

Status report of the IJCLab/USTC ATLAS project with new results using Runs 2 and 3 data

Xiaowen Su on behalf of the IJCLab/USTC team

14th Workshop of France China Particle Physics Laboratory, Nov. 7, 2023

Current members

French Group			Chinese Group		
Name	Title	Affiliation(Institute)	Name	Title	Affiliation(Institute)
<i>Leader</i> Zhiqing Zhang	Dr	IJCLab	<i>Leader</i> Haiping Peng	Pr	USTC
Xiaowen Su	PhD	IJCLab-USTC	Xiaowen Su	PhD	IJCLab-USTC
Juan Tafoya	PhD	IJCLab	Yingchun Zhu	Ass. Pr	USTC
Louis Fayard	Dr	IJCLab	Xin Chen	Pr	THU

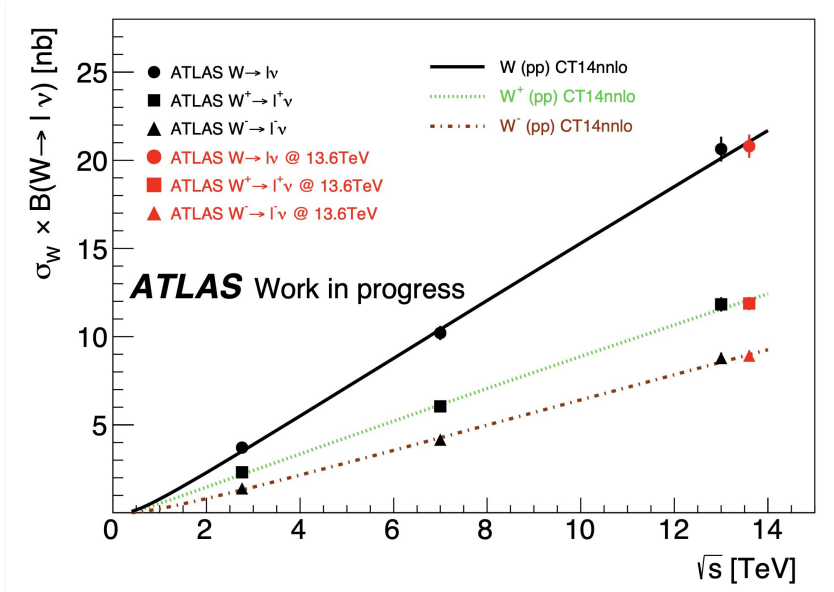
Overview

- **Two thesis defenses:**
 - Kunlin Han 2022
 - Juan Tafoya 2023
- **Three ATLAS publications:**
 - Generic search in multiple final states associated with a Z boson with full run 2 data at 13 TeV ([JHEP 06 \(2023\) 036](#)) - thesis work of Kunlin HAN
 - Top pair production cross section and its ratio with Z production cross section at 13.6 GeV ([arXiv:2308.09529](#))
 - Electron and photon efficiencies in LHC Run 2 with the ATLAS experiment ([arXiv:2308.13362](#))
- **Several ongoing analyses:**
 - Measurement of p_T distributions of the vector boson production at 5 and 13 GeV
 - **Measurement of differential cross sections of the W boson at 5 and 13 TeV**
 - **Measurement of production cross sections of vector bosons and their ratios at 13.6 TeV**
 - First joint analysis of PDFs and EW parameters at the LHC

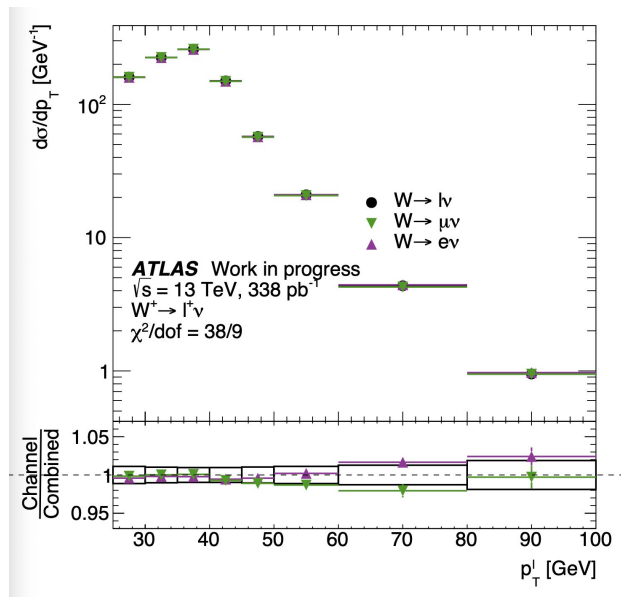
Showing in red is the focus of the talk

Precision measurements of electroweak parameters

Early run3 W/Z analysis

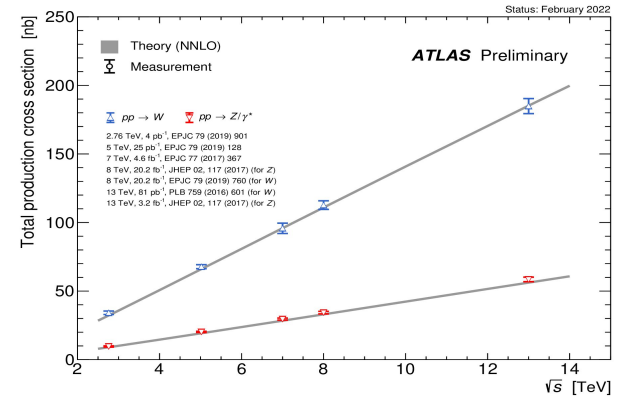


W differential cross-section with low pileup dataset



Overview

- The inclusive vector boson production cross sections and their ratios measured using full 2022 run 3 data ($\sim 29\text{fb}^{-1}$)
- **Motivation:**
 - Validate the detector performance
 - Test SM predictions at $\sqrt{s}=13.6\text{TeV}$

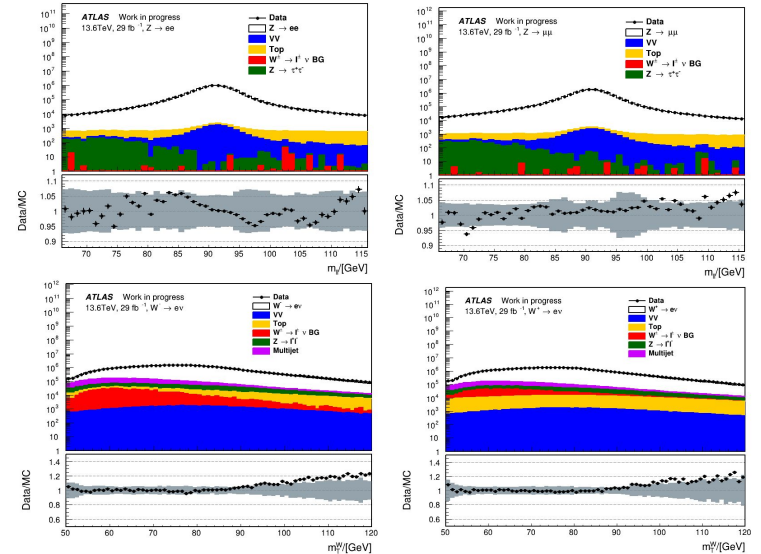


Fiducial phase space:

- Born lepton $p_T > 27\text{GeV}$, $|\eta| < 2.5$
- **Z:** $66 < m_{ll} < 116\text{GeV}$, **W:** $p_T^V > 25\text{GeV}$, $m_T^W > 50\text{GeV}$

Event Selection:

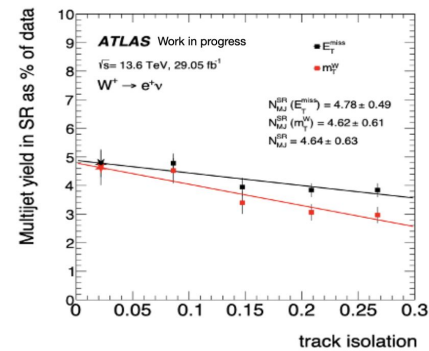
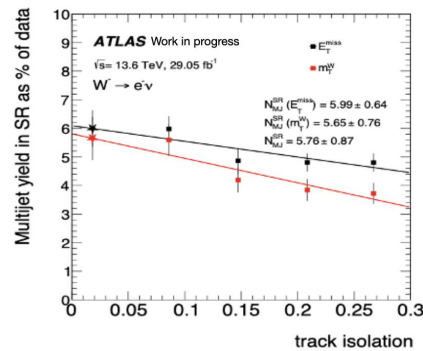
- Lowest unrescaled single lepton triggers
- **Electron:** $p_T > 27\text{GeV}$, $|\eta| < 2.47$, barrel-endcap crack veto
- **Muon:** $p_T > 27\text{GeV}$, $|\eta| < 2.5$
- **Z:** 2 OSSF leptons, $66 < m_{ll} < 116\text{GeV}$
- **W:** only 1 lepton, $E_T^{\text{miss}} > 25\text{GeV}$, $m_T^W > 50\text{GeV}$



Multijet

- Multijet background is estimated using data-driven method
- Define event categories corresponding to different regions in phase space and isolation
- Scan track isolation to reduce the bias of isolation variable
- Consistent MJ yields are obtained using different methods

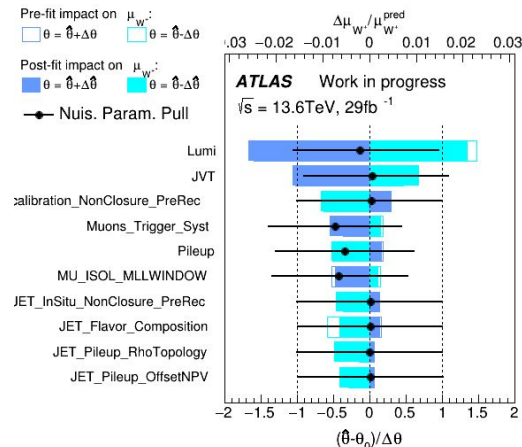
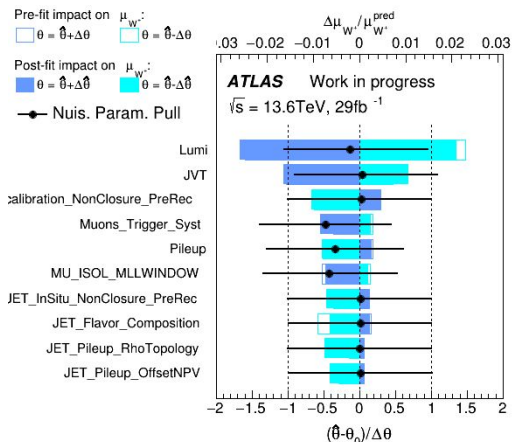
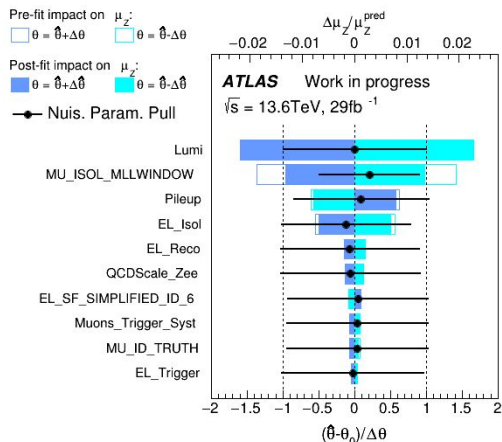
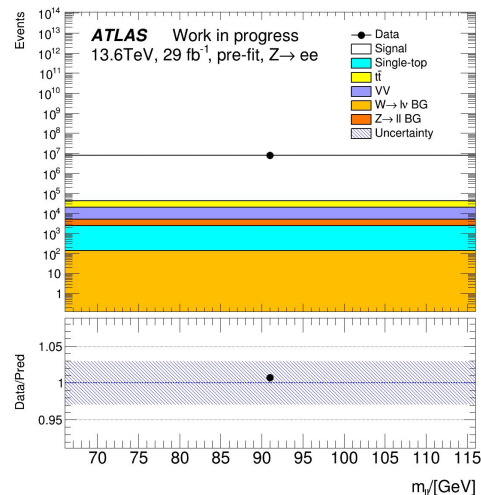
<p>Fit region (FR)</p> <ul style="list-style-type: none"> • Lepton $p_T > 27$ GeV • $E_{T\text{miss}} > 0$ GeV • $m_T^W > 0$ GeV • Pass isolation 	<p>Signal region (SR)</p> <ul style="list-style-type: none"> • Lepton $p_T > 27$ GeV • $ET_{\text{miss}} > 25$ GeV • $m_{TW} > 50$ GeV • Pass isolation
<p>Control region 1 (CR1)</p> <ul style="list-style-type: none"> • Lepton $p_T > 27$ GeV • $ET_{\text{miss}} > 0$ GeV • $m_{TW} > 0$ GeV • Fail isolation 	<p>Control region 2 (CR2)</p> <ul style="list-style-type: none"> • Lepton $p_T > 27$ GeV • $ET_{\text{miss}} > 25$ GeV • $m_{TW} > 50$ GeV • Fail isolation



Fitting

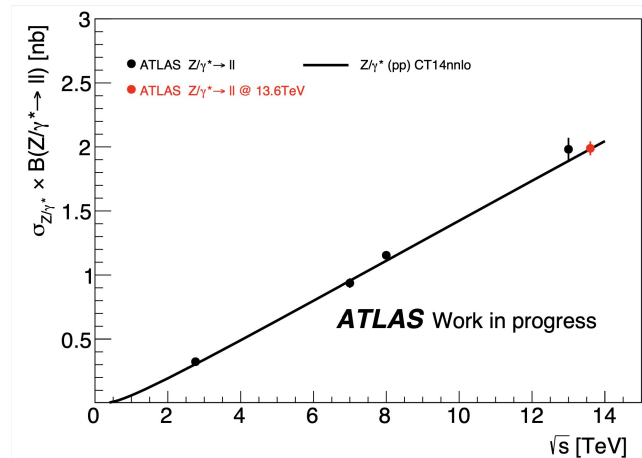
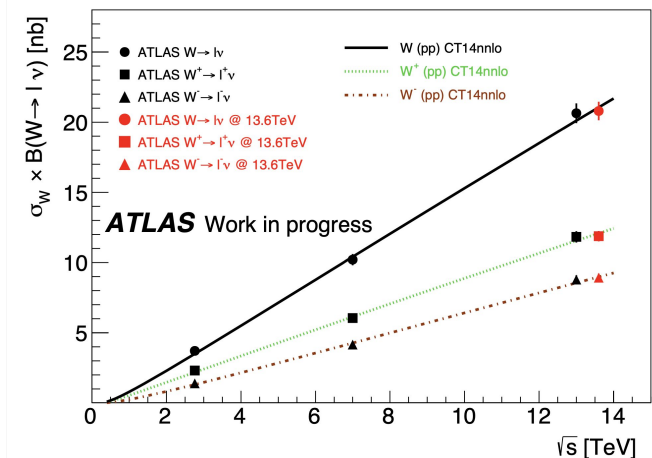
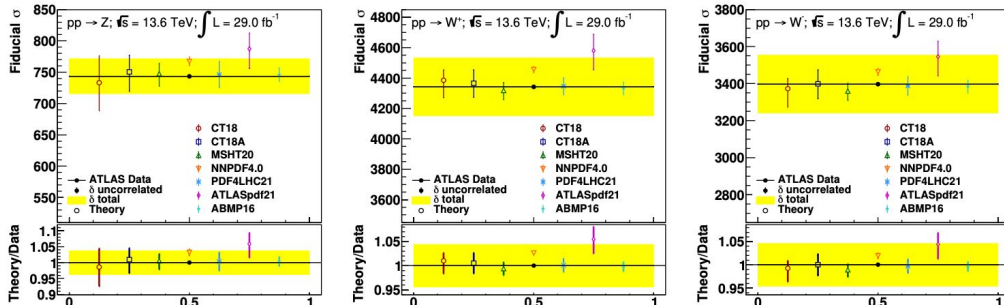
- The profile likelihood method is used to extract the cross-section
- Luminosity uncertainty is 2.2%
- Expected total relative uncertainty on $\sigma(Z)$ is $\sim 3\%$ and is $\sim 3.5\%$ for W
- Good agreement between the results and predictions is observed

$$L(\vec{n}; \mu_s, \vec{\theta}) = \prod_{c \in \text{channels}} \prod_{b \in \text{bins}} \text{Pois}(n_{\text{data}} | \mu_s S_{c,b} + B_{c,b}(\vec{\theta})) \prod_{i \in \text{NPs}} G(\theta_i)$$



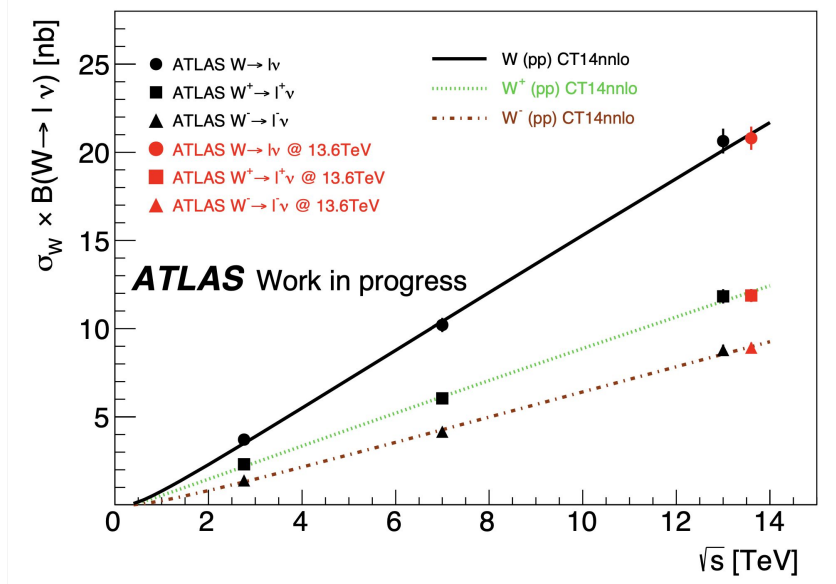
Results

- Theoretical predictions are calculated using DYTurbo + ReneSANCe at NNLO QCD + NLO EW and they agree at **per-mille** level with the ones obtained with MATRIX
- Reported in PMG PUB note ([Pub note](#))
- Good agreement is observed between measured results and theoretical predictions

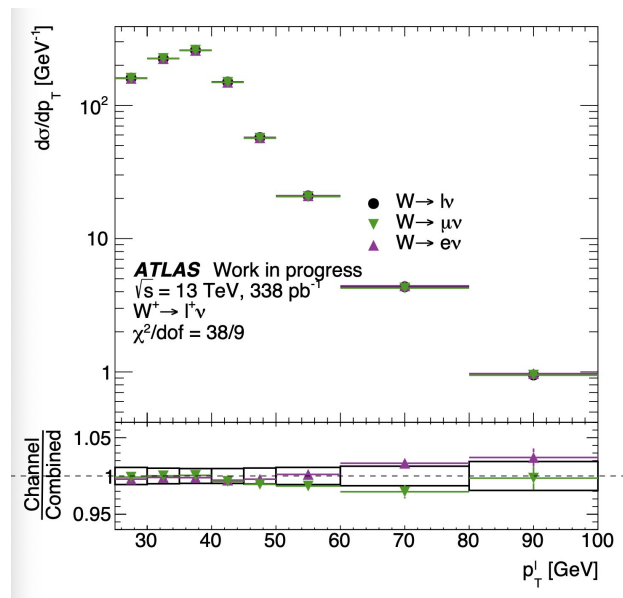


Precision measurements of electroweak parameters

Early run3 W/Z analysis



W differential cross-section with low pileup dataset



W differential cross-section with low-mu datasets

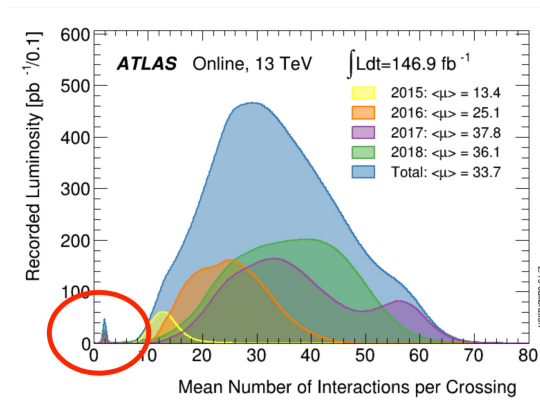
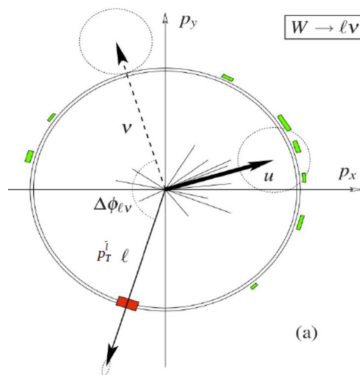
- Measure the W fiducial and differential cross sections with low pileup datasets
- The differential cross-sections are measured as the functions of p_T^ℓ and η_ℓ using low pileup datasets at $\sqrt{s}=5.02$ (~ 254.9 pb $^{-1}$) and 13 TeV (~ 338.1 pb $^{-1}$)
- Double differential cross-sections are also measured

Fiducial phase space:

- Born lepton $p_T > 25$ GeV, $|\eta| < 2.5$
- $p_T^{\nu} > 25$ GeV, $m_T^W > 50$ GeV

Event Selection:

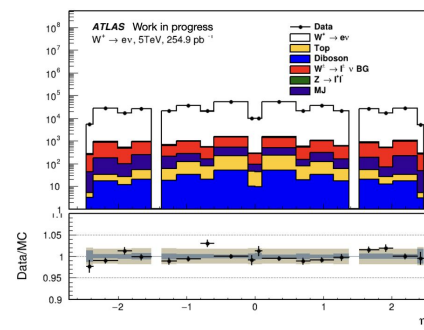
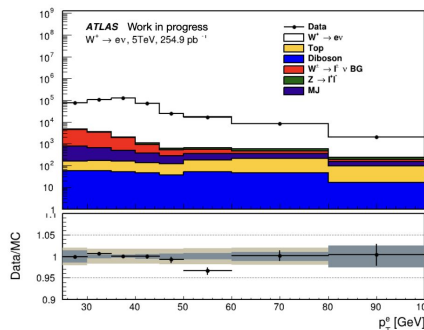
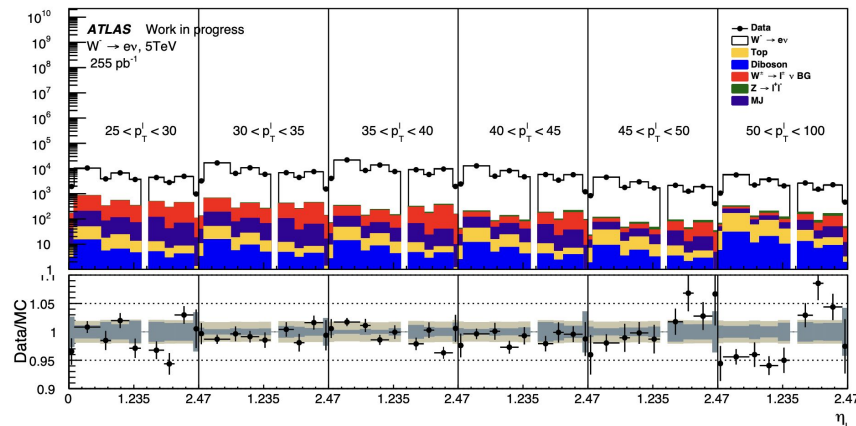
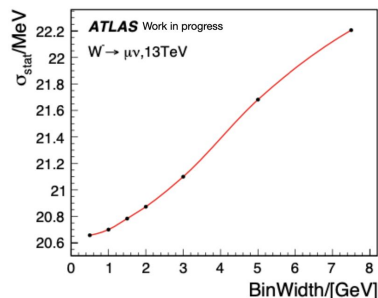
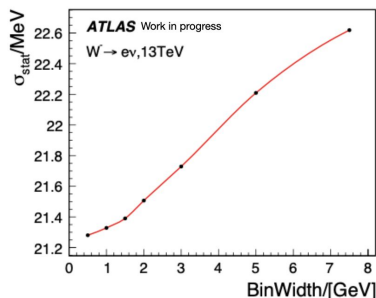
- Lowest unrescaled single lepton trigger
- **Electron:** $p_T > 25$ GeV, $|\eta| < 2.47$, crack veto
- **Muon:** $p_T > 25$ GeV, $|\eta| < 2.4$
- $E_T^{\text{miss}} > 25$ GeV, $m_T^W > 50$ GeV



Control plots

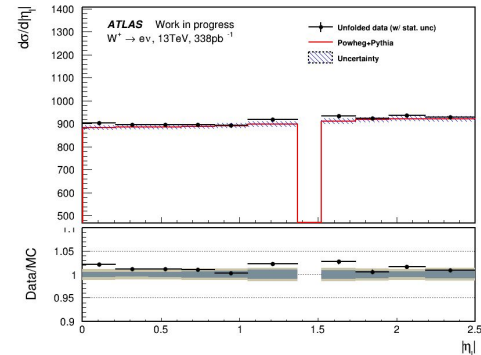
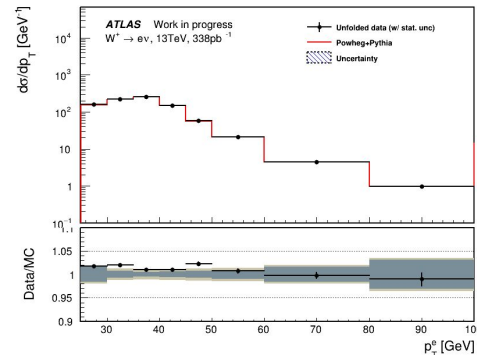
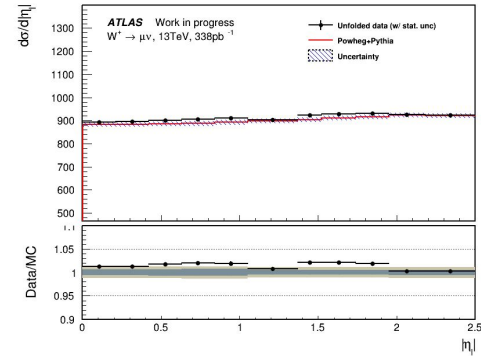
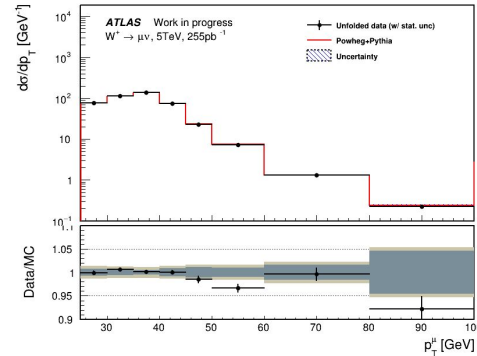
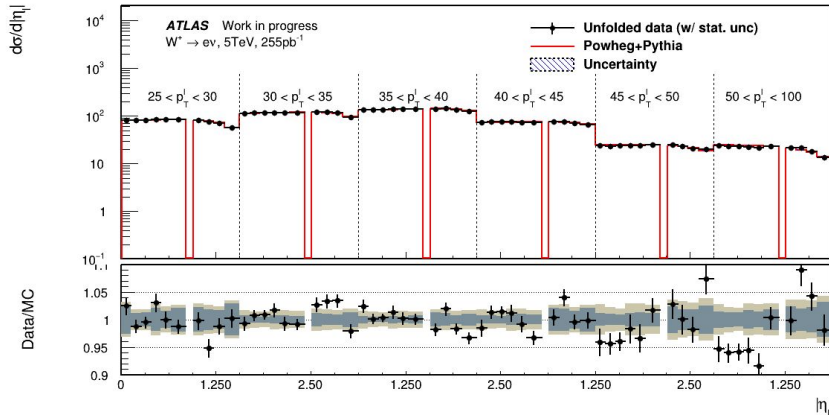
Binning

- p_T^l :
 - [25, 30, 35, 40, 45, 50, 60, 80, 100] GeV for 1D (more coarse binning for 2d).
 - The binning is optimized according to the resolution and m_W sensitivity
- η_l :
 - at **reco-level**, the SF binnings are used (different between electron and muon);
 - A common binning is used at **truth-level** for both electron and muon channels



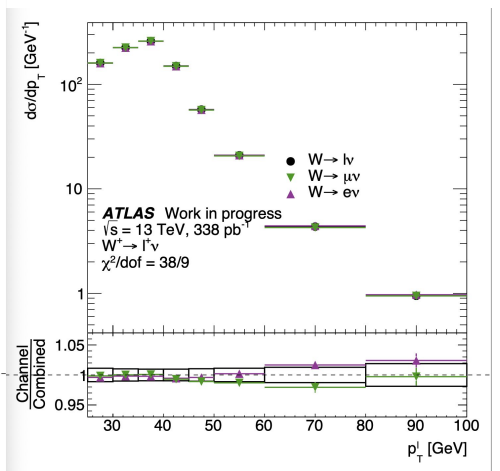
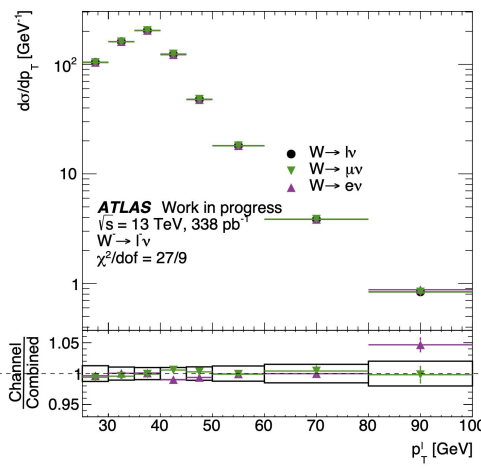
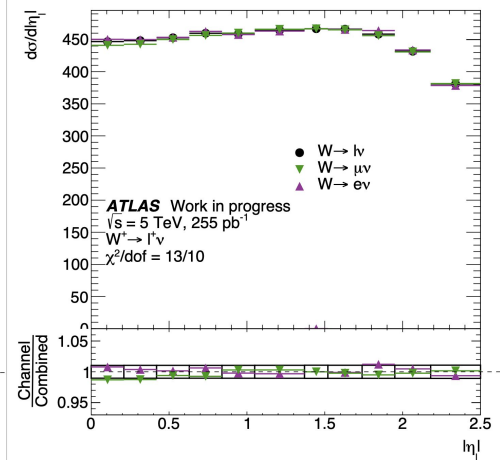
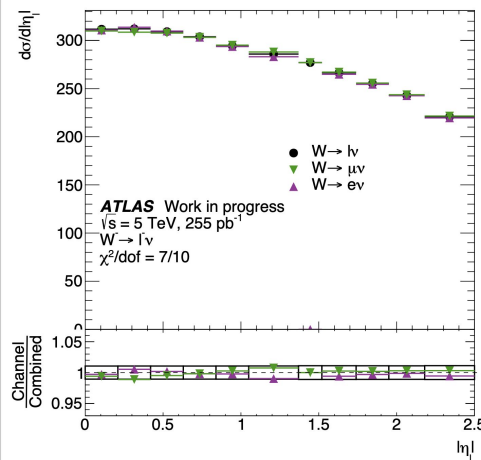
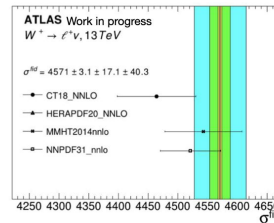
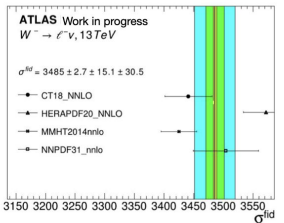
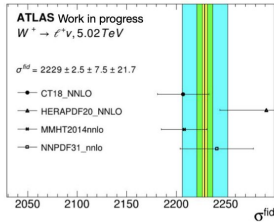
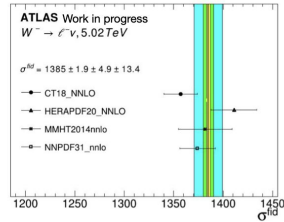
Unfolding

- Bayesian unfolding derives the p_T^l and η_l spectra corrected for detector effects at truth-level.
- **Unfolding:** use Bayesian iterations
- The iterations are optimized for bias and systematic uncertainties



Combination

- Electron and muon channels are combined using χ^2 minimization (**BLUE**)
- Good agreement between measured results and predictions
- The electron and muon channels are consistent



Summary

- **A lot of activities and achievements since the last workshop in 2021**
- **Kunlin has defended his thesis in 2022, Juan has defended in 2023**
- **Early Run-3 W/Z cross-section**
 - The fiducial cross-section of the Z boson has been out with Run-3 ttbar cross sections in arXiv:2308.09529
 - The other W/Z and their ratio results are ready and being reviewed in the SM group
 - The measurements provide a new point at 13.6 TeV in energy dependence plots
- **W differential cross-section with low pileup dataset**
 - The cross-section results are being finalized
 - Very good precision in systematics
 - The results will be used to constrain PDFs
 - The preliminary results have been used by Juan in doing the joint mW-PDFs fits