LP2025

ATLAS results on top, ttbar and associated cross sections

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(on behalf of the ATLAS Collaboration)

25$^{\text{th}}$ August 2025

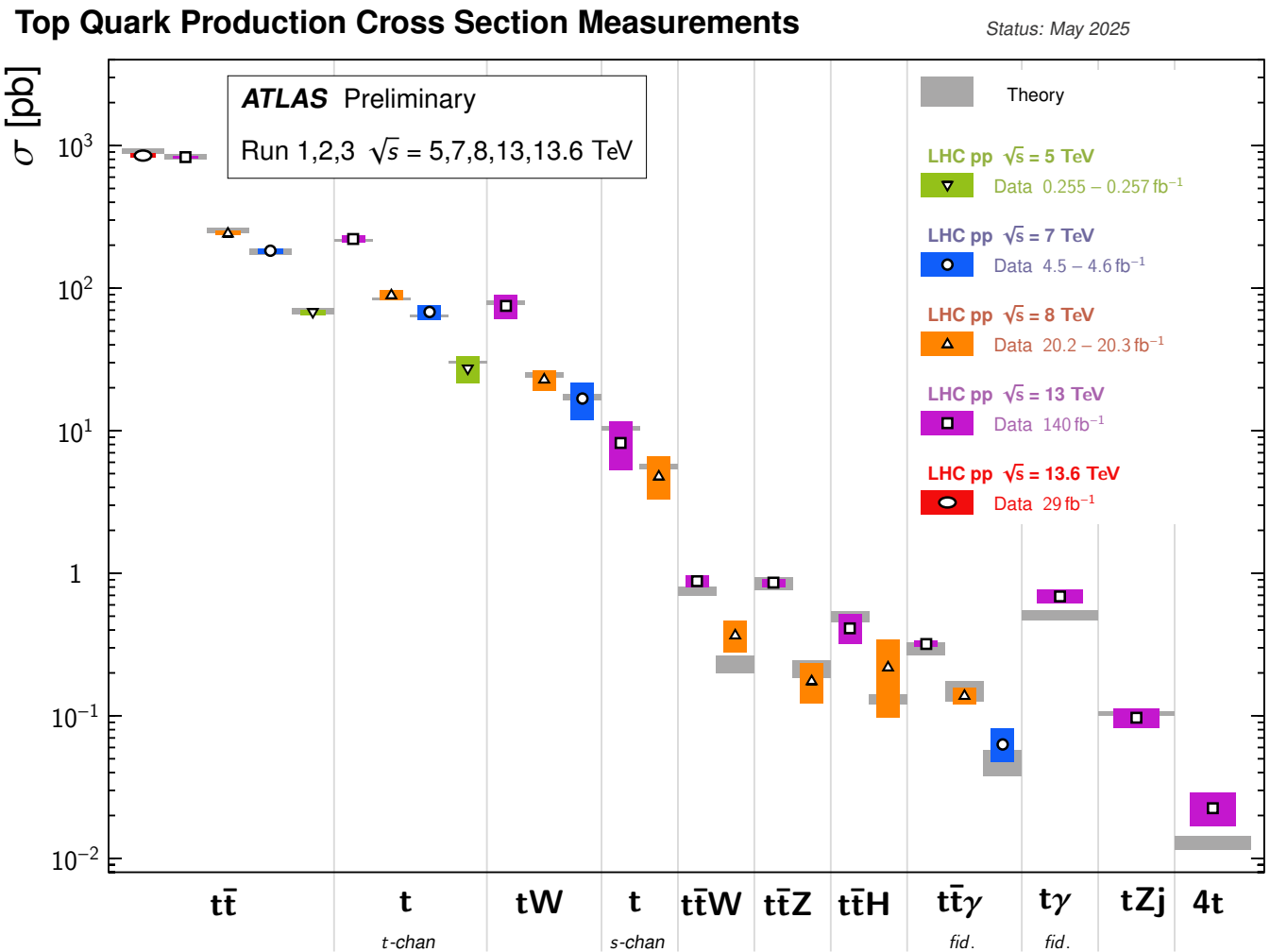
This project has received funding from the Czech Science Foundation under grant GA24-11373S and from the Primus research programme of Charles University (project No 21/SCI/017).

Top quark

- The heaviest known elementary particle
  - largest Yukawa coupling $y_t \approx 1$
  - unique properties from experimental and theoretical side
- Very short lifetime
  - the only quark which does not hadronize
  - properties studied via its decay products
- The main ingredient of many BSM scenarios

- **In this talk: summary of top-quark cross-section measurements in ATLAS**
- Top-quark properties in ATLAS presented by Katharina Voss (Monday 11:00)
- Top-antitop + heavy flavour in ATLAS presented by Alexander Khanov (Monday 11:40)
- Top-quark mass in ATLAS presented by Makoto Tomoto (Monday 15:00)
- ATLAS results at the top-antitop threshold by Yoav Afik (Thursday at 14:00)
- ATLAS EFT results in the top sector by Rui Zhang (Thursday at 14:40)
- Plenary talk about the top quark by Frederic Deliot (Monday 16:00)

Top quark production



ATL-PHYS-PUB-2025-024

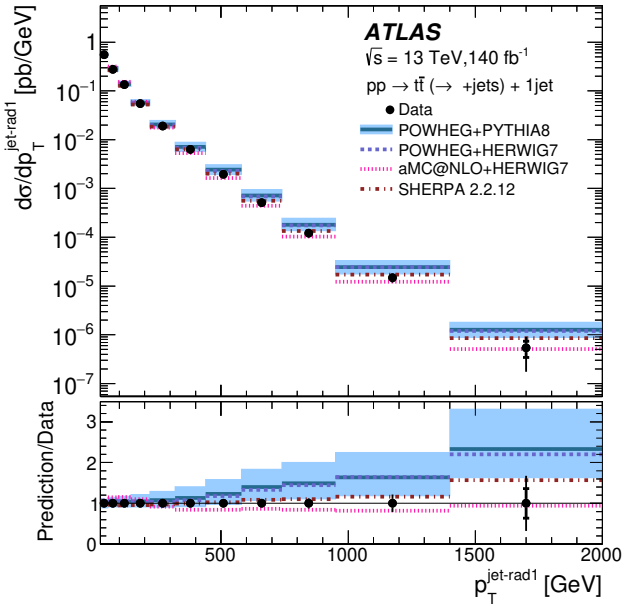
- Many production modes: top-antitop ($t\bar{t}$), single top, or associated production with bosons

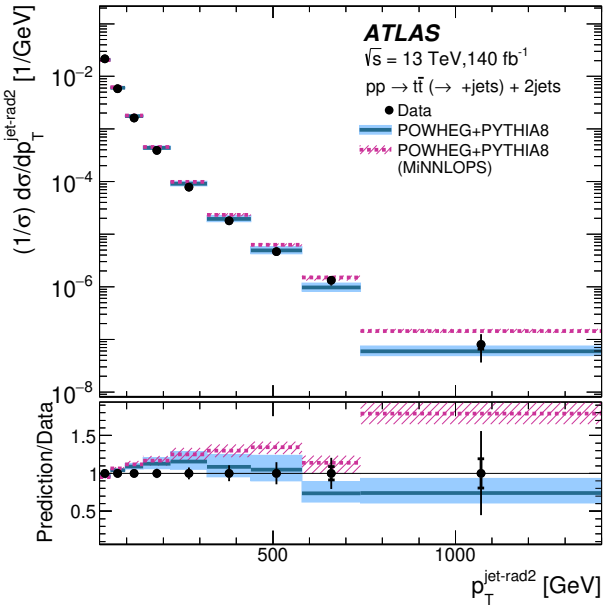
Recent cross-section results from the ATLAS Collaboration

- $t\bar{t}$ - Run2 differential cross sections: JHEP 08 (2024) 182
- $t\bar{t}$ - Run3 total cross section: Phys. Lett. B 848 (2024) 138376
- Single top tW - Run2 cross section: Phys. Rev. D 110 (2024) 072010
- WbWb - Run2 differential cross sections: arXiv:2506.14700 - **NEW**
- $t\bar{t}W$ - Run2 inclusive and differential cross sections: JHEP 05 (2024) 131
- $t\bar{t}Z$ - Run2 inclusive and differential cross sections: JHEP 07 (2024) 163
- $t\bar{t}\gamma\gamma$ - Run2 observation: arXiv:2506.05018 - **NEW**

$t\bar{t}$ differential cross sections

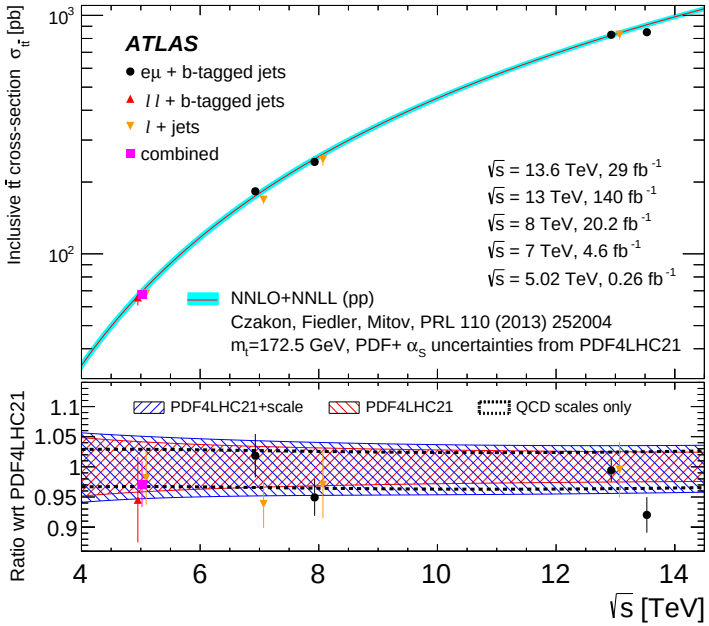
- JHEP 08 (2024) 182
- Single-lepton selection
- Measured absolute and normalised differential cross sections
  - many observables, defined using particle-level jets
  - also in the final state with 1 or 2 additional jets
- In general, good agreement with SM predictions
  - None of the MC predictions describe well all observables
  - NNLO QCD prediction more consistent with the measurement than NLO QCD (except p_{T} of the second hardest radiated jet)

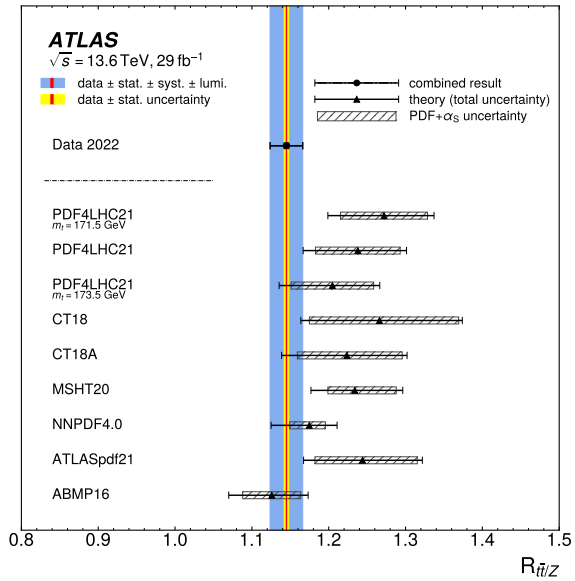




$t\bar{t}$ inclusive cross section at 13.6 TeV

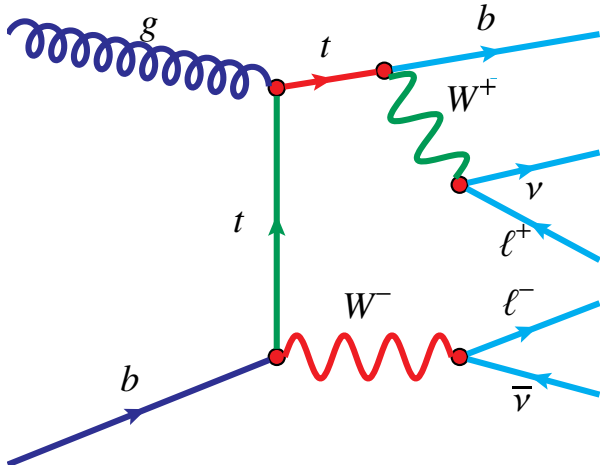
- Phys. Lett. B 848 (2024) 138376
- Dilepton selection
- Using 29 fb^{-1} of data collected in 2022
- $t\bar{t}$ cross-section measurement consistent with the SM prediction (NNLO QCD + NNLL)
  - limited by the luminosity and lepton uncertainties
- Measured also the ratio between $t\bar{t}$ and Z boson production in a fiducial phase space
  - uncertainties cancelled out leading to total uncertainty of 1.9%

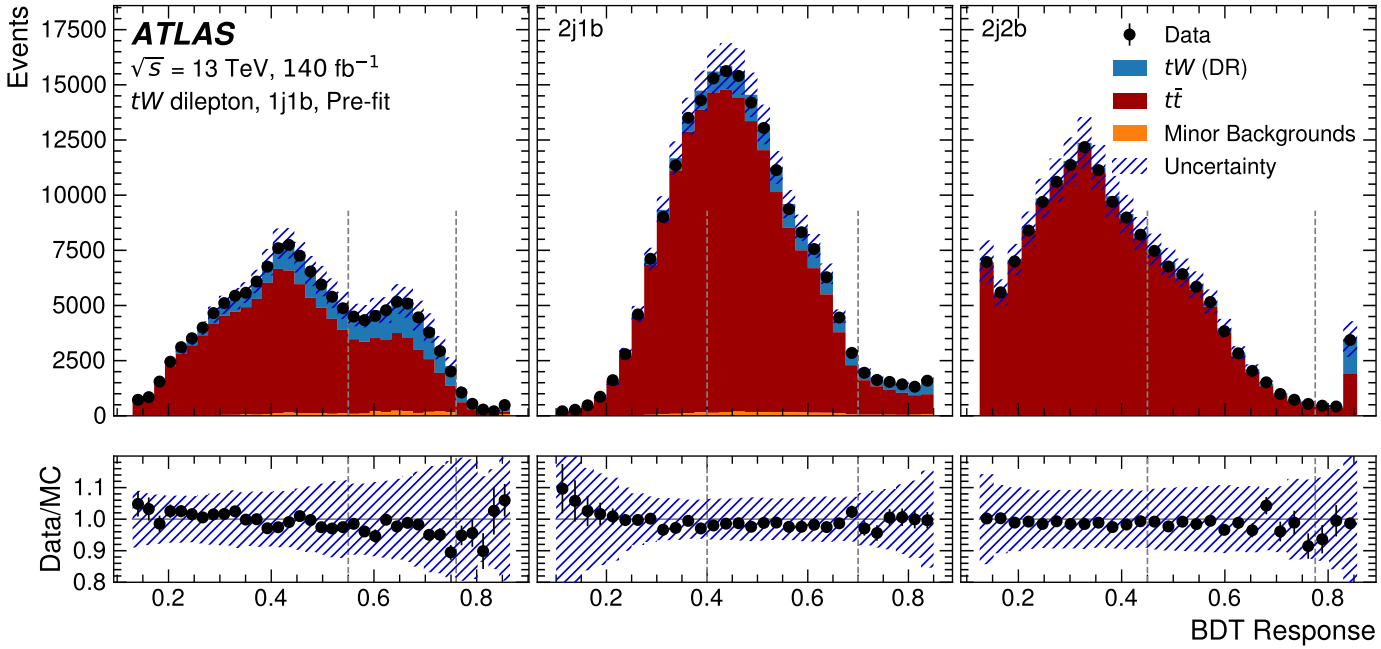




Single top tW

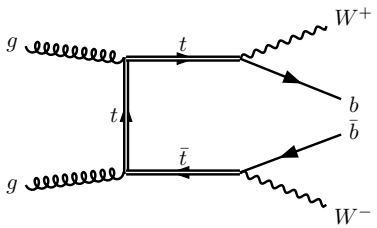
- Phys. Rev. D 110 (2024) 072010
- Dilepton selection
- Boosted Decision Trees to separate signal from background
- Measured inclusive cross section: 75^{+15}_{-14} pb
  - consistent with the SM prediction: $(79.3^{+1.9}_{-1.8}(\text{scale}) \pm 2.2(\text{PDF})$ pb at NLO QCD+NNLL)

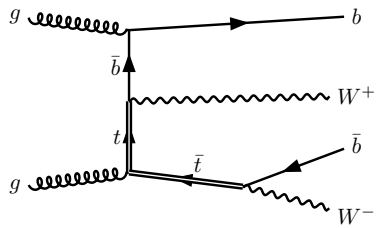


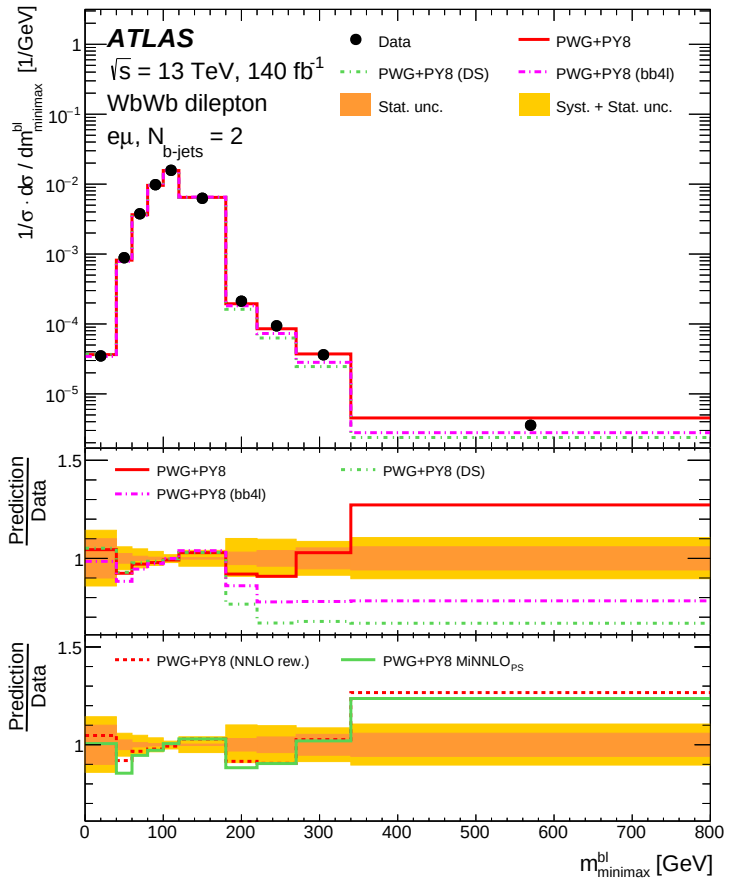


WbWb differential cross sections - NEW

- arXiv:2506.14700
- WbWb final state targets two modelling challenges:
  - top-quark decay
  - interference between $t\bar{t}$ and single top tW processes
- Dilepton selection
- Measured absolute and normalised differential cross-sections
  - many observables, defined using particle-level leptons and jets
  - main uncertainty: signal modelling
- Discrepancies between the measured distributions and SM predictions
  - Improvements needed for the modelling of WbWb final state

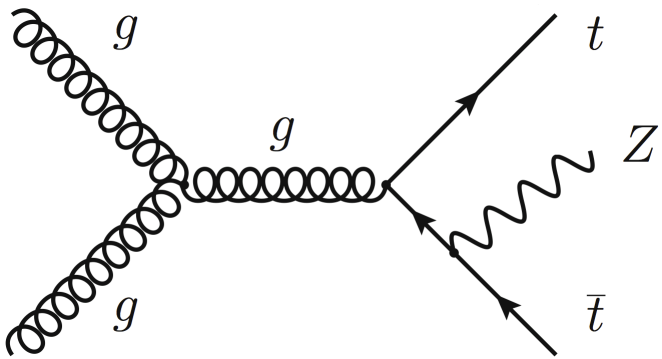


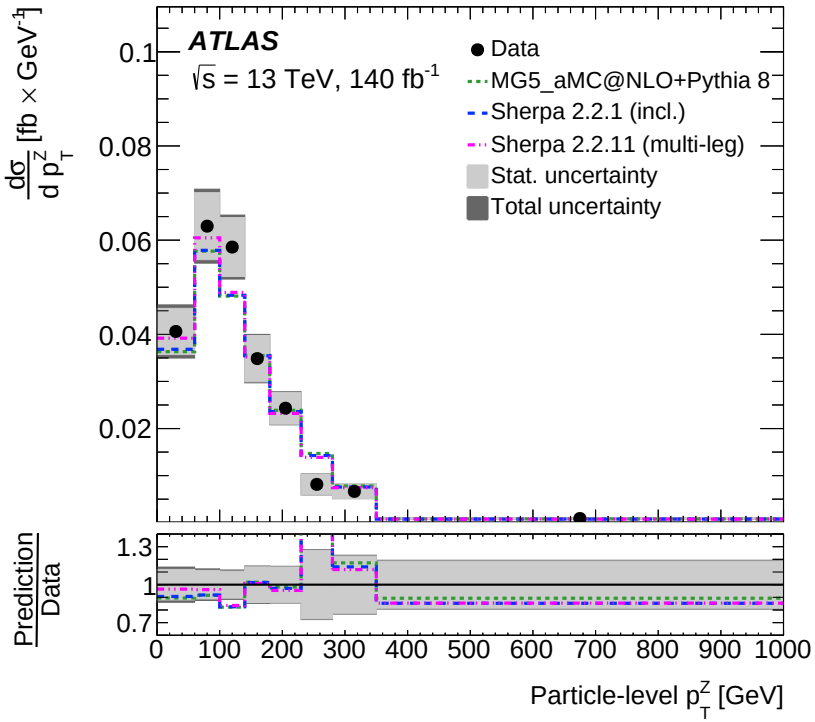




$t\bar{t}Z$

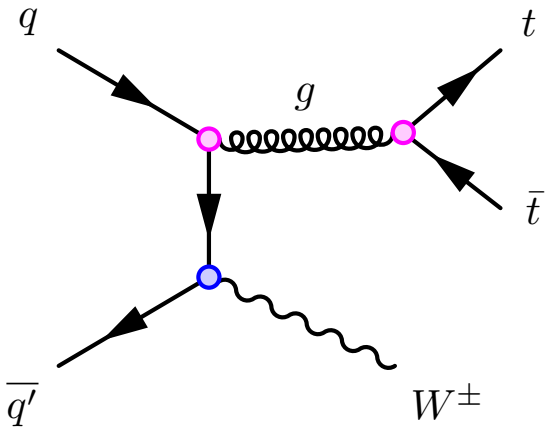
- JHEP 07 (2024) 163
- Selections with 2, 3, and 4 leptons
- Deep Neural Networks used to separate signal from background
- Measured cross section:
  $0.86 \pm 0.04(\mathrm{stat}) \pm 0.04(\mathrm{syst})$ pb
  - consistent with the SM prediction (0.86 ± 0.09 pb at NLO(QCD+EW)+NNLL)
- Differential cross sections
  - Many observables (N_{jets}, H_T^{ℓ}, p_T^t,...)
  - Unfolded to parton and particle level in fiducial phase spaces
  - Measured spectra consistent with SM

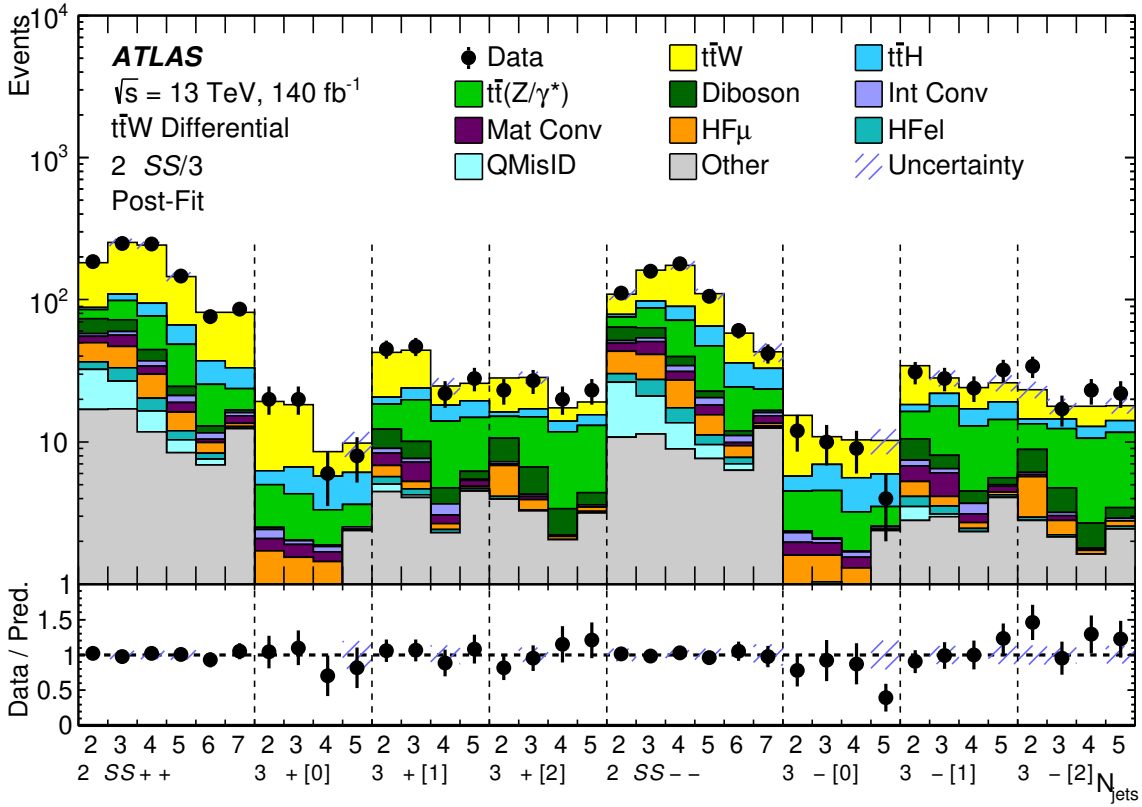




$t\bar{t}W$

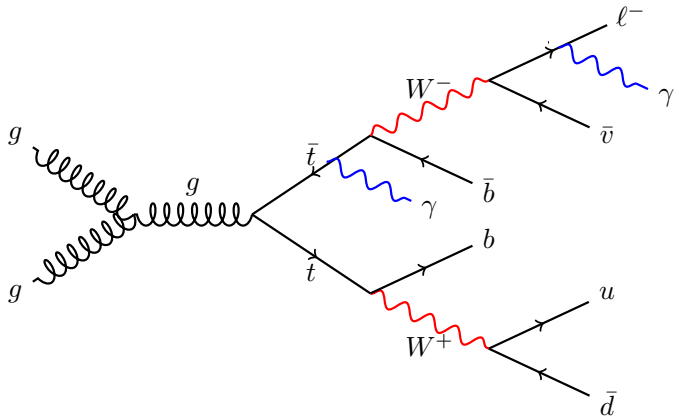
- JHEP 05 (2024) 131
- Two same-charge or three leptons
- Measured cross section: 0.88 ± 0.08 pb
  - consistent with the SM prediction (0.75 ± 0.05 pb at NNLO(QCD)+NLO(EW))
- First measurement of differential cross sections

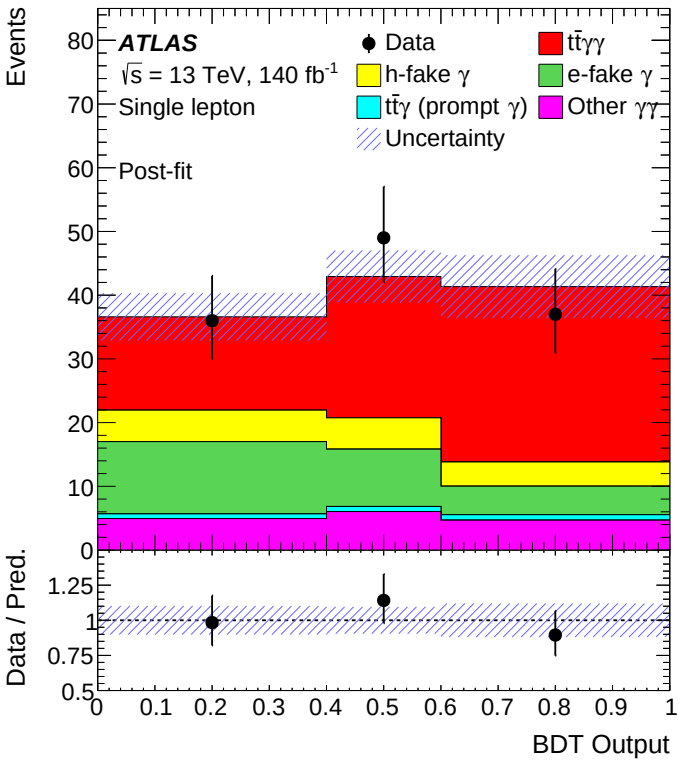




$t\bar{t}\gamma\gamma$ - NEW

- arXiv:2506.05018
- Boosted Decision Trees to separate signal from background
- First observation of $t\bar{t}\gamma\gamma$
  - Exected significance: 5.7σ
  - Observed significance: 5.2σ
- Measured cross section in a fiducial phase space at particle level: $2.42^{+0.58}_{-0.53}$ fb
  - tension with the SM prediction: $1.53^{+0.40}_{-0.52}(\text{scale})^{+0.05}_{-0.03}(\text{PDF})$ fb at LO QCD
    - more precise prediction not available
- Measured ratio of $t\bar{t}\gamma\gamma$ to $t\bar{t}\gamma$: $3.30^{+0.70}_{-0.65} \times 10^{-3}$
  - dominated by statistical uncertainties (systematic uncertainties cancel out in the ratio)





Summary

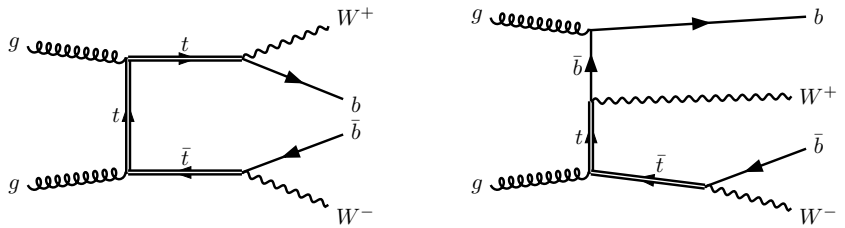
- The ATLAS experiment has an extensive physics program to target top-quark processes
- Recent highlights of cross-section measurements presented:
  - $t\bar{t}$ and tW inclusive cross section measurements
  - WbWb differential cross section measurement
  - $t\bar{t}W$ and $t\bar{t}Z$ inclusive and differential cross section measurements
  - $t\bar{t}\gamma\gamma$ observation

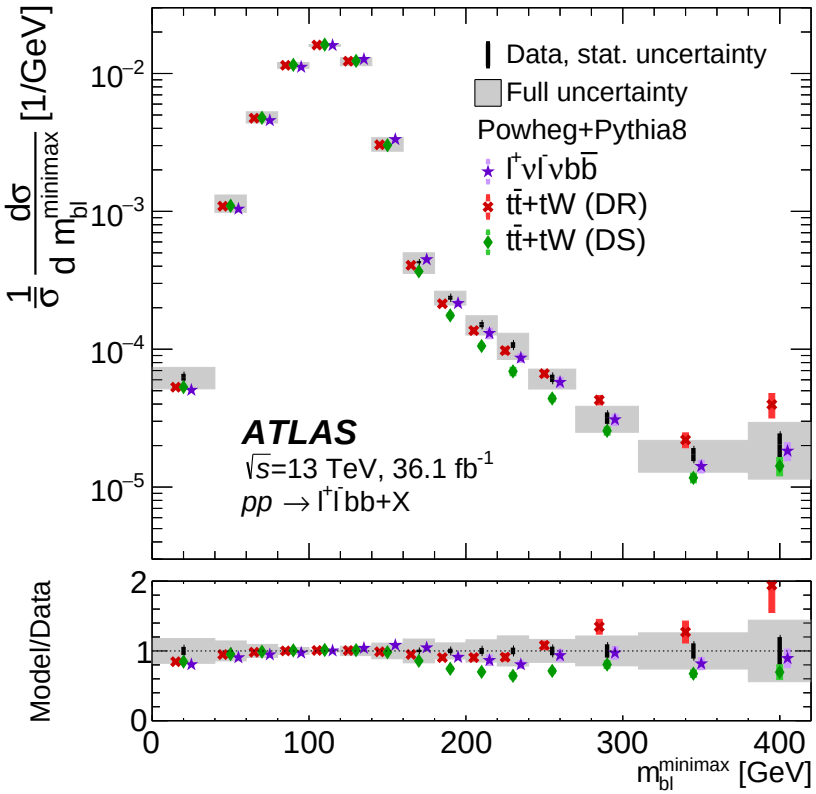
All ATLAS public results related to top physics:
https://twiki.cern.ch/twiki/bin/view/AtlasPublic/TopPublicResults

BACKUP

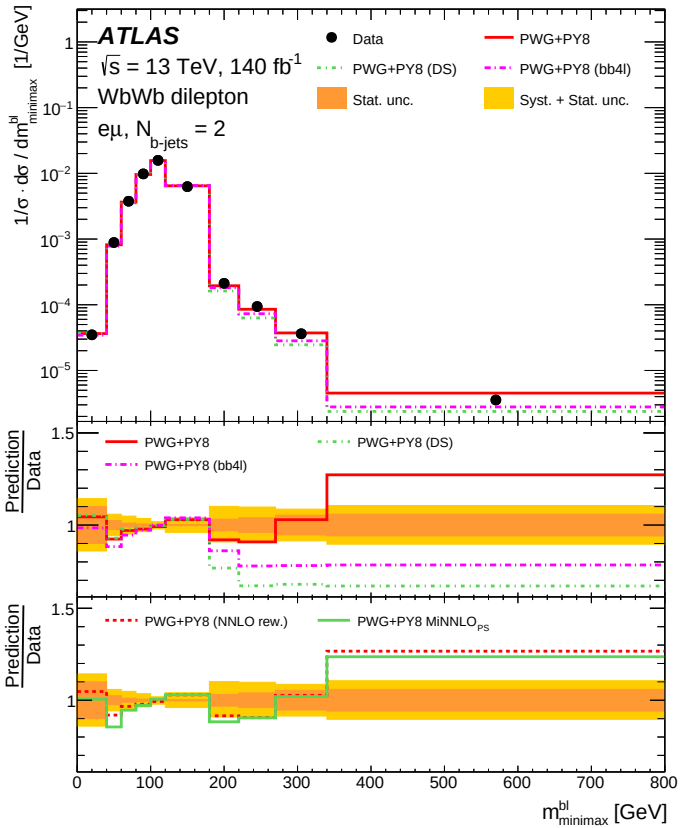
WbWb - comparison with previous publication

- Previous publication: Phys. Rev. Lett. 121 (2018) 152002
  - Better agreement between the measurement and the bb4l prediction





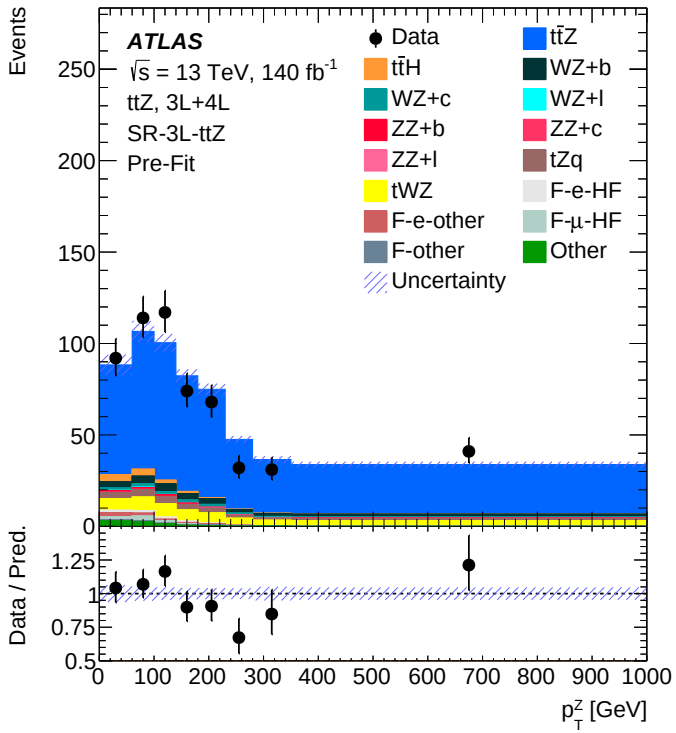
Phys. Rev. Lett. 121 (2018) 152002

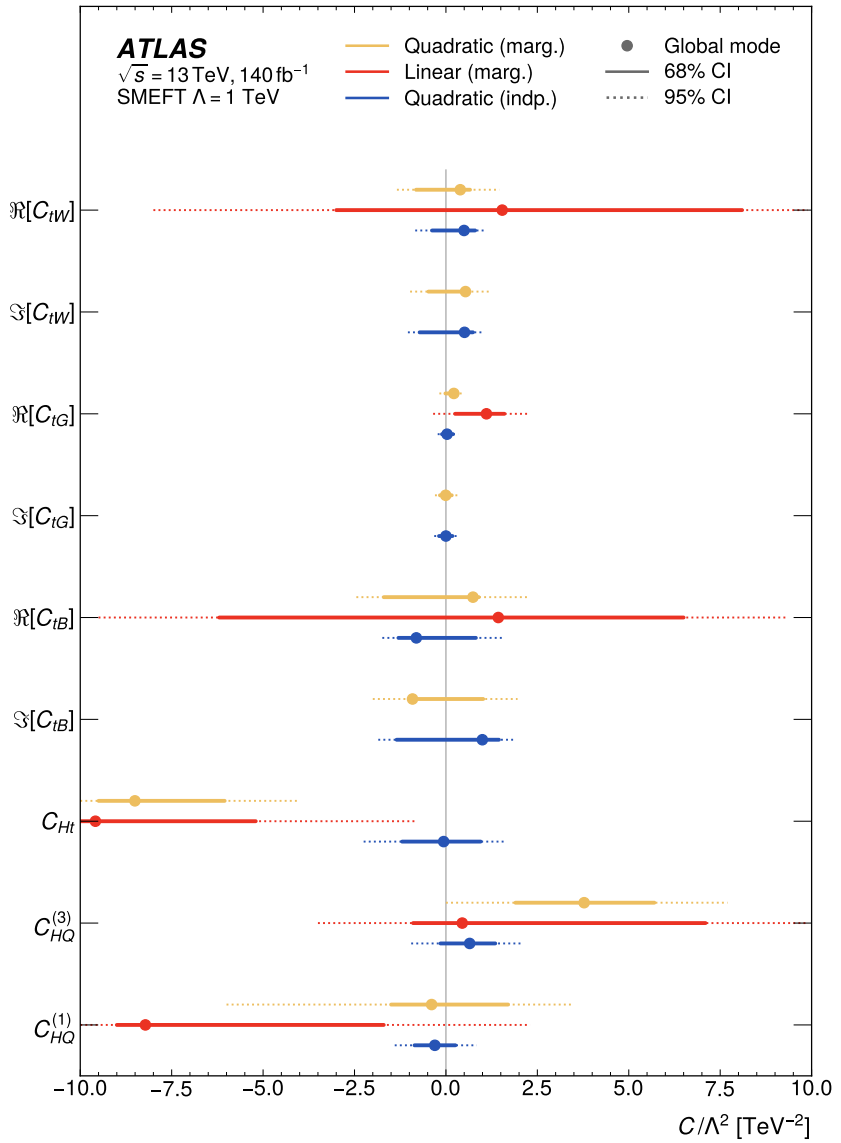


arXiv:2506.14700

$t\bar{t}Z$

- Differential cross sections
  - Many observables (N_{jets}, H_T^{ℓ}, p_T^t,...)
  - Unfolded to parton and particle level in fiducial phase spaces
  - Measured spectra consistent with SM
- Constrained top–electroweak and four-quark SMEFT operators





$t\bar{t}W$

- Differential cross sections
  - First such measurement in this topology
  - Jet and lepton observables (N_{jets}, H_T^{jet}, $\Delta\Phi_{\ell\ell}$,...)
  - Unfolded to particle level in a fiducial phase space
  - Measurements consistent with SM
- Measured $t\bar{t}W^+$ vs $t\bar{t}W^-$ charge asymmetry