

Effects of Initial-State Geometry on Jet Suppression in Peripheral Pb+Pb Collisions

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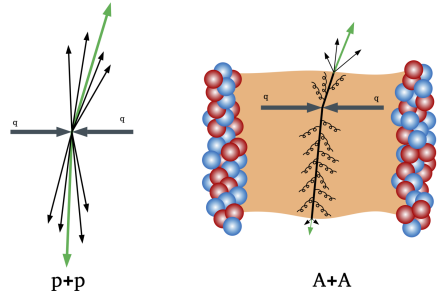
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Introduction

- ▶ High-energy Pb+Pb collisions at the LHC produce a hot, dense quark-gluon plasma (QGP) of deconfined quarks and gluons.
- ▶ The QGP behaves as a strongly coupled fluid with low shear viscosity; collective flow is one of its key signatures.
- ▶ Energetic partons interacting with the QGP can lose energy, leading to jet quenching and suppression of high- p_T particles.



Jet production in pp and AA collisions.
Image: M. Rybar/ATLAS Collaboration.

Nuclear modification factor

$$R_{AA}(p_T) = \frac{1}{\langle N_{\text{coll}} \rangle} \frac{dN_{AA}/dp_T}{dN_{pp}/dp_T}$$

- ▶ A larger centrality value corresponds to a larger impact parameter, and thus a smaller system size in AA collisions.
- ▶ However, substantial suppression of charged hadron spectra is observed in highly peripheral collisions, despite the expectation of negligible jet-QGP interactions in this regime.
- ▶ This discrepancy needs to be resolved before one can use jets as a reliable tool to probe properties of nuclear matter with small sizes.

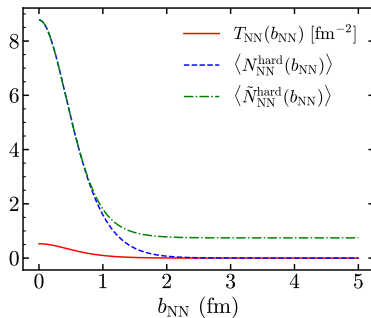
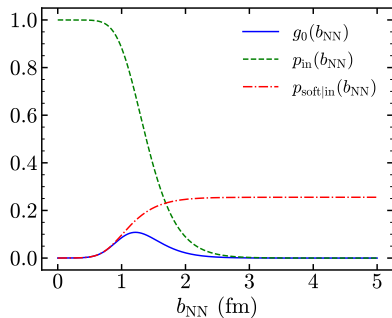
The geometric bias of jet quenching

$$R_{AA} = R_{AA}^{\text{bias}} R_{AA}^{\text{med}}$$

$$R_{AA}^{\text{bias}} = \frac{\langle N_{AA}^{\text{hard}} \rangle}{\langle N_{\text{coll}} \rangle \langle\langle N_{\text{NN}}^{\text{hard}} \rangle\rangle}$$

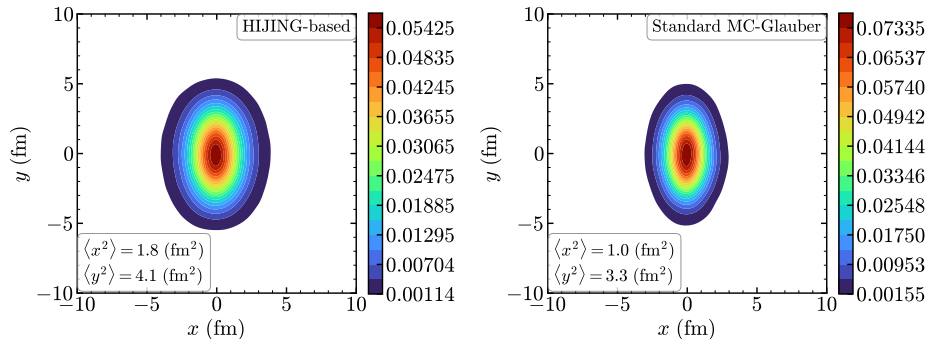
- ▶ If one assumes each binary NN collision produces the same number of hard partonic scatterings in AA and pp collisions, R_{AA}^{med} is the same as R_{AA} measured in experiments.
- ▶ However, this may not be true in reality.
- ▶ This is known as the geometric bias of jet quenching.
- ▶ The R_{AA} one observes in experiments is not only determined by parton-QGP interactions, but also affected by the initial geometry of AA collisions.

HIJING-based nucleon-nucleon collisions



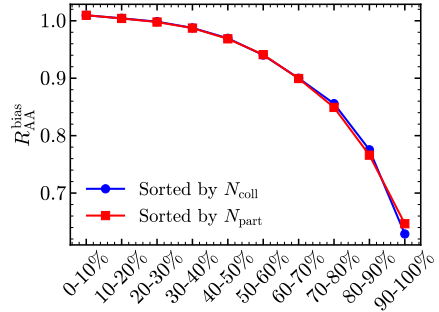
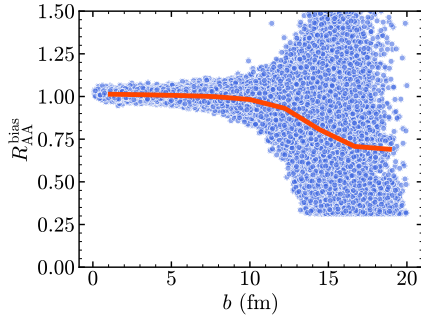
- ▶ At large b_{NN} , about 25% of inelastic scatterings are purely soft.
- ▶ The b_{NN} -averaged hard scattering number can be evaluated as $\langle\langle N_{NN}^{hard} \rangle\rangle = 2.38$.

Nucleus-nucleus collisions



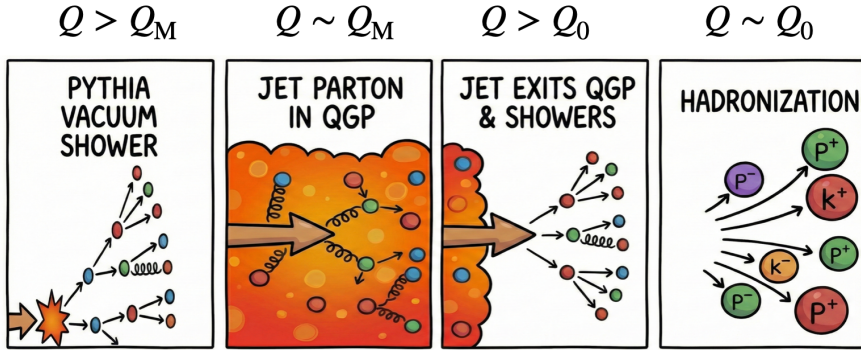
- ▶ One binary collision may generate zero, one, or multiple hard scatterings.
- ▶ The hard collision vertices from the HIJING-based model tend to be more sparsely distributed than those from the standard MC-Glauber model in peripheral collisions.
- ▶ No obvious difference can be seen in the charged hadron R_{AA} due to the weak parton energy loss in peripheral collisions.

The geometric bias factor of jet quenching



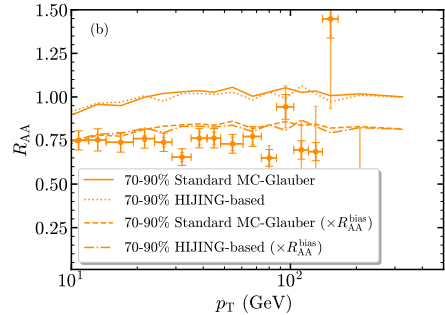
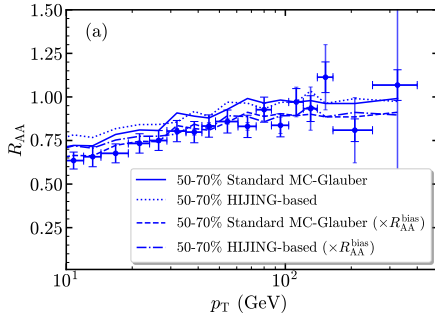
- ▶ This causes a bias in R_{AA} that is not related to the nuclear modification of jet partons inside the QGP.
- ▶ One can clearly observe a “suppression” of jets at large centrality. This “suppression” is not attributed to parton energy loss.
- ▶ Instead, it arises from a smaller hard scattering number per binary collision in peripheral AA collisions compared to unbiased NN collisions.

Scale-segmented evolution of jet partons



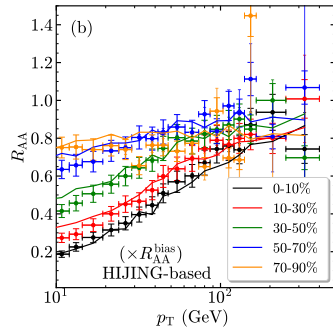
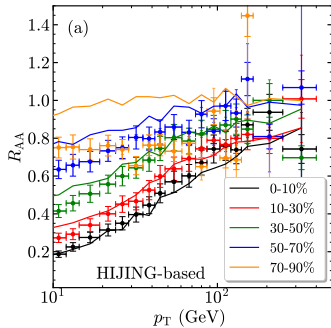
- ▶ These partons are first evolved down to the medium scale of the QGP (Q_M) via the Pythia vacuum showers.
- ▶ After that, jet partons interact with the QGP within the linear Boltzmann transport (LBT) model.
- ▶ Once the partons exit the QGP, they are returned to Pythia for further vacuum showers down to Q_h , followed by hadronization.

Effects of geometric bias on hadron suppression



- Effect of the geometric bias becomes more prominent in more peripheral collisions.
- Multiplying R_{AA} by the bias factor R_{AA}^{bias} results in a slight decrease of R_{AA} for the 50–70% centrality class, and a significant decrease for the 70–90% centrality class.
- The experimentally observed suppression of high- p_T hadrons in highly peripheral heavy-ion collisions is predominantly driven by the initial-state collision geometry rather than the final-state parton energy loss.

Centrality dependence of the charged hadron R_{AA}



- ▶ The initial vertices of jet partons sampled by the HIJING-based model and the standard Glauber model have little impact on the parton energy loss inside the QGP.
- ▶ One clearly observes the increasing impact of R_{AA}^{bias} on the charged hadron R_{AA} as centrality increases.
- ▶ By combining the geometric bias effect obtained using the HIJING-based model and the parton-QGP interactions simulated using the LBT model, we achieve a satisfactory description of the centrality dependence of the charged hadron R_{AA} .

Conclusions

- ▶ The different initial distributions of hard scattering vertices between the two models have little impact on the charged hadron R_{AA} , since substantial difference only exists at large centralities where the parton energy loss is weak.
- ▶ The suppression of charged hadrons observed in highly peripheral collisions is predominantly driven by the dilute nucleon overlap in the initial state, rather than an onset of strong jet-QGP interactions.
- ▶ By combining the geometric bias effect obtained from the HIJING-based model and the QGP effect simulated using the LBT model, we achieved a unified description of the charged hadron R_{AA} from small to large centralities in Pb+Pb collisions at $\sqrt{s_{NN}} = 5.02$ TeV.