LABORATÓRIO DE INSTRUMENTAÇÃO
E FÍSICA EXPERIMENTAL DE PARTÍCULAS
partículas e tecnologia

Probing the CP nature of the top-Higgs coupling in ATLAS

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Outline

- For motivation and analysis strategy check:
  - talk by Ana Luísa Carvalho
  - poster by Luis Coelho
- I'll focus on a limited set of important aspects of the analysis

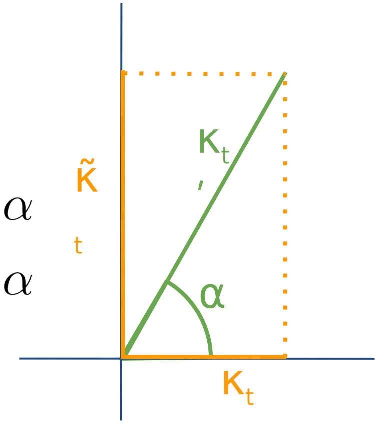
1. Signal modelling
2. $t\bar{t}$+b modelling
3. Impact of systematic uncertainties
4. Background-only fits to data
5. Conclusion

1.
Signal modelling

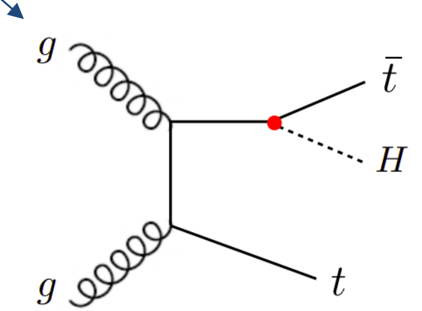
Signal definition

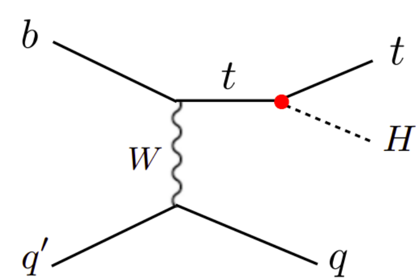
$$\mathcal{L}_{tth} = y_t \bar{\psi}_t \kappa'_t (\cos\alpha + i\gamma_5 \sin\alpha)\psi_t h$$
$$= y_t \bar{\psi}_t (\kappa_t + i\gamma_5 \tilde{\kappa}_t)\psi_t h$$

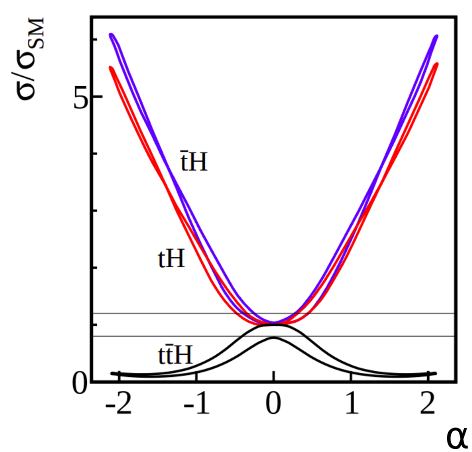
$$\kappa_t \equiv \kappa'_t \cos\alpha$$
$$\tilde{\kappa}_t \equiv \kappa'_t \sin\alpha$$



- Signal is primarily **ttH** with H→bb, drives the analysis strategy
- Top-Higgs coupling also affects **tH**
  - Not very different final state
  - Cross-section strongly affected by CP-odd coupling
- Assuming H→bb is SM







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Signal modelling

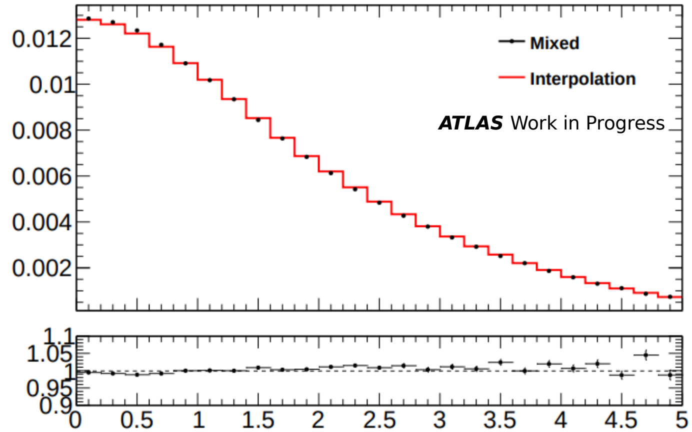
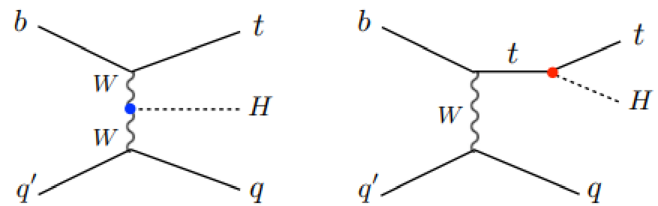


Figure: $\Delta\eta(tlep, thad)$

- Monte Carlo samples available for a few points in parameter space
- For **ttH**, using CP-even and CP-odd yields per bin weighted as:

$$y(\kappa_t, \tilde{\kappa}_t) = \kappa_t^2 y_{\text{even}} + \tilde{\kappa}_t^{\,2} y_{\text{odd}}$$

- **tH** is more complicated due to interference
- Parametrise yields per bin using a polynomial with all possible terms



$$\frac{y(\kappa_t, \tilde{\kappa}_t)}{y_{\text{even}}} = A\kappa_t^2 + B\tilde{\kappa}_t^{\,2} + C\kappa_t + D\tilde{\kappa}_t + E\kappa_t\tilde{\kappa}_t + F$$

- Find coefficients by fitting MC samples available for several points
- Implementation and validation of these parameterisations driven by LIP

2.

$t\bar{t}$+b modelling

tt̄+b

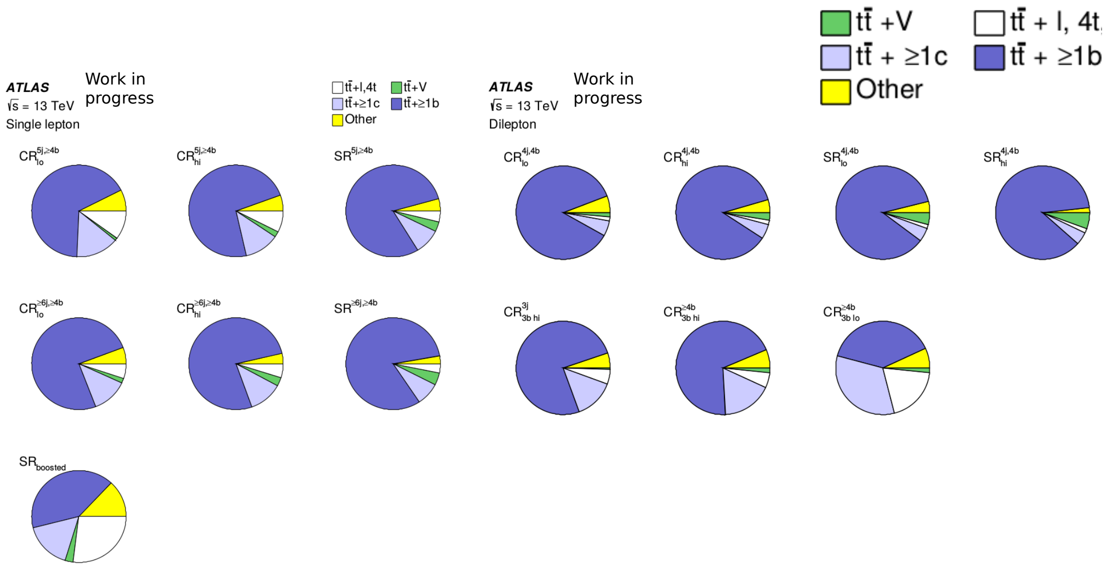
tt̄+jets samples split into tt̄+light, tt̄+c, tt̄+b based on truth-level hadrons

At least one b-hadron matched to a jet (not from top decay) → **tt̄+b**

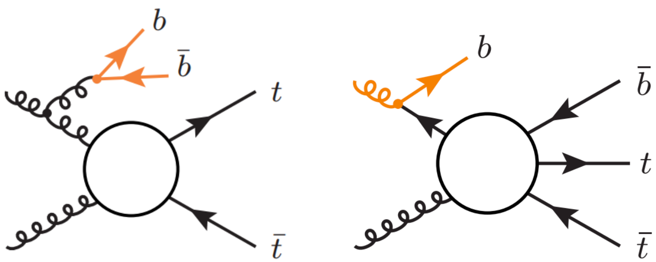
Not tt̄+b and at least one c-hadron matched to a jet (not from top decay)→ **tt̄+c**

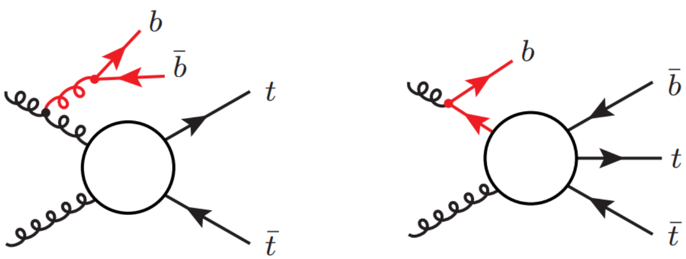
Not tt̄+b and not tt̄+c → **tt̄+light**

tt̄+b is the dominant background in all analysis regions



$t\bar{t}$ 5-flavour scheme vs $t\bar{t}+b\bar{b}$ 4-flavour scheme





S. Pozzorini

$t\bar{t}$ 5FS

Matrix element is $t\bar{t}$ @NLO

Additional b-quarks from parton-shower

Massless b-quarks, possibly in initial state (5-flavour scheme)

Merging with $t\bar{t}$+c and $t\bar{t}$+light for free

Many alternative predictions for systematic estimation

$t\bar{t}+b\bar{b}$ 4FS

Matrix element is $t\bar{t}+b\bar{b}$ @NLO

Massive b-quarks, no b-quarks in initial state (4-flavour scheme)

No ‘recipe’ from theorists for merging with $t\bar{t}$+light and $t\bar{t}$+c

Not sufficient options ready for two-point systematic estimation

$t\bar{t}$+b modeling

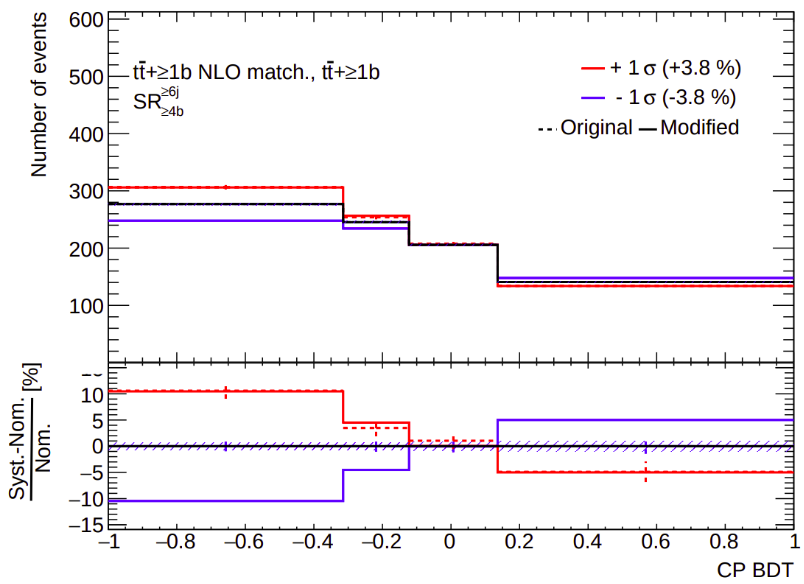
Nominal tt+b model: $t\bar{t}+b\bar{b}$ 4FS

Not all uncertainties covered by $t\bar{t}+b\bar{b}$ 4FS alternative predictions:

- Compare alternative **$t\bar{t}$ 5FS** predictions
- Use relative variation as systematic uncertainty

For each uncertainty, a constrained parameter θ added to the profile-likelihood fit

- θ=0: nominal
- θ=+1: alternative prediction
- θ=-1: symmetric of +1



3.
Impact of systematic uncertainties

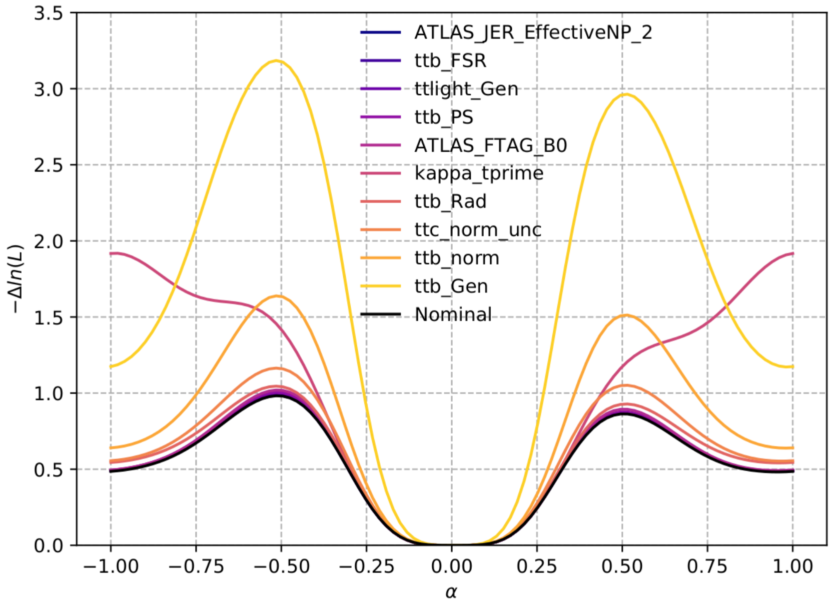
Impact of systematic uncertainties

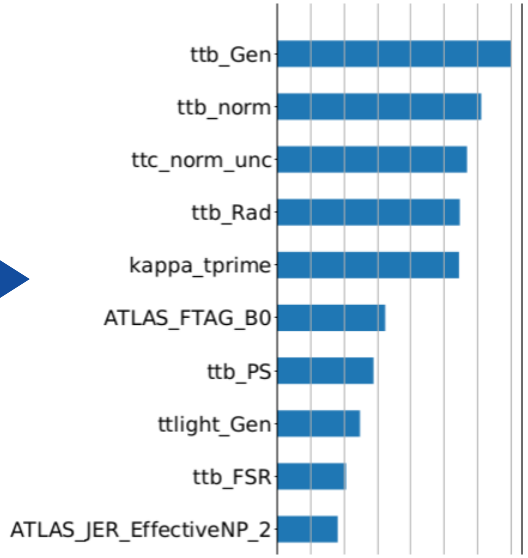
How much does each systematic uncertainty affect our sensitivity?

How do they rank in importance?

Likelihood scan removing each uncertainty from the fit at a time

Subtract in quadrature the size of 1σ bands from the one in the nominal fit





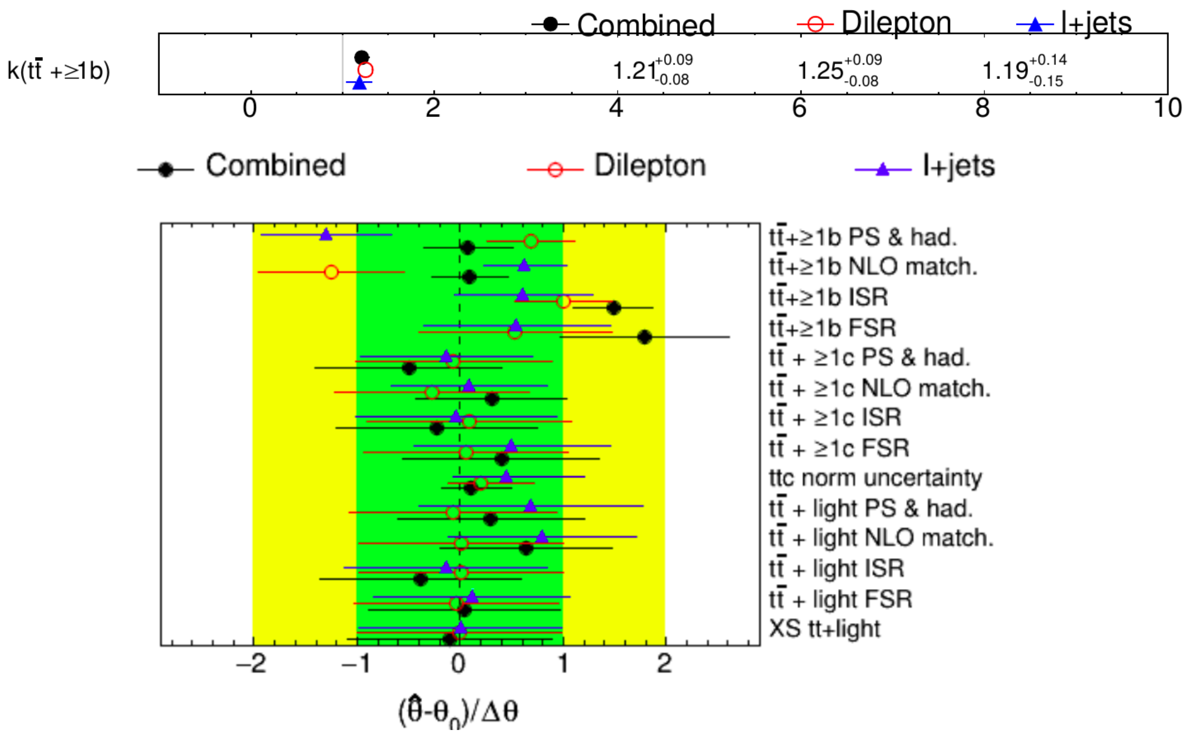
tt+b modelling uncertainties dominate

(plots for l+jets channel alone)

4.
Background-only fits to data

Background-only fit to data

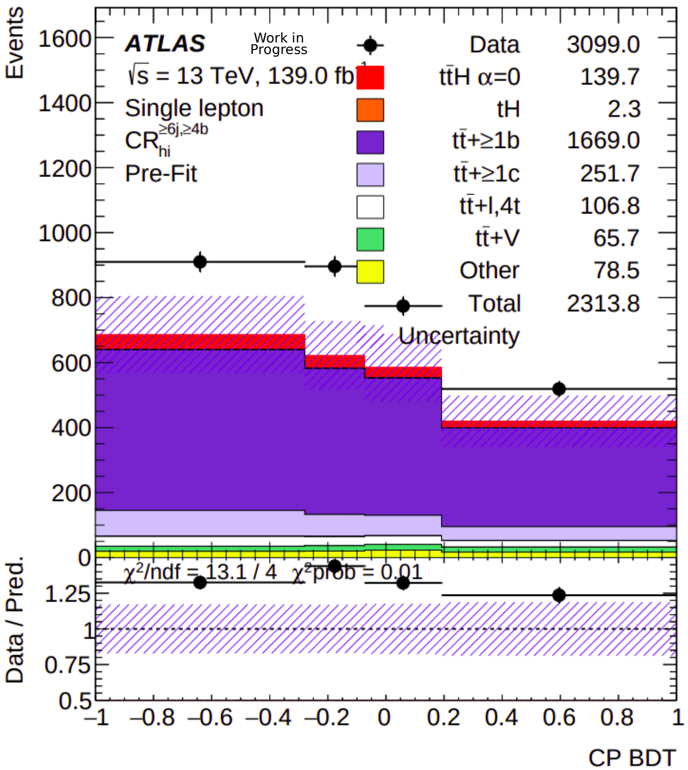
- Validate background model by fitting it to data in signal-depleted bins

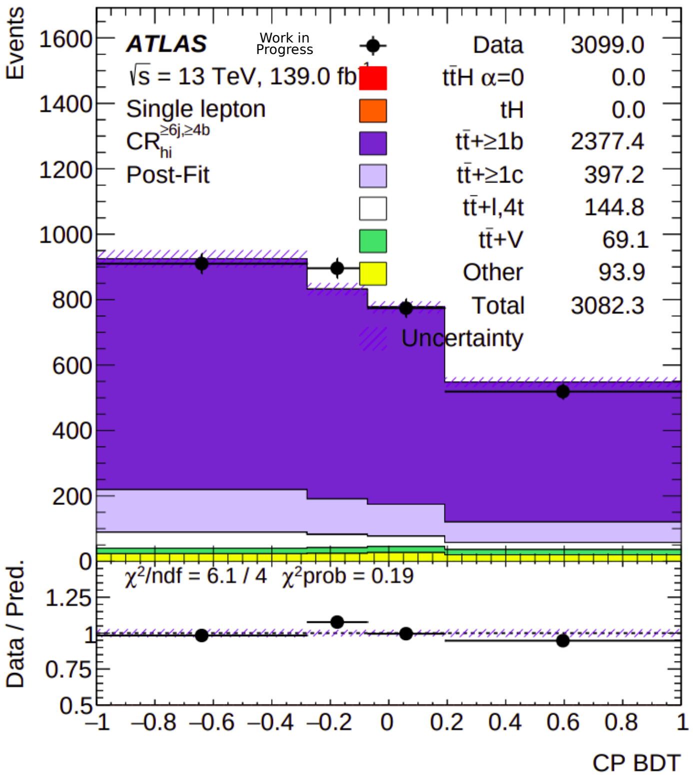


- tt+b normalisation corrected by a factor of 1.21
- Different pulls between individual channels and combination
- Most pulls well understood

Post-fit modelling

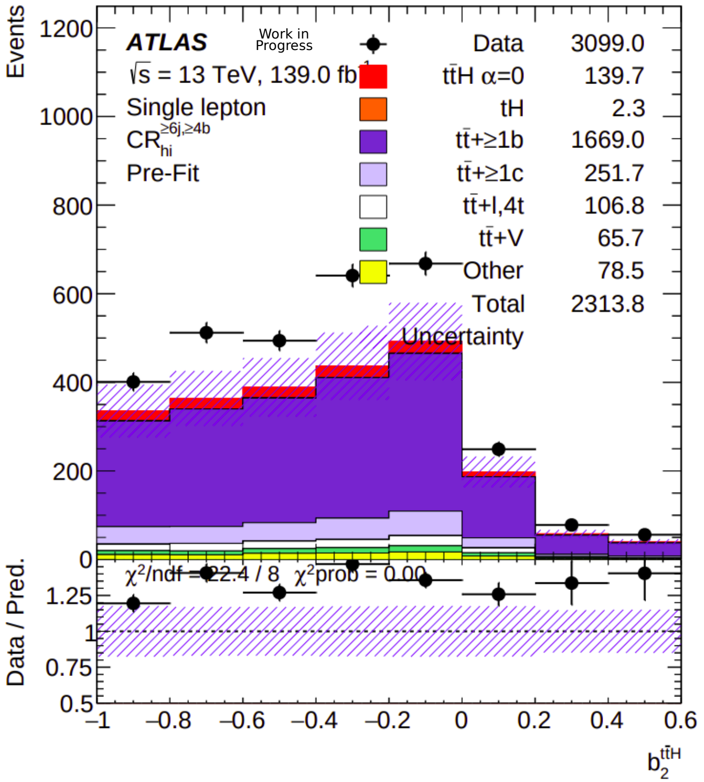
- Fit corrects modelling of the fitted distributions…

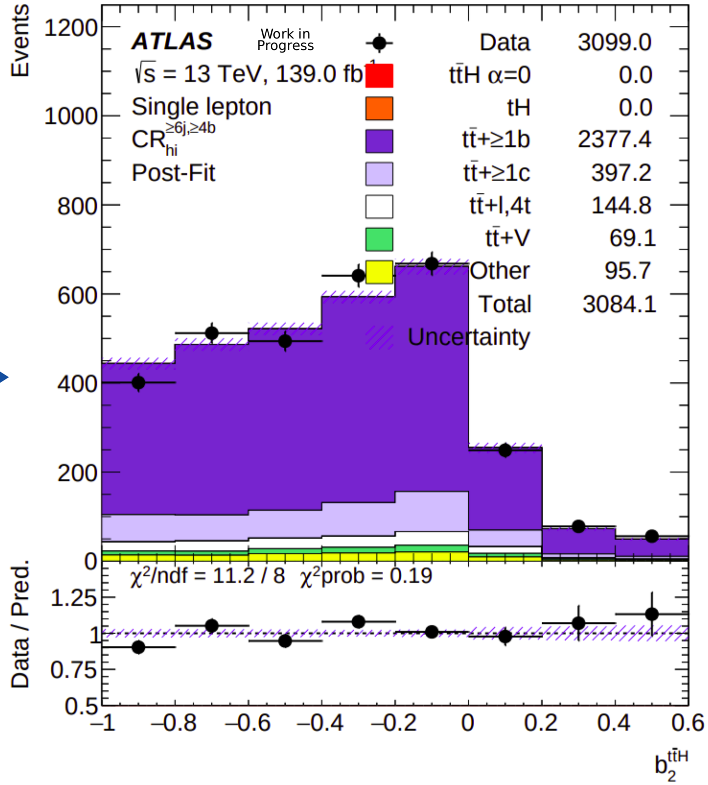




Post-fit modelling

- … but also of the distributions of CP BDT input features





5.
Summary

Summary

A source of CP violation in the Higgs sector could manifest itself in Yukawa couplings

- **ttH production at the LHC is the best direct probe for such a scenario**

In ATLAS tt(H→bb) analysis, implemented and validated signal parameterisation as a function of CP-odd coupling

Analysis limited by tt+b modelling uncertainties

- Addressing it with state-of-the-art tt+b predictions
- Using profile-likelihood fit to constrain uncertainties
- Good post-fit data/MC agreement validates model

Currently dedicating most time to writing thesis

SM analysis in approval process

CP-odd analysis should follow shortly after

Thank you