Looking for QGP signatures in ultraperipheral PbPb collisions

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Abstract. Ultraperipheral collisions of relativistic heavy ion beams lead to a diverse set of photon-nucleus (photonuclear) interactions. The measurements of particles and their interaction produced in photonuclear reactions can shed light on the QCD dynamics of these novel, extremely asymmetric colliding systems, with energies between those available at RHIC and the LHC. Previous studies by ATLAS indicate significant elliptic and triangular flow coefficients in these events [1]. Thus, it is imperative to check these events for other potential QGP signatures including radial flow, strangeness enhancement, and enhanced baryon/meson production. This proceeding presents the measurement of charged hadron yields in photonuclear collisions using 5.02 TeV Pb+Pb data collected in 2018 by ATLAS, with a dedicated photo-nuclear event trigger. The charged hadron yields are presented as a function of pseudorapidity and transverse momentum in different categories of event multiplicity. The results are compared with 5.02 TeV *p*+Pb data collected in 2016 by ATLAS, at the same event multiplicities. The results are also compared with calculations from DPMJET and hydrodynamic-based models. These comparisons enable detailed characterizations of photonuclear collision properties, including the photon energy distribution, and whether small QGP droplets may be formed.

1 Introduction

Ultra-relativistic collisions of Pb ions create a strongly interacting matter called Quark-Gluon Plasma (QGP) in which quarks and gluons are locally deconfined. QGP-like signals have been observed in smaller systems like *p*+Pb, *pp*, *d*+Au, etc. The strong electromagnetic fields around the ions in these collisions correspond to a flux of quasi-real, high-energy photons. These photons can break apart the other colliding nuclei, resulting in photon-nucleus or photon-photon interactions when the nuclei have significantly large impact parameters [2, 3]. These collisions are collectively termed "ultra-peripheral collisions" (UPCs), and effectively constitute one of the smallest collision systems.

Two-particle azimuthal correlations have been measured in such photo-nuclear events [1] by ATLAS [4] at LHC. These results indicate significant non-zero elliptic and triangular flow coefficients, i.e., v_2 and v_3, respectively which are interpreted in terms of a hydrodynamically flowing medium [5]. In Ref. [5], the authors make the specific prediction that the radial

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flow [6], a signature of QGP, is essentially the same in UPC and p+Pb collisions, as measured via the mean p_T of charged and identified particles.

Thus, the analysis presented here is motivated by two central physics questions: (1) Can the underlying physics processes in UPC events be well modeled, and (2) is there strong evidence for the formation of small QGP droplets that flow hydrodynamically in these UPC events? The analysis begins to address whether there is radial flow of the fluid as quantified by the p_T distributions of charged hadrons. The results also show the first demonstration of V^0 reconstruction, including K^0_S, Λ, Ξ^-, in this collision system, which can be used to study other effects such as strangeness enhancement and baryon/meson enhancement.

In this proceeding, we present inclusive yields of primary charged hadrons as a function of η and p_T, and in selections of charged particle multiplicity N_{ch}^{rec} in Pb+Pb UPC and p+Pb collisions [7]. Detailed comparisons of these measurements with the Monte Carlo (MC) model DPMJET-III [8] enable key constraints on the physics processes. Detailed comparisons between Pb+Pb UPC and p+Pb data enable tests of the hydrodynamical model predictions [5].

2 Data sample and selections

The analysis of photo-nuclear events utilizes the 2018 Pb+Pb 5.02 TeV data set with an integrated luminosity of 1.73 nb^{-1} and comparable event selection cuts as the photo-nuclear flow analysis [1]. Photo-nuclear events are selected mainly via the presence of a rapidity gap, $\sum_\gamma \Delta\eta^{rec}$, and single-sided nuclear breakup, referred to as "0nXn". The 2016 p+Pb 5.02 TeV data set with an integrated luminosity of 0.10 nb^{-1} is also utilized for comparison purposes.

Each event is characterized by the number of reconstructed tracks with $p_T > 0.4$ GeV and $|\eta| < 2.5$, referred to as N_{ch}^{rec}. MC studies indicate that selections on N_{ch}^{rec} correspond to equivalent selections on truth-level charged particles also with $p_T > 0.4$ GeV and $|\eta| < 2.5$, but with $N_{ch}^{truth} \approx 1.2 \times N_{ch}^{rec}$. The charged-particle yield is corrected for reconstruction and selection inefficiency, as well as for contributions from tracks that are not associated with primary particles, and extrapolated down to $p_T = 0$ GeV.

3 Results and comparisons

The charged-hadron yields in Pb+Pb UPC and p+Pb collisions as a function of p_T in six exclusive intervals of η and integrated over all p_T as a function of η are shown in Figures 1 and 2 respectively. Negative η corresponds to the Pb-going direction, and positive η corresponds to the photon-going and proton-going directions in Pb+Pb UPC and p+Pb, respectively. The Pb+Pb UPC distribution is highly asymmetric, given the lower energy of the photon compared with the energy per nucleon in the opposing Pb nucleus.

Figure 3 shows $\langle p_T \rangle$ for $p_T > 0$ GeV as a function of N_{ch}^{rec} in two η regions, [-1.6,-0.8] and [0.8,1.6], in Pb+Pb UPC and p+Pb collisions. At negative η, $\langle p_T \rangle$ between the two collision systems is comparable. In contrast, on the photon-going side ($\eta > 0$), there is a large difference in the $\langle p_T \rangle$ between the two collision systems for all N_{ch}^{rec}. The substantially larger $\langle p_T \rangle$ at negative η in Pb+Pb UPC and its comparable magnitude in p+Pb may already hint at a contribution from radial flow, as discussed earlier. Further tests measuring the $\langle p_T \rangle$ of identified hadrons are needed to confirm this hypothesis.

Figure 4 (left) shows the charged hadron yield at generator level in DPMJET-III as a function of η, compared to the experimental results in Pb+Pb UPC collisions. The $dN_{ch}/d\eta$ distribution in DPMJET-III gives a reasonable description of the particle yield at backward rapidity, while consistently over-predicting the yield at forward rapidity. Consequently, a $\langle \eta \rangle$ closer to 0 is observed in DPMJET-III model compared to UPC data as shown in Figure 4 (right).

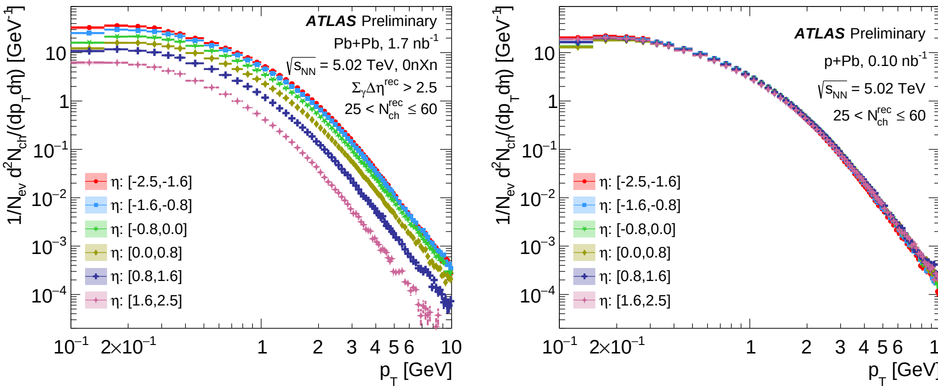

Figure 1. Shown are the charged-hadron yields as a function of p_T in six η selections. The left panel is for UPC Pb+Pb collisions and the right panel is for p+Pb collisions. Statistical uncertainties are shown as vertical lines and systematic uncertainties as open boxes. For most points, the systematic uncertainties are smaller than the markers.

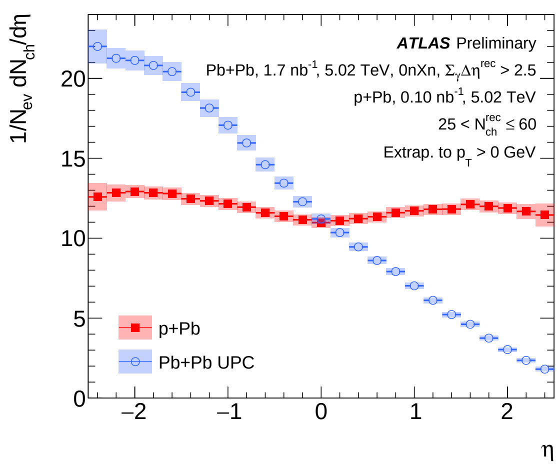

Figure 2. Shown are the charged-hadron yields as a function of η extrapolated to $p_T > 0$ GeV for Pb+Pb UPC and p+Pb collisions. The statistical uncertainties are shown as vertical lines and systematic uncertainties as open boxes.

4 Conclusion

Charged-hadron yields as a function of transverse momentum p_T and pseudorapidity η, and in selections in event multiplicity N_{ch}^{rec}, are quantified in UPC photo-nuclear interactions by ATLAS at LHC. Also, $\langle\eta\rangle$, the mean value of yields measured in $|\eta| < 2.5$, and $\langle p_T\rangle$, the mean value of yields measured in η intervals, are measured within selections of N_{ch}^{rec}. Monte Carlo DPMJET-III does not describe the detailed charged-hadron distributions. Potential signatures of collectivity including radial expansion are tested via the $\langle p_T\rangle$ comparison in Pb+Pb UPC and p+Pb collisions. The larger $\langle p_T\rangle$ at backward compared to forward rapidity in Pb+Pb UPC may suggest the presence of hydrodynamic radial flow.

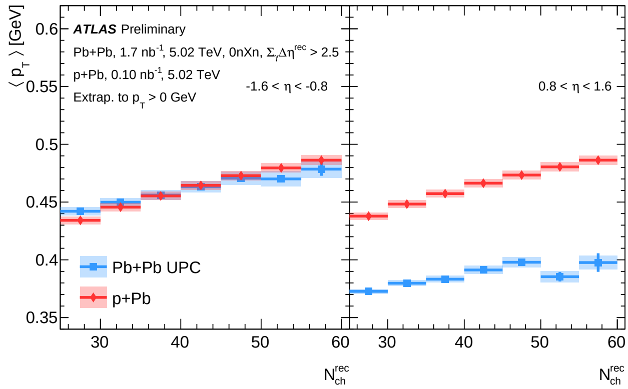

Figure 3. Shown are the $\langle p_{\mathrm{T}} \rangle$ of charged-hadron yields, extrapolated to $p_{\mathrm{T}} > 0$ GeV, as a function of $N_{\mathrm{ch}}^{\mathrm{rec}}$ in Pb+Pb UPC collisions and p+Pb collisions in two different η slices, [-1.6,-0.8] (left) and [0.8,1.6] (right). Vertical lines are statistical uncertainties and shaded boxes are systematic uncertainties.

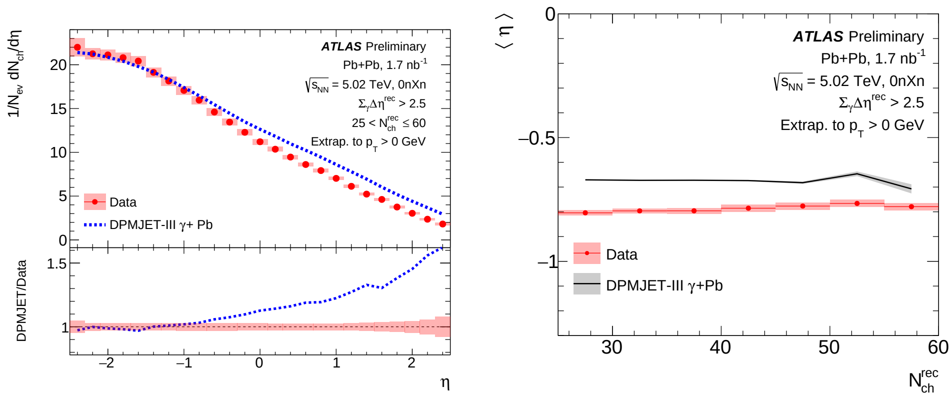

Figure 4. Shown are the charged-hadron yields as a function of η (left) and $\langle \eta \rangle$ as a function of $N_{\mathrm{ch}}^{\mathrm{rec}}$ (right), in extrapolated to $p_{\mathrm{T}} > 0$ GeV in Pb+Pb UPC collisions compared to DPMJET-III model. The statistical uncertainties are shown as vertical lines and systematic uncertainties as open boxes.

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