Equivalence Role of Magnetic Field and Angular Momentum on Quark Gluon Plasma

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When two heavy nuclei collide in peripheral collision in heavy ion collision experiments (HIC), a huge magnetic field can be produced according to Biot Savart law. The field strengths can approximately be m_π^2 in RHIC energy and $10m_\pi^2$ in LHC energy [1] . It can decay with time, its detailed space-time profile has been investigated recently in many references. The reader may see Refs. [1–3] and references therein. In off-central or peripheral HIC, a huge angular velocity can also be created [6, 7]. So it will be a very interesting topic to study these two aspects comparatively, which is aimed in the present draft. A before-collision picture is drawn in Fig. (1), where two nuclei are approaching each other along the beam axis (say y-axis). Then after the collision, those two nuclei will pass each other as shown in Fig. (2), where their overlapping domain will create the super quark-gluon plasma (QGP) medium. Since the medium will face a huge magnetic field and angular velocity, the medium can face the forces - Lorentz force due to magnetic field B, Coriolis force, and centrifugal force due to angular velocity Ω or angular momentum L. Due to the first two forces, medium constituent particles, having random velocities in any direction, will exhibit a circular motion. So reader may expect a rotating cylindrical medium for simplicity, although in actual case a tilted medium is expected. During the lifetime of the medium, two other time scales, due to two forces - Lorentz and Coriolis forces, play interesting roles. The present work is intended to explore this comparative analysis.

There are many similarities between this magnetic field B and angular velocity Ω production in peripheral heavy ion collision experiments. If you consider the y-direction as the beam axis, as shown in Figs. (1), (2), then both B and Ω will be produced along the z-direction.

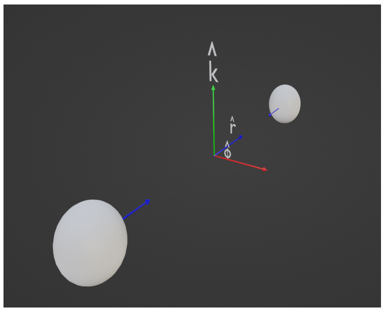

FIG. 1: Two nuclei approaching each other for collision

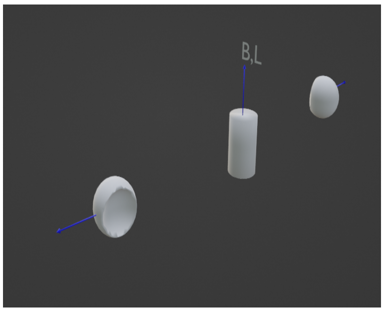

FIG. 2: Two nuclei separating from each other after collision

Now, medium constituent particles can have random velocity distribution. To make the comparison between Lorentz and Coriolis forces, let us focus on the particle (say u quark), having velocity along the x-direction. Now, the magnitude of Lorentz Force due to the magnetic field will be,
$|F_{mag}| = |q(\vec{v} \times \vec{B})| = qVB$,
which can be written as,
$F_{mag} = \frac{mv}{\tau_B}$.
On the other hand, the magnitude of Coriolis Force will be

$|F_{coriolis}| = |2m\gamma(\vec{v} \times \vec{\Omega})| = 2m\gamma v\Omega$,
which can also be written as,
$|F_{coriolis}| = \frac{m\gamma v}{\tau_\Omega}$, with $\gamma = \frac{1}{\sqrt{1 - \frac{v^2}{c^2}}}$ and $\tau_\Omega = 1/(2\Omega)$ [8]. Considering velocity of u quark as

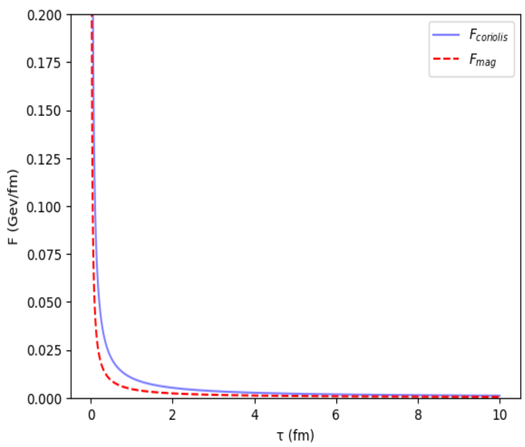

FIG. 3: Comparison between F_{mag} and $F_{coriolis}$ with respect to their respective τ values

$v = 0.9$, charge $q = \frac{2e}{3}$, rest mass $m = 0.005$ GeV, we can draw two forces - Lorentz force F_{mag} and Coriolis force $F_{Coriolis}$ in terms of their corresponding time scale τ_B and τ_Ω, as shown in Fig. (3). The reader can notice one interesting fact - the Coriolis force is more dominating than the Lorentz force. How τ_B plays an important role in creating anisotropic transportation in QGP medium is well studied in earlier Refs. [9, 10]. While the role of Coriolis force on anisotropic transportation in QGP medium is ignored in literature except the recent Ref. [8]. The future aim of this present work is to observe the detailed role of these two forces in QGP phenomenology by adopting detailed space-time evolution of the magnetic field and angular momentum, which is under progress.

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