Almost LO Shear Viscosity at High Chemical Potentials

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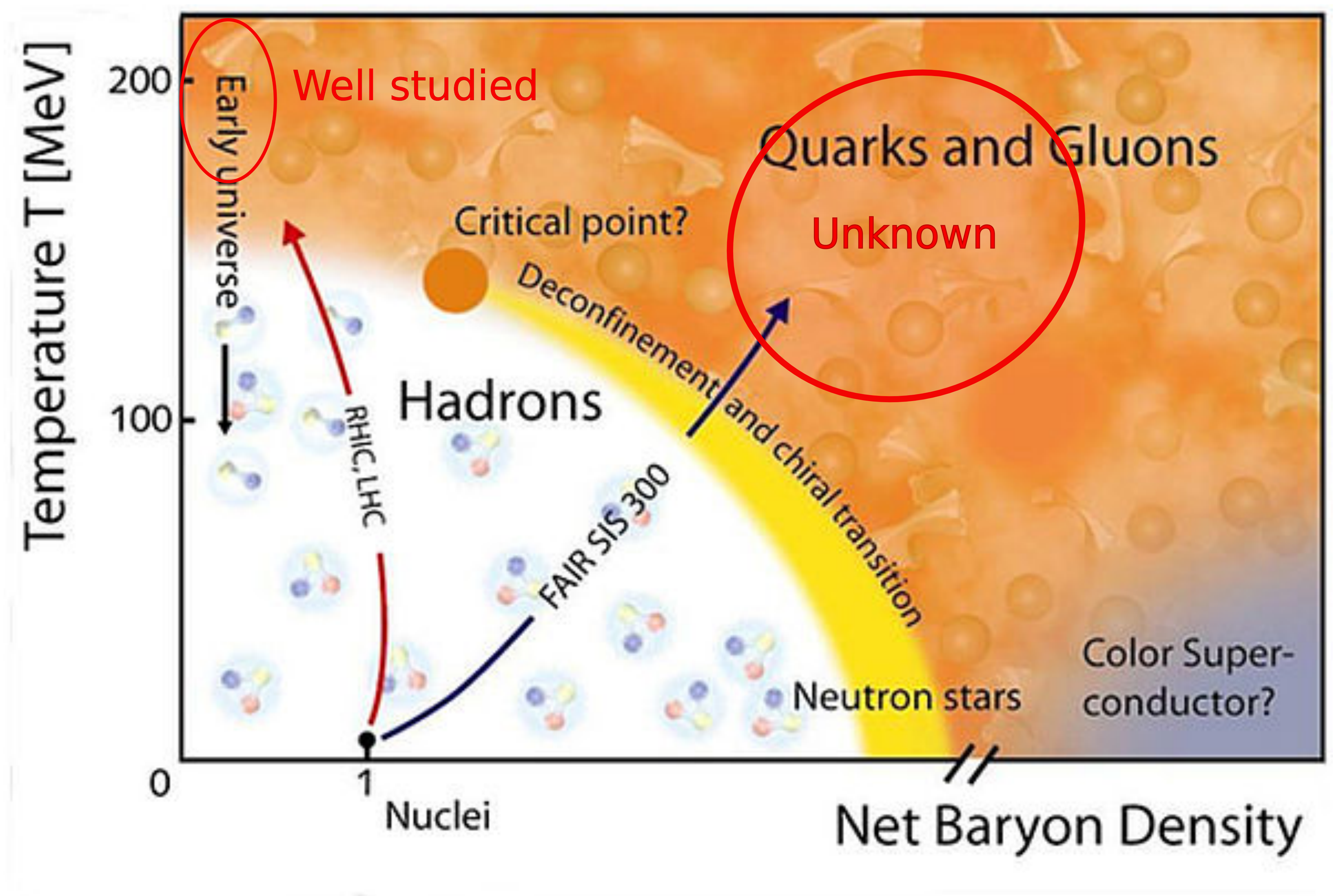
Motivation

- High density high temperature region is very unknown
- Perturbation theory should work better - $m_D \sim g^2(T^2+\mu^2)$
- Accessible for GSI experiments



GSI Helmhotz Center for Heavy-Ion Physics

Shear Viscosity and Boltzmann Equation

In a fluid system near equilibrium:

- T^{ij} corrected from its equilibrium form:

$$T^{ij} = P\delta^{ij} - \eta\left(\partial^i u^j + \partial^j u^i - \frac{2}{3}\delta^{ij}\partial\cdot u\right) - \zeta\delta^{ij}\partial\cdot u$$

- Keeping only first order in the collision term:

$$\left[\frac{\partial}{\partial t} + \vec{v_p}\cdot\frac{\partial}{\partial\vec{x}}\right] f_0^a(\vec{p},\vec{x},t) = -(\mathcal{C}[f_1^a])(\vec{p},\vec{x},t)$$

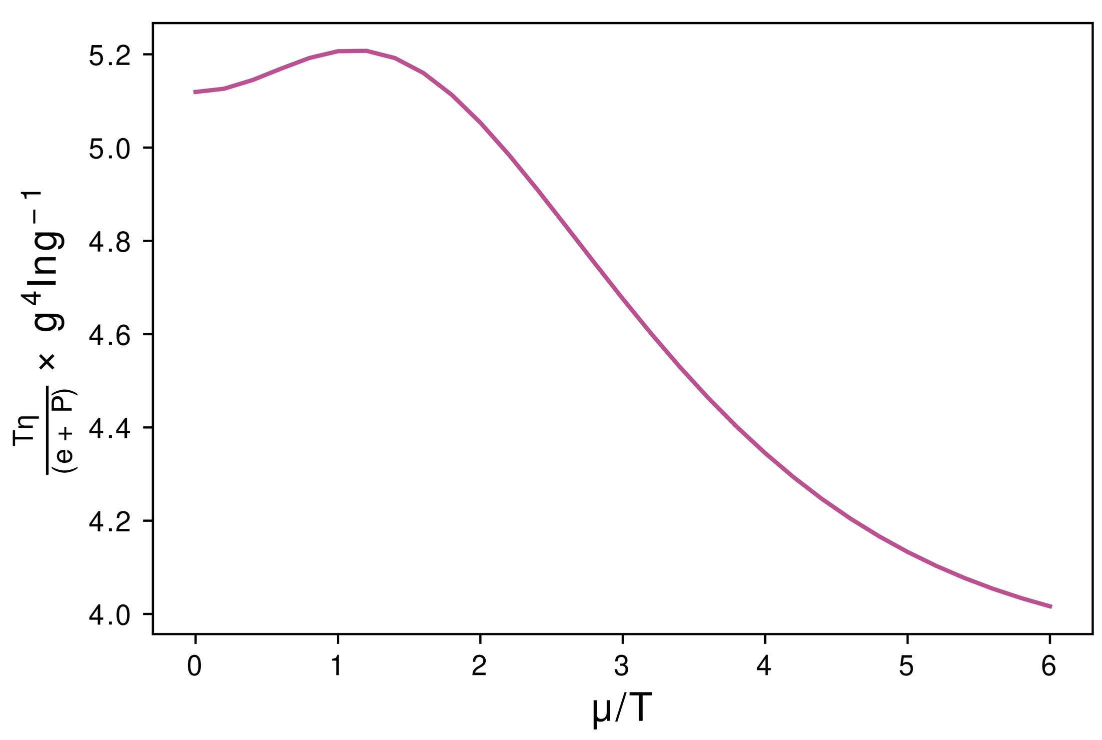
- Our departure from equilibrium:

$$f_1(\vec{p}) = \frac{\beta^2}{\sqrt{6}}\left(\partial_i u_j + \partial_j u_i - \frac{2\delta_{ij}\partial_k u_k}{3}\right)\sqrt{\frac{2}{3}}\left(\hat{p}_i\hat{p}_j - \frac{1}{3}\delta_{ij}\right)\chi(p)$$

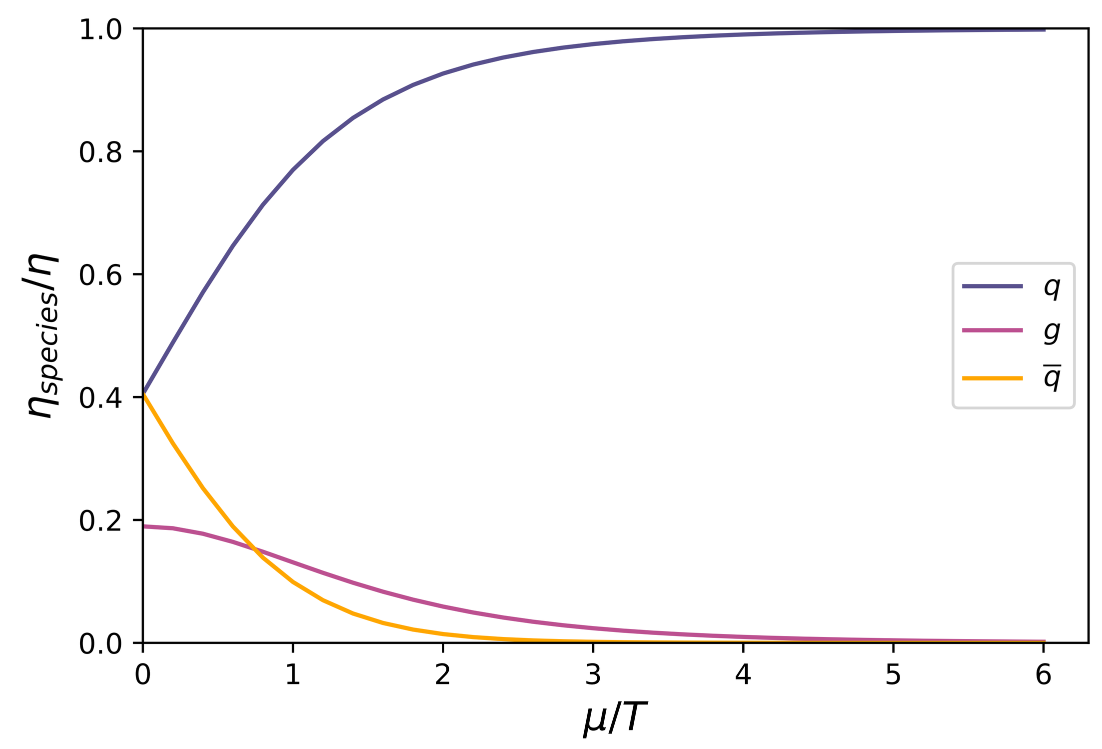
- Collision integral:

$$\begin{aligned}(\chi_{ij},\mathcal{C}\chi_{ij}) = \frac{\beta^3}{8}\sum_{abcd}\int_{\vec{p},\vec{k},\vec{p}',\vec{k}'} &\frac{|\mathcal{M}_{abcd}(P,K,P',K')|^2}{2p\,2k\,2p'\,2k'}(2\pi)^4\delta^4(P+K-P'-K') \\ &\times f_0^a(p)f_0^b(k)\left[1\pm f_0^c(p')\right]\left[1\pm f_0^d(k')\right] \\ &\times\left[\chi_{ij}^a(\vec{p}) + \chi_{ij}^b(\vec{k}) - \chi_{ij}^c(\vec{p'}) - \chi_{ij}^d(\vec{k'})\right]^2\end{aligned}$$

Leading Log Results



Kinematic shear viscosity $\eta T/(e+P)$ as a function of μ.
$\rightarrow$ high-density fluid will relax somewhat more quickly than one at vanishing chemical potential



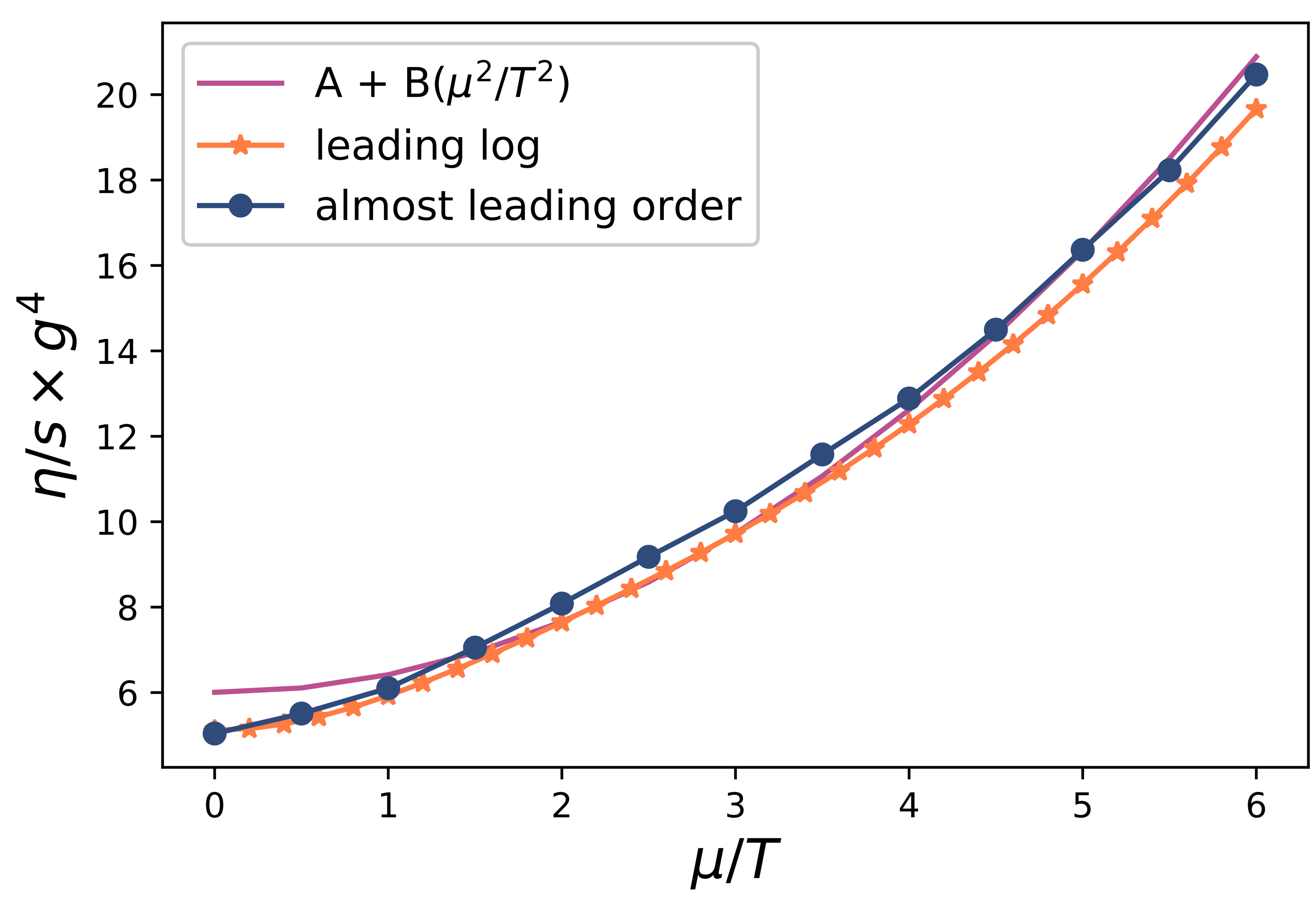
Contribution from each diagram to shear viscosity, $a_{mn}^{(\mathrm{A/B/C...})}a_n$, normalized by the sum of all contributions, as a function of chemical potential.

For more leading log results:

Almost Leading Order Results

In this plot we compare leading order results for a basis of size 2 to our results for leading log order with $m_D^2 = T^2 + \mu^2/\pi^2$. The curve found follows a similar behavior to what was observed for leading log:

$$g^4\eta/s = A + B\mu^2/T^2$$



Variational Solution

$$\mathcal{Q}[\chi] = (\chi_{i\ldots j}, S_{i\ldots j}) - \frac{1}{2}(\chi_{i\ldots j},\mathcal{C}\chi_{i\ldots j})$$

- S is the source term

$$(S_{ij},\chi_{ij}) = \sum_m a_m\tilde{S}_m$$

- $\mathcal{C}$ is the collision operator

$$(\chi_{ij},C\chi_{ij}) = \sum_{m,n} a_m\tilde{C}_{mn}a_n,$$

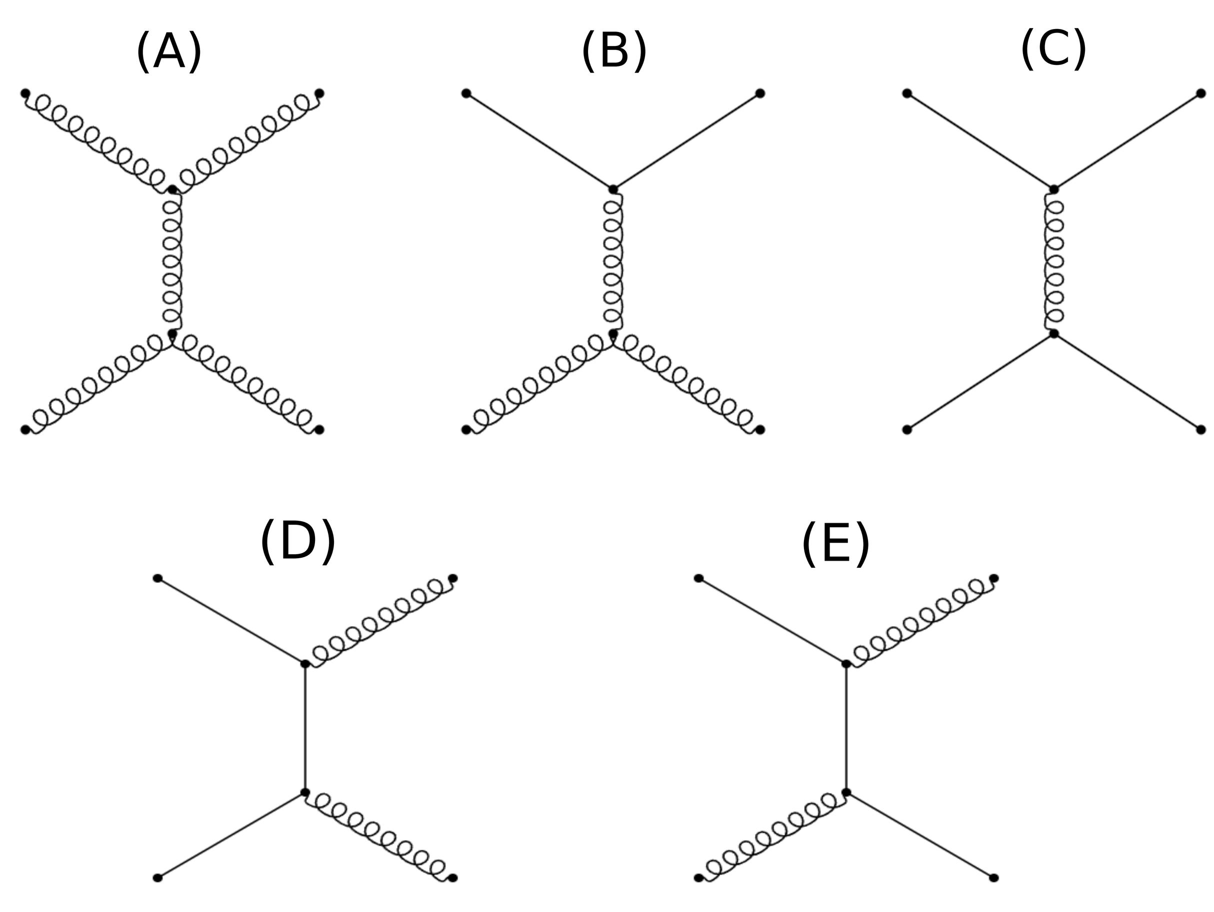
And

$$\tilde{S}_m = \left(S_i,\phi_i^{(m)}\right),\quad \tilde{C}_{mn} = \left(\phi_i^{(m)}, C_i\phi_i^{(n)}\right)$$

Viscosity comes from maximizing $\mathcal{Q}$:

$$\eta = \frac{2}{15}\mathcal{Q}_{max}$$

Feynman Diagrams



HTL Approximation

Diagrams A,B,C require the inclusion of screening traditionally done with HTL approximation. For a fermion-dominated system, exact screening is known and we can compare: