Differential HH Production at NNLO in the HEFT

Javier Mazzitelli
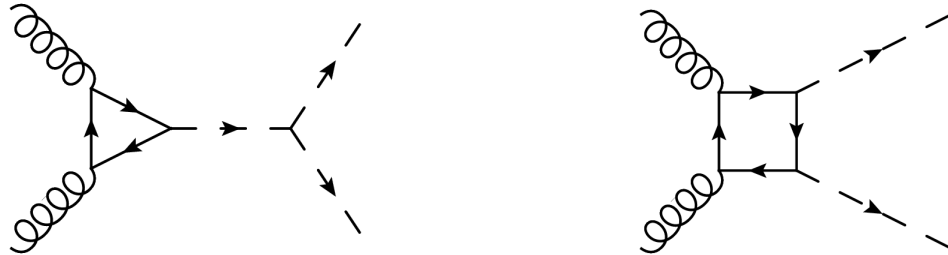
Universität Zürich UZH

in collaboration with
Daniel de Florian, Massimiliano Grazzini, Catalin Hanga,
Stefan Kallweit, Jonas Lindert, Philipp Maierhofer, Dirk Rathlev

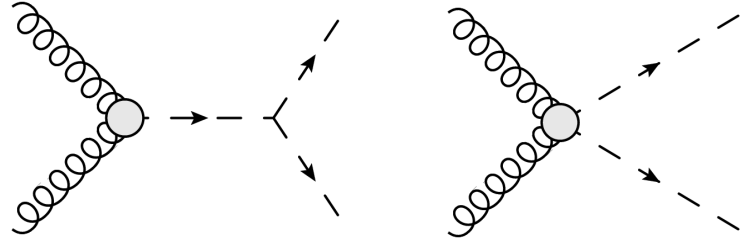HH subgroup meeting– October 2016

Introduction

- Gluon fusion → main Higgs pair production mechanism at the LHC in the SM
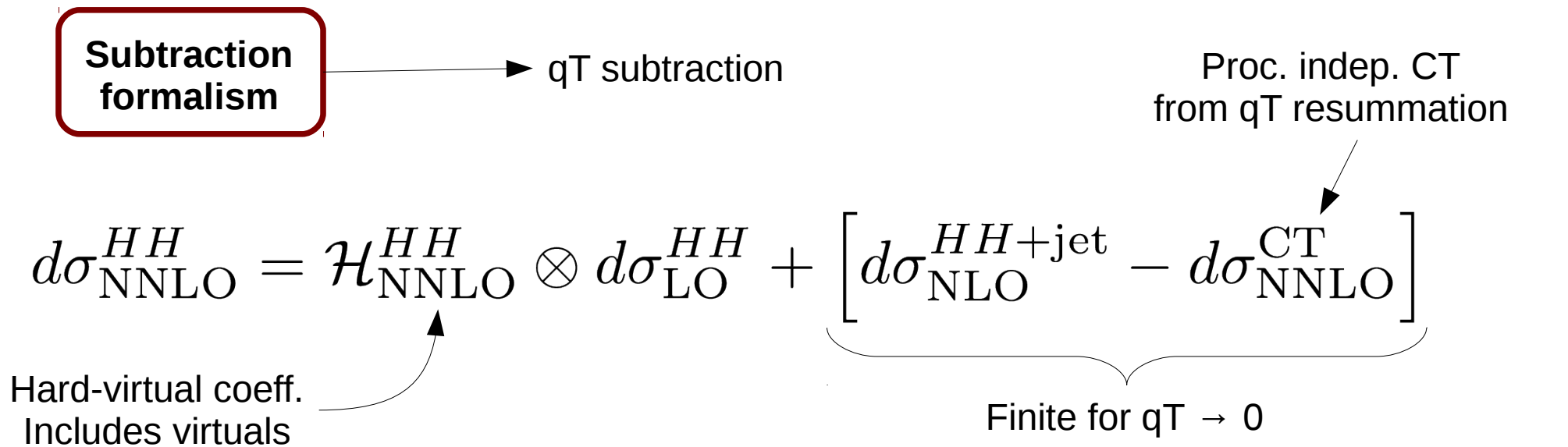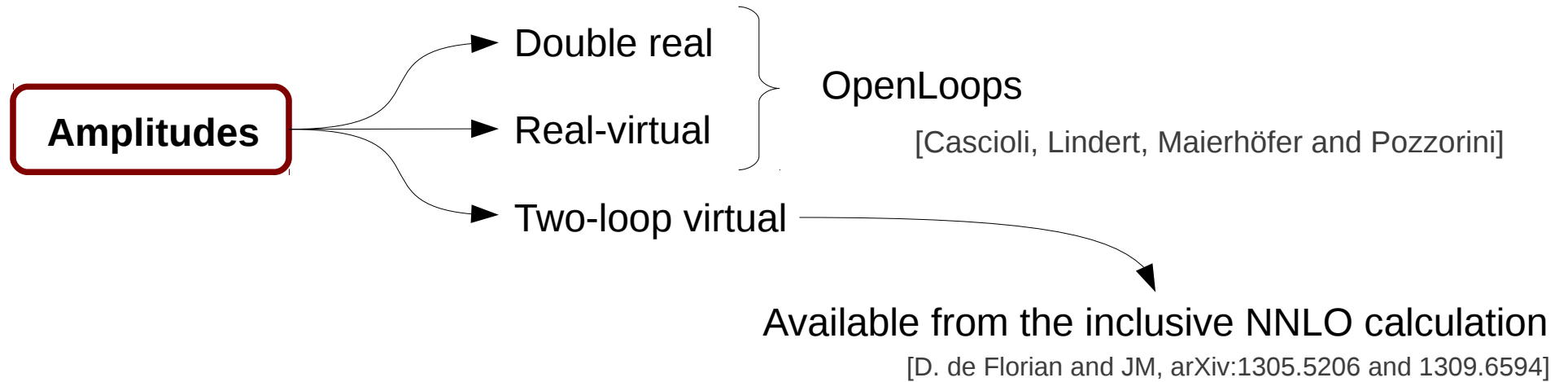

- Huge QCD NLO corrections (~70%) with sizeable uncertainties (~±15%)   (Talk by Stephen Jones)

[S. Borowka et al.,arXiv:1604.06447 and 1608.04798]

- Full NNLO out of scope

Work within the Higgs
Effective Field Theory (HEFT)

- NNLO + threshold resummation at NNLL available ⟶ Large increase (~20%) w.r.t. NLO

⟶ Substantial reduction of scale uncertainty (~±5%)

BSM: NNLO including dim 6 operators
in progress [de Florian, Fabre, Mazzitelli]

[D. de Florian and JM, arXiv:1505.07122]

- Fully differential calculation at NNLO in QCD is desirable

[de Florian, Grazzini, Hanga, Kallweit, Lindert, Maierhoefer, JM and Rathlev, arXiv:1606.09519]

Technical ingredients

Amplitudes

- Double real
- Real-virtual
- Two-loop virtual

OpenLoops

[Cascioli, Lindert, Maierhöfer and Pozzorini]

Available from the inclusive NNLO calculation

[D. de Florian and JM, arXiv:1305.5206 and 1309.6594]

Subtraction formalism

qT subtraction

Proc. indep. CT
from qT resummation

$$d\sigma_{\mathrm{NNLO}}^{HH} = \mathcal{H}_{\mathrm{NNLO}}^{HH} \otimes d\sigma_{\mathrm{LO}}^{HH} + \left[d\sigma_{\mathrm{NLO}}^{HH+\mathrm{jet}} - d\sigma_{\mathrm{NNLO}}^{\mathrm{CT}} \right]$$

Hard-virtual coeff.
Includes virtuals

Finite for qT → 0

[Catani, Grazzini, hep-ph/0703012]

Results for LHC@14TeV → Not exact LO reweighting yet
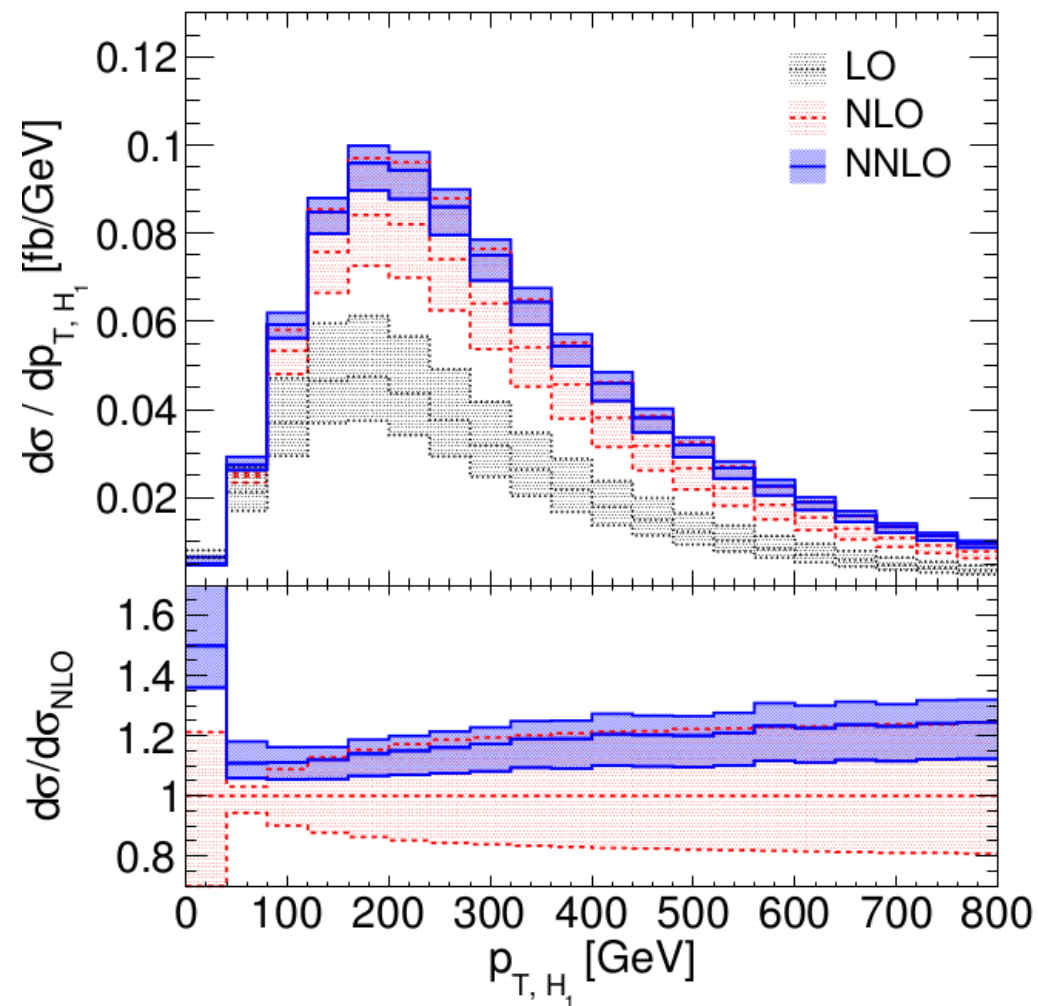Ratio NNLO/NLO is our main result so far
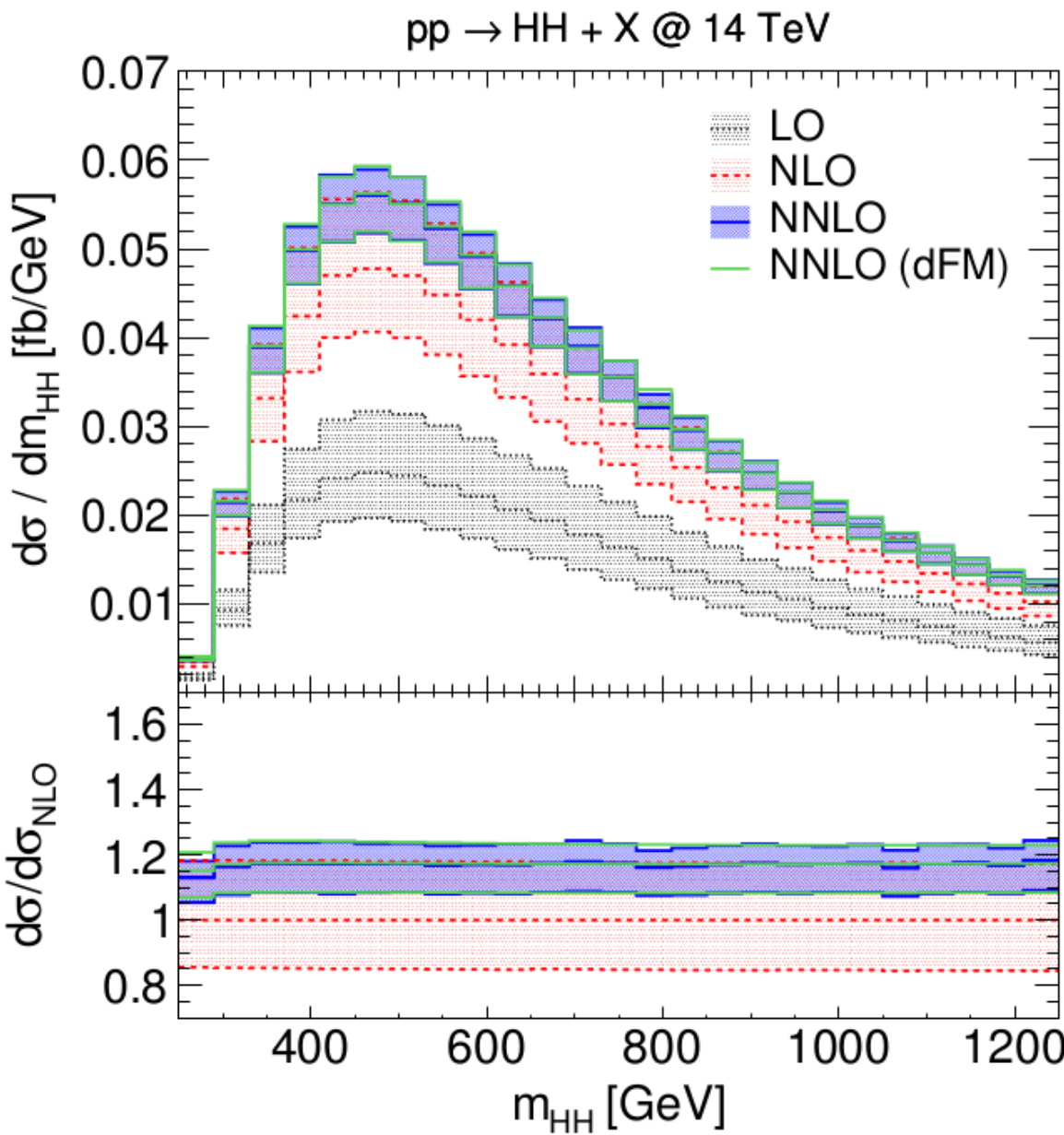
pp → HH + X @ 14 TeV

NNLO corrections:

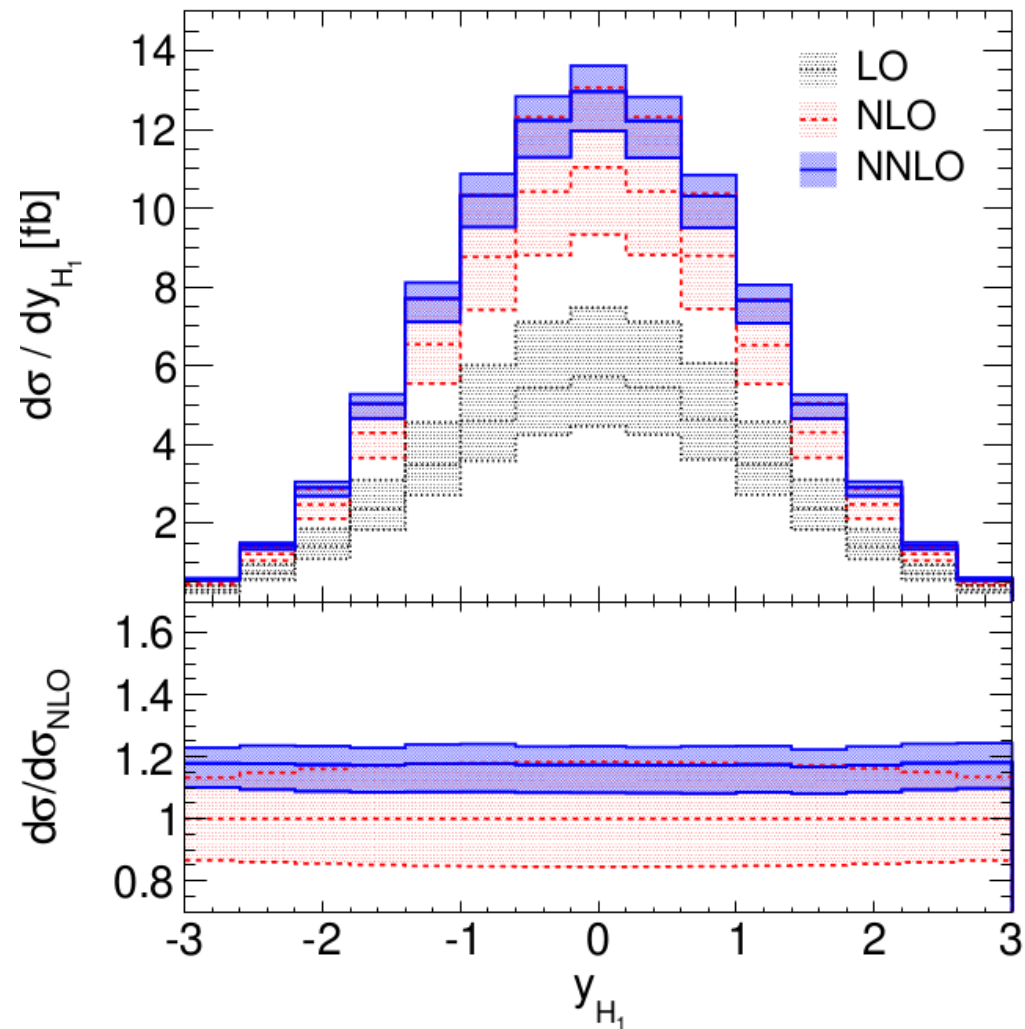• Almost flat in m_{HH}

• About 18% increase w.r.t. NLO

• Scale uncertainties: ~ ±6.5%

• Overlap with NLO band
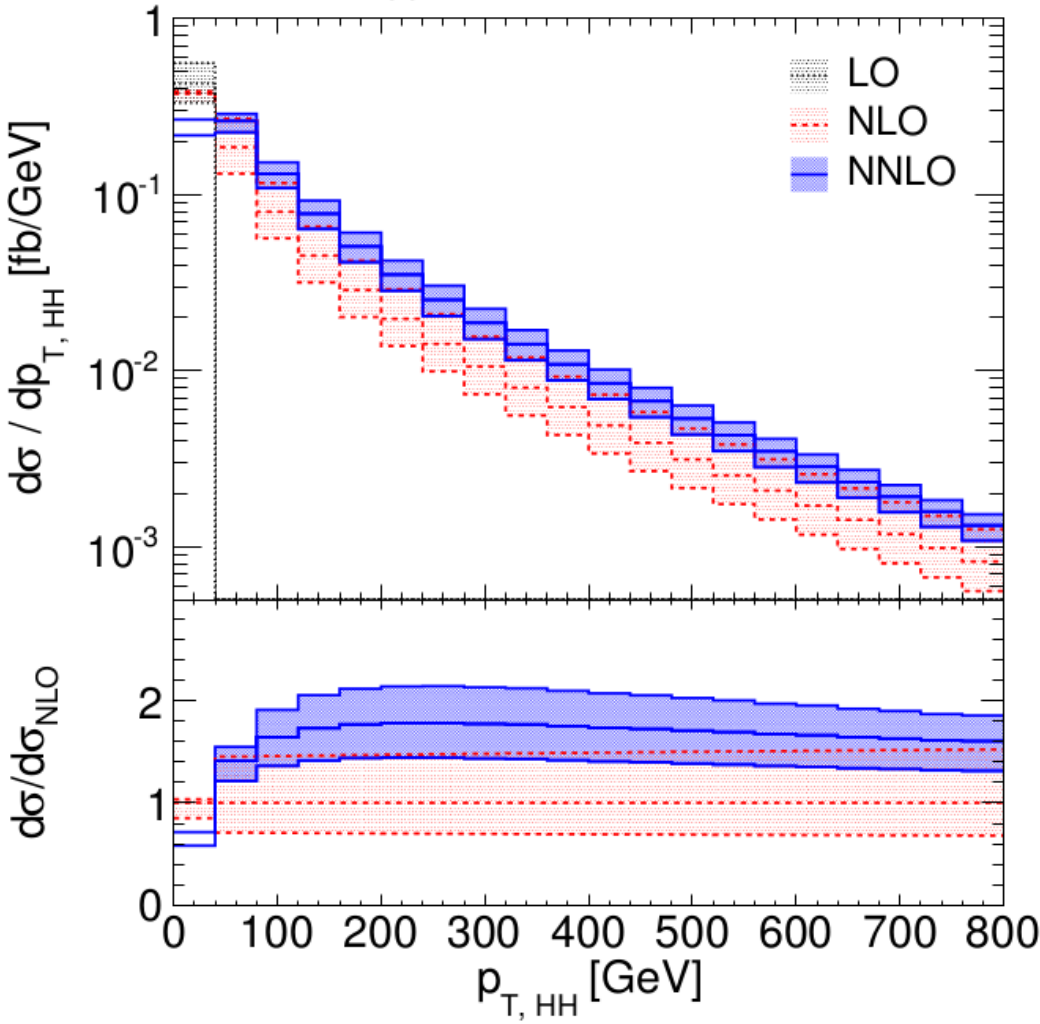
Perfect agreement with
the analytical NNLO result

- Mild increase of NNLO/NLO towards larger $p_{T,H1}$
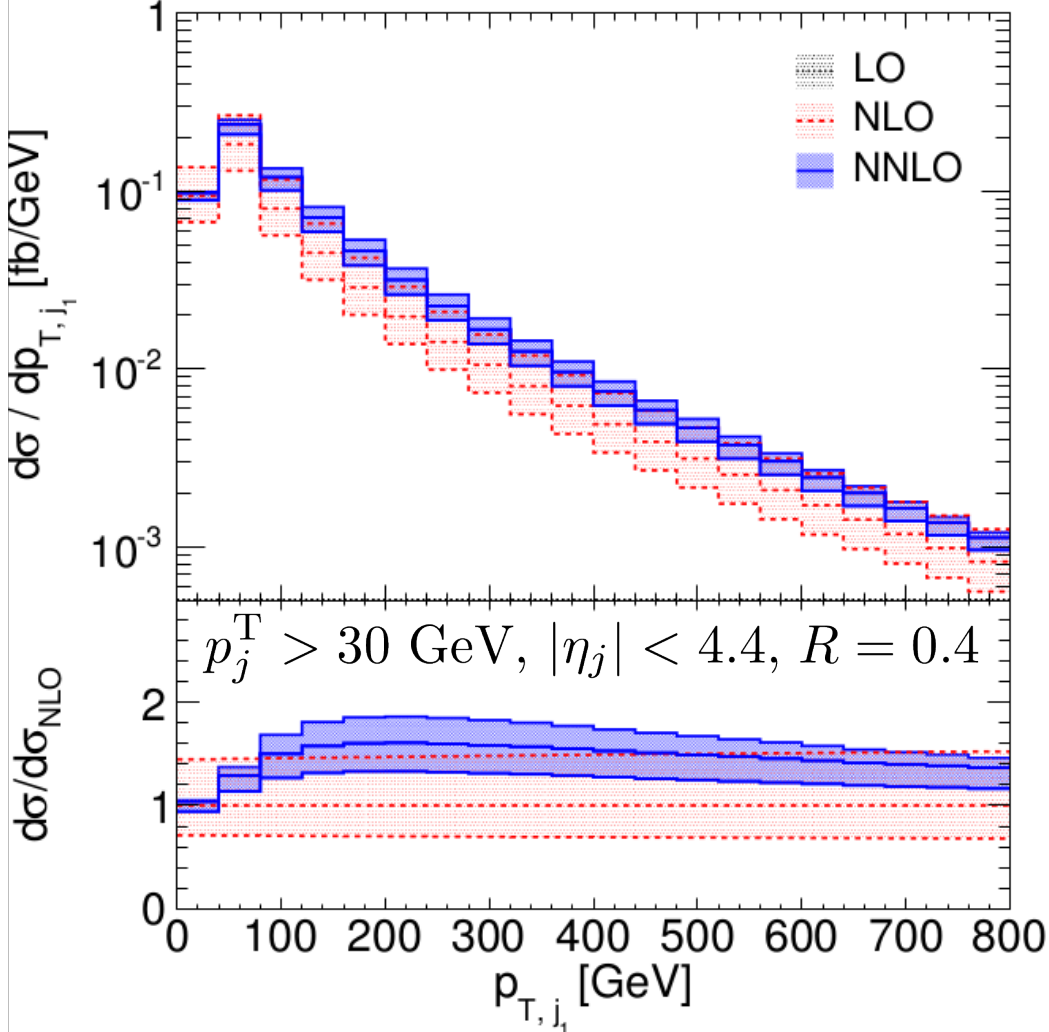
- Almost flat NNLO/NLO for y_{H_1}

For all the distributions shown so far, plus pT_{H_2}, y_{H_2} and y_{HH}, scale uncertainties $\pm(5\text{-}12)\%$ compared to $\pm(15\text{-}20)\%$ at NLO

Results for LHC@14TeV

- Distributions trivial or not defined at LO → NNLO is effectively NLO

- NNLO corrections up to 80-60%

- Sizeable uncertainties at NNLO: 30-40%

- Proper description at $p_{T,HH} \to 0$ needs pT-resummation

$\Delta\varphi_{HH}$, ΔR_{H1j1}, ΔR_{H2j1} distributions in arXiv:1606.09519

Outlook

- Inclusion of Higgs decays

- Inclusion of finite top quark mass effects at NLO

- Estimation of HEFT associated uncertainty

- First combination of full NLO and NLO HEFT recently performed [S. Borowka et al., arXiv:1608.04798]

$$d\sigma^{\mathrm{NLO}} \times (d\sigma^{\mathrm{NNLO}}/d\sigma^{\mathrm{NLO}})_{\mathrm{HEFT}}$$

- Not the only way to combine these results, e.g.:
  Compute NNLO contributions reweighting with the exact LO (projection to born kinematics)

- Different procedures → estimation of the HEFT uncertainty for NNLO distributions