Data-driven constraints on the drag and diffusion of light partons

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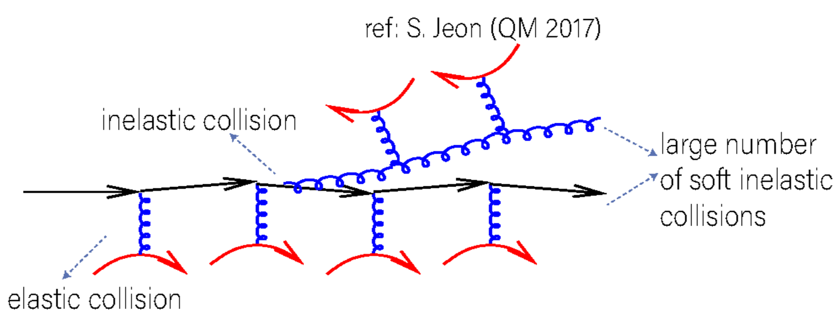
I. Parton energy loss: hard-soft factorization



Interactions with the medium:
- Large number of soft interactions
- Rare hard interactions

Parton energy loss reformulated as **hard interactions + diffusion process**[1].

$$(\partial_t + \vec{v}\cdot\nabla_{\vec{x}})f(\vec{p},\vec{x},t) = -\mathbb{C}^{1\leftrightarrow 2}[f] - \mathbb{C}^{2\leftrightarrow 2}[f]$$

$$(\partial_t + \vec{v}\cdot\nabla_{\vec{x}})f(\vec{p},\vec{x},t) = -\mathbb{C}^{\text{large}-\omega}(\mu_\omega) - \mathbb{C}^{\text{large-angle}}(\mu_{\tilde{q}_\perp},\Lambda) - \mathbb{C}^{\text{split}}(\Lambda) - \mathbb{C}^{\text{diff}}(\mu_{\tilde{q}_\perp},\mu_\omega)$$

ω is the energy of the radiated parton, $\tilde{q}_\perp \equiv \sqrt{q^2-\omega^2}$, q is its momentum transfer.

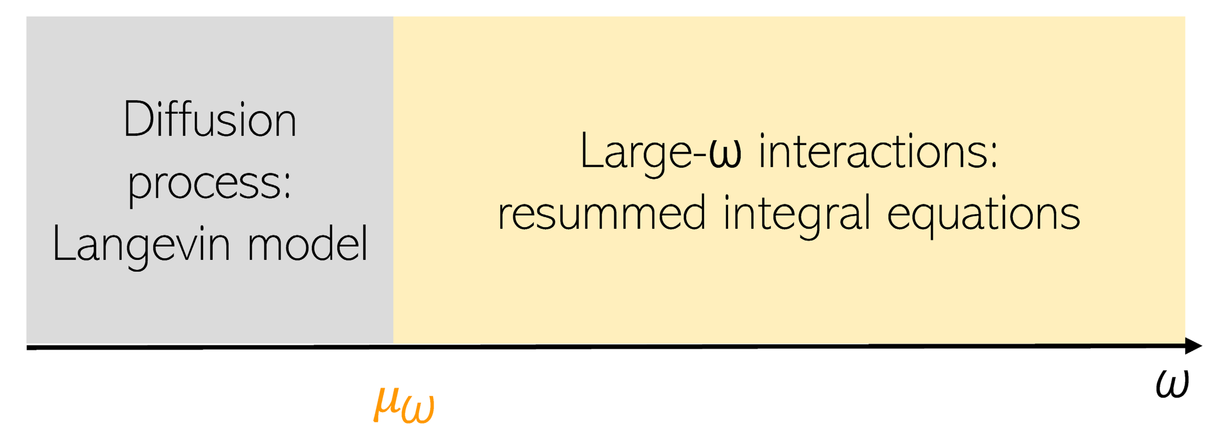
μ_ω, $\mu_{\tilde{q}_\perp}$, Λ are cutoffs between soft and hard interactions.

$gT \ll \mu_{\hat{q}_\perp}$, $\mu_\omega \ll T$, $3T \ll \Lambda \ll E_0$, where E_0 is the initial parton energy.

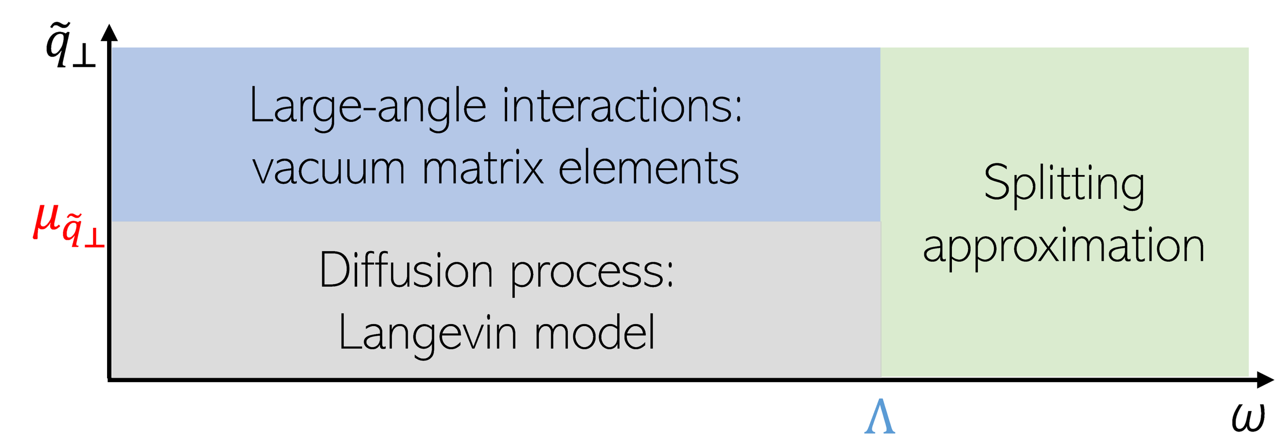
Benefits of the hard-soft reformulated model:
- systematic factorization of soft and hard interactions
- efficient and flexible description of soft interactions
- possibility of extending to next-to-leading order

II. Treatments of different processes

Inelastic interactions - $\mathbb{C}^{1\leftrightarrow 2}$:



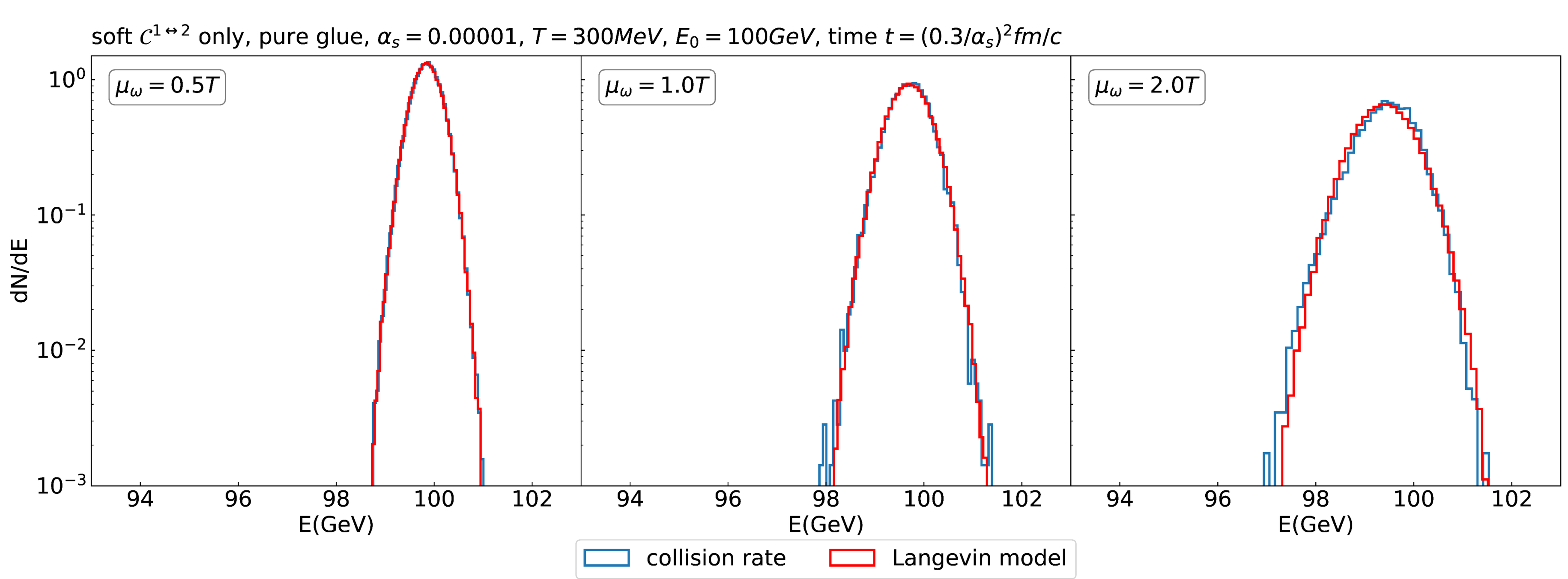
Elastic interactions - $\mathbb{C}^{2\leftrightarrow 2}$:



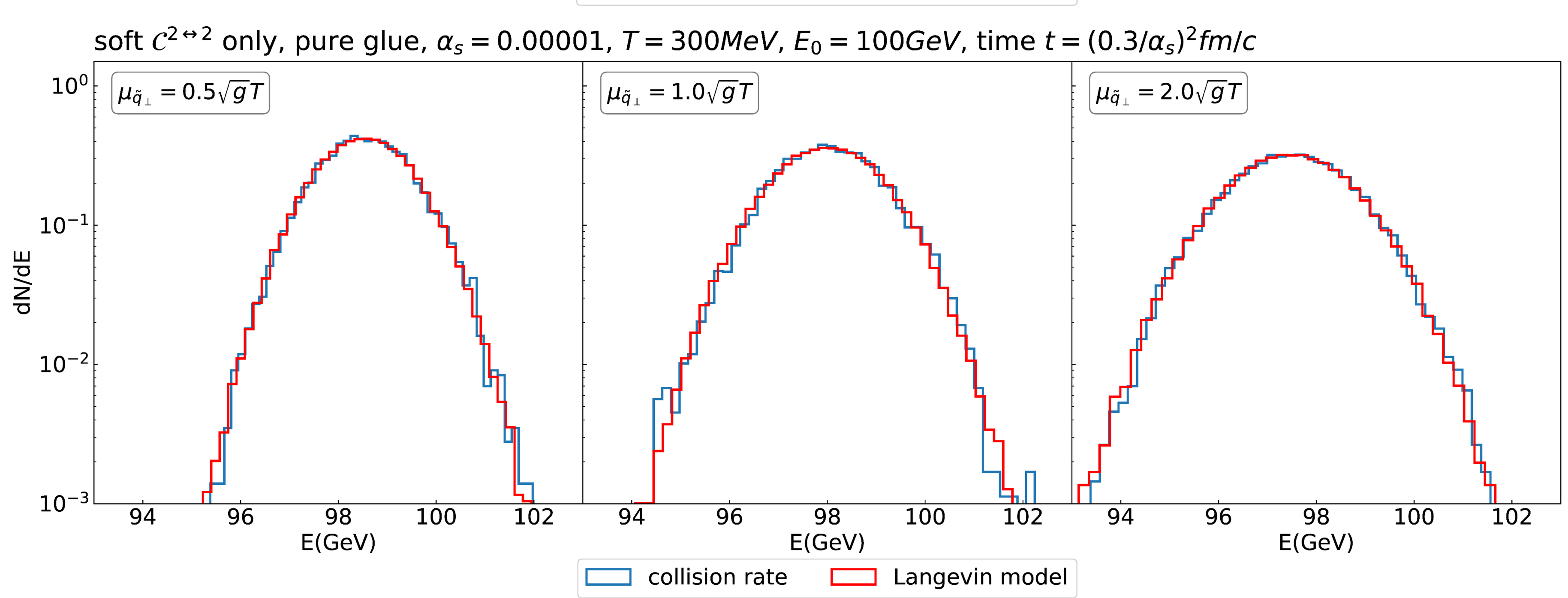
We add this reformulated model as a high-energy, low-virtuality module in the **JETSCAPE** framework[2].

III. Comparison between diffusion and collision rate

Soft interactions are usually treated with a collision rate, while in the hard-soft reformulated model, frequent soft interactions are treated with a Langevin model.



Inelastic

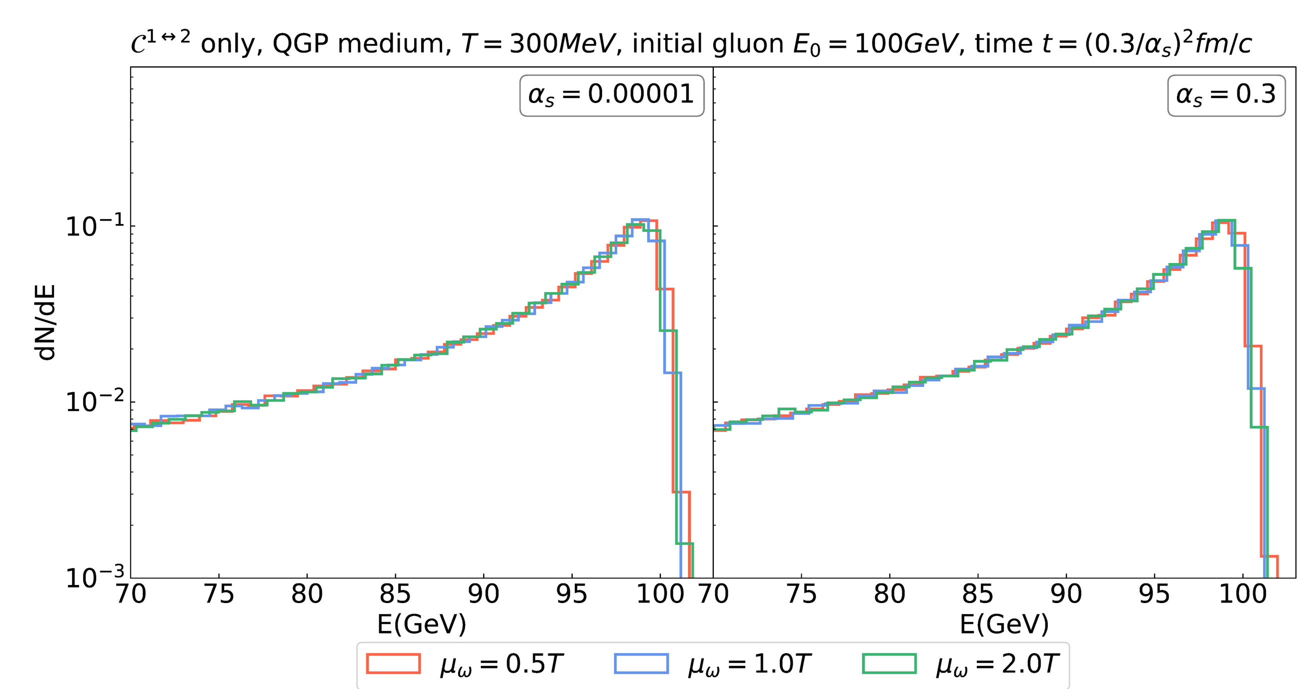


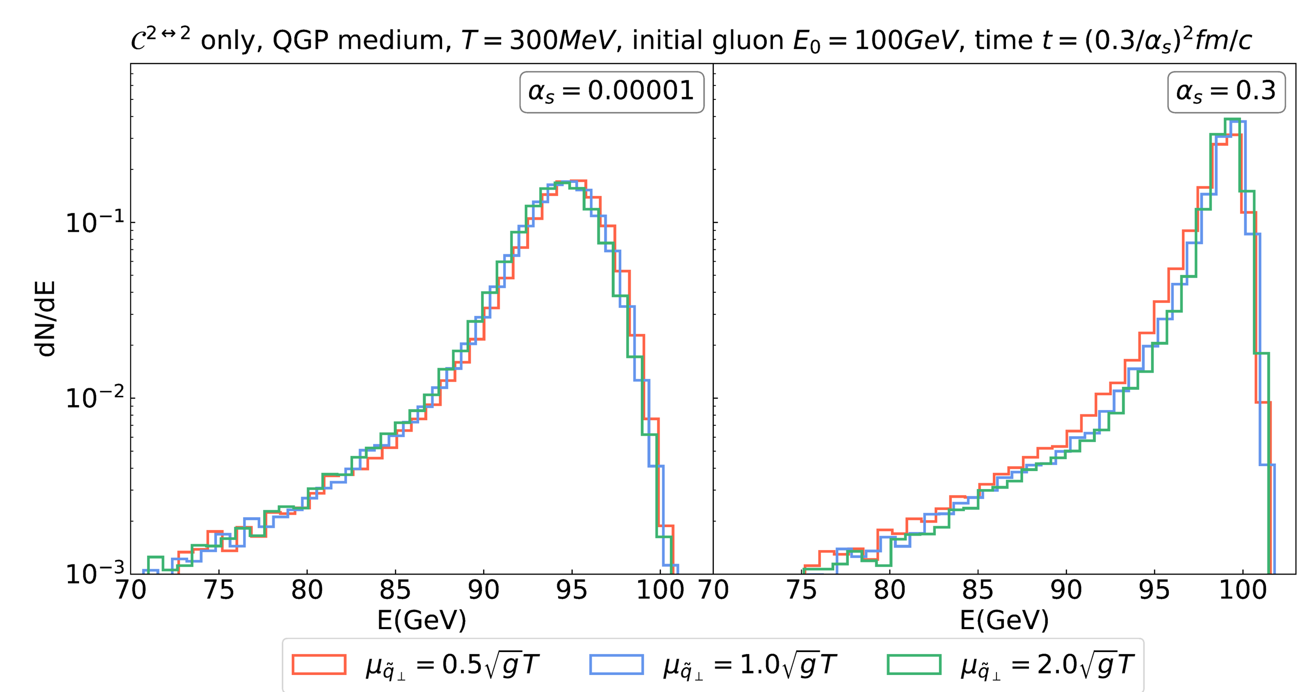
Elastic

Both the elastic and inelastic soft parton-medium interactions can be described by a diffusion process at small coupling.

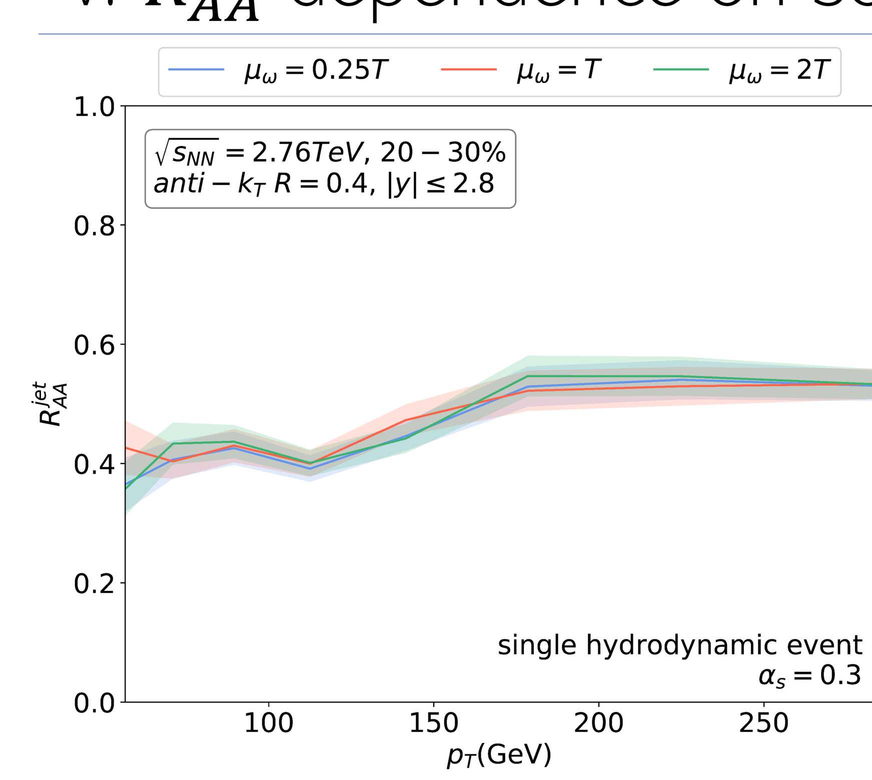
IV. Cutoff dependence of energy distribution

We check the dependence of the single parton energy distribution on the hard-soft cutoff to validate the model.





V. R_{AA} dependence on soft-hard cutoff

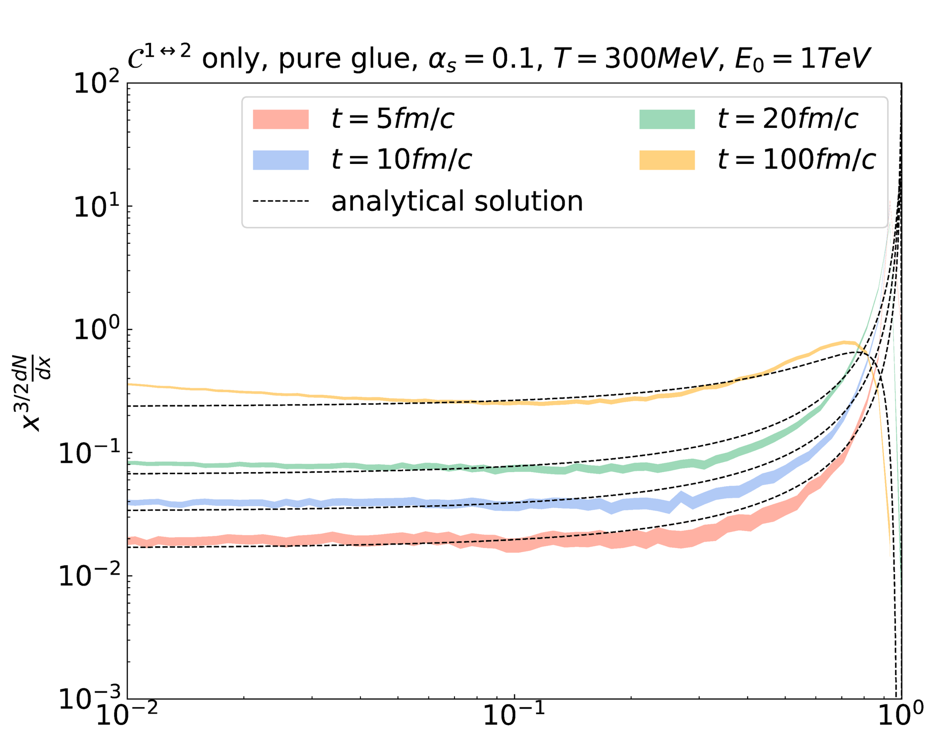


- include both elastic and inelastic interactions
- realistic initial parton distribution is given by Pythia
- partons are produced at the center of the medium

R_{AA} consistent with different inelastic cutoffs

VI. Comparison with analytical approximation

An analytical solution[3] is known for the in-medium gluon cascade assuming:
- successive branchings are independent
- approximate inelastic differential rate valid in deep LPM region



Analytical distribution of gluons:

$$x^{3/2}\frac{dN}{dx} = \frac{\tau}{(1-x)^{3/2}}e^{-\pi[\tau^2/(1-x)]}$$

where $x \equiv \omega/E_0$ is the energy fraction, N is the number of gluons,

and $\tau \equiv \frac{\alpha_s N_c}{\pi}\sqrt{\frac{\hat{q}}{E}}t$.

In the small-x region, the power-law spectrum xdN/dx scales as $1/\sqrt{x}$. The analytical solution is well-reproduced by the full QCD numerical model.

VII. Outlook

- apply Bayesian analysis on drag and diffusion coefficients
- introduce running of the coupling

References

1. Ghiglieri, Moore, Teaney, JHEP03 (2016) 095
2. Putschke, et al., arXiv:1902.05934 (2019).
3. Blaizot, Iancu, Mehtar-Tani. *PRL* 111.5 (2013):052001.

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