Standard Model Theory for Collider Physics

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- Need to be precise on cross-sections and SM parameters

$$m_H,\, m_t,\, \alpha_s, \ldots$$

Vacuum stability in the SM at NNLO requires

Degrassi et al; Bezrukov et al; Alekhin, Djouadi, Moch; Masina (2012)

$$m_H \geq 129.2 + 1.8 \times \left(\frac{m_t^{\text{pole}} - 173.2\,\text{GeV}}{0.9\,\text{GeV}} \right) - 0.5 \times \left(\frac{\alpha_s(M_Z) - 0.1184}{0.0007} \right) \pm 1.0\,\text{GeV}$$

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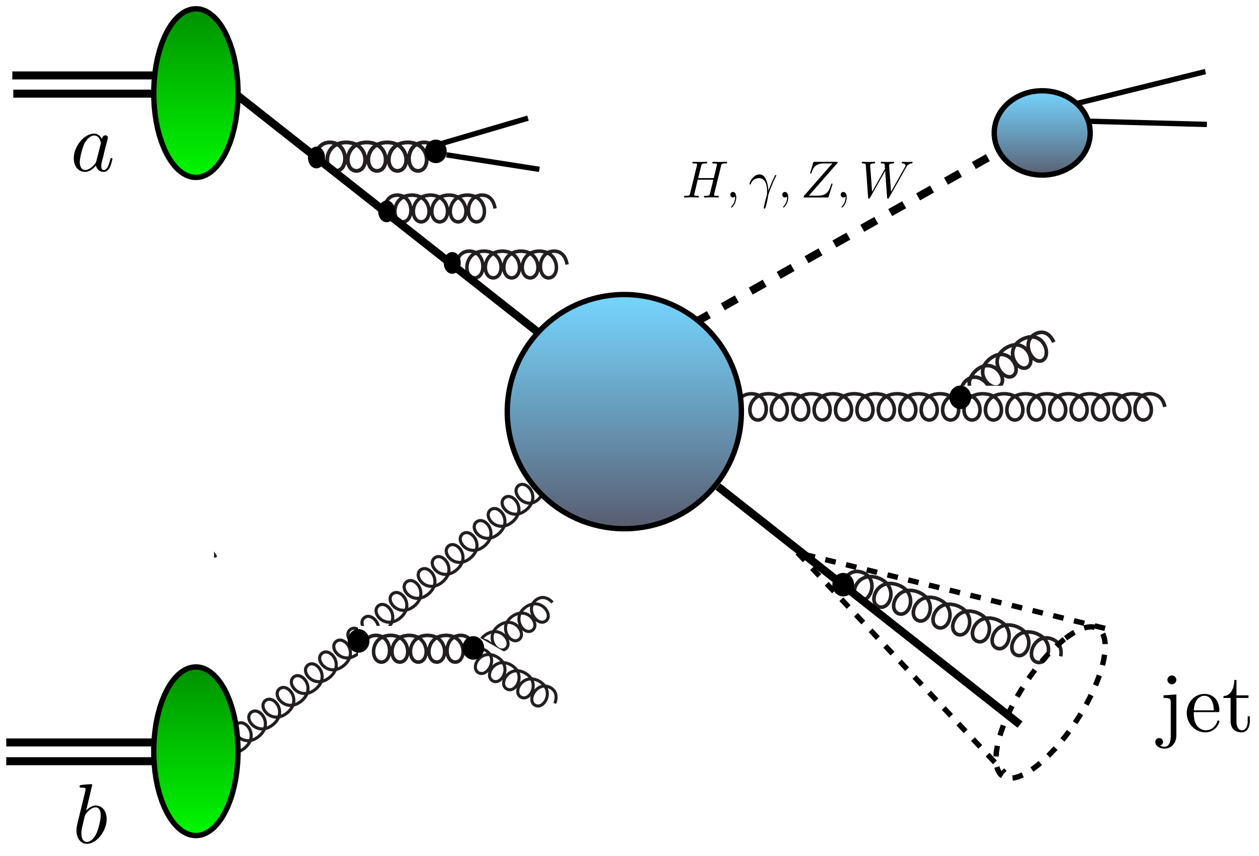
This Talk

Toolkit for precise TH predictions at the LHC

- In the LHC era, QCD is everywhere!



non-perturbative parton distributions

$$d\sigma = \sum_{ab} \int dx_a \int dx_b \, f_a(x_a, \mu_F^2) f_b(x_b, \mu_F^2) \times d\hat{\sigma}_{ab}(x_a, x_b, Q^2, \alpha_s(\mu_R^2)) + \mathcal{O}\left(\left(\frac{\Lambda}{Q}\right)^m\right)$$

perturbative partonic cross-section

Partonic cross-section: expansion in $\alpha_s(\mu_R^2) \ll 1$ $\quad d\hat{\sigma} = \alpha_s^n \, d\hat{\sigma}^{(0)} + \alpha_s^{n+1} \, d\hat{\sigma}^{(1)} + \ldots$

- Require precision for perturbative and non-perturbative contribution

PDFs

- Several groups provide pdf fits + uncertainties
- Differ by: data input, TH/bias, HQ treatment, coupling, etc

set	H.O.	data	$\alpha_s(M_Z)@NNLO$	uncertainty	HQ	Comments
MSTW 2008	NNLO	DIS+DY+Jets	0.1171	Hessian (dynamical tolerance)	GM-VFN (ACOT+TR')	old HERA DIS
CT10	NNLO	DIS+DY+Jets	0.118	Hessian (dynamical tolerance)	GM-VFN (SACOT-X)	New HERA DIS
NNPDF 2.3	NNLO	DIS+DY+Jets +LHC	0.1174	Monte Carlo	GM-VFN (FONLL)	New HERA DIS
ABKM	NNLO	DIS+DY(f.t.)	0.1135	Hessian	FFN BMSN	New HERA DIS
(G)JR	NNLO	DIS+DY(f.t.)+ some jet	0.1124	Hessian	FFN (VFN massless)	valence like input pdfs
HERA PDF	NNLO	only DIS HERA	0.1176	Hessian	GM-VFN (ACOT+TR')	Latest HERA DIS

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up to 5% ! >15% in Higgs cross section

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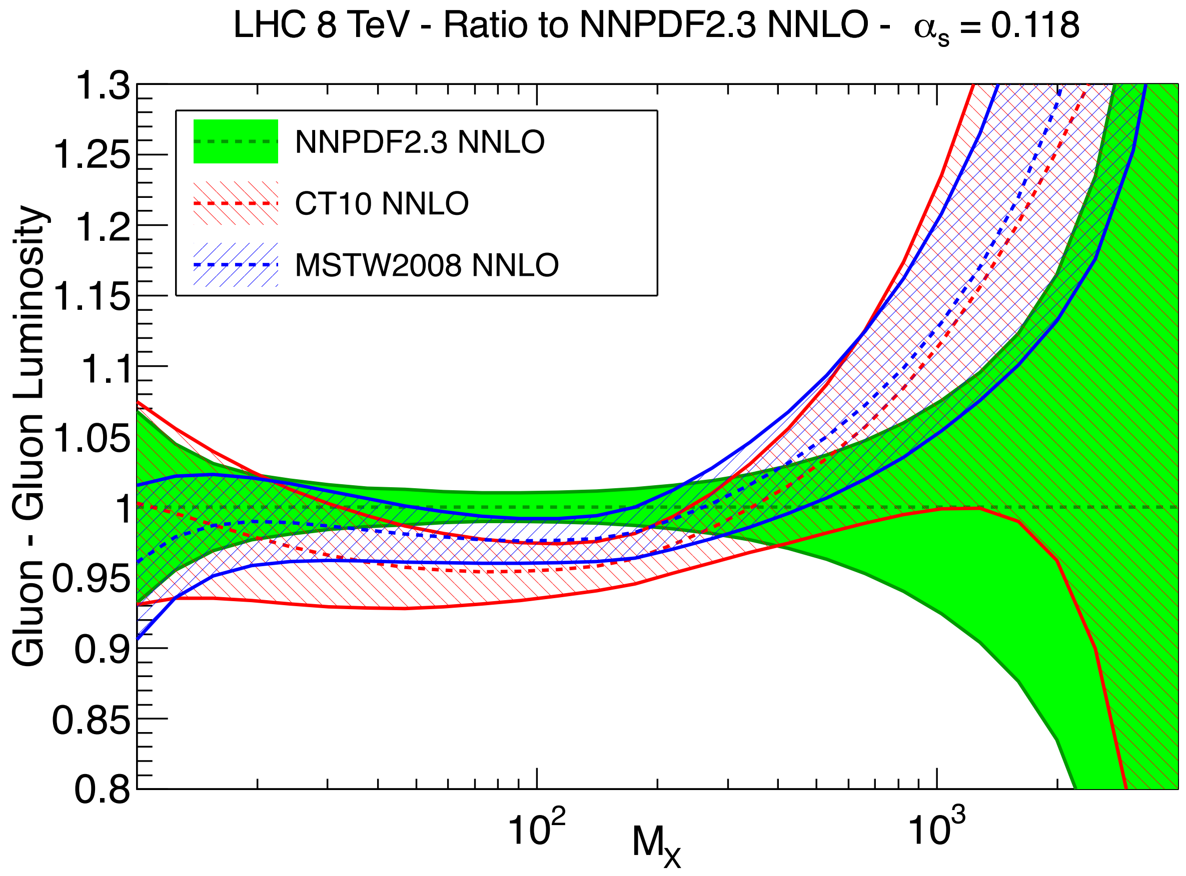
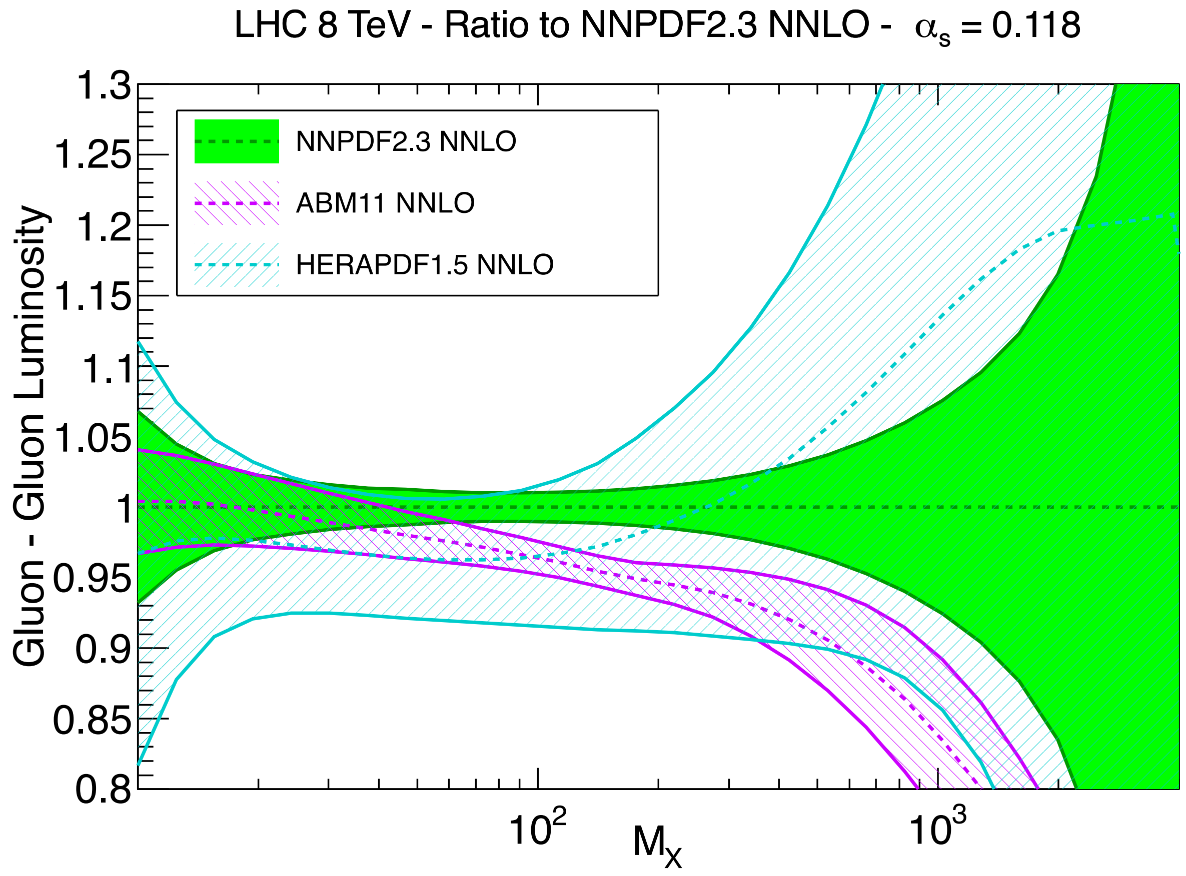
Luminosities with common $\alpha_s = 0.118$

PDF4LHC, Ball et al

$$\mathcal{L}_{ij}(\tau \equiv M_X^2/S) = \frac{1}{S}\int_\tau^1 \frac{dx}{x} f_i(x, M_X^2) f_j(\tau/x, M_X^2)$$

gluon-gluon

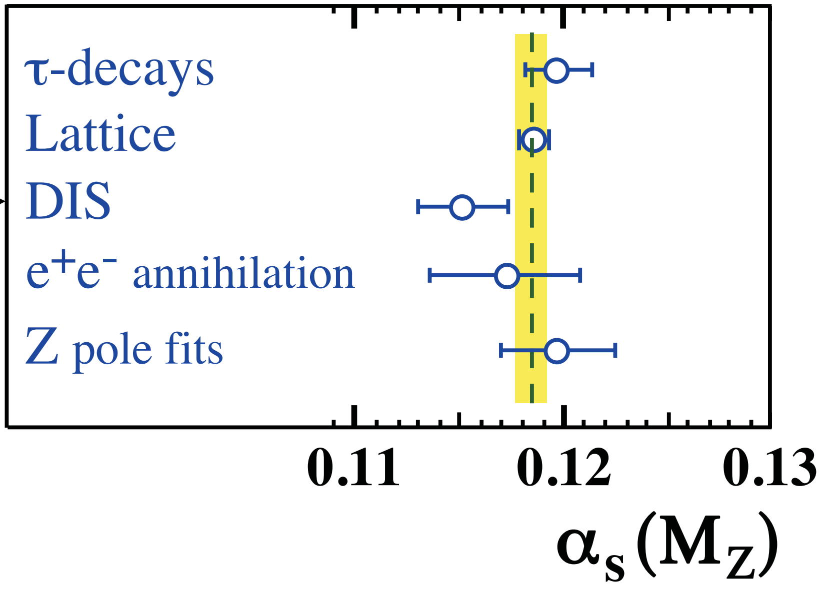




- Good agreement for global fits but deviations as large as uncertainties
- Larger differences with “non-global” results
- 2x larger uncertainties for gluon

- One main issue is the coupling constant

PDG **S. Bethke** $\alpha_s(M_Z) = 0.1184 \pm 0.0007$ →



- Optimistic value for the uncertainty at the LHC
- DIS (PDFS) not well covered : some experiments pull value down

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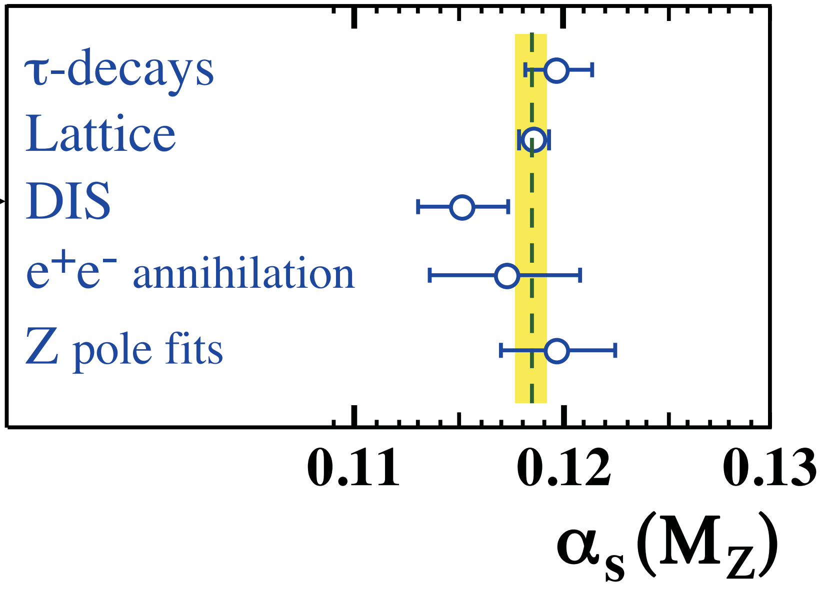

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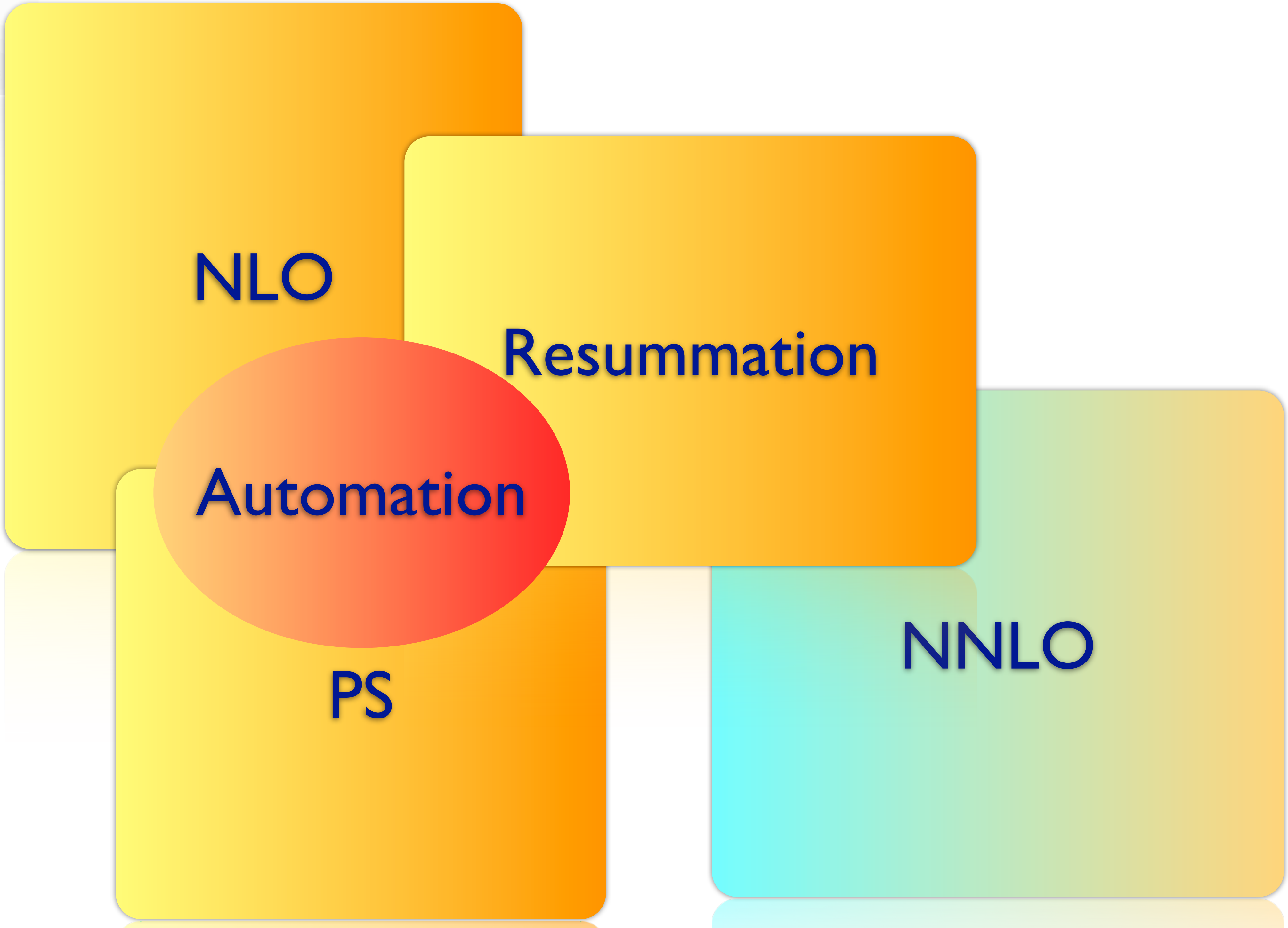
PDH4LHC recommendation

- Compute pdfs uncertainties using MSTW & CT & NNPDF (68%cl)
- Obtain the envelope of all bands and use

$$\Delta\alpha_s(M_Z) = \pm 0.0012\,(\pm 0.002)\ \text{at}\ 68\%\,(90\%)\,\text{c.l.}$$

- Precise LHC data will have important effect on validation & improvement

The perturbative toolkit for precision at colliders



NLO

Resummation

Automation

PS

NNLO

The NLO revolution

Why NLO?

- Accurate Theoretical Predictions
  - shape and normalization
  - first error estimate
- Large Corrections : check PT   Higgs
- Opening of new channels
- Effect of extra radiation
  - jet algorithm dependence

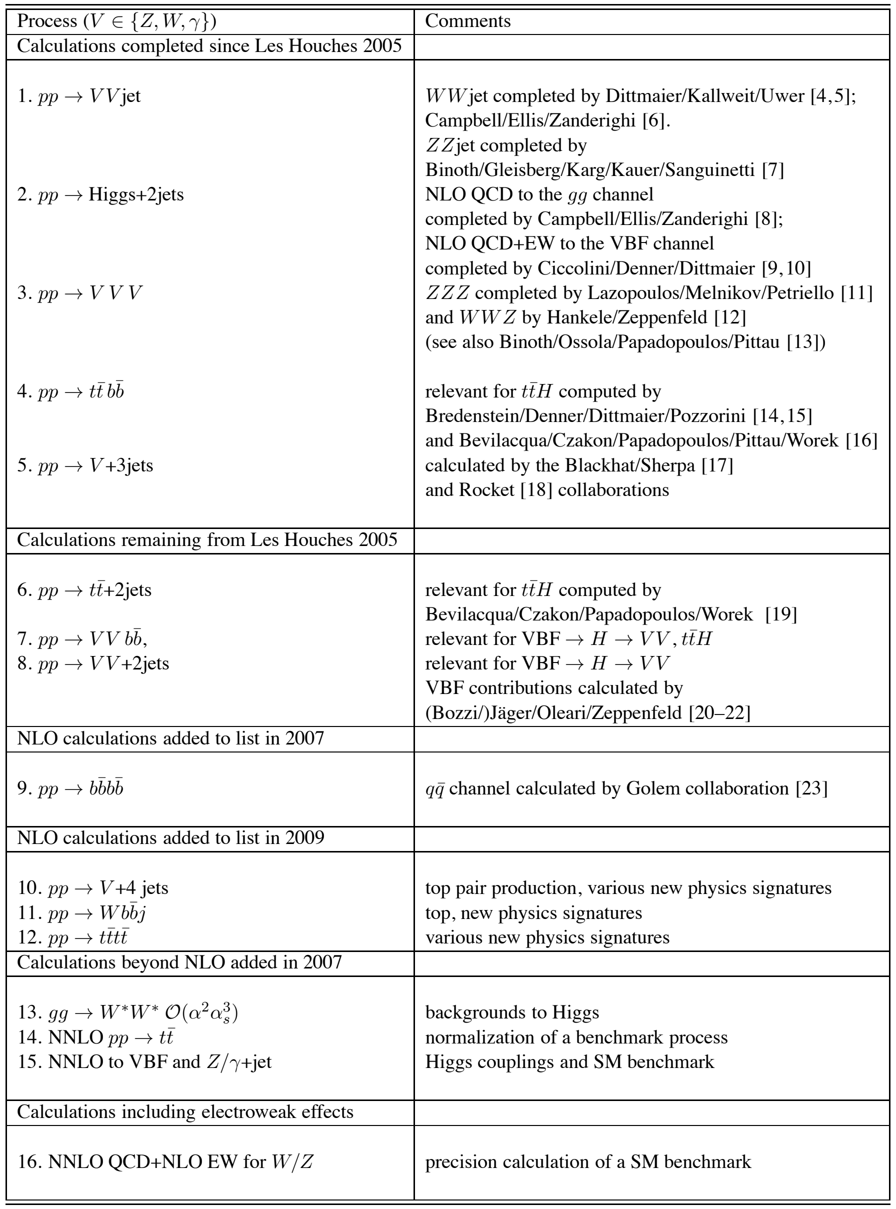
Amazing progress in the last few years

→ Large multiplicities relevant for LHC

- Improved techniques for loop
- High level of automation

talk by Zvi Bern

Experimenter's wish-list



Process ($V \in \{Z, W, \gamma\}$)	Comments
Calculations completed since Les Houches 2005	
1. $pp \to VV$jet	WWjet completed by Dittmaier/Kallweit/Uwer [4,5]; Campbell/Ellis/Zanderighi [6]. ZZjet completed by Binoth/Gleisberg/Karg/Kauer/Sanguinetti [7]
2. $pp \to$ Higgs+2jets	NLO QCD to the gg channel completed by Campbell/Ellis/Zanderighi [8]; NLO QCD+EW to the VBF channel completed by Ciccolini/Denner/Dittmaier [9,10]
3. $pp \to V\,V\,V$	ZZZ completed by Lazopoulos/Melnikov/Petriello [11] and WWZ by Hankele/Zeppenfeld [12] (see also Binoth/Ossola/Papadopoulos/Pittau [13])
4. $pp \to t\bar{t}\,b\bar{b}$	relevant for $t\bar{t}H$ computed by Bredenstein/Denner/Dittmaier/Pozzorini [14,15] and Bevilacqua/Czakon/Papadopoulos/Pittau/Worek [16]
5. $pp \to V$+3jets	calculated by the Blackhat/Sherpa [17] and Rocket [18] collaborations
Calculations remaining from Les Houches 2005	
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7. $pp \to VV\,b\bar{b}$,	relevant for VBF $\to H \to VV$, $t\bar{t}H$
8. $pp \to VV$+2jets	relevant for VBF $\to H \to VV$ VBF contributions calculated by (Bozzi/)Jäger/Oleari/Zeppenfeld [20–22]
NLO calculations added to list in 2007	
9. $pp \to b\bar{b}b\bar{b}$	$q\bar{q}$ channel calculated by Golem collaboration [23]
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10. $pp \to V$+4 jets	top pair production, various new physics signatures
11. $pp \to Wb\bar{b}j$	top, new physics signatures
12. $pp \to t\bar{t}t\bar{t}$	various new physics signatures
Calculations beyond NLO added in 2007	
13. $gg \to W^*W^*$ $\mathcal{O}(\alpha^2\alpha_s^3)$	backgrounds to Higgs
14. NNLO $pp \to t\bar{t}$	normalization of a benchmark process
15. NNLO to VBF and Z/γ+jet	Higgs couplings and SM benchmark
Calculations including electroweak effects	
16. NNLO QCD+NLO EW for W/Z	precision calculation of a SM benchmark

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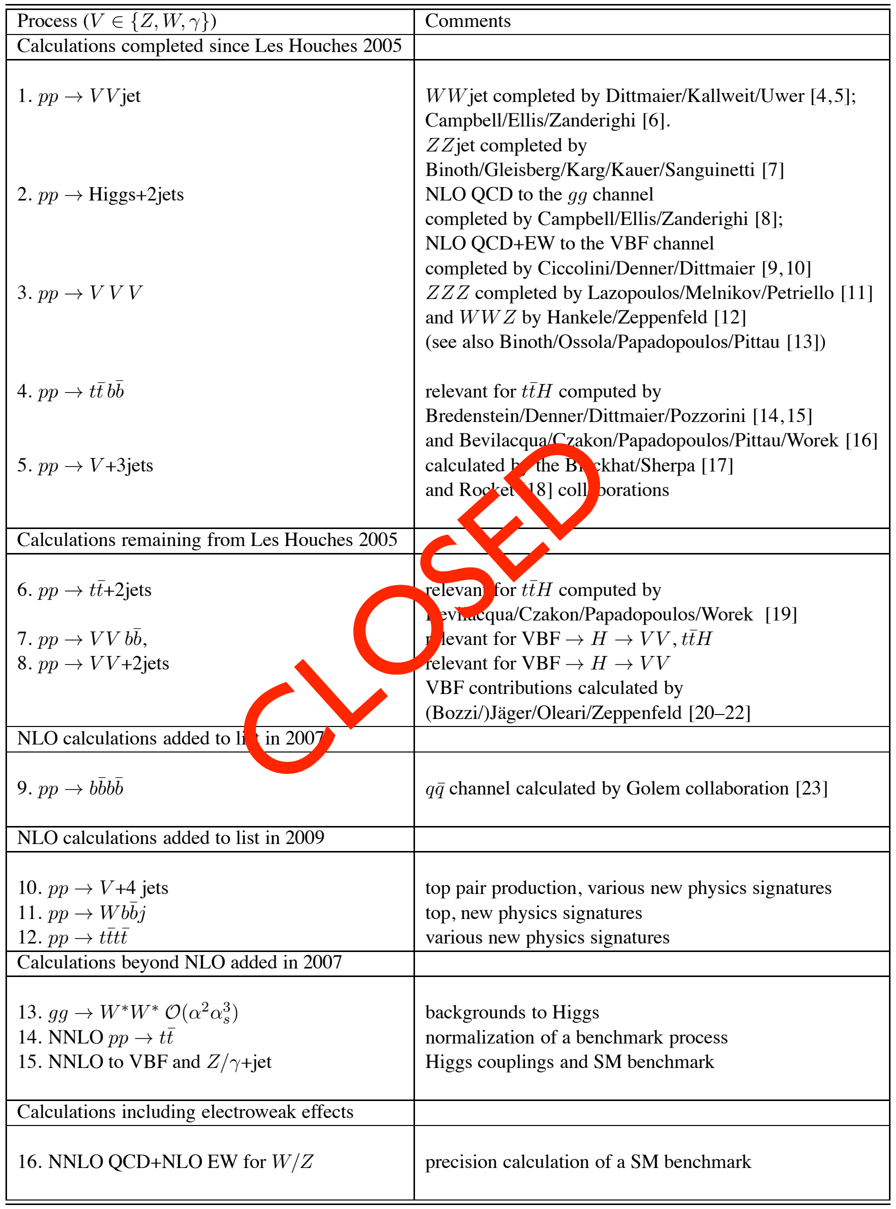

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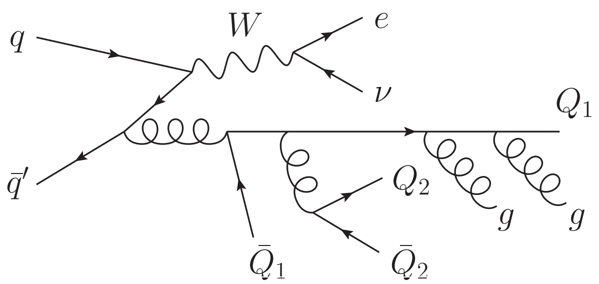
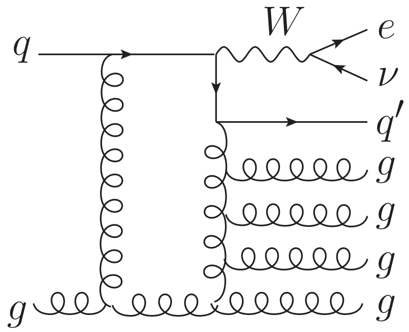
A very recent example : W+5 jets !!

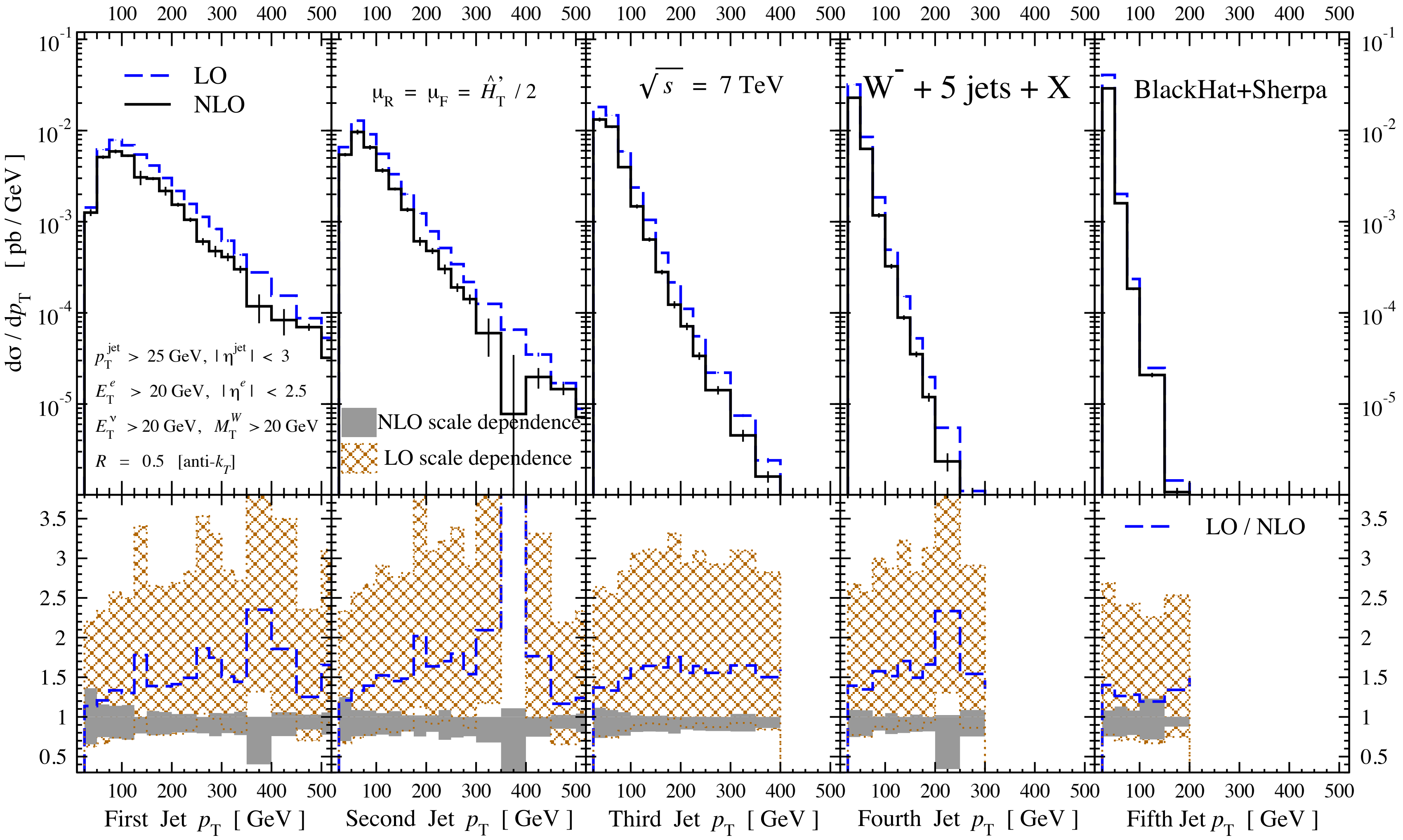
BlackHat Collaboration, Z.Bern et al





Real $2 \to 8$ SHERPA   Virtual $2 \to 7$ BlackHat

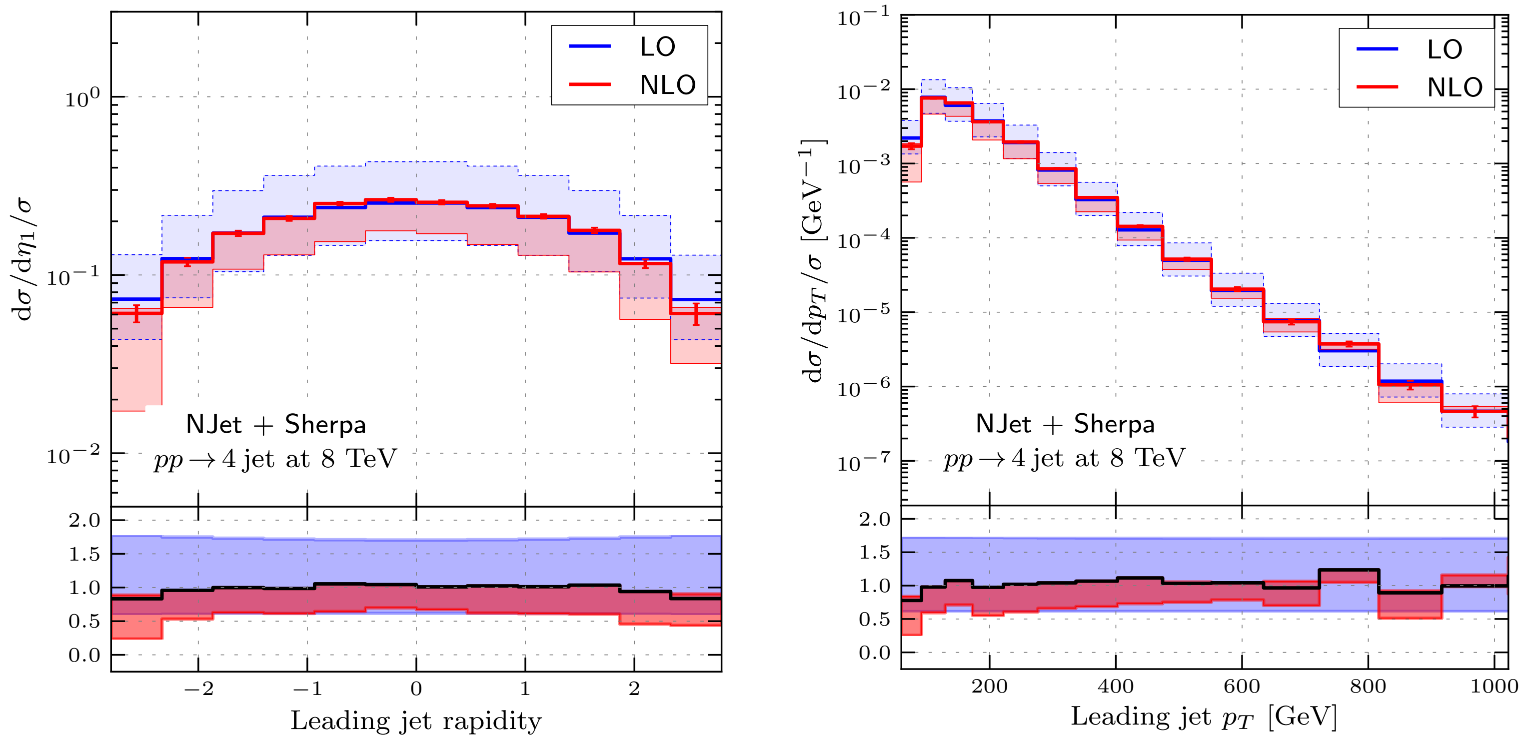
Dynamical Scale choice $\mu_R = \mu_F = \frac{\hat{H}'_T}{2} \equiv \frac{1}{2}\sum_m p_T^m + E_T^W$



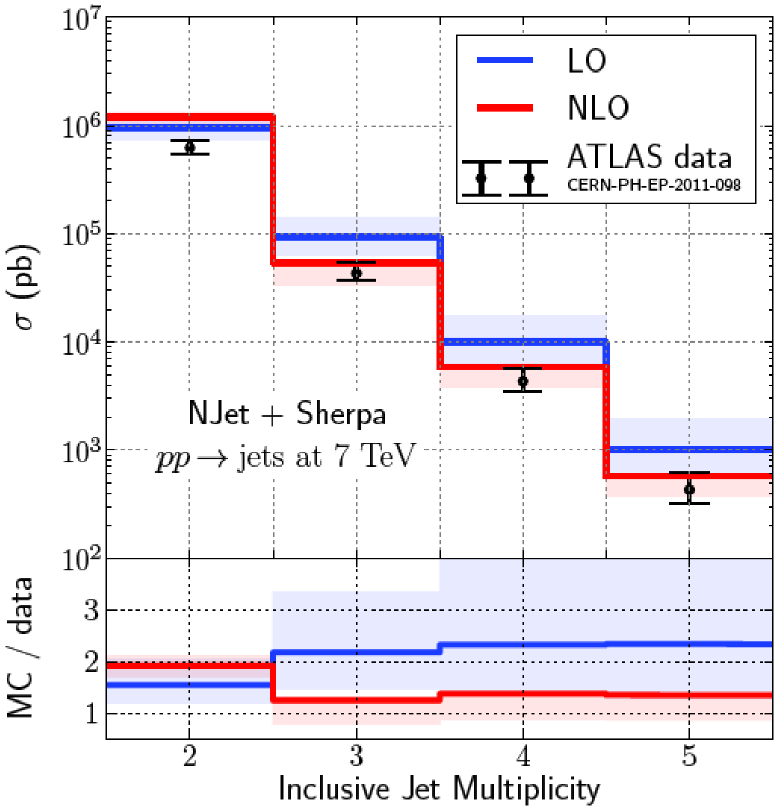
- Dramatic reduction in scale dependence (~20%)
- Up to 50% correction (non-trivial in shape)

Multi-jet production

Njet+Sherpa (Badger, Biedermann, Uwer, Yundin)



in perfect agreement with previous calculation by BlackHat (Z.Bern et al)



$pp \to 5$ jets at NLO

- Preliminary results for 5 jets in good agreement with data!

- Final goal: Really automatic NLO calculations

zero cost for humans

  - Specify the process (input card)
  - Input parameters
  - Define final cuts

- Automatic NLO calculation "conceptually" solved

  - in a few years a number of codes (among others)

Blackhat+Sherpa   GoSam + Sherpa/MadGraph

MadLoop+MadFKS   CutTools   OpenLoops+Sherpa

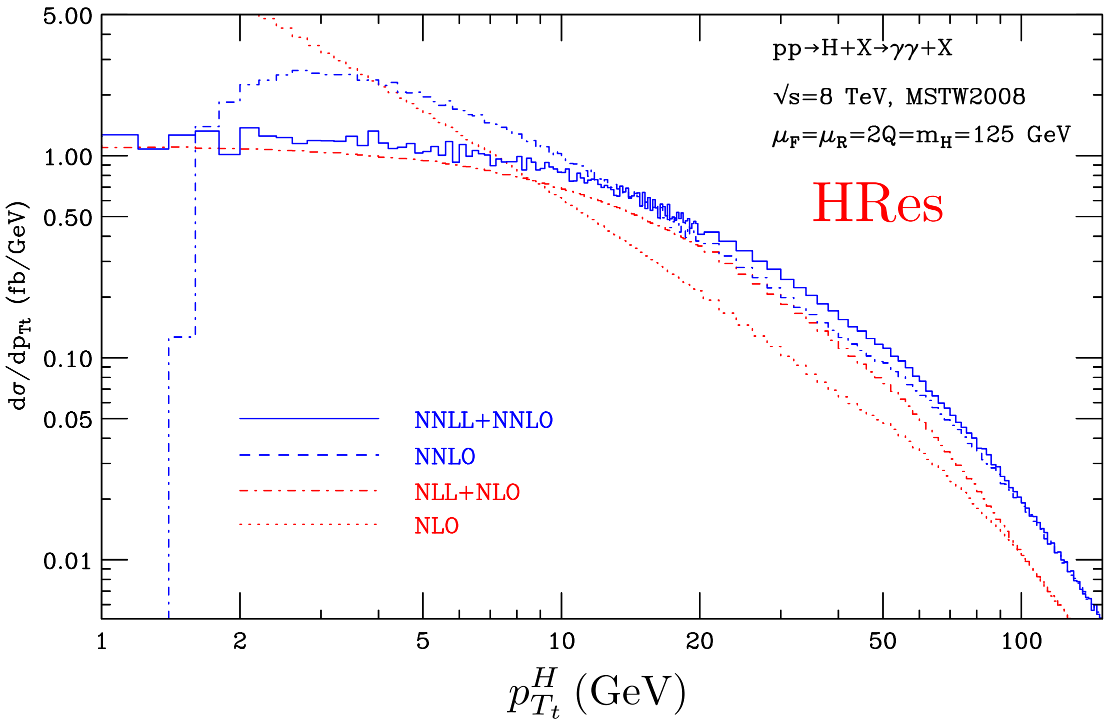
✓ compete on precision, flexibility, speed, stability, ...

✓ many features : uncertainties, ...

Best solution still to emerge, but not more NLO wish-list, do it yourself!

- Individual calculations still relevant!   ✓ open the way to new methods

Resummation

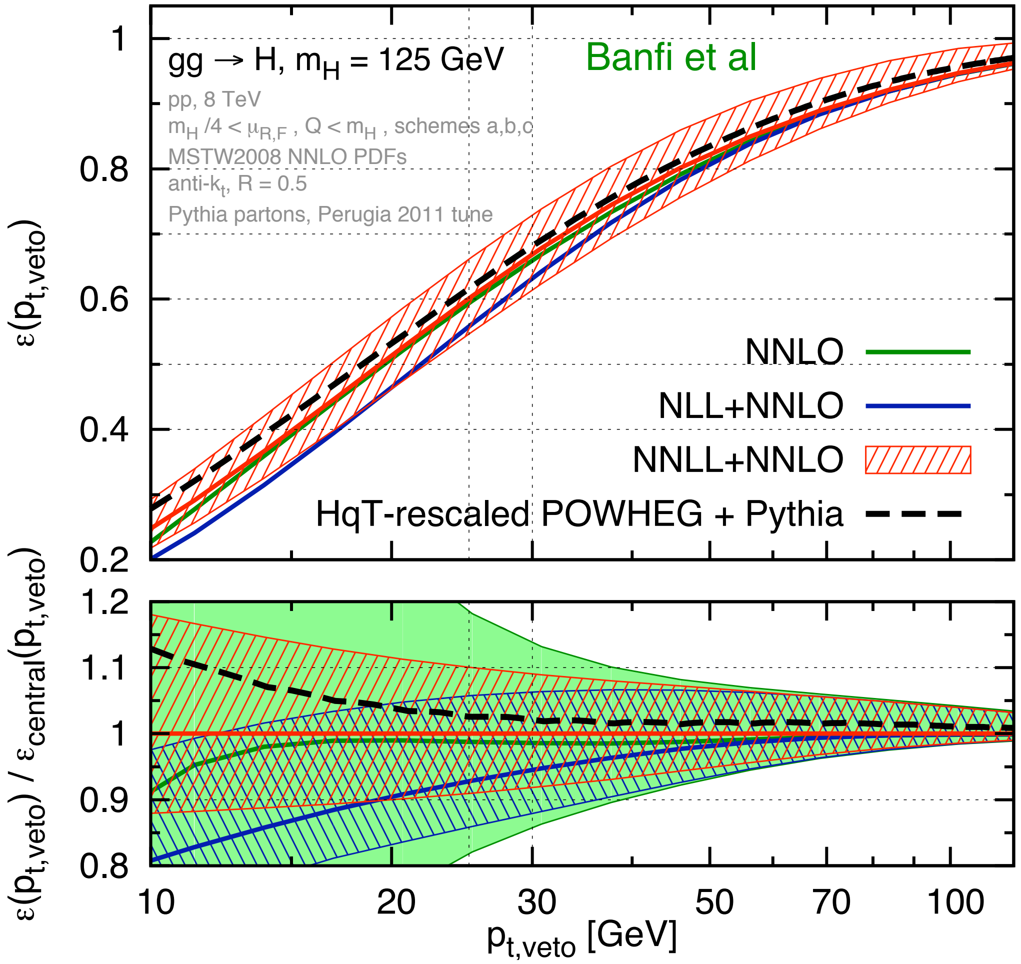


Higgs transverse momentum

deF, Ferrera, Grazzini, Tommasini (2012)

- Large logarithmic corrections spoil convergence in boundaries of phase space

State of the art: NNLL



Jet veto in Higgs @ NNLL

Banfi, Monni, Salam, Zanderighi (2012)

Stewart, Tackmann, Walsh, Zuberi (2013)

- Reduction in uncertainty ~10-13%
- Validation of tools

Merging NLO with Parton Showers

- Resumation to NLL accuracy + realistic final states
- Allow to carry NLO precision to all aspects of experimental analysis

  - MC@NLO Frixione, Webber
  - POWHEG Nason; Frixione, Nason, Oleari

- Can be interfaced to different tools : Herwig, Phytia,Sherpa

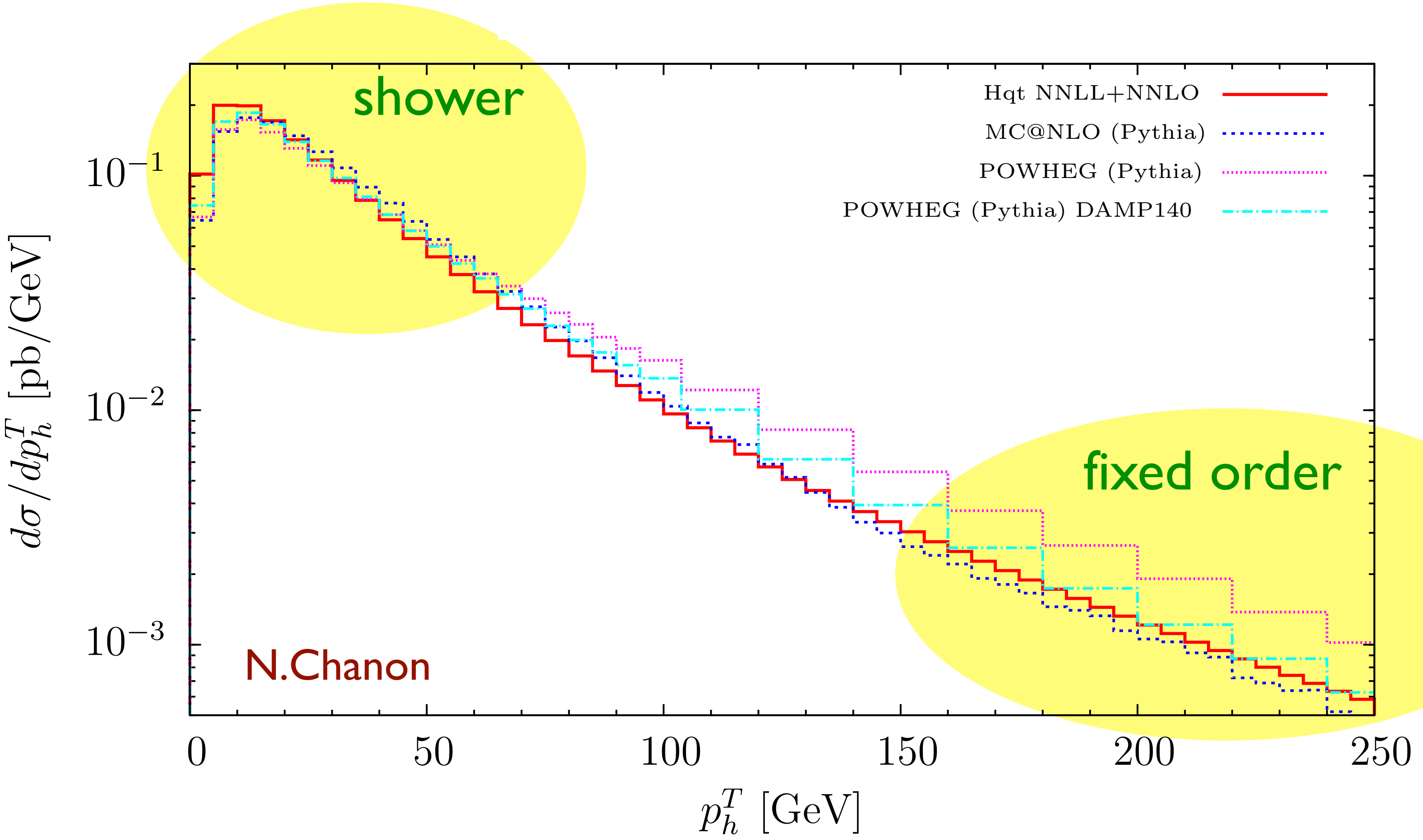
- MC@NLO and POWHEG

treat radiation differently but formally same NL accuracy

Differences usually small

Higgs counterexample

addressed by POWHEG



Automation

- Provide large library of processes or different degree of automation
- aMC@NLO: full automation of NLO and PS in MC@NLO framework
  Frederix, Frixione, Hirschi, Pittau, Maltoni, Torrelli
- POWHEG-BOX framework Aioli, Nason, Oleari, re
- Sherpa : real matrix elements matching MC@NLO and POWHEG
  Krauss, Höche, Siegert, Schönher
- POWHEL: automation of ME from HELAC with POWHEG-Box
  Papadopoulos, Garzelli, Kardos, Trocsanyi
- POWHEG Box + Madgraph4 Campbell, Ellis, Frederix, Nason, Oleari, Williams
- MINLO Hamilton, Nason, Oleari, Zanderighi
- UNLOPS Lönnbland, Prestel

+ many others

NNLO the new frontier

- Some measurements to few percent accuracy

✓ $e^+e^- \to 3\,\text{jets}$

$e^-p \to (2+1)\,\text{jets}$

✓ $pp \to V$

$pp \to \text{jets}$ partial

$pp \to V + \text{jets}$

✓ $pp \to t\bar{t}$

$\mathcal{O}(\alpha_s^2)$

Match experimental accuracy
Extract accurate information

- Some processes with still (potentially) large NNLO corrections

✓ $pp \to H$

✓ $pp \to \gamma\gamma$

$pp \to VV$

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meaningful comparison
solid estimate of uncertainties

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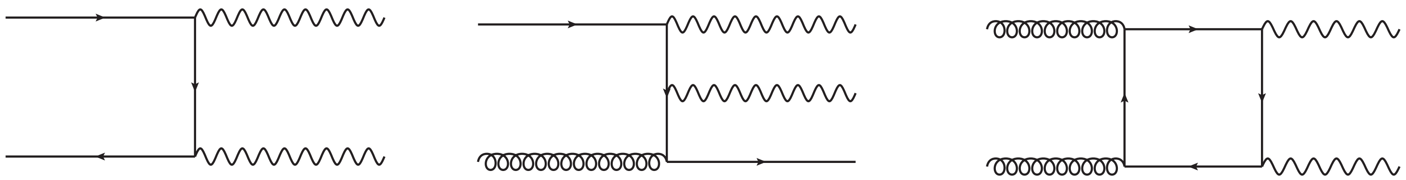
Keep Theorists employed after all the automatic machinery at NLO...

$pp \to \gamma\gamma$

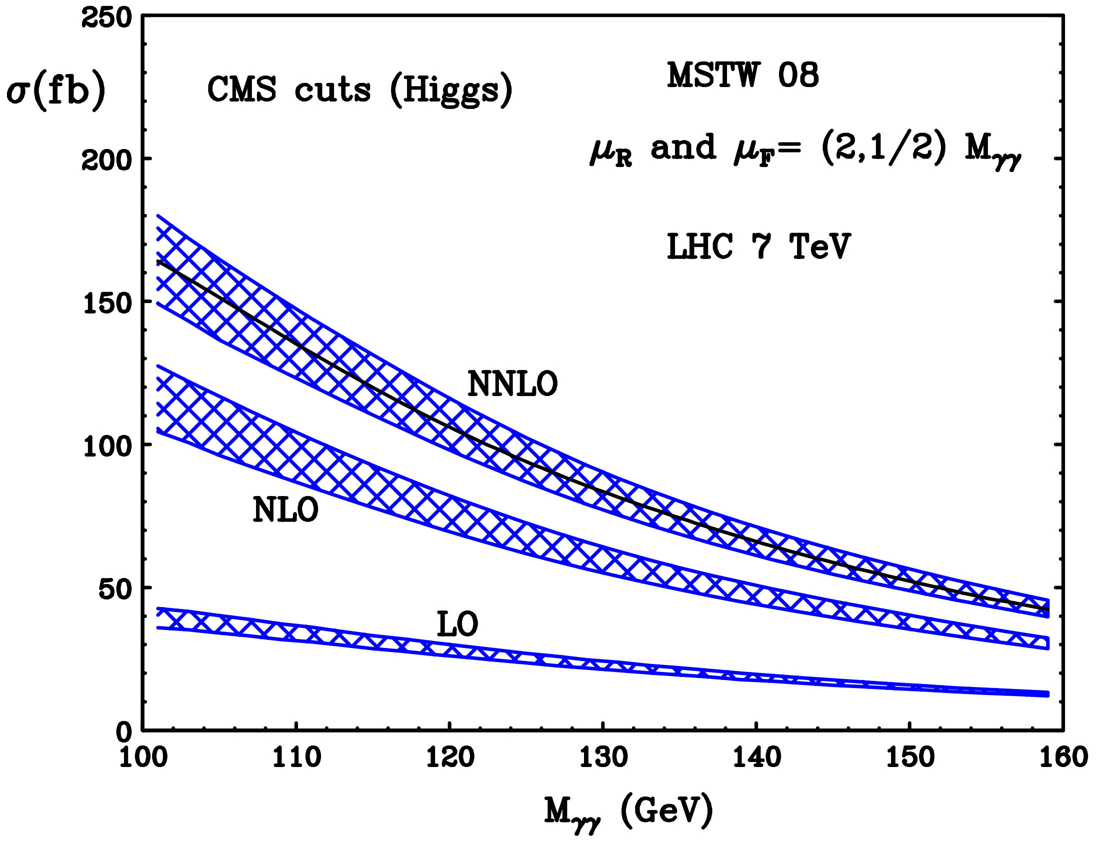
S.Catani, L.Cieri, DdeF, G.Ferrera, M.Grazzini (2012)

- Invariant mass : 40-50 % corrections



$q\bar{q}$ $\qquad$ qg $\qquad$ gg

α_s^0 $\qquad$ α_s^1 $\qquad$ α_s^2

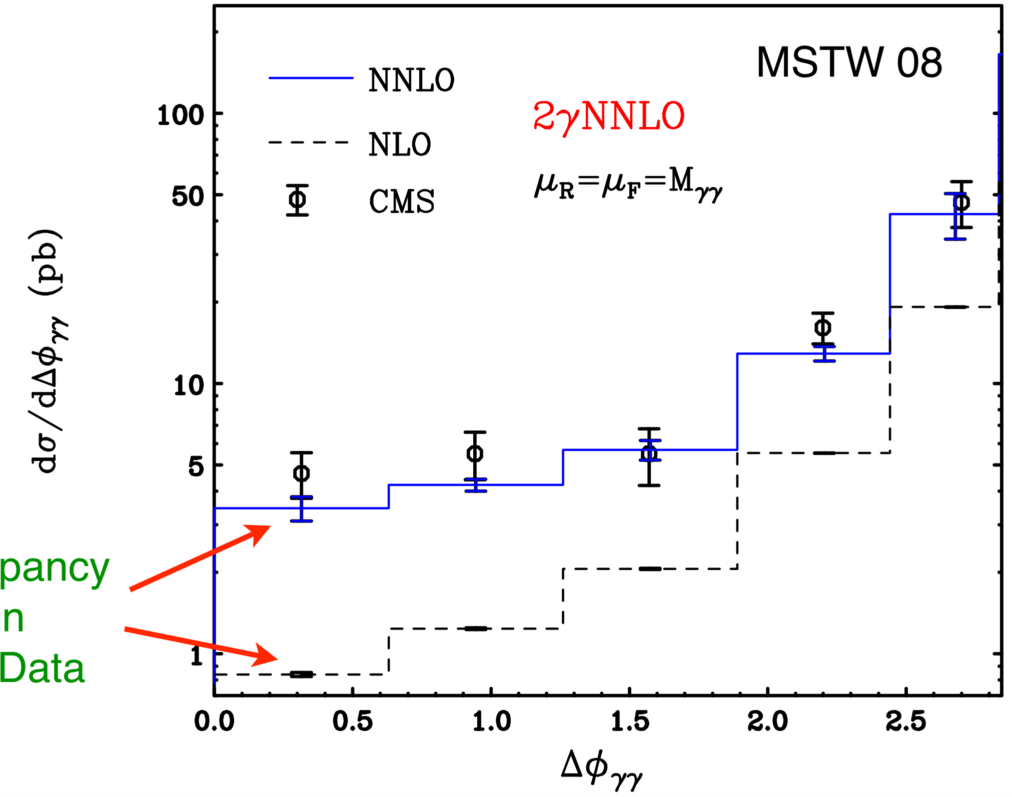


Open new channel at NLO,NNLO

- Azimuthal difference

α_s^2 Needed to understand LHC data

(effectively NLO)



large discrepancy between NLO and Data

$pp \to t\bar{t}$

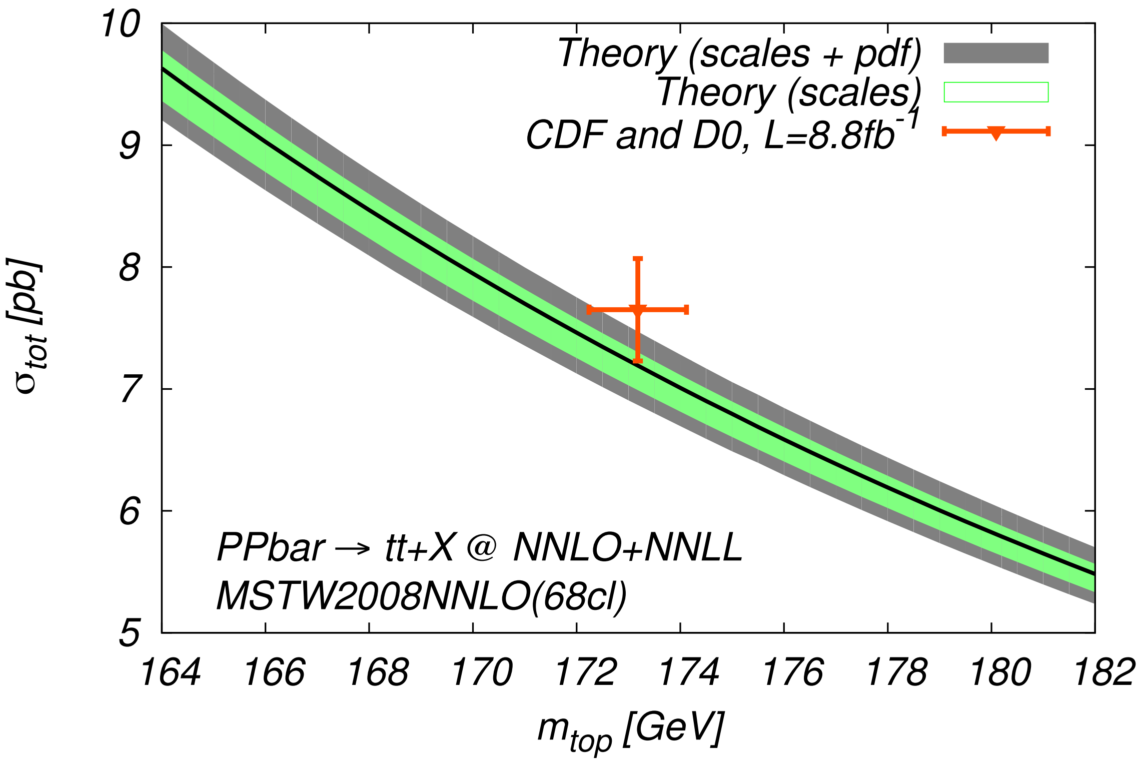
- Very relevant observable at colliders
- LHC will reach better than 5% accuracy
- top mass, pdfs, new physics

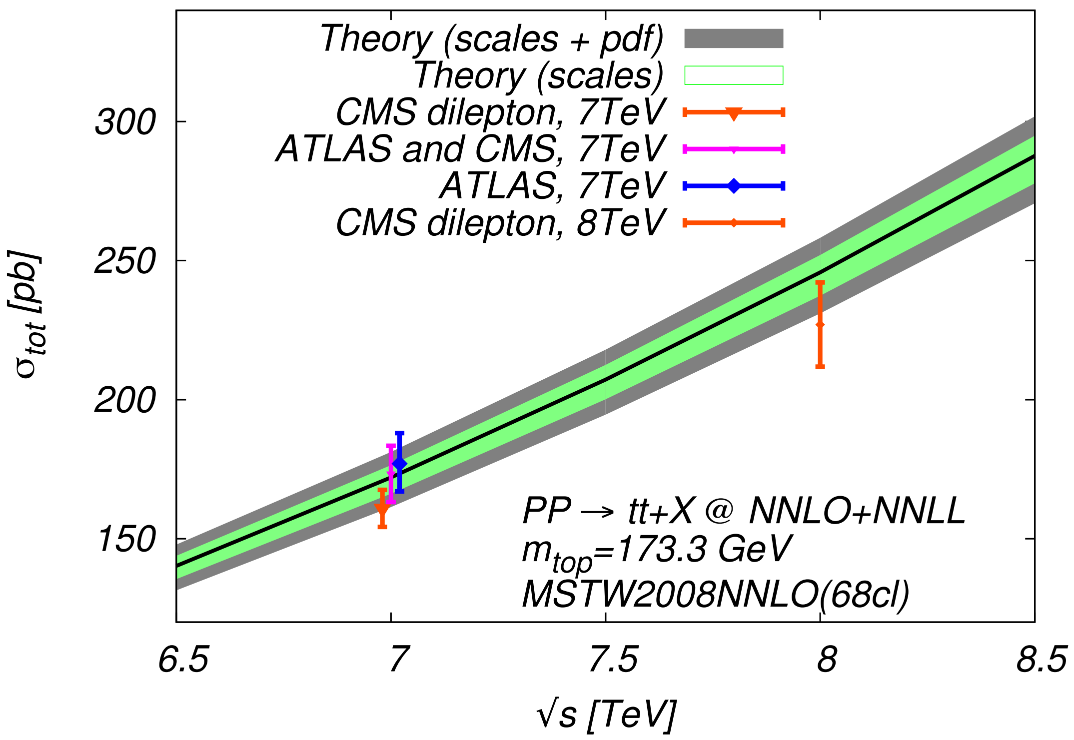
(inclusive)Full NNLO (+NNLL) available

<5% TH uncertainties

Czakon, Fiedler, Mitov (2013)

Collider	$\sigma_{\rm tot}$ [pb]	scales [pb]	pdf [pb]
Tevatron	7.164	$+0.110(1.5\%)$ $-0.200(2.8\%)$	$+0.169(2.4\%)$ $-0.122(1.7\%)$
LHC 7 TeV	172.0	$+4.4(2.6\%)$ $-5.8(3.4\%)$	$+4.7(2.7\%)$ $-4.8(2.8\%)$
LHC 8 TeV	245.8	$+6.2(2.5\%)$ $-8.4(3.4\%)$	$+6.2(2.5\%)$ $-6.4(2.6\%)$
LHC 14 TeV	953.6	$+22.7(2.4\%)$ $-33.9(3.6\%)$	$+16.2(1.7\%)$ $-17.8(1.9\%)$



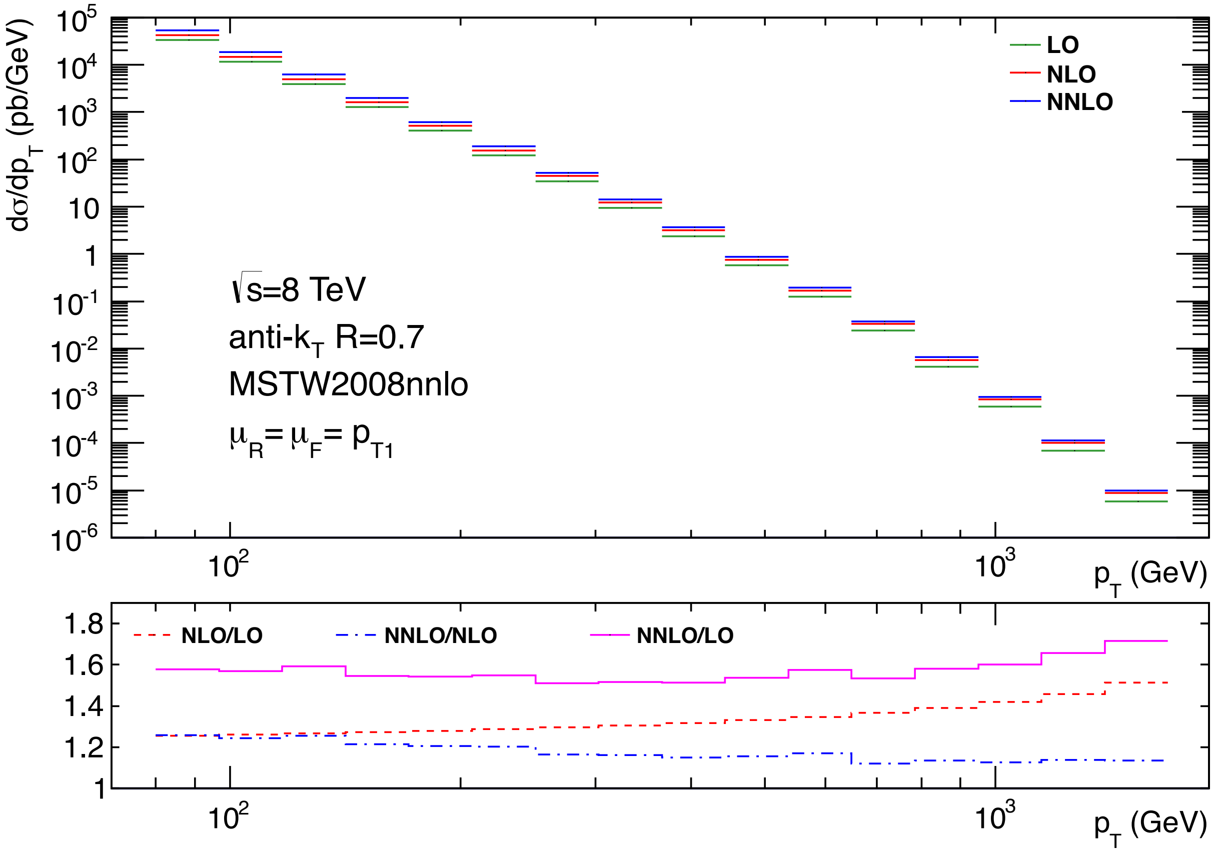


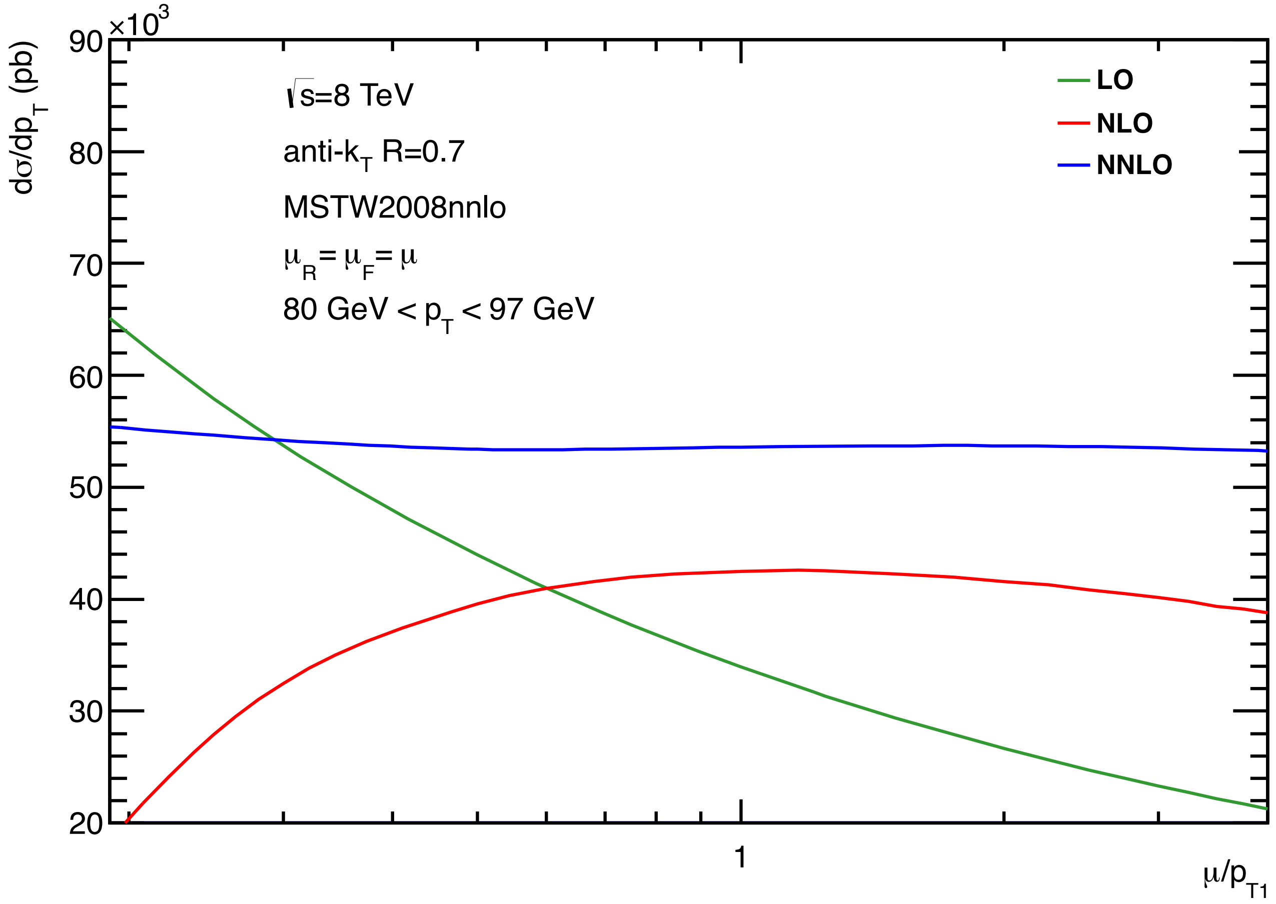
- Precision for mass
- Precision for gluon pdf

$pp \to 2\,\text{jets}$

A. Gehrmann-De Ridder, T. Gehrmann, E.W.N. Glover, J.Pires (2013)

- Pure gluon (leading colour) using antenna subtraction : NNLOJET





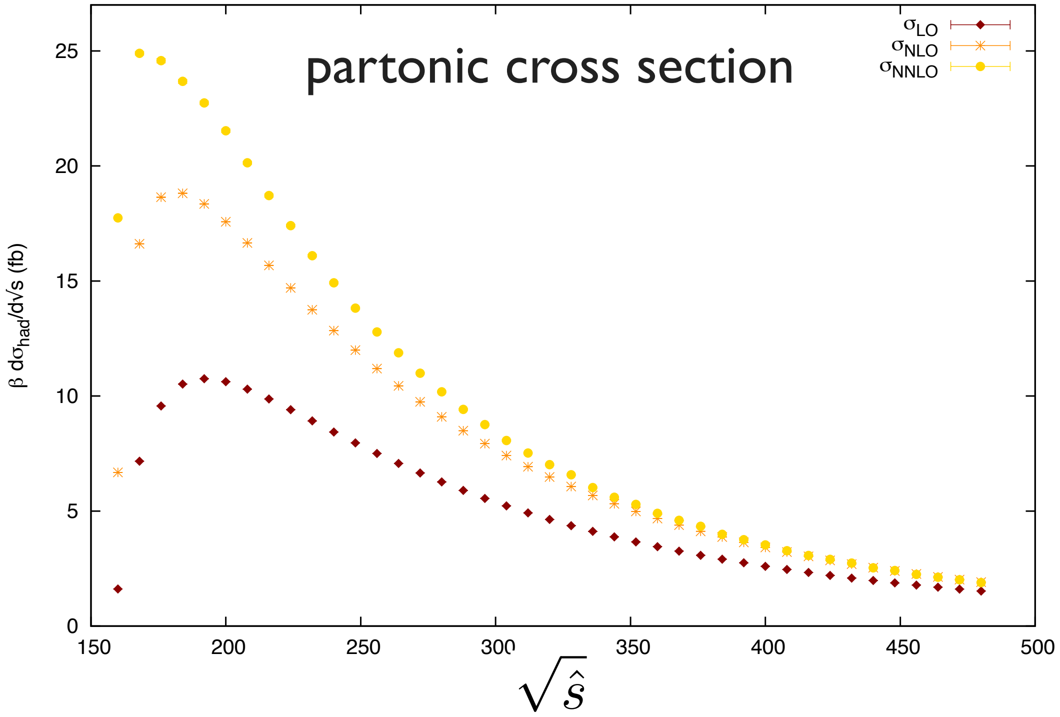
- 15-25% increase
- K-factor ~flat

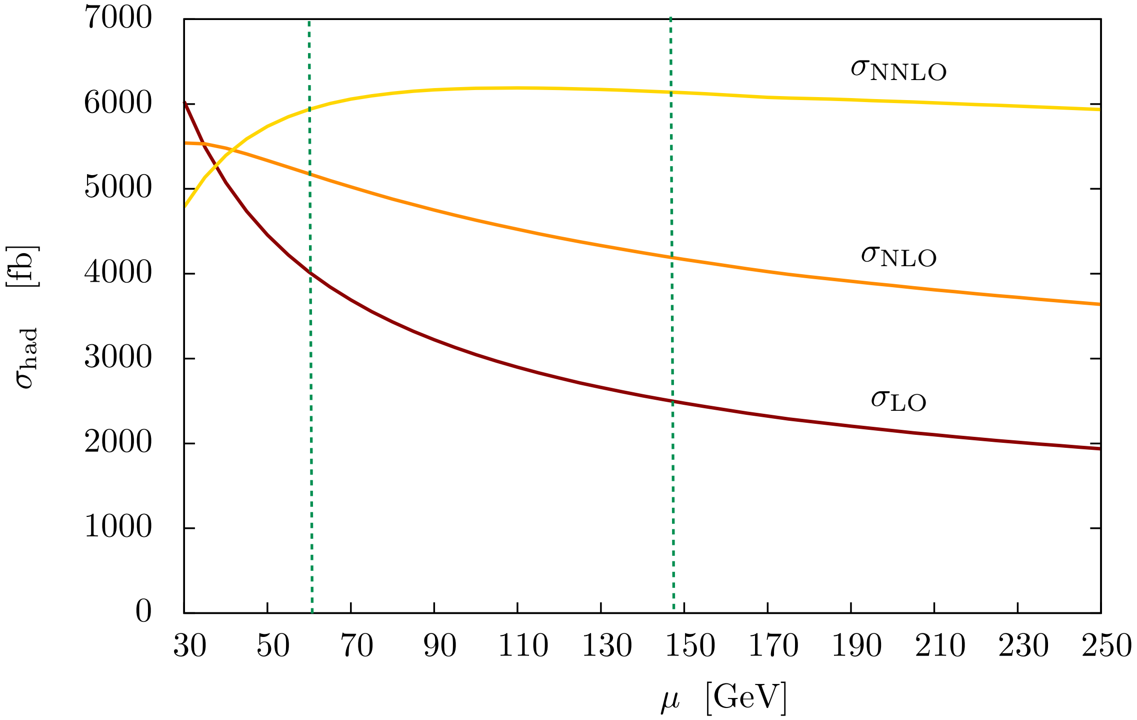
- Amazing reduction in scale dependence : precision for LHC

Similar results expected for other partonic channels

$pp \to H + \text{jet}$

R.Boughezal, F.Caola, K.Melnikov, F.Petriello, M.Schulze (2013)





- Pure gluon only $\quad p_T^{\text{jet}} > 30\,\text{GeV}$

$$\sigma_{\text{LO}}(pp \to Hj) = 2713^{+1216}_{-776}\ \text{fb},$$
$$\sigma_{\text{NLO}}(pp \to Hj) = 4377^{+760}_{-738}\ \text{fb},$$
$$\sigma_{\text{NNLO}}(pp \to Hj) = 6177^{-204}_{+242}\ \text{fb}.$$

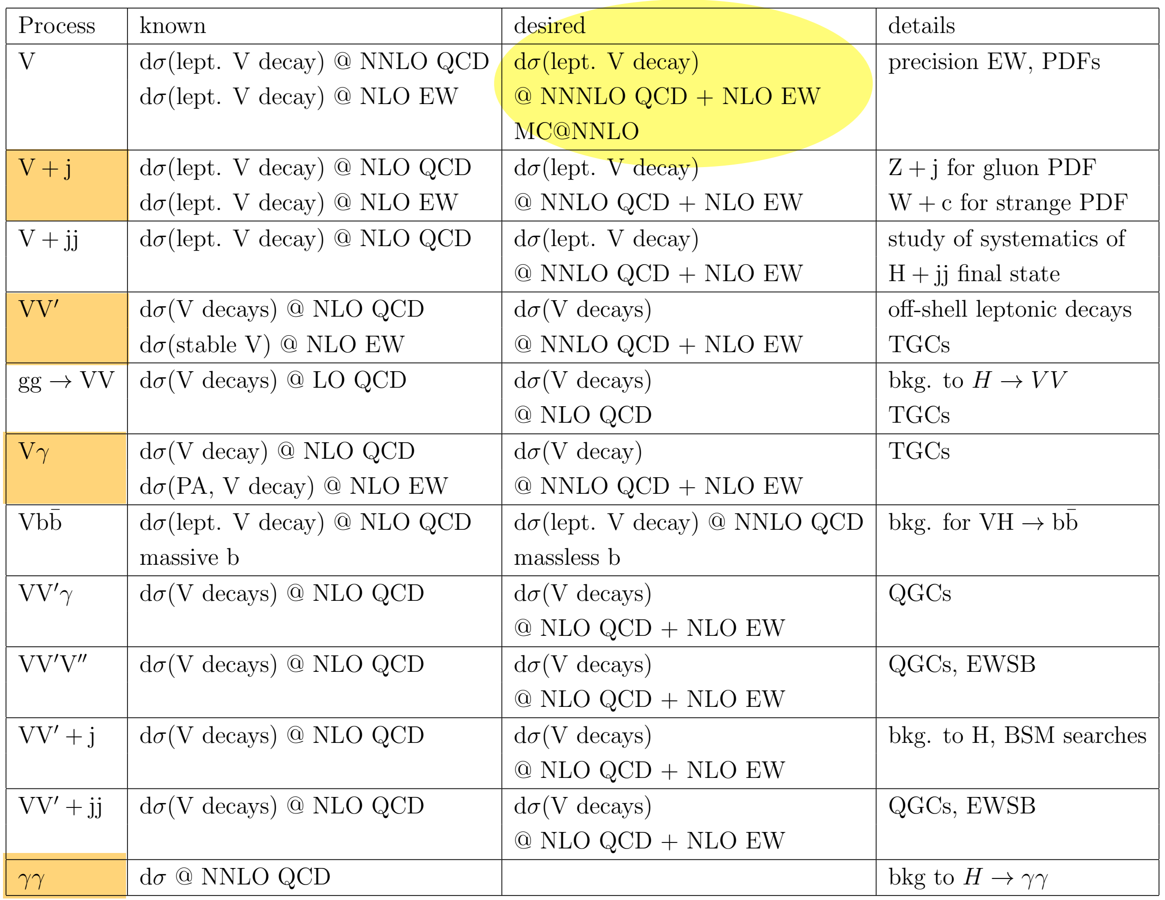
+60% NLO

+30-40% NNLO

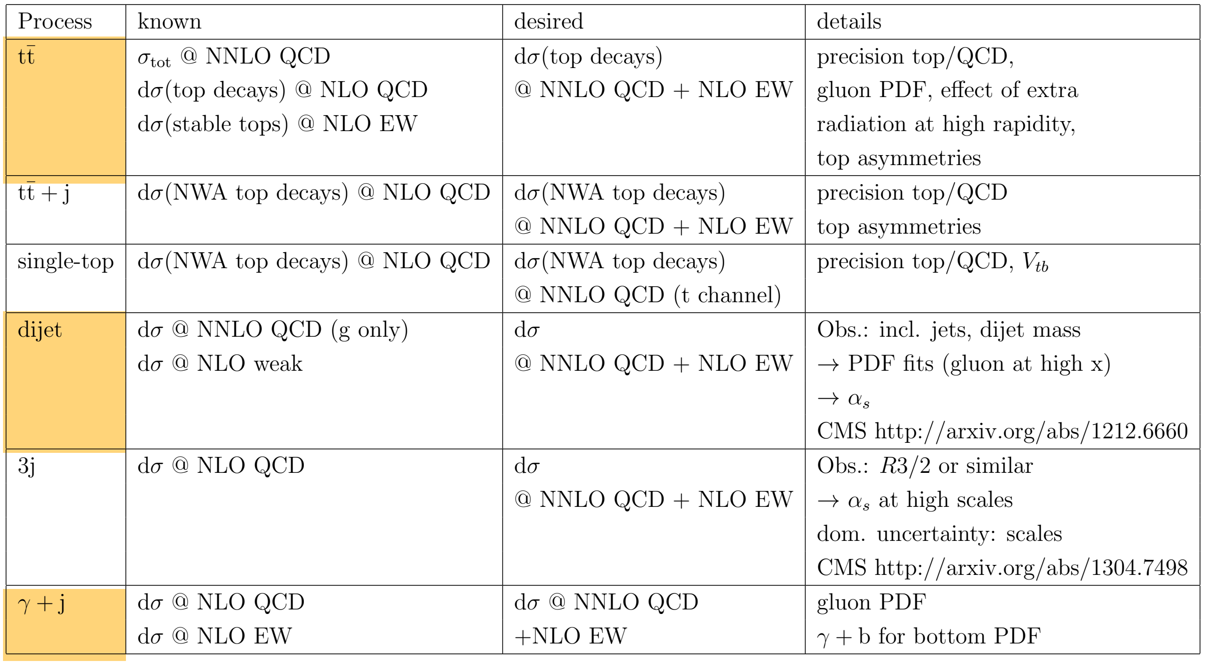
- Another case of significantly reduced scale dependence ~4%

Les Houches NNLO wish-list (2013)

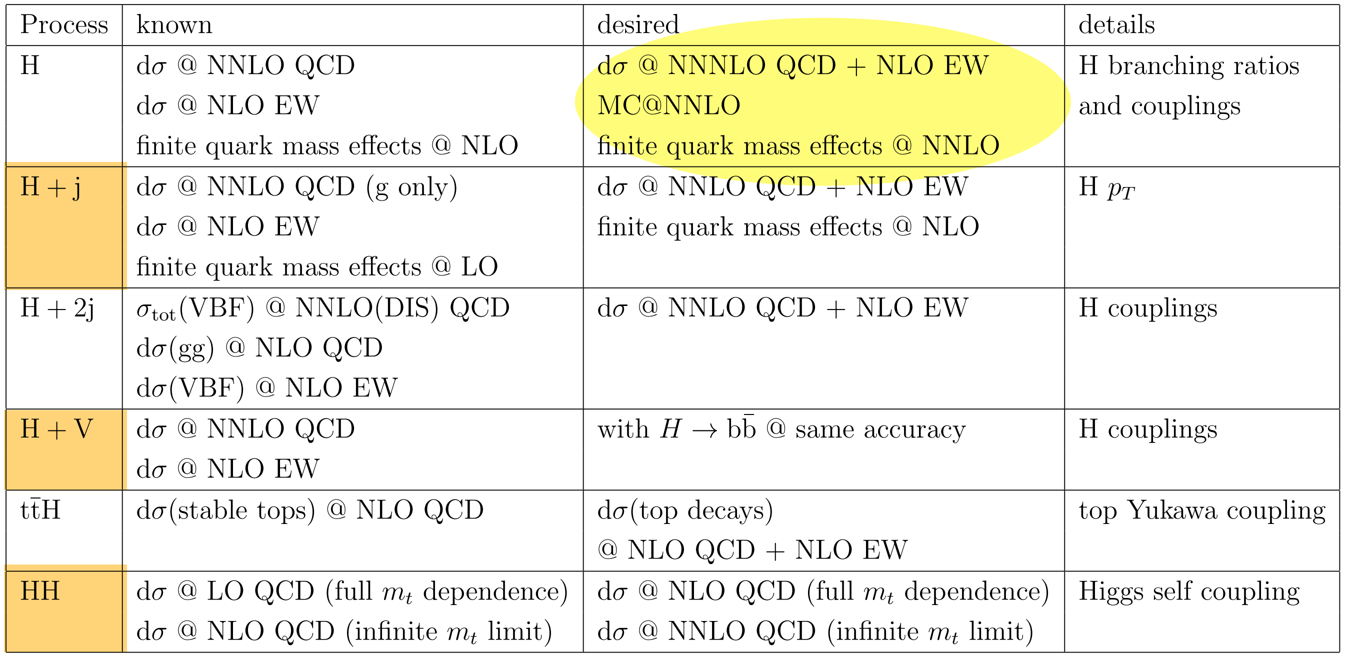
- Many of them doable in the next few years
- More realistic final states (V, top with decays)
- Larger multiplicities not possible yet
- Automation far away
- Shower requires increase in accuracy
- NLO EW corrections needed



Process	known	desired	details
V	$d\sigma$(lept. V decay) @ NNLO QCD $d\sigma$(lept. V decay) @ NLO EW	$d\sigma$(lept. V decay) @ NNNLO QCD + NLO EW MC@NNLO	precision EW, PDFs
$V+j$	$d\sigma$(lept. V decay) @ NLO QCD $d\sigma$(lept. V decay) @ NLO EW	$d\sigma$(lept. V decay) @ NNLO QCD + NLO EW	$Z+j$ for gluon PDF $W+c$ for strange PDF
$V+jj$	$d\sigma$(lept. V decay) @ NLO QCD	$d\sigma$(lept. V decay) @ NNLO QCD + NLO EW	study of systematics of $H+jj$ final state
VV'	$d\sigma$(V decays) @ NLO QCD $d\sigma$(stable V) @ NLO EW	$d\sigma$(V decays) @ NNLO QCD + NLO EW	off-shell leptonic decays TGCs
$gg \to VV$	$d\sigma$(V decays) @ LO QCD	$d\sigma$(V decays) @ NLO QCD	bkg. to $H \to VV$ TGCs
$V\gamma$	$d\sigma$(V decay) @ NLO QCD $d\sigma$(PA, V decay) @ NLO EW	$d\sigma$(V decay) @ NNLO QCD + NLO EW	TGCs
$Vb\bar{b}$	$d\sigma$(lept. V decay) @ NLO QCD massive b	$d\sigma$(lept. V decay) @ NNLO QCD massless b	bkg. for $VH \to b\bar{b}$
$VV'\gamma$	$d\sigma$(V decays) @ NLO QCD	$d\sigma$(V decays) @ NLO QCD + NLO EW	QGCs
$VV'V''$	$d\sigma$(V decays) @ NLO QCD	$d\sigma$(V decays) @ NLO QCD + NLO EW	QGCs, EWSB
$VV'+j$	$d\sigma$(V decays) @ NLO QCD	$d\sigma$(V decays) @ NLO QCD + NLO EW	bkg. to H, BSM searches
$VV'+jj$	$d\sigma$(V decays) @ NLO QCD	$d\sigma$(V decays) @ NLO QCD + NLO EW	QGCs, EWSB
$\gamma\gamma$	$d\sigma$ @ NNLO QCD		bkg to $H \to \gamma\gamma$



Process	known	desired	details
$t\bar{t}$	$\sigma_{\rm tot}$ @ NNLO QCD $d\sigma$(top decays) @ NLO QCD $d\sigma$(stable tops) @ NLO EW	$d\sigma$(top decays) @ NNLO QCD + NLO EW	precision top/QCD, gluon PDF, effect of extra radiation at high rapidity, top asymmetries
$t\bar{t}+j$	$d\sigma$(NWA top decays) @ NLO QCD	$d\sigma$(NWA top decays) @ NNLO QCD + NLO EW	precision top/QCD top asymmetries
single-top	$d\sigma$(NWA top decays) @ NLO QCD	$d\sigma$(NWA top decays) @ NNLO QCD (t channel)	precision top/QCD, V_{tb}
dijet	$d\sigma$ @ NNLO QCD (g only) $d\sigma$ @ NLO weak	$d\sigma$ @ NNLO QCD + NLO EW	Obs.: incl. jets, dijet mass → PDF fits (gluon at high x) $\to \alpha_s$ CMS http://arxiv.org/abs/1212.6660
3j	$d\sigma$ @ NLO QCD	$d\sigma$ @ NNLO QCD + NLO EW	Obs.: $R3/2$ or similar $\to \alpha_s$ at high scales dom. uncertainty: scales CMS http://arxiv.org/abs/1304.7498
$\gamma+j$	$d\sigma$ @ NLO QCD $d\sigma$ @ NLO EW	$d\sigma$ @ NNLO QCD +NLO EW	gluon PDF $\gamma+b$ for bottom PDF



Process	known	desired	details
H	$d\sigma$ @ NNLO QCD $d\sigma$ @ NLO EW finite quark mass effects @ NLO	$d\sigma$ @ NNNLO QCD + NLO EW MC@NNLO finite quark mass effects @ NNLO	H branching ratios and couplings
$H+j$	$d\sigma$ @ NNLO QCD (g only) $d\sigma$ @ NLO EW finite quark mass effects @ LO	$d\sigma$ @ NNLO QCD + NLO EW finite quark mass effects @ NLO	H p_T
$H+2j$	$\sigma_{\rm tot}$(VBF) @ NNLO(DIS) QCD $d\sigma$(gg) @ NLO QCD $d\sigma$(VBF) @ NLO EW	$d\sigma$ @ NNLO QCD + NLO EW	H couplings
$H+V$	$d\sigma$ @ NNLO QCD $d\sigma$ @ NLO EW	with $H \to b\bar{b}$ @ same accuracy	H couplings
$t\bar{t}H$	$d\sigma$(stable tops) @ NLO QCD	$d\sigma$(top decays) @ NLO QCD + NLO EW	top Yukawa coupling
HH	$d\sigma$ @ LO QCD (full m_t dependence) $d\sigma$ @ NLO QCD (infinite m_t limit)	$d\sigma$ @ NLO QCD (full m_t dependence) $d\sigma$ @ NNLO QCD (infinite m_t limit)	Higgs self coupling

Electroweak corrections at large energies

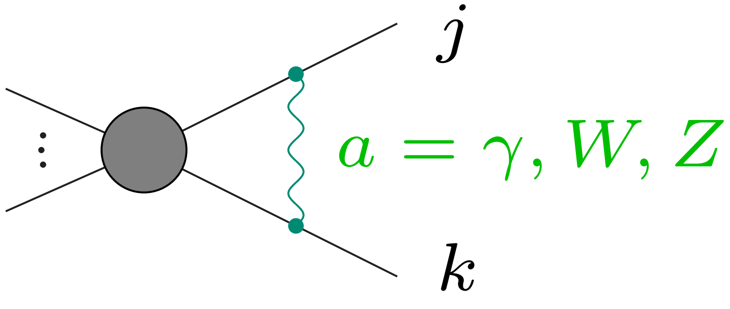
- Sudakov logarithms induced by soft gauge-boson exchange

at $\sqrt{s} \sim 1\,\mathrm{TeV}$

S. Dittmaier

$$\delta_{\mathrm{LL}}^{1-\mathrm{loop}} \sim -\frac{\alpha}{\pi s_{\mathrm{W}}^2} \ln^2\left(\frac{s}{M_{\mathrm{W}}^2}\right) \quad \simeq -26\%$$

$$\delta_{\mathrm{LL}}^{2-\mathrm{loop}} \sim +\frac{\alpha^2}{2\pi^2 s_{\mathrm{W}}^4} \ln^4\left(\frac{s}{M_{\mathrm{W}}^2}\right) \simeq 3.5\%$$



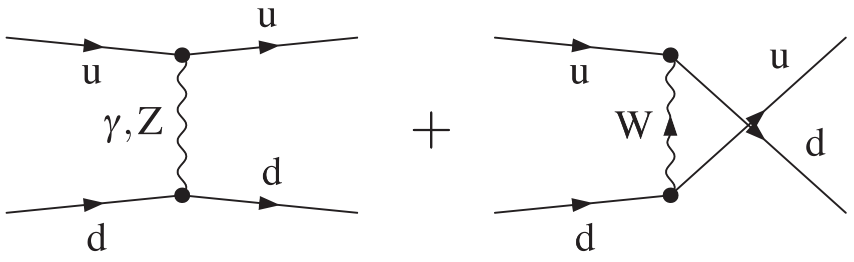
- still sizable at 2-loops

$s, |t|, |u| \gg M_W^2$

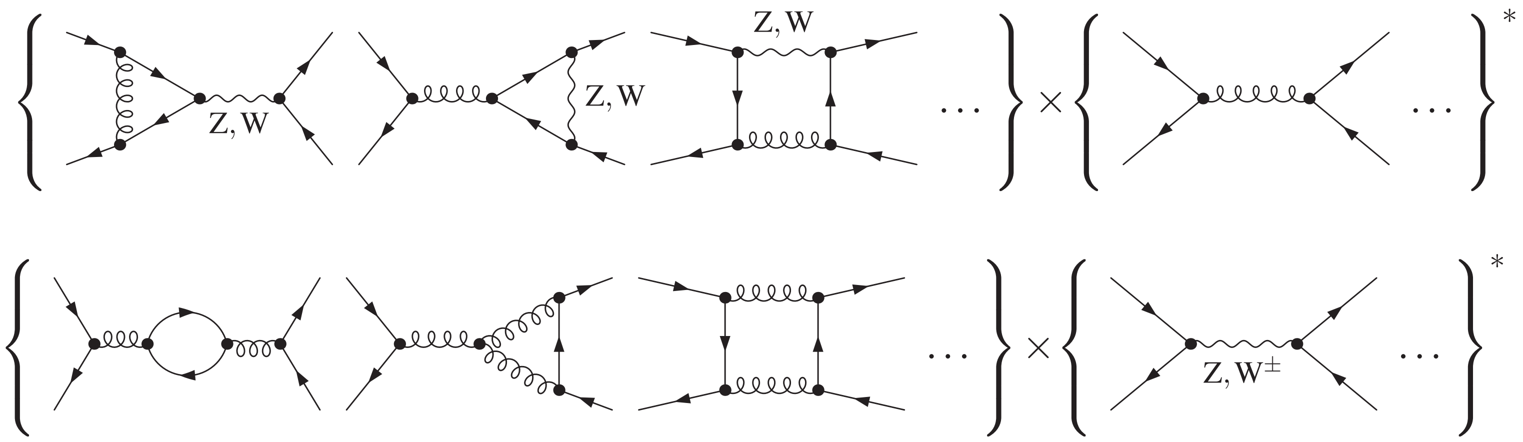
Dijet production

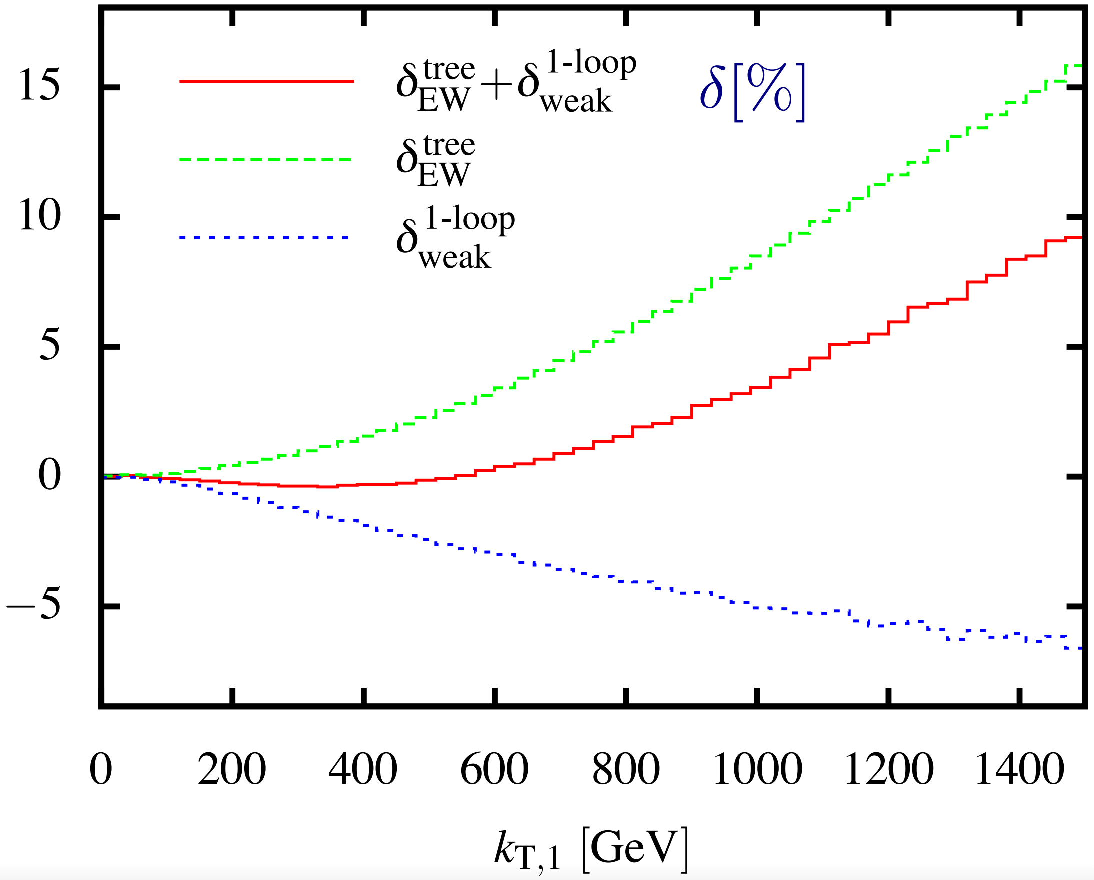
Dittmaier, Huss, Speckner

tree EW



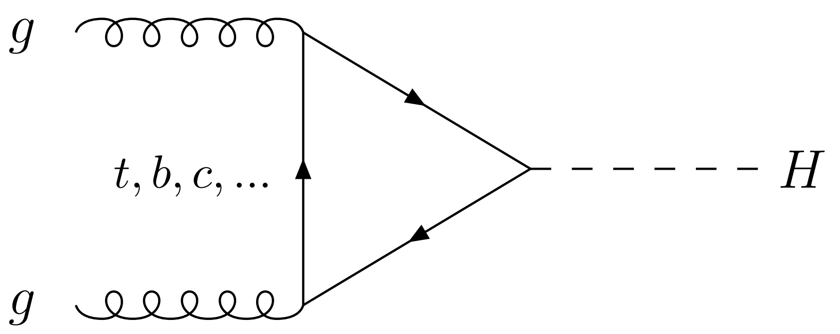
1-loop EW



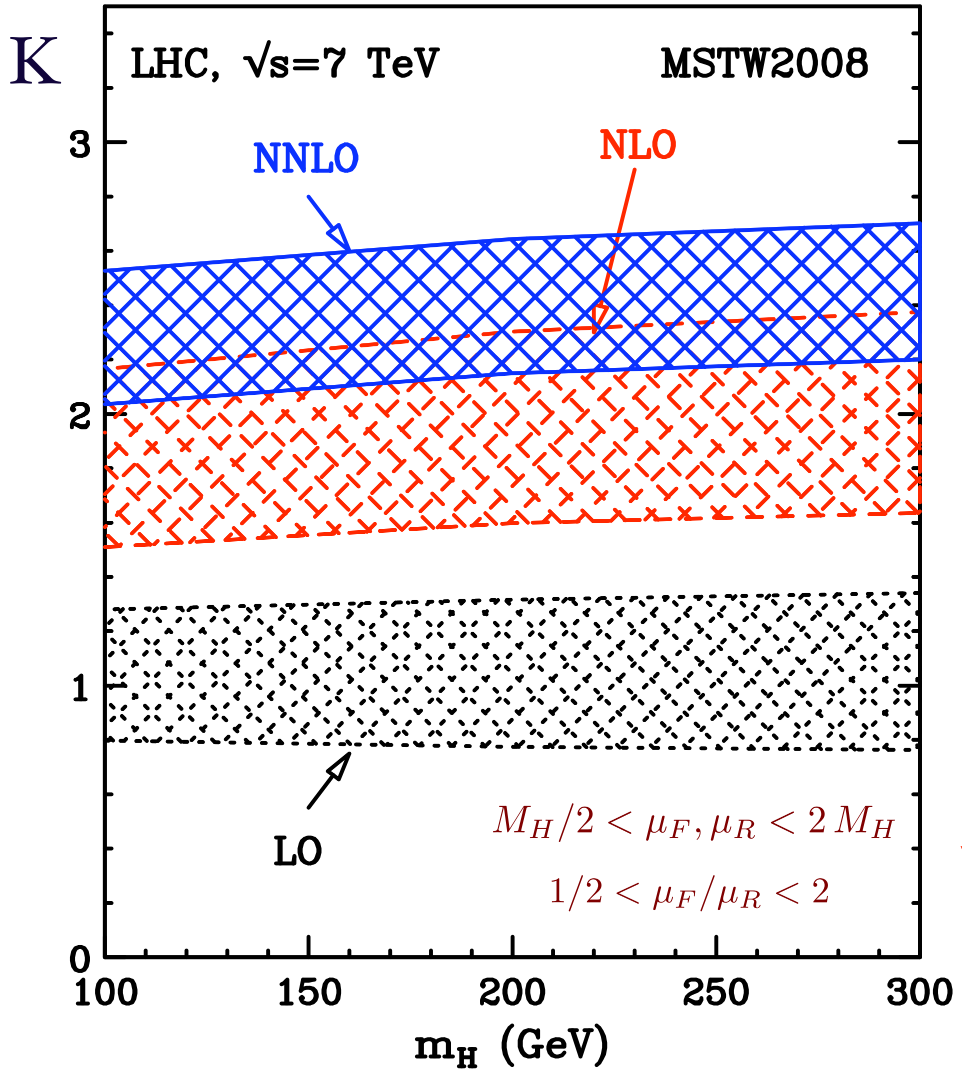


Higgs Boson

- Gluon-gluon fusion dominates due to large gluon luminosity



- QCD corrections are huge!



$$K = \frac{\sigma^{NNLO(NLO)}}{\sigma^{LO}}$$

NLO Dawson (1991); Djouadi, Spira, Zerwas (1991)
Graudenz, Spira, Zerwas (1993)

NNLO Harlander, Kilgore (2002)
Anastasiou, Melnikov (2002)
Ravindran, Smith, van Neerven (2003)

Improved Higgs Cross-section @ LHC

- NNLL Resummation 9% at 7 TeV Catani, deF., Grazzini, Nason (2003)
- Two loop EW corrections not negligible ~ 5%
  Aglietti, Bonciani, Degrassi, Vicini (2004)
  Degrassi, Maltoni (2004)
  Actis, Passarino, Sturm, Uccirati (2008)
- Mixed EW-QCD effects evaluated in EFT approach Anastasiou et al (2008)
- + Mass effects, Line-shape, interferences, ... Higgs Cross-Section WG

$$\sigma(\mathrm{m_H} = 125\,\mathrm{GeV}) = 19.27^{\overset{\text{scale}}{+7.2\%}\ \overset{\text{pdf}+\alpha_S}{+7.5\%}}_{-7.8\%\ -6.9\%}\ \mathrm{pb}$$

deF, Grazzini

- Still sizable uncertainties but great improvement over the last years
- And more precise results possible in near future

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deF, Grazzini

Higher orders

LHC data and more observables

- Still sizable uncertainties but great improvement over the last years
- And more precise results possible in near future

Even Higher orders N^3LO

- 3 loop form factor
  Baikov et al (2009)
  Gehrmann et al (2010)
  Lee, Smirnov, Smirnov (2010)

- Triple real emission : threshold expansion Anastasiou, Duhr, Dulat, Mistlberger (2013)

- Subtraction terms
  Höschele, Hoff, Pak, Steinhauser, Ueda (2013)
  Buehler, Lazopoulos (2013)

- Missing
  - 2 loop + single emission
  - 1 loop + double emission

  work in progress

- Possible to reach Soft-Virtual approx. (and beyond) in near future

- Resummation at N^3LL : soft contributions Moch, Vermaseren, Vogt (2005)

Conclusions

Amazing work in the last few years → direct consequence of LHC

- PDFs: precision and uncertainties
- NLO : multileg processes and automatic!
- NNLO finally reaching $2 \to 2$ processes
- Resummation setting NNLL as new standard
- Improvements for NLO+PS and high degree of automation
- + many other issues not discussed (including jet structure)!

Conclusions

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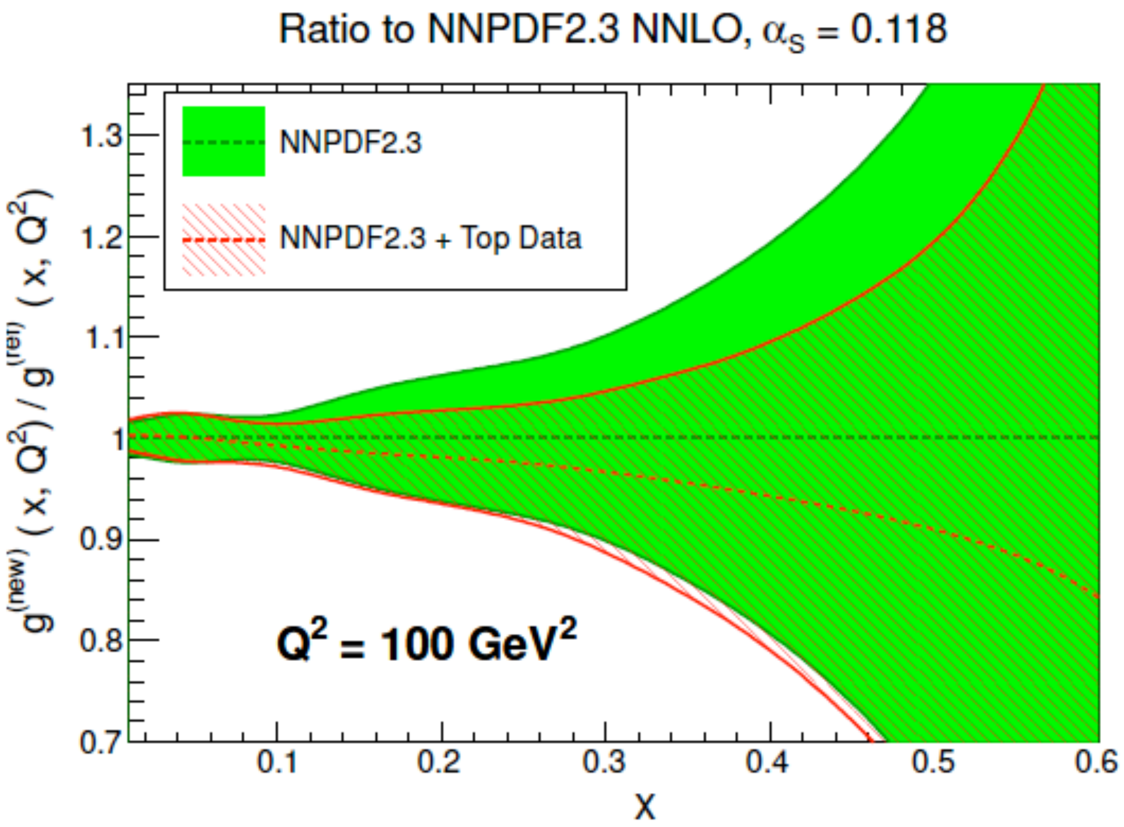
Thanks to Eric Laenen, Sven Moch, Thomas Gehrmann, Aude Gehrmann-De Ridder, Nigel Glover, Stefan Dittmaier, Massimiliano Grazzini and Joey Huston for discussions

Thanks!

Backup Slides

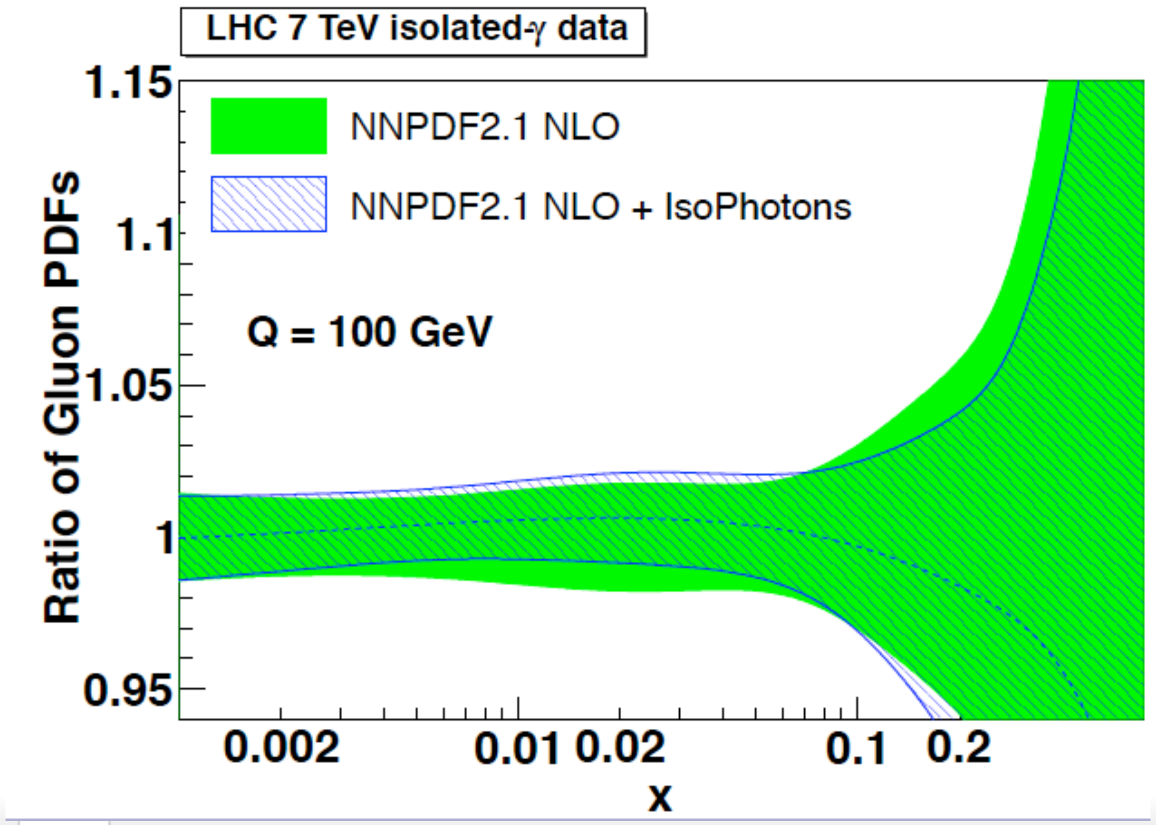
Effect of top cross section in gluon determination



Czakon, Mangano, Mitov, Rojo (2013)

20% reduction in uncertainty at large x (where correlation is most significant)

Effect of prompt photons in gluon determination



moderate reduction of uncertainties in region relevant for Higgs production

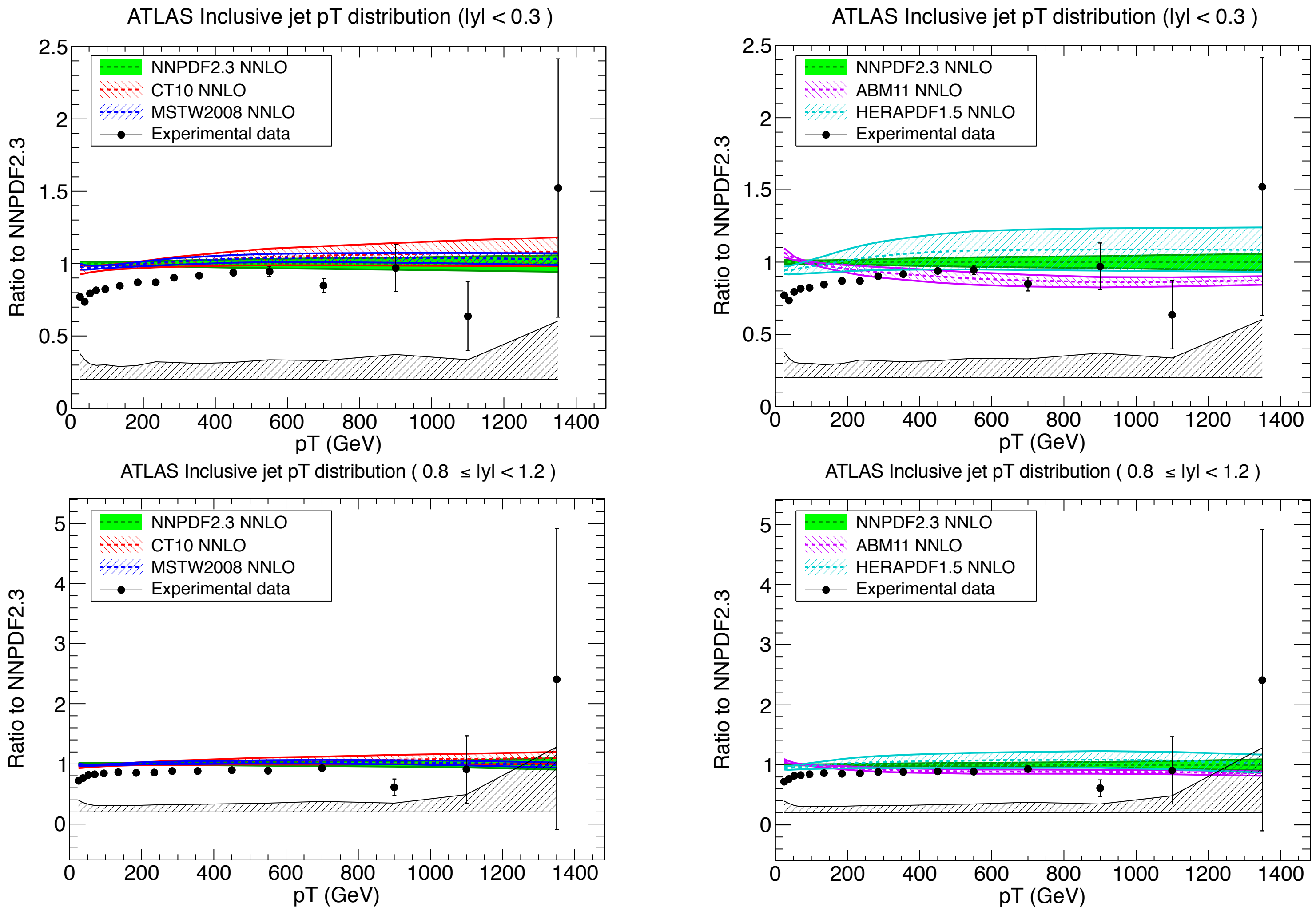
D'Enterria, Rojo

need more precise data for photon+jet

Large p_T gauge boson production also relevant

Comparison to LHC jet data (Atlas 2010)

Ball et al (2012)



Reasonable agreement

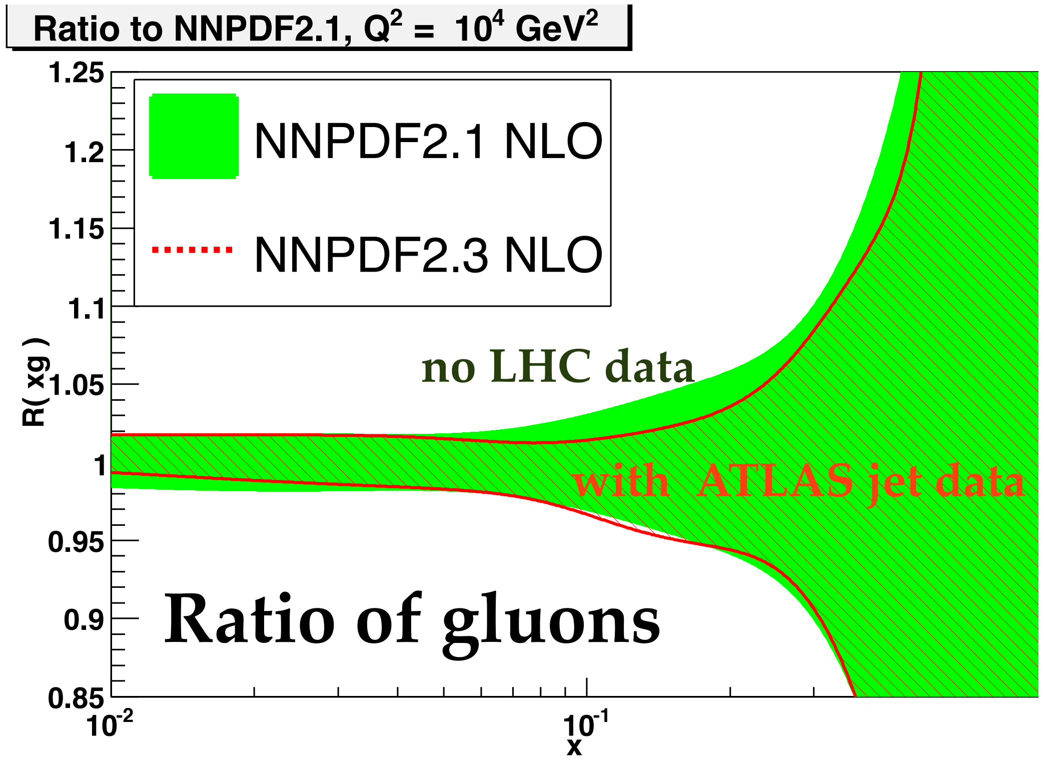
Still large systematic uncertainties

No NNLO calculation available yet

Use NLO or NLO+threshold corrections

Larger impact expected with full data set

J.Rojo, DIS2013



- First NNLO calculations achieved using different methods

Sector decomposition	Anastasiou, Melnikov, Petriello Czakon Boughezal, Melnikov, Petriello Anastasiou, Herzog, Lazopoulos ...
q_T - subtraction	Catani, Grazzini Catani, Cieri, deF., Ferrera, Grazzini
Antenna subtraction	Gehrmann-De Ridder, Glover, Gehrmann; + Daleo, Luisoni, Boughezal, Ritzmann, Monni, ...

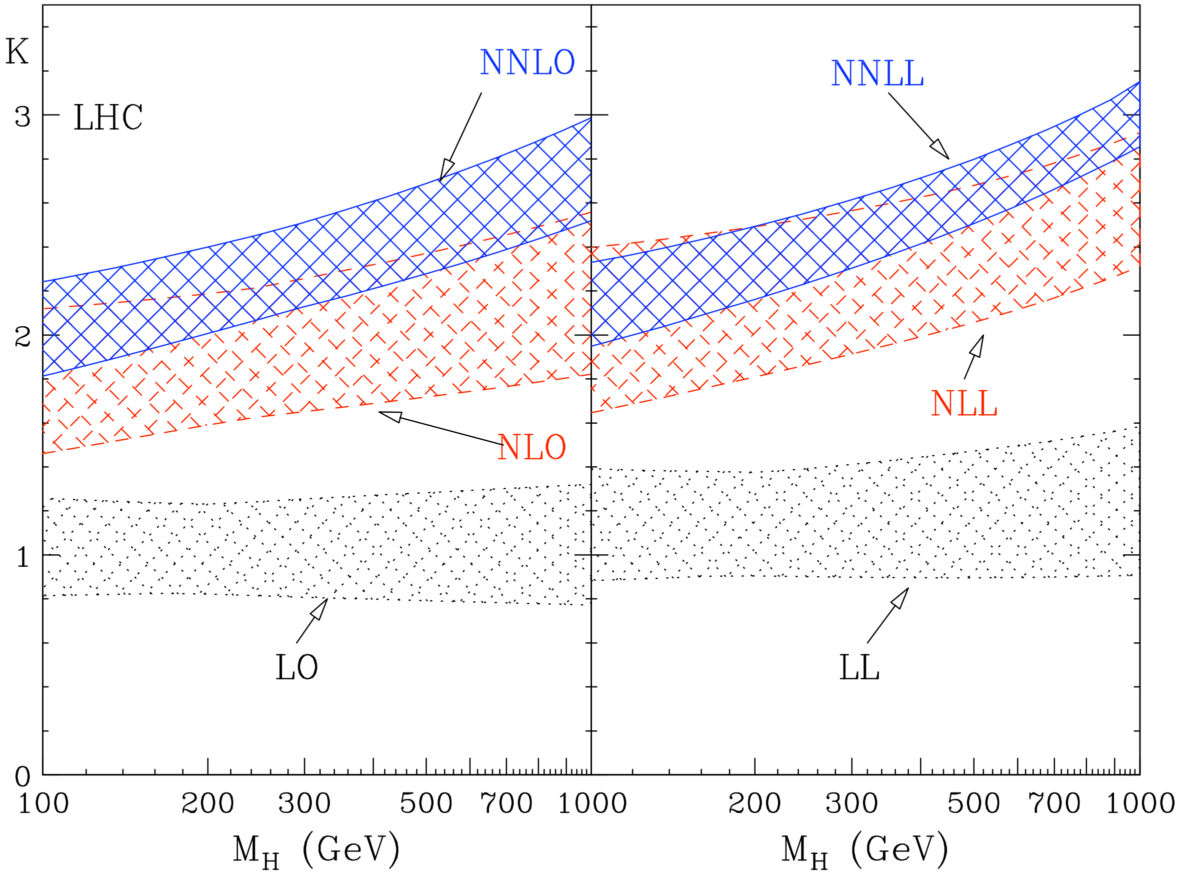
- Bottleneck in virtual amplitudes with many legs but do not underestimate numerical/stability issues in real contributions

- Automation in NNLO still far away

- Matching NNLO with Shower will require increase in logarithmic accuracy of shower (NLL in all emissions?)

Higgs: Improvements over NNLO

- QCD corrections dominated by soft and virtual gluon radiation

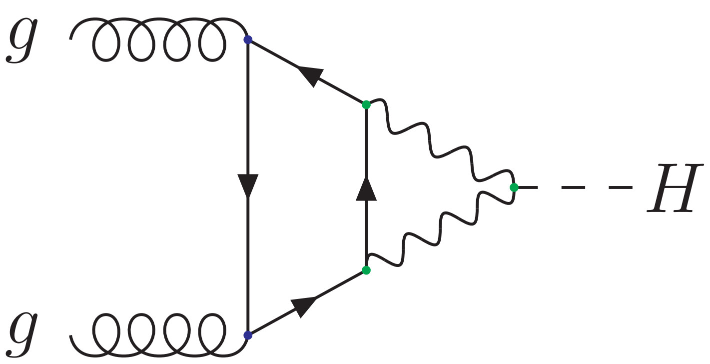


Threshold NNLL (+NNLO) Resummation

9% at 7 TeV, 13% at Tevatron

Catani, deF, Grazzini, Nason (2003)

- Two loop EW corrections not negligible ~ 5%



Aglietti, Bonciani, Degrassi, Vicini (2004)
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