The effect of medium responce on baryon-to-meson ratio in jets

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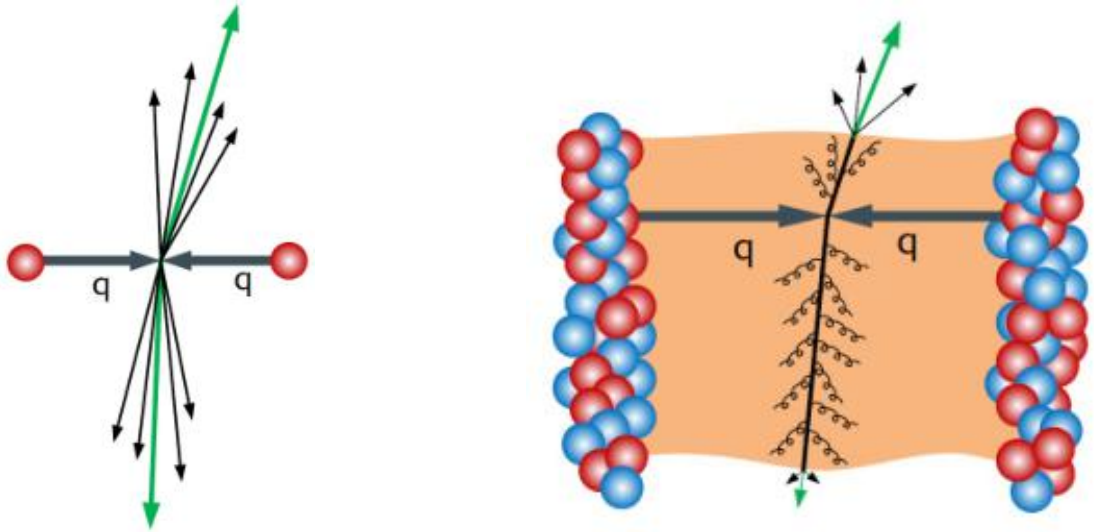
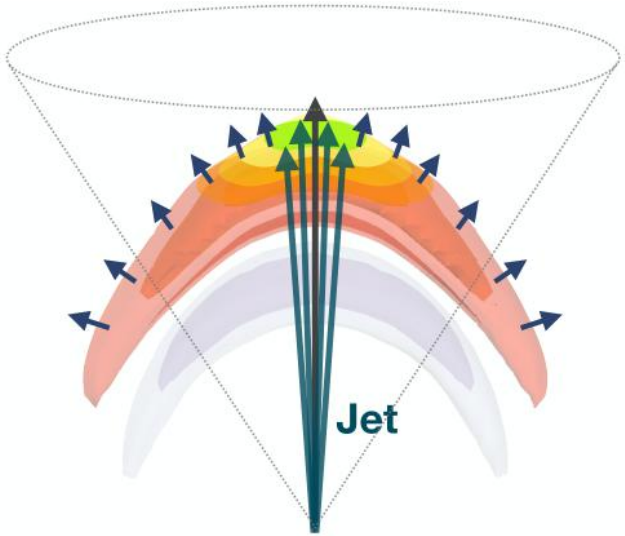
Motivation

Jets play an essential role in studying the properties of QGP medium.



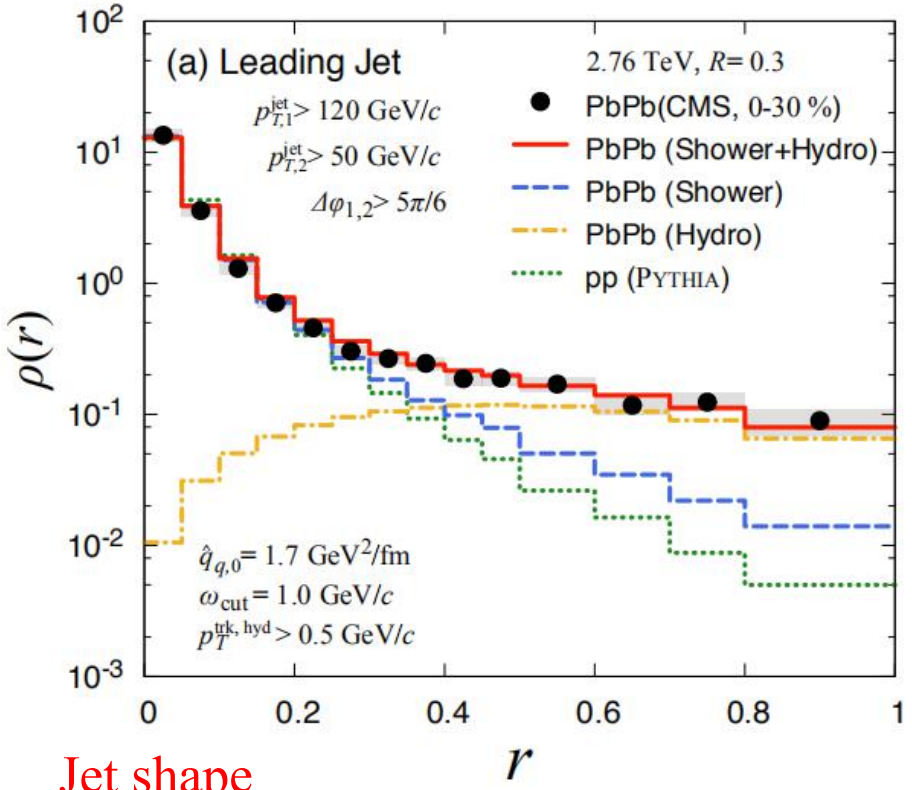
Jet queching due to the medium existence causes the modification of jet spectra and jet substructure.



It is important to determine the final jet.

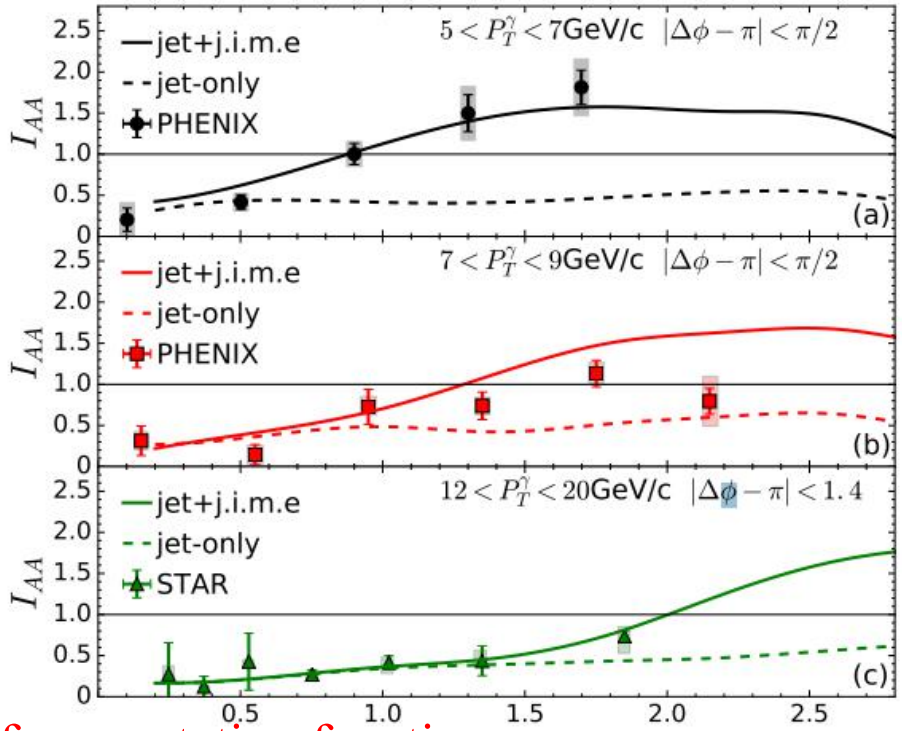
- The leading hadrons throughout medium
- The redistribution of the lost energy of hard partons(in the form of recoil partons propagate or additional jet-induced fluid flowed with strong radial medium flow.)

Motivation



Jet shape

Tachibana.PhysRevC.95.044909



Jet fragmentation function

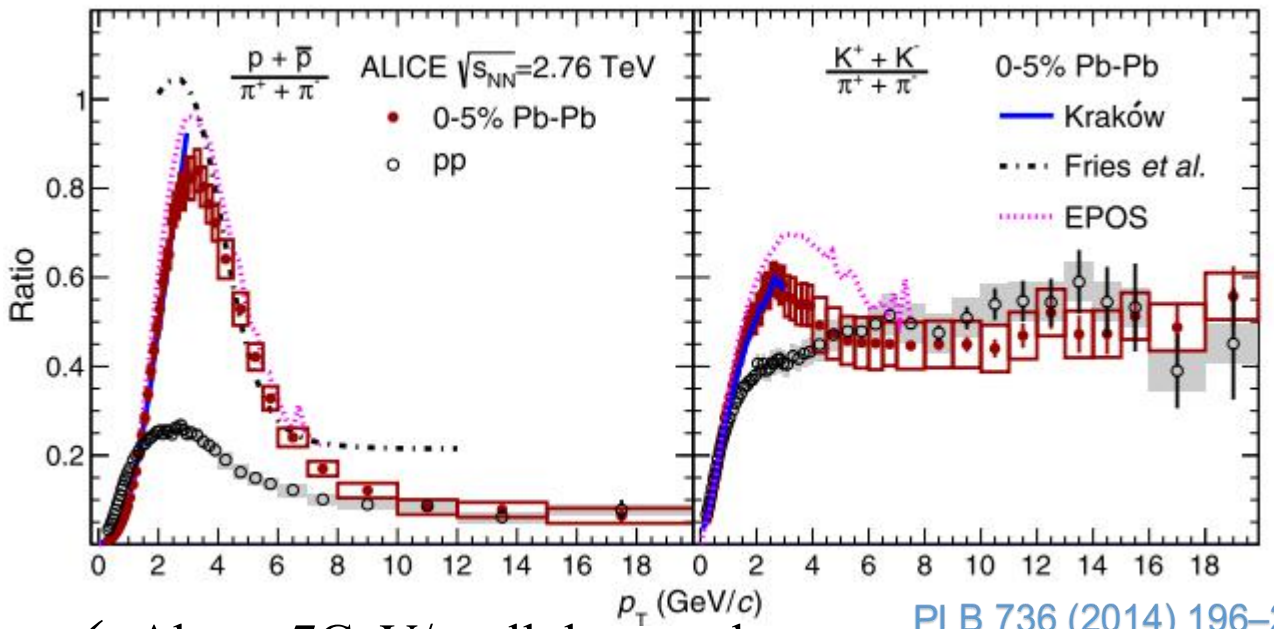
Phys.Lett. B777 (2018) 86-90

Medium responce in the final reconstructed jet can't be neglected in heavy ion collision, especially for the study of some jet-hadron based substructure obervables.

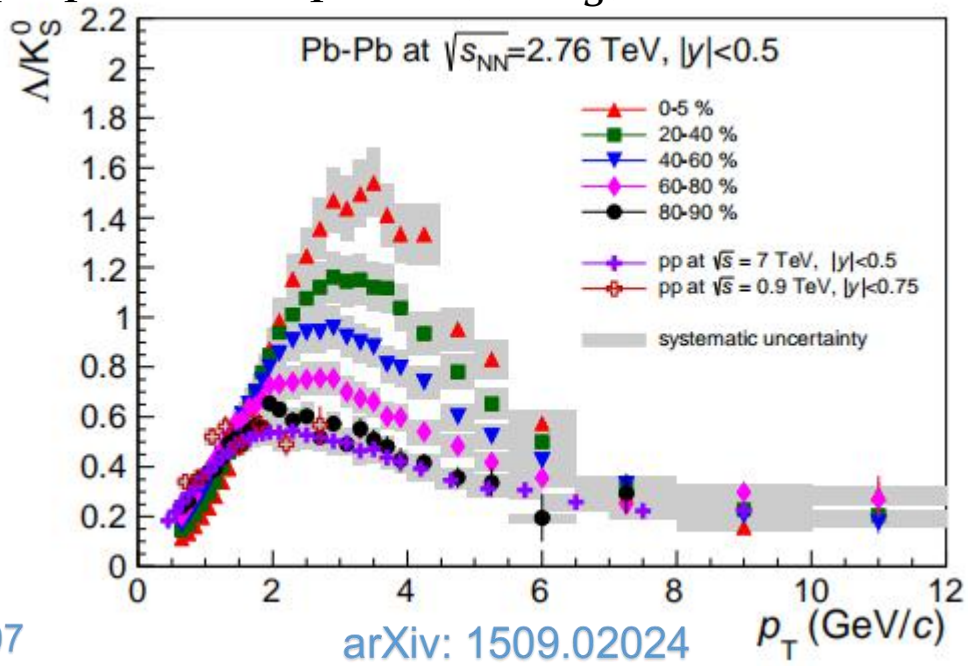
So baryon-to-meson ratio in jet is sensitive to medium responce?

Motivation

The strong centrality dependence of the ratio of inclusive pt spectrum of p to π,(Λ/k_s^0).



PLB 736 (2014) 196–207



arXiv: 1509.02024

✓ Above 7GeV/c, all data tends to pp.

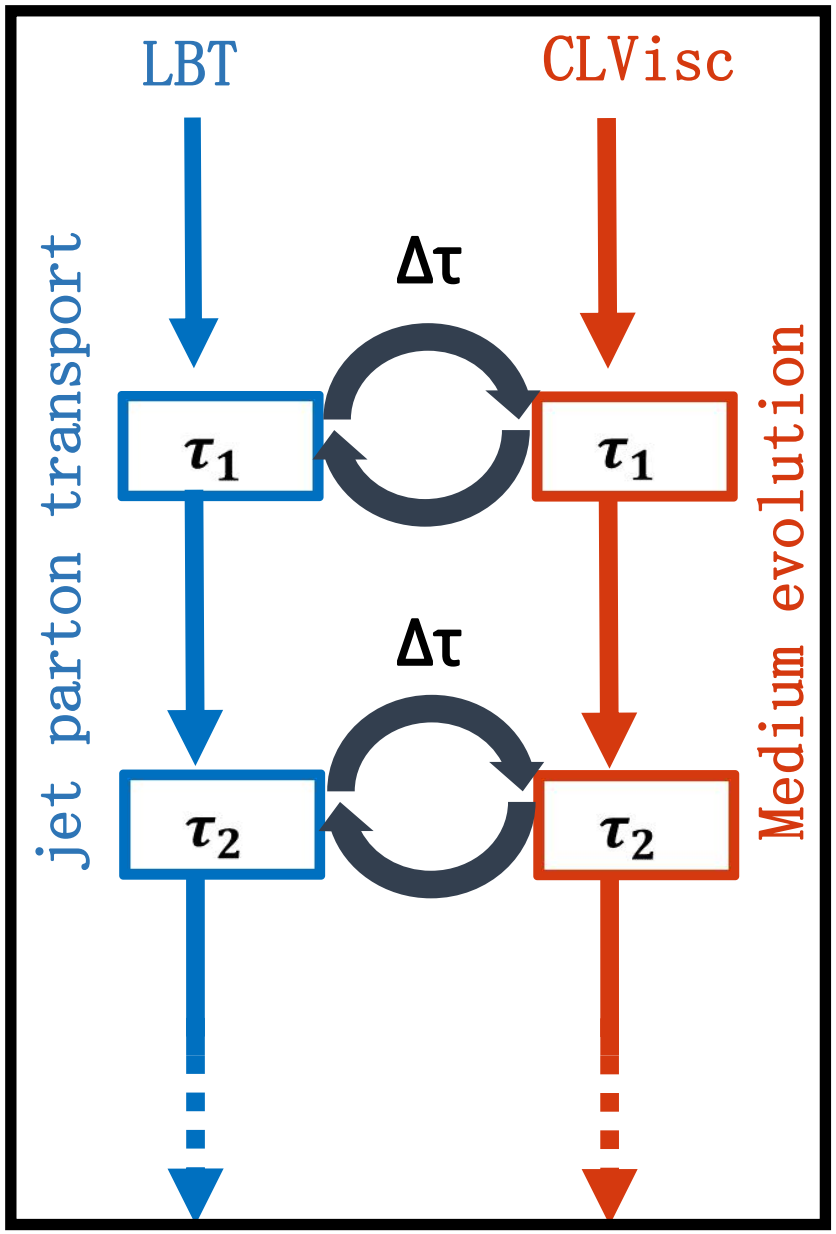
jet fragmentation

✓ Below 2~3GeV/c, all data can be produced by the hydro model and coalescence model.

Collective behavior(strong radial flow)

Is there an increase of baryon-to-meson ratio in jet due to different hadronization mechanism for hadrons from jet-induced flow and hard partons' fragmentation?

Model description

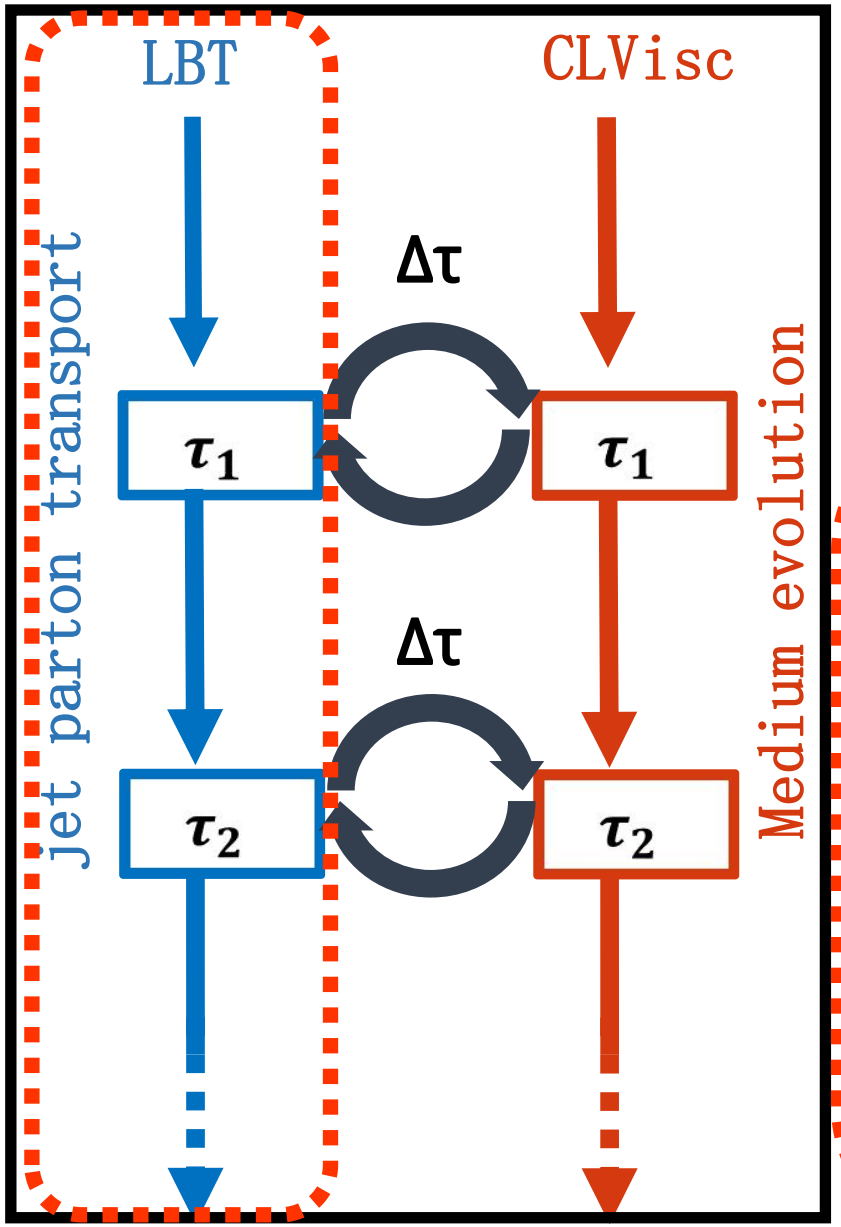


CoLBT-hydro model:

Linear Boltzmann jet transport model + **3+1D hydrodynamical model**

- ✓ Formulated in Milne Coordinate (τ-η).
- ✓ Simulated in sync with each other.

Model description



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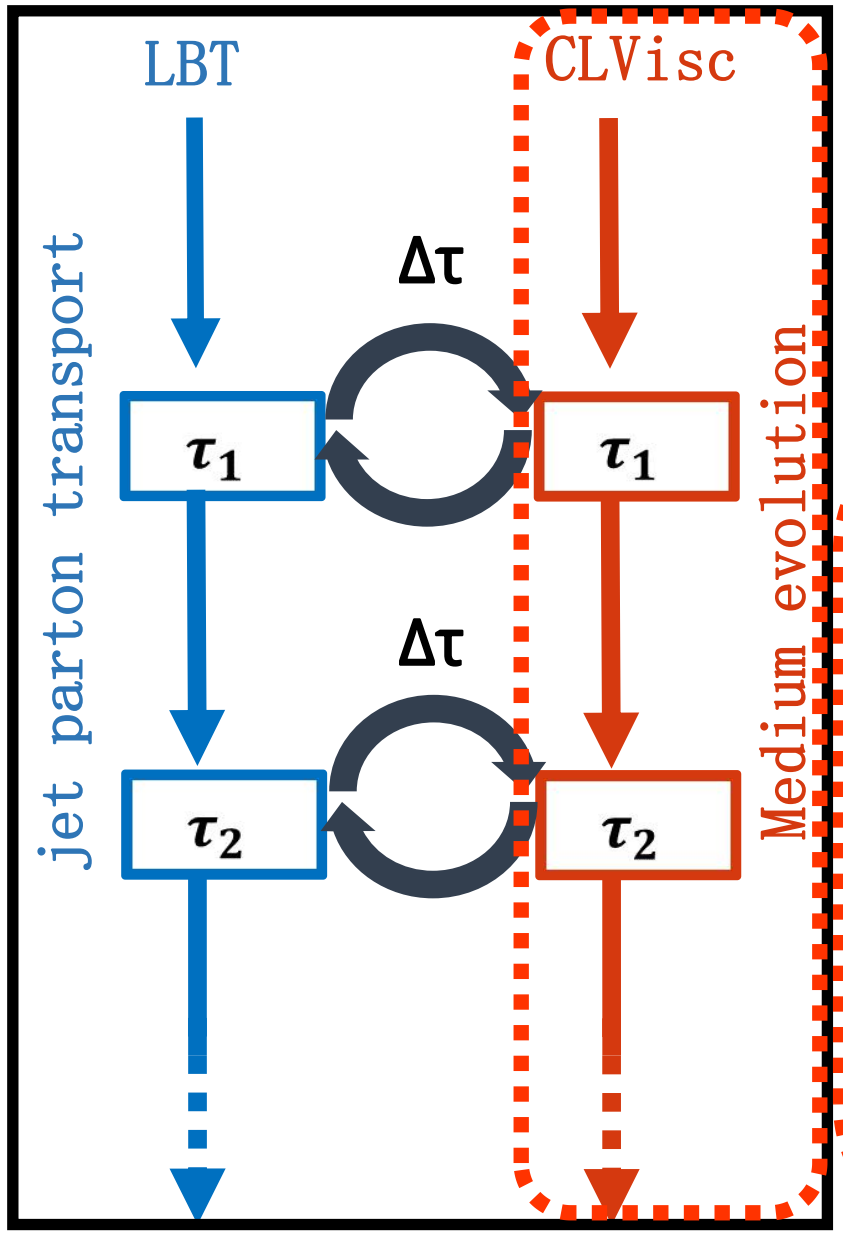
LBT model: Monte Carlo model for jet tranpsort in QGP on basis of

$$p_a\cdot\partial f_a=\int\sum_{bcd}\prod_{i=b,c,d}\frac{d^3p_i}{2E_i(2\pi)^3}(f_cf_d-f_af_b)|\mathcal{M}_{ab\to cd}|^2$$
$$\times\frac{\gamma_b}{2}S_2(\hat{s},\hat{t},\hat{u})(2\pi)^4\delta^4(p_a+p_b-p_c-p_d)+\text{inelastic},$$

- ✓ All Partons tracked: jet shower partons, thermal recoiled partons, negative partons for back reaction.
- ✓ Radiational processes included.

$$\frac{d\Gamma_a^{\text{inel}}}{dzdk_\perp^2}=\frac{6\alpha_sP_a(z)k_\perp^4}{\pi(k_\perp^2+z^2m^2)^4}\frac{p\cdot u}{p_0}\hat{q}_a(x)\sin^2\frac{\tau-\tau_i}{2\tau_f}$$

Model description



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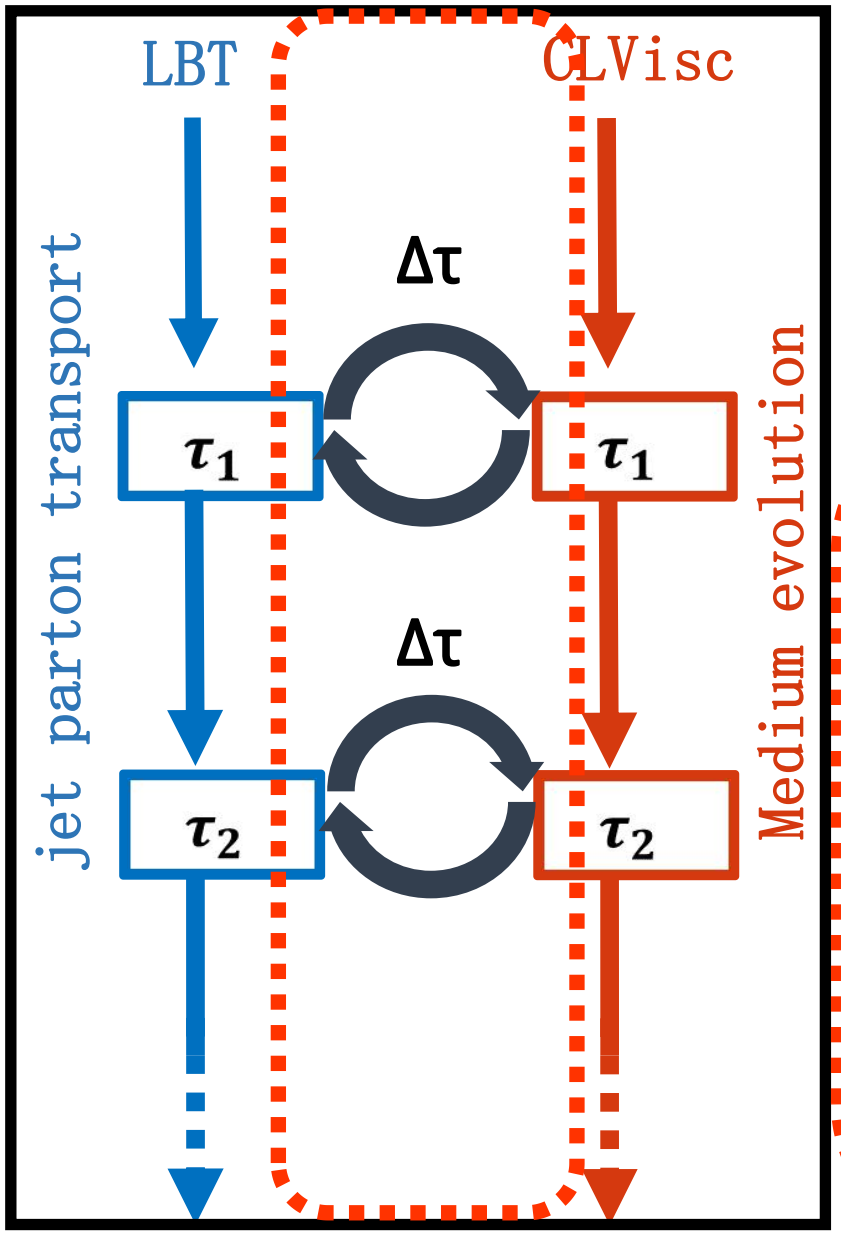
3+1D hydrodynamical model: based on several conservation equations.

- ✓ Calculate medium information by solving conservation equation.
- ✓ Get the hadron spectrum from hypersurface according to Cooper Frye
- ✓ Resonance hadrons decay.

Model description



CoLBT-hydro model:

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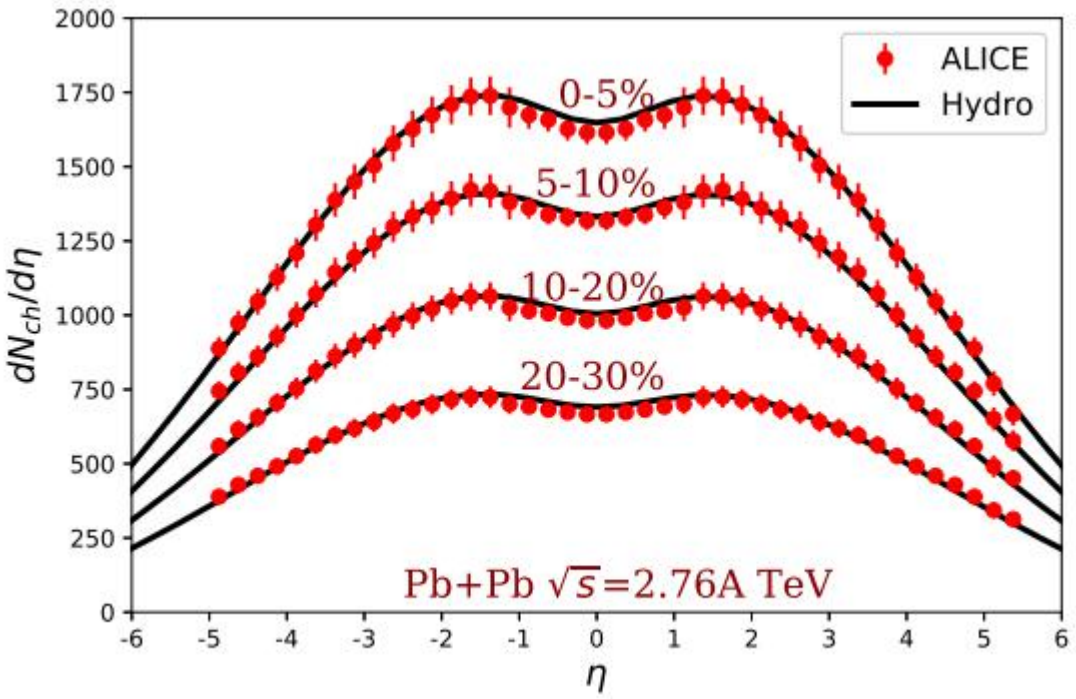
Jet medium interaction.

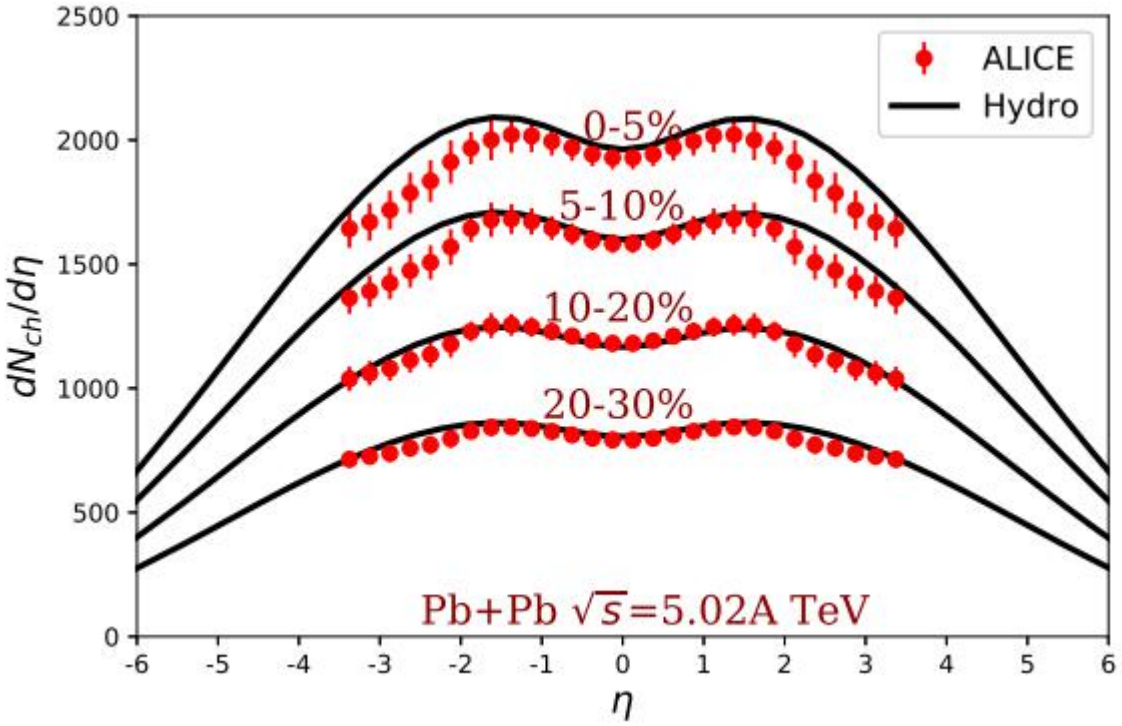
$$\partial_\mu T^{\mu\nu}_{QGP}(x) = j^\nu_{jet}(x)$$

$$j^\nu_{jet}(x) = \sum_i \frac{\theta(p^0_{cut} - p_i \cdot u) p^\nu_i}{\Delta\tau} \delta^3(\vec{x} - \vec{x}_i)$$

- ✓ One assumption: instantaneous local thermalization of deposited energy and momentum
- ✓ Two kinds of partons: soft partons ($p \cdot u < p^0_{cut}$) and negative partons($p \cdot u < 0$) deposited as source term.

Background medium





- The initial time τ and the scale factor k for medium evolution.

  (0.2, 1.60) for PbPb 2.76 TeV and (0.2, 1.45) for PbPb 5.02 TeV

- The strong coupling constant $\alpha_s = 0.16$ in Pb-Pb collisions.

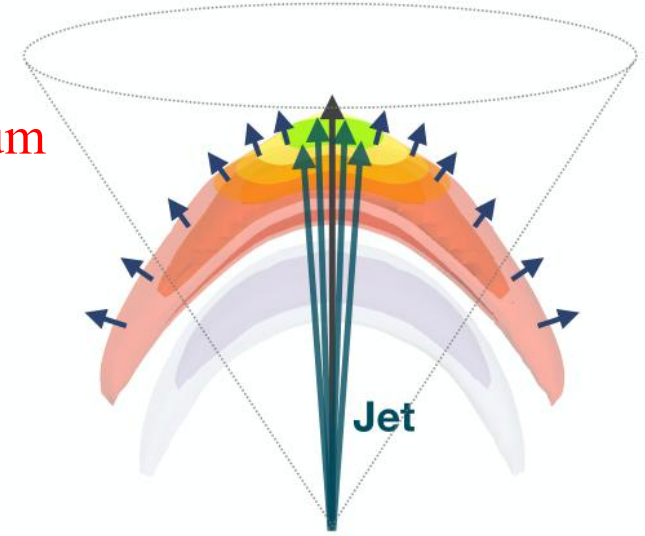
Hadron spectrum in jet

Hadron spectrum in final jet.

$$\left.\frac{dN_h}{dx}\right|_{tot} = \left.\frac{dN_h}{dx}\right|^{\Delta/jet}_{hydro} + \left.\frac{dN_h}{dx}\right|_{LBT}$$

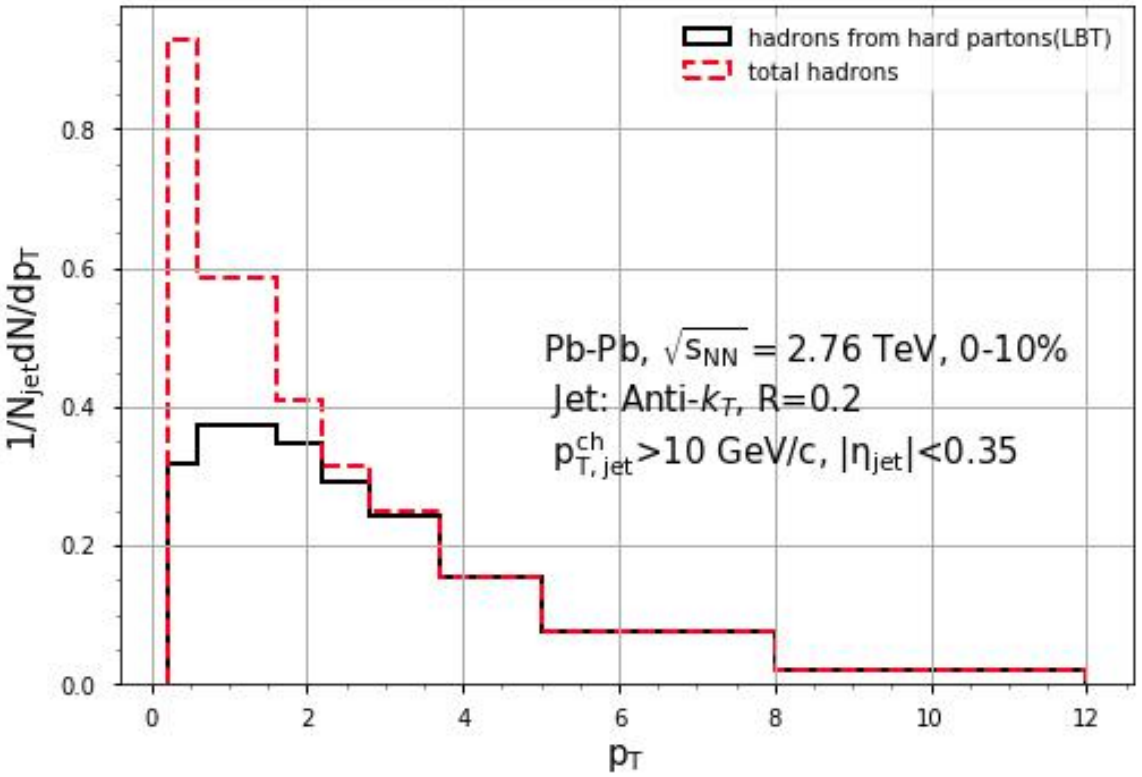
Hadron spectrum from jet-induced medium flow.

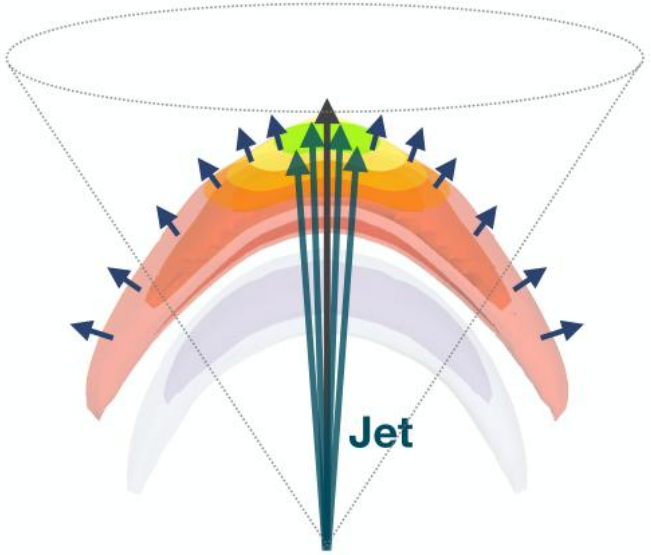
$$\left.\frac{dN_h}{dx}\right|^{\Delta/jet}_{hydro} = \left.\frac{dN_h}{dx}\right|^{w/jet}_{hydro} - \left.\frac{dN_h}{dx}\right|^{no/jet}_{hydro}$$



Hadron spectrum from hard partons throughout the medium.

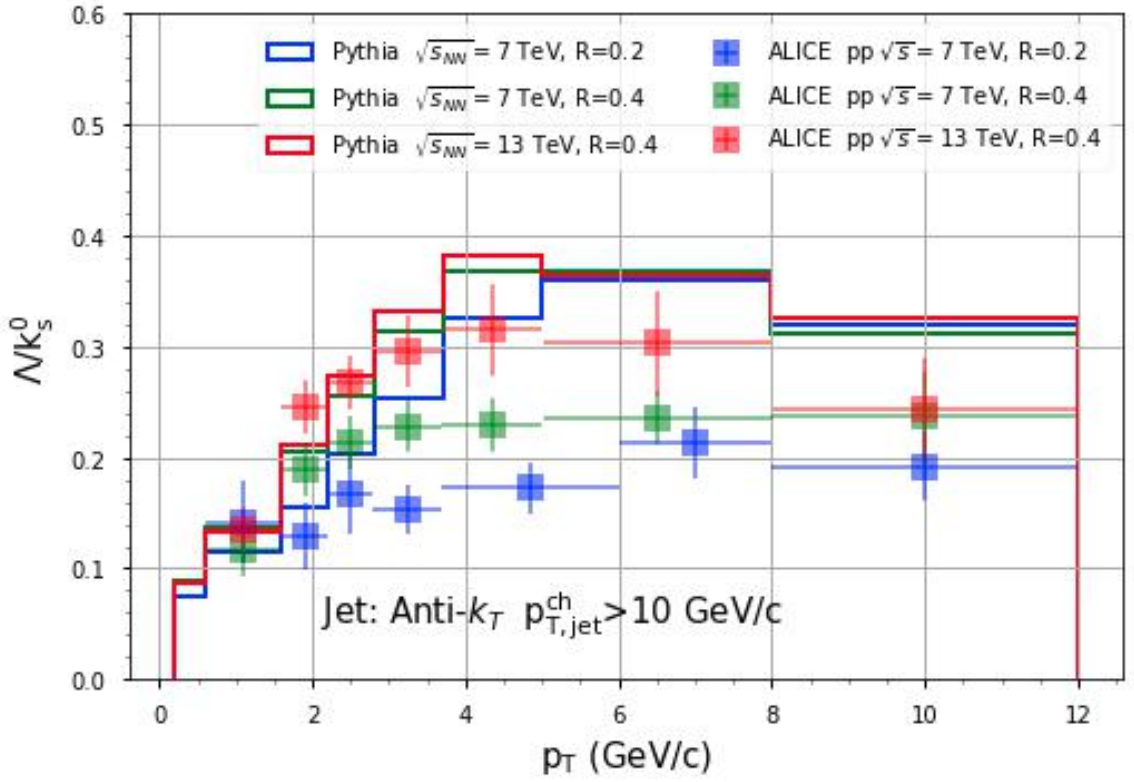
Hadron spectrum in inclusive jet at Pb-Pb 2.76 TeV

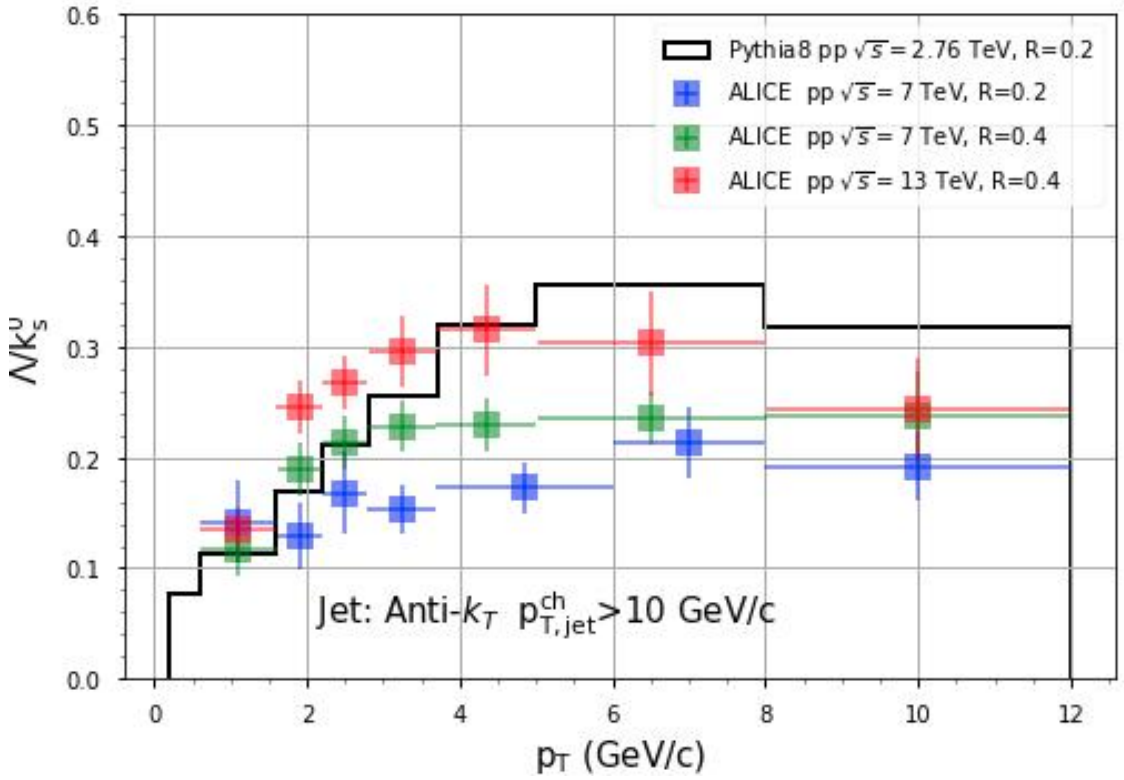




- No contribution from jet-induced medium flow at P_T>3.5 GeV/c.

Λ/k_s^0 in inclusive jet in pp collisions



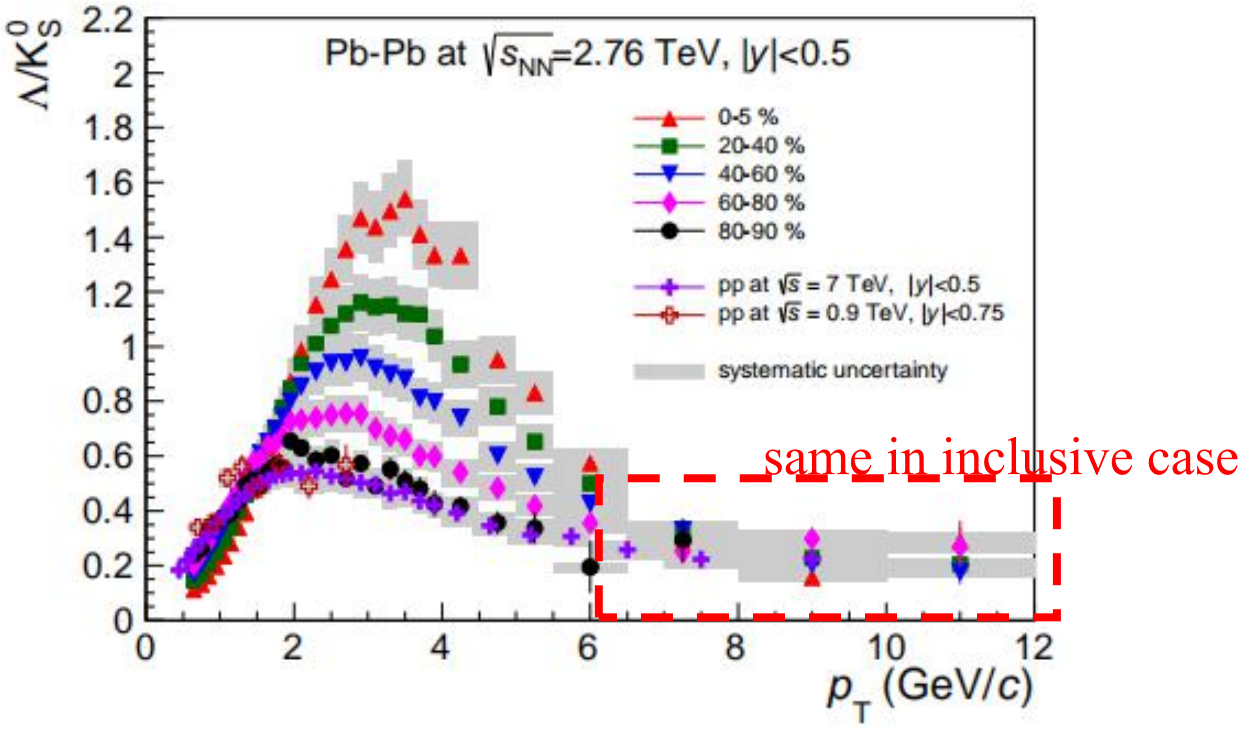


- Pythia results can't describe the data well.
- Λ/k_s^0 from pythia is almost independent of the collisional energy and little dependent on jet cone size.
- Λ/k_s^0 reach the maximum around P_T=4 GeV and tend to be the same at larger P_T.

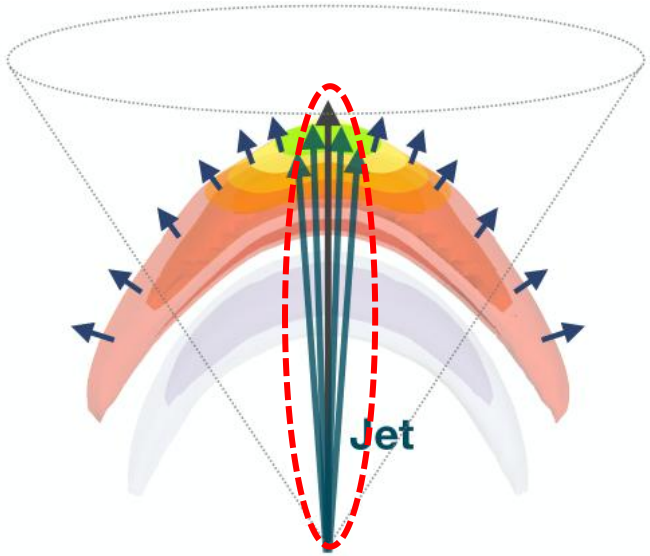
Λ/k_s^0 in hadrons from jet fragmentaion(LBT) in Pb-Pb 2.76 TeV

Due to model constrains, we just make an assumption that:

Λ/k_s^0 in hadrons from jet partons fragmentaion in Pb-Pb collisions is the same with Λ/k_s^0 in jet in p-p collisions



same in inclusive case



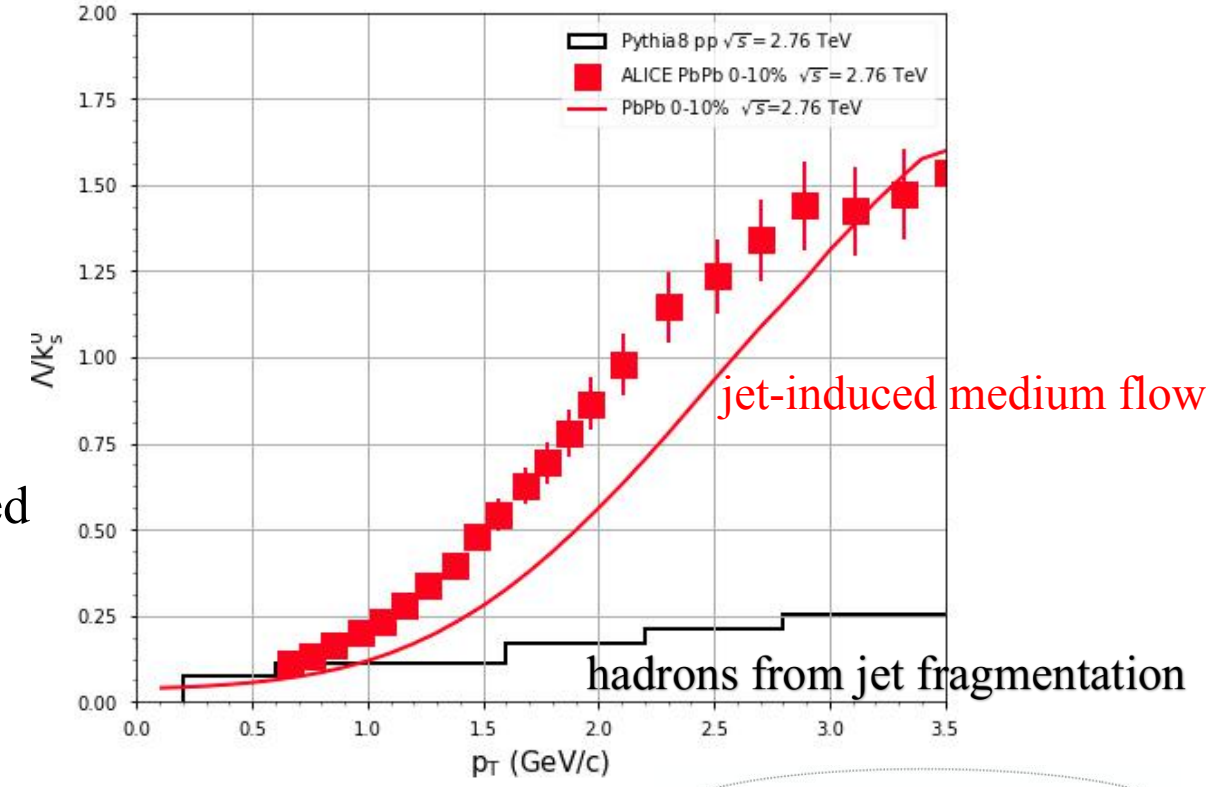
hadrons from jet fragmentation

- This assumption may be valid for large hardon pt range, not for small and intermediate pt range.
- In jet case, the ratio of quark jet to gluon jet increases due to medium effect may make baryon-to-meson ratio smaller at the intermediate pt range in Pb-Pb collisions compared with that in p-p collisions.

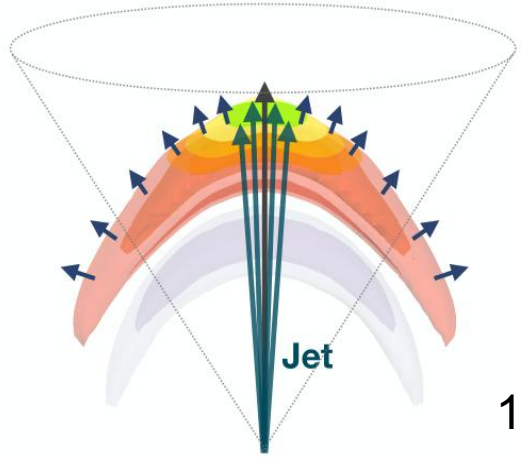
Λ/k_s^0 in jet-induced medium flow in Pb-Pb 2.76 TeV

Assumption: baryon-to-meson ratio in jet from jet-induced medium flow is the same with that in background medium.

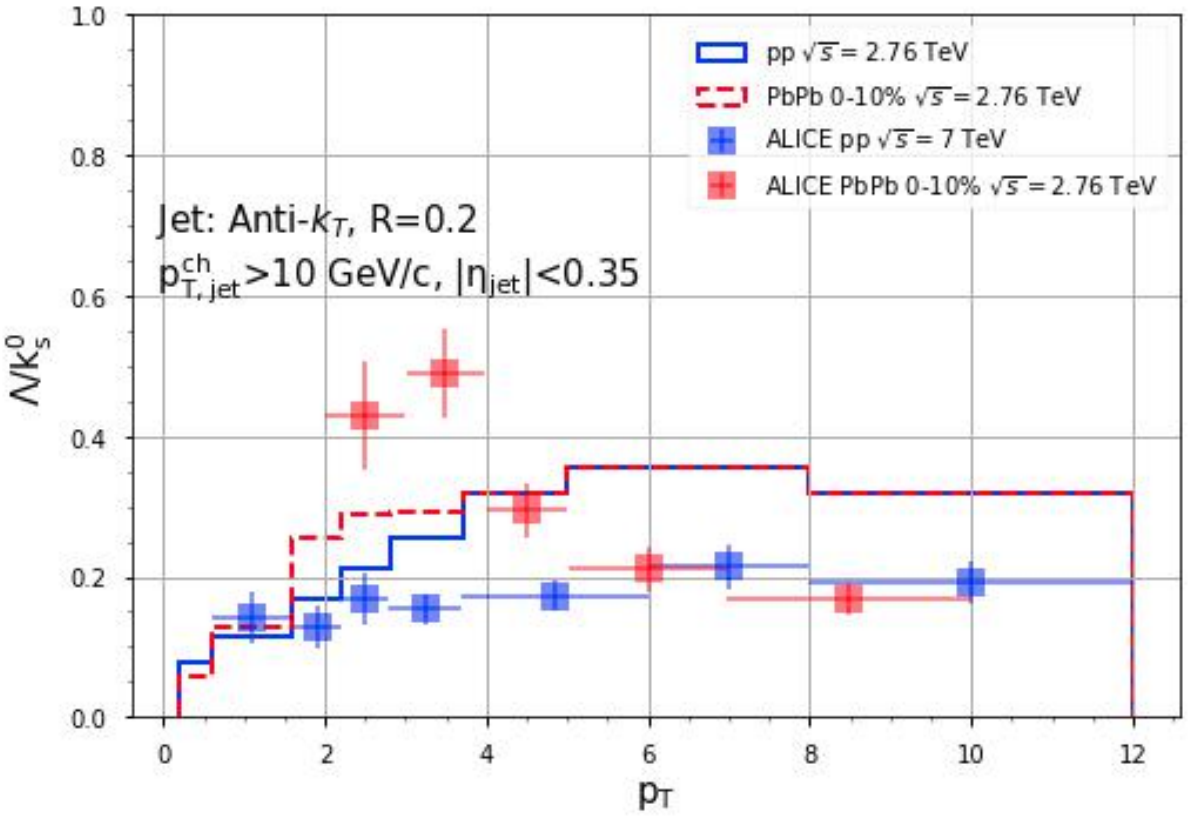
- jet-induced medium flow can be considered as collective behavior described by hydrodynamic model.
- jet-induced medium flow can be strongly affected by the strong background radial flow.



- The result is underestimated compare to the experiment.
- The maximum value of Λ/k_s^0 is up to 1.55 at P_T~3.5 GeV, which is much larger than that in pp collisions



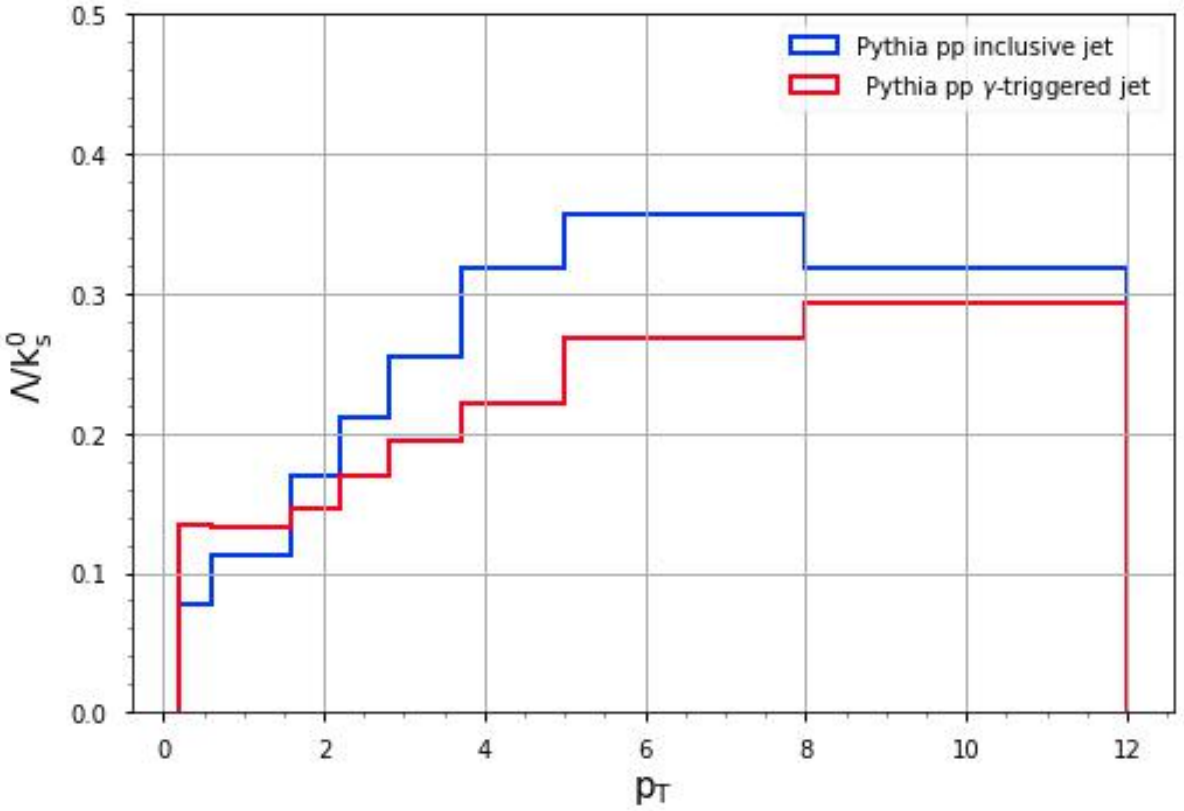
Λ/k_s^0 in inclusive jet from p-p and Pb-Pb collisions



Compared to the experimental results, the enhancement of Λ/k_s^0 in jet at 2<P_T<6 GeV/c is smaller. The reasons may come from

- Baryon-to-meson ratio in jet from pythia is larger than experimental data at intermediate P_T range in pp collisions.
- Under the assumption, baryon-to-meson ratio in jet from jet fragmentation(LBT) is the same with that in pp collision. But the relative ratio of quark jet to gluon jet in Pb-Pb collisions will be modified, and it may result in the suppresion of baryon-to-meson ratio from jet fragmentation in Pb-Pb collision at the intermediate P_T range.

baryon-to-meson ratio in γ-triggered jet



inclusive jet

p-p $\sqrt{s}$=2.76 TeV

R=0.2, $p^{\mathrm{ch}}_{T,\mathrm{jet}}$>10GeV/c

γ-triggered jet

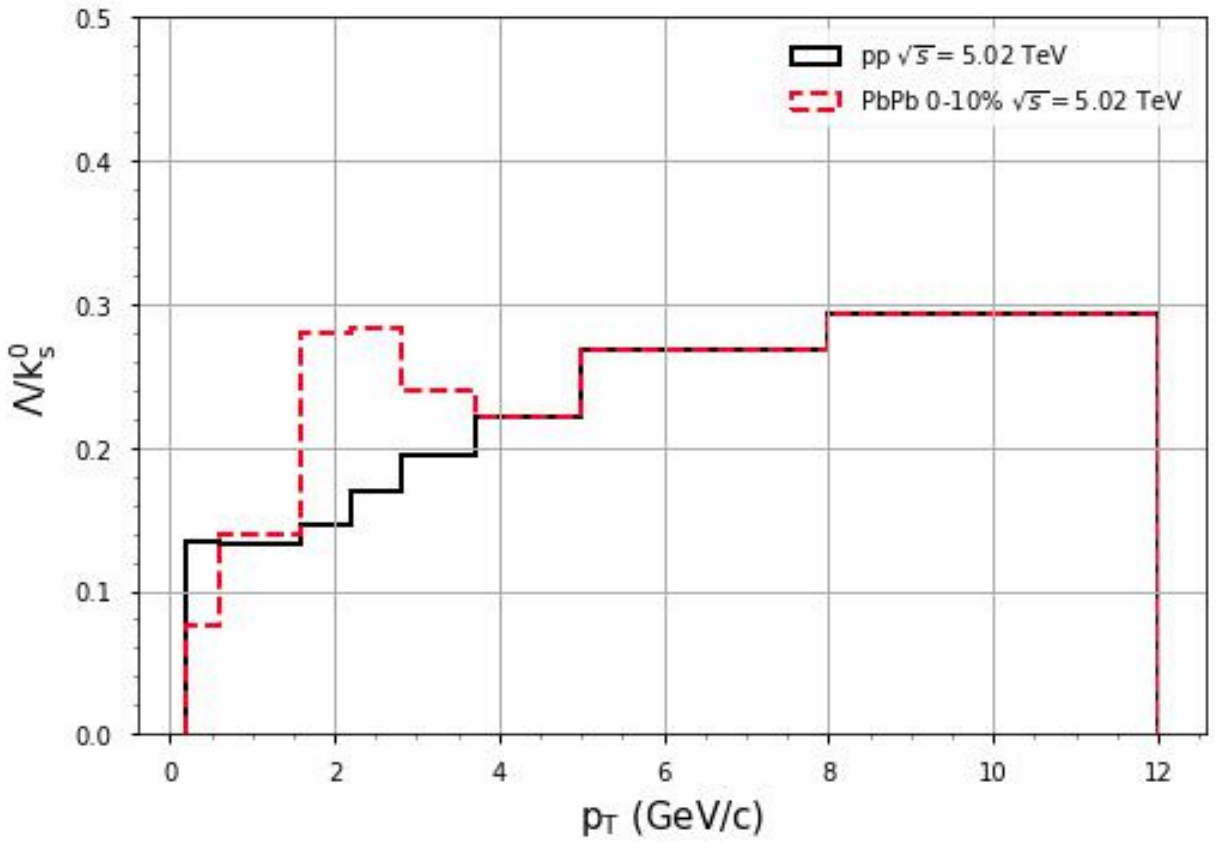
p-p $\sqrt{s}$=5.02 TeV

R=0.3, $p^{\mathrm{ch}}_{T,\mathrm{jet}}$>30GeV/c, p^{γ}_{T}>60GeV/c

Larger collisional energy, larger jet cone size, larger jet p_T, but Λ/k^0_s in γ-triggered jet is smaller than that in inclusive jet at the intermediate p_T range.

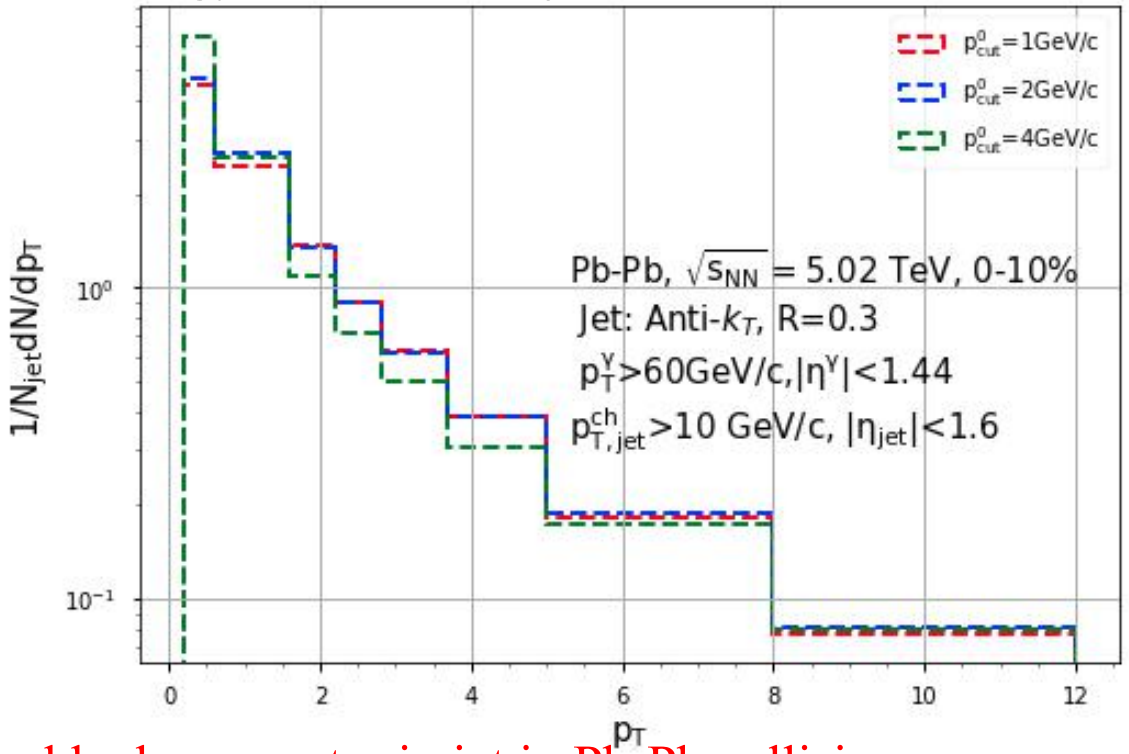
The relative ratio of quark jets to gluon jets is different. More quark jets in γ-triggered jet.

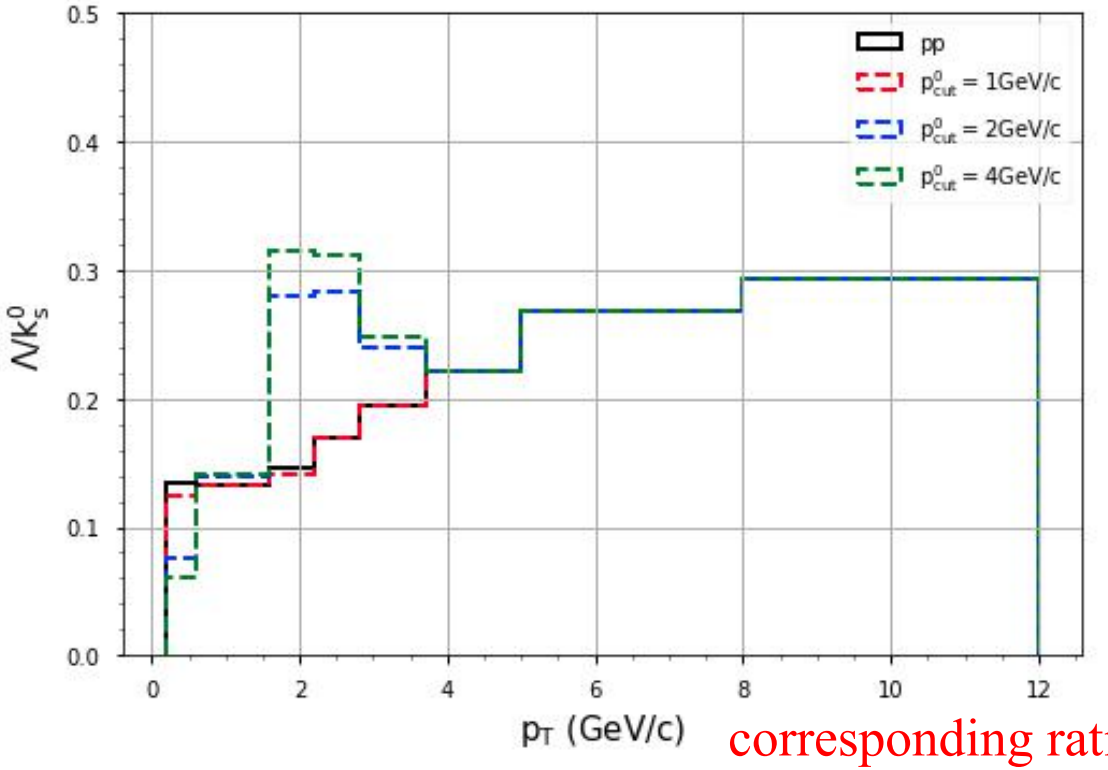
baryon-to-meson ratio in gamma-triggered jet



Parameter p^0_{cut} dependence

p^0_{cut}: used to judge whether the particle is deposited into medium, and determine how much energy transfer from jet to the medium





final hadron spectra in jet in Pb-Pb collision

corresponding ratio

- Hadron pt spectra and the correspondind baryon-to-meson ratio shows some dependence on p^0_{cut}
- Hadron pt spectra in jet in Pb-Pb collision is not sensitive to p^0_{cut} when p^0_{cut}=1 and 2 GeV/c, but the baryon-to-meson is.

Summary

We calculate strange baryon-to-meson ratio in jet in p-p and Pb-Pb collisions with two assumptions, due to model constrains.

- Strange baryon-to-meson ratio in jet increases at intermediate pt range in Pb-Pb collisions, compared with that in p-p colliison.
- But not enough to describe the data.

What can we get:

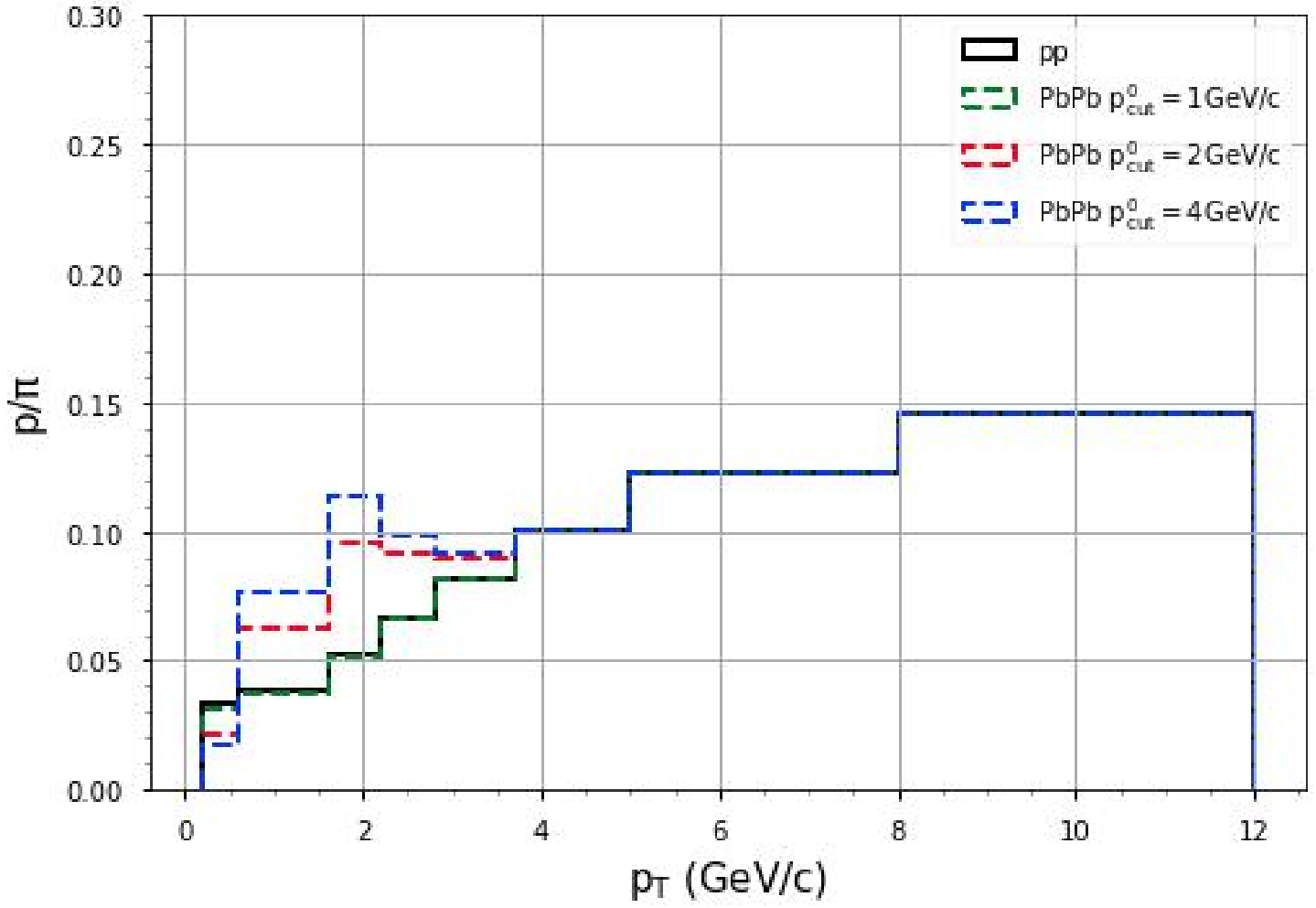
- baryon-to meson ratio in jet have potential to be a observable to study the medium responce. It provide a way to constrain the parameters in our CoLBT-hydro model.
- The enhancement of baryon-to-meson in jet in Pb-Pb collisions may causes by two factors: the larger baryon-to-meson ratio in jet-induced medium flow, the suppressed baryon-to-meson ratio from jet fragmentation in Pb-Pb collisions due to the modification of the fraction of quark jets to gluon jets.

What problem we need to solve:

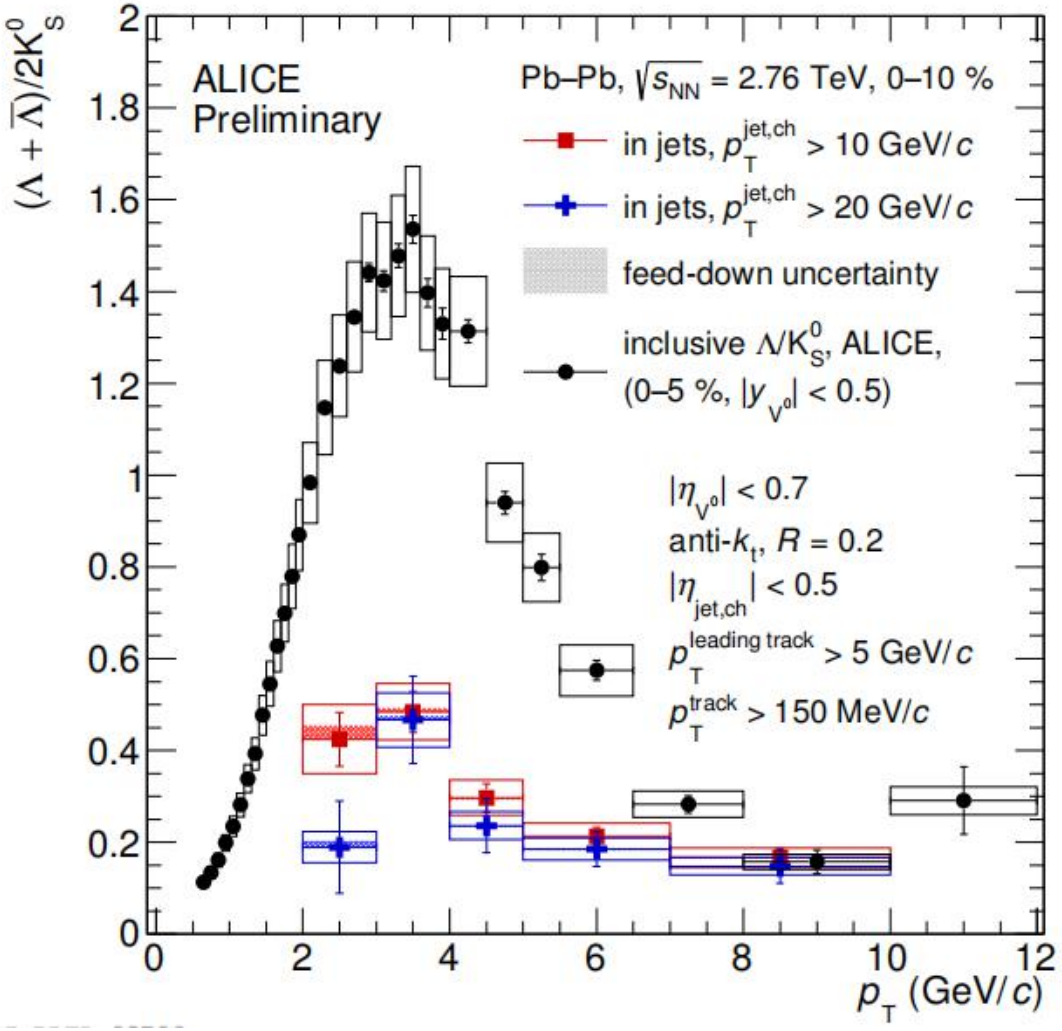
- baryon-to-meson ratio in jet in p-p collision
- Some conclusion need more evidence to be proved.

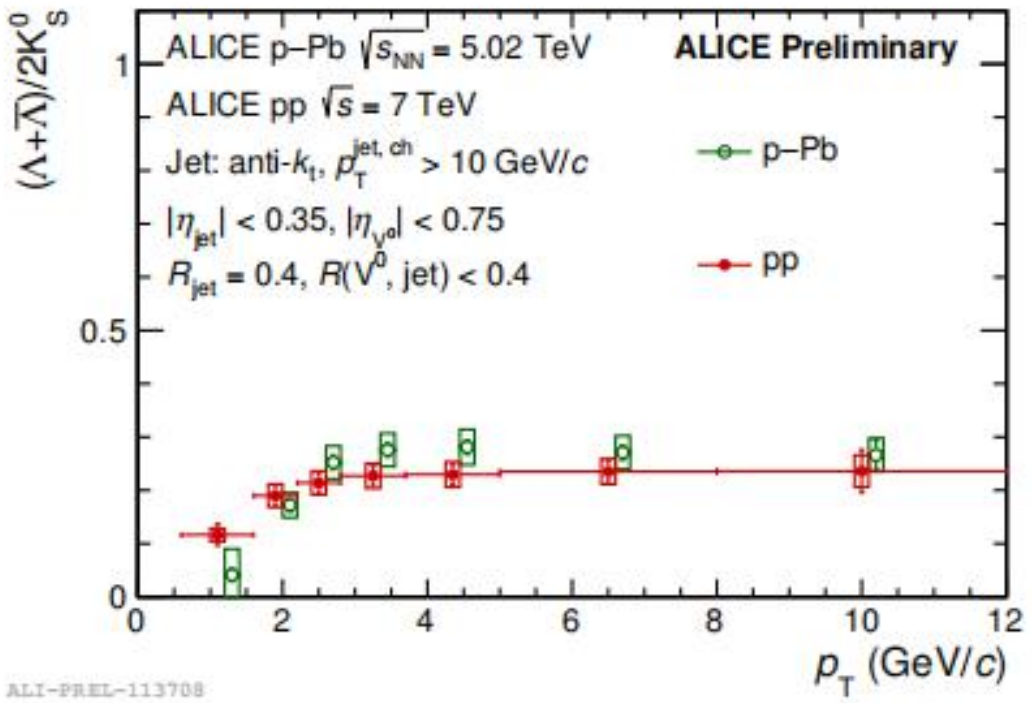
back up

p/π in gamma-triggered jet at PbPb 5.02 TeV

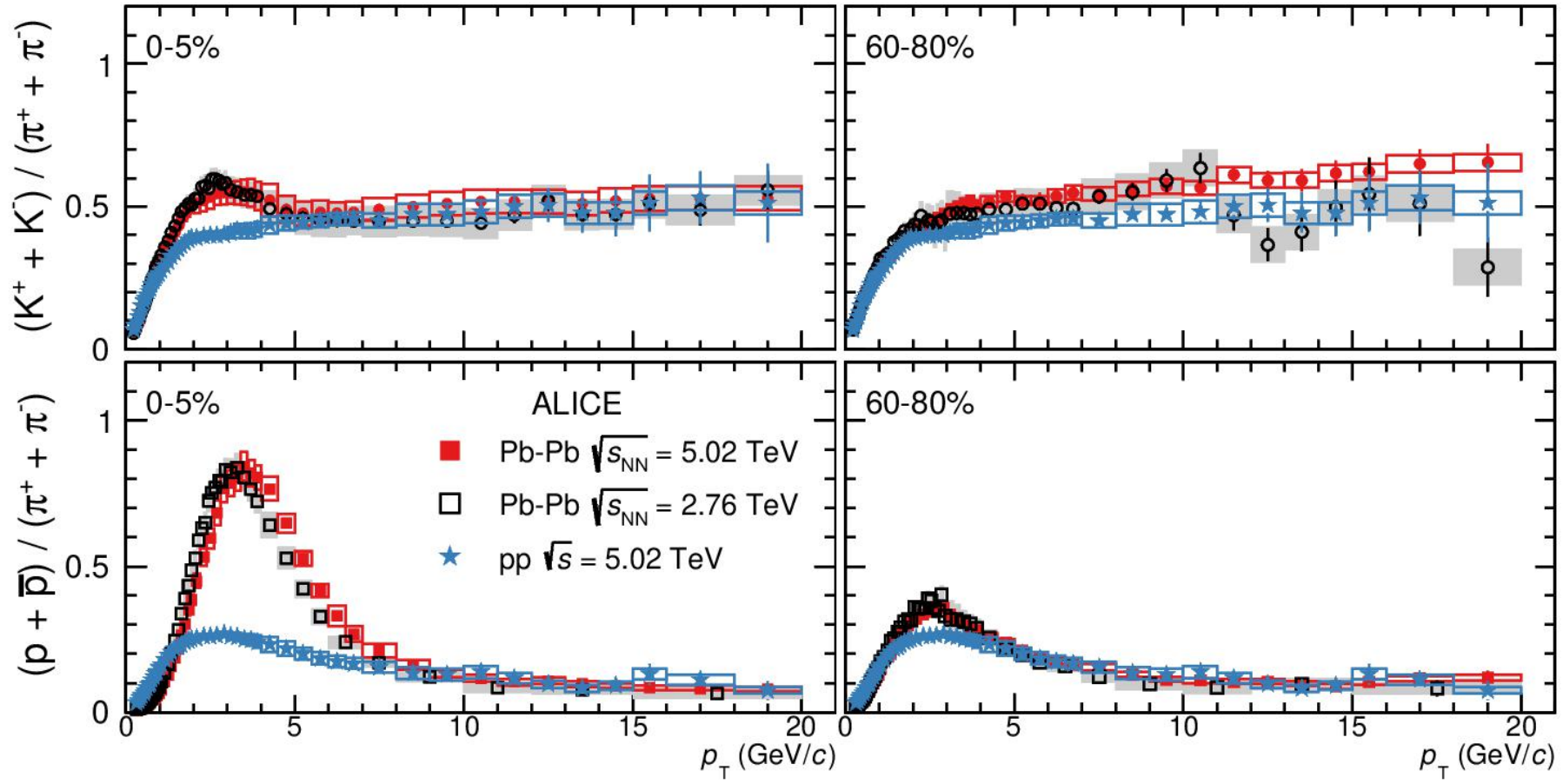


Λ/k_s^0 in PbPb 2.76(ALICE)



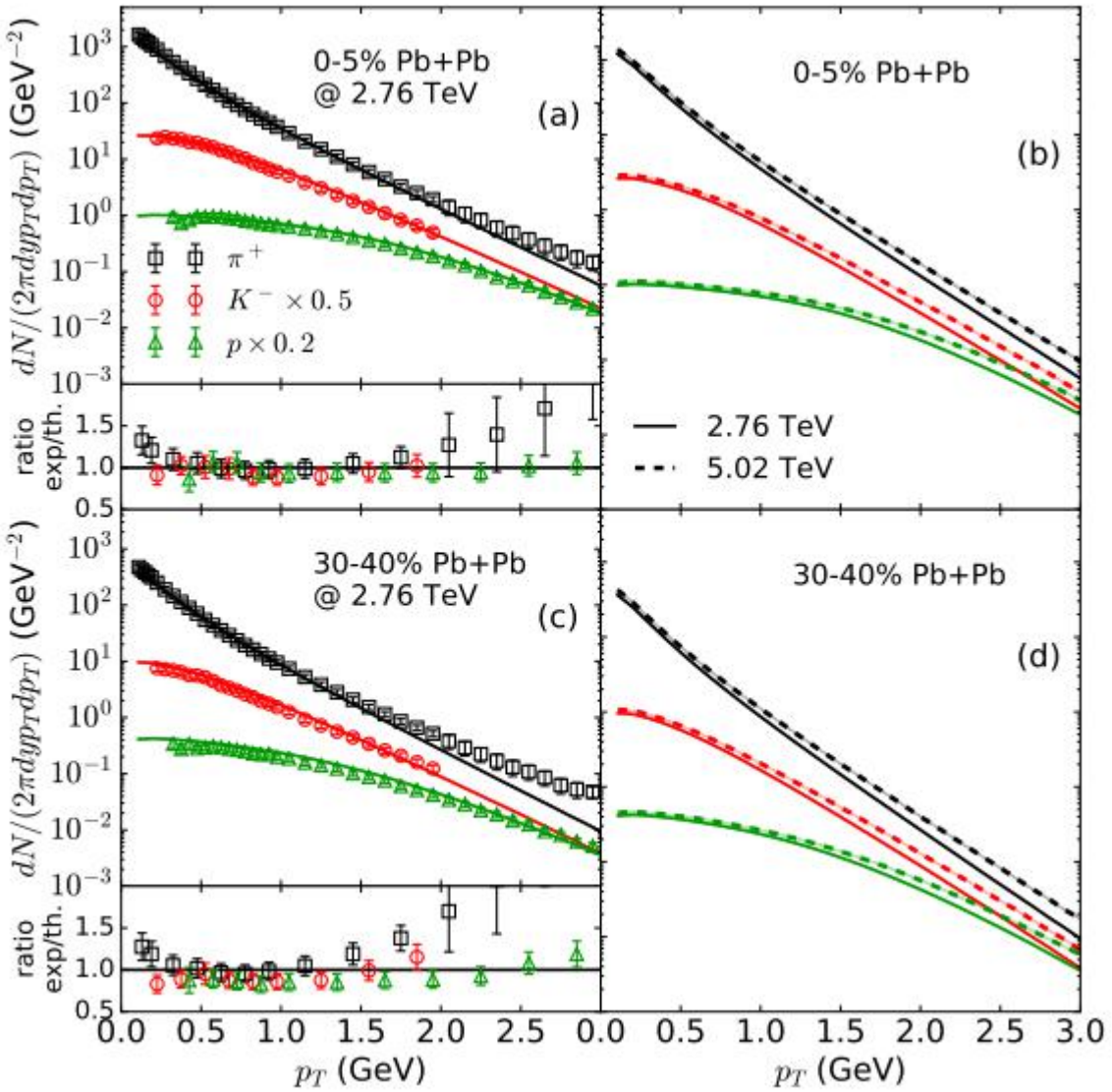


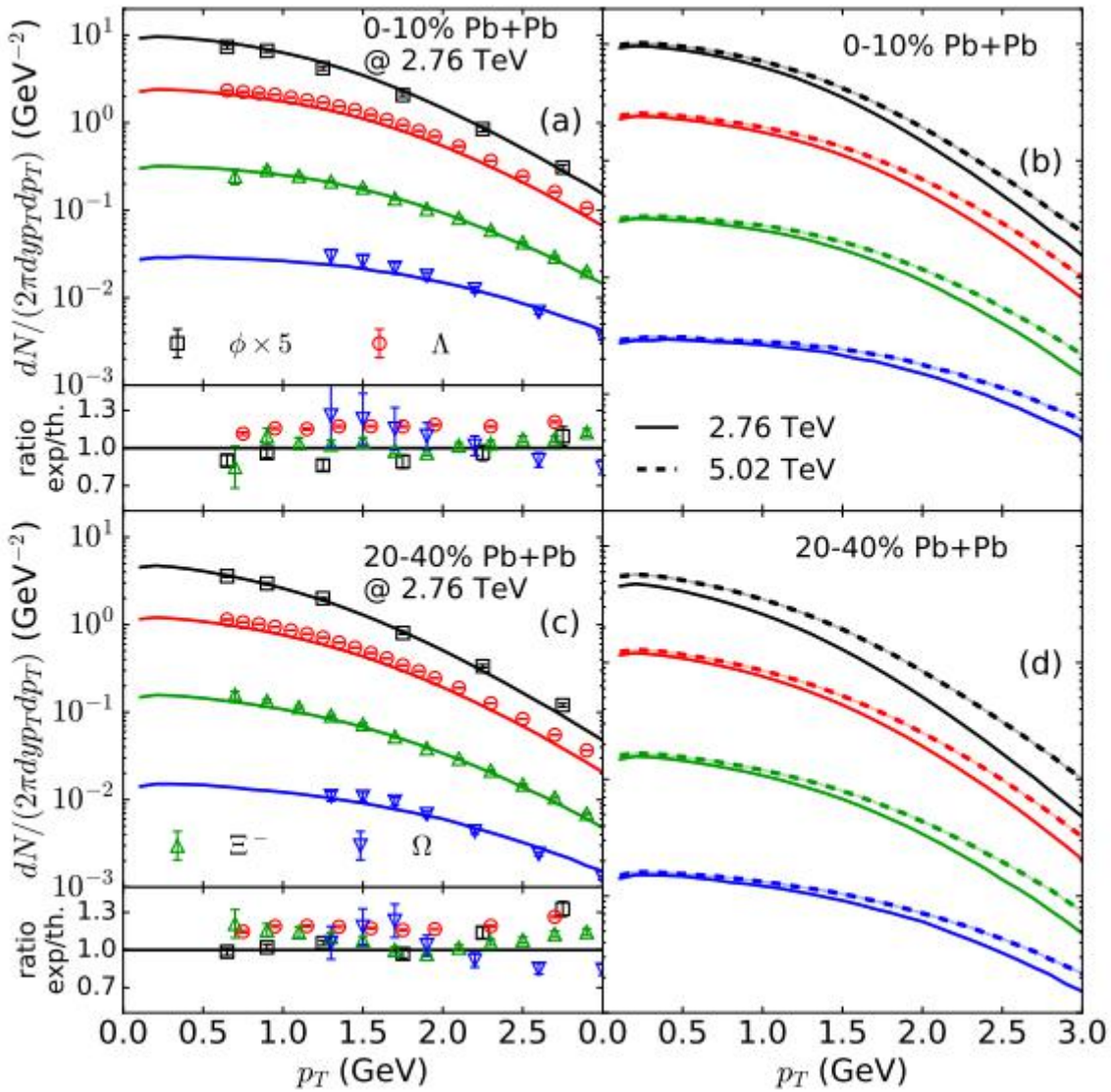
Centrality dependence of p/π and k/π in PbPb 5.02



arXiv:1910.07678

Hydrodynamic description for different species pt spectra





Phys.Rev. C95 (2017) no.6, 064913