Jet production and correlations in heavy ion collisions

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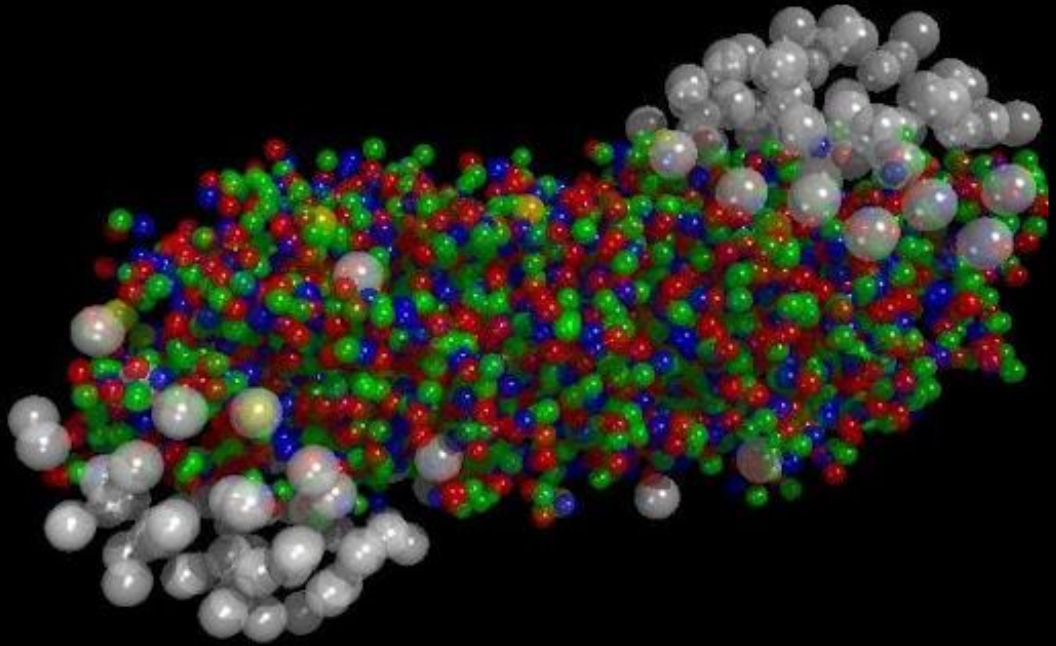
Heavy Ion Collisions

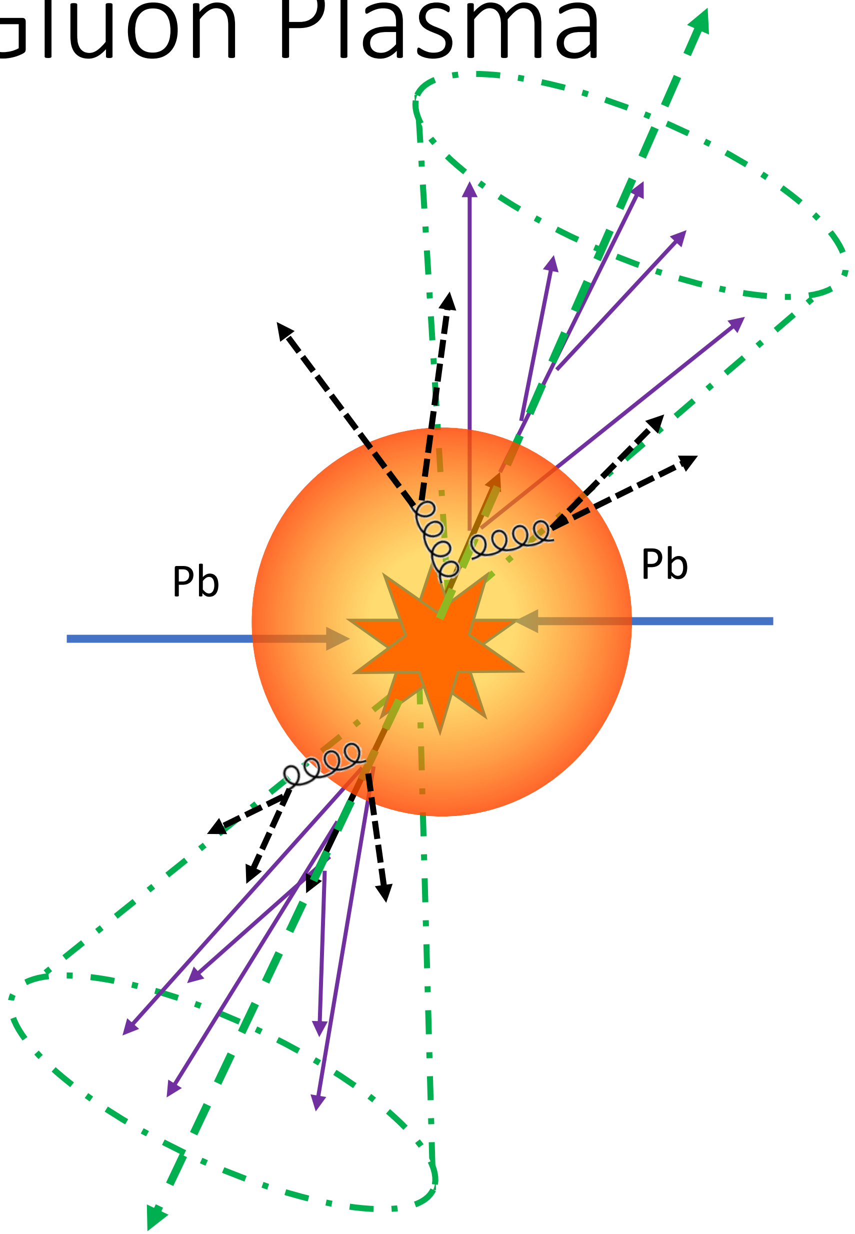
- Heavy Ion collisions can produce a state of deconfined nuclear matter called the Quark Gluon Plasma (QGP)
- Enables the study of properties of the strong force normally hidden behind confinement
- Through the comparison of yields in heavy ion collisions to *pp* one can understand the properties of interactions with the QGP



Jets as Probe of the Quark Gluon Plasma

- Jets are correlated cones of particles produced through the evolution of high p_T partons produced in hard QCD interactions
  - Produced early in the collision

- In heavy ion collisions the partons interact with the nuclear medium resulting in an effect known as *jet quenching*

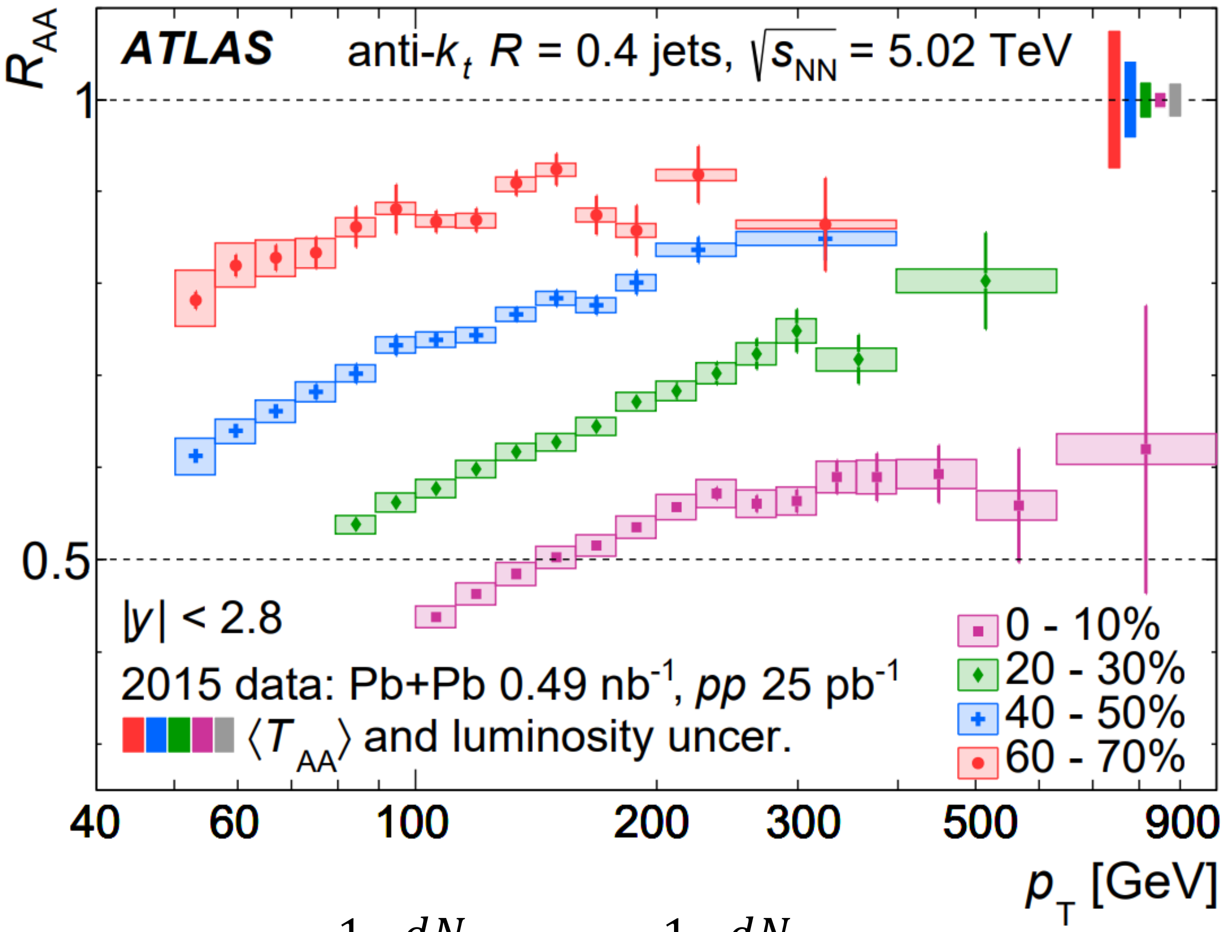


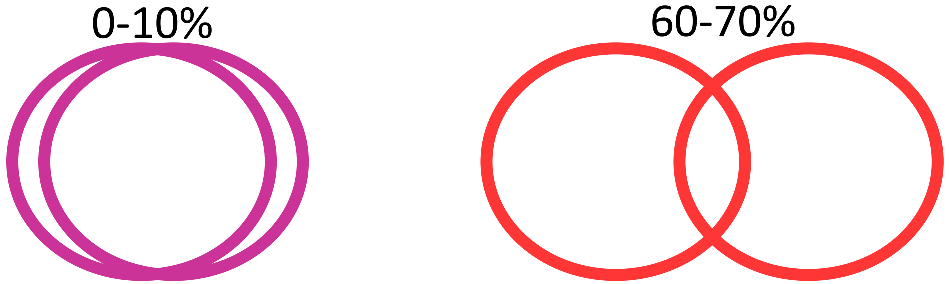
PhysLetB.2018.10.076

Nuclear Modification of jet production at LHC

Partons produced in hard scattering lose energy as they traverse the nuclear medium resulting in ‘jet quenching’

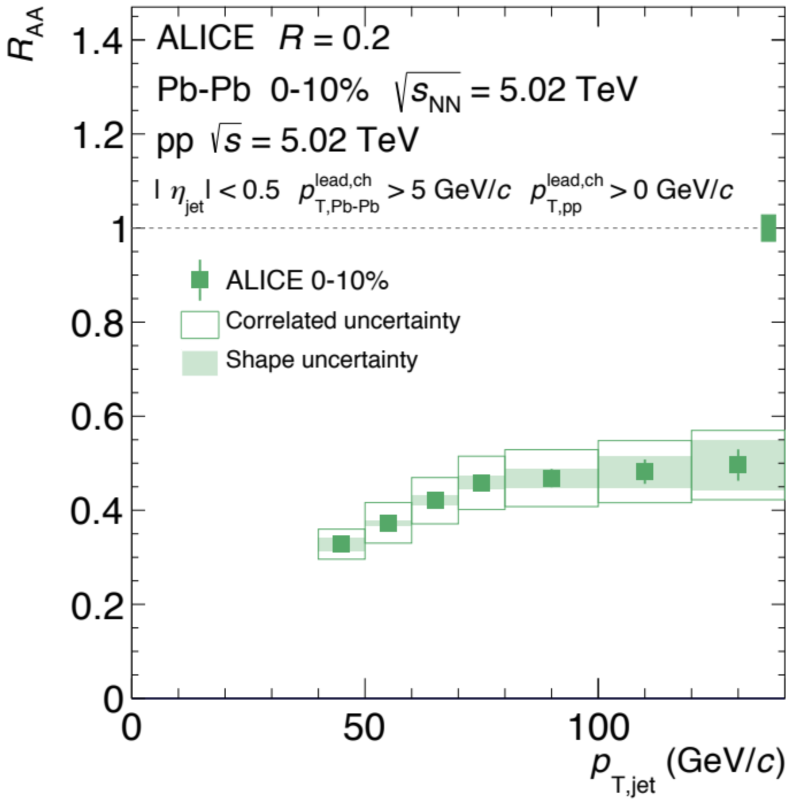
Significant energy loss for $R = 0.4$ jets is observed across centrality

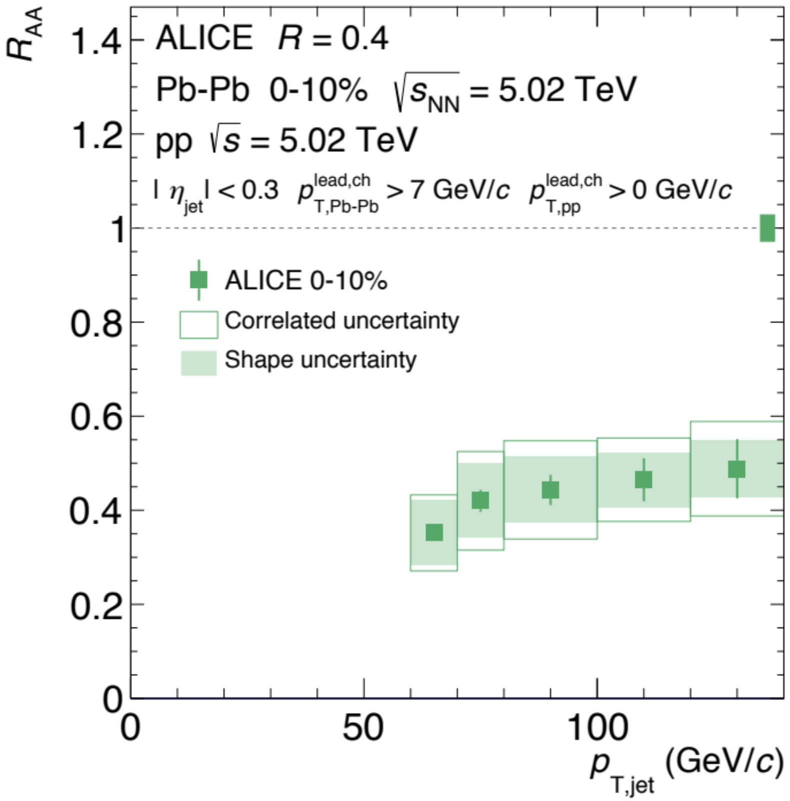




$$R_{AA} = \frac{\frac{1}{N_{evt}} \frac{dN_{PbPb}}{dp_T dy}}{\langle T_{AA} \rangle \frac{d\sigma_{pp}}{dp_T dy}} = \frac{\frac{1}{N_{evt}} \frac{dN_{PbPb}}{dp_T dy}}{\langle N_{coll} \rangle \frac{dN_{pp}}{dp_T dy}}$$

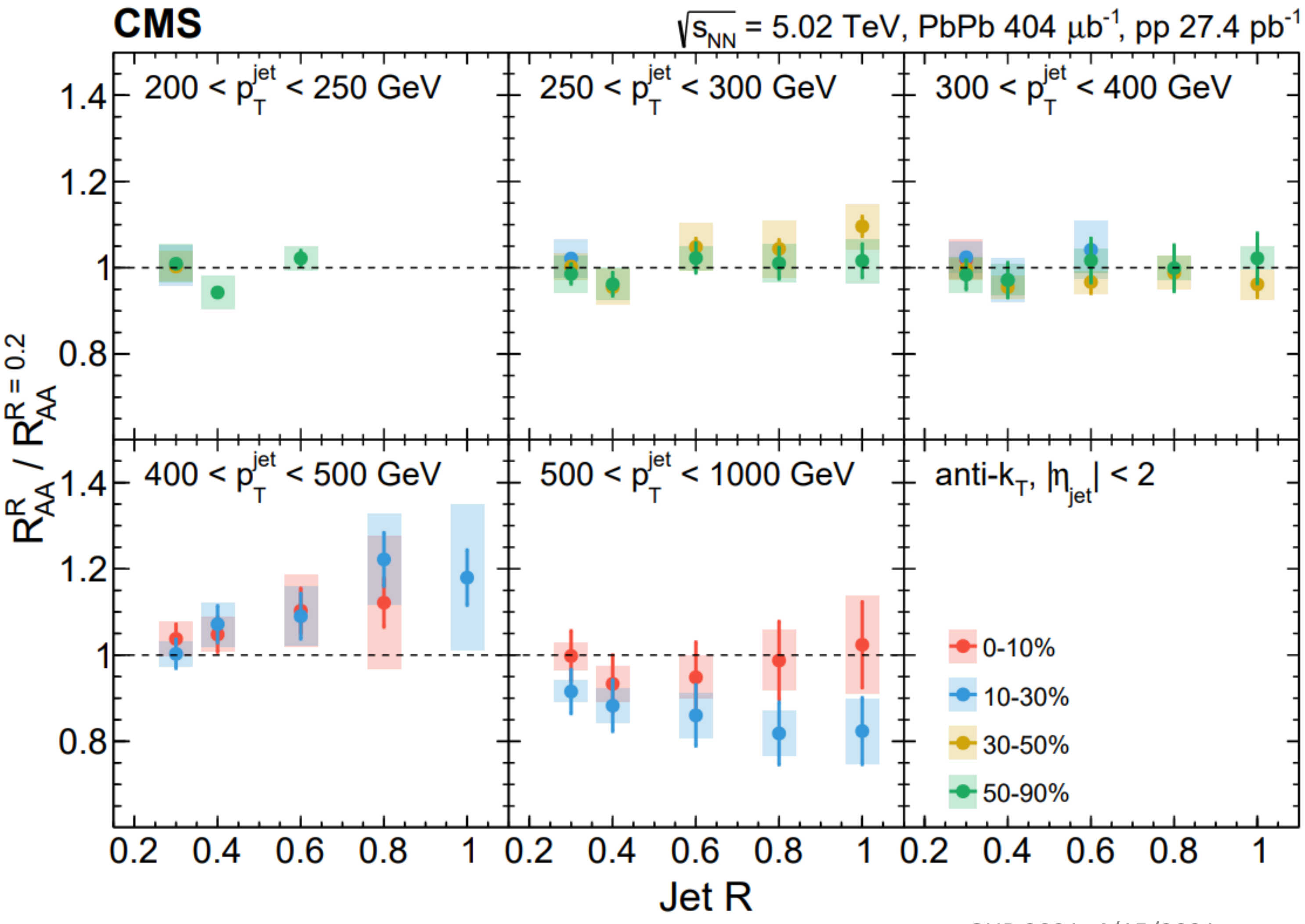
Nuclear Modification of jet Production at LHC





- ALICE has measured the R_{AA} for R = 0.2 and R = 0.4 jets down to lower p_T^{Jet} in central Pb+Pb
- Observes no evidence for size dependence to suppression between R = 0.2 and R = 0.4 jets

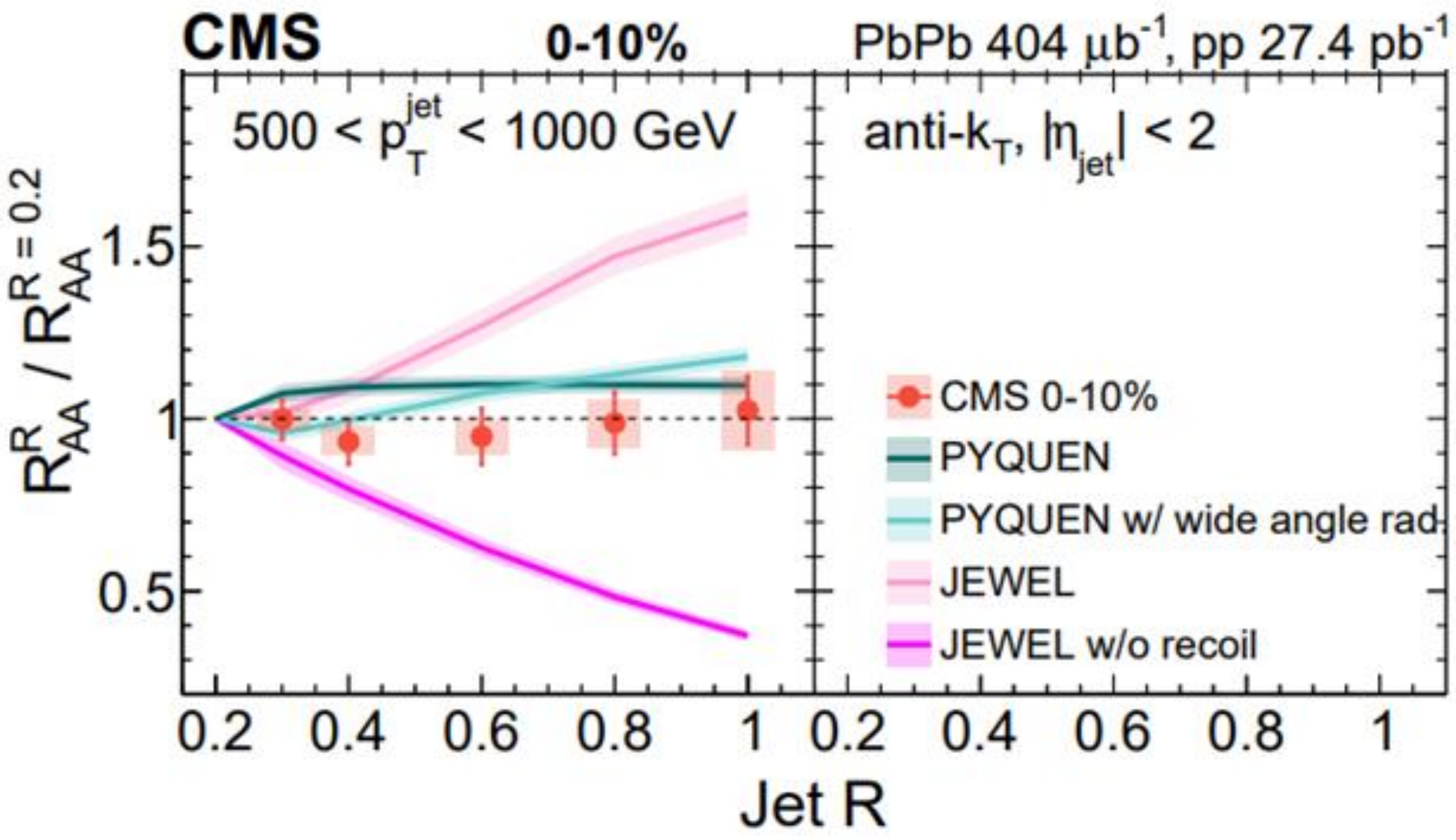
Nuclear modification factor: Radius Scan



- Sensitive to balance between increasing radiative sources and recovering re-distributed energy
- No modification from $R_{AA}^{0.2}$ is observed for 30-90% events out to 400 GeV
- Potential for minor enhancement of large R Jets is observed 0-30% events in 400-500 GeV
- CMS observes no radius dependence to the R_{AA} in 0-10% central Pb+Pb for $500\text{ GeV} < p_T^{Jet} < 1\text{ TeV}$
  - Potential relative suppression observed for large R jets in 10-30%

arXiv:2102.13080

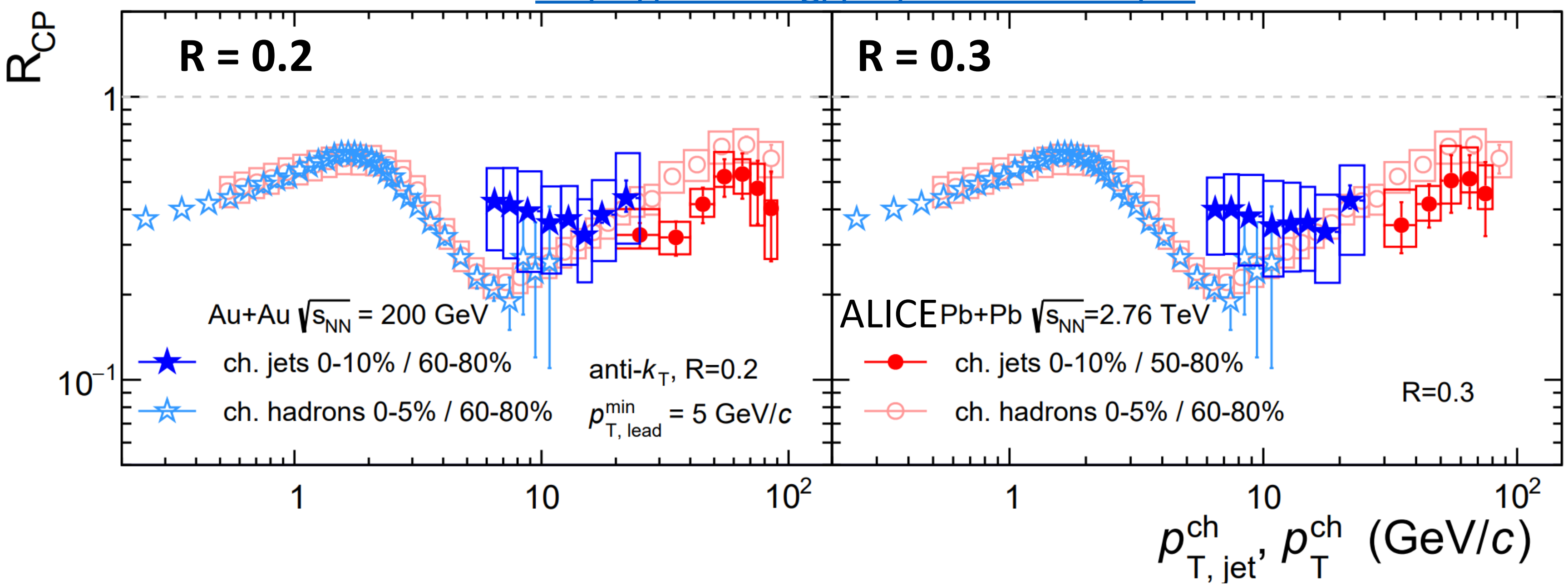
Nuclear modification factor: Radius Scan



- Sensitive to balance between increasing radiative sources and recovering re-distributed energy
- Enables simultaneous comparisons of model calculations across jet Radii

Nuclear Modification of Jets in Au+Au at RHIC:

https://arxiv.org/pdf/2006.00582.pdf



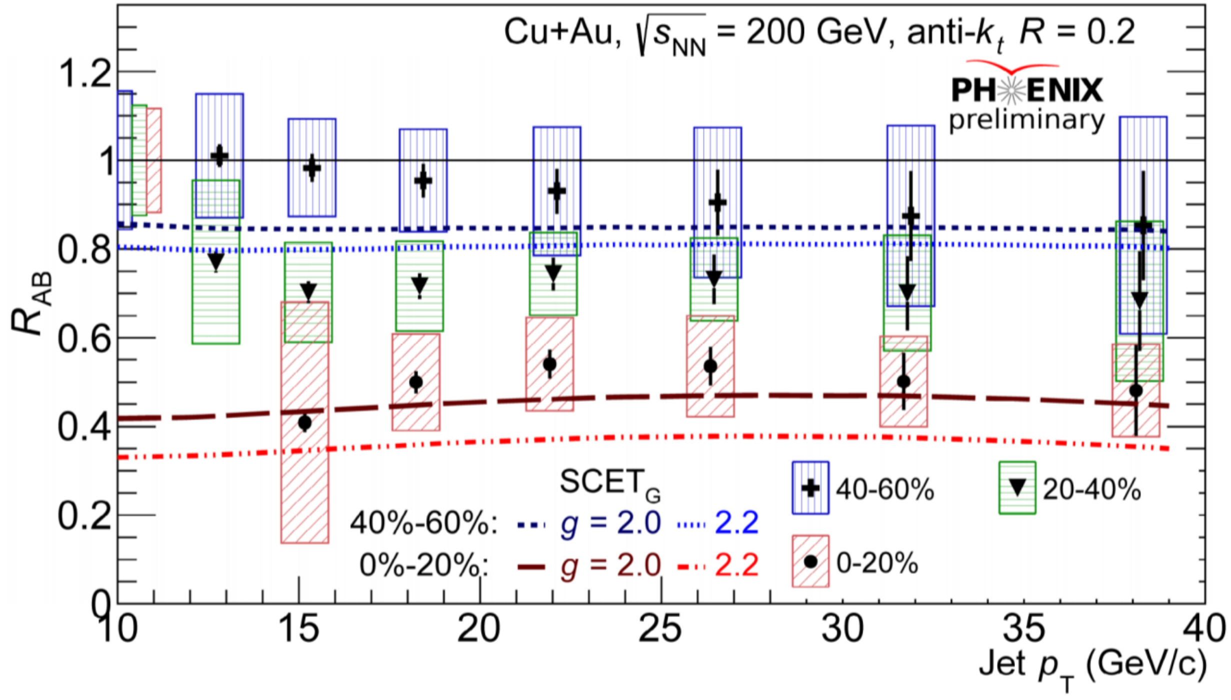
- Similar level of jet and charged hadron suppression observed at RHIC and LHC energies
  - Different underlying spectral shapes at 200 GeV versus 2.76 TeV

- No clear evidence for jet size or p_T dependence to the R_{CP} observed by STAR

Look forward to future jet measurements from sPHENIX!

Nuclear Modification of Jets in Cu+Au

- Clear centrality dependence to modification
- No significant p_T dependence observed
- Similar suppression as seen in 0-20% Cu+Au events as observed in Au+Au (R_{CP}) and Pb+Pb (R_{AA}) collisions

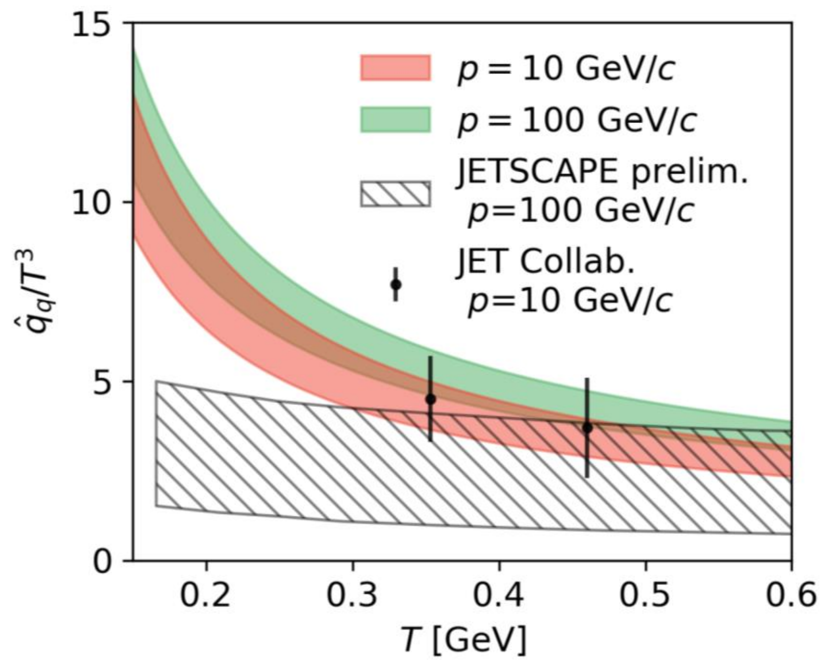


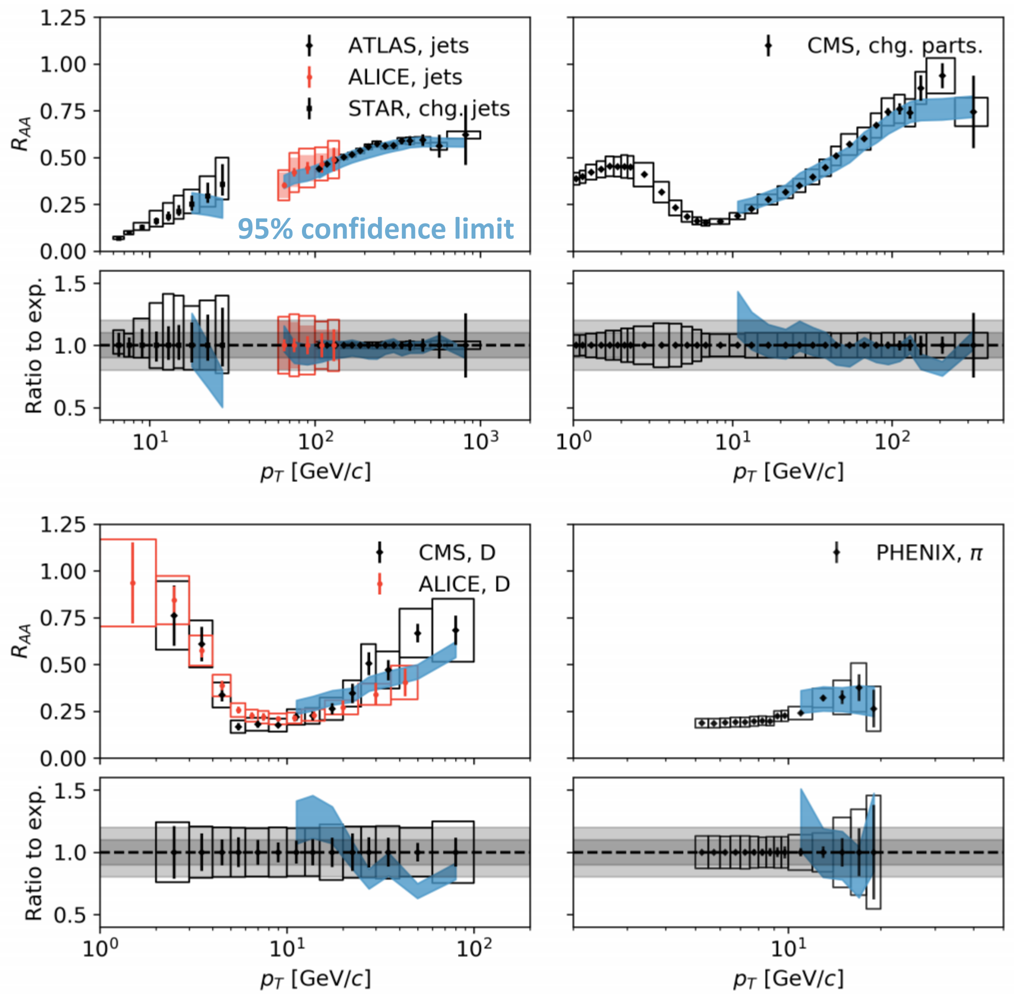
Global Bayesian Analyses

https://arxiv.org/pdf/2010.13680.pdf

Theory collaborations use R_{AA} measurements from both RHIC and LHC experiments in Bayesian analyses to extract insight on the QGP properties

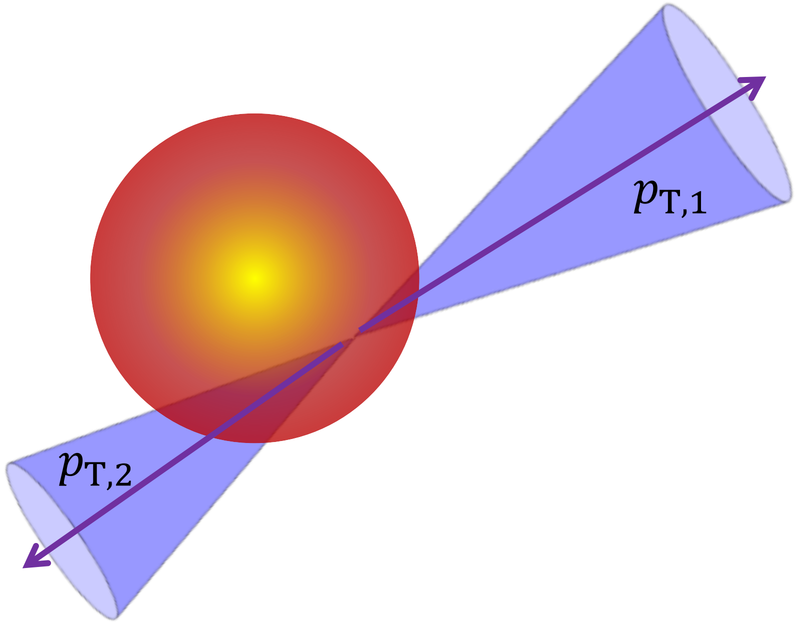
- Recent publications by Weiyao Ke and Xin-Nian Wang, as well as the JETSCAPE collaboration highlight extractions of jet transport coefficient $\hat{q}$

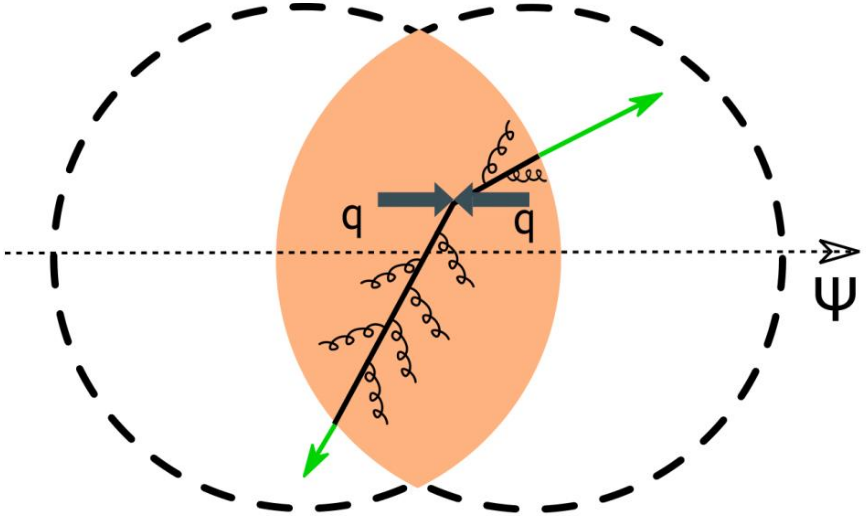




Probing Jet Energy Loss

- Dijet Momentum Balance
  - ➢Sensitive to path length dependent energy loss and fluctuations
- Jet v_n
  - ➢Path length dependent energy loss can cause enhanced jet yield in-plane vs. out-of-plane: positive v_2
  - ➢v_{3+} can give insight to the role of initial state fluctuations to jet quenching

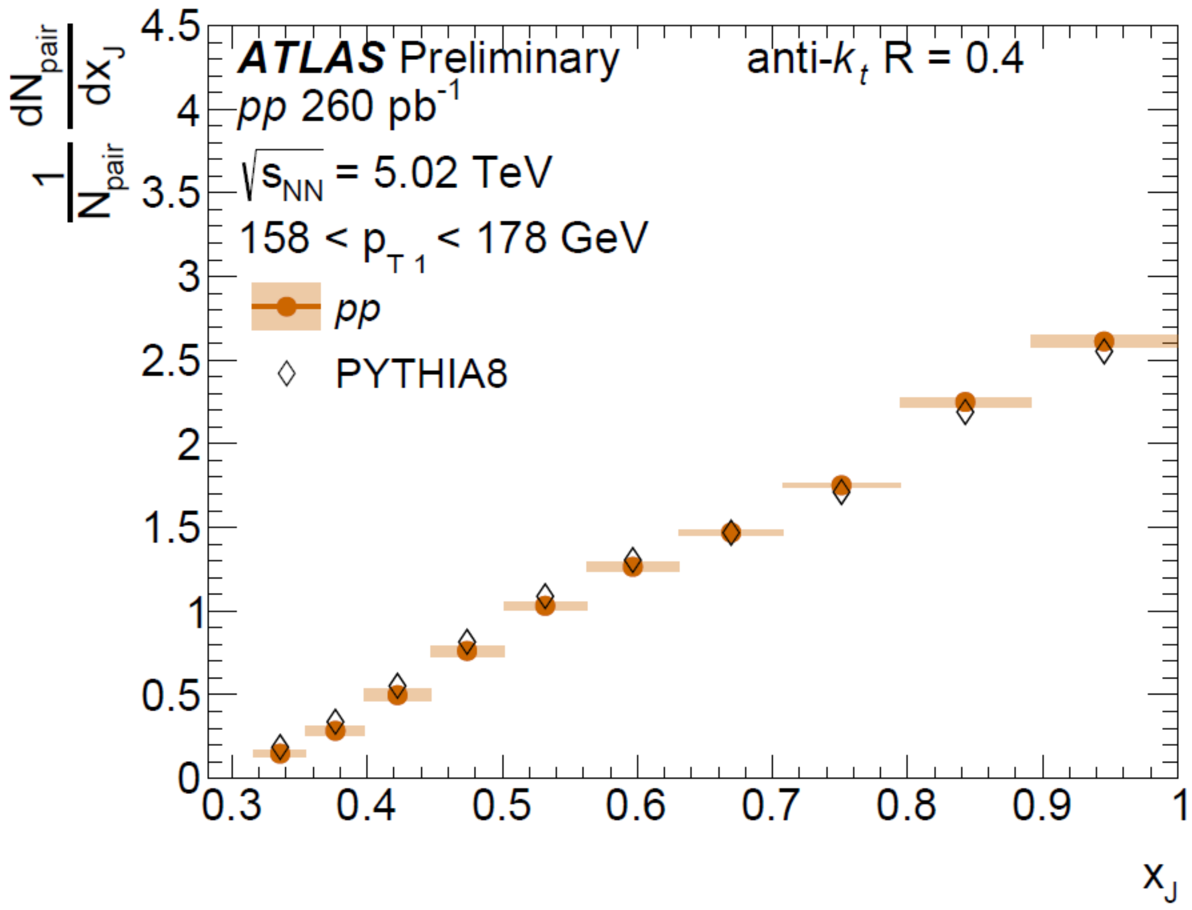


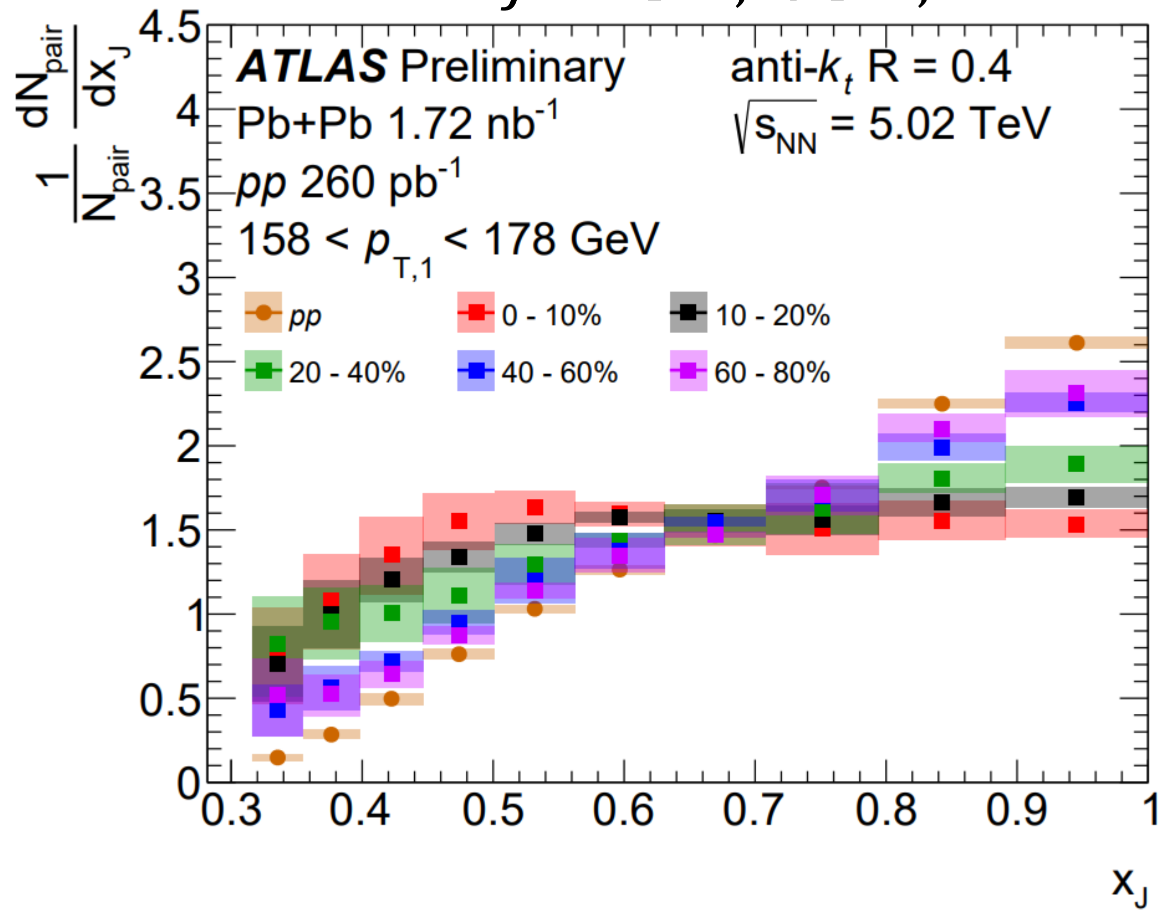


https://cds.cern.ch/record/2720247

DiJet Momentum Balance

$$x_J = p_{T,2}/p_{T,1}$$





- Back-to-back dijet pairs in *pp* collisions strongly favor symmetric momentum
- In Pb+Pb collisions observe significant enhancement of asymmetric dijets

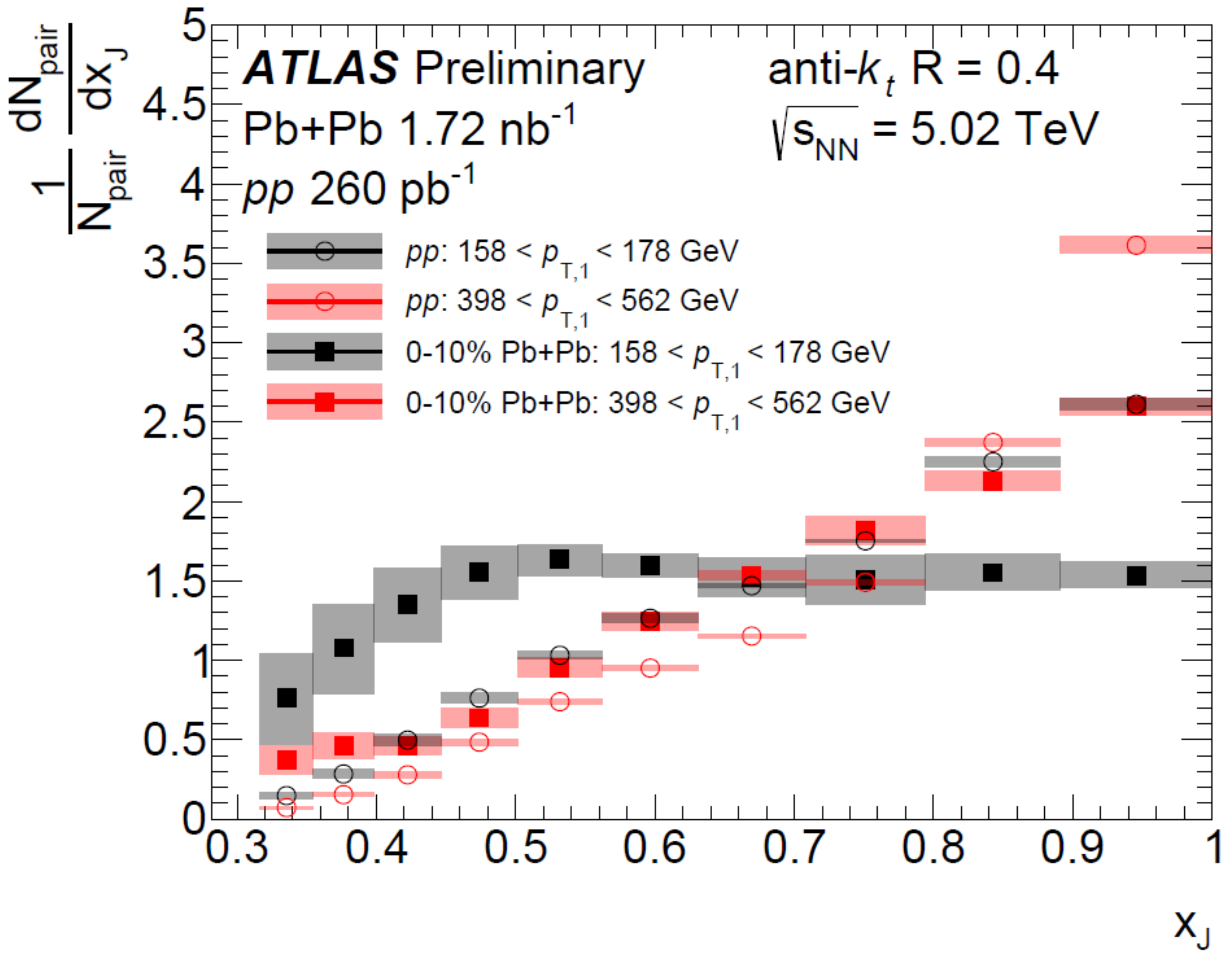
https://cds.cern.ch/record/2720247

DiJet Momentum Balance

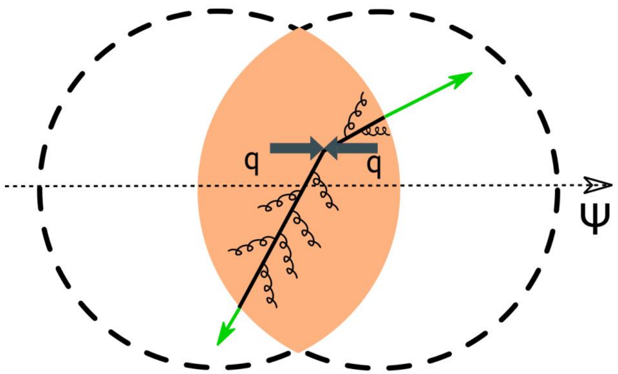
$$x_J = p_{T,2}/p_{T,1}$$

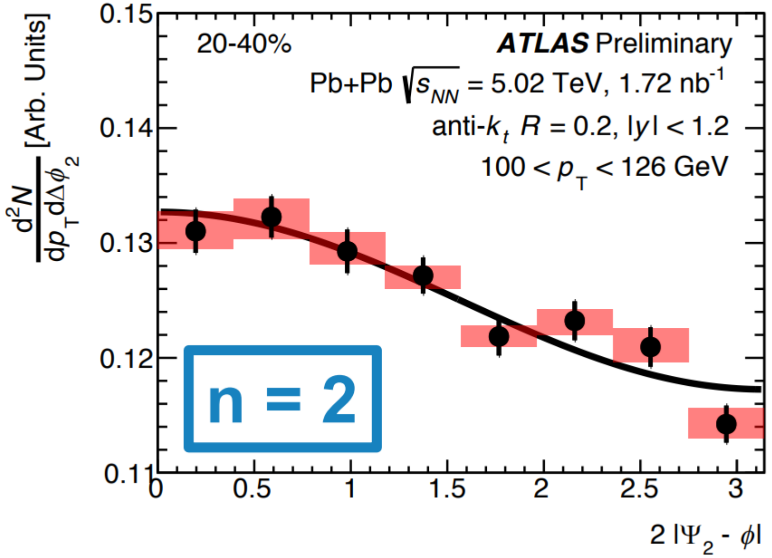
Observe significant suppression of symmetric dijets in Central Pb+Pb across jet p_T

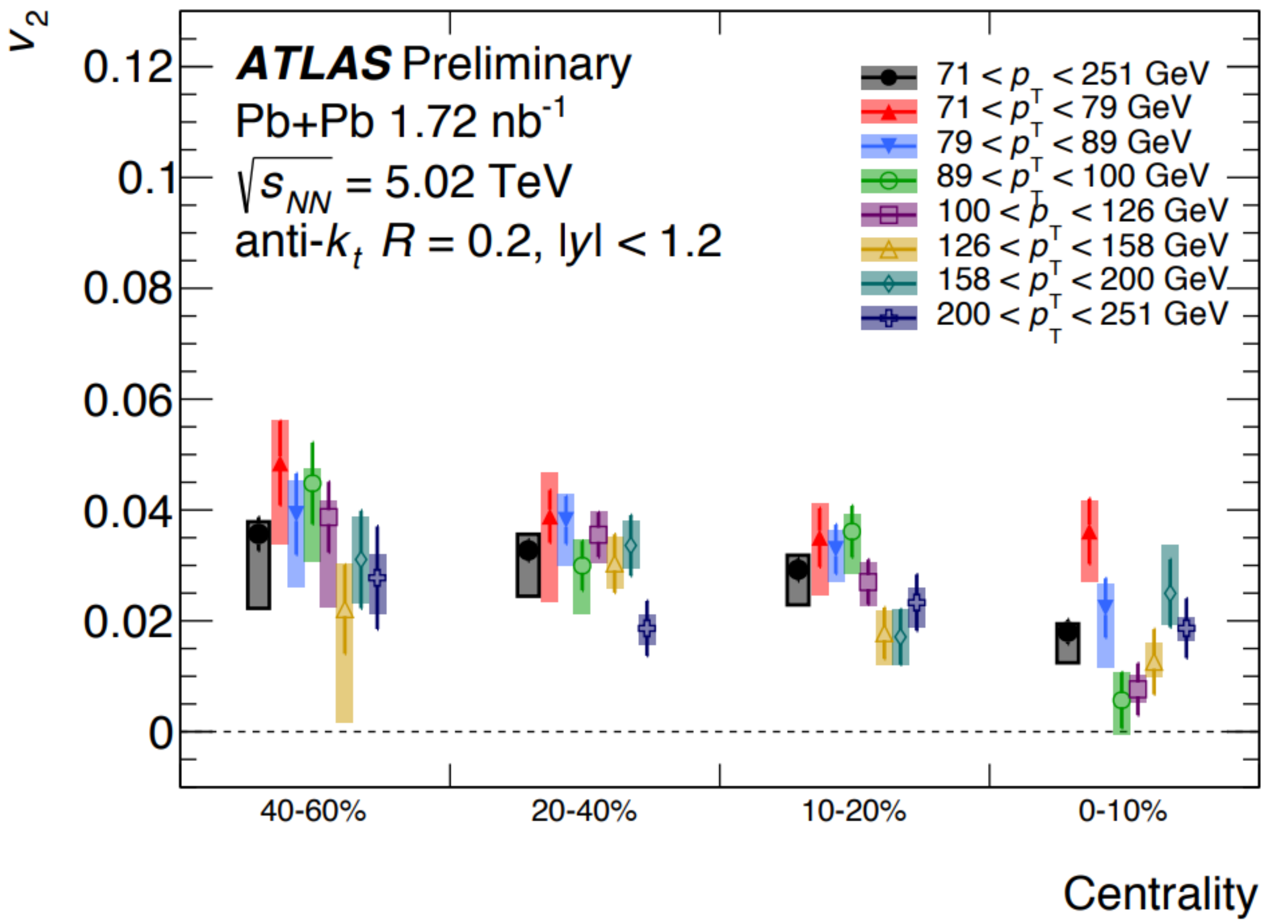
- ➢ subleading jet loses more energy than the leading jet potentially due to traversing a larger distance in the medium



Jet v_2







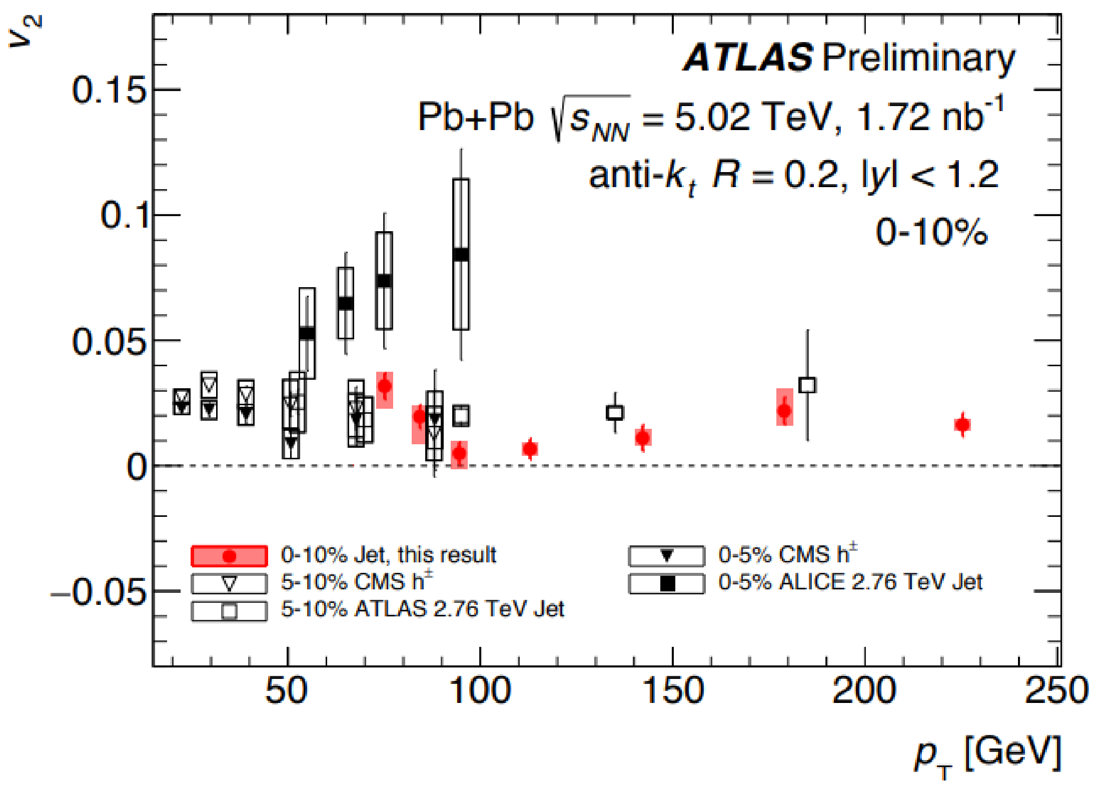
ATLAS observes for $R = 0.2$ Jets a significant 1-4% jet v_2 on inclusive jet p_T

- ➢ v_2 is enhanced in more elliptical initial states (mid central, peripheral)

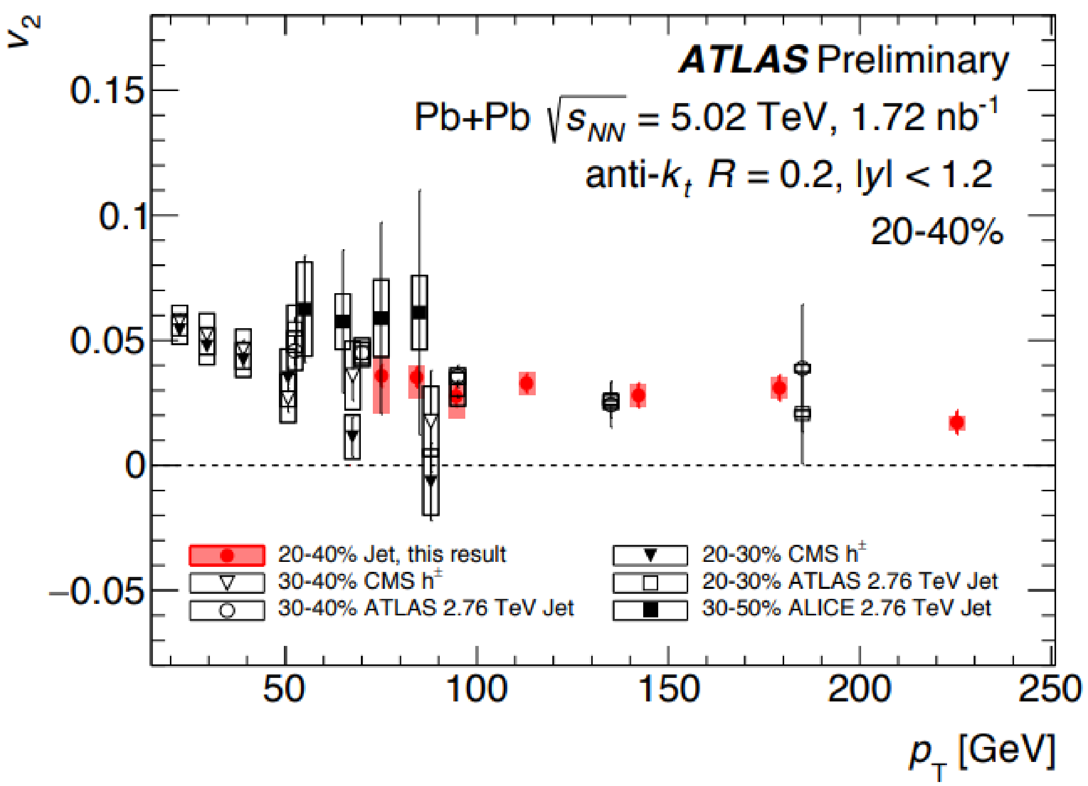
ATLAS-CONF-2020-019
CMS charged particle: arXiv:1702.00630
ATLAS 2.76 TeV: arXiv:1306.6469
ALICE 2.76 TeV: arXiv:1509.07334

Jet v_2

0-10%



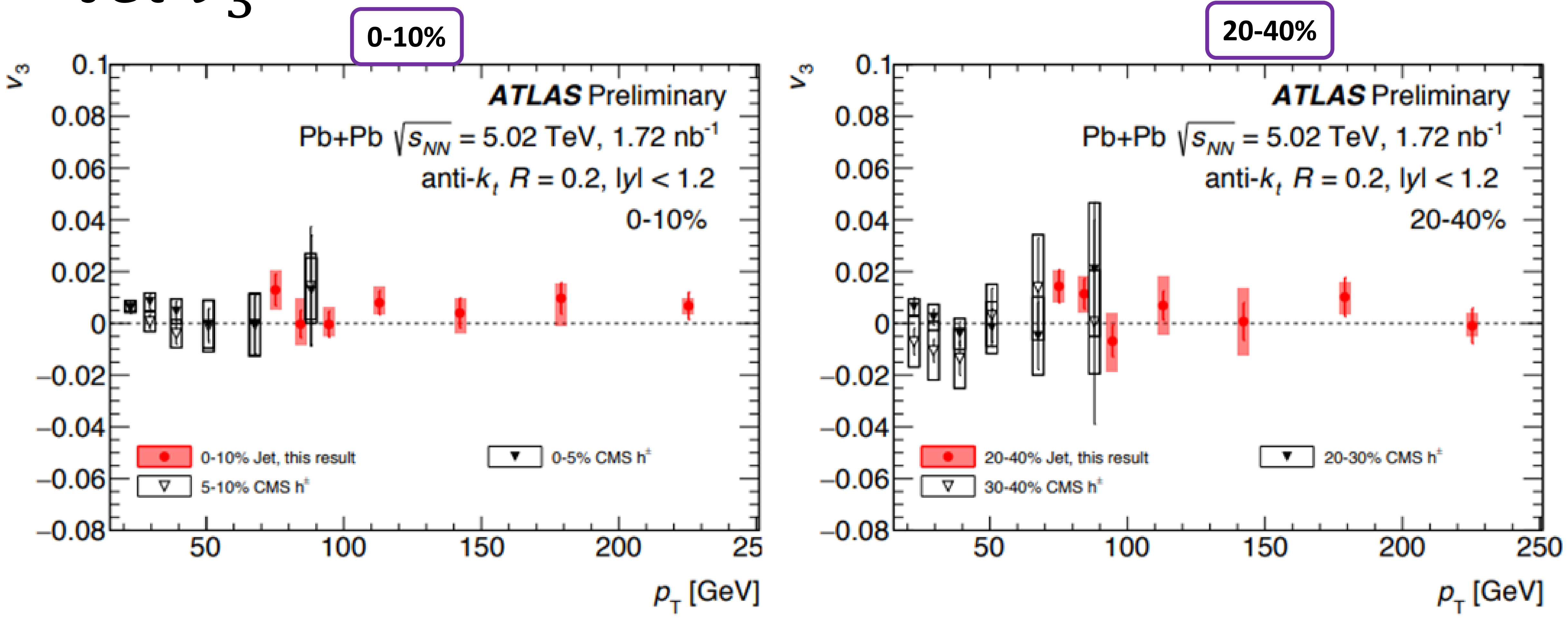
20-40%



- Jets observed at 5.02 TeV by ATLAS observe similar v_2 to charged hadrons at 5.02 TeV by CMS
  - ALICE measured systematically larger Jet v_2 in 0-5% events at $\sqrt{s_{NN}}$ = 2.76 TeV than other measurements

ATLAS-CONF-2020-019
CMS charged particle: arXiv:1702.00630

Jet v_3

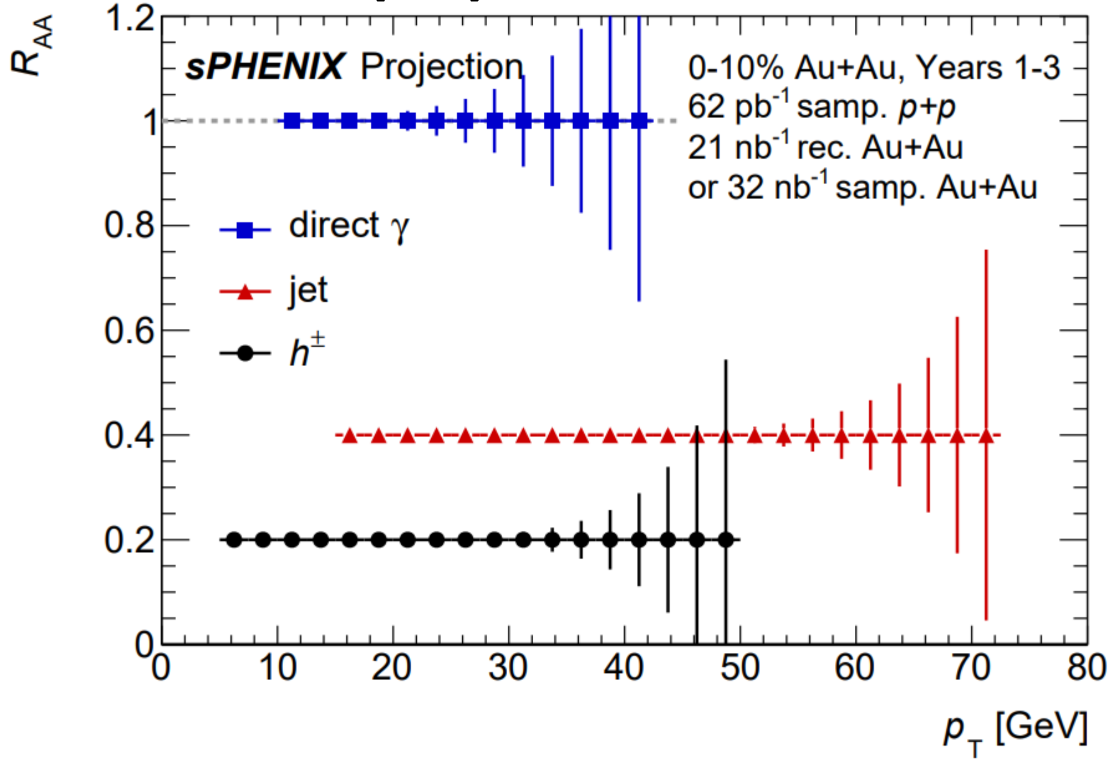


No evidence observed in ATLAS or CMS for non-zero v_3

Summary and Outlook:

- Many exciting measurements of jet production and correlations from both LHC and RHIC experiments
  - Too many to have covered here
- Ongoing developments and improvements in theory allows for comparisons providing insight to the properties of interactions with the QGP
- Look forward to results using high luminosity run 3 LHC data and from the future sPHENIX experiment
  - See Yeonju Go's talk in this session

[BUP] sPH-TRG-2020-001



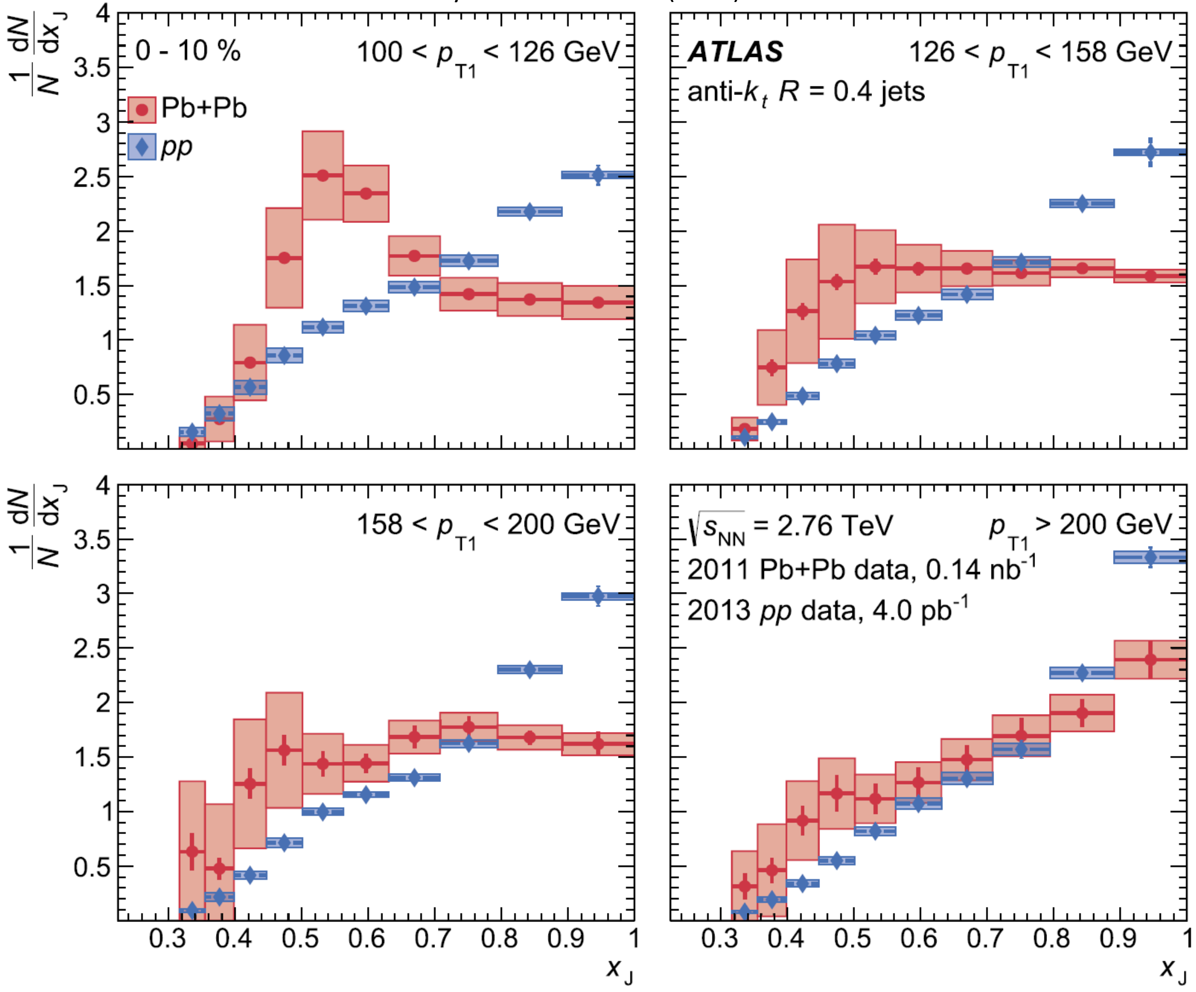
backups

Dijet momentum balance: 2.76 TeV

- At $\sqrt{s_{NN}} = 2.76$ TeV ATLAS observed an enhancement of dijets with $x_J \approx 0.5$ for $p_{T,1} > 100\ GeV$

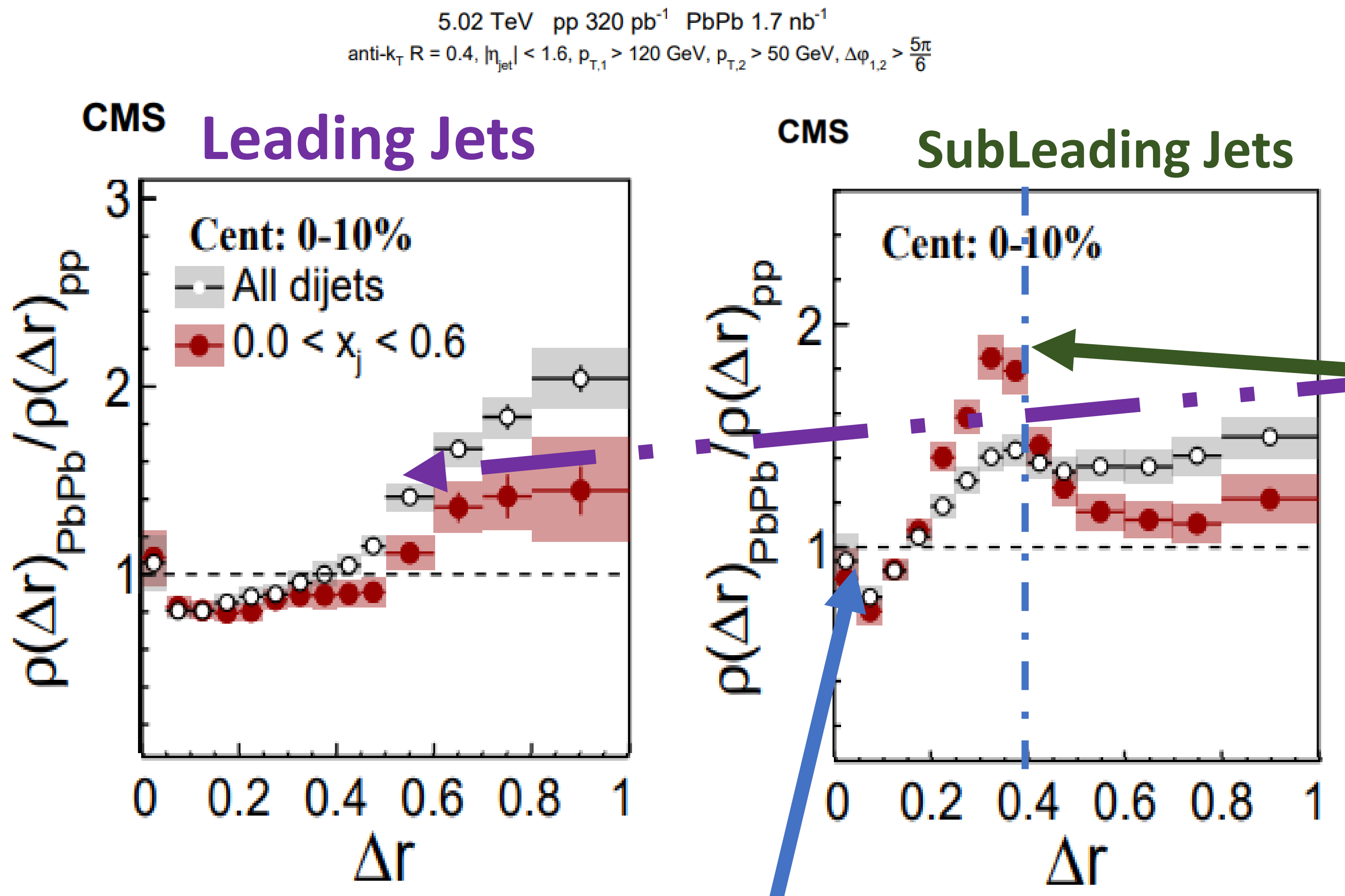
- By 126 GeV the observed peak has faded and the distribution is consistent with flat for $x_J > 0.5$

Physics Letters B 774 (2017) 379–402



[arXiv:2101.04720](https://arxiv.org/abs/2101.04720)

ρ is proportional to track momentum density in a radius window



Clear enhancement of momentum caried near the edges of the **subleading jet** compared to the **leading jet**

Clear depletion of momentum near the core of the jet for the **subleading jet**

Quenched jets observe significant broadening