USTC - Particle and Nuclear Physics

NPMiniWorkshop

喷注物理最新实验进展

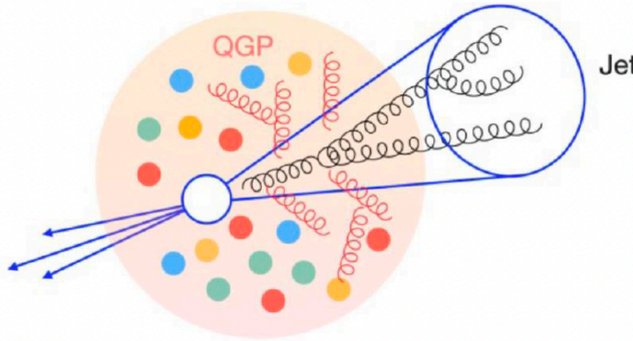
Yaxian MAO (毛亚显)

Central China Normal University

華中師範大學
CENTRAL CHINA NORMAL UNIVERSITY

Jets as a probe of the quark-gluon plasma

- Study structure of QGP by understanding jet modification from medium interaction (jet quenching)

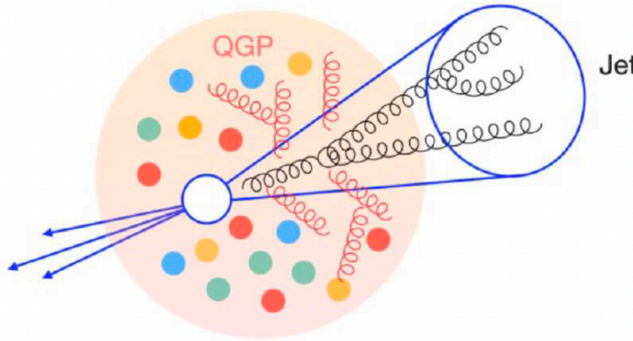


https://www.int.washington.edu/node/776

- Several types of jet observables
  - Jet yields and constituents → suppression and energy redistribution
  - Jet reconstruction and declustering → jet substructure modification
  - Jet correlations and tagging → angular deflection and asymmetry

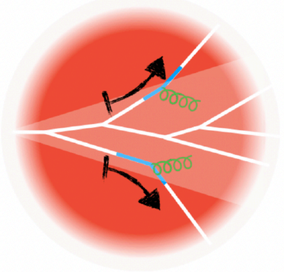
Jets as a probe of the quark-gluon plasma

- Study structure of QGP by understanding jet modification from medium interaction (jet quenching)

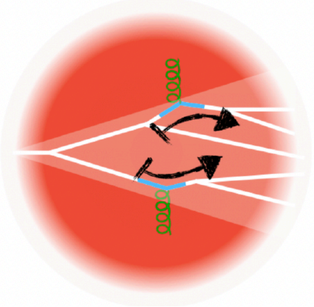


- Several types of jet observables
  - Jet yields and constituents → suppression and energy redistribution
  - Jet reconstruction and declustering → jet substructure modification
  - Jet correlations and tagging → angular deflection and asymmetry

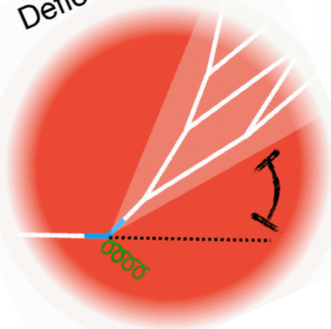
Energy Redistribution (“loss”) ://www.int.washington.edu/node/776



Substructure modification

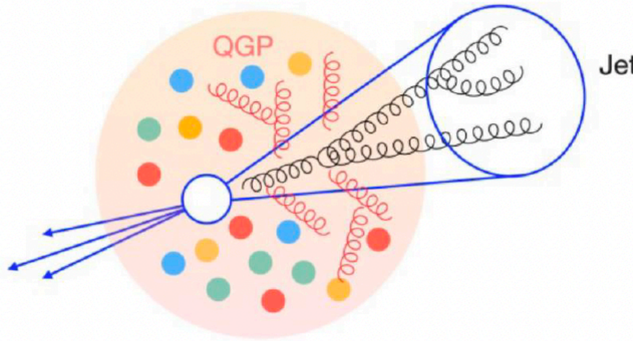


Deflection



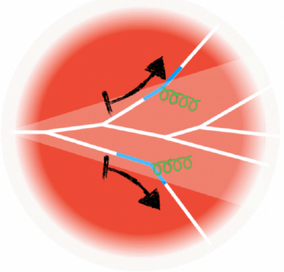
Jets as a probe of the quark-gluon plasma

- Study structure of QGP by understanding jet modification from medium interaction (jet quenching)

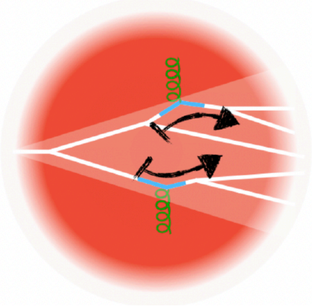


- Several types of jet observables
  - Jet yields and constituents → suppression and energy redistribution
  - Jet reconstruction and declustering → jet substructure modification
  - Jet correlations and tagging → angular deflection and asymmetry

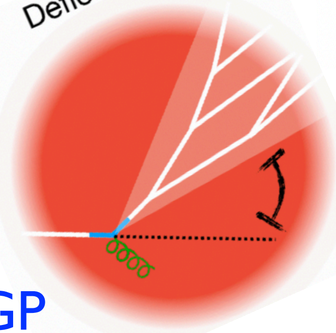
Energy Redistribution (“loss”) ://www.int.washington.edu/node/776



Substructure modification

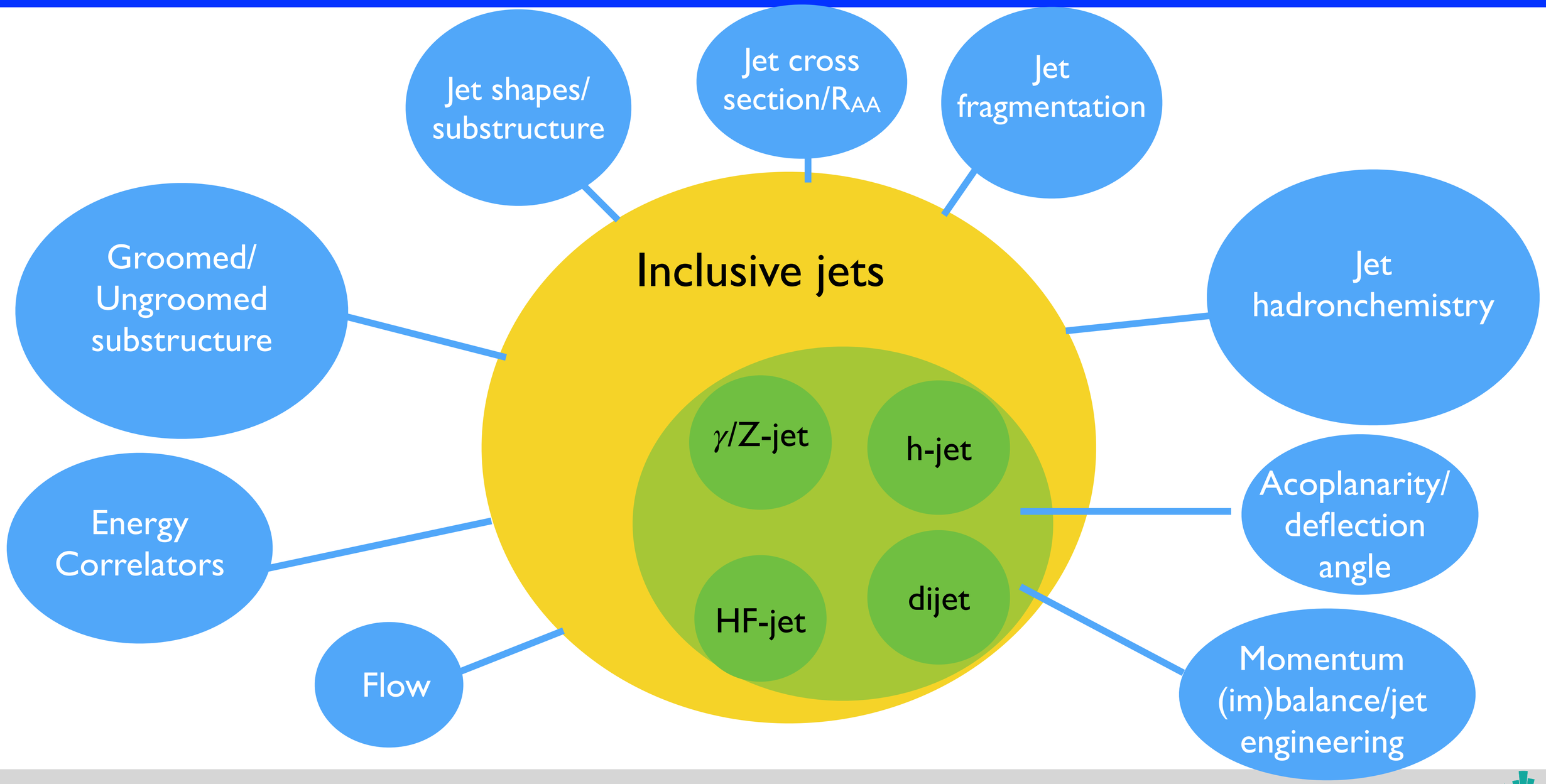


Deflection

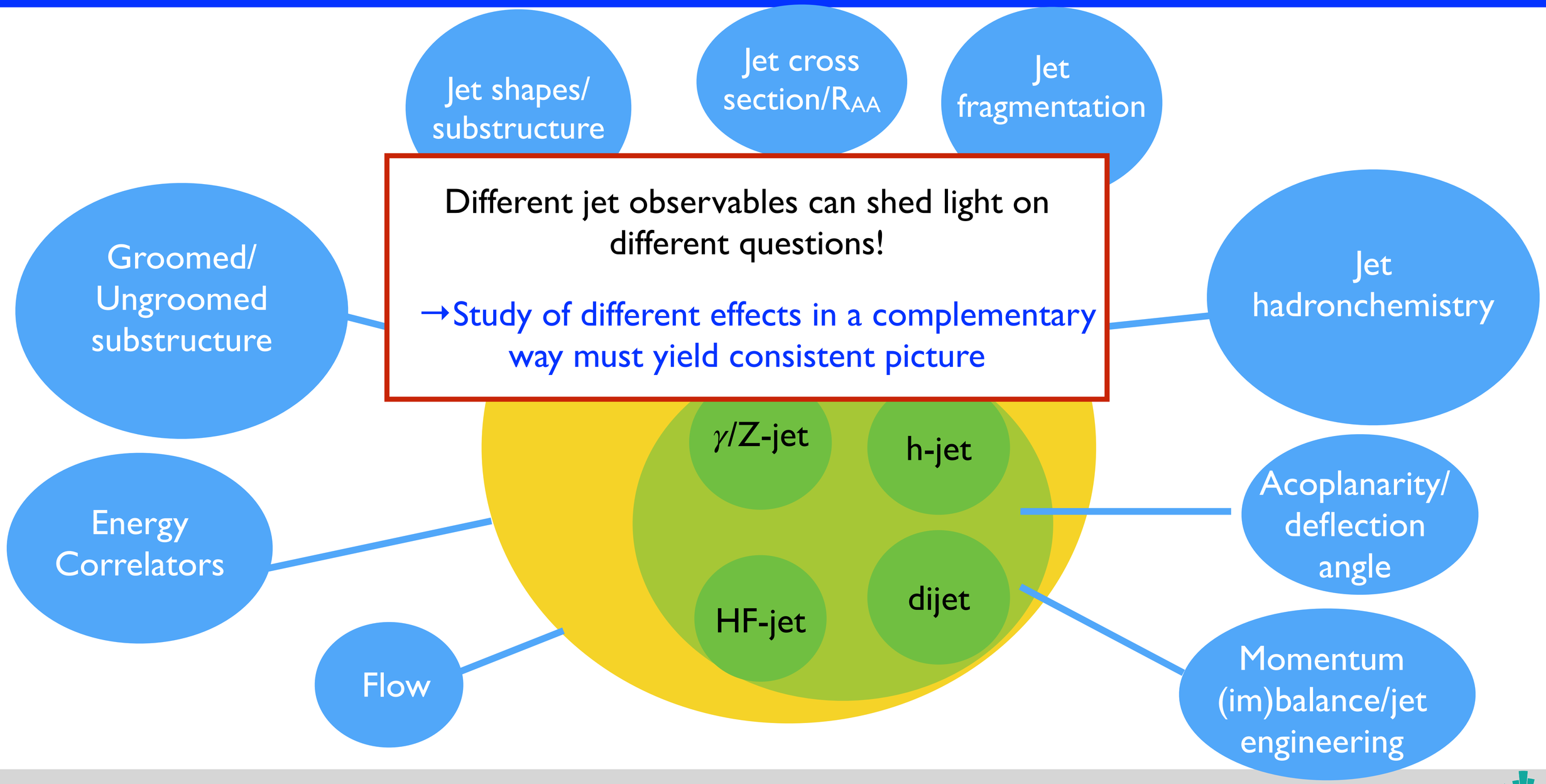


Goal: design observables to disentangle effects and extract properties of the QGP

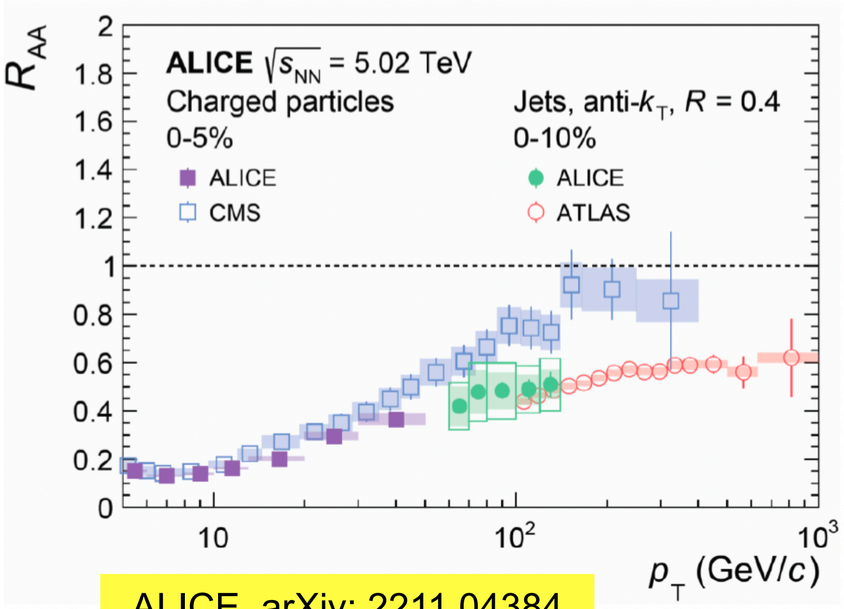
A (incomplete) roadmap of jet measurements



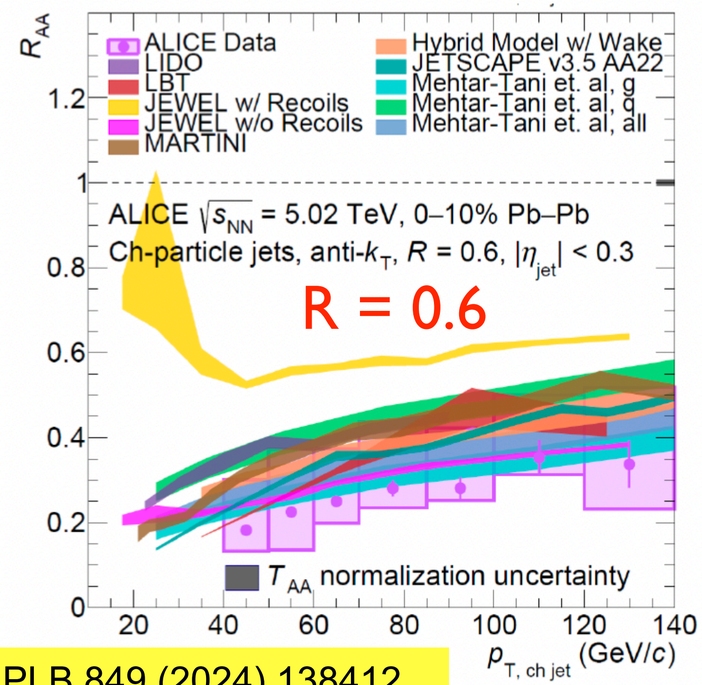
A (incomplete) roadmap of jet measurements



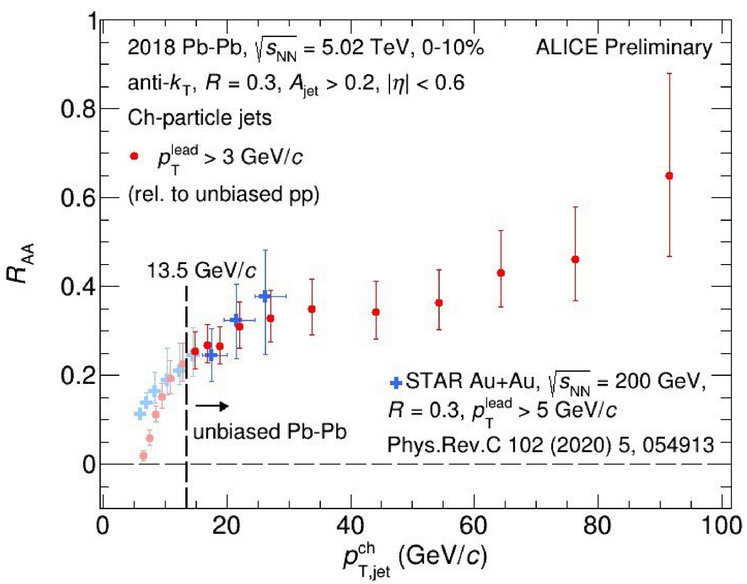
Jet suppression and energy redistribution



ALICE, arXiv: 2211.04384

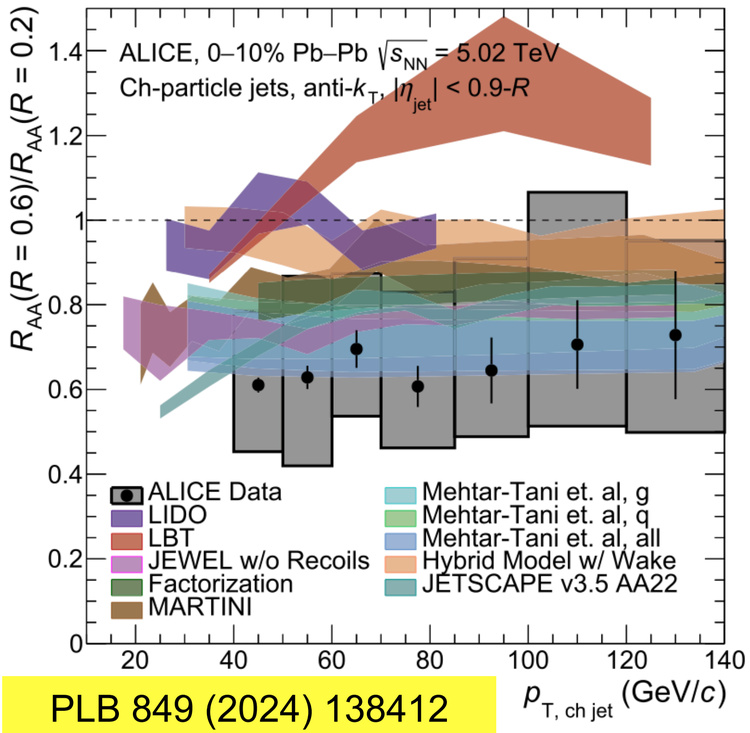


PLB 849 (2024) 138412



- Jet and high p_T hadron suppression observed over extensive range
  - Interplay between high p_T and jet results
- New ML&ME techniques allow for the extension to lower jet p_T and large R
  - Allows for an overlapping regime between RHIC and LHC

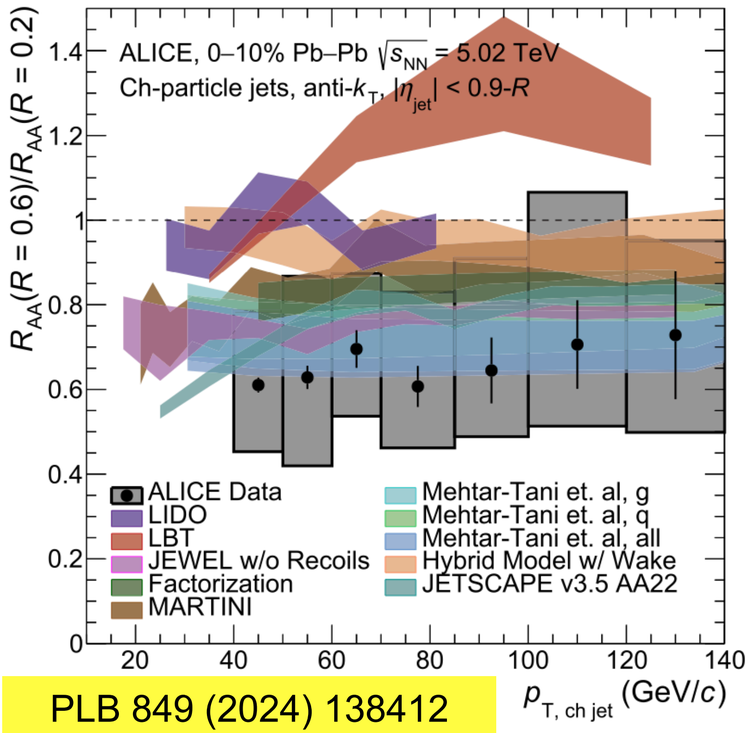
R dependence of jet quenching



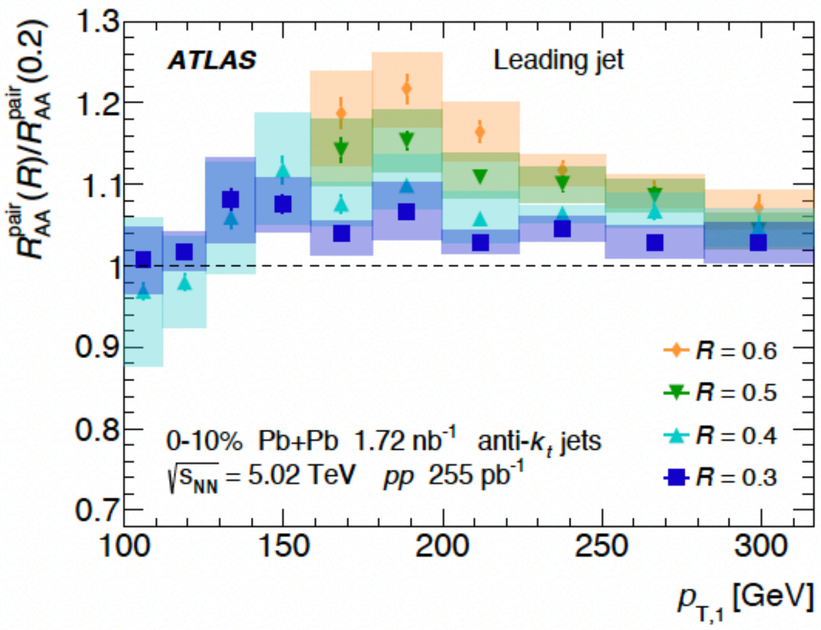
PLB 849 (2024) 138412

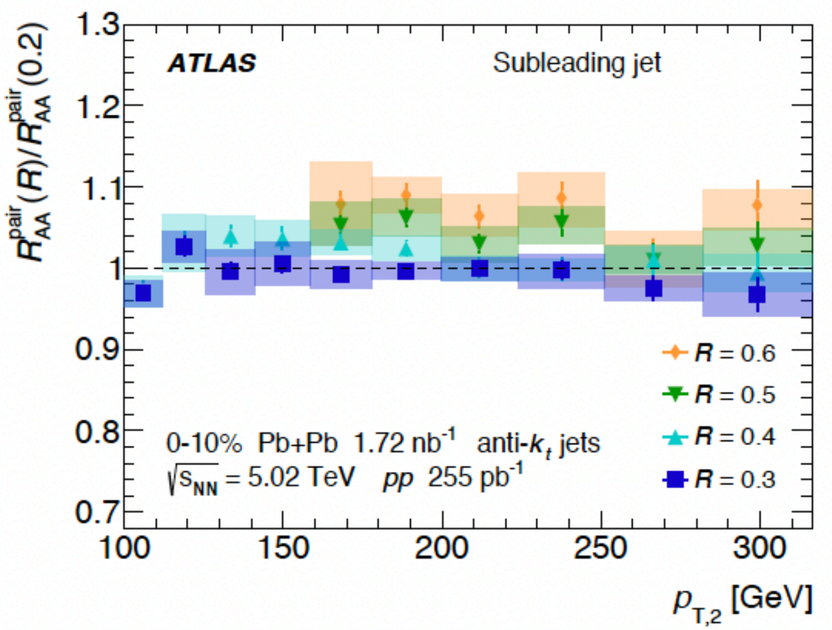
- Inclusive jets R_{AA} ratio from ALICE: larger radius jets more suppressed

R dependence of jet quenching



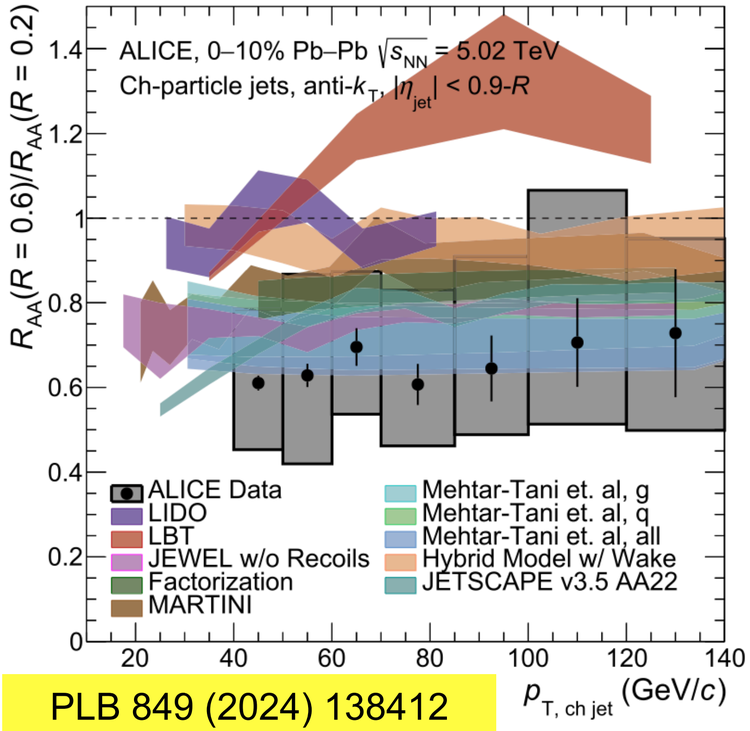
PLB 849 (2024) 138412



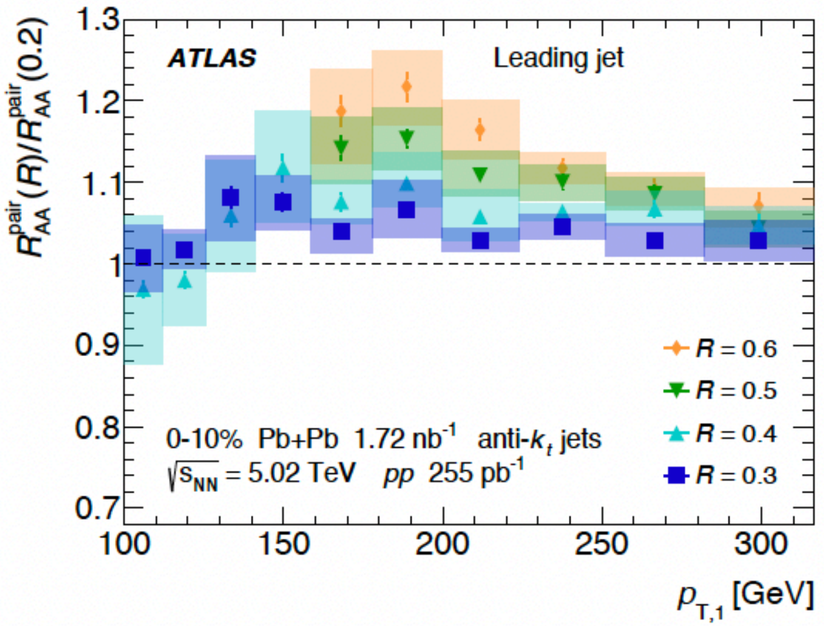


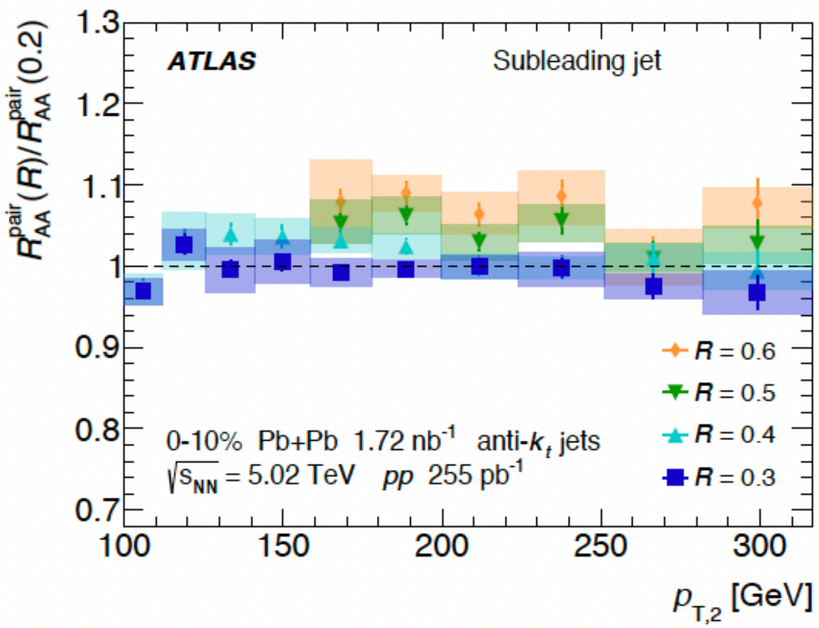
- Inclusive jets R_{AA} ratio from ALICE: larger radius jets more suppressed
- Dijet pair R_{AA} ratio from ATLAS: larger radius jets less suppressed

R dependence of jet quenching

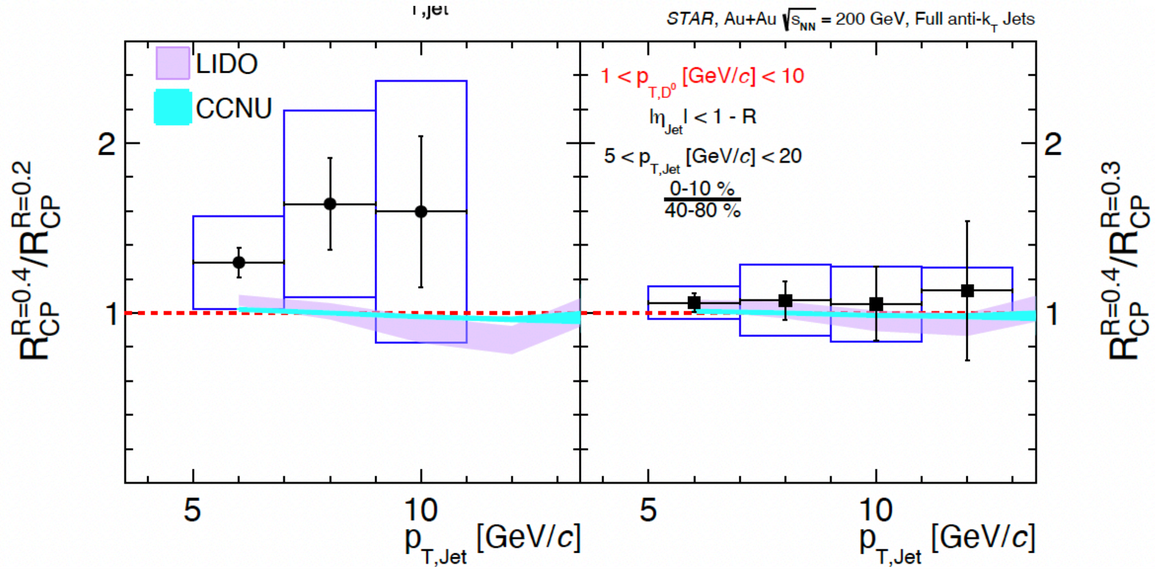


PLB 849 (2024) 138412

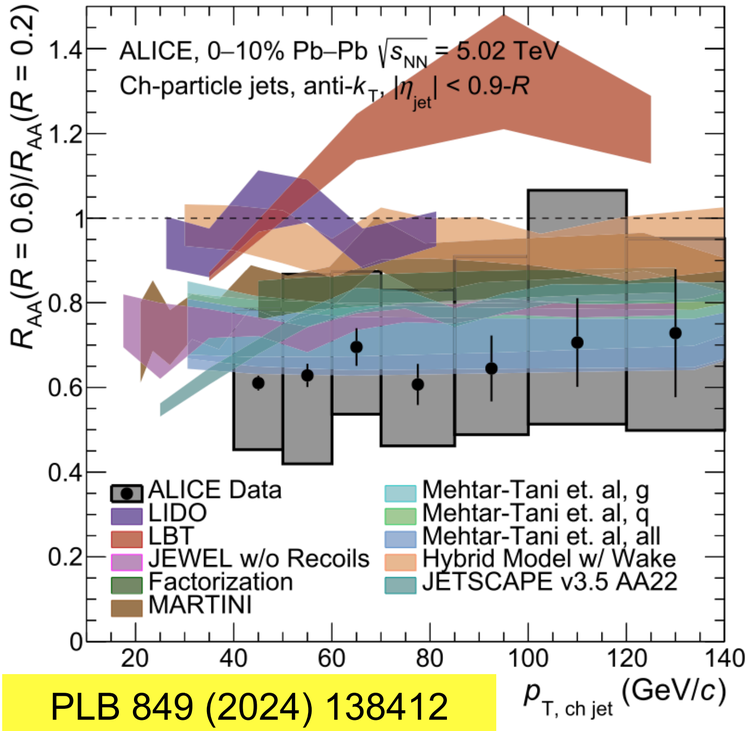




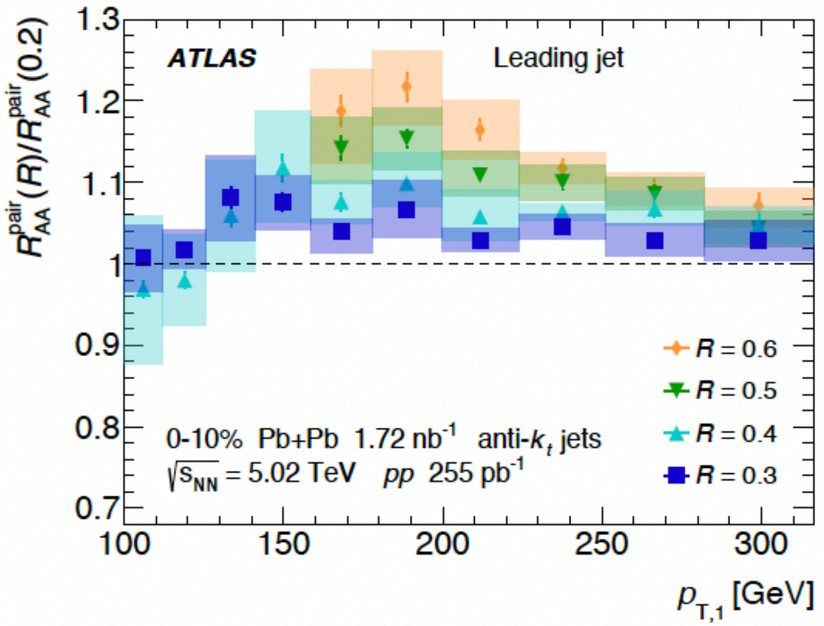
- Inclusive jets R_{AA} ratio from ALICE: larger radius jets more suppressed
- Dijet pair R_{AA} ratio from ATLAS: larger radius jets less suppressed
- B-jet R_{cp} ratio from STAR: no strong radius dependence

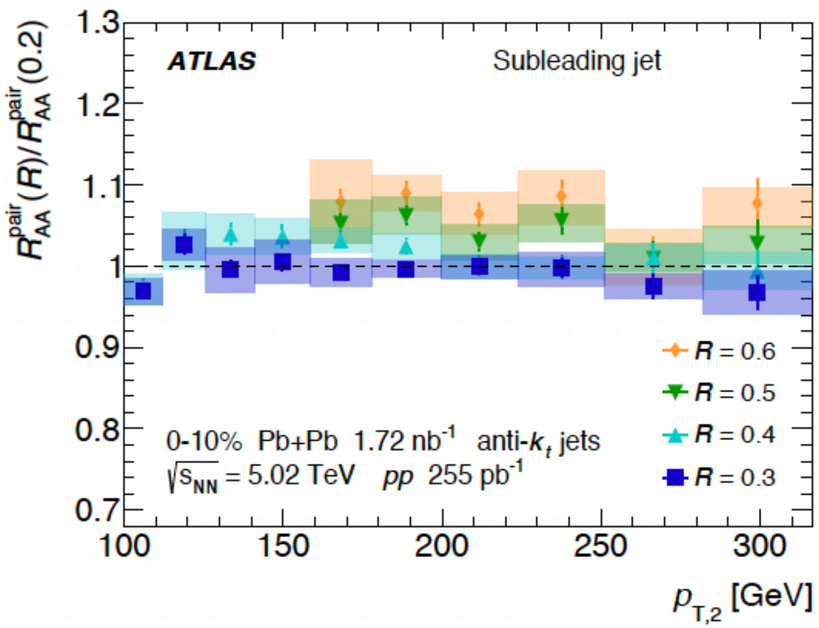


R dependence of jet quenching

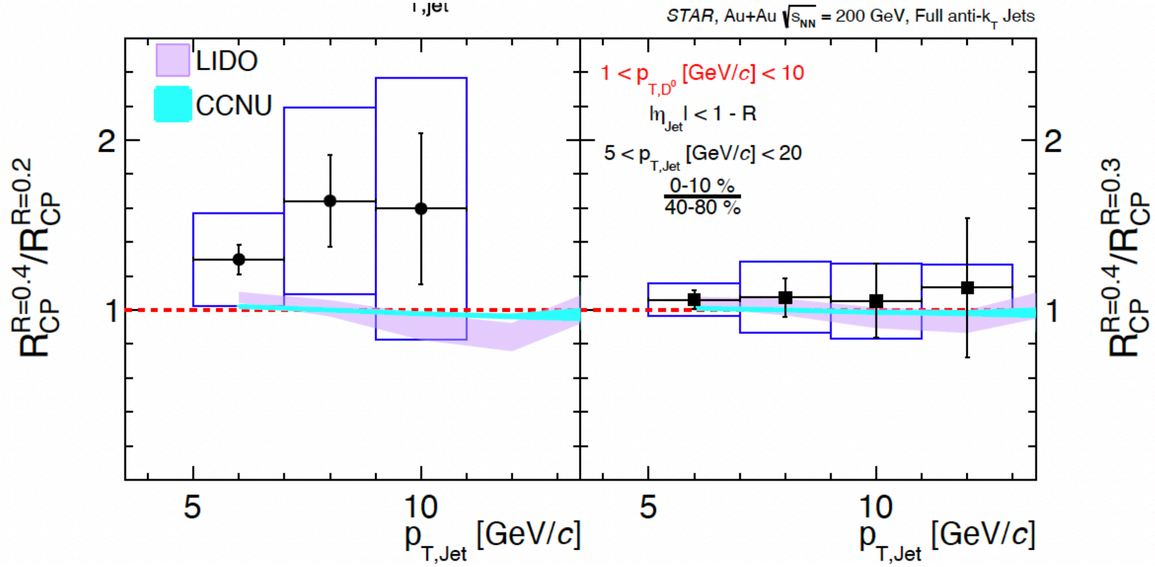


PLB 849 (2024) 138412

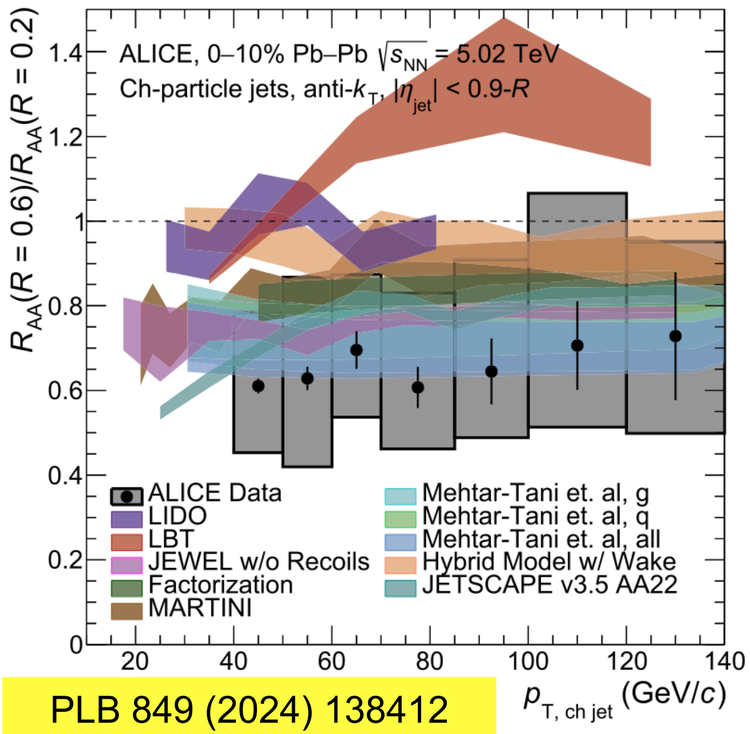




- Not the same jet type (inclusive vs. dijet vs. b-jet)
- Not the same kinematics (q/g fraction and jet structure can be different)
- p_T dependence of energy loss are quite different (no matching for different R jets)

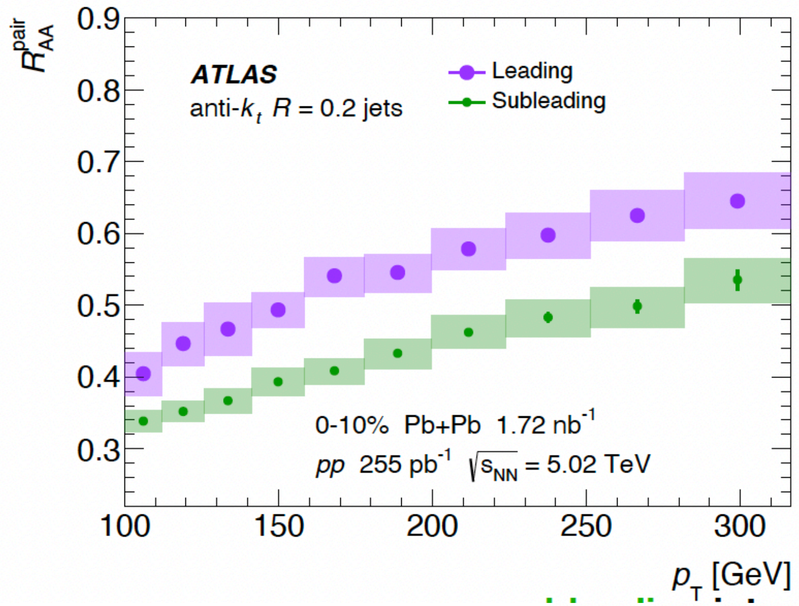


R dependence of jet quenching

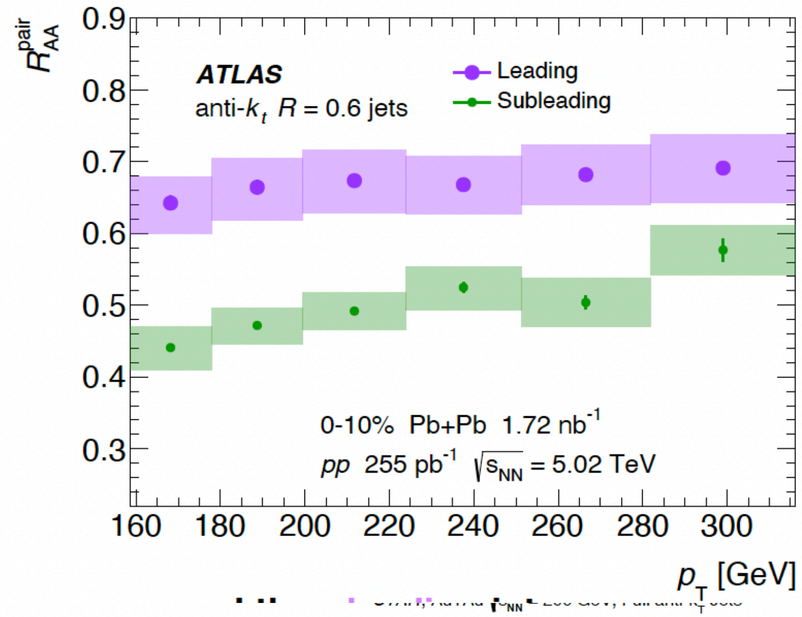


PLB 849 (2024) 138412

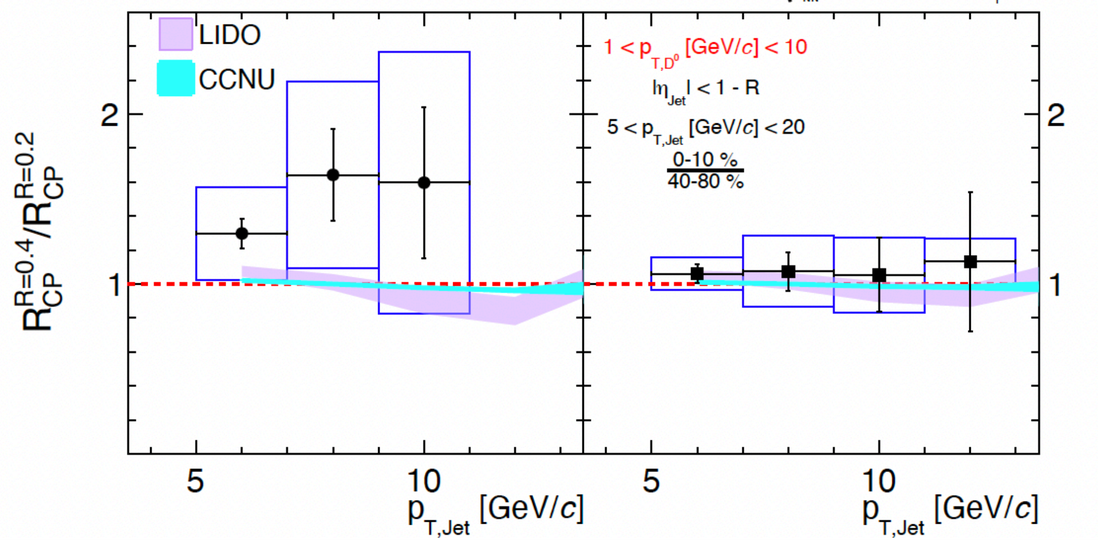
R = 0.2



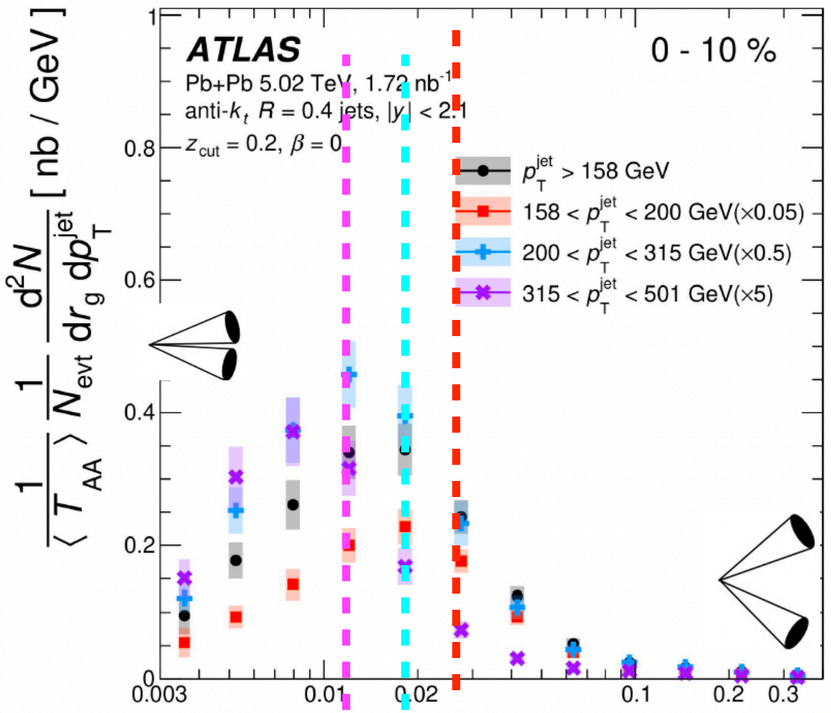
R = 0.6

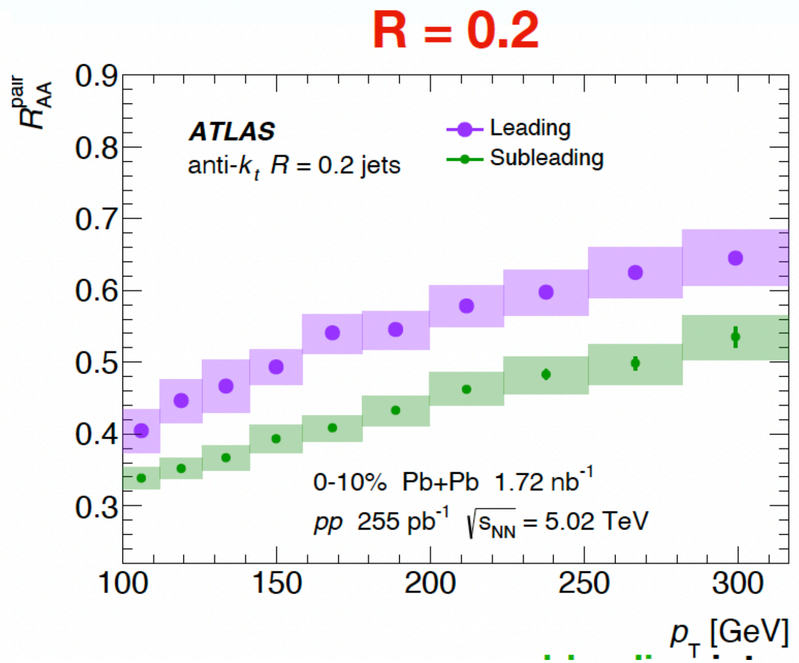


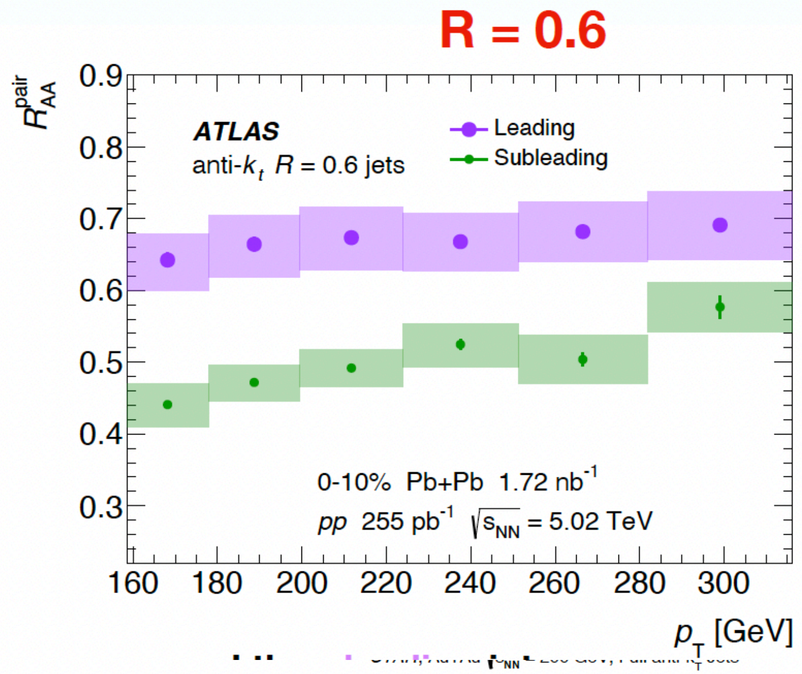
- Not the same jet type (inclusive vs. dijet vs. b-jet)
- Not the same kinematics (q/g fraction and jet structure can be different)
- p_T dependence of energy loss are quite different (no matching for different R jets)



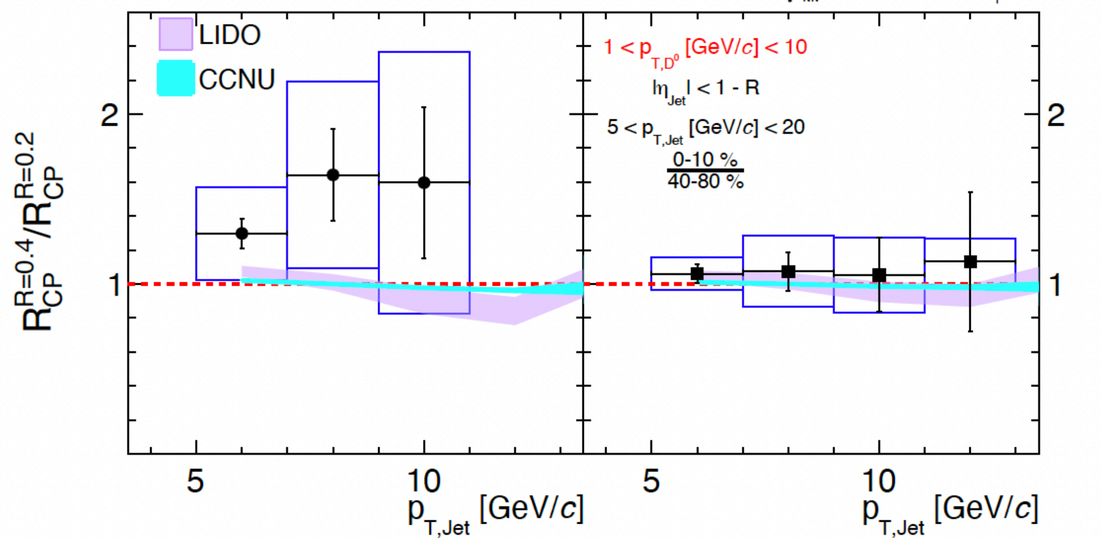
R dependence of jet quenching







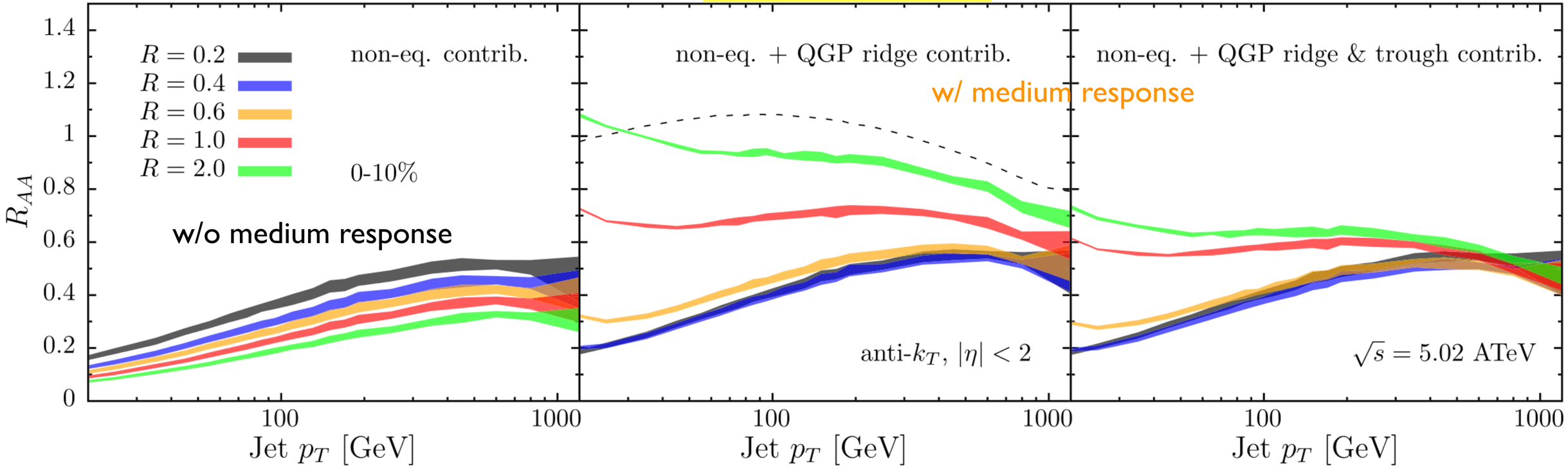
- Not the same jet type (inclusive vs. dijet vs. b-jet)
- Not the same kinematics (q/g fraction and jet structure can be different)
- p_T dependence of energy loss are quite different (no matching for different R jets)



Theory input: R dependence of jet quenching

- R dependence of jet R_{AA} can be sensitive to medium response effect and help to disentangle energy loss mechanisms
  - competing effect between the amount/how energy redistributed and ability to recover it

PRL 124 (2020) 052301

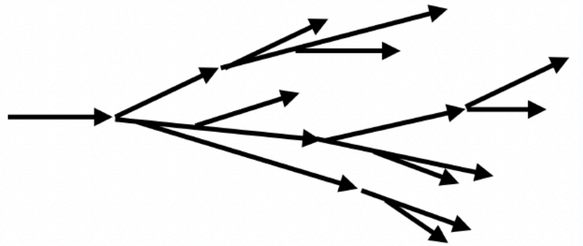


- Hybrid model predicts different (even reversed) R-dependence of jet R_{AA} due to medium response

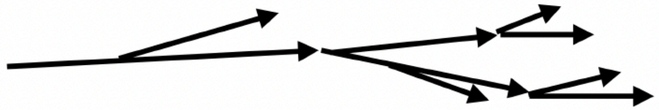
→More differential and consistent analyses needed!

Energy loss dependence on parton flavor/mass

Gluon-initiated shower



Quark-initiated shower



$$\frac{C_A}{C_F} = \frac{9}{4}$$

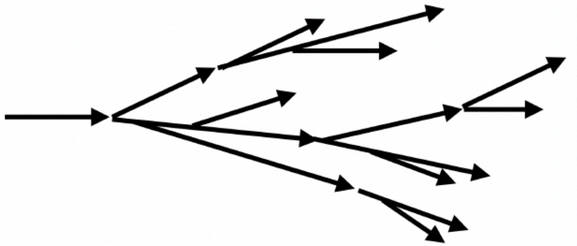
Casimir color factors

Gluon-initiated showers are expected to have a broader and softer fragmentation profile than quark-initiated showers

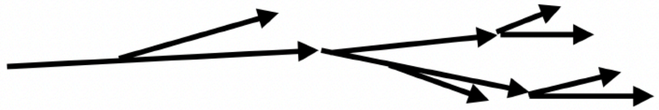
- Color charge dependence of energy loss: $E_{\text{loss}}^{\text{gluon}} > E_{\text{loss}}^{\text{quark}}$

Energy loss dependence on parton flavor/mass

Gluon-initiated shower



Quark-initiated shower

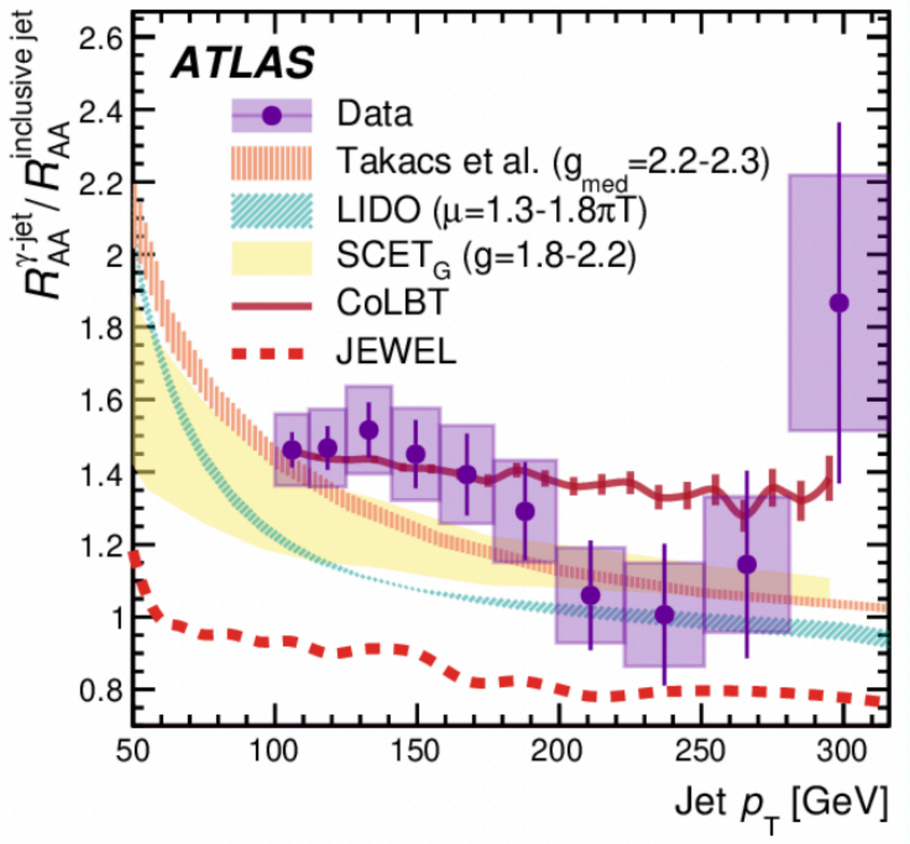


$$\frac{C_A}{C_F} = \frac{9}{4}$$

Casimir color factors

Gluon-initiated showers are expected to have a broader and softer fragmentation profile than quark-initiated showers

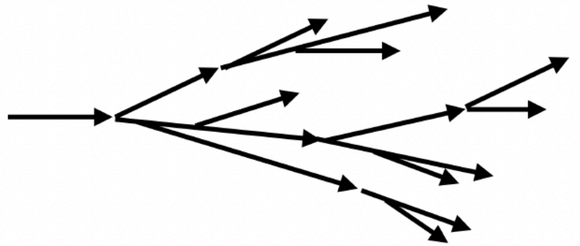
Phys. Lett. B 846 (2023) 138154



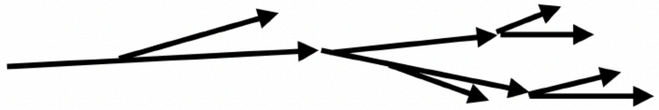
- Color charge dependence of energy loss: $E_{\text{loss}}^{\text{gluon}} > E_{\text{loss}}^{\text{quark}}$
- γ-tagged (quark enriched) jets are less suppressed than inclusive (gluon dominated) jets

Energy loss dependence on parton flavor/mass

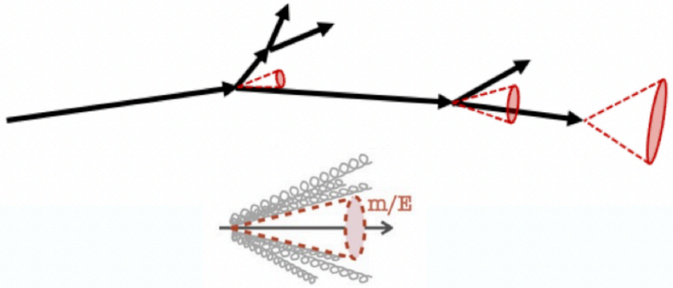
Gluon-initiated shower



Quark-initiated shower



Heavy-quark-initiated shower



$$\frac{C_A}{C_F} = \frac{9}{4}$$

Casimir color factors

Gluon-initiated showers are expected to have a broader and softer fragmentation profile than quark-initiated showers

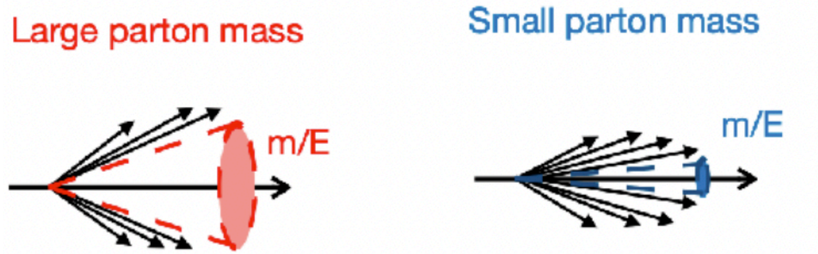
Mass effects

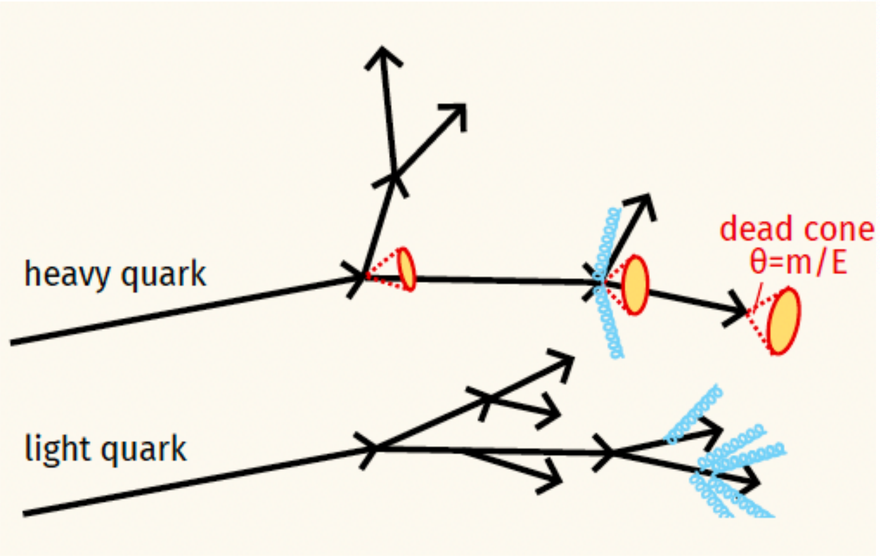
A harder fragmentation is expected in low energy heavy-quark initiated showers due to the presence of a dead cone which suppresses radiation close to the heavy-quark

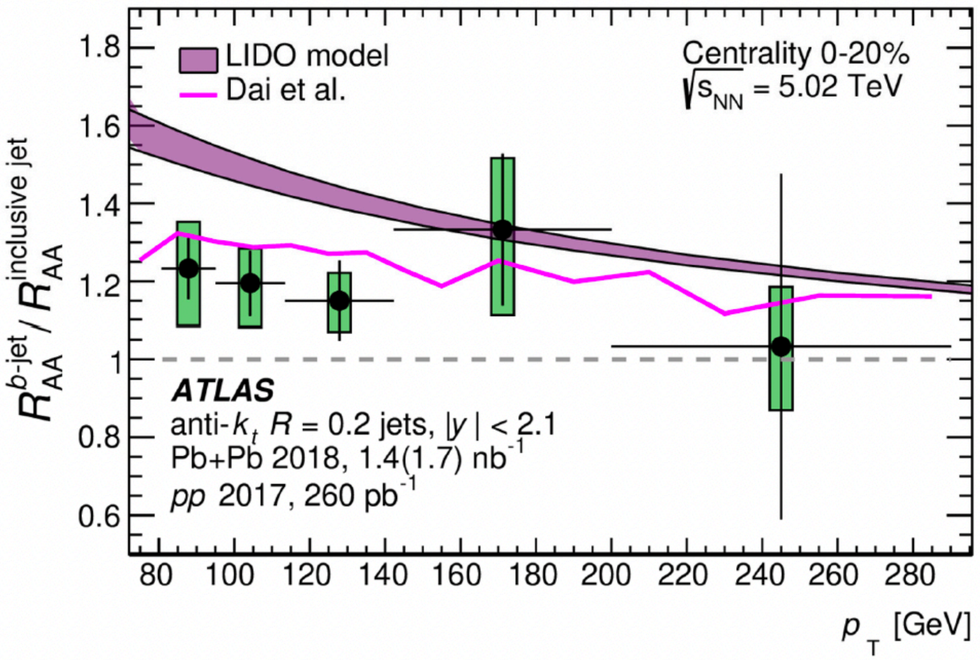
- Energy loss predicted to depend also on quark mass: reduction of gluon radiation from heavy quarks at small angles —"Dead Cone" effect
- Flavor dependence of energy loss: $E_{\text{loss}}^{\text{gluon}} > E_{\text{loss}}^{\text{light-quark}} > E_{\text{loss}}^{c} > E_{\text{loss}}^{b}$

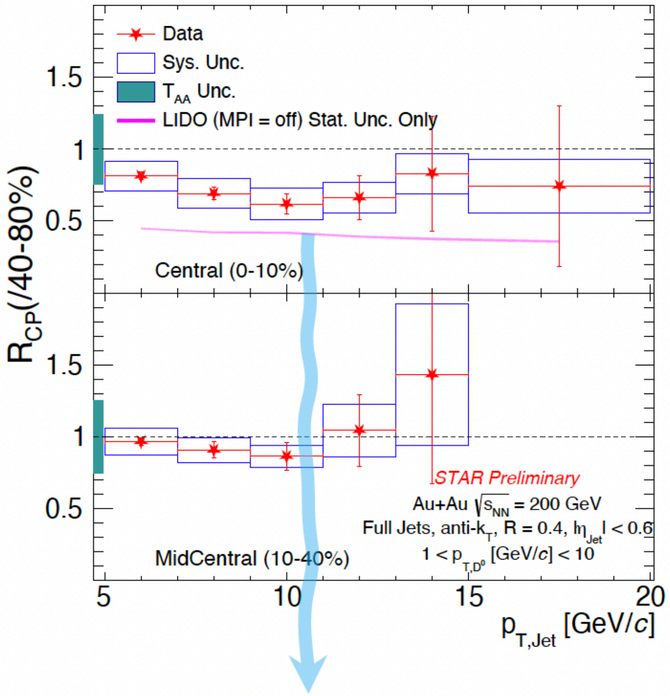
Mass/flavor dependence of energy loss

Dead-cone effect

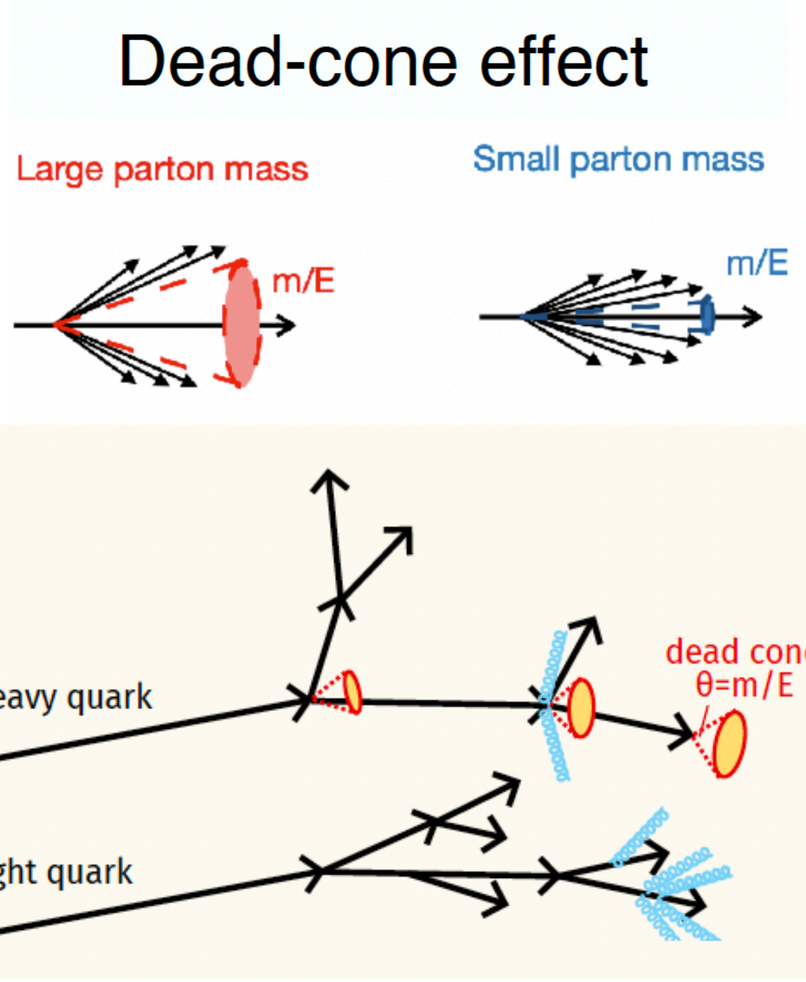


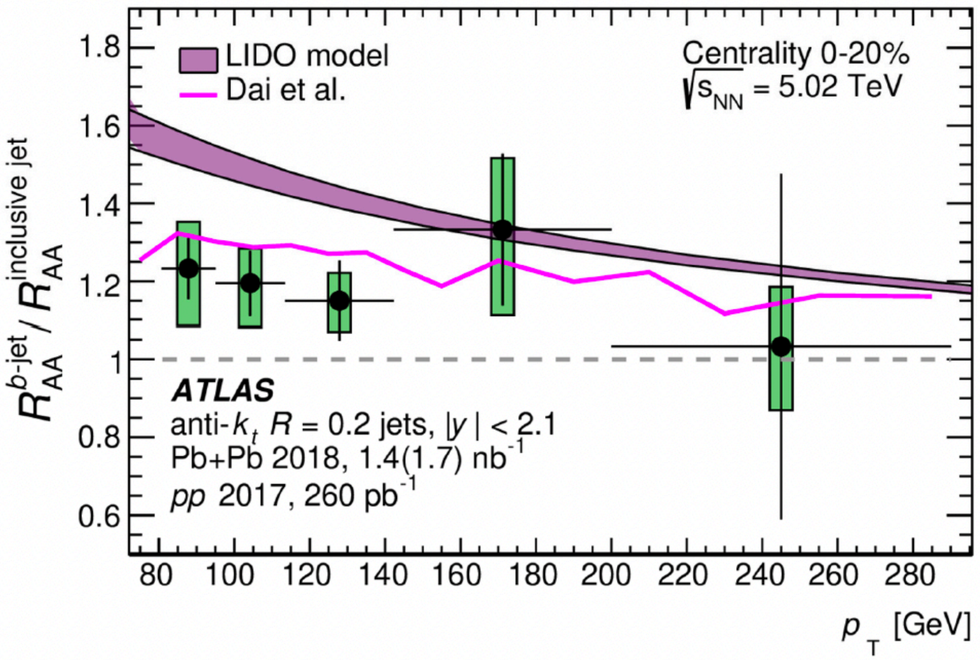


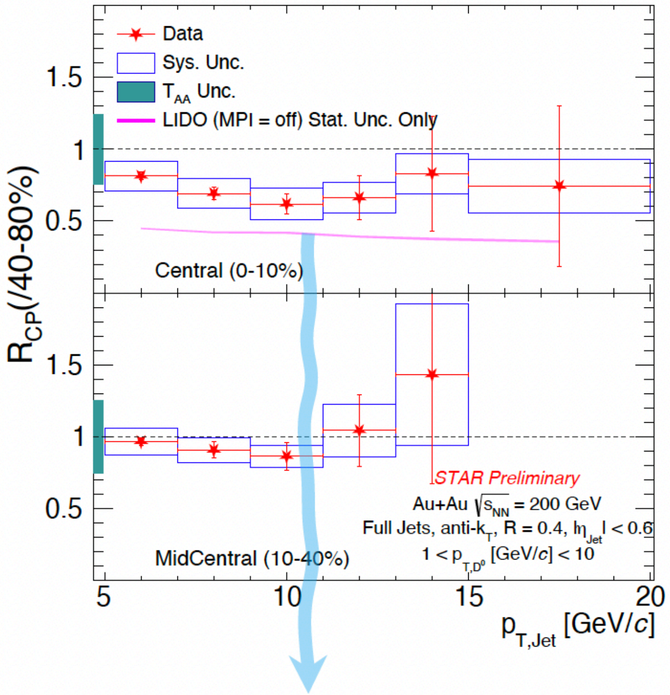




Mass/flavor dependence of energy loss

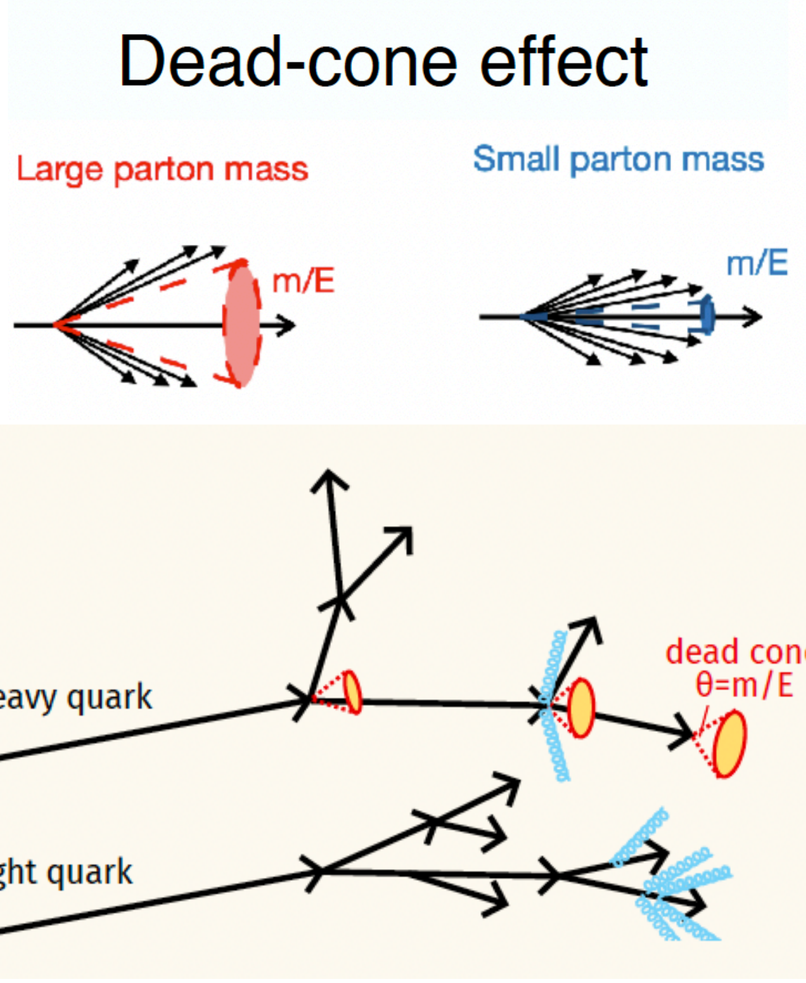


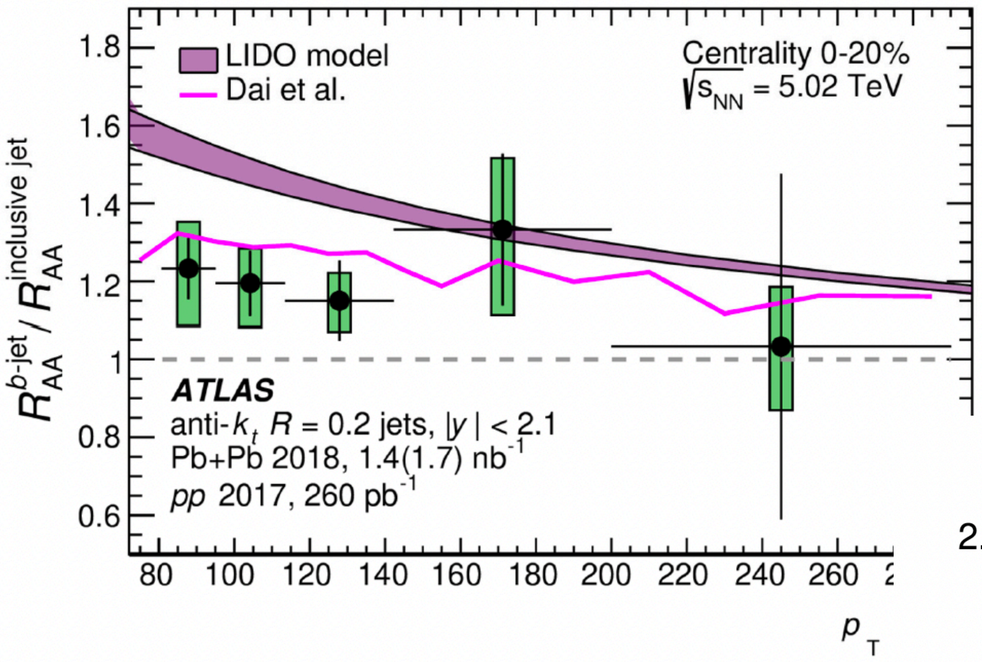


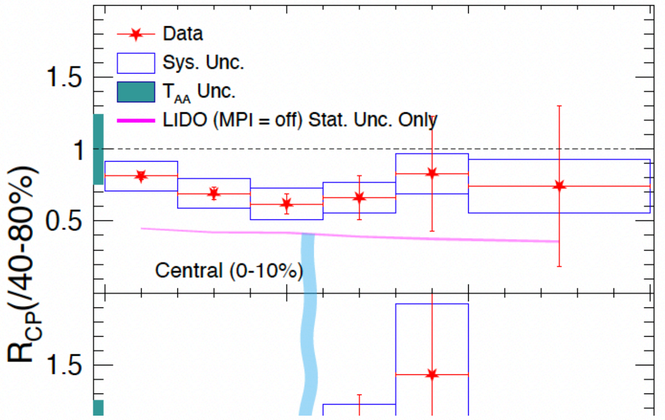


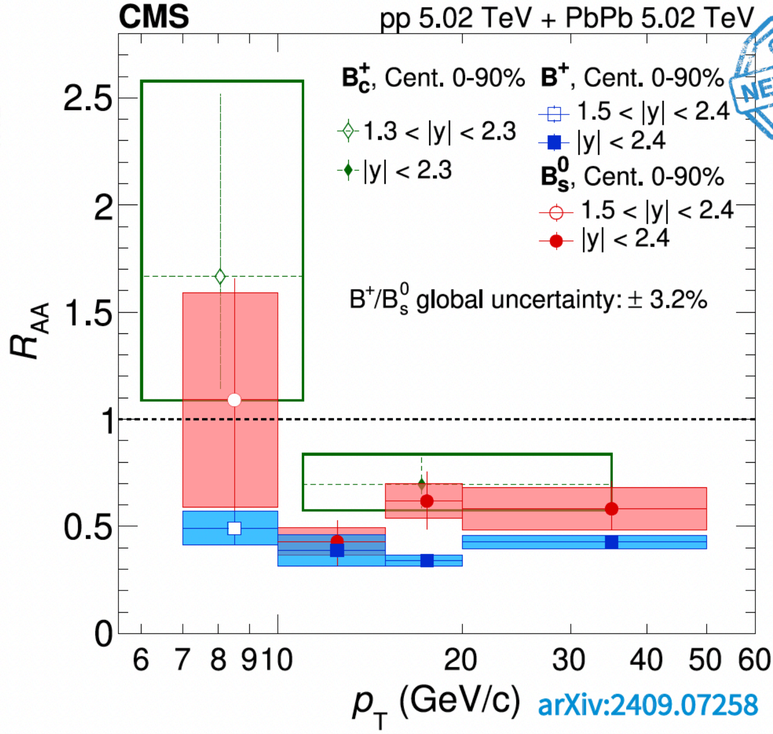
- Less suppression of b-jets than inclusive jets in most central collisions

Mass/flavor dependence of energy loss



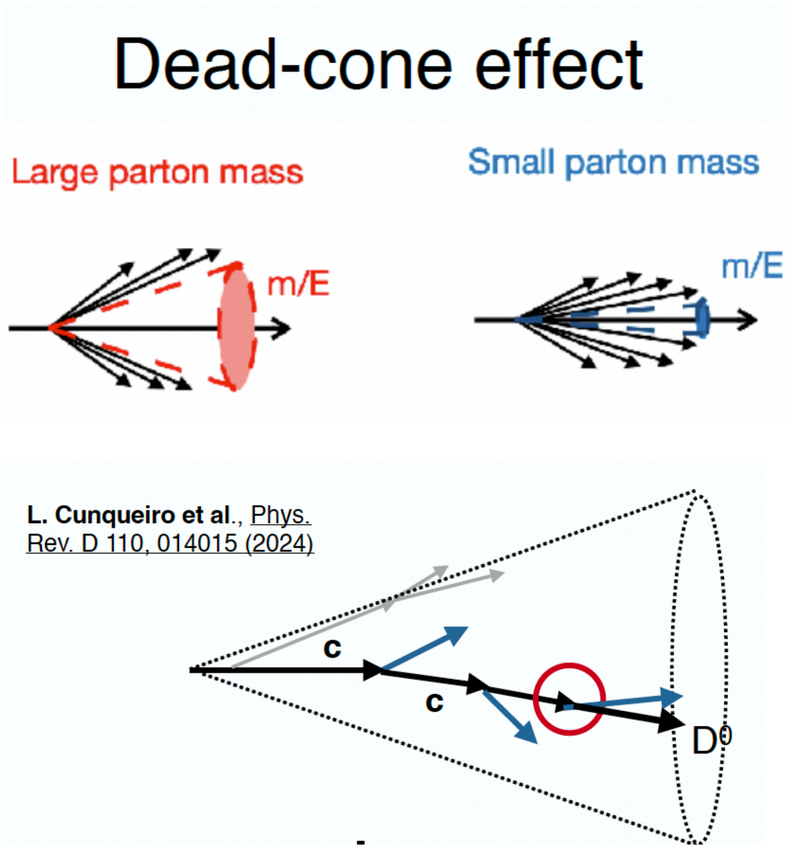


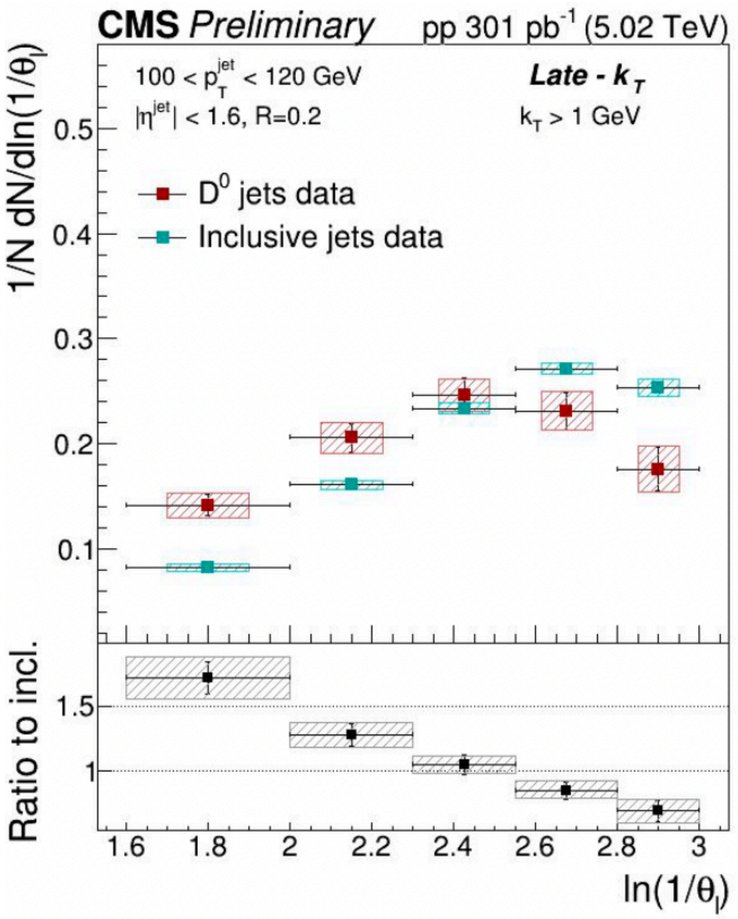


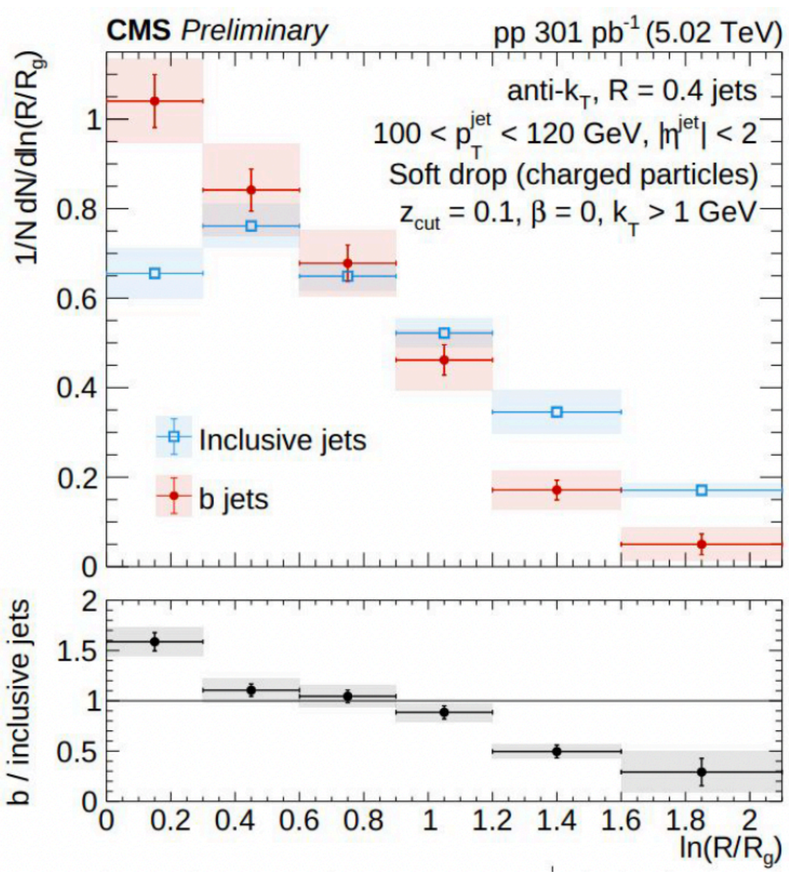


- Less suppression of b-jets than inclusive jets in most central collisions
- Indication of mass ordering from HF hadrons at high p_T

Search for dead-cone effects in pp

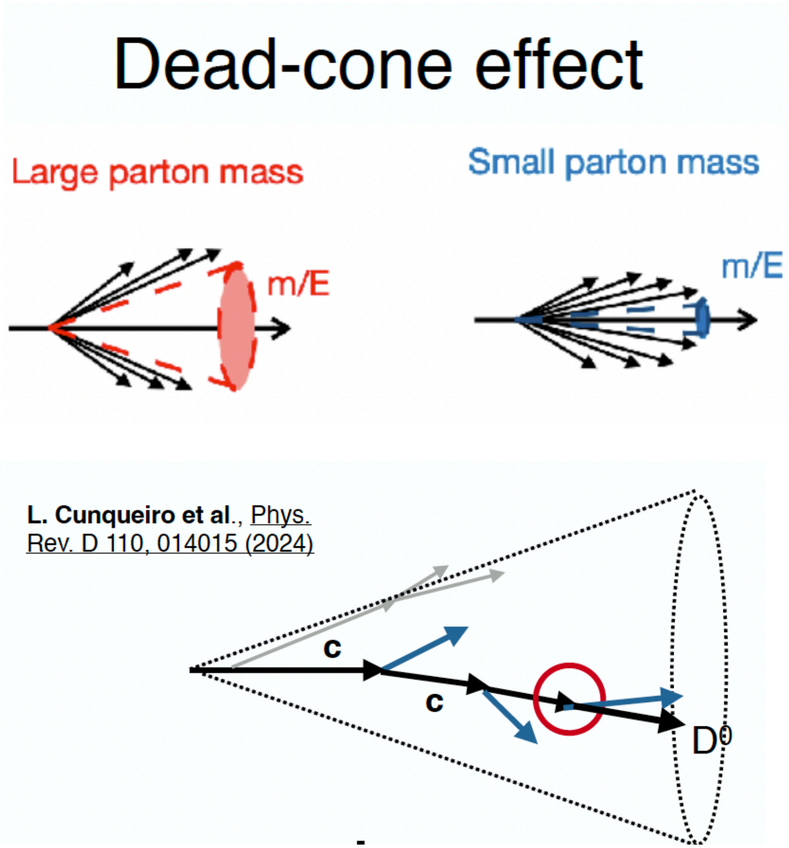


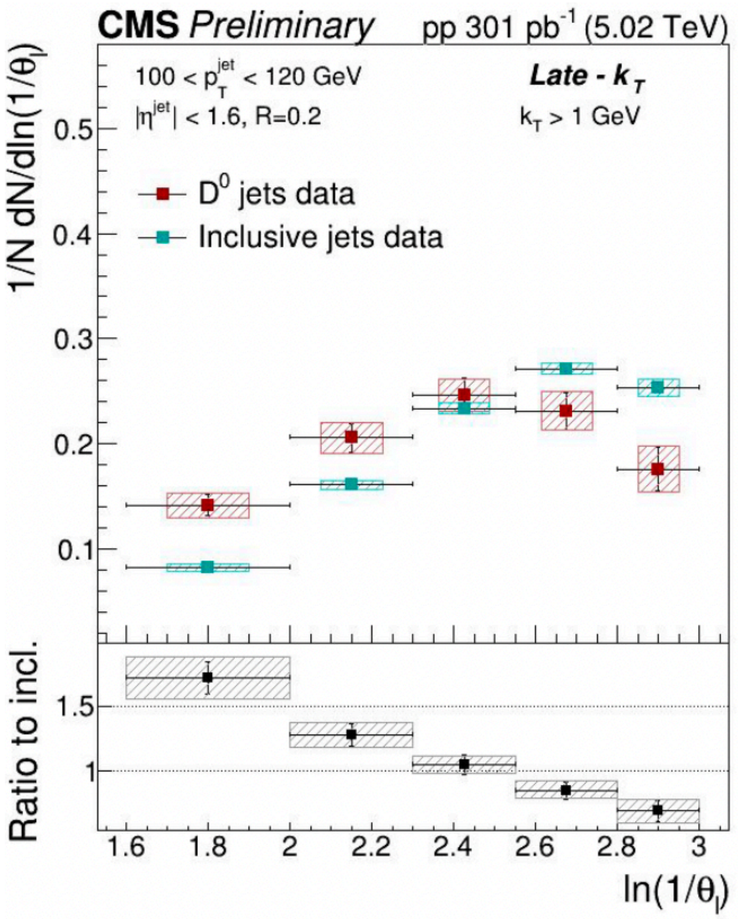


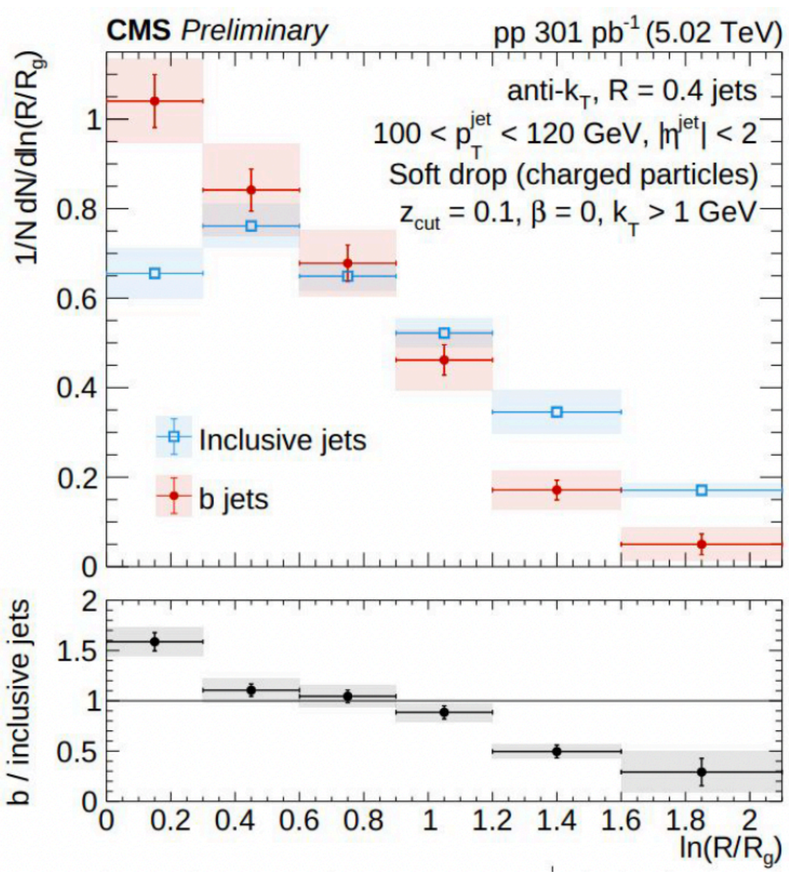


- Studying the hard collinear emissions by using CA declustering and late-k_T grooming algorithm for k_T >1

Search for dead-cone effects in pp

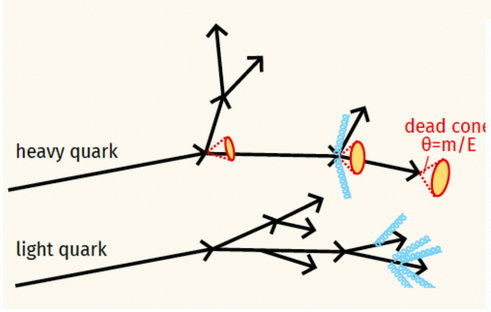


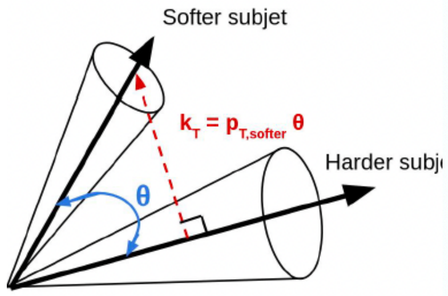


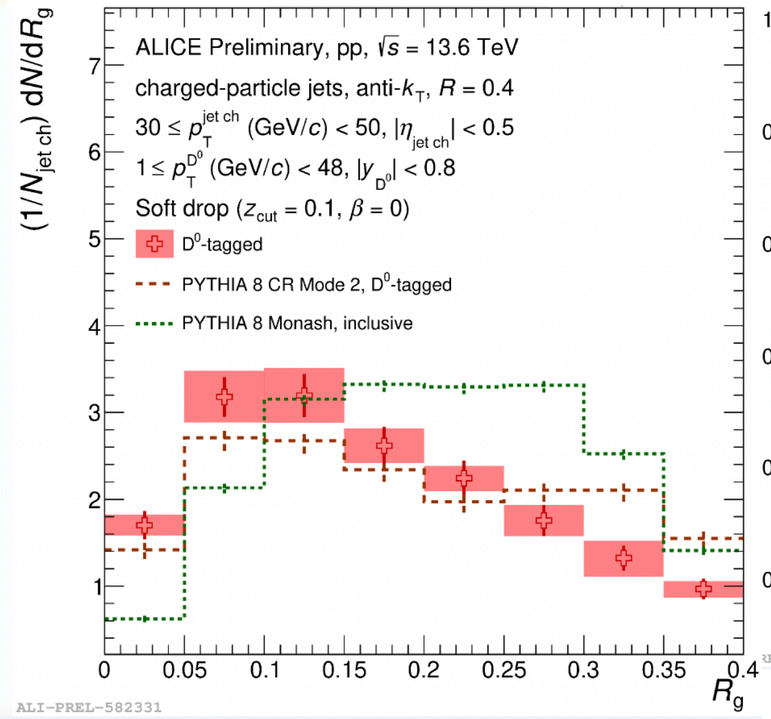


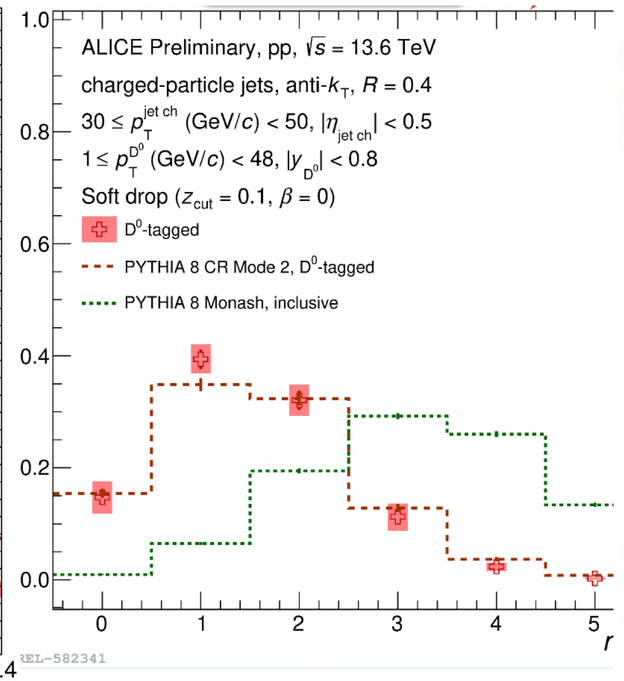
- Studying the hard collinear emissions by using CA declustering and late-k_T grooming algorithm for k_T >1
- A reduction of the collinear radiation for D/B-tagged jets with respect to inclusive one→ dead cone effect

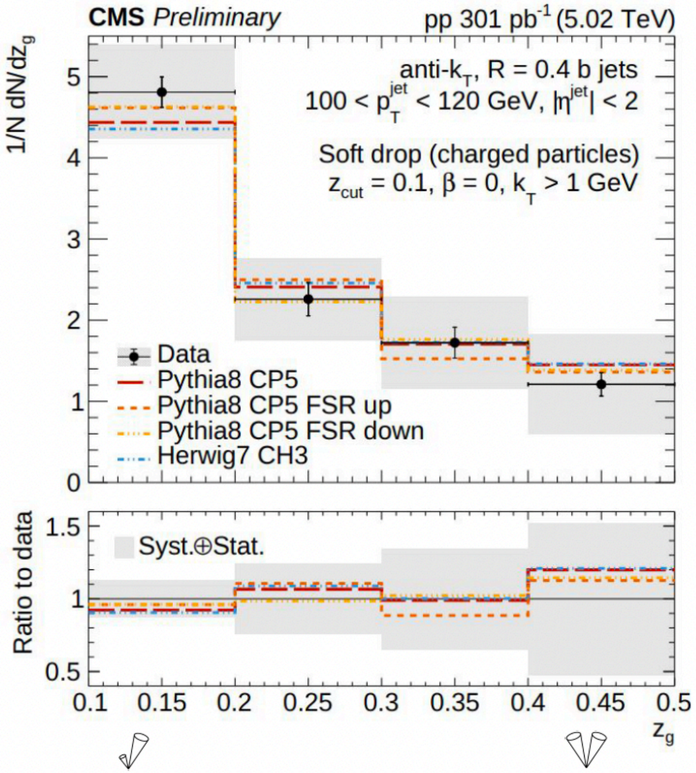
Mass/Flavor dependent jet substructure





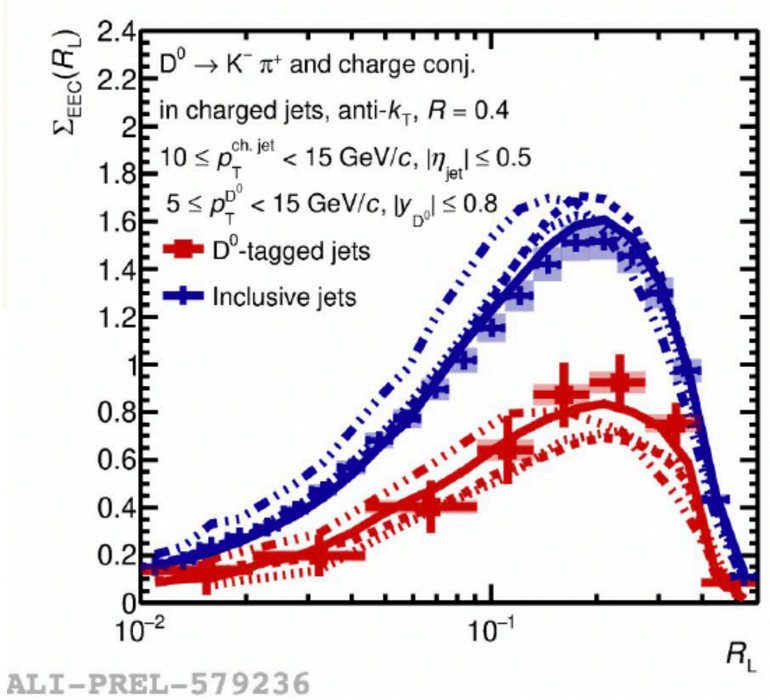


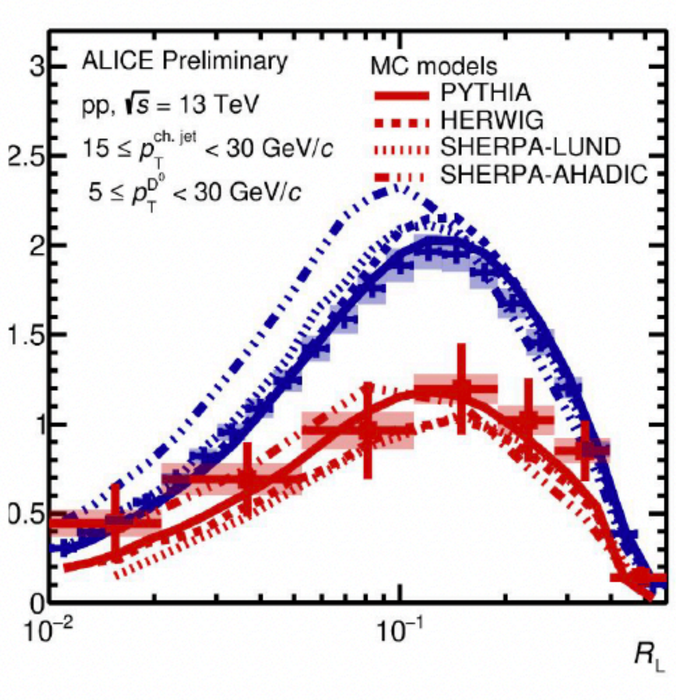


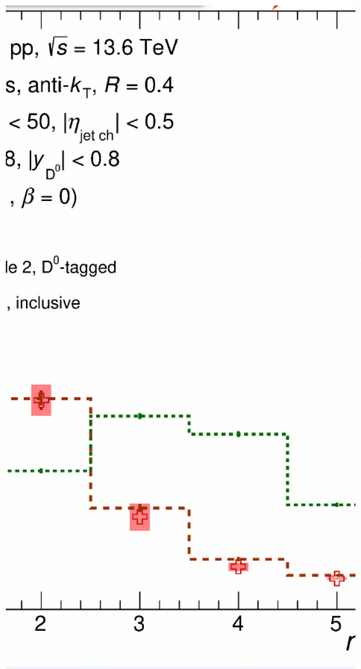


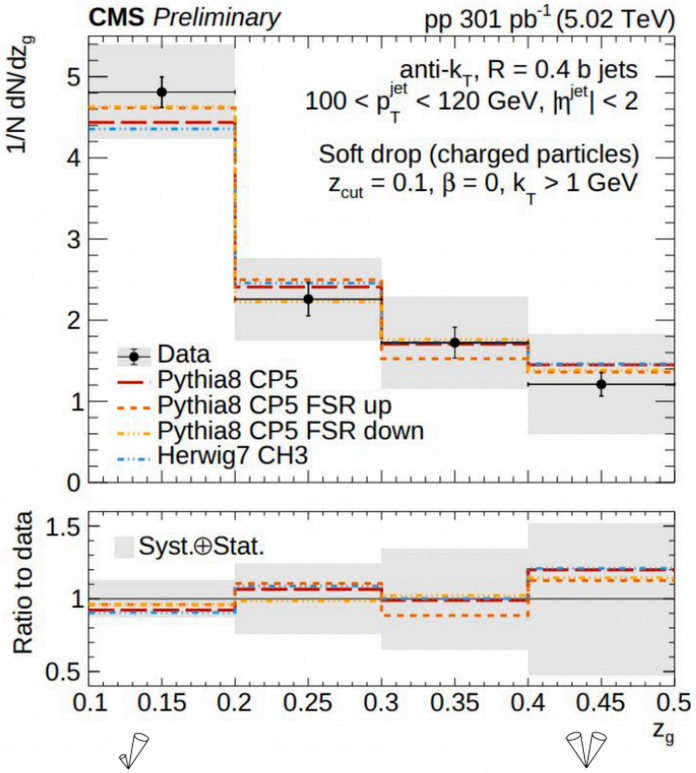
- More differential study on HF(c&b)-jet substructure, well reproduced by PYTHIA

Mass/Flavor dependent jet substructure



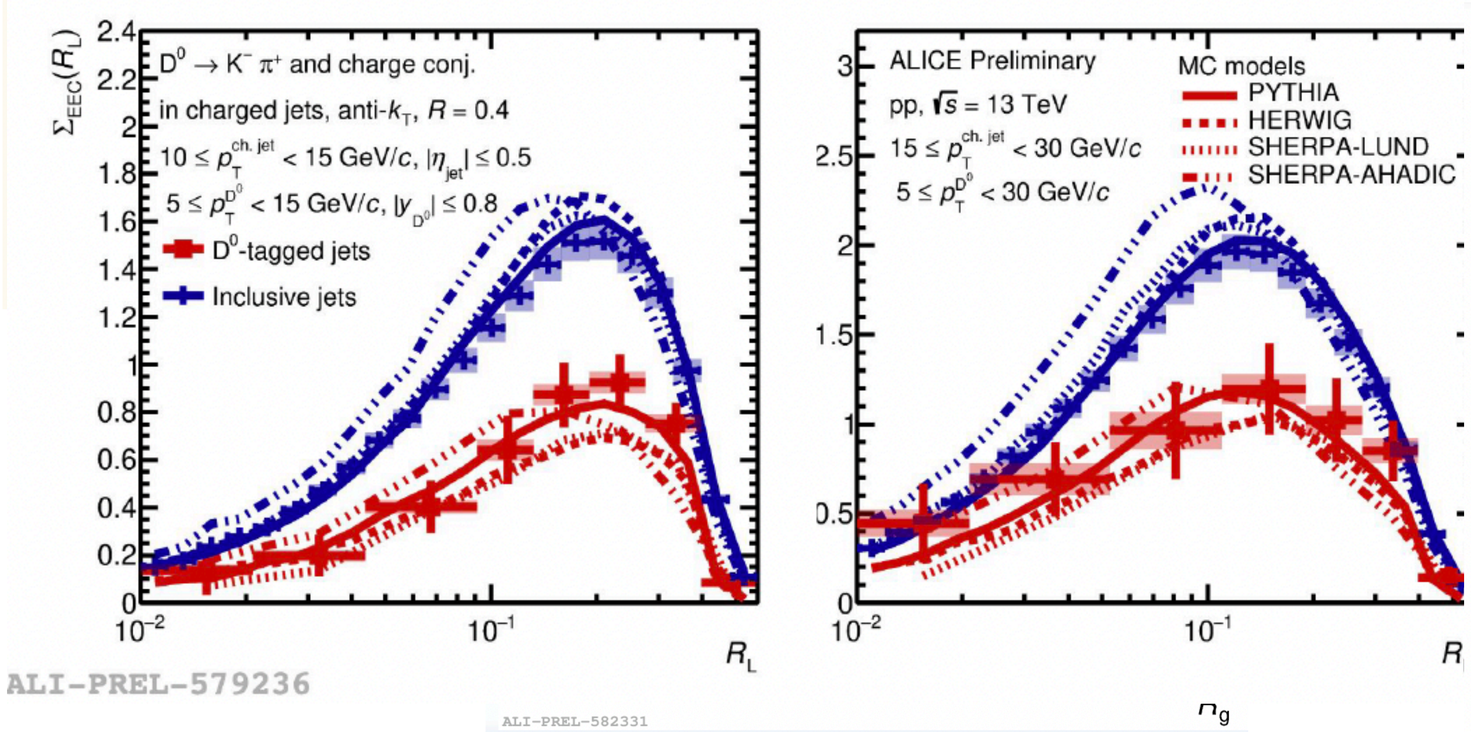


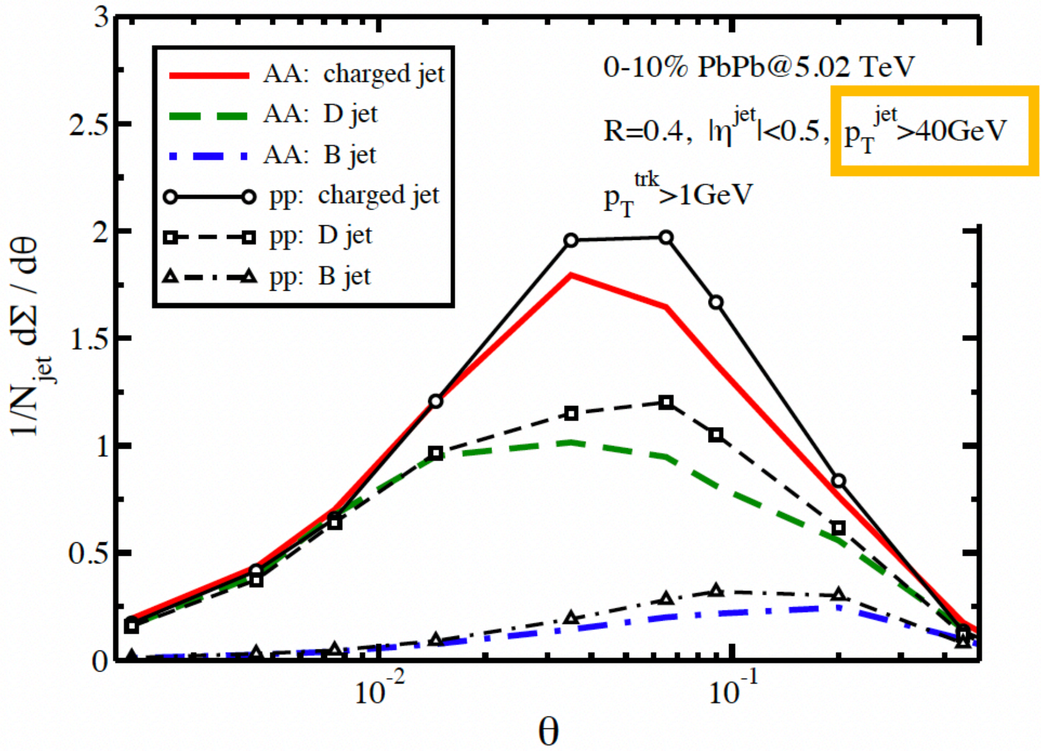




- More differential study on HF(c&b)-jet substructure, well reproduced by PYTHIA
- Clear flavor(mass) hierarchy observed in jet EEC measurements

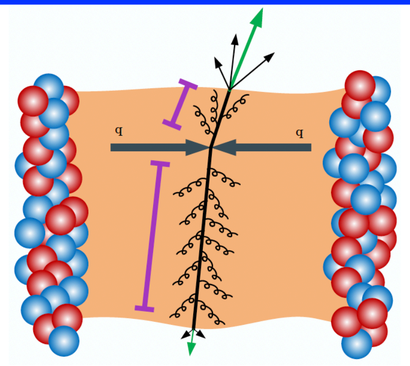
Mass/Flavor dependent jet substructure

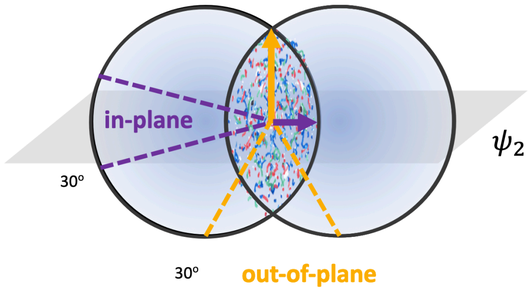


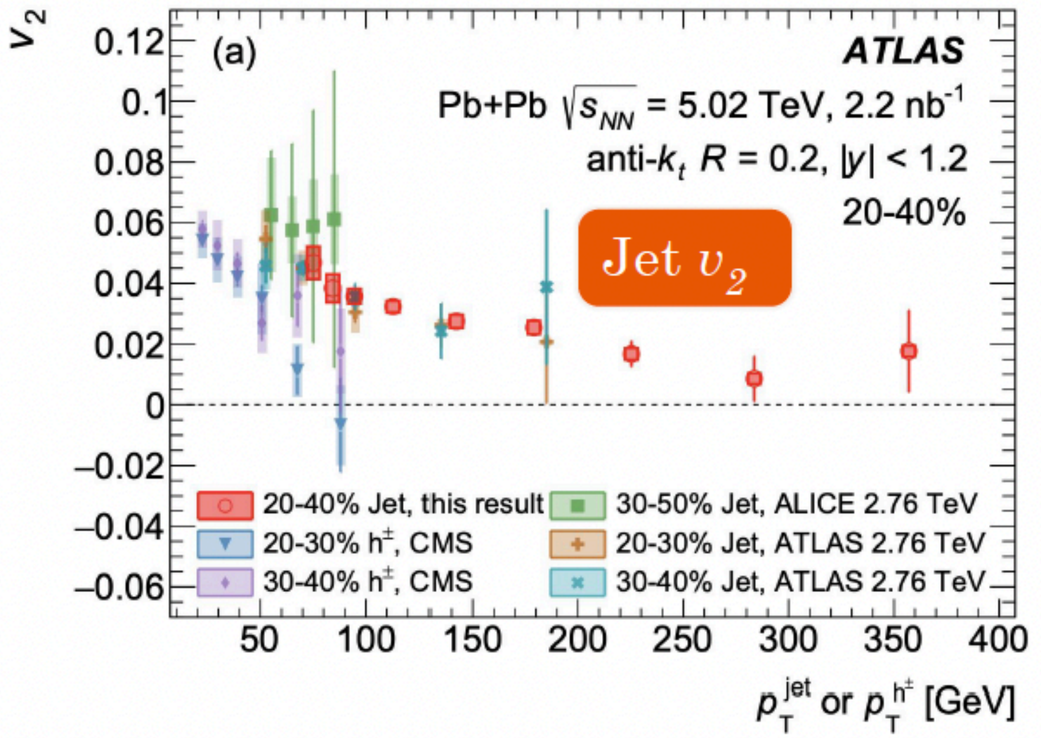


- More differential study on HF(c&b)-jet substructure, well reproduced by PYTHIA
- Clear flavor(mass) hierarchy observed in jet EEC measurements
- Theory already predicted the modifications in HI case →experimental measurements ongoing

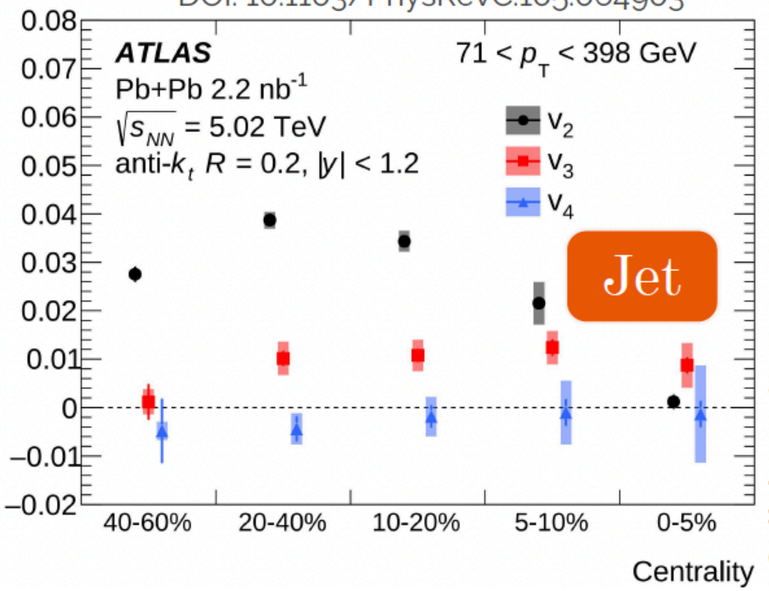
Path length dependence of jet energy loss





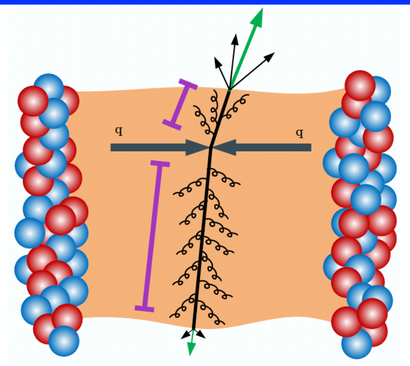


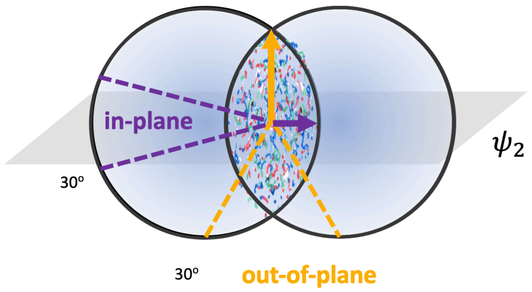
Phys.Rev.C 105 (2022) 6, 064903
DOI: 10.1103/PhysRevC.105.064903

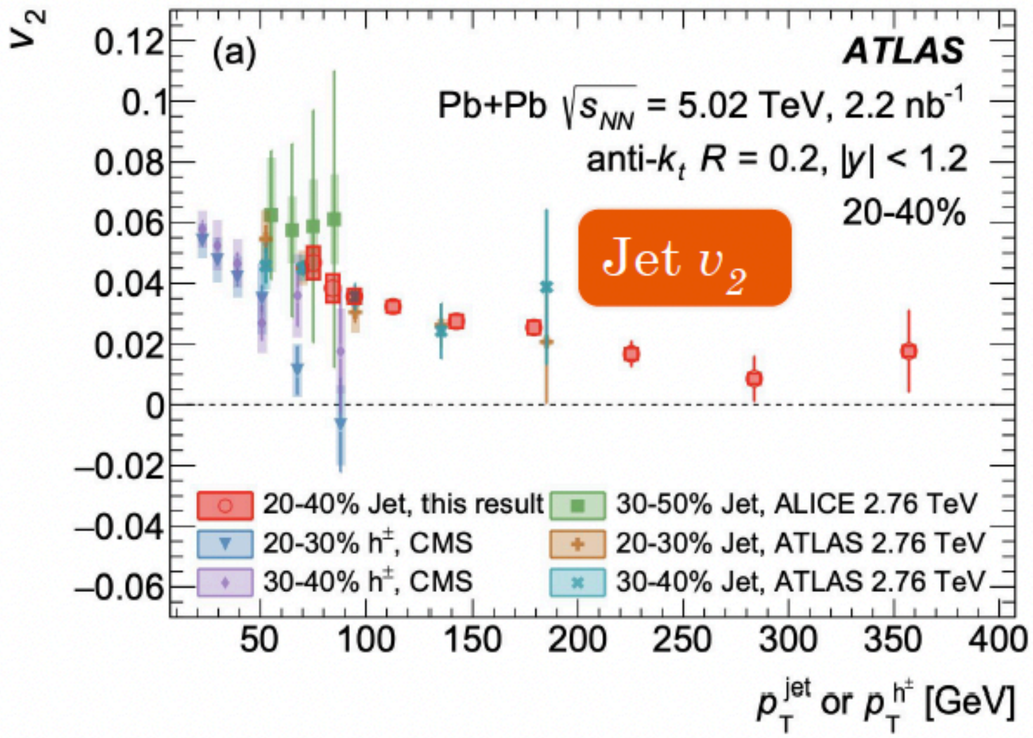


- In Pb+Pb collisions, jets have no-zero flow over a very large p_T range→path length depends of energy loss

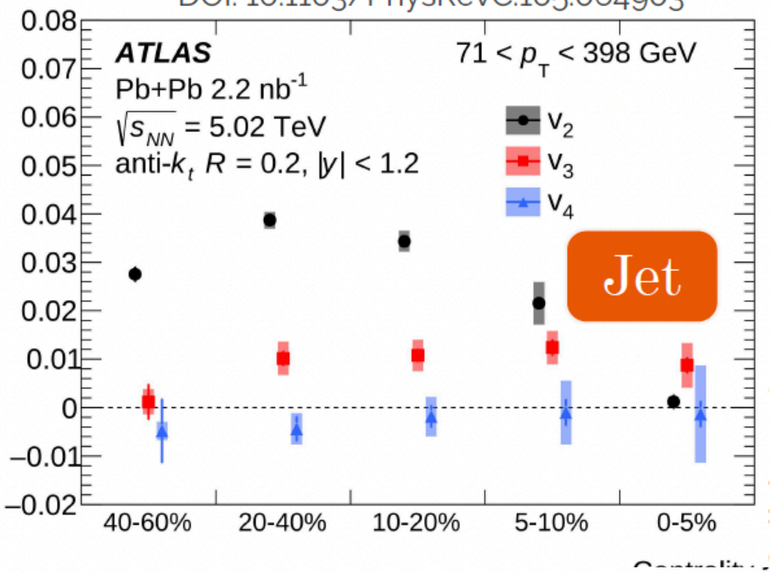
Path length dependence of jet energy loss

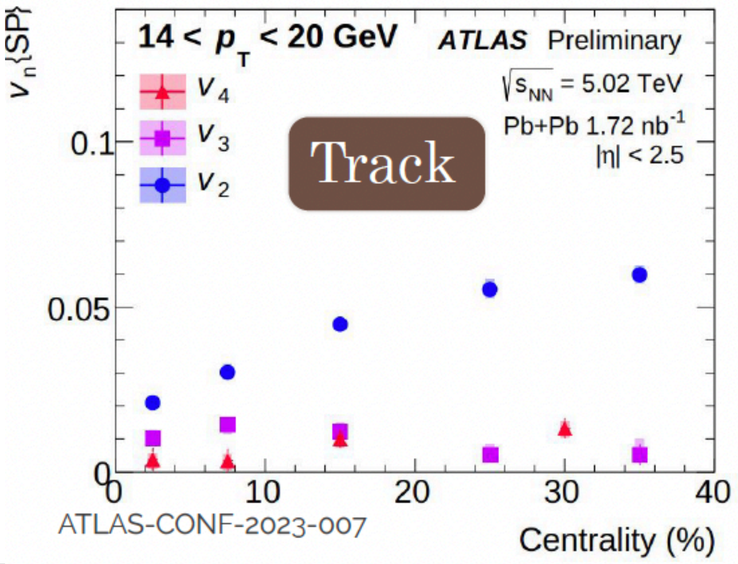






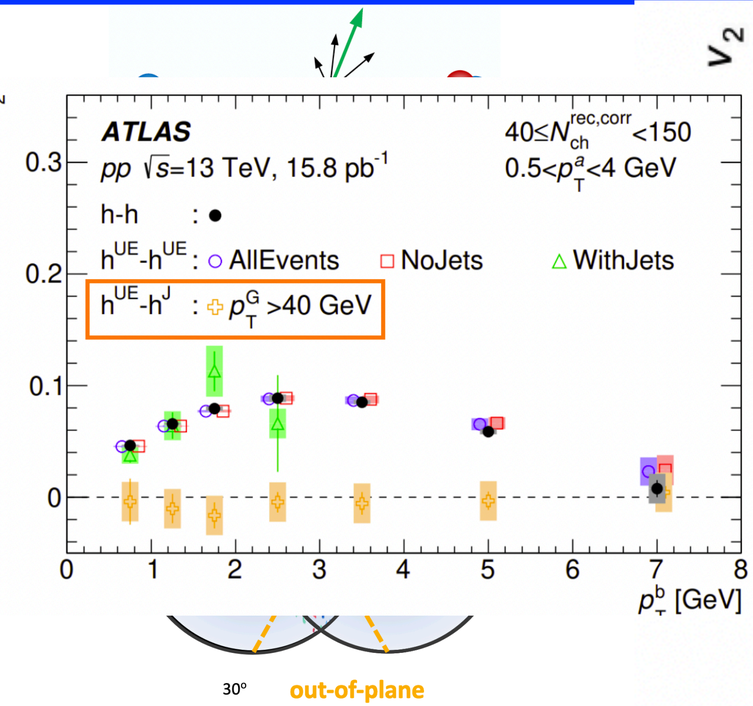
Phys.Rev.C 105 (2022) 6, 064903
DOI: 10.1103/PhysRevC.105.064903

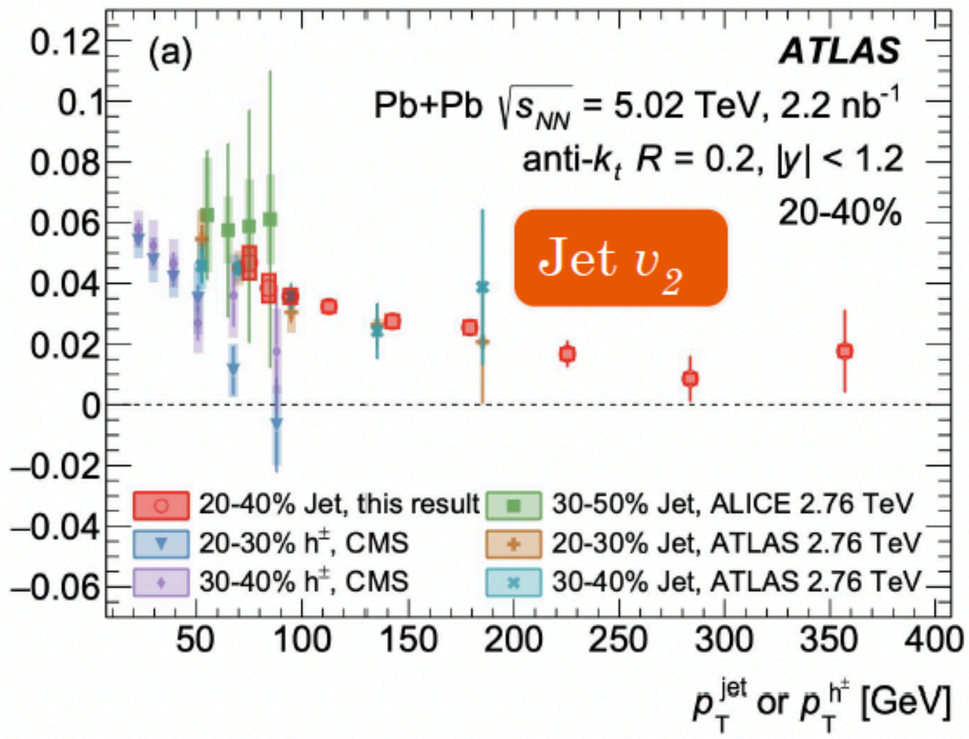




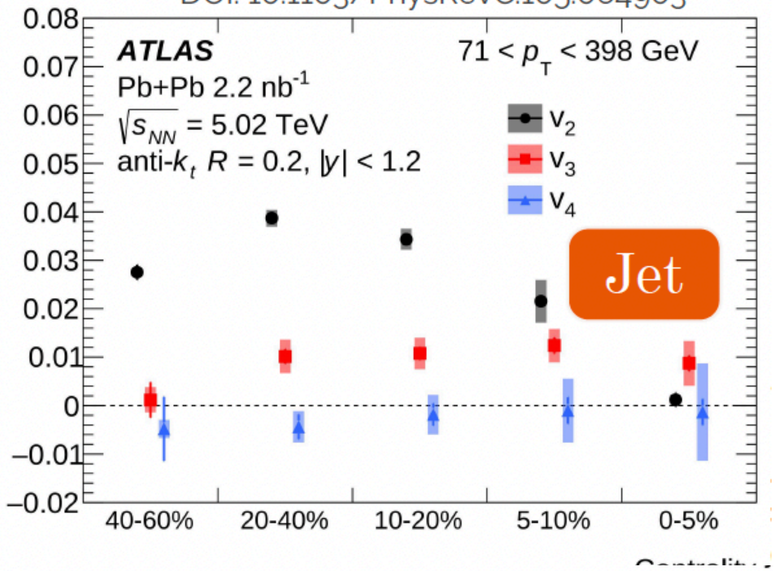
- In Pb+Pb collisions, jets have no-zero flow over a very large p_T range→path length depends of energy loss
- Similar centrality dependence of v_n for very high p_T charged-particle and jets →what could drive this?

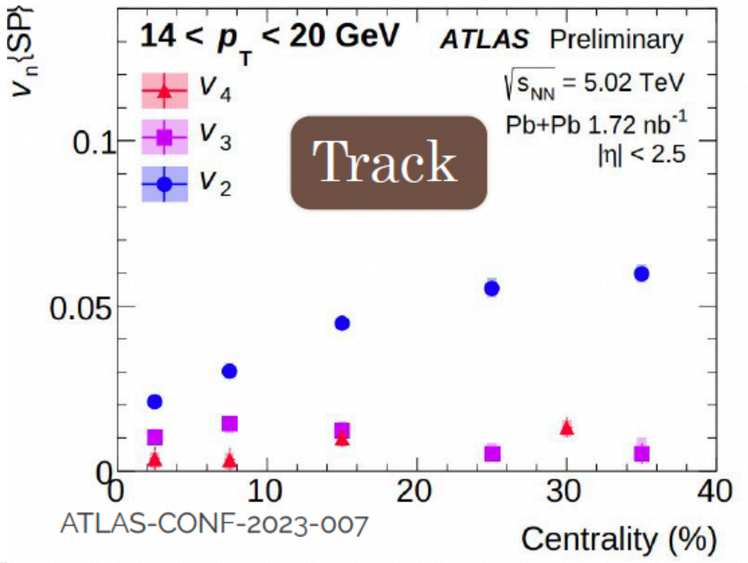
Path length dependence of jet energy loss





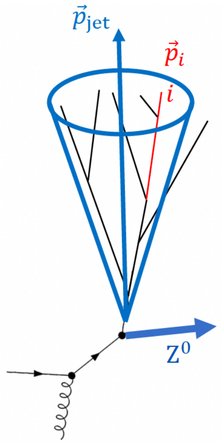
Phys.Rev.C 105 (2022) 6, 064903
DOI: 10.1103/PhysRevC.105.064903



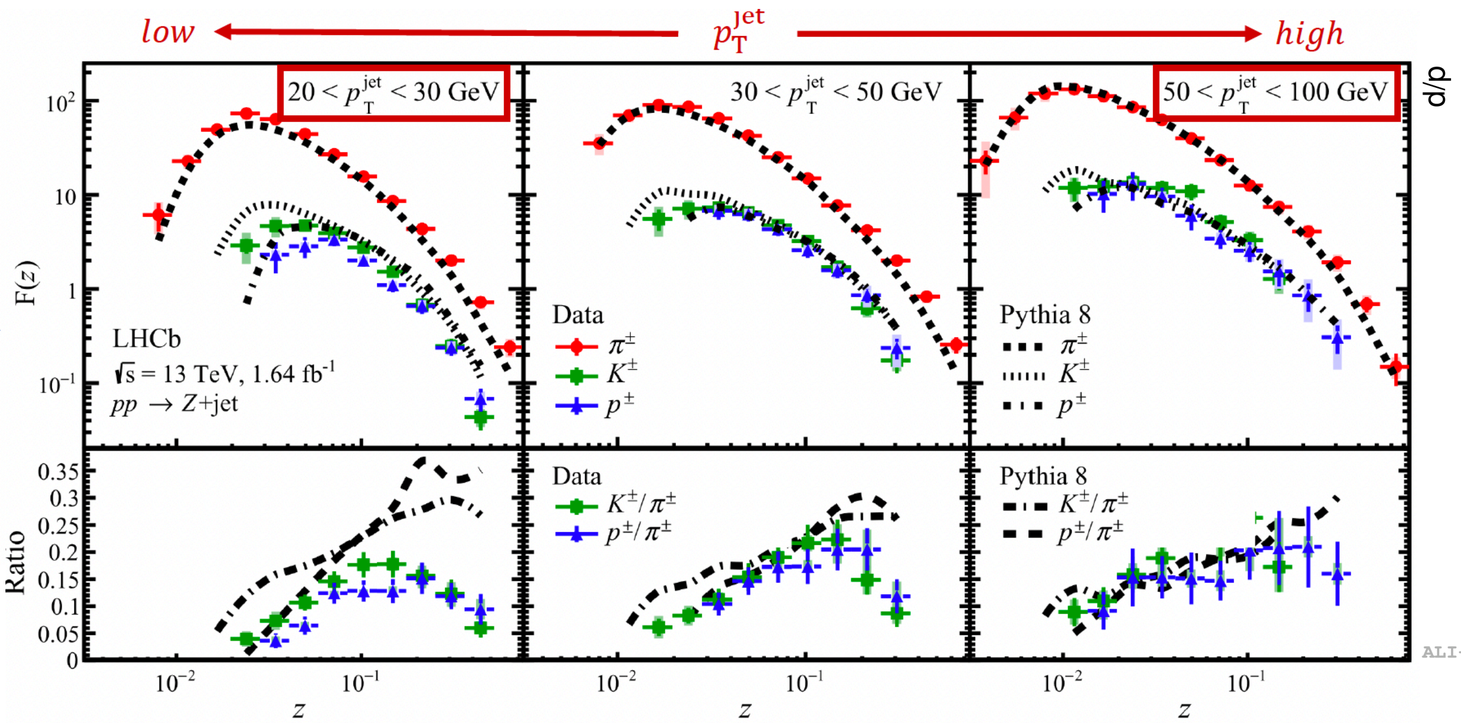


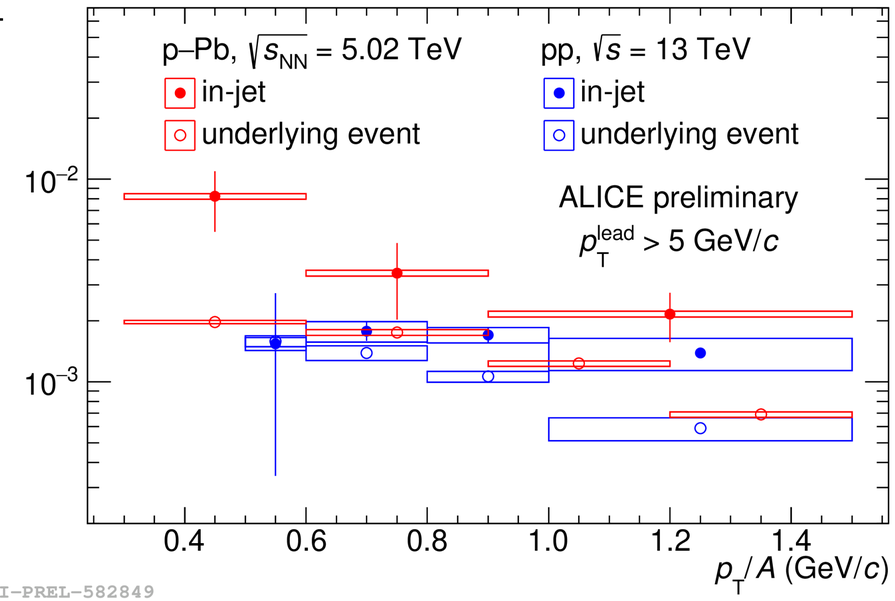
- In Pb+Pb collisions, jets have no-zero flow over a very large p_T range→path length depends of energy loss
- Similar centrality dependence of v_n for very high p_T charged-particle and jets →what could drive this?
- In pp collisions, jets does not affect UE collectivity

Jet fragmentation into LF particles



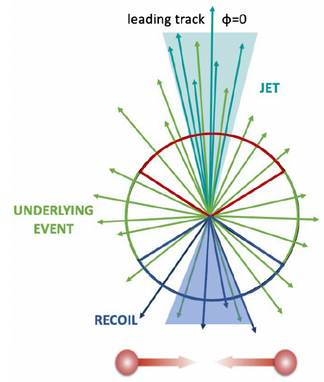
$$z = \frac{\vec{p}_{\rm jet} \cdot \vec{p}_i}{|\vec{p}_{\rm jet}|^2}$$





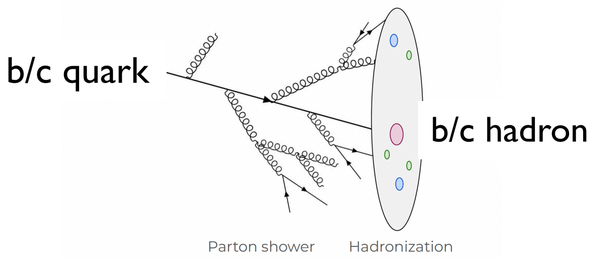
ALI-PREL-582849

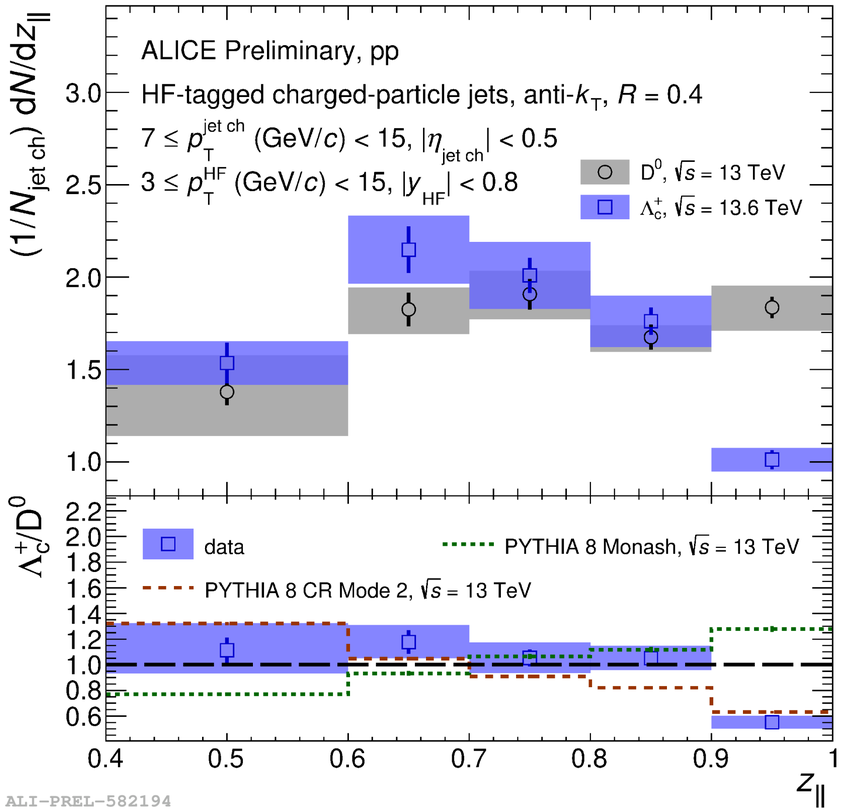
- Using the Z-tagged jets to study jet fragmentation and identified particles →important for the understanding of hadronization mechanisms
- Deutron/proton ratio in jets is higher in p-Pb than in pp, also higher in jets than in UE →hints of different particle composition in and out of jets

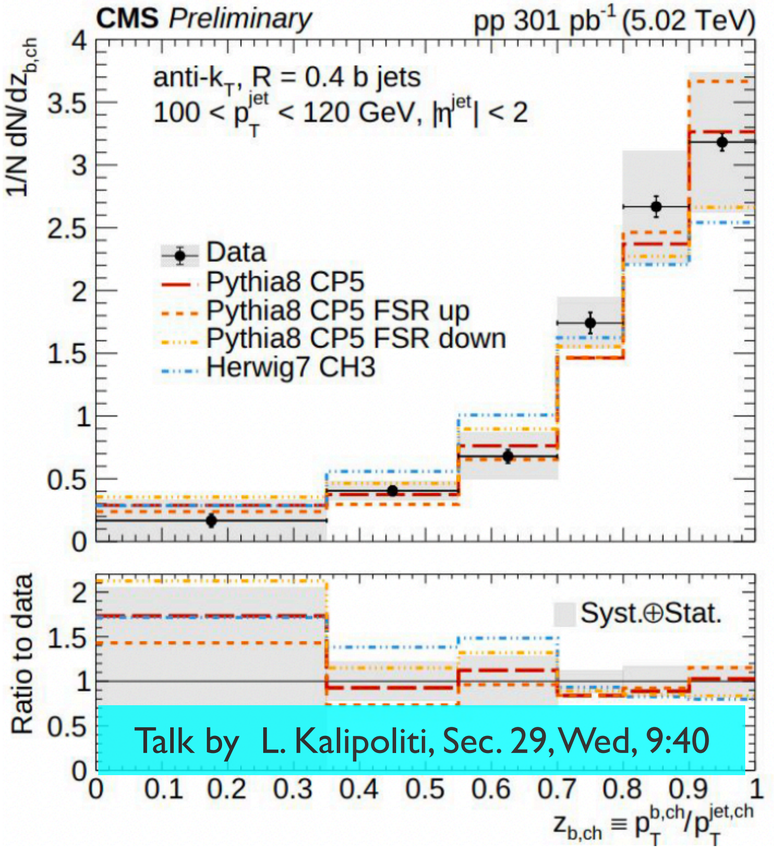


Toward: $|\Delta\phi| < 60°$
Transverse: $60° < |\Delta\phi| < 120°$

Jet fragmentation into HF particles

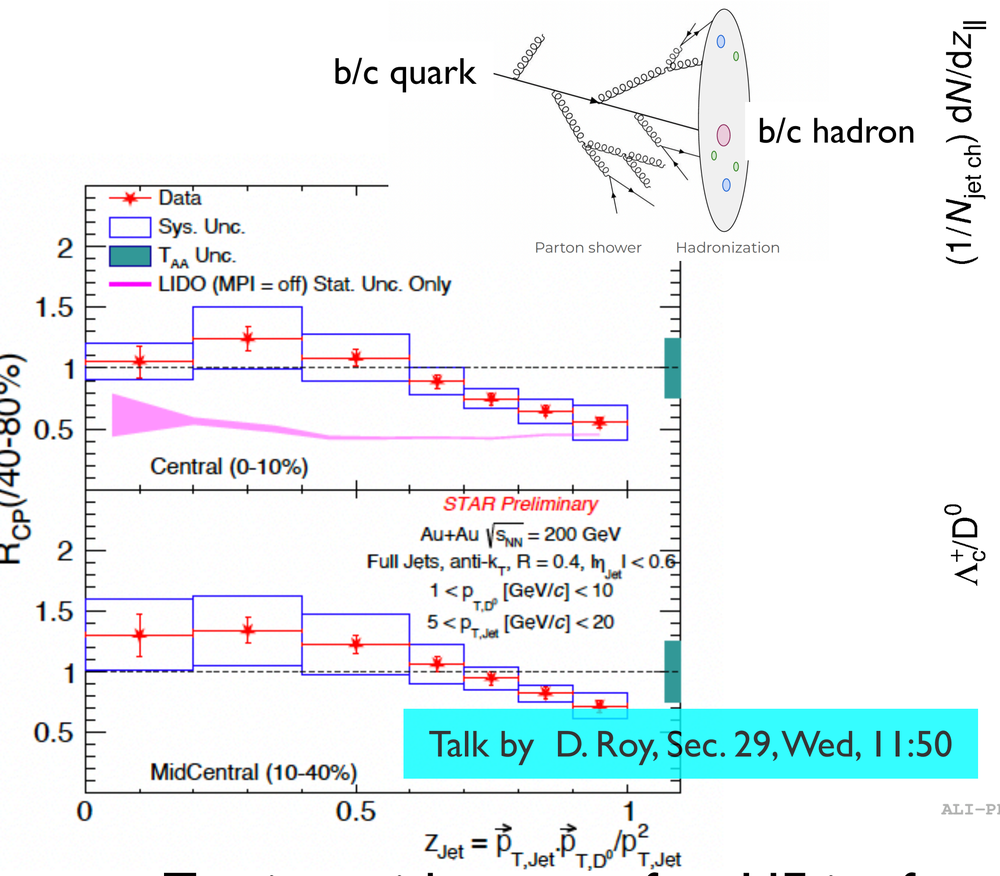




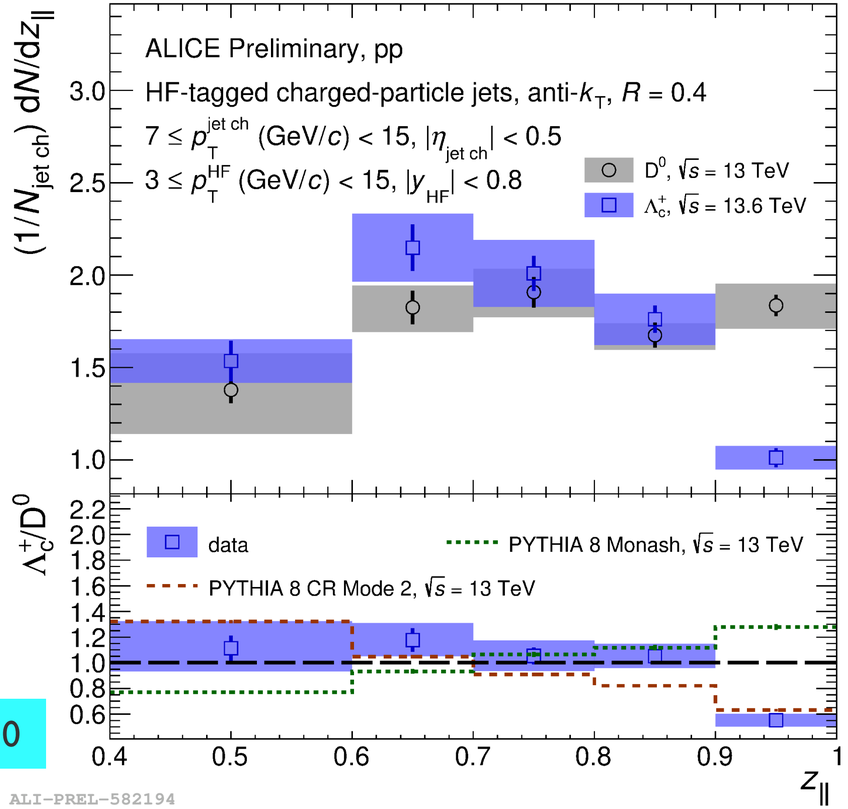


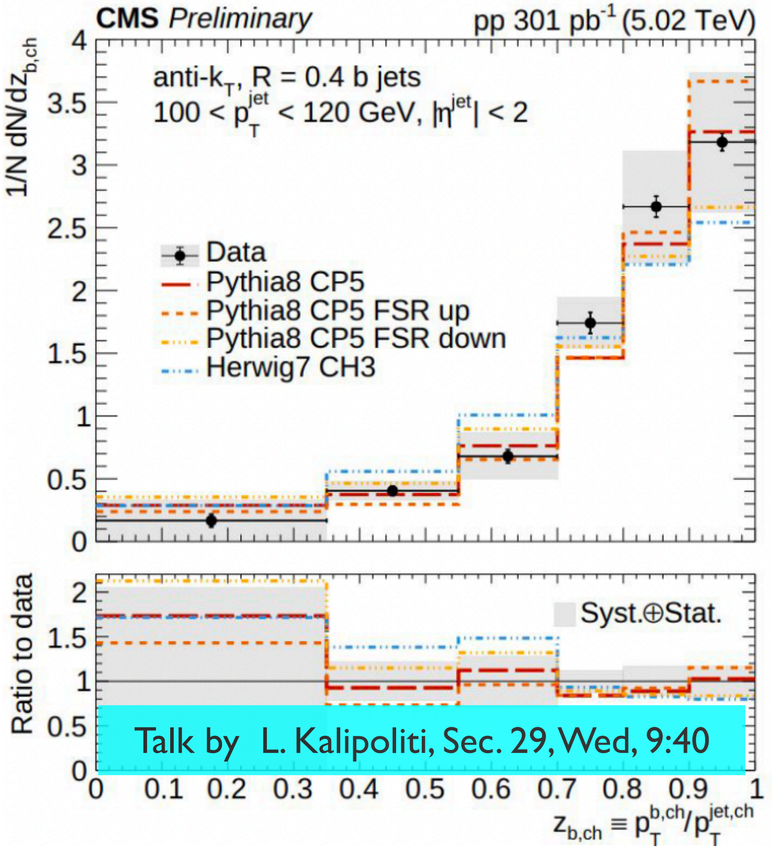
- Tension with even softer HF-jet fragmentation into Λ_c^+ baryons than D mesons

Jet fragmentation into HF particles



Talk by D. Roy, Sec. 29, Wed, 11:50



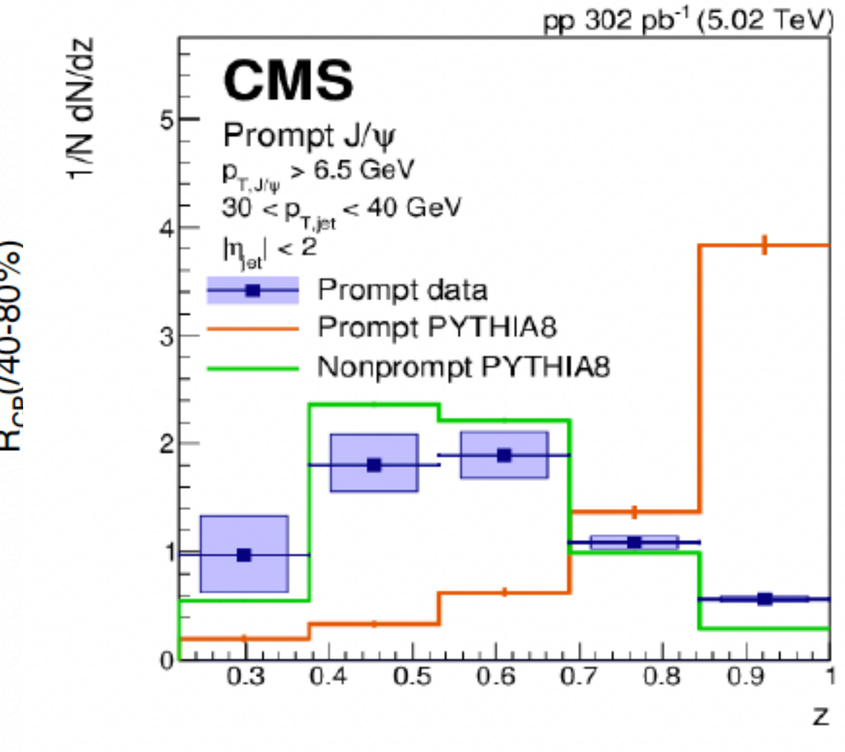


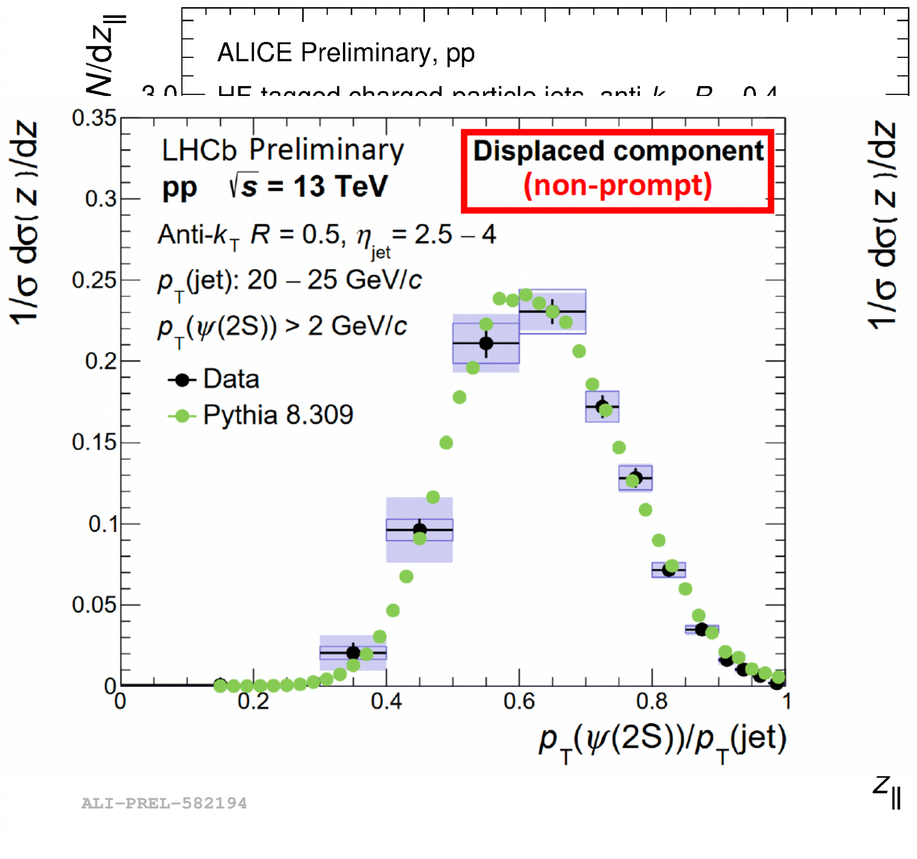
Talk by L. Kalipoliti, Sec. 29, Wed, 9:40

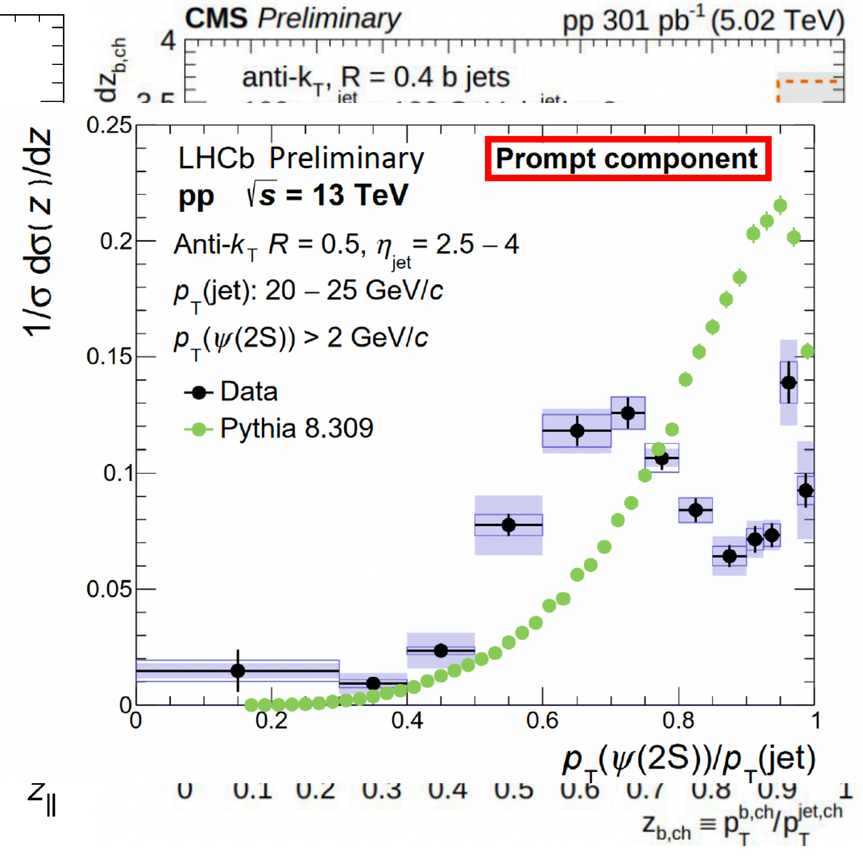
- Tension with even softer HF-jet fragmentation into Λ_c^+ baryons than D mesons
- Hints of D^0-tagged jets fragmentation softer in most central Au+Au collisions

Jet fragmentation into HF particles

PLB 825 (2022) 136842

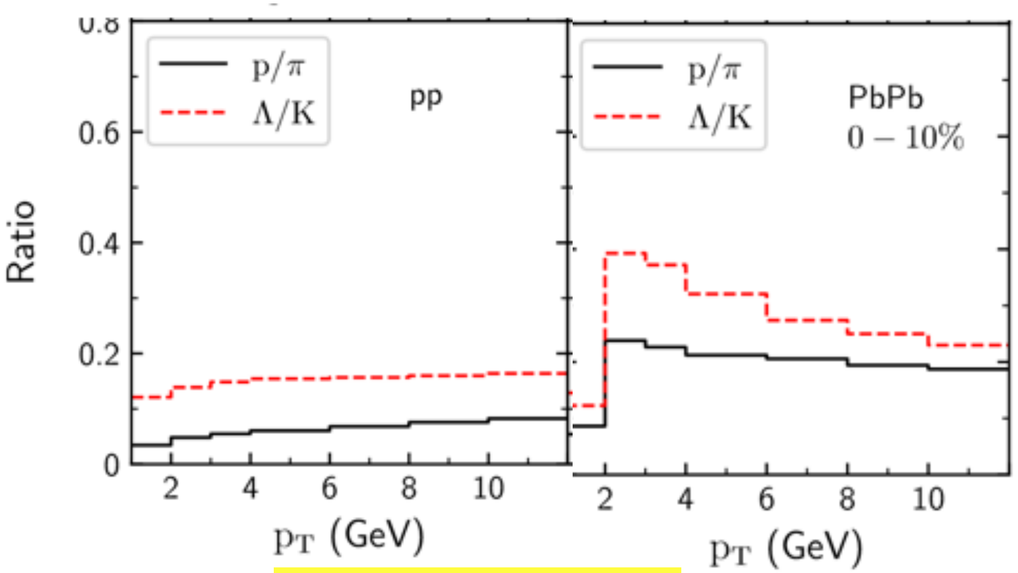






- Tension with even softer HF-jet fragmentation into Λ_c^+ baryons than D mesons
- Hints of D^0-tagged jets fragmentation softer in most central Au+Au collisions
- PYTHIA can't produce quarkonium jet fragmentation ψ(2S) →further development of theoretical models are needed

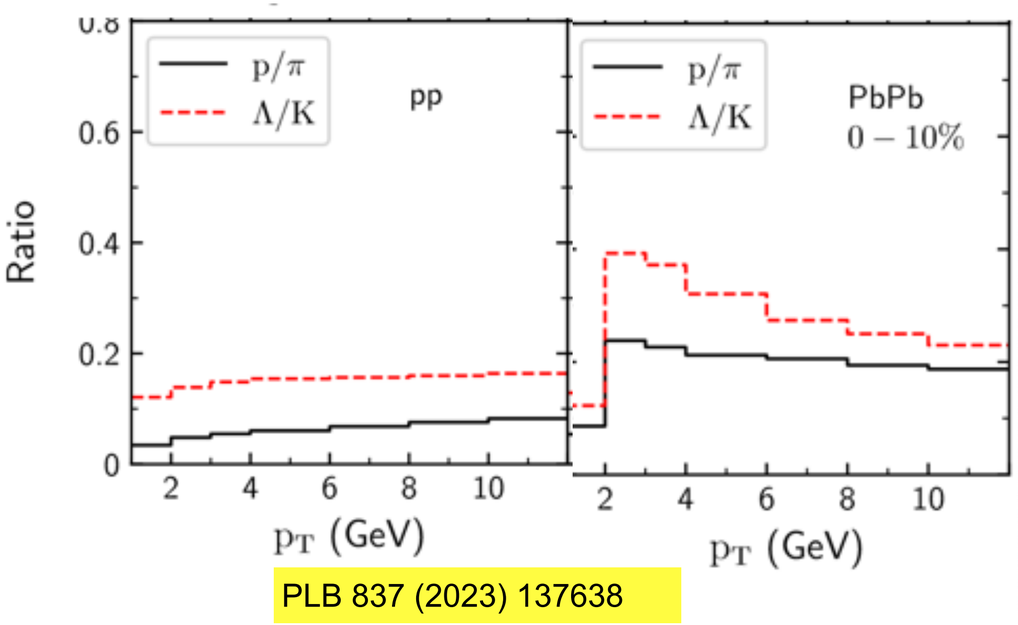
Jet fragmentation and hadron chemistry



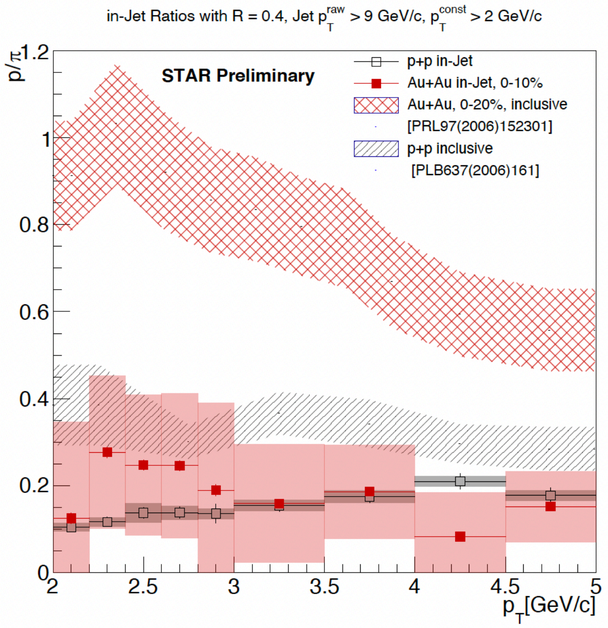
PLB 837 (2023) 137638

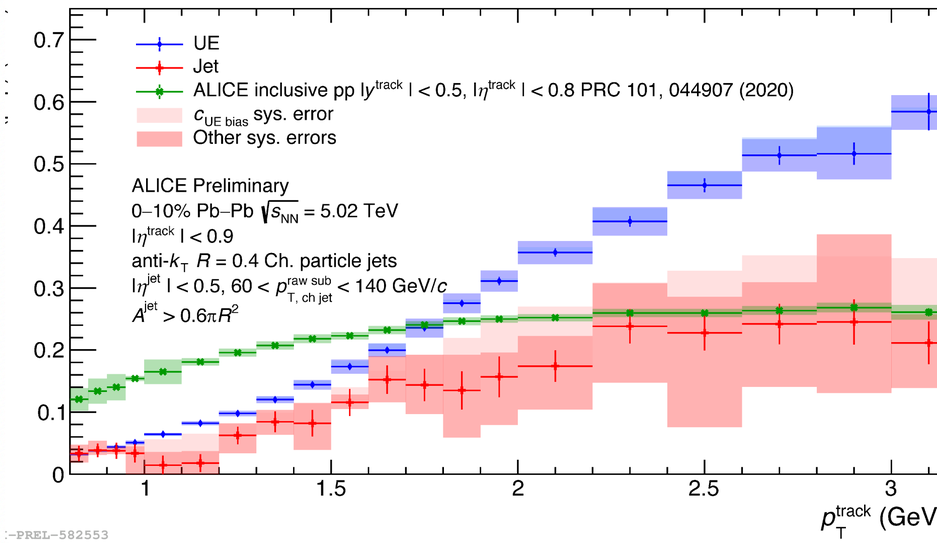
- Study jet hadron chemistry with identified particles to understand the hadronization and jet fragmentations

Jet fragmentation and hadron chemistry



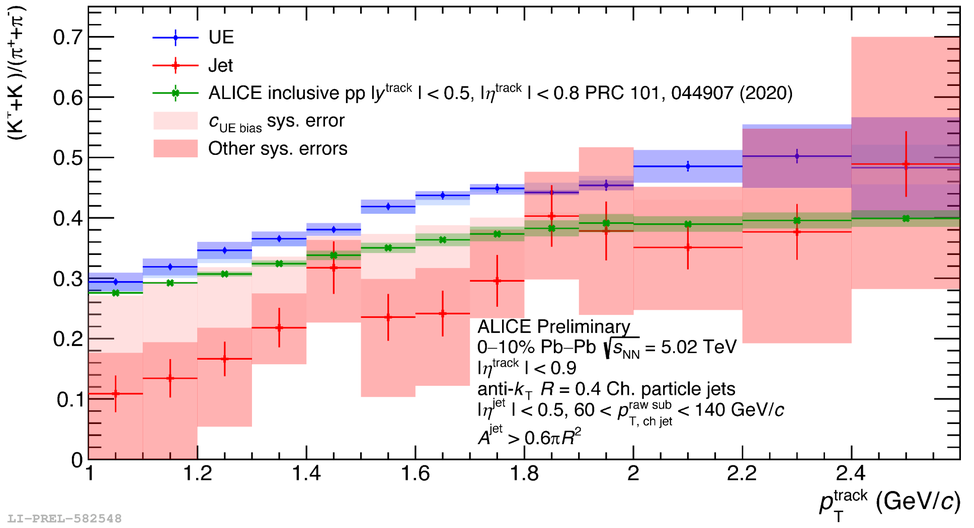
PLB 837 (2023) 137638



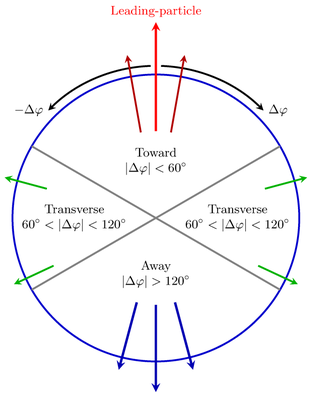


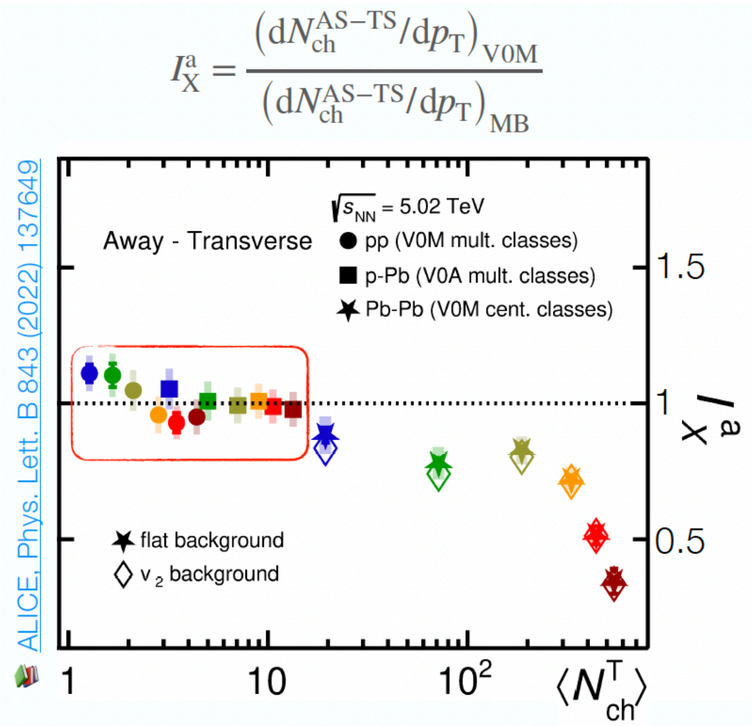
- Study jet hadron chemistry with identified particles to understand the hadronization and jet fragmentations
- Baryon to meson ratio measured by STAR and ALICE in AA collisions

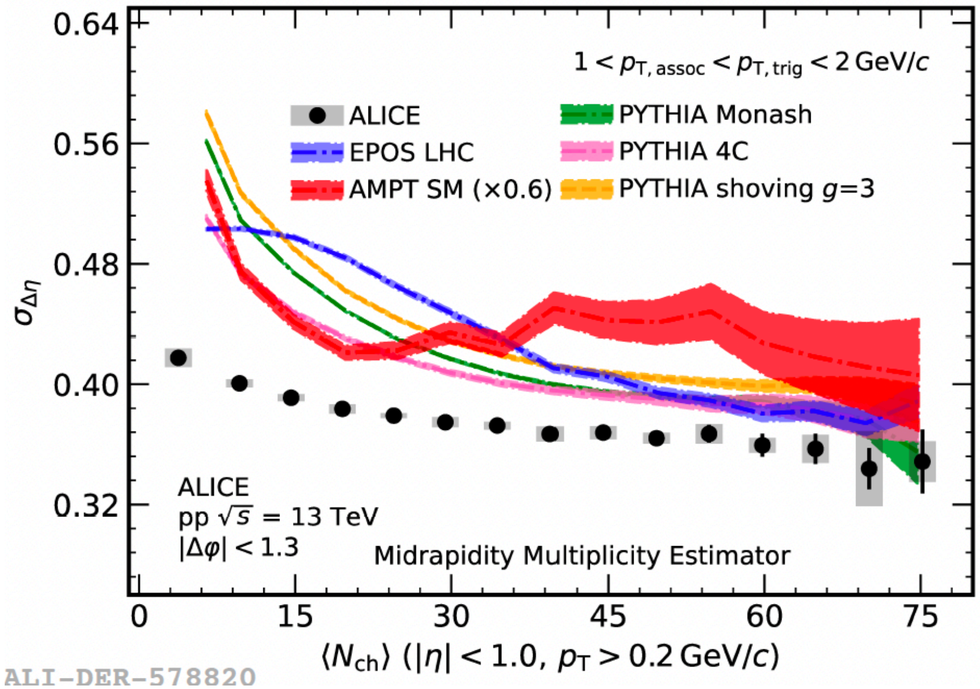
→uncertainty dominates! Precision measurements needed



Search for jet quenching in small systems

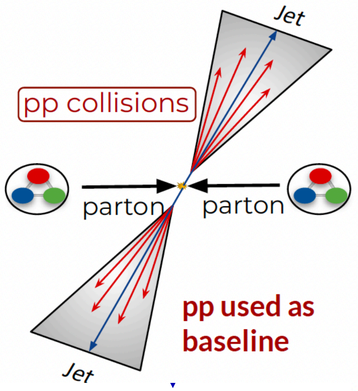


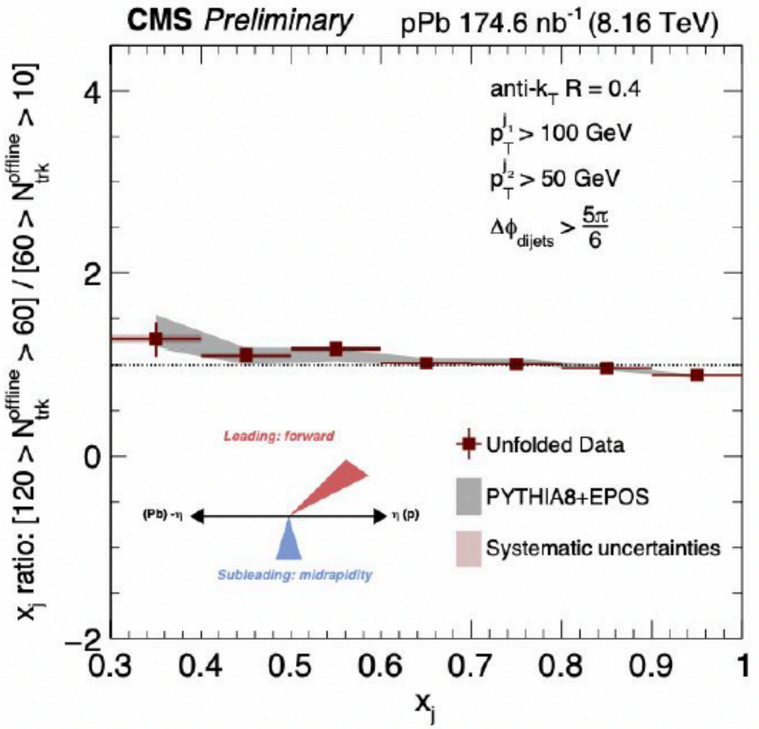


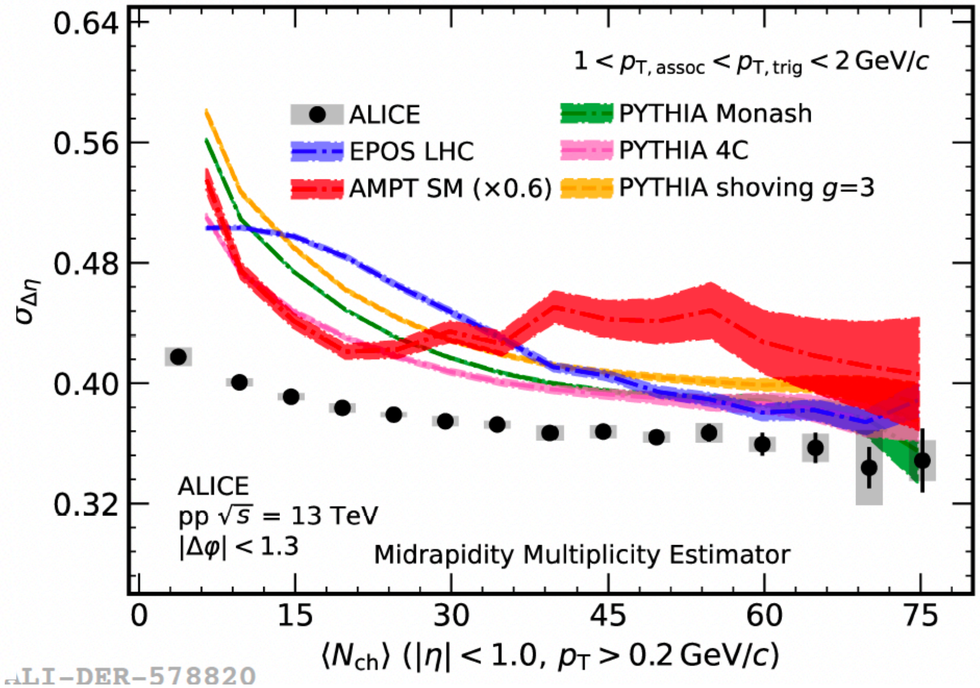


- Using particle correlation methods to study associated particles behavior as a function of (transverse) multiplicity
  - No enhancement (suppression) observed for Near (Away) side in pp and p-Pb collisions
  - Peak width become narrower in HM events for low p_T associated particles

Search for jet quenching in small systems



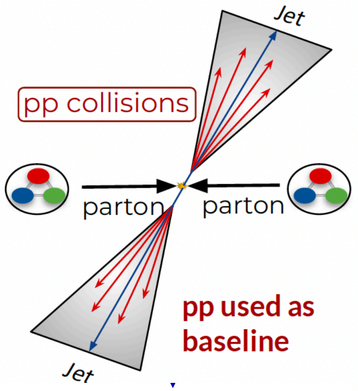


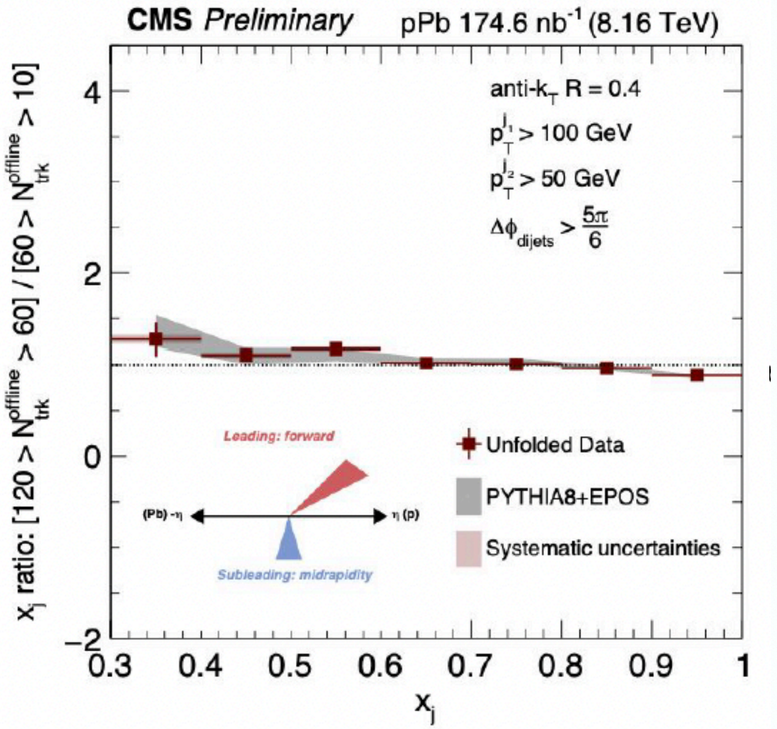


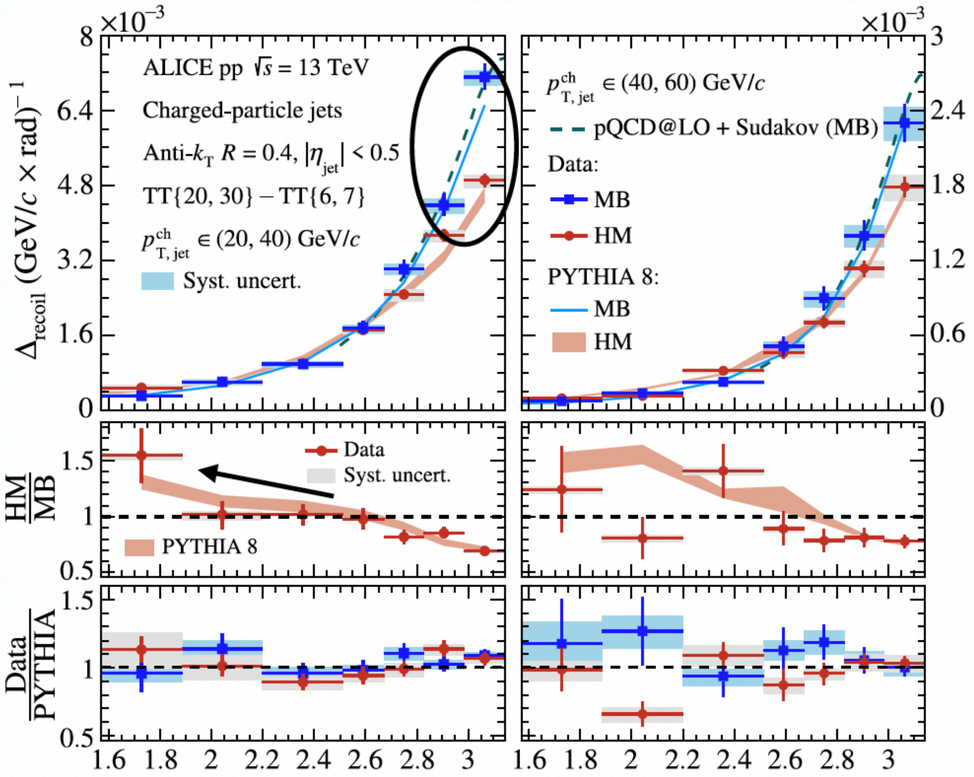
ALI-DER-578820

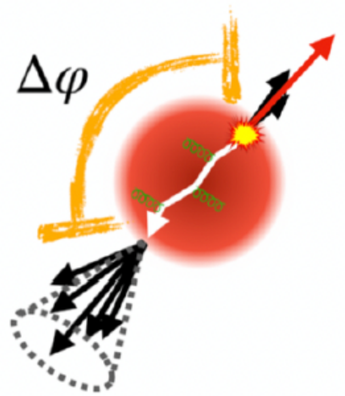
- With full jet reconstruction, study the dijet balance or h-jet azimuthal correlations
  - No modification observed at HM of jet-jet geometry

Search for jet quenching in small systems



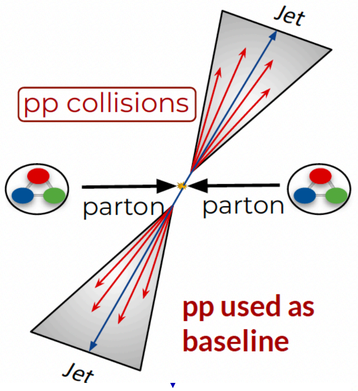


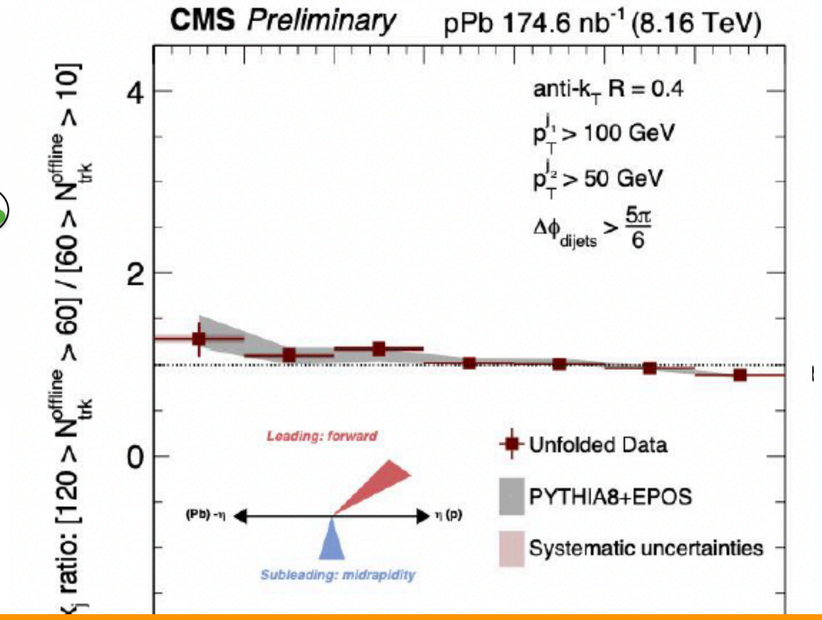


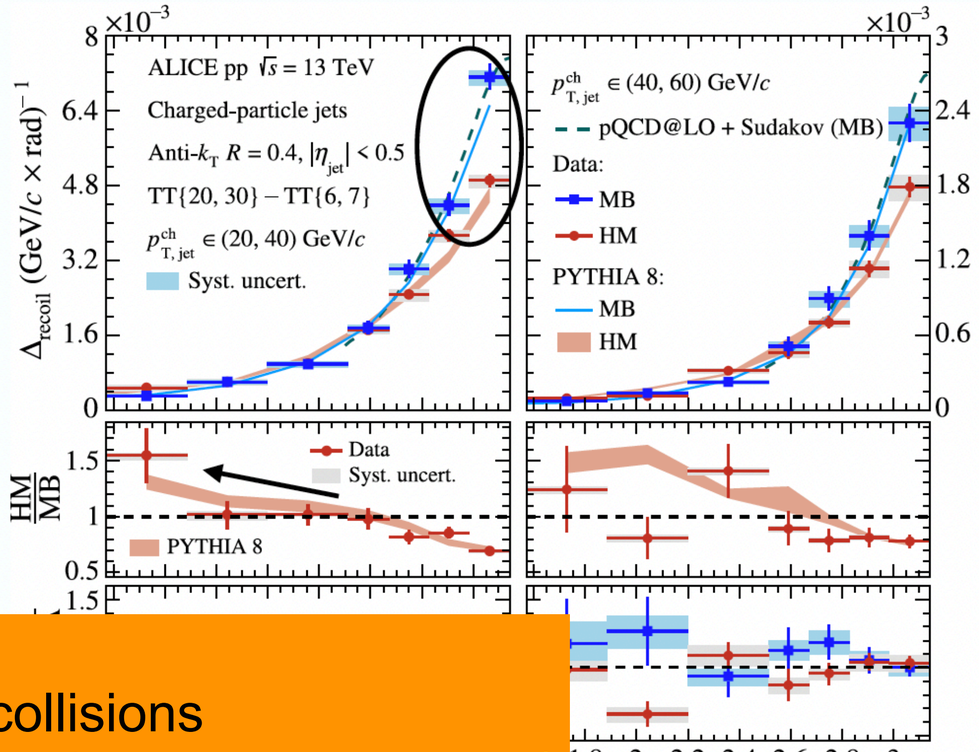


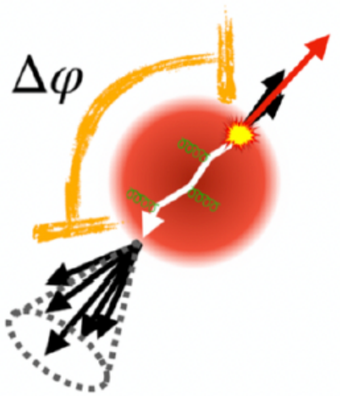
- With full jet reconstruction, study the dijet balance or h-jet azimuthal correlations
  - No modification observed at HM of jet-jet geometry
  - Azimuthal broadening in HM events observed for recoiling jets with high p_T trigger particles

Search for jet quenching in small systems









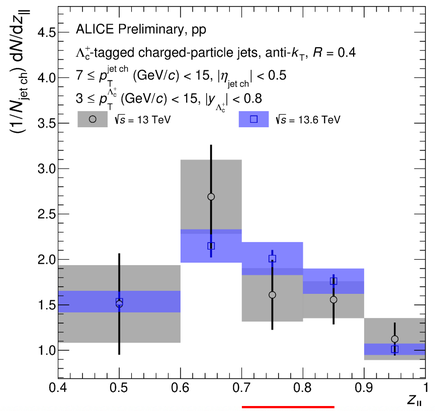
Outlook to Run 3 and 4:
→ Search for energy loss effects with light ion collisions
(e.g. O-O, Ar-Ar, low N_{part}, multiplicity similar to p-Pb, known geometry)

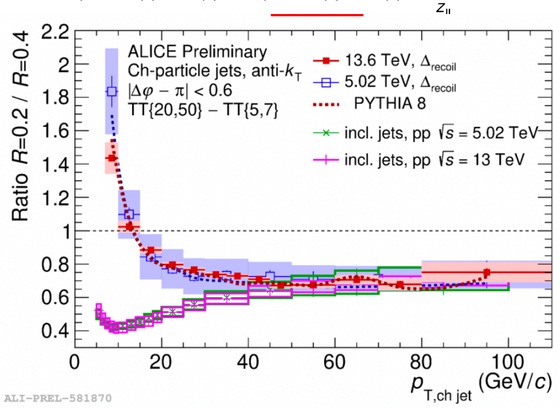
- With full jet reconstruction, study the dijet balance or h-jet azimuthal correlations
  - No modification observed at HM of jet-jet geometry
  - Azimuthal broadening in HM events observed for recoiling jets with high p_T trigger particles

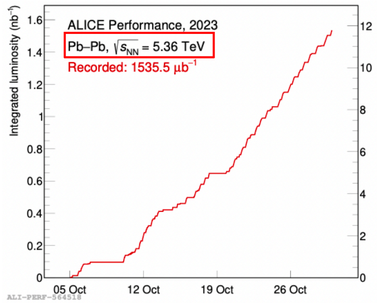
➡ Consistency study of between particle and jet correlations?

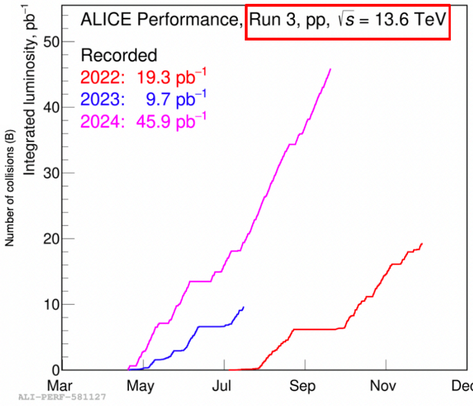
Looking towards the future with jets

- Beautiful and exciting new results are shown and discussed at this conference!
- Precision and differential measurements allowed for rare hard probes measurements using LHC Run 3 high statistics data at highest energies
  - R dependence
  - Flavor/mass dependence
  - Path length dependence
  - Jet fragmentation and hadron chemistry
  - Medium response
  - …



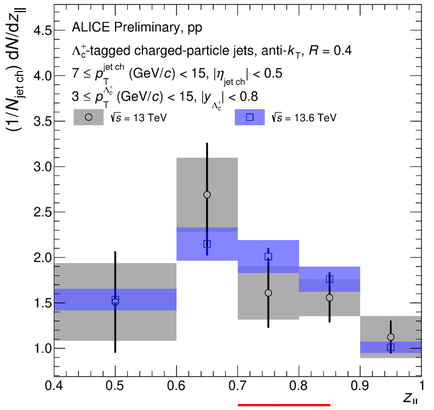


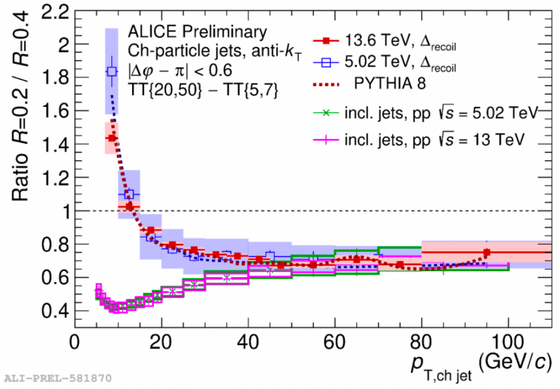


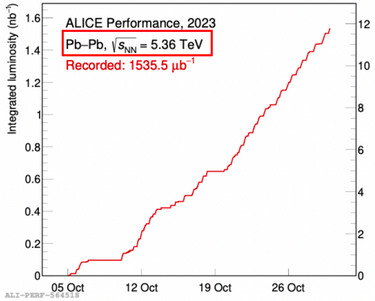


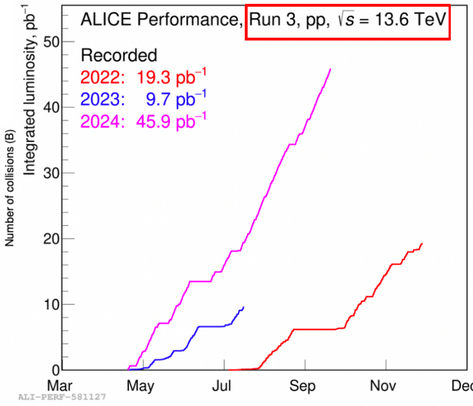
Looking towards the future with jets

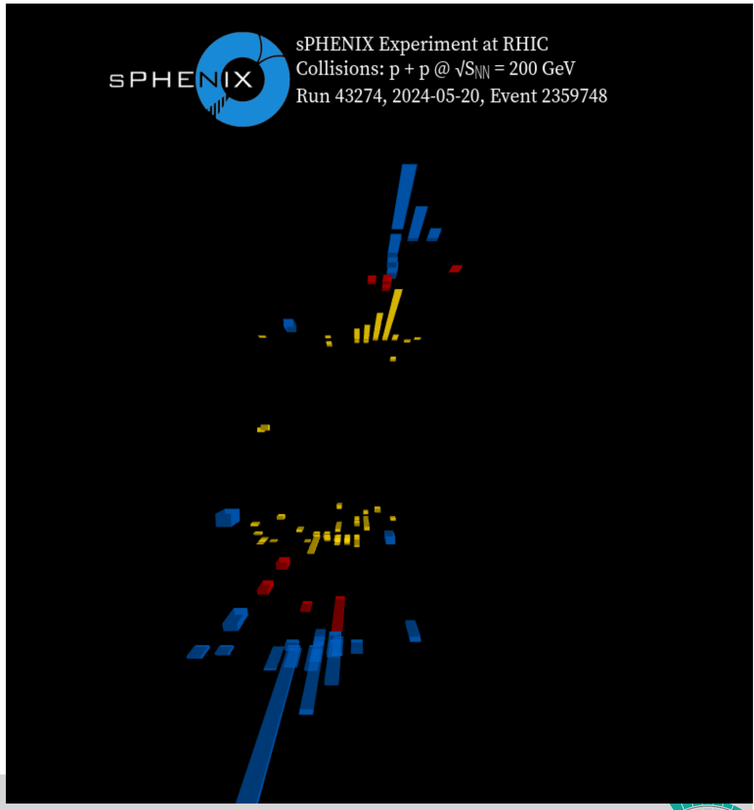
- Beautiful and exciting new results are shown and discussed at this conference!
- Precision and differential measurements allowed for rare hard probes measurements using LHC Run 3 high statistics data at highest energies
  - R dependence
  - Flavor/mass dependence
  - Path length dependence
  - Jet fragmentation and hadron chemistry
  - Medium response
  - …
- sPHENIX jet physics will be started soon!









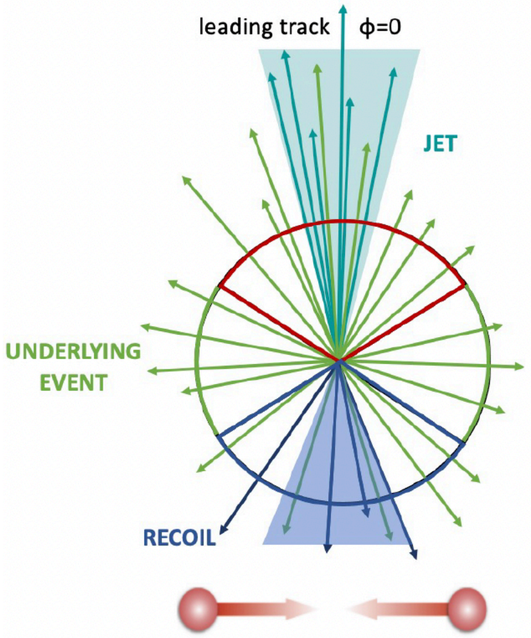


Stay tuned! Thank you for your attention!

Backup

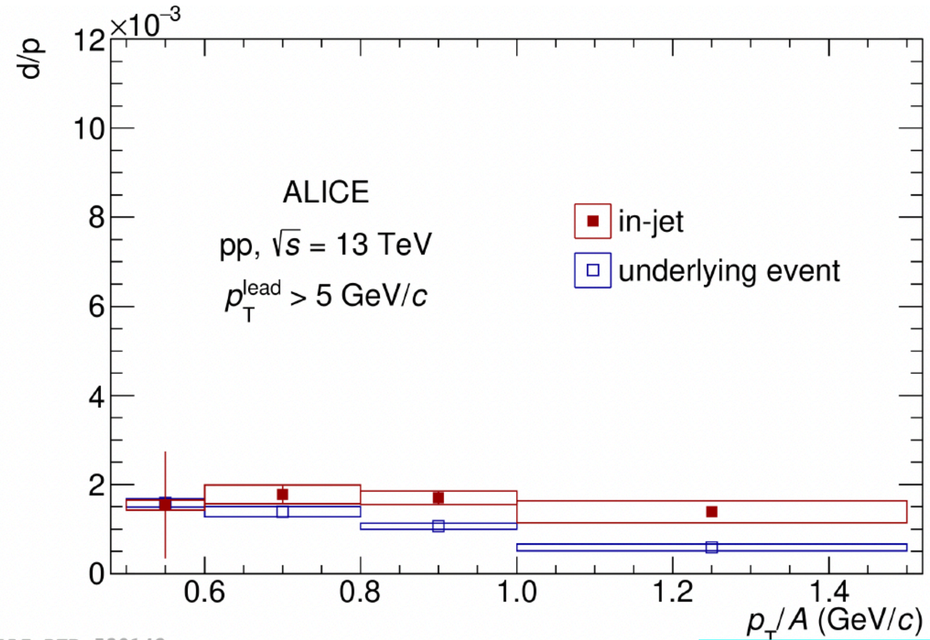

Workshop on “Advances, Innovations, and Future Perspectives in High-Energy Nuclear Physics”
“高能核物理进展、创新与展望”国际研讨会
October 19-24, 2024, Science Hall, CCNU, No.152 Luoyu Road, Wuhan
https://indico.cern.ch/event/1430136/

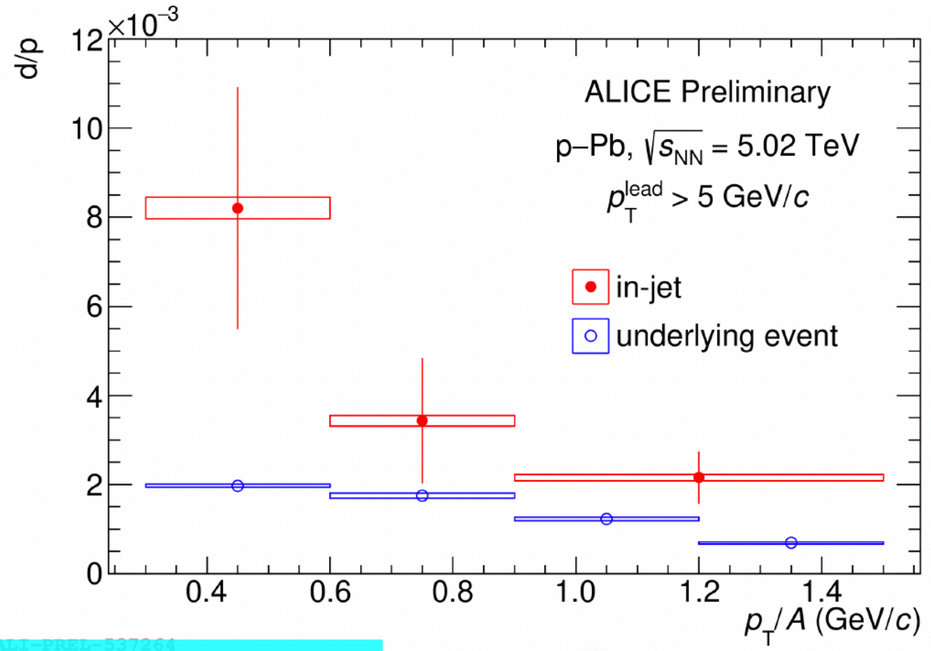
Light nuclei production in and out of jets



Toward: $|\Delta\phi| < 60°$

Transverse: $60° < |\Delta\phi| < 120°$





Talk by C. Pinto, Sec. 32, Wed, 10:50

pp

p—Pb

- Using the 2-particle correlations to study the nuclear particle production in jets and in Underlying Events (UE)
- D/p ratio in jets is increased with respect to in UE events
- Higher d/p ratio in jets in p-Pb collisions wrt in pp →hints of different particle composition in and out of jets