Fiducial cross-sections at higher orders

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LHCHXS KICK-OFF MEETING ON FIDUCIAL CROSS SECTIONS
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Higher orders and Higgs: status

In the (very) recent past, three major improvements in our theoretical modeling for the Higgs

- N^{3}LO cross section, fully inclusive
  [Anastasiou, Duhr, Dulat, Mistlberger (2015)]

- NNLO H+J cross section, fully exclusive
  [Boughezal, FC, Melnikov, Petriello, Schulze (2015); Boughezal, Focke, Giele, Liu, Petriello (2015)]

- NNLO VBF cross section, fully exclusive
  [Cacciari, Dreyer, Karlberg, Salam, Zanderighi (2015)] —> Frédéric's talk

  The NNLO results are fully exclusive —> direct access to the fiducial region

  The N^{3}LO result is inclusive, but can provide important information for the fiducial region as well (e.g. jet vetoes)

Why fixed order

No matter how precise, a pure fixed order computation WILL NOT

- give you events
- give you a proper description of the IR physics, both perturbative (e.g Sudakov region) and non-perturbative

HOWEVER

- in its range of applicability (largish p_T, not so exclusive quantities) it provides the CLEANEST POSSIBLE THEORETICAL PREDICTION
- if computed at high-enough orders, most of the not-so-large logs will be properly described (also matching ambiguities reduced)
- framework systematically improvable, reasonable control on uncertainties (although we may be already hitting the wall where scale variation is no longer a good estimate)
- when PRECISION is the goal, ONE OF THE KEY PLAYERS

Fiducial results for gluon fusion: H+J@NNLO

H+J@NNLO: status

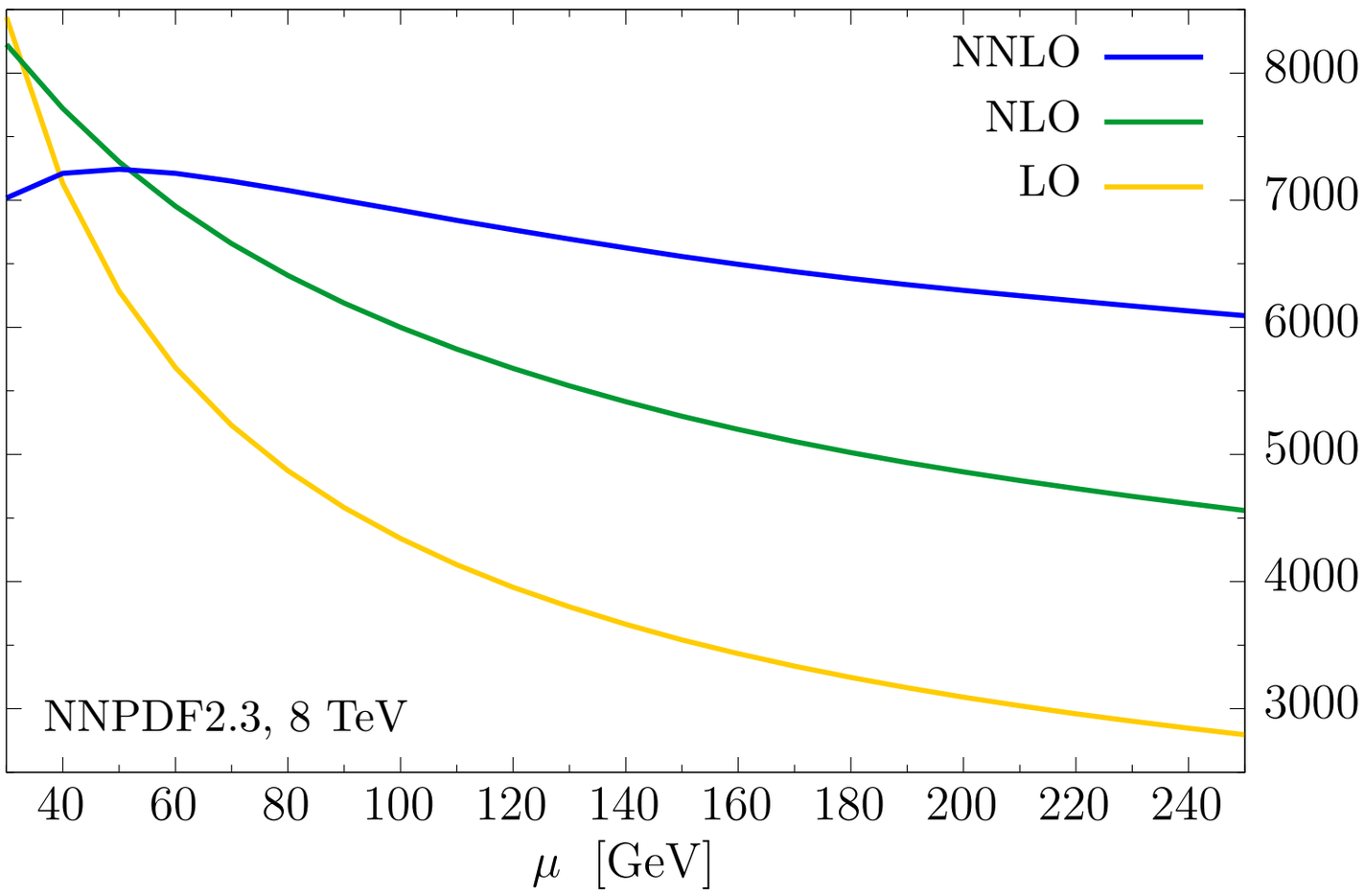
- computed from different methods —> VERY IMPORTANT validations possible
  - Boughezal, FC, Melnikov, Petriello, Schulze —> Sector Decomposition + FKS (Czakon; Boughezal, Melnikov, Petriello; Czakon, Heymes)
  - Boughezal, Focke, Giele, Liu, Petriello —> N-jettiness slicing (Boughezal, Focke, Liu, Petriello; Gaunt, Strahlhofen, Tackmann, Walsh)
  - a third computation is along the way: Chen, Gehrmann, Jaquier, Glover —> antenna subtraction
- what this can provide
  - NNLO accurate description for arbitrary differential distributions, with arbitrary jet algorithm / parameters. State-of-the-art predictions for the first (NNLO) and second (NLO) jet bins
- however, in the HEFT only. Good description up to p_T ~ 150 GeV. Do not expect very good modeling at 400 GeV…
- so far, no public codes (state of the art theory —> user friendly implementation is not our main concern now)
- getting results can be computing intensive (~1K CPU), results must be carefully checked

WILL REQUIRE SOME EFFORT IN COORDINATING THEORY CAPABILITY // EXPERIMENTAL DESIDERATA

H+J@NNLO: sample results

1-JET FIDUCIAL CROSS SECTION

- EFT; anti-k_T, R=0.5, $p_{T,cut}$ = 30 GeV
- NNPDF23 parton sets, $\mu = m_H = 125$ GeV



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

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

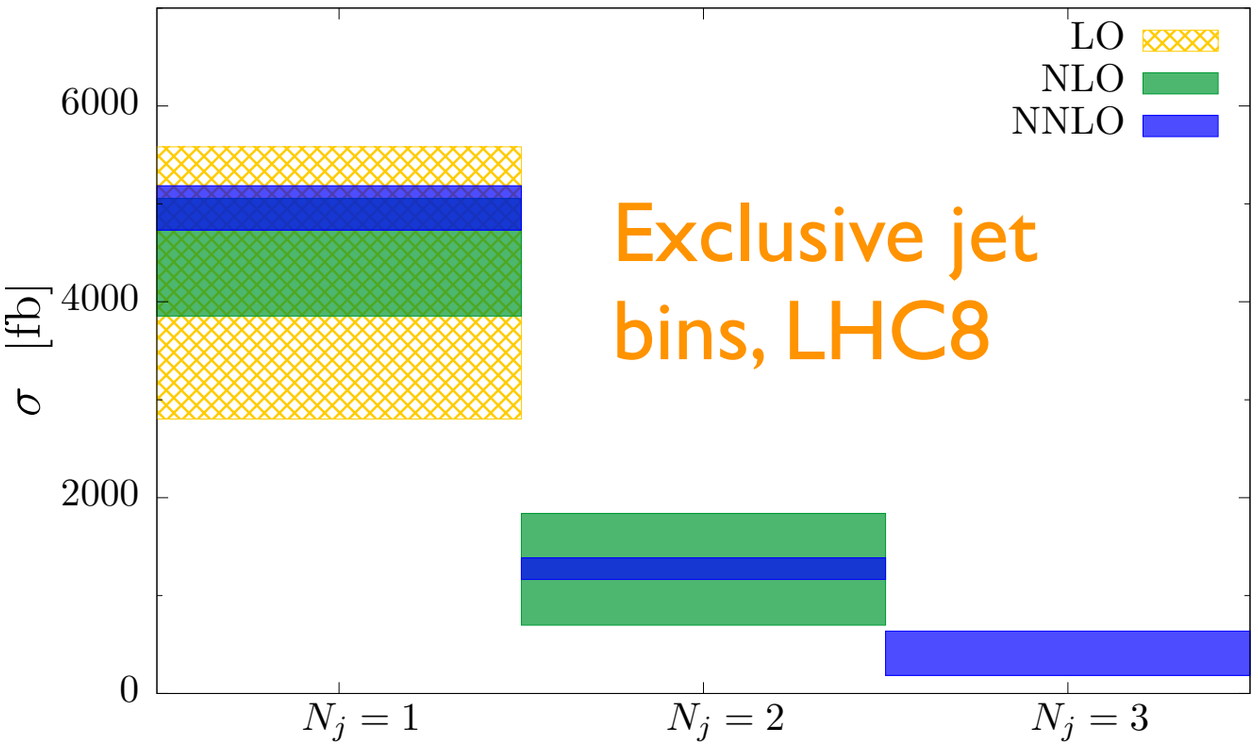
$$\sigma_{\rm NNLO} = 6.7^{+0.5}_{-0.6}\ {\rm pb}$$

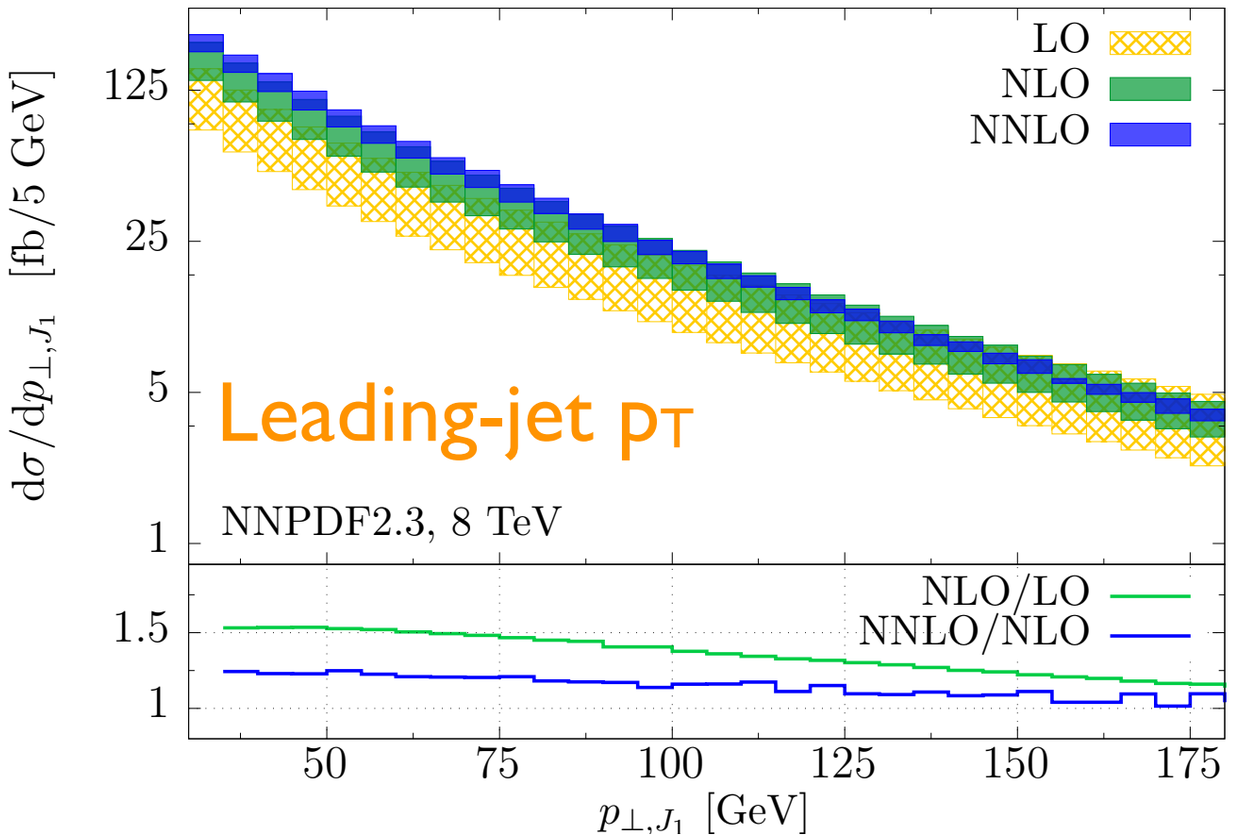
$$K^{m_H}_{\rm NNLO} \sim 20\%,\ K^{m_H/2}_{\rm NNLO} \sim 4\%$$

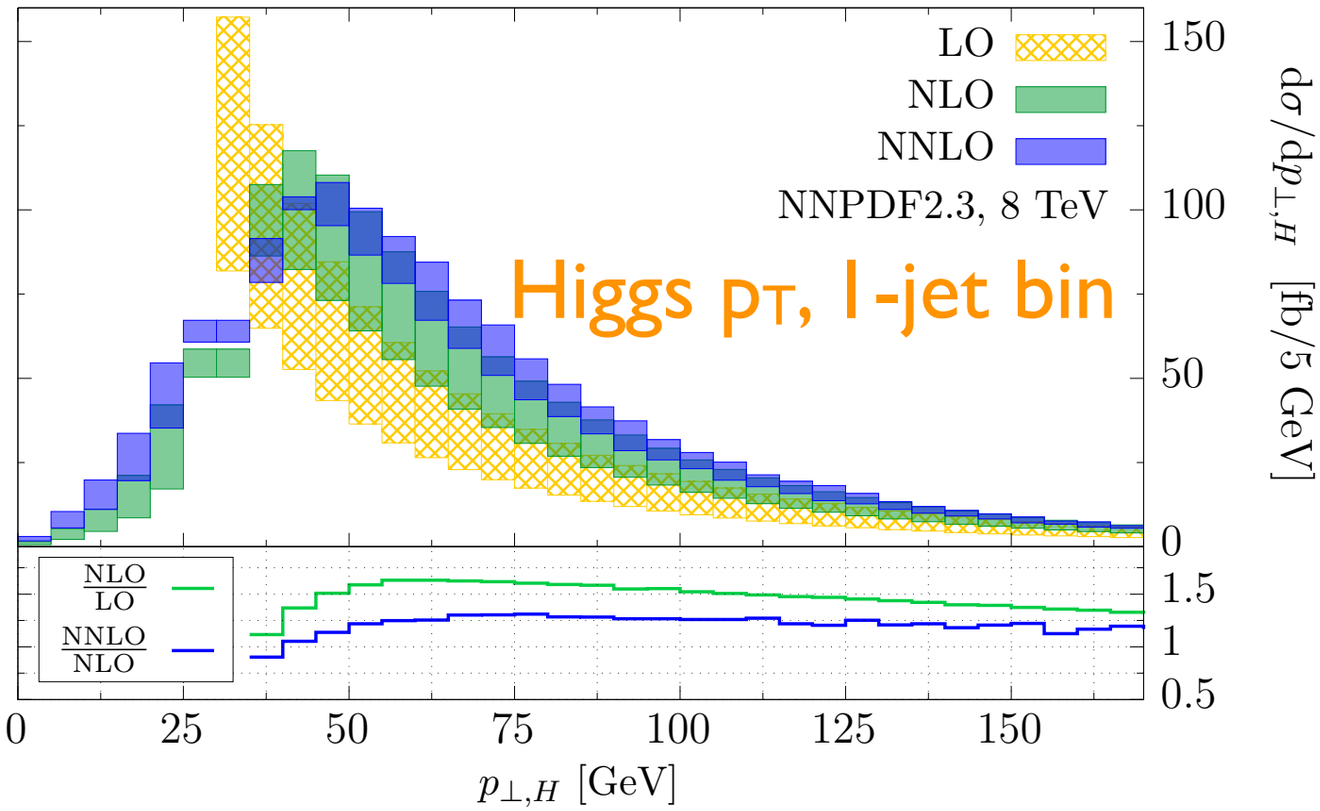
$$\delta^{\rm PDF4LHC}_{\rm PDF} \sim 5\%$$

Sizable corrections, significantly reduced scale uncertainty

H+J@NNLO: sample results







- Non trivial shapes (fixed scale)
- Bulk of corrections at small p_T
- At large p_T, K->1
- Significantly reduced scale uncertainties

Jet-veto cross-section

[Many thanks to P. F. Monni and F. Dulat]

Combining H+1@NNLO and inclusive Higgs@N³LO:

EFFICIENCIES ONE ORDER HIGHER

LHC13, NNPDF2.3, anti-k_T, R=0.5, $\mu_0=m_H$, $Q_{res} = m_H/2$, $p_{T,veto}$ = 30 GeV

0-jet bin

ord	$\sigma^{\text{f.o.}}_{0-\text{jet}}$ (JVE)	$\sigma^{\text{f.o.+NNLL}}_{0-\text{jet}}$ (JVE)	$\sigma^{\text{f.o.+NNLL}}_{0-\text{jet}}$ (scales)
NNLO	$26.2^{+4.0}_{-4.0}$ pb	$25.8^{+3.8}_{-3.8}$	$25.8^{+1.6}_{-1.6}$
N³LO	$27.2^{+2.7}_{-2.7}$ pb	$27.2^{+1.4}_{-1.4}$	$27.2^{+0.9}_{-0.9}$

≥1-jet bin

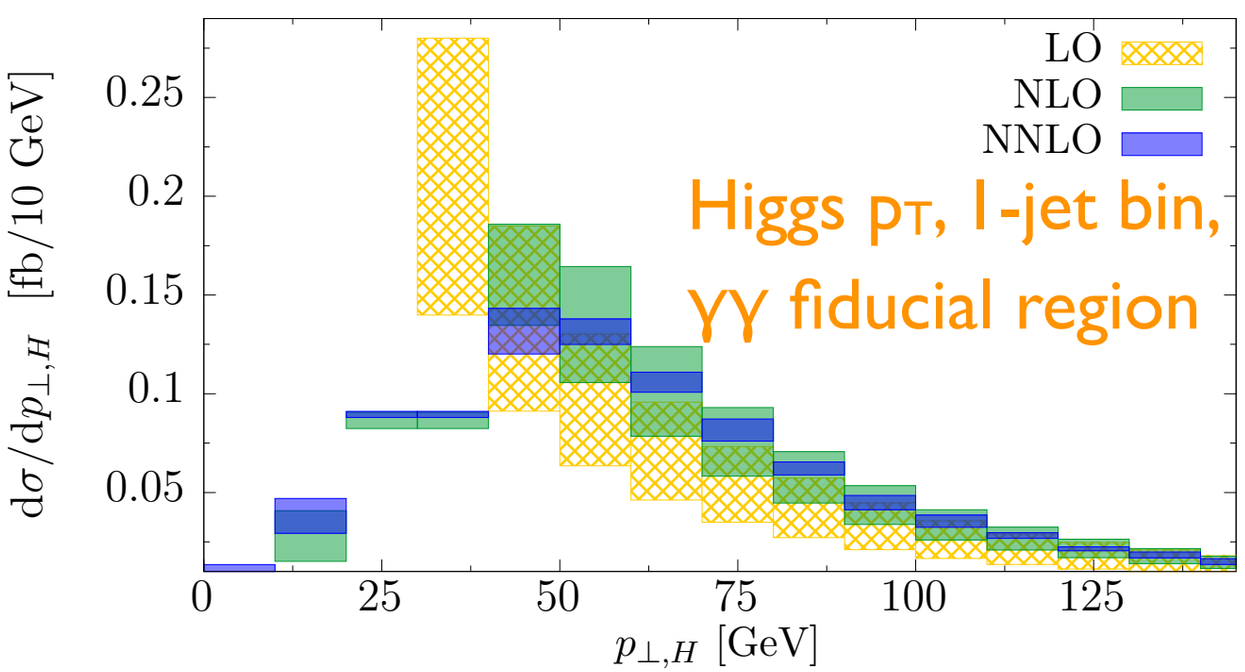
ord	$\sigma^{\text{f.o.}}_{\geq 1-\text{jet}}$ (scales)	$\sigma^{\text{f.o.}}_{\geq 1-\text{jet}}$ (JVE)	$\sigma^{\text{f.o.+NNLL}}_{\geq 1-\text{jet}}$ (JVE)
NLO	$14.7^{+2.8}_{-2.8}$ pb	$14.7^{+3.4}_{-3.4}$	$15.1^{+2.7}_{-2.7}$
NNLO	$17.5^{+1.3}_{-1.3}$ pb	$17.5^{+2.6}_{-2.6}$	$17.5^{+1.1}_{-1.1}$

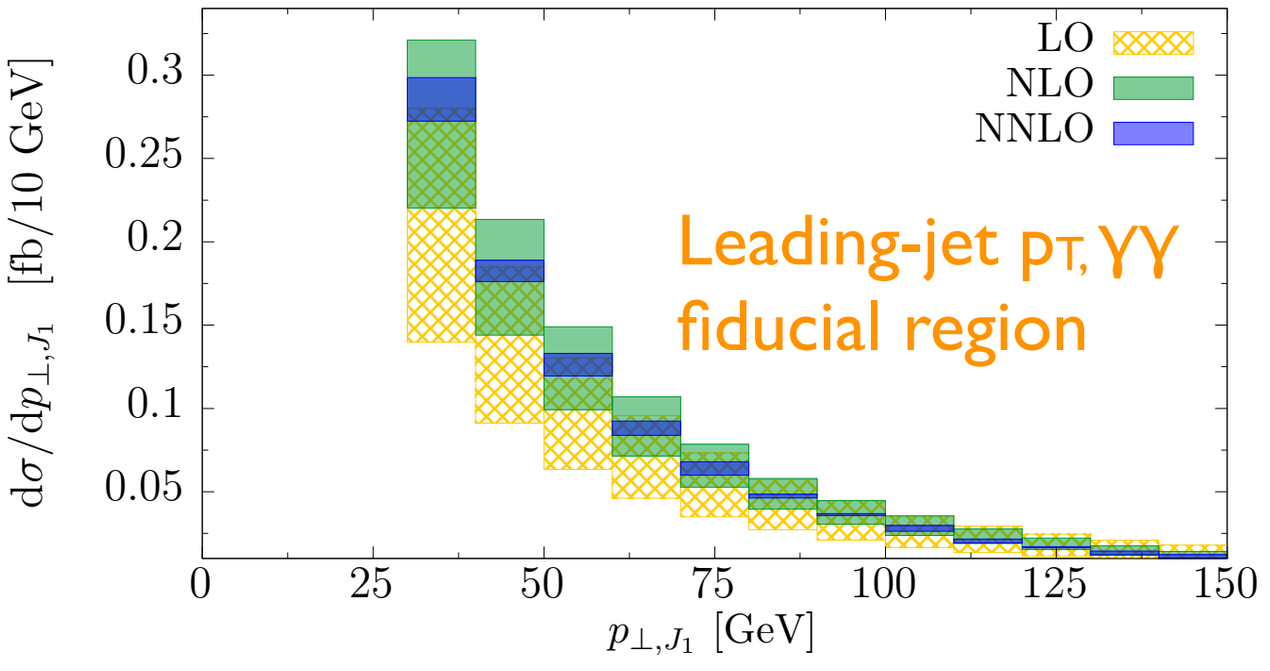
- Logs under control
- No breakdown of f.o.perturbation theory for p_T ~ 30 GeV
- Reliable error estimate from lower orders
- Significant decrease of pert. uncertainty

Predictions for the fiducial region

THE FIDUCIAL REGION, INCLUDING HIGGS DECAY PRODUCTS, IS FULLY ACCESSIBLE

LHC8, H-> γγ, ATLAS-like cut, $\mu_0 = m_H/2$. Preliminary results





Preliminary analysis: ~percent modification of the fiducial acceptance $\sigma_{\gamma\gamma}/\sigma_H$ when moving from NLO to NNLO, for central scales

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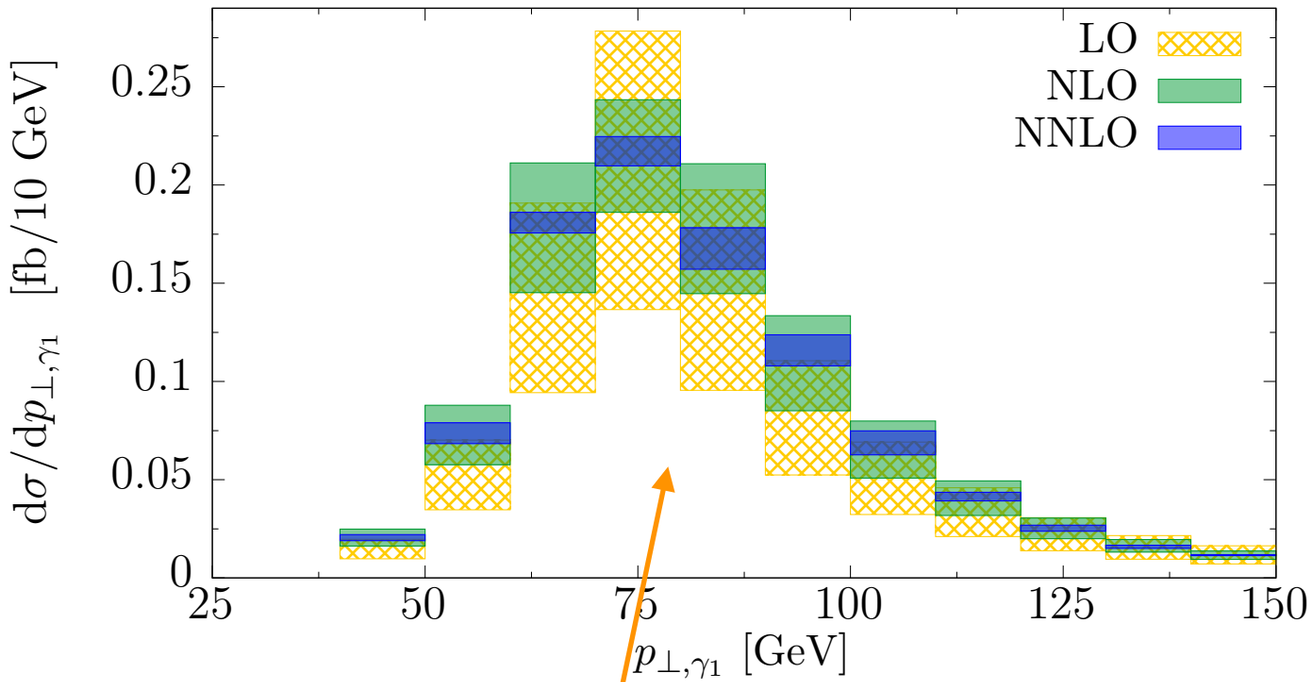
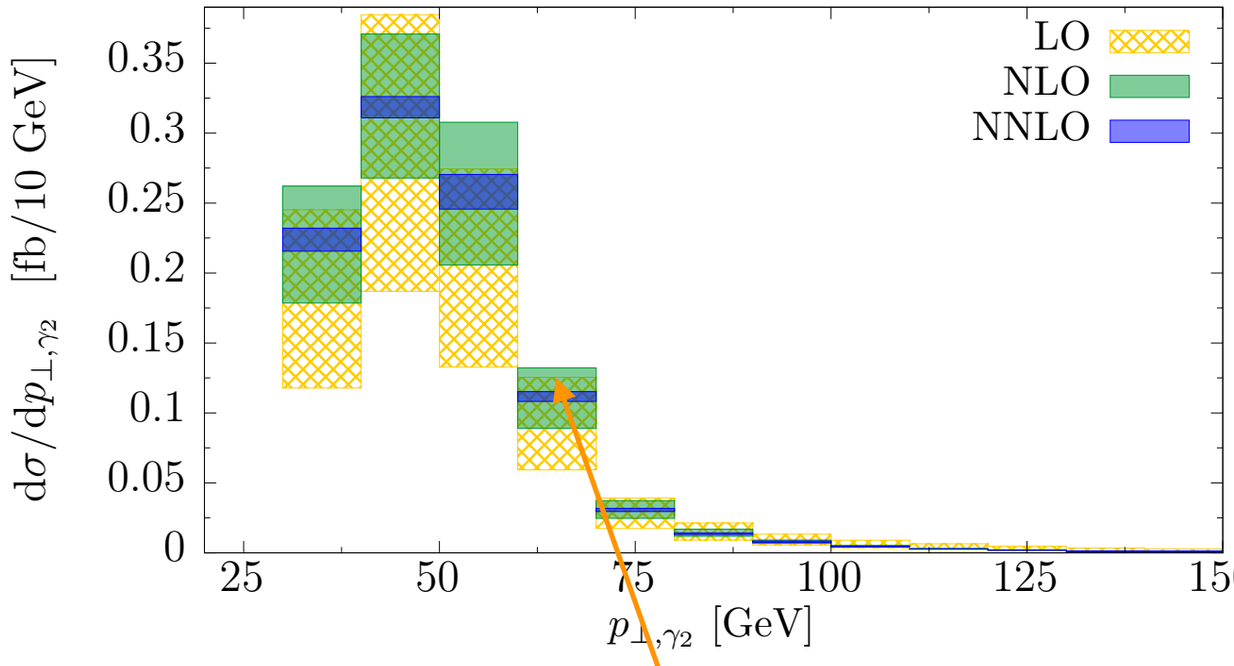


Leading photon pT



Sub-leading photon pT

Conclusions

NEW DEVELOPMENTS IN HIGHER ORDER COMPUTATIONS LEAD TO PRECISE PREDICTIONS FOR THE FIDUCIAL REGION

- Limiting extrapolation bias to a minimum
- Good control on the theory

- Can compute to very good accuracy arbitrary fiducial quantities
  - fully validated for Higgs-related observables (jet vetoes…)
  - preliminary investigations for the γγ system
- State-of-the art computations
  - CPU-intensive, no public codes yet
- IDEALLY, AGREEMENT ON EXPERIMENTAL DESIDERATA
  - Realistic set-up, full set of cuts for LHC13, within the HXSWG
  - This is the main input we need for now (future: public codes…)