

LOCATING THE QCD CRITICAL POINT USING HOLOGRAPHIC BLACK HOLES

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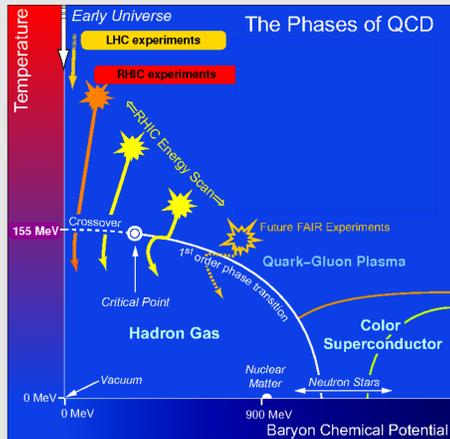
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Motivation

Study the transition between hadrons and the QGP in search of the QCD Critical Point using a Black Hole Engineered Holographic approach.



- **Heavy Ion Collisions:** Explore the phase diagram by changing \sqrt{s} of colliding ion beams
- **Lattice QCD:** Perform calculations at $\mu_B=0$, and extrapolate via Taylor expansion to finite μ_B .
- **Black Hole Engineering:** Determine properties of the sQGP through holography.
- **Susceptibilities of Conserved Charges:** Are sensitive to the Critical Point, and can be measured.

Susceptibilities

The Baryonic Susceptibilities χ_n^B are defined as [1]

$$\chi_n = \frac{\partial^n}{\partial (\mu_B/T)^n} \left(\frac{P}{T^4} \right)$$

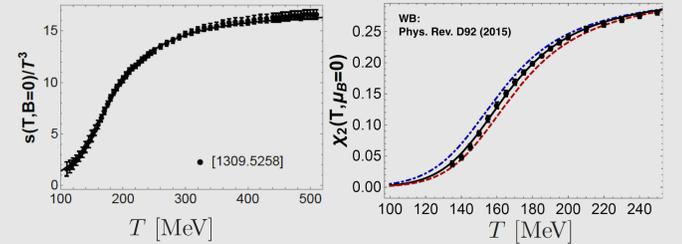
mean : $M = \chi_1$ $M/\sigma^2 = \chi_1/\chi_2$
variance : $\sigma^2 = \chi_2$ $S\sigma = \chi_3/\chi_2$
skewness : $S = \chi_3/\chi_2^{3/2}$ $\kappa\sigma^2 = \chi_4/\chi_2$
kurtosis : $\kappa = \chi_4/\chi_2^2$ $S\sigma^3/M = \chi_3/\chi_1$

Black Hole Model

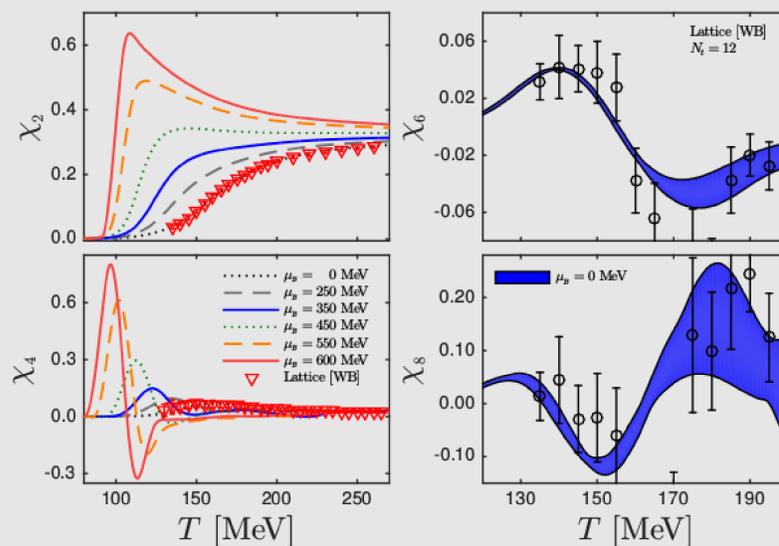
Lagrangian of non-conformal General Relativity in 5 dimensions [2, 3]

$$S = \frac{1}{16\pi G_5} \int dx^5 \sqrt{-g} \left[\mathcal{R} - \frac{1}{2} (\partial_M \phi)^2 - \underbrace{V(\phi)}_{\text{non-conformal}} - \frac{1}{4} \underbrace{f(\phi) F_{MN}^2}_{\mu_B \neq 0} \right]$$

- Input parameters are fixed by Lattice data at $(T, \mu_B=0)$ in a self-consistent gravitational setup
- Non-conformal Equation of State
 - at finite T and finite μ_B
 - with a critical end point
 - agrees with the available lattice data at small μ_B
- Near perfect fluidity
 - Ability to compute transport coefficients near the crossover and at large μ_B



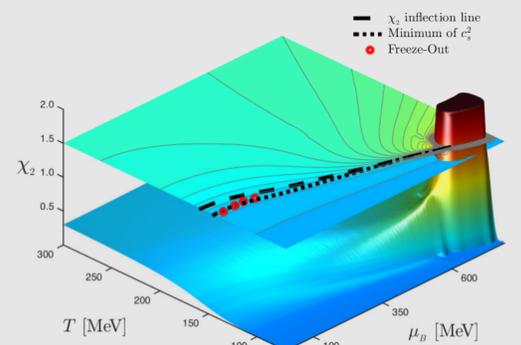
Holographic Susceptibilities and Critical Point



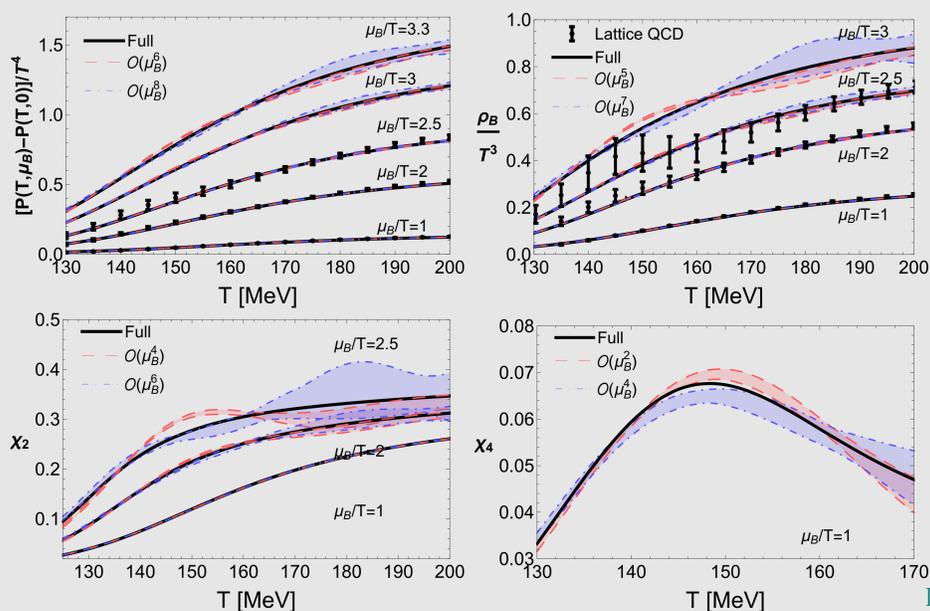
BH: [3] Lattice: [4, 5]

Critical end point found at:

$$\mu_B = 723 \pm 36 \text{ MeV} \quad T = 89 \pm 11 \text{ MeV}$$



Taylor Expansion in Terms of $\chi_n(T, \mu_B=0)$



$$\frac{P}{T^4} = \sum_{n=0}^{\infty} \frac{\chi_{2n}}{(2n)!} \left(\frac{\mu_B}{T} \right)^{2n}$$

$$\frac{\rho_B}{T^3} = \sum_{n=1}^{\infty} \frac{\chi_{2n+1}}{(2n-1)!} \left(\frac{\mu_B}{T} \right)^{2n-1}$$

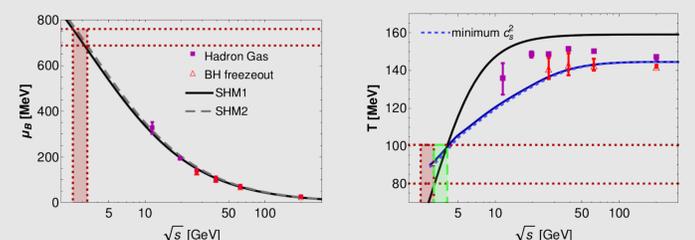
$$\chi_2 = \sum_{n=0}^{\infty} \frac{\chi_{2n+2}}{(2n)!} \left(\frac{\mu_B}{T} \right)^{2n}$$

$$\chi_4 = \sum_{n=0}^{\infty} \frac{\chi_{2n+4}}{(2n)!} \left(\frac{\mu_B}{T} \right)^{2n}$$

Lattice: [6]

\sqrt{s} Estimates to hit the Critical Point

- Freeze out parameters are extracted from χ_1/χ_2 and χ_3/χ_2 by comparing the ratios with the corresponding net-proton moments from STAR [7].
- We estimate the collision energy needed to hit the critical end point to be: $\sqrt{s} = 2.5 - 4.1 \text{ GeV}$ HRG: [8] SHM: [9]



Conclusions

The engineered Black Hole Model

- Reproduces the available lattice data at small μ_B .
- contains a critical end point located at $\mu_B = 724 \pm 36 \text{ MeV}$ and $T = 89 \pm 11 \text{ MeV}$
- Allows us to compute transport coefficients, baryonic susceptibilities, and extract freeze-out parameters
- Estimates that the collision energy needed to hit the CEP should be $\sqrt{s} = 2.5 - 4.1 \text{ GeV}$

References

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