Nuclear modification of high $p_{\rm T}$ single inclusive hadron and dihadron production at RHIC and the LHC

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Abstract

The suppression of high $p_{\rm T}$ single inclusive hadron and dihadron productions in high-energy heavy-ion collisions at RHIC and the LHC is studied within a next-to-leading order pQCD parton model. The jet quenching effect is included via the medium-modified fragmentation functions based on the higher-twist energy loss formalism. The evolution of the bulk medium is simulated by a (2+1)-dimensional viscous hydrodynamic model. The jet transport coefficient $\hat{q}_0$ is quantitatively extracted for A+A collisions at both RHIC and the LHC energies by comparing with experimental data. Our results show that $\hat{q}_0$ extracted from dihadron suppression is consistent with single hadron suppression. We also predict dihadron I_{AA} for central and non-central Pb+Pb collisions at $\sqrt{s_{\rm NN}} = 5.02$ TeV.

NLO pQCD parton model and modified fragmentation functions

♦ In A+A collisions, dihadron spectra can be given by:

$$\frac{d\sigma}{dy_1 d^2p_T^{h1} dy_2 d^2p_T^{h2}} = \sum_{abcd} \int d^2b d^2r t_A(\vec{r}) t_B(|\vec{r}-\vec{b}|) dx_a dx_b dz_c dz_d$$
$$\times f_{a/A}(x_a,\mu^2,\vec{r}) f_{b/B}(x_b,\mu^2,(|\vec{r}-\vec{b}|)) \frac{\hat{s}}{2\pi z_c^2 z_d^2} \times \frac{d\sigma}{d\hat{t}}(ab\to cd)$$
$$\times D_{h/c}(z_c,\mu^2,\Delta E_c) D_{h/d}(z_d,\mu^2,\Delta E_d) \delta^4(p_a+p_b-p_c-p_d) + O(\alpha_s^3)$$

$t_A(\vec{r})$–thickness function: Woods-Saxon, $f_{a/A}$–PDF: CTEQ6.6M, EPS09,

$\frac{d\sigma}{d\hat{t}}$–hard scattering cross section, $D_{h/c}(z_c,\mu^2,\Delta E_c)$–Kretzer, modified FFs.

♦ Modified fragmentation functions in QGP medium:

$$D_{h/c}(z_c,\mu^2,\Delta E_c) = (1-e^{-\langle N_g\rangle}) \left[\frac{z_c'}{z_c} D^0_{h/c}(z_c',\mu^2) + \langle N_g\rangle \frac{z_g'}{z_c} D^0_{h/g}(z_g',\mu^2)\right]$$
$$+ e^{-\langle N_g\rangle} D^0_{h/c}(z_c,\mu^2)$$

♦ Total energy loss of jet in high-twist method:

$$\frac{\Delta E}{E} = C_A \frac{\alpha_s}{2\pi} \int d\tau \int_0^{Q^2} \frac{dl_T^2}{l_T^4} \int_\epsilon^{1-\epsilon} dz \left[1+(1-z)^2\right] \times \hat{q}_F(y) 4sin^2\left(\frac{l_T^2 \tau}{4z(1-z)E}\right)$$

♦ Single hadron suppression factor: $R_{AA} = \frac{dN_{AA}/dyd^2p_T}{T_{AA}(b) d\sigma_{pp}/dyd^2p_T}$

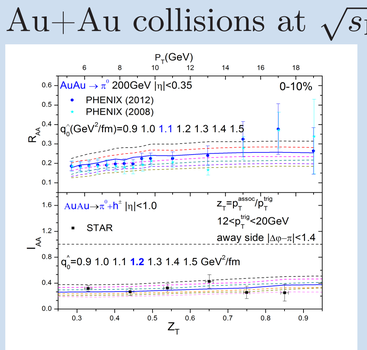
Dihadron: $I_{AA}(z_T) = \frac{D_{AA}(z_T)}{D_{pp}(z_T)} = \frac{D_{AA}(p_T^{assoc})}{D_{pp}(p_T^{assoc})}$,

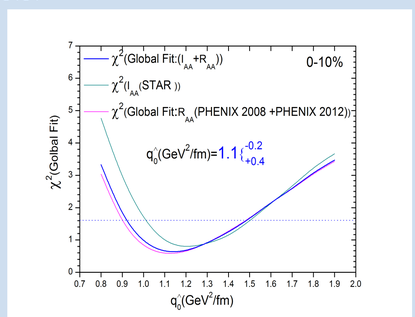
where $z_T = p_T^{assoc}/p_T^{trig}$, $D_{AA}(z_T, p_T^{trig}) \equiv \frac{1}{N_{AA}^{trig}} \frac{dN_{AA}^{h_1 h_2}}{dz_T}$.

Extract $\hat{q}_0$ at RHIC

♦ Central Au+Au collisions

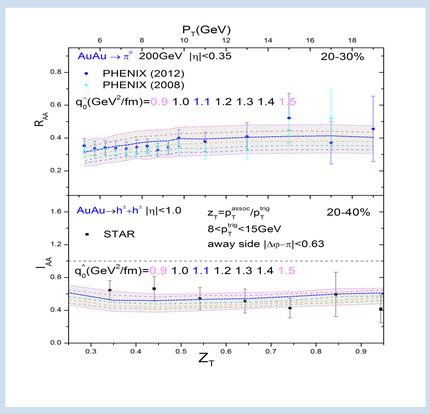
First we get the single hadron and dihadron suppression factors with different values of $\hat{q}_0$ for central Au+Au collisions at $\sqrt{s_{\rm NN}} = 200$ GeV.





Then a global χ^2 fit is performed for both single hadron R_{AA} and dihadron I_{AA}. We find that dihadron $\hat{q}_0$ is consistent with the single hadron.

♦ Centrality of 20 - 40%



Next we calculate R_{AA} and I_{AA} in the 20 - 40 centrality with $\hat{q}_0$ extracted from central Au+Au collisions. They fit good with experimental data.

Conclusion

♦ Large $p_{\rm T}$ hadrons are studied in a NLO pQCD parton model in heavy-ion collisions with mFFs due to jet quenching.

♦ We obtain $\hat{q}_0 \approx 1.1\{^{-0.2}_{+0.4}$ GeV^2/fm for central Au+Au collisions at $\sqrt{s_{\rm NN}} = 0.2$ TeV and $\hat{q}_0 \approx 1.6\{^{+0.5}_{-0.3}$ GeV^2/fm for Pb+Pb central collisions at $\sqrt{s_{\rm NN}} = 2.76$ TeV.

♦ $\hat{q}_0$ extracted from di-hadron suppression is consistent with single hadron.

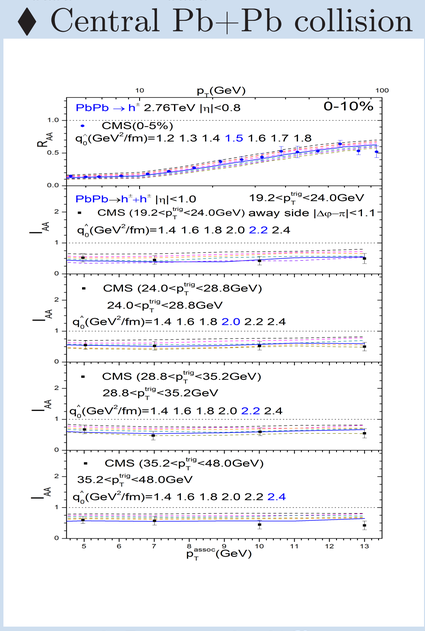
♦ The single hadron R_{AA} and dihadron I_{AA} with the $\hat{q}_0$ extracted from central A+A collisions can give a good description of experimental data for the non-central collisions.

♦ We also have predicted the dihadron suppression factors I_{AA} for central and non-central Pb+Pb collisions $\sqrt{s_{\rm NN}} = 5.02$ TeV.

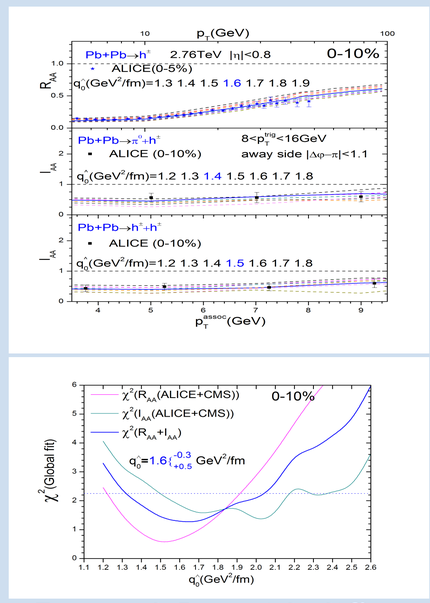
Extract $\hat{q}_0$ at the LHC ($\sqrt{s_{\rm NN}} = 2.76$ TeV)

We also extract $\hat{q}_0$ from central Pb+Pb collisions at $\sqrt{s_{\rm NN}} = 2.76$ TeV. Then we still use them to calculate the R_{AA} and I_{AA} for non-central collisions.

♦ Central Pb+Pb collision

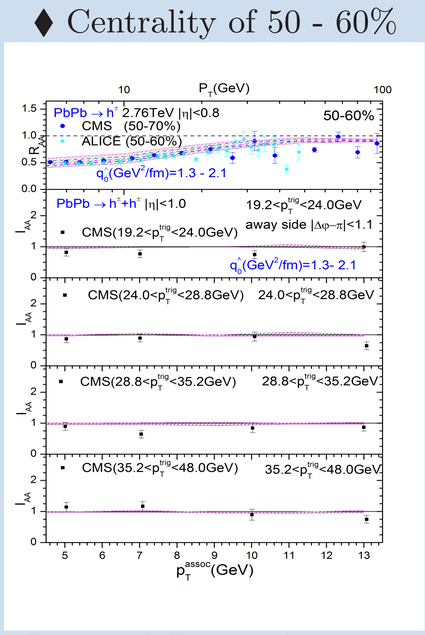


△ R_{AA} and I_{AA} with different values of $\hat{q}_0$ in 0 - 10% Pb+Pb collisions at $\sqrt{s_{\rm NN}} = 2.76$ TeV as compared to CMS data.



△ R_{AA} and I_{AA} with different $\hat{q}_0$ for central Pb+Pb collisions as compared to ALICE data. And global fit χ^2 as a function of $\hat{q}_0$.

♦ Centrality of 50 - 60%

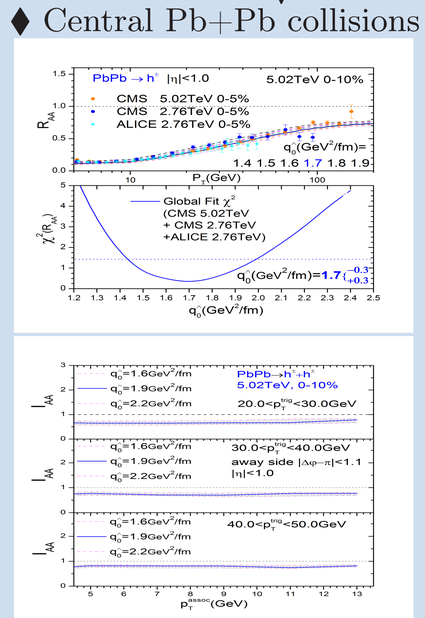


△ R_{AA} and I_{AA} in the 50 - 60 % centrality with $\hat{q}_0$ extracted from central Pb+Pb collisions as compared to experimental data.

Prediction for dihadron I_{AA} at $\sqrt{s_{\rm NN}} = 5.02$ TeV

Finally we predict the dihadron I_{AA} for central and non-central Pb+Pb collisions at $\sqrt{s_{\rm NN}} = 5.02$ TeV. As for the single hadron R_{AA}, we compare them not only with the experimental data of $\sqrt{s_{\rm NN}} = 2.76$ TeV but also with the data of $\sqrt{s_{\rm NN}} = 5.02$ TeV, because those three data sets are very close to each other.

♦ Central Pb+Pb collisions

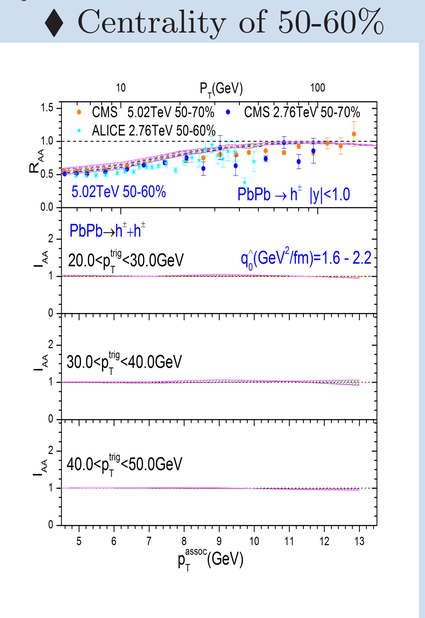


◁ Single hadron R_{AA} with different $\hat{q}_0$ for central Pb+Pb collisions at $\sqrt{s_{NN}} = 5.02$ TeV as compared to ALICE and CMS data.

▷ The prediction of high p_T^{trig} dihadron suppression factors in the 0 - 10% centrality with the values of $\hat{q}_0$ extracted from single hadron.

◁ The prediction of dihadron I_{AA} for Pb+Pb collisions in the centrality of 50-60% with $\hat{q}_0$ extracted from central collisions.

♦ Centrality of 50-60%



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