Enhancement of baryon-to-meson ratios around jets as a signature of medium response

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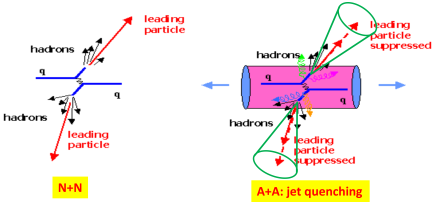
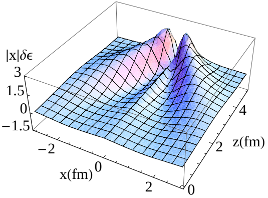
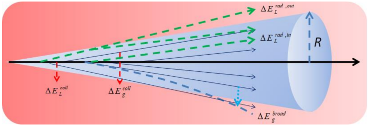
Content

Jet quenching



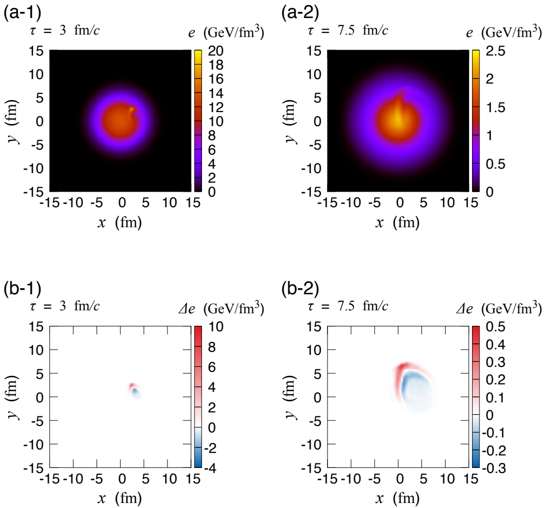


(1)jet energy loss (2)jet deflection and broadening (3)modification of jet structure (4)jet-induced medium excitaion(medium response)



Full jet evolution and energy loss in QGP

- Jets are spray of particles originating from fragmentation of hard-scattered partons.
- Jet reconstruction: recombine hadron (or parton) fragments to approximate the original hard parton’s energy and momentum.
- They are expected to provide more detailed information about jet-medium interaction.



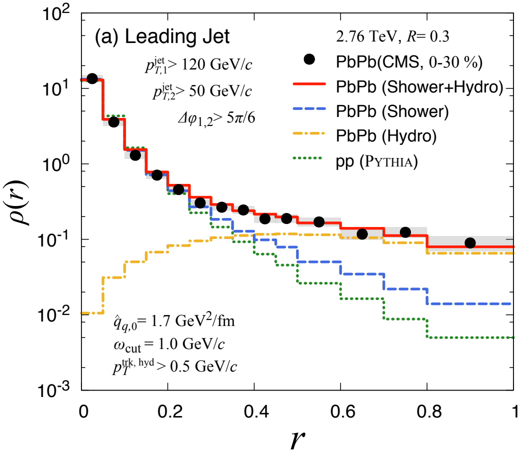
Jet-fluid model:

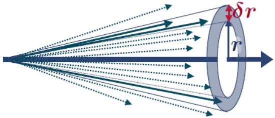
$$\frac{\mathrm{d}f}{\mathrm{d}t} = \mathrm{C}[f], \quad \partial_\mu T^{\mu\nu} = J^\nu$$

- Jet deposits energy and momentum into medium, and induces V-shaped wave fronts.
- The wave fronts carry energy and momentum, propagates forward and outward, and depletes the energy behind the jet (diffusion wake).
- Jet-induced flow and the radial flow of medium are pushed and distorted by each other.

[Chang, GYQ, PRC 2016;Tachibana, Chang, GYQ, PRC 2017;Chang, Tachibana, GYQ, PLB 2020]

Redistribution of lost energy from quenched jets



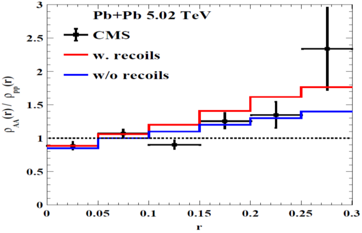


The contribution from the hydro part is quite flat and finally dominates over the shower part in the region from $r = 0.4 - 0.5$.

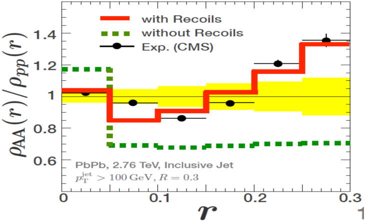
Signal of jet-induced medium excitation in full jet shape at large r.

[Chang, GYQ, PRC 2016;Tachibana, Chang, GYQ, PRC 2017;Chang, Tachibana, GYQ, PLB 2020]

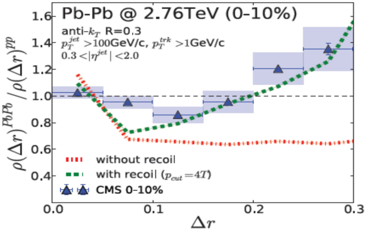
Other similar results on medium response



[Luo, Cao, He, Wang, arXiv:1803.06785]



[Elayavalli, Zapp, JHEP 2017]



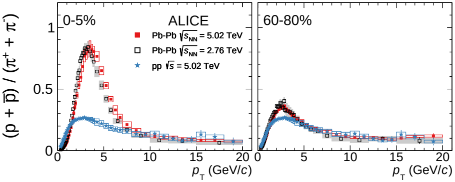
[C. Park, S. Jeon, C. Gale, 2018]

The inclusion of medium response can naturally explains the enhancement of jet shape at larger radius.

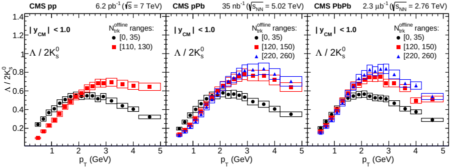
How about particle compositions around jets?

- Due to the interaction with the medium, the lost/deposited energy will be(partially) thermalized.
- The particles (and their chemical compositions) produced from jet-excited energy should be different from those from vacuum-like energy.
- As a result of the coalescence of jet-excited partons, jet-medium interaction can lead to the enhancement of baryon-to-meson ratio at intermediate p_T around the quenched jets.
- Since the lost energy can flow to large angles, we expect that the B/M enhancement should depend on the distance with respect to the jet axis.

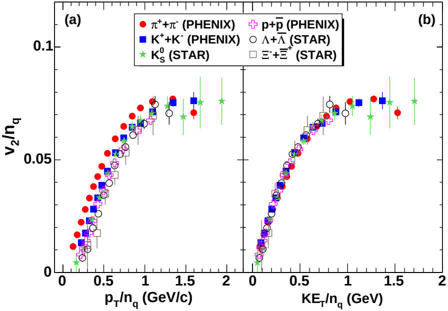
B/M enhancement and v_2 NCQ scaling of bulk matter



[ALICE, Phys. Rev. C **101**, no.4, 044907 (2020)]



[CMS, Phys. Lett. B **768**, 103-129 (2017)]

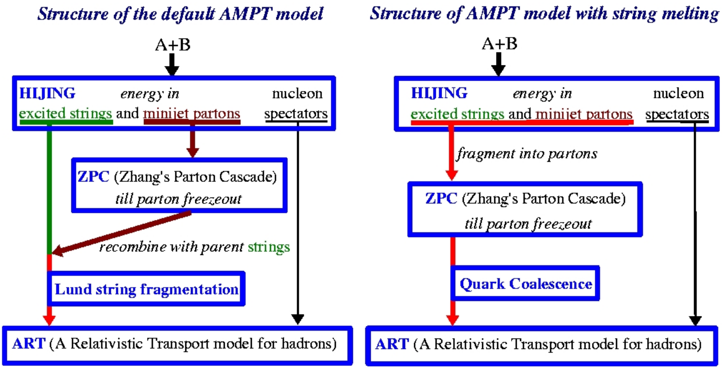


[PHENIX, Phys. Rev. Lett. **98**, 162301 (2007)]

- Particle flow in quark level.
- Parton recombination is very important in forming intermediate p_T hadrons.

Coalescence of thermal partons from QGP can naturally explain the NCQ scaling of v_2 and the enhancement of baryon-to-meson ratio at intermediate p_T.

A Muti-Phase Transport (AMPT) model



Structure of the default(left) AMPT model and AMPT with string melting(right).

[Lin, Ko, Zhang, Pal, PRC72, 064901 (2005)]

AMPT contains 4 main stages:initial condition, parton cascade, hadronization and hadron cascade.

AMPT has been able to describe many bulk and jet observables: flow, dijet and gamma-jet asymmetries, jet shape, jet fragmentation function, etc.

Reconstruct jet and correlation between jet and charged-particles

The correlation between jet and charged particle

- We apply the FASTJET framework with the anti-k_{T} algorithm to reconstruct jets in Pb+Pb and p+p events. The jet cone size is taken to be $\mathrm{R} = 0.4$.
- PbPb collisions for 4 centrality:0-10%,10-30%,30-50%,50-100%.
- We use mixed-event method to correct the limited acceptance.
- After the acceptance correction, we use the side-band method to subtract the background from uncorrelated pairs and long-range correlations.
- We can construct the three-dimensional distribution $\frac{\mathrm{d}^3 N}{\mathrm{d}p_{\mathrm{T}}\mathrm{d}\Delta\eta\mathrm{d}\Delta\phi}$ of charged particles around the jets.

Mixed-event method for jet-particle correlation

The signal pair distribution $S(\Delta\eta, \Delta\phi)$ represents the yield of jet-particles pairs from the same jet-triggered event, normalized by N_{jet},

$$S(\Delta\eta, \Delta\phi) = \frac{1}{N_{\mathrm{jet}}} \frac{\mathrm{d}^2 N^{\mathrm{same}}}{\mathrm{d}\Delta\eta \mathrm{d}\Delta\phi}. \tag{1}$$

The mixed-event pair distribution $ME(\Delta\eta, \Delta\phi)$ is

$$ME(\Delta\eta, \Delta\phi) = \frac{1}{N_{\mathrm{jet}}} \frac{\mathrm{d}^2 N^{\mathrm{mix}}}{\mathrm{d}\Delta\eta \mathrm{d}\Delta\phi}. \tag{2}$$

The ratio $ME(0,0)/ME(\Delta\eta, \Delta\phi)$ is the normalized correction factor.
the two-dimensional particle yield (distribution) per trigger jet is obtained as follows:

$$\frac{1}{N_{\mathrm{jet}}} \frac{\mathrm{d}^2 N}{\mathrm{d}\Delta\eta \mathrm{d}\Delta\phi} = \frac{ME(0,0)}{ME(\Delta\eta, \Delta\phi)} S(\Delta\eta, \Delta\phi), \tag{3}$$

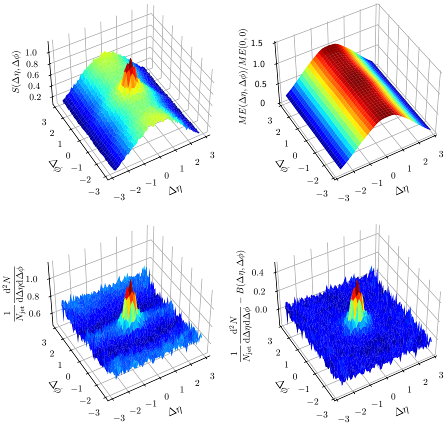
Mixed-event method for jet-induced identified particles

$\frac{d^3N}{dp_T d\Delta\phi d\Delta\eta}$ for identified particles.

We apply the mixed-event method for jet-induced identified particles. Here is illustrated using $0-10\%$ Pb+Pb collisions with proton in $2 < p_T < 3$ GeV.

- The upper left is the signal pair distribution $S(\Delta\eta, \Delta\phi)$,
- the upper right is the normalized mixed-event pair distribution $ME(\Delta\eta, \Delta\phi)$,
- the lower left is the acceptance-corrected distribution,
- the lower right is the final background-subtracted jet-triggered proton yield.

Similar procedure apply to 4 centrality ($0-10\%$, $10-30\%$, $30-50\%$, $50-100\%$) and 7 different p_T bin for p, π, Λ and K.



p_{T} and Δr distribution of the jet-correlated charged particles

Using the three-dimensional charged particle distribution $\frac{\mathrm{d}^3 N}{\mathrm{d}p_{\mathrm{T}}\mathrm{d}\Delta\phi\mathrm{d}\Delta\eta}$ around the jets, we may integrate out the pseudorapidity and angular parts ($\Delta\eta$ and $\Delta\phi$) to obtain the p_{T} distributions of identified particles around reconstructed jets:

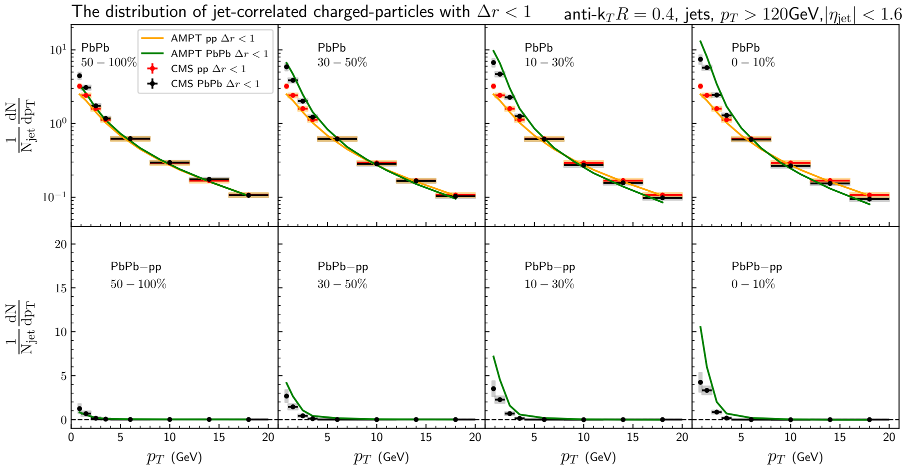
$$\frac{\mathrm{d}N}{\mathrm{d}p_{\mathrm{T}}} = \int \mathrm{d}\Delta\phi \int \mathrm{d}\Delta\eta \frac{\mathrm{d}^3 N}{\mathrm{d}p_{\mathrm{T}}\mathrm{d}\Delta\phi\mathrm{d}\Delta\eta}\bigg|_{\Delta r<1}. \tag{4}$$

One may further study the Δr distribution of identified particles in the region with $\Delta r < 1$ around jets, which can be obtained as follows:

$$\frac{\mathrm{d}N}{\mathrm{d}\Delta r} = \int \mathrm{d}\Delta\phi \int \mathrm{d}\Delta\eta \int dp_{\mathrm{T}} \frac{\mathrm{d}^3 N}{\mathrm{d}p_{\mathrm{T}}\mathrm{d}\Delta\phi\mathrm{d}\Delta\eta} \times \delta(\Delta r - \sqrt{(\Delta\phi)^2 + (\Delta\eta)^2}). \tag{5}$$

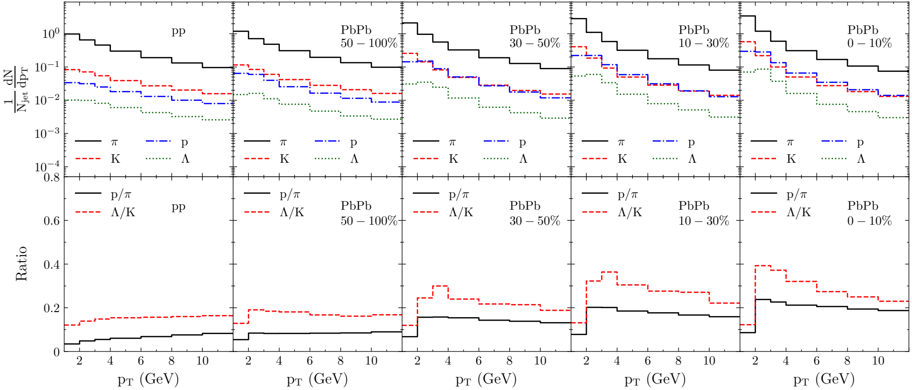
In practice, we construct the above identified particle distribution in annular rings of width $\delta r = 0.05$ around jet axis.

Jet-induced particle yield around jets



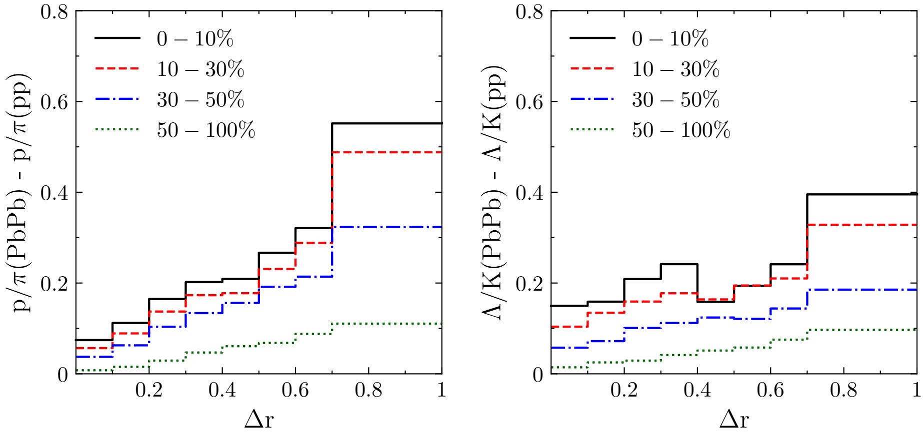
Jet quenching leads to the enhancement of soft particles and the suppression of hard particles around the jets. Such effect is more pronounced for more central collisions.

B/M enhancement around jets: p_T dependence



We find a strong enhancement of B/M ratios for associated particles at intermediate p_T around the quenched jets, due to the coalescence of jet-excited medium partons.

B/M enhancement around jets:radial dependence



For intermediate p_T (2-6 GeV) regime, the enhancement of jet-induced B/M ratios is stronger for larger distance because the lost energy from quenched jets can diffuse to large angle.

Summary

- Medium response is an important aspect of jet quenching.
- The energy deposited by the quenched jet is carried by soft particles at large angles.
- The enhancement of the baryon-to-meson ratios at intermediate p_T around the quenched jets
  - A unique signature of medium response.
  - Dose not depend on the model details of jet quenching and parton coalescence.
- More sophisticated models can be used for more precise descriptions.

Thank you!