VH inputs:
YR5 Kick-off Meeting

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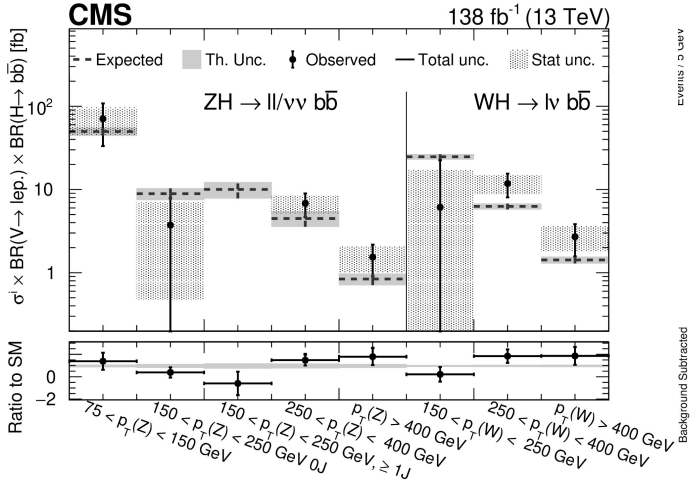
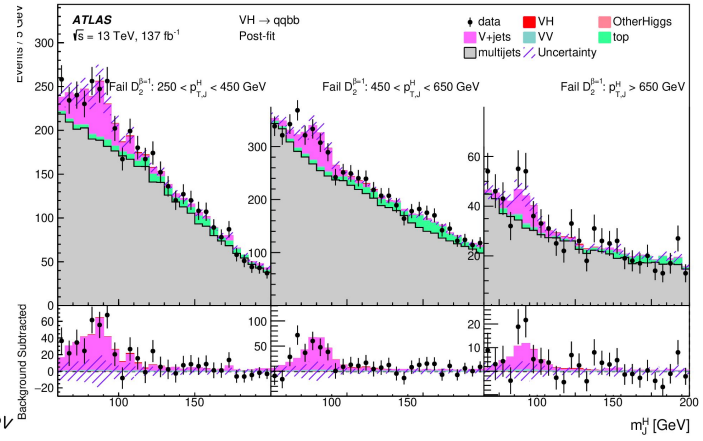
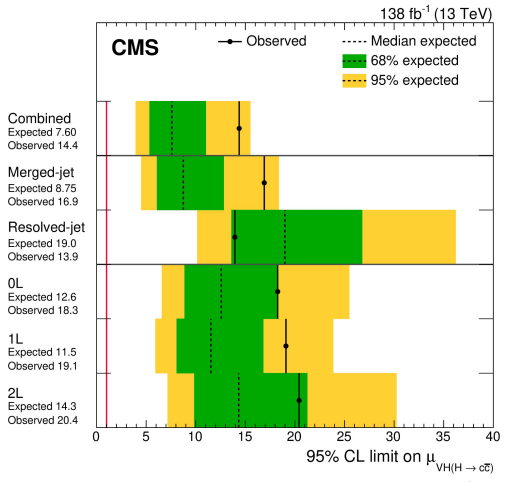
Setting the stage: from experiment

Impressive experimental progress on VH during LHC Run 2

- Cross section measurements in more bins for VH(bb)
- Boosted regime for H⟶bb: Targeting both leptonic and hadronic decay modes of V
- More decay modes reaching good precision (important for low V pT): H⟶γγ, ττ, WW
- Leading source of information for direct H⟶cc determination







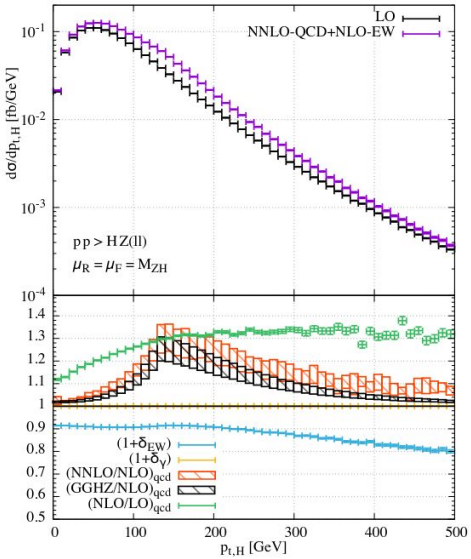
Setting the stage: from theory

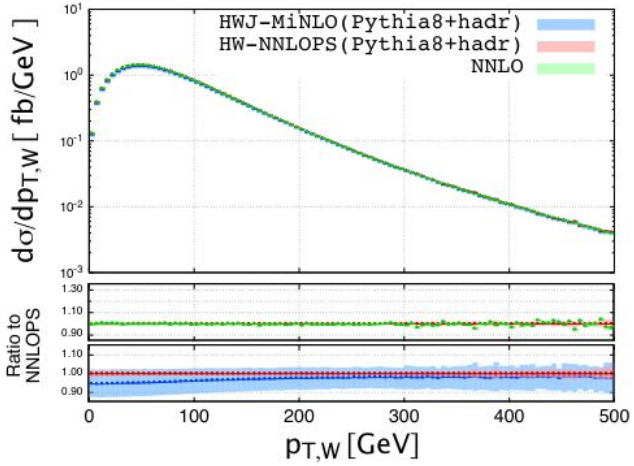
Yellow Report 4

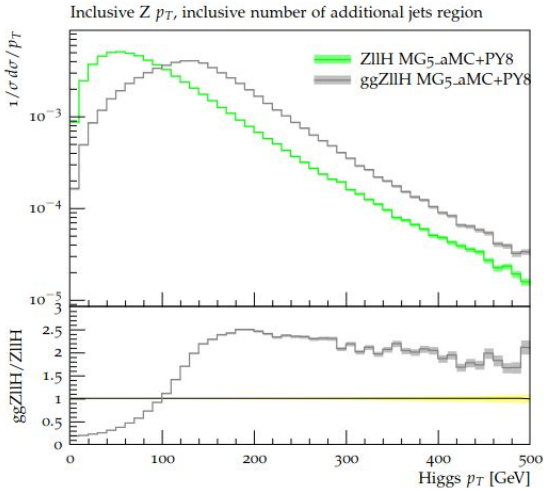
Yellow Report 4 contains a nice set of predictions

- NLO, NNLO in QCD, NLO electroweak
- Impact of higher-order corrections shown for H, decay products of V, correlation between V&H systems
- NLO+PS (POWHEG/MG5_aMC + PYTHIA6/PYTHIA8/HERWIG7), NNLOPS predictions included
- LO ggZH predictions

Predictions at sqrt(s) = 13 TeV in fiducial phase space







Ad interim predictions at sqrt(s) = 13.6 TeV

LHCHWG-2024-001

Table 3: WH cross sections at the LHC at 13.6 TeV and corresponding scale and PDF+α_s uncertainties computed according to the PDF4LHC recommendation.

$pp \to WH$ (NNLO QCD + NLO EW)								
m_H [GeV]	σ [pb]	+Scale %	-Scale %	$\pm$(PDF+α_s)%	$\pm$PDF%	$\pm\alpha_s$%	W^+H [pb]	W^-H [pb]
125	1.457	+0.4	-0.7	$\pm$1.8	$\pm$1.6	$\pm$0.9	0.8889	0.5677
125.09	1.453	+0.4	-0.7	$\pm$1.8	$\pm$1.6	$\pm$0.9	0.8870	0.5664
125.38	1.442	+0.4	-0.7	$\pm$1.8	$\pm$1.6	$\pm$0.9	0.8801	0.5620

Table 4: ZH cross sections at the LHC at 13.6 TeV and corresponding scale and PDF+α_s uncertainties computed according to the PDF4LHC recommendation.

$pp \to ZH$ (NNLO QCD + NLO EW)							
m_H [GeV]	σ [pb]	+Scale %	-Scale %	$\pm$(PDF+α_s)%	$\pm$PDF%	$\pm\alpha_s$%	$\sigma(gg \to ZH)$ [pb]
125	9.439E-01	+3.7	-3.2	$\pm$1.6	$\pm$1.3	$\pm$0.9	1.360E-01
125.09	9.422E-01	+3.8	-3.2	$\pm$1.6	$\pm$1.3	$\pm$0.9	1.359E-01
125.38	9.361E-01	+3.8	-3.2	$\pm$1.6	$\pm$1.3	$\pm$0.9	1.347E-01

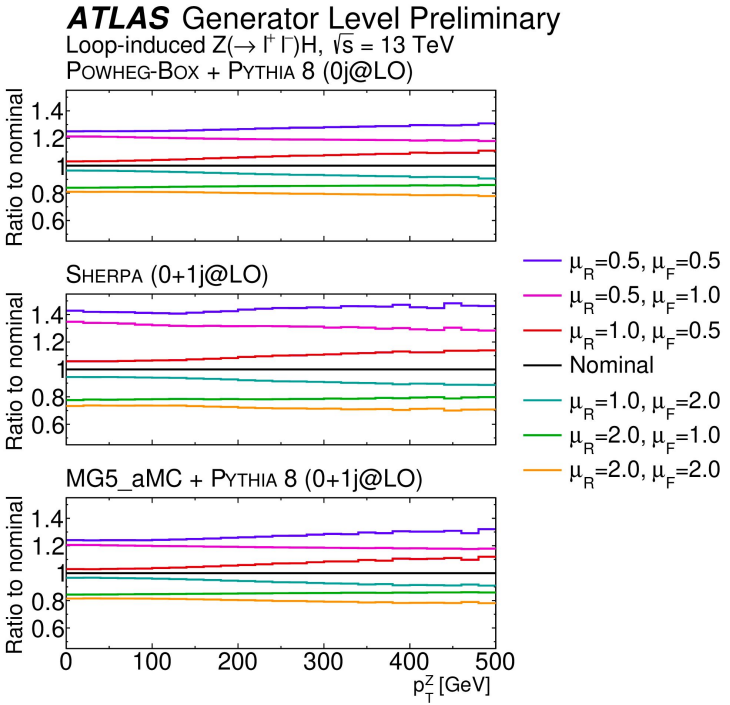
Still missing w.r.t. Run 2:

- ggZH unc. : we do have numbers available from theorists
- Differential higher-order corrections (e.g., NLO EWK) [at least as a function of V p_T]

Differential NLO prediction for ggZH

- Large uncertainty due to scale variation at LO

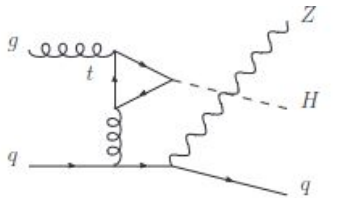
ATL-PHYS-PUB-2022-055

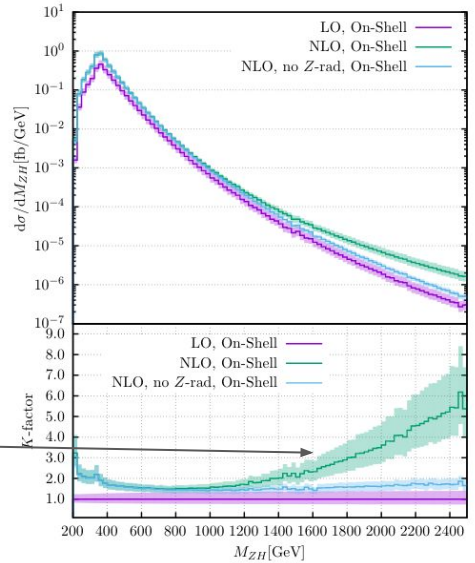


- Differential NLO prediction: natural progression w.r.t. YR4

- NLO/LO k-factor can be large
- Relative small reduction in systematic uncertainty

$\sqrt{s}$	LO [fb]	NLO [fb]
13 TeV	$52.42^{+25.5\%}_{-19.3\%}$	$103.8(3)^{+16.4\%}_{-13.9\%}$
13.6 TeV	$58.06^{+25.1\%}_{-19.0\%}$	$114.7(3)^{+16.2\%}_{-13.7\%}$
14 TeV	$61.96^{+24.9\%}_{-18.9\%}$	$122.2(3)^{+16.1\%}_{-13.6\%}$





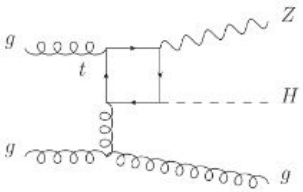
Vitti, Gröber et al. (2022)

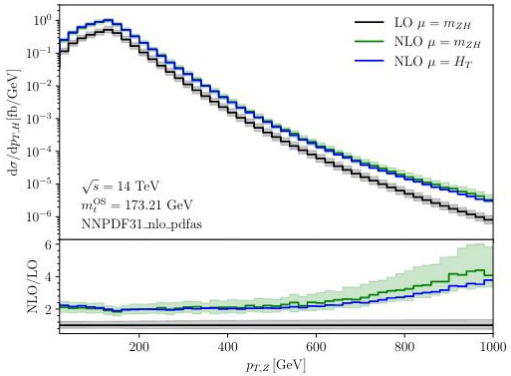
Differential NLO prediction for ggZH (2)

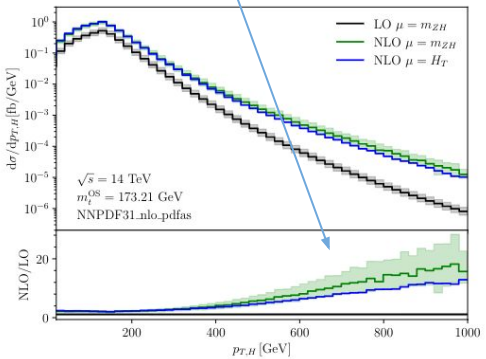
Details in M. Vitti's talk @ LHCHXS WG meeting

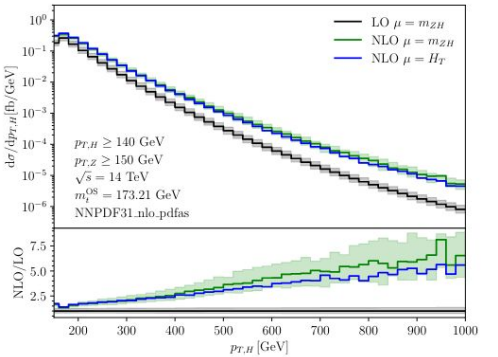
- NLO/LO k-factor depends on
  - variable of choice
  - selection conditions on kinematics
- Cross-check planned between Heinrich, Jones et al. (2022) and Vitti, Gröber et al. (2022)
- Minimum update expected:
  Single- or double-differential k-factor
- Optimistic scenario:
  Calculation available for full event generation (e.g. in POWHEG)

Heinrich, Jones et al. (2022)









Comparing different generators and uncertainties

- Comparison of NLO predictions from POWHEG, Sherpa, MC@NLO
  → relative comparison on fraction of events with negative weights
  (MC@NLO and Sherpa are less popular in experiment due to negative weight issues)

- Comparison with different parton showers in NLO+PS predictions:
  PYTHIA8 vs HERWIG7

  - POWHEG+PYTHIA8 vs POWHEG+HERWIG7
    YR4 has POWHEG+PYTHIA6, MG5_aMC+PYTHIA8/HERWIG7 predictions

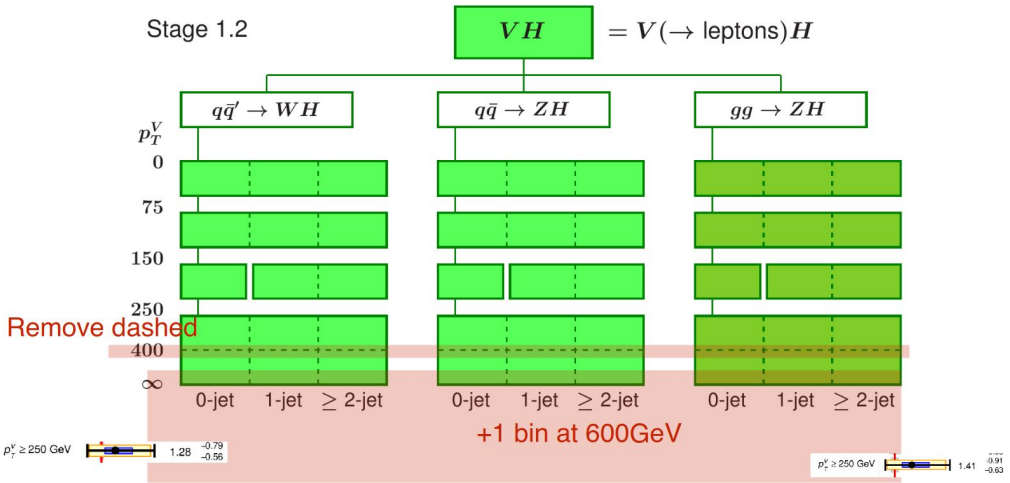
- Parton shower variation in NNLOPS predictions. Try NLL PS - Panscales?
  - Inclusion of parton shower uncertainty on predictions from generators

- Check the impact of underlying event tune on predictions

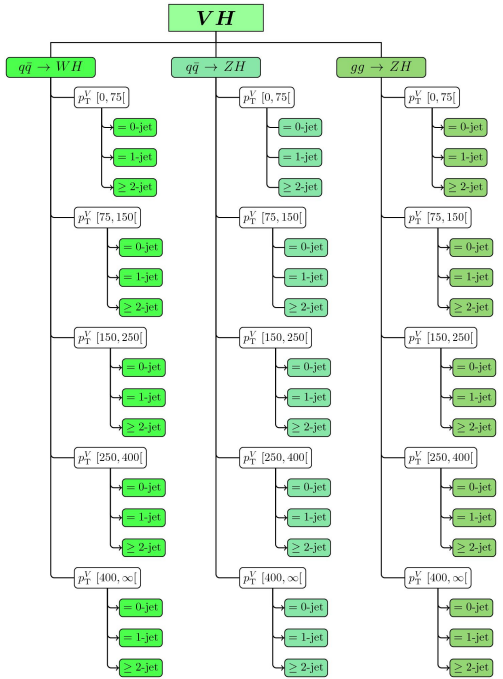
STXS 1.3 predictions

- Include predictions in STXS 1.3 bins in YR5: cross section + uncertainty
- Could serve as a standard reference for future

Proposal for STXS 1.3



Fine split from ATL-PHYS-PUB-2018-035



- Three high p_T bins: [250, 400), [400, 600), >= 600 GeV
- At a later stage, adding additional variables: $\Delta\varphi_{ll}$, m_T^{total}

Expansion of existing predictions

- Extend the H p_T range of prediction: YR4 has up to 500 GeV

- Predictions in terms of additional jet activity: different jet sizes

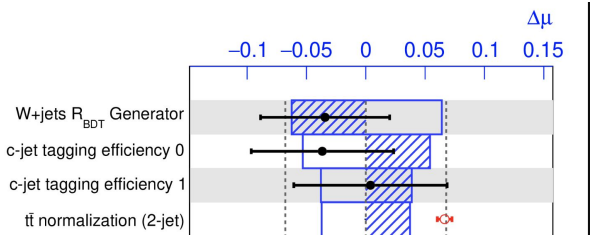
- Double differential predictions: YR4 has H p_T for different V p_T,
  - aim for 2-D predictions of H p_T vs V p_T
  - try combination of other variables

- Studies on angular variables: effects of kinematic selections

- Final obvious update for fiducial cross sections: sqrt(s) = 13 → 14 TeV

What about backgrounds?

WH ranking from ATLAS



- V+b/c jets is a key background in VHbb analysis:
  very different predictions and models used by ATLAS and CMS
  (very expensive MC, multileg@NLO+extra legs@LO)

  → Make a common choice to be suggested in YR5?
  → [possibly lowering the precision to ease production and tests?]

- Excellent initiative in the ttH group towards consensus over common tt+HF sys models and samples