



Barcelona Institute of
Science and Technology

Measurement of the four-top-quark production in 13 TeV pp collisions with the ATLAS experiment

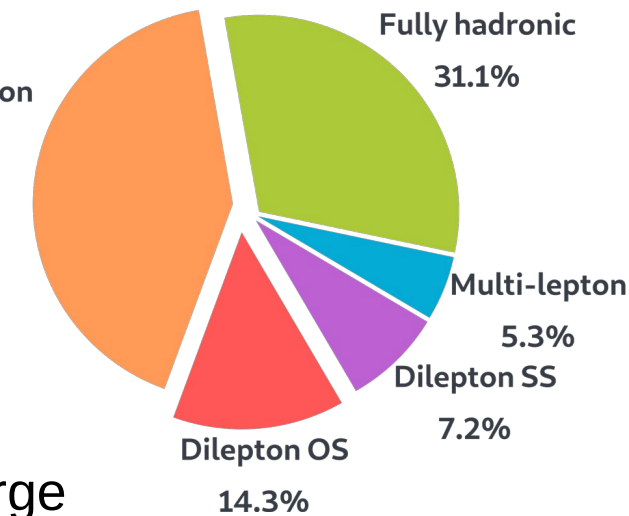
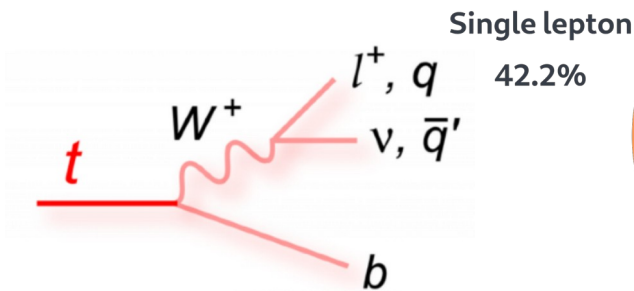
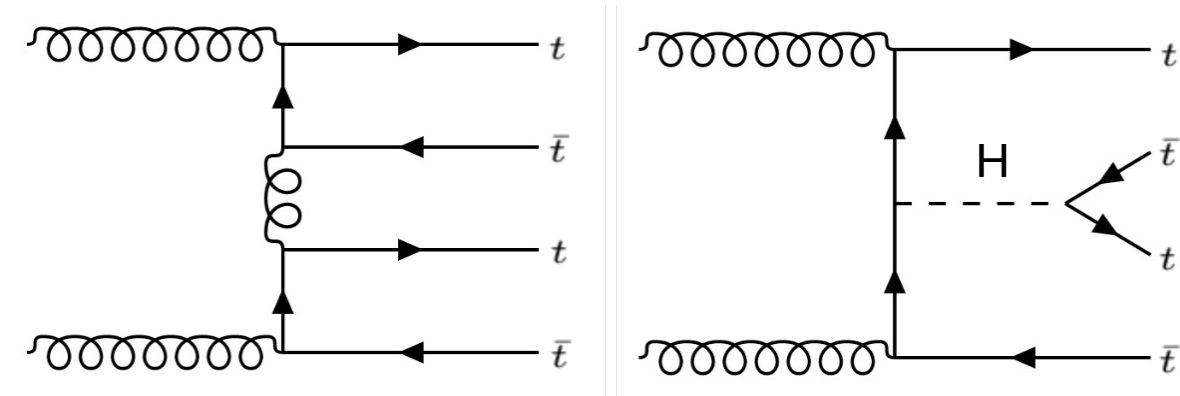
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on behalf of the ATLAS Collaboration

MoriondEW
22 March 21

Introduction

- Four top production: $pp \rightarrow t\bar{t}t\bar{t}$, is a rare and theoretically challenging process
 - $\sigma^{\text{NLO}}(\text{tttt}) = 12.0 \pm 2.4 \text{ fb}$ at NLO QCD+EW at 13 TeV
[arXiv:1711.02116 \[hep-ph\]](https://arxiv.org/abs/1711.02116)
- Sensitive to the top-Higgs Yukawa coupling
- Extremely high energy scale production makes it naturally sensitive to many BSM models, e.g.
 - Gluino pair production in SUSY
 - Heavy pseudoscalar/scalar boson in 2HDM
 - Four-fermion contact interaction within EFT



• Signatures:

→ **2ℓSS / 3ℓ** :

→ Low branching fraction, but small background (ttW, ttZ, non-prompt leptons, charge misidentification)

→ [Eur. Phys. J. C \(2020\) 80:1085](https://arxiv.org/abs/1908.07407)

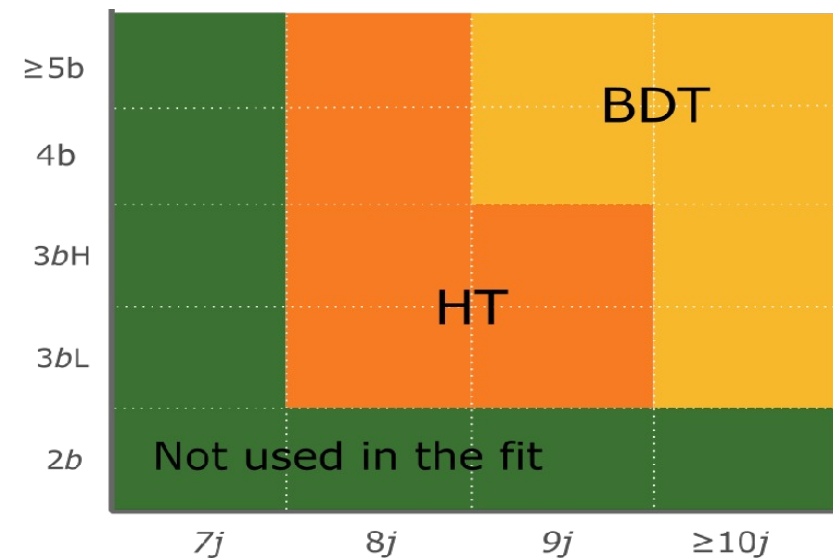
→ **1ℓ / 2ℓOS** :

▪ Dominant branching fraction, but large background from tt+jets

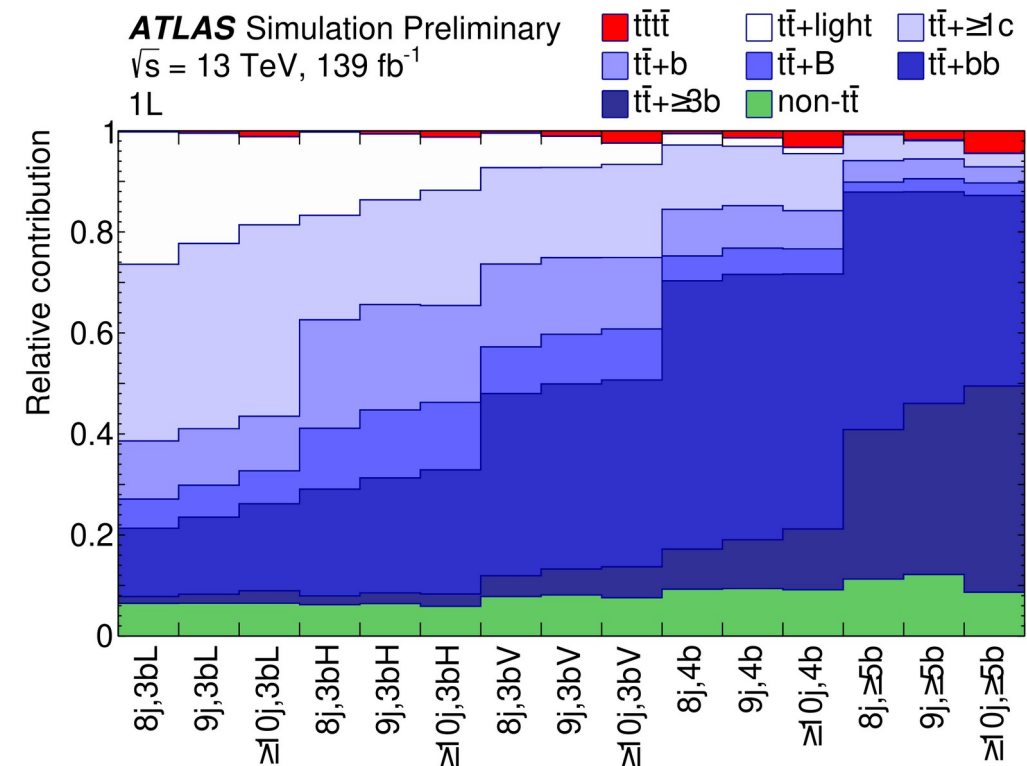
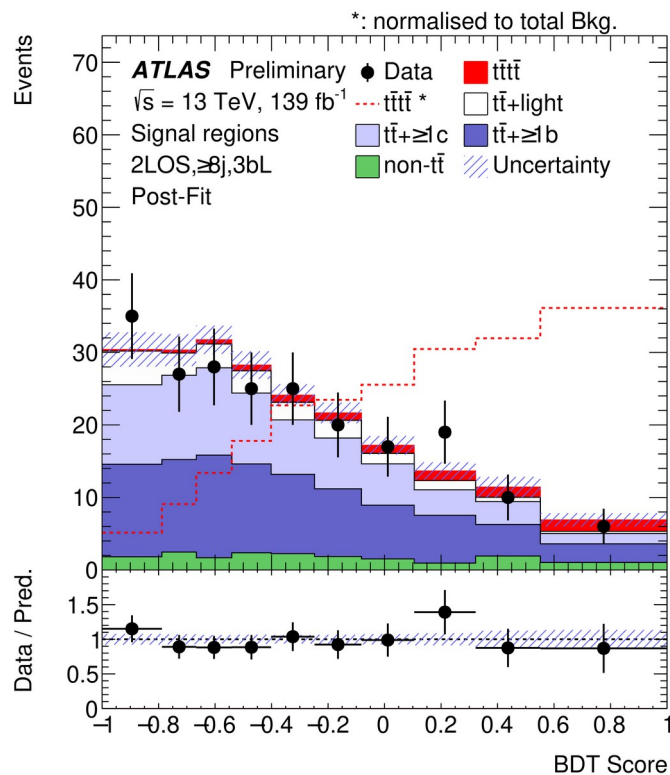
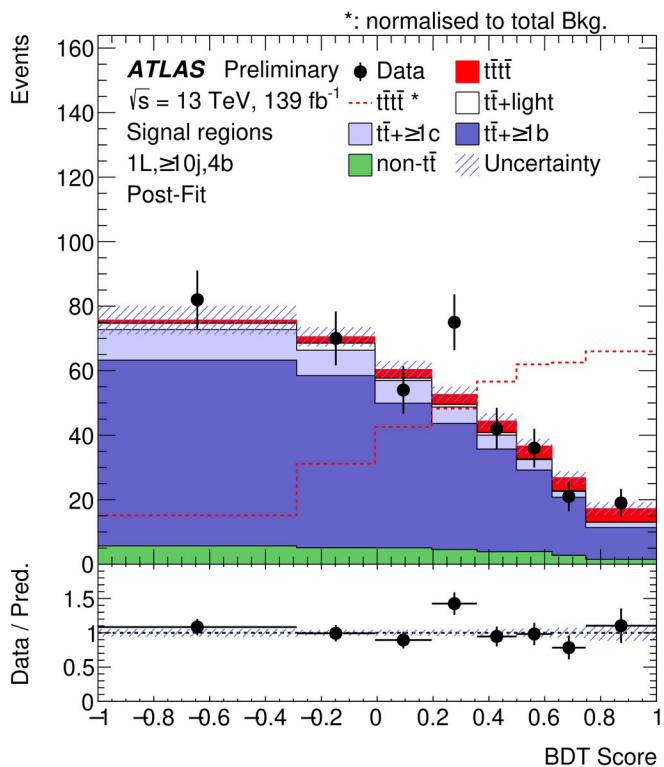
▪ [ATLAS-CONF-2021-013](https://arxiv.org/abs/2103.12918)

Analysis Strategy (1 ℓ /2 ℓ OS Channel)

- Event signature characterized by one or two OS leptons and high jet multiplicity and b-jet multiplicities
- Main background: $t\bar{t}$ +jets (incl heavy-flavor) production, which is challenging to model accurately by the MC simulation
- Signal extracted via profile likelihood fit across all event categories accounting for a complex model of systematic uncertainties

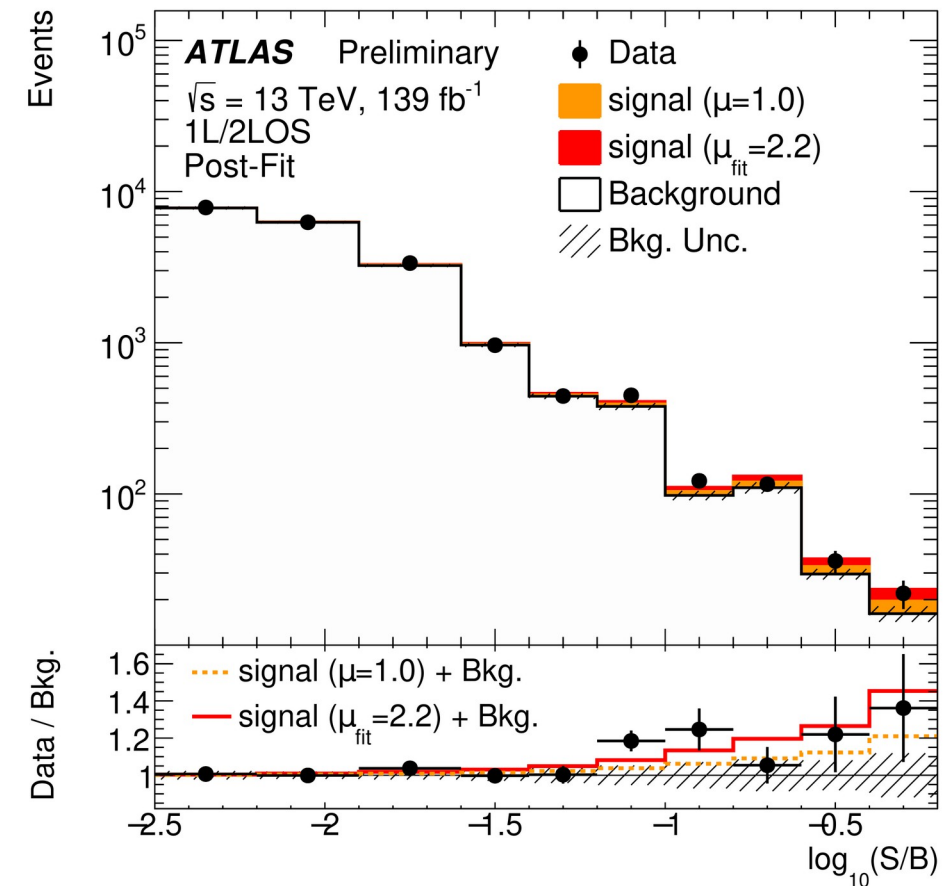
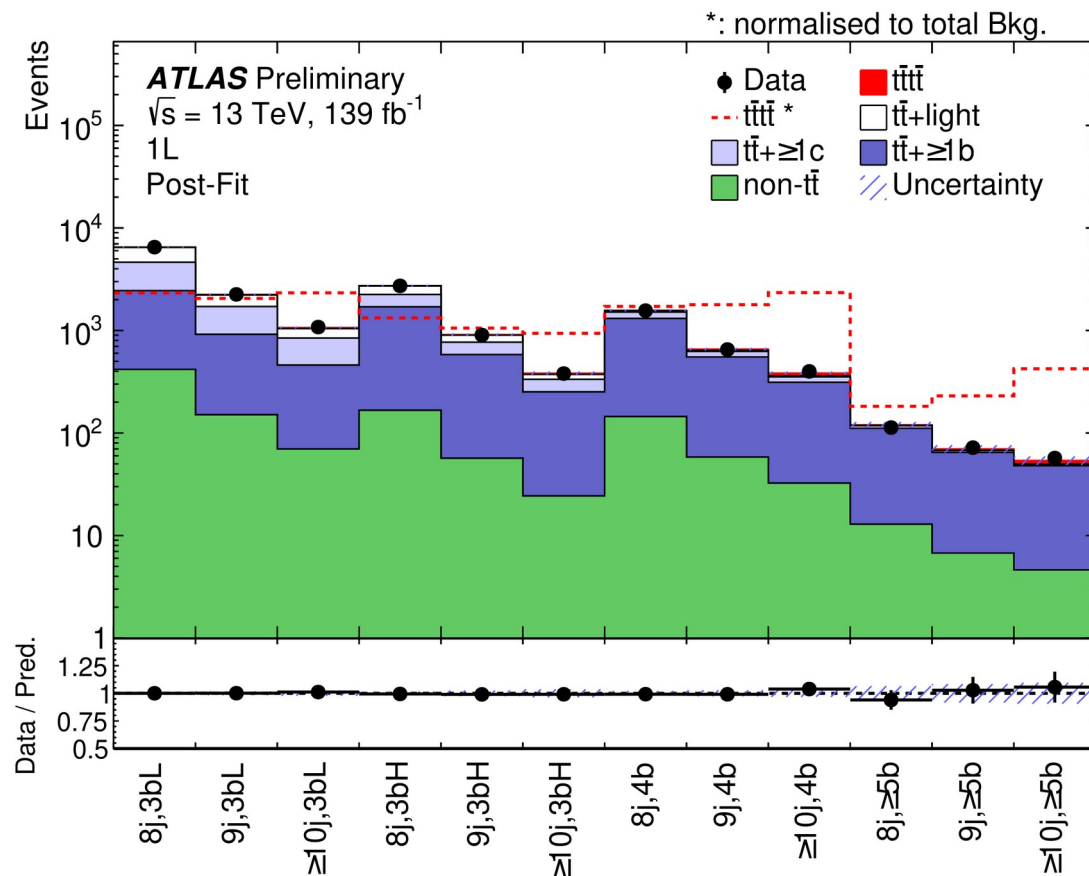


Example BDTs



1L/2LOS Result

- Good agreement obtained between data and post-fit prediction
- Dominant uncertainties on signal strength from $t\bar{t}t$ theoretical cross-section and modelling, and from $t\bar{t}+\geq 1b$ modelling.
- The extracted signal strength is: $\mu = 2.2^{+0.7}_{-0.7}(\text{stat.})^{+1.5}_{-1.0}(\text{syst.}) = 2.2^{+1.6}_{-1.2}$

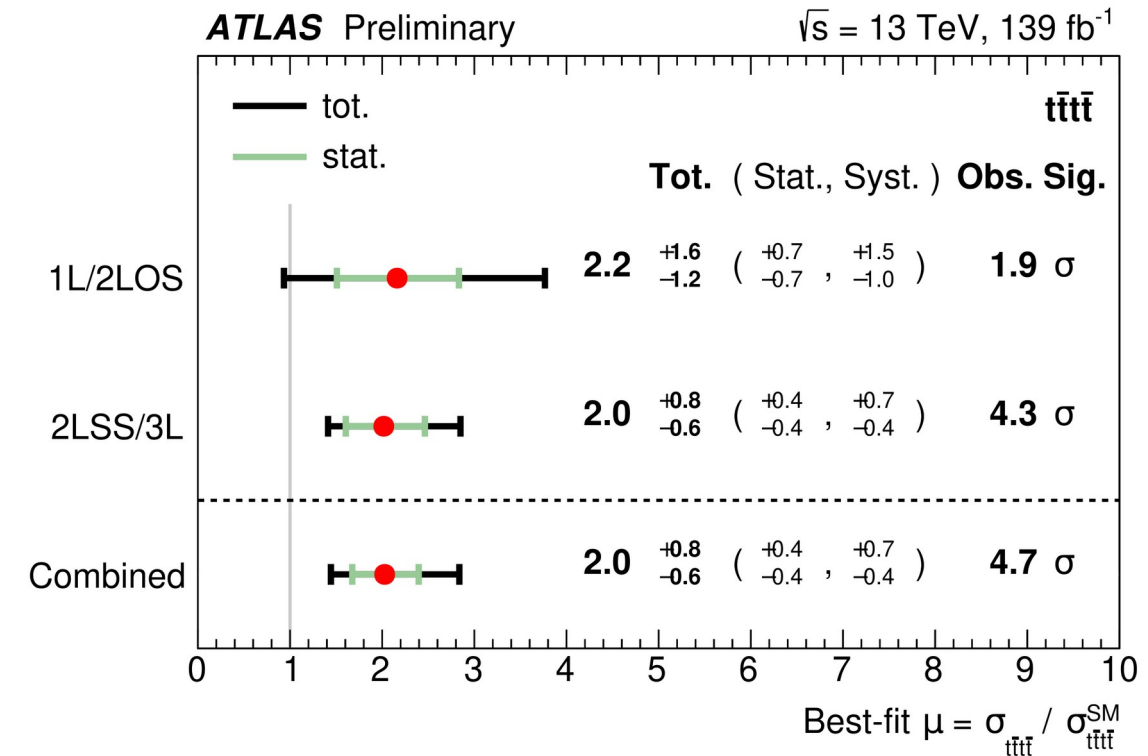


- Signal strength in $1\ell/2\ell$ OS and 2ℓ SS/ 3ℓ channels found to be in good agreement
 → Combine for improved sensitivity

- The combined four-top-quark production cross section is measured to be:

$$\sigma_{t\bar{t}t\bar{t}} = 25^{+7}_{-6} \text{ fb} \quad \sigma_{t\bar{t}t\bar{t}}^{SM} = 12.0 \pm 2.4 \text{ fb}$$

- with a corresponding observed (expected) signal significance of **4.7 (2.6)** standard deviations over background-only hypothesis
- It is consistent within **2.0** standard deviations with the Standard Model expectation



BACKUP

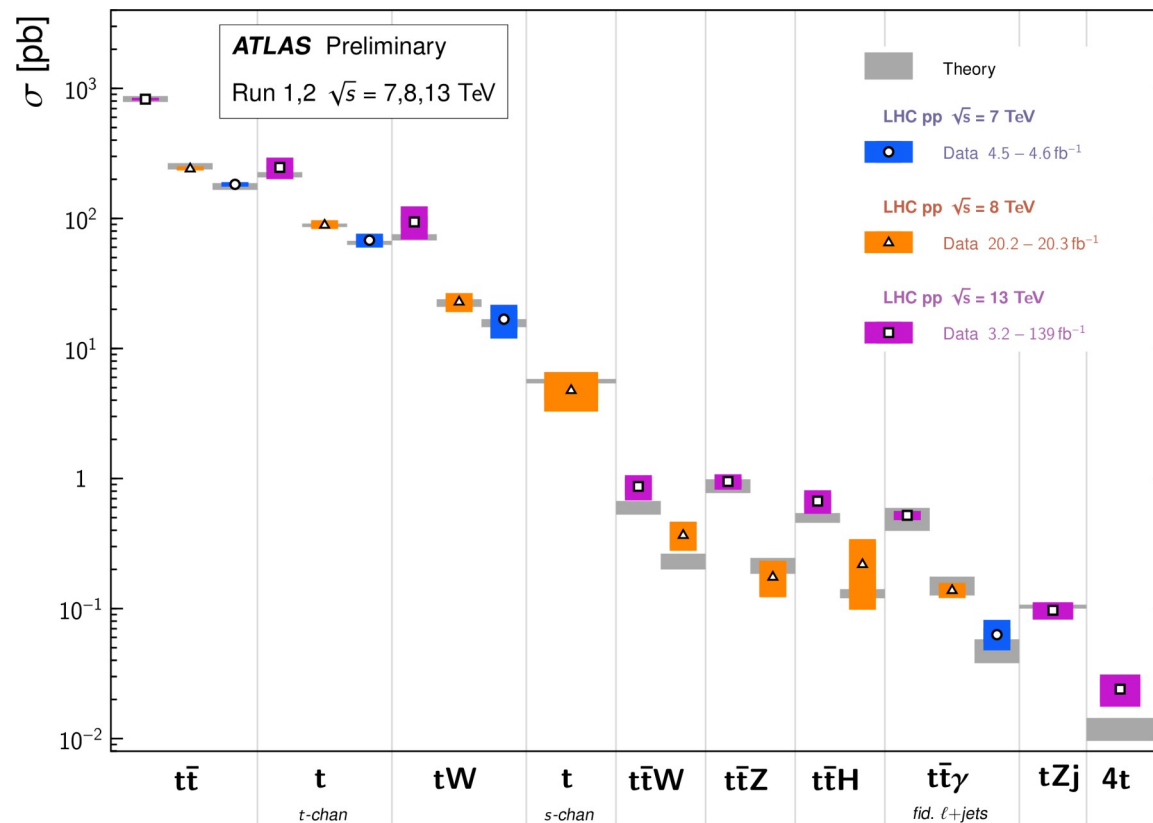
Top Quark Production Cross Section Measurements

- Largest background by top quark pair production
 - Expected number of events during Run 2 (139 fb^{-1})
 - ◆ $\sim 100\text{M}$ events for top quark pair production
 - ◆ $\sim 1\text{k}$ events for four-top-quark

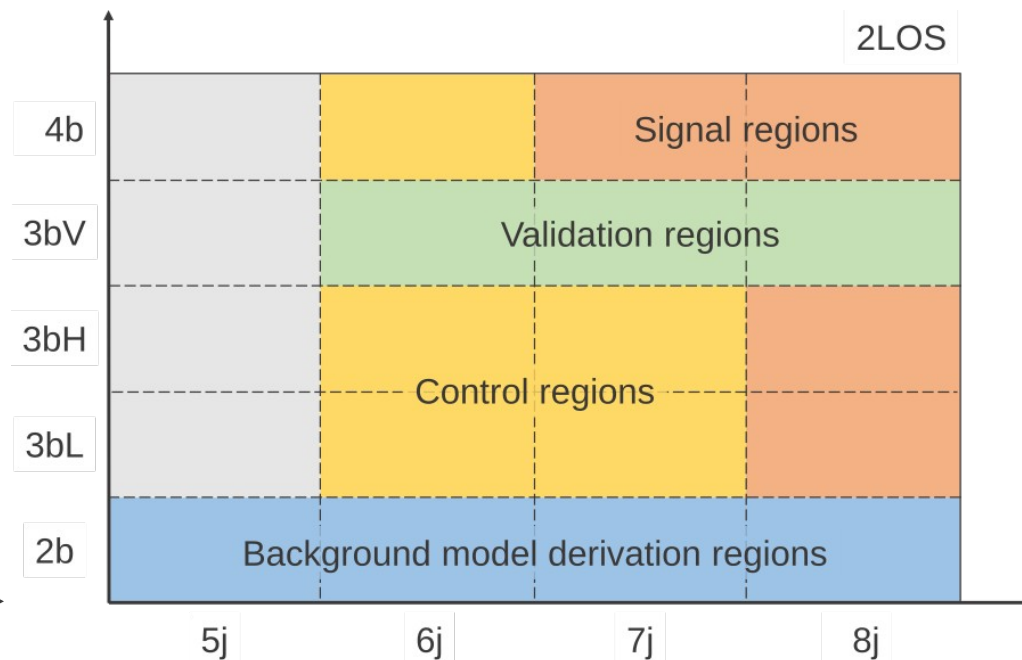
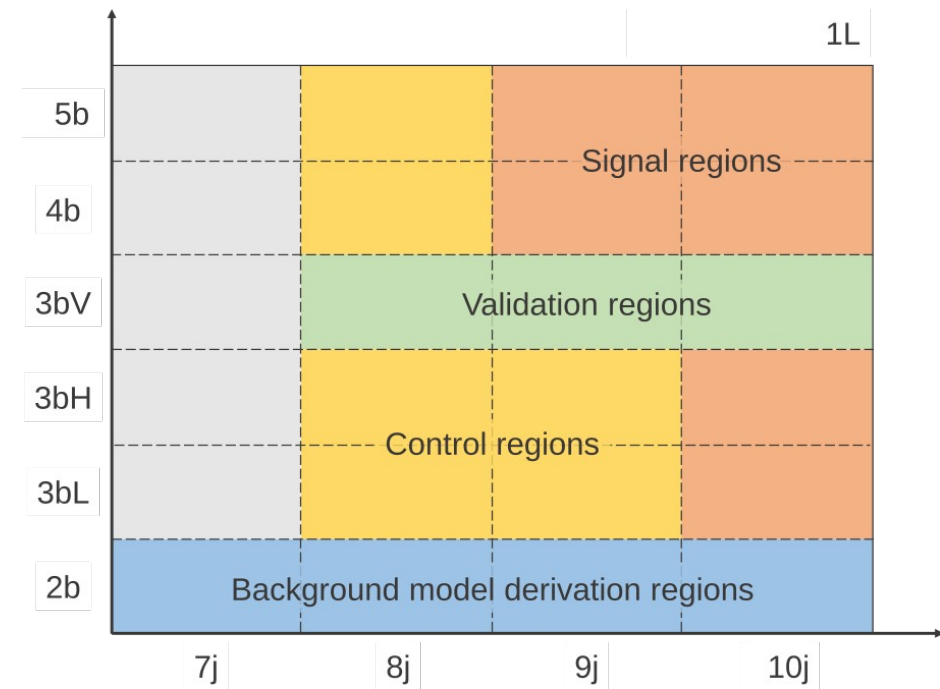
[ATLAS Top public results](#)

Top Quark Production Cross Section Measurements

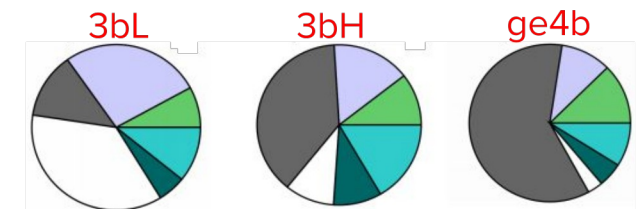
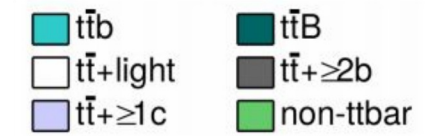
Status: November 2020

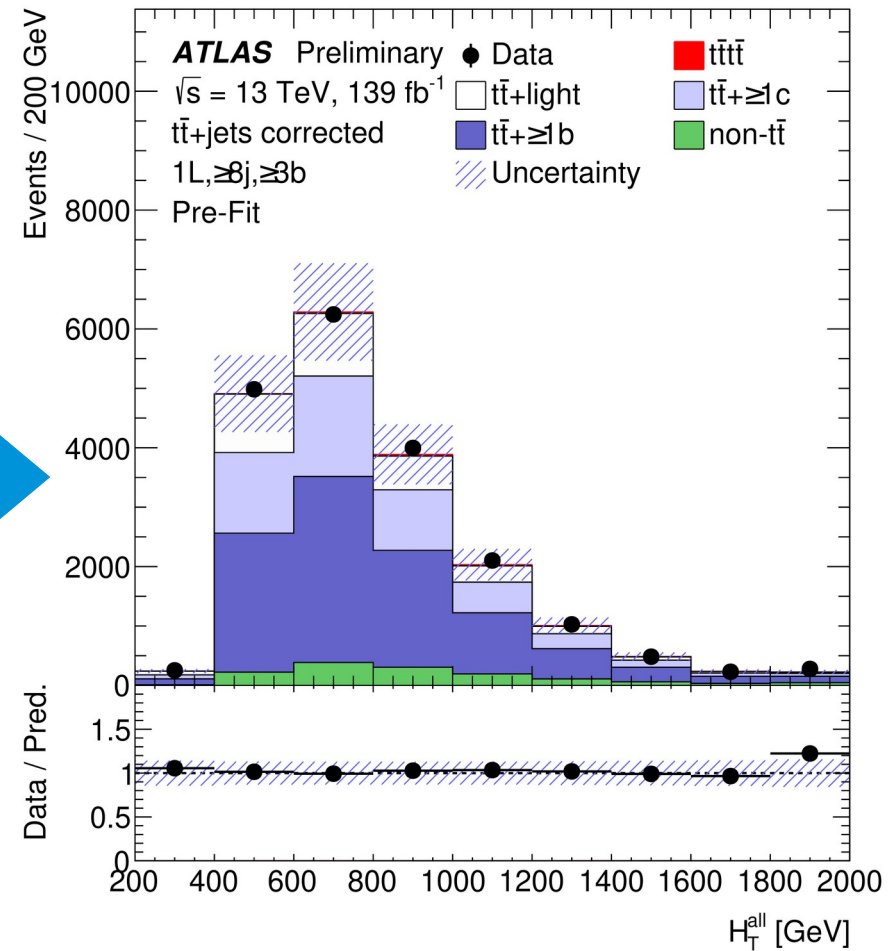
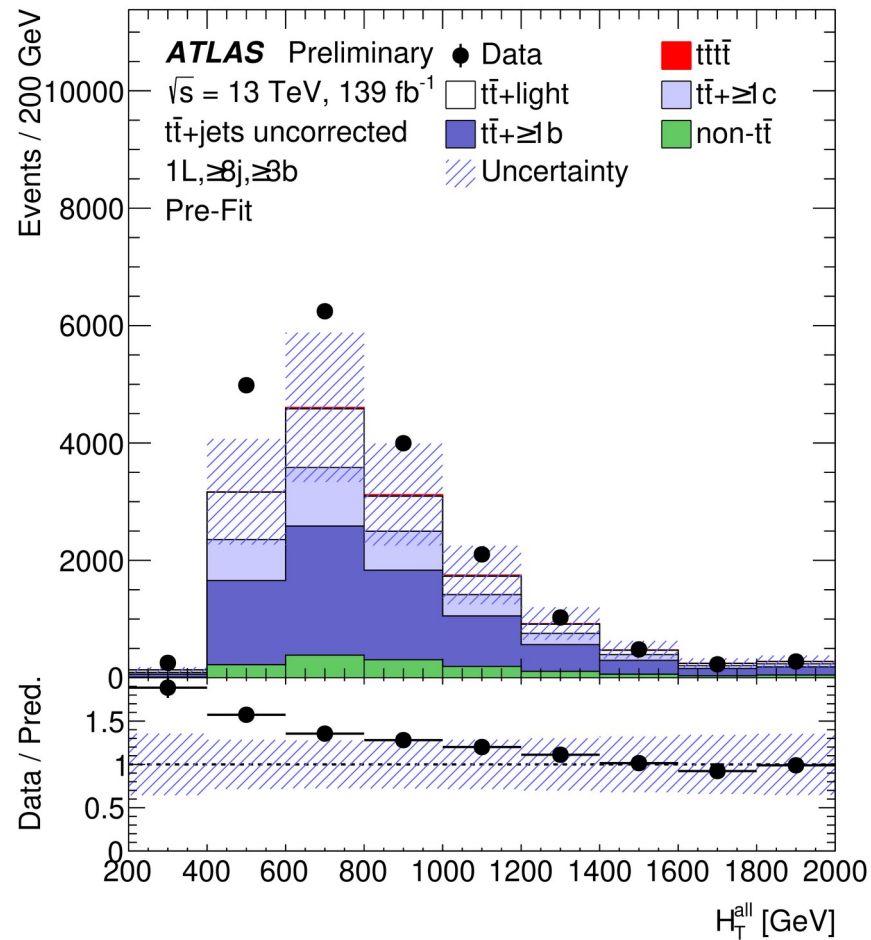


Analysis Strategy (1L/2LOS Channel)



Nb@70%	Nb@60%	Nb@85%	Name
=3	≤2	-	3bL
=3	=3	≥4	3bH
≥4	-	-	ge4b





Uncertainty source	σ_μ	
Signal Modelling		
$t\bar{t}\bar{t}$ cross section	+0.75	-0.20
$t\bar{t}\bar{t}$ modelling	+0.66	-0.27
Background Modelling		
$t\bar{t}+\geq 1b$ modelling	+0.72	-0.59
$t\bar{t}+\geq 1c$ modelling	+0.41	-0.31
$t\bar{t}$ +jets reweighting	+0.30	-0.25
Other background modelling	+0.30	-0.24
$t\bar{t}$ +light modelling	+0.15	-0.12
Experimental		
Jet energy scale and resolution	+0.49	-0.30
b -tagging efficiency and mis-tag rates	+0.38	-0.26
MC statistical uncertainties	+0.21	-0.19
Luminosity	+0.07	-0.03
Other uncertainties	+0.05	-0.03
Total systematic uncertainty	+1.45	-1.04
Statistical uncertainty	+0.67	-0.65

Pre-fit impact on μ :

$\square \theta = \hat{\theta} + \Delta\theta$ $\square \theta = \hat{\theta} - \Delta\theta$

Post-fit impact on μ :

$\blacksquare \theta = \hat{\theta} + \Delta\theta$ $\blacksquare \theta = \hat{\theta} - \Delta\theta$

\bullet Nuis. Param. Pull

