γ-jet fragmentation function & jet-induced medium excitation

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Outlines

1 Introduction

2 Model description

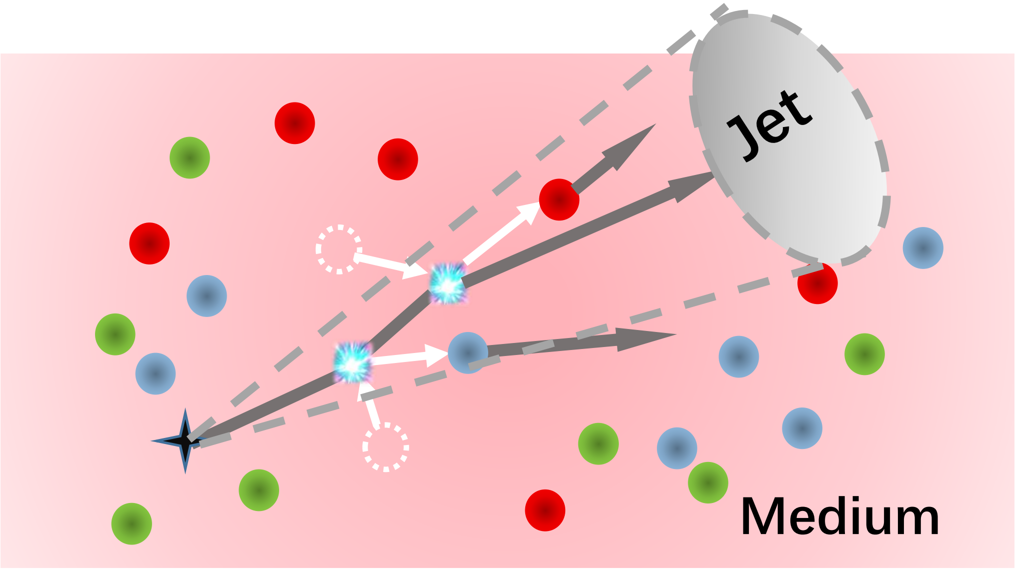
- Linear Boltzmann transport model(LBT)
- 3+1D hydrodynamic model(CLVisc)
- CoLBT-hydro model for jet transport and jet-induced medium excitation.

3 Results

- Medium modification of γ-triggered fragmentation function at RHIC
- Medium modification of γ-triggered fragmentation function at LHC

4 Summary and outlook

Motivation



To probe quark-gluon plasma:

✓ Observables : based on jet

✓ Phenomenon: jet quenching due to QGP medium effect

- Elastic scattering with medium constituents
- Medium-induced gluon radiation

✓ Technique: jet tomography

✓ suspression of leading hadrons
✓ dihadron and γ-hadron correlations

extended →

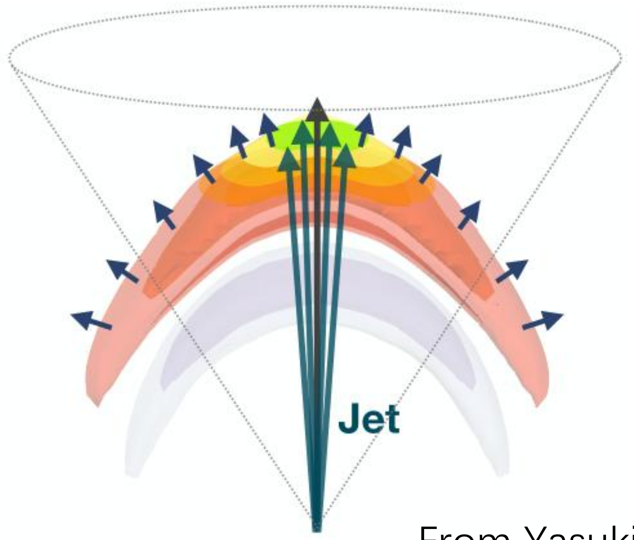
✓ jet spectra modification
✓ dijet and γ-jet correlations
✓ jet profiles

Motivation

It is very important to determine the medium-modified jet:

- **Energy loss of the leading shower partons**
- **The redistribution of the lost jet energy with medium flow.**

The study of medium response to jet-deposited energy is essential for a complete understanding of jet-medium interaction



From Yasuki Tachibana

Frameworks for the study of medium response to jet transport

✓ **Full Boltzmann transport approach**

Bulk matter: a collection of quasi-classical gluons and quarks

✓ **Jet+hydrodynamics approach**

Bulk matter: simulated by relativistic hydrodynamics

Jet: jet transport equations or Monte Carlo model.

Problems in some study:

- **No recoil partons contribution in final reconstructed jet**
- **Neglect the effect of medium response on the subsequent evolution of hard jets**
- **No concurrent to simulate for both jet transport and medium evolution.**

Linear Boltzmann Transport model(LBT)

CoLBT-hydro model

Linear Boltzmann Transport model (LBT) + 3+1D hydrodynamic model (CLVisc)

- ✓ Jet transport is simulated according to linear Boltzmann equations

$$p_1 \cdot \partial f_1(x_1, p_1) = E_1(\mathcal{C}_{\text{el}} + \mathcal{C}_{\text{inel}})$$

- ✓ Elastic scattering and medium-induced gluon radiation

$$\frac{dN_g^a}{dzdk_\perp^2 dt} = \frac{2\alpha_s C_A P_a(z)}{\pi} \frac{k_\perp^4}{(k_\perp^2 + z^2 m^2)^4} \cdot \frac{p \cdot u}{p_0} \hat{q}_a(x) sin^2(\frac{t - t_i}{\tau_f}),$$

- ✓ Keep track of jet shower partons and thermal recoil partons.
- ✓ Introduce "negative partons" as back reaction.

Jet-induce medium partons

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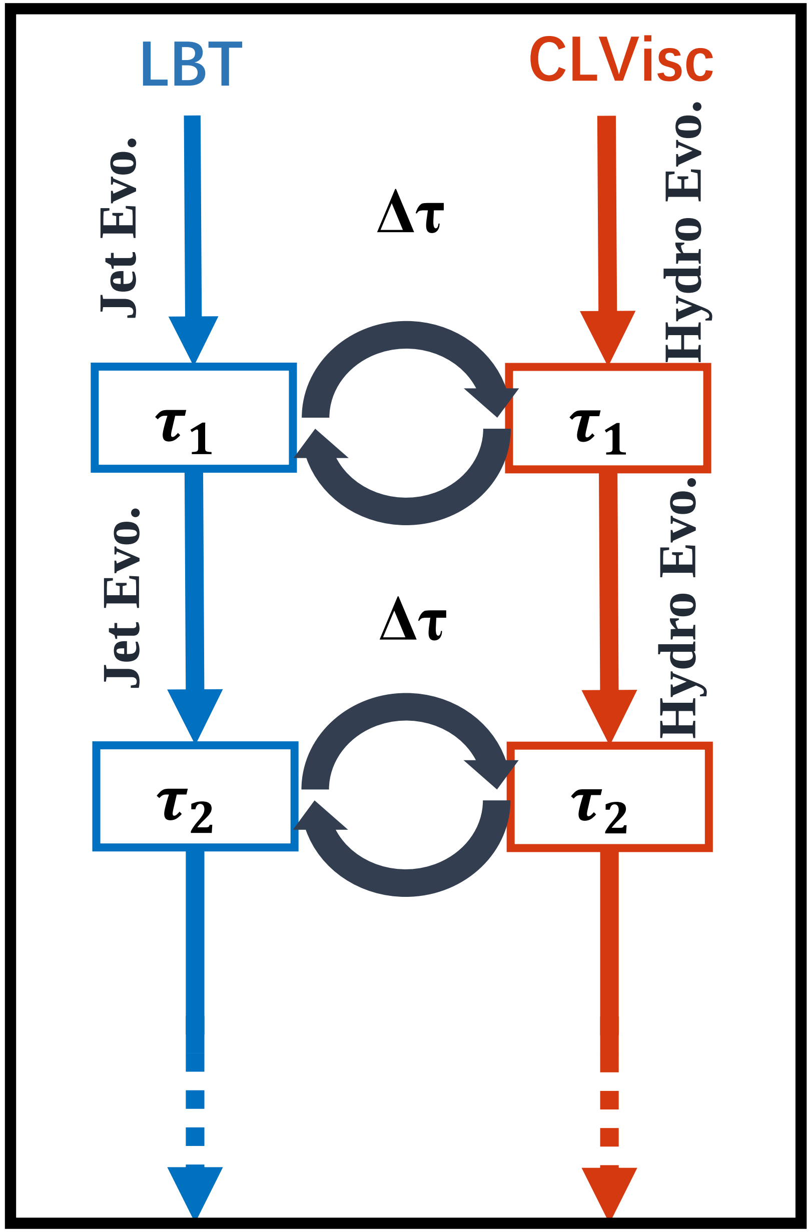
Jet-induce medium partons

- ✓ Hydrodynamic evolution of bulk medium
- ✓ Hadron spectrum calculated from freeze-out hypersurface
- ✓ Hadron resonance decay

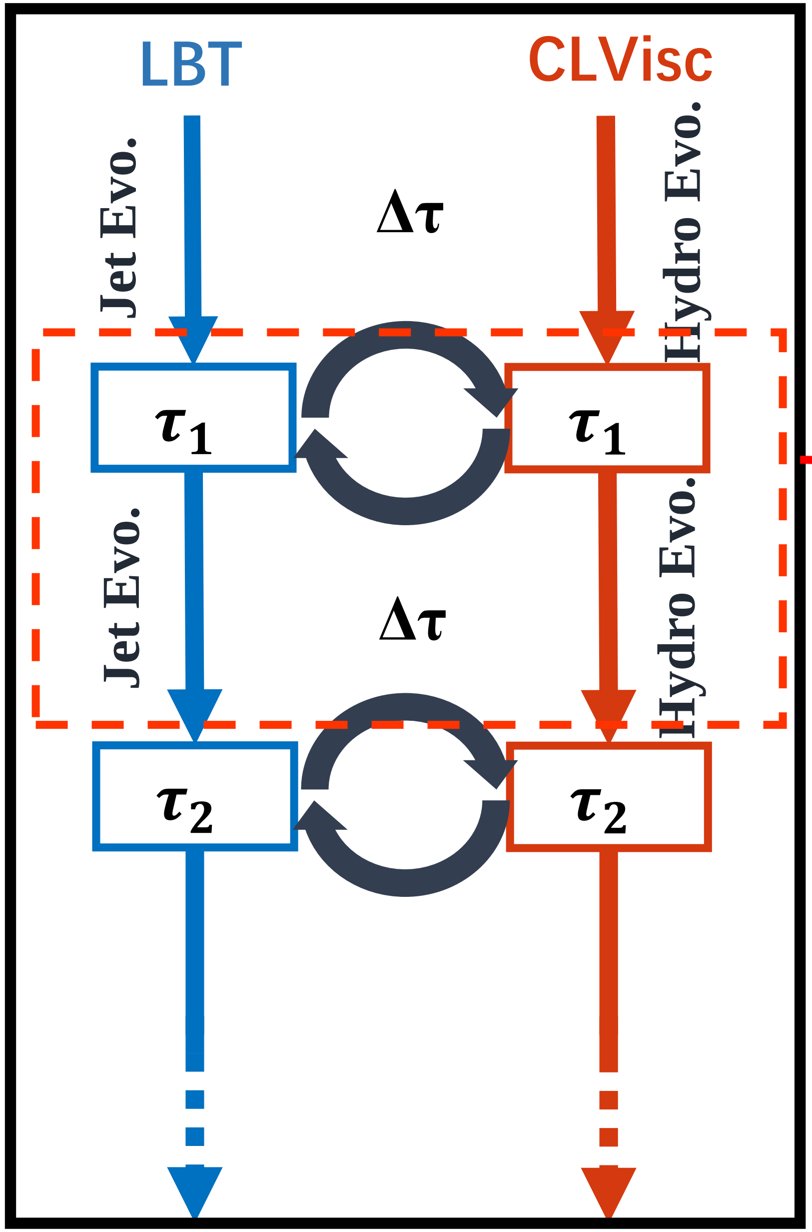


CoLBT-hydro model

Linear Boltzmann Transport model (LBT) + 3+1D hydrodynamic model (CLVisc)

- ✓ formulated in Milne coordinates $(\tau, x_\perp, \eta_s)$
- ✓ simulated in sync with each other

CoLBT-hydro model



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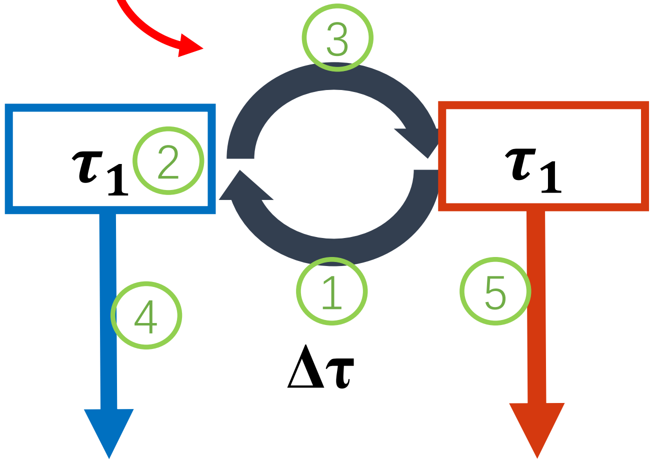


① provide medium info (T, u) to jet partons

② carry out jet shower partons' transport according to medium info.

③ soft($p \cdot u < p^0_{cut}$) and 'negative'($p \cdot u < 0$) partons deposited into medium as source term

④ hard($p \cdot u \geq p^0_{cut}$) partons propagate in LBT frame

⑤ update the medium info through solving $\partial_\mu T^{\mu\nu} = j^\nu$

Hydrodynamic equations with source term

Assumption: Instantaneous local thermalization of deposited energy and momentum

Hydrodynamic equation with source term

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

- $T^{\mu\nu}_{QGP}$: **Energy-momentum tensor of QGP fluid**
- j^ν_{jet}: **Energy and momentum deposited from jet**

source term:

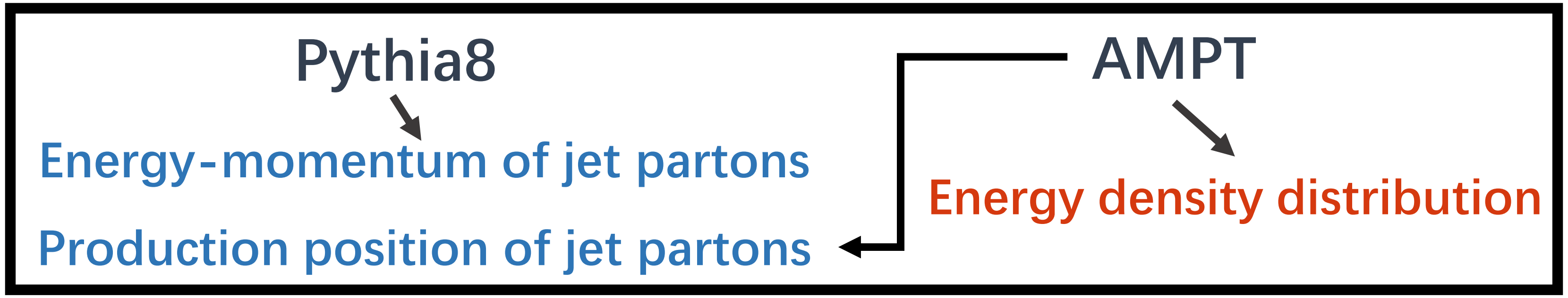
$$j^\nu_{jet}(x) = \sum_i \frac{\theta(p^0_{cut} - p_i \cdot u)p^\nu_i}{\Delta\tau}\delta^3(\vec{x} - \vec{x}_i)$$

- soft partons ($p \cdot u < p^0_{cut}$)
- negative partons ($p \cdot u < 0$)

Gaussian approximation:

$$\frac{\delta^3(\vec{x} - \vec{x}_i)}{\Delta\tau} \rightarrow \frac{1}{\tau\Delta\tau(2\pi)^{3/2}\sigma^2_r\sigma_{\eta_s}} exp[-\frac{(\vec{x}_\perp - \vec{x}_{\perp i})^2}{2\sigma^2_r} - \frac{(\eta_s - \eta_{si})^2}{2\sigma^2_{\eta_s}}]$$

Initial condition



AMPT:

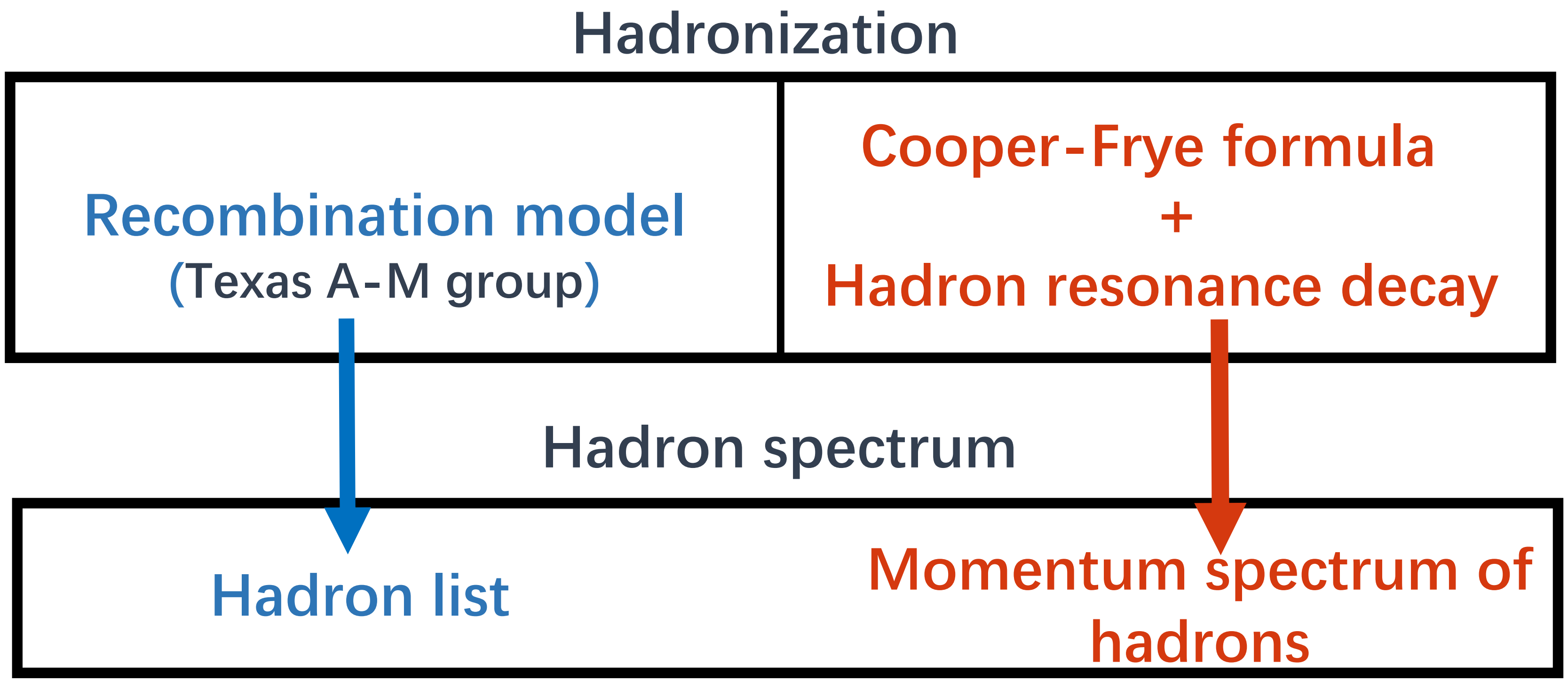
- ✓ Energy density distribution includes transverse and longitudinal fluctuation.
- ✓ Production positions of jet partons: sampled from spatial distribution of binary hard processes.

Pythia8:

- ✓ Energy-momentum of jet partons

different in each event.

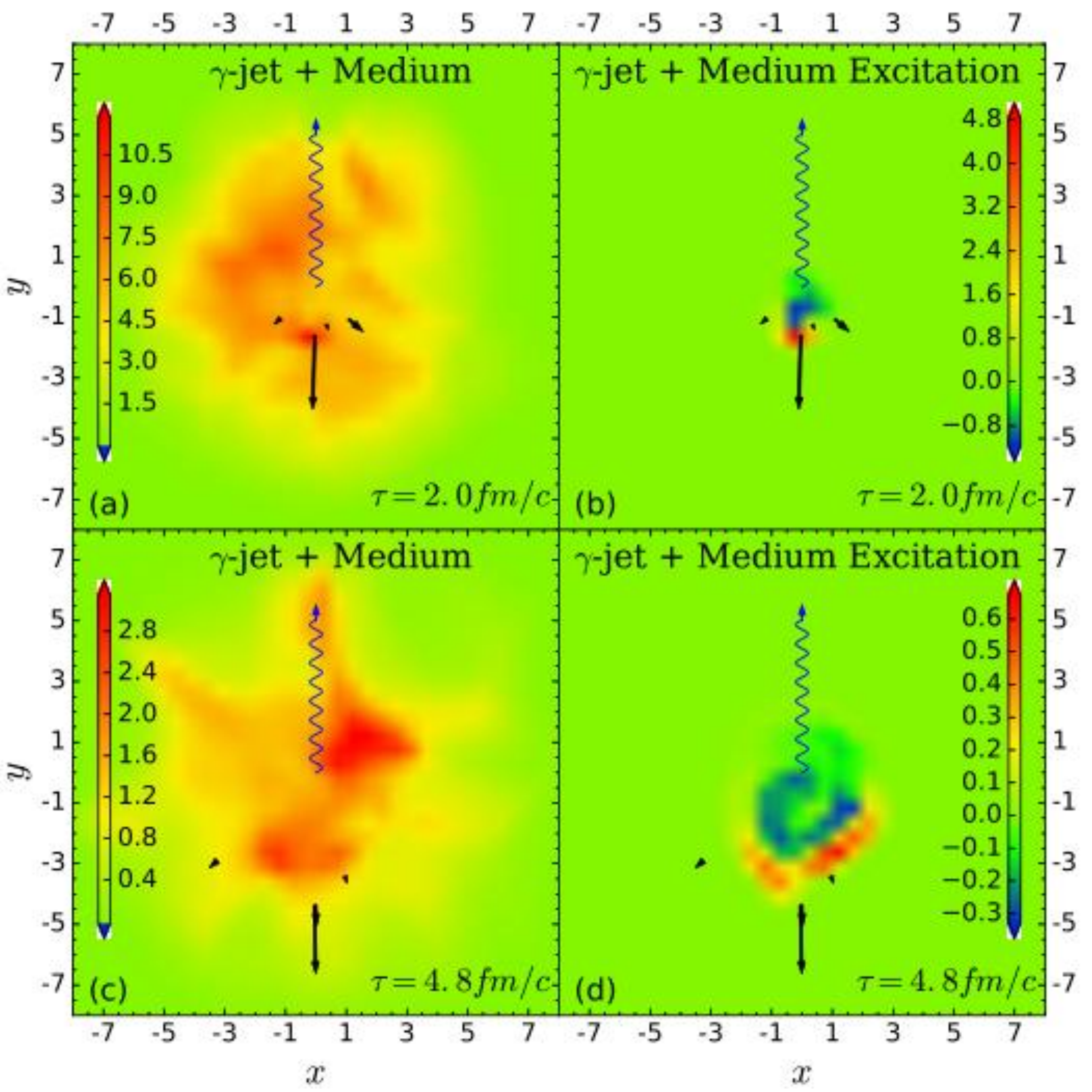
Hadronization



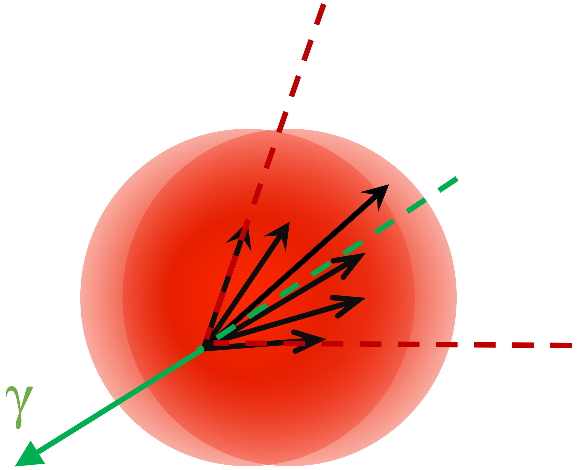
Not consider:

- ✓ Recombination between jet shower partons and thermal partons
- ✓ hadron cascade

Jet transport and jet-induce medium excitation



Medium modification of γ-triggered fragmentation function



$$z = \frac{p_T^h}{p_T^\gamma} \qquad \varepsilon = \log\frac{1}{z} \qquad D(z) = \frac{1}{N_{event}}\frac{dN}{dz}$$

$$I_{AA}(z) = \frac{D_{AA}(z)}{D_{pp}(z)} \qquad I_{AA}(\varepsilon) = \frac{D_{AA}(\varepsilon)}{D_{pp}(\varepsilon)}$$

In our calculation:

- ✓ p+p results :
  jet partons from Pythia8 + recombination model
- ✓ Au+Au results :

$$D(z) = \left.\frac{dN_h}{dydz}\right|_{LBT} + \left.\frac{dN_h}{dydz}\right|_{hydro}^{w/jet} - \left.\frac{dN_h}{dydz}\right|_{hydro}^{no/jet}$$

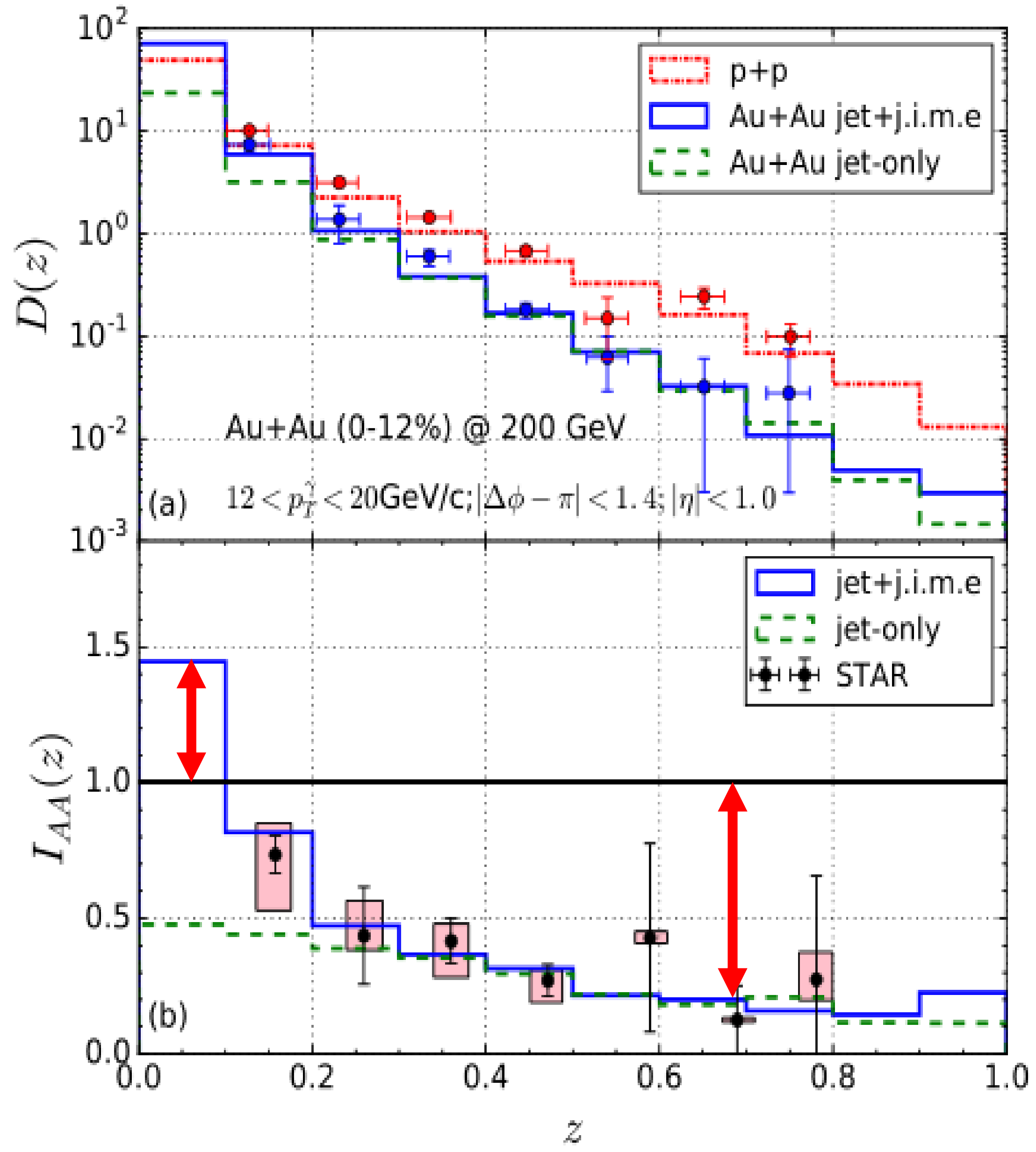
background

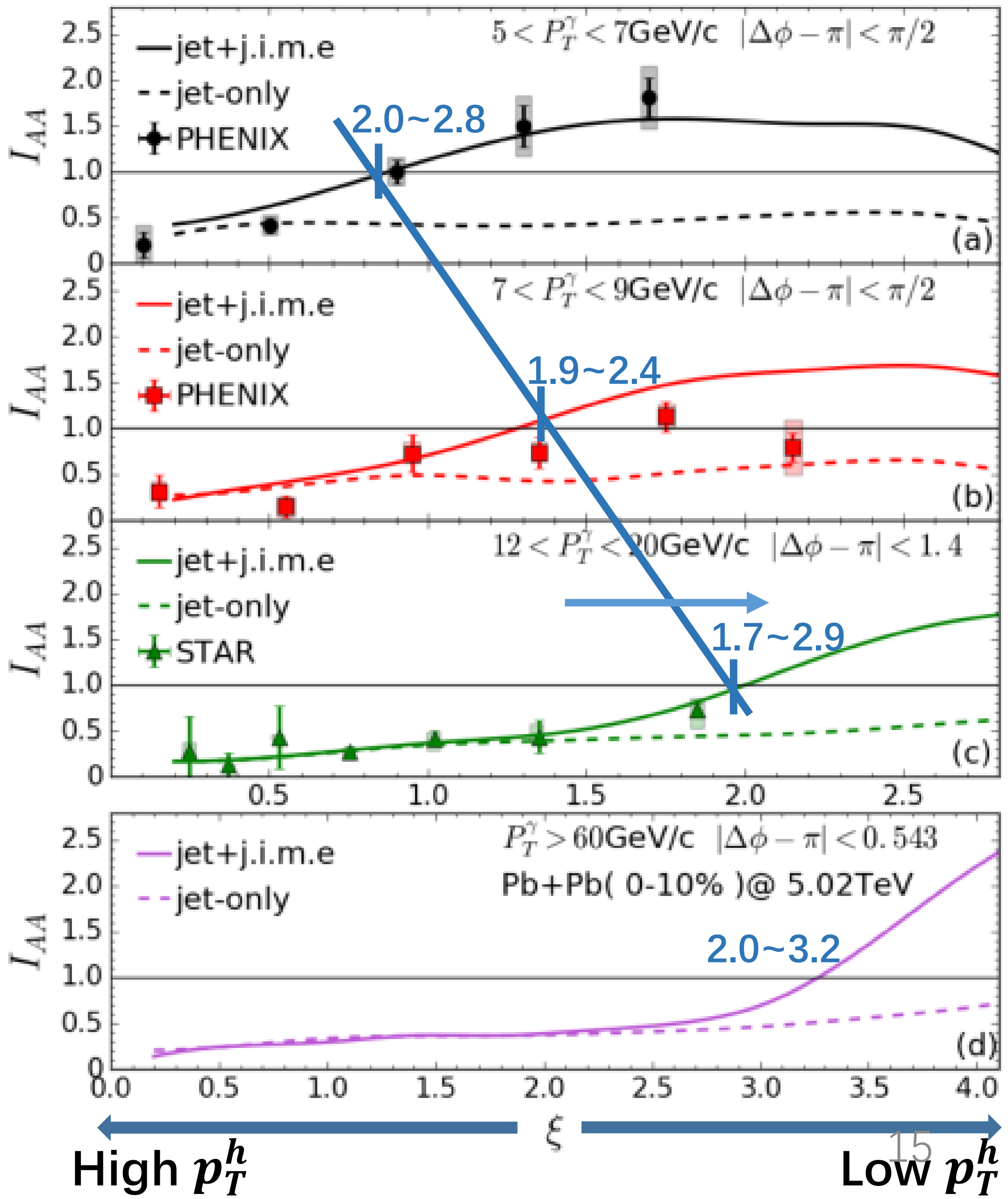
Remnant recoil parton contribution

Medium response by energy-momentum deposition

jet-induced medium excitation(j.i.m.e)

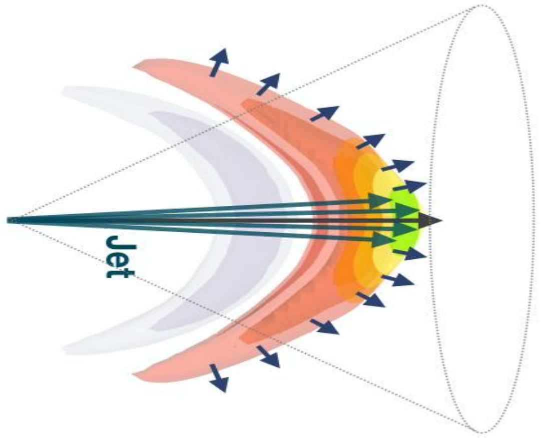
Medium modification of γ-triggered fragmentation function





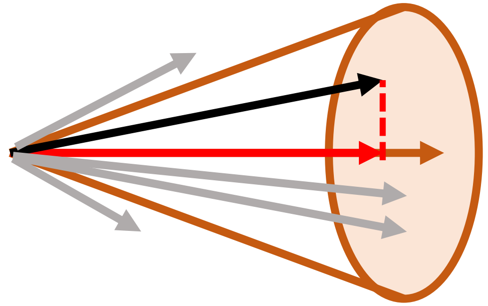
γ-triggered fragmentation function at LHC energy

Jet reconstruction



Jet-hadron FF

$$D(\varepsilon) = \frac{1}{N_{jet}} \frac{dN}{d\varepsilon} \qquad \varepsilon = \log \frac{1}{z}$$



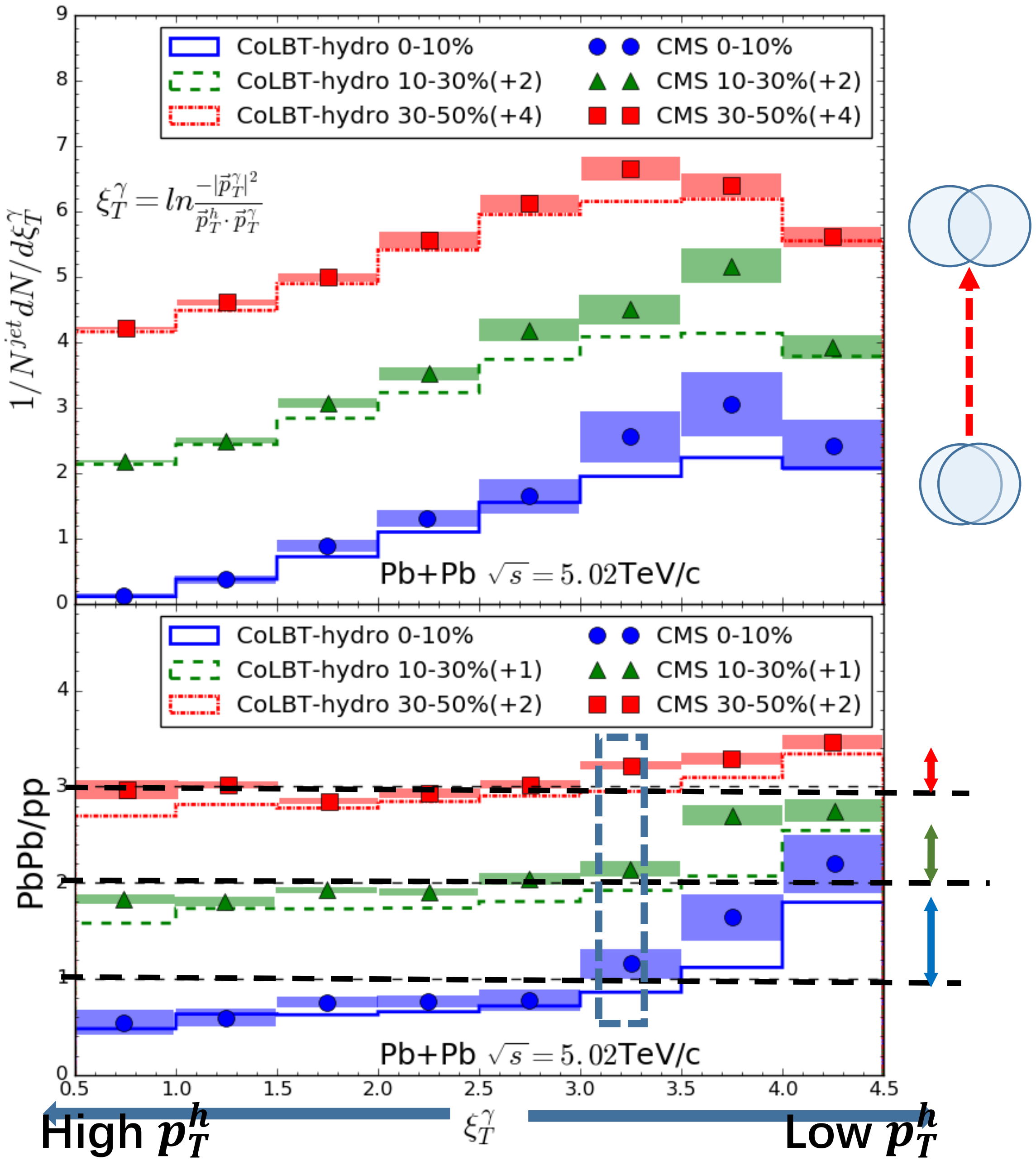
$$z = \frac{p_{||}^{h}}{p^{jet}}$$

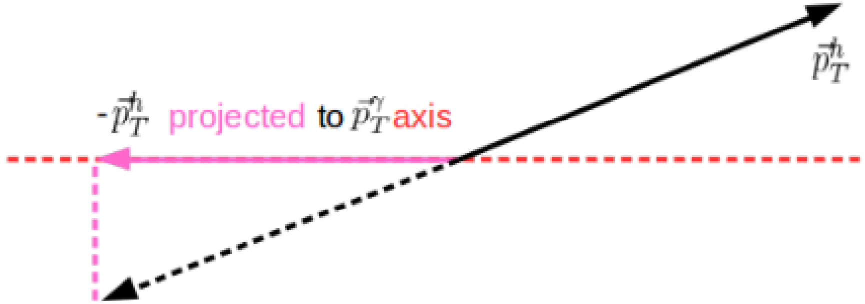
In our calculation,

Use all final particles from both jet shower particles and j.i.m.e with Anti-k_T algorithm in the FASTJET framework.

Project $p_T^h(p^h)$ onto jet axis and look at the fraction in $p_T^{jet}(p^{jet})$

γ-triggered fragmentation function at LHC energy





$$\xi_T^\gamma = ln\frac{-|\vec{p}_T^\gamma|^2}{\vec{p}_T^h \cdot \vec{p}_T^\gamma},$$

✓ Based on the initial parton energy before jet quenching approximately.

Centrality dependence:

✓ Enhancement of low p_T^h hadrons

✓ Suppression of high p_T^h hadrons

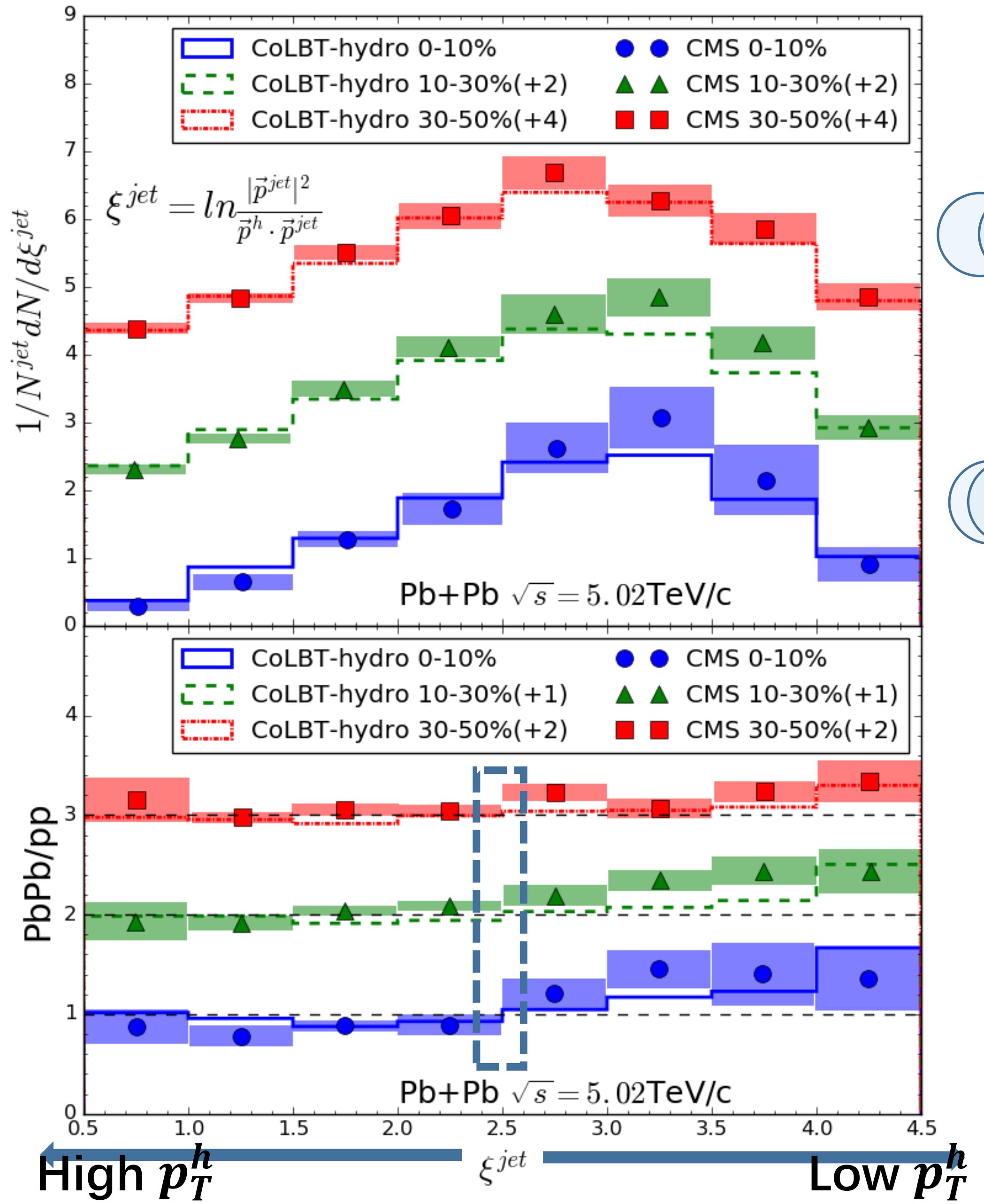
→ path length and temperature different

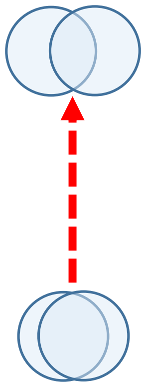
No(slightly) centrality dependence:

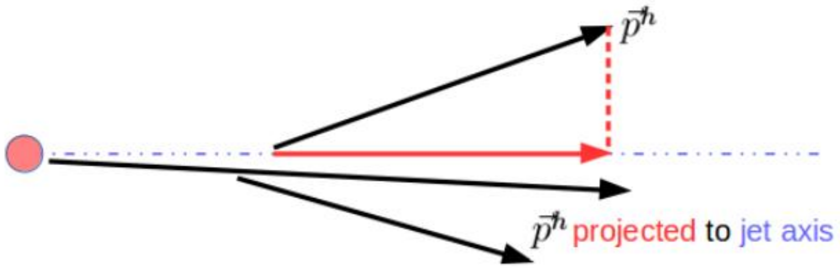
✓ Transition point ($I_{AA} = 1$) from relative enhancement to suppression.

$$\varepsilon_T^\gamma \approx 3.2 \rightarrow p_T^h \approx 2\sim3 \text{ GeV}$$

γ-triggered fragmentation function at LHC energy







$$\xi^{jet} = ln\frac{|\vec{p}^{jet}|^2}{\vec{p}^h \cdot \vec{p}^{jet}}$$

- ✓ Based on reconstructed jet energy

Centrality dependence:

- ✓ Enhancement of low p_T^h hadrons
- ✓ Suppression of high p_T^h hadrons

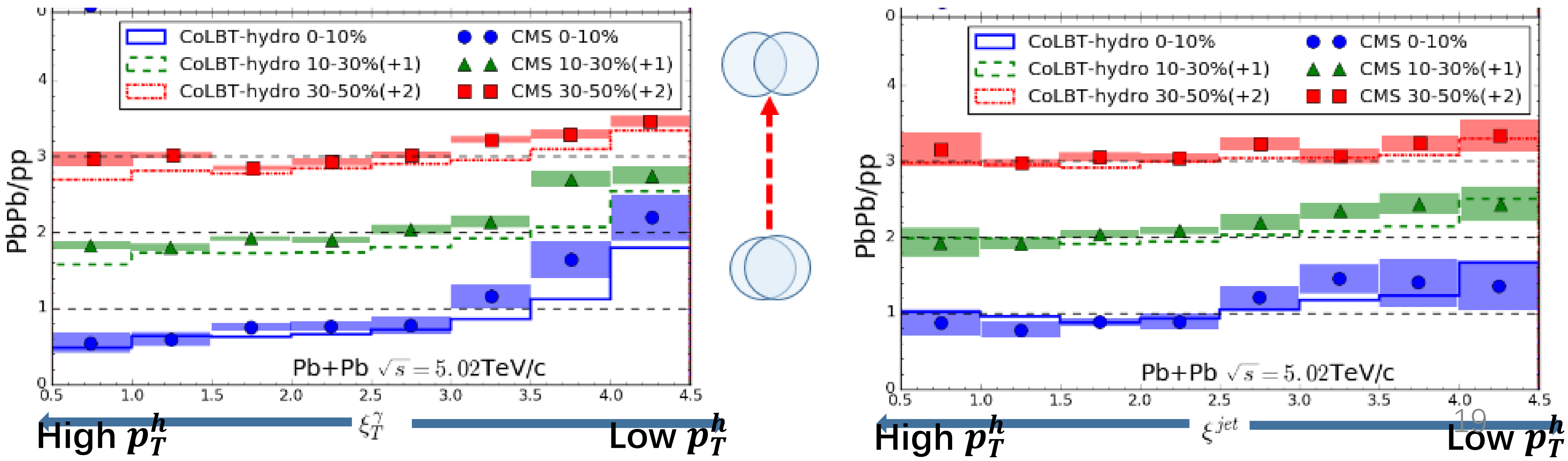
  path length and temperature different

No(slightly) centrality dependence:

- ✓ Transition point ($I_{AA} = 1$) from relative enhancement to suppression.

  $\varepsilon^{jet} \approx 2.5 \rightarrow p_T^h \approx 2\text{~}3$ GeV

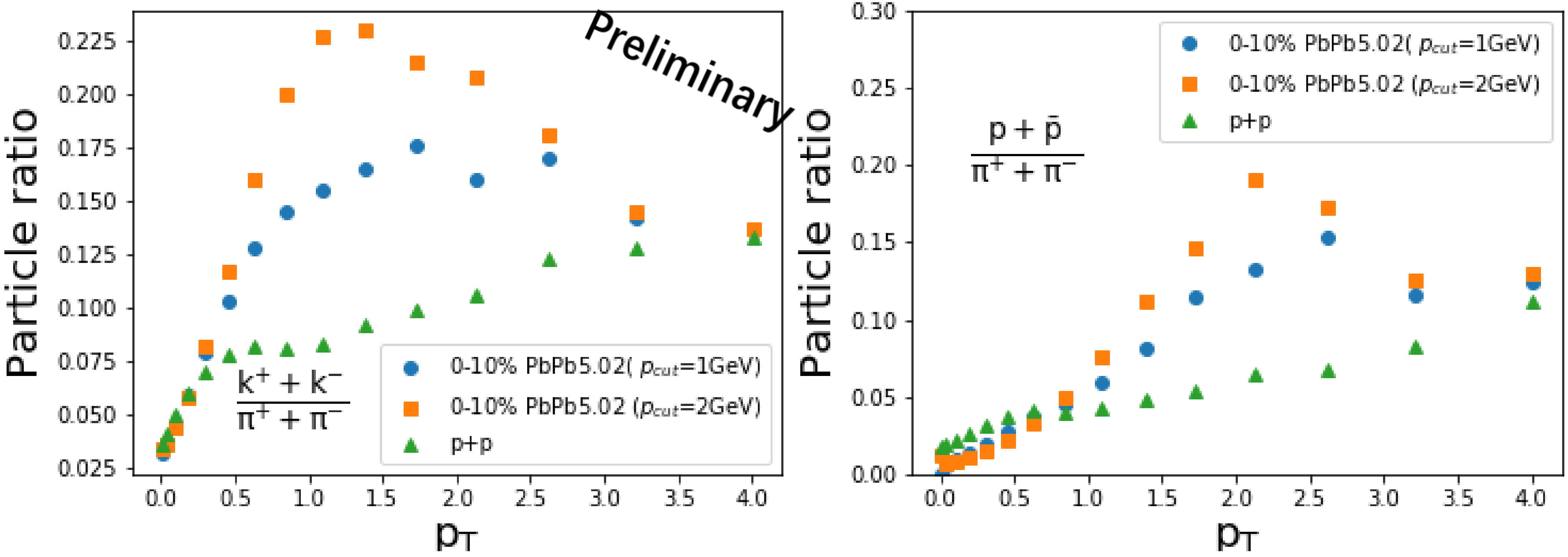
γ-triggered fragmentation function at LHC energy



The modification in the ratio PbPb/pp is more apparent in the ε_T^γ case than in the ε^{jet} case.

- ✓ Reconstructed jet energy is smaller than initial parton energy(γ energy) in p+p collision
- ✓ Jet lose their energy and momentum due to jet quenching in Pb+Pb collision

Particle ratio in reconstructed jet



Summary and outlook

Summary:

- ✓ We develop CoLBT-Hydro model for simultaneous event-by-event simulations of jet propagation and hydrodynamic evolution of the bulk medium including jet-induced medium excitation.
- ✓ Medium response is important in analysis of jet-related observables.

Outlook:

1. The improvement of CoLBT-hydro model
2. More jet-related observables calculated using CoLBT-hydro model.