The 7th Asian Triangle Heavy-Ion Conference (ATHIC 2018)

BARYON NUMBER FLUCTUATIONS IN THE 2+1 FLAVOR LOW ENERGY EFFECTIVE THEORY

Rui Wen

Dalian University of Technology

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*based on : R. W. ,Chuang Huang,Wei-jie Fu ,arXiv:1809.04233

OUTLINE

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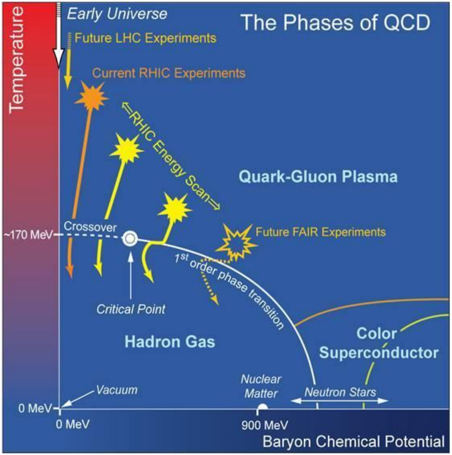
Introduction



Effective action

The PQM scale-dependant effective action

$$\Gamma_k = \int_x [\bar{q}(\gamma_\mu\partial_\mu - \gamma_0(\mu + igA_0)))q + h\bar{q}\Sigma_5 q + tr(\partial_\mu\Sigma \cdot \partial_\mu\Sigma^\dagger) + \tilde{U}_k(\Sigma) + V_{glue}(L, \bar{L})] \tag{2.1}$$

$\int_x \equiv \int_0^{1/T} dx_0 \int d^3x_i$

local potential approximation (LPA)

$$\partial_t Z_{\phi/q} = 0, \partial_t h_{l/s} = 0$$

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Σ means the meson field

$$\Sigma = T_a(\sigma_a + i\pi_a), a = 0, 1, ...8,$$
$$\Sigma_5 = T_a(\sigma_a + i\gamma_5 \pi_a)$$

$T_a = \lambda_a/2$, λ_a are the Gell-Mann matrices.

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$$\tilde{U}_k(\Sigma) = U_k(\rho_1, \tilde{\rho_2}) - c_k \xi - j_L \sigma_L - j_S \sigma_S$$

$U_k(\rho_1, \tilde{\rho_2})$ chirally invariant term
$SU_V(3) \times SU_A(3) \times U_V(1) \times U_A(1)$
$\xi = det(\Sigma) + det(\Sigma^\dagger)$ Kobayashi-Maskawa-'t Hooft(KMT) term
$j_L \sigma_L, j_S \sigma_S$ the linear sigma terms

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The Polyakov loops

$$L(x) = \frac{1}{N_c}\langle Tr\mathcal{P}(x)\rangle, \quad \bar{L} = \frac{1}{N_c}\langle Tr\mathcal{P}^\dagger(x)\rangle$$

with $\mathcal{P}(x) = \mathcal{P}exp(ig\int_0^\beta d\tau A_0(x,\tau))$

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$$\frac{V_{glue}}{T^4} = -\frac{1}{2}a(t)\bar{L}L + \frac{c(t)}{2}(L^3 + \bar{L}^3) + d(t)(\bar{L}L)^2 \\ + b(t)\ln(1 - 6\bar{L}L + 4(L^3 + \bar{L}^3) - 3(\bar{L}L))$$

reduced temperature $t = (T - T_c)/T_c$, $t_{YM} = \alpha t_{glue}$

[arXiv:1307.5958] Pok Man Lo et al.

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The Wetterich equation

$$\partial_t \Gamma_k = -Tr(G_k^{q\bar{q}} \partial_t R_k^q) + \frac{1}{2} Tr(G_k^{\phi\phi} \partial_t R_k^\phi)$$

$t = ln(k/\Lambda)$

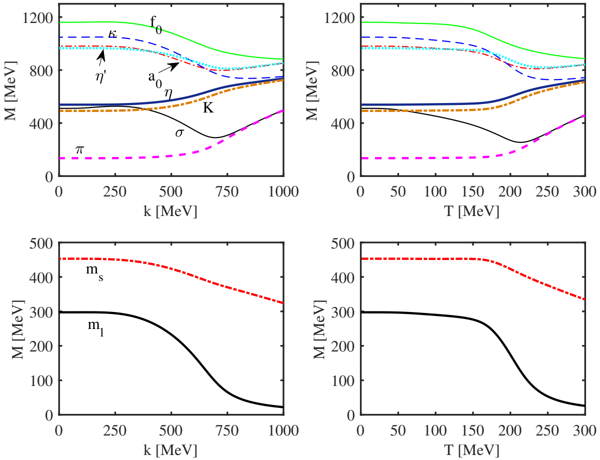
The flow equation

$$
\begin{aligned}
\partial_t U_k(\rho_1, \tilde{\rho}_2) = \frac{k^4}{4\pi^2}\{&3l_0^{(B)}(m_{\pi,k};T) + 4l_0^{(B)}(m_{K,k};T)) \\
&+ l_0^{(B)}(m_{\eta,k};T) + l_0^{(B)}(m_{\eta',k};T)) + 3l_0^{(B)}(m_{a0,k};T)) \\
&+ 4l_0^{(B)}(m_{\kappa,k};T) + l_0^{(B)}(m_{f0,k};T)) + 3l_0^{(B)}(m_{\sigma,k};T)) \\
&- 4N_c[2l_0^{(F)}(m_{l,k};T,\mu) + l_0^{(F)}(m_{s,k};T,\mu)]\}
\end{aligned} \tag{2.2}
$$

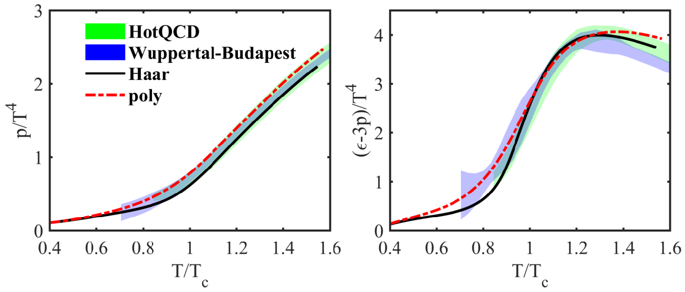
here

$$
\begin{aligned}
l_0^{(B)}(m) &= \frac{k}{3E_{\phi,k}}(1 + 2n_B(E_{\phi,k})) \\
l_0^{(F)}(m) &= \frac{k}{3E_{q,k}}(1 - n_F(E_{q,k} - \mu) - n_F(E_{q,k} + \mu))
\end{aligned} \tag{2.3}
$$

The meson and quark masses changed with scale k and temperature T



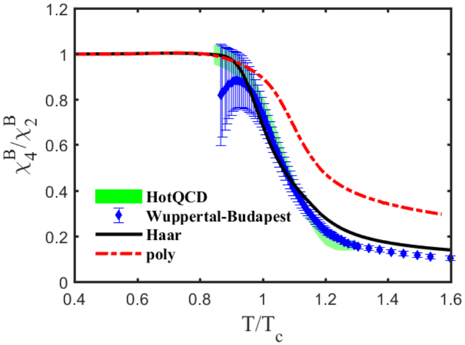
The pressure p and the trace anomaly $\Delta = \epsilon - 3p$ $(\alpha = 0.52, T_c^{glue} = 270MeV)$



$T_\chi = 194MeV$
hotQCD [arXiv:1407.6387] $T_\chi = 154MeV$
Wuppertal-Budapest [arXiv:1309.5258] $T_\chi = 156MeV$

The culumants $\chi_n^B = \frac{\partial^n}{\partial(\mu_B/T)^n}\frac{P}{T^4}, n \in \mathbb{Z}$

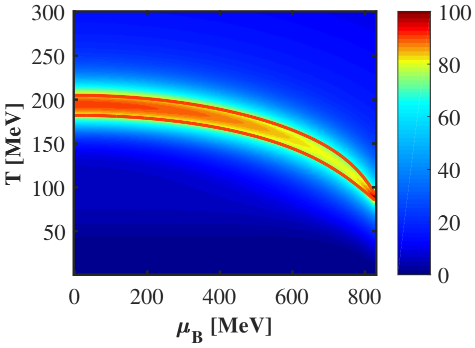
The kurtosis ratio $R_{42} = \chi_4^B/\chi_2^B$



hotQCD [arXiv:1708.04897]
Wuppertal-Budapest[arXiv:1305.5161]

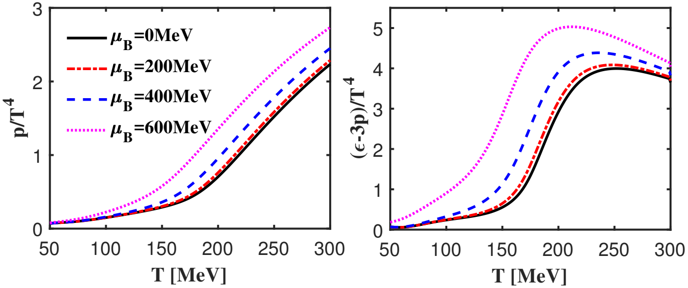
Chiral transition diagram

(identified by $\left|\frac{\partial\rho_1}{\partial T}\right|$) 90%

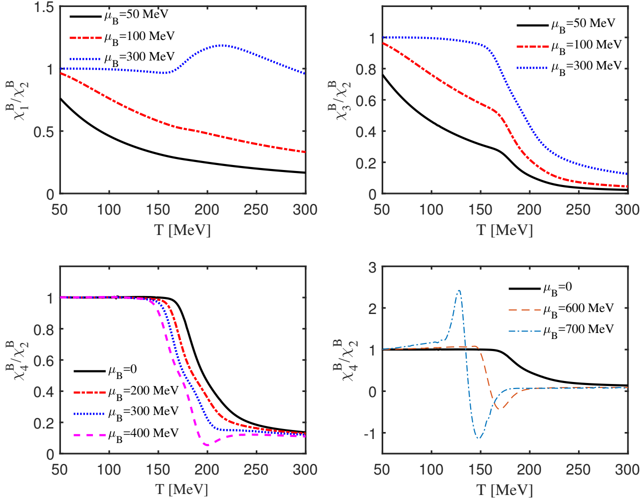


$(T_C = 84MeV, \mu_{BC} = 840MeV)$

The pressure and the trace anomaly



Ratios of baryon number fluctuations



Summary and outlook

- The pressure, trace anomaly and the kurtosis agree with the lattice results.
- The EoS and baryon number fluctuations up to the four order at finite baryon chemical potential are also calculated.
- In the future, lots of things can be done,for instance, going beyond the LPA truncation,considering the electric charge and strangeness chemical potentials,extending the low energy effective theory to the 2+1 flavor QCD.

Thank you

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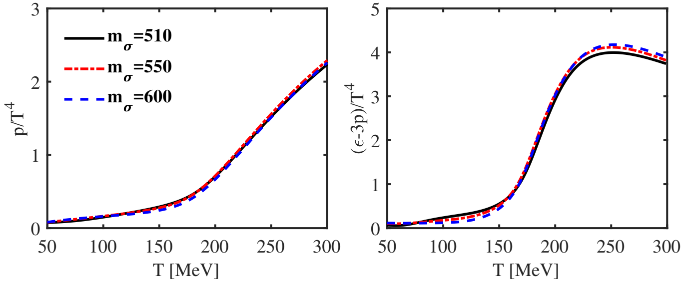
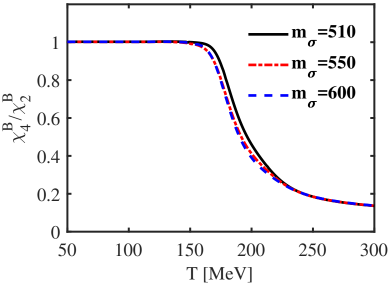
Backup

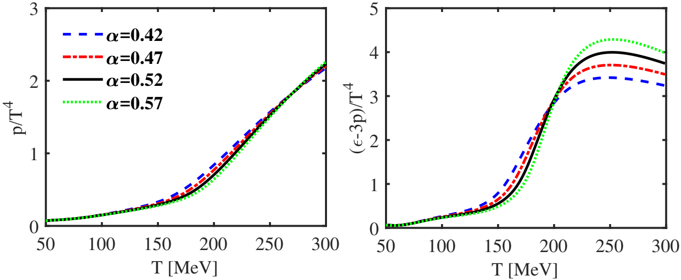
The pressure and the trace anomaly m_σ



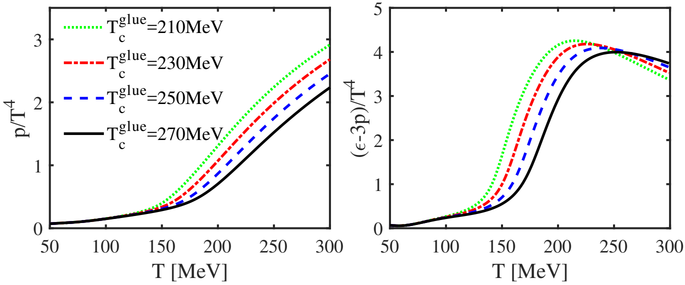
The kurtosis ratio m_σ



The pressure and the trace anomaly α



The pressure and the trace anomaly T_c^{glue}



- $$U_{k=\Lambda}=-\int_{\Lambda}^{\infty}dk\frac{k^5N_c}{3\pi^2}\Big(\frac{2}{E_l}(n_F(x_l,T,L,\bar{L})+n_F(\bar{x}_l,T,\bar{L},L)+\frac{1}{E_s}(n_F(x_s,T,L,\bar{L})+n_F(\bar{x}_s,T,\bar{L},L)\Big) \quad (4.1)$$

  $$m_{l/s,k>\Lambda}=m_{l/s,k=\Lambda},$$

- $$\frac{\partial U_{total}}{\partial\sigma_l}=\frac{\partial U_{total}}{\partial\sigma_s}=\frac{\partial U_{total}}{\partial L}=\frac{\partial U_{total}}{\partial\bar{L}}=0 \quad (4.2)$$

Result

Initial conditions

- the UV cutoff $\Lambda = 1GeV$
  $$U(\rho,\tilde{\rho}_2)_\Lambda = \lambda_{10}\rho_1 + \frac{\lambda_{20}}{2}\rho_1^2 + \lambda_{01}\rho_2$$
- $h_l = h_s = 6.5$, $c_k = 4808MeV$
  $j_l = (121MeV)^3, j_s = (336MeV)^3$
  $\lambda_{10} = (654MeV)^2$, $\lambda_{20} = 31$, $\lambda_{01} = 11.9$
- $f_\pi = 92MeV, f_K = 115MeV$
  $m_\pi = 135MeV, m_K = 492MeV,$
  $m_\sigma = 510MeV, m_\eta^2 + m_\eta'^2 = 1.22 \times 10^6 MeV^2$
  $m_l = 299MeV, m_s = 454MeV$