STXS Status Report

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Cross Sections vs. Direct Interpretations.

Fully fiducial cross sections

✓ Allow for maximal theory and model independence

✗ Requires sacrificing sensitivity

- Measurements must use “simple” cuts (e.g. no MVAs)
- Must design measurements to be agnostic about production modes
  (If experimental efficiencies depend on production mode, efficiency corrections introduce dependence on assumed SM production mode mix)

Direct interpretation (Run 1 μ fits, direct κ or EFT fits)

✓ Maximum possible sensitivity by using advanced analysis techniques

✗ Theory predictions and *uncertainties* are fully folded into the measurements

- Any nontrivial theory changes require new results from experiments

Simplified Template Cross Sections

⇒ Try to have the best of both worlds: Maintain sensitivity while reducing theory dependence

Defining Properties.

Cross sections in truth regions defined in terms of production mode and kinematic regions

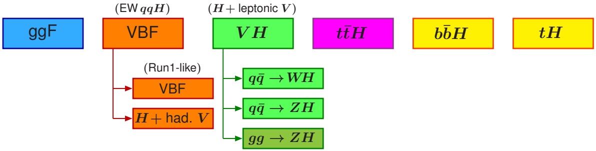
- Allow complex, optimal experimental selections by allowing for some acceptance corrections and extrapolations
- Use simple truth definitions abstracted from measurement categories
  - Avoid large or unnecessary extrapolations or theory dependences in the measurement
- SM processes act as kinematic templates
  - Only assume SM behaviour inside each bin and production mode, but not between different bins and production modes.
  - If this becomes limitation, further split bins and/or add additional templates (e.g. CP-odd Higgs)

Designed for combination of all Higgs decay channels

- Non-Higgs backgrounds are subtracted
- Inclusive over the Higgs decays (only cut on Higgs rapidity)
- Common object definitions

Stages.

- Stage 0: Split by production mode (restricted to $|Y_H| < 2.5$)
  - Replaces Run1-like μ measurements



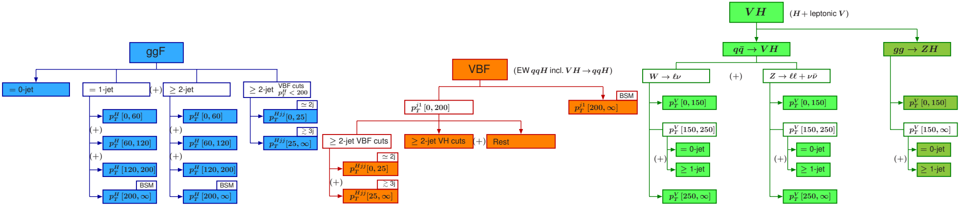
(EW qqH)
($H+$ leptonic V)

ggF
VBF
VH
$t\bar{t}H$
$b\bar{b}H$
tH

(Run1-like)
VBF
$H+$ had. V

$q\bar{q}\to WH$
$q\bar{q}\to ZH$
$gg\to ZH$

- Stage 1: Split modes into dominant kinematic regions
  - Most (if not all) regions accessible with full Run 2 dataset



ggF
$=$ 0-jet
$=$ 1-jet
(+)
$\geq$ 2-jet
$\geq$ 2-jet VBF cuts $p_T^H < 200$
p_T^H $[0, 60]$
(+)
p_T^H $[60, 120]$
(+)
p_T^H $[120, 200]$
BSM
p_T^H $[200, \infty]$
$\simeq$ 2j
p_T^{Hjj} $[0, 25]$
$\gtrsim$ 3j
p_T^{Hjj} $[25, \infty]$

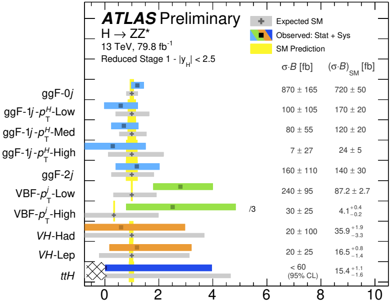
VBF
(EW qqH incl. $VH\to qqH$)
p_T^{j1} $[0, 200]$
BSM
p_T^{j1} $[200, \infty]$
$\geq$ 2-jet VBF cuts
$\geq$ 2-jet VH cuts
(+)
Rest
$\simeq$ 2j
p_T^{Hjj} $[0, 25]$
(+)
$\gtrsim$ 3j
p_T^{Hjj} $[25, \infty]$

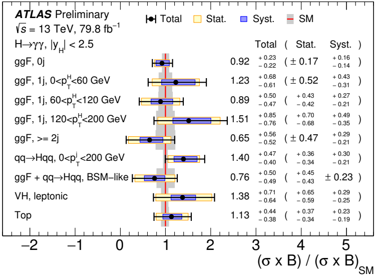
VH
($H+$ leptonic V)
$q\bar{q}\to VH$
$gg\to ZH$
$W\to\ell\nu$
(+)
$Z\to\ell\ell+\nu\bar{\nu}$
p_T^V $[0, 150]$
p_T^V $[150, 250]$
$=$ 0-jet
(+)
$\geq$ 1-jet
p_T^V $[250, \infty]$
p_T^V $[0, 150]$
p_T^V $[150, \infty]$
$=$ 0-jet
(+)
$\geq$ 1-jet

- With real-life experience, considering several changes: revised Stage 1.1 ($\to$ see later)

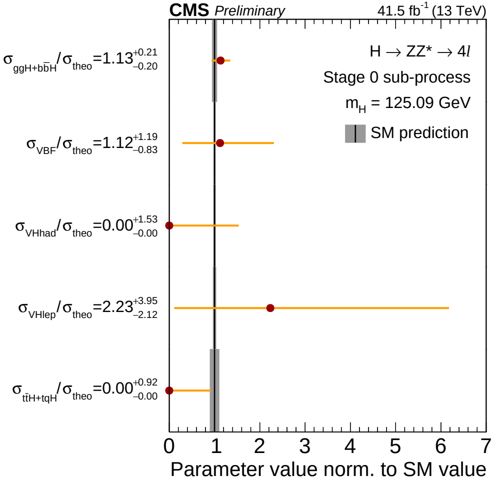
Updated Measurements with 2017 data.

$H \to ZZ^*$ and $\gamma\gamma$ (80 fb^{-1})





$H \to ZZ^*$ (41 fb^{-1})



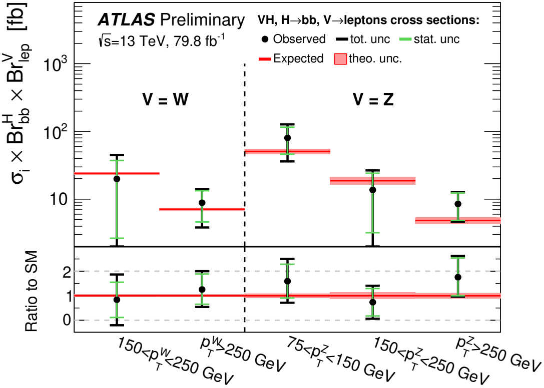
[CMS-PAS-HIG-18-001]

[ATLAS-CONF-2018-018, ATLAS-CONF-2018-028]

First Measurements in $H \to b\bar{b}$ and $H \to \tau\tau$.

$H \to b\bar{b}$ (80 fb^{-1})

[ATLAS-CONF-2018-053]



$H \to \tau\tau$ (36 fb^{-1}) [ATLAS arXiv:1811.08856]

Process	Particle-level selection	σ [pb]	σ^{SM} [pb]
ggF	$N_{\mathrm{jets}} \geq 1,\ 60 < p_T^H < 120\,\mathrm{GeV},\ \lvert y_H \rvert < 2.5$	$1.79 \pm 0.53\,(\mathrm{stat.}) \pm 0.74\,(\mathrm{syst.})$	0.40 ± 0.05
ggF	$N_{\mathrm{jets}} \geq 1,\ p_T^H > 120\,\mathrm{GeV},\ \lvert y_H \rvert < 2.5$	$0.12 \pm 0.05\,(\mathrm{stat.}) \pm 0.05\,(\mathrm{syst.})$	0.14 ± 0.03
VBF	$\lvert y_H \rvert < 2.5$	$0.25 \pm 0.08\,(\mathrm{stat.}) \pm 0.08\,(\mathrm{syst.})$	0.22 ± 0.01

STXS Uncertainty Framework.

There are two aspects to theory uncertainties

- (Perturbative) uncertainties on SM predictions for each bin
  - Directly enter in interpretation step
  - Also enter in measurement step whenever two bins are merged
  - → Also requires correlating theory uncertainties between measurement and interpretation
  - → Need a consistent and coherent treatment of theory uncertainties including correlations across kinematic regions and production modes
- Residual theory uncertainties due to shape inside a bin
  - Evaluated via PS/UE uncertainties, MC scale variations, PDF uncertainties

New in Stage 1.1

- Extend bin definitions with dedicated subbins for theory uncertainties
  - Can use the same bin uncertainty methods to explicitly probe and account for dominant residual uncertainties
  - Allows for smoother binning evolution

STXS Uncertainty Framework.

Requirements

- Consistency under bin merging and splitting
  - Single (*yield*) uncertainty for each production mode or bin is insufficient (e.g. simple scale-variation uncertainty per bin or production mode is not enough)
  - Essential to account for (anti)correlation effects between bins (*migrations*) so cut-induced uncertainties properly cancel when bins are added/combined
- Parametrize/implement in terms of mutually independent (uncorrelatd) nuisance parameters (NPs)
  - Identify/define uncorrelated theory uncertainty sources and associate them with corresponding nuisance parameter θ_i
- Need to evaluate a separate impact $\Delta_{b,i}$ of each nuisance parameter (source) θ_i for each bin b
  - Quite nontrivial, have to make some assumptions/choices
- Flexibel/general enough to allow switching theory inputs and utilizing future improved predictions

Uncertainties With Multiple Bin Boundaries.

Each bin can have multiple boundaries, and each boundary can be shared by different bins

- Consider each bin boundary as potential source of uncertainty 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 $\sigma_a = \sum_i \sigma_{ai}$ and $\sigma_b = \sum_j \sigma_{bj}$
  - Consider binning uncertainty anticorrelated (migration) between σ_a and σ_b, fully correlated (yield) among subbins

$$\theta_{a/b}: \quad \Delta_{a/b} \times \big\{\{x_{ai}\}, -\{x_{bj}\}\big\} \qquad \text{with} \qquad \sum_i x_{ai} = \sum_j x_{bj} = 1$$

  - x_{ai} and x_{bj} specify how $\Delta_{a/b}$ gets distributed among the subbins
  - Limiting case: Global yield uncertainty for total cross section

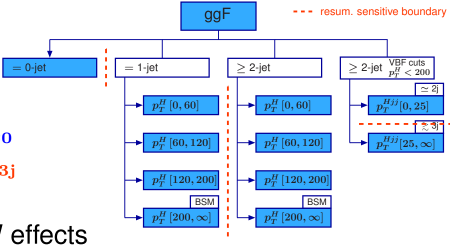
In the following: Application to VH and VBF

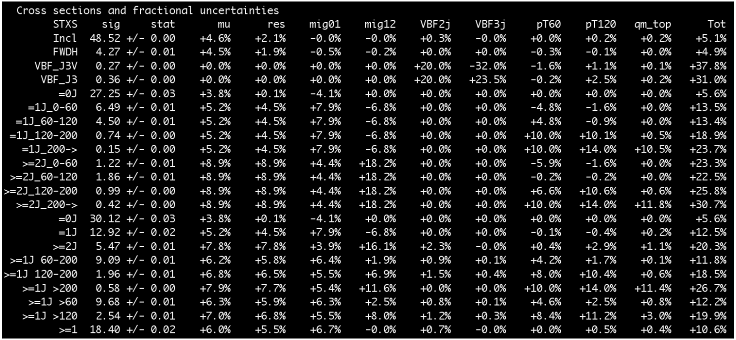
- Based on initial proposal (using Stage 1 bins) in LH2017 [arXiv:1803.07977]

Recap: Approach Is Already Used for ggF.

Current scheme (`see here` for details)

- 9 NPs for QCD uncertainties:
  - 2 yield: θ_μ, $\theta_{\rm res}$
  - 4 migration across jet bin and p_T^H boundaries: $\theta_{0/1}$, $\theta_{1/2}$, θ_{60}, θ_{120}
  - 2 for VBF-like region: $\theta_{\rm VBF2j}$, $\theta_{\rm VBF3j}$
  - 1 high-p_T/finite-m_t effects: θ_t
- Still missing: m_b, $y_t y_b$, y_b^2 (bbH), EW effects





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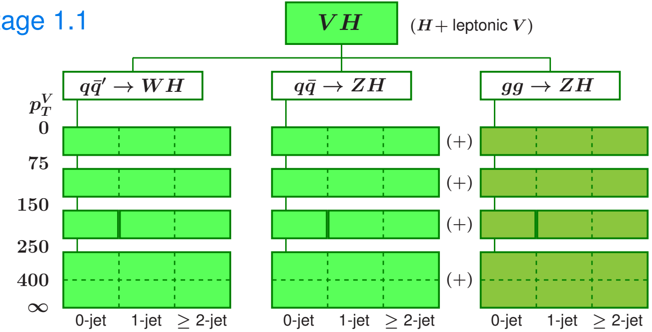
  Cross sections and fractional uncertainties
          STXS     sig      stat        mu       res     mig01     mig12    VBF2j    VBF3j     pT60     pT120   qm_top     Tot
          Incl  48.52 +/- 0.00     +4.6%     +2.1%     -0.0%     -0.0%    +0.3%    -0.0%    +0.0%    +0.2%    +0.2%    +5.1%
          FWDH   4.27 +/- 0.01     +4.5%     +1.9%     -0.5%     -0.2%    +0.0%    +0.0%    -0.3%    -0.1%    +0.0%    +4.9%
       VBF_J3V   0.27 +/- 0.00     +0.0%     +0.0%     +0.0%     +0.0%   +20.0%   -32.0%    -1.6%    +1.1%    +0.1%   +37.8%
        VBF_J3   0.36 +/- 0.00     +0.0%     +0.0%     +0.0%     +0.0%   +20.0%   +23.5%    -0.2%    +2.5%    +0.2%   +31.0%
           =0J  27.25 +/- 0.03     +3.8%     +0.1%     -4.1%     +0.0%    +0.0%    +0.0%    +0.0%    +0.0%    +0.0%    +5.6%
      =1J_0-60   6.49 +/- 0.01     +5.2%     +4.5%     +7.9%     -6.8%    +0.0%    +0.0%    -4.8%    -1.6%    +0.0%   +13.5%
    =1J_60-120   4.50 +/- 0.01     +5.2%     +4.5%     +7.9%     -6.8%    +0.0%    +0.0%    +4.8%    -0.9%    +0.0%   +13.4%
   =1J_120-200   0.74 +/- 0.00     +5.2%     +4.5%     +7.9%     -6.8%    +0.0%    +0.0%   +10.0%   +10.1%    +0.5%   +18.9%
     =1J_200->   0.15 +/- 0.00     +5.2%     +4.5%     +7.9%     -6.8%    +0.0%    +0.0%   +10.0%   +14.0%   +10.5%   +23.7%
     >=2J_0-60   1.22 +/- 0.01     +8.9%     +8.9%     +4.4%    +18.2%    +0.0%    +0.0%    -5.9%    -1.6%    +0.0%   +23.3%
   >=2J_60-120   1.86 +/- 0.01     +8.9%     +8.9%     +4.4%    +18.2%    +0.0%    +0.0%    -0.2%    -0.2%    +0.0%   +22.5%
  >=2J_120-200   0.99 +/- 0.00     +8.9%     +8.9%     +4.4%    +18.2%    +0.0%    +0.0%    +6.6%   +10.6%    +0.6%   +25.8%
    >=2J_200->   0.42 +/- 0.00     +8.9%     +8.9%     +4.4%    +18.2%    +0.0%    +0.0%   +10.0%   +14.0%   +11.8%   +30.7%
           =0J  30.12 +/- 0.03     +3.8%     +0.1%     -4.1%     +0.0%    +0.0%    +0.0%    +0.0%    +0.0%    +0.0%    +5.6%
           =1J  12.92 +/- 0.02     +5.2%     +4.5%     +7.9%     -6.8%    +0.0%    +0.0%    -0.1%    -0.4%    +0.2%   +12.5%
          >=2J   5.47 +/- 0.01     +7.8%     +7.8%     +3.9%    +16.1%    +2.3%    -0.0%    +0.4%    +2.9%    +1.1%   +20.3%
    >=1J 60-200   9.09 +/- 0.01     +6.2%     +5.8%     +6.4%     +1.9%    +0.9%    +0.1%    +4.2%    +1.7%    +0.1%   +11.8%
   >=1J 120-200   1.96 +/- 0.01     +6.8%     +6.5%     +5.5%     +6.9%    +1.5%    +0.4%    +8.0%   +10.4%    +0.6%   +18.5%
     >=1J >200   0.58 +/- 0.00     +7.9%     +7.7%     +5.4%    +11.6%    +0.0%    +0.0%   +10.0%   +14.0%   +11.4%   +26.7%
      >=1J >60   9.68 +/- 0.01     +6.3%     +5.9%     +6.3%     +2.5%    +0.8%    +0.1%    +4.6%    +2.5%    +0.8%   +12.2%
     >=1J >120   2.54 +/- 0.01     +7.0%     +6.8%     +5.5%     +8.0%    +1.2%    +0.3%    +8.4%   +11.2%    +3.0%   +19.9%
          >=1  18.40 +/- 0.02     +6.0%     +5.5%     +6.7%     -0.0%    +0.7%    -0.0%    +0.0%    +0.5%    +0.4%   +10.6%
```

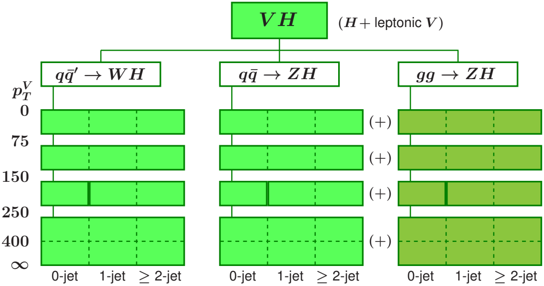
VH Stage 1.1.

Revised Stage 1.1



- Split $p_T^V [0, 150] \to [0, 75], [75, 150]$
- Mimic $gg \to ZH$ bins with $q\bar{q} \to ZH$, so they can be merged bin-by-bin
  - Likely to remain merged for a while
- Add dashed subbin boundaries for theory uncertainties
  - Add boundary at $p_T^V = 400$
  - Add 0/1-jet and 1/2-jet boundaries everywhere

VH Uncertainties.



Current scheme

- QCD uncertainties: 7 sources/NPs
  - 1 overall yield: $\theta^{\mathrm{y}}_{\mathrm{VH}}$
  - p_T^V migrations: θ_{75}, θ_{150}, θ_{250}, θ_{400}
  - jet-bin migrations: $\theta_{0/1}$, $\theta_{1/2}$
- Same NPs for $q\bar{q}' \to WH$ and $q\bar{q} \to ZH$
  - i.e., they are fully correlated, which is okay at present level
- Independent set of NPs for $gg \to ZH$
  - i.e., uncorrelated from $q\bar{q} \to ZH$
  - In principle should be correlated with ggF (especially jet bins)
- EW uncertainties: to be done
  - Could imagine 3 sources: Sudakov and hard effects: θ_{Sud}, $\theta^{\mathrm{WH}}_{\mathrm{hard}}$, $\theta^{\mathrm{ZH}}_{\mathrm{hard}}$

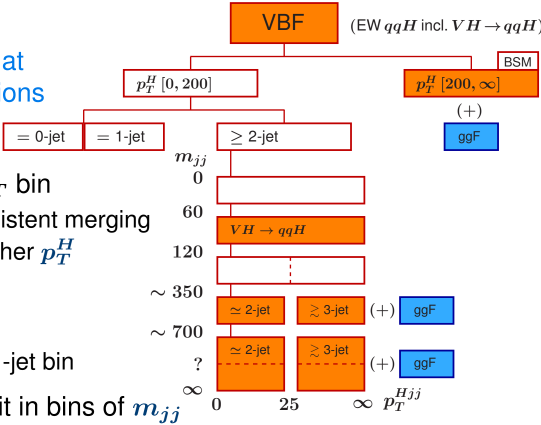
Parametrization of VH Uncertainties.

<table>
<tr><th></th><th colspan="3">[0,75]</th><th colspan="3">[75, 150]</th><th colspan="3">[150,250]</th><th colspan="3">[250,400]</th><th colspan="3">[400,∞]</th></tr>
<tr><th></th><th>0-jet</th><th>1-jet</th><th>2-jet</th><th>0-jet</th><th>1-jet</th><th>2-jet</th><th>0-jet</th><th>1-jet</th><th>2-jet</th><th>0-jet</th><th>1-jet</th><th>2-jet</th><th>0-jet</th><th>1-jet</th><th>2-jet</th></tr>
<tr><td>$\theta^{\mathrm{y}}_{\mathrm{VH}}$</td><td colspan="15">$+$</td></tr>
<tr><td>θ_{75}</td><td colspan="3">$-$</td><td colspan="12">$+$</td></tr>
<tr><td>θ_{150}</td><td colspan="6">$-$</td><td colspan="9">$+$</td></tr>
<tr><td>θ_{250}</td><td colspan="9">$-$</td><td colspan="6">$+$</td></tr>
<tr><td>θ_{400}</td><td colspan="12">$-$</td><td colspan="3">$+$</td></tr>
<tr><td>$\theta_{0/1}$</td><td>$-$</td><td>$+$</td><td></td><td>$-$</td><td>$+$</td><td></td><td>$-$</td><td>$+$</td><td></td><td>$-$</td><td>$+$</td><td></td><td>$-$</td><td>$+$</td><td></td></tr>
<tr><td>$\theta_{1/2}$</td><td></td><td>$-$</td><td>$+$</td><td></td><td>$-$</td><td>$+$</td><td></td><td>$-$</td><td>$+$</td><td></td><td>$-$</td><td>$+$</td><td></td><td>$-$</td><td>$+$</td></tr>
</table>

- For now p_T^V migrations are independent of jet bins and vice versa
- In principle various options/choices for how to evaluate impacts (Δ_i) and also for how to distribute them among subbins (x_{ij})
  - → See next talk by Thomas Calvet for details of current estimation using available scale variations

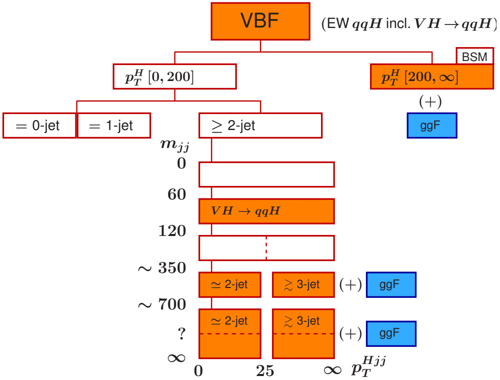
VBF Stage 1.1.

Practical experience has shown that VBF needs more substantial revisions



- Change $p_T^{j1} \to p_T^H$ in high-p_T bin
  - Align with ggF to allow consistent merging
  - Allow for further splits at higher p_T^H
- Split out 0,1-jet bins
  - Unlikely to be measureable, but there is some hope for 1-jet bin
- For remaining $\geq$ 2-jet bin, split in bins of m_{jj}
  - No additional cut on $\Delta\eta_{jj}$
  - Allow theory uncertainty treatment based on thinking about m_{jj} spectrum (analogous to p_T^V spectrum in VH)
- Possible QCD uncertainty sources/NPs
  - 1 overall yield ($\theta^{\mathrm{y}}_{\mathrm{VBF}}$) and p_T^H migration (θ_{200})
  - m_{jj} migrations: θ_{60}, θ_{120}, θ_{350}, θ_{700}, $\theta_{?}$, and p_T^{Hjj} migrations: θ_{25}

VBF m_{jj} Binning.



VBF (EW qqH incl. $VH \to qqH$)

BSM

p_T^H $[0, 200]$

p_T^H $[200, \infty]$

$(+)$

ggF

$= 0$-jet

$= 1$-jet

≥ 2-jet

m_{jj}

0

60

$VH \to qqH$

120

~ 350

$\simeq 2$-jet

$\gtrsim 3$-jet

$(+)$ ggF

~ 700

$\simeq 2$-jet

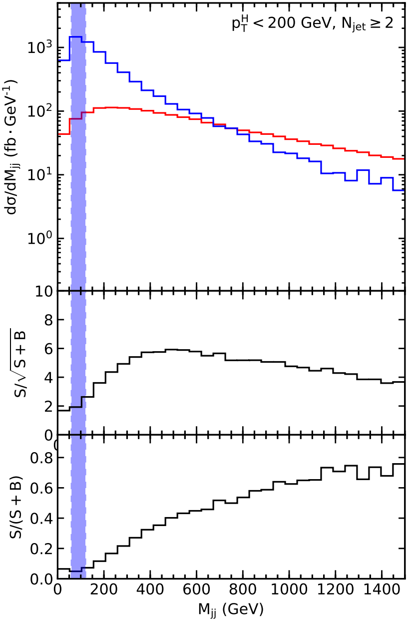
$\gtrsim 3$-jet

?

$(+)$ ggF

∞

0 25 ∞ p_T^{Hjj}

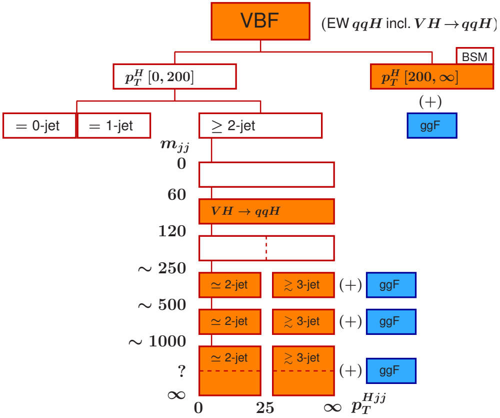


Main question is to decide on m_{jj} bins

- Sensitivity in m_{jj} varies a lot between different analyses
  - Need at least two splits
  - Different options considered

→ To be discussed tomorrow morning

VBF m_{jj} Binning.



VBF

(EW qqH incl. $VH \to qqH$)

BSM

p_T^H [0, 200]

p_T^H [200, ∞]

(+)

ggF

= 0-jet

= 1-jet

≥ 2-jet

m_{jj}

0

60

$VH \to qqH$

120

∼ 250

≃ 2-jet

≳ 3-jet

(+)

ggF

∼ 500

≃ 2-jet

≳ 3-jet

(+)

ggF

∼ 1000

≃ 2-jet

≳ 3-jet

?

(+)

ggF

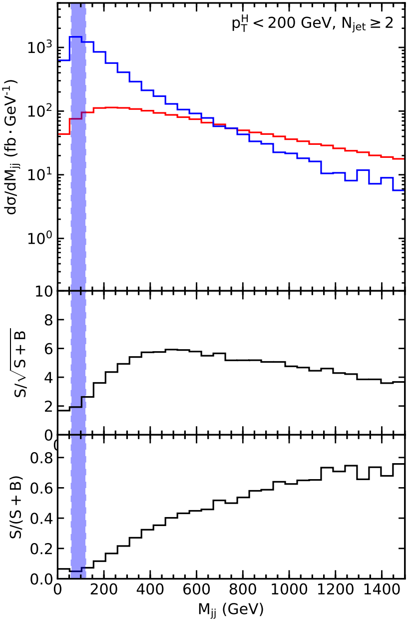
∞

0

25

∞

p_T^{Hjj}



Main question is to decide on m_{jj} bins

- Sensitivity in m_{jj} varies a lot between different analyses
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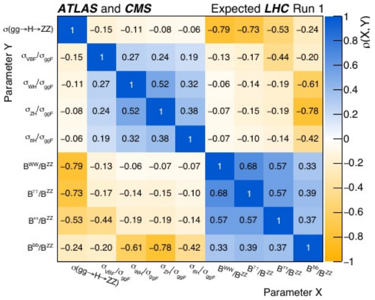
Presentation of Experimental Results.

Higgs couplings results from ATLAS, CMS and CMS+ATLAS include generic models

→ Intended to be recast into specific models

→ Provided information:

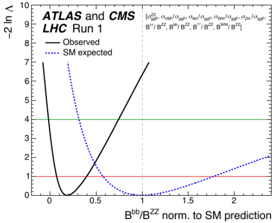
- Central values of parameters of interest
- Uncertainties
- Correlation matrix



	$\sigma(gg\to H\to ZZ)$	$\sigma_{VBF}/\sigma_{ggF}$	σ_{WH}/σ_{ggF}	σ_{ZH}/σ_{ggF}	$\sigma_{ttH}/\sigma_{ggF}$	B^{WW}/B^{ZZ}	$B^{\gamma\gamma}/B^{ZZ}$	$B^{\tau\tau}/B^{ZZ}$	B^{bb}/B^{ZZ}
$\sigma(gg\to H\to ZZ)$	1	−0.15	−0.11	−0.08	−0.06	−0.79	−0.73	−0.53	−0.24
$\sigma_{VBF}/\sigma_{ggF}$	−0.15	1	0.27	0.24	0.19	−0.13	−0.17	−0.44	−0.20
σ_{WH}/σ_{ggF}	−0.11	0.27	1	0.52	0.32	−0.06	−0.14	−0.19	−0.61
σ_{ZH}/σ_{ggF}	−0.08	0.24	0.52	1	0.38	−0.07	−0.15	−0.19	−0.78
$\sigma_{ttH}/\sigma_{ggF}$	−0.06	0.19	0.32	0.38	1	−0.07	−0.10	−0.14	−0.42
B^{WW}/B^{ZZ}	−0.79	−0.13	−0.06	−0.07	−0.07	1	0.68	0.57	0.33
$B^{\gamma\gamma}/B^{ZZ}$	−0.73	−0.17	−0.14	−0.15	−0.10	0.68	1	0.57	0.39
$B^{\tau\tau}/B^{ZZ}$	−0.53	−0.44	−0.19	−0.19	−0.14	0.57	0.57	1	0.37
B^{bb}/B^{ZZ}	−0.24	−0.20	−0.61	−0.78	−0.42	0.33	0.39	0.37	1

→ Allows accurate recasting if:

- Likelihood is quasi-Gaussian
- No correlations between measurement and recasting uncertainties (e.g theory systematics)



Neither fully true in practice, can we improve ?

Taylor Expansion of $-2\log L$.

[see **Andrew's talk** for details]

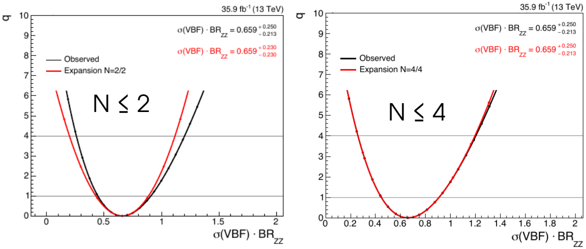
Expand -2 log L in powers of x – x̂ (x̂ = best fit value)

$$T(x_1,\ldots,x_d)=\sum_{n_1=0}^{\infty}\cdots\sum_{n_d=0}^{\infty}\frac{(x_1-a_1)^{n_1}\cdots(x_d-a_d)^{n_d}}{n_1!\cdots n_d!}\left(\frac{\partial^{n_1+\cdots+n_d}f}{\partial x_1^{n_1}\cdots\partial x_d^{n_d}}\right)(a_1,\ldots,a_d)$$

N=2 term gives the usual covariance matrix, consider adding N= 3, 4 as well

Use finite-difference formulas to compute HO derivatives, need careful choice of step size → using larger values (~2σ range) seems to lead to stable results.

Seems to work quite well!



However gets expensive CPU-wise: ~150k evaluations of L for N=4.

(results much worse when not including cross-terms)

Correlating Theory Uncertainties.

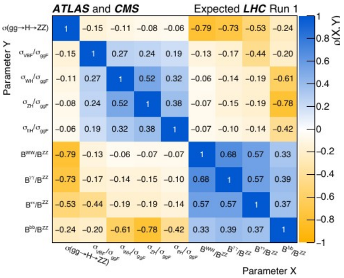
Uncertainties + correlations include all systematics – the corresponding nuisance parameters are profiled away

⇒ Includes theory systematics in particular : cannot correlate measurement uncertainties and those at the recasting stage

⇒ Typically leads to underestimated uncertainties (add in quadrature whereas they should add linearly)

→ Can solve this by reporting the measured values of the (leading) theory uncertainty NPs together with those of the POIs

→ Larger set of results cov matrix of si $(n_{\mathrm{PoIs}} + n_{\mathrm{NPs}})^2$ instead of just n_{PoIs}^2



Parameter Y	$\sigma(gg\to H\to ZZ)$	$\sigma_{VBF}/\sigma_{ggF}$	σ_{WH}/σ_{ggF}	σ_{ZH}/σ_{ggF}	$\sigma_{ttH}/\sigma_{ggF}$	B^{WW}/B^{ZZ}	$B^{\gamma\gamma}/B^{ZZ}$	$B^{\tau\tau}/B^{ZZ}$	B^{bb}/B^{ZZ}
$\sigma(gg\to H\to ZZ)$	1	−0.15	−0.11	−0.08	−0.06	−0.79	−0.73	−0.53	−0.24
$\sigma_{VBF}/\sigma_{ggF}$	−0.15	1	0.27	0.24	0.19	−0.13	−0.17	−0.44	−0.20
σ_{WH}/σ_{ggF}	−0.11	0.27	1	0.52	0.32	−0.06	−0.14	−0.19	−0.61
σ_{ZH}/σ_{ggF}	−0.08	0.24	0.52	1	0.38	−0.07	−0.15	−0.19	−0.78
$\sigma_{ttH}/\sigma_{ggF}$	−0.06	0.19	0.32	0.38	1	−0.07	−0.10	−0.14	−0.42
B^{WW}/B^{ZZ}	−0.79	−0.13	−0.06	−0.07	−0.07	1	0.68	0.57	0.33
$B^{\gamma\gamma}/B^{ZZ}$	−0.73	−0.17	−0.14	−0.15	−0.10	0.68	1	0.57	0.39
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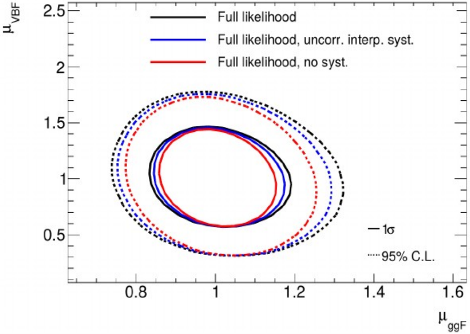

Summary and Outlook.

- Finalizing Stage 1.1 (name to be decided ...)
  - Target are full Run 2 measurements
- STXS theory uncertainty framework
  - Finalizing VH and VBF
  - Need to revisit ggF in context of Stage 1.1
- Longterm goal is to provide a reference framework for STXS reinterpretations that can be used by experiments as well as theorists
- Ongoing discussions on how to best present experimental results
  - Also in more general context of Higgs combination group, but directly relevant for STXS

Discussion Session Tomorrow Morning

- Stage 1.1 binning, with main focus on revised VBF binning
- Incorporation of final-state decay information into STXS

Backup Slides

Bin Merging.

Different decay channels have different sensitivities

- Allow for each analysis to merge bins as appropriate
  - Possible and likely merges are indicated by (+) in diagrams
- Maximal split can be achieved in combination of all channels
  - But in principle requires all analyses to implement and evaluate systematic uncertainties (acceptances) for all bins, even if most get merged later

2 bins or not 2 bins (aka to merge or not to merge)

✓ Two bins have similar acceptance

- Bins can be split in the combination (unbiased, only some loss in sensitivity)

✗ Two bins have different acceptance

- Do not merge bins if at all possible, otherwise combine and assign uncertainty in measurement

✗ BSM-sensitive ("overflow") bins

- keep separate if at all possible, even limits are useful and interesting

⇒ If in doubt, provide results at different granularity
(to satisfy both "split-if-you-can" and "merge-if-you-can" voices)

Simple Toy Example.

Consider a simple scenario: $\sigma_{ab} = \sigma_a + \sigma_b$

$$N_i^{\rm meas} = A_{i,a} \times \sigma_a \qquad\qquad + A_{i,b} \times \sigma_b$$

$N_i^{\rm meas}$: observed yields in analysis categories

σ_a, σ_b, σ_{ab}: measured cross sections (POI)

A_i: SM acceptances times efficiencies

- $A_{i,a}$ and $A_{i,b}$ introduce “residual” theory dependence
  - Try to align categories and cross sections $i = 1 \approx a$, $i = 2 \approx b$ so A is roughly diagonal (minimize unfolding corrections)

Simple Toy Example.

Consider a simple scenario: $\sigma_{ab} = \sigma_a + \sigma_b$

$$N_i^{\mathrm{meas}} = A_{i,a} \times \sigma_a \qquad + A_{i,b} \times \sigma_b$$

$\downarrow$ merge σ_a and σ_b

$$\begin{aligned} N_i^{\mathrm{meas}} &= A_{i,a} \times \frac{\sigma_a^{\mathrm{SM}}}{\sigma_{ab}^{\mathrm{SM}}} \times \sigma_{ab} + A_{i,b} \times \frac{\sigma_b^{\mathrm{SM}}}{\sigma_{ab}^{\mathrm{SM}}} \times \sigma_{ab} \\ &= A_{i,ab} \times \sigma_{ab} \end{aligned}$$

N_i^{meas}: observed yields in analysis categories

σ_a, σ_b, σ_{ab}: measured cross sections (POI)

A_i: SM acceptances times efficiencies

- $A_{i,a}$ and $A_{i,b}$ introduce "residual" theory dependence
  - Try to align categories and cross sections $i = 1 \approx a$, $i = 2 \approx b$ so A is roughly diagonal (minimize unfolding corrections)
- Combining σ_a and σ_b introduces explicit dependence on $\sigma_a^{\mathrm{SM}}/\sigma_b^{\mathrm{SM}}$
  - Conversely, splitting σ_{ab} removes it
  - a and b can be kinematic regions or different production modes