Exploring the high baryon-density regime of the QCD phase diagram within a dynamically initialized hybrid model

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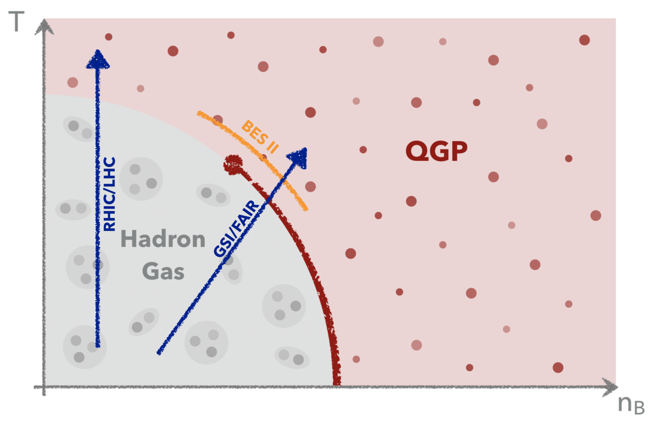
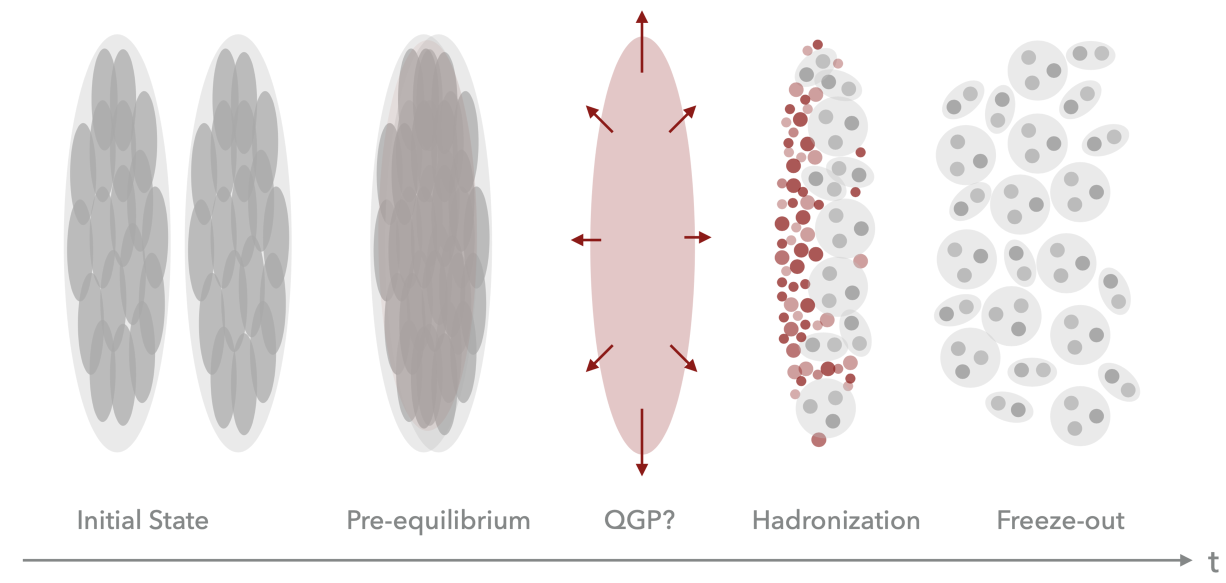
Motivation

- QCD phase diagram studied in heavy-ion collisions
- Collisions at FAIR/NICA energies give access to high baryon density regime
  - → 1st order phase transition
  - → Possible critical end point?



- Hybrid approach to simulate heavy-ion collisions at FAIR/NICA energies



Model Description

Initial Conditions: SMASH

- Transport approach with hadronic degrees of freedom [1, 2]
- Initial conditions extracted on hypersurface of constant proper time
- Dynamical initialization [5] (work in progress): $\partial_\mu T^{\mu\nu} = j^\nu \quad \partial_\mu N^\mu = \rho$

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Hydrodynamic Evolution: vHLLE

- 3+1D viscous hydrodynamics code [3]: $\partial_\mu T^{\mu\nu} = 0 \quad \partial_\mu N^\mu = 0$
  with $T^{\mu\nu} = \varepsilon\, u^\mu u^\nu - (p + \Pi)\Delta^{\mu\nu} + \pi^{\mu\nu}$ and $N^\mu = n\, u^\mu$
- Particle lists are transformed into fluid elements applying Gaussian smearing
- Particlization hypersurface at constant energy density

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Particlization: Cooper-Frye Sampler

- Transform thermodynamic quantities into particles [4]
- Energy and momentum distributed according to Cooper-Frye Formula

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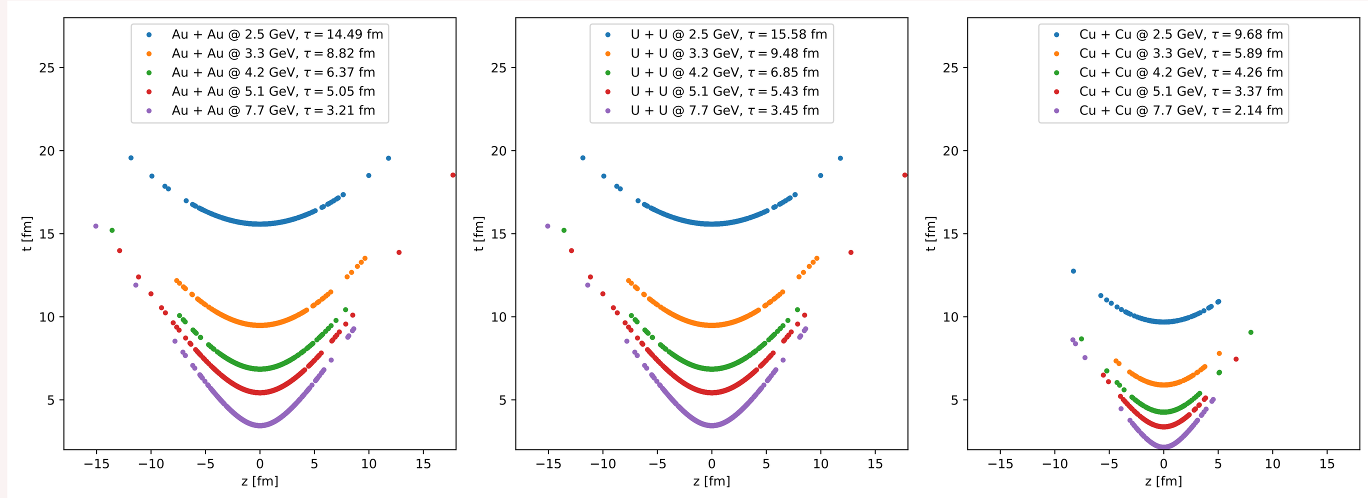
Hadronic Afterburner: SMASH

- Propagate particles and perform interactions until medium is too dilute:
- Perform final resonance decays
- Effective solution of rel. Boltzmann Eq.: $p^\mu \partial_\mu f + m\partial_{p_\mu}(F^\mu f) = C(F)$

Results

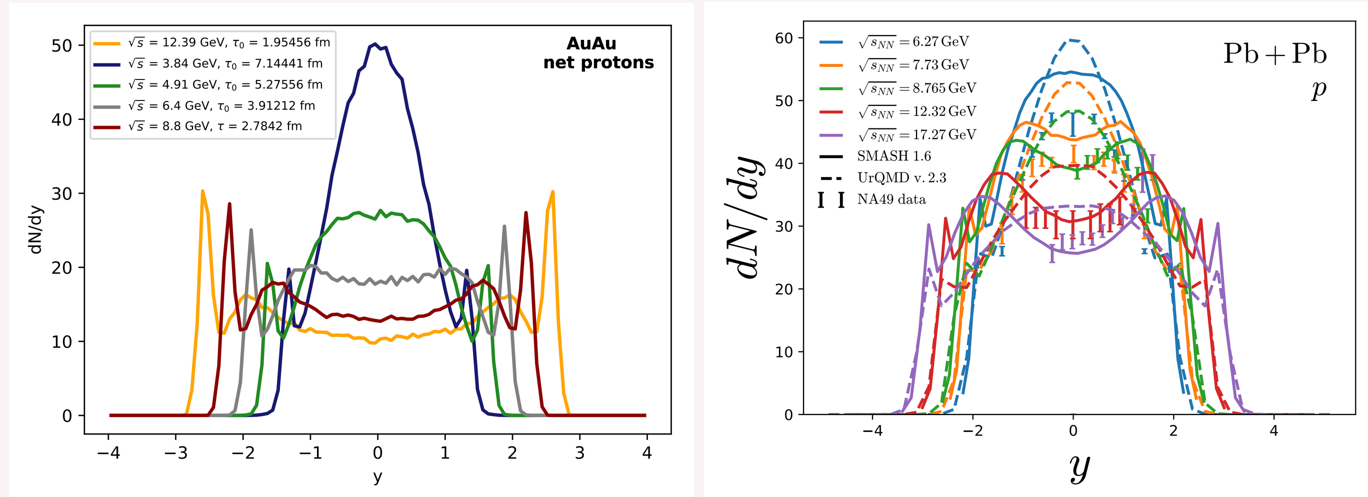
Iso-τ Hypersurface

- Nuclei passing time:
  $\tau_0 = 2\,R/\sqrt{\left(\sqrt{s_{NN}}/2m_N\right)^2 - 1}$
- Propagate particles until hypersurface is crossed
- Remove particles from evolution
- Evolve SMASH until all particles were removed



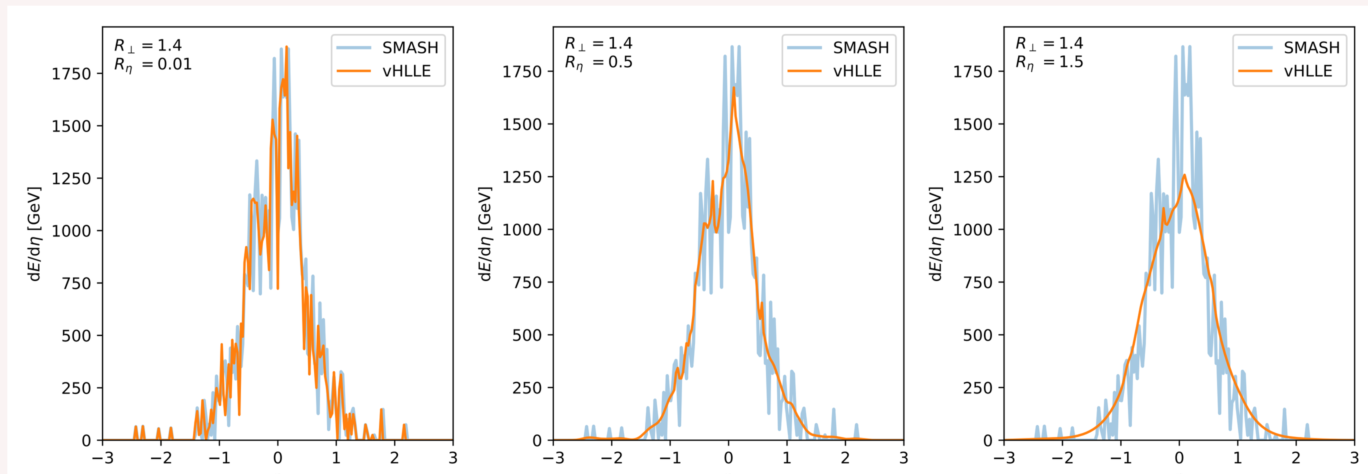
Initial Particle Spectra

- Left: Net-proton spectra for AuAu collisions on the τ_0-hypersurface (not smeared)
- Right: Final state net-proton spectra for PbPb collisions obtained by running SMASH only, as compared to UrQMD results and NA61 data, taken from: arXiv: 1909.05586



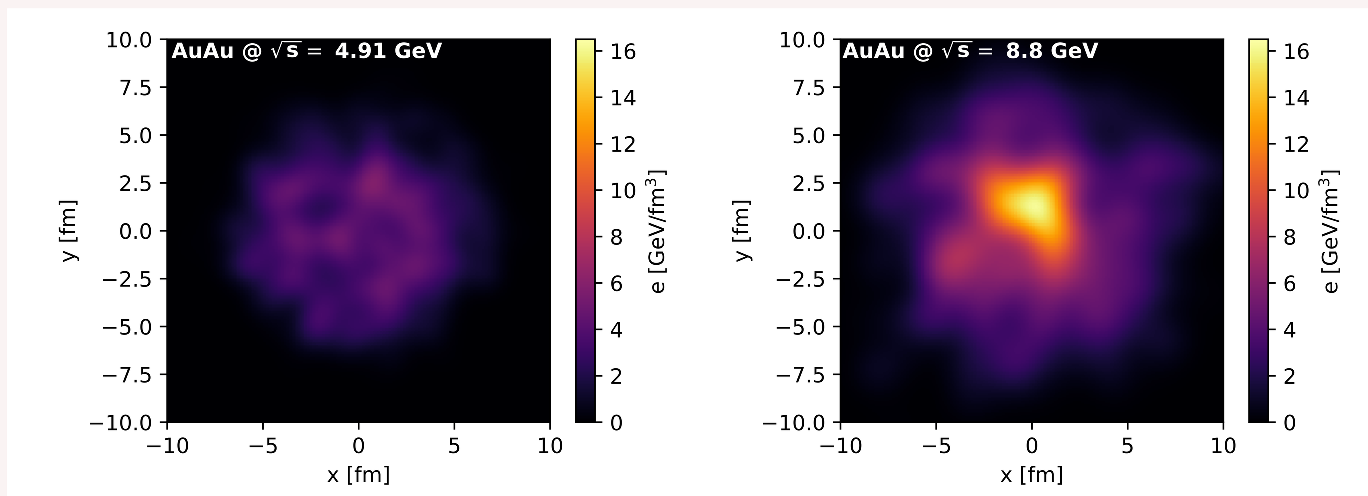
Initial Energy Spectra

- Initial longitudinal energy distribution at $\tau = \tau_0$ for different smearing parameters to distribute energy and momentum
- Spectators excluded
- Conservation of energy and baryon number at SMASH → vHLLE interface



Initial Energy Density

- Central AuAu collision
- Single event energy density in transverse plane $\eta = 0$
- Proper Time: $\tau = \tau_0$



Outlook

- Determine final state bulk observables for varying collision systems and energies
- Systematically study the effect of applying different equations of state
- Search for signatures of a QGP formation in different collision systems
- Study effect on electromagnetic probes

References

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