Full jet evolution in quark-gluon plasma and nuclear modification of jet structure in Pb+Pb collisions at the LHC

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Abstract: We study the evolution of full jets in quark-gluon plasma (QGP) via solving a set of coupled differential transport equations for the three-dimensional momentum distributions of quarks and gluons contained in the full jet shower. In our jet evolution equations, we include all partonic splitting processes in the dense nuclear medium. We also include the collisional energy loss and transverse momentum broadening for both leading and radiated partons of the full jets due to elastic collisions with the medium constituents. We keep track of both the energies and the transverse momenta of all partons within the full jet shower, thus the modification of both jet energy and jet structure due to jet-medium interaction can be studied straightforwardly. Combining with realistic (2+1)-dimensional viscous hydrodynamic calculation for the space-time profile of the hot and dense nuclear medium produced in Pb+Pb collisions, we apply our formalism to calculate the nuclear modification of single inclusive jet spectra, and the momentum imbalance of photon-jet and dijet pairs at the LHC.The jet shape (at the partonic level) is also studied for the quenched/modified jets in Pb+Pb collisions at the LHC. We further present detailed studies on the roles of different jet-medium interaction mechanisms on the modification of jet energy and jet structure.

$$\frac{d}{dt}f_j(\omega_j,k_{j\perp}^2,t)=\hat{e}\frac{\partial f_j}{\partial\omega_j}+\frac{1}{4}\hat{q}\nabla_{k_\perp}^2 f_j+\sum_i\int d\omega_i dk_{i\perp}^2\tilde{\Gamma}_{i\to j}(\omega_j,k_{j\perp}^2|\omega_i,k_{i\perp}^2)f_i(\omega_i,k_{i\perp}^2,t)-\sum_i\int d\omega_i dk_{i\perp}^2\tilde{\Gamma}_{j\to i}(\omega_i,k_{i\perp}^2|\omega_j,k_{j\perp}^2)$$

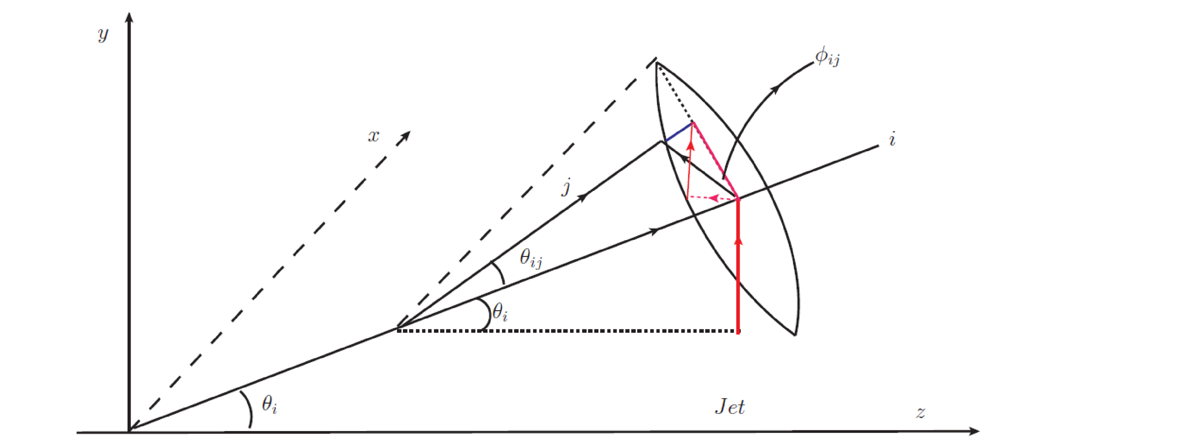
Collisional energy loss — K_T broadening — Radiation

g

$$\frac{d}{dt}f_g(\omega_j,k_{j\perp}^2,t)=\hat{e}\frac{\partial f_g}{\partial\omega_j}+\frac{1}{4}\hat{q}\nabla_{k_\perp}^2 f_g$$
$$+\int d\omega_i dk_{i\perp}^2\tilde{\Gamma}_{g\to gg}(\omega_j,k_{j\perp}^2|\omega_i,k_{i\perp}^2)f_g(\omega_i,k_{i\perp}^2,t)$$
$$+\int d\omega_i dk_{i\perp}^2\tilde{\Gamma}_{q\to gq}(\omega_j,k_{j\perp}^2|\omega_i,k_{i\perp}^2)f_q(\omega_i,k_{i\perp}^2,t)$$
$$-\frac{1}{2}\int d\omega_i dk_{i\perp}^2\tilde{\Gamma}_{g\to gg}(\omega_i,k_{i\perp}^2|\omega_j,k_{j\perp}^2)f_g(\omega_j,k_{j\perp}^2,t)$$
$$-\frac{n_f}{2}\int d\omega_i dk_{i\perp}^2\tilde{\Gamma}_{g\to q\bar{q}}(\omega_i,k_{i\perp}^2|\omega_j,k_{j\perp}^2)f_g(\omega_j,k_{j\perp}^2,t)$$

q

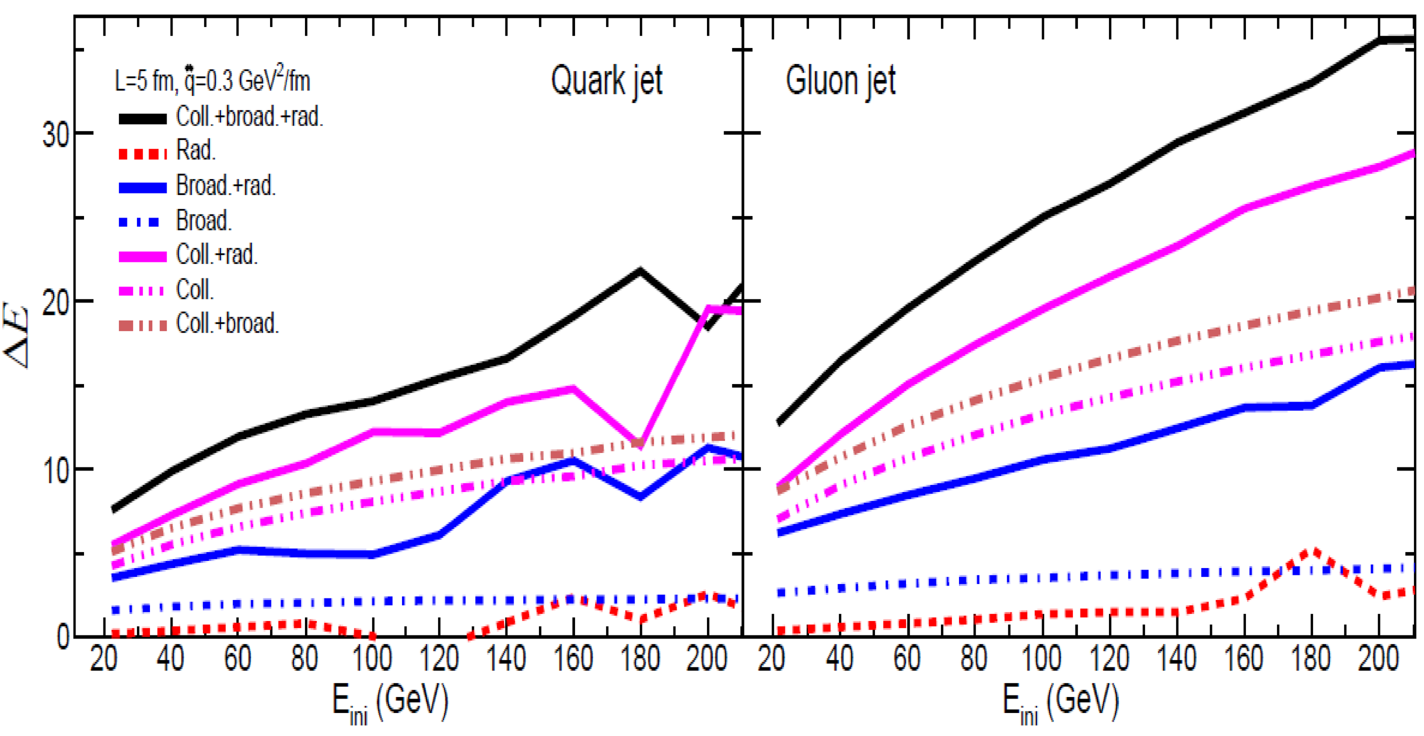
$$\frac{d}{dt}f_q(\omega_j,k_{j\perp}^2,t)=\hat{e}\frac{\partial f_q}{\partial\omega_j}+\frac{1}{4}\hat{q}\nabla_{k_\perp}^2 f_q$$
$$+\int d\omega_i dk_{i\perp}^2\tilde{\Gamma}_{q\to qg}(\omega_j,k_{j\perp}^2|\omega_i,k_{i\perp}^2)f_q(\omega_i,k_{i\perp}^2,t)$$
$$+n_f\int d\omega_i dk_{i\perp}^2\tilde{\Gamma}_{g\to q\bar{q}}(\omega_j,k_{j\perp}^2|\omega_i,k_{i\perp}^2)f_g(\omega_i,k_{i\perp}^2,t)$$
$$-\int d\omega_i dk_{i\perp}^2\tilde{\Gamma}_{q\to qg}(\omega_i,k_{i\perp}^2|\omega_j,k_{j\perp}^2)f_q(\omega_j,k_{j\perp}^2,t)$$



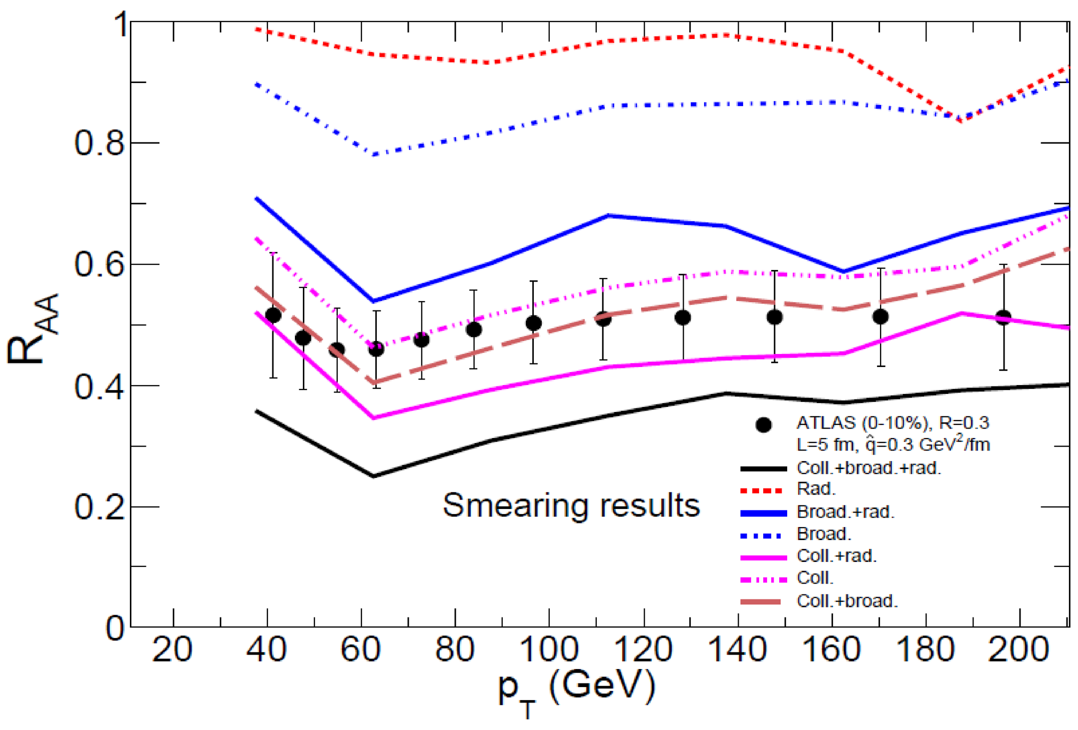
$$\Gamma_{i\to j}(\omega_j,k_{j\perp}^2|\omega_i,k_{i\perp}^2)=\frac{2\alpha_s}{\pi}\frac{xP_{i\to j}(x)\hat{q}(t)}{\omega_j k_\perp^4}\sin^2\frac{t-t_i}{2\tau_f}$$

Shift Γ to $\tilde{\Gamma}$ by geometry

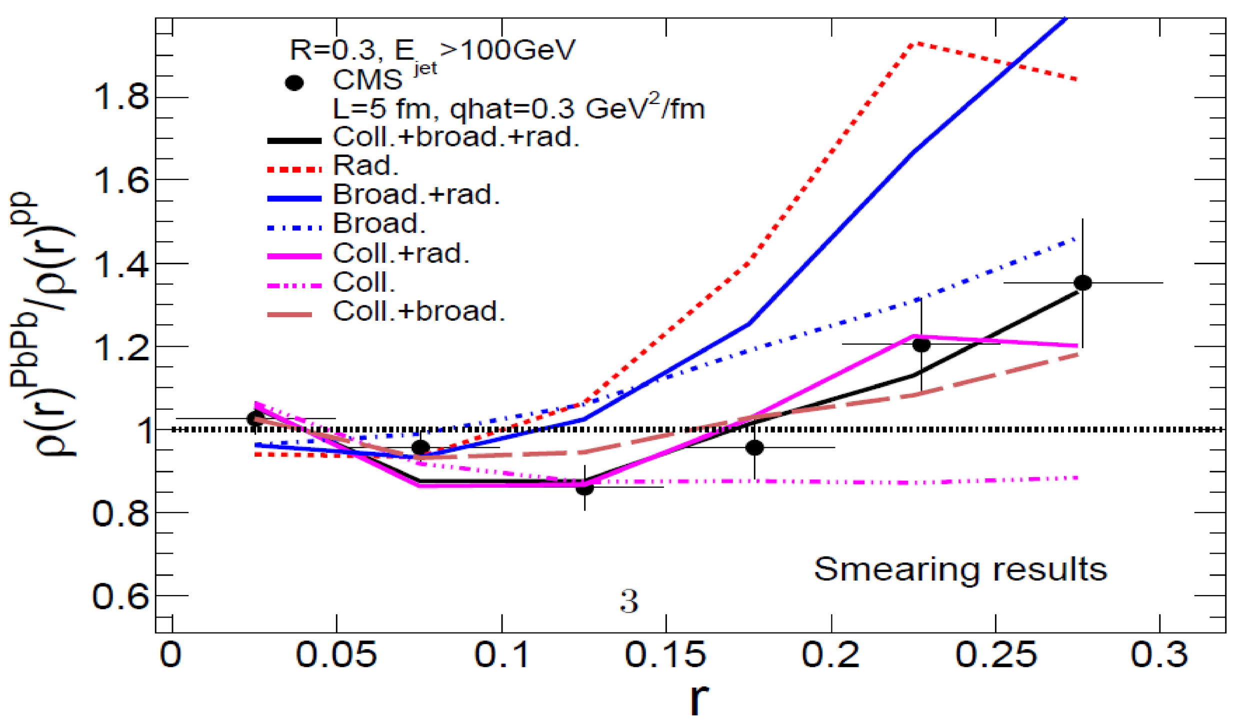
Analysis in 'brick'



The energy loss induced by different jet-medium interaction mechanisms after a quark/gluon jet with varying energy passes through a 'brick' of quark-gluon plasma.

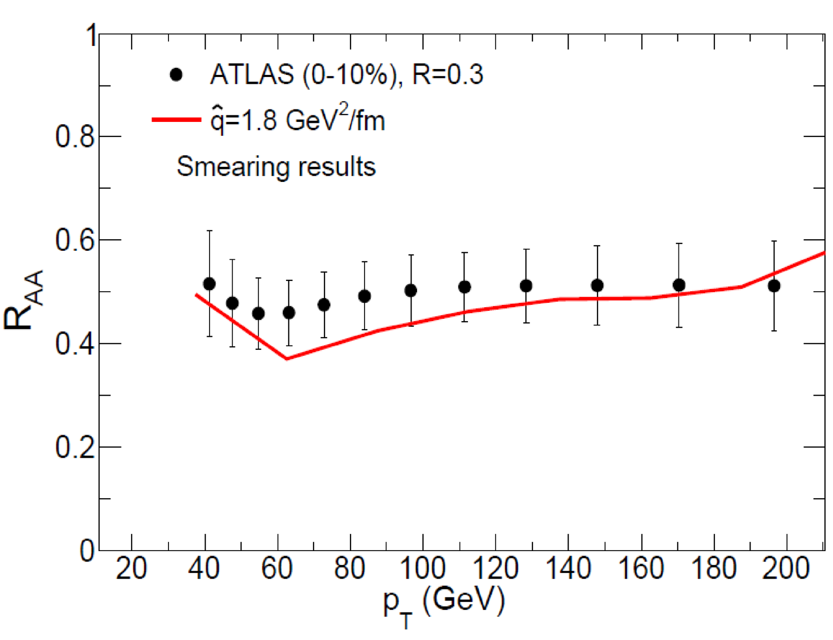


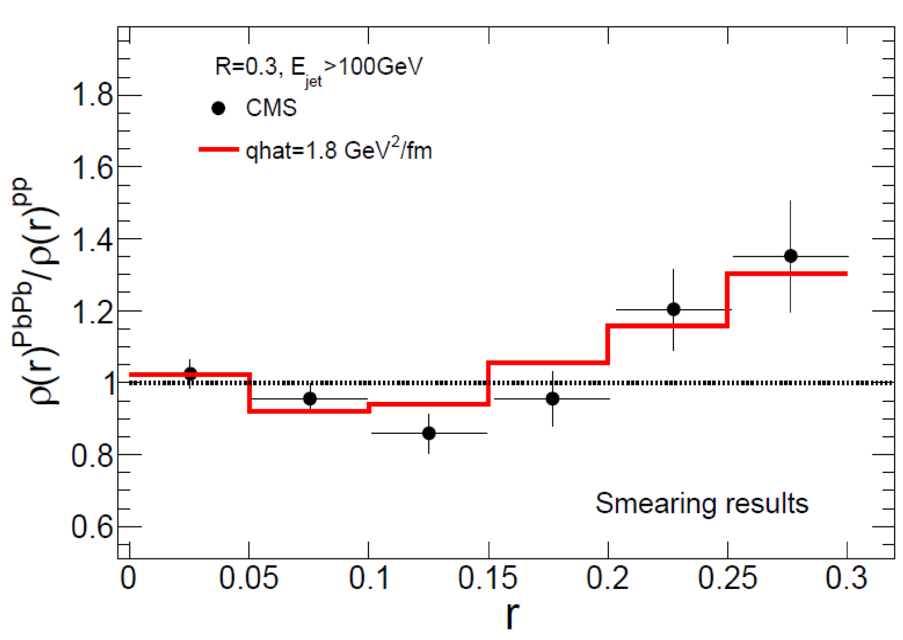
Induced R_{AA} by different jet-medium interaction mechanisms, assuming all hard partons from Pb+Pb collisions pass through the 'brick'.

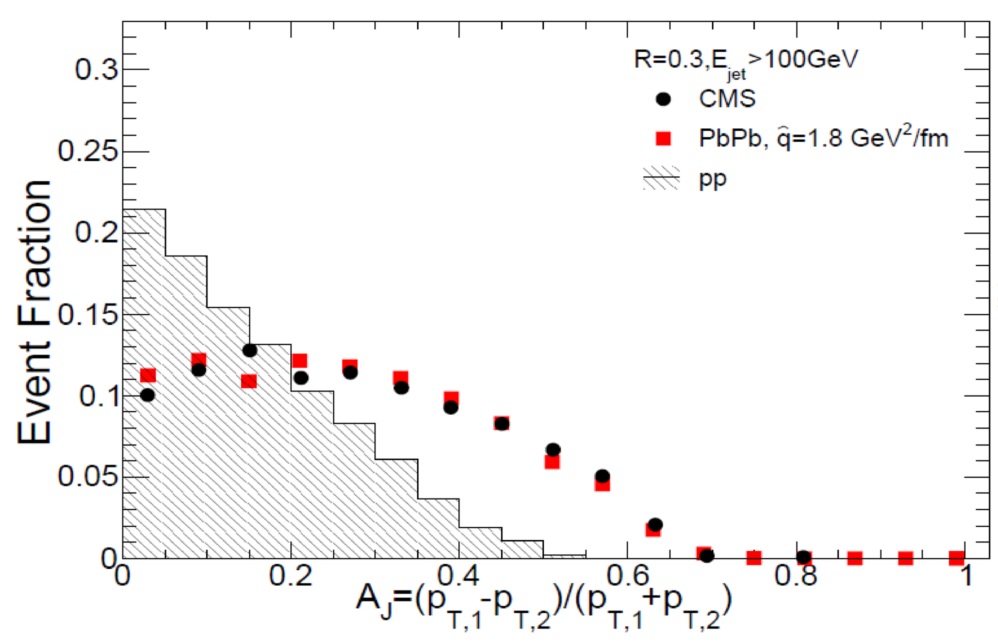


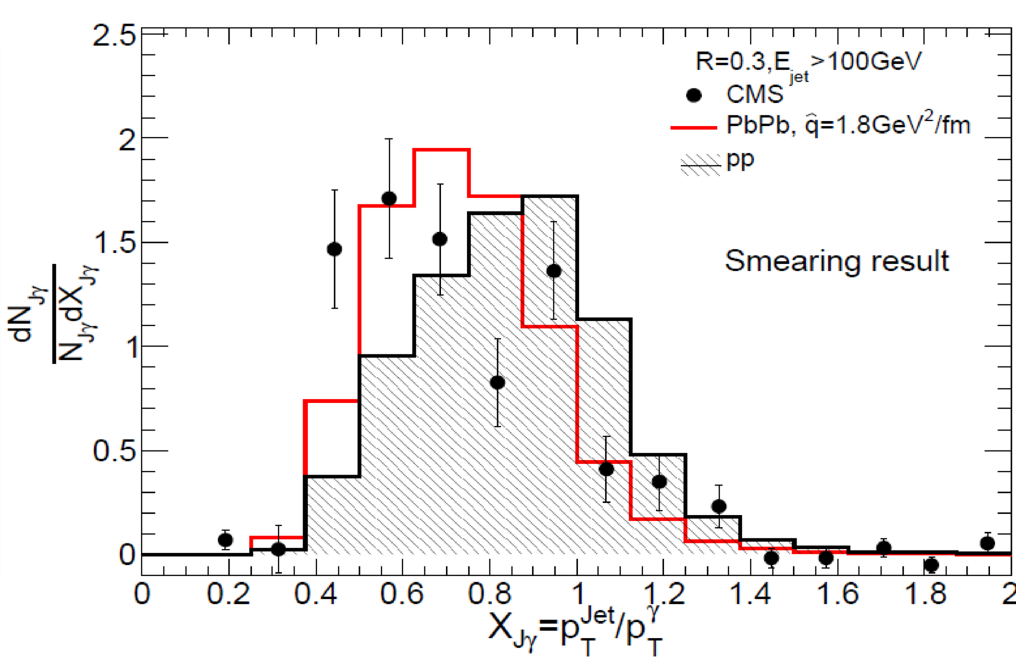
Modification of the jet shape due to different jet-medium interaction mechanisms, assuming all hard partons from Pb+Pb collisions pass through the 'brick'.

Results in Pb+Pb collisions









Full jet R_{AA} — Ratio of jet shape — Di-jet asymmetry — P_T fraction in γ-jet

Conclusion:

1. While transverse momentum broadening or medium-induced radiations lead little direct energy loss, collisional term plays a key role in the process of jet energy loss. That's because transverse momentum broadening and medium-induced radiations can only transfer the energy of jet from center to periphery or from hard partons to soft partons , while elastic collisions make all partons in the jet shower lose energy into medium directly. Meanwhile, collisional energy loss can be enhanced by the other mechanisms, especially by medium-induced radiations because it increases the number of partons in the jet shower.
2. While collisional energy loss suppresses the jet shape at peripheral region, transverse momentum broadening and medium-induced radiations can enhance it due to they transfer jet energy form center to periphery, which is crucial to describe the experimental data.

References:

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4. Ning-Bo Chang and Guang-You Qin, in preparation.