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Magnetic Catalysis in Holographic Model with two Types of Anisotropy for Heavy Quarks

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My collaborators:

Magnetic Catalysis in Holographic Model with two Types of Anisotropy for Heavy Quarks (arXiv:2305.06345)

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Outline:

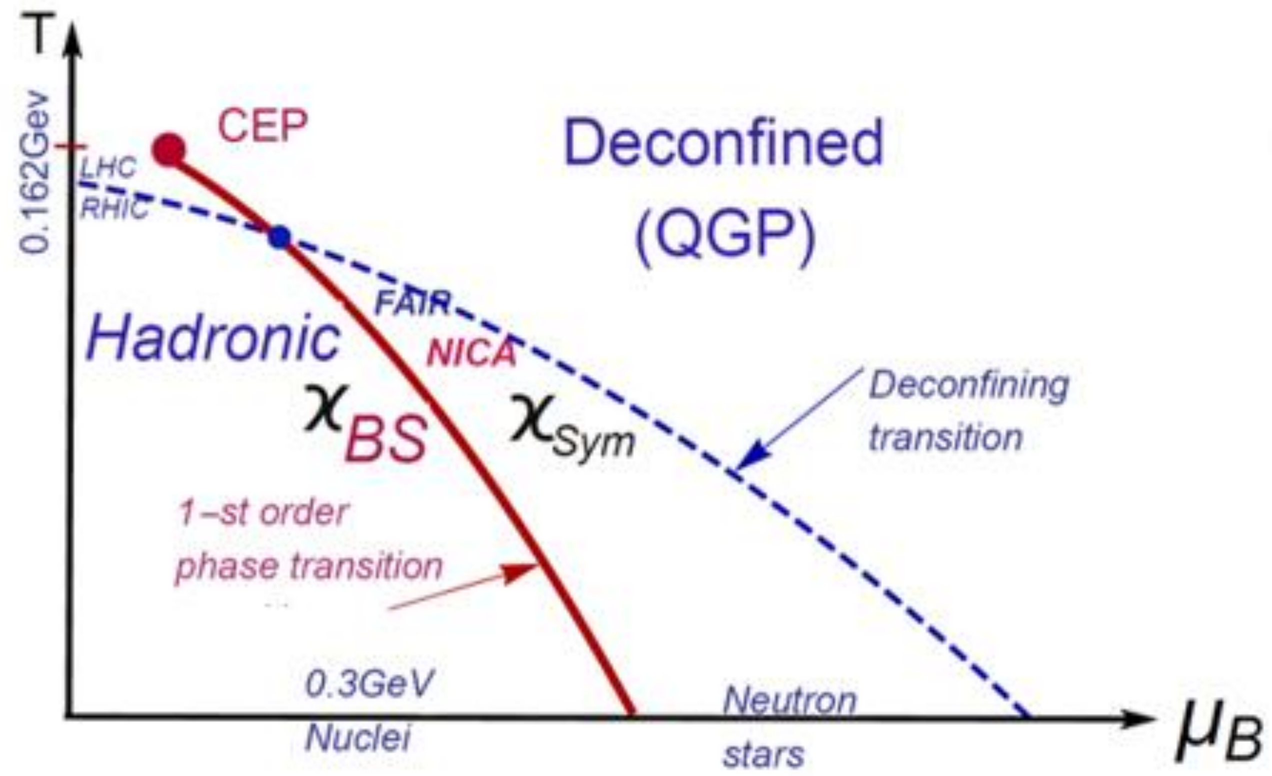
- Introduction
- Set up a Question?
- Approach: AdS/CFT or Gauge/Gravity Duality
- Results
- Summary

Introduction: QCD phase diagram: Experiments

RHIC (2000); LHC (2010)

FAIR (Facility for Antiproton and Ion Research) → Search for signs of the phase transition between hadronic matter and QGP

NICA (Nuclotron-based Ion Collider fAcility) → Search for new phases of baryonic matter



Introduction: Heavy ion collisions (HIC)

QGP Can teach us about properties of the high temperature phase of QCD.

Noncentral relativistic HIC → Anisotropic Plasma

D. Mateos, D. Trancanelli, 2011; Aref 'eva, Golubtsova, JHEP, 2014

There is a strong magnetic field at the early stages of relativistic HIC → $eB \sim 0.3\ GeV^2$

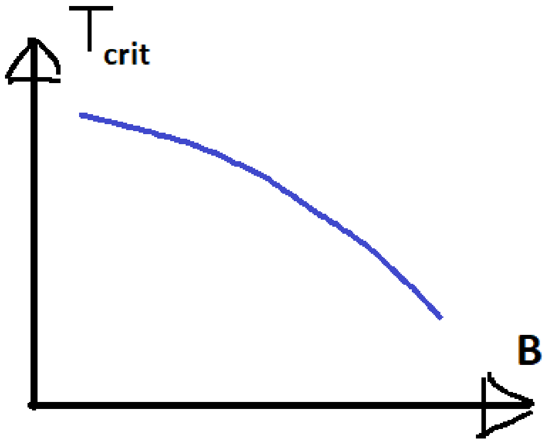
Skokov, Illarionov, Toneev, 2009; Voronyuk, Toneev, Cassing, Bratkovskaya, Konchakovski, Voloshin, 2011

Set up a Question:

What is the effect of magnetic field on the phase transition temperature?

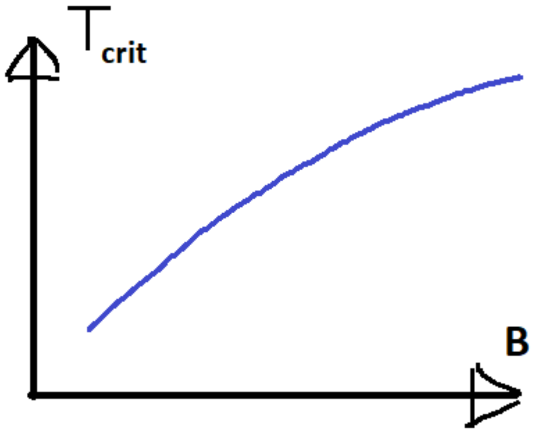
1- Inverse Magnetic Catalysis (IMC)

Mao, PLB, 2016; Bohra, Dudal, Hajilou, Mahapatra, PLB, 2019; Aref’eva, Rannu, Slepov, JHEP, 2020



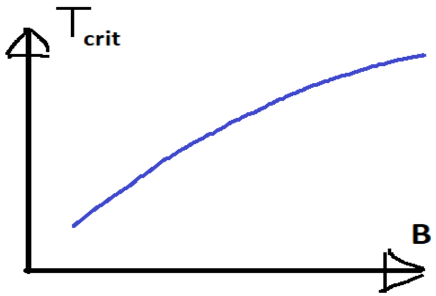
2- Magnetic Catalysis (MC)

Miransky, Shovkovy, PRD, 2002;
He, Yang, Yuan, 2020



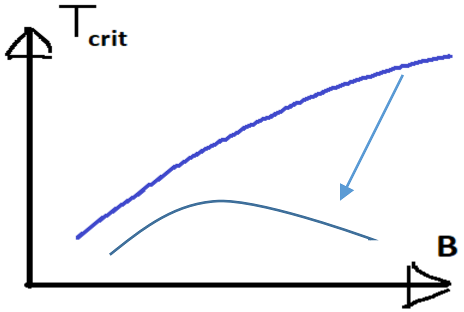
2nd part of the question:

How spatial anisotropy changes the effect of MC?



What is the effect of spatial anisotropy on the phase transition temperature?

We will find that anisotropy changes the location of PT as



Spatial anisotropy gives correct total multiplicity produced in HIC:

To produce total multiplicity we consider anisotropy: $\mathcal{M}_{\nu} \sim s^{\frac{1}{2+\nu}}$.

$\Rightarrow$ $\nu = 4.45$

Aref 'eva, Golubtsova, JHEP, 2014

Our Approach:

Perturbation no longer works.
The approach is AdS/CFT conjectured by Maldacena, 1998.

Classical gravity $\Longleftrightarrow$ Strongly coupled QFT

Anti-de Sitter Space (AdS) $\longleftrightarrow$ Vacuum state

Black hole temperature $\longleftrightarrow$ Temperature in QCD

Maldacena, Adv.Theor. Math.Phys. 1998; Witten, Adv.Theor.Math. Phys. 1998

Our Model:

$$\mathcal{L} = \sqrt{-g}\left[R - \frac{f_0(\phi)}{4}F_0^2 - \frac{f_1(\phi)}{4}F_1^2 - \frac{f_3(\phi)}{4}F_3^2 - \frac{1}{2}\partial_\mu\phi\,\partial^\mu\phi - V(\phi)\right]$$

$$\phi = \phi(z),$$

$$\text{Electric anzats } F_0: \quad A_0 = A_t(z), \quad A_{i=1,2,3,4} = 0,$$

$$\text{Magnetic anzats } F_k: \quad F_1 = q_1\, dx^2 \wedge dx^3, \quad F_3 = q_3\, dx^1 \wedge dx^2.$$

$F_0 \longleftrightarrow$ Chemical potential

$F_1 \longleftrightarrow$ Spatial anisotropy

$F_3 \longleftrightarrow$ Magnetic field

Aref'eva, Rannu,
Slepov, JHEP, 2021

Our ansatz for the metric:

$$ds^2 = \frac{L^2}{z^2}\mathfrak{b}(z)\left[-g(z)\,dt^2 + dx_1^2 + \left(\frac{z}{L}\right)^{2-\frac{2}{\nu}} dx_2^2 + e^{c_B z^2}\left(\frac{z}{L}\right)^{2-\frac{2}{\nu}} dx_3^2 + \frac{dz^2}{g(z)}\right]$$

$$\mathfrak{b}(z) = e^{2A(z)} = e^{-cz^2/2-2(p-c_B\,q_3)z^4}$$

Warp factor

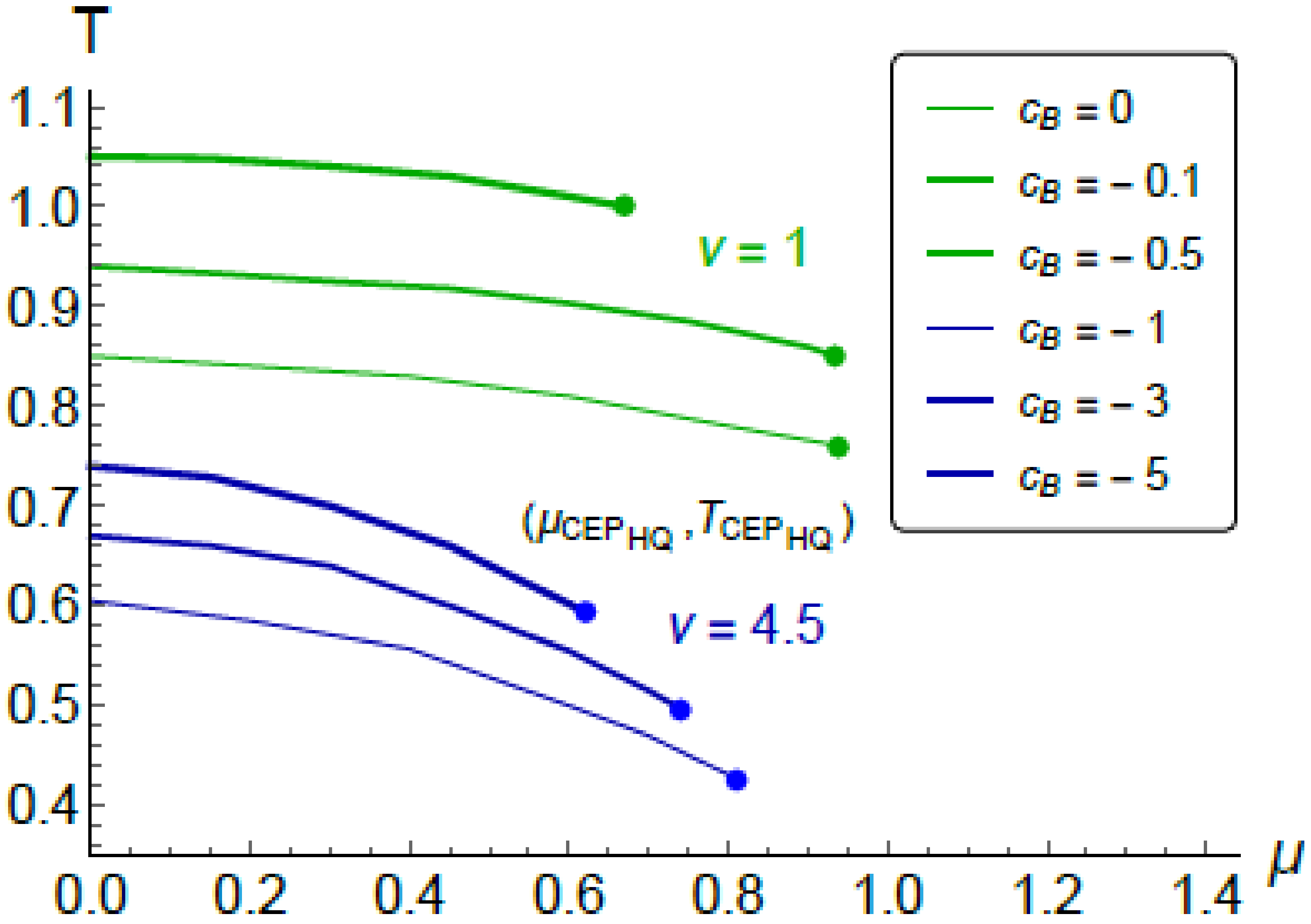
Isotropic $\nu = 1$

Anisotropic $\nu = 4.5$

Gauge coupling function: $f_0 = e^{-(R_{gg}+\frac{c_B q_3}{2})z^2}\,\frac{z^{-2+\frac{2}{\nu}}}{\sqrt{\mathfrak{b}}}$

Phase diagram considering anisotropy:

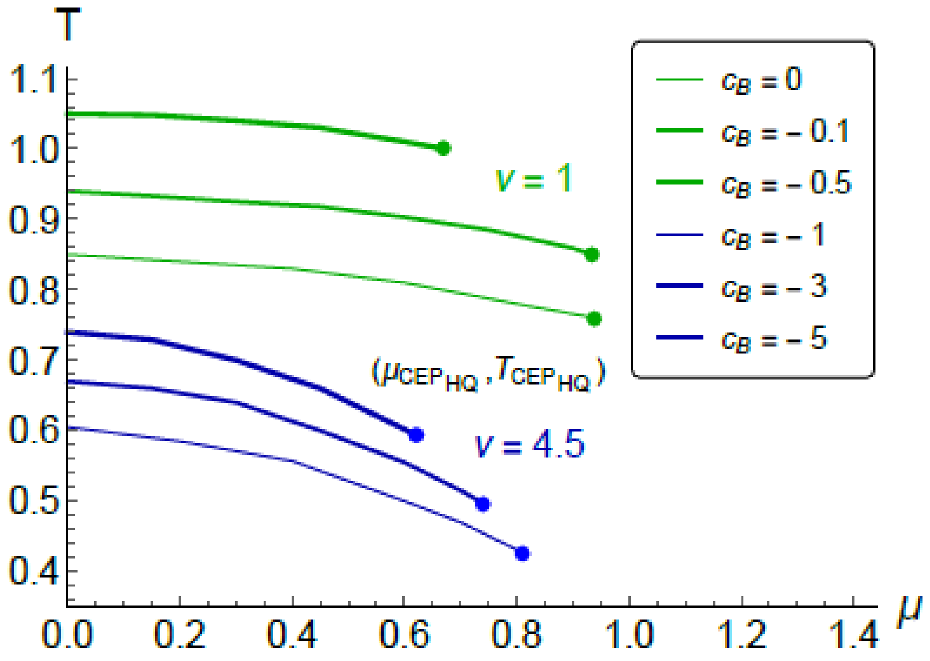
$q_3 = 5$



Summary:

- We found the holographic model that possess **magnetic catalysis** phenomenon.

- Anisotropy **decreases** the area of confinement/deconfinement phase transition.



Thank you very much for your attention!