

Search for CP violation in WH production in 13 TeV pp collisions with the ATLAS detector

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Ricardo Barrué, on behalf of the ATLAS Collaboration



TÉCNICO
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Fundação
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e a Tecnologia

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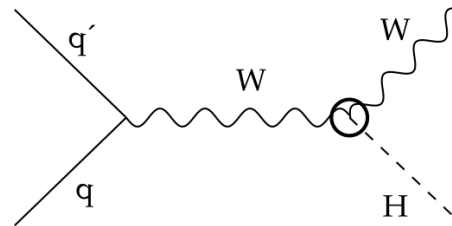
$$O_{H\widetilde{W}} = H^\dagger H \epsilon_{\mu\nu\rho\sigma} W^{I\mu\nu} W^{I\rho\sigma}$$

Motivation

BSM sources of CP violation required to explain baryonic asymmetry.

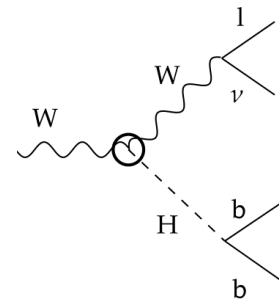
Searching for CP violation in HWW in WH production

- **probes specifically HWW interaction (not possible in VBF)**



SMEFT, Warsaw basis, **1** dimension-6 CP-odd operator, $O_{H\widetilde{W}}$

$$|M|^2 = \underbrace{|M|_{SM}^2}_{\text{CP-even}} + \underbrace{\frac{c_{H\widetilde{W}}}{\Lambda^2} 2 \Re \left(M_{O_{H\widetilde{W}}}^* M_{SM} \right)}_{\text{CP-odd}} + \underbrace{\frac{c_{H\widetilde{W}}^2}{\Lambda^4} |M|_{O_{H\widetilde{W}}}^2}_{\text{CP-even}}$$



Analysis overview - I

Spin-off of ATLAS VH(bb/cc) analysis ([JHEP 04 \(2025\) 075](#)), targeting WH(bb) events:

- One isolated electron or muon + missing transverse energy
- Resolved regime ($p_T^W < 400$ GeV) with 2 b -tagged small-R ($R=0.4$) jets
- Boosted regime ($p_T^W > 400$ GeV) with large-R jet ($R=1.0$) with two b -tagged subjects

Events in resolved regime further categorized in p_T^W and #jets (reconstruction-level)

Several control regions defined in resolved and boosted regimes

CP-odd observable

$$\cos \delta^+ = \frac{\vec{p}_\ell^{(W)} \cdot (\vec{p}_H \times \vec{p}_W)}{|\vec{p}_\ell^{(W)}| |\vec{p}_H \times \vec{p}_W|}$$

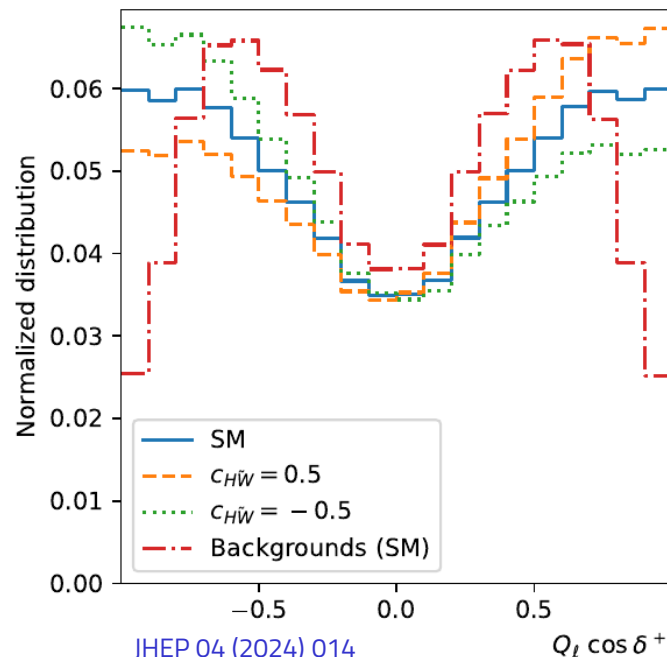
$\vec{p}_\ell^{(W)}$: momentum of lepton in W boson rest frame

CP-odd observable: $\cos \delta^+$ ([JHEP 04 \(2015\) 103](#))

- Weighting by lepton charge, $Q_\ell \cos \delta^+$, increases sensitivity ([JHEP 04 \(2024\) 014](#))

Neutrino reconstructed from W mass constraint

- Selecting solution that minimizes $|\beta_z^W - \beta_z^H|$ (β_z : longitudinal boost)

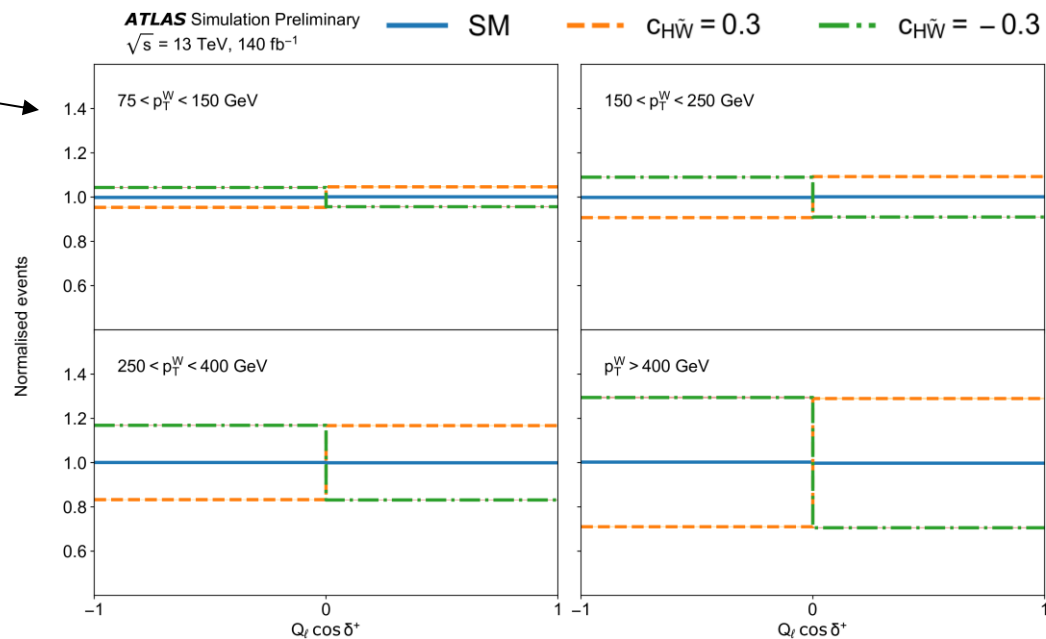


Analysis overview - II

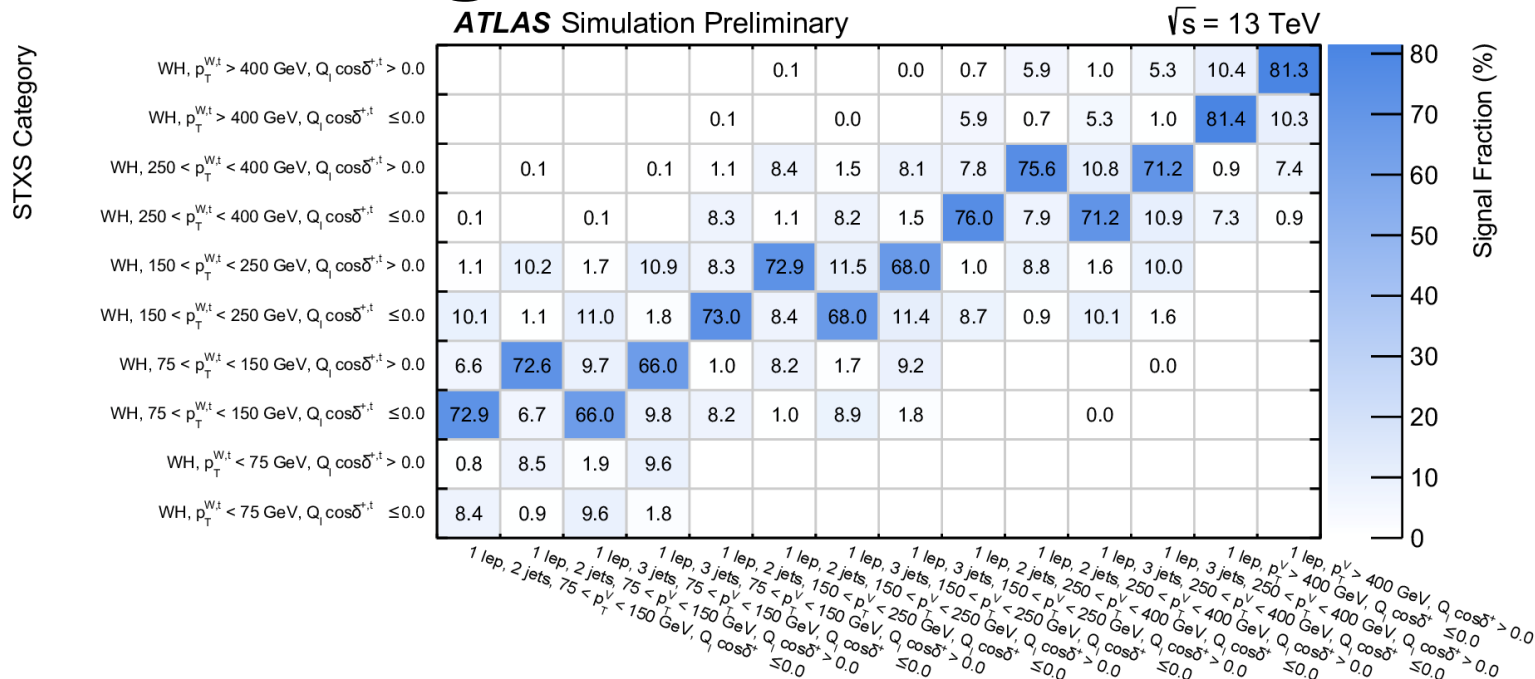
Splitting signal regions into
 $Q_\ell \cos \delta^+ \leq 0$ and $Q_\ell \cos \delta^+ > 0$

Fitting S/B BDT in STXS-style
 templates split in $Q_\ell \cos \delta^+ \times p_T^W$

Interpreting STXS signal strengths
 as a function of $c_{H\widetilde{W}}$



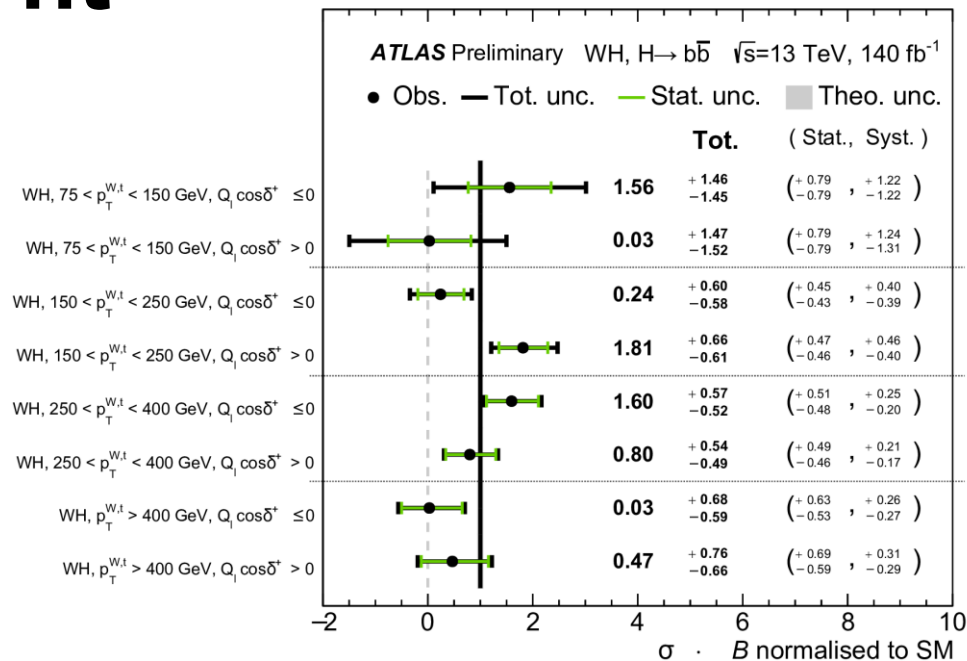
STXS categorization



Misassignment of events largely due to mismeasured p_T^W

Results – STXS fit

Large set of uncertainties,
including migration between
 $Q_\ell \cos \delta^+$ categories for main
backgrounds



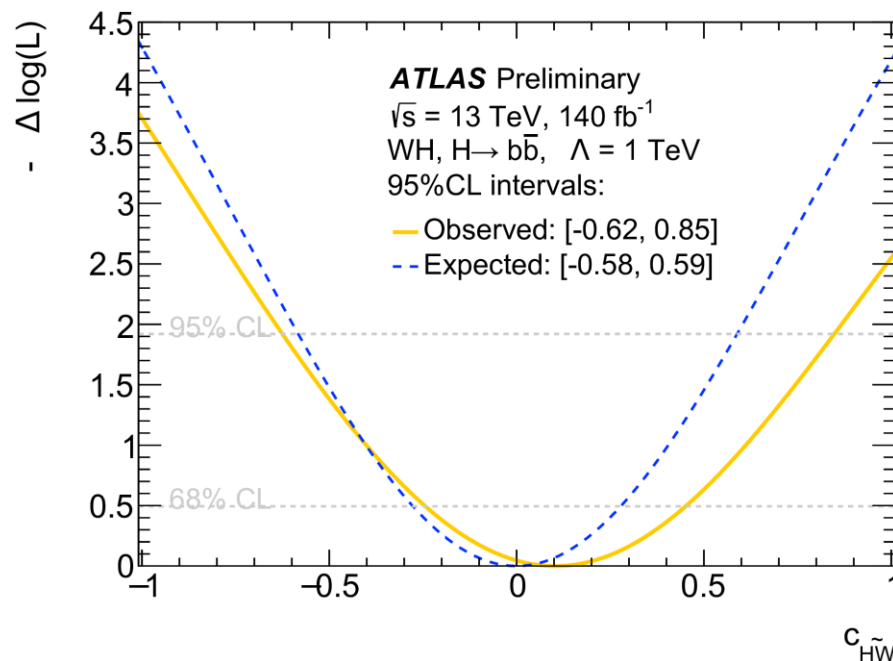
STXS results consistent with SM within 2σ

Results - Interpretation

Analytical parametrization of STXS signal strengths as a function of $c_{H\widetilde{W}}$ derived using SMEFTsim3 and Rivet.

To factorize out normalization effects:

- Parametrization linear in $c_{H\widetilde{W}}$
- Signal strength in each p_T^W STXS category

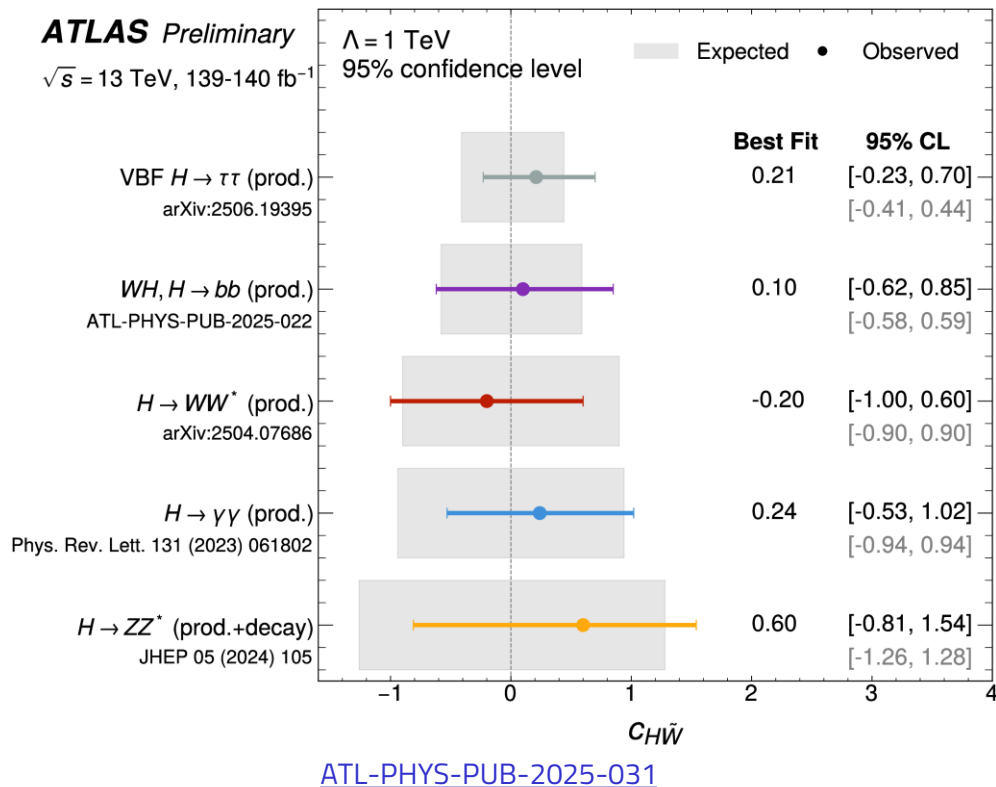


Conclusions

First ATLAS search for CP violation
in HWW vertex in WH(bb)

- Competitive limits
- Complementary to VBF
- Opens the door for additional property measurements in VH

Stay tuned !



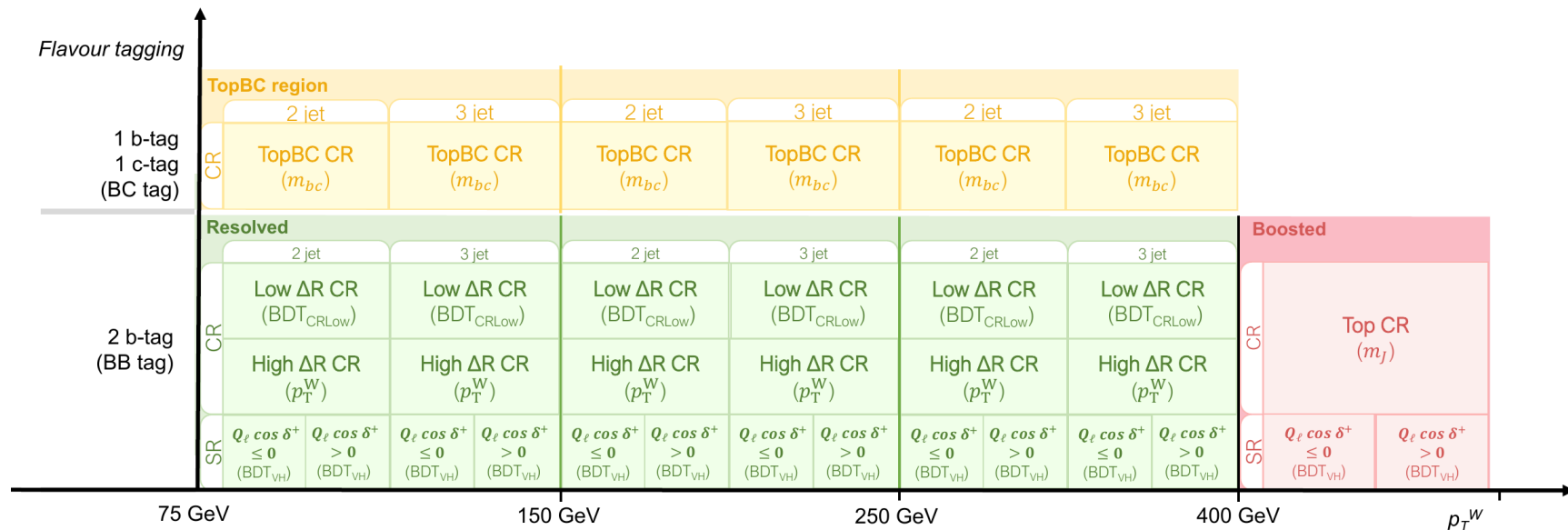
Backup

Differences to ATLAS VH(bb/cc) analysis

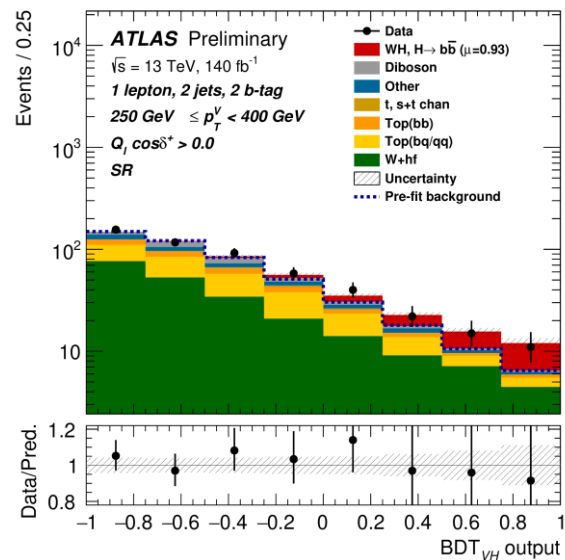
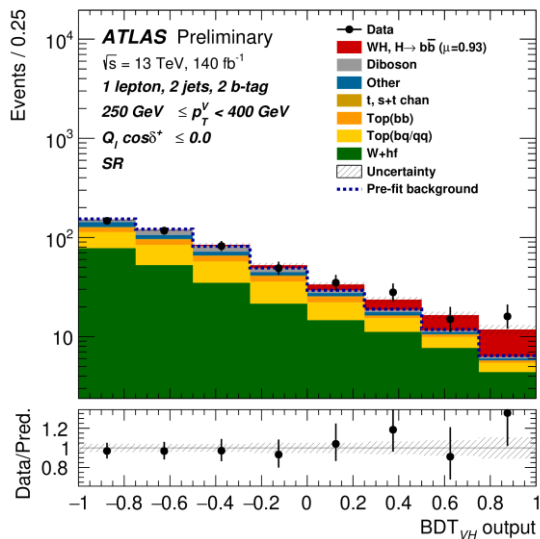
Key differences to ATLAS VH(bb/cc) analysis ([JHEP 04 \(2025\) 075](#)):

- Removed all $H \rightarrow cc$ categories and zero- and two-lepton $H \rightarrow bb$ categories (low sensitivity)
- Removed events with hadronic taus (worse resolution)
- Merged $400 < p_T^W < 600$ and $p_T^W > 600$ GeV categories (reduce fluctuations from $Q_\ell \cos \delta^+$ split)
- Adjusted boundaries of resolved Top(bc) control region: $[250, \infty[\rightarrow [250, 400]$ GeV
- Treated ZH contribution as background, with overall normalization uncertainty
- Removed all Z+jets systematics, except for overall normalization uncertainty
- Removed background modelling uncertainties based on removed regions (e.g. 2L- $\rightarrow$ 1L acceptance)
- Added relative acceptance uncertainty between $Q_\ell \cos \delta^+$ categories for Top(bb) and W+HF

Analysis categories

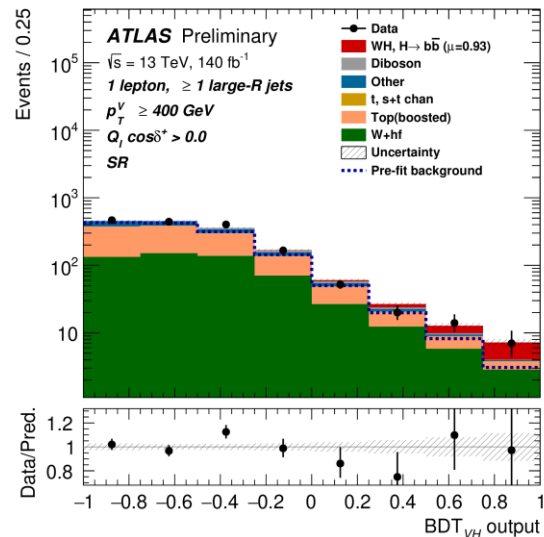
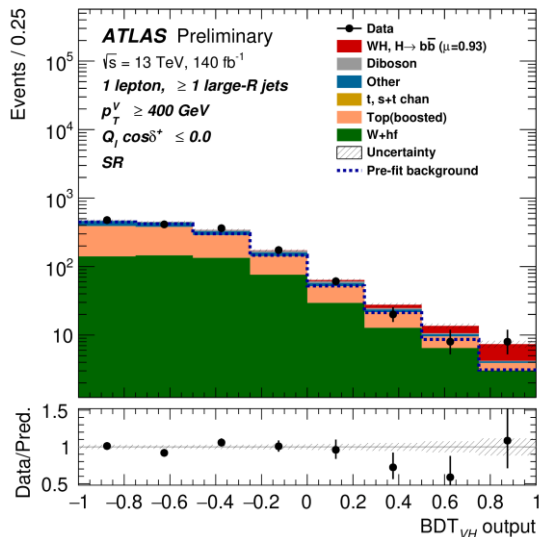


Selected post-fit plots - resolved



Agreement in split SRs within 1σ around unity, same agreement in CRs as VH analysis

Selected post-fit plots - resolved



Agreement in split SRs within 2σ around unity, same agreement in CRs as VH analysis.