Measurement of W boson production in Pb+Pb collisions at 5.02 TeV with the ATLAS detector

Motivation

- Ultrarelativistic heavy-ion collisions may produce a hot and dense state of strongly interacting matter, called the quark-gluon plasma (QGP). Particles, which do not carry colour charges, are well suited to study the initial stages of the collision.
- *W* bosons and their leptonic decays are colourless, thus their production yields in Pb+Pb collisions are expected to **scale with** $\langle T_{AA} \rangle$ as:

$$N^{W\to\mu\nu} = N_{\text{evt}} \cdot \langle T_{AA} \rangle \cdot \sigma_W^{pp}$$

where N_{evt} is the total number of inelastic Pb+Pb collisions, $\langle T_{AA} \rangle$ is the average nuclear thickness function and σ_W^{pp} is the *W* boson production cross-section in pp collisions.
- In Pb+Pb collisions one expects to be sensitive to the **isospin effect**, which modifies the relative yields of W^+ and W^- bosons in comparison to *pp* collisions due to the presence of neutrons in the lead nuclei. One can quantify this effect using the pseudorapidity dependence of the lepton charge asymmetry:

$$A_\ell = \frac{N^{W^+\to\ell^+\nu_\ell} - N^{W^-\to\ell^-\nu_\ell}}{N^{W^+\to\ell^+\nu_\ell} + N^{W^-\to\ell^-\nu_\ell}}$$

- In addition, *W* boson production in Pb+Pb collisions may provide information on the nuclear modifications to free PDF (**nPDF**).

Data analysis

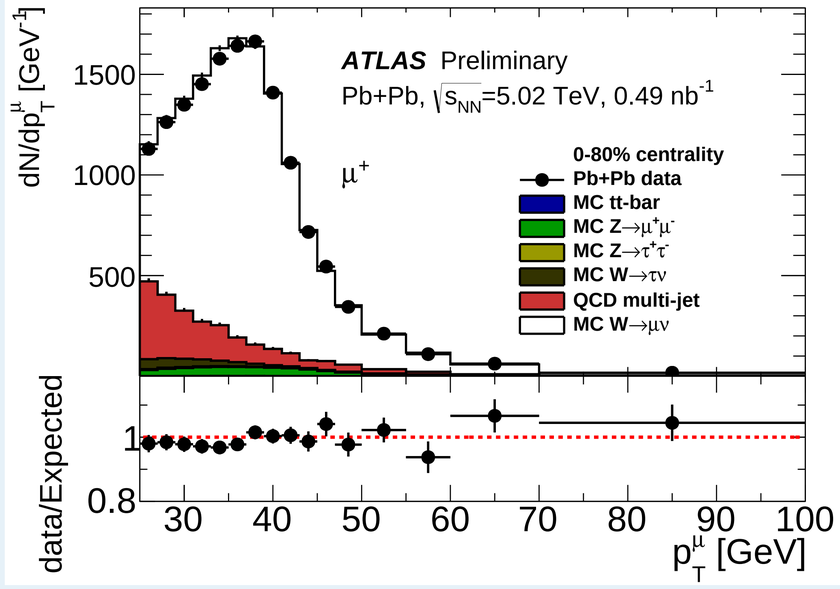
- W boson production is studied in the **muon decay channel [1]**.
- The measurement uses the full set of Pb+Pb collisions at 5.02 TeV recorded by ATLAS in 2015, which corresponds to an integrated luminosity of 0.49 nb^{-1}.
- Event selection:
  - high-quality muon candidate triggered by the muon trigger with $p_{\text{T}}^{\mu} > 15$ GeV,
  - muon isolation requirement based on the sum of transverse momenta of tracks in a cone around the muon,
  - veto on $Z \to \mu^+\mu^-$ events.
- The fiducial phase space region is defined by:
  - $p_{\text{T}}^{\mu} > 25$ GeV,
  - $0.1 < |\eta_\mu| < 2.4$,
  - $p_{\text{T}}^{\nu} > 25$ GeV,
  - $m_{\text{T}} = \sqrt{2 p_{\text{T}}^{\nu} p_{\text{T}}^{\mu} (1 - \cos\Delta\phi_{\mu,\nu})} > 40$ GeV.
- Missing transverse momentum $p_{\text{T}}^{\text{miss}}$ reconstructed from track momenta is used as a proxy for p_{T}^{ν}.
- *W* boson candidates are assigned to centrality classes based on the total transverse energy deposited in the ATLAS forward calorimeters.

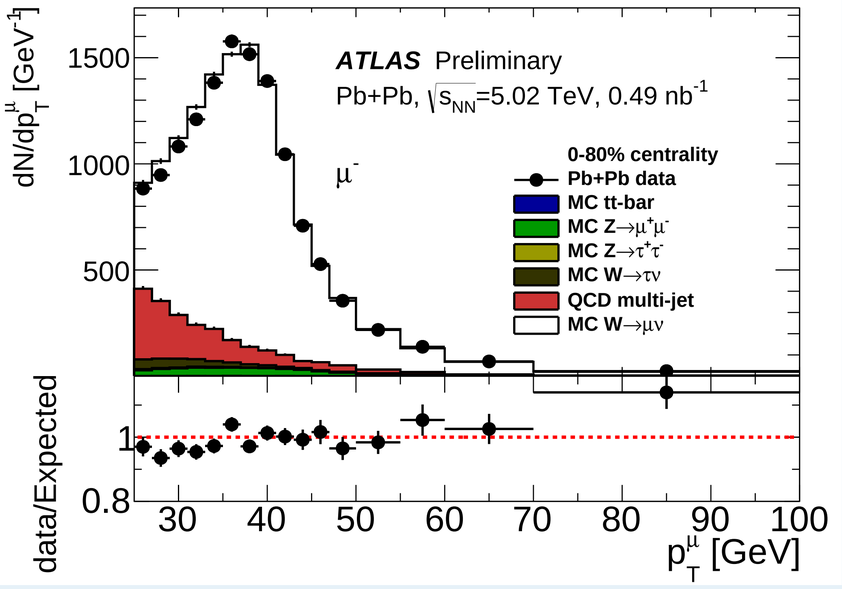
Reference

[1] ATLAS-CONF-2017-067

Control plots

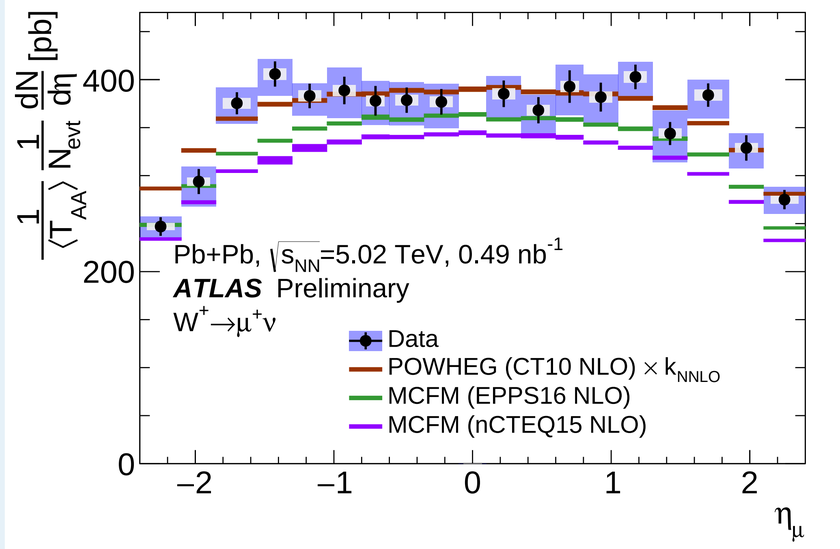
- The most dominant background contribution comes form semi-leptonic decays of heavy quarks or in-flight pion/kaon decays (**QCD multi-jet background**). It is evaluated with a data-driven approach from kinematic distributions of muons failing the isolation requirement. It varies from 6% to 12% depending on the centrality class.
- Other significant background contributions arise mostly from **electroweak processes**, like $Z \to \mu^+\mu^-$ decays or $W^\pm \to \tau^\pm\nu$ decays with tau leptons decaying subsequently to muons. These backgrounds are estimated using Monte Carlo events generated with Powheg+Pythia8 at NLO accuracy, separately for pp, pn, np and nn collisions and are at the level of 5%.

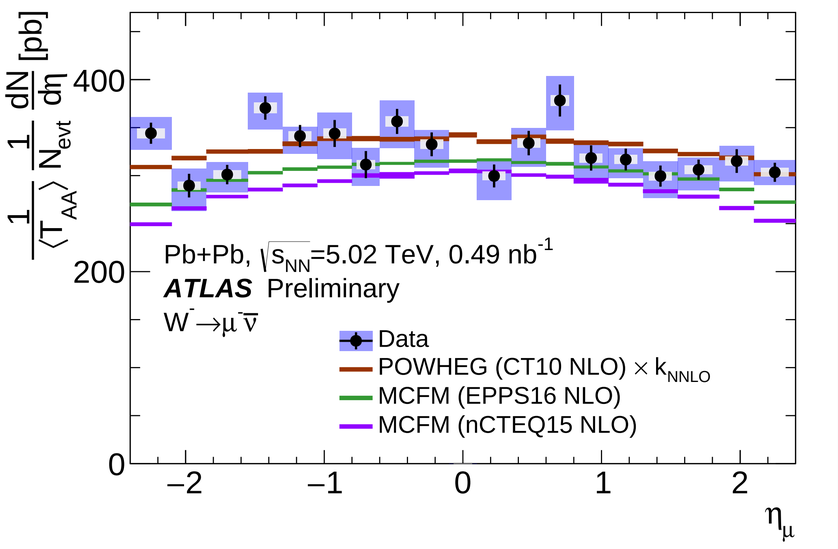




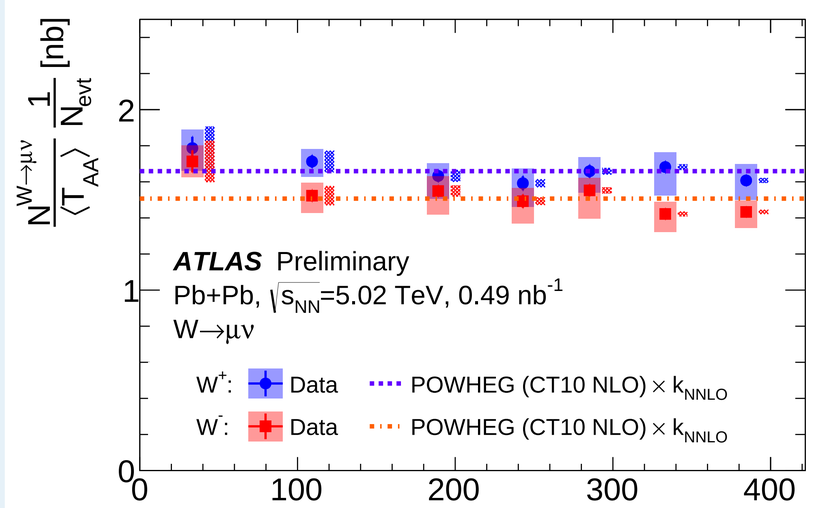
Results

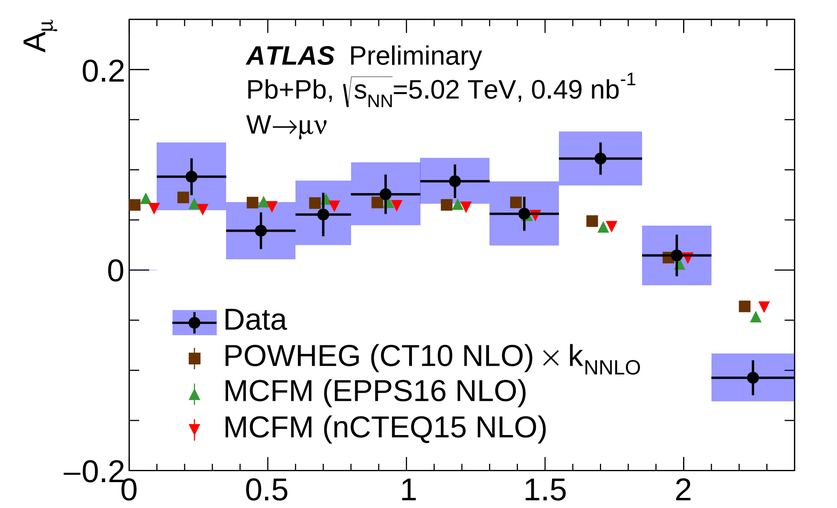
- Scaled *W* boson production yields are measured differentially in the muon pseudorapidity, integrated over centrality classes.
- Results are compared to the Powheg predictions scaled to NNLO accuracy and a good agreement is observed. Another comparison is made to calculations based on NLO MCFM using the most recent nPDF sets: EPPS16 and nCTEQ15. Both predictions tend to underpredict yields observed in data.





- Scaled W boson production yields do not depend on the collision centrality.
- These observations are consistent with the expectation that *W* bosons and their leptonic decay products do not interact with the QGP.
- The muon charge asymmetry is measured as a function of absolute muon pseudorapidity. The measurement is consistent with all predictions in $|\eta_\mu| < 1.4$, while small discrepancies are observed in the forward direction.





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