Recent ATLAS results from the Edinburgh group

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on behalf of the group

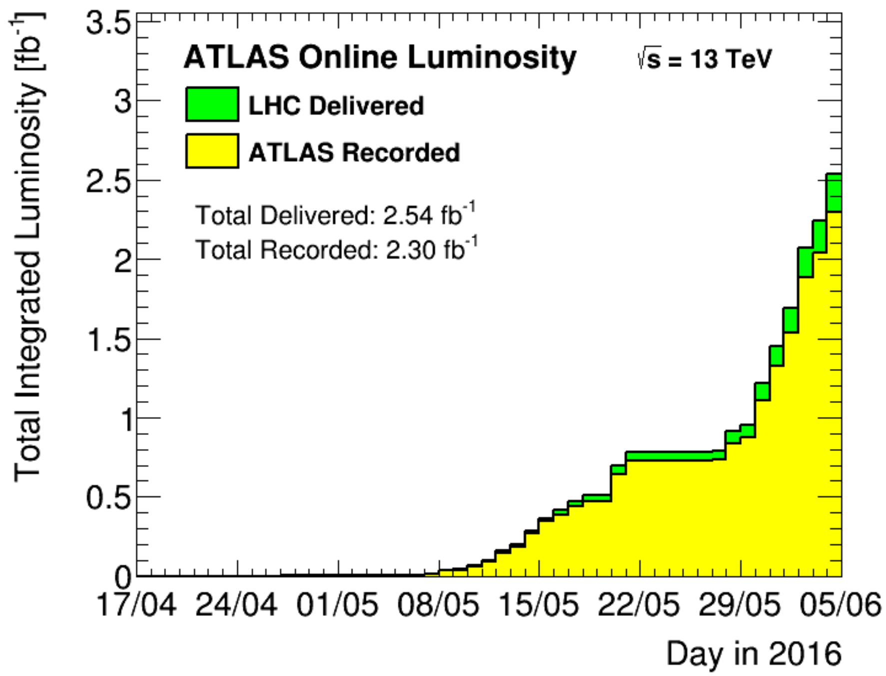
(with particular thanks to Flavia for the diboson slides!)

Edinburgh All-PPE meeting

6 June 2016

Introduction

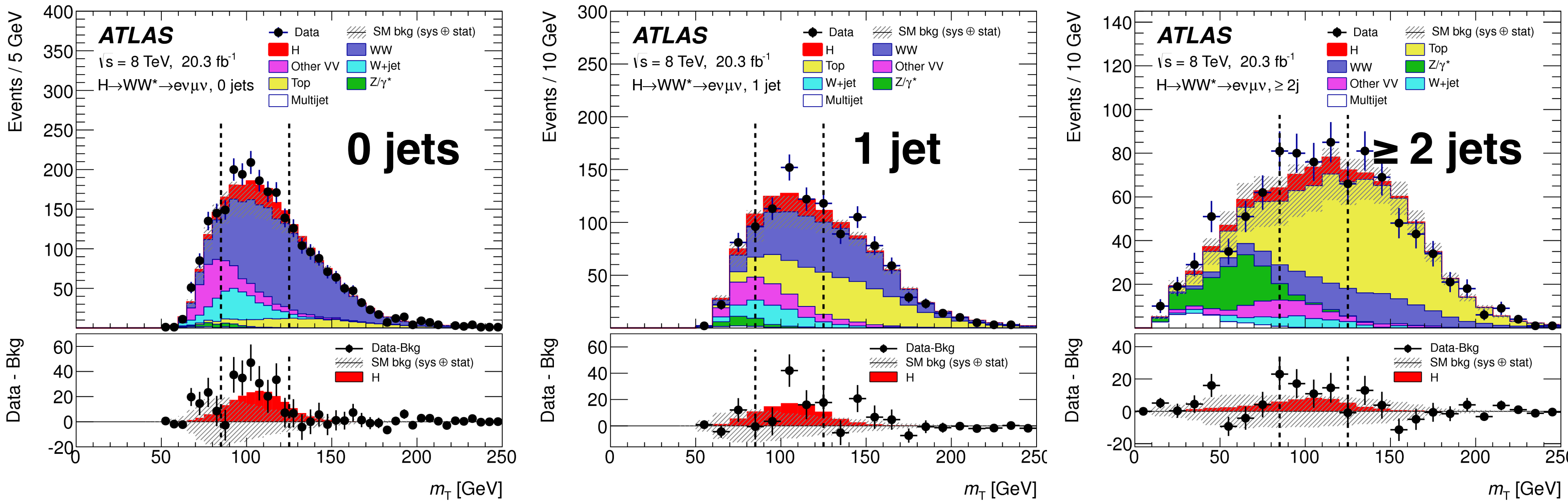
- Year of transition for the ATLAS Edinburgh group
  → *Run 1 winding down, first Run 2 data analysis*
- Run 1: Full exploration of Higgs data
  → *H → WW differential cross section*
- Run 2: Search for new phenomena
  → *Diboson resonance search*



H $\rightarrow$ WW differential

H → WW differential

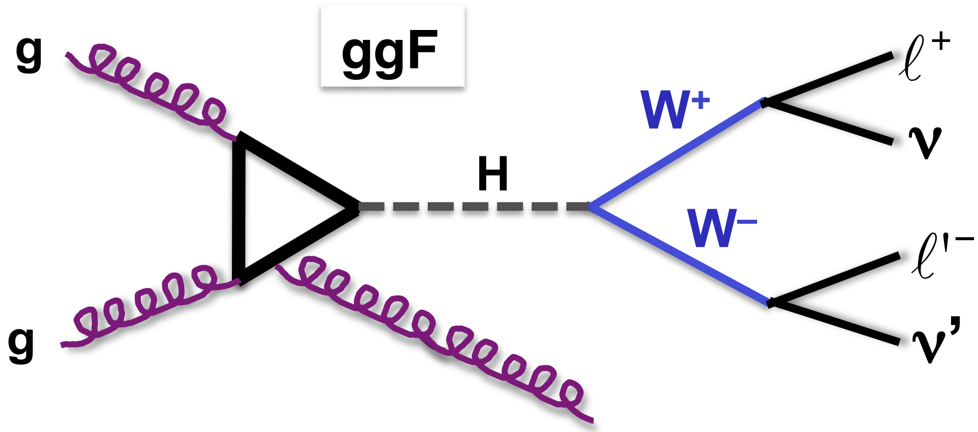
- Build off of the Run 1 “legacy” analysis
  - → *Object & event selection, background estimates, systematics*
- Three signal regions targeting ggF production



- Optimized cut on event discriminant, the transverse mass M_T

H → WW differential

- Answer questions about the behavior of QCD



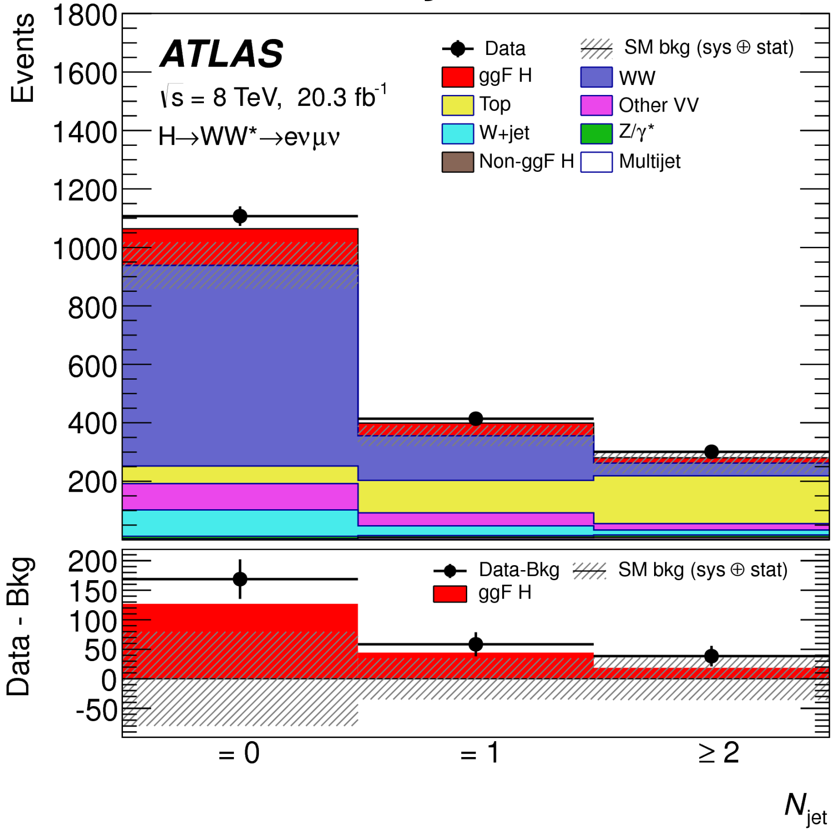
- What is the transverse momentum (p_T) of the Higgs boson?

- What is the rapidity of the two-lepton system?

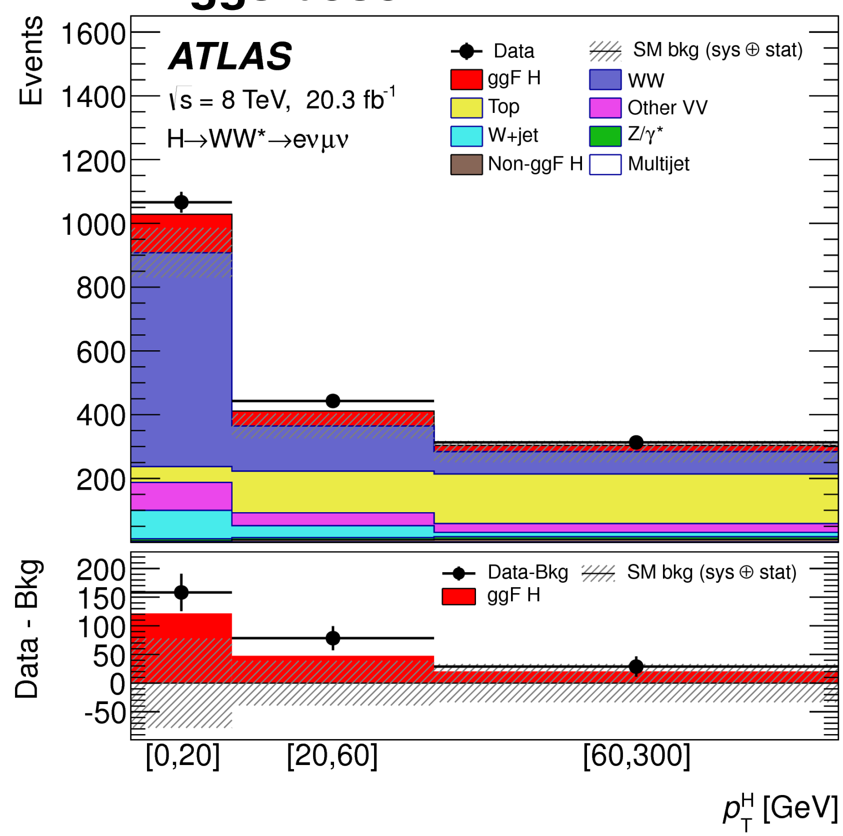
- How many jets are produced in these events?
- What is the transverse momentum (p_T) of the leading jet?
- How often is there *no* reconstructed jet?

The data

Number of jets



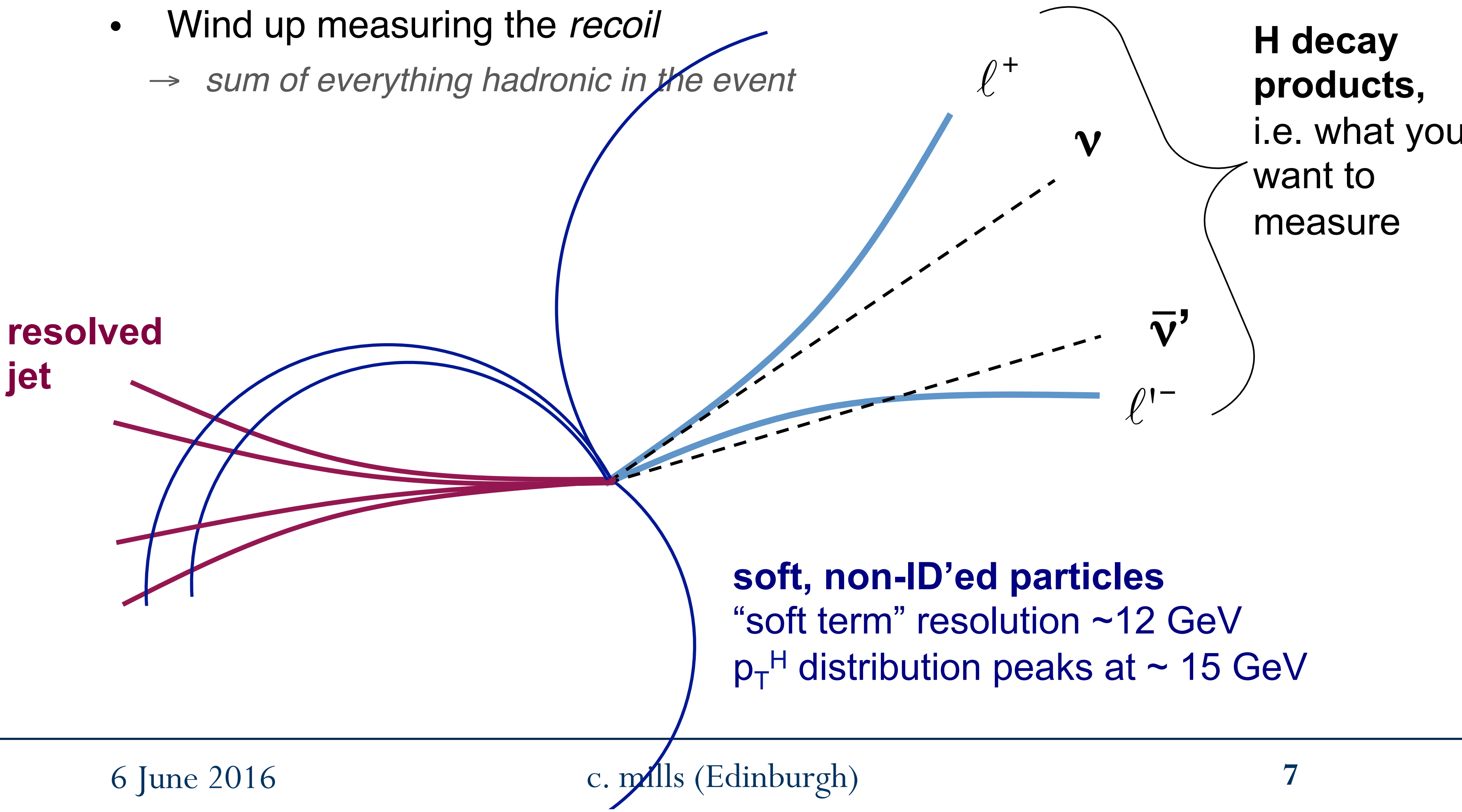
Transverse momentum of the Higgs boson



- Summed over the three signal regions
- Estimate signal yield = data – background in each bin

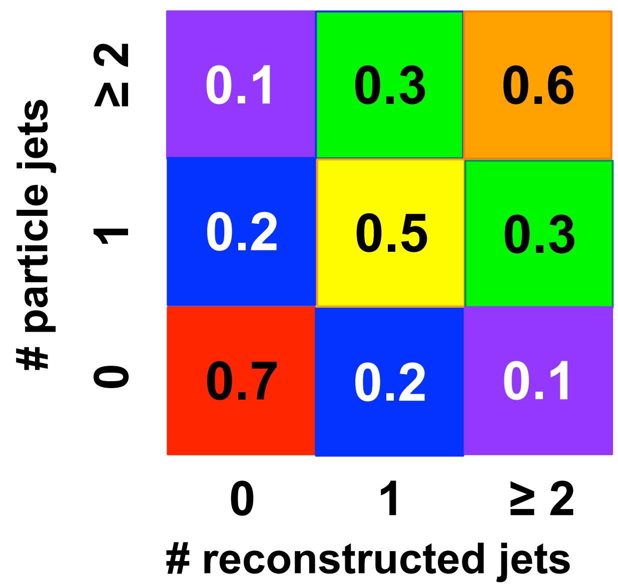
Reconstruction and Resolution

- p_T of the H = vector sum of neutrino + charged lepton p_T
- Neutrinos: missing transverse energy – vector opposite of all other momenta in the event, including leptons
- Wind up measuring the *recoil*
  - → *sum of everything hadronic in the event*



Unfolding detector effects

- Response matrix from signal MC connects reco <-> truth
  - → *"truth" is defined using stable particles (hadrons, leptons)*
- Large migrations between Njet categories, bins in $p_T(H)$
- Cartoon example: jet multiplicity
  - → *Each column a probability distribution*

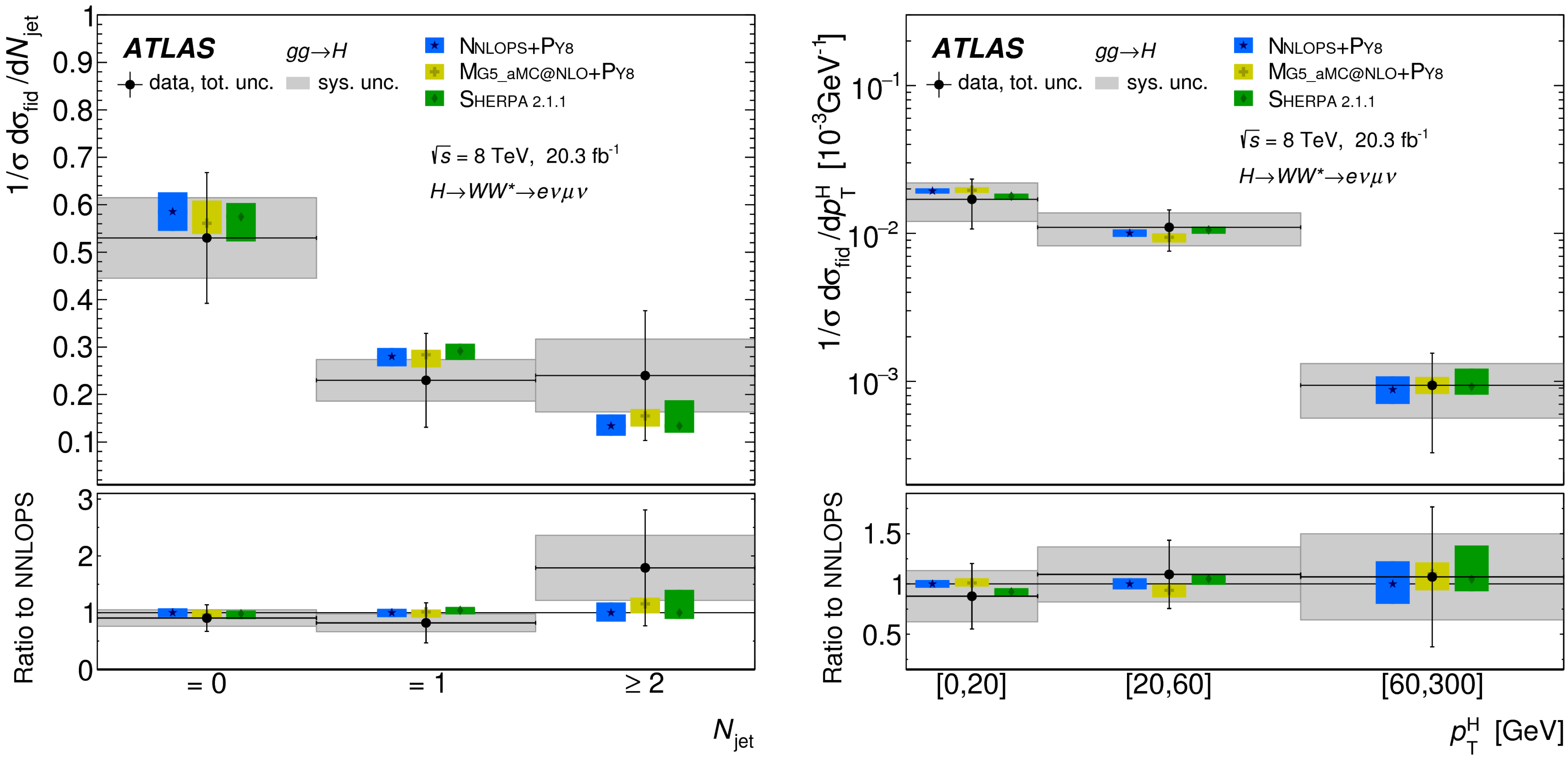


- Bayesian iterative unfolding
- Iterations remove bias from prior but inflate stat. uncertainty
- Two-dimensional unfolding accounts for correlation between Njet, $p_T(H)$

Njet and $p_T(H)$

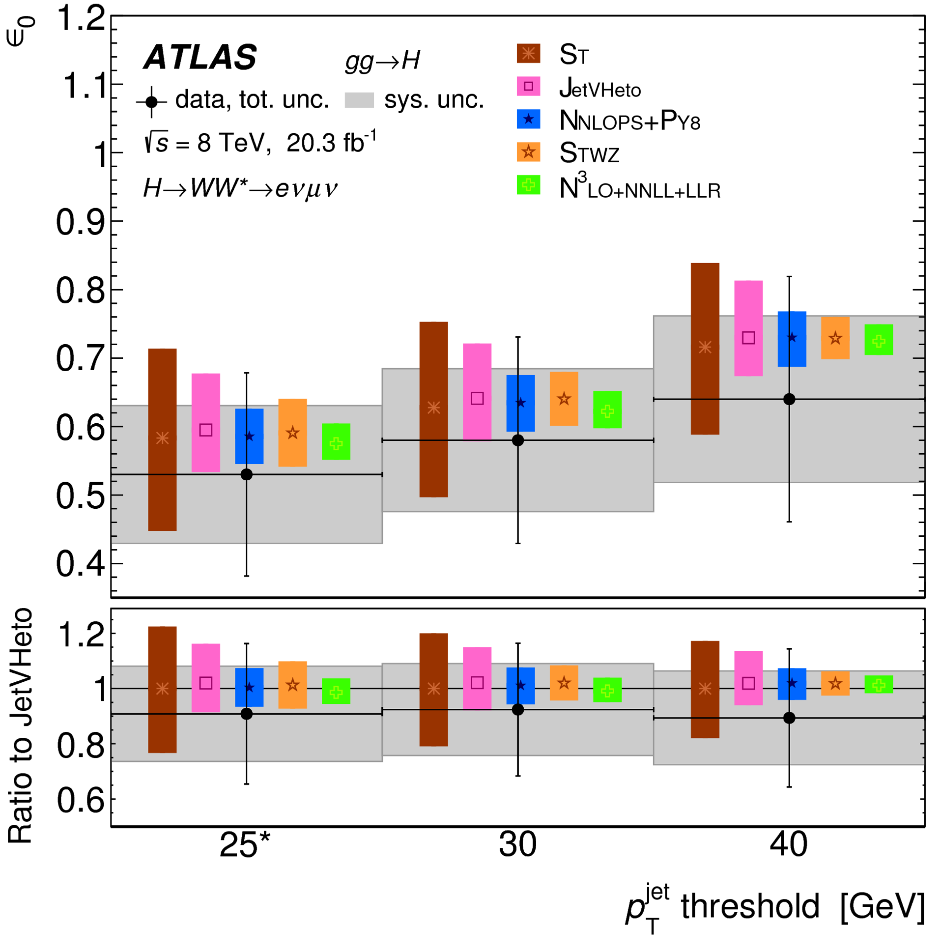
Normalized to unit integral

Compared to NLO MC with Pythia8 parton shower



Jet veto efficiency

Probability to have no reconstructed jets in the event as a function of the p_T threshold applied



ST = most conservative (but widely accepted) Stewart-Tackmann approach, NNLO

JetVHeto = includes resummation calculation to account for softer parton radiation

25 GeV* indicates 30 GeV threshold for $2.5 < |\eta| < 4.5$

→ analysis cuts

Results

- Measured fiducial cross section:

$$\sigma_{\text{ggF}}^{\text{fid}} = 36.0 \pm 7.2\,(\text{stat}) \pm 6.4\,(\text{sys}) \pm 1.0\,(\text{lumi})\ \text{fb}$$

→ *Dominant uncertainties are statistical (20%), WW background theory model (14%)*

→ *Both can improve, WW background will be challenging (requires improvement in parton-shower tuning and matching with matrix-element calculations in concert with analysis optimization)*

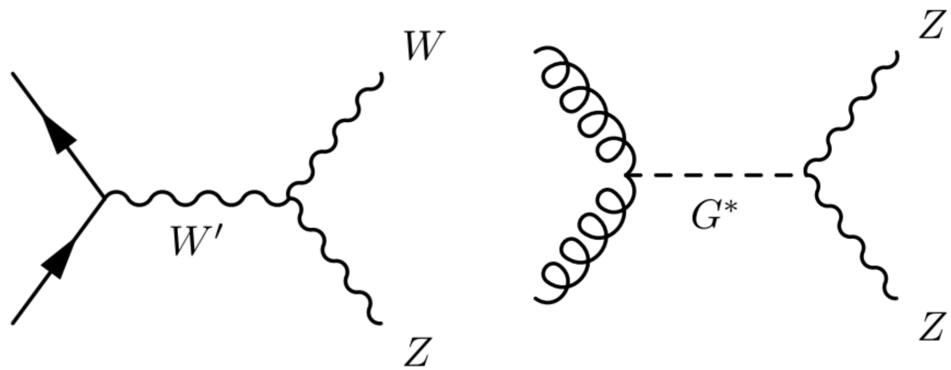
- NNLO+NNLL from Higgs XS WG:

$$\sigma_{\text{ggF}}^{\text{fid}} = 25.1\ ^{+1.8}_{-2.0}\,(\text{scale})\ ^{+1.9}_{-1.7}\ (\text{PDF})\ \text{fb}$$

analysis lead by Edinburgh + Oxford (Paul, CM, Victoria from EDI)

Diboson searches

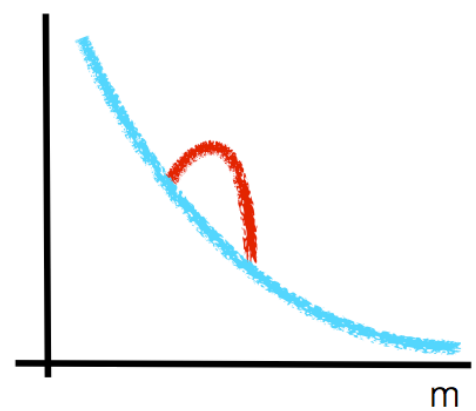
Diboson Searches Overview



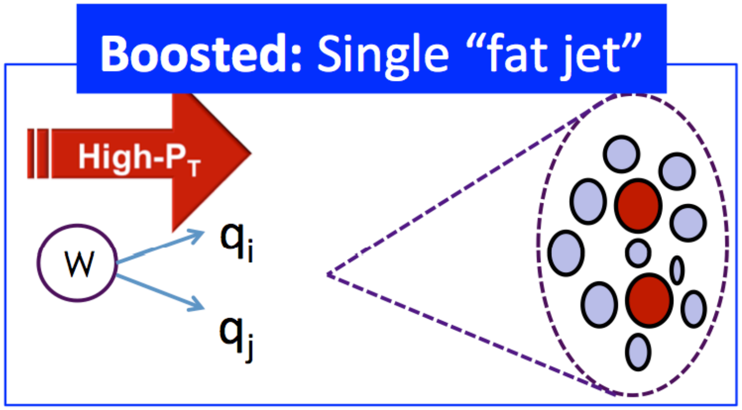
Branching Fractions

	W	Z
$l\nu$, ll	22%	7%
$\tau\nu$, $\tau\tau$	11%	3%
$\nu\nu$	-	20%
qq	67%	70%

- High mass diboson resonances
  - → *Predicted in many extensions of SM*
  - → *Spin 0 (Higgs-like scalars), spin 1 (W', HVT), spin 2 (RS gravitons)*
- At least one boson decaying into quarks
  - → *llqq, lvqq, vvqq, qqqq and combination*
- Bump hunt: search for localised excess in the invariant mass (or transverse mass) distribution
- Reject X+jets background by identifying "boosted" signature of high-p_T boson decaying to quarks



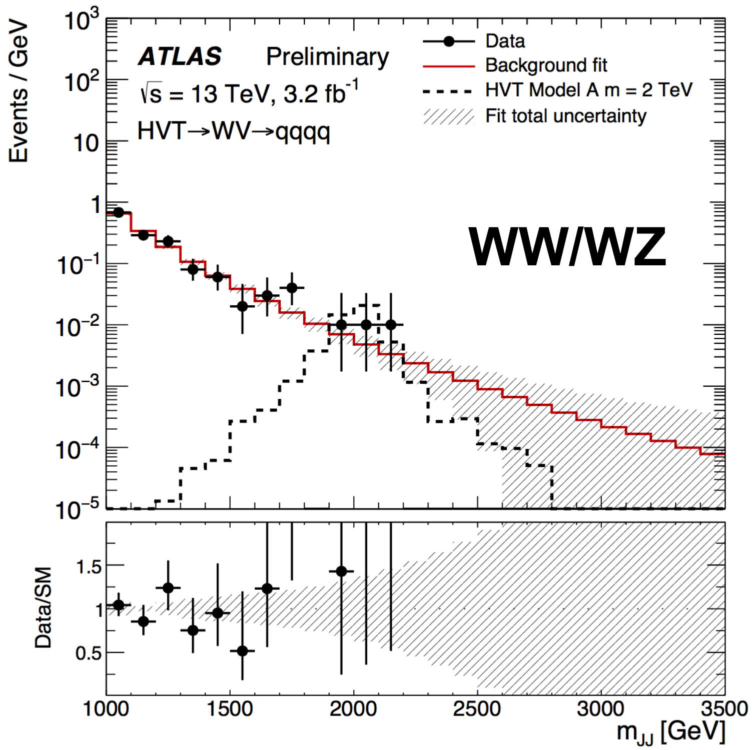
Boosted Boson Tagging

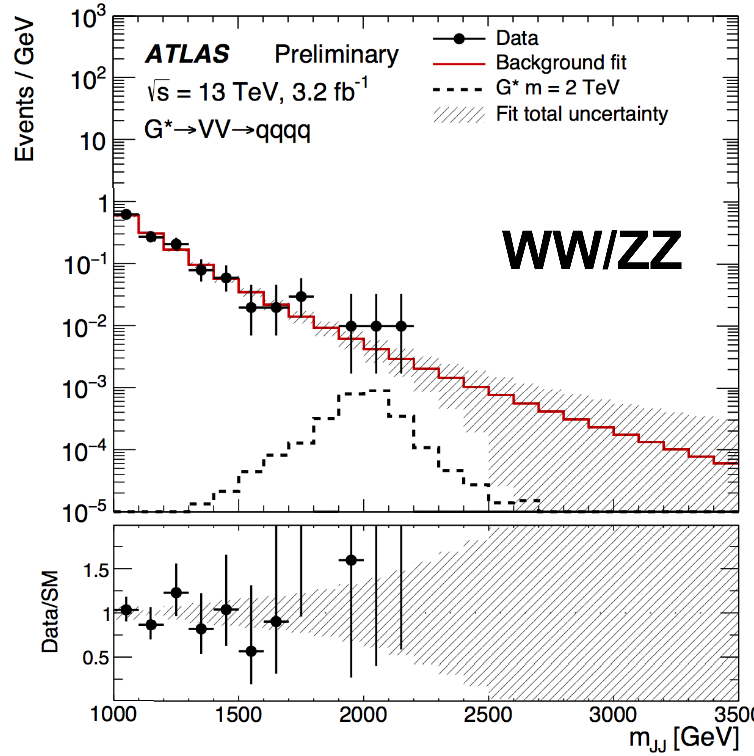


- All channels require at least one large-R jet:
  - → *Small-radius jet finding with anti-k_t , R = 1.0, R = 0.2 sub-jets trimmed if $p^i_T > 0.05\ p^J_T$*
  - → *$p_T(J) > 200$ GeV, $|\eta| < 2$*
- R2D2 boson tagger:
  - → *"medium" working point: 50% eff, 98% BG rejection*
    - m(J): 15 GeV mass window centered in 83.2 GeV for W and 93.4 GeV for Z
    - Substructure variable: $D_2^{(\beta=1)}$ (J): 4th order polynomial, p_T dependent

Tim, Yanyan, Ben W, Flavia

Results – VV → JJ



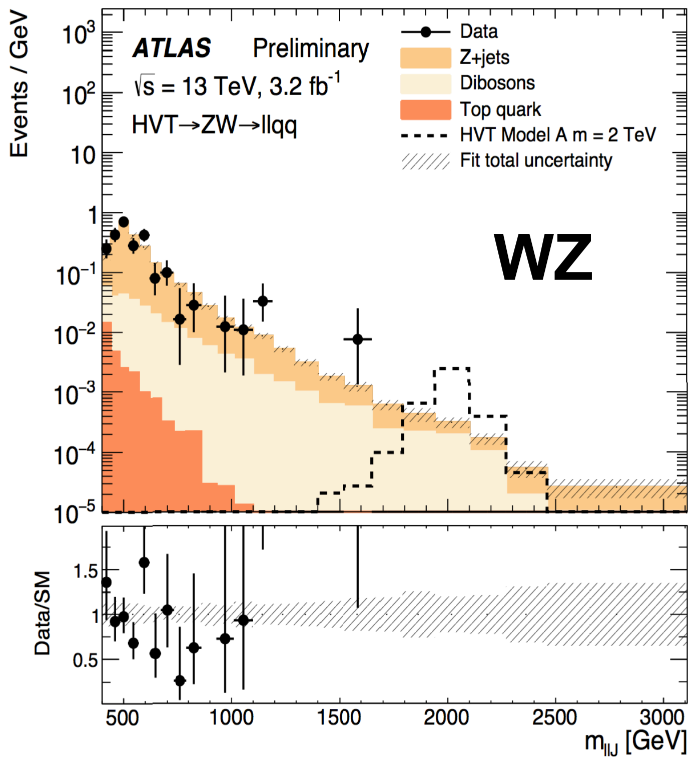


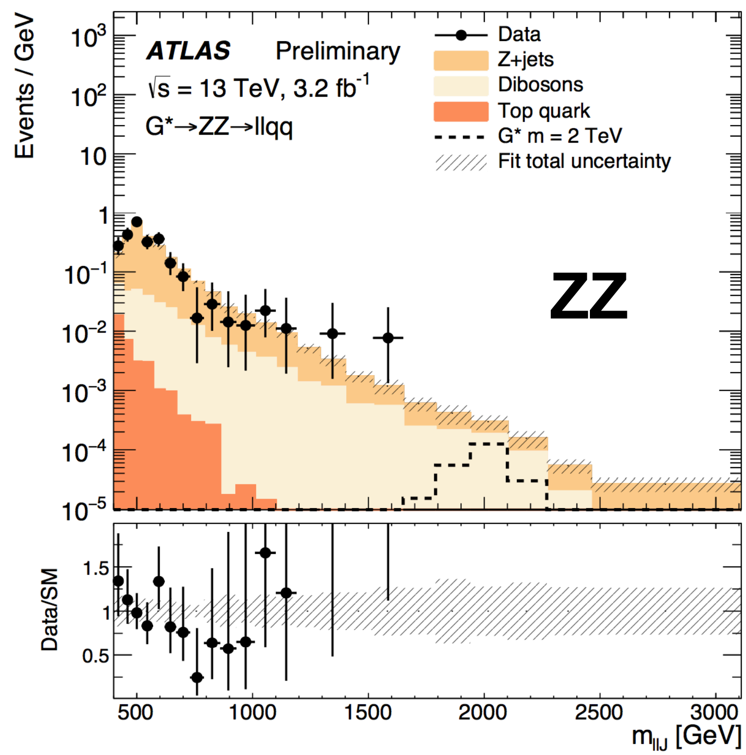
- Background modelled by a fitting function
- No significant excess

→ *Reminder: Run-1 had a ~3σ local excess around 2 TeV*

Yanyan, Ben W, Sebastian, Christos

Results – VV → llqq



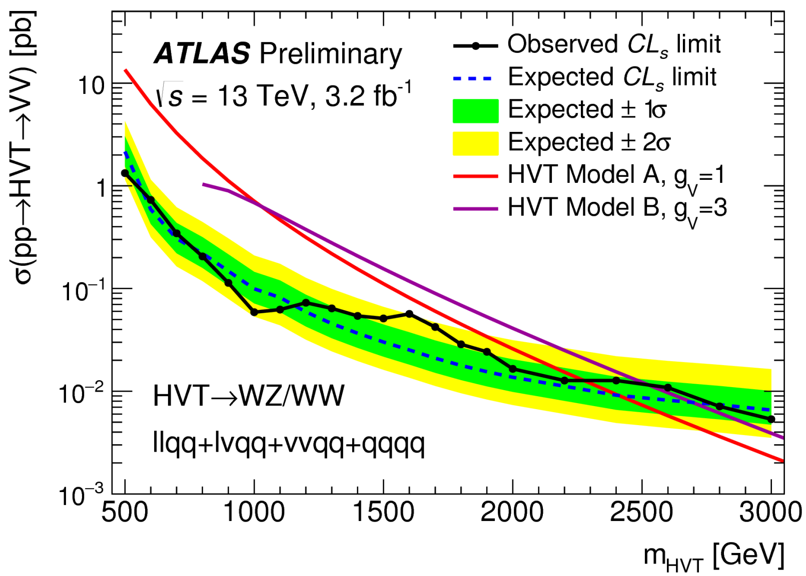


- Background template taken from MC; Fit simultaneously signal and control regions, to constrain the normalisation
- No significant excess

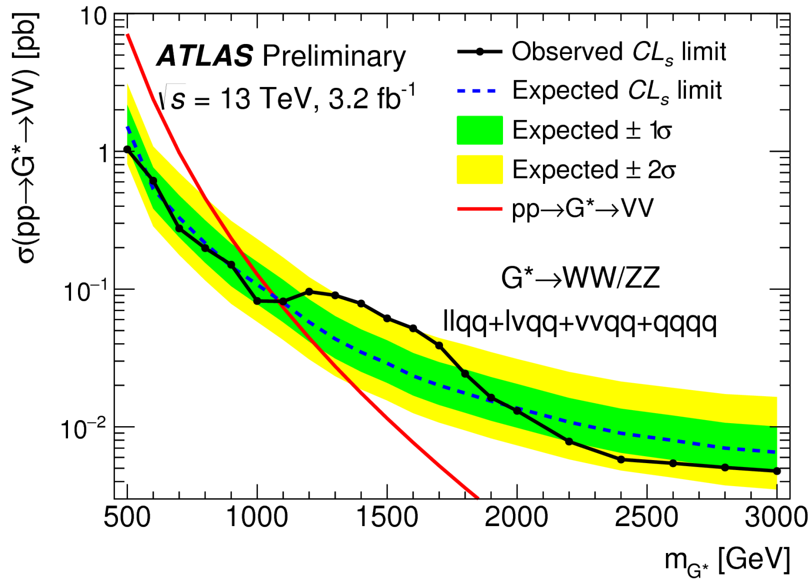
Flavia, Andreas, Christos

Combination

HVT W'/Z'



RS Graviton



- No significant excess observed
- Sensitivity improved by a factor 2, at 2 TeV, w.r.t. Run-1 analyses at 8 TeV
- Paper to be submitted in the next weeks ☺

Flavia, Andreas

conclusions and next steps

Conclusions and next steps

- H → WW differential cross section wraps up Run 1
  → *Maximise physics output of Run 1, lay groundwork for Run 2*
- Diboson searches using 13 TeV data
  → *No corroboration of Run-1 excess at 2 TeV*
  → *750 GeV $\gamma\gamma$ bump means that this will remain interesting!*

New directions:

Search: Left-right symmetric models (Christos & co)

→ *Restore parity to the Standard Model by introducing right-handed W, Z bosons (W_R, Z_R) and right-handed neutrinos (N_R – N_e, N_μ, N_τ), as well as extra Higgs Bosons*

Measure: top-Higgs associated production (Phil, Victoria & co)

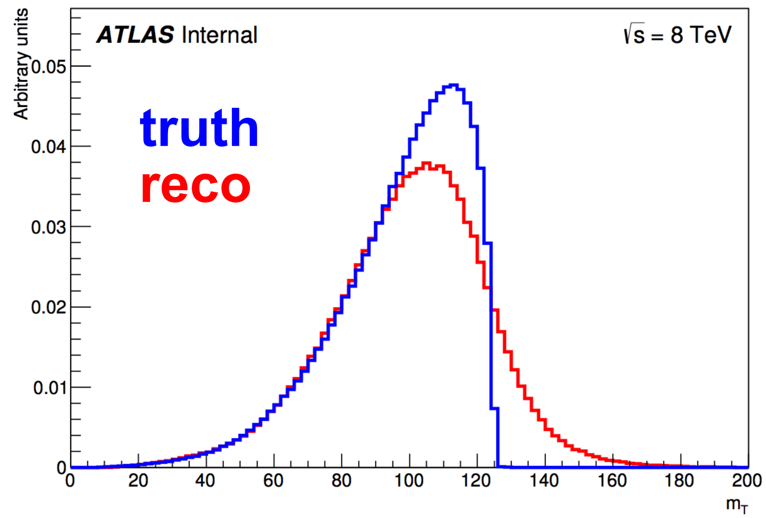
→ *Direct test of the strongest predicted Yukawa coupling*
  - Huge cross-section increase 8 → 13 TeV, benefit from larger dataset

→ *Build towards Higgs pair production searches and measurements*
  - Measure H boson self-coupling – will need HL-LHC data, complementary to upgrade efforts

backup

Fiducial volume

- Define fiducial volume close to signal-region selection
  - → *But common across jet bins, using only leptonic information*
  - → *No m_T cut because of large truth <-> reco migrations*

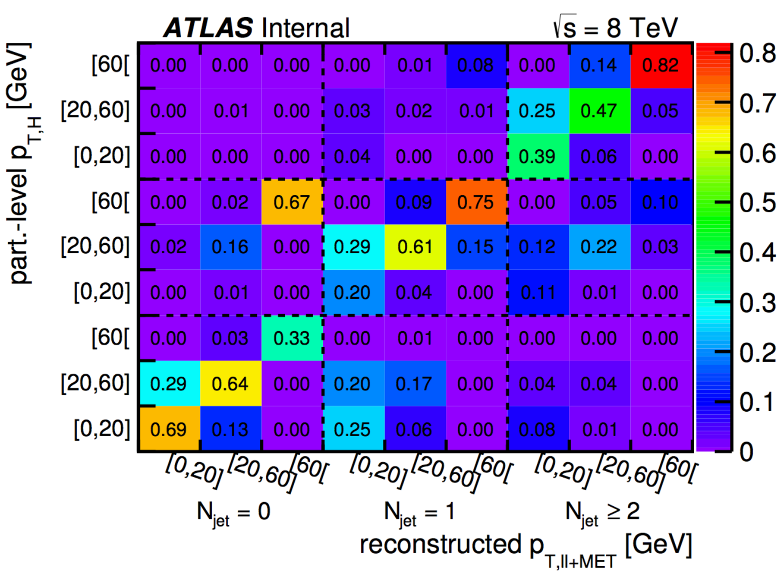


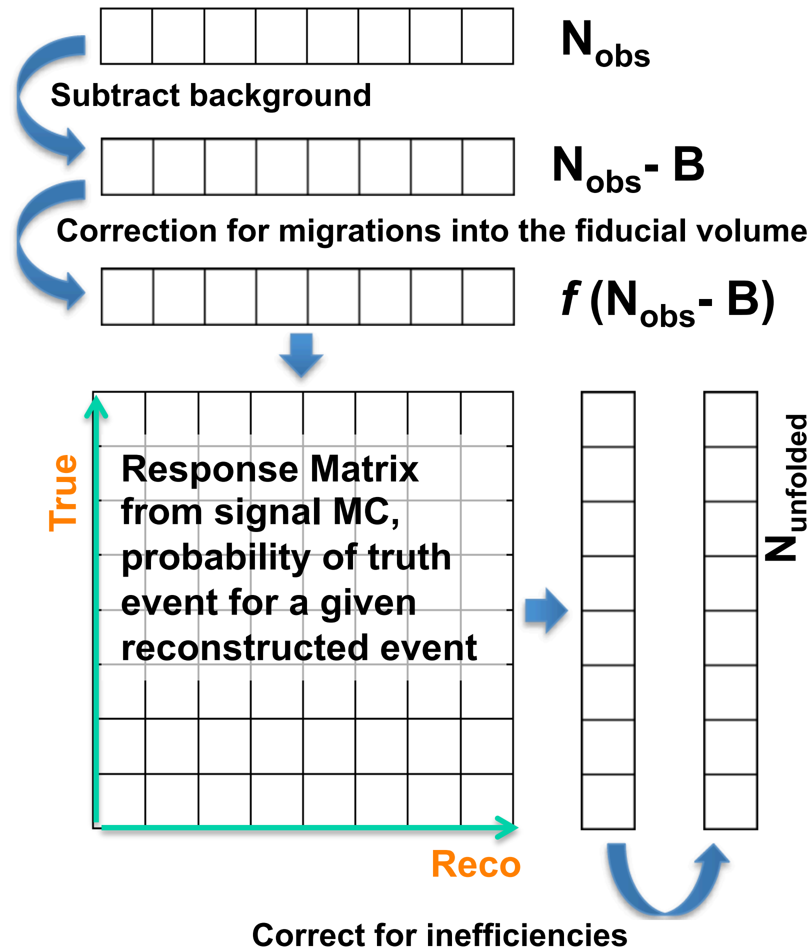
Object selection	
Electrons	$p_T > 15$ GeV, $\lvert\eta\rvert < 1.37$ or $1.52 < \lvert\eta\rvert < 2.47$
Muons	$p_T > 15$ GeV, $\lvert\eta\rvert < 2.5$
Jets	$p_T > 25$ GeV if $\lvert\eta\rvert < 2.5$, $p_T > 30$ GeV if $2.5 \leq \lvert\eta\rvert < 4.5$
Event selection	
Preselection	$p_T^{lead}(\ell) > 22$ GeV
	$m_{\ell\ell} > 10$ GeV
	$E_T^{miss} > 20$ GeV
Topology	$\Delta\phi_{\ell\ell} < 1.8$
	$m_{\ell\ell} < 55$ GeV

Table 6: Summary of selection cuts which define the fiducial region for the cross-section measurements.

Correction for detector effects

- AKA "Unfolding" from reconstructed to particle-level quantities
- Large migrations between Njet categories and bins of p_T^H, $p_T^{lead\ jet}$
  - → *Iterative Bayesian unfolding to correct for detector resolution*
  - → *Technical advances needed to integrate this with profile likelihood fit → cut-and-count, no fit used in this analysis*





Uncertainties

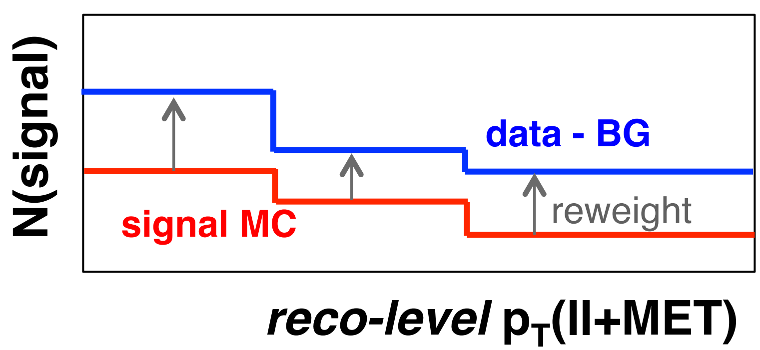
- Statistical: treated with pseudoexperiments
  → *Except statistical uncertainty from CR yields: direct propagation*
- Experimental systematics: exactly as in ggF+VBF paper
- BG theoretical systematics: re-evaluated for modified SR
  → *Shape systematics for Y(ll), pT(llMET), pT(leadjet)*
- Signal theoretical systematics:
- Unfolding procedure: use nominal response object to unfold "Asimov" data created by reweighting signal MC so that it matches the observed signal = data – BG

- In all cases, correlations are preserved when summing backgrounds, jet bins, etc.

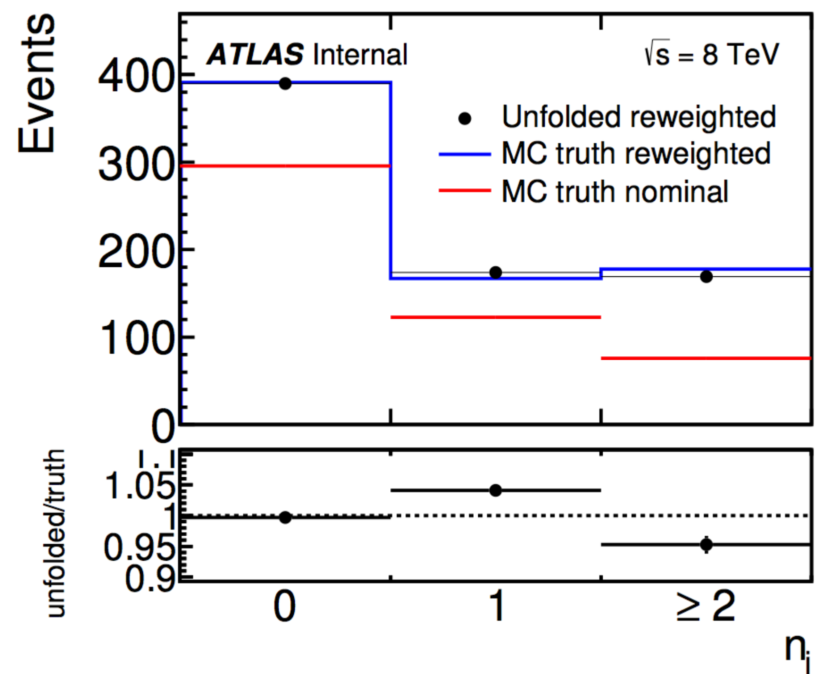
Unfolding uncertainties

Test dependence of our results on the similarity of our signal MC to the truth

1) Use **nominal response object** to unfold "Asimov" data created by **reweighting signal MC** so that it matches the observed signal = data - BG



2) Then compare at truth level the **reweighted signal MC truth distribution with unfolded results: few % or better typical**



blue vs. black is the systematic (also ratio plot)
red vs blue shows the size of the reweighting