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Nuclear Physics A 967 (2017) 51–58

NUCLEAR PHYSICS A

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# Heavy Ion Results from ATLAS

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**Abstract**

These proceedings provide an overview of the new results obtained with the ATLAS detector at the LHC, which were presented in the Quark Matter 2017 conference. These results were covered by twelve parallel talks, one flash talk and eleven posters. These proceedings group these results into five areas: initial state, jet quenching, quarkonium production, longitudinal flow dynamics, and collectivity in small systems.

*Keywords:* ATLAS, heavy-ion collisions, quark-gluon plasma, jet quenching, flow decorrelation, multi-particle cumulants

## 1. Introduction

In order to reliably extract the properties of the Quark Gluon Plasma (QGP) created in heavy ion collisions at the LHC, one needs to first achieve a detailed understanding of the space-time evolution of the system. This requires improving the precision of the measurements on existing observables, exploring new observables, as well as studying the dependence on the type of collision systems or the collision energies. In this conference, ATLAS showed many new results obtained from high statistics $pp$ data at 2.76, 5.02 and 13 TeV, $p$+Pb data at 5.02 and 8.16 TeV, as well as Pb+Pb data at 2.76 and 5.02 TeV, collected in the Run 1 (2010–2013) and Run 2 (2015–2016) periods. These results range from constraining the initial state of the heavy ion collisions, to understanding the interaction of the hard probes with the QGP and the longitudinal expansion of the QGP, and to the clarification of the origin of collective behavior in small collision systems.

## 2. Initial state

Because of the strong electromagnetic field associated with the highly boosted nuclei at the LHC, Ultra Peripheral heavy-ion Collisions (UPC) can be used to study the scattering of the quasi-real photons emitted coherently from nuclei as they pass by each other. In Pb+Pb collisions, such photon-photon scattering processes are enhanced by a factor of $Z^4 \sim 4.5\times10^7$ compared to $pp$ collisions. Two interesting processes, $\gamma\gamma\rightarrow\mu^+\mu^-$ and $\gamma\gamma\rightarrow\gamma\gamma$, have been measured by ATLAS [1]. These processes can be cleanly identified event by event, as the signal is usually associated with very simple final-state topology with very little additonal event activity. The differential cross-section for $\gamma\gamma\rightarrow\mu^+\mu^-$, proportional to $\alpha_{\rm em}^2$, is found to be well described by a leading order QED calculation provided by the STARlight model. The $\gamma\gamma\rightarrow\gamma\gamma$

[1] A list of members of ATLAS Collaboration and acknowledgements can be found at the end of this issue.

http://dx.doi.org/10.1016/j.nuclphysa.2017.05.076

process has significantly smaller cross section at lowest order, i.e $\propto \alpha_{em}^4$, due to the requirement of one-loop box diagrams involving fermions. Nevertheless, 13 events have been identified passing the fiducial kinematic cuts. The significance of the observation is $4.4\sigma$, which agrees well with the $3.8\sigma$ expected from the QED calculation. Both measurements provide an important experimental constraint on photon fluxes in ultra-peripheral Pb+Pb collisions.

The UPC also provides a unique opportunity to study the parton distribution function in the colliding nuclei (nPDF) via the measurement of photo-nuclear dijet production [2], where one quasi-real photon is emitted coherently from one nucleus and scatters inelastically with the second nucleus and produces dijets in the final state: $\gamma$+Pb$\rightarrow$dijets+X. The nucleus emitting the photon remains intact, while the other nucleus dissociates and produces fragments in the forward direction. Such events can be cleanly selected by requiring spectator neutrons detected only in one of the zero-degree calorimeters situated in the beam fragmentation region. Due to the relatively low $p_T$ of the photon, this process is sensitive to the nPDF at low $x$ in the Pb and moderate momentum transfer $Q^2$. Figure 1 shows the differential cross-section as a function of $x$ for different $H_T$. The $H_T$ is the scalar-sum of the $p_T$ of the jets, therefore $H_T^2$ is a proxy for $Q^2$. The results from Fig. 1 span a $x$ and $Q^2$ region not covered in previous measurements.

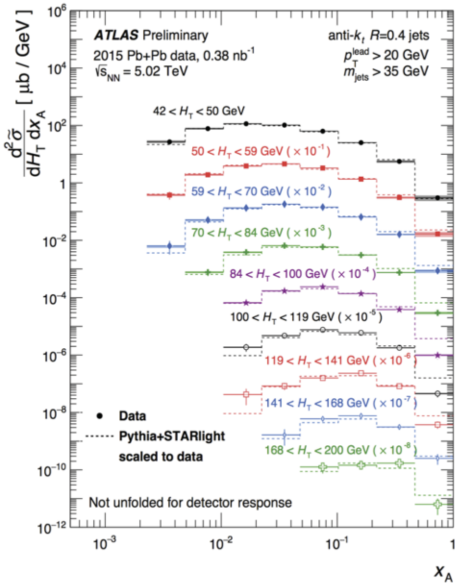


Figure 1. Differential cross-section $d\sigma/dH_T dx$ as a function of $x$ for different bins of $H_T$. The dashed lines represent the cross-section from Pythia+STARlight scaled to have the same integral as the data within the fiducial region of the measurement.

A more traditional way of constraining the nPDF is through the measurement of electro-weak bosons such as $Z$ and $W$. ATLAS studied $Z$ boson production in $p$+Pb and Pb+Pb collisions via the nuclear modification factors, $R_{p\mathrm{Pb}}$ and $R_{\mathrm{AA}}$, respectively [3]. The $\eta$ dependence of $R_{p\mathrm{Pb}}$ shows slight forward-backward asymmetry consistent with nuclear isospin effects. The $R_{\mathrm{AA}}$ in Pb+Pb collisions shows little modification as a function of either $\eta$ or centrality. Thanks to the large integrated luminosity, the uncertainty of $R_{\mathrm{AA}}$ is no longer dominated by the $Z$ yield as in the past, instead it is dominated by the uncertainty associated with the Glauber model. Given the lack of nuclear effects, the $Z$ boson production with sufficient statistical precision may be used as an alternative baseline for studying the nuclear modification factors for other hard processes.

## 3. Jet quenching

Using the high statistics Pb+Pb data and $pp$ reference data collected in Run 2, ATLAS made the first measurement of inclusive jet production at 5.02 TeV [4]. This result provides a detailed study of $R_{\mathrm{AA}}$ as a function of $p_T$, centrality and rapidity $y$. The $R_{\mathrm{AA}}$ in central collisions, as shown in Fig. 2 (left), reveals a clear increase with $p_T$ and flattening behavior above 200–300 GeV. The behavior is consistent with the results at 2.76 TeV, but the systematic uncertainties are much reduced thanks to the cancellation of the uncertainty between $pp$ and Pb+Pb. This cancellation is possible because the $pp$ reference data are taken just prior to the heavy-ion run, and therefore have the same detector condition. The large statistics also allow the study of the evolution of $R_{\mathrm{AA}}$ as a function of rapidity, which is quantified via a double ratio: $R_{\mathrm{AA}}(|y|)/R_{\mathrm{AA}}(|y| < 0.3)$. Any deviation of this double ratio from one indicates a $y$ dependence of $R_{\mathrm{AA}}$. This ratio is observed in Fig. 2 (right) to be flat with $y$ at low $p_T$, but for the first time, it is observed to decrease with $y$ at high $p_T$. This behavior reflects an interplay between $y$-dependent composition and the spectral