#CP3

Dynamical initialization at RHIC-BES energies

Ruri Otsuka (Sophia Univ.), Tetsufumi Hirano (Sophia Univ.)

r-otsuka-ep8@eagle.sophia.ac.jp

Abstract

We describe space-time evolution of hadronic/quark matter produced in heavy ion collisions at RHIC-BES energies from the dynamical initialization model. Solving hydrodynamic equations with source terms in one-dimensionally expanding coordinates, we investigate collision energy, rapidity and centrality dependences of dynamical initialization processes and how the system draws the trajectory in $T-\mu_\mathrm{B}$ plane within the model of the equation of state with the first order phase transition.

1. Introduction

- **Purpose of heavy ion collisions at RHIC-BES energies**

Search for the QCD critical point and the first order phase transition

RHIC top energies: No phase transition, crossover between hadronic and quark matter

RHIC–BES energies: Critical point and first order phase transition between the QGP phase and the hadron phase (?)

- **Importance of dynamical description in heavy ion collisions**

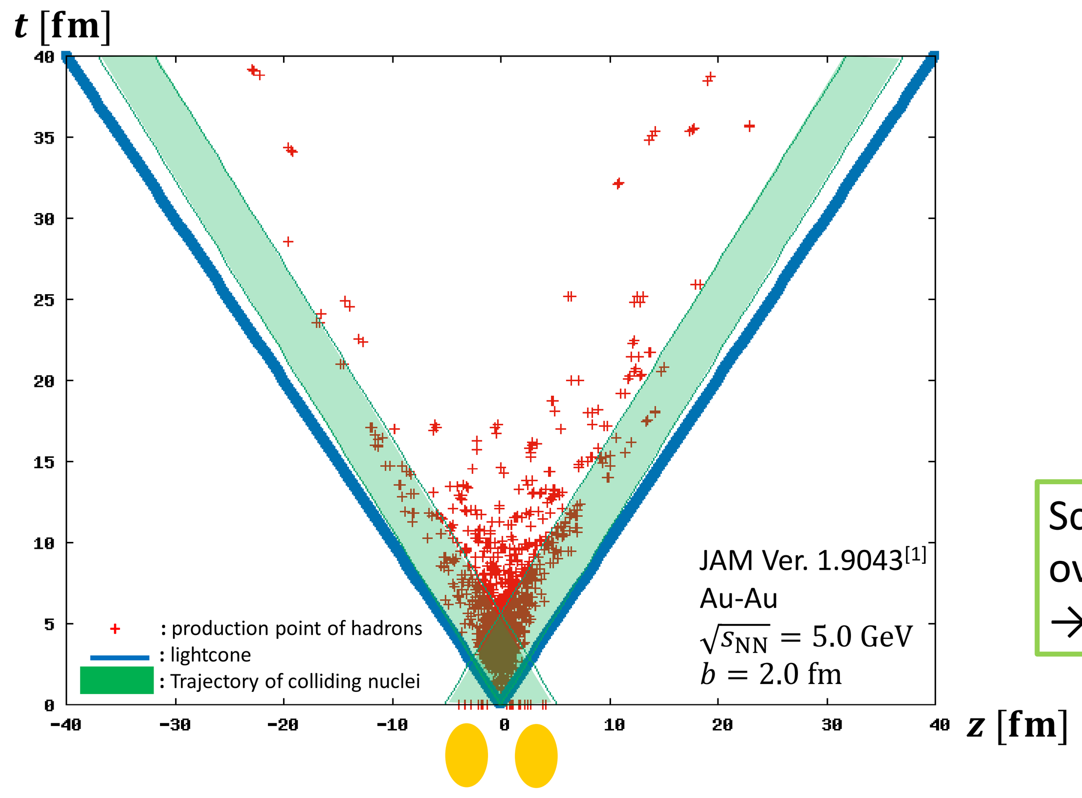
RHIC top energies: Hydrodynamics is successful in description of the QGP fluid evolution

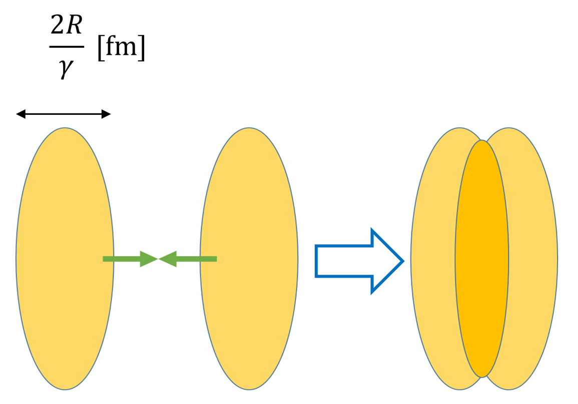
RHIC BES energies: Directly utilize the model at RHIC top energies?

- **Finite overlap time**

RHIC-BES energies: Insufficient Lorentz contraction

→How to initialize the fluids during overlapping of two colliding nuclei?





Scattered production points in the overlapping region
→No τ = const. or t = const.

[1] Y. Nara *et al.*, Phys. Rev. C61, 024901 (2000).

- **Dynamical initialization model[2]**

[2] M. Okai *et al.*, Phys. Rev. C95, 054914 (2017).

Initialize hydrodynamic fields using hydrodynamic equations with source terms

・No need to initialize hydrodynamic fields at constant initial time

・Model source terms putting produced hadrons into fluids

・Generate fluids even during overlapping of two colliding nuclei

- **Purpose of this study**

Dynamics of systems produced in heavy ion collisions at RHIC-BES energies from the dynamical initialization model

2. Model

Relativistic hydrodynamical model including dynamical initialization

1. Initial particle production

Event generator, JAM Ver. 1.9043 [1]

[Setting]

Au-Au, $\sqrt{s_\mathrm{NN}}$ = 5.0 GeV, 10.0 GeV, 20.0 GeV

Baryon-Baryon (on), Baryon-Meson (off), Meson-Meson (off)

2. Dynamical initialization and fluid evolution

- **Relativistic hydrodynamics with source terms**

Continuity equation of {energy and momentum, baryon number} with source terms

Assuming one dimensional expansion and no viscosity for simplicity

$$\begin{cases} \partial_\mu T^{\mu\nu} = J^\nu \\ \partial_\mu N^\mu_\mathrm{B} = \rho \end{cases} \quad (\mu,\nu = t,z)$$

$$\begin{cases} T^{\mu\nu} = \varepsilon u^\mu u^\nu - p\Delta^{\mu\nu} \\ N^\mu_\mathrm{B} = n_\mathrm{B} u^\mu \end{cases} \quad (\mu,\nu = t,z)$$

Energy density ε
Fluid flow velocity u^μ
Isotropic pressure p
Baryon density n_B
$\Delta^{\mu\nu} \equiv g^{\mu\nu} - u^\mu u^\nu$

In actual simulations, hydrodynamic equations are solved in Milne coordinates

Initial proper time: $\tau_0 = 0.1$ fm

- **Equation of state[1][3]**

[3] J. Sollfrank *et al.*, Phys. Rev. C55, 392(1997).

$$p = p(\varepsilon, n_\mathrm{B})$$

The first order phase transition model

QGP phase: Bag model
bag constant: $B^{1/4} = 235$ MeV, effective number of flavor: $N_\mathrm{f} = 2.5$, massless quarks

Hadron phase: Hadron resonance gas with mean fields
mean field repulsion: $K = 450\ \mathrm{fm}^3$ MeV

- **Modeling of the source term in Milne coordinates**

$$\begin{cases} J^\mu_i d\tau = \dfrac{A^\mu_i}{\Delta S} \dfrac{1}{\sqrt{2\pi\sigma_\eta^2}} e^{-\frac{(\eta-\eta_i(\tau_i))^2}{2\sigma_\eta^2}} \\ \rho_i d\tau = \dfrac{B_i}{\Delta S} \dfrac{1}{\sqrt{2\pi\sigma_\eta^2}} e^{-\frac{(\eta-\eta_i(\tau_i))^2}{2\sigma_\eta^2}} \end{cases} \quad (\mu = \tau,\eta)$$

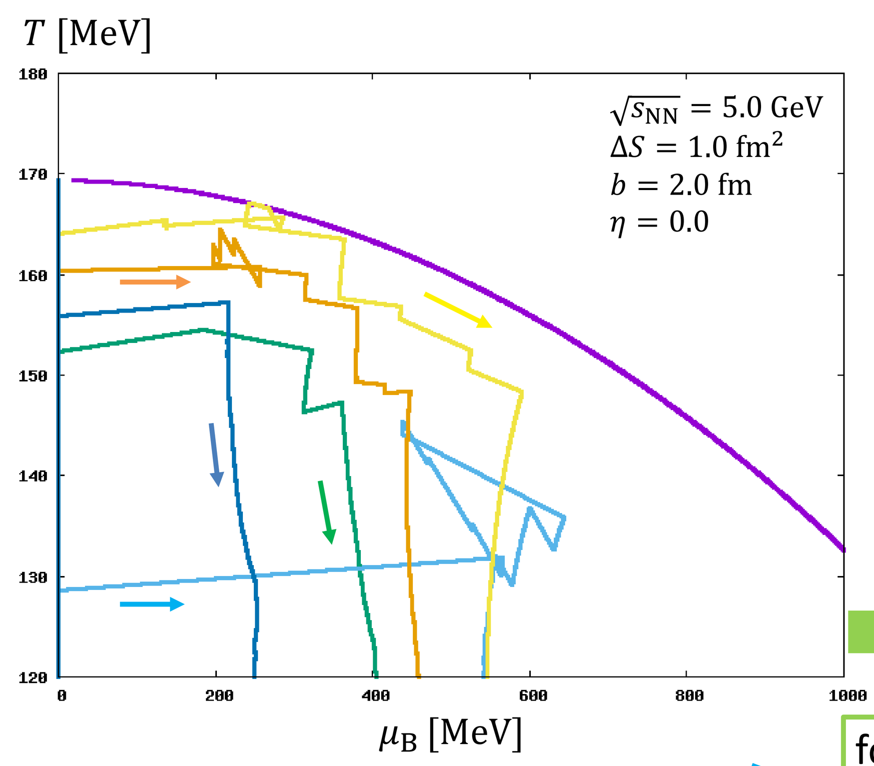
Smearing Area $\Delta S = 1.0\ \mathrm{fm}^2$
Gaussian width $\sigma_\eta = 0.5$
Rapidity of a particle η_i
Energy of a particle E_i
Momentum of a particle p_i
Baryon number of a particle B_i

$$\begin{cases} A^\tau_i = E_i \cosh\eta - p_i \sinh\eta \\ A^\eta_i = -E_i \sinh\eta + p_i \cosh\eta \end{cases}$$

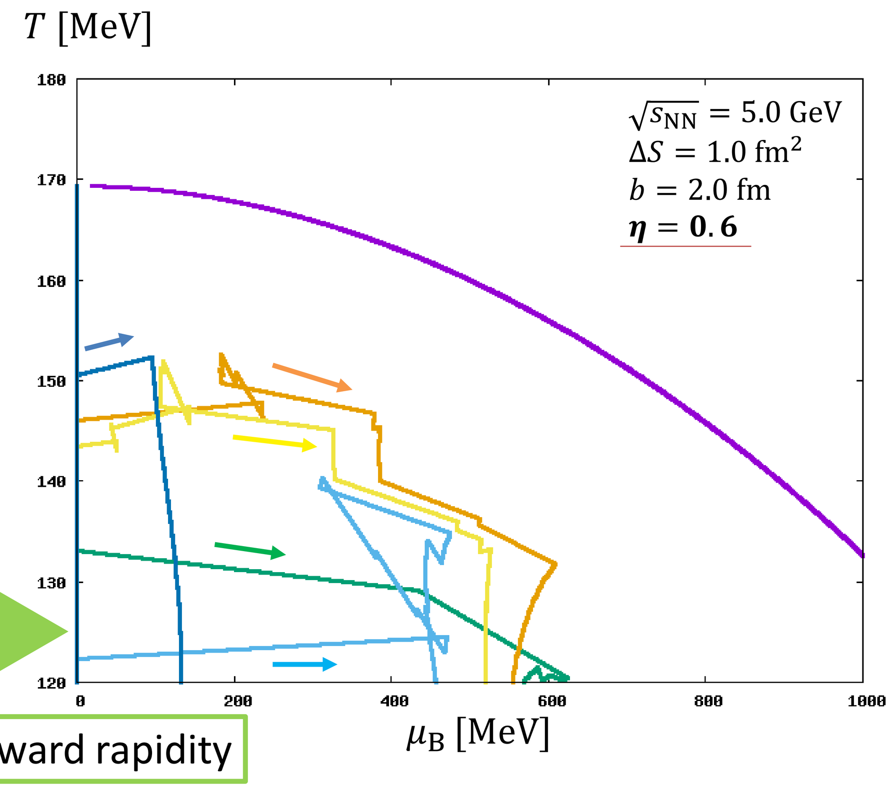
3. Result

Trajectories of 5 sample events in $T-\mu_\mathrm{B}$ planes

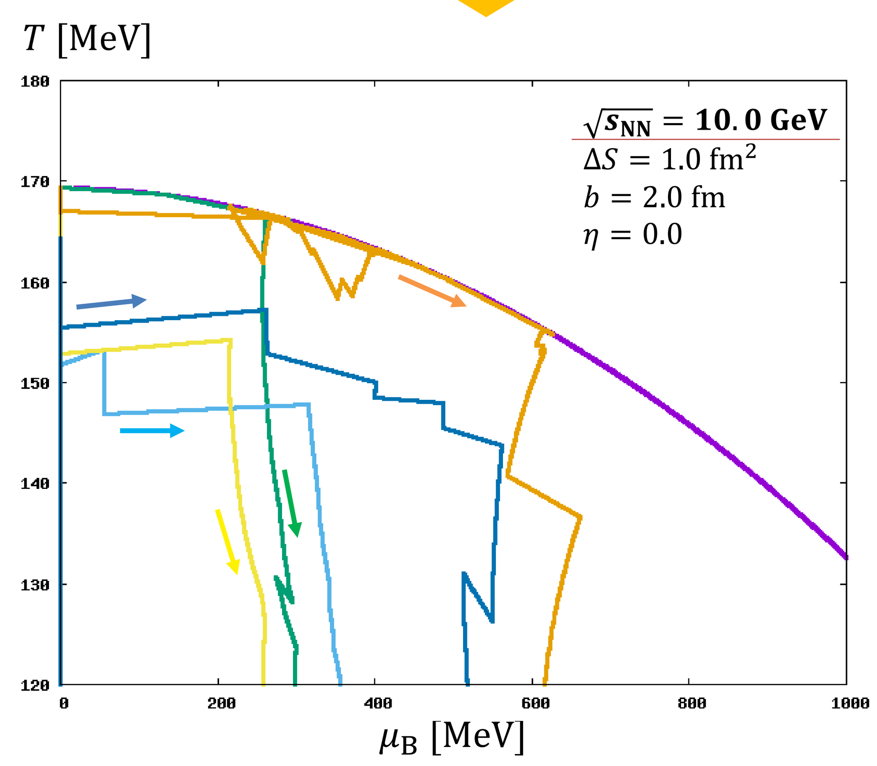
Vertical axis: T [MeV], Horizontal axis: μ_B [MeV], —— : phase boundary



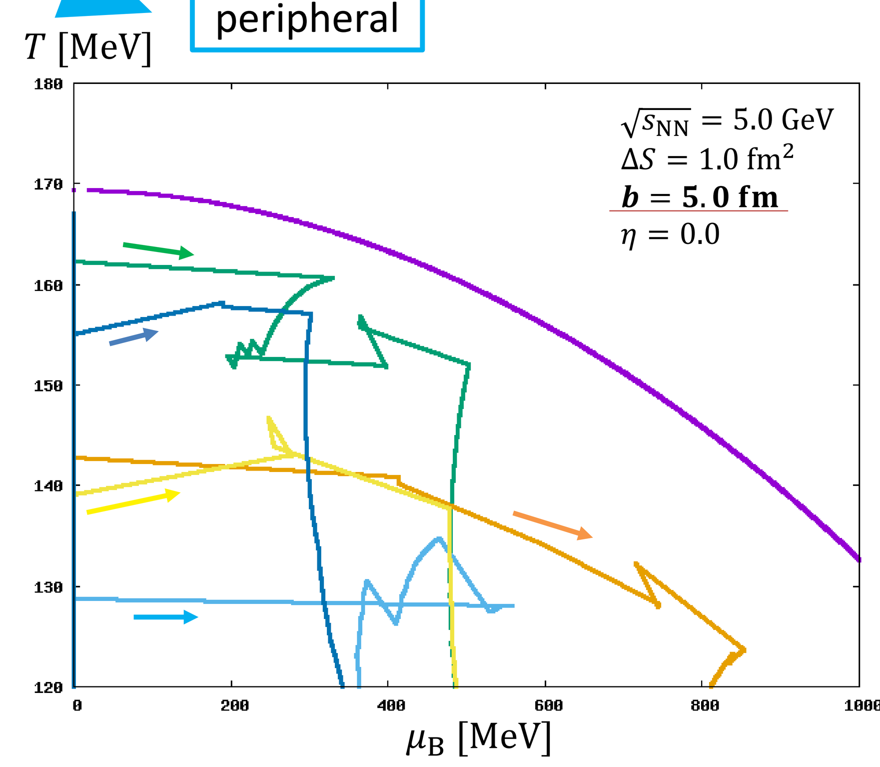
forward rapidity



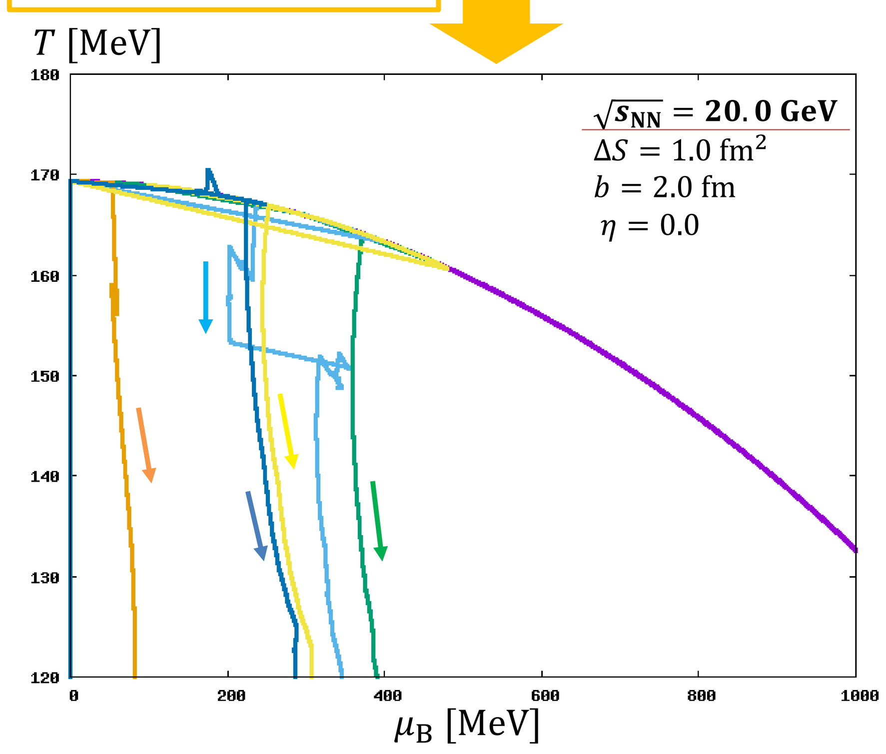
Larger colliding energy



peripheral



Larger colliding energy



・The system heats up due to meson production first.

・Once baryons no longer interact with other hadrons, they are absorbed by a fluid so that it gets denser later.

・After no more initial hadrons, the fluid cools down along the adiabatic path.

・The system tends to reach phase boundary as increasing collision energies.

4. Summary and Outlook

・We investigated dynamics of the system produced in heavy ion collisions at RHIC-BES energies from the dynamical initialization framework.

・How the system evolves in $T-\mu_\mathrm{B}$ plane is studied by drawing a trajectory on an event-by-event basis.

・We plan to use a model of the equation of state with a QCD critical point and the first order phase transition between the QGP phase and the hadron phase.