Calculation of VH STXS uncertainties in CMS

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Introduction

- Proposal for evaluating theoretical uncertainties for VH STXS measurements already made by ATLAS in discussion with XSWG: http://cdsweb.cern.ch/record/2649241/files/ATL-PHYS-PUB-2018-035.pdf
- These slides: attempt to follow the procedures outlined in the note to derive uncertainties
  - Only showing scale uncertainties at V p_T boundaries , but other uncertainties can be calculated following the same procedure
  - For discussion today: results come out differently from ATLAS note ➔ something in the procedure must be different

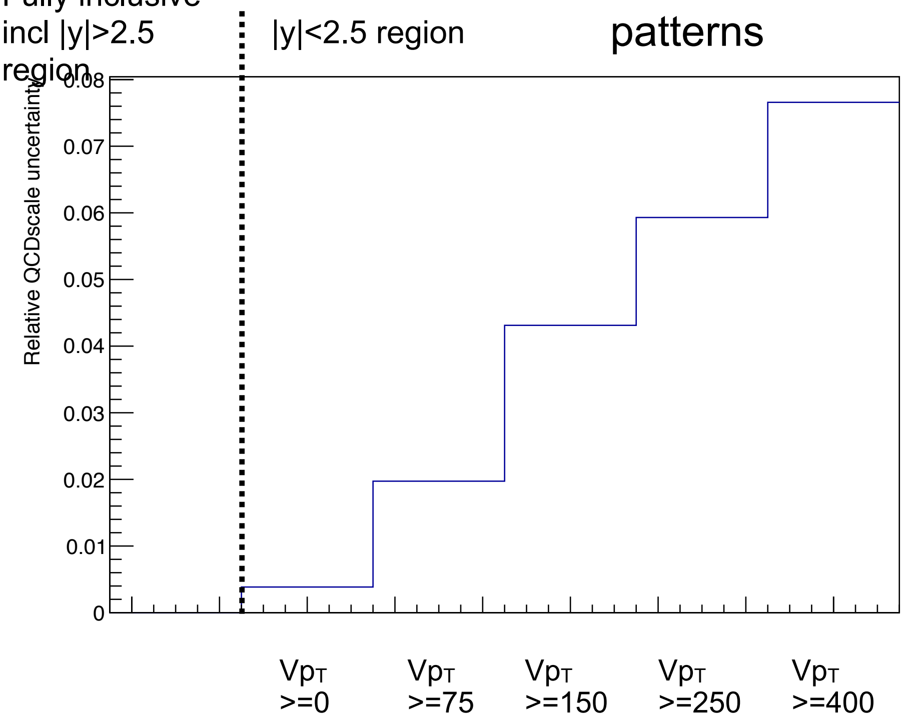
Procedure for evaluating scale uncertainties

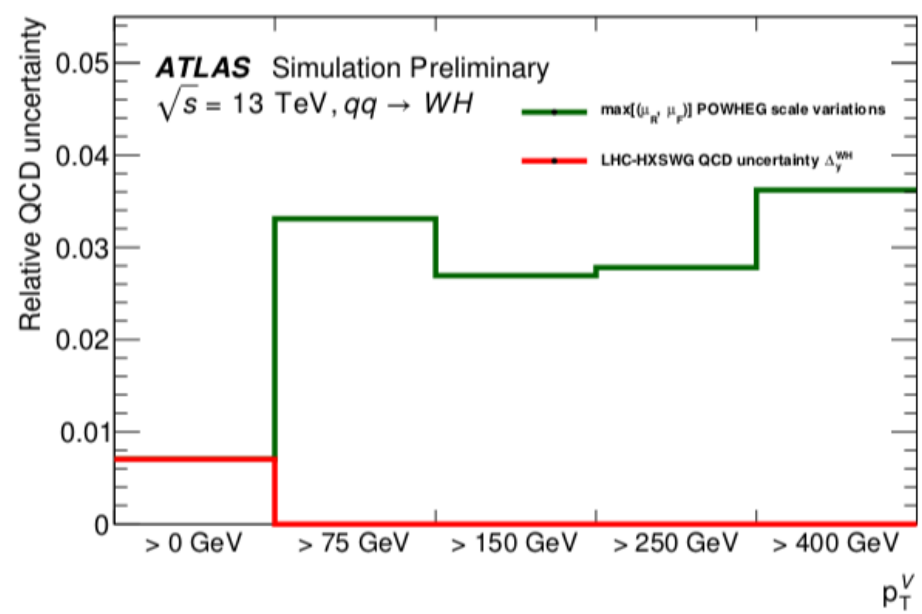
- Consider the full sample with no reco-level cuts applied
- Evaluate renormalisation- and factorisation scale variations in 6 pairs around the nominal values, avoiding the anti-correlated variations (μ_R = 2, μ_F = 0.5) and (μ_R = 0.5, μ_F=2)
- At each generator-level V p_T boundary (75, 150, 250, 400 GeV), take the largest absolute change in cross section in the V p_T>= X GeV bin due to any of the 6 variations as the uncertainty in that bin.
- We only want to take acceptance effects into account ➔ normalisation is such that in the inclusive sample the uncertainty due to the renormalisation and factorisation scale is 0
  - Normalisation of the sample with a given (μ_R, μ_F) variation applied is the same as with (μ_R=1, μ_F=1)

Example in action: WH

- In each bin V p_T >= X GeV, find the largest variation in **absolute** cross section from the 6 pairs of (μ_R, μ_F) variations
  - This is the baseline value, which we will divide by the relevant total cross section in a given bin to determine the relative uncertainty to apply
  - **In the figure below: absolute uncertainty divided by cross section in bin V p_T >= X GeV**

One difference between the ATLAS approach and the CMS figure is that in the CMS case the forward region is not treated as part of the Vp_T bins. Would expect small differences from this, but does not explain the different patterns

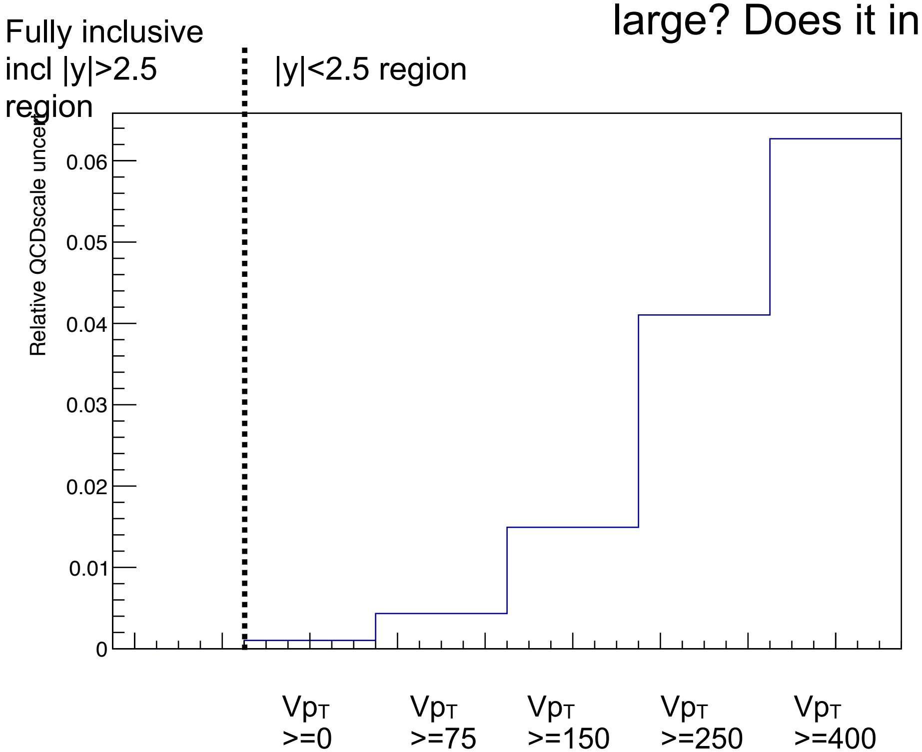


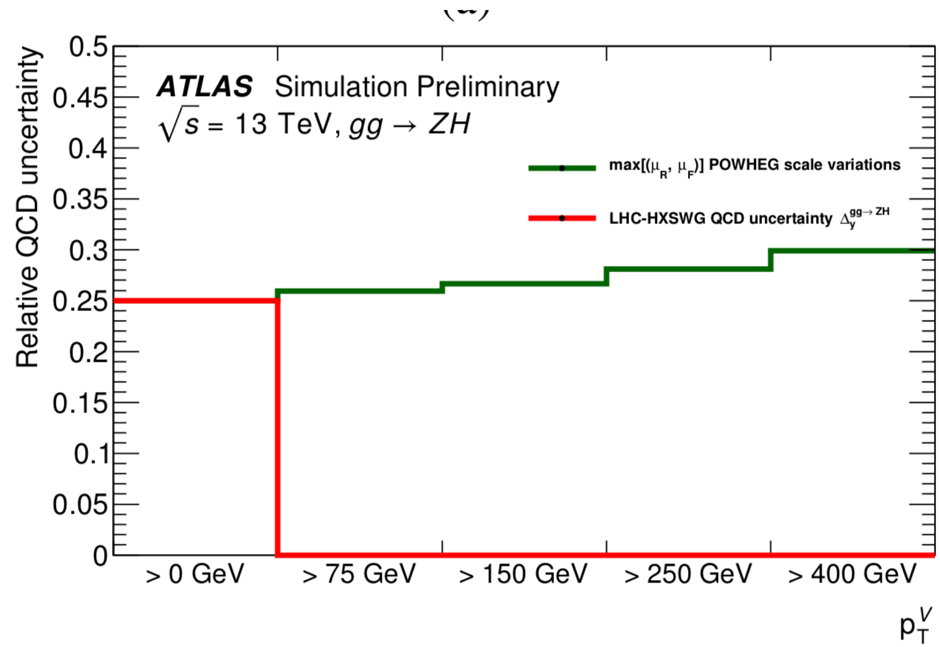


Example in action: ggZH

- In each bin V p_T >= X GeV, find the largest variation in **absolute** cross section from the 6 pairs of (μ_R, μ_F) variations
  - This is the baseline value, which we will divide by the relevant total cross section in a given bin to determine the relative uncertainty to apply
  - **In the figure below: absolute uncertainty divided by cross section in bin V p_T >= X GeV**

Same comment about the treatment of the forward region as on previous slide applies
How come ggZH relative uncertainty in V p_T>75 GeV bins is so large? Does it include the inclusive cross-section uncertainty?





Question about correlation schemes

p_T^V bin [GeV]	Δ_{75}	Δ_{150}	Δ_{250}	Δ_{400}
[0, 75[	$-\Delta_{75}/\sigma_{[0,75[}$	$-\Delta_{150}/\sigma_{[0,150[}$	$-\Delta_{250}/\sigma_{[0,250[}$	$-\Delta_{400}/\sigma_{[0,400[}$
[75, 150[	$+\Delta_{75}/\sigma_{[75,\infty[}$	$-\Delta_{150}/\sigma_{[0,150[}$	$-\Delta_{250}/\sigma_{[0,250[}$	$-\Delta_{400}/\sigma_{[0,400[}$
[150, 250[	$+\Delta_{75}/\sigma_{[75,\infty[}$	$+\Delta_{150}/\sigma_{[150,\infty[}$	$-\Delta_{250}/\sigma_{[0,250[}$	$-\Delta_{400}/\sigma_{[0,400[}$
[250, 400[	$+\Delta_{75}/\sigma_{[75,\infty[}$	$+\Delta_{150}/\sigma_{[150,\infty[}$	$+\Delta_{250}/\sigma_{[250,\infty[}$	$-\Delta_{400}/\sigma_{[0,400[}$
[400, ∞[	$+\Delta_{75}/\sigma_{[75,\infty[}$	$+\Delta_{150}/\sigma_{[150,\infty[}$	$+\Delta_{250}/\sigma_{[250,\infty[}$	$+\Delta_{400}/\sigma_{[400,\infty[}$

Scheme-1
"long-range" correlation scheme

p_T^V bin [GeV]	Δ_{75}	Δ_{150}	Δ_{250}	Δ_{400}
[0, 75[	$-\Delta_{75}/\sigma_{[0,75[}$	0	0	0
[75, 150[	$+\Delta_{75}/\sigma_{[75,\infty[}$	$-\Delta_{150}/\sigma_{[75,150[}$	0	0
[150, 250[	$+\Delta_{75}/\sigma_{[75,\infty[}$	$+\Delta_{150}/\sigma_{[150,\infty[}$	$-\Delta_{250}/\sigma_{[150,250[}$	0
[250, 400[	$+\Delta_{75}/\sigma_{[75,\infty[}$	$+\Delta_{150}/\sigma_{[150,\infty[}$	$+\Delta_{250}/\sigma_{[250,\infty[}$	$-\Delta_{400}/\sigma_{[250,400[}$
[400, ∞[	$+\Delta_{75}/\sigma_{[75,\infty[}$	$+\Delta_{150}/\sigma_{[150,\infty[}$	$+\Delta_{250}/\sigma_{[250,\infty[}$	$+\Delta_{400}/\sigma_{[400,\infty[}$

Scheme-2
"short-range" correlation scheme (although the 'short' only applies in one direction) ➔ **used in the analysis?**

V p_T bin	Δ75	Δ150	Δ250	Δ400
[0,75[	$-\Delta_{75}/\sigma_{[0,75[}$	0	0	0
[75,150[	$+\Delta_{75}/\sigma_{[75,150[}$	$-\Delta_{150}/\sigma_{[75,150[}$	0	0
[150,250[	0	$-\Delta_{150}/\sigma_{[150,250[}$	$-\Delta_{250}/\sigma_{[150,250[}$	0
[250,400[	0	0	$+\Delta_{250}/\sigma_{[250,400[}$	$-\Delta_{400}/\sigma_{[250,400[}$
[400,inf]	0	0	0	$+\Delta_{400}/\sigma_{[400,inf]}$

Tentative scheme-3
Why not just apply short-range correlation in both directions?

Question about merging bins and measuring cross-sections

- Maximum-split scheme used for uncertainty evaluation has more bins than we will actually measure
- Practically would expect that the fine process splitting is used in the preparation of the workspaces, with uncertainties as evaluated in max-split scheme applied, and multiple processes assigned a common POI (implicit merging of bins)
  - Is this what was done in the ATLAS analysis?
- How does the scheme hold when we measure cross-sections instead of μ's in the STXS bins?
  - Measuring cross-sections: inclusive theory uncertainties should not be taken into account
  - Have to evaluate acceptance uncertainties for individual analyses like it has been done in the past, except normalisation is not to inclusive cross section, but to cross section in each STXS bin