Nuclear modification of jet shape for inclusive jets and γ-jets at the LHC energies

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Outline

- Framework of coupled jet-fluid model
- Jet energy loss
- Modification of jet shape
- Analysis and Predication
- Summary
Coupled jet-fluid model

Jet shower evolution via Boltzmann transport equations + Hydrodynamic medium response
Boltzmann transport equation

\[ f_j(\omega_j, k_{j\perp}^2, t) = \frac{dN_j(\omega_j, k_{j\perp}^2, t)}{d\omega_j dk_{j\perp}^2} \]

\[ \frac{d}{dt} f_j(\omega_j, k_{j\perp}^2, t) = \delta_j \frac{\partial}{\partial \omega_j} f_j(\omega_j, k_{j\perp}^2, t) \]

\[ + \frac{1}{4} \hat{q}_j \nabla^2_{k\perp} f_j(\omega_j, k_{j\perp}^2, t) \]

\[ + \sum_i \int d\omega_i dk_{i\perp}^2 \tilde{\Gamma}_{i\rightarrow j}(\omega_j, k_{j\perp}^2 | \omega_i, k_{i\perp}^2) f_i(\omega_i, k_{i\perp}^2, t) \]

\[ - \sum_i \int d\omega_i dk_{i\perp}^2 \tilde{\Gamma}_{j\rightarrow i}(\omega_i, k_{i\perp}^2 | \omega_j, k_{j\perp}^2) f_j(\omega_j, k_{j\perp}^2, t) \]

\[ \Gamma(\omega, k_{\perp}^2 | E, 0) = \frac{2\alpha_s}{\pi} \frac{xP(x)\hat{q}(t)}{\omega k_{\perp}^4} \sin^2 \frac{t - t_i}{2\tau_f} \]

\[ \hat{\epsilon} = \frac{\hat{q}}{4T}, \quad \hat{q}(\tau, \vec{r}) = \hat{q}_0 \cdot \frac{T^3(\tau, \vec{r})}{T_0^3(\tau_0, \vec{0})} \cdot \frac{p \cdot u(\tau, \vec{r})}{p_0} \]
Hydrodynamic medium response

\[ \partial_\mu T^{\mu \nu}_{\text{QGP}} = 0 \Rightarrow \partial_\mu T^{\mu \nu}_{\text{QGP}}(x) = J^\nu(x) \]

\[ J^\nu(x) = \sum_i \int \frac{d\omega_i dk_i^2}{2\pi} d\phi_i \delta^{(3)} \left( x - x_0^{\text{jet}} - \frac{k_i}{\omega_i} t \right) \times k_i^\nu \left( \hat{e}_i \frac{\partial}{\partial \omega_i} + \frac{1}{4} \hat{q}_i \nabla_{k_\perp}^2 \right) f_i(\omega_i, k_i^2, t) \]

\[ \Delta e = e|_{w/jet} - e|_{w/ojet} \]
Coupled jet-fluid model

Boltzmann transport equation for jet shower evolution

\[ p^\text{jet}_T (R) = p^\text{shower}_T (R) \]

\[ p^\text{shower}_T (R) = \sum_i \int_R d\omega_i d^2 k_{i\perp} \omega_i f_i(\omega_i, k_{i\perp}^2) \]

Hydrodynamic medium response

\[ p^\text{hydro}_T (R) = \int d^3 p p_T \left( \frac{d\Delta N^\text{hydro}}{d^3 p} \right) \]

\[ \frac{d\Delta N^\text{hydro}}{d^3 p} = \left| \frac{dN^\text{hydro}}{d^3 p} \right|_{\text{w/ jet}} - \left| \frac{dN^\text{hydro}}{d^3 p} \right|_{\text{w/o jet}} \]
At same collision energy, jets with lower $p_T$ have flatter jet shape. For jets with same $p_T$, jet shape is flatter at larger collision energy.
Jet energy loss: $R_{AA}$

\[
R_{AA} = \frac{\frac{1}{\langle N_{\text{coll}} \rangle} \frac{d^2 N_{AA}}{d\eta dp_T}}{\frac{d^2 N_{pp}}{d\eta dp_T}}
\]

Using jet $R_{AA}$ to fix the value of $\hat{q}_0$ at 2.76 TeV and 5.02 TeV.
Jet energy loss: $\gamma$-jet asymmetry

Our theoretical results have same feature as the experimental data. Medium response shifts the $X_{J\gamma}$ distribution to large $X_{J\gamma}$ mildly.
Jet energy loss: **cone size dependence**

Medium response feeds back more energy as cone size increasing, **which is important to the cone size dependence of jet $R_{AA}$**.
Jet shape modification: inclusive jets

Jet shape is modified little at small r, suppressed at middle r and enhanced at large r.

The ratio is a non-monotonic function of r.
Jet shape modification: $\gamma$-jets

Jet shape at small $r$ is suppressed, the ratio increases monotonically as $r$. 
Jet shape modification is not very sensitive to jet flavor, but sensitive to jet energy.
Analysis: Energy loss due to different mechanisms

Collisional energy loss contributes most, medium induced radiation contributes least.
Analysis: Effects of different mechanisms on Jet shape

For lower energy jet, its inner core is easier to be modified. Rad. and Broad. transport energy from center to periphery, Coll. leads inner core losing less fraction of energy than outer part. For lower energy jet, its inner core is easier to be modified.
Predication: $P_T^{Jet}$, $\sqrt{s}$ and flavor dependence
Summary

- Coupled jet-fluid model are constructed to study the evolution of the partonic jet shower in the QGP medium, can describe the nuclear modification of the full jet energy and jet structure at both 2.76A TeV and 5.02A TeV.

- Medium response feeds back some energy, and is important to jet shape at large r and cone size dependence of jet $R_{AA}$.

- Collisional energy loss contributes most to full jet energy loss, and is necessary to explain the non-monotonic modification of jet shape function for jets with higher energy.

- Modification of jet shape is sensitive to jet energy and collision energy, and insensitive to jet flavor. More measurements can verify our theory.

Thanks for your attention!