Rotational effect of quarkonium dissociation

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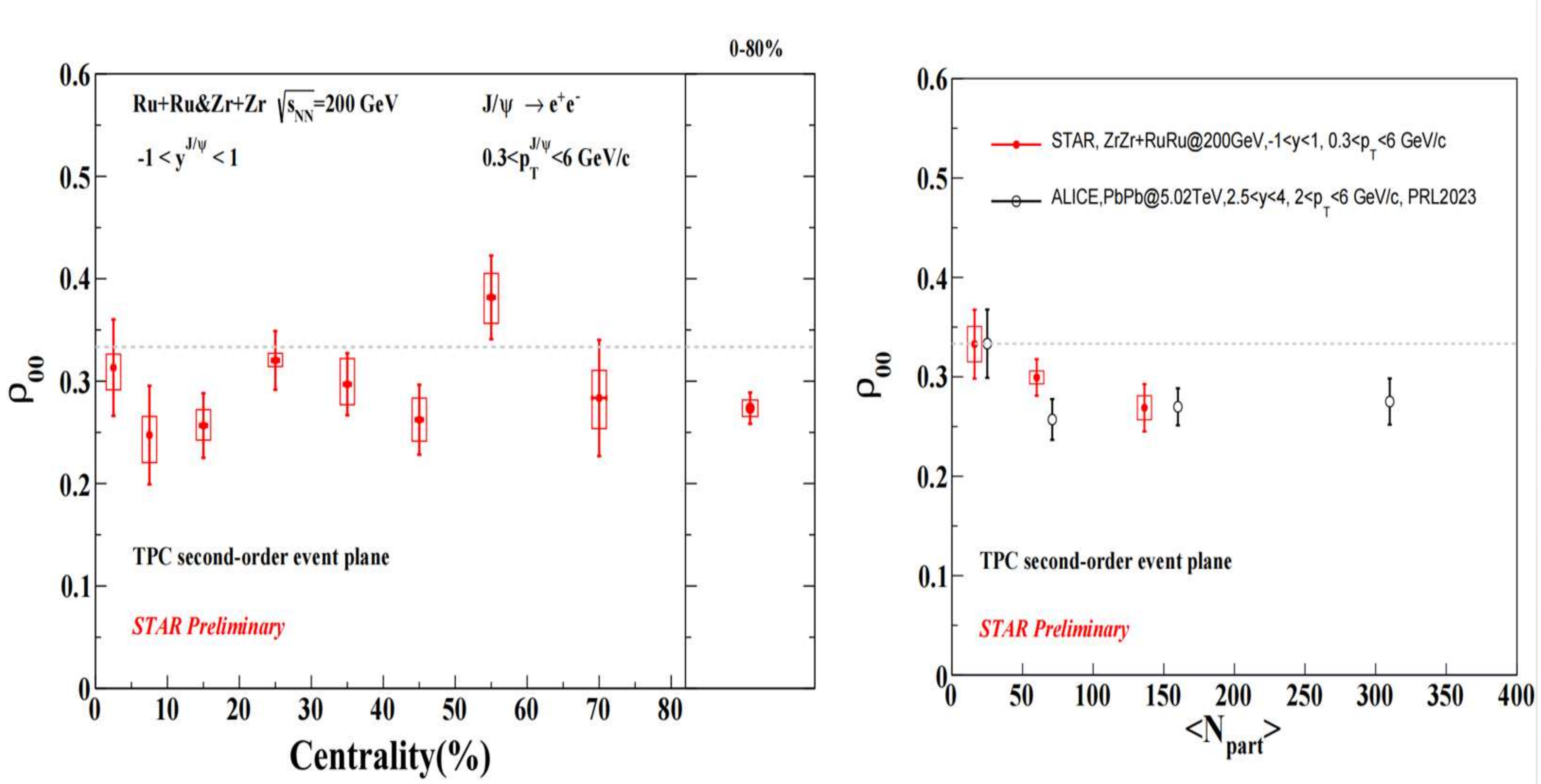
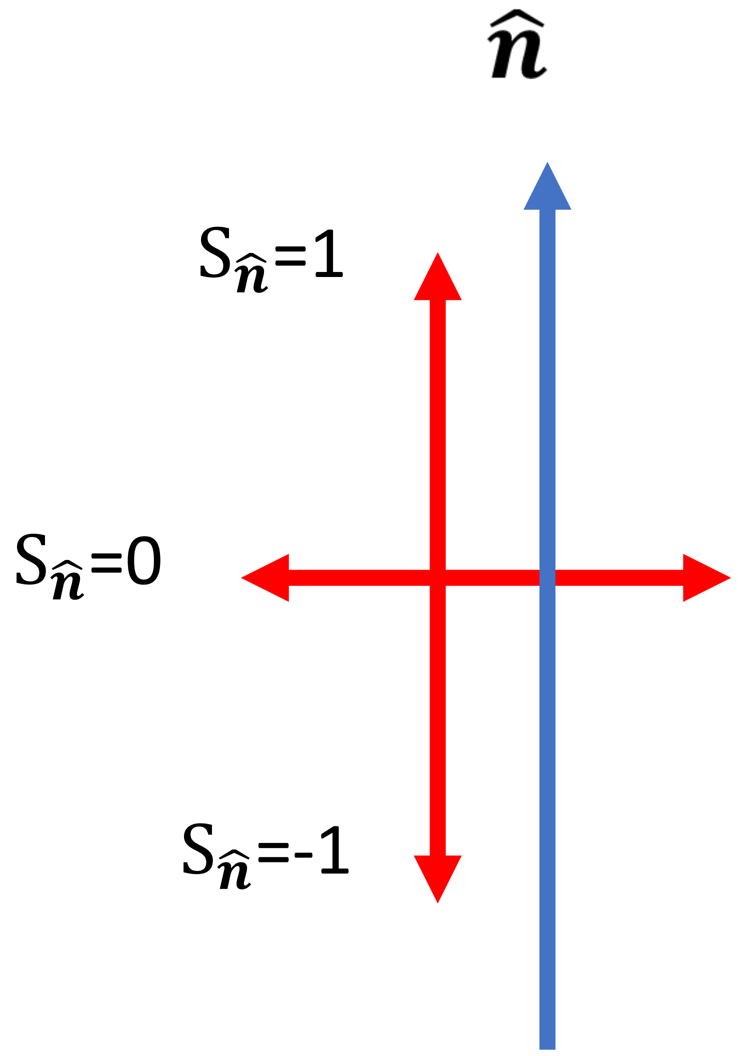
Introduction



Experimental data from STAR Collaboration

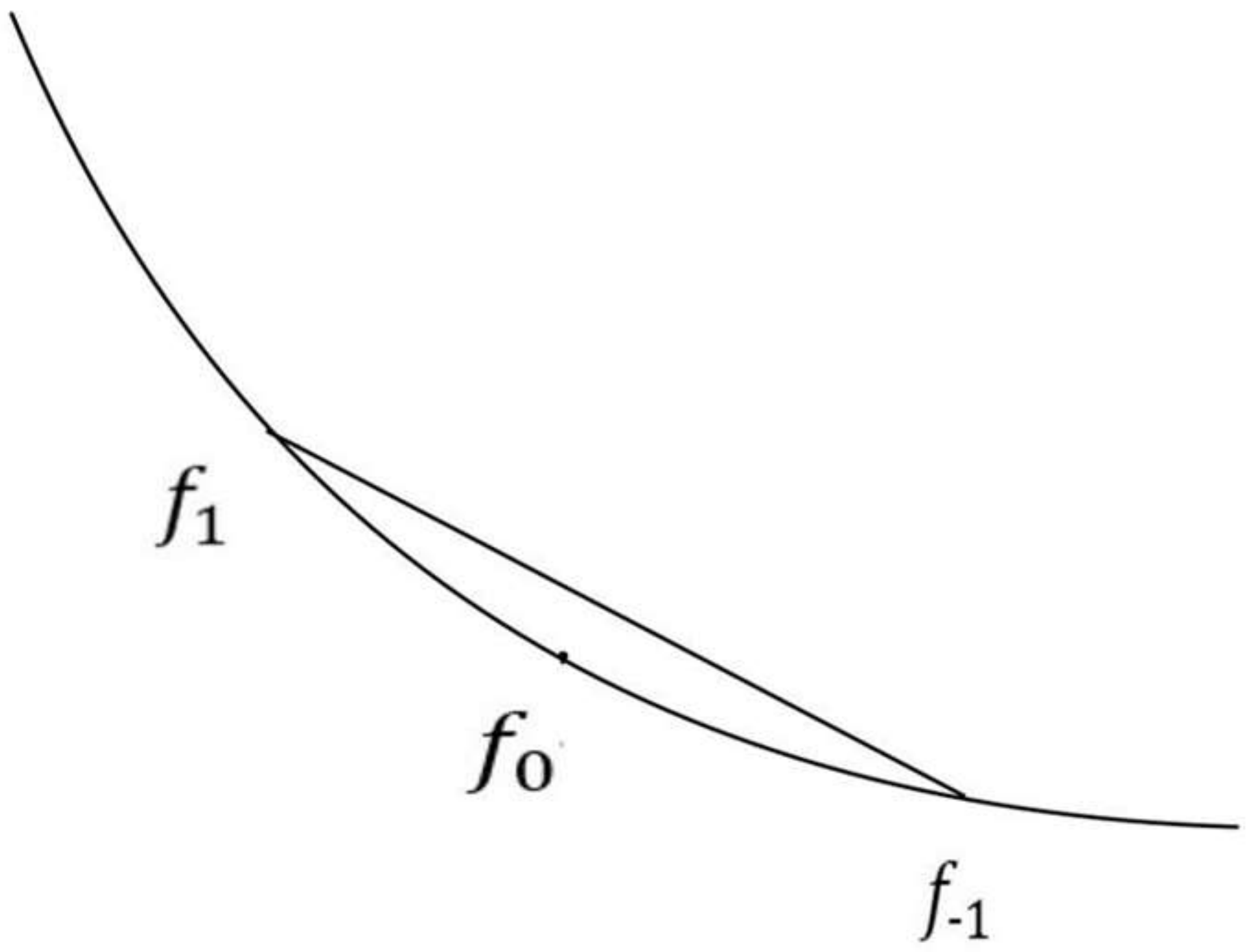


Recently, RHIC has found that ρ_{00} is less than 1/3 with a significance of 3.5 σ for p_T ranging from 0.3 < p_T < 6.0 GeV/c and for events spanning 0-80% centrality[1].

$\rho_{00} < 1/3 \Leftrightarrow$number of $S_{\hat{n}}$=0 $< 1/3$(total number)

[1] STAR Collaboration, SPIN2023 (2024) 236.

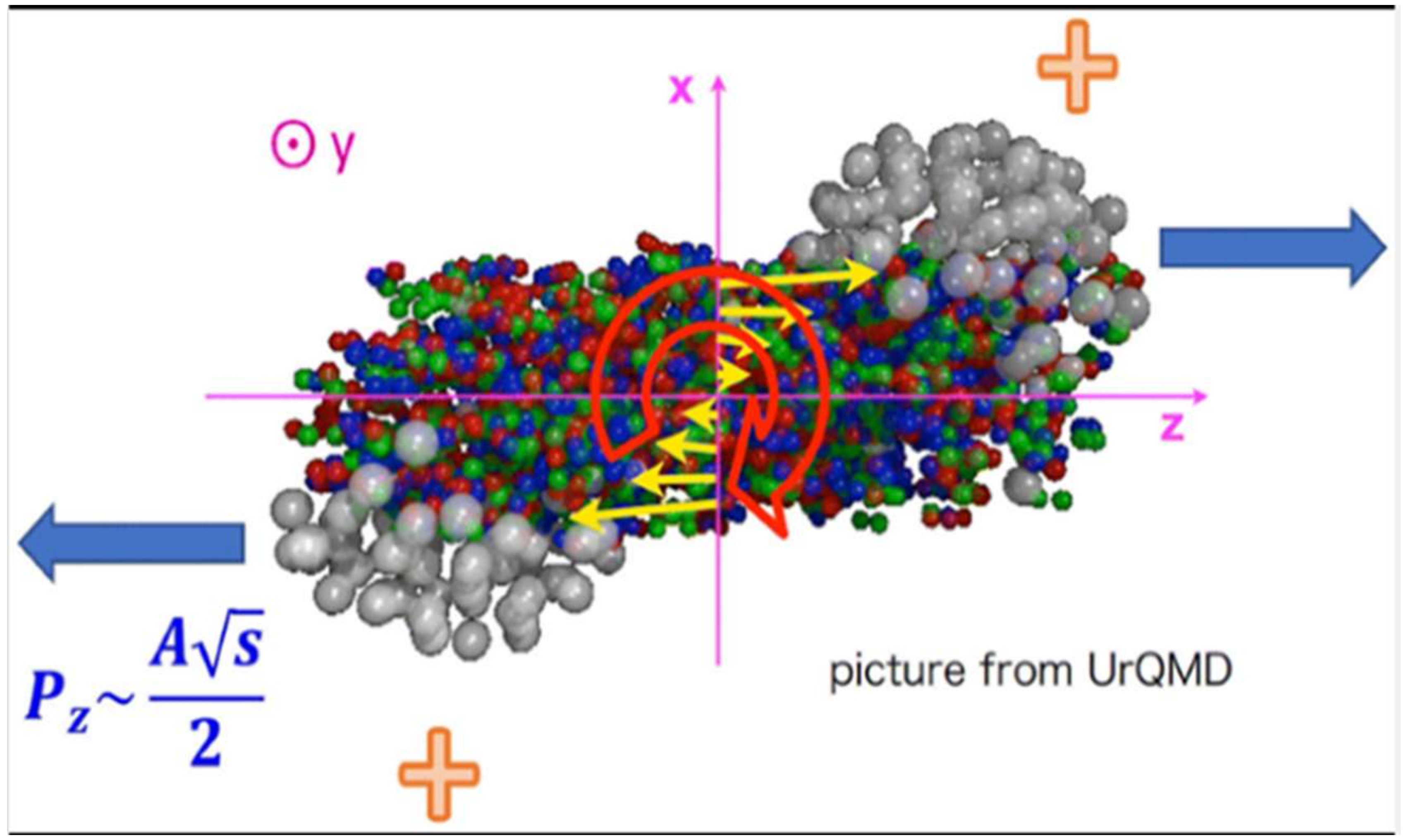
Method



The remaining J/ψ particles in different spin direction：

$f_i \propto e^{-C_i t} \propto \rho_{\mathrm{ii}}$ ， $C_i = \Gamma_0 + \Gamma_i^{(1)} = \Gamma_0 + \#S_i\omega$

$f_1 + f_{-1} > 2f_0 \Rightarrow \rho_{11} + \rho_{-1-1} > 2\rho_{00} \Rightarrow \rho_{00} < \frac{1}{3}$



Non-central heavy ion collision form QGP vortices with very large angular momentum

Method

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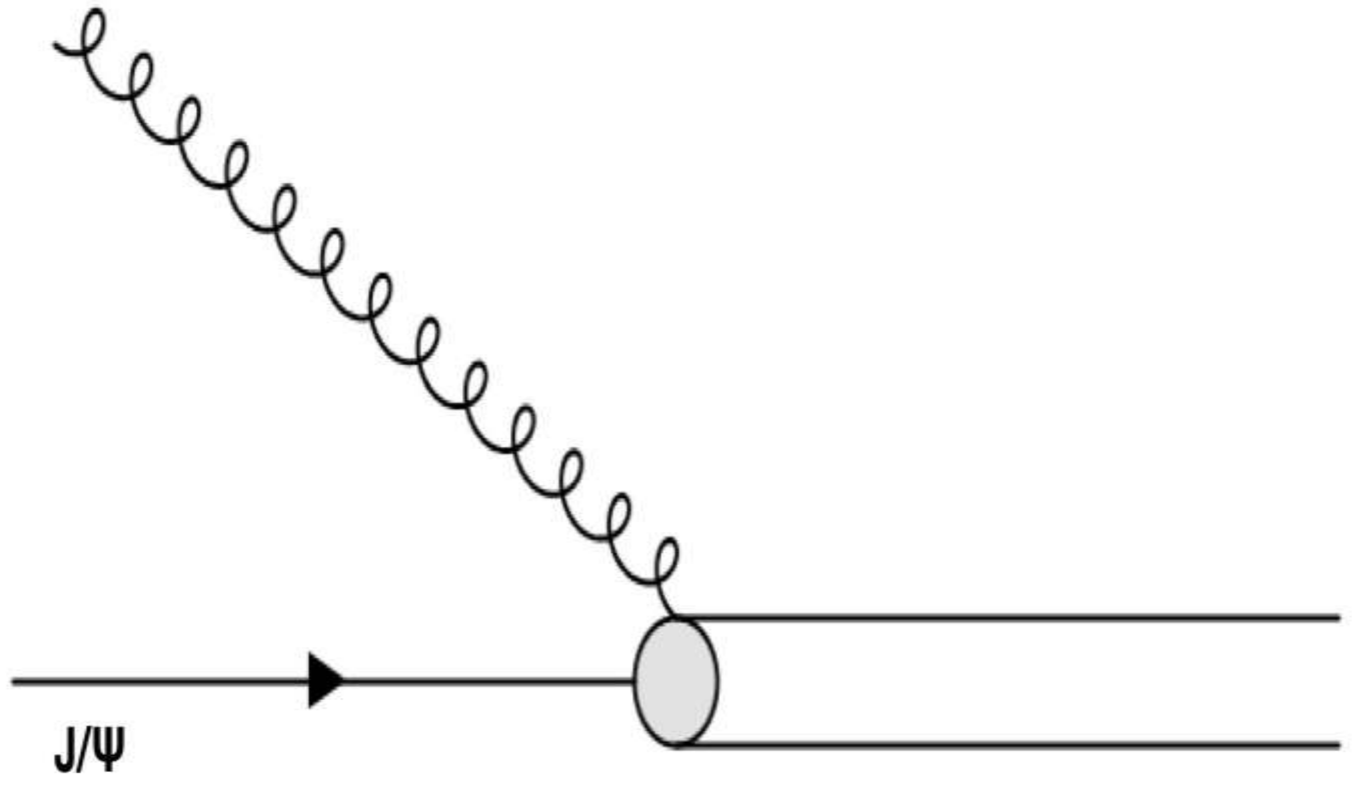
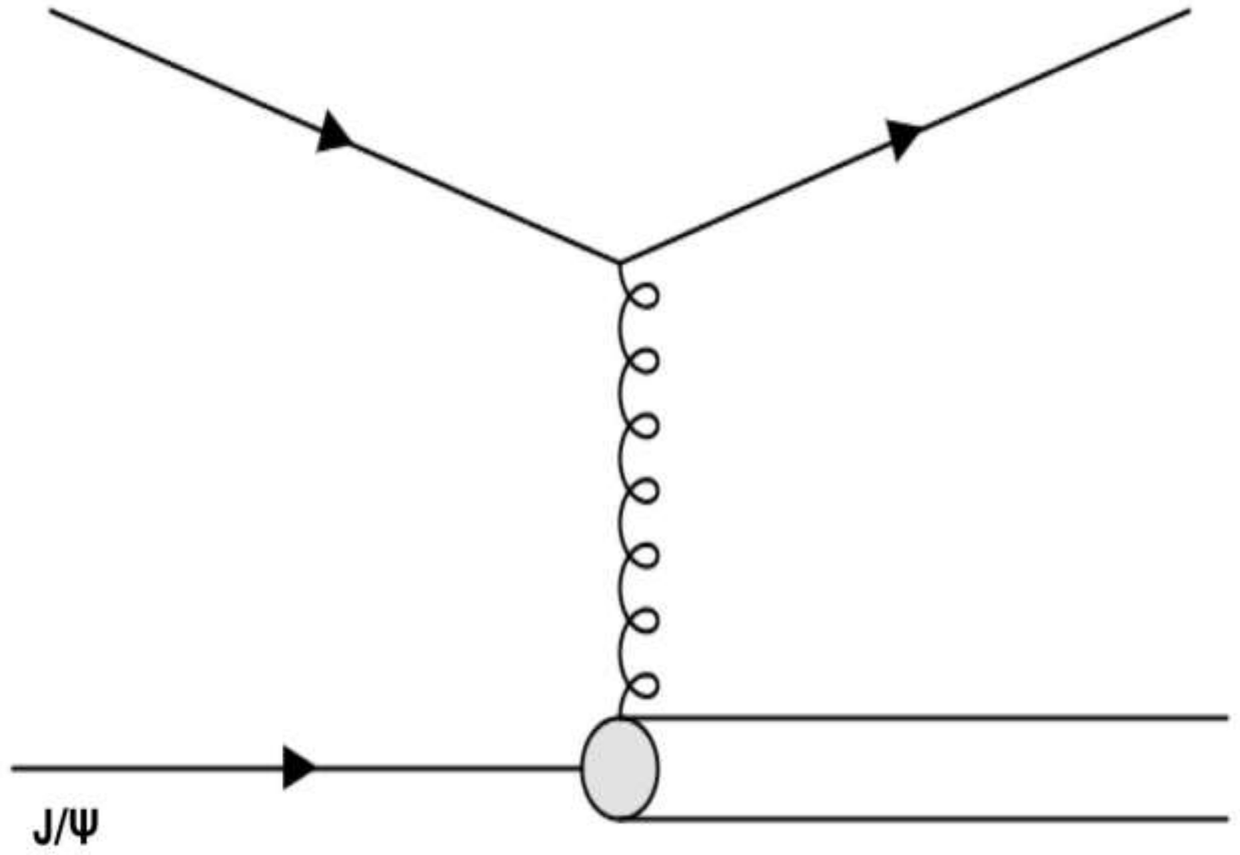
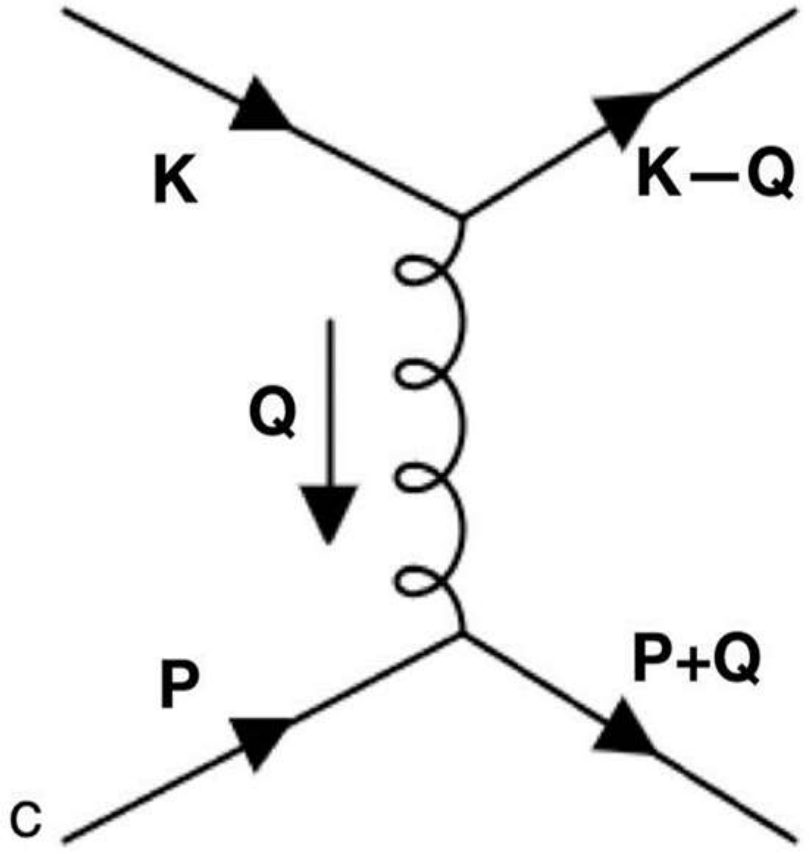


LO



NLO

Quasi-free

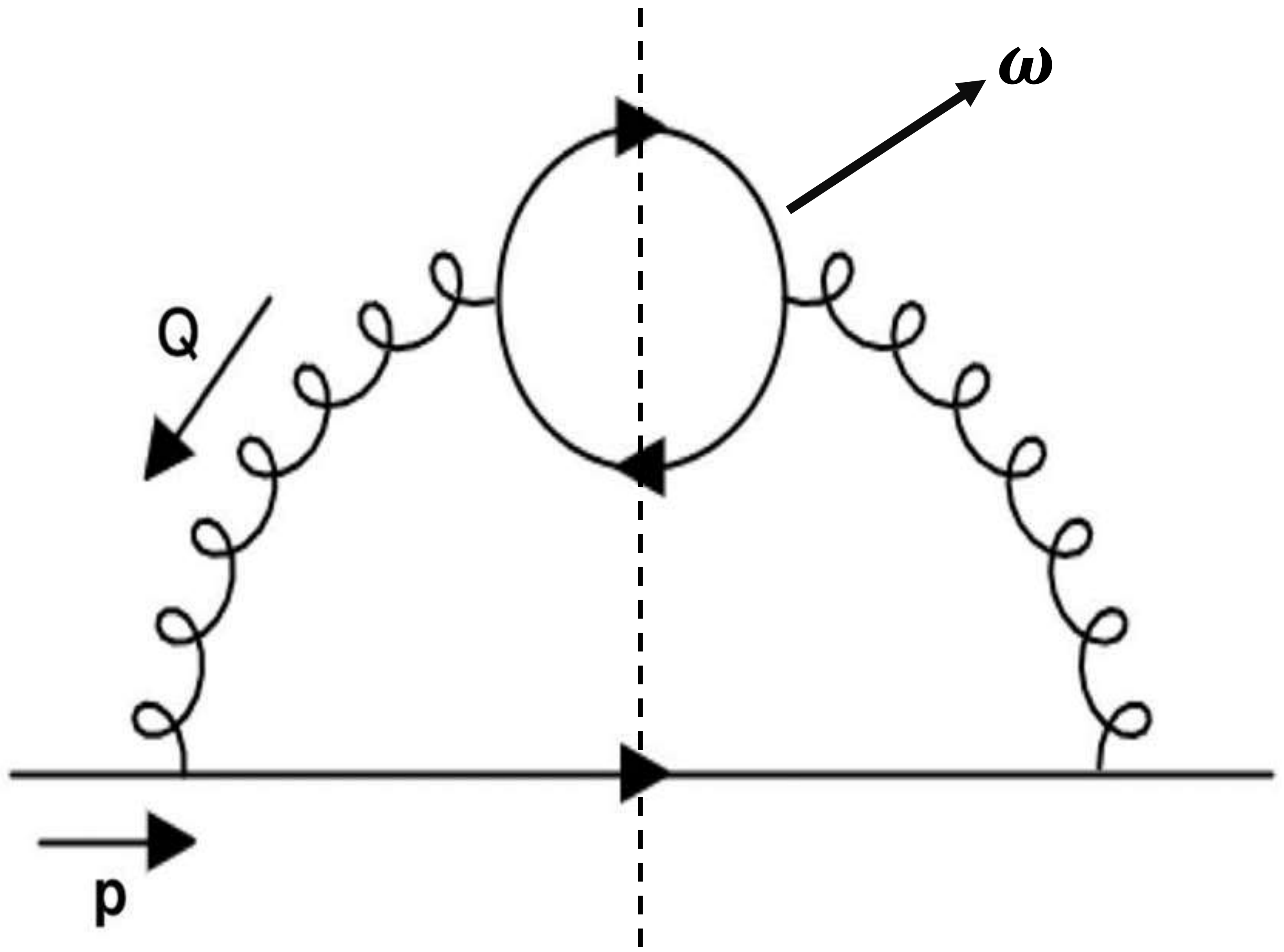


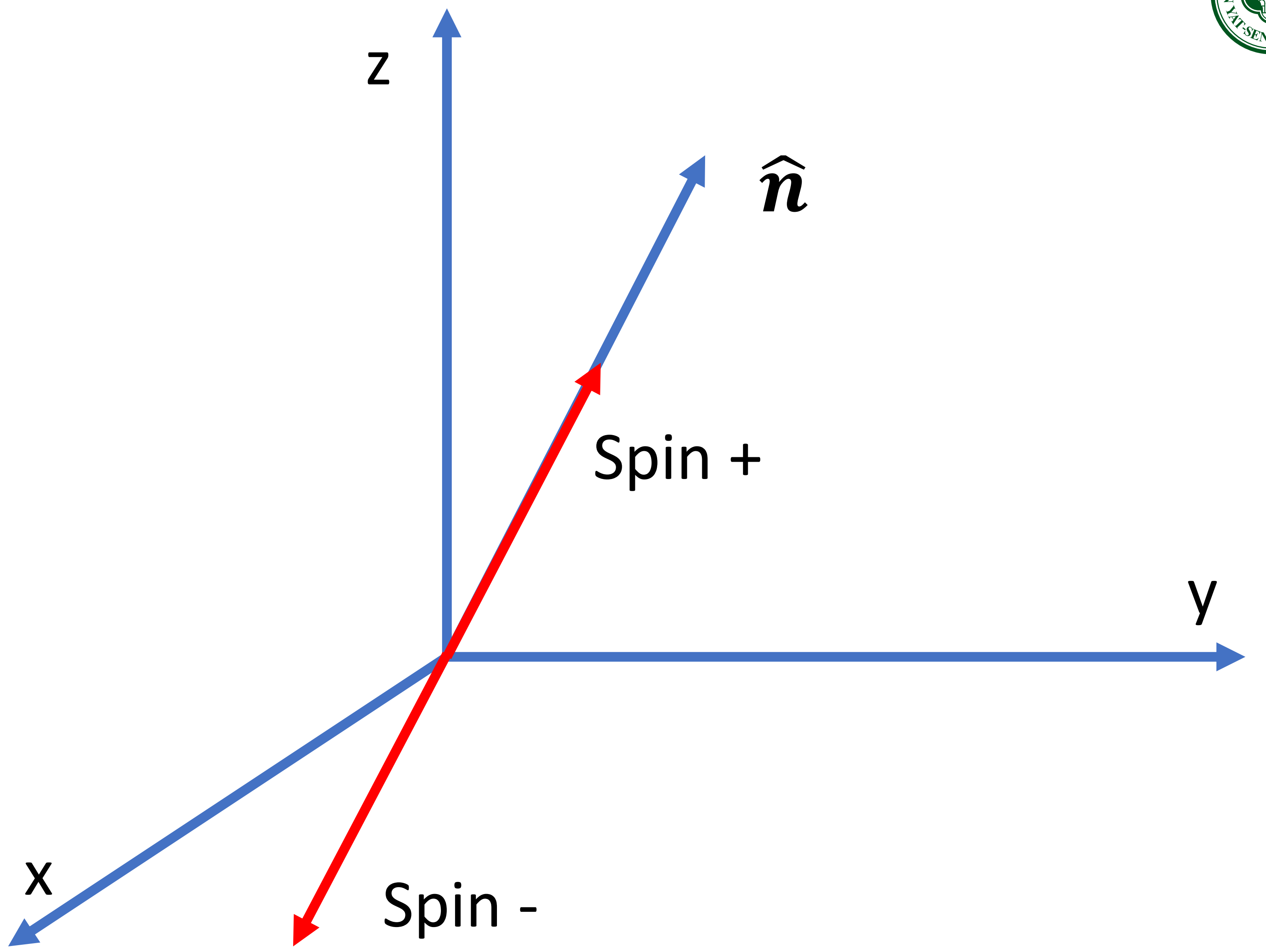
Scattering of c quark and quarks in QGP

The LO contributes small to dissociation rate when the binding energy is small[2], so we primarily consider the NLO, while treating the c or $\bar{c}$ quark in the J/ψ particle as quasi-free particles.

[2] L. Grandchamp, R. Rapp, Phys. Lett. B 523:60-66 (2001)

Method





In order to obtain the dissociation rate, we need to first calculate the charm quark self-energy $\Sigma^{>}(\mathrm{p})$.

Damping rate $\Gamma_s^{(1)}$:

$$\Gamma_{\mathrm{s}}^{(1)} = \frac{1}{\mathrm{E}} \mathrm{tr}[\mathrm{u_s(p)\bar{u}_s(p)}\Sigma^{>}(\mathrm{p})]$$

$$\mathrm{u_s(p)} \simeq \sqrt{m} \begin{pmatrix} \left(1 - \frac{\vec{p}\cdot\vec{\sigma}}{2m}\right)\xi_s \\ -\left(1 + \frac{\vec{p}\cdot\vec{\sigma}}{2m}\right)\xi_s \end{pmatrix}$$

$$\xi_+ = \frac{1}{\sqrt{2(1-\hat{n}_z)}} \begin{pmatrix} \hat{n}_x - i\hat{n}_y \\ 1 - \hat{n}_z \end{pmatrix}, \xi_- = \frac{1}{\sqrt{2(1+\hat{n}_z)}} \begin{pmatrix} \hat{n}_x - i\hat{n}_y \\ -1 - \hat{n}_z \end{pmatrix}$$

$$\mathrm{tr}[\mathrm{u_s(p)\bar{u}_s(p)}\Sigma^{>}(\mathrm{p})] \propto s$$

Result

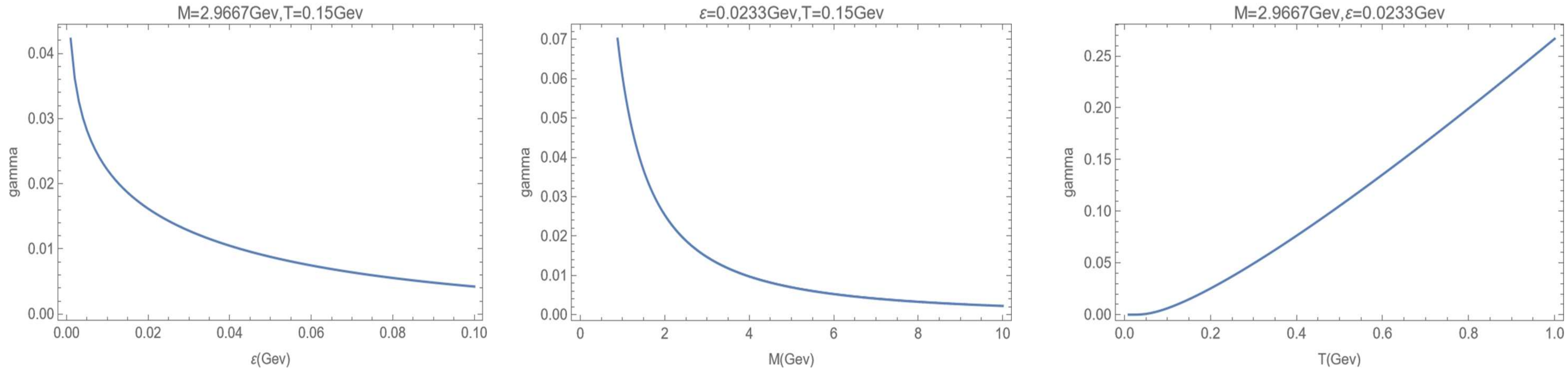
In the quark-gluon plasma rest frame, we can obtain $\Gamma_s^{(1)}$:

$$\Gamma_s^{(1)} = g^4 \frac{N_c^2 - 1}{2N_c} \mathrm{A}_1(p, p^0, \epsilon, \mathrm{T}, \mathrm{M}) S(\hat{\boldsymbol{n}} \cdot \boldsymbol{p})(\boldsymbol{p} \cdot \boldsymbol{\omega}) + g^4 \frac{N_c^2 - 1}{2N_c} \mathrm{A}_2(p, p^0, \epsilon, \mathrm{T}, \mathrm{M}) S\hat{\boldsymbol{n}} \cdot \boldsymbol{\omega}$$

($\hat{\boldsymbol{n}}$ represents an arbitrarily chosen spin quantization axis, $\boldsymbol{\omega}$ represents the vorticity vector,S represents the spin quantum number)

Under the limit $p \to 0$:

$$\Gamma_s^{(1)} = g^4 \frac{N_c^2 - 1}{2N_c} A_2(p, p^0, \epsilon, \mathrm{T}, \mathrm{M}) S\hat{\boldsymbol{n}} \cdot \boldsymbol{\omega}$$

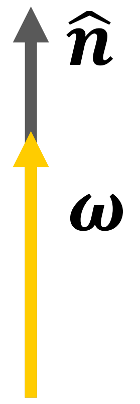


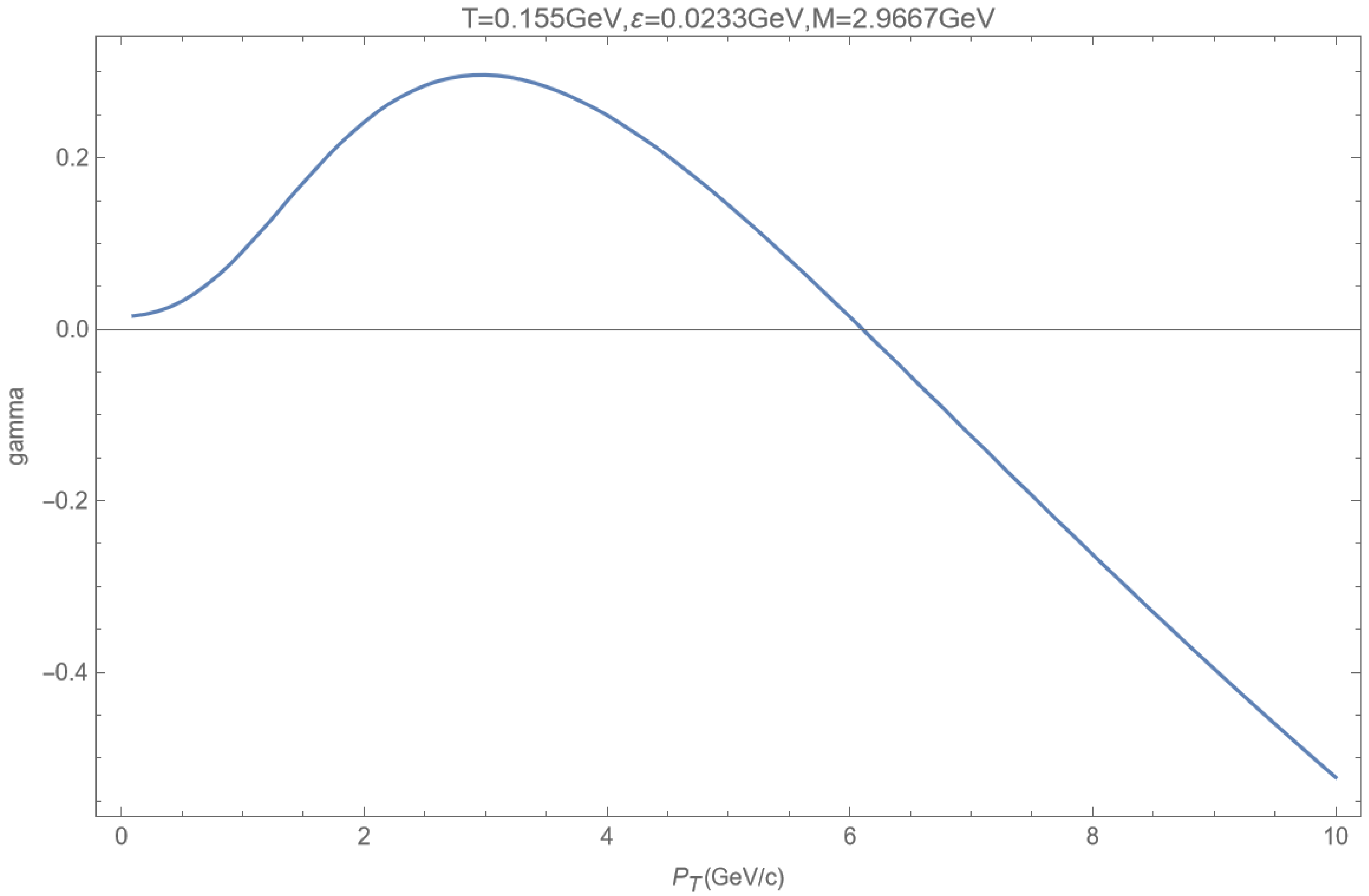
$$(\text{gamma} = g^4 \frac{N_c^2 - 1}{2N_c} \mathrm{A}_2(p, p^0, \epsilon, \mathrm{T}, \mathrm{M}))$$

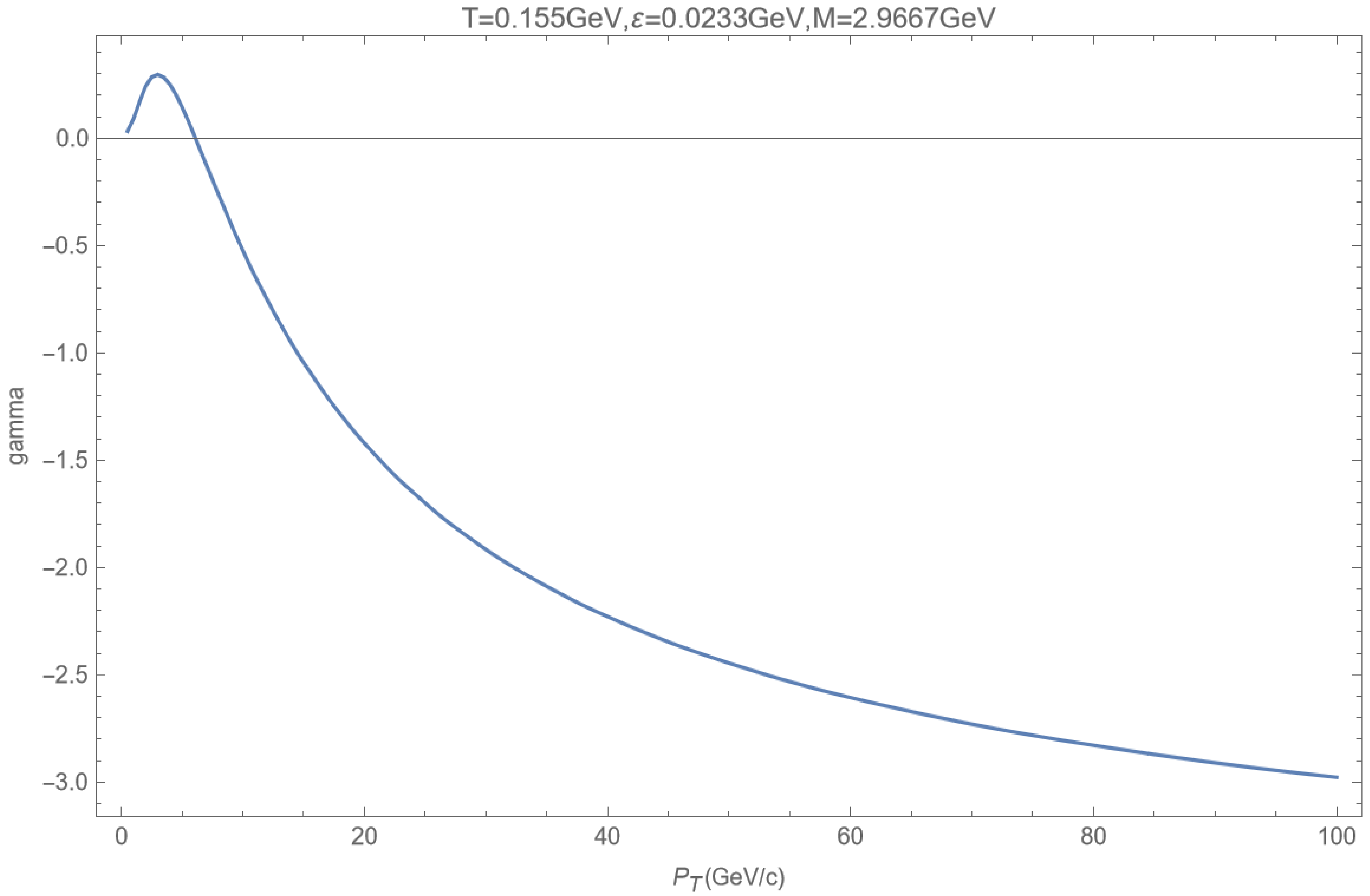
Result

Another limit: we focus on the mid-rapidity region and average over the azimuthal angle of the transverse momentum:

$$\Gamma_s^{(1)} = g^4 \frac{N_c^2 - 1}{2N_c} A_3(p, p^0, \epsilon, \mathrm{T}, \mathrm{M}) \mathrm{S}\omega$$







$$(\text{gamma} = g^4 \frac{N_c^2 - 1}{2N_c} \mathrm{A}_3(p, p^0, \epsilon, \mathrm{T}, \mathrm{M}))$$

Gamma initially increases with transverse momentum, then decreases, and ultimately tends to a constant value(When p is large, the non-zero gamma originates from the integration over the virtual gluon momentum q).

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Thank you

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