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Jet-bin and p_T uncertainty parametrization for ggF STXS

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with input from discussions including people from ATLAS, CMS and theory

WG1 ggF subgroup meeting: uncertainties in kinematic regions

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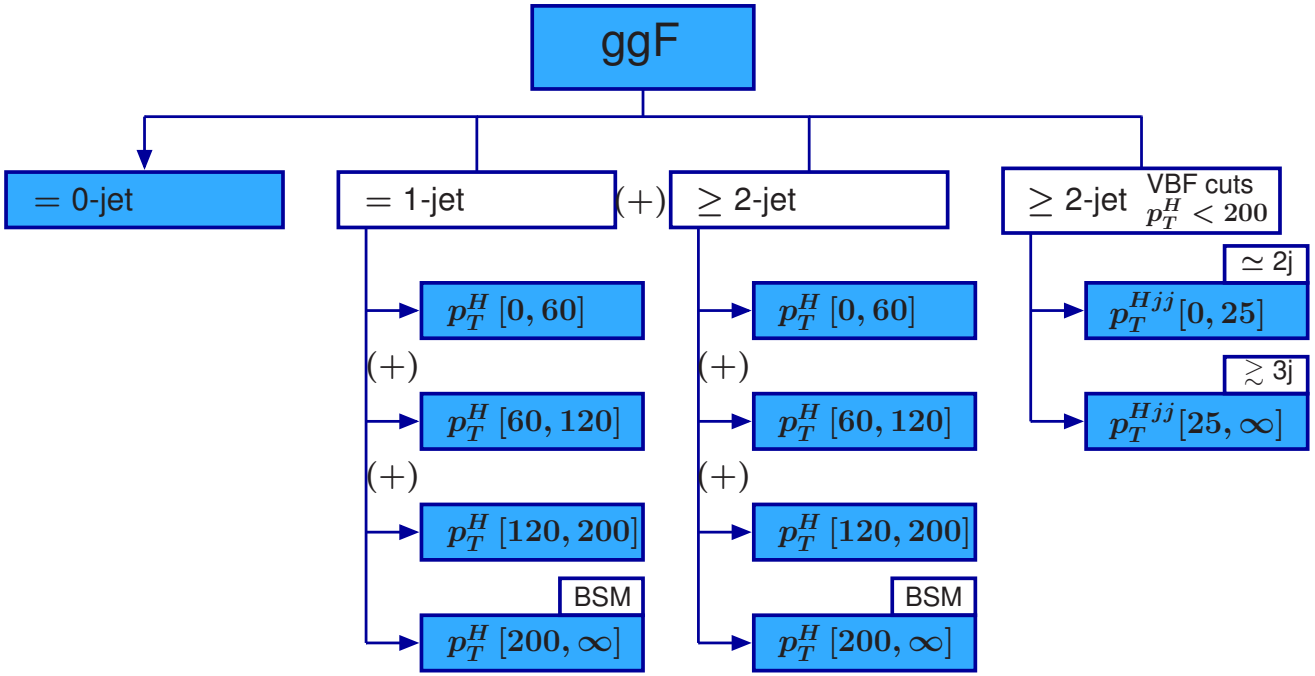
Simplified template cross sections (STXS).

- Measurement of cross sections per production mode in kinematic “bins”
- Most relevant uncertainties for ggF: jet bin uncertainties, Higgs p_T shape, ggF with VBF topology (background in VBF selection)

Two aspects to uncertainties:

- Residual theoretical uncertainties related to “unfolding” experimental event categories to STXS “bins”
- Uncertainties in interpretation of STXS



Treatment of theory uncertainties in kinematic bins.

- Implementation of uncertainties (in measurement or interpretation) requires to have uncertainties per bin, and their correlations
  - ⋆ Particularly important when binning introduces source of uncertainties that affects each bin but cancels in their sum
  - ⋆ Experimental implementation in terms of $\pm 100\%$ correlated or uncorrelated nuisance parameters

→ Identify and distinguish different sources of uncertainties and evaluate also their correlations between kinematic bins

- Possible parametrization of binning uncertainties discussed in `YR4` Section 1.4.2a and shown in `talk at November WG1 meeting`
- Discussed extensively at STXS working meeting at DESY in December 2016 with ATLAS, CMS and theory participants

  [Nicolas Berger, Kurt Brendlinger, Glen Cowan, Michael Duehrssen-Debling, Paolo Francavilla, Jim Lacey, Elisabetta Pianori, Daniel Rauch, KT, Luca Perrozzi, David Sperka, Andre David Tinoco Mendes, Emanuele Bagnaschi, Andrea Banfi, Markus Ebert, Nicolas Greiner, Stefan Kallweit, Stefan Liebler, Voica Radescu, Lorena Rothen, FT, Robert Thorne]

Multiple bin boundaries.

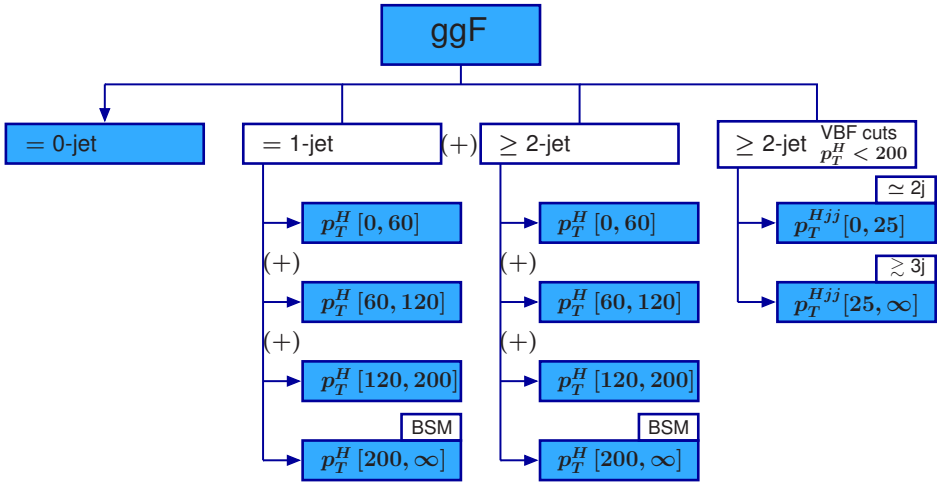
- Each bin can have multiple boundaries, and each boundary can be shared by different bins
- Consider every single bin boundary when all additional subdivisions are removed and parametrize in terms of independent yield and migration uncertainties
- Consider binning cut "a/b" with $\sigma_{ab} = \sigma_a + \sigma_b$ and associated $\Delta_{a/b}$ (anticorrelated between σ_a and σ_b)
- Allow for additional subbins such that $\sigma_a = \sum_i \sigma_a^i$ and $\sigma_b = \sum_j \sigma_b^j$
- Consider binning uncertainty as fully correlated among subbins and implement with a single nuisance parameter

$$\theta_{a/b}: \quad \Delta_{a/b} \times \{\{x_a^i\}, -\{x_b^j\}\} \qquad \text{with} \qquad \sum_i x_a^i = \sum_j x_b^j = 1$$

  where x_a^i and x_b^j specify how $\Delta_{a/b}$ gets distributed among the subbins
- Consider each binning cut/bin boundary as source of migration uncertainty

Going through the different boundaries: jet bins.

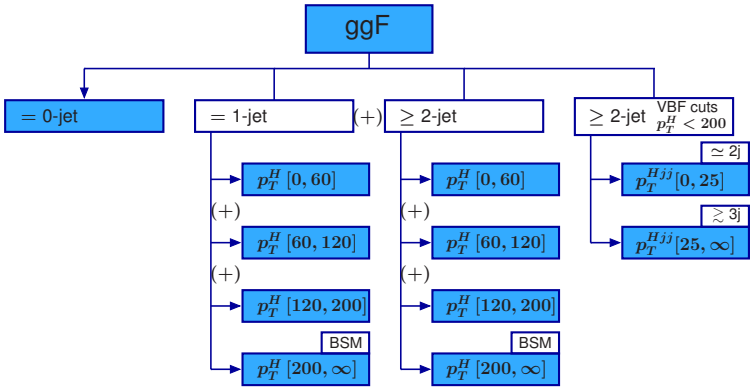
- Remove p_T bins $\rightarrow$ inclusive-in-p_T^H jet bins (=0/=1/$\geq$2)
  - $\rightarrow$ 2 migration sources, $\Delta_{0/1}$ and $\Delta_{1/2}$
- Well-known, the new question is how to evaluate the x_i to distribute the uncertainties among p_T^H bins
- One possibility is using MC to evaluate the x as proposed by `Dag's talk in November WG1 meeting`
  - ⋆ Results in flat relative uncertainty over the p_T^H bins



- Not discussing the VBF topology bins for now, which will need separate treatment

Going through the different boundaries: p_T^H.

- Remove jet bins $\rightarrow$ inclusive-in-jets p_T^H bins
- E.g. bin boundary at 60 GeV
  - ⋆ $+\Delta_{60}$ as uncertainty for $p_T^H > 60$ GeV
    - ▶ Distribute among [60,120], [120,200] (and [200,∞]) in $=$1j and $\geq$2j bins
  - ⋆ $-\Delta_{60}$ as uncertainty for $p_T^H < 60$ GeV
    - ▶ Distribute among $=$1j and $\geq$2j bins
- Additional uncertainties from jet binning within each p_T^H bin
  - ⋆ Not necessarily covered by inclusive-in-p_T^H jet bin uncertainties
  - ⋆ E.g. $+\Delta_{1/2}^{60}$ for $=$1j [60,120] and $-\Delta_{1/2}^{60}$ for $\geq$2j [60,120]
- Analogously for other p_T^H boundaries



- Perturbative series different once m_t effects important
- Treat p_T^H >200 GeV bin separately

General parametrization.

Bin	θ_y (θ_φ) Δ_y (Δ_φ)	$\theta_{0/1}$ $\Delta_{0/1}$	$\theta_{1/2}$ $\Delta_{1/2}$	θ_{60} Δ_{60}	$\theta^{60}_{1/2}$ $\Delta^{60}_{1/2}$	θ_{120} Δ_{120}	$\theta^{120}_{1/2}$ $\Delta^{120}_{1/2}$	θ_{200} Δ_{200}	$\theta^{200}_{1/2}$ $\Delta^{200}_{1/2}$
incl	$y_{\geq 0}$	0	0	0	0	0	0	1	0
$=$ 0j	y_0	-1	0	0	0	0	0	0	0
$=$ 1j	y_1	X_1	-1	$\cdots - z_1$	-1	$z_3 - \cdots$	-1	z_4	-1
$\geq$ 2j	$y_{\geq 2}$	$1 - X_1$	$+1$	$z_1 - \cdots$	$+1$	$\cdots - z_3$	$+1$	$1 - z_4$	$+1$
$\geq$ 1j [0,60]	$y_{\geq 1} x_1$	x_1	$x_1 - x'_1$	-1	0	$-x$	0		
$=$ 1j [0,60]	$y_1 x_1$	$x_1 z_1$	$-x'_1$	$-z_1$	0	$\cdots$	0		
$\geq$ 2j [0,60]	$y_{\geq 2} x_1$	$x_1(1 - z_1)$	$+x_1$	$-(1 - z_1)$	0	$\cdots$	0		
$\geq$ 1j [60,120]	$y_{\geq 1} x_2$	x_2	$x_2 - x'_2$	$+(1 - x)$	0	$-(1 - x)$	0		
$=$ 1j [60,120]	$y_1 x_2$	$x_2 z_2$	$-x'_2$	$\cdots$	-1	$-z_2$	0		
$\geq$ 2j [60,120]	$y_{\geq 2} x_2$	$x_2(1 - z_2)$	$+x_2$	$\cdots$	$+1$	$-(1 - z_2)$	0		
$\geq$ 1j [120,200]	$y_{\geq 1} x_3$	x_3	$x_3 - x'_3$	$+x$	0	$+1$	0		
$=$ 1j [120,200]	$y_1 x_3$	$x_3 z_3$	$-x'_3$	$\cdots$	0	$\cdots$	-1		
$\geq$ 2j [120,200]	$y_{\geq 2} x_3$	$x_3(1 - z_3)$	x_3	$\cdots$	0	$\cdots$	$+1$		
$\geq$ 1j [200,∞)	$y_{\geq 1} x_4$	x_4	$x_4 - x'_4$					1	0
$=$ 1j [200,∞)	$y_1 x_4$	$x_4 z_4$	$-x'_4$					z_4	-1
$\geq$ 2j [200,∞)	$y_{\geq 2} x_4$	$x_4(1 - z_4)$	x_4					$1 - z_4$	$+1$

Comments, summary and outlook.

Comments on the table

- The x_i and z_i in each column are in principle different, just wanted to avoid cluttering the notation
- Always $\sum_i x_i = 1$

- This is the minimal set of NP needed to capture jet- and p_T-binning related uncertainties for ggF STXS
- Next needed step: evaluate uncertainties and x
  - ⋆ Everything orange could come e.g. from resummed jet bins with x_i from Dag (note that $y_{\geq 1} = y_1 + y_{\geq 2}$)
  - ⋆ It would make sense to identify Δ_{200} with finite-m_t uncertainties (and then perhaps set $x_4 = 0$)

→ Dag's talk in this meeting

- Additional sources for independent nuisance parameters to be taken into account: VBF topology-related uncertainties, PDFs, EW, $y_t y_b$ contributions
  - ⋆ Also discussed in December, but for another day