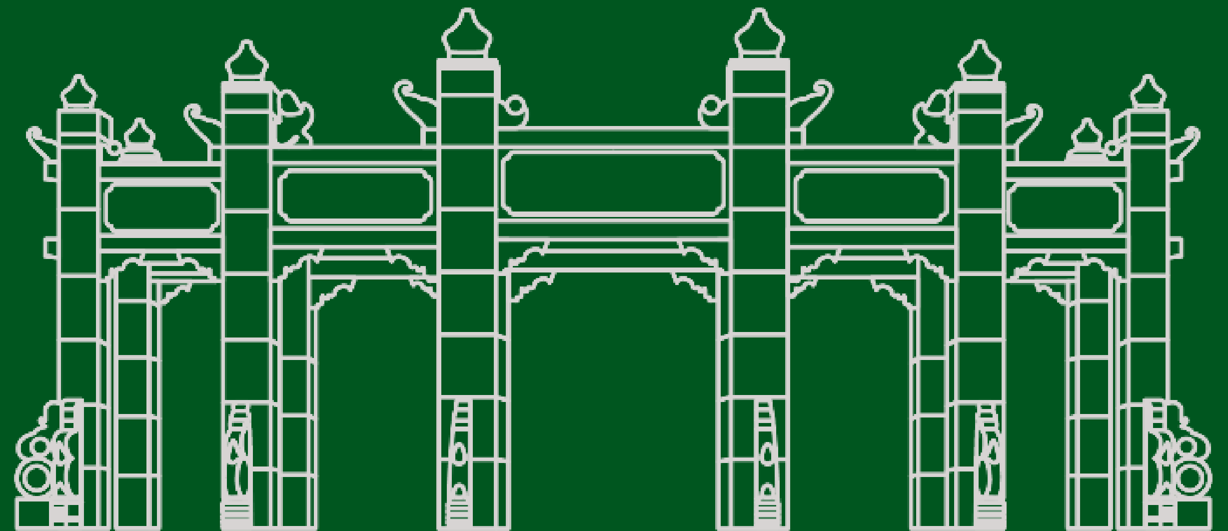
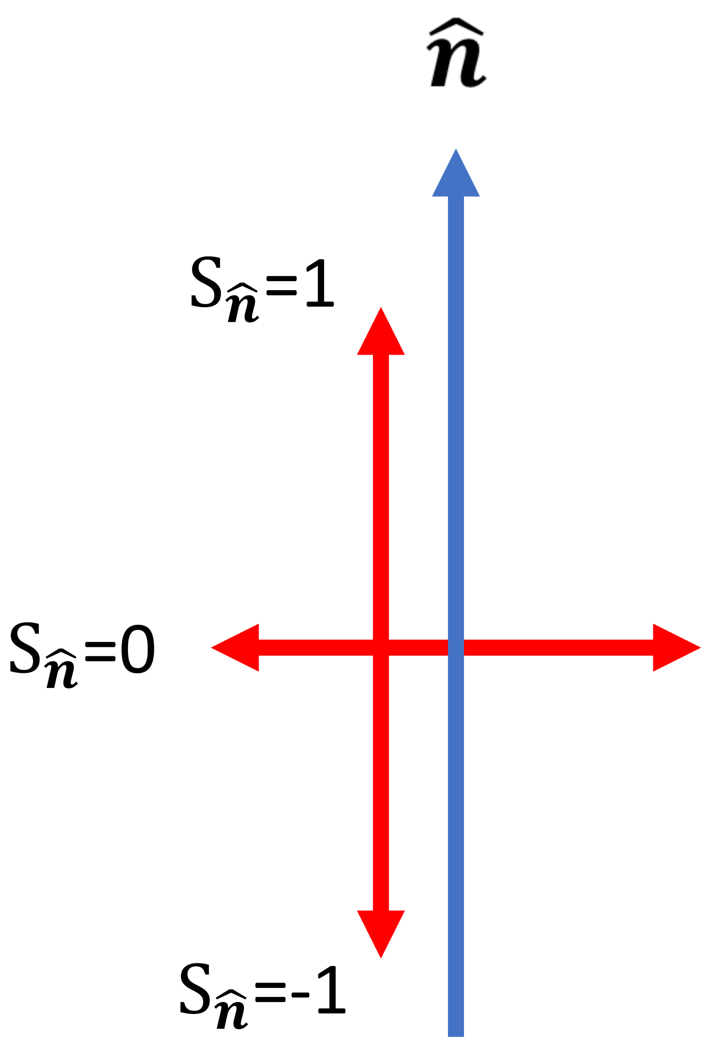
Rotational effect of quarkonium dissociation

Yuhao Liang 2024 12 10 Advisor Shu Lin



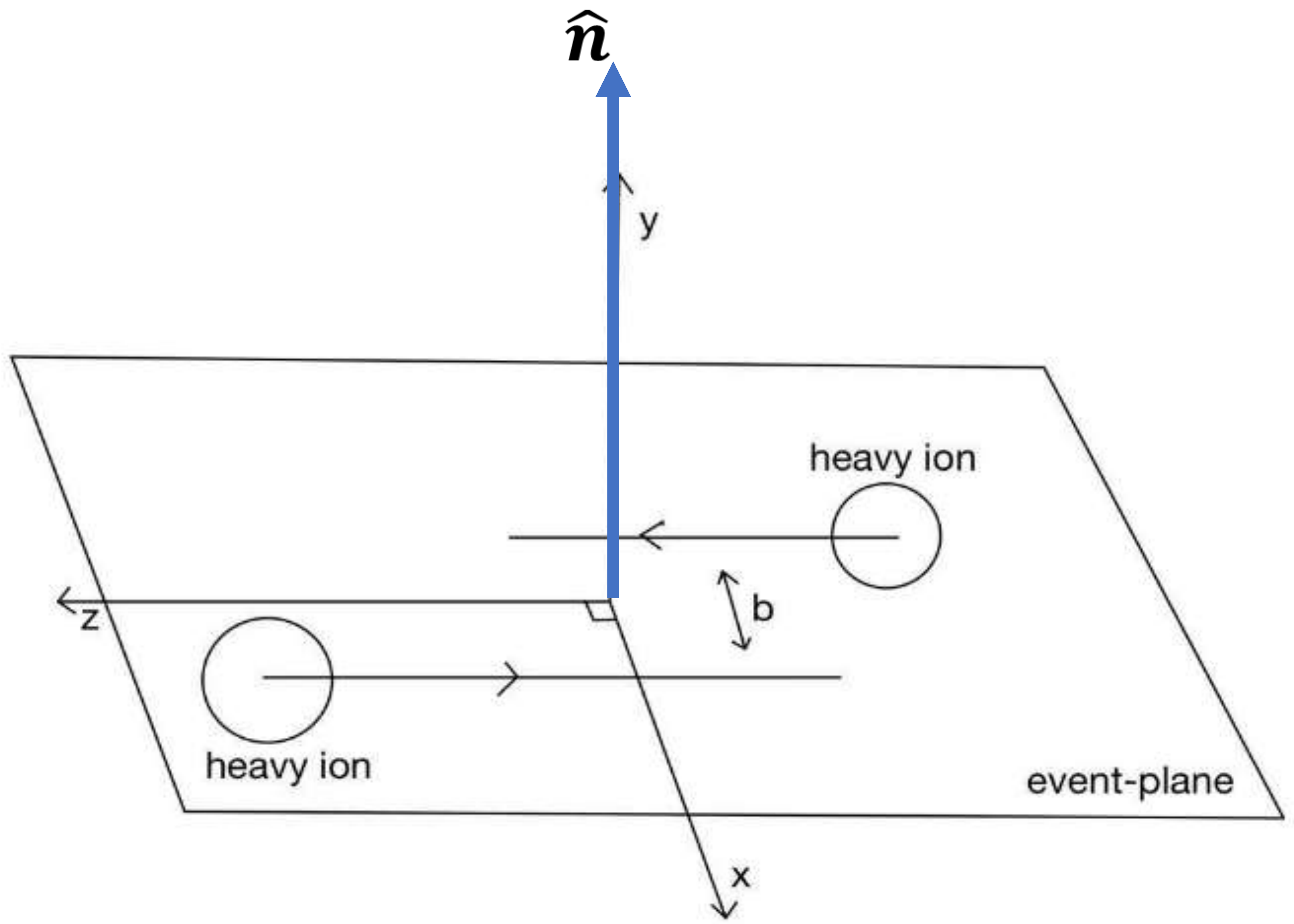
Introduction



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

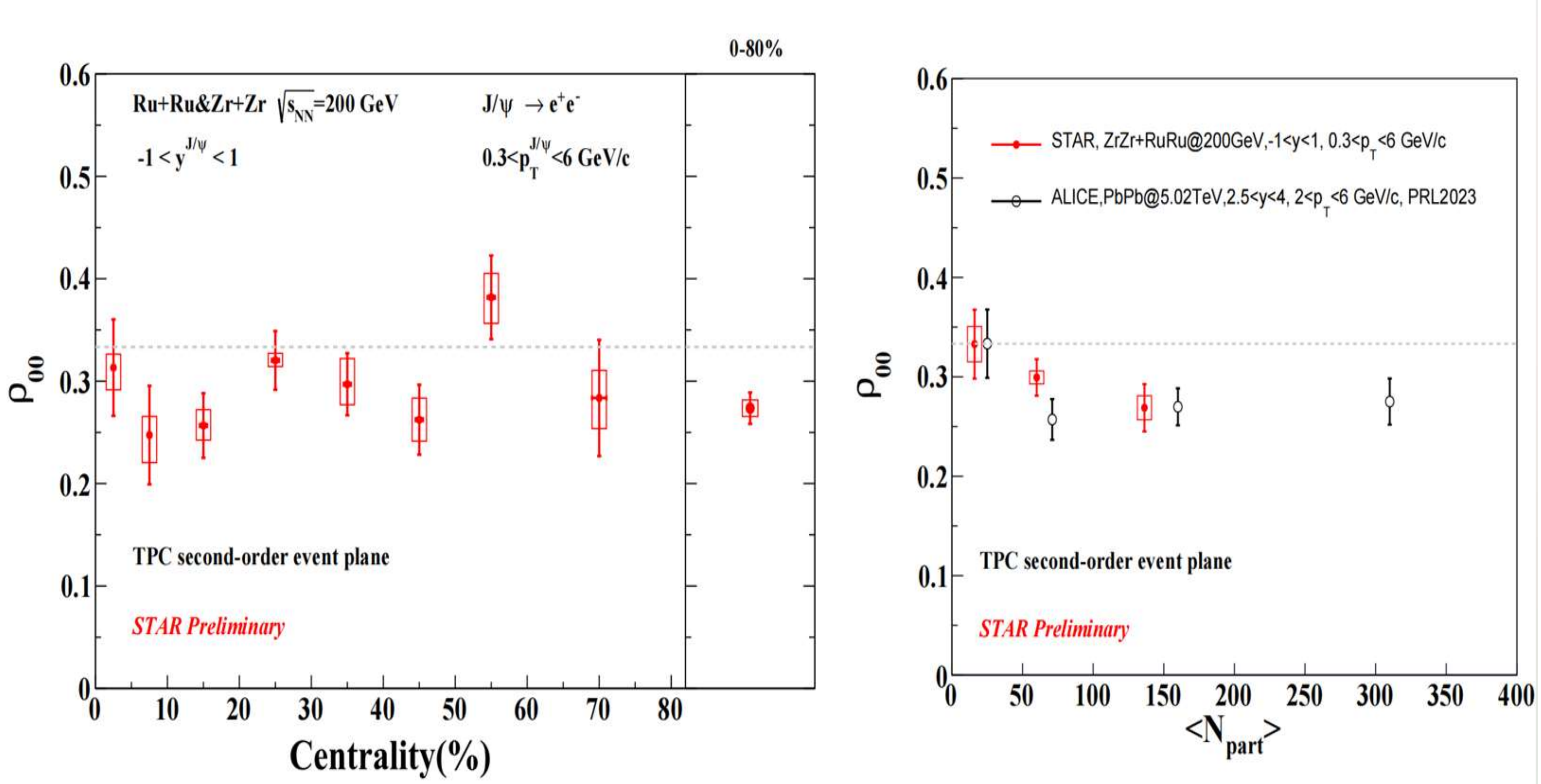
$$\begin{pmatrix} \rho_{-1-1} & \rho_{-10} & \rho_{-11} \\ \rho_{0-1} & \rho_{00} & \rho_{01} \\ \rho_{1-1} & \rho_{10} & \rho_{11} \end{pmatrix}$$

$$\sum_i \rho_{ii}=1$$

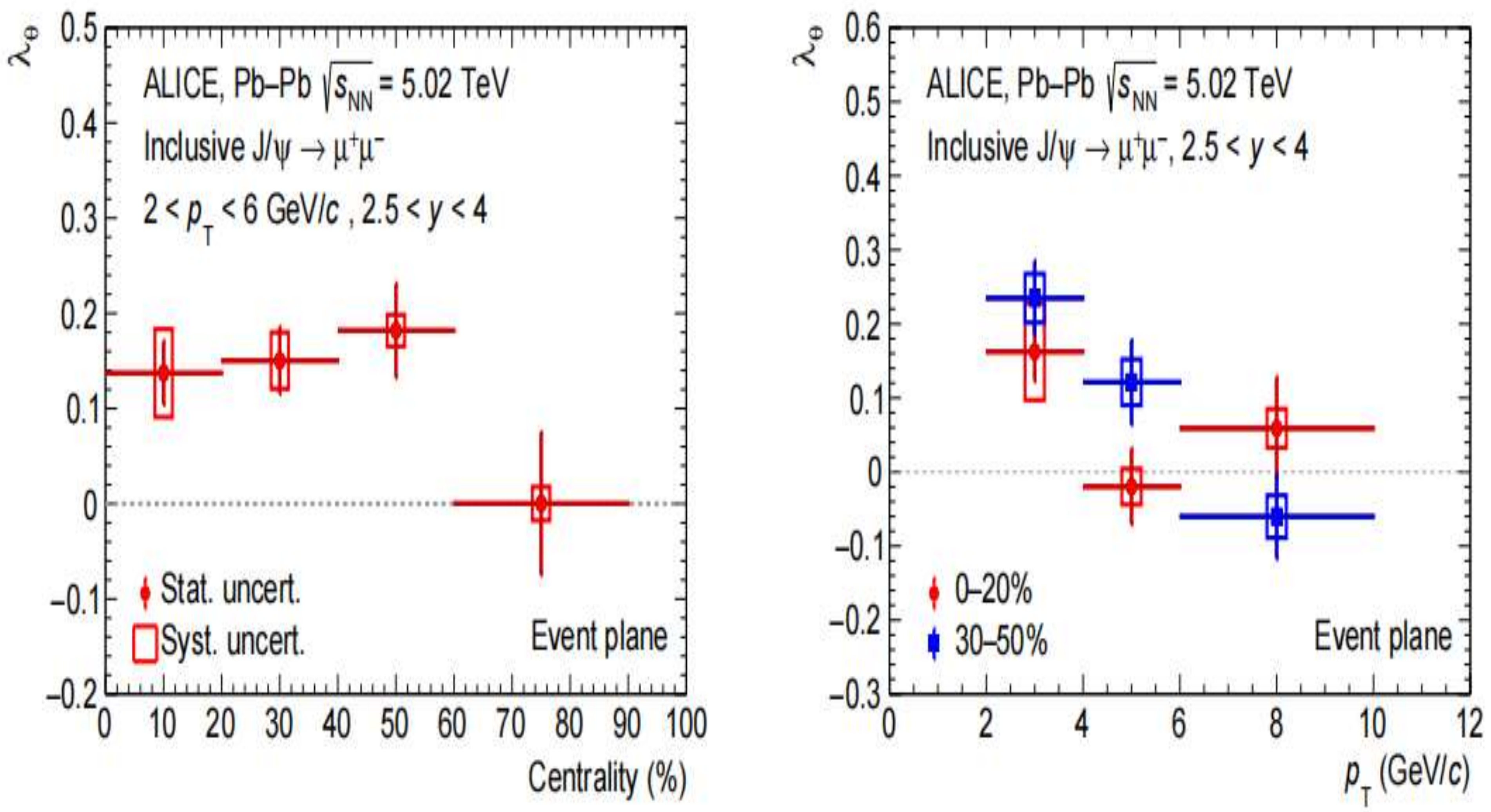


Collision parameter

Introduction



Experimental data from STAR Collaboration



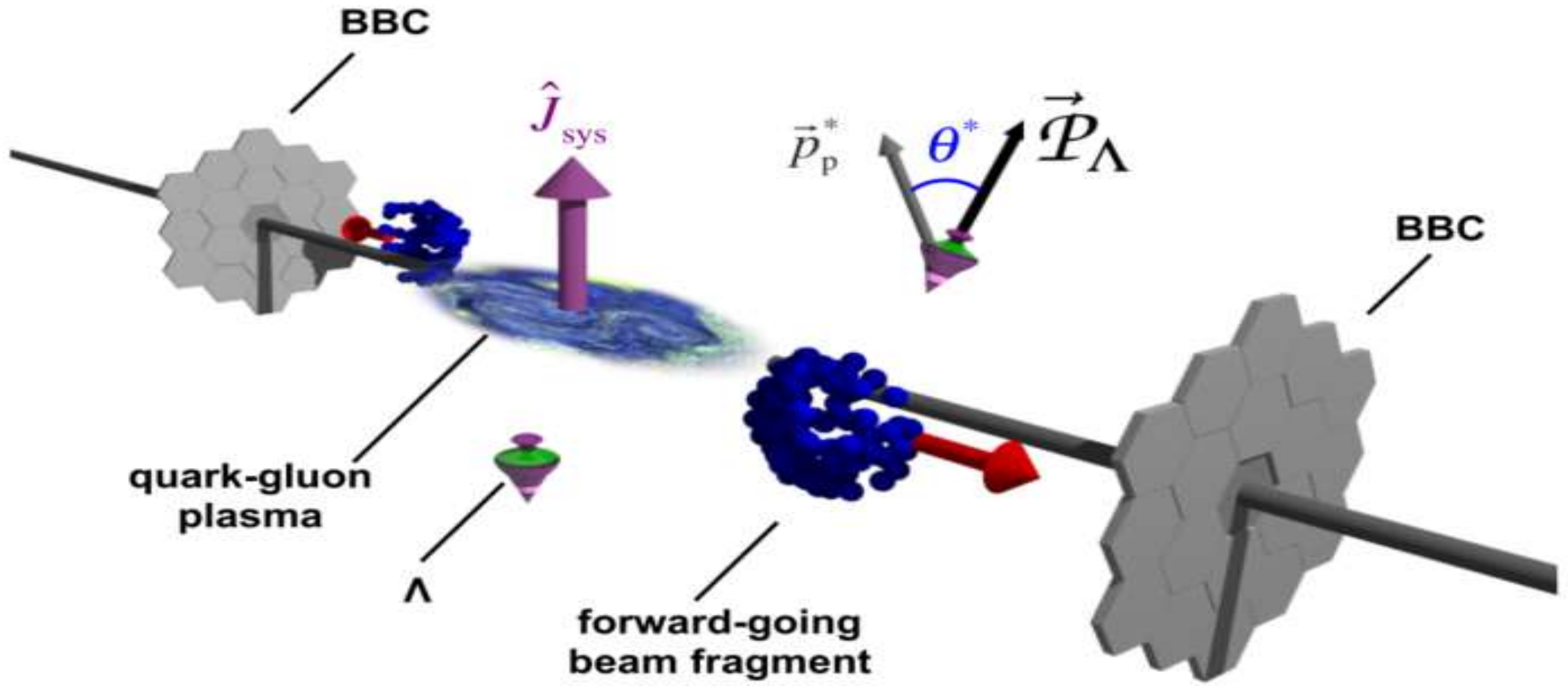
Experimental data from ALICE Collaboration

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].

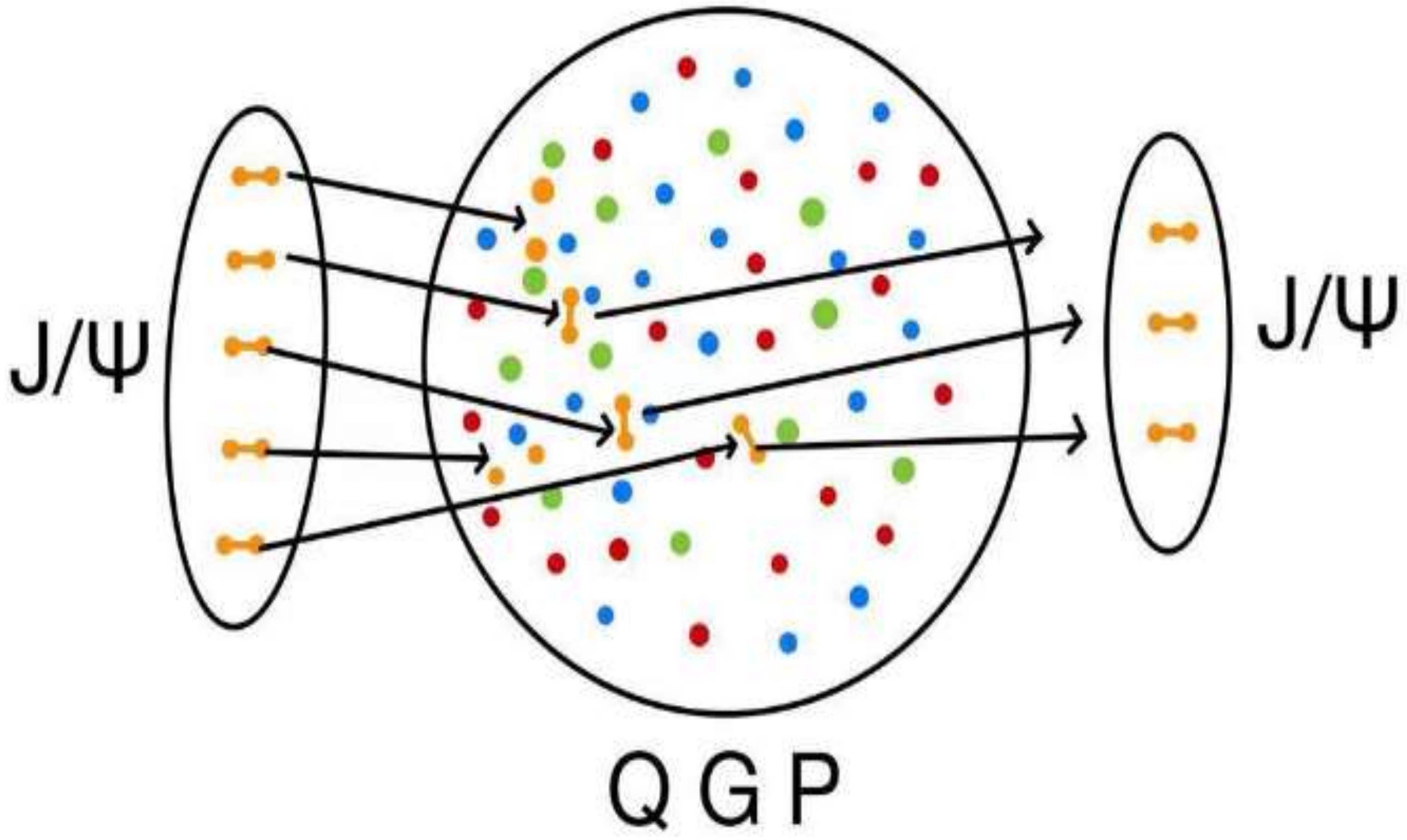
A similar spin polarization has been observed at the LHC[2].

[1] STAR Collaboration, SPIN2023 (2024) 236.
[2] Phys. Rev. Lett. 131 (2023) 042303

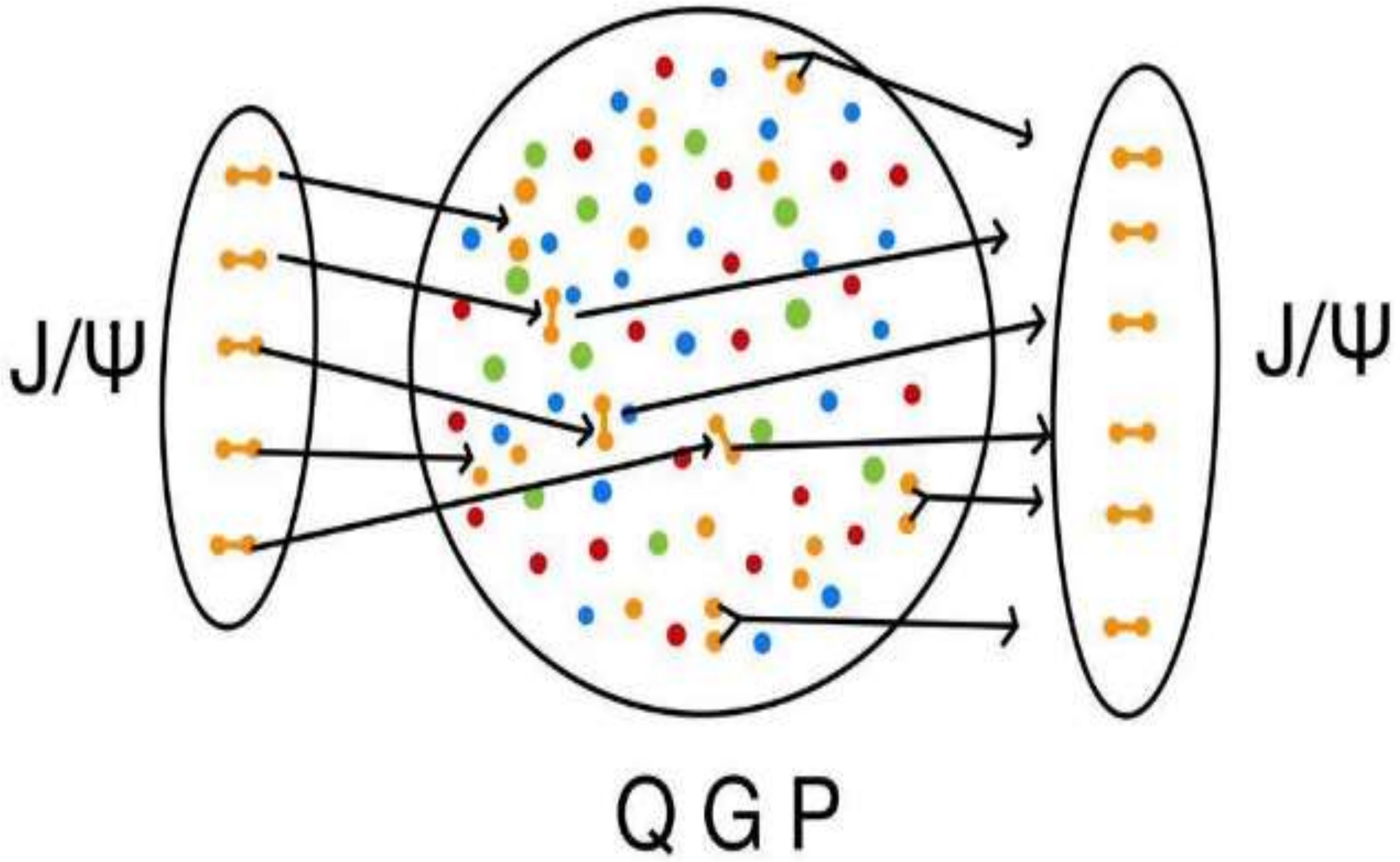
Introduction



The main contribution to the polarization of Lambda hyperon comes from vorticity[3]



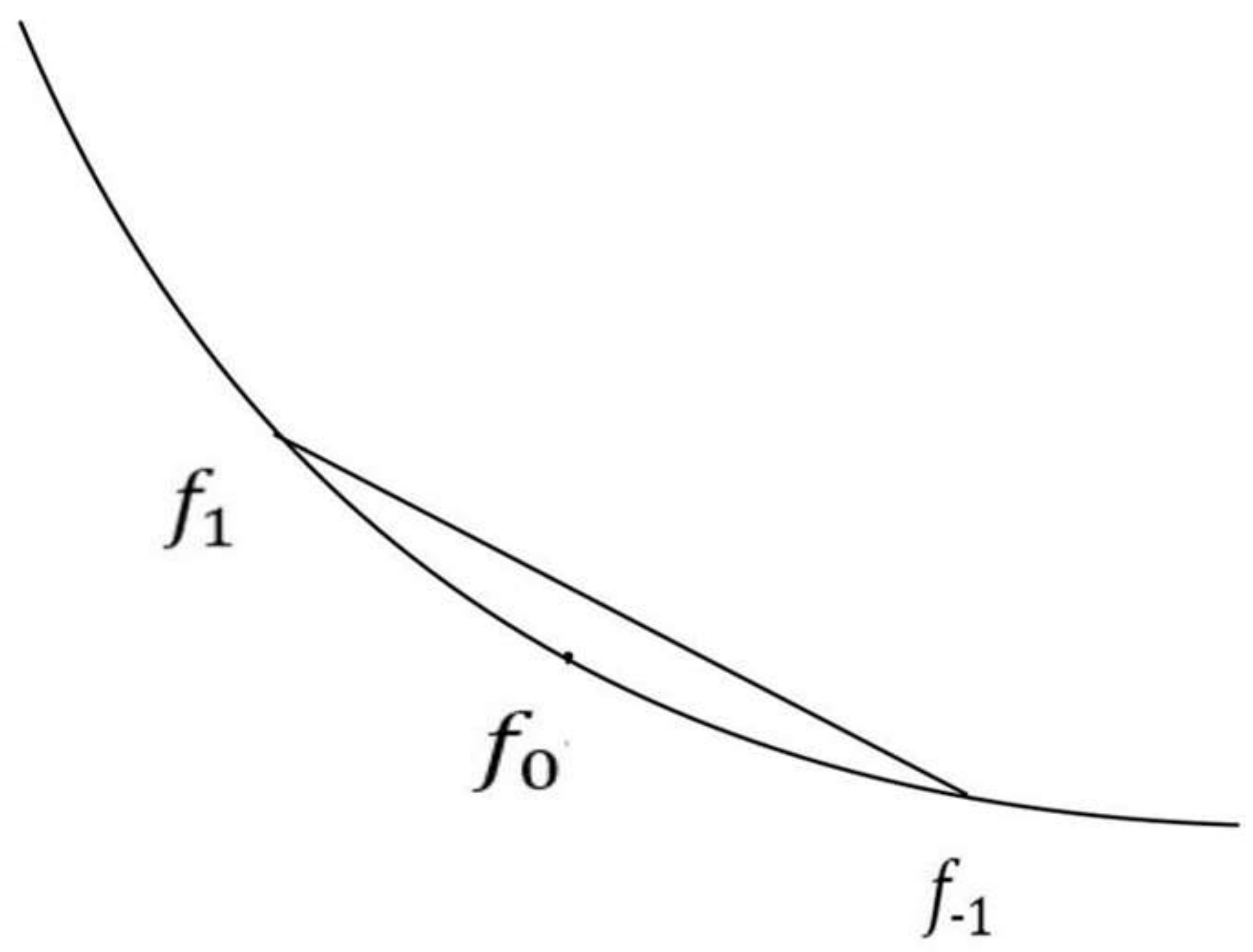
Low energy scale（dissociation）

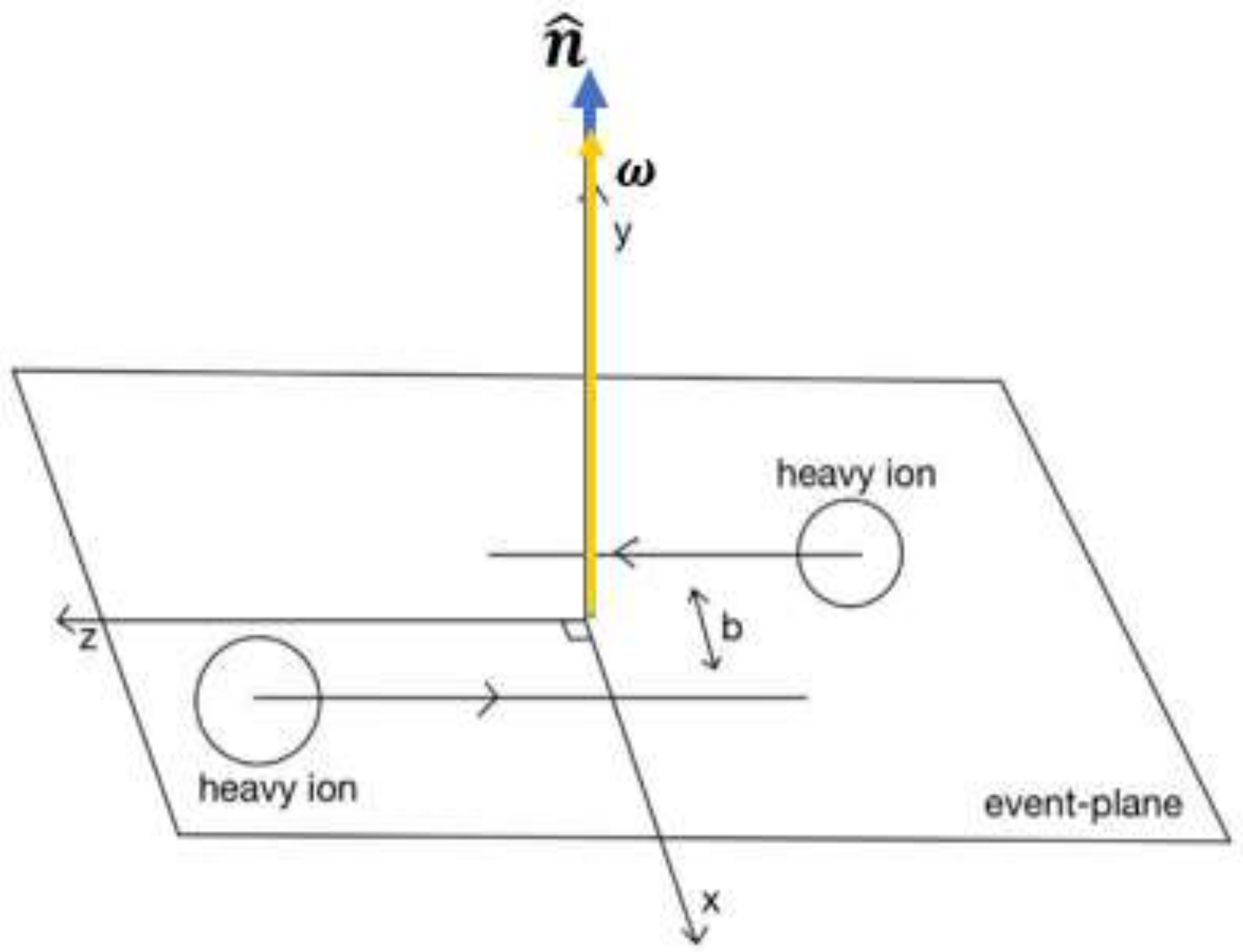


High energy scale (dissociation+regeneration)

[3] B. Fu, K. Xu, X. G. Huang and H. Song. Hydrodynamic study of hyperon spin polarization in relativistic heavy ion collisions [J]. Phys. Rev. C, 2021(103): 024903.

Possible Mechanism:



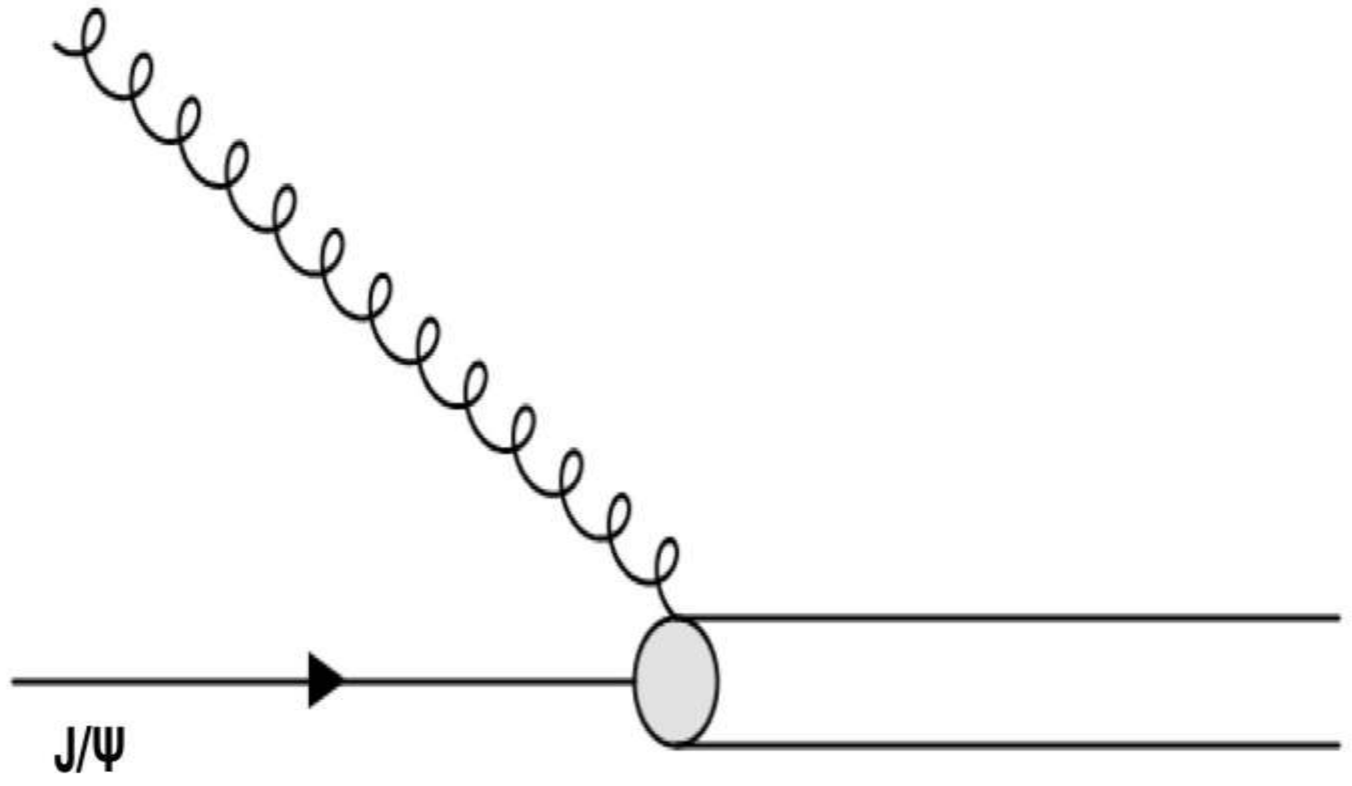


The remaining J/ψ particles in different spin direction：

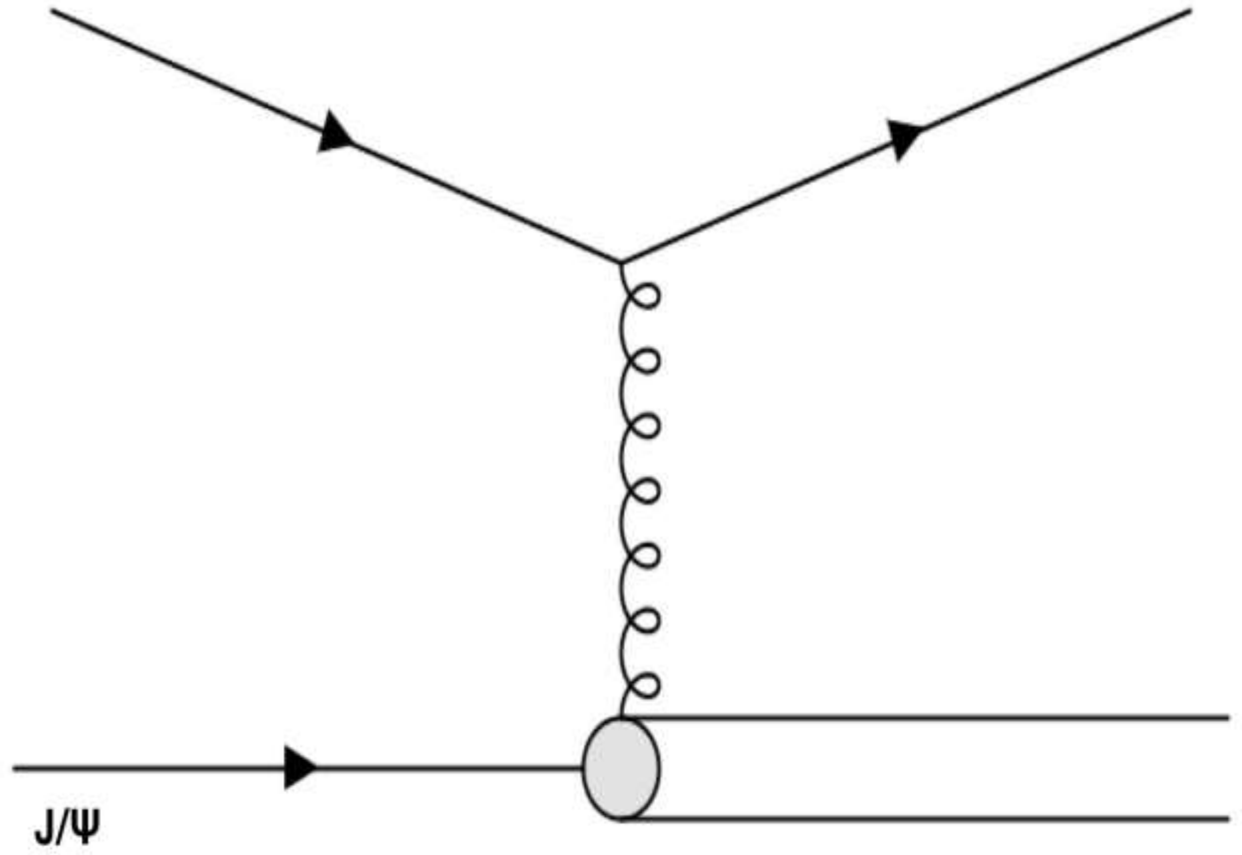
$$f_i \propto e^{-C_i t} \propto \rho_{ii}\ ,\quad C_i = \Gamma_0 + \Gamma_i^{(1)} = \Gamma_0 + \#S_i\omega$$

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

Method



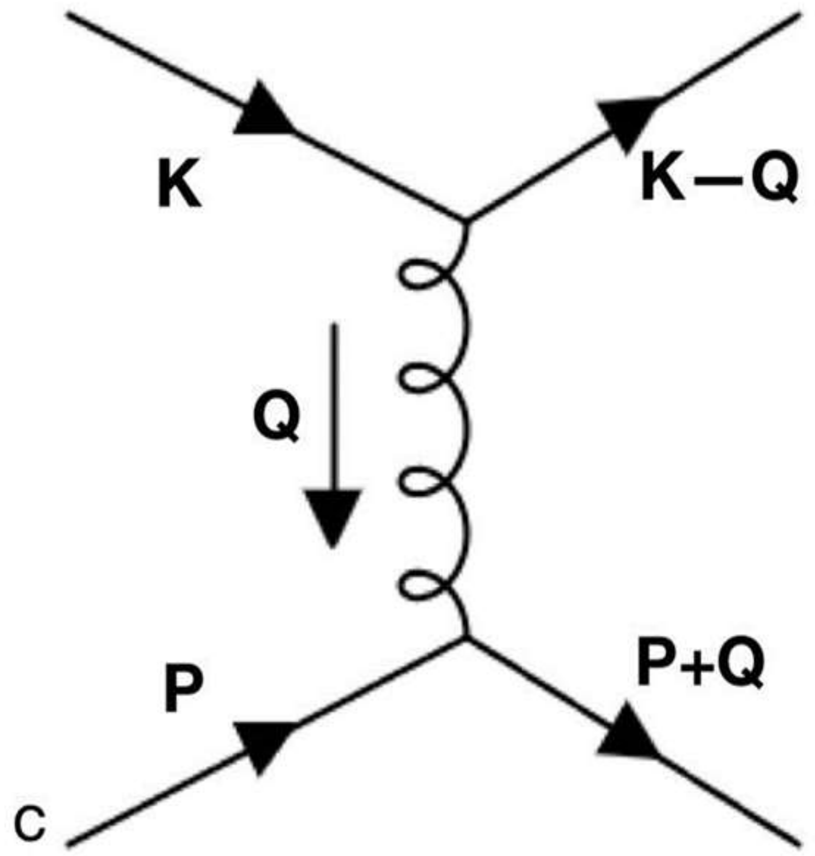
LO($\sigma \sim \varepsilon^{\frac{5}{2}}$)



NLO

Quasi-free

$\varepsilon \rightarrow 0$

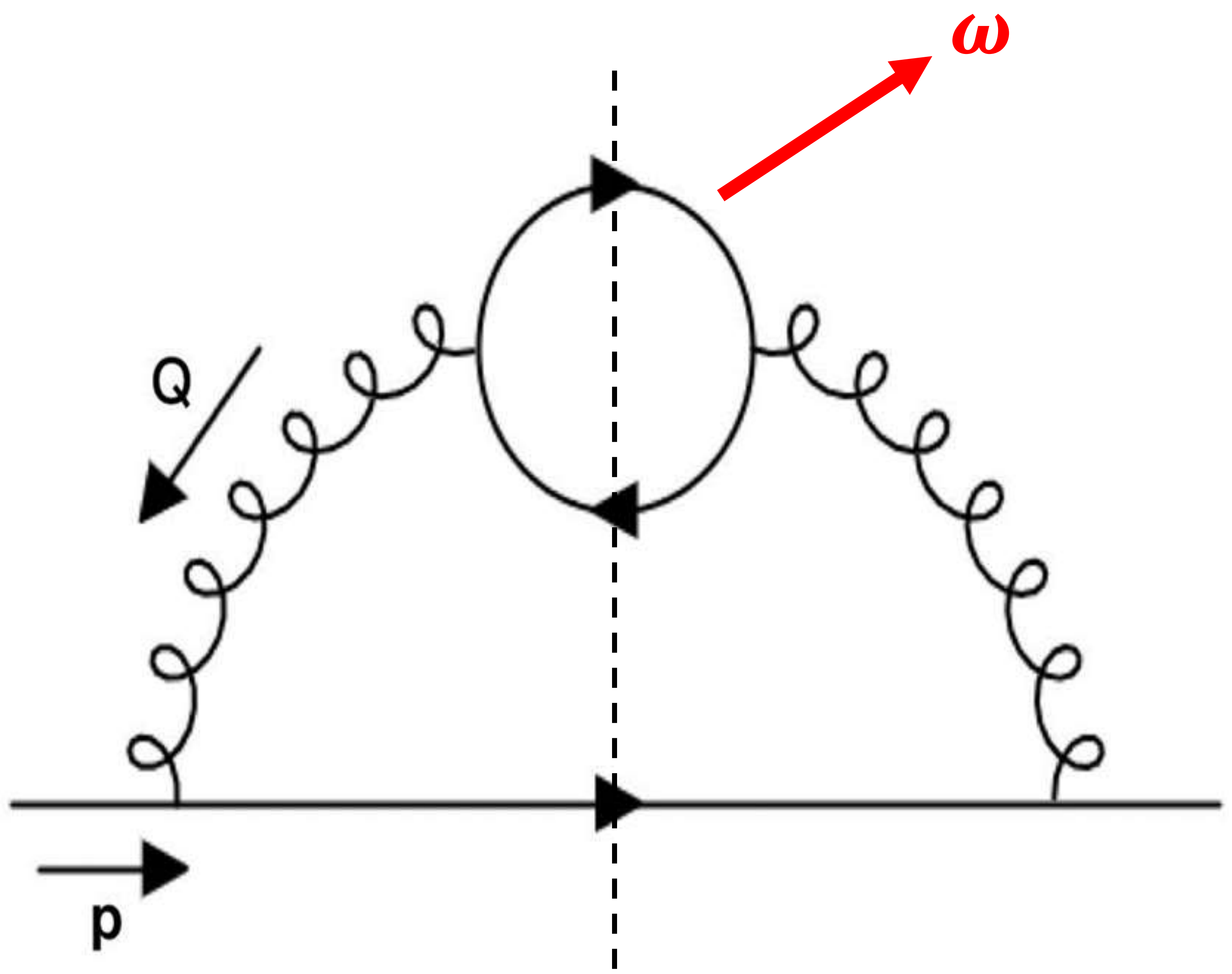


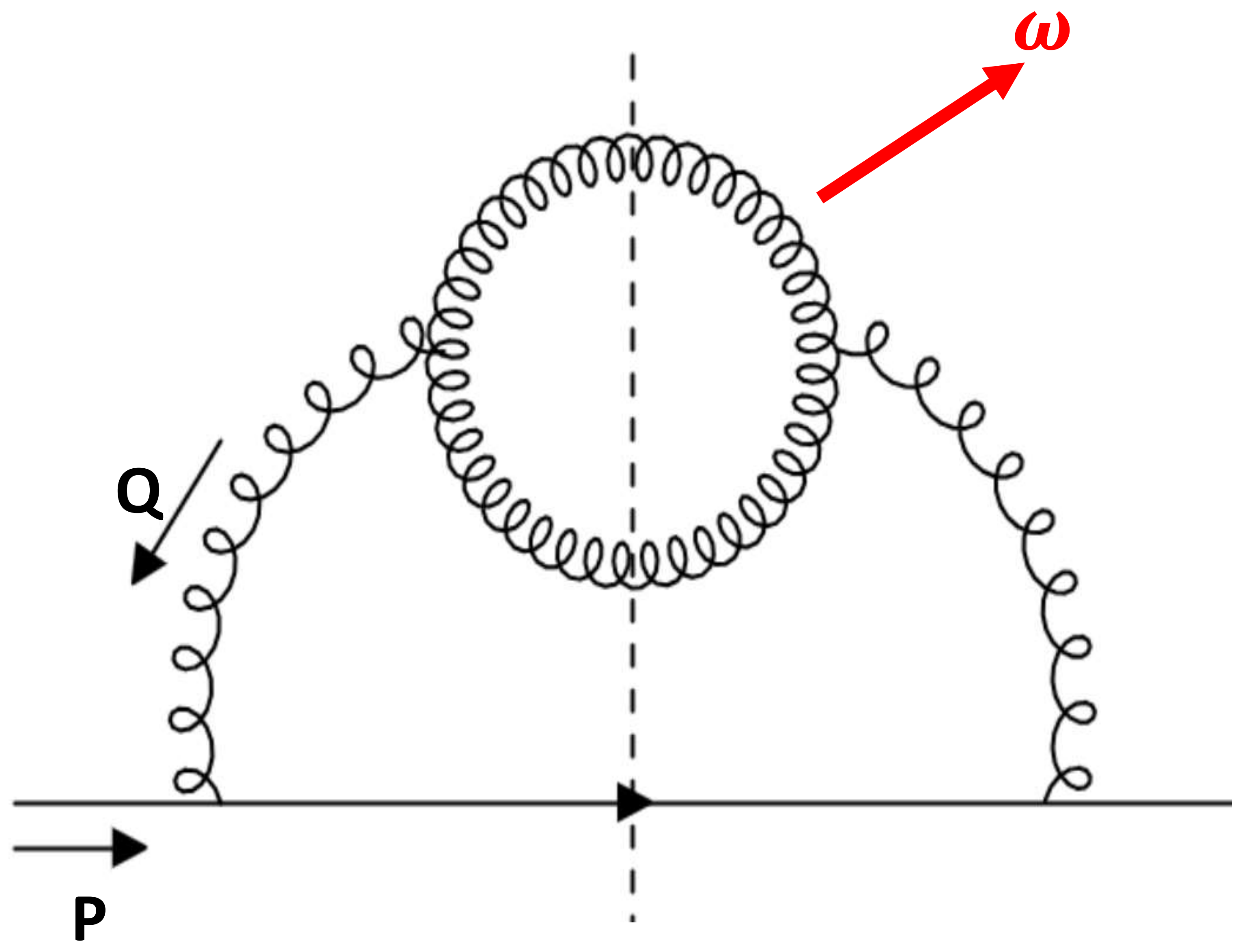
Scattering of c quark and quarks in QGP

The LO contributes small to dissociation rate when the binding energy is small[4].

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

Method





Vortical correction to propagator[5,6,9]:

$$S^{<(1)}(K) = -2\pi \frac{1}{2} K^{\mu} \tilde{\Omega}_{\mu\nu} \gamma^{\nu} \gamma^{5} \delta(K^2) \epsilon(k_0) \beta \tilde{f}'(k_0)$$

Vortical correction to propagator[7,8,9]:

$$D_{\mu\rho}{}^{<(1)}(K) = 2\pi\epsilon(k_0)\delta(K^2)\left[+\frac{iP_{\mu\Lambda}K^{\Lambda}P_{\rho\Sigma}P^{\Sigma\beta}}{2{k_0}^2}\partial_{\beta} f(k_0) - (\mu \leftrightarrow \rho) - i\frac{\epsilon_{\mu\rho\alpha\beta}K^{\alpha}u^{\beta}}{{k_0}^2} Q^{\nu}\omega_{\nu}\beta f'(k_0)\right]$$

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

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

[5] J.-h. Gao, J.-Y. Pang, and Q. Wang, Phys. Rev. D 100, 016008 (2019)
[6] R.-h. Fang, L.-g. Pang, Q. Wang, and X.-n. Wang, Phys. Rev. C 94, 024904 (2016)
[7] X.-G. Huang, P. Mitkin, A. V. Sadofyev, and E. Speranza, JHEP 10, 117 (2020)
[8] K. Hattori, Y. Hidaka, N. Yamamoto, and D.-L. Yang, JHEP 02, 001 (2021)
[9]D. Hou, S. Lin, Phys. Lett. B 818 (2021) 136386.

Result

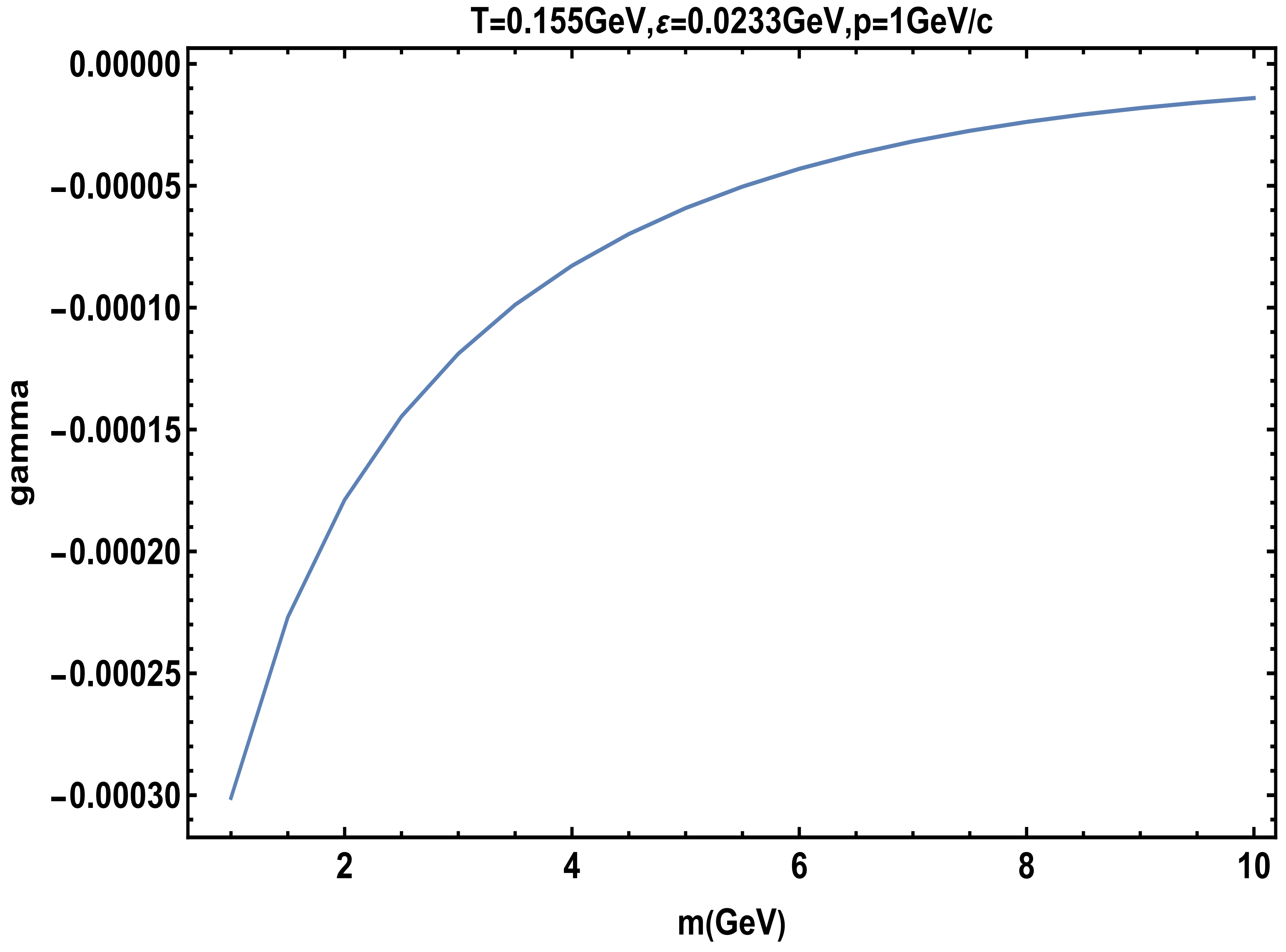
In the quark-gluon plasma rest frame, we can obtain $\Gamma_s^{(1)}$:

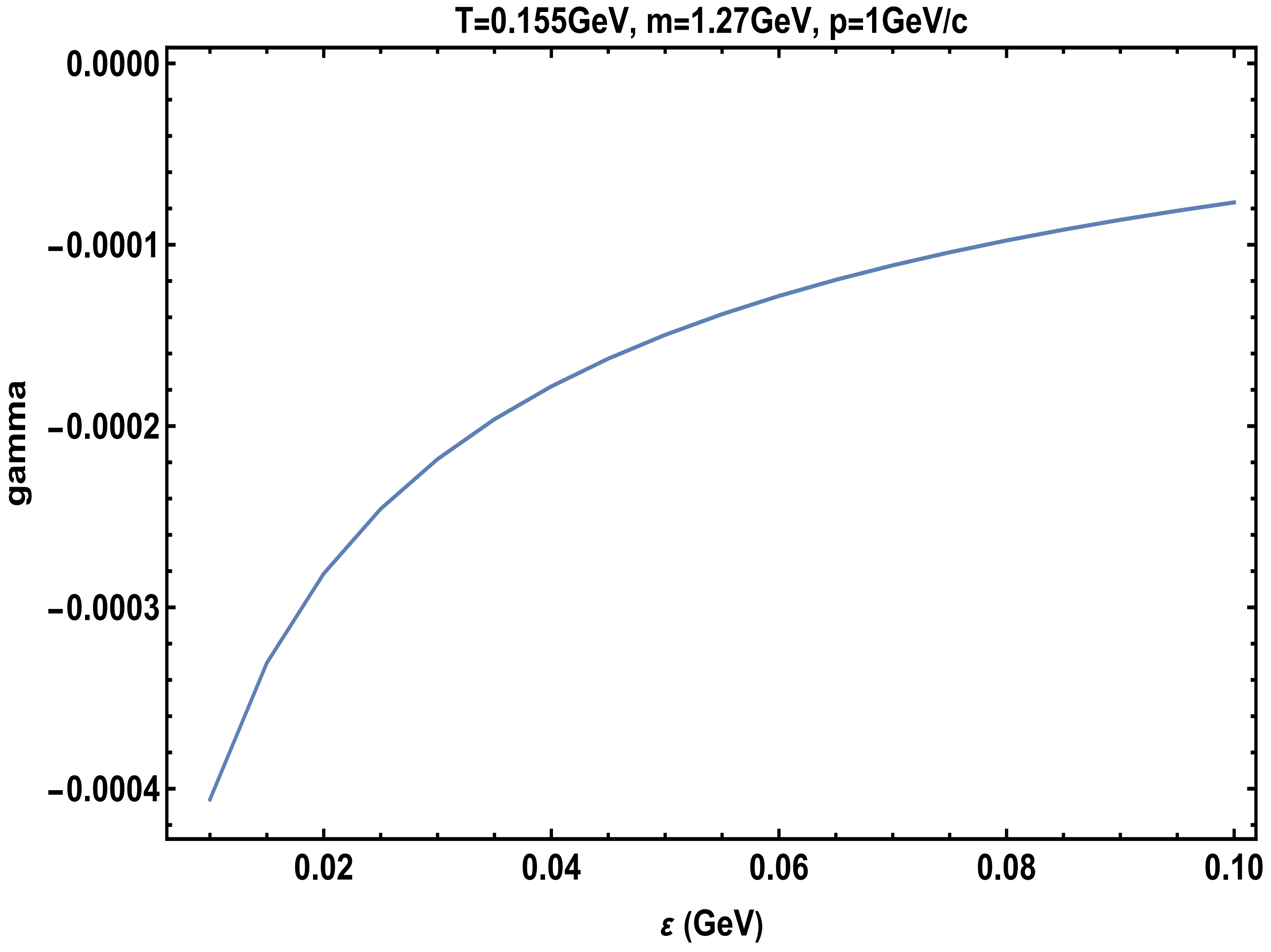
$$\Gamma_s^{(1)} = g^4 \mathrm{A}_1(p, p^0, \epsilon, \mathrm{T}, \mathrm{M}) s(\hat{\boldsymbol{n}} \cdot \hat{\boldsymbol{p}})(\hat{\boldsymbol{p}} \cdot \boldsymbol{\omega}) + g^4 \mathrm{A}_2(p, p^0, \epsilon, \mathrm{T}, \mathrm{M}) s\hat{\boldsymbol{n}} \cdot \boldsymbol{\omega}$$

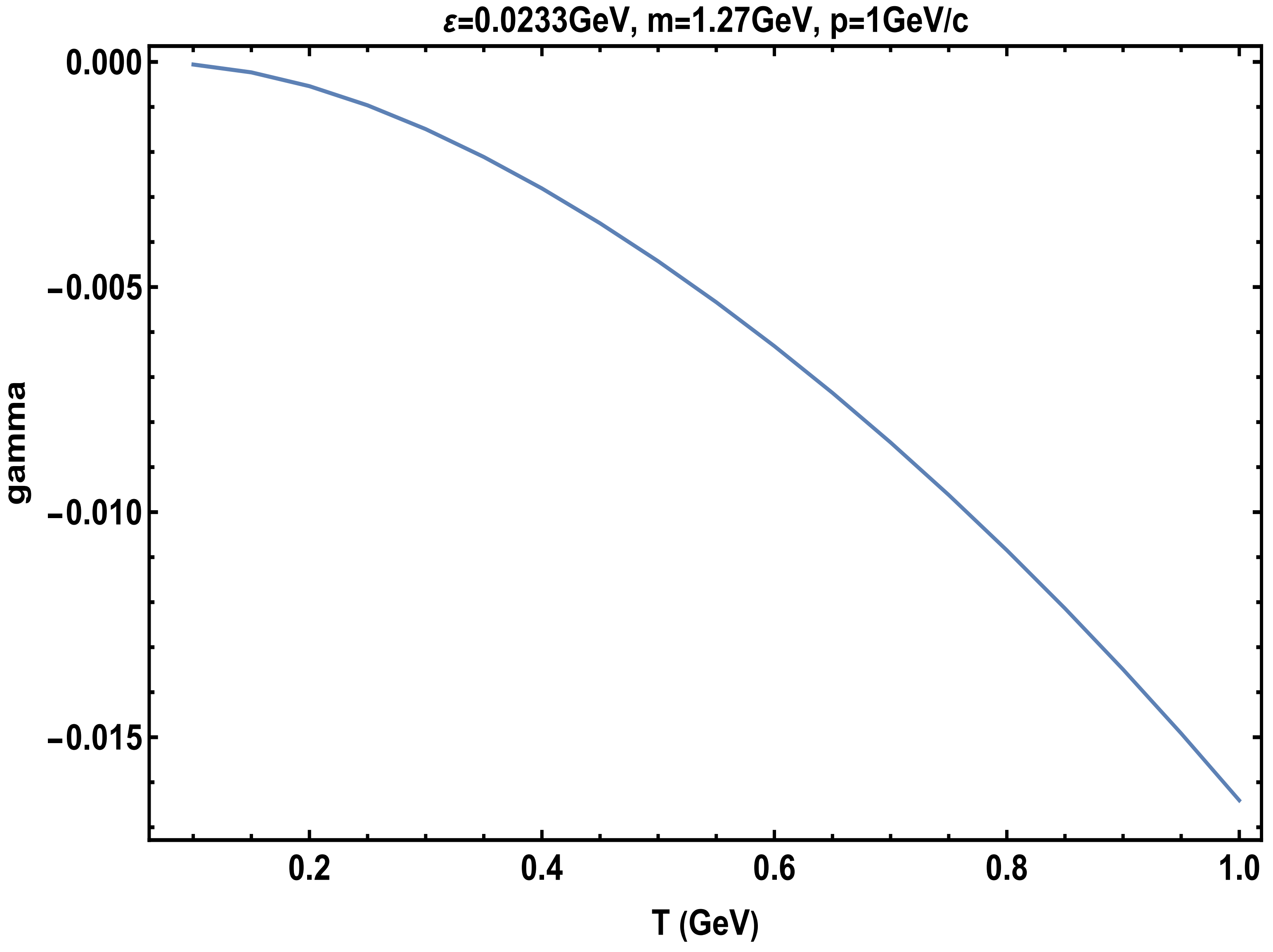
($\hat{\boldsymbol{n}}$： spin quantization axis, $\boldsymbol{\omega}$： vorticity , s： spin quantum number)

First part:

$$\Gamma_s^{(1)} = g^4 \mathrm{A}_1(p, p^0, \epsilon, \mathrm{T}, \mathrm{M}) s(\hat{\boldsymbol{n}} \cdot \hat{\boldsymbol{p}})(\hat{\boldsymbol{p}} \cdot \boldsymbol{\omega})$$







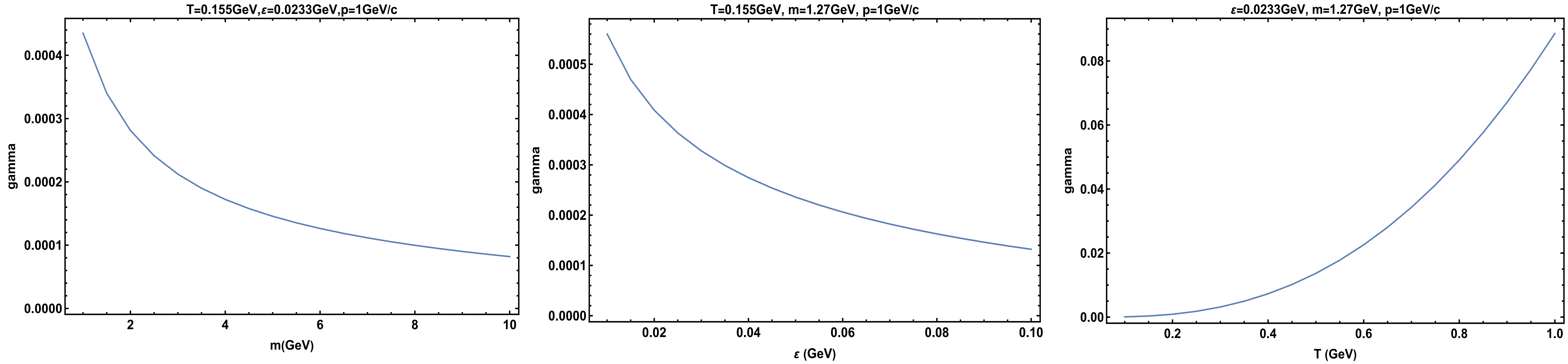
$$\Gamma_s^{(1)} \sim \ln \epsilon$$

$$(\mathrm{gamma} = g^4 \mathrm{A}_1(p, p^0, \epsilon, \mathrm{T}, \mathrm{M}))$$

Result

Second part：

$$\Gamma_s^{(1)} = g^4 A_2(p, p^0, \epsilon, T, M) s\hat{\boldsymbol{n}} \cdot \boldsymbol{\omega}$$



$$\Gamma_s^{(1)} \sim \ln \epsilon$$

$$(\text{gamma} = g^4 A_2(p, p^0, \epsilon, T, M))$$

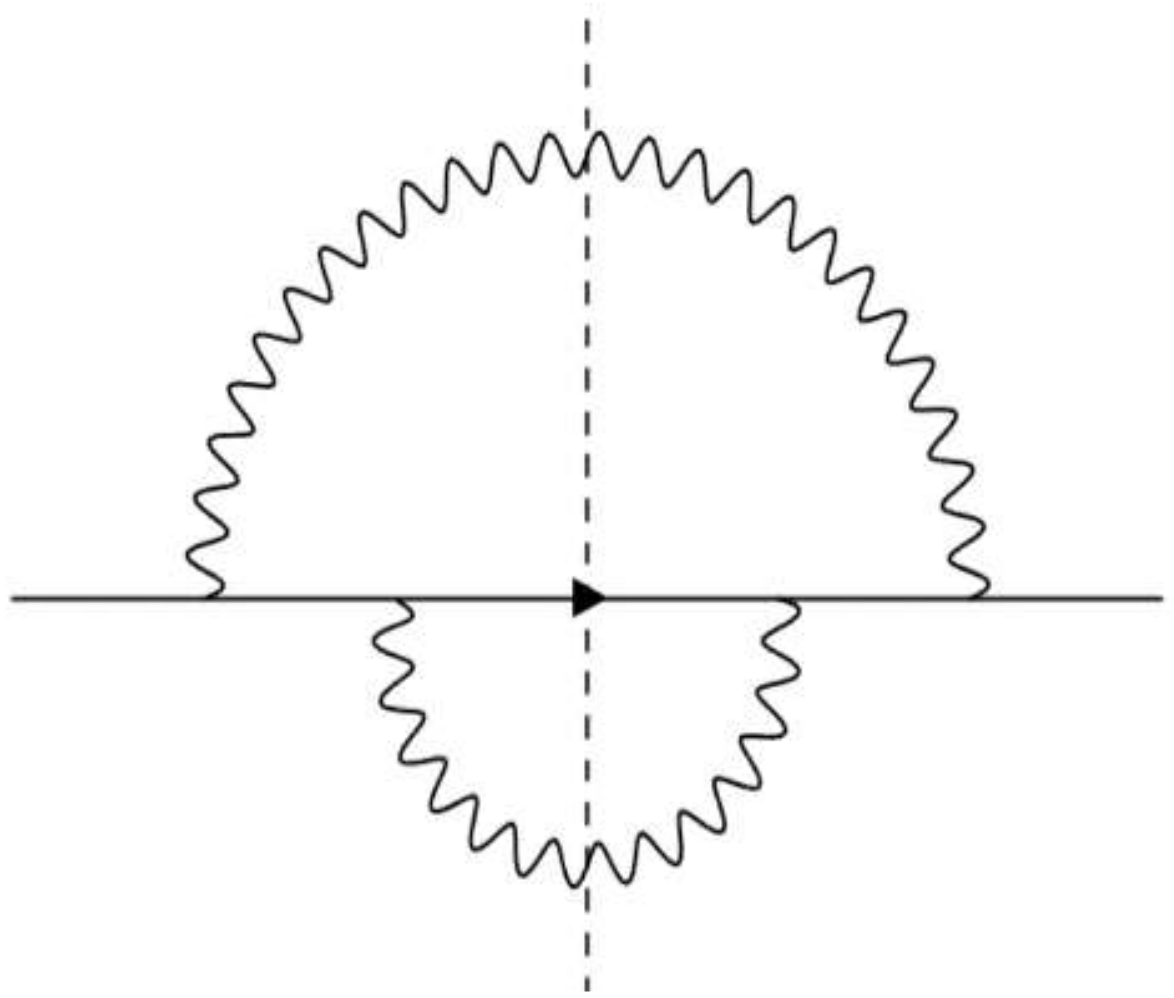
$$\Gamma_1^{(1)} = \Gamma_{1/2}^{(1)} + \Gamma_{1/2}^{(1)} = 2\,\Gamma_{1/2}^{(1)},\ \Gamma_0^{(1)} = \frac{2}{\sqrt{2}}(\Gamma_{1/2}^{(1)} + \Gamma_{-1/2}^{(1)}) = 0,\ \Gamma_{-1}^{(1)} = \Gamma_{-1/2}^{(1)} + \Gamma_{-1/2}^{(1)} = 2\,\Gamma_{-1/2}^{(1)}$$

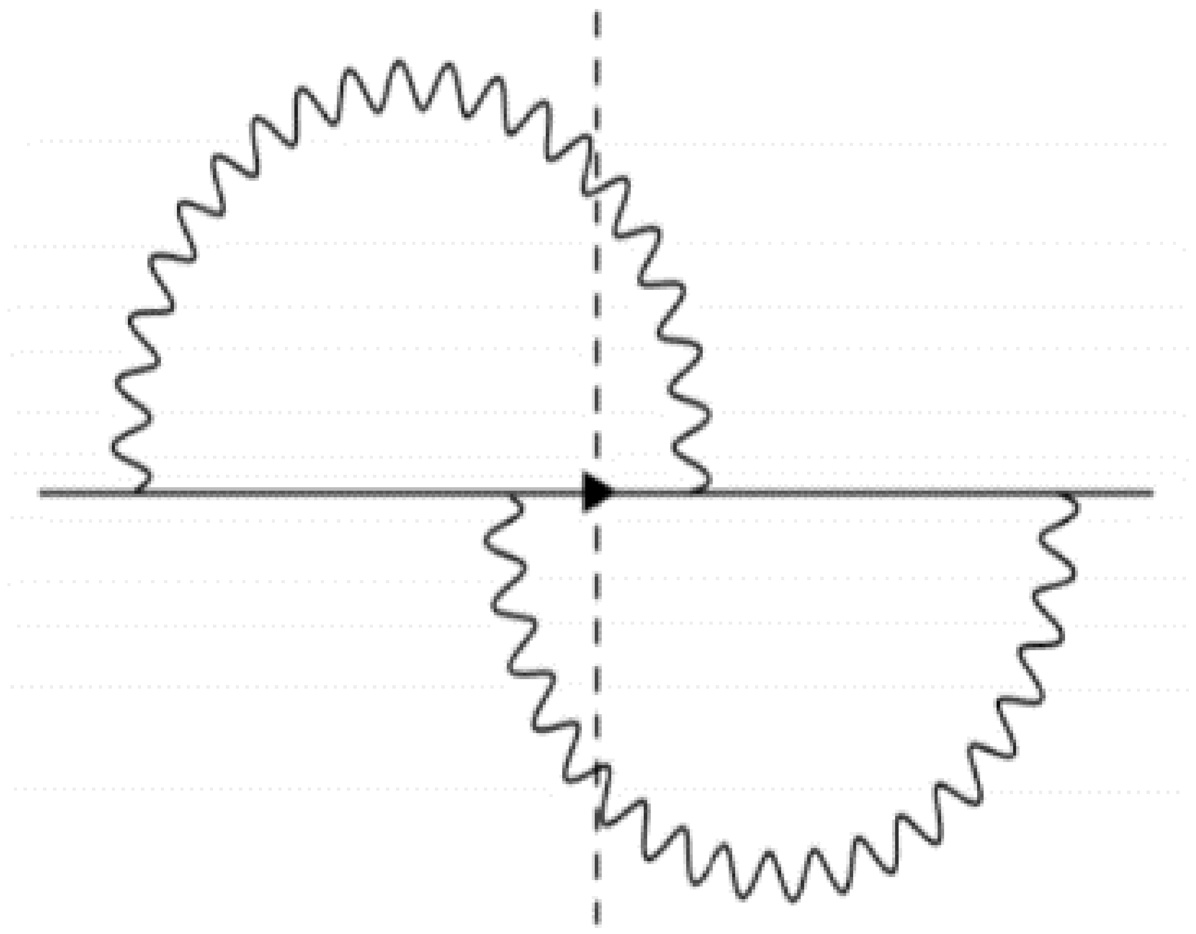
Summary&Outlook

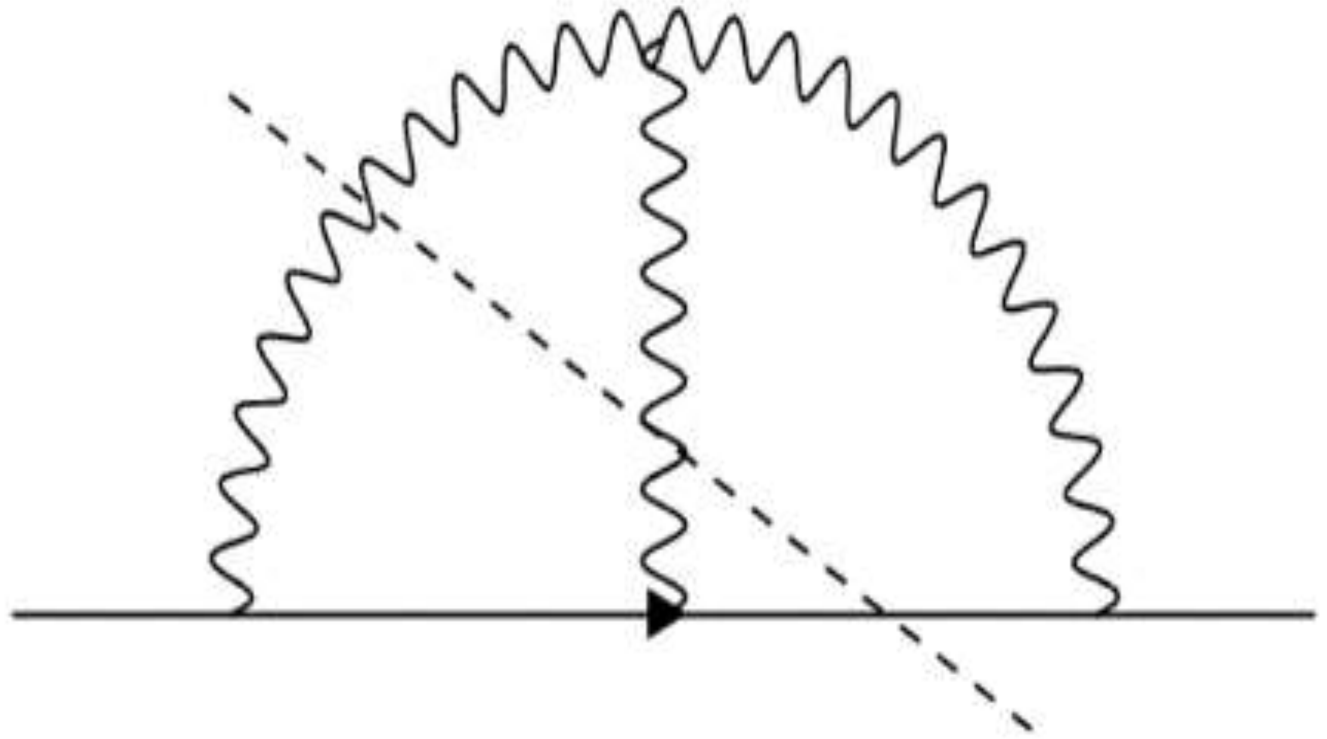
Expectation: $f_i \propto e^{-C_i t} \propto \rho_{\mathrm{ii}}$, $C_i = \Gamma_0 + \Gamma_i^{(1)} = \Gamma_0 + \#S_i\omega$

The results under Coulomb scattering: $\Gamma_s^{(1)} = g^4 \mathrm{A}_1 s(\hat{\boldsymbol{n}} \cdot \hat{\boldsymbol{p}})(\hat{\boldsymbol{p}} \cdot \boldsymbol{\omega}) + g^4 \mathrm{A}_2 s \hat{\boldsymbol{n}} \cdot \boldsymbol{\omega}$

Outlook: Regarding Compton scattering calculations, further phenomenological studies…







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Thank you

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