Search for four-top-quark production at √s = 13 TeV with the ATLAS detector at the LHC

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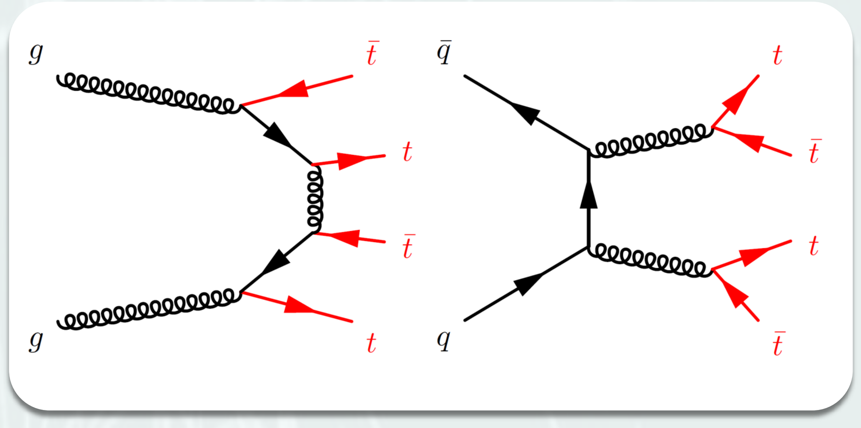
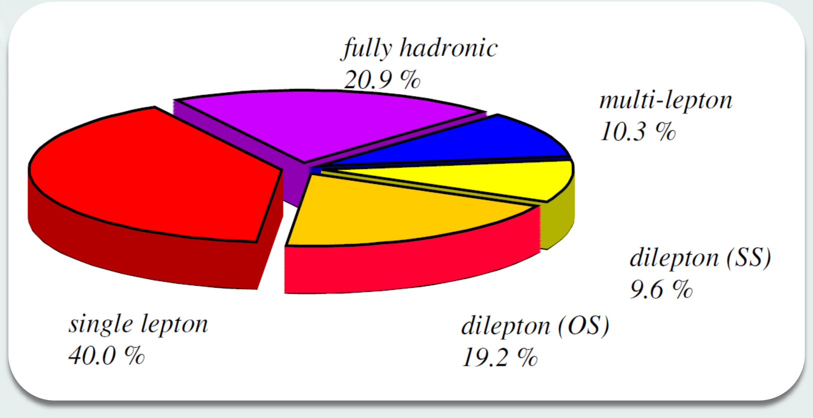
1. Introduction

- LHC: unique window to search for rare SM signatures

- Extremely **rare process**: SM $t\bar{t}t\bar{t}$ cross-section ≈ 9.2 fb (NLO in QCD), but powerful probe for many signatures of BSM physics;
- Current **limits**: obs (exp) 95% CL of 4.5 (2.3) times SM expectation [1];
- Can be studied in **a variety of final states/channels**, topology given by the decays of each W-boson (t → Wb);

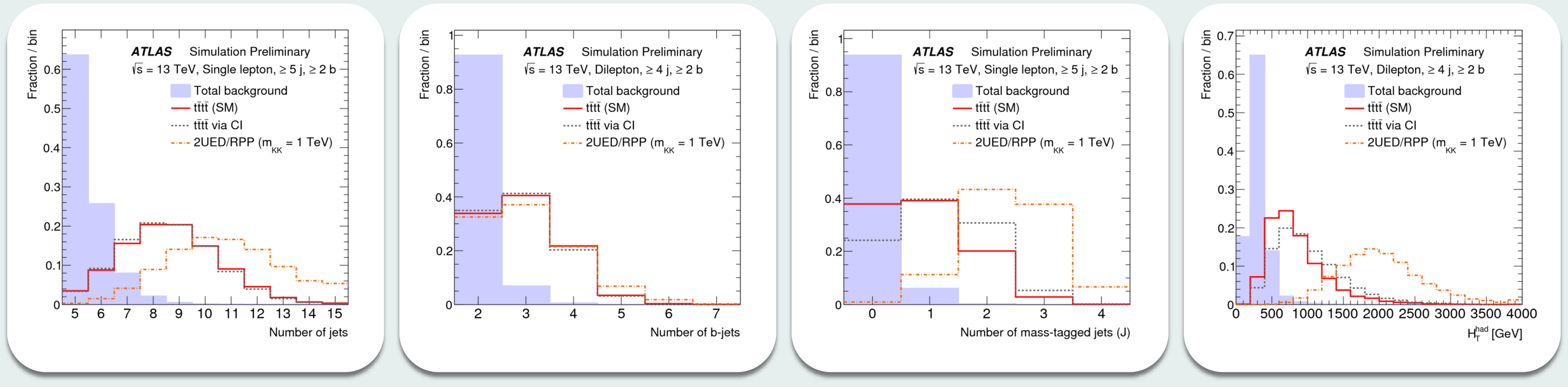




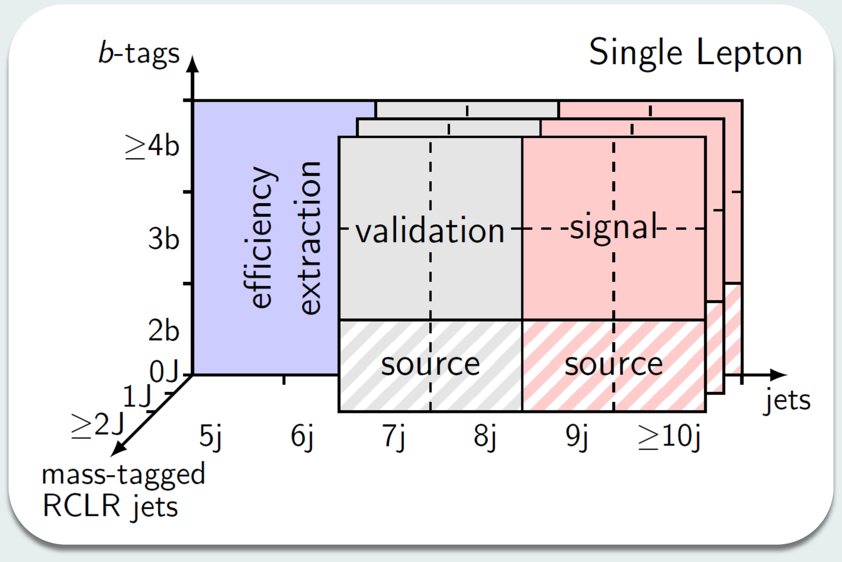
- **2 new searches** [2, 3] for SM four-top-quark production using 36.1 fb^{-1} of pp data at √s=13 TeV collected by the ATLAS detector during 2015 and 2016;
- **Main focus here** on the search using final states with the largest branching fraction (**single-lepton** and **opposite-sign dilepton**), and its combination with the search using **same-sign** (SS) dilepton and **trilepton** events.

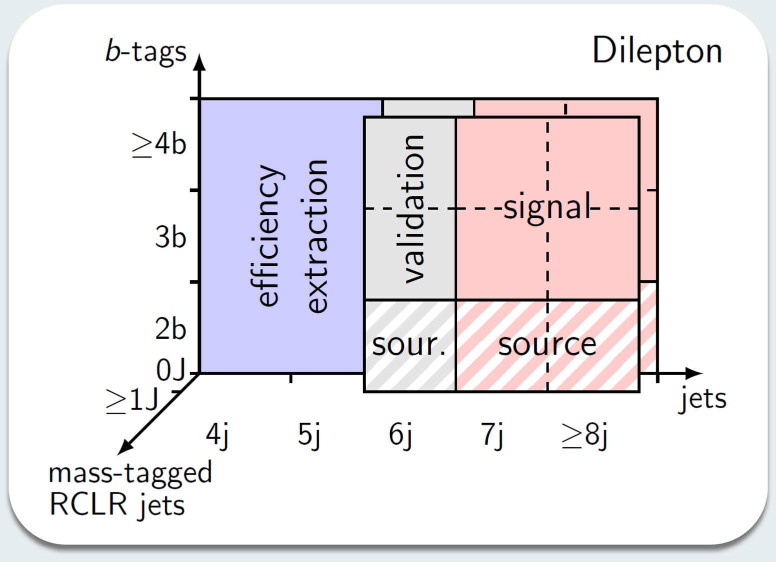
2. Single lep. + OS dilep. search [2]

- Final states with a **single electron or muon**, or **dilepton events with 2 opposite-sign** charged electrons or muons: **small signal on top of large background** dominated by production of $t\bar{t}$ + extra jets;
- Exploit the high **jet** (j), **b-tagged jet** (b) and **reclustered large-R jet** (J) multiplicities, and the high **scalar sum of the jet transverse momenta** (HT_{had}):



- Events in each of the 2 channels are **classified** according to their event topology: highest sensitivity categories in single-lepton (OS dilepton) channel requiere at least **10 (8) jets, 4 b-tagged jets and 2 (1) reclustered jets**:



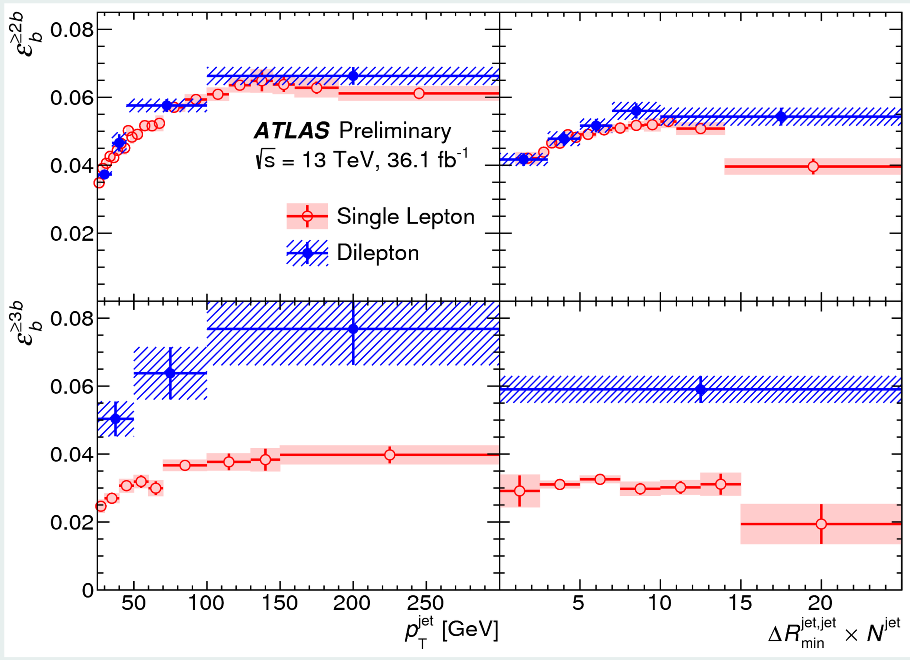


3. Data-driven tt+jets estimation

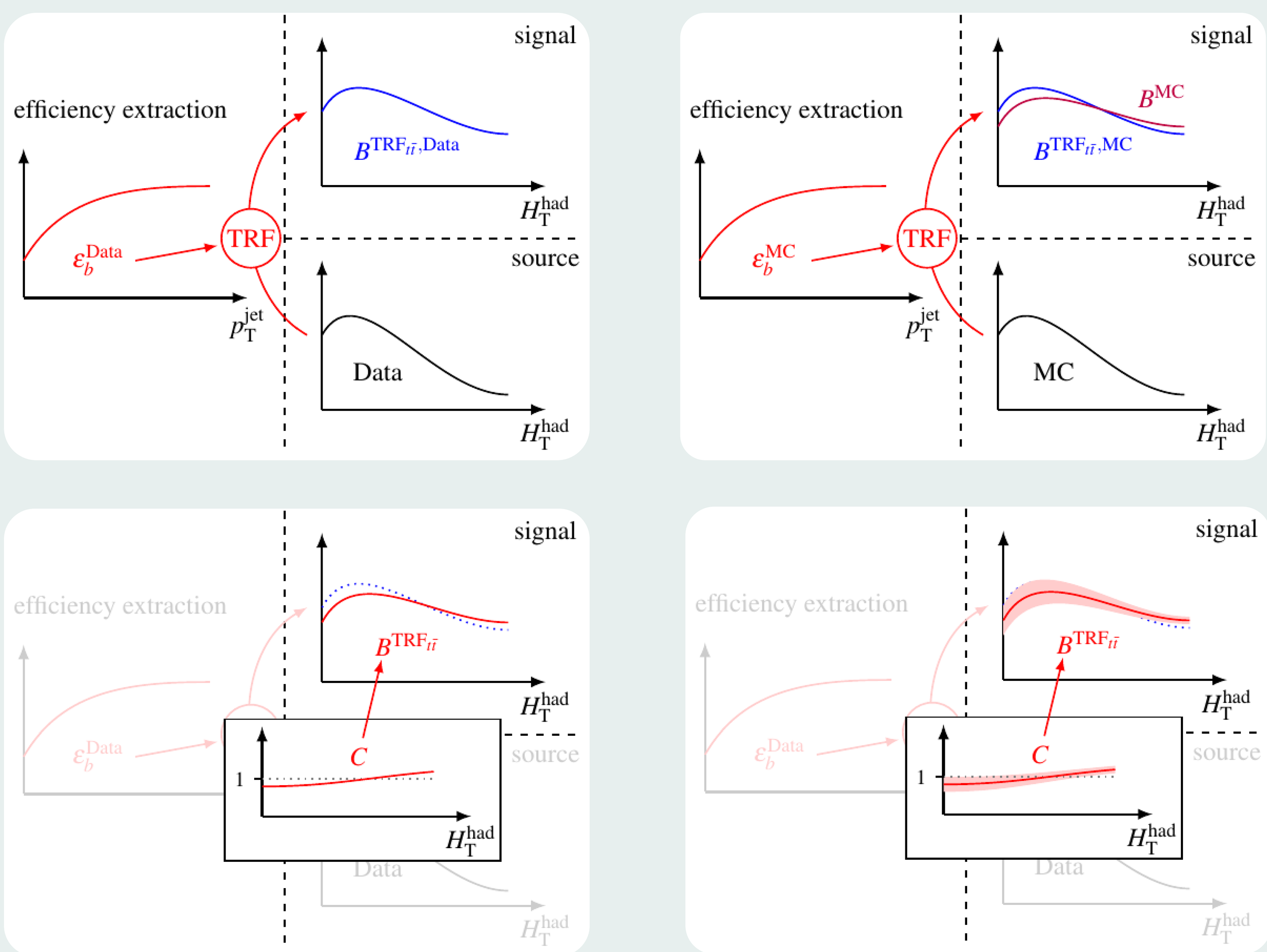
- Inclusive **tt MC simulation** at NLO in QCD **is not expected to model** the very high jet/b-tagged regions well, relies on the description through parton showers with consequently large uncertainties;
- Developed a **data-driven method to estimate the dominant tt+jets backround:** assumes that the probability of b-tagging a jet in tt+jets event is essentially independent of the number of additional jets;
- **Tag-rate-function** (TRF) formalism: for a given event with Nj jets, the probability P of containing exactly one b-tagged jet can be calculated as:

$$P(N_b = 1) = \sum_{i=1}^{N_j} \left(\varepsilon_i \prod_{j \neq i} (1 - \varepsilon_j) \right)$$

where the b-tagging efficiencies (ε_j) are extracted as a function of jet p_T and the minΔR for the given jet wrt. to all other jets, multiplied by Nj;



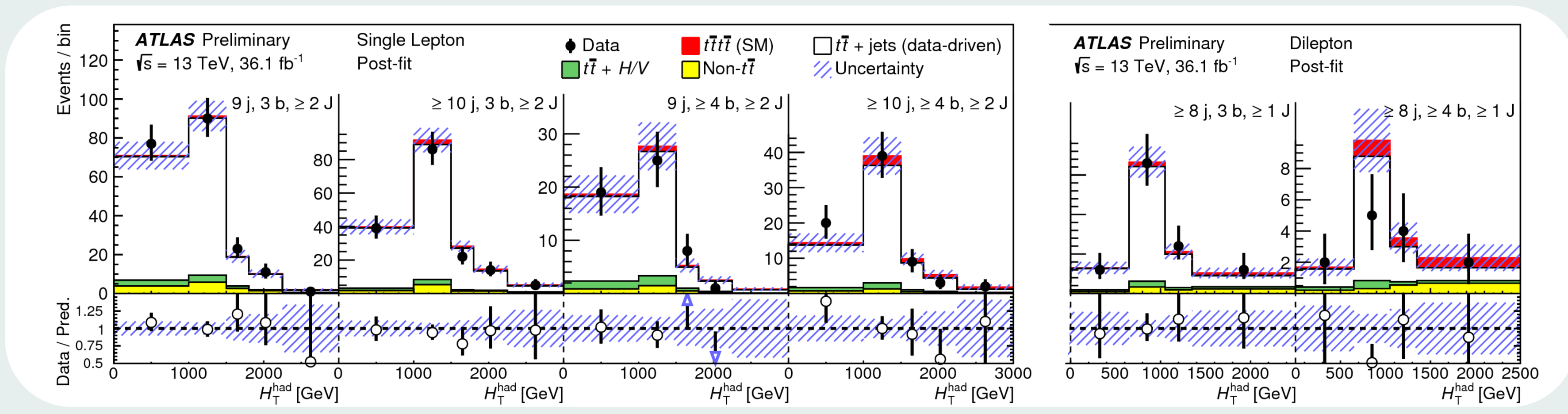
- Extract **effective b-tagging efficiencies** from low Nj data ('efficiency extraction' regions) , **reweight** (via tag-rate-function (TRF) formalism) the data in Nb=2 regions ('source regions') **and predict tt+jets in signal regions** with same Nj/NJ, but larger Nb:



- All steps applied to MC simulated tt+jets events: **derive a correction factor** C for each considered bin, reweighting the prediction by less than 20%;
- A **full set of systematic uncertainties** is derived by repeating the procedure on MC simulated events with systematic variations applied.

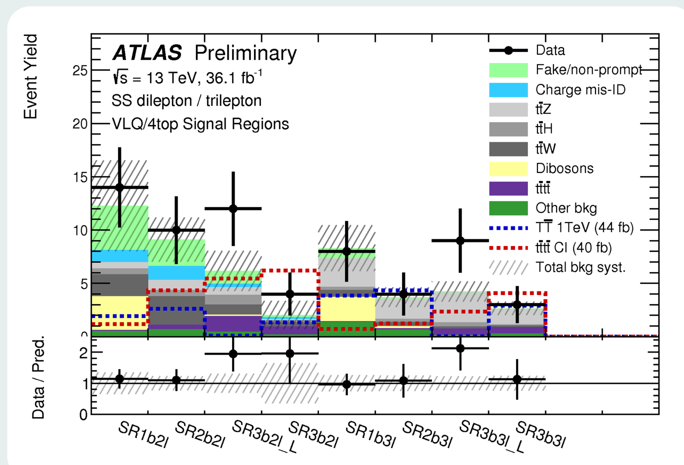
4. Results and combination

- In the single lep. + OS dilep. channel, a **simultaneous fit** is performed to the HT_{had} discributions **in 20 signal regions**, data-driven estimation of tt+jets;

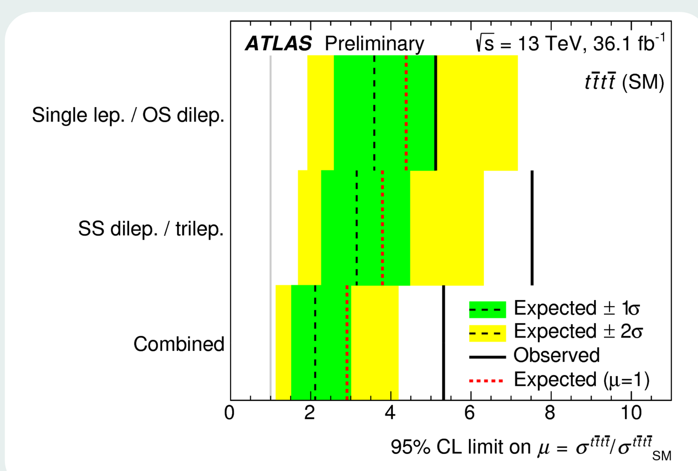


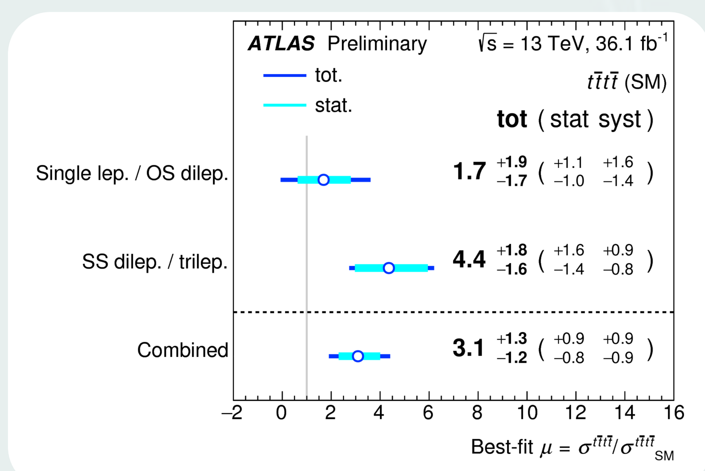
- **SS dilep. / trilep. cut-and-count analysis [3]** in several regions, with data-driven estimations of non-prompt lepton and mis-identified charged leptons:

Region name	N_j	N_b	N_ℓ	Lepton charges	Kinematic criteria
SR1b2ℓ	≥ 1	1	2	++ or −−	H_T > 1000 GeV and E_T^{miss} > 180 GeV
SR2b2ℓ	≥ 2	2	2	++ or −−	H_T > 1200 GeV and E_T^{miss} > 40 GeV
SR3b2ℓ_L	≥ 7	≥ 3	2	++ or −−	500 < H_T < 1200 GeV and E_T^{miss} > 40 GeV
SR3b2ℓ	≥ 3	≥ 3	2	++ or −−	H_T > 1200 GeV and E_T^{miss} > 100 GeV
SR2b2ℓ	≥ 2	2	2	++ or −−	H_T > 1200 GeV and E_T^{miss} > 40 GeV
SR1b3ℓ	≥ 1	1	3	any	H_T > 1000 GeV and E_T^{miss} > 140 GeV
SR2b3ℓ	≥ 2	2	3	any	H_T > 1200 GeV and E_T^{miss} > 100 GeV
SR3b3ℓ_L	≥ 5	≥ 3	3	any	500 < H_T < 1000 GeV and E_T^{miss} > 40 GeV
SR3b3ℓ	≥ 3	≥ 3	3	any	H_T > 1000 GeV and E_T^{miss} > 40 GeV



- **Results in both channels combined:** excess of events over the SM background prediction observed with a significance of **2.8σ** (**1.0σ**). **Excess** driven by the SS dilep. / trilep channel; compatibility between two channels quantified to be 31%;
- Assuming no signal, obs. (exp.) 95% CL **upper limit** of **5.3 (2.1)** times SM expectation.





References

[1] CMS Collaboration, Search for standard model production of four top quarks with same-sign and multilepton final states in proton-proton collisions at √s = 13 TeV, Eur. Phys. J. C 78 (2018) 140

[2] ATLAS Collaboration, Search for four-top-quark production in the single-lepton and opposite-sign dilepton final states in pp collisions at √s = 13 TeV with the ATLAS detector, to be published

[3] ATLAS Collaboration, Search for new phenomena in events with same-charge leptons and b-jets in pp collisions at √s = 13 TeV with the ATLAS detector, to be published