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# Report from WG1 VH/VBF Subgroup (Experiment)

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On behalf of WG1 VH/VBF subgroup

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LHC Higgs Cross Section Working Group Assembly

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# Overview of Activity

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- Since formation of subgroup last summer:
  - Early coordination with Higgs groups inside ATLAS/CMS
  - VH/VBF subgroup meetings with updates and questions
  - Dec. MC/Tools workshop <https://indico.cern.ch/event/345455/>
  - Experimental results still coming out and requiring advice
- Very enlightening collaboration with theory colleagues
  - Experiments now catching up to cutting edge tools
- Validation of NLO tools against standard Run 1 samples
  - Focus on particle-level differential distributions
  - Extra attention to higher- $p_T$  regions of phase space
- See [document](#) with summary of discussion points and wish list for Run 2 / Yellow Report 4

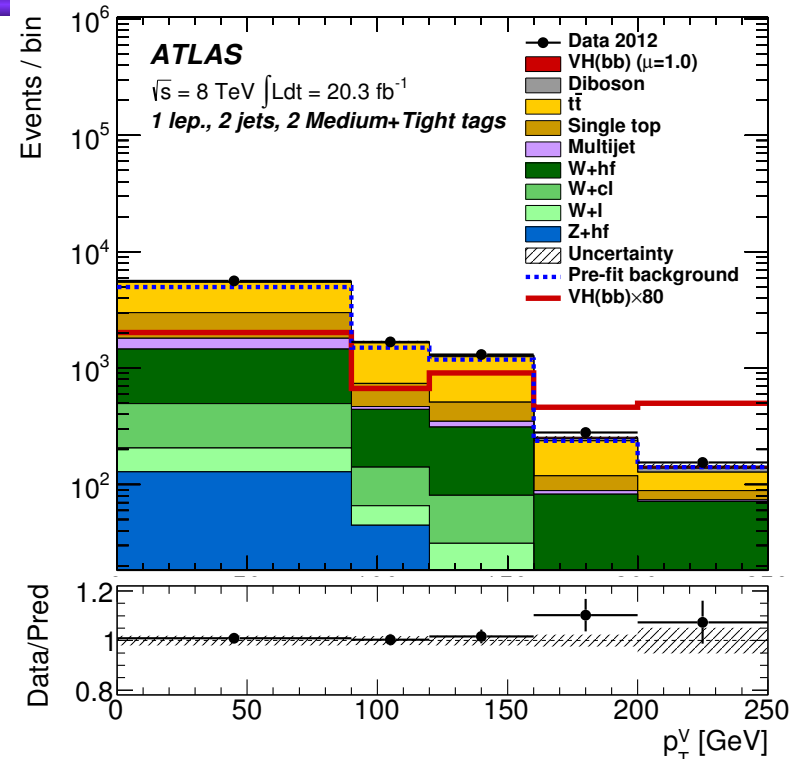
# Progress and Remaining Questions

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- Emphasis on preparing tools for Run 2 startup / MC prod.
  - Signal event generation at particle level
  - Comparisons of NLO calculations and generators
  - Signal differential cross-section calculations (covered by FT)
  - Background event generation
- Seeking coherence between experimental treatments
  - Tools that are common or easily integrated into frameworks
  - Communication within subgroup for cross-checks on results
- Questions on best/most correct use of existing tools
- Document addresses points separately for VH and VBF

# VH Signal at NLO and NNLO

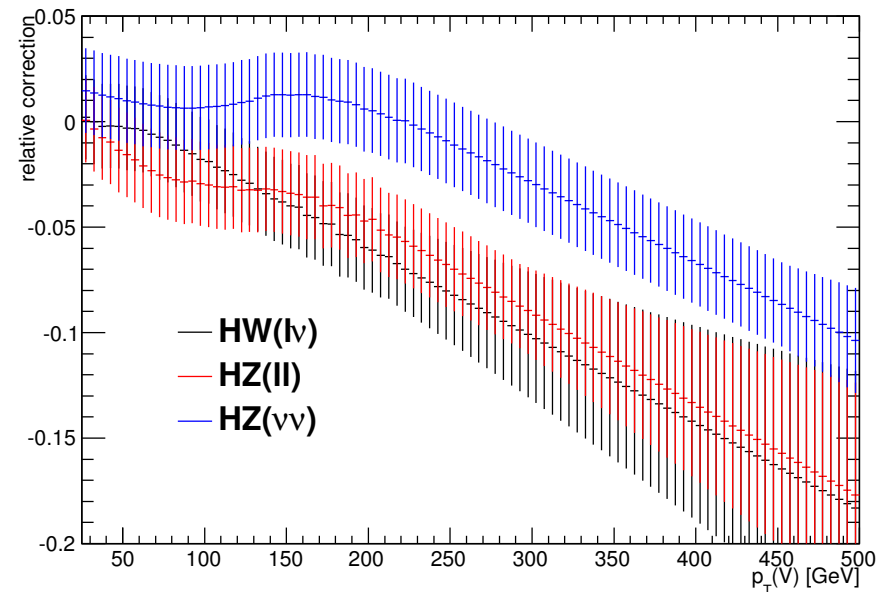
- Regions of high boson  $p_T$  are crucial to VH measurements, esp. for bb channels
- Reweighting to NNLO calculations has not been adopted widely, but is high priority for Run 2 preparation



- Gluon-induced ZH becomes more important at 13 TeV
  - Up to 25% of cross section around  $p_T(V)=200 \text{ GeV}$
  - Large scale uncertainty used in Run 1 publications: 50%
  - What can be done to reduce this uncertainty?

# VH NLO Electroweak Corrections

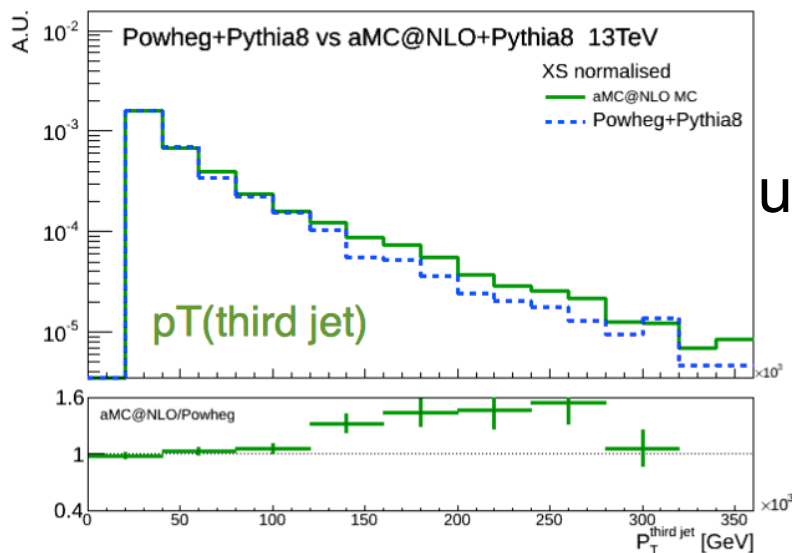
- Apply  $p_T$ -dependent corrections to inclusive  $\sigma$ 
  - Have calculated these for many channels and phase spaces with HAWK
  - Significant corrections at large boson  $p_T$
- Implemented as common function, but needs to be updated for Run 2 energies and channels
  - Correction to other distributions?



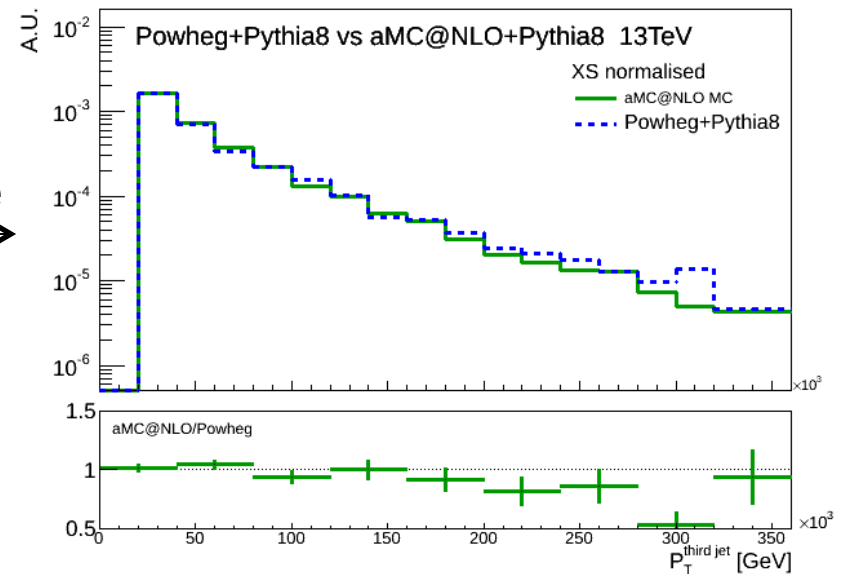
- Uncertainty accord:
  - absolute uncertainty on correction defined as  $\max\{2\%, \Delta^2\}$ , where  $\Delta$ =full correction
  - Captures higher-order effects

# VH Parton Shower Uncertainties

- Dominant uncertainty in VH signal estimation
  - Estimated by comparing POWHEG+Pythia8 and POWHEG+Herwig samples over a wide range of boson  $p_T$
  - Need for rigorous, coherent treatment of the PS uncertainty
- Wish for validation/comparison of matching schemes at particle level in relevant phase space, esp. high  $p_T$



update →



# V+Jets Backgrounds (!)

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- Not strictly Higgs cross section, but these dominate in all VH signal regions and require advanced tools
  - Fit to data in the end, but reliable differential xsec is crucial
- Different treatment between ATLAS (SHERPA) and CMS (MG/ME), with comparison to other generators
  - Wish to ramp up comparisons in the working group, especially for differential distributions across different generators
  - Matching and merging schemes are crucial for describing the wide range of jet multiplicities

# VBF Signal Calculations

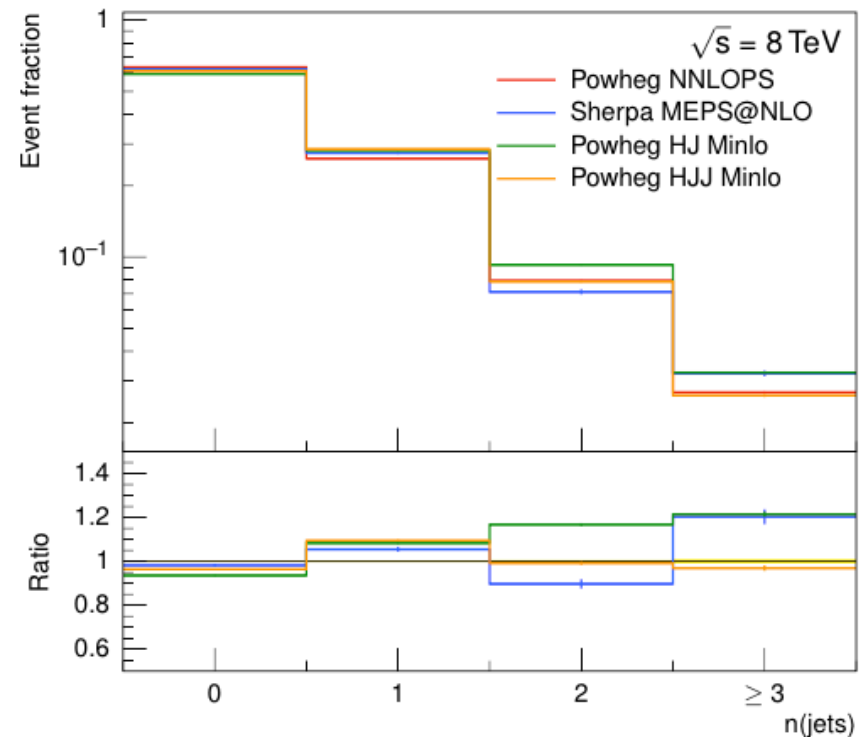
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- See Francesco's talk for discussion of NNLO reweighting and future studies of merging & matching effects
- Key experimental question is central jet veto efficiency
  - Investigate 3rd jet  $p_T$  at NLO
  - POWHEG BOX / MG5\_aMC@NLO / HERWIG++ have VBF HJJJ
  - Note that MG5\_aMC@NLO does not have merging for VBF H+1j (i.e., VBFHJJJ)
- As with other generators, wish for framework updates:
  - Les Houches Accord 3 to produce all variations at once
  - LHAPDF for new uncertainties



# Gluon-Fusion-Induced H+jets

- Major background in the VBF signal region
  - Collaborating with WG1 ggF subgroup to share studies
  - Powheg HJ and HJJ should be usable with careful merging (may require particular selections to avoid overlap)
  - Madgraph5\_aMC@NLO also provides G-F H+2j at NLO, with all samples merged
- HJJ calculations with GoSAM are in experiments; expect results/comparisons with theory papers soon
  - Allows for calculation in restricted phase space of VBF event selection



# VVjj Backgrounds

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- Continuum VV+jj production is a background to any off-shell Higgs studies
  - Relevant also for off-shell working subgroup; would like to set up discussion soon on the issues and latest progress
- Calculations exist at NLO QCD, but event generation takes some time; need validation with new generators
  - PHANTOM, WHIZARD, POWHEG, VBFNLO
  - All decay modes included?
- Some questions on WZjj availability at NLO with PS
  - Definitely on the wishlist for Run 2

# Summary/Conclusions

- Interactions in subgroup have raised the bar for treatment of signal in experiments!
- Significant activity with NLO calculations and MC
  - Learning curve for experimental groups to adopt latest tools and adjust parameters wisely
  - Priority for NNLO reweighting of NLO MC
- Outstanding questions
  - Validation of matching and merging methods on NLO samples
  - Comparisons at particle level
  - Multi-leg backgrounds to VH and VBF
- YR4 would be a natural place to collect studies and common results for 13 TeV

