# Role of interaction on electrical conductivity of QGP in presence of magnetic field

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Recently, through lattice quantum chromo dynamics (LQCD), Bali et al. [1] have addressed thermodynamics of quark gluon plasma (QGP) in presence of magnetic field, where thermodynamical quantities like pressure, energy density, entropy density get suppresing values with respect to their Stephan-Boltzmann (SB) limit. The suppression increases as temperature ($T$) and magnetic field ($B$) reduce. Ref. [2] can realize the reduction of thermodynamical quantities at $B = 0$ as reduction of degeneracy factors, when we move from high $T$ QGP phase to low $T$ hadronic matter (HM) phase. The present work has extended that interacting QGP picture for finite magnetic field case by finding a gross temperature and magnetic field dependent degeneracy factor $g(T, B)$.

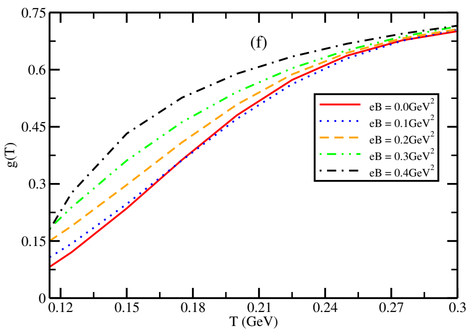


FIG. 1: Degeneracy factors $g(T)$ at for different strengths of magnetic field are obtained by matching LQCD data [1].

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TABLE I: Different values of $a_{0,1,2,3}$, given in Eq. (1) for different magnetic field strengths

| **eB(GeV$^2$)** | **$a_0$** | **$a_1$** | **$a_2$** | **$a_3$** |
|---|---|---|---|---|
| 0.0 | 0.834334 | 0.122845 | 3.87082 | -0.620074 |
| 0.1 | 0.751006 | 0.797544 | 21.6385 | 0.934298 |
| 0.2 | 0.743269 | 0.615513 | 21.2978 | 0.727439 |
| 0.3 | 0.786970 | 0.404290 | 12.8704 | 0.17983 |
| 0.4 | 0.864099 | 0.0778032 | 2.03964 | -0.77928 |

By matching the LQCD data points of thermodynamical quantities of QGP for $eB = 0$, 0.1, 0.2, 0.3, 0.4 GeV$^2$ [1], we find a parametric form

$$g(T) = a_0 - \frac{a_1}{e^{a_2(T-0.17)} + a_3} , \qquad (1)$$

where values of $a_{0,1,2,3}$ for different $eB$'s are given in Table. (I). These $g(T)$ for different $eB$'s are plotted in Fig. (1), where we notice that by reducing the degeneracy factor of QGP with reducing the temperature and magnetic field, one can properly map quark-hadron phase transition along temperature and magnetic field axis as described in Fig. (1)

After building the quasi-particle description of interacting QGP system in presence of magnetic field, next we are interested to find their impact on its transport Coefficient like electrical conductivity, which play a vital role in time evolotion of magnetic field $B(t)$ [3].

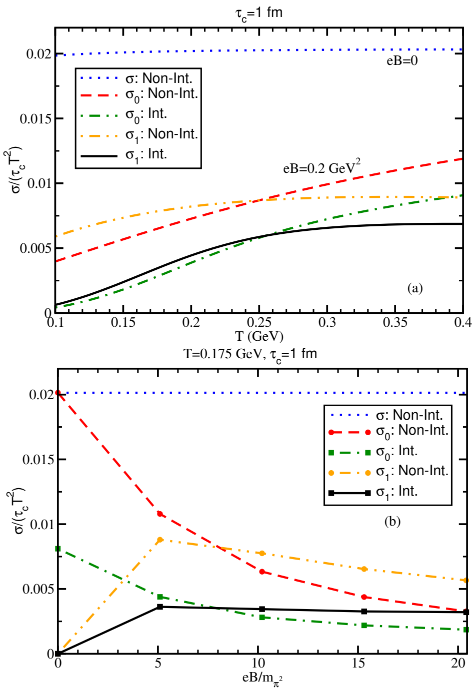


FIG. 2: Temperature and magnetic field dependence of electrical conductivity of non-interacting and interacting QGP system.

In absence of magnetic field, medium follow isotropic transport properties, for which we will get single component of electrical conductivity ($\sigma$), but they become multi-component in presence of magnetic field. We will get two main electrical conductivity components - normal ($\sigma_0$) and Hall ($\sigma_1$) coefficients, whose standard relativistic expressions are given below

$$\sigma_{0,1} = \sum_{i=u,d,s} \frac{g\tilde{e}_i^2\beta}{3}\int \frac{d^3k}{(2\pi)^3}\frac{\vec{k}^2}{(\vec{k}^2+m_i^2)}\tau_c \left(\frac{(\tau_c/\tau_B)^{0,1}}{1+(\tau_c/\tau_B)^2}\right) f_i(1-f_i) \quad (2)$$

where $g = 12$, $\tilde{e}^2_{u,d,s} = \frac{4e^2}{9}, \frac{e^2}{9}, \frac{e^2}{9}$, $m_{u,d,s} =$ 0.005, 0.005, 0.100 GeV, $f_i$ is Fermi-Dirac distribution function. In above equation, $\tau_B = \omega/(eB)$ is appeared as a new time scale due to magnetic field along with the relaxation time $\tau_c$, already existed at $B = 0$. One should notice that the charge neutral gluon does not have any role in electrical conductivity.

Using Eq. (2) at $B = 0$, $\sigma/(\tau_c T^2)$ for non-interacting QGP system is obtained and shown by dotted line in Fig. (2), which looks like straight horizontal line of SB limit for thermodynamical quantities. Next we have plotted normal (dash line) and Hall (dash-double-dotted line) components of electrical conductivity $\sigma_{0,1}$ for non-interacting QGP, which exhibit suppresed value with respect to $\sigma$. When we plug in the interaction through $g(T, B)$ in Eq. (2), conductivity will be suppresed more. From Fig.2(b), one can see that at $B \to 0$, normal components $\sigma_0$ of transport coefficients coincide with their without field isotropic value $\sigma$ and Hall components $\sigma_1$ becomes zero as expected. As $B$ becomes non-zero and increases Hall components also become non-zero and grow up, whereas normal components are reduced. The $B$ dependence is hidden in $\tau_B = \omega/(\tilde{e}B)$ and approximately $\sigma_0 \propto \frac{1}{1+(\tau_c/\tau_B)^2}$ and $\sigma_1 \propto \frac{(\tau_c/\tau_B)}{1+(\tau_c/\tau_B)^2}$ functional dependence are reflected in in Figs. 2(b). Analyzing the Hall component anisotropic factor $\frac{(\tau_c/\tau_B)}{1+(\tau_c/\tau_B)^2}$, we can get peak its value around $\tau_B \approx \tau_c$ and then it can be reduced with $B$. A detail investigation can be seen in Ref. [4]. The message of increasing electrical conductivity (normal component) with decreasing magnetic field might prevent decay of external magnetic field in RHIC or LHC experiments. according to Ref. [3]. Although a details phenomenological studies is required to check this by using our calculated $\sigma^0(T, B)$.

## References


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