W-boson production measurement in p–Pb collisions with ALICE

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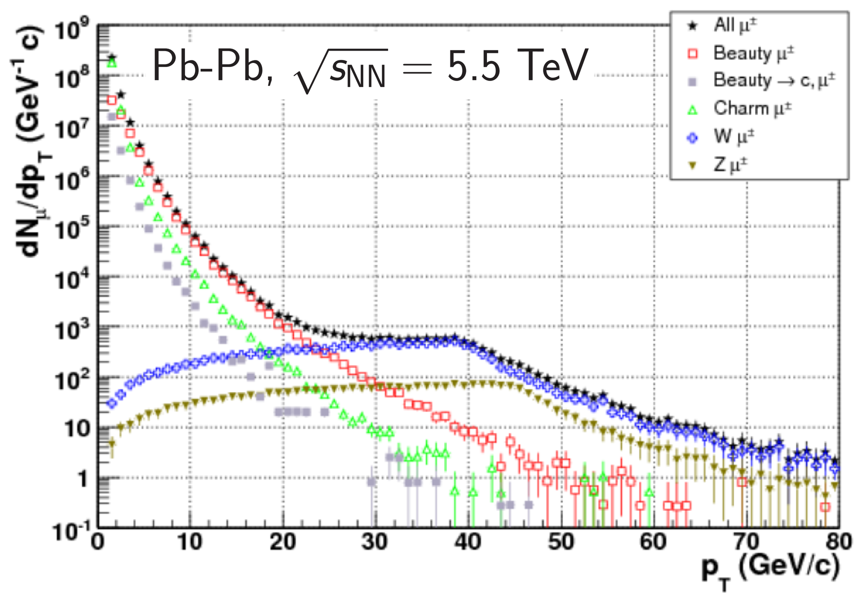
Why and how

Motivations

- $W^{\pm}$ are produced in initial hard scatterings and are not affected by the strong interaction.
- In Pb–Pb collisions: test the scaling of hard processes with the number of binary nucleon-nucleon collisions.
- In p–Pb collisions: investigate cold nuclear matter effects and constrain nuclear PDF.



Performance studies: Z. Conesa del Valle
[ALICE-INT-2006-021 & Eur. Phys. J. C49 (2007) 149]
based on $L = 5 \cdot 10^{26} \mathrm{cm}^{-2}\mathrm{s}^{-1}$, $t = 10^6$

Measurement in ALICE

- In the muonic decay channel $W^{\pm} \to \mu^{\pm} + \nu$
- Forward muon spectrometer

Data sample

- p–Pb collisions at $\sqrt{s_{NN}} = 5.02$ TeV with two opposite configurations of circulating beams.
- Trigger condition: coincidence between a signal in both the VZERO detectors (the minimum bias trigger) and in the muon trigger system for tracks with $p_T \gtrsim 4$ GeV/c.
- Integrated luminosity: p-going direction: $5.01 \pm 0.17\ \mathrm{nb}^{-1}$, Pb-going direction: $5.81 \pm 0.18\ \mathrm{nb}^{-1}$

Track selection

- Geometrical acceptance selection: $-4 < \eta^{\mu}_{lab} < -2.5$, $170^o < \theta^{\mu}_{abs} < 178^o$
- Muon identification: matching of reconstructed tracks in the trigger and tracking systems.
- Fake and beam-gas track rejection: cut on the product of the momentum and the transverse distance of the track to the interaction vertex.

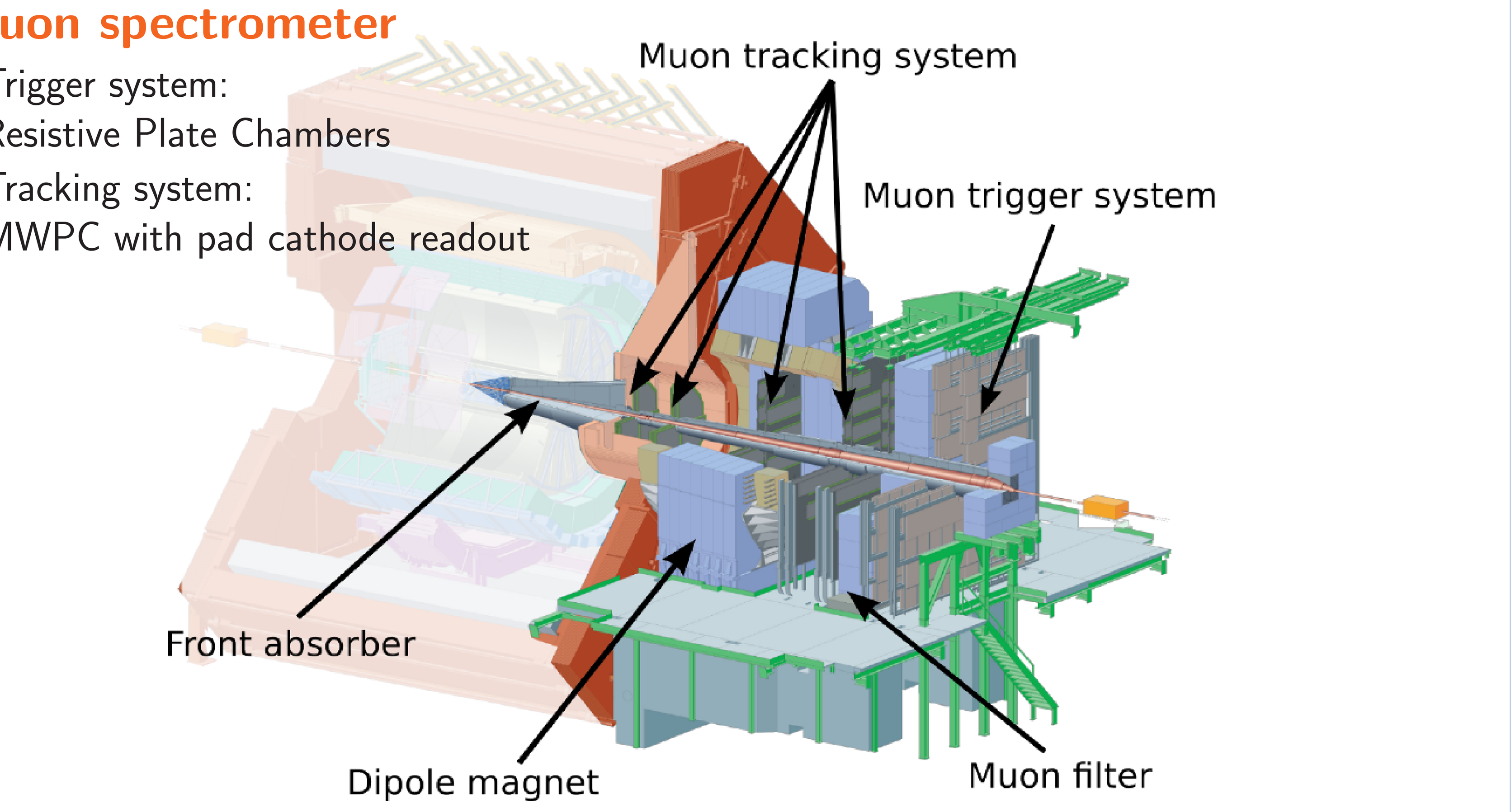
Event activity selection

- Estimators: Clusters in the 2nd SPD layer (CL1), multiplicity in VZERO (V0A, V0C) and neutron energy in ZDC (ZNA, ZNC) **(A. Toia, in this conference)**

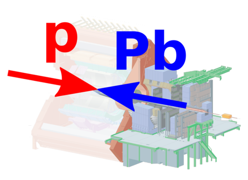
ALICE apparatus

Muon spectrometer

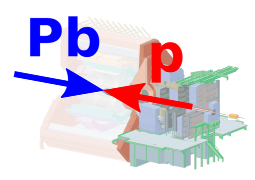
- Trigger system: Resistive Plate Chambers
- Tracking system: MWPC with pad cathode readout



The muon spectrometer acceptance:



$2.03 < y^{\mu}_{cms} < 3.53$
p-going direction



$-4.46 < y^{\mu}_{cms} < -2.96$
Pb-going direction

The proton beam direction defines positive rapidities.

Other detectors used in this analysis:

- Silicon Pixel Detector (SPD): vertex reconstruction and multiplicity estimation ($|\eta_{lab}| < 1.4$).
- VZERO: scintillator arrays, V0A ($2.8 < \eta_{lab} < 5.1$) and V0C ($-3.7 < \eta_{lab} < -1.7$), for trigger and multiplicity estimation.
- Zero Degree Calorimeter (ZDC): ± 112.4 m from the interaction point, event class estimation.

Analysis method

The number of $\mu^{\pm} \leftarrow W^{\pm}$ is extracted by fitting the p_T-distribution of single muons.

$$f(p_T) = N_{bkg} \cdot f_{bkg}(p_T) + N_{\mu \leftarrow W} \cdot f_{\mu \leftarrow W}(p_T) + N_{\mu \leftarrow Z/\gamma*} \cdot f_{\mu \leftarrow Z/\gamma*}(p_T) \qquad (1)$$

Background description

- ATLAS function $f_{bkg}(p_T) = A \cdot \exp(-B \cdot p_T) + C \cdot \frac{\exp(-D \cdot \sqrt{p_T})}{p_T^{2.5}}$ [ATLAS-CONF-2011-078]
- Only the 2nd term of ATLAS function: $f_{bkg}(p_T) = A \cdot \frac{\exp(-B \cdot \sqrt{p_T})}{p_T^{C}}$
- $\mu^{\pm} \leftarrow B + \mu^{\pm} \leftarrow D$ template from FONLL-based MC simulations [JHEP **1210** (2012) 137]

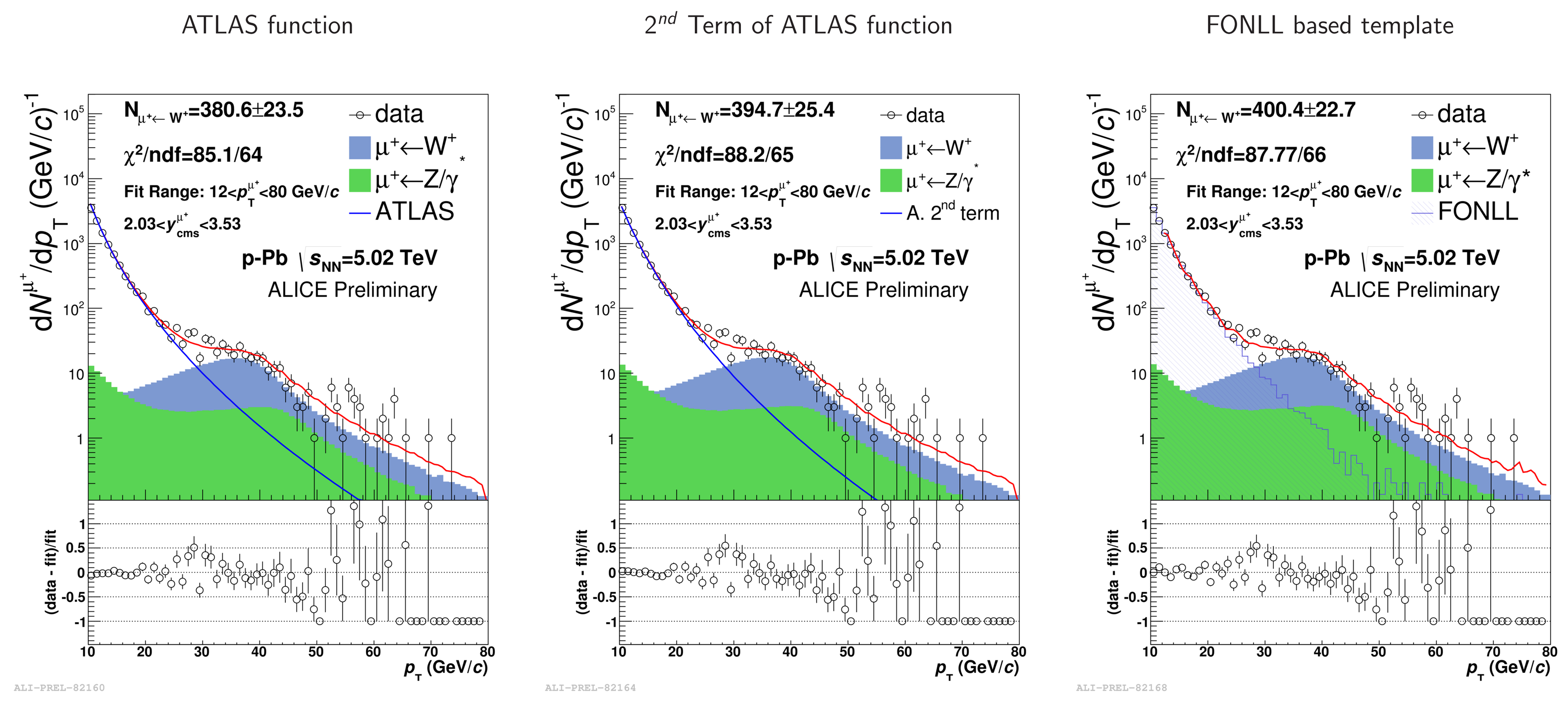
$W^{\pm}$ and Z^0/γ^* templates

Templates from realistic simulations of $W^{\pm}$ and Z^0/γ^*

- POWHEG [JHEP 0807 (2008) 060] generator with CTEQ6m PDF set and GEANT3 for muon propagation through the apparatus with detailed description of detector effects: templates used for signal extraction.
- Pythia-based MC (CTEQ6l PDF set and EPS09 nPDF): estimation of shadowing effects and systematics on MC generators.
- Simulations performed both for pp and pn collisions. p–Pb templates obtained by combining the results as:

$$\frac{1}{N_{pPb}} \cdot \frac{dN_{pPb}}{dp_T} = \frac{Z}{A} \cdot \frac{1}{N_{pp}} \cdot \frac{dN_{pp}}{dp_T} + \frac{A-Z}{A} \cdot \frac{1}{N_{pn}} \cdot \frac{dN_{pn}}{dp_T} \qquad (2)$$

- Systematic uncertainty on the efficiency due to imperfect detector description in the MC obtained by varying the detector parameters in the simulations within a realistic range.



Signal extraction

- Fractions $N_{\mu \leftarrow Z/\gamma*}/N_{\mu \leftarrow W}$ fixed: estimated with POWHEG (Pythia6.4 for systematics).
- Max-Likelihood fit method.
- Fit to data repeated by varying:
  - p_T-range of the fit.
  - Background description.
  - MC templates obtained with two sets of realistic description of the detector.
  - Two sets of $N_{\mu \leftarrow Z/\gamma*}/N_{\mu \leftarrow W}$

Raw number of $\mu^+ \leftarrow W^+$ and $\mu^- \leftarrow W^-$

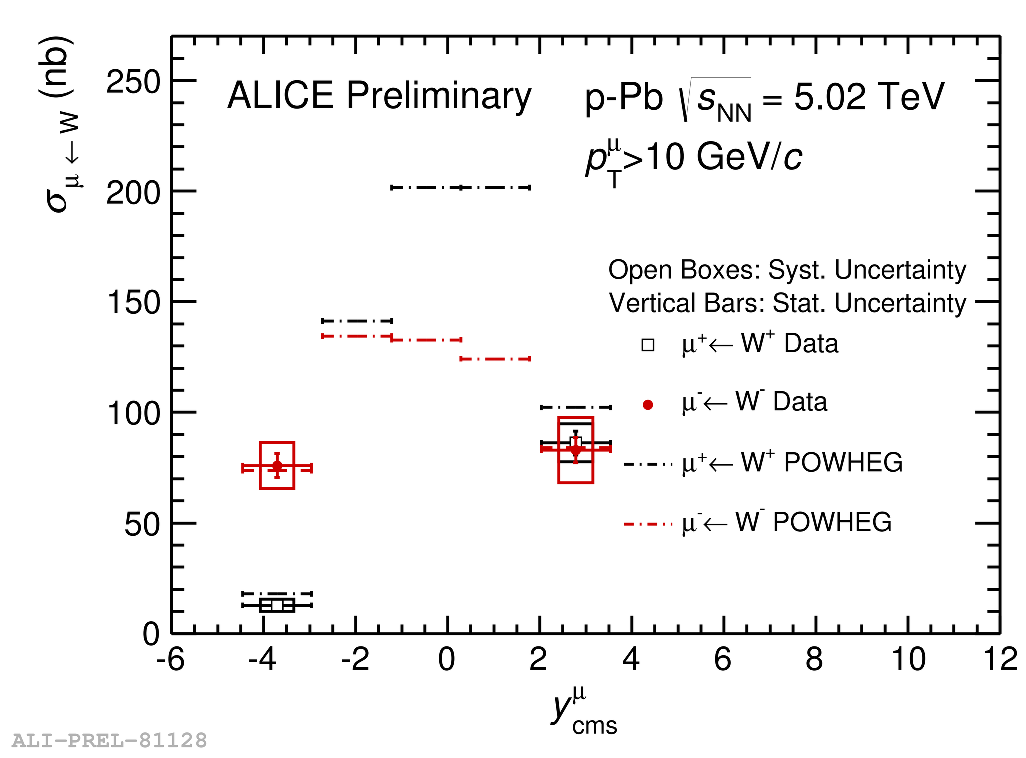
- Extracted by integrating the $\mu^{\pm} \leftarrow W^{\pm}$ templates for $p^{\mu}_T > 10\mathrm{GeV}/c$

Systematic uncertainties

Signal extraction	from ∼ 8% to ∼ 24%
Acc.×Eff.	2.7%
Luminosity	3.4%, 3.2%
Pileup	from 0 to 7.5%
$\langle N_{coll} \rangle$	from 8% to 21%

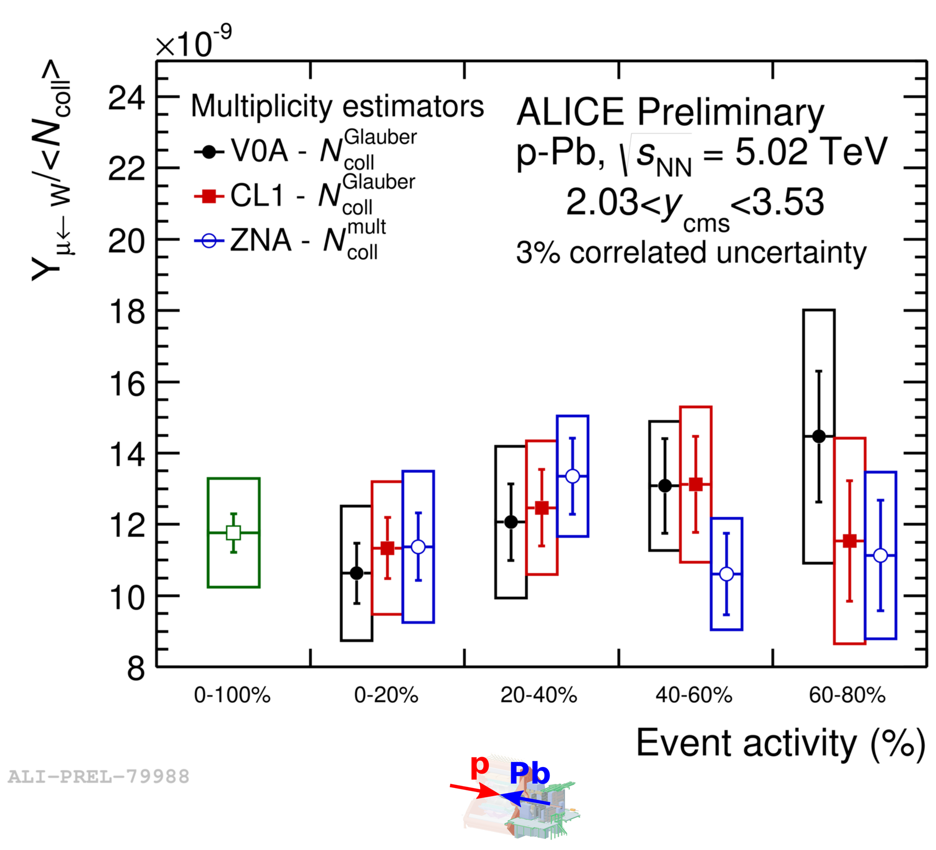
Results

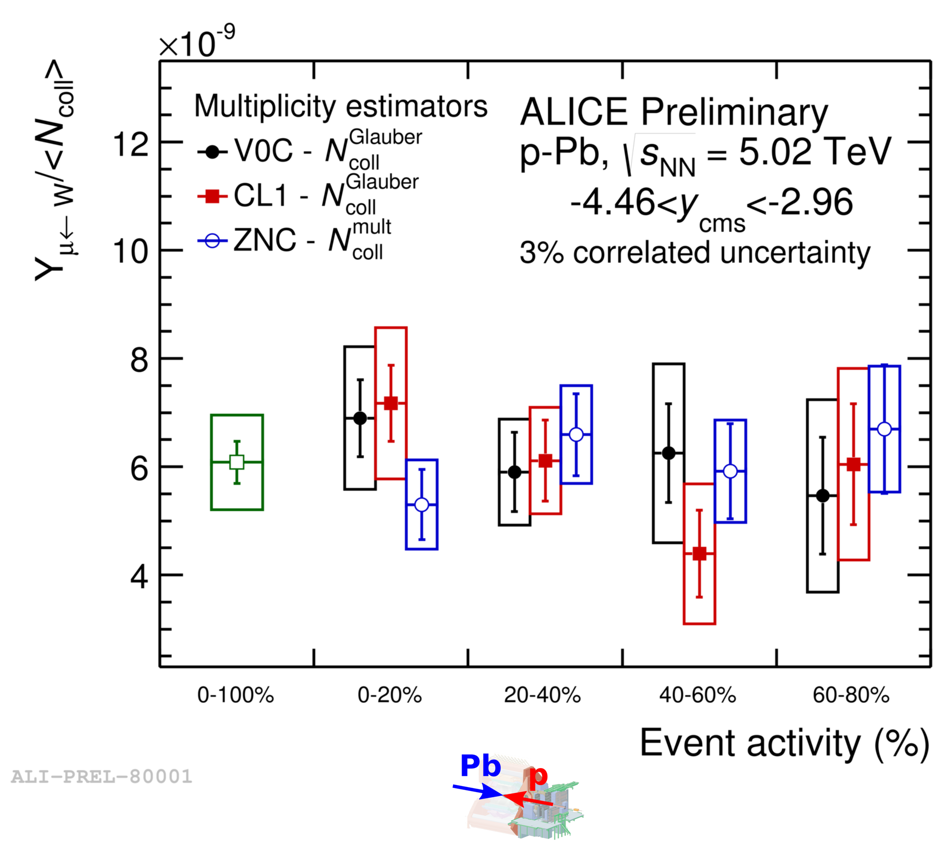
$\mu^+ \leftarrow W^+$ and $\mu^- \leftarrow W^-$ cross sections



- Cross sections measured in $2.03 < y^{\mu}_{cms} < 3.53$ and $-4.46 < y^{\mu}_{cms} < -2.96$. Large difference between $\mu^+ \leftarrow W^+$ and $\mu^- \leftarrow W^-$ at backward rapidity, comparable at forward rapidity.
- POWHEG cross section at $\sqrt{s_{NN}} = 5.02$ TeV:
  - σ^{hard}_{NN}: pp and pn productions combined using Eq.2; $\sigma^{hard}_{AB} = AB\sigma^{hard}_{NN}$
- Our measurements agree with the expectations from POWHEG within 1.5σ.
- POWHEG predictions do not include shadowing effects.

$\mu^{\pm} \leftarrow W^{\pm}$ yield normalized to $\langle N_{coll} \rangle$





- Results for $\mu^+ \leftarrow W^+$ and $\mu^- \leftarrow W^-$ are added together to increase the statistics.
- $\langle N^{Glauber}_{coll} \rangle$ values estimated using Glauber fits for V0A, V0C and CL1 multiplicity distributions.
- $\langle N^{mult}_{coll} \rangle$ for ZNA and ZNC estimators: from $\langle N^{mult}_{part} \rangle$ calculated by scaling the $\langle N_{part} \rangle$ in minimum-bias collisions by the ratio between the average multiplicity density measured at mid-rapidity for a given ZN energy event class and the one measured in minimum bias collisions.
- Within uncertainties, the yield of $\mu^{\pm} \leftarrow W^{\pm}$ per binary collision is independent of the collision multiplicity.

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