Transport properties of the QGP in the dynamical quasi-particle model with a CEP

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In collaboration with
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O. S., J. Aichelin and E. Bratkovskaya, PRD 105 (2022) 054011

O. S., D. Fuseau, J. Aichelin and E. Bratkovskaya, PRC 103 (2021) no.5, 054901

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Strong-interaction matter under extreme conditions

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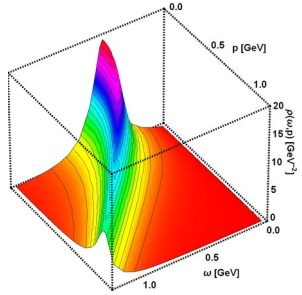
HFHF

Dynamical Quasi-Particle Model

- The QGP phase is described in terms of strongly-interacting off-shell quasiparticles - quarks and gluons with Lorentzian spectral functions:

$$\rho_j(\omega,\mathbf{p}) = \frac{\gamma_j}{\tilde{E}_j}\left(\frac{1}{(\omega-\tilde{E}_j)^2+\gamma_j^2} - \frac{1}{(\omega+\tilde{E}_j)^2+\gamma_j^2}\right) \equiv \frac{4\omega\gamma_j}{\left(\omega^2-\mathbf{p}^2-M_j^2\right)^2+4\gamma_j^2\omega^2}$$

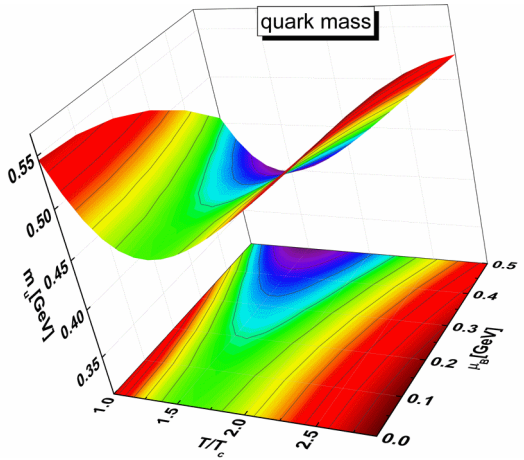


resummed propagators: $\Delta_i(\omega,\mathbf{p}) = \dfrac{1}{\omega^2-\mathbf{p}^2-\Pi_i}$ & self-energies: $\Pi_i = m_i^2 - 2i\gamma_i\omega$

$$\gamma_j(T,\mu_B) = \frac{1}{3}C_j\frac{g^2(T,\mu_B)T}{8\pi}\ln\left(\frac{2c_m}{g^2(T,\mu_B)}+1\right)$$

$$m^2_{q(\bar{q})}(T,\mu_B) = C_q\frac{g^2(T,\mu_B)}{4}T^2\left[1+\left(\frac{\mu_B}{3\pi T}\right)^2\right]$$

$$s^{dqp} = -\int\frac{d\omega}{2\pi}\frac{d^3p}{(2\pi)^3}\left[d_g\frac{\partial n_B}{\partial T}\left(\mathrm{Im}(\ln -\Delta^{-1}) + \mathrm{Im}\,\Pi\,\mathrm{Re}\,\Delta\right) + \sum_{q=u,d,s} d_q\frac{\partial n_F(\omega-\mu_q)}{\partial T}\left(\mathrm{Im}(\ln -S_q^{-1}) + \mathrm{Im}\,\Sigma_q\,\mathrm{Re}\,S_q\right) + \sum_{\bar{q}=\bar{u},\bar{d},\bar{s}} d_{\bar{q}}\frac{\partial n_F(\omega+\mu_q)}{\partial T}\left(\mathrm{Im}(\ln -S_{\bar{q}}^{-1}) + \mathrm{Im}\,\Sigma_{\bar{q}}\,\mathrm{Re}\,S_{\bar{q}}\right)\right]$$



Input: entropy density as a f(T)

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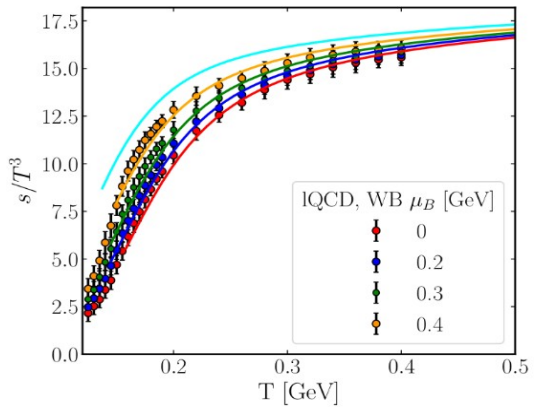
Coupling constant:

$$g^2(s/s_{SB}) = d\left((s/s_{SB})^e - 1\right)^f$$



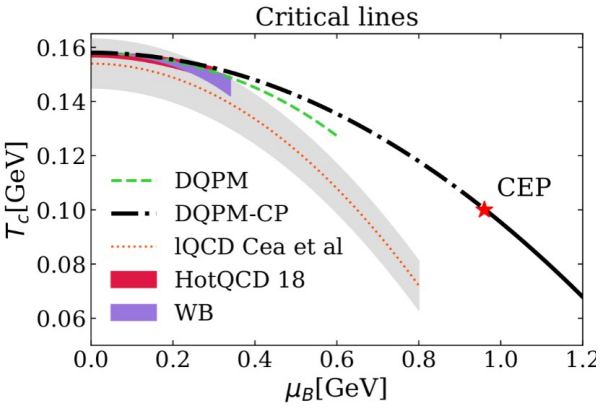
Peshier, Cassing, PRL 94 (2005) 172301; Cassing, NPA 791 (2007) 365; H. Berrehrah, E. Bratkovskaya, T. Steinert, W. Cassing, Int. J. Mod. Phys. E 25 (2016), 164200; P. Moreau, O. Soloveva , L. Oliva, T. Song, W. Cassing, E. Bratkovskaya, PRC 100 (2019) , 014911;

Quasiparticle model with CEP

- DQPM-CP for high μ_B, including the CEP region based on the scaling properties of the entropy density from the PNJL model

  D. Fuseau, T. Steinert, J. Aichelin PRC 101 (2020) 6 065203

- DQPM-CP interpolates EoS and microscopic properties between two asymptotics - high $T \gg T_c$, $\mu_B = 0$ and $T > T_c$, $\mu_B \gg T$
- EoS and transport coefficients of the QGP phase for the wide range of $T > T_c$, μ_B

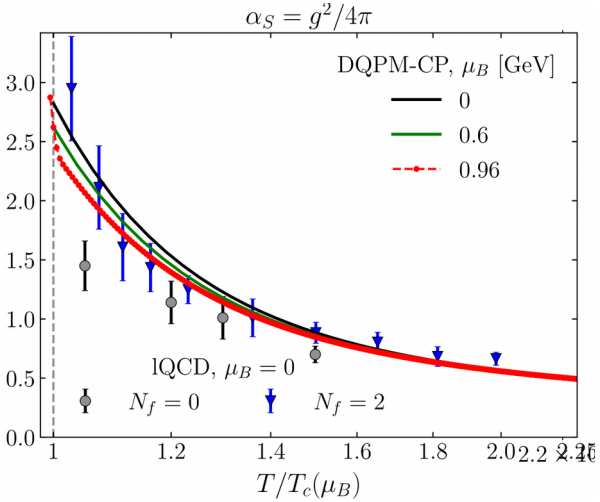


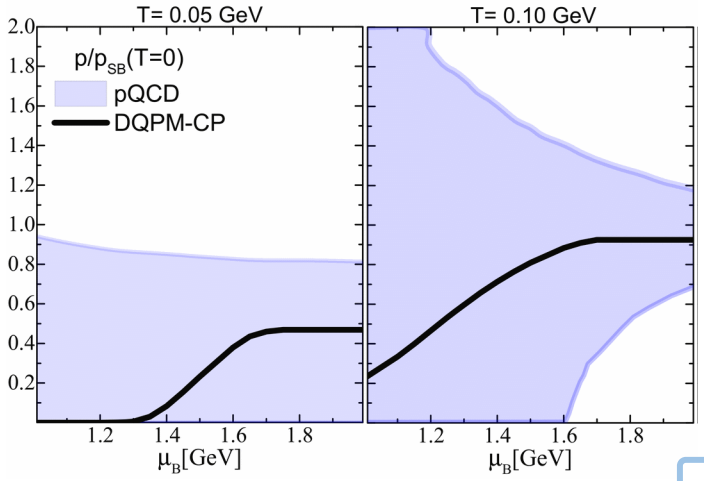
CEP: $(T_c, \mu_B) = (100,960)$ MeV , $\mu_B/T = 9.6$

EoS : for $\mu_B/T < 2$ agreement with lQCD for $\mu_B/T > 6$ agreement with pQCD

Near CEP:

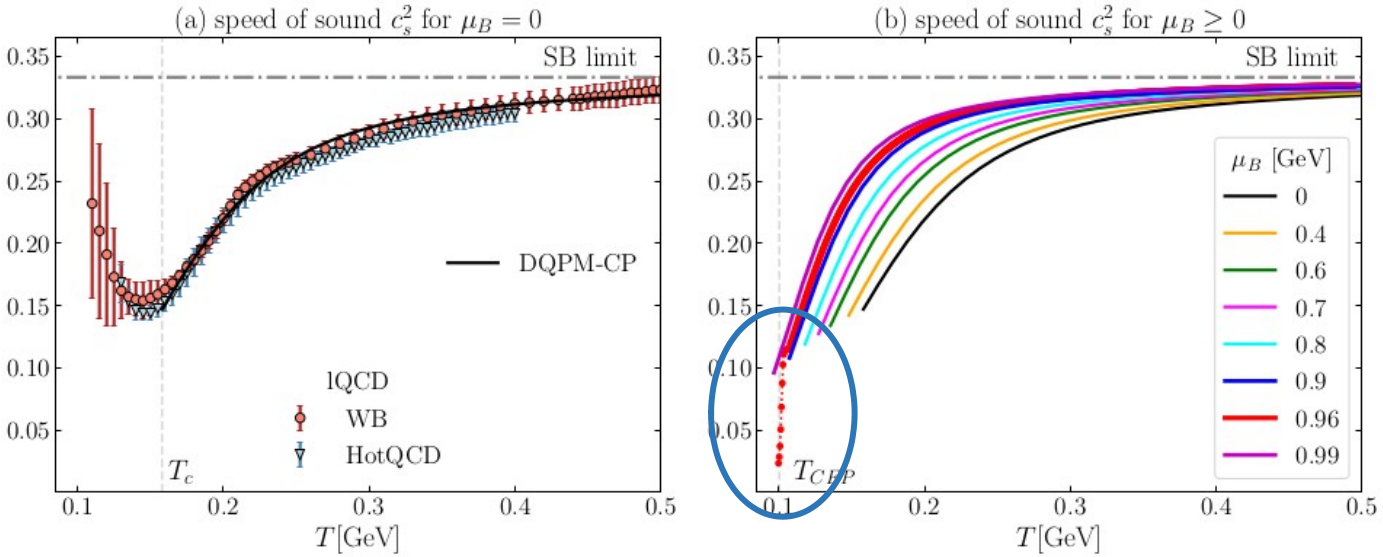
$$g^2 = f(s^{PNJL}(T/T_c)) \rightarrow g^2(T/T_c)$$

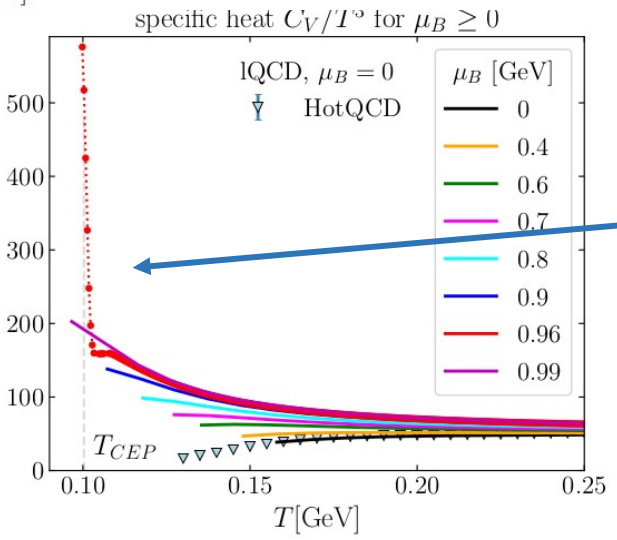




Speed of sound & Specific heat

- EoS : for $\mu_B/T < 2$ agreement with lQCD for $\mu_B/T > 6$ agreement with pQCD





Near CEP critical scaling can be seen:

$$\ln(C_V) = -\alpha \cdot \ln(T - T_{CEP}) + const$$

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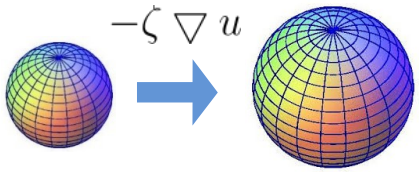
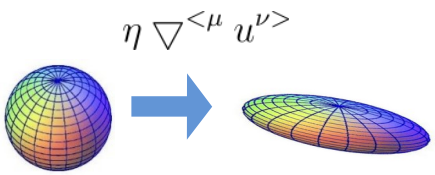
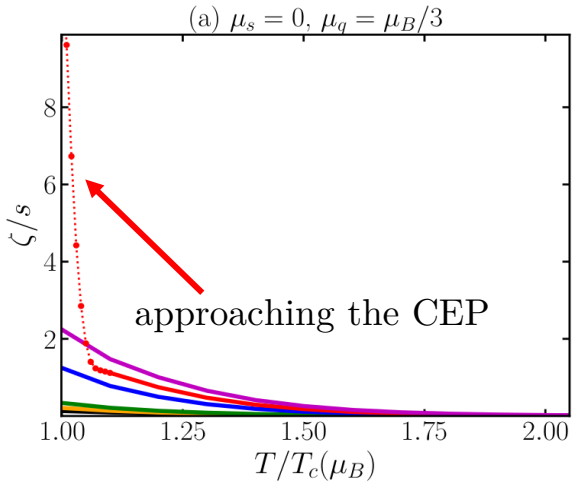
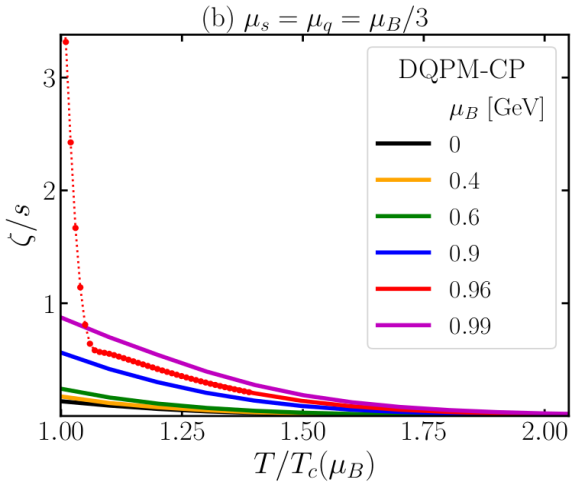
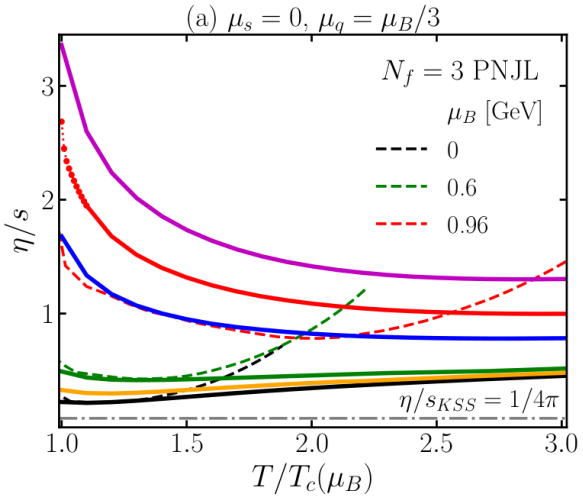
Shear and bulk viscosities near the CEP

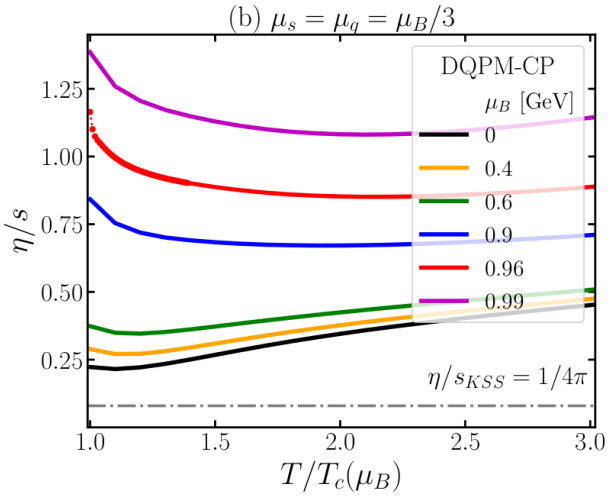












- Sudden rise of specific bulk viscosity approaching the CEP

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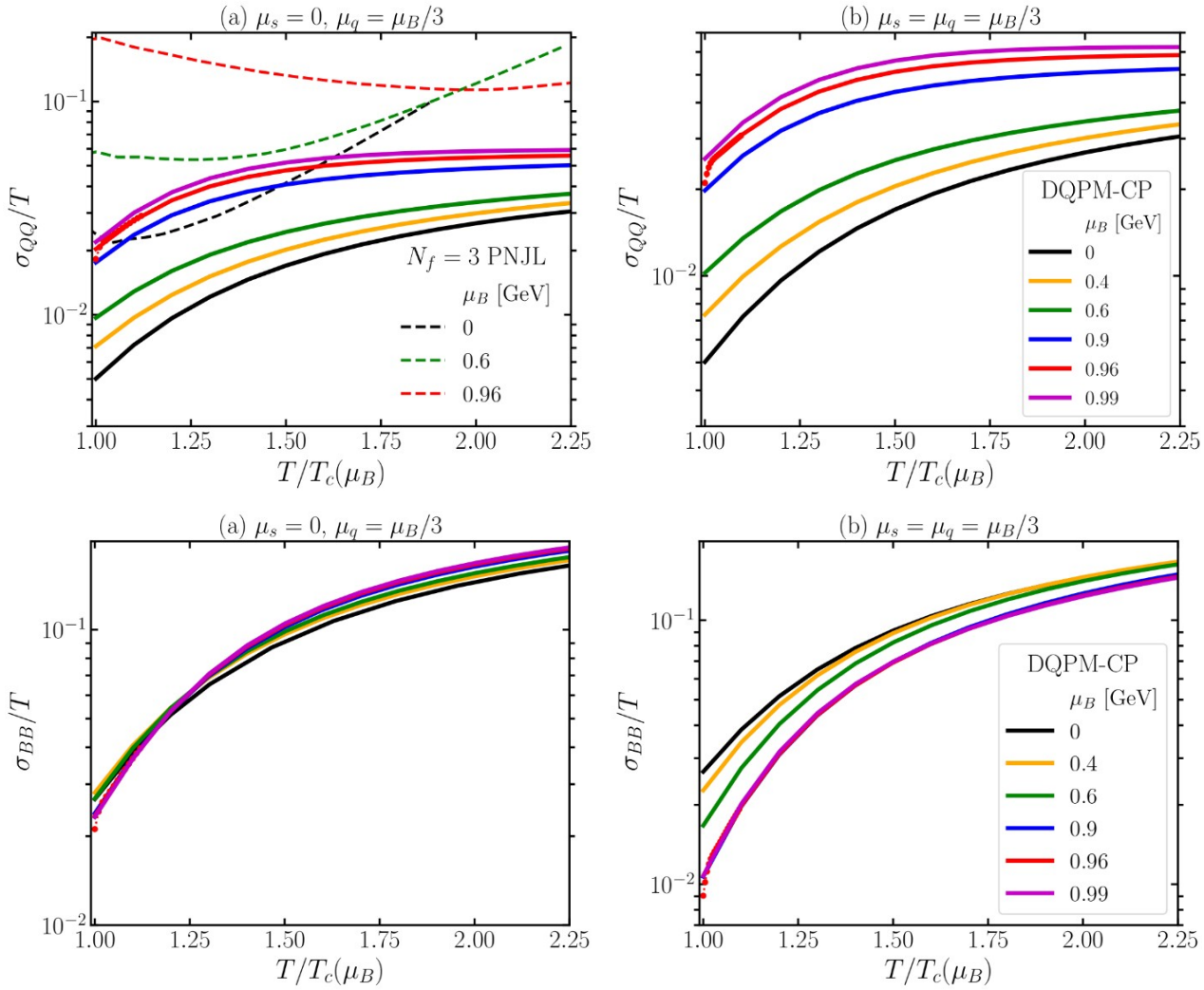
Transport coefficients near the CEP

$\sigma_q = \kappa_q / T$



B,Q,S diffusion coefficients have pronounced $\mu_{B/S}$-dependence

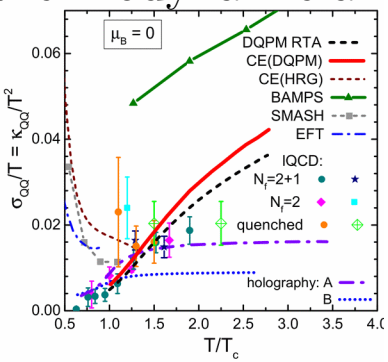
- Only small increase approaching the CEP

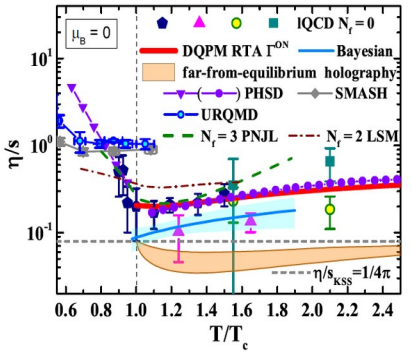
Summary

Transport properties of the strongly-interacting QGP matter at finite **T** and $\mu_{B/S}$ have been investigated.

Influence of an order of a phase transition on thermodynamic and transport properties has been studied.

- Transport coefficients can differ among the models, which have similar phase structures and EoS





The presented results are model dependent, however, qualitatively in agreement with the results from various effective models such as PNJL, NJL, LSM, and (non)conformal holographic models (see J. Grefa 6:06 PM).

- We have found that the DQPM-CP estimates of the specific bulk viscosity show a rapid increase when approaching the CEP from the high T region originating from the rapid decrease of the speed of sound
- While specific shear viscosity and the B, Q, S conductivities have only a small enhancement $\leq$10%, caused mainly by the critical contribution of the effective coupling constants

See also **jet transport coefficicents**
I. Grishmanovskii poster T04_1

Non-equilibrium microscopic transport approach (DQPM for partonic phase)

QGP out-of equilibrium ⟷ HIC