Modification of hadron multiplicity ratios at the chiral phase transition

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Overview

Motivation

Investigation of the impact of a first-order chiral phase transition and critical point on hadron multiplicity ratios

Model description

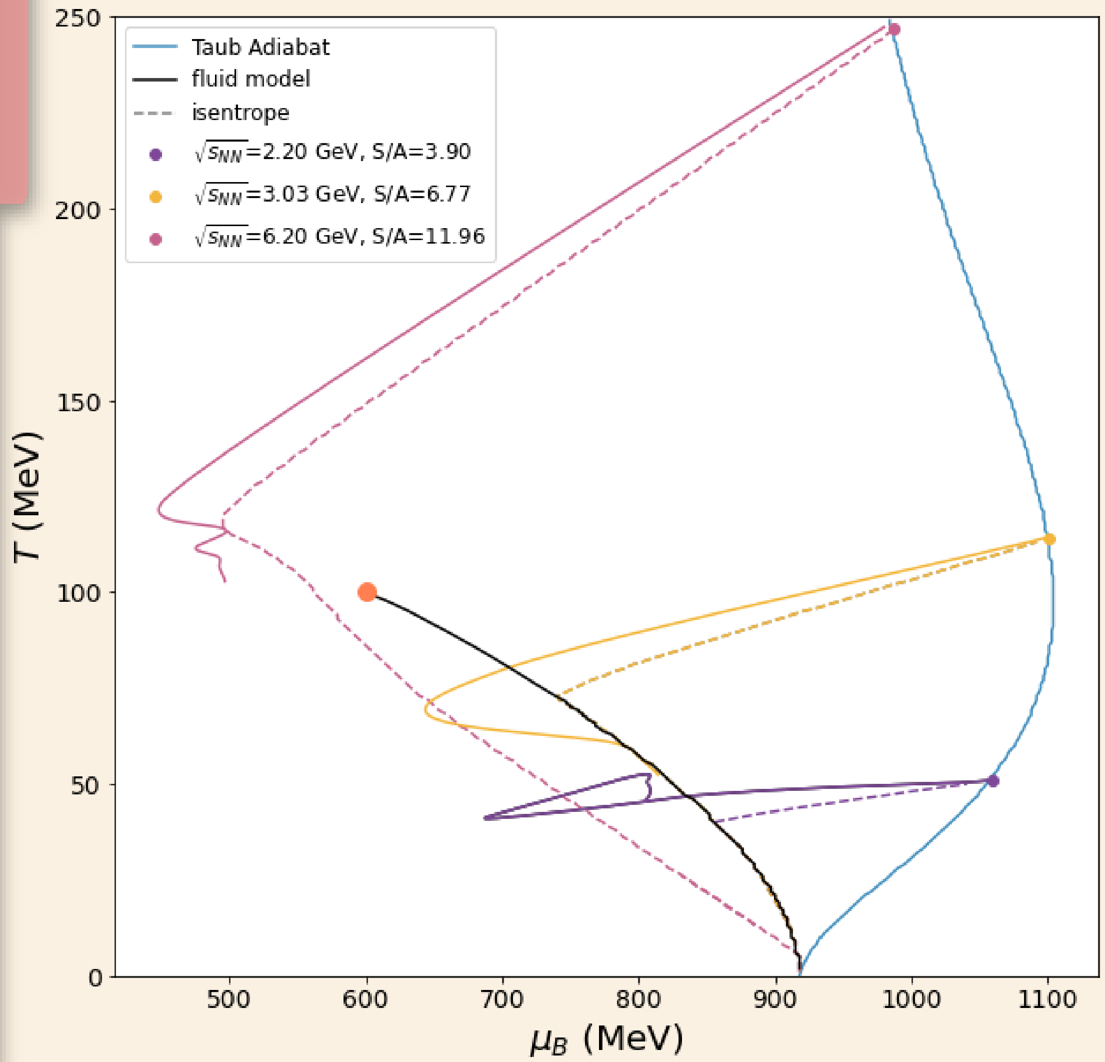
- Dynamical expansion of the hot and dense matter with a Bjorken hydrodynamics expansion coupled to the explicit evolution of the chiral order parameter (σ) at center-of-mass energies from 2 to 7 GeV

- The chiral dynamics is implemented using a Langevin equation including dissipation and noise (Christoph Herold et, al, 2018)

$$\mathcal{L} = \bar{q}\left(i\gamma^{\mu}\partial_{\mu} - g\sigma\right)q + \frac{1}{2}(\partial_{\mu}\sigma)^2 - U(\sigma)$$

$$\ddot{\sigma} + \left(\frac{D}{\tau} + \eta\right)\dot{\sigma} + \frac{\delta\Omega}{\delta\sigma} = \xi$$

Simulation



Initial conditions from Taub Adiabat equation

$$(P_0 + \varepsilon_0)(P + \varepsilon_0)n^2 = (P_0 + \varepsilon)(P + \varepsilon)n_0^2$$

P: Pressure (quark pressure and pion pressure)
ε: Energy density
n: Baryon density

Isentropes

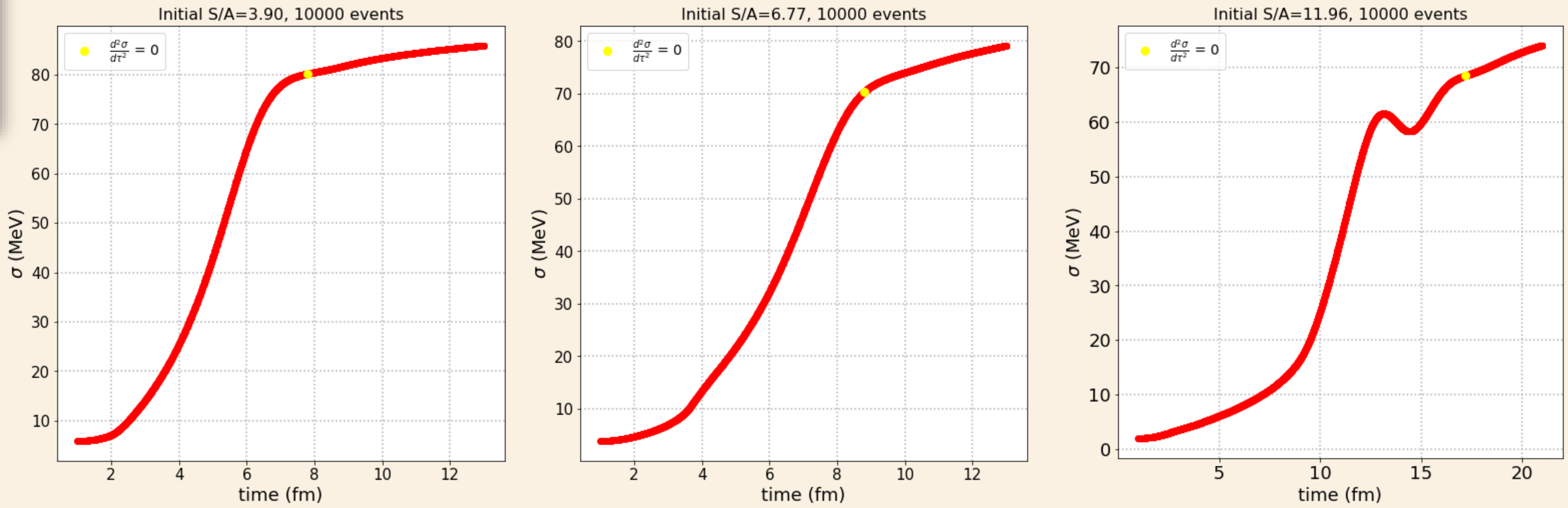
(μ_B, T) under constant entropy per baryon (S/A)

Bjorken hydrodynamics simulation

- Input: initial temperature and chemical potential of given S/A
- Duration: from τ=0 fm/c to τ=13 fm/c
- Output: proper time (τ), μ_B, T, S/A, n, σ

Chiral order parameter evolution

σ evolutions from simulation

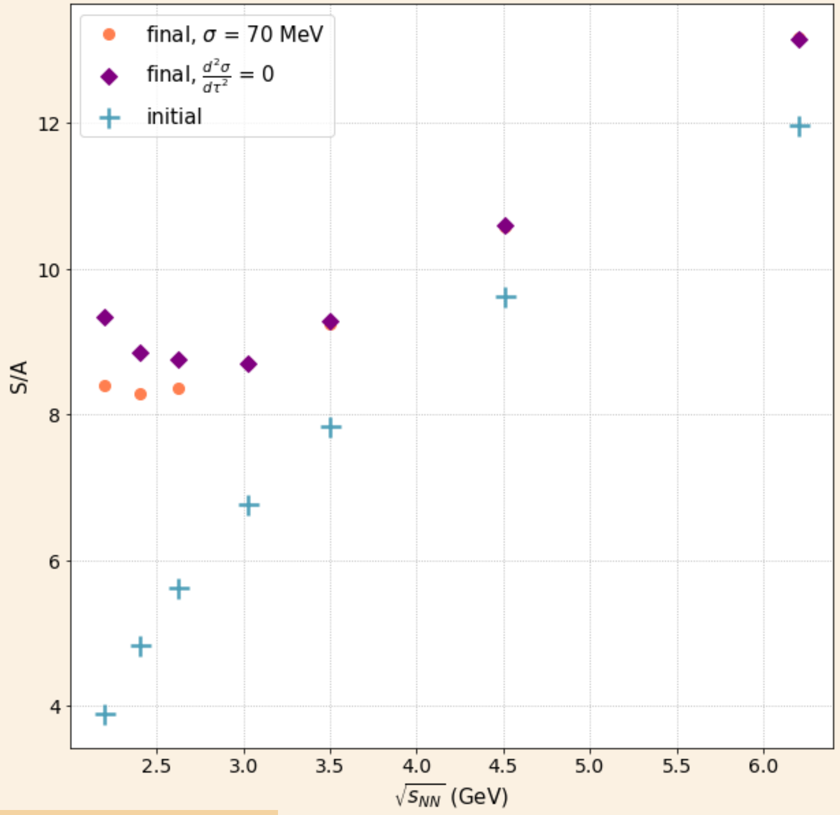


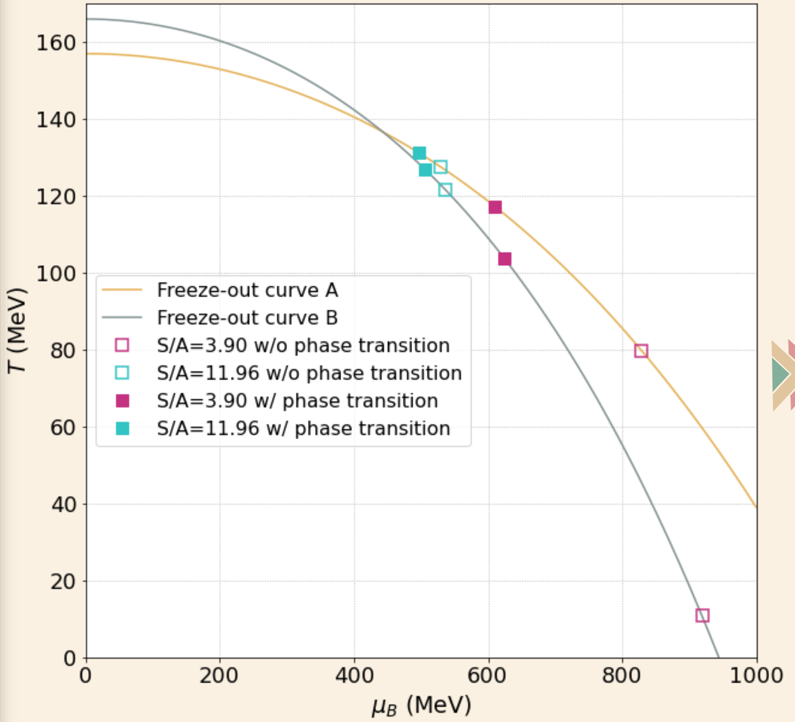
Freeze-out S/A selection criteria

- The first point with $\frac{d^2\sigma}{d\tau^2} = 0$ after the time has passed 7 fm/c
- The point when σ reaches 70 MeV

S/A mapping

- Map each initial and final S/A to center-of-mass energies of given S/A
- Each final S/A is selected via freeze-out selection criteria
- Enhancement of S/A at lowest $\sqrt{s_{NN}}$



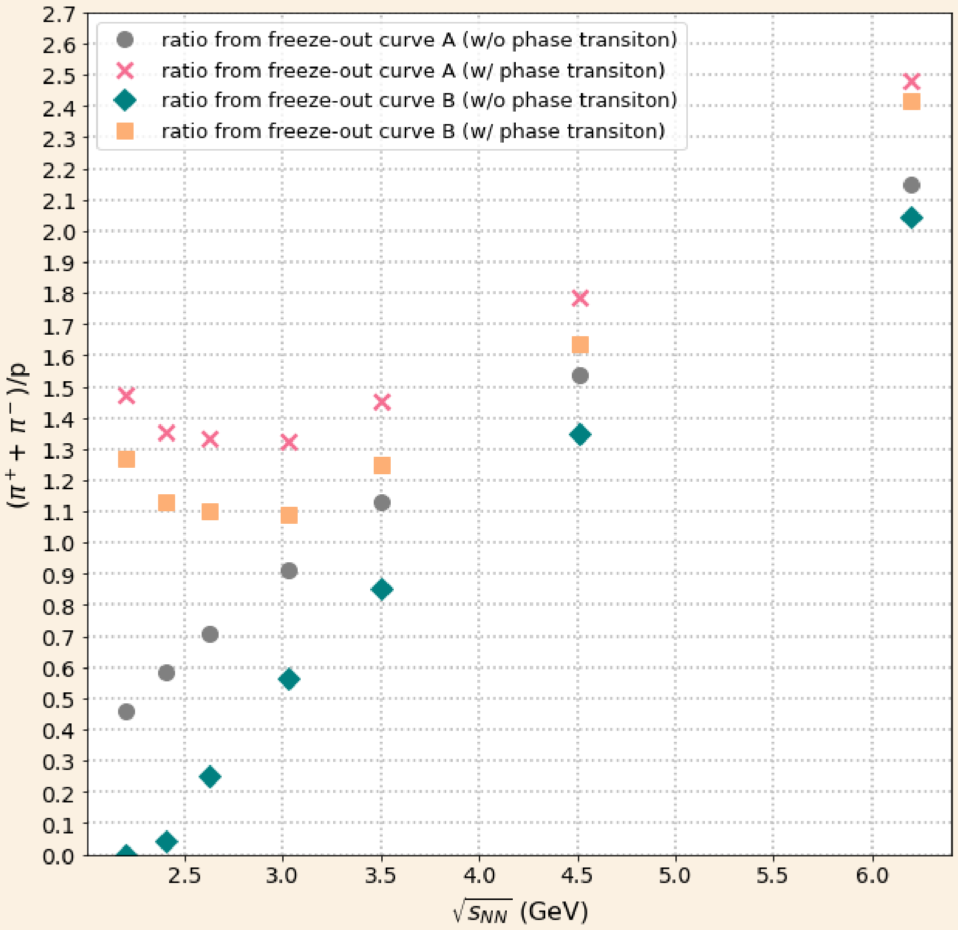


- Define two freeze-out curves

- A: $T(\mu_B) = 166\ MeV - 1.39x10^{-4}\ MeV^{-1}\mu_B{}^2 - 5.3x10^{-11}\ MeV^{-3}\mu_B^4$ (J. Cleymans at al, 2005)
- B: $T(\mu_B) = 157\ MeV - 1.00x10^{-4}\ MeV^{-1}\mu_B{}^2 - 1.8x10^{-11} MeV^{-3}\mu_B^4$ (V. Vovchenko, 2016)

Hadron multiplicity ratios

Receive total particle yield of π^+, π^- and p of given initial and final S/A for each freeze-out curve from Thermal-FIST[1] and calculate the ratio of $(\pi^+ + \pi^-)/p$



Conclusion

- After mapping the initial and final S/A to a hadron resonance gas, we are able to quantify the shift of hadron multiplicity ratios for each freeze-out curves.
- Phase transition can be identified by hadron multiplicity shift.

1. V. Vovchenko, H. Stoecker, *Thermal-FIST: A package for heavy-ion collisions and hadronic equation of state*, Comput. Phys. Commun. **244**, 295 (2019), arXiv:1901.05249 [nucl-th]