PROCEEDINGS OF SCIENCE

W/Z boson production and properties measurements

Marco MUSICH*
INFN - Sez. di Torino
E-mail: marco.musich@to.infn.it

Nicola ORLANDO
Dipartimento di Matematica e Fisica "Ennio De Giorgi", Università del Salento
INFN - Sez. di Lecce
E-mail: nicola.orlando@le.infn.it

Observation of the electroweak gauge bosons via their decays to electrons and muons provide an important test of the Standard Model of particle physics. Inclusive W and Z boson cross section measurements provide checks of Next-to-Next-to-Leading-Order perturbative QCD calculations, while differential and double-differential Drell-Yan cross section investigate both QCD and PDF constraints. The measurement of the associated production of jets and vector bosons allows for stringent constraints of perturbative QCD calculations and is sensitive to the presence of new physics beyond the Standard Model. Measurements of jet production rates in association with W, Z/γ^{*}, in proton-proton collisions at 7 and 8 TeV center-of-mass energy are presented, using data collected with the ATLAS and CMS detector. Measurements include inclusive jet multiplicity, differential jet cross sections, as well as associated charm- and bottom-quark jet production.

VI Italian workshop on p-p physics at the LHC,
8-10 May 2013
Acquario di Genova, Ponte Spinola, Area Porto Antico, Genova, Italy

*Speaker.

 http://pos.sissa.it/

PoS(LHCPP2013)019

1. Inclusive W/Z measurements

The study of $W^{\pm}$ and Z[1] vector bosons production in proton-proton collisions at the LHC represents an important test of perturbative QCD calculations, and can be used to constrain the parton density functions (PDF) of the proton. The Next-to-Next-to-Leading-Order (NNLO) QCD predictions with different generators and QCD tunings are tested using several W and Z measurements with ATLAS [1] and CMS [2] collision data, at a center of mass energy of 7 and 8 TeV. Processes involving vector bosons play an important role in Higgs boson studies, as well as in the searches of new physics phenomena, since they are often the dominant background. Precise measurements of the properties of the W and Z bosons are essential for understanding and testing the Standard Model at the new energy regime reached at the LHC.

The inclusive vector boson cross section has been previously measured by ATLAS and CMS at a center-of-mass energy of 7 TeV [3, 4]. The measurement at $\sqrt{s} = 8$ TeV by CMS [5] makes use of an integrated luminosity of 19 pb^{-1}. The Z boson inclusive cross section is measured from the invariant mass distribution of the dilepton final state in the range $60 < M_{\ell\ell} < 120$ GeV for high p_T leptons in the pseudorapidity range of $|\eta| < 2.4$. $W^{\pm}$ boson cross inclusive cross section is extracted by means of a binned maximum likelihood fit to the missing transverse energy distribution for single isolated leptons in the range $|\eta| < 2.1$. The final results are then compared to the theoretical NNLO FEWZ [6] predictions with a MSTW2008 [7] PDF set, for muons and electrons final state, and for the dilepton combination (Fig.1). These measurements are consistent between the different channels, and in agreement with NNLO cross section calculations.

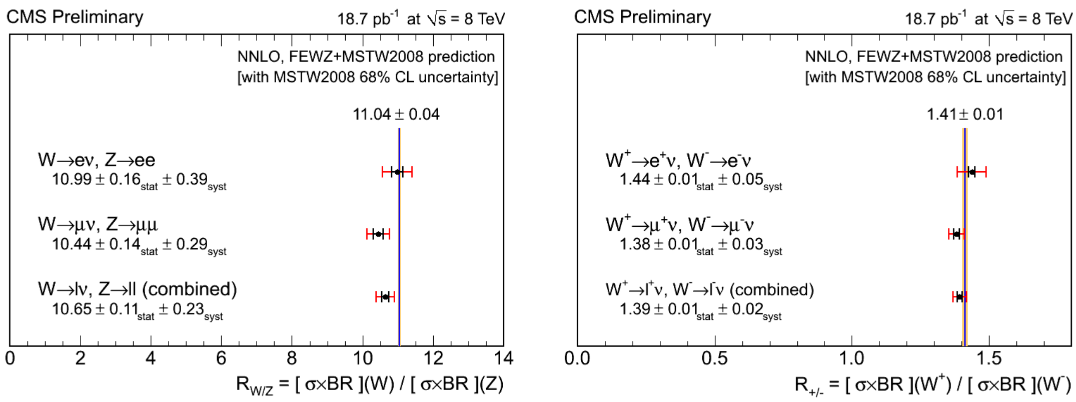

Figure 1: Summary of the W to Z (left) and W^+ to W^- (right) production cross sections times branching ratio in the leptonic channel $\sigma_V \times BR(V \to \ell), V = Z, W^{\pm}$. Measurements in the electron and muon channels, and combined, are compared to the theoretical predictions (yellow band) 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. Luminosity uncertainties cancel in the ratios.

The Drell-Yan differential cross section $d\sigma/dM$ for Z bosons has been measured by CMS [8] in the electron and muon pairs decay channels in the range $15< M_{\ell\ell} <1500$ GeV, along with the

[1] In the following by "Z" boson it is intended Z^0/γ^*, being understood that the virtual photon contribution is not treated separately.

double-differential cross section $d^2\sigma/dMdY$ in rapidity bins in the mass range of 20< $M_{\ell\ell}$ <1500 GeV. The dilepton mass is corrected for the leptons final state radiation (FSR). The results, presented in Fig.2 left, are compared with the predictions of perturbative QCD calculations at NNLO (FEWZ) using the CT10 [9] PDF set. Including the correlations between the two channels, the normalized χ^2 calculated with total uncertainties on the combined results is 1.1 between data and theory expectation. ATLAS presented a similar measurement [10] in the electron channel in the mass range 116< $M_{\ell\ell}$ <1500 GeV, outside the Z resonant peak, both at the dressed (FSR corrected) and Born level. The ATLAS measured cross section at dressed level shows (Fig.2 right) that NLO QCD predictions are not completely satisfactory in describing the data.

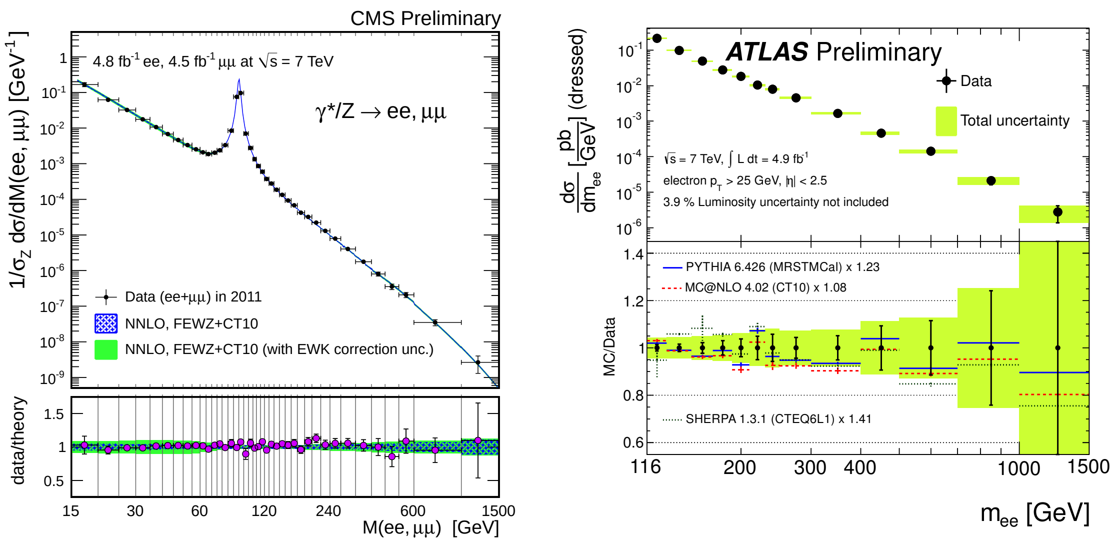

Figure 2: Left: combined Drell-Yan invariant mass spectrum in the $Z \to \ell^+\ell^-$ channel, normalized to the Z-peak region $r = (1/\sigma_Z d\sigma/dM)$, as measured by CMS [8] compared to FEWZ [6] NNLO calculations. The lower left panel shows overall good agreement between data and the theory prediction. The blue error band for the theory calculation includes the statistical error from the FEWZ calculation and PDF uncertainty combined in quadrature. The uncertainty of electroweak correction including $\gamma\gamma$ initiated processes effect is added in the green error band. Right: the high mass region of the Drell-Yan invariant mass spectrum as measuread by ATLAS [10]. In the lower right panel the measurement is compared to the predictions of the PYTHIA, MC@NLO and SHERPA MC generators including their statistical uncertainties. The cross-section predictions of each generator have been scaled by a global factor as indicated on the ratio plots to match the total number of events observed in data.

In hadron-hadron collisions, the W and Z vector bosons are produced with a momentum component transverse to the beam axis, which is balanced by a recoiling hadronic system mainly arising from initial state QCD radiation of quarks and gluons. The measurement transverse momentum of the boson offers a very sensitive way of studying dynamical effects of the strong interactions, complementary to measurements of the associated production of the bosons with jets (see Sec.2). The simple signatures of $Z \to \ell^+\ell^-$ production, which can be identified with small background, enable a precise measurement of the boson transverse momentum p_T^Z and thus provide an ideal ground for testing predictions of QCD and phenomenological models. Moreover, the knowledge of the p_T^Z distribution is crucial to improve the modelling of W boson production needed for a precise measurement of the W mass, in particular in the low p_T^W region which dominates the cross section

[11, 12]. At low boson p_T^Z values, some discrepancy with the spectrum measured by CMS [13] is observed at $\sqrt{s}$ = 8 TeV when comparing different PYTHIA [14] tunes (Fig. 3 left). Resummed Next-to-Leading-Order plus Next-to-Next-to-Leading-Log (NLO+NNLL) QCD calculations implemented in RESBOS [15, 16] are in good agreement with the spectrum observed by ATLAS [17] for p_T^Z < 10 GeV while Leading Order (LO) Monte Carlo (MC) multileg predictions (ALPGEN[18], POWHEG[19], SHERPA[20]) provide an adequate description of the spectrum at high values of p_T^Z > 20 GeV (Fig. 3 right). MC@NLO [21] is found to be inconsistent with the data.

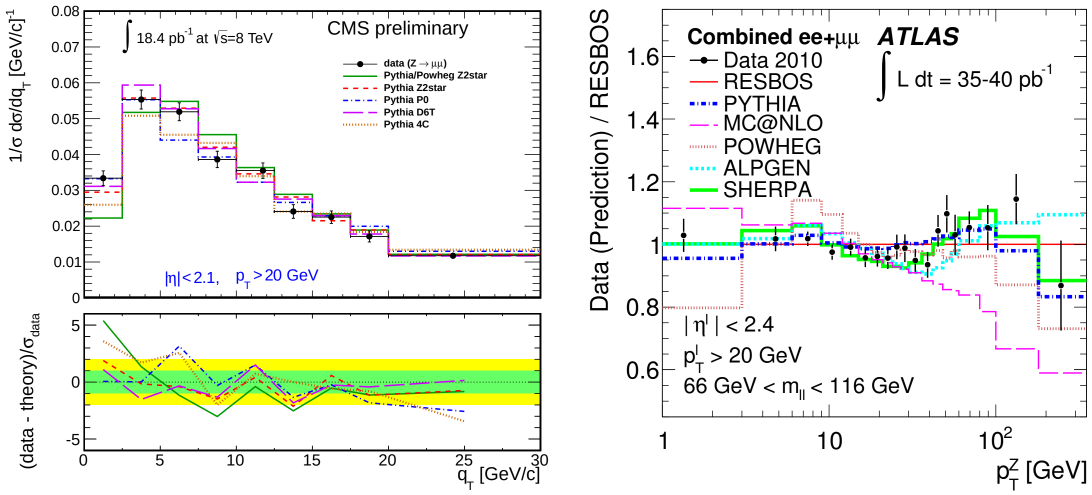

Figure 3: Left: the momentum distribution of the Z boson measured by CMS [13] at $\sqrt{s}$ = 8 TeV in the low momentum range $0 < p_T^Z < 30$ GeV compared with different PYTHIA tunes predictions. The lower left panel shows the discrepancy between data and the PYTHIA predictions in number of standard deviations. While most of the discrepancy is contained in a 2σ envelope, different tunes differ in individual bins up to 5 standard deviations. Right: the ratios of the ATLAS [17] 7 TeV data and various generator predictions over the RESBOS prediction for the normalized differential cross section as a function of p_T^Z.

The angular correlation between the leptons produced in the $Z \to \ell^+\ell^-$ decay is sensitive to the transverse momentum of the Z boson. In particular the ϕ^*_η angle is correlated to the quantity $p_T^Z/m_{\ell\ell}$ and therefore probes the same physics as the transverse momentum p_T^Z. The ϕ^*_η angle is defined as $\phi^*_\eta = \tan(\frac{\phi_{acop}}{2}) \cdot \sin(\theta^*_\eta)$ where $\phi_{acop} = \pi - \Delta\phi(\ell^+, \ell^-)$ being the azimuthal opening angle between the two leptons and the angle θ^*_η is a measure of the scattering angle of the leptons with respect to the proton beam direction in the rest frame of the dilepton system. The angle θ^*_η is defined via $\cos(\theta^*_\eta) = \tanh[\frac{[\eta(\ell^+)-\eta(\ell^-)]}{2}]$. The ϕ^*_η angle is an optimal experimental observable to probe the low-p_T^Z domain of Z production because it depends exclusively on the directions of the two lepton tracks, which are better measured than their momenta. Values of ϕ^*_η ranging from 0 to 1 probe the p_T^Z distribution mainly up to $\sim$ 100 GeV. ATLAS data [22] is compared to NLO+NLLL QCD predictions (RESBOS, Banfi et al. [23, 24]), fixed order NNLO (FEWZ) calculations and some MC event generators (Fig.4). The measurement is typically one order of magnitude more precise than the present theoretical uncertainties. The ϕ^*_η variable measured in $Z \to \ell^+\ell^-$ events from D0 [25] has been found in the past to be one of the most effective handles on the description of the underlying event at the Tevatron [26], and has been effectively used to discriminate Monte Carlo tunes. The study of this variable shows potential for improving the low p_T^Z spectrum description also at the LHC.

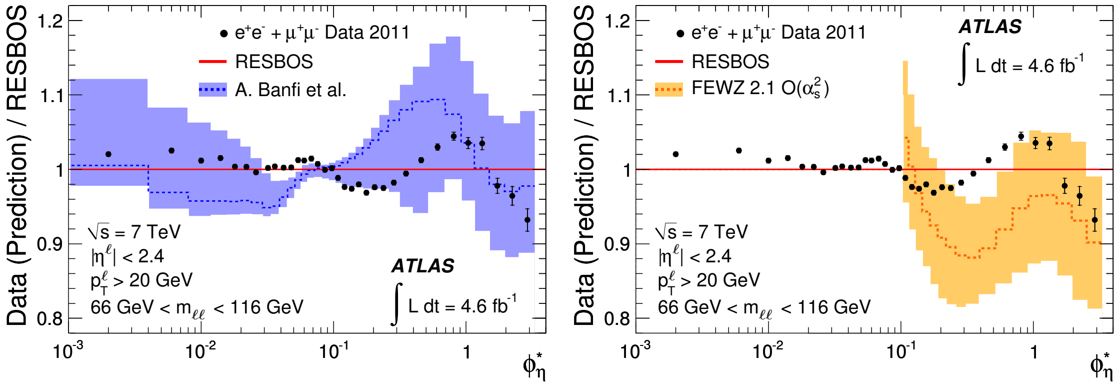

Figure 4: The ratio of the combined normalised differential cross section from ATLAS [22] to RESBOS predictions as a function of ϕ^*_η. The measurement is also compared to predictions, which are represented by a dashed line, from [24] (left) and to the prediction from FEWZ 2.1 (right).

2. Associated production of vector bosons and jets

Vector bosons (V = W or Z) produced in association with jets (V + jets in the following) provide a precise way to test pertubative QCD predictions. The small theoretical uncertainty on the V + jets production together with the small experimental uncertainty on the selection of the V + jets signal, makes it possible to study higher order pertubative effects and PDFs. The V + jets production is one of the most important background processes in many searches for new physics phenomena, therefore a good understanding of it is vital for searches at the LHC. Measurements from ATLAS and CMS using data at $\sqrt{s}$ = 7 TeV are reported. The experimental results are corrected for detector effects and are compared with predictions from BLACKHAT [27], POWHEG, MC@NLO, MCFM [28], MADGRAPH [29], ALPGEN and SHERPA. The leading order (LO) matrix element (ME) MC event generators are interfaced with PYTHIA and HERWIG [30] for parton showering (PS) with the exception of SHERPA which uses its own built-in PS. The NLO ME calculations from POWHEG and MC@NLO are interfaced with PYTHIA and HERWIG and their predictions are provided at particle level (NLO+PS). The MC samples from MADGRAPH, ALPGEN and SHERPA have been normalized, for the inclusive V production, to the NNLO cross section calculated with FEWZ. Details on the exact MC configurations including the used PDFs and the choice of scales can be found in the cited articles.

The jet multiplicity in Z + jets data (Fig.5 left) measured by ATLAS [31] is well predicted by BLACKHAT+SHERPA parton level NLO calculation including the generation of up to four hard partons. The NLO+PS prediction from MC@NLO is NLO for the inclusive Drell-Yan production and is only LO for the Z + 1-jet (Fig.5). The complexity of an exact ME calculation increases dramatically as a function of N_{jets}. While an exact ME calculation is available here, to LO for up to five partons, jet multiplicity in data extends to $N_{jets} \geq 6$. The prediction obtained using MC that include the PS are capable, within the present uncertainties, of describing the event rate as a function of N_{jets} observed in data.

An inclusive observable of high interest, in LHC searches, is the Z transverse momentum (Fig.5 right) which shows a systematic trend as a function of p_T^Z for the ME+PS comparisons. ME+PS predicts an event yield higher than what is observed in data, the size of this effect is consistent with the reduction of the Z + jets cross section due to higher-order electroweak corrections [32]. In searches for new physics with jets and invisible energy that have $Z \to \nu\nu$ as irreducible background, a systematic effect of this order will decrease the discovery potential of the smallest signals of interest.

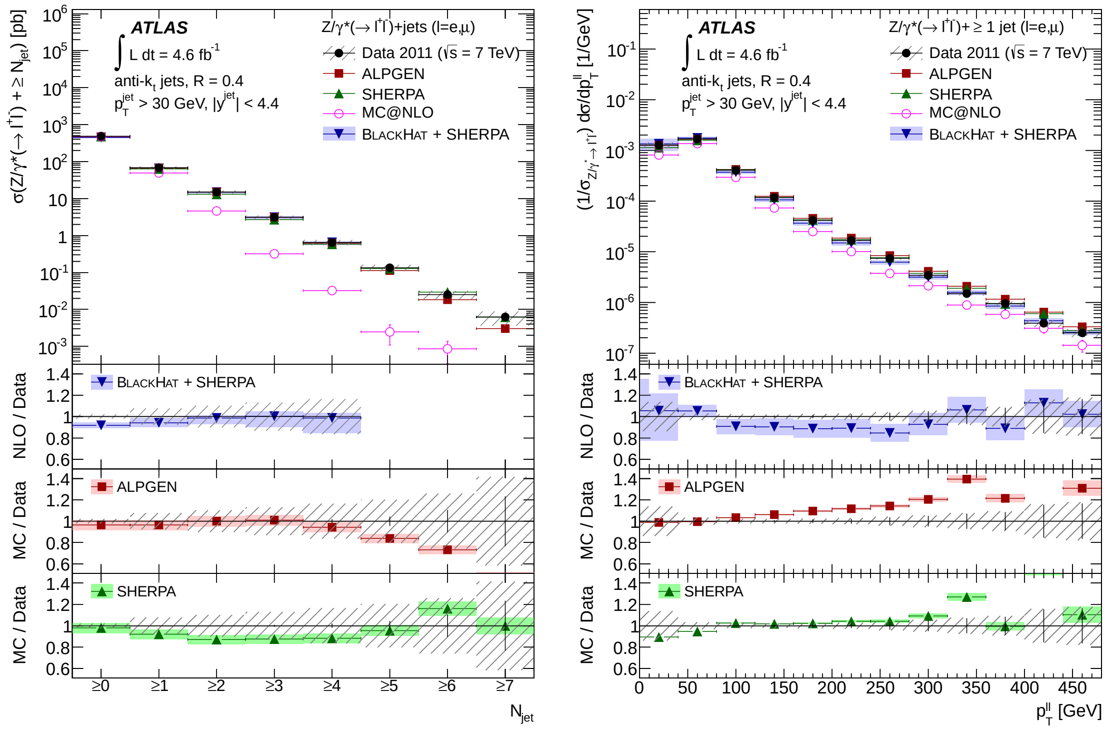

Figure 5: Z+jets cross section measured by ATLAS [31] as a function of the jet multiplicity (left) and of the transverse momentum of the Z boson (right) for data (full circles) and for various MC predictions.

Azimuthal correlations $\Delta\phi(Z, j_i)$ and $\Delta\phi(j_i, j_j)$ for $N_{jets} \geq 3$ are measured by CMS [33] in an attempt to complement the picture in terms of angular properties (Fig.6). 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 despite the fact that, beyond the subleading jet, additional radiation comes exclusively from PS. High jet multiplicity implies a large scale and an increased phase space available for parton emission.

The question of whether the strange content of the proton is suppressed with respect to the light quarks, is directly assessed by CMS with the measurement of the W plus charm cross section [34] and the ratio of $R_c^{\pm} = \frac{\sigma(W^+ + \bar{c})}{\sigma(W^- + c)} \sim \frac{\bar{s} + |V_{dc}|^2 \bar{d}}{s + |V_{dc}|^2 d}$ which, modulo Cabibbo-sopressed terms, is sensitive to the strange/anti-strange ratio. The measurements are consistent with the strange suppression s/d $\leq$

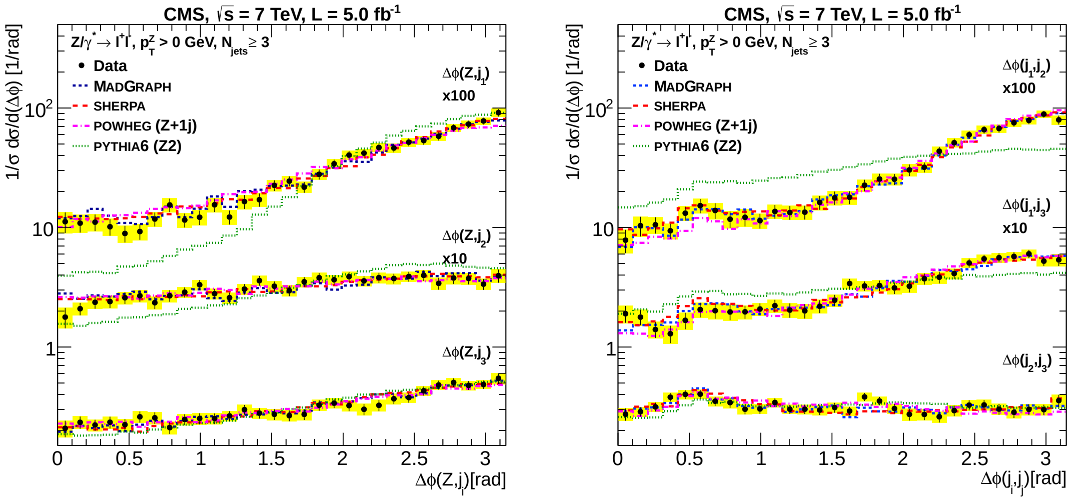

Figure 6: Z+jets cross section measured by CMS [33] as a function of the azimuthal correlations $\Delta\phi(Z, j_i)$ (left) and $\Delta\phi(j_i, j_j)$ (right) for $N_{jets} \geq 3$ for data (full circles) and for various MC predictions.

0.5 which is predicted by MSTW08, CT10 [9] and NNPDF2316 [35] (Fig.7). The study of the ratio $R_c^Z = \frac{\sigma(Z+c)}{\sigma(Z+jets)} \sim \frac{c+\bar{c}}{\Sigma(q+\bar{q})}$ measured in Z plus charm events could be used to further constrain the proton charm content [36].

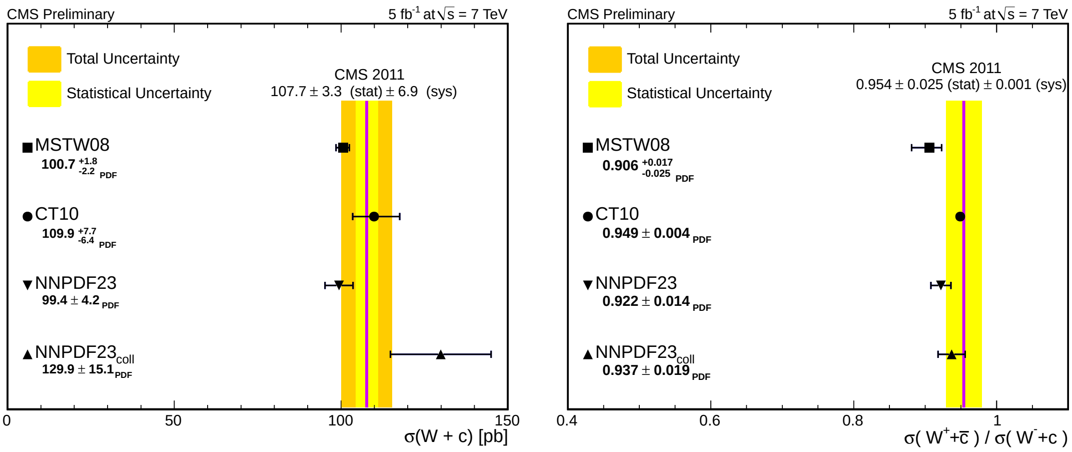

Figure 7: Cross section measured [34] for the W+charm process (left) and the $\sigma(W^+ + \bar{c})/\sigma(W^- + c)$ cross section ratio (right).

The production of a W in association with two b-jets ($W + b\bar{b}$) is important for the studies of $WH \to Wb\bar{b}$. This motivates the measurement of the $Wb\bar{b}$ cross section which is found to be 0.53 $\pm$ 0.05 (stat) $\pm$ 0.1 (sys) pb, in very good agreement with the NLO prediction 0.52 $\pm$ 0.03 pb [37]. On the other hand, a systematic bias is observed in the W plus 1 b-jet final state (Fig.8 left) [38]. The disagreement becomes more significant if the single top contribution is not subtracted from the cross section measurement [38] (Fig.8 right).

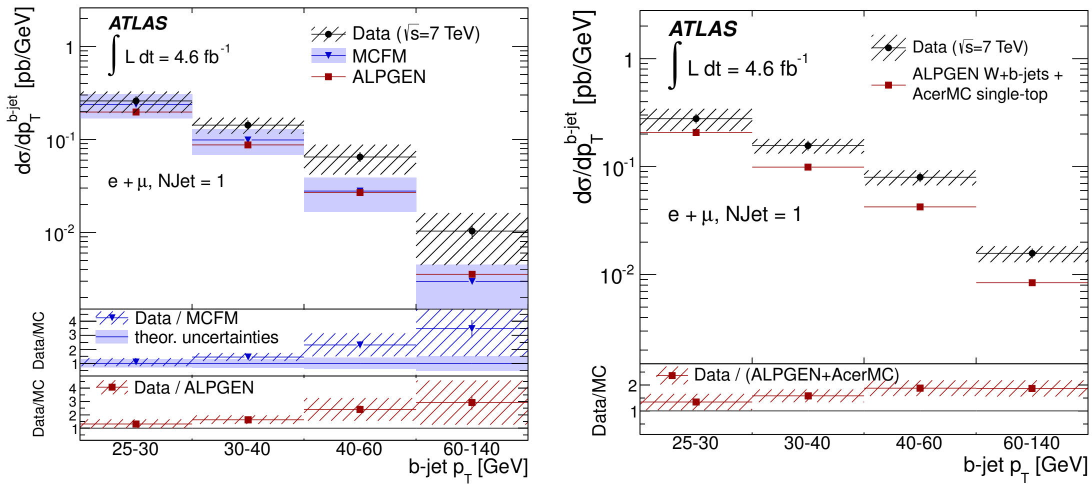

Figure 8: Cross sections measured [38] as a function of the b-jet p_T for the W+b process (left) and for the combined W+b plus single top processes (right).

3. Conclusions

Standard Model W, Z boson measurements in LHC proton-proton collision at a center of mass energy of 7 TeV and 8 TeV with the ATLAS and CMS experiment have been presented. Results on the Drell-Yan process cross section and of the angular correlations in Drell-Yan lepton pairs via the ϕ^*_η variable, at 7 TeV have been measured and compared with different theoretical expectation from several Monte Carlo generators and PDF sets. Some discrepancy in the multileg LO description of the distribution of the Z boson transverse momentum is observed at low boson p_T values, with significant variations from different tunes. The ϕ^*_η variable measured in $Z \to \ell^+\ell^-$ events at Tevatron has been found in the past to be one of the most effective handles on the description of the underlying event and has been effectively used to discriminate Monte Carlo tunes. The study of this variable shows potential for improving the low p_T^Z spectrum description also at the LHC. The substantial amount of delivered data to the experiments has made it possible to probe extreme kinematics of the V + jets signal that were not previously accessible. Vector bosons plus heavy flavours events could be used to constrain PDF sets. In particular the W plus charm topology has been shown to be effective to discriminate different descriptions of the strange sea of the proton. In summary with the available amount of data, no evidence of significative deviations from the theoretical predictions are observed. Results generally agree with the Standard Model predictions, however, different levels of agreement has been observed among the various predictions and data, reflecting to some extent the current understanding of the LHC data.

References

[1] G. Aad *et al.* [ATLAS Collaboration], “The ATLAS Experiment at the CERN Large Hadron Collider,” JINST **3** (2008) S08003.

[2] S. Chatrchyan *et al.* [CMS Collaboration], “The CMS experiment at the CERN LHC,” JINST **3** (2008) S08004.

[3] G. Aad *et al.* [ATLAS Collaboration], "Measurement of the inclusive $W^{\pm}$ and Z/gamma cross sections in the electron and muon decay channels in pp collisions at $\sqrt{s} = 7$ TeV with the ATLAS detector," Phys. Rev. D **85** (2012) 072004 [arXiv:1109.5141 [hep-ex]].

[4] S. Chatrchyan *et al.* [CMS Collaboration], "Measurement of the Inclusive W and Z Production Cross Sections in pp Collisions at $\sqrt{s} = 7$ TeV," JHEP **1110** (2011) 132 [arXiv:1107.4789 [hep-ex]].

[5] S. Chatrchyan *et al.* [CMS Collaboration], "Inclusive W/Z cross section at 8 TeV," CMS-PAS-SMP-12-011.

[6] K. Melnikov and F. Petriello, "Electroweak gauge boson production at hadron colliders through O(alpha(s)**2)," Phys. Rev. D **74** (2006) 114017 [hep-ph/0609070].

[7] A. D. Martin, W. J. Stirling, R. S. Thorne and G. Watt, "Parton distributions for the LHC," Eur. Phys. J. C **63** (2009) 189 [arXiv:0901.0002 [hep-ph]].

[8] S. Chatrchyan *et al.* [CMS Collaboration], "Measurement of the differential and double-differential Drell-Yan cross sections in proton-proton collisions at $\sqrt{s}$ = 7 TeV," CMS-PAS-SMP-13-003.

[9] H. -L. Lai, M. Guzzi, J. Huston, Z. Li, P. M. Nadolsky, J. Pumplin and C. -P. Yuan, "New parton distributions for collider physics," Phys. Rev. D **82** (2010) 074024 [arXiv:1007.2241 [hep-ph]].

[10] G. Aad *et al.* [ATLAS Collaboration], "Measurement of the high-mass Drell-Yan differential cross-section in pp collisions at sqrts =7 TeV with the ATLAS detector," ATLAS-CONF-2012-159.

[11] T. Aaltonen *et al.* [CDF Collaboration], "First Run II Measurement of the W Boson Mass," Phys. Rev. D **77** (2008) 112001 [arXiv:0708.3642 [hep-ex]].

[12] V. M. Abazov *et al.* [D0 Collaboration], "Measurement of the W boson mass," Phys. Rev. Lett. **103** (2009) 141801 [arXiv:0908.0766 [hep-ex]].

[13] S. Chatrchyan *et al.* [CMS Collaboration], "Measurement of the transverse momentum distributions of Z Bosons decaying to dimuons in pp collisions at $\sqrt{s}$=8 TeV," CMS-PAS-SMP-12-025.

[14] T. Sjostrand, S. Mrenna and P. Z. Skands, "PYTHIA 6.4 Physics and Manual," JHEP **0605** (2006) 026 [hep-ph/0603175].

[15] G. A. Ladinsky and C. P. Yuan, "The Nonperturbative regime in QCD resummation for gauge boson production at hadron colliders," Phys. Rev. D **50** (1994) 4239 [hep-ph/9311341].

[16] C. Balazs and C. P. Yuan, "Soft gluon effects on lepton pairs at hadron colliders," Phys. Rev. D **56** (1997) 5558 [hep-ph/9704258].

[17] G. Aad *et al.* [ATLAS Collaboration], "Measurement of the transverse momentum distribution of Z/γ^{*} bosons in proton-proton collisions at $\sqrt{s} = 7$ TeV with the ATLAS detector," Phys. Lett. B **705** (2011) 415 [arXiv:1107.2381 [hep-ex]].

[18] M. L. Mangano, M. Moretti, F. Piccinini, R. Pittau and A. D. Polosa, "ALPGEN, a generator for hard multiparton processes in hadronic collisions," JHEP **0307** (2003) 001 [hep-ph/0206293].

[19] S. Alioli, P. Nason, C. Oleari and E. Re, "Vector boson plus one jet production in POWHEG," JHEP **1101** (2011) 095 [arXiv:1009.5594 [hep-ph]].

[20] T. Gleisberg, S. .Hoeche, F. Krauss, M. Schonherr, S. Schumann, F. Siegert and J. Winter, "Event generation with SHERPA 1.1," JHEP **0902** (2009) 007 [arXiv:0811.4622 [hep-ph]].

[21] S. Frixione and B. R. Webber, "Matching NLO QCD computations and parton shower simulations," JHEP **0206** (2002) 029 [hep-ph/0204244].

[22] G. Aad *et al.* [ATLAS Collaboration], "Measurement of angular correlations in Drell-Yan lepton pairs to probe Z/gamma* boson transverse momentum at sqrt(s)=7 TeV with the ATLAS detector," arXiv:1211.6899 [hep-ex].

[23] F. Landry, R. Brock, P. M. Nadolsky and C. P. Yuan, "Tevatron Run-1 Z boson data and Collins-Soper-Sterman resummation formalism," Phys. Rev. D **67** (2003) 073016 [hep-ph/0212159].

[24] A. Banfi, M. Dasgupta, S. Marzani and L. Tomlinson, "Predictions for Drell-Yan ϕ^* and Q_T observables at the LHC," Phys. Lett. B **715** (2012) 152 [arXiv:1205.4760 [hep-ph]].

[25] V. M. Abazov *et al.* [D0 Collaboration], "Precise study of the Z/γ^* boson transverse momentum distribution in $p\bar{p}$ collisions using a novel technique," Phys. Rev. Lett. **106** (2011) 122001 [arXiv:1010.0262 [hep-ex]].

[26] J. Alcaraz Maestre *et al.* [SM AND NLO MULTILEG and SM MC Working Groups Collaboration], "The SM and NLO Multileg and SM MC Working Groups: Summary Report," arXiv:1203.6803 [hep-ph].

[27] C. F. Berger, Z. Bern, L. J. Dixon, F. Febres Cordero, D. Forde, H. Ita, D. A. Kosower and D. Maitre, "An Automated Implementation of On-Shell Methods for One-Loop Amplitudes," Phys. Rev. D **78** (2008) 036003 [arXiv:0803.4180 [hep-ph]].

[28] J. M. Campbell and R. K. Ellis, "MCFM for the Tevatron and the LHC," Nucl. Phys. Proc. Suppl. **205-206** (2010) 10 [arXiv:1007.3492 [hep-ph]].

[29] J. Alwall, M. Herquet, F. Maltoni, O. Mattelaer and T. Stelzer, "MadGraph 5 : Going Beyond," JHEP **1106** (2011) 128 [arXiv:1106.0522 [hep-ph]].

[30] G. Corcella, I. G. Knowles, G. Marchesini, S. Moretti, K. Odagiri, P. Richardson, M. H. Seymour and B. R. Webber, "HERWIG 6: An Event generator for hadron emission reactions with interfering gluons (including supersymmetric processes)," JHEP **0101** (2001) 010 [hep-ph/0011363].

[31] G. Aad *et al.* [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," arXiv:1304.7098 [hep-ex].

[32] A. Denner, S. Dittmaier, T. Kasprzik and A. Muck, "Electroweak corrections to dilepton + jet production at hadron colliders," JHEP **1106** (2011) 069 [arXiv:1103.0914 [hep-ph]].

[33] S. Chatrchyan *et al.* [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 [arXiv:1301.1646 [hep-ex]].

[34] S. Chatrchyan *et al.* [CMS Collaboration], "Measurement of associated charm production in W final states at $\sqrt{s}$ = 7 TeV," CMS-PAS-SMP-12-002.

[35] R. D. Ball *et al.* [NNPDF Collaboration], "Unbiased global determination of parton distributions and their uncertainties at NNLO and at LO," Nucl. Phys. B **855** (2012) 153 [arXiv:1107.2652 [hep-ph]].

[36] W. J. Stirling and E. Vryonidou, "Charm production in association with an electroweak gauge boson at the LHC," Phys. Rev. Lett. **109** (2012) 082002 [arXiv:1203.6781 [hep-ph]].

[37] S. Chatrchyan *et al.* [CMS Collaboration], "Measurement of the production cross section of W bosons in association with two b jets in pp collisions at $\sqrt{s}$=7 TeV," CMS-PAS-SMP-12-026.

[38] G. Aad *et al.* [ATLAS Collaboration], "Measurement of the cross-section for W boson production in association with b-jets in pp collisions at sqrt(s) = 7 TeV with the ATLAS detector," arXiv:1302.2929 [hep-ex].

PoS(LHCPP2013)019