Testing the Standard Model in boosted top quark production with the ATLAS experiment at the LHC

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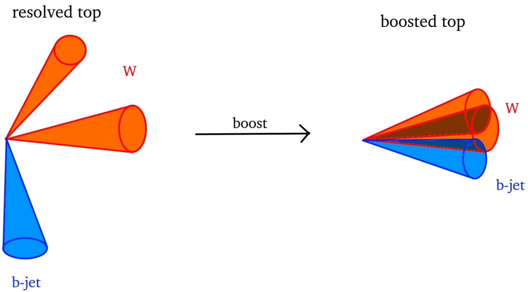
Boosted top quark production

- Hadronically decaying boosted top quarks
  - $p_{\mathrm{T}} \gtrsim 300\ \mathrm{GeV}$
  - Decay products start to overlap - different identification methods are needed
- New physics can alter top quark production especially in the boosted phase space
- Boosted top quarks identified within large-R jets
  - Reduced combinatorics
  - Possibility to use large-R jet triggers



Recent ATLAS measurements exploring boosted top quarks

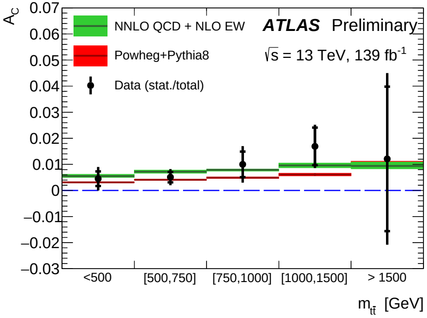
- $t\bar{t}$ charge asymmetry, 139 fb^{-1}:
  - lepton+jets selection: ATLAS-CONF-2019-026
- $t\bar{t}$ differential cross sections, 36 fb^{-1}:
  - all-hadronic selection: Phys. Rev. D 98, 012003 (2018)
  - lepton+jets selection: Eur. Phys. J. C 79, 1028 (2019)
- **NEW**: $t\bar{t}$ differential cross sections, 139 fb^{-1}
  - lepton+jets selection: ATLAS-CONF-2021-031

$t\bar{t}$ charge asymmetry

$t\bar{t}$ charge asymmetry

- ATLAS-CONF-2019-026
- Evidence for charge asymmetry
- Lepton+jets
- Boosted top quark identified in large-R jets (anti-k_t $R = 1.0$):
  - topological cell clusters as input
  - trimming
  - jet $p_{\mathrm{T}} > 350\ \mathrm{GeV}$
  - top-tagging based on jet mass and subjettiness ratio τ_{32}
    - ATLAS-CONF-2017-064
- Unfolded to parton level using Fully Bayesian Unfolding
- Main uncertainties in the boosted phase space: Data statistics

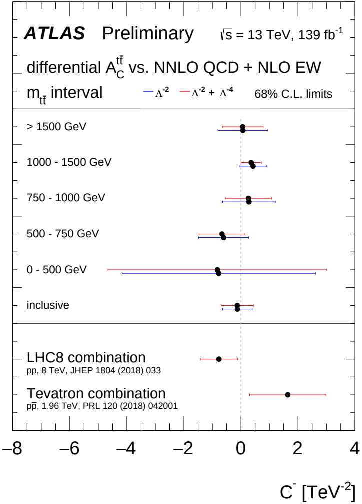
$$A_C = \frac{N(\Delta|y| > 0) - N(\Delta|y| < 0)}{N(\Delta|y| > 0) + N(\Delta|y| < 0)}$$



$t\bar{t}$ charge asymmetry, cont.

- Measurement consistent with SM prediction
- 68% CL on parameter C^{-}/Λ^2
  - linear combination of seven 4-fermion operators in the Warsaw basis

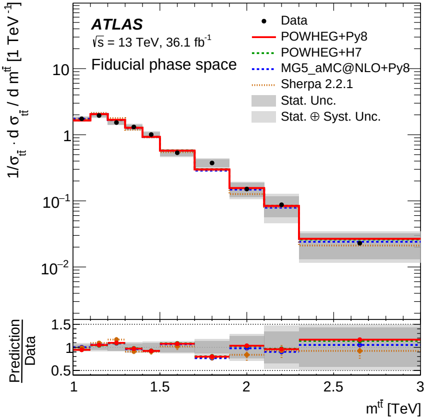
$$C_u^1 = C_{qq}^{(8,1)} + C_{qq}^{(8,3)} + C_{ut}^{(8)}$$
$$C_u^2 = C_{qu}^{(1)} + C_{qt}^{(1)}$$
$$C_d^1 = C_{qq}^{(8,1)} - C_{qq}^{(8,3)} + C_{dt}^{(8)}$$
$$C_d^2 = C_{qd}^{(1)} + C_{qt}^{(1)}$$
$$C_u^1 = C_d^1 = C^1$$
$$C^- = C^1 - C^2$$



$t\bar{t}$ differential cross sections all-hadronic

$t\bar{t}$ differential cross sections, all-hadronic

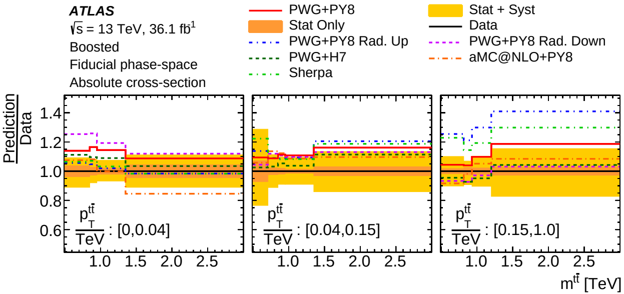
- Phys. Rev. D 98, 012003 (2018)
- 36 fb^{-1}
- All-hadronic
  - both top quarks boosted
- Boosted top quark identified in large-R jets (anti-k_t $R = 1.0$):
  - topological cell clusters as input
  - trimming
  - jet $p_\mathrm{T} > 350$ GeV
  - top-tagging based on jet mass and subjettiness ratio τ_{32}
    - ATLAS-CONF-2017-064
- Main uncertainties: Data statistics, JES, top-tagging
- Measurement consistent with the SM prediction



$t\bar{t}$ differential cross sections lepton+jets

$t\bar{t}$ differential cross sections, lepton+jets

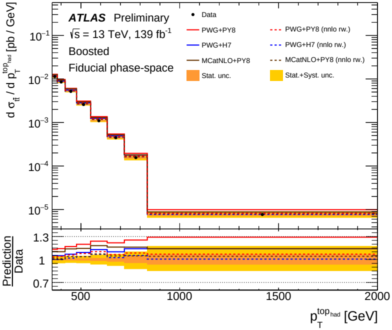
- Eur. Phys. J. C 79, 1028 (2019)
- Boosted top quark identified in reclustered jets:
  - anti-k_t $R = 1.0$ using anti-k_t $R = 0.4$ calibrated jets as input
  - trimming
  - jet $p_{\mathrm{T}} > 350$ GeV
  - jet mass $\in [120, 220]$ GeV
- Main uncertainty: signal modeling
- Single/Double differential cross sections at particle and parton levels
- Several tested MC configurations are disfavored



NEW: $t\bar{t}$ differential cross sections lepton+jets

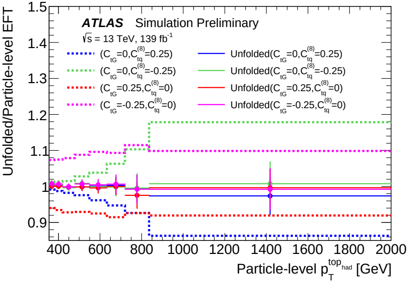
NEW: $t\bar{t}$ differential cross sections, lepton+jets

- ATLAS-CONF-2021-031
- Full Run2
- Boosted top quark identified in reclustered jets:
  - anti-k_t $R = 1.0$ using anti-k_t $R = 0.4$ calibrated jets as input
  - jet $p_{\mathrm{T}} > 355$ GeV
  - jet mass $\in [120, 220]$ GeV
- Unfolded to particle level using iterative Bayesian unfolding
- Main uncertainty: Signal modeling
- See analysis details in the talk from Federica Fabbri on July 26 at 14:15



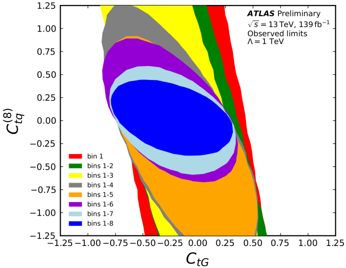
NEW: $t\bar{t}$ differential cross sections, cont.

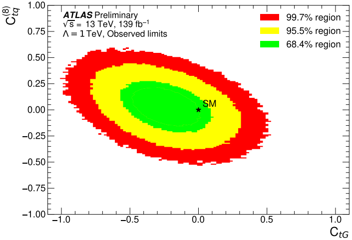
- The measurement is consistent with the SM prediction
- EFT interpretation to constrain Wilson coefficients C_{tG} and $C_{tq}^{(8)}$:
  - using hadronic top p_{T}
- Using only dim-6 terms linear in $(1/\Lambda^2)$
- $\Lambda = 1$ TeV
- `EFTfitter` used to extract the limits
  - arXiv:1605.05585
- Neglecting background dependence on Wilson coefficients
  - high purity of signal events
- Tested the impact of Wilson coefficients on the unfolding
  - found negligible impact on unfolding results



NEW: $t\bar{t}$ differential cross sections, cont.

- Investigated how the 95% credibility area changes when adding the bins one-by-one from the lowest p_{T} bin to highest p_{T} bin
- Obtained more stringent limits on $C_{tq}^{(8)}$ than in the recent global fit arXiv:2105.00006





Wilson coefficient	Marginalised 95% intervals		Individual 95% intervals		
	Expected	Observed	Expected	Observed	Global fit [101]
C_{tG}	[-0.44, 0.44]	[-0.68, 0.21]	[-0.41, 0.42]	[-0.63, 0.20]	[0.007, 0.111]
$C_{tq}^{(8)}$	[-0.35, 0.35]	[-0.30, 0.36]	[-0.35, 0.36]	[-0.34, 0.27]	[-0.40, 0.61]

Summary

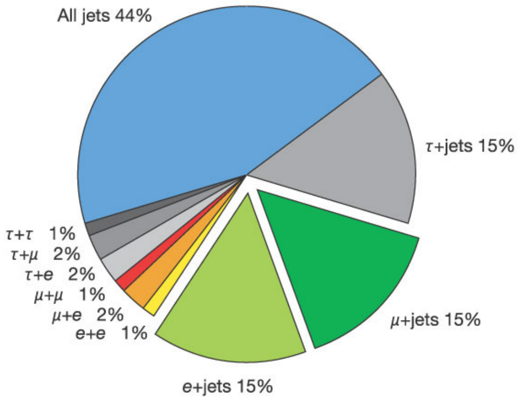
- Boosted top measurements probe the TeV scale
- **New $t\bar{t}$ differential cross section measurement in the boosted phase space**
- All measurements in ATLAS consistent with the Standard Model predictions
- Large potential to improve the MC configurations for the future
- Valuable inputs for the global EFT fits

- Outlook
  - Better top-tagging techniques developed and can be used
    - Identification using a Deep Neural Network ATLAS-CONF-2017-064
  - Use full Run-2 data

Backup

$t\bar{t}$ decay channels

- Decay $t \longrightarrow Wb$ in $\sim$100%
  - Signature depends on the decay mode of the W boson (leptonic or hadronic)
- Main selection regions for $t\bar{t}$: dilepton, lepton+jets, all-jets



Type of measurements in ATLAS

- **Inclusive**
  - full phase space
  - fiducial phase space
- **Differential** - cross section as a function of certain observable defined at
  - parton level
    - full phase space
    - fiducial phase space
  - particle level
    - fiducial phase space

Parton level

- defined using particles before hadronization

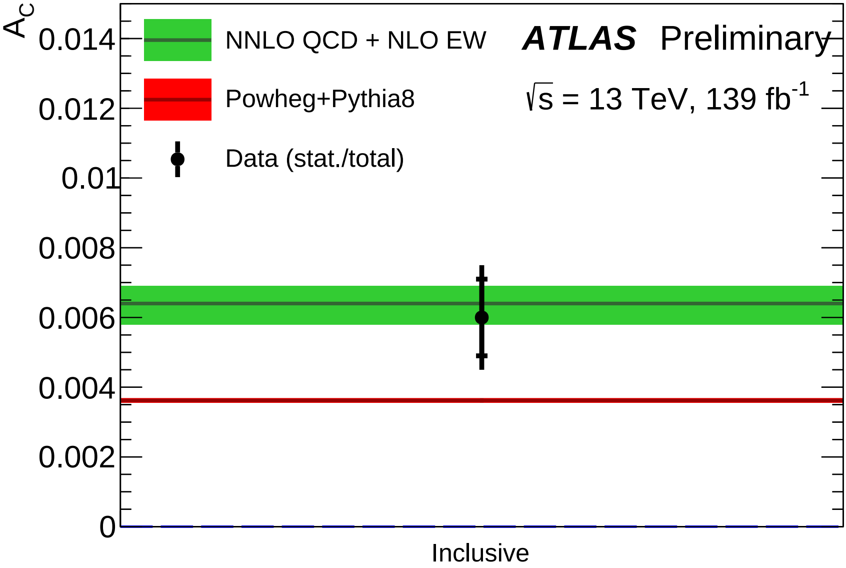
Particle level

- defined using stable particles after hadronization $(c\tau > 1\ \mathrm{cm})$
$\Rightarrow$ reduction of signal modeling uncertainties

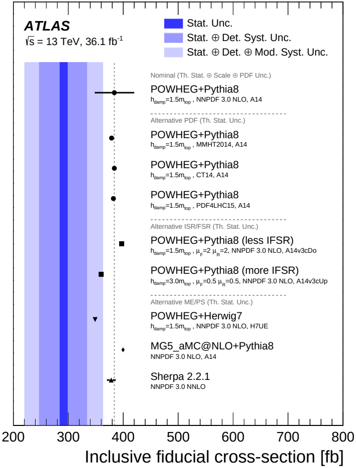
Fiducial phase space

- typically chosen to be close to the phase space of the selected data
- can use parton or particle level observables

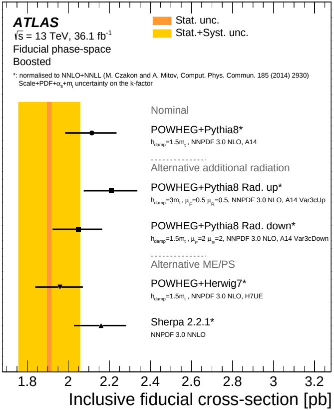
Inclusive charge asymmetry



Inclusive $t\bar{t}$ differential cross section in fid. region, all-hadronic



Inclusive $t\bar{t}$ differential cross section in fid. region, lepton+jets



Inclusive $t\bar{t}$ differential cross section in fid. region, lepton+jets, NEW