Effects of the equation of state on hadron spectra and elliptic flow

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Introduction

Objective

Test the sensitivity of physical observables to different EoS with NexSPheRIO in Au+Au collisions at RHIC energies.

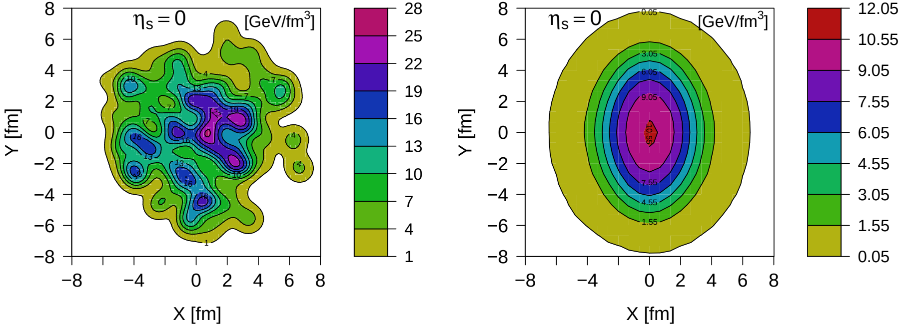
Tools:

- Hydrodynamic model without viscosity (SPheRIO).
  - Initial conditions (IC): NEXUS [Phys.Rev.C 65, 054902, (2002)].
  - Hydrodynamic evolution: SPheRIO [Braz.J.Phys. 35, 24, (2005)].
  - Equation of State (EoS) $\rightarrow$ important role for investigating the hydrodynamical evolution $\rightarrow$ affects particle spectra, collective flow and other experimental observables.
  - Decoupling criteria: Cooper-Frye [Phys.Rev.D 10, 196, (1974)].

Hydrodynamic Model

Initial Conditions - energy density profile

IC: generated by NEXUS $\rightarrow$ two different approaches:



- Random fluctuating events (left).
- Smoothed IC by averaging over a big number of events (right).

Smoothed Particle Hydrodynamics

- Parametrize the matter flow in terms of discrete Lagrangian coordinates (namely, SPH particles).
- Entropy and baryon number $\rightarrow$ assigned to the SPH particles as a conserved quantity.
- EoM $\rightarrow$ derived by variational principle in terms of SPH particle degrees of freedom.

Hydrodynamic Model
Equation of State

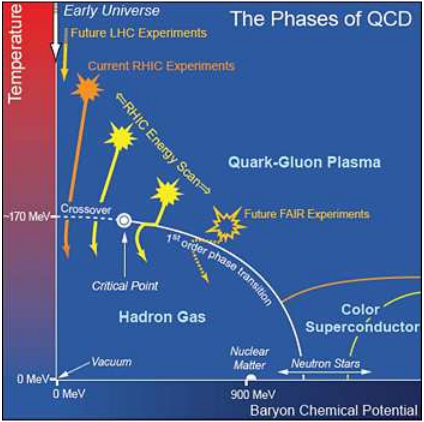


Fig. from bnl.gov

- First order phase transition → ideal gas (QGP) and resonance gas model with strangeness (H).
- Lattice QCD (strongly interacting QGP) → smooth transition:
  - Lattice fit (Pasi) [arXiv:0912.2541].
  - Lattice inspired EoS (with phenomenological critical end point) [arxiv:hep-ph/0510096].

Particle Spectra and Elliptic Flow

Particle Spectra

Transverse momentum distribution of charged hadron measured in certain η or y range.

$$E\frac{d^3N}{d^3p} = \frac{1}{2\pi p_T}\frac{d^2N}{dydp_T} = \frac{1}{2\pi p_T}\sqrt{\frac{p_T^2\cosh\eta^2}{p_T^2\cosh\eta^2 + m^2}}\frac{d^2N}{d\eta dp_T}$$

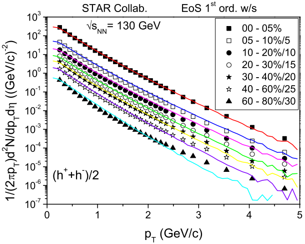
Elliptic Flow

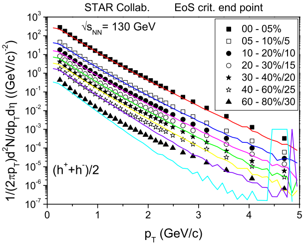
Elliptic flow $\rightarrow$ second Fourier coefficient of the azimuthal distribution:

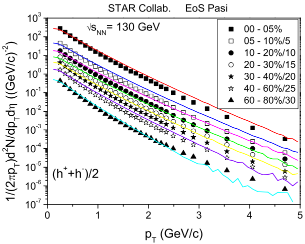
$$\begin{aligned} E\frac{d^3N}{d^3p} &= \frac{1}{2\pi p_T}\frac{d^2N}{dydp_T}[1 + 2v_1\cos(\phi - \psi_1) + 2v_2\cos[2(\phi - \psi_2)] + ...] \\ v_n &= \langle\cos[n(\phi - \psi_n)]\rangle \quad n = 1, 2, 3, ... \end{aligned}$$

Results: Particle Spectra $\sqrt{s_{NN}} = 130$ GeV

$-0.5 < \eta < 1$



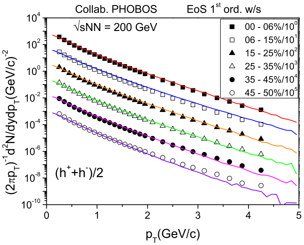


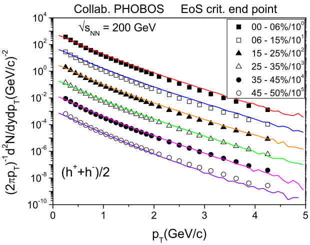


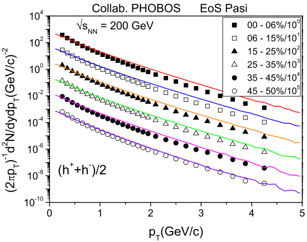
Exp. data from C. Adler et al. Phys.Rev.Lett. 89, 202301 (2002).

Results: Particle Spectra $\sqrt{s_{NN}} = 200$ GeV

$0.2 < y < 1.4$



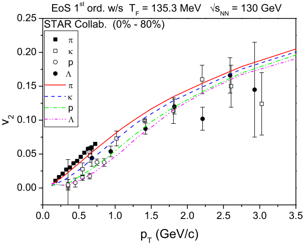


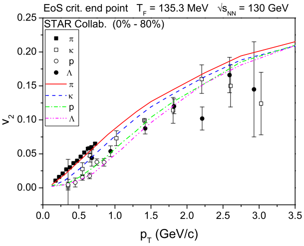


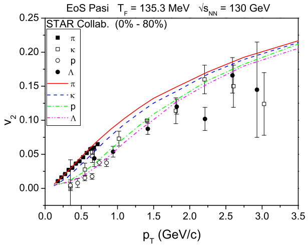
Exp. data from B.B. Back et al. Phys.Rev.B 578, 297 (2004).

Results: Elliptic Flow - $\sqrt{s_{NN}} = 130$ GeV

Elliptic flow - π, K, p, Λ.



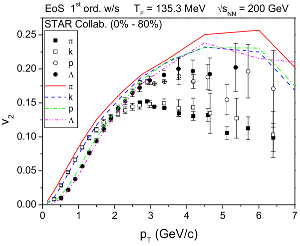


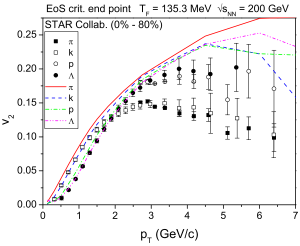


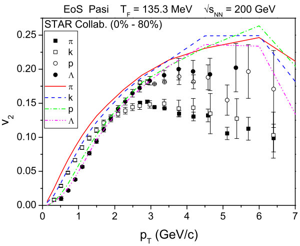
Exp. data from C. Adler et al. Phys.Rev.Lett. 87, 182301 (2001) and C. Adler et al. Phys.Rev.Lett. 89, 132301 (2002).

Results: Elliptic Flow - $\sqrt{s_{NN}} = 200$ GeV

Elliptic flow - π, K, p, Λ.



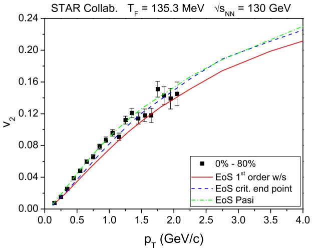


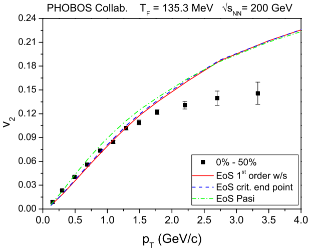


STAR data: B.I. Abelev et al. Phys.Rev.C 77, 054901, (2008).

Results: Elliptic Flow - all charged hadron

$\sqrt{s_{NN}} = 130$ GeV $\rightarrow |\eta| < 1.3$
$\sqrt{s_{NN}} = 200$ GeV $\rightarrow 0 < \eta < 1.5$





STAR data: K.H. Ackermann et al. Phys.Rev.Lett. 86, 402 (2001).

PHOBOS data: B.B. Back et al. Phys.Rev.C 72, 051901 (2005).

Conclusions

- Hadron spectra and elliptic flow $\rightarrow$ low sensitivity to the EoS: at least for small p_T, all the EoS describe the data reasonably well.

In the future:

- Investigate the effects of EoS on other physical observables, for example HBT.