Journal of Physics: Conference Series

PAPER • **OPEN ACCESS**

Comparative analysis of proton production as a function of quark content and collision geometry

To cite this article: D M Larionova *et al* 2020 *J. Phys.: Conf. Ser.* **1697** 012140

Comparative analysis of proton production as a function of quark content and collision geometry

D M Larionova, A Ya Berdnikov, Ya A Berdnikov, D O Kotov, Yu M Mitrankov

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

E-mail: dashalario@gmail.com

Abstract. Quark gluon plasma (QGP) is one of the most discussable objects in modern particle physics. One of the ways to study QGP is to measure production of different particles in various relativistic ion collisions. Nuclear modification factors (R_{AB}) for protons were previously measured in symmetric Au+Au collisions at $\sqrt{s_{NN}}$ = 200 GeV. Asymmetric Cu+Au system in comparison with Au+Au results allows to study the influence of collision geometry on proton production. This report presents invariant transverse momentum (p_T) spectra, R_{AB} values of protons obtained in Cu+Au collisions at the energy of $\sqrt{s_{NN}}$ = 200 GeV and the results of comparative analysis of proton (three valence quarks) and φ, π^0-mesons (quark antiquark pairs) production as a function of quark content and collision geometry (Cu+Au and Au+Au).

1. Introduction

Quark gluon plasma (QGP) is one of the most discussable objects in modern particle physics [1]. One of the ways to study QGP is to measure production of different particles in various relativistic ion collisions. Nuclear modification factors (R_{AB}) are a quantitative characteristic between nucleus-nucleus and nucleon-nucleon interactions and are calculated according to the formula:

$$R_{AB}(p_T) = \frac{1}{N_{coll}} \frac{d^2N_{A+A}(p_T)/dydp_T}{d^2N_{p+P}(p_T)/dydp_T}$$

where N_{coll}- average number of inelastic nucleon-nucleon collisions, calculated using the Glauber model, $d^2N_{AA}(p_T)/dydp_T$ and $d^2N_{pp}/dydp_T$ – are particle yields in a given transverse momentum interval and centrality class for A+A and p+p collisions consequently.

The R_{AB} for protons were previously measured in symmetric Au+Au [2] collisions at $\sqrt{s_{NN}}$ = 200 GeV. Study of proton production in asymmetric Cu+Au system in addition to Au+Au results allows to study the influence of collision geometry on proton production.

This report presents invariant transverse momentum (p_T) spectra, R_{AB} of $(p + \bar{p})/2$ obtained in Cu+Au collisions at the energy of $\sqrt{s_{NN}}$ = 200 GeV and the results of comparative analysis of proton (three valence quarks) and φ, π^0-mesons (quark-antiquark pairs) [3], [4] production as a function of quark content and collision geometry (Cu+Au and Au+Au [2]).

2. Analysis Method

PHENIX experiment [5] is the largest of the four experiments at RHIC (The Relativistic Heavy Ion Collider) and has many various detecting systems. The time-of-flight (TOF) system in conjunction with drift chambers (DC) serves as a particle identification device for hadrons. For every particle track mass-squared (m^2) is calculated according to the formula (1).

$$m^2 = \frac{p^2}{c^2}\left(\frac{t^2c^2}{L^2} - 1\right) \tag{1}$$

where p – is the momentum, L – particle path length, t – time of flight, c – speed of light. Fig. 1 presents m^2 versus transverse momentum (p_T) distribution for detected hadrons.
For particle identification, the parameterization of the particle's mass distribution in TOF was performed. The first step of the parametrization procedure is fitting $\pi^{\pm}$, $K^{\pm}$, p and $\bar{p}$ peaks in m^2 (p_T) distribution with Gauss plus parabola function for every p_T bin in each centrality (Fig. 2). In second step Gaussian mean and standard deviation (σ) distributions versus p_T were fitted (Fig. 3) with function (2).

$$[0] + [1]/x + [2]/(p_T^2) + [3]e^{\sqrt{p_T}} + [4]\sqrt{p_T} \tag{2}$$

In current analysis for protons identification 2 σ criteria with kaon veto was used. Hadron in TOF is identified as a proton only if its mass-squared m^2 satisfies inequalities (3), (4).

$$|m^2 - mean_{proton}| < 2\sigma_{proton} \tag{3}$$

$$m^2 > mean_{kaon} + 2\sigma_{kaon} \tag{4}$$

where $mean_{proton}$, $mean_{kaon}$, σ_{proton} and σ_{kaon} corresponds to parametrization values at p_T value of hadron.

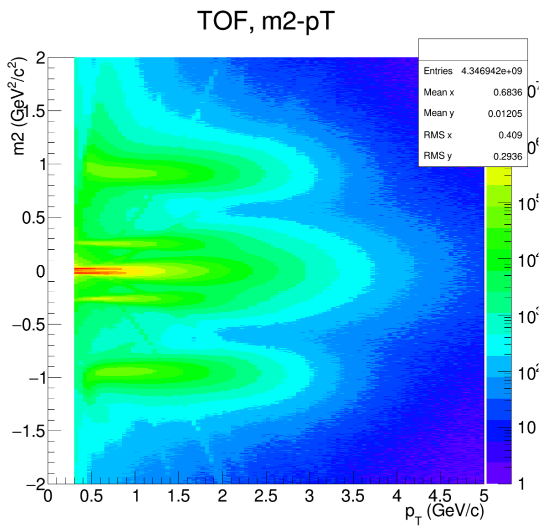

Figure 1. m^2 vs p_T as found from TOF timing, DC momentum, and the path length.

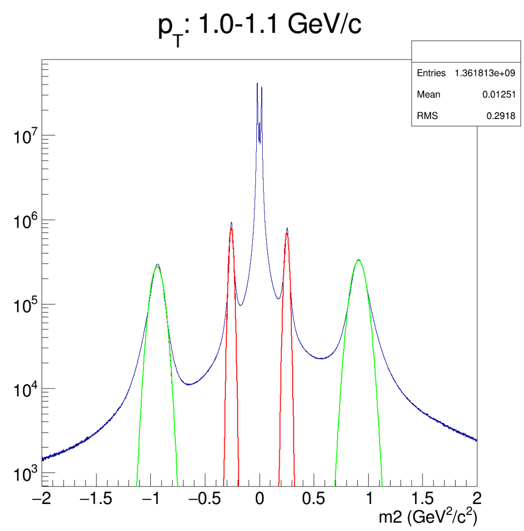

Figure 2. m^2 distribution example for p_T region 1.0-1.1 GeV/c

For evaluation of particle identification efficiencies Monte-Carlo simulation was processed. The efficiencies of protons identification were calculated as a ratio of measured to generated protons for every p_T bin.

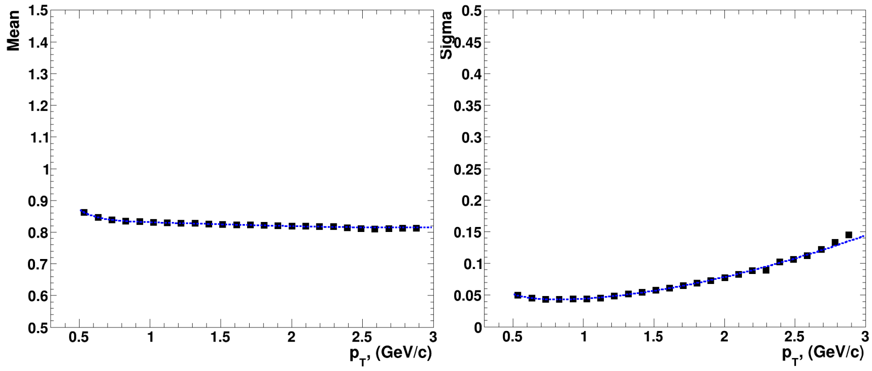

Figure 3. Example of the mean (left) and the standard deviation (right) of the m^2 distribution for protons as a function of p_T for centrality 0-20%

Another correction evaluated with the help of Monte-Carlo simulation is a Feed-down correction [2]. Feed-down fraction is the percentage of the total proton sample that likely comes from hyperon decays. In this paper only Λ-baryon decays were considered. All measurements of Λ implicitly include the Σ^0, which decays electromagnetically with 100% branching ratio to the Λ and a photon. Monte-Carlo simulation allows to calculate the feed-down ratios Λ/p and $\Lambda/\bar{p}$. This correction was applied in order not to consider protons from Λ decays in the final results.

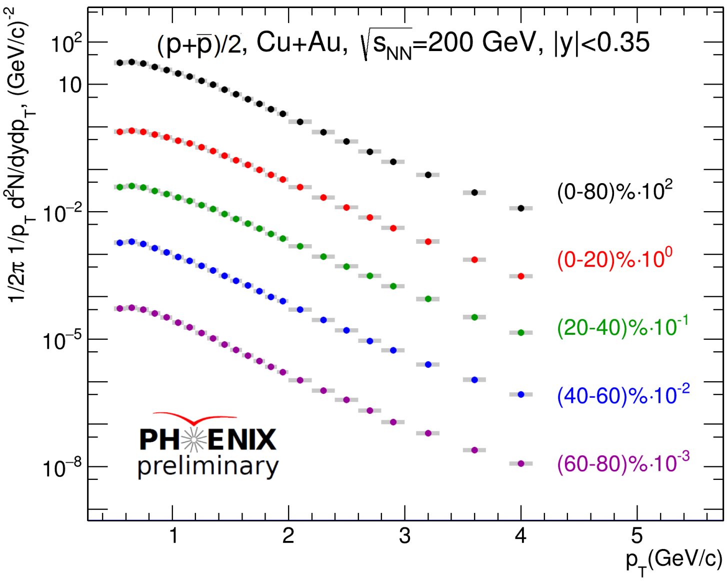

Figure 4. Transverse momentum spectra measured for $(p + \bar{p})/2$ in Cu+Au collisions at $\sqrt{s_{NN}}$ = 200 GeV

3. Results and discussion

Invariant p_T spectra were measured for protons in Cu+Au collisions at $\sqrt{s_{NN}}$ = 200 GeV at 5 centrality bins (0-80%, 0-20%, 20-40%, 40-60%, 60-80%) in p_T range 0.5 GeV/c - 3.9 GeV/c (Fig. 4).

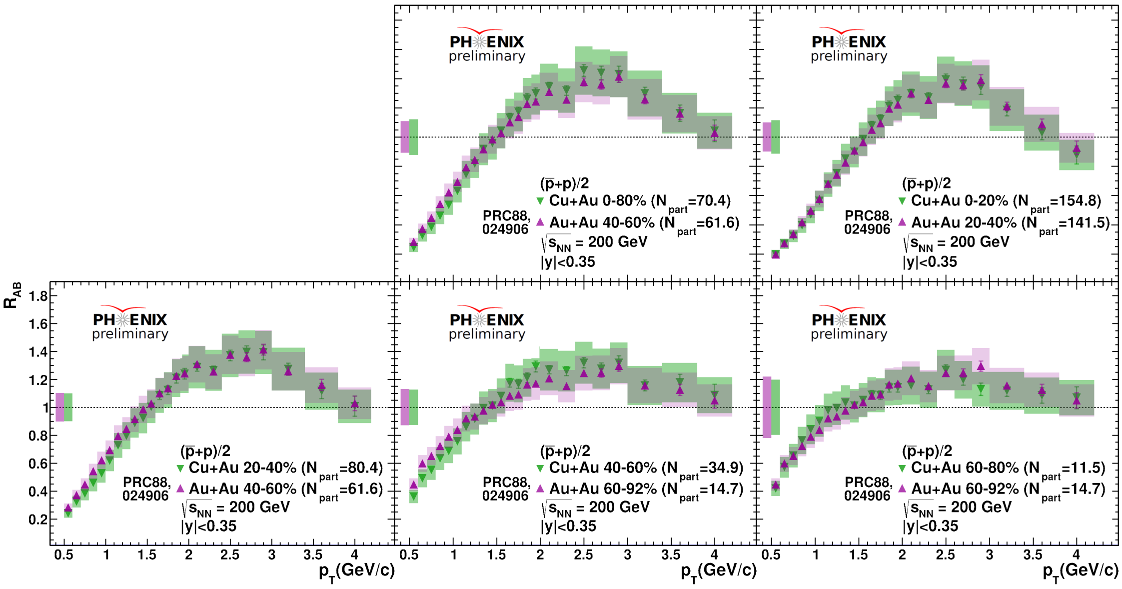

Figure 5. The comparison of $(p+\bar{p})/2$ R_{AB} in Cu+Au collisions at $\sqrt{s_{NN}}$ = 200 GeV to Au+Au collisions at $\sqrt{s_{NN}}$ = 200 GeV at similar N_{part} values [2]

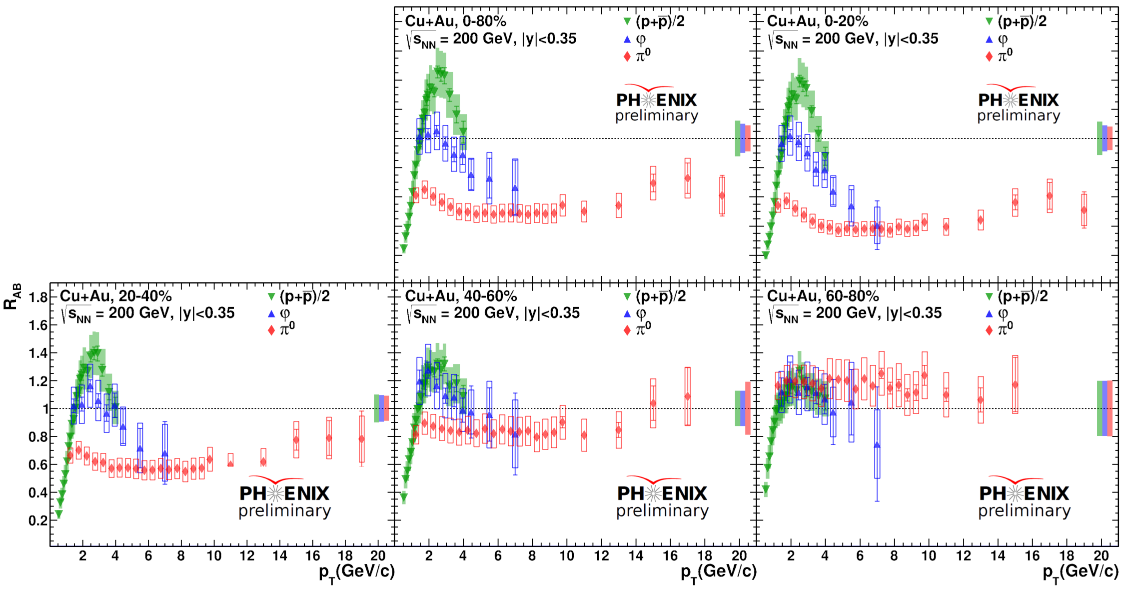

Figure 6. The comparison of $(p+\bar{p})/2$ to φ-meson and π^0-meson nuclear modification factors in Cu+Au collisions at $\sqrt{s_{NN}}$ = 200 GeV.

The comparison of $(p+\bar{p})/2$ R_{AB} in Cu+Au collisions at $\sqrt{s_{NN}}$ = 200 GeV to Au+Au collisions at $\sqrt{s_{NN}}$ = 200 GeV at a similar number of participants (N_{part}) [2] is shown in Fig. 5 For Cu+Au and Au+Au collisions R_{AB} values for protons are consistent at similar N_{part} values. It seems that proton production scales with the average size of the nuclear overlap region and do not depends on the details of its shape. The comparison of $(p + \bar{p})/2$ to φ-meson and π^0-meson R_{AB} in Cu+Au collisions at $\sqrt{s_{NN}} = 200$ GeV is presented in Fig. 6. For the most central Cu+Au collisions proton yields are enhanced ($R_{AB} > 1$) at $p_T > 2$ GeV/c, while π^0 and φ-mesons yields are suppressed. This difference gradually disappears with decreasing centrality.The same pattern was previously observed in Au+Au collisions at $\sqrt{s_{NN}} = 200$ GeV and was explained in the frame of recombination model [2].

4. Conclusion

This paper provides measurements of transverse momentum invariant spectra and nuclear modification factors for protons in Cu+Au collisions at $\sqrt{s_{NN}} = 200$ GeV. Proton R_{AB} values in asymmetric Cu+Au collisions are in agreement with proton R_{AB} values in Au+Au collisions at similar N_{part} values. Such coincidence shows that proton production scales with the average size of the nuclear overlap region and is independent of the details of its shape. The observed difference in R_{AB} values for protons, φ and π^0-mesons disappears from central to peripheral collisions. The similar behaviour of R_{AB} values in Au+Au collisions was explained on basis of recombination model. In this way the current study will provide additional information for further development of recombination model.

References

[1] Adox K et al 2005 *Nucl. Phys. A* **757** 184-283
[2] Adare A et al 2013 *Phys. Rev. C* **88** 024906
[3] Mitrankov Iu 2018 *PoS HardProbes2018* 108
[4] 2018 Berdnikov A, Berdnikov Ya, Kotov D, Mitrankov Yu *JoP Conf. Ser.* bf 1135(1) 012044
[5] Adcox K et al 2003 *Nucl. Instrum. Meth. A* **499** 469-479