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QCD results from ATLAS and CMS

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Summary. — The latest QCD measurements performed with the ATLAS and the CMS detectors operating at the Large Hadron Collider (LHC) are summarized. The results reported here are mostly based on 7 TeV data collected by the experiments during the 2011 and 2010 proton-proton data-taking periods corresponding respectively to integrated luminosity of 4.6 fb^{-1} and 36 pb^{-1}.

PACS 13.87.-a – Jets in large-Q^2 scattering.
PACS 14.70.-e – Gauge bosons.
PACS 14.65.-q – Quarks.
PACS 14.60.-z – Leptons.

1. – Introduction

The LHC physics program includes a wide spectrum of Higgs studies as well as direct and indirect beyond Standard Model (BSM) searches. The discovery potential of the LHC relies on the understanding of the strong interactions which are overwhelming in the LHC environment and affect substantially the underlying dynamics of rare processes or are dominant backgrounds.

We give a review of some recent "QCD measurements" performed by ATLAS and CMS in several final states including jets, sect. **2**, isolated photons and inclusive gauge bosons, sect. **3**, as well as gauge bosons production in association with jets and heavy flavors, sect. **4**; we finally summarize in sect. **5**.

2. – Soft QCD and jet physics

Inclusive final states occurring from low momentum transfer scales ($Q^2 \sim 1\,\mathrm{GeV}$) to the Z boson mass scale are very well studied at LHC in several event topologies, see *e.g.* [1, 2]. In these kinematic regimes the minimum bias interactions and the underlying event have been measured providing a solid test of current tunes used in several Monte Carlo (MC) event generators.

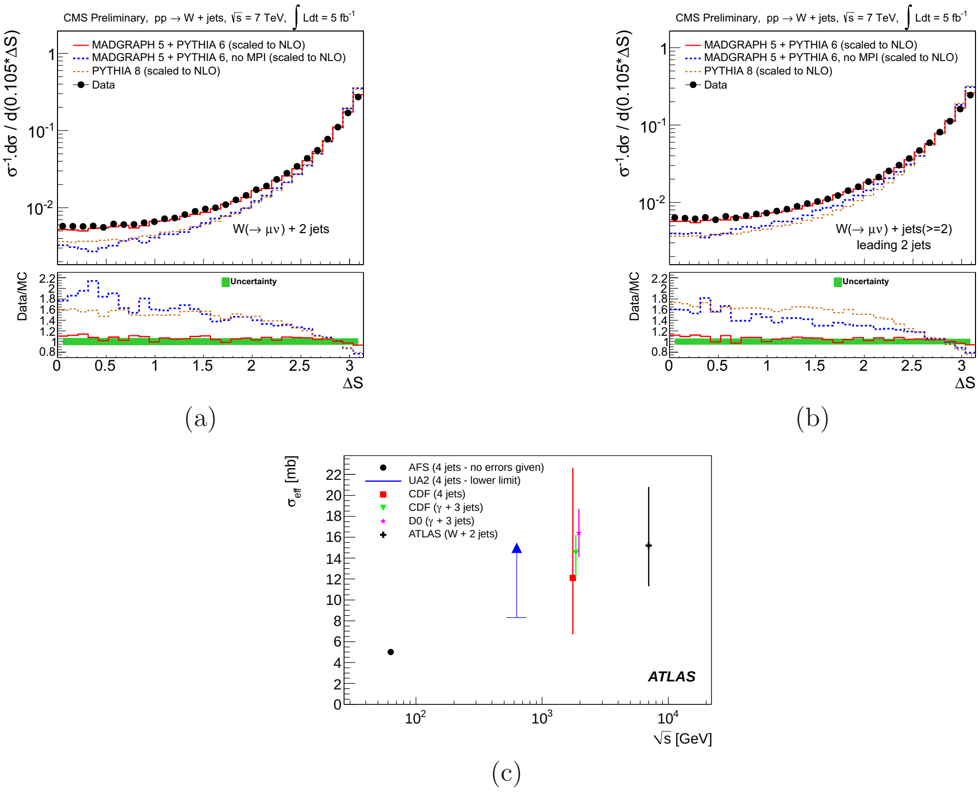


Fig. 1. – Measurement of the DPI sensitive observable ΔS by CMS [4] for two different event topologies and the center-of-mass energy dependence of $\sigma_{\rm eff}$ including the ATLAS [3] measurement which is compared to previous results obtained at different values of $\sqrt{s}$ and using different experimental signatures.

Recently, a dedicated focus has been given to the characterization of the hard double parton interaction (DPI) component of the underlying event using a W+2jets signature both in ATLAS [3] and CMS [4]. ATLAS reports the measurement of the effective area parameter $\sigma_{\rm eff}$ compared to previous measurements, fig. 1(c), performed at different center-of-mass energies and with different event topologies, confirming the universality of double parton interactions within the experimental uncertainties; instead in CMS several particle level distributions sensitive to DPI have been measured in W+2jets events, see for example fig. 1(a) and (b).

At high $p_{\rm T}$, jets cross section measurements provide access to the gluon parton density functions in the "high-x" region which is weakly constrained by Deep-Inelastic-Scattering data. The gluon density function has been constrained by ATLAS [5] by combining the jet cross section measurements at $\sqrt{s} = 7\,{\rm TeV}$ and $\sqrt{s} = 2.76\,{\rm TeV}$ in order to offset some large correlated systematic uncertainties. The gluon parton density function (PDF) extracted with a combined fit to the ATLAS and HERA data shows a better precision and an harder spectrum in the high-x region as can be observed in fig. 2.

More exclusive 2- and 3-jets topologies can be exploited to extract with great experimental precision the value of the strong coupling constant, α_s; in particular the ratio

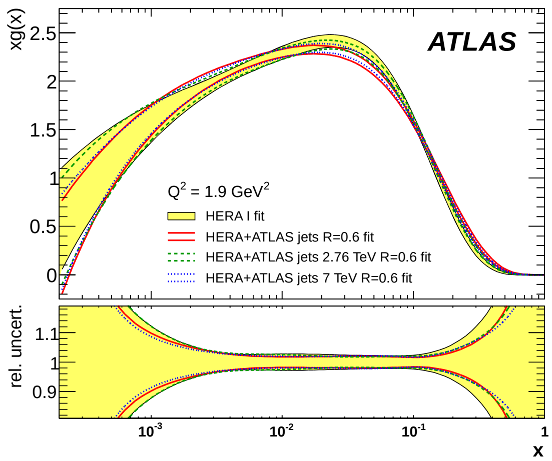


Fig. 2. – Momentum distributions density function of the gluon, xg(x), shown with relative experimental uncertainty as a function of x at the scale $Q^2 = 1.9\,\mathrm{GeV}^2$.

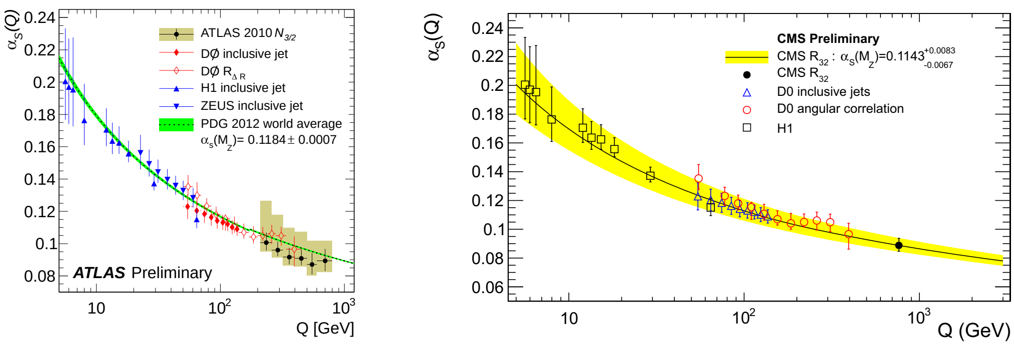


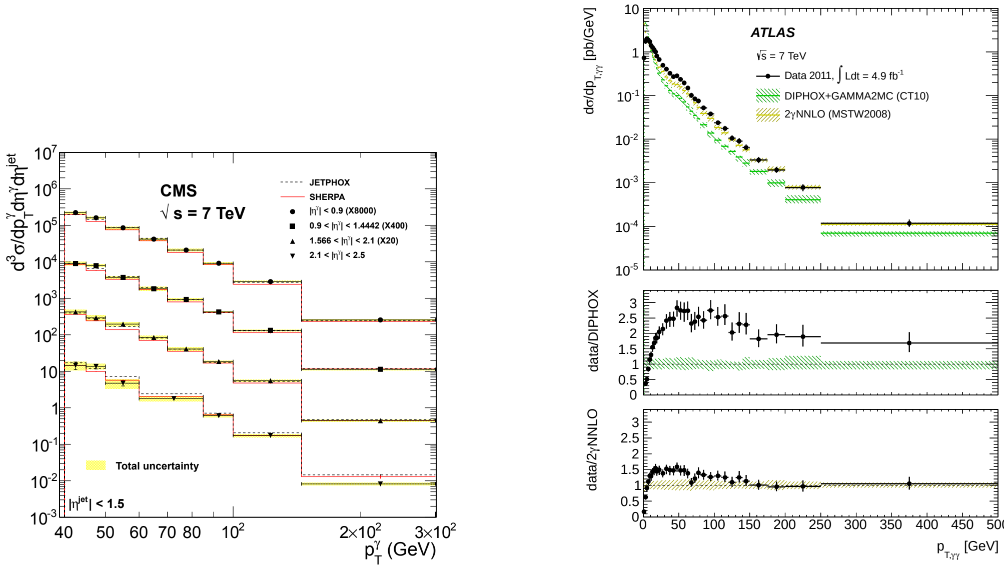
Fig. 3. – Measurement of the strong coupling constant, α_s, from the $R_{3/2}$ measurements in ATLAS (left) [6] and CMS (right) [7]; α_s is evolved at the Z-mass scale and is compared with the PDG world average value.

$R_{3/2}$ has been measured [6, 7] by ATLAS and CMS and it has been compared to the global PDG average and to previous measurements performed at Tevatron and HERA in fig. 3.

3. – Isolated photons and inclusive gauge boson measurements

Precise experimental probes of the QCD description of strong interactions are provided by photonic signatures and inclusive gauge boson production.

Isolated photons have been measured at LHC in great detail; they are established tools to study higher order perturbative QCD calculations, double parton interactions and gluon parton density function.



(a) (b)

Fig. 4. – Differential photon+jet [9] (a) and di-photon [10] cross sections (b) as function of the photon and di-photon transverse momentum as measured by CMS and ATLAS. The photon+jet cross section is presented in different photon rapidity slices. The data are compared to NLO and NNLO QCD calculations.

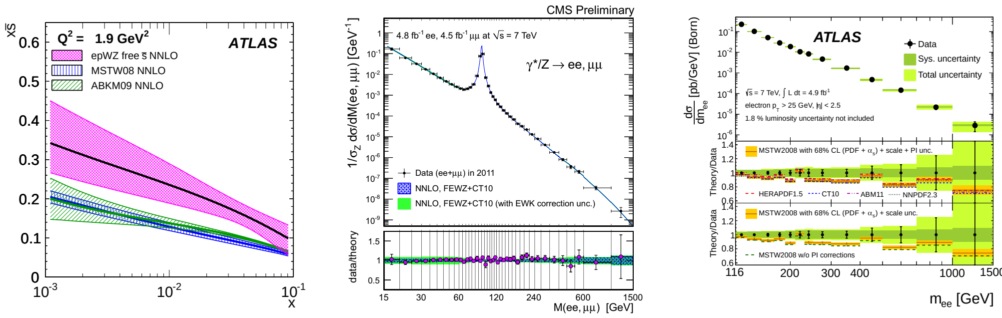
Isolated photon production in association with jets has been measured by ATLAS [8] and CMS [9] (fig. 4(a)) and they are compared with next-to-leading order (NLO) QCD calculations. The di-photon system studied by ATLAS [10] is instead more sensitive to beyond-NLO corrections as can be observed from the result shown in fig. 4(b).

The next-to-next-to leading order (NNLO) QCD calculations for W/Z production are a well establish ground to interpret the Drell-Yan data at LHC. The high theoretical and experimental precision for this final state results in a further constrain the strange quark density content of the proton [11], as can be seen from fig. 5(a), and it shows potential sensitivity to electroweak corrections to DY production including photon-induced lepton pairs production (fig. 5(b) and (c)).

Drell-Yan data is also an important tool used to constrain the W-p_{T}, an important input used to reduce the systematic uncertainty in the W-mass measurement. Transverse momentum spectrum at 7 TeV and 8 TeV have been measured by ATLAS [14] and CMS [15], see fig. 6(a) and (b). Recently it has been pointed out that the angular correlation of leptons produced in $Z/\gamma^\star$ decays encodes substantial information of the Z-p_{T} with reduced experimental uncertainties; a first measurement at LHC as been performed in ATLAS [16], see fig. 6(c).

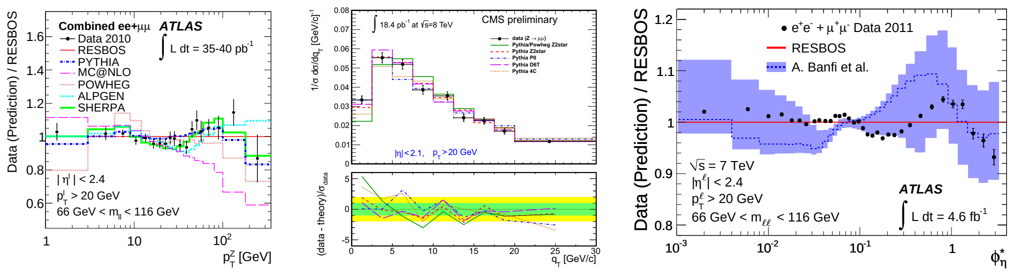
4. – Gauge boson production in association with jets

Jet production in association with gauge bosons is an important background to many BSM searches and rarer electroweak processes sensitive to new-physics effects via quantum corrections. This final states have been measured by ATLAS and CMS in various kinematic regimes.



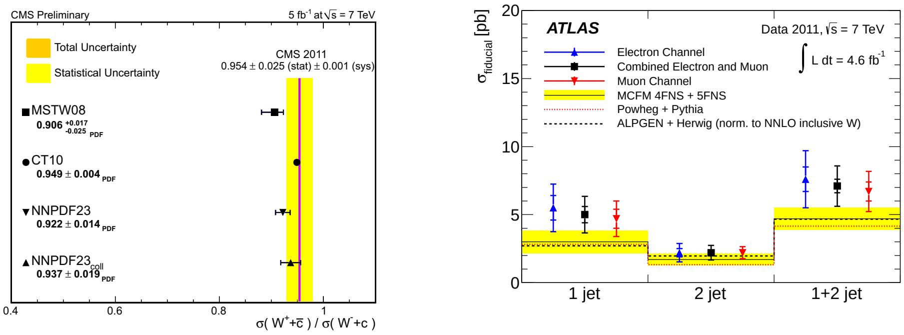
(a) (b) (c)

Fig. 5. – Momentum distributions density function of the strange anti-quark [11] as function of x at the scale $Q^2 = 1.9\,\mathrm{GeV}^2$ (a) and differential Drell-Yan cross section in bins of di-lepton invariant mass (b,c) [12, 13].



(a) (b) (c)

Fig. 6. – Z boson transverse momentum spectrum measured in ATLAS [14] (a) and CMS [15] (b) at center-of-mass energy of 7 and 8 TeV and $\phi^\star$ distribution measured by ATLAS (c) [16].



(a) (b)

Fig. 7. – $\sigma(W^+ + \bar{c})/\sigma(W^- + c)$ measured by CMS [19] and cross section for b-jets production in association with a W boson in jet multiplicity bins measured by ATLAS [21].

Recently two measurements of Z boson production in association with jets have been reported by ATLAS [17] and CMS [18] where a wide spectrum of particle level observables have been studied, including jet multiplicities up to seven and angular correlations among the Z boson and jets; with these two measurements a validatation of several modern event generators widely used by experimental communities at LHC is performed.

Beyond the use for event generator tests, the V+jets measurements are potentially sensitive to parton density functions. A well known example is the associated production of a W boson and a charmed hadron which, being a strange initiated process at leading order, can be used to constrain the strange parton density function thus providing a complementary information to the inclusive W/Z Drell-Yan data. The ratio $R^{\pm} = \sigma(W^+ + \bar{c})/\sigma(W^- + c)$ measured by CMS [19] is shown in fig. 7(a); a similar result is available from ATLAS [20].

B-jets production in association with a vector boson is of key interest in view of measuring the Higgs coupling to the 3rd fermion generation using the associated production mode VH($\rightarrow$ b$\bar{\text{b}}$); ATLAS [21] and CMS [22] results shows a substantial agreement of the data with the theory predictions for final states with two hard b-jets while some tensions are observed in the one jet final state as summarized by fig. 7(b).

5. – Conclusions

The LHC discovery potential and the test of the electroweak sector at quantum level depend on very accurate understanding of the strong interaction at the TeV scale. The wide spectrum of measurements from in ATLAS and CMS test in various phase space regions the most advanced theory predictions for jets, boson and boson plus jets cross sections. The LHC data have been successful used to constrain the parton density content of the proton and to derive PDFs with increased precision.

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