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Probing Hydrodynamics at 7.7 GeV: Model Comparisons of the Bulk Properties of Au+Au Collisions.

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Abstract

We study hydrodynamic effects of bulk properties of the matter produced in Au+Au collisions at $\sqrt{s_{NN}}$=7.7 GeV measuring production of the following particles $\pi^{\pm}$, $K^{\pm}$, $\bar{p}$ and p with AMPT, EPOS4, PYTHIA8 and SMASH Monte Carlo approaches. Mid-rapidity (|y| < 0.1) analysis of the transverse momentum spectra, mean transverse momentum, antiparticle-to-particle and mixed-particles ratios, in dependence of various collision centralities are presented and compared with the 2010 data collected by STAR experiment in the Beam Energy Scan (BES) program at the Relativistic Heavy Ion Collider (RHIC) [1].

Why studying hydrodynamics at 7.7 GeV?

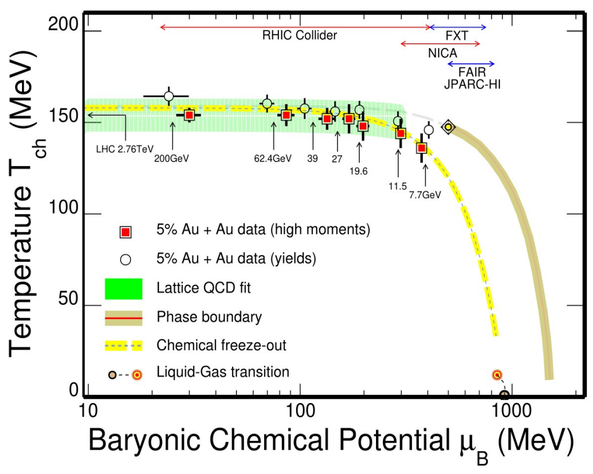

Fig1: A summary of the chemical freeze-out temperature T_{ch} (μ_B) distribution. Data points are from the 0-5% central Au+Au collisions at STAR BES.

At 7.7 GeV of centre-mass energy, experimental results suggest the presence of large net-baryon density region in the QCD phase diagram and strong baryon stopping. Is the system created close to thermal local equilibrium? Here we can test the limits and applicability of hydrodynamics, which have successfully described high-energy heavy-ion collisions (HEHIC). However, HEHIC models present limitations for energies below 10 GeV.

Transverse Momentum Spectra

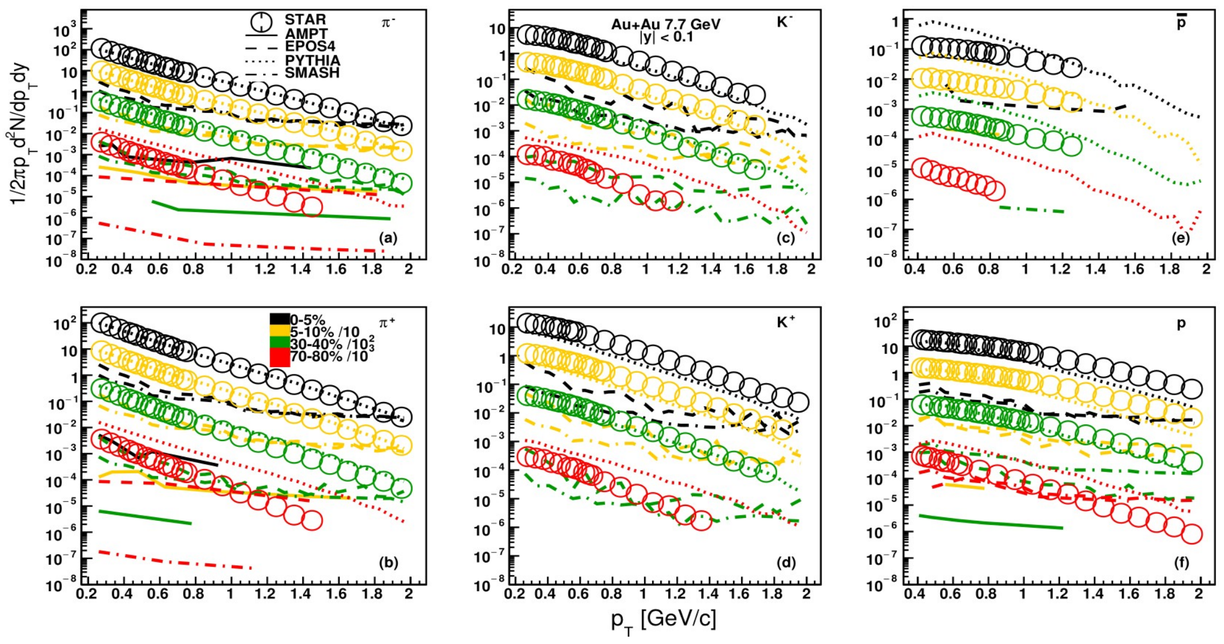

Fig 2: Transverse momentum (p_T) spectra for (a) π^-, (b) π^+, (c) K^-, (d) K^+, (e) $\bar{p}$ and (f) p in the mid-rapidity range (|y| < 0.1) in Au+Au collisions at $\sqrt{s_{NN}}$ = 7.7 GeV for 0-5%, 5-10%, 30-40% and 70-80% centrality classes for AMPT, EPOS4, PYTHIA8 and SMASH models in comparison with STAR experimental data [1]. Excluding the 0-5% spectra, the rest were scaled by a factor of 10 for visual clarity.

Models: Underlying Physics

Models	Initial Conditions	QGP phase (medium evolution)	Hadronization	Hadronic rescattering
AMPT[2]	Hijing model	Zhang's Parton Cascade model	Quark-coalescence	Extended ART model
EPOS4[3]	Parton-Based Gribov-Regge Theory. Core/corona separation.	(3+1)D viscous hydrodynamics	Cooper-Fry + Corona Fragmentation	UrQMD model
PYTHIA8[4]	Perturbative QCD	No	Lund String Fragmentation	No
SMASH[5]	Wood-Saxon distribution	No	PYTHIA8 model	Boltzmann equation

$\langle p_T \rangle$ vs $\langle N_{part} \rangle$

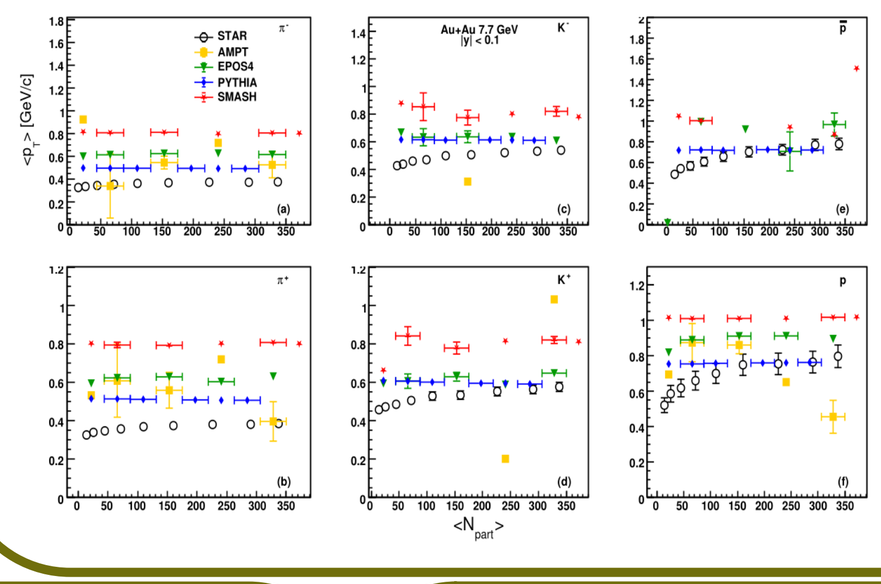

Fig 3: Average transverse momentum ($\langle p_T \rangle$) in dependence of ($\langle N_{part} \rangle$) for (a) π−, (b) π+, (c) K−, (d) K+, (e) p and (f) p particles.

Selection Criteria

We report on the transverse momentum spectra (p_T), average transverse momentum ($\langle p_T \rangle$) vs mean number of participants nucleons ($\langle N_{part} \rangle$), antiparticle/particle and mixed particles ratios. Selected pT range: 0.2-2.0 GeV for $\pi^{\pm}$ and $K^{\pm}$ and 0.4-2.0 GeV for $\bar{p}$ and p. All particles are analyzed within the rapidity range of (|y| < 0.1) and vertex radius range $\sqrt{x^2+y^2} <$ 2 cm.

Antiparticle-to-Particle Ratio

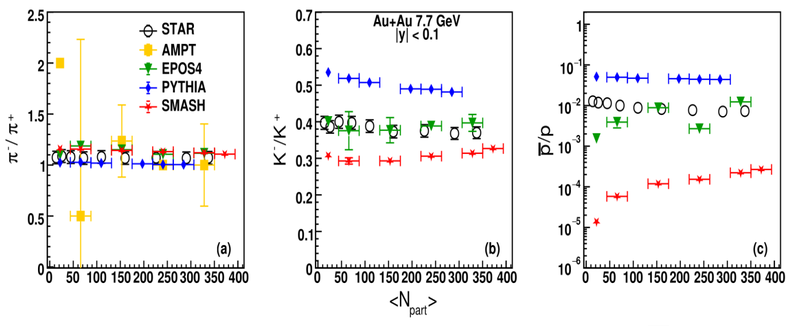

Fig. 4. (a) π^-/π^+, (b) K^-/K^+ and (c) $\bar{p}/p$ ratios as a function of $\langle N_{part} \rangle$.

Mixed-Particle Ratio

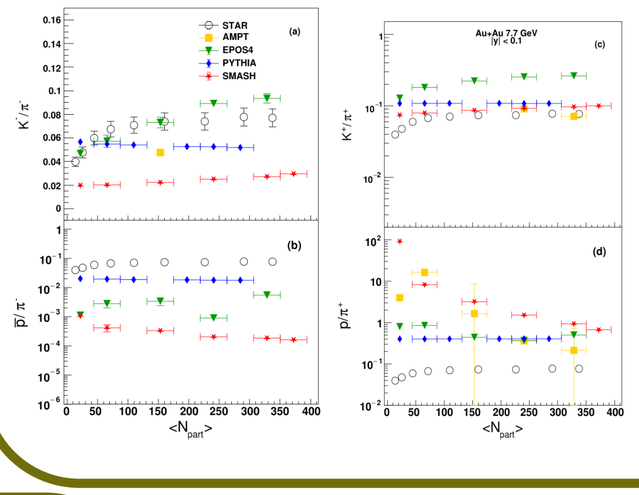

Fig. 5. (a) K−/π−, (b) $\bar{p}$/π−, (c) K+/π+ and (d) p/π+ ratios as a function of $\langle N_{part} \rangle$.

Conclusions

We have presented the transverse momentum and particle ratios dependence of different collision centrality, for mid-rapidity (|y| < 0.1) particle production of $\pi^{\pm}$, $K^{\pm}$, $\bar{p}$ and p with AMPT, EPOS4, PYTHIA8 and SMASH Monte Carlo models. For the p_T spectra analysis, PYTHIA8 predicts well the distributions of $\pi^{\pm}$ and $K^{\pm}$ particles from mid to central collisions. However, for the $\langle p_T \rangle$, it shows no dependence on the collision centrality. EPOS4 fairly describes the K^-/K^+ and $\bar{p}/p$ ratios from mid-to-central collisions, indicating hydrodynamical effects of this observable even at the low center-of-mass energy range. Other models demonstrated limited description of the experimental data, but further analysis is being conducted to improve the results by fine tuning of the model parameters.

Reference

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4. Bierlich C. et al. A comprehensive guide to the physics and usage of PYTHIA 8.3. SciPost Phys. Codebases 2022.
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