# Dissociation of Charmonium in Hot Medium and Magnetic Field

**Xingyu Guo**

**South China Normal University**

Da Teng, XYG, *Chin.Phys.C* 46 (2022) 9, 094104
Junjun Zhuo, XYG, in preparation

The 2nd Workshop on Ultra-Peripheral Collision Physics:
Strong Electromagnetic fields, UPC and EIC/EicC, USTC, 14 April 2024

# Contents

- Introduction
- Two-body Schrödinger equation with magnetic field
- Numerical results
- Summary

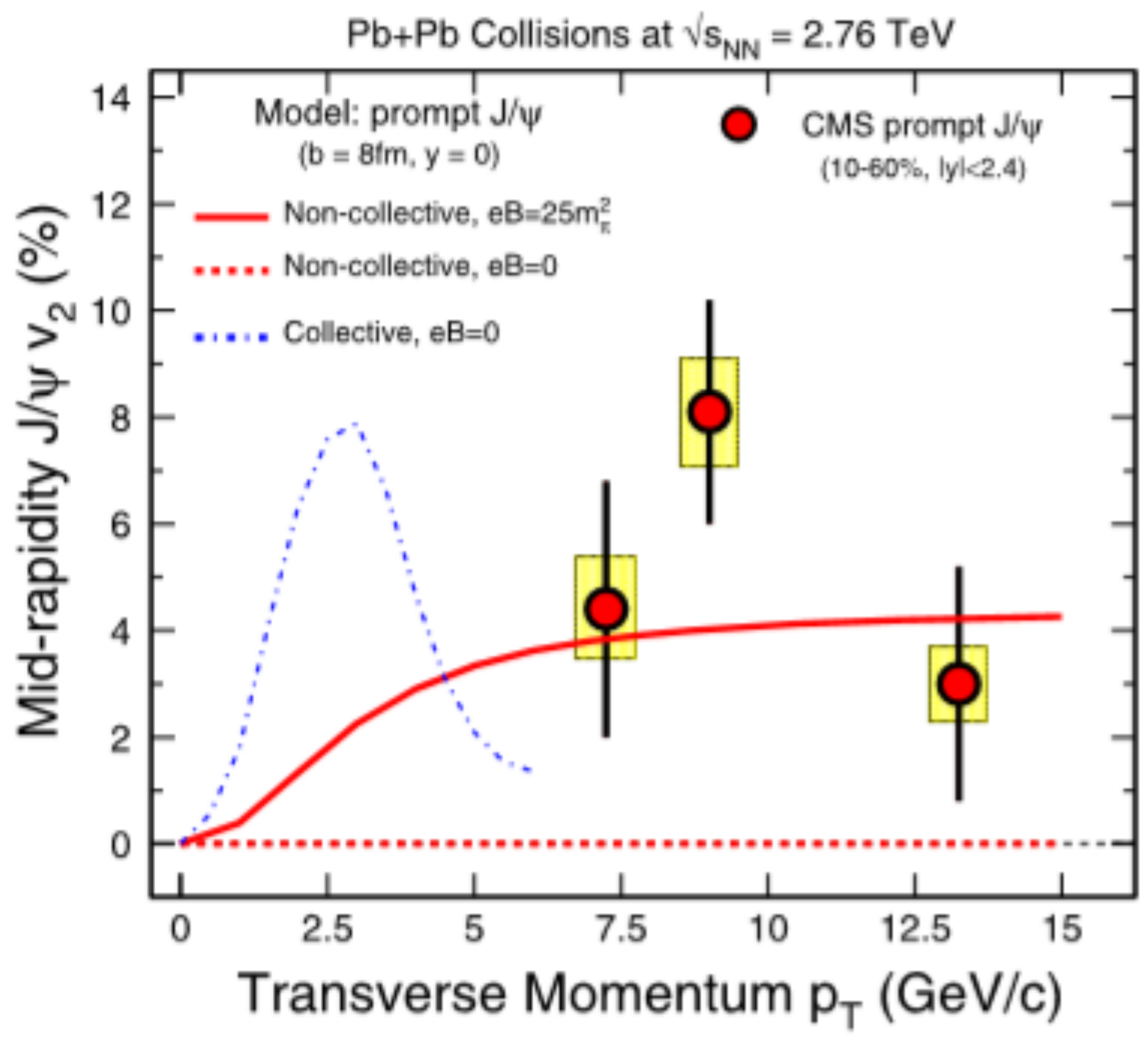
# Magnetic Field in HiC

- Large peak value, short(?) life-time
- Magnetic effects:
  - Anomalous transport
  - Anisotropy: $v_2$
  - Spin polarization / alignment
  - …

# Charmonium

- Charmonia are important probes of the QGP and the B field
  - Yield: suppression / enhancement
  - $v_2$
  - Spin alignment
  - ...

Magnetic effect?




XYG, Shuzhe Shi, Nu Xu, Zhe Xu, Pengfei Zhuang, *Phys.Lett.B* 751 (2015) 215-219

# Two-body Schrödinger equation with magnetic field

$$\left[\frac{\mathbf{p}^2}{m_c} + V - \frac{q(\mathbf{S}_a - \mathbf{S}_b)\cdot\mathbf{B}}{m_c} + \frac{q^2\mathbf{B}^2 r^2}{4m_c} + \frac{(q\mathbf{B}\times\mathbf{P}_{ps})\cdot\mathbf{r}}{2m_c}\right]\psi = \left[E - 2m_c - \frac{\mathbf{P}_{ps}^2}{4m_c}\right]\psi$$

$$\mathbf{P}_{ps} = \mathbf{P} + q(\mathbf{A}_c - \mathbf{A}_{\bar{c}})$$

"Magnetic Constraint"

"Lorentz Force"

- Magnetic field: constraining vs. dissociation
- Momentum: only dissociation
- Total momentum, orbital angular momentum and spin are not conserved.

# Two-body Schrödinger equation with magnetic field

$$\left[-\frac{d^2}{dr^2}+m_qV_c+\frac{1}{4}m_qV_s+\frac{1}{r^2}\boldsymbol{U}+\frac{q^2B^2}{4}r^2\boldsymbol{V}+\frac{qBP_{ps,\perp}}{2}r\boldsymbol{W}-\lambda\right]\boldsymbol{\Phi}^{t\pm}(r)=0,$$

$$\left[-\frac{d^2}{dr^2}+m_qV_c+\frac{1}{4}m_qV_s+\frac{1}{r^2}\boldsymbol{U}+\frac{q^2B^2}{4}r^2\boldsymbol{V}+\frac{qBP_{ps,\perp}}{2}r\boldsymbol{W}-\lambda\right]\boldsymbol{\Phi}^{t0}(r)-qB\boldsymbol{\Phi}^{s0}(r)=0,$$

$$\left[-\frac{d^2}{dr^2}+m_qV_c-\frac{3}{4}m_qV_s+\frac{1}{r^2}\boldsymbol{U}+\frac{q^2B^2}{4}r^2\boldsymbol{V}+\frac{qBP_{ps,\perp}}{2}r\boldsymbol{W}-\lambda\right]\boldsymbol{\Phi}^{s0}(r)-qB\boldsymbol{\Phi}^{t0}(r)=0.$$

$J/\psi^{\pm}$

$J/\psi^{0}$

$\eta_c$

Possibly spin alignment induced by B field?

# Potential and Parameters

$$V_c = \frac{\sigma}{2^{3/4}\Gamma(3/4)}\sqrt{\frac{r}{\mu}}K_{1/4}(\mu^2 r^2) - \alpha\frac{e^{-\mu r}}{r}$$

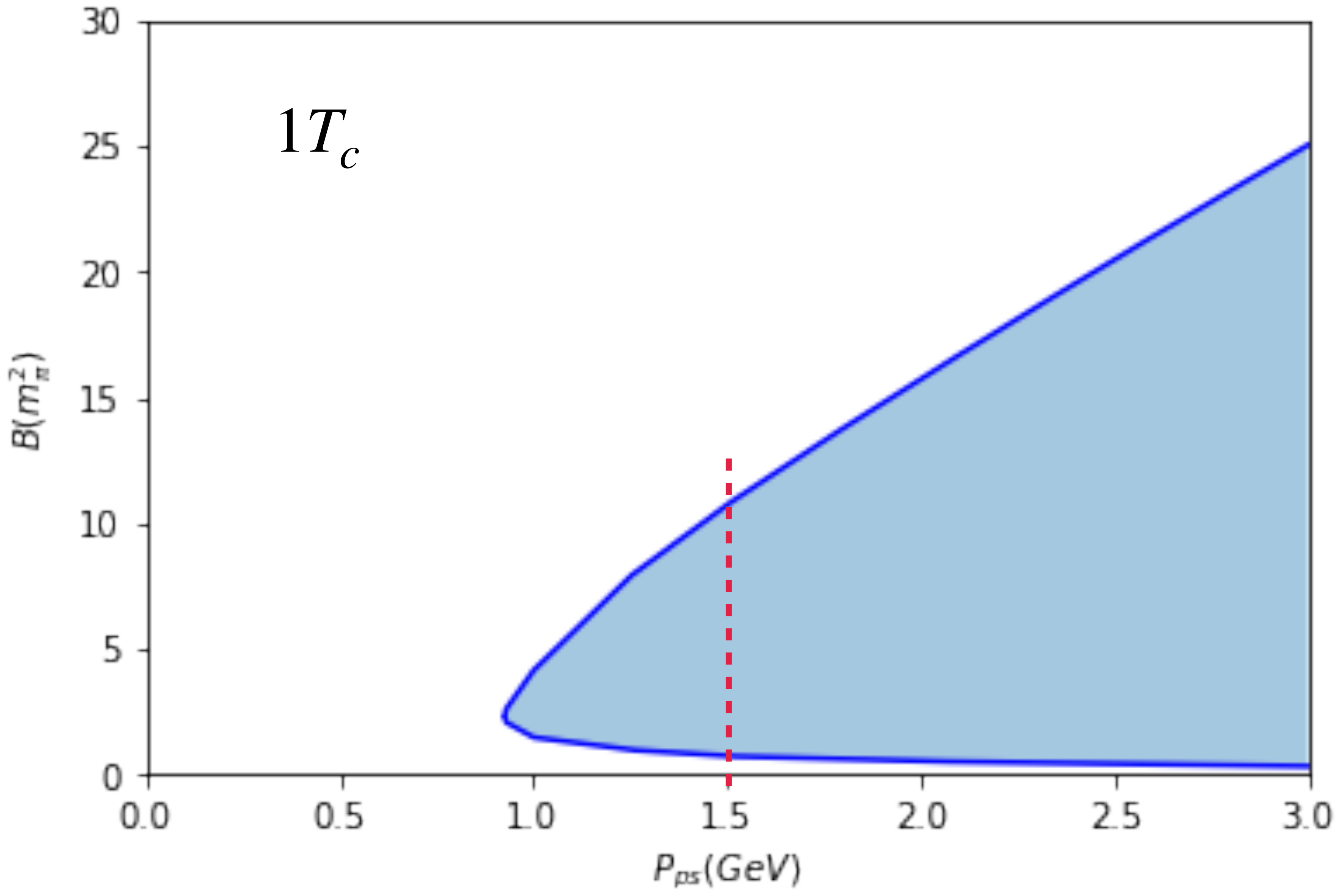
[H. Satz, J. Phys. G 32, R25 (2006)]

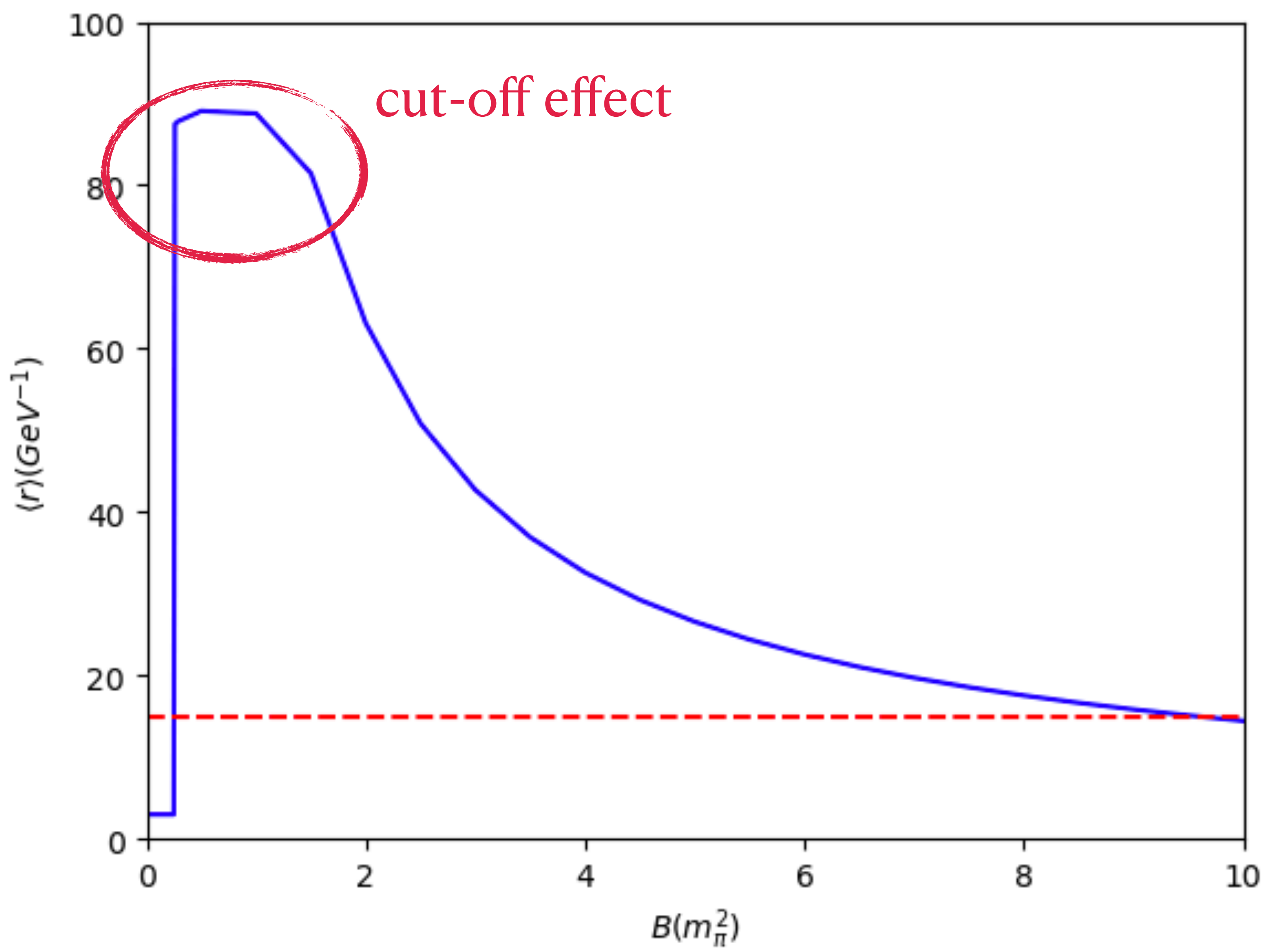
$$V_s = \beta e^{-\gamma r}$$

T. Kawanai and S. Sasaki, Phys. Rev. D 85, 091503 (2012)

$$m_c = 1.25 GeV, \alpha = \frac{12}{\pi}, \sqrt{\sigma} = 0.445 GeV, \beta = 1.982 GeV, \gamma = 2.06 GeV$$

# $J/\psi^{\pm}$



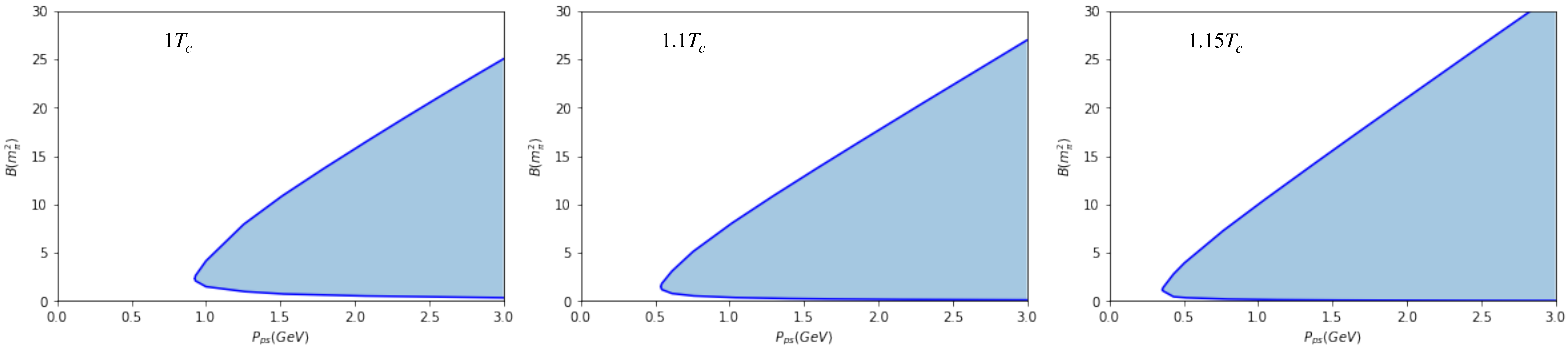




- Sudden dissociation at small B.
- Slow “recombination” at large B.



Da Teng, XYG, *Chin.Phys.C* 46 (2022) 9, 094104

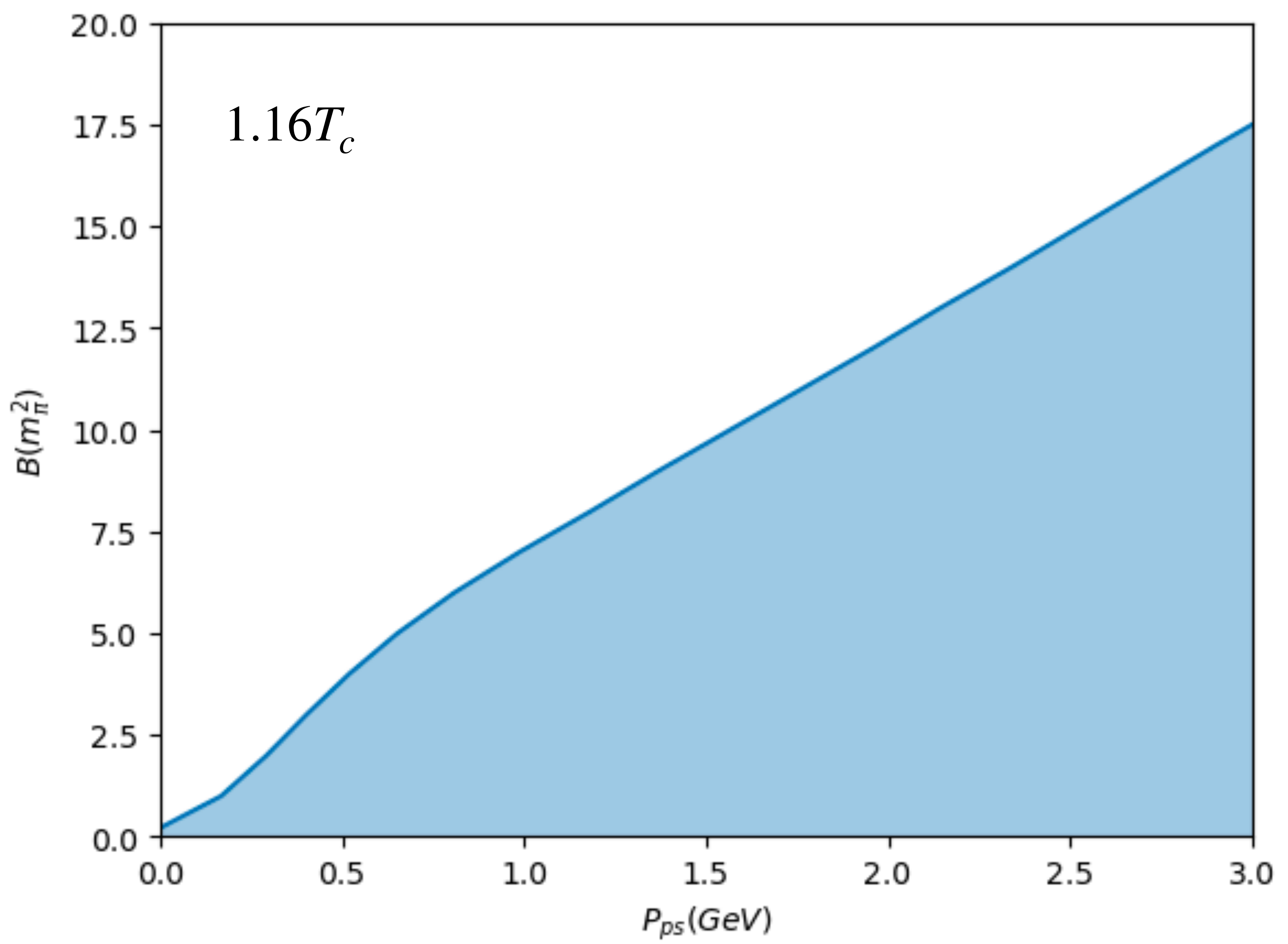
# $J/\psi^{\pm}$




- Dissociation at moderate B field and large momentum: suppression
- Easier to dissociate at higher temperature

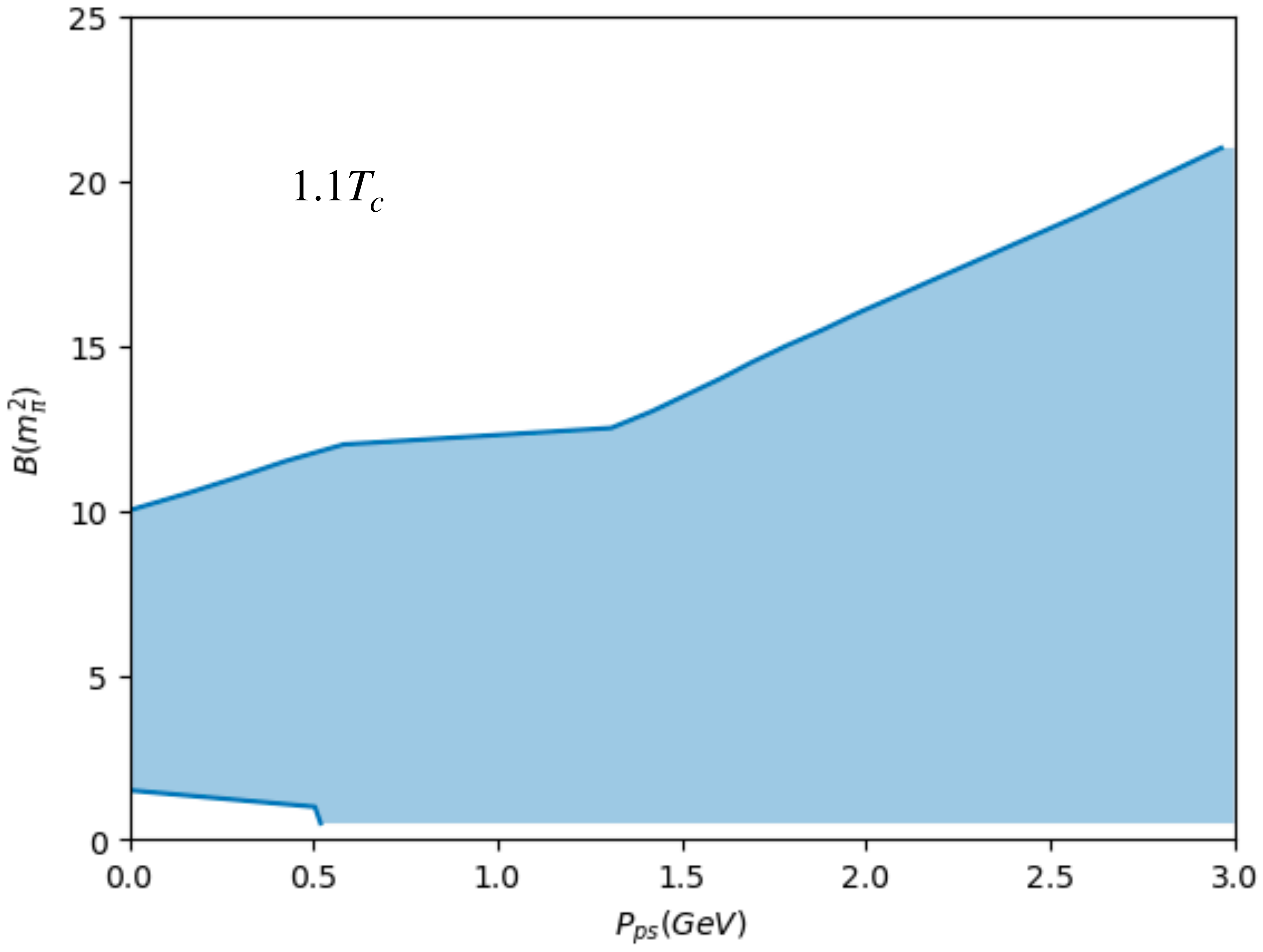
Da Teng, XYG, *Chin.Phys.C* 46 (2022) 9, 094104

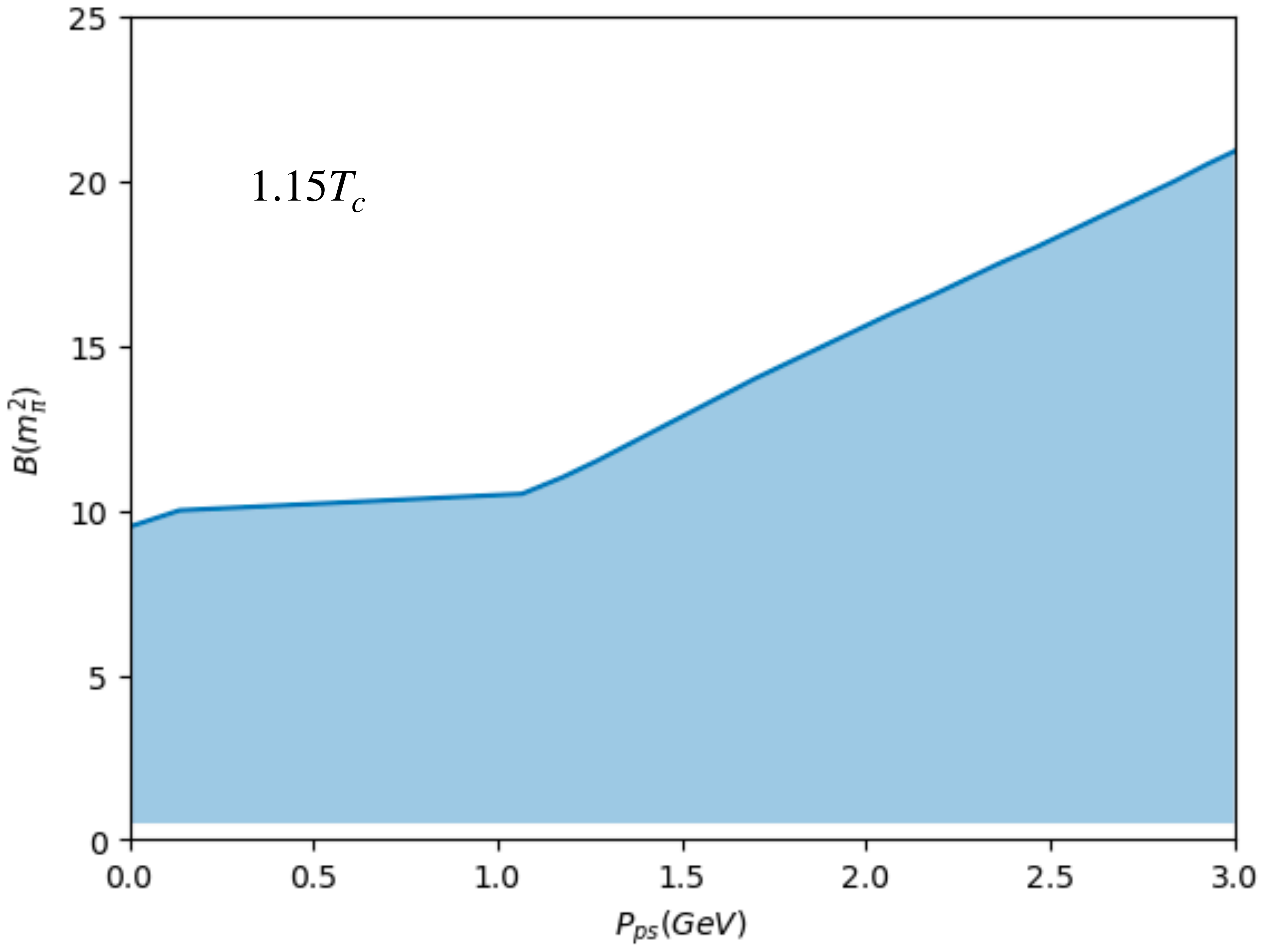
# Higher Temperature




- At temperature above $T_d$, magnetic field can form bounded states: enhancement?

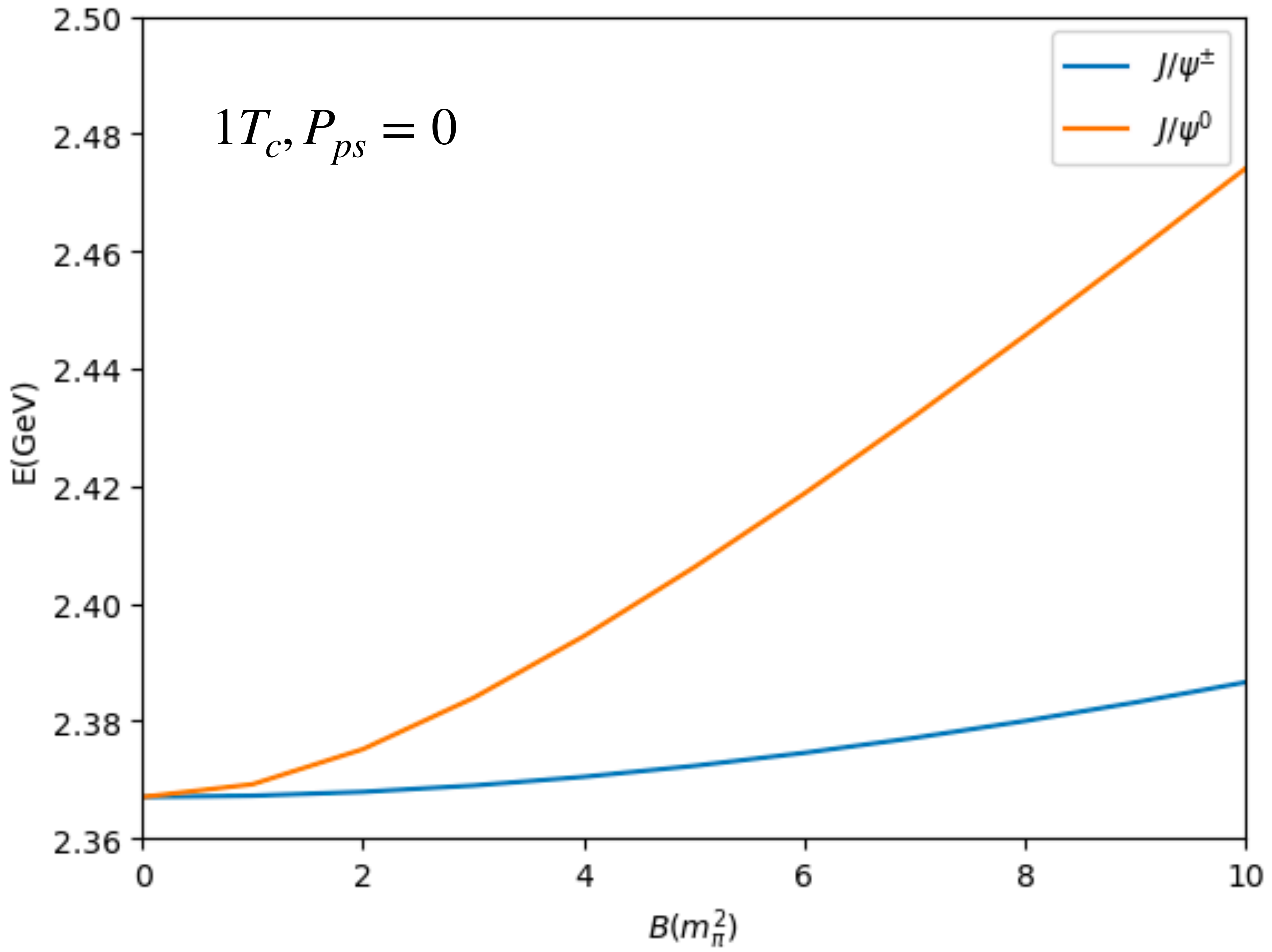
# $J/\psi^0$




- $J/\psi^0$ is easier to dissociate than $J/\psi^{\pm}$: $\rho_{00} < \frac{1}{3}$?

# Energy Splitting




- $J/\psi^0$ is “heavier” than $J/\psi^\pm$.

# Summary and Outlook

- We use Schrödinger equation to calculate $J/\psi$ states at finite temperature and temperature.
- Magnetic field has both suppression and enhancement effects on $J/\psi$ production.
- Magnetic field also causes splitting of $J/\psi^{\pm}$ and $J/\psi^{0}$ states, suggesting a $\rho_{00} < \frac{1}{3}$.
- All these effects are anisotropic.
- More quantitative calculation needed.