Heavy-Ion Collision Theoretical Modeling

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Overview:

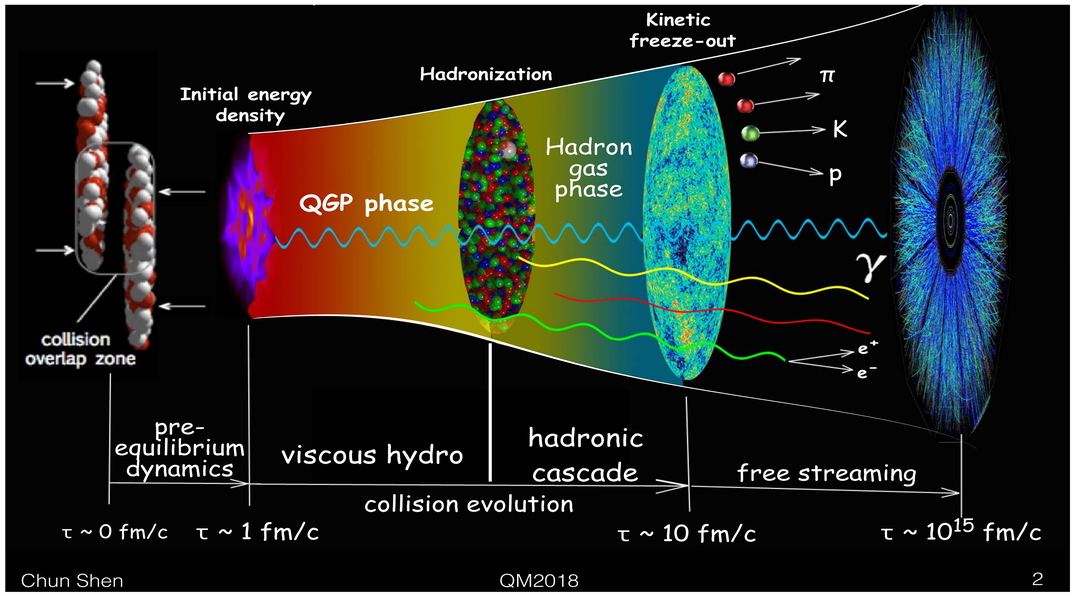
- In high-energy nuclear collisions, an exotic liquid state of matter called Quark-Gluon Plasma (QGP) is created
- The QGP fireball is extreme
  - Temperature = 1.8 – 6.9 trillion K
  - Volume = 10 – 1000 fm^3
  - Lifetime = 1 - 3 x 10^{-23} s
- We use computational simulations to model the multi-stage dynamics of heavy-ion collisions

Tools:

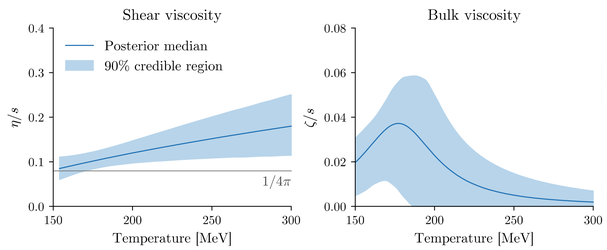
- Relativistic viscous hydrodynamics
- Computational fluid dynamics
- Kinetic theory + Boltzmann equation
- Monte Carlo simulations
- Heterogeneous computing (C++, CUDA, Python)

Goals:

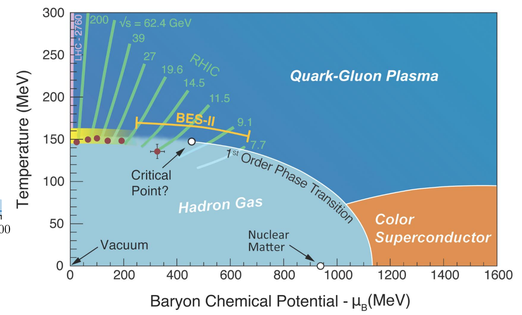
- Develop computational modules that can accurately describe the various stages of a heavy-ion collision
- Extract transport properties of the QGP from model-to-data analysis
- Understand why hydrodynamics is applicable for far-from-equilibrium systems



Overview of the timeline of a heavy-ion collision. 1 fm/c ~ 10^{-24} s! We work on pre-equilibrium, hydrodynamic, and hadronization models. A complete description requires a combination of several physical pictures, including the evolution of classical gluon fields, weakly and strongly interacting partonic dynamics, hadronic interactions and more…



Best extraction of QGP transport properties to date. QGP has the smallest specific shear viscosity of any measured fluid! (https://arxiv.org/abs/1804.06469v1)



A prediction of the QCD phase diagram. The Beam Energy Scan (B.E.S.) will search for existence of a critical point.

Collaborations:

JETSCAPE

- Jet-medium interactions
- Bayesian analysis of soft-medium dynamics
- Development of full C++ hybrid simulation model for heavy-ion collisions

BEST

- QCD with critical phenomena
- Low-energy collisions with net-baryon density
- Search for critical point in QCD phase diagram

What we currently work on:

- Viscous anisotropic hydrodynamics
- Modified equilibrium distribution
- Sampling hadronization phase with various viscous corrections
- Pre-equilibrium models and hydrodynamization
- Evolution near the QCD critical point
- Bayesian model-data calibration of QGP transport properties
- Energy and baryon dynamical sources for low-energy collisions
- Hydrodynamic attractors