Measurement of $t\bar{t}t\bar{t}$ production with the ATLAS detector

Frédéric Déliot
CEA-Saclay

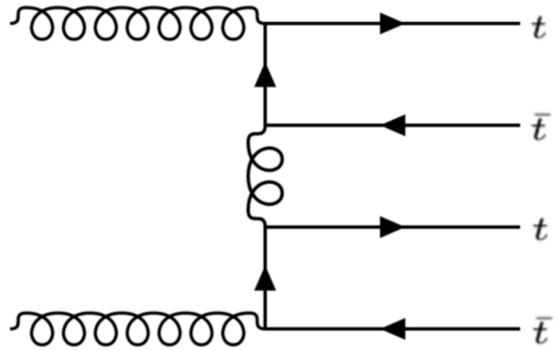
multilepton result: Eur. Phys. J. C 80 (2020) 1085
Single lepton/OS dilepton: ATLAS-CONF-2021-013

DE LA RECHERCHE À L'INDUSTRIE
cea

université
PARIS-SACLAY

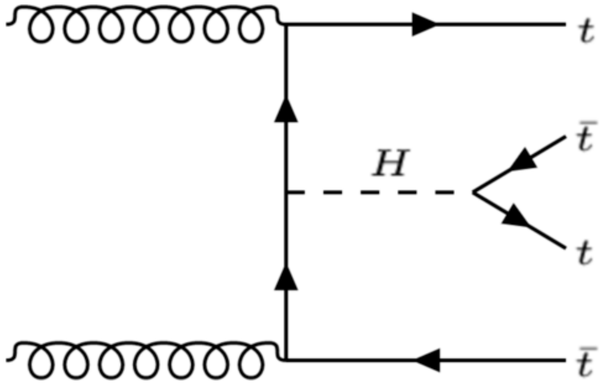
Motivation

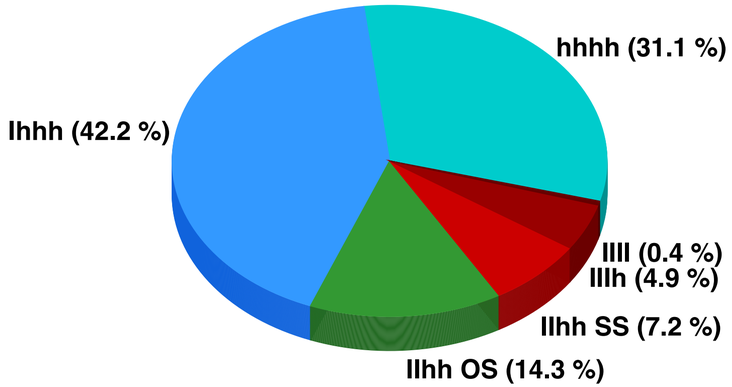
- Motivation
  - Rare process in the SM that was not observed so far: σ = 12 fb ±20% (QCD+EW NLO)
  - Very high-energy process, sensitive to many BSM models
  - Sensitive to the top Yukawa coupling and its properties (subleading diagram involving Higgs decays to $t\bar{t}$)



- Previous searches
  - CMS 36 fb^{-1} (SSML+1LOS): 1.4σ (exp: 1.1σ)
  - CMS 137 fb^{-1} (SSML): 2.6σ (exp: 2.7σ)
  - ATLAS 36 fb^{-1} (SSML+1LOS): 2.8σ (exp: 1.0σ)

- Channels
  - Two same-sign leptons or 3 leptons (2LSS/3L): small branching fraction, low background
  - One lepton or two opposite-sign leptons (1L/2LOS): larger branching fraction, larger background (from $t\bar{t}$+jets)



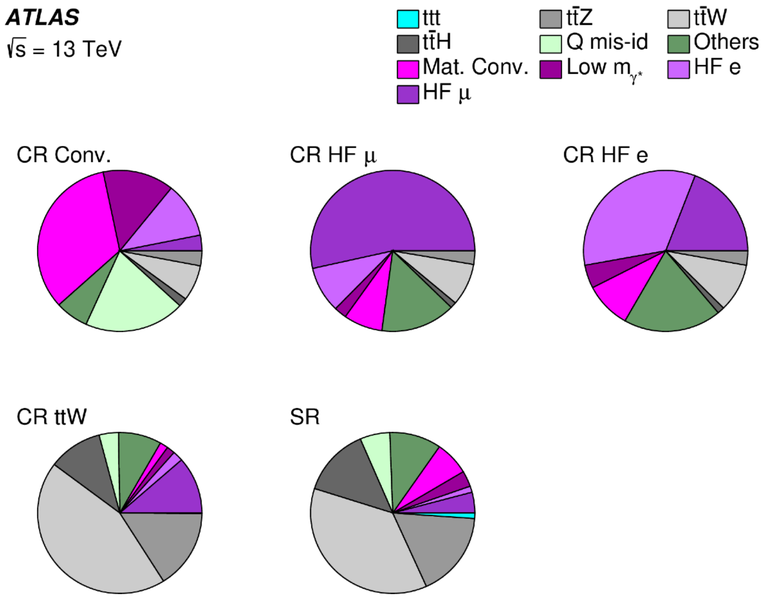


2LSS/3L: Analysis Strategy

Eur. Phys. J. C 80 (2020) 1085

- Main backgrounds:
  - $t\bar{t}V$: $t\bar{t}Z/H$ from MC, $t\bar{t}W$ normalisation from data in control region
  - Non prompt background ('fake' leptons): normalisation fitted in control regions
  - Charge mis-identified electrons: data driven method using Z → ee

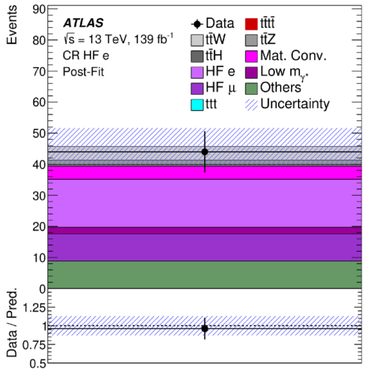
- Strategy
  - 4 control regions to fit the normalisation of the fake and ttW normalisation
    - 3 floating parameters for fakes from: conversion, γ*, lepton from heavy flavour jets (e/μ)
  - 1 signal region
    - Signal separated from background using a BDT

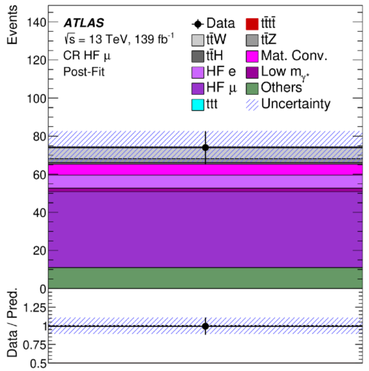


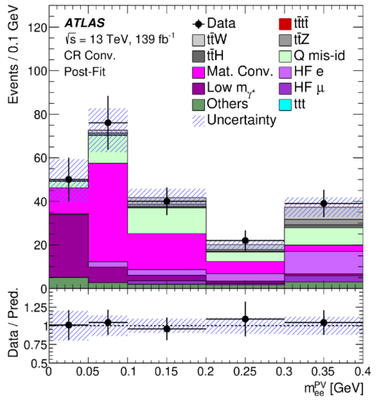
Region	Channel	N_j	N_b	Other requirements	Fitted variable
SR	2LSS/3L	≥ 6	≥ 2	$H_{\mathrm{T}} > 500$	BDT
CR Conv.	$e^{\pm}e^{\pm}\|\|e^{\pm}\mu^{\pm}$	$4 \leq N_j < 6$	≥ 1	$m_{ee}^{\mathrm{CV}} \in [0, 0.1\ \mathrm{GeV}]$ $200 < H_{\mathrm{T}} < 500$ GeV	m_{ee}^{PV}
CR HF e	$eee \,\|\|\, ee\mu$	-	$= 1$	$100 < H_{\mathrm{T}} < 250$ GeV	counting
CR HF μ	$e\mu\mu \,\|\|\, \mu\mu\mu$	-	$= 1$	$100 < H_{\mathrm{T}} < 250$ GeV	counting
CR ttW	$e^{\pm}\mu^{\pm}\|\|\mu^{\pm}\mu^{\pm}$	≥ 4	≥ 2	$m_{ee}^{\mathrm{CV}} \notin [0, 0.1\ \mathrm{GeV}]$, $\|\eta(e)\| < 1.5$ for $N_b = 2$, $H_{\mathrm{T}} < 500$ GeV or $N_j < 6$ for $N_b \geq 3$, $H_{\mathrm{T}} < 500$ GeV	$\Sigma p_{\mathrm{T}}^{\ell}$

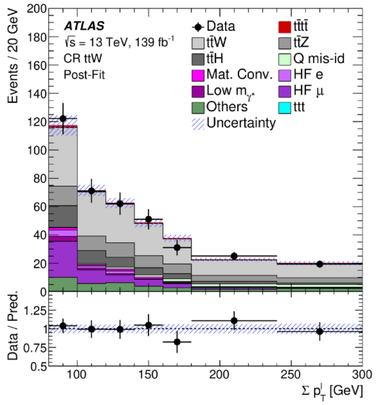
2LSS/3L: Results

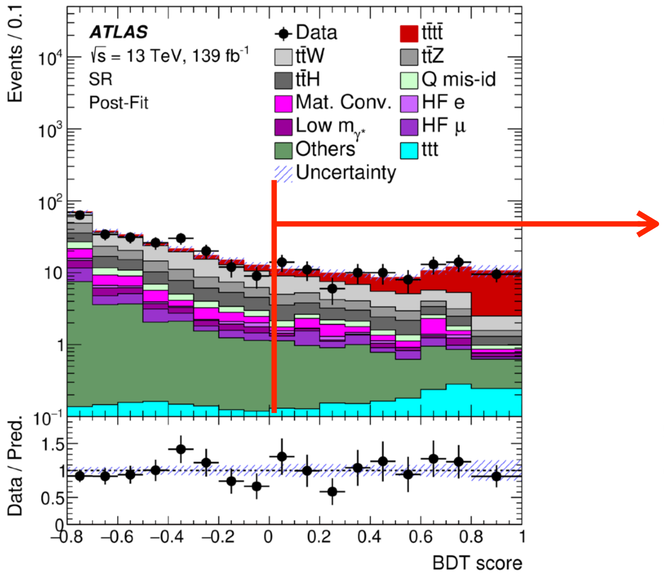
Eur. Phys. J. C 80 (2020) 1085

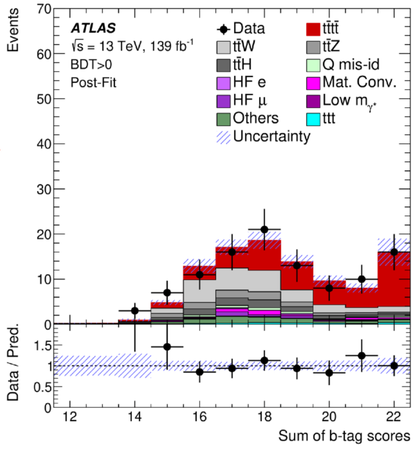










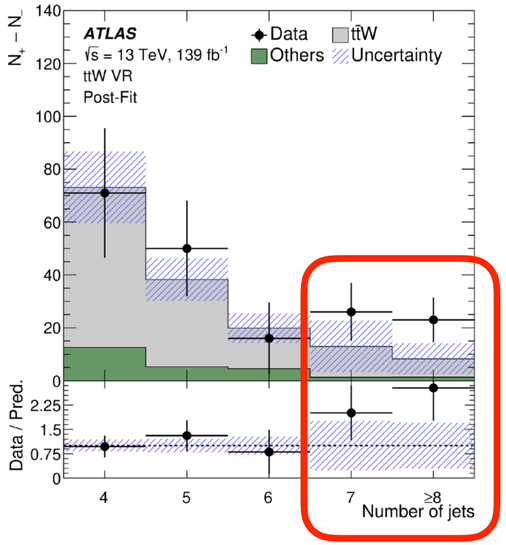


Parameter	$NF_{t\bar{t}W}$	$NF_{\text{Mat. Conv.}}$	$NF_{\text{Low } m_{\gamma^*}}$	$NF_{\text{HF } e}$	$NF_{\text{HF } \mu}$
Value	1.6 ± 0.3	1.6 ± 0.5	0.9 ± 0.4	0.8 ± 0.4	1.0 ± 0.4

- First evidence for $t\bar{t}t\bar{t}$ production:
  - Significance: 4.3 σ (obs), 2.4 σ (exp)

$$\sigma_{t\bar{t}t\bar{t}} = 24 \pm 5(\text{stat})\,^{+5}_{-4}(\text{syst})\,\text{fb} = 24\,^{+7}_{-6}\,\text{fb}$$

  - 1.7 σ above the SM value
  - Leading systematics: $t\bar{t}W$+≥ 8 jets production

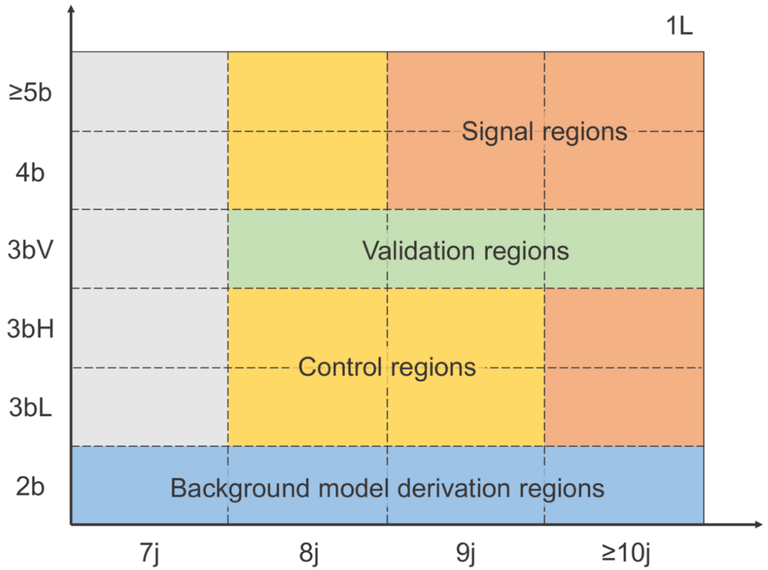


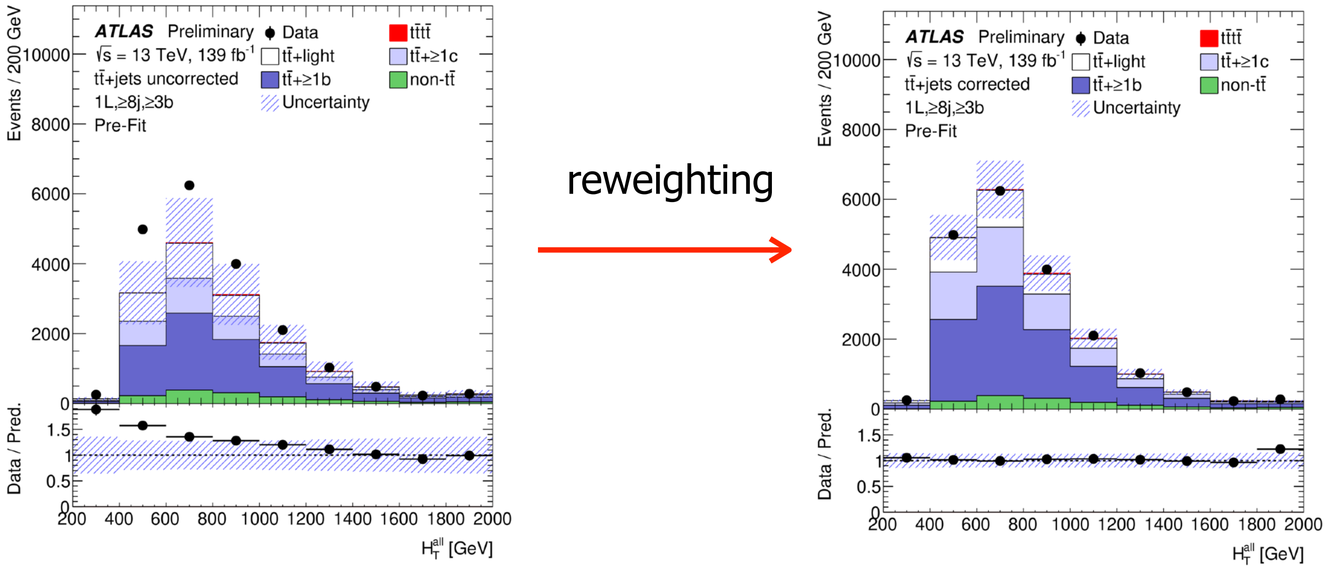
1L/2LOS: Analysis Strategy

ATLAS-CONF-2021-013

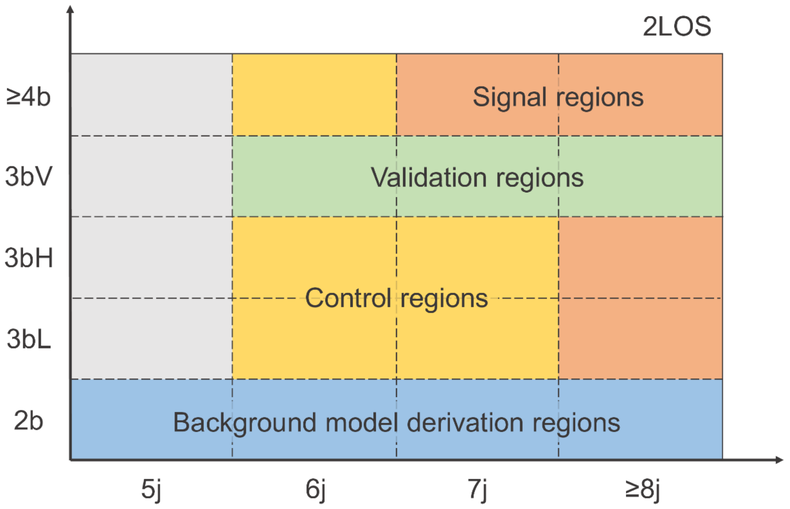
- Analysis regions:
  - Defined based on Njets, Nb-jets, and high(H)/low(L) b-tagging requirements
  - Main background in the signal regions: $t\bar{t}$+heavy flavour (HF) jets

- Strategy
  - Pre-fit corrections to adjust the underestimation of $t\bar{t}$+HF and the $t\bar{t}$+jets kinematics in high jet multiplicity
  - Sophisticated systematic scheme : Separate treatment of the different $t\bar{t}$+jets flavour components
  - BDT to separate signal from background in the signal regions
  - Profile likelihood fit on 21 regions (12 in 1L + 9 in 2LOS)





reweighting



1L/2LOS: Results and combination

ATLAS-CONF-2021-013

- 1L/2LOS result:
  - Significance: 1.9 σ (obs), 1.0 σ (exp)

$$\sigma_{t\bar{t}t\bar{t}} = 26 \pm 8\,(\text{stat.})\,^{+15}_{-13}\,(\text{syst.}) = 26\,^{+17}_{-15}\,\text{fb}$$

  - Main systematics: $t\bar{t}t\bar{t}$ signal modelling and modelling of $t\bar{t}$+≥1 b

- 2LSS/3L + 1L/2LOS combination
  - Significance: 4.7 σ (obs), 2.6 σ (exp)

$$\sigma_{t\bar{t}t\bar{t}} = 24 \pm 4\,(\text{stat.})\,^{+5}_{-4}\,(\text{syst.}) = 24\,^{+7}_{-6}\,\text{fb}$$

  - Consistent with the SM within 2 σ