Intra-jet asymmetry in heavy-ion collisions

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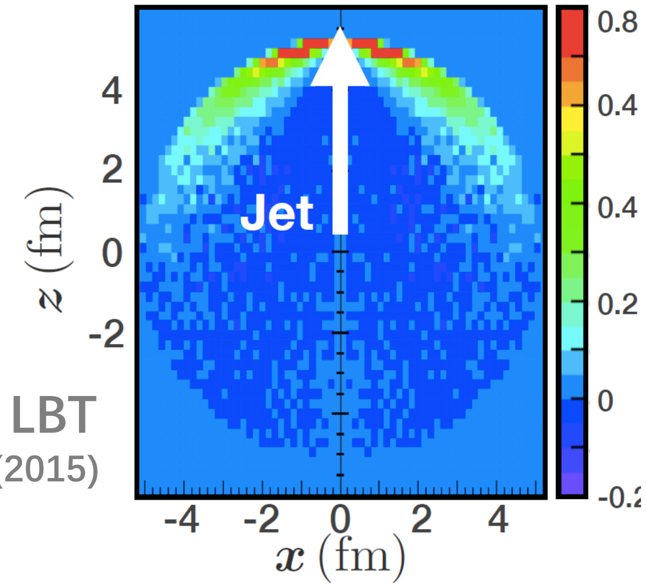
Jet induced medium response

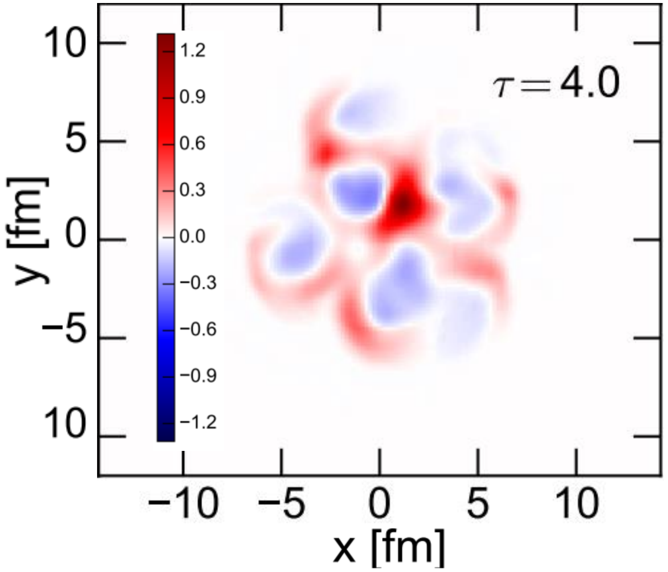
- **Structure of medium response**
  Hydro : Mach cone as hydro response.
  Transport : Mach cone like structure.

- **Diffusion wake**
  Unique structure of medium response

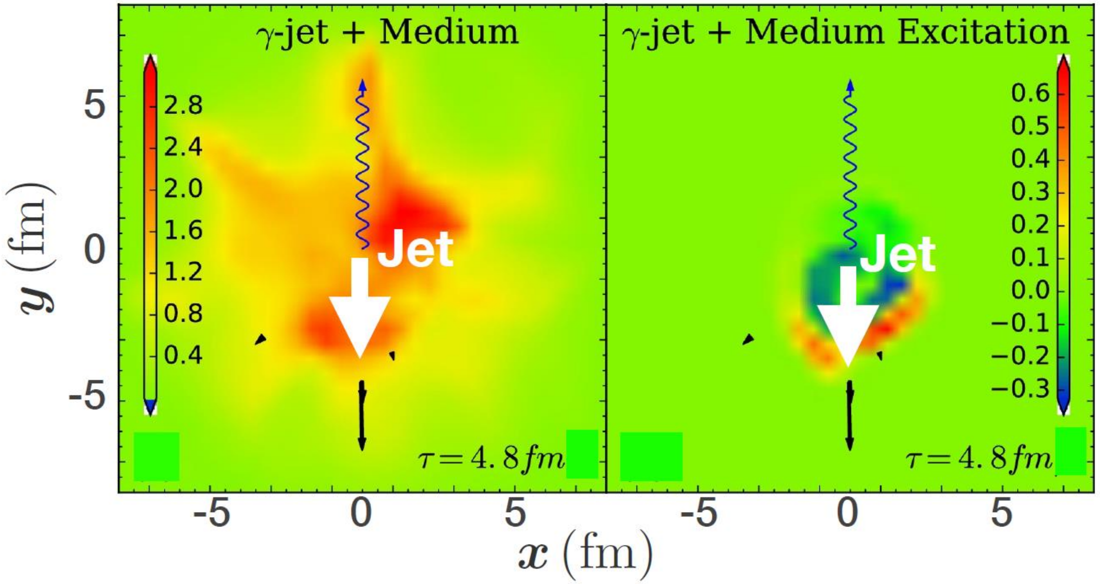
LBT
PRC 91, 054908 (2015)



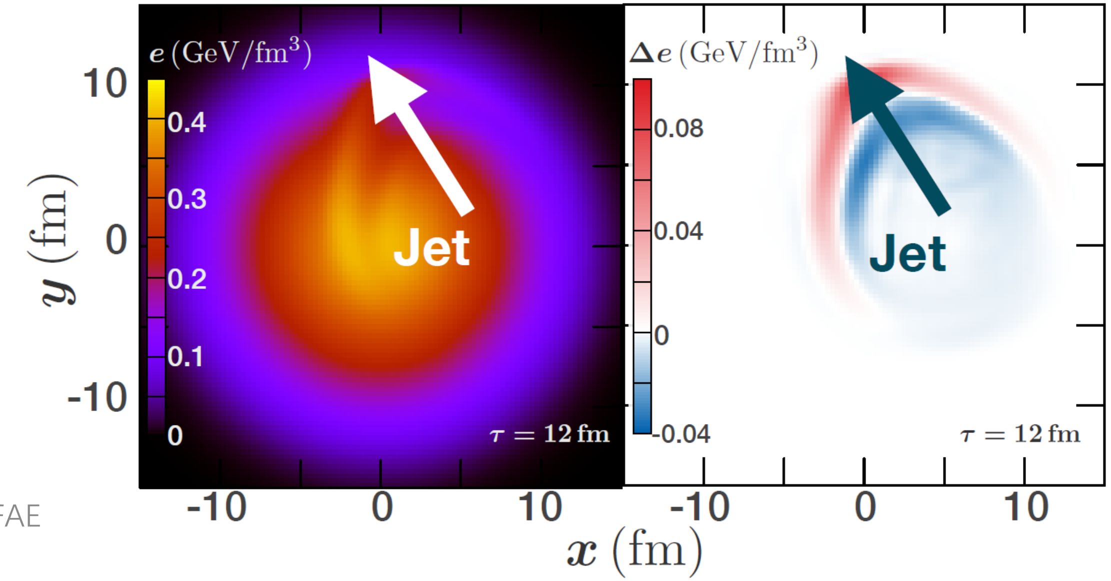
EPOS3-HQ Iurii Karpenko HP2018



CoLBT-hydro Chen et al, Phys.Lett. B777 86-90

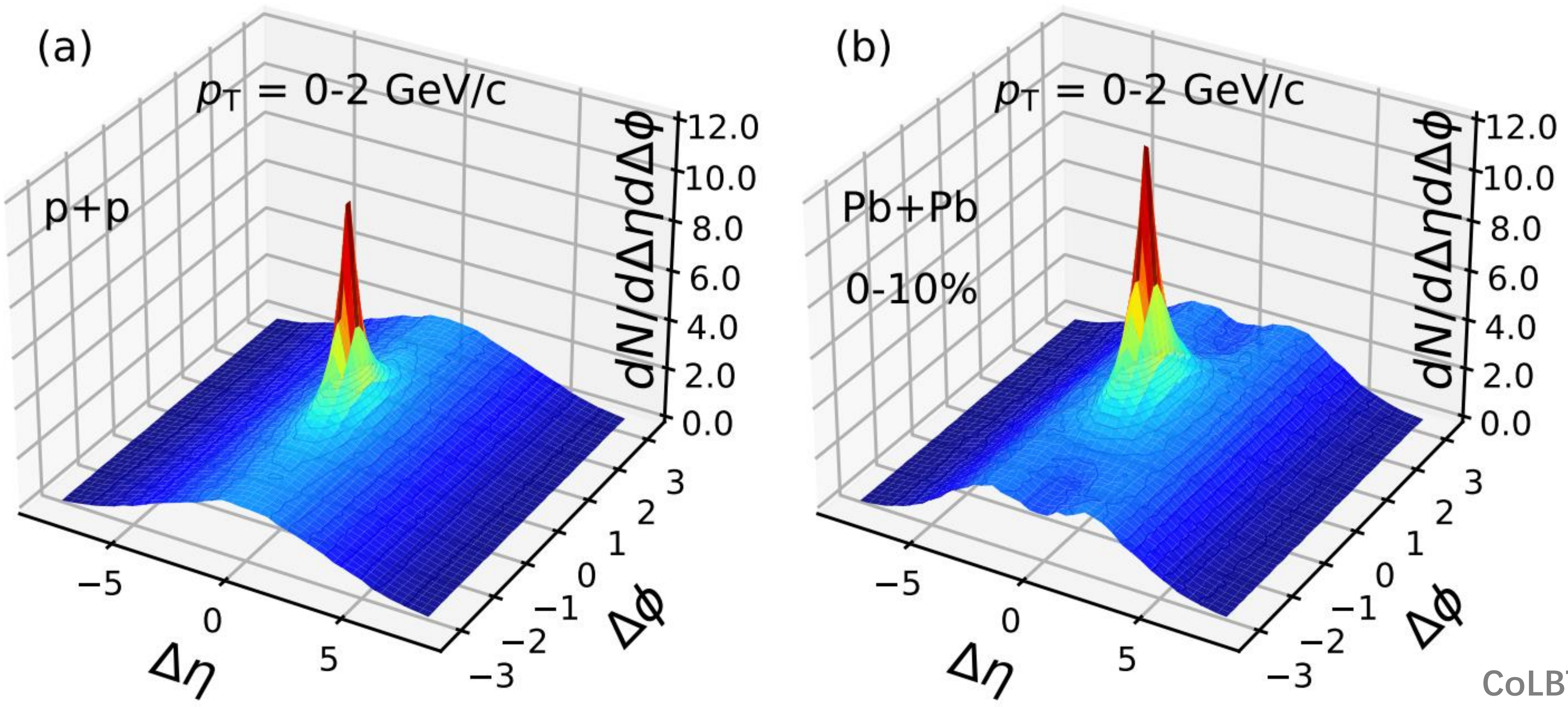


Jet-Fluid Tachibana, Chang, Qin, PRC 95, 044909



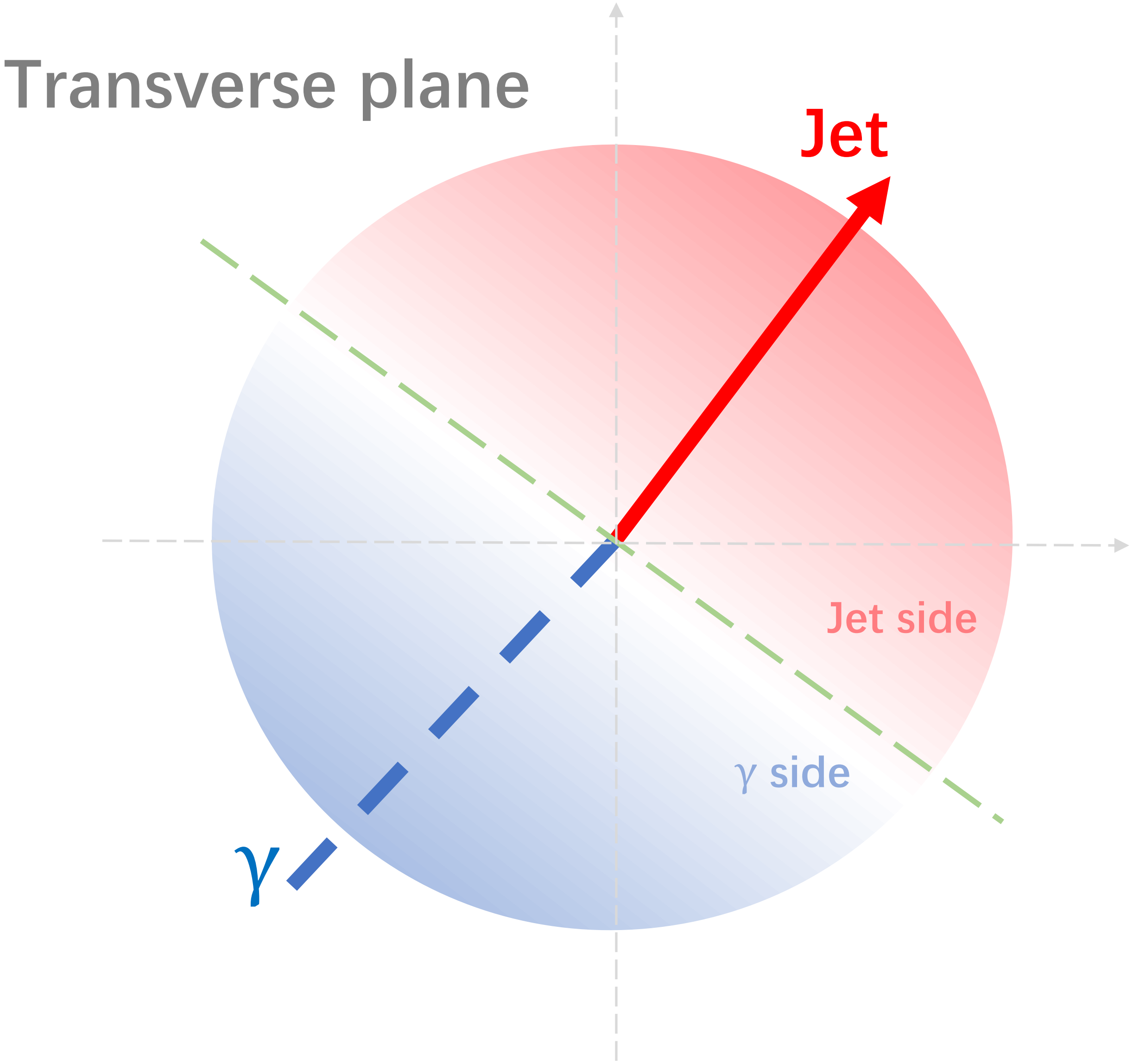
γ-jet particle number distribution (CoLBT-hydro)

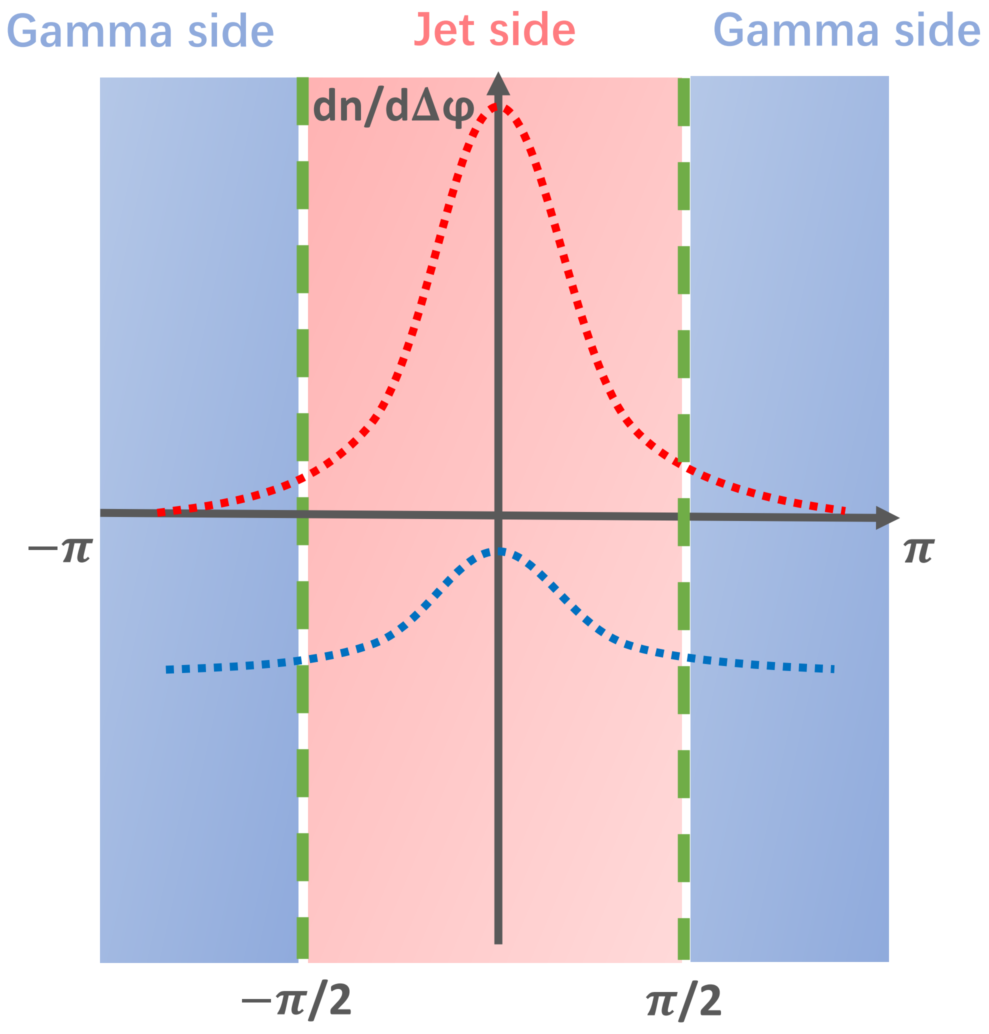
- **MPI ridge & diffusion wake valley**



Yang, Luo, Chen, Pang, Wang, PRL 130 (2023) 5,052301

Separate the contribution of diffusion wake

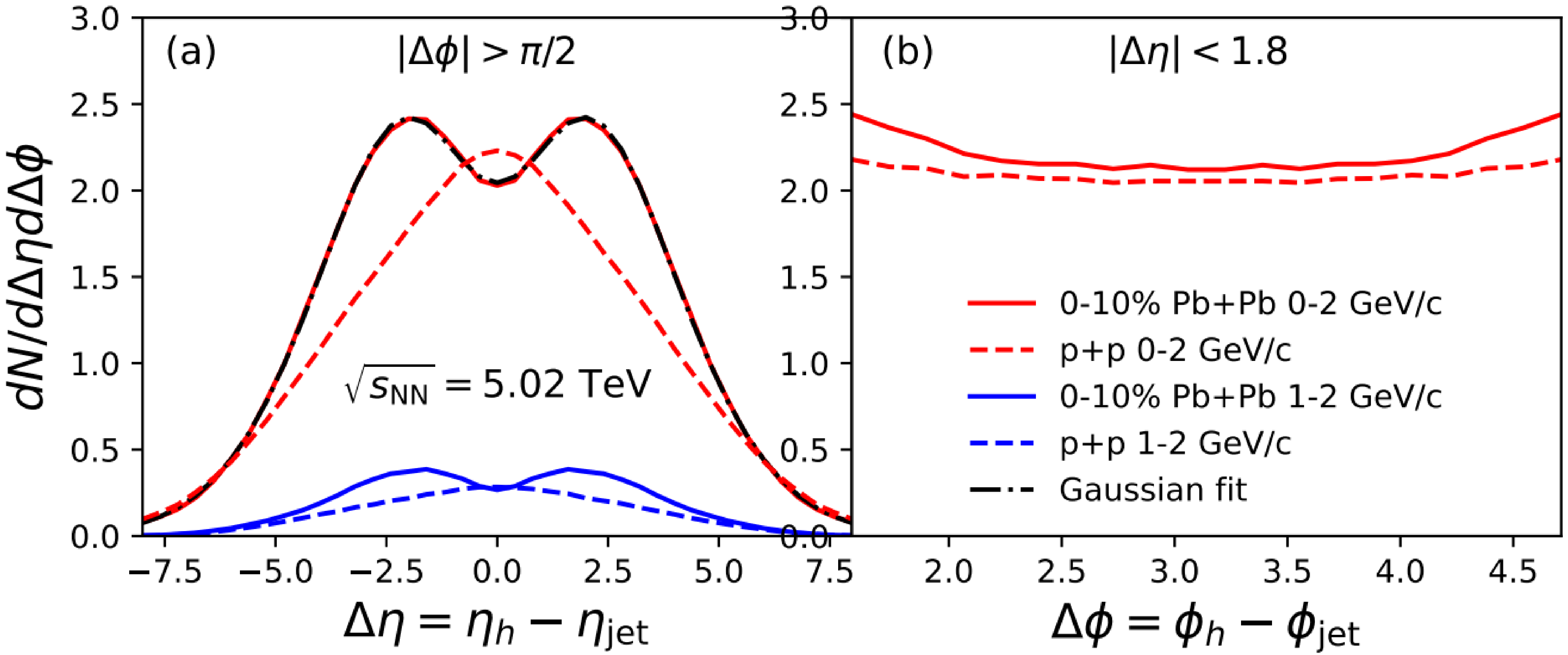




γ-jet particle number distribution (CoLBT-hydro)

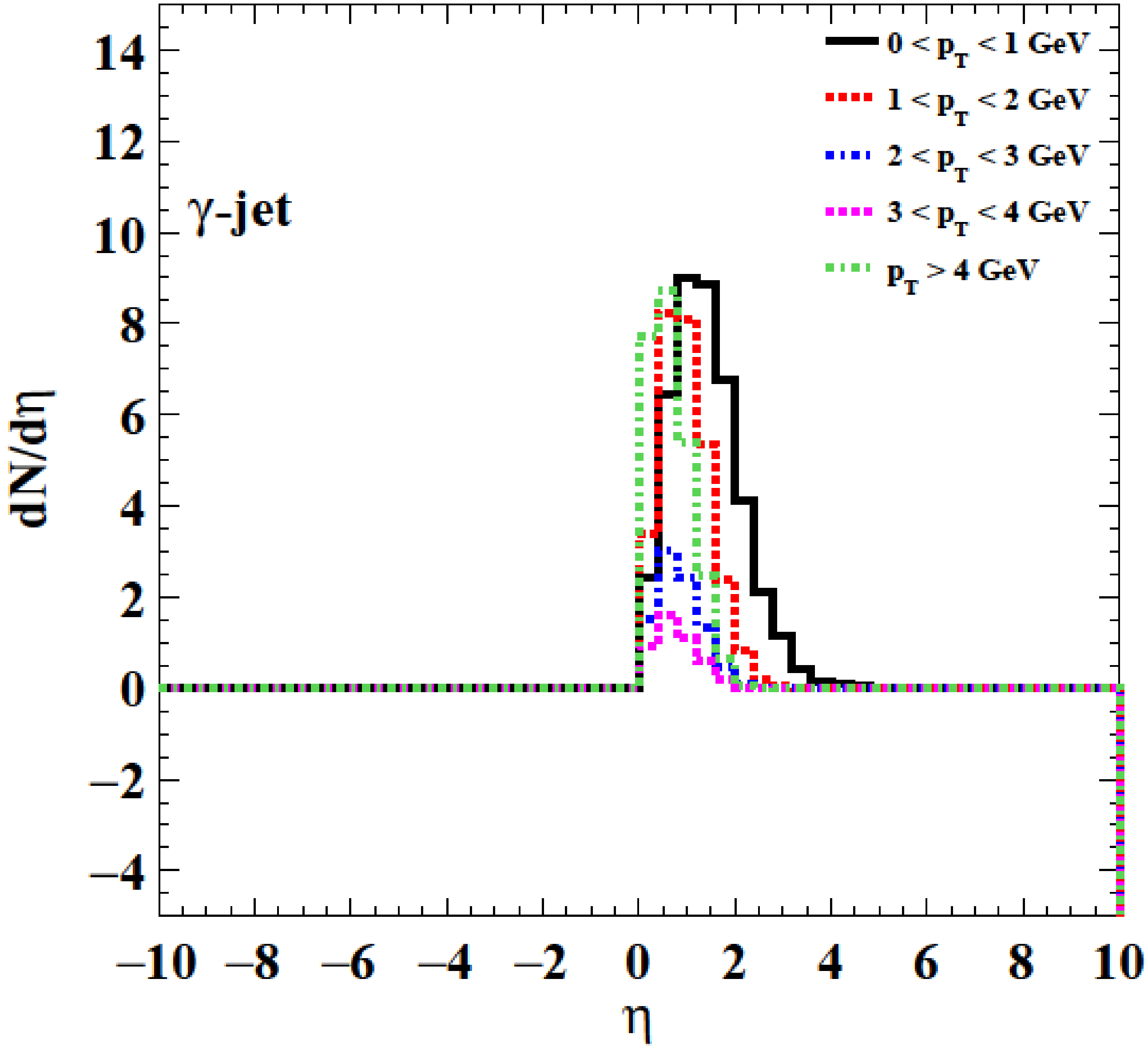
- **Longitudinal & transverse distribution.**

$$F(\Delta\eta) = \int_{\eta_{j1}}^{\eta_{j2}} d\eta_j F_3(\eta_j)(F_2(\Delta\eta, \eta_j) + F_1(\Delta\eta))$$



Yang, Luo, Chen, Pang, Wang, PRL 130 (2023) 5,052301

Winnowing jets in quark gluon plasma

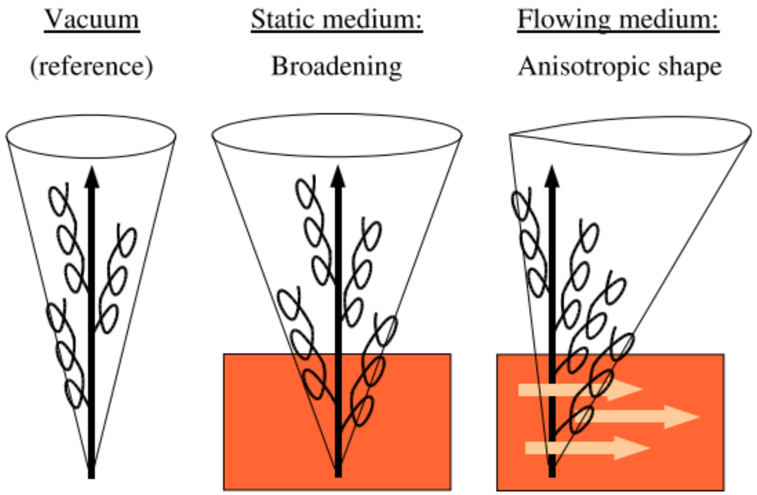


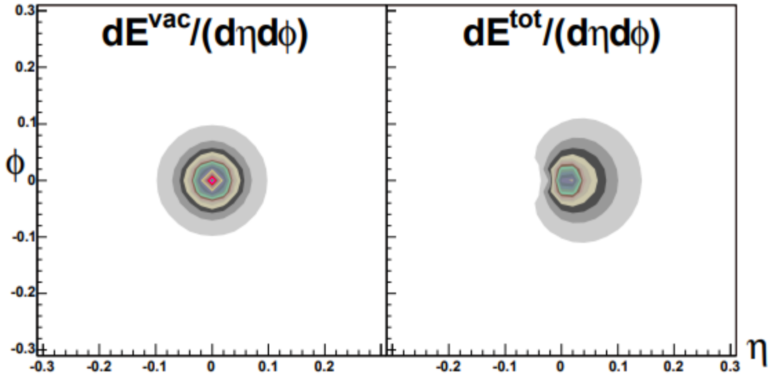
Jet-flow coupling in heavy-ion collisions

Armesto, Salgado, Wiedemann Phys.Rev.Lett.93:242301,2004

Measuring The Collective Flow With Jets

Néstor Armesto, Carlos A. Salgado and Urs Achim Wiedemann
Department of Physics, CERN, Theory Division, CH-1211 Genève 23, Switzerland
(Dated: October 8, 2018)





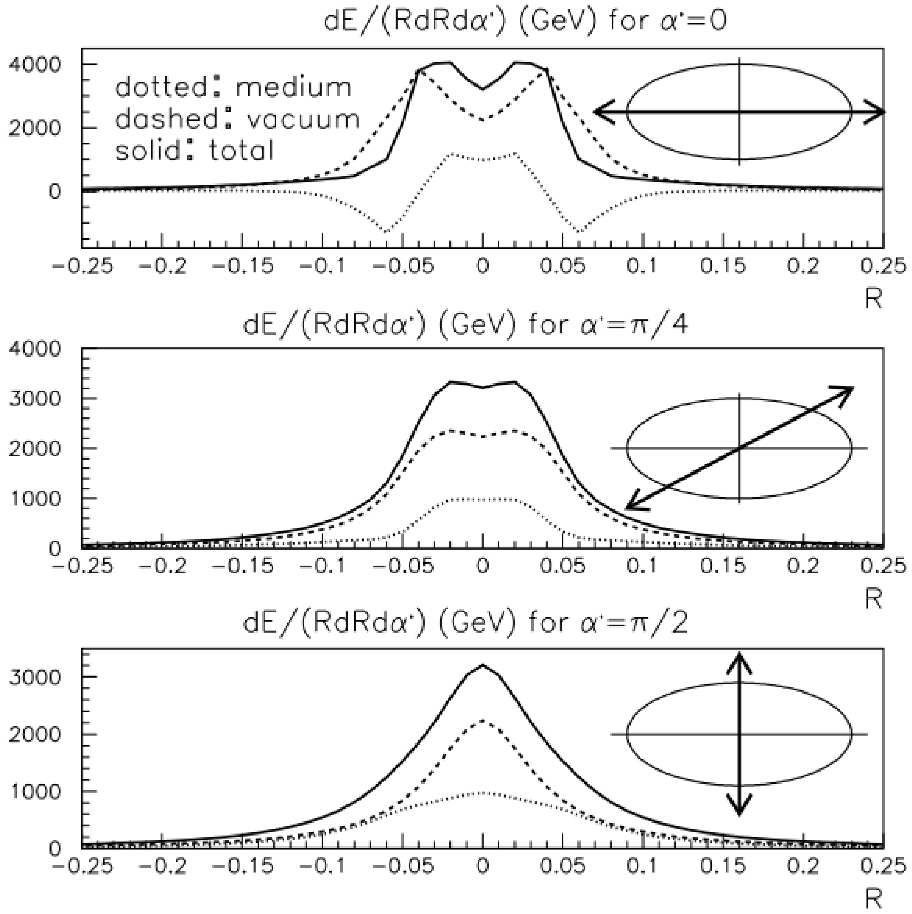
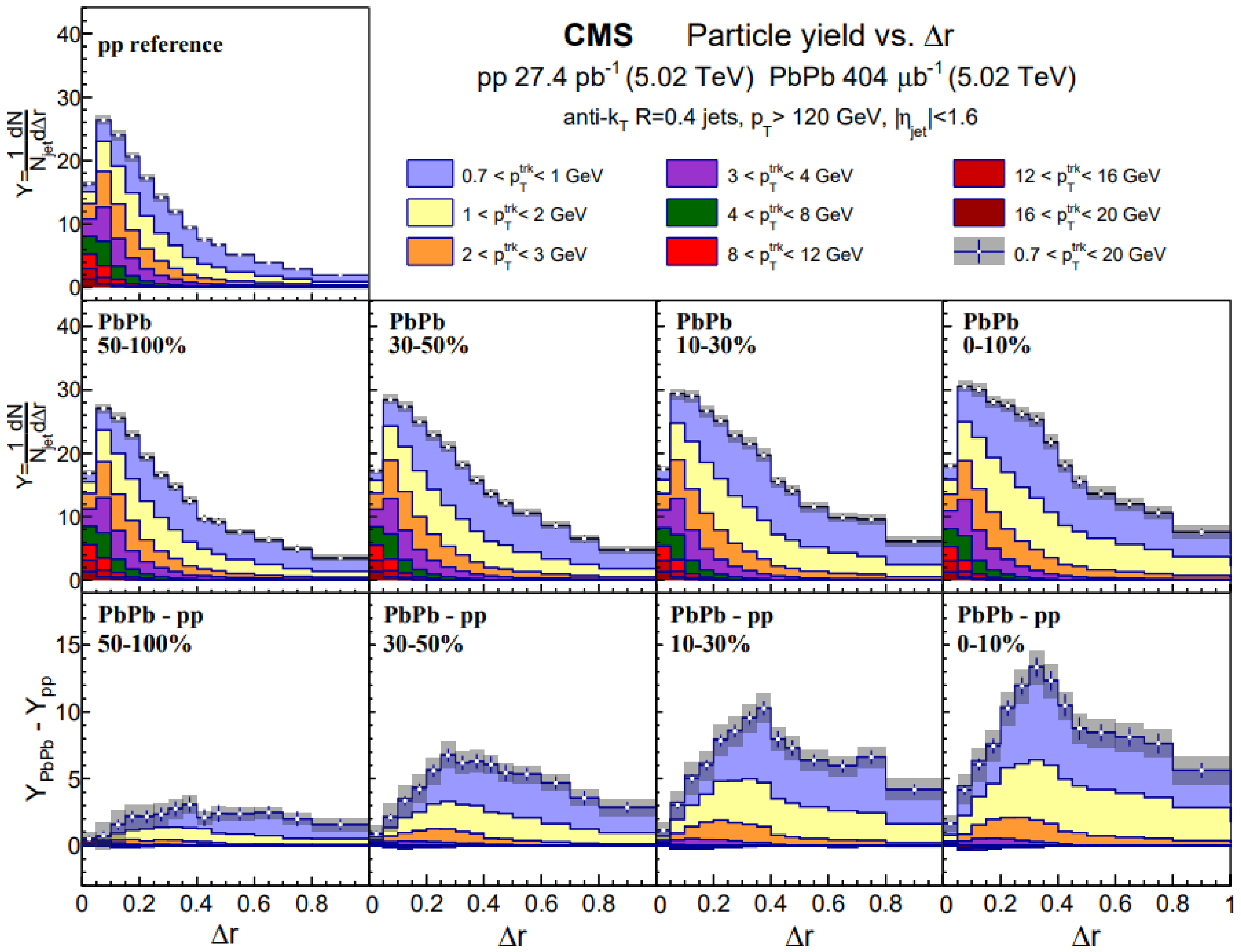


FIG. 2: Jet energy distribution for a sample of jets for which the medium was moving with equal probability in the positive and negative beam direction.

Jet-flow coupling in heavy-ion collisions



A Linear Boltzmann Transport (LBT) Model

Parton shower

Pythia Sherpa

Jet propagation

$$p_1 \cdot \partial f_1(x_1, p_1) = E_1\left(C_{elastic} + C_{inelastic}\right)$$

- **Rescattering**

  Shower-thermal & recoil-thermal

- **Back reaction**

  Track the initial thermal parton

Fragmentation

Recombination

LBT

Hard

Local medium information ε T $\boldsymbol{u}$

Hadronic observables

Initial profile

AMPT TRENTO

Medium evolution

$$\partial_\mu T^{\mu\nu} = 0$$

Cooper Frye

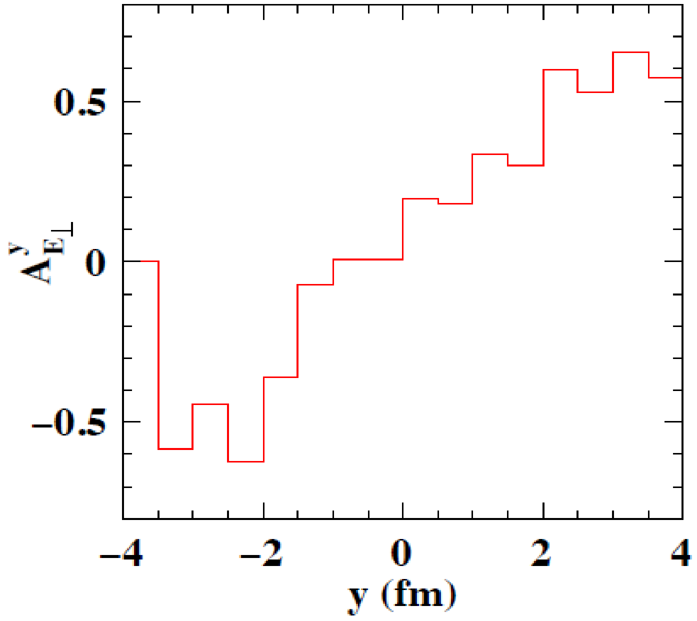
CLvisc

Soft

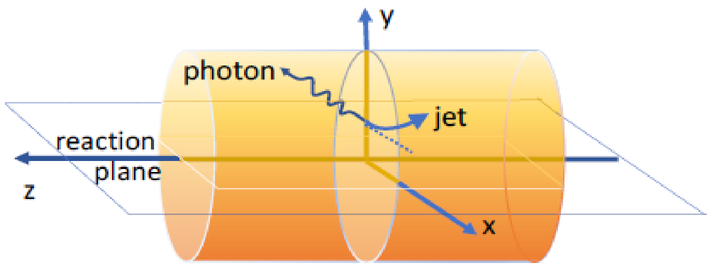
Gradient tomography for jet localization

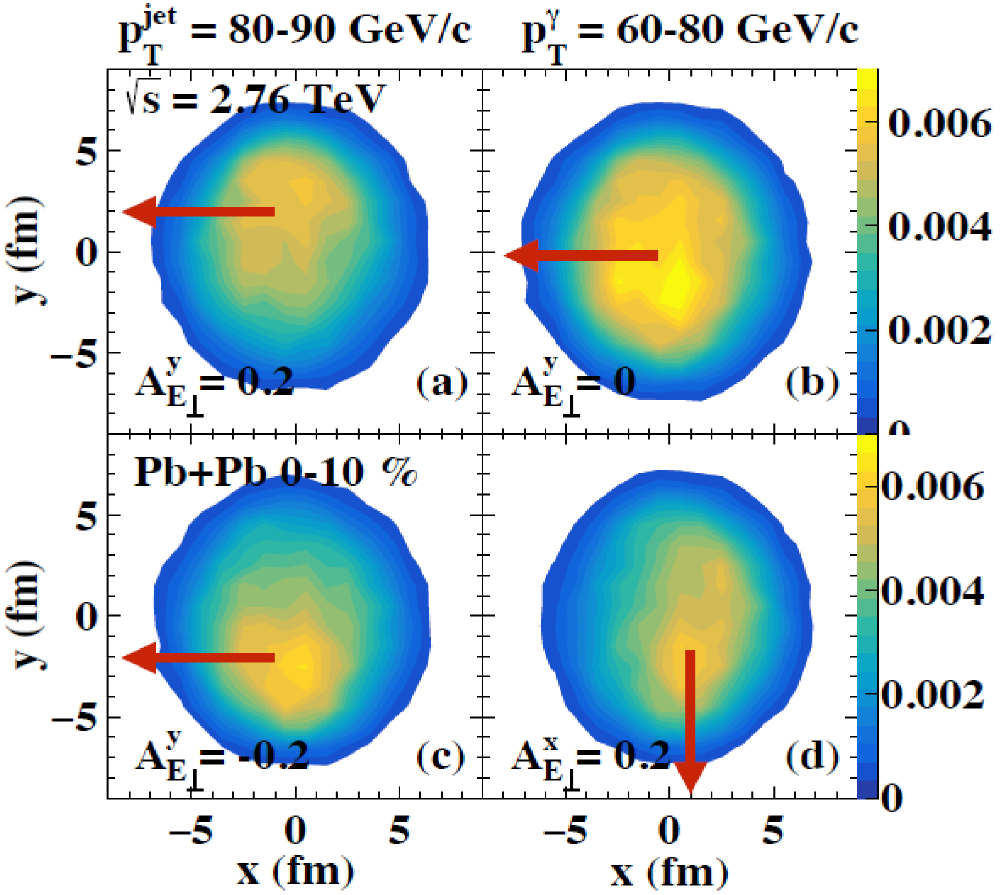
transverse energy asymmetry:

$$A_{E_\perp}^{\vec{n}} = \frac{\int d^3r d^3k f(\vec{k},\vec{r})\vec{k}\cdot\vec{n}}{\int d^3r d^3k f(\vec{k},\vec{r})|\vec{k}\cdot\vec{n}|}$$



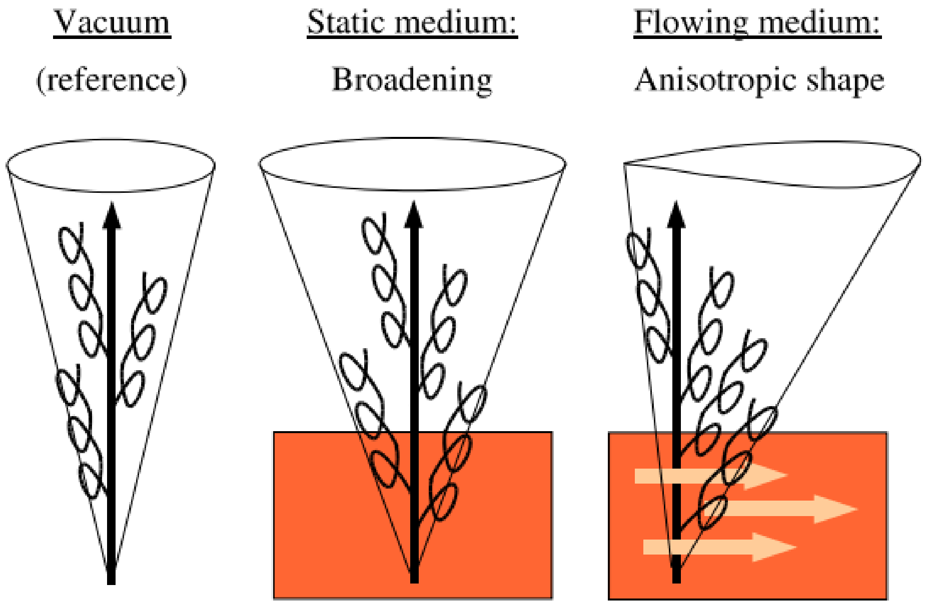
LBT+CLVisc hydro $p_T > 3$ GeV/c

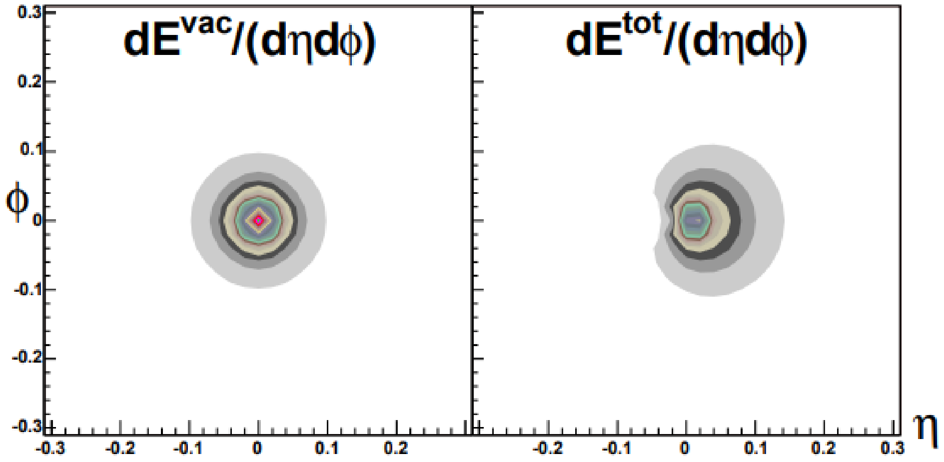


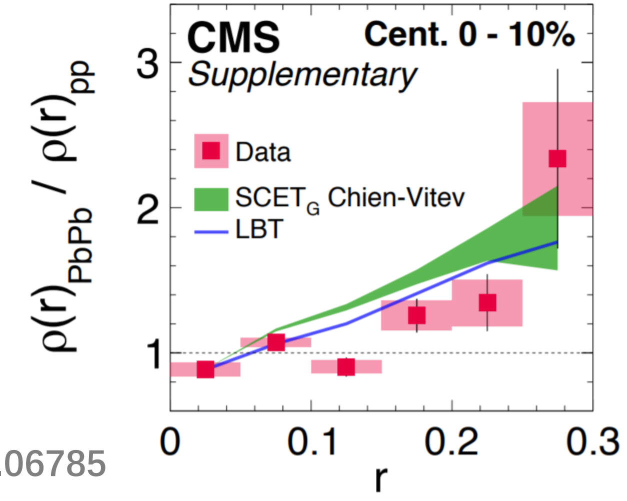


He, Pang & XNW, Phys Rev Lett 125 (2020) 12, 122301

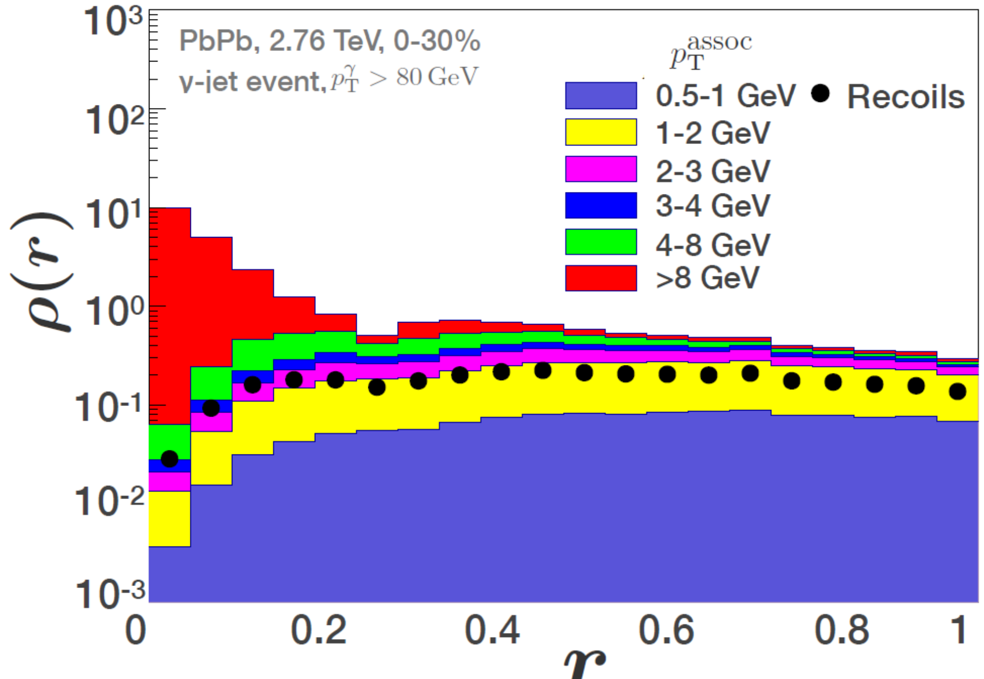
Jet shape within LBT model



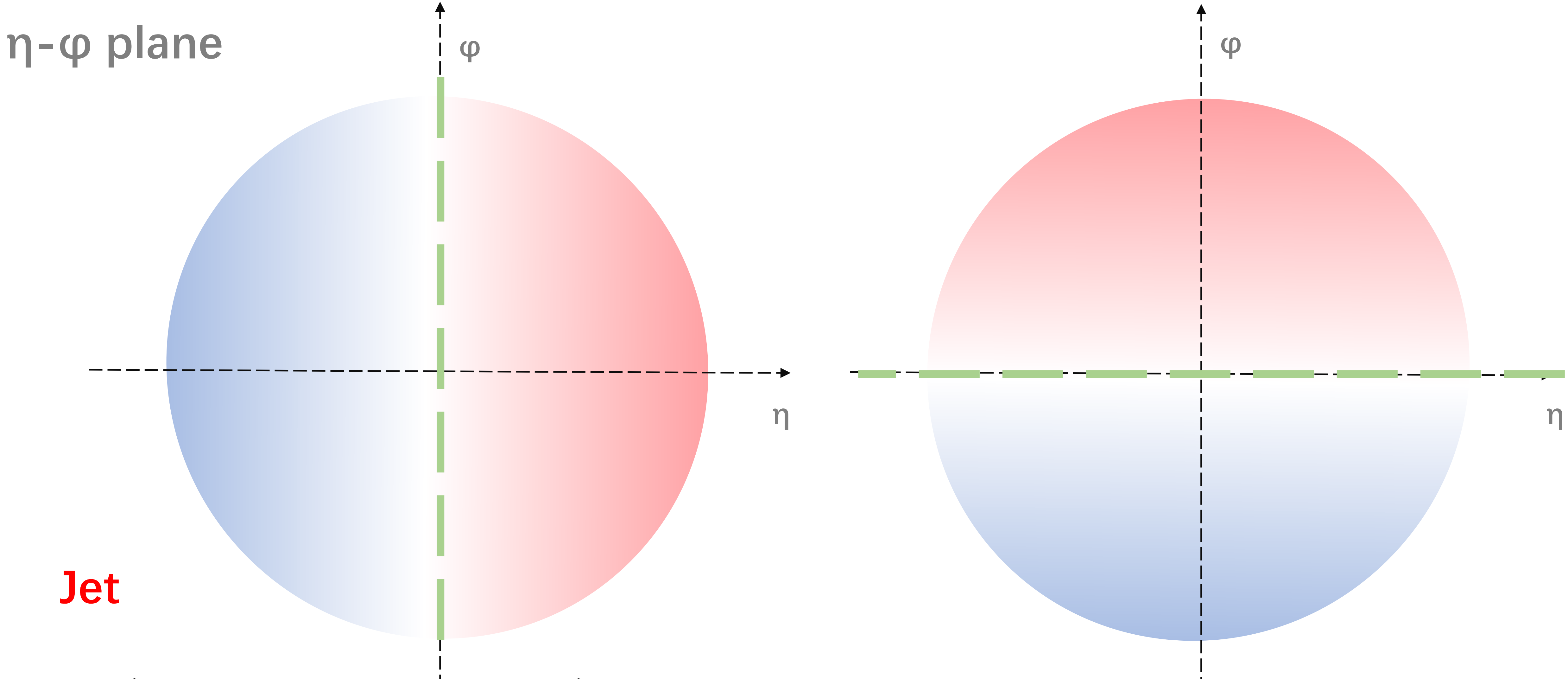




Luo, Cao, He, Wang, arXiv:1803.06785

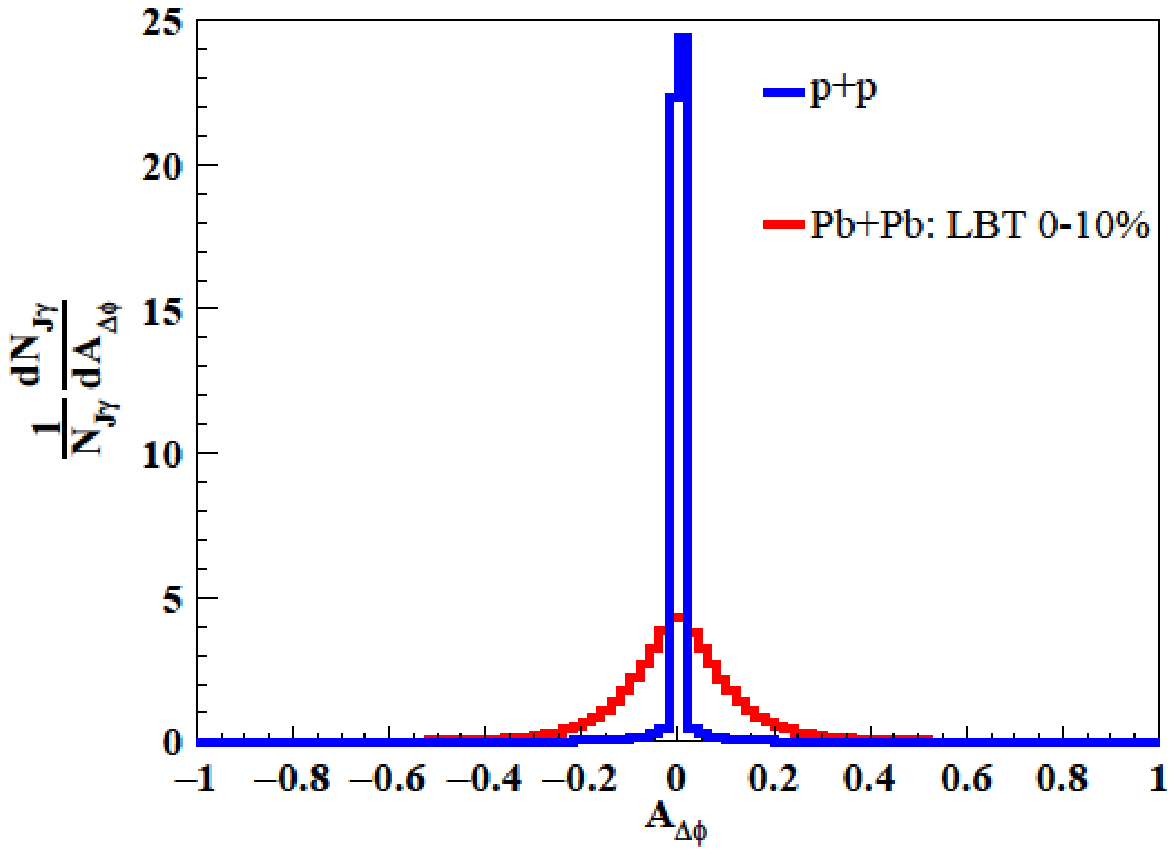


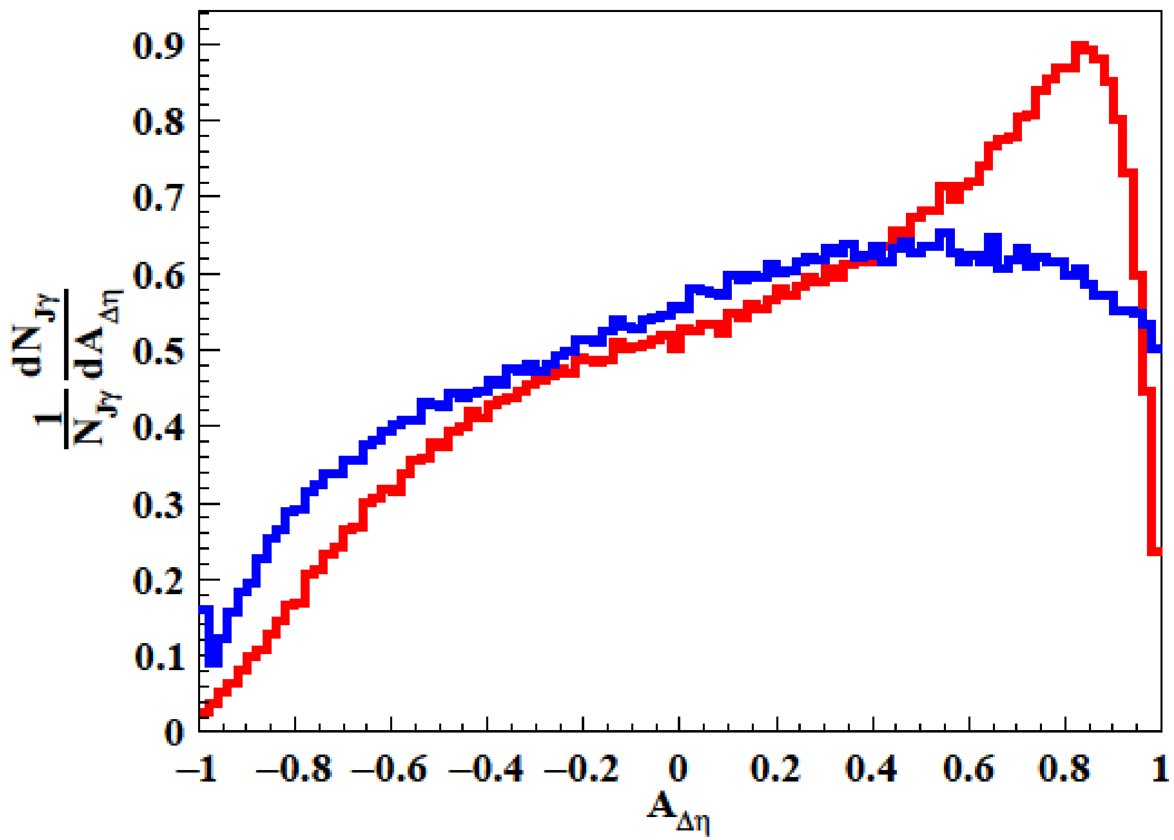
Phase-space cut and intra-jet asymmetry



$$A_\phi = \frac{\Sigma p_T^i \cdot \sin(\Delta\phi_{i,J}) \cdot \theta(\Delta\phi_{i,J}) - \Sigma p_T^i \cdot \sin(\Delta\phi_{i,J}) \cdot \theta(-\Delta\phi_{i,J})}{\Sigma p_T^i \cdot \sin(\Delta\phi_{i,J}) \cdot \theta(\Delta\phi_{i,J}) + \Sigma p_T^i \cdot \sin(\Delta\phi_{i,J}) \cdot \theta(-\Delta\phi_{i,J})}$$

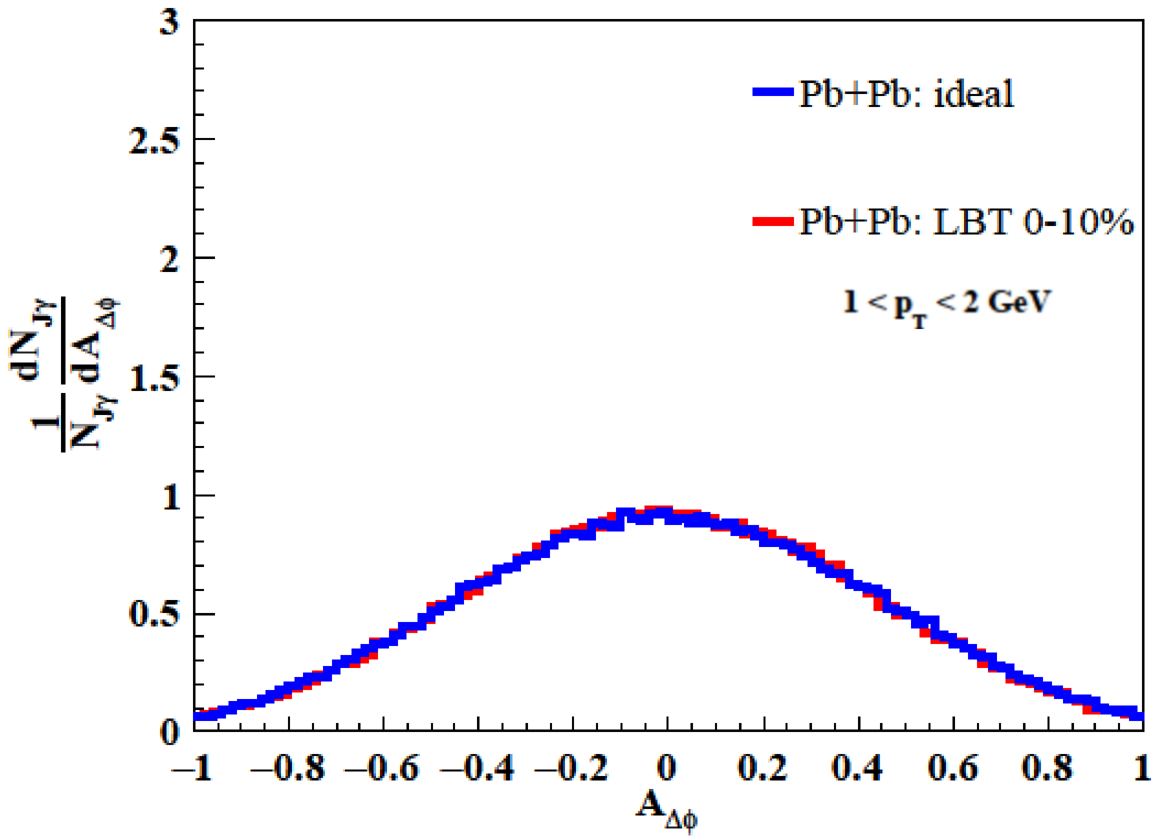
Intra-jet asymmetry increase in AA collisions

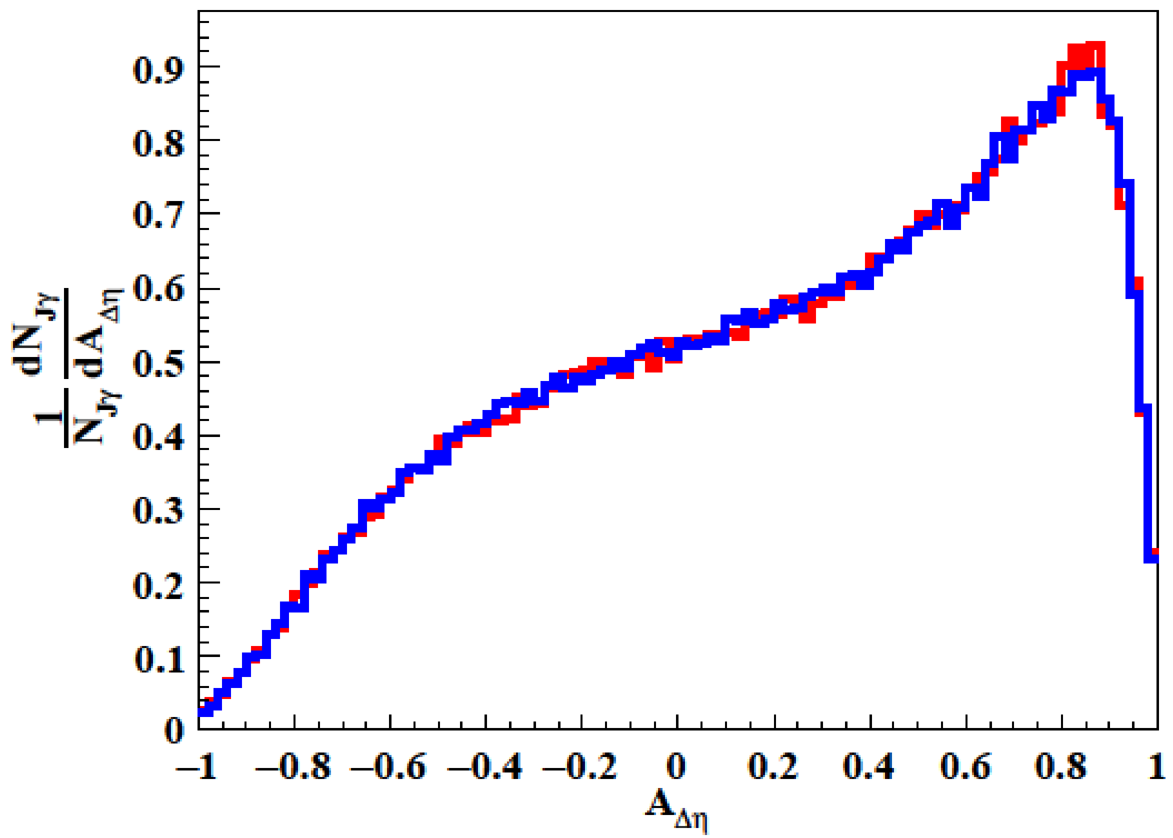




Preliminary

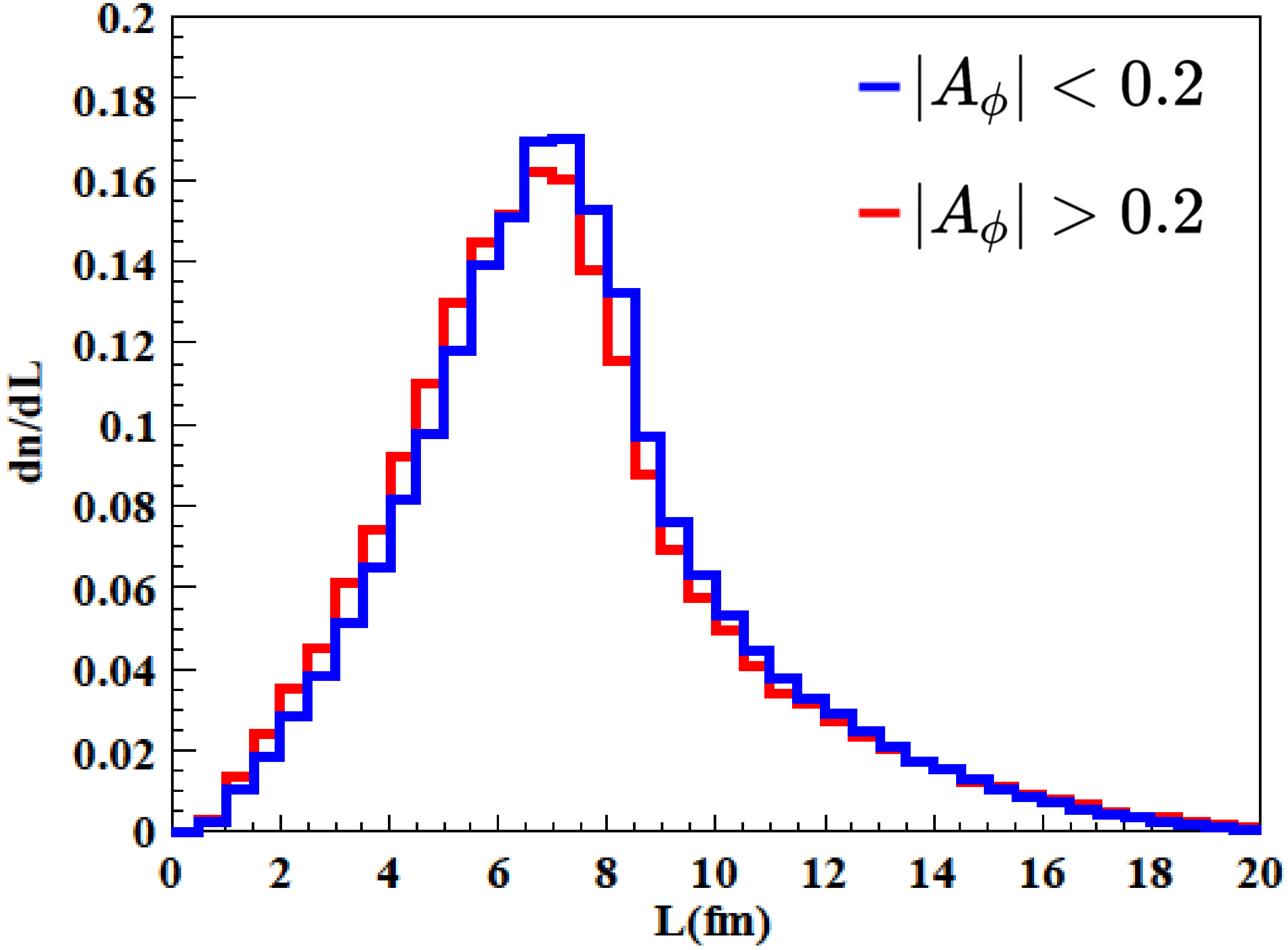
Ideal vs viscous



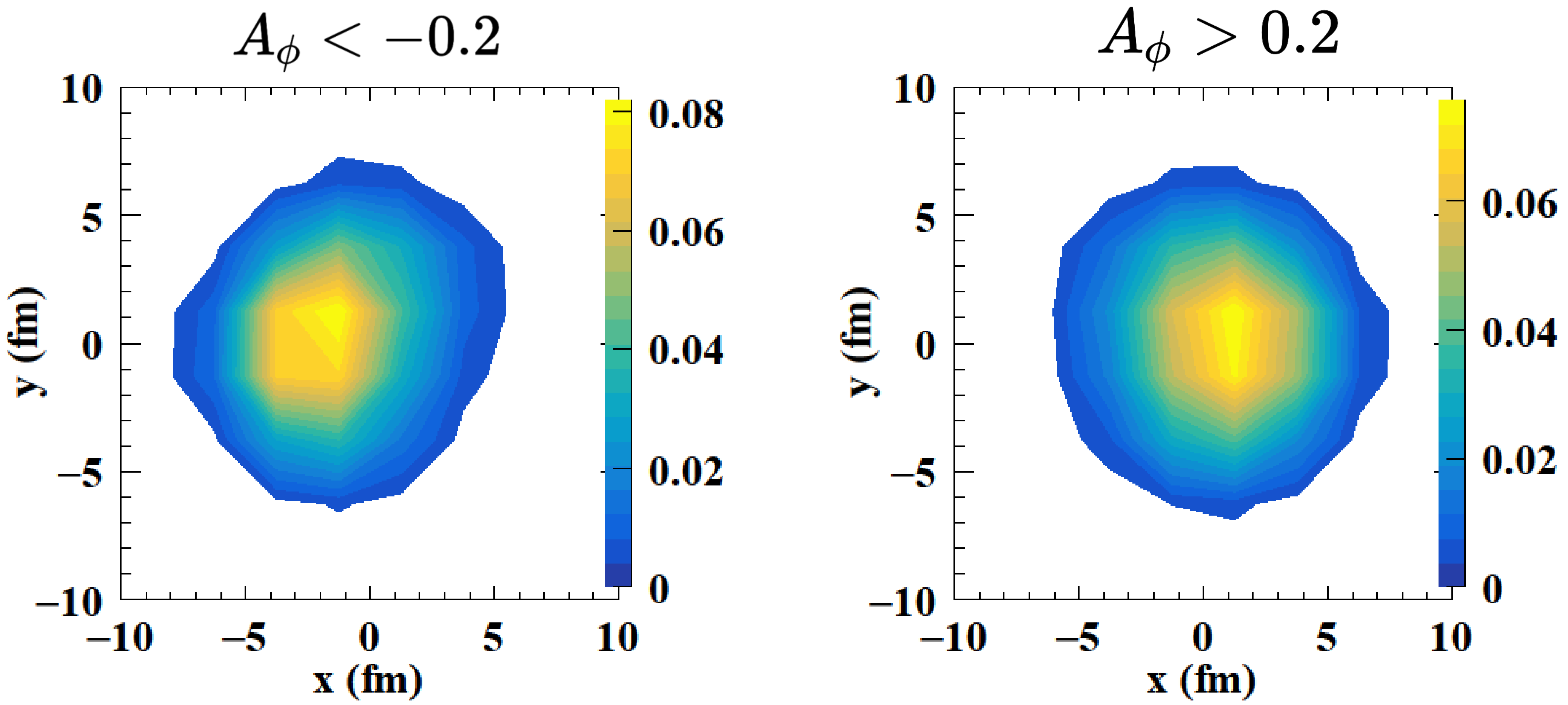


Preliminary

Path length distribution



Jet localization



Summary

- A new method to detect the effect of jet-flow coupling in heavy-ion collisions. Intra-jet asymmetry are observed at both the longitudinal and transverse direction.

Outlook

- Asymmetry in jet substructure.
- Measuring flow with jets.
  (Medium fluctuation, Hadron cascade, Medium-induced splitting)

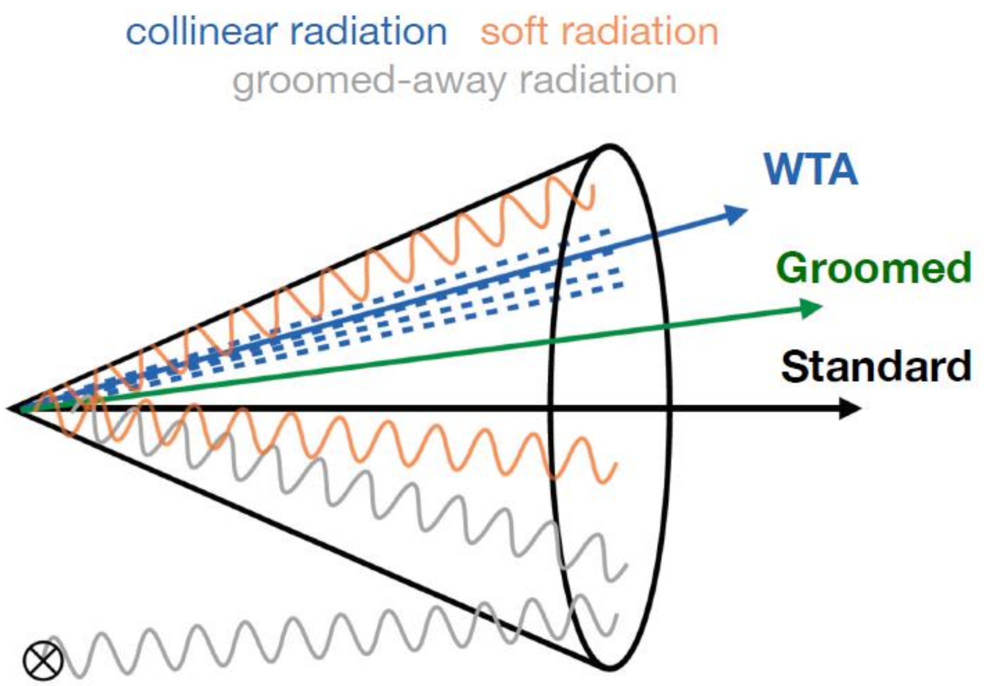
Asymmetry in jet substructure.

Angle between jet axes

- Standard axis:
  coordinates in (y, φ) of jet clustered with anti-k_T algorithm and combined with E-Scheme

- Groomed axis:
  standard axis of groomed (with Soft Drop) jet

- Winner-Takes-All (WTA) axis:
  - recluster jet with CA algorithm
  - $2 \rightarrow 1$ prong combination by taking direction of harder prong and $p_{\mathrm{T,tot}} = p_{\mathrm{T},1} + p_{\mathrm{T},2}$
  - Resulting axis insensitive to soft radiation at leading power



P. Cal et al., JHEP 04 (2020) 211

R. Cruz-Torres

Substructure observable: $\Delta R_{\mathrm{axis}} = \sqrt{(y_2 - y_1)^2 + (\varphi_2 - \varphi_1)^2}$ between two axes

A coupled LBT Hydro (CoLBT-hydro) Model

Parton shower
Pythia   Sherpa

Jet propagation

$$p_1 \cdot \partial f_1(x_1, p_1) = E_1(C_{elastic} + C_{inelastic})$$

- **Rescattering**

  Shower-thermal & recoil-thermal

  Parton above Pcut

Fragmentation

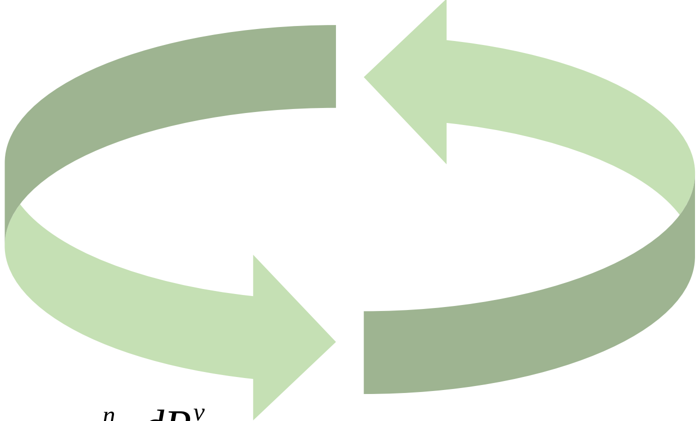
Recombination

LBT

Hard

Real time feed back

Local medium information ε T $\boldsymbol{u}$



$$j^\nu = \sum_{i=1}^{n} \frac{dP_i^\nu}{d\tau} \delta^3(\vec{X} - \vec{X}_i)\theta(P^0_{\rm cut} - P_i \cdot u)$$

Initial profile
AMPT   TRENTO

Medium evolution

$$\partial_\mu T^{\mu\nu} = j^\nu$$

- **Source term**

  Parton below Pcut
- **Negative source**

  Initial thermal parton

Cooper Frye

CLvisc

Soft

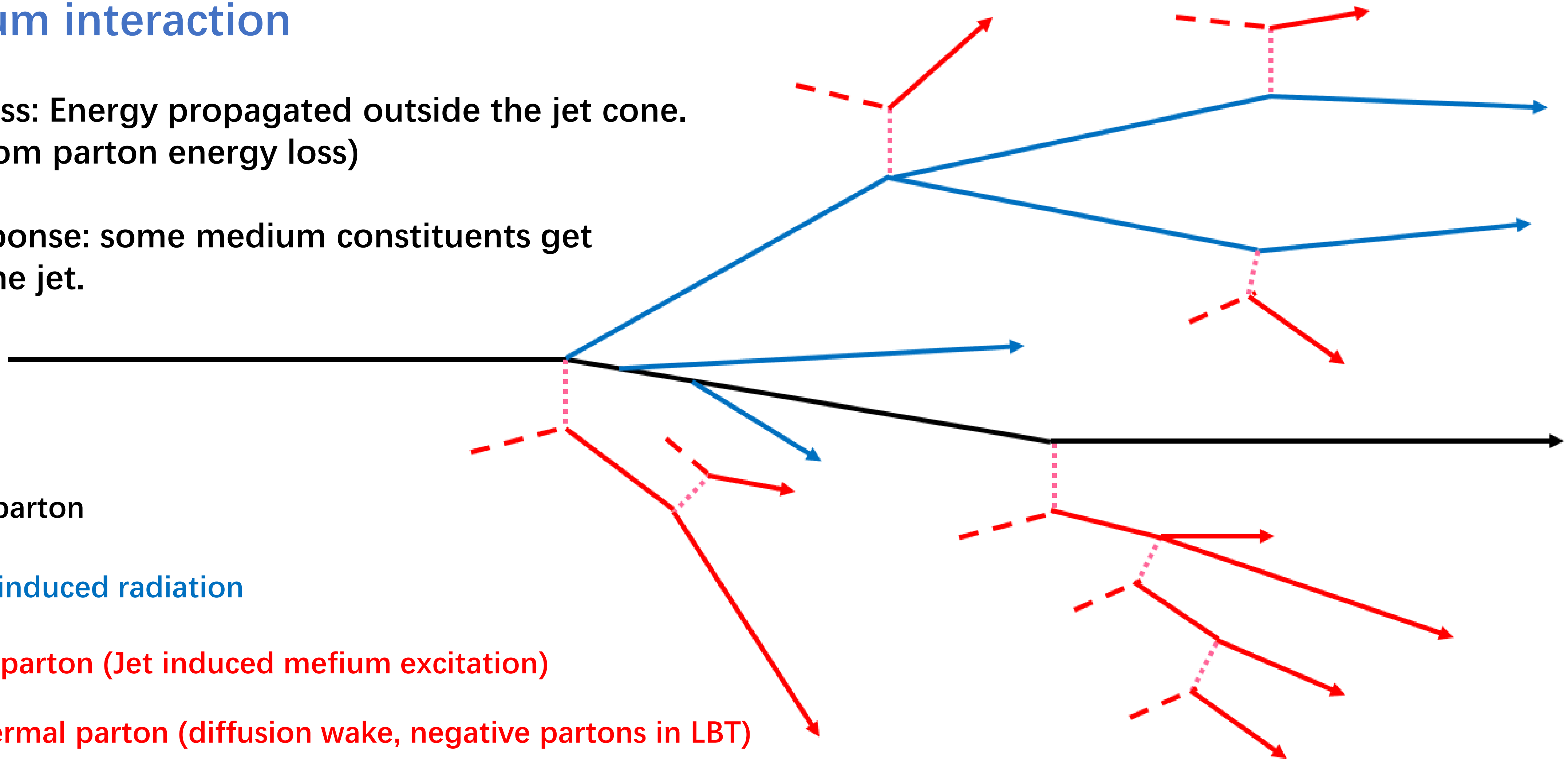
Hadronic observables

Jet propagation in the QGP medium

Jet-medium interaction

- Jet energy loss: Energy propagated outside the jet cone.
  (Different from parton energy loss)

- Medium response: some medium constituents get
  excited by the jet.



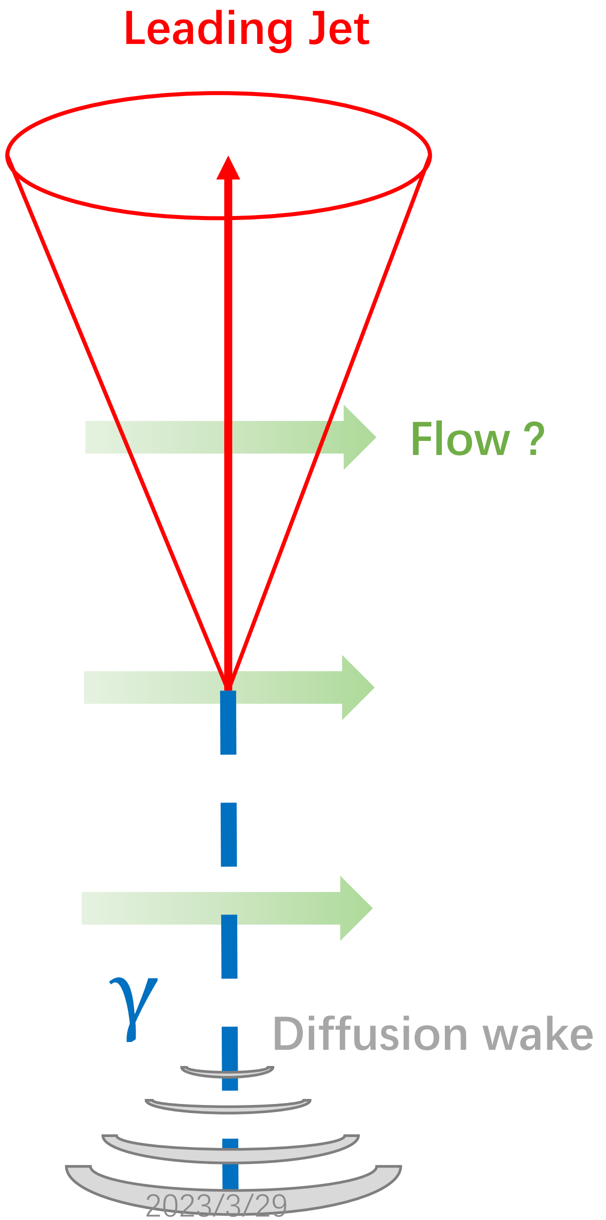
Leading parton

Medium induced radiation

Recoiled parton (Jet induced mefium excitation)

Initial thermal parton (diffusion wake, negative partons in LBT)

Do we have to look at the large rapidity jets ?



The longitudinal flow