

Fully differential N³LO predictions for boosted Higgs-strahlung

Federico Silvetti

Durham University, Institute for Particle Physics Phenomenology

29th September 2026, QCD@LHC2026, University of Oxford

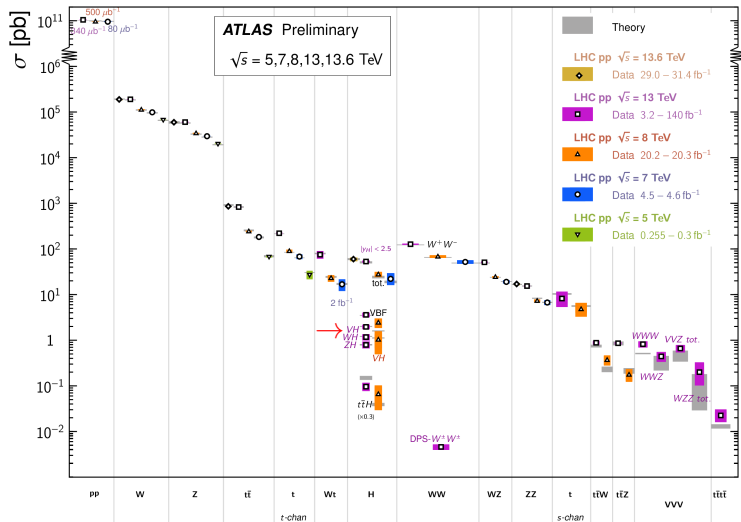
Based on [2606.31286](#), with A. Gehrmann-De Ridder, Alexander Huss, Matteo Marcoli, Pier Francesco Monni, Emanuele Re, Luca Rottoli and Paolo Torrielli



Higgs-strahlung at the LHC

Standard Model Production Cross Section Measurements

Status: July 2026

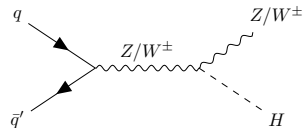


- ▶ Third Higgs production at the LHC

$$\sigma_{VH} < \sigma_{VBF} < \sigma_{ggH}$$

- ▶ Direct probe of Higgs–vector boson coupling

- ▶ Access to Yukawa couplings



The boosted-Higgs regime

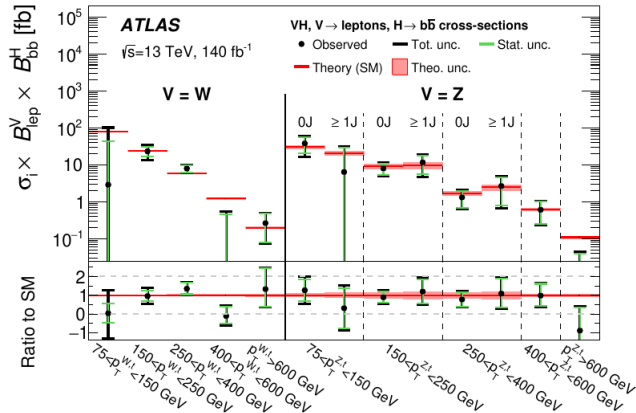
Selecting a high- p_T^H Higgs trades signal rate for improved background discrimination.

→ Butterworth, Davison, Rubin, Salam [0802.2470](#)

ATLAS: $V \rightarrow \text{leptons}$, $H \rightarrow b\bar{b}$

JHEP 04 (2025) 075

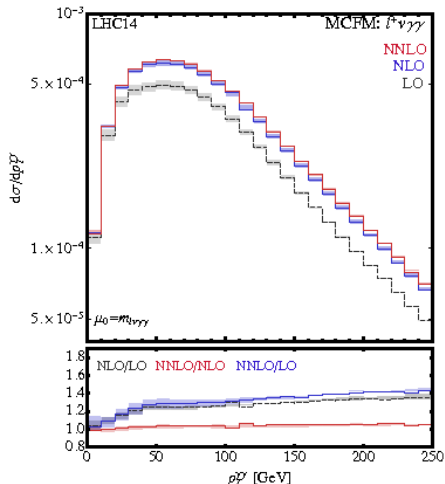
$$\Delta R_{b\bar{b}} \sim \frac{2m_H}{p_T^H}$$



- Collimated $b\bar{b}$ decay: large- R jet reconstruction and tagging.
- High-momentum spectra probe energy-growing SMEFT contributions.
- High- p_T bins are statistically limited (but will not at HL-LHC).

The boosted-Higgs regime

Campbell, Ellis, Williams [1601.00658v2](#)



Drell-Yan like inclusive QCD corrections known to N³LO.

Baglio, Duhr, Mistlberger, Szafron [2209.06138](#)

Differential predictions relevant for fiducial analyses were previously up to NNLO were studied extensively.

→ Ferrera, Grazzini, Tramontano [1107.1164](#)

→ Astill, Bizon, Re, Zanderighi [1603.01620](#)

Many other approaches for higher-order QCD, see [C. Signorile-Signorile's talk](#).

NNLO → N³LO via q_T slicing for W^+H

- ▶ First fully differential N³LO prediction for boosted W^+H .
- ▶ Fiducial cross sections and p_T^H spectra.
- ▶ Explore size of residual QCD uncertainty.

$$d\sigma = \int_{q_T < q_T^{\text{cut}}} d\sigma^{\text{singular}} + \int_{q_T > q_T^{\text{cut}}} d\sigma^{\text{regular}} + \mathcal{O}((q_T^{\text{cut}}/Q)^p)$$

- ▶ In the unresolved region, (small-) q_T structure of color-singlet production is universal .
- ▶ The resolved region is a higher-multiplicity fixed-order calculation.
- ▶ The cut must be small enough for power corrections, but not so small that the real-emission calculation becomes unstable.

see also [R. Poncelet's talk from yesterday](#)

$$d\sigma_{N^{(k+1)}\text{LO}}^F = \mathcal{H}_{N^{(k+1)}\text{LO}}^F \otimes d\sigma_{\text{LO}}^F + \int_{q_T > q_T^{\text{cut}}} \left[d\sigma_{N^k\text{LO}}^{F+1\text{jet}} - d\sigma_{N^{(k+1)}\text{LO}}^{F,\text{CT}} \right] + \mathcal{O}((q_T^{\text{cut}}/Q)^p)$$

- In the unresolved region, (small-) q_T structure of color-singlet production is universal .
- The resolved region is a higher-multiplicity fixed-order calculation.
- The cut must be small enough for power corrections, but not so small that the real-emission calculation becomes unstable.

see also [R. Poncelet's talk from yesterday](#)

RadISH

- Direct-space resummation of q_T up to N^3LL'

Monni, Re, Torrielli [1604.02191](#)

Bizon, Monni, Re, Rottoli, Torrielli [1705.09127](#)

- Similar strategy previously applied to fiducial Drell-Yan

Chen, Gehrmann, Glover et al. [2203.01565](#)

We consider $pp \rightarrow W^+(\rightarrow e^+\nu_e)H$

$$d\sigma = \underbrace{d\sigma_{\alpha_s^3}}_{q_T \text{ slicing}} + \underbrace{d\sigma_{\alpha_s^{0,1,2}} + d\sigma_{y_t\alpha_s^2}}_{\text{NNLOJET local subtraction}}$$

NNLOJET

- Parton-level Monte Carlo event generator based on antenna subtraction

Gehrmann-De Ridder, Gehrmann, and Glover [0505111](#)

Currie, Glover, and Wells [1301.4693](#)

NNLOJET [2503.22804](#)

- Studies of $VH + 1 \text{ jet}$ @ NNLO

Gauld, Gehrmann-De Ridder et al. [2009.14209](#),
[2110.12992](#)

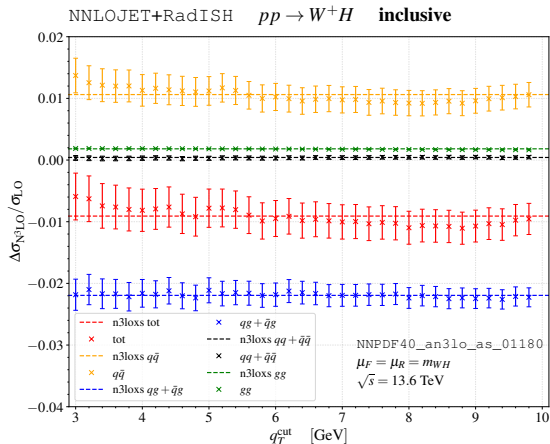
- 1-loop real-virtual amplitudes provided by OpenLoops2

Buccioni, Lang, Lindert et al. [1907.13071](#)

- Contributions from top loops are included separately.

Brein, Harlander, Wiesemann, Zirke [1111.0761](#)

Validation: inclusive W^+H production



- No p_T cuts, on shell W^+ .
- Benchmark slicing against n3loxs N³LO result.

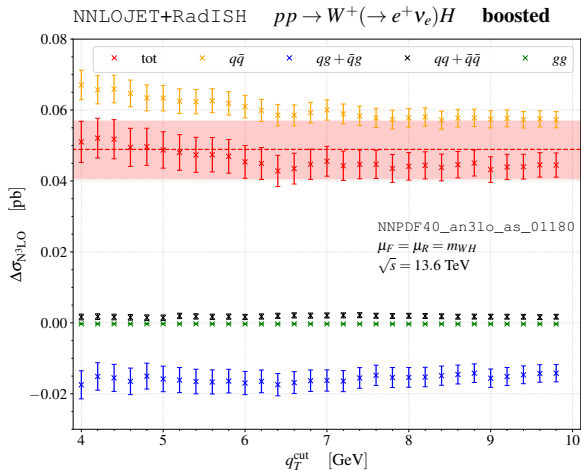
Baglio, Duhr, Mistlberger, Szafron [2209.06138](#)

- Agreement is found channel by channel for

$$q\bar{q}, \quad qg + \bar{q}g, \quad qq + \bar{q}\bar{q}, \quad gg.$$

- The result is stable for approximately $3 \text{ GeV} \lesssim q_T^{cut} \lesssim 10 \text{ GeV}$.

Controlling the slicing uncertainty



- Partial cancellation $q\bar{q}$ and $qg + \bar{q}g$ contributions *to* reduced accuracy on combination.
- fiducial cuts are staggered: no linear power corrections

$$\delta\sigma \sim \mathcal{O}((q_T^{\text{cut}}/Q)^2).$$

- $q_T^{\text{cut}} = 5$ GeV is safely above the numerical-instability region and small enough to suppress power corrections.
- Error band is estimated from envelope of $q_T^{\text{cut}} \pm (1\text{GeV})$ variations and Monte Carlo errors.

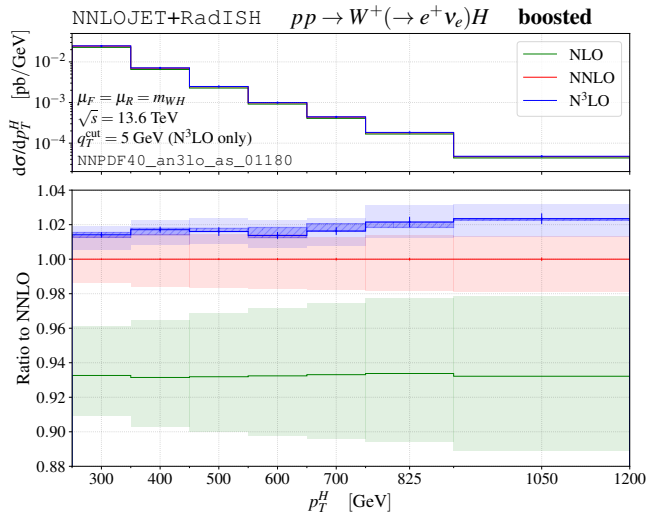
Fiducial cross sections

σ [pb]	Boosted	Boosted	"STXS"
	$p_T^H \geq 250$ GeV	$p_T^H \geq 400$ GeV	$p_T^H \geq 400$ GeV, $p_T^W \geq 250$ GeV
LO	$2.457^{+2.5\%}_{-2.5\%}$	$0.4639^{+4.7\%}_{-4.4\%}$	$0.4639^{+4.7\%}_{-4.4\%}$
NLO	$3.324^{+3.3\%}_{-2.8\%}$	$0.6368^{+4.0\%}_{-3.5\%}$	$0.5858^{+2.8\%}_{-2.5\%}$
NNLO	$3.564^{+1.4\%}_{-1.4\%}$	$0.6835^{+1.4\%}_{-1.7\%}$	$0.6116^{+0.7\%}_{-1.0\%}$
N ³ LO	$(3.62 \pm 0.01)^{+0.5\%}_{-0.8\%}$	$(0.694 \pm 0.002)^{+0.7\%}_{-0.7\%}$	$(0.621 \pm 0.002)^{+0.6\%}_{-0.5\%}$

Highlights:

- ▶ **Boosted:** N³LO adds about +1.5% and reduces the scale band below 1%.
- ▶ **"STXS":** The correction is again about +1.5%, despite a small NNLO scale band.
- ▶ **Effect of fiducial cuts:** the inclusive N³LO correction is negative, while the boosted one is positive.

Boosted p_T^H spectrum



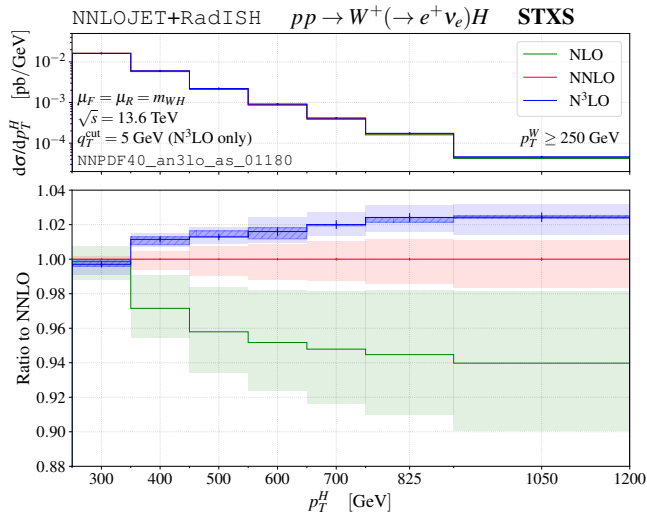
- First p_T^H N³LO prediction for boosted W^+H .
- The N³LO shift is positive and remarkably stable:

$$\Delta_{N^3\text{LO}} \simeq +1.5\% - 2\%$$

across the displayed p_T^H range.

- Scale uncertainty is about 1% near $p_T^H = 300$ GeV and grows in the tail.
- Small slicing variation $\rightarrow$ negligible power corrections.

STXS p_T^H spectrum



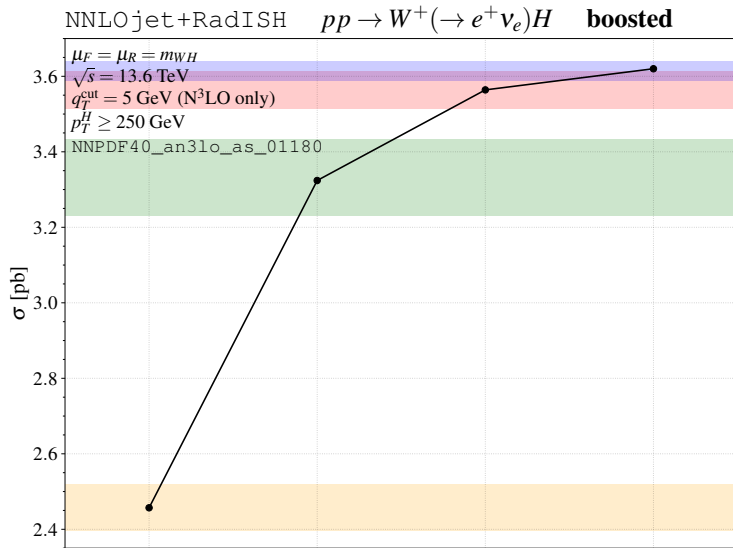
- ▶ The additional p_T^W cut changes the correction near threshold.
- ▶ Small negative shift around $p_T^H \simeq 250 \text{ GeV}$, followed by a 2–3% positive correction in the tail.
- ▶ Large p_T^H bins are less sensitive to the p_T^W cut $\rightarrow$ the two setups become more similar.
- ▶ The first bin is dominated by symmetric cut configuration. linear power corrections are calculated and included explicitly.

- ▶ Boosted W^+H production is a precision probe of Higgs interactions at the LHC and HL-LHC.
- ▶ q_T slicing through RadISH+NNLOJET enables the first fully **differential** N³LO prediction for W^+H .
 1. **The perturbative series is not yet fully stable** in the boosted region.
 2. **N³LO corrections are phenomenologically relevant in face of future experimental precision.**
 - ▶ They are of order 1–2%, comparable to the NNLO scale uncertainty.
 - ▶ Top-Yukawa-induced terms are also about the same size.
 3. **Scale uncertainty is reduced to around, or below, one percent in p_T^H tail.**
- ▶ The same strategy also applies to boosted ZH , with the separate addition of loop-induced $gg \rightarrow ZH$.

Thank you
question time?

Backup

convergence plots



convergence plots

