Uploaded after the meeting:
→ Corrections on some formulas p10

Signal uncertainties in STXS stage 1 for VH(bb)

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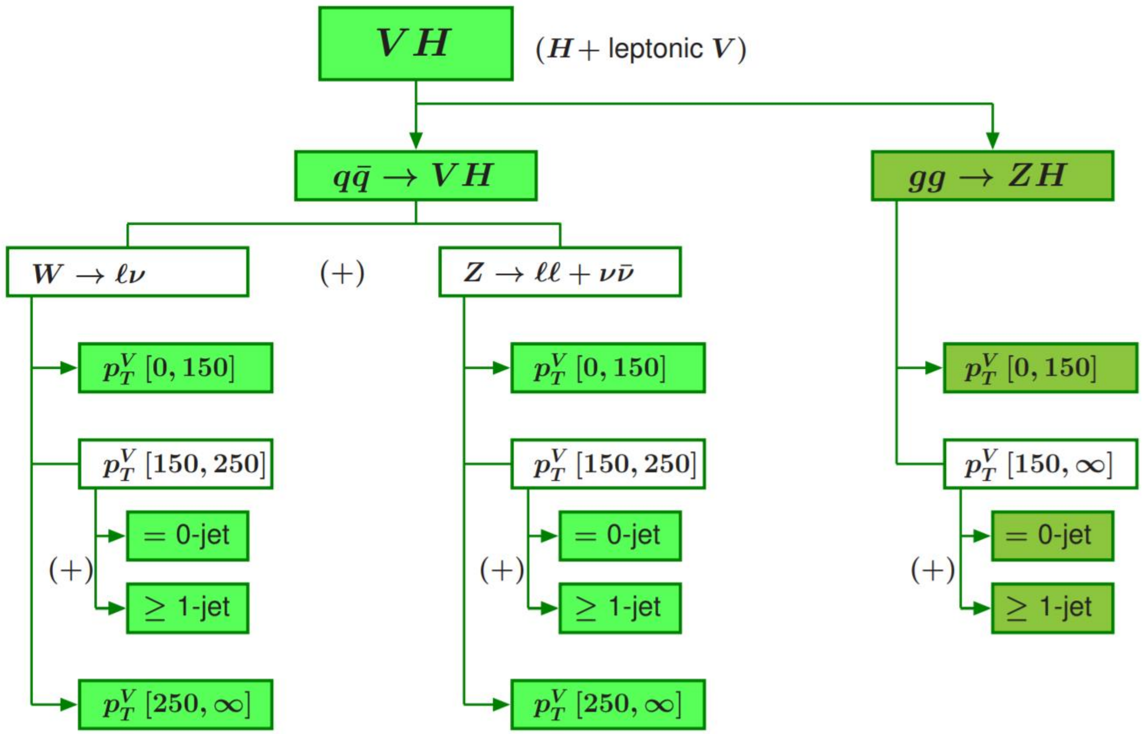
Stony Brook University
ATLAS EXPERIMENT

Introduction: STXS binning

- Stage 1: truth binning based on VH(bb) analysis categories
  - Reduce impact of theory on the measurement (no acceptance, …)



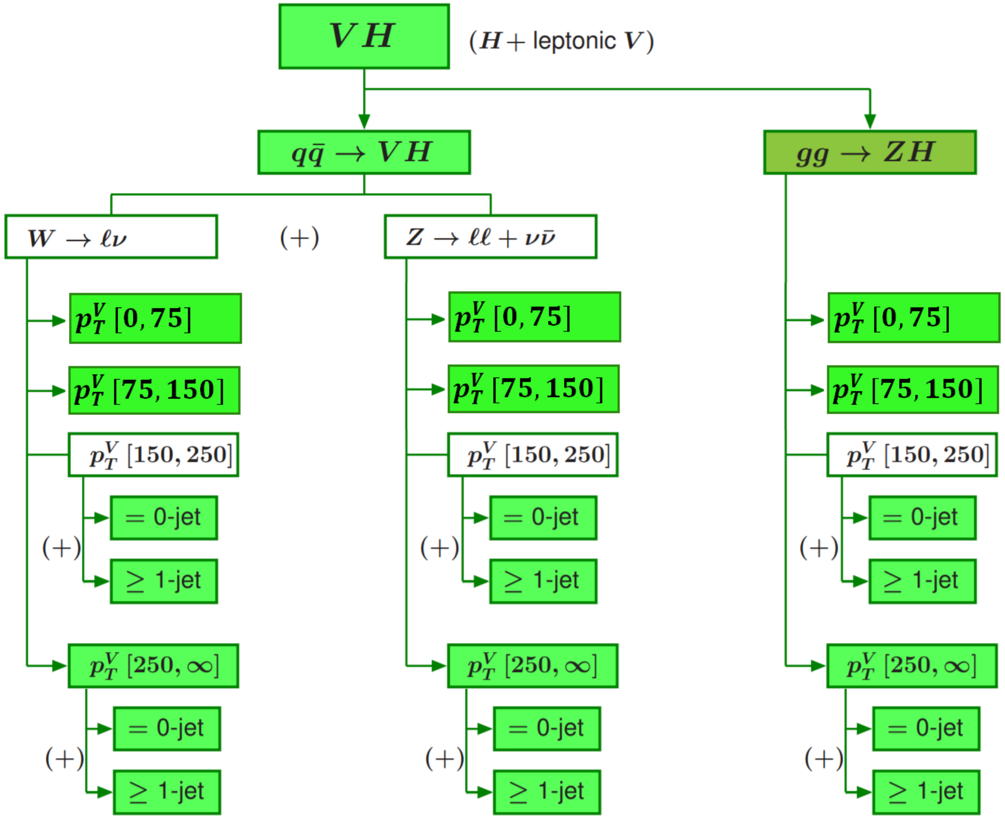
Split production mode:
→ qq/gg initiated
→ different calculations

Split with variables used for analysis categorization:
→ W/Z, $p_T(V)$, N(jets) not from Higgs

Original plan: [LHC report 4 (click me)]

Introduction: STXS binning

- Stage 1: truth binning based on VH(bb) analysis categories
  - Reduce impact of theory on the measurement (no acceptance, …)



Analysis already use finer categorization

Implement stage 1+:

→ Get closer to analysis bins

→ Left figure with split Z to ll/vv

Consider a finer "stage 1++":

→ Towards stage 2:

Split at $p_T(V)$ = 400 GeV

→ For analysis unc. estimation:

More N(add jet) bins (≥2)

N(add jet) also for low $p_T(V)$?

Goal: derive uncertainties for stage 1++ and merge where needed

3 signal uncertainty sets to discuss:

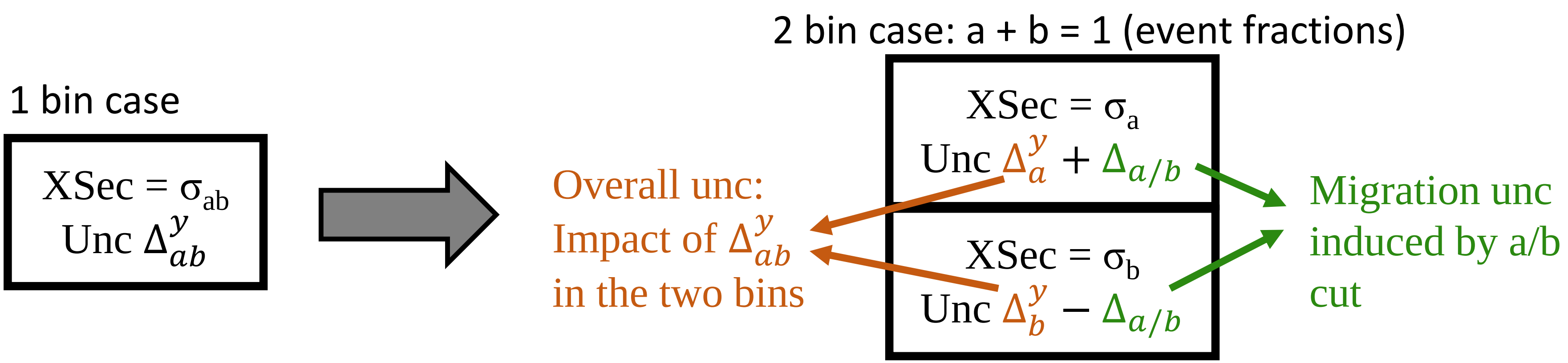
-> Scale
-> PDF
-> PS / UE

Scale Variations: The Big Guys

- Problematic: how to deal with bin migration/correlation
- 2 bins (a and b) case: the generic parametrization

Uncertainty matrix = correlated + anti-correlated components

$$C(\{\sigma_a, \sigma_b\}) = \begin{pmatrix} (\Delta^y_a)^2 & \Delta^y_a \Delta^y_b \\ \Delta^y_a \Delta^y_b & (\Delta^y_b)^2 \end{pmatrix} + \begin{pmatrix} \Delta^2_{a/b} & -\Delta^2_{a/b} \\ -\Delta^2_{a/b} & \Delta^2_{a/b} \end{pmatrix}$$



LHC report 4 (click me) for more details

Scale Variations: The Big Guys

- Parametrization in the VH(bb) stage 1 case
  - Showing WH here, in stage 1 same table for ZH (from Les Houches 2017, click me)

$q\bar{q}' \to W$	QCD uncertainties $\Delta^{y}_{\rm WH}$	$\Delta^{\rm WH}_{150}$	$\Delta^{\rm WH}_{250}$	$\Delta^{\rm WH}_{0/1}$
p_T^V [0,150]	x_1	-1	$-y$	
p_T^V [150,250]	x_2	$+1-y$	$-(1-y)$	0
$=$ 0-jet	$x_2 z$	$+(1-y)z$	$-(1-y)z$	$+1$
$\geq$ 1-jet	$x_2(1-z)$	$+(1-y)(1-z)$	$-(1-y)(1-z)$	-1
p_T^V $[250,\infty]$	x_3	y	$+1$	

$$unc_{[0,150]} = x_1\,\Delta^{y}_{WH} - \Delta^{WH}_{150} - y_2\,\Delta^{WH}_{250}$$

$$unc_{[150,250]} = x_2\,\Delta^{y}_{WH} + (1-y_1)\Delta^{WH}_{150} - y_2\,\Delta^{WH}_{250}$$

Sign: keep track of correlation
Actual unc size: squared sum

$$unc_{[250,\infty]} = x_3\,\Delta^{y}_{WH} + y_1\,\Delta^{WH}_{150} + \Delta^{WH}_{250}$$

- How to compute all parameters ?

Original proposal: $x_{[250,\infty]} = \Delta^{y}_{[250,\infty]}/\Delta^{y}$

$\Delta^{y}_{250} \sim \Delta^{y}_{[250,\infty]}$

- Over-enhancement issue:

$$unc_{[250,\infty]} = (\Delta^{y}_{250}/\Delta^{y})\,\Delta^{y} + y_1\,\Delta_{150} + \Delta_{250}$$

Can new scheme solve this ?

Parameter Calculation Proposal

- Calculating the x_i/y/z:

	Δ	$Δ_{75}$	$Δ_{150}$	$Δ_{250}$	$Δ_{150J}$	$Δ_{250J}$
0-75	$y_{[0,75]}$ / y_{Total}	-1	- $y_{[0,75]}$ / $y_{[0,150]}$	- $y_{[0,75]}$ / $y_{[0,250]}$		
75-150	$y_{[75,150]}$ / y_{Total}	$y_{[75,150]}$ / $y_{[75,\infty]}$	- $y_{[75,150]}$ / $y_{[0,150]}$	- $y_{[75,150]}$ / $y_{[0,250]}$		
150-250 0J	$y_{[150,250]+0J}$ / y_{Total}	$y_{[150,250]+0J}$ / $y_{[75,\infty]}$	$y_{[150,250]+0J}$ / $y_{[150,\infty]}$	- $y_{[150,250]+0J}$ / $y_{[0,250]}$	-1	
150-250 1J+	$y_{[150,250]+1J+}$ / y_{Total}	$y_{[150,250]+1J+}$ / $y_{[75,\infty]}$	$y_{[150,250]+1J+}$ / $y_{[150,\infty]}$	- $y_{[150,250]+1J+}$ / $y_{[0,250]}$	1	
250+ 0J	$y_{[250,\infty]+0J}$ / y_{Total}	$y_{[250,\infty]+0J}$ / $y_{[75,\infty]}$	$y_{[250,\infty]+0J}$ / $y_{[150,\infty]}$	$y_{[250,\infty]+0J}$ / $y_{[250,\infty]}$		-1
250+ 1J+	$y_{[250,\infty]+1J+}$ / y_{Total}	$y_{[250,\infty]+1J+}$ / $y_{[75,\infty]}$	$y_{[250,\infty]+1J+}$ / $y_{[150,\infty]}$	$y_{[250,\infty]+1J+}$ / $y_{[250,\infty]}$		1
Sum to	1	0	0	0	0	0

Replace:

"relative unc fraction"

$$x_{[250,\infty]} = \Delta^{y}_{[250,\infty]} / \Delta^{y}$$

"yields fractions (bin acceptance)"

$$x_{[250,\infty]} = y_{[250,\infty]} / y_{[0,\infty]}$$

In the [250, ∞[(without considering N(jet) split)

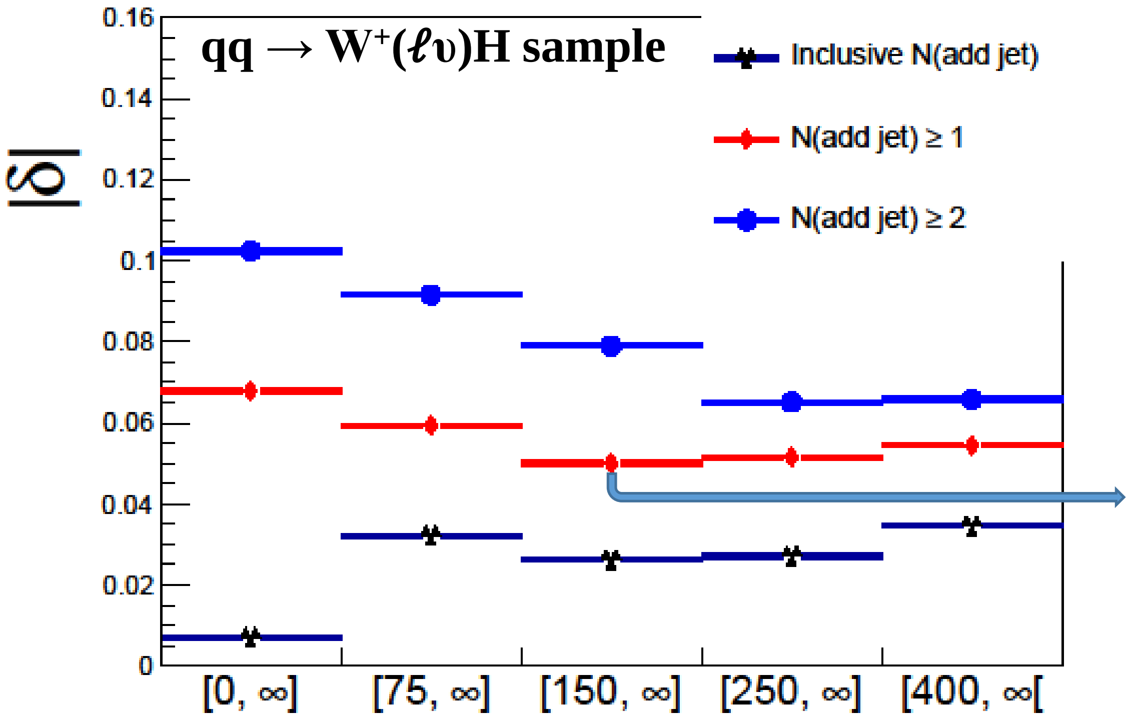
$$unc_{[250,\infty]} = \Delta * \frac{y_{[250,\infty[}}{y_{[0,\infty[}} + \Delta_{75} \frac{y_{[250,\infty[}}{y_{[75,\infty[}} + \Delta_{150} \frac{y_{[250,\infty[}}{y_{[150,\infty[}} + \Delta_{250}$$

Estimations of Δs

- Available ingredients:

→ Overall relative unc. δ from NNLO QCD cross-section in YR4

→ Relative uncertainties $\delta_{[a,b]}$ on $y_{[a,b]}$ from Powheg+MINLO with non-diagonal scale variation by a factor of 2



Read as:

For $p_T(V) > 150$ GeV (bin 3) and N(add jets) ≥ 1 (red points)

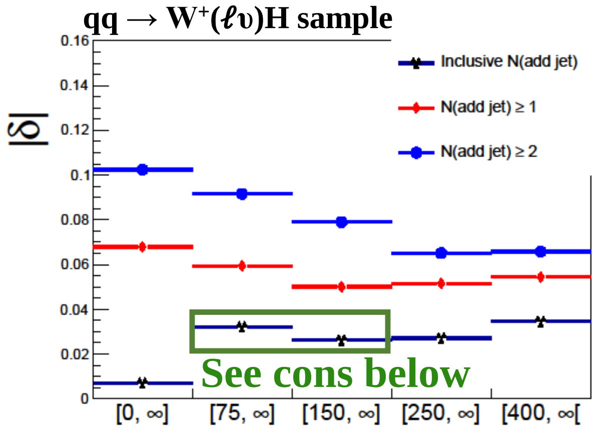
Rel unc: $\delta_{[250,\infty[\,\cup\,[1jet]} = 5.01\%$

Estimations of Δs

➢ Available ingredients:

→ Overall relative unc. δ from YR4

→ Relative uncertainties $\delta_{[a,b]}$ on $y_{[a,b]}$ from Powheg+MINLO



➢ Proposal for Δs:

→ In our same example:

$$y_{[250,\infty[} * \delta_{[250,\infty[} = \Delta * \frac{y_{[250,\infty[}}{y_{[0,\infty[}} + \Delta_{75} \frac{y_{[250,\infty[}}{y_{[75,\infty[}} + \Delta_{150} \frac{y_{[250,\infty[}}{y_{[150,\infty[}} + \Delta_{250}$$

→ When solving the equations (with approximations):

$$\Delta = y_{tot} \cdot \delta$$
$$\Delta_{75} = y_{[75,\infty[} \cdot (\delta_{[75,\infty[} \ominus \delta)$$
$$\Delta_{150} = y_{[150,\infty[} \cdot (\delta_{[150,\infty[} \ominus \delta_{[75,\infty[})$$
$$\Delta_{250} = y_{[250,\infty[} \cdot (\delta_{[250,\infty[} \ominus \delta_{[150,\infty[})$$
$$\Delta_{150J} = y_{[150,250[\,\cup\,[\geq 1 jet]} \cdot (\delta_{[150,250[\,\cup\,[\geq 1 jet]} \ominus \delta_{[150,\infty[})$$
$$\Delta_{250J} = y_{[250,\infty[\,\cup\,[\geq 1 jet]} \cdot (\delta_{[250,\infty[\,\cup\,[\geq 1 jet]} \ominus \delta_{[250,\infty[})$$

Pro

Quadrature subtraction naturally remove some double-counting

Cons

Ill defined if relative uncertainty reduce with $p_T(V)$ or N(add jet)

Δ_{150} for us

Estimations of Δs

- Frank's proposal: if ill defined use 0.5*relative variation
  - Applied also to sub-sequent Δ's
  - Also consider applying it only to ill defined Δ's
  - Which error propagation is the more correct ?

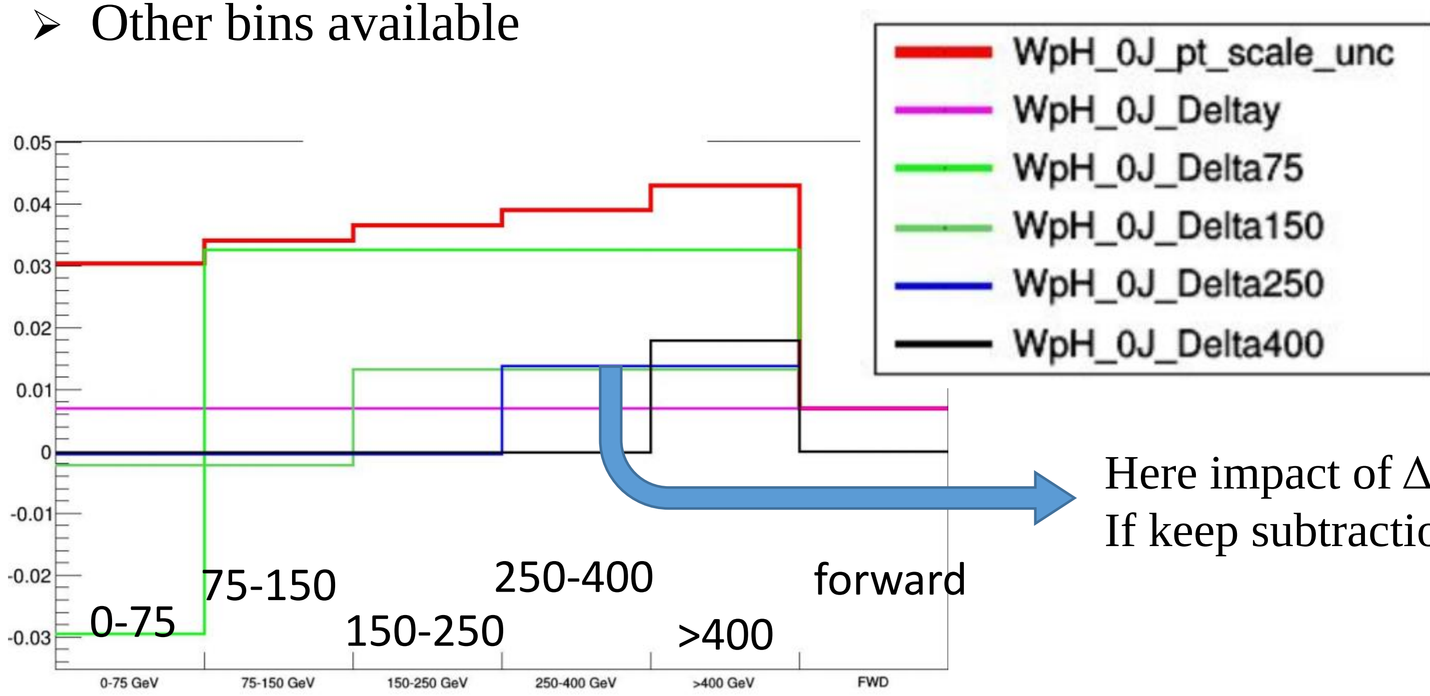
$$
\begin{aligned}
\Delta &= y_{tot} \cdot \delta \\
\Delta_{75} &= y_{[75,\infty[} \cdot (\delta_{[75,\infty[} \ominus \delta) \\
\Delta_{150} &= y_{[150,\infty[} \cdot (\delta_{[150,\infty[} \ominus \delta_{[75,\infty[}) \\
\Delta_{250} &= y_{[250,\infty[} \cdot (\delta_{[250,\infty[} \ominus \delta_{[150,\infty[}) \\
\Delta_{150J} &= y_{[150,250[\,\cup\,[\geq 1 jet]} \cdot (\delta_{[150,250[\cup\,[\geq 1 jet]} \ominus \delta_{[150,\infty[}) \\
\Delta_{250J} &= y_{[250,\infty[\,\cup\,[\geq 1 jet]} \cdot (\delta_{[250,\infty[\cup\,[\geq 1 jet]} \ominus \delta_{[250,\infty[})
\end{aligned}
$$

⇒

$$
\begin{aligned}
\Delta &= y_{tot} \cdot \delta \\
\Delta_{75} &= y_{[75,\infty[} \cdot \delta_{[75,\infty[} \\
\Delta_{150} &= y_{[150,\infty[} \cdot (0.5) \cdot \delta_{[150,\infty[} \\
\Delta_{250} &= y_{[250,\infty[} \cdot (0.5) \cdot \delta_{[250,\infty[} \\
\Delta_{150J} &= y_{[150,250[\,\cup\,[\geq 1 jet]} \cdot \delta_{[150,250[\cup\,[\geq 1 jet]} \\
\Delta_{250J} &= y_{[250,\infty[\,\cup\,[\geq 1 jet]} \cdot \delta_{[250,\infty[\cup\,[\geq 1 jet]}
\end{aligned}
$$

Result for the Δs

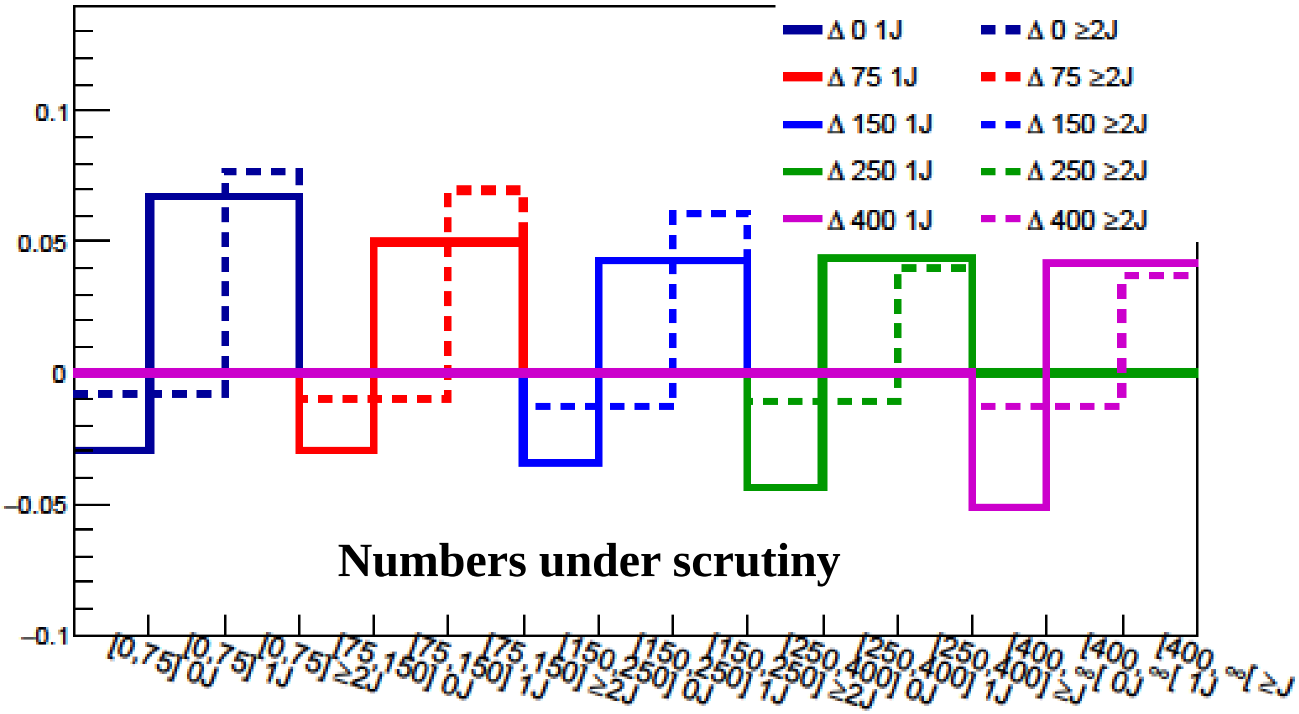
- Frank's proposal: if ill defined use 0.5*relative variation
  - Applied also to sub-sequent Δ's
- Impact of Δ's in the stage1++ bins:
  - Showing here no add jet bin for qq → W$^+$(ℓυ)H
  - Other bins available



Here impact of Δ_{250} is ~1.3%
If keep subtraction def ~0.7%

Result for the Δs

- Frank's proposal: if ill defined use 0.5*relative variation
  - Applied also to sub-sequent Δ's
- Impact of Δ's in the stage1++ bins:
  - Showing here no add jet bin for qq → $W^+(\ell\upsilon)H$
  - Other bins available

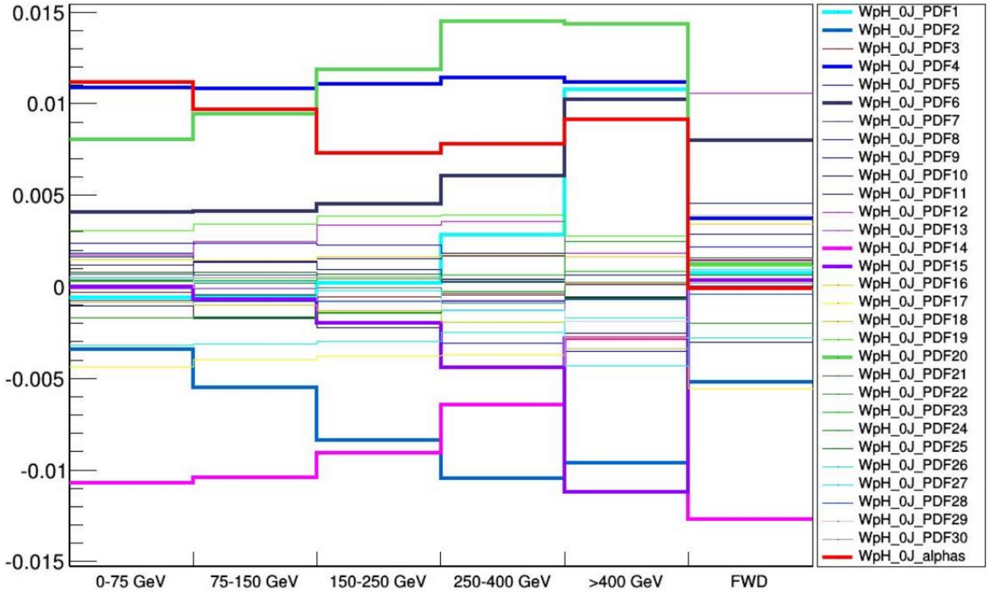


2 signal uncertainty sets left to discuss:

- ~~-> Scale~~
- -> PDF
- -> PS / UE

PDF uncertainties

- Want to use the relative PDF variation in each stage1++ bin:
  - Use PDF4LHC_nlo_30_pdfas (click me) set
  - Compute variation w.r.t first weight
  - Use yields per in each bin: $var[i] = \frac{y\_pdf[i] - y\_pdf[0]}{y\_pdf[0]} \; \forall\, i \in [1,30]$
- α_S uncertainty as average of up/down relative uncertainties on yields.



Only few variations > 0.5%

→ Can merge small variations

→ Maximum impact 1.5%

1 signal uncertainty set left to discuss:

- ~~-> Scale~~
- ~~-> PDF~~
- -> PS / UE

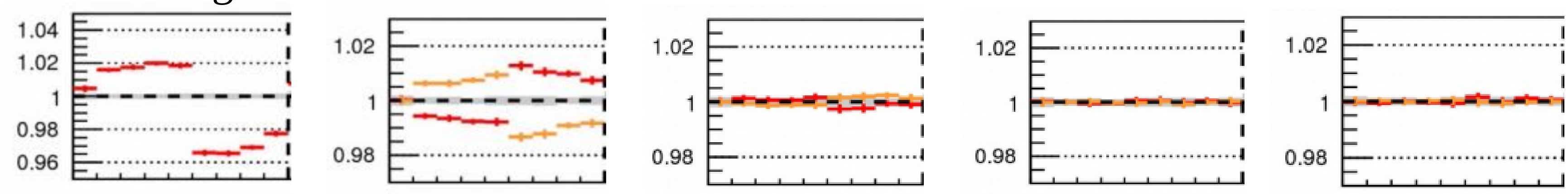
Parton Shower / UE uncertainties

- Important source of uncertainty for EPS:
  - Acceptance uncertainty
- Estimated comparing different samples across STXS bins:
  - Powheg+Pythia8 (nom), Powheg+Herwig7, MPI up/down, Ren up/down, Var1 and Var2 up/down (primordial-kT and ISR-cutoff variations).

qq → W(ℓυ)H sample

Relative variation over Powheg+Pythia8:

Herwig7 Ren MPI Var1 Var2



Binning: [foward] – [N(add jets)=0]x([0, 75] [75, 150] [150, 250] [250, ∞])
– [N(add jets)≥1]x([0, 75] [75, 150] [150, 250] [250, ∞])

Now talking of only 2-4% effects
→ Main effect on N(jets)
Note: expect bigger impact from shape/acceptance

Conclusion

Conclusion

- First implementation of the stage 1++ scale uncertainties ~ready to go:
  - Calculation based on inclusive bin acceptances (y's) and their associated relative uncertainties (δ's)
  - Still some tunable items: "δ-subtraction" and "δ*0.5"
  - Final uncertainties Δ's showing ~1 to 4% effects
- PDFs/alpha_S based on standard approach:
  - Relative uncertainties on yields following recommendations
  - Unc < 1.5% with p_T(V) and N(jet) trends.
- PS/UE uncertainties:
  - Sample differences across the STXS bins
  - ~2/4% with N(jet slope)
  - Still stage 1+ (don't expect new conclusions with 1++)

Thank you for your attention