Color Superconductivity in magnetized three flavor quark matter

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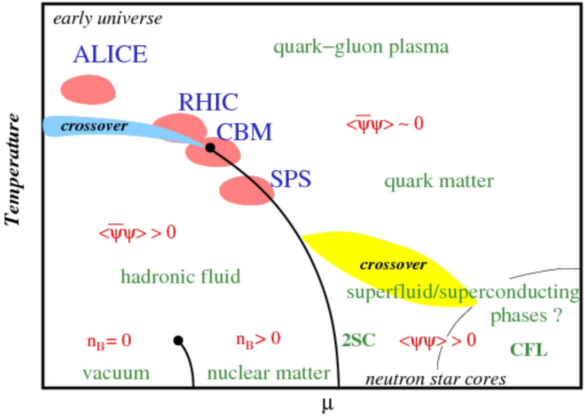
Overview

QCD phase diagram



[1]

[1] http://inspirehep.net/record/1181776/plots

Effect of magnetic field at high temperature and high density

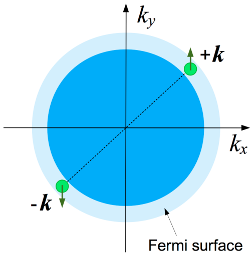
- Unusually high magnetic fields can be found in nature.
- In heavy ion collisions magnetic fields of the order of 15 m_π^2 can be generated [2]
- Intense magnetic fields are also found in neutron stars and early universe.[3]
- Lattice QCD shows magnetic fields can significantly affect the chiral condensate. [4]
- Studies have been made in perturbative QCD and effective models too.

[2] Int.J.Mod.Phys.Rev.D 81, 114031

[3] Phys.Lett.B265,258(1991), Phys.Lett.B319,178(1993), Astrophys. J. 392, L9(1992)

[4] JHEP 1202, 044(2012), Phys. Rev. D 86, 071502 (2012)

Superconductivity



[5]

- Discovered by H.K. Onnes in 1911.
- Theoretical explanation given by BCS in 1957.
- Fermi Surface unstable in presence of attractive interaction.
- Similar phenomenon possible in presence of quark matter.

[5] http://inspirehep.net/record/805336

Nambu Jona-Lasinio Model

$$
\begin{aligned}
\mathcal{H} &= \psi^\dagger(-i\boldsymbol{\alpha}\cdot\boldsymbol{\nabla} - qBx\alpha_2 + \gamma^0 m)\psi \\
&- G_s \sum_{A=0}^{8}\left[(\bar{\psi}\lambda^A\psi)^2 - (\bar{\psi}\gamma^5\lambda^A\psi)^2\right] \\
&- G_D \sum_{A=0}^{8}\left[(\bar{\psi}^c\lambda^A\psi)^2 - (\bar{\psi}^c\gamma^5\lambda^A\psi)^2\right] \\
&+ K\left[det_f[\bar{\psi}(1+\gamma_5)\psi] + det_f[\bar{\psi}(1-\gamma_5)\psi]\right]
\end{aligned} \tag{1}
$$

Thermodynamic Potential and Gap Equations

$$\Omega = \Omega^{sc}_{\frac{1}{2}} + \Omega^{s}_{\frac{1}{2}} + \Omega^0 + \Omega^1 + 4G_s I_s^{i^2} - 4k I_s^u I_s^d I_s^s + \frac{\Delta^2}{4G_D} - \frac{k}{4} I_s^3 I_D^2$$

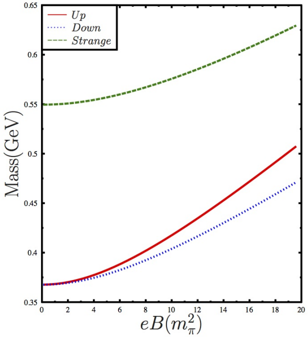
By minimizing the thermodynamic potential, one gets the following four self consistent gap equations.

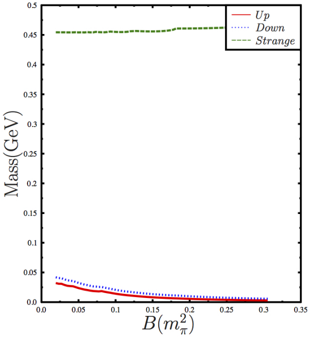
- $M_u = M_{0u} - 4GI_s^u + 2kI_s^s I_s^d$, where $I_s^i = \langle \bar{\psi}^i \psi^i \rangle$
- $M_d = M_{0d} - 4GI_s^d + 2kI_s^s I_s^u$
- $M_s = M_{0s} - 4GI_s^s + 2kI_s^u I_s^d + k\frac{I_D^2}{4}$
- $\Delta = (2G_D - \frac{1}{2}kI_s^s)I_D$, where $I_D = \langle \bar{\psi}_c^{ia} \gamma^5 \psi^{jb} \rangle \epsilon^{ij} \epsilon^{3ab}$

Charge neutrality Conditions

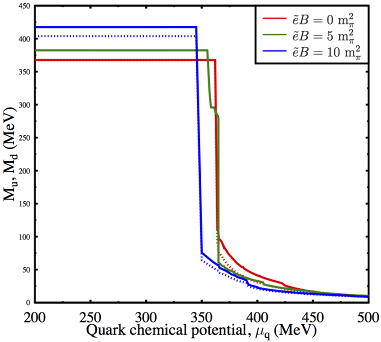
- $\rho_E = \frac{2}{3}\rho_u - \frac{1}{3}\rho_d - \frac{1}{3}\rho_s - \rho_e = 0$
- $\rho_8 = \sum_i \frac{1}{\sqrt{3}}(2\rho^{i1} - \rho^{i2} - \rho^{i3}) = 0$

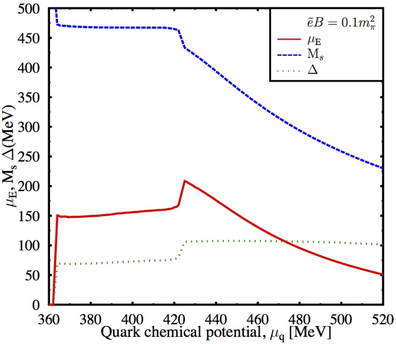
Mass Vs. Magnetic Field(Without Charge Neutrality)



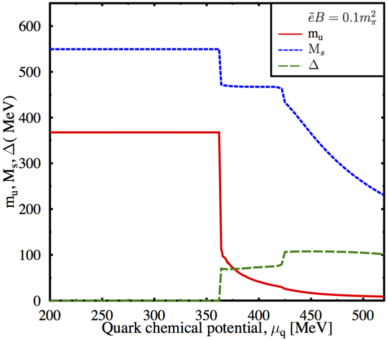


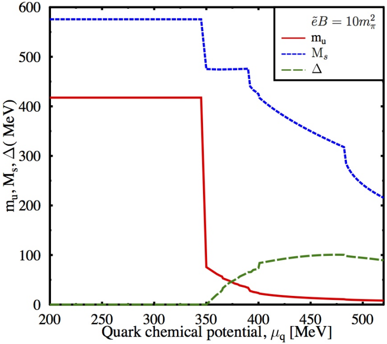
Gaps Vs. Chemical Potential (Charge Neutral Matter)





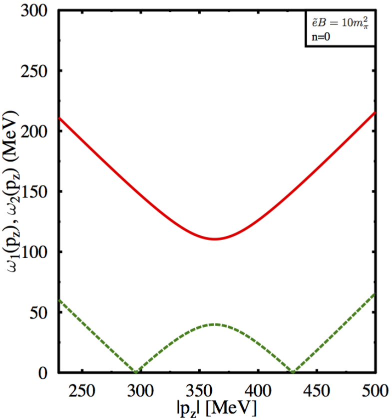
Gaps for $\tilde{e}B$=0.1, 10 m_π^2 (With charge neutrality)





Dispersion for Gapless mode

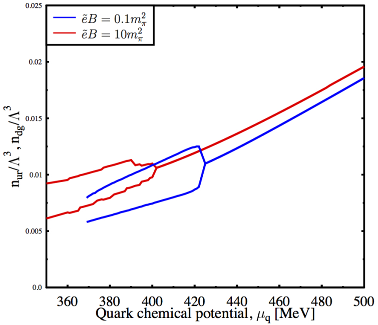
$$\omega_{\pm}^{11} \equiv \omega_{\pm}^{u} = \bar{\omega}_{\pm} + \delta\epsilon_n \pm \delta\mu$$
$$\omega_{\pm}^{21} \equiv \omega_{\pm}^{d} = \bar{\omega}_{\pm} - \delta\epsilon_n \mp \delta\mu$$

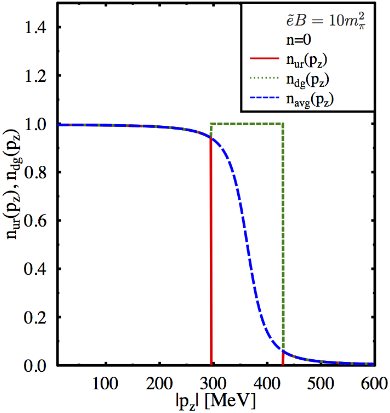


$$\rho^{u}_{sc} = \sum_{n} \frac{\alpha_n \tilde{e} B}{(2\pi)^2} \int dp_z [\frac{1}{2}(1 - \frac{\bar{\zeta}_{n-}}{\bar{\omega}_{n-}})(1 - \theta(-\omega^d_n)) - \frac{1}{2}(1 - \frac{\bar{\zeta}_{n+}}{\bar{\omega}_{n+}})]$$

$$\rho^{d}_{sc} = \sum_{n} \frac{\alpha_n \tilde{e} B}{(2\pi)^2} \int dp_z [\theta(-\omega^d_n) + \frac{1}{2}(1 - \frac{\bar{\zeta}_{n-}}{\bar{\omega}_{n-}})(1 - \theta(-\omega^d_n)) - \frac{1}{2}(1 - \frac{\bar{\zeta}_{n+}}{\bar{\omega}_{n+}})]$$

Density Mismatch (cont.)





THANK YOU