EPJ Web of Conferences **182**, 02069 (2018) https://doi.org/10.1051/epjconf/201818202069
ICNFP 2017

Recent PHENIX results on high-p_T light hadron production

Dmitry Kotov[1,a], on behalf of the PHENIX collaboration

[1] *Peter the Great St.Petersburg Polytechnic University (SPbPU), 195251, Russia, 195251, St.Petersburg, Polytechnicheskaya, 29*

Abstract. Production of Quark Gluon Plasma (QGP) has been established in central heavy ion collisions (Au+Au, Cu+Cu) at RHIC energies. Observation of strong suppression of hadron yields at high transverse momentum served as one of the most important evidences in favor of production of a new state of matter in such collisions. Recent RHIC run with asymmetric collision system (Cu+Au) provides the means to systematically study suppression pattern of hadrons in different nuclear overlap geometry needed to improve theoretical description of parton energy loss in QGP. Non-zero elliptic flow and a hint of suppression of high p_T hadrons suggests that mini-QGP can be formed in collisions of light and heavy nuclei characterized by high charged particle multiplicities. To address the question of collective behavior in small systems RHIC provided series of geometry controlled experiments with highly asymmetric systems (p+Al, p+Au, ^{3}He+Au). The recent results from the PHENIX experiment at RHIC on π^0 and η mesons production in asymmetric systems will be presented and discussed.

1 Introduction

Jet quenching is one of the evidences of quark-gluon plasma (QGP) formation in central heavy ion collisions [1]. Experimentally jet-quenching at RHIC and LHC is observed as suppression of leading particles such as π^0, η-mesons and jets, which are directly associated with partons, formed in the medium [2]. RHIC results from Au+Au and Cu+Cu collisions showed suppression of high-p_T particles as expected from parton energy loss in a hot and dense medium [3]. An additional insight into the mechanism of particle production and parton energy loss can be gained from interactions of asymmetric Cu+Au collisions. Configuration of two different nuclei, Cu and Au, opens an opportunity to study particle production in different initial collision geometries. Despite the fact that number of nucleons participating in interaction is similar for symmetric and assymetric collisions, the shape of overlap region is different, which can influence particle production.

Relativistic Heavy Ion Collider (RHIC) at Brookhaven National Laboratory is one of the biggest operating particle accelerators designed to study heavy ion collisions at high energies. RHIC is a flexible and reliable accelerator complex with an extensive experimental program. A lot of operational time is devoted to beam energy scan and switching between colliding nuclei. In total RHIC delivered 9 combinations of nuclei and 11 energies and beam luminosity is being continuously increased from to run to run. In 2012 RHIC delivered successful Cu+Au run at $\sqrt{s_{NN}} = 200$ GeV.

[a] e-mail: dmitriy.kotov@gmail.com

Recent measurements at the LHC and RHIC revealed presence of flow-like collective effects in collisions of light and heavy nuclei characterized by high charged particle multiplicities [4]. Different techniques and physical observables were utilized to understand whether these collective effects are driven by hydrodynamics similar to that in heavy ion collisions or can be explained by cold nuclear matter effects. The PHENIX experiment has performed a series of geometry-controlled experiments in p+Au, d+Au and ^{3}He+Au collisions at $\sqrt{s_{NN}}$ = 200 GeV for a systematic test of hydrodynamic models.

This paper presents results from PHENIX experiment at RHIC on π^0 and η mesons production in a number of asymmetric systems (p+Au, d+Au, ^{3}He+Au, Cu+Au) at $\sqrt{s_{NN}}$ = 200 GeV.

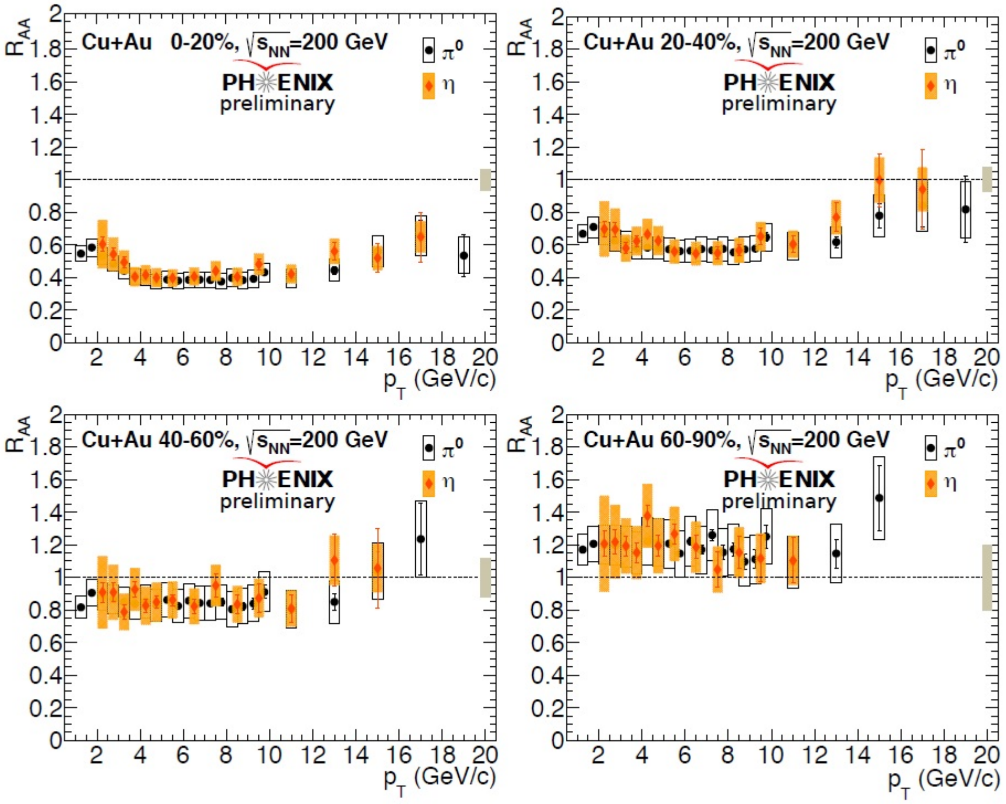

Figure 1. Nuclear modification factors R_{AA} measured for π^0 and η mesons as a function of transverse momentum p_T in Cu+Au collisions at $\sqrt{s_{NN}}$ = 200 GeV. Results are presented for different centrality intervals. Here and throughout the paper error bars correspond to statistical uncertainties. Open boxes show systematic uncertainties. Scaling uncertainty is presented with dashed boxes at unity.

2 Experimental setup and data analysis

PHENIX experimental setup consists of two central and two forward muon spectrometers. Each central spectrometers covers 90 degrees in azimuth ϕ and 0.7 units in pseudorapidity η. Muon spectrometers have full coverage in azimuth at forward and backward rapidity.

Beam-Beam counters (BBC) are used for triggering and determination of event centrality. Charged particle tracking is performed with drift (DC) and pad chambers (PC). Neutral clusters and mesons are reconstructed with electromagnetic calorimeter (EMCal) consisting of PbSc and PbGl sectors. New detectors are central (VTX) and forward silicon vertex detectors (FVTX). Each of them has full coverage in azimuth and cover a wide rapidity range up to 2.2 for the FVTX. These detectors improve tracking and are used to separate charm and bottom by measuring distances of closest approach - distance between tracks and primary vertex. More detailed description of the PHENIX experiment can be found elsewhere [5].

Physics program of the PHENIX experiment is mostly devoted to the study of QCD matter under extreme energy densities and temperatures: system where quarks and gluons are dominating degrees of freedom. All results presented in this proceeding were obtained with the PHENIX experiment at RHIC.

Neutral pions π^0 and η mesons are reconstructed in $\gamma\gamma$ decay channel using EMCal for γ clusters measurement. Meson yields are extracted in different transverse momentum p_T and centrality bins from invariant mass $\gamma\gamma$ distributions. Good signal to background ratio and lots of statistics allow to measure $\pi^0$and η meson yields up to high p_T.

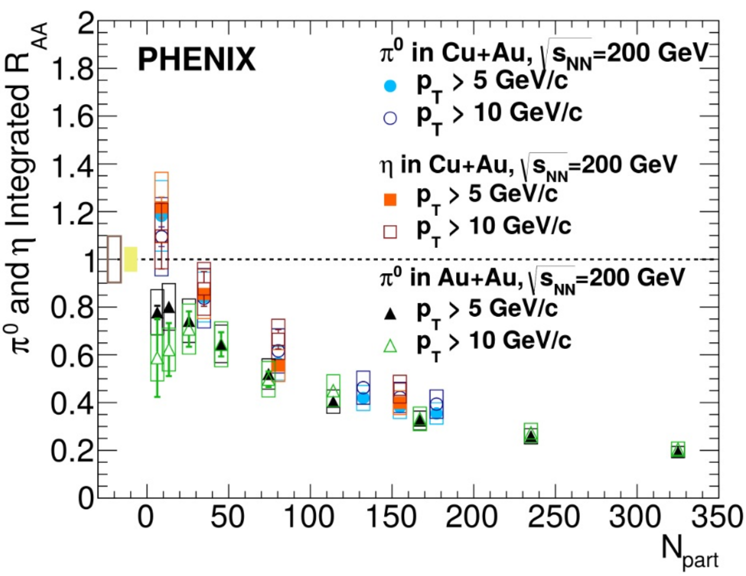

Figure 2. Integrated over transverse momentum p_T nuclear modification factors R_{AA} measured for π^0 and η mesons as a function of N_{part} in Cu+Au and Au+Au collisions at $\sqrt{s_{NN}}$ = 200 GeV.

3 Results

To look at collective effects a nuclear modification factor R_{AA} is usually used. It is defined as a ratio of yields measured for a particle in heavy ion and p+p collisions divided by corresponding number of binary nucleon-nucleon collisions N_{coll}.

Different p_T dependence of R_{AA} includes enhancement of the particle yields at the intermediate p_T which is a characteristic of Cronin effect (R_{AA} > 1) and is often explained as multiple parton scaterring in the initial state, suppression of particle yields ($R_{AA} < 1$) which is called jet-quenching and is explained by parton energy loss before fragmentation, and also the case when collective effects are absent ($R_{AA} = 1$).

Figure 1 presents R_{AA} factors measured for π^0 and η mesons in central, semi-central and peripheral Cu+Au collisions at $\sqrt{s_{NN}}$ = 200 GeV. Production of π^0 and η mesons is suppressed by about a factor of two in most central Cu+Au collisions which is consistent with parton energy loss in hot and dense medium. Nuclear modification factors for π^0 and η mesons are consistent within uncertainties, which suggests that suppression occurs at the parton level followed by fragmentation in vacuum. In peripheral collisions we observe a hint of enhancement for both mesons. A similar behavior of R_{AA} was previously observed for reconstructed jets in the same collision system [6].

Figure 2 presents p_T integrated nuclear modification factors for π^0 and η mesons respectively in Cu+Au collisions at $\sqrt{s_{NN}}$ = 200 GeV. Suppression pattern of mesons is similar in Cu+Au and Au+Au collisions for N_{part} values larger than 50. At N_{part} values smaller than 50 (peripheral collisions) π^0 and η mesons are less suppressed in Cu+Au than in Au+Au. Both π^0 and η mesons exhibit a hint of enhancement in peripheral Cu+Au collisions at $\sqrt{s_{NN}}$ = 200 GeV.

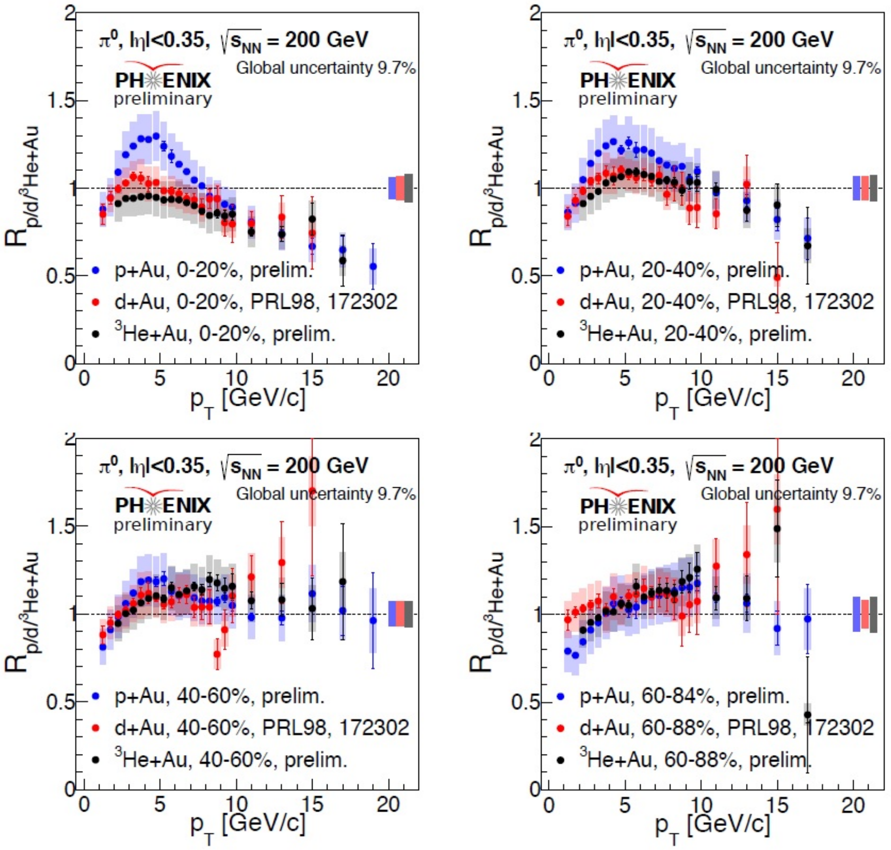

Figure 3. Nuclear modification factors R_{AA} measured for π^0 mesons in p+Au, d+Au and ^{3}He+Au collisions at $\sqrt{s_{NN}}$ = 200 GeV as a function of transverse momentum p_T.

Figure 3 shows nuclear modification factors R_{AA} measured for neutral pions π^0 in p+Au, d+Au and ^{3}He+Au collisions at $\sqrt{s_{NN}}$ = 200 GeV as a function of transverse momentum for different centralities. Centralities for small systems are determined similarly as for large systems [7]. One can see that p+Au results show large centrality dependence, d+Au results agree with p+Au at high p_T, ^{3}He+Au results agree with p+Au and d+Au at high p_T. At moderate p_T an ordering is seen in most central collisions.

Such a centrality dependence of nuclear modification factors for π^0 in small systems came as a surprise and these results present a challenge for conventional models. However there are models which successfully describe the effect. They explain centrality dispersion of R_{AA} by a bias in centrality determination caused by "smaller" effective size of protons which carry a high-x parton. Predictions of one of such models [8] for neutral mesons in ^{3}He+Au collisions are shown with green curves in Figure 4. One can see that curves reasonably reproduce nuclear modification factors R_{AA} measured for these particles in central and peripheral collisions.

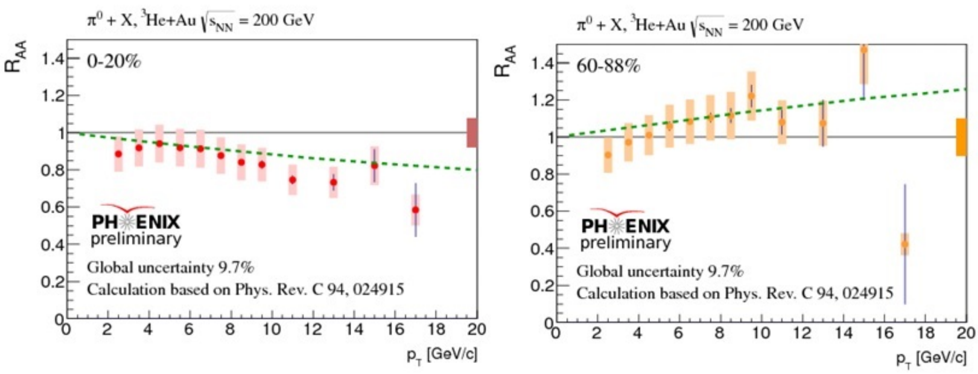

Figure 4. Nuclear modification factors R_{AA} measured for π^0 mesons in ^{3}He+Au collisions at $\sqrt{s_{NN}}$ = 200 GeV as a function of transverse momentum p_T in comparison with model predictions from [8]

4 Conclusions

The PHENIX experiment has measured π^0 and η meson production in a number of of asymmetric systems (p+Au, d+Au, ^{3}He+Au, Cu+Au) at $\sqrt{s_{NN}}$ = 200 GeV.

In small systems R_{AA} for π^0 mesons shows surprising centrality dependence: enhancement in peripheral collisions and suppression in central. In p+Au, d+Au and ^{3}He+Au collisions at all centralities π^0 meson nuclear modification factors R_{AA} are consistent at high-p_T. At moderate p_T an hierarchy in R_{AA} pattern can be seen in most central collisions: $R_{\text{p+Au}} > R_{\text{d+Au}} > R_{\text{He+Au}}$.

In large systems such as Cu+Au π^0 and η meson measurement show suppression in most central collisions and non-zero enhancement in most peripheral collisions which is very consistent with the previous jet measurements [6]. Suppression pattern of π^0 and η mesons in Cu+Au collisions looks similar to the one observed in Au+Au collisions at $N_{part} > 50$, which suggests that suppression level depends on nuclei overlap size and not on its geometry.

We acknowledge support from Russian Ministry of Education and Science, state assignment 3.1498.2017/4.6.

References

[1] K. Adcox et al. (PHENIX collaboration), Nucl. Phys. A **757**, 184 (2005)
[2] S. Adler et al. (PHENIX collaboration), Phys. Rev. C **75**, 024909 (2007)
[3] A. Adare et al. (PHENIX collaboration), Phys. Rev. Lett **109**, 152301 (2012)
[4] A. Adare et al. (PHENIX collaboration), Phys. Rev. Lett **115**, 142301 (2015)
[5] K. Adcox et al. (PHENIX collaboration), Nucl. Instr. and Meth. **A499**, 469 (2003)
[6] A. Timilsina, Nucl. Phys. A. **956**, 537 (2016)
[7] A. Adare et al. (PHENIX collaboration), Phys. Rev. C **90**, 034902 (2014)
[8] D. McGlinchey, and J. L. Nagle, and D. V. Perepelitsa, Phys. Rev. C **94**, 024915 (2016)