The Impact of Memory on Heavy Quarks Dynamics in Hot QCD Medium

CETHENP 2022

Jai Prakash
Indian Institute of Technology, Goa

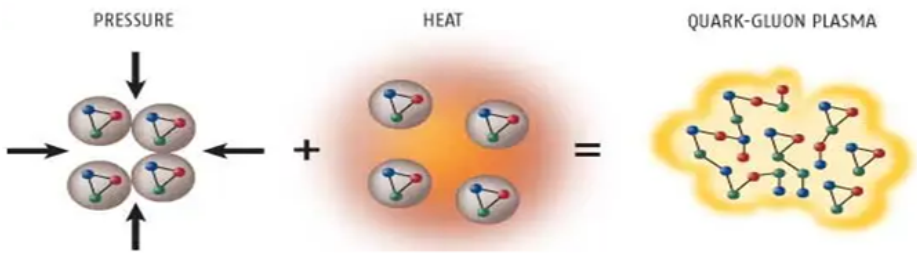
November 16, 2022

In Collaboration with: Marco Ruggieri, Pooja,
Santosh Kumar Das

Quark Gluon Plasma(QGP)

QGP forms at very high temperature and density

$Temperature >\sim 10^{12} K$ ($\sim$175MeV)



QGP help us to study :

- Early universe
- Core of the Neutron star

QGP Cont..

Why heavy quark used as probe to study QGP?

$\tau_c \gg \tau_{u,d}$	Relaxation time of charmed quarks is more than light quarks
$M_c \gg T_o$	No thermal production since mass of charmed quark is high
$M_c \gg M_{u,d}$	Mass of the charmed quark is greater than the light quark

$M_c \rightarrow$ Mass of charm quark
$\tau \rightarrow$ Relaxation time
$M_{u,d} \rightarrow$ Mass of light quark

Langevin: Without Memory

- Langevin Equation

$$\frac{d\mathbf{p}}{dt} = -\gamma \mathbf{p}(t) + \eta(t) \tag{1}$$

  - $\langle \eta(t) \rangle = 0$
  - $\langle \eta(t)\eta(t') \rangle = 2D\delta(t - t')$

- Generalised Langevin Equation (GLE)

$$\boxed{\frac{dp}{dt} = -\int_0^t \gamma(t, t')p(t')dt' + \eta(t)}$$

  - $\eta(t) \rightarrow$ stochastic force

Langevin: With Memory

- The correlation of fluctuations

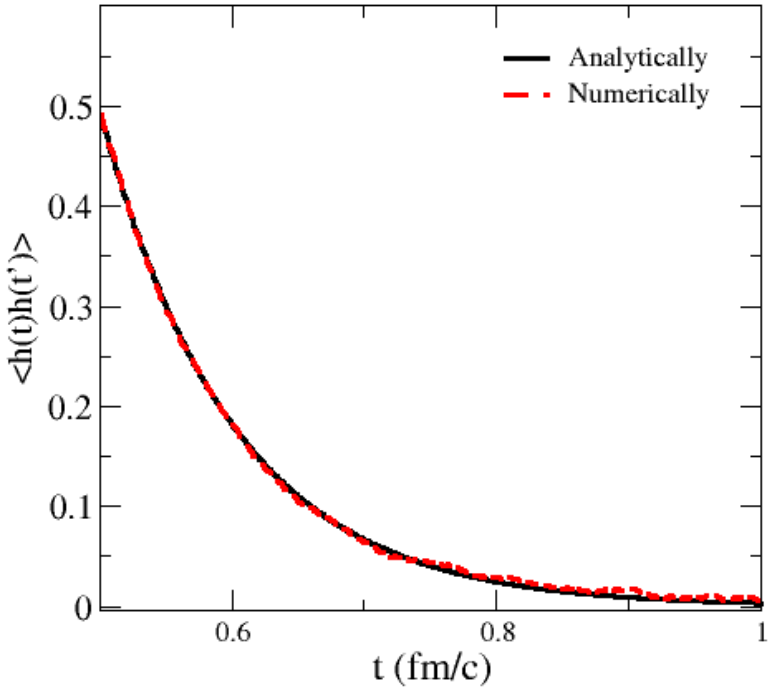
$$\langle \eta(t)\eta(t') \rangle = 2Df(|t-t'|)$$
$$\langle \eta(t) \rangle = 0$$
$$f(|t-t'|) = \frac{1}{2\tau} e^{-|t-t'|/\tau}$$
$$\langle \eta(t)\eta(t') \rangle = 2D \frac{e^{-|t-t'|/\tau}}{2\tau}$$

- Ancillary process

$$\frac{dh}{dt} = -\alpha h + \alpha\rho$$
$$\Delta h = -\alpha h \Delta t + \alpha\rho(t)\sqrt{\Delta t}$$

$$\langle h(t)h(t')\rangle \approx \frac{e^{-\alpha|t-t'|}}{2}$$

$\alpha = \frac{1}{\tau}$ (τ, *Memory Time*)



$$\eta(t) = \sqrt{\frac{2D}{\tau}}h(t)$$

- As, $\tau \to 0$

$$\alpha\langle h(t)h(t')\rangle \approx \delta(t-t')$$

- HQ evolution with memory,

$$\Delta p = -\Delta t \int_0^t [\gamma(t,t')p(t')dt'] + \sqrt{\frac{2D}{\tau}} h(t)\Delta t$$

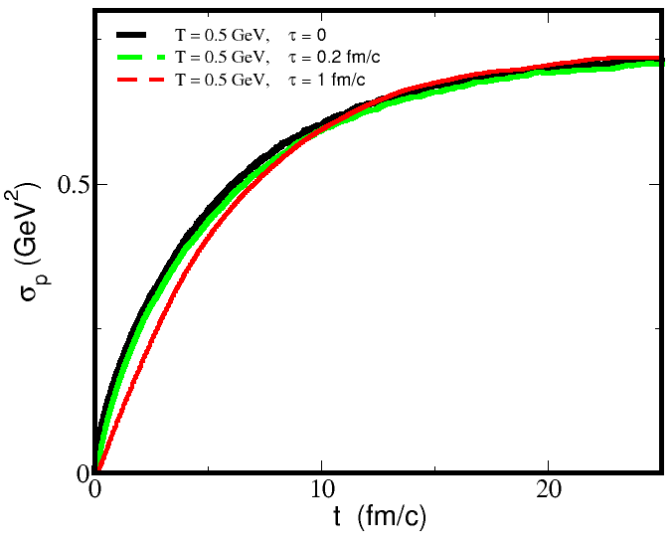
$$\gamma(t,t') = \frac{1}{ET}\langle \eta(t)\eta(t')\rangle$$

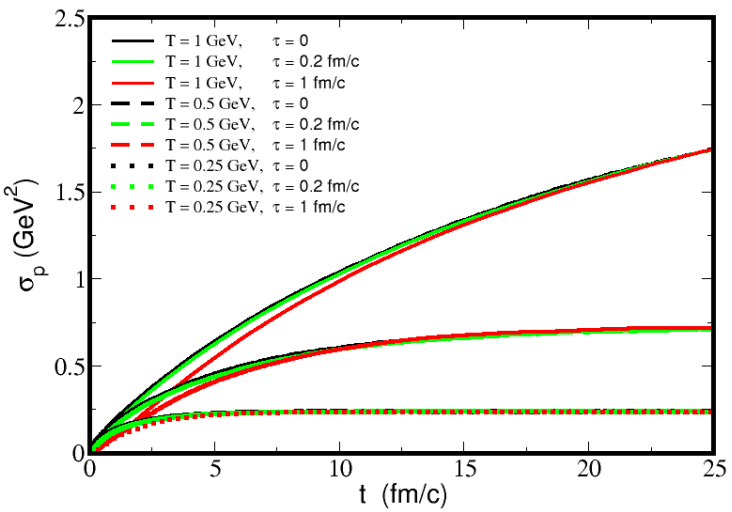
$$\gamma(t,t') = \frac{2D}{ET}\frac{e^{-|t-t'|/\tau}}{2\tau}$$

Memory Observation

- Momentum broadening,

$$\sigma_p = \langle (p_T - \langle p_T \rangle)^2 \rangle$$

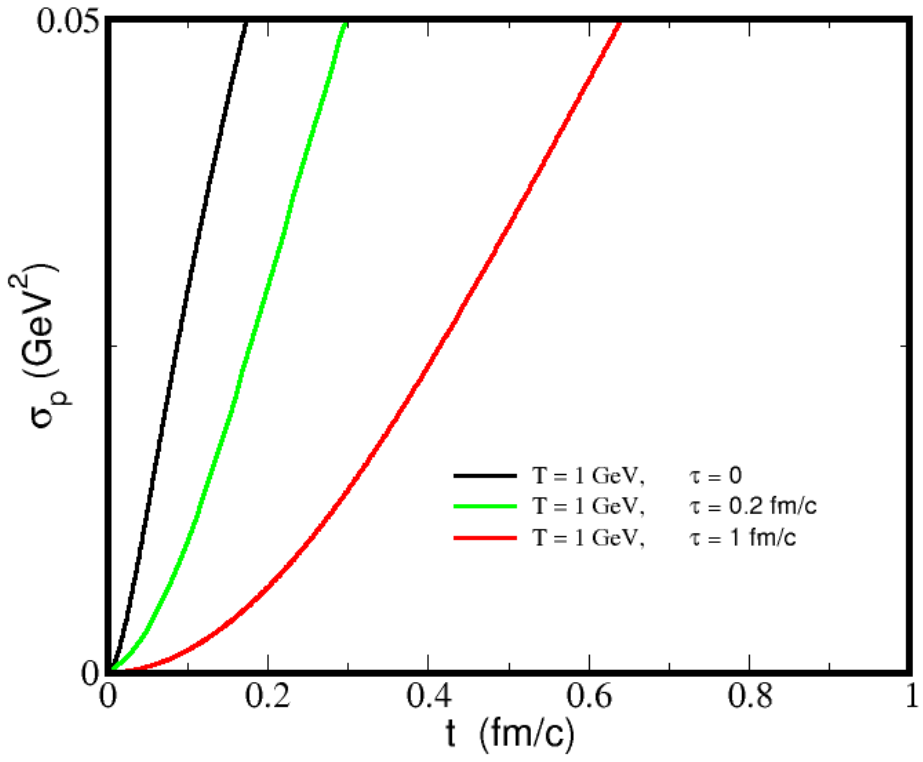




- Memory slows down the σ_p

M. Ruggieri, Pooja, J. Prakash and, S. K. Das,

[Phys.Rev.D 106 (2022) 3, 034032.]



- The nonlinear increase of σ_p

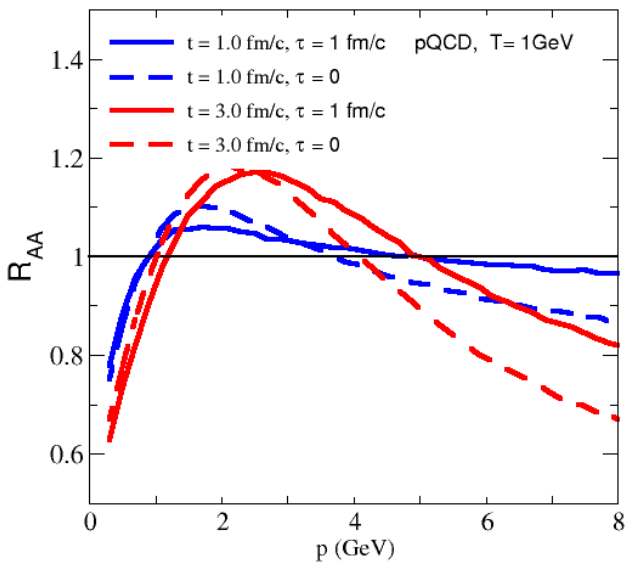
M. Ruggieri, Pooja, J. Prakash and, S. K. Das,

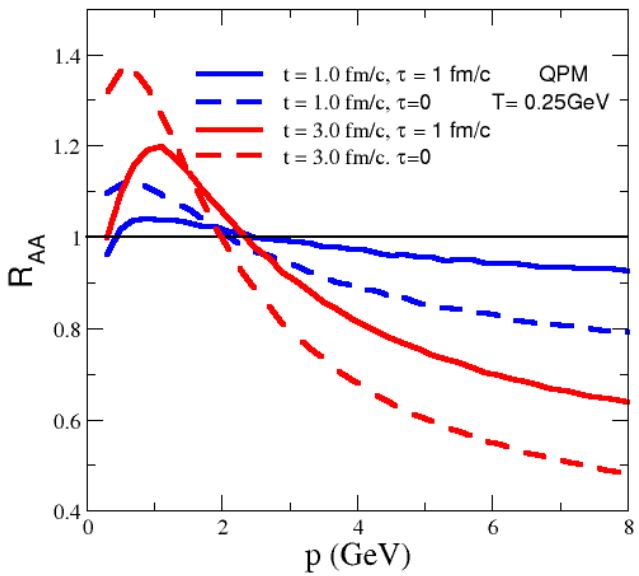
[Phys.Rev.D 106 (2022) 3, 034032.]

Results

- Nuclear modification factor,

$$R_{AA}(p_T) = \frac{f_{\tau_f}(p_T)}{f_{\tau_i}(p_T)}$$

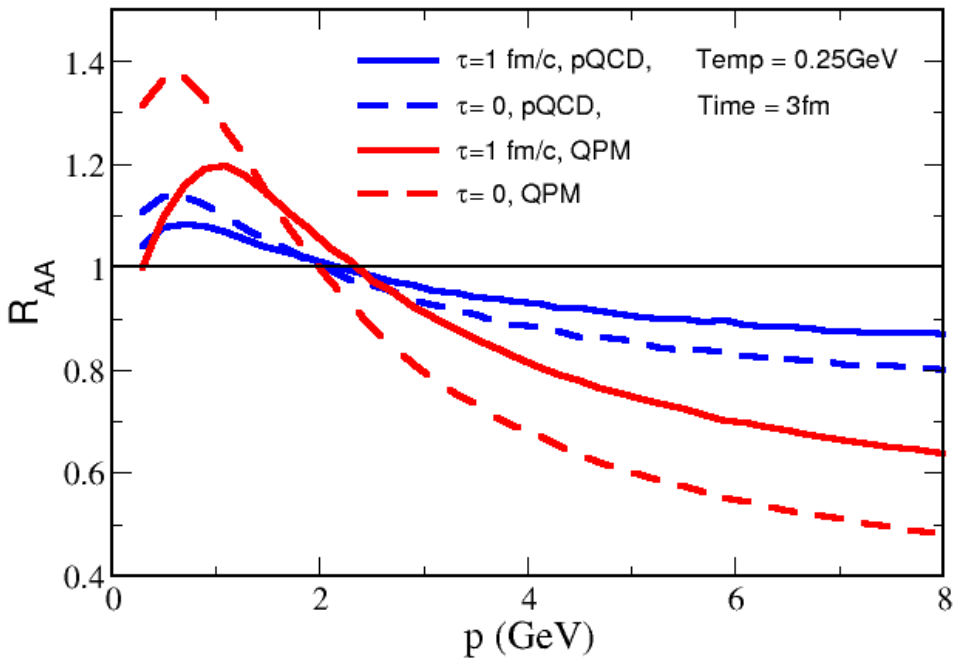




Memory slows down the formation of R_{AA}

M. Ruggieri, Pooja, J. Prakash and, S. K. Das,
[Phys.Rev.D 106 (2022) 3, 034032.]

- Nuclear modification factor, $R_{AA}(p_T)$



M. Ruggieri, Pooja, J. Prakash and, S. K. Das,

[Phys.Rev.D 106 (2022) 3, 034032.]

Summary

- We study the processes with time-correlated noise.
- We have seen that the energy loss is lower in the presence of the memory and the thermalization time is higher.
- Memory delays the dynamics of the heavy quarks in the QGP.
- The memory slows down the momentum broadening as well as the formation, R_{AA} of HQs.