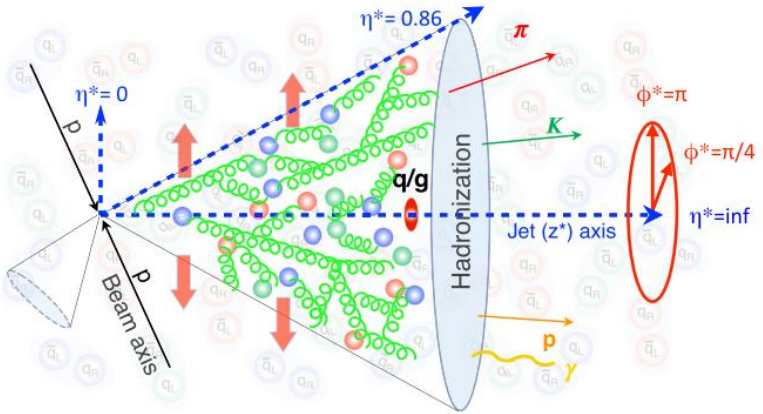
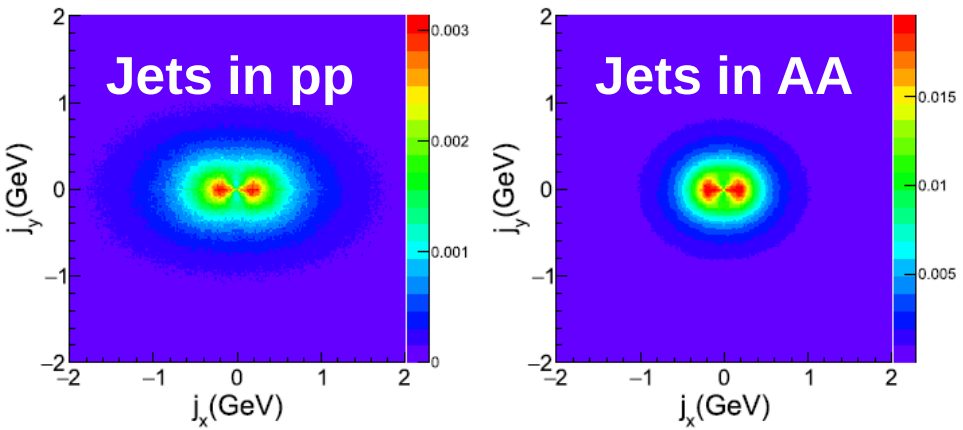
Particle correlations and elliptic anisotropy inside jets ---- New perspectives for jet quenching

Peng Ru / 茹芃

South China Normal University

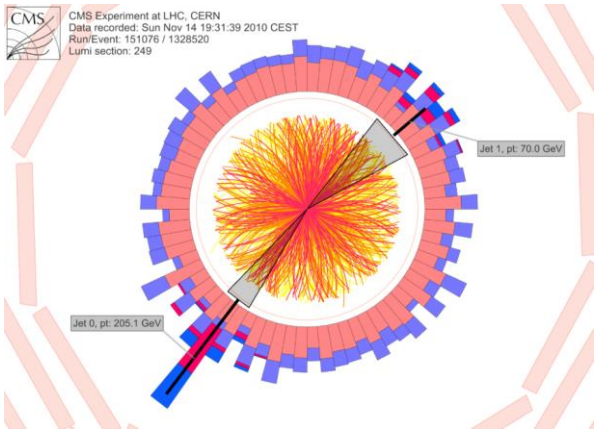
In collaboration with
Meng-Quan Yang, Jin-Wen Kang, Wei-Xi Kong and Ben-Wei Zhang

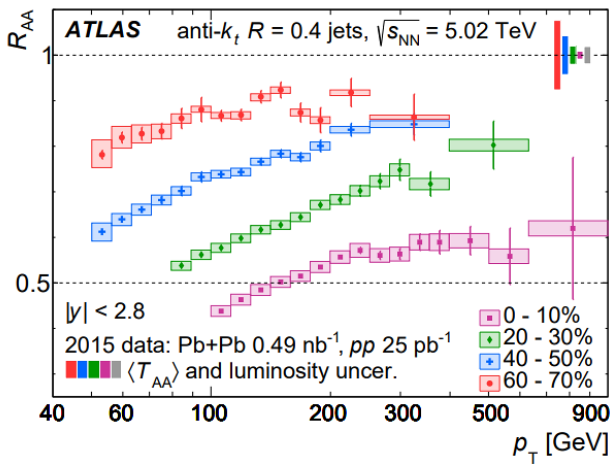




Part I: Background

Jet as a whole object





ATLAS, PLB 790 (2019) 108

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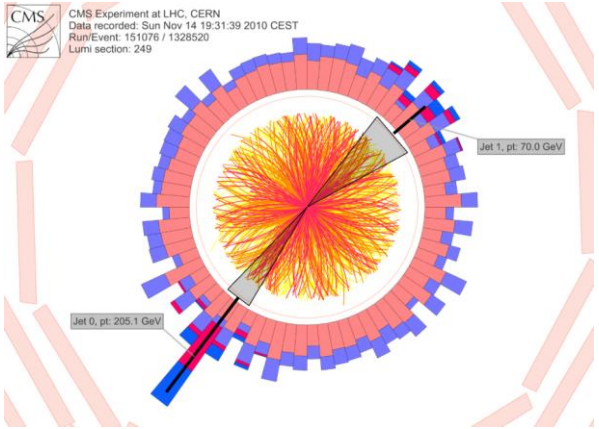
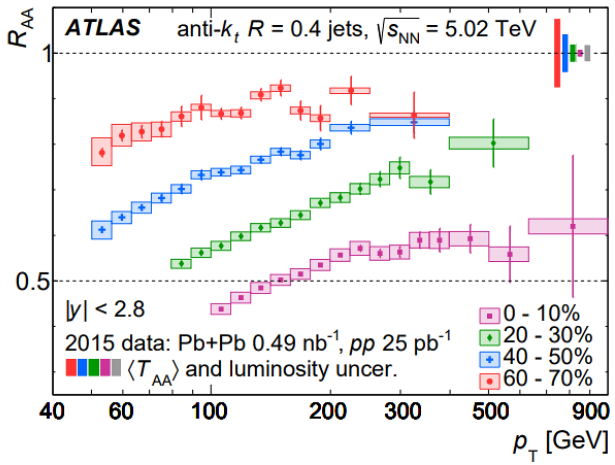
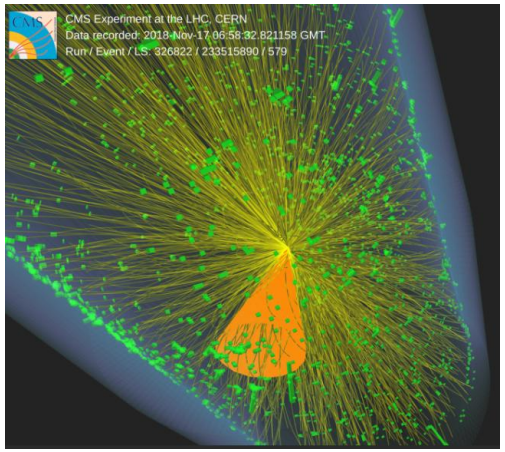


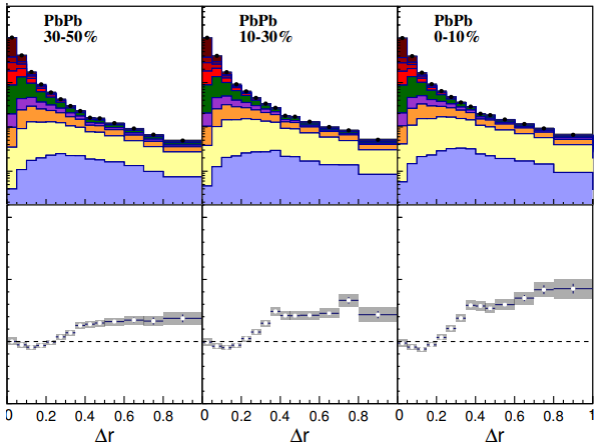


ATLAS, PLB 790 (2019) 108

Jet substructures:

single inclusive measurements

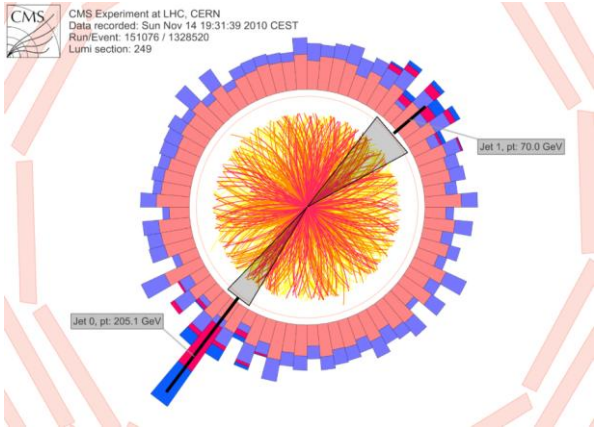


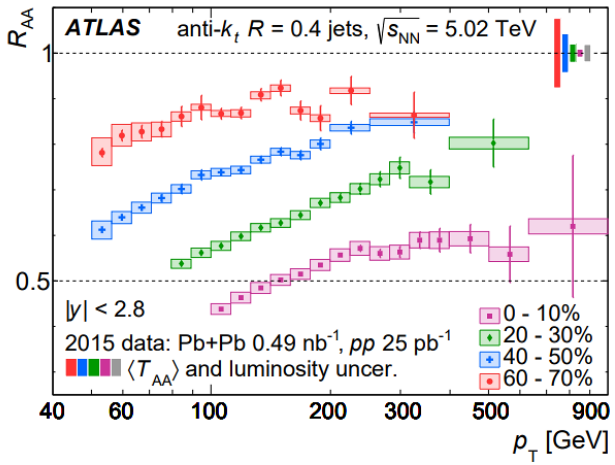


CMS, JHEP 05 (2018) 006

Part I: Background

Jet as a whole object





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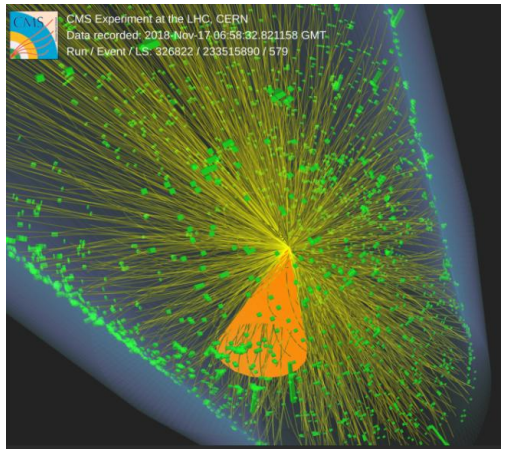
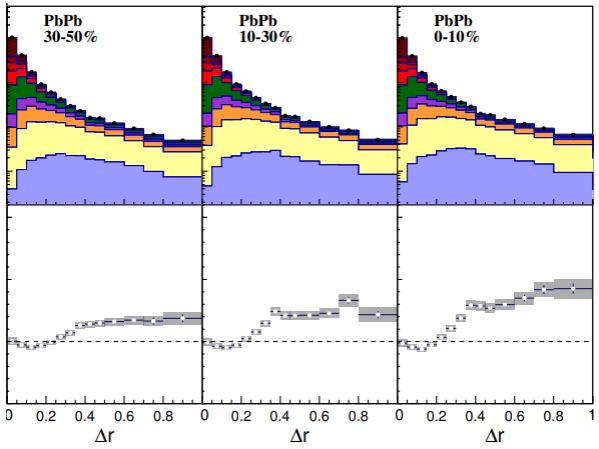
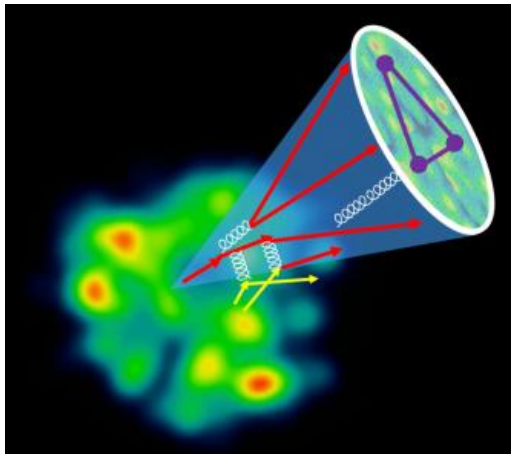


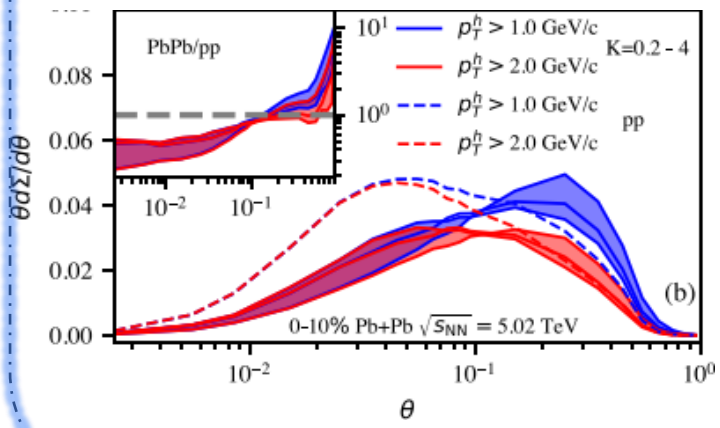


CMS, JHEP 05 (2018) 006

Jet substructures:

high-dimensional measurements

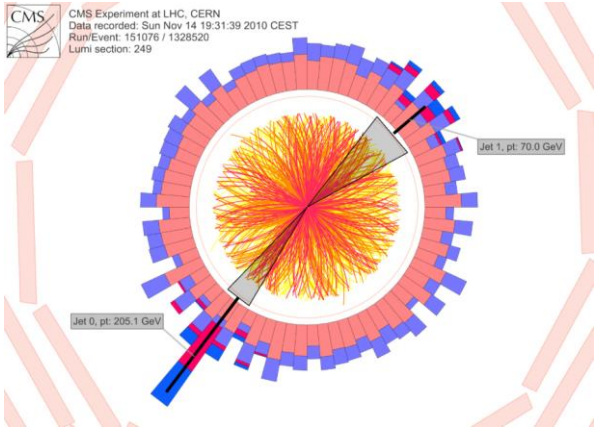


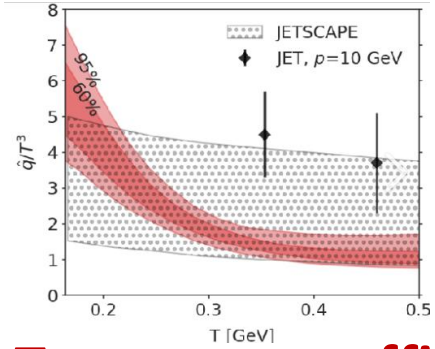


Yang, He, Moult, Wang, PRL(2024)

Part I: Background

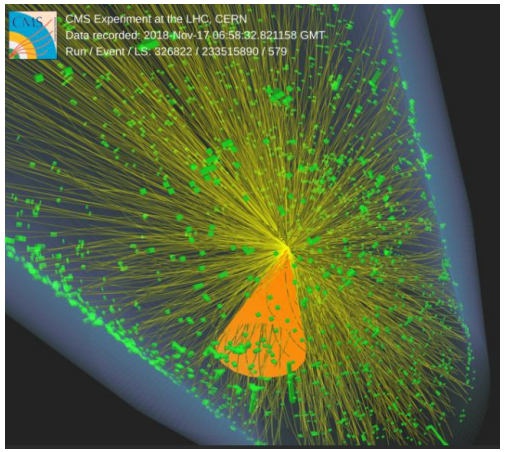
Jet as a whole object

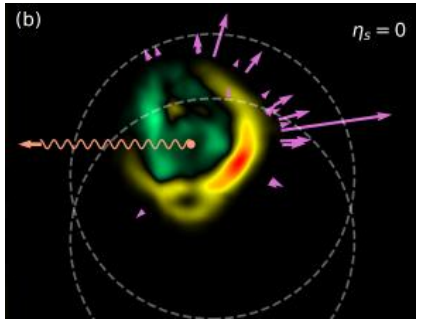




e.g. Transport coefficient

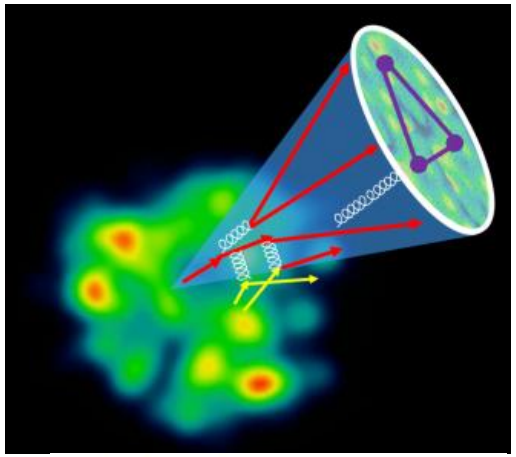
Jet substructures: single inclusive measurements

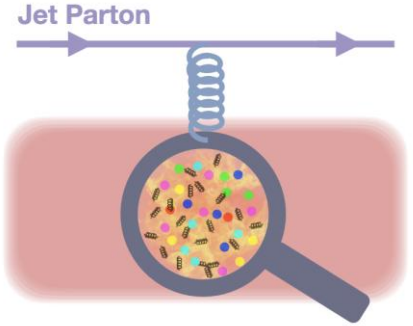




e.g. medium response

Jet substructures: high-dimensional measurements



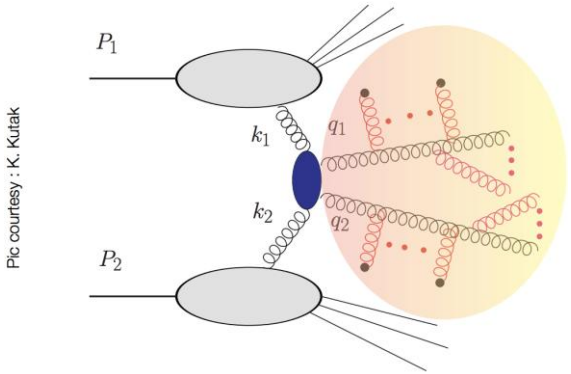


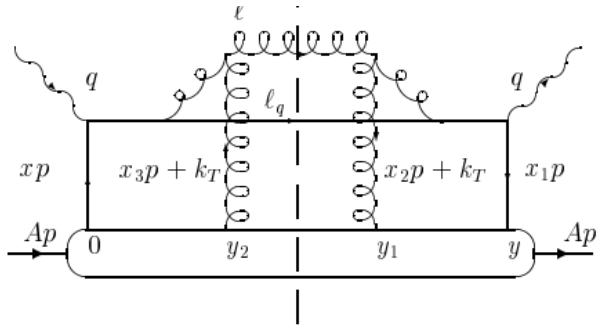
e.g. short-distance structures

Different features explored with observations at different dimensions

Part I: Background

Jets as hard probes

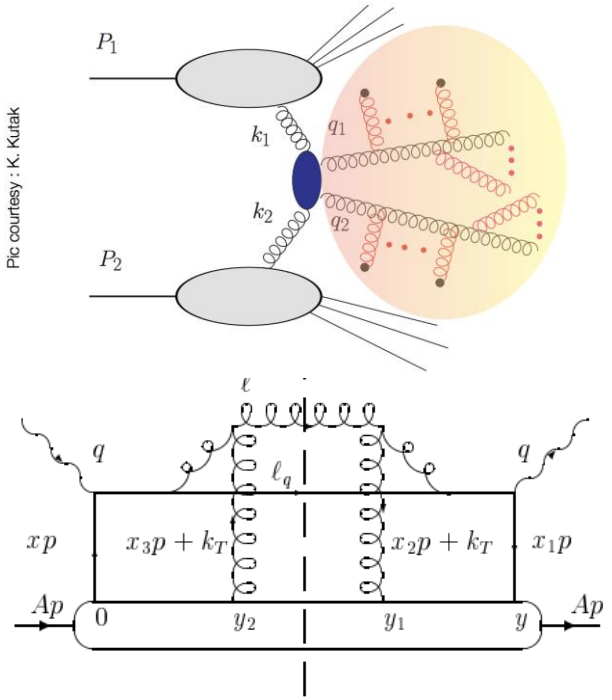




Study non-perturbative physics with perturbative controllable observable.

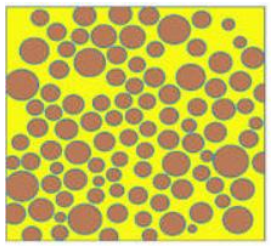
Part I: Background

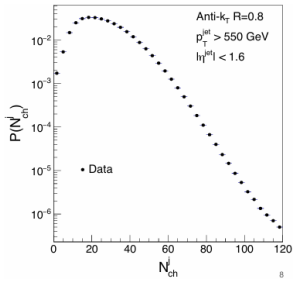
Jets as hard probes

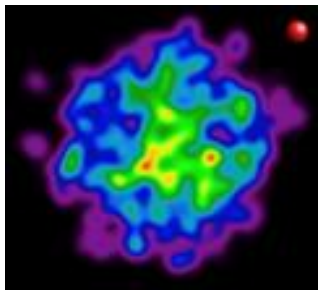


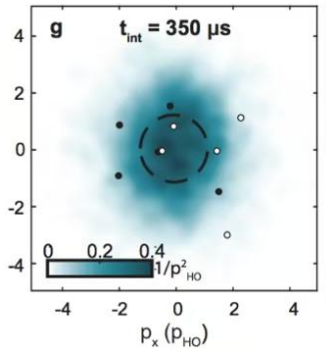
Study non-perturbative physics with perturbative controllable observable.

Jets as an ensemble of many-particle system





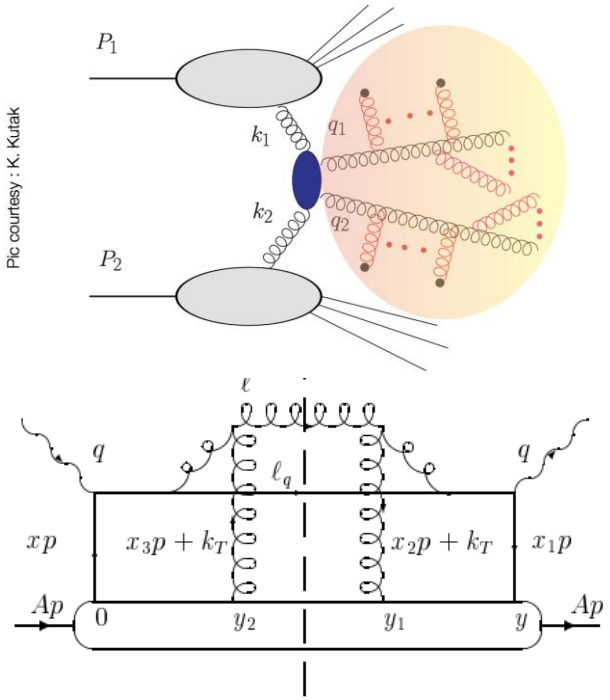




Study QCD with many-body effects using effective models.

Part I: Background

Jets as hard probes



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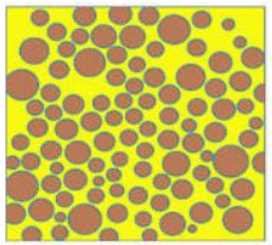
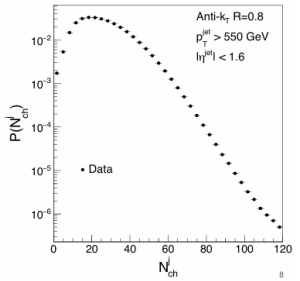
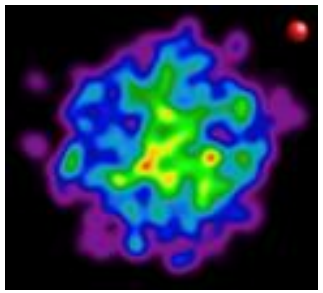
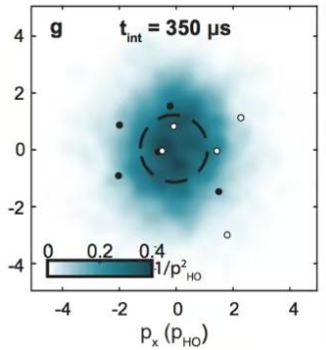


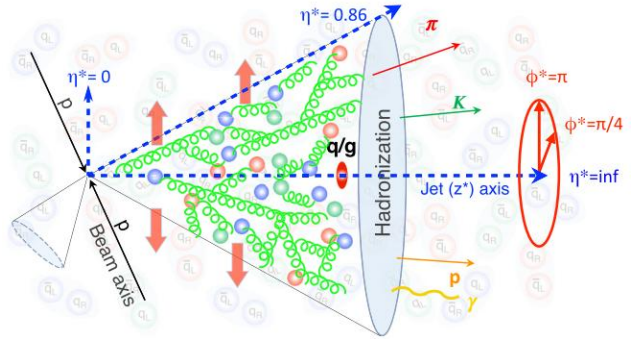


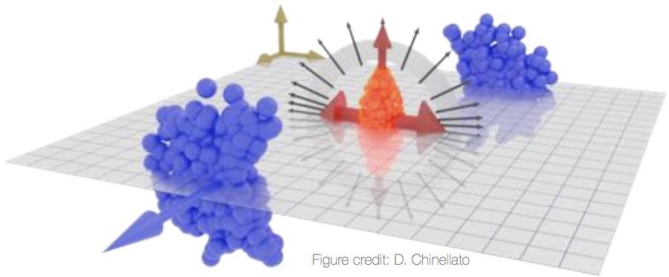




Study QCD with many-body effects using effective models.

Jets as collision systems

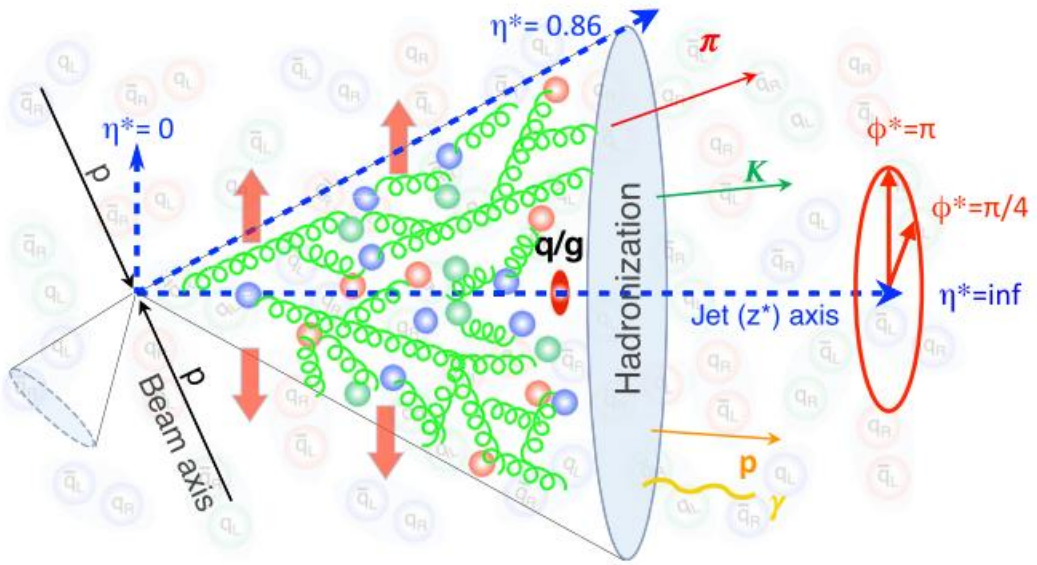




Methods of correlations & fluctuations in AA/pA/pp systems may be useful.

Part I: Background

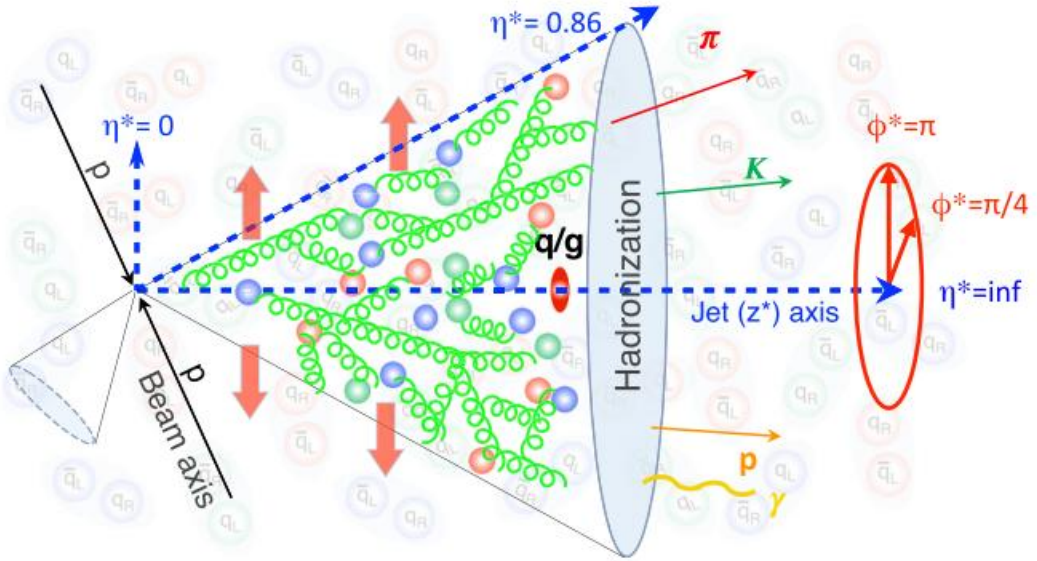
CMS Collaboration, PRL 133, 142301 (2024)



Two-particle azimuthal correlation in the frame with longitudinal direction parallel to jet axis.

Part I: Background

CMS Collaboration, PRL 133, 142301 (2024)



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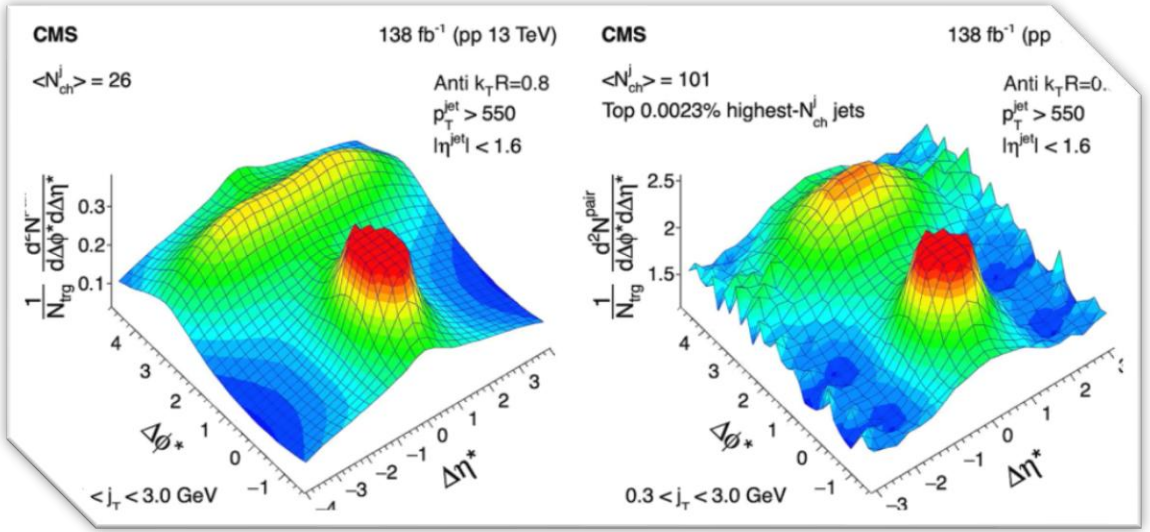
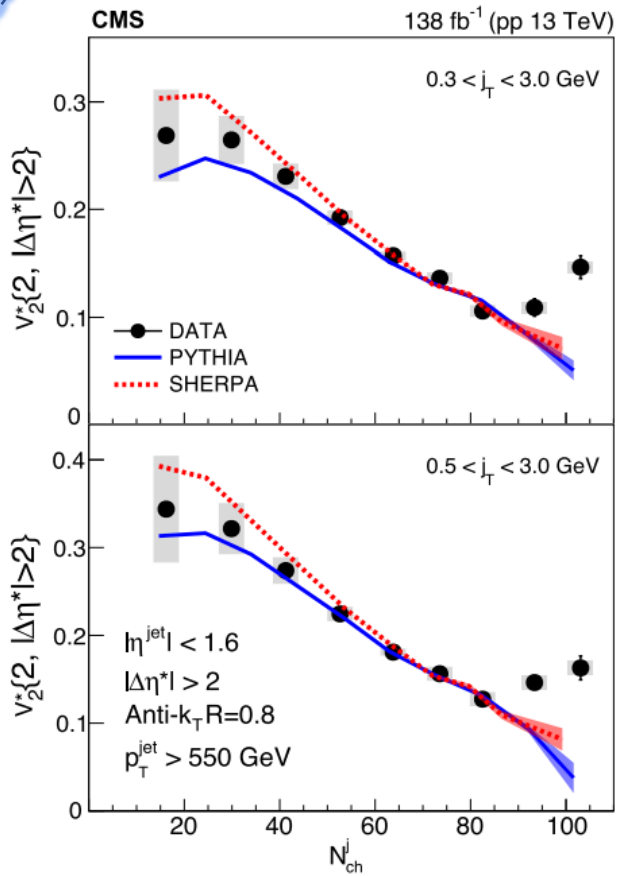


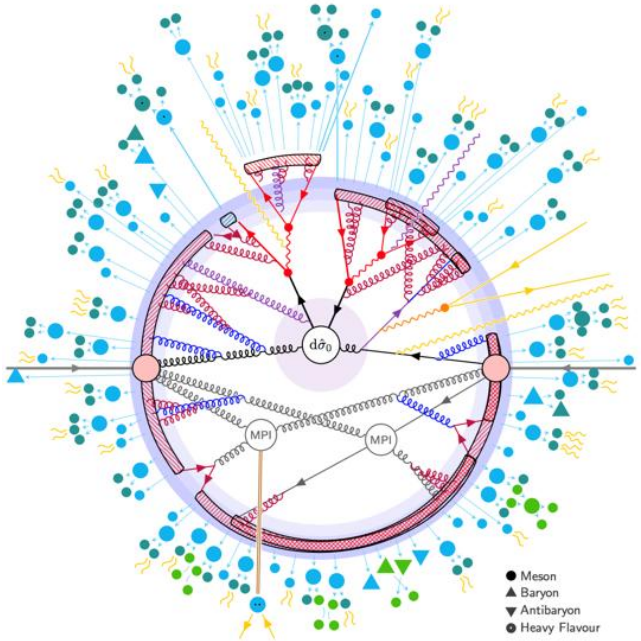
Long-range collectivity seems to arise in jets with very-high multiplicity, similar to that in AA.

A new window to study QCD collectivity.

Part I: Background

CMS, PRL 133, 142301 (2024)

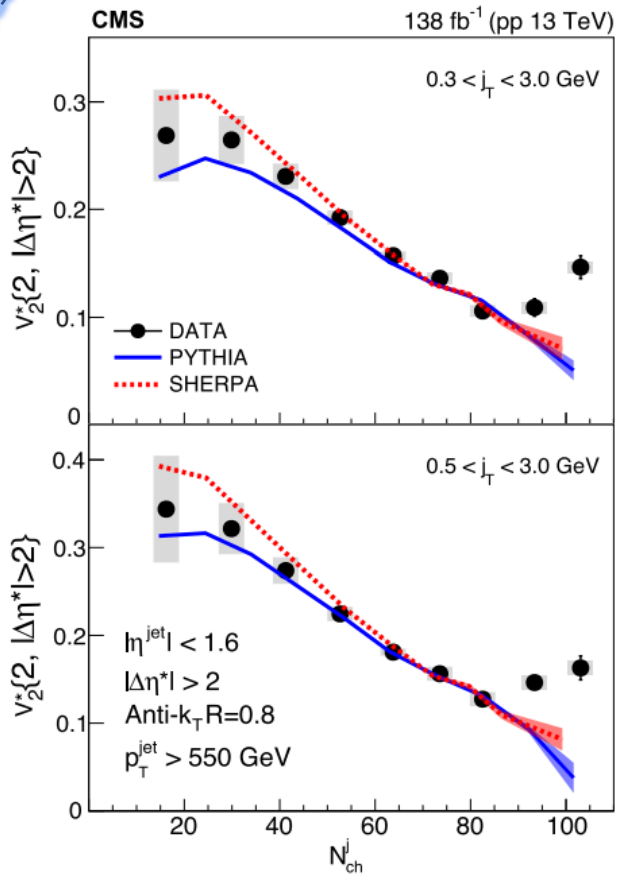


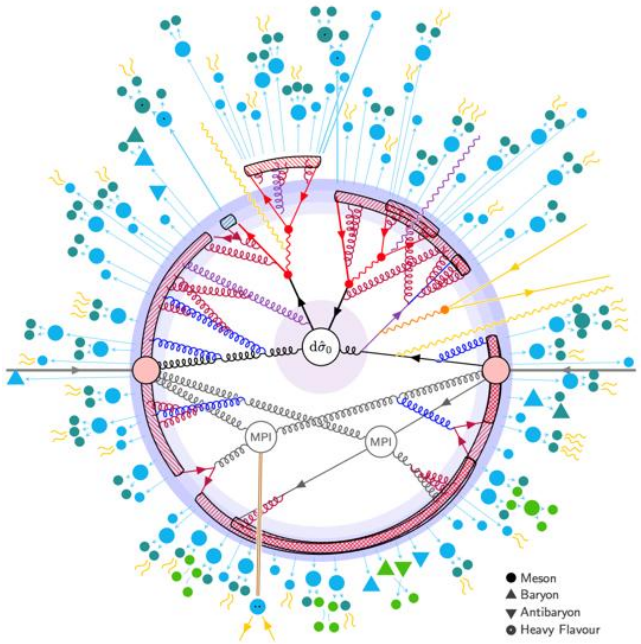


Such a phenomenon can be studied with MC event generator like PYTHIA and SHERPA.

Part I: Background

CMS, PRL 133, 142301 (2024)





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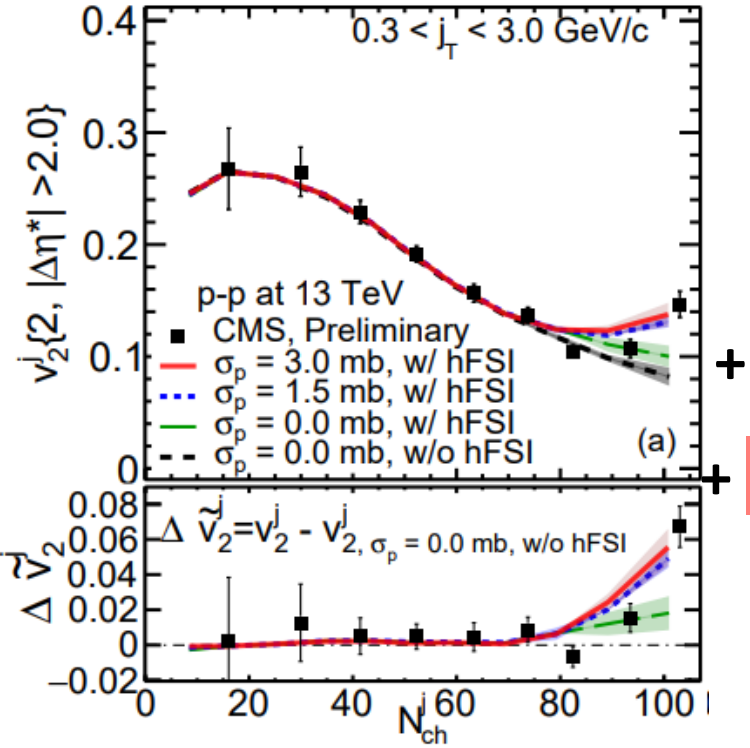
Zhao, Lin, Wang, 2401.13137



PYTHIA + AMPT + UrQMD

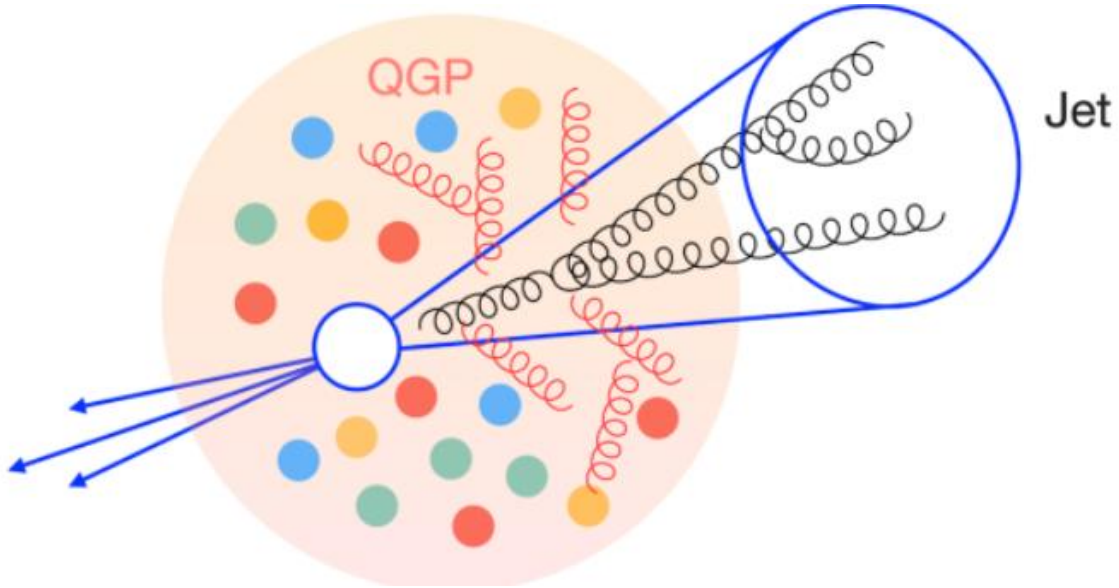
Demonstrating a possible mechanism.

Establishing an effective framework to study many-particle effects in jets.

Part II: Modifications on in-jet v_2 in QGP

How two-particle azimuthal correlation will be affected in presence of QGP medium?

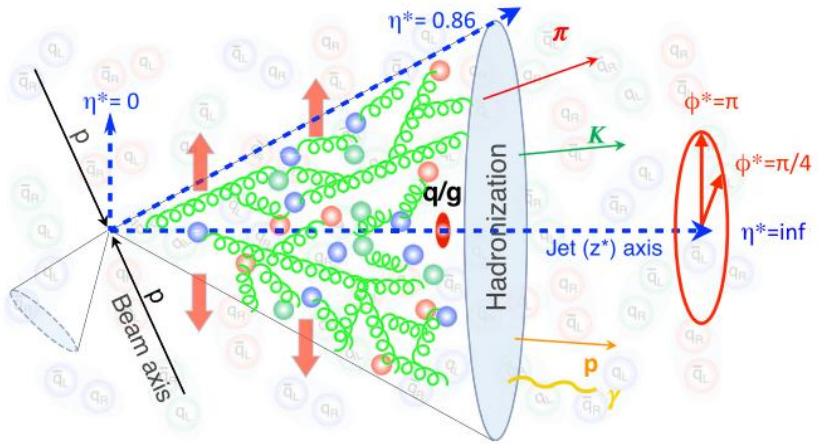
What properties of QGP can be learned from the modifications of the correlations?



Part II: Modifications on in-jet v_2 in QGP

Sources of in-jet v_2 in the vacuum: 1. Non-dynamical

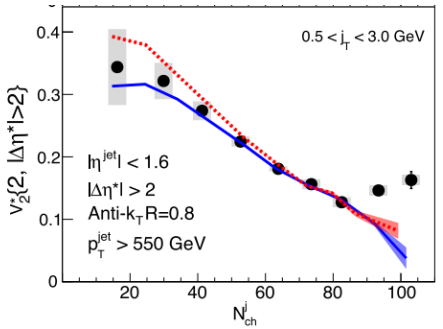
Momentum balance



Enhanced two-particle back-to-back correlations which contribute to $v_2\{2\}$

Decreases with increasing particle multiplicity in jets.

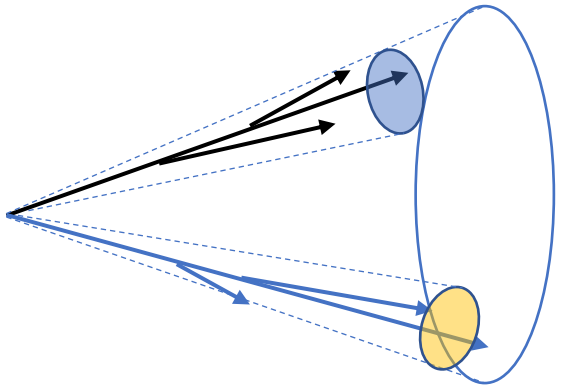
Exist also in quenched jets.



Part II: Modifications on in-jet v_2 in QGP

Sources of in-jet v_2 in the vacuum: 2. Dynamical

Partonic cascade stage



1. Parton splitting

Away-side & near-side correlations

Part II: Modifications on in-jet v_2 in QGP

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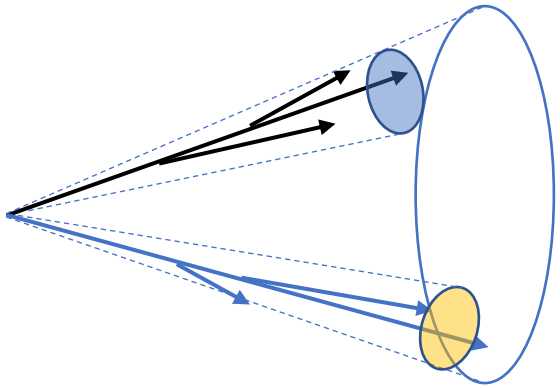
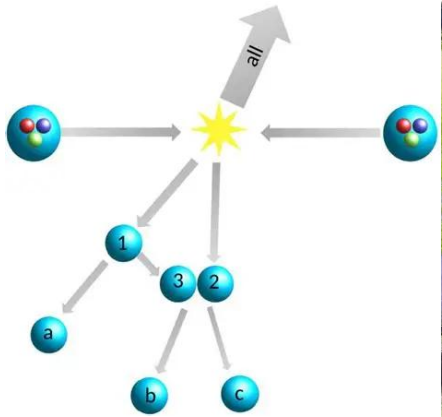
Partonic cascade stage





1. Parton splitting

2. Parton re-scattering/collectivity

Away-side & near-side correlations

More important at higher multiplicity

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Sources of in-jet v_2 in the vacuum: 2. Dynamical

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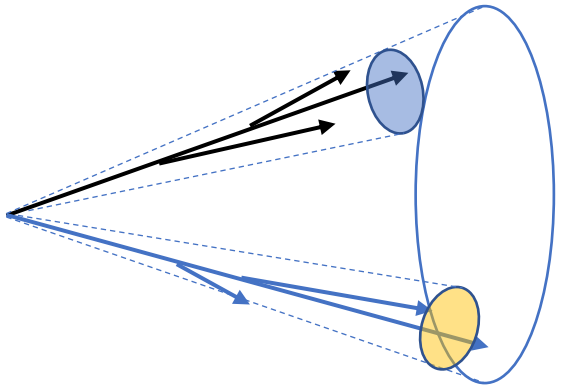

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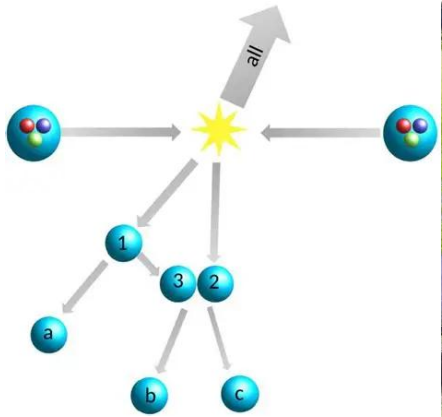

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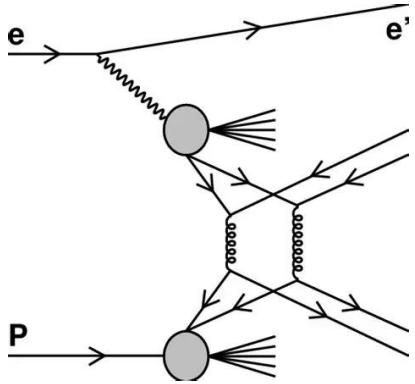


3. Other effects: e.g. MPI

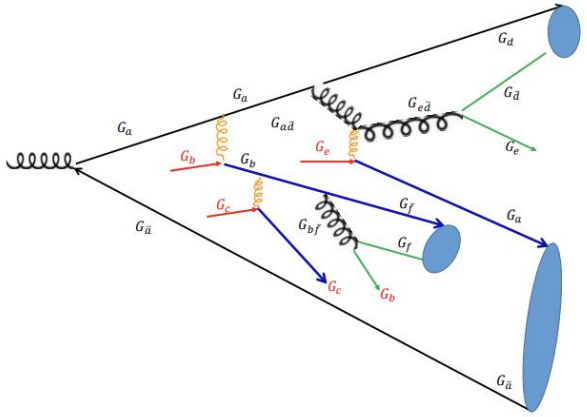
Away-side & near-side correlations

More important at higher multiplicity

Part II: Modifications on in-jet v_2 in QGP

Sources of in-jet v_2 in the vacuum: 2. Dynamical

Hadronisation and Hadronic cascade stage



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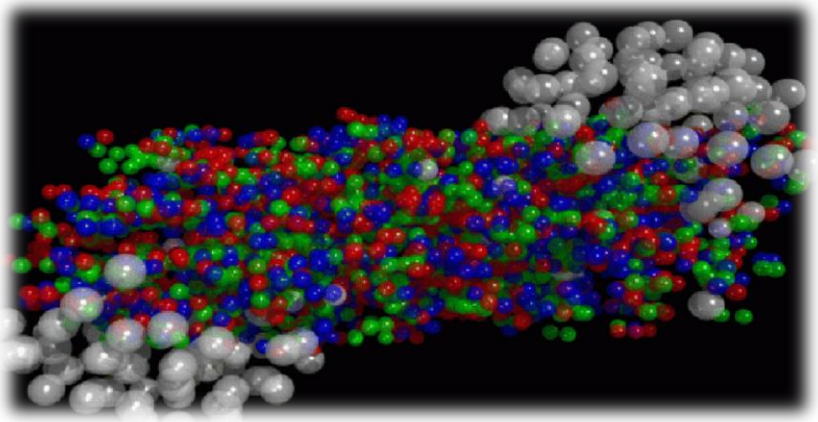
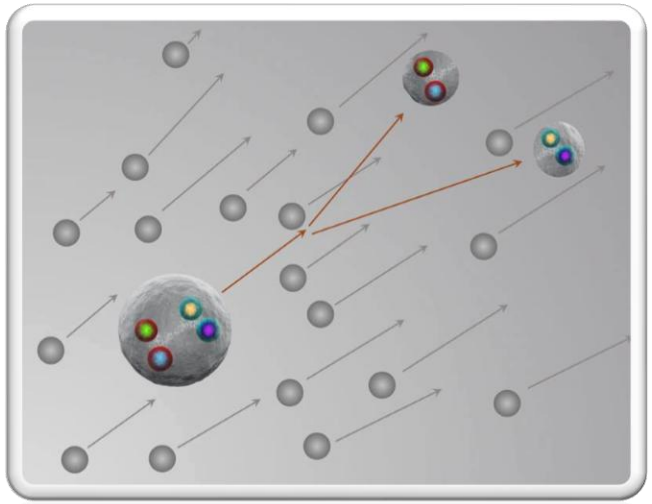


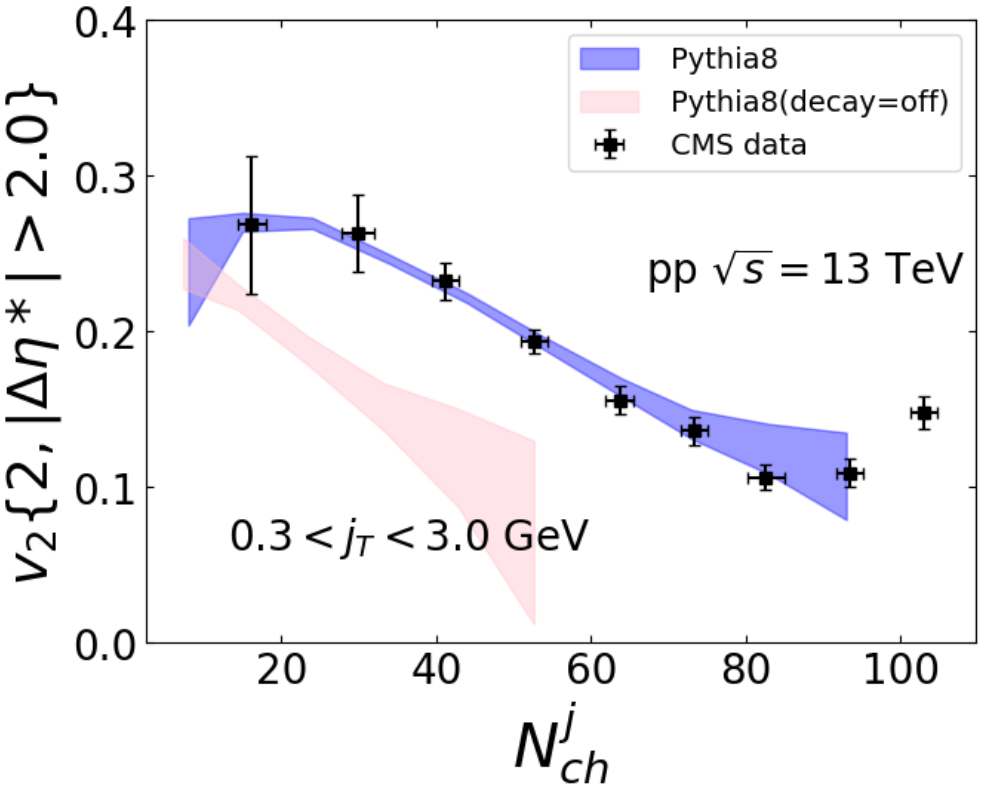
2. Hadron rescattering



3. Hadron decay

Part II: Modifications on in-jet v_2 in QGP

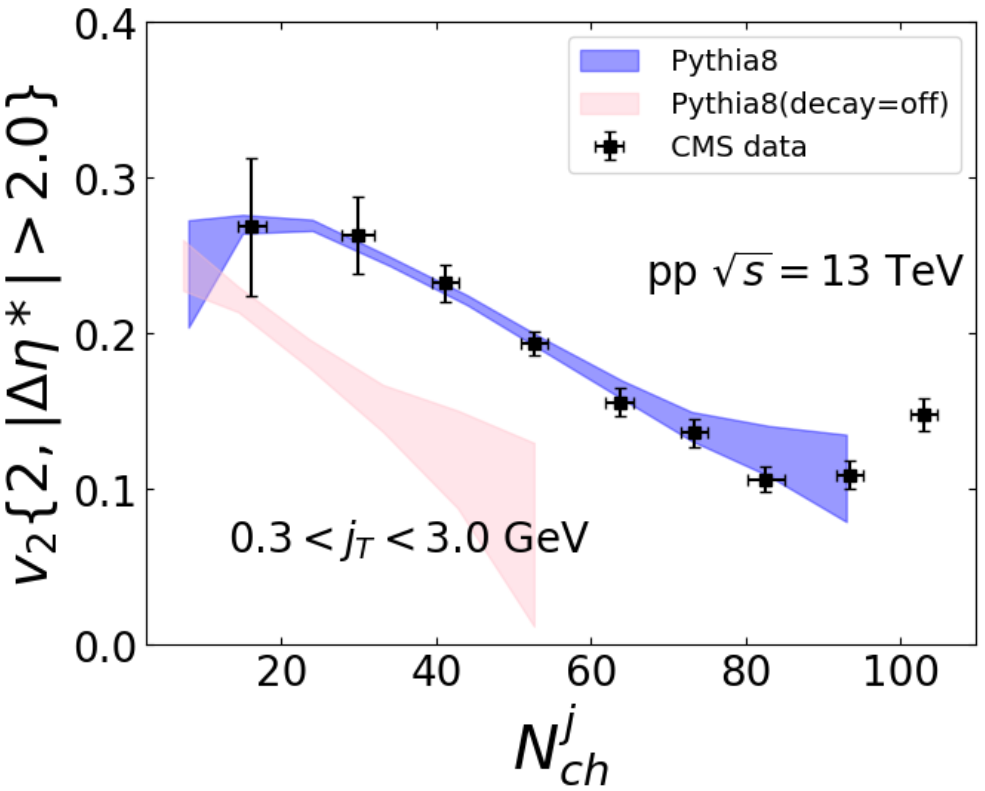
Nice description of the data in pp with PYTHIA8



Yang(杨梦权), Kong, Ru, Zhang, PLB(2025).
Yang, et al. in preparation.

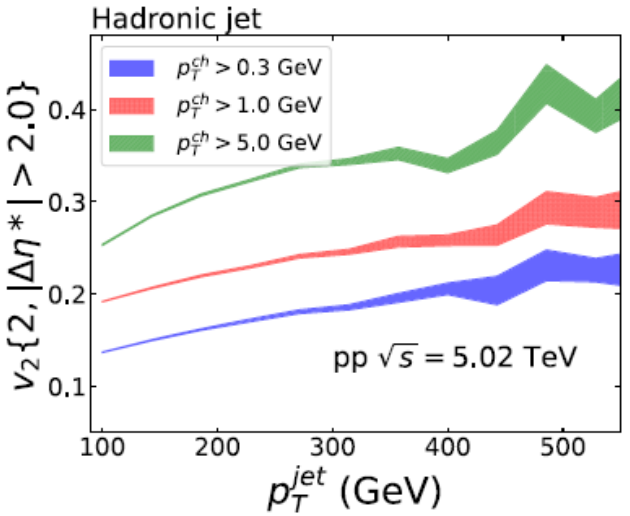
Part II: Modifications on in-jet v_2 in QGP

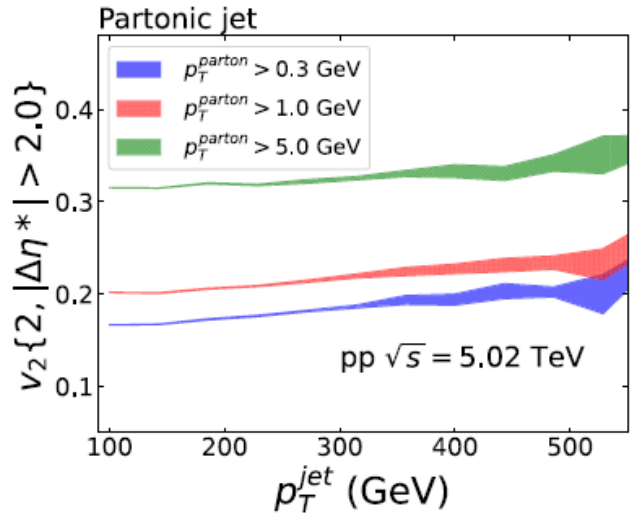
Nice description of the data in pp with PYTHIA8



Yang(杨梦权), Kong, Ru, Zhang, PLB(2025).
Yang, et al. in preparation.

In general, all the dynamics-induced correlations can be modified with the presence of nuclear medium.



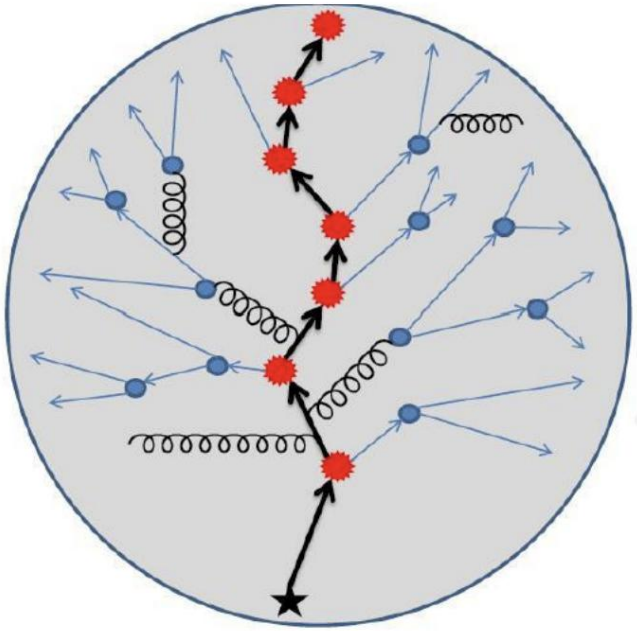


Observable sensitive to parton splitting.

Partonic/hadronic rescattering suppressed.

Part II: Modifications on in-jet v_2 in QGP

Simulating propagation of jet partons in QGP with LBT model



He, Luo, Wang, Zhu, PRC 91 (2015).
Luo, Cao, He, Wang, PLB 782 (2018).

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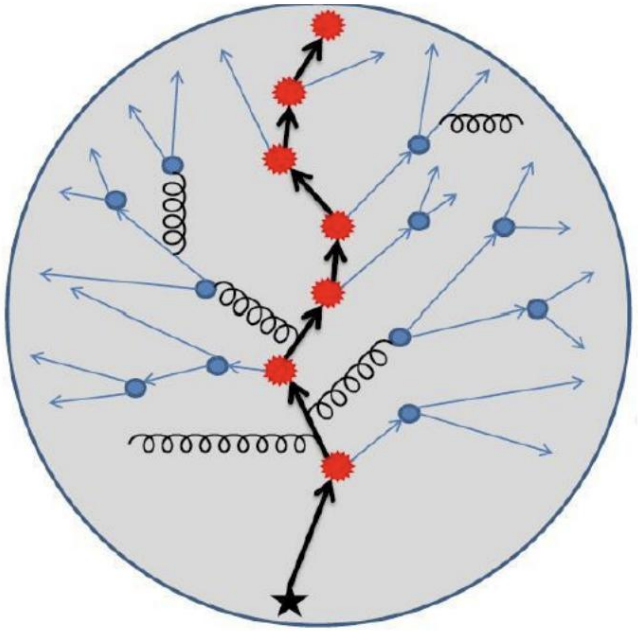

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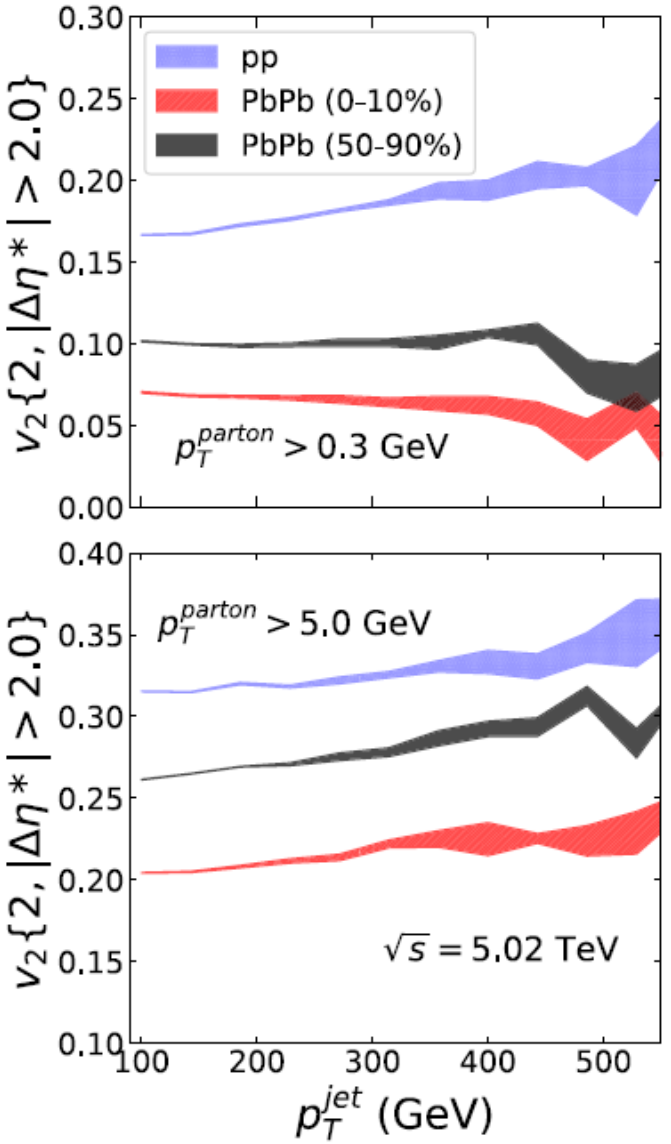
Luo, Cao, He, Wang, PLB 782 (2018).



$v_2\{2\}$ are strongly suppressed by the presence of medium.

Similar suppression when excitation particles are excluded.

Suppression become stronger for higher medium temperature, larger medium size, stronger parton-medium interaction.

Both elastic and inelastic scattering give contributions.

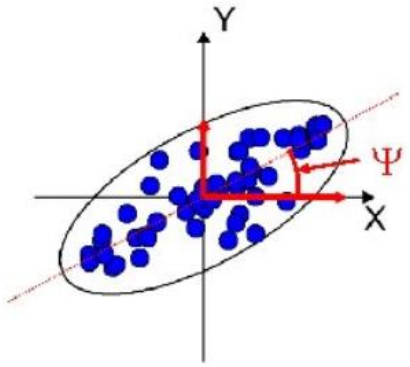
Part II: Modifications on in-jet v_2 in QGP

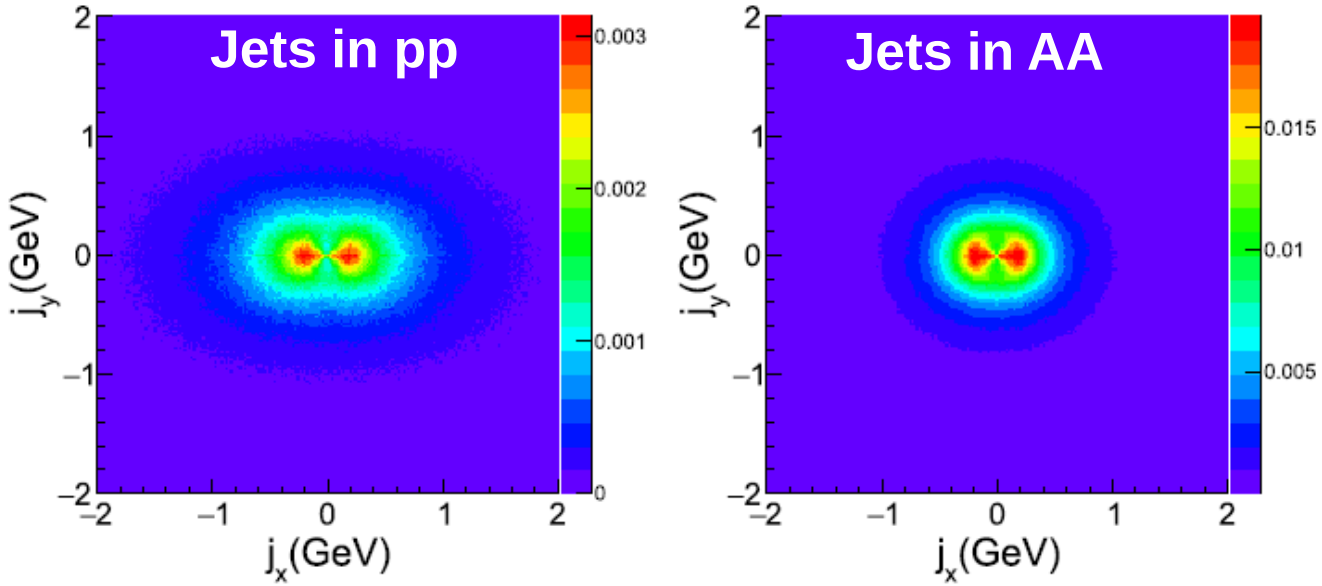
Extending the event-plane method to jet frame

$$v_n\{EP_k\} = \frac{\langle \cos\left(n(\phi - \Psi_k)\right)\rangle}{\sigma_k^n}$$

$$\sigma_k^n = \langle \cos\left(n(\Psi_k - \Psi)\right)\rangle$$

$$\tan\left(k\Psi_k\right) = \frac{\sum_i w_i \sin\left(k\phi_i\right)}{\sum_i w_i \cos\left(k\phi_i\right)}$$



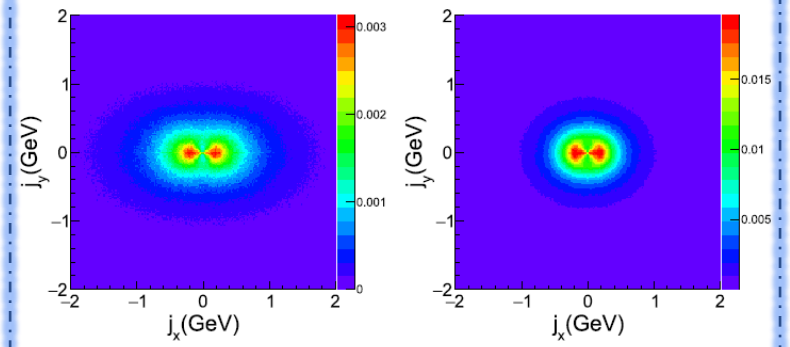


More isotropic distributions in quenched jets.

Clear back-to-back structures seen in both pp and AA.

Part III: Summary & Outlook

Summary



New perspectives for jet quenching:

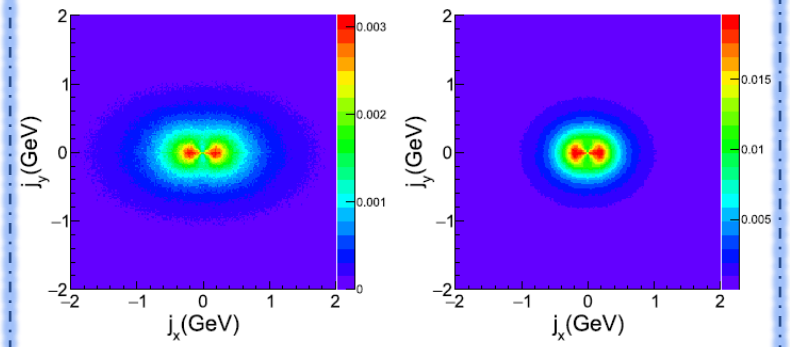
Energy loss & Information loss

Dissipative nature of jet transport.

Sensitive to medium properties.

Part III: Summary & Outlook

Summary



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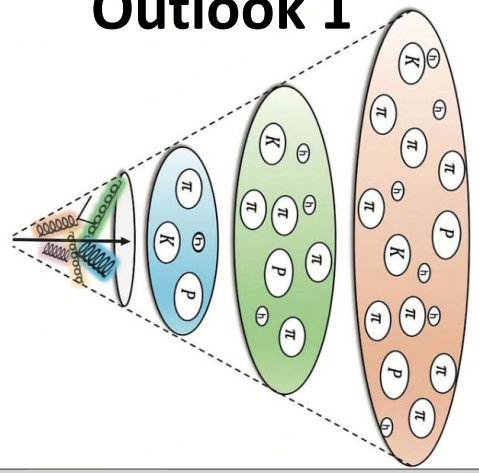
Outlook 1



More realistic simulation for AA.

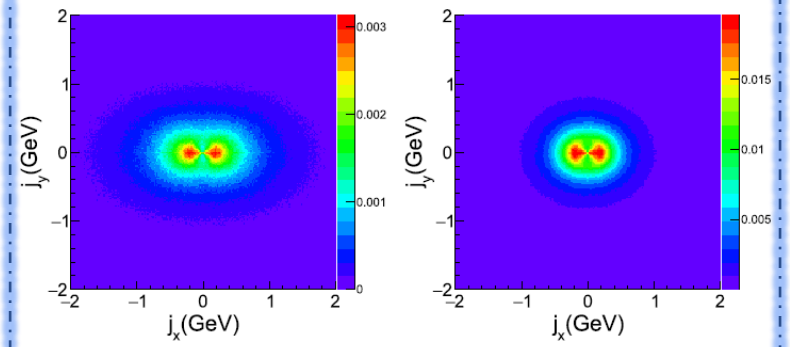
Hybrid hadronization (e.g. Freeze out, Coalescence, fragmentation)

See W. Zhao PRL(2020,2022)

Partonic and hadronic rescattering.

Part III: Summary & Outlook

Summary



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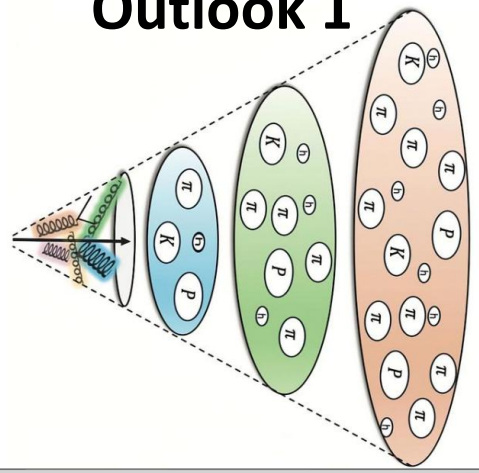

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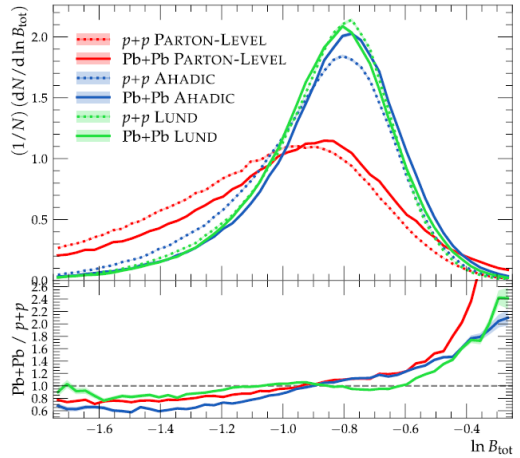
Outlook 2



Other observables in jet frame.

e.g. event shape in jet frame.

Kang(康锦文), et al, in preparation.