From R_{AA} to energy loss temperature proportionality factor

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Abstract

When traversing QCD medium, high $p_\perp$ partons lose energy, which is measured by suppression, and also predicted by various energy loss models. A crucial test of different energy loss mechanisms is their dependence on the medium temperature. Though it is commonly assumed that this dependence is cubic, different effects such as Debye screenings, finite parton masses, infrared cutoffs, etc., modify it differently for different energy loss models. Therefore, providing a theoretical procedure which is able to extract this temperature proportionality factor directly from the suppression data, would enable both differentiating between different energy loss models and gaining better understanding of parton-QGP interactions. In this work [1], we propose a method (based on our recently developed DREENA framework [2]) to infer the energy loss temperature dependence from high $p_\perp$ suppression, and demonstrate that our procedure presents a reliable tool for such a purpose.

Introduction

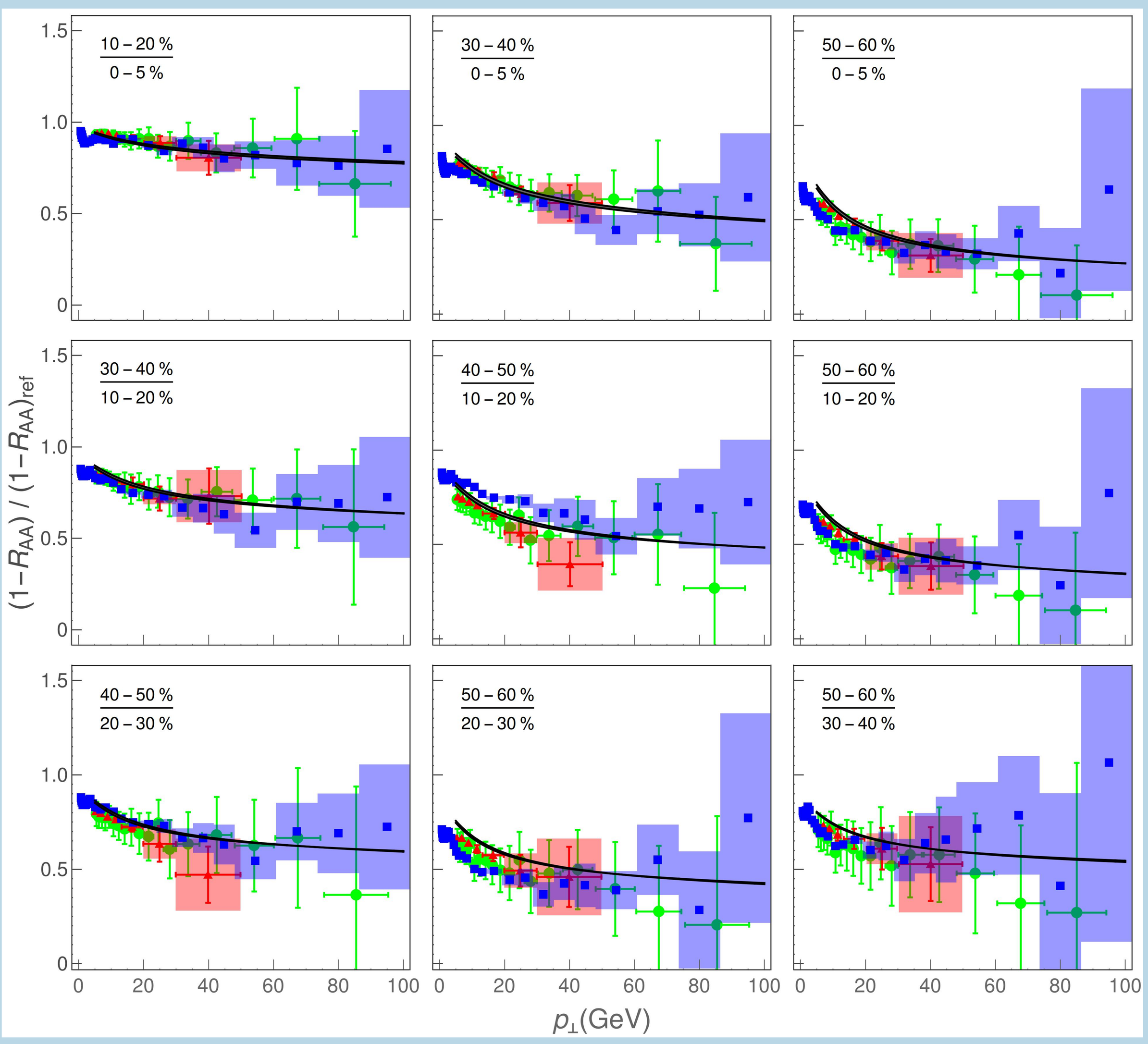
- **DREENA**: **D**ynamical **R**adiative and **E**lastic **EN**ergy loss **A**pproach: numerical procedure for suppression calculations based on dynamical energy loss formalism.
- **Analytical scaling argument**: within our energy loss formalism, in high-$p_\perp$ region and for more peripheral collisions, fractional energy loss and R_{AA} **approximated** by:

$$\Delta E/E \approx \eta T^a L^b \implies R_{AA} \approx 1 - \xi T^a L^b$$

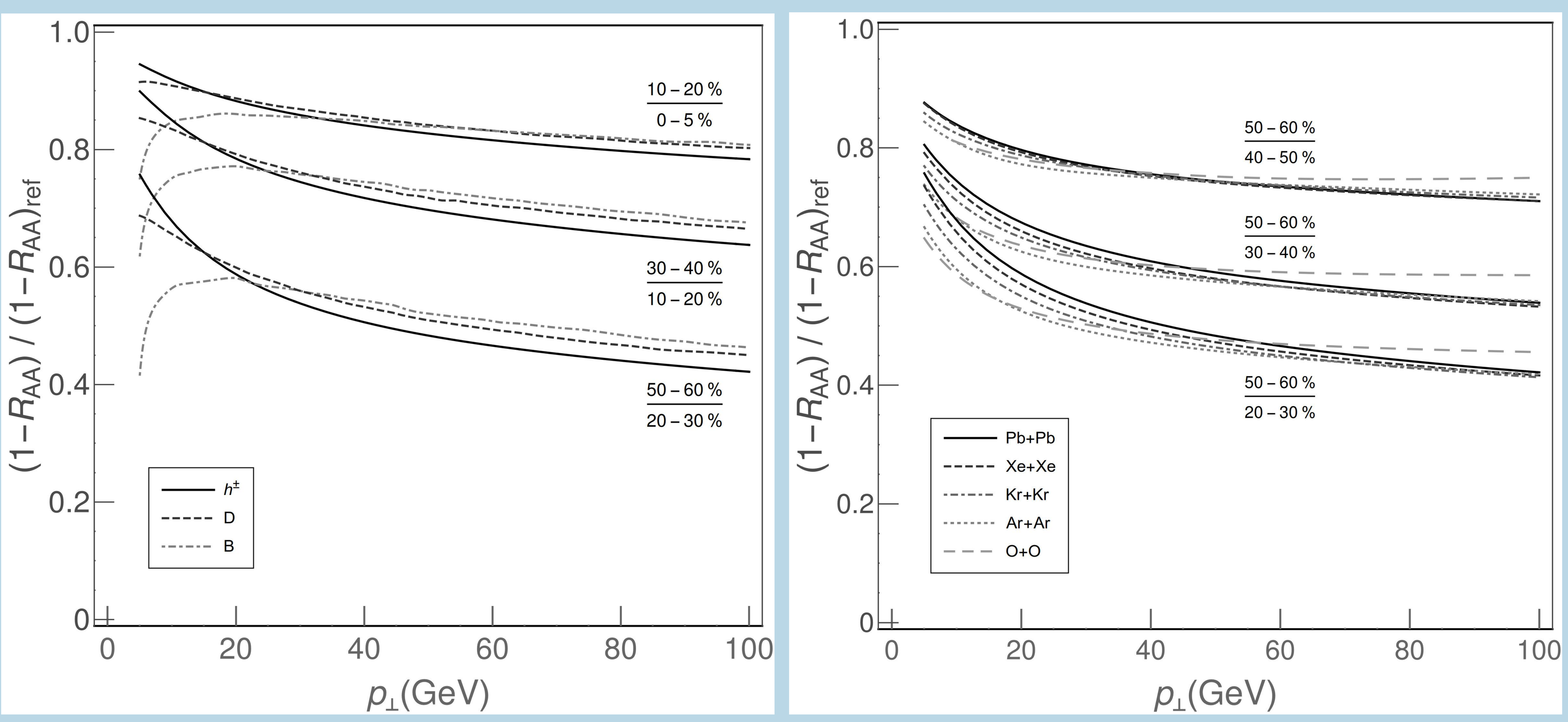
- **Energy loss temperature dependence.** It is commonly believed that the temperature dependence of high-$p_\perp$ partons energy loss is cubic. Our previous work [3] indicates that this dependence is in fact **between linear and quadratic**.
- **How to infer the value of a from R_{AA} data?**

Numerical results

- We present a comparison of our theoretical results for $1 - R_{AA}$ ratios generated within our full-fledged DREENA-C framework for Pb+Pb collisions at $\sqrt{s_{NN}} = 5.02$ TeV with **ATLAS**, **CMS** and **ALICE** data and **observe excellent agreement**:



- $1 - R_{AA}$ ratio predictions for **probes with different mass** in $\sqrt{s_{NN}} = 5.02$ TeV $Pb+Pb$ collisions; as well as for **smaller collision systems:**



References

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[3] M. Djordjevic and M. Djordjevic, Phys. Rev. C 92, 024918 (2015).
[4] M. Djordjevic, D. Zigic, M. Djordjevic and J. Auvinen, arXiv:1805.04030 [nucl-th] (PRC Rapid Communications, in press, 2019).

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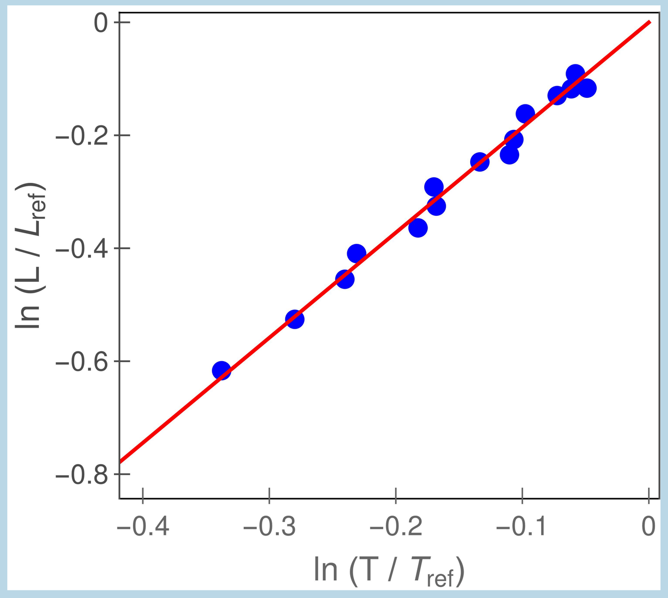
Methods

- We consider a new quantity:

$$\frac{1 - R_{AA}}{1 - R_{AA}^{ref}} = \left(\frac{T}{T_{ref}}\right)^a \cdot \left(\frac{L}{L_{ref}}\right)^b \implies$$

$$\ln\left(\frac{1 - R_{AA}}{1 - R_{AA}^{ref}}\right) \approx a \ln\left(\frac{T}{T_{ref}}\right) + b \ln\left(\frac{L}{L_{ref}}\right)$$

- Are $\ln(T/T_{ref})$ and $\ln(L/L_{ref})$ correlated?



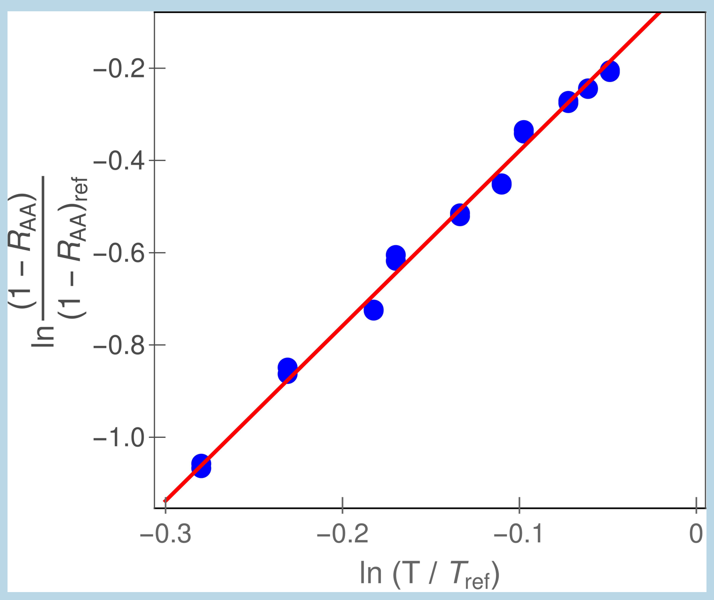
- We observe **linear dependence**, with $\boldsymbol{k \approx 1.86}$, which simplifies our equation:

$$\ln\left(\frac{1 - R_{AA}}{1 - R_{AA}^{ref}}\right) \approx (a + kb) \ln\left(\frac{T}{T_{ref}}\right)$$

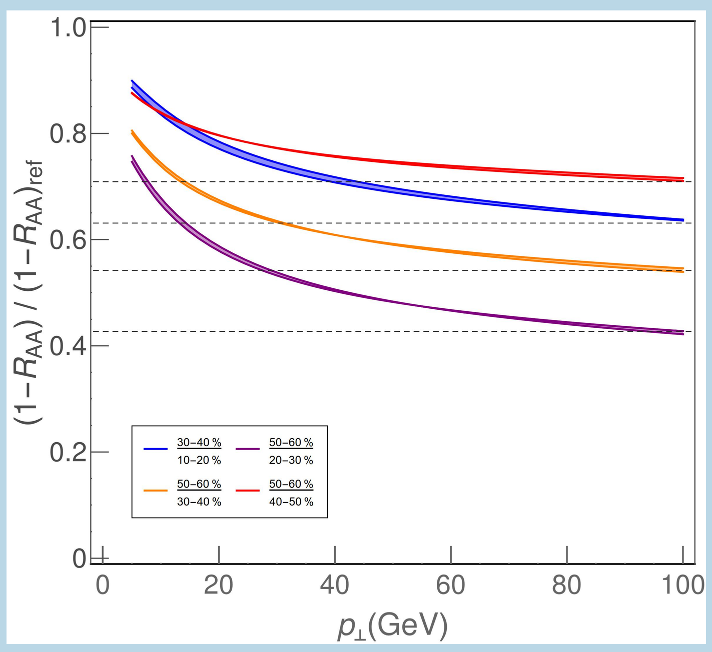
- We have previously determined the value of b [4]: $b \approx 1.4 \implies$ by **fitting the data obtained by our full-fledged DREENA-C numerical procedure to this dependence, we can determine the value of a!**

Extraction of the temperature proportionality factor

- By fitting the data (using the R_{AA} results at $p_\perp = 100$ GeV generated within our full-fledged DREENA-C numerical procedure) to the above functional dependence, we extract the value of temperature-dependence coefficient: $\boldsymbol{a \approx 1.2}$.



- We use the values $a = 1.2$ and $b = 1.4$ to check the validity of the scaling argument upon which our method relies - **we observe that the full-fledged DREENA-C $1-R_{AA}$ ratio calculation approaches the approximated value in high-$p_\perp$ region!**



Summary

- We present a method to infer the temperature-dependence coefficient a of the energy loss of high-$p_\perp$ partons in QCD medium from R_{AA} data.
- To illustrate how R_{AA} data can be used for such purpose, we introduce analytical scaling arguments which follow from our dynamical energy loss formalism.
- R_{AA} data generated within our full-fledged DREENA-C numerical procedure is then used to extract the value of a.
- Extracted value of the temperature proportionality factor ($a \approx 1.2$) in accordance with previous work [3], which suggested that this dependence is between linear and quadratic.
- Numerical calculations compared with experimental data and show excellent agreement.
- The extracted value of the temperature coefficient is used to confirm the validity of our scaling argument, which gives us confidence in the validity of our method.