Pseudorapidity distributions of charged particles in pp($\bar{p}$), p(d)A and AA collisions using Tsallis thermodynamics

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The pseudorapidity distributions of charged particles measured in p+p($\bar{p}$) collisions for energies ranging from $\sqrt{S_{NN}}$=23.6 GeV to 13 TeV and A+A collisions at RHIC and LHC are investigated in the fireball model with Tsallis thermodynamics [1]. We assume that the rapidity axis is populated with fireballs following q-Gaussian distribution and the charged particles follow the Tsallis distribution in the fireball. We also extend the fireball model to asymmetric collision systems, i.e., d+Au collisions at $\sqrt{S_{NN}}$=200 GeV and p+Pb collisions at $\sqrt{S_{NN}}$= 5.02 TeV, by taking into account the asymmetric geometry configuration. The model can fit well the experimental data for all the collision systems and centralities investigated. The collision energy and centrality dependence of the model parameters for the symmetric (asymmetric) collision system, i.e., the central position y_0 (y_{0a}, y_{0A}) and its width σ (σ_a, σ_A) of the fireball distribution, are also investigated and discussed. The results suggest that the fireball model with Tsallis thermodynamics can be used as a universal framework for the pseudorapidity distributions of charged particles in high energy collisions at RHIC and LHC.

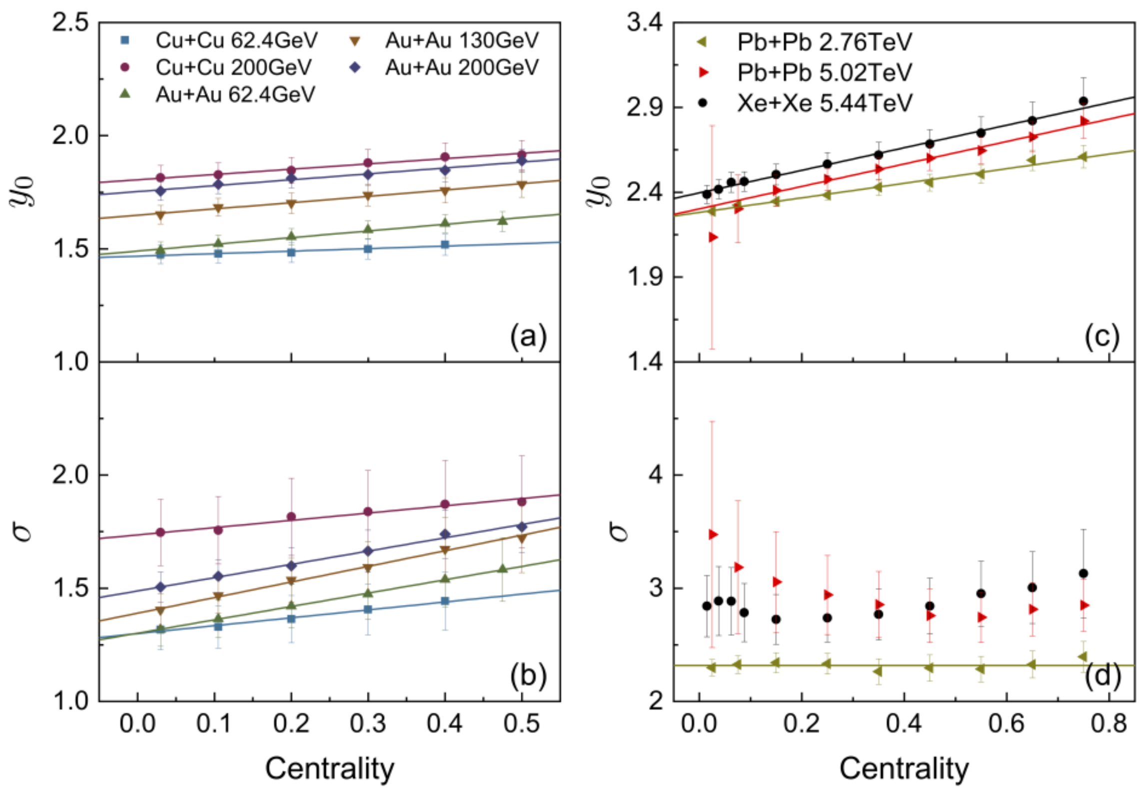

Fig. 1. (Color online) The centrality (0 represents the most central collisions) dependence of the y_0 and **σ** in Cu+Cu collisions at $\sqrt{S_{NN}}$=62.4, 200 GeV, Au+Au collisions at $\sqrt{S_{NN}}$=62.4, 130, 200 GeV, Pb+Pb collisions at $\sqrt{S_{NN}}$=2.76, 5.02 TeV and Xe+Xe collisions at $\sqrt{S_{NN}}$=5.44 TeV. The lines are the linear fitting results.

In Fig. 1, the centrality dependence of the y_0 and σ are shown for A+A collisions at $\sqrt{S_{NN}}$>60 GeV. A nice linear relation between y_0 and centrality is found. We performed linear fits shown with the lines in Fig. 1(a) and (c). The positive slope indicates that the stopping power is decreasing from central to peripheral collisions because there are more collisions and dissipation processes at central collisions comparing with peripheral collisions. The linear behavior of the width σ versus centrality is also observed at RHIC. The fitting results are shown by the lines in Fig. 1(b) and (d). For the collisions at LHC, σ shows different dependence on centrality. For Pb+Pb collisions at $\sqrt{S_{NN}}$=2.76 TeV, σ tends to be a constant for all the centralities and a constant line is plotted. While the collision energy goes up, i.e., Pb+Pb collisions at $\sqrt{S_{NN}}$=5.02 TeV and Xe+Xe at $\sqrt{S_{NN}}$=5.44 TeV, σ can only be roughly a constant within errors but it can not be conclusive. This is because the relatively limited η acceptance respect to the extremely high collision energies at LHC and the model parameter σ are not well constrained by the experimental data and show large errors.

In Fig. 2, the centrality dependence of the $y_{0a(A)}$ and $\sigma_{a(A)}$ are shown for p(d)+A collisions. The linear relation between $y_{0a(A)}$ ($\sigma_{a(A)}$) and the centrality can be seen. We also performed the linear fits shown with lines. Different from both the p+p and A+A collisions, negative slopes of the lines of $y_{0a(A)}$ ($\sigma_{a(A)}$) are found in the direction of the heavy nucleus beam. This may indicate the different dynamics in p+A collisions from the symmetric collisions because of the asymmetric configuration.

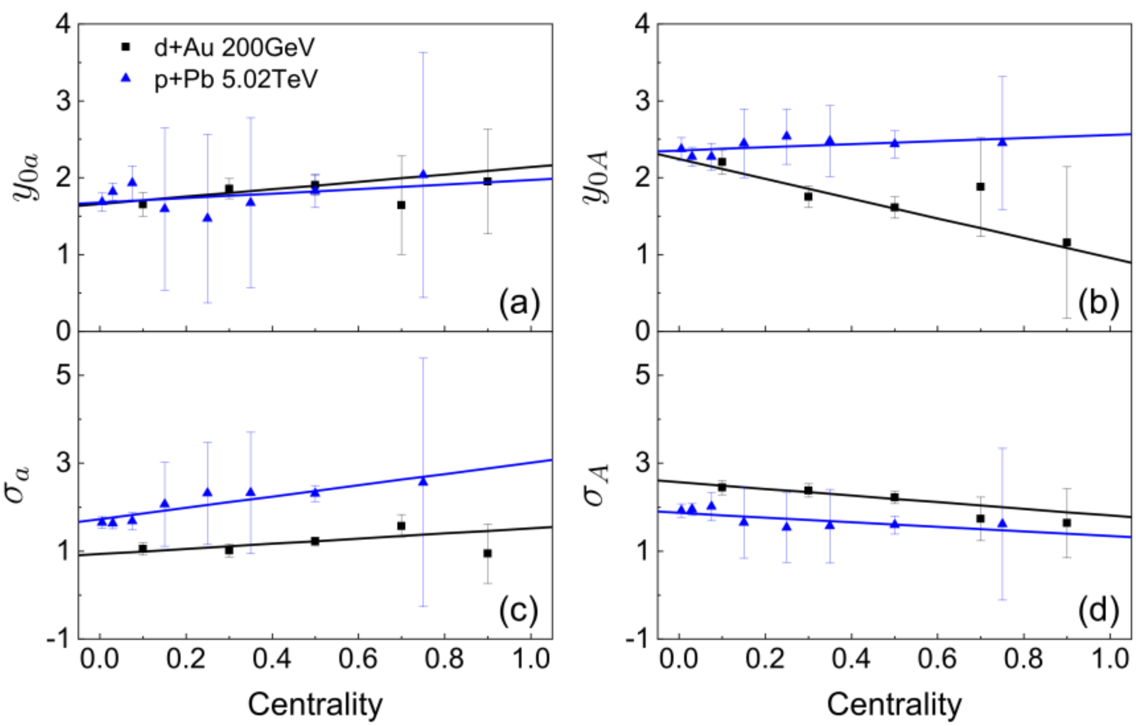

Fig. 2. (Color online) The centrality (0 represents the most central collisions) dependence of the y_{0a}, y_{0A},and $\boldsymbol{\sigma_a}$ and $\boldsymbol{\sigma_A}$ in d+Au collisions at $\sqrt{S_{NN}}$=200 GeV, and p+Pb collisions at $\sqrt{S_{NN}}$=5.02 TeV. The lines are the linear fitting results.

[1] J.Q. Tao, M. Wang, H. Zheng. W.C. Zhang, L.L. Zhu and A. Bonasera, 2021 J. Phys. G: Nucl. Part. Phys. https://doi.org/10.1088/1361-6471/ac1393 [arXiv: 2011.05026].