Data-Driven Predictions for Small System Energy Loss

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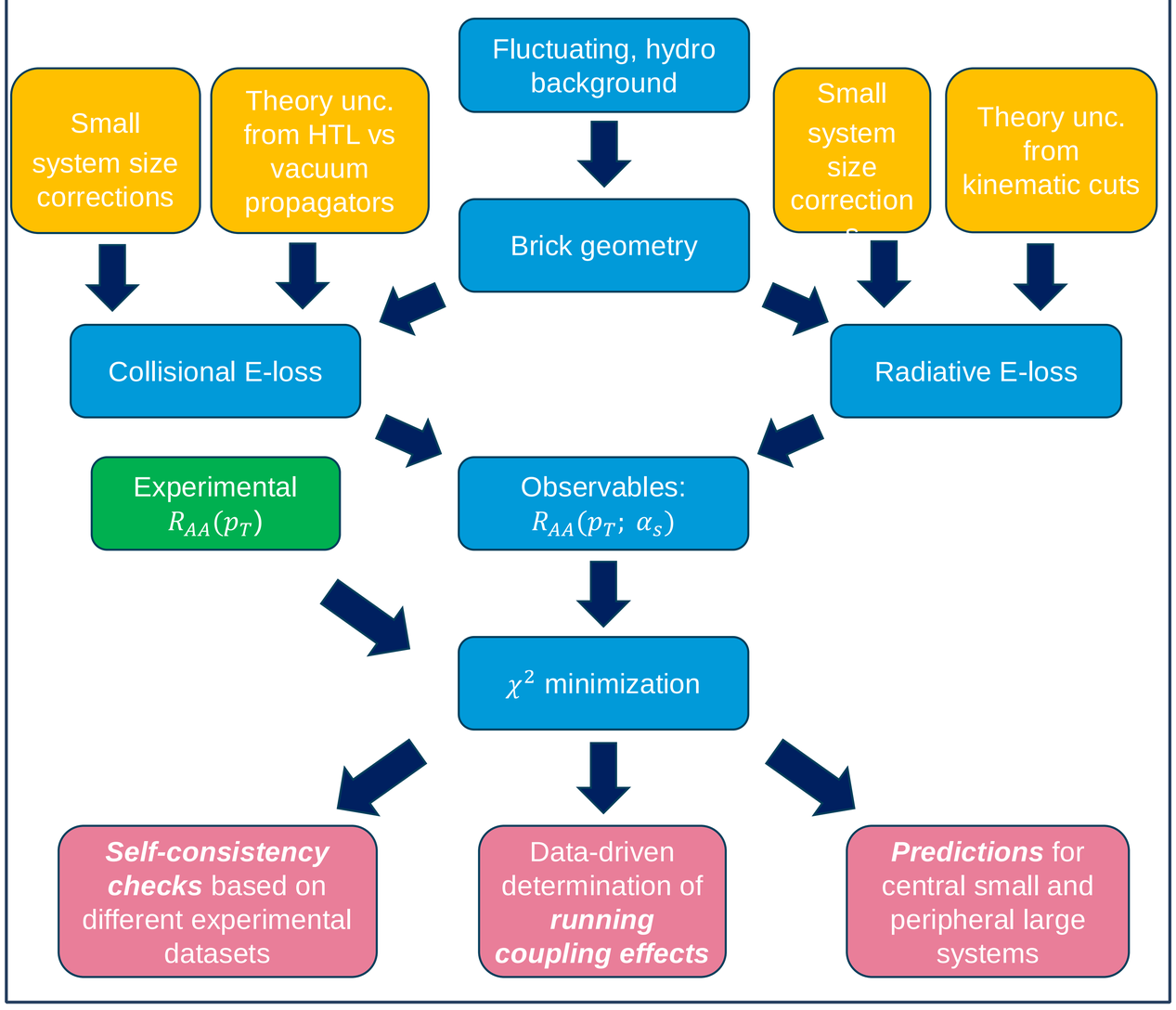
*Based on **CF** and W. A. Horowitz, PLB **864**, 139437 (2025) and arXiv:2504.XXXXX*

1 Motivation

There is strong evidence that Quark-Gluon Plasma (QGP) forms in heavy-ion collisions at RHIC and the LHC, including from elliptic flow, strangeness enhancement, and jet quenching. More recently, elliptic flow and strangeness enhancement have also been observed in small $p\,/\,d\,+\,A$ collision systems, consistent with predictions from relativistic viscous hydrodynamics. However, jet quenching signatures in small systems remain largely ambiguous, particularly R_{pA}, due to centrality bias and Glauber model dependence, making it difficult to determine whether QGP is formed in these systems.

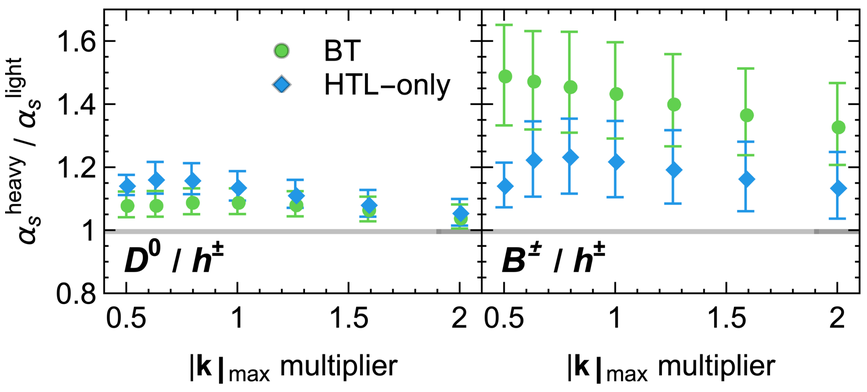
2 Procedure



3 Self-consistency checks

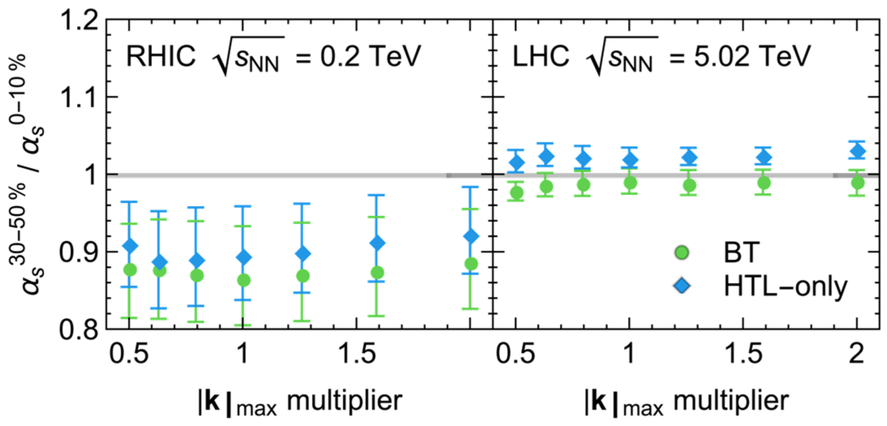
We extract α_s in different collision systems to assess the self-consistency of our model and comment on potential missing physics

Ratio of extracted α_s in heavy- to light-flavor final states



- 20-40% increased α_s extracted for heavy compared to light flavors. Potentially resolved by different fraction of collisional vs radiative E-loss

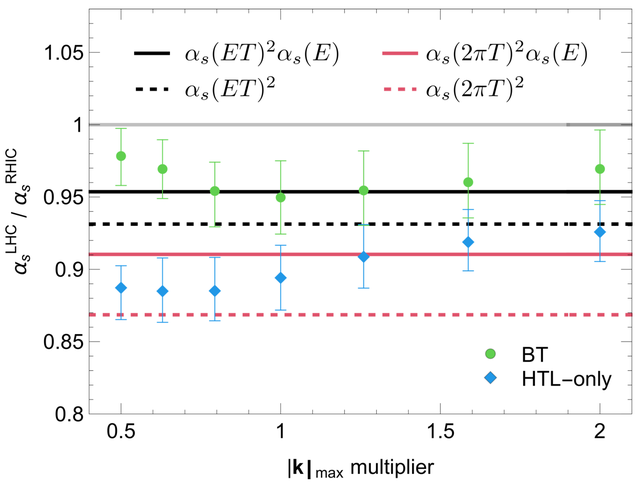
Ratio of extracted α_s in semi-central to central systems



- Percent-level agreement between semi-central and central α_s at LHC
- 10% difference at RHIC

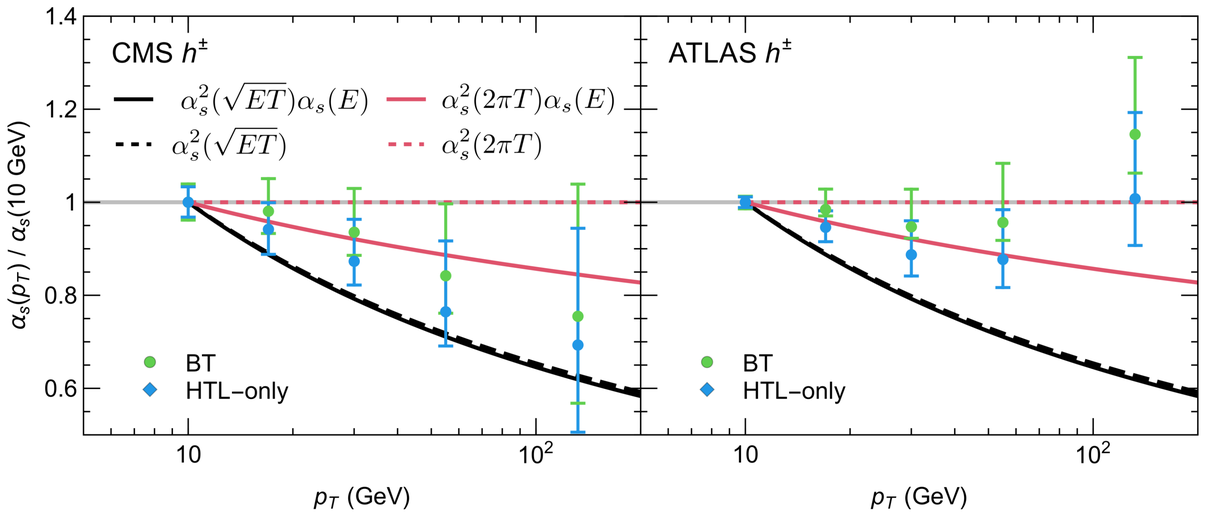
4 Running coupling from data

Extraction of α_s at RHIC and LHC separately



- We find that α_s at RHIC is ~5-10% larger than that at LHC
- Depends significantly on collisional energy loss implementation (HTL-only vs BT)
- HTL-only favors coupling running predominantly at temperature scale, while BT favors coupling running at momentum scale∂

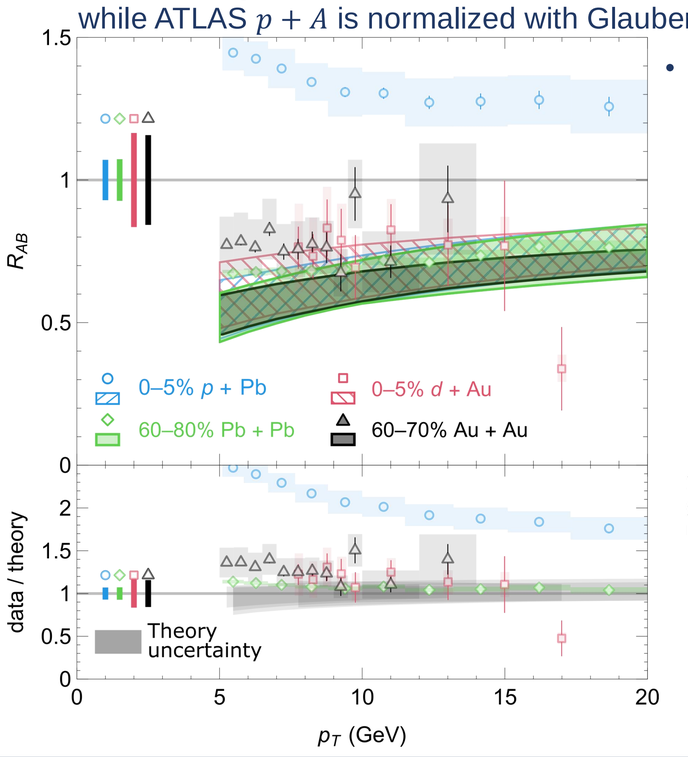
Extraction of α_s in disjoint p_T ranges



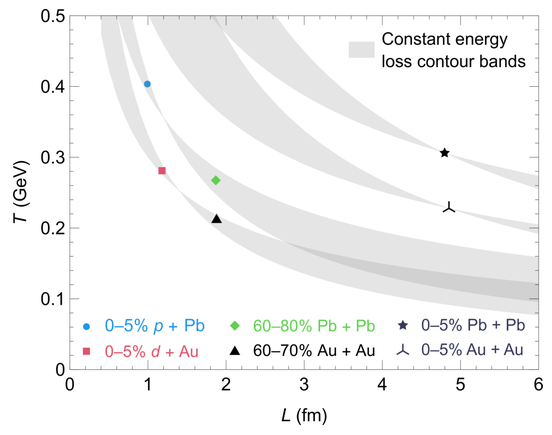
- We find that ATLAS data favors coupling running only at temperature while CMS favors coupling running partially with momentum
- HTL-only favors coupling running at harder scale compared to BT

5 Predictions for small and peripheral systems

- With no further fitting, we make predictions for central small systems and peripheral large systems at RHIC and LHC.
- We find equal suppression for 60-70% $A + A$ as for 0-5% $p\,/\,d\,+\,A$, compatible with PHENIX data for $d\,+\,A$ and $A\,+A$ and for ATLAS data for $A + A$, but incompatible with ATLAS $p + A$ data. **NB**: PHENIX $d + A$ data is normalized by prompt photons, while ATLAS $p + A$ is normalized with Glauber model.



- We further compute suppression in multiple simple parametric models and find equal suppression for 60-70% $A + A$ and 0-5% $p/d + A$ regardless of weak or strong coupling, single hard or multiple soft scattering, and collisional or radiative energy loss



6 Future Work

- Predictions for O + O collisions at RHIC and LHC
- Analytic running coupling calculations
- High-p_T v_2 in our analysis from both small and large systems
- Dihadron correlation in our analysis.

7 Acknowledgements

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