Dynamical equilibration of strongly-interacting 'infinite' parton matter

Vitalii Ozvenchuk,

in collaboration with

E.Bratkovskaya, O.Linnyk, M.Gorenstein, W.Cassing

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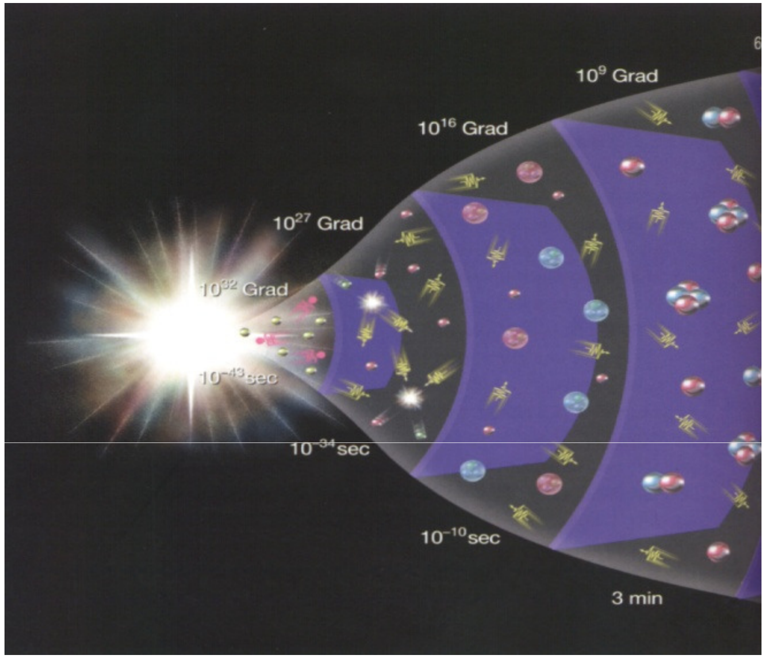
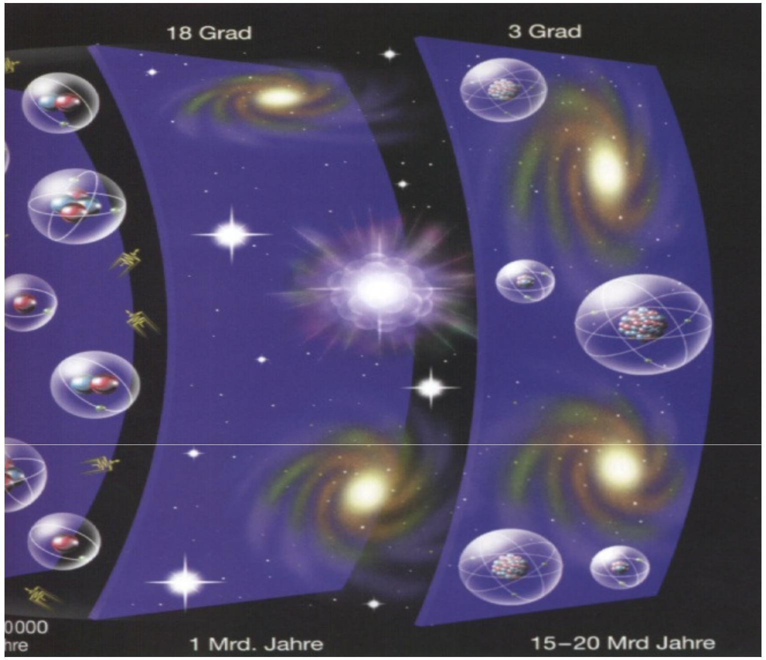
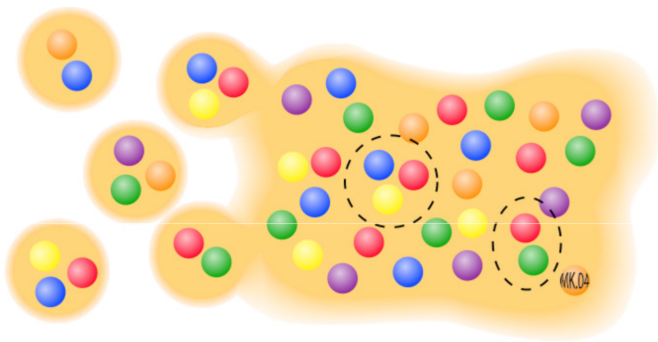
Motivation





How and on what timescales a global thermodynamic equilibrium can be achieved in heavy-ion collisions?

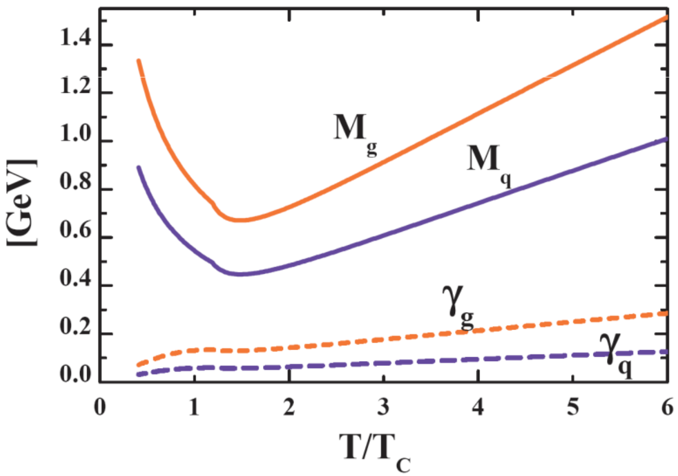
Transport description of the partonic and hadronic phases



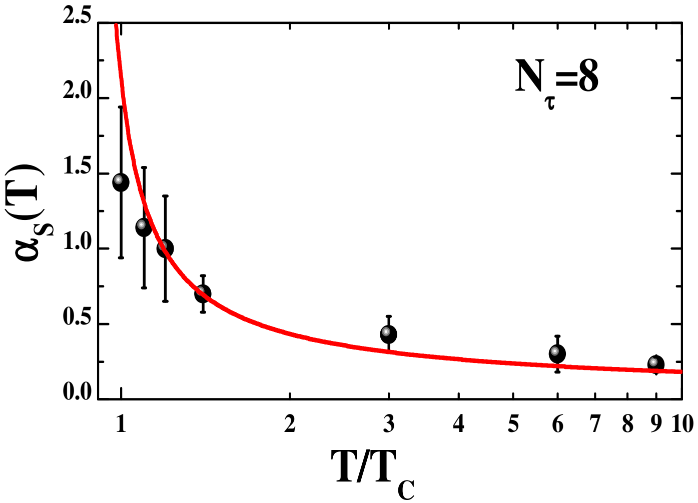
Parton-Hadron-String Dynamics (PHSD)

The Dynamical Quasiparticle Model (DQPM)

$$\rho(\omega) = \frac{\gamma}{\mathbf{E}} \left(\frac{1}{(\omega - \mathbf{E})^2 + \gamma^2} - \frac{1}{(\omega + \mathbf{E})^2 + \gamma^2} \right)$$



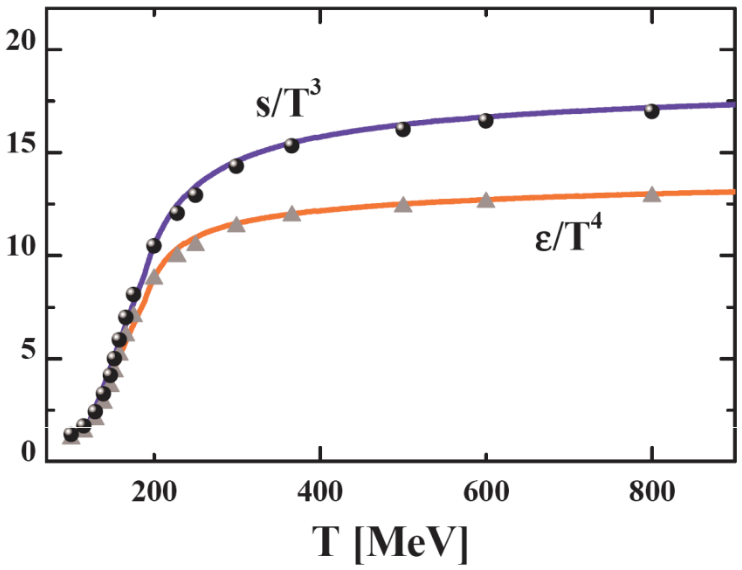
one-loop pQCD

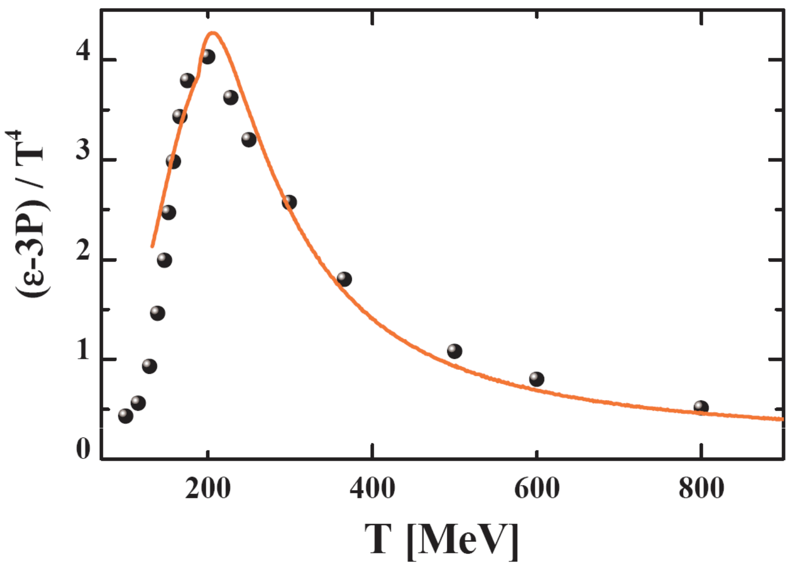


lattice QCD

Cassing, NPA **791** (2007) 365: NPA **793** (2007)

The Dynamical Quasiparticle Model (DQPM)





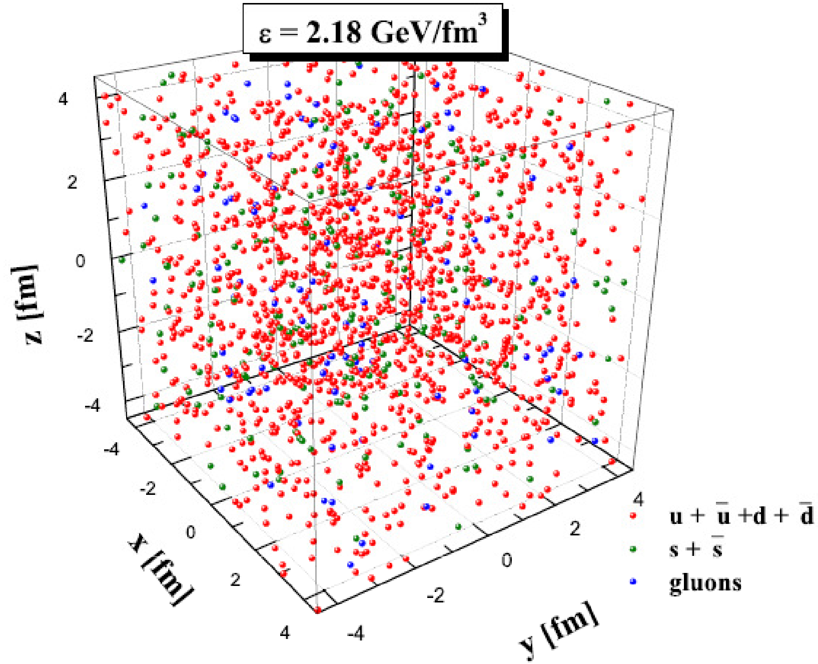
Y. Aoki *et al.*, JHEP **0906** (2009) 088

The agreement is sufficiently good!!!

E. L. Bratkovskaya, W. Cassing, V. P. Konchakovski, O. Linnyk, Nucl. Phys. **A 856** (2011) 162

Initialization

Periodic boundary conditions



Volume = 9^3 fm^3

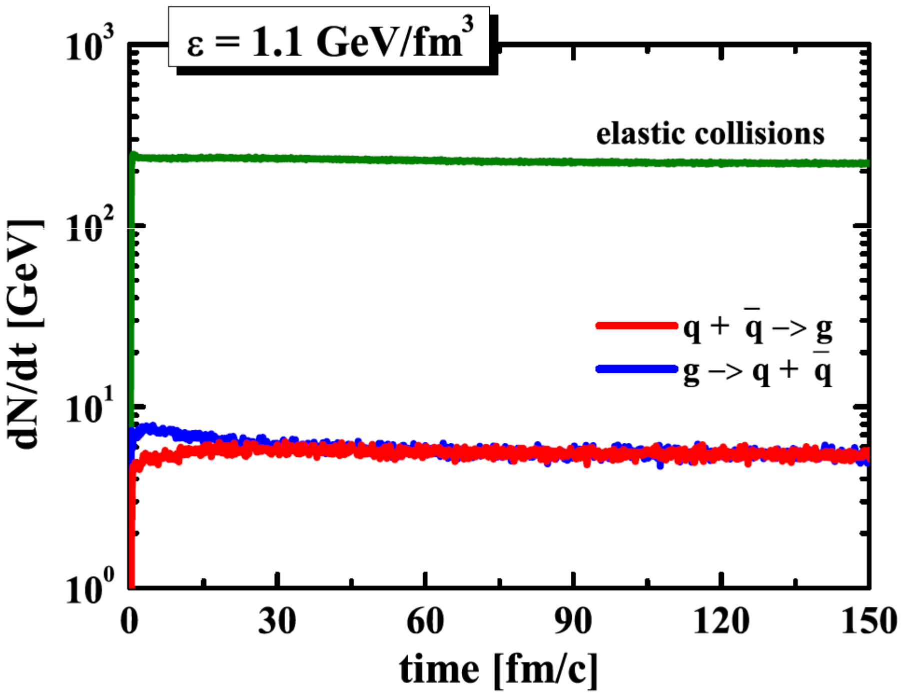
Random space positions

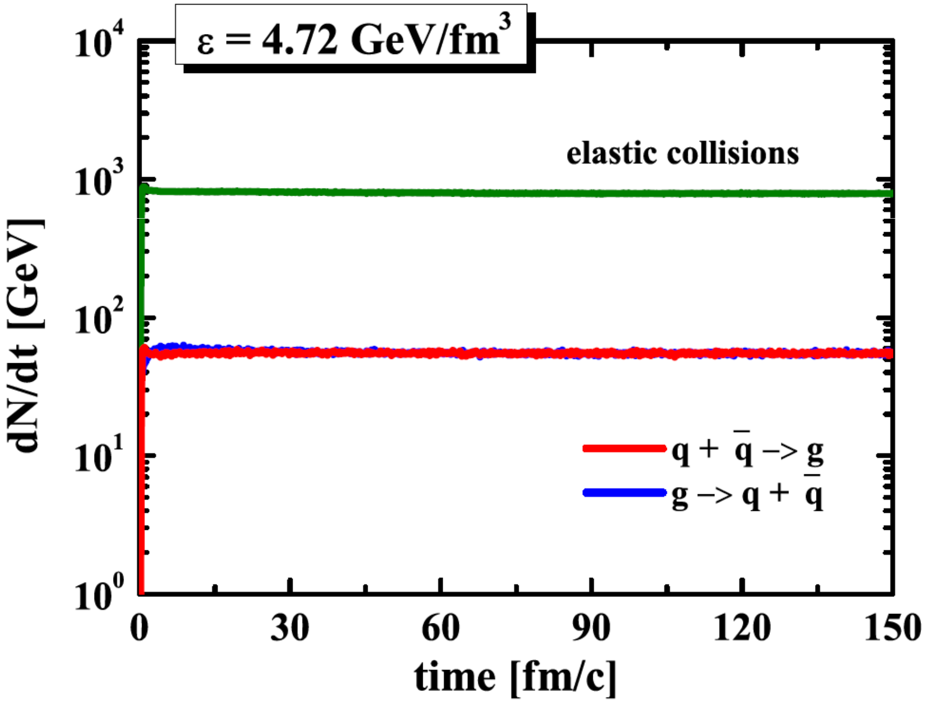
Momenta distributed according to the Fermi-Dirac distributions at given energy density and chemical potential

The system is out of equilibrium initially!!!

Detailed balance

$$u + \bar{u} \longleftrightarrow g \longleftrightarrow s + \bar{s}$$

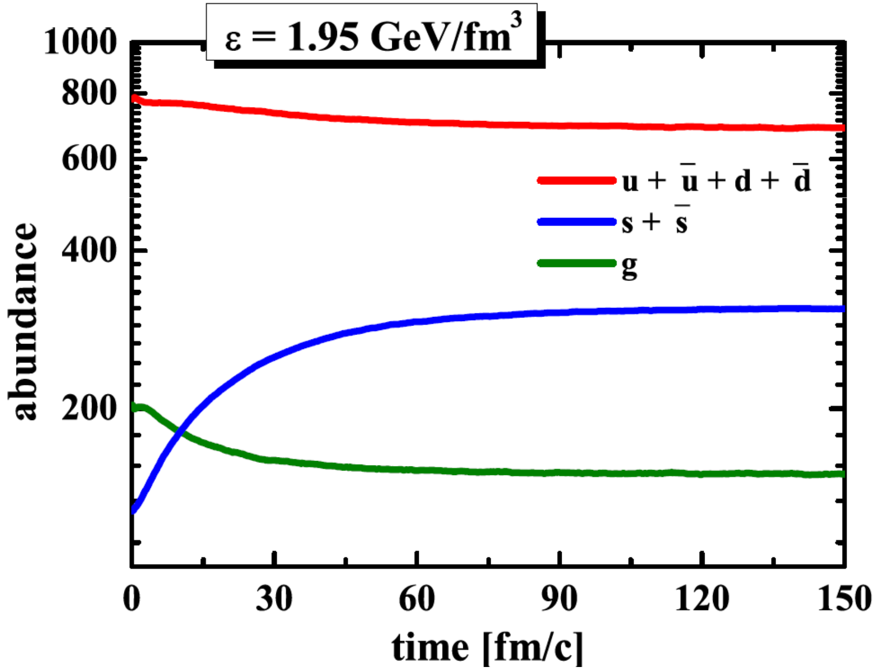


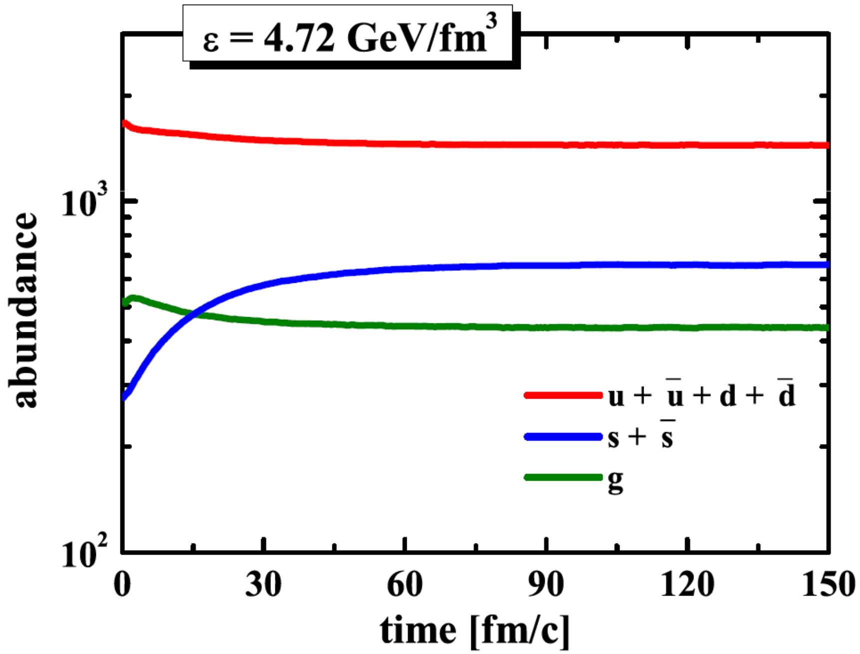


Chemical equilibration

In equilibrium:

$$\frac{N_g}{N_{q+\bar{q}}} \approx \frac{\int_0^\infty d\omega\omega^2 \frac{1}{e^{\omega/T}-1}}{\int_0^\infty d\omega\omega^2 \frac{1}{e^{\omega/T}+1}} \frac{d_g}{d_{q+\bar{q}}} e^{-\frac{(M_g - M_{q(\bar{q})})}{T}}$$





$$\frac{N_g}{N_{q+\bar{q}}} \approx \frac{1}{7}$$

$$\frac{N_g}{N_{q+\bar{q}}} \approx \frac{1}{5}$$

Total number of particles

The total number of quarks (gluons) in equilibrium:

$$N = V d_{q(g)} \int_0^\infty \frac{d\omega}{2\pi} \int \frac{d^3p}{(2\pi)^3} 2\,\omega \rho_{q(g)}(\omega, \mathbf{p}) e^{-\omega/T} \Theta(p^2)$$

spectral function:

$$\rho_{q(g)}(\omega) = \frac{\gamma_{q(g)}}{E} \left(\frac{1}{(\omega - E)^2 + \gamma_{q(g)}^2} - \frac{1}{(\omega + E)^2 + \gamma_{q(g)}^2} \right)$$

with convention:

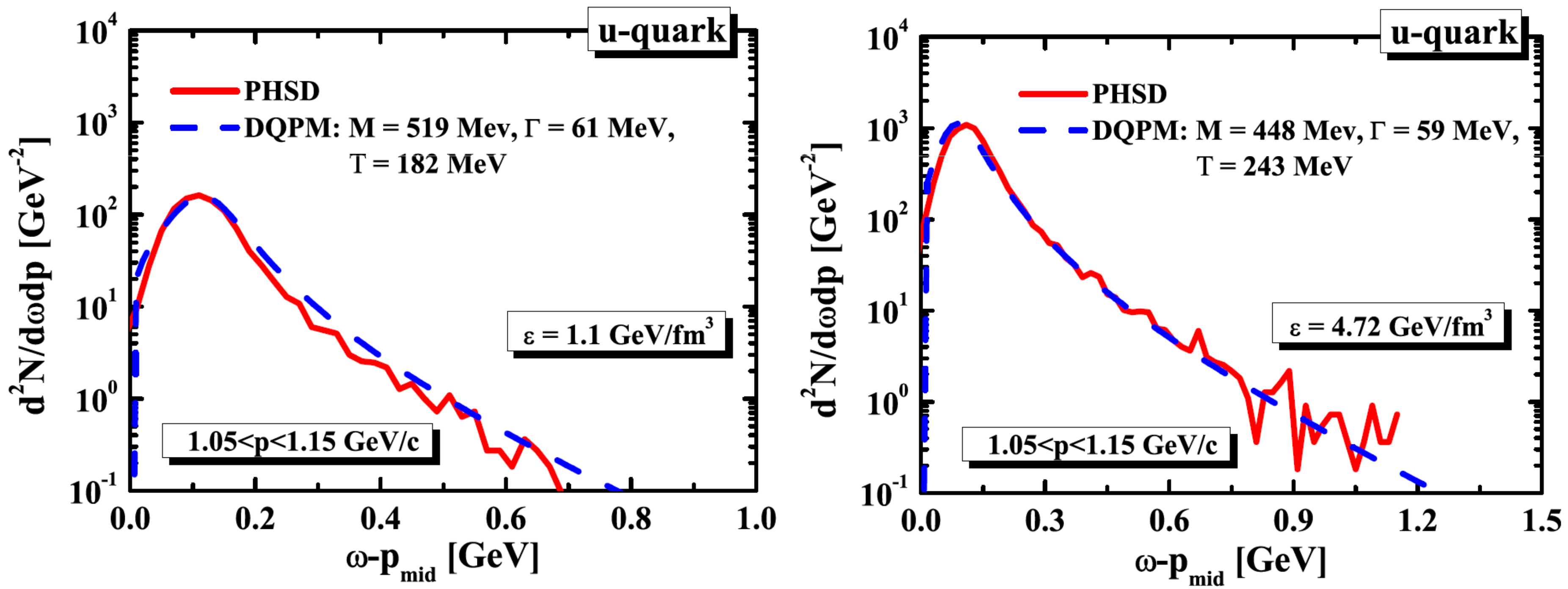
$$E^2(\mathbf{p}) = \mathbf{p^2} + M_{q(g)}^2 - \gamma_{q(g)}^2$$

normalization:

$$\int_{-\infty}^{\infty} \frac{d\omega}{2\pi} \omega \rho_q(\omega, \mathbf{p}) = \int_0^{\infty} \frac{d\omega}{2\pi} 2\omega \rho_q(\omega, \mathbf{p}) = 1$$

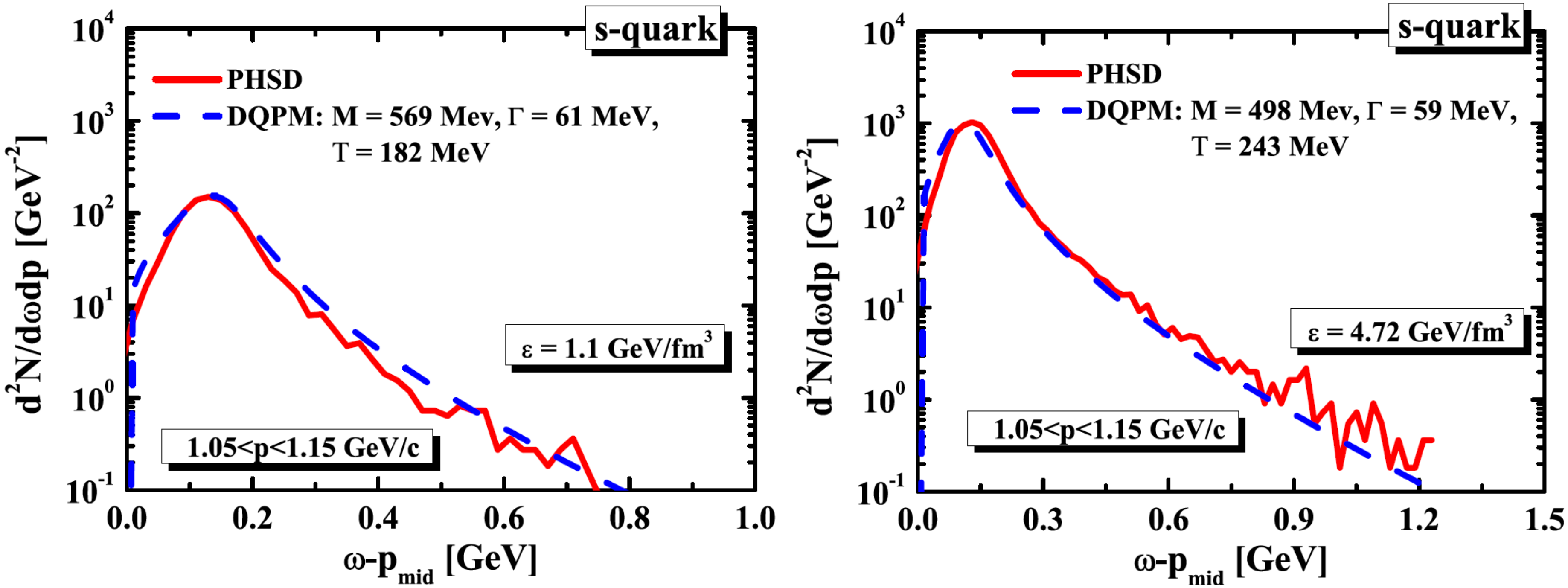
Thermal equilibration (u-quark)

$$\frac{d^2N}{d\omega dp} = \frac{V d_u}{2\pi^3} p_{mid}^2 \, \omega \rho_u(\omega, p_{mid}) e^{-\omega/T}$$



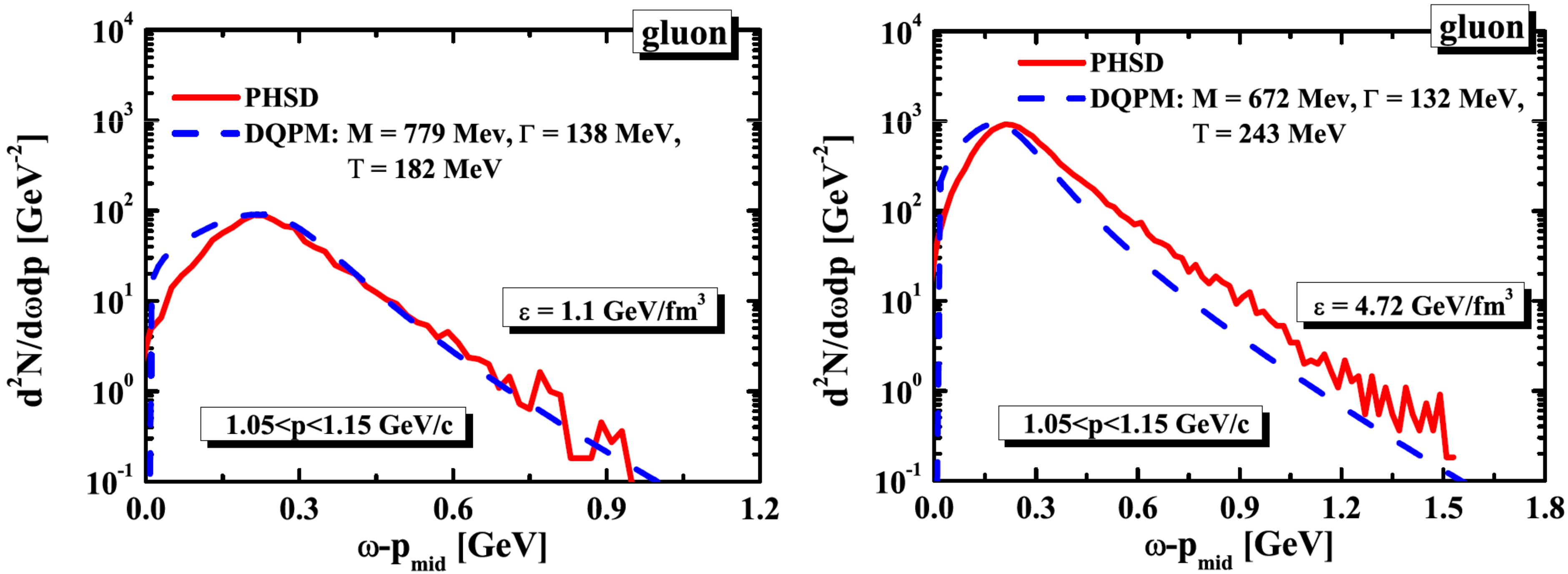
Thermal equilibration (s-quark)

$$\frac{d^2N}{d\omega dp} = \frac{V d_s}{2\pi^3} p_{mid}^2 \, \omega \rho_s(\omega, p_{mid}) e^{-\omega/T}$$



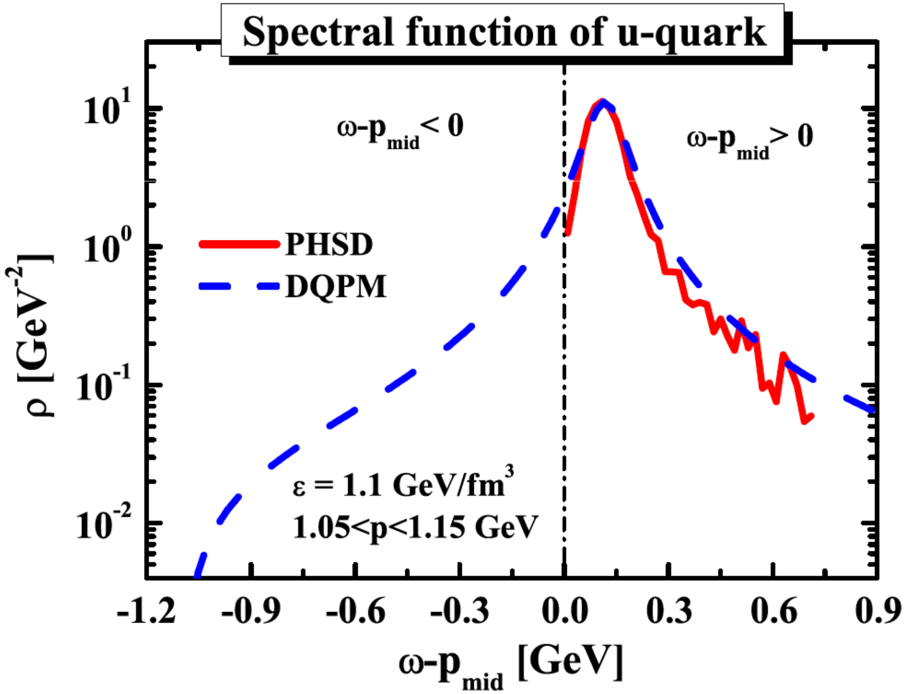
Thermal equilibration (gluon)

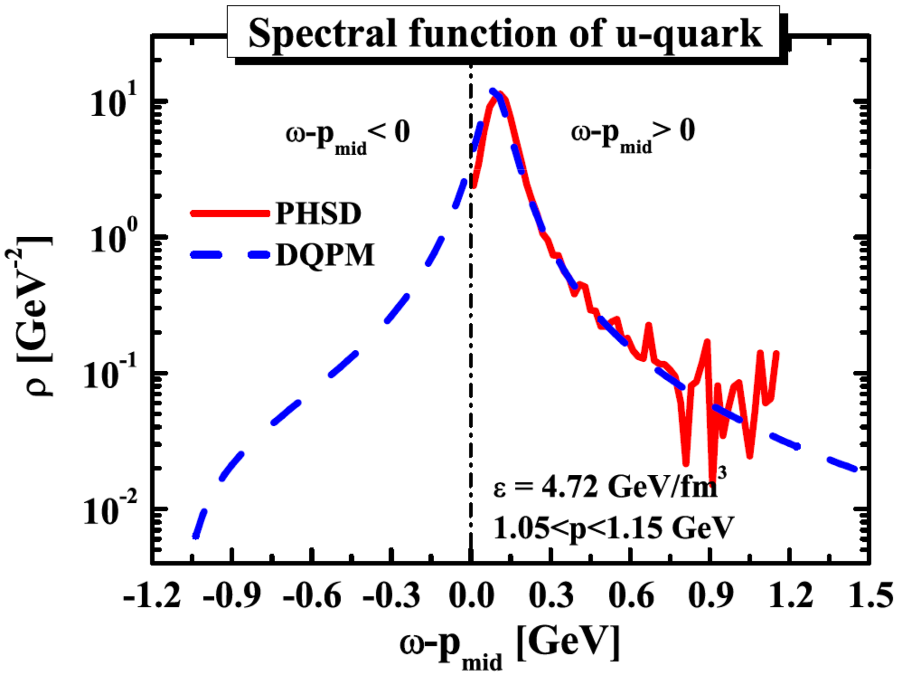
$$\frac{d^2N}{d\omega dp} = \frac{V d_g}{2\pi^3} p_{mid}^2 \, \omega \rho_g(\omega, p_{mid}) e^{-\omega/T}$$



Spectral function (u-quark)

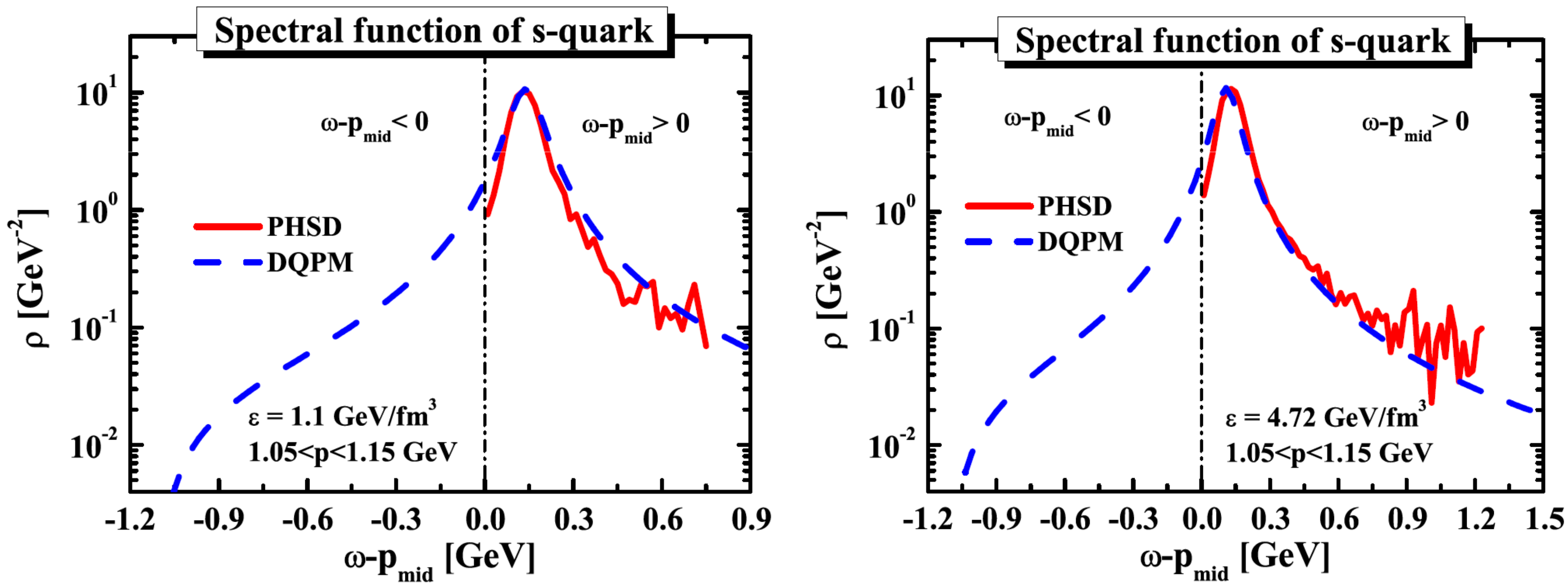
$$\rho_u(\omega) = \frac{\gamma_u}{E}\left(\frac{1}{(\omega - E)^2 + \gamma_u^2} - \frac{1}{(\omega + E)^2 + \gamma_u^2}\right)$$





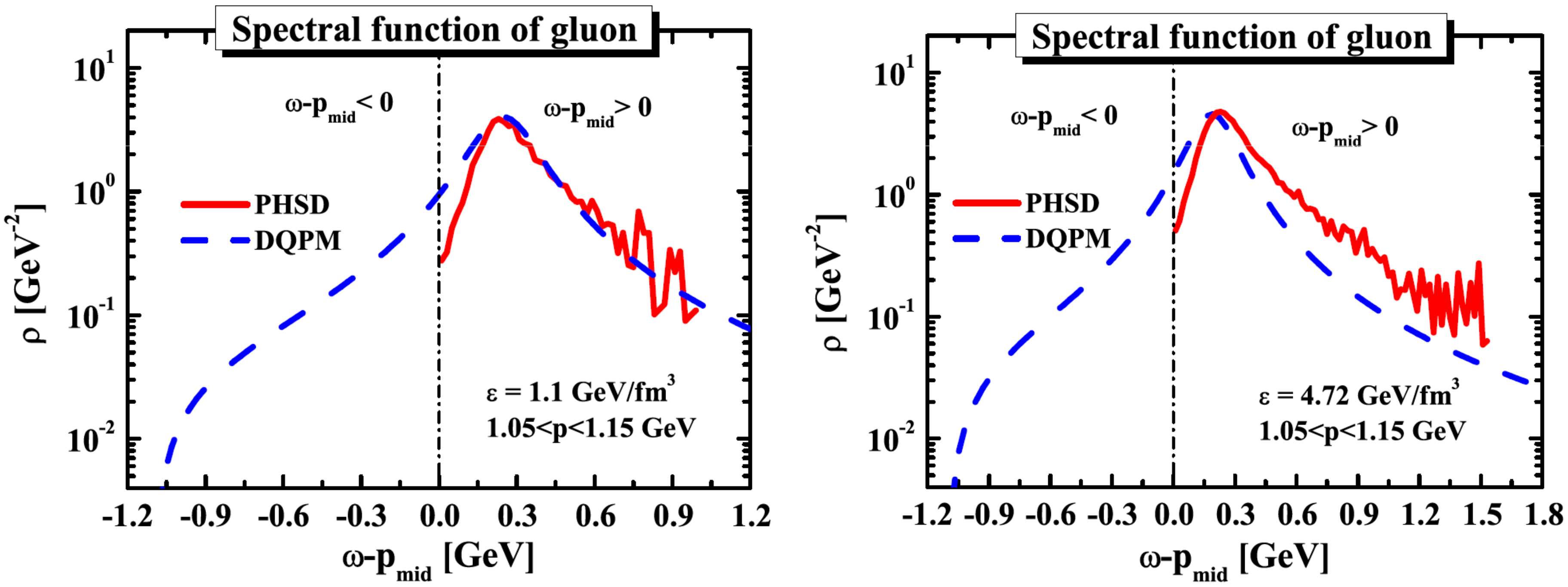
Spectral function (s-quark)

$$\rho_s(\omega) = \frac{\gamma_s}{E}\left(\frac{1}{(\omega - E)^2 + \gamma_s^2} - \frac{1}{(\omega + E)^2 + \gamma_s^2}\right)$$



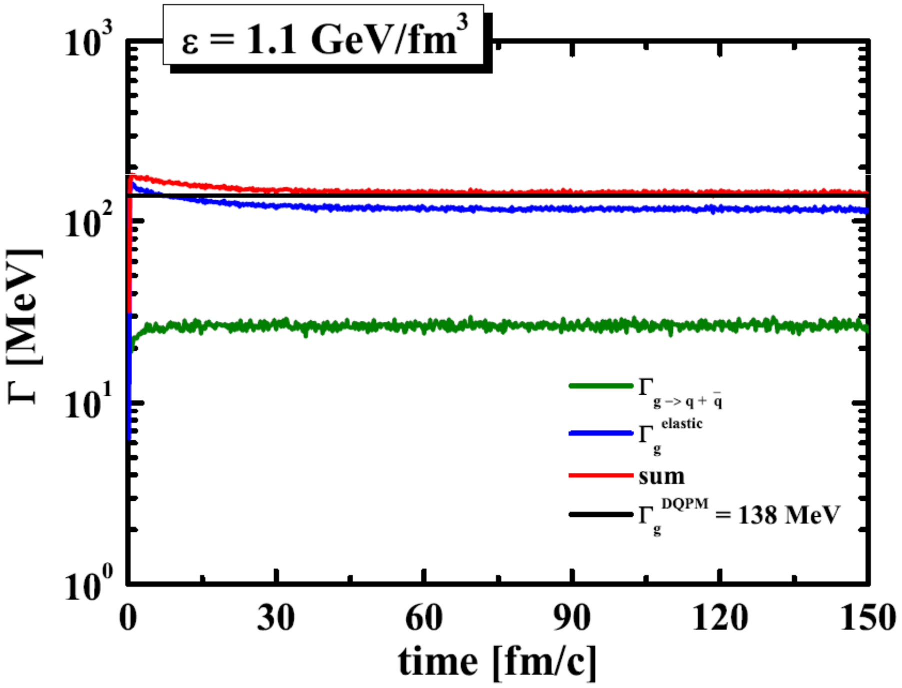
Spectral function (gluon)

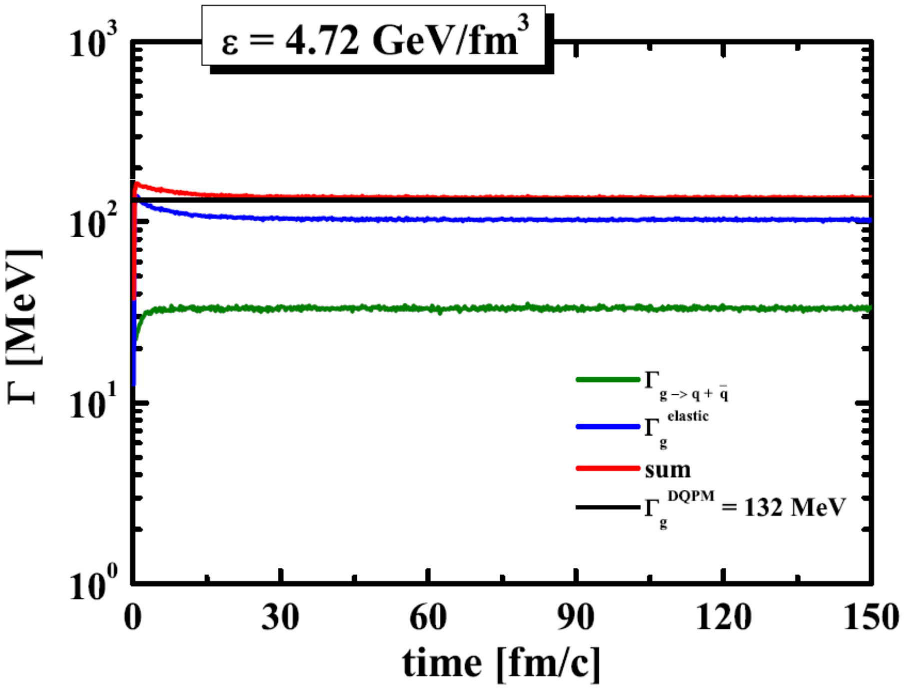
$$\rho_g(\omega) = \frac{\gamma_g}{E}\left(\frac{1}{(\omega - E)^2 + \gamma_g^2} - \frac{1}{(\omega + E)^2 + \gamma_g^2}\right)$$



Gluon width

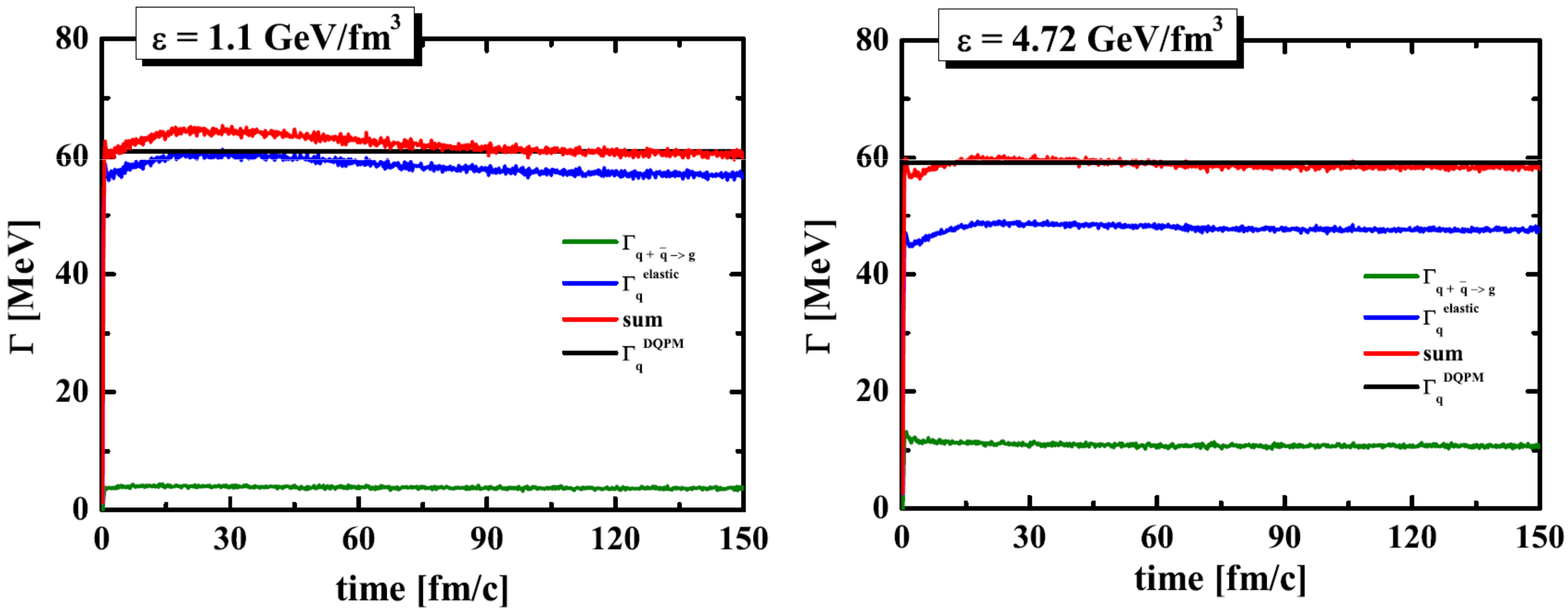
$$\Gamma_g^{DQPM} = \hbar c \frac{\left(\frac{dN}{dt}\right)_{g \to q+\bar{q}}}{N_g} + \hbar c \frac{\left(\frac{dN}{dt}\right)_{elastic}}{N_g}$$



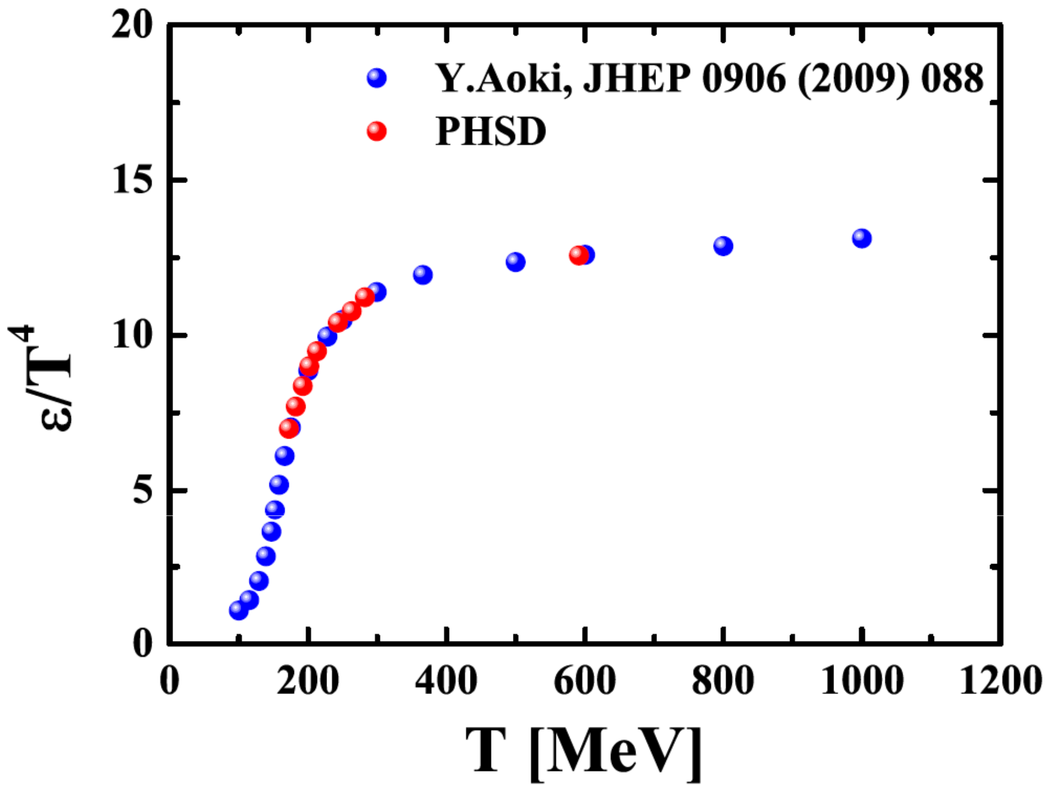


Quark width

$$\Gamma_q^{DQPM} = \hbar c \frac{(\frac{dN}{dt})_{q+\bar{q}\to g}}{N_{q+\bar{q}}/2} + \hbar c \frac{(\frac{dN}{dt})_{elastic}}{N_{q+\bar{q}}}$$



Equation of state



PHSD is numerical realization of lattice QCD in and ouf of equilibrium!!!

Conclusions

- We have studied the kinetic and chemical equilibration in ‘infinite’ parton matter within the Parton-Hadron-String Dynamics transport approach.

- The ‘infinite’ matter has been simulated within a cubic box with periodic boundary conditions initialized at different energy densities.

- Abundances of the final particles depend on the energy density.

- The system evolves into an ensemble of partons in chemical and thermal equilibrium.

- PHSD is a numerical realization of lQCD in and out of equilibrium.

Thanks to

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