Jet-flow coupling in heavy-ion collisions
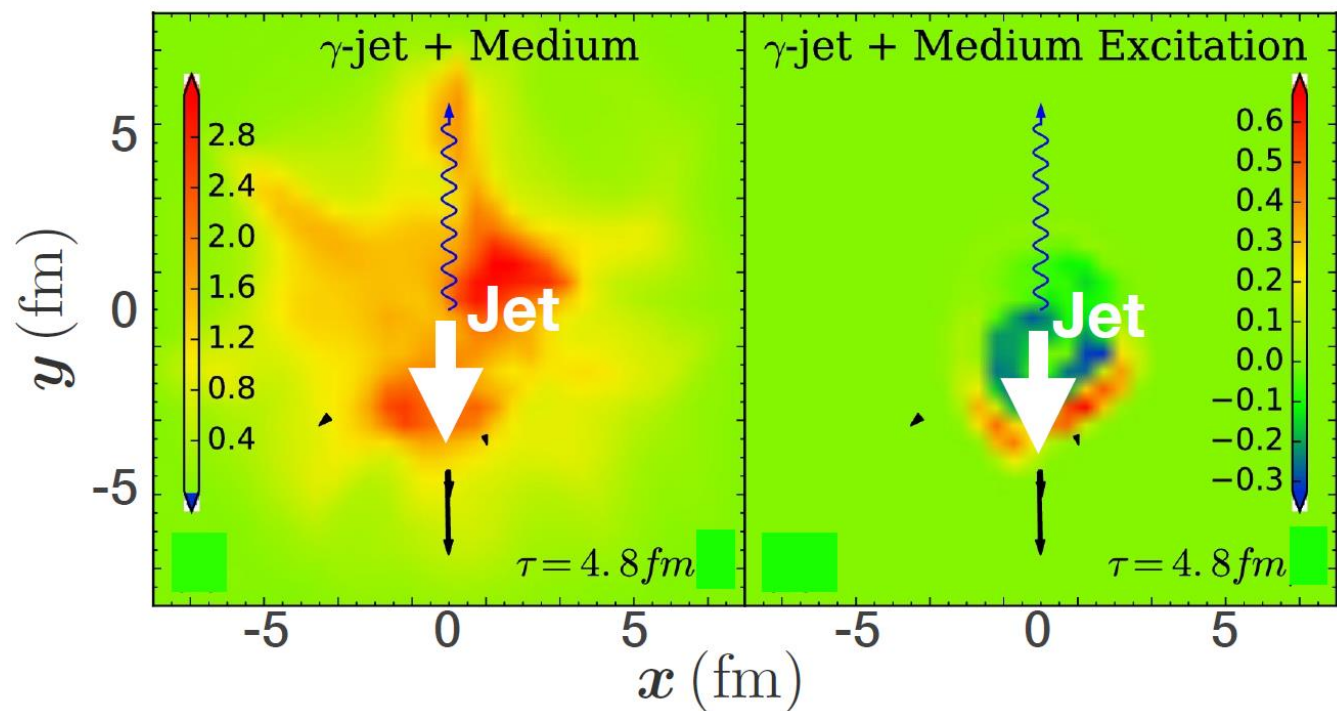
Tan Luo

Hunan University

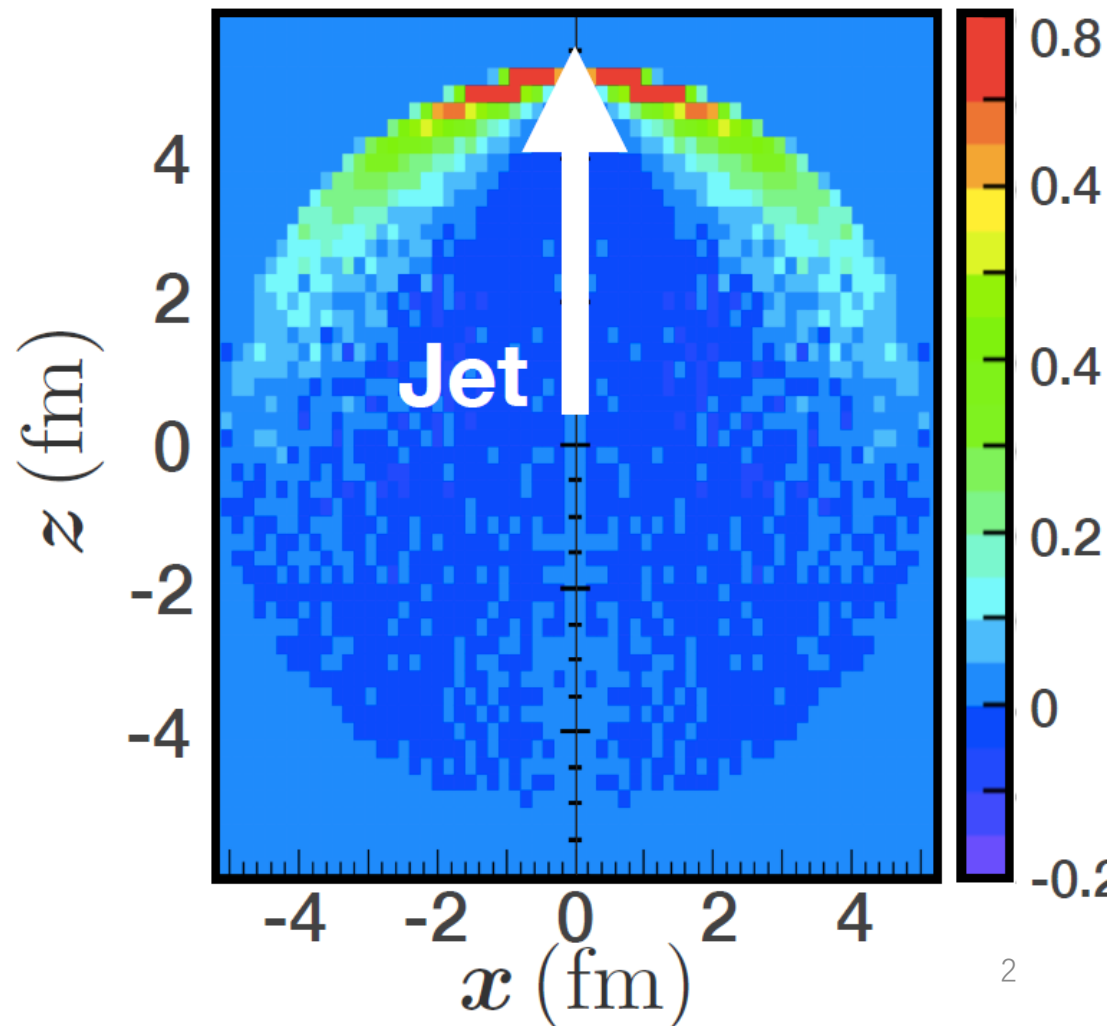In collaboration with Yayun He, Carlos A. Salgado and Xin-Nian Wang

Jet transport in a flowing medium

- **Structure of medium response**
  Jet induced mach cone followed by a diffusion wake.
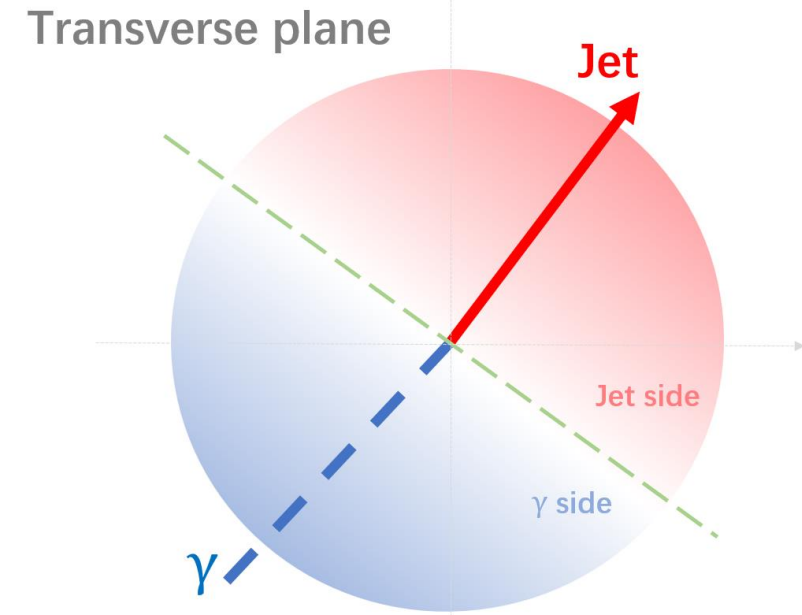
- **Distorted due to jet-medium interaction**

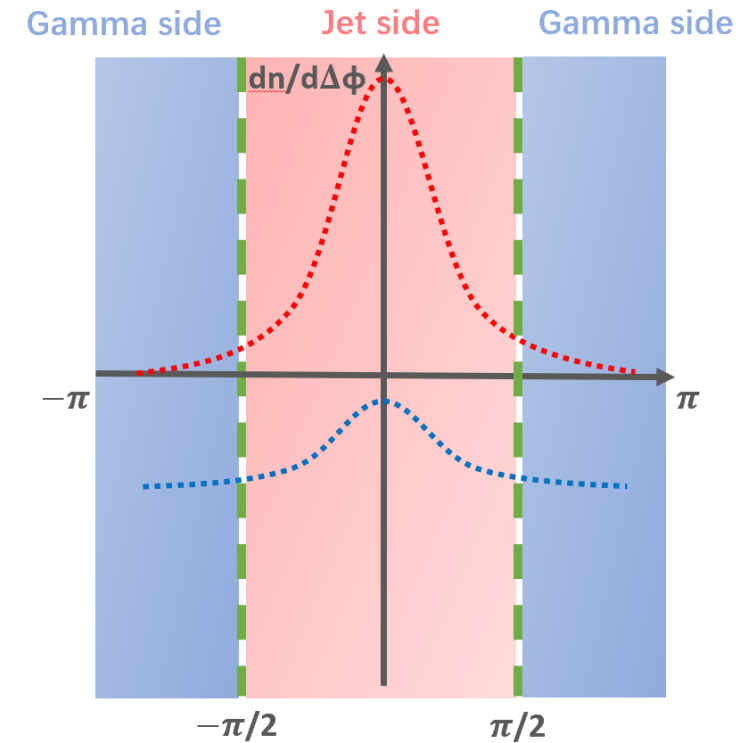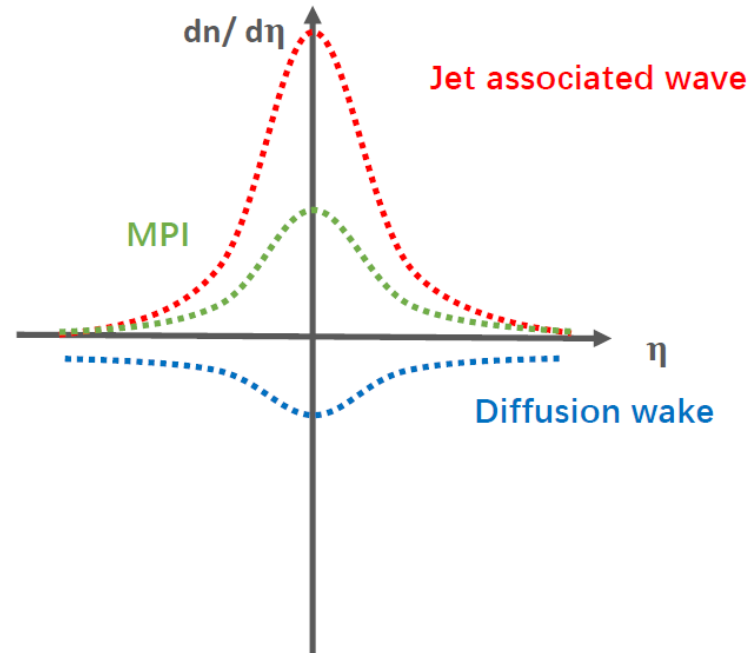LBT PRC 91, 054908 (2015)
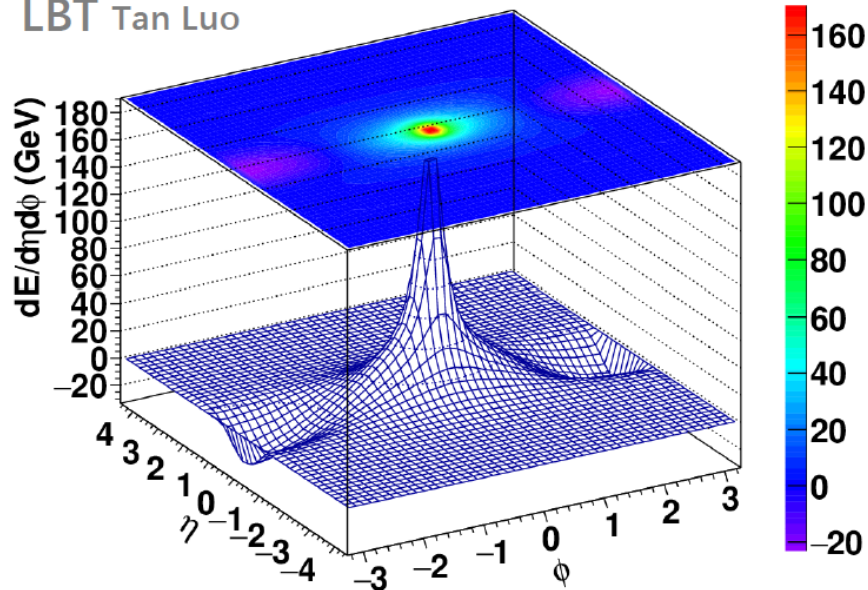
CoLBT-hydro   Phys.Lett. B777 86-90

Separate the contribution of diffusion wake

- A phase space cut in the transverse plane.
  (Jet hemisphere & γ hemisphere)

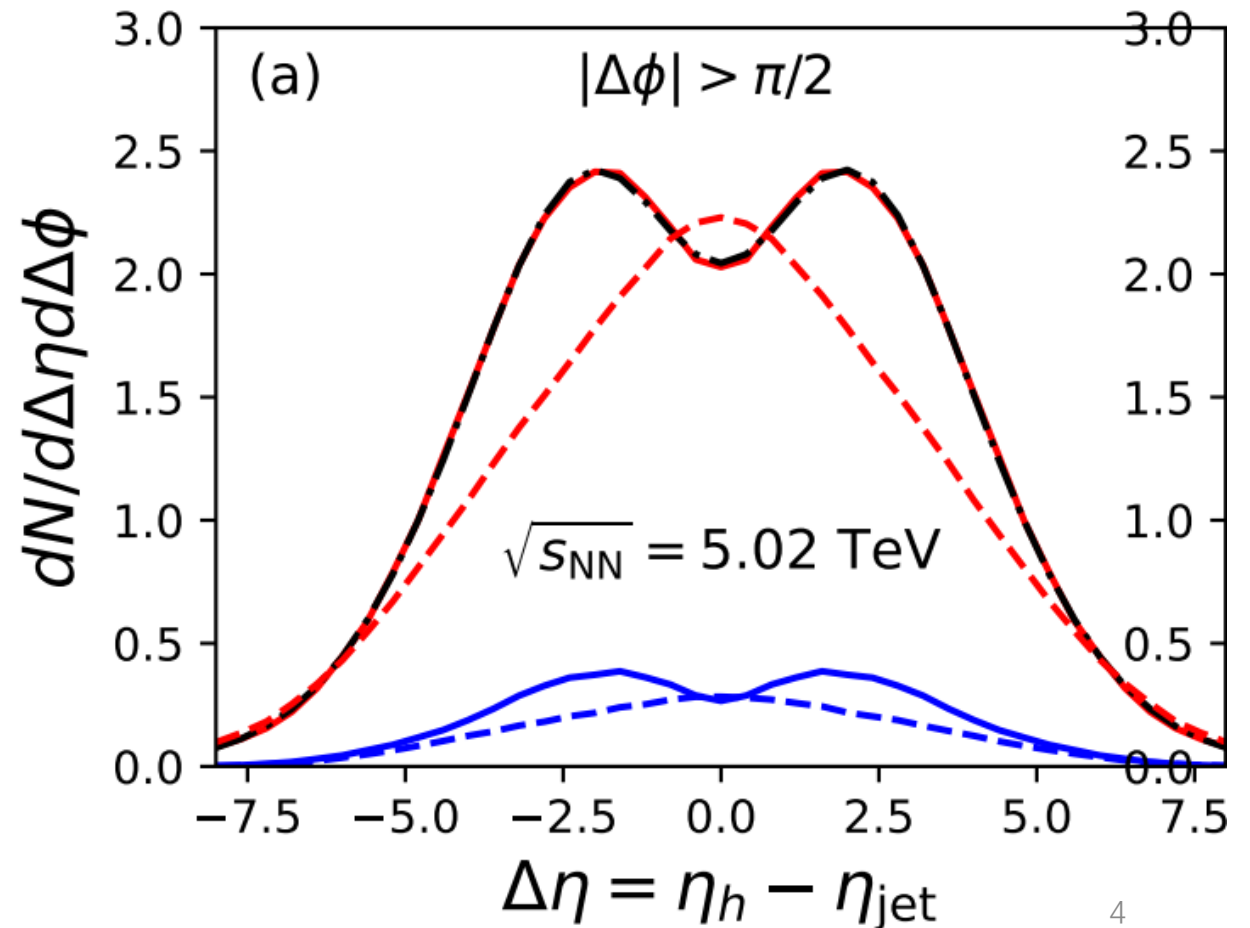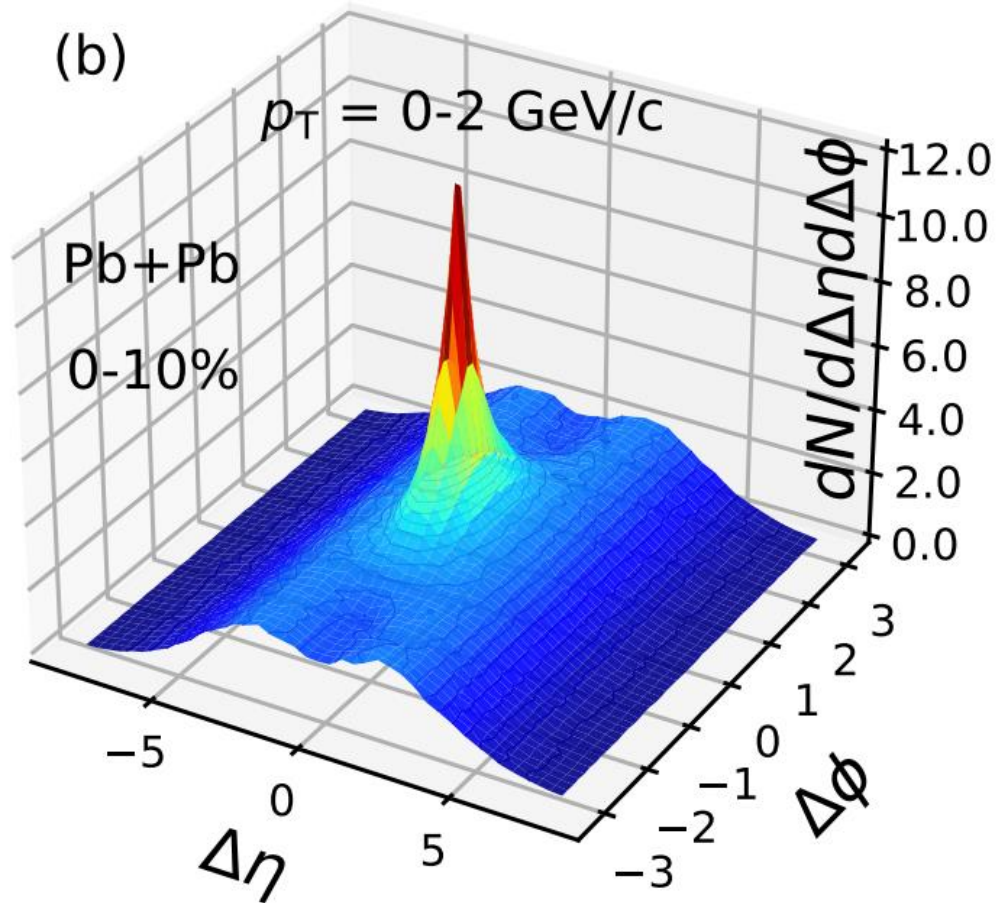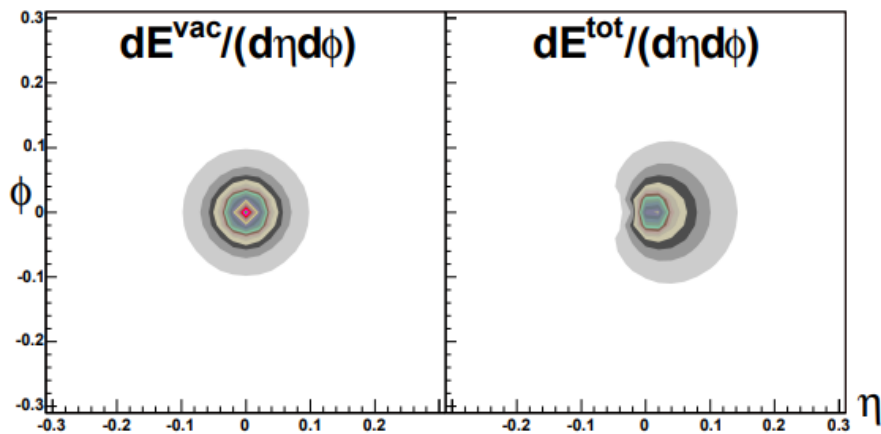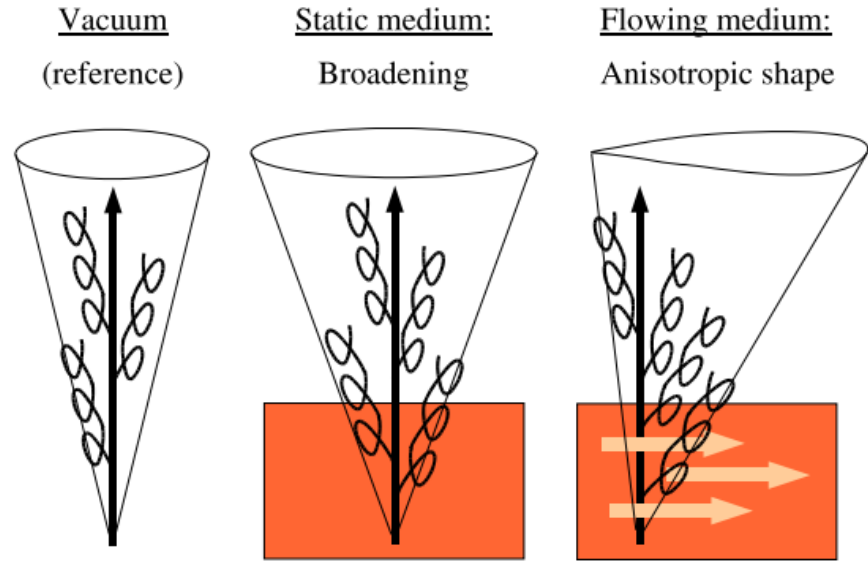- Diffusion wake show up in the γ hemisphere.

γ-jet particle number distribution

- **MPI ridge & diffusion wake valley (γ-jet particle number distribution)**

- **Quantify the wake with Gaussian fit**

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

Intra-jet asymmetry (Jet winnowing)

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

Intra-jet asymmetry (The contribution from flow)

Vacuum (reference)

Static medium: Broadening

Flowing medium: Anisotropic shape

$dE^{vac}/(d\eta d\phi)$

$dE^{tot}/(d\eta d\phi)$

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

CMS   Particle yield vs. Δr

pp 27.4 pb^{-1} (5.02 TeV)   PbPb 404 μb^{-1} (5.02 TeV)

anti-k_T R=0.4 jets, p_T > 120 GeV, $|\eta_{jet}|$<1.6

$0.7 < p_T^{trk} < 1$ GeV
$1 < p_T^{trk} < 2$ GeV
$2 < p_T^{trk} < 3$ GeV
$3 < p_T^{trk} < 4$ GeV
$4 < p_T^{trk} < 8$ GeV
$8 < p_T^{trk} < 12$ GeV
$12 < p_T^{trk} < 16$ GeV
$16 < p_T^{trk} < 20$ GeV
$0.7 < p_T^{trk} < 20$ GeV

pp reference

$Y = \frac{1}{N_{jet}} \frac{dN}{d\Delta r}$

PbPb 50-100%
PbPb 30-50%
PbPb 10-30%
PbPb 0-10%

PbPb - pp 50-100%
PbPb - pp 30-50%
PbPb - pp 10-30%
PbPb - pp 0-10%

$Y_{PbPb} - Y_{pp}$

Δr

A Linear Boltzmann Transport (LBT) Model

Parton shower
Pythia   Sherpa

Jet propagation

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

- **Rescattering**
  Shower-thermal & recoil-thermal
- **Back reaction**
  Track the initial thermal parton

Local medium information ε T $\boldsymbol{u}$
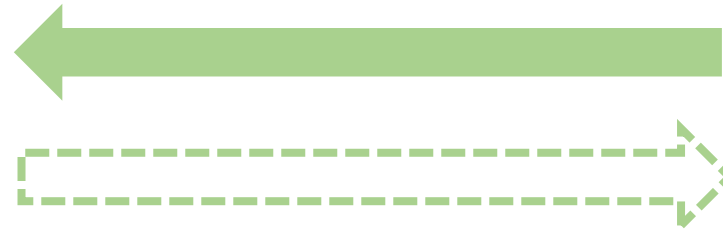
Initial profile
AMPT   TRENTO

Medium evolution

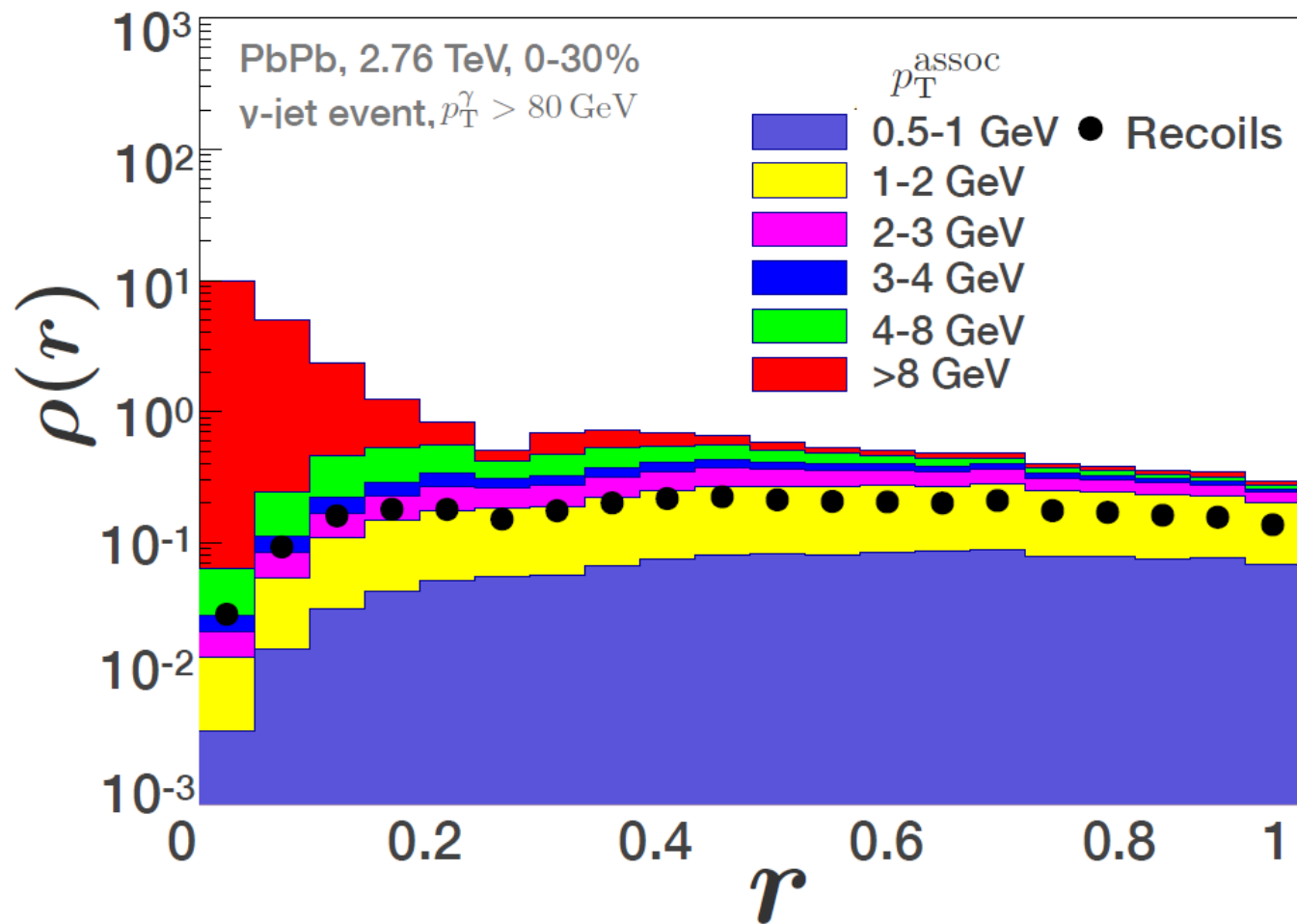$$\partial_\mu T^{\mu\nu} = 0$$

LBT Phys.Rev.C 109 (2024) 3, 034919

Fragmentation   Recombination
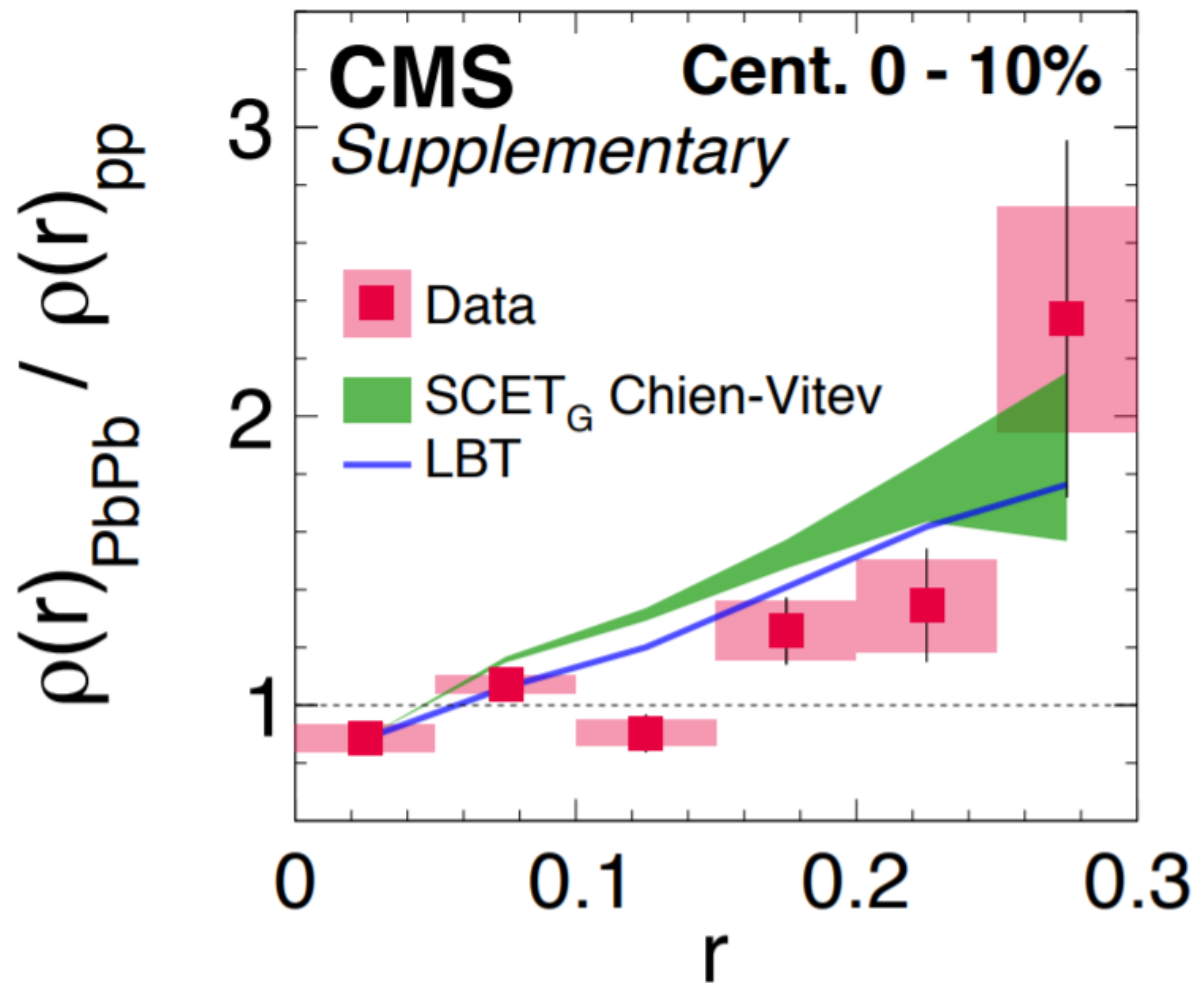
Cooper Frye

LBT
Hard

Hadronic observables

CLvisc
Soft

Jet shape within LBT model

LBT Phys.Lett.B 782 (2018) 707-716
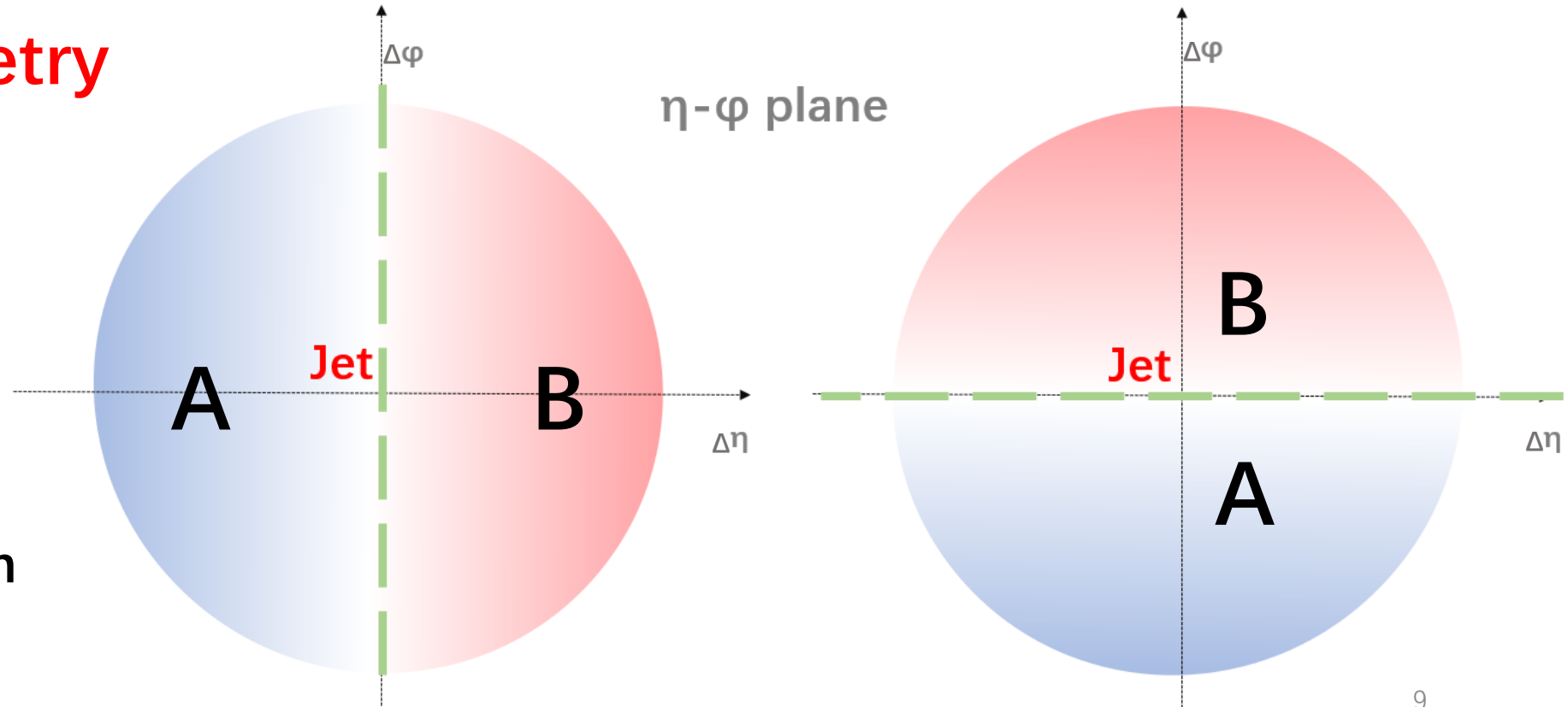
Phase-space cut and intra-jet asymmetry

- A phase space cut inside jet cone (the Δη-Δφ plane). (A .vs. B)

Intra-jet asymmetry
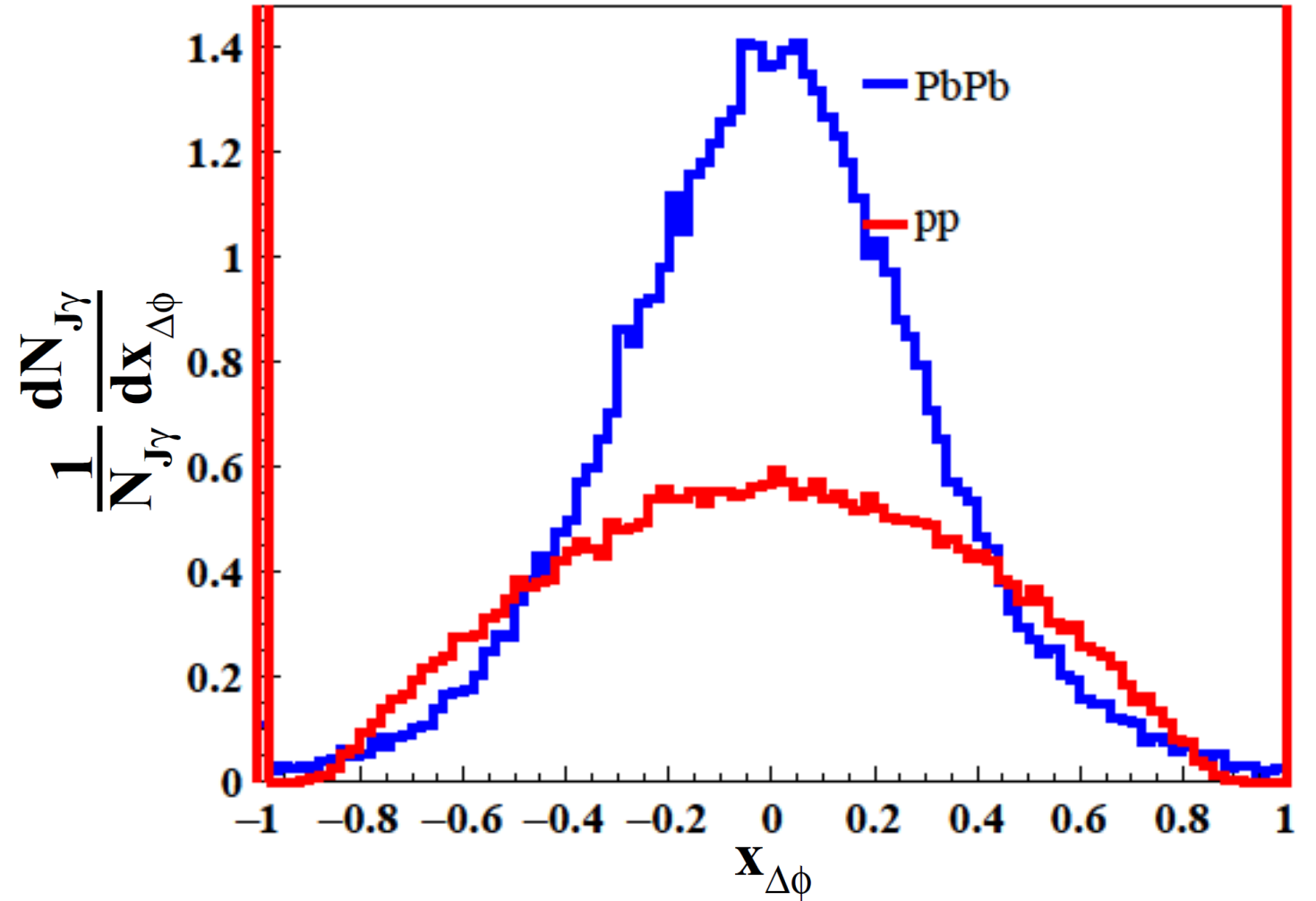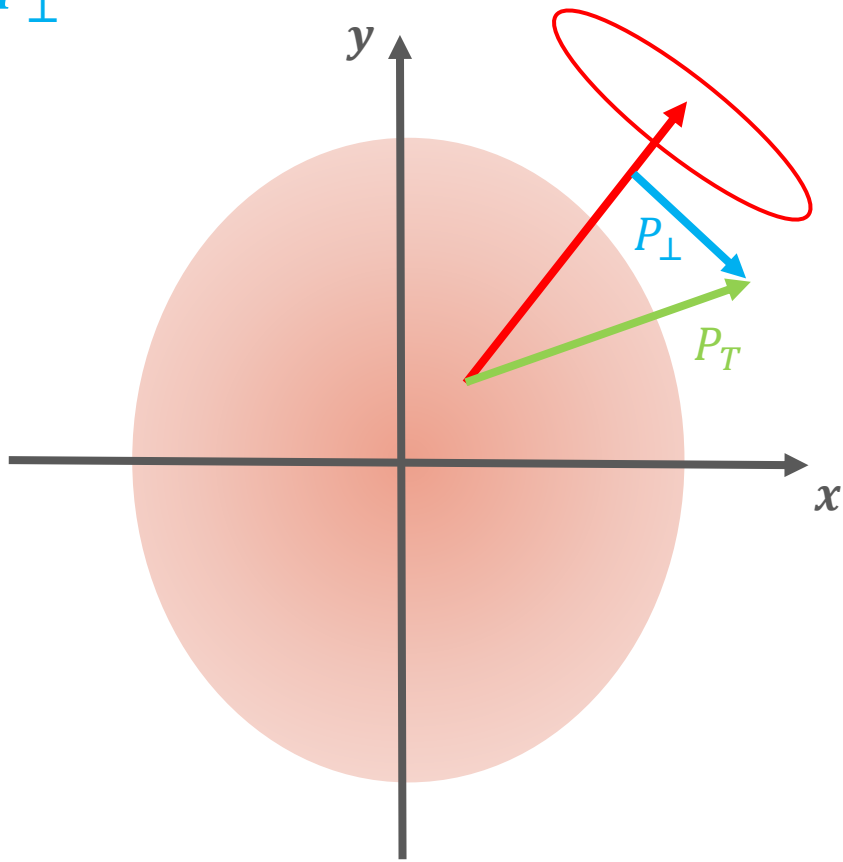
$$\chi = \frac{Q_A - Q_B}{Q_A + Q_B}$$

Particle number

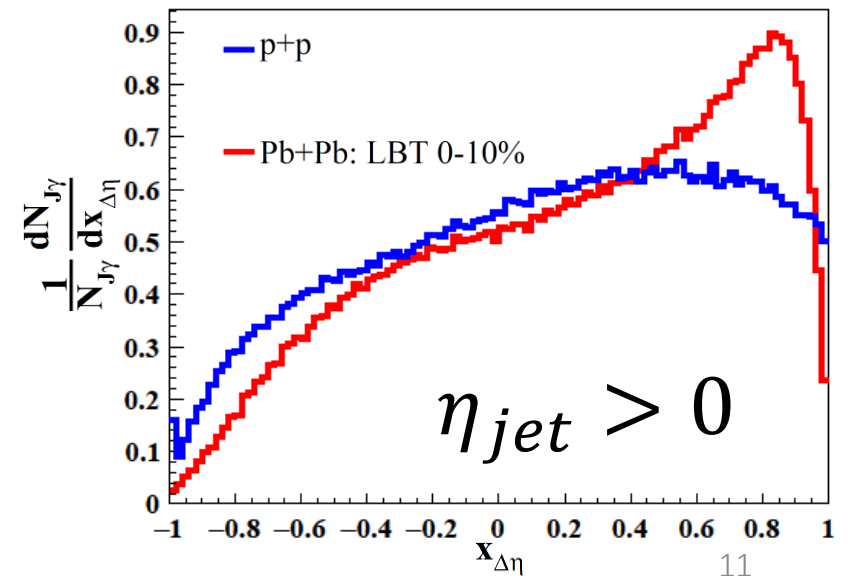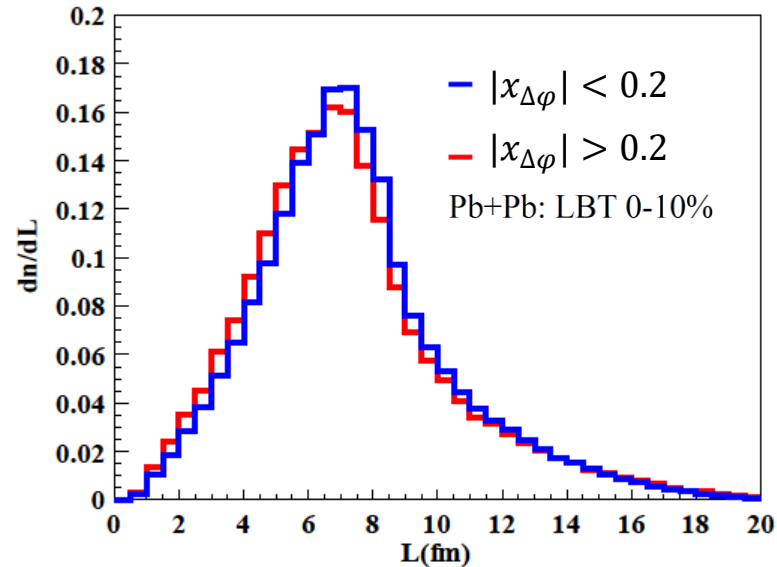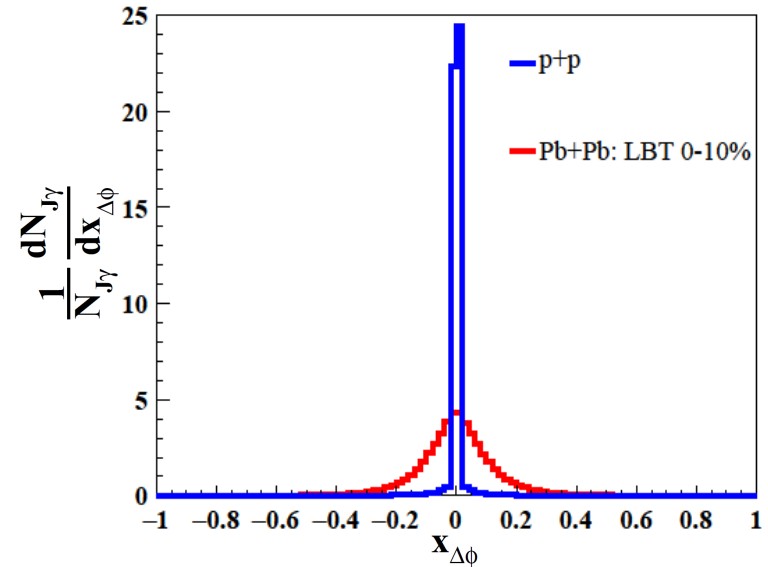Transverse momentum (Jet shape)

η-φ plane
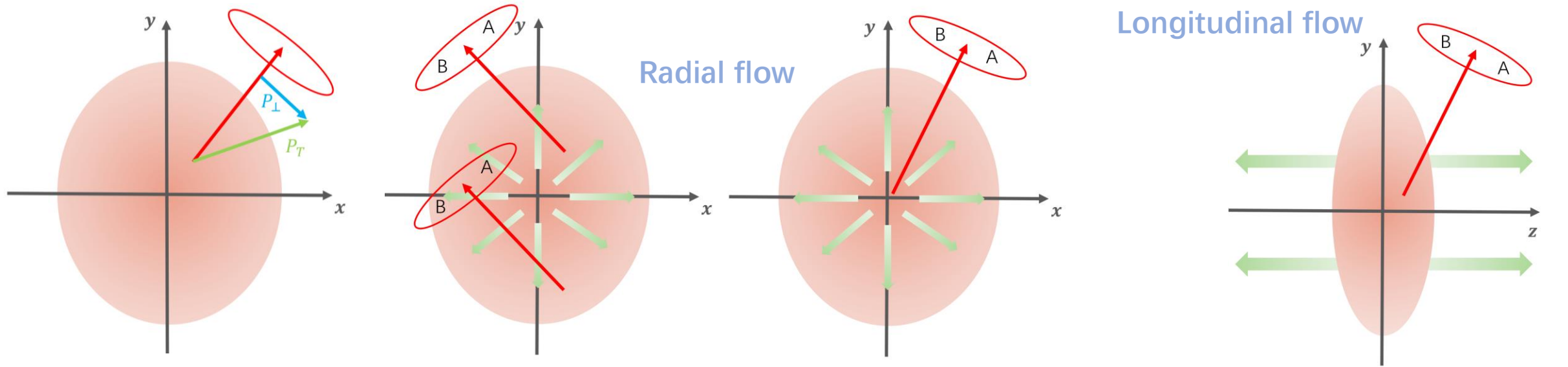
Intra-jet asymmetry (γ-jet)
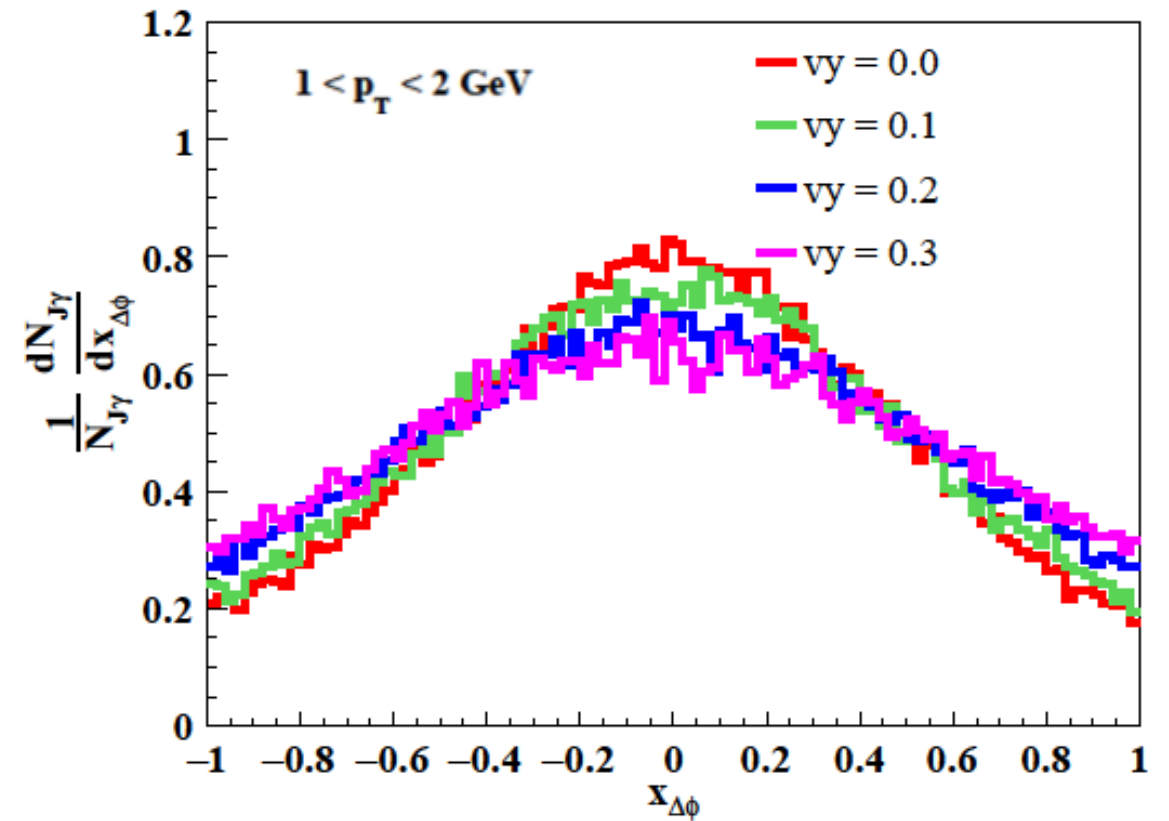
$$X= \frac{Q_A - Q_B}{Q_A + Q_B}$$

P_T: fluctuation!
$P_\perp$
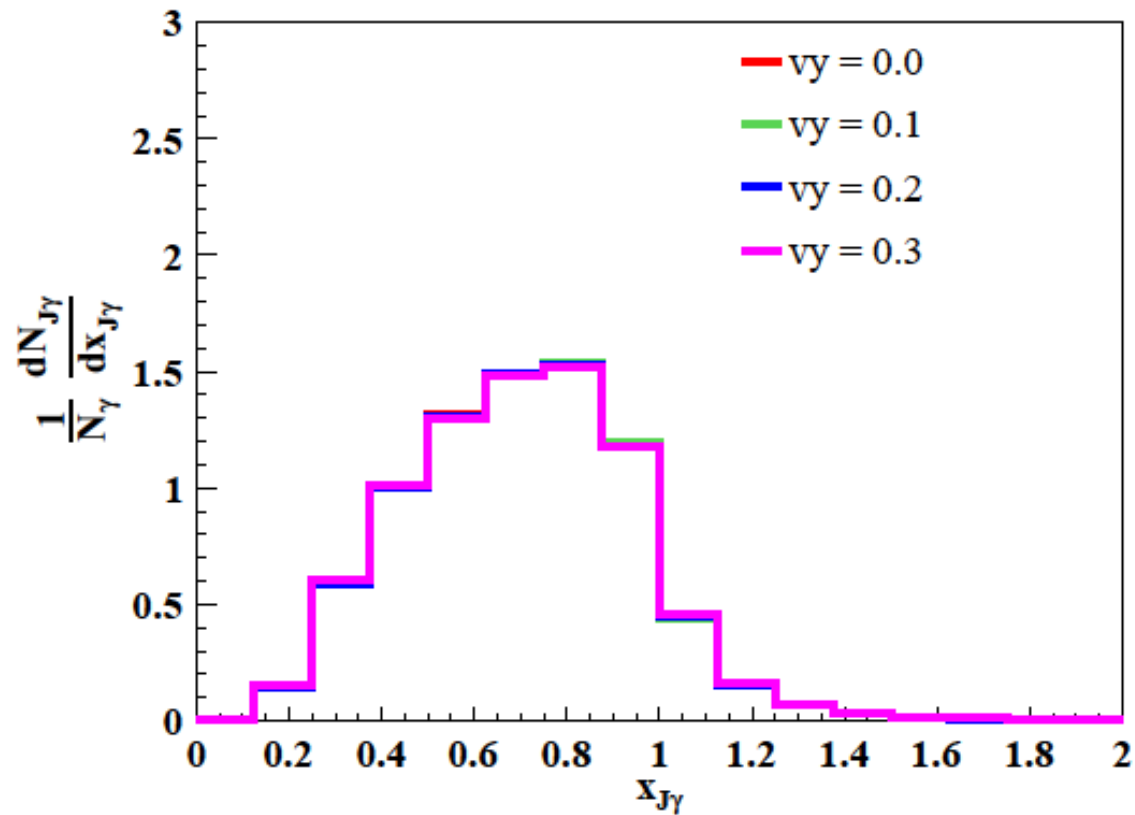
Intra-jet asymmetry increase in AA collisions
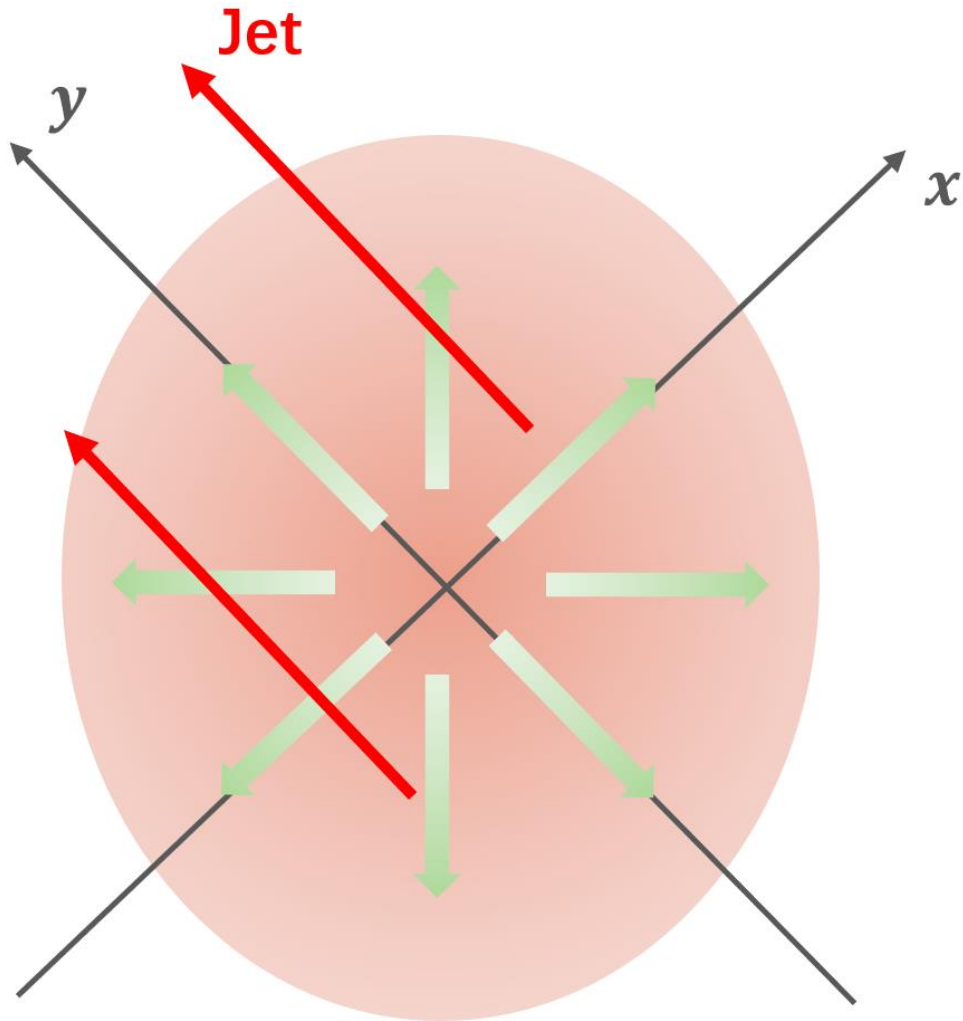

Radial flow

Longitudinal flow

Intra-jet asymmetry & Jet-flow coupling
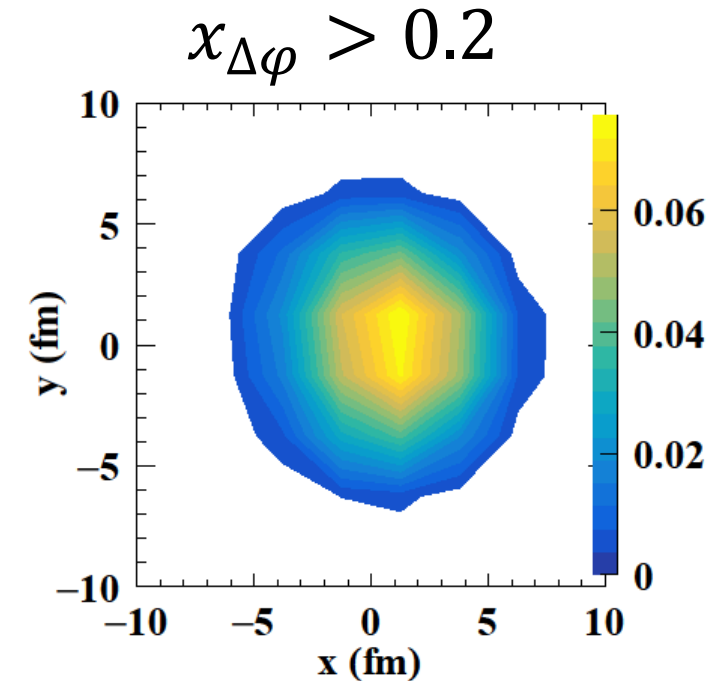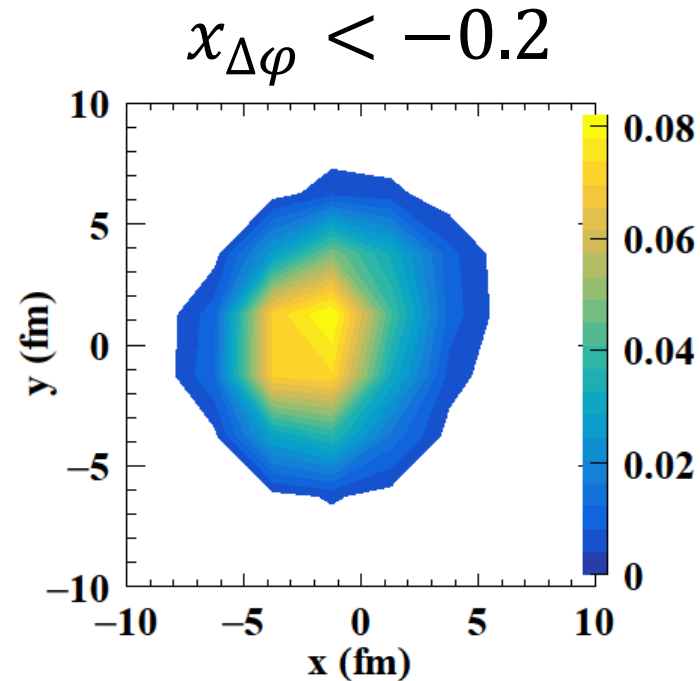
Uniform medium with different flow velocities

Jet localization (γ-jet)

Since the relative angle between jet and the event plane is random, we can use the jet axis as the coordinate axis y' in the transverse plane.

Multiple jets(Dijet) will give an even better localization. (Interplay with the jet-induced diffusion wake)

$$x_{\Delta\varphi} < -0.2 \qquad\qquad x_{\Delta\varphi} > 0.2$$

Jet localization (Dijet)

More jets, more information, better localization.
(Interplay with the jet-induced diffusion wake)
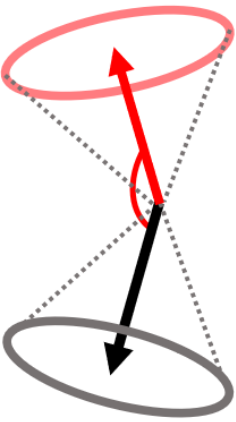
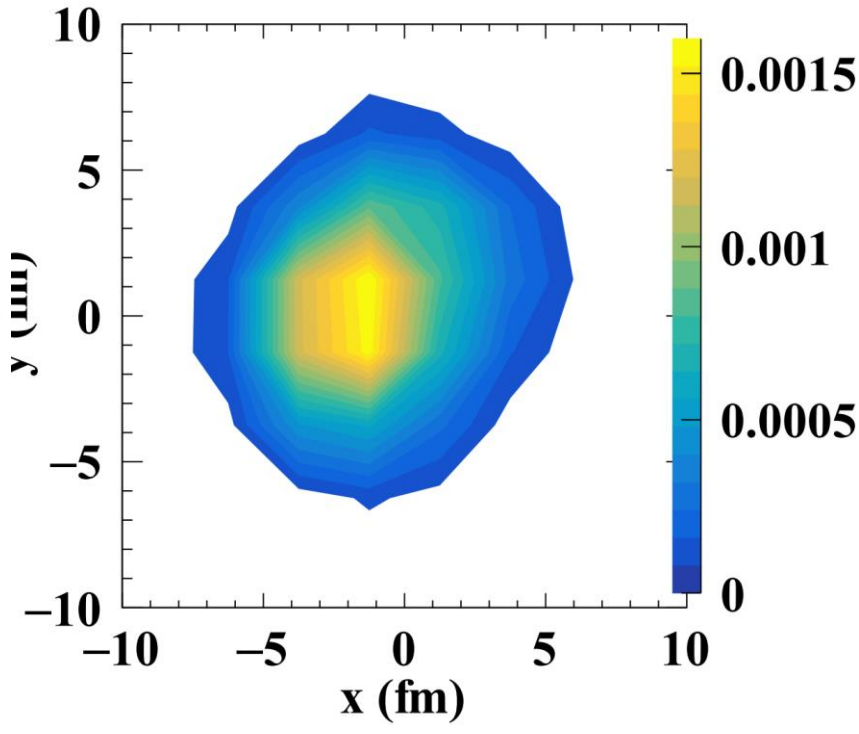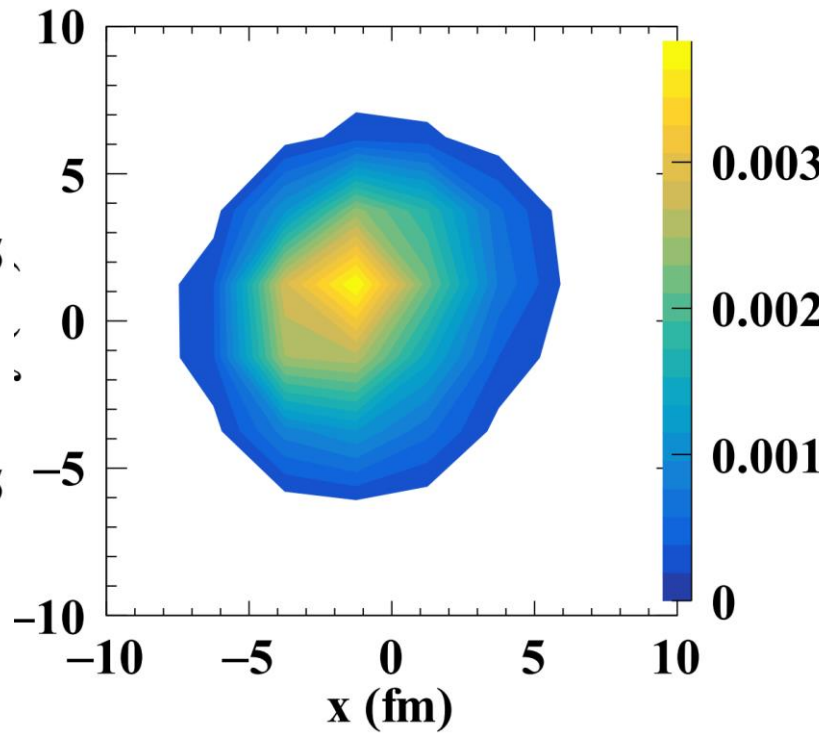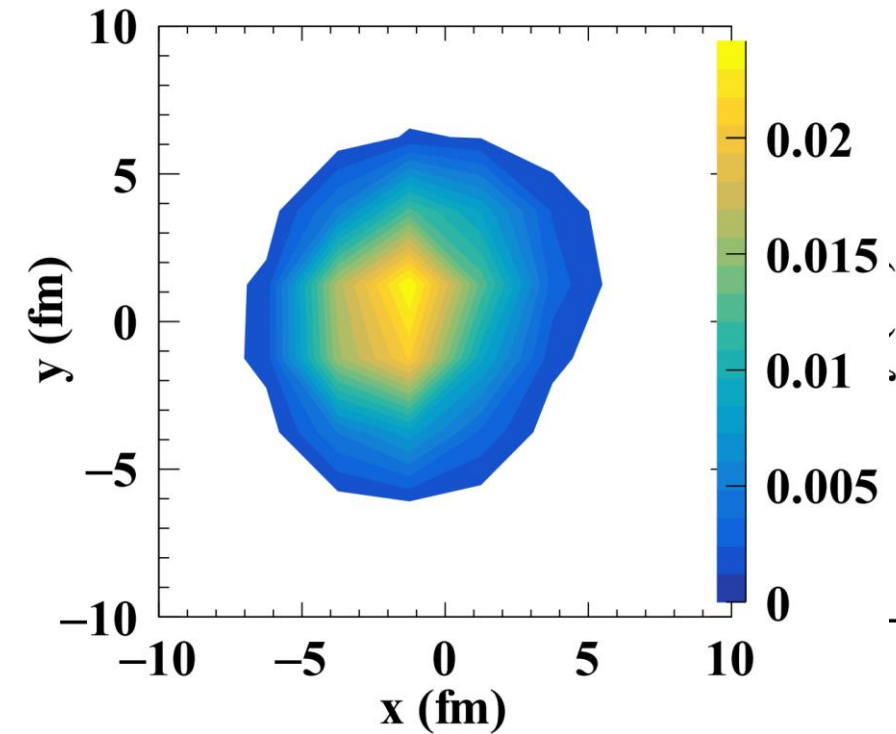$$x_{1\Delta\varphi} < -0.2$$

$$x_{1\Delta\varphi} < -0.2$$

$$x_{1\Delta\varphi} < -0.2$$

$$x_{2\Delta\varphi} > 0.2$$

$$x_{2\Delta\varphi} < -0.2$$

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

- Measuring flow with jets.
  (Medium fluctuation, Hadron cascade, Medium-induced splitting)