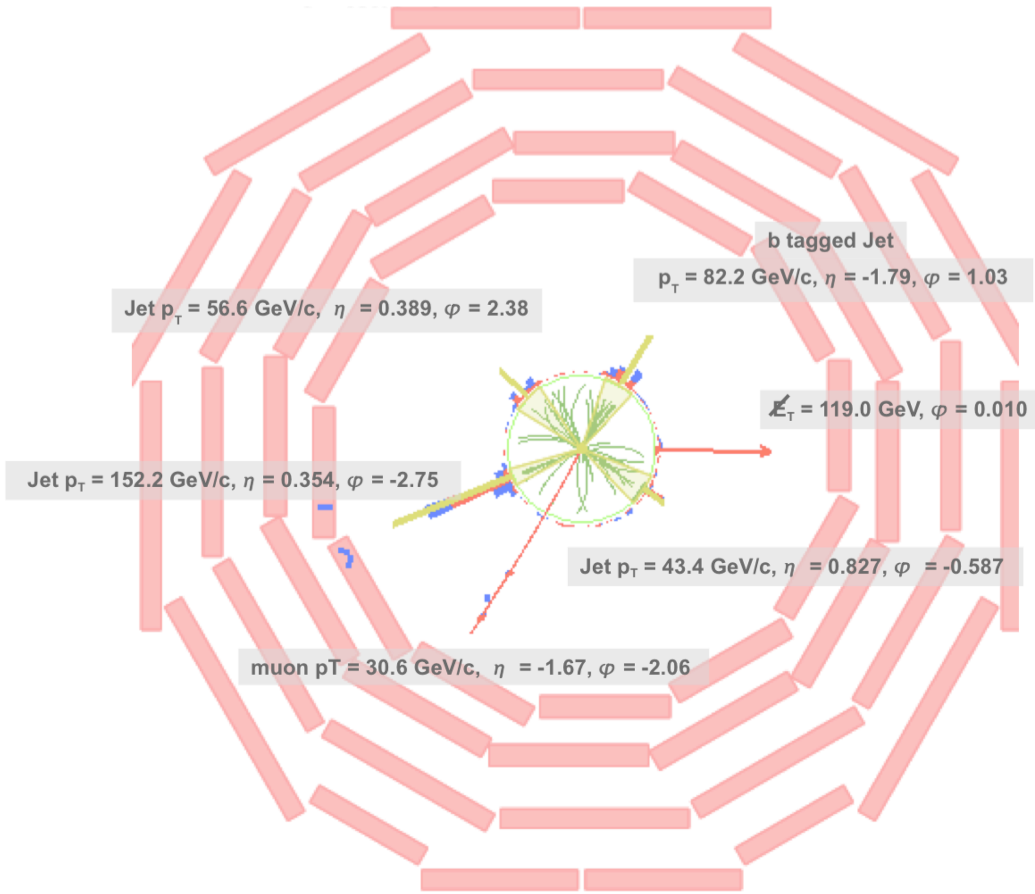
Top P_T measurements at the LHC



HELMHOLTZ | ASSOCIATION

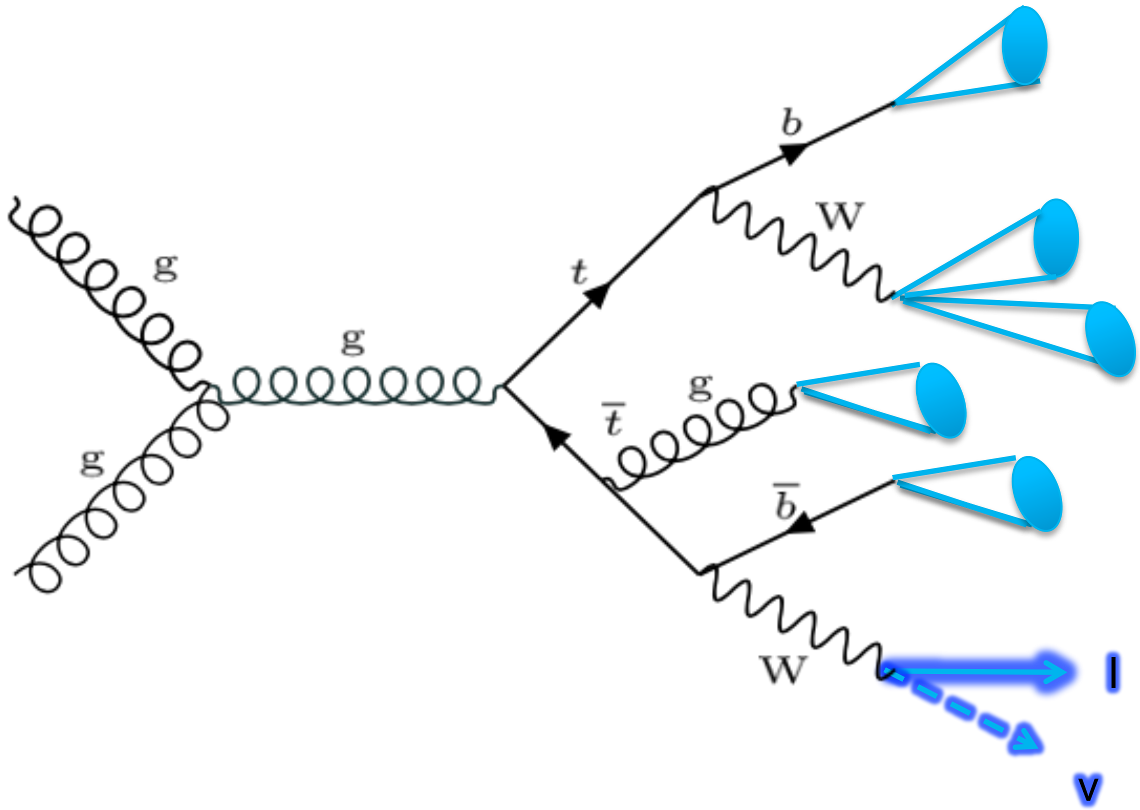
James Keaveney, DESY, September 2017

DESY

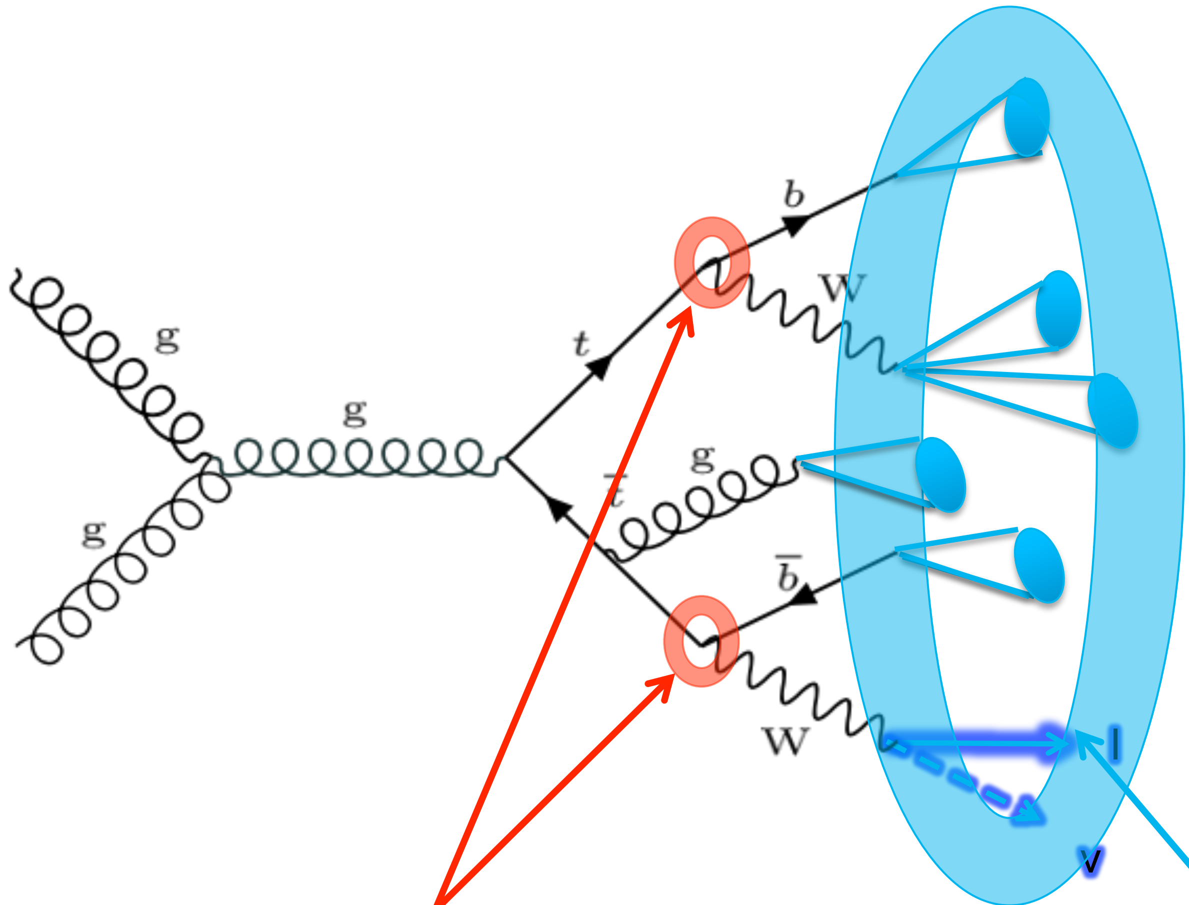
Today's talk

- Review of the Top pt saga:
  - What do we actually measure?
  - Review of the results from ATLAS, CMS
  - Outlook

What do we actually measure?



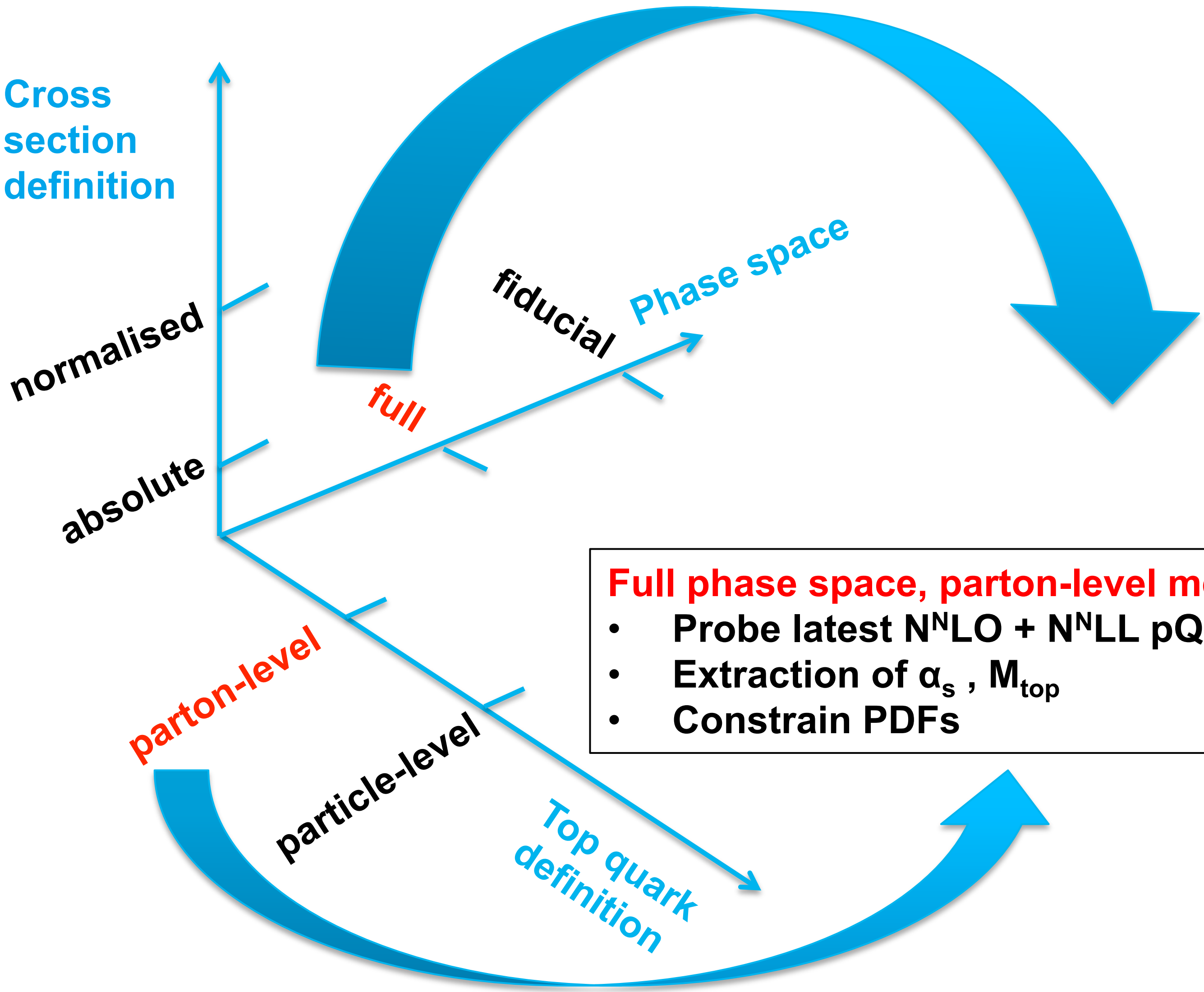
What do we actually measure?



Parton level -
- **after radiation**
- **before decay**

Particle level -
- **after decay, parton shower, hadronisation**

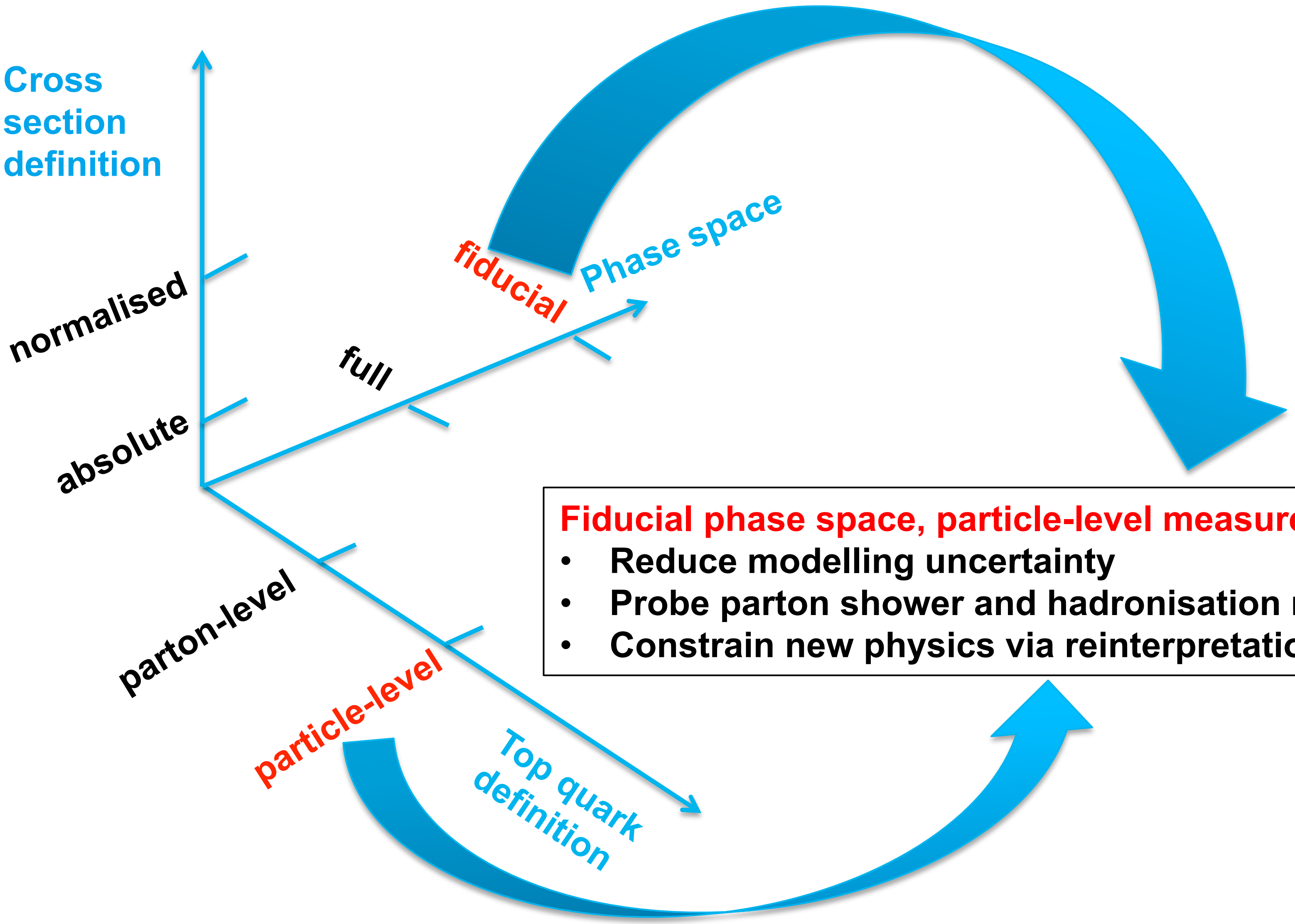
What do we actually measure?



Full phase space, parton-level measurements

- Probe latest N^{N}LO + N^{N}LL pQCD
- Extraction of α_s , M_{top}
- Constrain PDFs

What do we actually measure?



Fiducial phase space, particle-level measurements

- Reduce modelling uncertainty
- Probe parton shower and hadronisation models
- Constrain new physics via reinterpretation

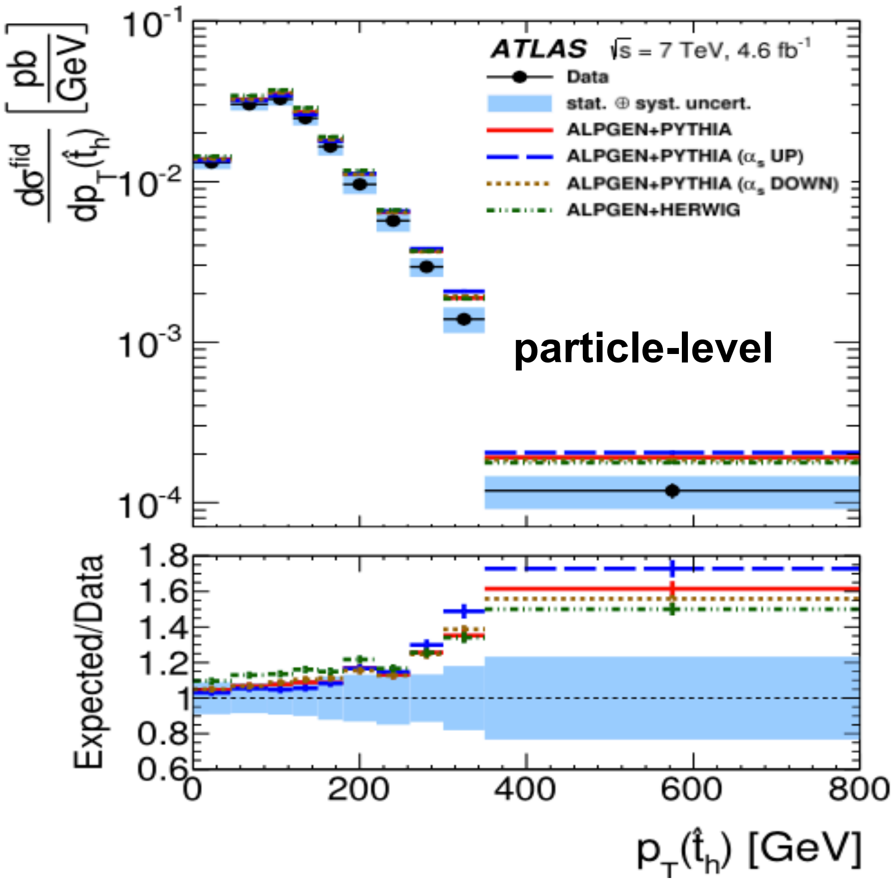
ATLAS + CMS measurements so far

- Top Pt in tt events is one of the key observables measured by ATLAS+CMS
- Its precise modeling is important
  - Largely defines the collimation of top decay products
  - Sensitive to M_{tt} among other search observables
  - Sensitive to kinematics of leptons, jets, -> crucial for triggering, reconstruction.
- Differential tt x-sections as a function of Top Pt are measured in multiple decay channels, kinematic regimes and top quark definitions

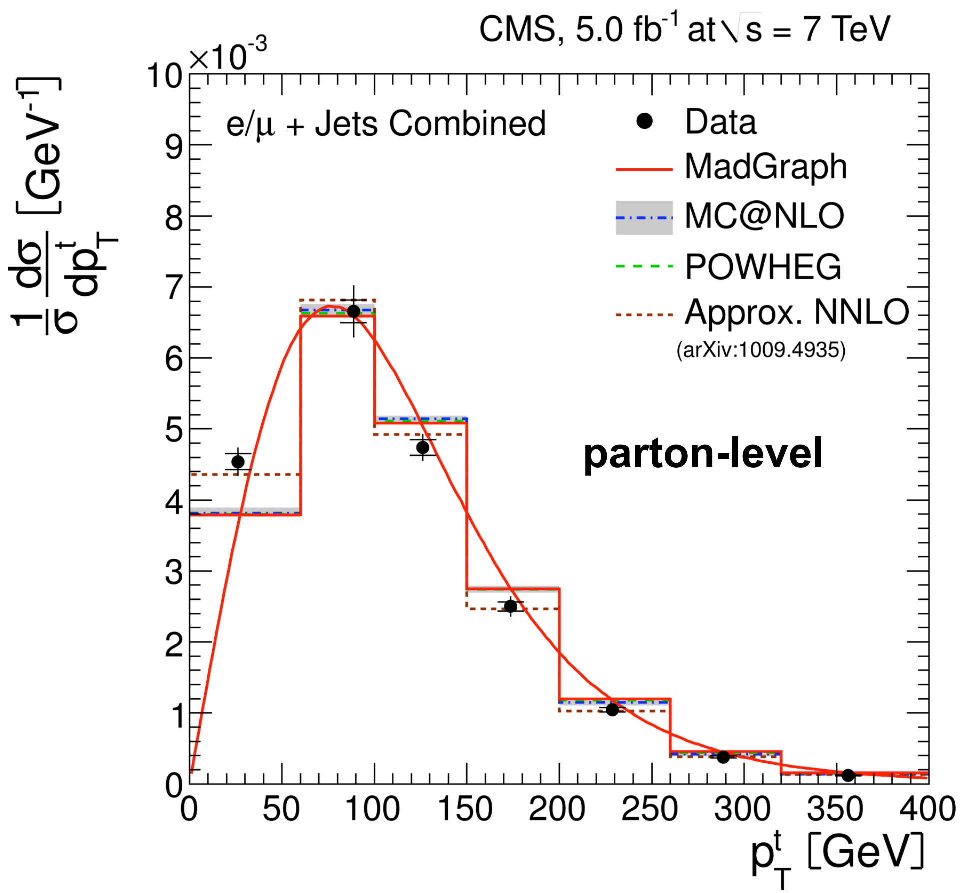
	parton-level	particle-level	boosted	2D
7 TeV	✓	✓		
8 TeV	✓	✓	✓	✓
13 TeV	✓	✓	✓	✓

Top Pt – the history (7 TeV)

- 7 TeV measurments revealed a clear mis-modelling of top pt
  - top pt <u>softer in data than MC</u>



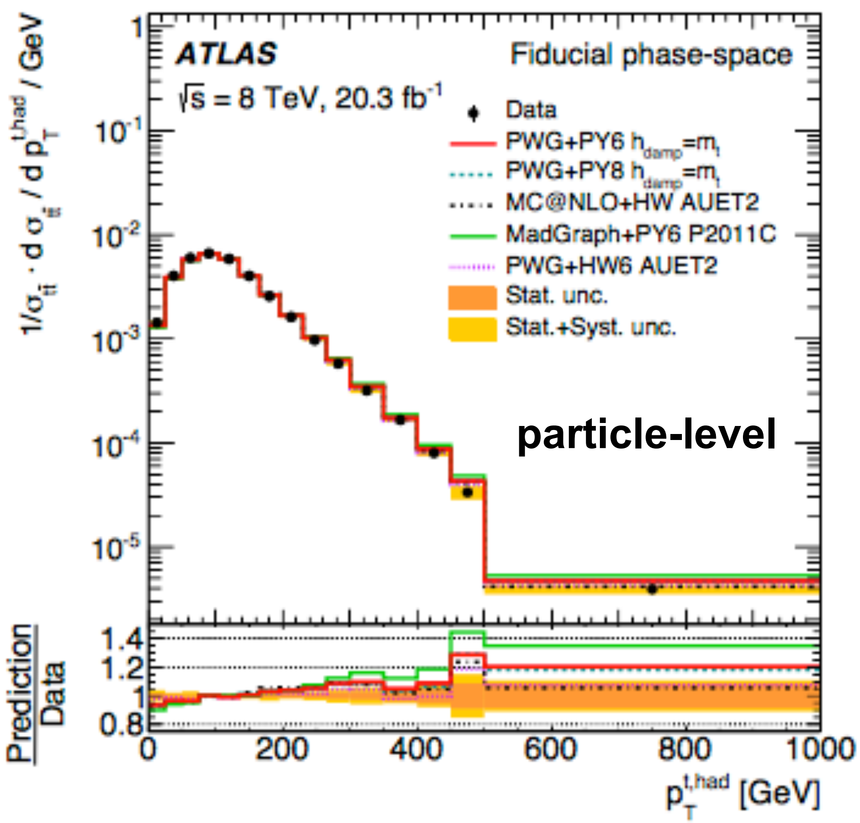
arXiv:1502.05923



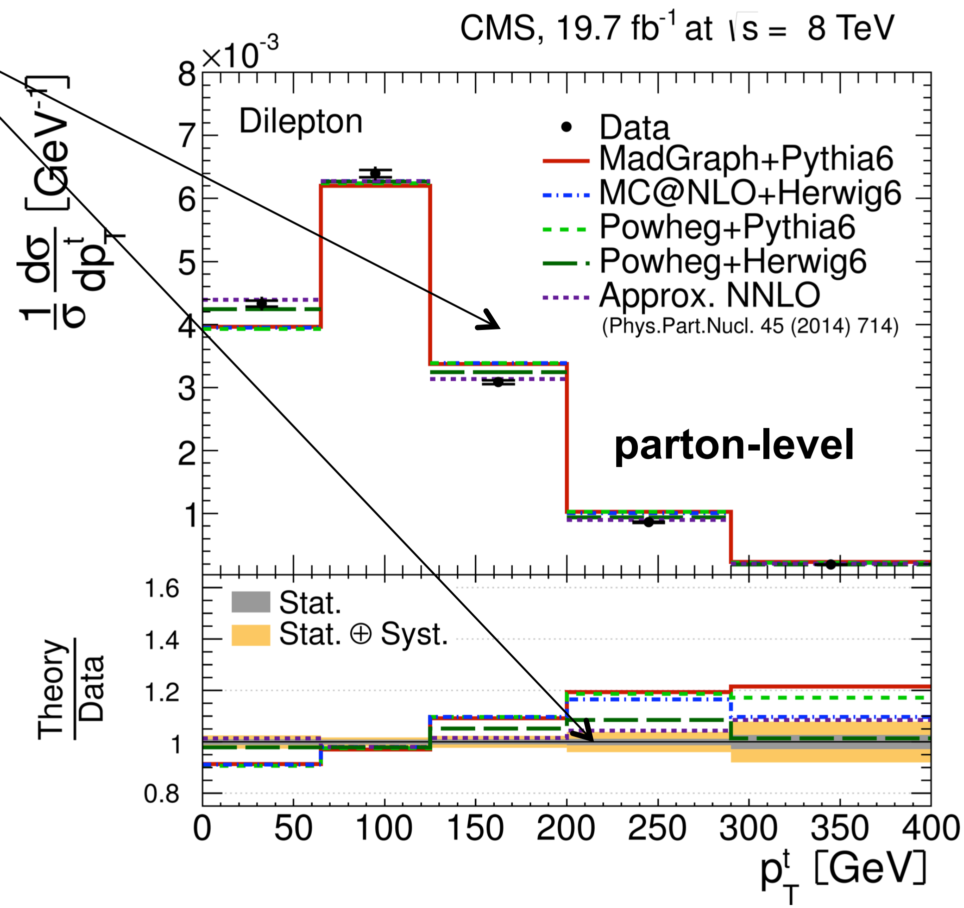
arXiv:1211.2220

Top Pt – the history (8 TeV)

- Similar effect at 8 TeV
  - top pt softer in data than MC
  - higher-order pQCD works better



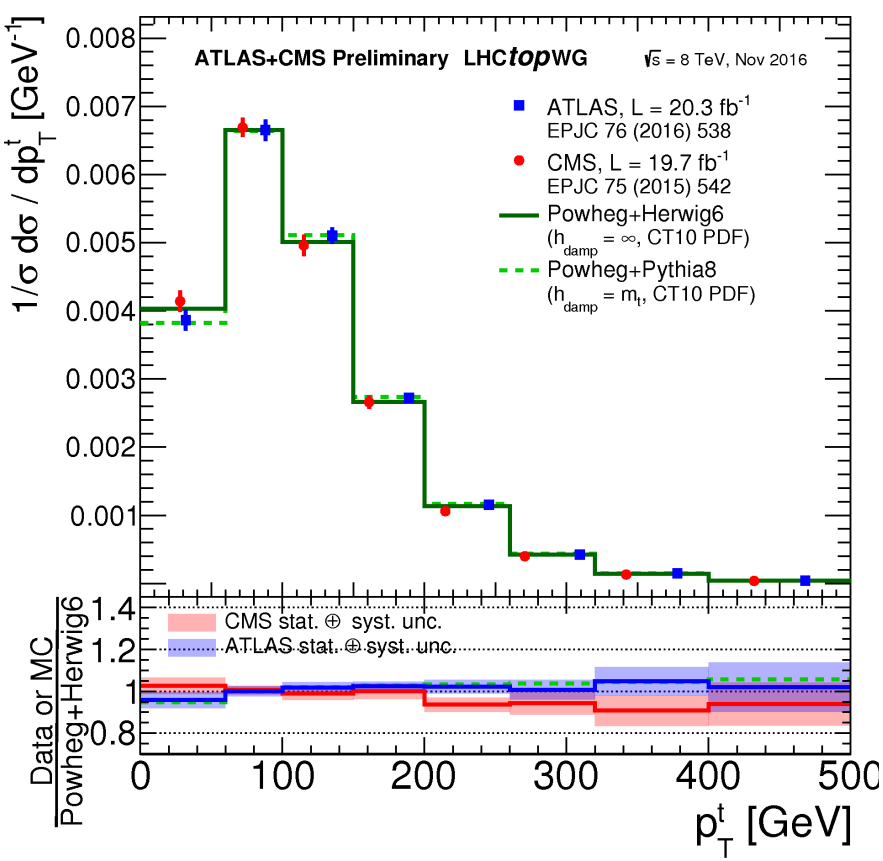
arXiv:1511.0471

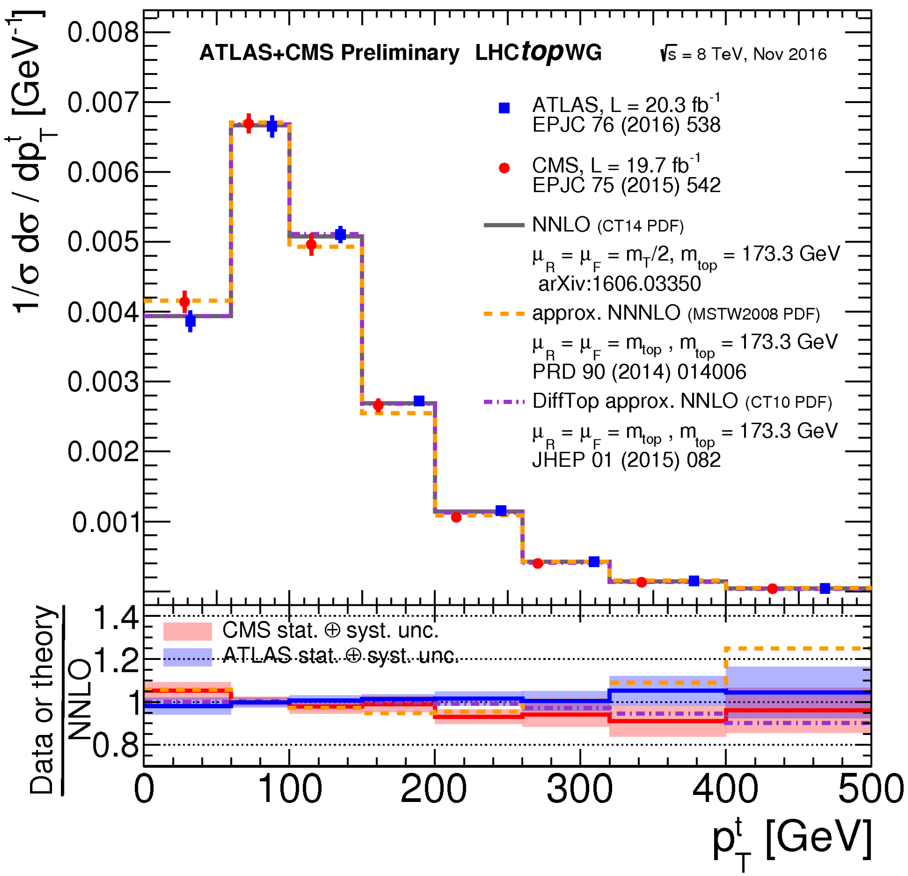


arXiv:1505.04480

Top Pt – the history (8 TeV)

> LHC***TOP***WG provides comparisons between ATLAS+CMS

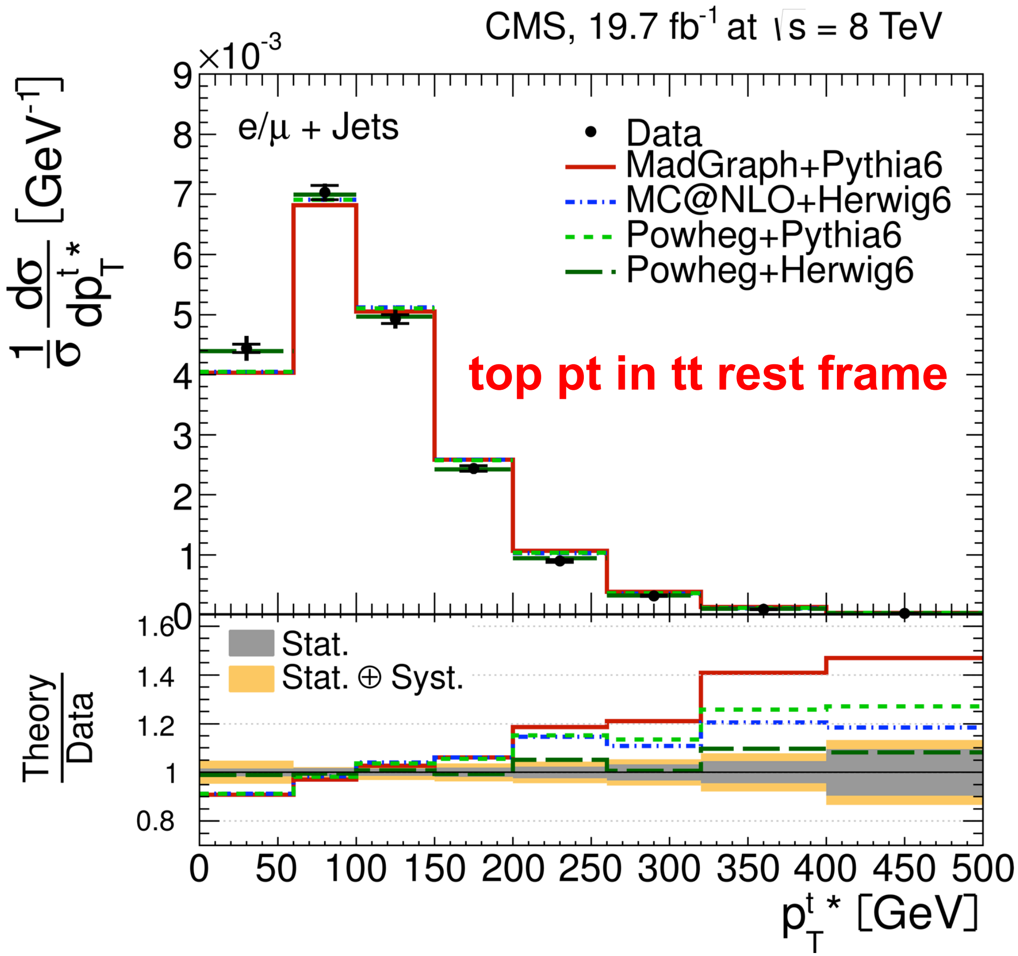


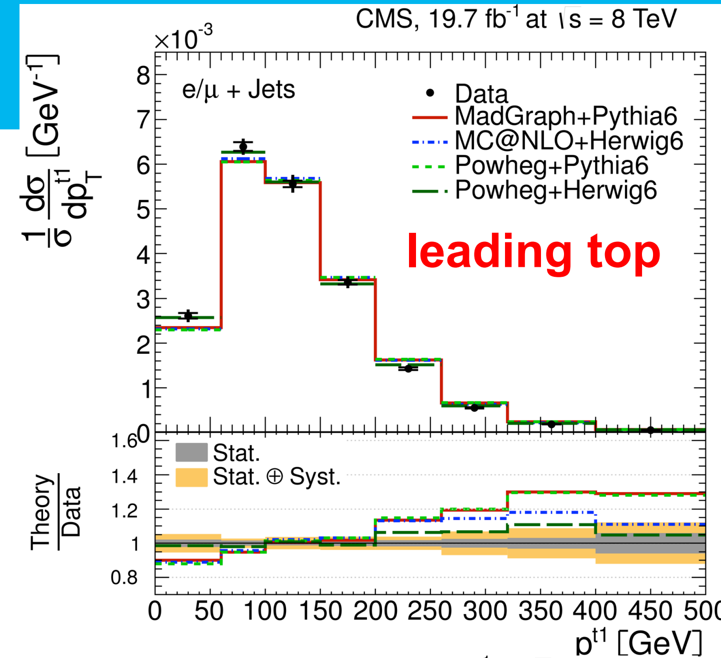


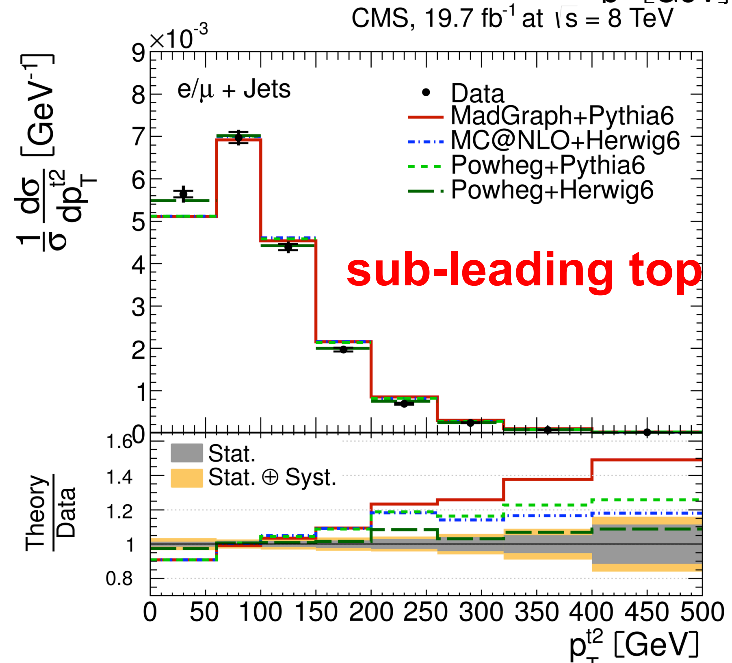
- Reasonable consistency w.r.t to uncertainties

Top Pt – the history (8 TeV)

- Cross-checked with derived variables
  - Little change in disagreement

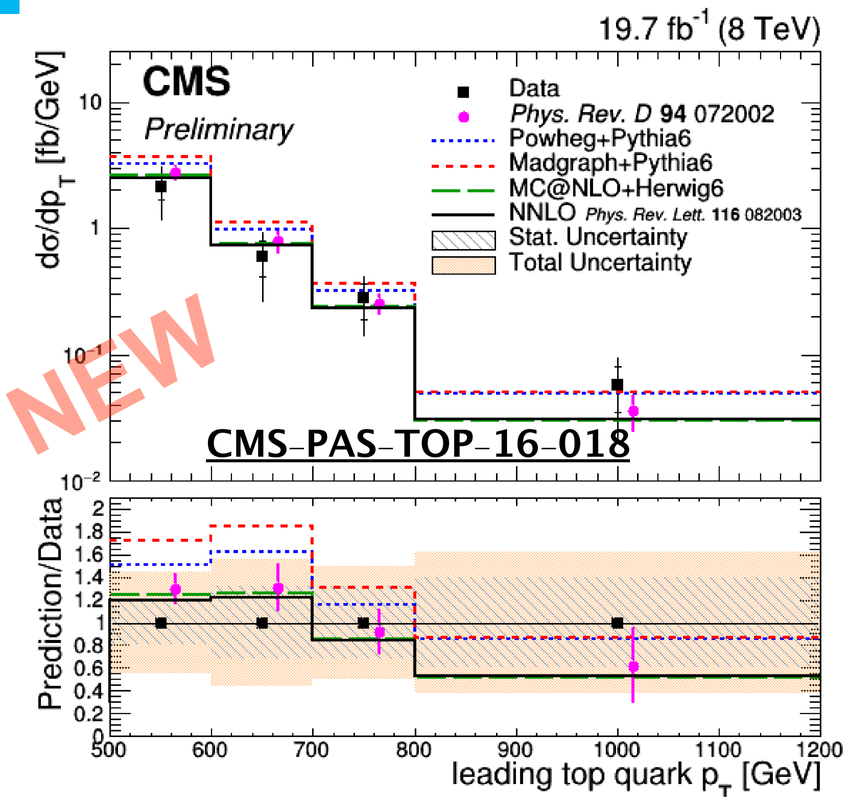


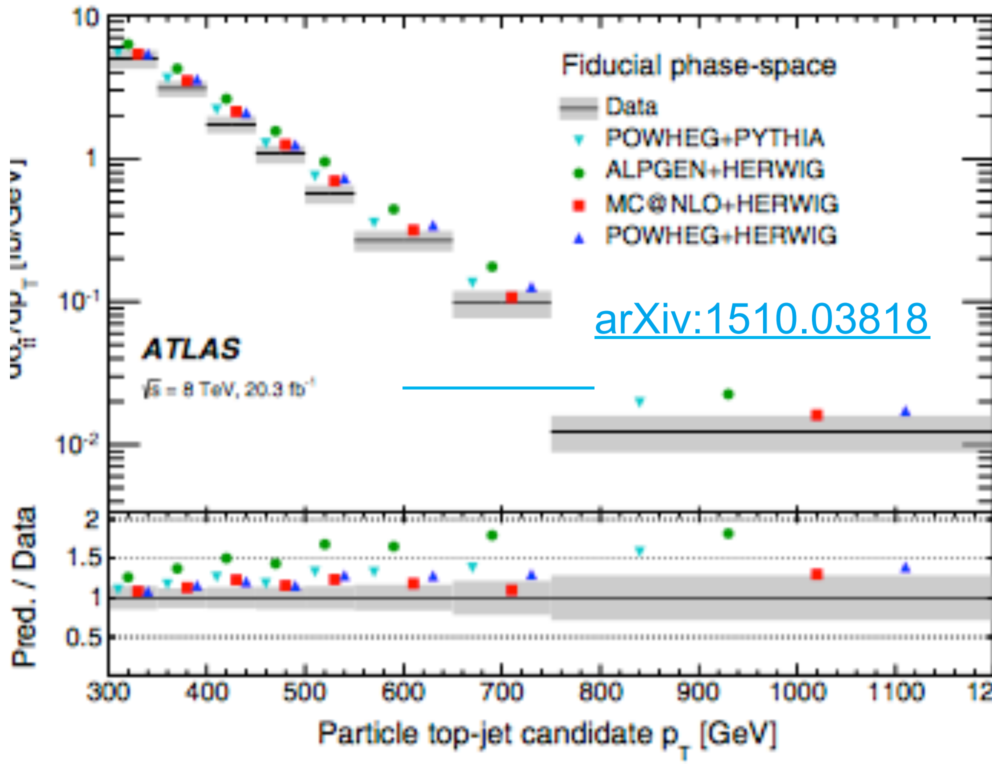




arXiv:1211.2220

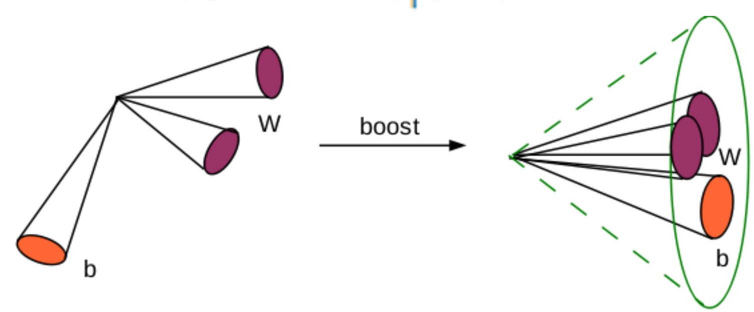
Top Pt – the history (8 TeV, boosted)





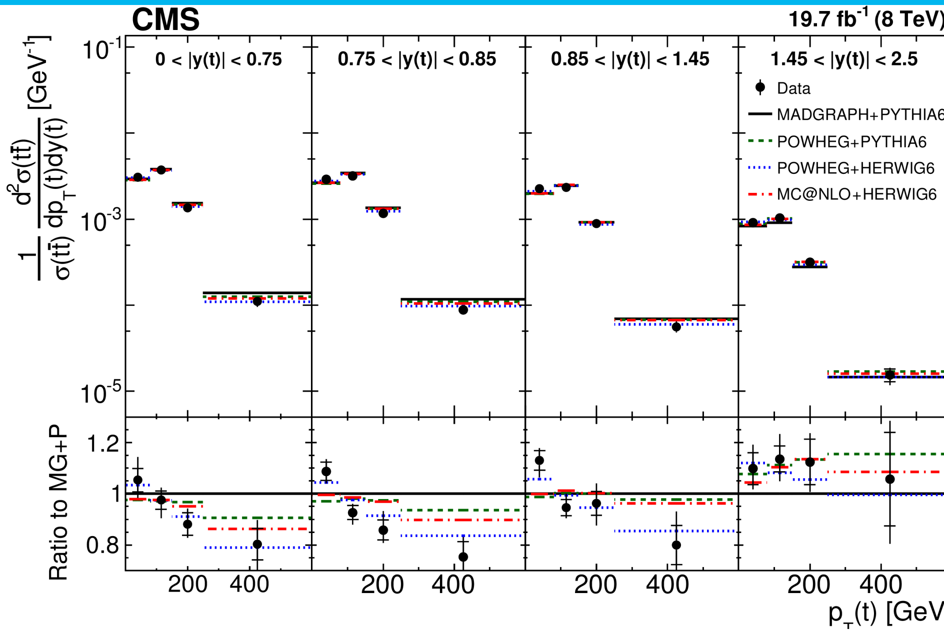
arXiv:1510.03818

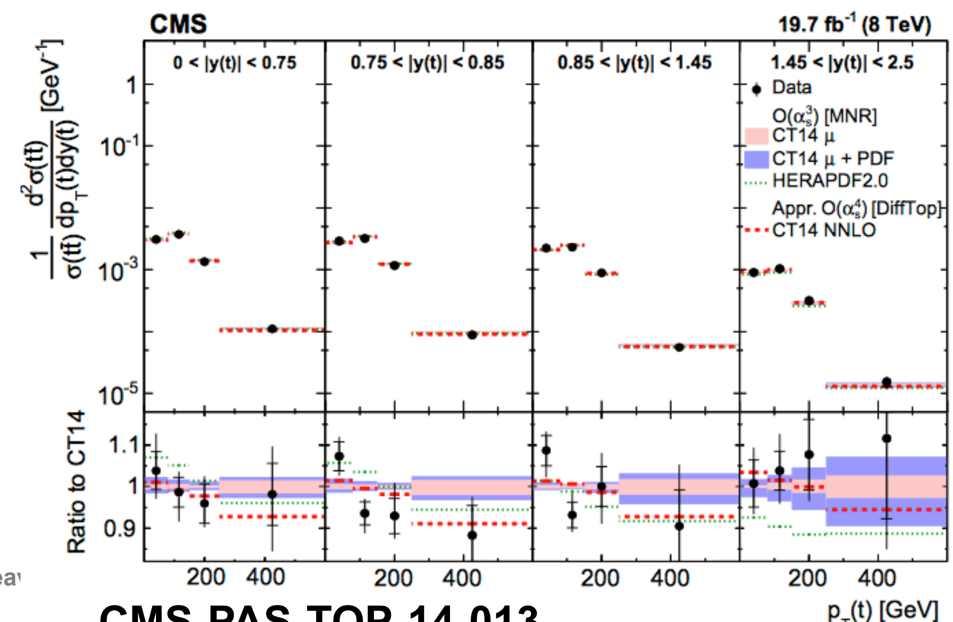
- Boosted (high-momentum) regime:
  - Top quarks recontructed as a single, large-area jet
- MC@NLO+HERWIG6 provides a reasonable description



Top Pt – the history (8 TeV)

- Check of pt modelling in rapidity bins
  - double-differential cross sections
- Disagreement largely consistent vs rapidity
- Future 2D measurements will benefit from more data

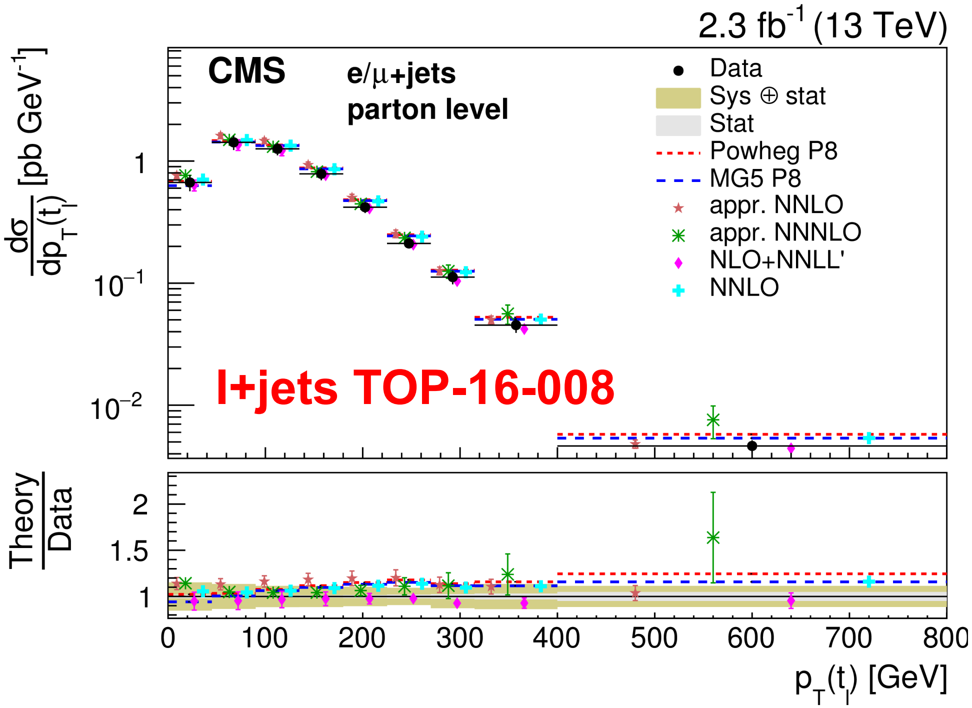


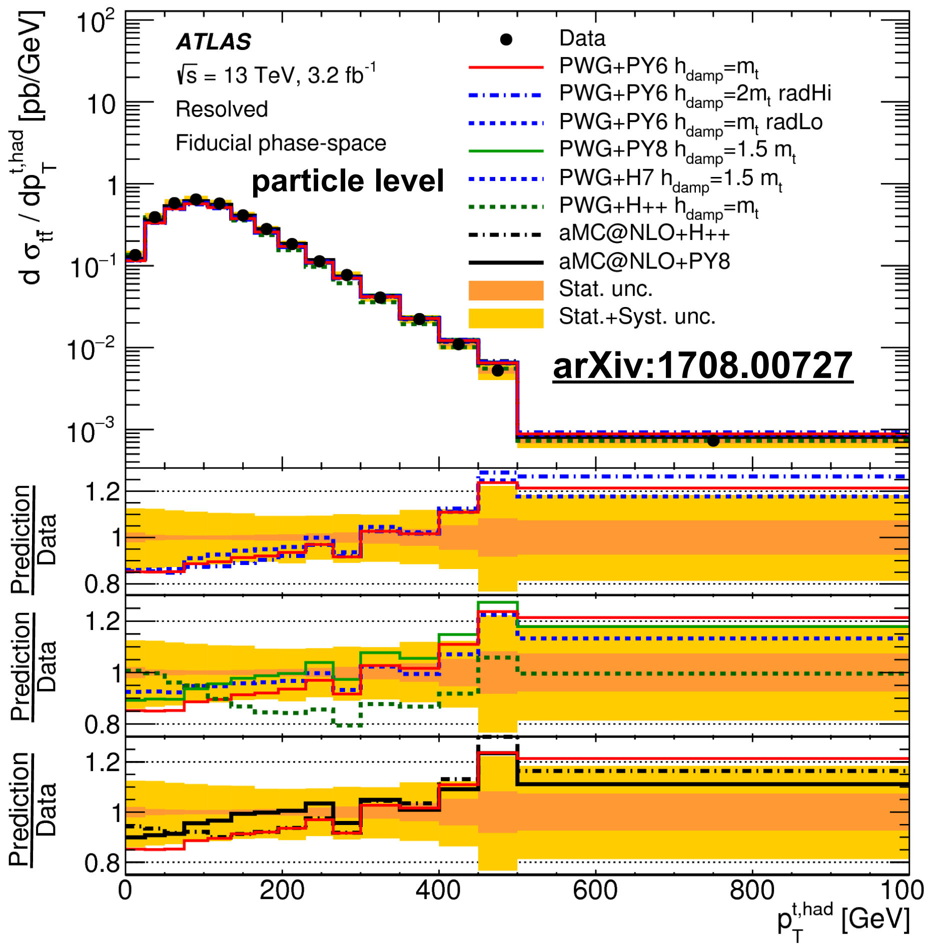


CMS-PAS-TOP-14-013

Top Pt – 13 TeV

> 13 TeV

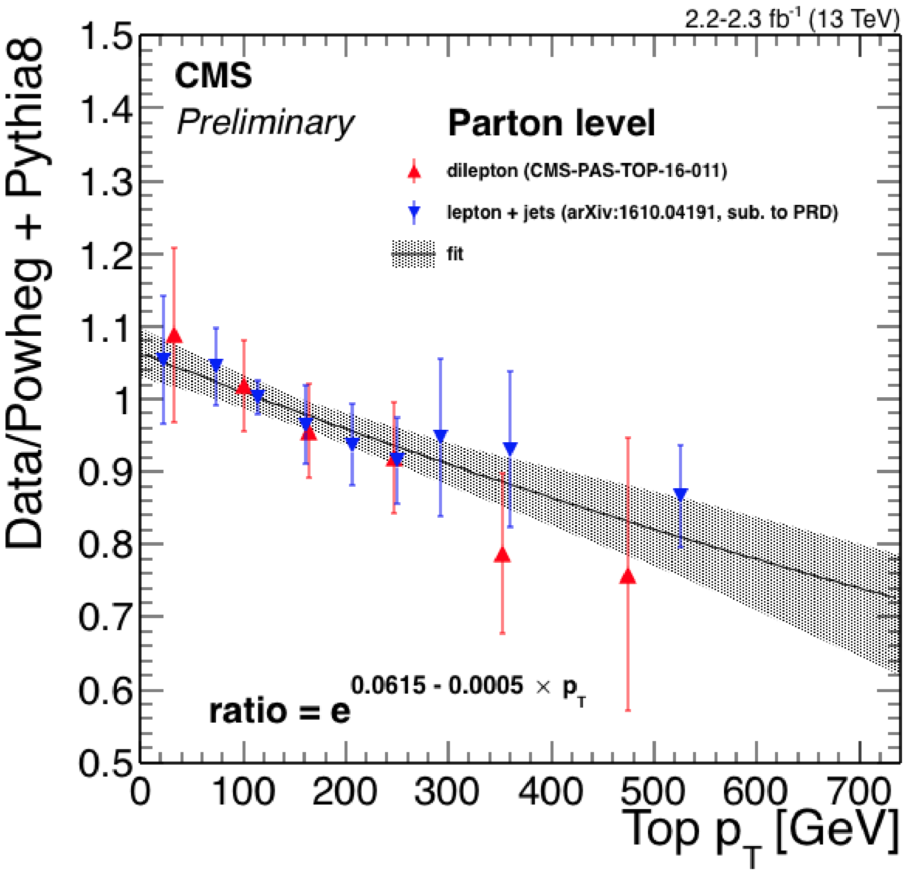


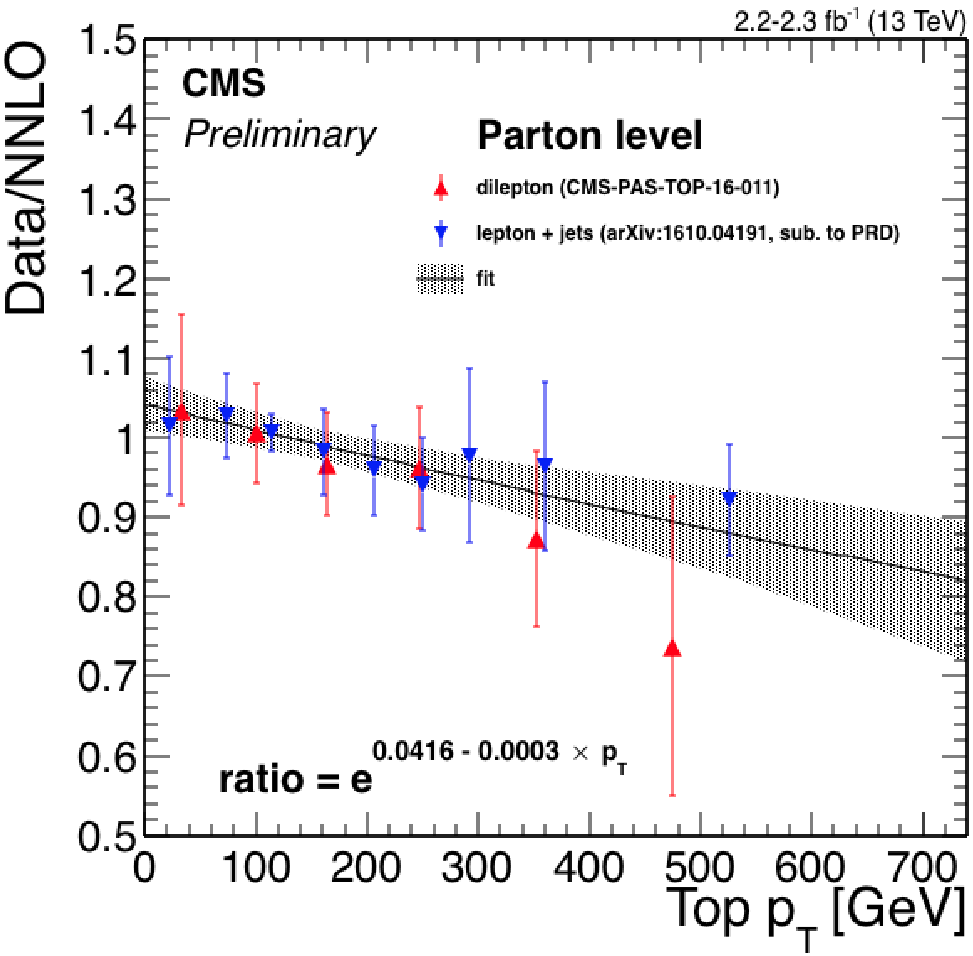


- Full NNLO+NNLL does a reasonable job
- Powheg + pythia8, MG5 + pythia show mild trends

- All MC setups show trends

Top Pt @ 13 TeV – CMS Summary

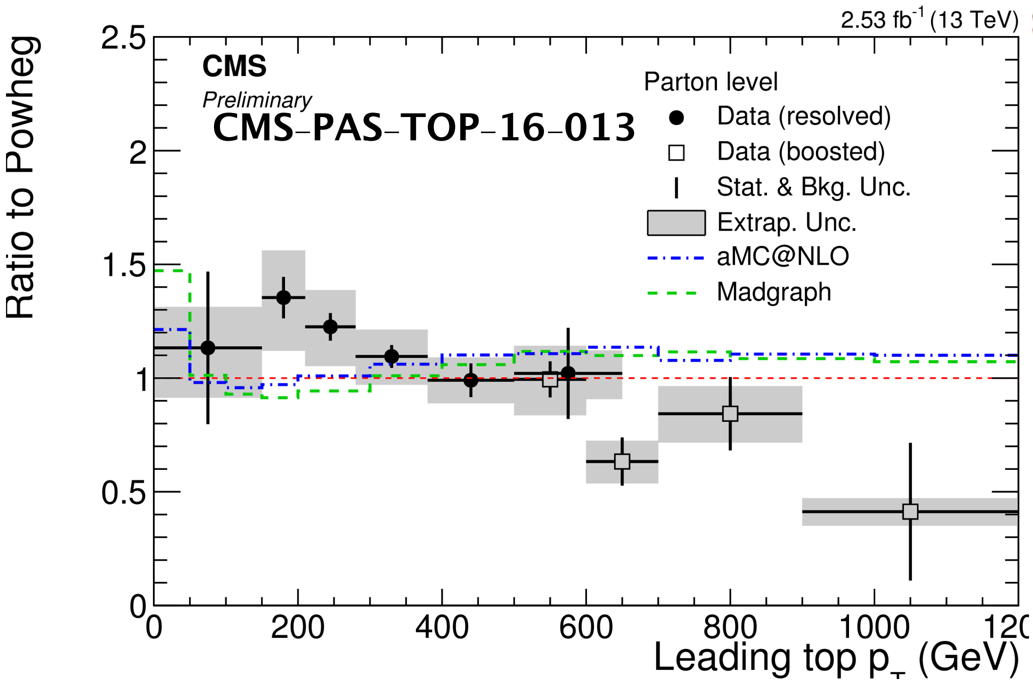


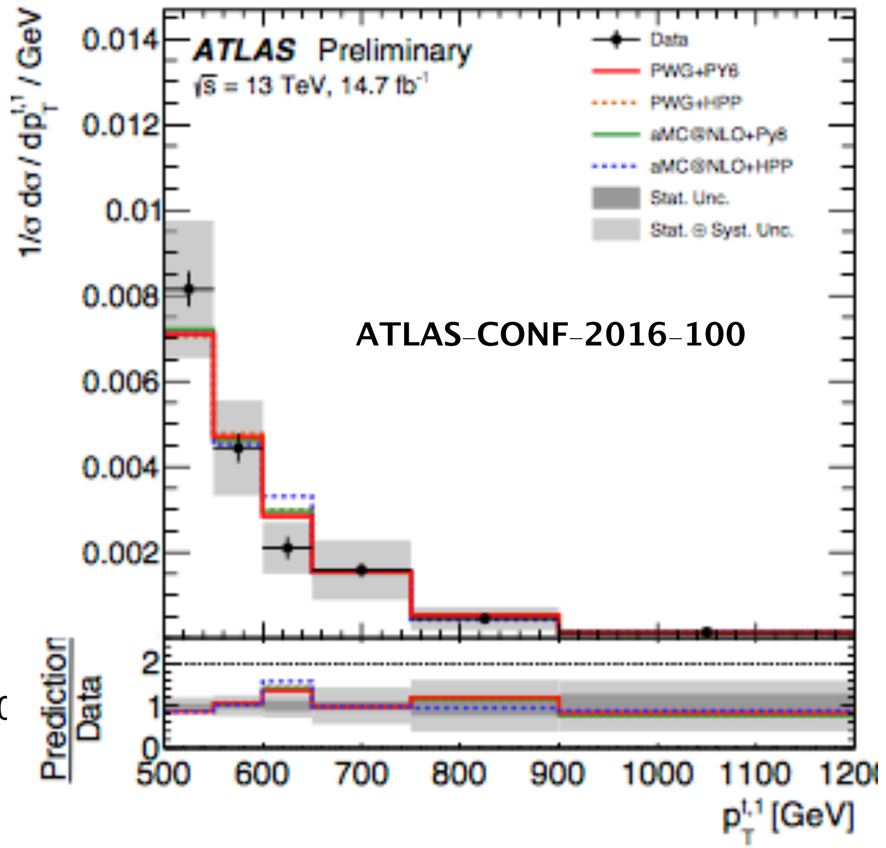


Exponential fits to DATA/Prediction in l+jets and dilepton

Quantifies the effect for NLO+PS MC and NNLO

Top Pt – 13 TeV (boosted)

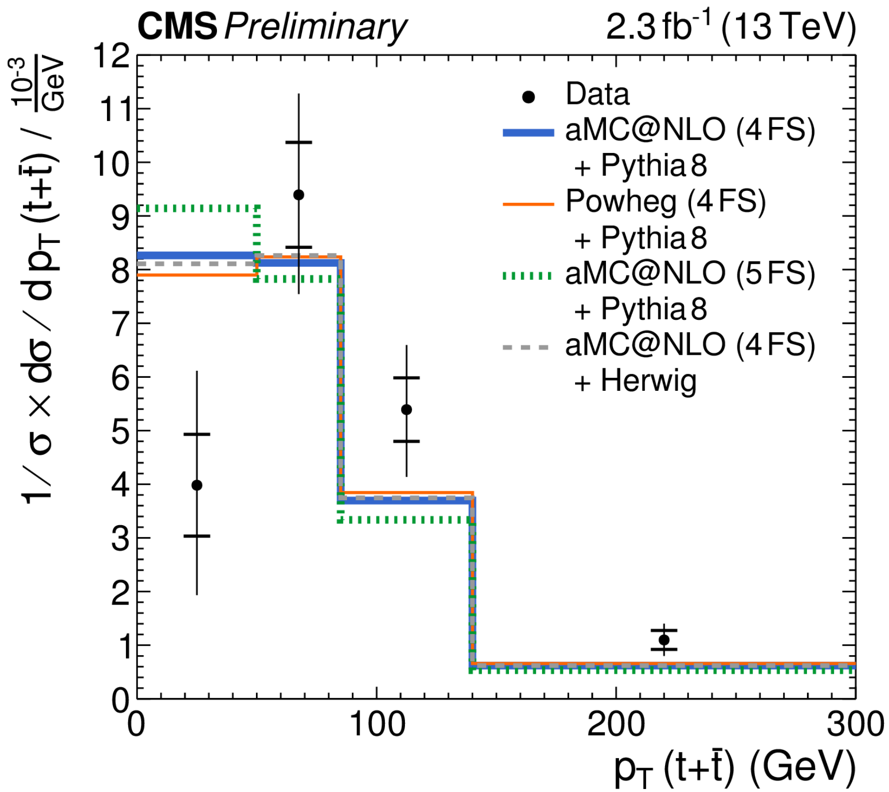


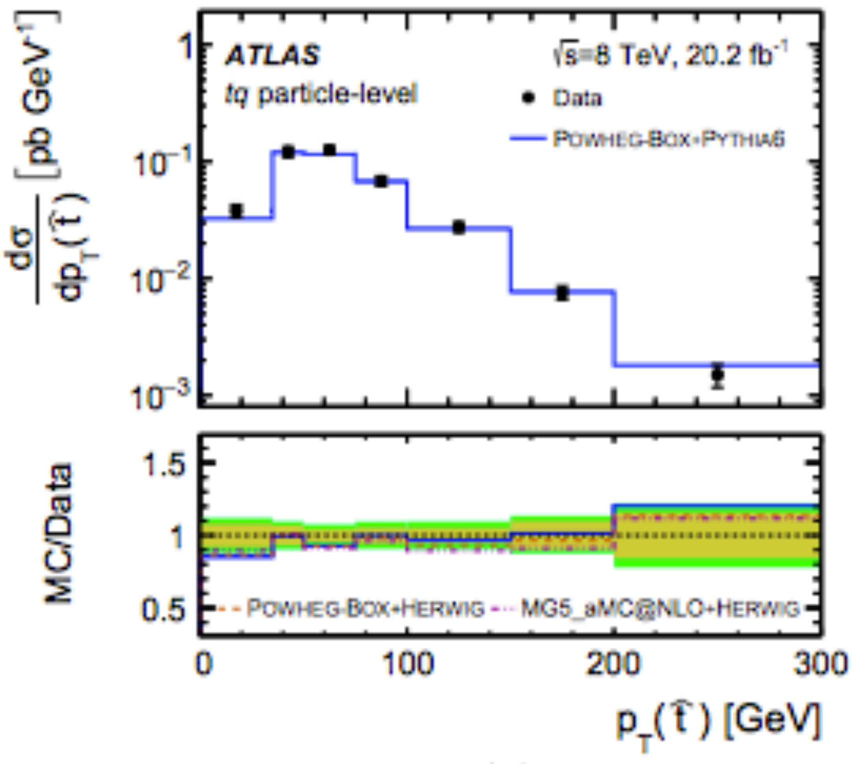


- Trend wrt all MC setups visible from resolved to boosted regimes
  - Powheg + pythia8, MG5 + pythia show mild trends

- Highly boosted region
- No sign of mis-modelling in MC

What about single top production?

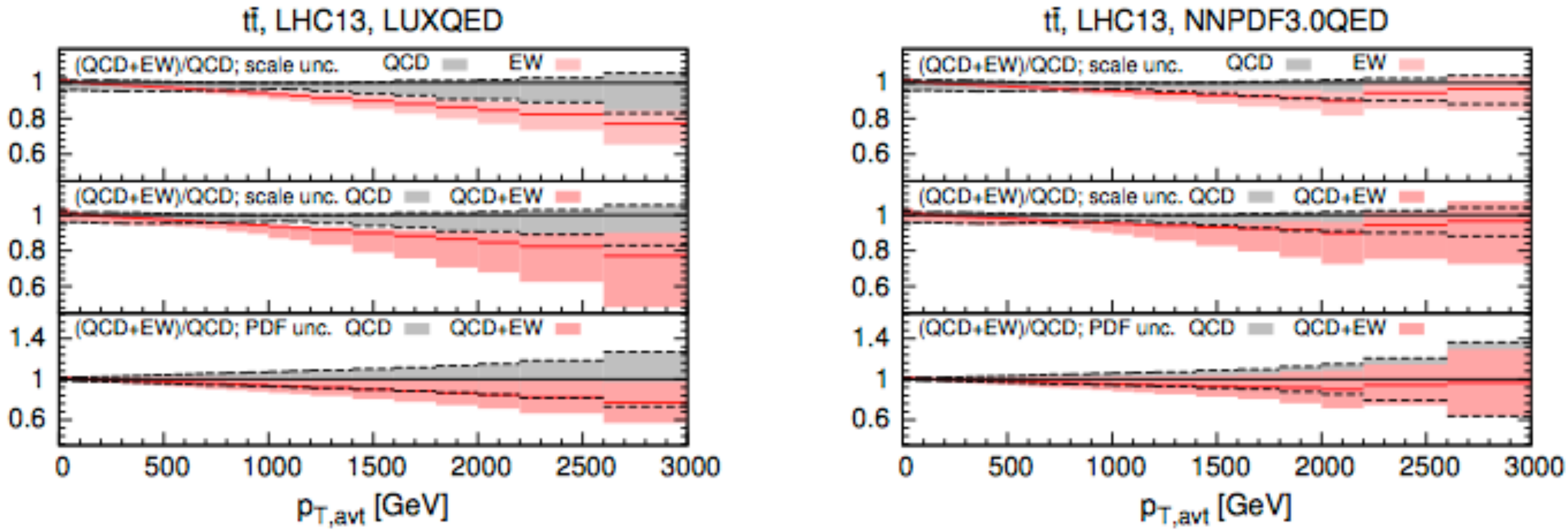




- First differential results for t-channel single top production not precise enough to say much…
- Measurements with 2016 data should reveal a potential effect

Electroweak corrections

- Latest predictions including α^3_{EW} corrections with *LUXQED* or *NNPDF3.0QED* PDFs promise a better description of data
- Need to be included in next round of comparisons



arXiv:1705.04105

Outlook

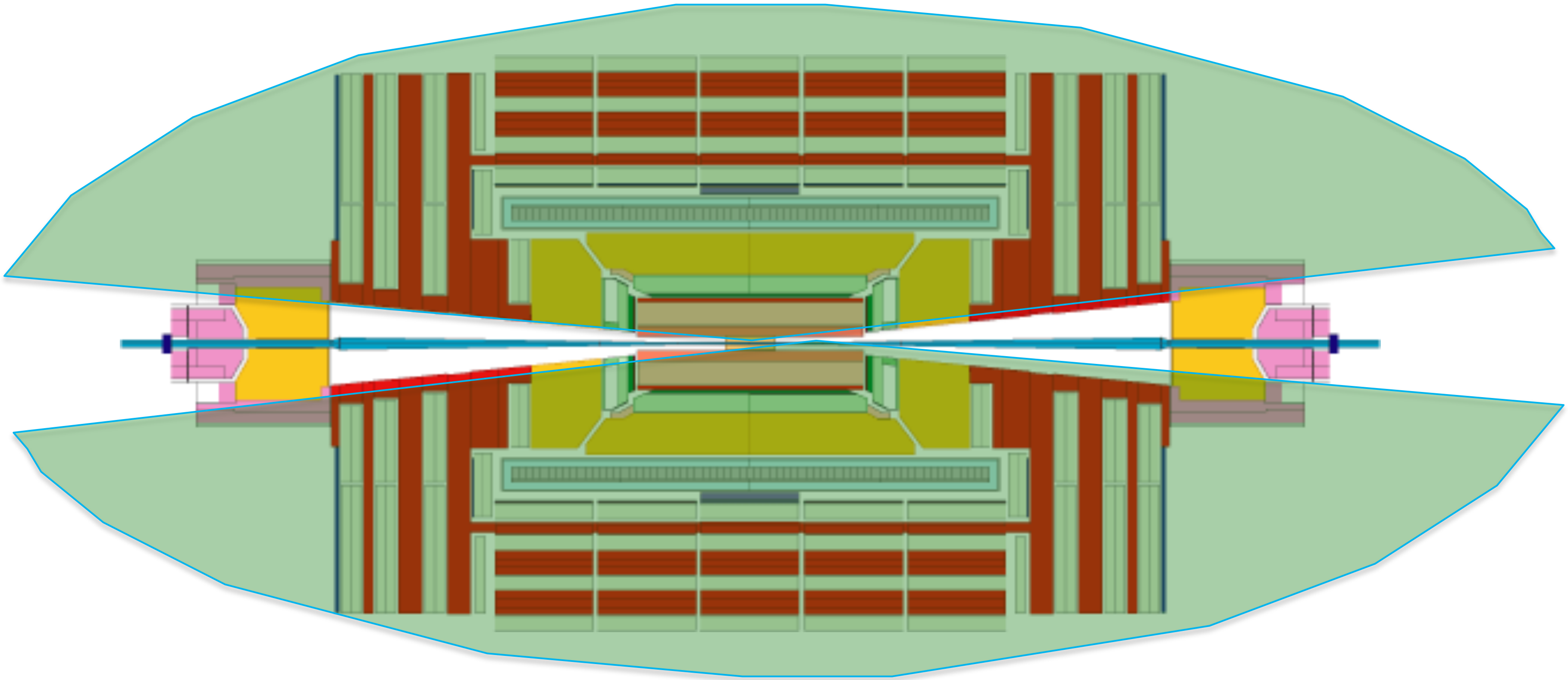
- Discrepancies between data and predictions for the Top pt spectrum.
  - Consistent across parton, particle levels and in boosted and resolved regimes.
  - Effect persists in 2D measurements, in tt-rest frame, and in (sub-)leading cases.
  - Effect is largest at 7 and 8 TeV w.r.t. MC predictions, NNLO improves agreement.
  - Predictions including NNLO+NLLO+EW corrections could yield further improvement.

- Further measurements with more stats will be revealing in certain phase space regions:
  - Populate the boosted region
  - Allowss finer 2D binning

- Otherwise measurements limited by systematics
- Detailed comparison to latest theory crucial, e.g., NNLO+NNLL+α^3_{EW}

BACKUP

Top quark definitions



Visible phase space:
Kinematic region accessed by CMS detector

ATLAS + CMS measurements so far

- Top Pt measured in multiple decay channels, kinematic regimes and top quark definitions

CMS

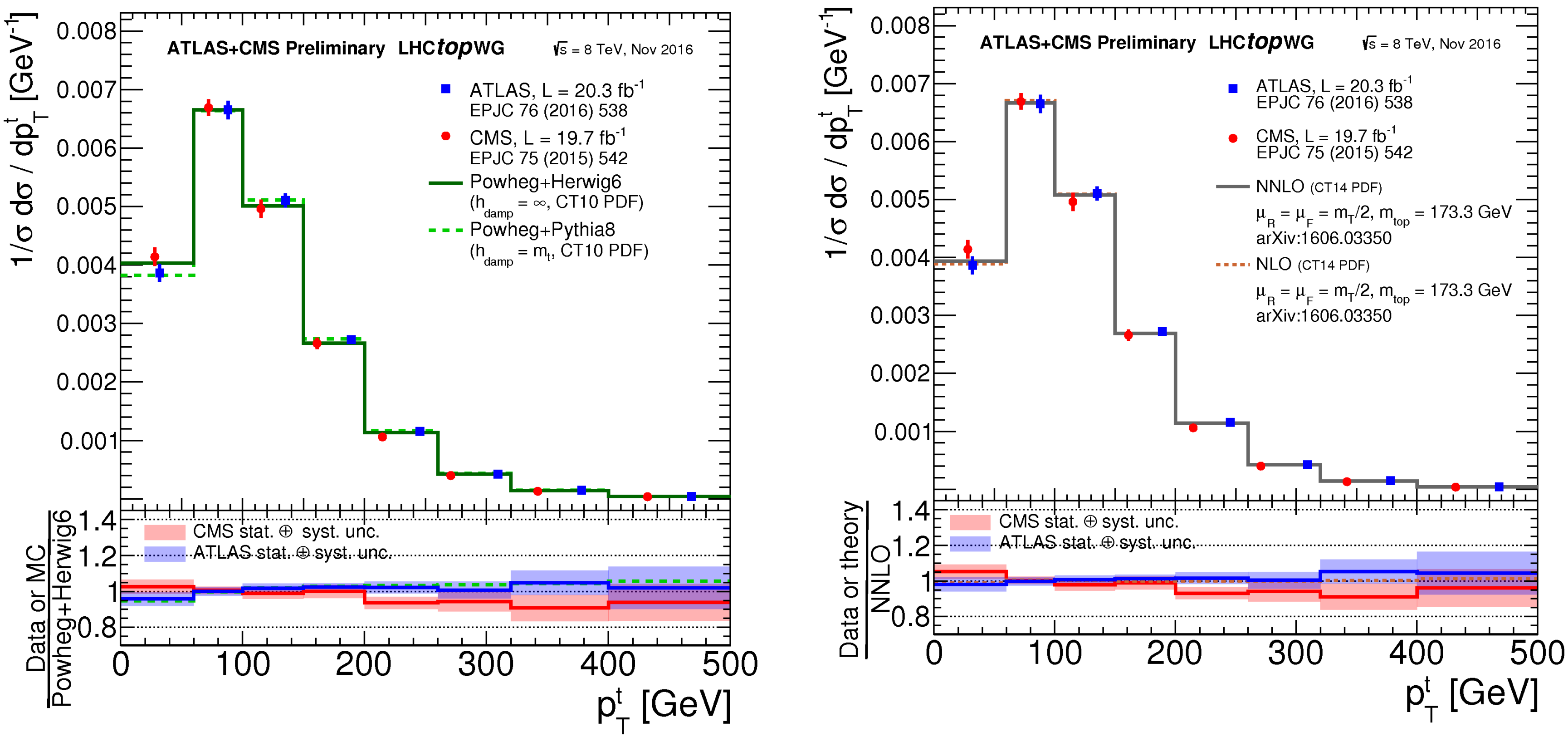
	parton-level	particle-level	detector-level	boosted	2D
7 TeV	l+jets, dilepton				
8 TeV	l+jets, dilepton , all-hadronic	all-hadronic	all-hadronic	l+jets, all-hadronic	dilepton (parton)
13 TeV	l+jets, dilepton, all-hadronic	l+jets, dilepton	all-hadronic	all-hadronic	l+jets (parton, particle)

ATLAS

	parton-level	particle-level	detector-level	boosted	2D
7 TeV	dilepton, l+jets	l+jets			
8 TeV	dilepton	l+jets		l+jets	
13 TeV		dilepton, l+jets		l+jets, all-hadronic	

Top Pt – the history (8 TeV)

- LHC***TOP***WG provides comparisons between ATLAS+CMS



Top Pt – the history (8 TeV)

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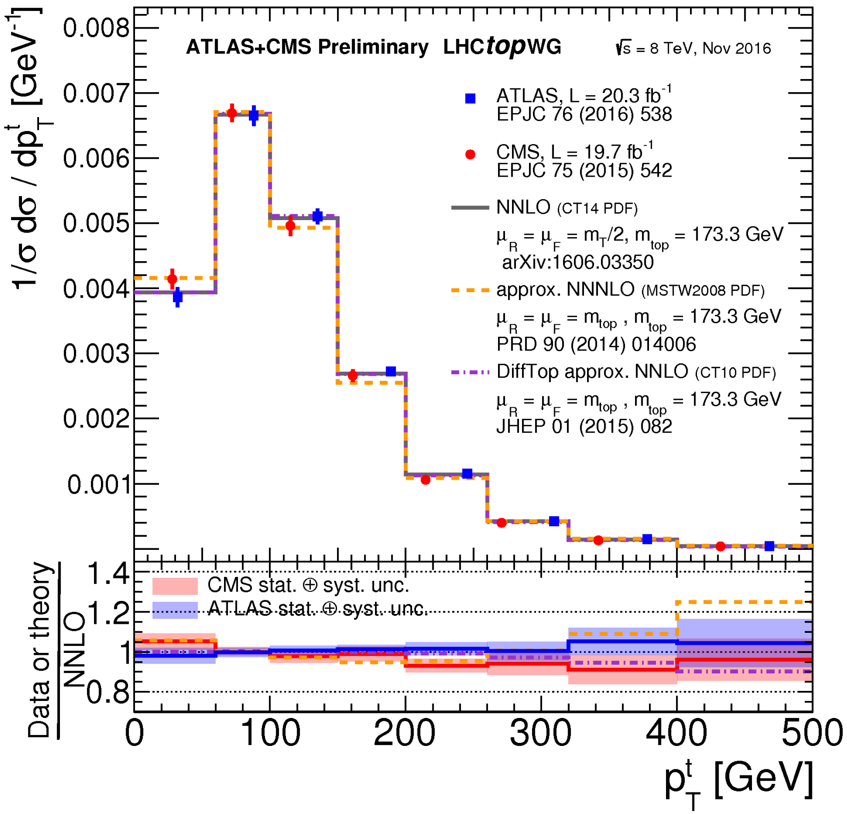
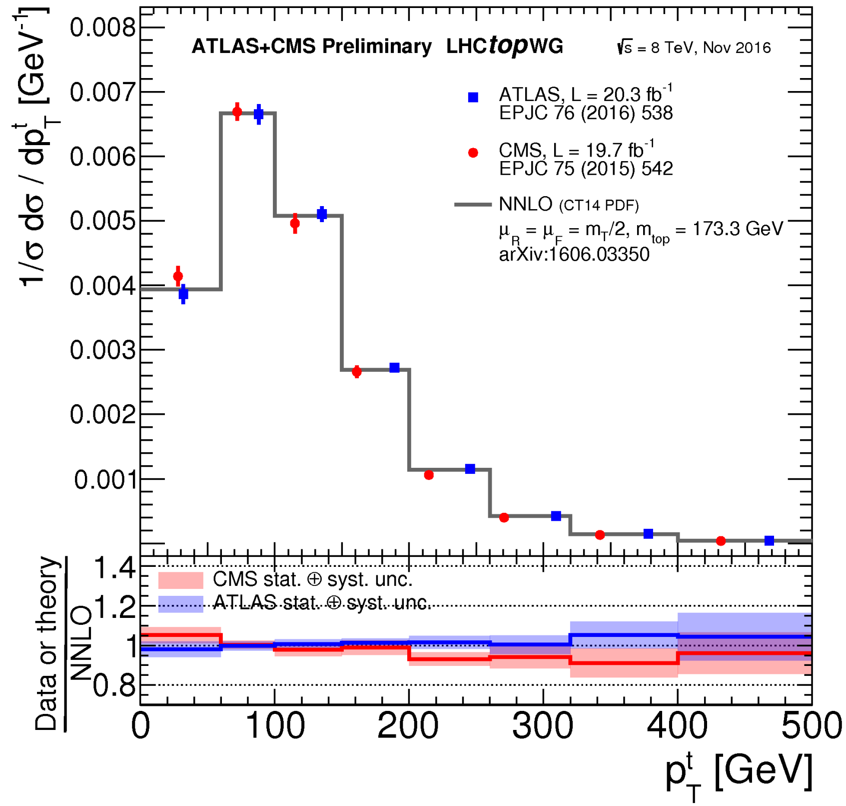
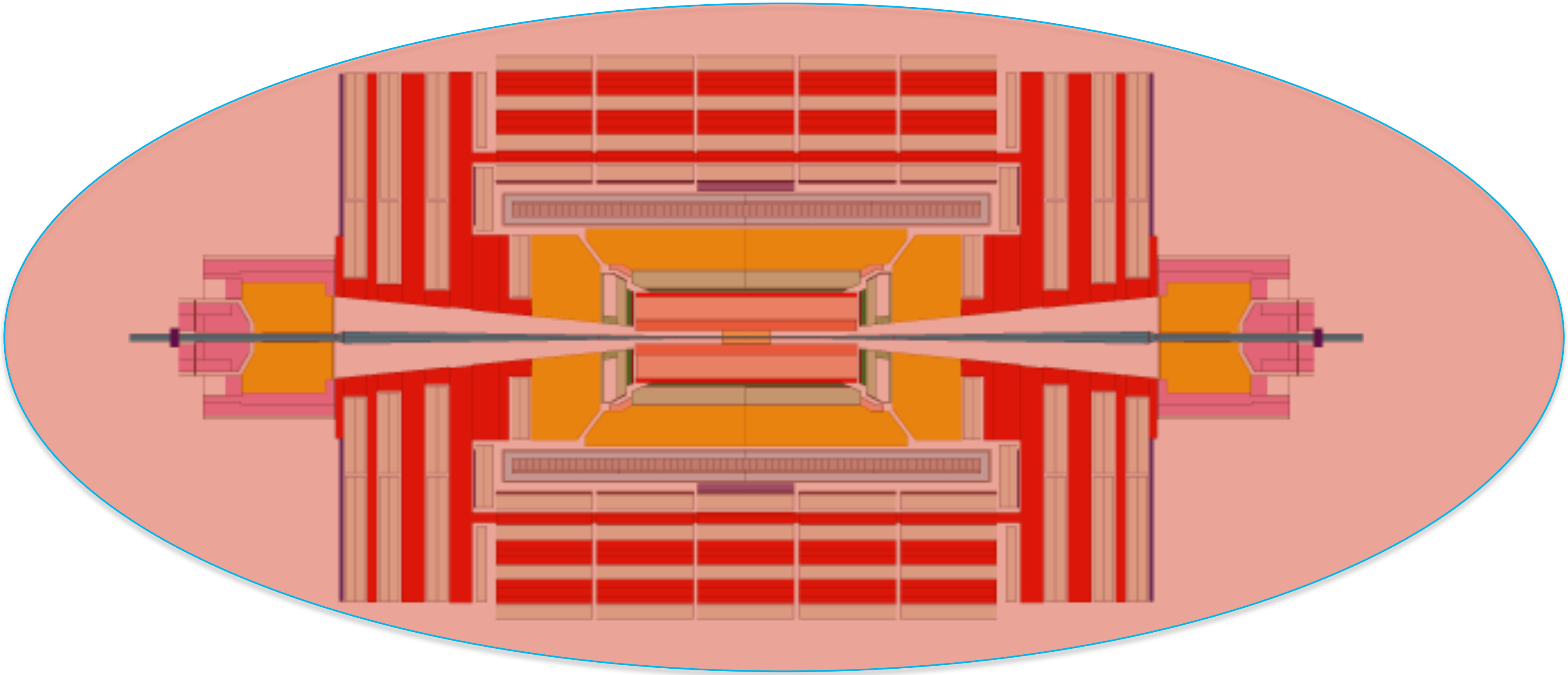




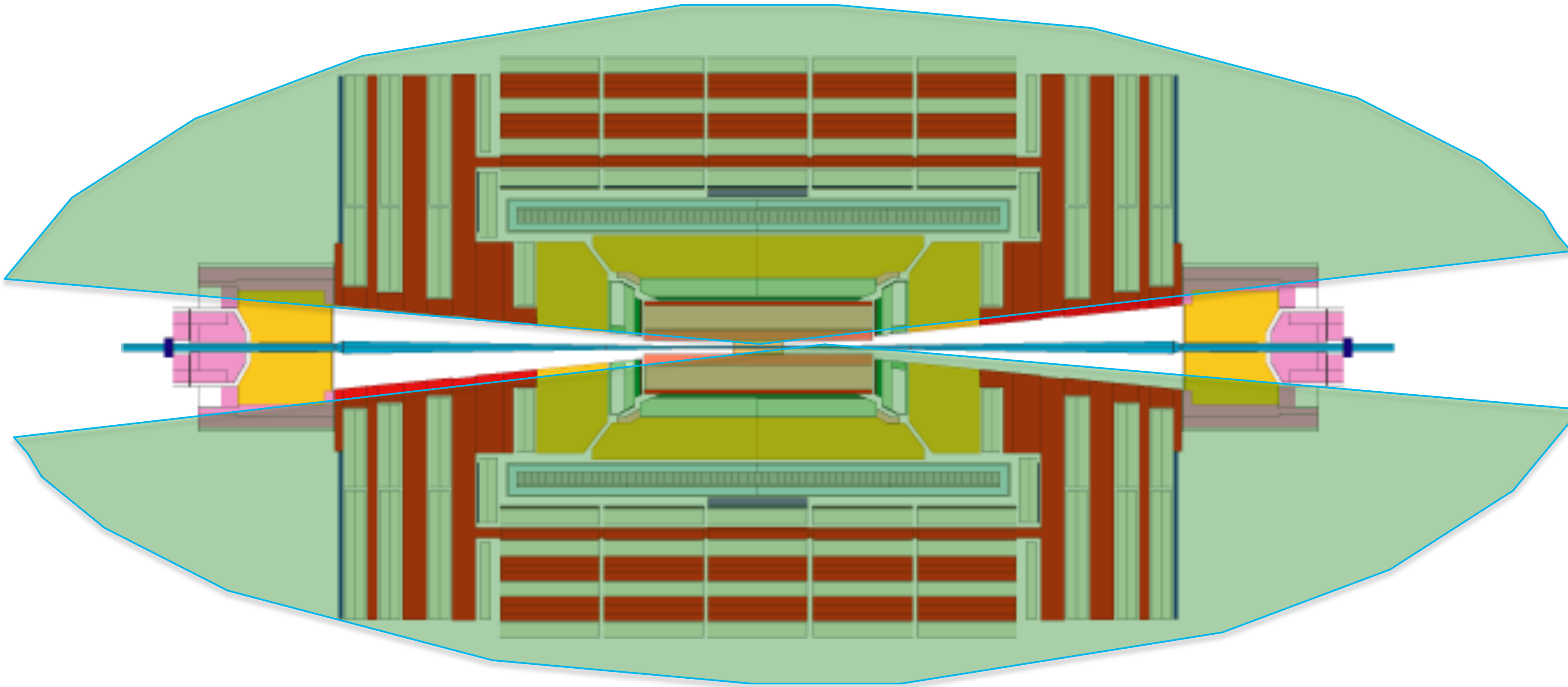
Top quark definitions



Full phase space:

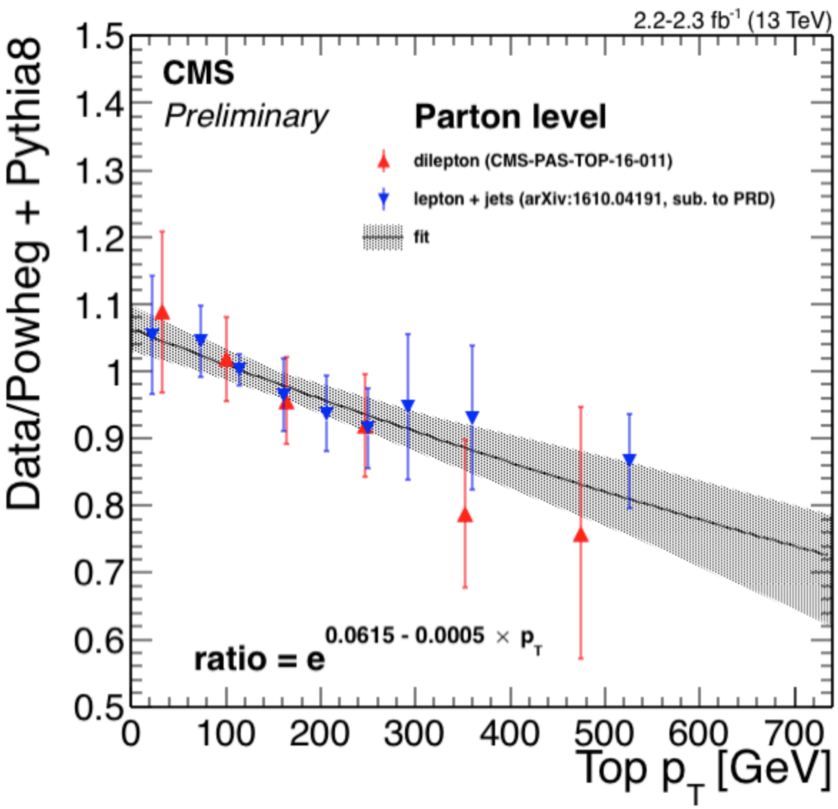
Covers all possible tt kinematics.

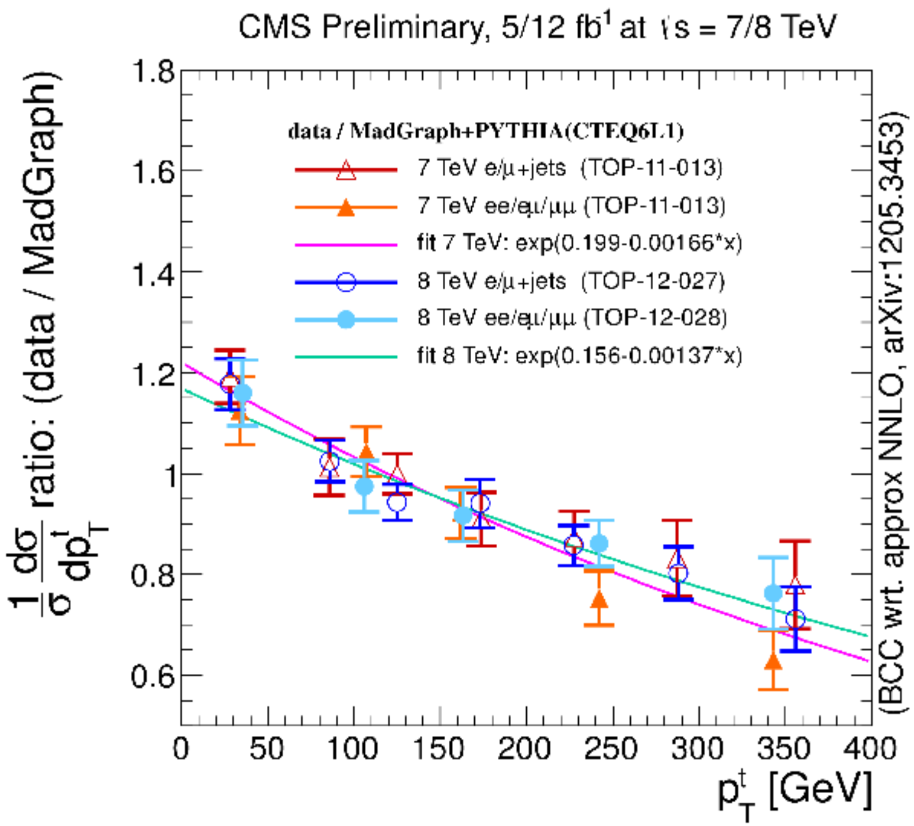
Top quark definitions



Visible phase space = kinematic region accessed by CMS detector
Fiducial phase space ~ Visible phase space

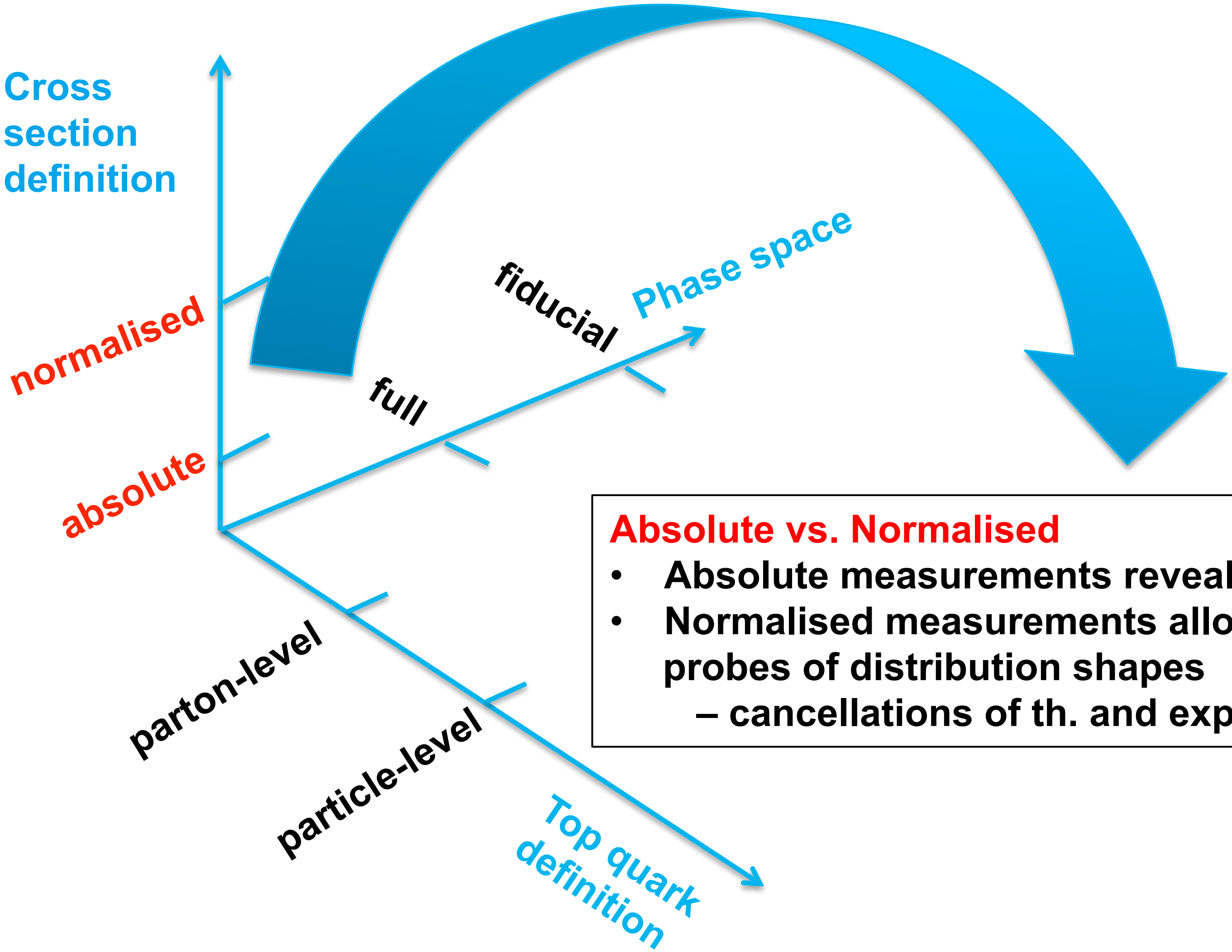
Default re-weighting parameterisations





- A parameterisation of the DATA/Powheg+P8 ratio is provided by the TOP-PAG
- 13 TeV parameterisation considers inter-bin correlations of each measurement but not between measurements
- Only valid up to ~700 GeV

What do we actually measure?



Absolute vs. Normalised

- Absolute measurements reveal maximal information
- Normalised measurements allow more precise probes of distribution shapes
  - – cancellations of th. and exp. uncertainties