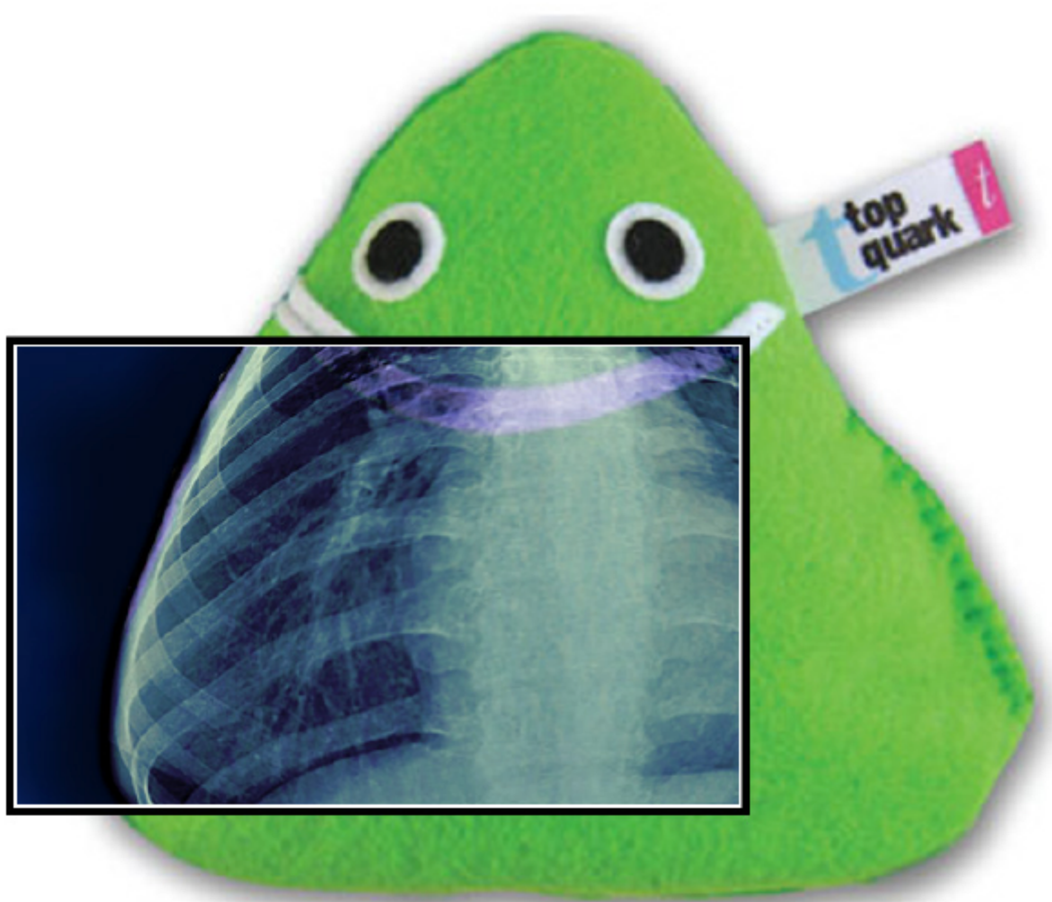
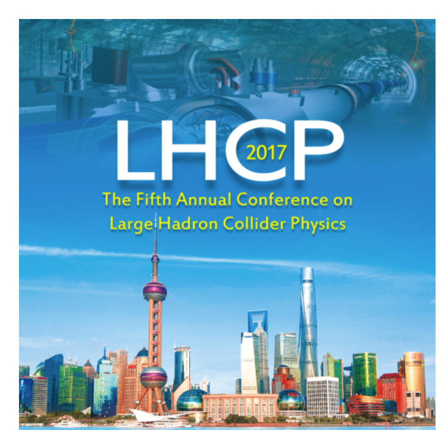
Top pair cross-sections in ATLAS



Dimitris Varouchas

on behalf of the ATLAS collaboration

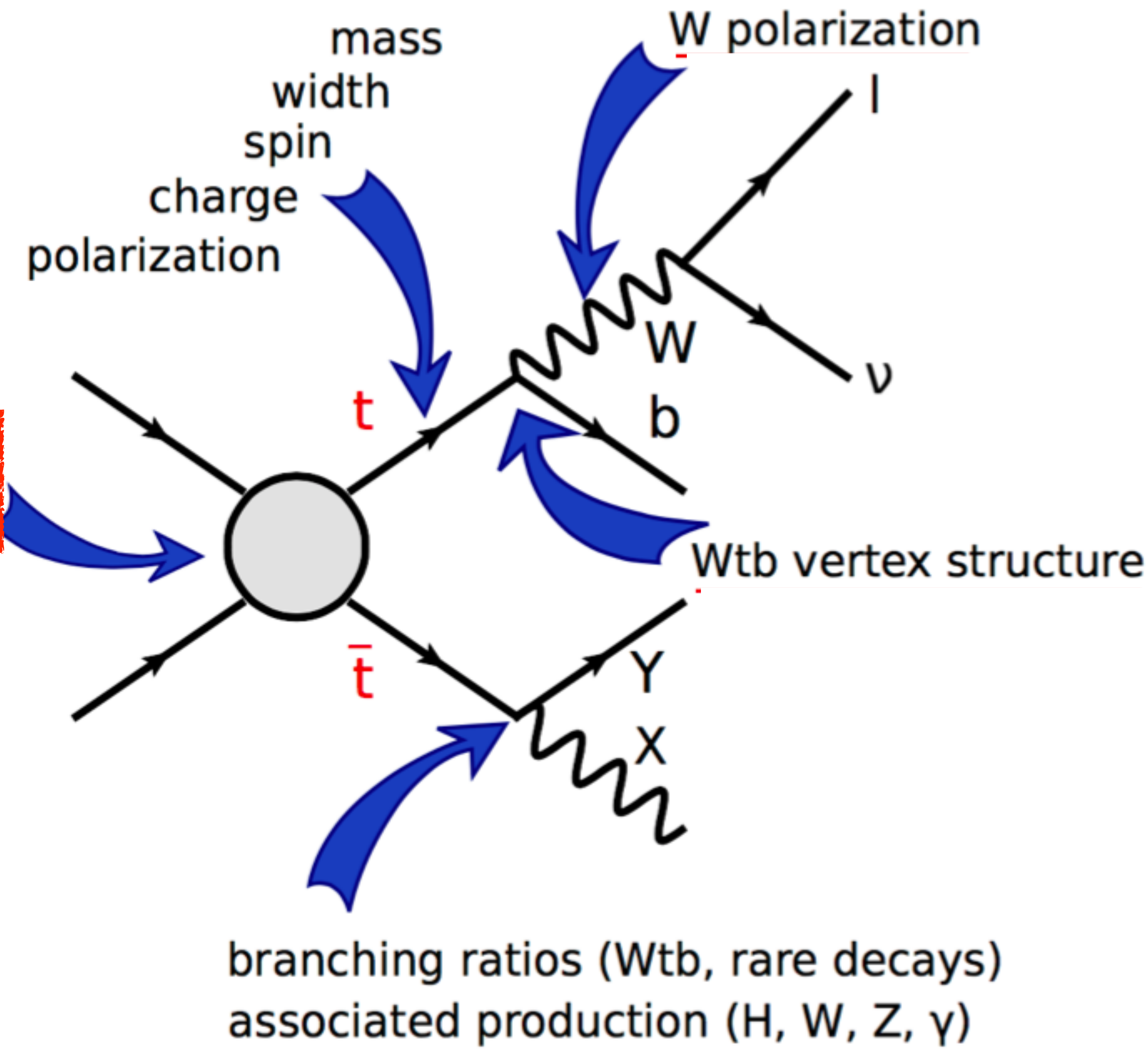


Shanghai, 18th May 2017

Top pair signatures

- **Rich topology** allowing a **plethora of studies**

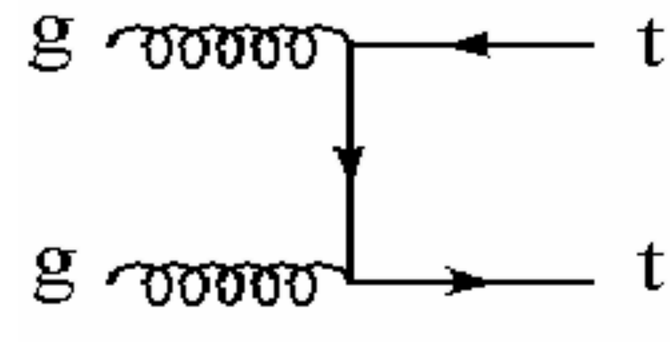
production cross-section
production mechanism

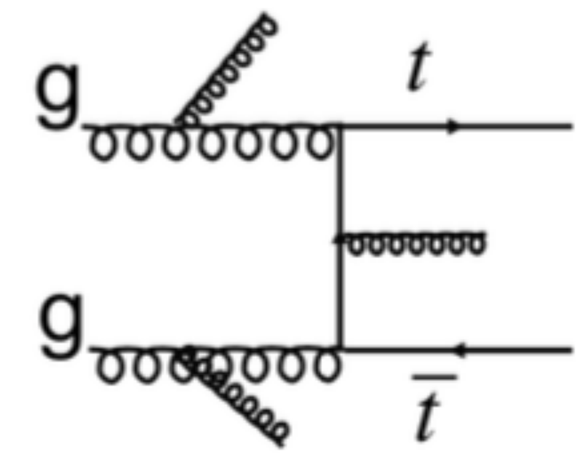


Focus of this talk: tt-bar inclusive and differential cross-section measurements in ATLAS at **13 TeV**

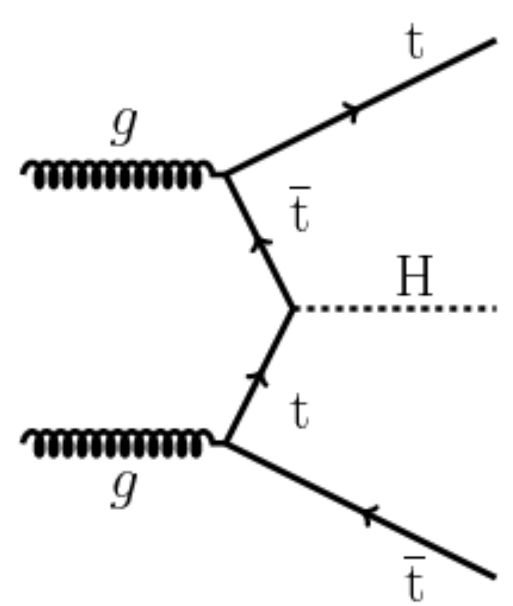
Why the top quark cross-section?

- **Strong tests** of **pQCD** and **SM**
  - ✦ Sensitivity to **gluon PDF** at high p_T, **α_s**, **top quark mass**
- Measurement of **QCD radiation** (**additional jets**) produced with ttbar is crucial for **tuning MC generator** parameters
  - ✦ Improve **modelling** of **parton shower** and **hadronization**
  - ✦ Improve overall **top kinematics description**
- **tt(+X)** is an important background of **rare SM processes** like **ttH**

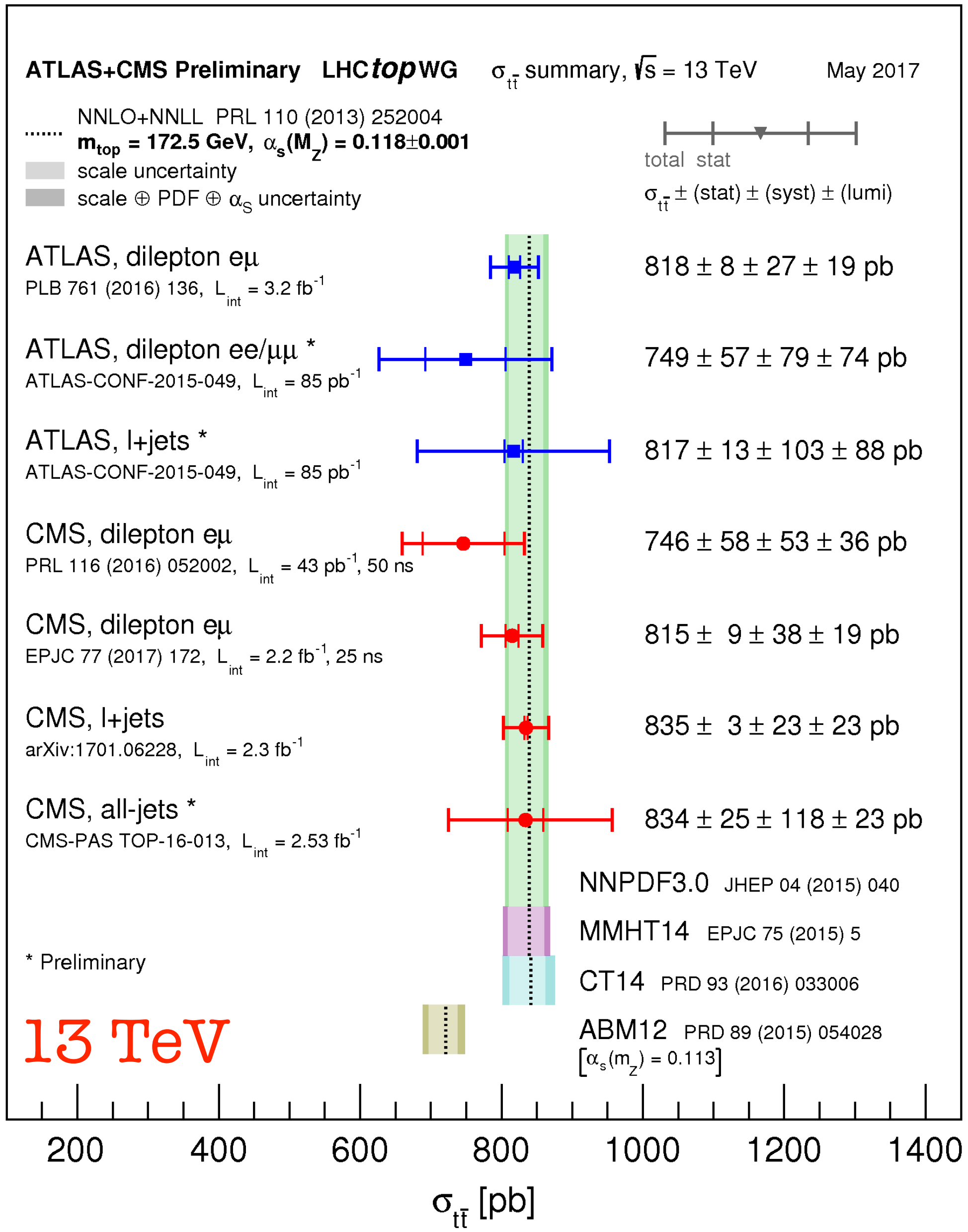


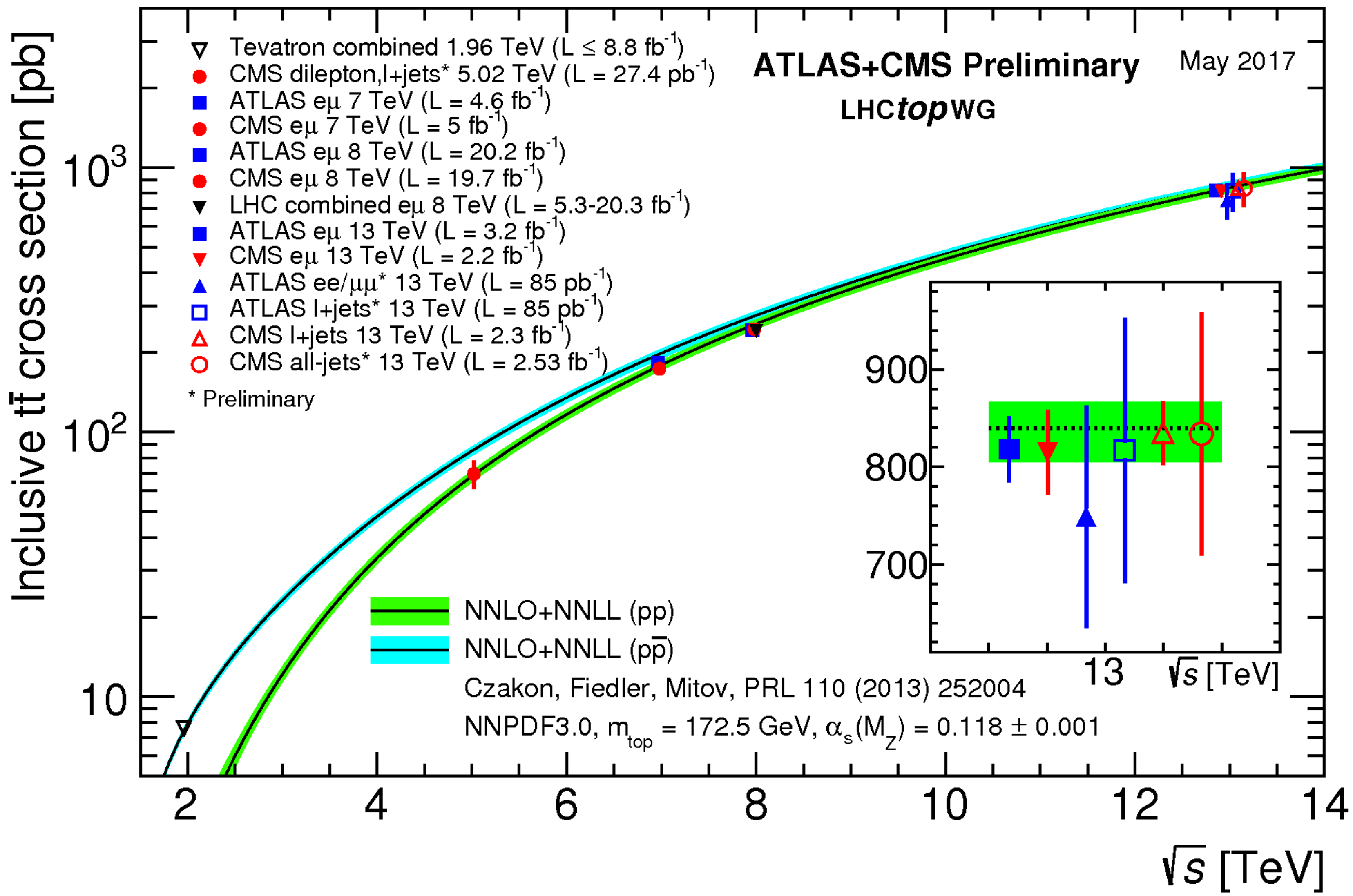


- If **new physics** exists, likely to **couple** with the **mass**
  - ✦ Top quark sensitive to new physics searches
  - ✦ **tt(+X)** is important component of **new physics signature** (SUSY, exotics)
    - ➡ **Differential** distributions more **sensitive** in probing such signals compared to inclusive



Inclusive ttbar cross-sections





- Measurements are in **agreement** with **theory**
- Inclusive measurements uncertainties are dominated by **theory uncertainties**
  - ✦ What can we (as experimentalists) do, to help improving theory uncertainties?
  - ➡ **Do differential measurements**

Cross-section ratio: $\sigma^{tot}(tt)/\sigma^{fid}(Z)$

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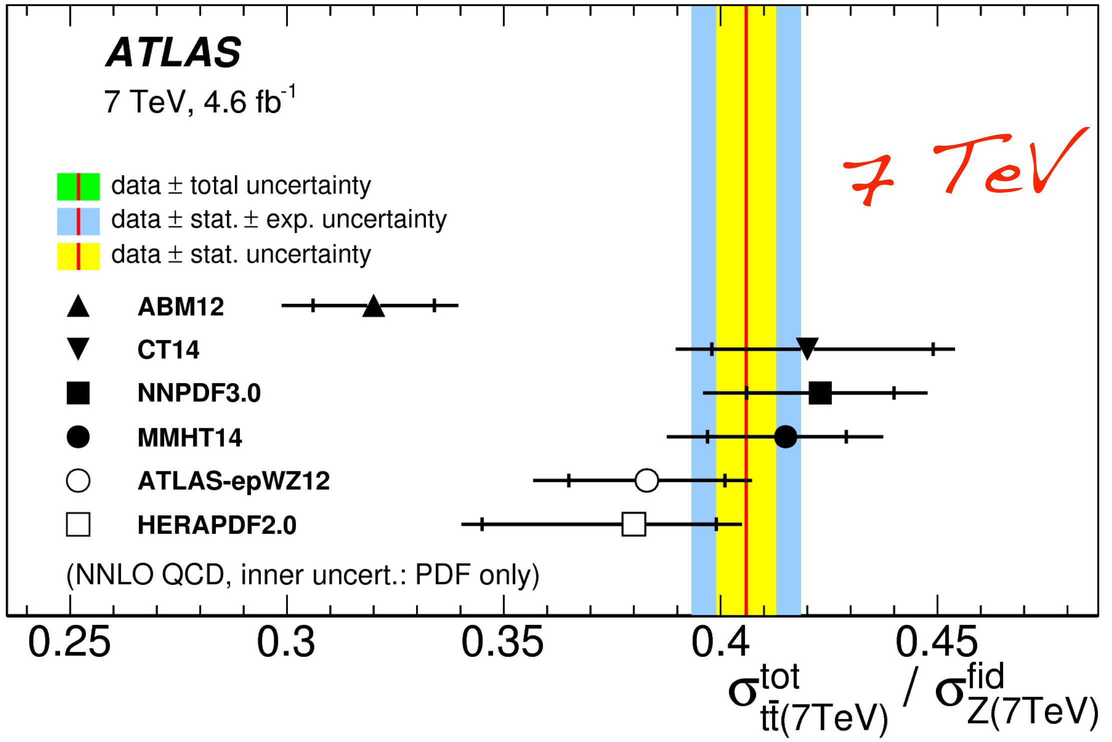
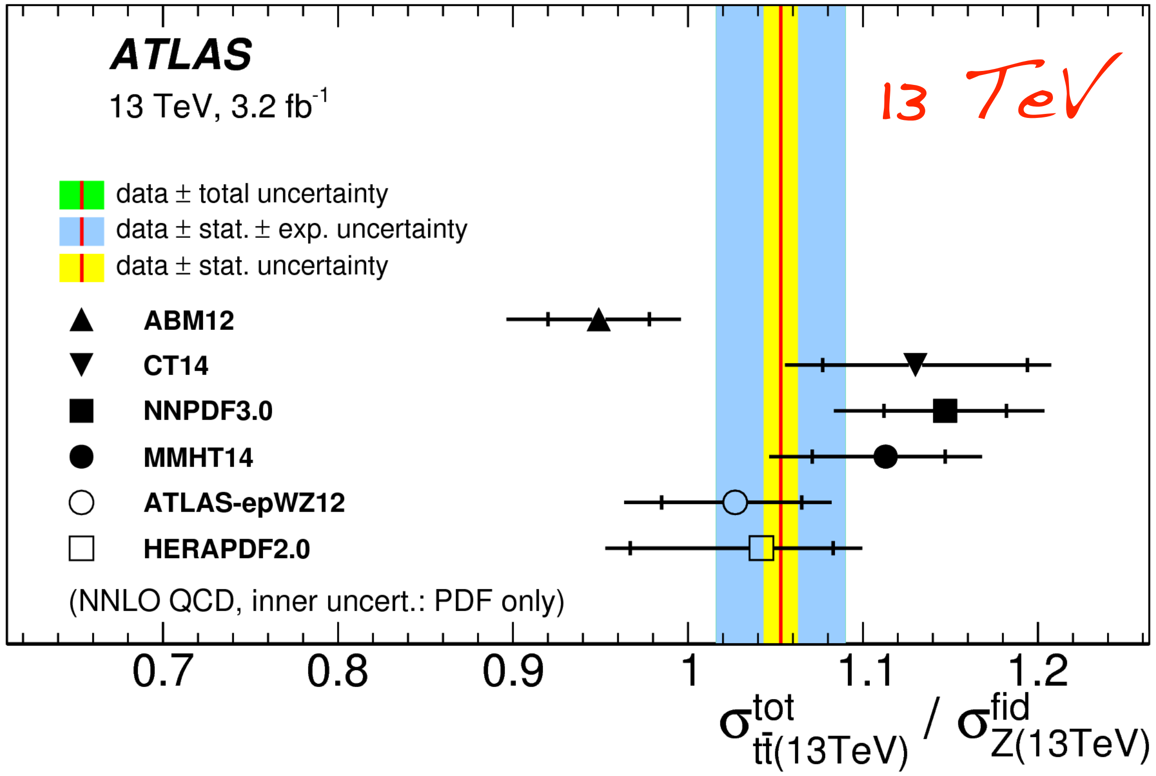
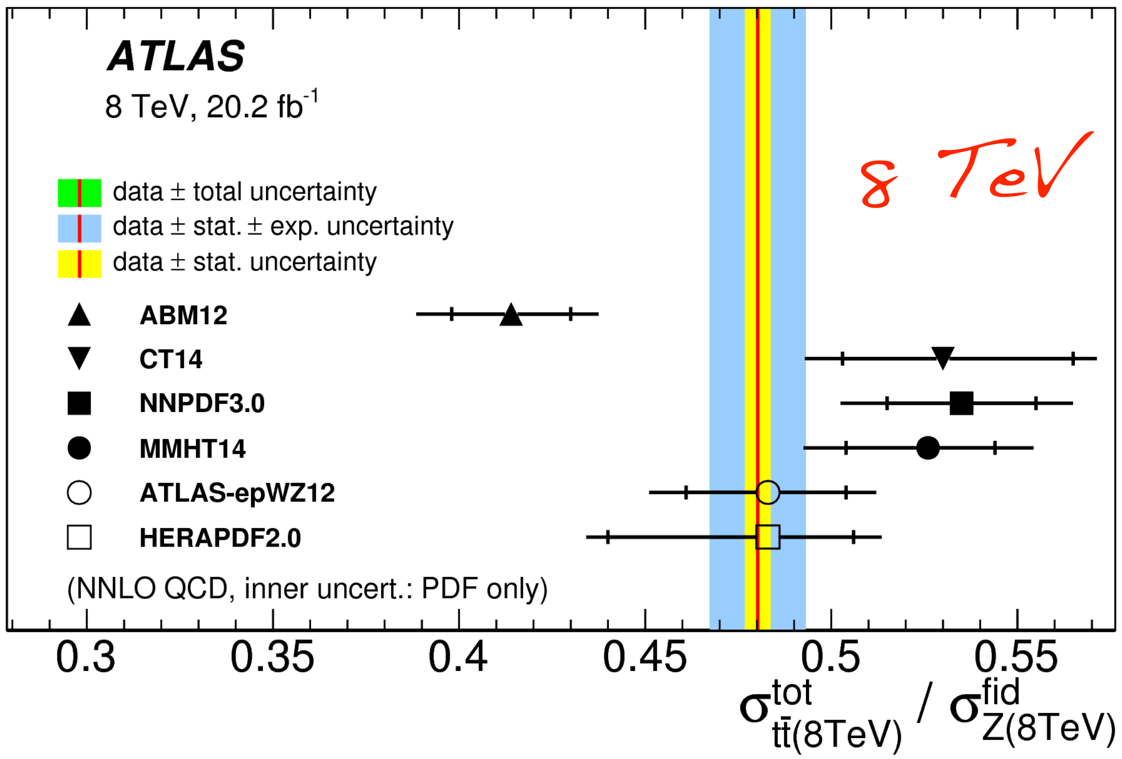
- Use previously published ATLAS **measurements** of ***ttbar*** and ***Z→ll***
- **Correlations** for systematic **uncertainties** taken into **account**
- Important **systematics cancel out**
- Compared to predictions at **NNLO** precision made with six **different PDF sets**

➡ ABM12 not compatible

- ✦ Uses lower value of α_s



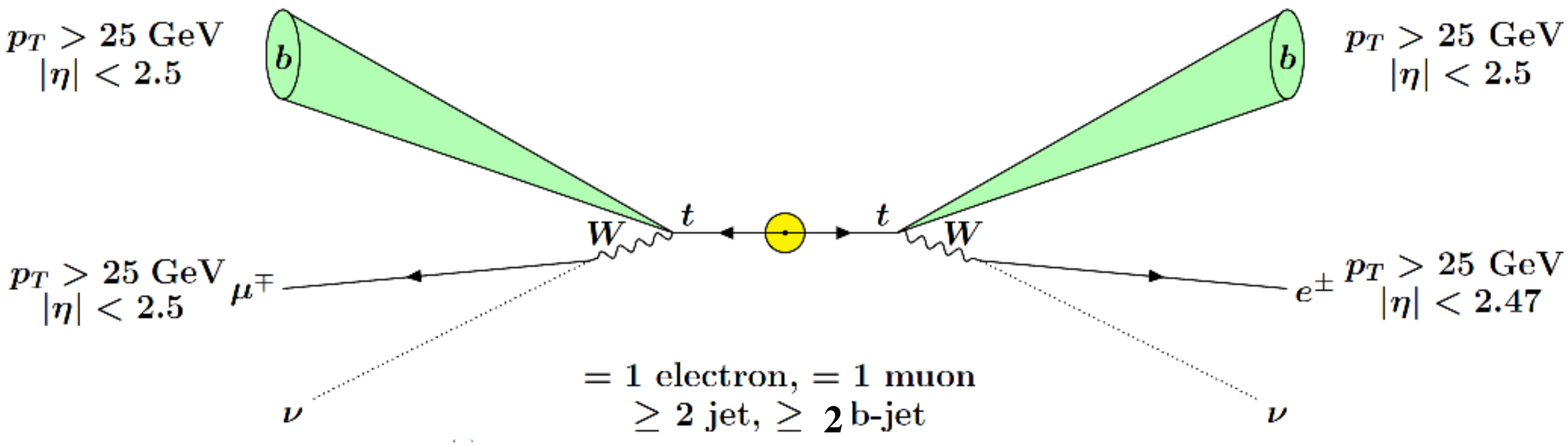




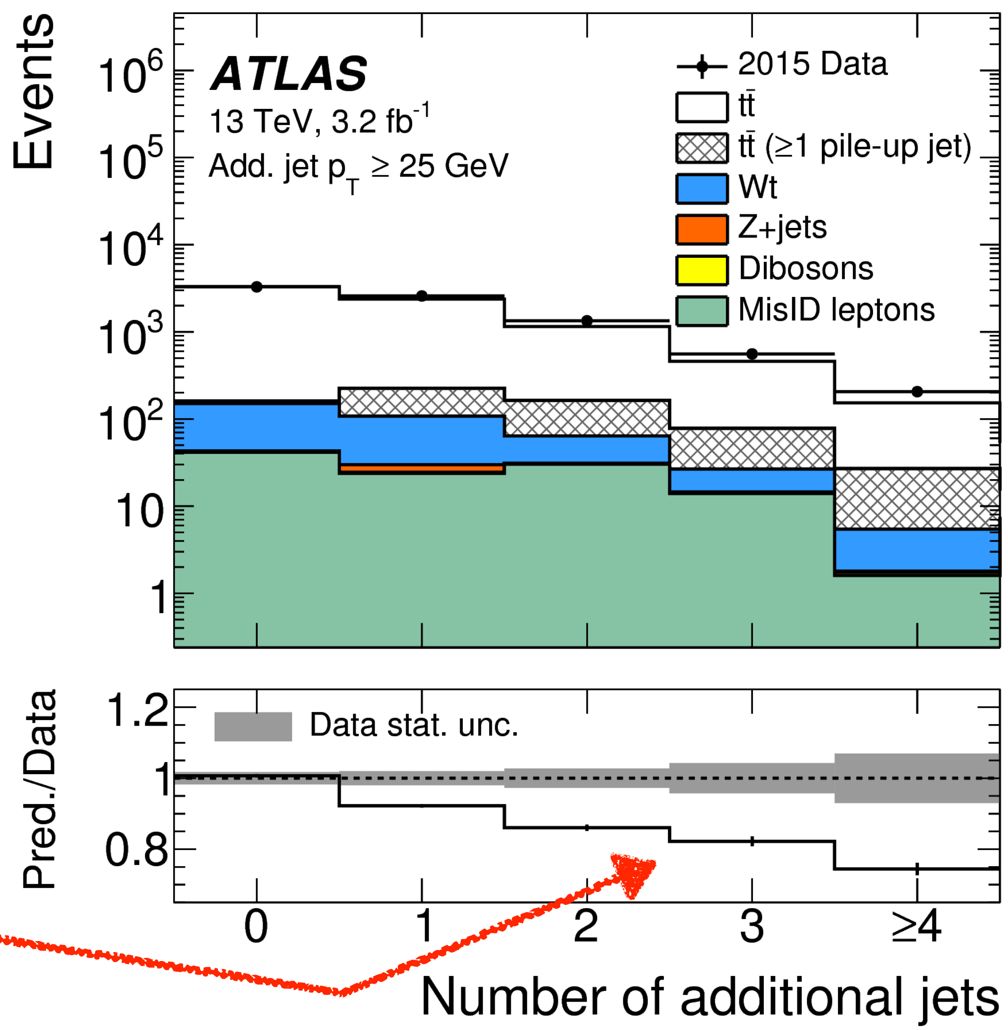
- Many more ratios are studied

Jet multiplicity in eμ channel

[1: E.P.J. C77 (2017) 220](#)
[2: E.P.J. C77 (2017) 299](#)



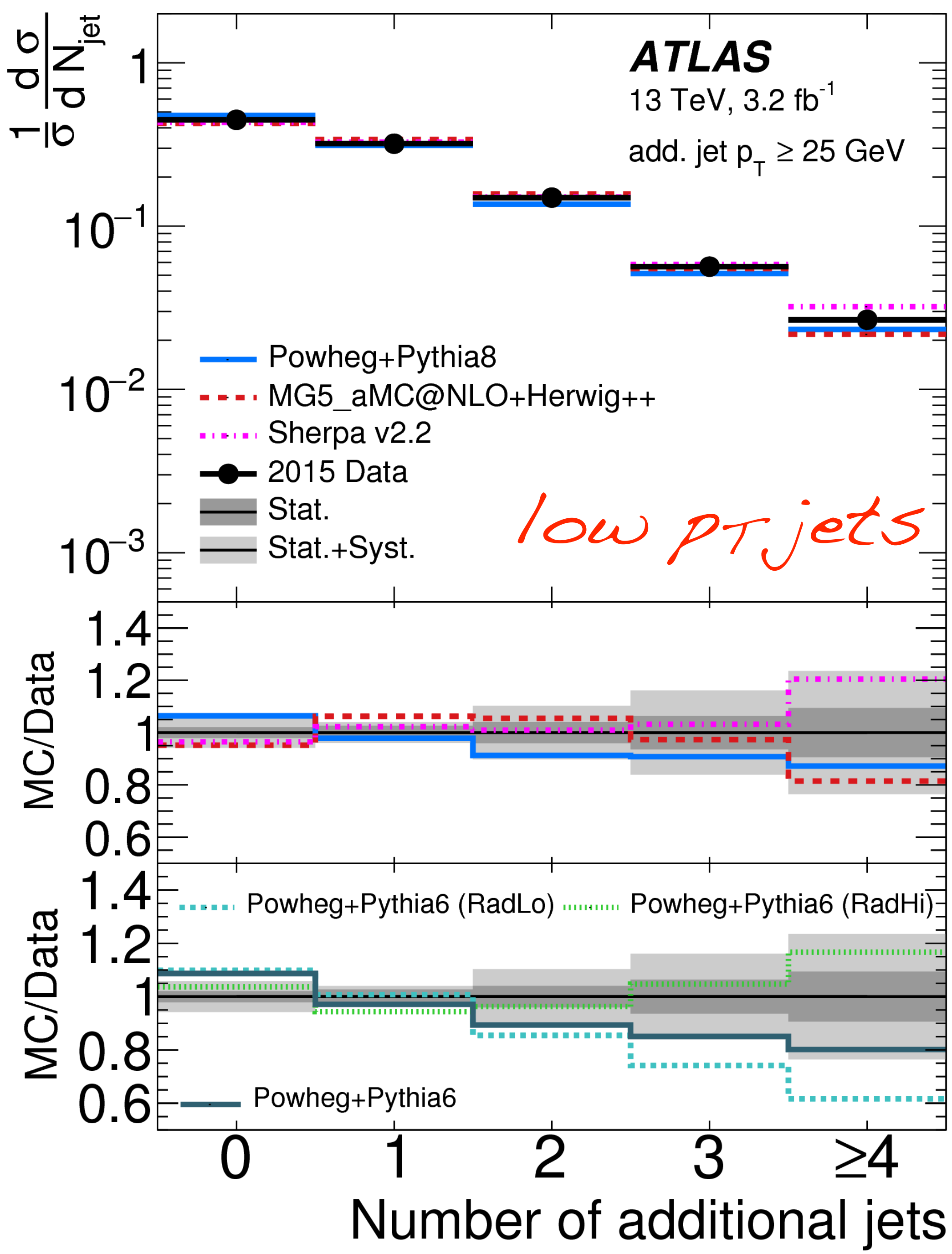
- **Clean signature**, background < 5%
- Small background ratio

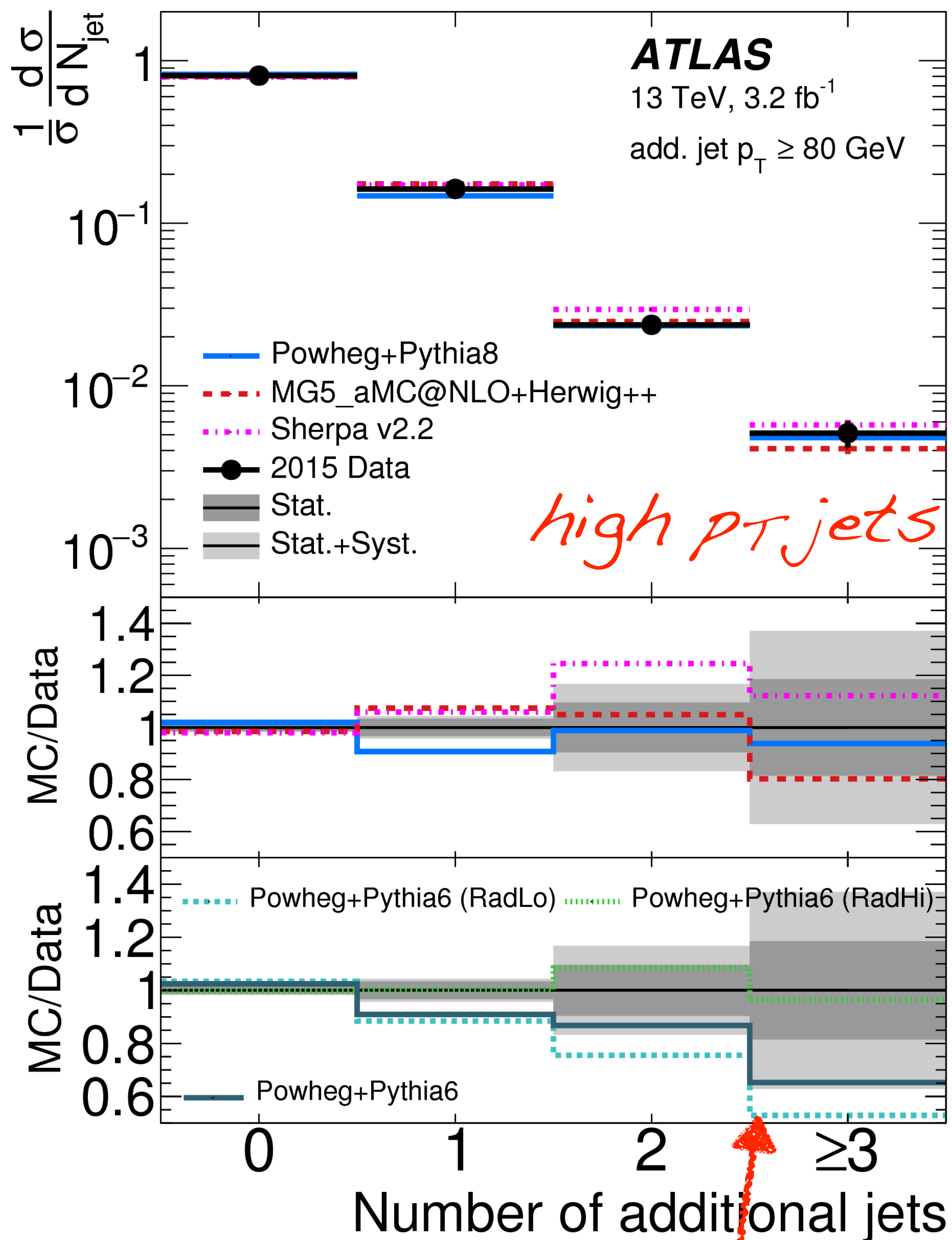


- Some discrepancy is observed at higher jet multiplicity bins

Jet multiplicity: results

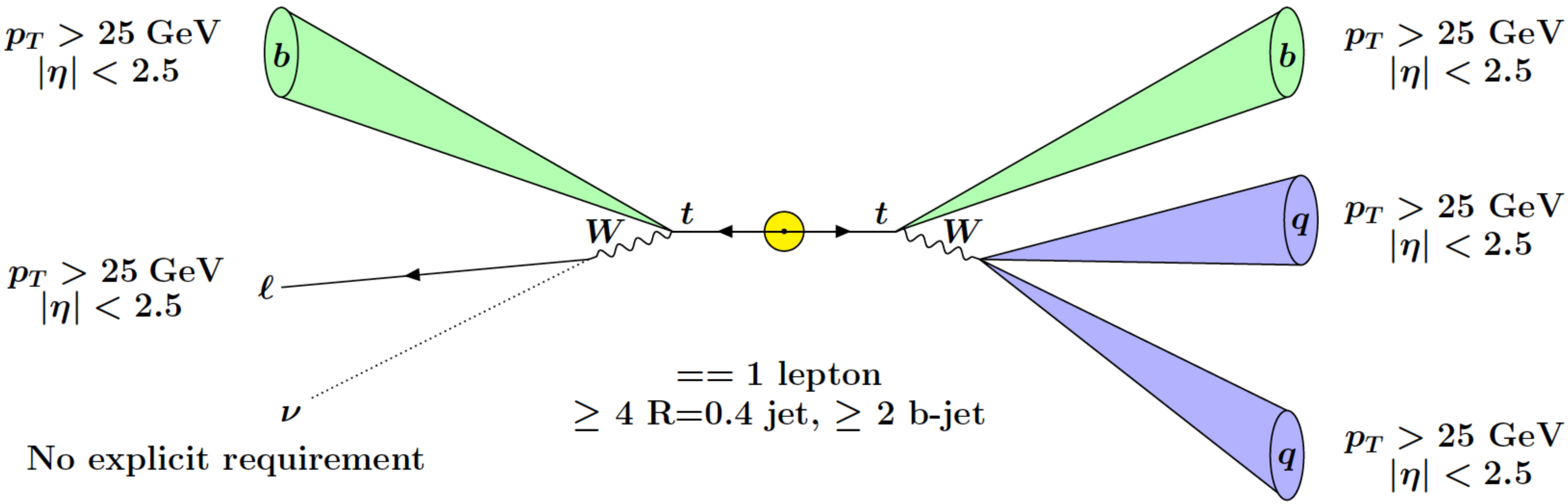
E.P.J. C77 (2017) 220





- Reasonable **compatibility** between **data** and **predictions**
- Some **sensitivity** on **QCD radiation** scale variations

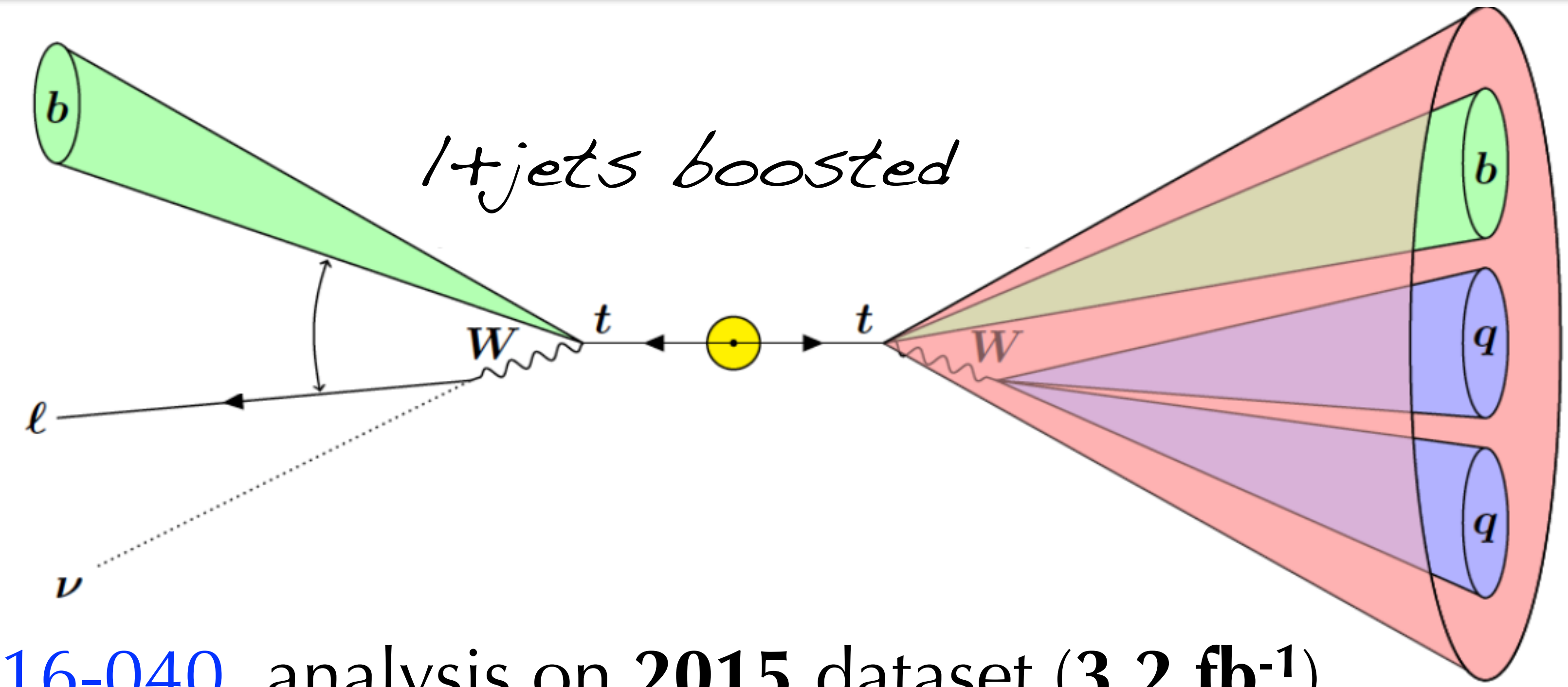
Lepton+jets resolved



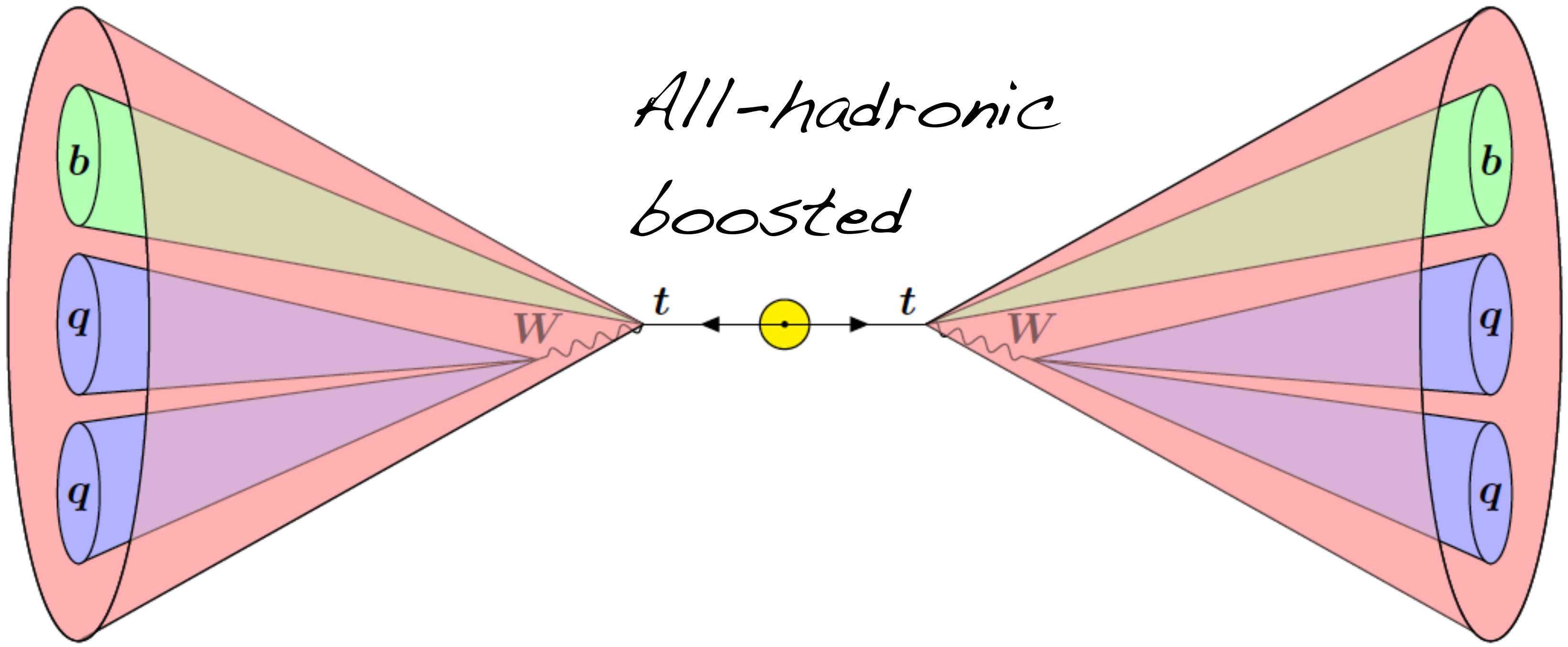
- **More background** compared to di-lepton
- Medium branching ratio

- ATLAS-CONF-2016-040, analysis on **2015** dataset (**3.2 fb^{-1}**)
- Unfold to the usual set of top and ttbar observables: p_T^t, $|y^t|$, $p_T^{t\bar{t}}$, $|y^{t\bar{t}}|$, $m^{t\bar{t}}$

Cross-section with boosted tops



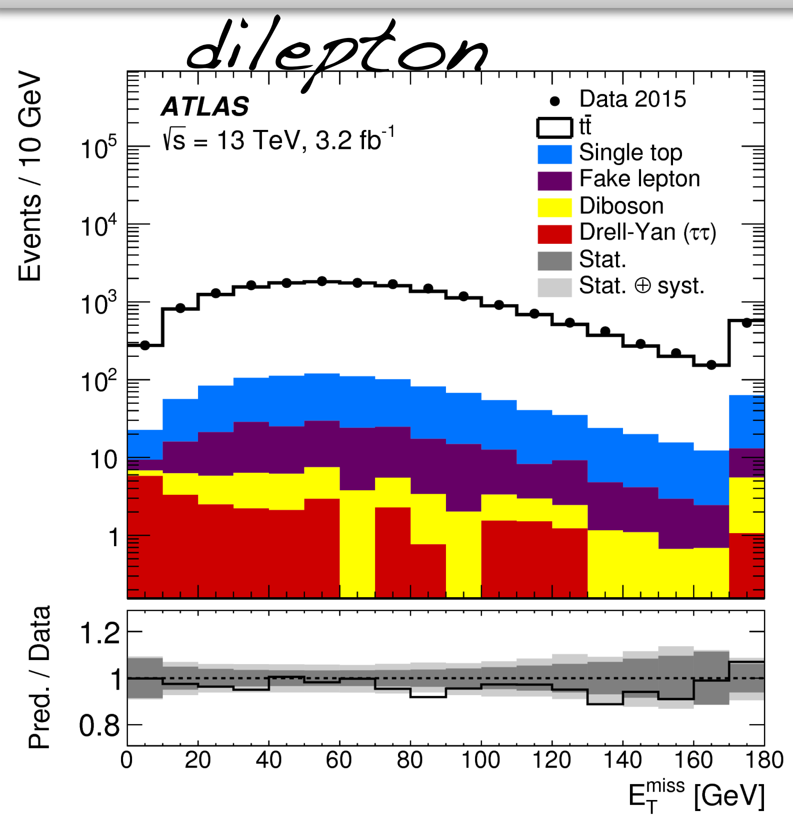
- ATLAS-CONF-2016-040, analysis on **2015** dataset (**3.2 fb^{-1}**)

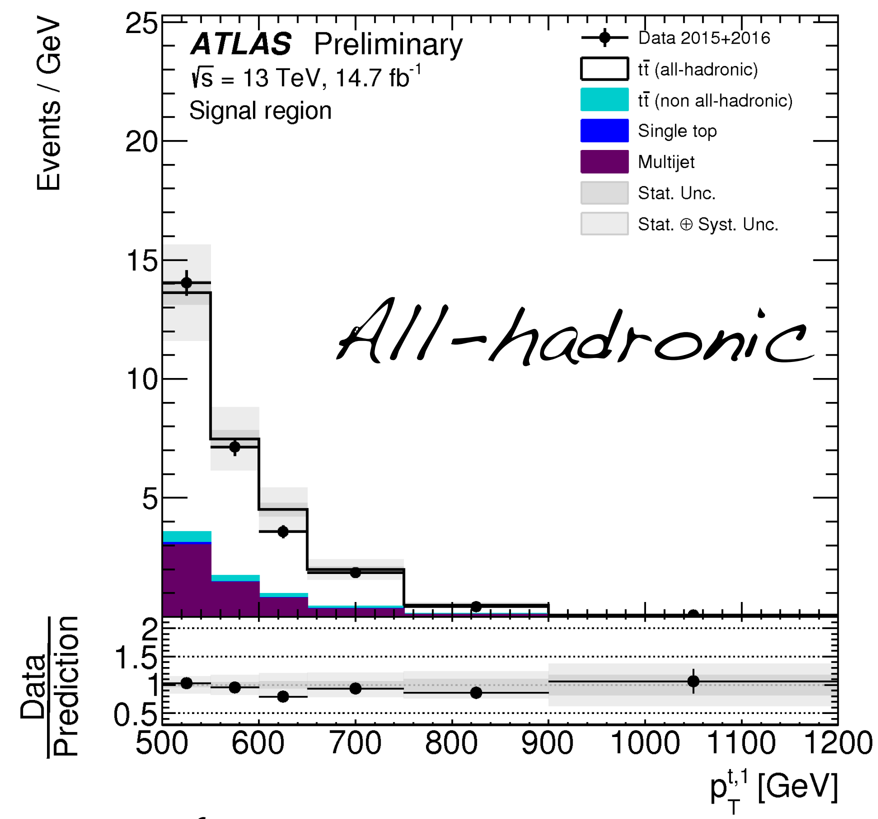


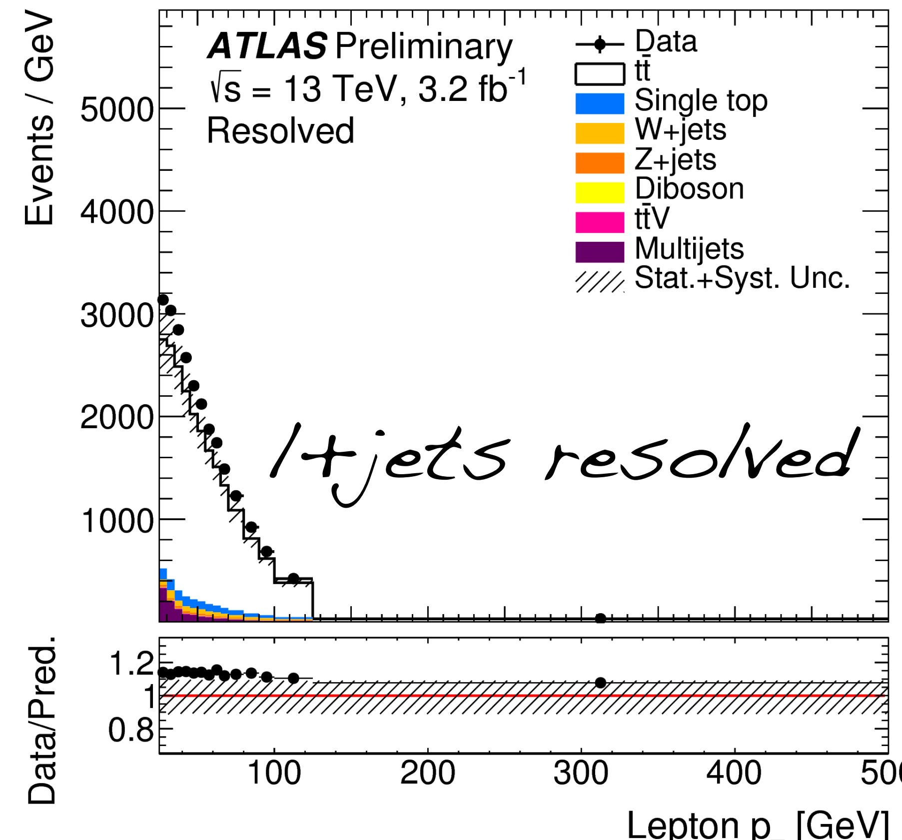
- ATLAS-CONF-2016-100, analysis on **2015+2016** dataset: **14.7 fb^{-1}**

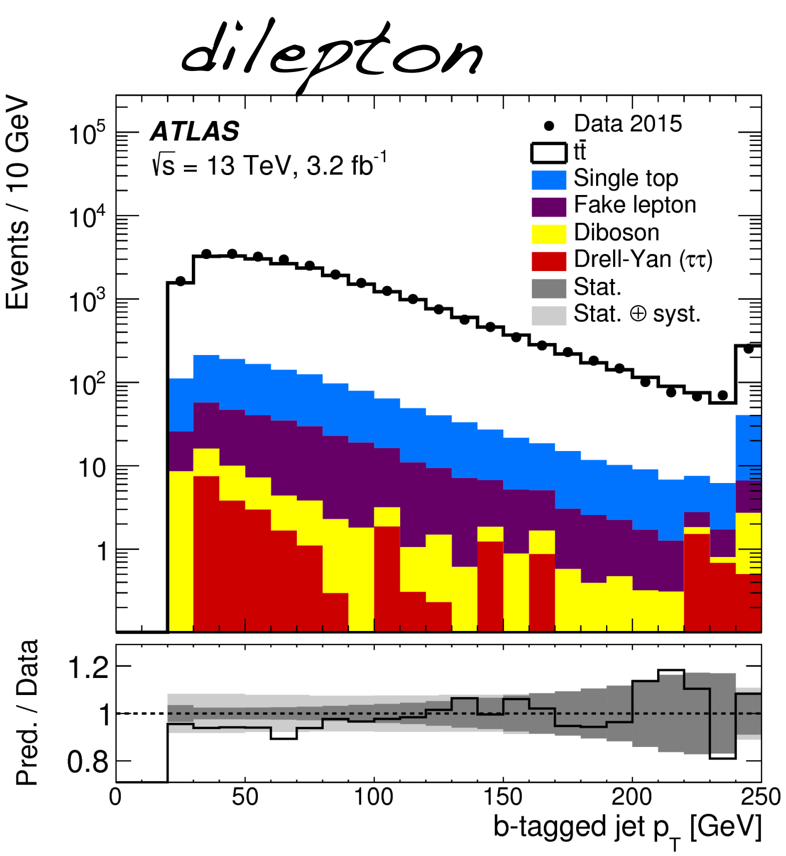
➡ Fore more details, M. Romano's talk on boosted objects

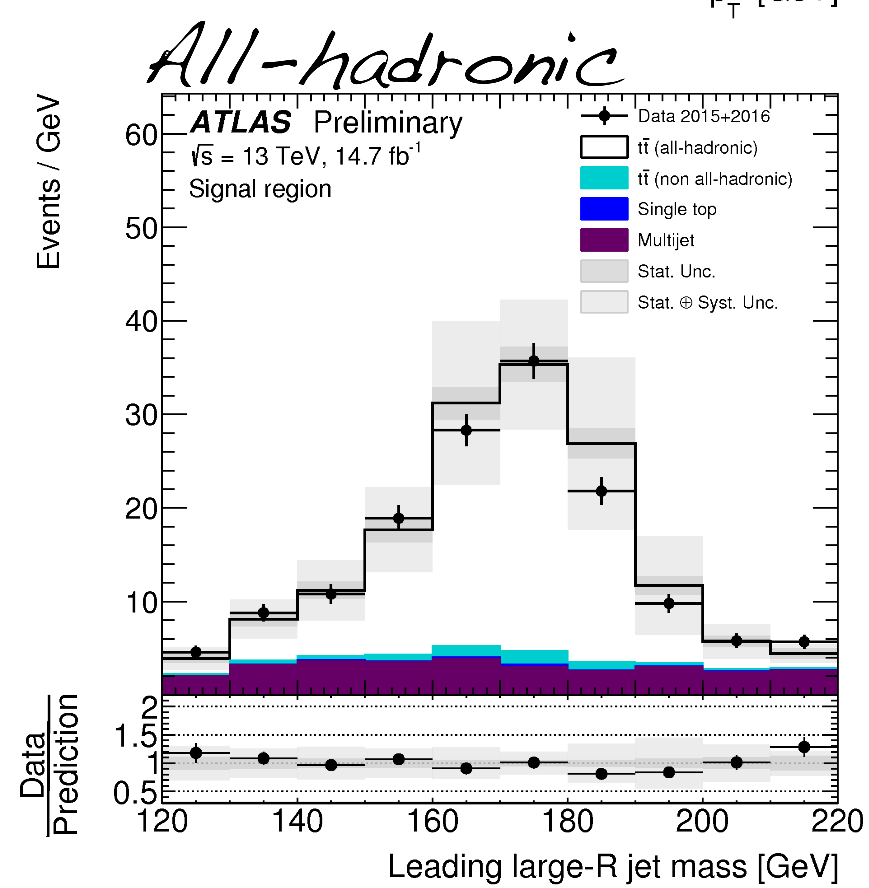
Control plots

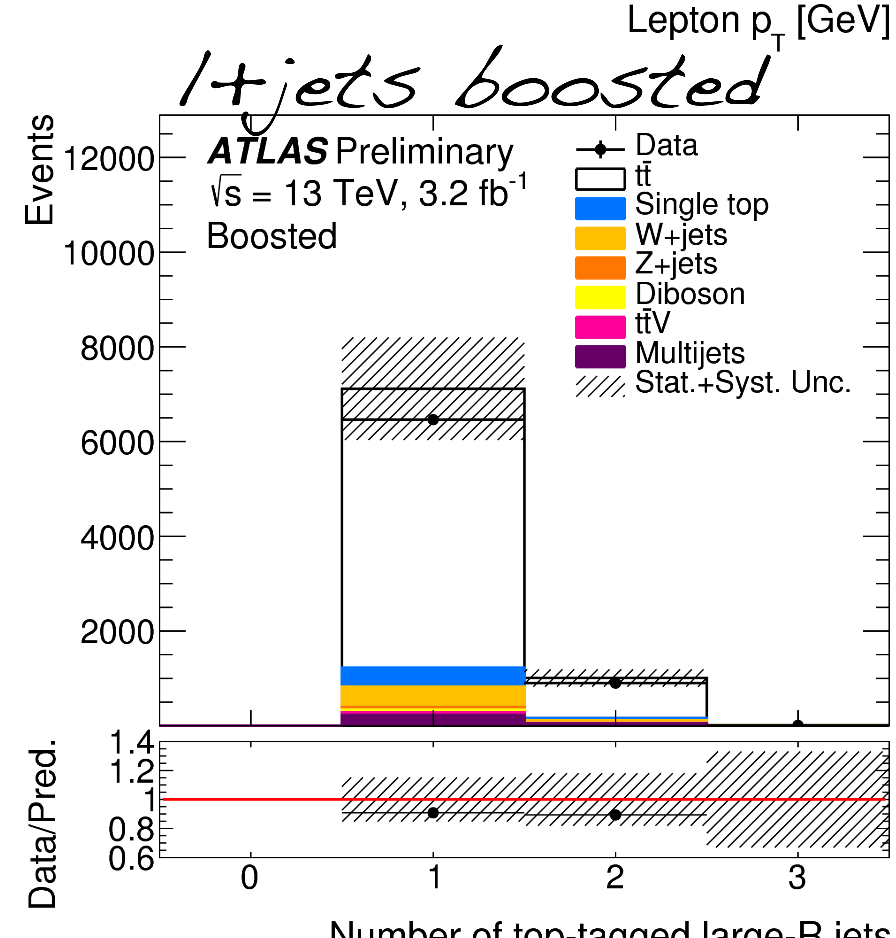






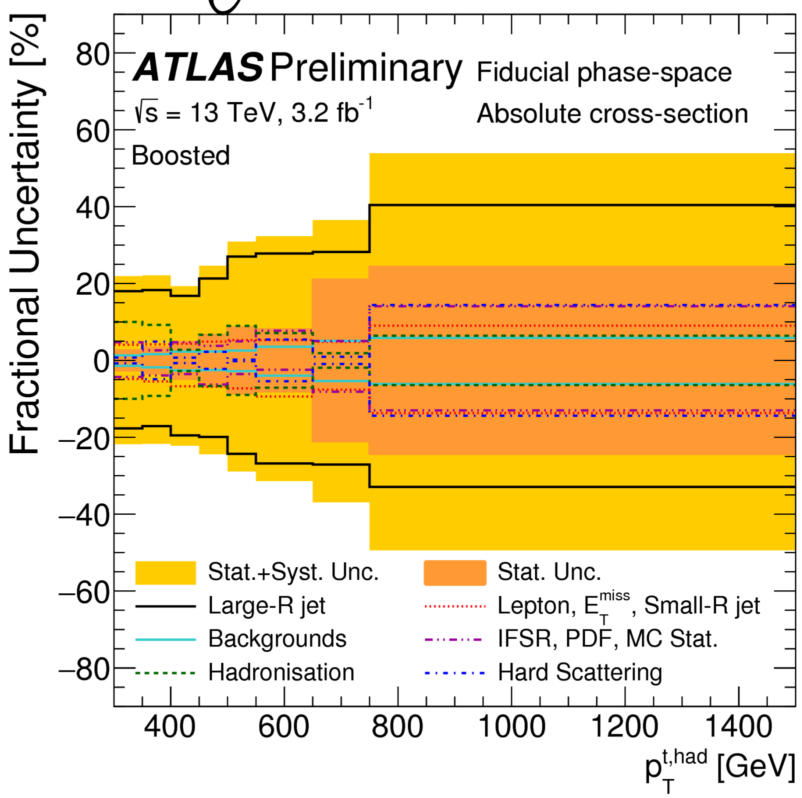




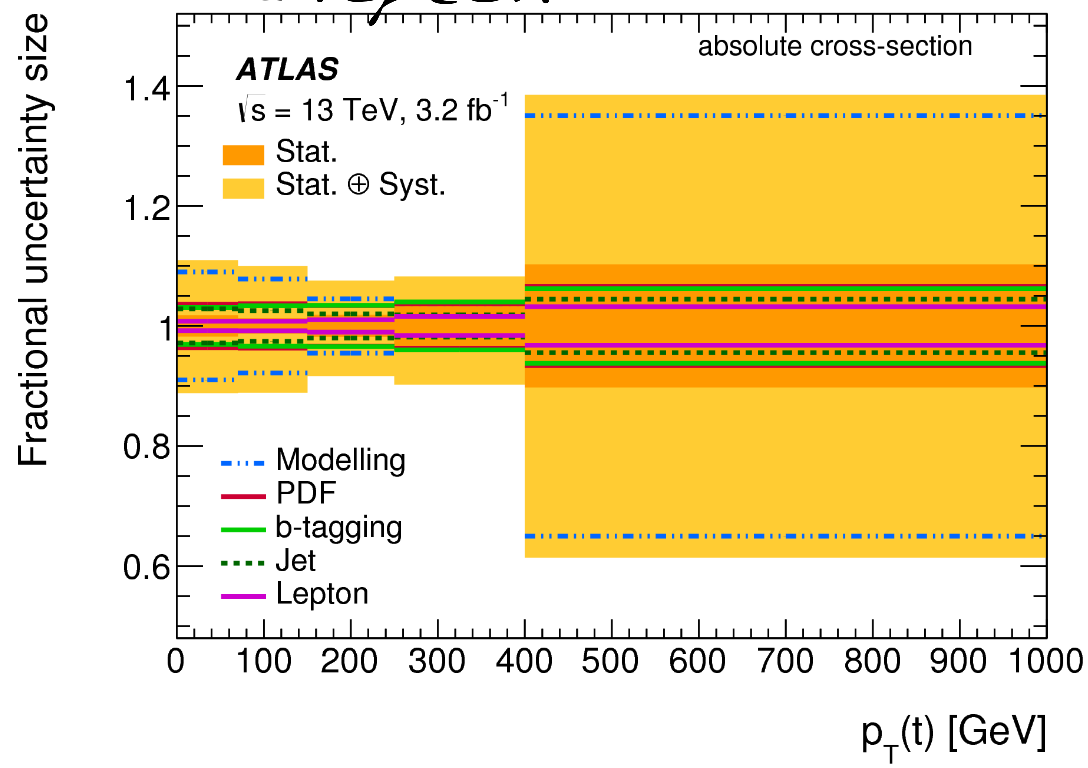


Uncertainties

l+jets boosted

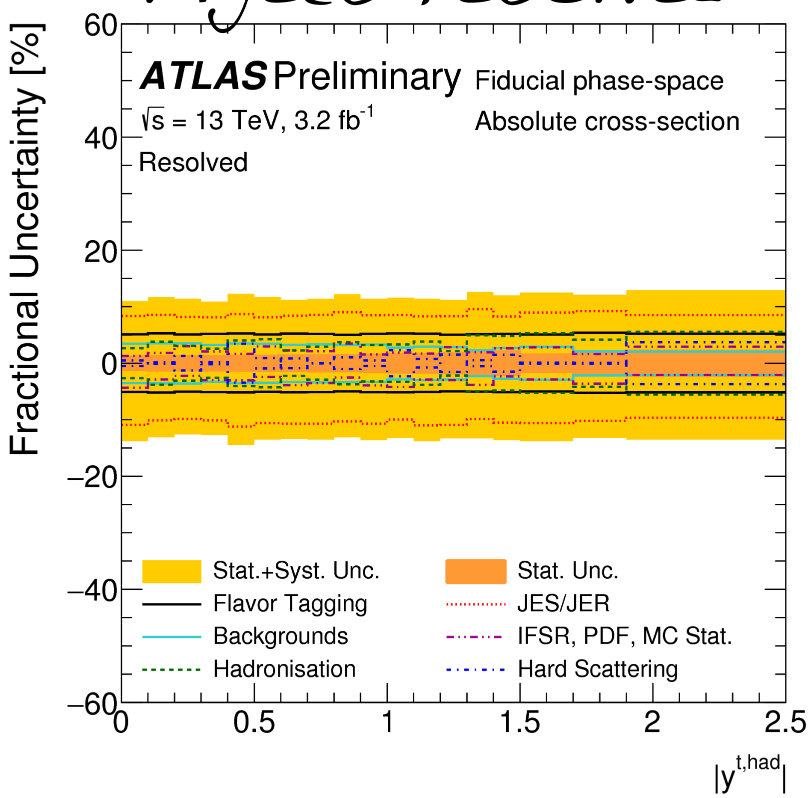


dilepton



- **MC generator modelling** systematics **important** in all analyses

l+jets resolved



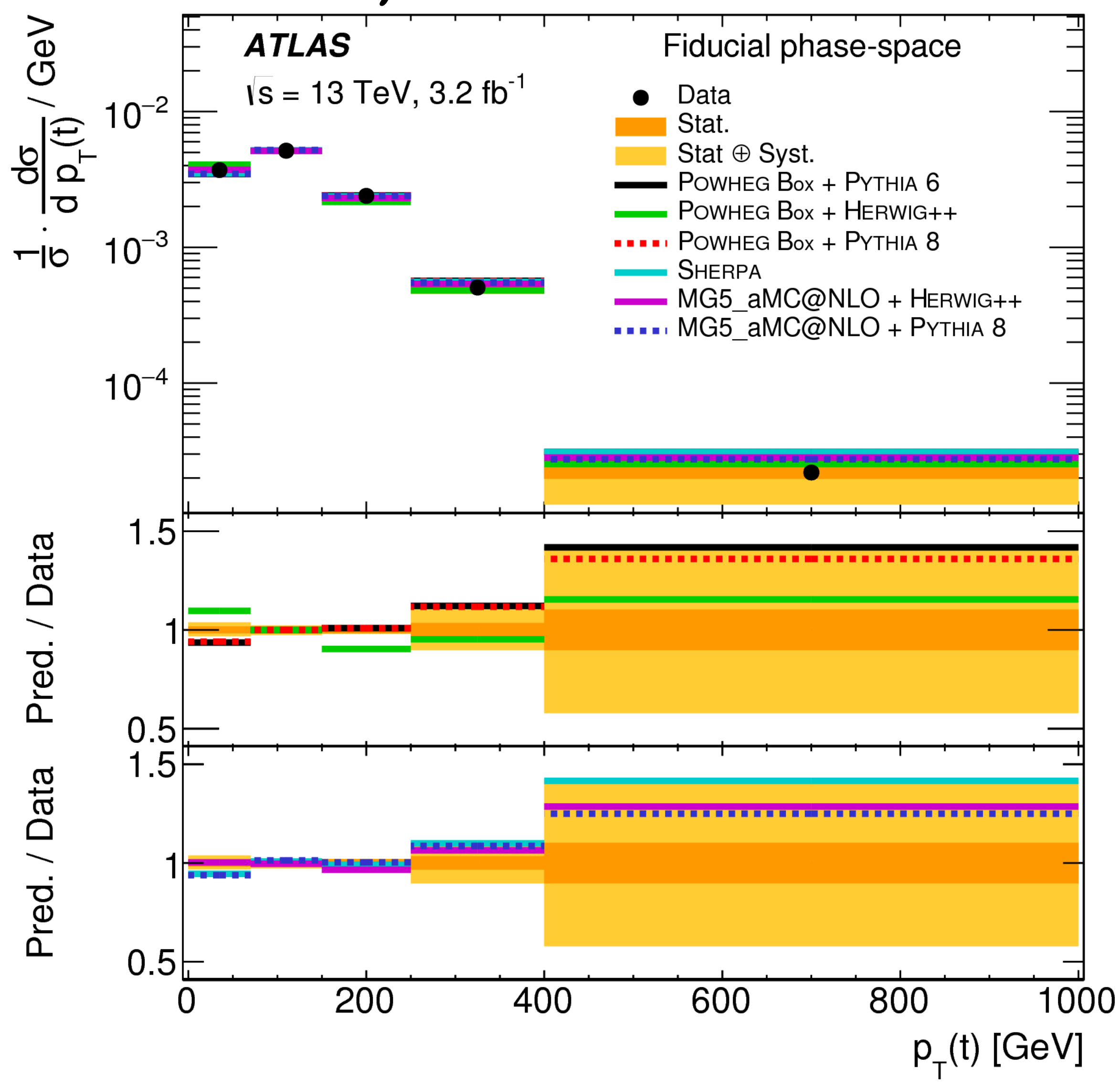
All-hadronic

Large-R jets	+18 / -15
Monte Carlo signal modelling	$\pm$17
b-tagging	+13 / -12
Pileup	$\pm$2.9
Luminosity	$\pm$2.9
Small-R jets	$\pm$1.0
Total Systematic Uncertainty	+29 / -24

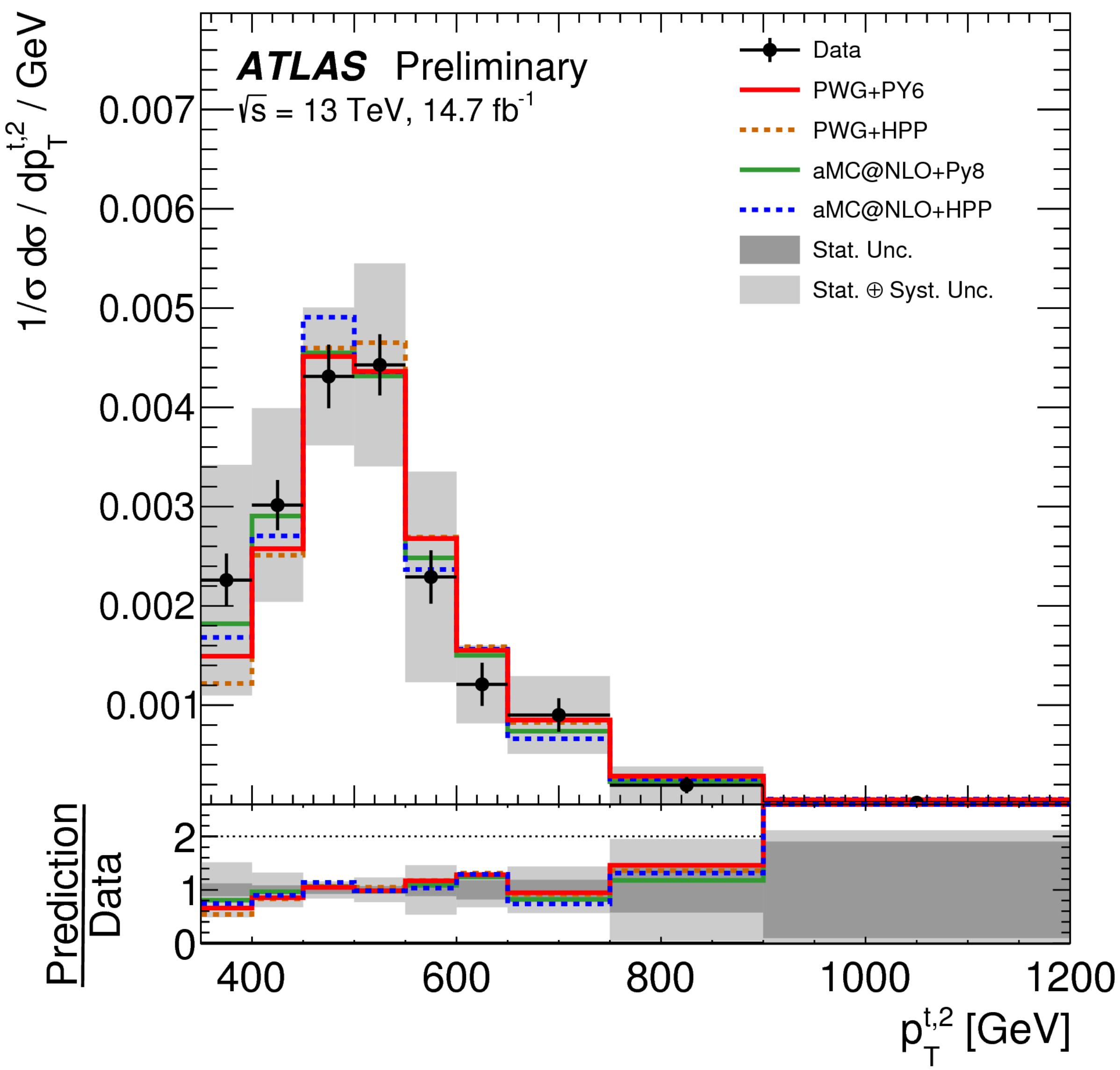
- **Jet related systematics** important as well

Top p_T

dilepton



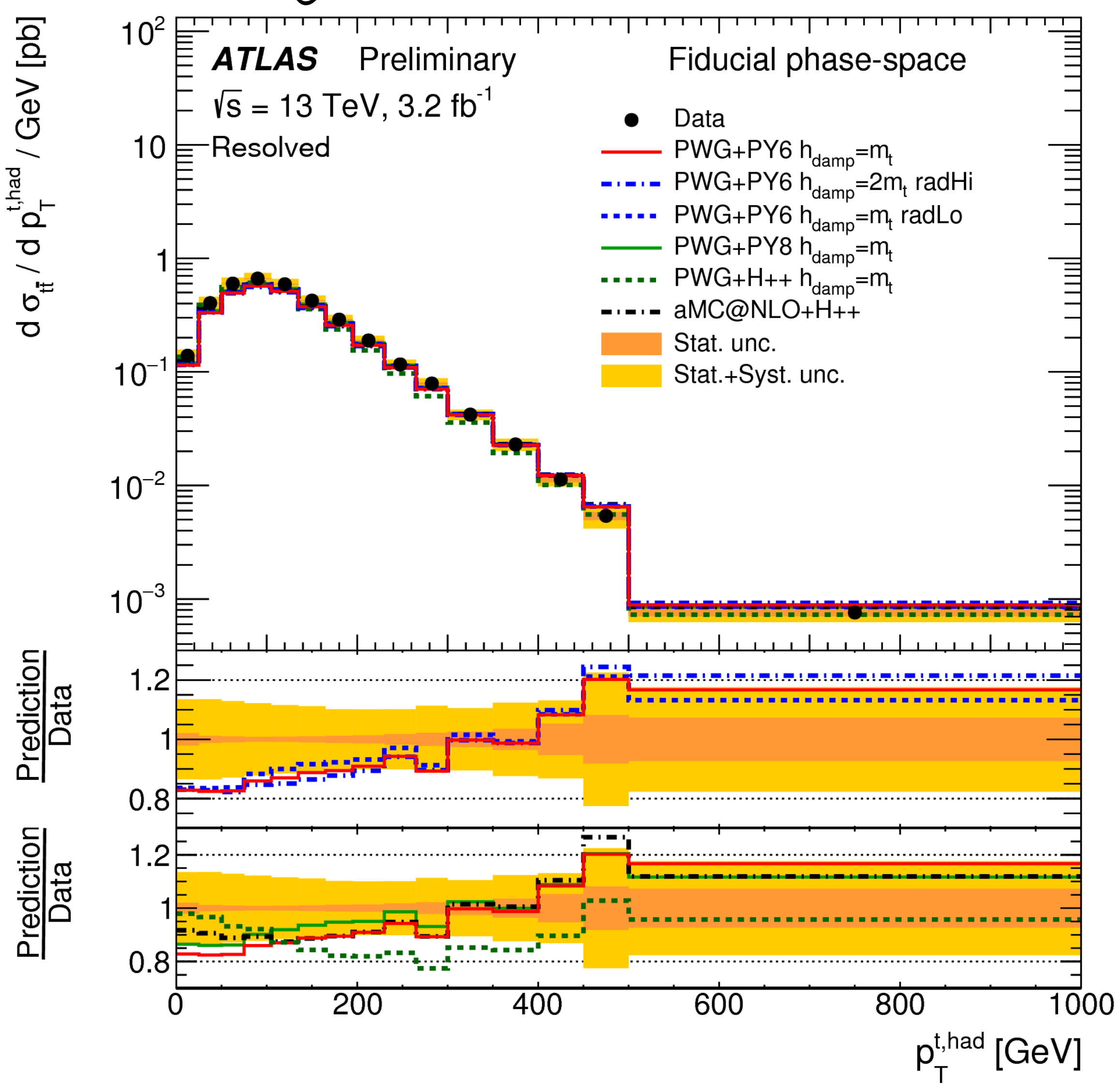
All-hadronic



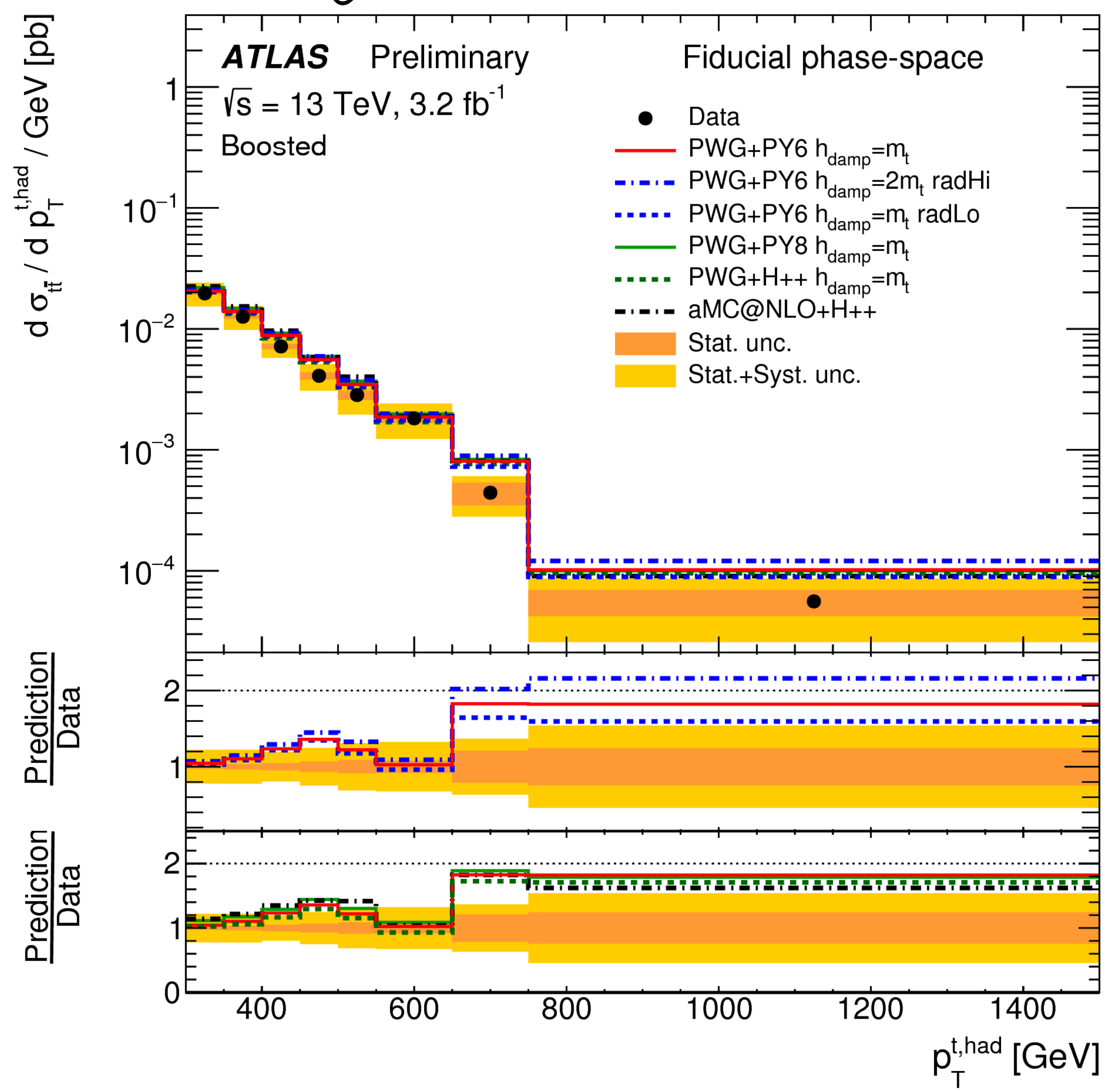
- **MC** predicts **harder p_T spectrum** than the one observed in **Data**
- Similar slope in all channels

Top p_T

l+jets resolved



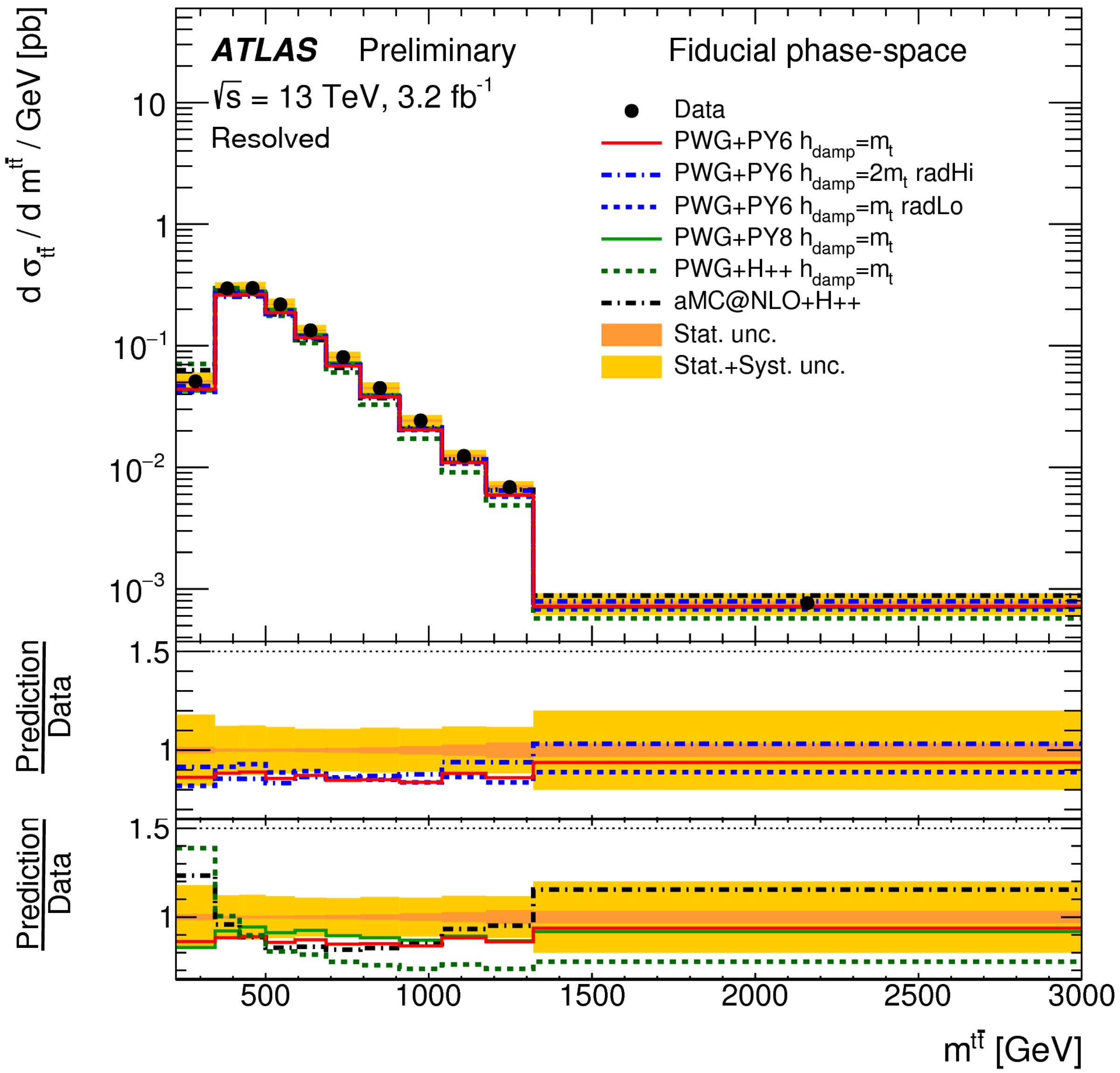
l+jets boosted



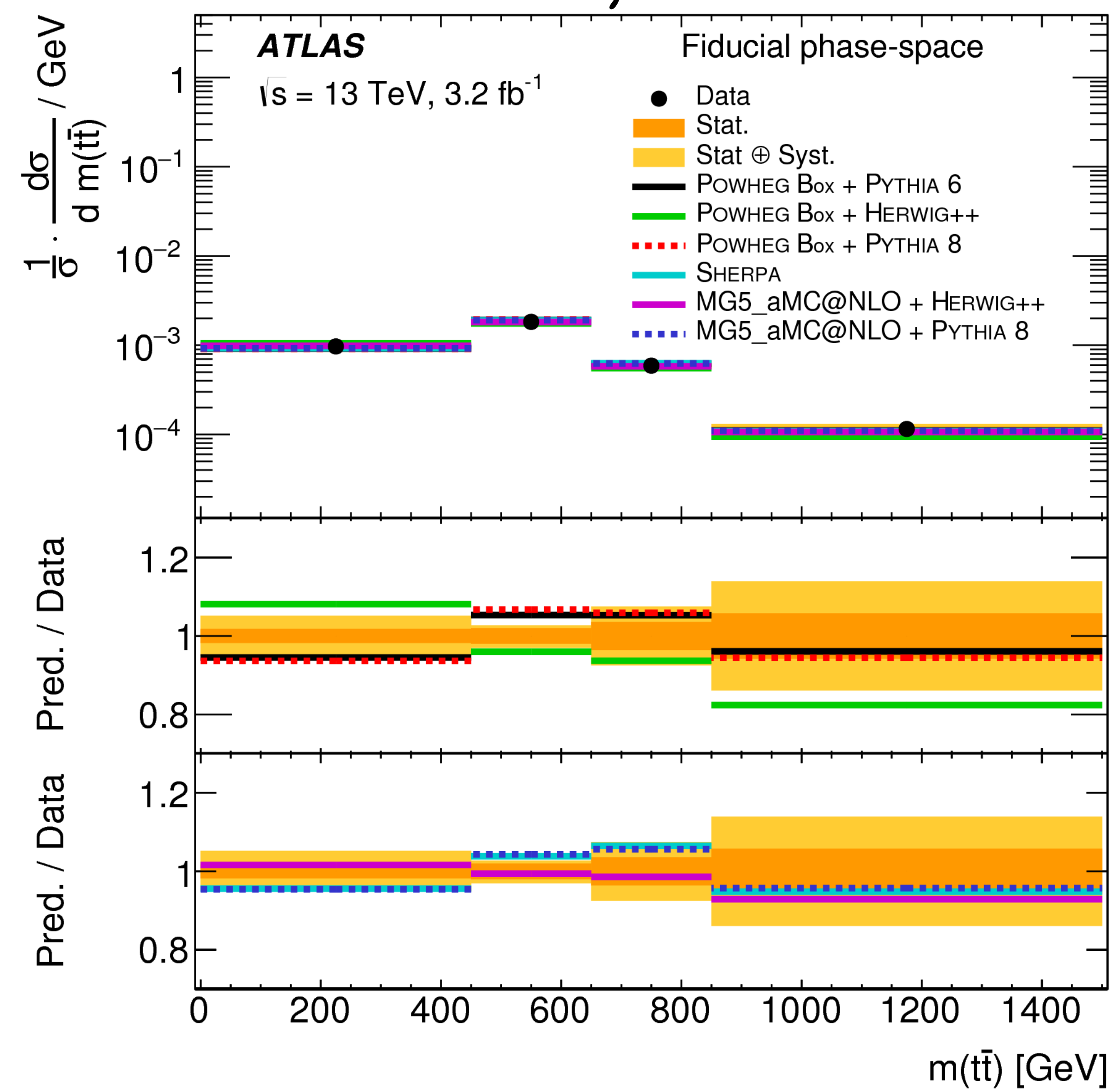
- **MC** predicts **harder p_T spectrum** than this observed in **Data**
- Similar slope in all channels

Top pair mass

l+jets resolved

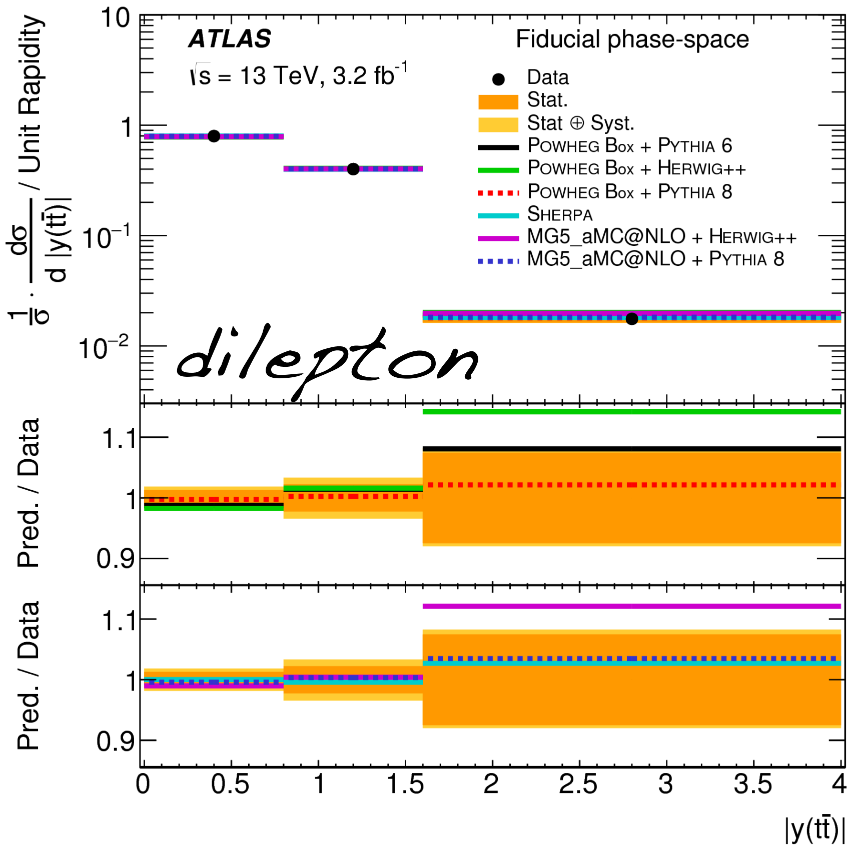


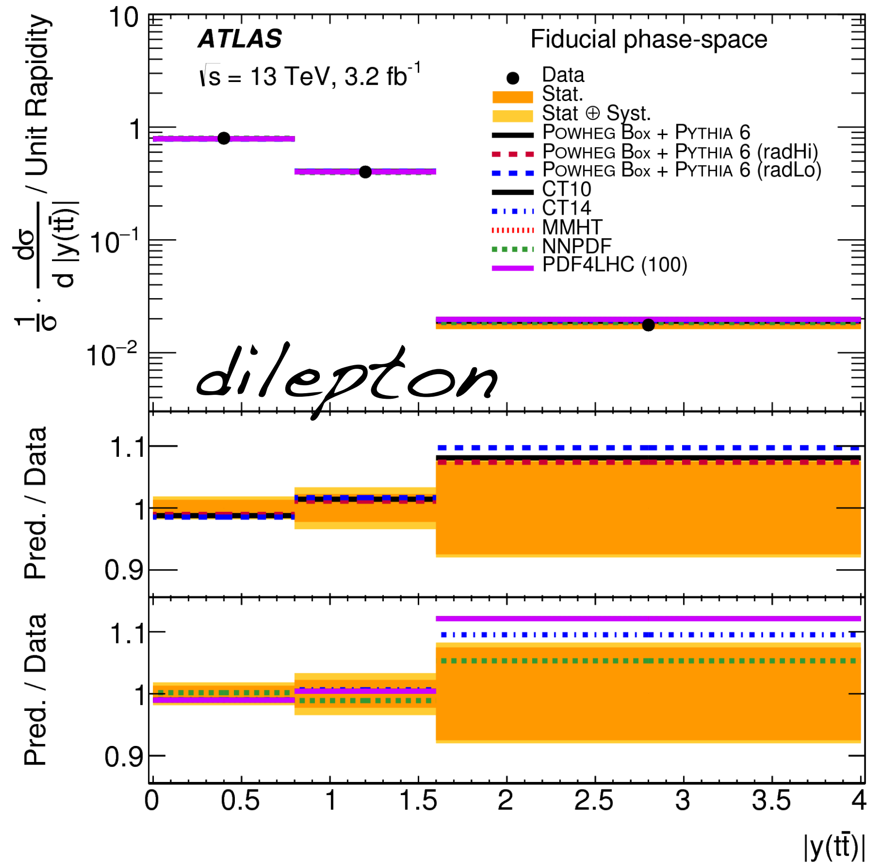
dilepton

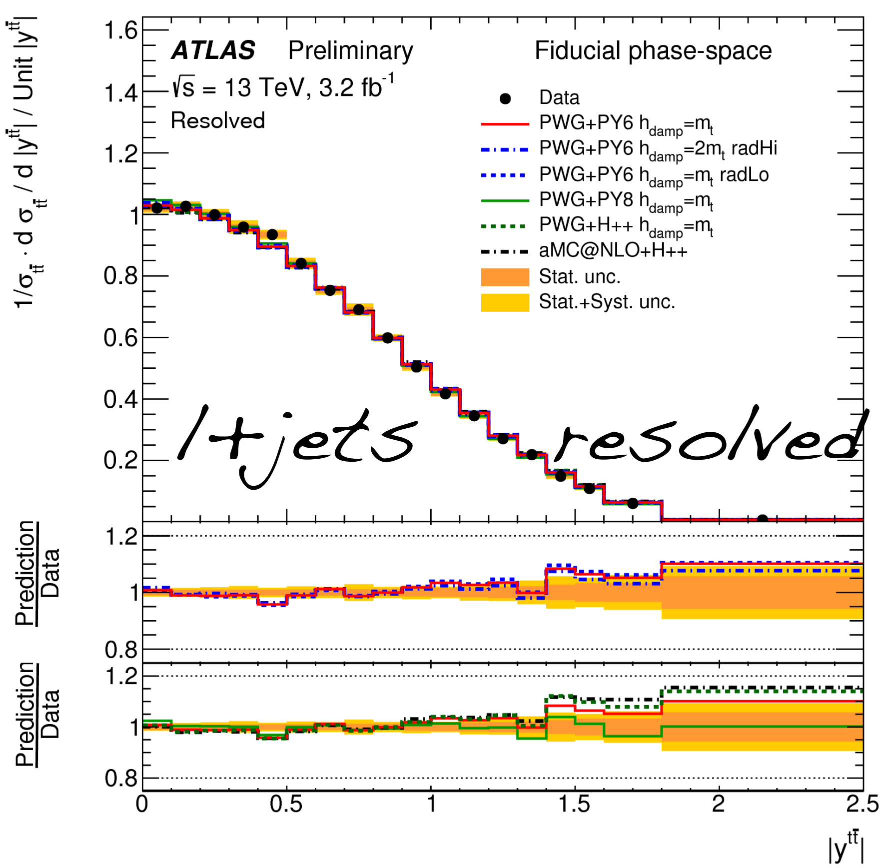


- **Sensitivity** to **MC generators** and **tunes**

Top pair rapidity



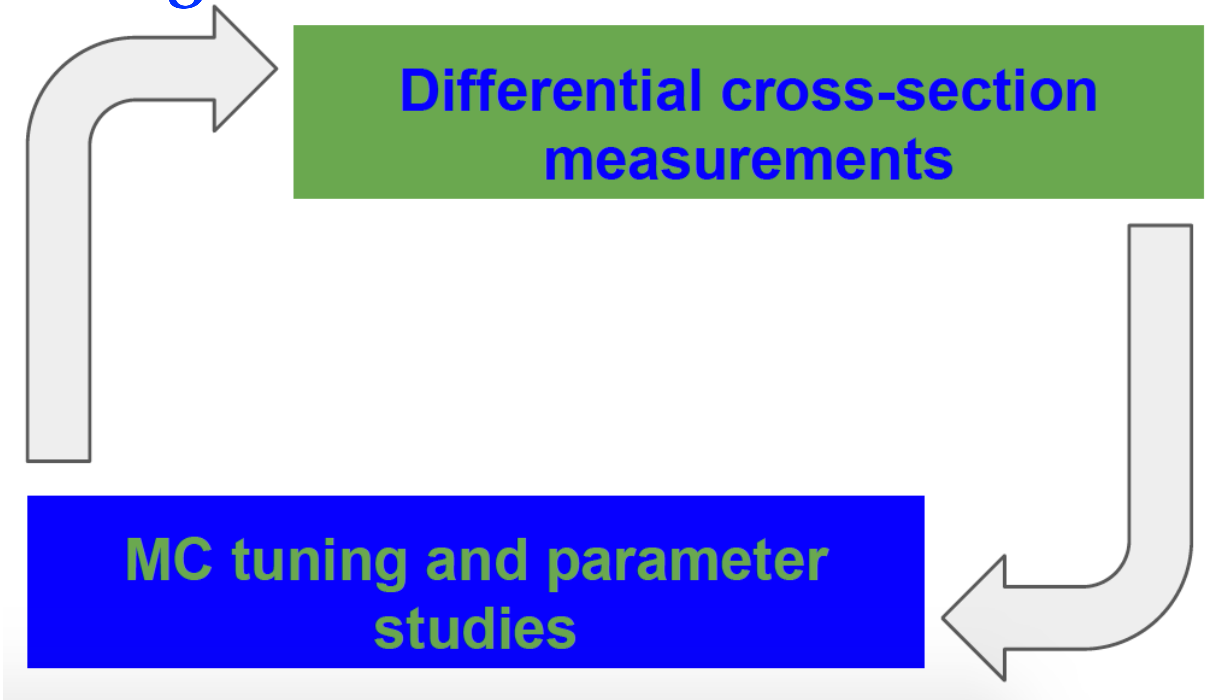




- **Low rapidity**: good agreement
- **High rapidity**: Increasing discrepancy

Conclusions

- After Higgs boson discovery: biggest anomaly **is ~~the X750 GeV diphoton resonance~~ the non-observation of new physics**
- Attacking the TeV scale on the most important front: **the top sector**
  - ✦ **Broad range** of **differential** ttbar cross-section measurements, **important** for **SM** and **BSM** physics
    - ✤ Analysing **13 TeV** to cover corners of phase space **not accessible in Run1**
    - ✤ **Larger uncertainties** are often the **MC modelling** and **jet energy scale**
- Measurements provide **discriminating power between MC models**
  - ✦ Use this information to **improve MC modelling** and thus **reduce MC modelling uncertainties**

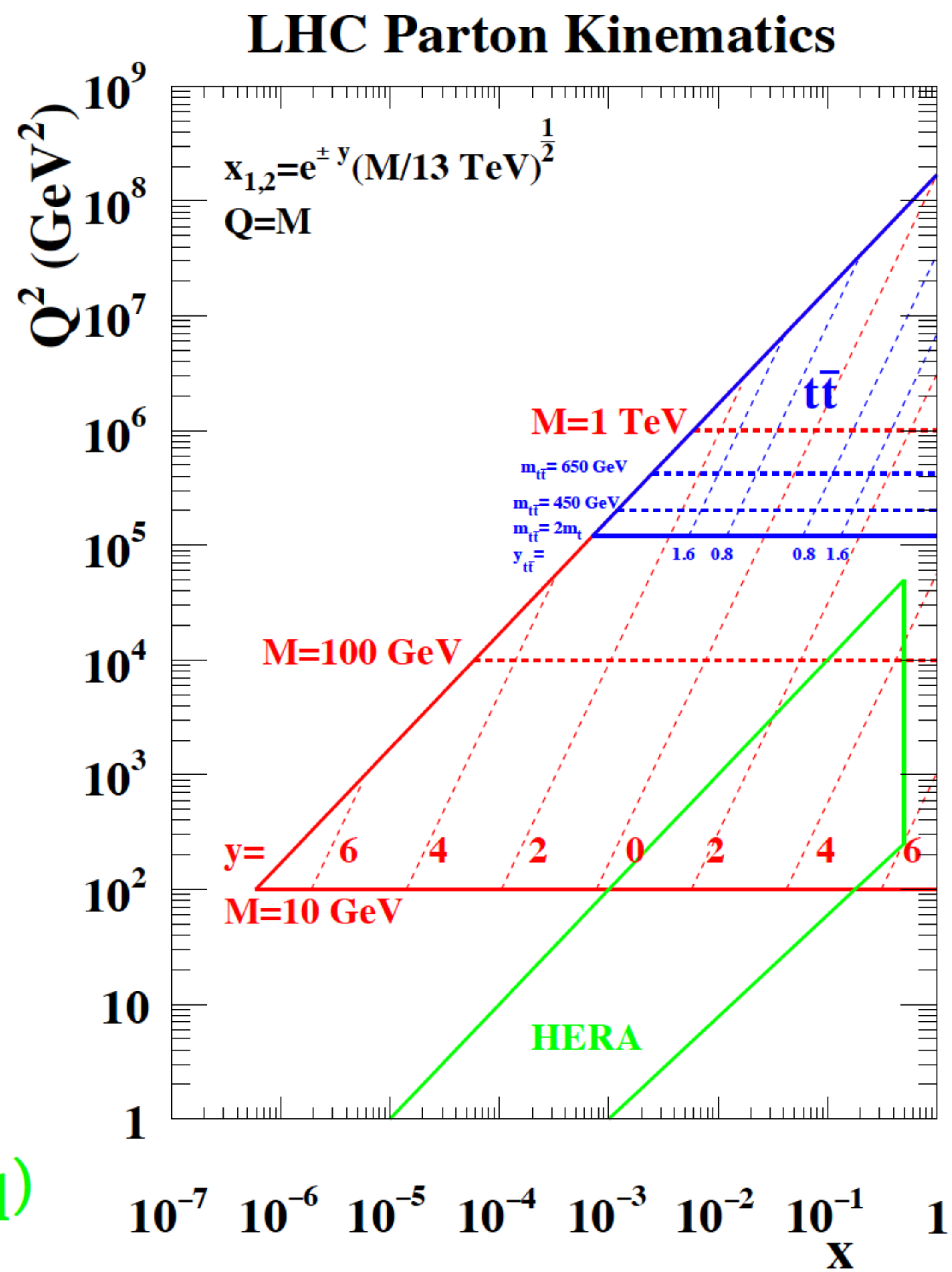


➡ **More** elaborate **results** to come using the full **2015+2016** dataset

➡ *Stay tuned!*

Back-up slides

PDF interpretations



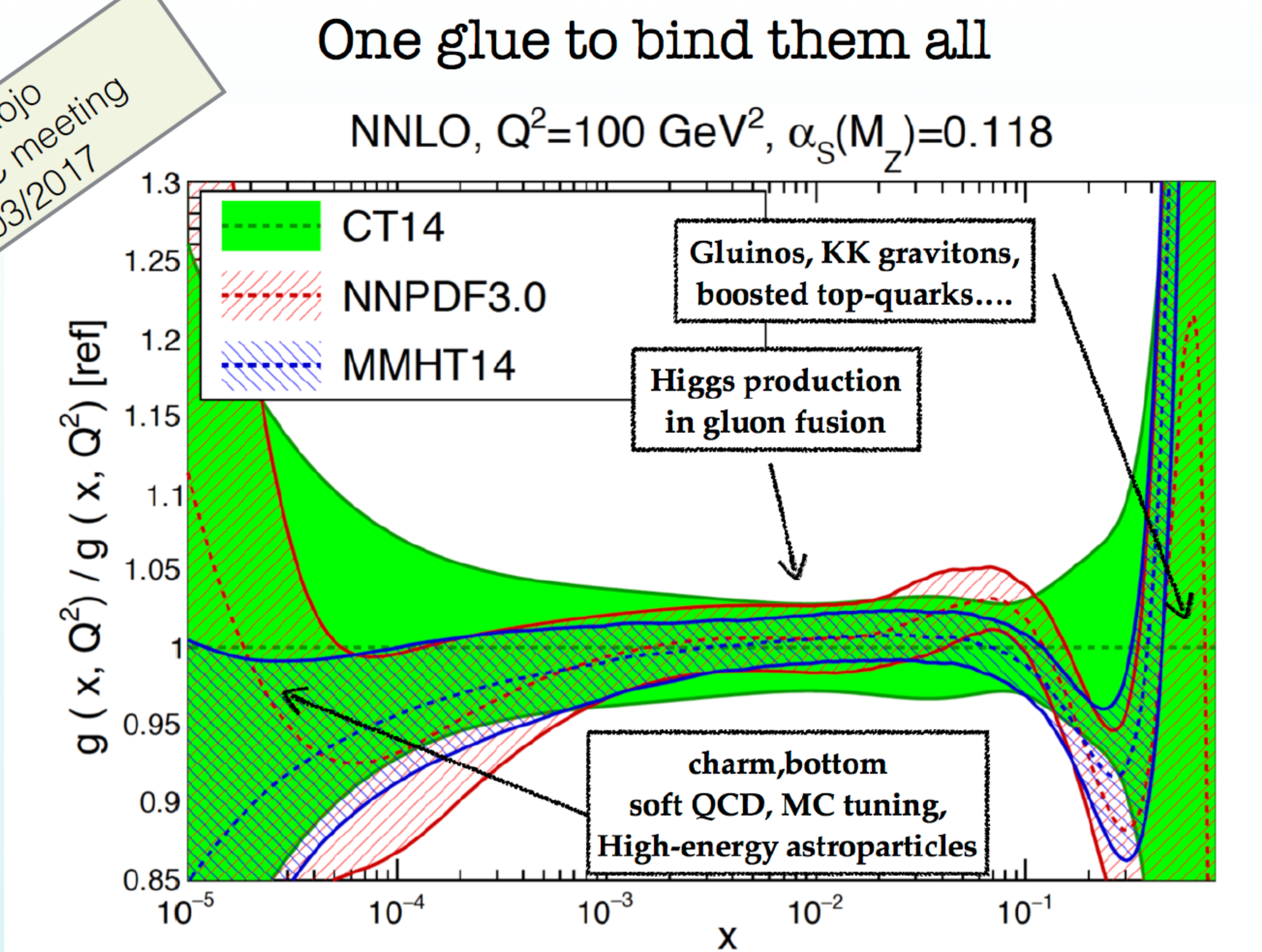
Red = area accessible at LHC

Blue = area accessible using $t\bar{t}$ decays

Green = HERA measurements (mostly q)

How well do we know the gluon density

Juan Rojo
PDF4LHC meeting
07/03/2017

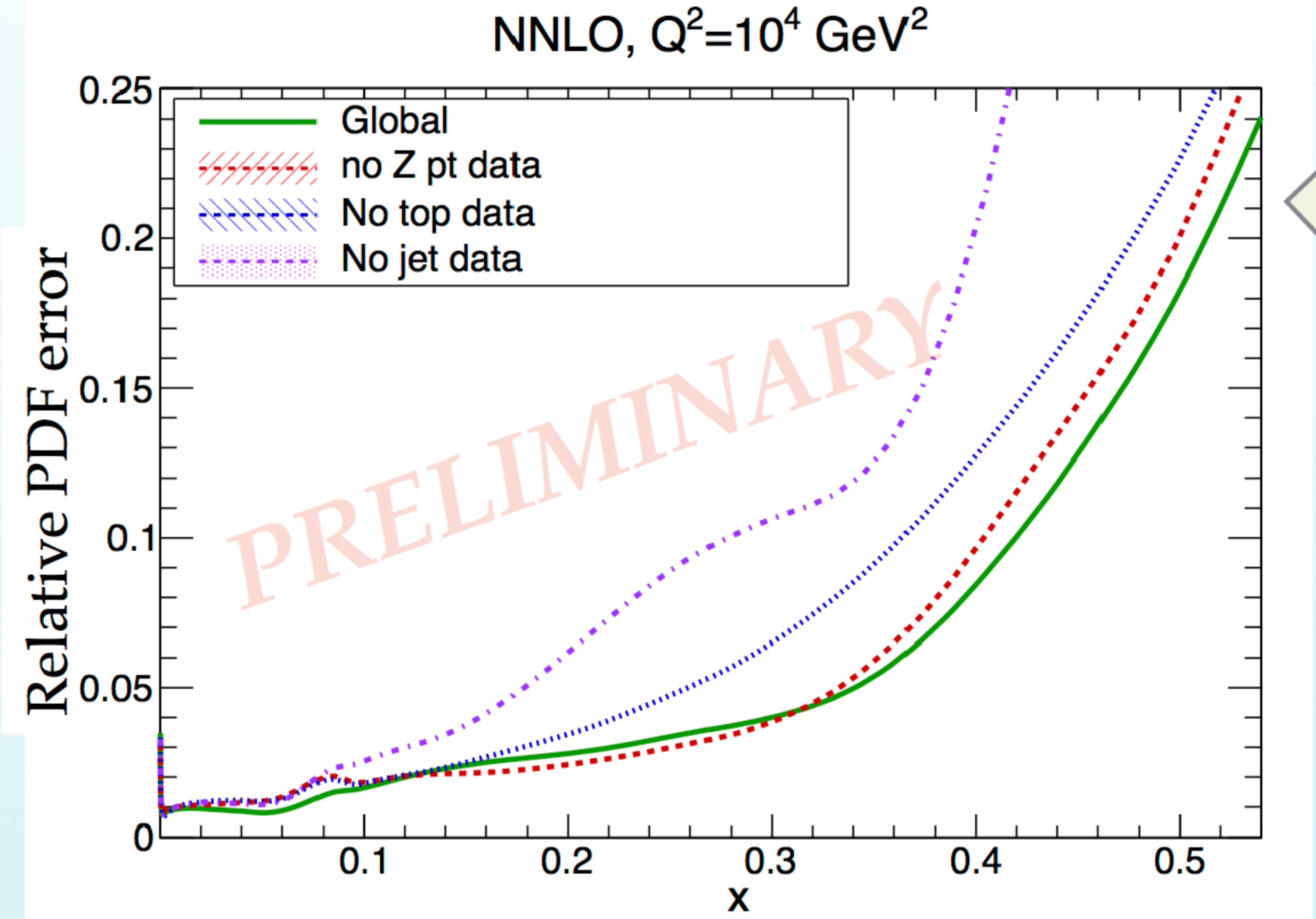


Exploit PDF-sensitive LHC measurements to **constrain the gluon at small-x!**

Impact of top cross sections on the gluon (NNPDF3.1)

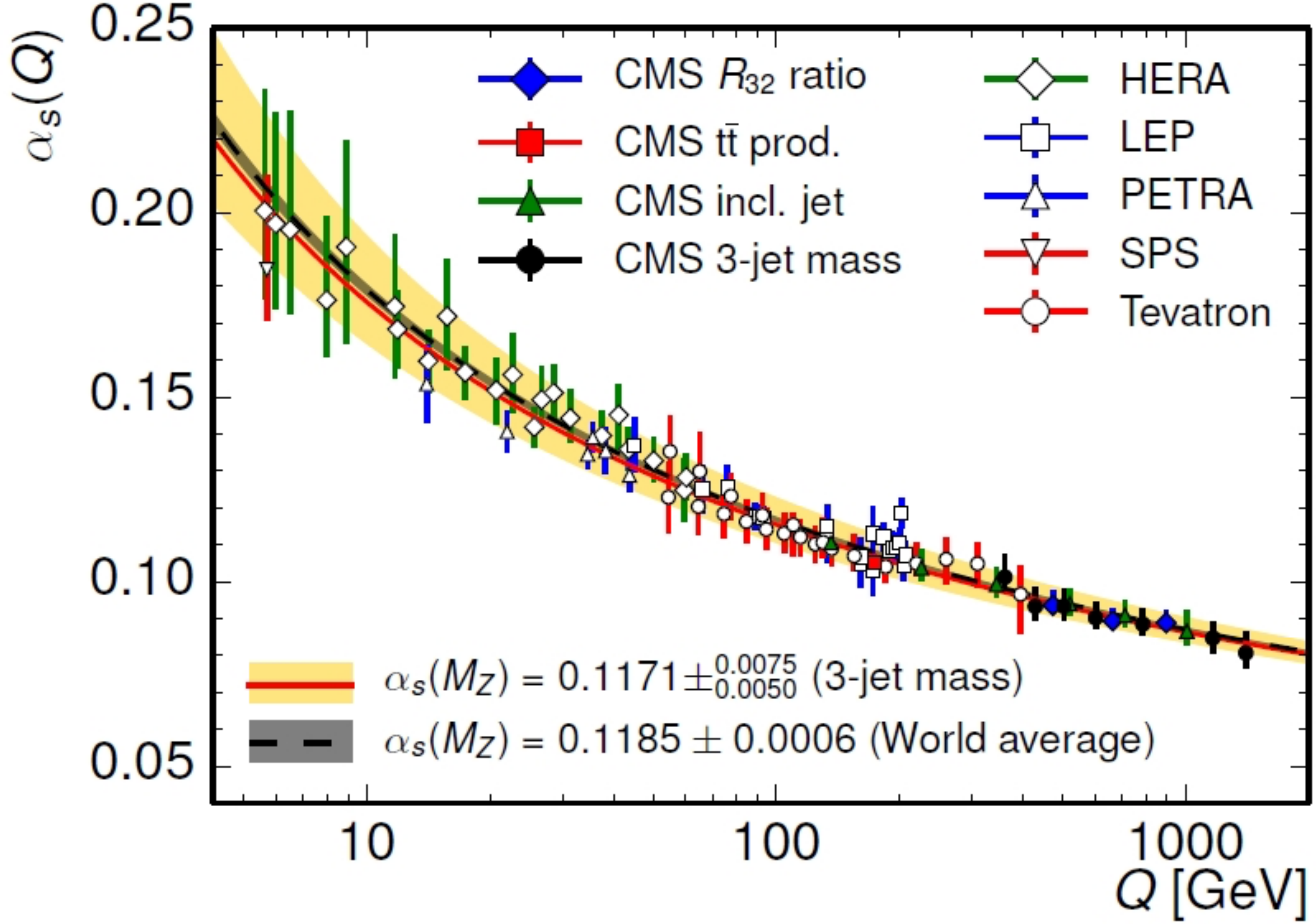
Impact on the gluon

- The **best precision in the large-x gluon** is achieved by **combining jets with top-pair and Z pt data**
- In terms of constraining power at large-x, we find the hierarchy: **jets > ttbar differential > Z pt**



Juan Rojo
PDF4LHC meeting
07/03/2017

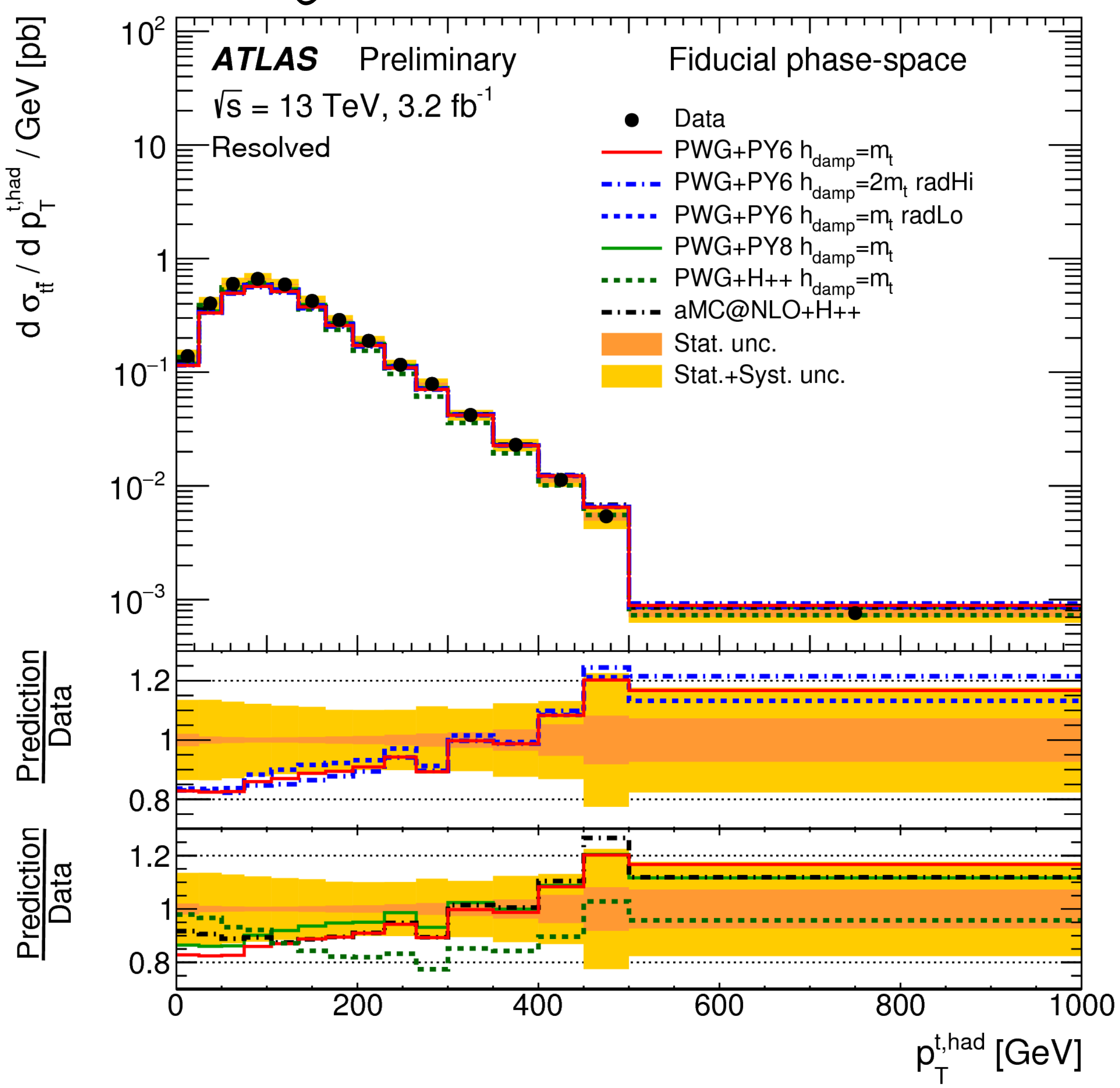
α_s



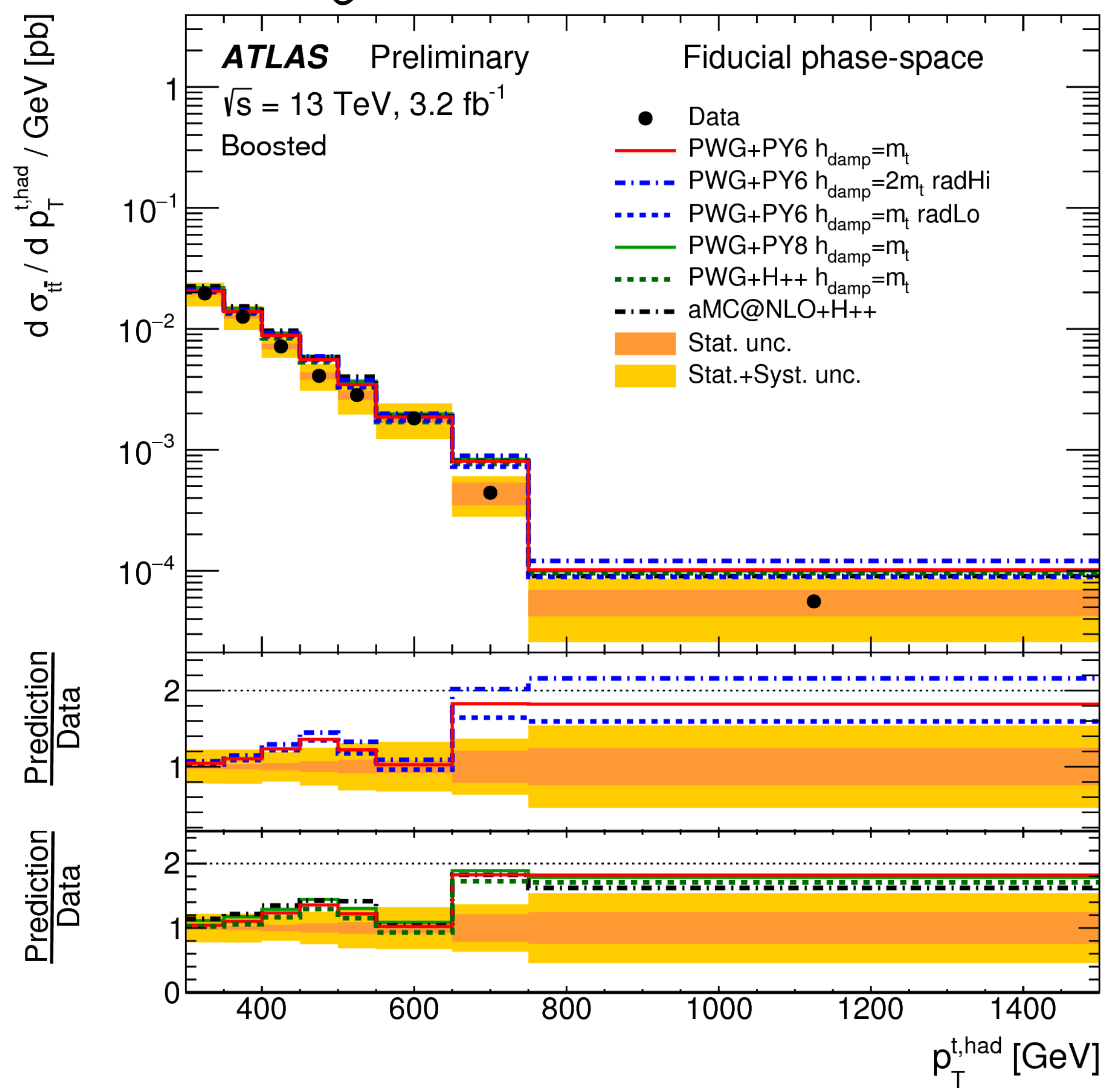
CMS R_{32} ratio
CMS $t\bar{t}$ prod.
CMS incl. jet
CMS 3-jet mass
HERA
LEP
PETRA
SPS
Tevatron
$\alpha_s(M_Z) = 0.1171 \pm^{0.0075}_{0.0050}$ (3-jet mass)
$\alpha_s(M_Z) = 0.1185 \pm 0.0006$ (World average)
$\alpha_s(Q)$
0.25
0.20
0.15
0.10
0.05
10
100
1000
Q [GeV]

Top p_T

l+jets resolved



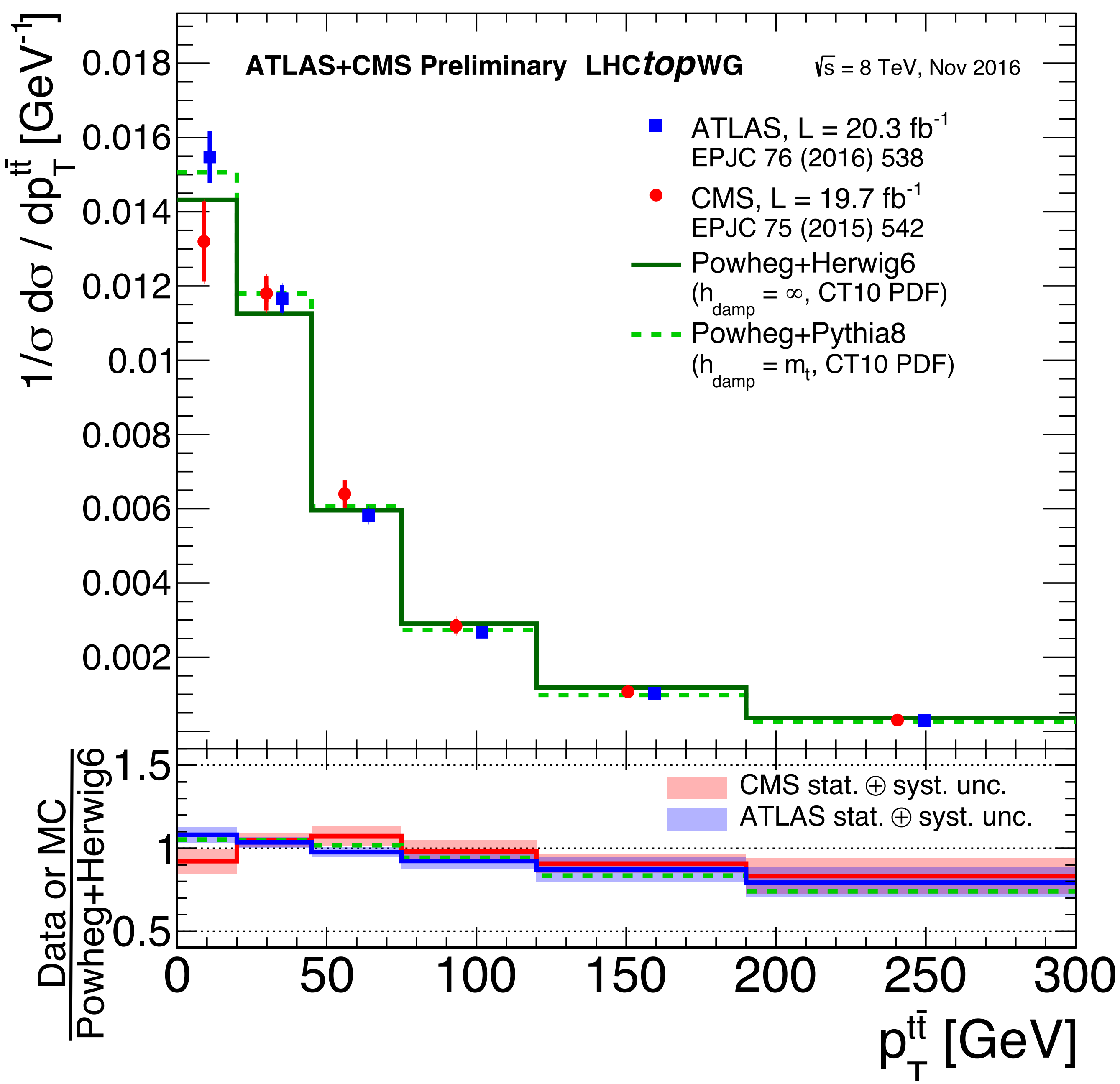
l+jets boosted



- **MC** predicts **harder p_T spectrum** than this observed in **Data**
- Similar slope in all channels

Top p_T in Run 1

LHC Top Working Group



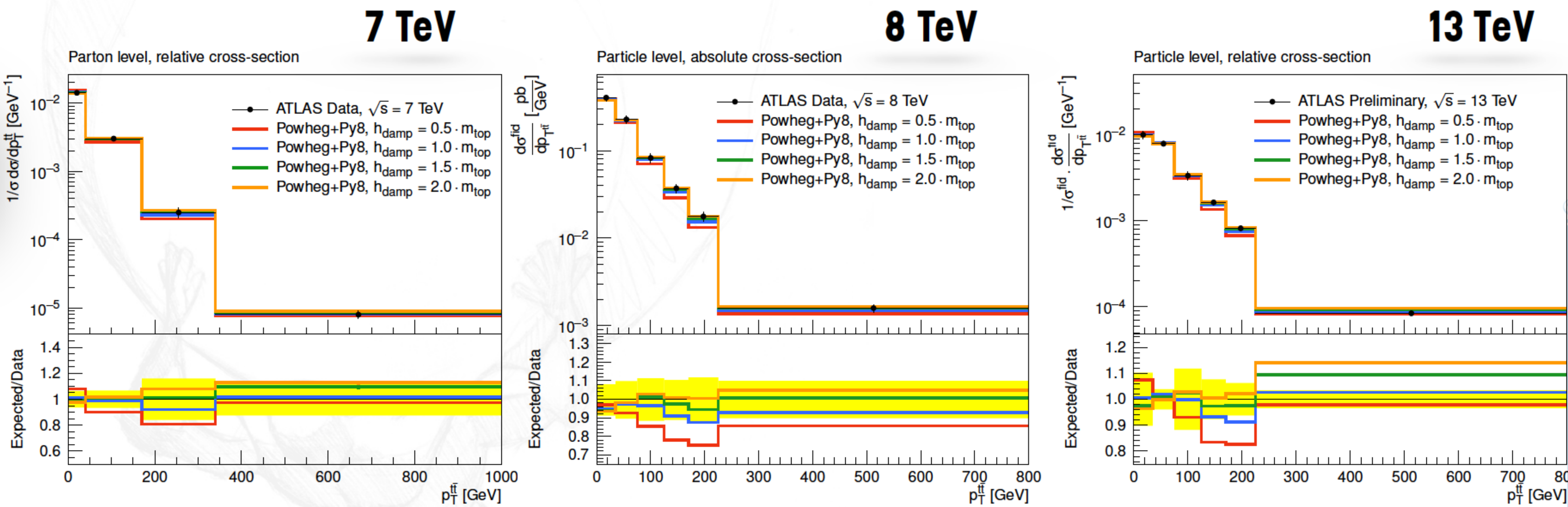
- Similar behaviour observed in **Run 1**
- Confirmed by **ATLAS and CMS**

MC Modelling studies

ATLAS-PUB-2016-020

- Comparison between unfolded ATLAS data and various MC generator predictions
  - 7, 8, 13 TeV RIVET routines

- Improve modelling of data through development of new MC generator configurations
  - Optimization of Powheg + {Pythia8, Herwig7}
    - Tune intrinsic merging and matching parameters



- Comparisons of
  - Variation of scales and tune
  - Different parton shower interfaces
  - Different NLO generators including NLO multileg genera

h$_{damp}$ parameter is used as a resummation damping factor, which is one of the parameters controlling the ME/PS matching in Powheg and effectively regulates the high-**p**T radiation.

ttbar reco

- **Dilepton: neutrino weighting method**
  - Under-constrained of kinematics equation cannot be solved analytically
  - Add constraints: mass of the top, mass of the W, eta of neutrinos

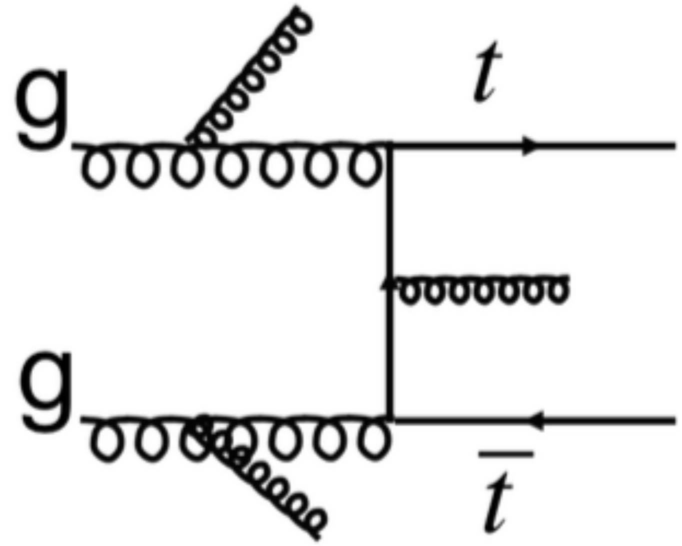
$$(\ell_{1,2} + \nu_{1,2})^2 = m_W^2 = (80.2\ \mathrm{GeV})^2,$$
$$(\ell_{1,2} + \nu_{1,2} + b_{1,2})^2 = m_t^2 = (172.5\ \mathrm{GeV})^2,$$
$$\eta(\nu),\ \eta(\bar{\nu}) = \eta_1,\ \eta_2,$$

  - Scan on eta from -5 to 5
  - The observed met value in each event is used to determine which solutions are more likely to be correct
  - Two possible solutions for each assumption of $\eta(\nu)$ and $\eta(\bar{\nu})$. Only real solutions without an imaginary component are considered

- **Lepton+jet: pseudo-top algorithm**
  - Neutrinos 4-momentum
    - -x, -y from Met-x, Met-y
    - -z component calculated using the leptonic W boson mass constraint

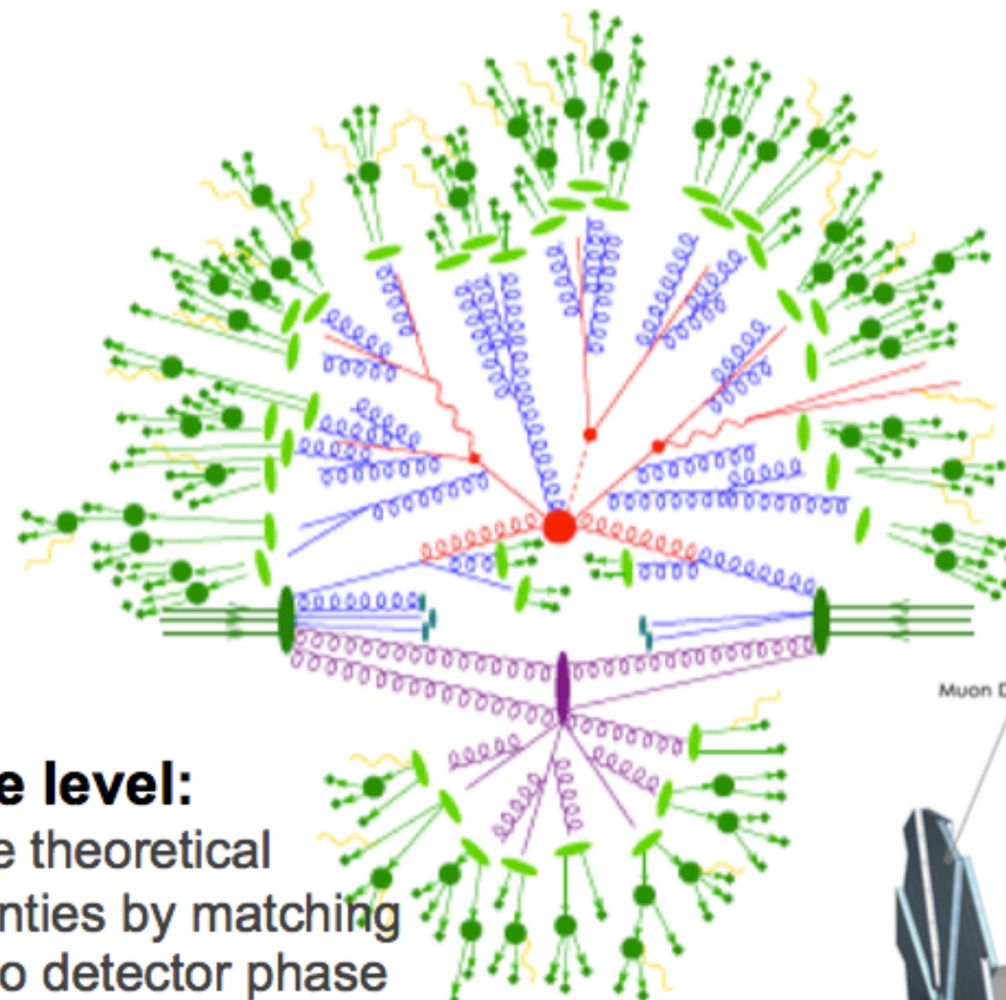
Unfolding of detector-level measurements

- **Unfolding:** making **detector** (reconstruction) measurements **comparable** to **theory**



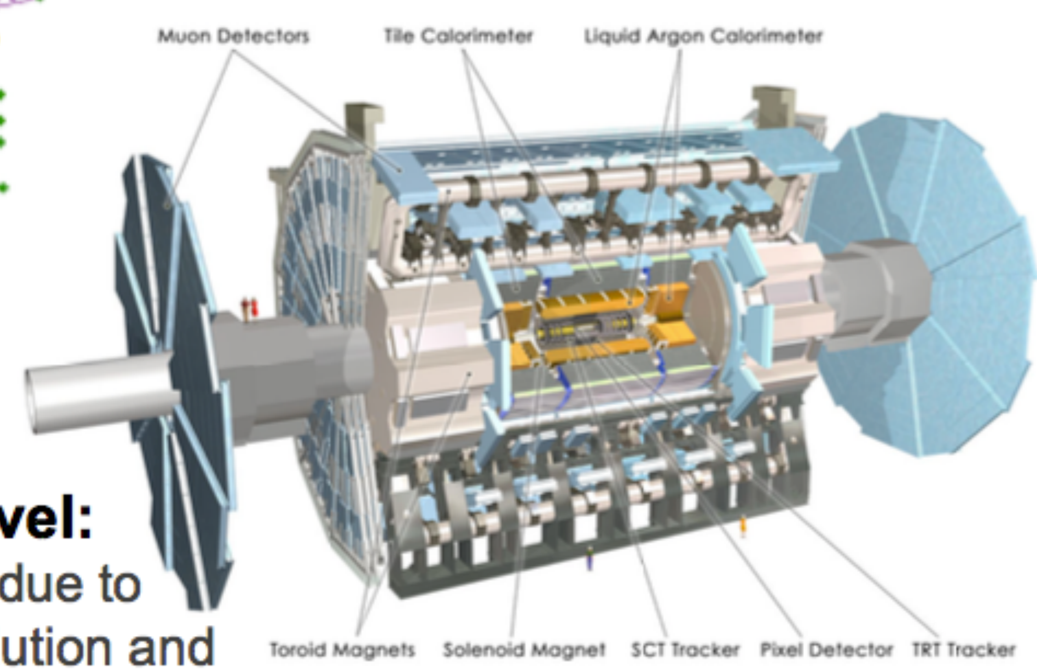
Parton level:
directly probes the ME, PDFs, α_s, M_{top} , etc…

but, large model dependence and hence large uncertainties



Particle level:
minimize theoretical uncertainties by matching closely to detector phase space

suffers mostly by non-perturbative effects (parton shower, fragmentation, hadronisation, PDFs …)

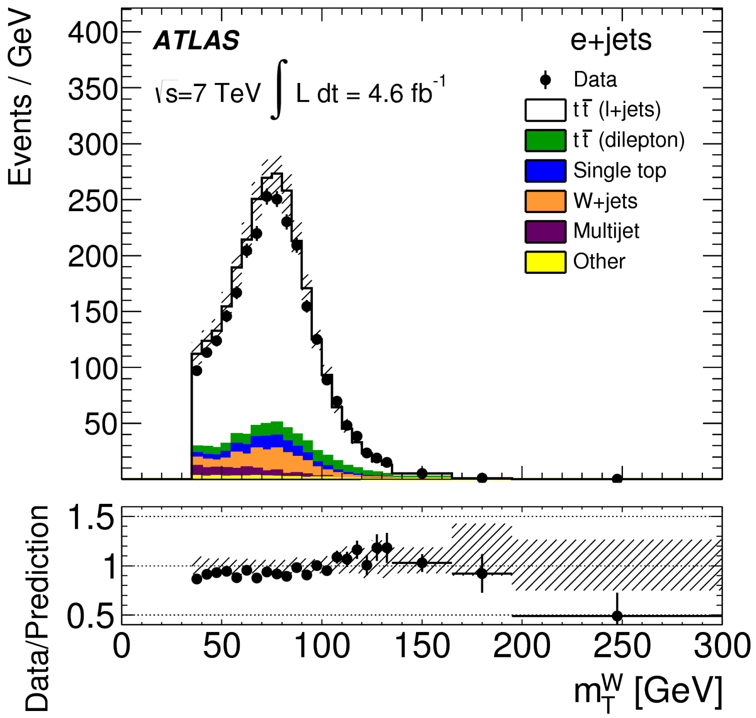


Detector level:
inefficiencies due to detector resolution and response

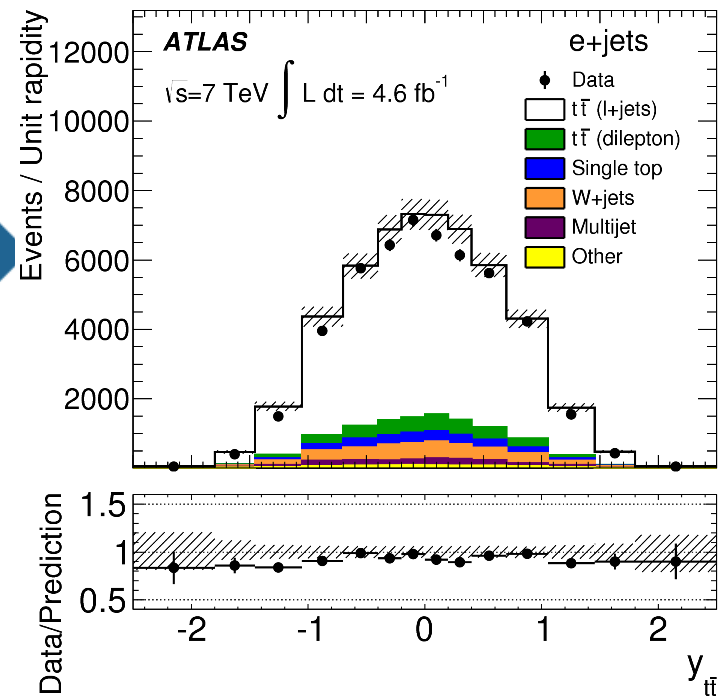
detector dependent modeling

The unfolding "journey"

(1) Event selection



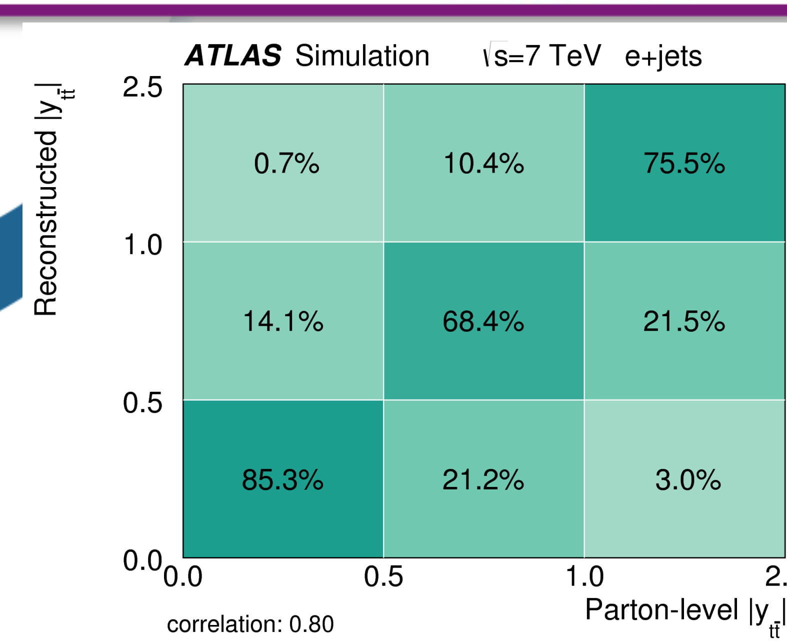
(2) tt̄ kinematic reconstruction



(3) Bin-wise cross section measurement

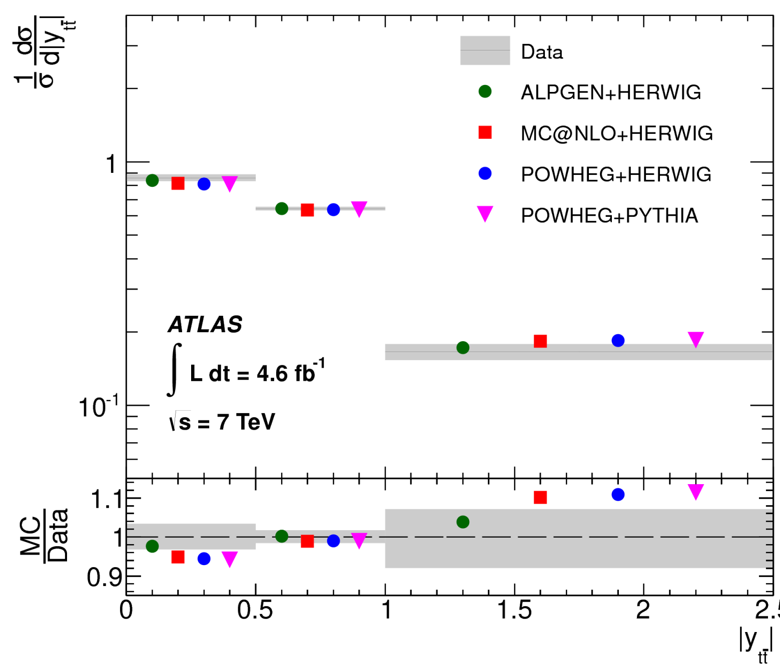
- Subtract background
- Unfolding: correct for detector effects and acceptance

$$\frac{1}{\sigma}\frac{d\sigma^i}{dX} = \frac{1}{\sigma}\frac{N^i_{\text{Data}} - N^i_{\text{BG}}}{\Delta^i_X \epsilon^i L}$$



Migration matrix: correct effects related to detector resolution

(4) Differential tt̄ cross sections



- **Compare** to **theory** predictions
- **Test** model of **new physics** that modify differential spectra