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W and Z boson precision measurements at ATLAS

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Summary. — The large statistics reachable at LHC and the clear signature of leptonic decays allow to perform high-precision measurements of W and Z bosons. In this contribution the most recent results are presented on W/Z studies at the centre-of-mass energy of 13 TeV. In addition, the first W mass measurement performed at LHC at $\sqrt{s} = 7$ TeV is also described.

1. – W and Z inclusive production cross-section and their ratios at $\sqrt{s} = 13$ TeV

Thanks to the high-precision reachable in their measurements, the W and Z vector bosons are considered Standard Model (SM) candles, also used for detector alignment and calibration. W/Z are important benchmarks for the understanding of strong (QCD) and electroweak (EW) processes and, from the comparison with available NNLO theoretical calculations, allow to constrain proton PDFs. The W and Z production cross-sections have been measured with early Run 2 data, corresponding to a luminosity of $81\,\text{pb}^{-1}$. W^+, W^- and Z cross-sections have been determined separately in the muon and electron channel with a cut-and-count technique [1] and found to be compatible, testing the lepton universality. The measurements are in agreement with theoretical calculations based on NNLO QCD with NLO EW corrections. The results have a global luminosity uncertainty of 2.1%, while the remaining experimental uncertainties in the $W^{\pm}$- and Z-boson channels are found to be under 3% and 1%, respectively.

The cross-section ratios W^+/W^-, $W^{\pm}/Z$ and $t\bar{t}/Z$ benefit from the reduction of several experimental uncertainties and from the cancellation of the luminosity systematics. The W^+/W^-, $W^{\pm}/Z$ and $t\bar{t}/Z$ ratios are sensitive to the PDFs of valence quarks, strange sea quark and gluons, respectively. In particular, $\sigma_{W^+}/\sigma_{W^-}$ is measured with

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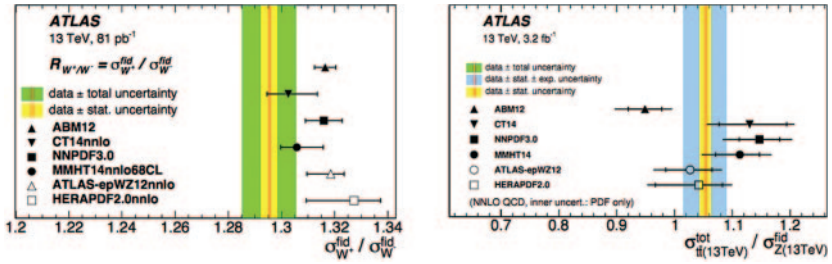

Fig. 1. – Ratios of $W^{\pm}/Z$ (left) and $t\bar{t}/Z$ (right) cross-sections compared to predictions with different PDF sets. The two measurements have been performed with data collected at 13 TeV corresponding to a luminosity of 81 pb^{-1} (left) and 3.2 fb^{-1} (right).

an uncertainty of 0.8%, which allows to discriminate among the various PDFs presented in fig. 1 (left).

The measurement of the $t\bar{t}/Z$ ratio has been performed at the different centre-of-mass energies of $\sqrt{s} = 7$, 8 and 13 TeV [2], exploring different Bjorken-x regions. Measured with a luminosity of 3.2 fb^{-1}, the $t\bar{t}/Z$ ratio at 13 TeV (fig. 1 (right)) shows excellent agreement with predictions, confirming that such measurement could be used to normalise cross-section measurements at different centre-of-mass energies. The results have a significant power to constrain the gluon distribution function at Bjorken-$x \sim 0.1$ and the total light-quark sea at $x < 0.02$, as demonstrated in [2] from a profiling analysis using the ATLAS-epWZ12 PDF set.

2. – Z + jets production at $\sqrt{s} = 13$ TeV

The Z boson produced in association with jets fits in this context. Dominated by strong interactions, it is a sensitive probe of the different Monte Carlo descriptions. The Z + jets events also constitute a non-negligible background for studies of the Higgs boson and in searches of new phenomena, where typically the jet multiplicities and kinematics are exploited to achieve a separation of the signal from the SM Z + jets process.

The Z + jets production has been measured with 2015 data corresponding to a luminosity of 3.2 fb^{-1} [3]. The fiducial cross-sections for $Z+ \geq 0$–7 jets have been measured

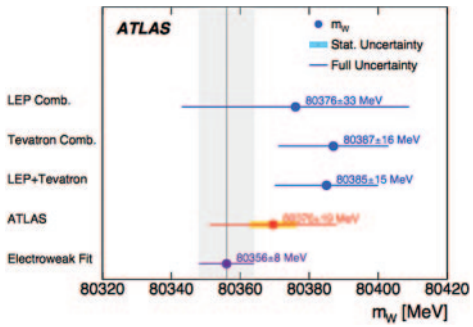

Fig. 2. – Comparison of the ATLAS measurement of the W mass with the SM predictions from the global fit, and with the combined LEP and Tevatron results.

with a precision ranging from 4% to 30%. Parton level distributions have been determined as a function of jet multiplicity and jet kinematic variables. The results show good agreement with the fixed-order $Z + \geq 1$ jet Njetti calculations, while MG5_aMC + Py8 CKKWL, which is based on LO matrix elements, models a too-hard jet spectrum. There is some evidence of deviations for high jet multiplicity, explained considering that the emission of partons for $Z + \geq 4$ jets is modelled by parton shower.

3. – W mass measurement at $\sqrt{s} = 7\,\text{TeV}$

The W mass is a fundamental parameter of the SM and at NLO it contains corrections due to top and Higgs electroweak loops, depending on m_t^2 and $\ln(m_H)$. In the global fit contest, constraints on new physics are limited by the precision on the W mass.

ATLAS performed the first measurement at LHC at $\sqrt{s} = 7\,\text{TeV}$, corresponding to a luminosity of $4.6\,\text{fb}^{-1}$ [4]. At LHC the measurement is particularly challenging, since 25% of the W production originates from the second generation of quarks, which affect the p_T distribution of the W boson: as a consequence, the mass measurement is sensitive to the s- and c-quark PDFs of the proton. The W events are selected requiring a high-p_T lepton and measuring the W recoil, to reconstruct the neutrino transverse momentum. The W mass is measured from fits on templates of the W transverse mass and the lepton transverse momentum, generated from Monte Carlo samples with different W mass values. In order to validate the analysis strategy and to constrain recoil and lepton calibrations, the Z mass has been measured with the same method. The combined result $m_W = (80370 \pm 19)\,\text{MeV}$ is in agreement with the LEP+Tevatron world average and with SM expectations (fig. 2). The result is dominated by the theoretical uncertainty, whose major sources are the QCD scale and the PDFs evolution.

4. – Conclusions

At the centre-of-mass energy of $\sqrt{s} = 13\,\text{TeV}$, several W/Z measurements have been performed, reaching a precision less than 3% (1%) in the inclusive $W(Z)$ cross-sections. An even higher sensitivity has been reached in the determination of the cross-sections ratios: in particular, W^+/W^- has been measured with a precision of 0.8%. The $Z+\text{jets}$ production has been studied up to high jet multiplicity and found in good agreement with NNLO calculations. ATLAS performed the first measurement of the W mass at $\sqrt{s} = 7\,\text{TeV}$, obtaining a value in agreement with the world average and consistent with SM expectations, the uncertainty being dominated by the theoretical contribution.

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