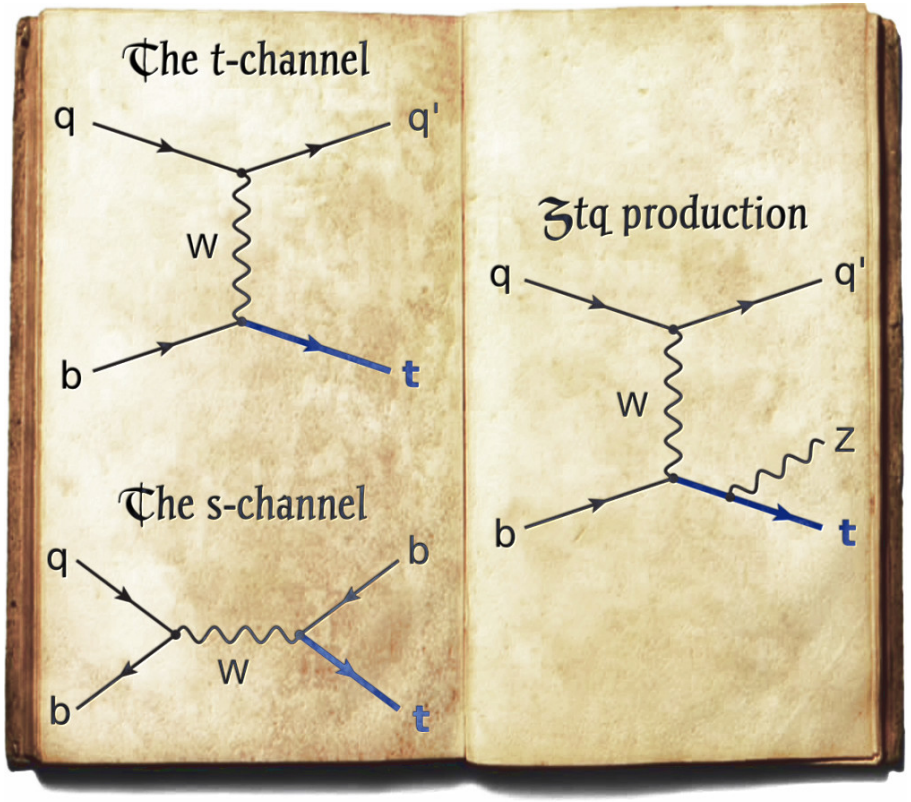
Single top plans for HL/HE YR



HLHE2018 workshop

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Outline & authors

- theory-inspired introduction
  - predictions for HE
  - modeling (4/5FS, channel separation)
  - potential EFT interpretations

E. Re., F. Caola

- common analysis techniques
  - MVA, unfolding (iterative Bayesian & TUnfold)
  - top quark reconstruction (t-channel/tZq)

common also for other studies
→ shared description?

- t-channel cross section (HL): 3 plots
  - charge ratio → sensitive to PDF
  - differential top quark pT, rapidity → sensitive to modeling, PDF
  - differential polarization angle → sensitive to EFT/Wtb couplings

M. Komm, W. A. Khan

- s-channel inclusive cross section (HL/HE): 2 plots
  - inclusive, differential cross-sections
  - analysis of high-Q2 regime → sensitive to EFT/Wtb couplings

K. Finelli

- tZq inclusive cross section (HL): ~1 plot (potentially also differential)

I. Cioara

- total: ~4 pages, 5-6 plots

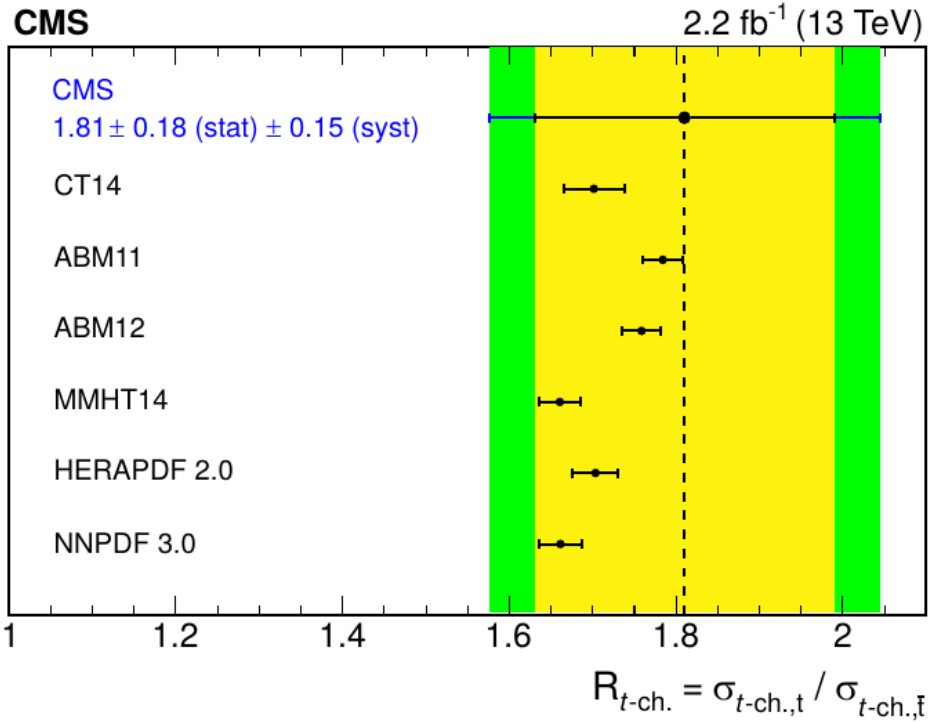
Motivation: t-channel

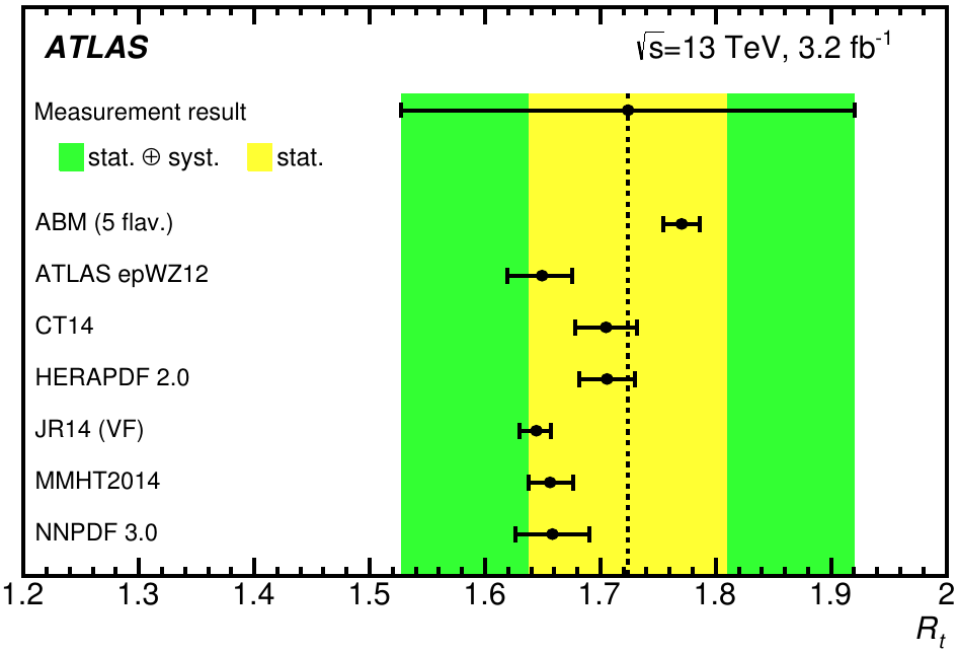
- inclusive cross section measurements @ 13 TeV
  - CMS: $\sigma_t = 238 \pm 13\ (\text{stat}) \pm 29\ (\text{syst})\ \text{pb}$ → Phys. Lett. B 72 (2017) 752
  - ATLAS: $\sigma_t = 247 \pm 6\ (\text{stat}) \pm 45\ (\text{syst})\ \text{pb}$ → JHEP04 (2017) 086

→ already dominated by systematic uncertainties using only data from 2015

→ further precision at HL only possible through in-depth study of experimental syst. & modeling

- charge ratio
  - allows for cancellation of systematic uncertainties

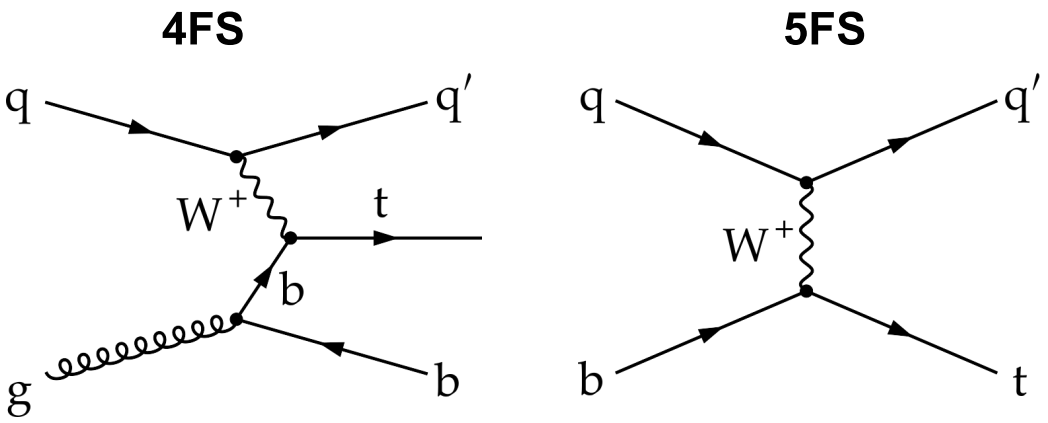




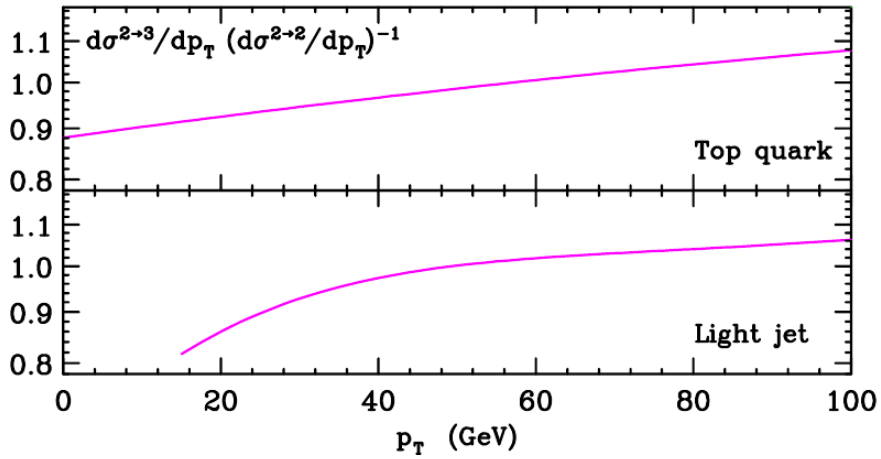
→ HL-LHC might provide additional input to u/d ratio in proton PDF

Motivation: t-channel (2)

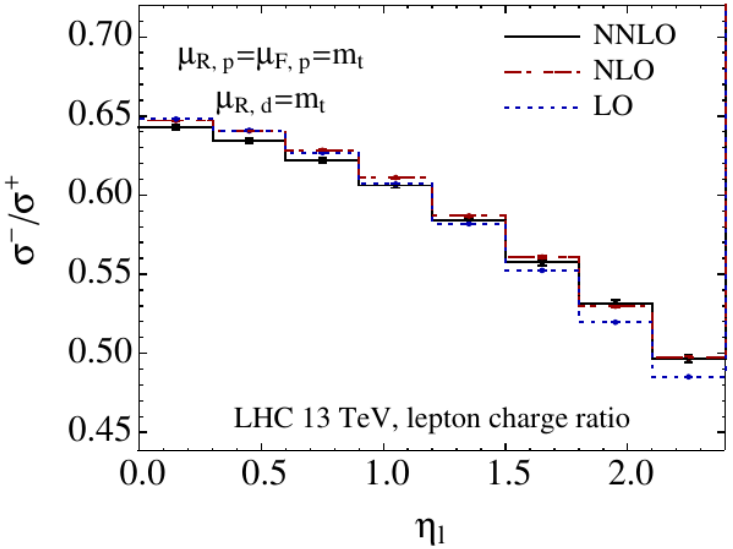
- differential cross sections
  - top quark p_{T} sensitive to flavor schemes



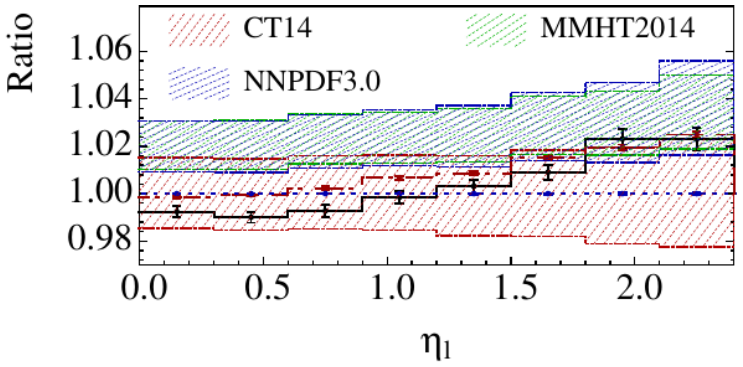
→ J. Campbell et al. Phys.Rev.Lett.102:182003, 2009



  - top quark rapidity sensitive to PDF



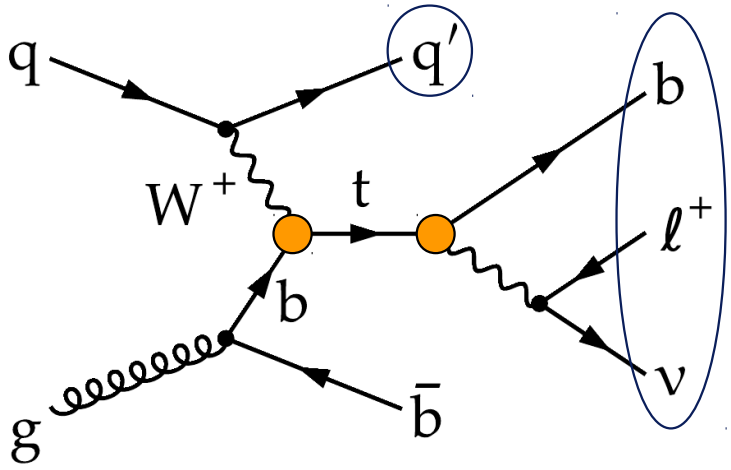
→ E. Berger, Phys. Rev. D 94, 071501 (2016)



Motivation: t-channel (3)

→ Nucl.Phys.B840:349-378,2010
→ Phys.Lett. B476 (2000) 323-330
→ Phys.Lett. B534 (2002) 97-105

- production of polarized top quark polarization

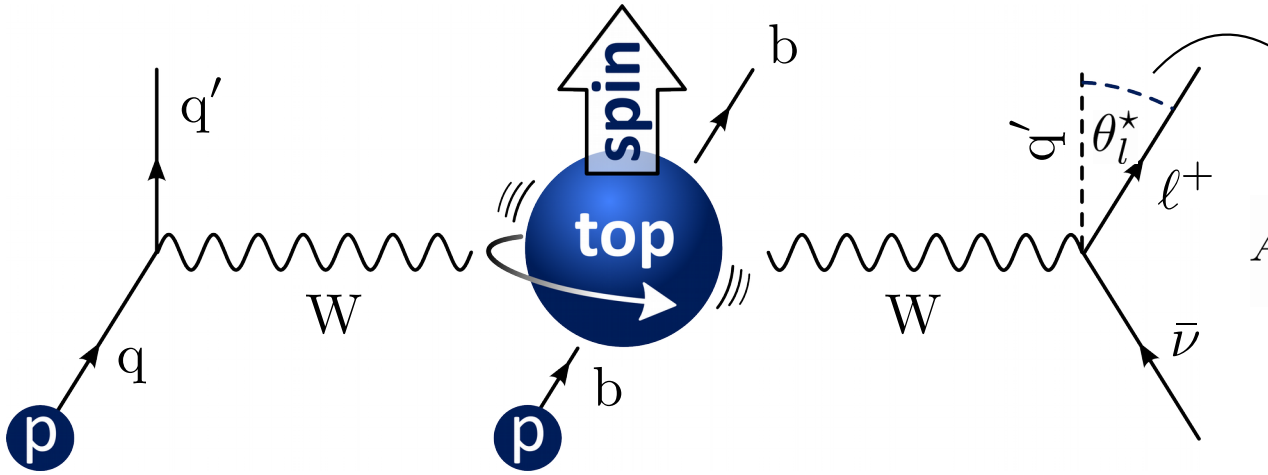


in SM: $\mathcal{L}^{\mathrm{SM}}_{Wtb} \propto \bar{b}\left(\boxed{\gamma_\mu}-\boxed{\gamma_\mu\gamma_5}\right)tW^\mu$

V − A

→ top quark spin aligned with spectator quark (q')
→ angular distributions of decay products dictated by coupling structure

- observable: angle between q' & lepton in top rest frame: $\cos\theta^\star_\ell = \dfrac{\vec{p}^{(\mathrm{t})}(\mathrm{q}')\cdot\vec{p}^{(\mathrm{t})}(\ell)}{|\vec{p}^{(\mathrm{t})}(\mathrm{q}')||\vec{p}^{(\mathrm{t})}(\ell)|}$



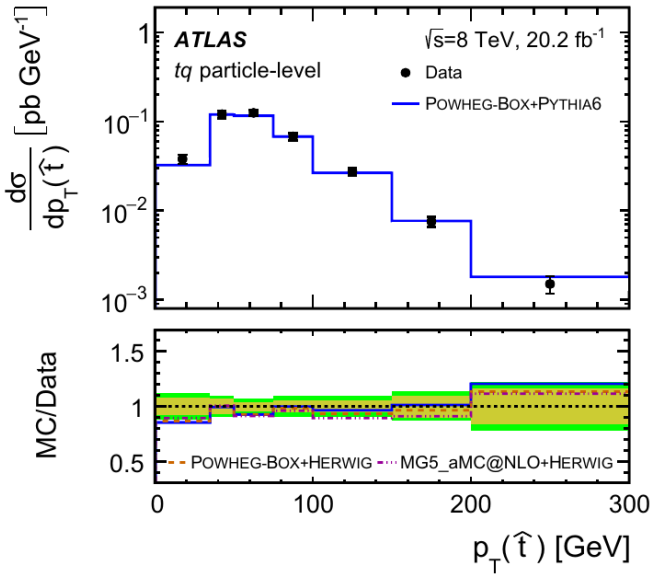
$A_l^{\mathrm{SM}} = \dfrac{N_\uparrow - N_\downarrow}{N_\uparrow + N_\downarrow} = \dfrac{1}{2}P_{\mathrm{t}}\cdot\alpha_l = 0.44$

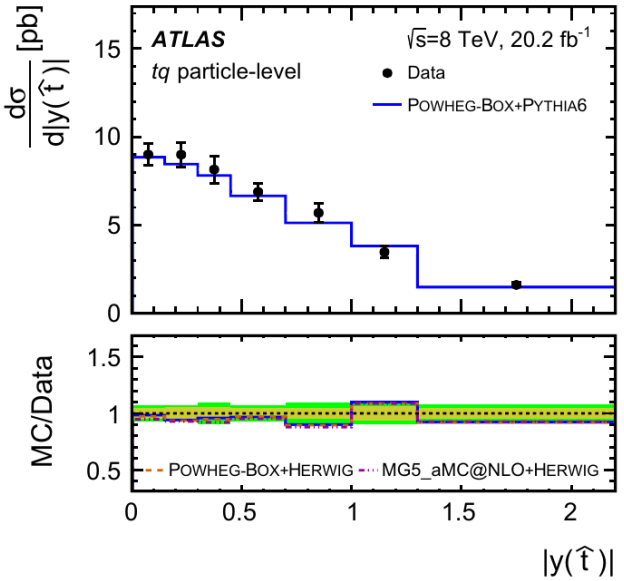
production: $\vec{s}_{\mathrm{top}}\cdot\vec{p}_{q'} \sim P_{\mathrm{top}}$

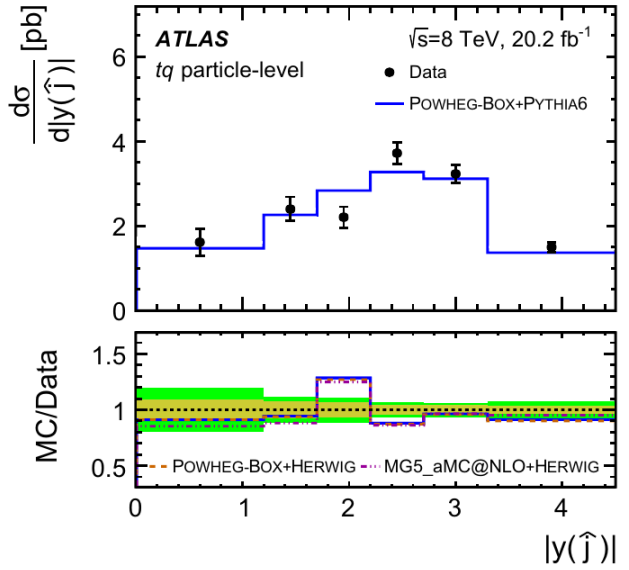
decay: $\vec{s}_{\mathrm{top}}\cdot\vec{p}_l \sim \alpha_l$

Previous differential measurements …

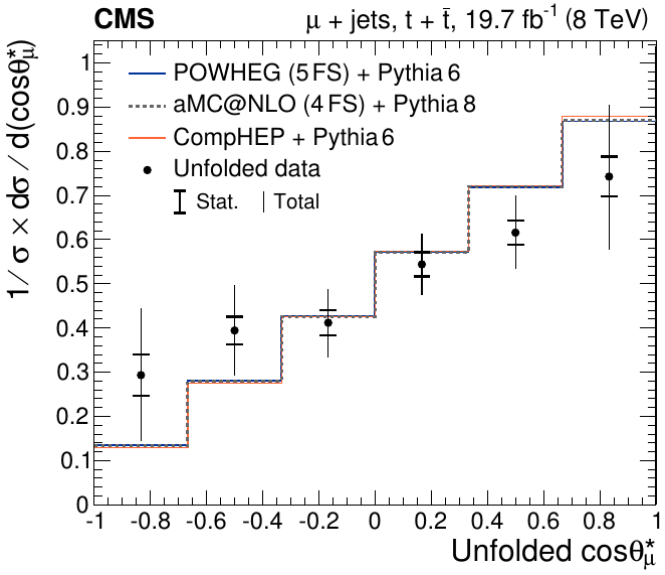
- top quark p_{T}, rapidity & spectator jet rapidity @ 8 TeV by ATLAS → Eur. Phys. J. C 77 (2017) 531

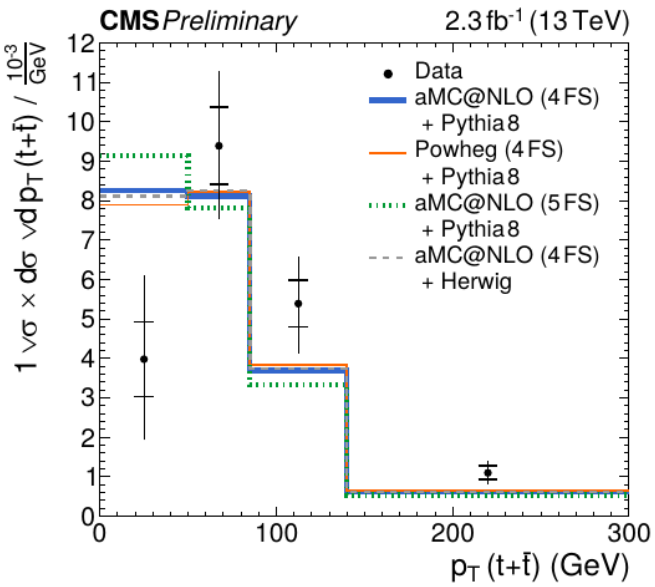


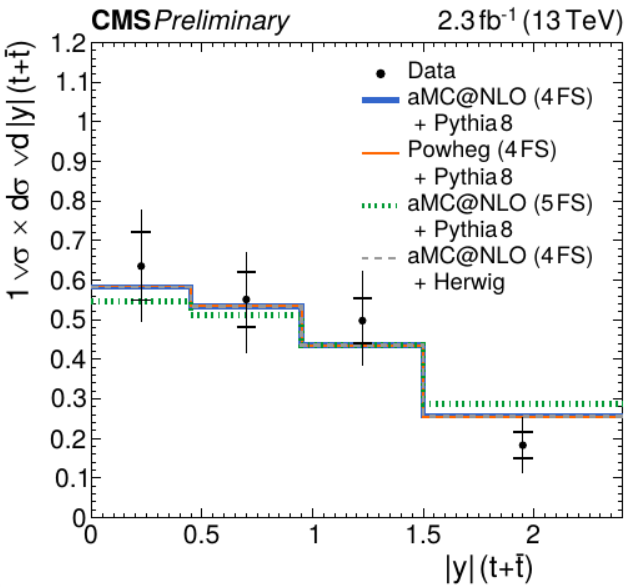




- polarization angle, top quark p_{T}, rapidity @ 8/13 TeV by CMS → JHEP 04 (2016) 073, TOP-PAS-16-004





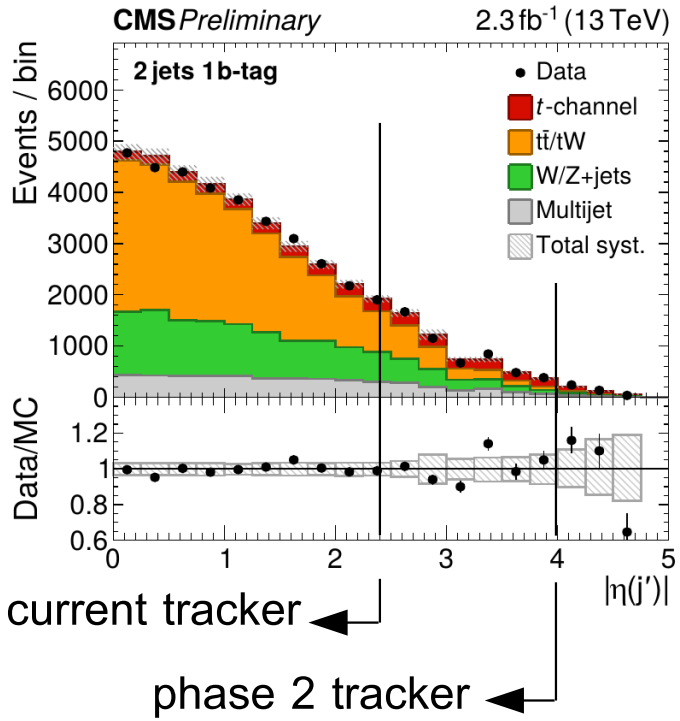


t-channel strategy

- goals
  - HL-LHC scenario only
  - employ standard single top t-channel selection (1 lepton & 2-3 jets w/ 1 b-tag)
  - assess sensitivity of charge ratio → evaluate potential gain in PDF fits
  - differential measurements
    - top quark p_{T}, rapidity
    - polarization angle → extract asymmetry & precision on Wtb couplings

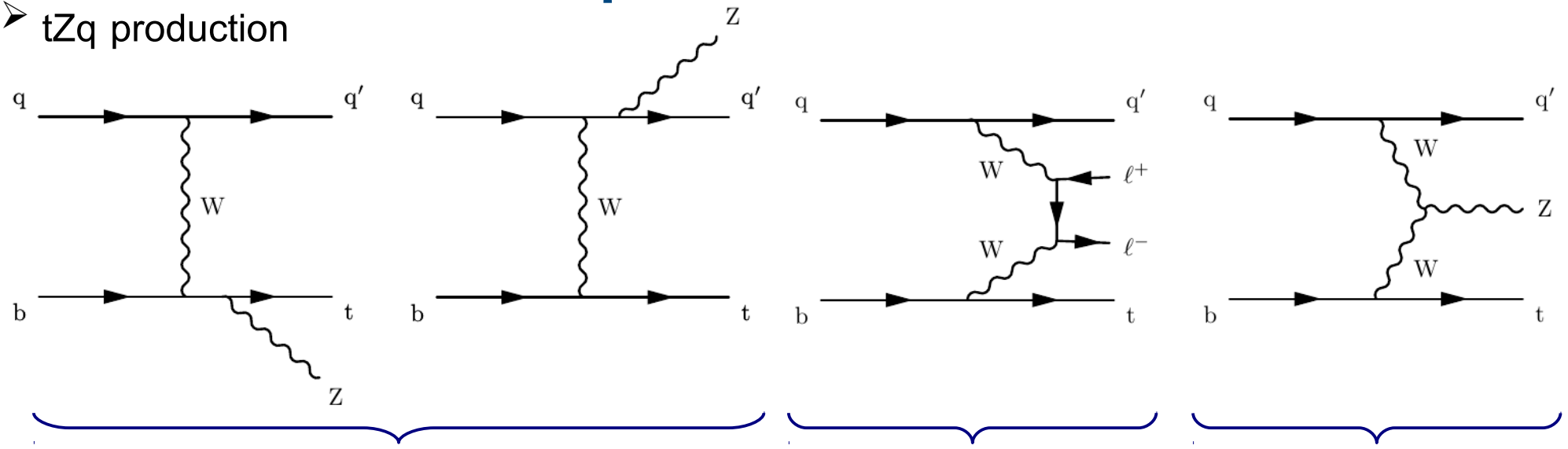
- workflow
  - simulation of multijet background not feasible
    → derive multijet contamination by extrapolating shape/yield from existing analyses at 13 TeV instead
  - use pseudorapidity of light jet to estimate precision of signal yield through fit
    → challenge: understand impact of pileup in forward region
  - estimate signal yield for top quark/antiquark & also as a function of the unfolding observables
  - unfold fit results to parton level using TUnfold

→ TOP-PAS-16-004



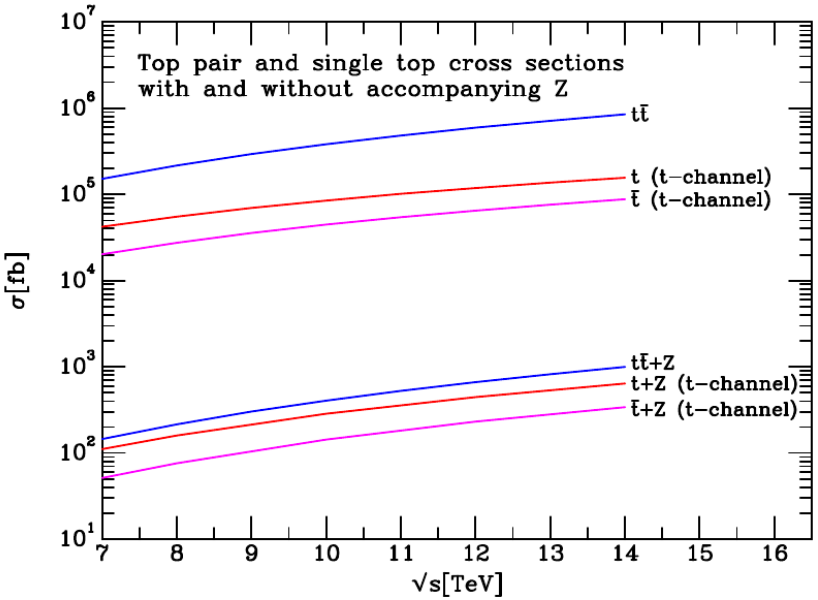
Motivation: tZq

- tZq production



- properties
  - very small contribution to total single top production
  - includes W & Z boson EWK couplings to fermions
  - sensitive to potential BSM scenarios, e.g.
    - anomalous gauge couplings
    - FCNC

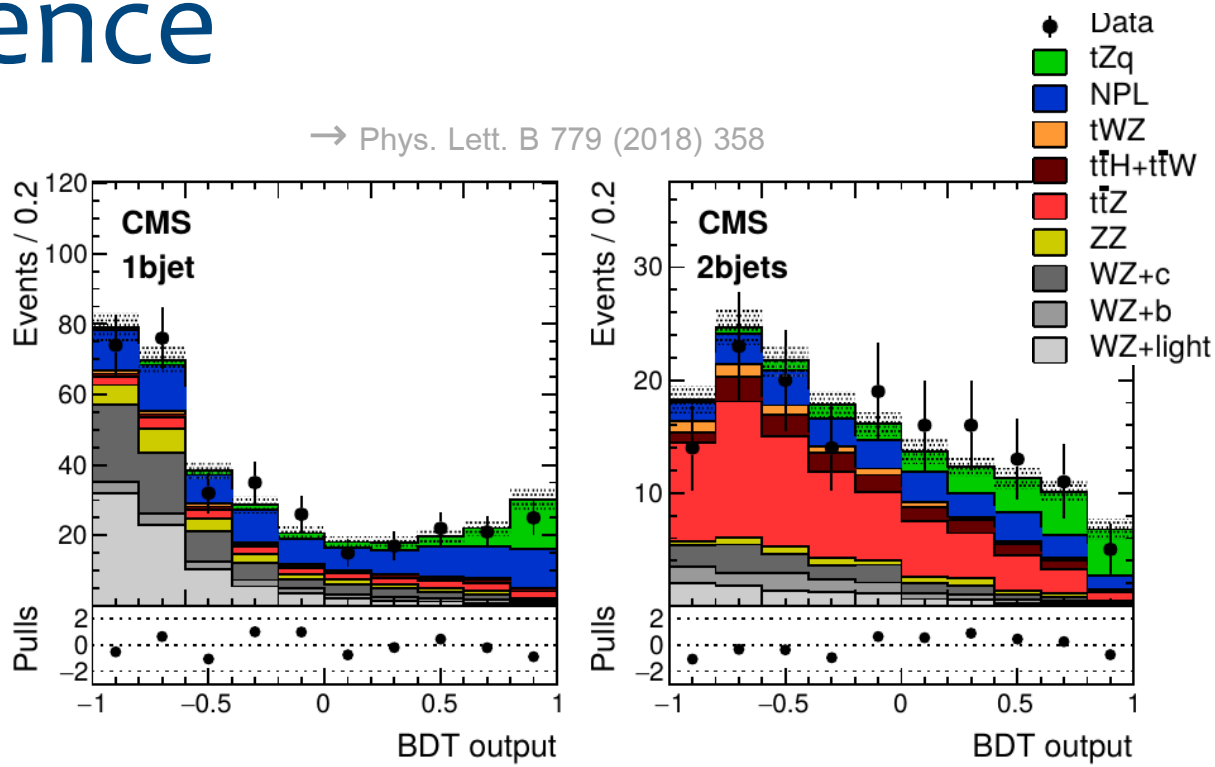
→ PhysRevD.87.114006



Recent tZq evidence

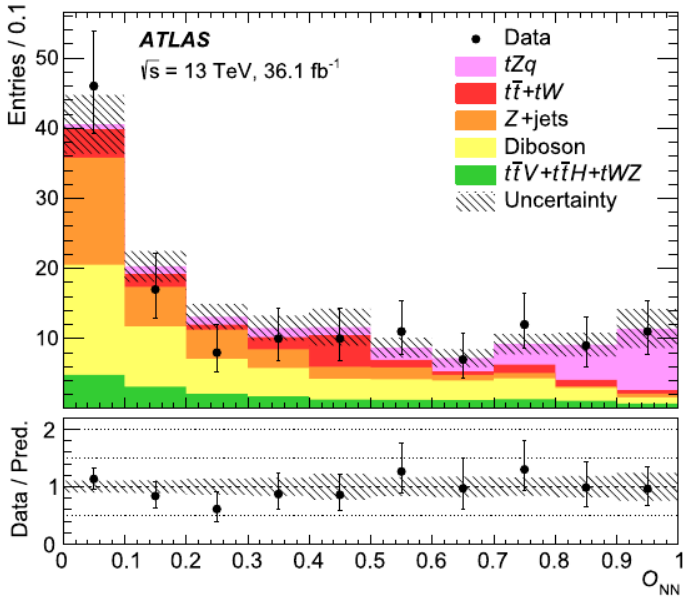
- CMS result
  - measured cross section
    (for $m_{\ell\ell} > 30$ GeV)
    $\sigma_{t\ell^+\ell^-q} = 123 \pm 27\%\ (\text{stat})$
    $\pm 23\%\ (\text{syst})$ fb
  - theory: $\sigma^{\text{NLO}}_{t\ell^+\ell^-q} = 94 \pm 3\%$ fb
    (calculated with MG5aMC@NLO)
  - observed significance: 3.7
    (3.1 expected)

→ Phys. Lett. B 779 (2018) 358



- ATLAS result
  - measured cross section (inclusive)
    $\sigma_{tZq} = 600 \pm 28\%\ (\text{stat})$
    $\pm 23\%\ (\text{syst})$ fb
  - theory: $\sigma^{\text{NLO}}_{tZq} = 800 \pm 7\%$ fb
    (calculated with MG5aMC@NLO)
  - observed significance: 4.2
    (5.4 expected)

→ Phys. Lett. B 780 (2018) 557



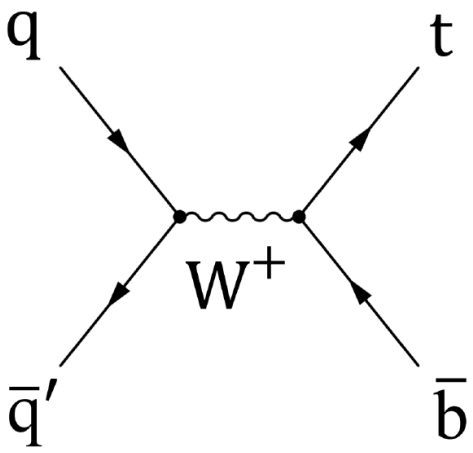
tZq strategy

- goals
  - assess achievable precision of inclusive cross section
    - focus on HL-LHC study
    - add HE-LHC if it fits in timescale
  - focus on 3 lepton channel
  - study possibility of adding also single lepton channel
    (dilepton channel very challenging due to high Drell-Yan background)
  - investigate prospects for differential measurement
    (not yet settled on observable)

- workflow
  - reuse existing ATLAS strategy at 13 TeV
  - employ MVA techniques to separate signal from background
  - challenge: fake background estimation
  - estimate precision through binned fit to pseudo data

Motivation: s-channel

- properties
  - small cross section: $\sigma^{\mathrm{NLO}}_{s\text{-ch}} = 11.4 \pm 0.4\ \mathrm{pb}$ (14 TeV)
  - sensitivity to anomalous couplings
    EFT observables of mass spectrum
  - particularly: probing process at high
    momentum transfers yields high sensitivity
    to anomalous Wtb couplings



- goals
  - assess reachable precision on cross section
  - study sensitivity to Wtb couplings
  - study cross section as a function of the momentum transfer
    for HE scenario (e.g. differentially)
  - determine if the high-Q2 (m_{tb}) region can be access already at HL-LHC

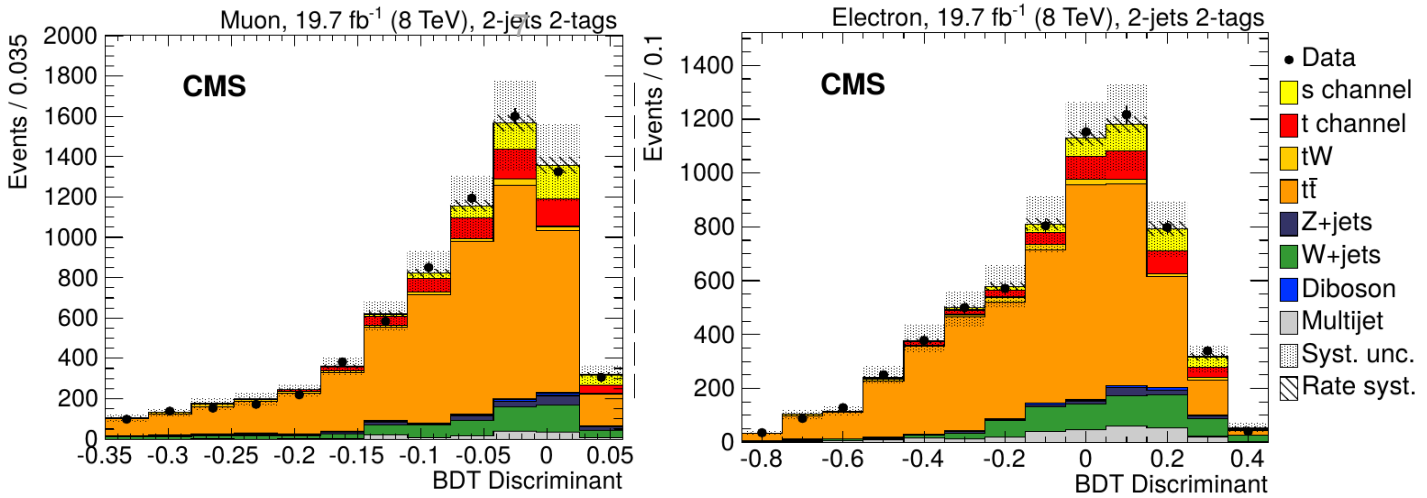
- strategy
  - signal region: 1 lepton + 2 b-tagged jets
  - similar to ATLAS 8 TeV result except using neural network instead of matrix element method
  - a fiducial selection on m_{tb} will be applied to study the high-Q2 region

Previous s-channel measurements

- only 7/8 TeV measurements so far
  (13 TeV challenging due to less steeply increasing cross section wrt. other processes)

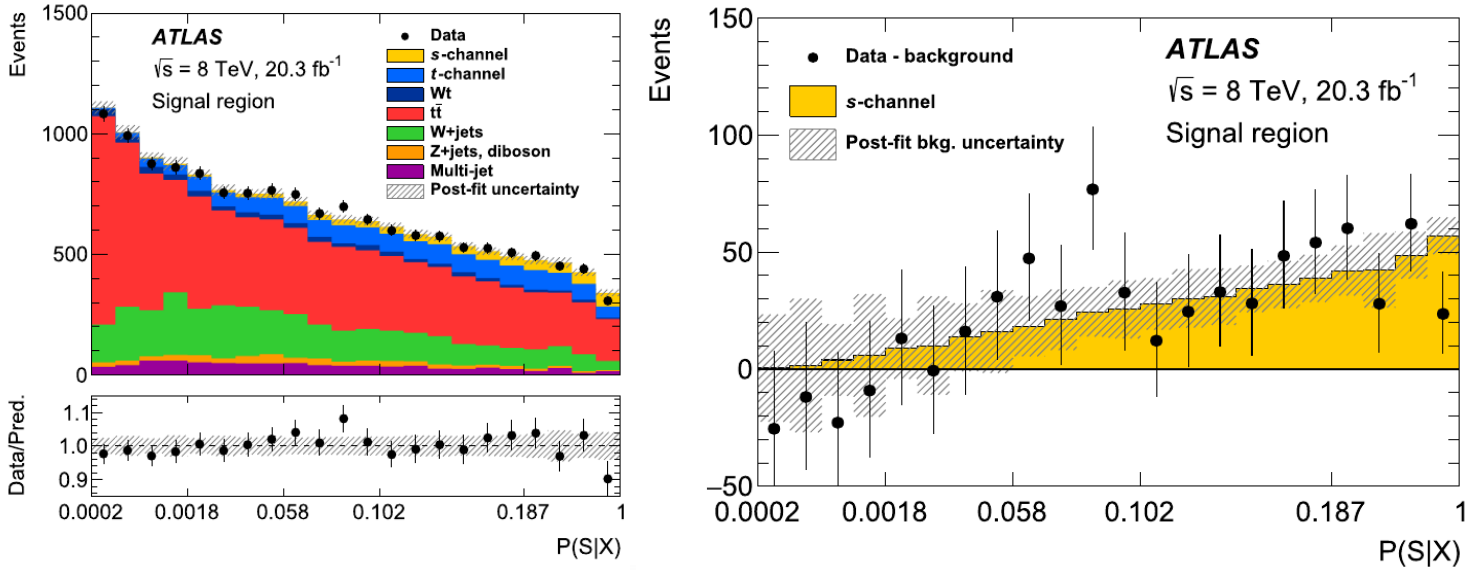
→ JHEP 09 (2016) 02

- **CMS**
  - observed sig.: 2.5
    (expected: 1.1)



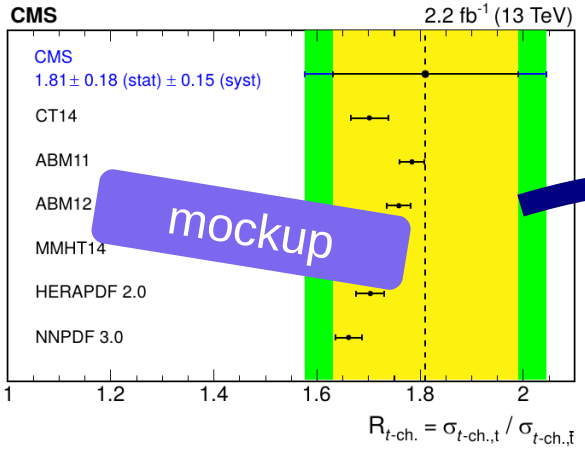
→ Phys. Lett. B756 (2016) 228

- **ATLAS**
  - observed sig.: 3.2
    (expected: 3.9)

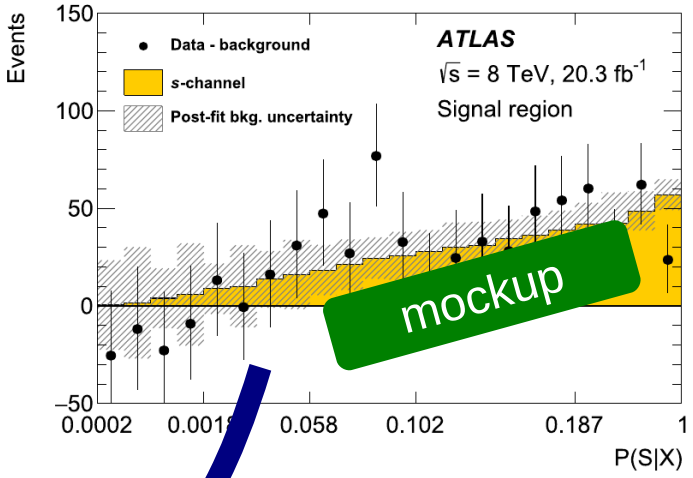


Conclusion

- single top plans for HL/HE YR

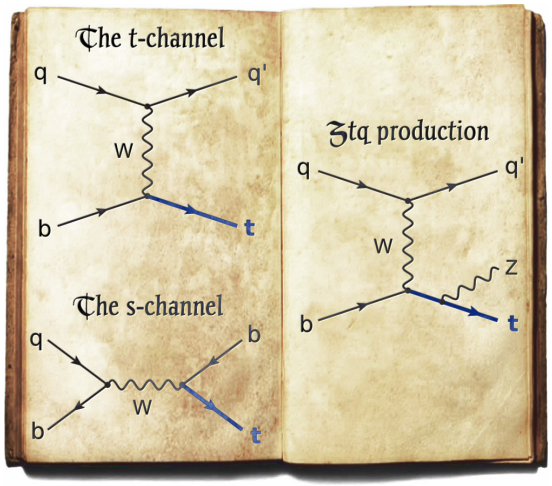


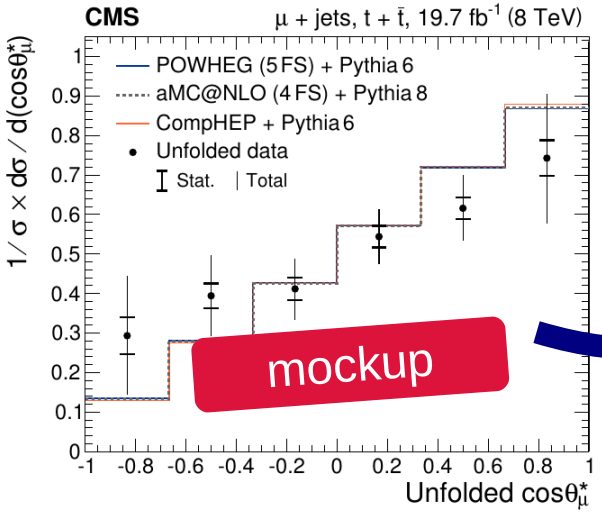
t-channel charge ratio



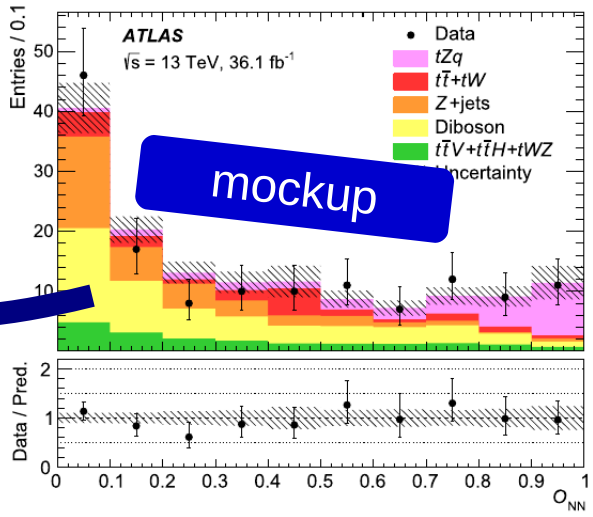
s-channel

inclusive & high-Q2





t-channel differential



tZq production

inclusive/differential