Differential $t\bar{t}$ cross-section measurements using boosted top quarks with 139 fb^{-1} of ATLAS data

Petr Jačka on behalf of the ATLAS experiment
TOP2021, 13-17 Sep 2021

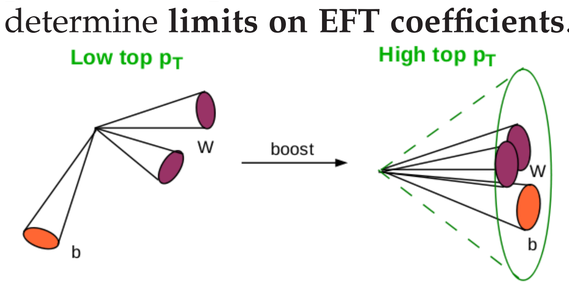
FZU Institute of Physics of the Czech Academy of Sciences

Introduction

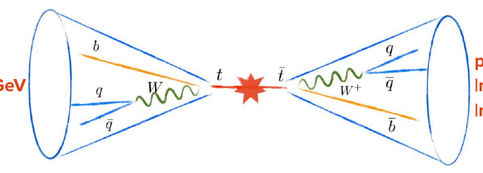
Top-quark pair production differential cross-sections are presented in two decay channels - **lepton+jets and all-hadronic** - with focus on **high p_T (boosted) top quarks**. Both measurements use the full Run 2 dataset of 13 TeV proton-proton collisions collected by the ATLAS in 2015-2018, corresponding to an integrated luminosity of 139 fb^{-1}. $t\bar{t}$ production with boosted tops is **sensitive to deviations from the Standard Model** (SM) prediction. This motivates for precise measurements in this topology. Results are compared with SM predictions and they are used **to set limits on the Wilson coefficients of the effective field theory** (EFT) extension of the SM. Details about measurements can be found in *ATLAS-CONF-2021-031* (lepton+jets) and *ATLAS-CONF-2021-066* (all-hadronic).

General strategy

Large-R jets with $R = 1.0$ are used to reconstruct highly boosted hadronic top ($p_T \gtrsim 2m_{top}$) decays. Leptonic tops are reconstructed from charged lepton, missing energy and b-tagged jet. **B-tagging and top-tagging** are used to suppress background. The remaining background contribution is determined by a combination of Monte Carlo samples and data-driven techniques. Measured distributions are then unfolded to the particle and parton level (all-hadronic only), where they are **compared to SM predictions** and used to determine **limits on EFT coefficients**.

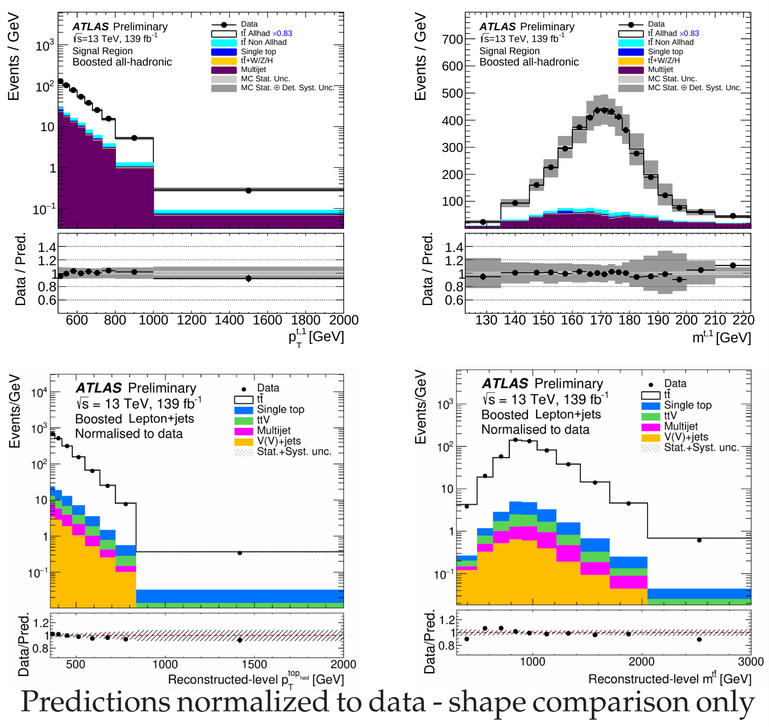


Hadronic event selection



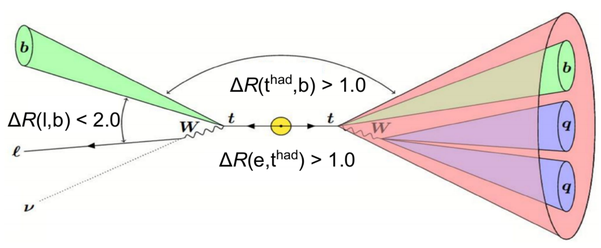
- **Large-R jets**: Anti-kt LCTopo $R = 1.0$ trimmed
- **Top-tagging**: DNN top-tagger based on large-R jet substructure variables
- **B-tagging**: Large-R jets matched to b-tagged track jets

Detector level plots



- Predictions normalized to data - shape comparison only
- Important to understand event composition and for validation

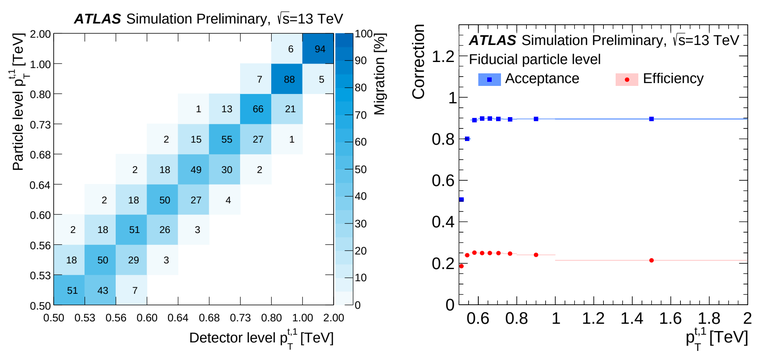
L+jets event selection



- Exactly one prompt lepton
- **Large-R jet** with $R = 1.0$: Reclustered from $R = 0.4$ anti-k_t calo jets
- At least two anti-k_t $R = 0.4$ b-tagged jets
- $E_T^{miss} > 20$ GeV, $E_T^{miss} + E_T^W > 60$ GeV

Unfolding

- **Iterative Bayesian method**
- **Particle level fiducial phase space**
  - Reconstructed from stable particles before their impact on detector with same kinematic requirements as at reco level
- **Parton level** (all-hadronic only)
  - Tops taken after final state radiation
  - $p_T^{t,1} > 500$ GeV, $p_T^{t,2} > 350$ GeV
  - For comparison with fixed order predictions



Background composition

Backround processes ordered by their contribution

Lepton+jets	All-hadronic
Single top	Multijet
$t\bar{t}$ +X(X=W,Z,H)	$t\bar{t}$ non-allhad
Multijet	Single-top
Others	$t\bar{t}$ +X(X=W,Z,H)

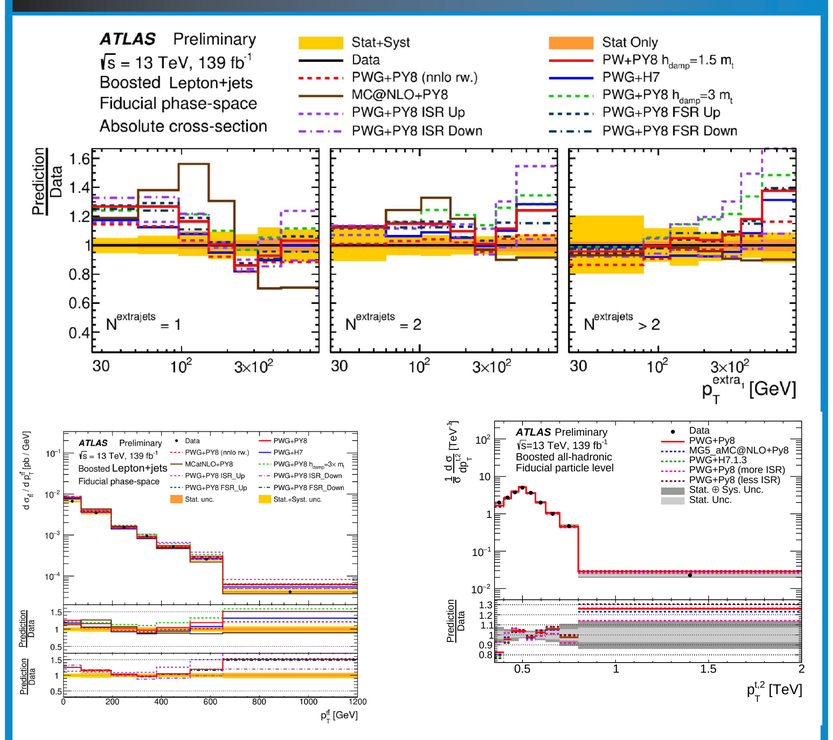
- **Multijet background** determined by data-driven techniques in both analyses: Matrix method (lepton+jets), ABCD method (all-hadronic)
  - Dominant in the all-hadronic measurement
- MC samples used to determine other backgrounds contributions
- **Wt single top** is a dominant background in lepton+jets measurement - special care needed due to ambibuity of Wt-channel definition

Uncertainties

Source	Lepton+Jets [%]	All-had [%]
Data Statistics	±0.4	±1.0
MC Statistics	±0.2	±0.5
Hard Scattering	±0.5	±0.9
Hadronization	**±2.0**	±4.3
Radiation	$^{+1.0}_{-1.6}$	±4.9
Jets	±0.7	±4.3
Top mass	$^{+0.8}_{-1.1}$	–
B-tagging	**±2.4**	±2.9
Top-tagging	–	**±7.8**
Lumi	±1.8	±1.7
Total	$^{+4.1}_{-4.3}$	**±11.7**

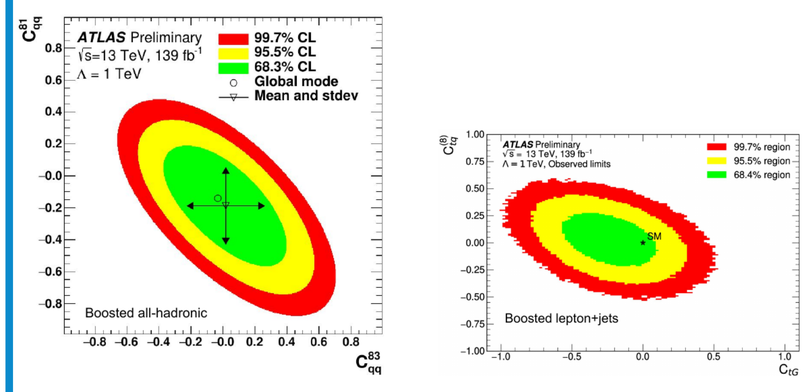
- **Hard scattering** and **B-tagging** are major sources of uncertainties in lepton+jets channel
- **Top-tagging** uncertainties dominates in all-hadronic channel
- Lepton+jets analysis use an additional data-to-MC large-R jet energy calibration on top of the common calibration
  - Significant reduction of jet energy scale uncertainties

Unfolded results



- Lepton+jets measurement provides absolute differential cross-sections
- All-hadronic measurement provides normalized spectra ($p_T^{t,2}$): shape comparison only
- $p_T^{extra_1}$: Additional jet with highest p_T
- Variables sensitive to radiation show discrepancies between data and predictions

EFT limits



- Boosted tops show good sensitivity to new physics
- 2D CL limits determined for the selected LO EFT operators from the Warsaw basis
  - 2 heavy-quark + 2 light-quark, 2 heavy-quark + bosons operators
- Top p_T used as a differential variable to fit the coefficients
- Lepton+jets: SM-EFT interference terms only
- All-hadronic: Both SM-EFT and EFT-EFT terms
- Results compatible with SM only hypothesis

Comparison to NNLO SM

- MATRIX provides NNLO distributions in limited phase space - after asymmetric cuts on tops p_T
- Fixed order (NLO and NNLO) SM predictions from MATRIX compared to measured boosted all-hadronic distributions unfolded to parton level
- In general, improvement observed when going to higher order predictions