AdS/CFT predictions for azimuthal and momentum correlations of heavy quarks in heavy ion collisions

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Motivation & Outline

- Want to understand relevant coupling scale of QGP
- Need observables to differentiate between strong- and weakly-coupled energy loss mechanisms
- We compare perturbative QCD [2] with our AdS/CFT predictions [1] for azimuthal correlations of bottom quarks in Pb+Pb collisions (\(\sqrt{s} = 2.76\text{TeV}\))
- We probe with two plausible 't Hooft coupling constants, \(\lambda_1 = 5.5\) with \(T_{QCD} = T_{SYM}\), and \(\lambda_1 = 12\alpha_s \approx 11.3\) with \(\alpha_s = 0.3\) and \(E_{QCD} = E_{SYM}\)

Energy Loss Model

- Bottom quarks are propagated through the plasma via the energy loss mechanism \(D(p)\) or \(D_{\text{const}}\)

\[ D(p) = -\mu_p \cdot F_1 + F_T^2 \]

where \(\mu = \pi \sqrt{X^2} / (2M_p)\) [1].

The stochastic equation of motion for a heavy quark is given by

\[ \frac{d\vec{\chi}}{dt} = -\mu \vec{p}_\chi + \kappa \vec{\xi} \]

\[ \kappa = \pi \sqrt{X^2} \gamma \]

\[ \kappa_L = \frac{\gamma}{\kappa} \approx \pi \sqrt{X^2} \gamma \]

in GeV

\[ \kappa_T = \pi \sqrt{X^2} \gamma \]

The correlations of transverse and longitudinal momentum kicks are given by

\[ \langle F_T^2(t_1)F_T^2(t_2) \rangle = \kappa_T \delta(t_1 - t_2) \]

and

\[ \langle F_L^2(t_1)F_L^2(t_2) \rangle = \kappa_L \delta(t_1 - t_2) \]

where

\[ \kappa_T = 2T^2 / D = \pi \sqrt{X^2} \gamma \]

and

\[ \kappa_L = \frac{\gamma}{\kappa} \approx \pi \sqrt{X^2} \gamma \]

\[ \kappa_T = \pi \sqrt{X^2} \gamma \]

NLO Azimuthal Correlations

\[ \frac{dN}{d\Delta p_T} \] correlations for NLO initialization of the \(D(p)\) model. The \([1-4]\text{GeV}\) correlations are entirely washed out, but the signal is still observable for the higher \(p_T\) classes.

\[ R_{AA} \]

\[ R_{AA} \] of prompt averaged \(D^0, D^+\) and \(D^{*+}\) compared with preliminary data from ALICE. The \(D(p)\) model breaks down for high \(p_T\) since the longitudinal fluctuations grow as \(T^2\).

Leading Order Correlations

- Azimuthal correlations similar for pQCD and AdS/CFT
- Momentum correlations exhibit order of magnitude difference for low \(p_T\)
- Initial momentum correlations reveal difference in momentum correlations is explained by bottom quarks pairs in a strongly coupled plasma being more strongly coupled in momentum than in a weakly coupled plasma

Comparison with pQCD

Initial \(p_T\) correlations

- \(\Delta p_T\) correlations for 40-60% centrality. Of note is the order of magnitude difference between the strong and weak coupling based correlations in the \([1-4]\text{GeV}\) momentum class. Naively, one may expect this difference to be caused by more efficient suppression of high \(p_T\) particles in the strongly coupled plasma, but as the initial momentum correlations show, this is not the case.

Conclusion

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References