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Talk:

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

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MOTIVATION

Why studying hydrodynamics at 7.7 GeV?

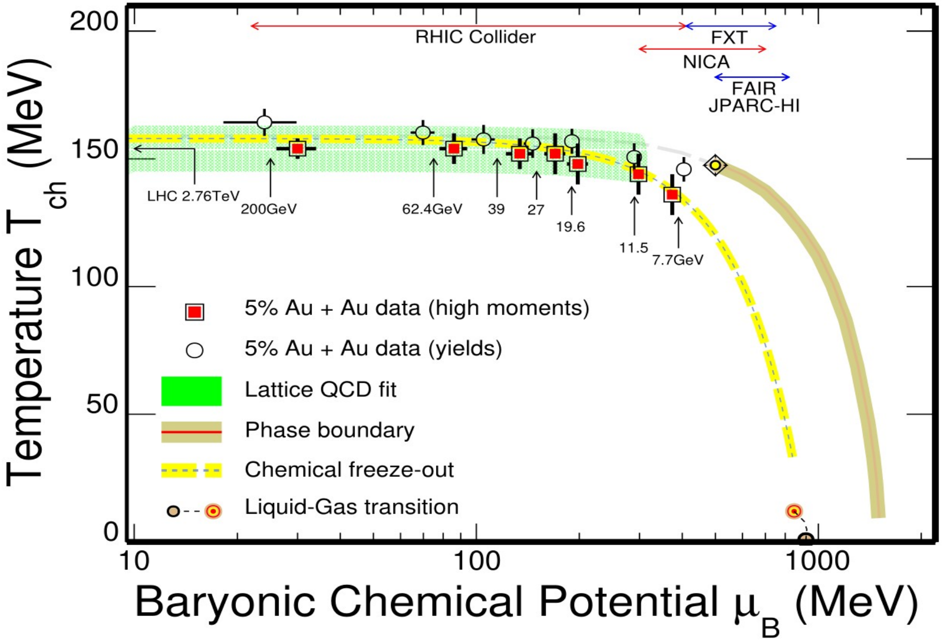


Fig1 [1]: A summary of the chemical freeze-out temperature Tch(μB) distribution. Data points are from the 0-5% central Au+Au collisions at STAR BES.

Challenges we still have:

- Baryon stopping and large net-baryon density.
- Non-equilibrium dynamics and applicability of hydrodynamics ?
- Initial conditions and geometry differences
- Equation of State at finite μ_B, hadronic rescattering, freeze-out dynamics.
- Event-generators limitations below ~10 GeV

$\sqrt{s_{NN}} \approx 7.7\, GeV$

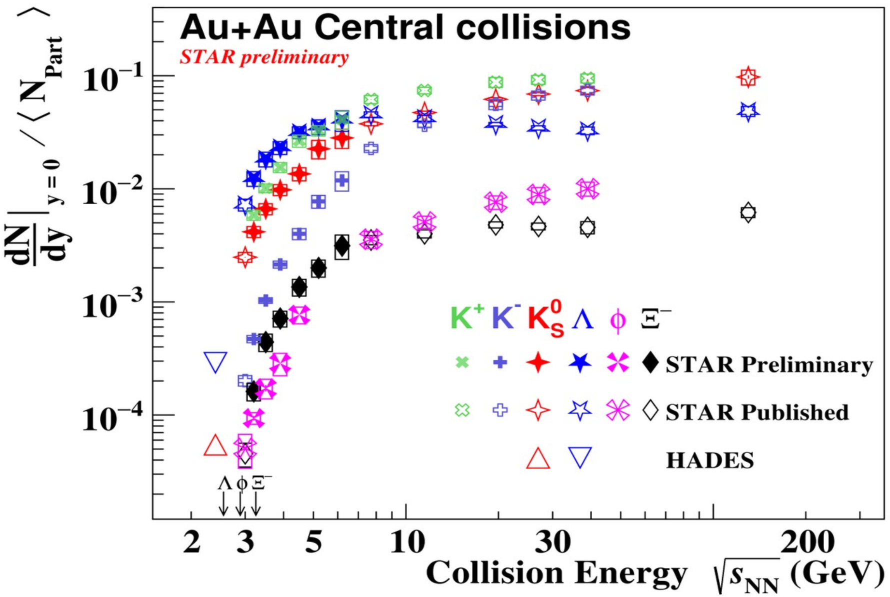
μ_B ~ 1000 MeV
T ~ 150 MeV

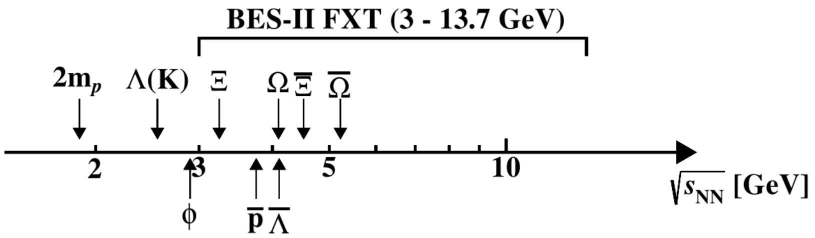
$\sqrt{s_{NN}} > 2.76\, TeV$

μ_B < 10 MeV
T ~ 150 MeV

PREVIOUS RESULTS

Strange Particles Production Near The Threshold





Rich structure in strangeness excitation functions.

➢ Production mechanisms are different at low and high energies (high and low baryon density).

Partonic interaction (pair production)

gg → **ss** or **qq** → **ss**

Hadronic interaction (associated production)

BB → **BYK** or **BB** → **BΞKK**

B: N, p, **Δ**, etc. Y: **Λ**, **Σ**, etc. K: **K**+, **K0**

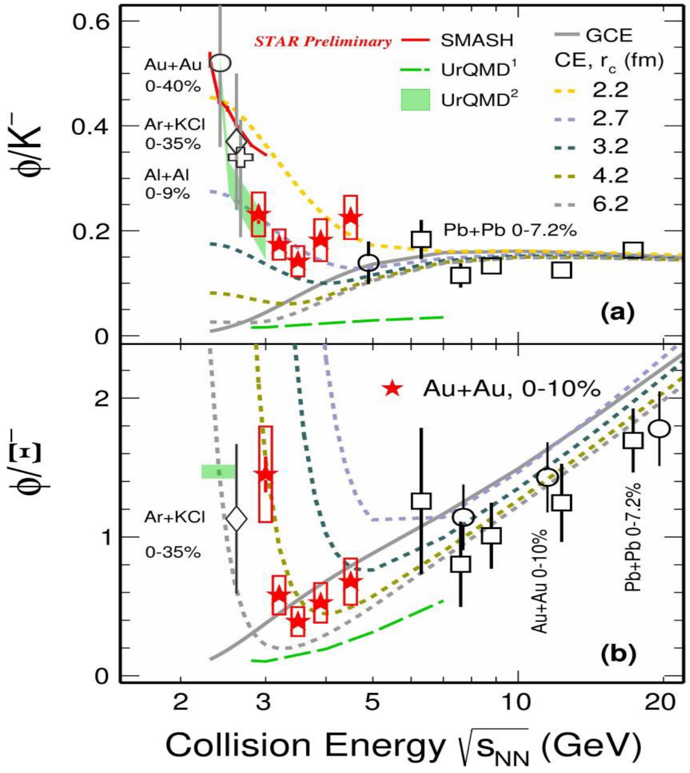
➢ Baryon-dominated to meson-dominated transitions

Ks0 and **Λ** mid-rapidity yield cross at ~ 8 GeV.

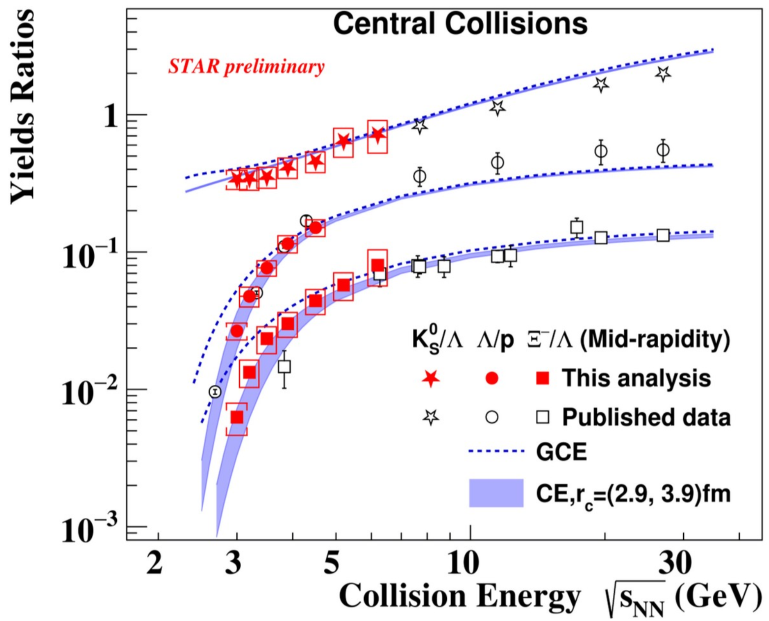
➢ First measurement of **Ξ**− near- / sub-threshold energies in Au+Au collision.

PREVIOUS RESULTS

Strange Particles Ratio



[2-4]



[5-9]

CE describe yield ratios with $\boldsymbol{r_c}$ ~ **3 − 4** fm, GCE fails below $\sqrt{S_{\mathbf{NN}}}$ ~ 5 GeV

Test of the medium properties in high baryon density region

OVERVIEW

- Introduction
  - Hydrodynamic Picture
  - Phenomenological Models and Frameworks
- Results
  - Transverse Momentum Spectra.
  - Average Transverse Momentum vs Average Number of Participants.
  - Antiparticle/Particle and Mixed Particles Ratio
  - Blast Wave Model Fitting
    - T_{kin} vs $<\beta>$ analysis
- Summary and Conclusions

INTRODUCTION

→ Hydrodynamical Picture

Space-Time Evolution

Hydrodynamics relies on local equilibrium:

- Conserved energy-momentum, conserved baryon number: $\partial_\mu T^{\mu\nu} = 0$ $\partial_\mu N_B^\mu = 0$
- Equation of State (EoS): $p = p\,(T, \mu_B)$ or $p = p(\varepsilon, n)$
- Initial conditions, transport coefficients, dissipative effects are necessary.

Local Conservation + EoS $\longrightarrow$ Collective expansion (flow)

Hydrodynamics describes how the energy, momentum, and conserved charges of the medium evolve continuously in space and time.

→ Phenomenological Models and Frameworks

Models	AMPT	EPOS4	PYTHIA	SMASH
Name	***A M**ulti-**P**hase **T**ransport **M**odel*	***E**nergy conserving quantum mechanical approach, based on **P**artons, parton ladders, strings, **O**ff-shell remnants, and **S**plitting of parton ladders.*	PYTHIA8 (Angantyr Model)	***S**imulating **M**any **A**ccelerated **S**trongly-interacting **H**adrons*
Physics	Transport Model	Hybrid Model (core/corona + hydro + hadronic cascade	Hadronic Model (pQCD+ Lund String Hadronization)	Hadronic Transport Model
Hydro stage	String-Melting	Yes	No	No
μ_B range	Medium-High	Medium	Low	High
Collectivity (flow)	Moderate-strong	Strong	Weak	Moderate
Energy range for heavy-ion collisions	≥ 5 GeV	≥ 4 GeV	≥ 4 GeV	$\gtrsim$1-2 GeV

SELECTION CRITERIA

- The experimental data presented here are based on data taken with the STAR experiment, program BES I, in Au+Au collisions at 7.7 GeV centre-mass energy, collected in the year 2010. [10]

- Observables analyzed: Transverse momentum spectra (pT), <pT> vs <Npart>, antiparticle/particle ratio, mixed particles ratio, blast-wave function fitting.

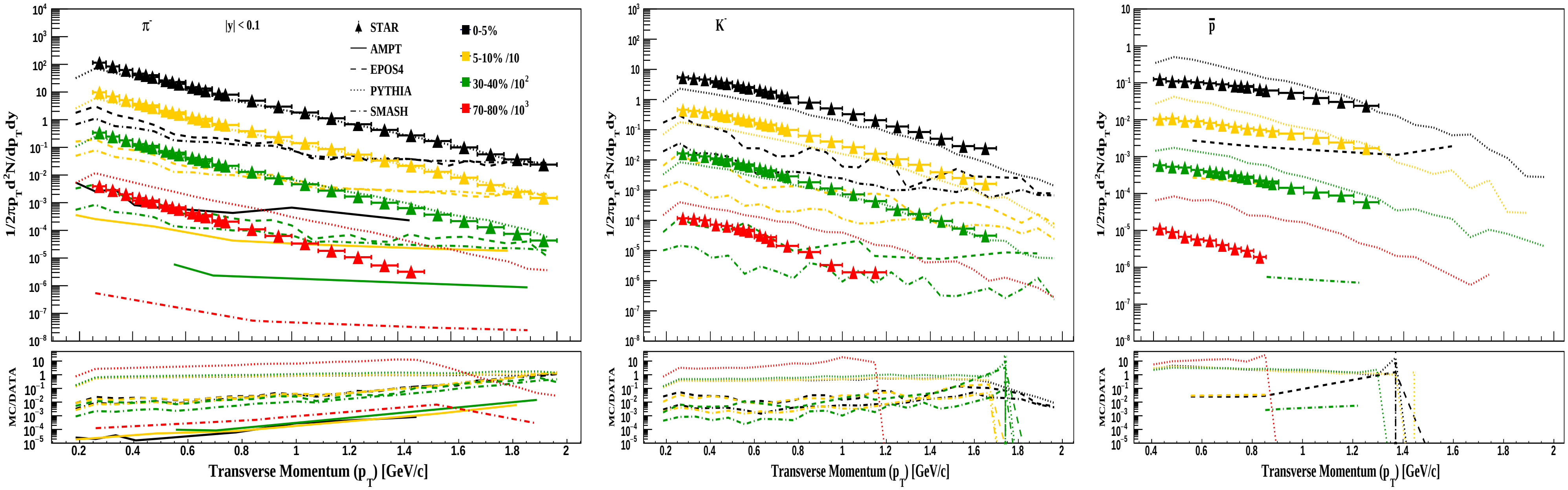
- Particles analyzed: π+, π-, K+, K-, p, $\bar{p}$

	π-	**π+**	**K-**	**K+**	**$\bar{p}$**	**p**
pT range	0.2-2.0 GeV				0.4-2.0 GeV	
y range	$\lvert y \rvert < 0.1$					
Vertex radius	$\sqrt{V_x^2+V_y^2}<2\,cm$					

Models	**N_{events}**
STAR	4000000
AMPT	360000
EPOS	80000
PYTHIA8	2700000
SMASH	2300000

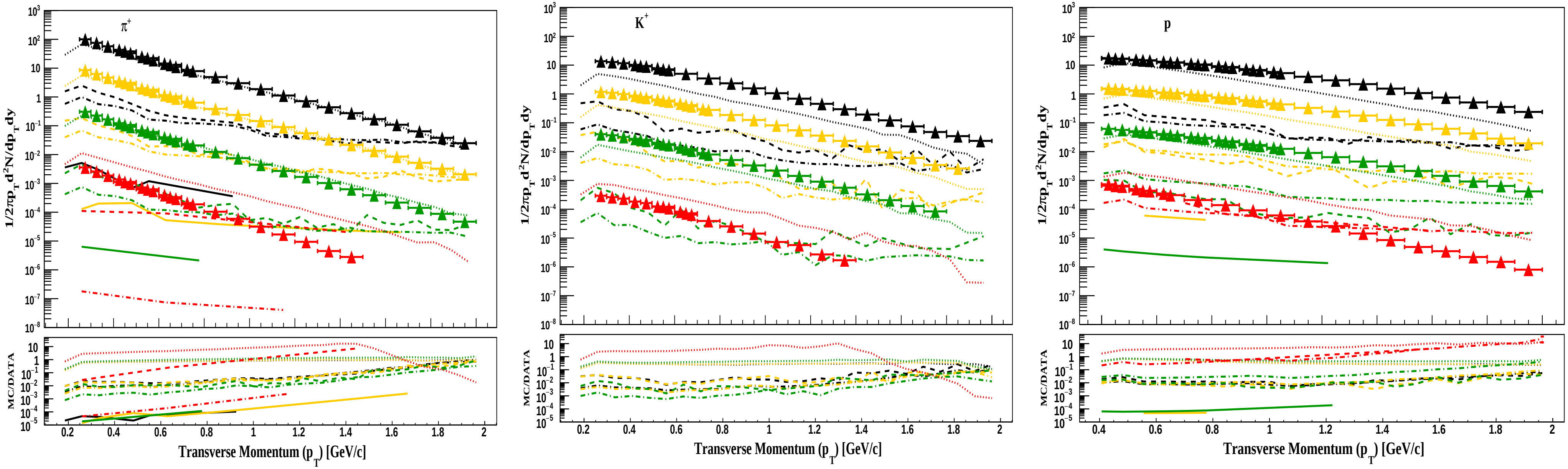
RESULTS

→ Transverse Momentum Spectra (antiparticles)



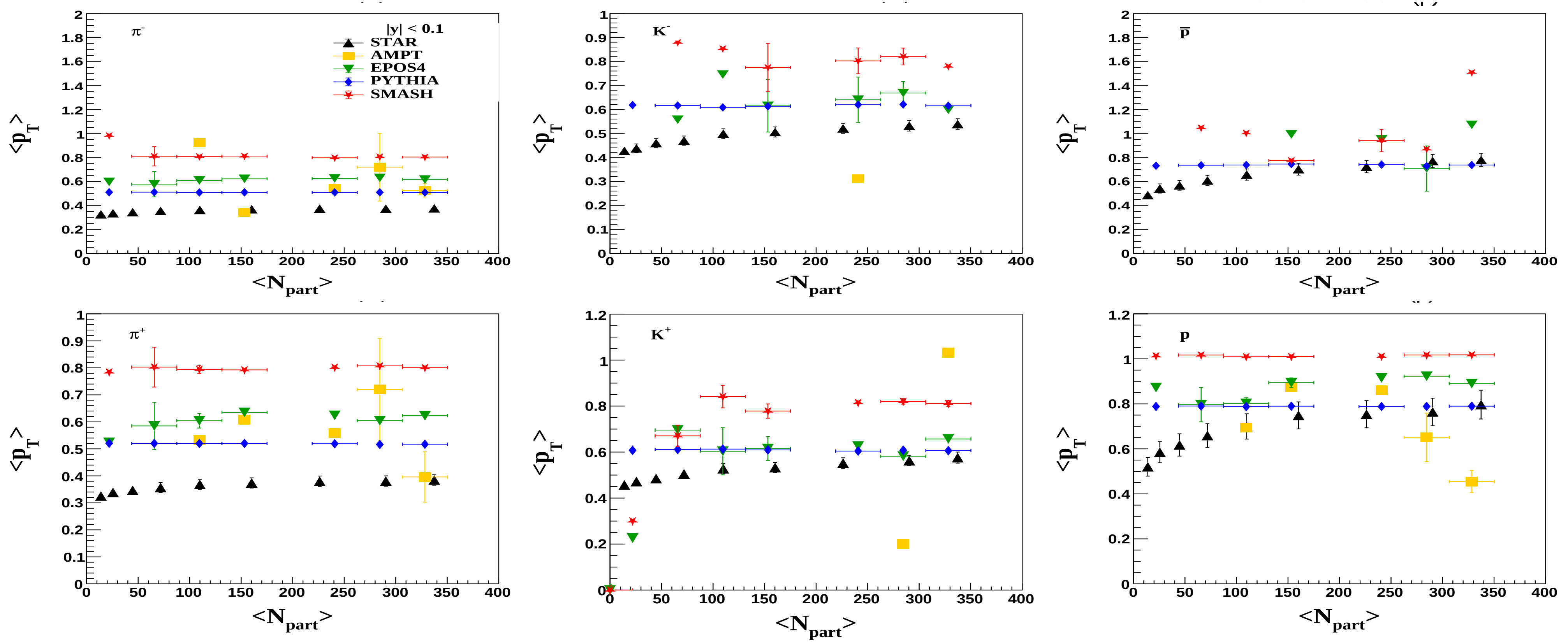
- pT distributions are normalized by <Npart> in each centrality class.
- The pT spectra follow the order π < K < p.
- PYTHIA8 fairly describes the experimental π+ distribution for 0-5%, 5-10% and 30-40% centrality classes.
- PYTHIA8 overestimates particle production in peripheral collisions.

→ Transverse Momentum Spectra (particles)



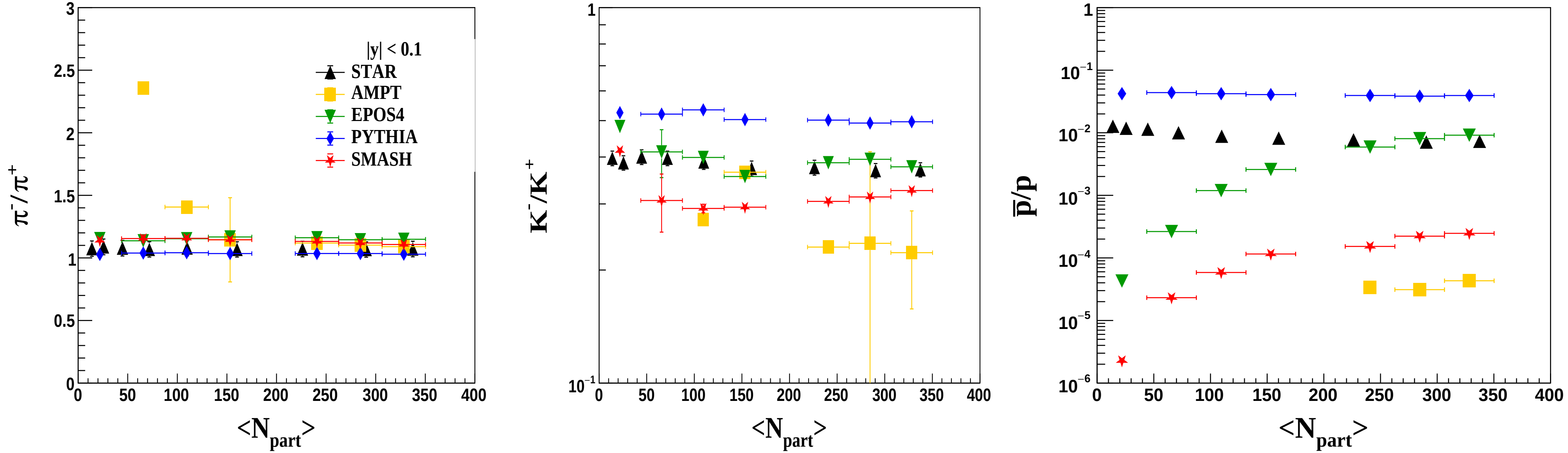
- AMPT fails to produce $K^{\pm}$ and $\bar{p}$/p at mid-rapidity.
- AMPT fails to predict particle production for 70-80% centrality class.

→ Average Transverse Momentum in Dependence of Centrality Classes



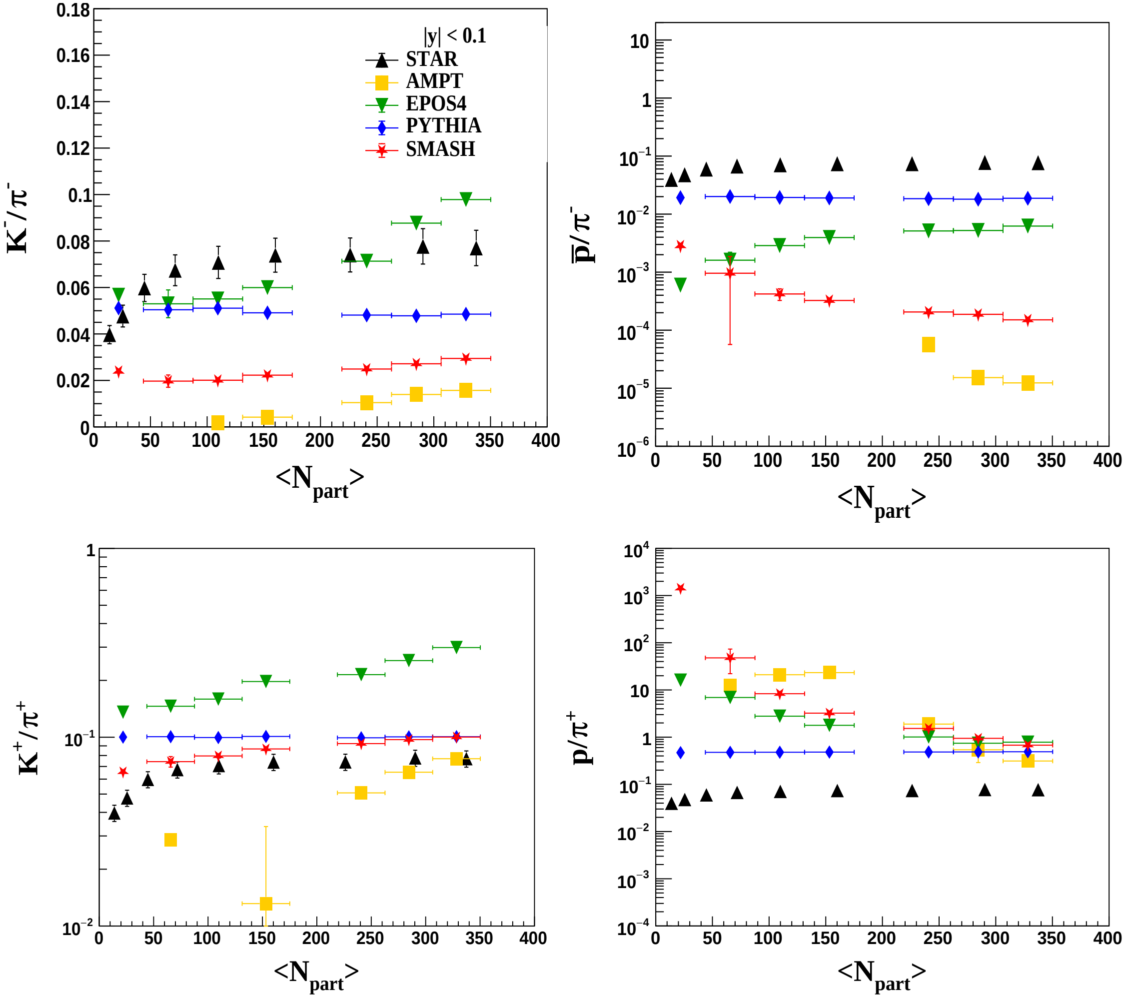
- Increase of <pT> with increasing hadron mass it reflects collective expansion in the radial direction.

→ Antiparticle/Particle Ratio



- $\pi^-/\pi^+ > 1$ indicating contributions from resonance decays (such as Δ).
- $K^-/K^+ < 1$ higher contribution from K^+ production.
- $\bar{p}/p < 1$ indicating large baryon stopping.
- PYTHIA shows the best agreement with π^-/π^+ ratio
- EPOS describes ratios K^-/K^+ and $\bar{p}/p$ the best, except for peripheral collisions.

→ Mixed Ratio



- The ratio K^+/π^+ is interesting:
  - ✔ PYTHIA8 weak dependence on centrality classes, indicating string fragmentation.
  - ✔ EPOS4 shows an enhanced ratio with <Npart>, could indicate QGP signals?
- The baryon/meson (p/π^+) ratio decreases from peripheral to central collisions.
- p/π^+ ratio is larger that the experimental data for all models.

→ Blast-Wave Function Fitting

- Boltzman-Gibbs Blast Wave Function

$$\frac{dN}{p_T\,dp_T} \sim \int_0^R r\,dr\,m_T\,I_0\left(\frac{p_T \sinh\rho}{T}\right) K_1\left(\frac{m_T \cosh\rho}{T}\right)$$

where

$m_T = \sqrt{m^2 + p_T^2}$	Transversal mass
$\rho(r) = \tanh^{-1}(\beta(r))$	Flow rapidity
$\beta(r) = \beta_S (r/R)^n$	Radial flow velocity
β_S	Surface velocity
r/R	Relative radial position

- The model assumes that the particles are locally thermalized with a common transverse collective flow velocity.

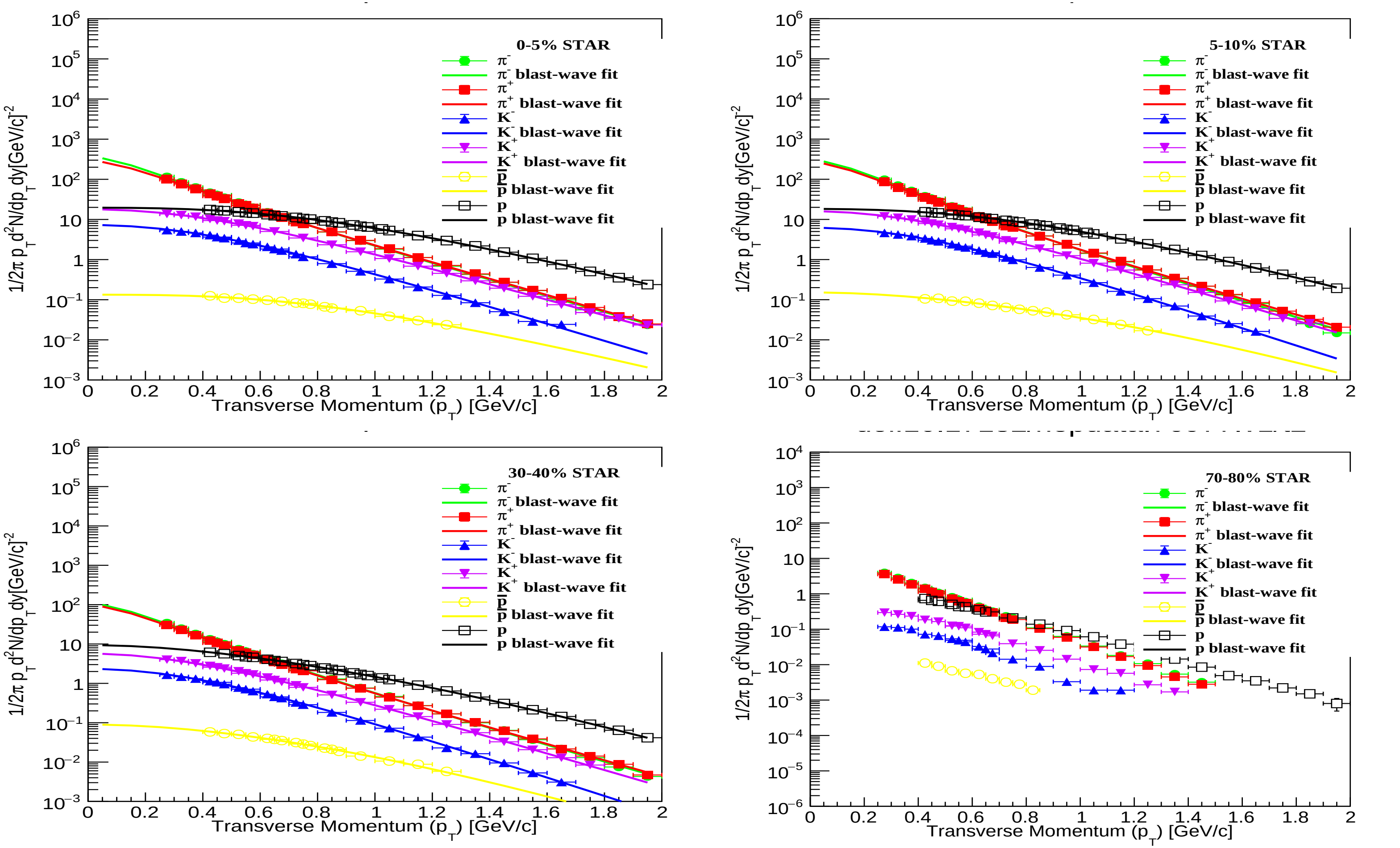
- The BW model is hydrodynamics-motivated but is not suited for describing hard processes at high pT ranges.

- We can use the BW model to extract the kinetic freeze-out paramters.

RESULTS

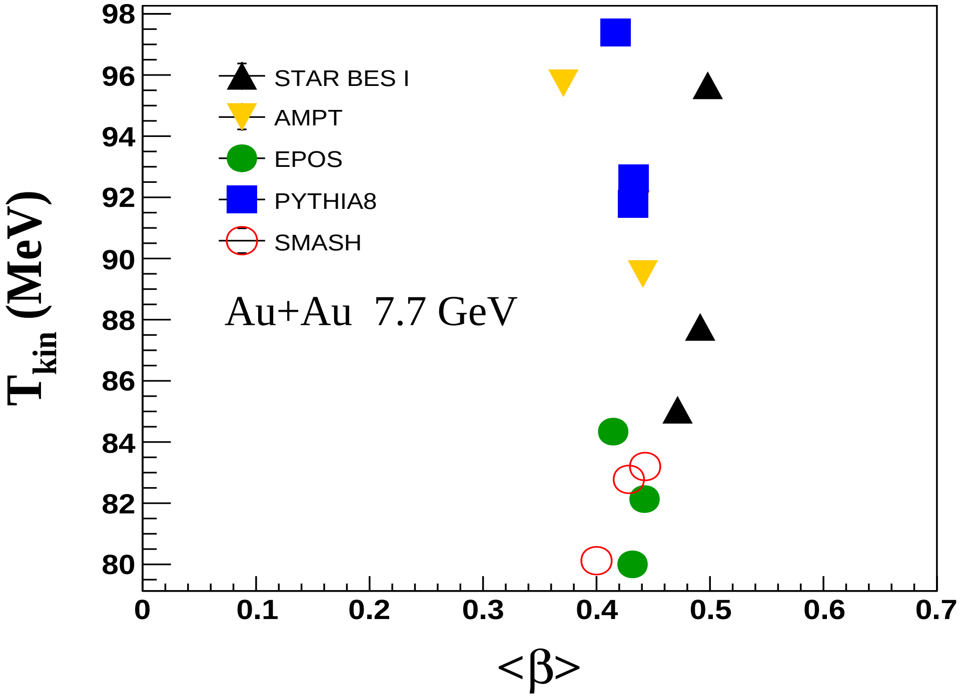
→ Blast-Wave Function Fitting

- Experimental Data Fitting



→ Blast-Wave Function Fitting
- T_{kin} vs <β>

For central to intermediate collisions



- We are considering the fitting parameters for 0-5%, 5-10% and 30-40% centrality classes.
- The average radial flow velocity is around 0.3-0.5 in general.
- Decrease in the temperature from intermediate to central collisions.

SUMMARY AND CONCLUSIONS

- We have presented the transverse momentum and particle ratio, in dependence of collision centrality, obtained from transport (AMPT and SMASH), hadronic (PYTHIA8) and hydrodynamical (EPOS4) models.
  - All models poorly describe the overall pT spectra for the particles considered.
  - Increase of <pT> with increasing hadron mass.
  - PYTHIA and EPOS4 show fair results with the π^-/π^+ and K^-/K^+ ratios, respectively.
  - EPOS4 and AMPT present an enhanced K^+/π^+ ratio that could indicate strangeness production mechanisms related to medium-effects.
- We computed the Boltzman-Gibbs Blast Wave function and estimate the kinetic freeze-out parameters for STAR BESI data and the system predicted by the considered models.
  - The BGBW satisfactory describes the experimental data for central-intermediate collisions.

Thank you

for

your attention

REFERENCE

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