How to test path-length dependence in energy loss mechanisms: analysis leading to a new observable

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Abstract

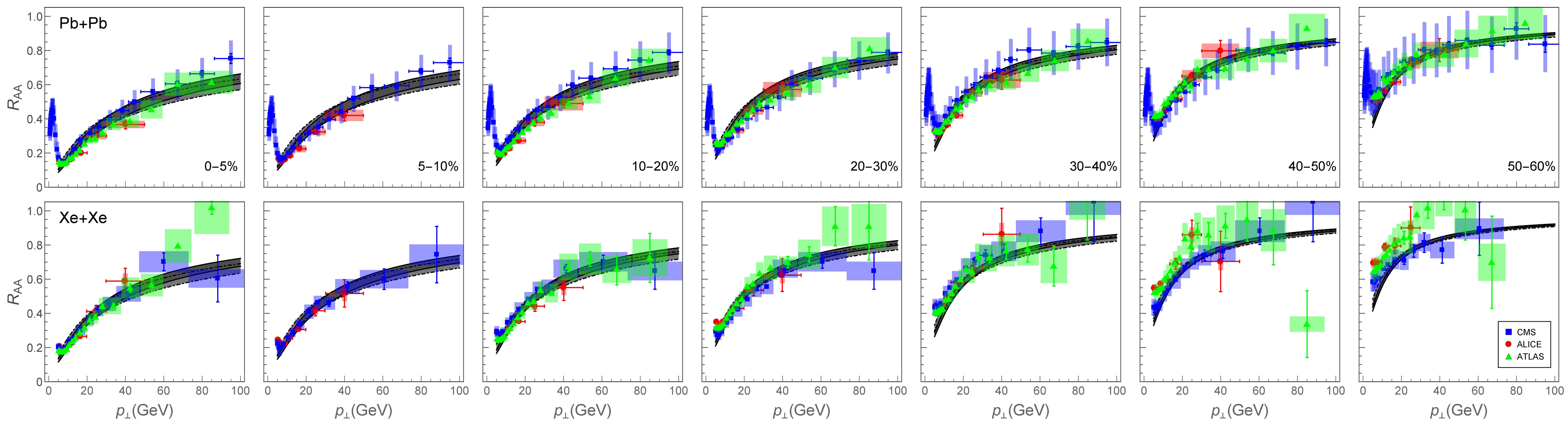
When traversing QCD medium, high $p_\perp$ partons lose energy, which is typically measured by suppression, and also predicted by various energy loss models. A crucial test of different energy loss mechanisms is their functional dependence on the length of traversed medium (i.e. path-length dependence). The upcoming experimental measurements will, for the first time, generate data that may allow to clearly assess this dependence, in particular, by comparing results from Pb+Pb collisions with future measurements in smaller systems. However, to perform such test, it is crucial to choose an optimal observable. To address this, we here use both analytical and numerical analysis to propose a novel - simple, yet accurate and robust - observable for assessing the path-length dependence of the energy loss [1]. Our numerical results show that, by using this observable, different (underlying) energy loss mechanisms may be directly differentiated from the experimental data, which is in turn crucial for understanding the properties of the created QCD medium.

Introduction

- Comparing predictions of different energy loss models, and different underlying energy loss mechanisms with experimental data is crucial for understanding properties of created QGP.
- The most basic signature for distinguishing different energy loss models is their path-length dependence (e.g. pQCD collisional with linear, pQCD radiative with quadratic, AdS holography models with third power dependence).
- The most direct probe of the path-length dependence would involve comparing experimental data (and the related theoretical predictions) for two collision systems of different sizes.
- How to choose an optimal system and an optimal observable for assessing the energy loss path-length dependence?

DREENA framework

- **D**ynamical **R**adiative and **E**lastic **EN**ergy loss **A**pproach: fully optimized numerical procedure for suppression calculations based on dynamical energy loss formalism.
- Version **C**: evolution taken in a simplest form (through constant temperature medium) [2]; version **B**: introduced medium evolution through 1+1D Bjorken expansion [3].



- Inclusion of QGP evolution has negligible effect on R_{AA}, which is consistent with the previous notion that R_{AA} is not very sensitive to medium evolution.

How to differentiate between different energy loss models?

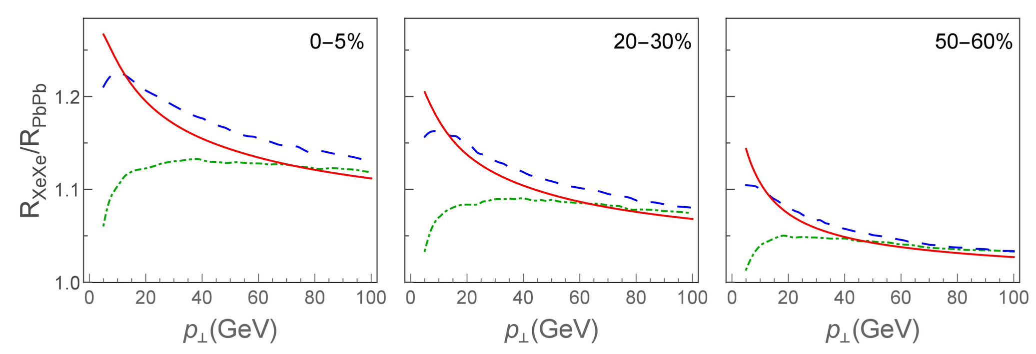
- Path-length dependence (energy loss $\sim L^b$) straightforwardly differentiates different energy loss models.
- Many energy loss models have linear ($b = 1$) or quadratic ($b = 2$) path-length dependence.
- The dynamical energy loss path-length dependence is between linear and quadratic, due to both collisional and radiative energy loss mechanisms included in the model.
- Path-length dependence provides an excellent signature differentiating between different energy loss models, and consequently also between the underlying energy loss mechanisms.

What is an appropriate system?

- Measurements on 5.02 TeV Pb+Pb already available, 5.44 TeV smaller systems (e.g. Xe+Xe) are also becoming available.
- The main property differentiating the two systems are their sizes ($A_{Pb} = 208$, $A_{Xe} = 129$).
- All other properties basically remain the same:
  - initial momentum distribution,
  - average temperature for each centrality region,
  - path-length distributions (up to rescaling factor $A^{1/3}$).
- Consequently, comparison of suppressions in Pb+Pb and Xe+Xe is an excellent way to study the path-length dependence.

What is an appropriate observable?

- The ratio of the two R_{AA}s seems a natural choice:



- However, in this way the path-length dependence cannot be naturally extracted
- What is the reason for this?

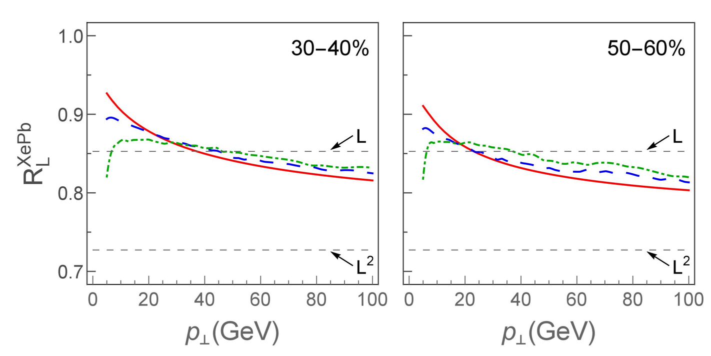
$$\Delta E/E \sim T^a L^b \implies \frac{R_{XeXe}}{R_{PbPb}} \approx 1 - \xi T^a L^b_{Pb}\left(1 - \left(\frac{A_{Xe}}{A_{Pb}}\right)^{b/3}\right)$$

What we propose

- If we use $1 - R_{AA}$ ratio [1] instead:

$$R^L_{XePb} \equiv \frac{1 - R_{XeXe}}{1 - R_{PbPb}} \approx \frac{\xi T^a L^b_{Xe}}{\xi T^a L^b_{Pb}} \approx \left(\frac{A_{Xe}}{A_{Pb}}\right)^{b/3}$$

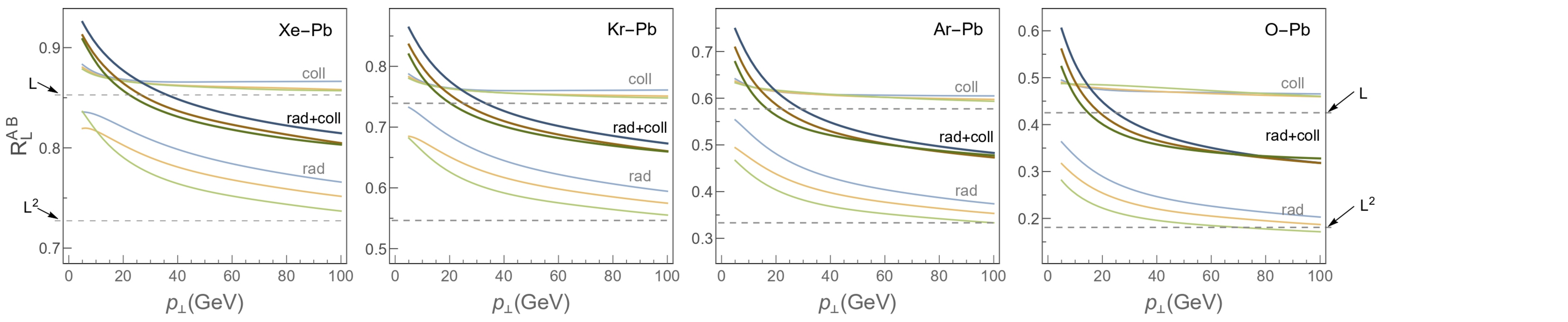
we see a simple dependence only on the size of the medium ($A^{1/3}$ ratio) and the path-length dependence (exponent b).



- 1-R_{AA} ratio therefore seems as a natural observable, which we call path-length sensitive suppression ratio.

What about other smaller systems?

- Precision measurements of smaller systems are expected to become available in the future Beam Size Scan (BSS) at the LHC.
- Can these systems be also used to extract path-length dependence of the energy loss?



- R^L_{AB} is almost independent on centrality
- for all four systems R^L_{AB} shows the same behavior
- recovers radiative and collisional path-length dependence
- smaller systems might be more convenient
- Consequently, we propose that R^L_{AB} is simple, robust and reliable observable for extracting path-length dependence.

References

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