

# Search for $t\bar{t}H$ production in the 4lepton+Jets channel at $\sqrt{s}=13$ TeV using 13.2 $fb^{-1}$ data collected by the ATLAS detector at the LHC



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## Why search for $t\bar{t}H$ production?

- Powerful probe to measure Yukawa coupling of the Higgs boson to the top quark
- May provide key insights about the underlying mechanisms of Electroweak Symmetry Breaking
- Has potential to identify and disambiguate new physics effects that can modify the  $t\bar{t}H$  production cross section relative to the SM expectation

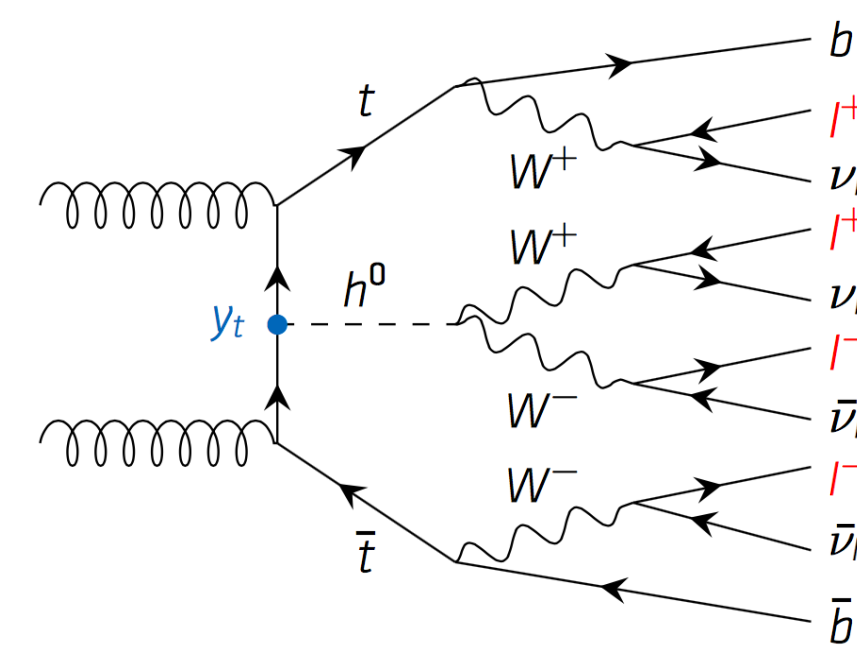


Figure 1:  $t\bar{t}H \rightarrow 4l$  Feynman diagram

## $t\bar{t}H$ in 4lepton final state

- Good signal/background
- Very pure channel as fraction of non-prompt leptons in 4l channel is very low compared to other channels

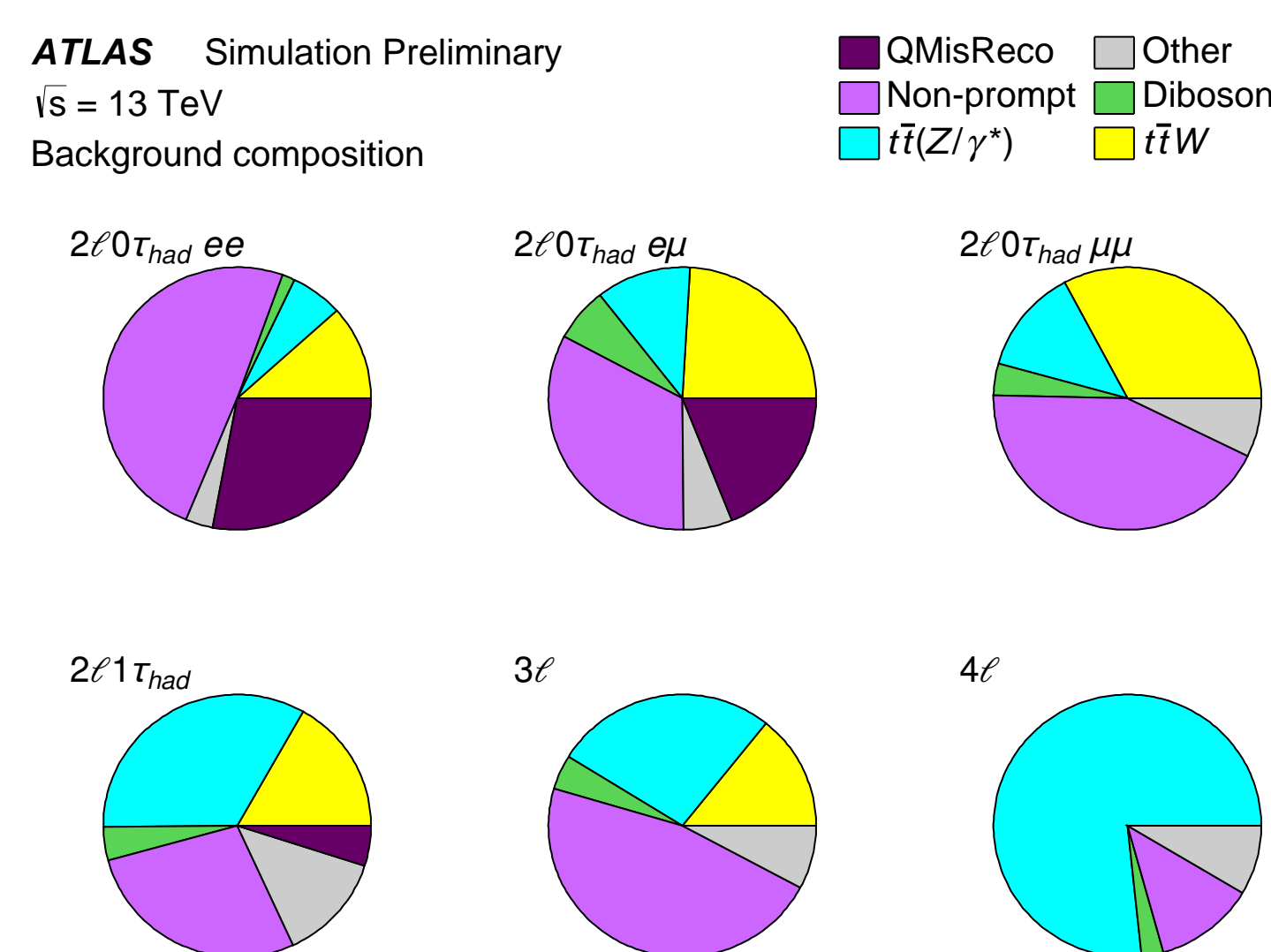


Figure 2: Background composition in the signal region

- Totally statistics limited channel; Has a great potential with more data

Higgs decay mode			
$\tau\tau$	$WW^*$	$ZZ^*$	Other
18%	72%	9%	2%

Table 1: Fraction of the expected  $t\bar{t}H$  signal arising from different Higgs decay modes in 4lepton final state

## Background Rejection

To reduce the background, we applied following selection cuts.

Selection Cut	Reduced Background
Exactly 4 tight isolated leptons $\exists \epsilon_i, q_i=0$	$t\bar{t}$ & Non-prompt lepton events
$M(l^+l^-, \text{OSSF}) \notin [81.2, 101.2]$ GeV	$ZZ$ & $ttZ$
$M(l^+l^-, \text{OSSF}) > 12$ GeV	Quarkonium decays
$\geq 2$ -jets with $\geq 1$ -btagged jet	$ZZ$
$M(l_0l_1l_2l_3) \in [100, 350]$ GeV	$ttZ$
$M(l_0l_1l_2l_3) \notin [120, 130]$ GeV	$H^- \rightarrow ZZ$

Table 2: Signal Region selection cuts; (OSSF = Opposite Sign Same Flavor)

## Estimation of fake lepton backgrounds

- Used semi data-driven “Fake Scale Factor” method
- Underlying idea is to correct Monte Carlo predictions according to lepton flavor and nature of environment in which it is produced
- Correction factors  $\lambda_l^e, \lambda_b^e, \lambda_l^μ, \lambda_b^μ$  are extracted from regions enriched in light and heavy flavor ( $b$ ) fakes.

$$N_{\text{Data}}^{f, \text{CR}} - N_{\text{others}}^{f, \text{CR}} = \lambda_l^f \cdot N_{tt}^{f, \text{CR}} + \lambda_b^f \cdot N_{Z+\text{jets}}^{f, \text{CR}} \quad (1)$$

## $t\bar{t}Z$ Validation Region

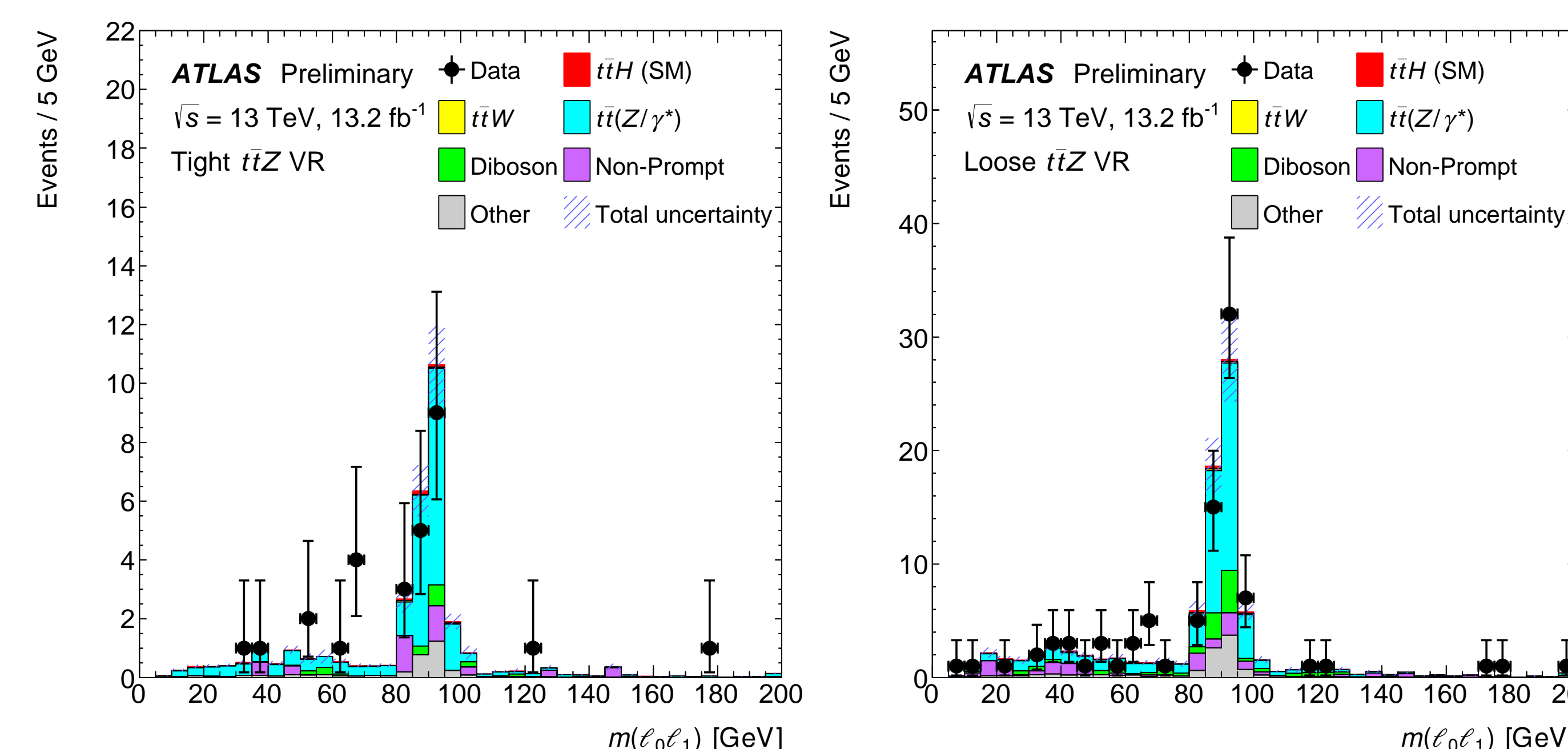


Figure 3: Invariant mass of leptons 0 and 1 for the a) tight and b) loose  $t\bar{t}Z$  validation regions.

Further details: ATLAS-CONF-2016-058

## Observed Event Yields

Expected signal, background yields and observed data events at  $\mathcal{L}=13.2/\text{fb}$

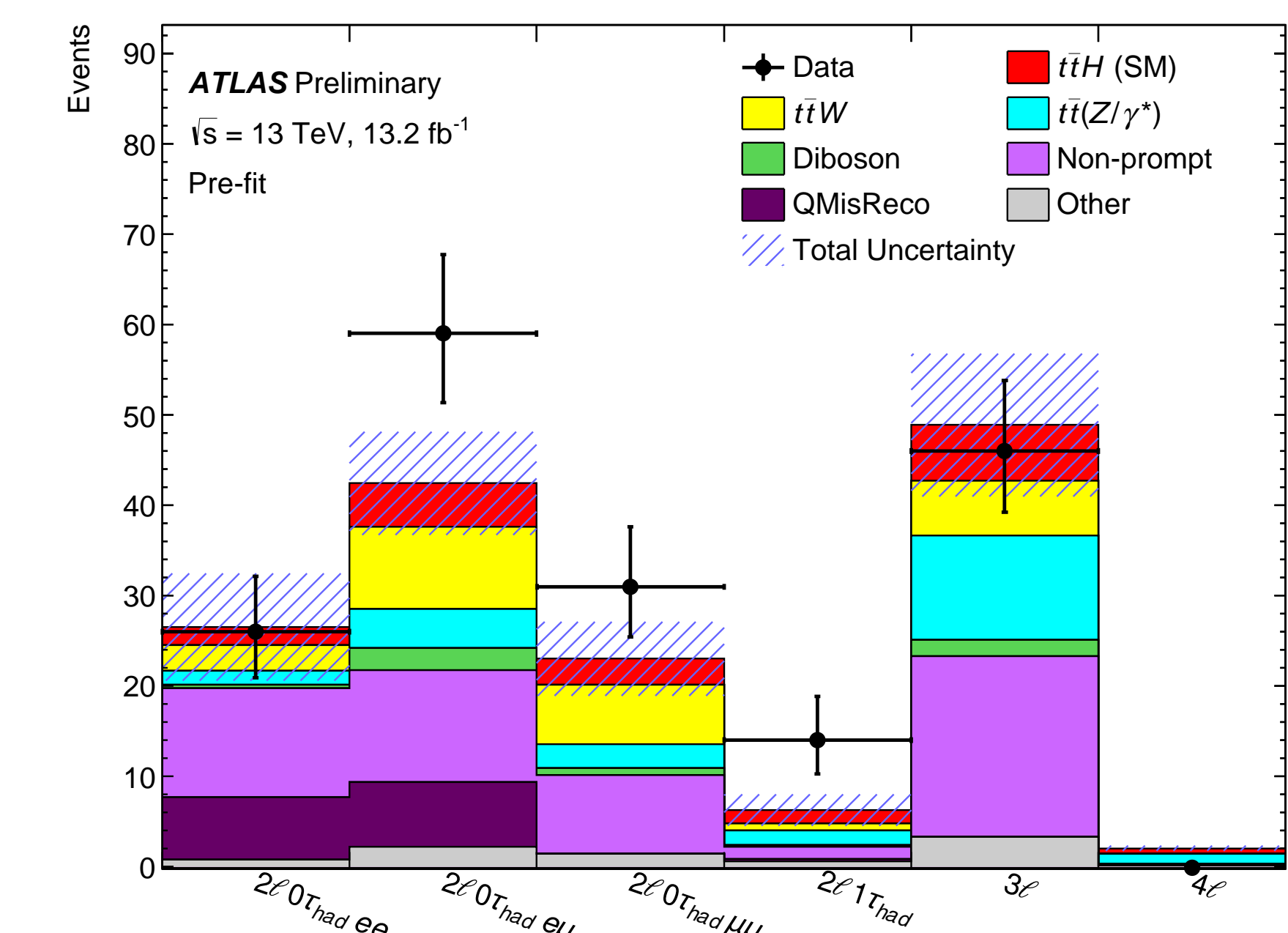


Figure 4: Signal and background predictions and observed data for each final state

$t\bar{t}Z/\gamma^*$	Diboson	Non-prompt leptons	Other
$1.12 \pm 0.20$	$0.04 \pm 0.04$	$0.18 \pm 0.10$	$0.12 \pm 0.05$
ttH	Total background	Data	
$0.59 \pm 0.10$	$1.46 \pm 0.25$	0	

Table 3: Expected and observed yields in the  $t\bar{t}H \rightarrow 4l$  signal region.

## Results

- Dominant systematic uncertainties come from  $t\bar{t}Z$  theory

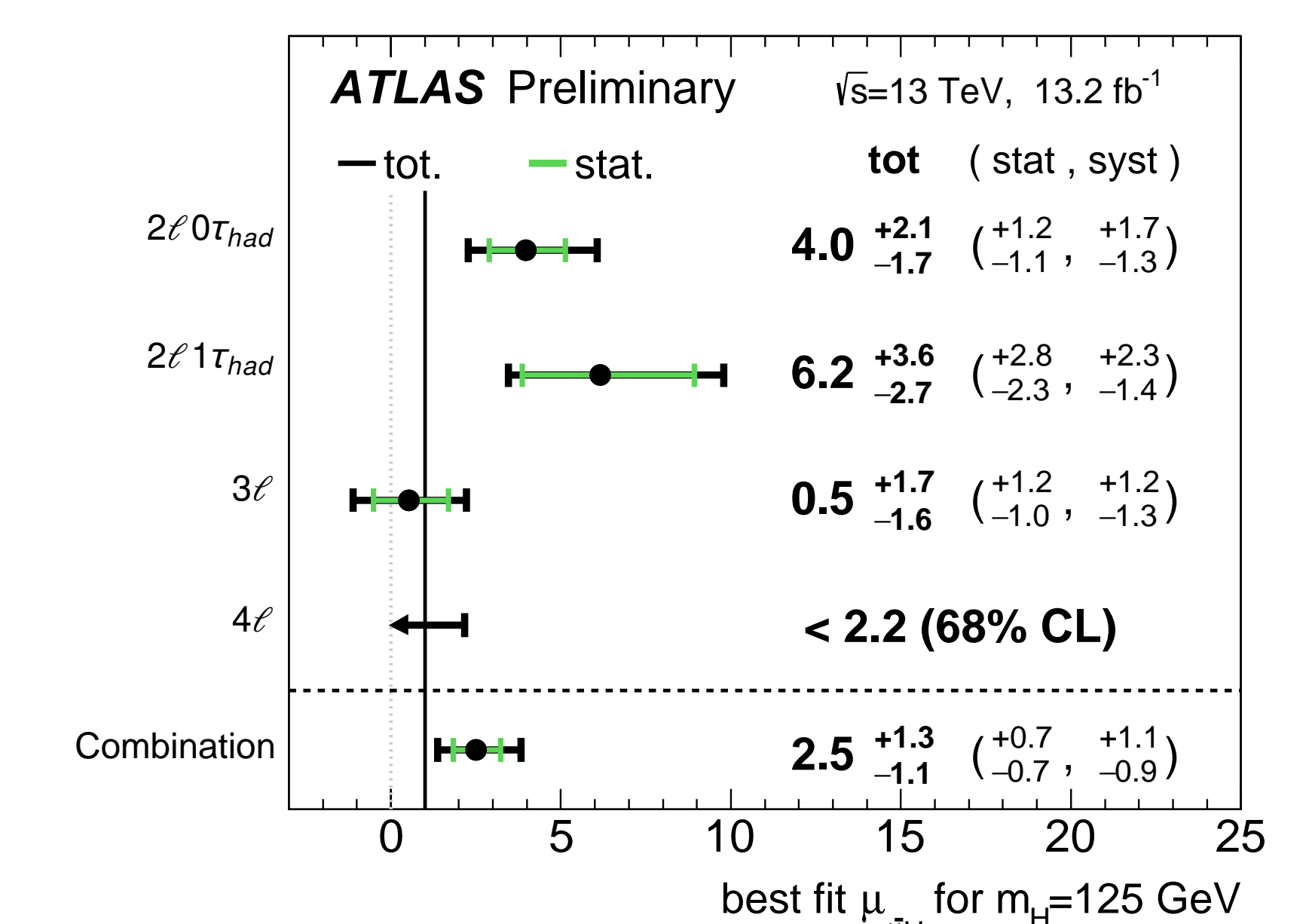


Figure 5: The best-fit value of the  $t\bar{t}H$  signal strength is obtained using maximum likelihood fit to observed data yields

$$\text{Best fit } \mu_{t\bar{t}H} = \frac{\sigma_{t\bar{t}H}}{\sigma_{SM}^{t\bar{t}H}} = 2.5_{-1.1}^{+1.3}$$