Jet-flow coupling in heavy ion collisions

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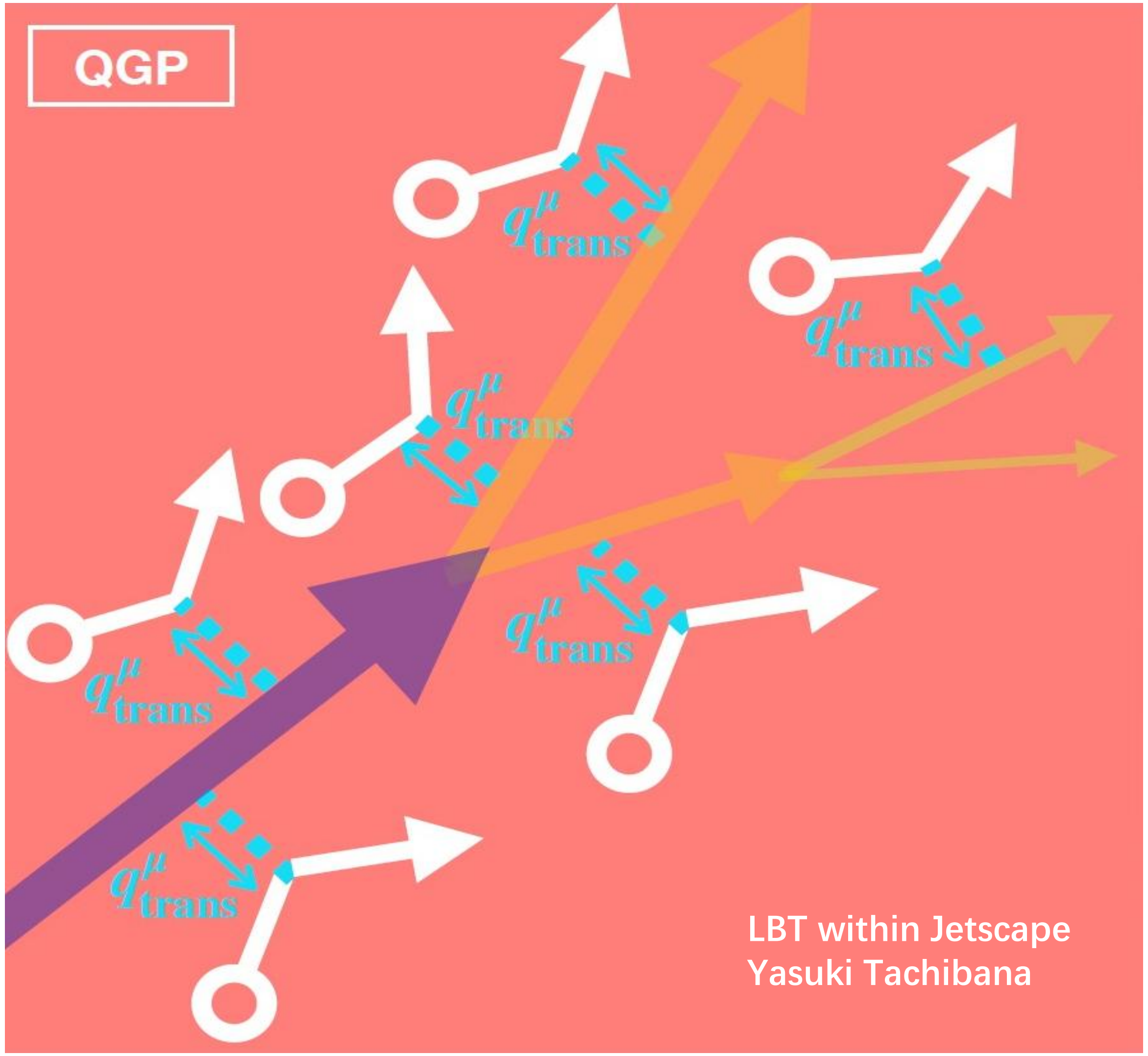
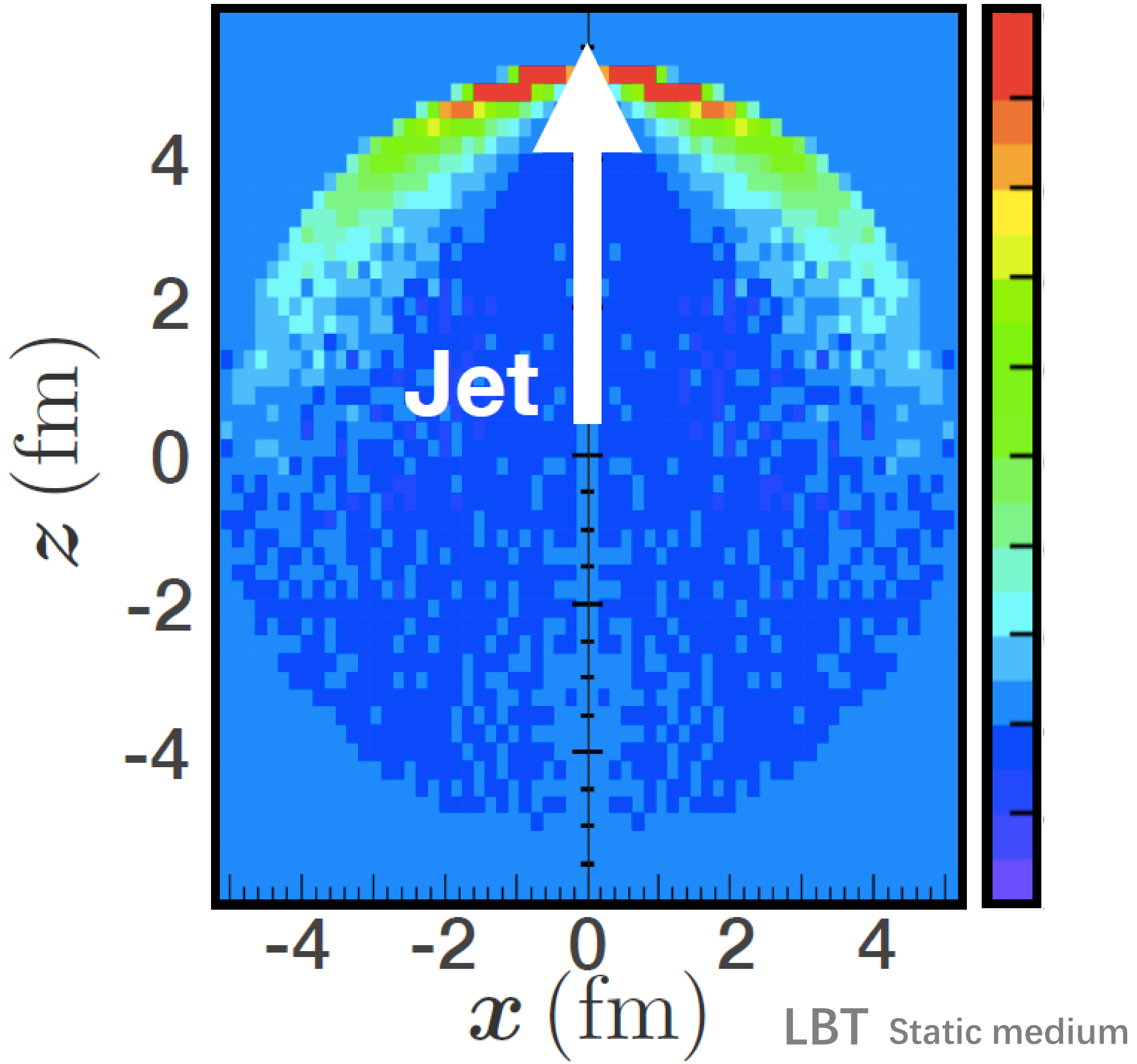
In collaboration with Yayun He, Carlos A. Salgado, Xin-Nian Wang

Jet induced medium response

Negative particle, Particle hole, Wake, Initial thermal parton

Energy-momentum conservation



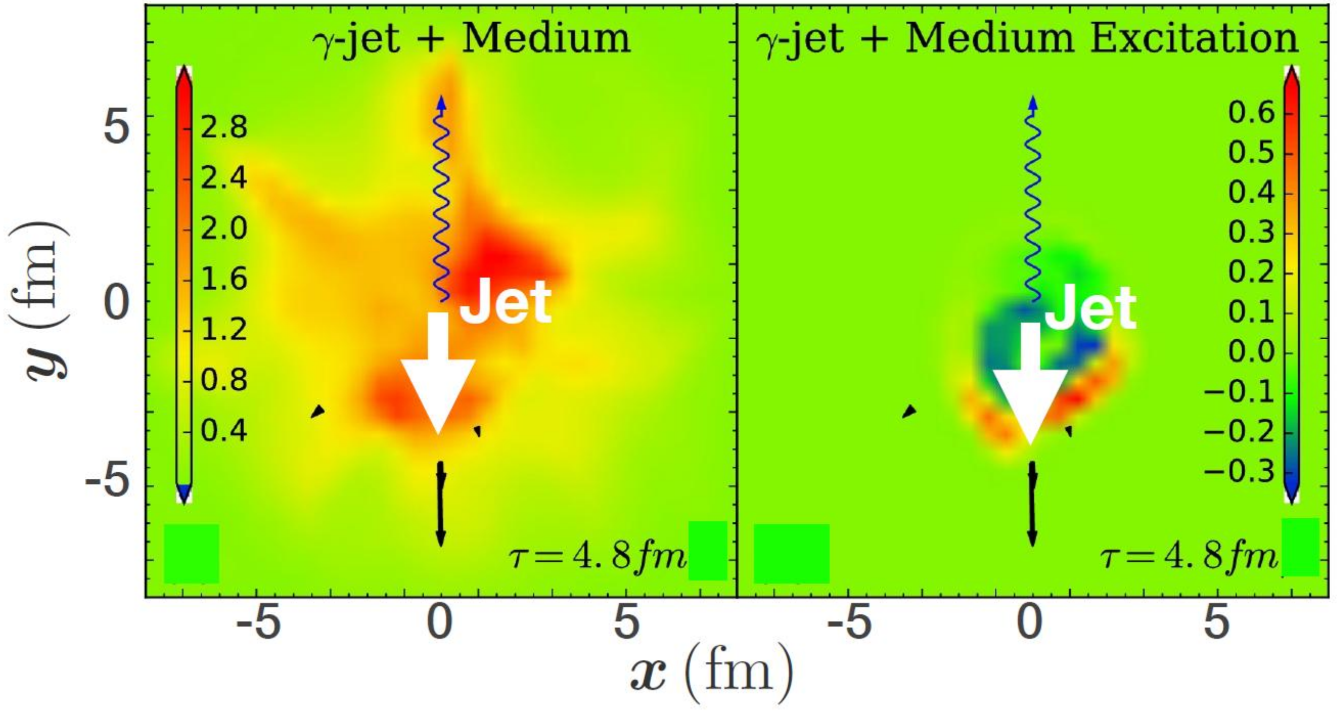


Jet induced medium response

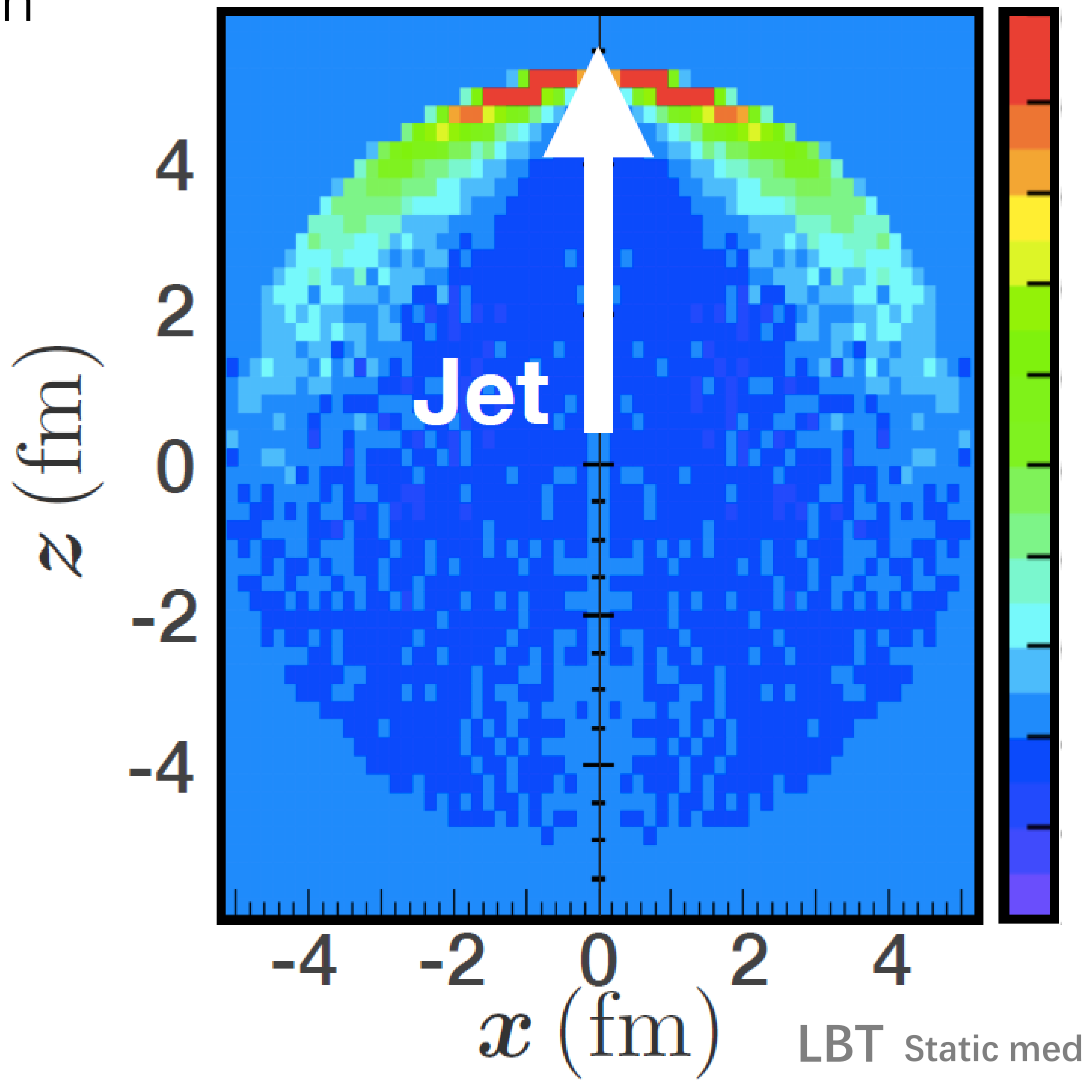
- **Structure of medium response**
  Jet induced mach cone followed by a diffusion wake.

- **Distorted due to jet-medium interaction**

CoLBT-hydro Phys.Lett. B777 86-90



Energy-momentum conservation

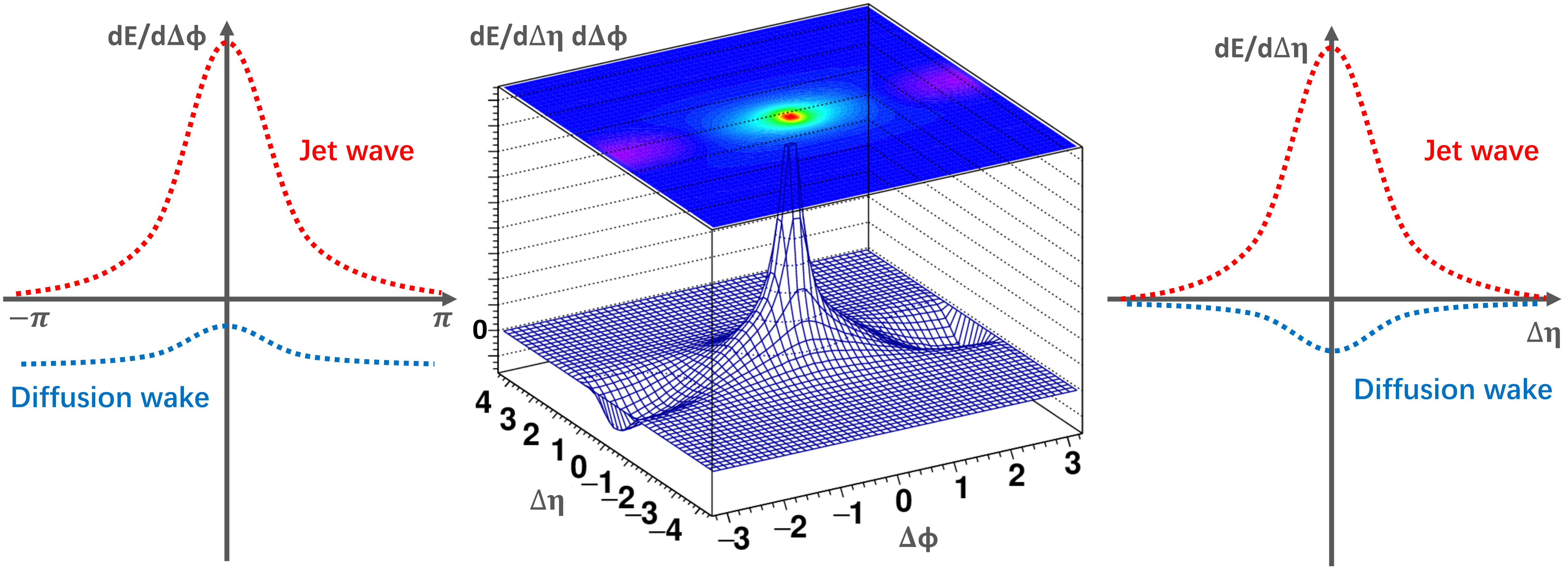


LBT Static medium

Jet induced medium response: a naive picture

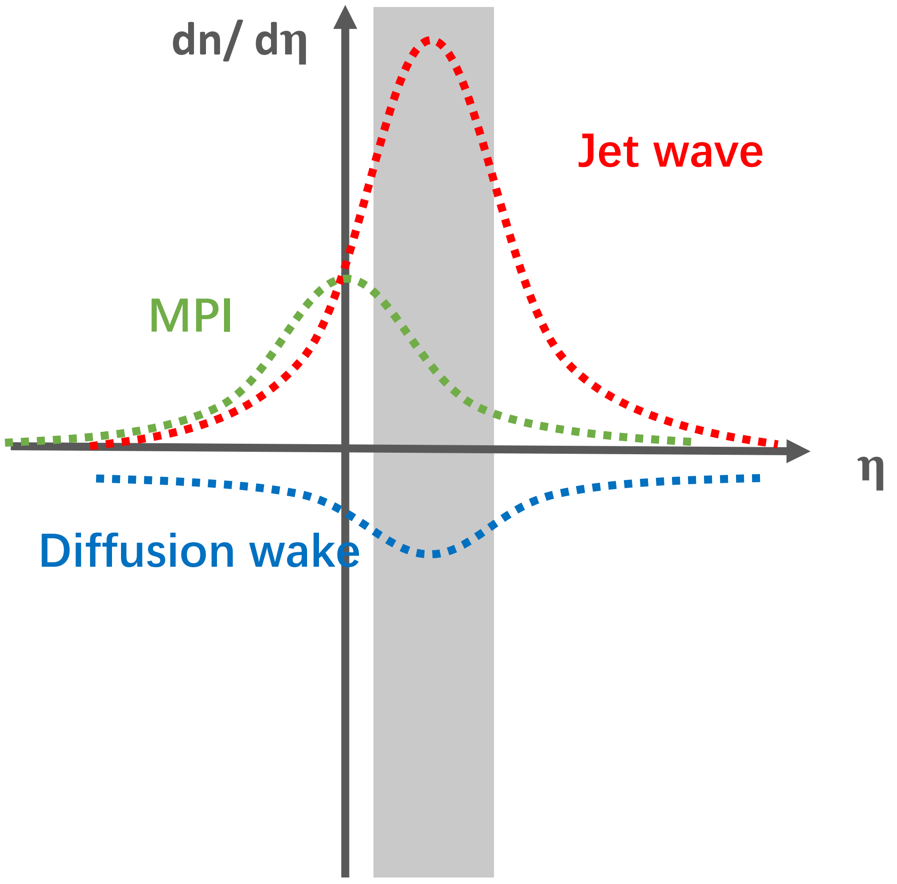
- The deep in the back side of the jet (Signal of the diffusion wake).

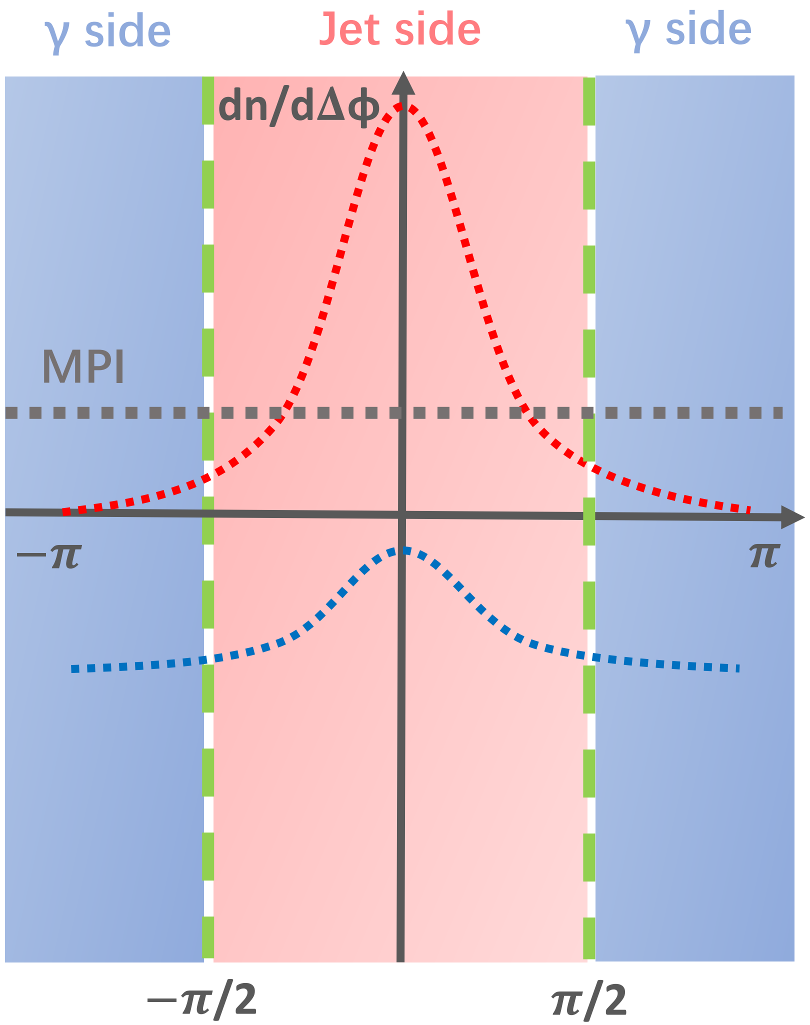
- The induced diffusion wake is locate at the same rapidity range as the jet.

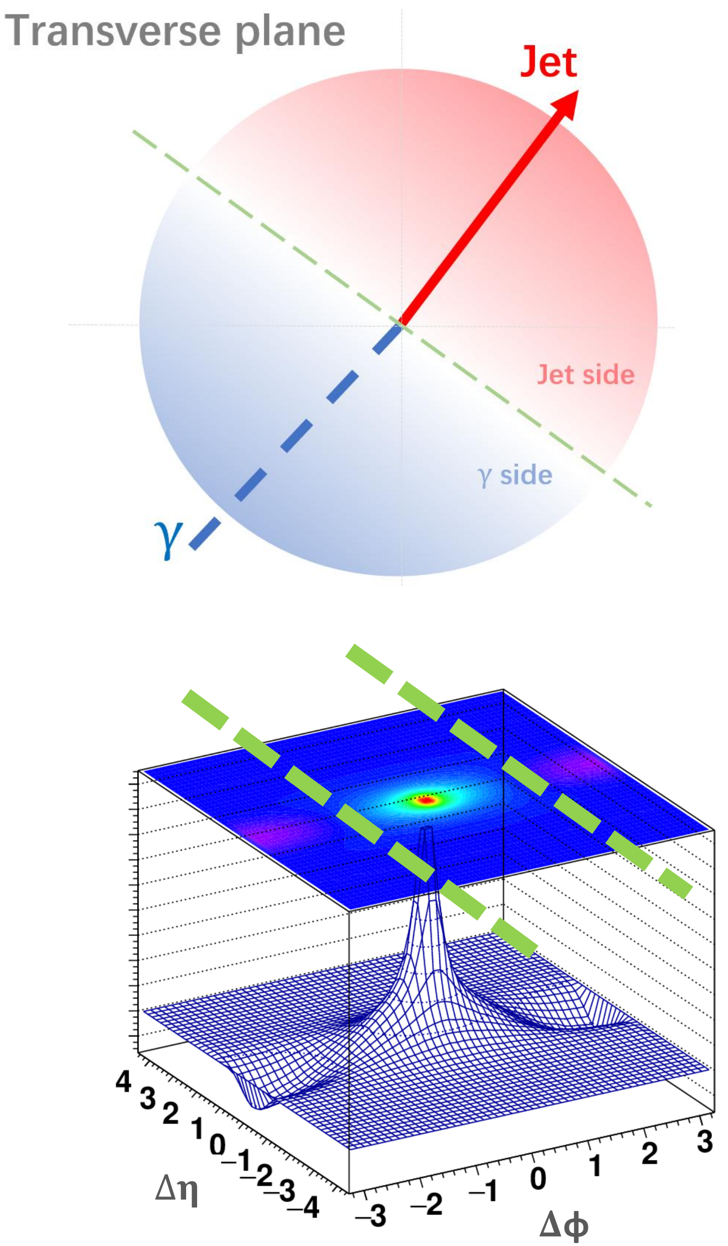


Searching for the diffusion wake

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



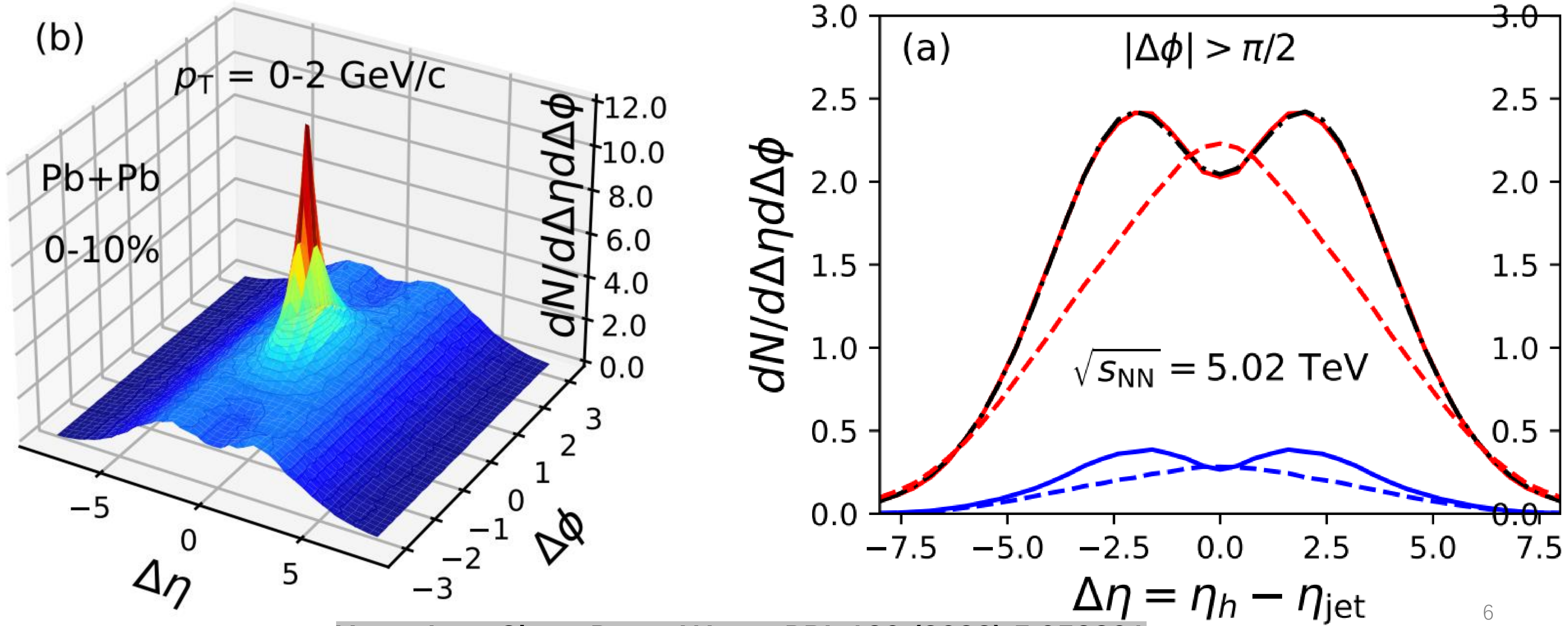




Diffusion wake in the longitudinal structure

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

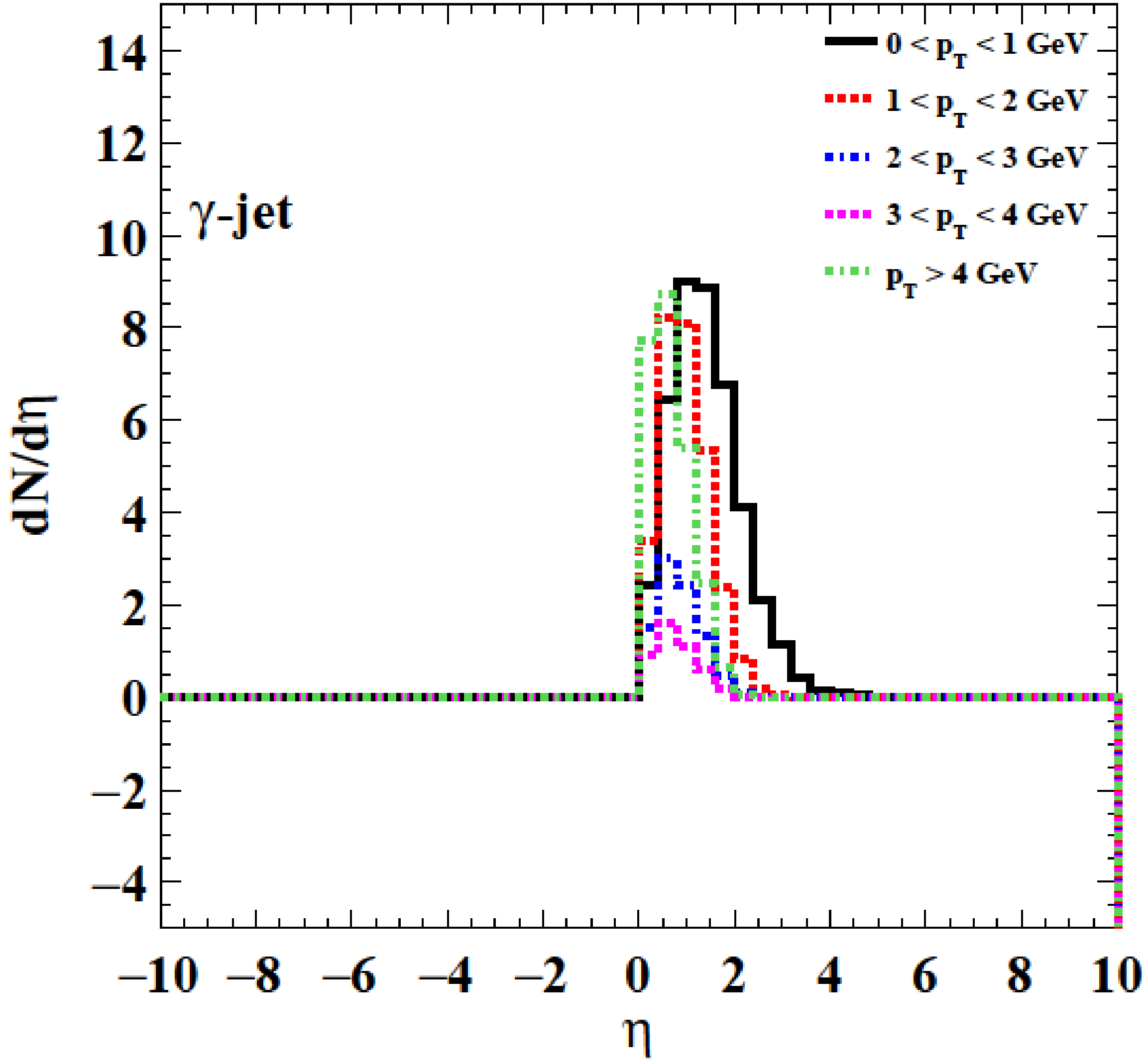
- **Quantify the wake with Gaussian fit**



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

Intra-jet asymmetry (Jet winnowing)

Jet side



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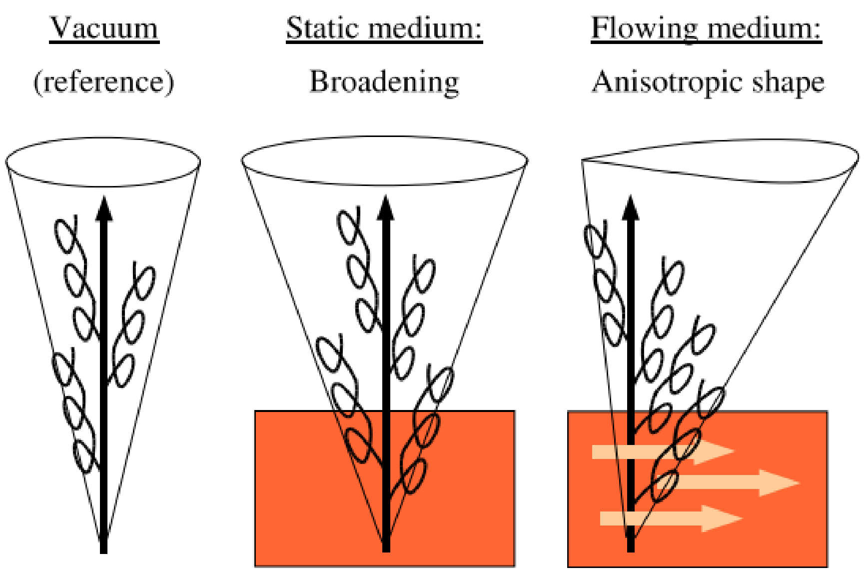
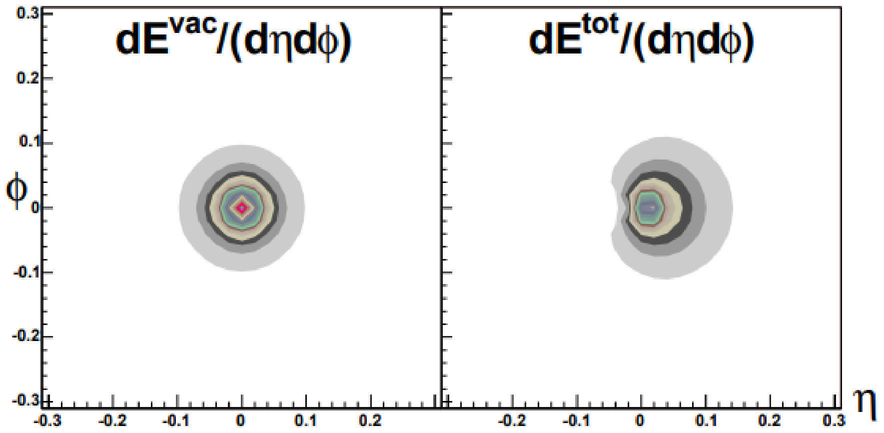
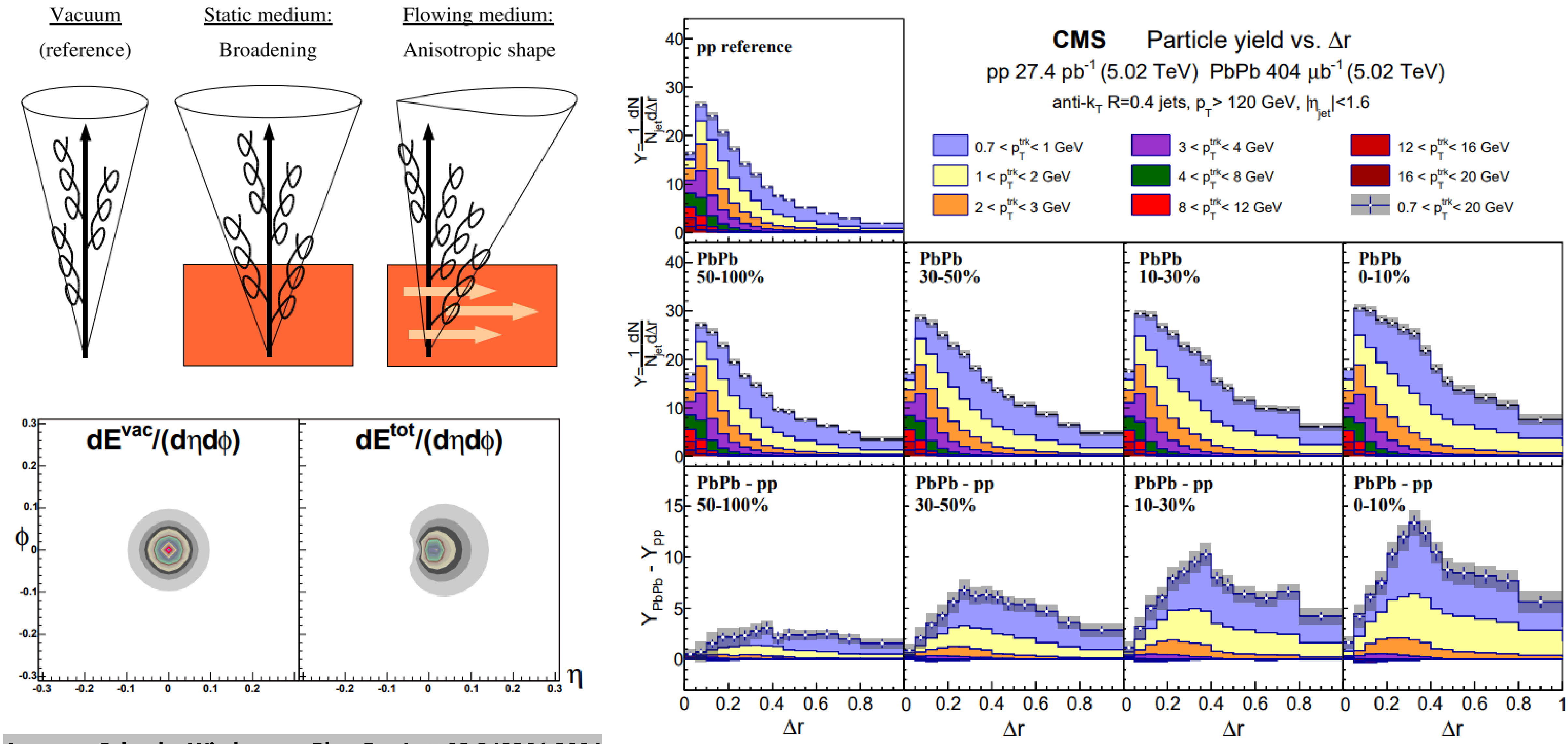




Armesto, Salgado, Wiedemann Phys.Rev.Lett.93:242301,2004

Intra-jet asymmetry (The jet-flow coupling)



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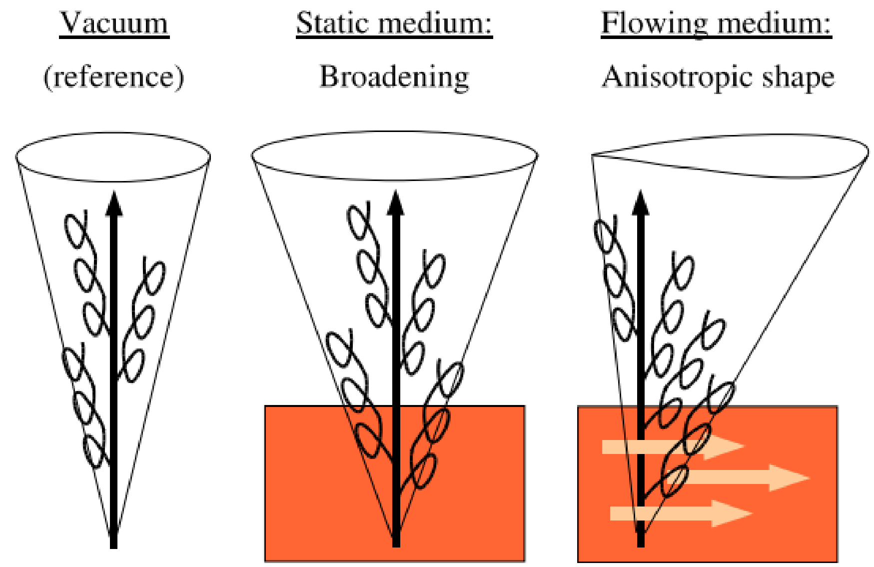

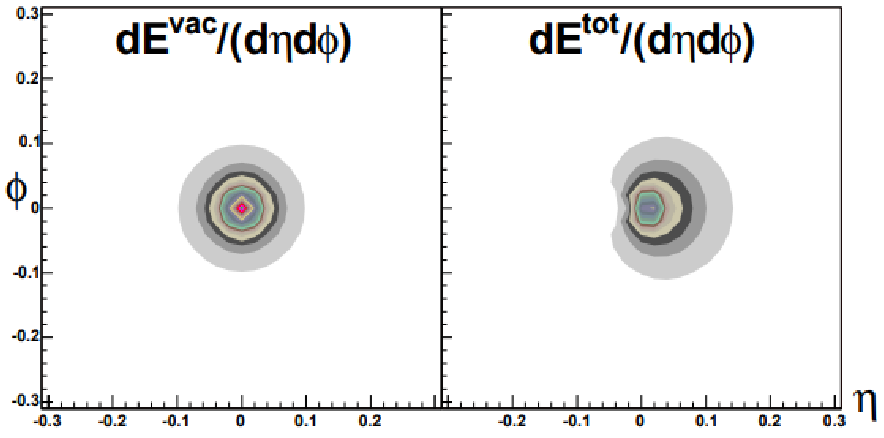

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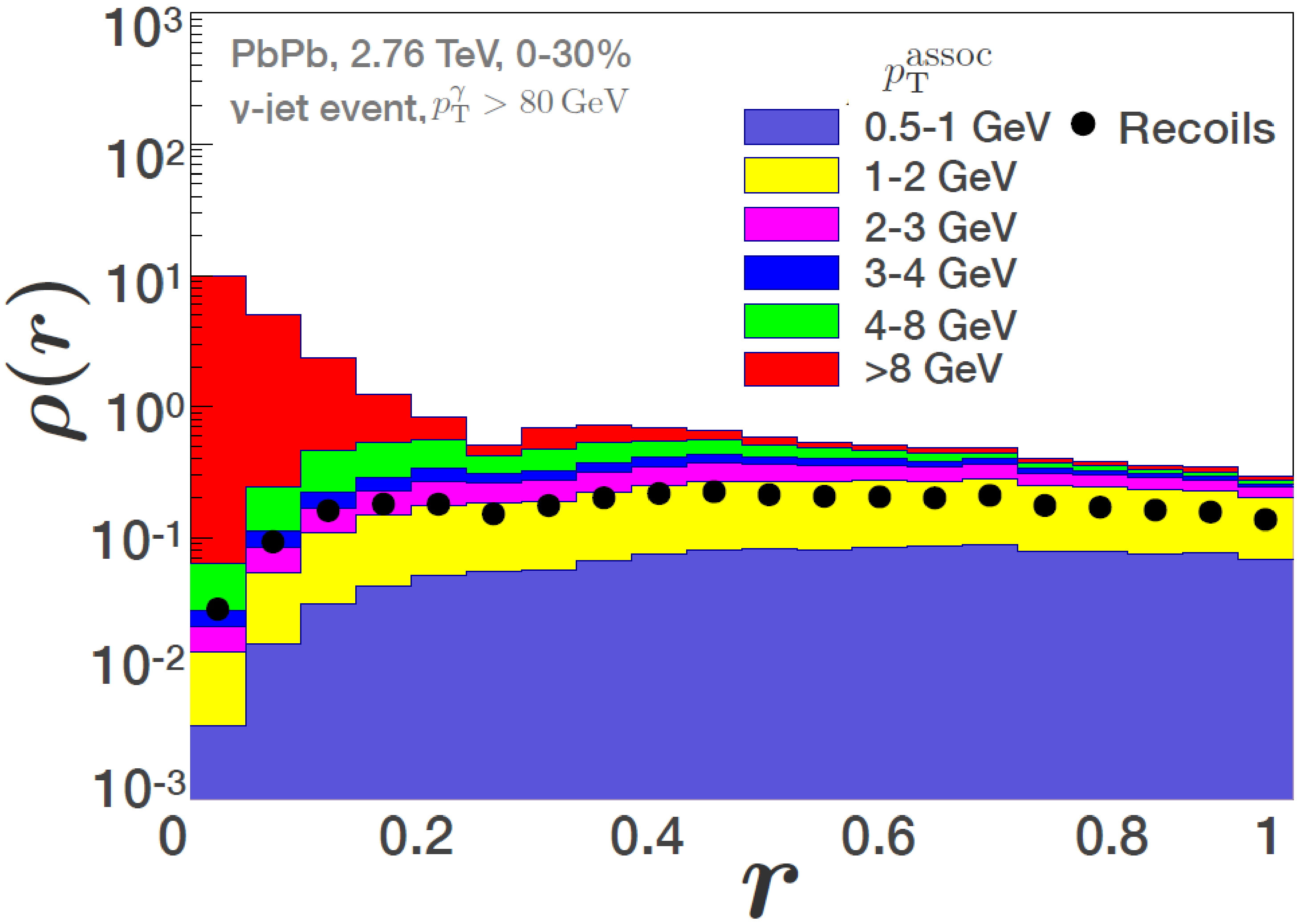
LBT Phys.Lett.B 782 (2018) 707-716



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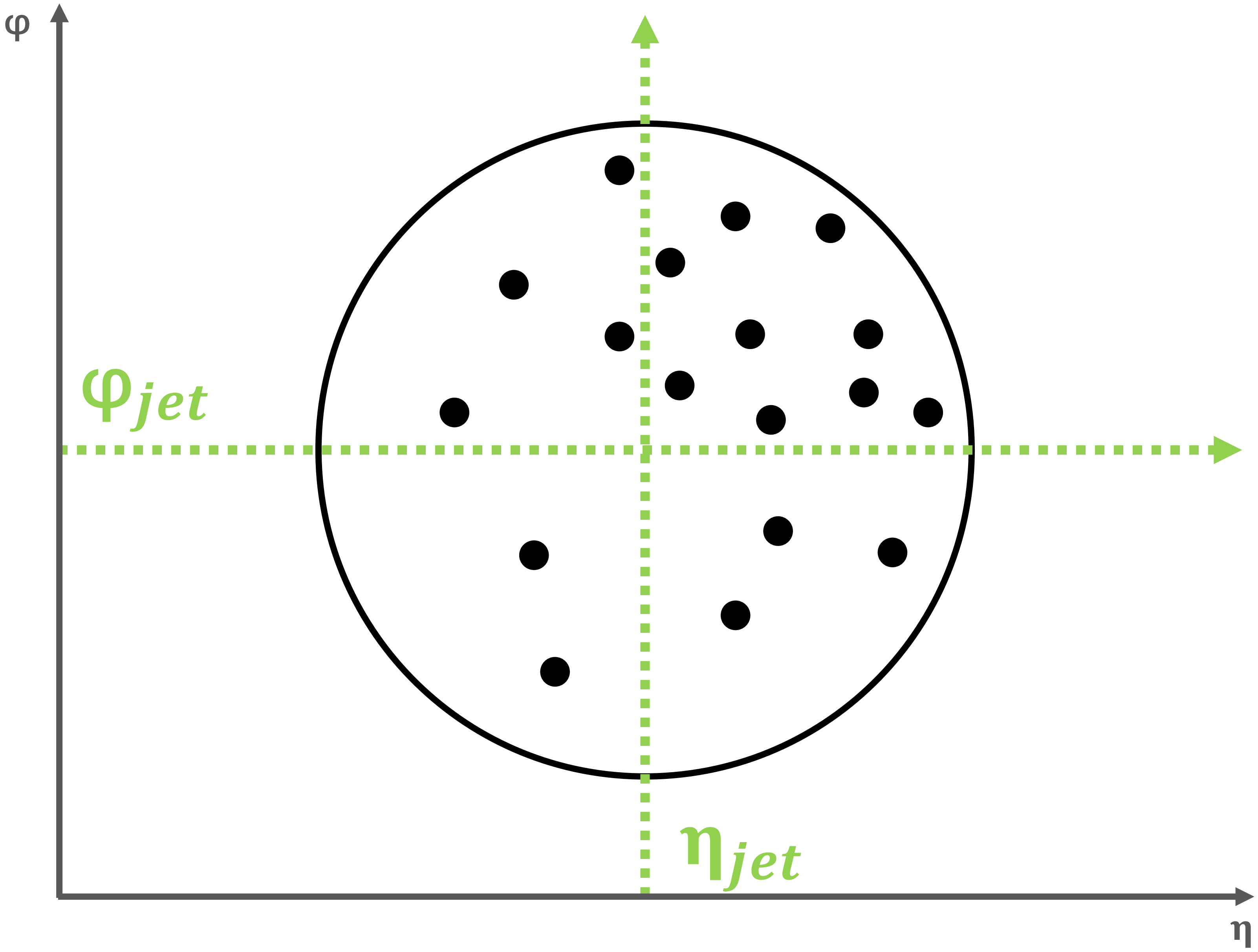
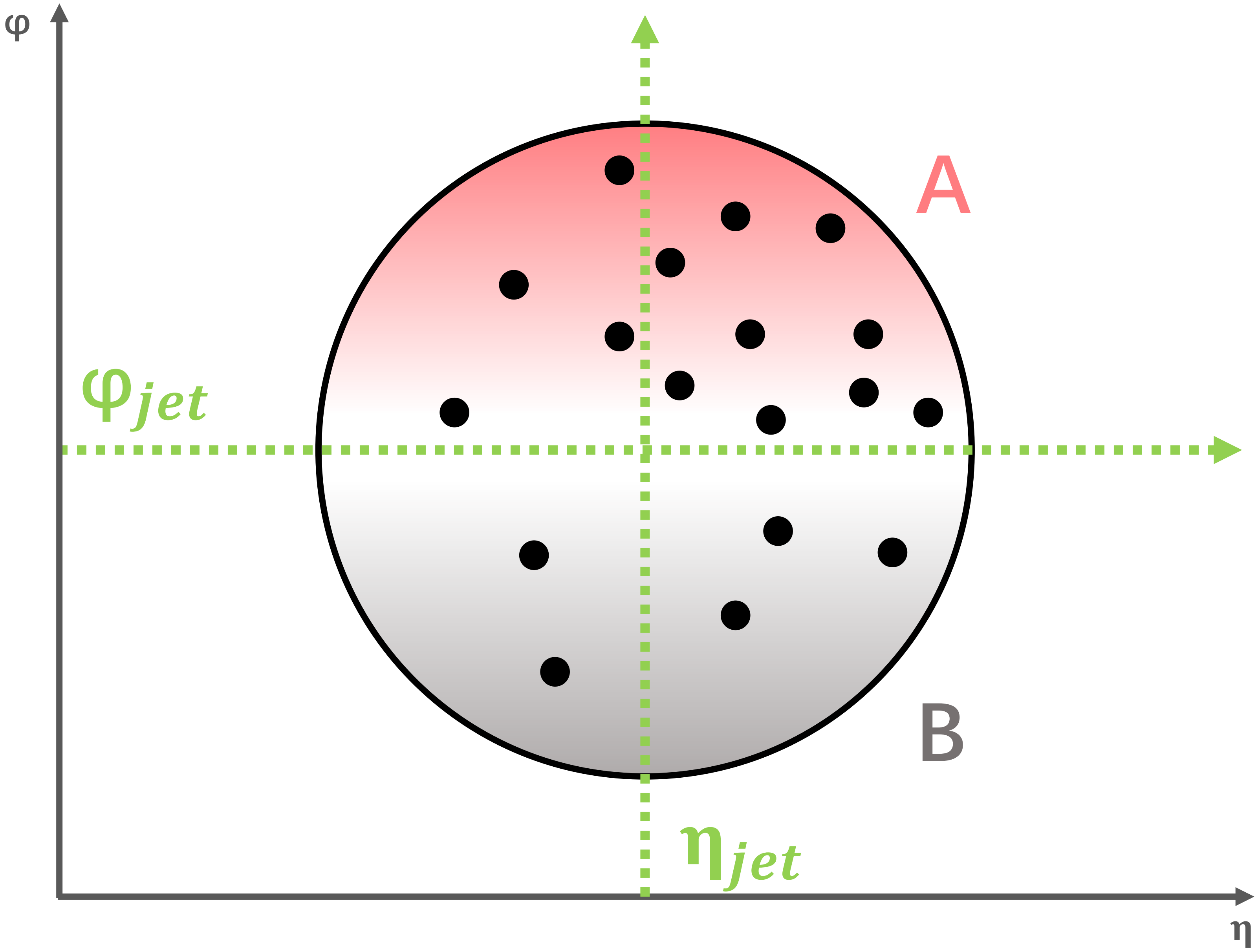


$$X = \frac{Q_A - Q_B}{Q_A + Q_B}$$

$$Q_A = \sum_{i \in A} p_{\perp i}$$
$$Q_B = \sum_{i \in B} p_{\perp i}$$

Intra-jet asymmetry (The jet-flow coupling)



$$X = \frac{Q_A - Q_B}{Q_A + Q_B}$$

$$Q_A = \sum_{i \in A} q_i$$
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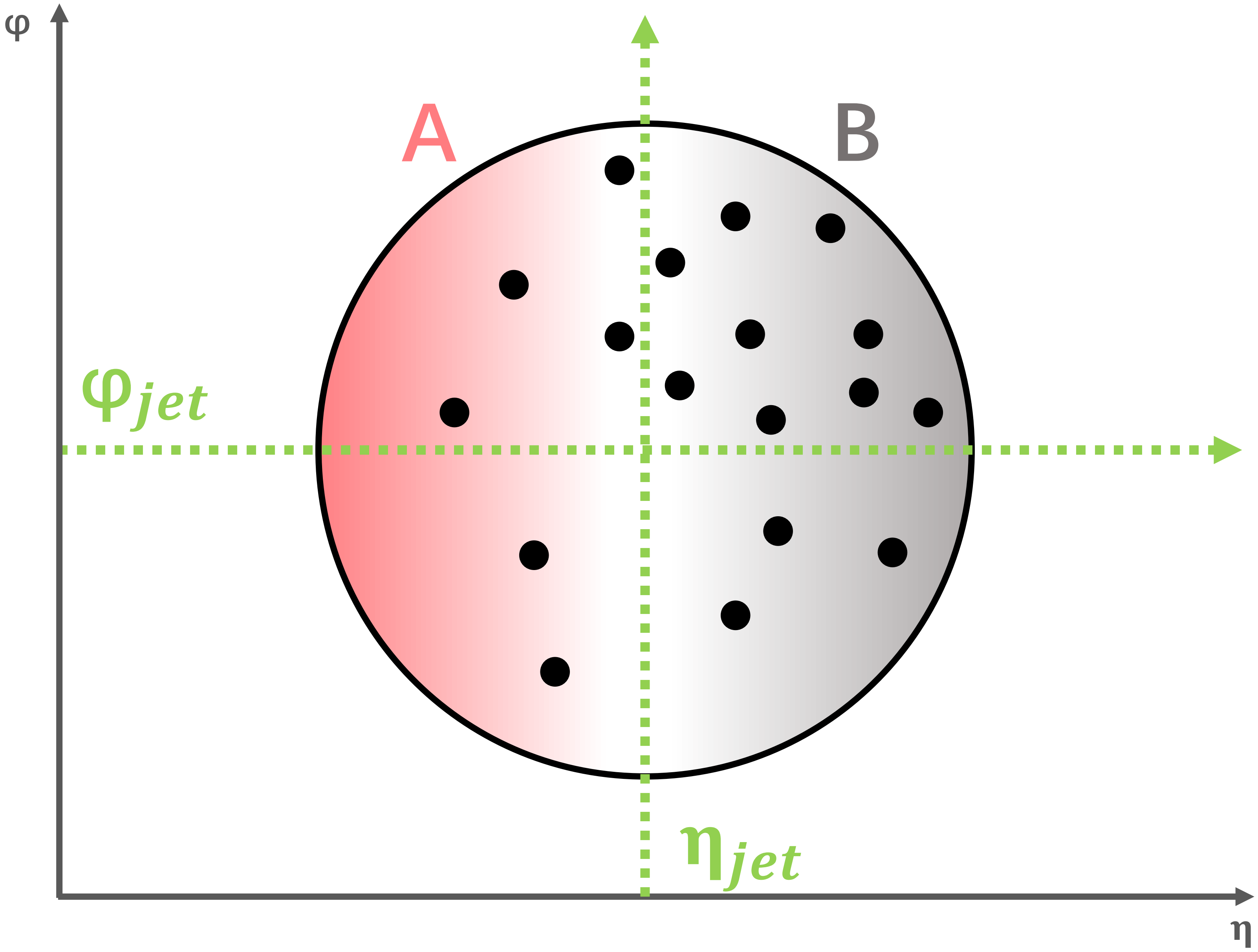
A ($\varphi_i > \varphi_{jet}$)

B ($\varphi_i < \varphi_{jet}$)

Intra-jet asymmetry (The jet-flow coupling)



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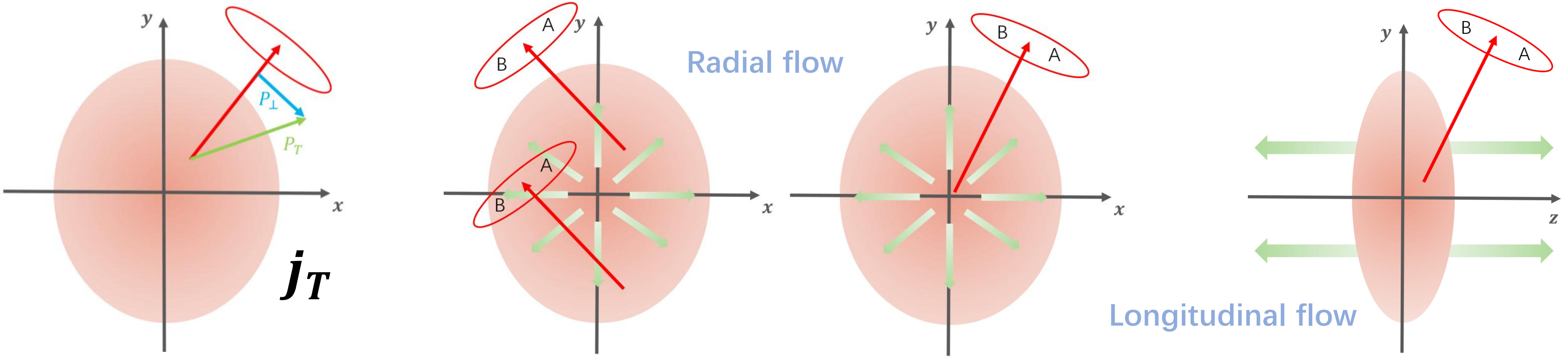
A $(\eta_i > \eta_{jet})$

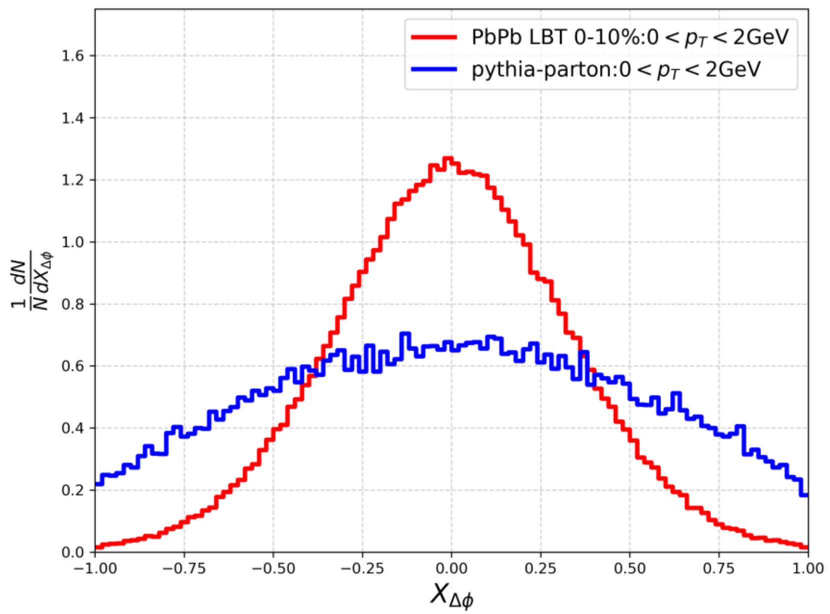
B $(\eta_i < \eta_{jet})$

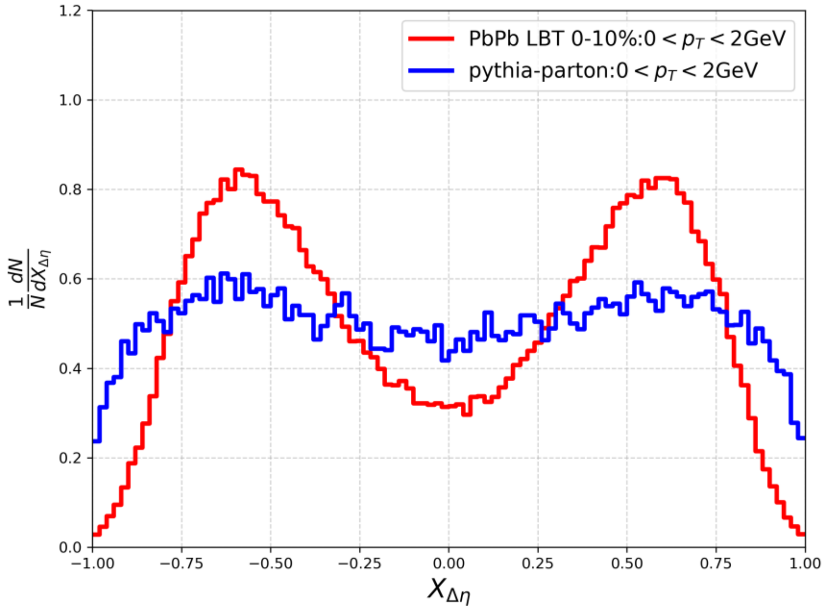
Intra-jet asymmetry in AA & pp collisions (γ-jet)



Flow .vs. Fluctuation

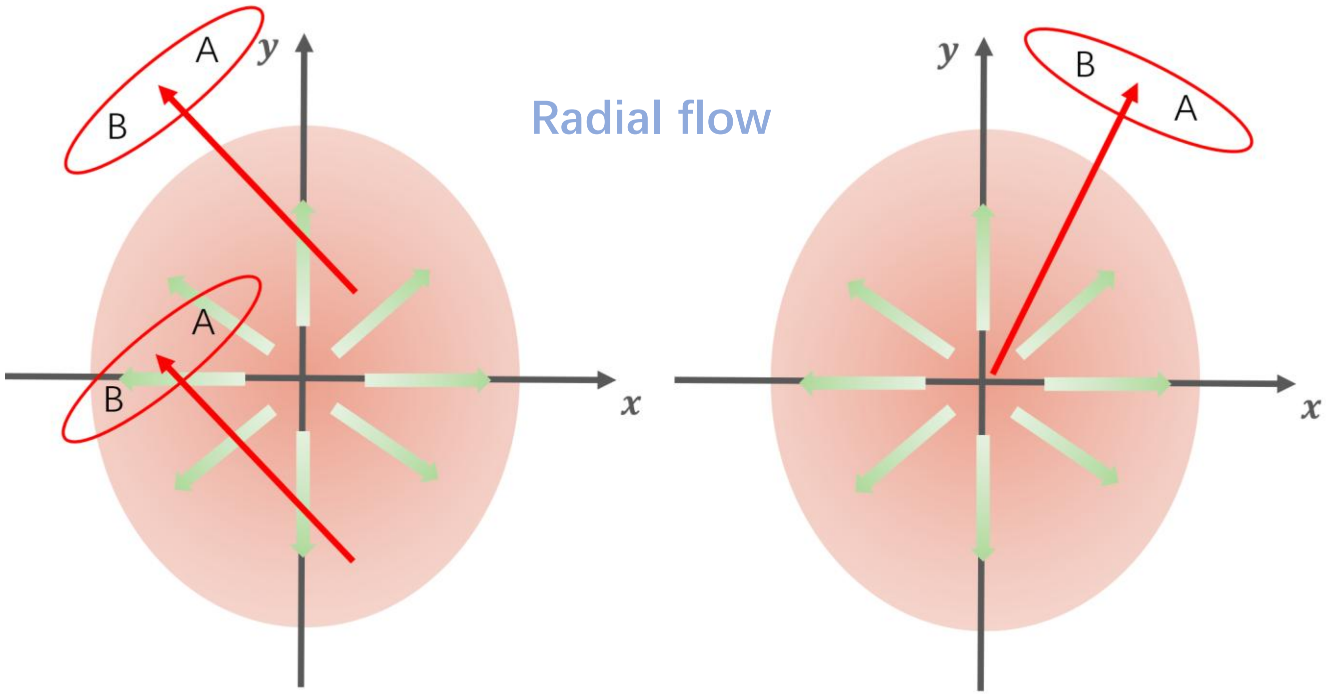
Increased jet multiplicity in AA collisions produces more symmetric jets than in pp.

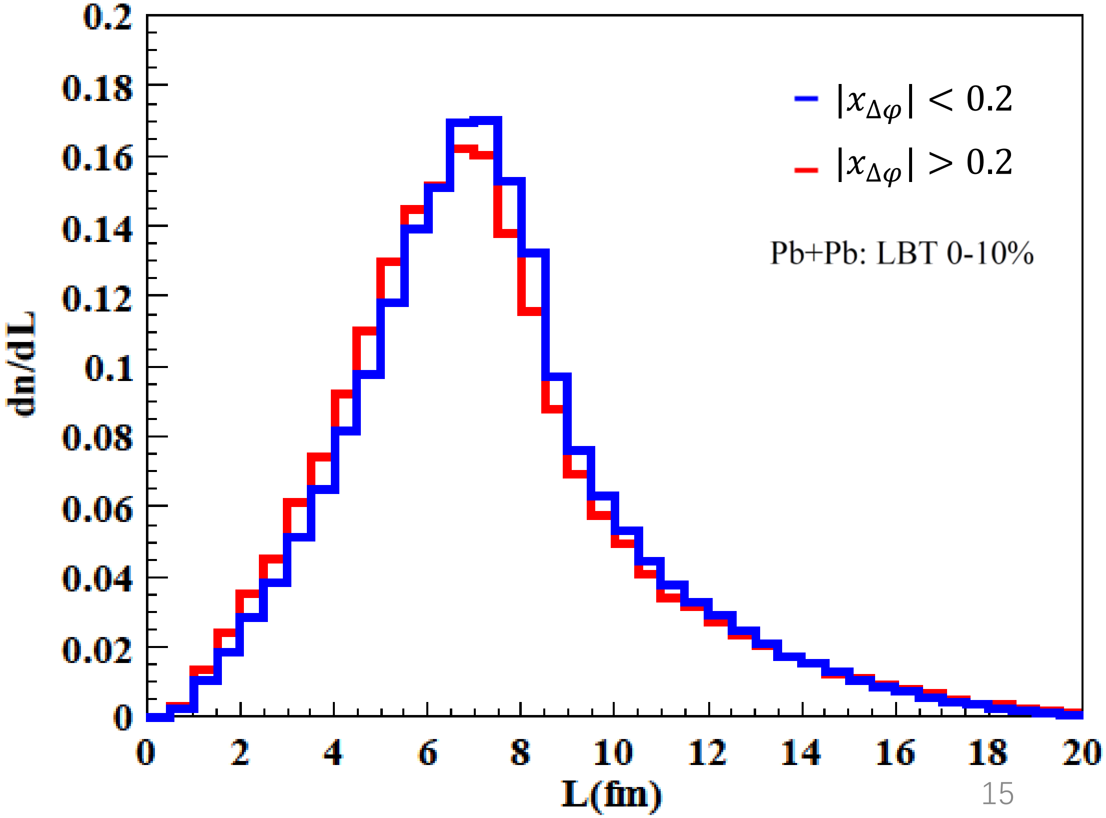




Intra-jet asymmetry in AA collisions (γ-jet)

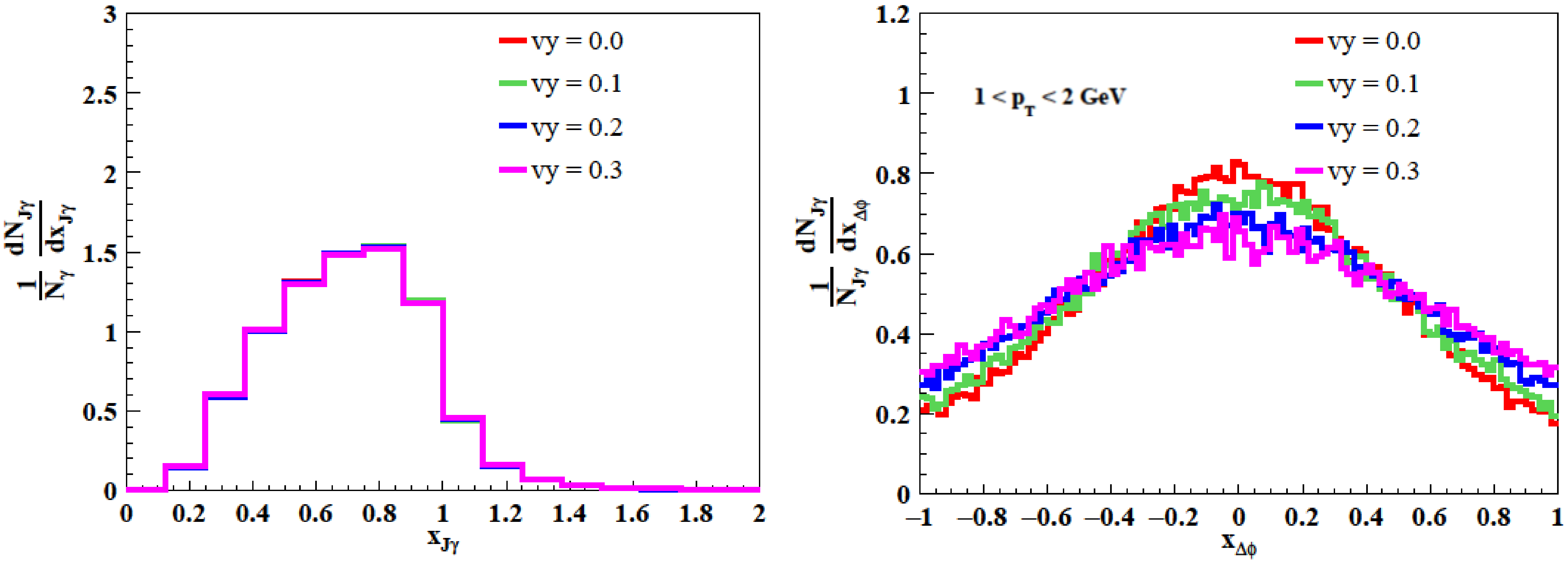
- Jets propagating perpendicularly to the flow will suffer stronger distortion.
- In average, the path length of the jets with larger asymmetry will be slightly shorter compared to jets that are more symmetric.



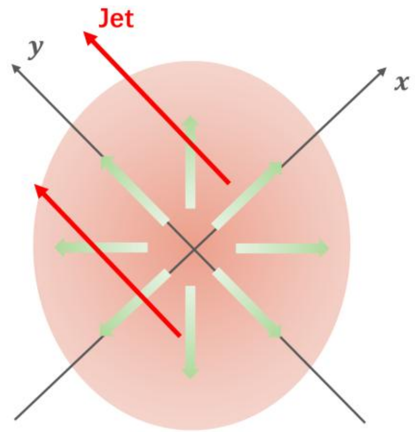


Intra-jet asymmetry & Jet-flow coupling (γ-jet)

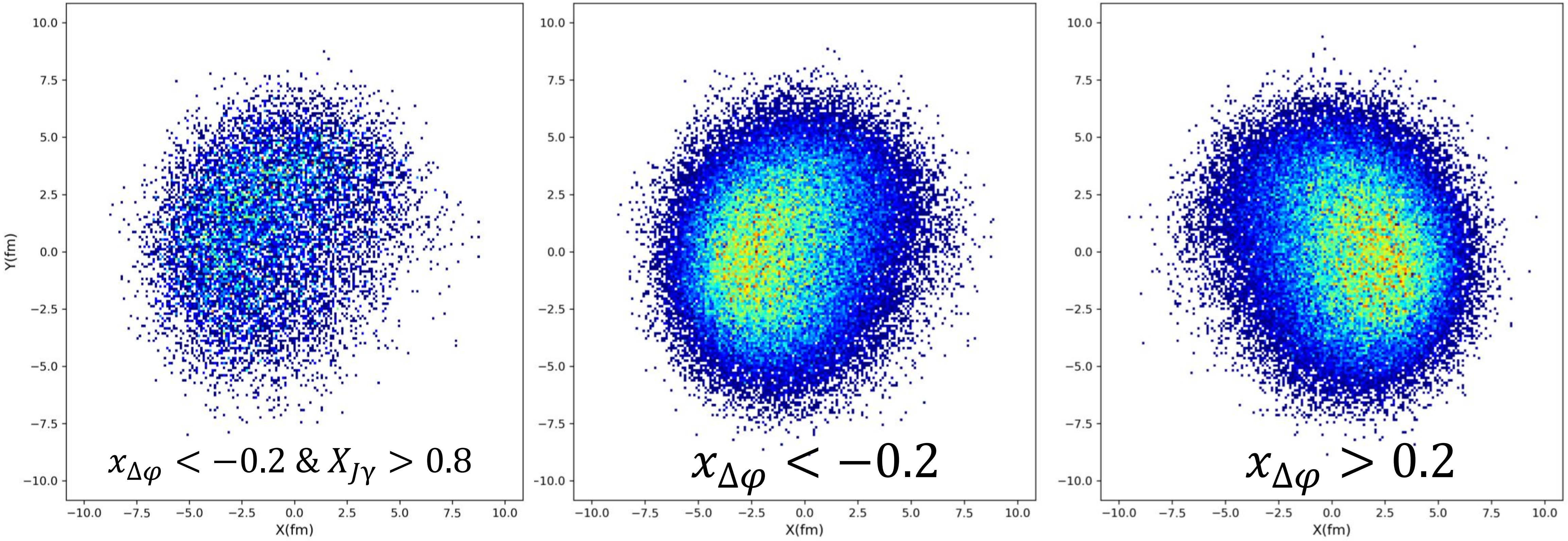
- Jet propagation in an uniform medium with different flow velocities.
- A clear broadening of the intra-jet asymmetry with the increasing flow velocities.



Jet localization with intra-jet asymmetry (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.
- Better localization in multiple jets (Dijet) events?



Jet localization with intra-jet asymmetry (Dijet)

More jets, more information, better localization.
(Interplay with the jet-induced diffusion wake)

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

$x_{1\Delta\varphi} < -0.2$
$x_{2\Delta\varphi} > 0.2$

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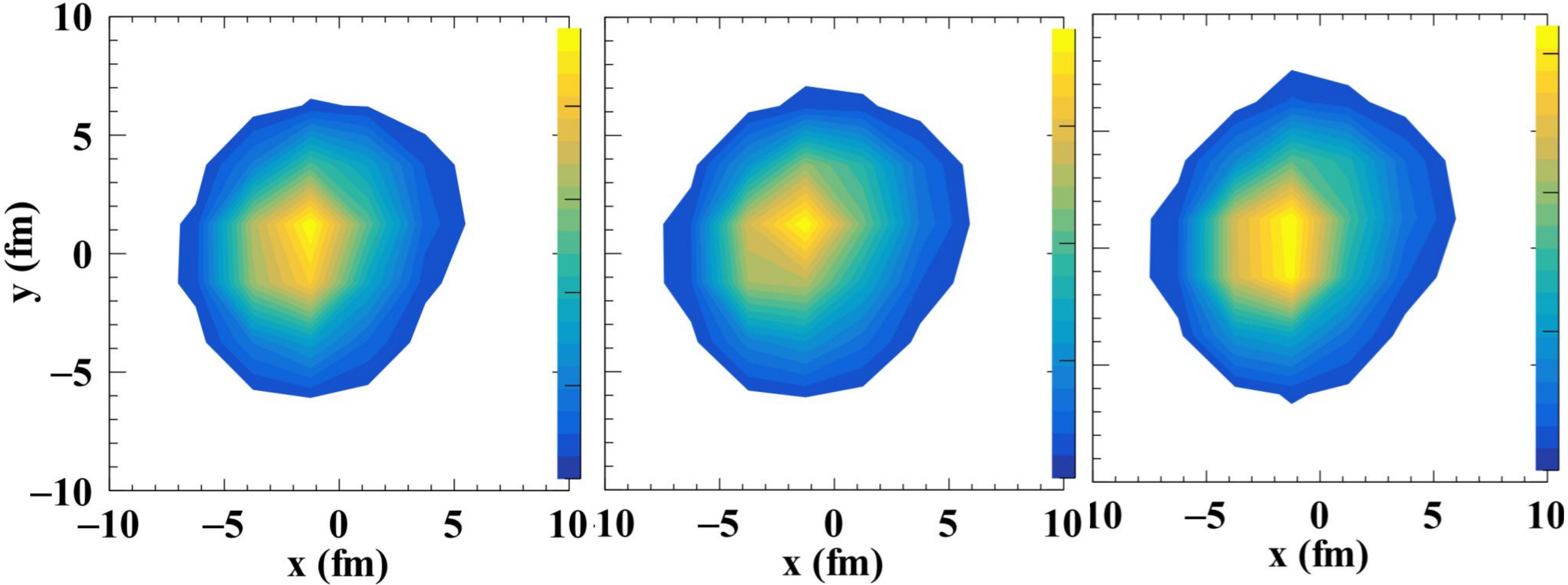
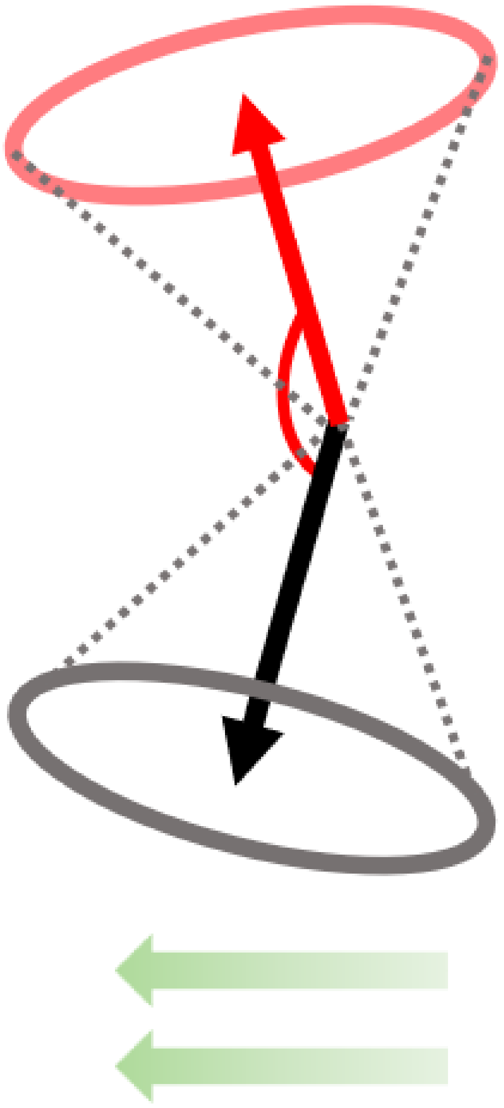




Summary

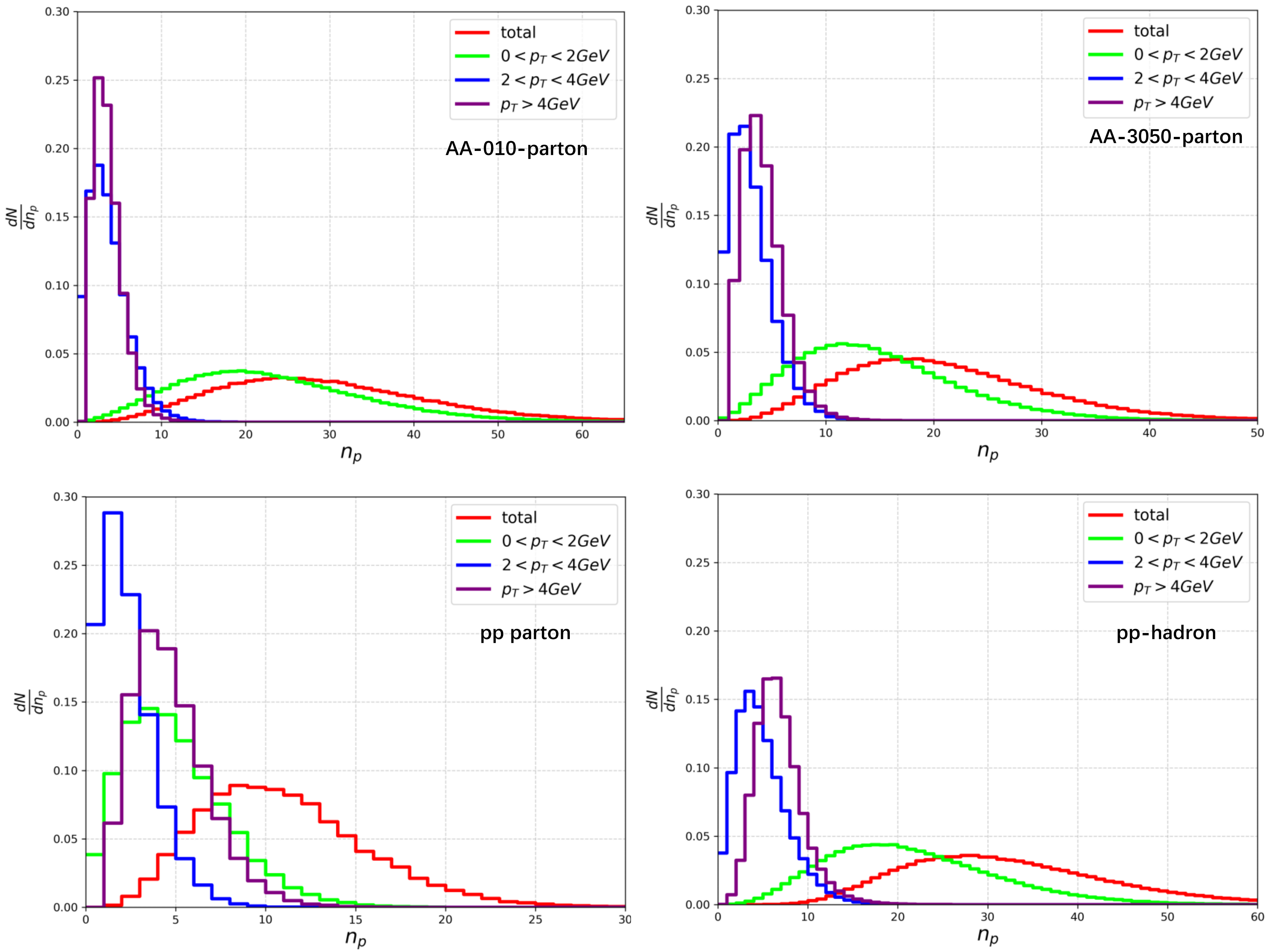
- A method to detect the effect of jet-flow coupling in heavy-ion collisions.
- Intra-jet asymmetry are observed at both the longitudinal and transverse direction.
- Intra-jet asymmetry can also be used in jet localization in heavy-ion collisions

Outlook

- Jet-flow coupling in QGP.
  (Medium fluctuation, Hadron cascade, Medium-induced splitting)

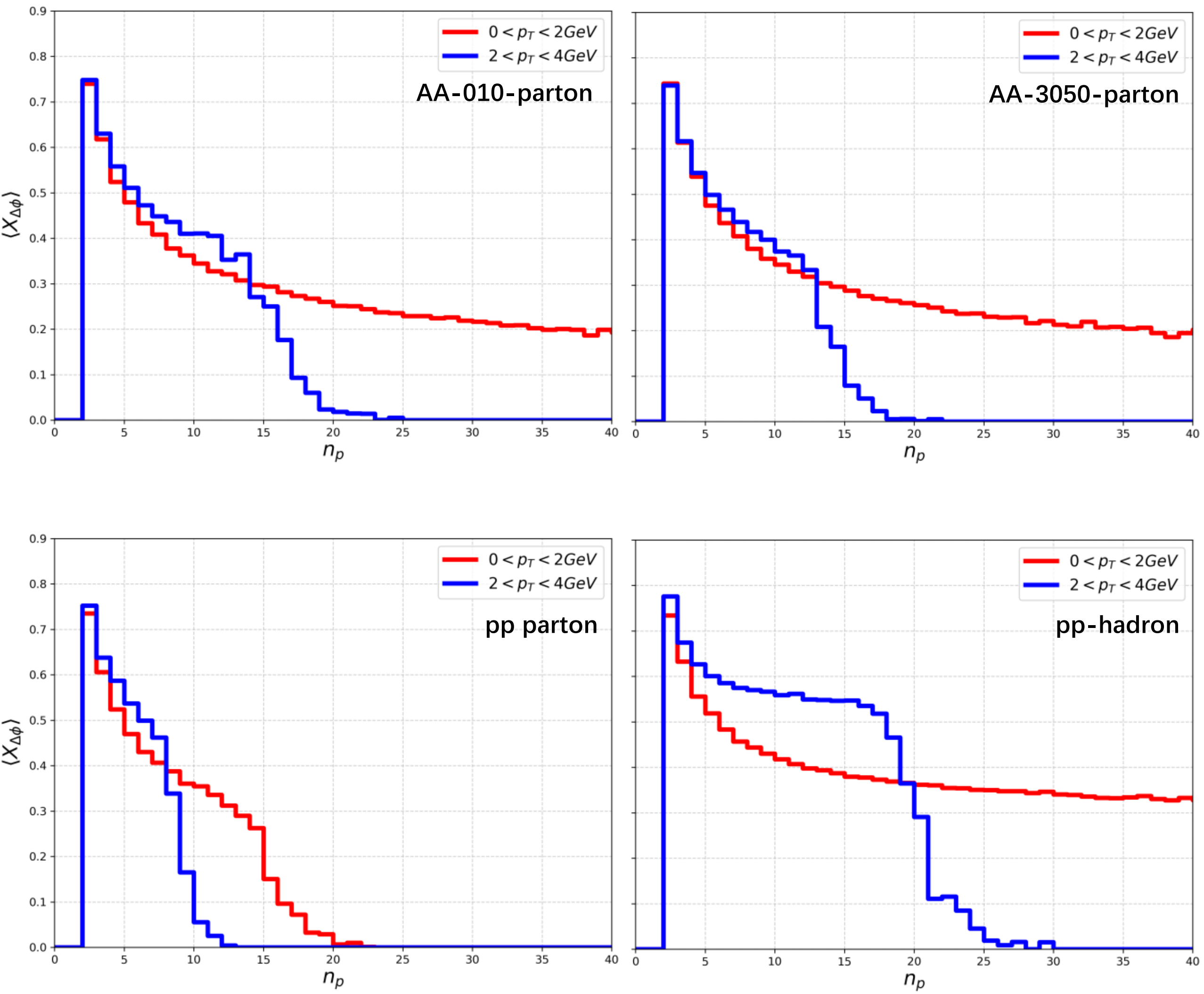

Thanks

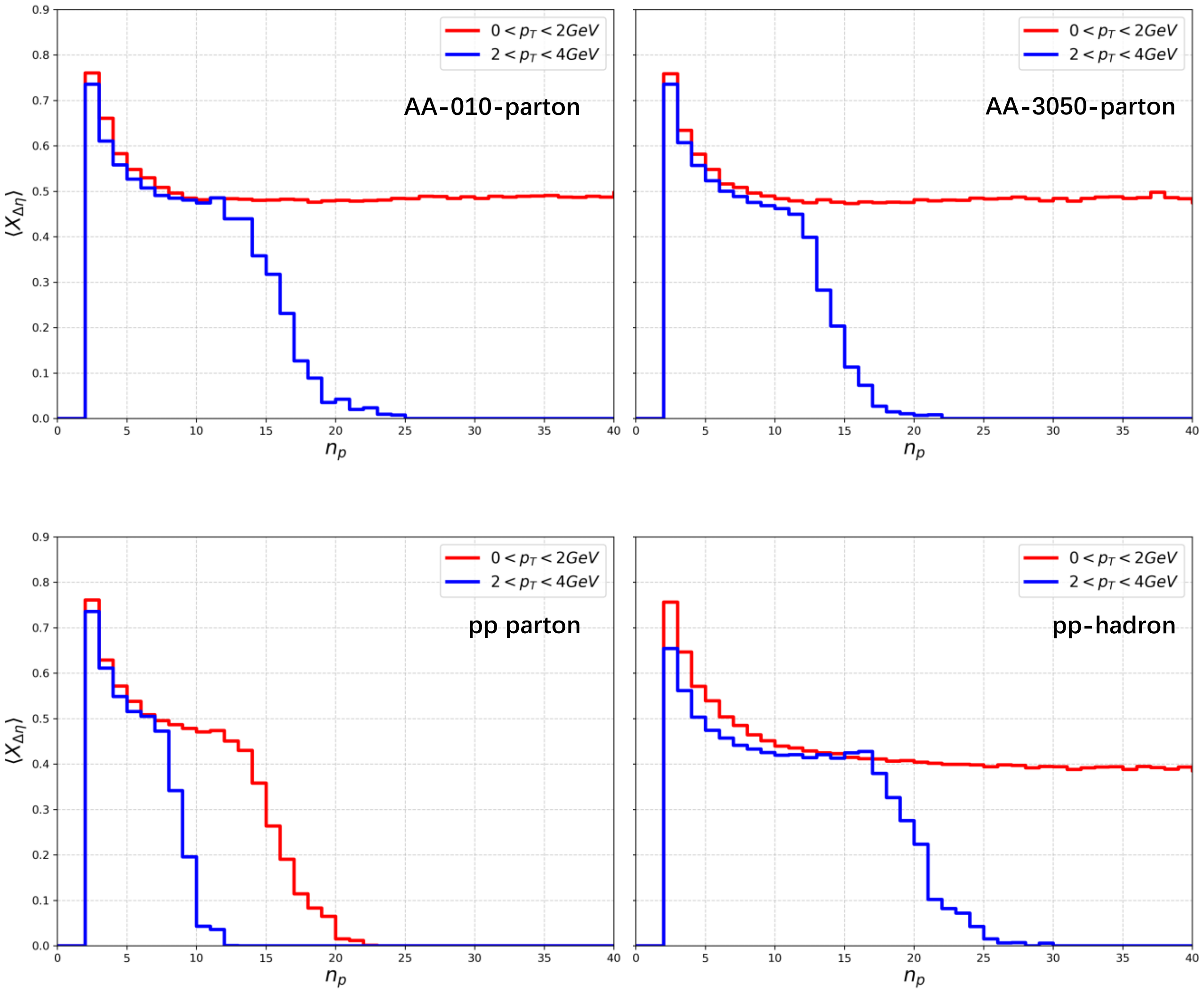
Jet multiplicity

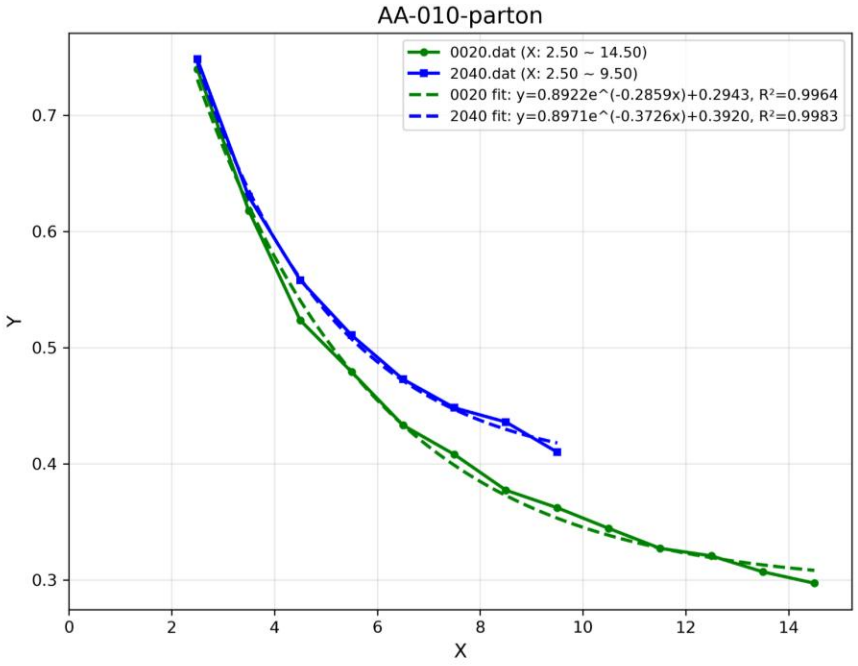


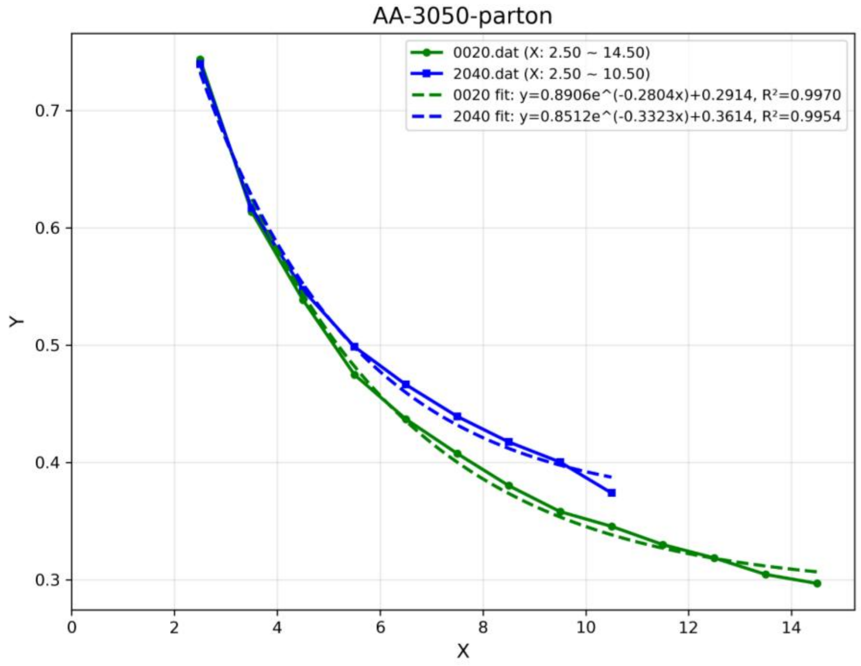
<A_phi>_dn_jet

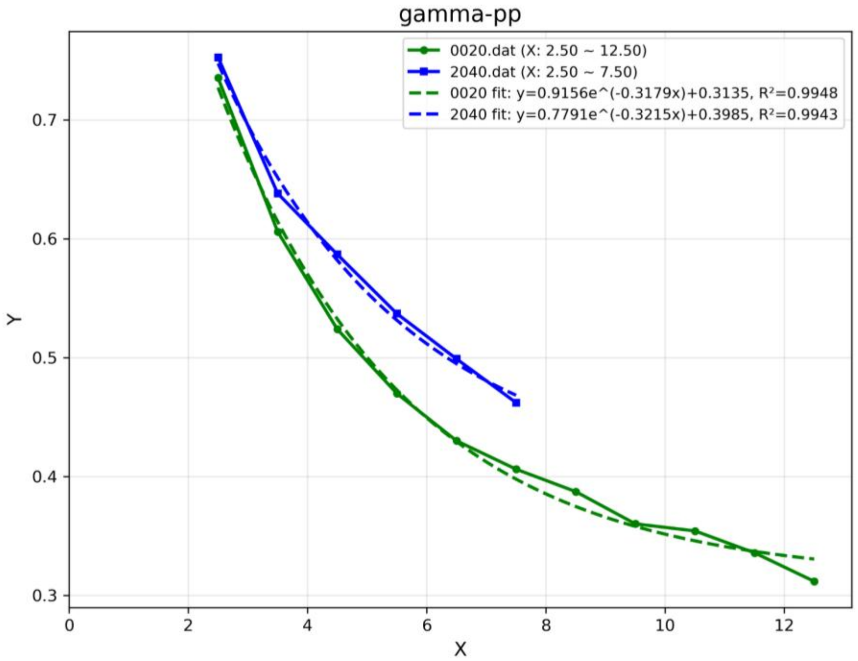
<A_eta>_dn_jet

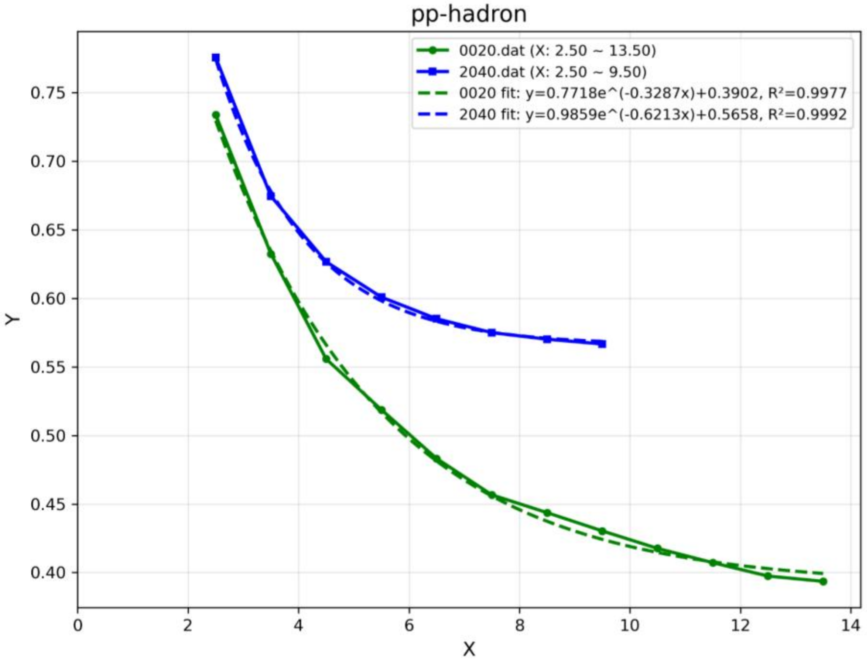


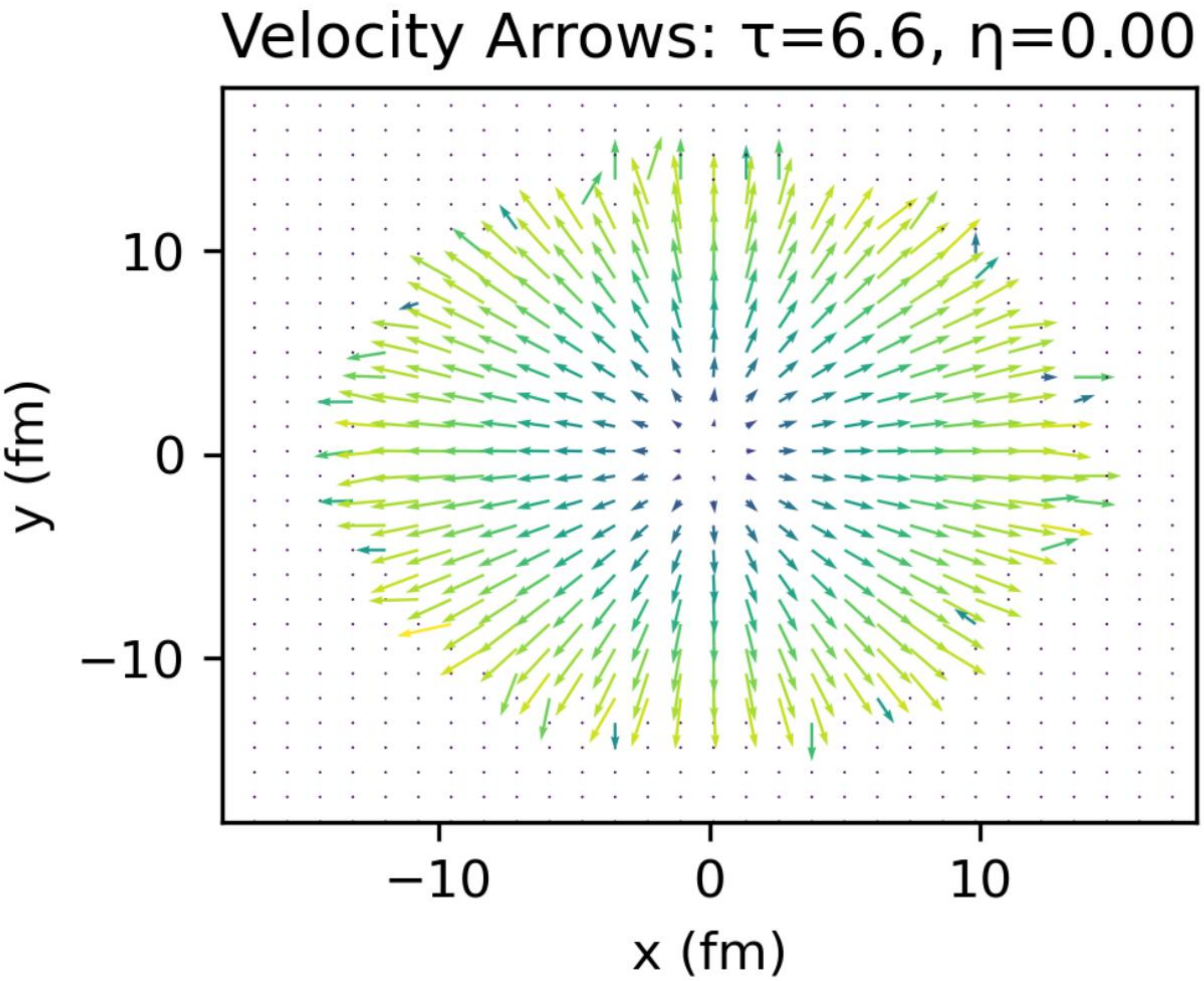



AA-010-parton
0020.dat (X: 2.50 ~ 14.50)
2040.dat (X: 2.50 ~ 9.50)
0020 fit: y=0.8922e^(-0.2859x)+0.2943, R²=0.9964
2040 fit: y=0.8971e^(-0.3726x)+0.3920, R²=0.9983
Y
X


AA-3050-parton
0020.dat (X: 2.50 ~ 14.50)
2040.dat (X: 2.50 ~ 10.50)
0020 fit: y=0.8906e^(-0.2804x)+0.2914, R²=0.9970
2040 fit: y=0.8512e^(-0.3323x)+0.3614, R²=0.9954
Y
X


gamma-pp
0020.dat (X: 2.50 ~ 12.50)
2040.dat (X: 2.50 ~ 7.50)
0020 fit: y=0.9156e^(-0.3179x)+0.3135, R²=0.9948
2040 fit: y=0.7791e^(-0.3215x)+0.3985, R²=0.9943
Y
X

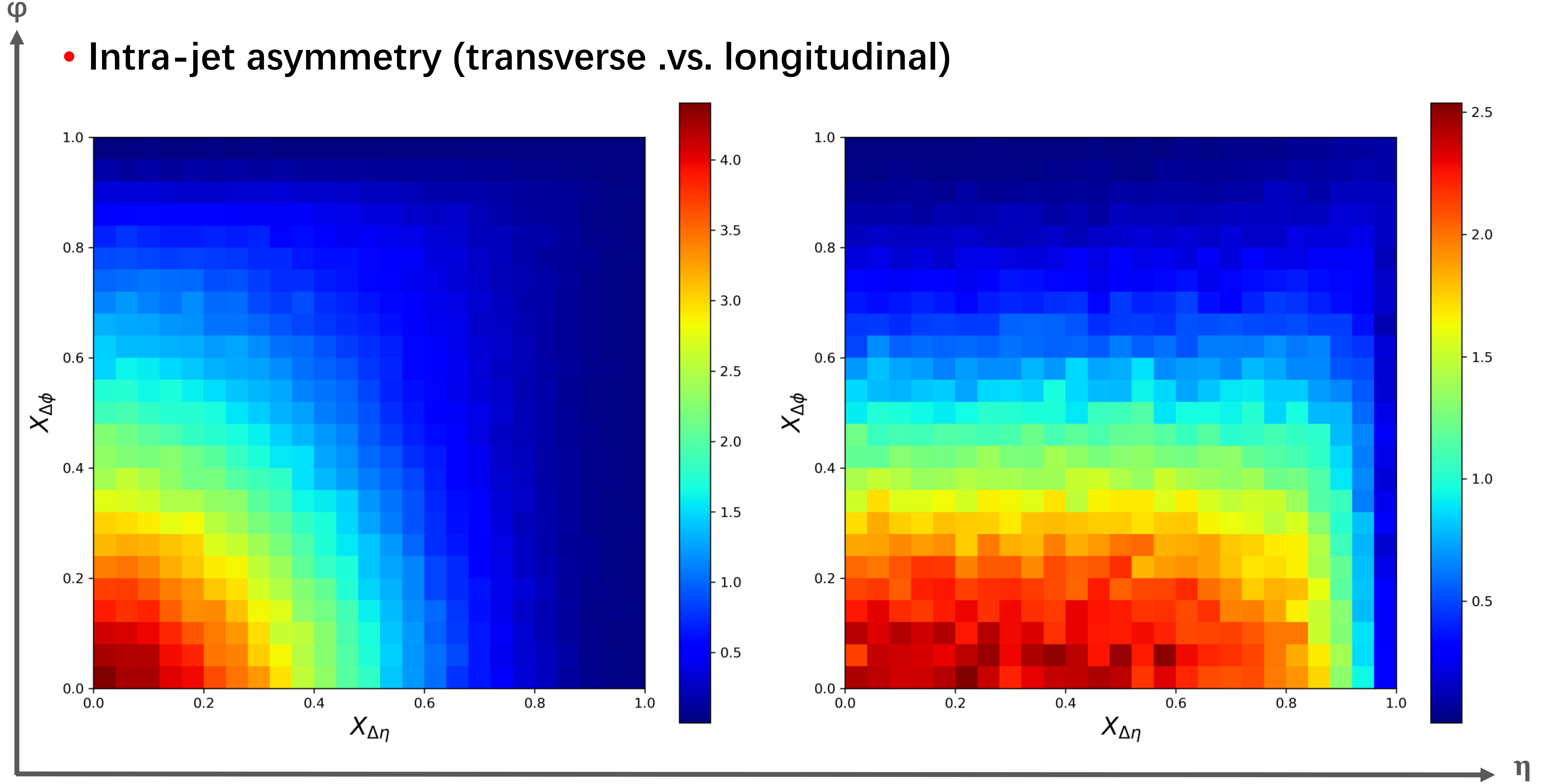

pp-hadron
0020.dat (X: 2.50 ~ 13.50)
2040.dat (X: 2.50 ~ 9.50)
0020 fit: y=0.7718e^(-0.3287x)+0.3902, R²=0.9977
2040 fit: y=0.9859e^(-0.6213x)+0.5658, R²=0.9992
Y
X



Velocity Arrows: τ=6.6, η=0.00
10
0
−10
y (fm)
−10
0
10
x (fm)

Intra-jet asymmetry in AA & pp collisions (γ-jet)

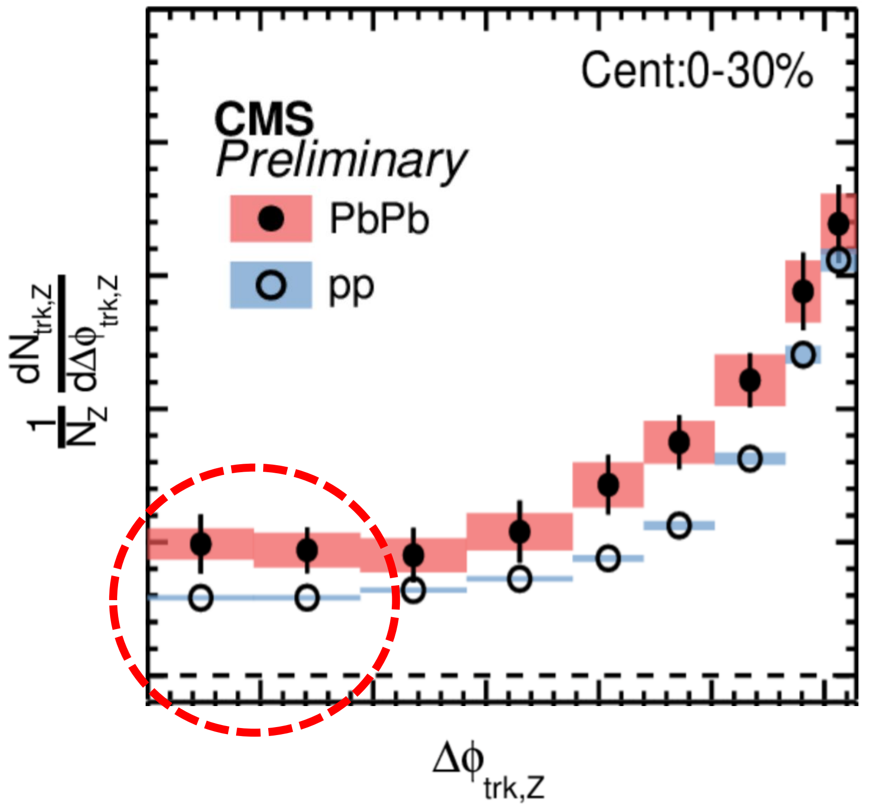
- Intra-jet asymmetry (transverse .vs. longitudinal)

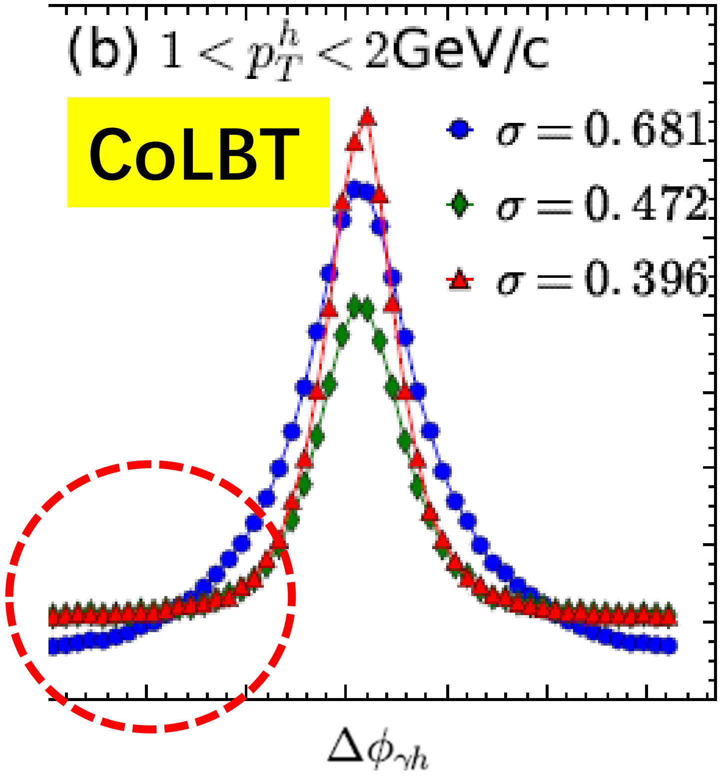


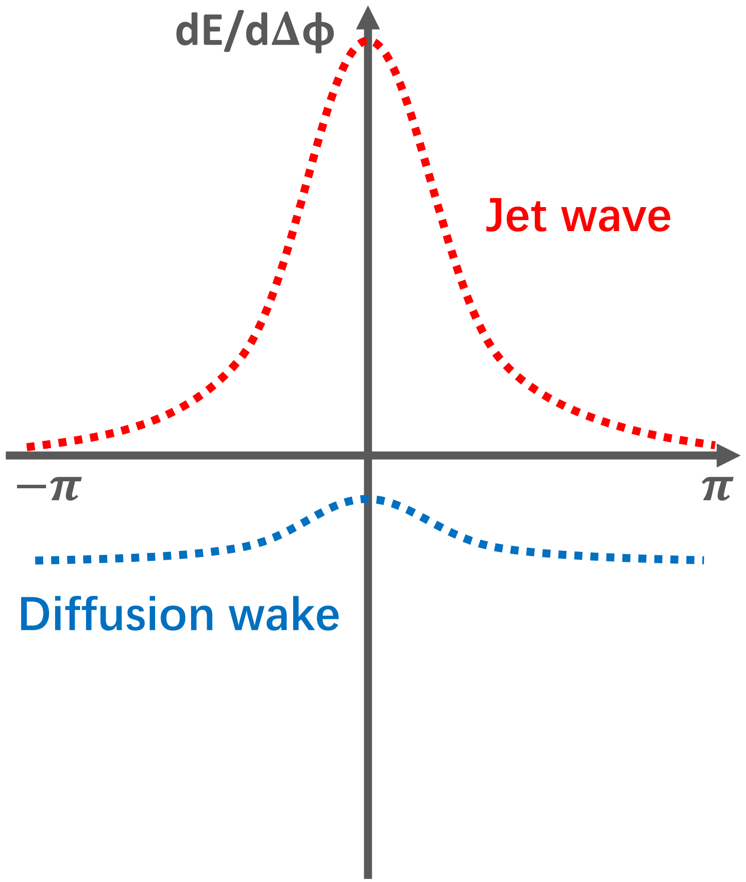
Searching for the diffusion wake: the background

- The deep in the back side of the jet (signal of the diffusion wake)

- Diffusion wake .vs. background







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

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

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

Initial profile
AMPT TRENTO

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

Fragmentation

Recombination

Cooper Frye

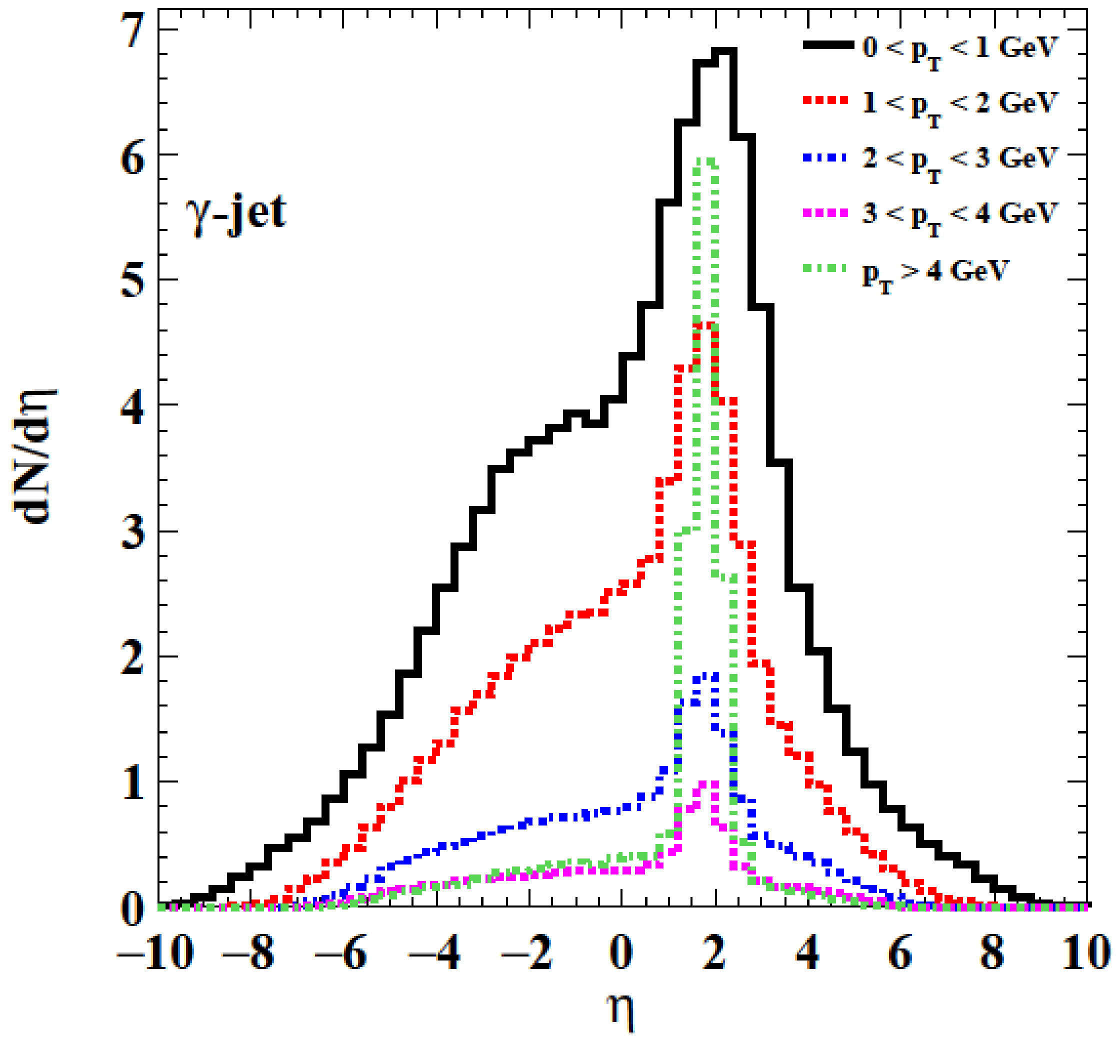
Hadronic observables

LBT
Hard

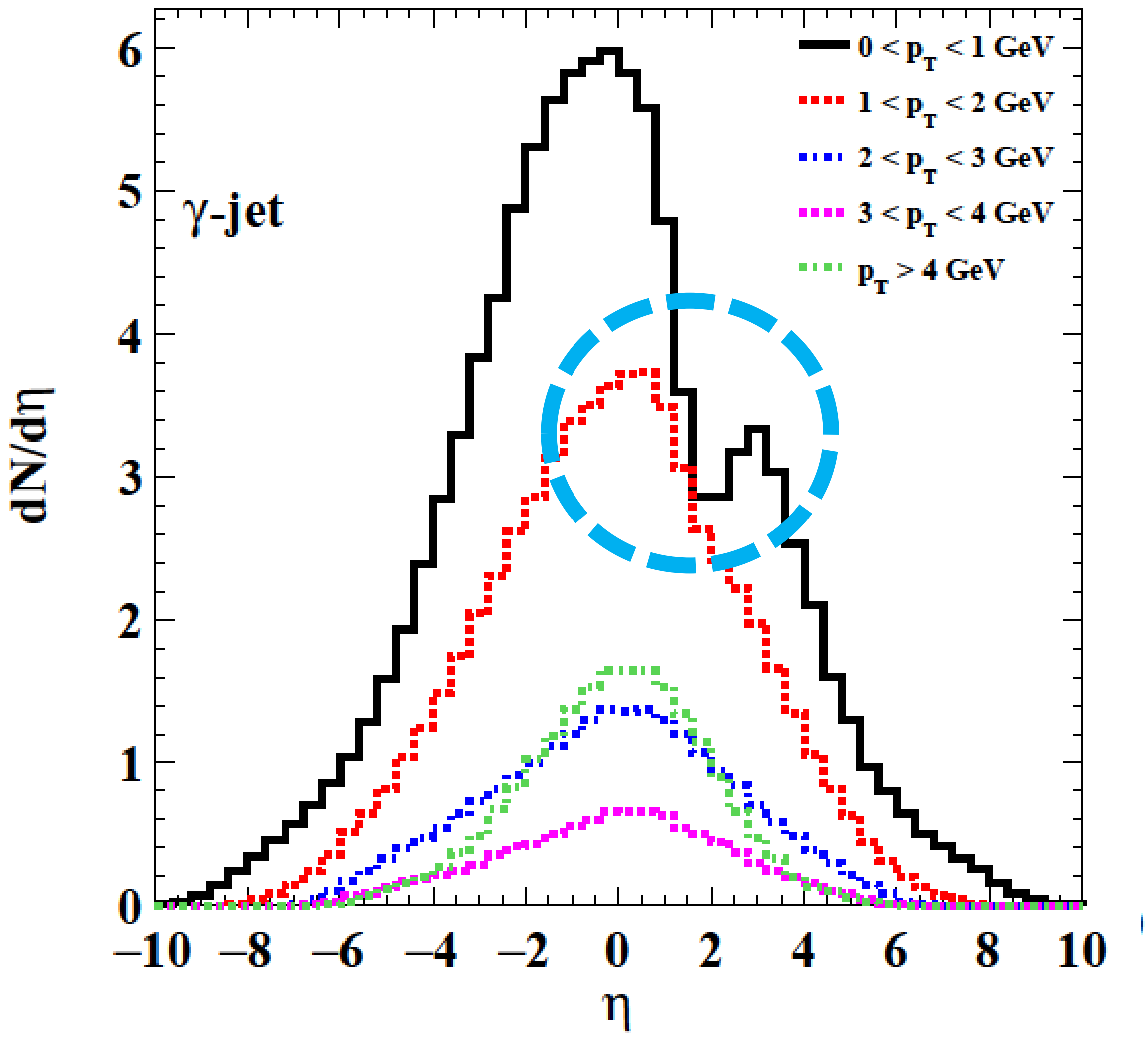
CLvisc
Soft

Searching for the diffusion wake

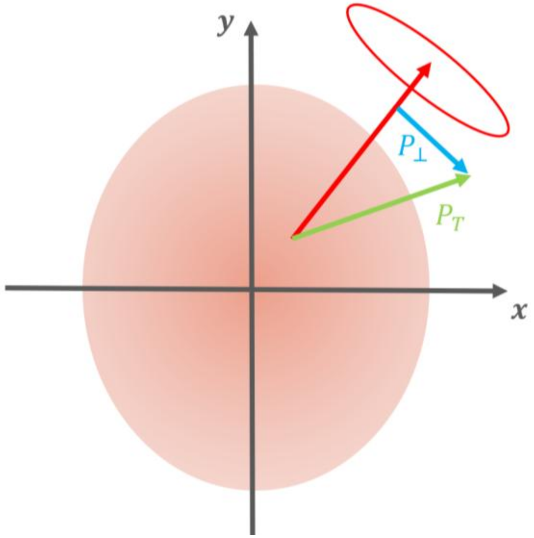
Jet side

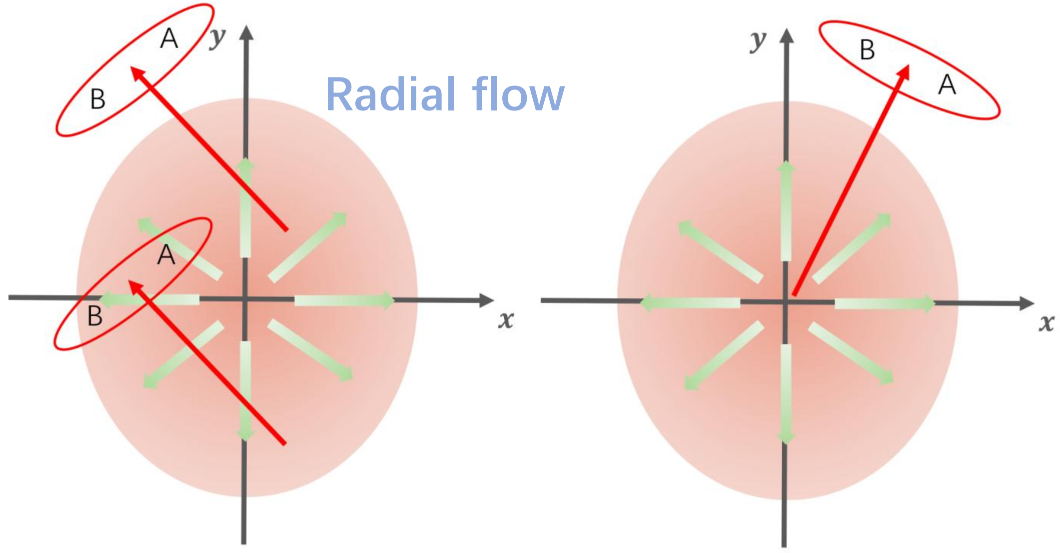


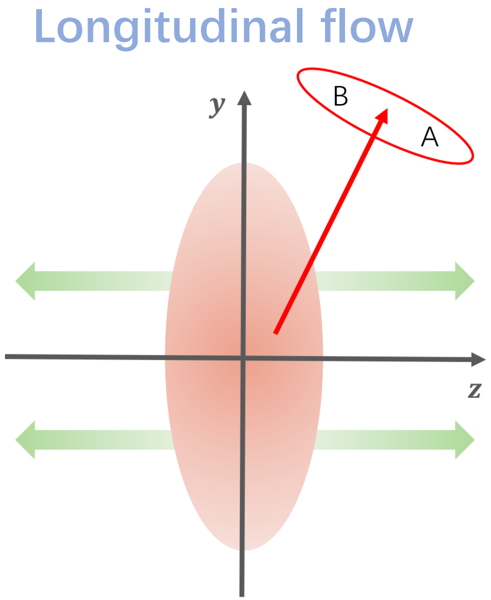
γ side

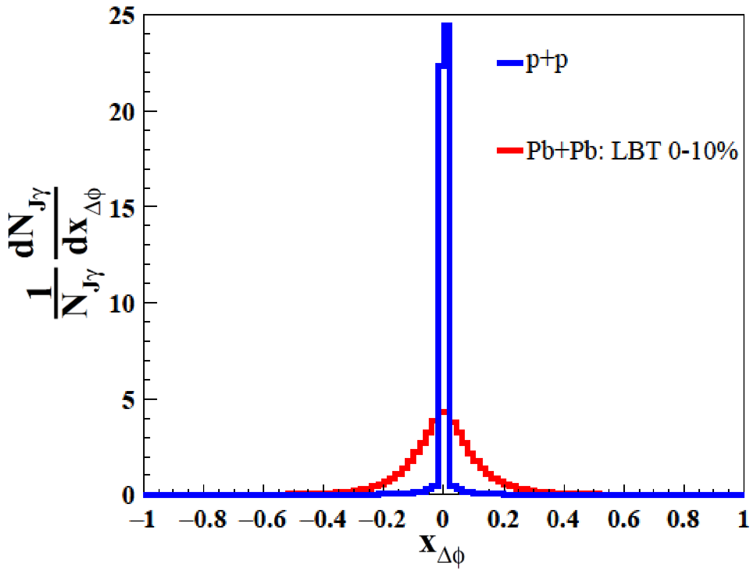


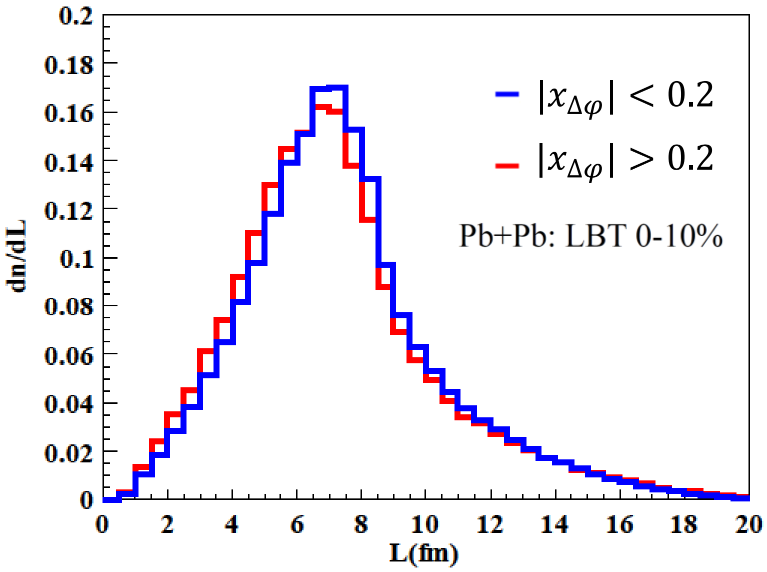
Intra-jet asymmetry increase in AA collisions (γ-jet)

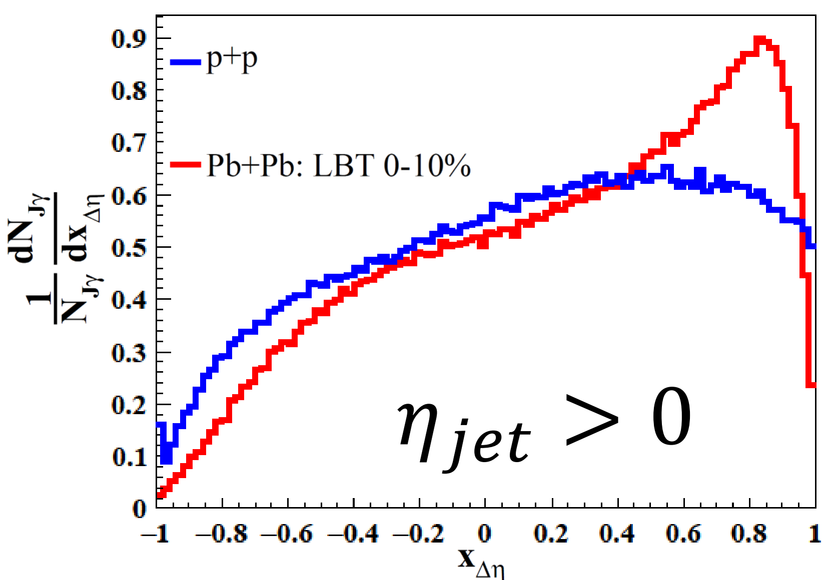












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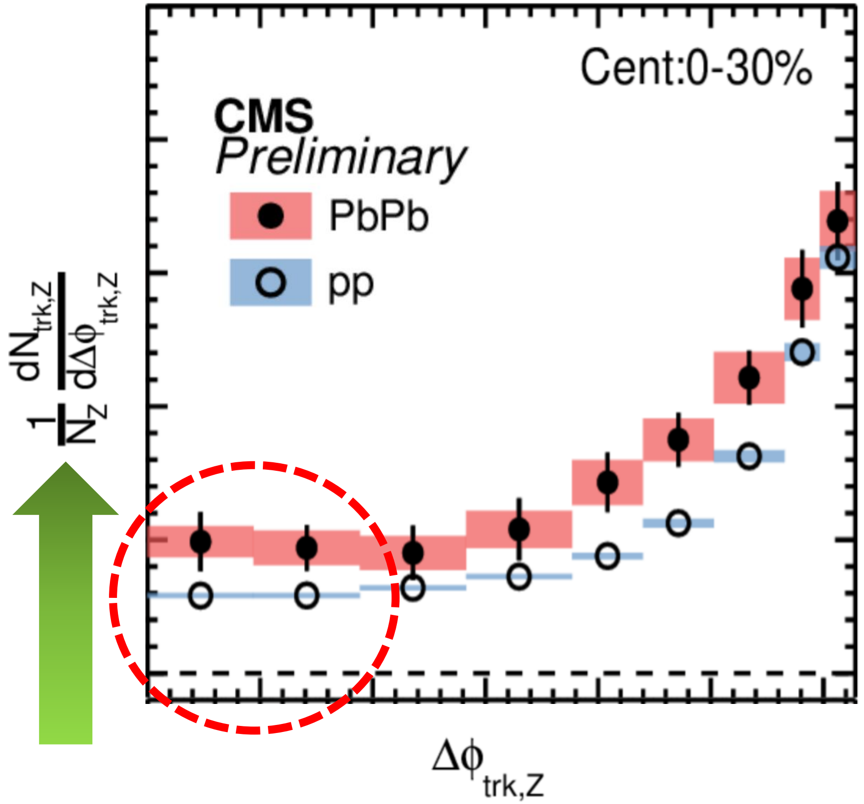
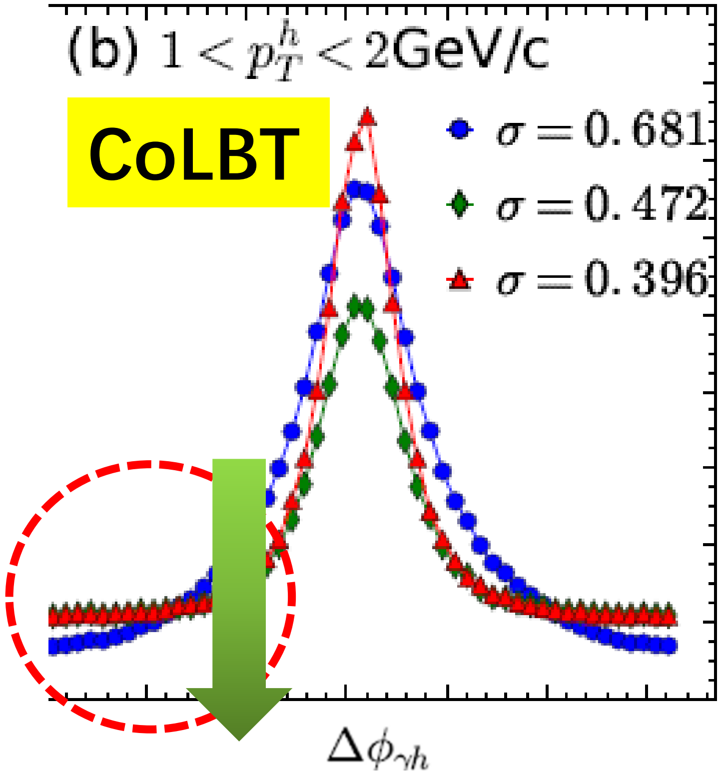
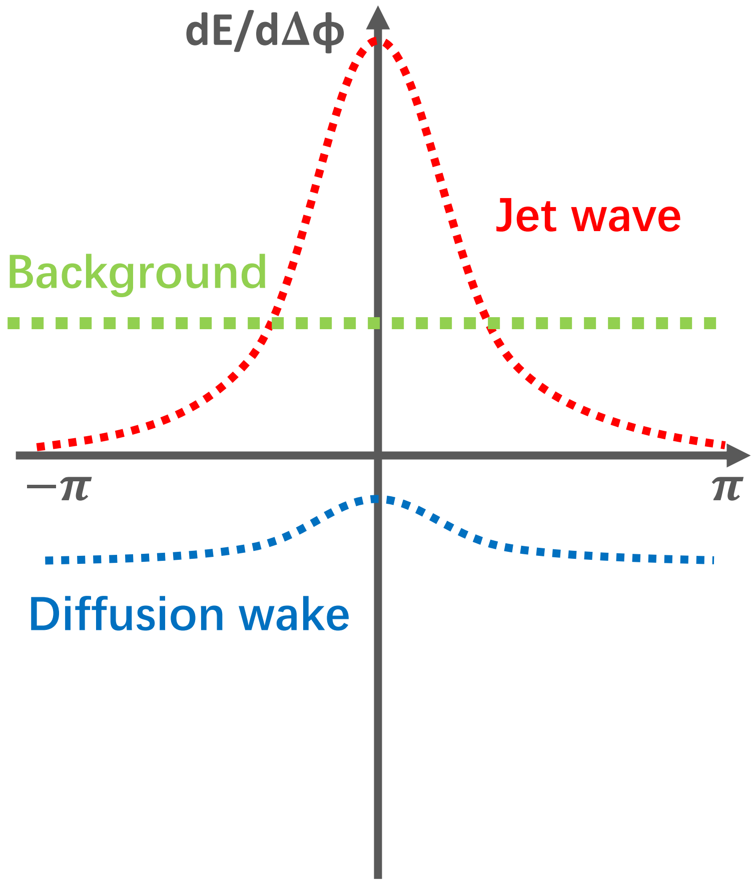
- The deep in the back side of the jet (Signal in the transverse structure)

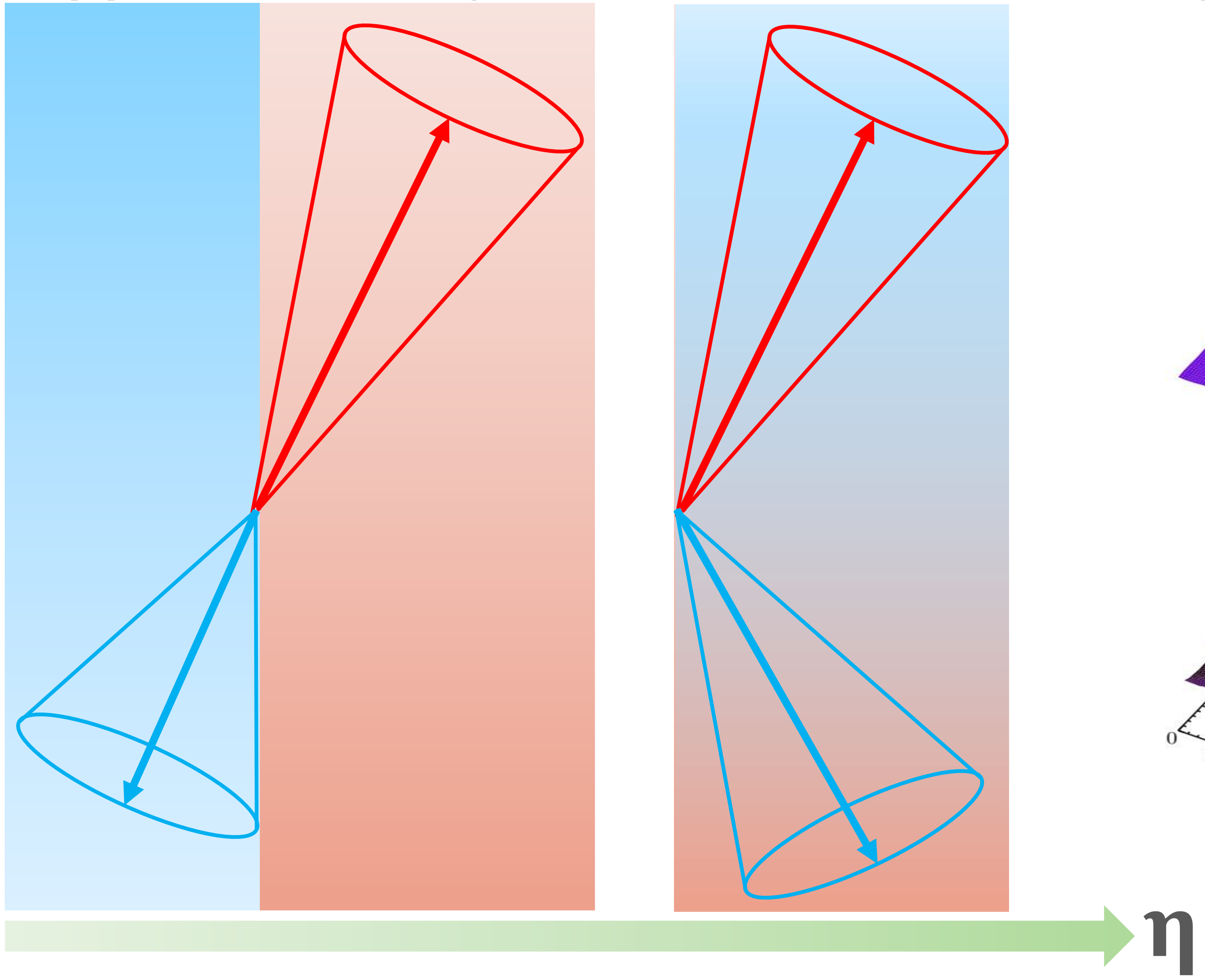
- Diffusion wake .vs. background



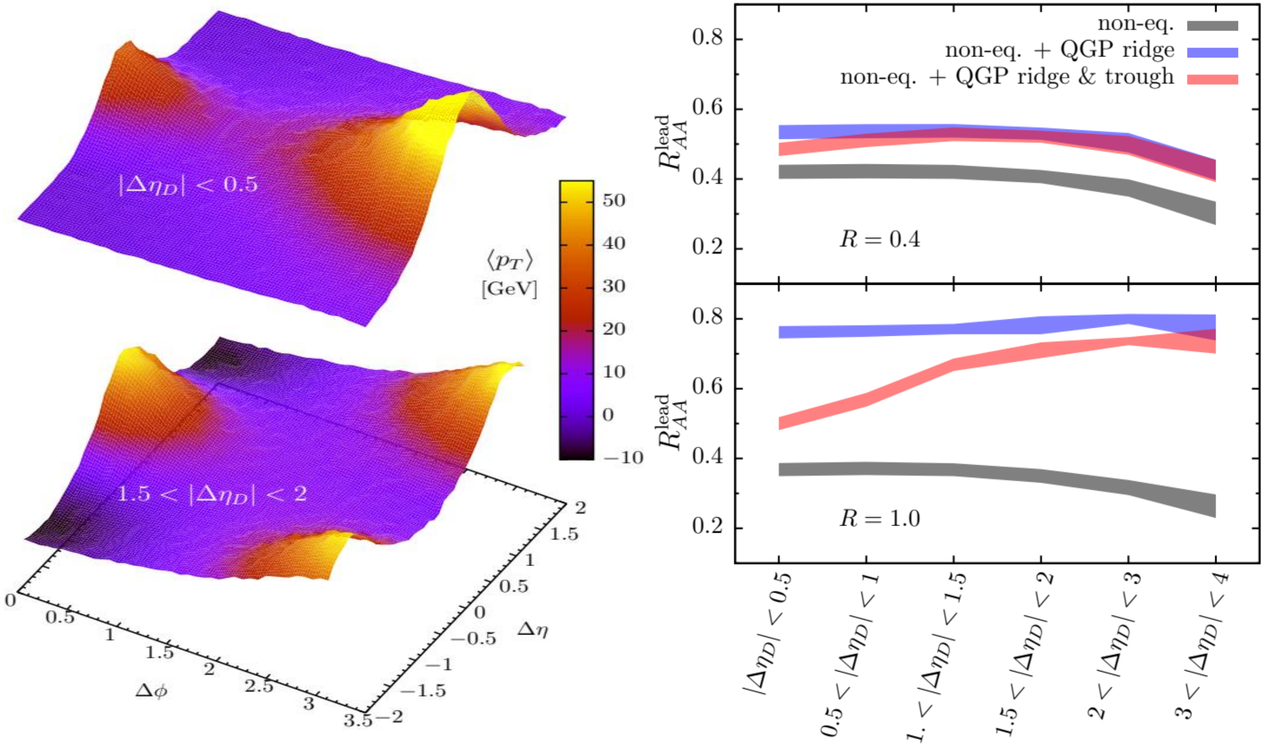




- **The effect of the diffusion wake could be observed by looking at the leading jet suppression in dijet events with different rapidity configuration.**



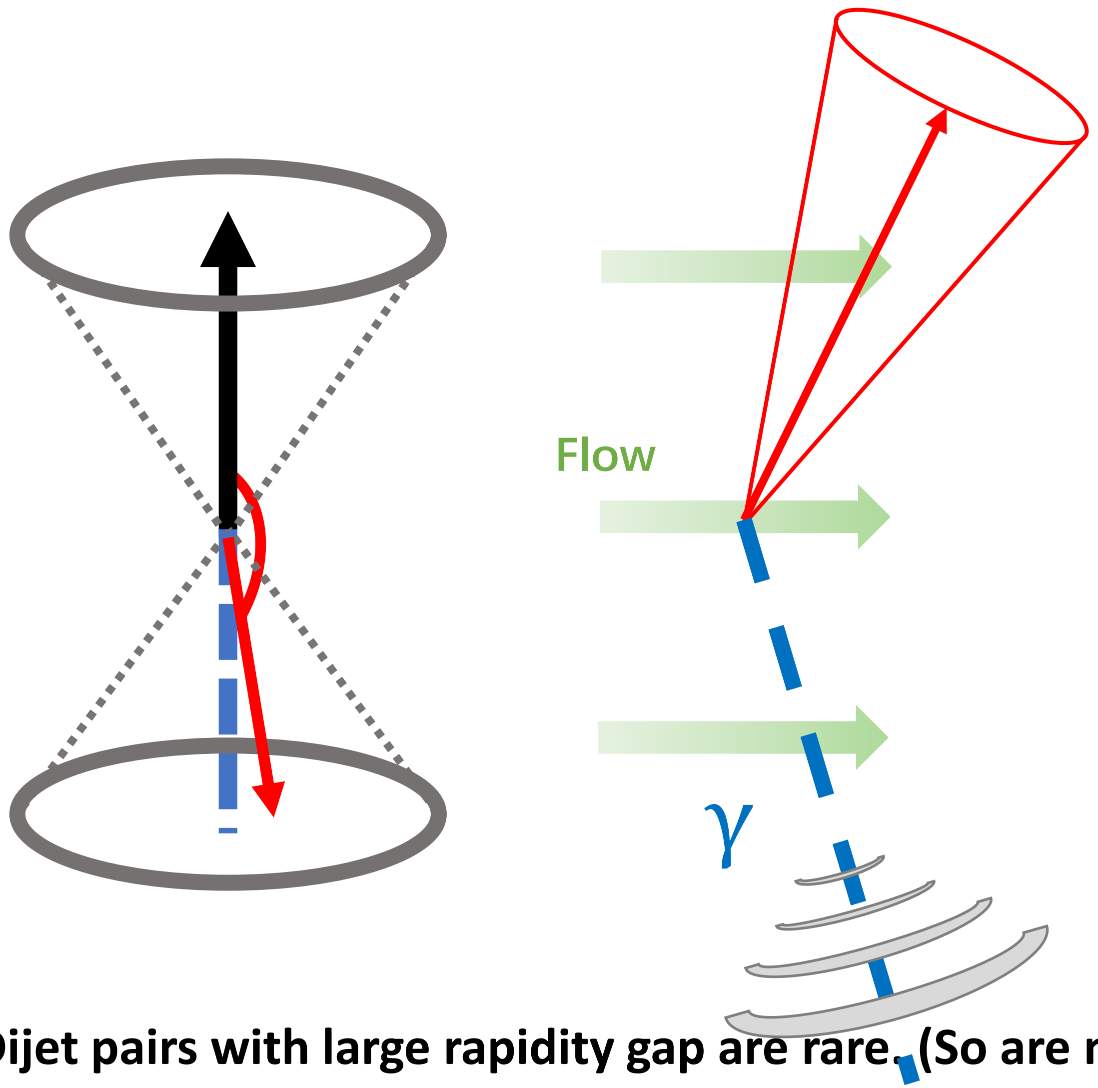
HYBRID Daniel Pablos Phys. Rev. Lett. 124, 052301 (2020)



- **Dijet pairs with large rapidity gap are rare. (So are many other proposed observables)**

Diffusion wake in the longitudinal structure

- The effect of the diffusion wake could be observed by looking at the leading jet suppression in dijet events with different rapidity configuration.



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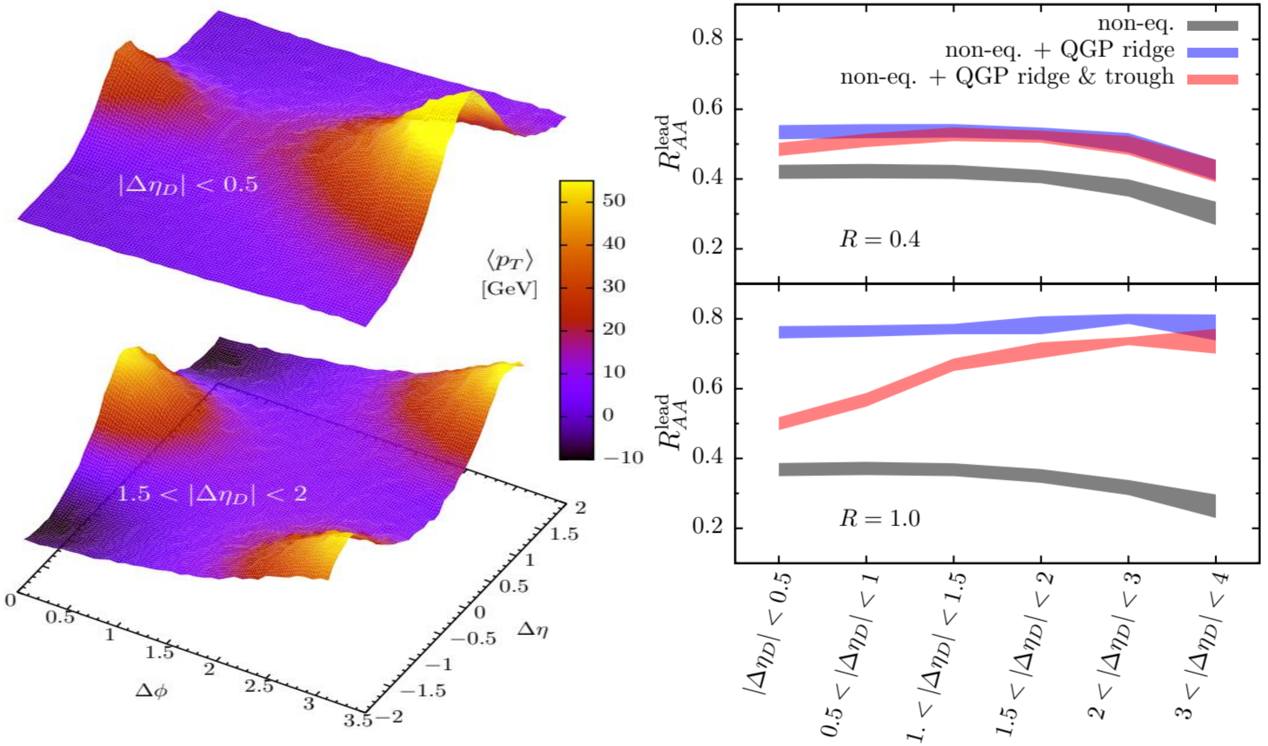
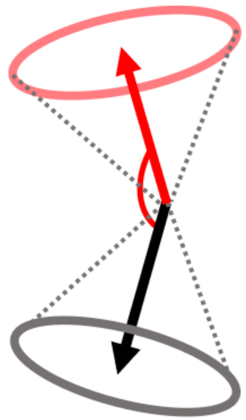


- Dijet pairs with large rapidity gap are rare. (So are many other proposed observables)

Jet localization (Dijet)

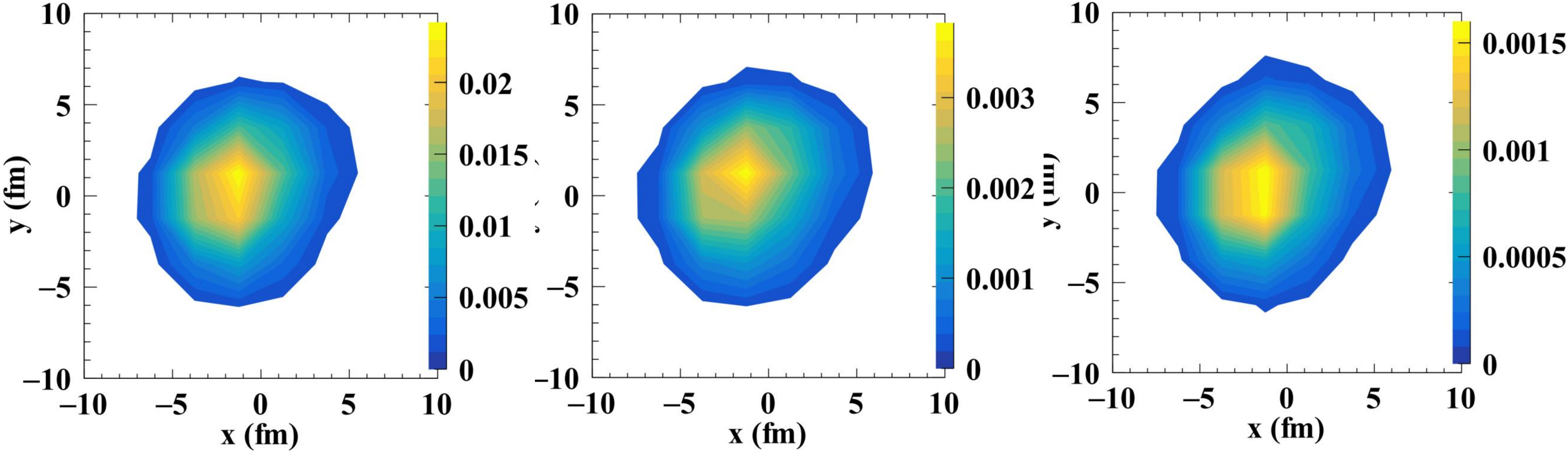
More jets, more information, better localization.
(Interplay with the jet-induced diffusion wake)



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

$x_{1\Delta\varphi} < -0.2$ $\quad x_{2\Delta\varphi} > 0.2$

$x_{1\Delta\varphi} < -0.2$ $\quad x_{2\Delta\varphi} < -0.2$



Intra-jet asymmetry increase in AA collisions (γ-jet)

- Large longitudinal asymmetry in pp .
- The longitudinal flow will push the particles inside the jet to the large rapidity range.