IL NUOVO CIMENTO Vol. 37 C, N. 1 Gennaio-Febbraio 2014
DOI 10.1393/ncc/i2014-11689-2

Colloquia: IFAE 2013

Main electroweak physics results from CMS and ATLAS experiments

A. Tropiano

Università di Firenze e INFN, Sezione di Firenze - Firenze, Italy and CERN - Geneva, Switzerland

ricevuto l'1 Ottobre 2013

Summary. — The latest electroweak results from CMS and ATLAS experiments, based on pp collision data taken at 7 and 8 TeV, are presented. In particular precise measurements of the inclusive and differential cross-sections for W and Z boson production, and for multi-boson production are shown.

PACS 14.70.Fm – W bosons.
PACS 12.60.Cn – Extensions of electroweak gauge sector.
PACS 13.85.Fb – Inelastic scattering: two-particle final states.
PACS 13.38.Be – Decays of W bosons.

1. – Introduction

The dominant mechanism for W and Z boson production in pp collisions at the Large Hadron Collider (LHC) is the annihilation of a valence quark from one proton with a sea antiquark from the other. The contribution from sea quark-antiquark scattering is also relevant, as a value of $Q^2 \sim M_Z^2$ is reached in the interactions between partons carrying a proton momentum fraction $10^{-3} < x < 10^{-1}$. Furthermore the process where a vector boson is produced in association with a jet depends primarily on the gluon content of the proton. Therefore, the W and Z production allows probing both the electroweak couplings to the quarks and constraining the PDFs.

Similarly the measurement of the diboson production is a direct test of triple gauge couplings (TGC). In the Standard Model only the charged triple gauge couplings, WWZ and WWγ, are allowed, while the neutral, ZZZ, ZZγ and Z$\gamma\gamma$, are forbidden. Any deviation of the latter from zero would be therefore an evidence of new physics beyond the Standard Model.

In the following the latest measurements of single and diboson cross-section measurements done by the CMS [1] and ATLAS [2] experiments at the LHC are reviewed and compared with expectations from the theory.

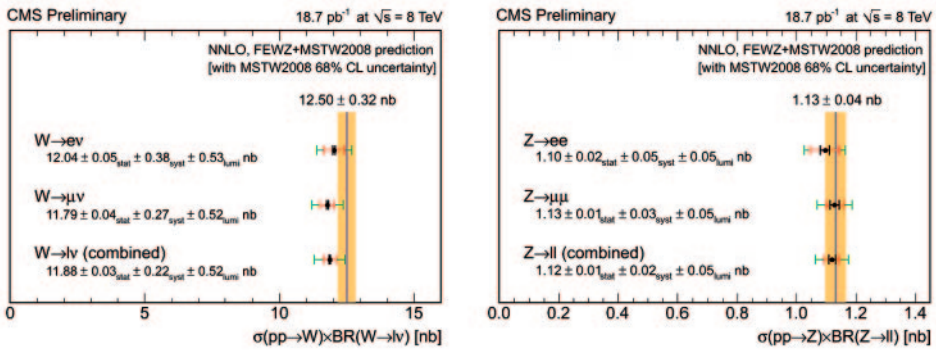

Fig. 1. – Summary of the W (left) and Z (right) production cross-section times branching ratio measurements. Measurements are compared to the theoretical predictions (yellow band) computed at the NNLO in QCD with FEWZ and the MSTW2008 PDF set. Statistical uncertainties are represented as black error bars, while the red error bars also include systematic uncertainties, the green error bars also include luminosity uncertainties.

2. – W and Z cross-section measurements

A precision measurement of the inclusive W and Z boson cross-sections at $\sqrt{s} = 8\,\text{TeV}$ [3] has been performed by the CMS experiment. The analysis was performed on a dataset with a low number of proton-proton interactions per bunch crossing to ensure a good missing transverse energy resolution and to keep low trigger thresholds. A data sample corresponding to an integrated luminosity of $18.7 \pm 0.9\,\text{pb}^{-1}$ was collected and both electron and muon final states were analyzed. The measured values are shown in fig. 1 and agree with NNLO cross-section calculations.

In addition to the analysis of 8 TeV data, several analyses have been updated by both experiments with the full dataset at 7 TeV. A measurement of the Drell-Yan differential cross-section $\mathrm{d}\sigma/\mathrm{d}M_{ll}$ in the dielectron and dimuon channels has been been performed [4] [5]. Distributions are unfolded for the effects of resolution and final state QED radiation. The $\mathrm{d}\sigma/\mathrm{d}M_{ll}$ results are overall in very good agreement with the NNLO theoretical predictions. ATLAS results compared with theoretical predictions and 3 different sets of PDFs are shown in fig. 2.

CMS and ATLAS also made measurements of Z/W+jets differential cross-section using $5\,\text{fb}^{-1}$ data at $\sqrt{s} = 7\,\text{TeV}$ collected during 2011. The jet multiplicity in Z+jets data collected by ATLAS [6] (fig. 3) is well predicted by BlackHat+Sherpa parton level NLO calculation (up to four hard partons). The complexity of an exact ME calculation increases dramatically as a function of N_{jets} so for $N_{jets} \geq 4$ LO predictions are used for comparison. For very high number of jets ($N_{jets} \geq 6$) Parton Shower seems capable of filling the phase space in terms of event rate. CMS collaboration has measured azimuthal correlations $\Delta\Phi(Z, j_i)$ and $\Delta\Phi(j_i, j_j)$ for $N_{jets} \geq 3$ [7]. This measurement complements the picture in terms of angular properties (fig. 4). Predictions from NLO+PS for the Z+1-jet final state are of particular interest here, and show agreement with $N_{jets} \geq 3$ data.

3. – Diboson production and limits on TGC couplings

The WW and ZZ production cross-sections are measured in proton-proton collisions at $\sqrt{s} = 7/8\,\text{TeV}$ by both ATLAS and CMS experiments [8, 9]. The measurements are performed in the leptonic decay modes and the measured cross-sections are consistent

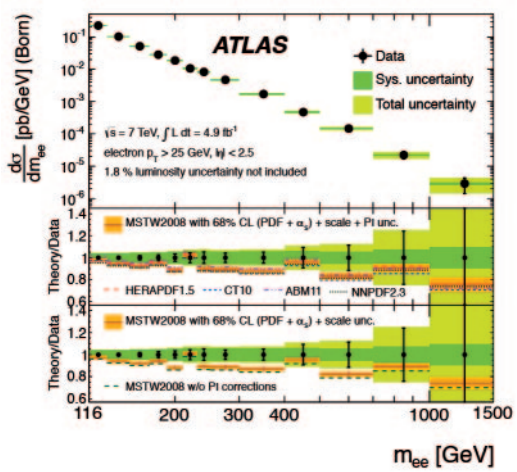

Fig. 2. – Measured differential cross-section at the Born level within the fiducial region (electron $p_T > 25\,\text{GeV}$ and $|\eta| < 2.5$) with statistical, systematic, and combined statistical and systematic (total) uncertainties. The measurement is compared to FEWZ 3.1 calculations at NNLO QCD with NLO electroweak corrections.

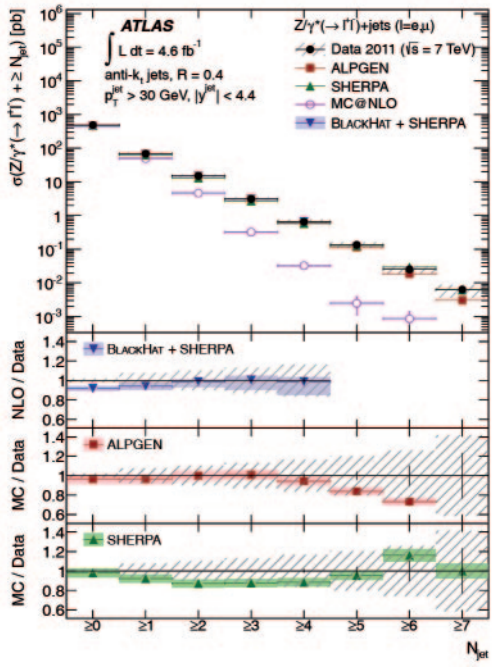

Fig. 3. – Cross-section measured as a function of the jet multiplicity by the ATLAS collaboration. The data are compared to NLO pQCD predictions from BlackHat+SHERPA corrected to the particle level, and the ALPGEN, SHERPA and MCatNLO event generators (see legend for details). The error bars indicate the statistical uncertainty on the data, and the hatched (shaded) bands the statistical and systematic uncertainties on data.

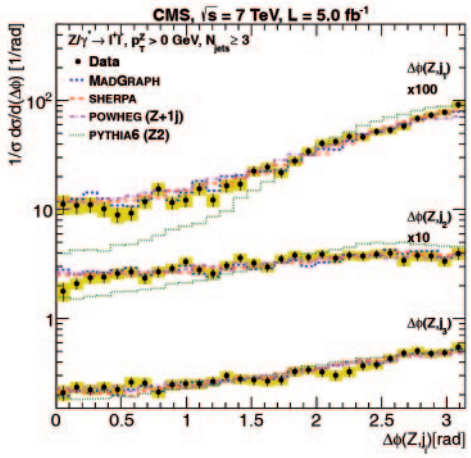

Fig. 4. – Distribution of $\Delta\Phi$ between Z and the three leading jets in the inclusive 3 jet multiplicity bin from data and MC simulations from Sherpa, Pythia6, Powheg and MadGraph. The data distributions are unfolded and compared to MC particle level distributions. The distributions are normalized by the cross-section integrated over the selected phase space. The error bars on the data points represent the statistical uncertainty on the data after the unfolding, the shaded (yellow) bands represent the sum of statistical and systematic errors.

with Standard Model predictions. Figure 5 shows the ZZ cross-section as a function of $\sqrt{s}$ for several experiments. The measured cross-section agrees over a wide range of energy.

The full data sample collected at $\sqrt{s} = 7\,\text{TeV}$ has been used to measure Wγ and Zγ production cross-sections and set limits on anomalous triple WWγ, ZZγ and Z$\gamma\gamma$ gauge couplings [10,11]. Preliminary results show no deviation from the Standard Model values.

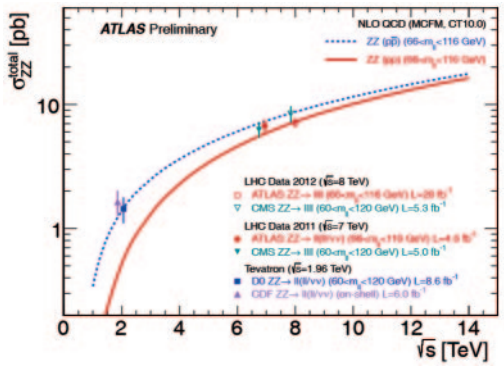

Fig. 5. – Comparison of experimental measurements and theoretical predictions of the total ZZ production cross-section as a function of centre-of-mass energy $\sqrt{s}$ from various experiments. Shown are experimental measurements from CDF and D0 in $p\bar{p}$ collisions at the Tevatron at $\sqrt{s} = 1.96\,\text{TeV}$, and experimental measurements from ATLAS and CMS in pp collisions at the LHC at $\sqrt{s} = 7\,\text{TeV}$ and $\sqrt{s} = 8\,\text{TeV}$. The blue dashed line shows the theoretical prediction for the ZZ production cross-section in $p\bar{p}$ collisions, calculated at NLO in QCD.

4. – Conclusions

ATLAS and CMS experiments at the LHC accomplished a large program of electroweak measurements testing the Standard Model with a precision comparable or even better than available (N)NLO predictions. The results are in agreement with expectations for production cross-sections over several order of magnitude. The measurements of inclusive and differential cross-sections of W and Z bosons provides significant constraints on PDFs. The measurements of diboson production set stringent limits on the triple gauge couplings. No significant deviation from the Standard Model is observed.

REFERENCES

[1] CMS Collaboration, *The CMS experiment at the CERN LHC*, *JINST*, **03** (2008) S08004.
[2] ATLAS Collaboration, *The ATLAS experiment at the CERN Large Hadron Collider*, *JINST*, **03** (2008) S08003.
[3] CMS Collaboration, *Measurement of the inclusive W and Z cross sections at 8 TeV*, to be published, CMS-PAS-SMP-12-011 (2013).
[4] CMS Collaboration, *Measurement of the differential and double-differential Drell-Yan cross sections in proton-proton collisions at* $\sqrt{s} = 7$ *TeV*, *JHEP*, **12** (2013) 030, CMS-PAS-SMP-13-003.
[5] ATLAS Collaboration, *Measurement of the high-mass Drell-Yan differential cross-section in pp collisions at* $\sqrt{s} = 7$ *TeV with the ATLAS detector*, *Phys. Lett. B*, **725** (2013) 223.
[6] ATLAS Collaboration, *Measurement of the production cross section of jets in association with a Z boson in pp collisions at sqrt(s) = 7 TeV with the ATLAS detector*, *JHEP*, **07** (2013) 032.
[7] CMS Collaboration, *Event shapes and azimuthal correlations in Z+jets events in pp collisions at* $\sqrt{s} = 7$ *TeV*, *Phys. Lett. B*, **722** (2013) 238.
[8] CMS Collaboration, *Measurement of W+W- and ZZ production cross sections in pp collisions at* $\sqrt{s} = 8$ *TeV*, *Phys. Lett. B*, **721** (2013) 190, arXiv:1301.4698 (2013).
[9] Atlas Collaboration, *Phys. Rev. D*, **87** (2013) 112001.
[10] CMS Collaboration, *Measurement of the* $W\gamma$ *and* $Z\gamma$ *inclusive cross sections in pp collisions at* $\sqrt{s} = 7$ *TeV and limits on anomalous triple gauge boson couplings*, submitted to *Phys. Rev. D* (2013), arXiv:1308.6832 (2013).
[11] Atlas Collaboration, *Phys. Rev. D*, **87** (2013) 112003.