

A novel model simulation for the parton energy loss in QGP

T. Kumaoka^{*1,*2,*3}

This study aims to clarify the parton energy loss mechanism in quark-gluon plasma (QGP), which is a matter phase formed at very high temperatures and pressure. In the ordinal state, quarks and gluons (parton) are confined in a hadron by the strong interaction described by quantum-chromodynamics (QCD). However, in QGP, these partons are deconfined, and the QCD interaction dominates. Although the QCD interaction is one of the most fundamental interactions, its properties are not completely clarified. The parton energy loss mechanism is also one of the unclarified properties of QGPs. Furthermore, QGP is believed to exist in the early universe, and understanding its properties is important for studying the formation of the universe.

QGP is produced by high-energy heavy-ion collisions at large accelerators such as the RHIC and LHC. Due to the very short lifetime of QGP and the fact that the size of QGP medium produced in heavy-ion collisions is identical to that of a nuclei, direct observation is impossible, rendering it difficult to study.

A high-momentum parton created at the initial collision passes through QGP medium while undergoing strong interactions. The parton then quickly decays into numerous hadrons (jets) after creation, making the direct observation of a parton impossible. However measuring the reconstructed jets allows to access to parton energy loss through QGP medium and distinguish among different mechanisms of parton interactions within QGP.

To date, the parton energy loss with QGP has been studied through independent measurements: the jet nuclear modification factor R_{AA}^{jet} corresponding to the ratio of jet rates using Pb-Pb collisions relative to p - p collisions and the azimuthal anisotropy (v_2^{jet}) of jet rates resulting from the different path-lengths crossed by the partons in QGP medium of an elliptically-shaped. However, confronting these measurements independently to parton energy loss models cannot elucidate the underlying mechanisms.

In this study, to quantify the energy loss per unit distance and constrain the models of the energy loss mechanisms (\hat{e}_n [GeV/fm ^{n}]), a simulation framework has been developed, where the energy loss is parametrized as the n -power of the path-length with QGP. The simulation results are compared with the results of R_{AA}^{jet} and v_2^{jet} measured by the LHC-ALICE experiment corresponding to p - p and Pb-Pb collisions at a collision energy of $\sqrt{s_{NN}} = 5.02$ TeV.

Evaluating the n -power parameter provides informa-

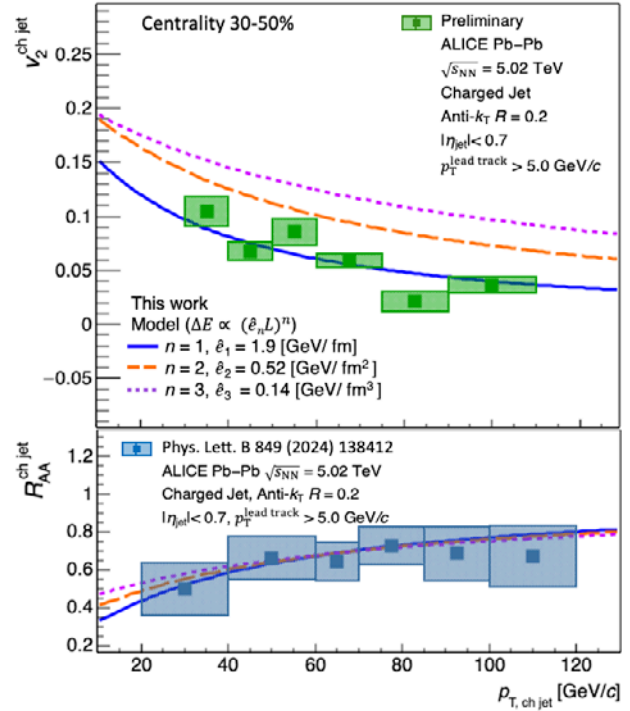


Fig. 1. R_{AA}^{jet} and v_2^{jet} of the simulation and measurement.

tion about possible energy-loss mechanics of the collisional, radiative, and AdS/CFT types. Comparing this simulation to the new measurements yields novel constraints on the path-length dependency of the parton energy loss within QGP.

In this simulation, the path length (L) was calculated using a simple Monte-Carlo-based approach on the Grauber model. The lost energy was estimated by $\Delta E = \hat{e}_n L^n$ [GeV]. Comparison of the simulation and measurement results give the suppression parameters \hat{e}_n and n . Figure 1 shows the results of R_{AA}^{jet} and v_2^{jet} of the simulations and measurements. The points represent measurement results and lines represent simulation results. The solid line is the $n = 1$ case, the broken line is the $n = 2$ case, and the dotted line is the $n = 3$ case. All R_{AA}^{jet} simulation results are consistent with measurements, while, for v_2^{jet} , the $n = 1$ result only reproduced the measurement value for the entire p_T region. Therefore, \hat{e}_n is determined as 1.9 GeV/c and $n = 1$.

The model with $n = 1$ successfully reproduced R_{AA}^{jet} and v_2^{jet} simultaneously with simple modeling. It should be further developed to examine other observables to strengthen the conclusion.

Reference

- 1) ALICE Collaboration, Phys. Lett. B **849**, 138412 (2024).

*1 Department of Physics, University of Tsukuba

*2 Department of Physics, University Grenoble Alpes

*3 RIKEN Nishina Center