Measurement of the vector-boson transverse momentum distributions with ATLAS

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on behalf of the ATLAS Collaboration

Standard Model at the LHC 2021

PNPI - NRC KI

ATLAS EXPERIMENT

Introduction

Precision measurements of p_T^Z is important to:

- Test and tune QCD models:
  - ❑Analytical calculations (resummations)
  - ❑Different Monte-Carlo approaches
  - ❑Validate and tune MC event generators
- Constraint on p_T^W spectrum – important for W-boson mass measurement
- Important input to the background predictions from MC simulations used in many analyses (SM and BSM)

This talk will cover:

- Measurement of the transverse momentum distribution of Drell-Yan lepton pairs in proton-proton collisions at $\sqrt{s} = 13$ TeV with the ATLAS detector (Eur. Phys. J. C 80 (2020) 616)

ϕ^*_η definition

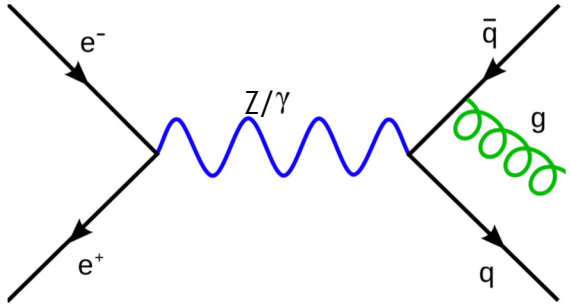
- Measurements of p_T^{ll} require a precise understanding of the transverse momentum p_T calibration and resolution of the final-state leptons
- Associated systematic uncertainties affect the resolution in p_T^{ll} and limit the ultimate precision of the measurements, particularly in the low-p_T domain
- New variable was introduced which depends exclusively on the directions of the two leptons, which are more precisely measured than their momenta.

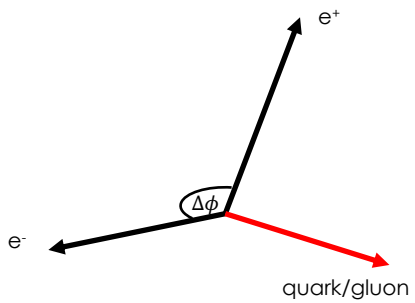
$$\phi^*_\eta = \tan\left(\frac{\pi-\Delta\phi}{2}\right) * \sin(\theta^*_\eta)$$

$$\theta^*_\eta = \arccos(\tanh(\frac{\eta^- - \eta^+}{2}))$$

- Approximate relationship:

$$\sqrt{2} m_Z \phi^*_\eta \approx p_T^{ll}$$





p_T of Drell–Yan lepton pairs at 13 TeV

Data

2015 and 2016 dataset (36.1 fb^{-1}) at 13 TeV is used.

Signal

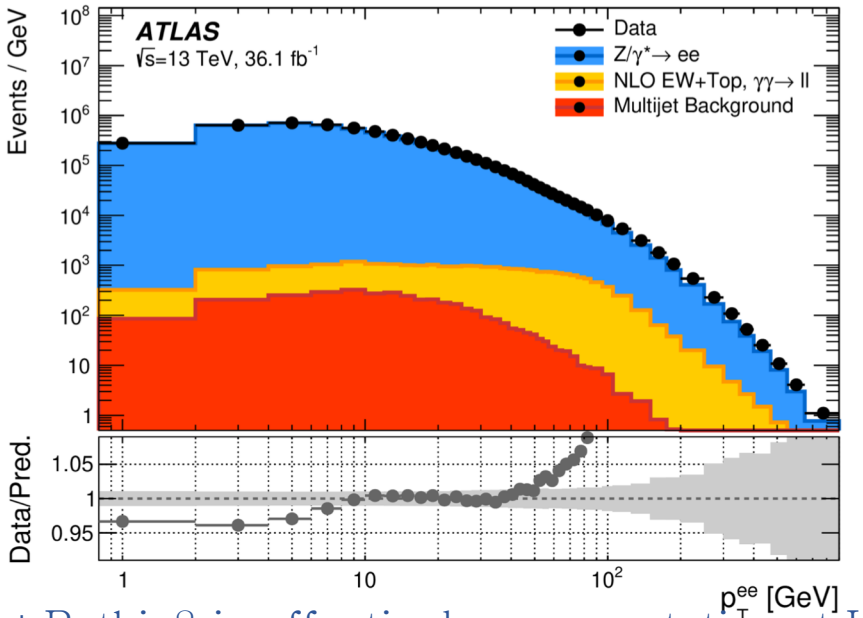
Powheg+ Pythia8

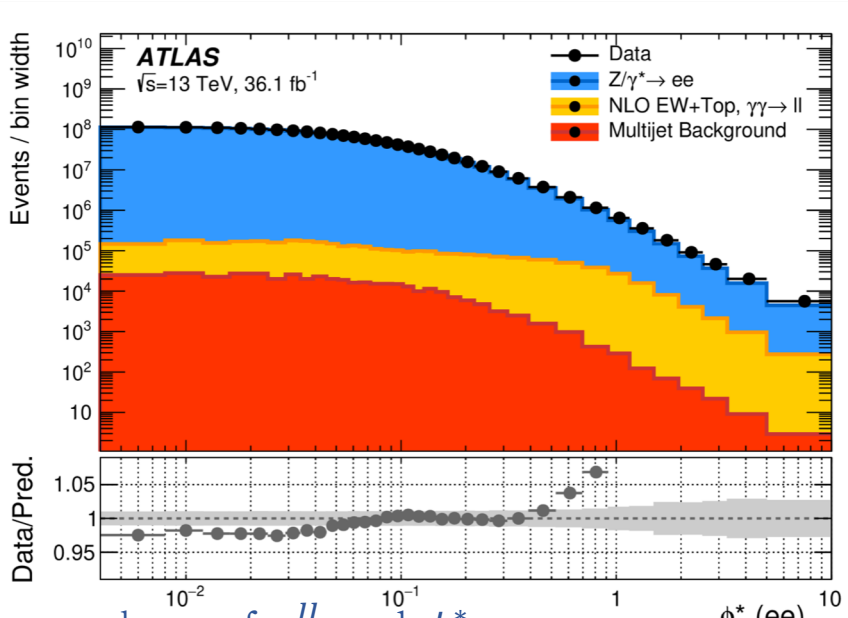
Background

- EW, top, $\gamma\gamma$ from MC
- Multijet – data-driven

Selection

Single lepton trigger,
Isolated leptons, $p_T > 27\ GeV$,
$|\eta_e| < 2.47, excluding\ 1.37 < |\eta_e| < 1.52$
$|\eta_\mu| < 2.5, 66 < m_{ll} < 116\ GeV$



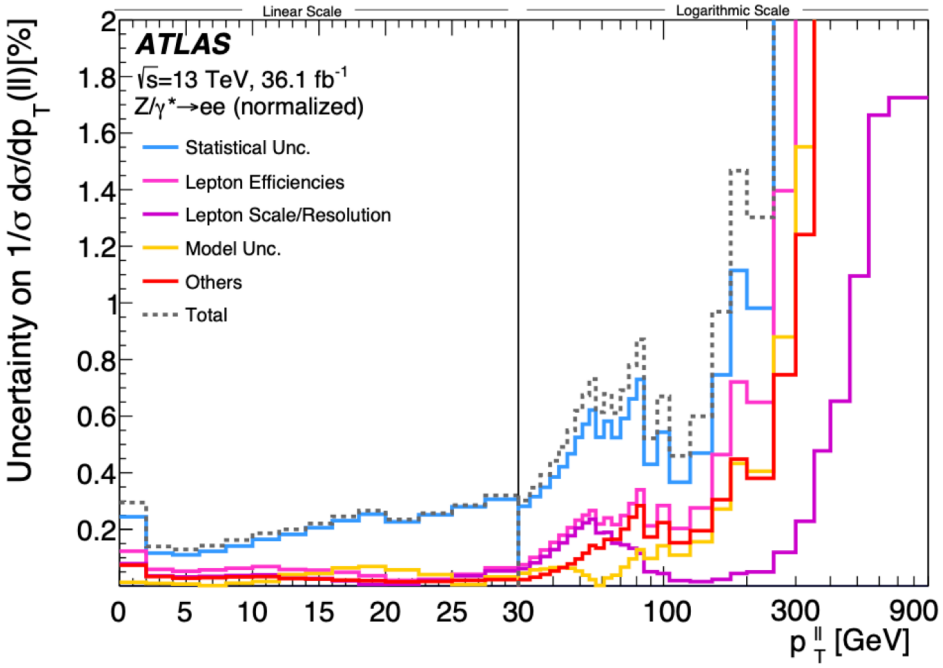


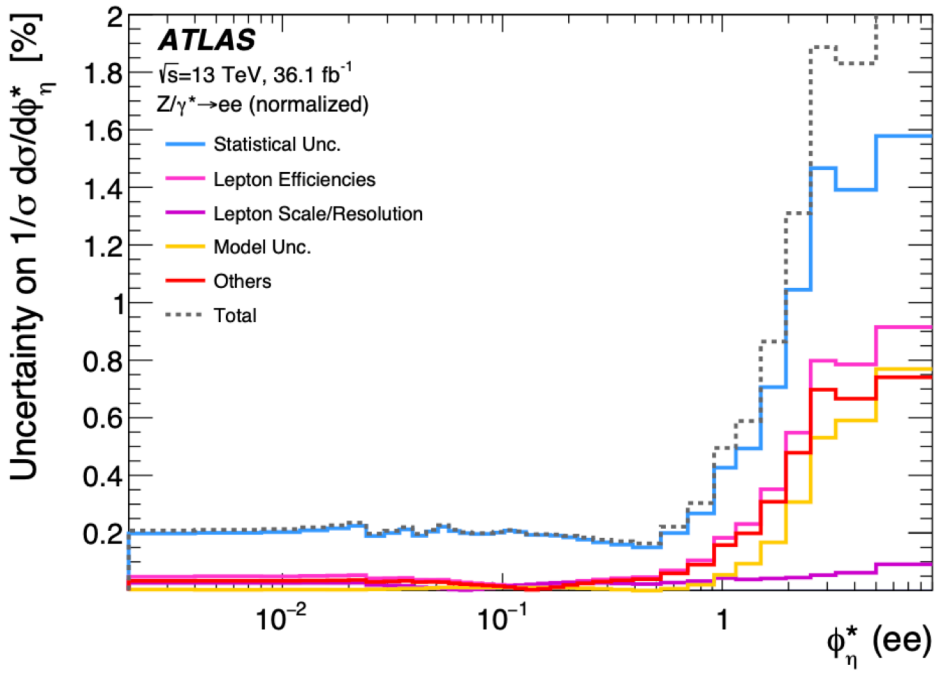
Powheg+ Pythia8 is effectively a computation at LO in α_s for large values of p_T^{ll} and ϕ_η^* – disagreement is expected.

Uncertainties: $p_T^{ll}(ee)$ and $\phi_\eta^*(ee)$

- Differential distributions within the fiducial volume are corrected for detector effects and bin-to-bin migrations using an iterative Bayesian unfolding method

$$p_T^l > 27\ \text{GeV}, |\eta_l| < 2.5, 66 < m_{ll} < 116\ \text{GeV}$$





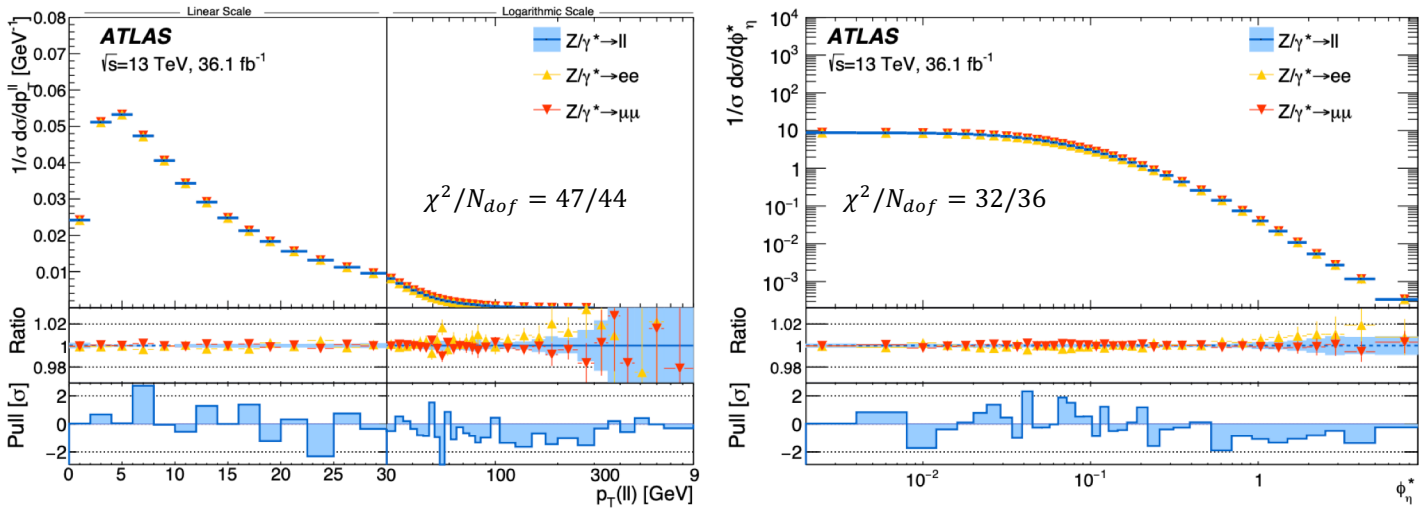
- Statistical uncertainties are dominant source
- High values of ϕ_η^* have smaller impact if compared to the high p_T^{ll} values

Combination of results

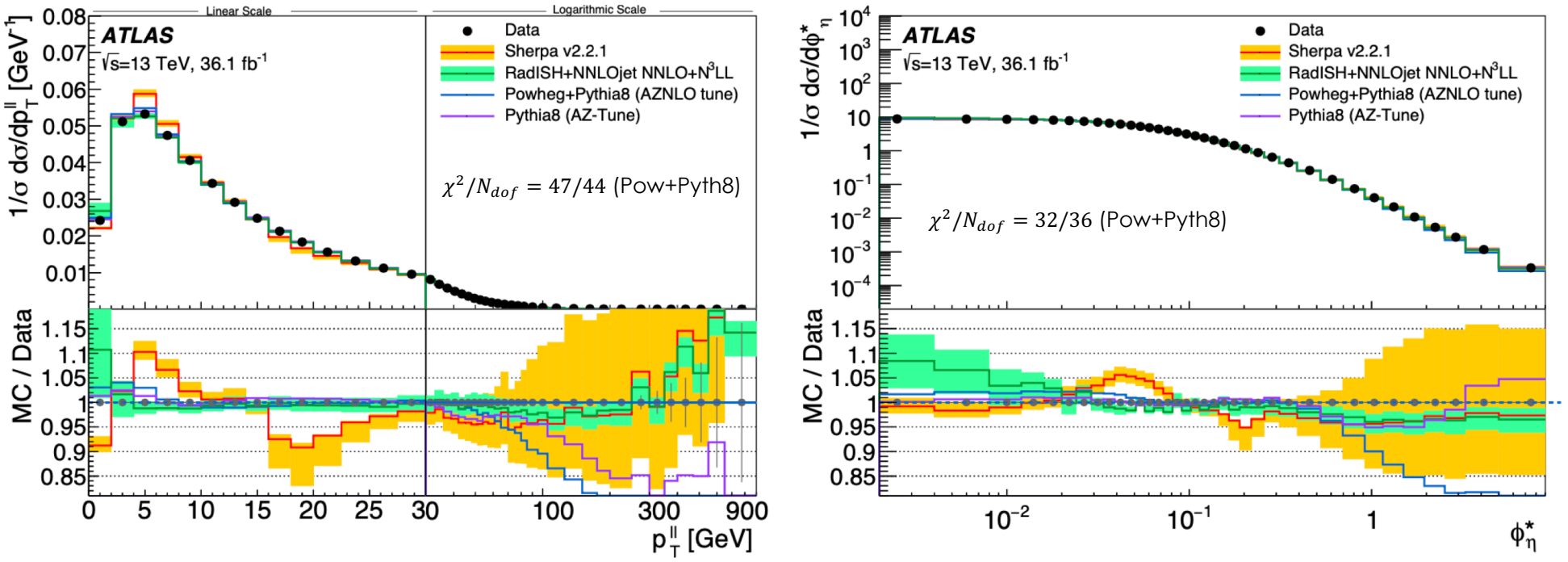
- Measurements performed separately in the electron and muon decay channels
- Results unfolded at born and dressed levels
- Two channels are combined (at born level) using χ^2 minimization, following the best linear unbiased estimator (BLUE) prescription
- Good agreement between channels
- Results on dressed level are about 2.4% lower compared to the Born level definition

Channel	Measured cross-section $\times\ \mathcal{B}(Z/\gamma^* \to \ell\ell)$ (value $\pm$ stat. $\pm$ syst. $\pm$ lumi.)	Predicted cross-section $\times\ \mathcal{B}(Z/\gamma^* \to \ell\ell)$ (value $\pm$ PDF $\pm\ \alpha_S \pm$ scale $\pm$ intrinsic)
$Z/\gamma^* \to ee$	$738.3 \pm 0.2 \pm 7.7 \pm 1$	
$Z/\gamma^* \to \mu\mu$	$731.7 \pm 0.2 \pm 11.3 \pm 1$	
$Z/\gamma^* \to \ell\ell$	$736.2 \pm 0.2 \pm 6.4 \pm 1$	$703^{+19}_{-24}\ ^{+6}_{-8}\ ^{+4}_{-6}\ ^{+5}_{-5}$ pb

arXiv:1612.03636

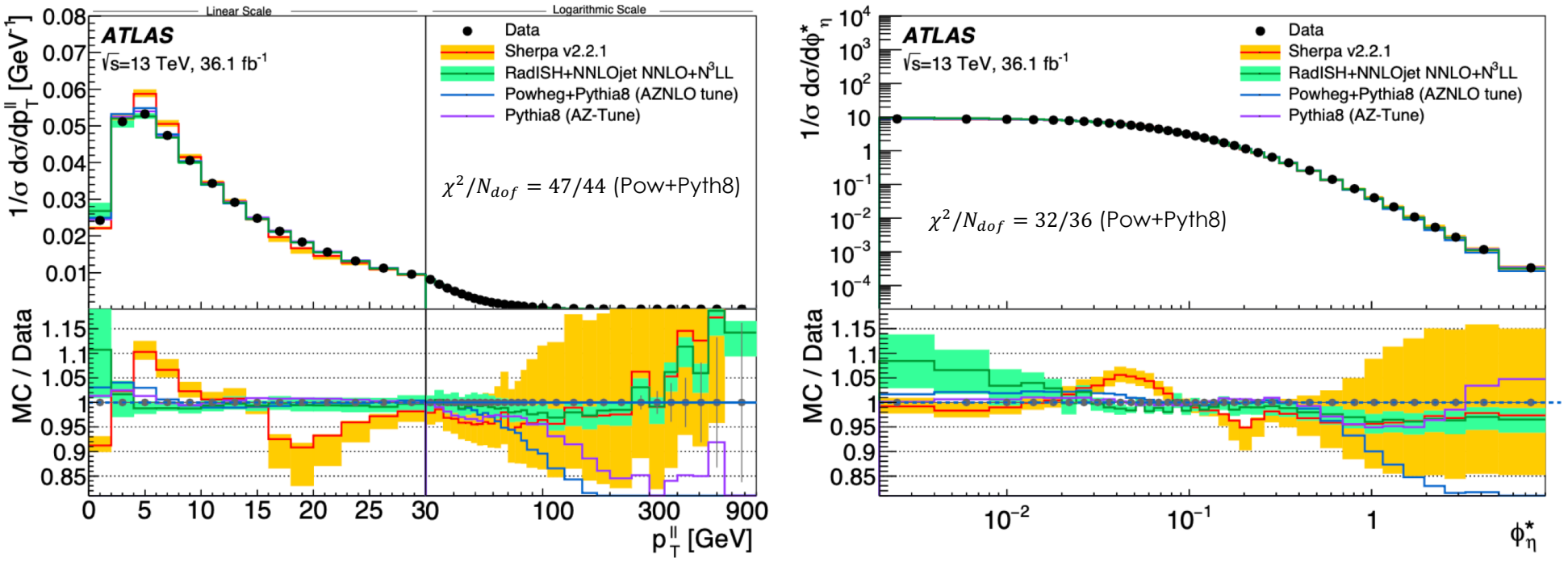


Comparison with theory predictions



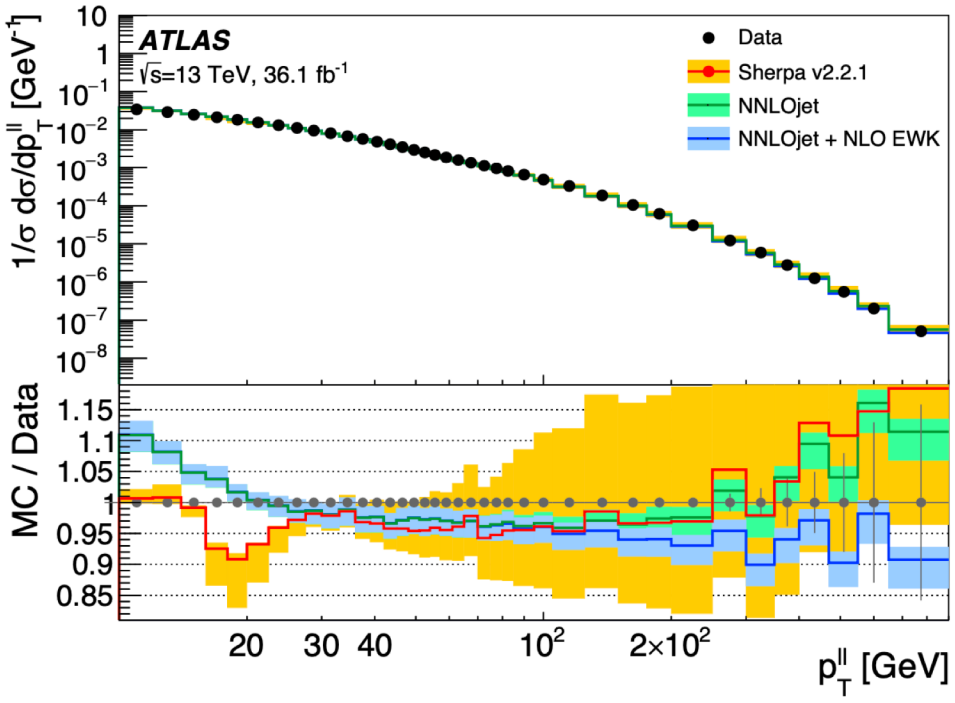
- Pythia 8 with ME at LO supplemented with a PS with AZ set of tuned parameters (optimized for 7 TeV data)
- Powheg+ Pythia8 using NLO ME and PS with AZNLO tune (optimized for 7 TeV data)
- Sherpa v2.2.1 – NLO-accurate ME for up to two partons and LO-accurate ME for up to four partons
- RadISH – combines a fixed-order NNLO prediction of Z+ jet production from NNLOJET with resummation of $\log(m_{ll}/p_T^{ll})$ terms at N^{3}LL accuracy

Comparison with theory predictions



- The predictions based on the Pythia8 are found to describe the 13 TeV data well at low p_T and ϕ_η^*
- The Sherpa prediction gives good description of the data at high p_T (about 4%)
- RadISH NNLO+ N^{3}LL prediction agrees with data for the full spectrum

Comparison with theory predictions



- NNLOjet: order $\alpha_s{}^3$, expected to describe well data only from p_T >15 GeV, overprediction at high p_T
- NNLOjet+ NLO EWK: EW corrections lead to a suppression at high p_T
- Both discrepancies are within uncertainties on the measurement

Summary

- Cross-sections differential in the transverse momentum of Z boson were measured covering up to TeV-range
- Relative precision is better than 0.2% (combined result, $p_T < 30$ GeV)
- Important information for validation/tuning of MC generators and measurements of W mass
- Pythia8 PS with parameters tuned to 7 TeV ATLAS data found to describe the 13 TeV data well at low p_T and ϕ_η^*

Thank you for your attention