Dijet, Dihadron and Hadron-Jet Correlations in Resummation Improved pQCD Approach - [PLB 773, 672; arχiv:1612.04202]

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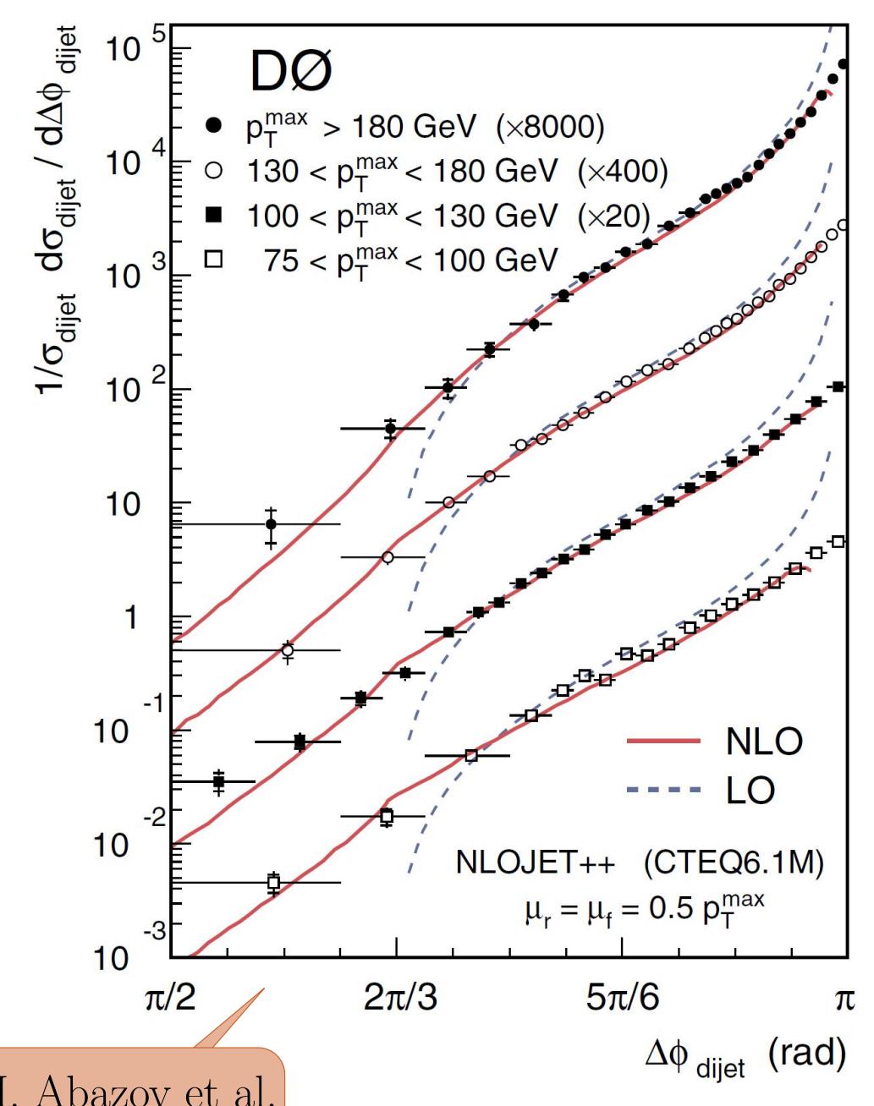
Sudakov Resummation



V. M. Abazov et al. Phys. Rev. Lett., 94:221801, 2005

$$\frac{\sigma_0 \sum_{i=0}^{n-1} \alpha_s^i L^i \;\Big|\; \sigma_0 \sum_{i=0}^{n-1} \alpha_s^i C^{(i)}}{\underset{\Uparrow}{\sigma_0 \sum_{i=n}^{\infty} \alpha_s^i L^i} \;\Big|\; \sigma_0 \sum_{i=n}^{\infty} \alpha_s^i C^{(i)}} \quad \Leftarrow \text{pQCD}$$

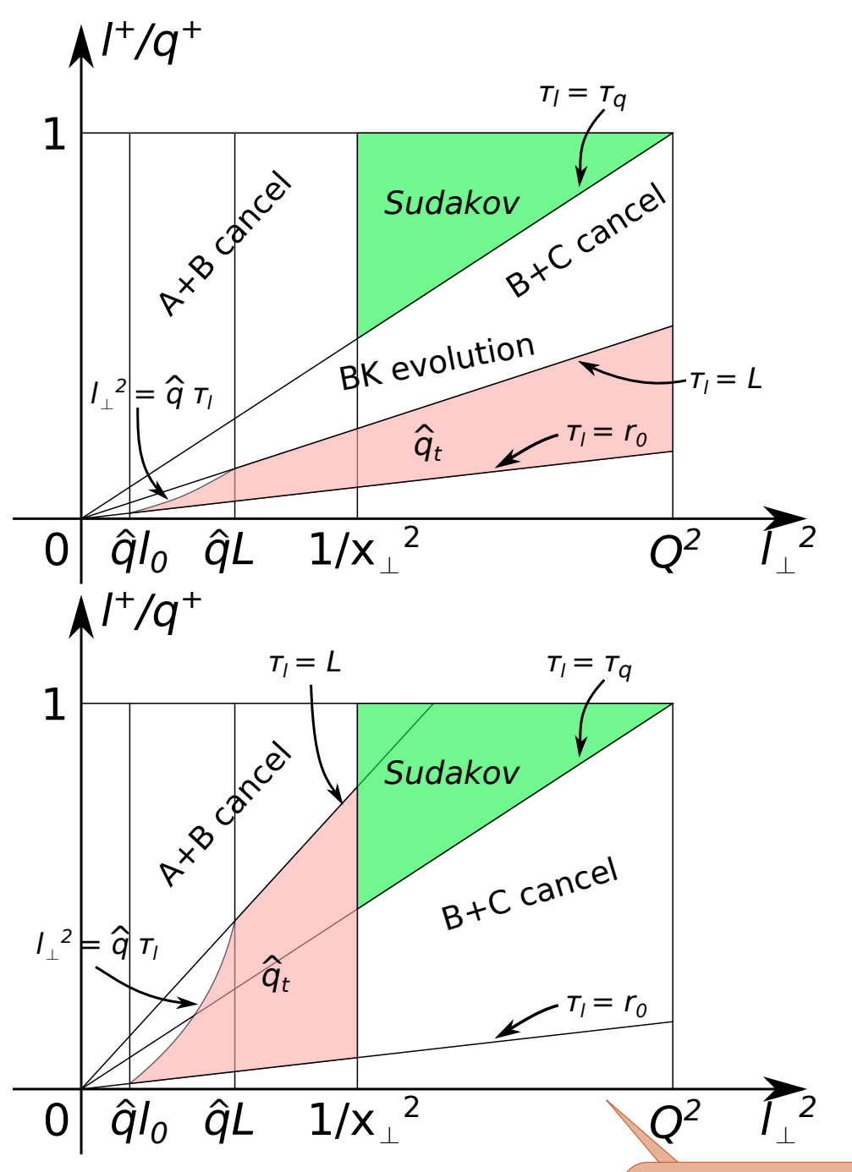
resummation

↖ negligible

We begin by noting that quantitative understanding of the azimuthal angular correlations have been lacking, due to diverging behaviour of perturbative calculations especially at regions close to π. The origin of these divergences comes from large Sudakov type logarithms in the conventional pQCD expansion. We thus need to employ the Sudakov resummation to compute an all order soft gluon radiations.

$$S_{AA}(Q^2,b) = S_p(Q^2,b) + S_{np}(Q^2,b) + \frac{b^2}{4}\left(\langle p_\perp^2\rangle_c + \langle p_\perp^2\rangle_d\right)$$

With the Sudakov resummation, we can take into account the vacuum Sudakov soft gluon radiations, together with the medium broadening effects. These effects are well separated in the kinematic phase-space and thus allowing us to set a *pp* baseline, then using this baseline to extract the QGP medium effects or the jet transport coefficient $\hat{q}$. These effects, known as the transverse momentum broadening and energy-loss are reflected in the two observables described below.



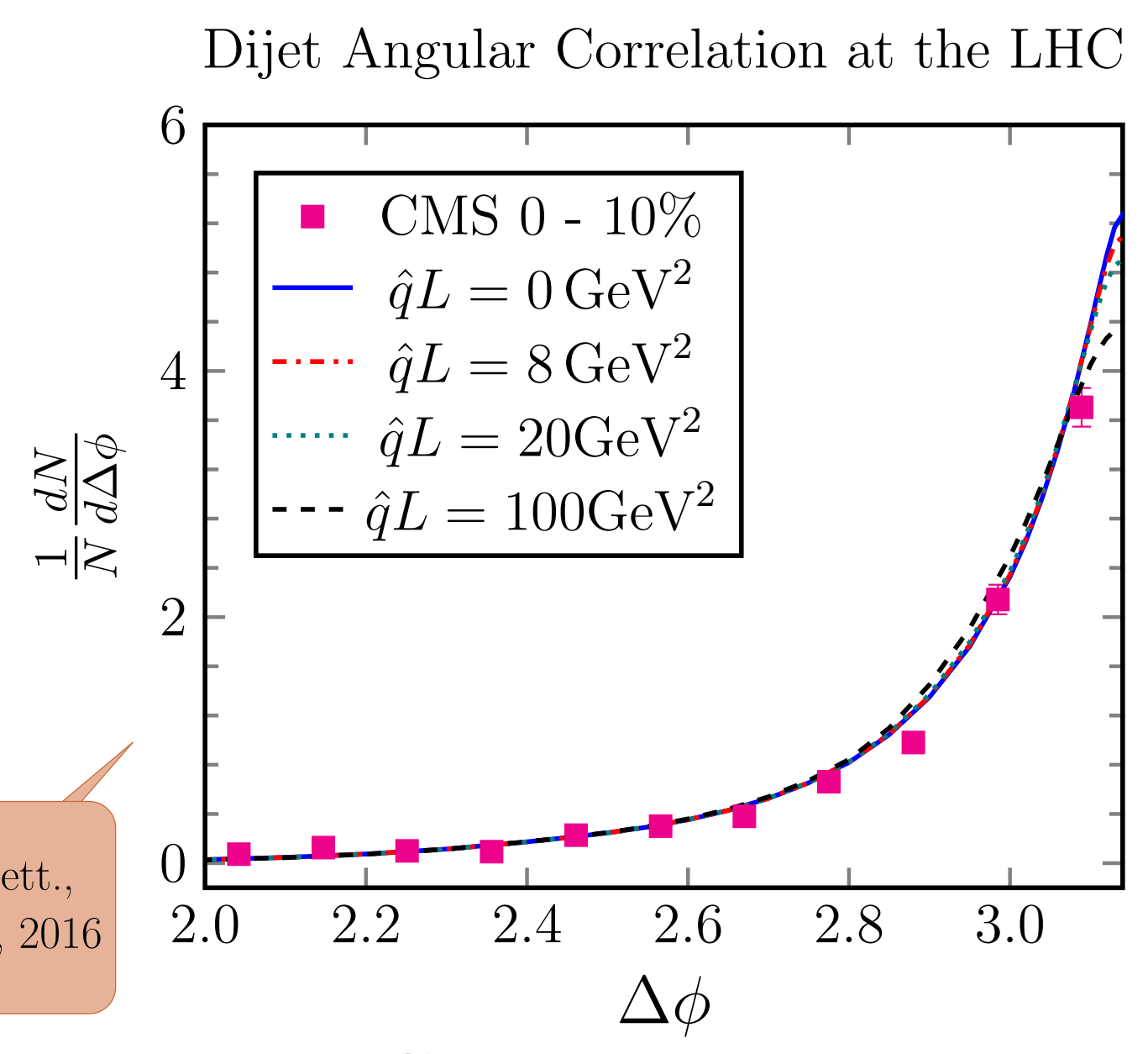
Phys. Rev., D 95.034007

Azimuthal Angular distribution

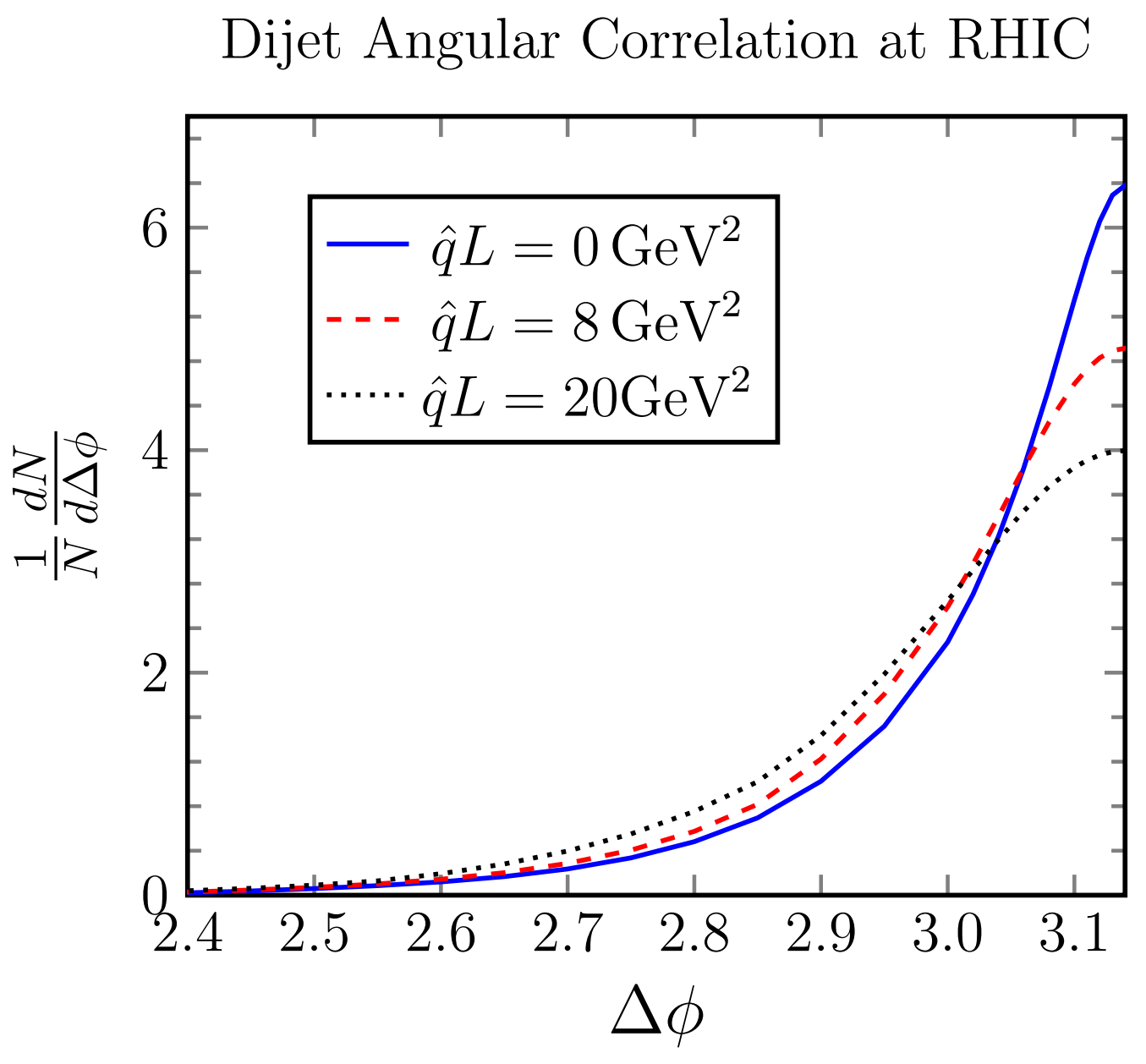
We can implement the framework of Sudakov resummation to calculate the dihadron differential cross-section.

$$\frac{d\sigma}{d\Delta\phi} = \sum_{a,b,c,d}\int p_\perp^{h_1}dp_\perp^{h_1}\int p_\perp^{h_2}dp_\perp^{h_2}\int\frac{dz_c}{z_c}\int\frac{dz_d}{z_d}\int b\,db\,J_0(q_\perp\cdot b_\perp)\,e^{-S(Q^2,b)}$$
$$x_a f_a(x_a,\mu_b)\,x_b f_b(x_b,\mu_b)\,\frac{1}{\pi}\frac{d\sigma_{ab\to cd}}{d\hat{t}}\,D_c(z_c,\mu_b)\,D_d(z_d,\mu_b)$$

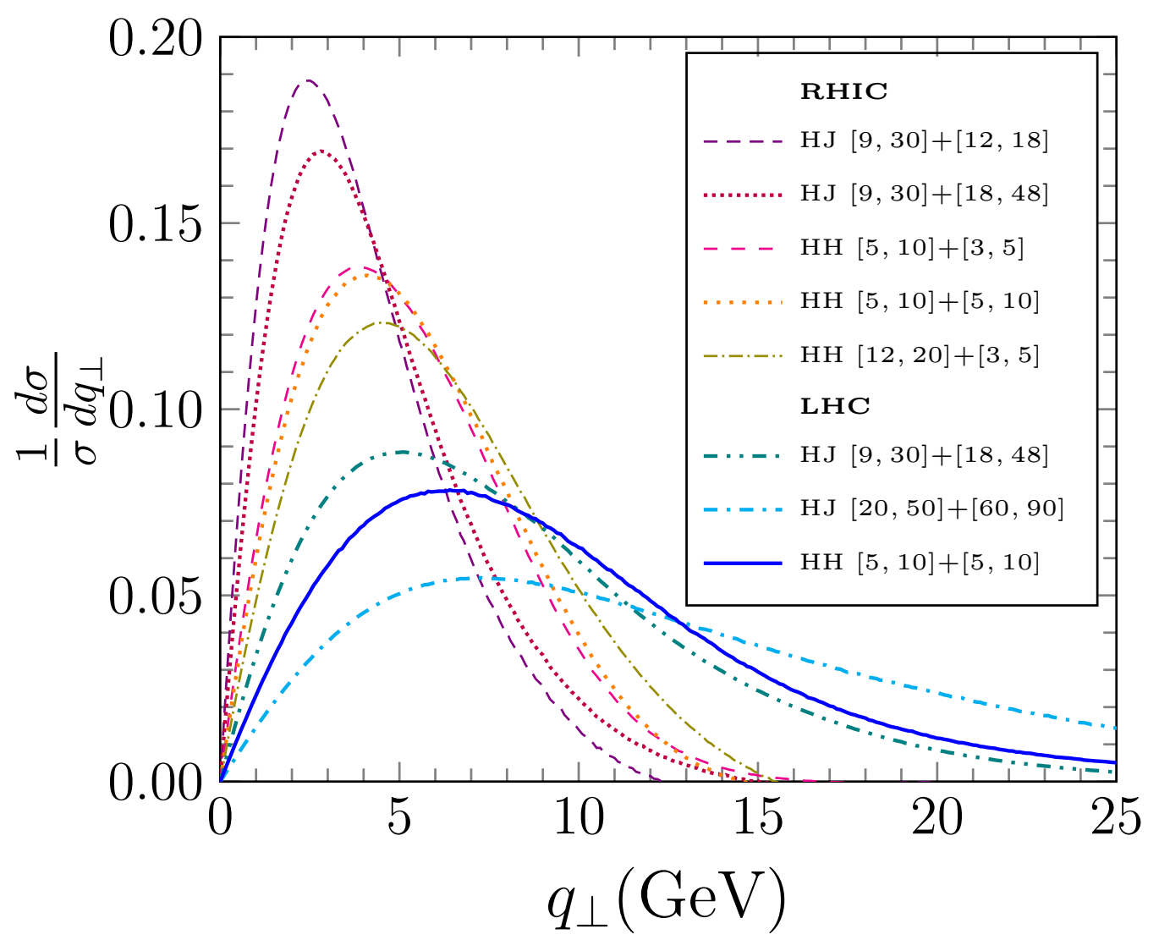
Note that this serves as a generaliztion of the application of the Sudakov resummation in the azimuthal angular distribution calculation. For hadron-jet, one simply convolute the partonic cross-section with only one fragmentation function. We can now compute a simple plot to compare the distribution at different energy regimes.


Dijet Angular Correlation at the LHC

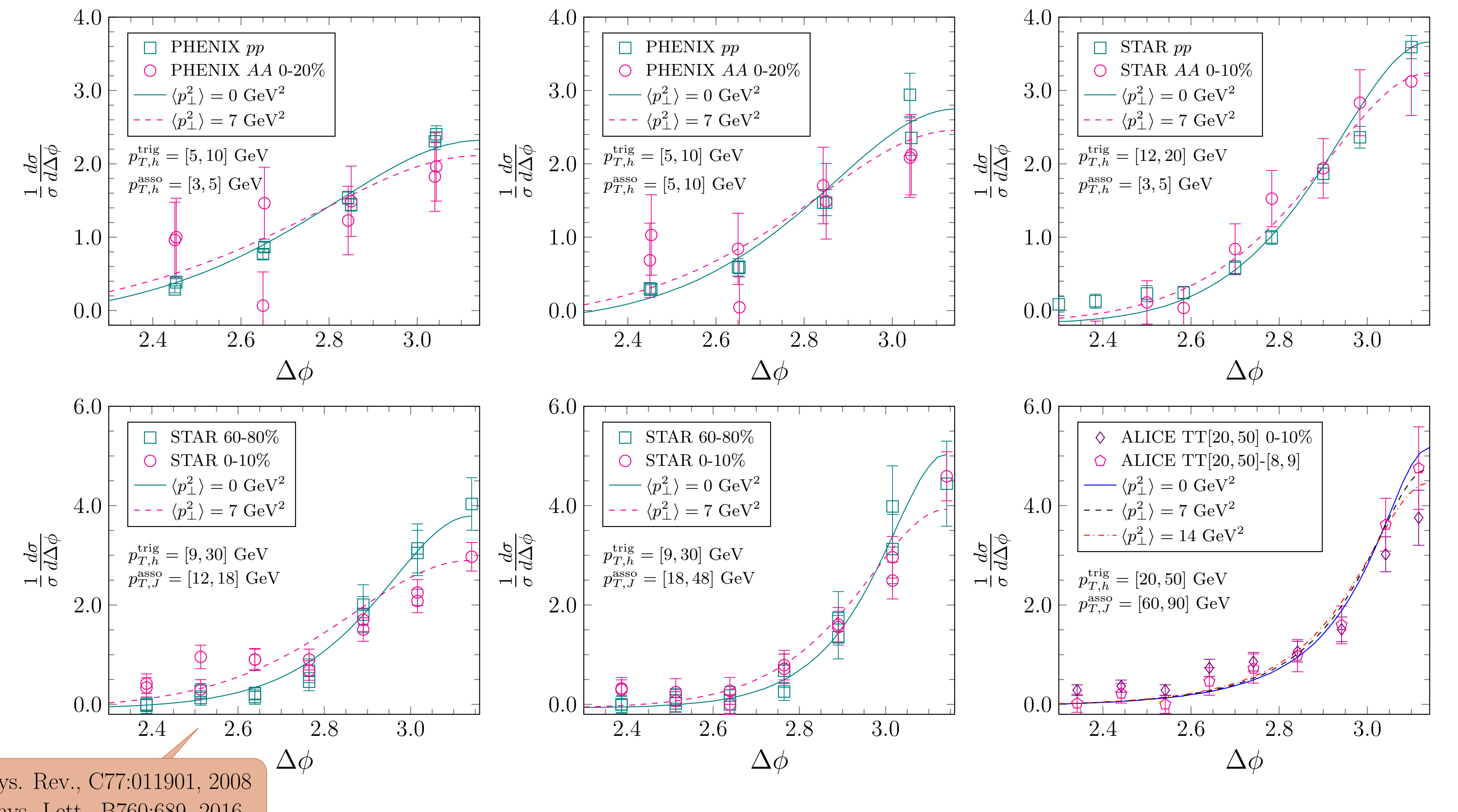
Phys. Lett., B763:208, 2016


Dijet Angular Correlation at RHIC

Notice that at RHIC energies, a very clear sign of broadening has been shown when a modest amount of medium effect is applied, thus showing the azimuthal angular distribution is a very sensitive observable in extracting $\hat{q}$. On the other hand at the LHC kinematics, the same amount of medium broadening seemed to have little to no effect on the angular distribution, this is due to the fact that the vacuum Sudakov factor overwhelms and suppresses the medium contributions, giving less sensitivity to extracting $\hat{q}$.



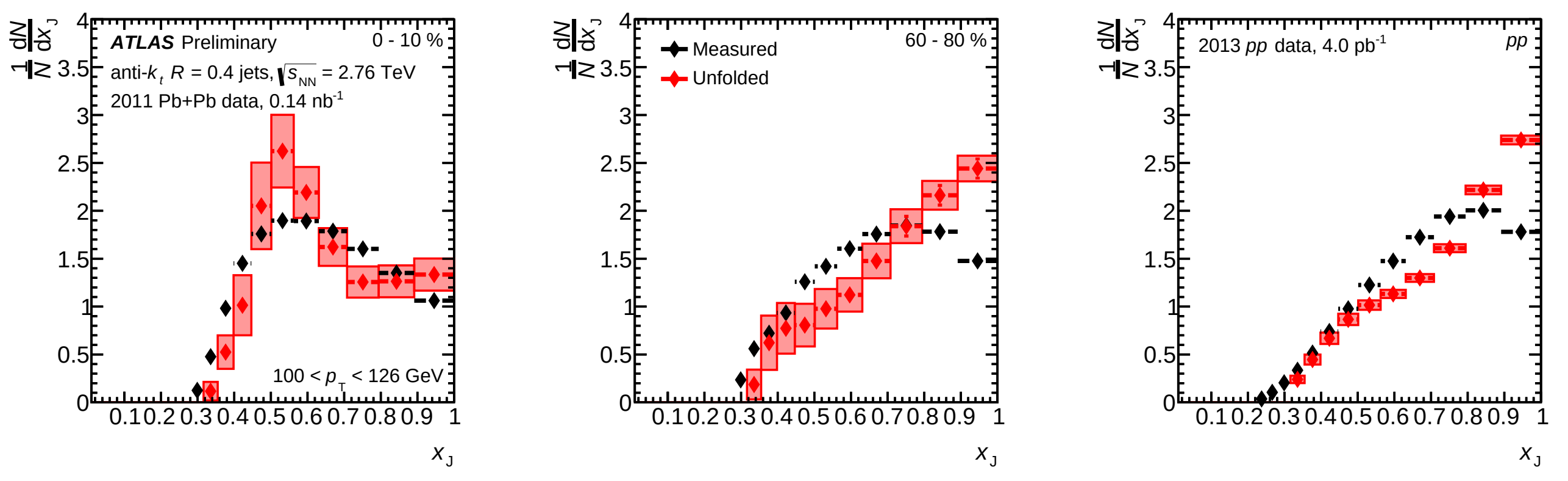
We can also plot the normalized $q_\perp$ distributions for dihadrons and hadron-jets in *pp* collisions, with the pocket formula $q_{\perp AA}^{*2} \simeq q_{\perp pp}^{*2} + \langle p_\perp^2\rangle$, we see that smaller $p_\perp$ jets are in general more effective in probing the medium-induced broadening effect via angular correlations.



Phys. Rev., C77:011901, 2008
Phys. Lett., B760:689, 2016
JHEP 09:170, 2015

Dijet Momentum Imbalance

Despite strong academic and phenomenological interest, all previous theoretical studies are based on the comparison with the uncorrected data which contains detector effects shown below the unfolded data published by ATLAS recently.



Nucl. Phys., A 956:653, 2016

We then developed a resummation improved formalism which incorporates both Sudakov resummation and perturbative calculation to describe the dijet momentum imbalance distribution.

$$\left.\frac{1}{\sigma}\frac{d\sigma}{dx_J}\right|_{\text{improved}} = \left.\frac{1}{\sigma_{\text{NLO}}}\frac{d\sigma_{\text{NLO}}}{dx_J}\right|_{0<\Delta\phi<\phi_m} + \left.\frac{1}{\sigma_{\text{Sudakov}}}\frac{d\sigma_{\text{Sudakov}}}{dx_J}\right|_{\phi_m<\Delta\phi<\pi}$$

Note that we need both perturbative calculation and resummation to correctly describe x_J data. Although it is difficult to distinguish the dominant contributions from these two formalisms by looking their x_J distribution, i.e. $x_J = 1$ corresponds to both back-to-back dijet and triple equal momenta jets, we see that they contribute separately in the $\Delta\phi$ distribution. Learning from our previous studies, we use a ϕ_m cut for our data selection such that $\Delta\phi < \phi_m$ jets uses perturbative calculation to take care of the hard splitting and $\phi_m < \Delta\phi$ jets uses resummation for soft radiations at dijet configurations.

$$q_\perp^2 = P_\perp^2(\pi-\Delta\phi)^2 \ll P_\perp^2 \quad\Rightarrow\quad \ln\frac{P_\perp^2}{q_\perp^2} \simeq \ln\frac{1}{(\pi-\Delta\phi)^2}$$

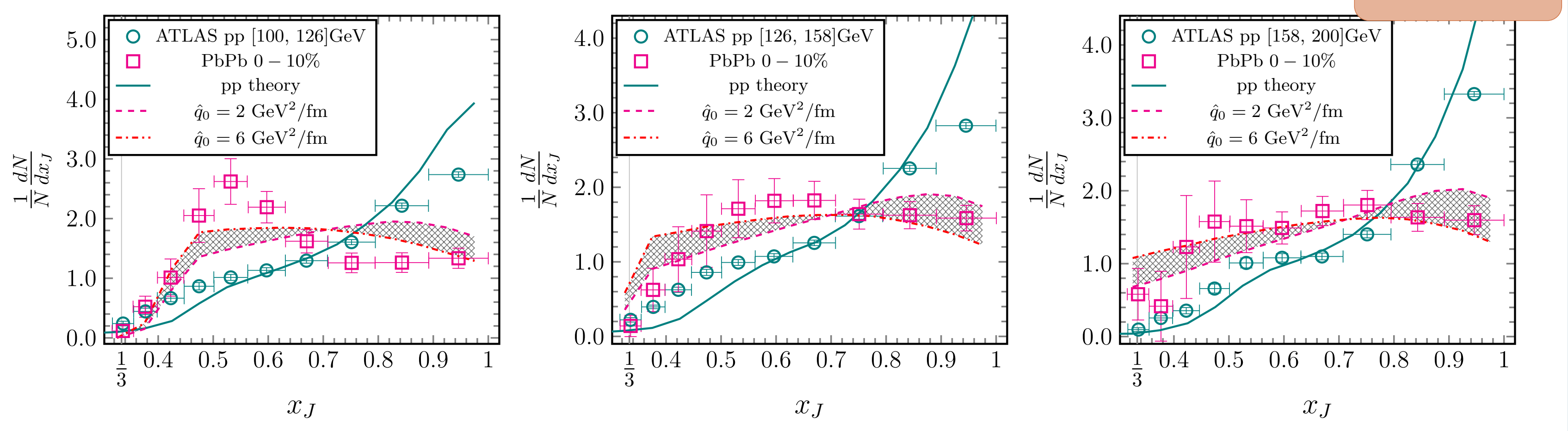
By employing the BDMPS energy-loss distribution, we can parametrize the transport coefficient using the formula below

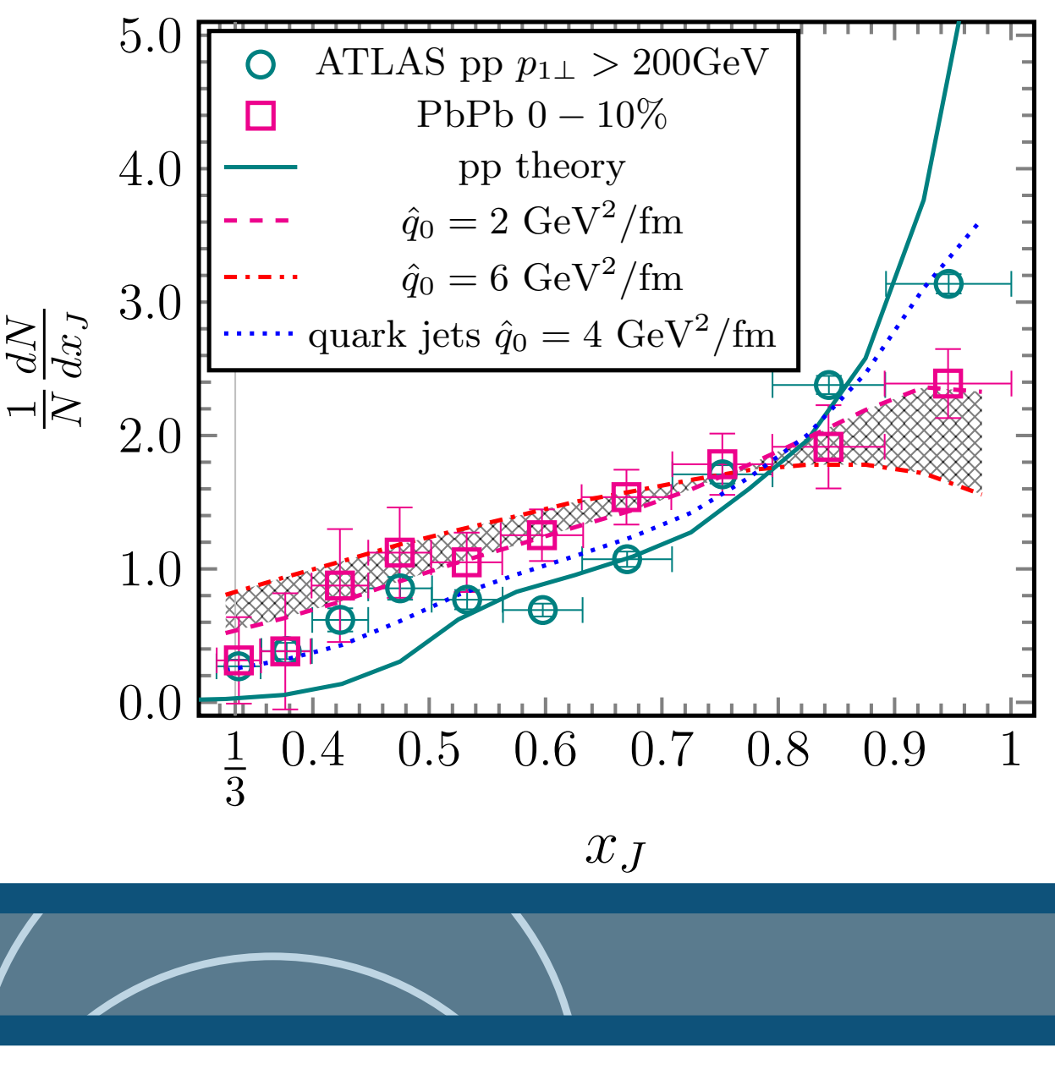
$$\epsilon D(\epsilon) = \sqrt{\frac{\alpha^2\omega_c}{2\epsilon}}\exp\left(-\frac{\pi\alpha^2\omega_c}{2\epsilon}\right)$$

Nucl. Phys., B 483:291, 1997 484:265, 1997 531:403, 1998

and simulate the propagation using the OSU 2+1-D hydro evolution to obtain the jet transport parameter $\hat{q}_0 \sim 2 - 6\mathrm{GeV}^2/\mathrm{fm}$ by comparing our calculations with the fully corrected 2.76A TeV ATLAS data for central *PbPb* collisions.

Phys. Rev., C77:064901, 2008





As shown, $\hat{q}_0 \sim 2 - 6\ GeV^2/fm$ can reasonably describe the data in central *PbPb* collisions at the LHC, for three relatively low $p_\perp$ bins. For the highest $p_\perp$ bin ($p_{1\perp} > 200\ GeV$), the data favours small value of $\hat{q}_0 \sim 2\,GeV^2/fm$. This is simply due to the increase of the quark jet fraction with increasing jet energies. The extracted value of $\hat{q}_0$ amounts to a typical energy loss of 20-30 GeV for gluon jets, and is consistent with our previous findings.

Please see poster for isolated-photon and jet momentum imbalance in *pp* and *PbPb* collision.