ETH zürich

Institute for Theoretical Physics
Eidgenössische Technische Hochschule Zürich

Towards NNLO+PS predictions for ttH production

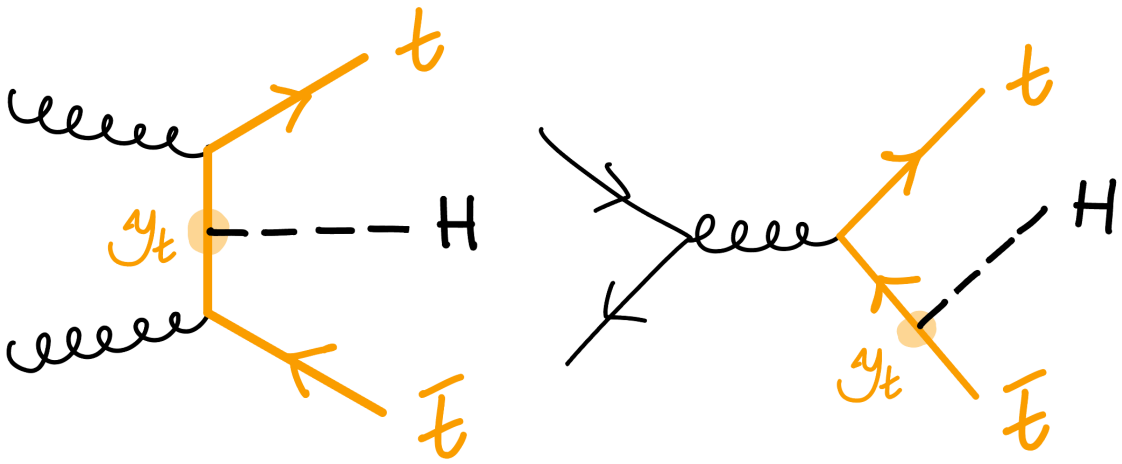
Christian Biello
ETH Zürich

in collaboration with
Javier Mazzitelli, Chiara Savoini, Chiara Signorile-Signorile, Marius Wiesemann

The 22nd Workshop of the LHCHWG
CERN, 05.12.2025

Towards NNLO+PS predictions for ttH production

The observation of ttH [1804.02610,1806.00425] in 2018 has been a milestone in LHC physics



First differential ATLAS and CMS measurements [2407.10896, 2407.10904, 2510.23755]

HL-LHC projections of experimental accuracy calls for precise theoretical predictions

Towards NNLO+PS predictions for ttH production

A MiNNLOPS event generator

ttHJ in POWHEG-BOX-RES [0409146, 0709.2092, 1002.2581, 1509.09071]

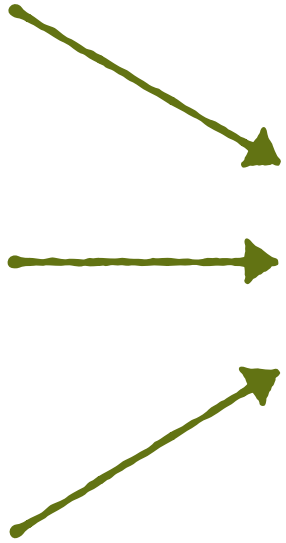
- NLO accurate for ttHJ
- Natural POWHEG matching in the ttHJJ region

MiNLO' procedure [1212.4504]

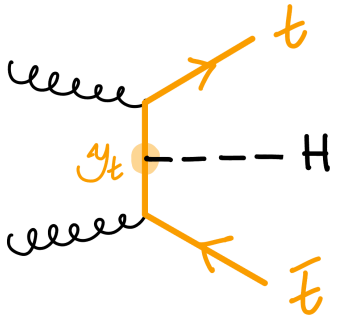
- NLO accurate for ttH

Additional NNLO contributions in the ttH kinematics [1908.06987]

- NNLO accuracy for ttH observables



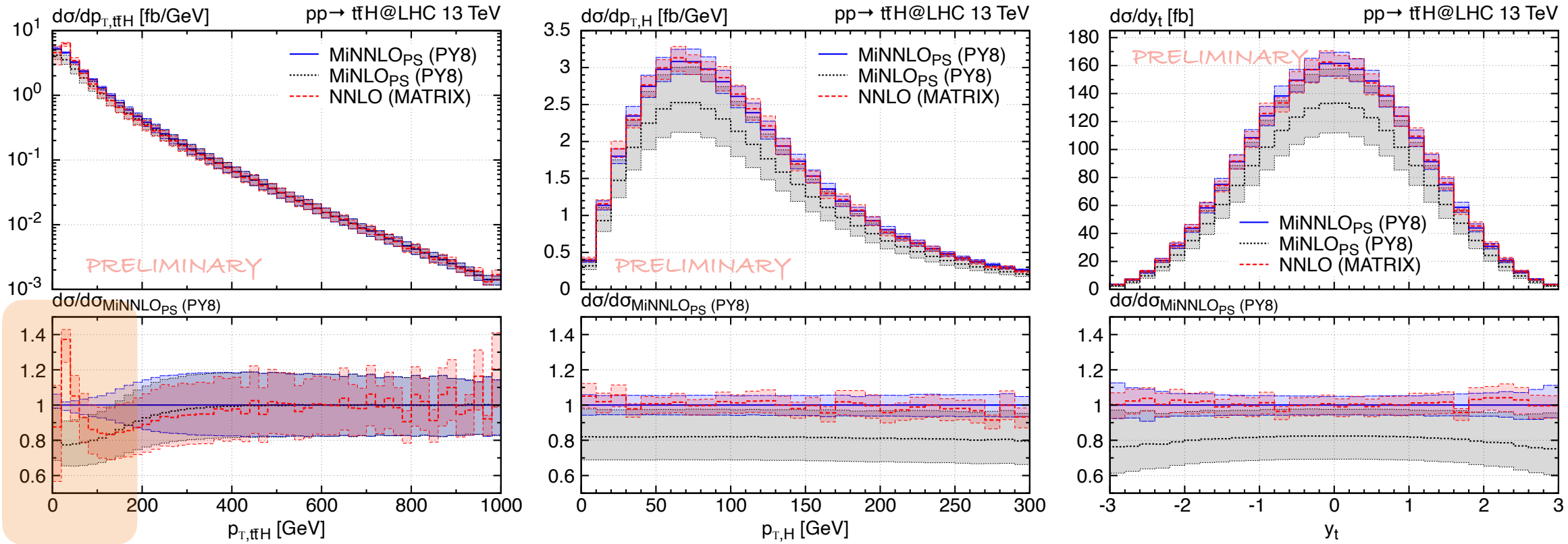
MiNNLOPS



Towards NNLO+PS predictions for ttH production

Test the accuracy by comparing with fixed-order calculations

Without including the two-loop contribution (0A), extensive comparison against the fixed-order predictions from MATRIX [2210.07846, 2411.15340] → very good agreement



Resummation effects

Towards NNLO+PS predictions for ttH production

The calculation is exact, except for the two-loop contribution, currently not known

It is important not to forget that the exact two-loop is missing with ongoing strong efforts, but we have to find a fair notation for the current cross-section predictions

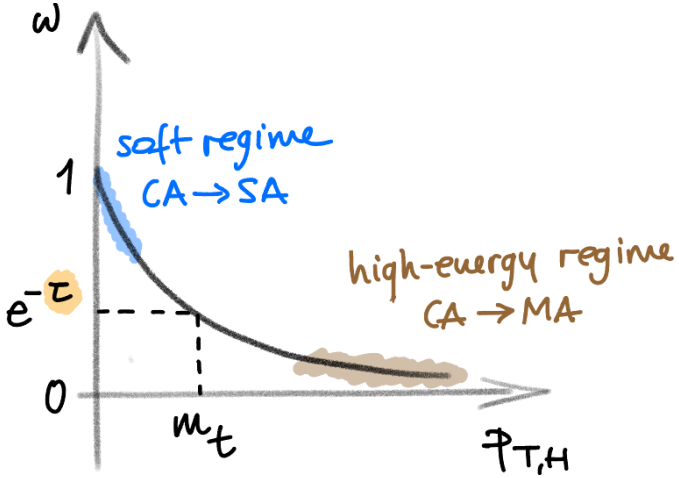
We rely on two approximations, as done for the differential NNLO calculation in MATRIX [2411.15340]
The new approach in MiNNLOPS is to combine at point-wise level the two approximations

Soft Higgs-boson approximation (SA)

based on Kniehl, Spira [hep-ph/9505225]
first application for ttH in Catani et al [2210.07846]
Two-loop input: $t\bar{t}$
Bärnreuther, Czakon, Fiedler [1312.6279]

Massification of top-quarks (MA)

based on Mitov, Moch [hep-ph/0612149]
and Wang, Xia, Yang, Ye [2312.12242]
Two-loop input: massless $q\bar{q}H$ amplitudes
Badger et al. [2412.06519] $\mathrm{MA}_{\mathrm{FC}}$



Combined approximation (CA)

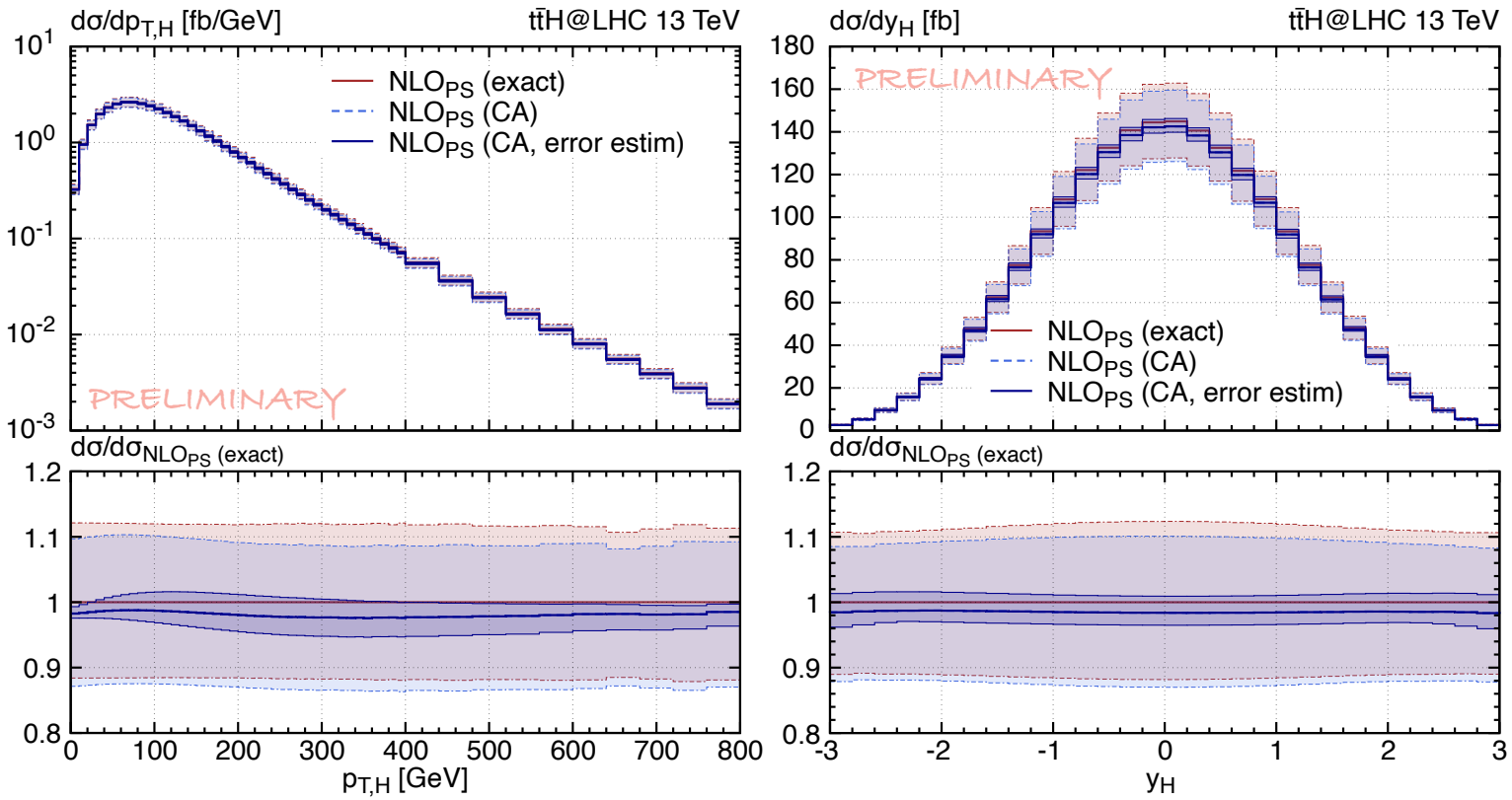
$$\mathrm{CA}_{\mathrm{FC}} = \omega\mathrm{SA} + (1-\omega)\mathrm{MA}_{\mathrm{FC}}$$

Towards NNLO+PS predictions for ttH production

NLO validation of the point-wise combined approximation (CA)

We have validated the combined approximation at one-loop and NLO where the exact result is known.

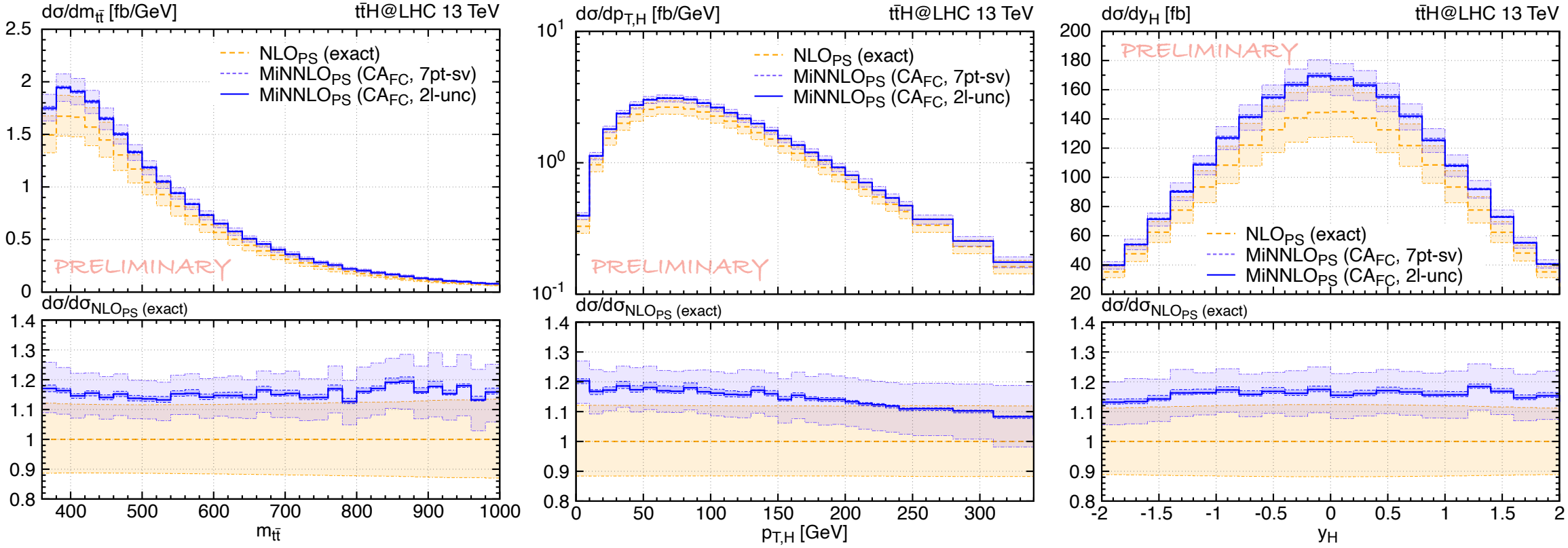
We have estimated the error using the dependence on the IR subtraction scale and on the turning point of the two approximations.



Towards NNLO+PS predictions for ttH production

The MiNNLOPS results with two-loop combined approximation

Positive NNLO corrections, reduction of scale uncertainty, small double-virtual uncertainty* (but conservative compared to the two-loop numerical contribution)



*the CA uncertainty at two-loop also includes the relative error of the CA one-loop compared to the exact one

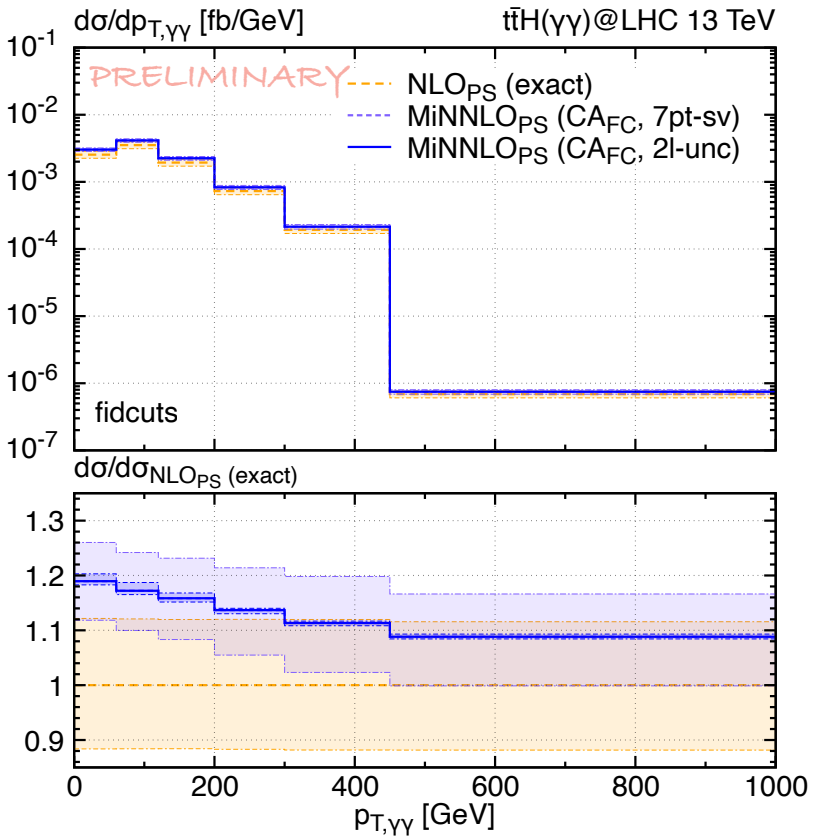
Towards NNLO+PS predictions for ttH production

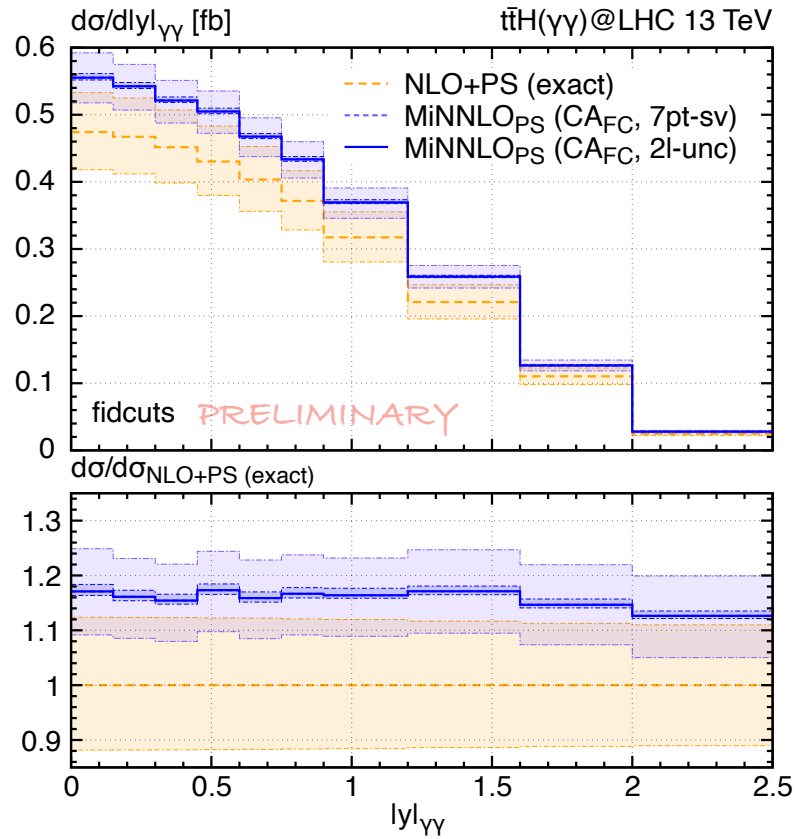
The advantage of an event generator: an example of fiducial studies

ttH($\gamma\gamma$)

We have showered the LHE events with the option to decay the Higgs into photons via PYTHIA8 and look at a fiducial region

$$p_T(\gamma_1) > 0.35\, m(\gamma_1,\gamma_2)$$
$$p_T(\gamma_2) > 0.25\, m(\gamma_1,\gamma_2)$$
$$\sum_{\Delta R(j,\gamma)<0.3} p_{T,j} < 10 \text{ GeV}$$





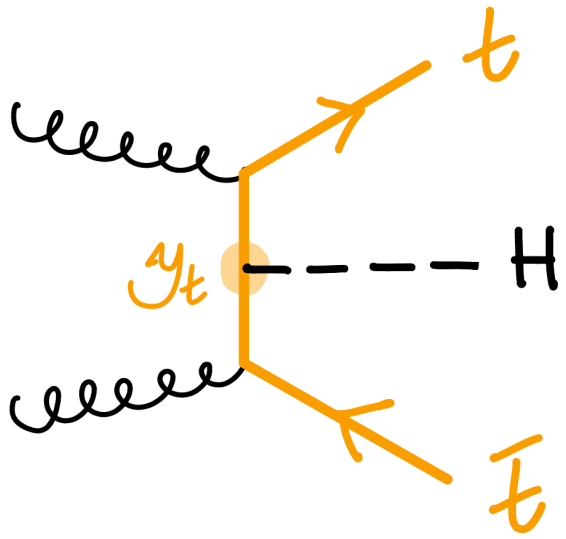
Conclusions

We have presented a novel MiNNLOPS generator for ttH production.

The calculation is naturally matched with parton showers, with the aim of making the code publicly available soon.

The NNLO calculation is exact except for the two-loop, which is estimated via a point-wise combination of two approximations in the soft and high-energy limit.

The estimation of the error due to the missing exact two-loop ingredient can be obtained by reweighting the events in POWHEG, similarly to the scale variation.



Thank you for your attention
...and stay tuned!