INI - 24: Plasmon mass scale in classical nonequilibrium gauge theory in two and three dimensions

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Introduction

Classical Yang-Mills (CYM) calculations have been used to model the **pre-thermal evolution** of the strongly interacting matter created in **ultrarelativistic heavy-ion collisions**. Our aim is to **study the limits of the quasiparticle picture** in real time classical Yang-Mills theory on a **lattice** in two and three spatial dimensions.

Initial conditions

3D: The **initial quasiparticle spectrum** satisfies:

$$f\left(k, t=0\right) = \frac{n_0}{g^2}\frac{k}{\Delta}\exp\left(\frac{-k^2}{2\Delta^2}\right).$$

With **momentum scale** Δ and **occupation number** n_0.
2D: **Gauge fixing deforms initial quasiparticle spectrum**. Use similar IC as in 3D and **measure** the **occupation number** n_0^{eff} and **momentum scale** Q_{eff} **gauge invariantly**

$$Q_{\text{eff}}^2(t) = \frac{1}{2}\frac{\left\langle \text{Tr}\left(\boldsymbol{D}\times\boldsymbol{B}\right)^2\right\rangle}{\left\langle \text{Tr}\left(\boldsymbol{B}^2\right)\right\rangle}. \quad (1)$$

$$n_0^{\text{eff}} = \frac{\pi g^2}{\left(N_{\text{c}}{}^2-1\right)}\frac{\epsilon^{2d}}{Q_{\text{eff}}^3}. \quad (2)$$

Extracting plasmon mass, 3 methods

DR **Effective dispersion relation** in the Coulomb gauge

$$\omega^2\left(k\right) = \frac{\left\langle\left|\dot{E}_i^a\left(k\right)\right|^2\right\rangle}{\left\langle\left|E_i^a\left(k\right)\right|^2\right\rangle},$$

fit as $\omega^2 = ak^2 + \omega_{pl}^2$.

UE **Add a uniform electric field** at $t = t_0$, **measure oscillations** of electric and magnetic energy vs t [3].

HTL Perturbation theory, **Hard Thermal Loop**

$$\omega_{pl}^2 = \frac{4}{3}g^2N_c\int\frac{\mathrm{d}^3k}{\left(2\pi\right)^3}\frac{f\left(k\right)}{k}.$$

Conclusions

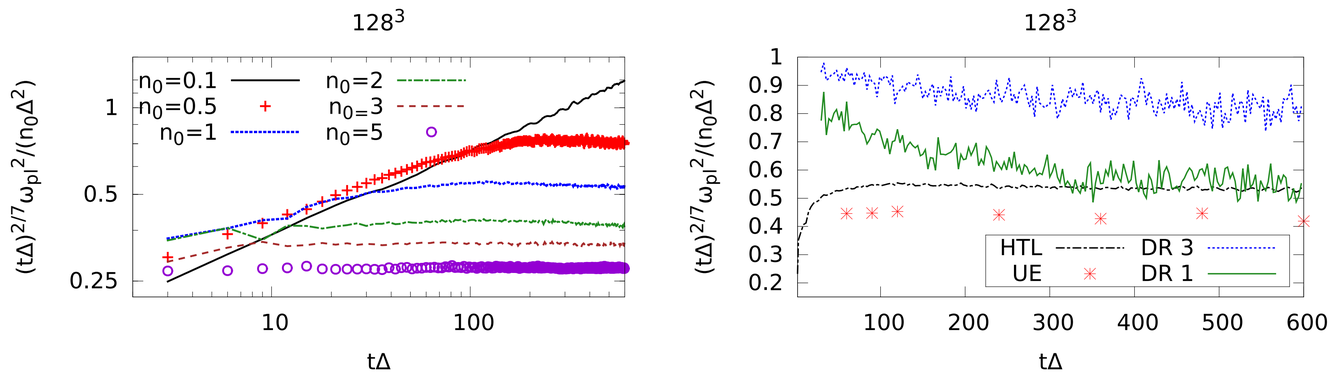
- Study the plasmon mass scale in CYM using 3 methods. The DR agrees with the other methods within a factor of two. **UE and HTL are in rough agreement**.
- The **UE and HTL methods agree in the continuum limit in 3D**. In 2D the difference between the two persists.
- The UE method is insensitive to ultraviolet and infrared cutoffs (3D). In 2D the extracted mass scale increases in the continuum limit for all methods.
- Time-dependence of ω_{pl}^2 consistent with $t^{-2/7}$ (3D) $t^{-1/3}$ (2D) power law.
- More on quasiparticles: **extraction of spectral function** from real time lattice simulations [4], see **poster** by **K. Boguslavski INI - 02**

References

[1] T. Lappi, J. Peuron, Phys. Rev. D95, 014025
[2] T. Lappi, J. Peuron, Phys. Rev. D97, 034017
[3] A. Kurkela, G. D. Moore, Phys.Rev. D89, 074036
[4] K. Boguslavski, A. Kurkela, T. Lappi, J. Peuron, arXiv:1804.01966 [hep-ph]

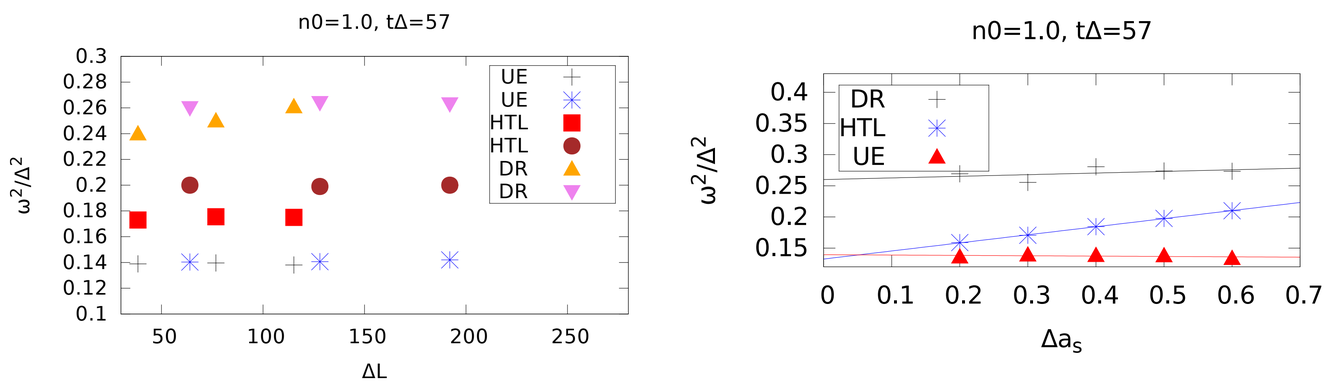
Results & dependence on the lattice cutoffs, 3D [1]

Dependence on **occupation number** and **time**:



- The late-**time evolution** is **consistent with** $t^{-2/7}$ **power law** [3].
- Higher occupation number → asymptotic regime reached faster.
- The DR method depends on maximum k^2/Δ^2 in fit (DR 1 vs. DR 3).

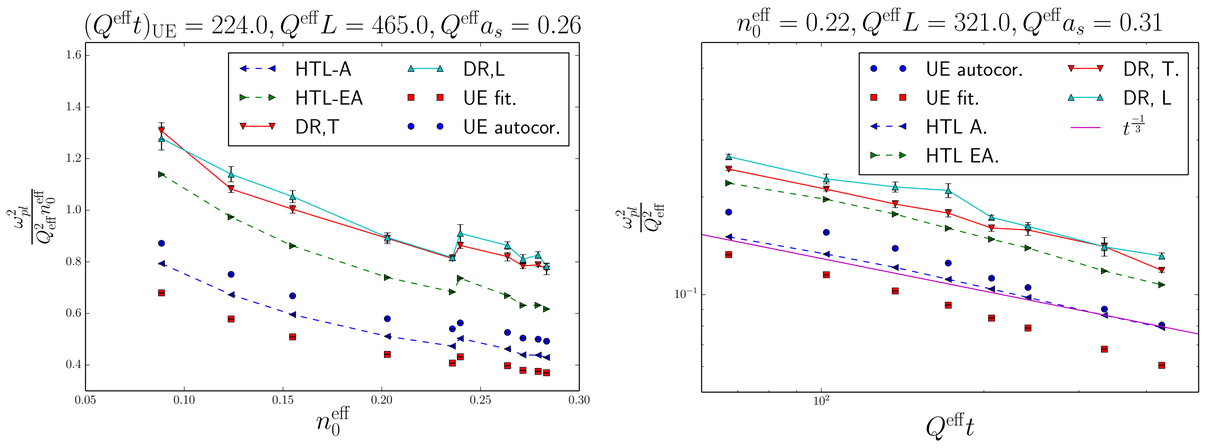
Dependence on **infrared cutoff** and **ultraviolet cutoff**:



- Left: infrared cutoff (lattice size $L\Delta$) dependence with two different ultraviolet cutoffs (lattice spacings $a_s\Delta = 0.3$ [up], $a_s\Delta = 0.5$ [down]). **We observe no significant IR-cutoff dependence.**
- Right: UV cutoff dependence. **The HTL and UE agree in the continuum limit.**

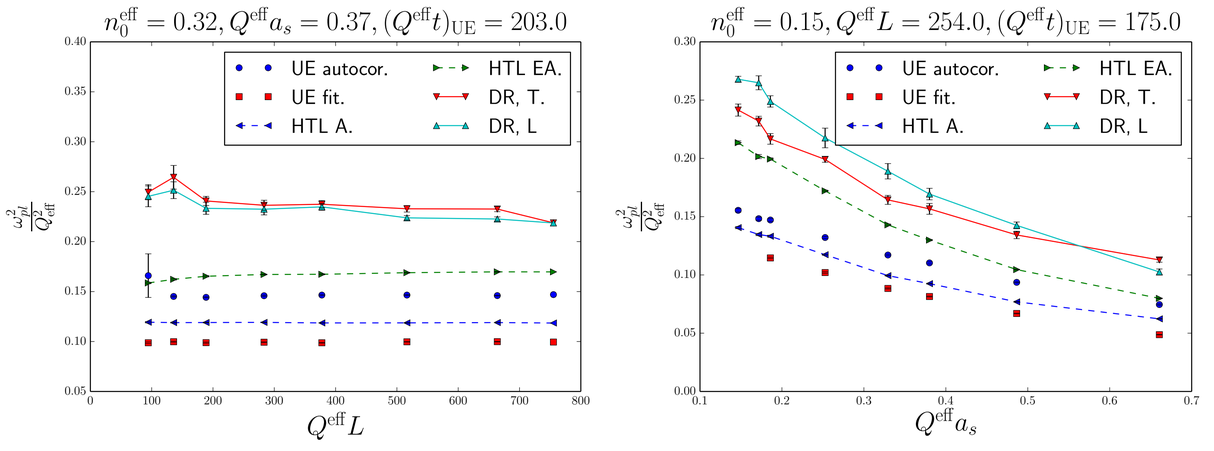
Results & dependence on the lattice cutoffs, 2D [2]

Dependence on **occupation number** and **time**:



- Right: Late-**time-evolution is consistent with** $t^{-1/3}$ **power law**.
- Left: **The occupation number dependence similar to 3D** - faster decrease of the mass scale for higher occupation number

Dependence on **infrared cutoff** and **ultraviolet cutoff**:



- Left: **Infrared cutoff** dependence like in 3D - **No cutoff dependence**.
- Right: **Ultraviolet cutoff** dependence different from 3D: **mass scale increases in the continuum limit**.
- Overall we find a rough agreement between UE and HTL methods. DR method agrees with the other methods within a factor of 2.