ATLAS ggF STXS Stage 1.2 Uncertainties: High-p_T^H Region

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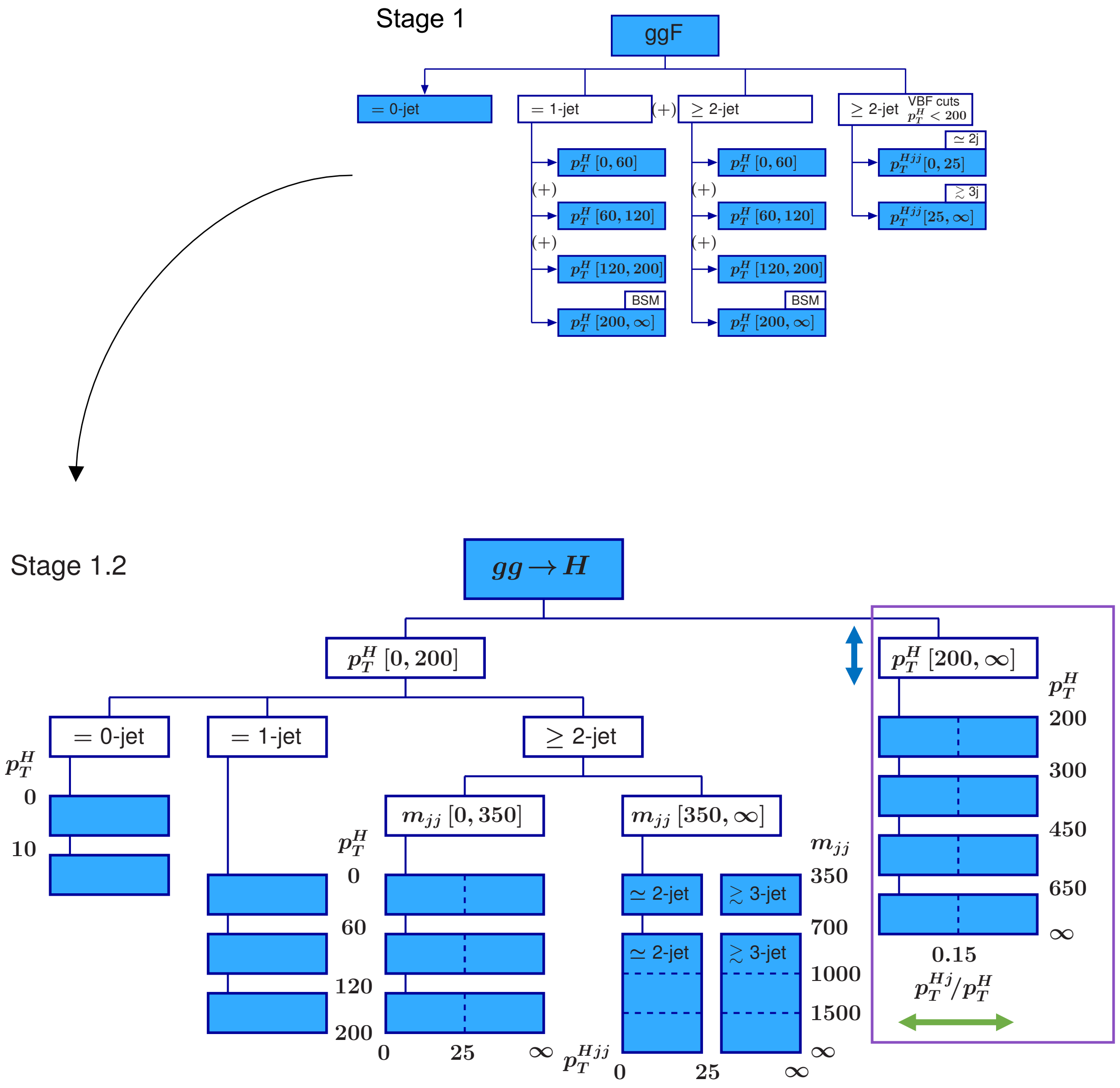
With thanks to Michael Spira, Matthias Kerner, Stephen Jones and Frank Tackmann for their input

Introduction: High-p_T^H STXS 1.2 Uncertainties

Focus of this talk: High p_T^H bins

- Treatment of uncertainties in low-p_T^H phase space was presented by Hui-Chi.
- A distinct nJets-inclusive p_T^H [200, ∞] bin did not exist in STXS Stage 1 scheme (p_T^H [200, ∞] bins instead defined separately in =1j and ≥2j phase spaces).
- Update required to more thoroughly treat top mass uncertainty, and to account for p_T^H and p_T^{Hj}/p_T^H binning of p_T^H [200, ∞] region.



Goal of the Uncertainty Scheme Update

- Consider two sources of uncertainty in p_T^H [200, ∞] bin:
  1) (μ_R, μ_F) dependence:
     - Normalization (overall yield effect)
     - Migration across p_T^H boundaries
     - Migration across p_T^{Hj}/p_T^H boundary
  2) Top mass scheme dependence:
     - Normalization (overall yield effect)

All plots and tables in the following slides are ATLAS preliminary, for the LHC Higgs WG2 Subgroup meeting only.

Overview of Samples

Calculations

NLO_SM:

- H+1j@NLO (from Matthias Kerner).
- m_t = 173.05 GeV, ≥ 1 jet with p_T>30 GeV
- 7-point variations of (μ_R, μ_F) around $E_T = \sqrt{M_H^2 + p_{T,H}^2}$
- PDF4LHC15_nnlo_mc

Pole mass:

- H+1j@LO with finite top mass (from Michael Spira).
- $\overline{MS}$ mass variations mt(mt), mt(E_T/2), mt(E_T), mt(2E_T), E_T as above.

Generated Events

MiNLO H+2j@NLO:

- Generator: Powheg
- Shower: Pythia8, AZNLO tune.
- PDF4LHC15_nlo_30_pdfas
- Rescaling for top mass effects

MiNLO H+1j@NLO:

- Generator: Powheg
- Shower: Pythia8, AZNLO tune
- PDF4LHC15_nlo_30_pdfas
- Rescaling for top mass effects, bornktmin=200

Generated Events

Powheg NNLOPS:

- Generator: Powheg
- Shower: Pythia8, AZNLO tune
- NNLOPS reweighting, rescaling for top mass effects.
- PDF4LHC15_nnlo_mc

MG5_aMC H+1j@NLO:

- Generator: MadGraph5_aMC@NLO.
- Shower: Pythia8, A14 tune
- NNPDF30_nlo_as_0118
- $m_t = \infty$, m_b=0
- HC_NLO_X0-heft model, $m_t = \infty$ (effective Higgs-gluon vertex)

MG5_aMC H+0,1,2j@NLO (FxFx):

- Generator: MadGraph5_aMC@NLO
- Shower: Pythia8, A14 tune
- NNPDF30_nlo_as_0118
- FxFx merging, merging scale = 30 GeV
- HC_NLO_X0-heft model, $m_t = \infty$ (effective Higgs-gluon vertex)

p_T^H Spectra

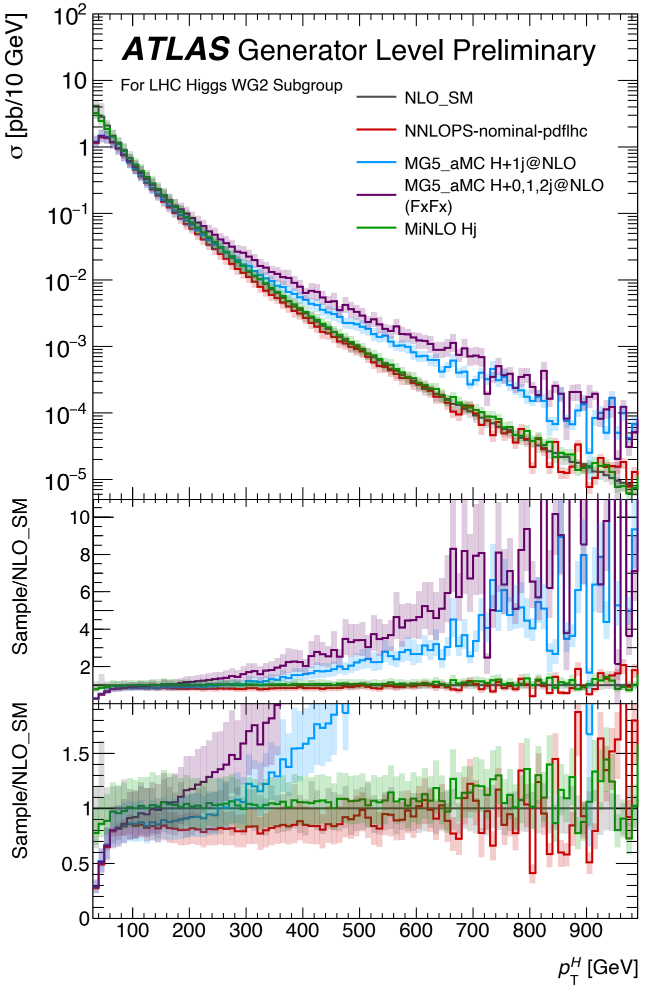
All samples normalized to the Powheg cross-section (28.3 pb).

Calculations used to derive uncertainties:

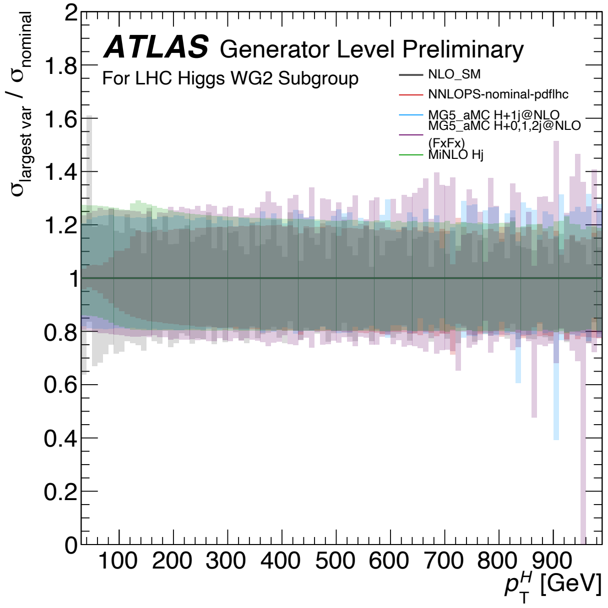
- **NLO_SM:** H+1j@NLO with finite top mass (from Matthias Kerner). Also provided largest and smallest (μ_R, μ_F) variations.
- **Pole mass:** H+1j@LO with finite top mass (from Michael Spira). Also provided $\overline{MS}$ mass variations mt(mt), mt(MT/2), mt(MT), mt(2MT).

Details on samples used for cross-checks are outlined in Hui-Chi's talk.

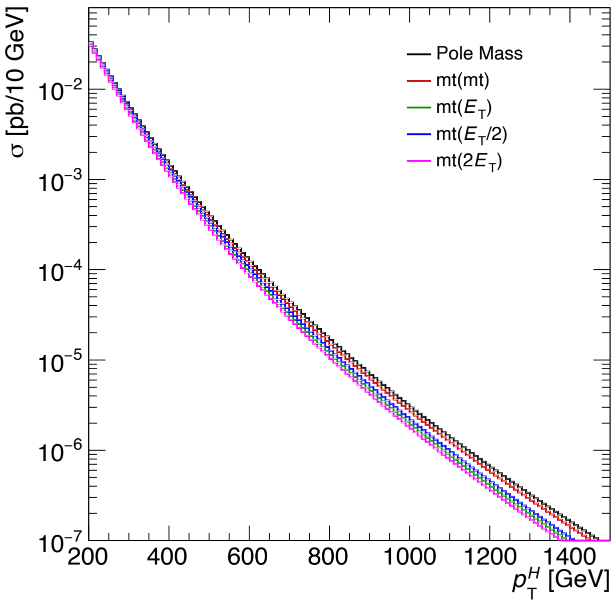
NLO samples: Cross-sections and envelope of (μ_R, μ_F) variations



NLO samples: Envelope of (μ_R, μ_F) variations / nominal cross-section



LO samples: Cross-sections for various top mass schemes (calcs. from Michael Spira [ref: ArXiV 2005.07762])



p_T^{Hj}/p_T^{H} Spectra

In what follows: jets selected from AntiKt4TruthDressedWZJets selection, with p_T>30 GeV.

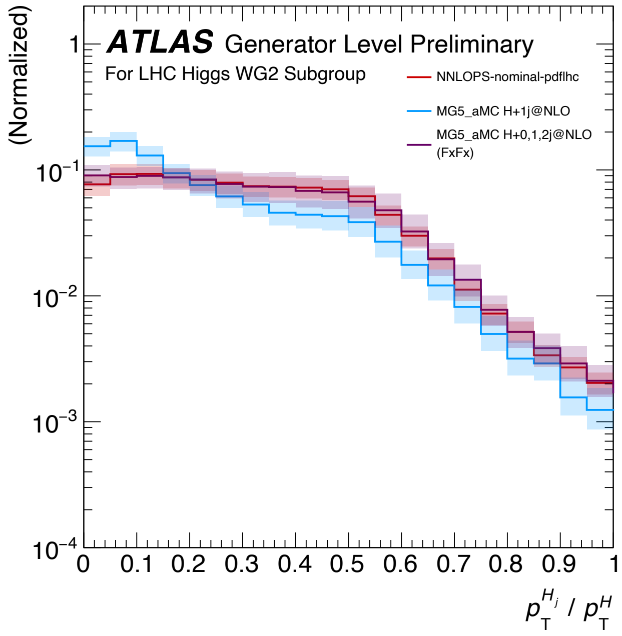
Samples used to derive uncertainties:

- NNLOPS-nominal-pdflhc: ATLAS Powheg+Pythia8 NNLOPS.

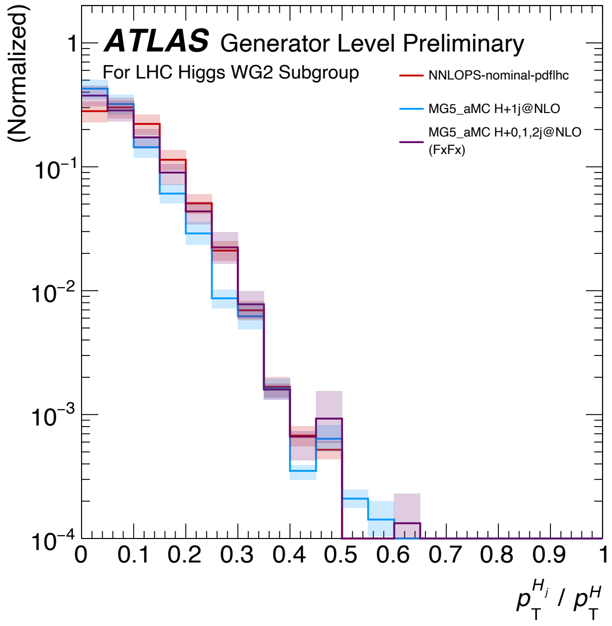
Samples used for cross-checks:

- MG5_aMC H+1j@NLO: H+1j@NLO generated by us, interfaced to Pythia8
- MG5_aMC H+0,1,2j@NLO (FxFx): H+0,1,2j@NLO with FxFx merging, interfaced to Pythia8.

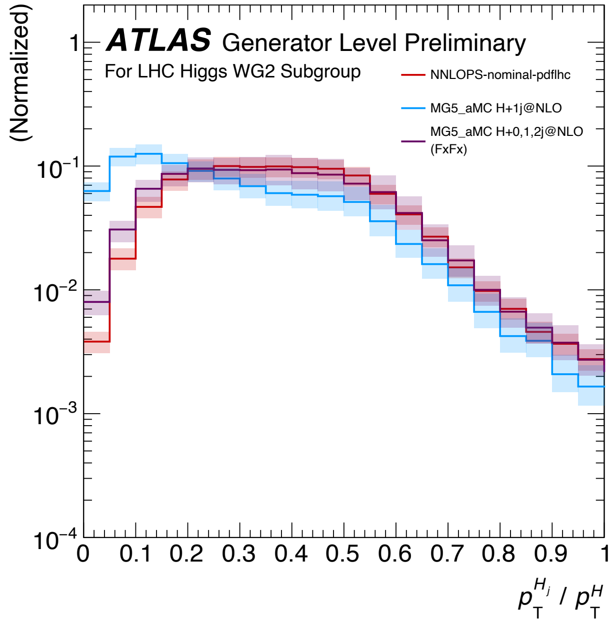
Cross-sections and envelope of (μ_R, μ_F) variations, for ≥ 1j events



Cross-sections for = 1j events



Cross-sections for ≥ 2j events



- Unsure where large difference between MG5_aMC H+1j@NLO and other samples comes from. Could be due to order of H+2j calculation (LO, vs. NLO for FxFx) or missing H+0j events (where higher jet multiplicities come from shower).

p_T^{Hj}/p_T^H Spectra

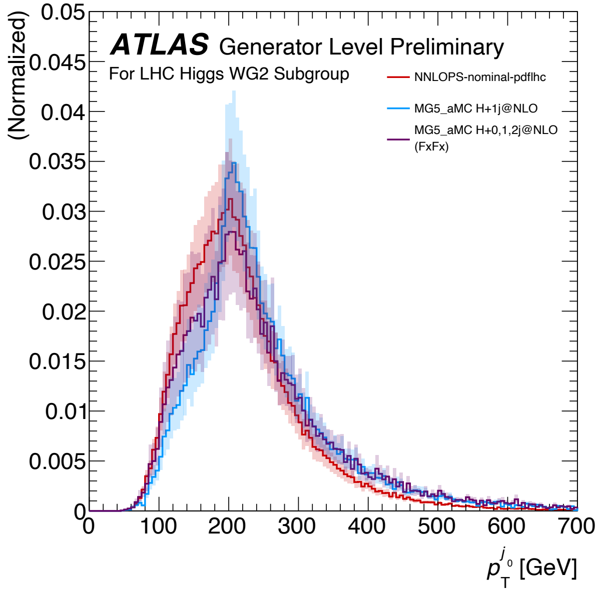
Samples used to derive uncertainties:

- NNLOPS-nominal-pdflhc: ATLAS Powheg+Pythia8 NNLOPS.

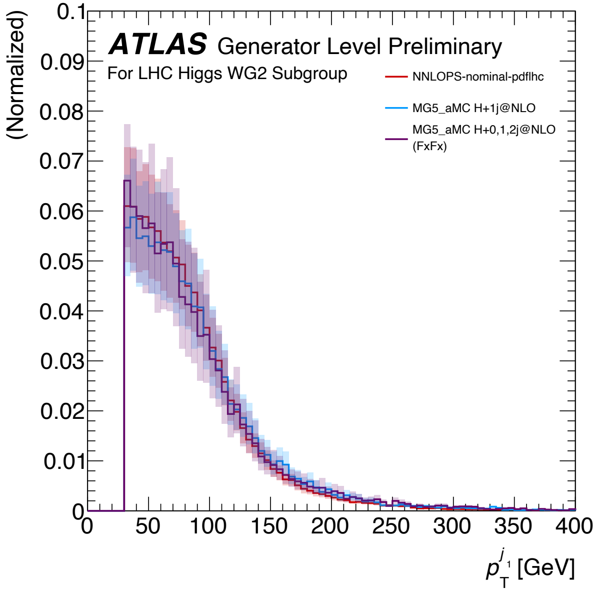
Samples used for cross-checks:

- MG5_aMC H+1j@NLO: H+1j@NLO generated by us.
- MG5_aMC H+0,1,2j@NLO (FxFx): H+0,1,2j@NLO with FxFx merging.

Leading jet pT spectrum with envelope of (μ_R, μ_F) variations, for $\geq$ 1j events



Subleading jet pT spectrum with envelope of (μ_R, μ_F) variations, for $\geq$ 2j events



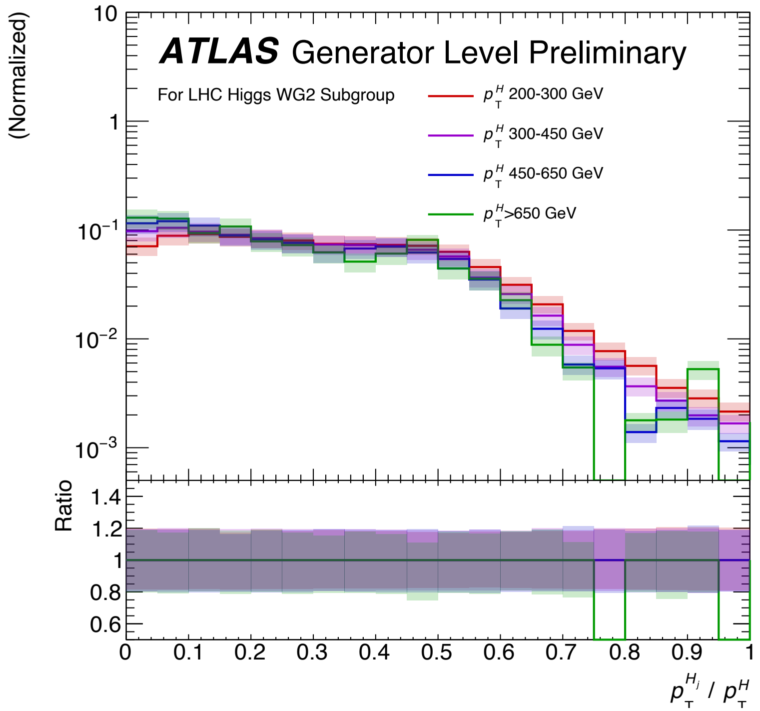
- p_T^{Hj}/p_T^H acts a proxy for $p_T^{\text{subleading jet}}$
- Leading jet p_T spectra show differences between samples that are consistent with p_T^{Hj}/p_T^H differences and expectations based on sample order: fewer low-p_T jets for H+1j@NLO than for other samples, fewer high-p_T jets for NNLOPS sample.
- Subleading jet p_T spectra are consistent between samples despite different order of H+2j calculation.

p_T^{Hj}/p_T^H Spectra

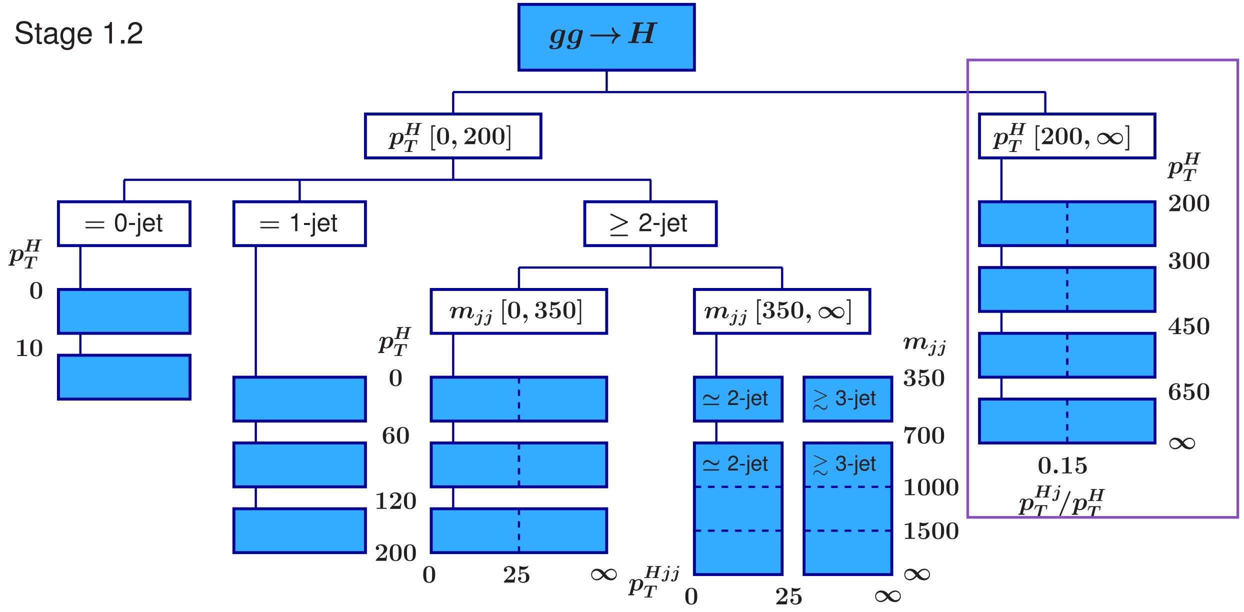
Samples used to derive uncertainties:

- **NNLOPS-nominal-pdflhc:** ATLAS Powheg+Pythia8 NNLOPS. Normalized to Powheg prediction: σ = 28.3 pb

Cross-sections and envelope of (μ_R, μ_F) variations, for $\geq$ 1j events, NNLOPS sample only



Stage 1.2



- The size of scale variations as a function of p_T^{Hj}/p_T^H does not seem to depend on the p_T^H bin, as intended.
  - ✓ Calculation has been done over the inclusive p_T^H>200 range and will be applied to individual p_T^H bins.

Results: (μ_R, μ_F) Scale Uncertainty in p_T^H bins

Long-Range Method

ρ-factor=0.5 applied to NP_{300}, NP_{450}, NP_{650}.

Raw numbers in backup

Rel [%]	total	p_T^H bin [GeV]			
	Sample: H+1j@NLO calculation with finite top mass				
Uncertainty	$\sigma_{[200,\infty)}$	$\sigma_{[200,300)}$	$\sigma_{[300,450)}$	$\sigma_{[450,650)}$	$\sigma_{[650,\infty)}$
NP_y	22.053	22.053	22.053	22.053	22.053
NP_{300}		-2.815	10.391	10.391	10.391
NP_{450}			-1.700	10.255	10.255
NP_{650}				-1.332	10.430
Total	22.053	22.232	24.438	26.481	28.430

ST Method

[arXiv:1107.2117]

Rel [%]	total	p_T^H bin [GeV]			
	Sample: H+1j@NLO calculation with finite top mass				
Uncertainty	$\sigma_{[200,\infty)}$	$\sigma_{[200,300)}$	$\sigma_{[300,450)}$	$\sigma_{[450,650)}$	$\sigma_{[650,\infty)}$
NP_y	22.053	28.028			
NP_{300}		-5.630	24.227		
NP_{450}			-3.399	23.129	
NP_{650}				-2.663	20.859
Total	22.053	28.588	24.464	23.282	20.859

Results: (μ_R, μ_F) Scale Uncertainty in p_T^{Hj}/p_T^H bins

Long-Range Method

No ρ-factor
(only two bins)

- Cut on p_T^H>200 GeV applied

	Sample: Powheg+Pythia8 NNLOPS		
Rel [%]	total	p_T^{Hj}/p_T^H bin	
Uncertainty	$\sigma_{[0,\infty)}$	$\sigma_{[0,0.15)}$	$\sigma_{[0.15,\infty)}$
NP_y	18.240	18.240	18.240
$NP_{0.15}$		-50.953	18.122
Total	18.240	54.120	25.712

- Overall (yield) uncertainties would be double-counted if NP_Y from calculation in pTH and pTHj/pTH bins were both applied.
- Proposed treatments detailed on later slide.

Consistent with size of existing $1 \leftrightarrow 2$ jet migration NP, from BLPTW method.

ST Method

	Sample: Powheg+Pythia8 NNLOPS		
Rel [%]	total	p_T^{Hj}/p_T^H bin	
Uncertainty	$\sigma_{[0,\infty)}$	$\sigma_{[0,0.15)}$	$\sigma_{[0.15,\infty)}$
NP_y	18.240	69.523	
$NP_{0.15}$		-50.953	18.122
Total	18.240	86.196	18.122

Uncertainties with p_T^{j1} as boundary in backup.

Results: Top Mass Scale Uncertainty

- Top mass scale uncertainty found by taking difference between cross-sections calculated at LO with:
  - Top mass set to pole mass
  - Top mass set according to dynamical scale, $\mathrm{mt}(E_T)$ (where $E_\mathrm{T} = \sqrt{M_H^2 + p_\mathrm{T}^2}$)
- Theorists suggest using **half** of the LO variation, to account for expected decrease on moving from LO to NLO.
- Scale uncertainty expected to be highly correlated across STXS bins → use a single NP_Y that takes a different value per bin.
  - Alternative using LR method, including migration effects, shown in backup.

In p_T^H bins

	Sample: H+1j@LO calculation with top pole mass				
Rel [%]	total	p_T^H bin [GeV]			
Uncertainty	$\sigma_{[200,\infty)}$	$\sigma_{[200,300)}$	$\sigma_{[300,450)}$	$\sigma_{[450,650)}$	$\sigma_{[650,\infty)}$
NP_y	4.433	3.494	7.279	11.242	15.159

Treatment of Corresponding NP

- Original proposal by theorists: Add the top mass uncertainty linearly to the overall uncertainty from μ_R/μ_F variations.
  - ➢ One NP would cover overall (yield) uncertainty in high-p_T^H regime. Value of the NP is the linear sum μ_R/μ_F effect on overall yield (~22%), and top mass scheme effect on yield (varies per p_T^H bin as in table).
- Preferred alternative: Provide a separate NP for top mass scheme uncertainty.
  - ➢ Uncertainty from top mass scheme dependence would be added quadratically, rather than linearly, to the rest.

The Full Picture: High-p_T^H STXS Bins

Option 1

- Replace existing yield nuisance parameters (NP_{mu}, NP_{res}) with $NP_{High\text{-}pTH}$, which is the ~22% NP_Y calculated using the H+1j@NLO (finite top mass) sample.
- Replace existing jet bin migration nuisance parameters (NP_{mig01}, NP_{mig12}) with $NP_{pTHj/pTH}$ calculated in p_T^{Hj}/p_T^H bins.

STXS bin	NP						TOTAL
	$NP_{High-p_T^H}$	$NP_{pTHj/pTH}$	$NP_{pTH\ 300}$	$NP_{pTH\ 450}$	$NP_{pTH\ 650}$	NP_{top}	
GG2H_PTH_200_300_PTHJoverPTH_0_15	22.05%	-50.95%	-2.82%			3.49%	55.70%
GG2H_PTH_300_450_PTHJoverPTH_0_15	22.05%	-50.95%	10.39%	-1.70%		7.28%	56.98%
GG2H_PTH_450_650_PTHJoverPTH_0_15	22.05%	-50.95%	10.39%	10.26%	-1.33%	11.24%	58.51%
GG2H_PTH_GT650_PTHJoverPTH_0_15	22.05%	-50.95%	14.55%	10.25%	10.43%	15.16%	61.14%
GG2H_PTH_200_300_PTHJoverPTH_GT15	22.05%	18.12%	-2.82%			3.49%	28.89%
GG2H_PTH_300_450_PTHJoverPTH_GT15	22.05%	18.12%	10.39%	-1.70%		7.28%	31.28%
GG2H_PTH_450_650_PTHJoverPTH_GT15	22.05%	18.12%	10.39%	10.26%	-1.33%	11.24%	34.00%
GG2H_PTH_GT650_PTHJoverPTH_GT15	22.05%	18.12%	10.39%	10.25%	10.43%	15.16%	36.96%

The Full Picture: High-p_T^H STXS Bins

Option 2

- Keep existing yield NPs (NP_{mu}, NP_{res})
- Also add $NP_{High\text{-}pTH}$ after quadrature subtraction of existing yield NPs from ~22% NP_Y calculated using the H+1j@NLO (finite top mass) sample, $NP_{High-p_T^H} = \sqrt{NP_Y^2 - NP_{mu}^2 - NP_{res}^2}$
- Replace existing jet bin migration nuisance parameters NP_{mig01}, NP_{mig12} with $NP_{pTHj/pTH}$ calculated in p_T^{Hj}/p_T^H bins.

STXS bin	NP								TOTAL
	NP_{mu}	NP_{res}	$NP_{High-p_T^H}$	$NP_{pTHj/pTH}$	$NP_{pTH\ 300}$	$NP_{pTH\ 450}$	$NP_{pTH\ 650}$	NP_{top}	
GG2H_PTH_200_300_PTHJoverPTH_0_15	5.85%	5.26%	20.60%	-50.95%	-2.82%			3.49%	55.70%
GG2H_PTH_300_450_PTHJoverPTH_0_15	6.24%	5.73%	20.36%	-50.95%	10.39%	-1.70%		7.28%	56.98%
GG2H_PTH_450_650_PTHJoverPTH_0_15	6.96%	6.59%	19.86%	-50.95%	10.39%	10.26%	-1.33%	11.24%	58.51%
GG2H_PTH_GT650_PTHJoverPTH_0_15	7.09%	6.74%	19.76%	-50.95%	14.55%	10.25%	10.43%	15.16%	61.14%
GG2H_PTH_200_300_PTHJoverPTH_GT15	8.47%	8.39%	18.55%	18.12%	-2.82%			3.49%	28.89%
GG2H_PTH_300_450_PTHJoverPTH_GT15	8.75%	8.73%	18.26%	18.12%	10.39%	-1.70%		7.28%	31.28%
GG2H_PTH_450_650_PTHJoverPTH_GT15	8.87%	8.87%	18.14%	18.12%	10.39%	10.26%	-1.33%	11.24%	34.00%
GG2H_PTH_GT650_PTHJoverPTH_GT15	8.87%	8.87%	18.13%	18.12%	10.39%	10.25%	10.43%	15.16%	36.96%

Conclusions

Summary

- First full high-p_T^H uncertainties scheme derived
  - Includes uncertainties due to dependence on the (μ_R, μ_F) scale (bins of p_T^H and p_T^{Hj}/p_T^H) and the top mass scale (bins of p_T^H).

Next Steps

- Several options to be settled on for final scheme:
  - Treatment of overall (yield) NPs
  - Treatment of top mass uncertainty (as separate NP, or added linearly to yield NPs)

- Hope to settle on a common scheme with CMS.

Backup

Method Used: Long-Range ST Method

- Calculate each Δ as the difference between the event yields of the nominal sample and the scale variation that gives the largest difference, in the inclusive region $[X,\infty)$ specified.
- Then express each absolute uncertainty $\Delta_{[X,\infty)}$ as a relative uncertainty $\delta_{[X,\infty)} = \Delta_{[X,\infty)}/\sigma_{[X,\infty)}$
  - Relative uncertainty over the fully inclusive range gives the overall relative (yield) uncertainty, which is used as a yield NP in all the bins.
  - Relative uncertainties are also calculated for each of the remaining $[X,\infty)$ ranges and applied **as** migration NPs to the bins above X.
  - The migration NP for the bin $[W,X)$ that lies immediately below the $[X,\infty)$ range takes on a value of $-\delta^*_{[W,X)} = -\delta_{[X,\infty)}\times\sigma_{[X,\infty)}/\sigma_{[W,X)}$, to ensure that migration NPs cancel when bins are grouped.
- Uncertainty in each exclusive bin (column) is the sum in quadrature of uncertainties in many inclusive regions.
  - Assumes that scale uncertainties over progressively-less-inclusive ranges are uncorrelated.
    - When this is not justified, it causes an undesirable blow-up of uncertainty when there are many preceding bins.
  - Solution: apply a ρ-factor of 0.5 to the migration uncertainties, reflecting our expectation that there is a degree of correlation between scale uncertainties across kinematic ranges.

Overview for uncertainty in p_T^H bins:

Rel [%]	total	p_T^H bin [GeV]				
Uncertainty	$\sigma_{[200,\infty)}$	$\sigma_{[200,300)}$	$\sigma_{[300,450)}$	$\sigma_{[450,650)}$	$\sigma_{[650,\infty)}$	
NP_y	$+\delta_{[200,\infty)}$	$+\delta_{[200,\infty)}$	$+\delta_{[200,\infty)}$	$+\delta_{[200,\infty)}$	$+\delta_{[200,\infty)}$	
NP_{300}	0	$-\delta_{[200,300)}$	$+\delta_{[300,\infty)}$	$+\delta_{[300,\infty)}$	$+\delta_{[300,\infty)}$	← Scale by $\rho = 0.5$
NP_{450}	0	0	$-\delta_{[300,450)}$	$+\delta_{[450,\infty)}$	$+\delta_{[450,\infty)}$	← Scale by $\rho = 0.5$
NP_{650}	0	0	0	$-\delta_{[450,650)}$	$+\delta_{[650,\infty)}$	← Scale by $\rho = 0.5$

Results: (μ_R, μ_F) Scale Uncertainty, p_T^{Hj}/p_T^H Bins

Sample: NNLOPS

ST method

$200<p_T^H<300$ GeV

Rel[%]	total	p_T^{Hj}/p_T^H bin	
Uncertainty	$\sigma_{[0,\infty)}$	$\sigma_{[0,0.15)}$	$\sigma_{[0.15,\infty)}$
NP_y	17.920	71.642	
$NP_{0.15}$		-53.402	17.814
Total	17.920	89.355	17.814

$300<p_T^H<450$ GeV

Rel[%]	total	p_T^{Hj}/p_T^H bin	
Uncertainty	$\sigma_{[0,\infty)}$	$\sigma_{[0,0.15)}$	$\sigma_{[0.15,\infty)}$
NP_y	19.227	64.436	
$NP_{0.15}$		-45.023	19.148
Total	19.227	78.607	19.148

$450<p_T^H<650$ GeV

Rel[%]	total	p_T^{Hj}/p_T^H bin	
Uncertainty	$\sigma_{[0,\infty)}$	$\sigma_{[0,0.15)}$	$\sigma_{[0.15,\infty)}$
NP_y	20.102	57.985	
$NP_{0.15}$		-37.917	20.120
Total	20.102	69.282	20.120

650 GeV $<p_T^H$

Rel[%]	total	p_T^{Hj}/p_T^H bin	
Uncertainty	$\sigma_{[0,\infty)}$	$\sigma_{[0,0.15)}$	$\sigma_{[0.15,\infty)}$
NP_y	21.136	59.760	
$NP_{0.15}$		-39.293	21.501
Total	21.136	71.521	21.501

Results: (μ_R, μ_F) Scale Uncertainty, p_T^{Hj}/p_T^H Bins

Sample: NNLOPS

LR method (no ρ-factor)

$200<p_T^H<300$ GeV

Rel [%]	total	p_T^{Hj}/p_T^H bin	
Uncertainty	$\sigma_{[0,\infty)}$	$\sigma_{[0,0.15)}$	$\sigma_{[0.15,\infty)}$
NP_y	17.920	17.920	17.920
$NP_{0.15}$		-53.402	17.814
Total	17.920	56.328	25.268

$300<p_T^H<450$ GeV

Rel [%]	total	p_T^{Hj}/p_T^H bin	
Uncertainty	$\sigma_{[0,\infty)}$	$\sigma_{[0,0.15)}$	$\sigma_{[0.15,\infty)}$
NP_y	19.227	19.227	19.227
$NP_{0.15}$		-45.023	19.148
Total	19.227	48.957	27.136

$450<p_T^H<650$ GeV

Rel [%]	total	p_T^{Hj}/p_T^H bin	
Uncertainty	$\sigma_{[0,\infty)}$	$\sigma_{[0,0.15)}$	$\sigma_{[0.15,\infty)}$
NP_y	20.102	20.102	20.102
$NP_{0.15}$		-37.917	20.120
Total	20.102	42.916	28.442

650 GeV $<p_T^H$

Rel [%]	total	p_T^{Hj}/p_T^H bin	
Uncertainty	$\sigma_{[0,\infty)}$	$\sigma_{[0,0.15)}$	$\sigma_{[0.15,\infty)}$
NP_y	21.136	21.136	21.136
$NP_{0.15}$		-39.293	21.501
Total	21.136	44.617	30.150

(μ_R, μ_F) Scale Uncertainty using p_T^{j1} as Boundary

p_T^{j1} instead of p_T^{Hj} / p_T^{H} bins

- Cut on $p_T^H > 200$ GeV applied
- Expect p_T^H dependence now, so divided into two p_T^H ranges.
- See blow-up of uncertainties in high pTH region, which motivates use of pTHj/pTH instead.

$200 < p_T^H < 650$ GeV

	Sample: Powheg+Pythia8 NNLOPS		
Rel [%]	total	p_T^{j1} bin [GeV]	
Uncertainty	$\sigma_{[0,\infty)}$	$\sigma_{[0,30)}$	$\sigma_{[30,\infty)}$
NP_y	18.659	18.659	18.659
$NP_{0.15}$		-52.916	18.400
Total	18.659	56.109	26.205

$p_T^H > 650$ GeV

	Sample: Powheg+Pythia8 NNLOPS		
Rel [%]	total	p_T^{j1} bin [GeV]	
Uncertainty	$\sigma_{[0,\infty)}$	$\sigma_{[0,30)}$	$\sigma_{[30,\infty)}$
NP_y	21.136	21.136	21.136
$NP_{0.15}$		-147.191	21.234
Total	21.136	148.701	29.960

	$200 < p_T^H < 650$ GeV					$p_T^H > 650$ GeV				
	Uncertainty			Relative Cross-Section		Uncertainty			Relative Cross-Section	
Rel [%] (LR method)	total	p_T^{j1} bin [GeV]		p_T^{j1} bin [GeV]		total	p_T^{j1} bin [GeV]		p_T^{j1} bin [GeV]	
Uncertainty (Sample)	$\sigma_{[0,\infty)}$	$\sigma_{[0,30)}$	$\sigma_{[30,\infty)}$	$\sigma_{[0,30)}$	$\sigma_{[30,\infty)}$	$\sigma_{[0,\infty)}$	$\sigma_{[0,30)}$	$\sigma_{[30,\infty)}$	$\sigma_{[0,30)}$	$\sigma_{[30,\infty)}$
Total (Powheg+Pythia8 NNLOPS)	18.240	54.120	25.712	26%	74%	21.136	148.701	29.960	13%	87%
Total (MG5_aMC H+1j@NLO)	22.309	97.774	32.241	20%	80%	20.877	196.061	29.907	10%	90%
Total (MG5_aMC H+0,1,2j@NLO (FxFx))	26.131	102.133	38.349	22%	78%	28.987	214.591	41.255	12%	88%

Results and Comparison: Top Mass Scale Uncertainty

- Values are **half** of difference calculated by comparing to top mass scale variation mt(MT), to account for expected decrease on moving from LO to NLO.

p_T^H bins

ρ-factor=0.7 applied to NP_{300}, NP_{450}, NP_{650} for LR method.

	Sample: H+1j@LO calculation with top pole mass				
Rel [%]	total	p_T^H bin [GeV]			
Uncertainty	$\sigma_{[200,\infty)}$	$\sigma_{[200,300)}$	$\sigma_{[300,450)}$	$\sigma_{[450,650)}$	$\sigma_{[650,\infty)}$
NP_y	4.433	4.433	4.433	4.433	4.433
NP_{300}		-1.495	5.537	5.537	5.537
NP_{450}			-1.361	8.198	8.198
NP_{650}				-1.446	10.611
Total	4.433	4.679	7.222	10.937	15.169

	Sample: H+1j@LO calculation with top pole mass				
Rel [%]	total	p_T^H bin [GeV]			
Uncertainty (Method)	$\sigma_{[200,\infty)}$	$\sigma_{[200,300)}$	$\sigma_{[300,450)}$	$\sigma_{[450,650)}$	$\sigma_{[650,\infty)}$
Total (LR)	4.433	4.679	7.222	10.937	15.169
Total (ST)	4.433	6.022	9.425	13.468	15.159

Results and Comparison: Top Mass Scale Uncertainty

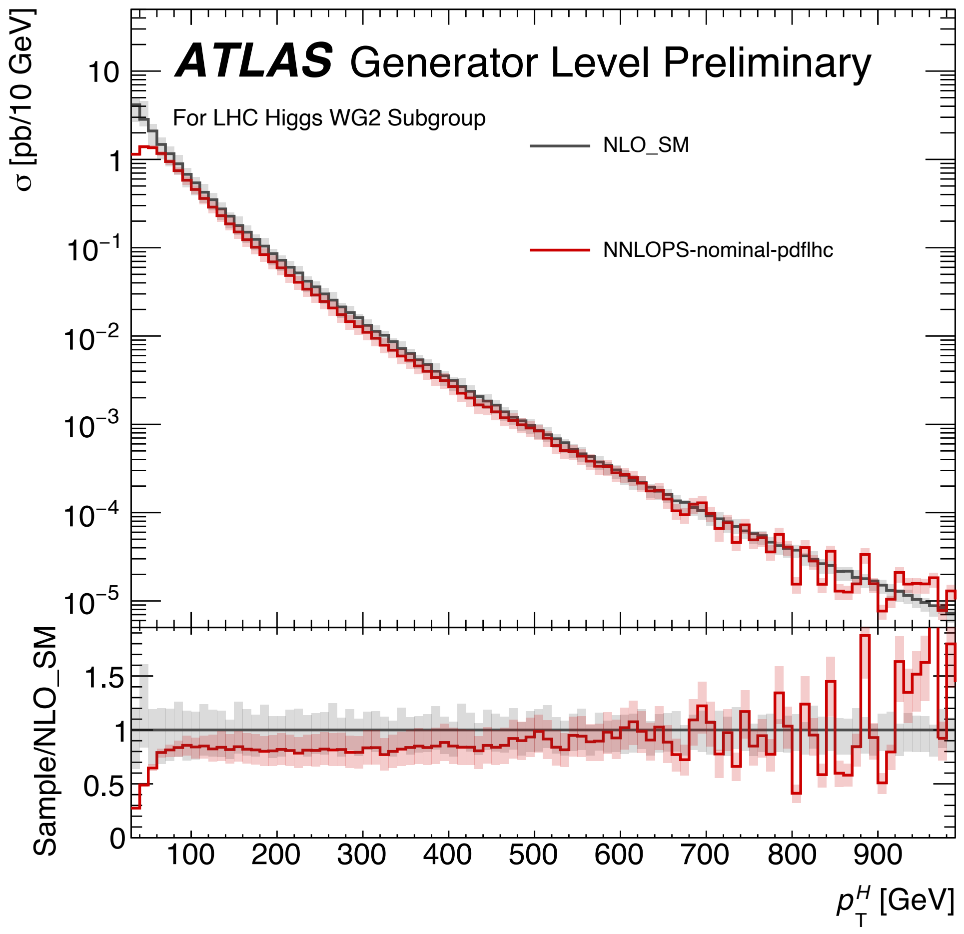
- Values are **half** of difference calculated by comparing to top mass scale variation mt(MT), to account for expected decrease on moving from LO to NLO.

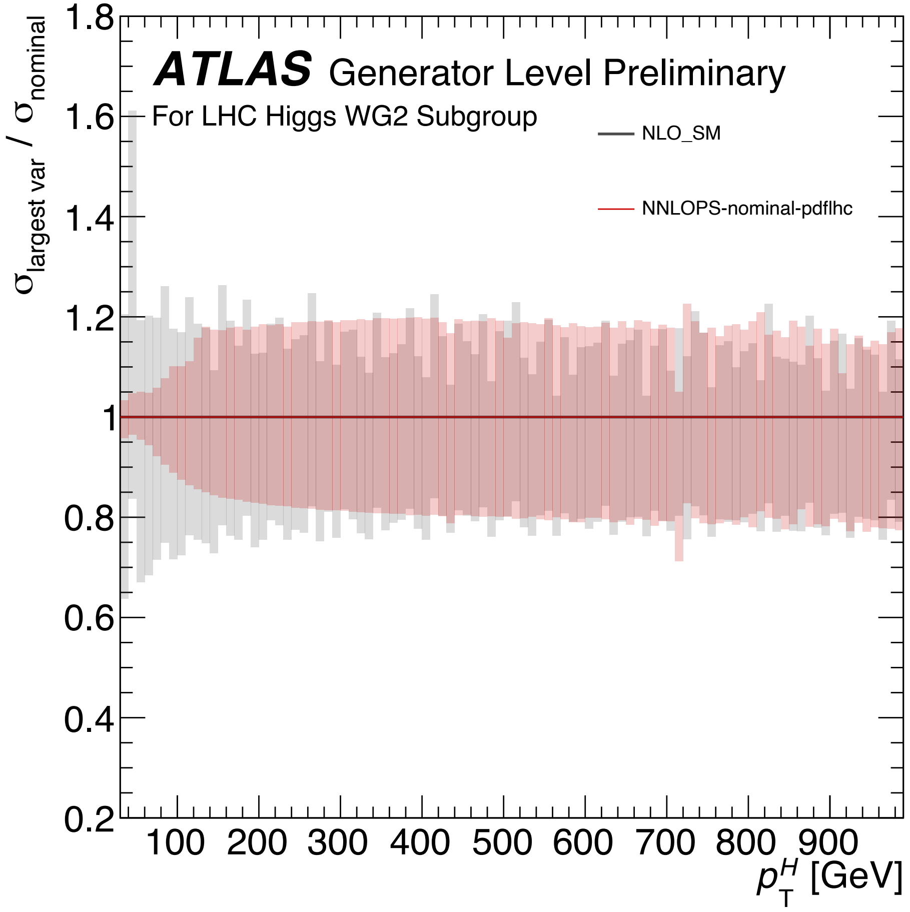
p_T^H bins

No ρ-factor applied

	Sample: H+1j@LO calculation with top pole mass				
Rel [%]	total	p_T^H bin [GeV]			
Uncertainty	$\sigma_{[200,\infty)}$	$\sigma_{[200,300)}$	$\sigma_{[300,450)}$	$\sigma_{[450,650)}$	$\sigma_{[650,\infty)}$
NP_y	4.433	4.433	4.433	4.433	4.433
NP_{300}		-2.136	7.909	7.909	7.909
NP_{450}			-1.944	11.712	11.712
NP_{650}				-2.066	15.159
Total	4.433	4.921	9.273	14.955	21.193

NNLOPS and NLO_SM Only





Comparisons of Methods

ST method, in p_T^H bins:

Rel [%]	total	p_T^H bin [GeV]			
Uncertainty	$\sigma_{[200,\infty)}$	$\sigma_{[200,300)}$	$\sigma_{[300,450)}$	$\sigma_{[450,650)}$	$\sigma_{[650,\infty)}$
NP_y	$+\Delta_{[200,\infty)}/\sigma_{[200,\infty)}$	$+\Delta_{[200,\infty)}/\sigma_{[200,300)}$			
NP_{300}	0	$-\Delta_{[300,\infty)}/\sigma_{[200,300)}$	$+\Delta_{[300,\infty)}/\sigma_{[300,450)}$		
NP_{450}	0	0	$-\Delta_{[450,\infty)}/\sigma_{[300,450)}$	$+\Delta_{[450,\infty)}/\sigma_{[450,650)}$	
NP_{650}	0	0	0	$+\Delta_{[650,\infty)}/\sigma_{[450,650)}$	$+\Delta_{[650,\infty)}/\sigma_{[650,\infty)}$

LR method, in p_T^H bins:

Rel [%]	total	p_T^H bin [GeV]				
Uncertainty	$\sigma_{[200,\infty)}$	$\sigma_{[200,300)}$	$\sigma_{[300,450)}$	$\sigma_{[450,650)}$	$\sigma_{[650,\infty)}$	
NP_y	$+\Delta_{[200,\infty)}/\sigma_{[200,\infty)}$	$+\Delta_{[200,\infty)}/\sigma_{[200,\infty)}$	$+\Delta_{[200,\infty)}/\sigma_{[200,\infty)}$	$+\Delta_{[200,\infty)}/\sigma_{[200,\infty)}$	$+\Delta_{[200,\infty)}/\sigma_{[200,\infty)}$	
NP_{300}	0	$-\Delta_{[300,\infty)}/\sigma_{[200,300)}$	$+\Delta_{[300,\infty)}/\sigma_{[300,\infty)}$	$+\Delta_{[300,\infty)}/\sigma_{[300,\infty)}$	$+\Delta_{[300,\infty)}/\sigma_{[300,\infty)}$	Scale by $\rho = 0.5$
NP_{450}	0	0	$-\Delta_{[450,\infty)}/\sigma_{[300,450)}$	$+\Delta_{[450,\infty)}/\sigma_{[450,\infty)}$	$+\Delta_{[450,\infty)}/\sigma_{[450,\infty)}$	Scale by $\rho = 0.5$
NP_{650}	0	0	0	$-\Delta_{[650,\infty)}/\sigma_{[450,650)}$	$+\Delta_{[650,\infty)}/\sigma_{[650,\infty)}$	Scale by $\rho = 0.5$

Overall (yield) uncertainty:

- ST: **Absolute** yield uncertainty over the full inclusive range is applied to the **first bin**.
- LR: **Relative** yield uncertainty over the full inclusive range is applied to **every bin** in that range.

Migration uncertainties:

- ST: **Absolute** uncertainty over an inclusive range >X is applied to bin [X, Y] and the one below it.
- LR: **Relative** yield uncertainty over an inclusive range >X is applied to every bin in that range. A different relative uncertainty is applied to the one below it so that they cancel when bins are grouped.