# New ATLAS $t\bar{t}H(b\bar{b})$ Run 2 Analysis

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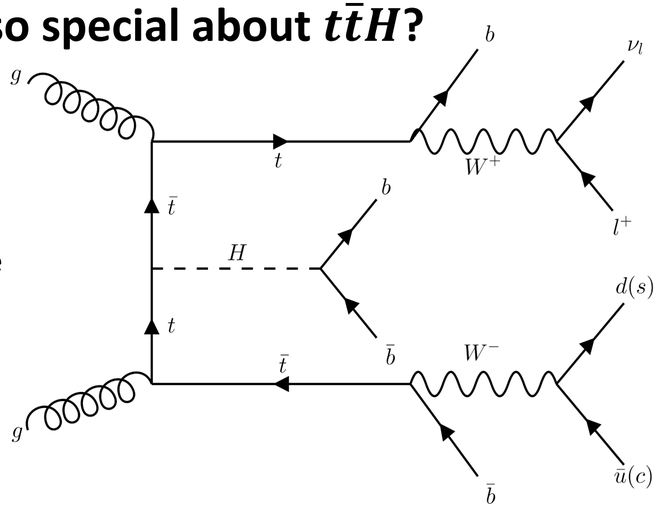
## What's so special about $t\bar{t}H$?

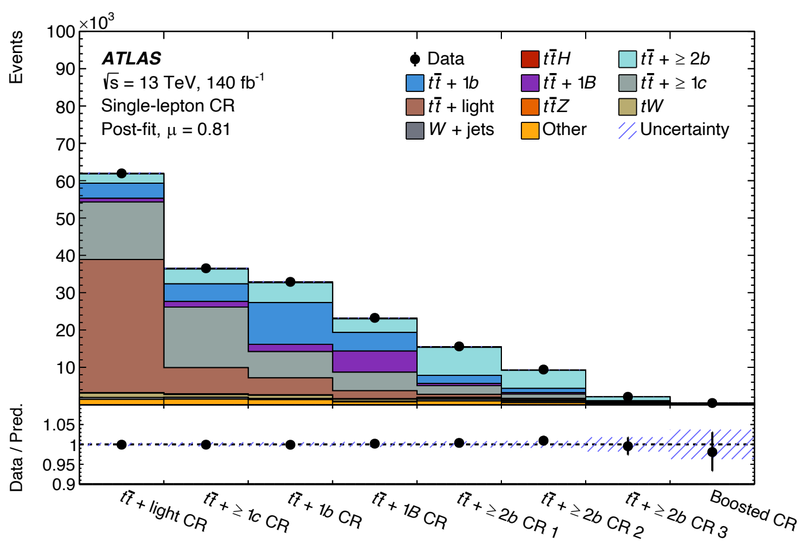
- It's a direct probe of the top Yukawa coupling, which is the largest in the Standard Model
- Measuring this could allow us to probe potential beyond the standard model effects
- Measuring the the $H(b\bar{b})$ final state presents a major challenge to discriminate the signal from the massive $t\bar{t}$ background

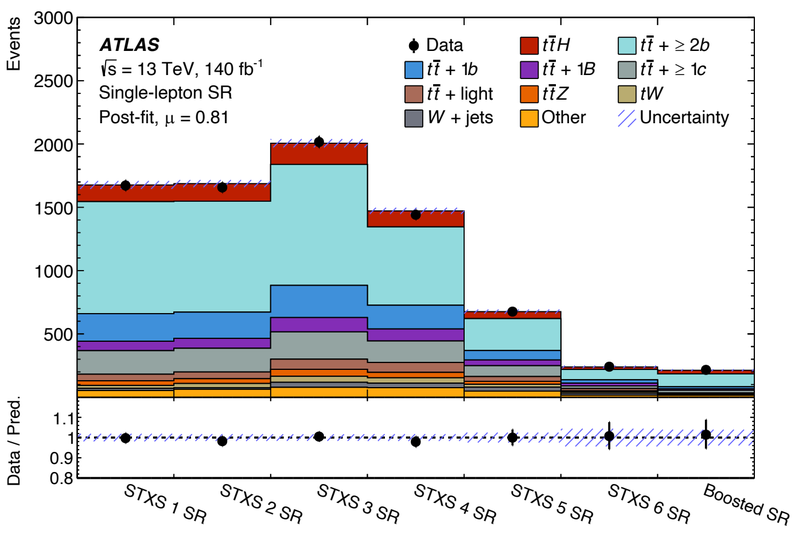



## What have we improved from the previous analysis?

- Improvements on object definitions, in particular Particle Flow for the jets and improved b-tagging
- Updated calibrations, along with better b-tagging uncertainties and new high $p_T$ extrapolation uncertainties[1] and looser event selection
- New attention-based transformer network[2] to improve the Higgs candidate reconstruction and define the signal and control region events
- Improved $t\bar{t}$ modelling, including systematics fully based on $t\bar{t}b\bar{b}$ matrix elements with 4 Flavor Scheme PDFs
- Looser event selection allows for eight control regions to control backgrounds in data and increases signal acceptance by a factor of three

## Event yields per region

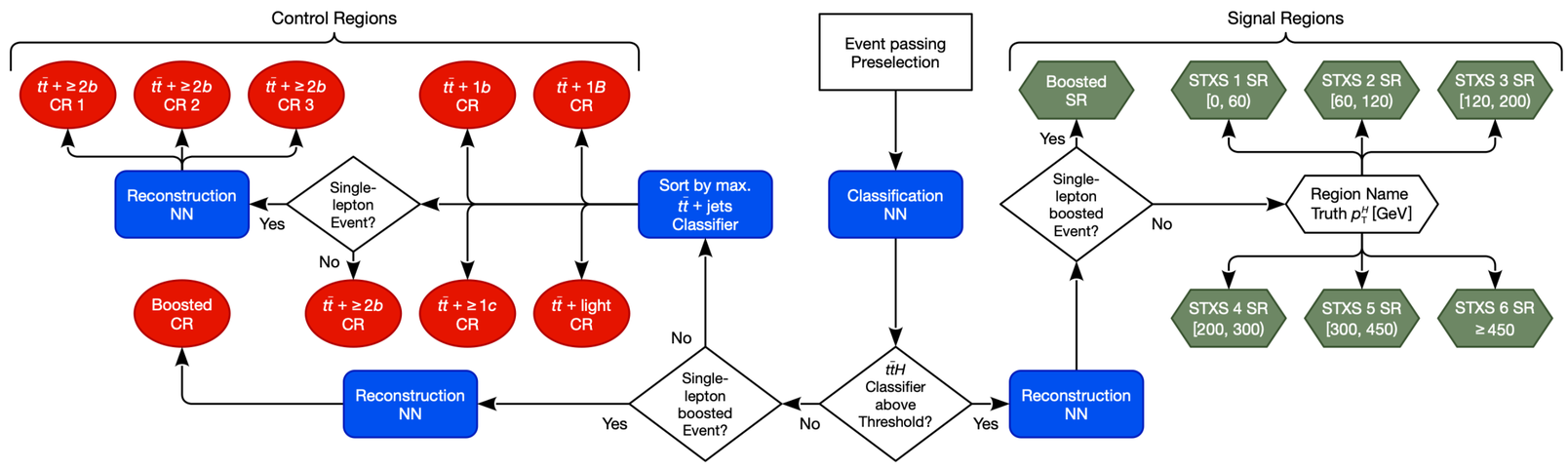



## Event pre-selection requirements

| Channel | # of jets | # of b-tags at 70% | # of b-tags at 85% | # of leptons | # of τ | # of RC jets |
|---|---|---|---|---|---|---|
| Di-lepton | ≥ 3 | ≥ 2 | ≥ 3 | 2 | - | - |
| $\ell$+jets resolved | ≥ 5 | ≥ 3 | ≥ 3 | 1 | ≤ 1 | - |
| $\ell$+jets boosted | ≥ 4 | - | ≥ 3 | 1 | ≤ 1 | ≥ 1 |

## Signal and control region split

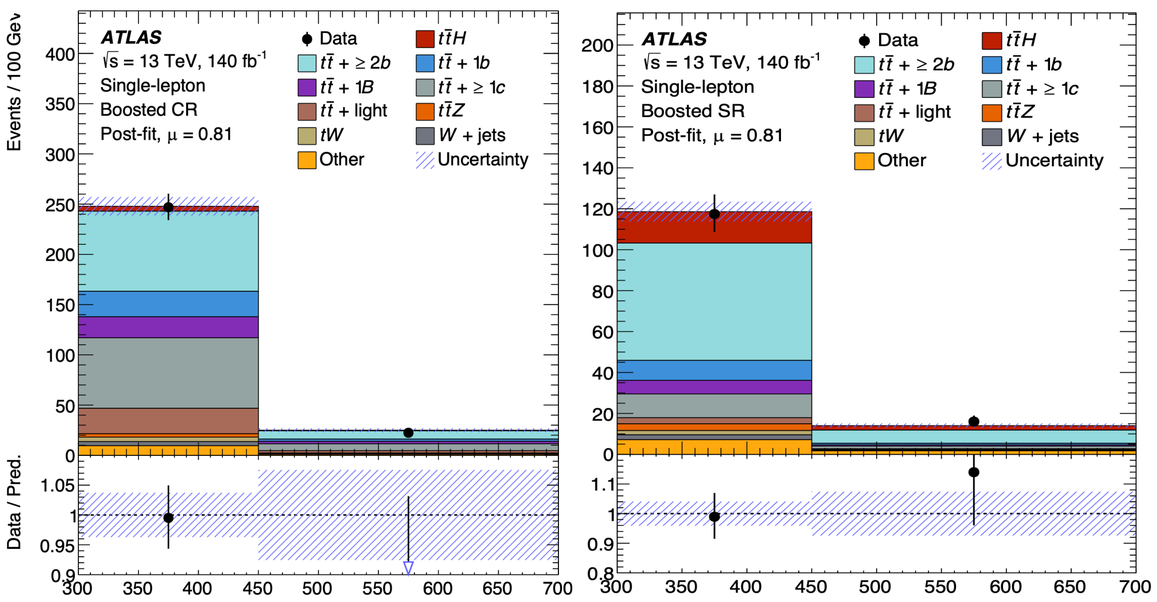



## Did sensitivity improve?

Yes! We select 64% (29%) more single lepton (di-lepton) events, respectively, leading to an overall signal observed (expected) significance of:

**4.6 (5.4)σ**

## Boosted regions



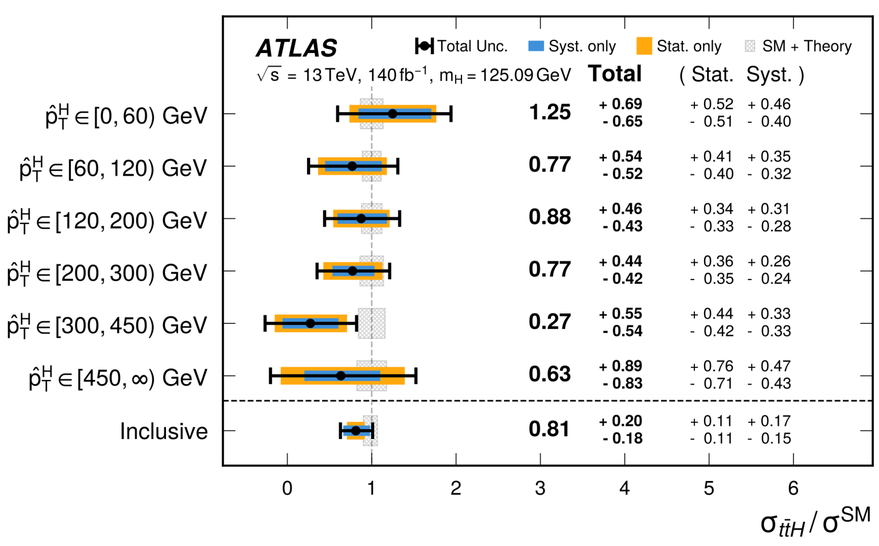

**Boosted Higgs candidates:**
Candidates are required to have $p_T > 300$ GeV and mass $\in [100, 140)$ GeV, contain at least two constituent sub-jets, among which exactly two are b-tagged at the 85% working point, and with a DNN score $P(H) > 0.4$.

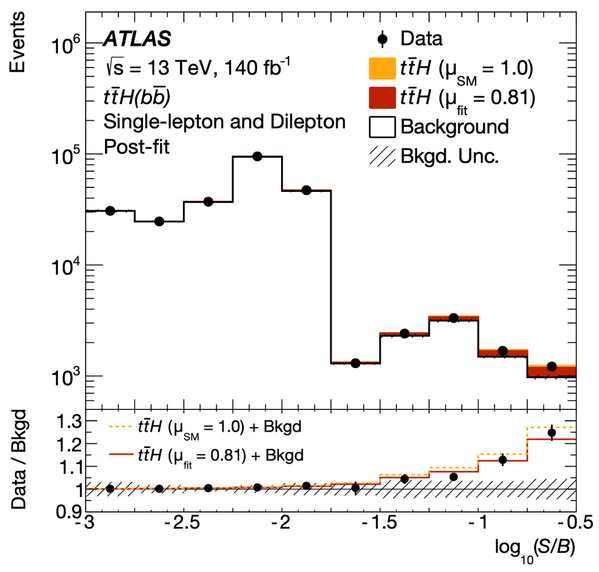
**Boosted enhancement:**
Our boosted events are defined as having as least one $\Delta R = 1$ re-clustered jet and at least one boosted Higgs candidate, as tagged by the boosted Higgs tagger. With this boosted selection we see an enhanced sensitivity of 15% high $p_t$ Higgs single-lepton STXS bin of $[450, \infty]$ GeV compared to where the resolved selection is applied to these events.

## Results

$$\sigma_{t\bar{t}H} = 411^{+54}_{-54}(stat.)^{+85}_{-75}(syst.)\text{fb}$$

$$\sigma_{t\bar{t}H,SM} = 507^{+35}_{-50}\text{fb}$$




## Summary

Overall, this analysis[3] is more sensitive and precise compared the previous analysis[4]. These improvements are mainly driven by the adoption of the transformer network, improved systematic model and looser event selection enabling improved signal and background separation. The statistically limited high $p_T$ event analysis is enhanced using a dedicated boosted analysis. This result is consistent with the SM prediction. We hope to improve the precision, especially in our statistically limited areas with the Run-3 data set.

## References


[1] ATLAS Collaboration, Simulation-based extrapolation of $b$-tagging calibrations towards high transverse momenta in the ATLAS experiment, ATL-PHYS-PUB-2021-003, 2021
[2] A. Vaswani et al., Attention Is All You Need, 2023, arXiv: 1706.03762
[3] Measurement of the associated production of a top-antitop-quark pair and a Higgs boson decaying into a $bb^-$ pair in $pp$ collisions at √s=13 TeV using the ATLAS detector at the LHC ERN-EP-2024-194, arXiv:2407.10904
[4] ATLAS Collaboration, Measurement of Higgs boson decay into $b$-quarks in associated production √s = 13TeV with the ATLAS detector, JHEP 06 (2022) 097


42nd International Conference on High Energy Physics, Prague, Cz, 18 - 24 Jul 2024