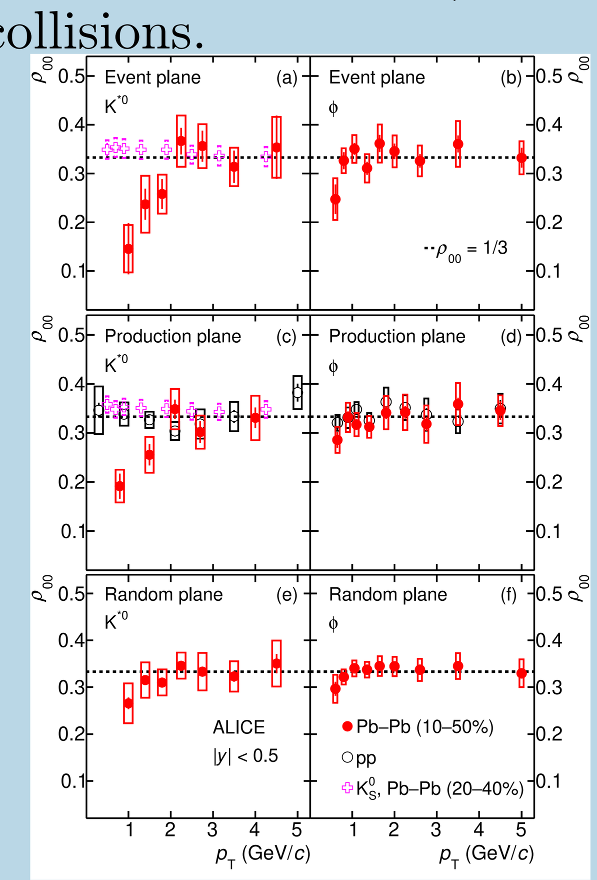
Spin alignment of vector mesons from quark dynamics in a rotating medium

Minghua Wei, Mei Huang
weiminghua@fudan.edu.cn, huangmei@ucas.ac.cn

Introduction

Spin alignment of vector meson ϕ and K^{*0} has been one of the intriguing topics in HICs. Experimental evidence suggests that spin density matrix element ρ_{00} has a remarkable deviation from 1/3 . ALICE collaboration has measured ρ_{00} for K^{*0} and ϕ meson at $\sqrt{s_{NN}} = 2.76$ TeV in Pb-Pb collisions.



Basic Concepts

- Metric in a uniform rotating frame

$$g_{\mu\nu} = \eta_{\mu\nu} + \eta_{\mu j}\delta^0_\nu v_j + \eta_{i\nu}\delta^0_\mu v_i + \eta_{ij}\delta^0_\mu\delta^0_\nu v_i v_j$$

Here,$\mu,\nu = 0,1,2,3$ and $i,j = 1,2,3$

- Spin connection

$$\begin{aligned}\Gamma_{ij0} &= \tfrac{1}{2}\left(\partial_i v_j - \partial_j v_i\right),\\ \Gamma_{i0j} &= \tfrac{1}{2}\left(\partial_i v_j + \partial_j v_i\right),\\ \Gamma_{0ij} &= -\tfrac{1}{2}\left(\partial_i v_j + \partial_j v_i\right),\\ \Gamma_{0i0} &= -\tfrac{1}{2}\left(v_j\partial_i v_j + v_j\partial_j v_i\right).\end{aligned}$$

- Spinor connection

$$\Gamma_{ij0} = \Omega^k\epsilon_{ijk} \quad \Gamma_0 = \frac{1}{8}\left[\gamma^i,\gamma^j\right]\Omega^k\epsilon_{ijk}$$

Models

The Lagrangian of the 3-flavor NJL model is given as follows:

$$\begin{aligned}\mathcal{L}_{\mathrm{NJL}} =& \bar\psi[i\bar\gamma^\mu(\partial_\mu + \Gamma_\mu) - m_f]\psi\\ &+ G_S\sum_{a=0}^{8}\left[\left(\bar\psi\lambda^a\psi\right)^2 + \left(\bar\psi i\gamma_5\lambda^a\psi\right)^2\right]\\ &- G_V\sum_{a=0}^{8}\left[\left(\bar\psi\gamma_\mu\lambda^a\psi\right)^2 + \left(\bar\psi i\gamma_\mu\gamma_5\lambda^a\psi\right)^2\right]\\ &- K\left[\det\bar\psi\left(1+\gamma_5\right)\psi + \det\bar\psi\left(1-\gamma_5\right)\psi\right]\end{aligned}$$

References

[1] M. Wei and M. Huang, *Spin alignment of vector mesons from quark dynamics in a rotating medium*, [arXiv:2303.01897 [hep-ph]].

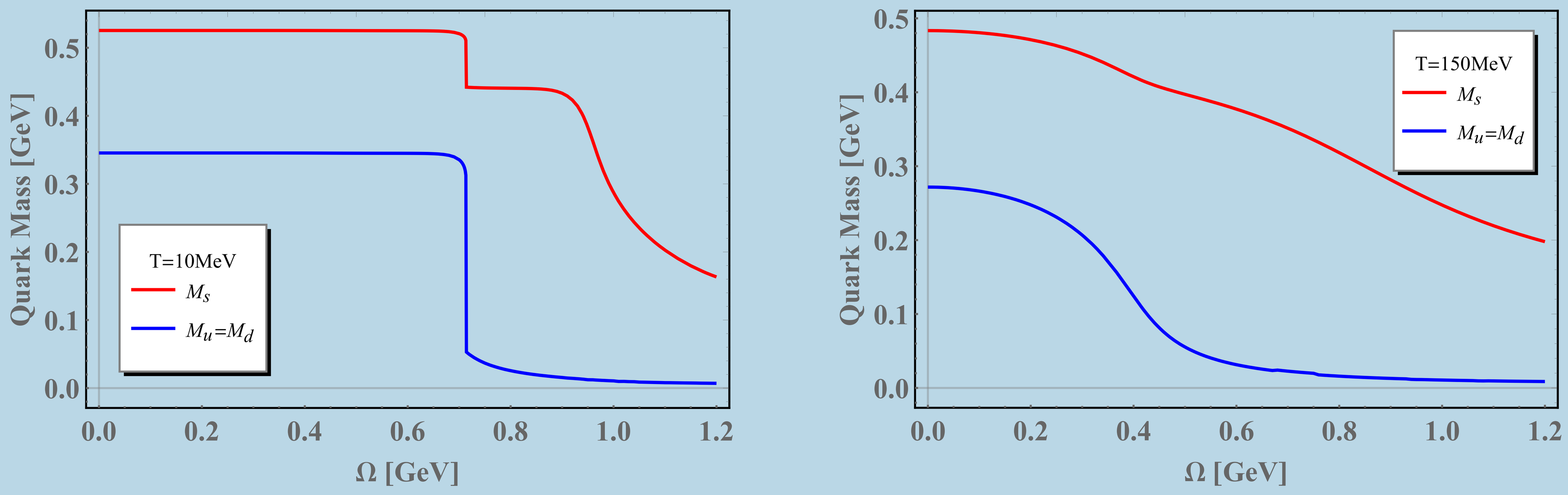
[2] Minghua Wei, Yin Jiang and M. Huang, *Mass splitting of vector mesons and spontaneous spin polarization under rotation **, Chin. Phys. C **46**, no.2, 024102 (2022) doi:10.1088/1674-1137/ac338e [arXiv:2011.10987 [hep-ph]].

Acknowledgements

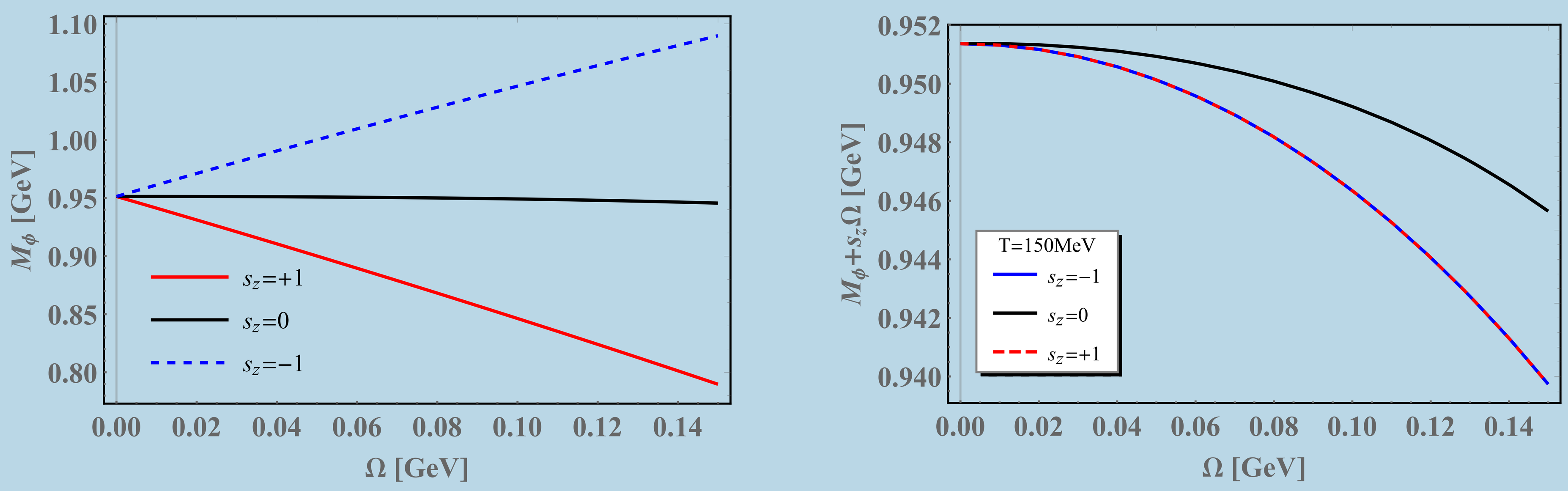
This work is supported by the National Natural Science Foundation of China (NSFC) Grant Nos. 12235016, 12221005, and the Strategic Priority Research Program of Chinese Academy of Sciences under Grant Nos XDB34030000.

Dynamical quark mass and vector meson mass

- The total grand potential is $\Omega_{\mathrm{tot}}(r) = \sum_{f=u,d,s}\left(2G_S\sigma_f^2 - \Omega_f\right) + 4K\sigma_u\sigma_d\sigma_s$;
- Chiral condensate will be suppressed under rotation;

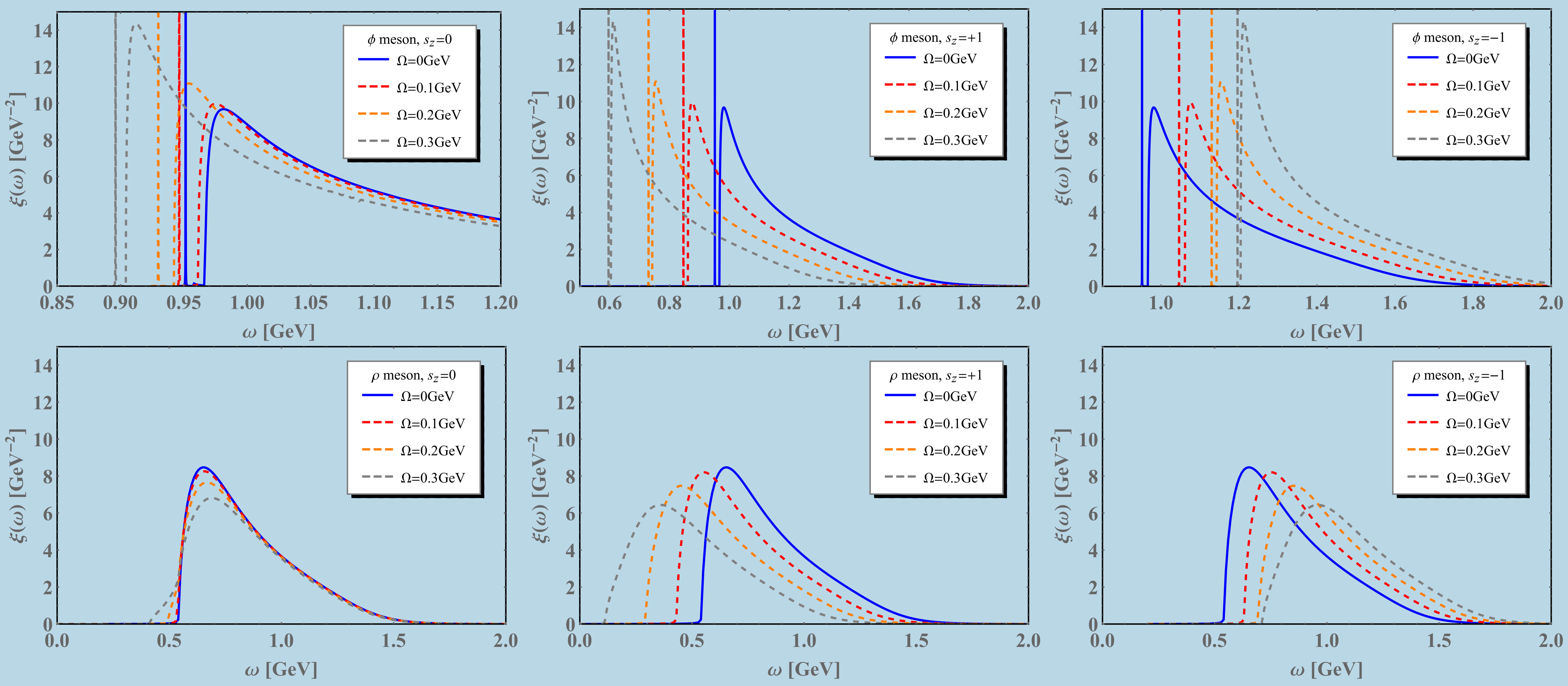


- The rotating angular velocity induces mass splitting of spin components for vector ϕ,ρ mesons $M_{\phi,\rho}(\Omega) \simeq M_{\phi,\rho}(\Omega=0) - s_z\Omega$.



Spectral functions in a rotating medium

- Spectrum functions is $\xi_{\lambda\lambda}(\omega) \equiv \frac{1}{\pi}\,\mathrm{Im}\,D_{\lambda\lambda}(\omega)$;
- Rotational effects are reflected in two aspects: the heights of the peaks are suppressed and the widths are broadened by the angular velocities.



Spin alignment of vector meson ϕ and ρ

- The particle number density $\bar\rho_{\lambda\lambda'}(\mathbf{q})$ can be expressed by $\bar\rho_{\lambda\lambda'}(\mathbf{q}) = \int d\omega\,\frac{2\omega}{e^{\omega/T}-1}\xi_{\lambda\lambda'}(\omega,\mathbf{q})$,
- In this investigation, we aim at a uniformly rotating medium and the created ϕ mesons are in global equilibrium.

$$\rho^{\Omega}_{00}(\mathbf{0}) \equiv \frac{\bar\rho_{00}(\mathbf{0})}{\bar\rho_{00}(\mathbf{0}) + \bar\rho_{11}(\mathbf{0}) + \bar\rho_{-1,-1}(\mathbf{0})}. \tag{1}$$