In his name

Chiral transition in the probe approximation from an Einstein-Maxwell-dilaton gravity model

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Wednesday Weekly Seminar (WWS)

2 June 2021

12 خرداد 1400

PHYSICAL REVIEW D **103,** 086021 (2021)

Chiral transition in the probe approximation from an Einstein-Maxwell-dilaton gravity model

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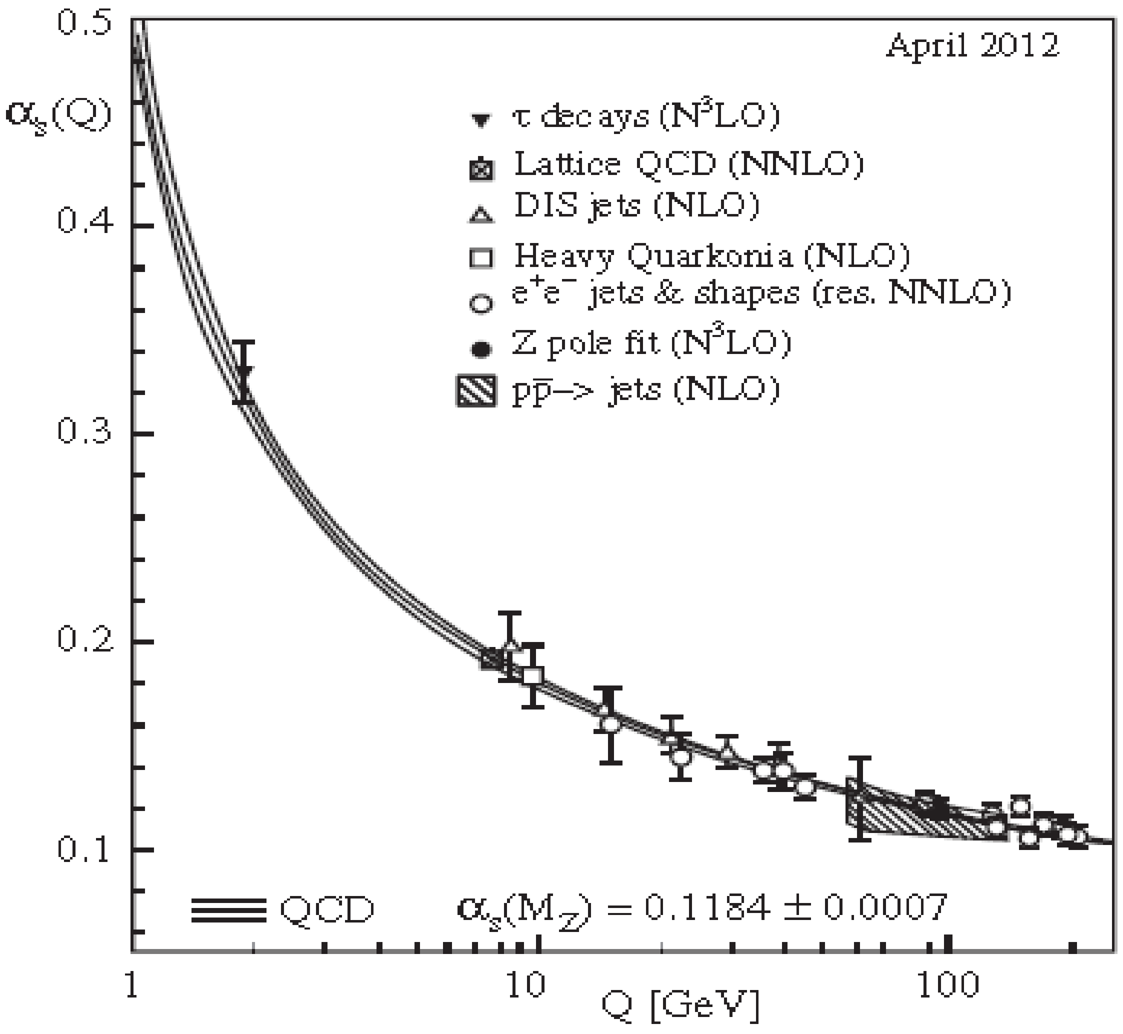
Outline:

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

Introduction:

One of the most important features of QCD is Confinement!

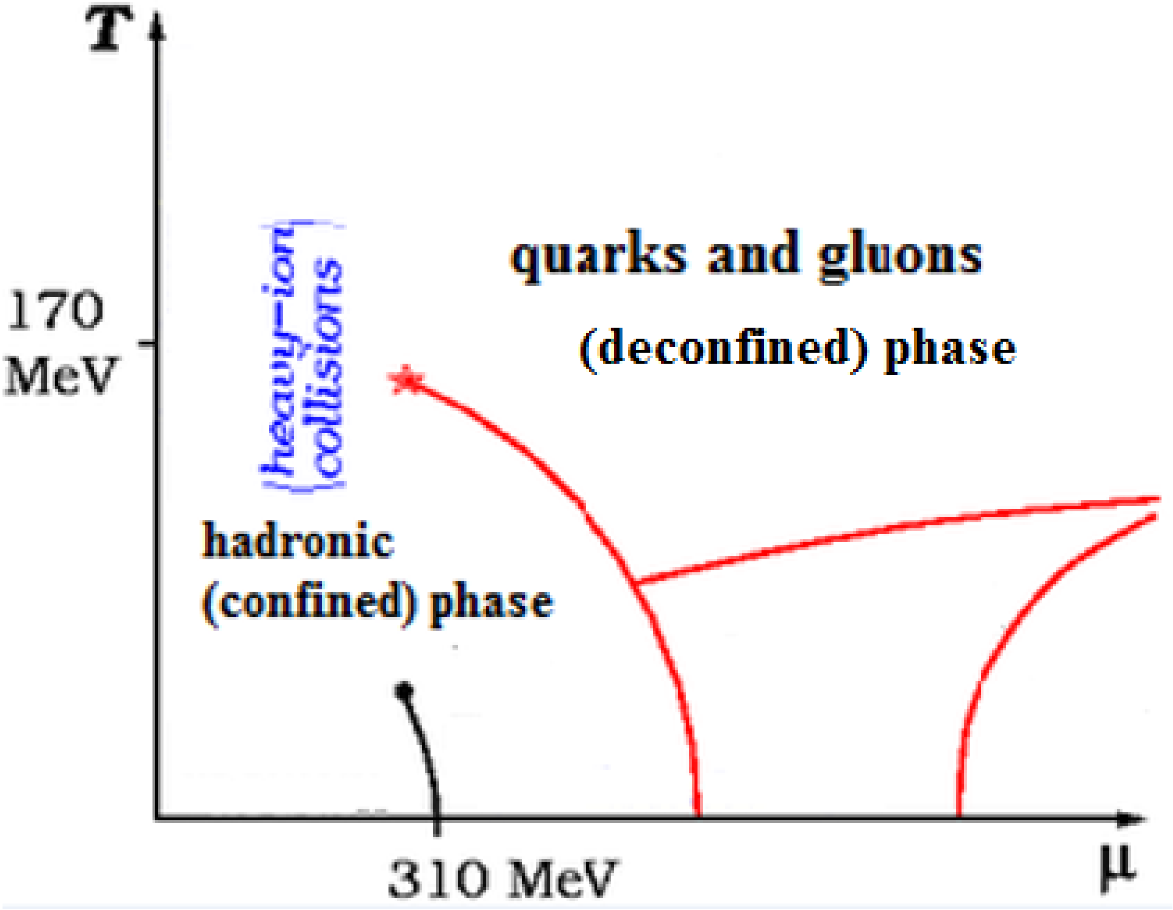
QCD Running coupling :



QFT and SM, "MATTHEW D. SCHWARTZ"

Introduction: confinement-deconfinement phase transition

QCD phase diagram:



Heavy Ion collision:

RHIC LHC

2Tc 5Tc

$T_c \sim 170$ MeV

eB=0.3 GeV^2

Introduction:

Cornell Potential: $$V(\ell) = -\frac{\kappa}{\ell} + \sigma_s \ell + C$$

QCD string tension

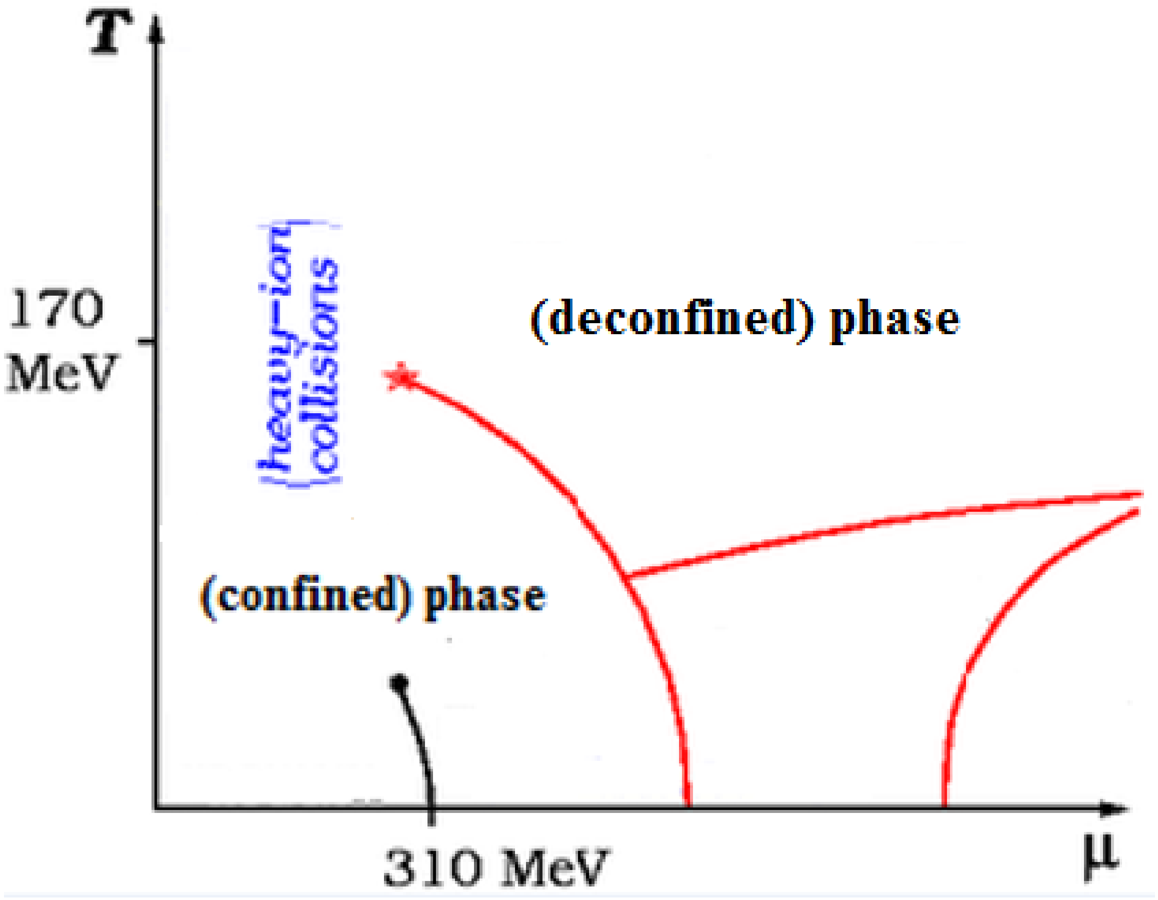
What is the effect of a background magnetic field on QCD string tension and deconfinement transition temperature?

Introduction: chiral phase transition

Chiral symmetry is expected to get restored at high T: $\langle \bar{\psi}\psi \rangle = 0$

At low temperature we have: $\langle \bar{\psi}\psi \rangle \neq 0$

Quark field operator



Question:

What is the effect of a background magnetic field on the chiral critical temperature, .i.e. T_chiral?

Approach:

Both of these phenomena are strong coupling effects which are not visible in perturbation theory.

So, we use Non-Perturbative approach, i.e. **AdS/CFT duality**

Classical gravity  Strongly coupled QFT

Methods:

Top-down models: Directly constructed from string theory:

J. Babington, J. Erdmenger, N. J. Evans, Z. Guralnik , I. Kirsch, M. Kruczenski, D. Mateos, R. C. Myers and D. J. Winters,…

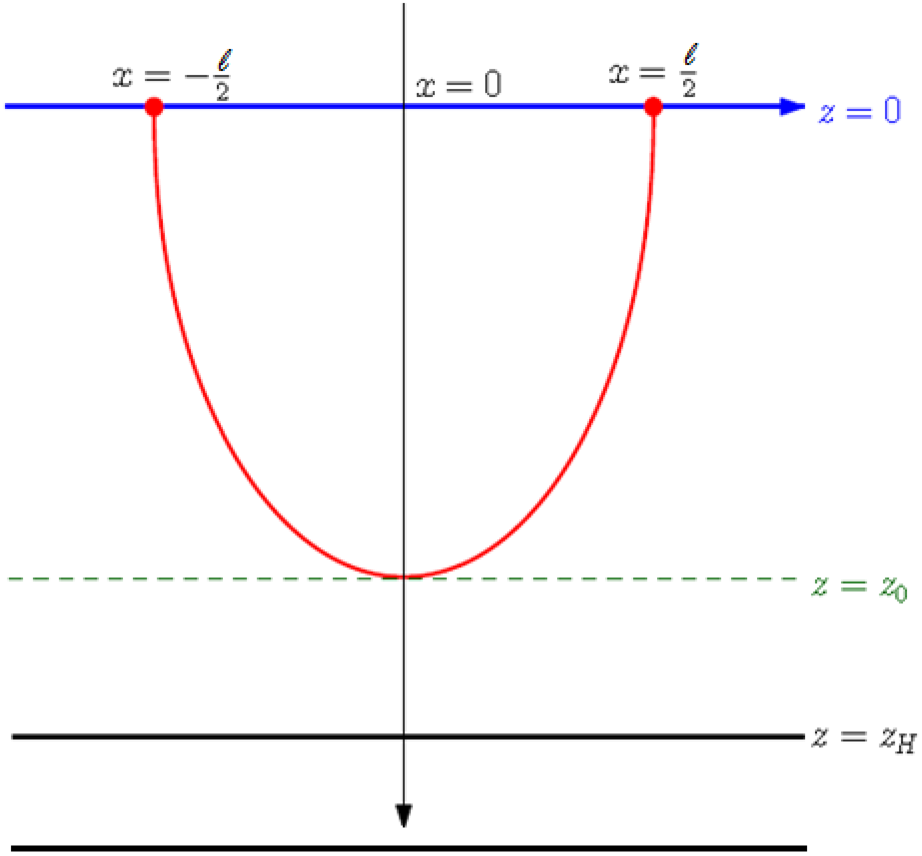
Bottom-up models: (phenomenological)

Introduce a dilaton field

J. Erlich, E. Katz, D. T. Son and M. A. Stephanov, A. Karch, B. Batell and T. Gherghetta, U. Gursoy, E. Kiritsis,…

To get a fields configuration which is both consistent with the equation of motions and realizes the linear Regge trajectory, dynamical AdS/QCD models were constructed by introduce a dilaton potential.

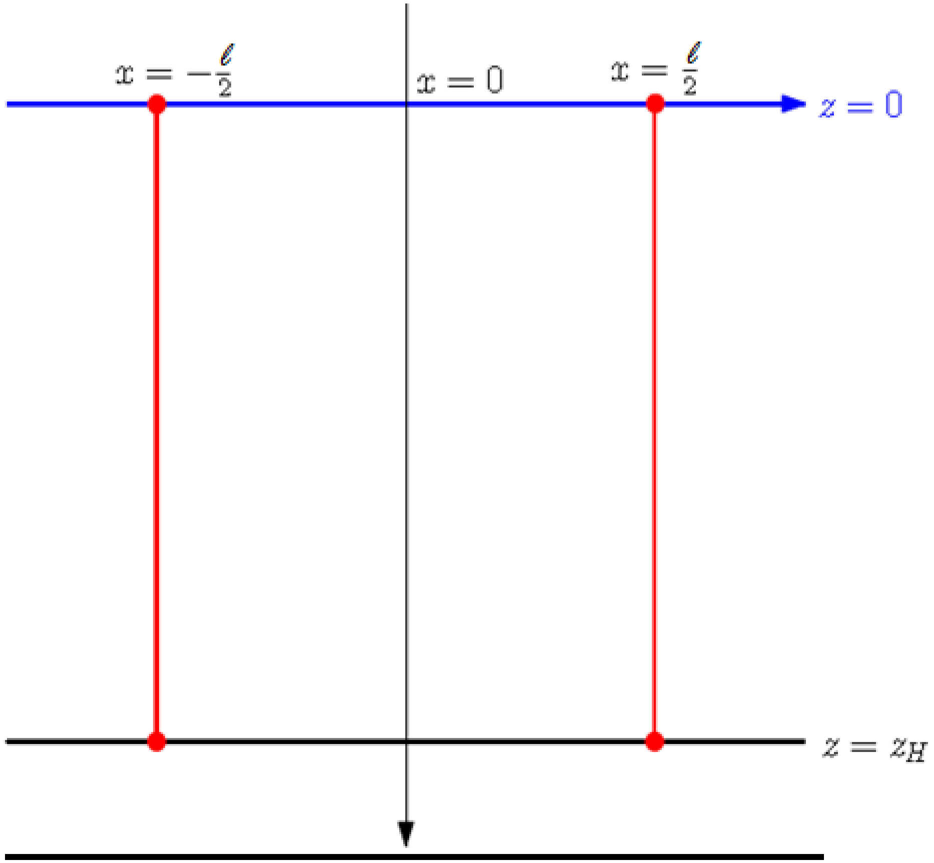
Holographic picture:



Small B H

Connected configuration

Meson bounded



Large B H

Disconnected configuration

Meson melted

Einstein-Maxwell-dilaton gravity with a magnetic field:

$$S_{EM} = -\frac{1}{16\pi G_5}\int d^5x\sqrt{-g}\left[R - \frac{f_1(\phi)}{4}F_{(1)MN}F^{MN} - \frac{f_2(\phi)}{4}F_{(2)MN}F^{MN} - \frac{1}{2}\partial_M\phi\partial^M\phi - V(\phi)\right]$$

Ansatz:

$$ds^2 = \frac{L^2 S(z)}{z^2}\left[-g(z)dt^2 + \frac{dz^2}{g(z)} + dy_1^2 + e^{B^2 z^2}\left(dy_2^2 + dy_3^2\right)\right]$$

$$\phi = \phi(z), \quad A_{(1)M} = A_t(z)\delta^t_M, \quad F_{(2)MN} = B\, dy_2 \wedge dy_3$$

Metric:

$$ds^2 = \frac{L^2 e^{2A(z)}}{z^2}\left[-g(z)dt^2 + \frac{dz^2}{g(z)} + dy_1^2 + e^{B^2 z^2}\left(dy_2^2 + dy_3^2\right)\right]$$

$$g(z) = 1 + \int_0^z d\xi\, \xi^3 e^{-B^2\xi^2 - 3A(\xi)}\left[K_3 + \frac{\tilde{\mu}^2}{2cL^2} e^{c\xi^2}\right], \quad K_3 = -\frac{\left[1 + \frac{\tilde{\mu}^2}{2cL^2}\int_0^{z_h} d\xi\, \xi^3 e^{-B^2\xi^2 - 3A(\xi) + c\xi^2}\right]}{\int_0^{z_h} d\xi\, \xi^3 e^{-B^2\xi^2 - 3A(\xi)}}$$

Dilaton:

$$\phi(z) = \int dz \sqrt{-\frac{2}{z}\left(3zA''(z) - 3zA'(z)^2 + 6A'(z) + 2B^4 z^3 + 2B^2 z\right)} + K_5$$

Ansatz: $$A(z) = -az^2$$

Dilaton:
$$\phi(z) = \frac{(9a - B^2)\log\left(\sqrt{6a^2 - B^4}\sqrt{6a^2z^2 + 9a - B^4z^2 - B^2} + 6a^2z - B^4z\right)}{\sqrt{6a^2 - B^4}} + z\sqrt{6a^2z^2 + 9a - B^2\left(B^2z^2 + 1\right)} - \frac{(9a - B^2)\log\left(\sqrt{9a - B^2}\sqrt{6a^2 - B^4}\right)}{\sqrt{6a^2 - B^4}}$$

$$B^4 < B_c^4 = 6a^2 \xrightarrow{a = 0.15\ \mathrm{GeV}^2} B_c \simeq 0.61\ \mathrm{GeV}$$

Reminder:

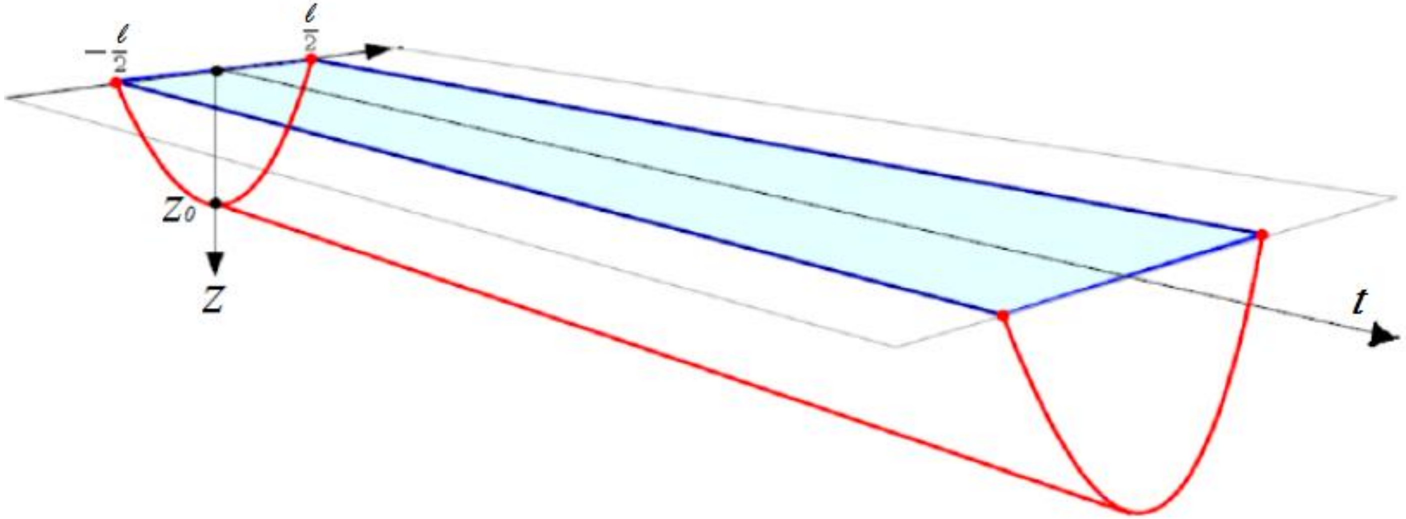
What is the effect of a background magnetic field on QCD string tension and deconfinement transition temperature?

Wilson loop:

$$\mathcal{T}\ \mathcal{F}(\ell,\mathcal{T}) = S_{NG}^{on-shell}(\ell,\mathcal{T})$$

Nambu-Goto action:

$$S_{NG} = \frac{1}{2\pi\,\ell_s^2}\int d\tau d\sigma\sqrt{-\det\ G_s}$$



$$(G_s)_{\alpha\beta} = (g_s)_{MN}\partial_\alpha X^M \partial_\beta X^N$$

Phys. Rev. Lett. 80, 4859 (1998) [hep-th/9803002]

Metric in string frame:

$$(g_s)_{MN} = e^{\sqrt{\frac{2}{3}}\phi} g_{MN}$$

$$ds_s^2 = \frac{L^2 e^{2A_s(z)}}{z^2}\left[-g(z)dt^2 + \frac{dz^2}{g(z)} + dy_1^2 + e^{B^2 z^2}\left(dy_2^2 + dy_3^2\right)\right]$$

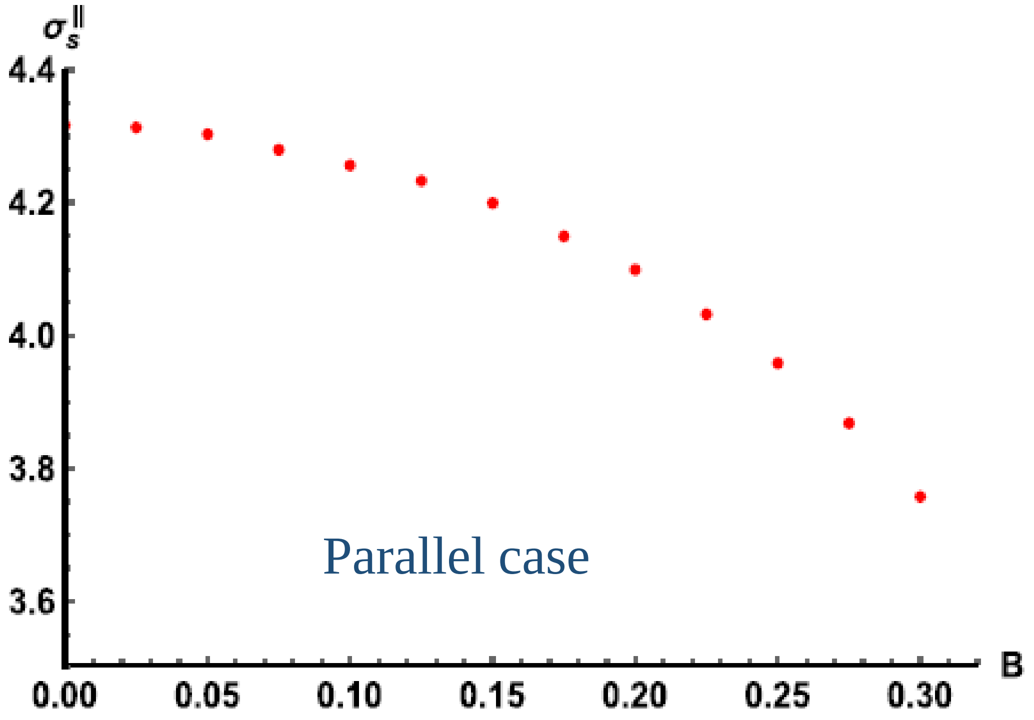
$$A_s(z) = A(z) + \sqrt{\frac{1}{6}}\ \phi(z)$$

We work in thermal-AdS background: $g(z) = 1$

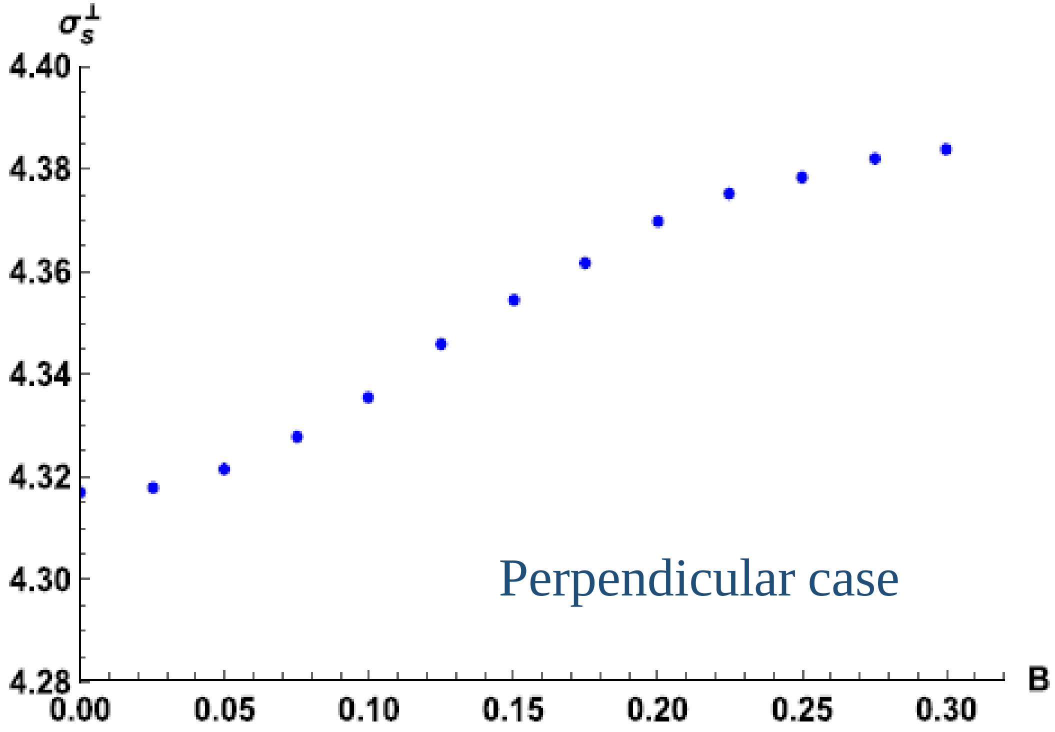
QCD string tension:

$$A(z) = -az^2$$

$$V(\ell) = -\frac{\kappa}{\ell} + \sigma_s \ell + C$$



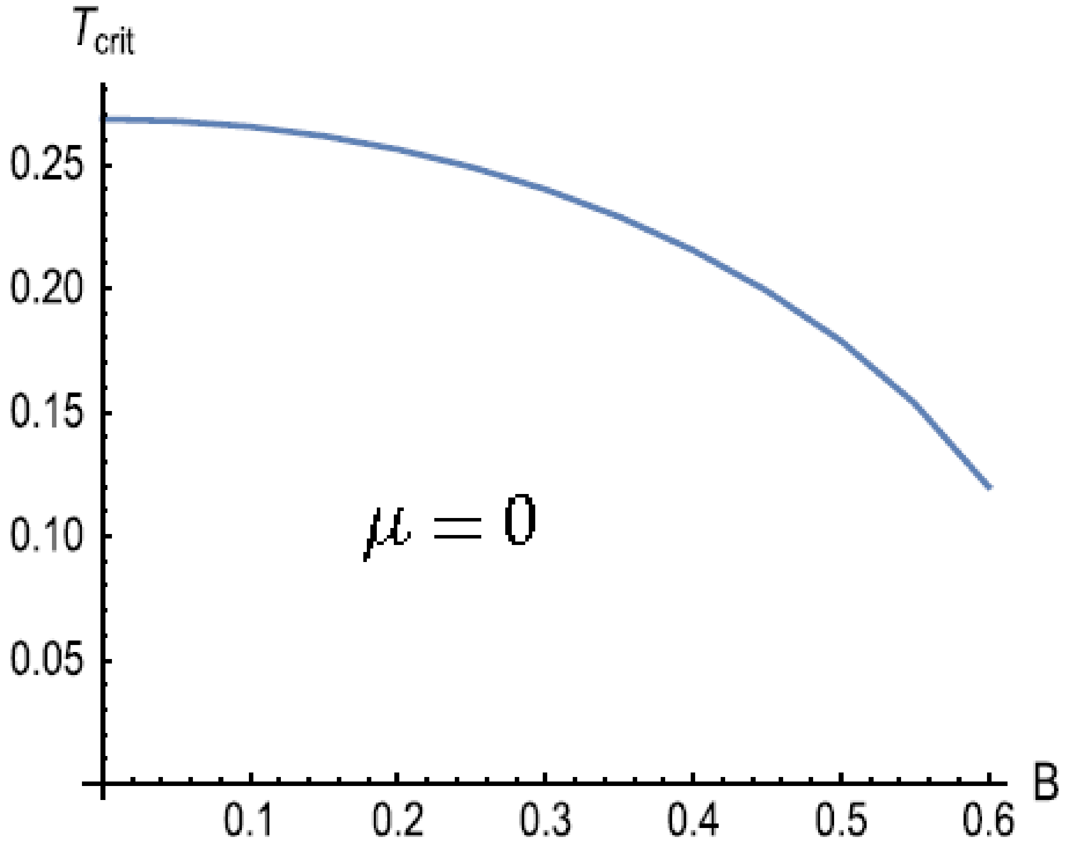
Parallel case



Perpendicular case

$$\mu = 0$$

Reminder: What is the effect of a background magnetic field on the deconfinement transition temperature?



$$A(z) = -az^2$$

We obtain inverse magnetic catalysis for the dual confinement-deconfinement transition.

Our main Question:

What is the effect of a background magnetic field on the chiral critical temperature, .i.e. T_chiral?

New form factor: $A_2(z) = -az^2 - dB^2z^5$

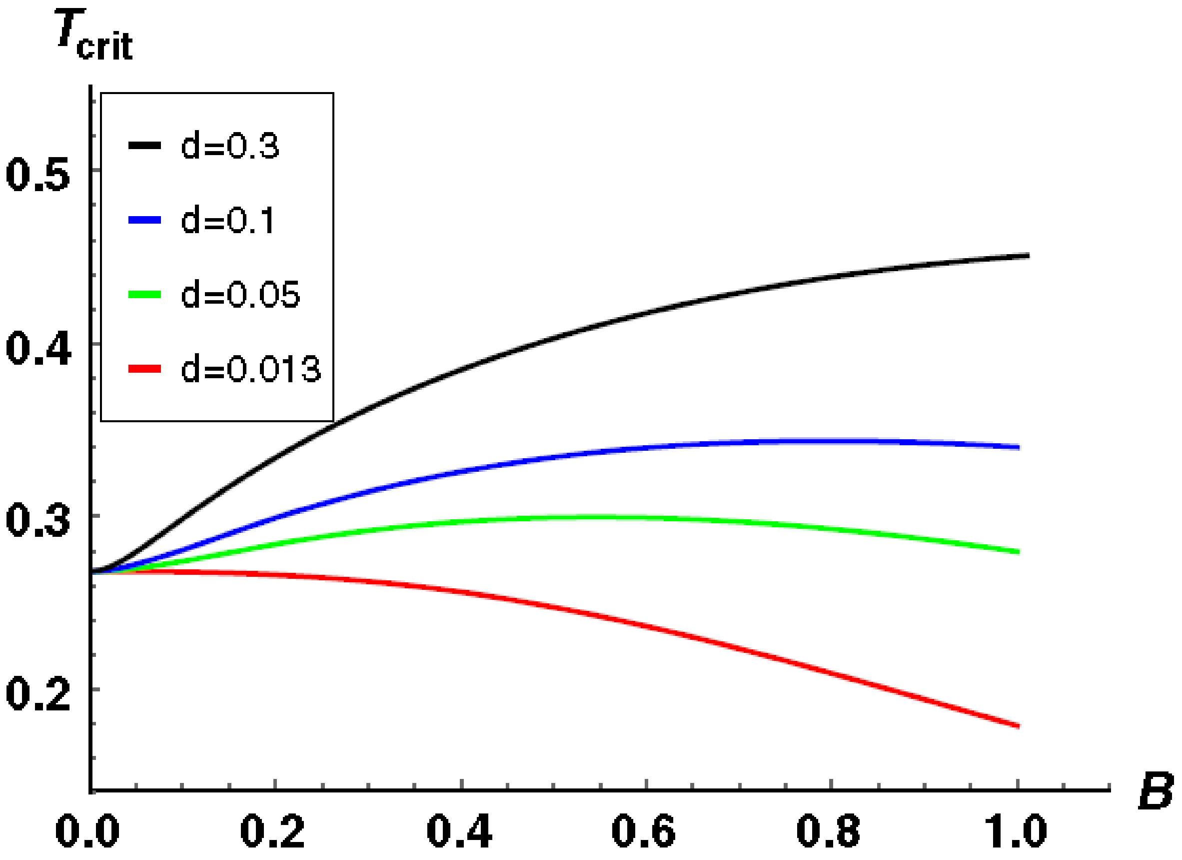
1- Real-valued dilaton field

2- Free energy of connected string < disconnected-one

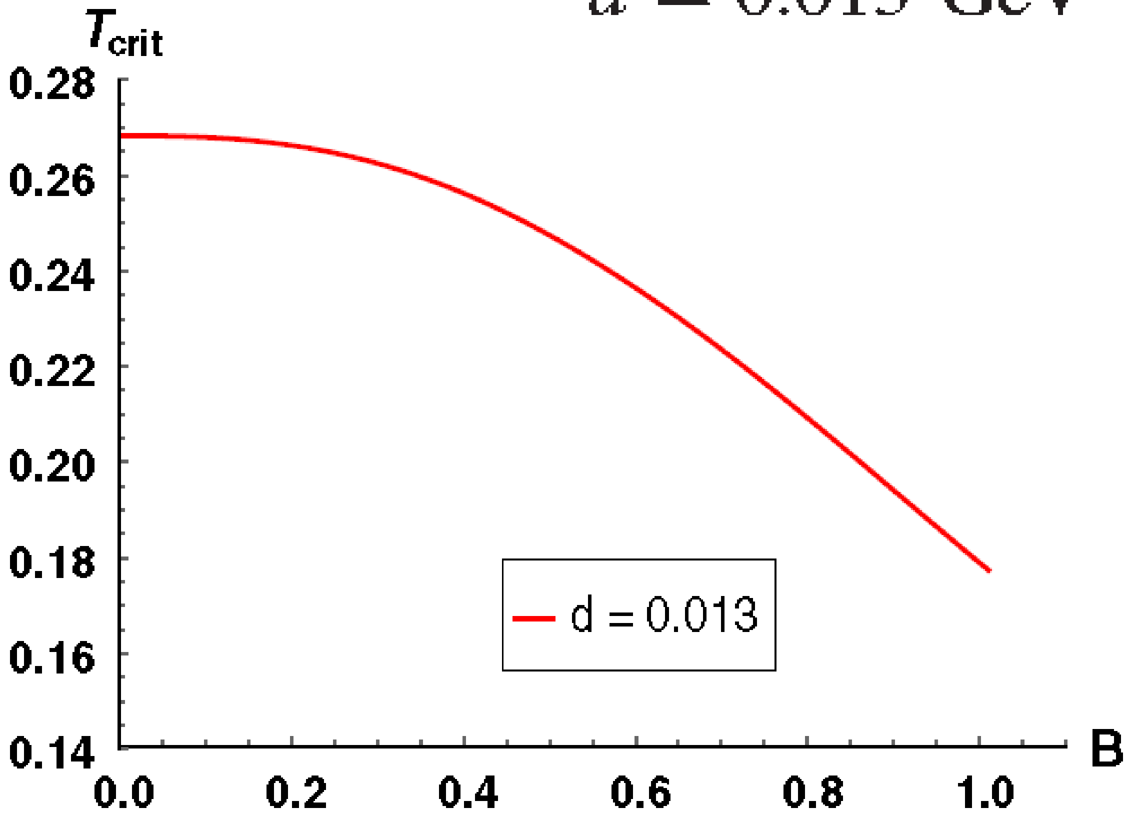
The maximum value of B-field is: $B_c \simeq 1.02 \text{ GeV}$

Fixing the d-value:

$$A_2(z) = -az^2 - dB^2z^5$$



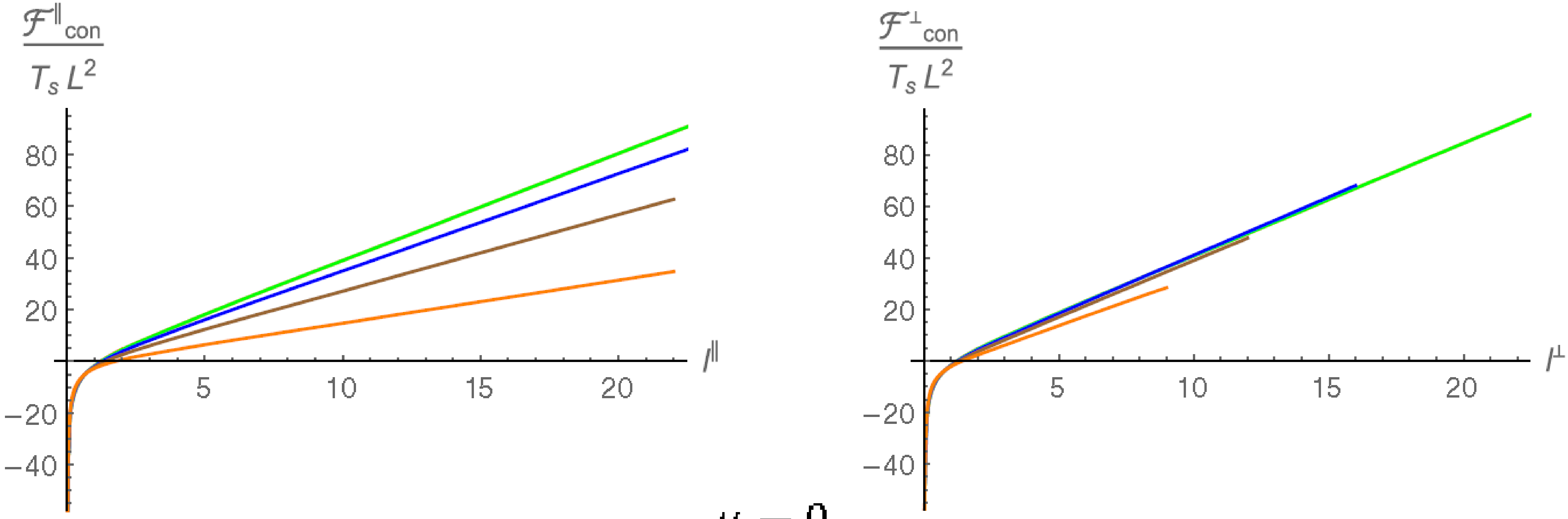
$d = 0.013\ \mathrm{GeV}^3$



$\mu = 0$

Cornell potential:

$$A_2(z) = -az^2 - dB^2 z^5$$

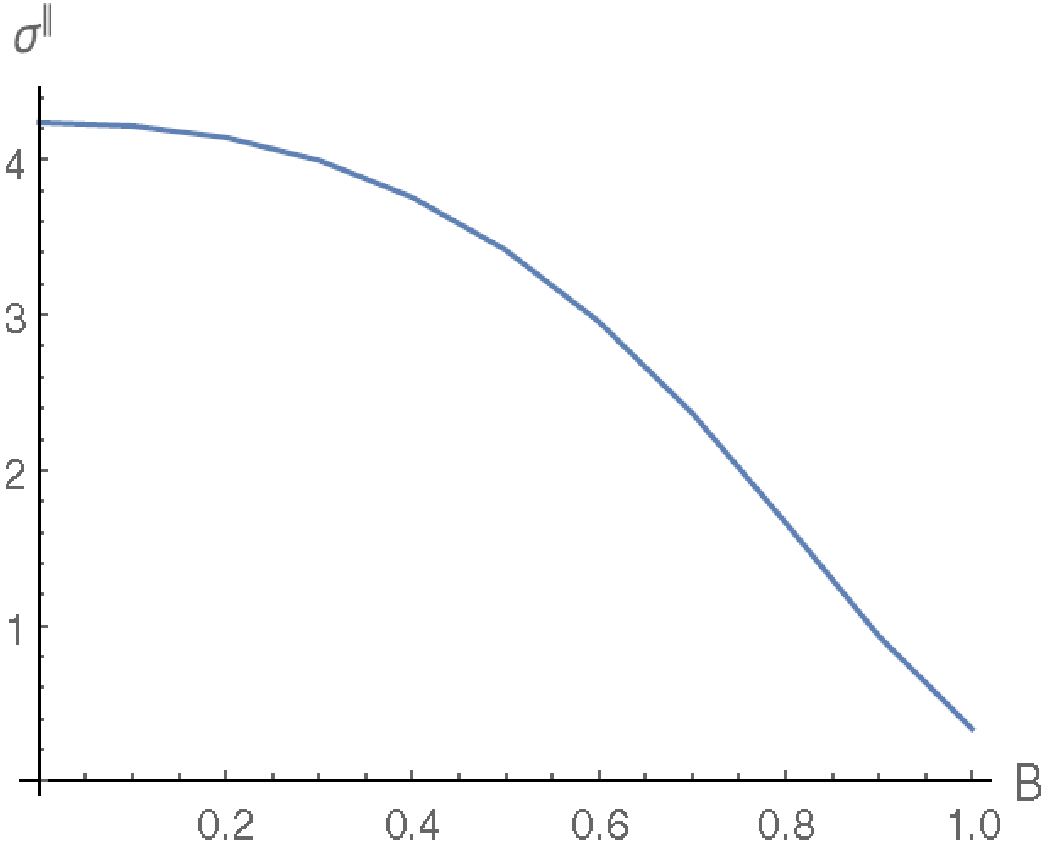


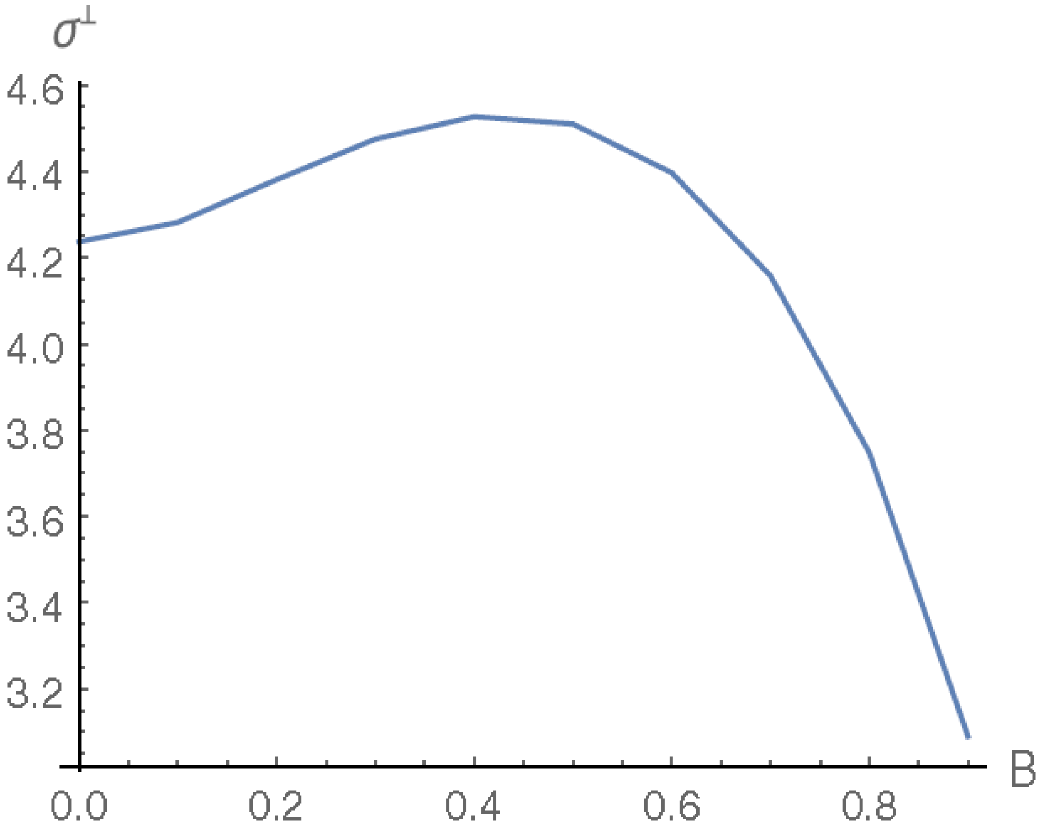
$\mu = 0$

red, green, blue, brown, and orange curves correspond to $B = 0$ 0.2, 0.4, 0.6, and 0.8 respectively. In units GeV.

Check the QCD string tension:

$$A_2(z) = -az^2 - dB^2z^5$$





$$\mu = 0$$

Our main Question:

What is the effect of a background magnetic field on the chiral critical temperature, .i.e. T_chiral?

Holographic action:

$$S_{\text{chiral}} = \frac{N_c}{16\pi^2}\int d^5x\sqrt{-g}e^{-\phi}\text{Tr}\left[|DX|^2 - m_5^2|X|^2 - \frac{f_2(\phi)}{3}(F_L^2 + F_R^2)\right]$$

Homogeneous condensate → $X(z, x^\mu) = X(z)$

B-field can be introduced in such a way that

$$D_\mu X = \partial_\mu X - iA_{L,\mu}X + iXA_{R,\mu}$$ →

$A_L = A_R$ → $D_\mu X \rightarrow \partial_\mu X$

Phys. Rev. D 93, 125004 (2016)   *Eur. Phys. J. C* **72,** 2096 (2012)

Equation of motion of the X-field:

$$X''(z) + X'(z)\left(-\frac{3}{z} + 2B^2 z + \frac{g'(z)}{g(z)} + 3A'(z) - \phi'(z)\right) + \frac{3e^{2A(z)}X(z)}{z^2 g(z)} = 0$$

Near boundary expansion: $X(z) = m_q z + m_q b_1 z^2 + \sigma z^3 + m_q b_2 z^3 \ln\sqrt{a}z + \mathcal{O}(z^4)$

$$b_1 = -2\sqrt{9a - B^2}$$

$$b_2 = -30a + 3B^2$$

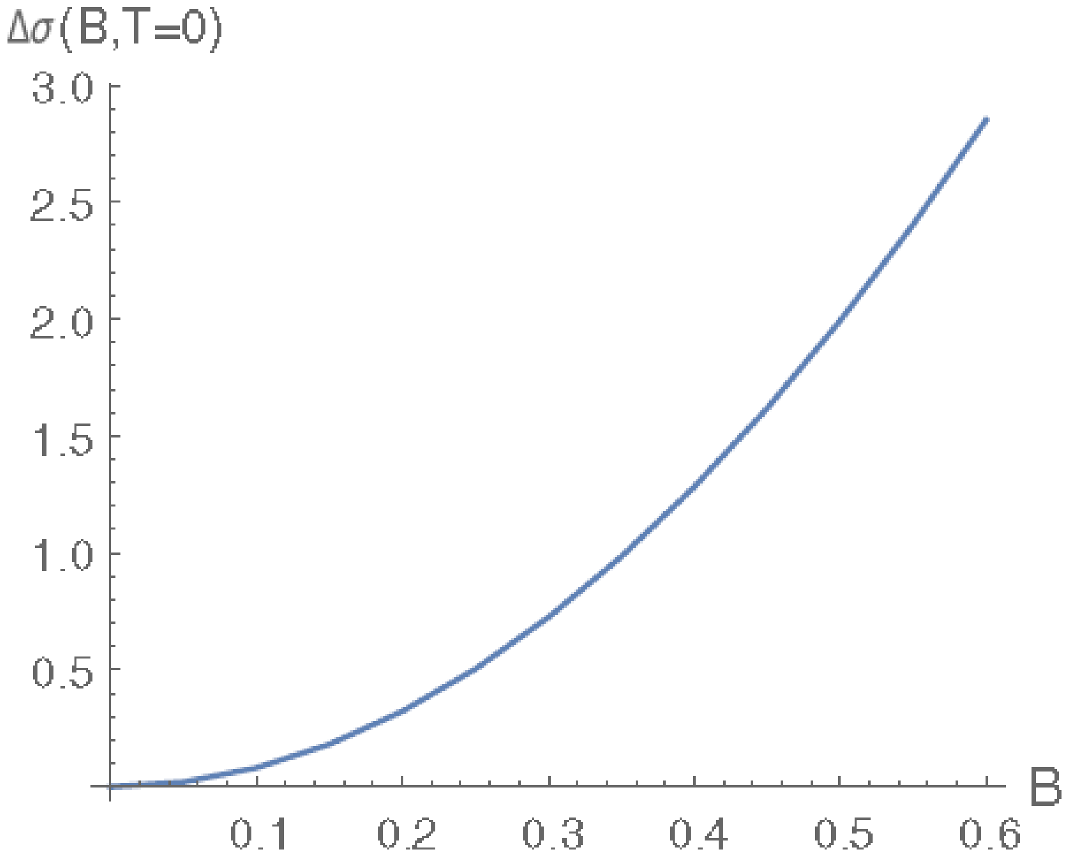
Chiral condensation:

$$\langle\bar{\psi}\psi\rangle_{B,T} = \frac{N_c}{2\pi^2}\sigma(B,T) + \frac{N_c m_q}{8\pi^2}(-18B^2 + 165a)$$

$\sigma(B,T)$ For deconfined phase

$\sigma(B,T=0)$ For confined phase

The chiral condensate in the confined phase for: $A(z) = -az^2$



$$\Delta\sigma(B, T=0) = \sigma(B, T=0) - \sigma(B=0, T=0)$$

$$m_q = 1.0 \text{ GeV}$$

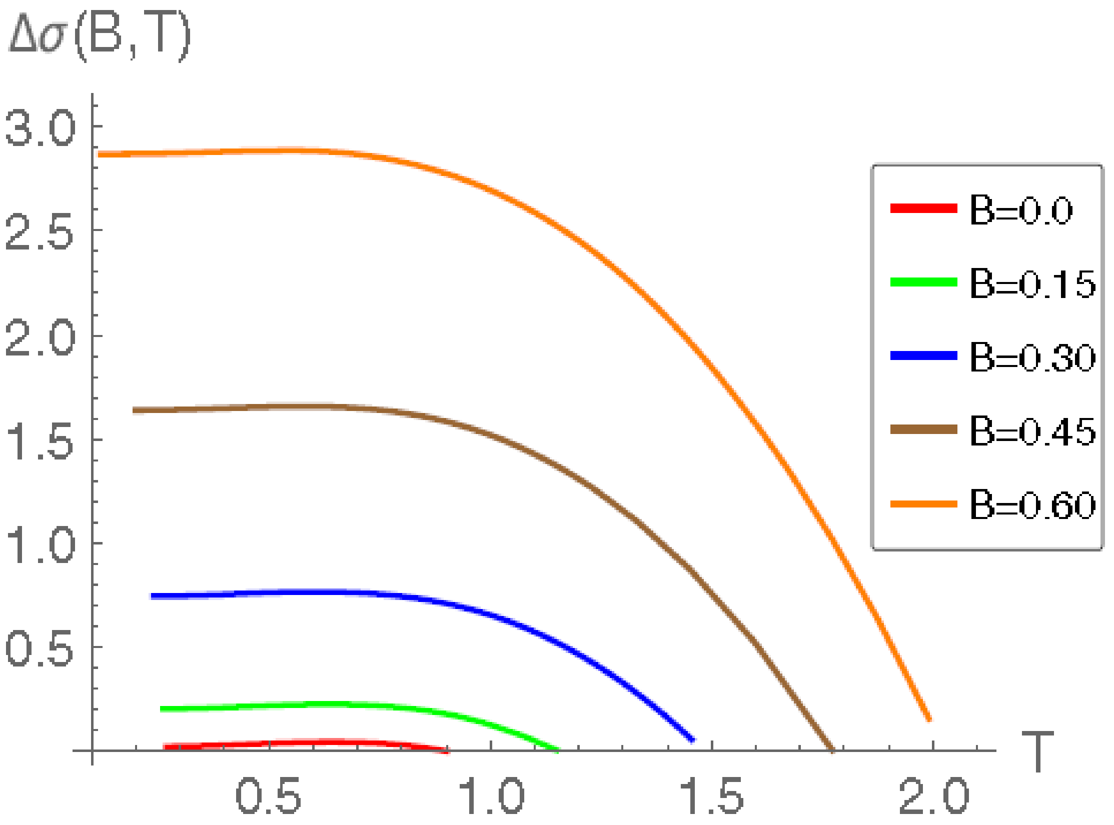
We observe magnetic catalysis.

Compatible with lattice results in:

Phys. Rev. D 86, 071502 (2012).

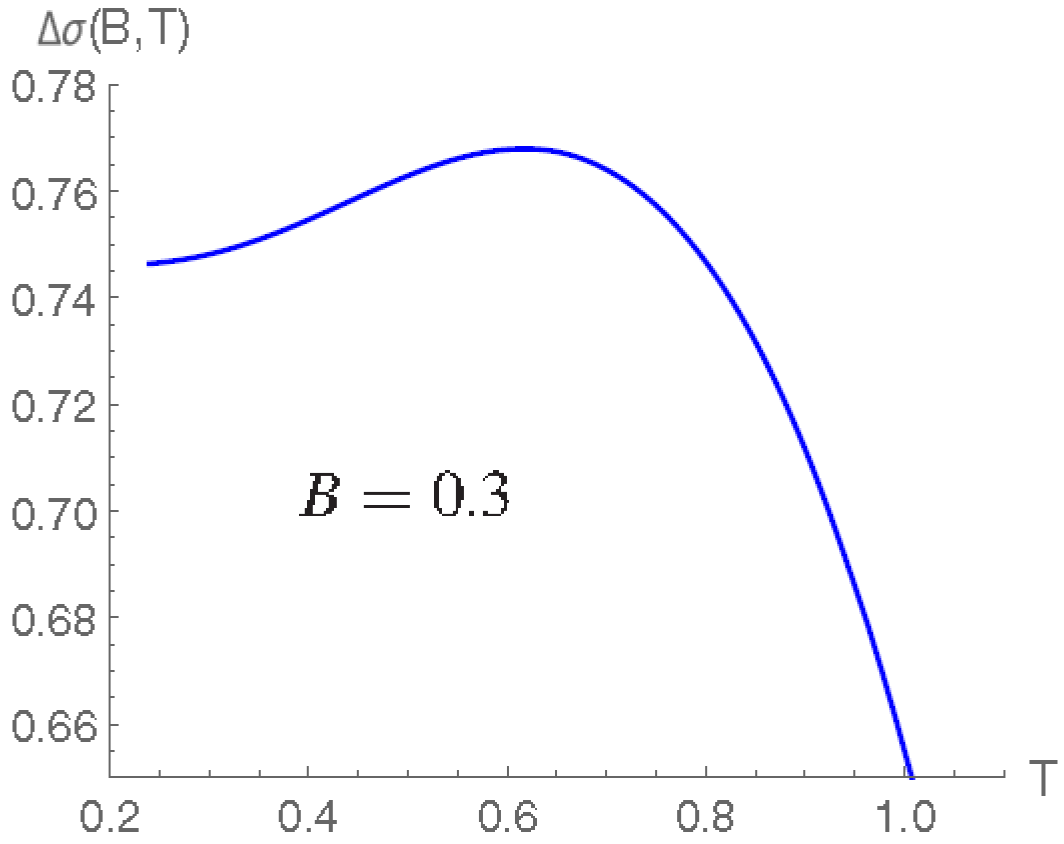
J. High Energy Phys. 02(2012) 044.

The chiral condensate in the deconfined phase for: $A(z) = -az^2$



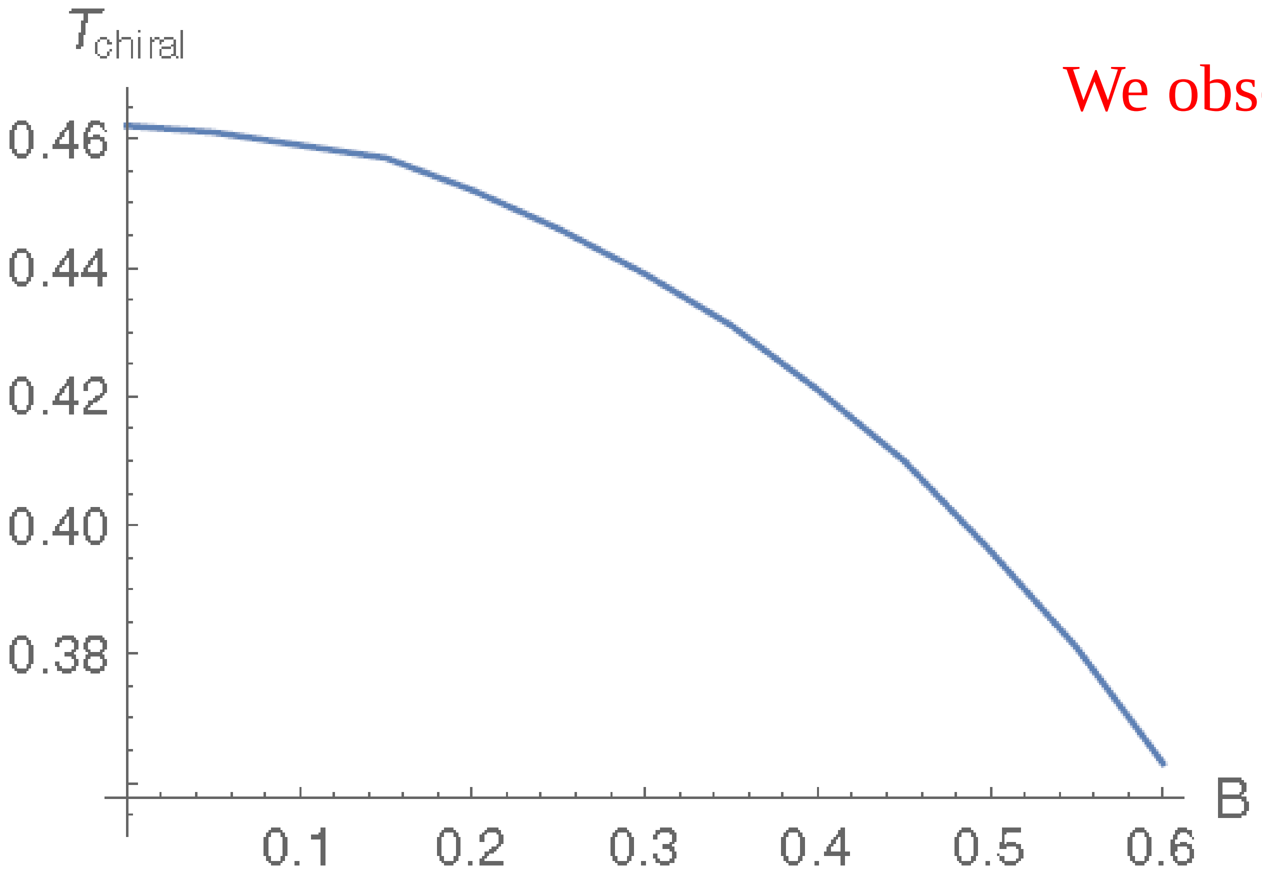
$$\Delta\sigma(B,T) = \sigma(B,T) - \sigma(B=0,T=0)$$

$m_q = 1.0$ GeV



Define the chiral critical temperature via the inflection point:

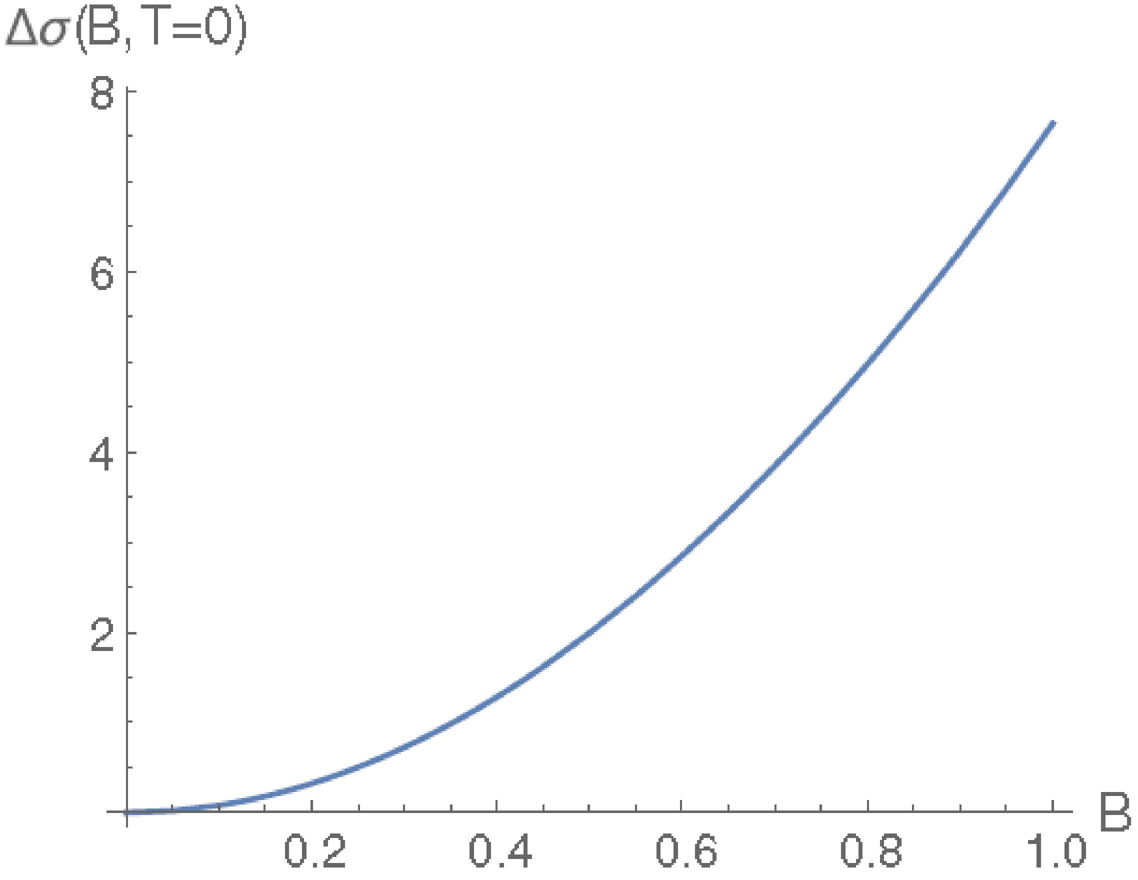
$$A(z) = -az^2$$



We observe inverse magnetic catalysis.

$m_q = 1.0\ \mathrm{GeV}$

The chiral condensate in the confined phase for: $A_2(z) = -az^2 - dB^2z^5$

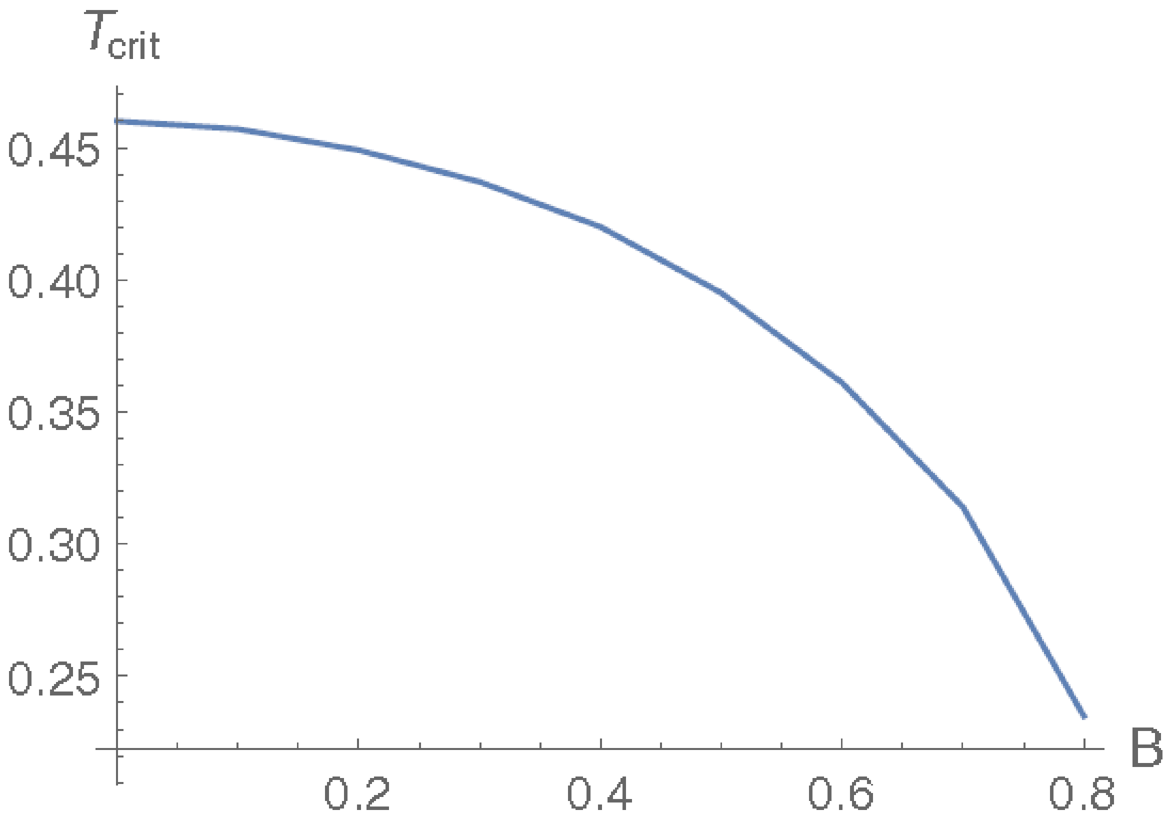


$$\Delta\sigma(B, T=0) = \sigma(B, T=0) - \sigma(B=0, T=0)$$

$$m_q = 1.0 \text{ GeV}$$

We observe magnetic catalysis.

Define the chiral critical temperature via the inflection point: $A_2(z) = -az^2 - dB^2z^5$



We observe inverse magnetic catalysis.

$m_q = 1.0$ GeV

Summary:

- We utilize the bottom-up holographic model to investigate the effect of magnetic field on the QCD string tension and deconfinement transition temperature.

- For the confined phase we observe the magnetic catalysis for chiral condensation for different values of B-field.
- Our results generally confirms the lattice results.

- We obtain inverse magnetic catalysis for the dual chiral transition tempreture for the deconfined phase .

Thanks…