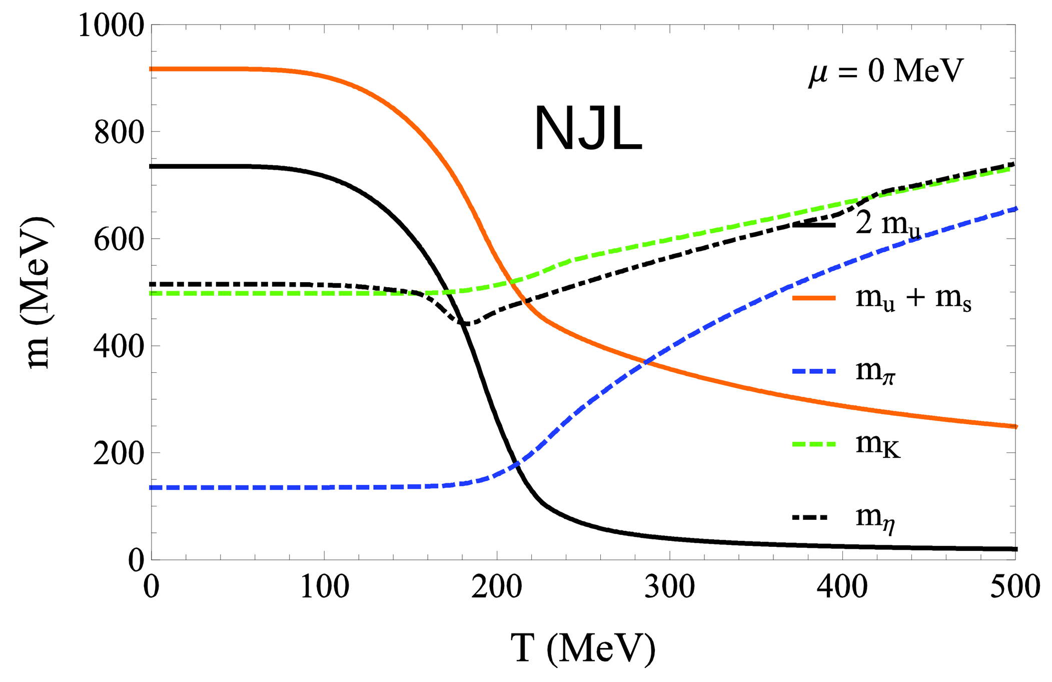
Equilibrium properties of the hot QGP

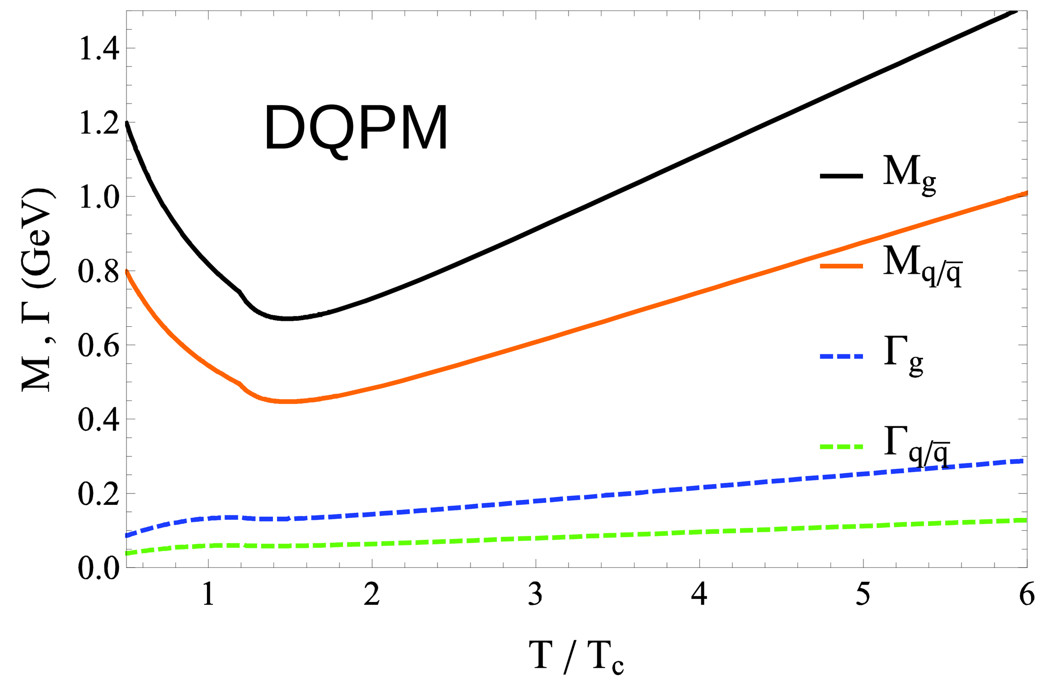
R. Marty et al.



Motivations

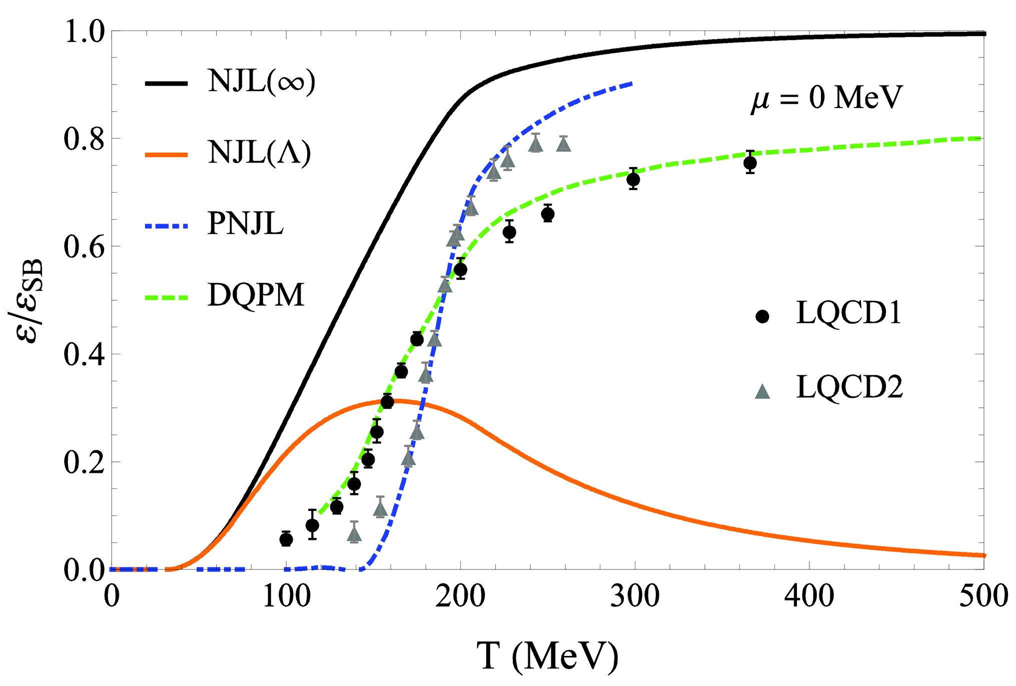
The properties of the Quark-Gluon Plasma (**QGP**) at high temperature are encoded in its transport coefficients which in principle can be calculated within lattice QCD or related effected approaches.

For that purpose, we compare the results from the Nambu-Jona-Lasinio (**NJL**) model with those of the Dynamical QuasiParticle Model (**DQPM**) as well as the available data from Lattice QCD.



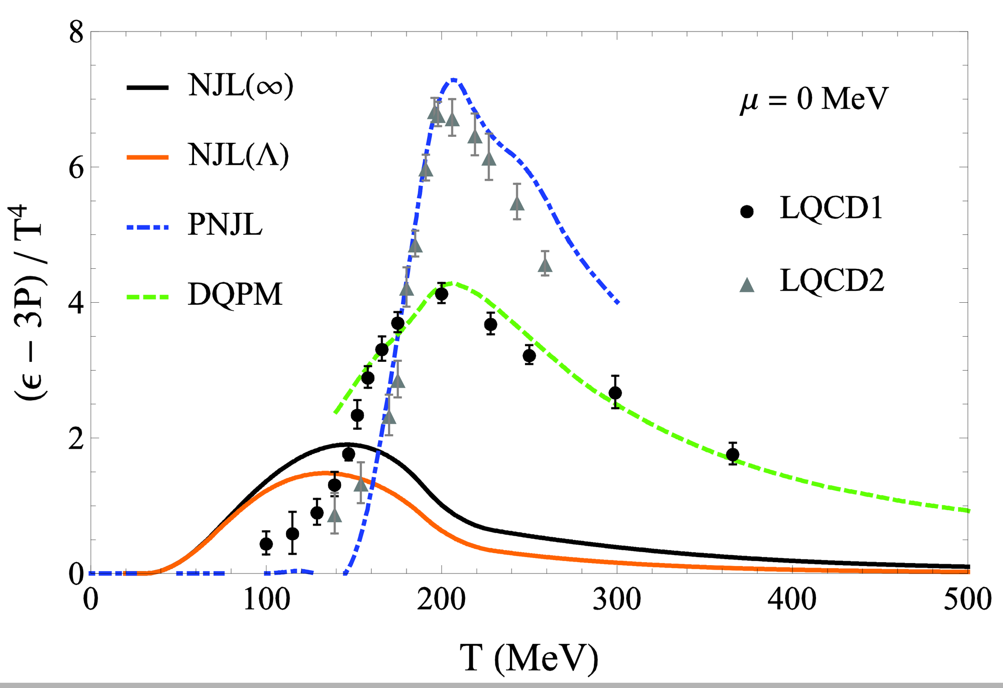
Equations of state

The equation of state (here the energy density divided by the Stefan Boltzmann limit) shows the variation of the numbers of **degrees of freedom** with temperature.



$$T^{\mu\nu}(T,\mu) = g\int_0^\infty \frac{d^3p}{(2\pi)^3} f(E)\frac{p^\mu p^\nu}{E}$$

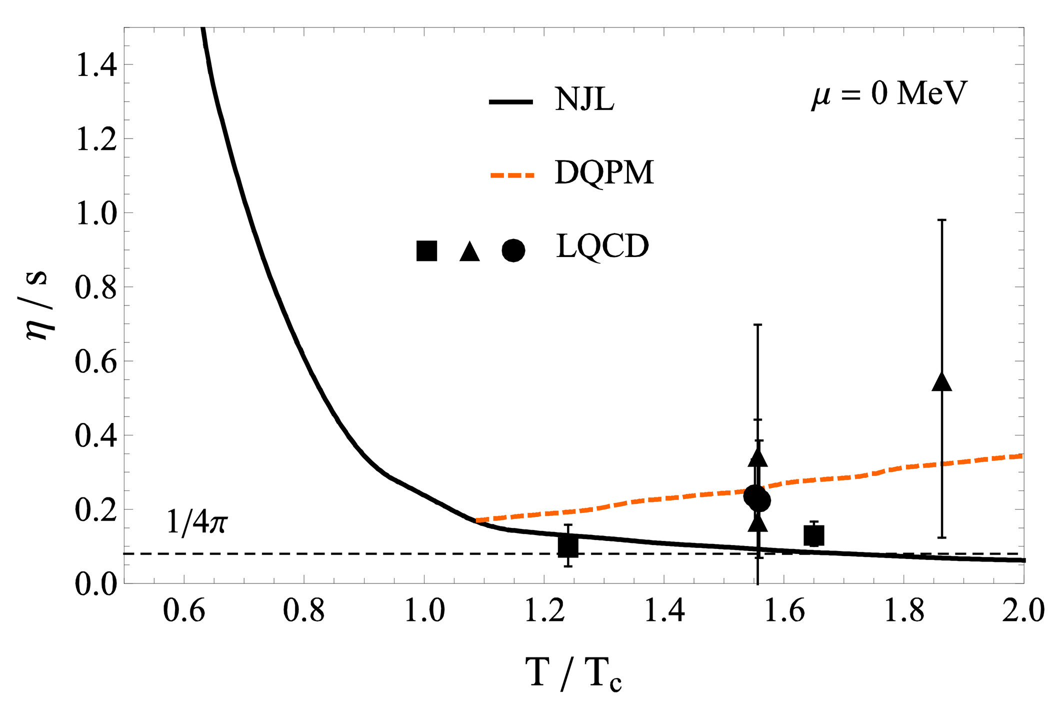
The energy density is extracted from the **energy-momentum tensor** (lhs for the NJL).



From the equation of state (which depends on the effective masses of the models), we can compute the **trace anomaly**, which gives a good estimate of the interaction intensity.

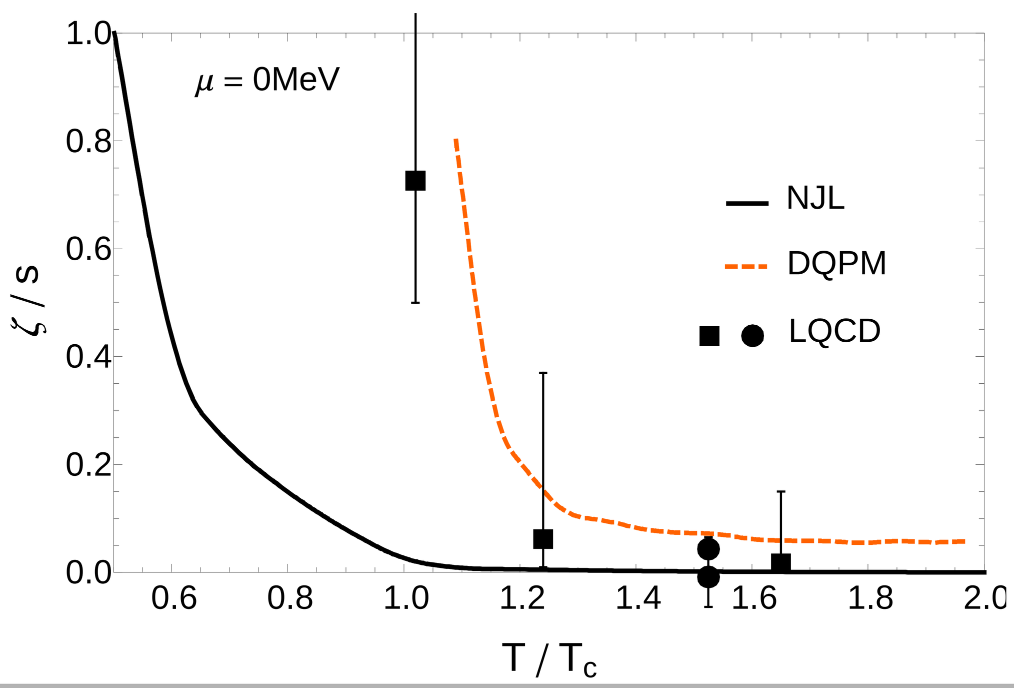
Viscosity

Macroscopic quantities such as the viscosity of a fluid can be extracted in the **relaxation time approximation**.



$$\eta(T,\mu) = \frac{1}{15T} g\int_0^\infty \frac{d^3p}{(2\pi)^3}\tau f(E)\frac{\mathbf{p}^4}{E^2}$$

$$\zeta(T,\mu) = \frac{1}{9T} g\int_0^\infty \frac{d^3p}{(2\pi)^3}\tau f(E)\frac{1}{E^2}\left[\mathbf{p}^2 - 3c_s^2\left(E^2 - T^2\frac{dm^2}{dT^2}\right)\right]^2$$

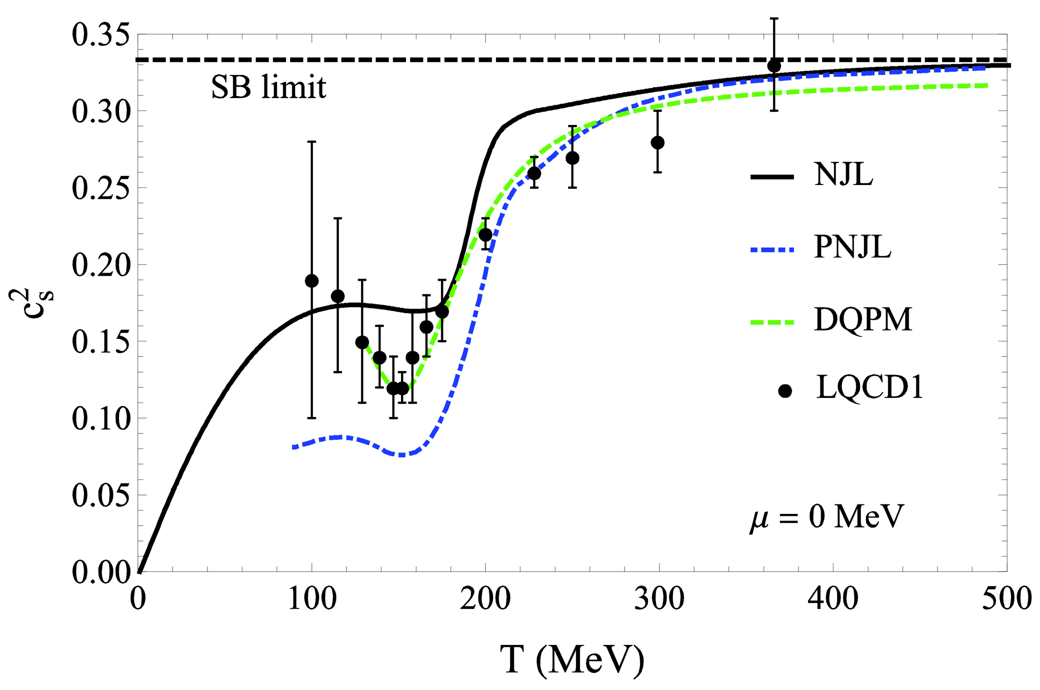


From elastic scattering (NJL) or the interaction rate (DQPM), we compute the **shear** (above) and **bulk** (left) **viscosities** which determine the transport properties of the system

Speed of Sound

Related to the equation of state, the **speed of sound** is of interest for the study of **fluctuations** and collective motion.

$$c_s^2 = \left(\frac{\partial P}{\partial \varepsilon}\right)_{n_B}$$

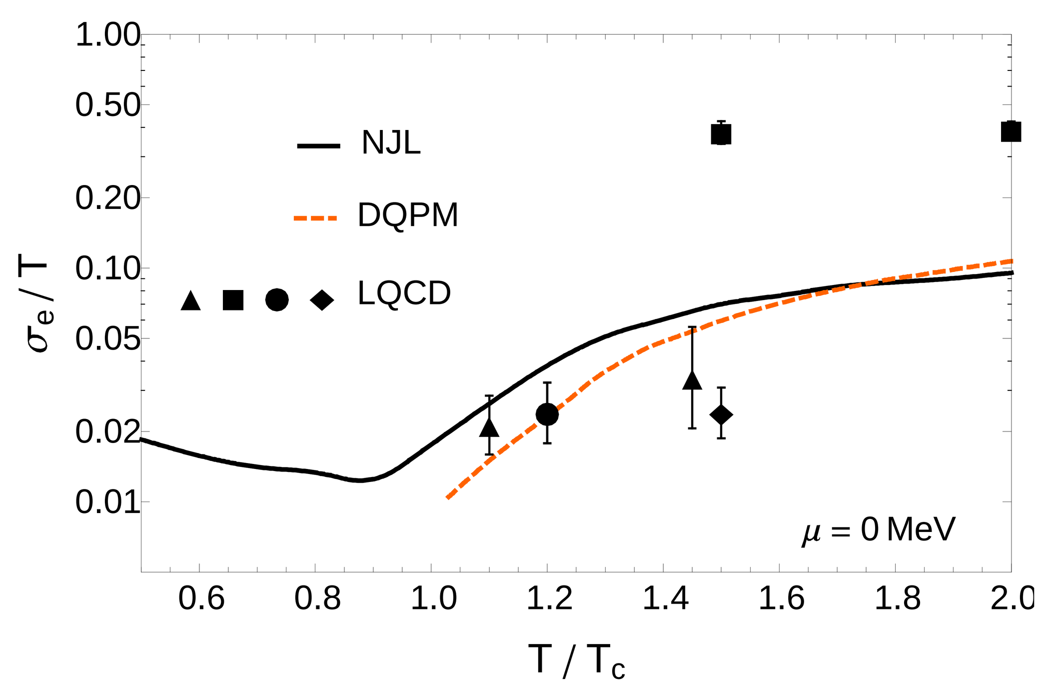


Electric conductivity

The **electric conductivity** of quarks is important for the propagation of **electro-magnetic fields** in the QGP.

$$\sigma_e(T,\mu) = \sum_q \frac{e_q^2\, n_q(T,\mu)\, \tau_q(T,\mu)}{m_q(T,\mu)}$$

$$\text{with} \quad e_q^2 = \frac{4\pi}{137}e^2$$



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Conclusion / outlook

The study of the equation of state and the transport coefficients from the NJL and DQPM shows that these models have **similar properties** and can be used in transport simulations. This is already the case for DQPM which is included in the **Parton-Hadron-String Dynamics** (PHSD) approach. The NJL model is currently under implementation.