Probing Jet Medium Interactions via $Z(H)$+Jet Momentum Imbalances - [arχiv:2001.07606, submitted to EPJC]

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Sudakov Resummation in pp collisions

Hard probes are used to study the nature of the novel Quark-Gluon Plasma (QGP) created in heavy-ion collisions, in which its transport properties, characterised by the so-called jet transport coefficient ($\hat{q}$) is important in the study of the QGP's Jet Quenching effect. This coefficient, defined as the square average of transverse kicks suffered by the jet from the QGP medium per unit length, reflects both the effects of p_T-broadening and jet energy-loss. Many studies have dedicated to extract the value of this parameter, and this current study aims to use a neutral Z or Higgs boson plus a jet correlation as probe to numerically extract $\hat{q}$. The advantages over dijet correlations is that neutral triggers does not interact with the medium preserving the initial information of the hard scattering, and unlike photon tags, $Z(H)$ has a cleaner production mechanism that could avoid source contaminations. As we know in perturbation theory where one usually expand the cross-section calculations in terms of the coupling α_s, would encounter divergences due to the appearance of large logs. Since $\hat{q}$ is sensitive to initial q_T kicks, we employed the q_T-resummation formalism given:

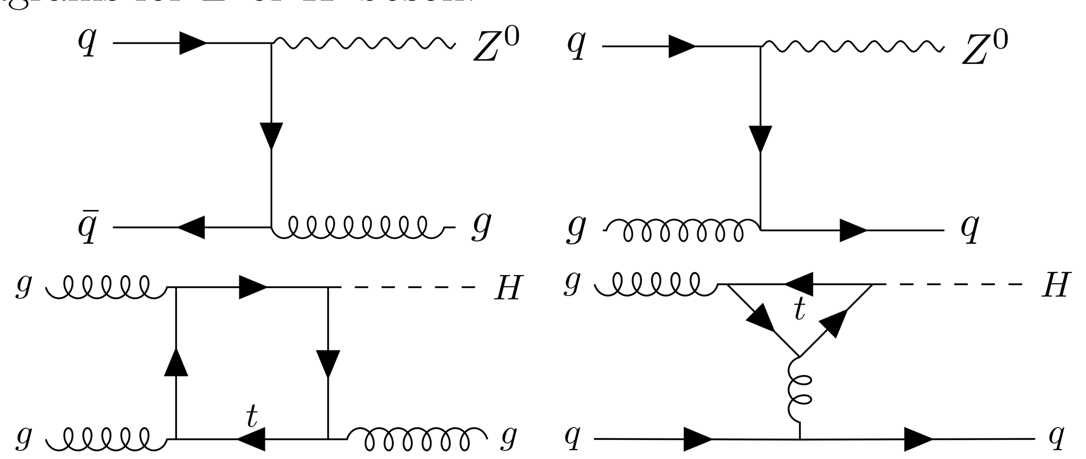
$$\begin{array}{c|c} \sigma_0 \sum_{i=0}^{n-1} \alpha_s^i L^i & \sigma_0 \sum_{i=0}^{n-1} \alpha_s^i C^{(i)} \Leftarrow \text{pQCD} \\ \hline \sigma_0 \sum_{i=n}^{\infty} \alpha_s^i L^i & \sigma_0 \sum_{i=n}^{\infty} \alpha_s^i C^{(i)} \\ \Uparrow & \nwarrow \\ \text{resummation} & \text{negligible} \end{array}$$

$$\frac{d^5\sigma}{dy_B dy_J dP_{J\perp}^2 d^2\vec{q}_\perp} = \sum_{ab} \sigma_0 \left[\int \frac{d^2\vec{b}_\perp}{(2\pi)^2} e^{-i\vec{q}_\perp\cdot\vec{b}_\perp} W_{ab\to BJ}(x_1, x_2, b_\perp) + Y_{ab\to BJ} \right]$$

where W encapsulates the initial parton distribution, soft Sudakov and hard factor with higher order corrections:

$$W = x_1 f_a(\mu_{\rm fac})\, x_2 f_b(\mu_{\rm fac})\, e^{-S_{\rm Sud}(\mu_{\rm fac},\mu_{\rm res}) - \mathcal{F}_{\rm NP}} H(\mu_{\rm res}, \mu_{\rm ren})$$

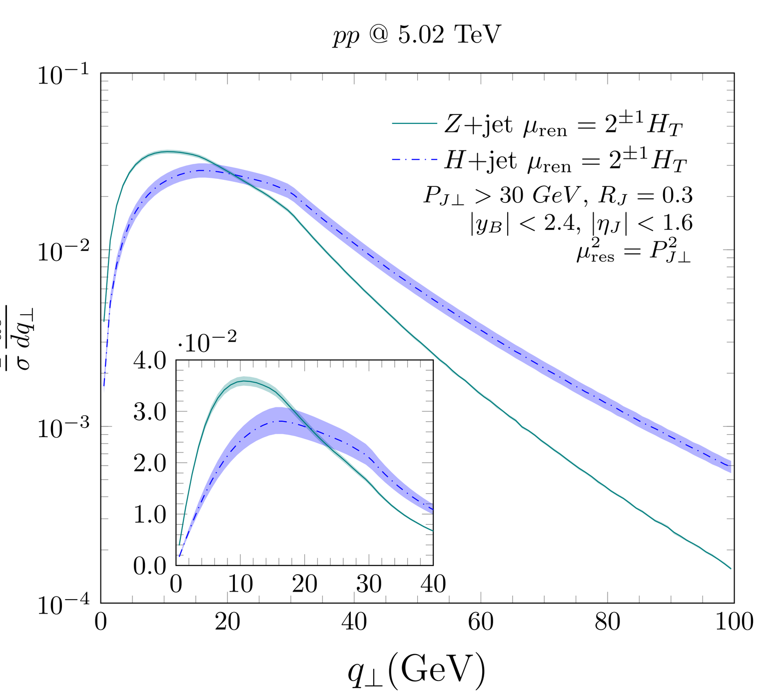
We begin setting the pp baseline by considering the following diagrams for Z or H boson:

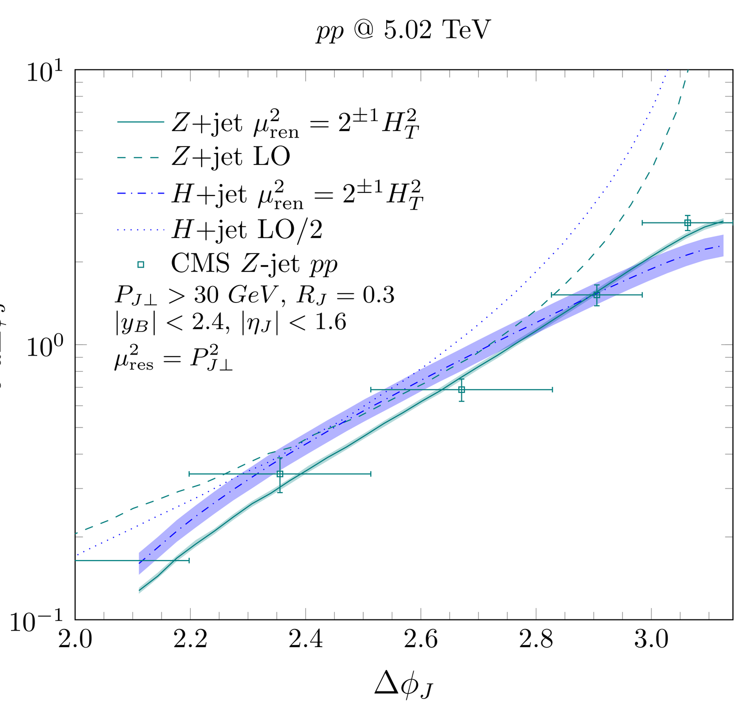


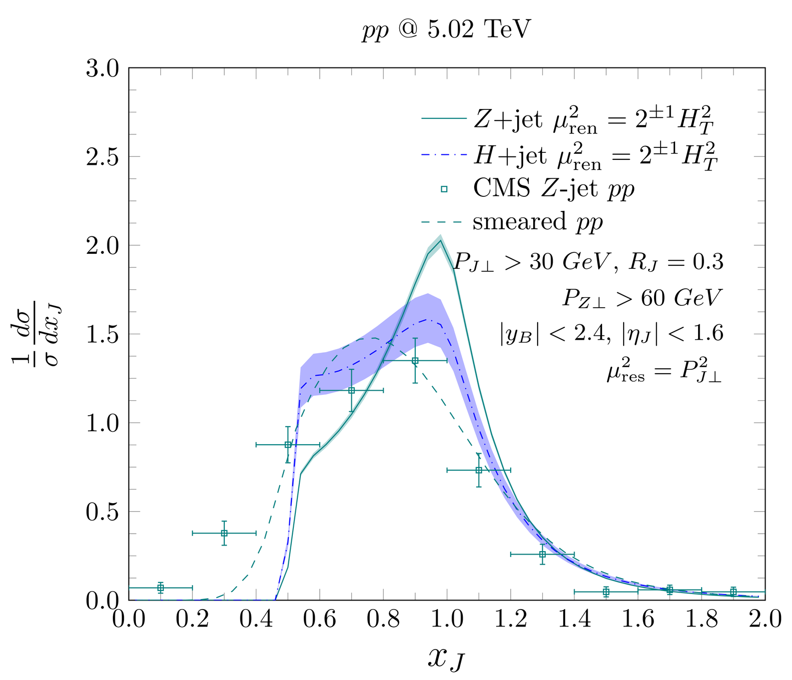
Note that the Sudakov factor takes into account the color exchanges between the two incoming partons, exchanges between the incoming and outgoing partons, and soft radiations outside of the jet cone. We then implemented the resummation improved pQCD approach shown below to calculate some of the observables sensitive to q_T effect:

$$\frac{1}{\sigma}\frac{d\sigma_{\rm improved}}{dx_J} = \frac{1}{N}\left(\frac{1}{\sigma_{\rm pQCD}} \frac{d\sigma_{\rm pQCD}}{dx_J}\bigg|_{\Delta\phi<\phi_m} + \frac{1}{\sigma_{\rm res}}\frac{d\sigma_{\rm res}}{dx_J}\bigg|_{\phi_m<\Delta\phi<\pi} \right)$$

A few conclusions could be drawn from the plots shown below. Firstly, convergence is achieved where normal pQCD calculation would diverge at regions ($q_T \approx 0$, $\Delta\phi \approx \pi$, $x_J \approx 1$). Second, we note that Higgs has a stronger Sudakov effect than Z due to its heavy mass and production channel, it also appears to be more scale sensitive than Z. Finally when looking at the azimuthal distribution, we can set $\phi_m = \frac{7}{8}\pi$ making resummation the dominating contribution for the momentum imbalance distribution using the resum improved pQCD approach.

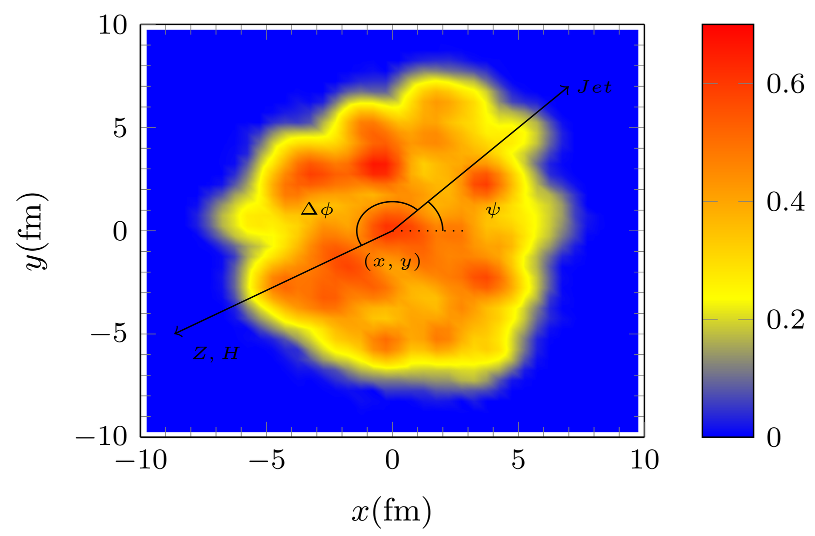






Jet Quenching and Momentum Imbalance

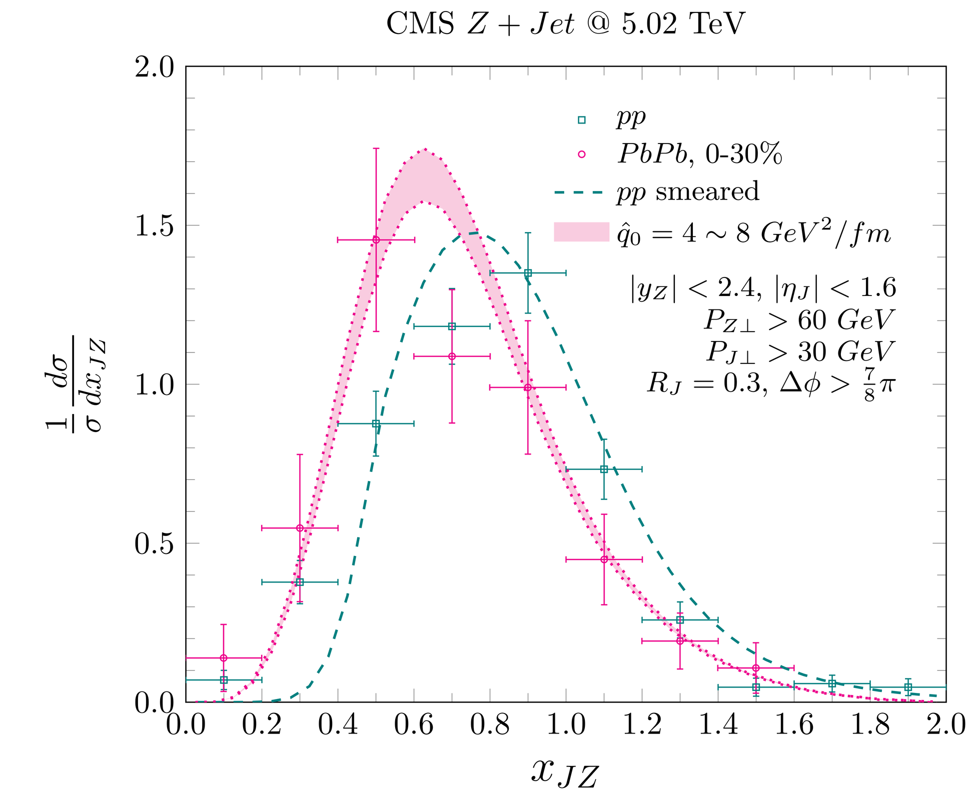
Once our baseline is fixed, we can then include the effects of the medium in our calculation.



We modelled the medium using the OSU VISHNU 2+1D hydro dynamic code to simulate the dynamic evolution of the medium and to generate its temperature profile, then the BDMPS energy-loss formalism is employed where we have parametrized the transport coefficient $\hat{q}$ as a function of the local temperature.

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

We have distinguished the quenching of quark and gluon jets with coloured weights in our formalism. We have also included a Gaussian smearing factor into the calculation for momentum imbalance to mimic detector responses in E_T sensitive observables. We see that the result limits the range of $\hat{q}_0$ to around $4 \sim 8$ GeV^2/fm, which agrees with our previous γ-jet studies at 5.02 TeV. However, future improvements can be made.



Shown below we have included a projection of the momentum imbalance distributions for $Z(H)$+jet at different boson p_T ranges, both smeared and unsmeared.