101° Congresso Nazionale

Roma, 21-25 settembre 2015

La Sapienza, 24/09/2015

Misura delle sezioni d'urto differenziali per la produzione di coppie $t\bar{t}$ nel canale l+jets nelle interazioni pp a $\sqrt{s}$=8 TeV con l'esperimento ATLAS a LHC

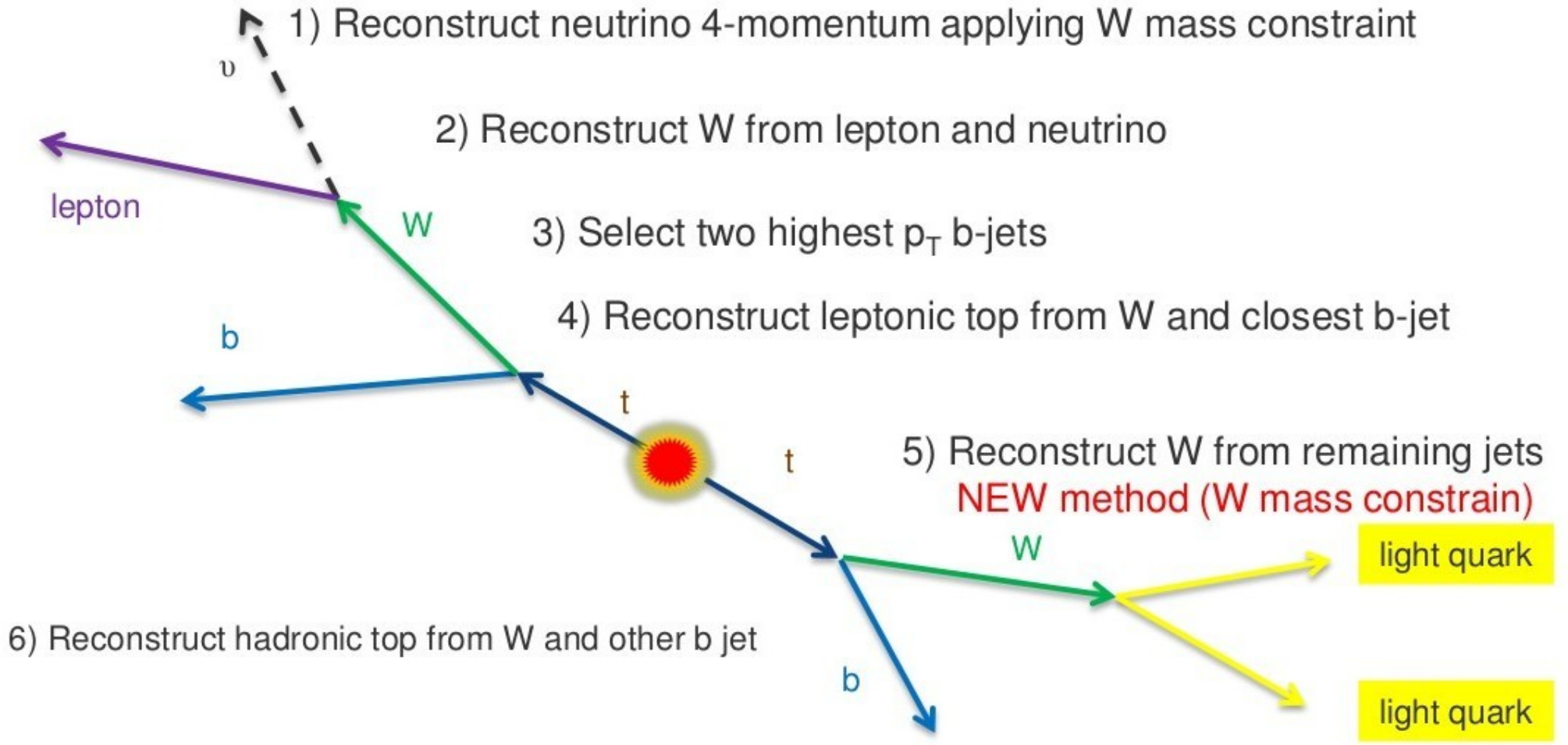
Valerio Scarfone

Universita` della Calabria & INFN Cosenza

Goals and motivation of the analysis

- Large cross-section of top quark pairs production allows detailed study of the differential cross sections
- Provide precise test of pQCD with a set of measurements that can be used to constrain various predictions, e.g.:
  - → Different generators (*POWHEG, MC@NLO, MadGraph)*
  - → Different tunes (*POWHEG* $h_{damp} = m_t$, $h_{damp} = \infty$)
  - → Different QCD radiation models (IFSR)
  - → Different PDF sets *(CT14nlo, NNPDF30nlo, MMHT2014nlo68cl, CJ12, METAv10LHC, HERA20NLO)*
- Top-quark pairs production is a leading background to many Higgs analyses and BSM searches

Top reconstruction



The top reconstruction is identical at detector and particle levels with the exclusion of the neutrino that at particle level is taken from the truth info

- $W^{lep} = (l^{\pm} + \nu)$ neutrino p_z from E_T^{miss} using M_W^{PDG} constraint from $W \rightarrow l \nu$ decay
- Leptonic top = W^{lep} + closest b-jet
- W^{had} = non b-tagged jet pair with its invariant mass M_{jj} closest to M_W^{PDG}
- Hadronic top = W^{had} + the remaining b-jet

Event selection

Event selection	
Trigger	Single lepton
Primary vertex	≥ 5 tracks with $p_{\mathrm{T}} > 0.4$ GeV
Exactly one	Muons: $p_{\mathrm{T}} > 25$ GeV, $\lvert\eta\rvert < 2.5$
isolated lepton	Electrons: $p_{\mathrm{T}} > 25$ GeV
	$\lvert\eta\rvert < 2.47$, excluding $1.37 < \lvert\eta\rvert < 1.52$
≥ 4 jets	$p_{\mathrm{T}} > 25$ GeV, $\lvert\eta\rvert < 2.5$
b-tagging	≥ 2 b-tagged jets at $\epsilon_b = 70\%$

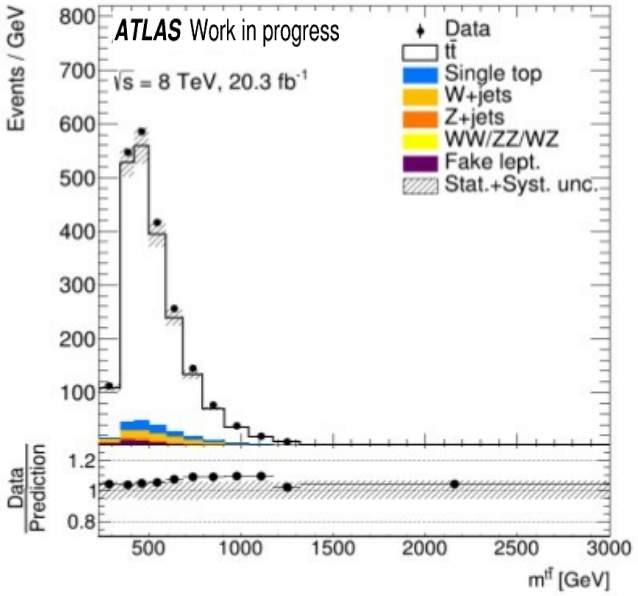
	e+jets	μ+jets
$t\bar{t}$	74000 ± 4700	92000 ± 5900
Single top	3600 ± 200	4400 ± 250
W+jets	3000 ± 300	4400 ± 400
Z+jets	1100 ± 550	570 ± 300
$WW/WZ/ZZ$	73 ± 40	67 ± 35
Non-prompt and fake lept.	2000 ± 900	1400 ± 600
Prediction	84000 ± 4900	103000 ± 6000
Data	89413	108131

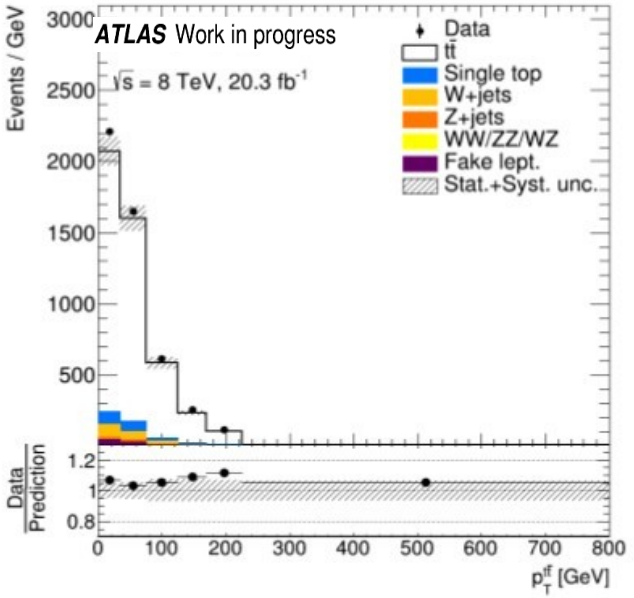
ATL-COM-PHYS-2015-792

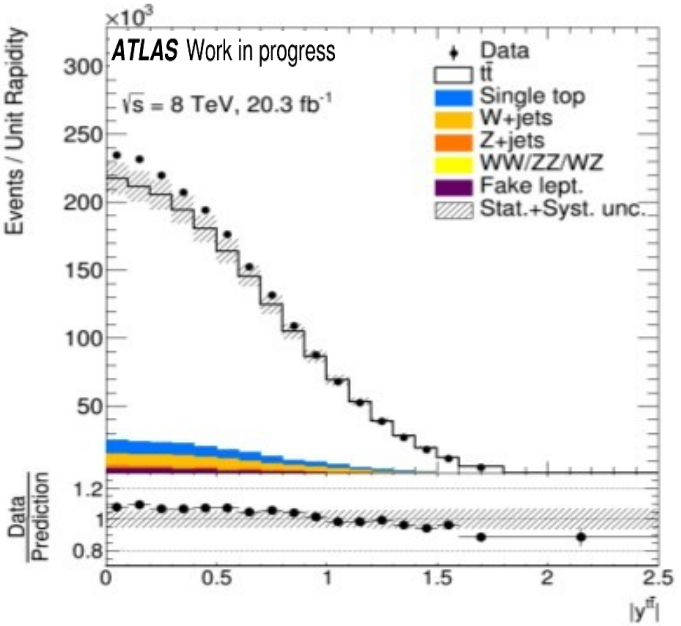
- Same event selection is applied to the electron and muon channels
- Good data/theory agreement

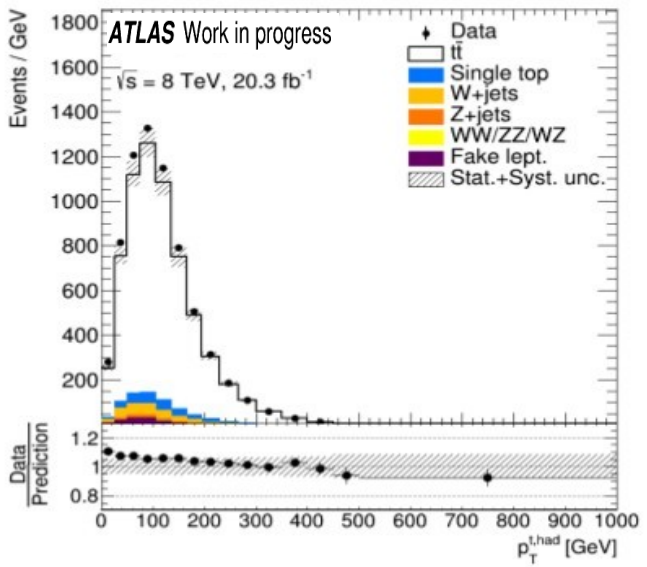
The uncertainties in the table contain statistical and systematic contributions added in quadrature

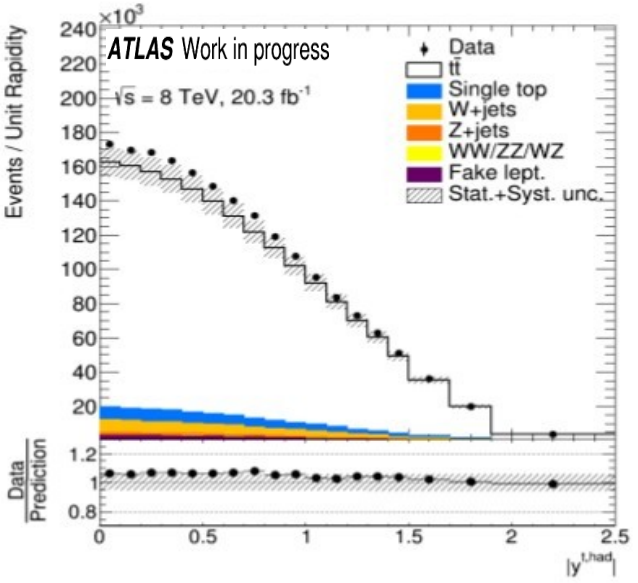
Control plots

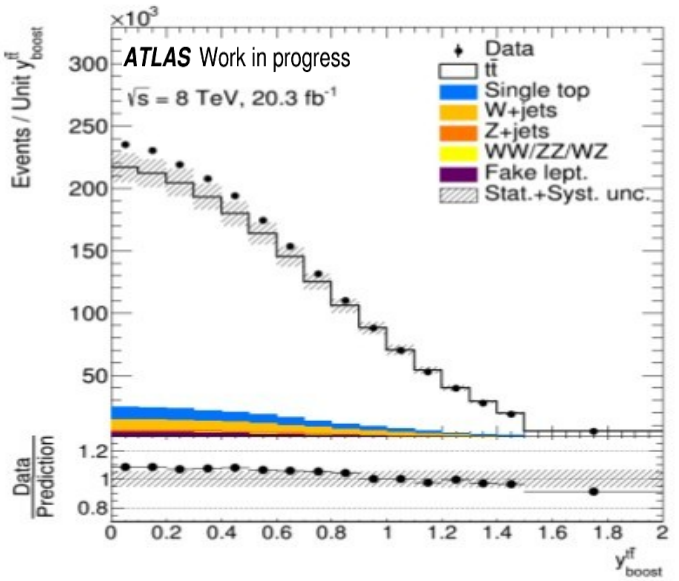










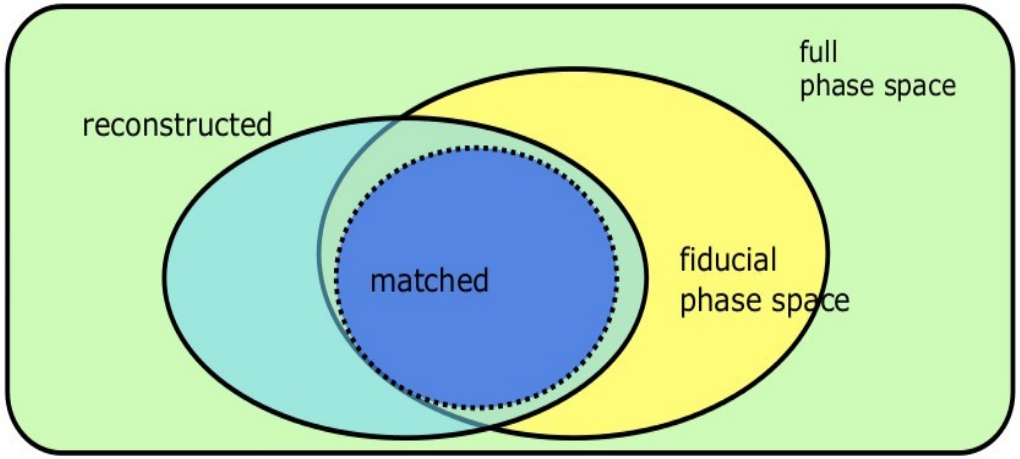


- New variable Y^{tt}_{boost} is defined as ½[$y_{t,lep}$ + $y_{t,had}$]

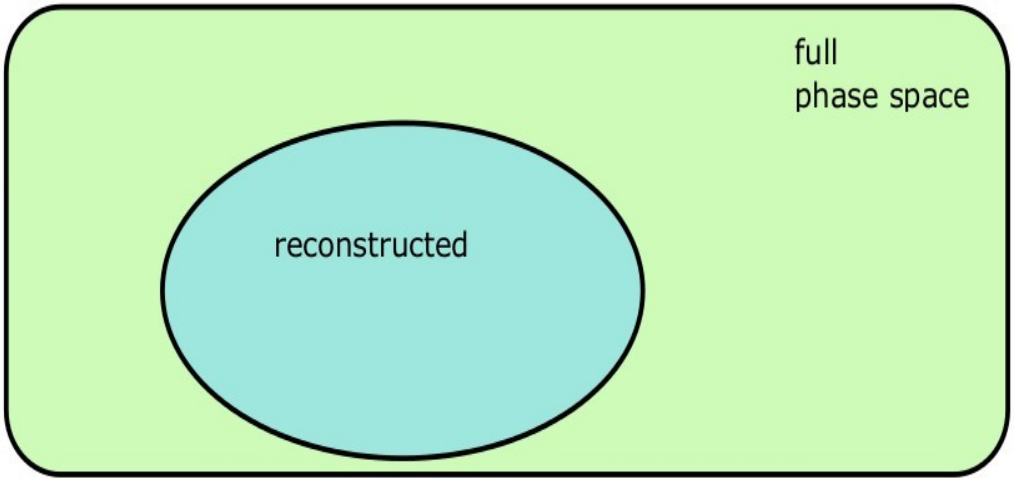
- Overall fair agreement at detector level between data and theory

Measurements

- Emphasis on top quark and $t\bar{t}$ pairs kinematics (transverse momentum, rapidity …)
- **Fiducial phase space** (“*particle-level*”) smaller extrapolation and uncertainties



- **Full phase-space** (“*parton-level*”) larger extrapolation also to regions not covered by the detector, allowing comparisons with NLO and future differential NNLO calculations and combinations with CMS

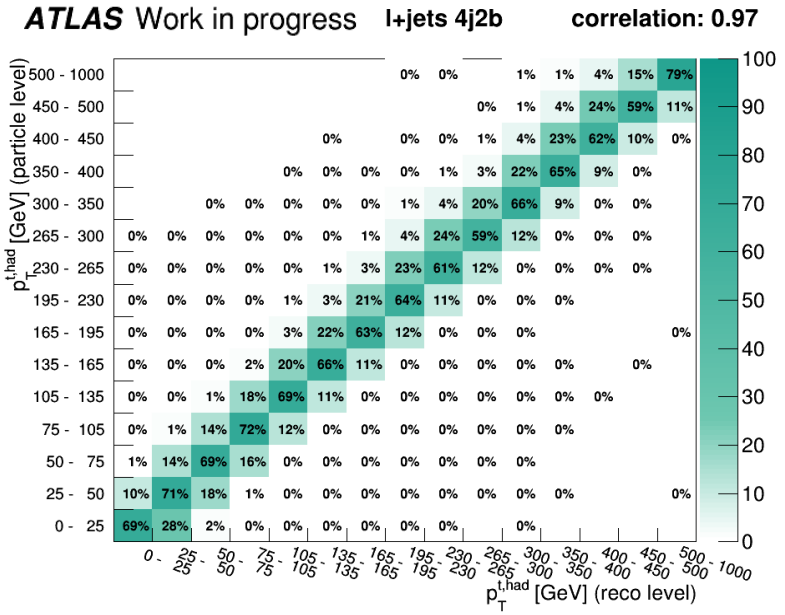


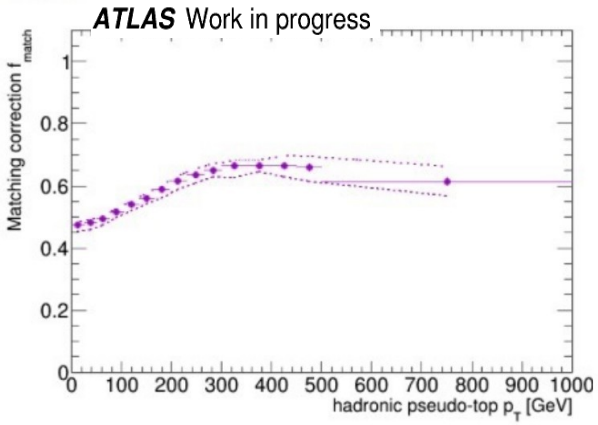
Differential Cross-sections

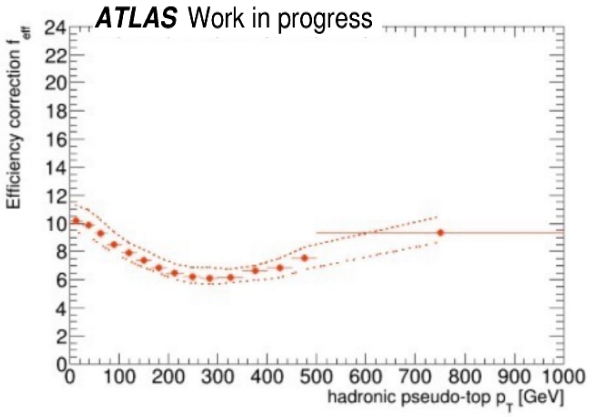
$$\frac{d\sigma^{\text{fid}}}{dX^i} \equiv \frac{1}{\mathcal{L} \cdot \Delta X^i} \cdot f^i_{\text{eff}} \cdot \sum_j \mathcal{M}^{-1}_{ij} \cdot f^j_{\text{match}} \cdot f^j_{\text{acc}} \cdot \left(N^j_{\text{reco}} - N^j_{\text{bg}}\right)$$

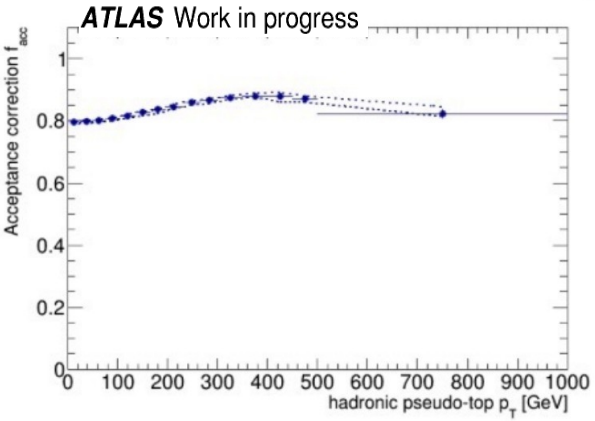
- The electron and muon channels are summed linearly before the Unfolding
- Iterative Bayesian unfolding ($N_{itr} = 4$) is applied to correct for

selection efficiency and detector acceptance and resolution, so that the resulting spectrum can be compared with theoretical predictions

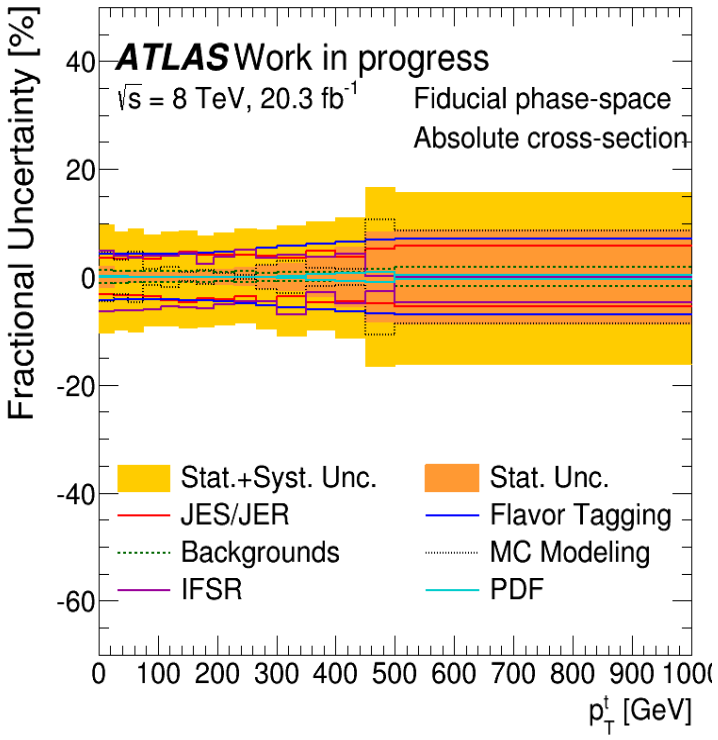


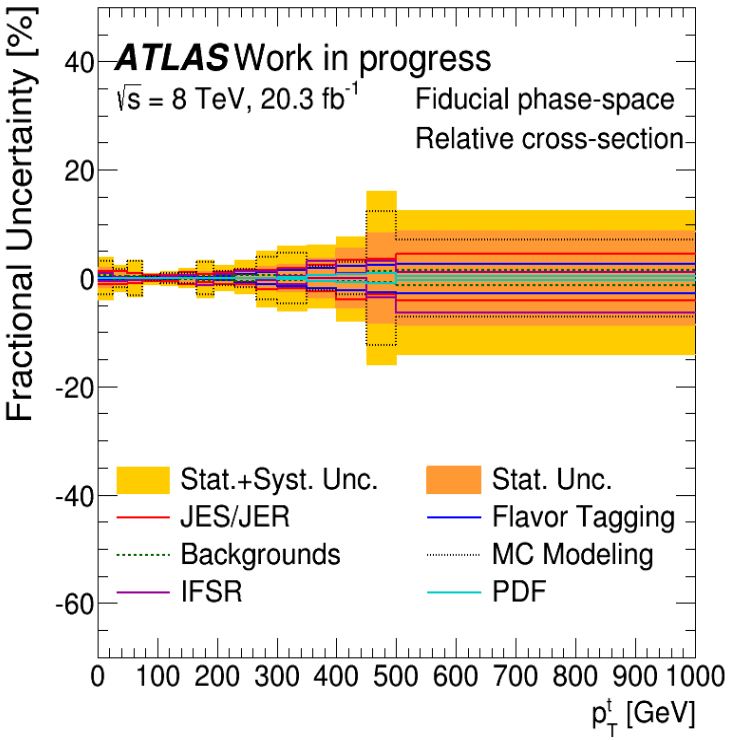


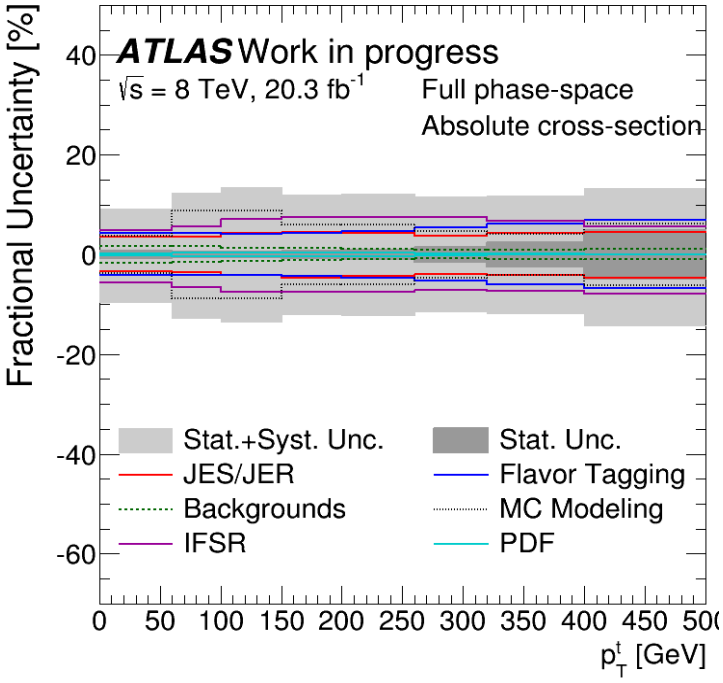


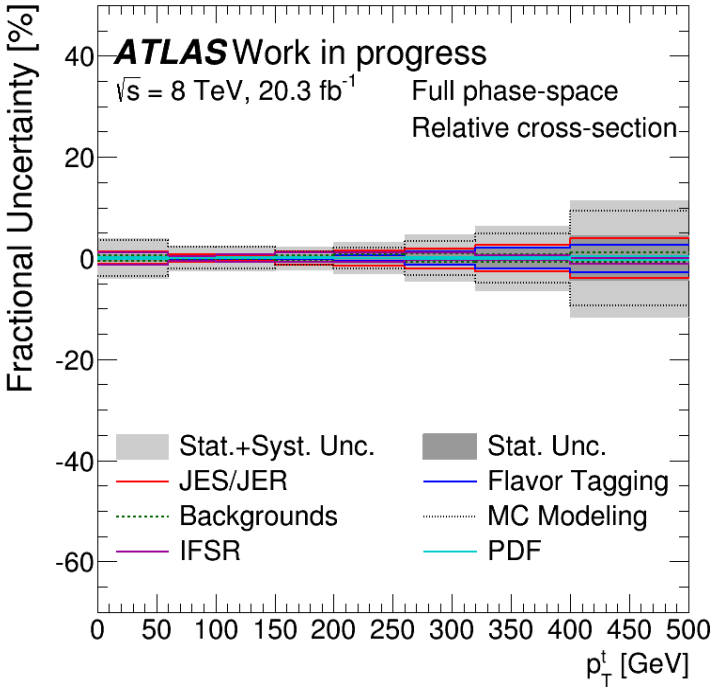


Systematics uncertainties









Detector modeling

- Jet Energy Scale
- Jet Energy Resolution
- Flavor tagging efficiency
- Lepton Identification
- E^{T}_{MISS}
- Pileup
- Luminosity

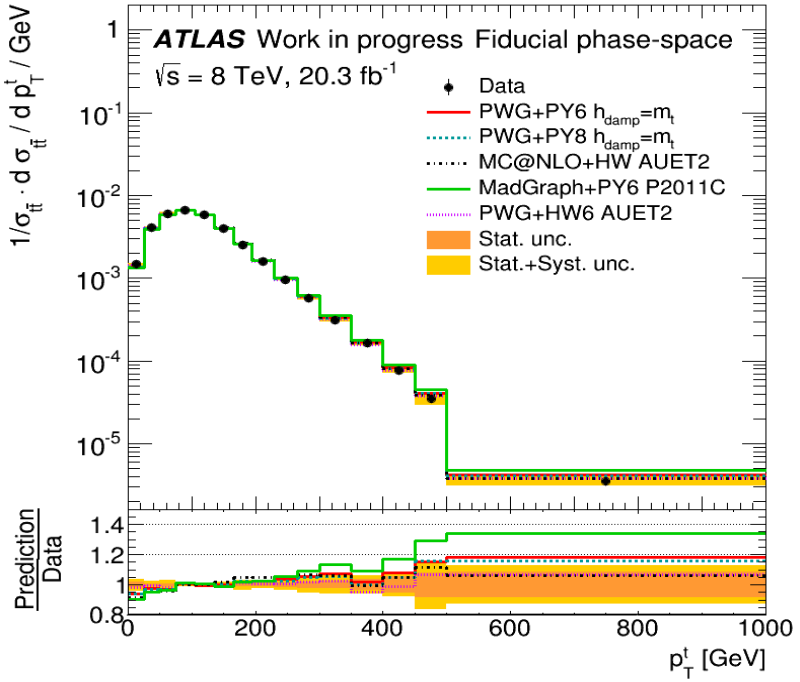
Signal modeling

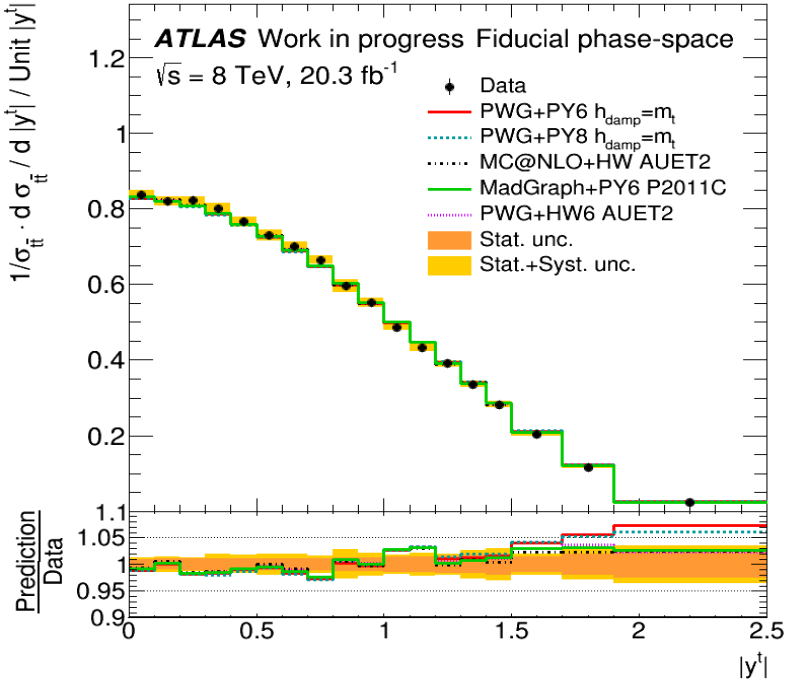
- Matrix element
- I/FSR
- Parton shower
- PDF (CT10nlo)

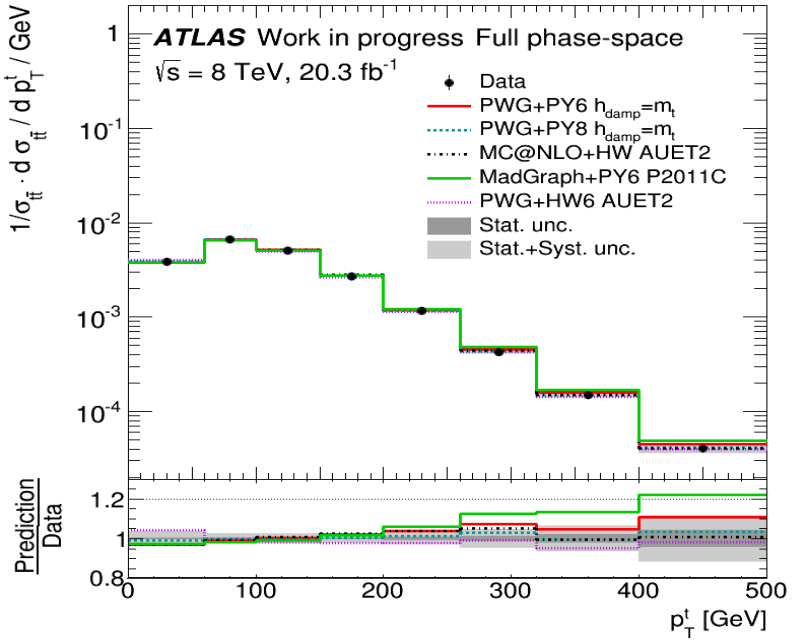
Background modeling

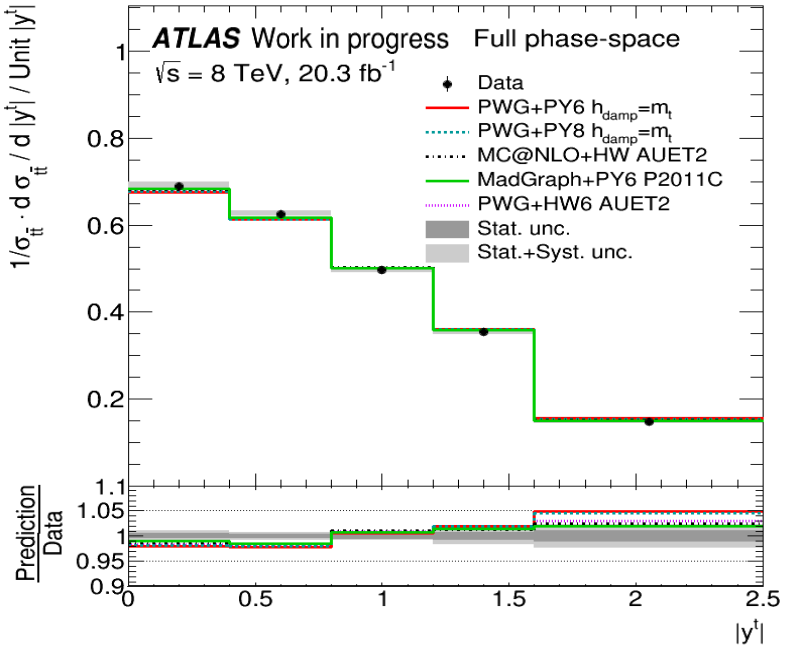
- W+jets SF
- Single top x-sec
- Z+jets x-sec
- VV x-sec

Results



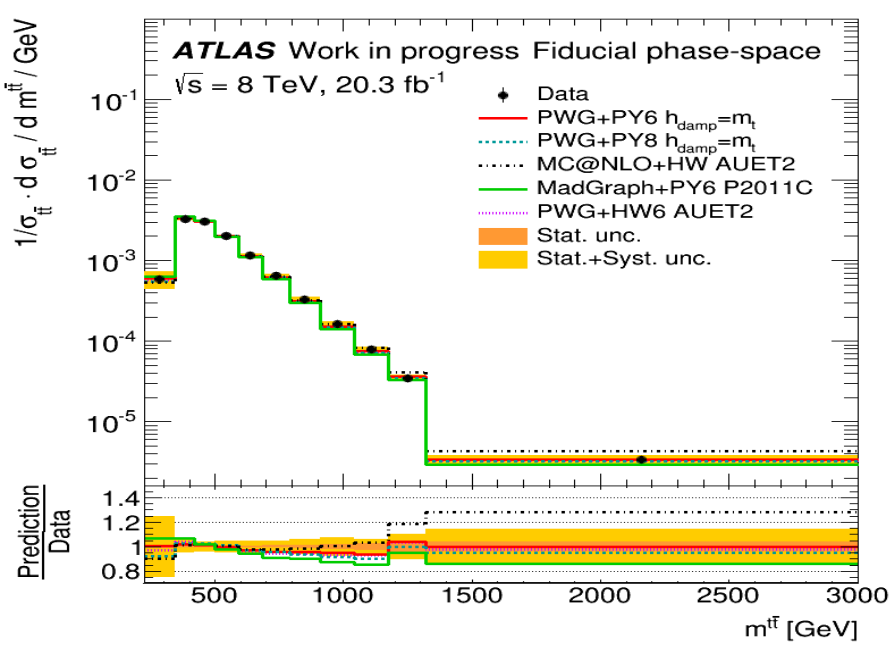


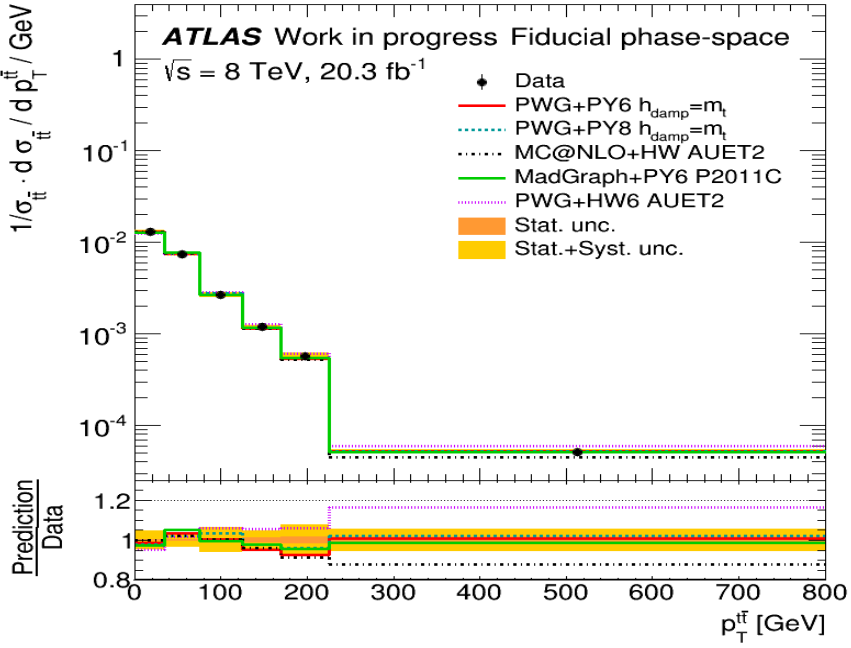


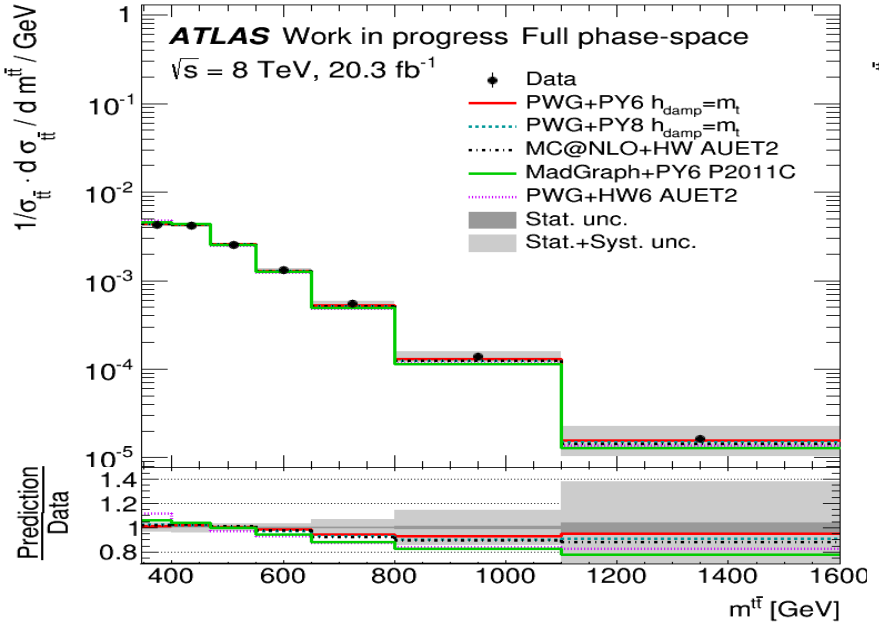


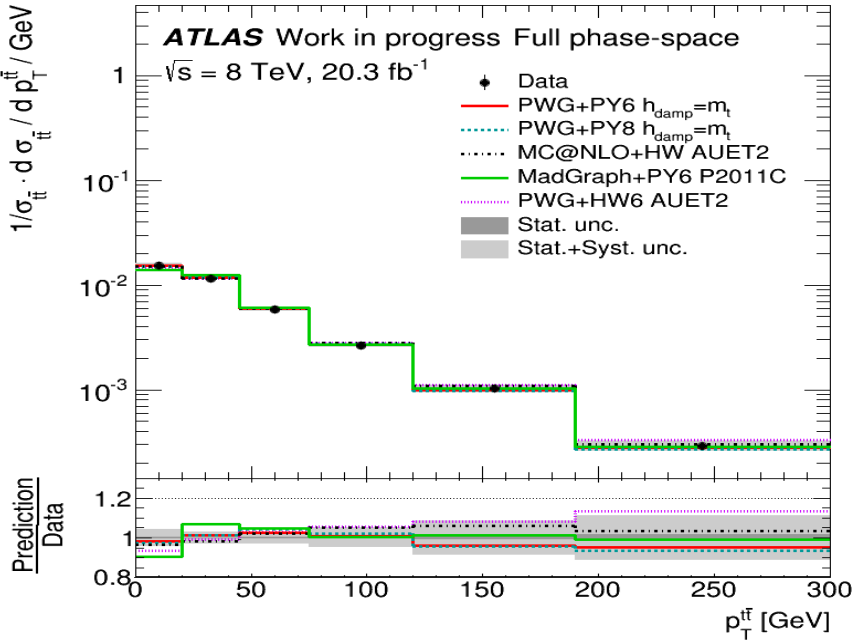
- **POWHEG+PY6**
  CT10nlo $h_{damp} = m_t$
  baseline sample
- **POWHEG+PY8**
  $h_{damp} = m_t$
  newer parton shower
- **MC@NLO+HW6**
  Alternate NLO generator and parton shower
- **MadGraph+PY6**
  LO/Multileg generator,
  CMS default
- **POWHEG+HW6**
  7 TeV default,
  Alternate parton shower

Normalized differential x-sec

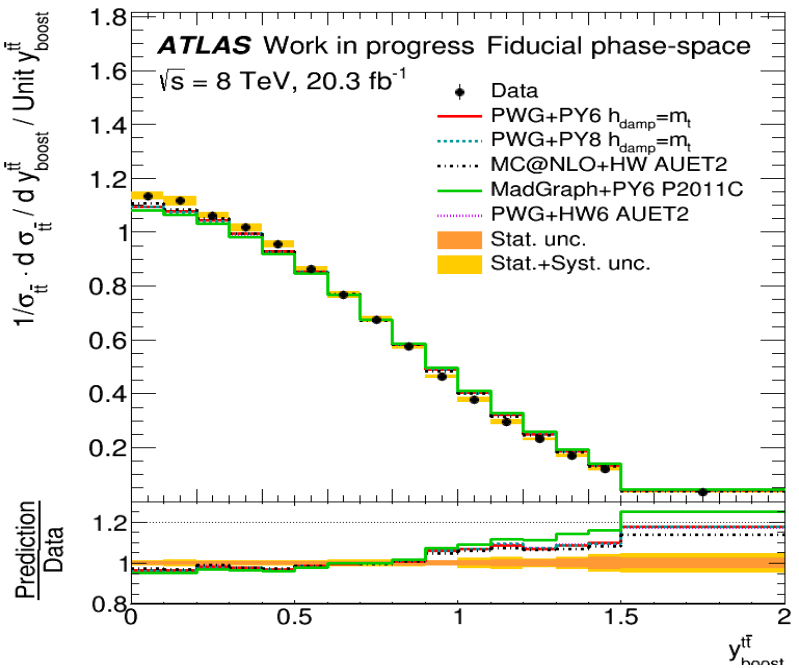


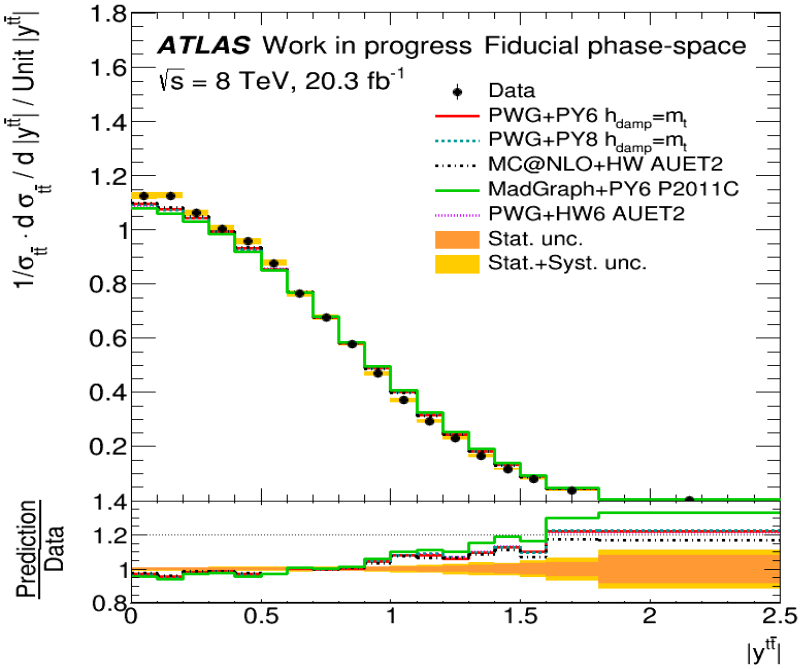


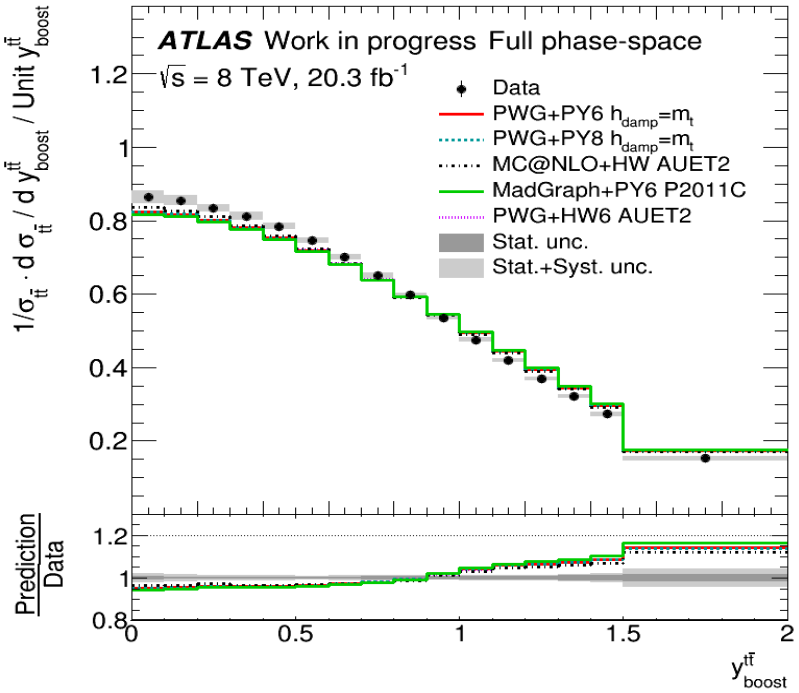


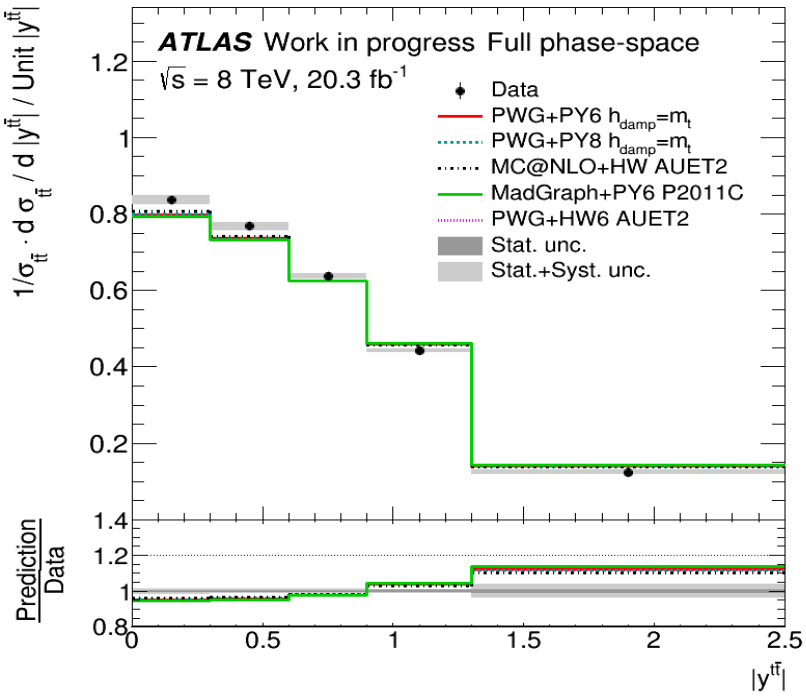


Normalized differential x-sec





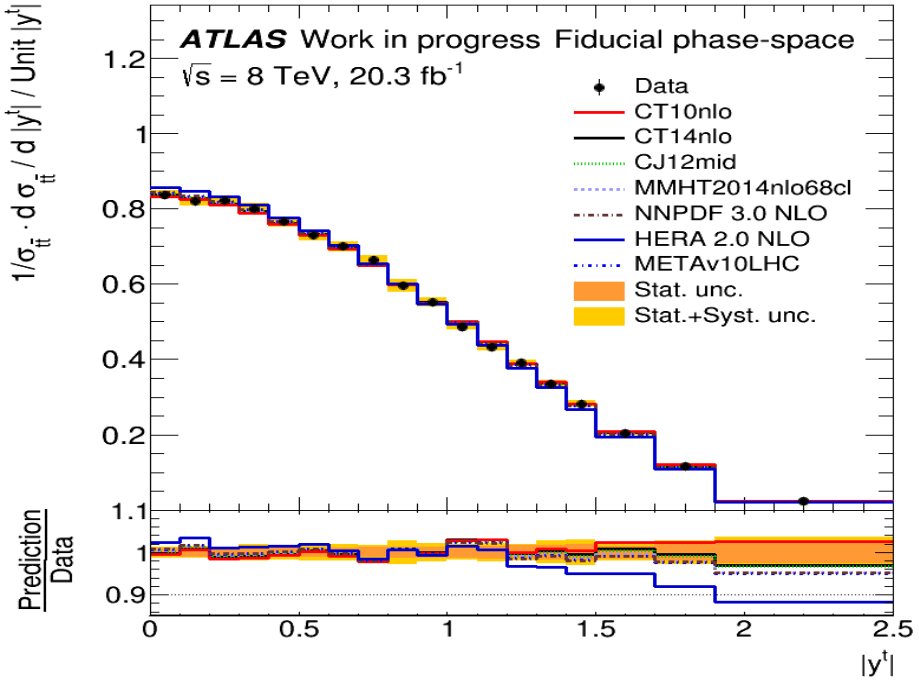


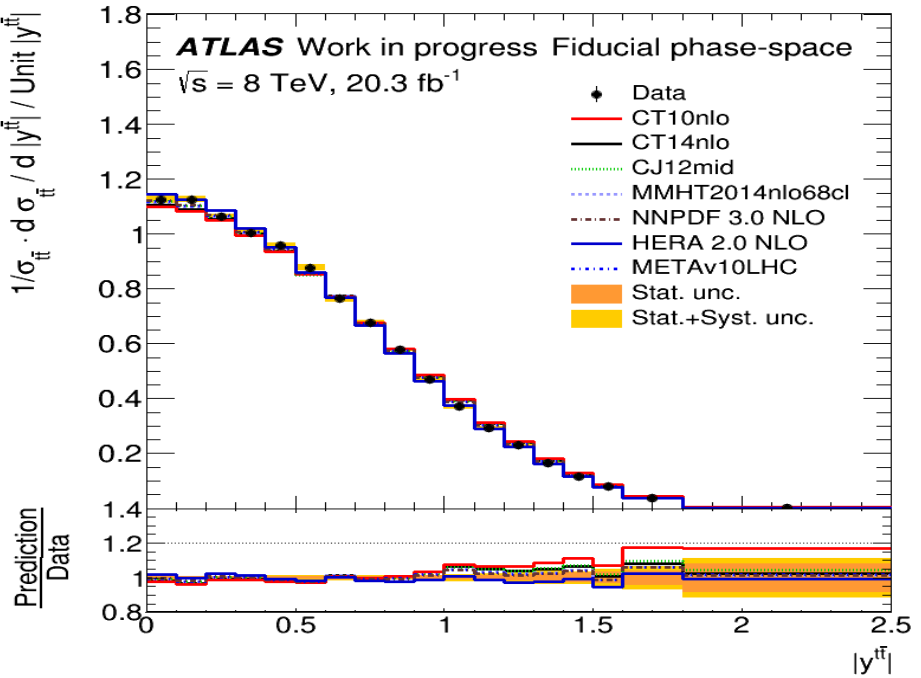


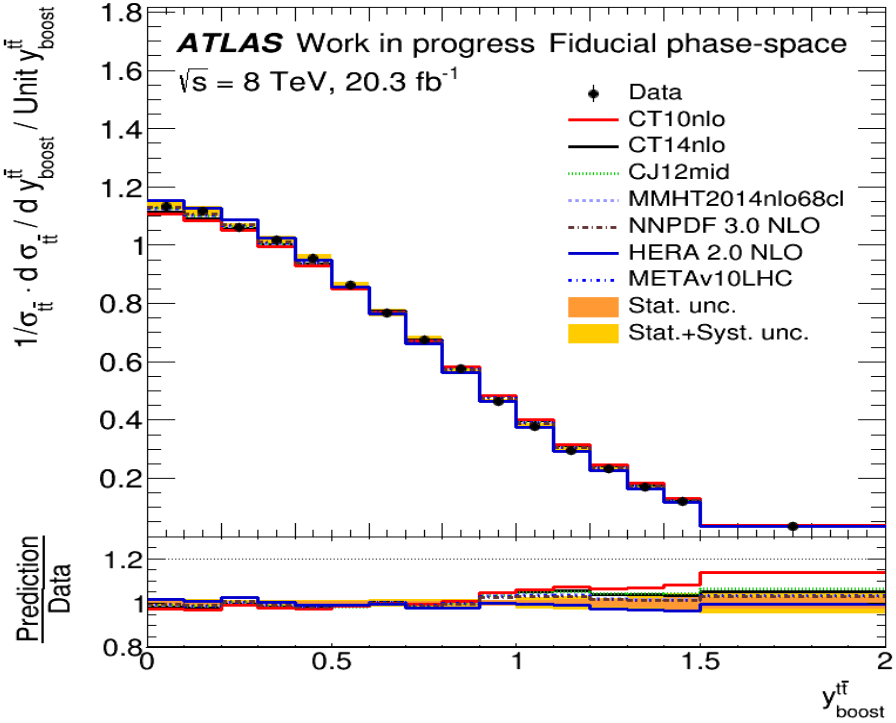
Large deviation at high $|y^{t\bar{t}}|$ range

Data tend to overestimate the prediction at high $Y^{t\bar{t}}_{boost}$ range

Run II PDFs







MC@NLO generator (native CT10nlo PDF's) reweighted with Run II PDF's

Run II PDF sets enhance the agreement in large-rapidity regions

Conclusions

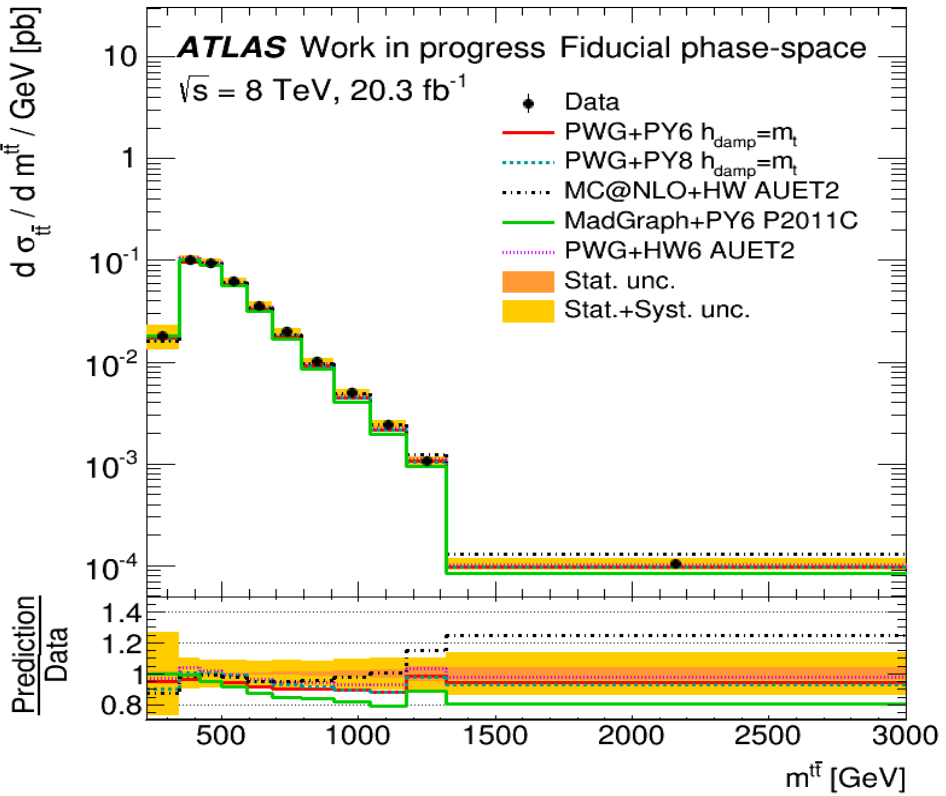
- This is an important measurement that allows a precise test of pQCD predictions, constraining MC generators, higher-orders calculations, and future NNLO differential predictions

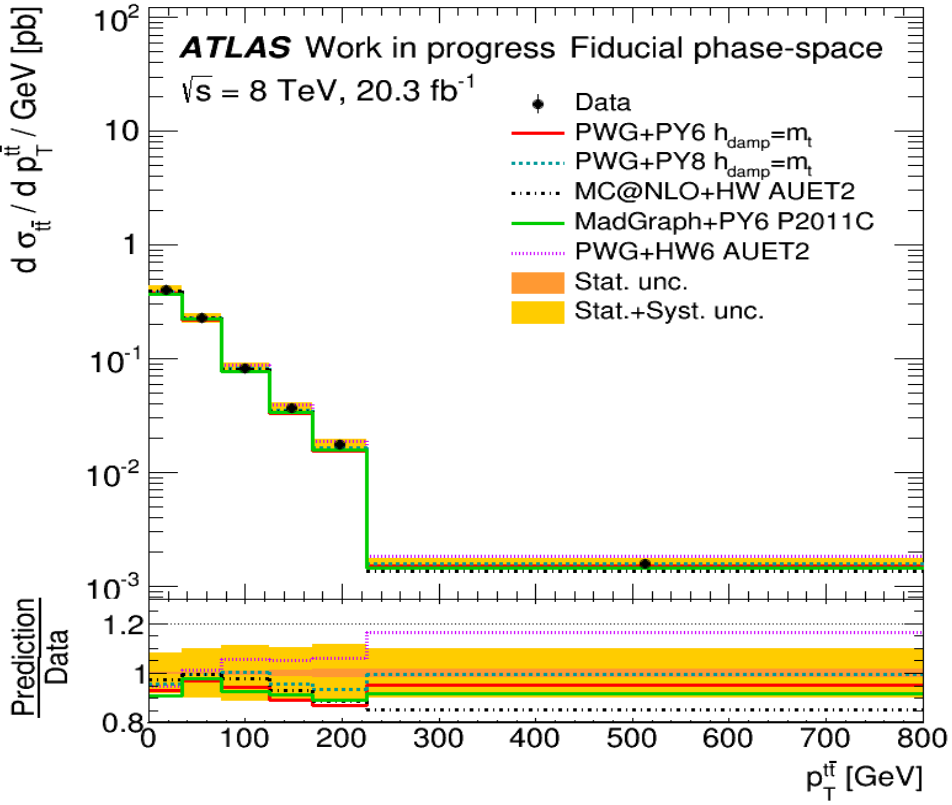
- It can contribute to future PDF fits, allowing better determination of PDFs

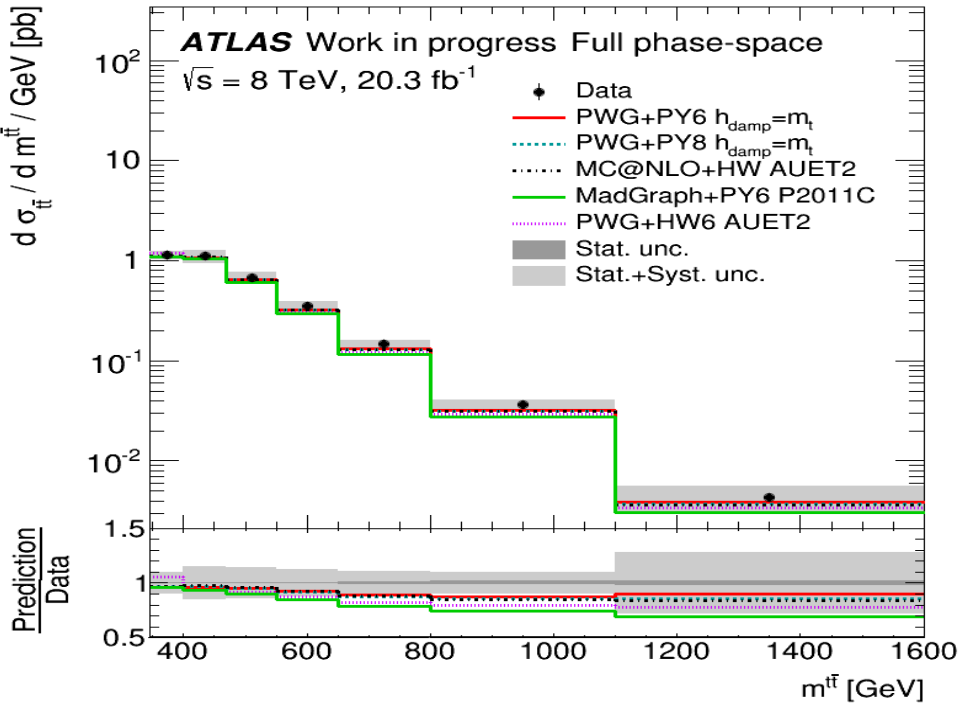
- Differential cross section as function of transverse momentum and rapidity of top quark and top quark pairs are not well described by all MC generators in the high p_T and y regions

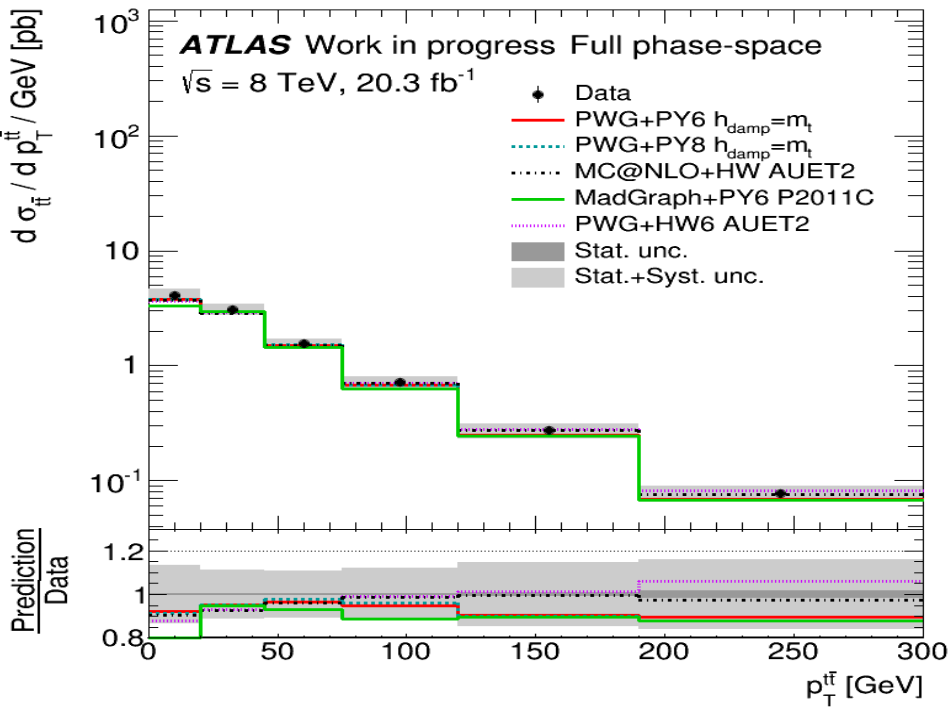
Backup

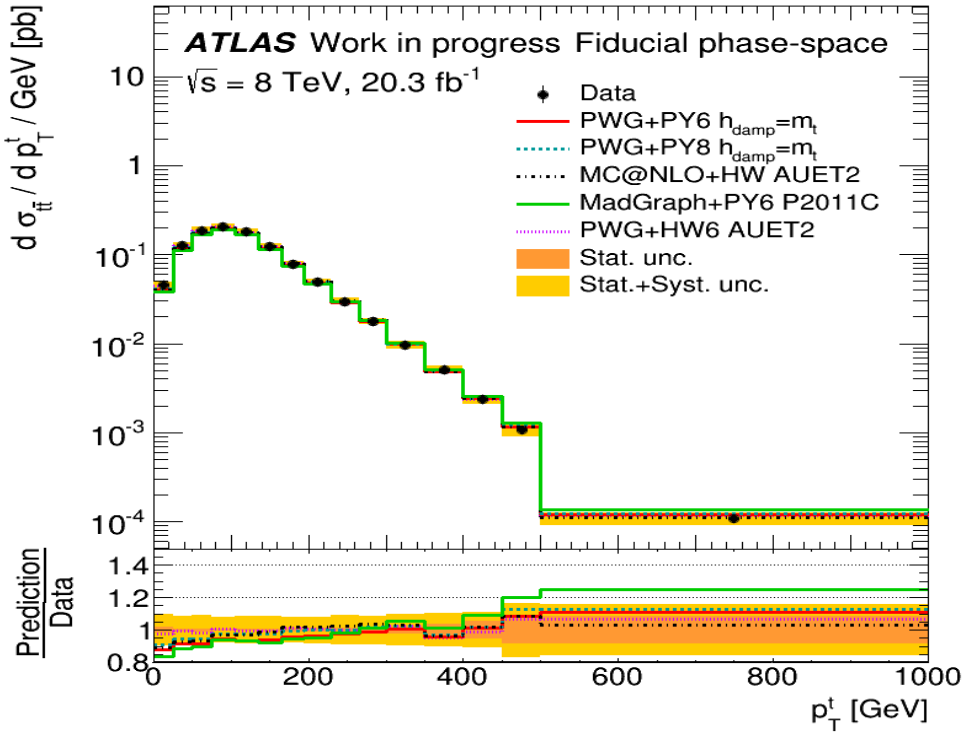
Slides

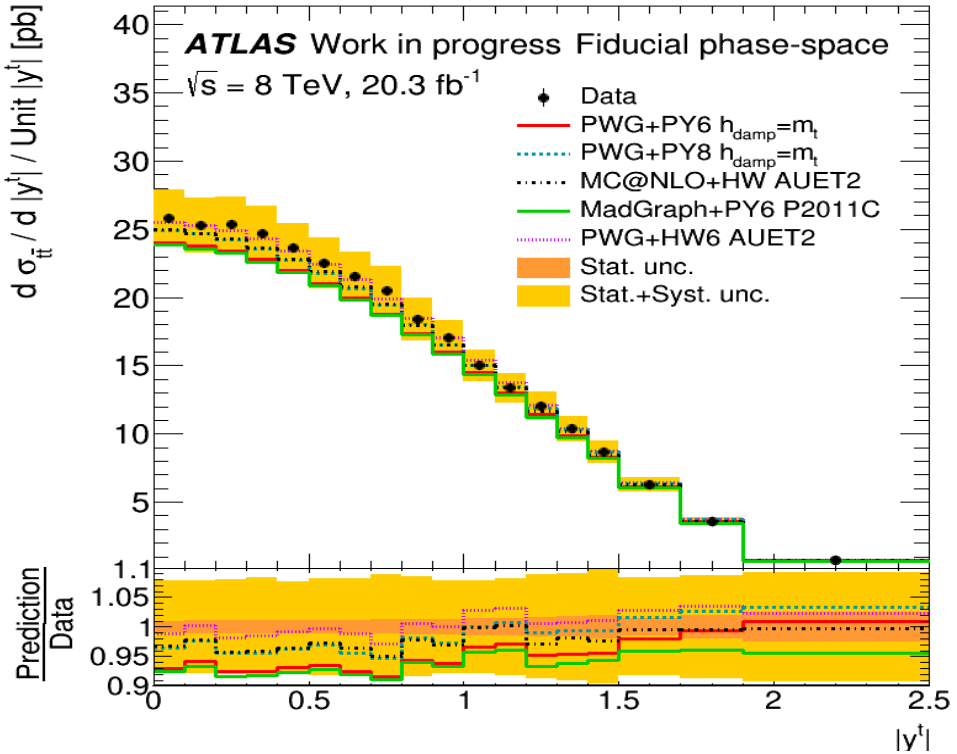

ATLAS Work in progress Fiducial phase-space
√s = 8 TeV, 20.3 fb-1
Data
PWG+PY6 hdamp=mt
PWG+PY8 hdamp=mt
MC@NLO+HW AUET2
MadGraph+PY6 P2011C
PWG+HW6 AUET2
Stat. unc.
Stat.+Syst. unc.
d σtt̄ / d mtt̄ / GeV [pb]
Prediction / Data
mtt̄ [GeV]

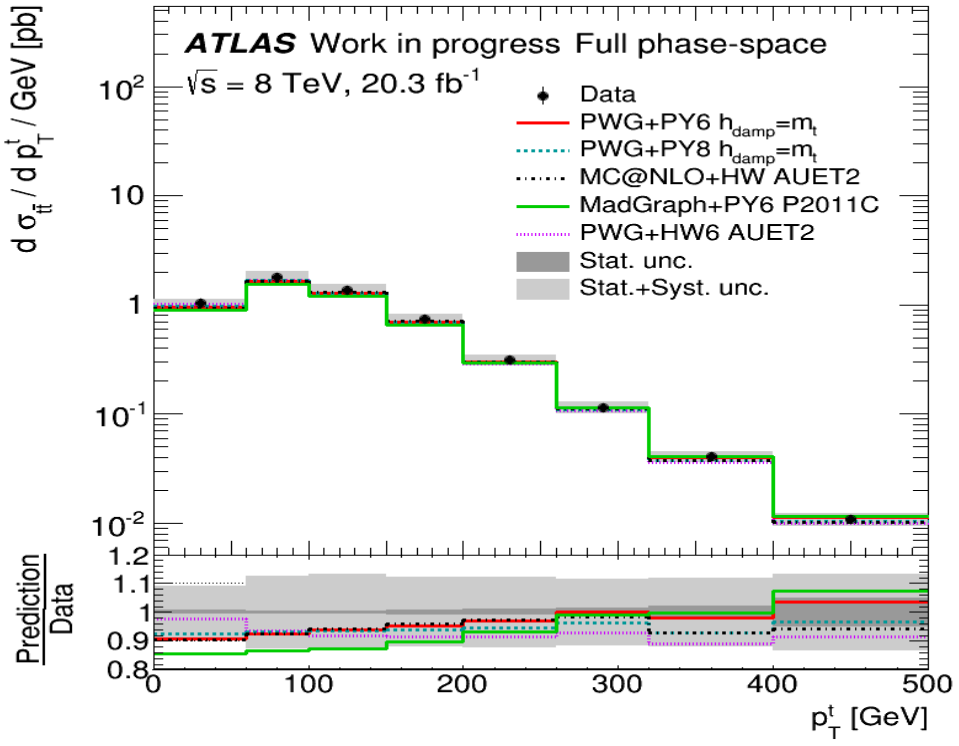

ATLAS Work in progress Fiducial phase-space
√s = 8 TeV, 20.3 fb-1
Data
PWG+PY6 hdamp=mt
PWG+PY8 hdamp=mt
MC@NLO+HW AUET2
MadGraph+PY6 P2011C
PWG+HW6 AUET2
Stat. unc.
Stat.+Syst. unc.
d σtt̄ / d pTtt̄ / GeV [pb]
Prediction / Data
pTtt̄ [GeV]

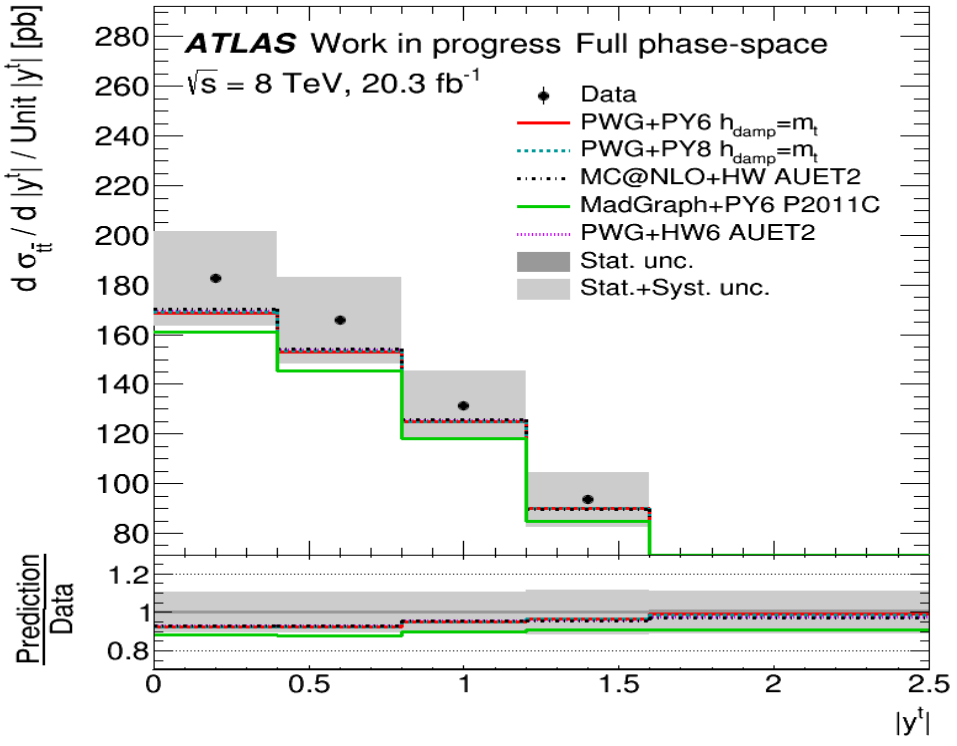

ATLAS Work in progress Full phase-space
√s = 8 TeV, 20.3 fb-1
Data
PWG+PY6 hdamp=mt
PWG+PY8 hdamp=mt
MC@NLO+HW AUET2
MadGraph+PY6 P2011C
PWG+HW6 AUET2
Stat. unc.
Stat.+Syst. unc.
d σtt̄ / d mtt̄ / GeV [pb]
Prediction / Data
mtt̄ [GeV]


ATLAS Work in progress Full phase-space
√s = 8 TeV, 20.3 fb-1
Data
PWG+PY6 hdamp=mt
PWG+PY8 hdamp=mt
MC@NLO+HW AUET2
MadGraph+PY6 P2011C
PWG+HW6 AUET2
Stat. unc.
Stat.+Syst. unc.
d σtt̄ / d pTtt̄ / GeV [pb]
Prediction / Data
pTtt̄ [GeV]


ATLAS Work in progress Fiducial phase-space
√s = 8 TeV, 20.3 fb-1
Data
PWG+PY6 hdamp=mt
PWG+PY8 hdamp=mt
MC@NLO+HW AUET2
MadGraph+PY6 P2011C
PWG+HW6 AUET2
Stat. unc.
Stat.+Syst. unc.
d σtt / d pTt / GeV [pb]
Prediction / Data
pTt [GeV]


ATLAS Work in progress Fiducial phase-space
√s = 8 TeV, 20.3 fb-1
Data
PWG+PY6 hdamp=mt
PWG+PY8 hdamp=mt
MC@NLO+HW AUET2
MadGraph+PY6 P2011C
PWG+HW6 AUET2
Stat. unc.
Stat.+Syst. unc.
d σtt / d |yt| / Unit |yt| [pb]
Prediction / Data
|yt|


ATLAS Work in progress Full phase-space
√s = 8 TeV, 20.3 fb-1
Data
PWG+PY6 hdamp=mt
PWG+PY8 hdamp=mt
MC@NLO+HW AUET2
MadGraph+PY6 P2011C
PWG+HW6 AUET2
Stat. unc.
Stat.+Syst. unc.
d σtt / d pTt / GeV [pb]
Prediction / Data
pTt [GeV]


ATLAS Work in progress Full phase-space
√s = 8 TeV, 20.3 fb-1
Data
PWG+PY6 hdamp=mt
PWG+PY8 hdamp=mt
MC@NLO+HW AUET2
MadGraph+PY6 P2011C
PWG+HW6 AUET2
Stat. unc.
Stat.+Syst. unc.
d σtt / d |yt| / Unit |yt| [pb]
Prediction / Data
|yt|

τ leptons

- Particle level

Since only “final states” are taken in account, we actually don’t look at the decay chains of the parton tops. We just care about leptons, jets and E_T^{miss} in the fiducial phase space

- Parton level

We check the first step decay chain of the W. A top that decays in $t \rightarrow b\ W$, if $W \rightarrow \tau\ \nu$ is considered “leptonic” regardless the actual decay of the tau. So we have to correct for the dilepton contribution.

Absolute or normalized spectra ?

- Absolute
  - Contain full information
  - Normalized can be calculated from these, even if systematics have to be handled carefully
  - Have a residual offset due to different acceptance of each MC generator that can lead to misleadingly high χ^2 values
- Normalized
  - Smaller systematics
  - Present the truly important piece of information: shape
  - Can still be handled for PDF fits (preference for abs, tough)
  - The way of CMS and previous ATLAS publications (boosted top pT is absolute only)
- After discussion with conveners and EB, we support publishing **normalized distributions** and keep absolute ones as auxiliary material if necessary.

Parton level Unfolding (Full Phase space)

$$\frac{\mathrm{d}\sigma^{\mathrm{full}}}{\mathrm{d}X^i} \equiv \frac{1}{\mathcal{L}\cdot\mathcal{B}\cdot\Delta X^i}\cdot \hat{f}^i_{\mathrm{eff}}\cdot\sum_j \hat{\mathcal{M}}^{-1}_{ij}\cdot \hat{f}^j_{\mathrm{acc}}\cdot \hat{f}^i_{\mathrm{ljets}}\cdot\left(N^j_{\mathrm{reco}}-N^j_{\mathrm{bg}}\right)$$

Correction factor to remove dilepton contribution