Electroweak precision measurements at ATLAS, CMS, and LHCb experiments

Eirini Kasimi*
on Behalf of ATLAS, CMS and LHCb Collaborations

*ATLAS - Aristotle University of Thessaloniki, Greece

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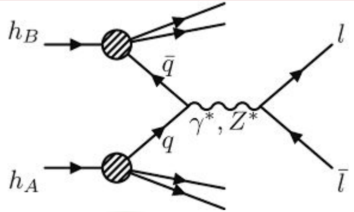
Why ElectroWeak Precision Measurements?

The LHC is effectively a **W and Z factory**
↓
billions of events available

W and **Z** bosons are **fundamental carriers of the EW interaction**

Provide **clean experimental signatures** (leptonic decays)
↓
high precision measurements possible

Drell-Yan Process



Stringent tests of the **Standard Model at quantum (loop) level**

Validate high-precision **QCD and electroweak calculations** across phase space

Key role in the Standard Model

Constrain **parton distribution functions (PDFs)**
↓
essential for precision modelling

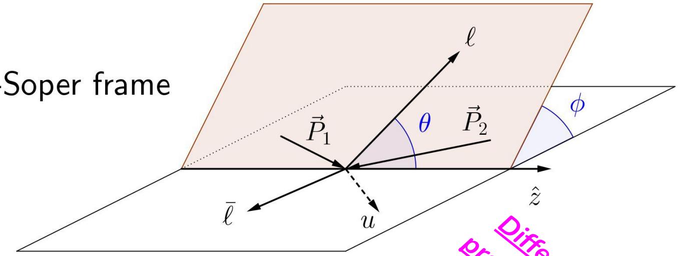
Indirect sensitivity to high-scale BSM physics

Angular structure of the EW bosons

General form of differential cross section for **spin-1 bosons (W, Z)**

- **9 harmonic polynomials and 8 dimensionless angular coefficients ($A_0 - A_7$)**
- **Angular coefficients A_i encode the production dynamics and the EW couplings governing boson production and decay**
- **The angular decomposition holds to all orders in QCD and provides results in the full phase space of the decay leptons.**

Collins-Soper frame



Different coefficients probe different physics:
$A_0, A_2 \rightarrow$ QCD dynamics
$A_4 \rightarrow$ EW couplings

Longitudinal polarization

- fraction of longitudinally polarised bosons

$$\frac{d\sigma}{d\cos\theta d\phi} \propto (1+\cos^2\theta) + \frac{1}{2}A_0(1-3\cos^2\theta) + A_1 \sin 2\theta\cos\phi + \frac{1}{2}A_2 \sin^2\theta\cos 2\phi$$
$$+A_3\sin\theta\cos\phi + A_4\cos\theta + A_5\sin^2\theta\sin 2\phi + A_6\sin 2\theta\sin\phi + A_7\sin\theta\sin\phi$$

Other coefficients (A_1, A_3, A_5–A_7)

- arise from **higher-order** effects
- typically small

Parity violation (EW physics)

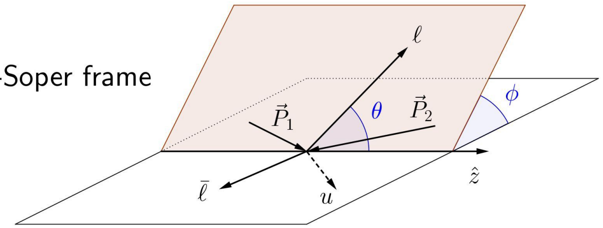
- encodes vector and **axial-vector** couplings of Z boson
- directly related to **A_{FB} and $\sin^2\theta_{eff}$**

Transverse structure

- related to **spin correlations**
- Lam–Tung relation: $A_0 \approx A_2$ (at LO)

From angular asymmetries to the weak mixing angle

Collins-Soper frame



$$\frac{d\sigma}{d\cos\theta d\phi} \propto (1+\cos^2\theta) + A_4 \cos\theta$$

A_4 induces an **asymmetry in angular distribution of leton pairs** -> forward ($\cos\theta > 0$) vs backward ($\cos\theta < 0$)

$$A_{FB} = \frac{N(\cos\theta^*>0)-N(\cos\theta^*<0)}{N(\cos\theta^*>0)+N(\cos\theta^*<0)} = \frac{N_F-N_B}{N_F+N_B}$$

Electroweak couplings

$$g_V = T_3 - 2Q\sin^2\theta_{\rm eff}$$
$$g_A = T_3$$
$$A_{FB} \Rightarrow g_V\, g_A$$

$$A_{FB} = \frac{3}{8}A_4$$

Direct connection between angular coefficient and observable

$$A_{FB} \longrightarrow \sin^2\theta_{\rm eff}$$

Weak mixing angle controls the **vector - axial structure**

Extracted from angular asymmetries

$$A_4 \longrightarrow A_{FB} \longrightarrow \sin^2\theta_{\rm eff}$$

$\sin^2\theta_{\rm eff}$ **includes radiative (loop) corrections → sensitive to higher-order and BSM effects**

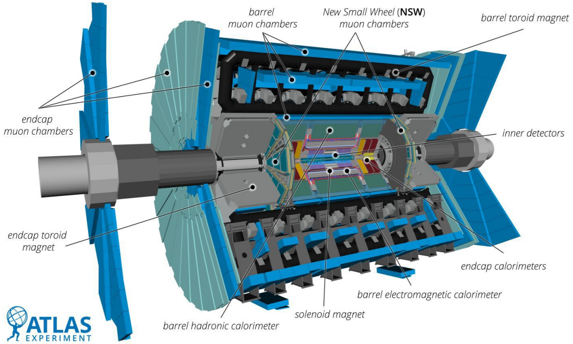
$\boldsymbol{k_f}$ is a flavour-dependent effective scaling factor absorbing higher order corrections ($k_f = 1$ at LO)

$$\sin^2\theta_{eff} = k_f \sin^2\theta_W \longrightarrow \sin^2\theta_W = 1 - \frac{m_W^2}{m_Z^2}$$

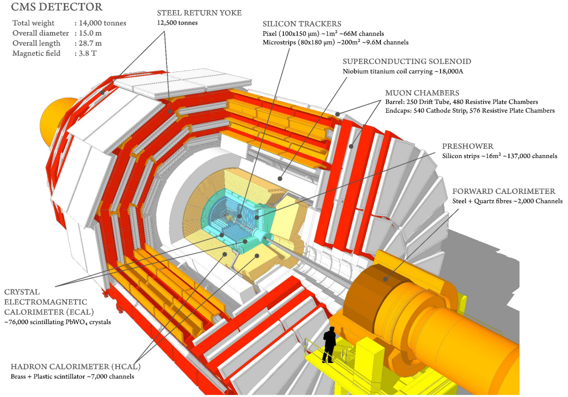
Indirect measurement of the W boson mass

ATLAS, CMS and LHCb experiments

ATLAS Experiment

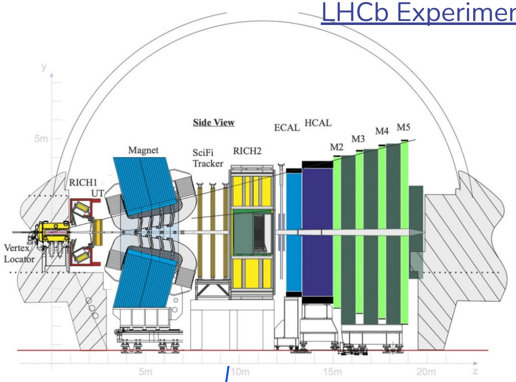


CMS Experiment



The **Large Hadron Collider** hosts three experiments performing precision measurements of EW processes: **ATLAS, CMS and LHCb**

LHCb Experiment



ATLAS and CMS

- general-purpose detectors
- nearly hermetic coverage in the **central pseudorapidity region**
- **excellent lepton and missing transverse momentum reconstruction**

LHCb

- forward spectrometer covering the **high pseudorapidity region**
- precise tracking and muon identification
- **unique sensitivity to both low and high Bjorken-x** regions

The complementarity of ATLAS, CMS and LHCb allows us to **probe different regions of phase space**, which is crucial for **reducing PDF uncertainties** in precision electroweak measurements

Measurement of the W boson angular coefficients & transverse momentum

arxiv: 2509.13759
(submitted to EPJC)

Center-of-mass energy	*Data Year*	*Integrated Luminosity*
$\sqrt{s}$ = 13 TeV	2017 - 2018	338 pb^{-1}

Setup

- **Signal channel:** $W \to \ell \nu_\ell$, $\ell = e, \mu$
- Angular coefficients defined in the **Collins–Soper frame**
- Low pile-up conditions enable an **optimised reconstruction of the** $\mathbf{p_T^W}$
- **Reconstruction effects:**
  - Neutrino p_Z ambiguity (twofold solution)
  - Migration between true and reconstructed p_T^W
  - Handled on a statistical basis by imposing a simple m_W constraint
- Combination of **electron and muon channels**

Strategy

- Measurement of **W-boson angular coefficients** A_i and differential cross-sections within the full phase space of the decay leptons
  - both extracted as function of $\mathbf{p_T^W}$
  - **Probe QCD dynamics and W-boson polarisation**
- **Backgrounds:** $W \to \tau\nu$ $Z \to \ell\ell$, $Z \to \tau\tau$, top ($t\bar{t}$ + single top), diboson QCD multijet (data-driven!)

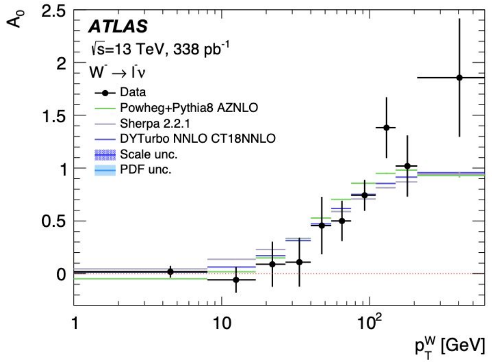
- **Main uncertainties:**
  - **Statistical uncertainty (dominant)**
    - Limited data size
    - Dominates across most $\mathbf{p_T^W}$ range
  - **Event migration / reconstruction effects (comparable with statistical uncertainty in intermediate $\mathbf{p_T^W}$)**
    - Neutrino p_Z ambiguity + detector resolution
    - Induces bin migration and correlations between A_i
  - **MC statistical uncertainty**
    - Finite MC sample size
    - Affects template modelling
  - **Hadronic recoil calibration (dominant experimental unc.)**
    - Impacts $\mathbf{p_T^W}$ reconstruction
    - Typically < 1%
  - **Background modelling**
    - Multijet, top, diboson
    - Up to ~2–3% at high $\mathbf{p_T^W}$ (mainly for cross-sections)

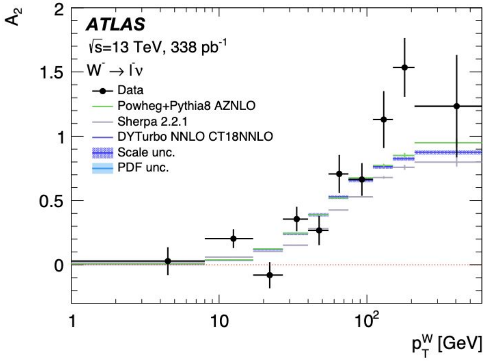
Measurement of the W boson angular coefficients & transverse momentum (2)

arxiv: 2509.13759
(submitted to EPJC)

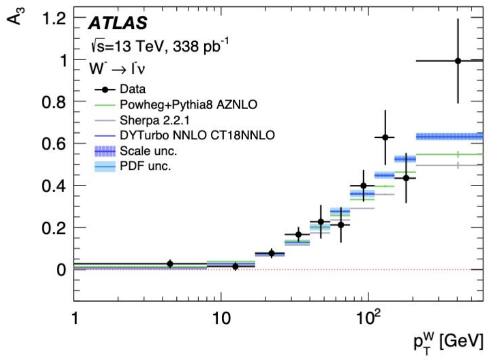
Results for W^-

First measurement of the full set of angular coefficients for the W-boson and differential cross-section measurement in p_T^W within the full phase space of the decay leptons

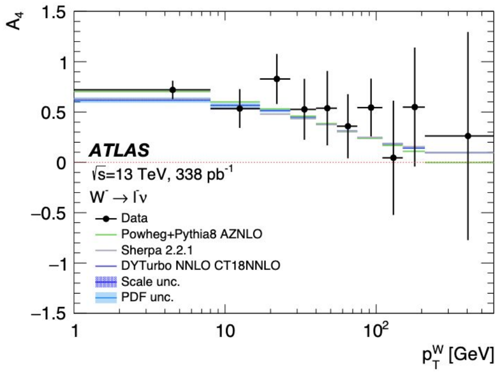




A_0 and $A_{2\text{-}4}$ clearly determined and with good agreement with theory predictions



Most precise measurement of A_3



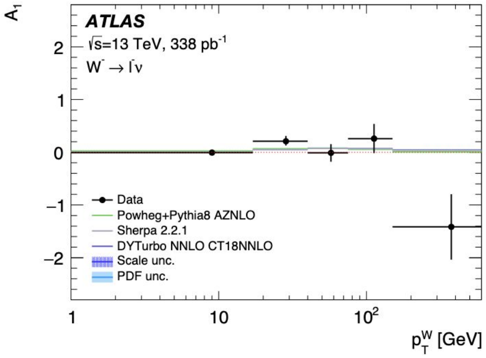
First direct measurement of A_0 and A_4

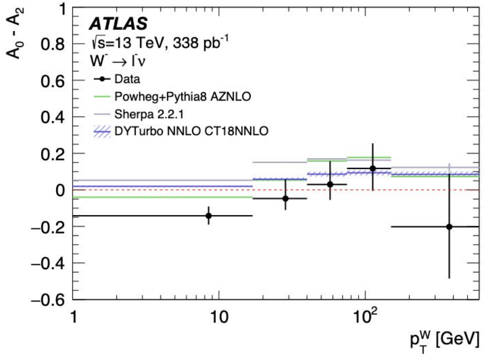
Measurement of the W boson angular coefficients & transverse momentum (3)

arxiv: 2509.13759
(submitted to EPJC)

Results for W^-

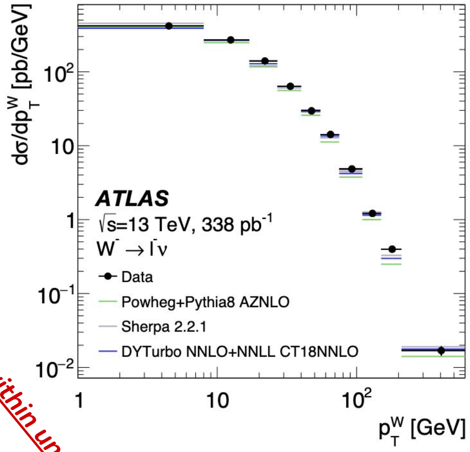
First measurement of the full set of angular coefficients for the W-boson and differential cross-section measurement in p_T^W within the full phase space of the decay leptons

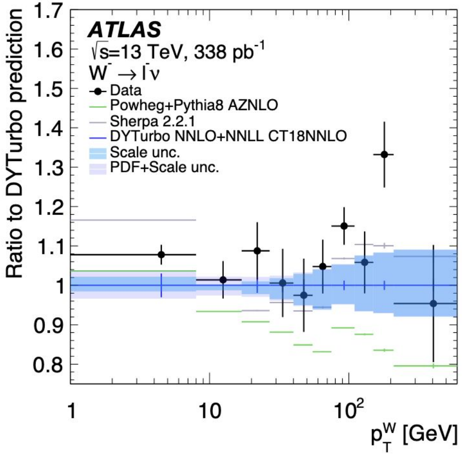




A_1, A_5–A_7 consistent with zero within uncertainties

No significant deviation from Lam–Tung relation observed ($A_0 - A_2 \approx 0$ within uncertainties)





Good agreement between measurements and theory predictions

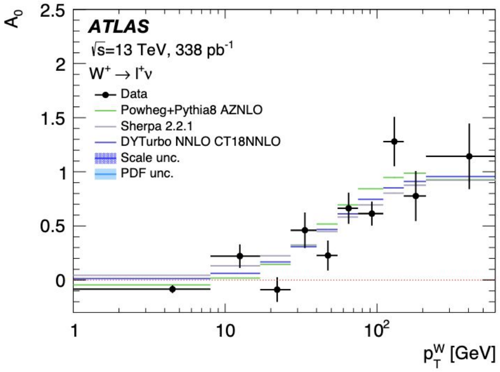
Measurement of the W boson angular coefficients & transverse momentum (4)

ATLAS EXPERIMENT

arxiv: 2509.13759
(submitted to EPJC)

Results for W^+

First measurement of the full set of angular coefficients for the W-boson and differential cross-section measurement in p_T^W within the full phase space of the decay leptons



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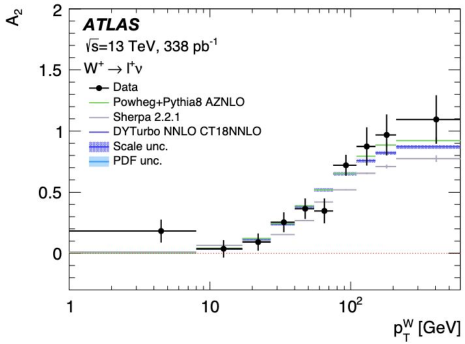
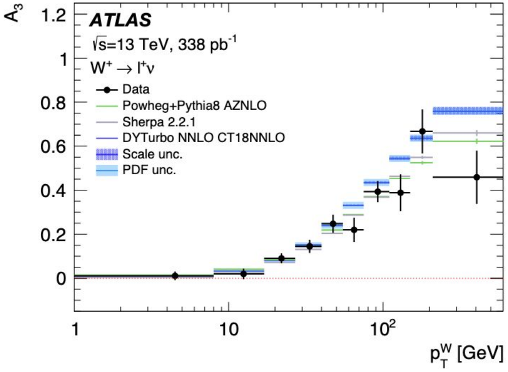
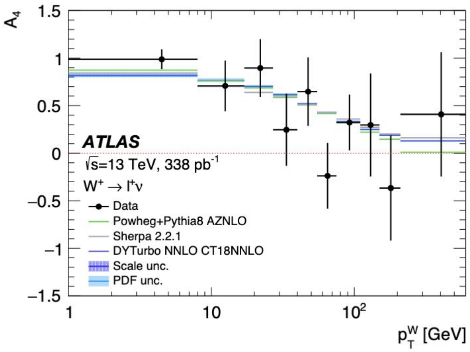




Most precise measurement of A_3



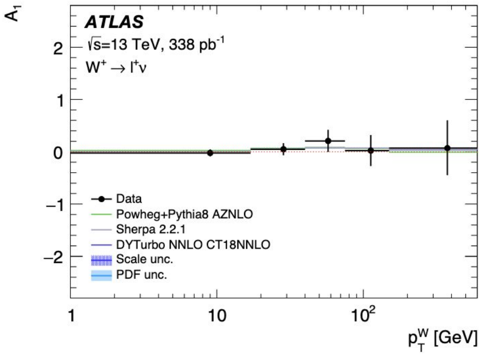
First direct measurement of A_0 and A_4

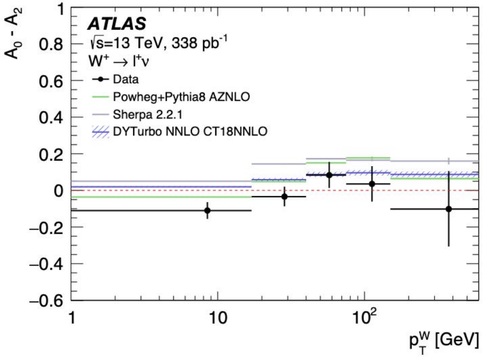
Measurement of the W boson angular coefficients & transverse momentum (5)

arxiv: 2509.13759
(submitted to EPJC)

Results for W^+

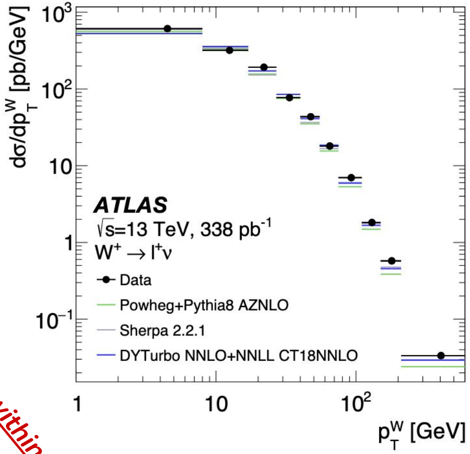
First measurement of the full set of angular coefficients for the W-boson and differential cross-section measurement in p_T^W within the full phase space of the decay leptons

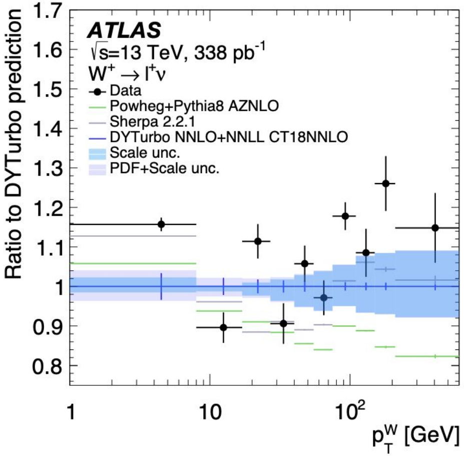




A_1, A_5–A_7 consistent with zero within uncertainties

No significant deviation from Lam–Tung relation observed ($A_0 - A_2 \approx 0$ within uncertainties)





Good agreement between measurements and theory predictions

Slightly larger deviations observed in W^+ channel, still compatible within uncertainties

arxiv: 2509.18817
(submitted to JHEP)

Measurements of the W → μν cross-sections & W-boson mass

Center-of-mass energy	Data Year	Integrated Luminosity
$\sqrt{s}$ = 5.02 TeV	2017	100 pb^{-1}

Setup

- **Signal channel:** W → μν
  - Muons reconstructed in the **forward region** $2.2 < \eta < 4.4$
  - Muon transverse momentum range $28 < p_T < 52$ GeV

Strategy

- Cross sections measured differentially in **twelve intervals of muon p_T**
- **Backgrounds:** light hadron, $Z \to \mu^+\mu^-$, $Z \to \tau^+\tau^-$, $W \to \tau\nu$, heavy-flavour hadrons decays, and top-quark decays
- **Main uncertainties:**
  - statistical
  - Dominant systematics:
    - W^+: charge-dependent momentum bias (~7% at high pT)
    - W^-: unfolding uncertainty (~8% at high pT)
    - subdominant: muon efficiency (~1%)
  - luminosity determination (dominant overall)

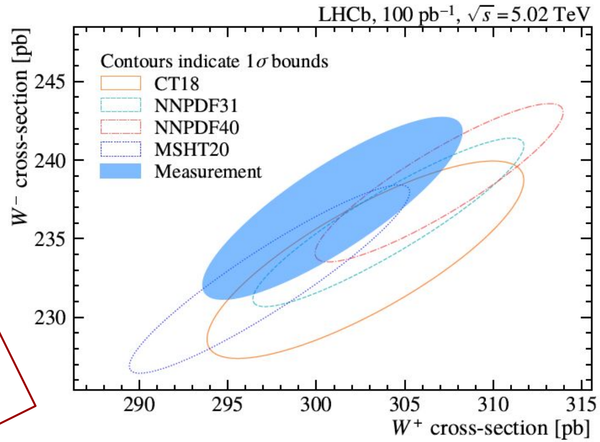
Provides strong constraints on PDFs at extreme Bjorken-x

Covered in detail in Miguel's talk

Results

$$\sigma_{W^+\to\mu^+\nu_\mu} = 300.9 \pm 2.4 \pm 3.8 \pm 6.0\,\text{pb},$$
$$\sigma_{W^-\to\mu^-\bar{\nu}_\mu} = 236.9 \pm 2.1 \pm 2.7 \pm 4.7\,\text{pb},$$

statistical uncertainty | systematic uncertainty | luminosity determination uncertainty



Consistent with theoretical predictions at fixed-order in the strong coupling

Measurements of the $W \to \mu\nu$ cross-sections & W-boson mass (2)

arxiv: 2509.18817
(submitted to JHEP)

LHCb

Center-of-mass energy	*Data Year*	*Integrated Luminosity*
$\sqrt{s}$ = 5.02 TeV	2017	100 pb^{-1}

Setup

- **Signal channel:** $W \to \mu\nu$
  - Muons reconstructed in the **forward region** $2.2 < \eta < 4.4$
  - Muon transverse momentum range $28 < p_T < 52$ GeV

Strategy

- Extraction of W boson mass
  - **differential cross-section data used in a fit**
- Main uncertainties:
  - experimental = statistical + systematics
  - **Dominant theoretical uncertainties**
    - Parton distribution functions (PDFs) (dominant)
    - Strong coupling value (α_s)
    - Missing higher-order QCD corrections
    - QED / final-state radiation modelling

Results

Proof-of-principle measurement

$$m_W = 80369 \pm 130 \pm 33\,\text{MeV},$$

experimental uncertainty

theoretical uncertainty

First demonstration of m_W extraction using differential cross-sections

In agreement with earlier measurements and indirect determinations based on EW precision data

LEP experiment	*CMS collaboration*
m_W = 80370.0 ± 3.3 MeV	m_W = 80360.2 ± 9.9 MeV

ATLAS collaboration	*LHCb collaboration*
m_W = 80366.5 ± 15.9 MeV	m_W = 80354.0 ± 2.3(stat) ± 10(exp) ± 17(th) ± 9(PDF)MeV

CDF collaboration	*D0 collaboration*
m_W = 80433.5 ± 9.4 MeV	m_W = 80367.0 ± 2.6 MeV

!!!Factorised approach: differential cross-sections → reduced theory dependence in m_W extraction!!

arXiv:2603.19963
(submitted to JHEP)

Measurements of the jet mass in hadronic decays and extraction of the W boson mass

Center-of-mass energy	*Data Year*	*Integrated Luminosity*
$\sqrt{s}$ = 13 TeV	2016-2018	138 fb^{-1}

Setup

- **Signal channel: Boosted W → qq' decays**
  - At high p_T the two quarks become **highly collimated**
  - Reconstructed as **a single large-radius jet**
  - Leading **anti-k_T (R = 0.8) jet**, **p_T > 575 GeV**

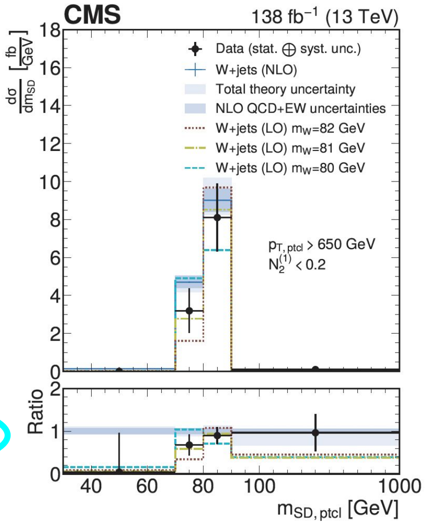
Strategy

- **2D unfolding in jet p_T and m_{SD}**
- Extract **m_W from a fit to the unfolded jet-mass distribution**
- Observable: **Soft-drop groomed jet mass (m_{SD})**
- **Backgrounds: QCD multijet, W+jets**
  - Background suppression: **soft-drop grooming and jet-substructure tagging**
- **Main uncertainties:**
  - Jet mass scale and resolution (dominant systematic)
  - **W-tagging efficiency**
  - **QCD modelling** (parton shower & hadronisation)

Results

Most precise determination of m_W in an all-jets final state at a hadron collider

$$m_W = 80.83 \pm 0.55\,\text{GeV}$$



Consistent with theoretical predictions and previous measurements

Precision **still not competitive with leptonic** W-mass measurements:

$$m_W = 80.3602 \pm 0.0099\,\text{GeV}$$

Phys. Lett. B 868 (2025) 139754

Measurements of the W boson decay branching fraction ratio B (W -> cq) / B (W -> qq̄')

Center-of-mass energy	Data Year	Integrated Luminosity
$\sqrt{s}$ = 13 TeV	2016-2018	138 fb^{-1}

Setup

- **Signal channel:** Semileptonic ttbar events (high-purity source of W bosons)
- **Event selection:**
  - $W \to \ell \nu_\ell$ **used to select events**
    - one prompt lepton (electron or muon)
    - at least 4 jets, including **2 b-tagged jets**
- Charm tagging:
  - charm jets identified using a **muon inside the jet**

Strategy

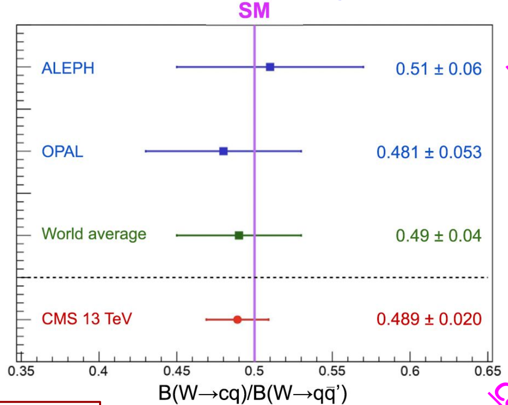
- Extraction of the R_c^W: event yields used in a fit
- Muon-in-jet method provides a **charm-enriched sample with low background**, constrained using data
- **Backgrounds:** Dileptonic ttbar, Single-top production, V + jets
- **Main uncertainties**
  - Charm-tagging: muon identification (Dominant, 2.6%)
  - Charm-tagging: muon rate in simulation (2.2%)
  - Parton-shower modelling (1.9%)

Results

$$R_c^W = 0.489 \pm 0.005\,(\text{stat}) \pm 0.019\,(\text{syst})$$

Good agreement with SM prediction

Improvement by a factor of two w.r.t. the world average



Most precise measurement

Sum of squared elements in the second row of CKM matrix

$$\Sigma = 0.970 \pm 0.041$$

Independent measurement from hadronic W decays

$$|V_{cs}| = 0.959 \pm 0.021$$

Consistency test of the CKM matrix unitarity

Still less precise from world average from leptonic/semileptonic charm hadron decays

$$|V_{cs}| = 0.975 \pm 0.006$$

Eur. Phys. J. C 84 (2024) 315

Measurement of the Z-boson double-differential transverse momentum and rapidity distributions in the full phase space of the decay lepton

Center-of-mass energy	Data Year	Integrated Luminosity
$\sqrt{s}$ = 8 TeV	2012	20.2 fb^{-1}

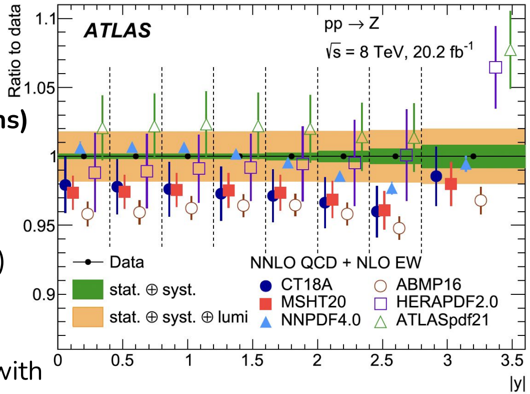
Setup

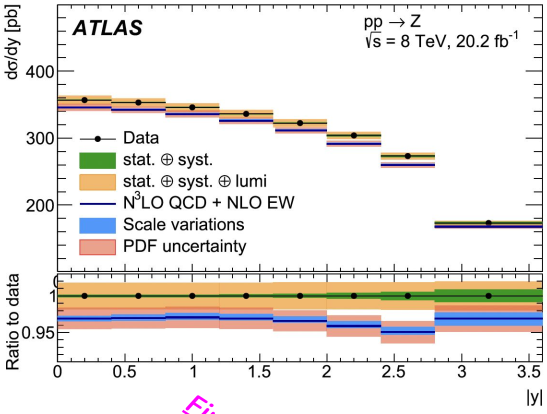
- **Signal channel:** $Z \rightarrow \ell^+\ell^-$, ℓ = e, μ
- **Full phase space measurement (no fiducial restrictions)**
- **Same angular decomposition framework with slide 3**

Strategy

- Measure **double-differential cross section** $d^2\sigma/(dp_T\, dy)$
- Observables: **Z-boson p_T and rapidity (y)**
- **Full phase space of decay leptons**
  - Enables direct and high-precision comparison with state-of-the-art QCD predictions
- **Backgrounds:** Top-quark, Diboson, $Z \rightarrow \tau\tau$, $\gamma\gamma \rightarrow \ell\ell$, Multijet and W+jets, Non-fiducial Z
- **Main uncertainties:**
  - Statistical (dominant; increases with |y|)
  - Luminosity uncertainty (~1.8%)
  - Lepton calibration (momentum/energy scale & resolution)
  - Unfolding / bin migration effects

Results





First precise measurement of the Z-boson production properties in the full phase space of the decay leptons

Precision at sub-percent level in central region

$$\sigma_Z = 1055.3 \pm 0.7\,(\text{stat.}) \pm 2.2\,(\text{syst.}) \pm 19.0\,(\text{lumi.})\ \text{pb}$$

Good agreement with state-of-the-art QCD predictions (N³LO + resummation)

Measurement of the Z-boson mass

Center-of-mass energy	Data Year	Integrated Luminosity
$\sqrt{s}$ = 13 TeV	2016	1.7 fb^{-1}

Setup

- **Signal channel:** $Z \to \mu^+\mu^-$
  - p_T > **20 GeV**
  - Pseudorapidity region: $2.2 < \eta < 4.4$
  - Dimuon invariant mass window $86 < m_{\mu\mu} < 96$ GeV

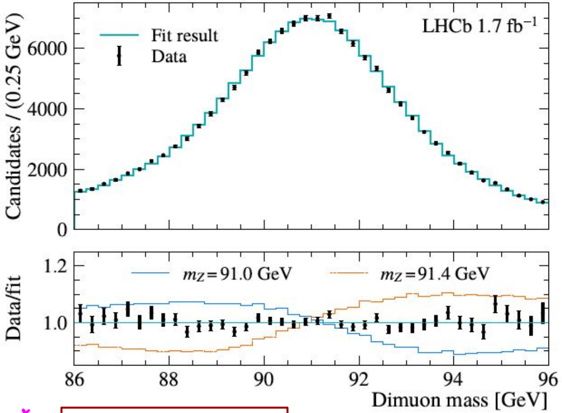
Strategy

- Precise **muon momentum calibration using Z, Y (main), and J/ψ decays**
- **Backgrounds:** $Z \to \tau^+\tau^-$, top-quark decays, vector-boson pairs and hadrons (negligible backgrounds ($O(10^{-3})$))
- **Main uncertainties:**
  - statistical
  - momentum calibration (dominated by **detector material modelling in simulation)**
- Extraction of Z boson mass
  - **template fit to the dimuon invariant mass distribution**

First dedicated measurement of Z mass at LHC

Results

Phys. Rev. Lett. **135**, 161802



statistical uncertainty

systematic uncertainty

$$m_Z = 91185.7 \pm 8.3 \pm 3.9\,\mathrm{MeV},$$

Consistent with previous measurements

Consistent with the predictions of global EW fits

LEP experiment	CDF collaboration
m_Z = 91187.6 ± 2.1 MeV	m_Z = 91192.0 ± 6.4 ± 4.0 MeV

Most Precise Measurement

Measurement of the effective leptonic weak mixing angle

CMS

Phys. Lett. B 866 (2025) 139526

Center-of-mass energy	Data Year	Integrated Luminosity
$\sqrt{s}$ = 13 TeV	2016 - 2018	138 fb^{-1}

Setup and Strategy

Channels: Z -> μμ, ee (+ forward electrons)
Topology: central + extended coverage
Method: A_{FB} + A_4

Results

$$\sin^2\theta^{\ell}_{\text{eff}} = 0.23152 \pm 0.00010\,(\text{stat}) \pm 0.00015\,(\text{exp}) \pm 0.00008\,(\text{theo}) \pm 0.00027\,(\text{PDF})$$

Consistent with the predictions of global EW fits

- **CMS: highest precision (at hadron colliders) $\sin^2\theta_{eff}$ measurement** using A_{FB} and angular analysis
  - **strongest experimental constraint**
- **ATLAS: angular analysis (A_4-driven)** with **broad phase-space coverage**
  - robust **probe of electroweak couplings**
- **LHCb: forward-region** A_{FB} measurement
  - **reduced PDF uncertainties and enhanced sensitivity to initial-state dynamics**

ATLAS EXPERIMENT

ATLAS-CONF-2018-037

Center-of-mass energy	Data Year	Integrated Luminosity
$\sqrt{s}$ = 8 TeV	2012	20.2 fb^{-1}

Setup and Strategy

Channels: Z -> μμ, ee
Topology: central and forward (electrons) region
Method: angular coefficients (A_4 sensitive to $\sin^2\theta_{eff}$)

Results

$$\sin^2\theta^{\ell}_{\text{eff}} = .23140 \pm 0.00021\,(\text{stat.}) \pm 0.00024\,(\text{PDF}) \pm 0.00016\,(\text{syst.})$$

LHCb

JHEP 12 (2024) 026

Center-of-mass energy	Data Year	Integrated Luminosity
$\sqrt{s}$ = 13 TeV	2016 - 2018	5.4 fb^{-1}

Setup and Strategy

Channels: Z -> μμ
Topology: forward region
Method: *A_{FB} (binned in $\Delta\eta$)*

Results

$$\sin^2\theta^{\ell}_{\text{eff}} = 0.23147 \pm 0.00044 \pm 0.00005 \pm 0.00023$$

statistical uncertainty
systematic uncertainty
fit model uncertainty

Conclusions

- **Electroweak precision measurements at the LHC provide a powerful framework to test the Standard Model with unprecedented accuracy**
  - Access to **fundamental parameters** through precision observables (m_W, m_Z, $\sin^2\theta_{eff}$)
  - Differential measurements play a crucial role in reducing **experimental and theoretical uncertainties**

- **The study of W and Z bosons is central to understanding the electroweak sector and probing its limits**
  - Z bosons offer a **clean laboratory for electroweak couplings and calibration**
  - W bosons provide sensitivity to **QCD dynamics, PDFs and polarisation effects**
  - Their interplay allows for **robust and complementary constraints** on the Standard Model

- **The complementarity of ATLAS, CMS and LHCb enhances the physics reach**
  - Extended phase-space coverage improves **PDF constraints and modelling**
  - Enables **high-precision and globally consistent measurements**

- **Full Run-3 dataset and HL-LHC will push precision to new levels, enhancing sensitivity to subtle deviations from the Standard Model and providing stringent constraints on PDFs and QCD dynamics**

Thank you!!!

Backup slides

JHEP 01 (2026) 047

Measurements of the inclusive W and Z boson production cross-sections & their ratios

Center-of-mass energy	*Data Year*	*Integrated Luminosity*
$\sqrt{s}$ = 13.6 TeV	2022	5.01 fb^{-1}

Setup

❖ **Signal channels:** $W \to \mu\nu$, $Z \to \mu^+\mu^-$

➢ W boson events contain: one **isolated high-p_T muon, missing transverse momentum** from the neutrino

➢ Z boson events contain: two **isolated muons of opposite charge** with an invariant mass window: **60 < $m_{\mu\mu}$ < 120 GeV**

Strategy

❖ Cross sections measured in **fiducial regions** and **extrapolated to total phase space using acceptance corrections**

❖ **Cross-section ratios reduce systematic uncertainties (luminosity cancellation)**

❖ **Backgrounds:** top-quark,diboson, $Z\to\tau\tau$, $W\to\tau\nu$, QCD multijet

❖ **Negligible statistical uncertainty → Precision is systematics-limited**

➢ **Dominated by luminosity uncertainty (~1.4%)**

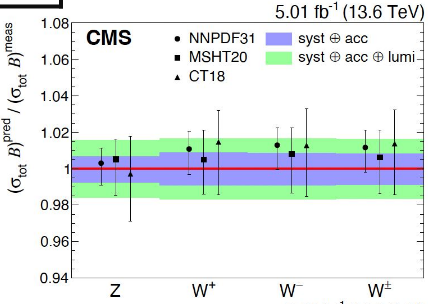
➢ Subdominant: muon efficiency, QCD modelling, PDFs

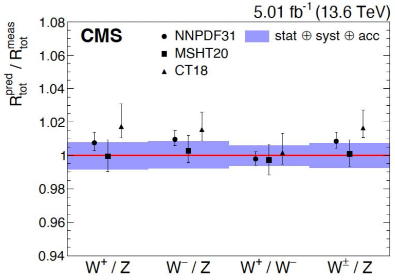
Results

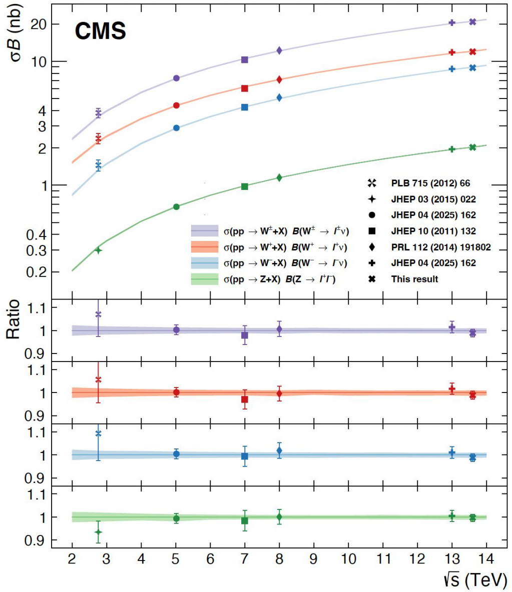
$$\sigma(pp \to W^+ + X)\mathcal{B}(W^+ \to \mu^+\nu_\mu) = 11.93 \pm 0.08\,(\text{syst}) \pm 0.17\,(\text{lumi}) ^{+0.07}_{-0.07}\,(\text{acceptance})\,\text{nb}$$

$$\sigma(pp \to W^- + X)\mathcal{B}(W^- \to \mu^-\overline{\nu}_\mu) = 8.86 \pm 0.06\,(\text{syst}) \pm 0.12\,(\text{lumi}) ^{+0.05}_{-0.06}\,(\text{acceptance})\,\text{nb}$$

$$\sigma(pp \to Z + X)\mathcal{B}(Z \to \mu^+\mu^-) = 2.021 \pm 0.009\,(\text{syst}) \pm 0.028\,(\text{lumi}) ^{+0.011}_{-0.013}\,(\text{acceptance})\,\text{nb}$$







$$R^{W^+/Z} = 5.906 \pm 0.004\,(\text{stat}) \pm 0.040\,(\text{syst}) ^{+0.022}_{-0.028}\,(\text{acceptance}),$$

$$R^{W^-/Z} = 4.382 \pm 0.003\,(\text{stat}) \pm 0.029\,(\text{syst}) ^{+0.023}_{-0.016}\,(\text{acceptance}),$$

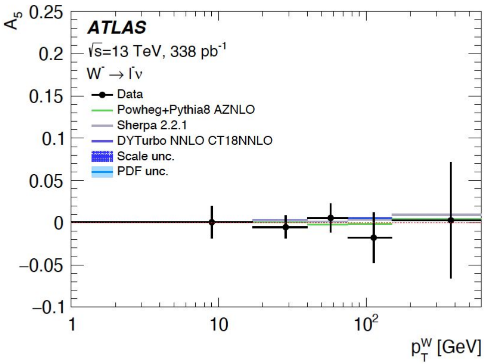
$$R^{W^+/W^-} = 1.348 \pm 0.001\,(\text{stat}) \pm 0.005\,(\text{syst}) ^{+0.006}_{-0.007}\,(\text{acceptance}).$$

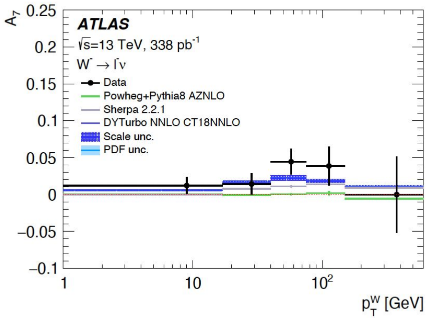
In agreement with theoretical calculations at NNLO QCD accuracy and NNLL qT resummation

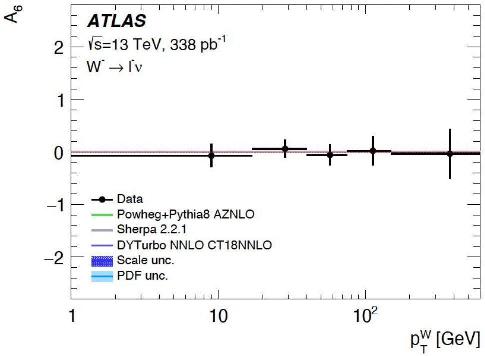
Measurement of the W boson angular coefficients & transverse momentum

arxiv: 2509.13759
(submitted to EPJC)

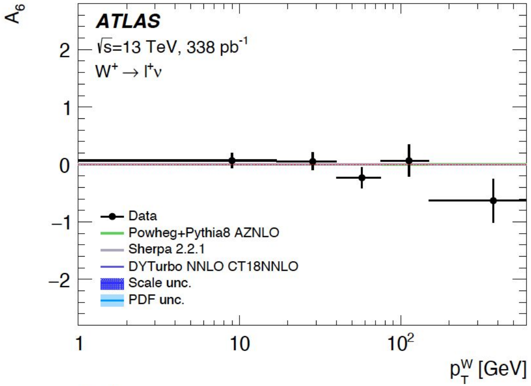
Results for W-

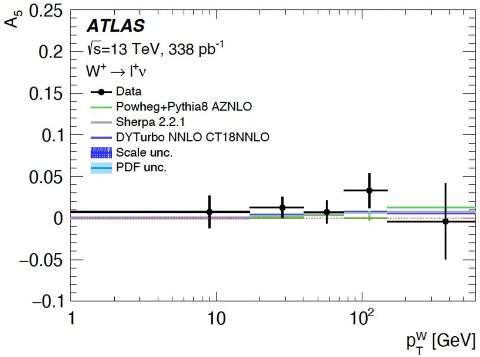


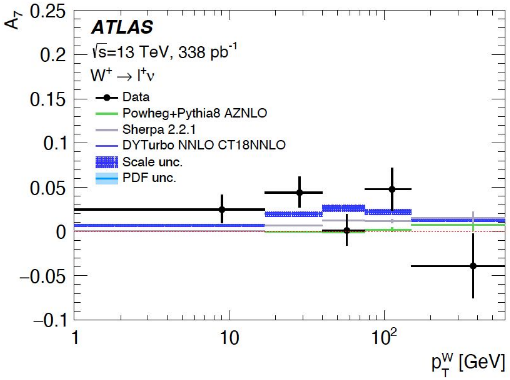




Results for W+







Measurement of the W boson angular coefficients & transverse momentum

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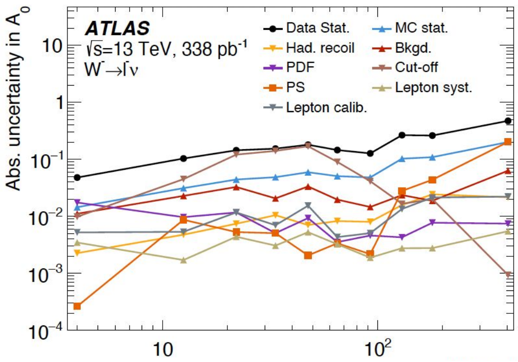
Results for W-



Results for W+