Physics of Beam Energy Scan II

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June 2017, BNL
what can we learn from BES-II

QCD critical point & phase diagram

properties of baryon-rich QGP

onset of chiral symmetry restoration

unexpected new phenomena
onset of chiral symmetry restoration: key observables

— through correlations related to anomalous hydrodynamic effects in QGP
— non-vanishing signals for CME, CVE etc. imply presence of chiral quarks
unexpected new phenomena

RHIC can create the most vortical fluid

\[ \omega = (9 \pm 1) \times 10^{21} \text{ s}^{-1} \]

persisting magnetic field at late times?

global polarization of Lambda baryons

arXiv:1701.06657
QCD critical point: key observables

STAR Preliminary

R. Esha: QM 2017

Transverse $30^\circ<\Delta\phi<150^\circ$ and $210^\circ<\Delta\phi<330^\circ$

S. Jowzaee: QM 2017

STAR Preliminary

arXiv:1610.07423
cumulants of net-B fluctuations

BNL-Bi: preliminary

$R_{32}^B = S_B \sigma_B$

QCD

HRG

STAR: $0.4 < p_T < 0.8$

STAR prel.: $0.4 < p_T < 2.0$

$T = 145$ MeV

$T = 155$ MeV

$T = 165$ MeV

$R_{12}^B = M_B / \sigma_B^2$

cumulants of net-p fluctuations

$MP / \sigma_P^2, MB / \sigma_B^2 \leftrightarrow \mu_B / T$
$\sqrt{s} \gtrsim 27 \text{ GeV}$: cumulants of net-p fluctuations are consistent with equilibrium (L)QCD, no sign of criticality.
LQCD, location of critical point: $\mu_B/T \lesssim 2$ presently disfavored

- analyzing radius of convergence

\[ r_{2n}^x = \left| \frac{2n(2n-1)\chi_{2n}^B}{\chi_{2n+2}^B} \right|, \quad r_c = \lim_{n \to \infty} r_{2n}^x \]
signs of cumulants near the critical point are universal, only in equilibrium

Stephanov: arXiv:1104.1627

dynamics can lead to different signs, universality lost

off-equilibrium Kibble-Zurek scaling, universality regained

(editor’s suggestion)

Kurtosis

insensitive to the initial condition

$$\tilde{\tau} = \tau - \tau_c, \quad t = \tilde{\tau}/\tau_{KZ}$$
properties of baryon-rich QGP: key observables

N. Magdy: SQM 2016

arXiv:1701.07065

arXiv:1701.06496
global data analysis using Bayesian inference

dependence of shear viscosity baryon chemical potential

$\sqrt{s} = 19.6 \text{ GeV}$

Auvinen et. al.: arXiv:1706.03666
hydrodynamics-based modeling including baryon diffusion

constrains baryon diffusion constant

presently, many important physics are absent in theory framework
by 2020: a comprehensive theory framework

- initial conditions: 3-d, conserved & axial charges
- chiral anomaly & EM fields
- hydrodynamic evolution: (3+1)-d, viscous, conserved currents
- fluctuations: critical mode & hydrodynamic
- global analysis of expt data
- EoS: LQCD model critical EOS
- hadronic dynamics
- explore new phenomena
precise data from BES-II for an extended range
& a comprehensive theory framework

discover or put constraints on the existence of a critical point in the QCD phase diagram

shear and bulk viscosities, baryon diffusion constant, EoS etc. of baryon-rich QGP with changing baryon doping

chiral symmetry restoration by observing correlations related to anomalous hydrodynamic effects

possible unexpected new physics