Measurements of transverse momentum of Z Boson with low pileup dataset

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On behalf of low mu analysis team

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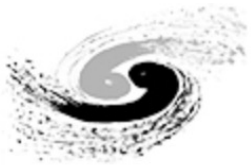

Institute of High Energy Physics
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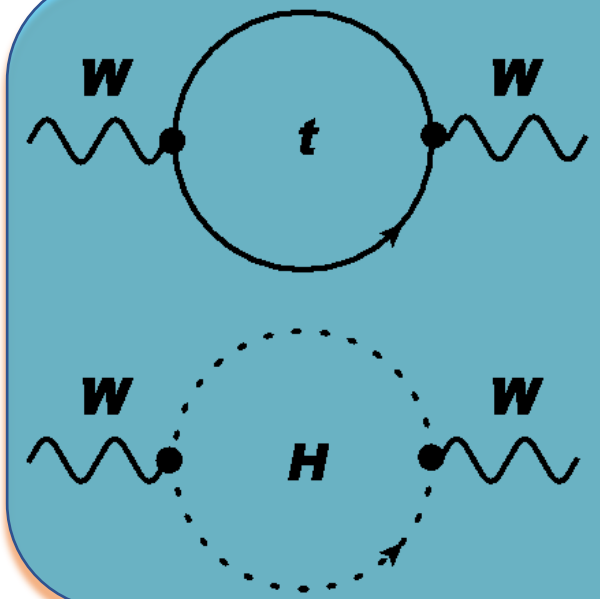
ATLAS EXPERIMENT

Outline

- Motivation for p_T^Z measurement
- Low-pileup dataset
- Transverse momentum measurement strategy
- Uncertainty estimation
- Results
- Summary

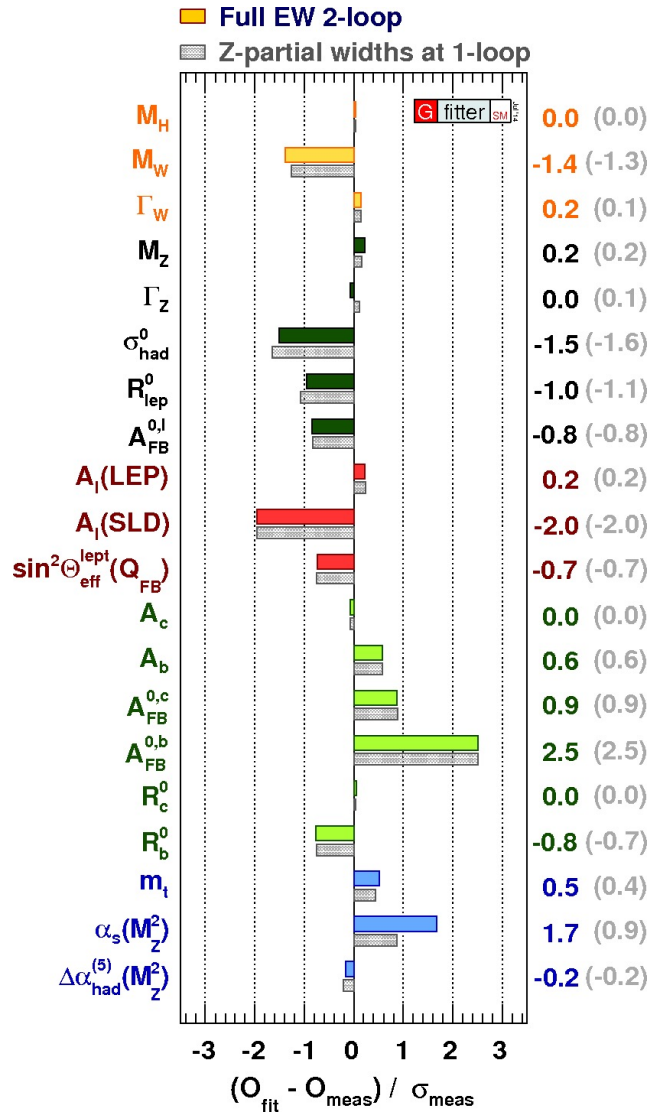
Importance of W mass measurement

Improving the precision of the m_W measurement is an important test of SM, and is sensitive to new physics.

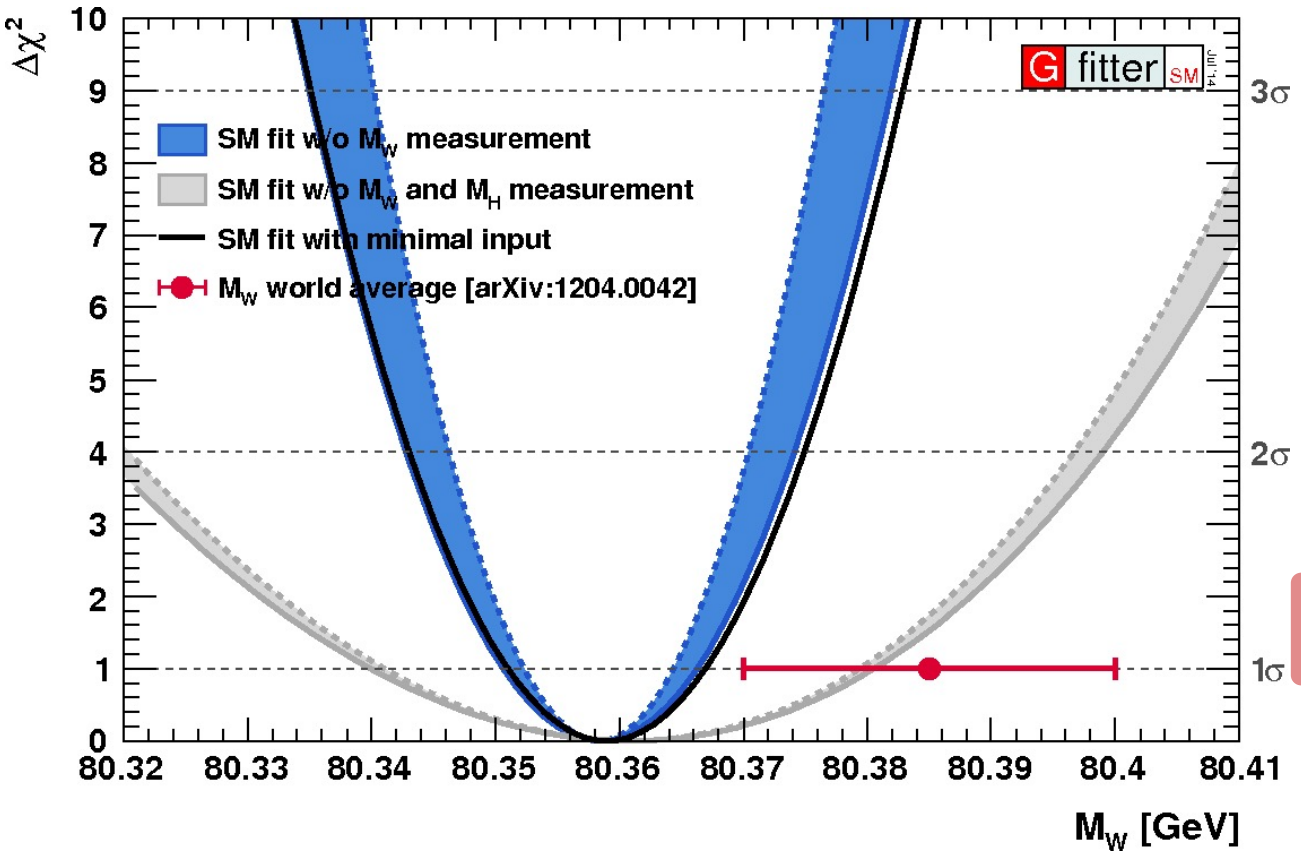


$$m_W^2\left(1-\frac{m_W^2}{m_Z^2}\right)=\frac{\pi\alpha}{\sqrt{2}G_\mu}(1+\Delta r),$$

Δr incorporates the effect of higher-order corrections. In the SM, Δr is particularly sensitive to the top-quark and Higgs-boson masses.



W mass precision measurement



m_W is one of the key parameter of the SM

$$\sin^2\theta_W = 1 - \left(\frac{M_W}{M_Z}\right)^2$$

m_W (EW fit) = 80.363 ± 0.007 GeV

PDG World Average:
$m_W =$
80379 ± 12 MeV

Tevatron: $m_W =$ 80387±16 MeV

ATLAS 7 TeV high μ run: $m_W = 80370 \pm 19$ MeV

Latest LHCb measurement:
$m_W = 30354 \pm 32$ MeV

Uncertainty of previous m_W measurement with ATLAS

W mass measurement with ATLAS at 7 TeV [arXiv:1701.07240]

Stat. Unc. (MeV)	Exp. Syst. Unc. (MeV)	Modelling Unc. (MeV)	Total Uncertainty (MeV)
6.8	10.6	***13.6***	18.5

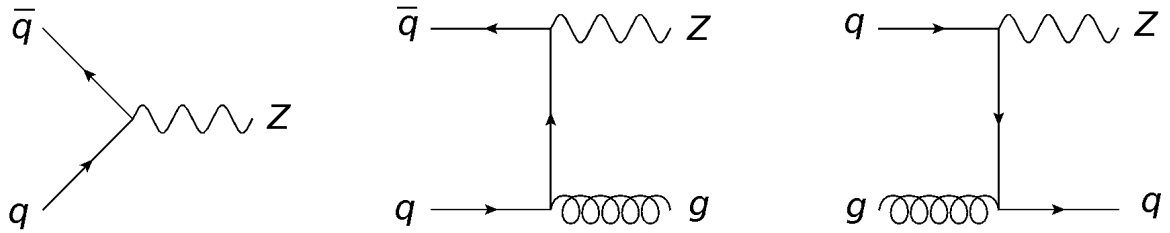
QCD Unc. ***8.3 MeV***	EW Unc. 5.5 MeV	PDF Unc. 9.2 MeV

m_W Unc. is dominated by QCD and PDF Unc.

QCD Unc. mainly comes from mismodelling of p_T^W < 30 GeV.

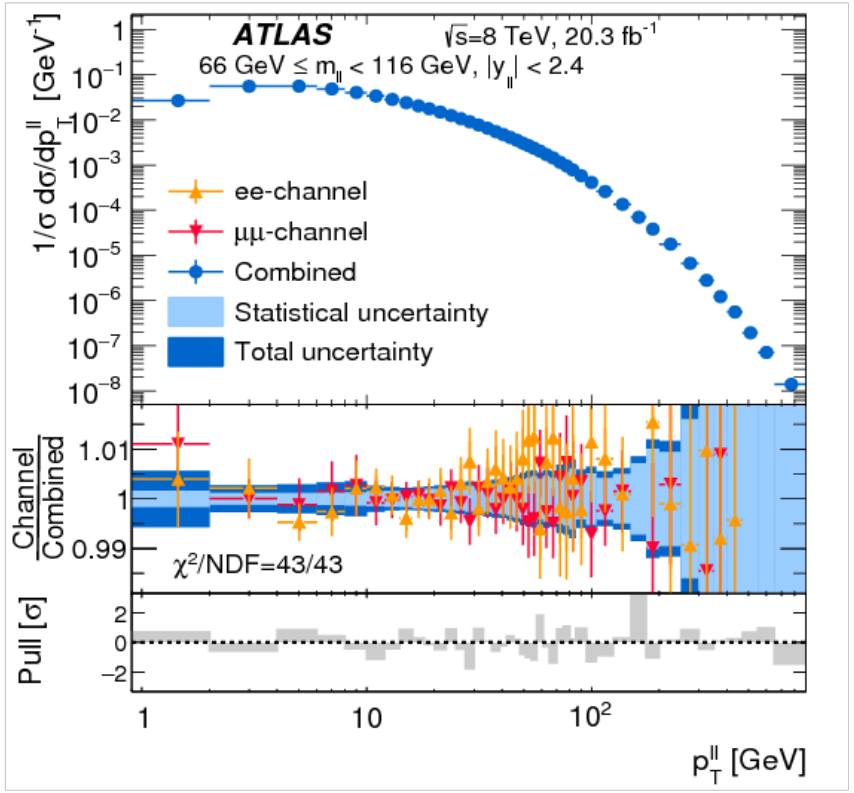
Motivation for p_T^Z measurement

Z boson is produced with non-zero p_T



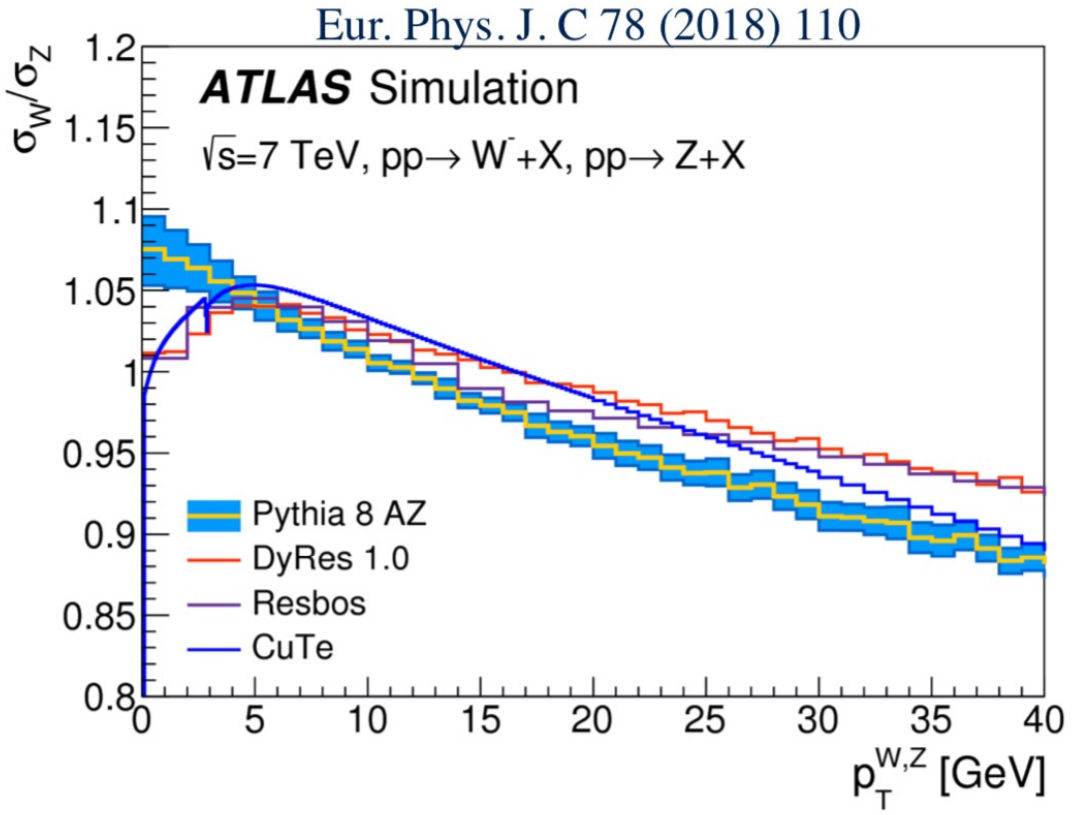
Precision p_T^Z measurement is an excellent probe of QCD, PDFs and Parton shower models.

arXiv:1512.02192

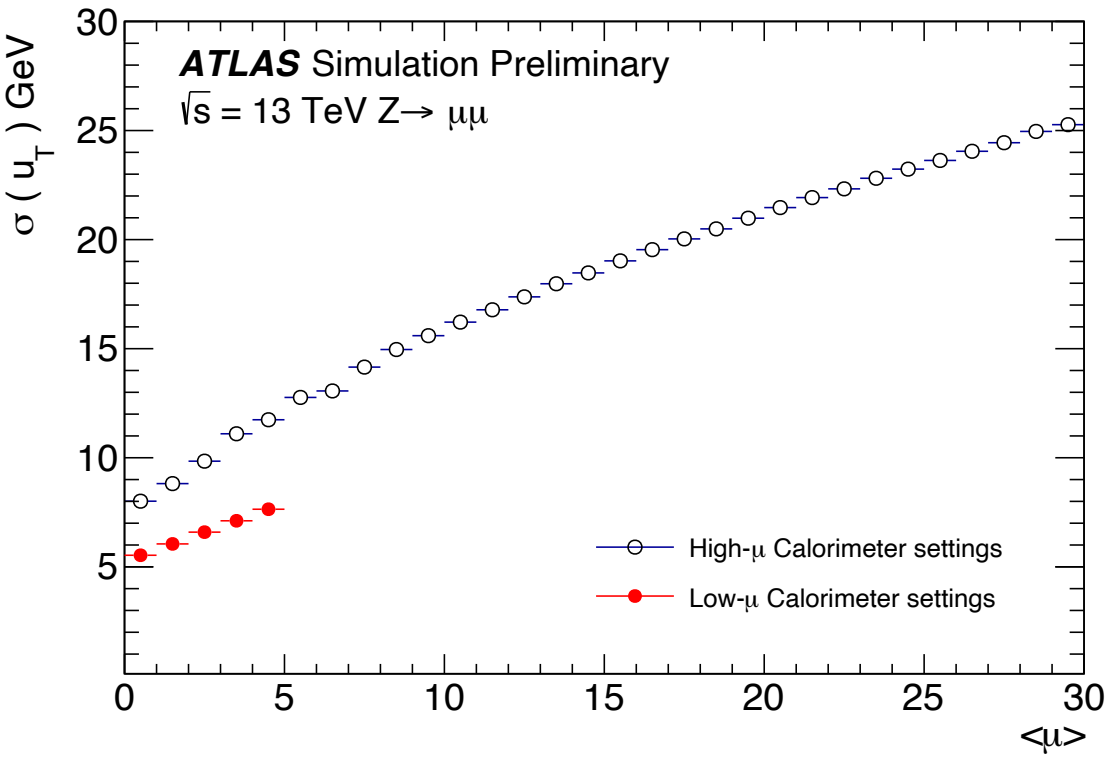


Low- μ dataset is fantastic opportunity to have first p_T^Z measurement at 5TeV with ATLAS!

W/Z p_T ratio modelling and measurement

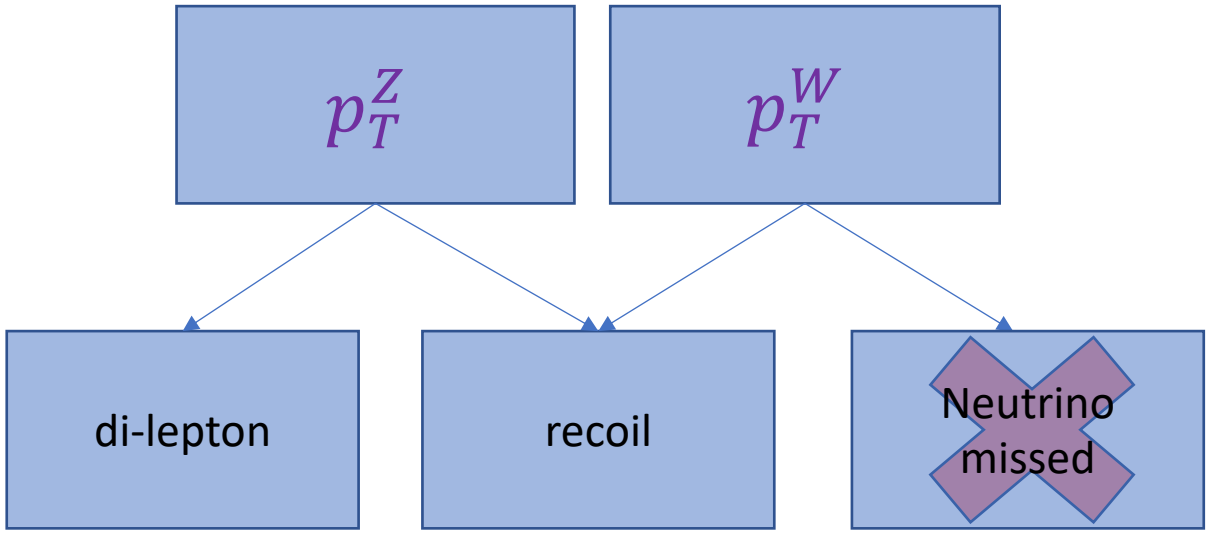


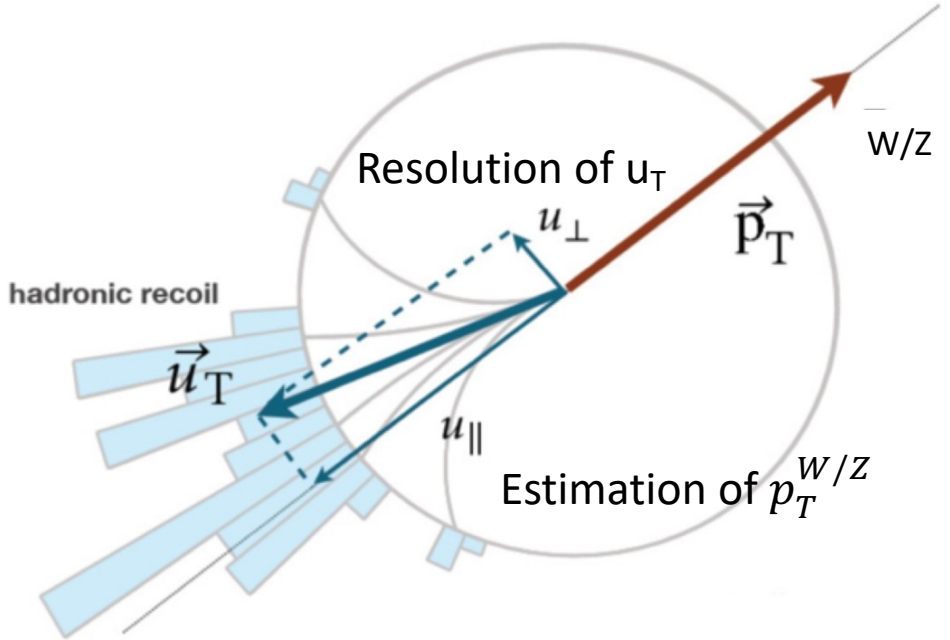
W/Z p_T measurements disagree with theoretic predictions



Pileup degrades measurement of the W/Z recoil.

The nice feature of p_T^Z measurement

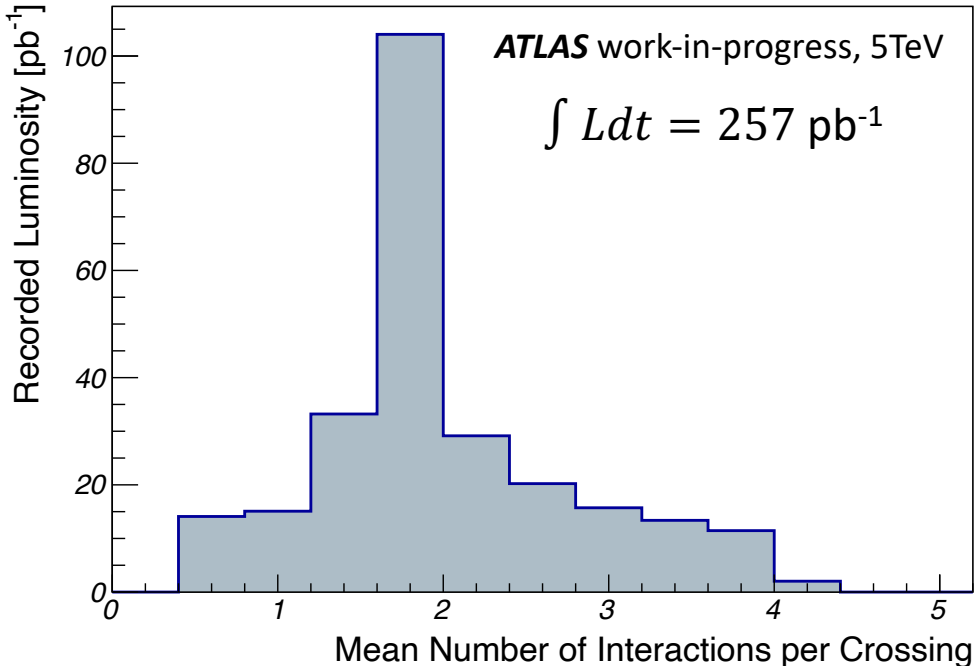


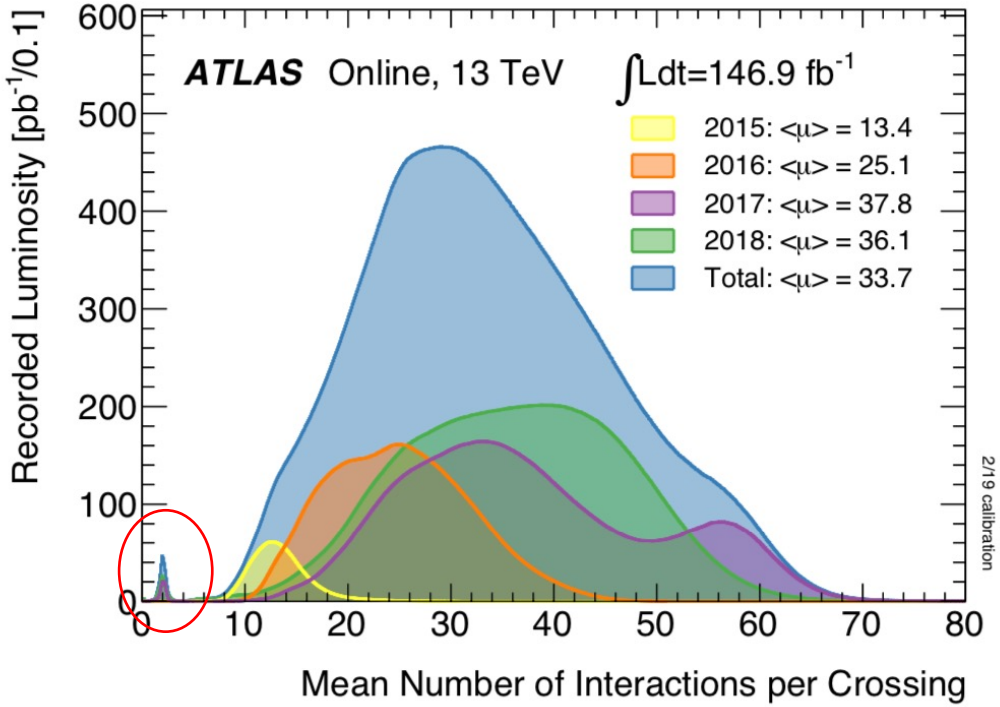


We measure p_T^Z using the lepton system and and validate had-recoil method for p_T^W measurement

Low pileup dataset

Pile-up: < μ >~ 2



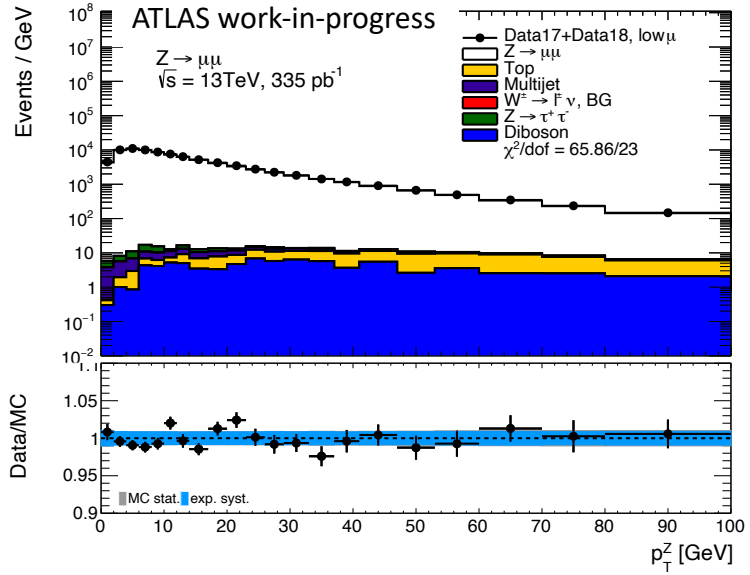


- **2017**:
  $\sqrt{s}$ = 5 TeV: 257 pb^{-1}

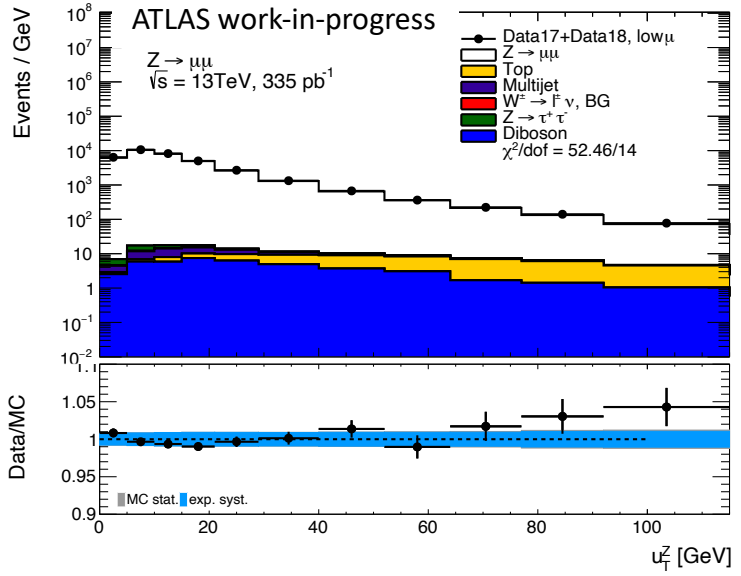
- **2017+2018**:
  $\sqrt{s}$ = 13 TeV: 335 pb^{-1}

Selections and background estimations

	Tracker acceptance	Isolation	ID operating point	Impact parameter	Kinematics
$Z \to e^+e^-$	$\|\eta\| < 2.47$, excluding crack $1.37 < \|\eta\| < 1.52$	$\frac{p_T^{\Delta R=0.2}}{p_T^l} < 0.1$	Medium LH	$\frac{d_0}{\sigma d_0} < 5, \Delta Z_0 * sin\theta < 0.5$	$p_T^l > 25\ GeV$ $66\ GeV < m_{ll} < 116\ GeV$
$Z \to \mu^+\mu^-$	$\|\eta\| < 2.4$		Medium	$\frac{d_0}{\sigma d_0} < 3, \Delta Z_0 * sin\theta < 0.5$	



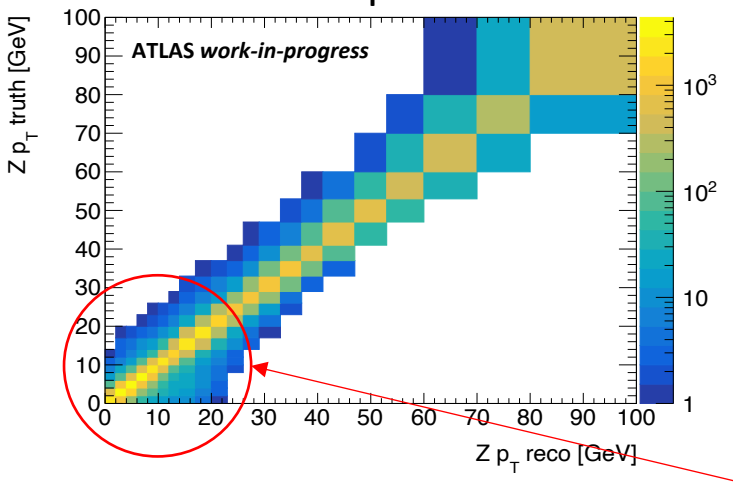
Measurement of p_T through di-leptons



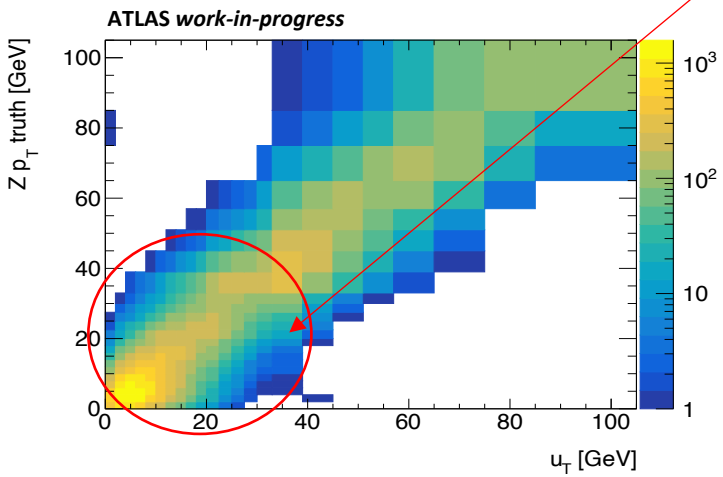
Estimation of p_T^Z using recoil

Bayesian unfolding strategy

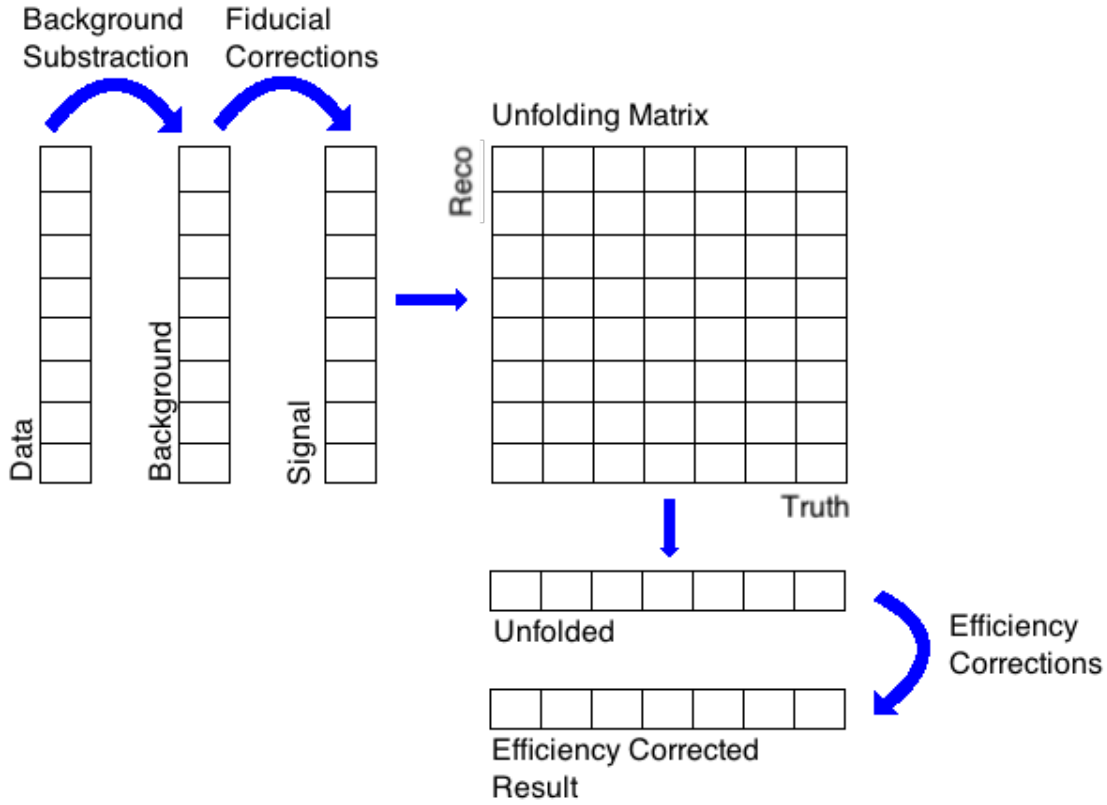
di-lepton



Hadronic recoil



Recoil resolution is much worse than di-lepton resolution.

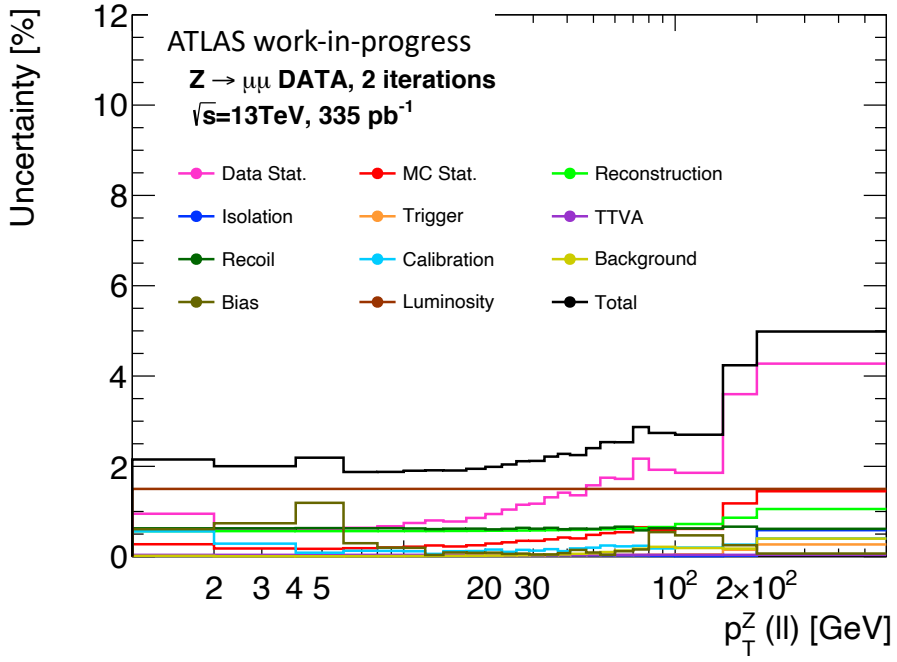


Unfolding procedure using Bayes' theorem

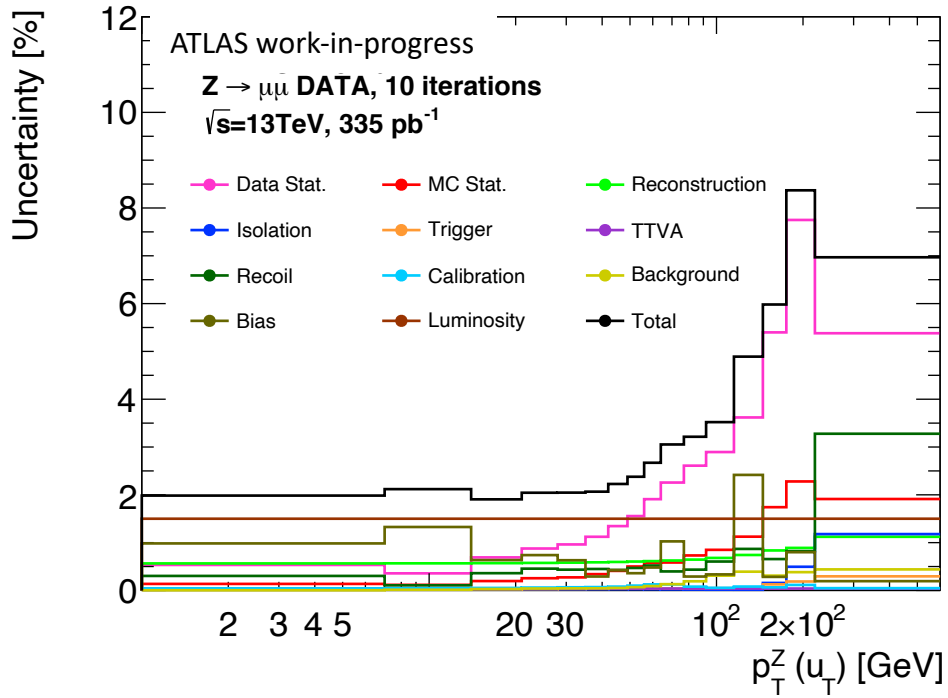
$$(P_{truth}|P_{reco}) = \frac{P(n_{reco}|n_{truth})P_{prior}(n_{truth})}{\Sigma_{n_{truth}} P(n_{reco}|n_{truth})P_{prior}(n_{truth})}$$

Uncertainty estimations

uncertainty of p_T through di-leptons

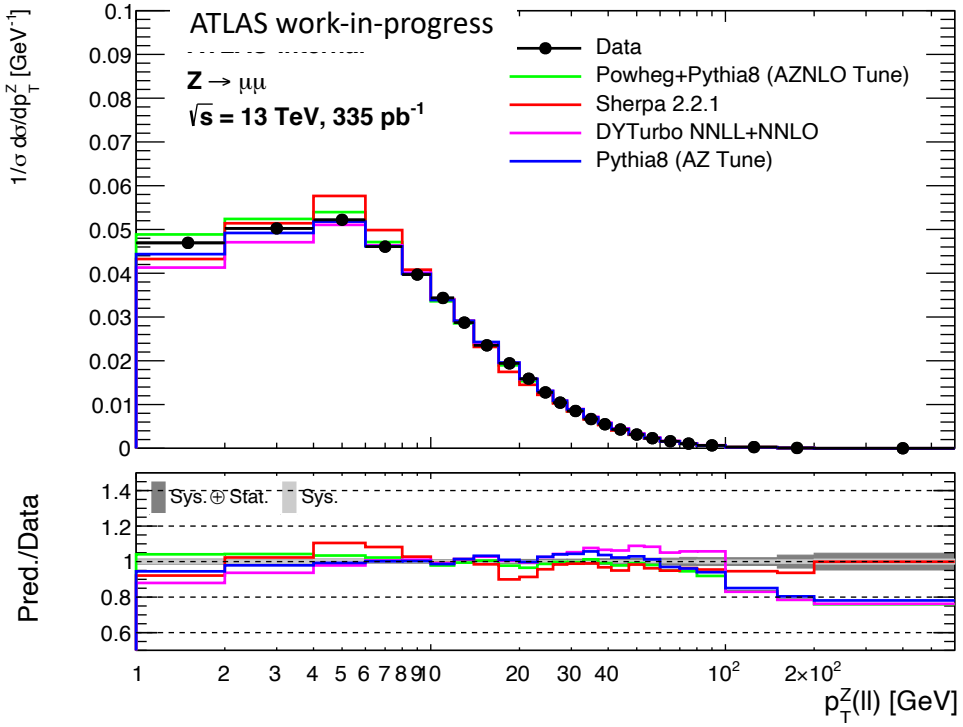


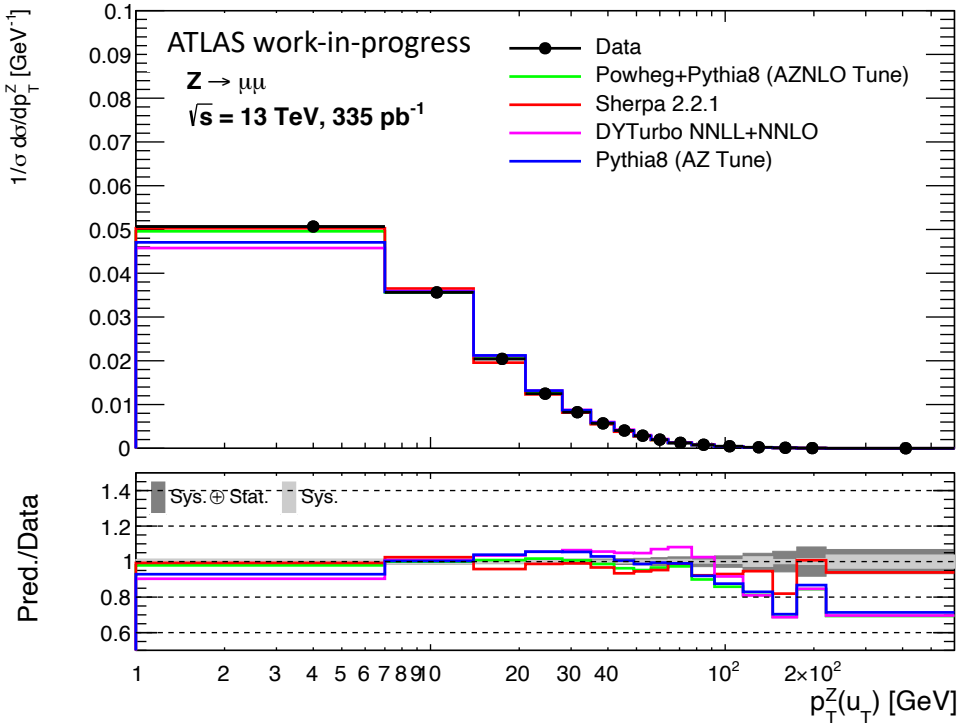
uncertainty of hadronic recoil u_T



- Luminosity uncertainty is 1.5%.
- Statistic uncertainty and unfolding bias uncertainty are the main contributions to overall uncertainty.

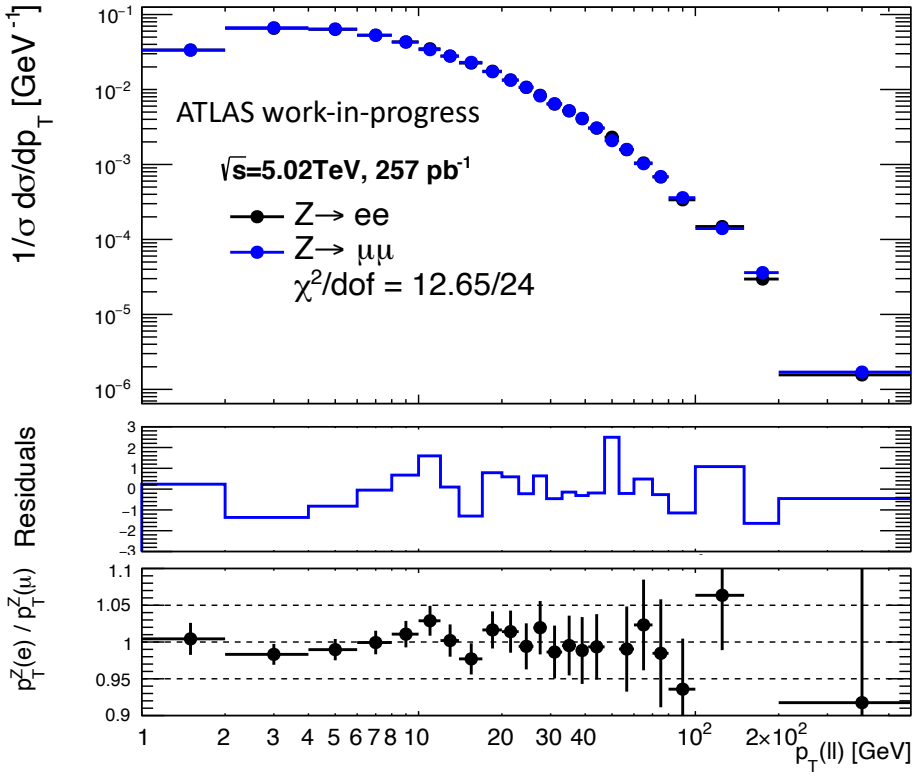
Unfolded results compared to predictions

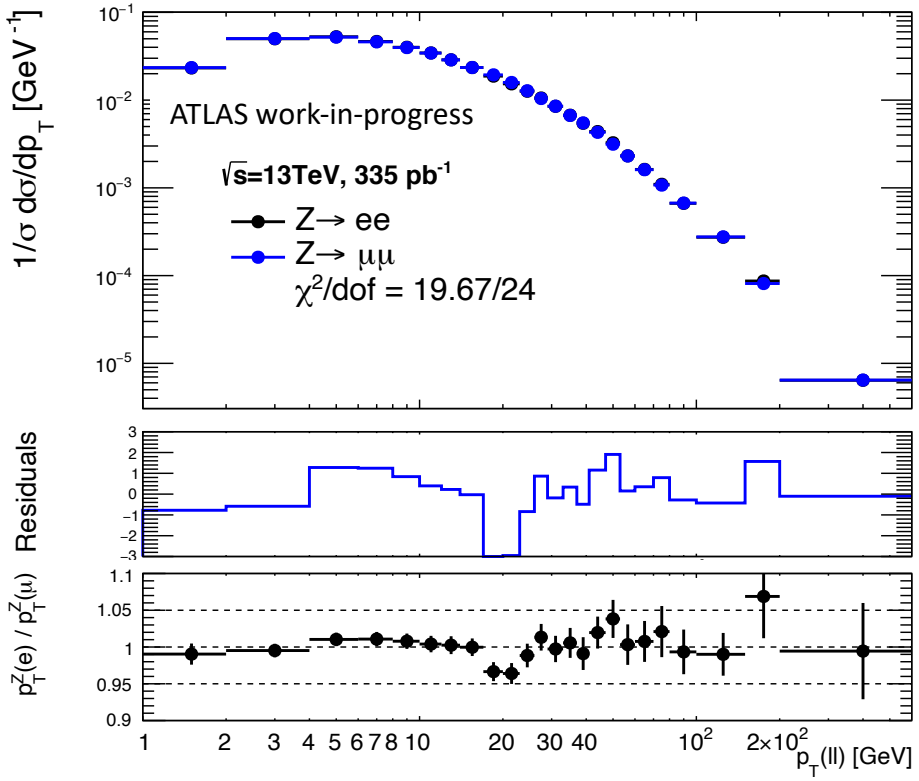




- Powheg+Pythia8 (AZNLO tune) is the best describing data in low pT region.
- Sherpa predicts the high pT region better.

Channels compatibility

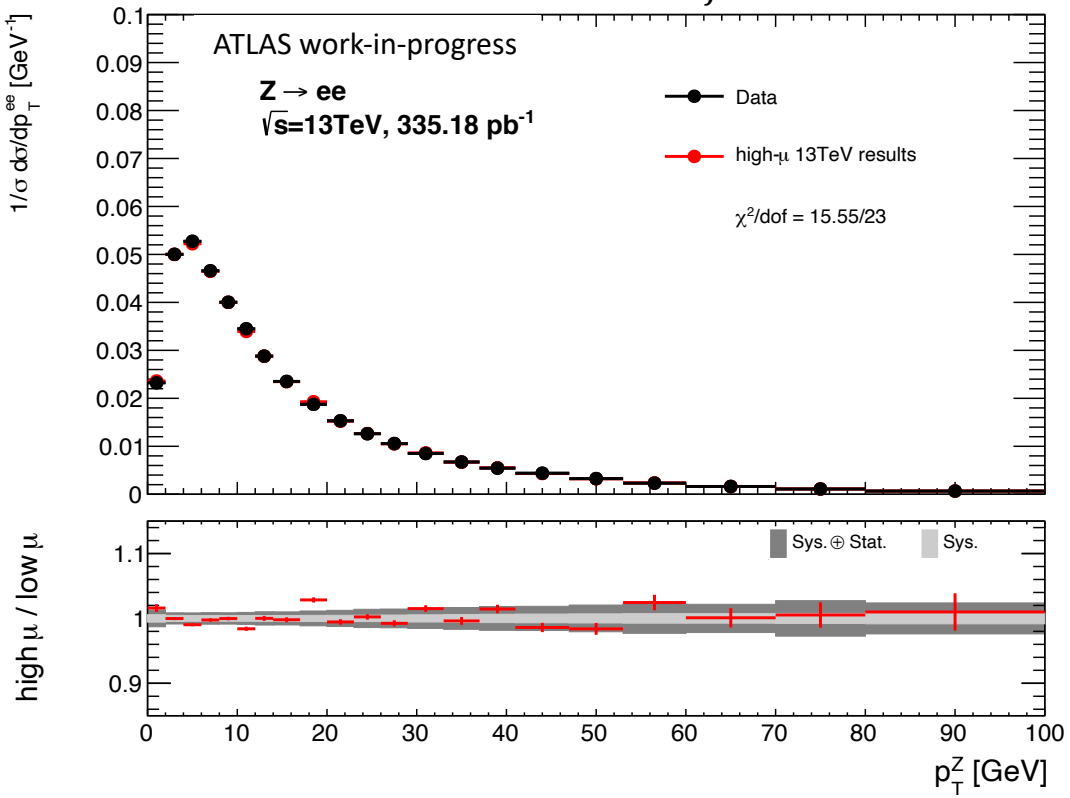




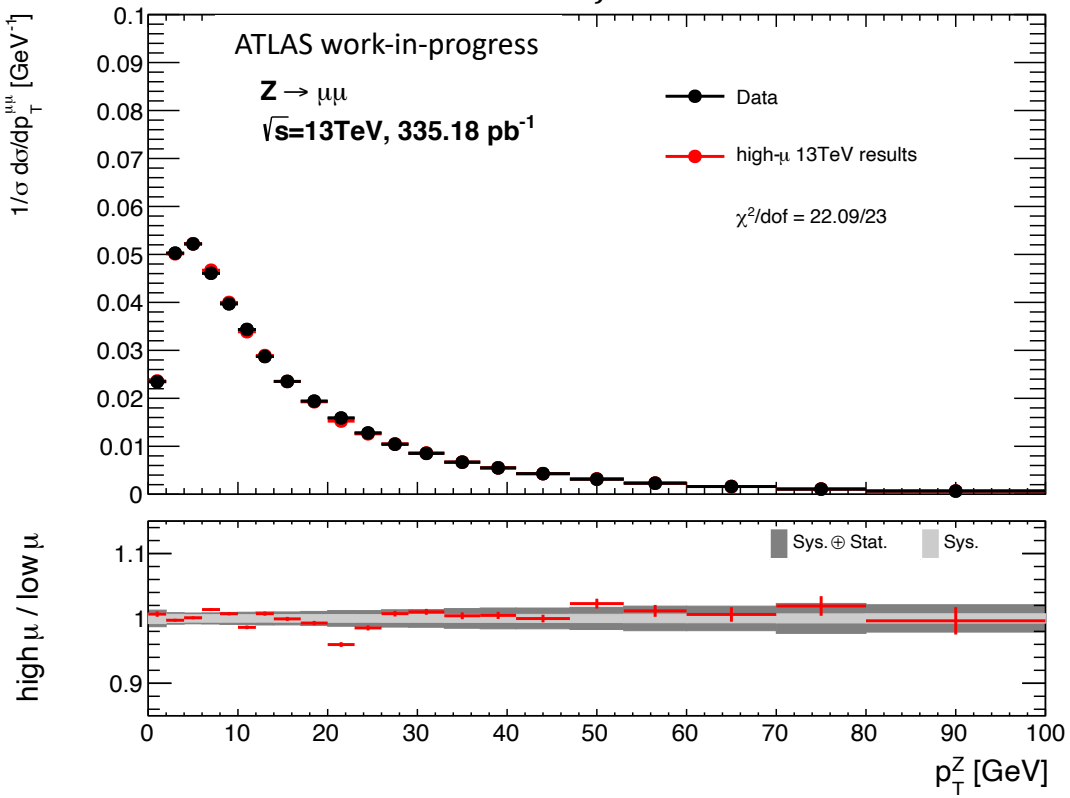
- Electron and muon channel results are in good agreement.

Compare with previous ATLAS 13TeV pT measurement

Electron channel: $\frac{\chi^2}{dof} = 0.68$



Muon channel: $\frac{\chi^2}{dof} = 0.96$



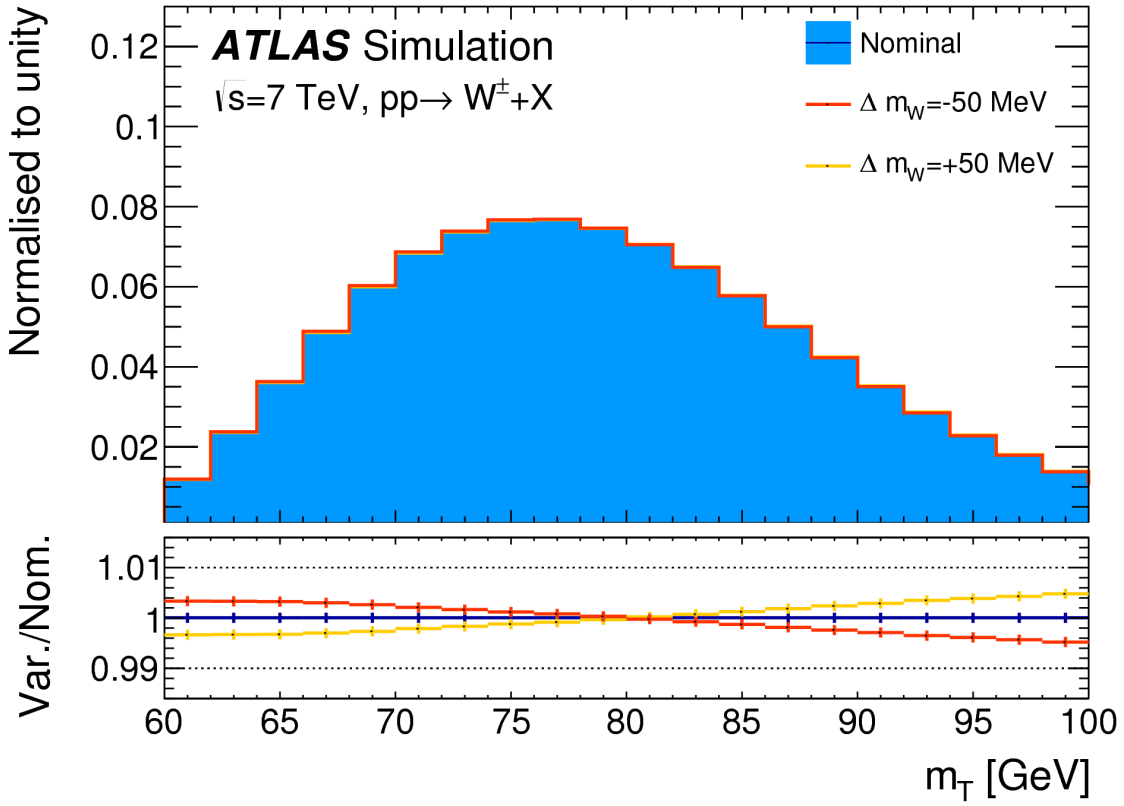
Our results are in good agreements with previous ATLAS p_T^Z measurements at 13 TeV

Previous pT paper: arxiv:1912.02844

Towards W mass measurement

How to measure W mass:

- Build MC templates for observables which depend on the W mass ($p_T^l, m_T^W = \sqrt{2p_T^l p_T^\nu (1 - cos\varphi_{l\nu})}$)
- Fit the χ2 distribution with a parabola to get the minimum which corresponds to the m_W.
- Good p_T^W and p_T^Z measurements are important inputs to W mass measurement.



Summary

- Results of p_T^Z measurements using low-pileup dataset at 5 and 13 TeV are presented. This is crucial input for W mass measurement.

- We plan to publish a p_T^W and p_T^Z paper for in 2022. Then the group will go working on the W mass measurement based on the studies.