Search for the elusive jet-induced diffusion wake with 2D tomography

arXiv:2101.05422

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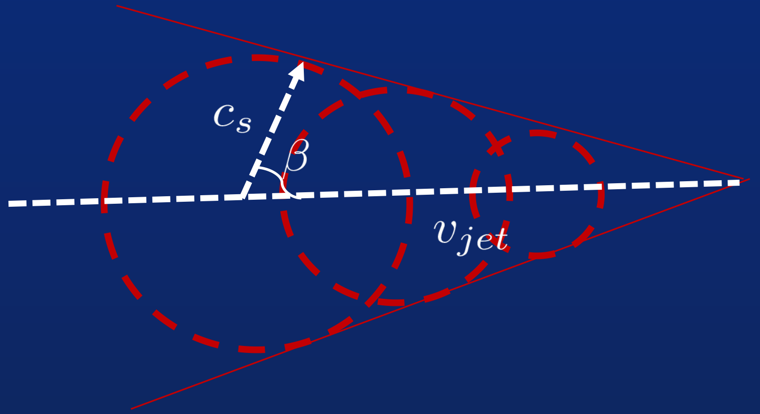
Jet quenching

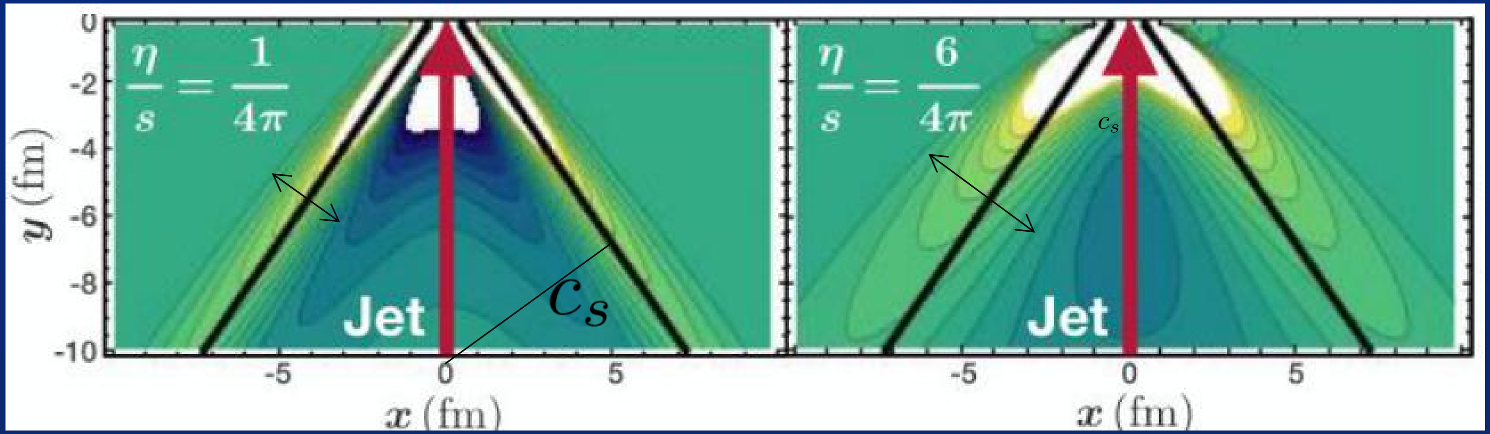
- QGP(quark-gluon plasma): A deconfined strongly interacting matter that behaves like a perfect fluid.

- Jet quenching: A good probe to glean QGP properties. Jets interact with medium and lose energy-momentum to it. Such strong jet-medium interaction leads to jet-induced medium response in the form of Mach-cone-like exciation.



Jet-induced medium response

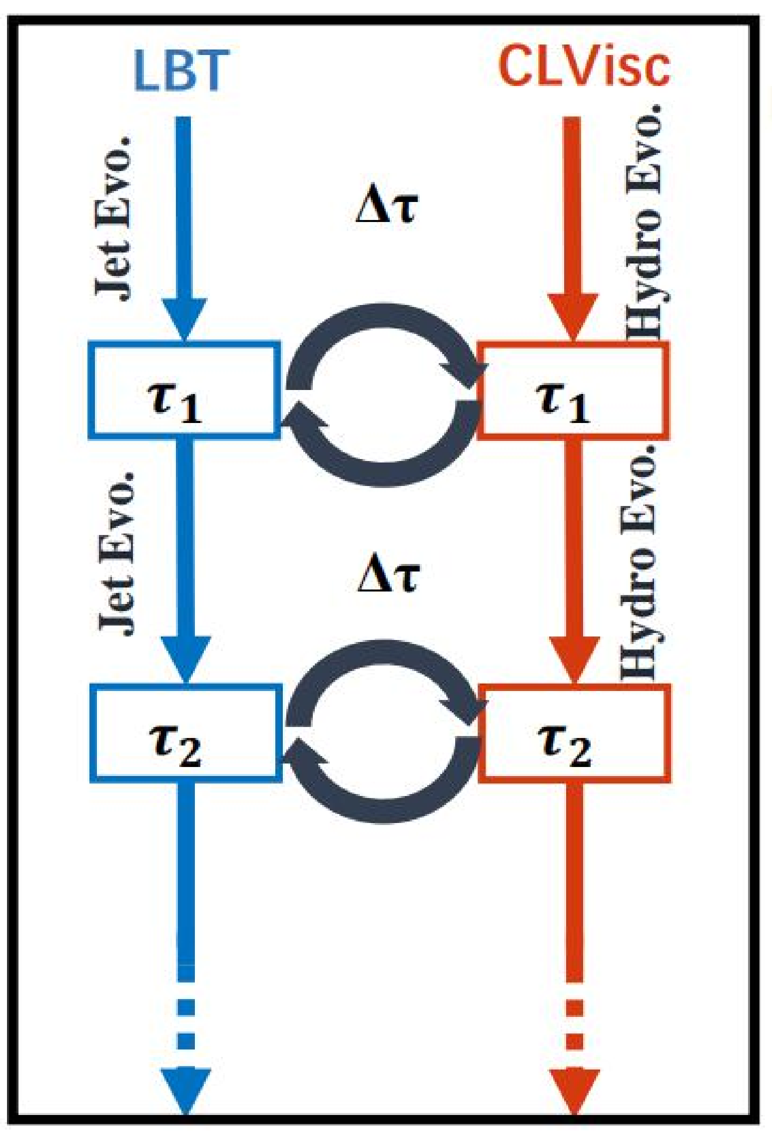
Jet-induced medium response in the form of Mach-cone-like excitation.



R.B.Neufeld. PRC79,054909(09')

- Mach cone angle is sensitive to EoS;
- Front wake width of Mach cone is related with viscous properties of QGP medium

CoLBT-hydro model



$$p\partial f(p) = -C(p) \quad (p\cdot u > p^0_{cut})$$

$$\partial T^{\mu\nu}(x) = j^\nu(x)$$

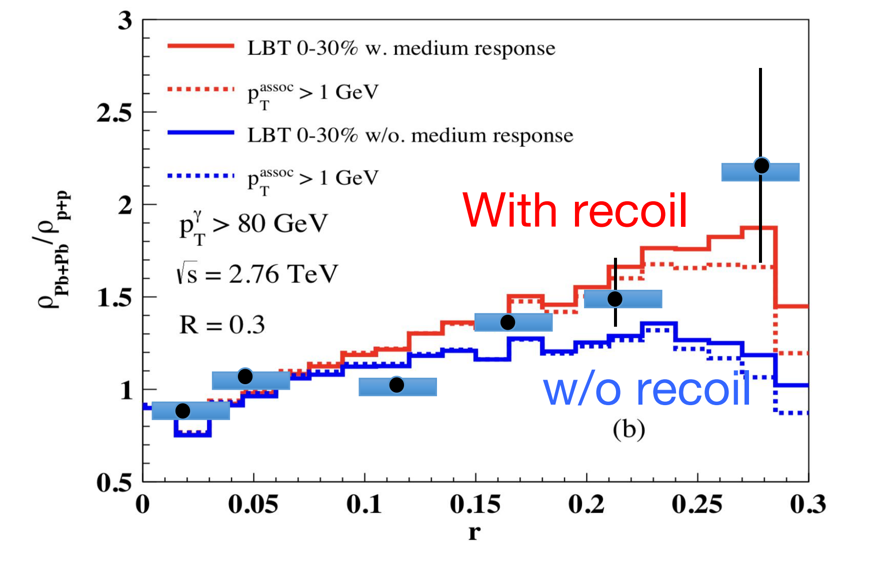
$$\partial j^\nu = \sum_i p_i^\nu \delta^{(4)}(x - x_i)\theta(p^0_{cut} - p\cdot u)$$

Concurrent and coupled evolution of bulk medium and jet showers

Medium modifications of gamma-jets at LHC

Jet Profile

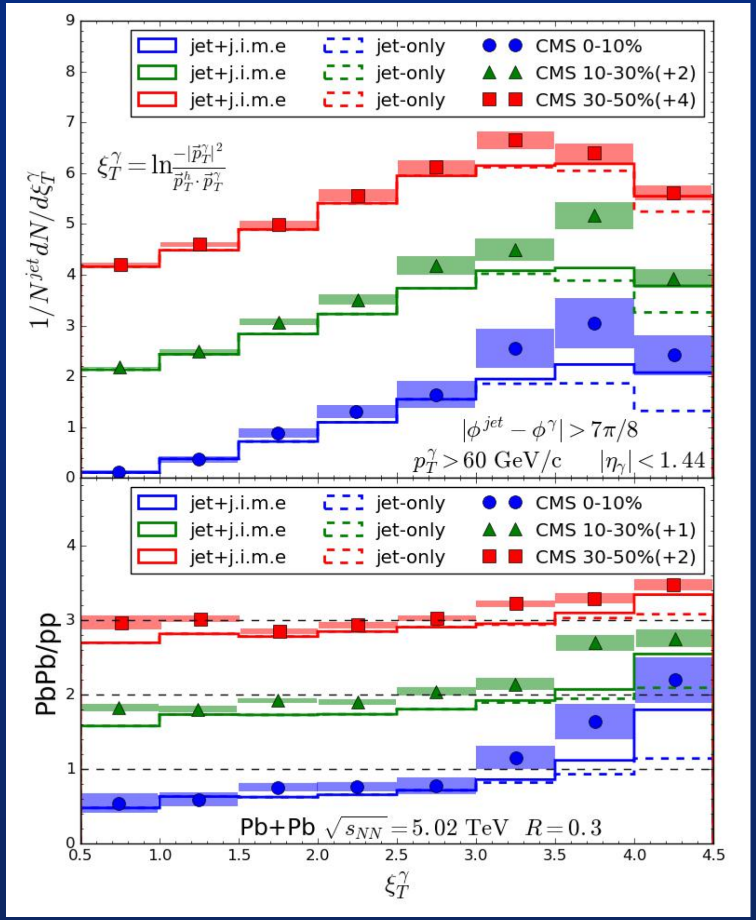
$$\rho(r) = \frac{1}{\Delta r}\frac{1}{N_{jet}}\sum_{jet}\frac{p_T^{jet}(r-\Delta r/2, r+\Delta r/2)}{p_T^{jet}(0,R)}$$



Luo, Cao, He & Wang, arXiv:1803.06785

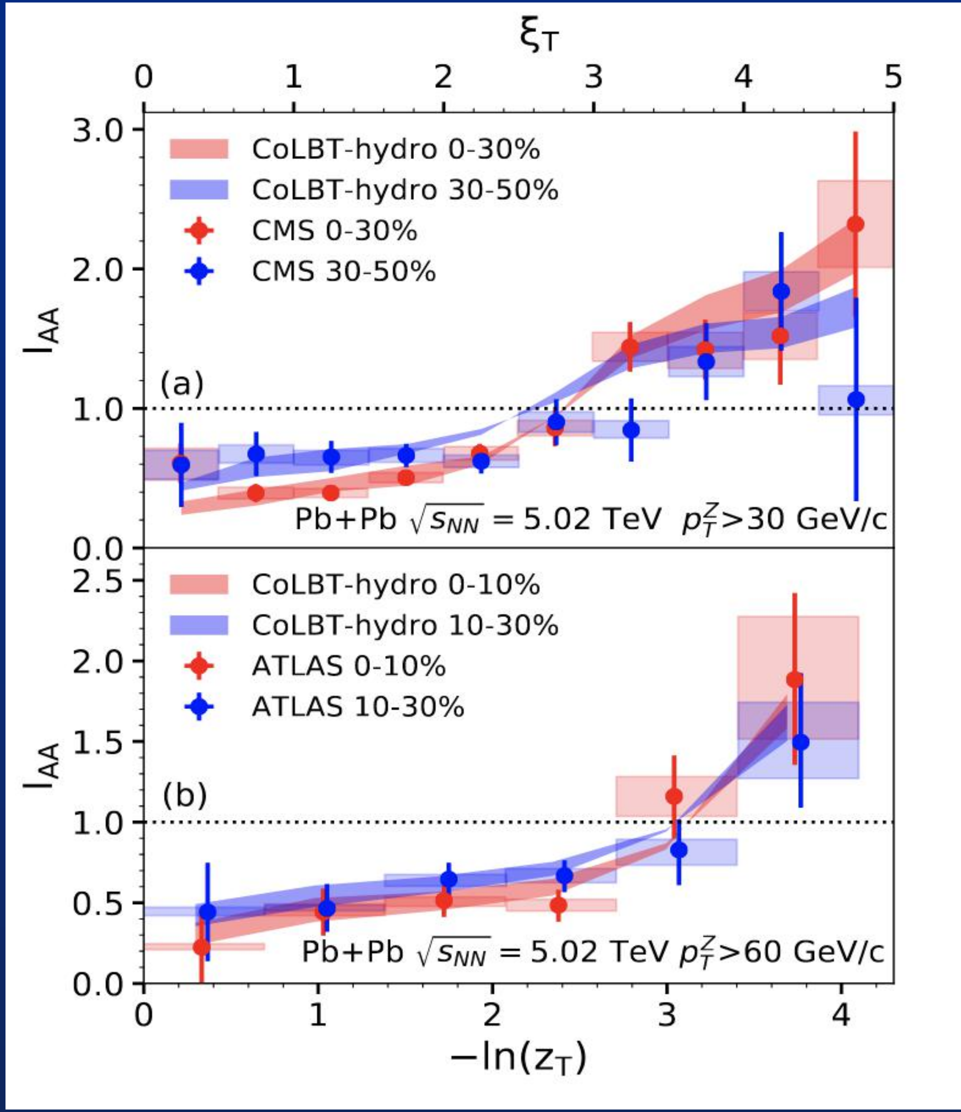
Jet-induced medium response can contribute to enhancement of soft hadrons within the jet cone

Jet fragmentation Function



Chen, Cao, Luo, Pang & Wang, arXiv: 2005.09678

Z-hadron correlations at LHC



$$\xi_T = -lnz_T = ln(p_T^Z/p_T^h)$$

Our simulation can fit CMS and ATLAS data.

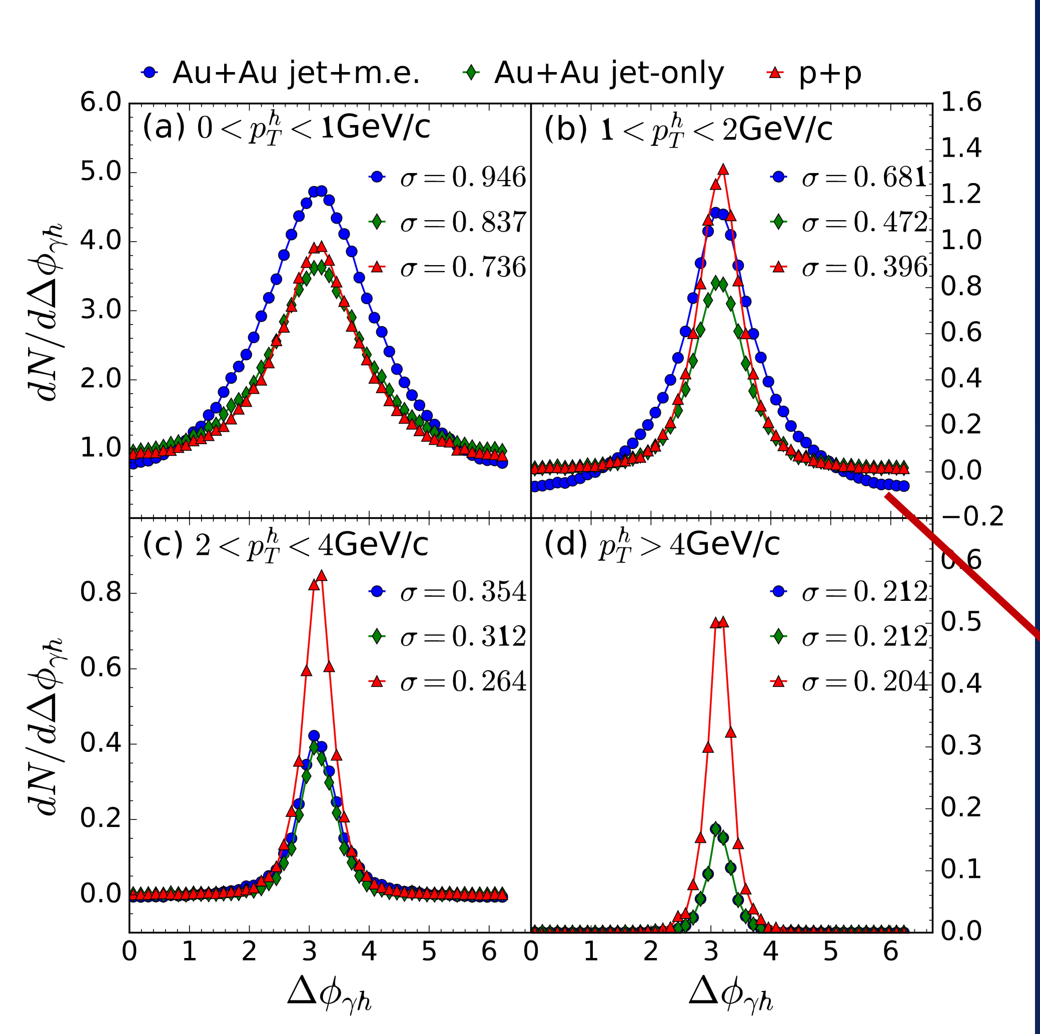
Soft hadrons enhancement is from jet-induced medium response as well as medium-induced gluon radiation.

Medium response:

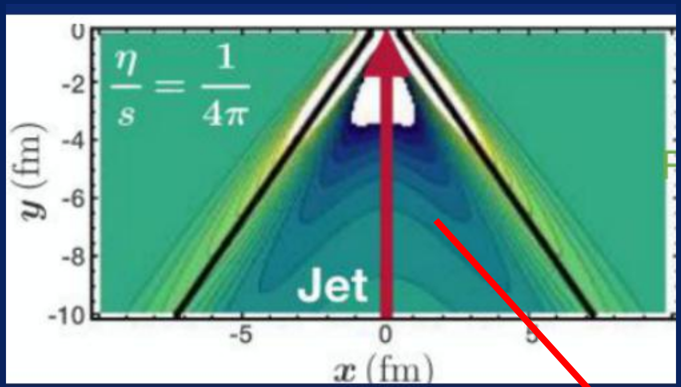
$$\omega \sim T$$

Soft gluon radiation:

Azimuthal distribution of soft hadrons at RHIC



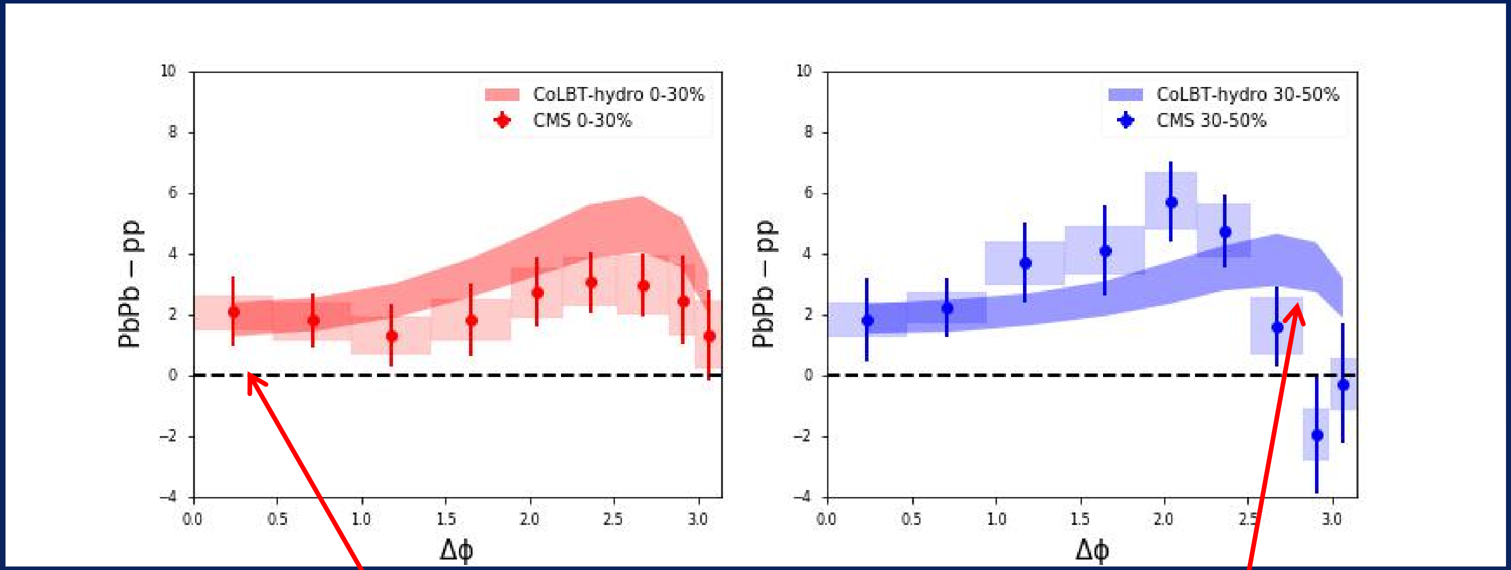
Chen, Cao, Luo, Pang & XNW, PLB777(2018)86



Diffusion wake

It is the signal of diffusion wake, because diffusion wake leads to the depletion of soft hadrons in the γ direction

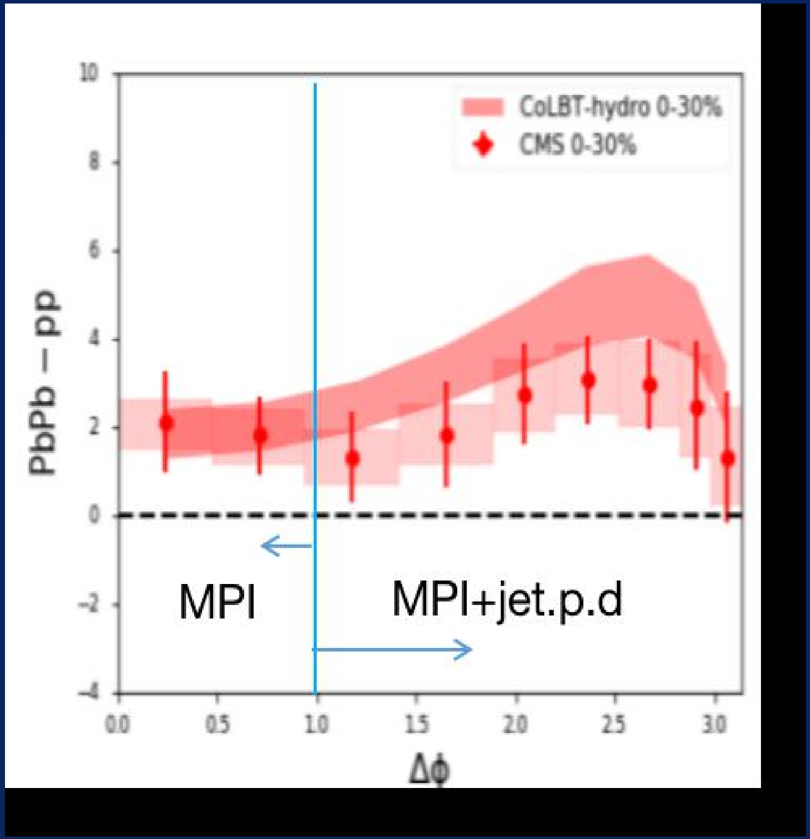
Azimuthal distribution of soft hadrons at LHC



Enhancement both at trigger and jet side

Why?

MPI subtraction in Z-hadron correlation

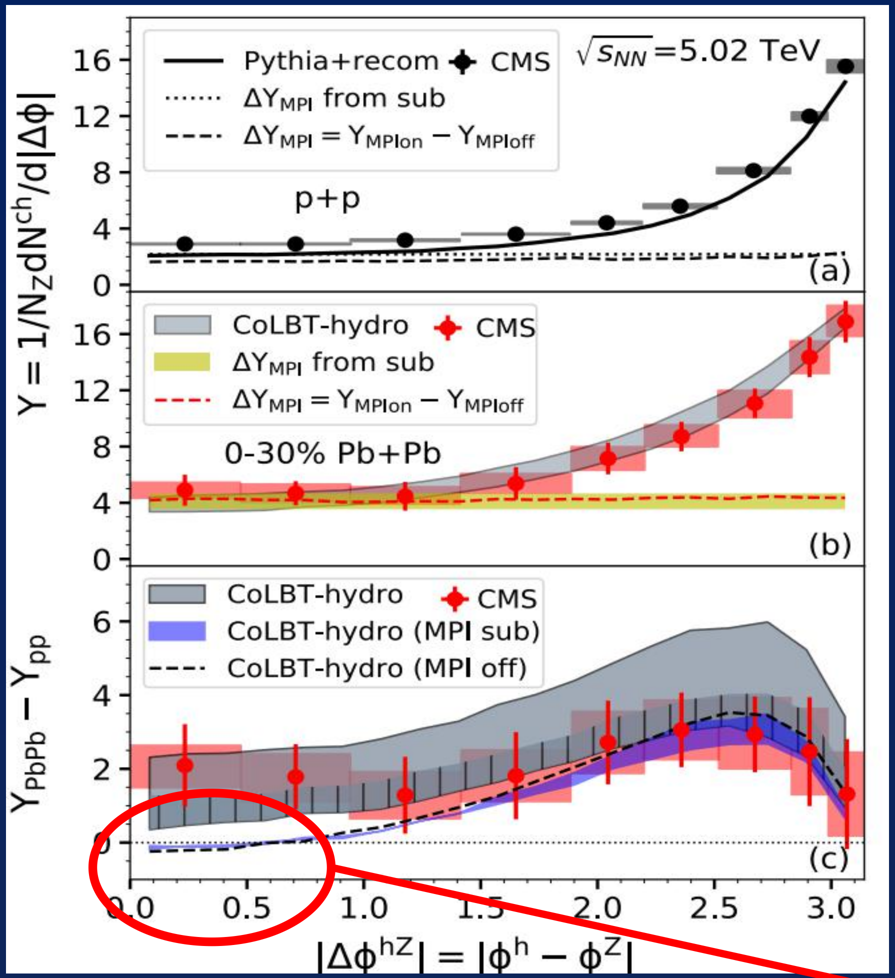


MPI (multiple parton interaction) is negligible in RHIC but becomes sizable in LHC

Mixed event subtraction:

$$\frac{dN^{hZ}_{MPI}}{d\phi} \approx \frac{dN^{hZ}_{mix}}{d\phi} - \int_1^{\pi} \frac{d\phi}{\pi}\left(\frac{dN^{hZ}}{d\phi} - \frac{dN^{hZ}}{d\phi}|_{\phi=1}\right)$$

MPI subtraction in Z-hadron correlation



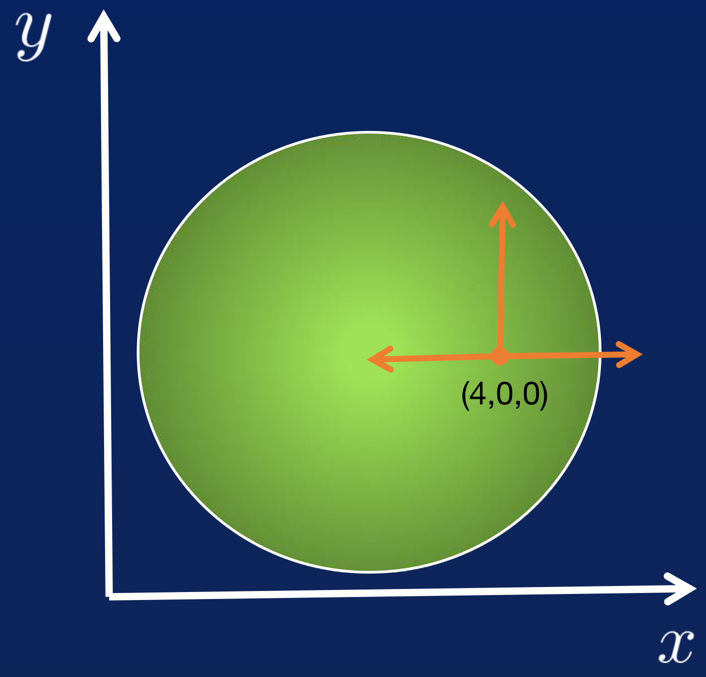
After MPI subtraction, we get negative value in trigger direction.

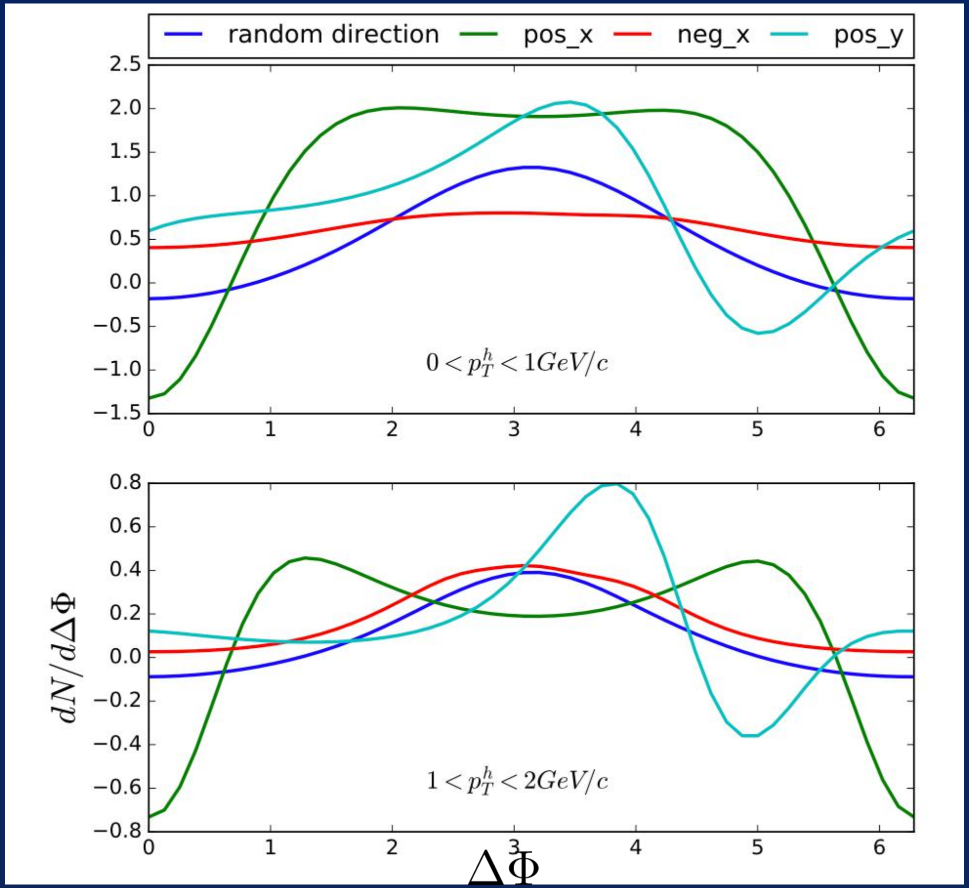
Expected

How to enhance diffusion wake effect?

CoLBT-hydro results and experimental data are averaged over

- the initial transverse position
- the direction of the Z/γ -jets





The structure of the azimuthal correlation is depend on the initial position, but smeared out in averaged events.

Wei, Xin-Nian(2018)

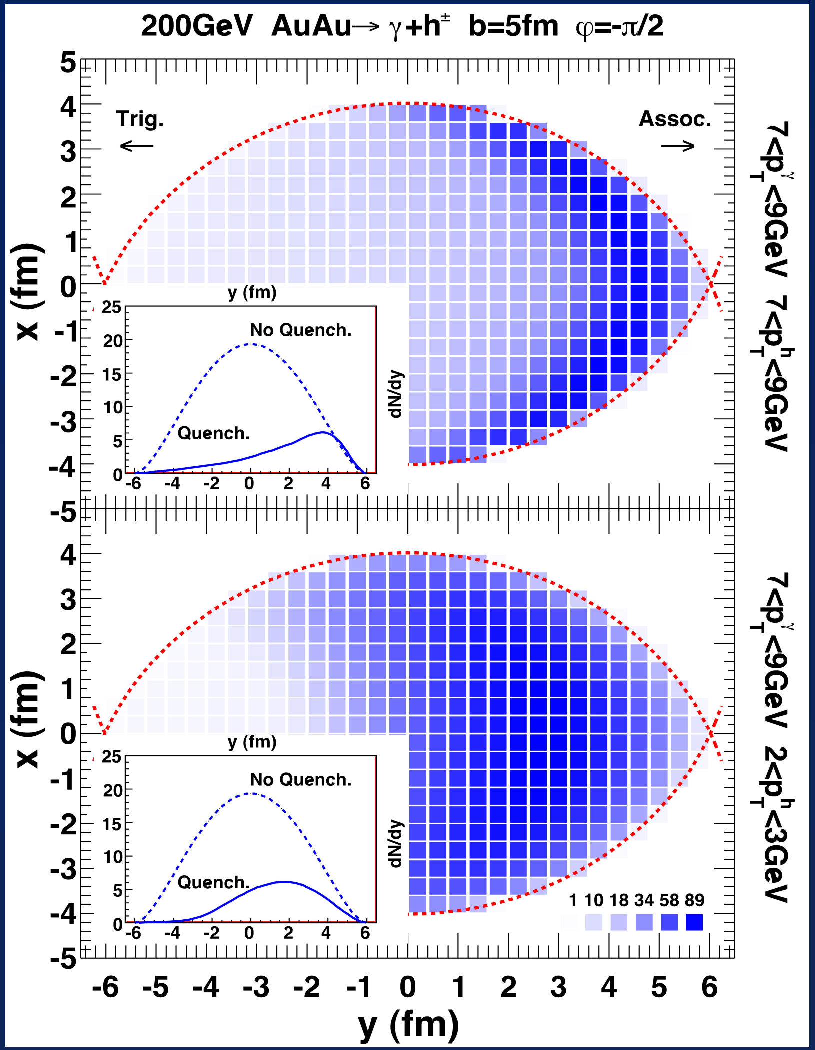
How to enhance diffusion wake effect?

2D jet tomography

longitudinal jet tomography:
larger jet path length in medium

transverse gradient jet tomography:
specific initial production region

Longitudinal jet tomography



$$p_T^h/p_T^\gamma \sim 1$$

Surface emission less energy loss.

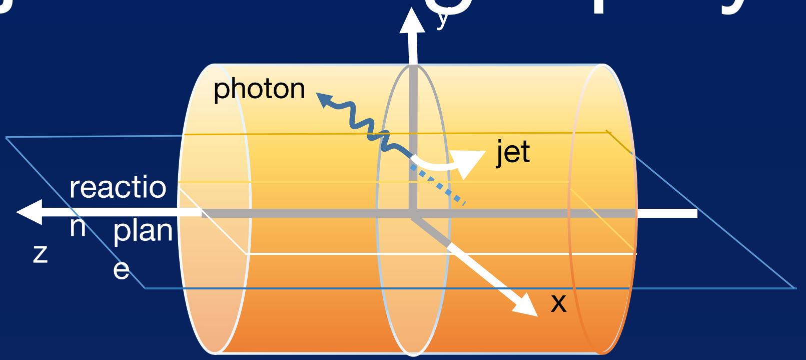
$$p_T^h/p_T^\gamma \sim 0.3$$

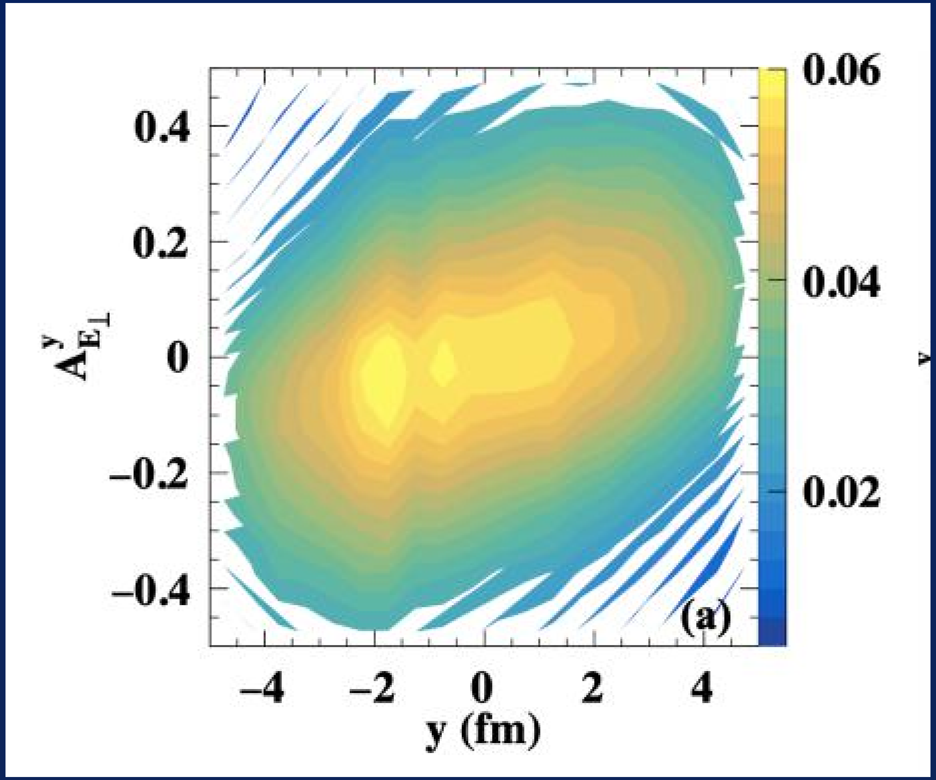
Volume emission more energy loss.

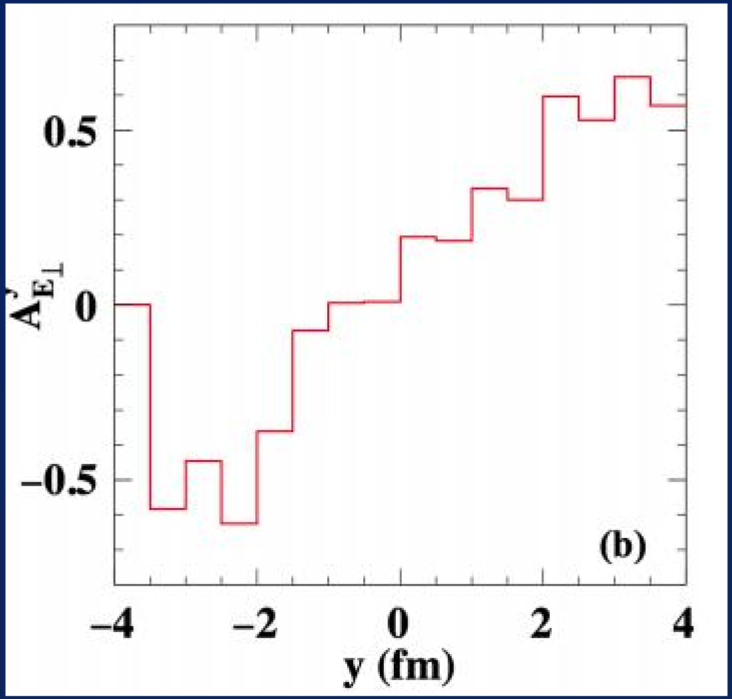
Zhang, Owens, Wang and XNW, Phys. Rev. Lett. 103, 032302 (2009)

Transverse gradient jet tomography

$$A^{\vec{n}}_{E_\perp} = \frac{\int d^3r d^3p f_a(\vec{p},\vec{r})\vec{p}_T\cdot\vec{n}}{\int d^3r d^3p f_a(\vec{p},\vec{r})}$$

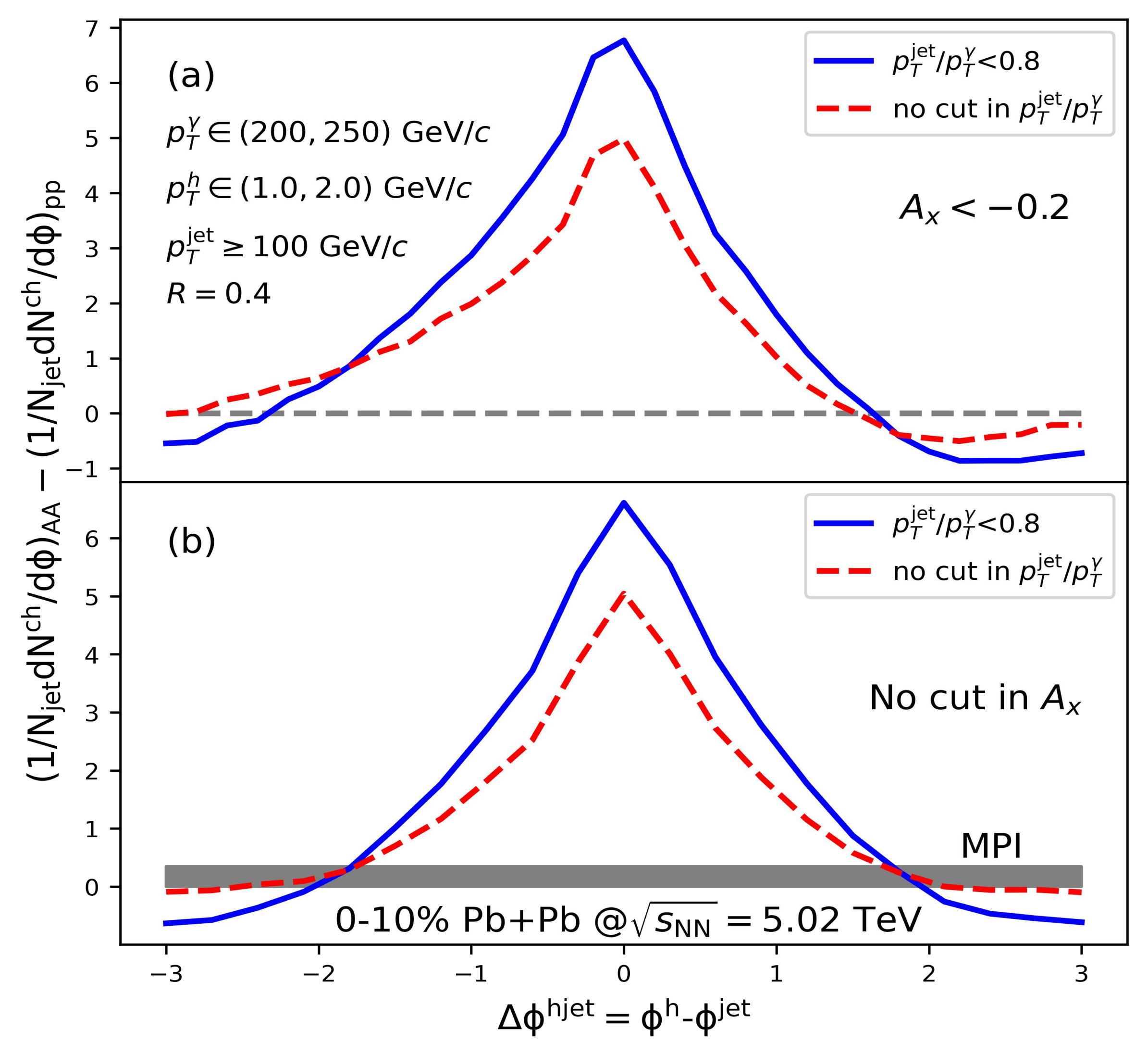


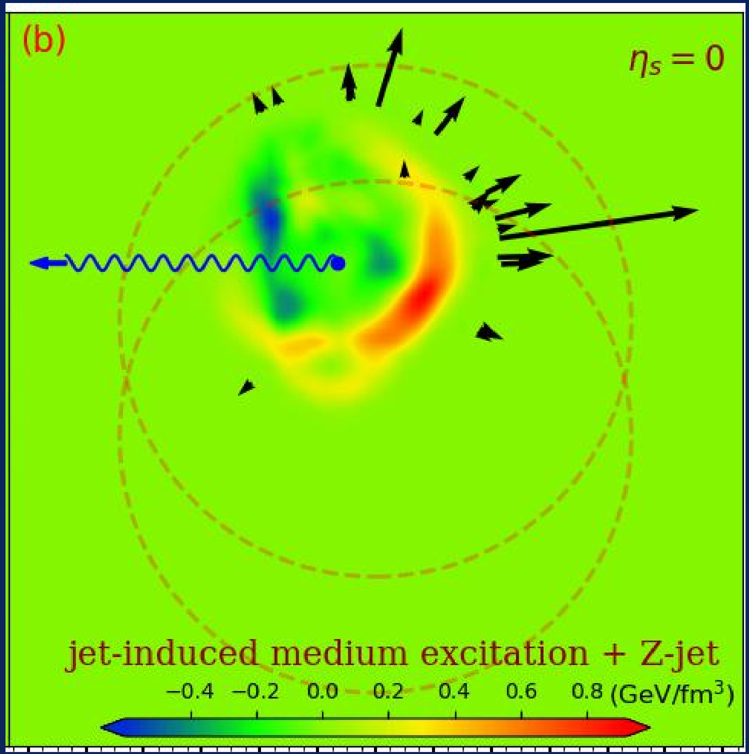




He, Pang & XNW, PRL 125 (2020) 12, 122301

Enhancing the diffusion wake





Summary

1. Jet-induced medium response leads to

    (1) enhancement of soft hadrons in jet direction

    (2) depletion of soft hadrons on the trigger side

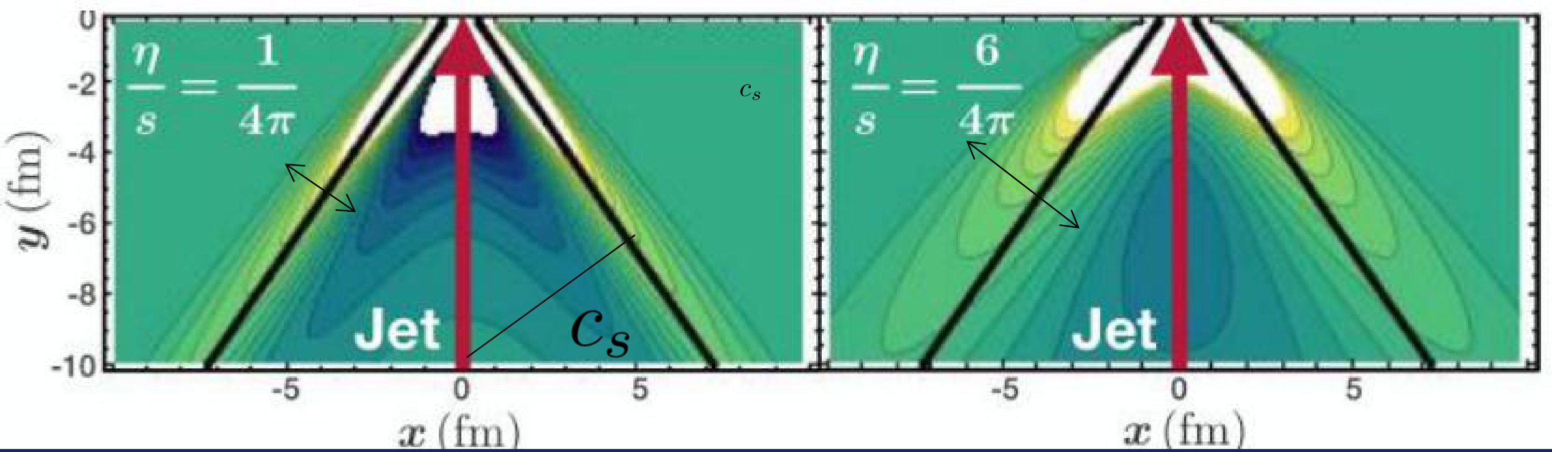
2. With MPI subtraction, we can get diffusion wake signal at LHC

3. Using 2D tomography is useful to enhance diffusion wake effect

Thanks

Jet-induced medium response

Jet-induced medium response in the form of Mach-cone-like excitation.



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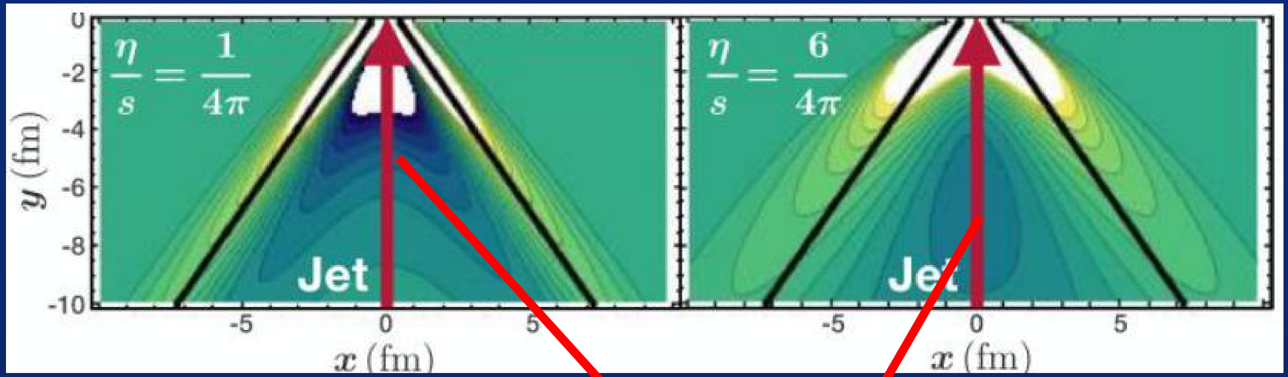
Medium response and diffusion wake

medium response: $\omega \sim T$

soft gluon radiation $\omega_g \sim \hat{q}\lambda^2 \sim T$

Energy scale



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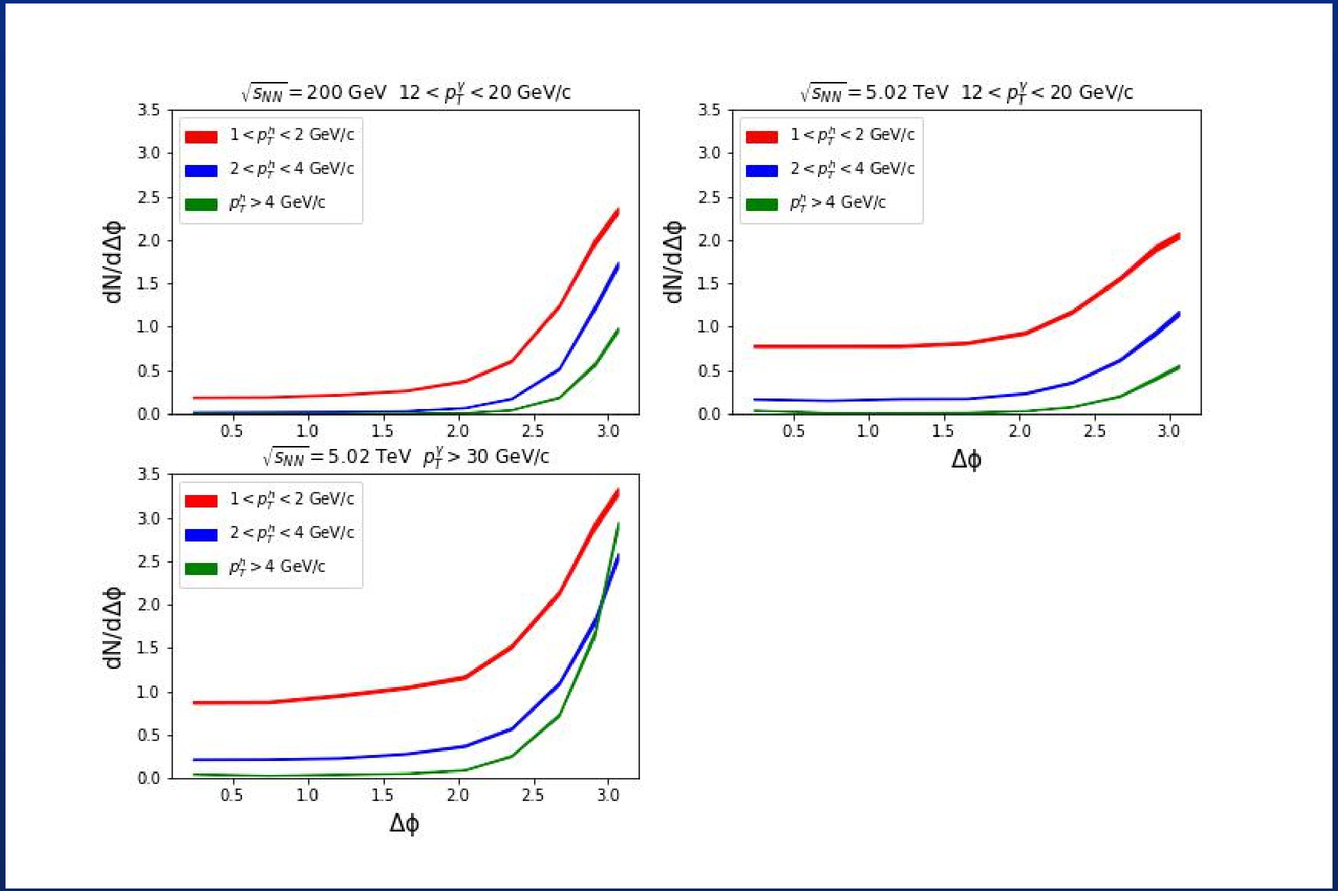
Diffusion wake

MPI effect of trigger energy and collision enenry



Medium response & soft gluon radiation

For the enhancement of soft hadrons, It is difficult to distinguish the contribution from medium response or medium-induced soft gluon radiation.

Medium responce: $\delta f(p) \sim e^{-p\cdot u/T}$ Energy scale: $\omega \sim T$

Soft radiated gluons: $\omega_g \sim \hat{q}\lambda^2 \sim T$

formation time: $\tau_f = \frac{2\omega}{k_T^2}$ $k_T^2 \approx \tau_f \hat{q}$ ⟶ $\tau_f \approx \sqrt{2\omega/\hat{q}}$

limited by the mean-free-path: $\tau_f \leq \lambda \sim 1/T$ $\hat{q} \sim T^3$