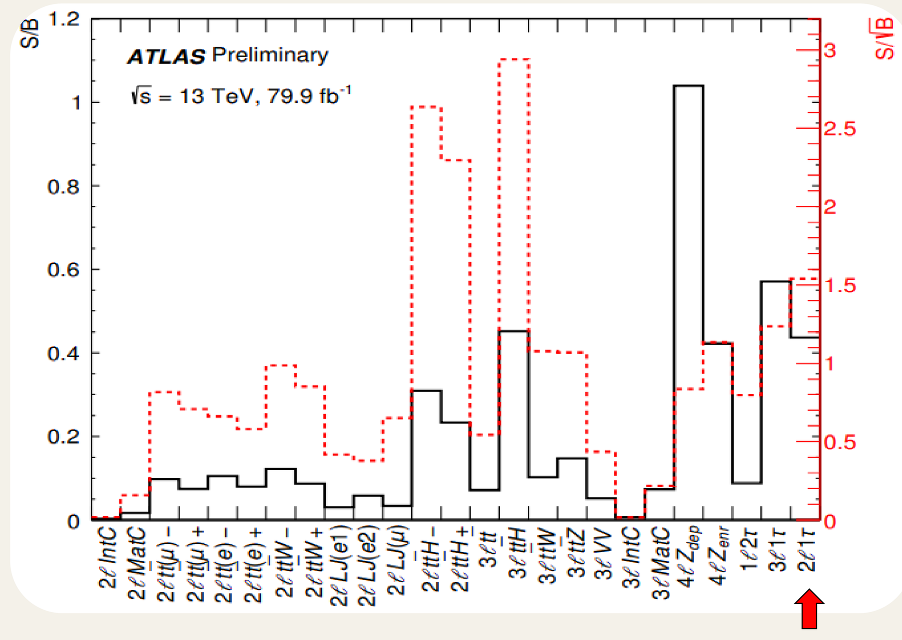
Fake-Rate determination for the $t\bar{t}H$ coupling measurement with a signature of two same electric charge light leptons associated with a tau using the ATLAS detector at the LHC

Santu Mondal, on behalf of the ATLAS collaboration

Introduction

- The associated production of a top-quark pair with the Higgs boson ($t\bar{t}H$) allows a direct measurement of top quark Yukawa coupling.
- A search for $t\bar{t}H$ in multilepton final state is presented.
- Search is based on 80 fb^{-1} dataset recorded with the ATLAS experiment during 2015-2017 at $\sqrt{s}$ = 13 TeV.
- Multilepton signatures are primarily sensitive to the decays $H \rightarrow WW^*$, $H \rightarrow \tau\tau$, and $H \rightarrow ZZ^*$.



- The $2\ell 1\tau_{had}$ final state is primarily sensitive to $H \rightarrow \tau\tau^*$, and $H \rightarrow WW^*$, and selected by the following requirements:
- Two light leptons (electrons or muons) of same charge.
- One hadronically decaying τ lepton oppositely charged to light leptons.
- At least 4 jets of which one b-tagged jet.

Background estimation

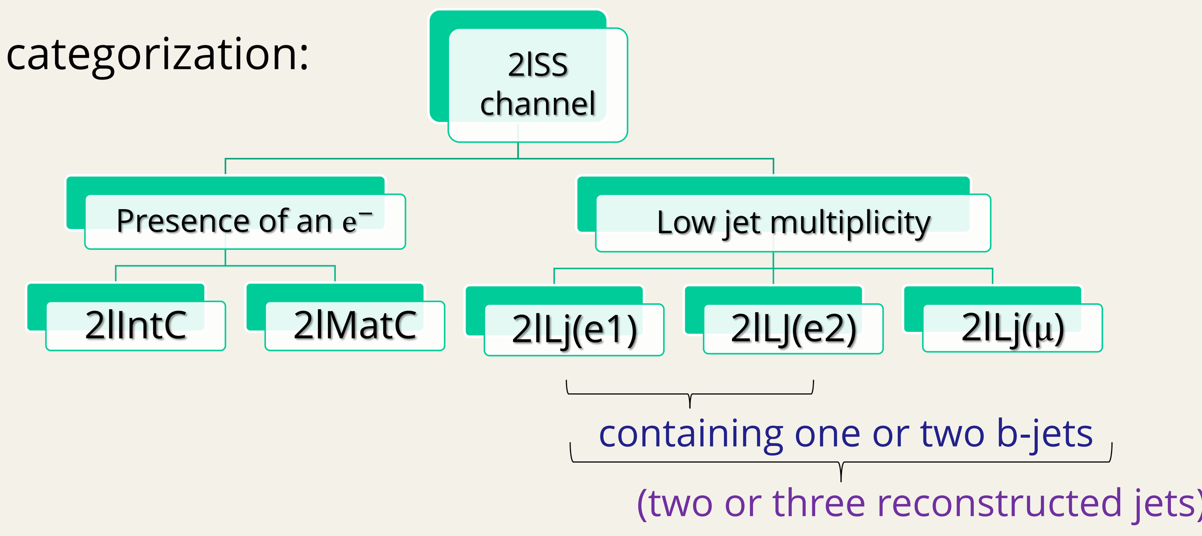
Irreducible backgrounds

- Mainly originate from $t\bar{t}W$ and $t\bar{t}(Z/\gamma^*)$, followed by VV production. Smaller contribution arising from the rare processes like tZ, tW, WtZ, $t\bar{t}WW$, VVV, $t\bar{t}$, $t\bar{t}t\bar{t}$.

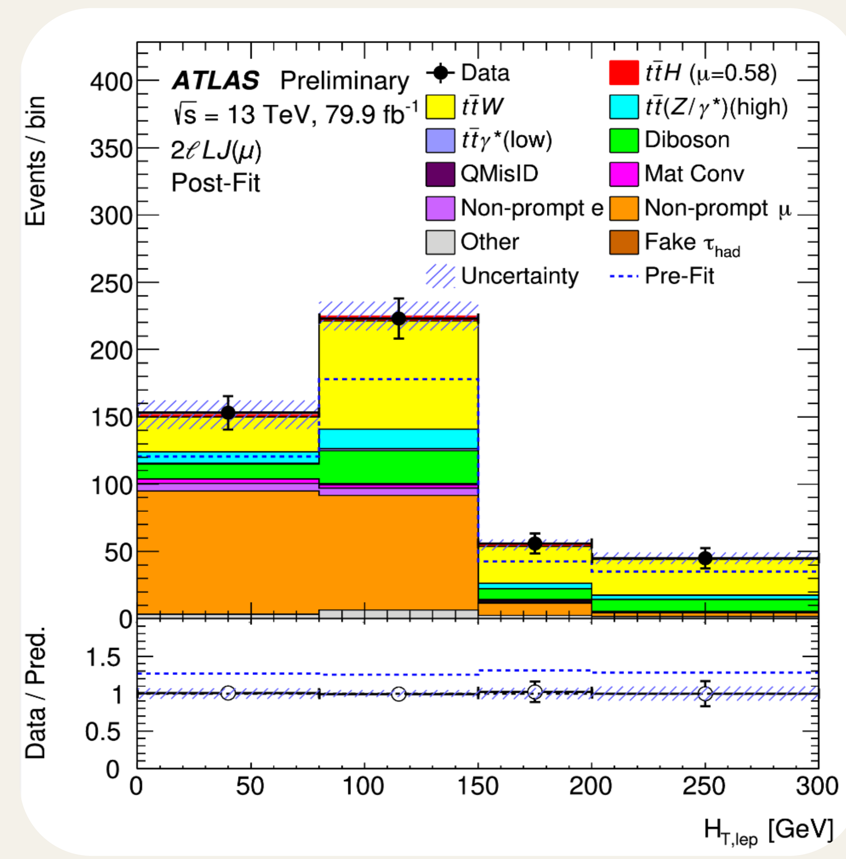
Reducible backgrounds

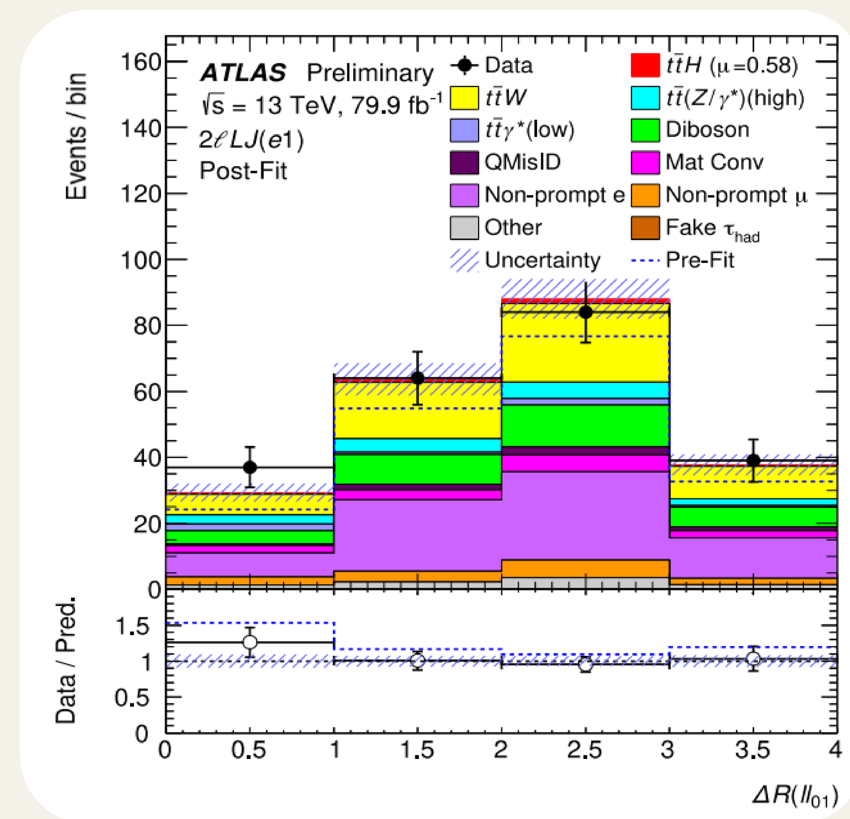
- Charge misassignment (QMisID) arises from hard bremsstrahlung as well as asymmetric conversion ($e^{\pm} \rightarrow e^{\pm}\gamma^* \rightarrow e^{\pm}e^{+}e^{-}$) or mismeasured track curvature.
- Non-prompt leptons originate from material conversions, heavy-flavour hadron decays or the improper reconstruction of other particles. The main contribution is coming from $t\bar{t}$.
- The fake τ_{had} background mainly arises from $t\bar{t}$ and $t\bar{t}V$ events with a jet misidentified as a τ_{had} candidate.

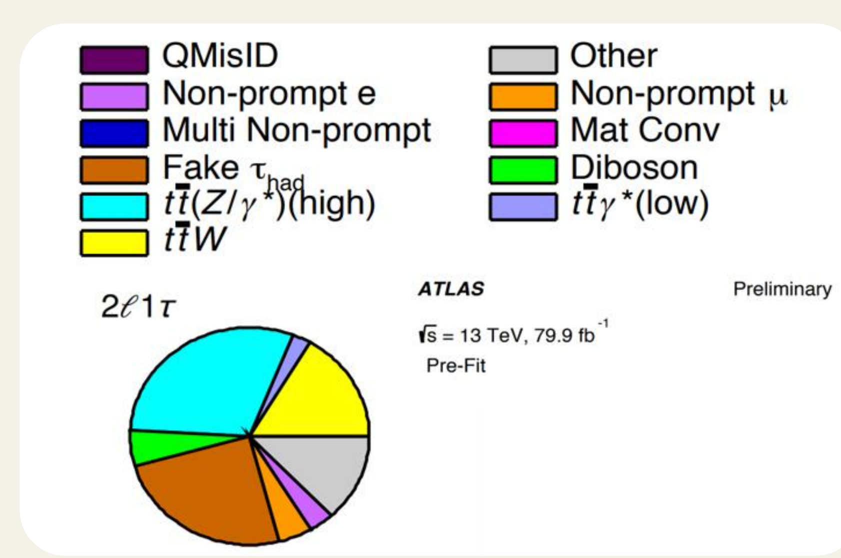
- The electron charge misassignment rate is measured in data using samples of $Z \rightarrow e^{+}e^{-}$ events.
- Event categorization:



- The categorisation according to the flavour of the sub-leading lepton is motivated by the fact that this lepton is more likely to be non-prompt.
- Event categories were used to determine the non-prompt light lepton background.
- Normalisation factors for non-prompt-lepton background contributions are estimated from the likelihood fit.







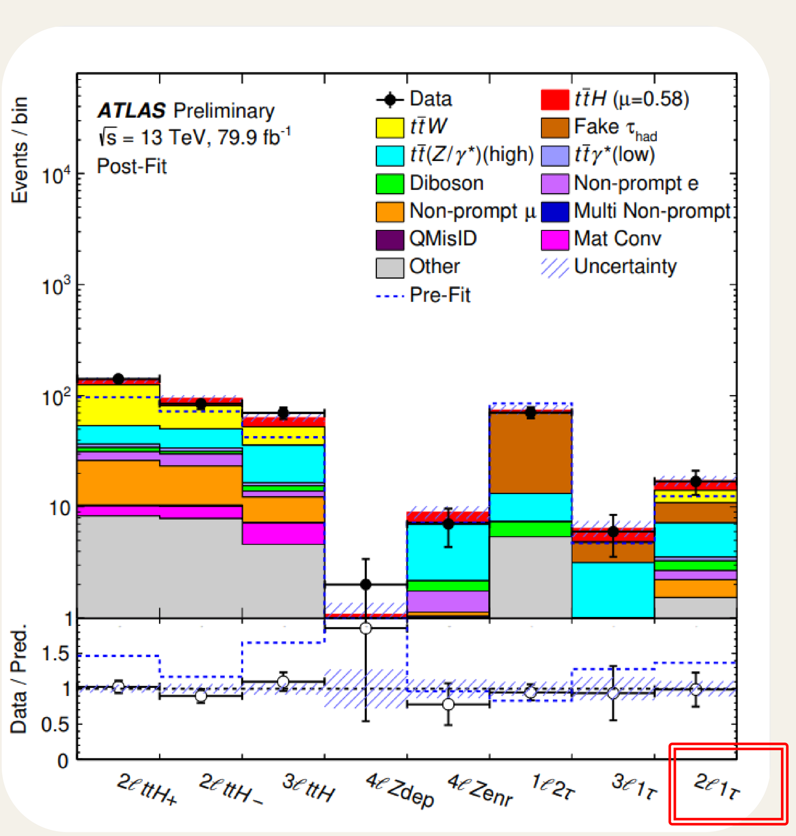
The fake τ_{had} background

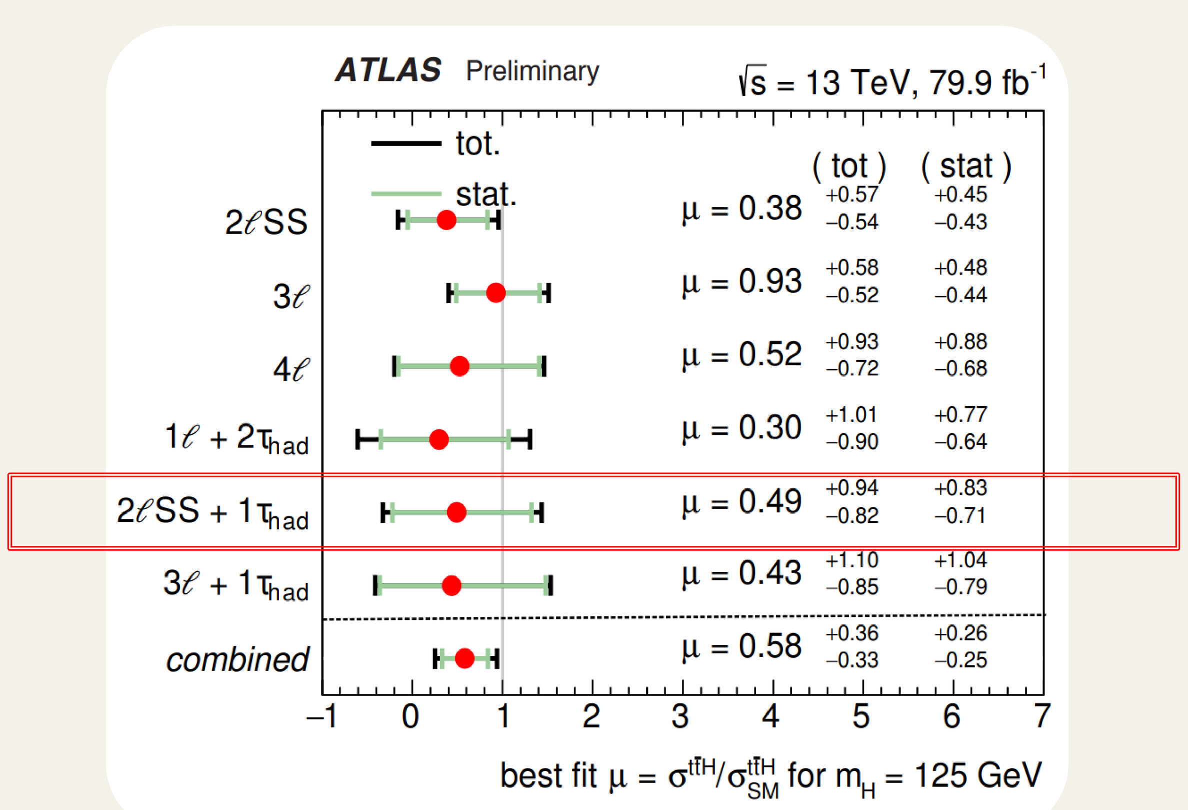
- Specific control region is primarily designed, enriched in dileptonic $t\bar{t}$ events, such that the selected τ_{had} candidates primarily originate from jets.
- It defined requiring two opposite-charge leptons, at least three jets, one b-tagged jet, and one τ_{had} candidate.
- It is used to determine a normalisation factor to correct mismodelling of the fake τ_{had} rate in the simulation.
- The normalisation factor (NF) is measured as a function of $p_T(\tau_{had})$.

	p_T (GeV)	NF		p_T (GeV)	NF
one-prong	25–45	1.05 ± 0.06	three-prong	25 – 50	1.25 ± 0.42
	≥ 70	0.64 ± 0.12		≥ 75	0.52 ± 0.71

- The fraction of fake τ_{had} background with an electron misidentified as a τ_{had} candidate is ~10% and is estimated with the simulation.
- The total systematic uncertainty depends on $p_T(\tau_{had})$ and is on average about 13% (60%) for one-prong (three-prong) τ_{had} candidates.

Results





- A maximum-likelihood fit is performed to determine the $t\bar{t}H$ cross section.
- The measured $t\bar{t}H$ production cross section (extrapolation to the inclusive phase space) is

$$\hat{\sigma}(t\bar{t}H) = 294^{+182}_{-162}\ \text{fb}$$

- The predicted SM cross section is

$$\sigma(t\bar{t}H) = 507^{+35}_{-50}\ \text{fb}$$

- The measured cross section is consistent with the SM prediction within uncertainties.

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SLEZSKÁ UNIVERZITA V OPAVĚ

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Motivation

- The associated production of a top-quark pair with the Higgs boson ($t\bar{t}H$) allows a direct measurement of top quark Yukawa coupling.
- A search based on $80\ \mathrm{fb}^{-1}$ dataset recorded with the ATLAS experiment during 2015-2017 at $\sqrt{s}$ = 13 TeV for $t\bar{t}H$ in multilepton final state is presented.
- Multilepton signatures are primarily sensitive to the decays $H \to WW^*$, $H \to \tau\tau$, and $H \to ZZ^*$.

Event selection

The $2l1\tau_{\mathrm{had}}$ final state is primarily sensitive to $H \to \tau\tau^*$, and $H \to WW^*$ and selected by the following requirements:

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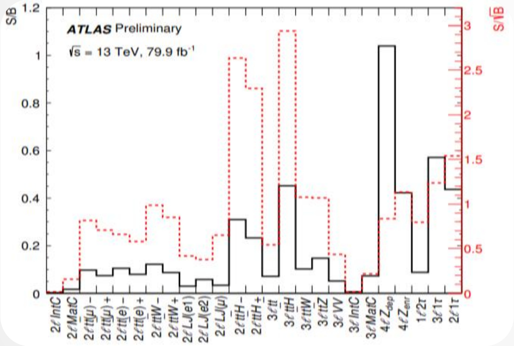


Pre-fit S/B (black line) and S/√ B (red dashed line) ratios for each analysis category

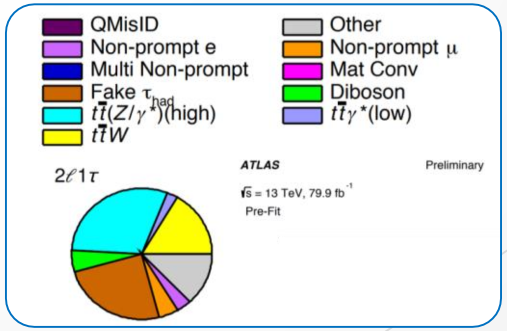
Backgrounds

Irreducible

- Mainly originate from $t\bar{t}W$ and $t\bar{t}(Z/\gamma^*)$, followed by VV production.
- Smaller contribution arising from the rare processes like tZ, tW, WtZ, $t\bar{t}WW$, VVV, $t\bar{t}t$, $t\bar{t}t\bar{t}$.

Reducible

- Charge misassignment. ($e^{\pm} \to e^{\pm}\gamma^* \to e^{\pm}\ e^{+}\ e^{-}$)
- Material conversions, heavy-flavour hadron decays or the improper reconstruction. The main contribution is coming from $t\bar{t}$.
- The fake τ_{had} background (from $t\bar{t}$ and $t\bar{t}V$ events with a jet misidentified as a τ_{had} candidate).



The fractional contributions of the various backgrounds in the $2l1\tau_{\mathrm{had}}$ final state

Estimation

- The electron charge misassignment rate is measured in data using samples of $Z \rightarrow e^+ + e^-$ events.

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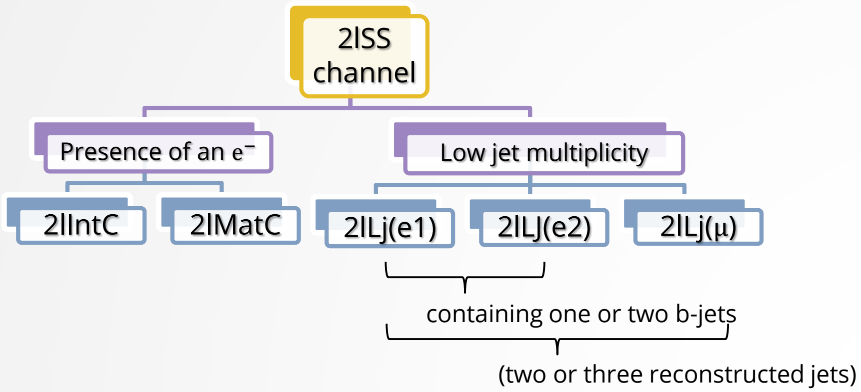
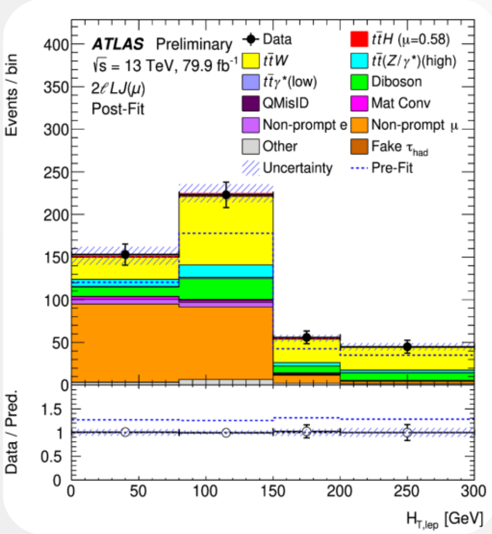
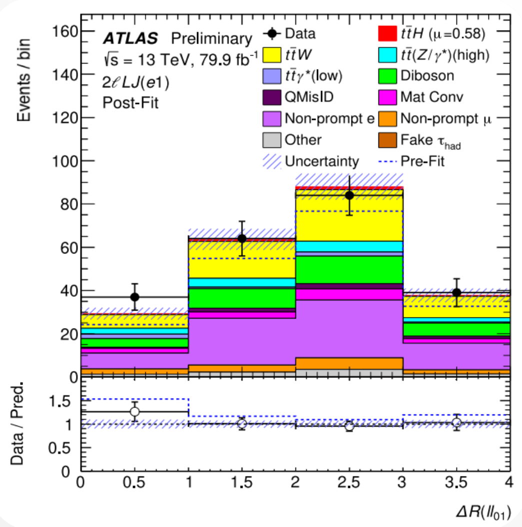
- Event categorization:



- Event categories were used to determine the non-prompt light lepton background.

- Normalisation factors for non-prompt-lepton background contributions are estimated from the likelihood fit.





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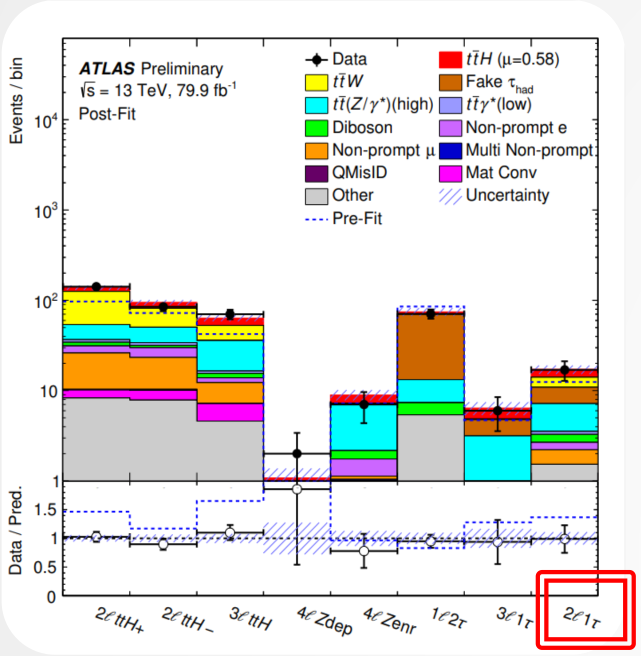
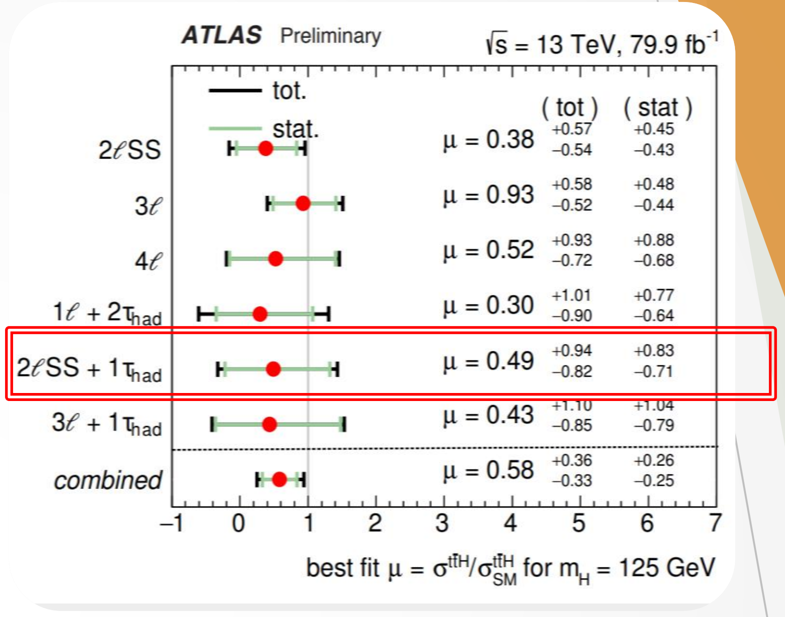


Comparison between data and prediction in the $t\bar{t}H$ to multi-lepton final states



The observed best-fit values of the $t\bar{t}H$ signal strength μ and their uncertainties by analysis channel and combined.

- A maximum-likelihood fit is performed to determine the $t\bar{t}H$ cross section.
- The measured $t\bar{t}H$ production cross section (extrapolation to the inclusive phase space) is

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