The Quark-Gluon-Plasma as a Dynamical Quasi-Particle Medium

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The Problem

- ***What*** are the QGP degrees of freedom (d.o.f): lQCD gives QGP EoS, which need to be interpreted in terms of d.o.f
- ***What*** are the temperature, quark chemical potential (T, μ) dependencies of QGP d.o.f
- ***What*** are the thermodynamic and transport properties of the QGP

The Model

- DQPM (Dynamical Quasi-Particle Model): d.o.f are strongly interacting quasi-particles
- QCD is a theory with a rich structure $\leftrightarrow$ DQPM is a model which reproduces QCD features at finite (T, μ)
- DQPM: 2PI-HTL approach + Quasiparticle width + Phenomenological flexibility

Results

- Good agreement between DQPM *vs* lQCD for thermodynamic (EoS, C_s^2) and transport quantities (η/s, ζ/s, $\sigma_e/T, \ldots$)
- DQPM allows to extrapolate to finite μ presently out of reach for lQCD.
- Comparison study of: on- *vs* off-shell, $\mu = 0$ *vs* finite μ, partonic *vs* hadronic medium

Model Details

d.o.f in DQPM

d.o.f: off-shell quark and gluon with finite mass and width

$$M_g(T,\mu) = \frac{g^2(T^\star/T_c(\mu))}{6}\left[(N_c + \frac{1}{2}N_f)T^2 + \frac{N_c}{2}\sum_q a_\mu \mu^2\right]$$

$$M_{q,\bar{q}}(T,\mu) = \frac{N_c^2-1}{8N_c}\, g^2(T^\star/T_c(\mu))\left[T^2 + a_\mu \mu^2\right]$$

with: $\mathbf{a_\mu = 1/\pi^2}$

$\mathbf{T^{\star 2} = T^2 + a_\mu \mu^2}$

$$\gamma_g(T,\mu) = \frac{1}{2}N_c\,\frac{g^2(T^\star/T_c(\mu))}{8\pi}\,T\,\ln\left(\frac{2c}{g^2(T^\star/T_c(\mu))}+1\right)$$

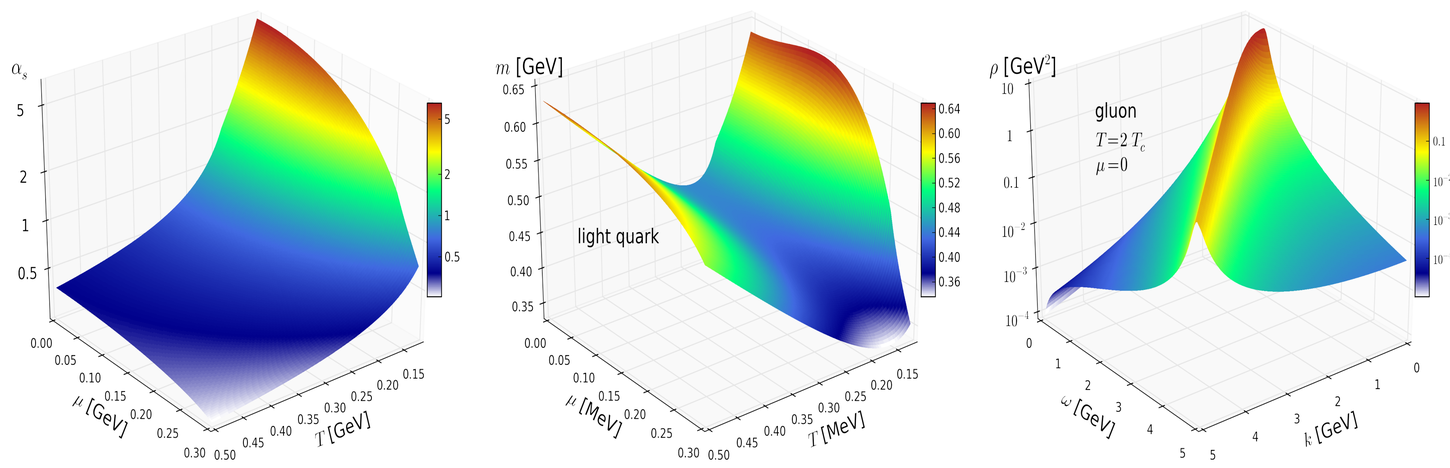
$$\gamma_{q,\bar{q}}(T,\mu) = \frac{1}{2}\,\frac{N_c^2-1}{2N_c}\,\frac{g^2(T^\star/T_c(\mu))}{8\pi}\,T\ln\left(\frac{2c}{g^2(T^\star/T_c(\mu))}+1\right)$$

$\boldsymbol{g(T)}$: effective coupling, IR enhancement

$$g^2(s/s_{SB}) = g_0\left(\left(\frac{s}{s_{SB}}\right)^b - 1\right)^d$$

with: $g_0 = 170, b = -0.178, d = 1.146$

$\left[g^2(s/s_{SB}) \to s/s_{SB}\big|_{lQCD} \to g^2(T/T_c)\right]$



DQPM at finite (T, μ)

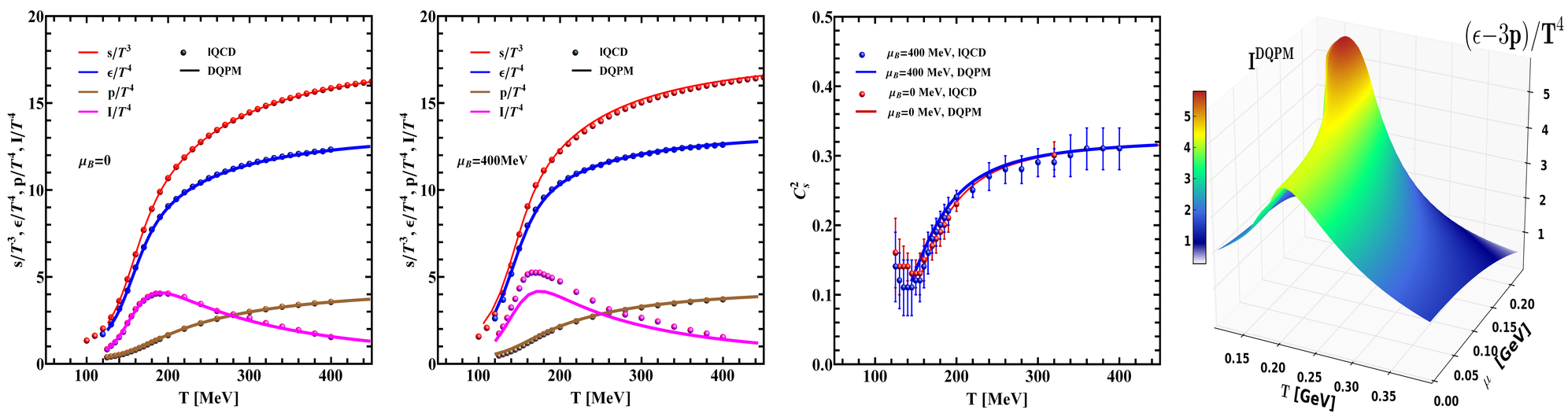
Scaling hypothesis: • $\boldsymbol{g(T/Tc(\mu=0)) \to g(T^\star/T_c(\mu))}$ • Constant energy density ϵ at $T = T_c(\mu)$ with ϵ at $T_c(\mu=0) \approx 0.158$ GeV is fixed by lQCD.

$\looparrowright$ • $\boldsymbol{T_c(\mu) = T_c(\mu=0)\sqrt{1-\alpha\mu^2} \approx T_c(\mu=0)\left(1-\alpha/2\mu^2+\ldots\right)}$, with $\alpha_{DQPM} \approx 8.79\ \mathrm{GeV}^{-2} \leftrightarrow \alpha_{lQCD} \approx 8.796\ \mathrm{GeV}^{-2}$

DQPM Results *vs* lQCD

QGP thermodynamics at (T, μ)

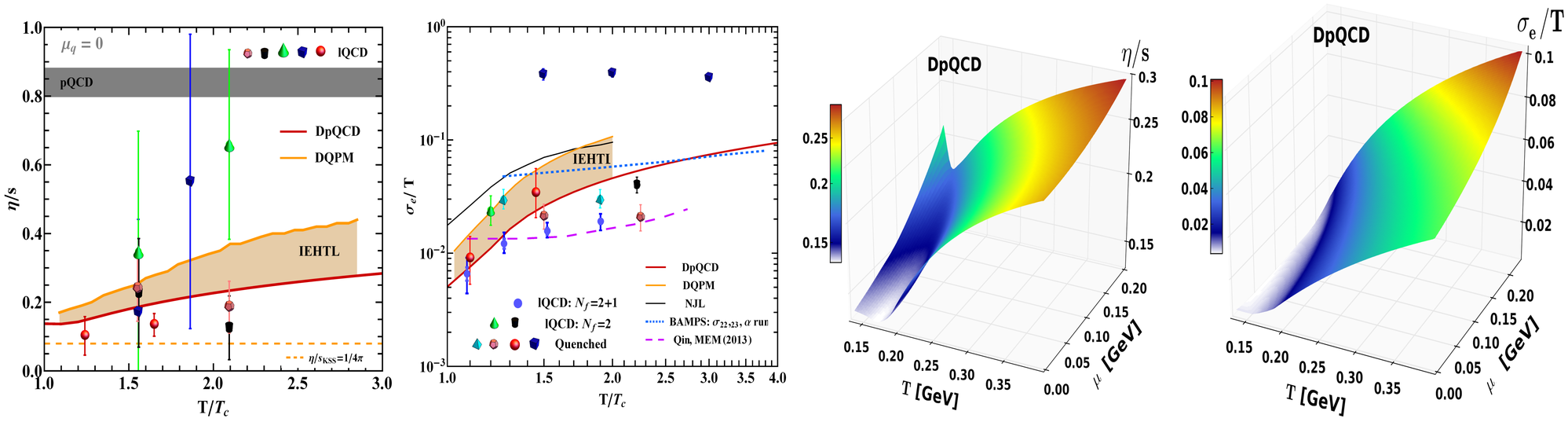
- Fix the T, μ dependencies of QGP d.o.f
- Smooth transition from partonic-hadronic world: Non-pQCD treatment



- **Good description of QGP thermodynamics within DQPM, including speed of sound**

QGP transport at (T, μ)

- q, g partonic cross section evaluated for on- and off-shell massive q, g at (T, μ)
- Smooth increase of η/s, σ/s, $\ldots$*vs* T and μ
- Minimum around T_c at $\mu = 0$ and finite μ



- **Consistent microscopic evaluation of QGP transport coefficients, in agreement with lQCD**

References

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