Measurement of the $t\bar{t}t\bar{t}$ production cross-section in pp collisions at $\sqrt{s} = 13$TeV with the ATLAS detector

***Based on** ATLAS-CONF-2021-013*

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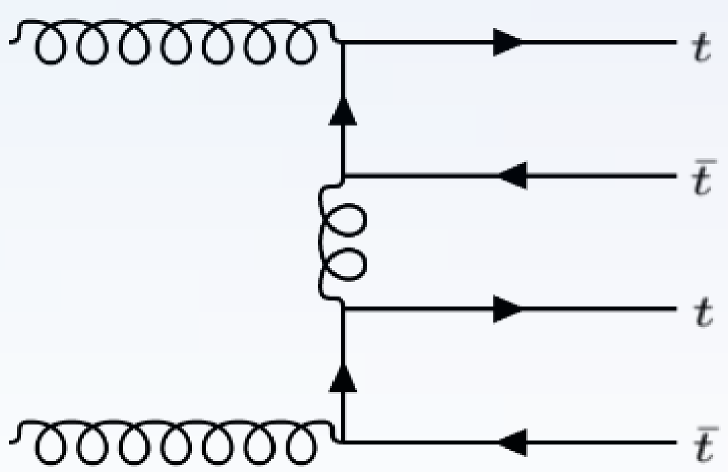
1. INTRODUCTION

Very rare top process!

SM cross section at 13 TeV:

$$\sigma_{t\bar{t}t\bar{t}} = 12.0 \pm 2.4 \text{ fb at NLO QCD + EW}$$

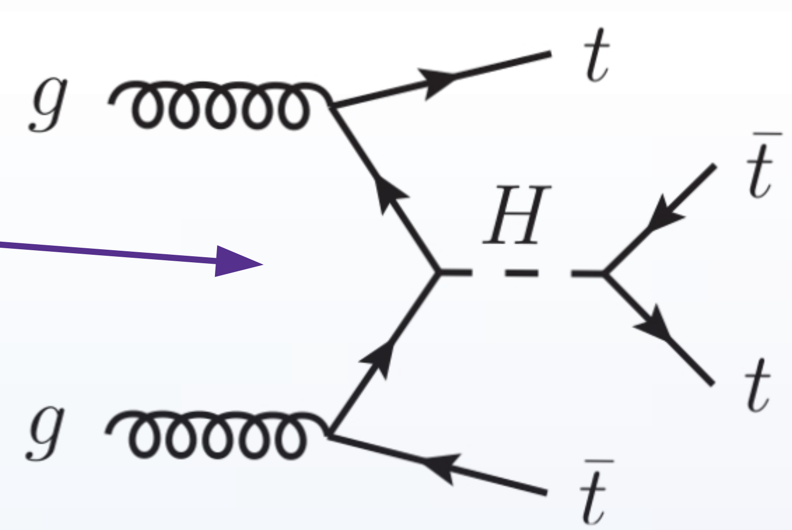
Leading QCD production



Top-Yukawa coupling

The $t\bar{t}t\bar{t}$ cross section is sensitive to the **magnitude** and **CP properties** of the Yukawa coupling of the top quark and the Higgs boson

Leading order Higgs / EW Feynman diagram



Sensitivity to BSM

Enhancement of the $t\bar{t}t\bar{t}$ cross section...

In **SUSY** via gluino pair production

In **two-Higgs-doublet model** (2HDM) via production of heavy pseudoscalar boson

Four fermion couplings in **EFT**

2. ANALYSIS CHANNELS

Fig. 1: Branching of four W bosons

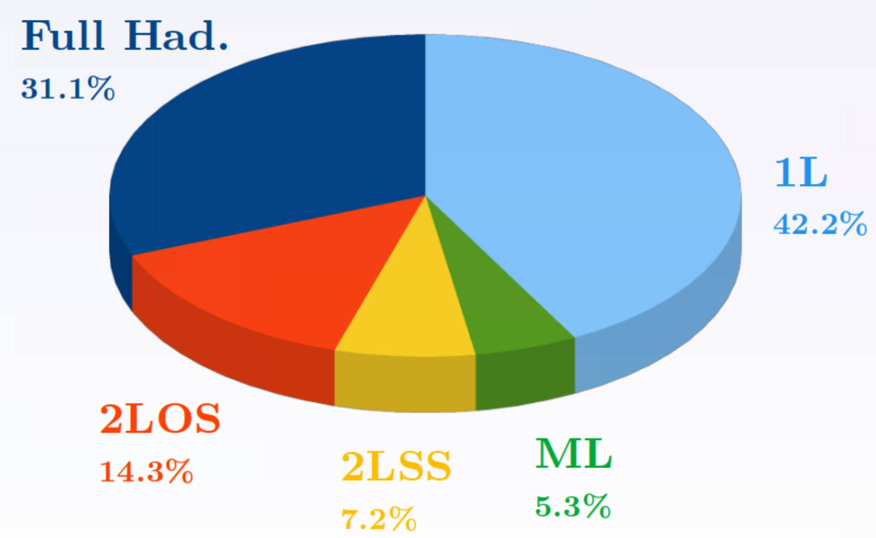
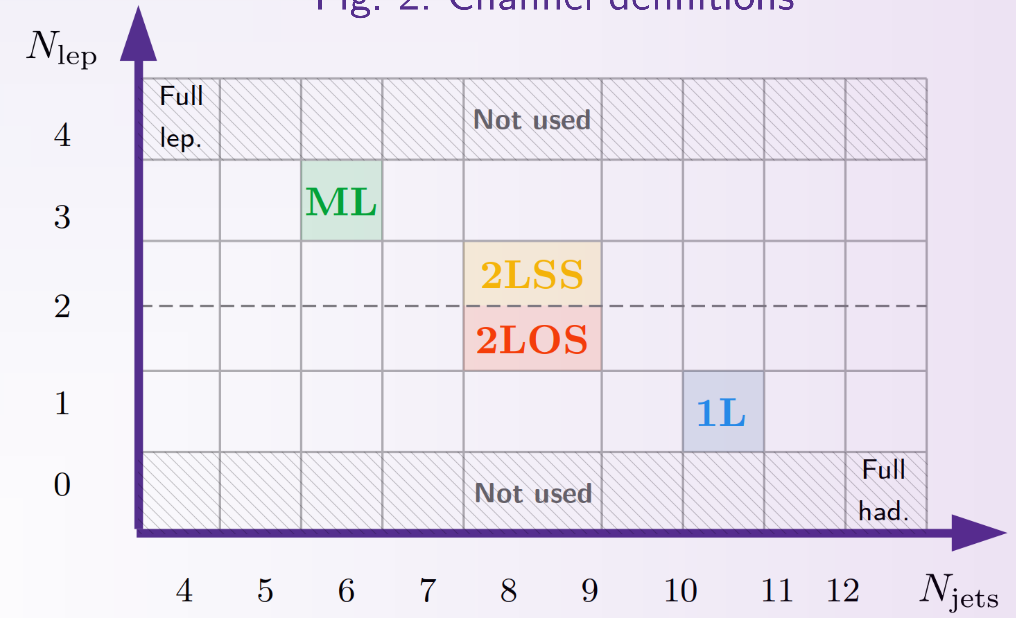


Fig. 2: Channel definitions



LHC $\sqrt{s}$ = 13 TeV Significance obs. (exp.) [σ]	ATLAS 36.1 fb^{-1}	CMS 35.8 fb^{-1}	CMS 137 fb^{-1}	ATLAS 139 fb^{-1}
2LSS/ML	3.0 (0.8) [1]	1.6 (1.0) [3]	2.6 (2.7) [5]	4.3 (2.4) [6]
				This poster
1L/2LOS	1.0 (0.6) [2]	0.0 (0.4) [4]	———	1.9 (1.0)
Combination	2.8 (1.0) [2]	1.4 (1.1) [4]	———	4.7 (2.6)

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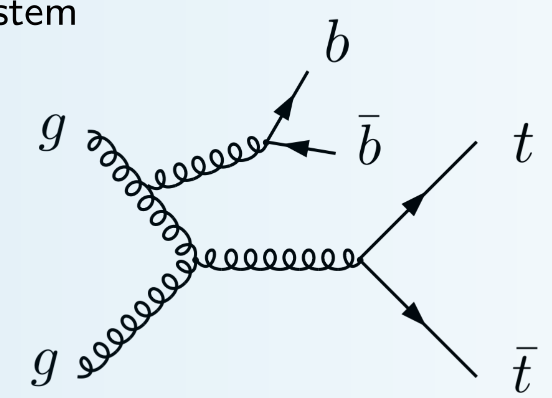
3. ANALYSIS OVERVIEW

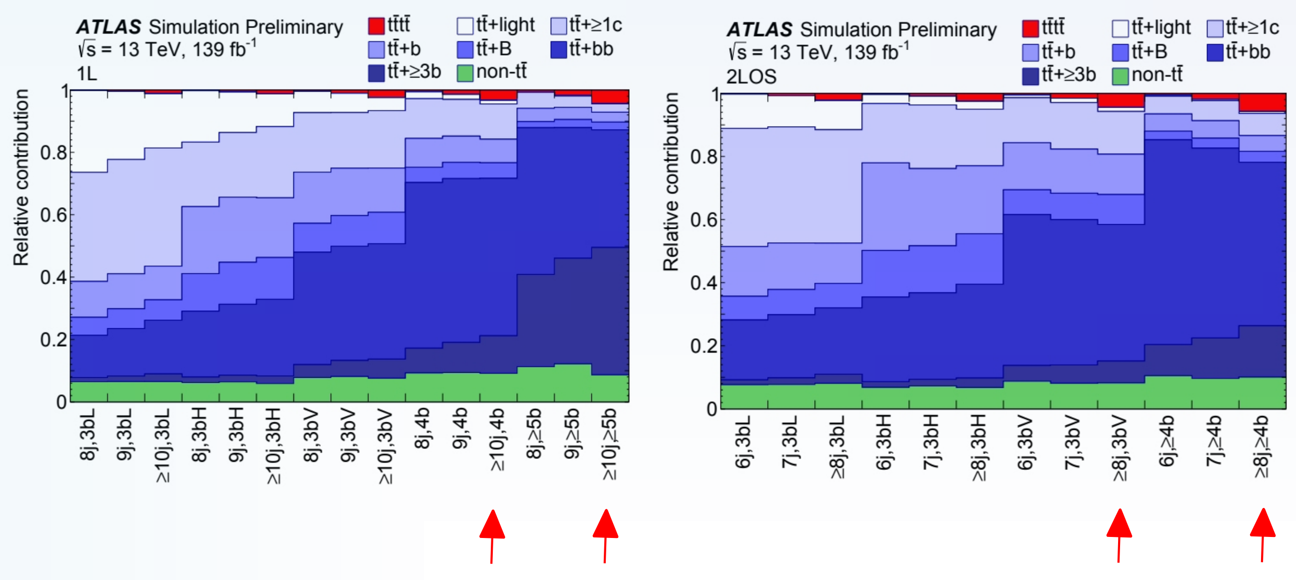
Main background $t\bar{t}$+jets

Background components defined according to **flavour** of jets not from $t\bar{t}$ system



$t\bar{t}+b\bar{b}$ is the main background in the signal sensitive regions

Fig. 3: Relative contribution of signal and backgrounds in all regions in 1L (left) and 2LOS (right) channels



Regions used in the analysis

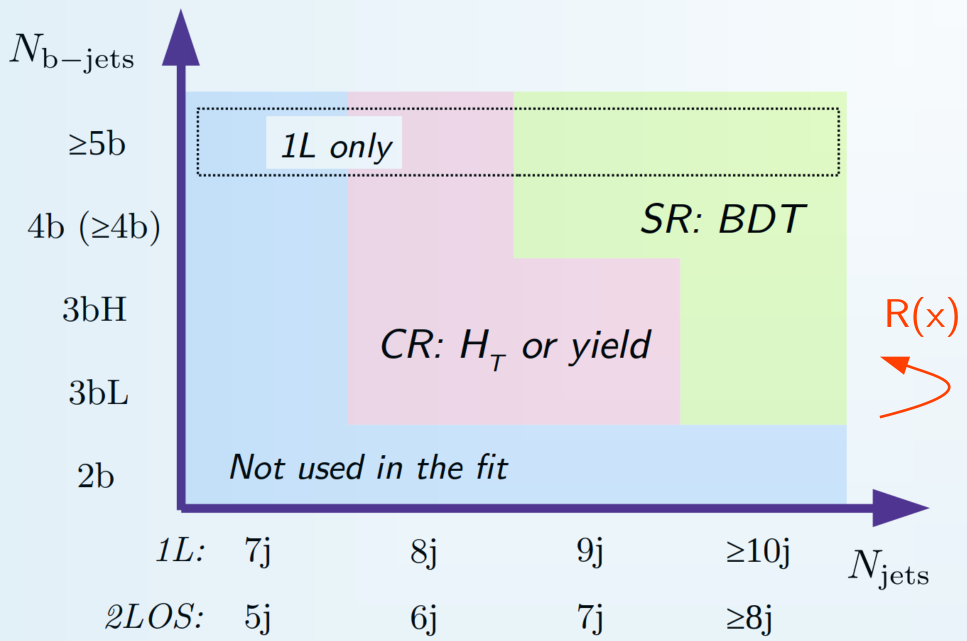


Fig. 4: Schematic view of the event categorisation

Events divided based on 70% OP b-tagging requirements
- provides separation between $t\bar{t}$+jets flavour components
- further split into 3bH/3bL based on 60% and 85% OP

14 BDT variables are related to transverse kinematics, multiplicity and substructure of large-R jets, jet tagging, b-tagging, MET and lepton information.
The **most discriminating** variable in both channels is the **sum of pseudocontinuous b-tagging score**

Reweighting factors R(x)
derived in 2b regions and propagated to CR/SR regions

Pre-fit corrections to MC mismodelling of $t\bar{t}$+HF

A) Flavour rescaling

Corrects the **underestimation of $t\bar{t}$ + heavy flavour (HF) jets** production in MC simulation
- Factors derived from fit to data exploiting different $t\bar{t}$+jets flavour fractions across regions defined by various b-tagging requirements

B) Sequential kinematic reweighting

Used to mitigate the **kinematic mismodelling observed in $t\bar{t}$ + jets** MC
- The reweighting factors R(x) are used to correct distributions of the variables most representative of the global kinematics of the events:

$$R(x) = \frac{\mathrm{Data}(x) - \mathrm{MC}^{\mathrm{non}-t\bar{t}}(x)}{\mathrm{MC}^{t\bar{t}}(x)}$$

$t\bar{t}$ + jets MC normalization
corrected to data
in each (N_{jets}, $N_{\mathrm{LR\text{-}jets}}$) bin

→

H_T spectrum
corrected using H_T related variable
in each $N_{\mathrm{LR\text{-}jets}}$ bin

→

Spectrum of average ΔR
Between any two jets in each (N_{jets}, $N_{\mathrm{LR\text{-}jets}}$) bin corrects mismodelling of angular distributions

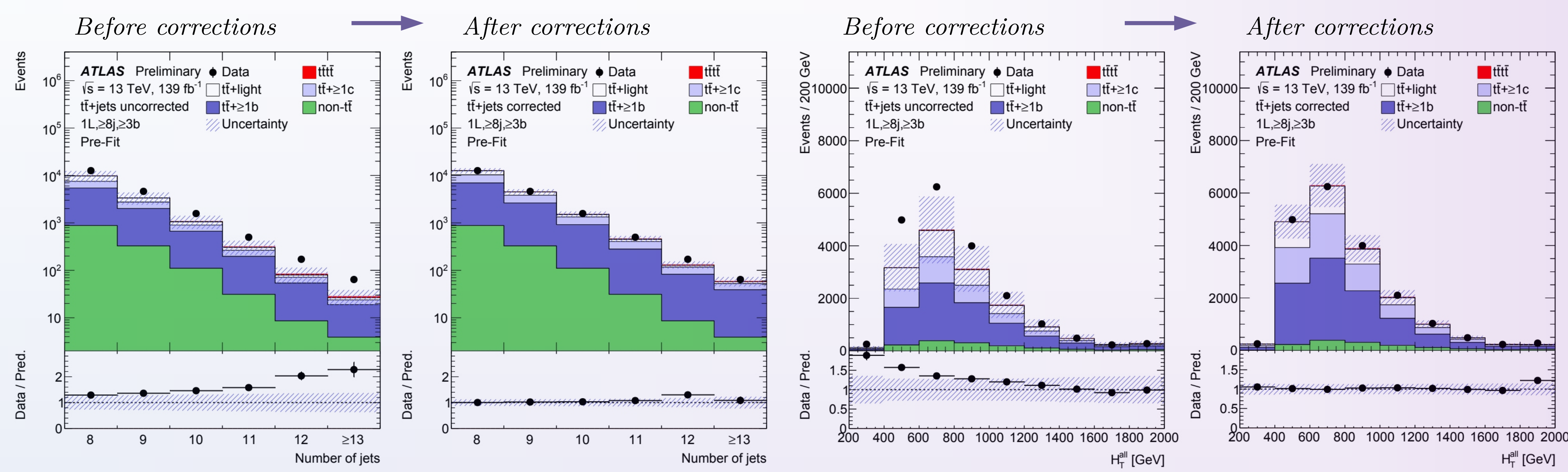


Fig. 5: The N_{jets} and H_T^{all} distributions in the ($N_{jets} \geq 8$, $N_{b\text{-}jets} \geq 3$) region in the 1L channel before (left) and after (right) the corrections

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4. 1L/2LOS RESULTS

Binned profile likelihood fit to extract $t\bar{t}t\bar{t}$ signal strength μ, defined as the ratio of the measured $t\bar{t}t\bar{t}$ production cross-section to that predicted by the Standard Model. There are 21 regions used in the fit (12 in 1L + 9 in 2LOS) in which **BDT** and $\mathbf{H_T^{all}}$ are fitted in signal and control regions respectively.

Fitted signal strength in 1L/2LOS: $\mu = 2.2 \pm 0.7(\text{stat.})^{+1.5}_{-1.0}(\text{syst.}) = 2.2^{+1.6}_{-1.2}$

Measurement **uncertainty** dominated by **modelling** of $t\bar{t}t\bar{t}$ signal and the $t\bar{t}$+HF background

Uncertainty source	$\Delta\sigma_{t\bar{t}t\bar{t}}$ [fb]	
Signal Modelling		
$t\bar{t}t\bar{t}$ modelling	+8	-3
Background Modelling		
$t\bar{t}+\geq 1b$ modelling	+8	-7
$t\bar{t}+\geq 1c$ modelling	+5	-4
$t\bar{t}$+jets reweighting	+4	-3
Other background modelling	+4	-3
$t\bar{t}$+light modelling	+2	-2
Experimental		
Jet energy scale and resolution	+6	-4
b-tagging efficiency and mis-tag rates	+4	-3
MC statistical uncertainties	+2	-2
Luminosity	< 1	
Other uncertainties	< 1	
Total systematic uncertainty	+15	-12
Statistical uncertainty	+8	-8
Total uncertainty	+17	-15

Tab. 1: Contribution from different systematic sources to the measured $t\bar{t}t\bar{t}$ production cross section

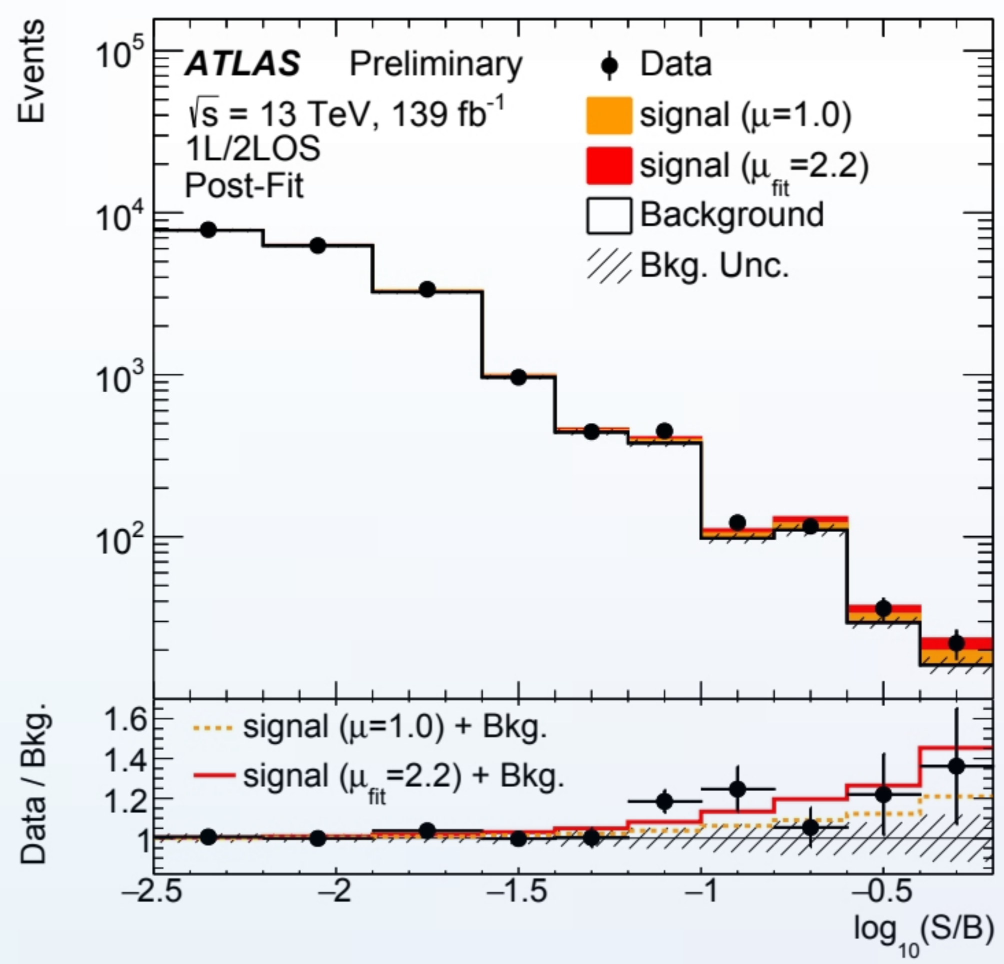
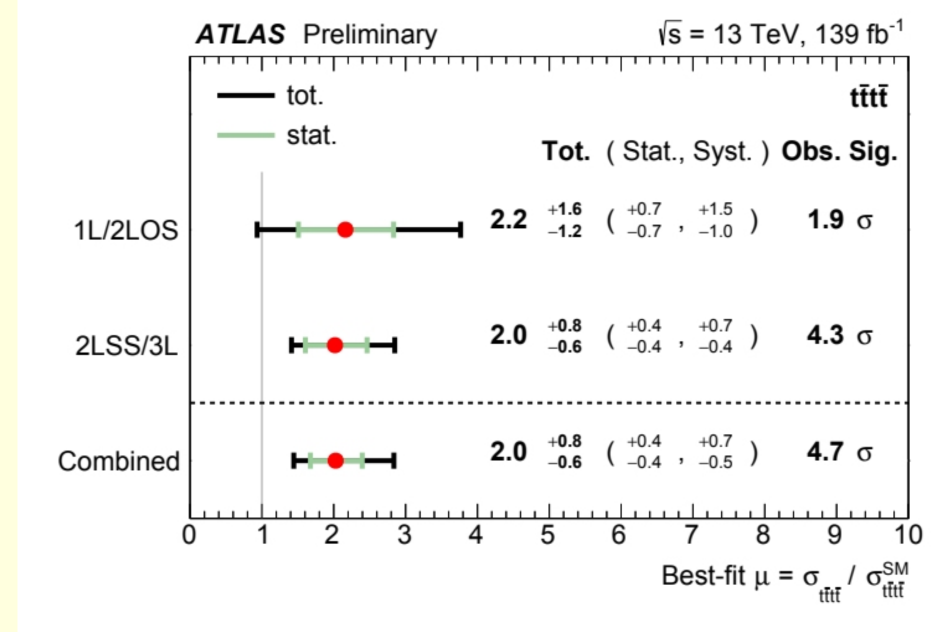


Fig. 6: Observed & expected event yields

5. COMBINATION RESULTS

Combination of 1L/2LOS with 2LSS/ML was performed via a simultaneous profile-likelihood fit in all regions of both analyses with all systematic uncertainties.

- Different dominant systematics in the two channels
  → impact of correlations is small



Combined result for 1L/2LOS and 2LSS/ML channels

$$\sigma_{t\bar{t}t\bar{t}} = 25^{+7}_{-6}\ \text{fb}$$ **4.7 σ** (2.6 σ expected)

Measured cross section is **consistent with SM** within 2.0 standard deviations

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