Top quark pair production cross-section measurements with the ATLAS detector

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on behalf of the
ATLAS Collaboration

EPS 2017

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ATLAS EXPERIMENT

overview I

- ATLAS have a comprehensive suite of measurements focusing on top pair production.

- why?
  - sensitivity to BSM physics
  - better Standard Model constraints
  - improve our *modeling* of the Standard Model

overview II

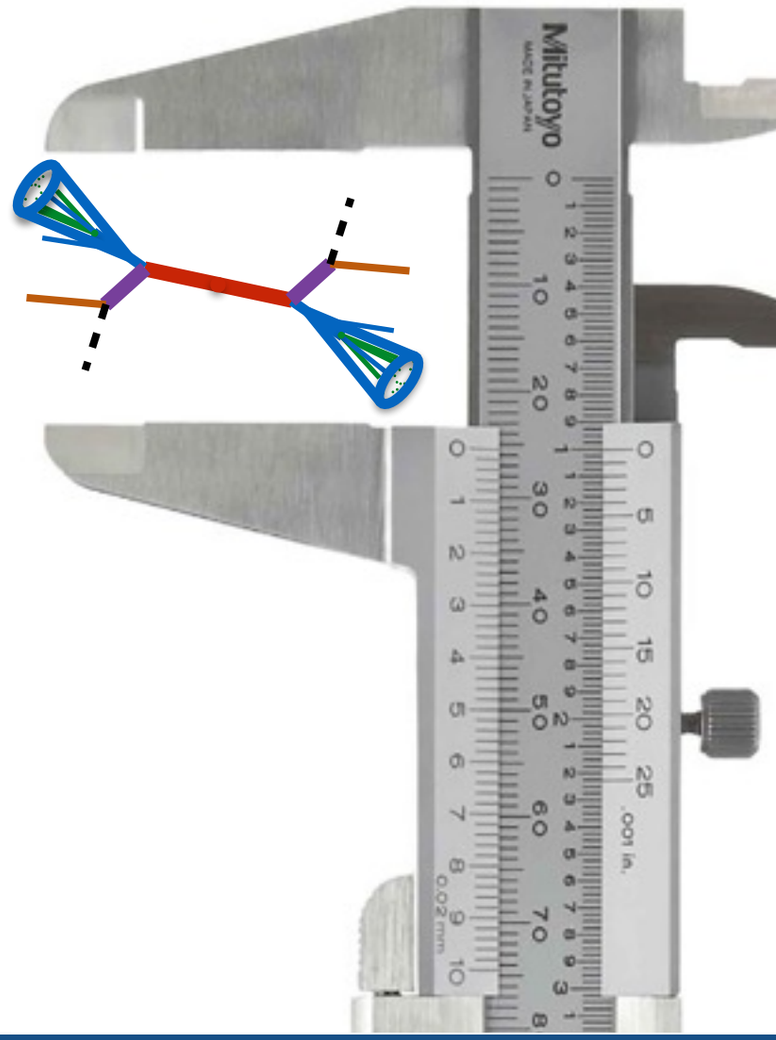
here we'll concentrate on new 8 and 13 TeV results, all of which have unfolded the data to *particle level* where appropriate.

"pseudo-top" fiducial definitions have been used:

https://twiki.cern.ch/twiki/bin/view/LHCPhysics/ParticleLevelTopDefinitions

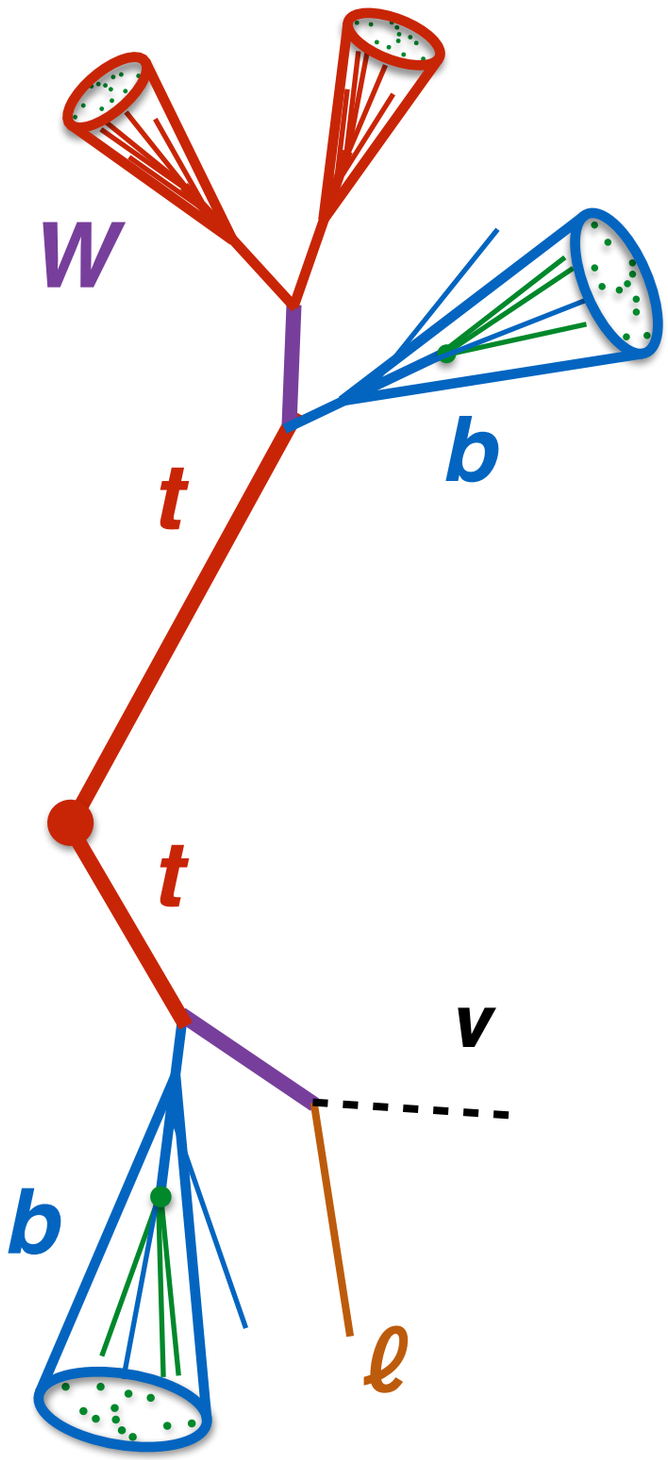
I'll show a number of measurements in a broad range of event topologies.

please follow links for more details!



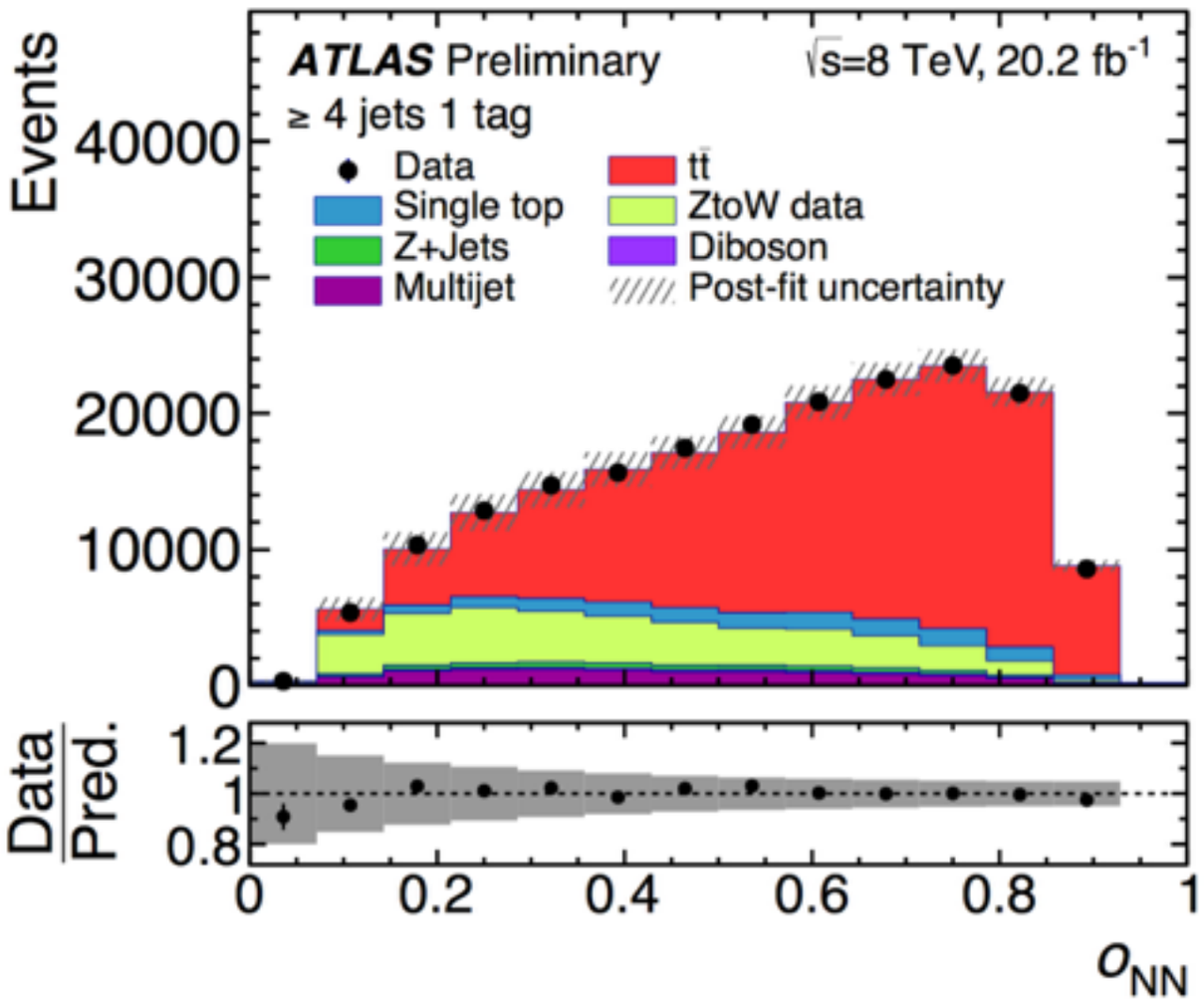
inclusive 8 TeV *tt* cross section measurement in the one-lepton channel

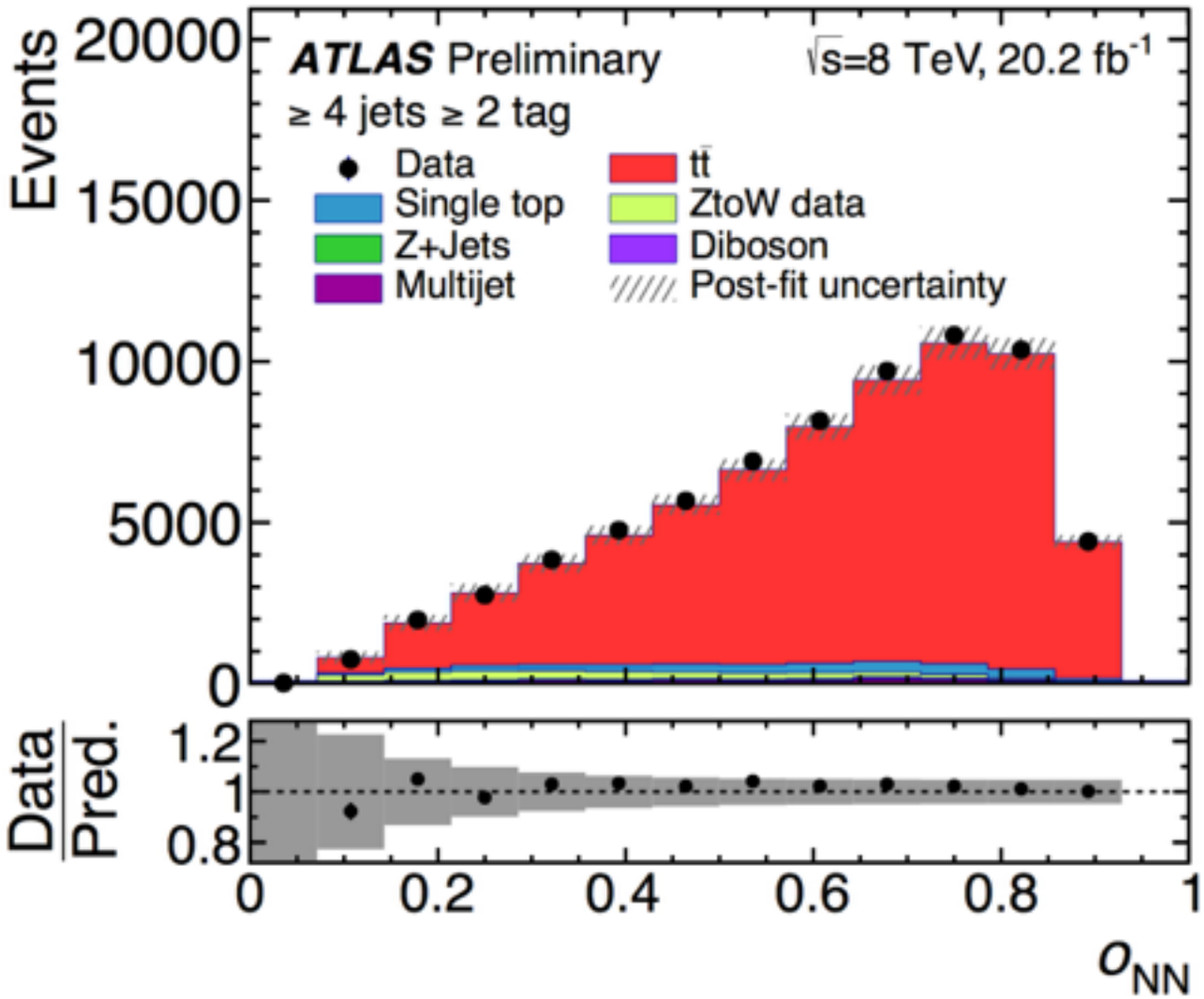
- ~70% signal purity
- largest backgrounds: *W*+jets, single top
- to constrain backgrounds:
  - 3 signal regions (n jets + n tags)
  - neural network with kinematic observable inputs
  - likelihood fit
- uncertainties becoming competitive with *eμ* channel



ATLAS-CONF-2017-054

8 TeV ℓ+jets inclusive cross section results

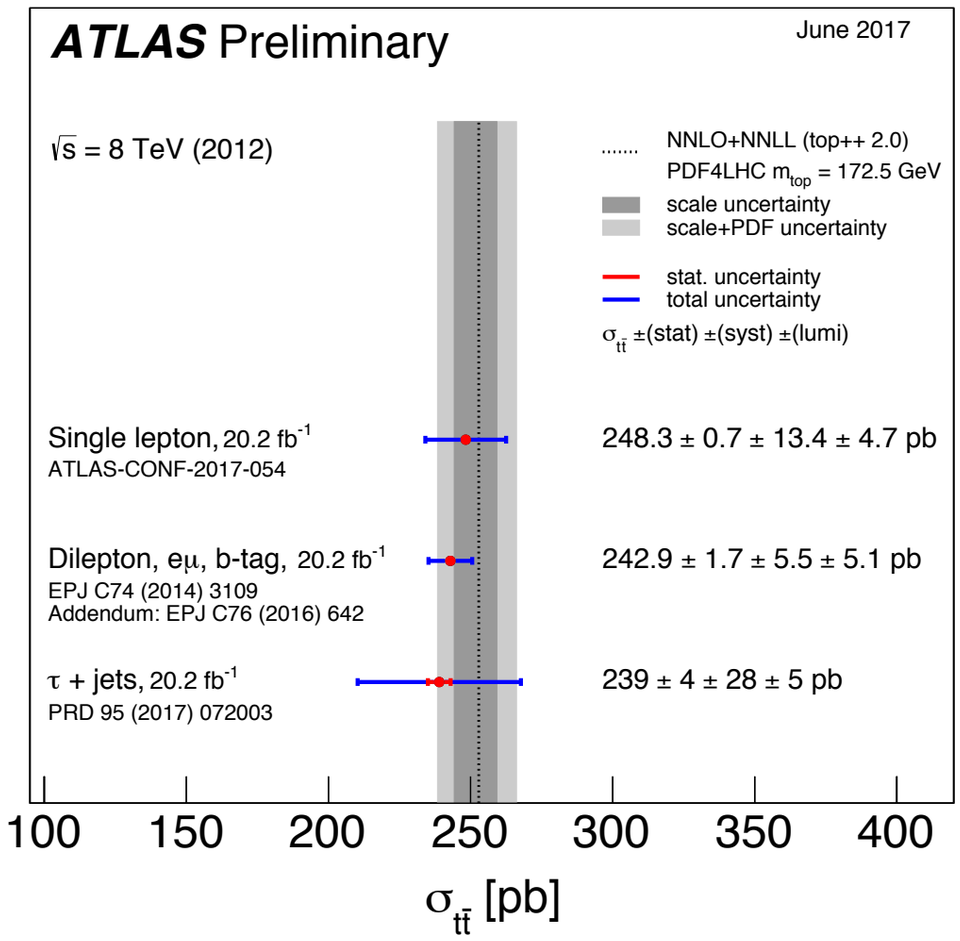




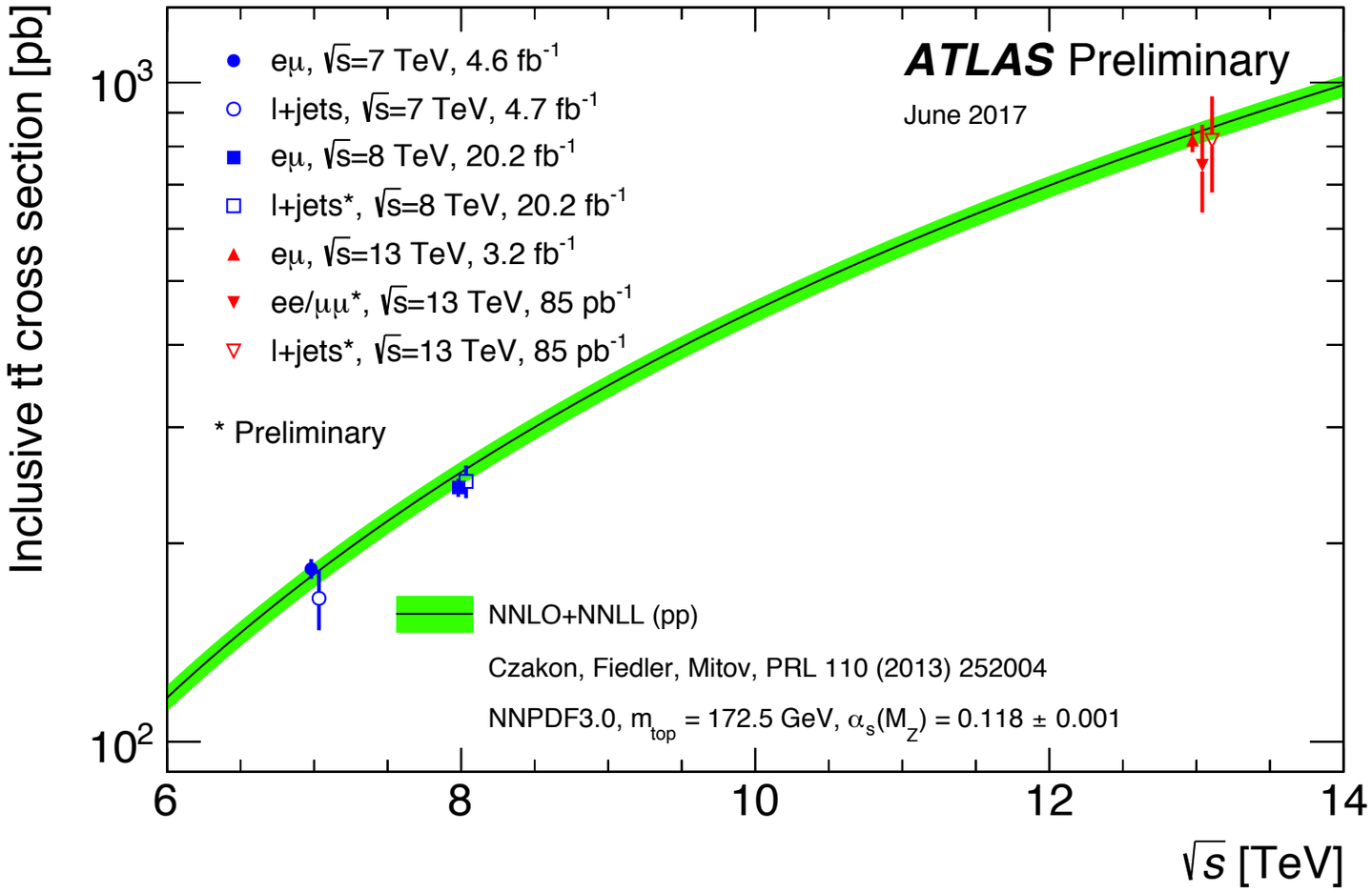
$$\sigma_{t\bar{t}} = 248.3 \pm 0.7\,(\text{stat.})$$
$$\pm 12.8\,(\text{syst.}) \pm 4.7\,(\text{lumi.})\ \text{pb}$$

largest uncertainties:
MC modeling, JES, lepton ID and trigger

inclusive cross sections at ATLAS



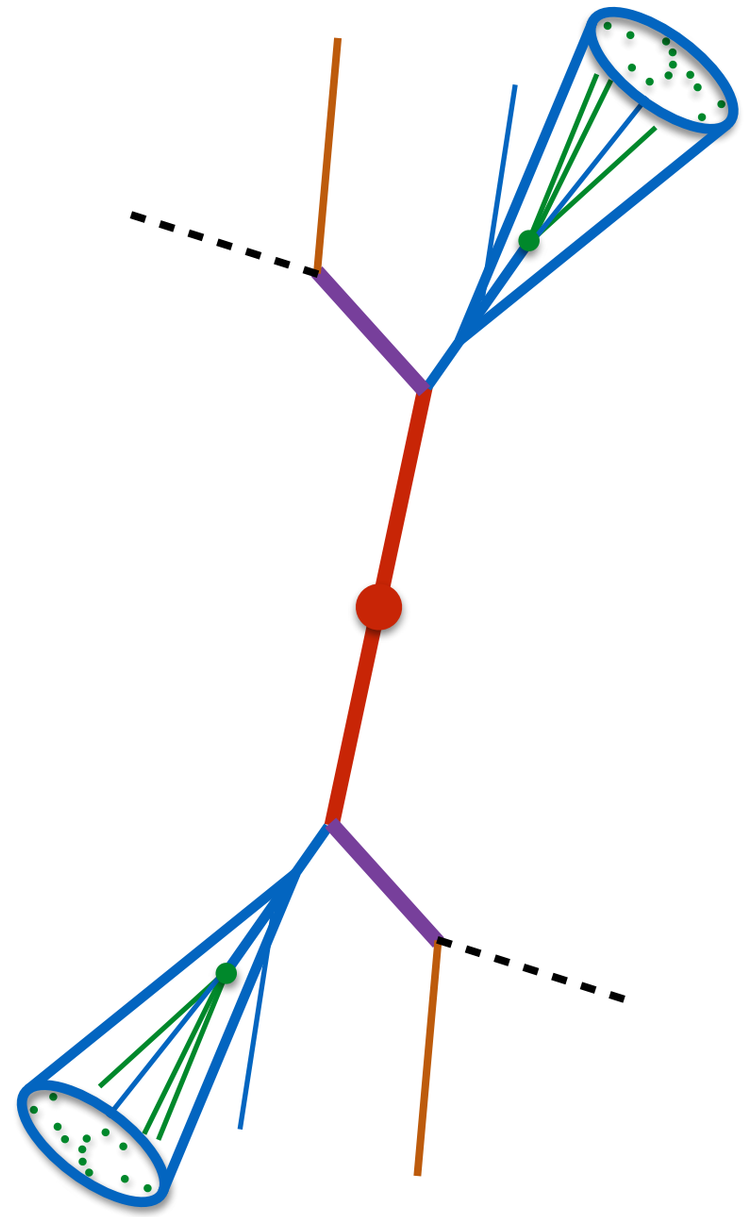
8 TeV inclusive *tt* cross section measurements from ATLAS



7, 8, 13 TeV inclusive *tt* cross section measurements from ATLAS

measurement of lepton differential distributions in *tt* events

- use *eμ* events for background rejection
- ~90% signal purity (main background: *Wt*)
- interpretations:
- **gluon PDF constraints**
- top pole mass (see presentation by Richard Nisius this afternoon)



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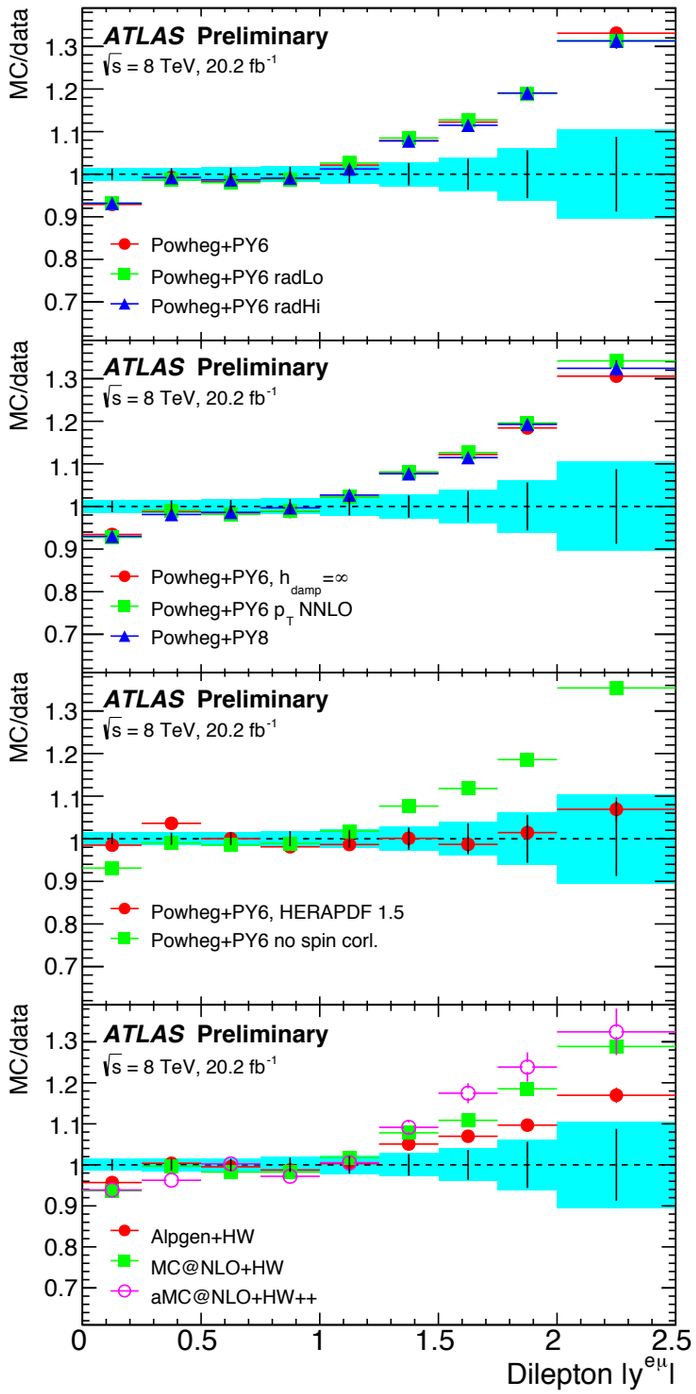
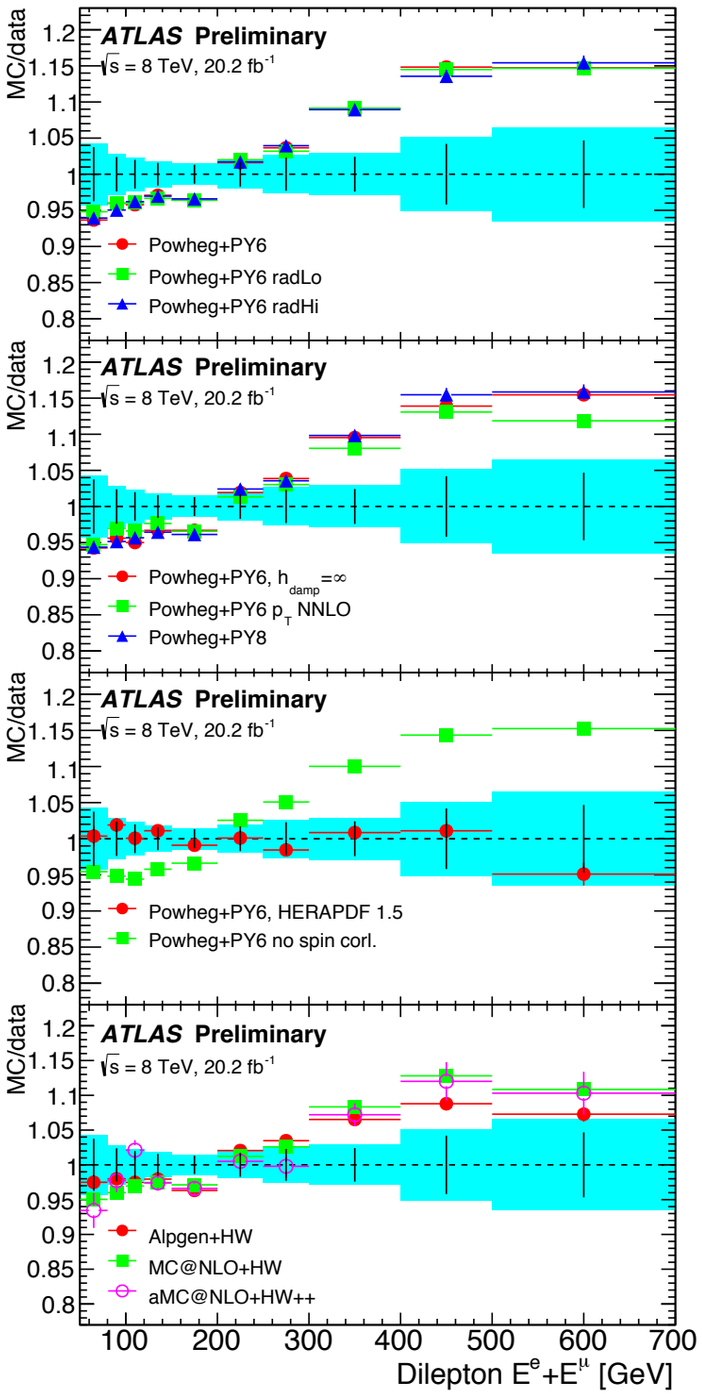
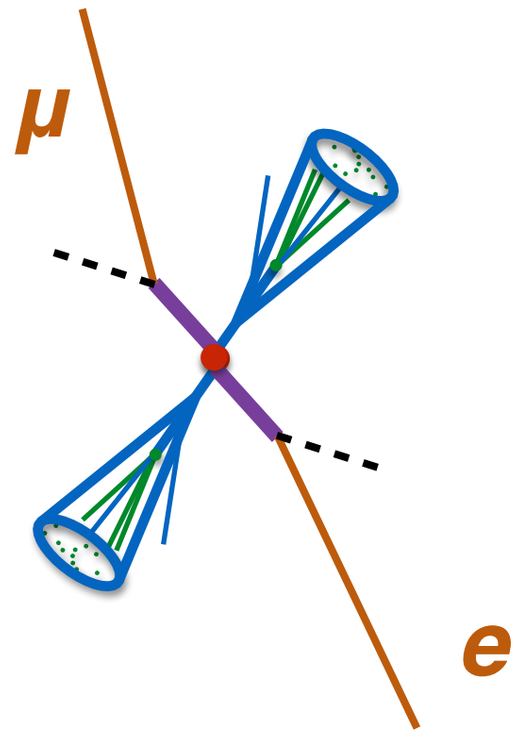
lepton differential distributions



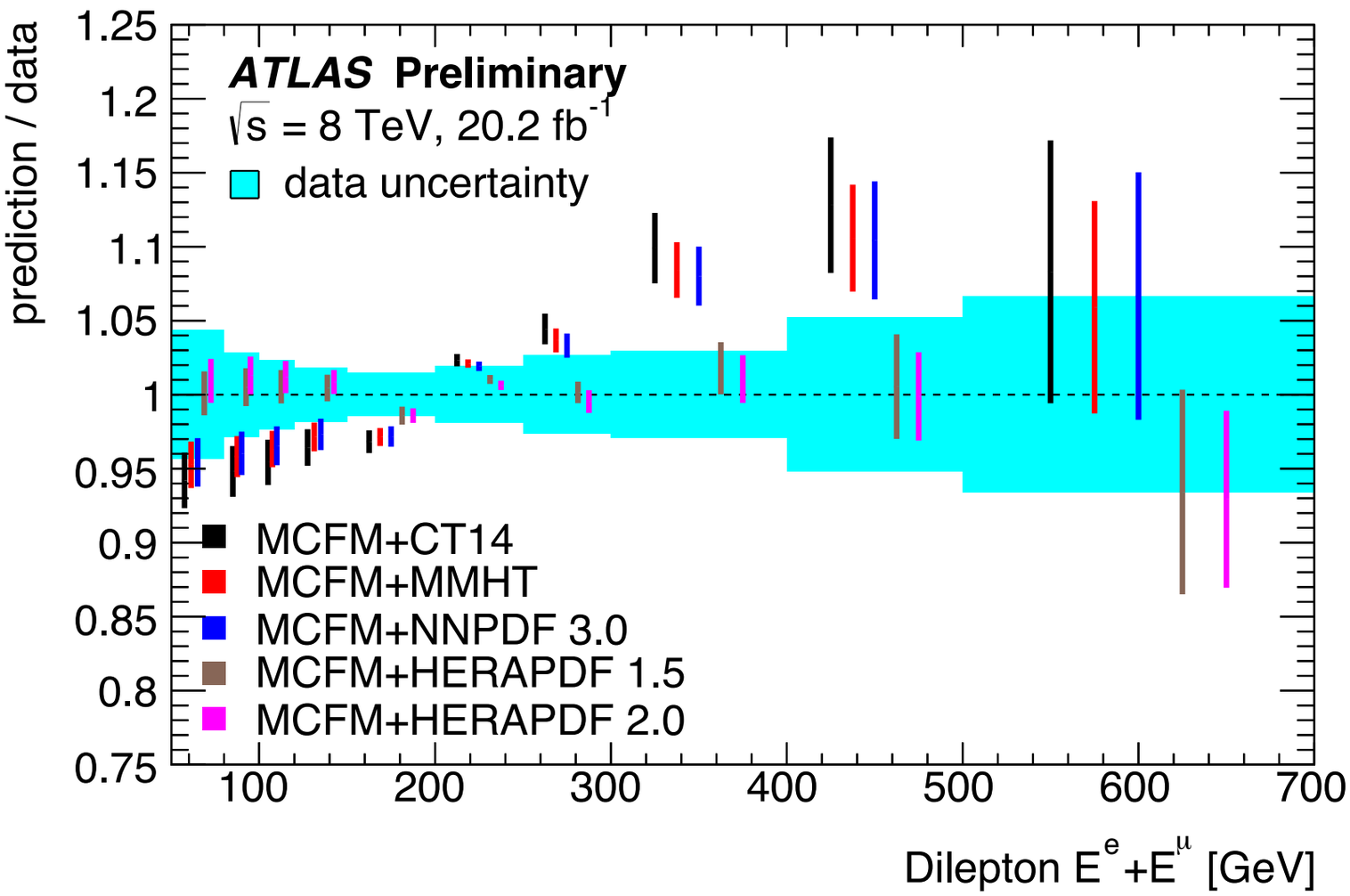


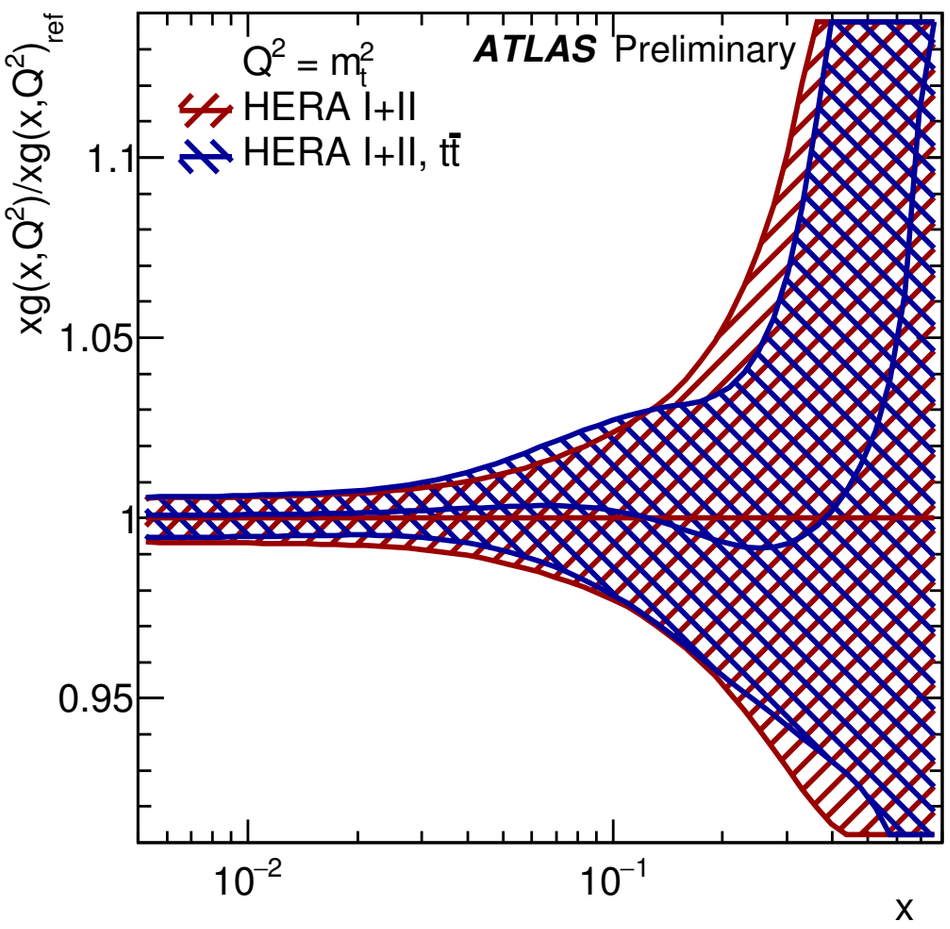


largest uncertainties: MC modeling, lepton ID and trigger

significant discrepancies with data from some generator setups

lepton differential distributions: sensitivity to PDF





several observables have sensitivity to choice of PDF!

differential fiducial cross-section measurements at 13 TeV

- $e\mu$ channel: high purity, $\mathcal{O}$(95%)
- single-lepton channel: more kinematic reach
- all-hadronic channel: no invisibles in final state, still $\mathcal{O}$(80%) purity

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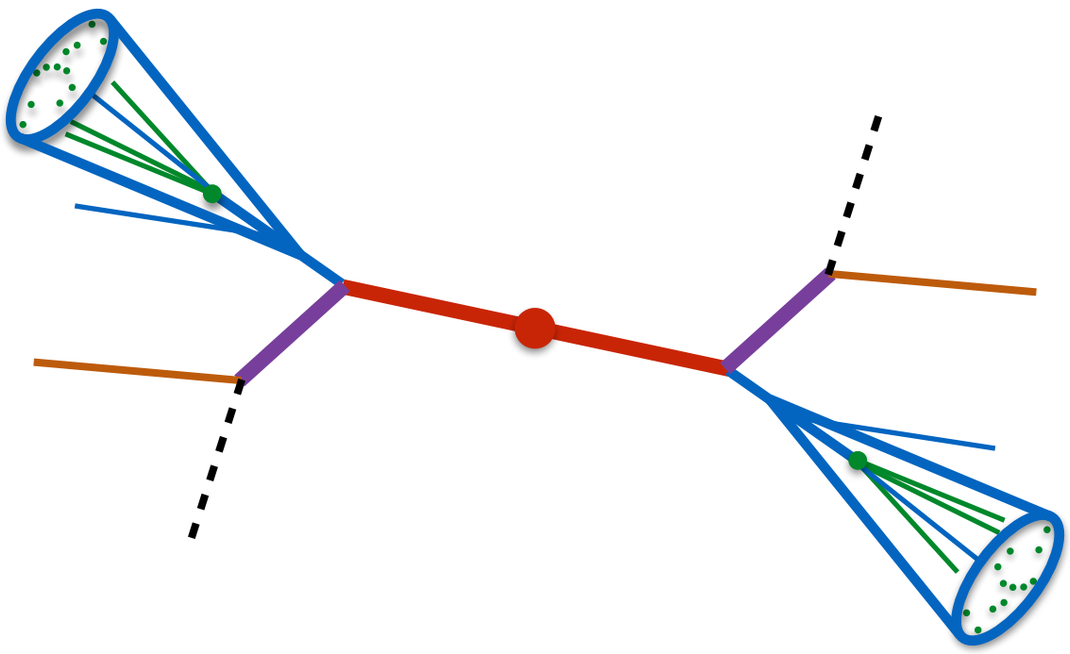
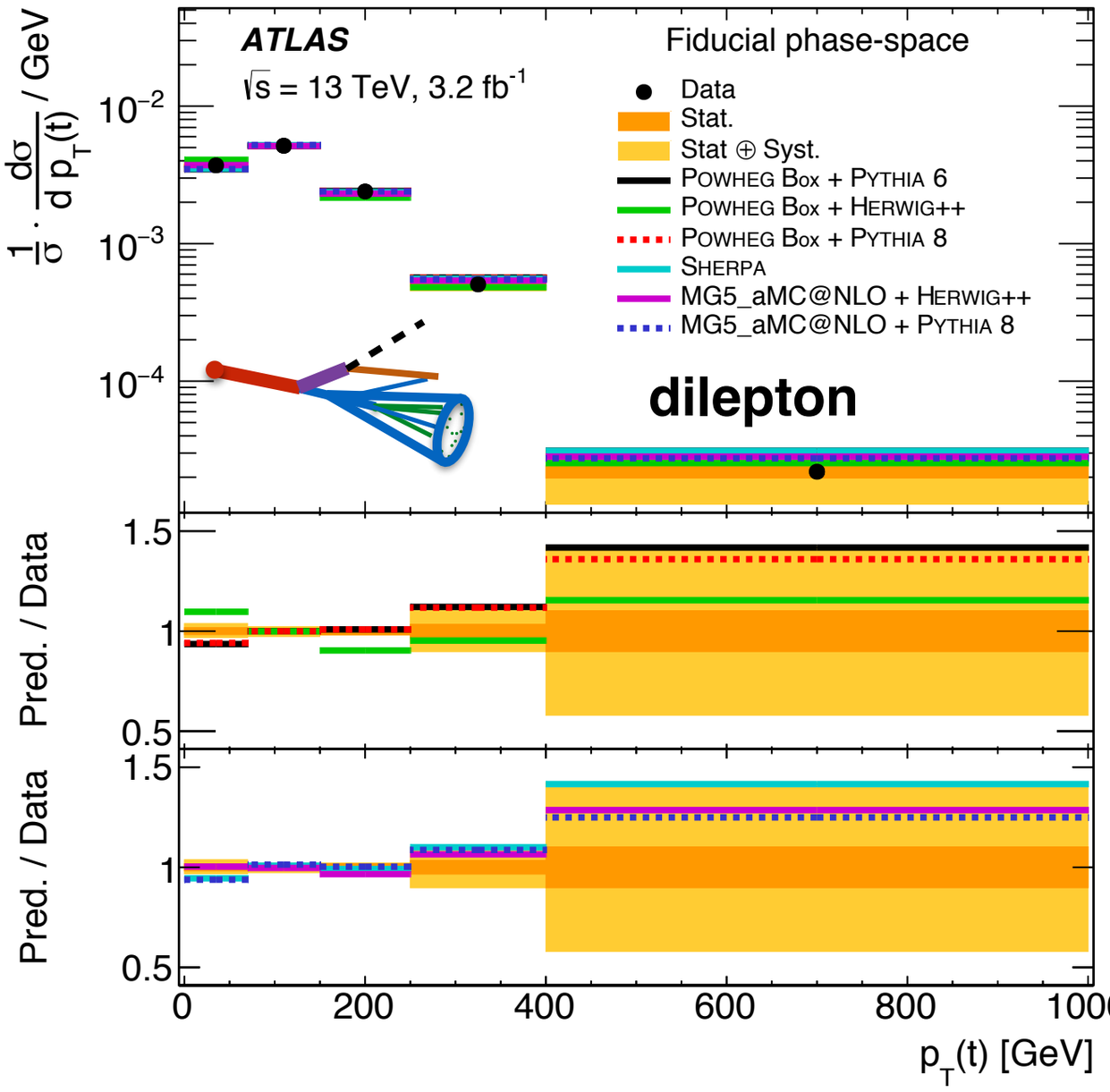
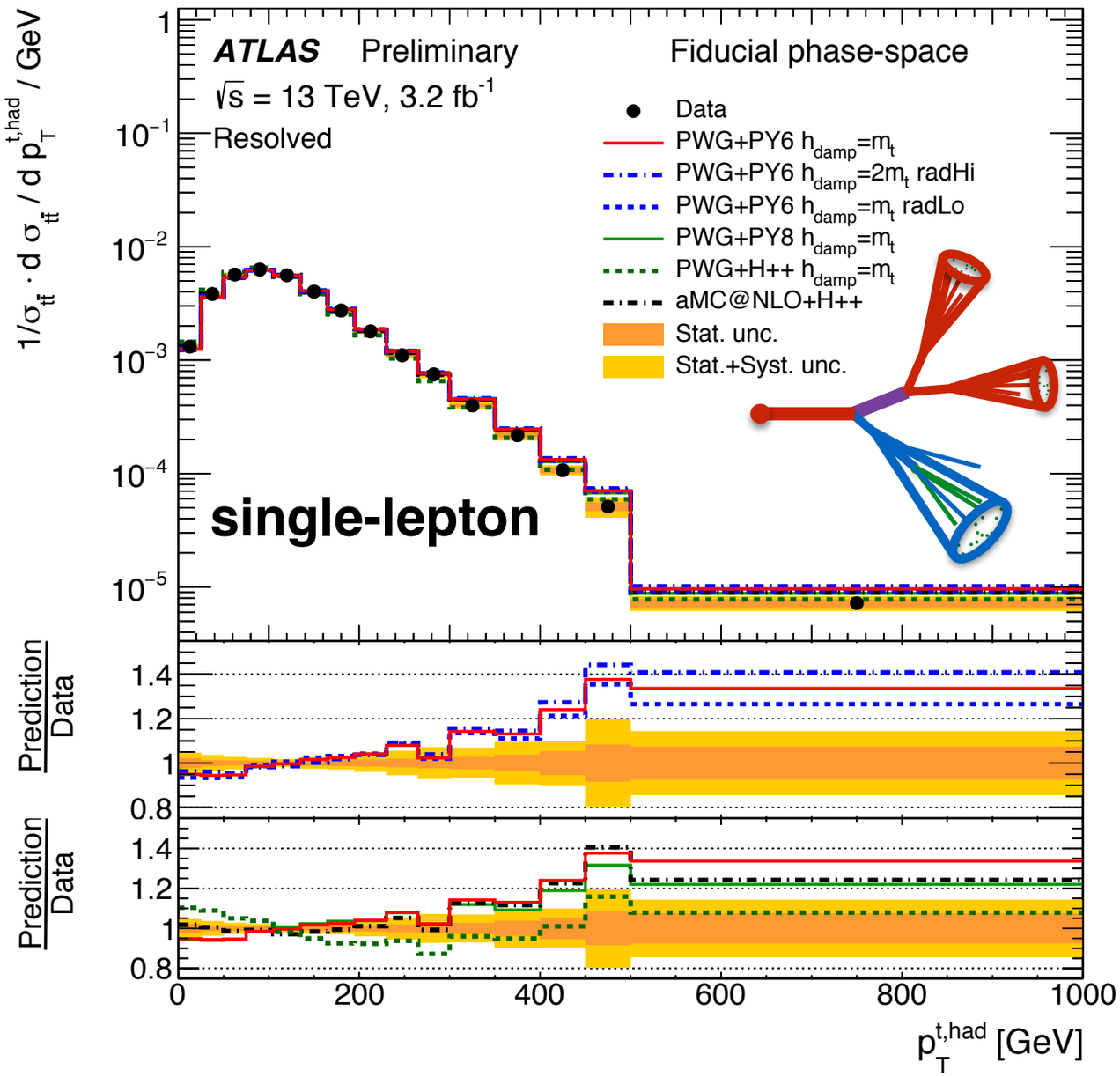
Eur. Phys. J. C77 (2017) 299



pseudo-top p_T





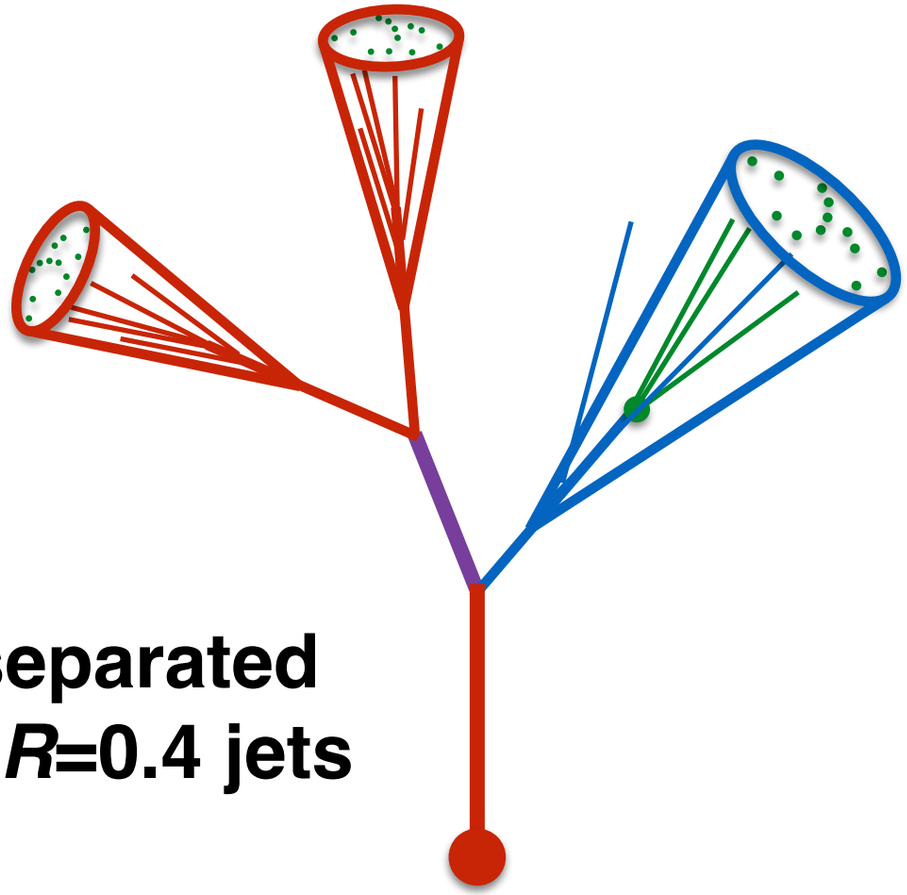
clear shapes from prediction w.r.t. data
largest uncertainties: *tt* modeling, *b*-tagging

resolved and boosted top reconstruction

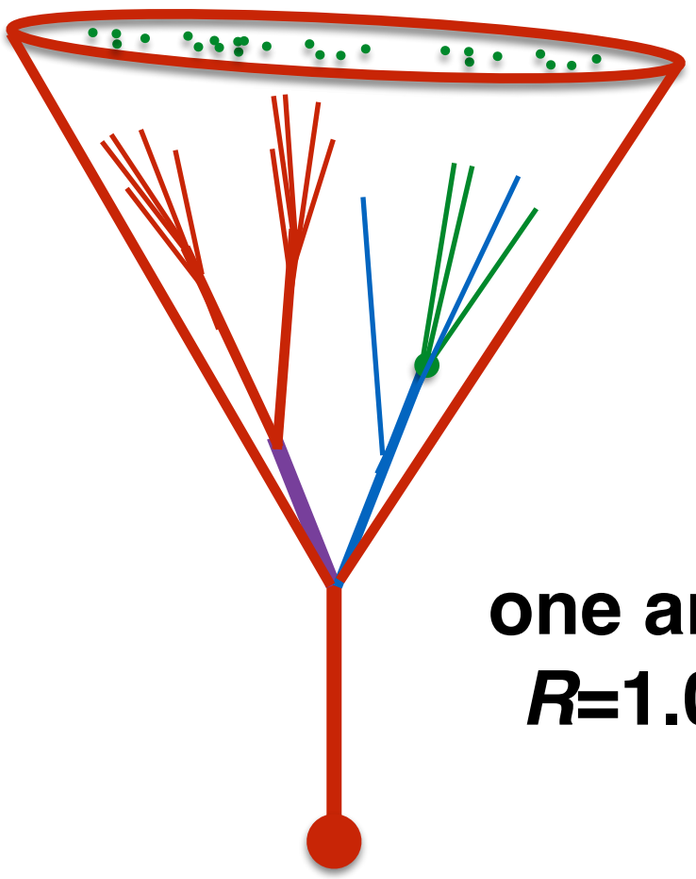
higher pseudo-top p_T

“resolved”

“boosted”



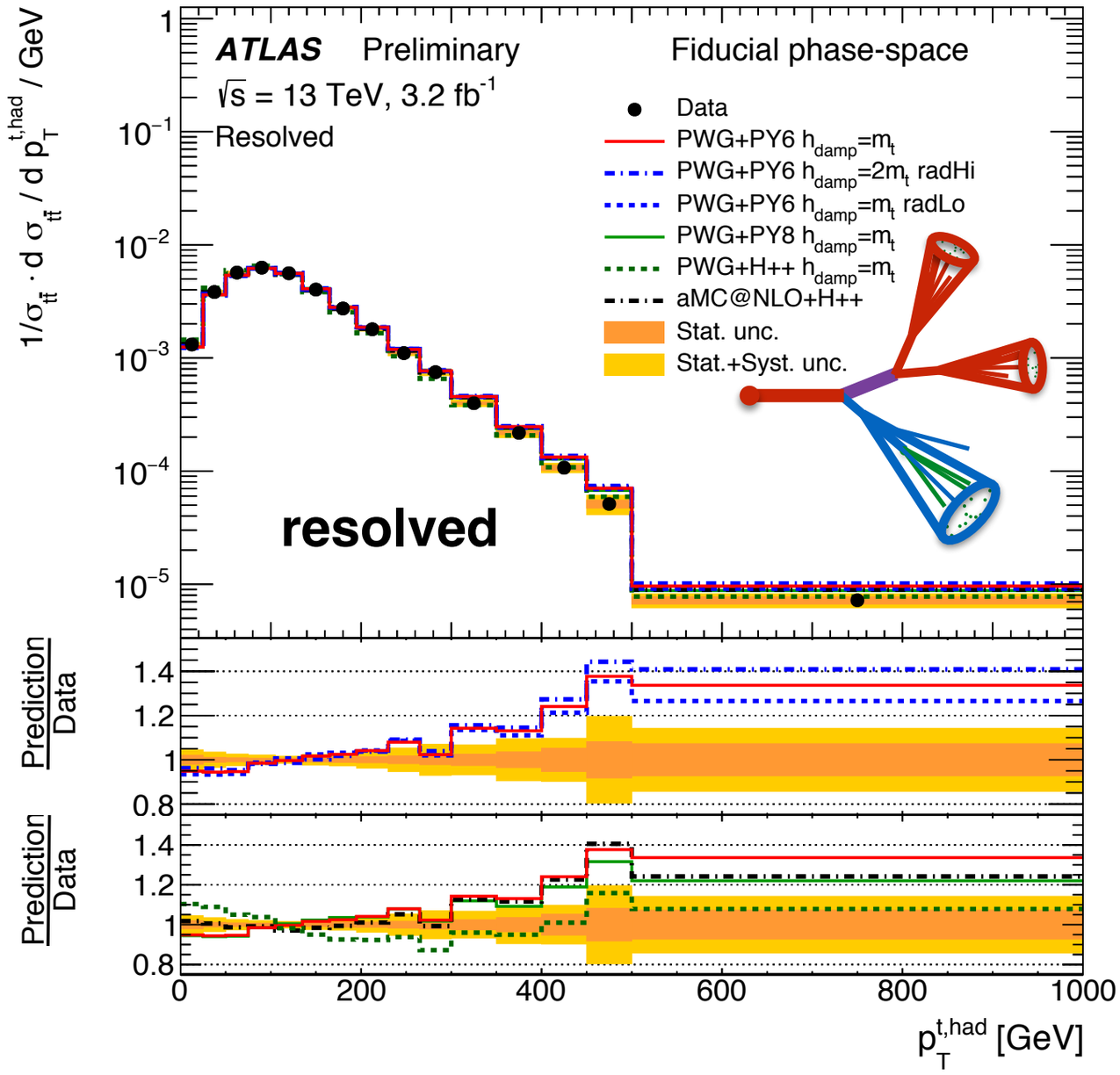
well-separated anti-k_t R=0.4 jets

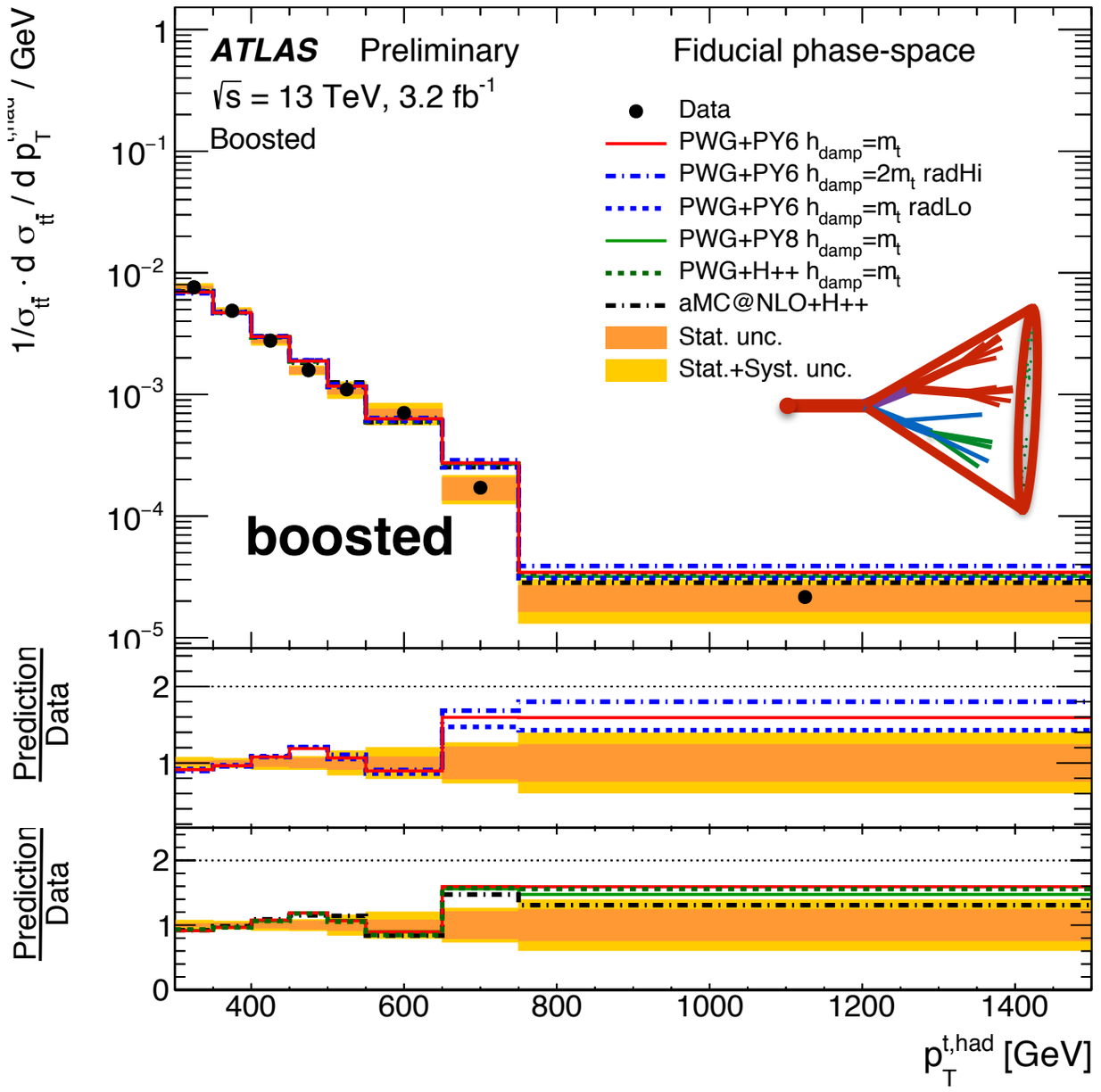


one anti-k_t R=1.0 jet

pseudo-top p_T: resolved and boosted

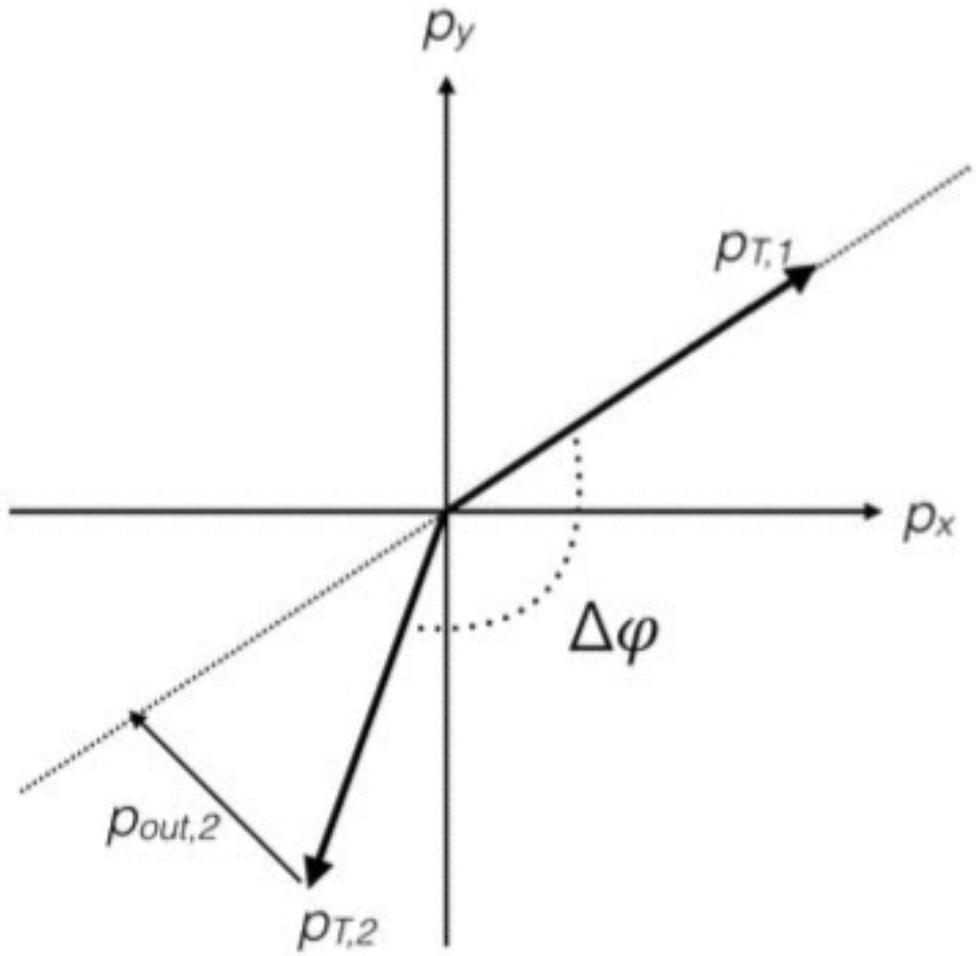
similar features seen using different reconstruction methods
large-*R* jet JES uncertainty becomes dominant at high-p_T

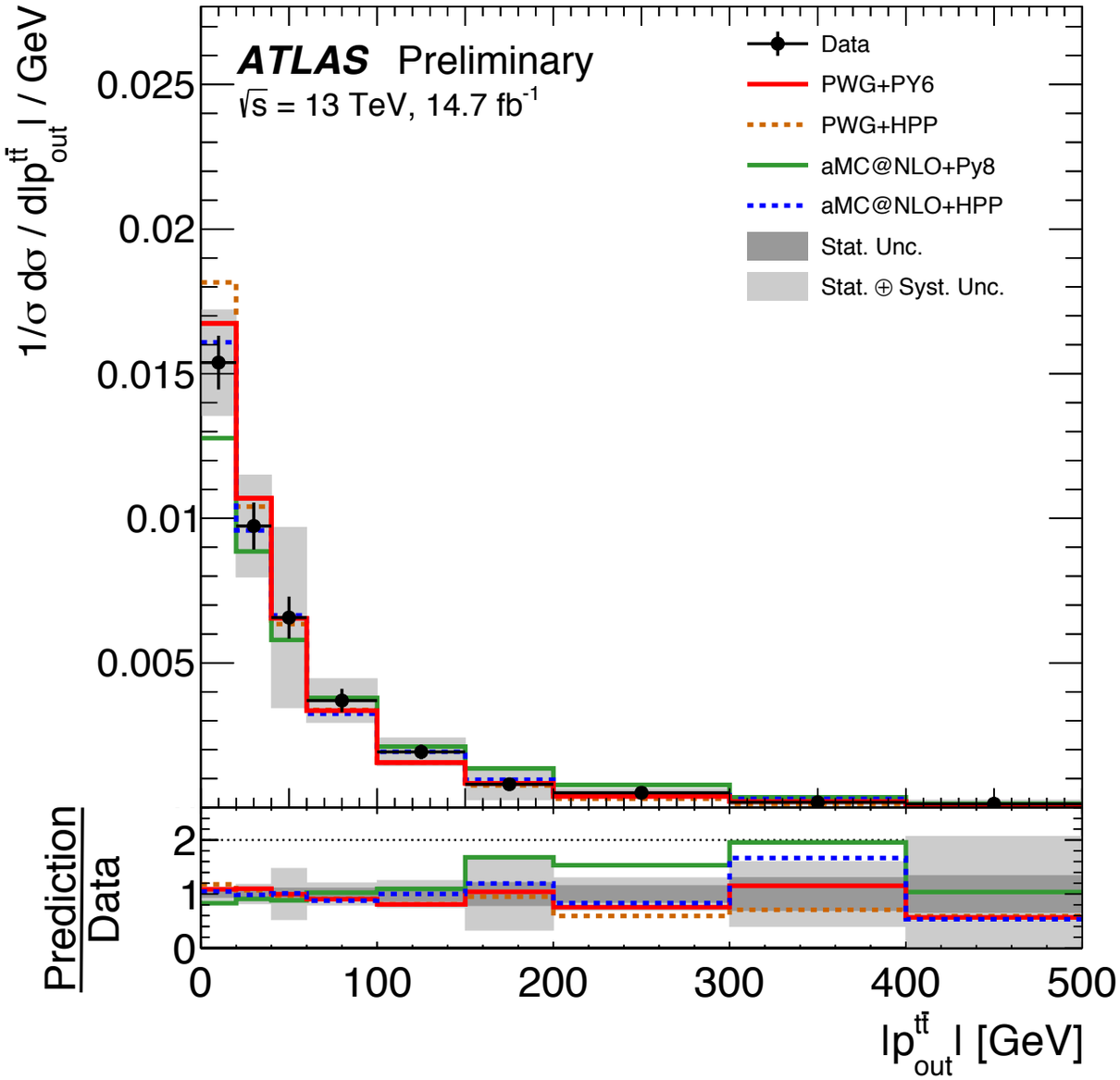




observables in the all-hadronic channel

many angular observables in addition to those measured in the 2- and 1-lepton channels





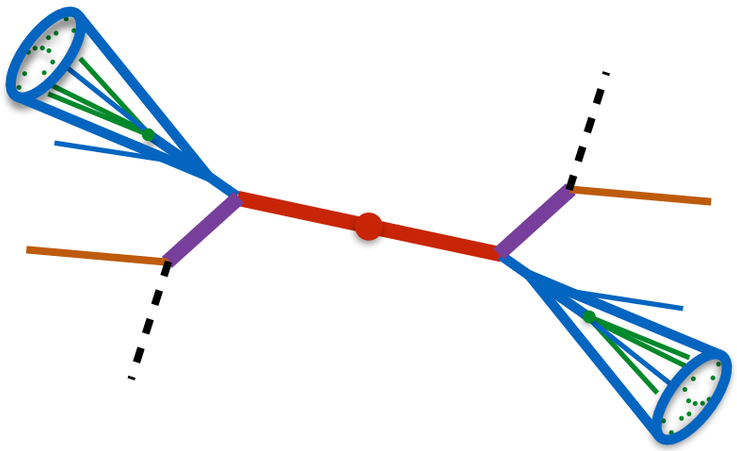
summary

- I've shown a small slice of the ATLAS top pair production measurement program.

- please take a look at the full suite of results from these and other measurements:

  https://twiki.cern.ch/twiki/bin/view/AtlasPublic/TopPublicResults

- more certainly to come!



measurement of lepton differential distributions in *tt* events

Generator	p_{T}^{ℓ}, $p_{\mathrm{T}}^{e+\mu}$	$p_{\mathrm{T}}^{e\mu}$, $m^{e\mu}$, $p_{\mathrm{T}}^{e+\mu}$	$\lvert\eta^{\ell}\rvert$, $\lvert y^{e\mu}\rvert$	$\lvert\eta^{\ell}\rvert$, $\lvert y^{e\mu}\rvert$, $E^{e+\mu}$	All
N_{dof}	16	26	16	25	69
MCFM + CT14	19.5	29.6	24.2	32.4	73.0
MCFM + MMHT	19.3	29.6	23.4	30.7	72.0
MCFM + NNPDF 3.0	19.9	29.7	20.1	27.4	69.3
MCFM + HERAPDF 1.5	16.1	28.8	21.5	26.1	68.8
MCFM + HERAPDF 2.0	15.3	30.0	22.7	27.4	69.0
MCFM + CT14	0.24	0.28	0.086	0.15	0.35
MCFM + MMHT	0.25	0.28	0.10	0.20	0.38
MCFM + NNPDF 3.0	0.23	0.28	0.22	0.34	0.47
MCFM + HERAPDF 1.5	0.45	0.32	0.16	0.40	0.48
MCFM + HERAPDF 2.0	0.51	0.27	0.12	0.34	0.48

Table 11: χ^2 values (top) and associated probabilities (bottom) for comparison of combinations of measured normalised differential fiducial cross-sections with the predictions of MCFM with various PDF sets. Contributions via $W \to \tau \to e/\mu$ decays are not included, and the MCFM predictions have been corrected to include QED final-state radiation effects. The results take into account the uncertainties on both the measurements and predictions.

ATLAS-CONF-2017-044

measurement of lepton differential distributions in *tt* events

Table 2: The seven input variables of the NN, ordered by their discriminating power.

Variable	Definition
m_{12}	The smallest invariant mass between jet pairs.
$\cos(\theta^*)_{bjj}$	Angle between the hadronic top-quark momentum and the beam direction in the $t\bar{t}$ rest frame.
$m(\ell\nu b)$	Mass of the reconstructed semileptonically decaying top quark.
A	Aplanarity, as defined in Eq. 6
$m(bjj)$	Mass of the reconstructed hadronically decaying top quark.
$m_{\ell 1}$	The smallest invariant mass between the charged lepton and a jet.
m_{23}	The second smallest invariant mass between jet pairs.

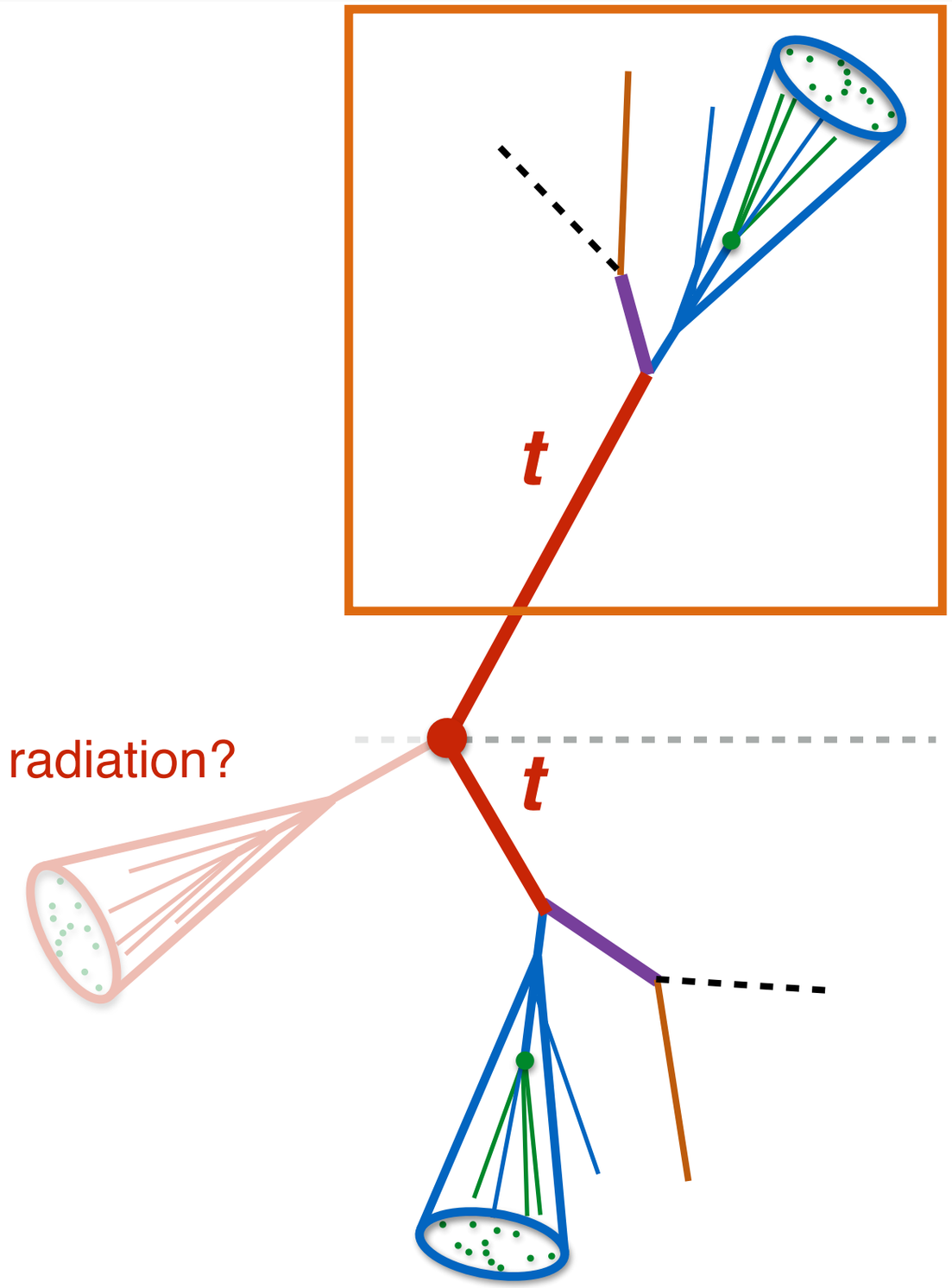
ATLAS-CONF-2017-054

measurement of lepton differential distributions in *tt* events

Predictions	$p_{\mathrm{T}}(t)$		$\lvert y(t)\rvert$		$p_{\mathrm{T}}(t\bar{t})$		$\lvert y(t\bar{t})\rvert$		$m(t\bar{t})$	
	χ^2/NDF	p-value	χ^2/NDF	p-value	χ^2/NDF	p-value	χ^2/NDF	p-value	χ^2/NDF	p-value
Powheg + Pythia 6	5.2/4	0.27	0.5/3	0.92	5.5/6	0.48	0.6/2	0.74	3.9/4	0.42
Powheg + Pythia 8	4.6/4	0.33	1.3/3	0.73	5.1/6	0.53	0.0/2	1.00	5.7/4	0.22
Powheg + Herwig++	14.6/4	0.01	1.4/3	0.71	4.1/6	0.66	1.0/2	0.61	12.0/4	0.02
MG5_aMC@NLO + Herwig++	2.0/4	0.74	1.3/3	0.73	0.6/6	1.00	0.2/2	0.90	0.9/4	0.92
MG5_aMC@NLO + Pythia 8	3.6/4	0.46	0.6/3	0.90	10.7/6	0.10	0.1/2	0.95	2.7/4	0.61
Sherpa	3.8/4	0.43	0.8/3	0.85	0.7/6	0.99	0.0/2	1.00	2.3/4	0.68
Powheg + Pythia 6 (radHi)	7.8/4	0.10	0.6/3	0.90	0.9/6	0.99	0.4/2	0.82	3.8/4	0.43
Powheg + Pythia 6 (radLow)	5.5/4	0.24	0.8/3	0.85	9.6/6	0.14	0.8/2	0.67	4.5/4	0.34

Eur. Phys. J. C77 (2017) 299

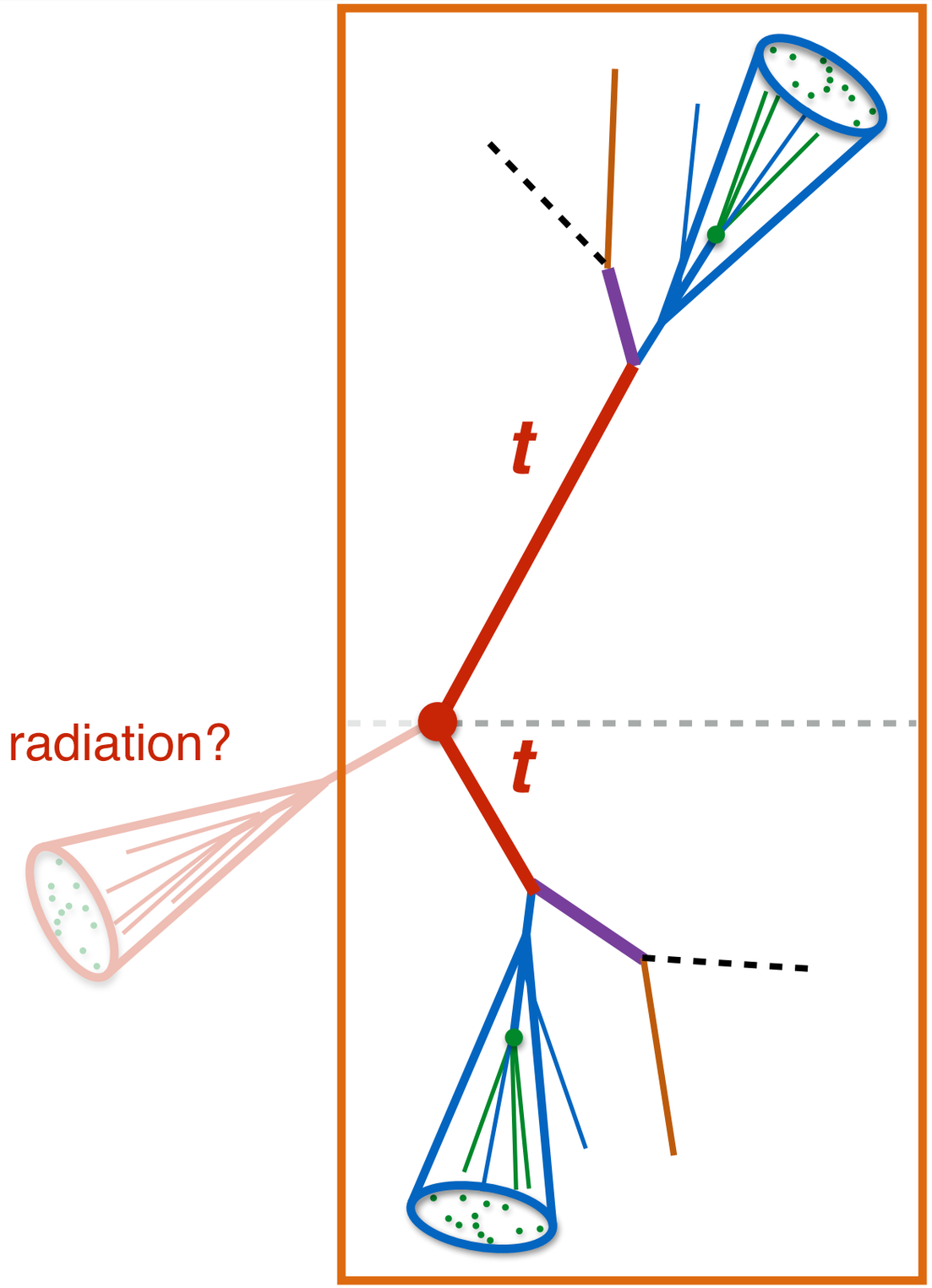
observables for individual top quarks



pseudo-top |*y*|

pseudo-top p_T

observables for the *tt* system

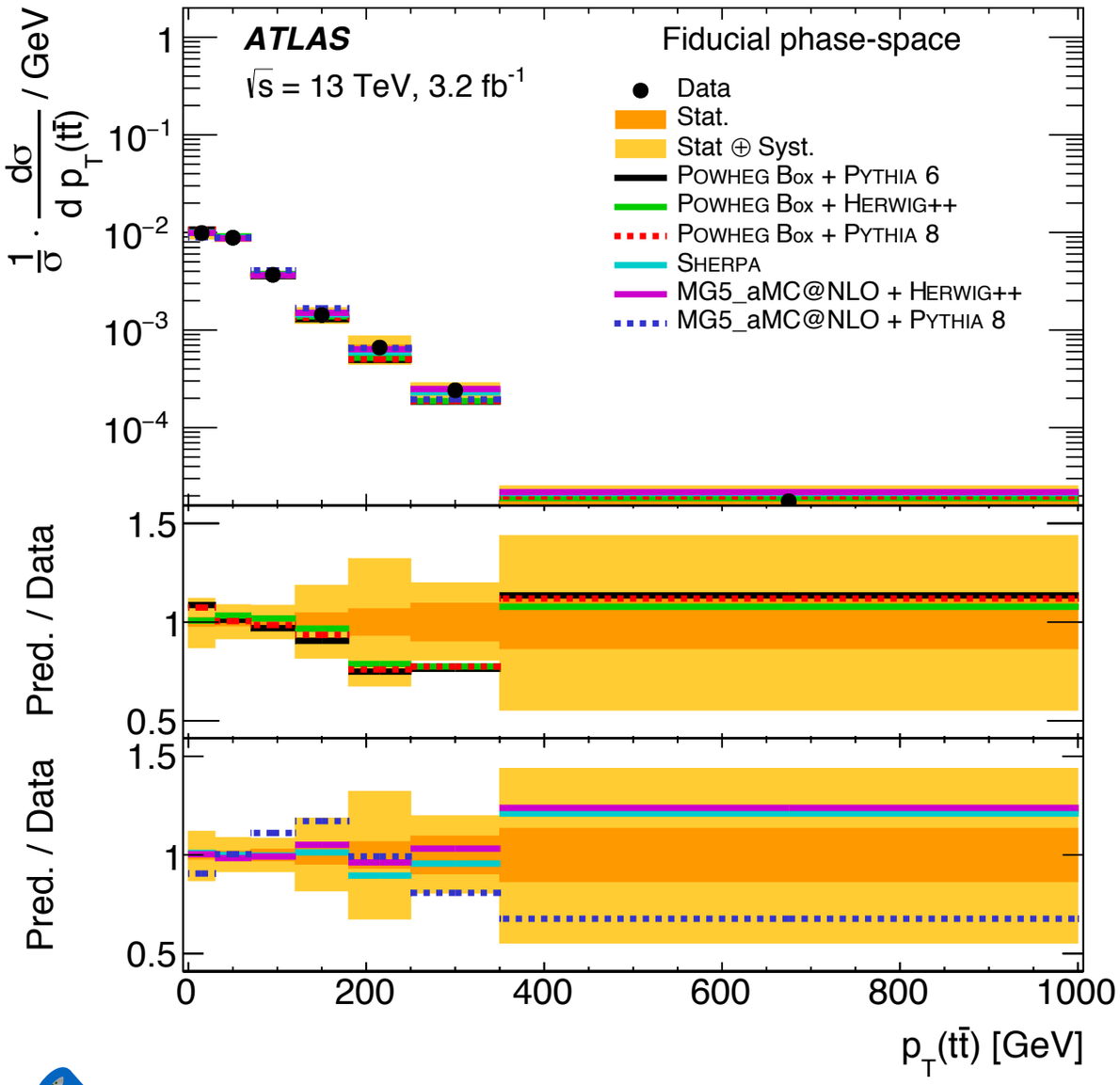


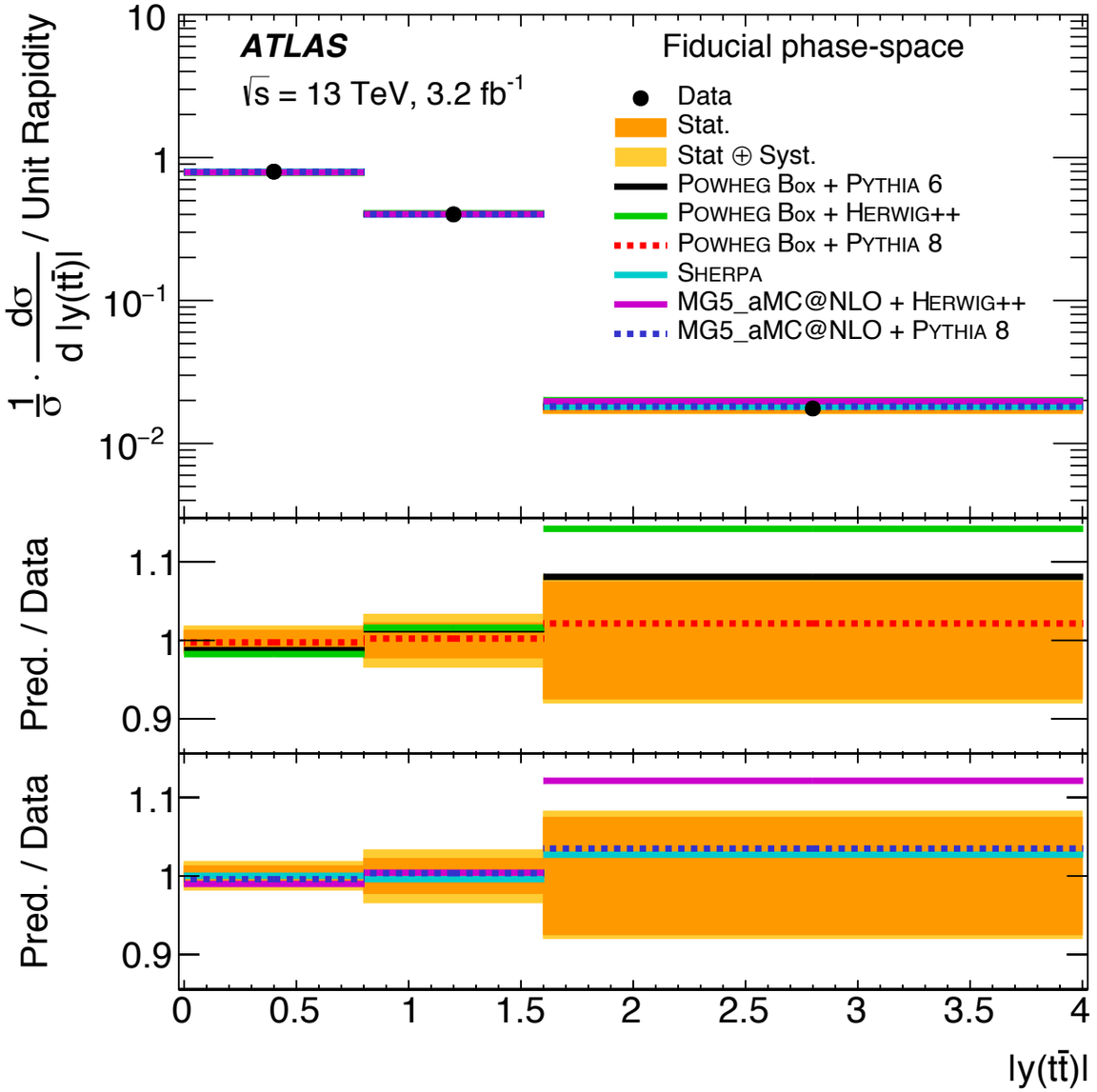
tt **|*y*|**

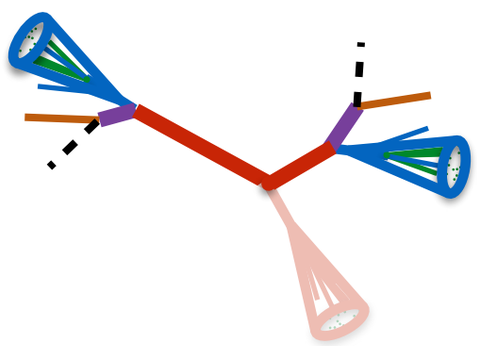
tt **p_T**

tt **mass**

tt system results



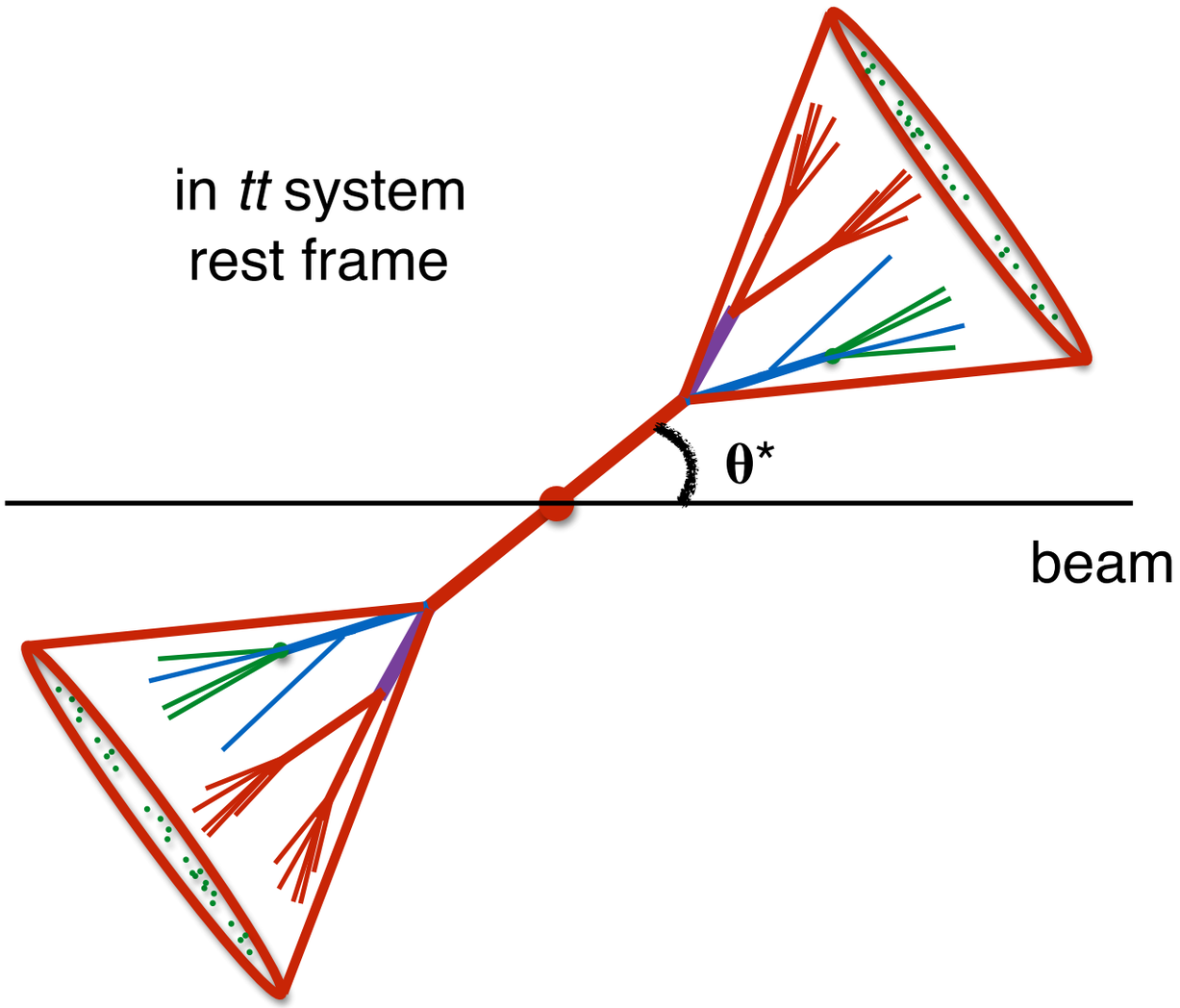


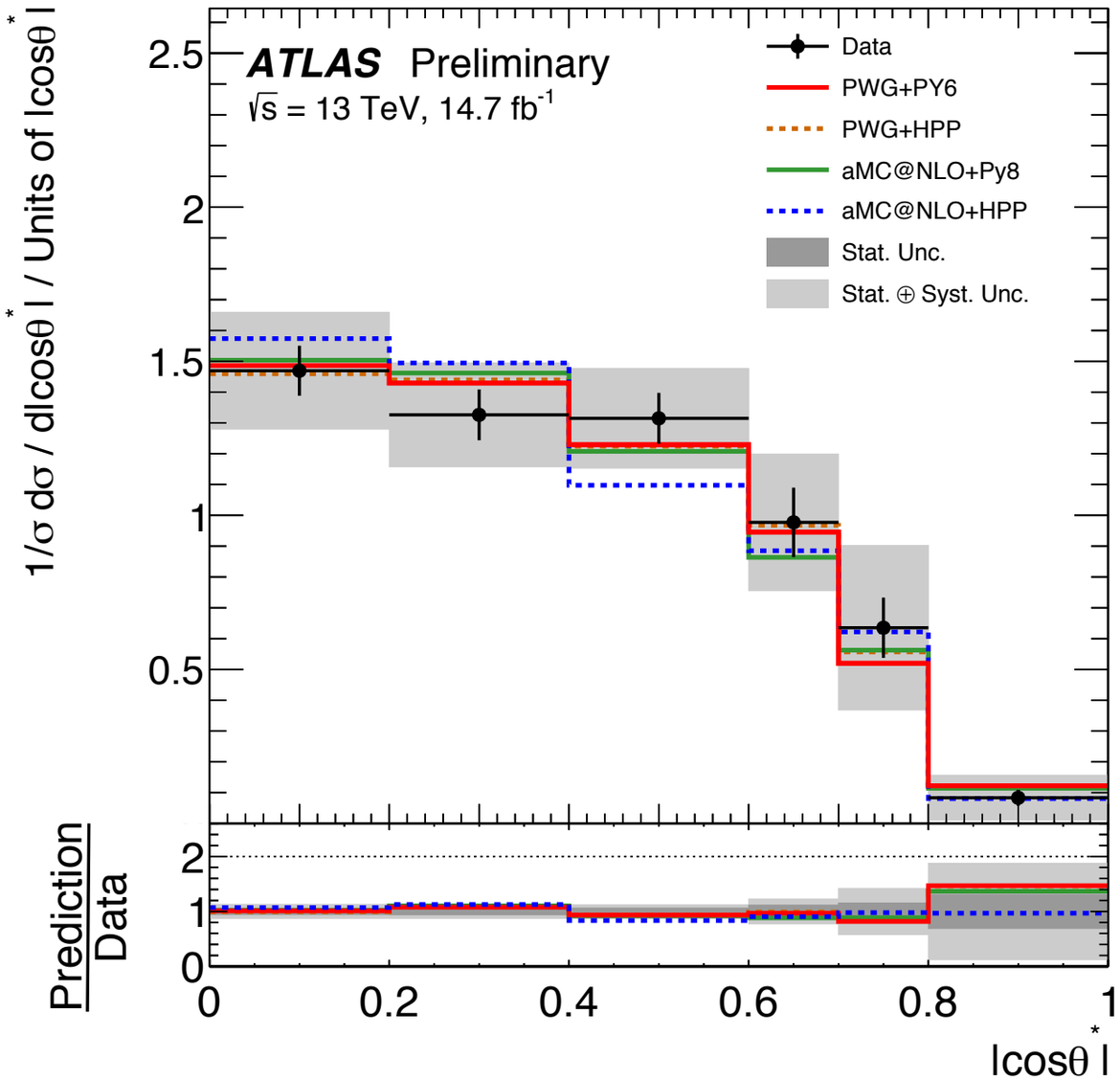


***tt* p_T**

***tt* y**

$|\cos\theta^*|$


in $t\bar{t}$ system
rest frame
θ^*
beam


ATLAS Preliminary
$\sqrt{s}$ = 13 TeV, 14.7 fb^{-1}
Data
PWG+PY6
PWG+HPP
aMC@NLO+Py8
aMC@NLO+HPP
Stat. Unc.
Stat. ⊕ Syst. Unc.
$1/\sigma\, d\sigma / d|\cos\theta^*|$ / Units of $|\cos\theta^*|$
Prediction / Data
$|\cos\theta^*|$