

W and Z at the LHC

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Summary. — W and Z bosons will be produced at high rates at the LHC. The understanding of these processes will be very important for all the LHC physics program. We discuss the ATLAS and CMS detectors potential for an early measurement of W and Z inclusive cross-sections and lepton asymmetries, the prospects for the precision measurement of the W boson mass and for the study of di-bosons production processes.

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PACS 14.70.Hp – Z bosons.

1. – Introduction

W and Z bosons will be abundantly produced at the LHC. The W(Z) production cross-sections at $\sqrt{s} = 14$ TeV is 20 nb (2 nb), *i.e.* about seven times larger than at the Tevatron. These processes are theoretically well understood and the decays into leptons (namely electrons and muons) provide an extremely clear experimental signature. All these features make their study very important in the early LHC running for detector understanding and calibration/alignment purposes and for the first physics measurements, while increased integrated luminosities will give access also to the precision measurement of fundamental electroweak parameters (*e.g.*, W mass). An overview of the ATLAS [1] and CMS [2] potential for some selected measurements with W and Z bosons is presented.

2. – Inclusive W/Z cross-section measurements

$Z \rightarrow ll$ are selected by requiring two isolated and well-reconstructed leptons of opposite charge, with high transverse momentum (typically $p^T > 20$ –25 GeV) and with an invariant mass in a window about M_Z . The resulting sample is very pure, with residual backgrounds (W+jets, $Z \rightarrow \tau\tau$, $t\bar{t}$, di-jets) at the level of 0.1% (fig. 1 left).

The selection of $W \rightarrow l\nu$ events is based on the requirement of one isolated lepton; moreover, a cut on the missing transverse energy due to the neutrino and/or on the transverse mass (M^T) is applied, as it is very useful in rejecting most of the QCD background (fig. 1 right). A detailed discussion of the events selection can be found in [3, 4] and [5].

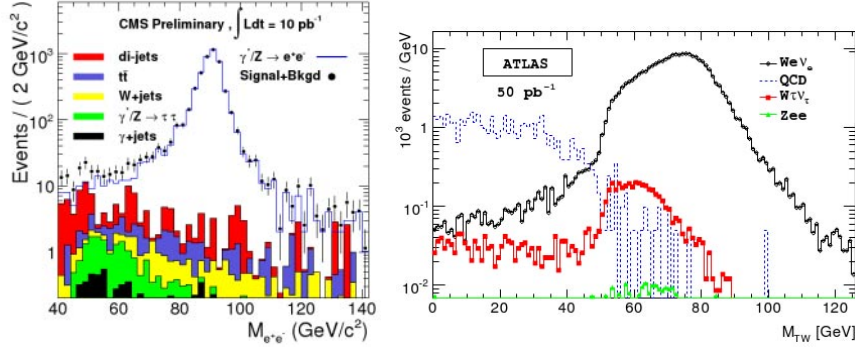


Fig. 1. – Invariant mass distribution of $Z \rightarrow ee$ events (left) and transverse mass distribution of $W \rightarrow e\nu$ events (right).

The W/Z inclusive cross-section measurement will be one of the very first physics measurements (with $10\text{--}50\text{ pb}^{-1}$) at the LHC. The cross-section is given by the following relation:

$$(1) \quad \sigma = \frac{N_{\text{signal}} - N_{\text{bkg}}}{\epsilon A \int L dt},$$

where N_{signal} and N_{bkg} are the number of signal and background events, A is the geometrical/kinematic acceptance, ϵ is the efficiency and $\int L dt$ is the integrated luminosity. The measurement will be dominated by the luminosity uncertainty (3–7%, 10% at the start-up). The statistical uncertainty is expected to be $\sim 1\%$ with about 10 pb^{-1} . The uncertainty on the acceptance gives a contribution of about 2% [5]. Experimental uncertainties related to the trigger efficiency and lepton reconstruction/identification efficiencies will be a few % at the beginning, but are expected to improve with the statistics as they are planned to be measured from $Z \rightarrow ll$ samples with the “tag-and-probe” method. Data-driven approaches will also be applied to estimate the residual background from jets faking leptons, that is the most uncertain source of background and is not reliably predictable by means of Monte Carlo simulations. The control samples are defined by relaxing one of the lepton identification requirements in order to get a QCD enriched sample to model the background in the signal region.

3. – Lepton charge asymmetry in W events

The measurement of differential rapidity distributions and lepton asymmetries will be also feasible with initial luminosities and provide a useful tool to constrain Parton Distribution Functions.

For example, the lepton charge asymmetry in W events, defined as

$$(2) \quad \sigma = \frac{d\sigma/d\eta(l^+) - d\sigma/d\eta(l^-)}{d\sigma/d\eta(l^+) + d\sigma/d\eta(l^-)},$$

is directly sensitive to the u and d quarks PDFs. For leptons within the detectors acceptance, it varies between 10% and 20% as a function of the lepton pseudorapidity (fig. 2).

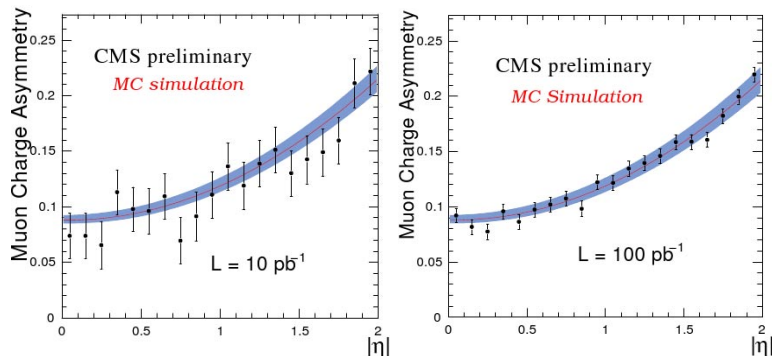


Fig. 2. – (Colour on-line) Muon charge asymmetry as a function of the muon pseudorapidity for $\int Ldt = 10 \text{ pb}^{-1}$ (left) and $\int Ldt = 100 \text{ pb}^{-1}$ (right). The blue band corresponds to the PDF uncertainty.

Being most of the uncertainties reduced in the ratio, this measurement is expected to provide constraints on the PDFs already with integrated luminosities of about 100 pb^{-1} [6].

4. – W mass measurement

The measurement of the W boson mass (M_W) is an example of precision measurement of a fundamental electroweak parameter. An improved measurement of M_W will allow to set strong indirect constraints on the Higgs boson mass. The aimed precision of 15 MeV at the LHC (to be compared to the current 25 MeV) will be achieved combining channel and experiments.

The approaches for such a precision measurement are different. One, studied by the ATLAS Collaboration, is the traditional approach used at hadron colliders and consists in fitting W data (lepton p^T , M^T) with Z tuned Monte Carlo samples generated at different values of M_W . An excellent modelling of the both of the physics and of the detector performances is needed. A recent review of the performances expected by ATLAS is discussed in [5] for a luminosity of about 15 pb^{-1} . With such luminosity, the measurement is dominated by statistical and experimental systematic uncertainties ($O(100)$ MeV) and, although it is not competitive, it will be extremely important for an early commissioning of the method. An uncertainty of about 20 MeV with 10 fb^{-1} can be foreseen in each leptonic channel [1].

An alternative approach, explored by CMS, is the use of templates built from the data themselves using $Z \rightarrow ll$: the experimental distributions scaled to the boson mass in W events are predicted from the corresponding distributions measured from $Z \rightarrow ll$ along with the theoretical ratio between W and Z differential cross-sections, that can be reliably calculated using perturbative QCD. The advantage of this second approach is that many of the common uncertainties between W and Z are reduced in the ratio. With 10 fb^{-1} , a statistical uncertainty of 15 MeV is foreseen for each leptonic channel and an experimental systematic uncertainty of about 20 MeV is expected from the measurement from the electron p^T spectrum, however with precision requirements much looser than those needed by the Monte Carlo template one [7].

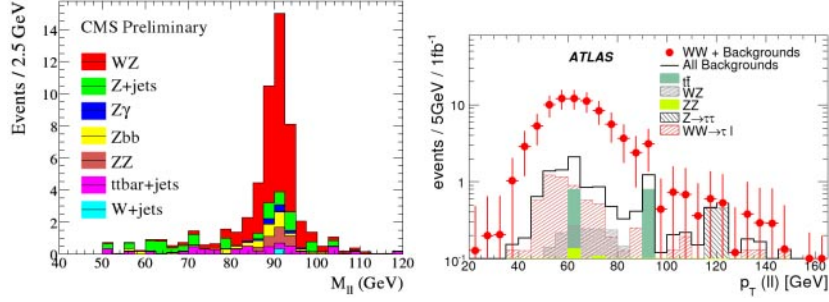


Fig. 3. – Left: Z candidate invariant mass from a WZ samples for all four channels combined, normalized to integrated luminosity of 300 pb^{-1} [8]. Right: transverse momentum distribution of lepton pairs in WW events, normalized to 1 fb^{-1} [5].

5. – Di-bosons production

The study of di-bosons production at the TeV scale constitutes a unique opportunity to test the Standard Model (SM) at the highest possible energies: any deviation of the measured production cross-section or of the Triple Gauge Couplings (TGCs) from the SM predictions will be an indication of New Physics. These processes are moreover backgrounds to other searches (Higgs, Susy, ...). The production cross-sections for all di-boson processes (WZ, ZZ, WW, $W\gamma$ and $Z\gamma$) are relatively large and these processes are expected to be observed already with luminosities of a few hundred inverse picobarns at the LHC (fig. 3). With higher integrated luminosities, an improvement on the limits on the TGCs will be possible.

REFERENCES

- [1] ATLAS COLLABORATION, *The ATLAS experiment at the CERN LHC*, *JINST*, **3** (2008) S08003.
- [2] CMS COLLABORATION, *The CMS experiment at the CERN LHC*, *JINST*, **3** (2008) S08004.
- [3] CMS COLLABORATION, *Towards a Measurement of the Inclusive $W \rightarrow \mu\nu$ and $Z \rightarrow \mu^+\mu^-$ Cross Sections in pp Collisions at $\sqrt{s} = 14 \text{ TeV}$* , CMS PAS EWK-07-002 (2007).
- [4] CMS COLLABORATION, *Towards a Measurement of the Inclusive $W \rightarrow e\nu$ and $Z \rightarrow e^+e^-$ Cross Sections in pp Collisions at $\sqrt{s} = 14 \text{ TeV}$* , CMS PAS EWK-08-005 (2008).
- [5] ATLAS COLLABORATION, *Expected Performance of the ATLAS Experiment Detector, Trigger and Physics*, CERN-OPEN-2008-020 (December 2008).
- [6] CMS COLLABORATION, *Measurement of the Muon Charge Asymmetry in the $pp \rightarrow W+X \rightarrow \mu\nu$ process at $\sqrt{s} = 14 \text{ TeV}$* , CMS PAS EWK-08-002 (2008).
- [7] BÜGE V., GHEZZI A., JUNG C., MALBERTI M., QUAST G. and TABARELLI DE FATIS T., *Prospects for the precision measurement of the W mass with the CMS detector at the LHC*, *J. Phys. G: Nucl. Part. Phys.*, **34** (2007) N193N220.
- [8] CMS COLLABORATION, *Study of the process $pp \rightarrow WZ^0 \rightarrow l^\pm\nu l^+l^-$ ($l = e, \mu$) at CMS*, CMS PAS EWK-08-003 (2008).