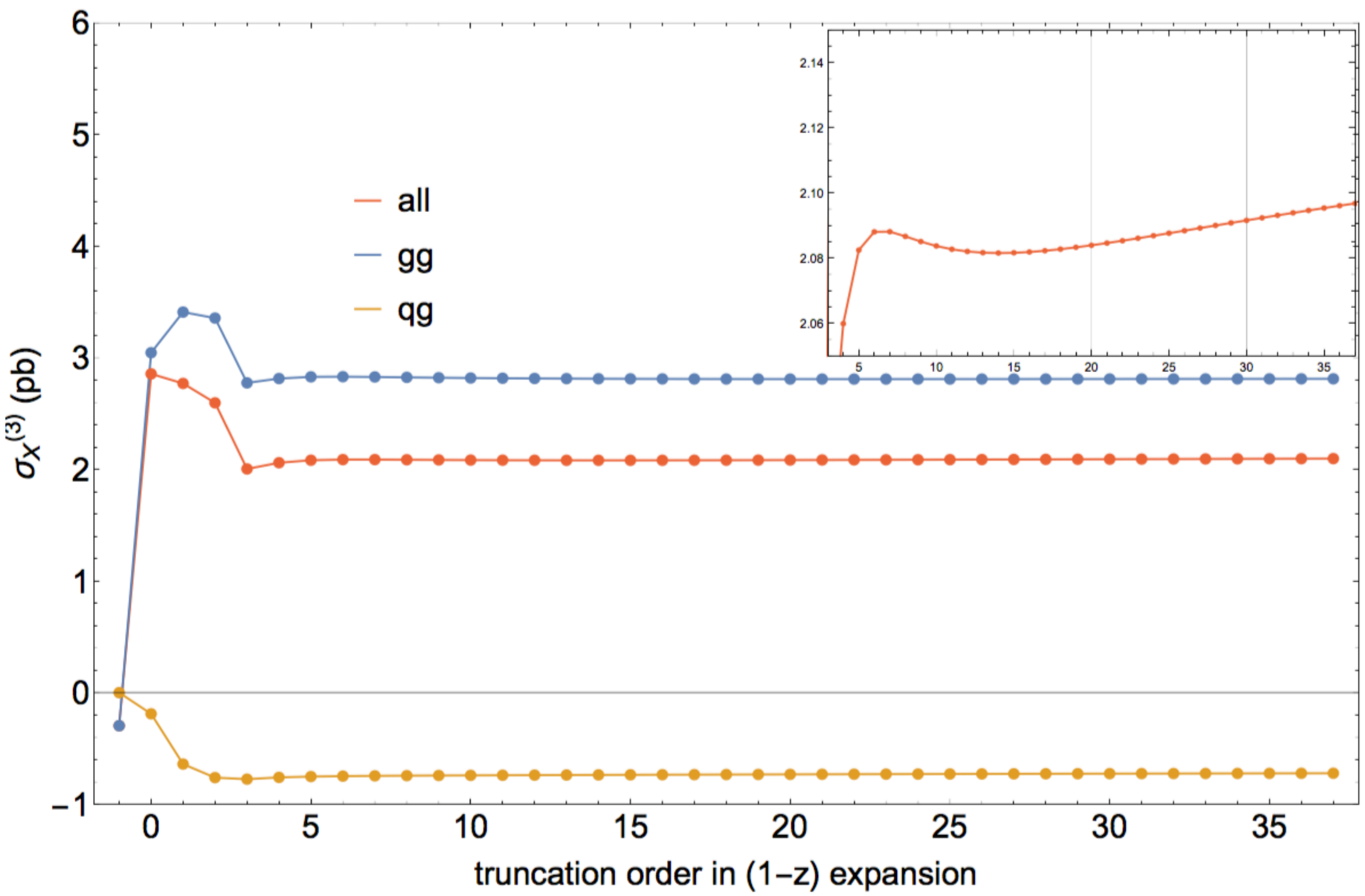
➡ **The approximation works to better than 0.5 % for $m_H < 300$ GeV**

gg→H at N3LO

C.Anastasiou, C.Duhr, F.Dulat, F.Herzog, B.Mistlberger (2015)

Really impressive achievement:

- first complete calculation at N3LO in hadronic collisions !
- O(10^5) diagrams; O(10^3) master integrals



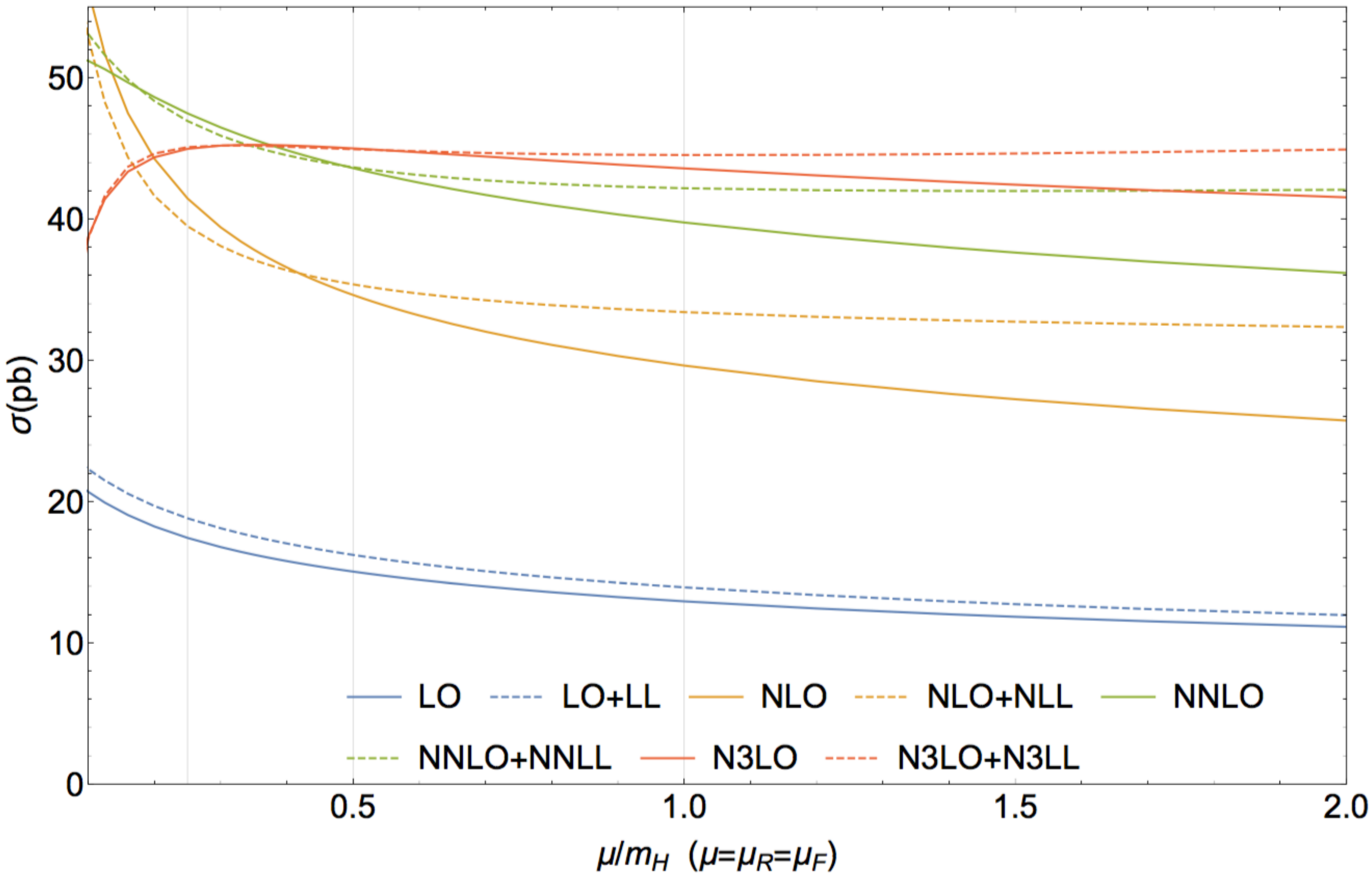
Obtained through a series expansion around the soft limit (37 terms !)

$$1 - z = 1 - m_H^2/\hat{s}$$

"distance" from partonic threshold

gg→H at N3LO

C.Anastasiou, C.Duhr, F.Dulat, F.Herzog, B.Mistlberger (2015)



Important reduction of perturbative uncertainties

N3LL resummation also available but it has practically no effects at $\mu = m_H/2$

gg→H at N3LO

C.Anastasiou, C.Duhr, F.Dulat, E.Furlan, T.Gehrmann, F.Herzog,
A.Lazopoulos, B.Mistlberger (2016)

N3LO calculation accompanied by a thorough study of the remaining theoretical uncertainties

$\delta(\text{scale})$	$\delta(\text{trunc})$	$\delta(\text{PDF-TH})$	$\delta(\text{EW})$	$\delta(t,b,c)$	$\delta(1/m_t)$
$^{+0.10\text{ pb}}_{-1.15\text{ pb}}$	± 0.18 pb	± 0.56 pb	± 0.49 pb	± 0.40 pb	± 0.49 pb
$^{+0.21\%}_{-2.37\%}$	$\pm 0.37\%$	$\pm 1.16\%$	$\pm 1\%$	$\pm 0.83\%$	$\pm 1\%$

missing higher-orders

uncertainty from the soft expansion

missing N3LO PDFs

missing mixed QCD-EW corrections

uncertainty from heavy-quark mass dependence

uncertainty in the $1/m_t$ included corrections

$$\sigma = 48.58\,\text{pb}^{+2.22\,\text{pb}\,(+4.56\%)}_{-3.27\,\text{pb}\,(-6.72\%)}\ (\text{theory}) \pm 1.56\,\text{pb}\,(3.20\%)\ (\text{PDF}+\alpha_s)$$

This result and its uncertainties have been discussed within the HXSWG

gg→H at N3LO

M.Bonvini et al. (2016) (see also M.Spira, T.Schmidt (2015))

Impact of N3LL resummation on top of N3LO very minor

Th uncertainties: authors of N3LO calculation recommend a linear combination:

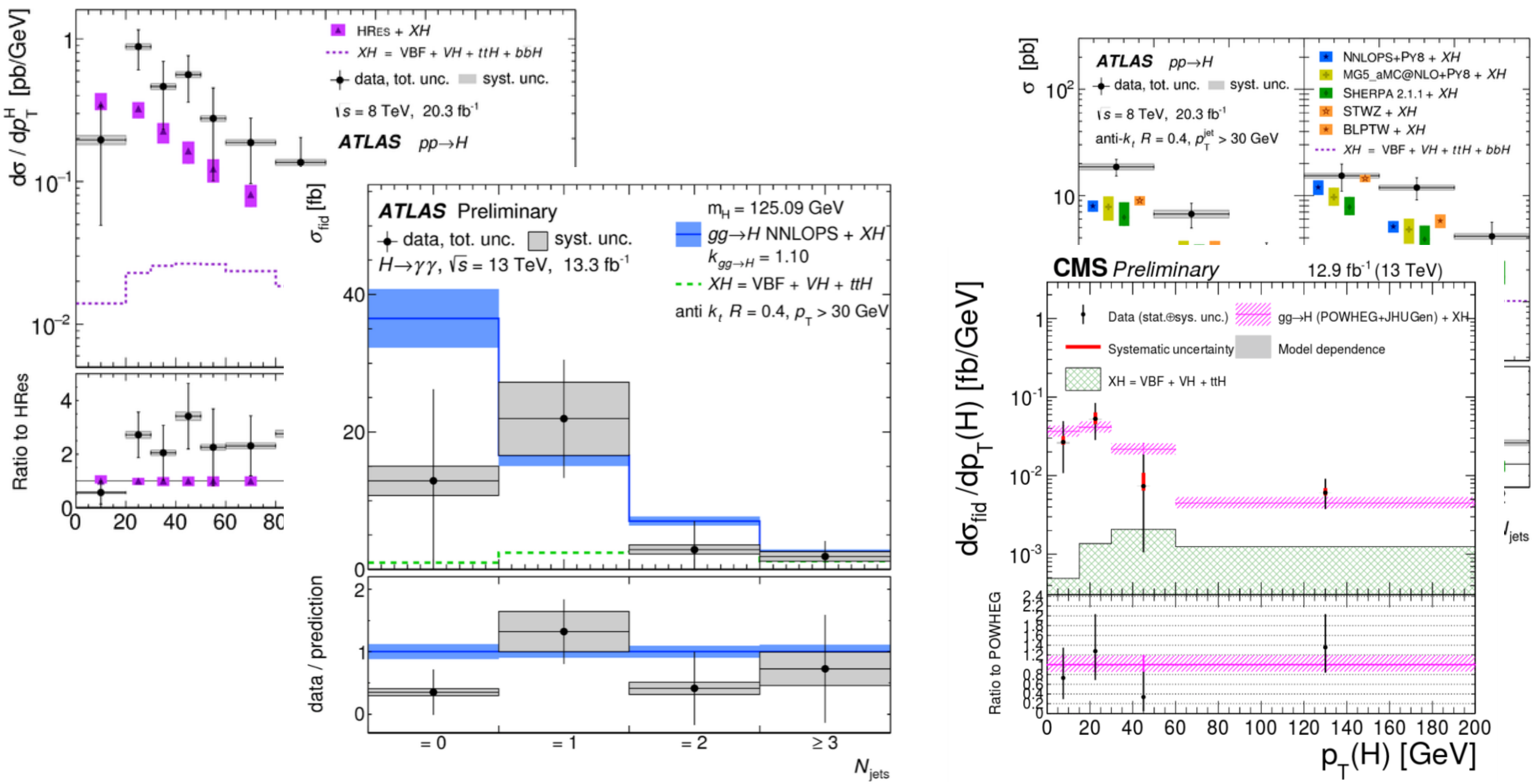
- if you repeat the calculation N times you find always the same result !
- but 100% exactly flat prior looks unrealistic

→ **New HXSWG recommendation:**

$$\sigma = 48.58\,\mathrm{pb}^{+2.22\,\mathrm{pb}\,(+4.56\%)}_{-3.27\,\mathrm{pb}\,(-6.72\%)}\ (\mathrm{theory}) \pm 1.56\,\mathrm{pb}\,(3.20\%)\ (\mathrm{PDF}+\alpha_s)$$

- Central value: stick to N3LO
- Theory Uncertainty: treat it as 100% flat and, when needed, symmetrise it and convert to a Gaussian by dividing by $\sqrt{3}$ → $\Delta_{th}=3.9\%$

Differential distributions



Will current theoretical accuracy be enough ? TH improvements in ggF may come from:

- going beyond the large-m_{top} limit
- compute further terms in the perturbative expansion

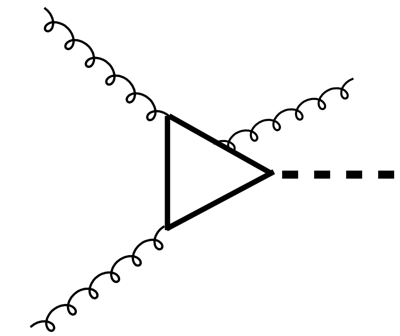
H+jet(s)

When the Higgs recoils against one parton the LO is of relative order α_S

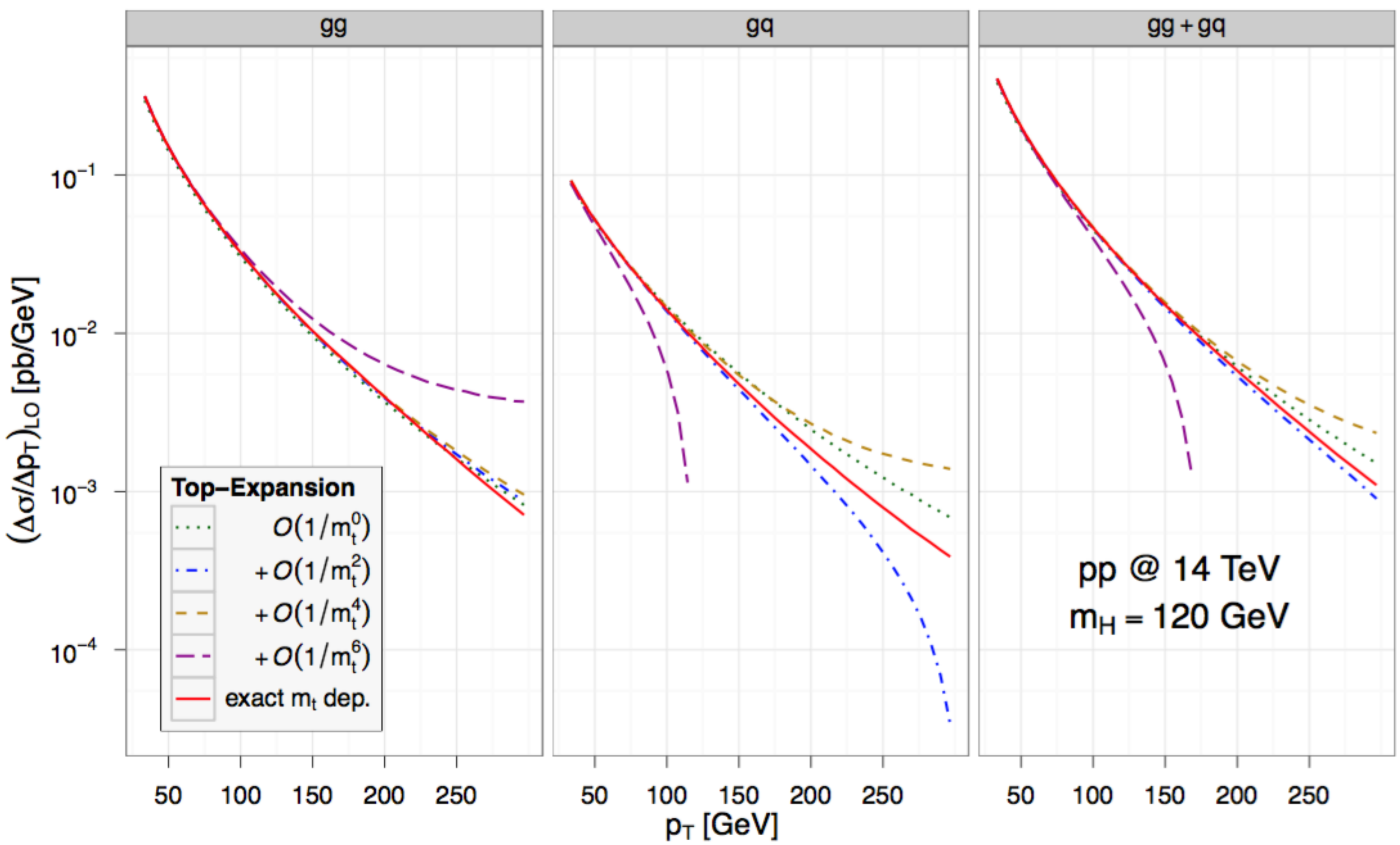
Exact result including mass dependence known for many years

Large-m_t expansion does not work so well as in the inclusive case

Bound to fail at high p_T (recoling radiation resolves the heavy-quark loop)



R.K.Ellis et al (1988);
U. Baur and E.W.N.Glover (1990)



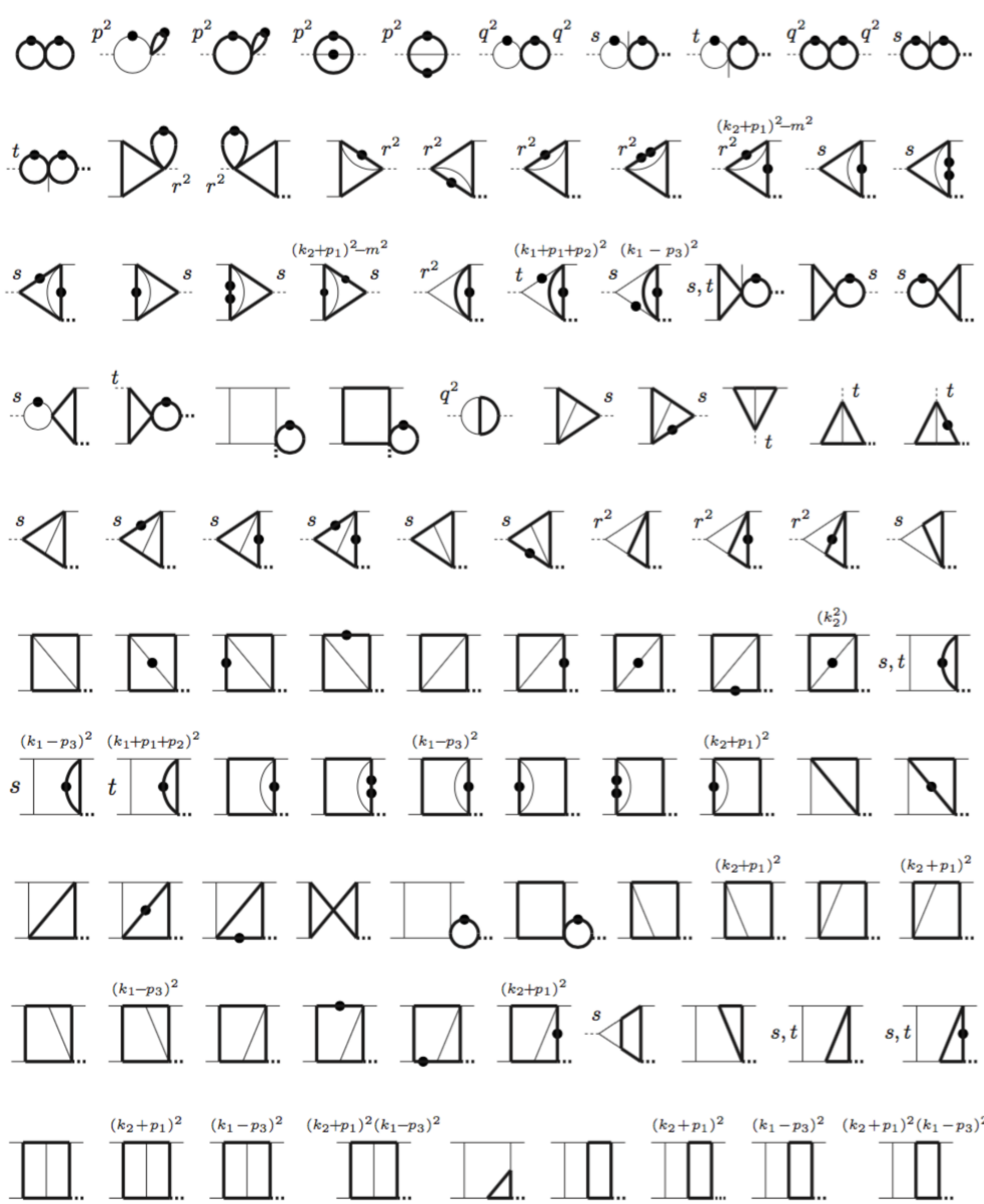
R.Harlander, T.Neumann,K.Ozeren, M.Wiesemann (2012)

NLO corrections are known only in the large-m_{top} approximation (part of inclusive NNLO cross section)

D. de Florian, Z.Kunszt, MG (1999)
V.Ravindran, J.Smith, V.Van Neerven (2002)
C.Glosser, C.Schmidt (2002)

Beyond the large-m_{top} limit

Exact calculation requires 2-loop amplitudes with different mass scales: this is at the forefront of current technologies !



Two-loop planar master integrals recently computed in terms of elliptic functions: this is an important first step

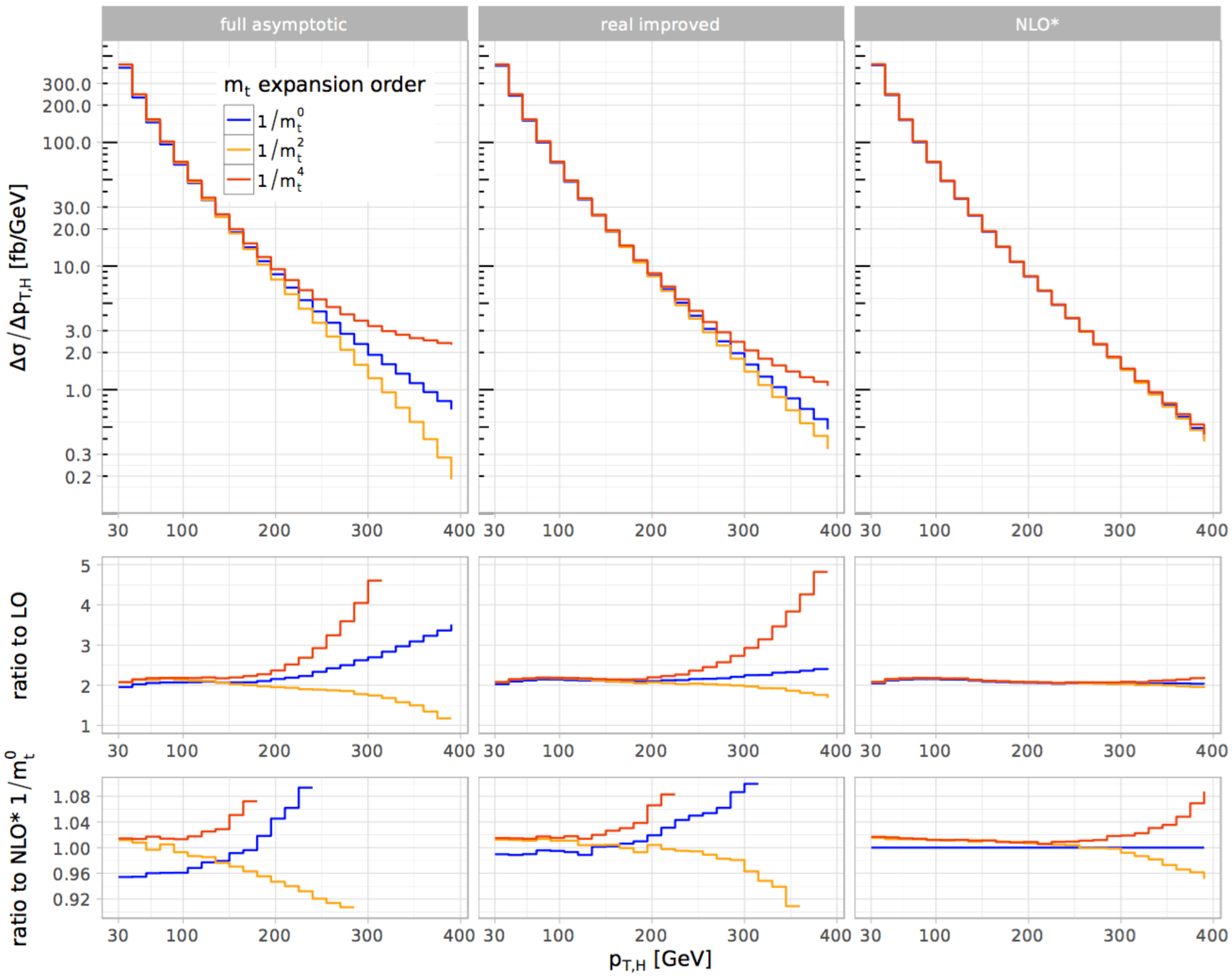
R.Bonciani et al. (2016)

Exciting but….not even enough to get the leading color contribution !

H+jet(s)

In the meanwhile: make the best use of what is available

T.Neumann, C.Williams (2016)



Compute the NLO corrections by using exact amplitudes when possible (plus expansion in $1/m_{top}$) for the finite part of the missing two loop amplitude

It pushes the reliability of the large-m_{top} approximation a bit further !

But at high-p_T the exact result is really needed !

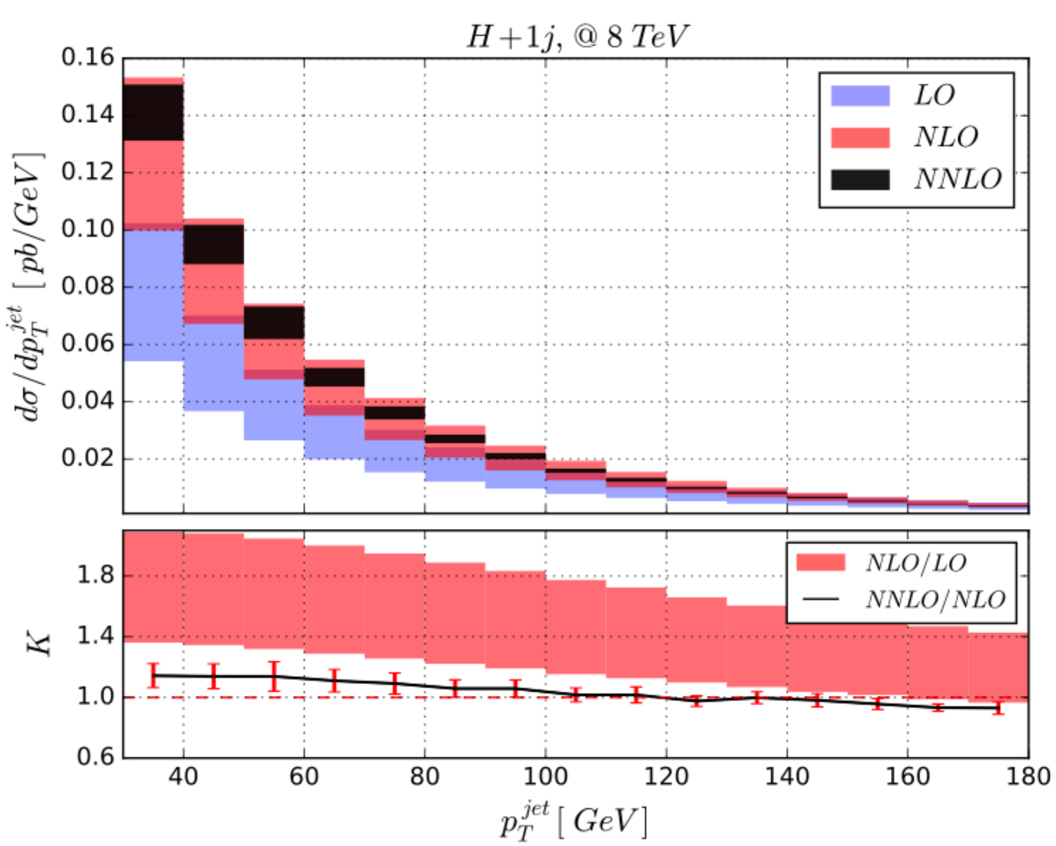
H+jet(s) at NNLO

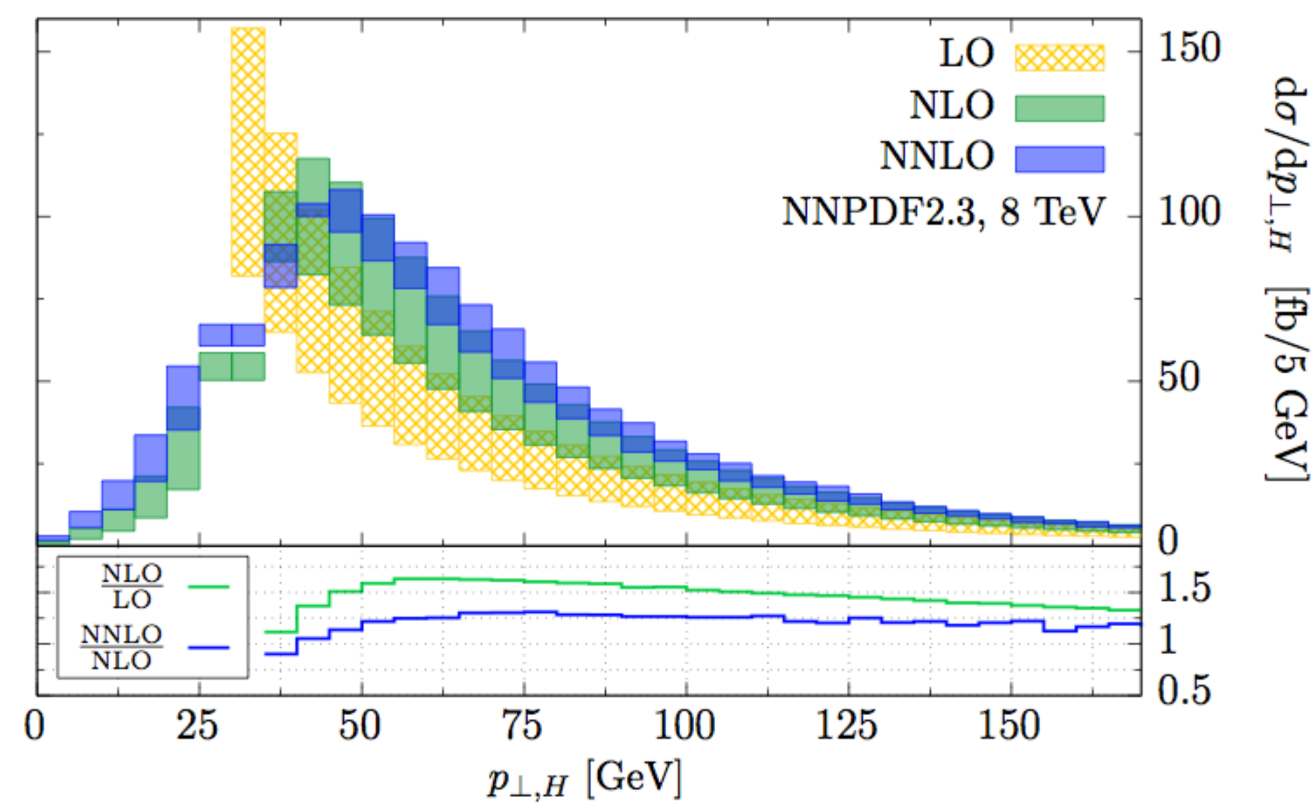
X. Chen, T. Gehrmann, N. Glover, M. Jaquier (2014,2016)
R.Boughezal, F.Caola, K.Melnikov, ,F.Petriello, M.Schulze (2015)
R.Boughezal, C.Focke, W.Giele ,X.Liu, F.Petriello (2015)

Fully differential NNLO computation for a 2→2 process

Calculation carried out with three independent methods (N-jettiness, antenna subtraction, sector improved residue subtraction)

Important to validate NNLO results for such a complex final state

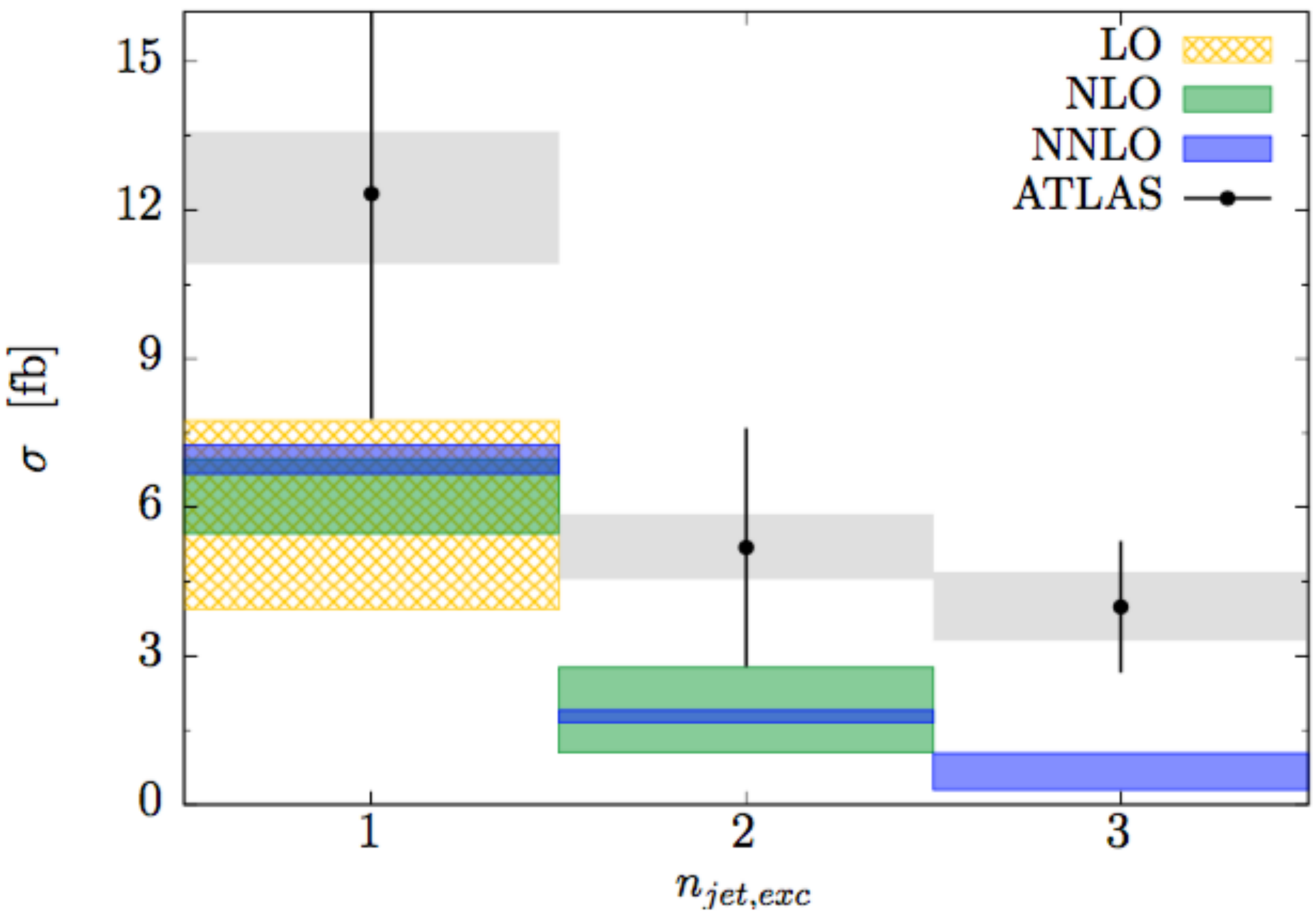




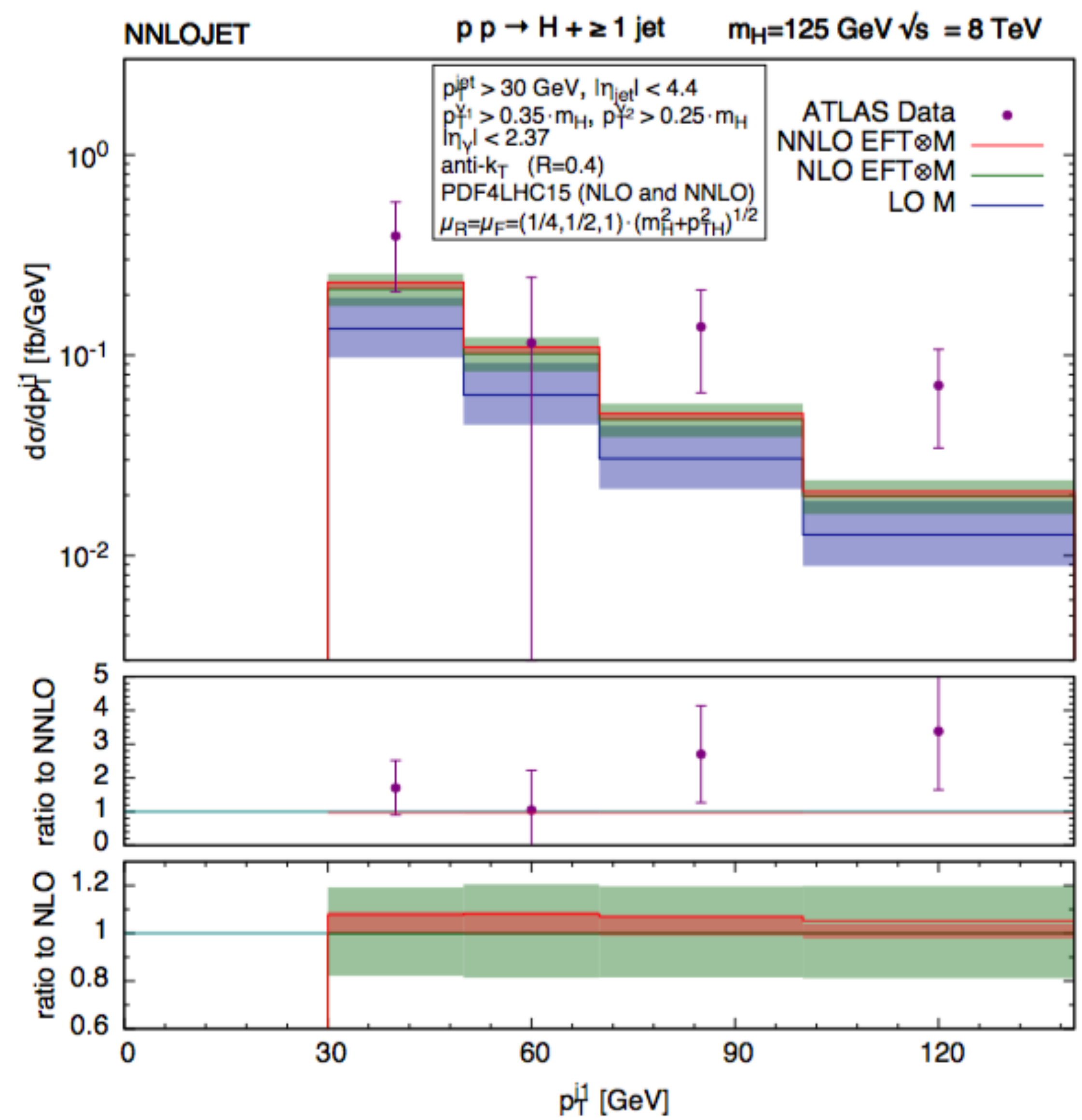
Same order in α_S as N3LO for the inclusive cross section

H+jet(s) at NNLO

Being fully differential the computation permits a direct comparison with data



F.Caola, K.Melnikov, M.Schulze (2015)



Wait for more data at 13 TeV

X. Chen, T. Gehrmann, N. Glover, M. Jaquier (2016)

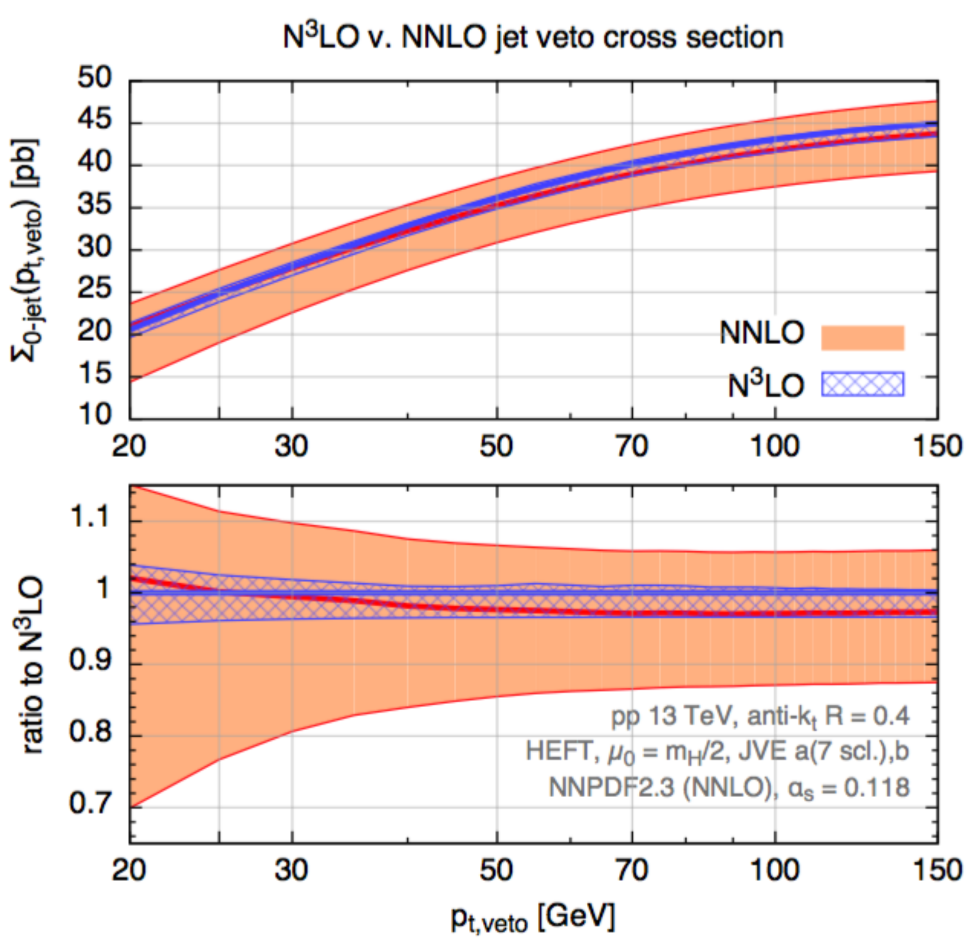
Jet-veto

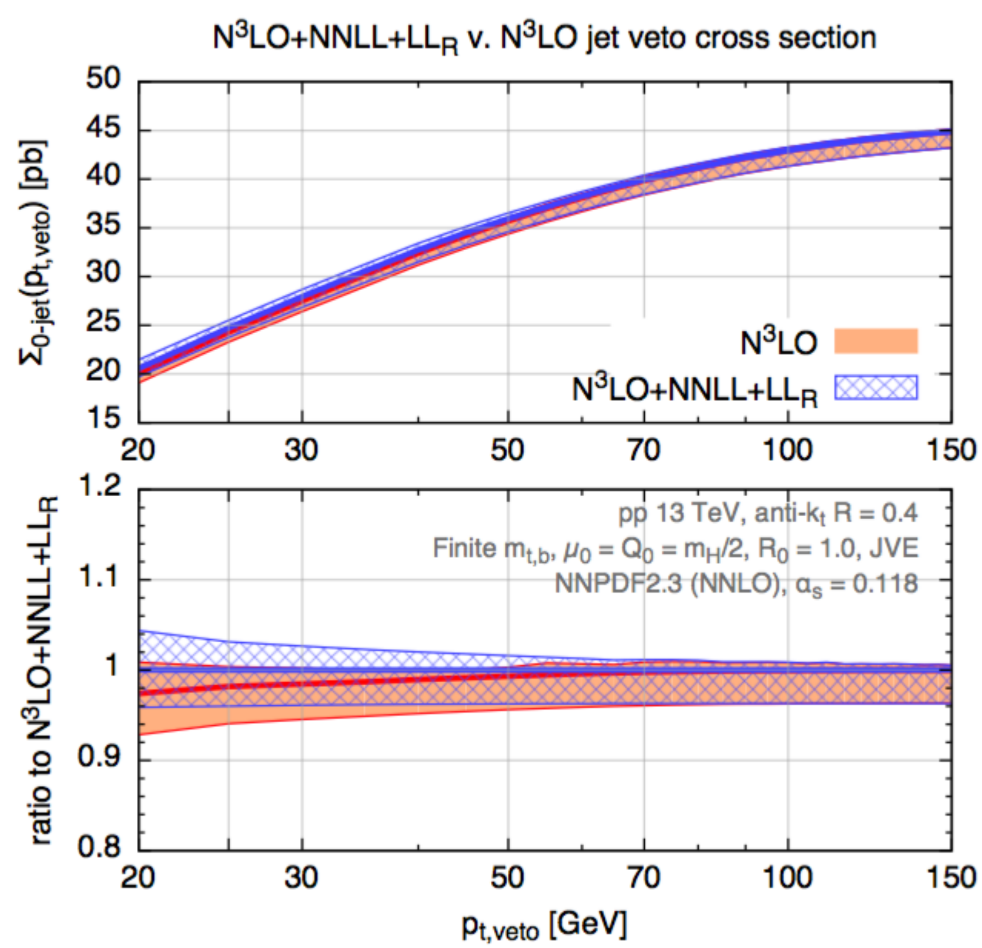
A. Banfi, F. Caola, F.A. Dreyer, P.F. Monni,
G.P. Salam, G. Zanderighi, F. Dulat (2016)

The cross section in the 0-jet bin can be obtained from the inclusive cross section by subtracting the H+jet(s) cross section at the same order in α_S

➡ It is now possible to obtain the 0-jet cross section at N^3LO

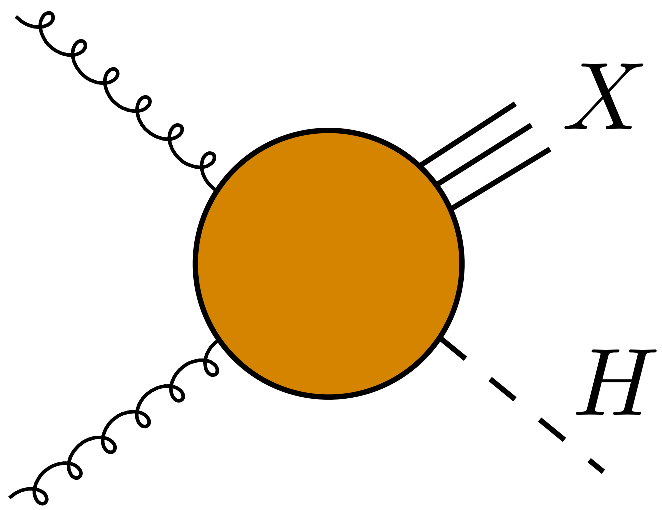
Combine with the jet-veto resummation at NNLL and LL resummation for the jet radius dependence





No breakdown of fixed-order calculation for $p_T = 30$ GeV

Transverse-momentum spectrum



When we are inclusive over the radiation recoiling against the Higgs boson we measure the p_T spectrum

Rapidity distribution mainly driven by PDFs

➡ Effect of QCD radiation mainly encoded in the p_T spectrum

Higgs production at high-p_T can be useful to test new physics scenarios

⟶ talk by M.Spira

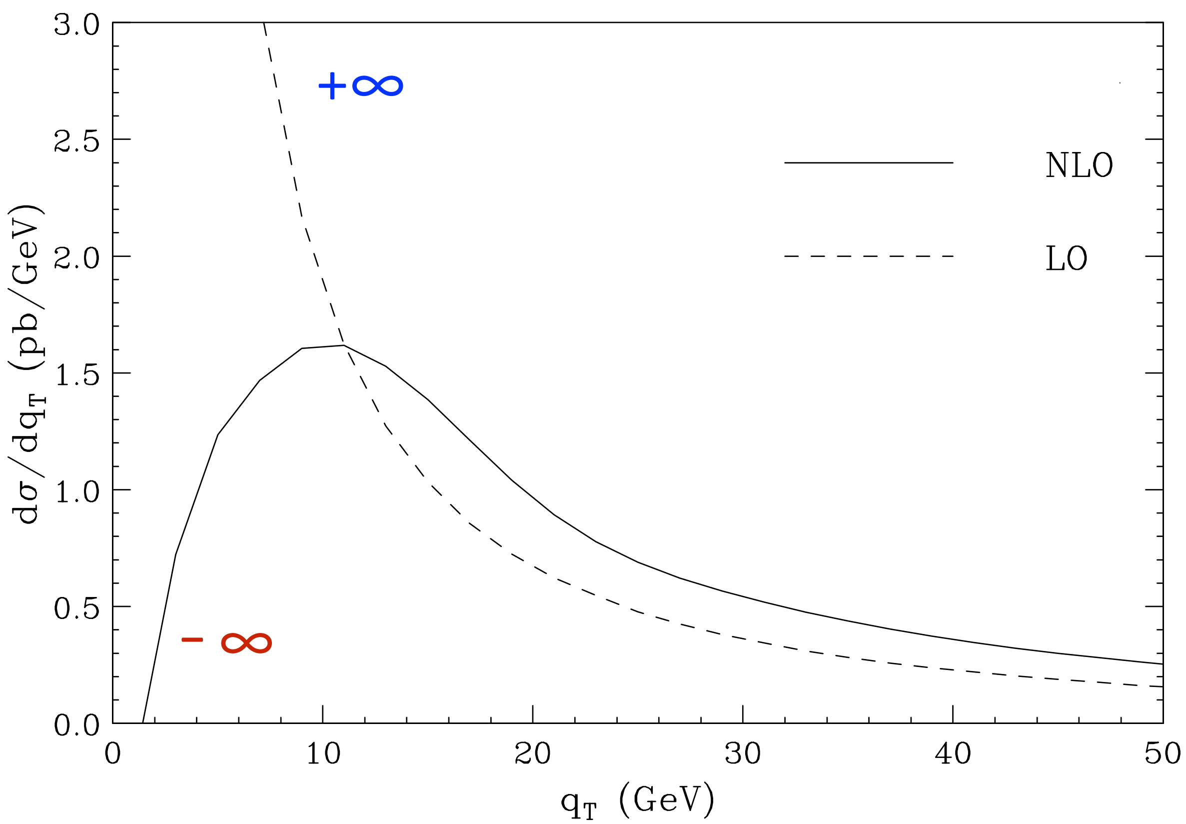
When considering the transverse momentum spectrum it is important to distinguish two regions of transverse momenta

The region $p_T \sim m_H$ can be described by fixed order H+jet(s) calculations

Transverse-momentum spectrum

In the region $p_T << m_H$ large logarithmic corrections of the form $\alpha_S^n \ln^m m_H^2/p_T^2$ appear that originate from soft and collinear emission

→ the perturbative expansion becomes not reliable



LO: $\frac{d\sigma}{dp_T} \to +\infty$ as $p_T \to 0$

NLO: $\frac{d\sigma}{dp_T} \to -\infty$ as $p_T \to 0$

→ **Resummation needed (effectively performed by standard MC generators)**

State of the art NNLL+NNLO results including mass effects available

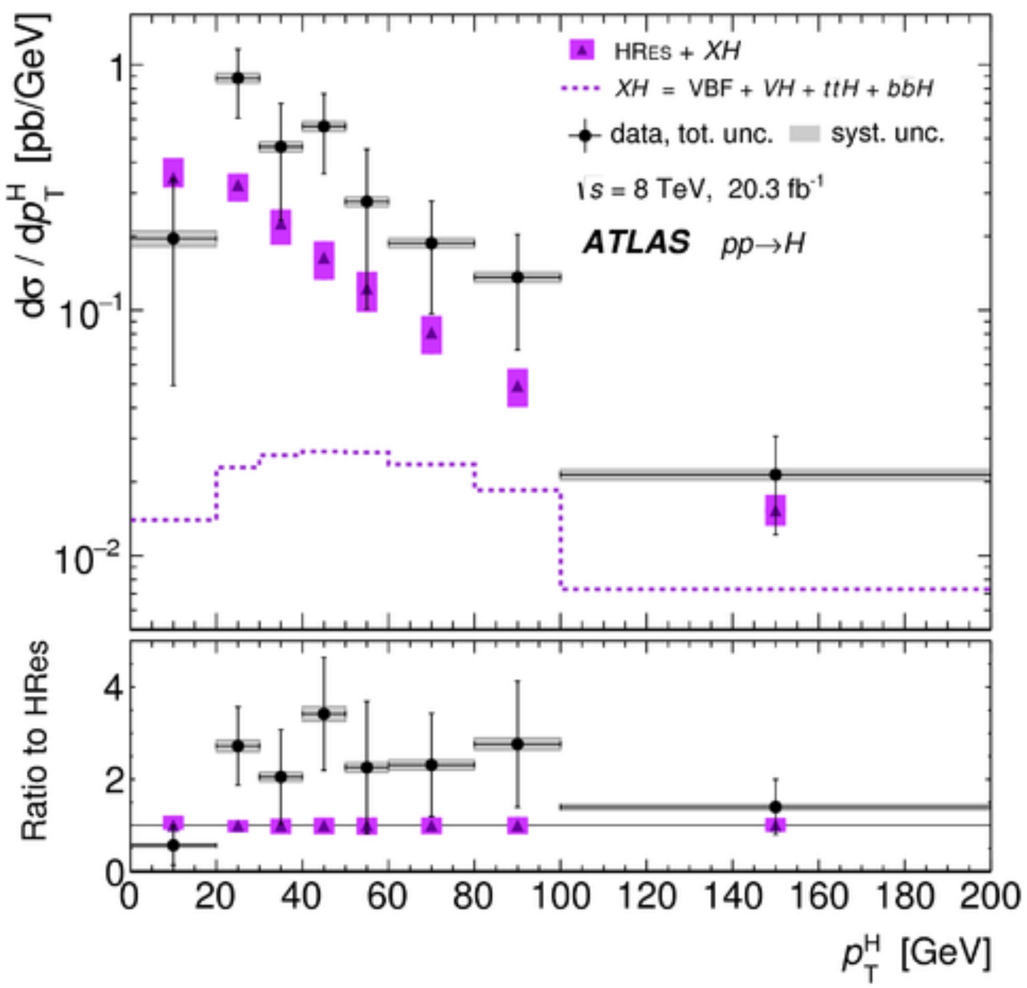
HRes: includes Higgs decays

D. de Florian, G.Ferrera, D. Tommasini, MG (2011)
H.Sargsyan, MG (2013)

Transverse-momentum spectrum

In the region $p_T \ll m_H$ large logarithmic corrections of the form $\alpha_S^n \ln^m m_H^2/p_T^2$ appear that originate from soft and collinear emission

→ the perturbative expansion becomes not reliable



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D. de Florian, G.Ferrera, D. Tommasini, MG (2011)
H.Sargsyan, MG (2013)

Beyond current accuracy

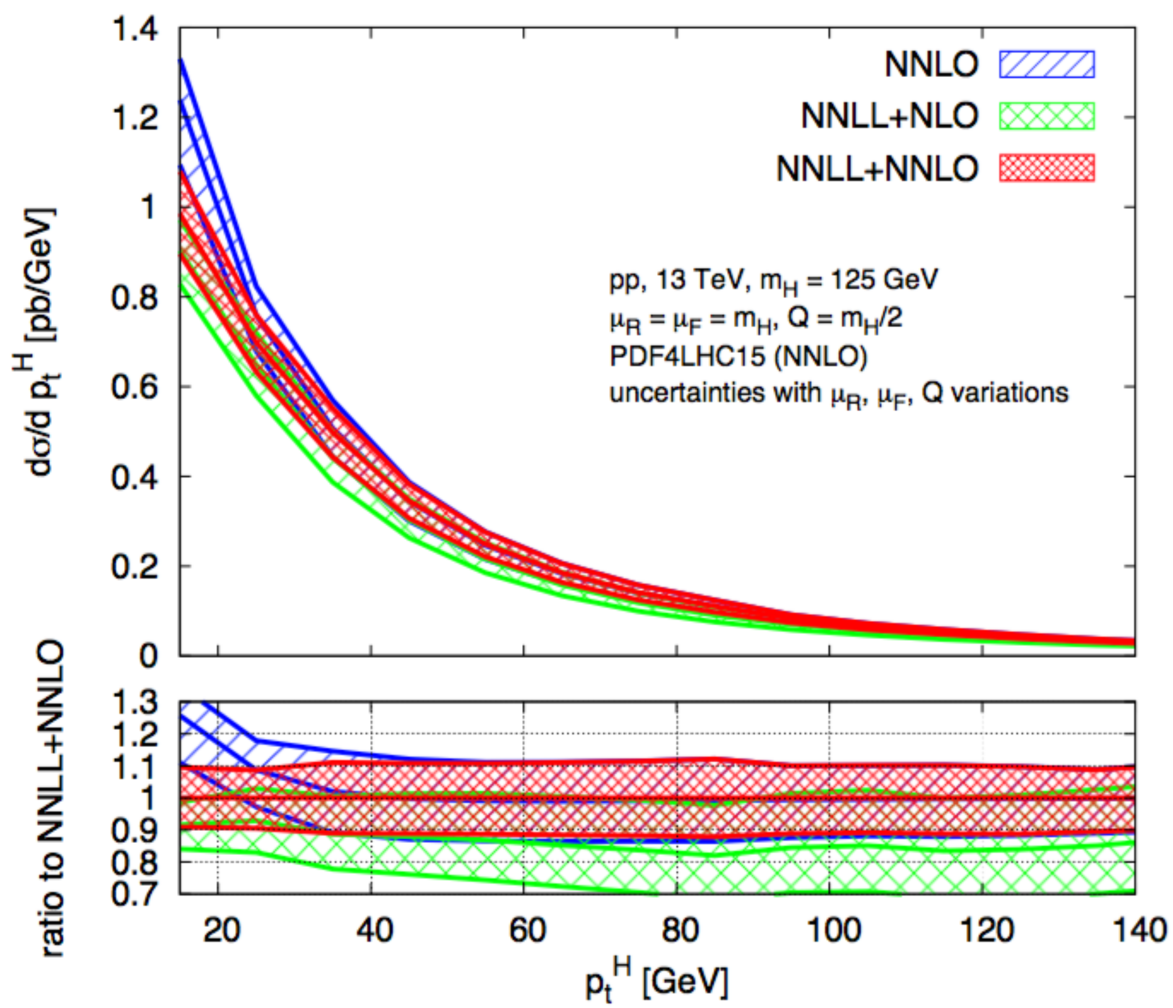
The H+jet calculation at NNLO can be used to improve the resummed calculation

First work in this direction has been presented recently

To match the resummed and fixed order calculations one needs to push the fixed order to the very low p_T region

The resummation coefficient required to do the matching has been recently computed

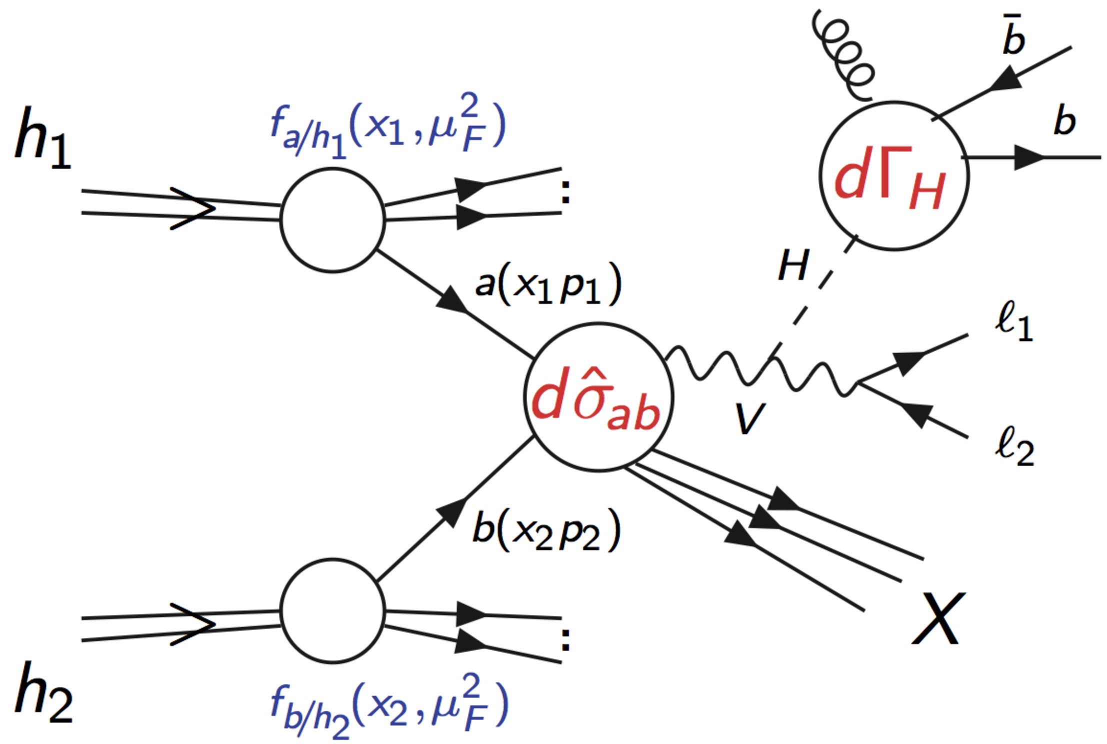
Y. Li and H. X. Zhu (2016)



P.Monni, E.Re,P.Torrielli (2016)

Progress can be expected in the near future

VH



Total cross section well under control (NNLO effects roughly the same as for Drell-Yan)

W.Van Neerven et al. (1991)
O.Brein, R.Harlander, A.Djouadi (2000)

Top mediated contributions (1-3%)

O.Brein, R.Harlander, M.Wiesemann, T.Zirke (2012)

gg→ZH loop induced (~ 5%)

B.Kniehl (1990)

NLO QCD+EW corrections available in HAWK A.Denner, S.Dittmaier, S.Kallweit,A.Muck (2012)

Fully differential NLO corrections to production and H→bb decay known

A.Banfi, J.Cancino (2012)

Fully differential NNLO corrections available in the program VHNNLO, also including H→bb decay at NLO

G.Ferrera, F.Tramontano, MG (2011,2014)

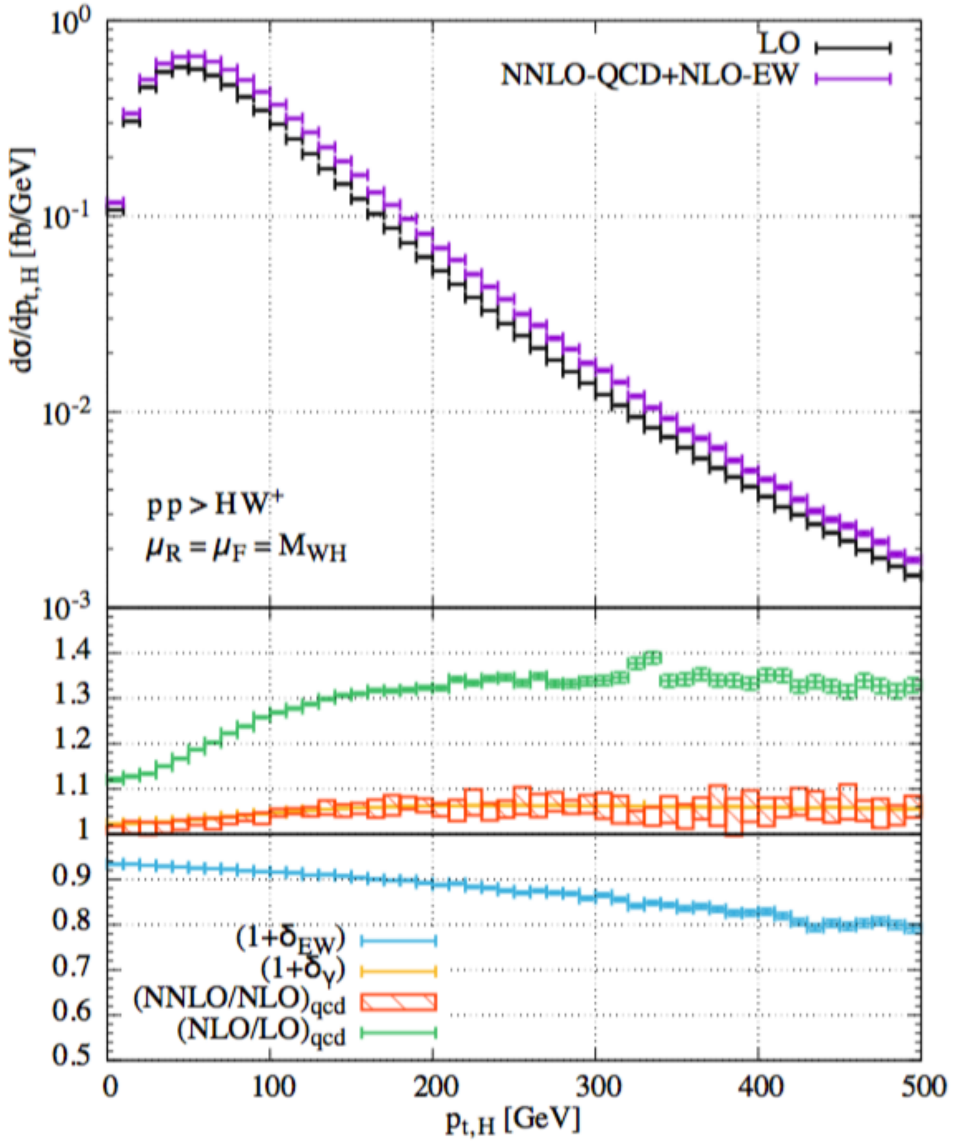
Differential NNLO H→bb decay rate also available

C.Anastasiou et al. (2012)
Z.Trocsanyi et al (2014)

NNLO corrections for production + NLO decay now also in MCFM

R.Boughezal et al (2016)

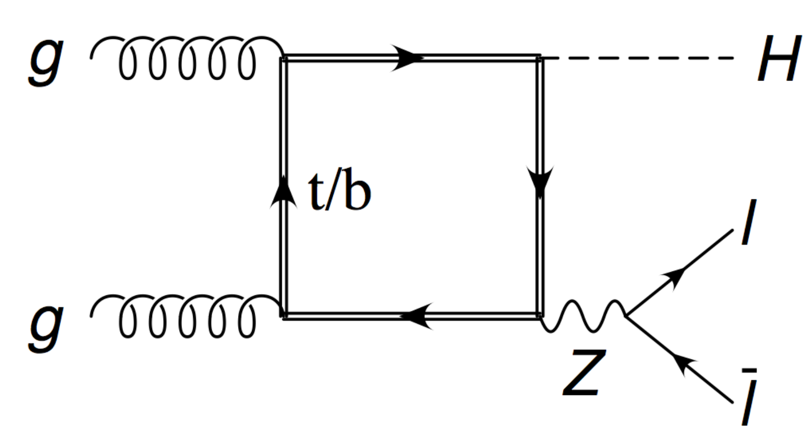
VH



S.Dittmaier et al. HXSWG YR4 (2016)

Fiducial and differential cross sections at NNLO QCD+NLO-EW obtained within the HXSWG (combination of VHNNLO and HAWK results)

The major problem for ZH is the gg induced loop contribution (first appears at NNLO and leader to large uncertainties !)



Impact of gg → ZH

σ (fb)	NLO	NNLO (DY-like)	NNLO
LHC8	$0.2820^{+2\%}_{-2\%}$	$0.2574^{+3\%}_{-4\%}$	$0.3112^{+3\%}_{-2\%}$
LHC14	$0.2130^{+10\%}_{-12\%}$	$0.1770^{+7\%}_{-6\%}$	$0.2496^{+5\%}_{-2\%}$

+21%

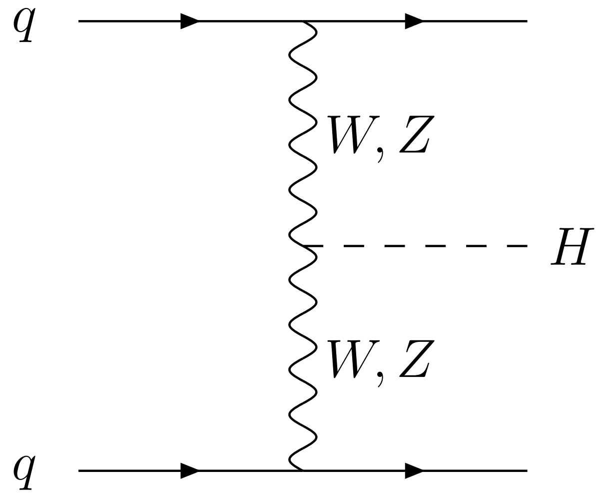
+41%

Very important in the boosted region

NLO corrections known only in large m_t limit (~100%)

L.Altenkamp et al. (2012)

VBF



Second important production channel: distinctive signature with little jet activity in the central rapidity region

QCD corrections at NLO of O(10%)

T. Han, S. Willenbrock (1991)
T. Figy, C. Oleari, D. Zeppenfeld (2003)
J. Campbell, K. Ellis (2003)

NLO QCD and EW interactions implemented in HAWK and VBFNLO: they tend to compensate each other

M.Ciccolini, A.Denner, S.Dittmaier (2007)

Other radiative contributions:

Interference with gluon fusion

Andersen, Binoth, Heinrich, Smillie (2007)
Andersen, Smillie (2008)
Bredenstein, Hagiwara, Jäger (2008)

Other refinements include some NNLO contributions like gluon-induced diagrams (well below 1%)

R.Harlander, J.Vollinga,M.Weber (2008)

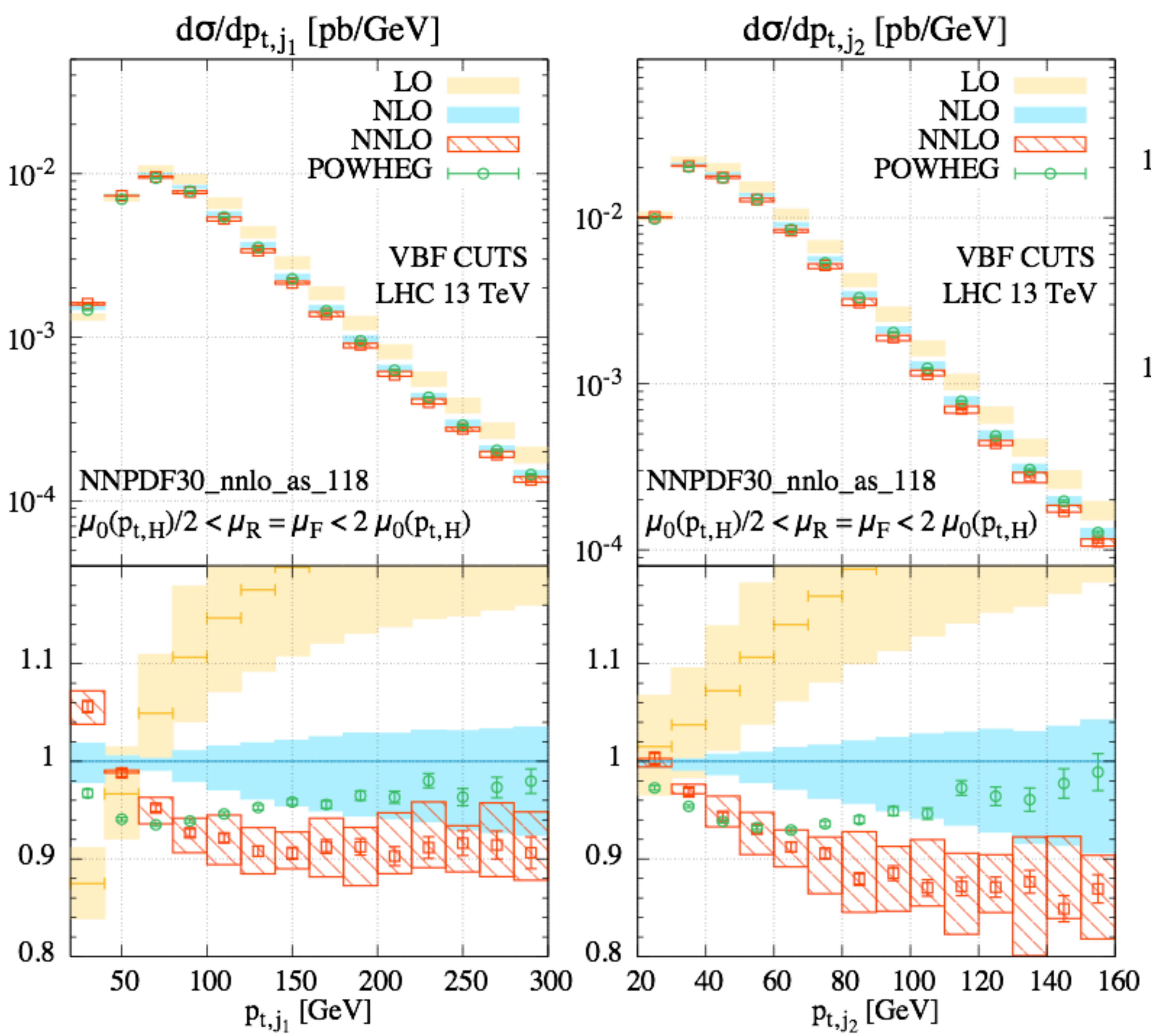
and the more relevant DIS like NNLO contributions computed within the structure function approach (1% effect)

P.Bolzoni, F.Maltoni, S.Moch, M.Zaro (2010)

Hjj in NLO+PS implemented in POWHEG and aMC@NLO

VBF

Theoretical control appears to be at the level of accuracy to which the process itself can be defined but....



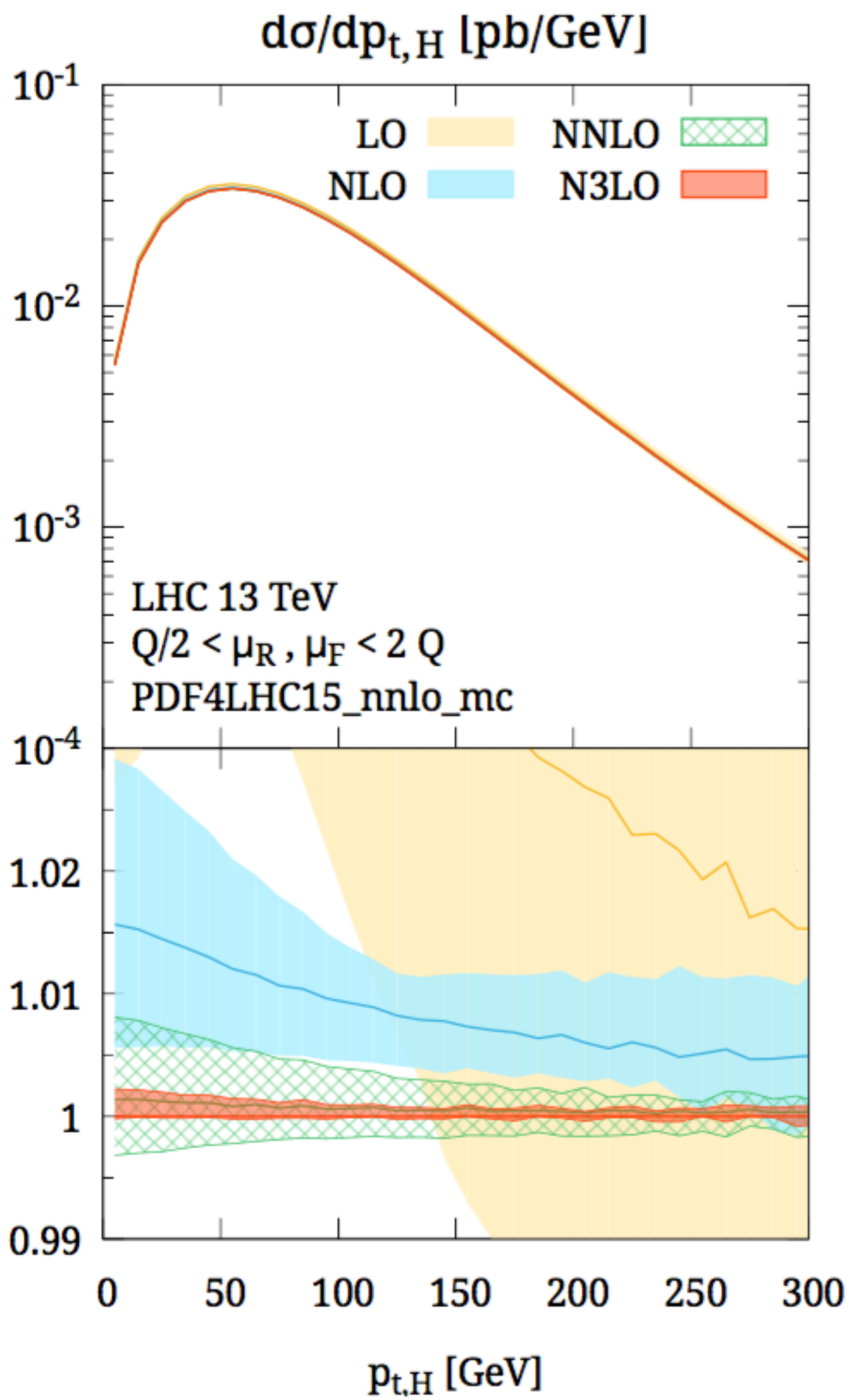
Fully exclusive NNLO computation recently completed shows that NNLO corrections make p_T spectra softer

➡ larger impact when VBF cuts are applied

	$\sigma^{(\text{no cuts})}$ [pb]	$\sigma^{(\text{VBF cuts})}$ [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	$3.888\,^{+0.016}_{-0.012}$	$0.826\,^{+0.013}_{-0.014}$
	-1%	-6%

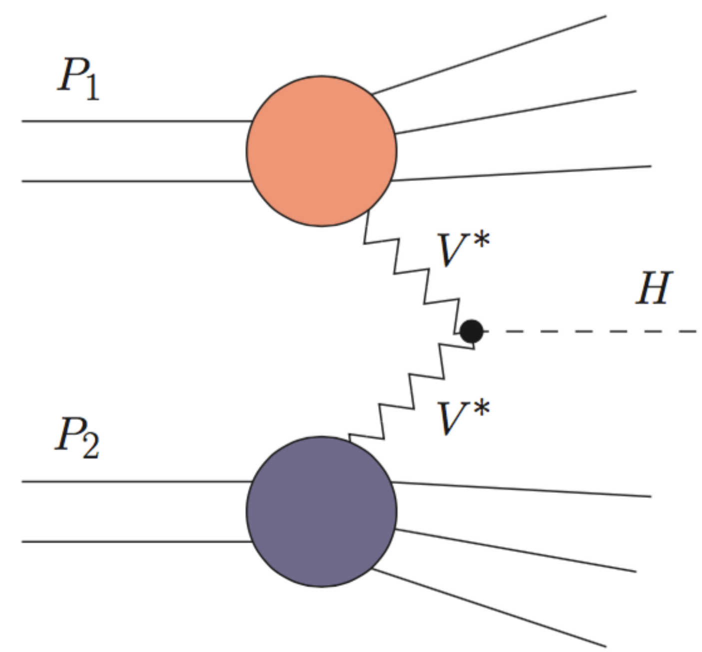
M.Cacciari, F.Dreyer, A.Karlberg, G.Salam, G.Zanderighi (2015)

VBF



Inclusive N3LO recently completed (still in the structure function approach: neglecting color connections between the upper and lower part of the diagrams)

F.Dreyer, A.Karlberg (2016)



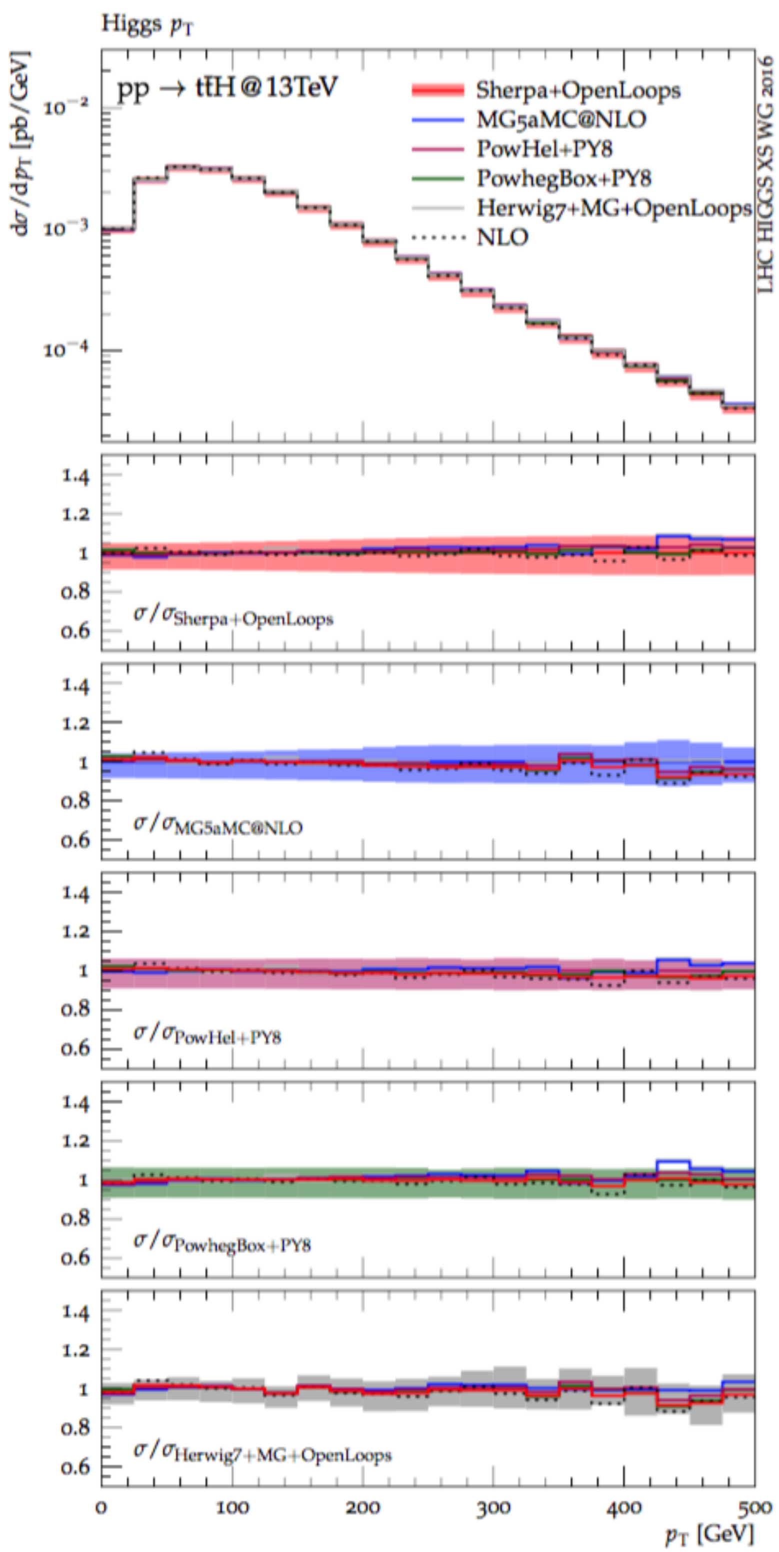
Residual scale uncertainty at the per mille level

Could potentially lead to a differential N3LO calculation with the same method adopted at NNLO

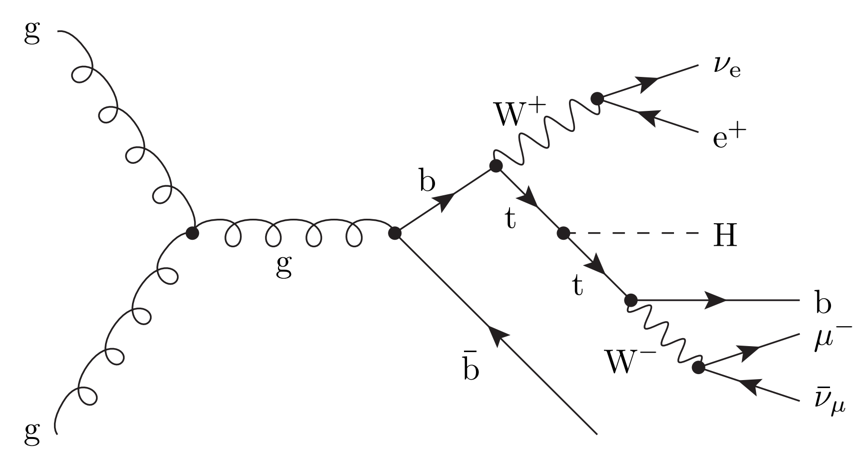
ttH

Total cross section known at NLO: uncertainties at the level of 9% (scale) and 8% (PDF+α_S)

W.Beenhakker et al. (2001)
S.Dawson, L.Reina (2002)



Realistic parton level simulations including top decays and all non-resonant contributions, off-shell effects and interferences



A.Denner , R.Feger (2015)

For both signal and backgrounds it is crucial to account for spin correlations

R.Frederix et al (2014)

Various NLO+PS implementations:

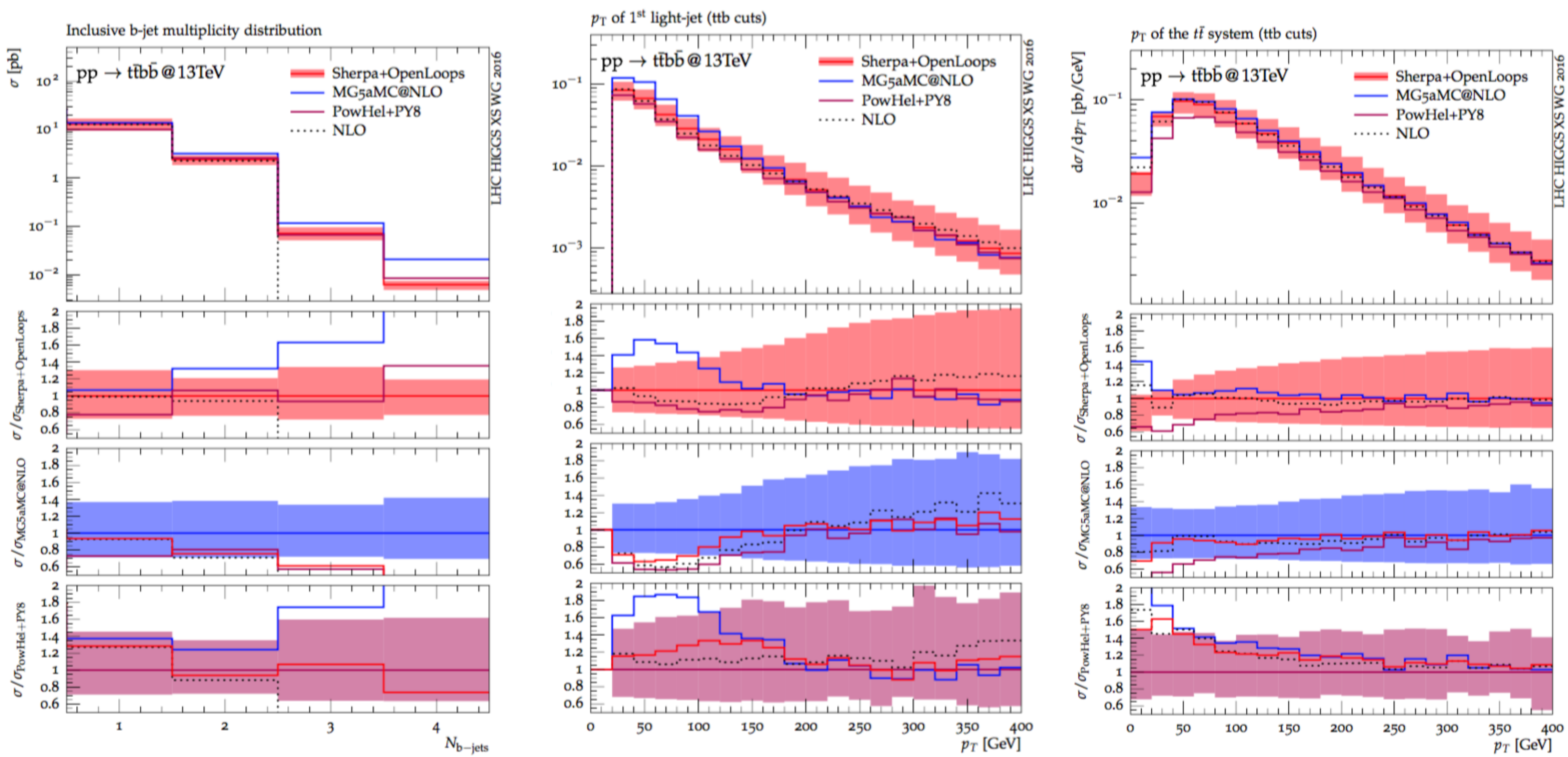
Validation for HXSWG YR4 → Good compatibility

QCD+EW corrections

S.Frixione et al (2014, 2015)
see also Z.Yu et al (2014)

ttH

Main problem is to reach a good understanding of backgrounds



S.Guidon,C.Neu , S.Pozzorini, L.Reina, YR4 HXSWG (2016)

NLO+PS simulations show some discrepancies: to be understood

NNLO+PS

NLO matching well established (MC@NLO, POWHEG, Sherpa....)
NNLO matching still in its infancy

NNLOPS: use MINLO to obtain a NLO generator for both H and H+jet(s)

Enforce correct NNLO normalisation by reweighing the inclusive rapidity distribution to a NNLO parton level calculation

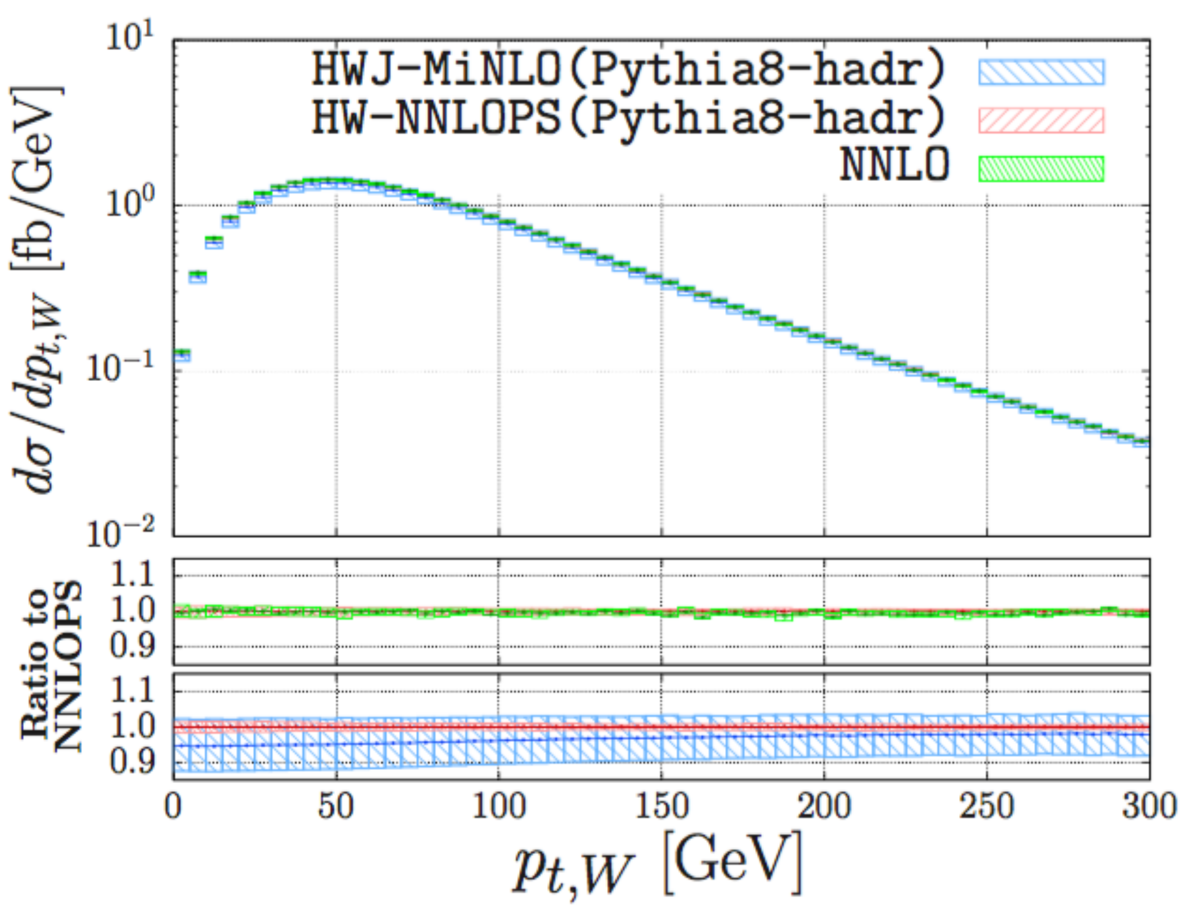
K.Hamilton, P.Nason,G.Zanderighi (2014,2015)

➡ This is enough to achieve NNLO accuracy

Done for gg→H and Drell-Yan

Now implemented also for WH

G.Zanderighi et al (2016)

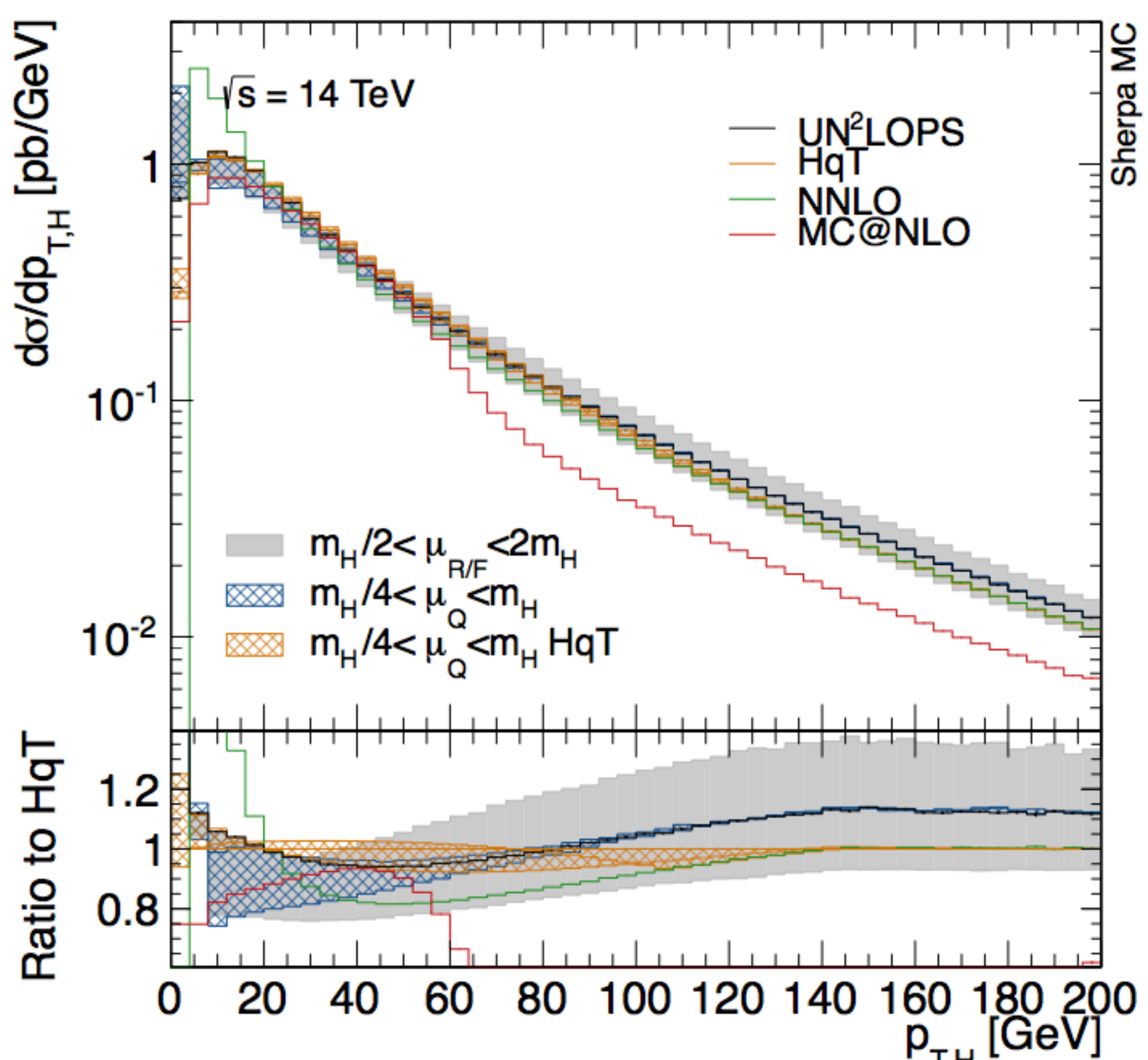


NNLO+PS

UN²LOPS: use S-MC@NLO + UNLOPS + q_T slicing

N.Lavesson, L.Lonnblad (2008)
S.Hoeche, Y.Li, S.Prestel (2014)

Start from S-MC@NLO simulation for H+jet(s) for $p_T > p_{T\,cut}$ and complement it with NNLO information below the cut



NNLO virtual corrections confined in the low p_T region while in the POWHEG-MINLO approach they are spread over the whole p_T region

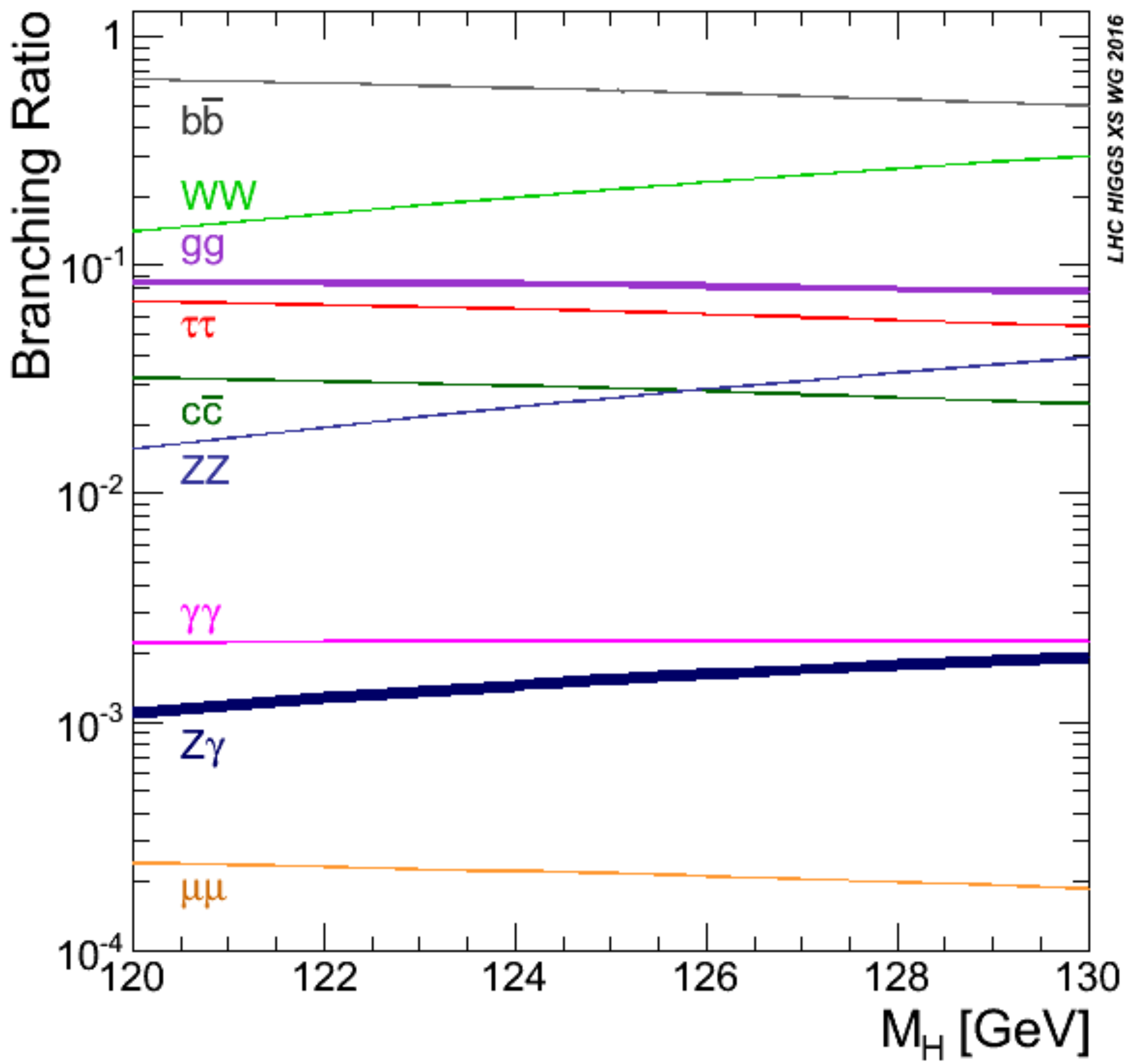
A third approach based on GENEVA has been implemented only for Drell-Yan

S.Alioli et al. (2016)

Still LL accuracy but improvements come from having full NNLO in

Higgs decays

A.Denner, S.Heinemeyer, A. Mück,
I.Puljak, D.Rebuzzi (HXSWG YR4, 2016)



Results based on HDECAY and Prophecy4f which include all relevant QCD and EW corrections

$$\Gamma_H = \Gamma^{HD} - \Gamma^{HD}_{ZZ} - \Gamma^{HD}_{WW} + \Gamma^{Proph.}_{4f}$$

New version of HDECAY includes EW corrections in fermionic decays and MSbar input masses

Higgs decays

For M_H = 125 GeV

YR3 → YR4

Channel	$\Delta\alpha_S$	Δm_b	Δm_c	THU
$b\bar{b}$	$^{-2.3\%}_{+2.3\%} \rightarrow ^{-1.4\%}_{+1.4\%}$	$^{+3.3\%}_{-3.2\%} \rightarrow ^{+1.7\%}_{-1.7\%}$	$^{+0.0\%}_{-0.0\%}$	$^{+2.0\%}_{-2.0\%} \rightarrow ^{+0.5\%}_{-0.5\%}$
$\tau\tau$	$^{+0.0\%}_{-0.0\%}$	$^{+0.0\%}_{-0.0\%}$	$^{+0.0\%}_{-0.0\%}$	$^{+2.0\%}_{-2.0\%} \rightarrow ^{+0.5\%}_{-0.5\%}$
$\mu\mu$	$^{+0.0\%}_{-0.0\%}$	$^{+0.0\%}_{-0.0\%}$	$^{+0.0\%}_{-0.0\%}$	$^{+2.0\%}_{-2.0\%} \rightarrow ^{+0.5\%}_{-0.5\%}$
$c\bar{c}$	$^{-7.1\%}_{+7.0\%} \rightarrow ^{-1.9\%}_{+1.9\%}$	$^{+0.0\%}_{-0.0\%}$	$^{+6.2\%}_{-6.1\%} \rightarrow ^{+5.3\%}_{-5.2\%}$	$^{+2.0\%}_{-2.0\%} \rightarrow ^{+0.5\%}_{-0.5\%}$
gg	$^{+4.2\%}_{-4.1\%} \rightarrow ^{+3.0\%}_{-3.0\%}$	$^{+0.1\%}_{-0.1\%}$	$^{+0.0\%}_{-0.0\%}$	$^{+3.0\%}_{-3.0\%}$
$\gamma\gamma$	$^{+0.0\%}_{-0.0\%}$	$^{+0.0\%}_{-0.0\%}$	$^{+0.0\%}_{-0.0\%}$	$^{+1.0\%}_{-1.0\%}$
$Z\gamma$	$^{+0.0\%}_{-0.0\%}$	$^{+0.0\%}_{-0.0\%}$	$^{+0.0\%}_{-0.0\%}$	$^{+5.0\%}_{-5.0\%}$
WW	$^{+0.0\%}_{-0.0\%}$	$^{+0.0\%}_{-0.0\%}$	$^{+0.0\%}_{-0.0\%}$	$^{+0.5\%}_{-0.5\%}$
ZZ	$^{+0.0\%}_{-0.0\%}$	$^{+0.0\%}_{-0.0\%}$	$^{+0.0\%}_{-0.0\%}$	$^{+0.5\%}_{-0.5\%}$

D.Rebuzzi, HXSWG meeting, july 2016

Significant reduction of PU and TH uncertainties on the partial widths

Off-shell Higgs

Most of Higgs studies performed so far involve on-shell Higgs bosons

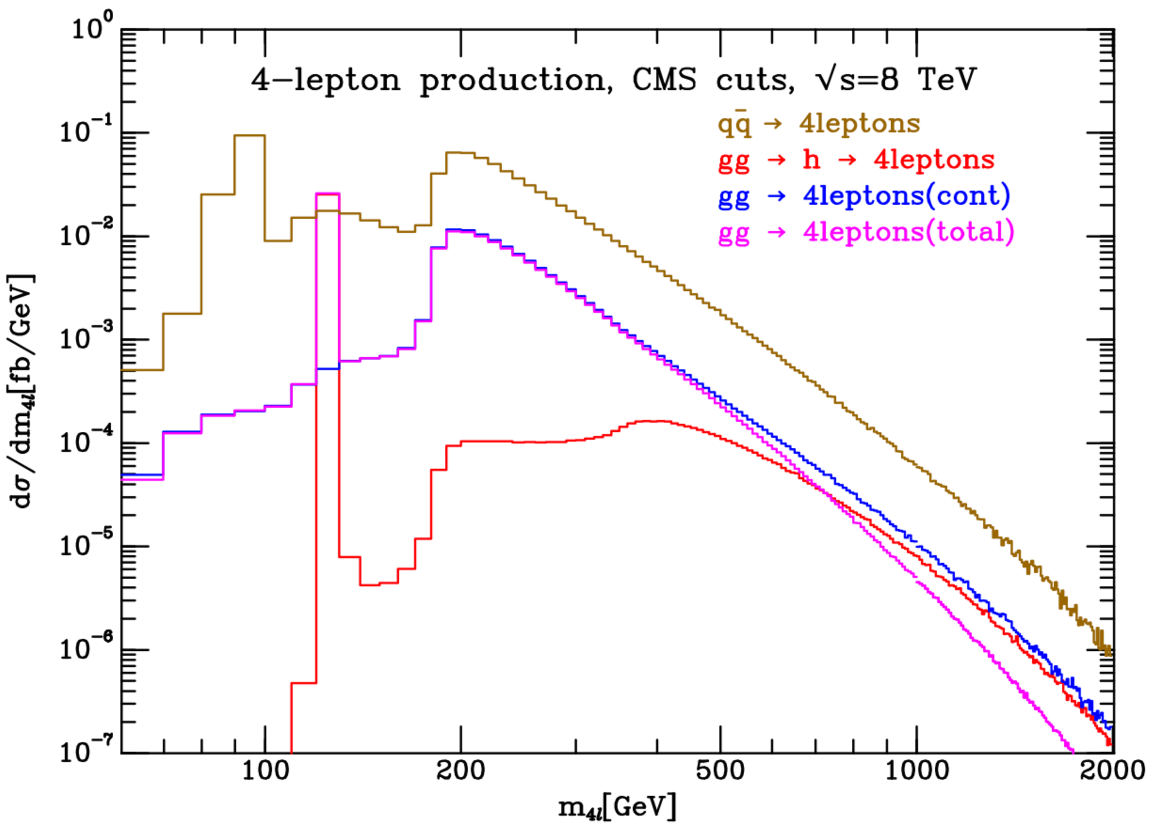
➡ This is because the on-shell signal is by far the cleanest and dominant

But for the process $i \to H \to j$ the on-shell cross section is $\sigma_{\text{on-shell}} \sim (g_i\, g_j)^2 / \Gamma_H$: impossible to study Higgs couplings and width separately

Off-shell production allows us to break this degeneracy since the corresponding cross section is independent on the width $\sigma_{\text{off-shell}} \sim (g_i\, g_j)^2$

➡ Ratio $\sigma_{\text{off-shell}} / \sigma_{\text{on-shell}}$ is thus sensitive to Γ_H

F.Caola,K.Melnikov (2013)



In the off-shell region the effect of the interference is large and negative

Off-shell measurements thus rely on good knowledge of SM prediction in this region

N.Kauer, G.Passarino (2012)
J.Campbell,K.Ellis,C.Williams (2013)

Possible also in VBF

J.Campbell, K.Ellis (2015)

Off-shell Higgs

Further progress in the off-shell region requires improved predictions for ZZ background and signal background interference

NNLO predictions for qqbar→ZZ

F.Cascioli, T.Gehrmann, S.Kallweit, P. Maierhöfer, A. von Manteuffel, S.Pozzorini, D.Rathlev, L.Tancredi, E. Weihs, MG(2014)

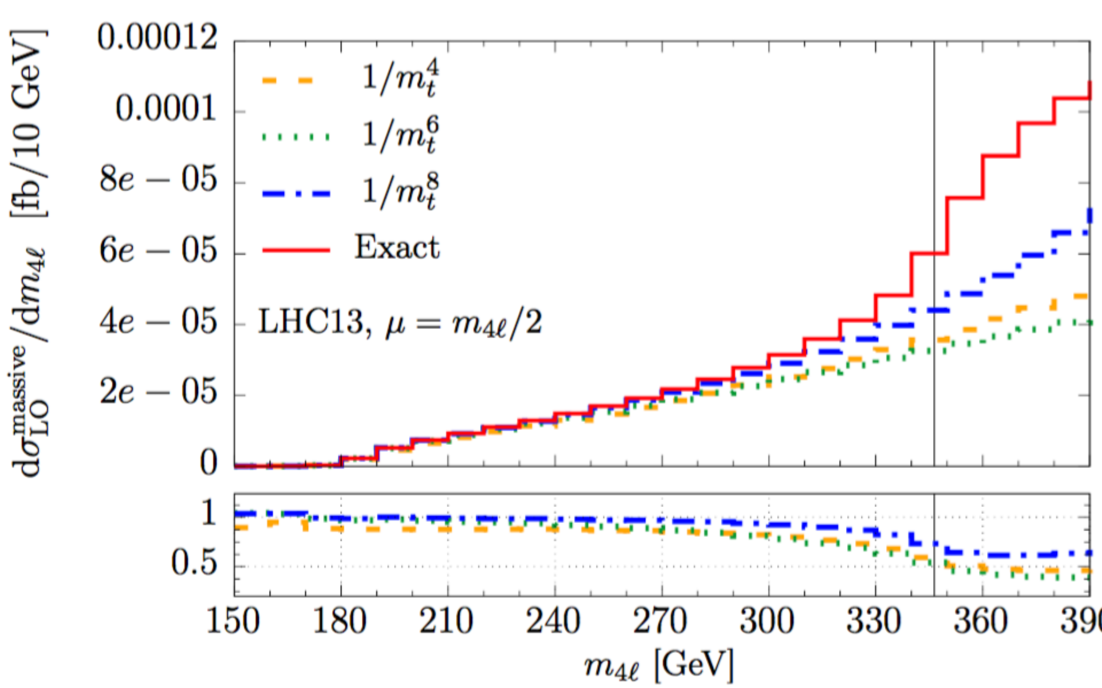
Two-loop amplitudes for gg→ZZ available

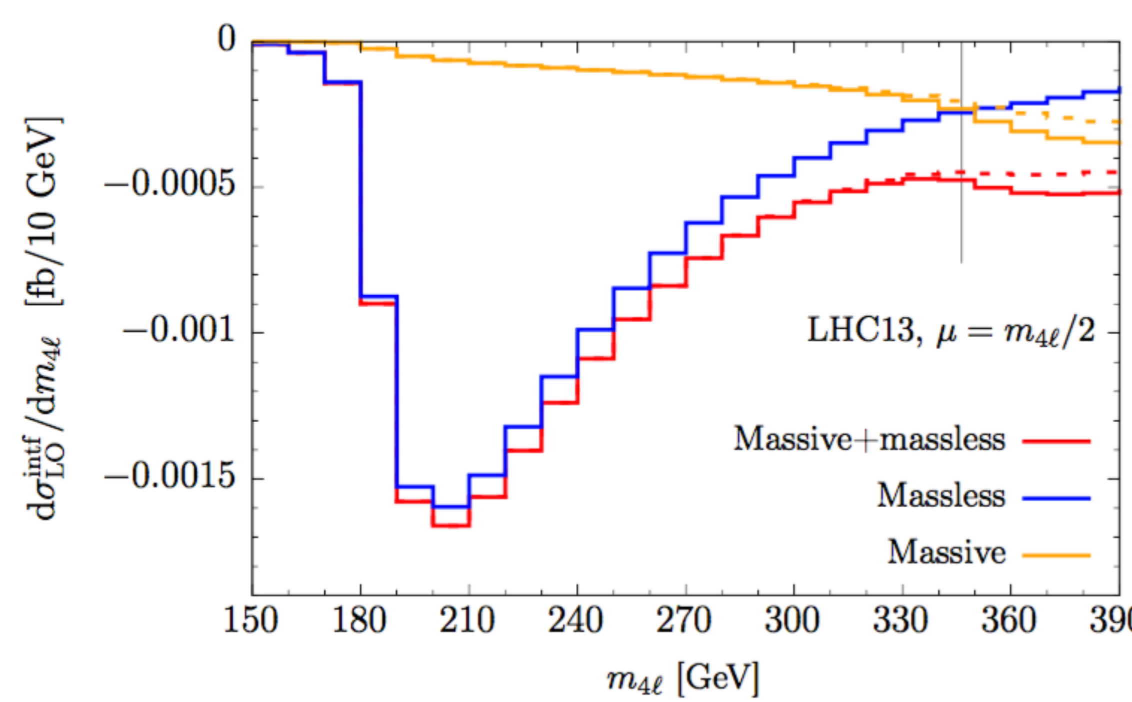
F.Caola et al. (2015)
A. von Manteuffel, L.Tancredi (2015)

→ NLO calculations for gg→ZZ and interference now possible (with massless quarks in the two-loop diagrams)

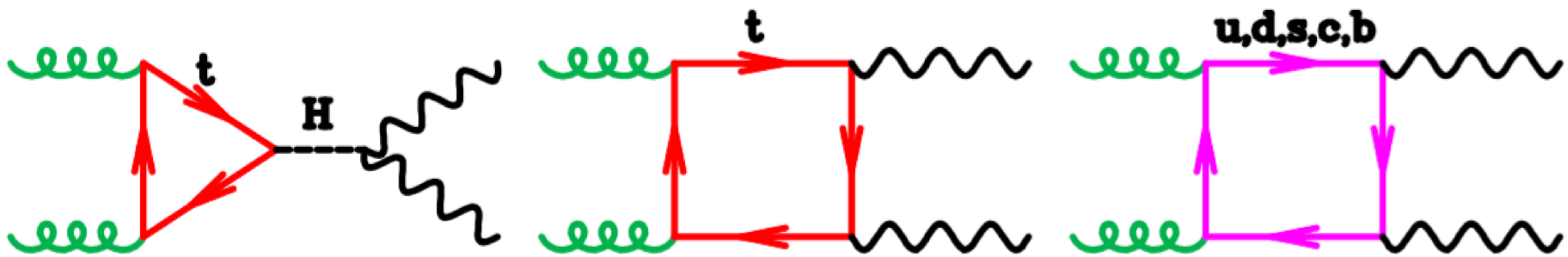
Top-quark contributions important for the interference

M.Dowling, K.Melnikov (2015)



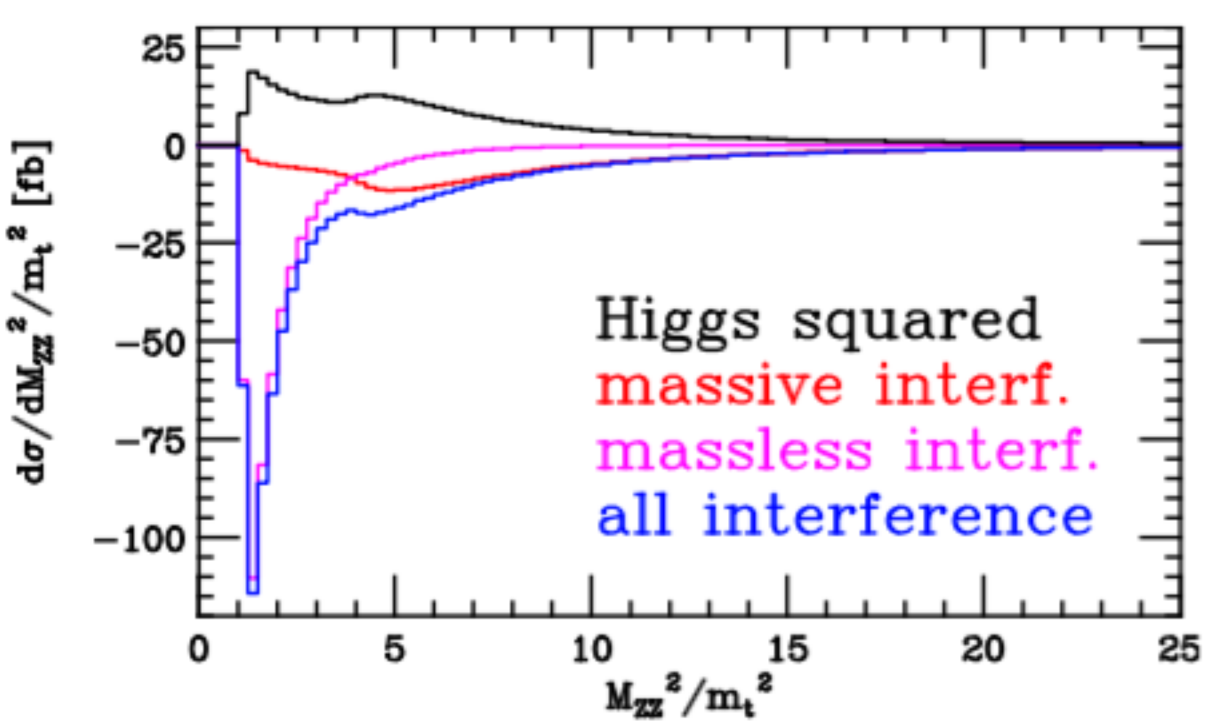


Off-shell Higgs



NLO corrections recently computed by two groups

1) On-shell vector bosons but extrapolation of the top quark contribution beyond the $2m_{top}$ threshold



Impact of NLO corrections in the high mass region identical to that for the Higgs signal

J.Campbell, M.Czakon, K.Ellis, S.Kirchner (2016)

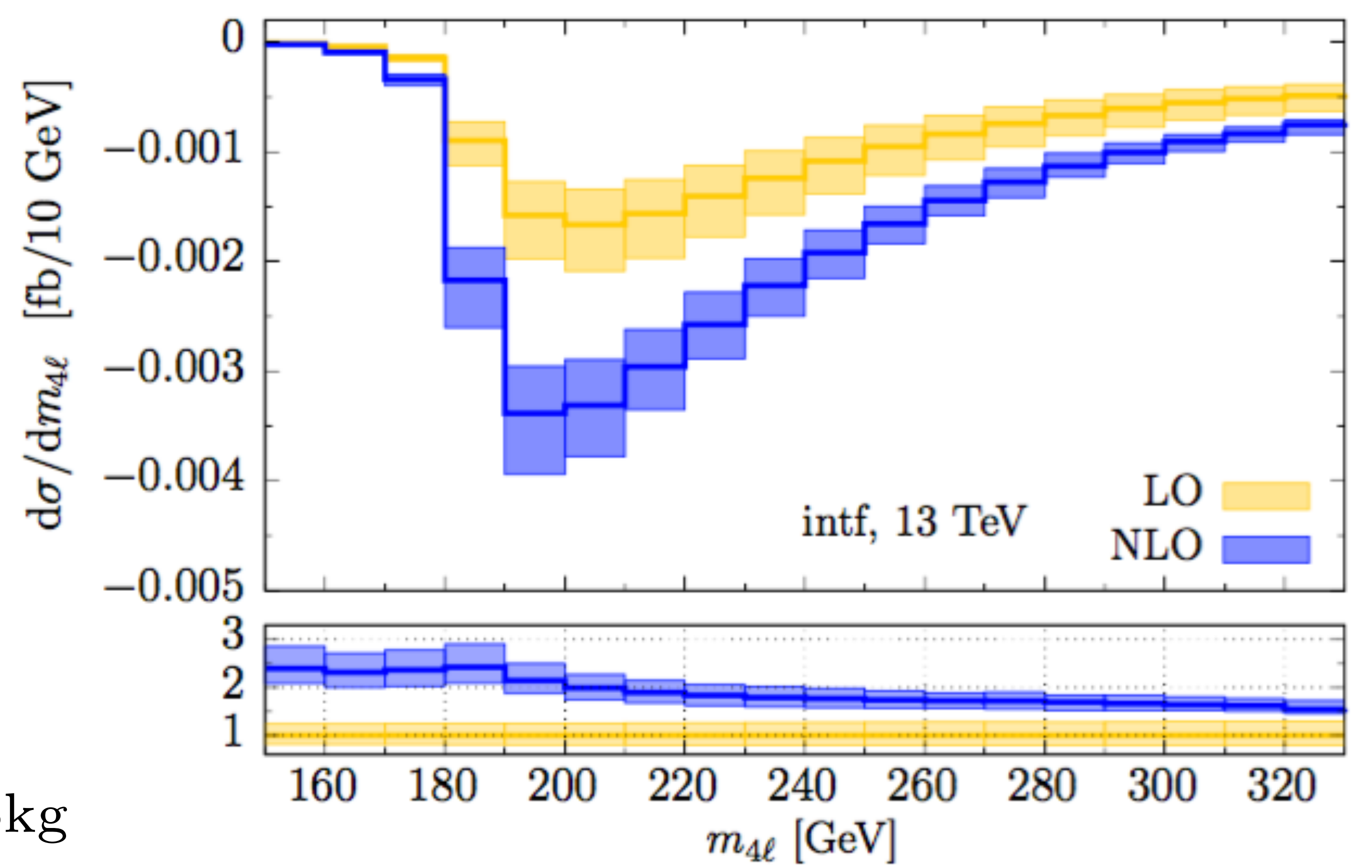
Off-shell Higgs

2) Including the leptonic decay but with the top quark contributions traded as an expansion in $1/m_{top}$

Results strictly valid only below the top threshold

The naive expectation

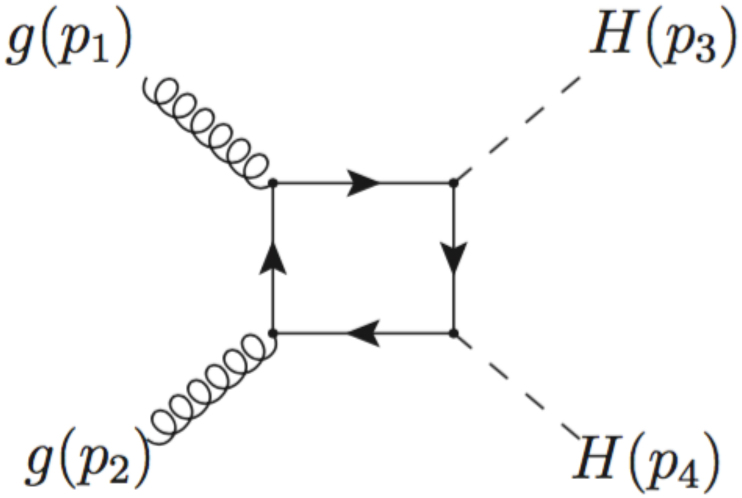
$$K_{\rm int} \sim \sqrt{K_{\rm sig} K_{\rm bkg}}$$

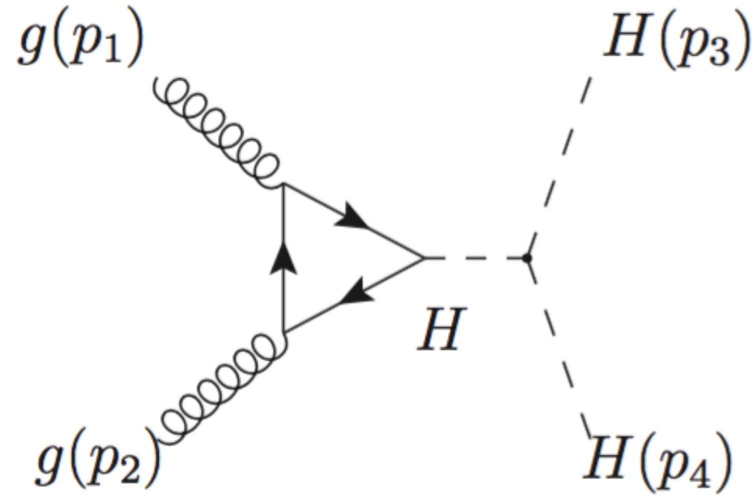


Seems to be valid both locally and globally except around the ZZ threshold, where $K_{\rm int} > K_{\rm sig}, K_{\rm bkg}$

F.Caola, M.Dowling, K.Melnikov, R.Röntsch, L.Tancredi (2016)

Double Higgs production





Large cancellations and small available phase space makes rate very small

It is the process that gives direct access to the Higgs self coupling λ

Up to very recently QCD corrections at NLO and NNLO known only in the large-m_{top} approximation

S.Dawson,S.Dittmaier,M.Spira (1998)
D. de Florian, J.Mazzitelli (2013)

NNLL resummation available

D. de Florian, J.Mazzitelli (2015)

Main issue: large-m_{top} approximation known not to work so well

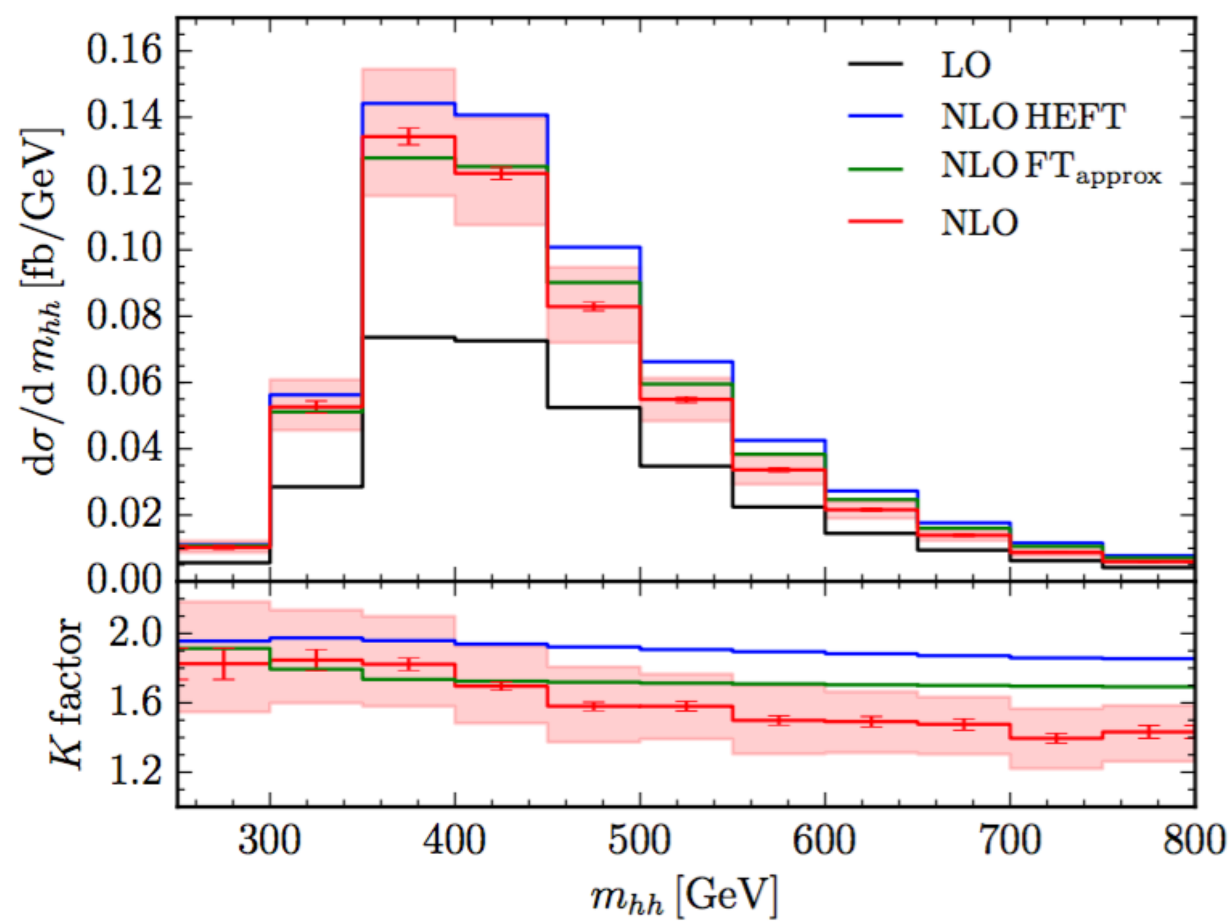
J.Grigo et al. (2013)

Double Higgs production

Recent breakthrough: exact NLO calculation completed

S.Borowka et al (2016)

Multi scale two-loop integrals evaluated numerically



Accurate predictions must account for exact NLO

Promising for other important multi scale NLO calculations (H +jet, gg→ZH...)

Mass effects only in real emission

F.Maltoni et al. (2014)

$\sqrt{s}$	LO	B-i. NLO HEFT	NLO FT_{approx}	NLO
14 TeV	$19.85^{+27.6\%}_{-20.5\%}$	$38.32^{+18.1\%}_{-14.9\%}$	$34.26^{+14.7\%}_{-13.2\%}$	$32.91^{+13.6\%}_{-12.6\%}$
100 TeV	$731.3^{+20.9\%}_{-15.9\%}$	$1511^{+16.0\%}_{-13.0\%}$	$1220^{+11.9\%}_{-10.7\%}$	$1149^{+10.8\%}_{-10.0\%}$

Double Higgs production

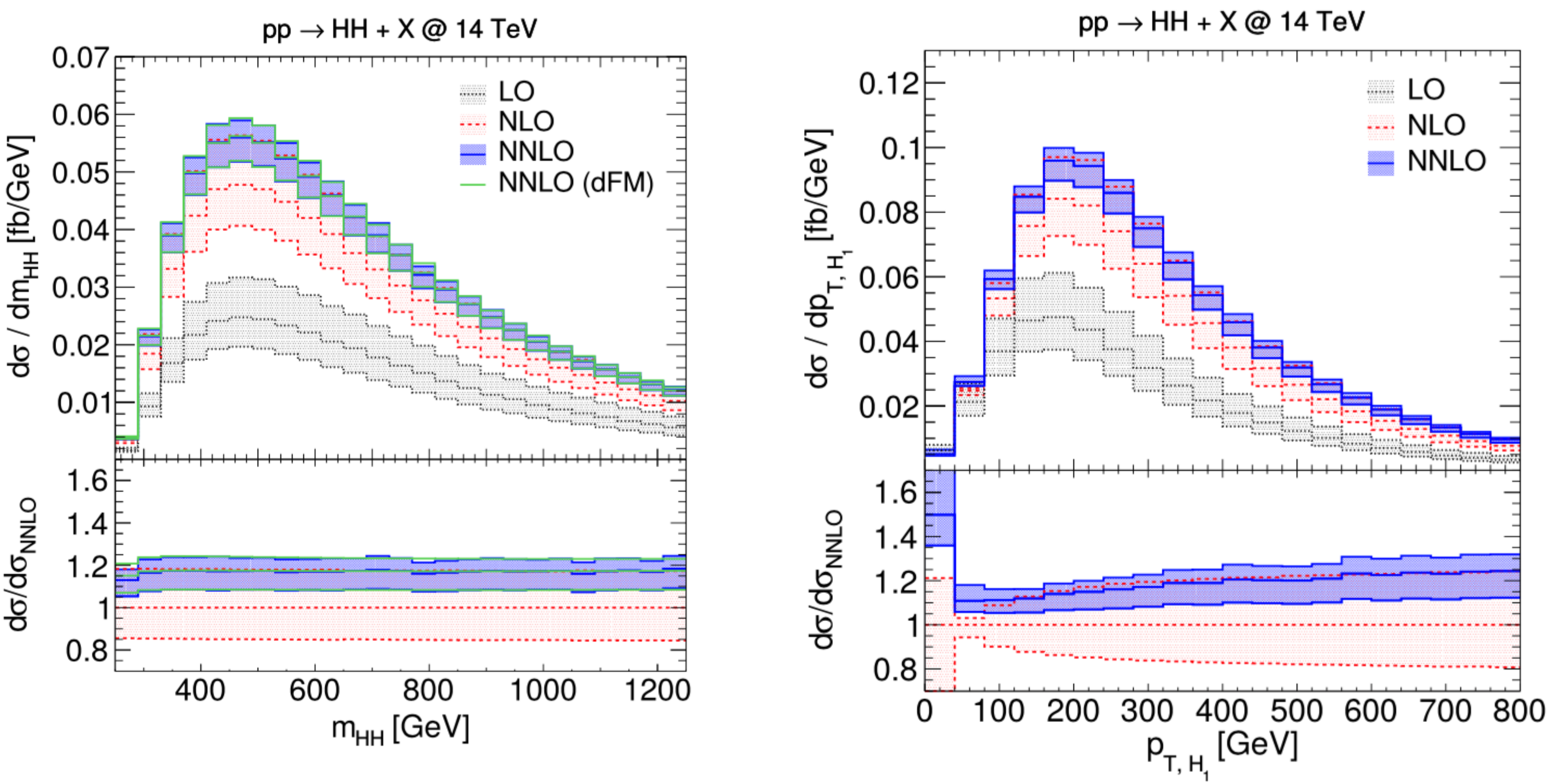
Fully differential NNLO recently completed

D. de Florian, C.Hanga, S.Kallweit,J.Lindert, P.Maierhöfer, J.Mazzitelli, D.Rathlev, MG (2016)

Effective lagrangian for HH production up to NNLO

J.Grigo,K.Melnikov, M.Steinhauser (2014)
M.Spira (2016)

Dedicated implementation in Openloops
+q_T subtraction → MATRIX



Double Higgs production

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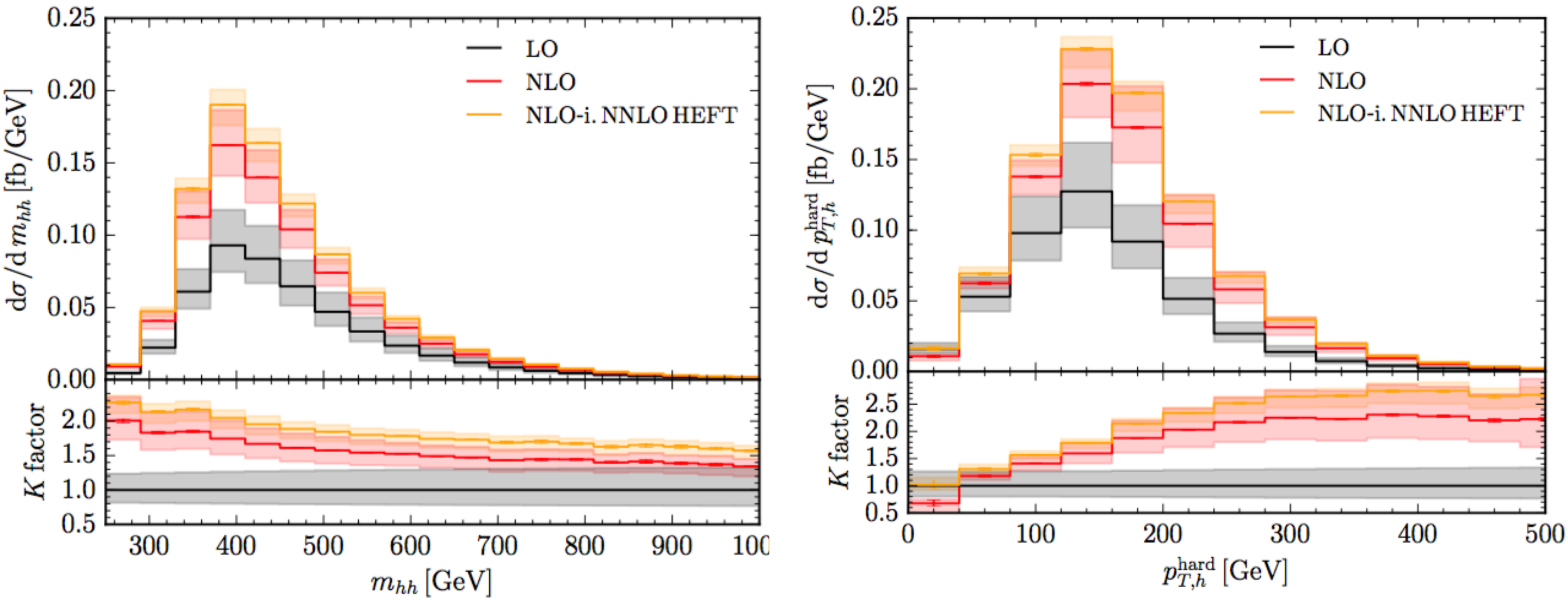
D. de Florian, C.Hanga, S.Kallweit,J.Lindert, P.Maierhöfer, J.Mazzitelli, D.Rathlev, MG (2016)



First attempt to combine with exact NNLO: differential NNLO/NLO K-factors used to rescaled exact NLO

Summary

- The current LHC data indicate that the Higgs boson is perfectly consistent with what predicted by the SM

- This conclusion is based on a good control on SM predictions to which the data are compared, including radiative corrections

- I have reviewed the current status of theoretical predictions for Higgs boson production and decay, focusing on the most recent developments

- The general picture is that SM predictions are in good shape

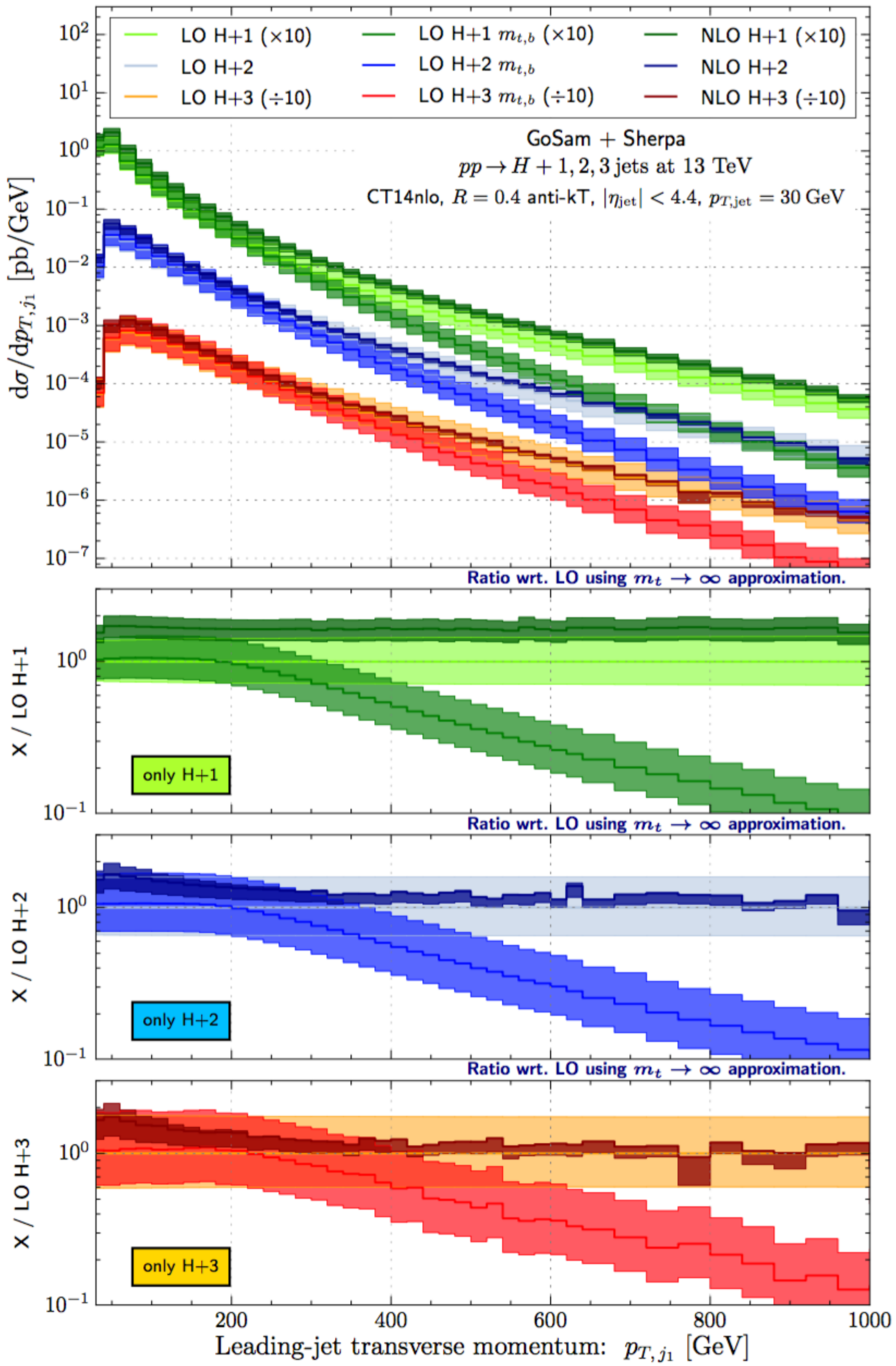
  - For the dominant $gg \to H$ channel QCD predictions are essentially pushed to the next order → reduction of perturbative uncertainties

  - Still important limitations come from the use of EFT

- NNLO MC tools for specific processes allow us to fully exploit NNLO results

H+3 jets at NLO

N.Greiner, S.Höche, G.Luisoni, M.Schönherr, J.Winter, V. Yundin (2016)



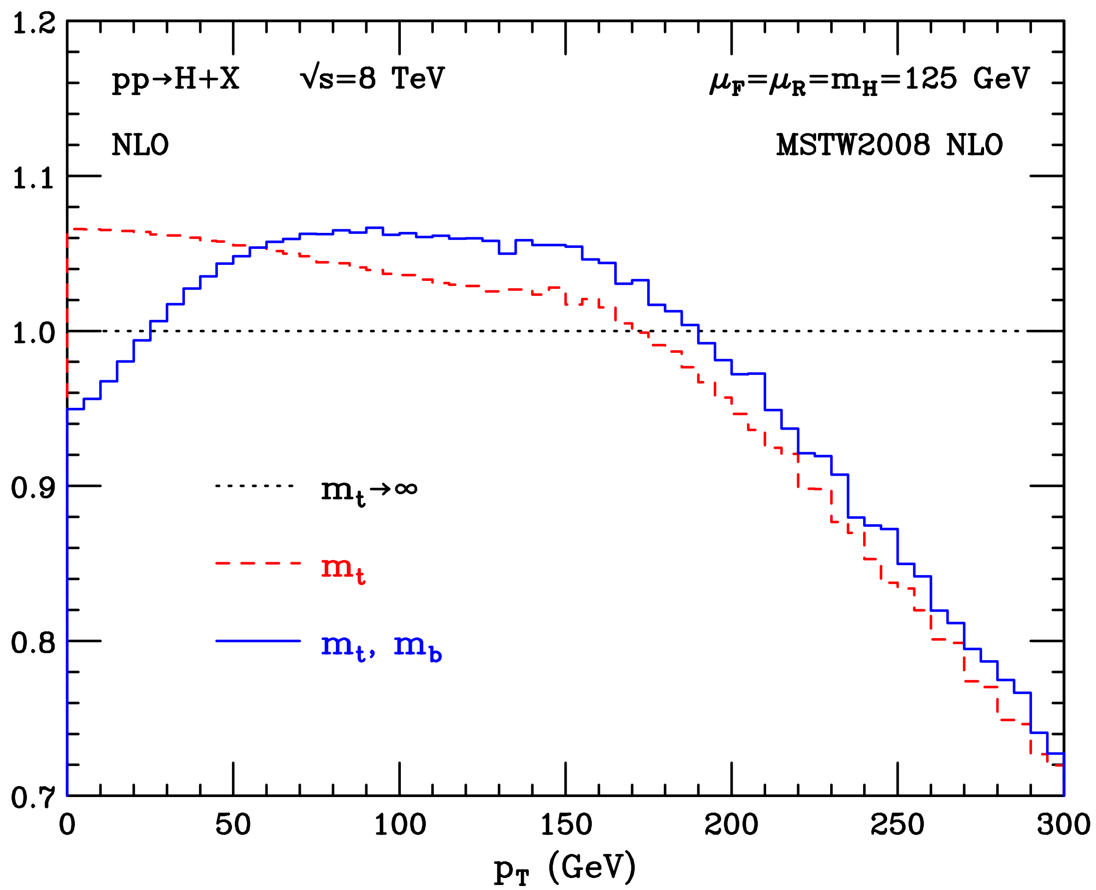
Important background to VBF

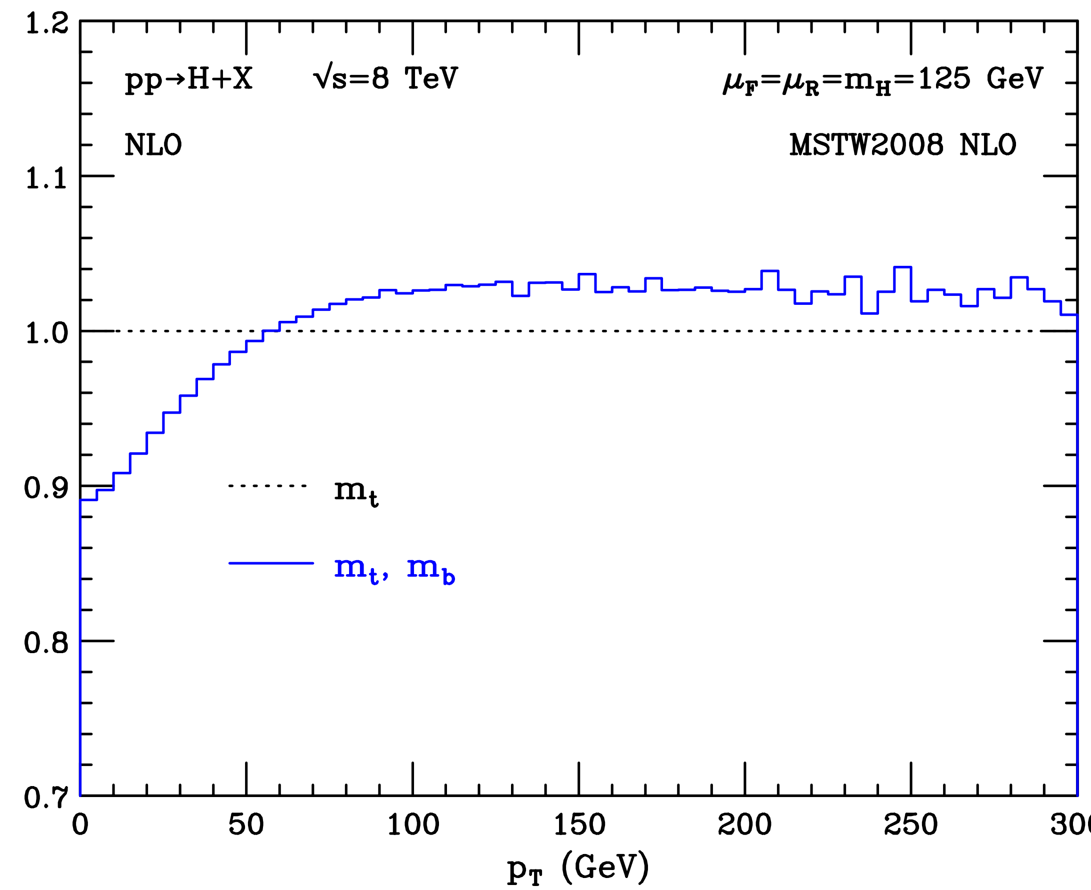
NLO results known only in the large-m_{top} limit

LO mass effects

Transverse momentum of the hardest jet plays the role of resolving the effective coupling

Mass effects





In the low p_T region finite m_t effects don't change the shape significantly but finite m_b effects do it (it becomes a three-scale problem) !

Treated by using different resummation scales in the resummed calculation

M.Grazzini,H.Sargsyan (2012)
R. V. Harlander, H. Mantler, M.Wiesemann (2014)

Progress in the understanding of m_b effects through resummation of the abelian contributions to $gg \to gH$

K.Melnikov, S.Penin (2016)