Quark Matter 2022-2023: jet parallel session review

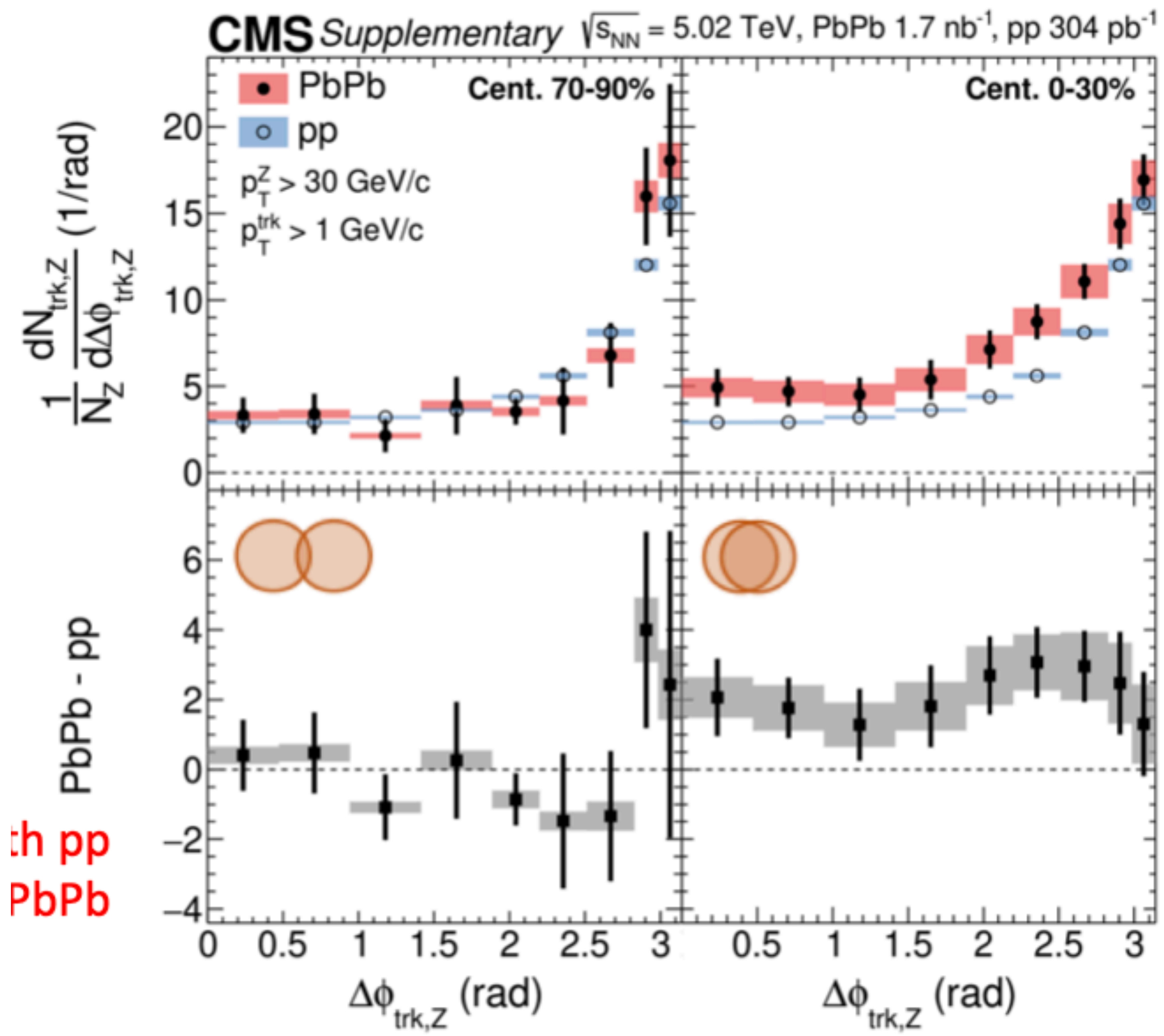
Hadrons recoiling from high-p_{T} trigger: Z-boson correlations by CMS

- Chun Chou's Talk
- Kaya Katar's Talk

arXiv:2103.04377v2

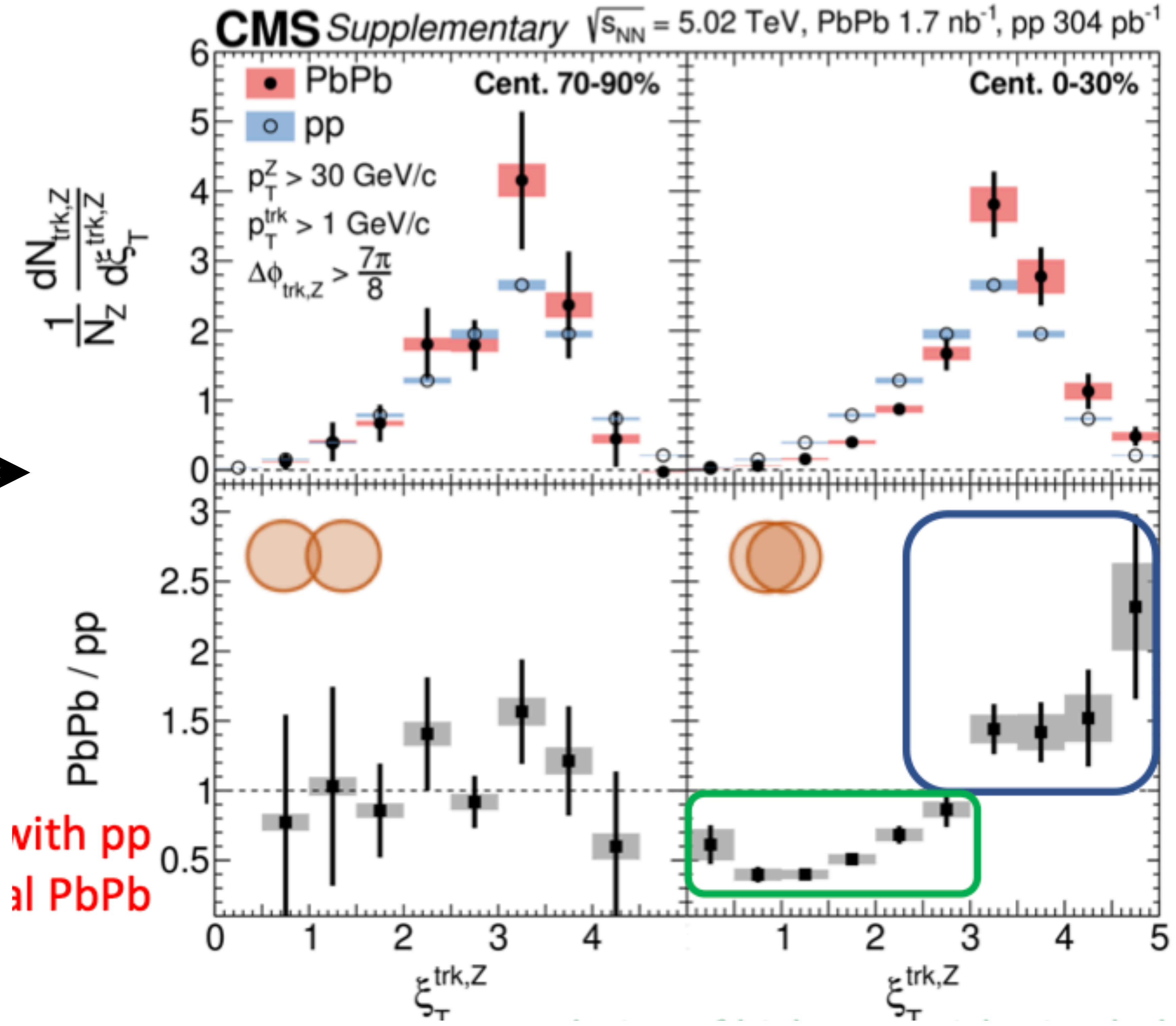
- **EW bosons** tag the parton kinematics→ way to understand medium response
  - $\gamma/Z + jet$ = way to measure parton medium interactions with jet FF
  - Z is not sensitive to strong interaction, and "cleaner" than photons : no Z from fragmentation/radiation/decay

$$\Delta\varphi = (\varphi^{\mathrm{trig}} - \varphi^{\mathrm{h}})$$



Integrate away side peak $\Delta\varphi > 7/8\pi$

$$\xi_{\mathrm{T}}^{\mathrm{trk,Z}} = \ln\frac{-|\mathrm{p}_{\mathrm{T}}^{\mathrm{Z}}|}{\mathrm{p}_{\mathrm{T}}^{\mathrm{trk}} \cdot \mathrm{p}_{\mathrm{T}}^{\mathrm{Z}}}$$



Excess of low p_{T} particles

Consistent with pp in peripheral PbPb

Excess of particles with pT > 1 in central PbPb across $\Delta\varphi$

Consistent with pp in peripheral PbPb

Depletion of high p_{T} particles

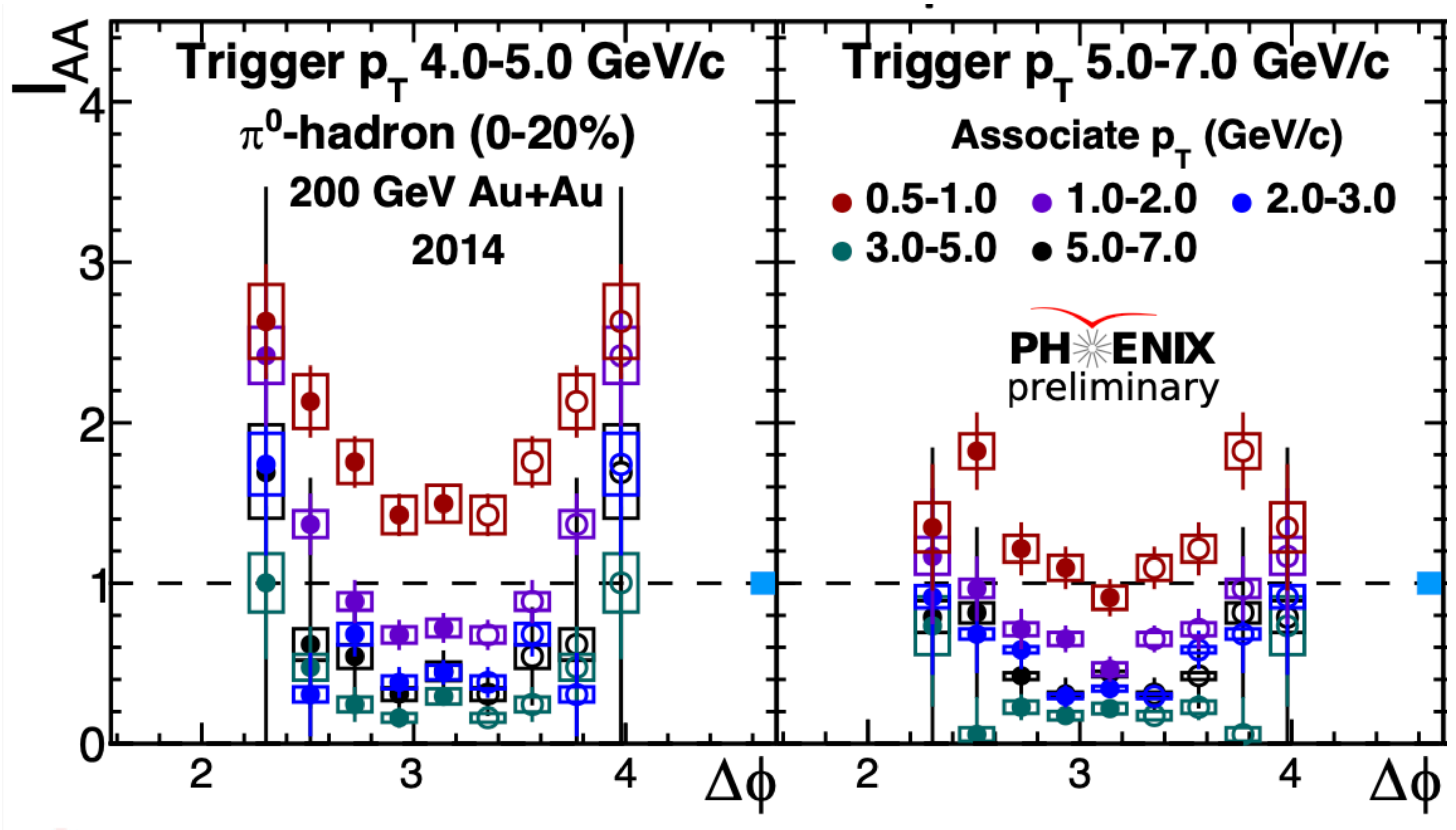
Hadrons recoiling from high-p_T trigger: γ—hadron correlations by PHENIX

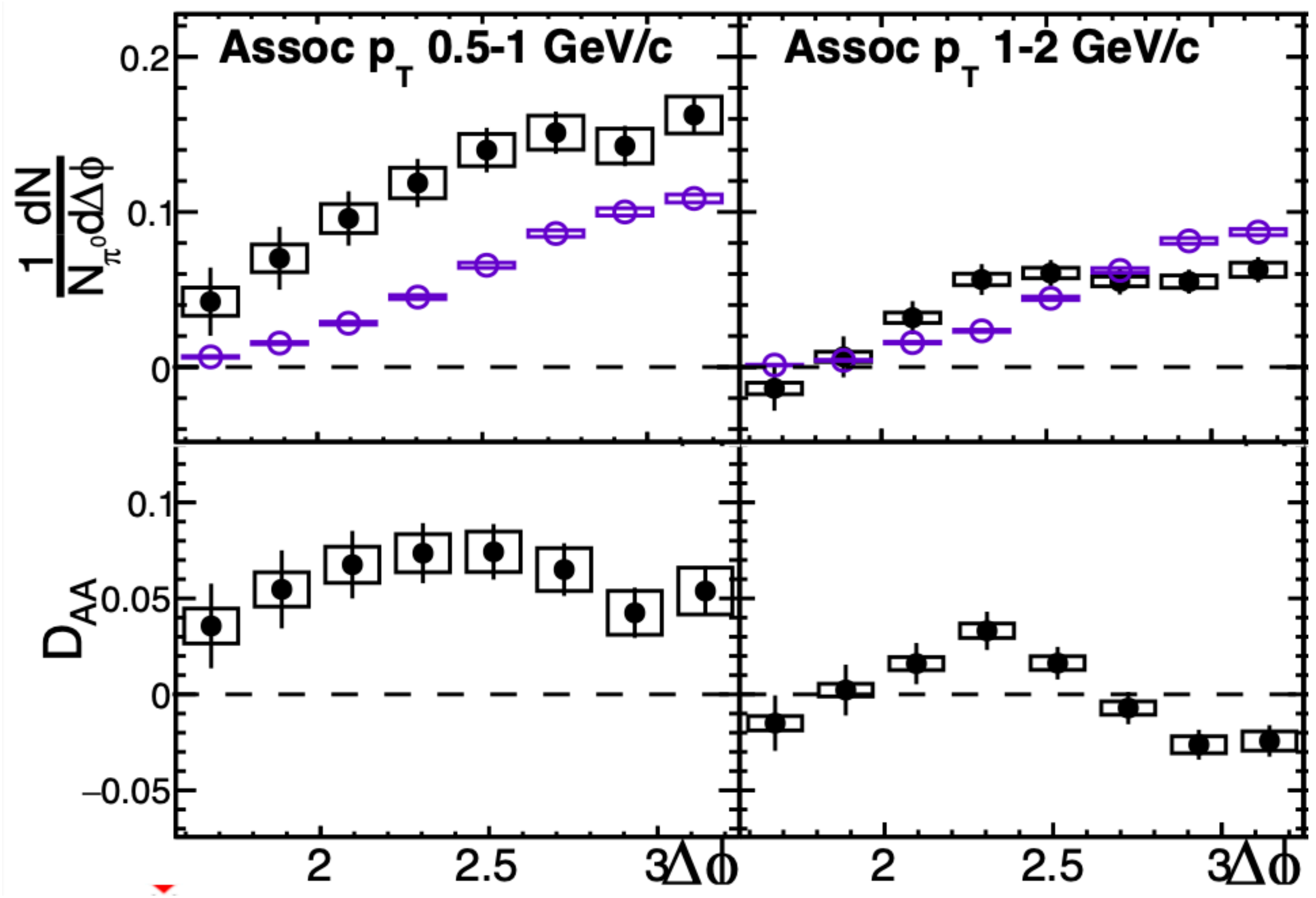
- Megan Connors's Talk

Azimuthal correlations distributions $\Delta\varphi = (\varphi^{trig} - \varphi^{h})$, integration of the away side yield as a function of $\Delta\varphi$

- I_{AA} = **ratio of yields in AA over the one in pp**

- D_{AA} = **difference of angular correlations in AA and in pp**





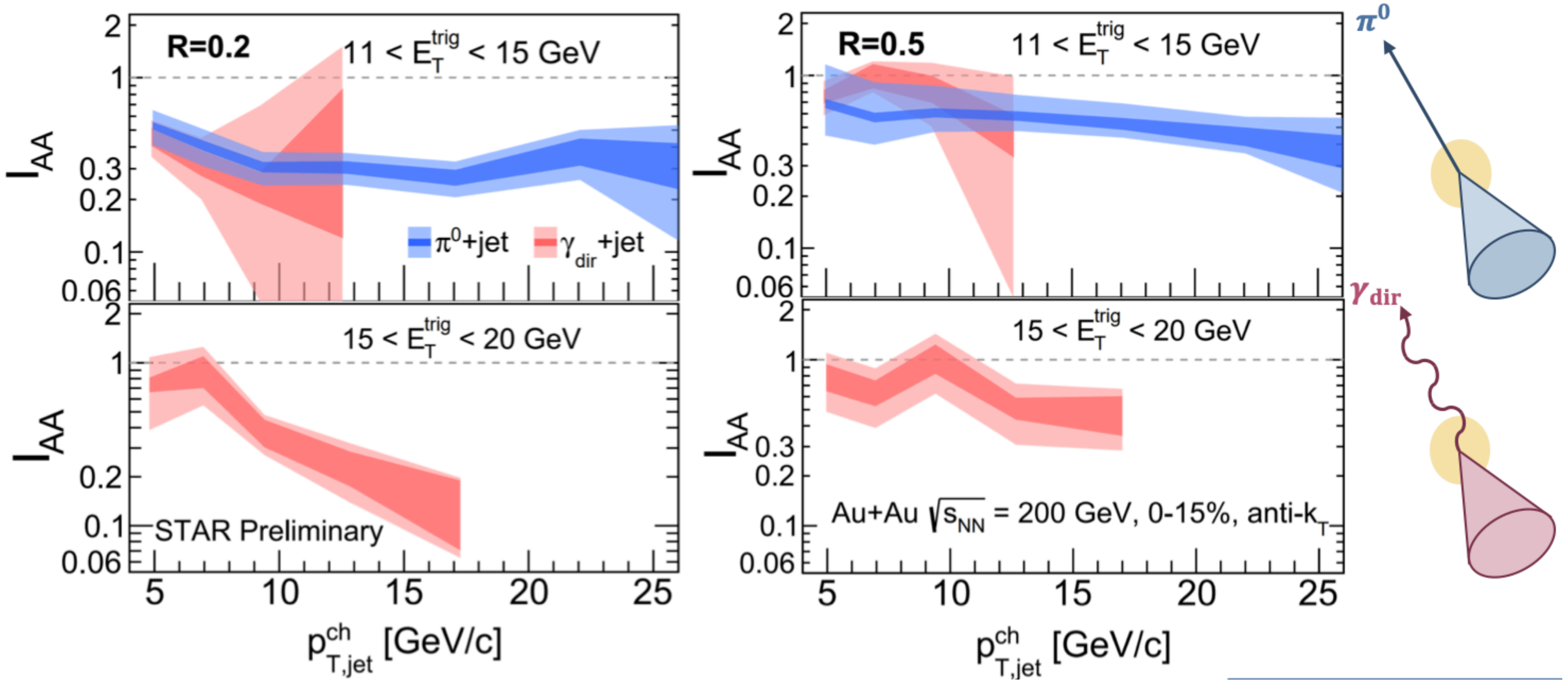
Suppression of high momentum hadrons

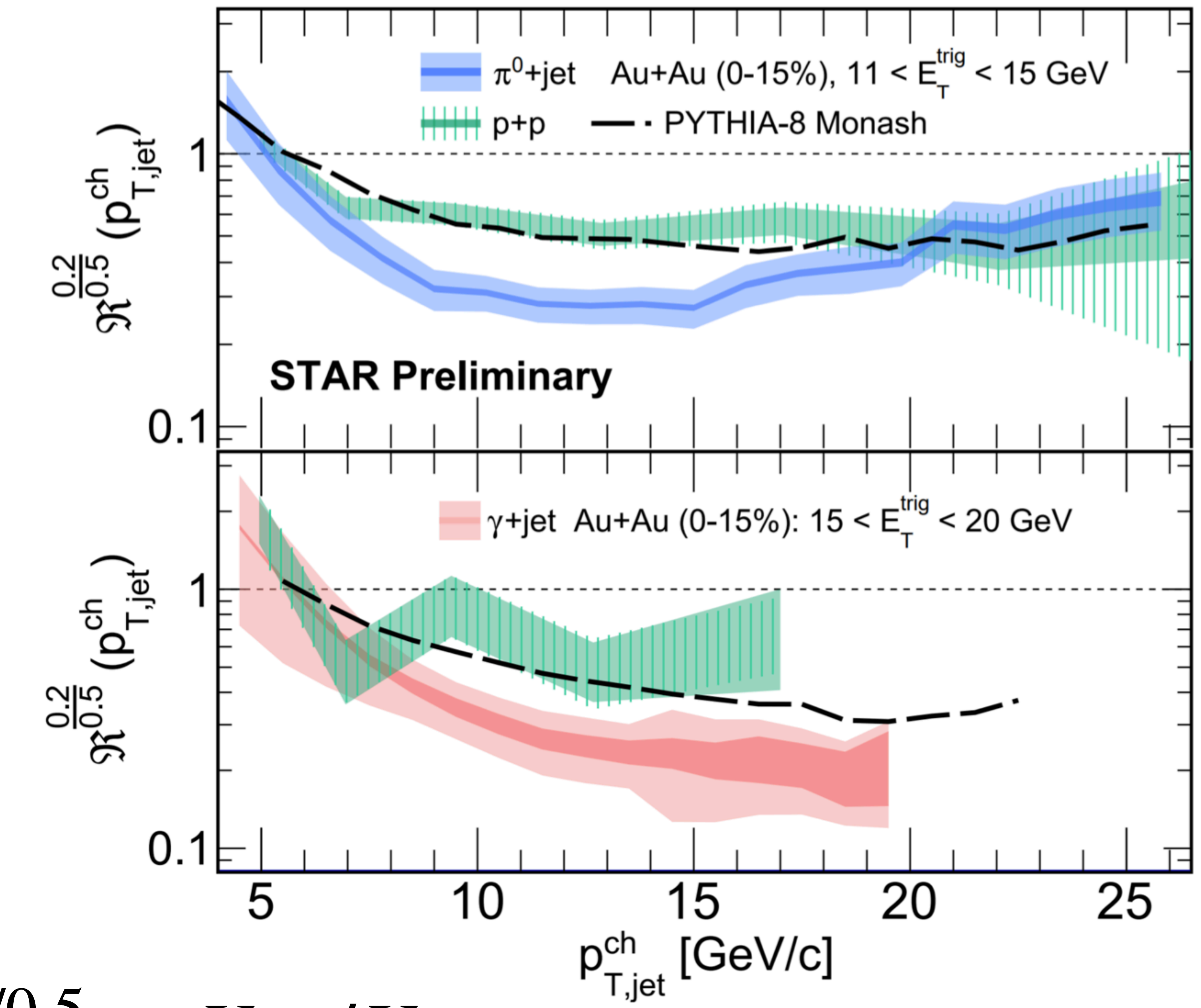
Enhancement most pronounced at large angles for lower p_T hadrons

- $D_{AA} > 0$ enhancement; $D_{AA} < 0$ suppression

Hadrons recoiling from high$-p_T$ trigger: γ^{dir}/π^0-jet correlations by STAR

arXiv:2212.09202 ▸ *Derek Anderson's Talk*





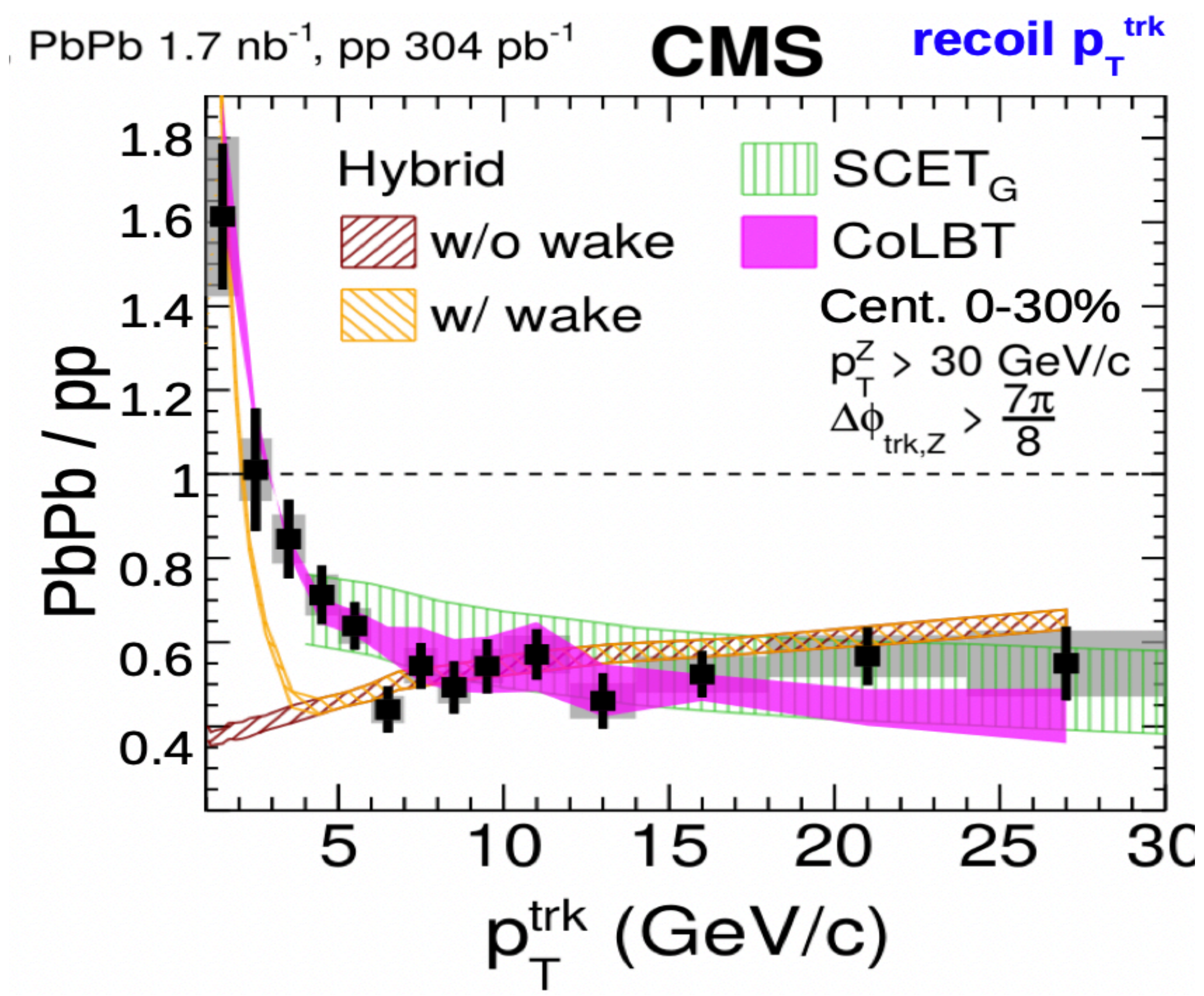
- I_{AA} = **ratio of yields in AA over the one in pp**
  - ***R* = 0.2 more suppressed than 0.5** :
    indication of energy redistributed to wide angles
- $R^{0.2/0.5} = Y_{0.2}/Y_{0.5}$
- $R^{0.2/0.5} < 1$ in pp due to **jet shape in the vacuum**
- $R^{0.2/0.5}$ in Pb—Pb significantly lower than in pp

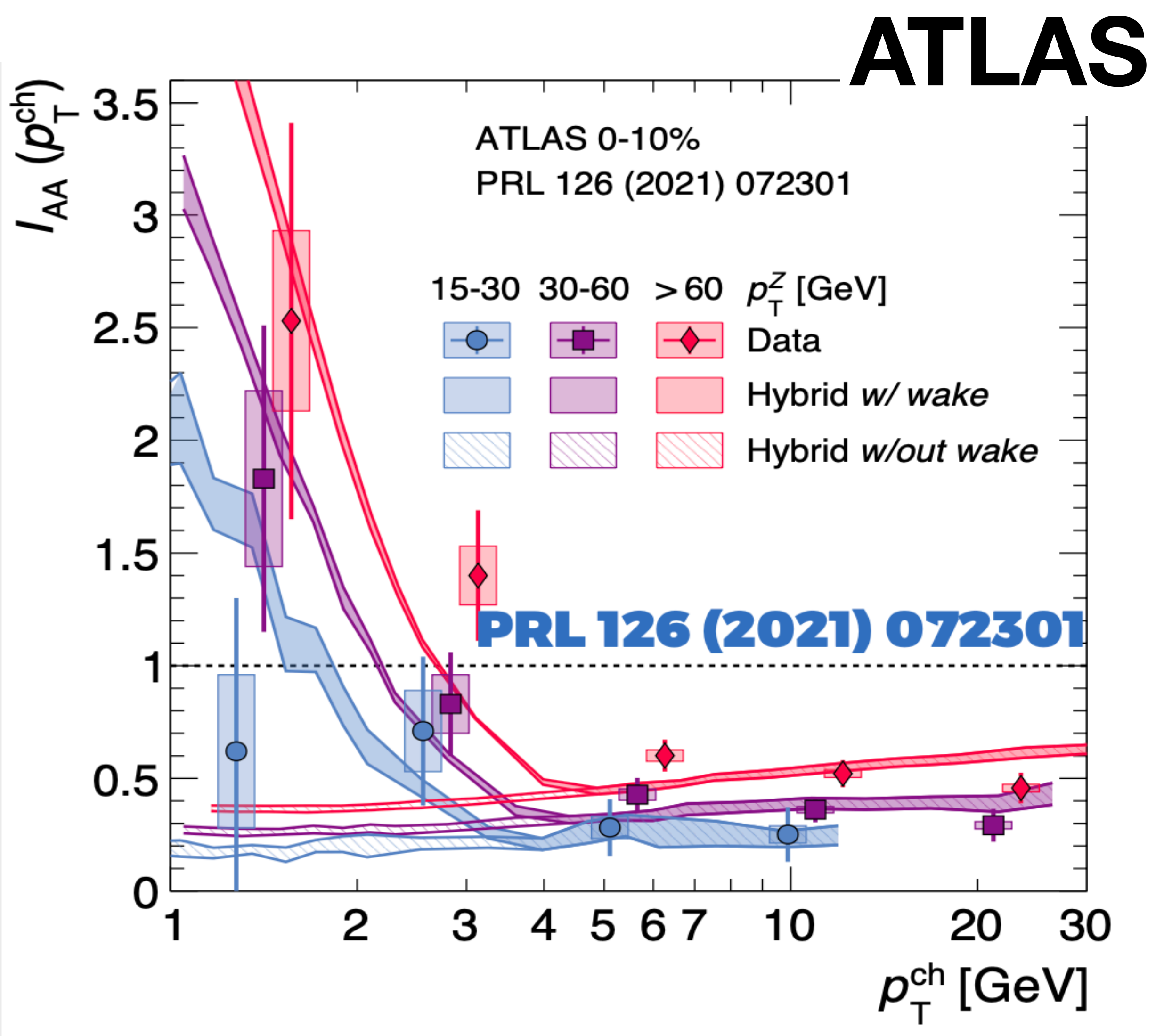
- In Au—Au suppression wrt to pp: observation of significant medium-induced intra-jet broadening

Hadrons recoiling from high-p_T trigger: different models for studying recoil jet

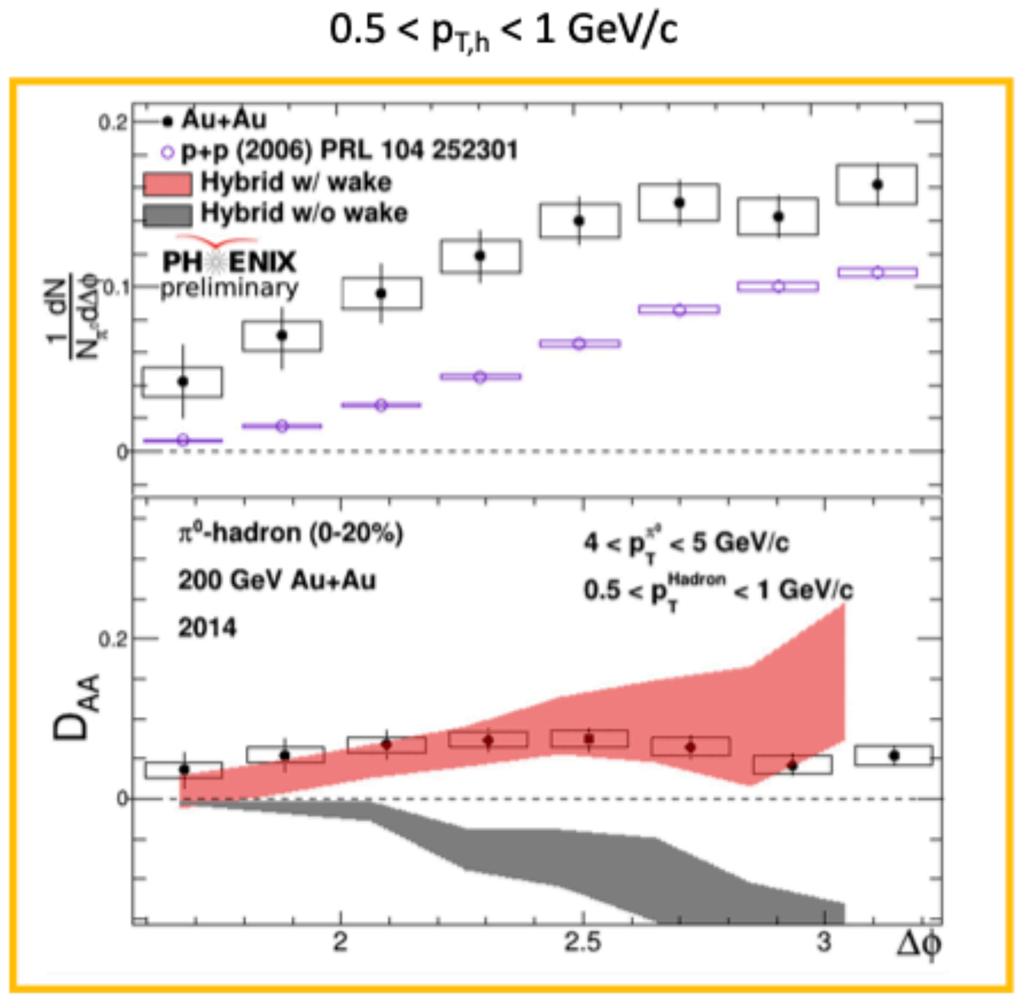
- *Kaya Katar's Talk*
- *Christopher McGinn's Talk*
- *Megan Connors's Talk*

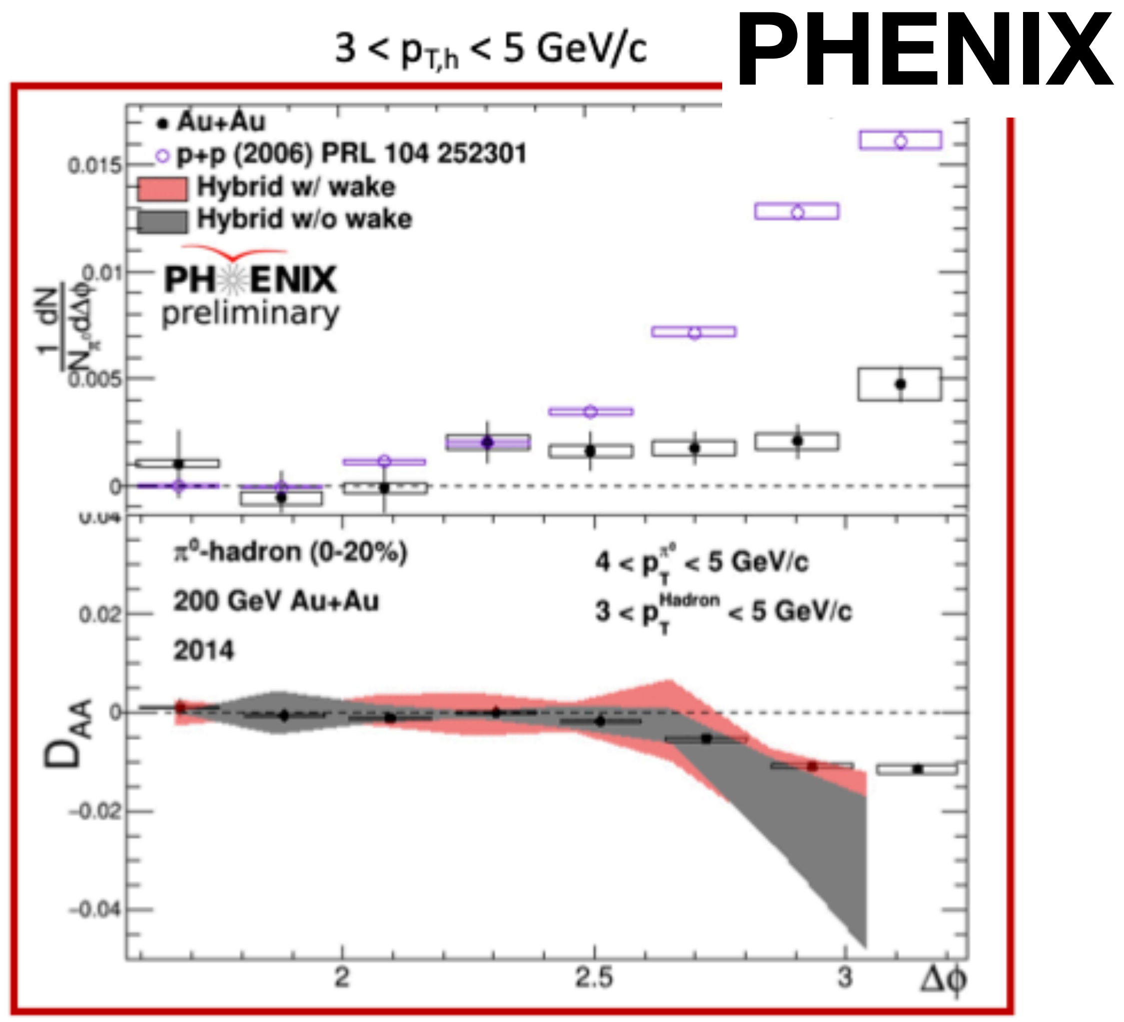
Z—hadron correlations in Pb—Pb @ 5.02 TeV





γ^{dir}—hadron correlations in Au—Au @ 200 GeV





- **CoLBT**: feeds quenched jet energy into hydrodynamics evolution

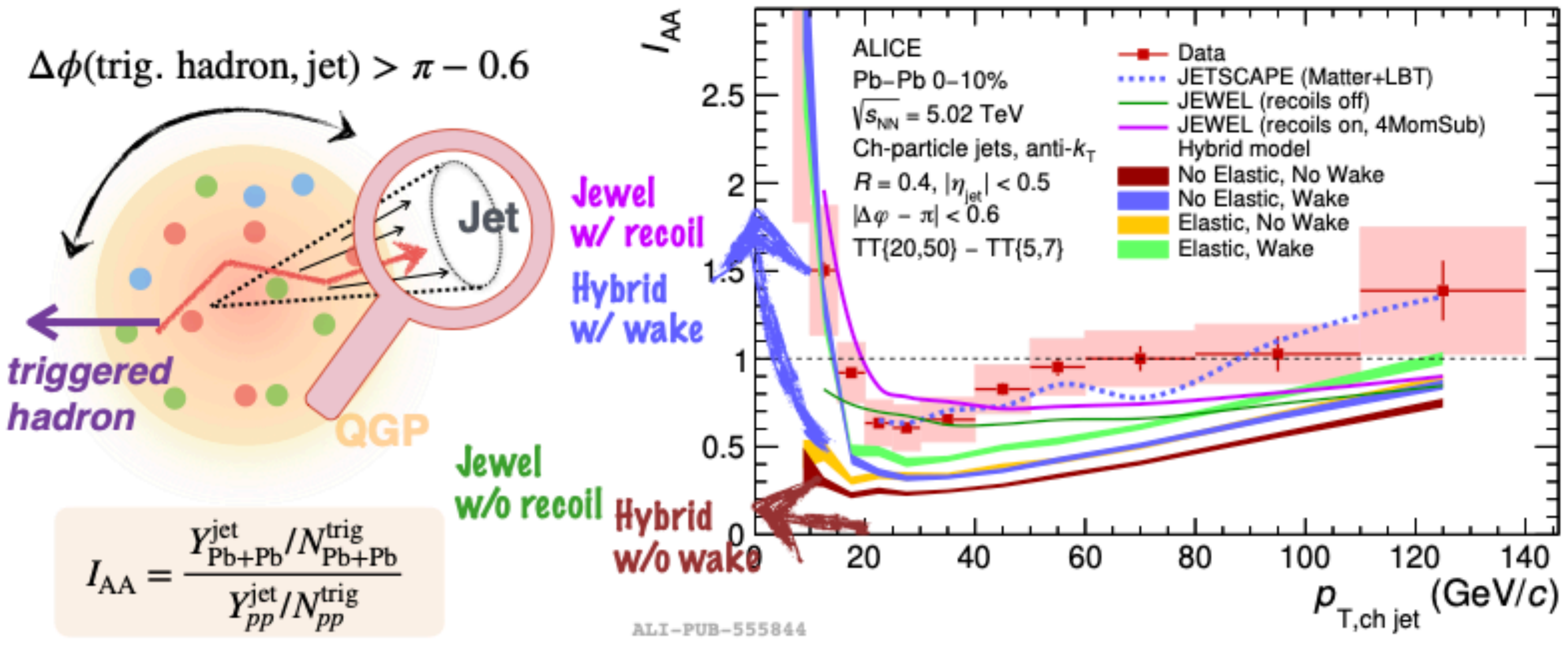
  Consistent with data both for low-p_T and high-p_T

- **Hybrid model w/ wake (include medium response)** qualitatively describes rising trend at low p_T (recoil as the parton passes through)
- **Hybrid model w/out wake (no medium response)** not describes the low p_T

Hadrons recoiling from high-p_T trigger: hadron—jet measurement by ALICE

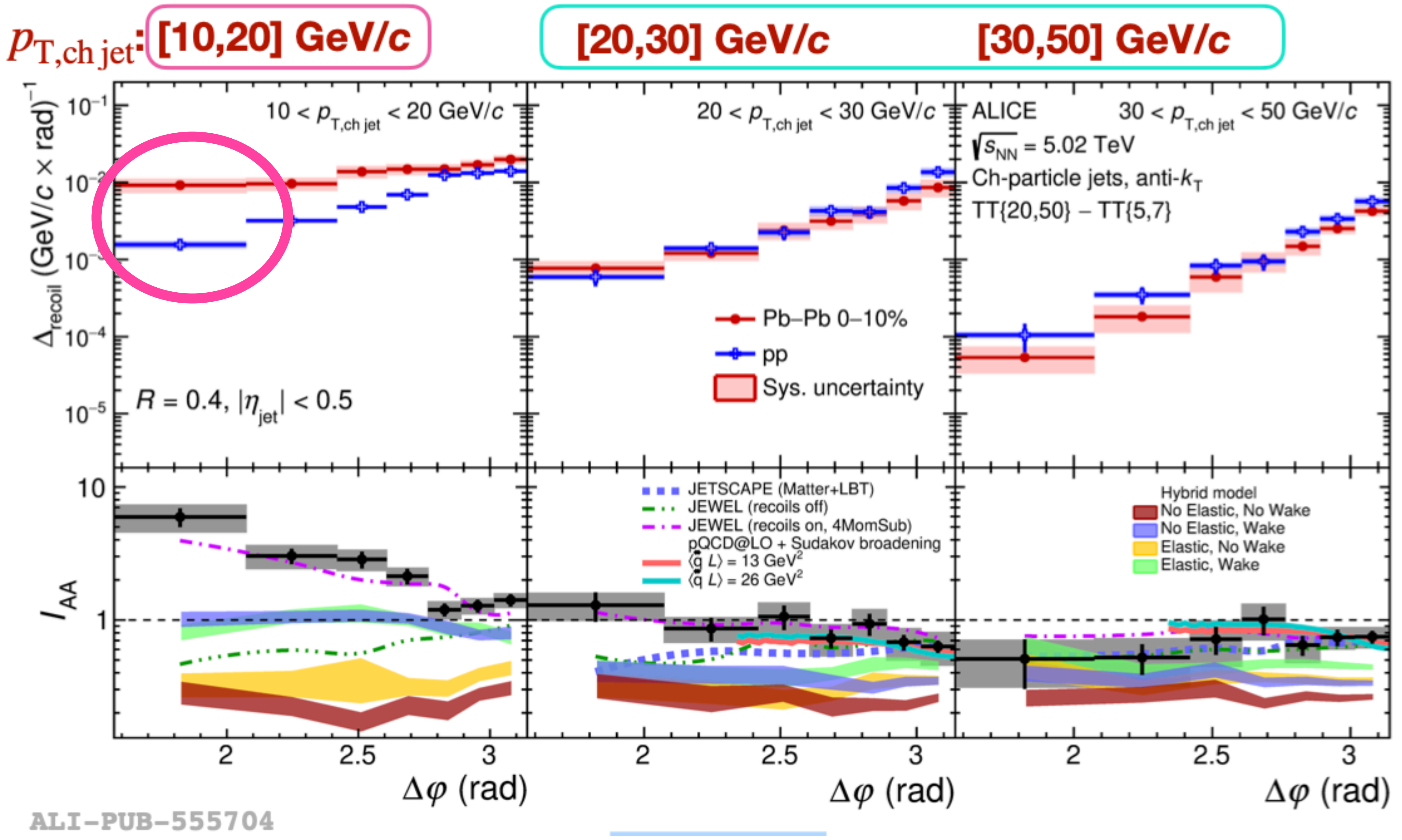
- Jaime Norman's Talk
- Yongzhen Hou's Talk HP23

Measure trigger-normalised yield of charged-particle jets recoiling from high-p_T trigger hadrons



$$I_{AA} = \frac{Y^{jet}_{Pb+Pb}/N^{trig}_{Pb+Pb}}{Y^{jet}_{pp}/N^{trig}_{pp}}$$

Transverse momentum $p_{T,jet}$ of recoil jet → energy loss



- Increase of correlated yield of soft structures $p_{T,\,jet}$< 20 GeV/c
- Suppression at 20 < $p_{T,\,jet}$< 80 GeV/c jet energy loss
- Rising trend with $p_{T,\,jet}$:

  less trigger surface bias when $p_{T,\,jet} >> p_{T,\,trig}$
- Difference between models w/ and w/o medium response
- Data described by Hybrid w/ wake, JEWEL w/ recoil

Opening angle $\Delta\varphi$ of jet relative to trigger axis → jet acoplanarity

- No broadening for [20,500] GeV/c
- Significant broadening for [10,20] GeV/c
- JEWEL w/ recoil captures all features of data

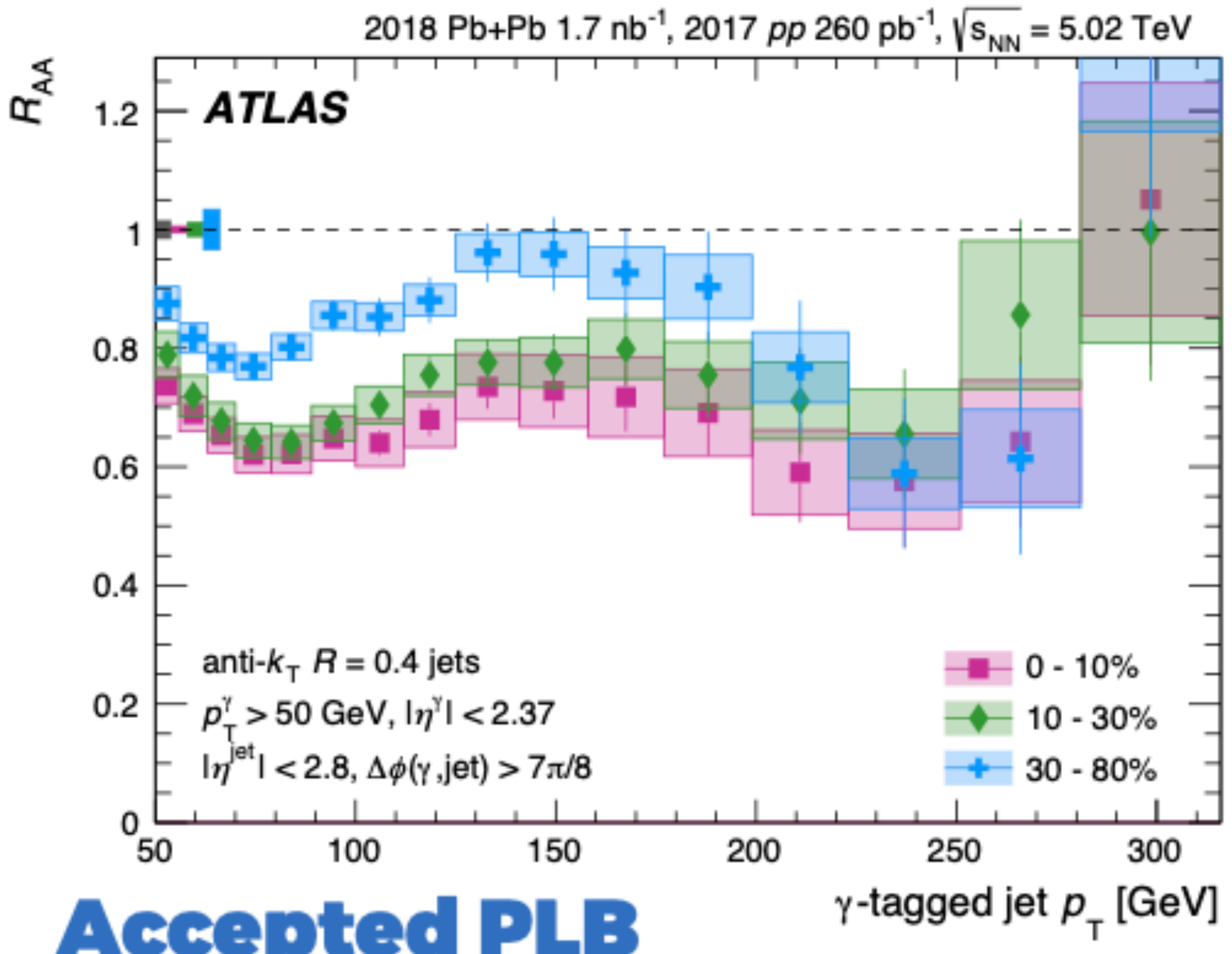
Hadrons recoiling from high-p_T trigger: γ-jet R_{AA} by ATLAS

arXiv:2008.09811

Christopher McGinn's Talk

Comparing photon-tagged jet R_{AA} and inclusive jet R_{AA}, one can see sensitivity to colour charge

Centrality ordered suppression: 0-10% most suppressed



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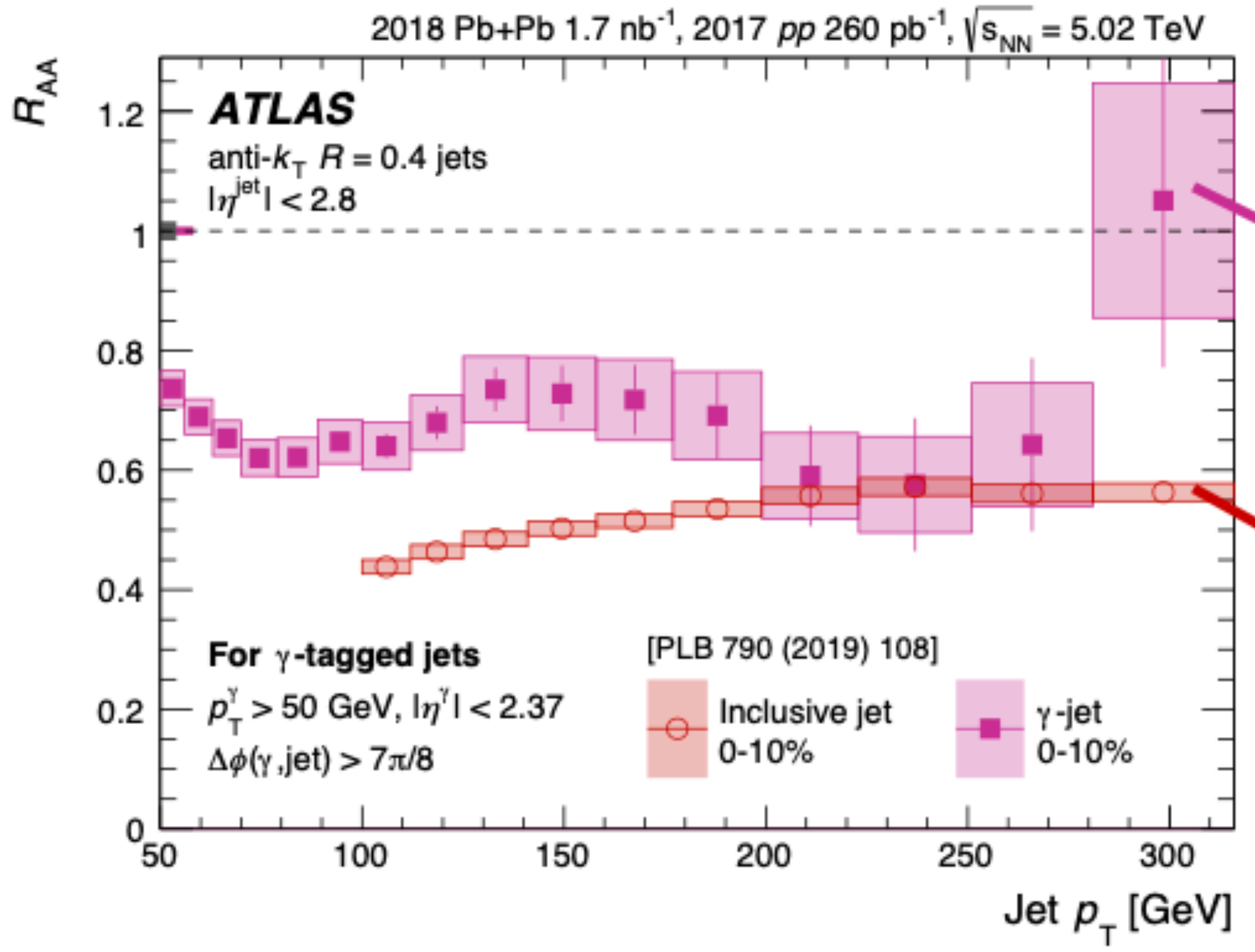
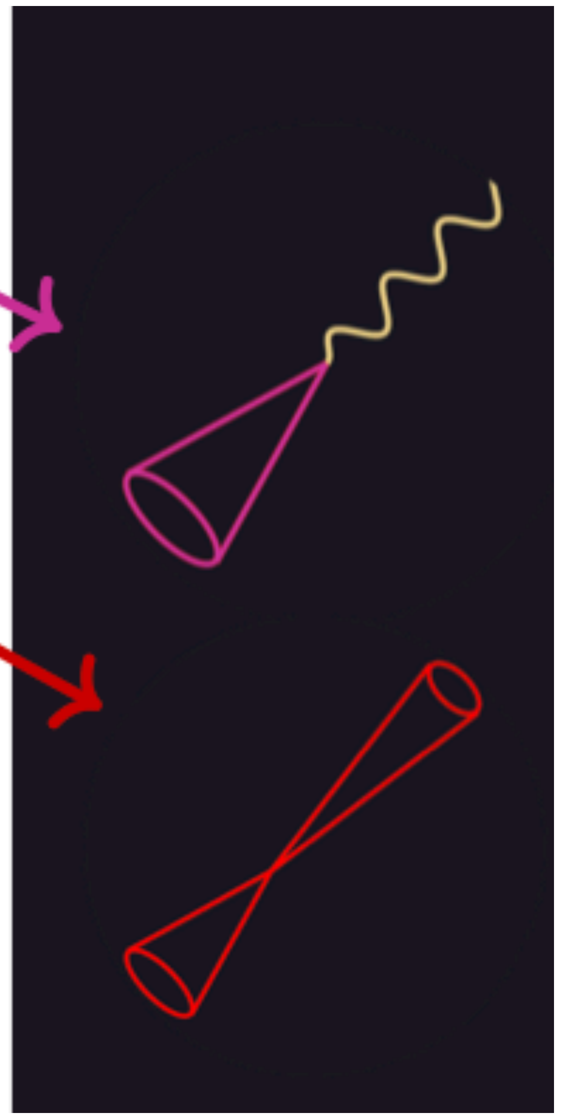




0-10% γ-tagged jet R_{AA}> inclusive jet R_{AA}

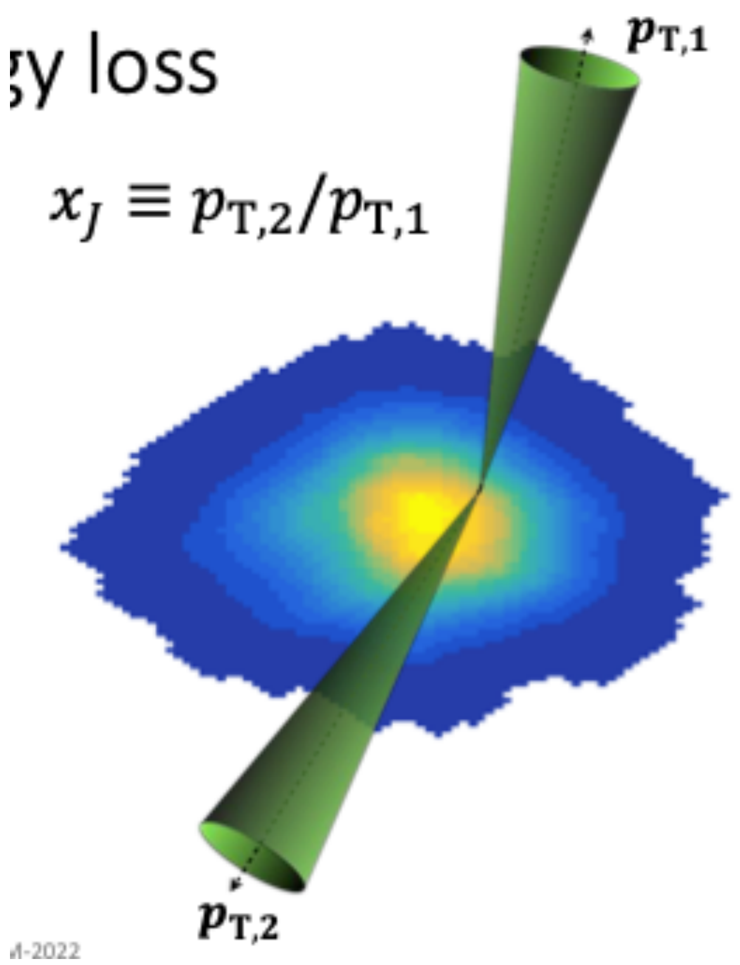
Different quark/gluon fraction

RAA of γ-tagged jets are higher than the one of inclusive jets by ~0.15 in central collisions

Indicate more energy loss of gluon-initiated jets compared to quark-initiated jets

Dijets: jet correlations by ATLAS

‣ Timothy Rinn's Talk



- Jet suppression and "quenching" in QGP characterised with nuclear modification factor R_{AA}
- Jet energy loss in the QGP observed to fluctuate:
  - Back-to-back jet pairs provide access to *asymmetric energy loss*
  - $x_j = \frac{p_T^{\text{subleading}}}{p_T^{\text{leading}}}$ $\qquad \frac{1}{N_{evt}\langle T_{AA}\rangle}\frac{dN_{pair}}{dx_J}$
  - Absolutely normalised x_j distribution provides insight into the dynamics of dijet energy loss

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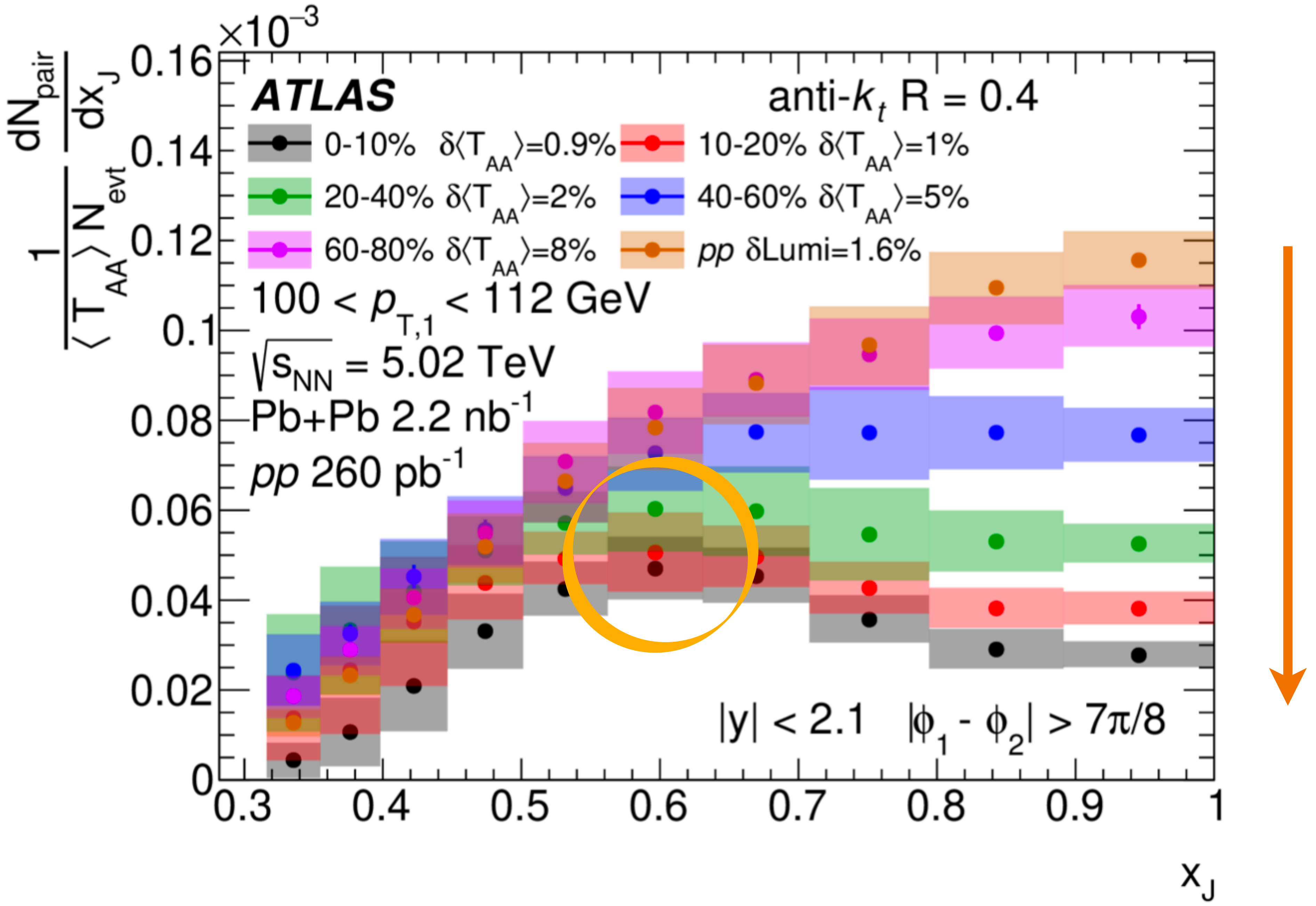
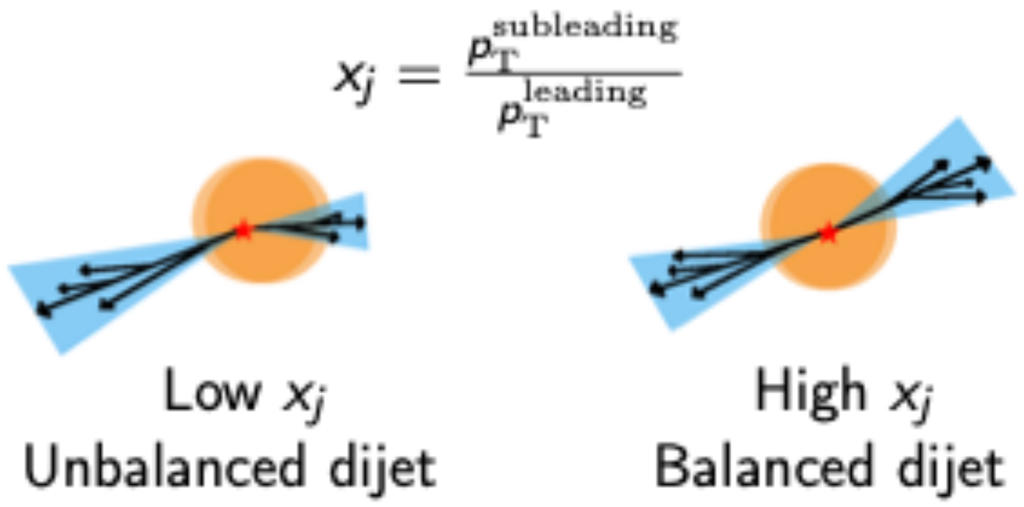




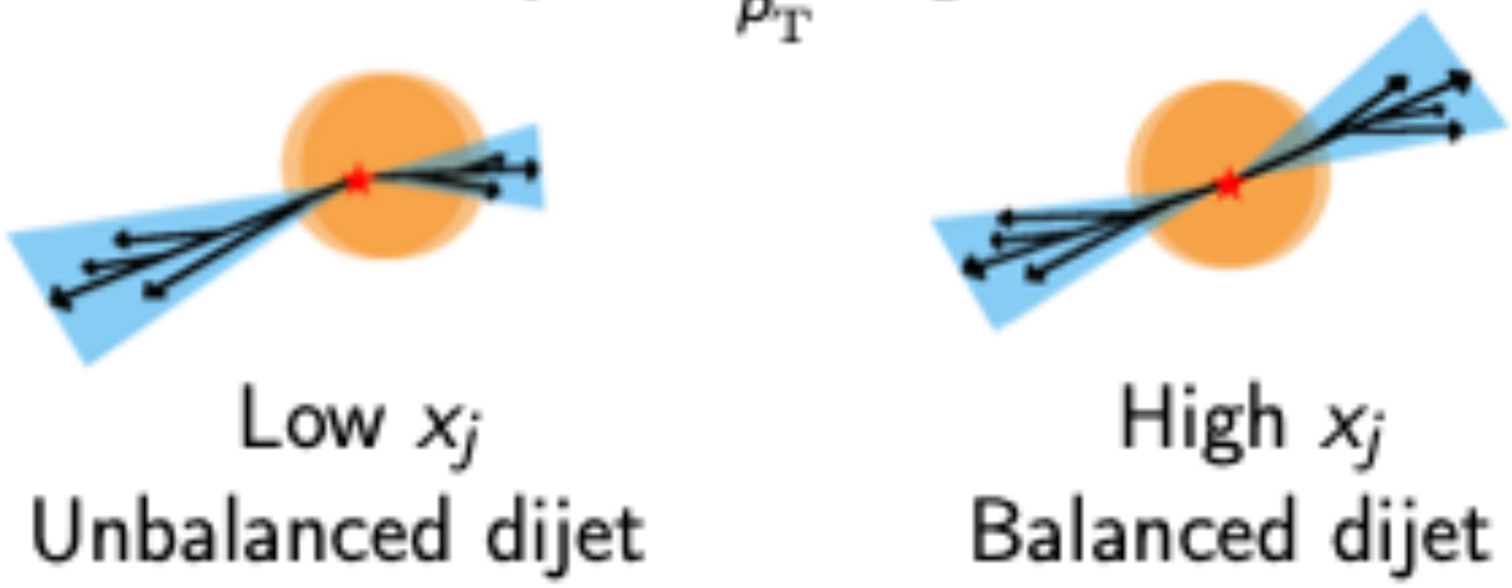
- Peak structure at intermediate x_j due to the suppression of symmetric dijets
- Suppression of balanced jets and enhancement of imbalanced jets with respect to pp collisions
- suppression of balanced dijets evolves with centrality

Dijets: Jet to charged-particle angular correlations by CMS

Dijets can provide more information than inclusive jets:

- More sensitive to fluctuations in the energy loss
- Put more constraints on path-length dependence

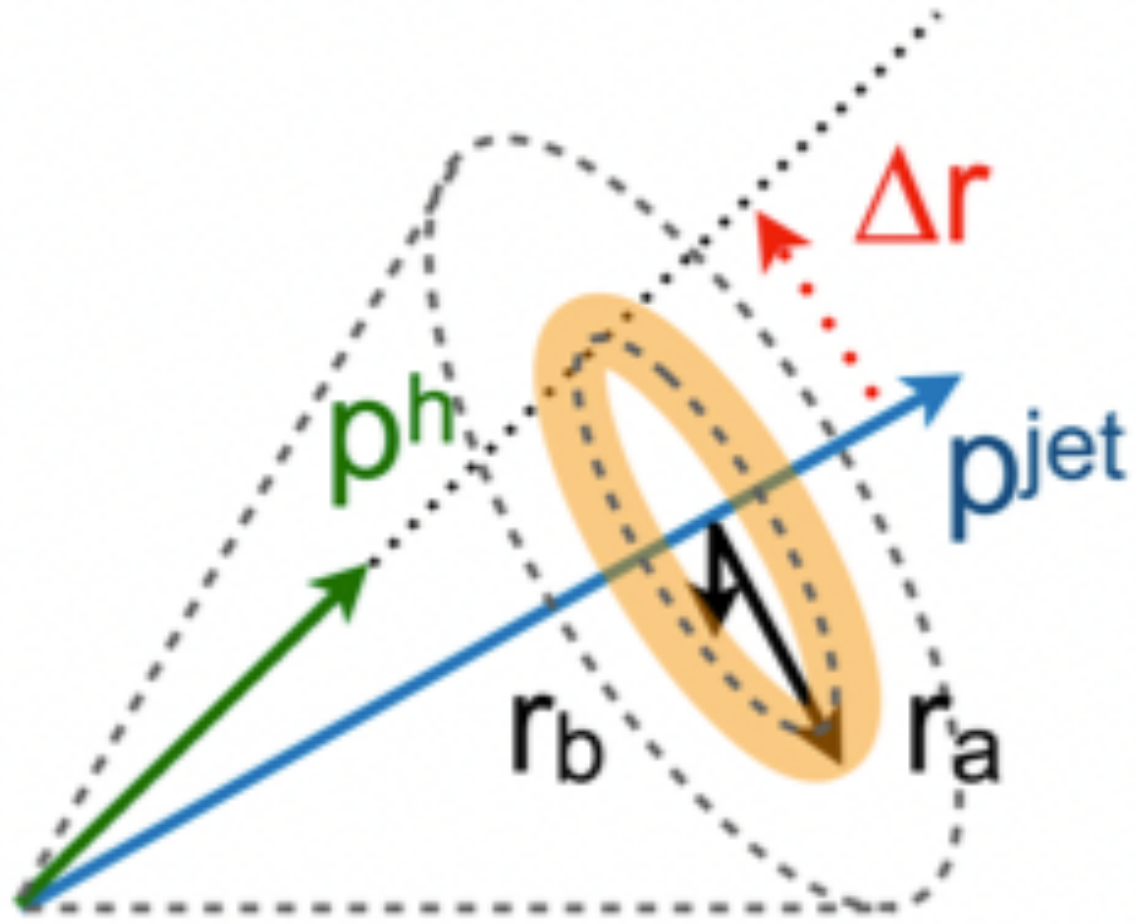
$$x_j = \frac{p_{\mathrm{T}}^{\mathrm{subleading}}}{p_{\mathrm{T}}^{\mathrm{leading}}}$$



Jet shape = radial momentum density profile of the jet

transverse momentum weighted distribution of particles around the jet axis, ra and rb define the annular edge

- [Jussi Viinikainen's Talk]

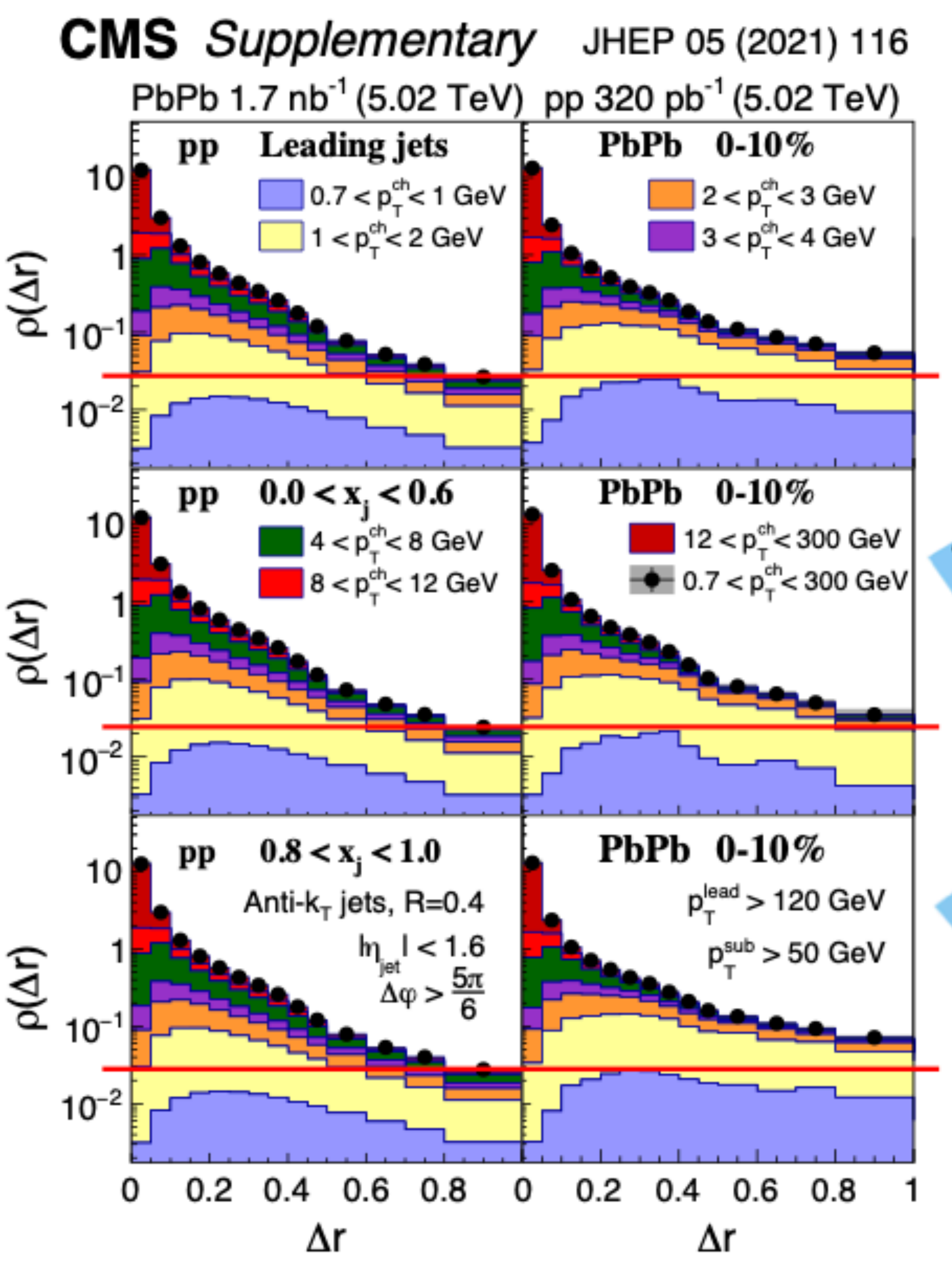


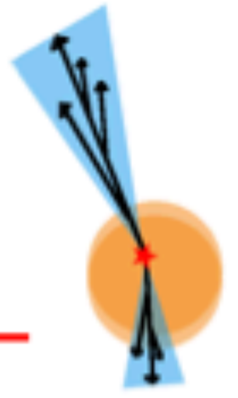
$$\rho(\Delta r) = \frac{1}{\delta r}\frac{1}{N_{\mathrm{jets}}}\sum_{\mathrm{jets}}\frac{\sum_{\mathrm{track}\in(r_a,r_b)} p_{\mathrm{T}}^{\mathrm{track}}}{p_{\mathrm{T}}^{\mathrm{jets}}}$$

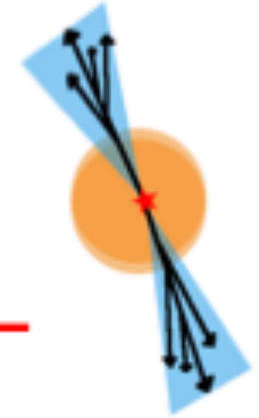
$$\Delta r = \sqrt{(\varphi_{\mathrm{jet}} - \varphi_{\mathrm{track}})^2 + (\eta_{\mathrm{jet}} - \eta_{\mathrm{track}})^2}$$

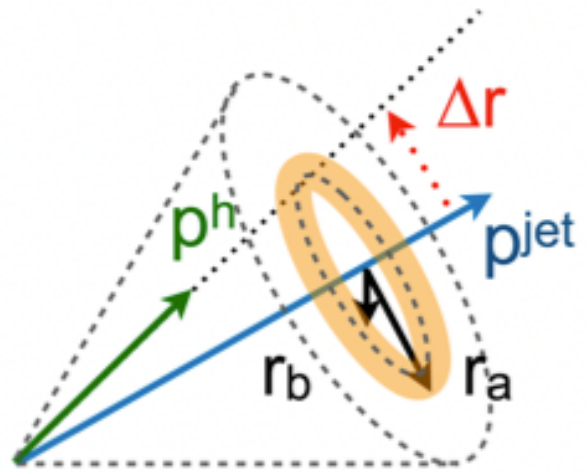
Radial profile: leading jets with CMS

Jussi Viinikainen's Talk





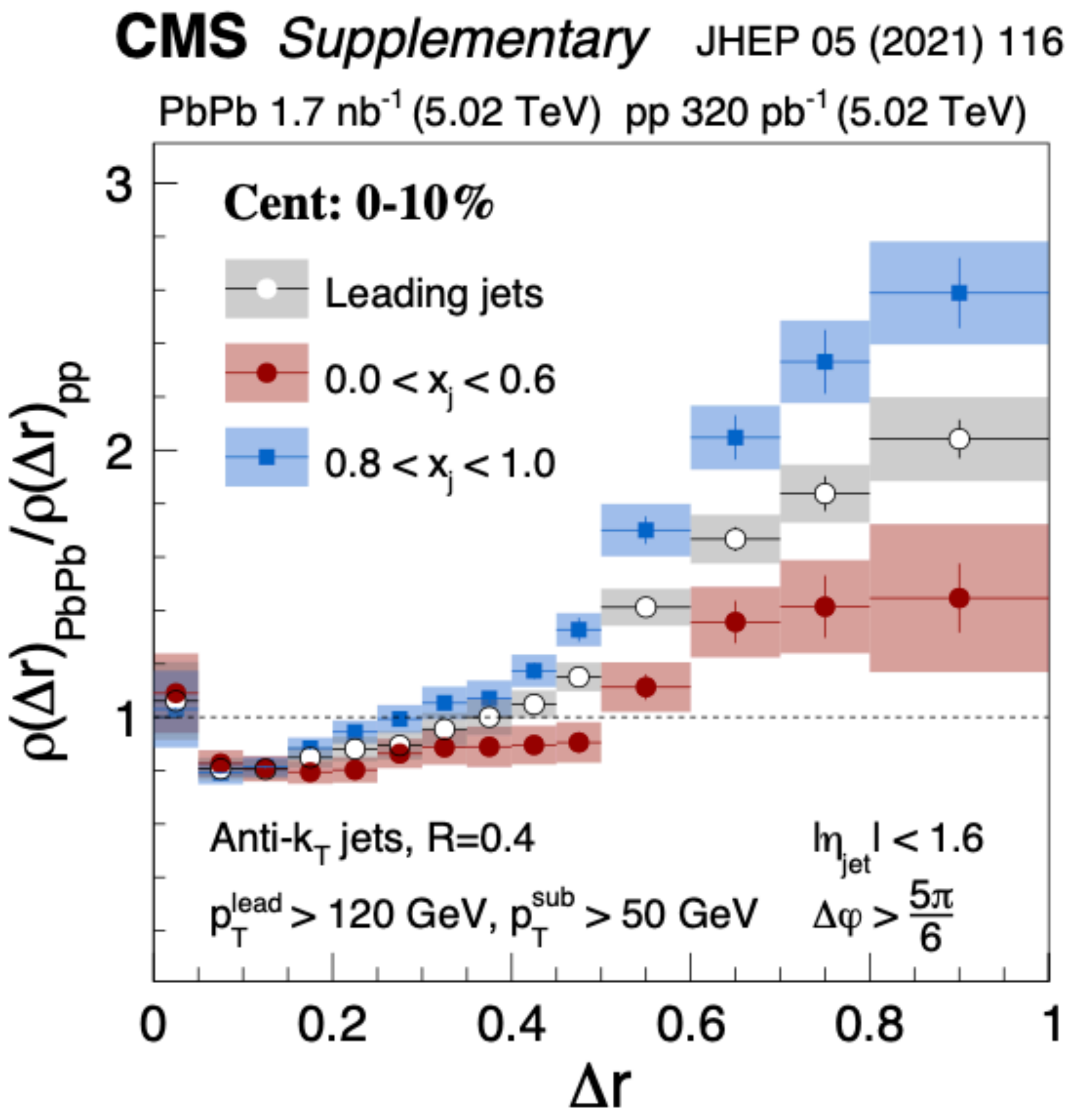


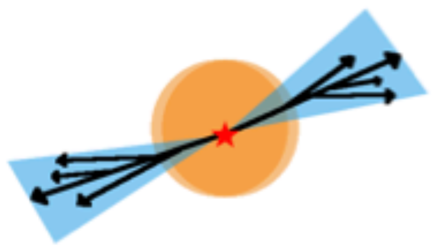


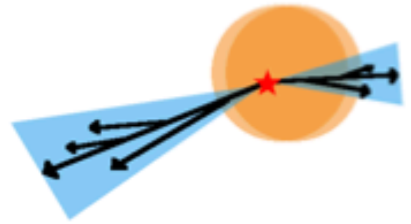
$$\rho(\Delta r) = \frac{1}{\delta r}\frac{1}{N_{\text{jets}}}\sum_{\text{jets}}\frac{\sum_{\text{track}\in(r_a,r_b)} p_T^{\text{track}}}{p_T^{\text{jets}}}$$

$$\Delta r = \sqrt{(\varphi_{\text{jet}} - \varphi_{\text{track}})^2 + (\eta_{\text{jet}} - \eta_{\text{track}})^2}$$

- Shapes wider in central PbPb compared to pp
- Widening is due to low-pT particles at large radii
- Differences between x bins best seen in a ratio plot





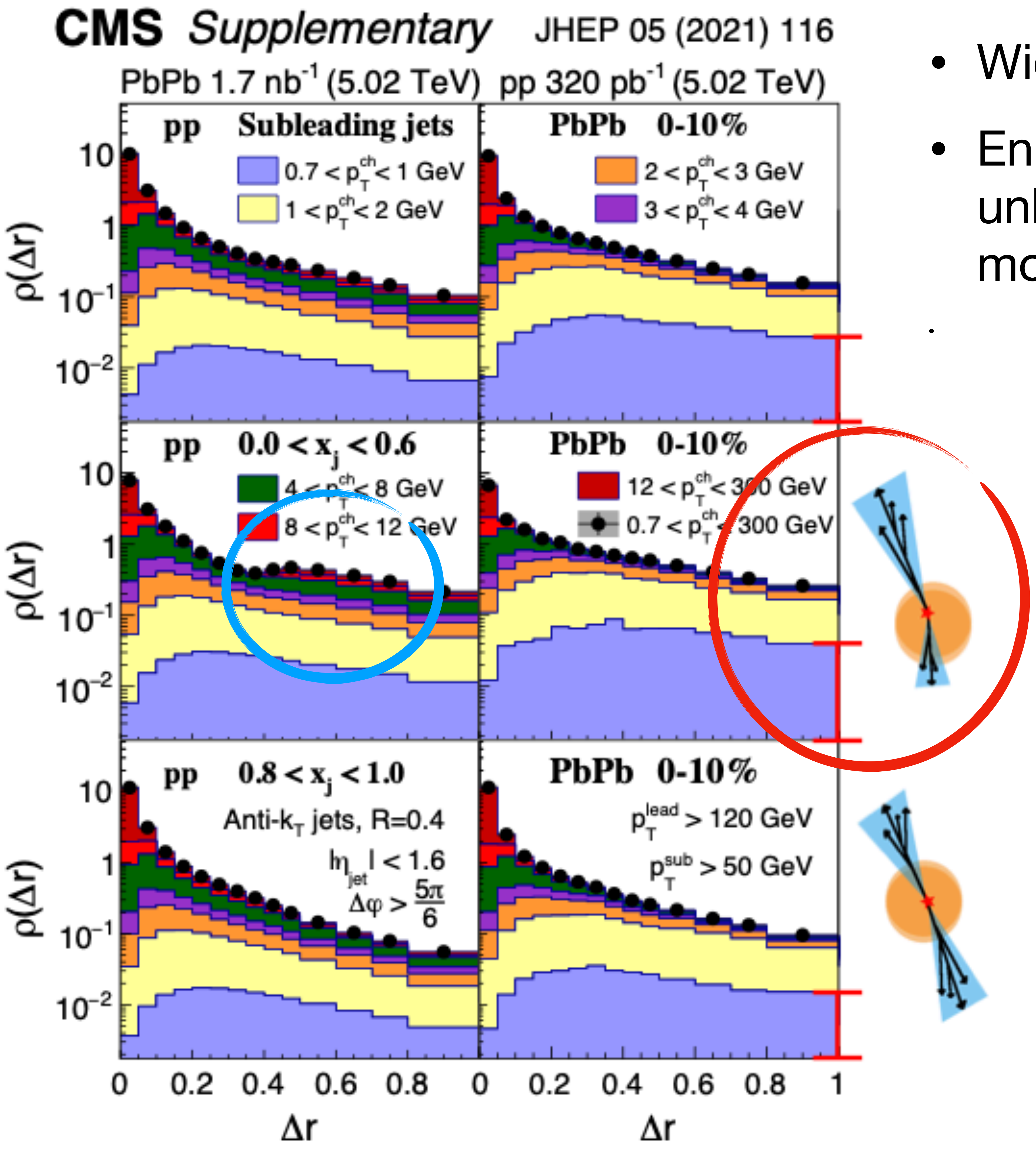


Modifications are the greatest in balanced events

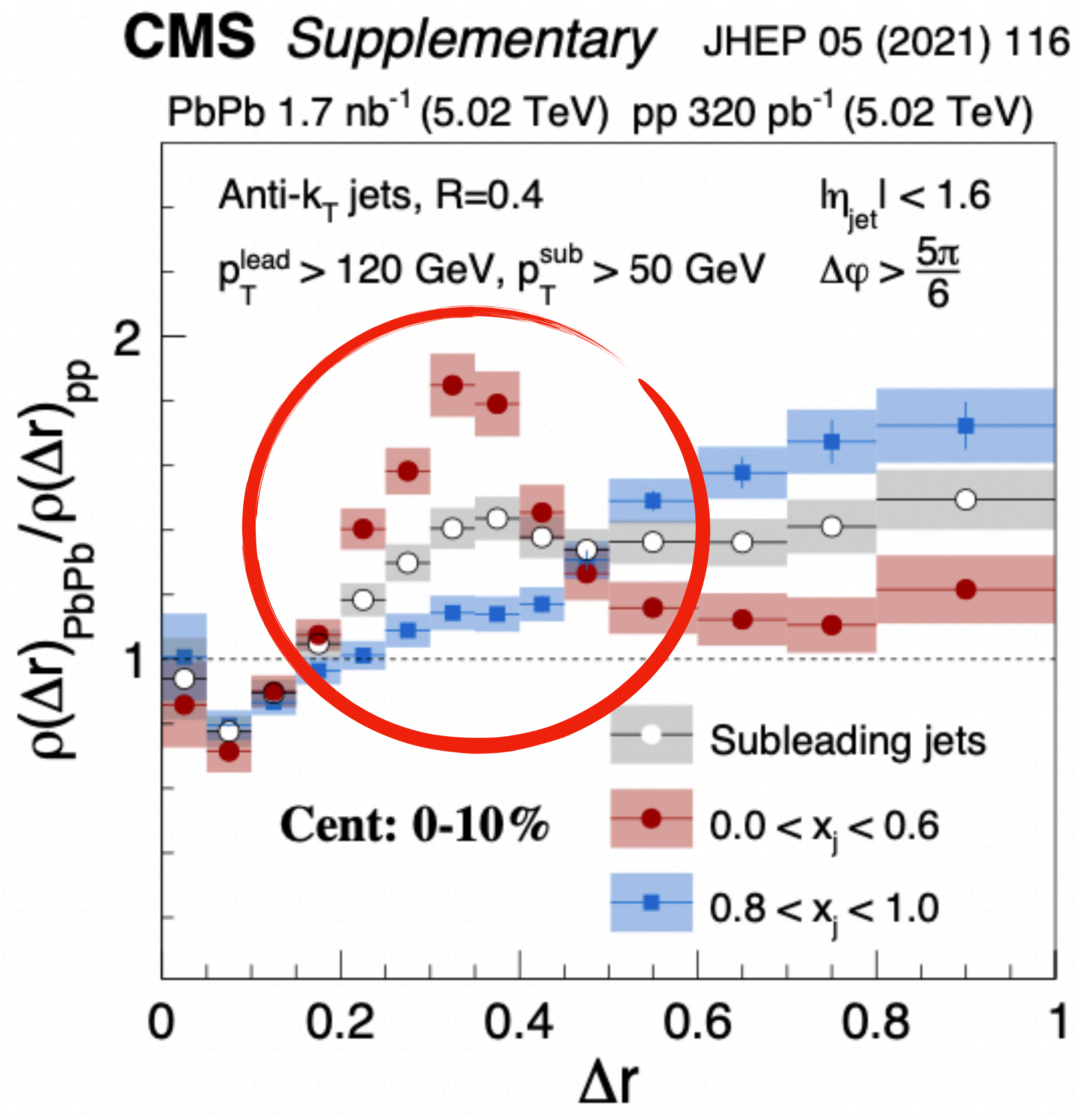
Consistent with expectation that unbalanced events caused by energy loss fluctuations or surface bias

Radial profile: subleading jets with CMS

Jussi Viinikainen's Talk



- Widening is greatest in unbalanced events
- Enhancement of high-pT particles outside of jet cone in unbalanced pp events: third jet likely needed to produce the momentum imbalance in pp

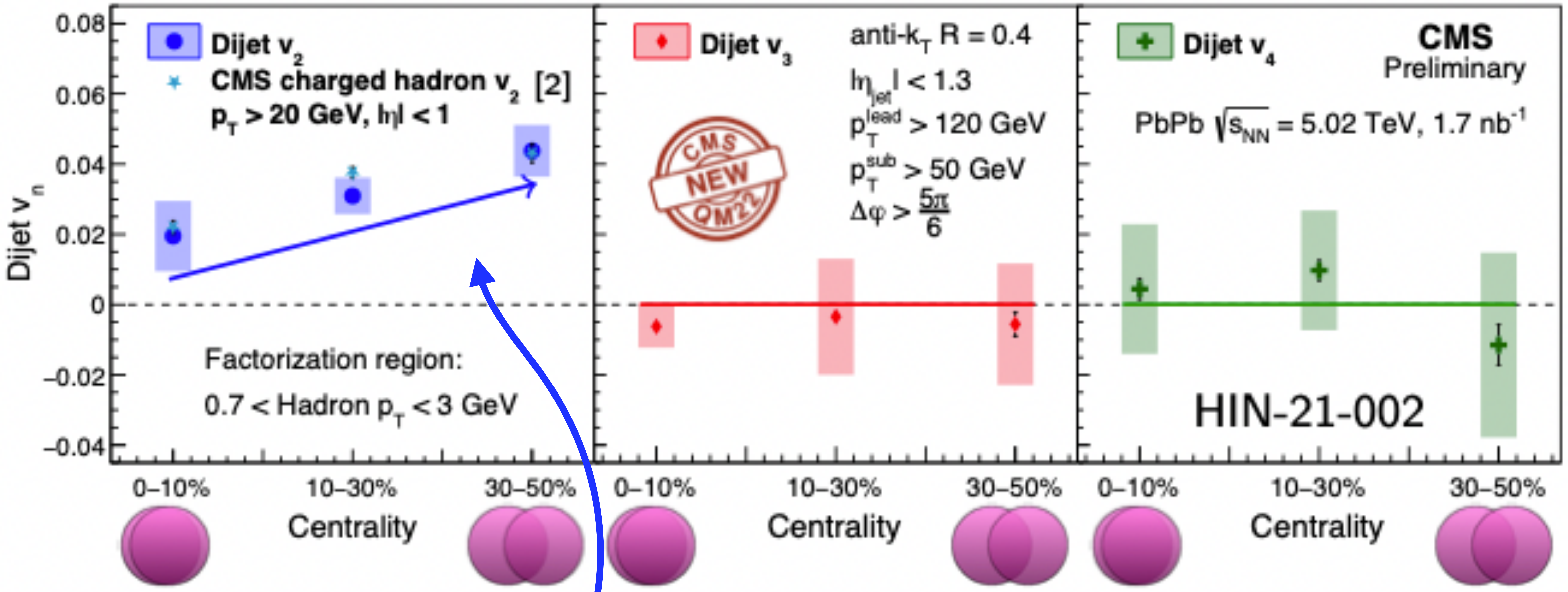


- Biggest modifications in unbalanced events
- Results consistent with hypothesis that the unbalanced events are more surface biased → subleading jet larger distance in plasma than leading jet

Dijet sensitive to path length: CMS vs ATLAS

- [Jussi Viinikainen's Talk]

Dijet



- [Anne Sickles's Talk]

Inclusive jet

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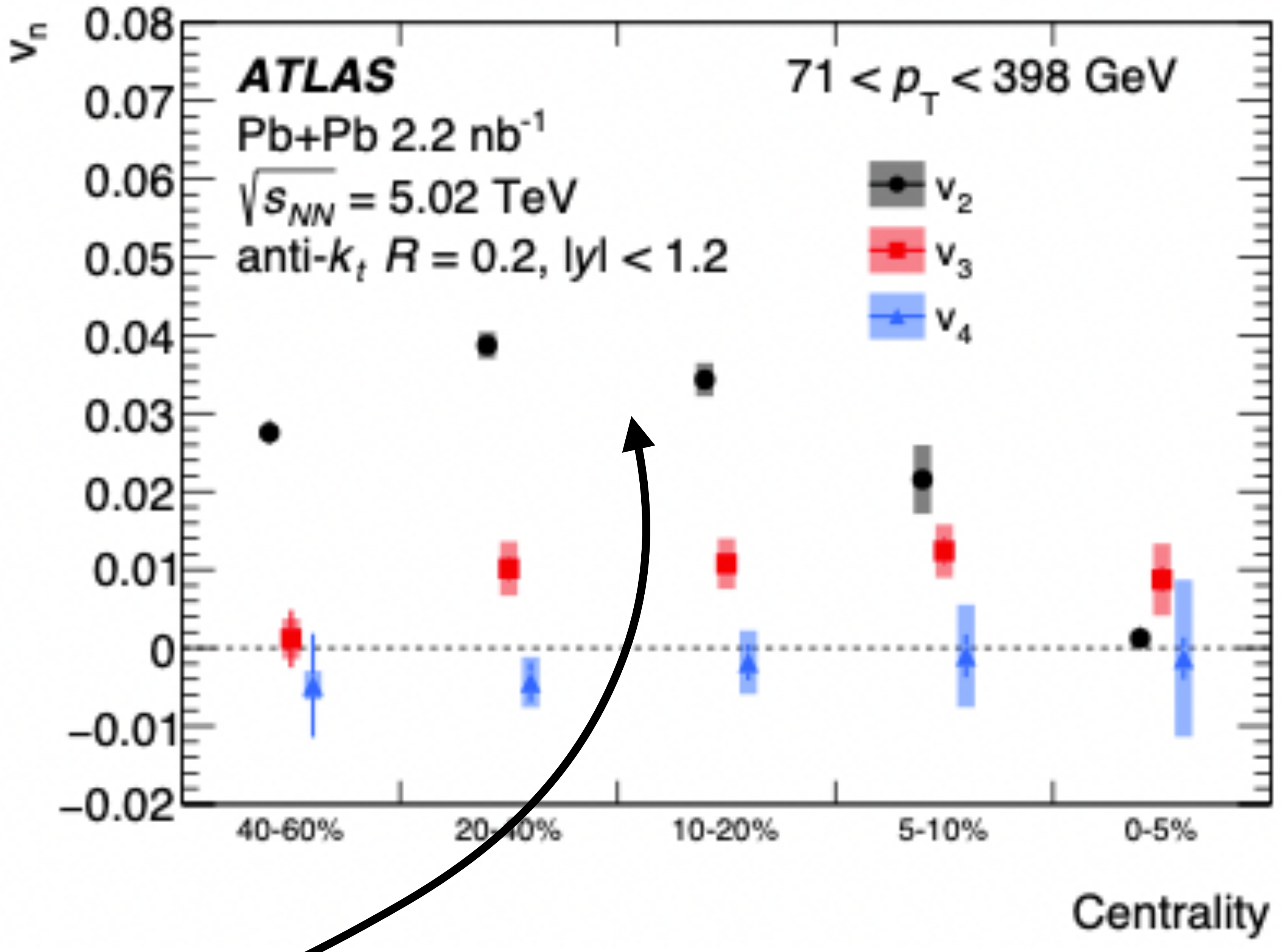
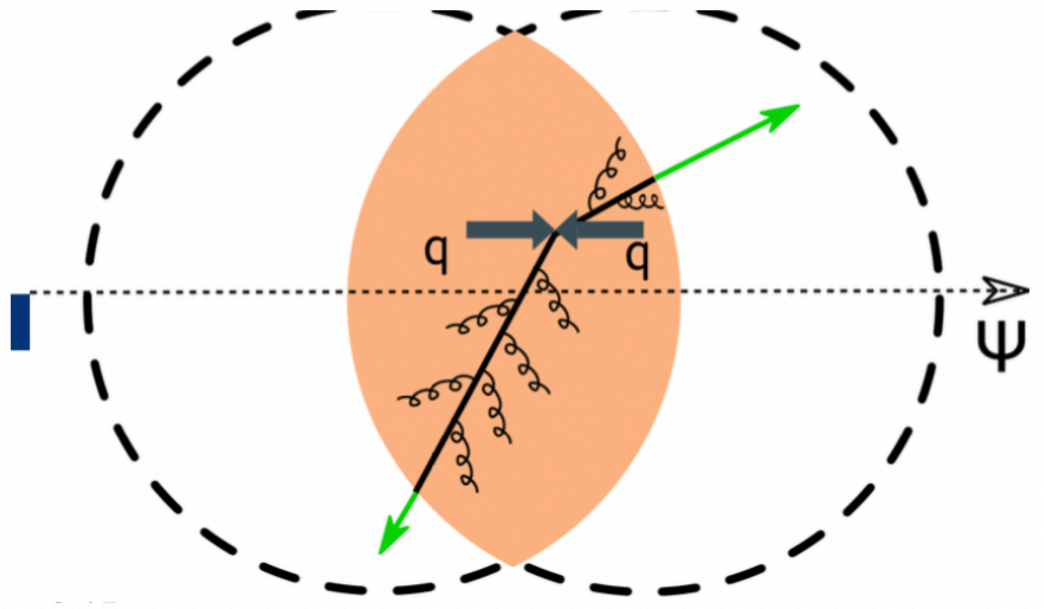


- v_2 increases towards more peripheral events
- More different path-lengths for *more almond-like initial geometry*
- v_3 consistent with zero for dijets and positive for inclusive
- v_4 compatible with zero →No measurable impact from medium density fluctuations

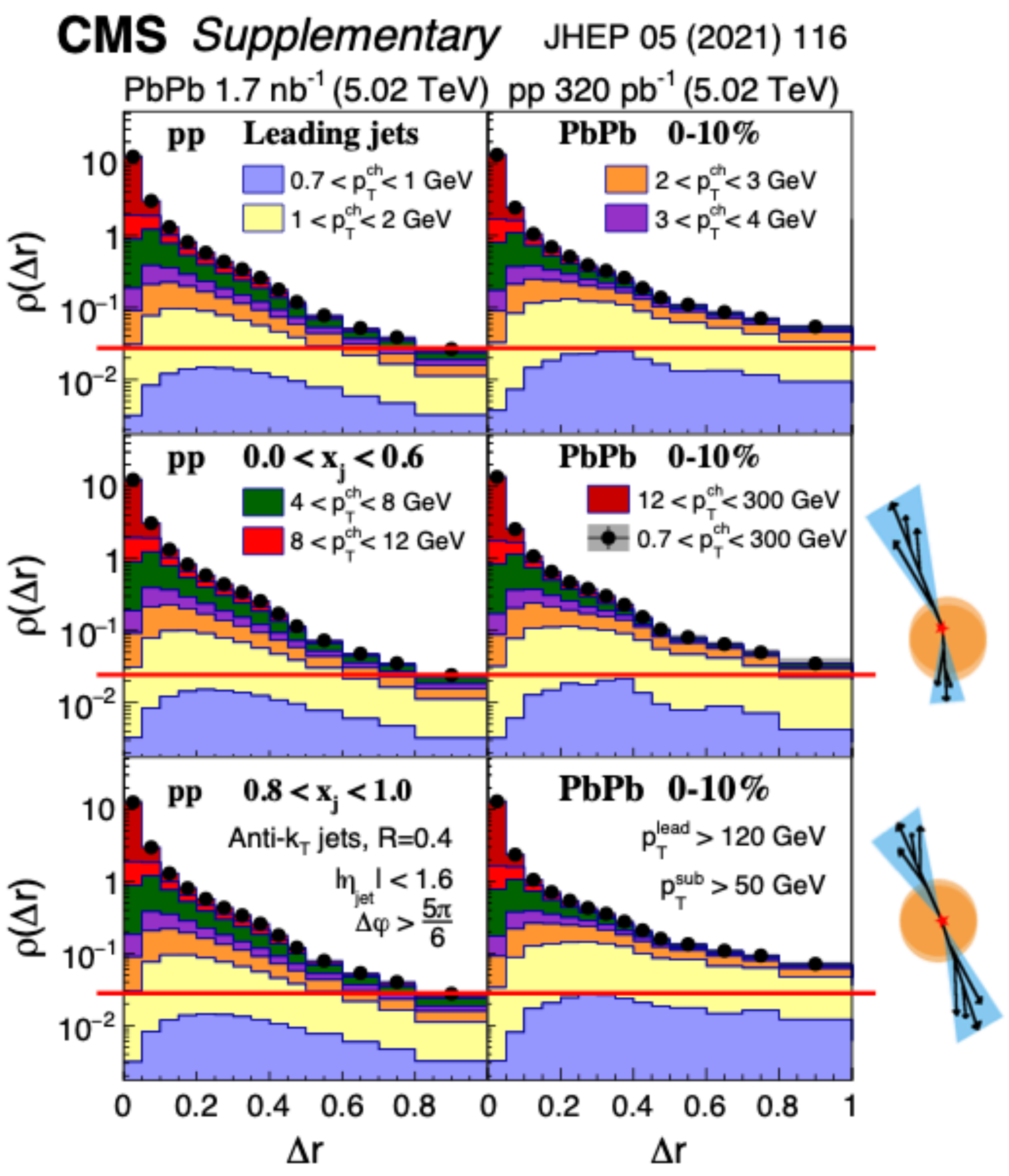


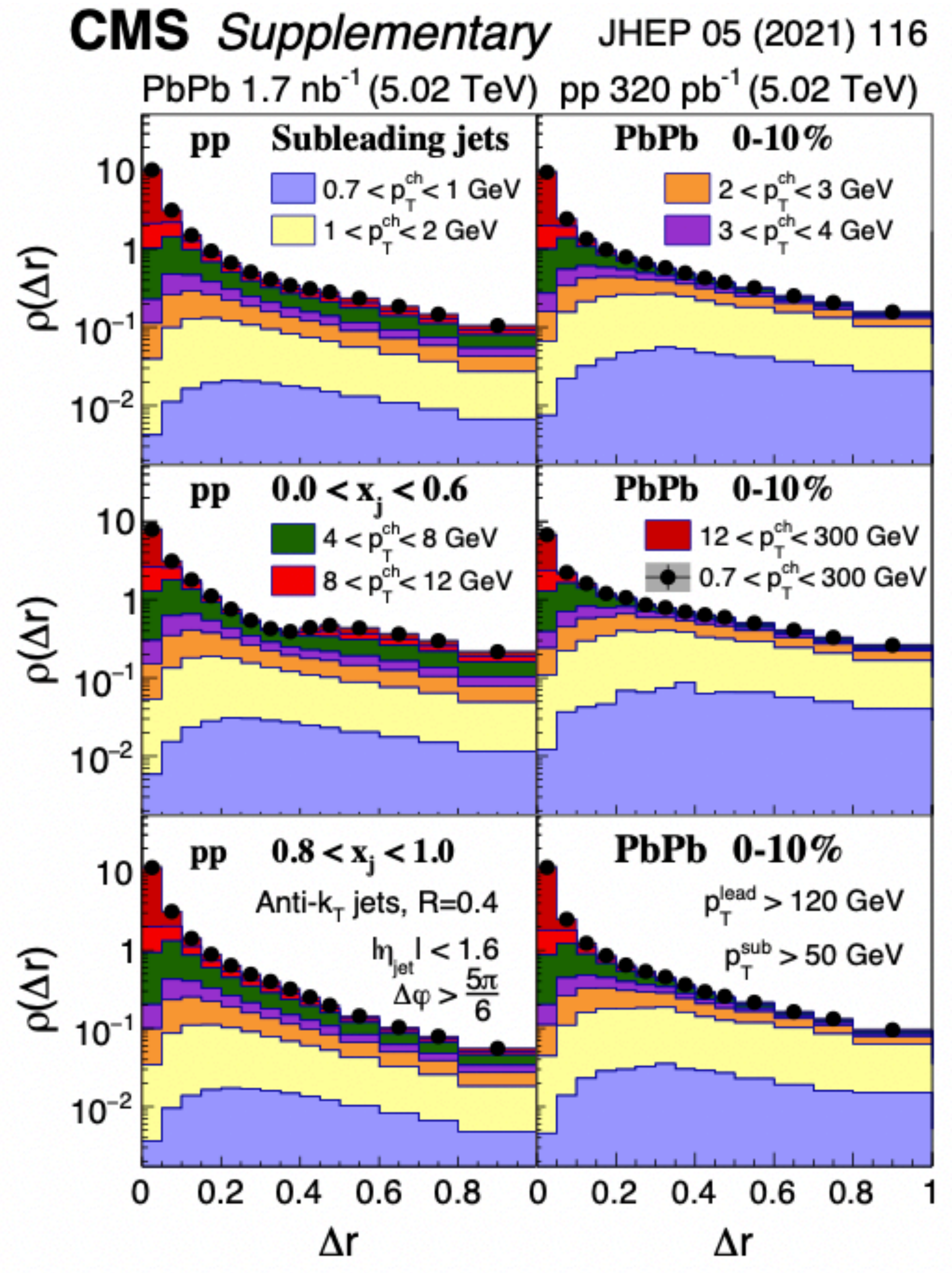
Thank you for the attention!

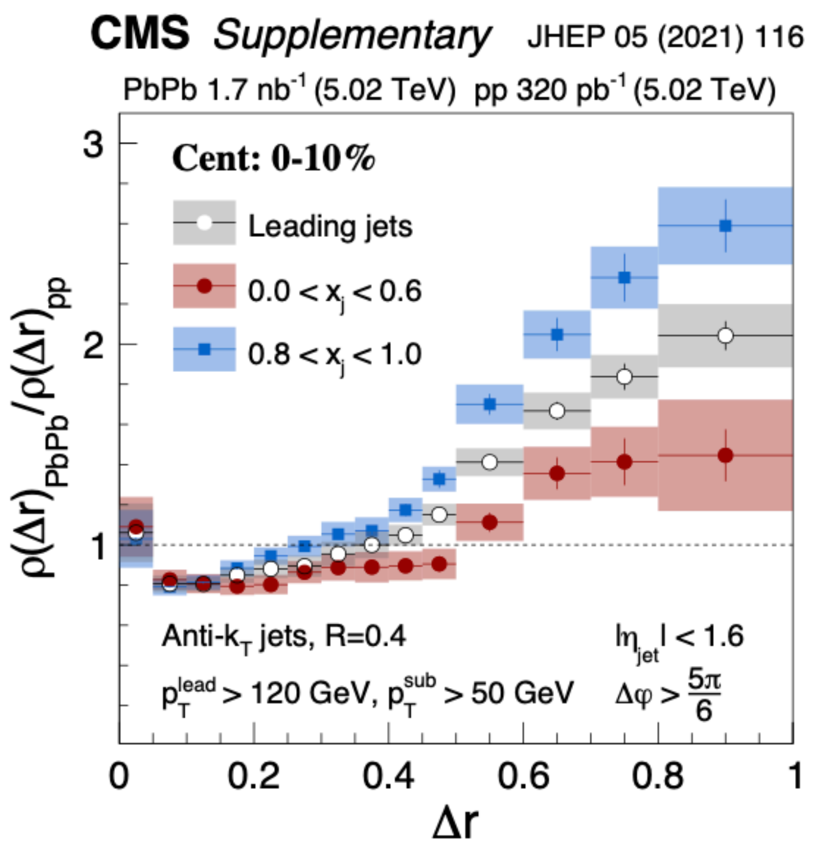
Radial profile: leading and subleading jets with CMS detector

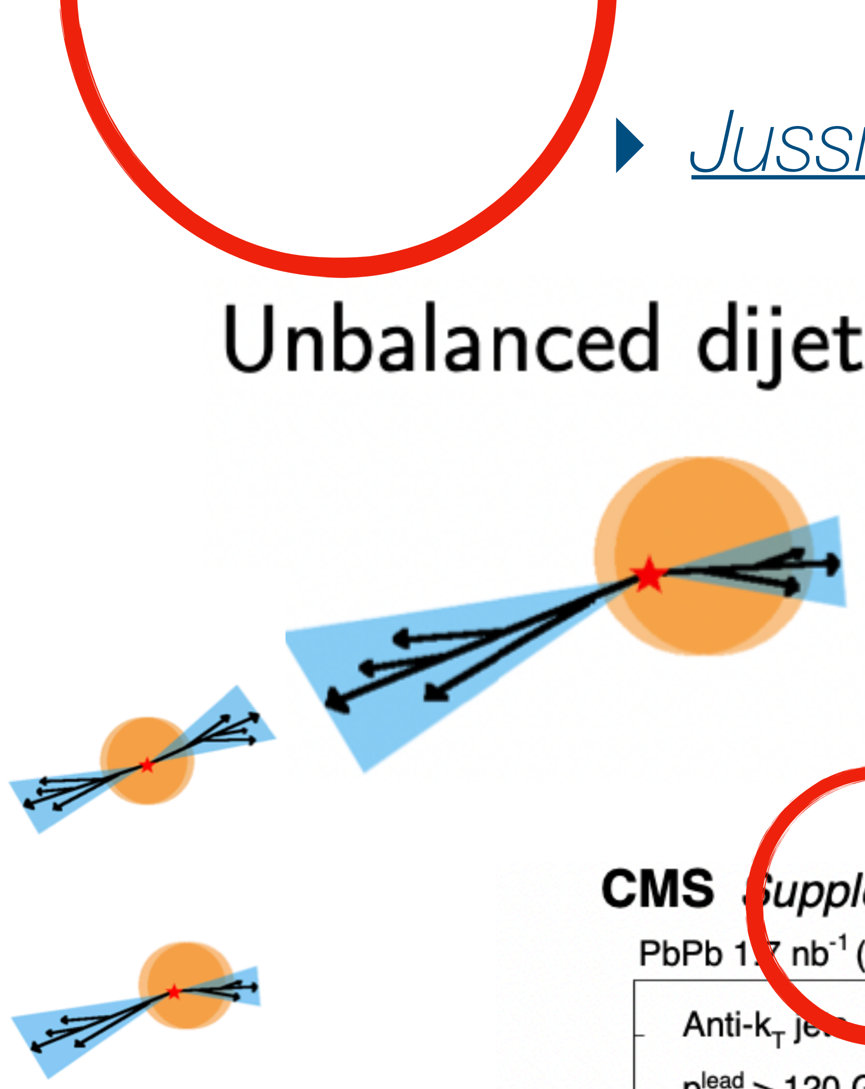
‣ [Jussi Viinikainen's Talk]

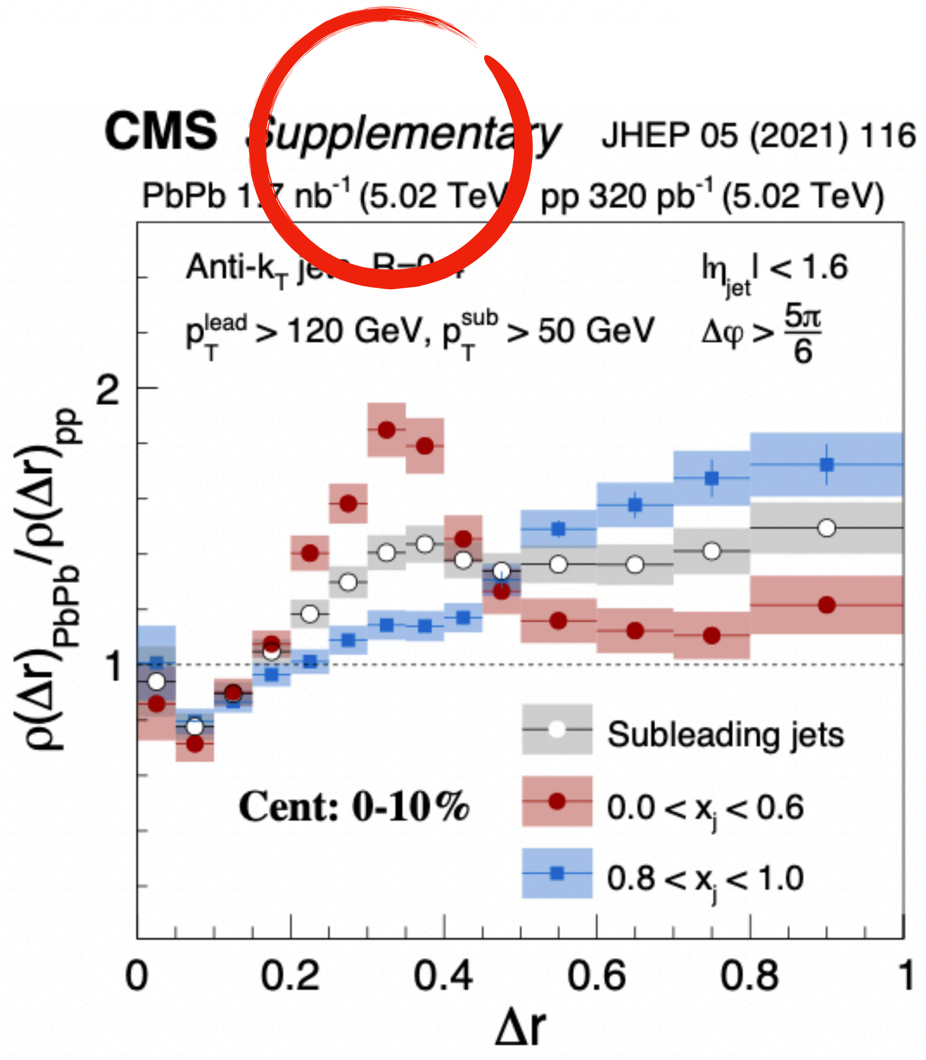
Unbalanced dijet, low x_j











Leading jets
Modifications are the greatest in balanced events
Consistent with expectation that unbalanced events caused by energy loss fluctuations or surface bias

Widening is greatest in unbalanced events

Unbalanced bin highest around Δr = 0.3
⇒ Unbalanced events are the most quenched

Ratio in unbalanced bin close to 1 at high Δr
Contribution from 3-jet events in pp makes reference wider

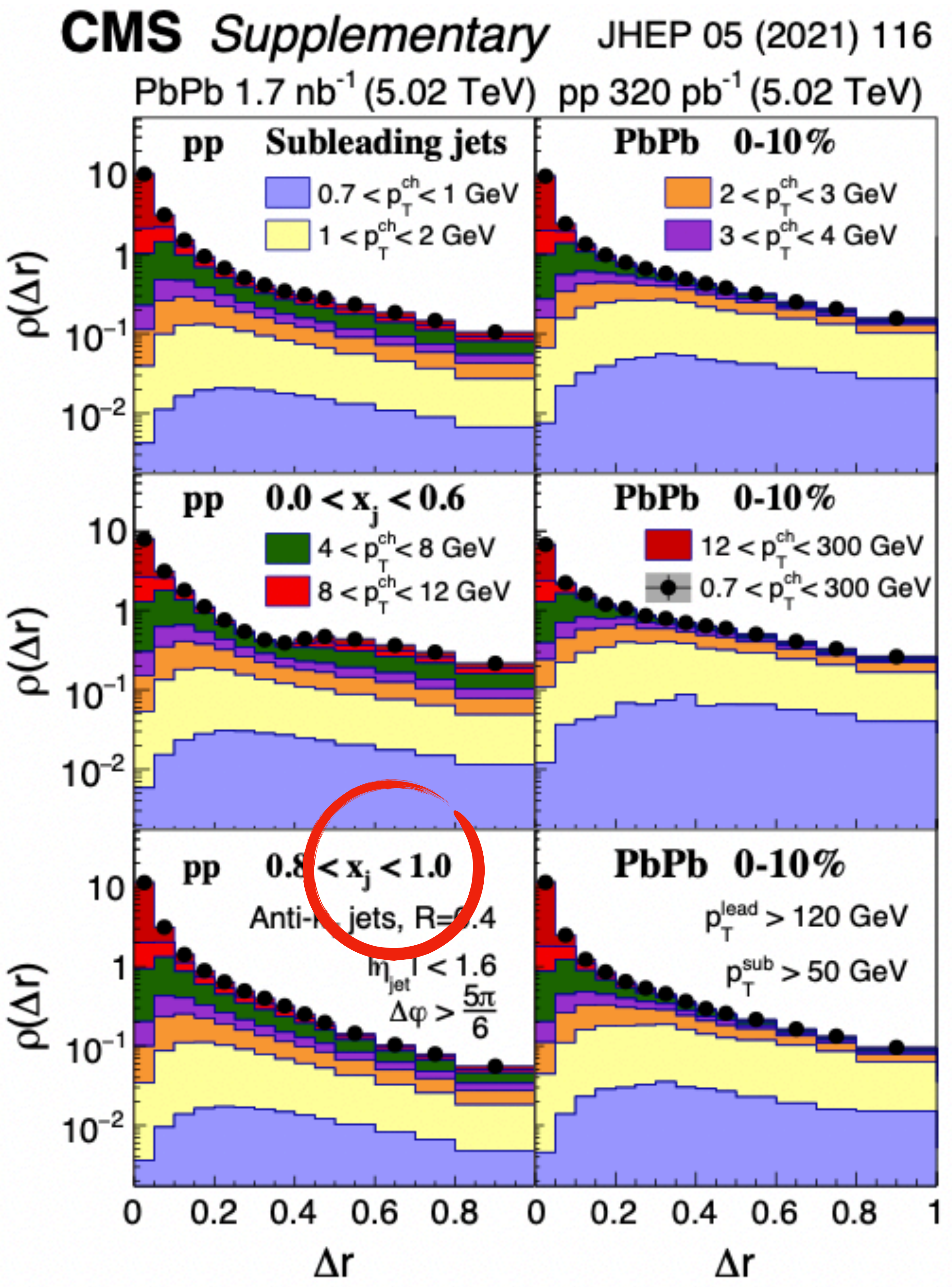
Shapes wider in central PbPb compared to pp
Widening is due to low-pT particles at large radii
Differences between x bins best seen in a ratio plot

Subleading jets: biggest modifications in unbalanced events

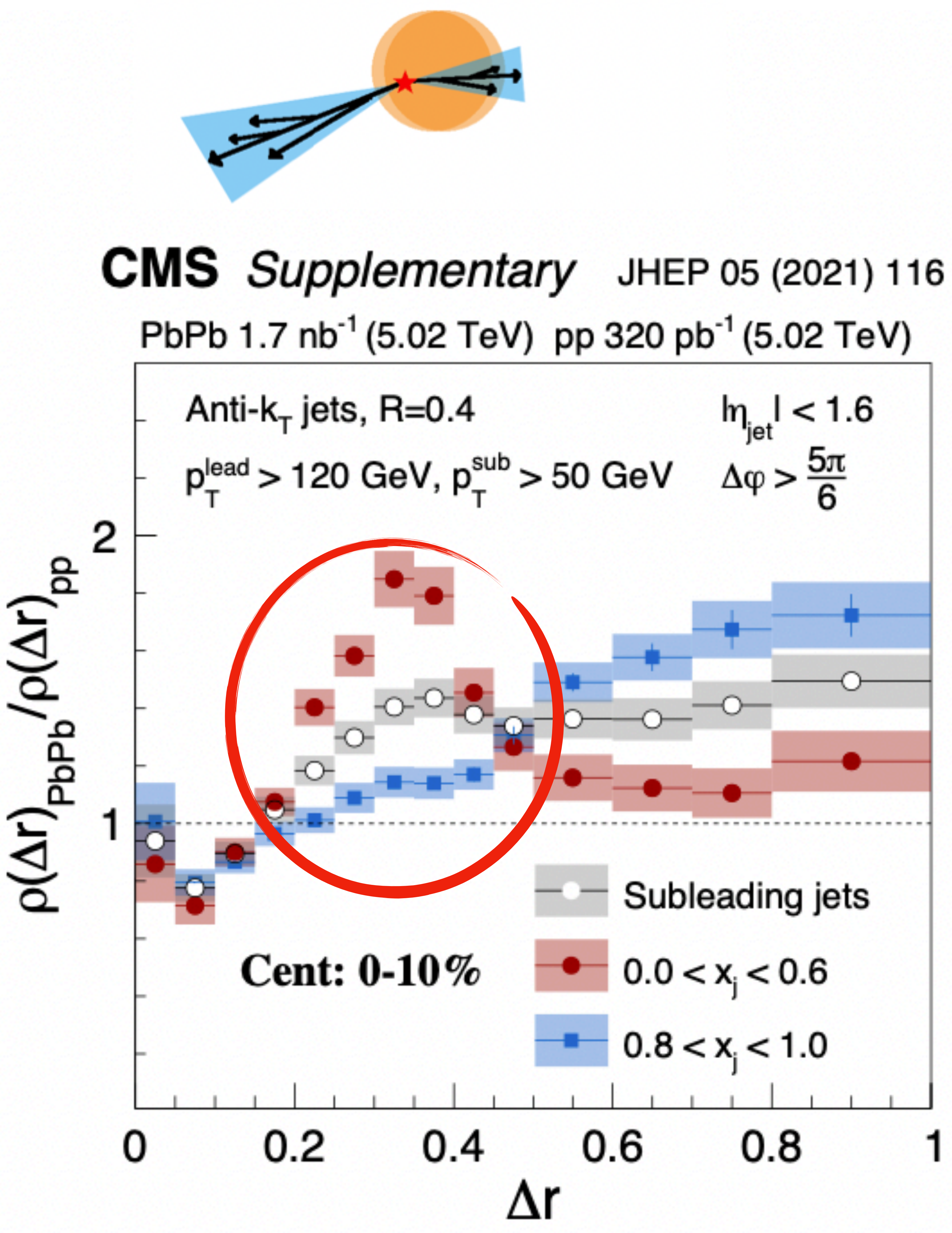
R > 0.4: PbPb-to-pp ratio closer to one. Enhancement high p^{ch}

Radial profile:
Studies of in-medium modification of dijets in PbPb collisions at 5.02 TeV with the CMS detector

- [Jussi Viinikainen's Talk]



Unbalanced dijet, low x_j



Subleading jets: biggest modifications in unbalanced events

R > 0.4: PbPb-to-pp ratio closer to one. Enhancement high p_T^{ch} particles around Δr = 0.5 in pp

Unbalanced configuration in pp case: there is likely to be a third jet in the subleading side to balance out the momentum

Results consistent with hypothesis that the unbalanced events are more surface biased → subleading jet larger distance in plasma than leading jet

arXiv:2008.09811

Christopher McGinn's Talk

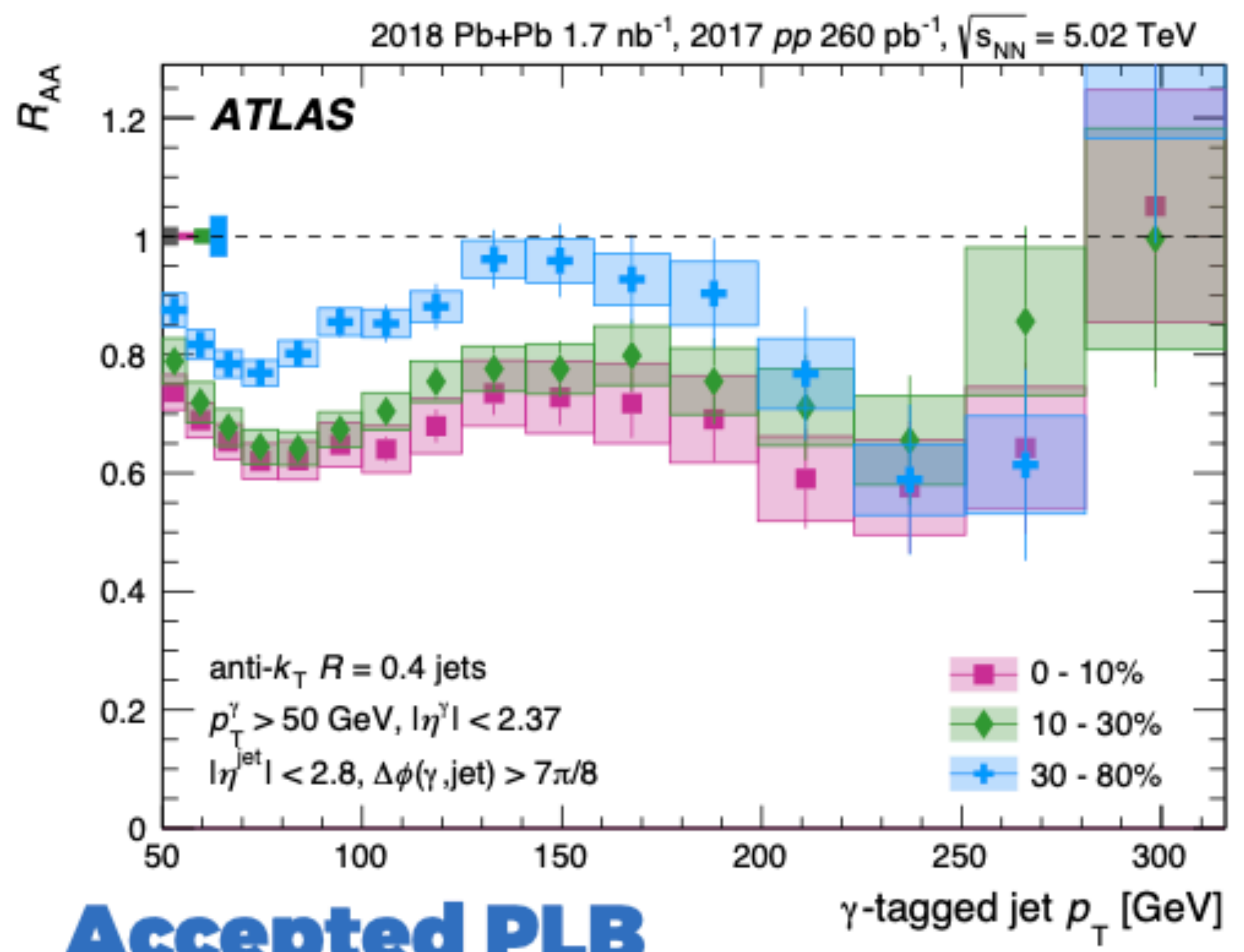
Hadrons recoiling from high-p_{T} trigger: γ-jet by CMS

Comparing photon-tagged jet R_{AA} and inclusive jet R_{AA}, one can see sensitivity to colour charge

Centrality ordered suppression: 0-10% most suppressed

0-10% γ-tagged jet R_{AA}> inclusive jet R_{AA}!

- Quark vs Gluon medium interactions one possible explanation:



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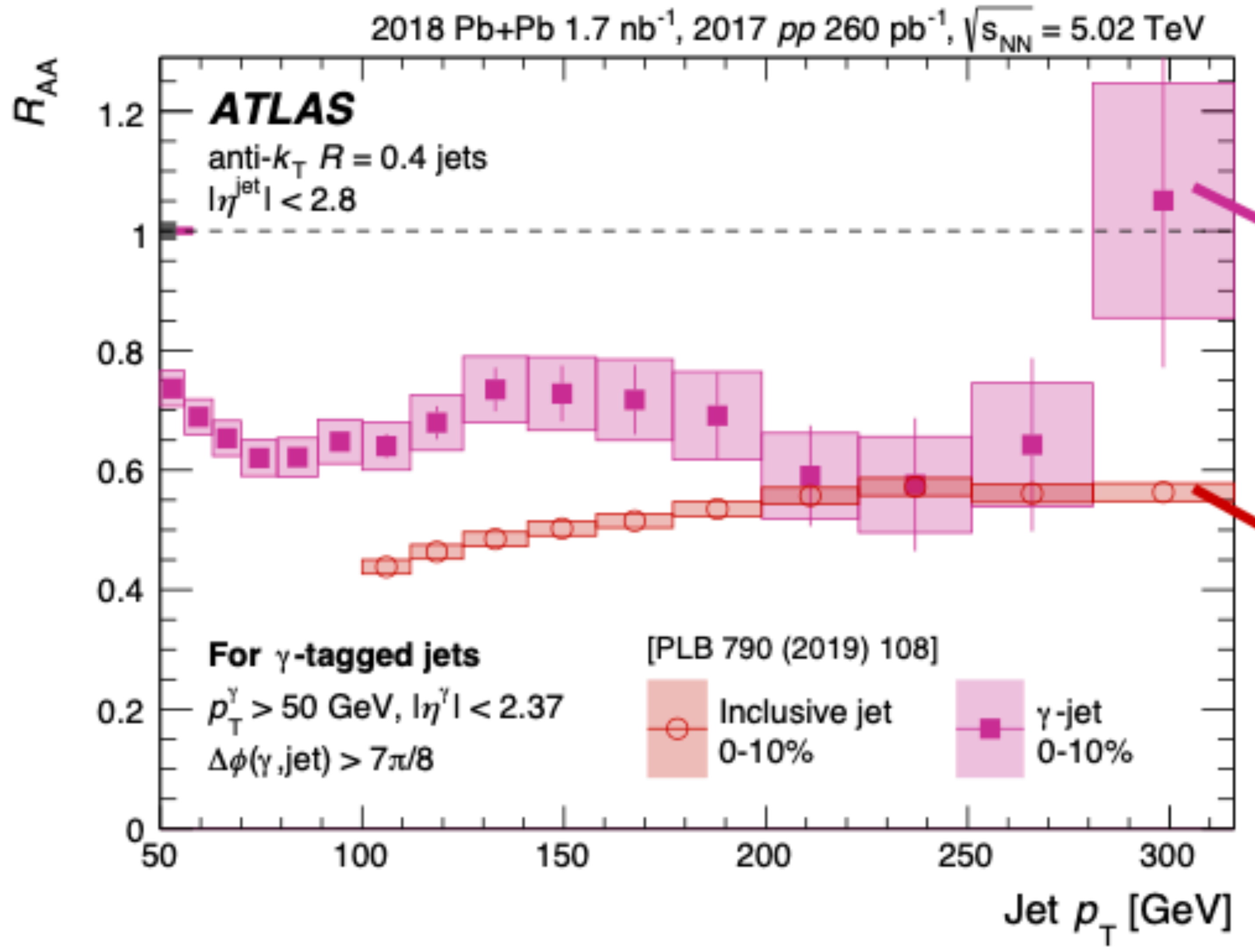
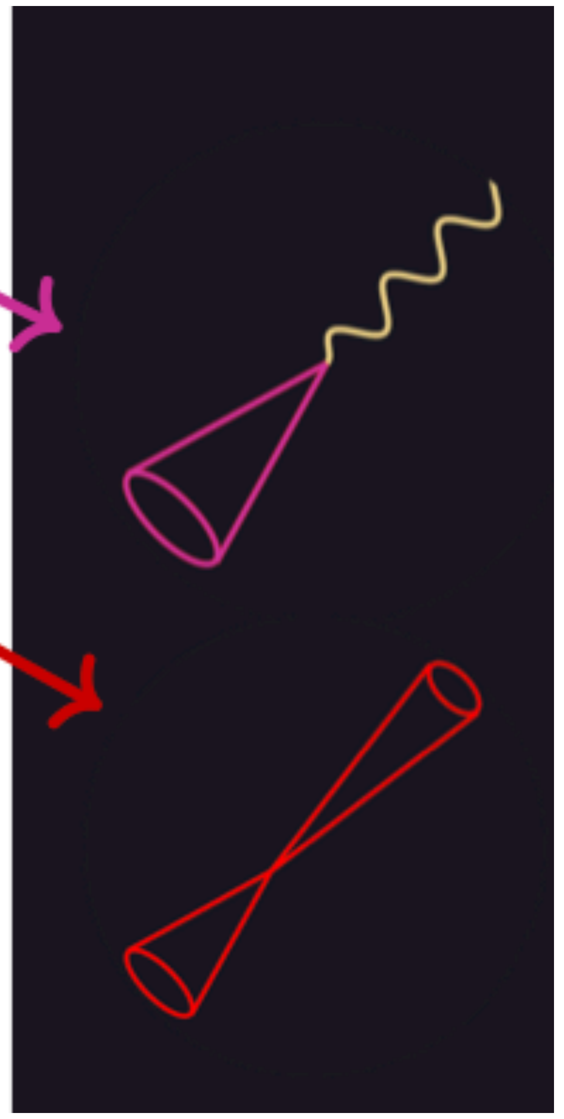




Different quark/gluon fraction

RAA of γ-tagged jets are higher than the one of inclusive jets by ~0.15 in central collisions

Indicate more energy loss of gluon-initiated jets compared to quark-initiated jets

Dijets with ATLAS

$R^{pair}_{AA}(p_{T,1})$ quantifies the suppression of the leading jet in a dijet

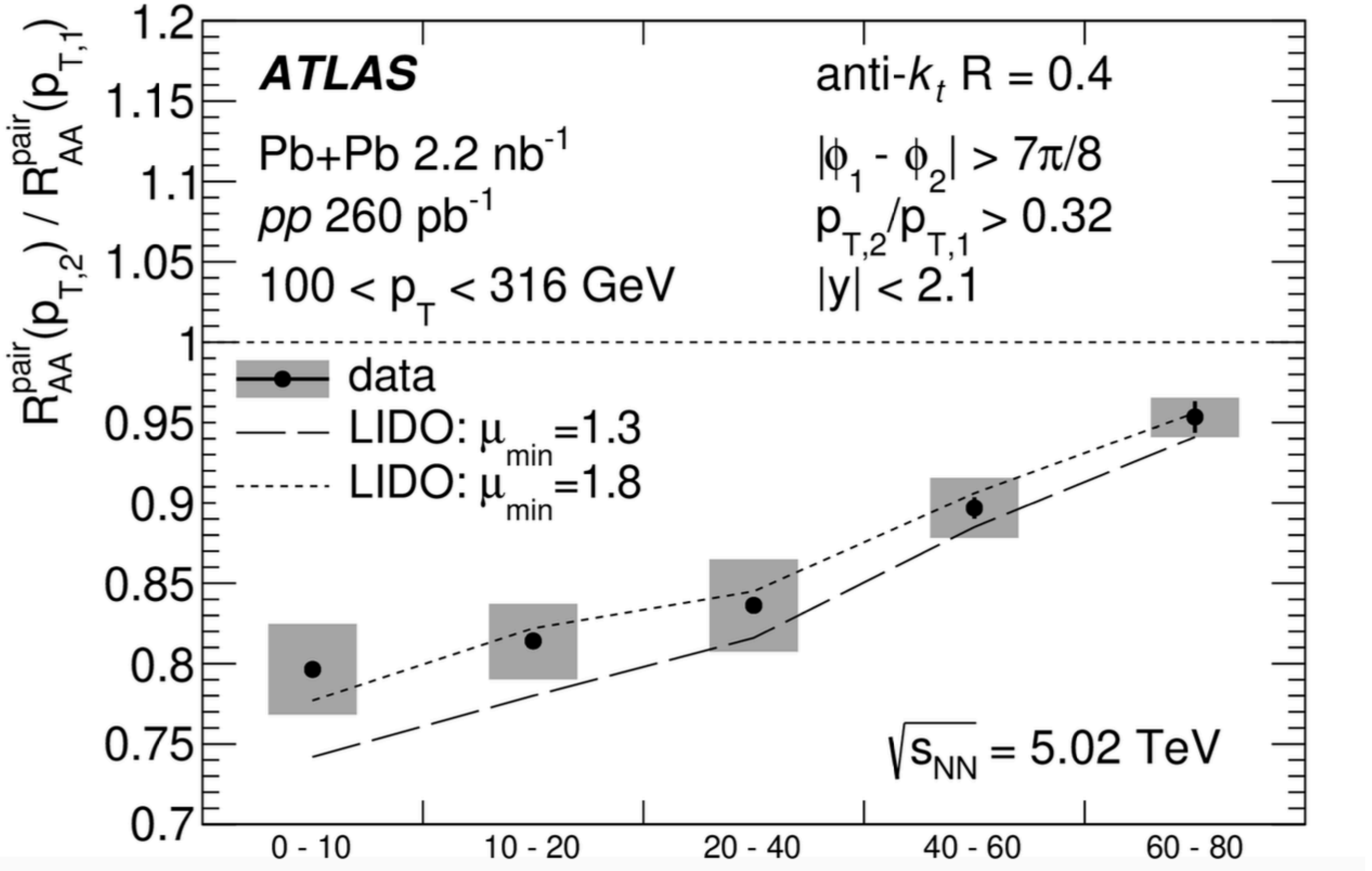
$R^{pair}_{AA}(p_{T,2})$ quantifies the suppression of the subleading jet in a dijet

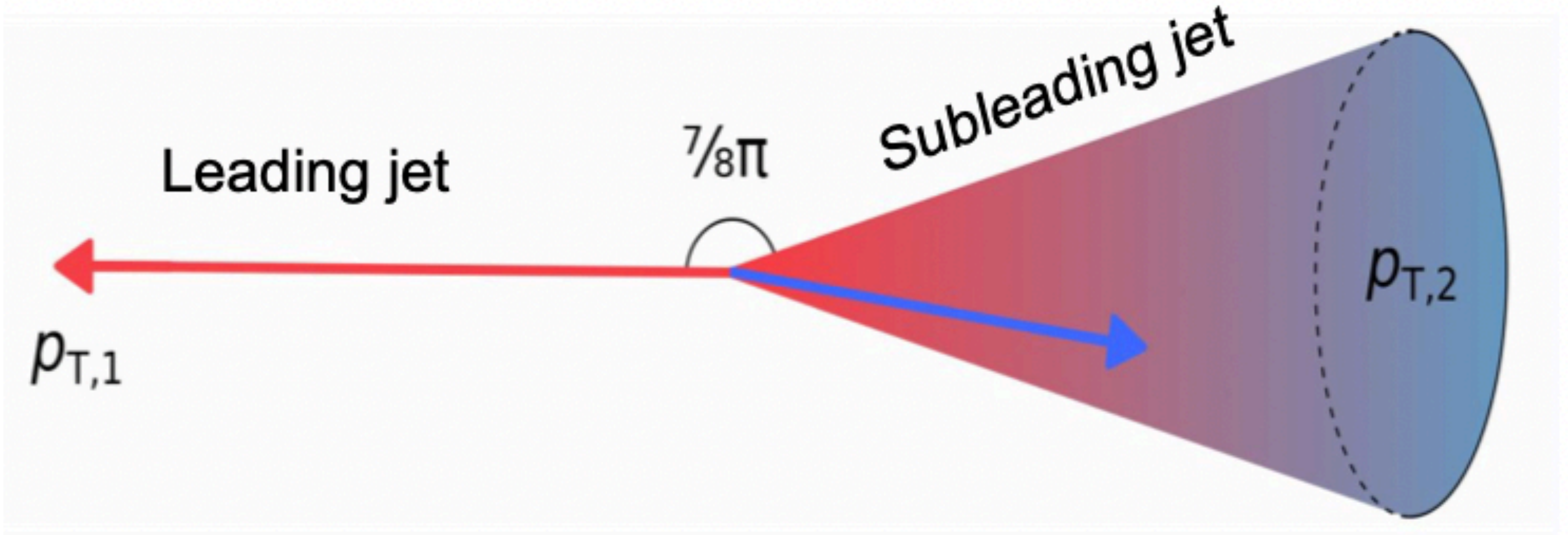
Evidence for suppression of subleading jets relative to leading jets is observed

- peripheral Pb+Pb: smaller, but still significant suppression of subleading jets

This is observed to be largely independent of jet p_T and this behavior is seen in all centralities. In central collisions, subleading jets are observed to be 20% more suppressed than the leading jets. In peripheral collisions, the suppression of subleading jets relative to leading jets is reduced, but the stronger suppression of sub- leading jets remains significant. These measurements provide new information about the role of path-length dependence and fluctuations in jet energy loss which will help constrain models of parton energy loss in the quark-gluon plasma

Timothy Rinn's Talk





Introduction:

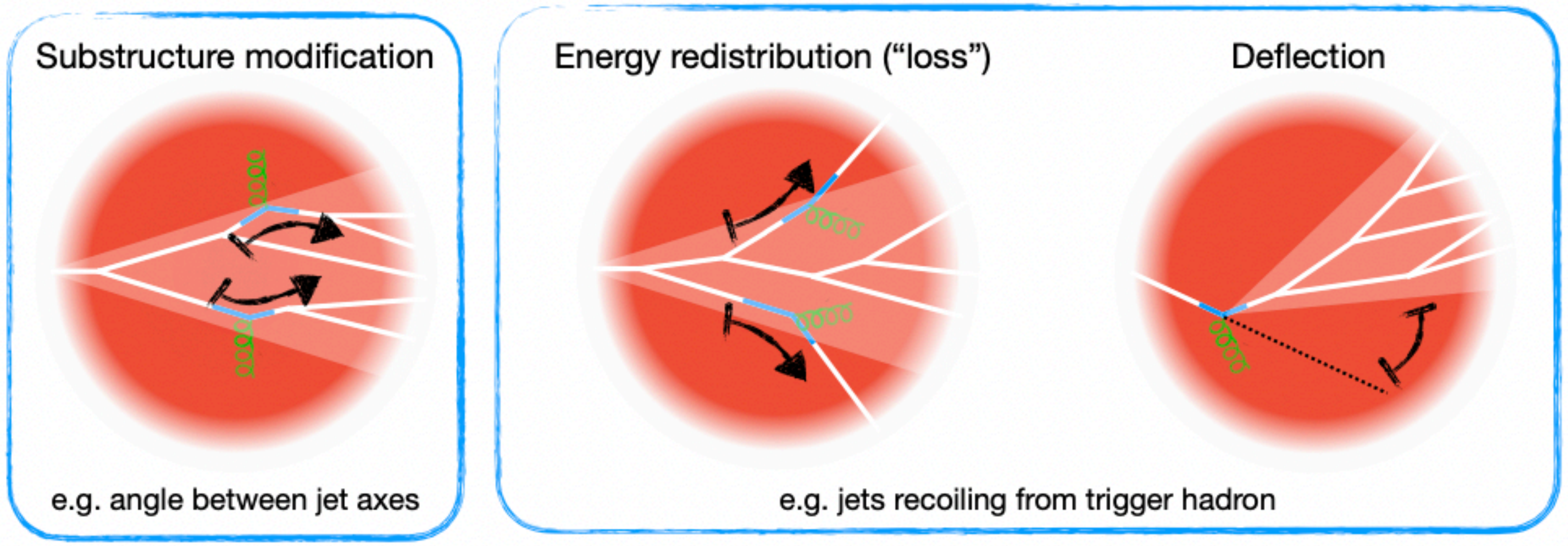
- [Jana Bielcikova's Talk HP23]

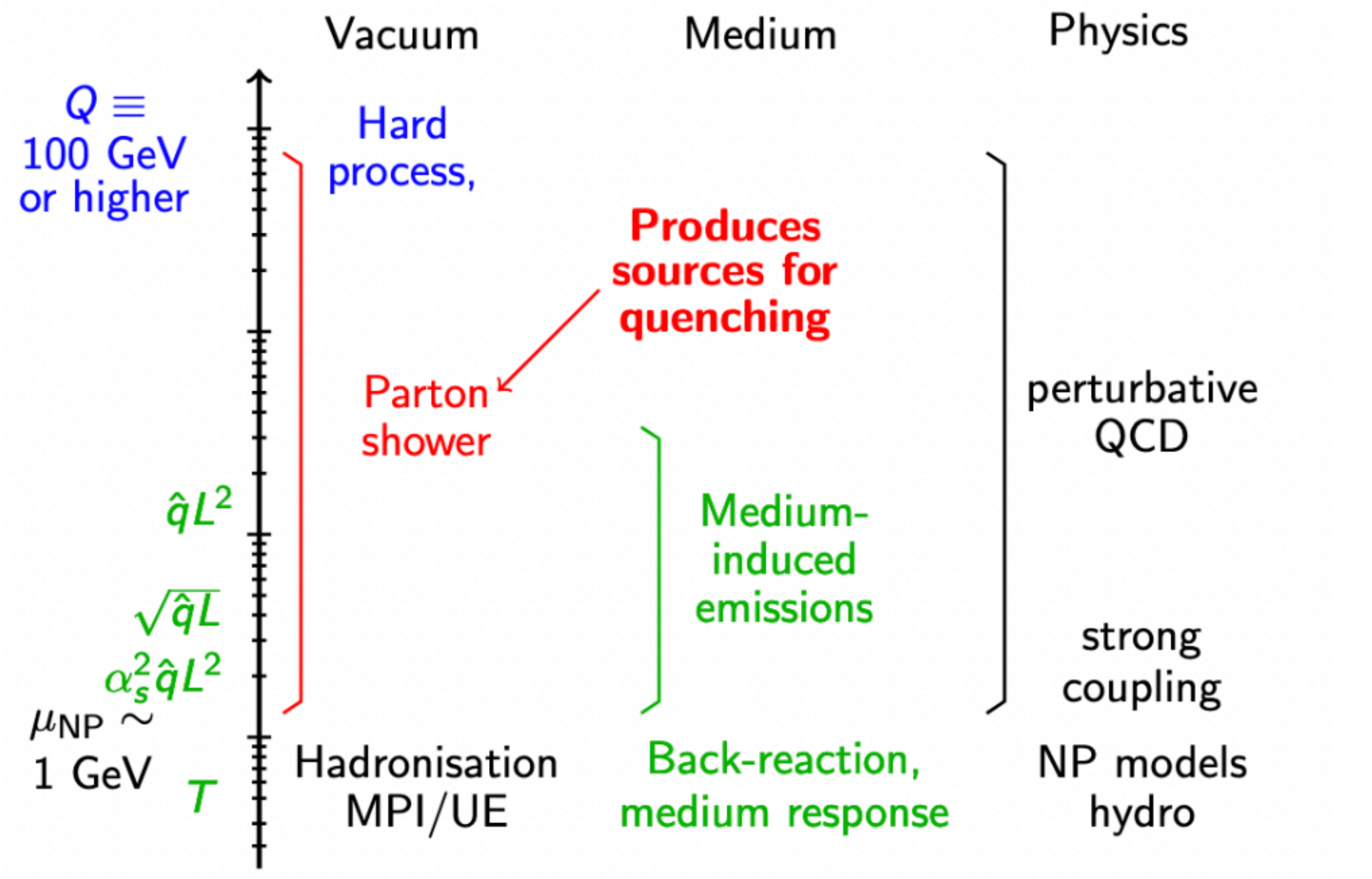
Jets are not point-like, but complex & multiscale objects

Useful for probing medium in different scale

Modifications in the jet production and fragmentation in order to:

- isolate different physics mechanisms
- to validate theory
- characterise the QGP





sketch from G.Soyez

Outline:

- Introduction
- Hadrons recoiling from high-p_{T} trigger
- Jet substructure
- Dijets
- Jet energy loss
- Geometry
- Small systems

Hadrons recoiling from high-p_T trigger: CMS vs PHENIX

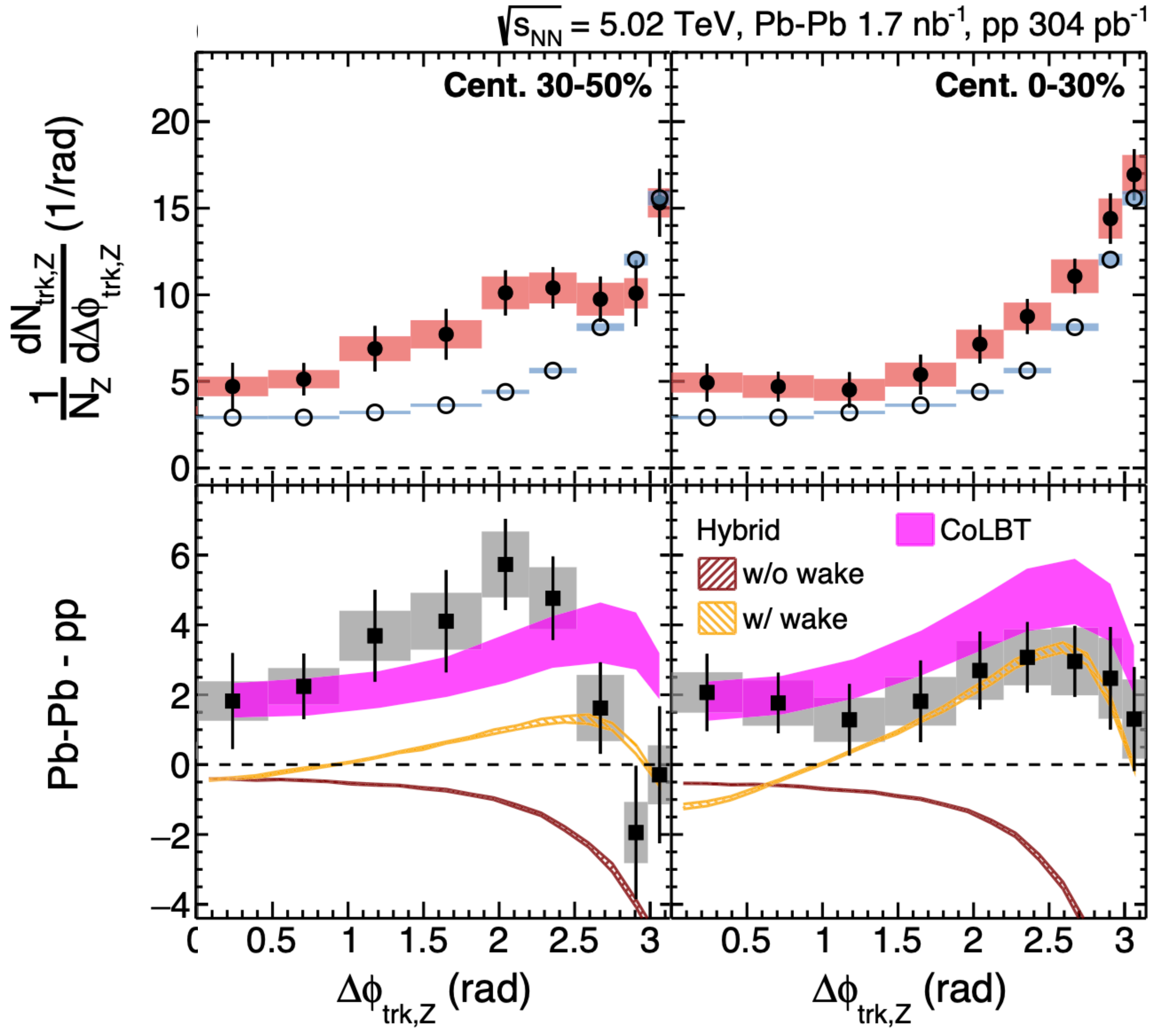
π^0- hadron: to explore lower momentum jets & fragments

- D_{AA} = ***difference of yields in AA and in pp***
- Hybrid model shows different behaviour with and without wake (medium response)

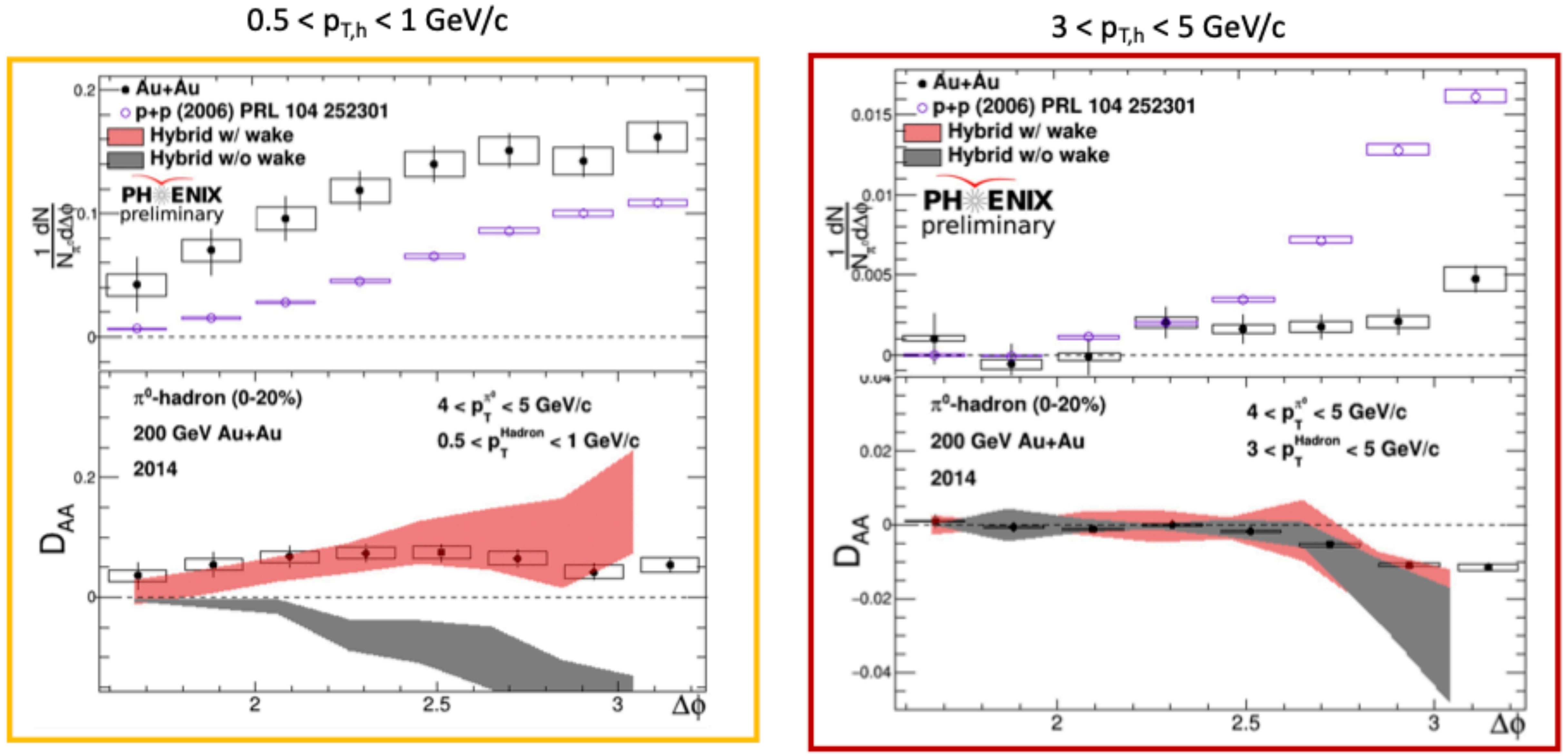
pT dependence π^0- hadron may imply wake is more relevant for low pT hadrons

- $\gamma/Z + jet$ = way to measure parton medium interactions with jet FF

Kaya Katar's Talk



Megan Connors's Talk



Hybrid model with wake consistent with PHENIX data

- The wake is more pronounced for low pT hadrons

Hadrons recoiling from high-p_T trigger: Gamma jet Raa Pb+Pb with ATLAS

arXiv:2008.09811

- Christopher McGinn's Talk

Observe centrality ordered suppression(left), 0-10% most suppressed

- 0-10% γ-tagged jet R_{AA}> inclusive jet R_{AA}! (right)
  - Quark v. Gluon medium interactions one possible explanation Slope of spectra in pp differ enough to cause a10%effect
  - Isospin and nPDF effects cause another 10% but opposite in sign

Two factors to consider besides the **different quark/gluon fraction** between the γ-tagged jet and inclusive jets...

1) p^{jet} **distribution difference** within a simple model of fractional energy loss, this effect could cause the γ-tagged jet R_{AA} to be larger by ~0.1
2) **2) Isospin and nPDF effect**

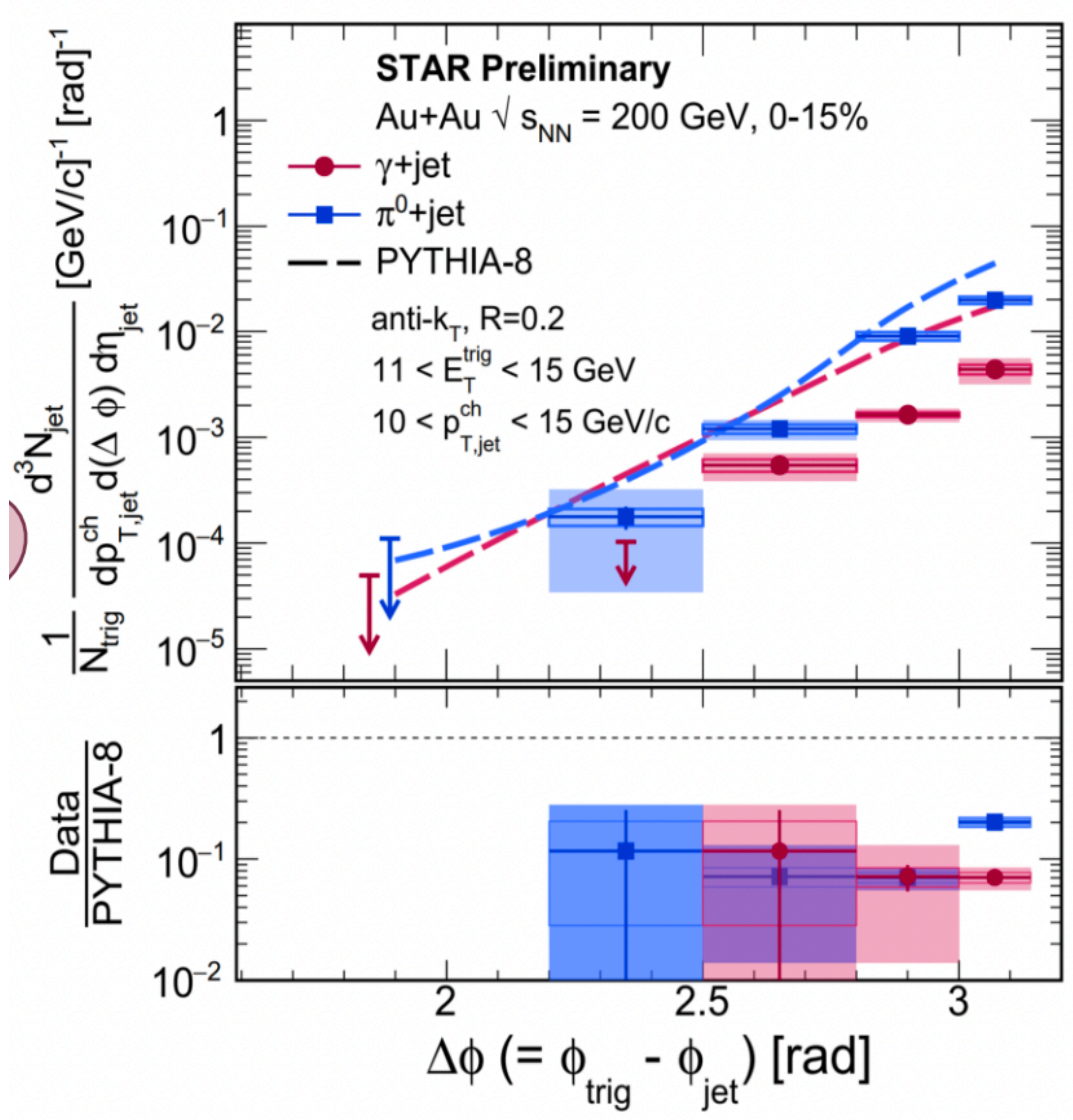
this effect may suppress the γ-tagged jet R_{AA} by ~0.05-0.1 compared to the inclusive jet R_{AA} depending on the p

.

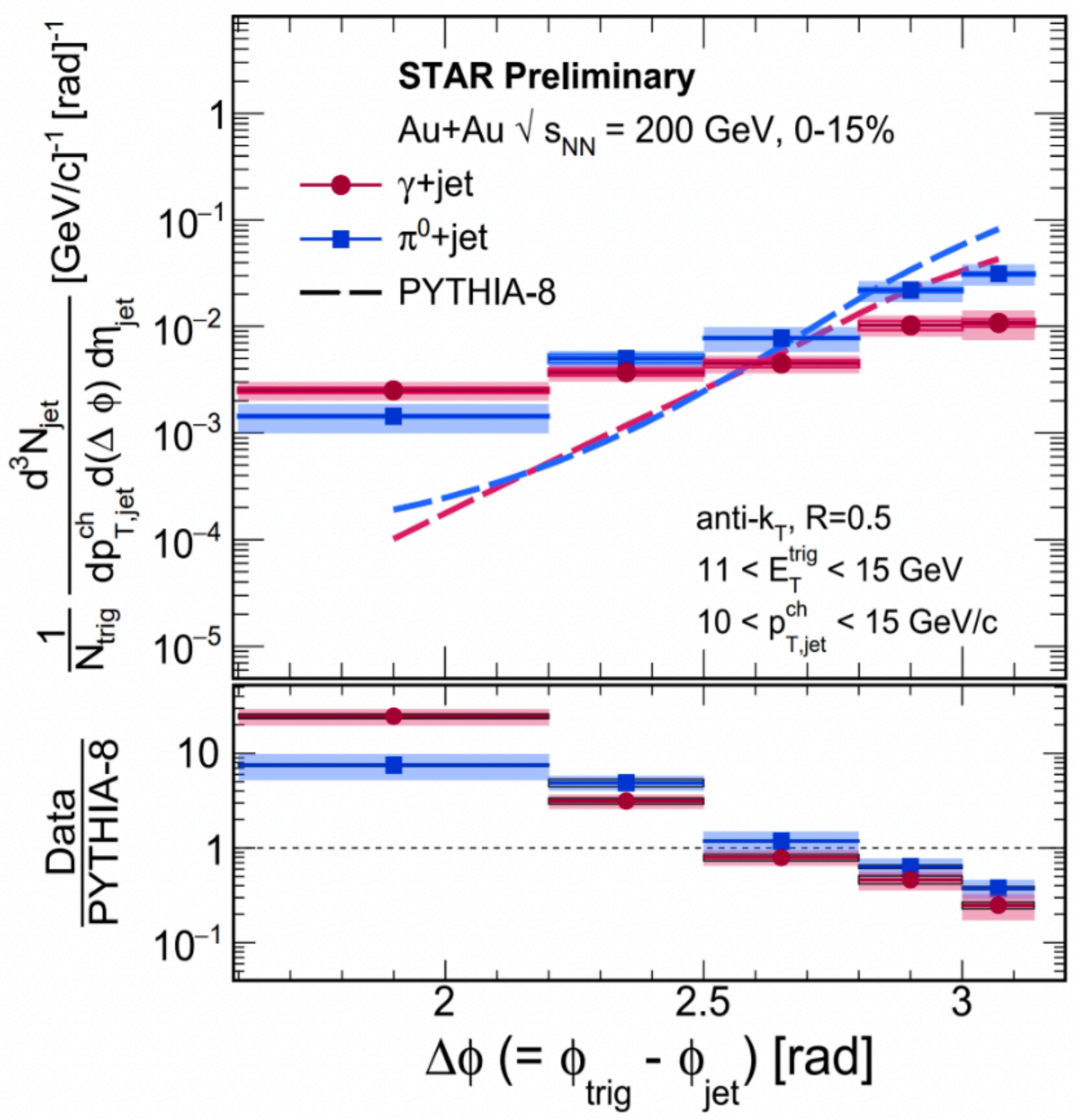
Hadrons recoiling from high-pT trigger :

- Derek Anderson's Talk
- Rey Cruz-Torres's Talk
- Yongzhen Hou's Talk HP23

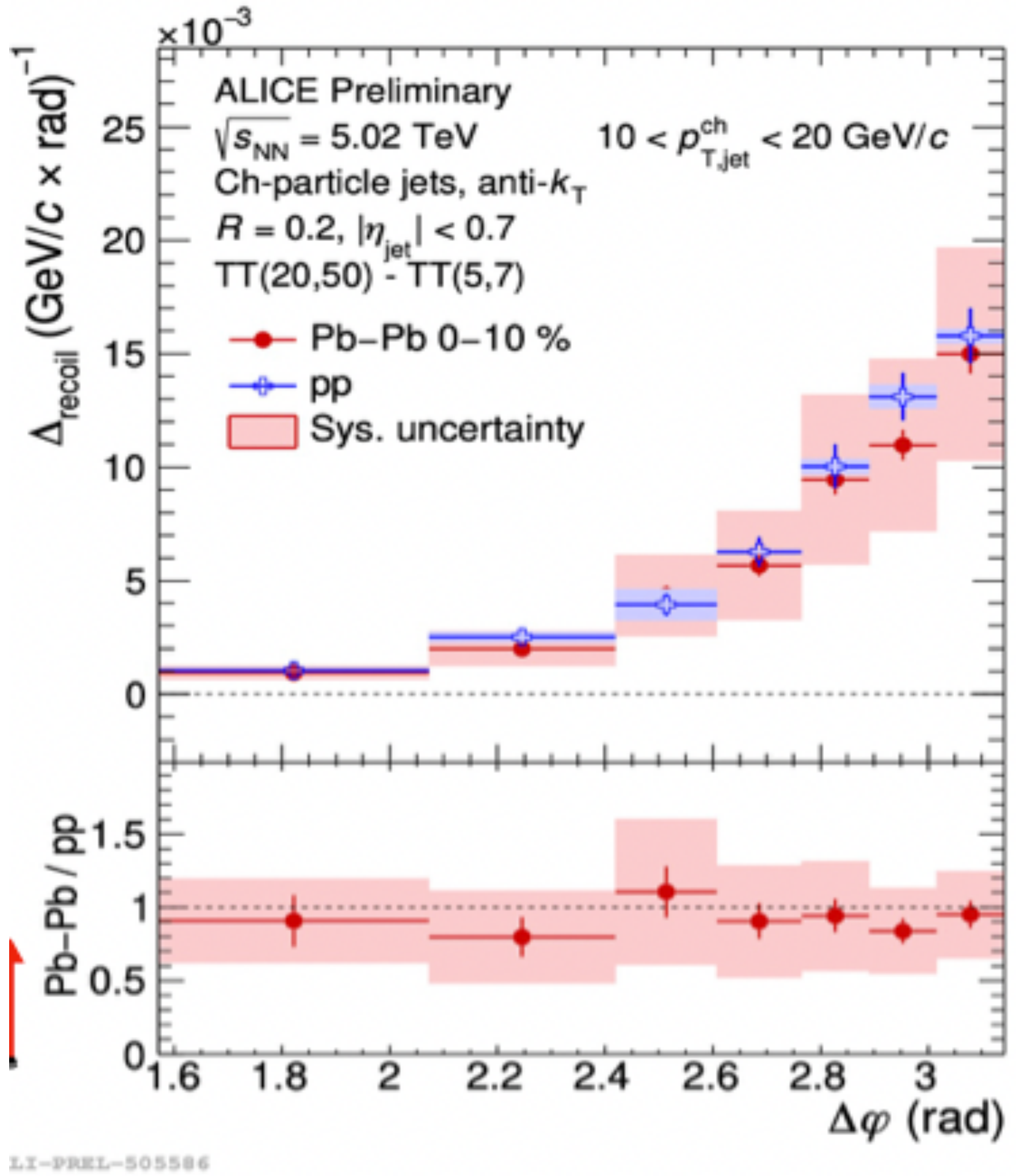
R=0.2



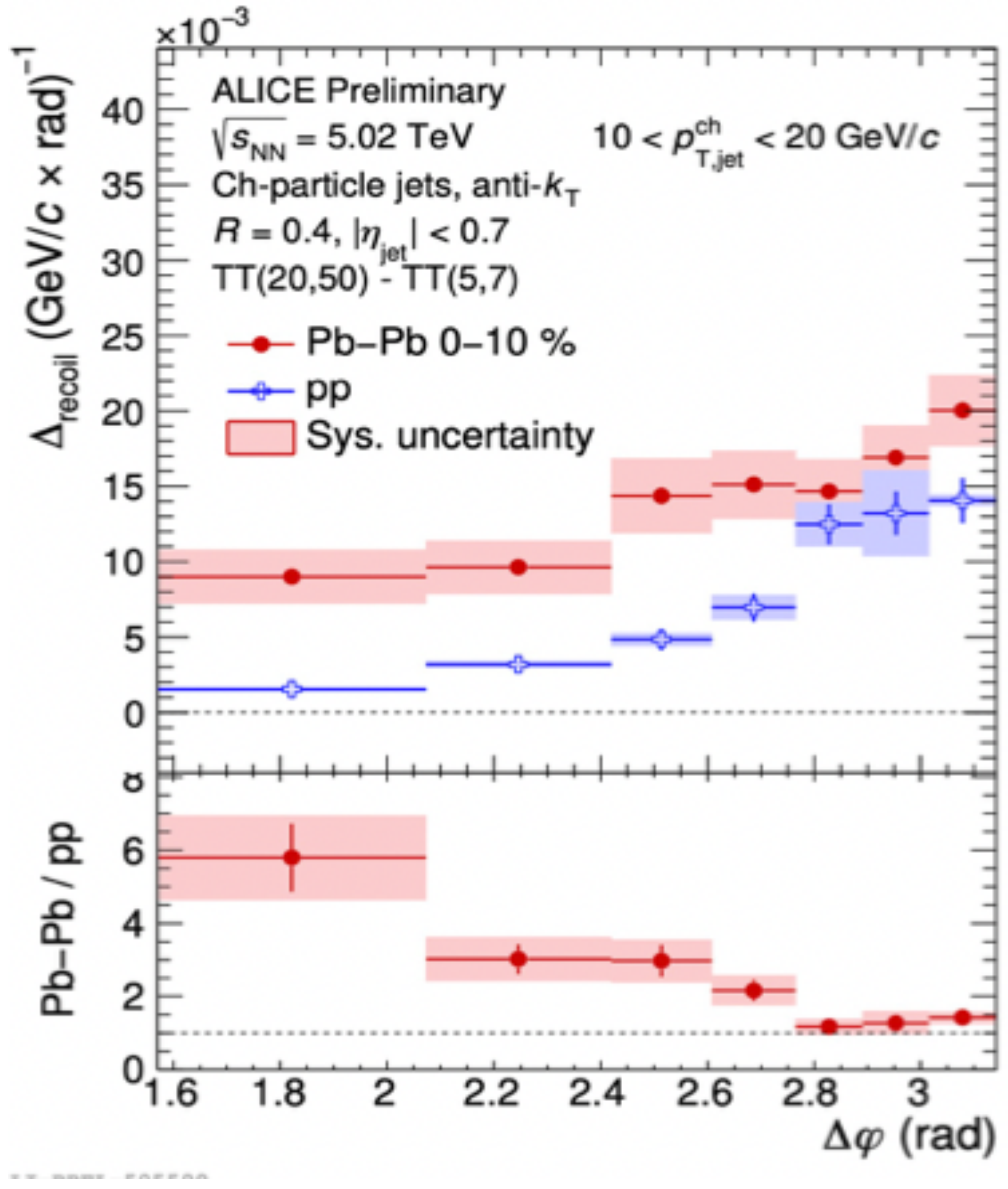
R=0.5



R=0.2



R=0.4



- no modification (small R, large pT)
- large modification (large R, low pT)

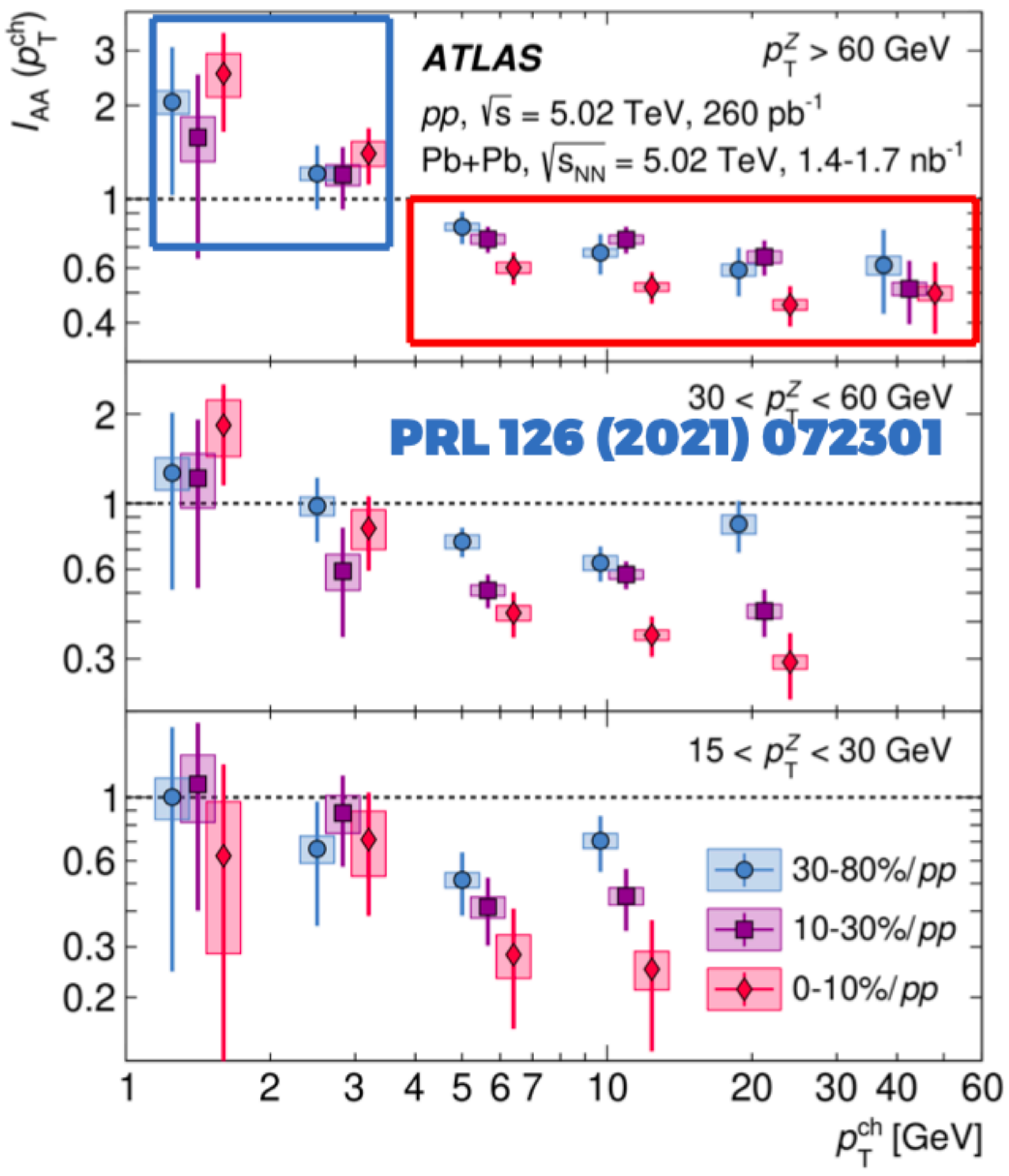
Increase of correlated yield of very soft structures

Significant jet azimuthal broadening in QGP

Hadrons recoiling from high-p_T trigger: Z-hadron correlations in Pb+Pb with ATLAS

‣ Christopher McGinn's Talk

arXiv:2008.09811



- Integration away-side peak $\Delta\varphi > \frac{3}{4}\pi$ to obtain $D(z_T)$ "fragmentation function"

Modifications of the jet particles in the recoil region:

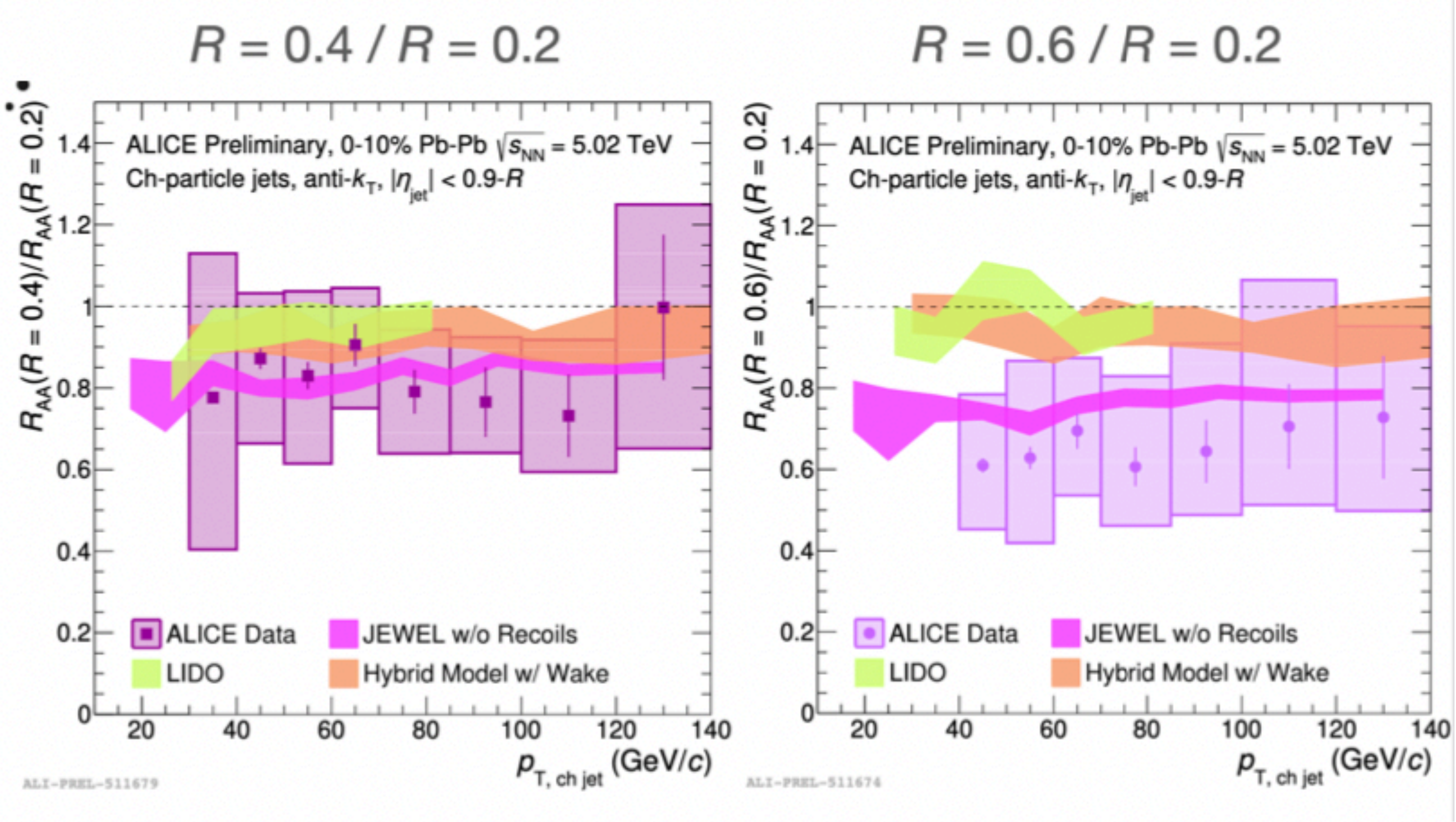
$$I_{AA}(p_T^{ch}) = D(z_T)_{PbPb}/D(z_T)_{pp}$$

- I_{AA} values: suppressed below unity at large p_T
  - Central events → hotter QGP → larger suppression
  - For $p_T > 60$ GeV:
    - suppression at high p_T
    - enhancement at low p_T

Softening: charged-particle p_T distribution in Pb+Pb collisions is softer than that in pp collisions

R-dependence of inclusive jet suppression and groomed jet splittings in heavy-ion collisions with ALICE

▸ [Hannah Bossi's Talk]



Radial scan

R_{AA}: *R*-dependence way to disentangle energy loss mechanisms

At fixed jet p_T, large-*R* jets potentially select jets that were more "active" → that are thus more quenched

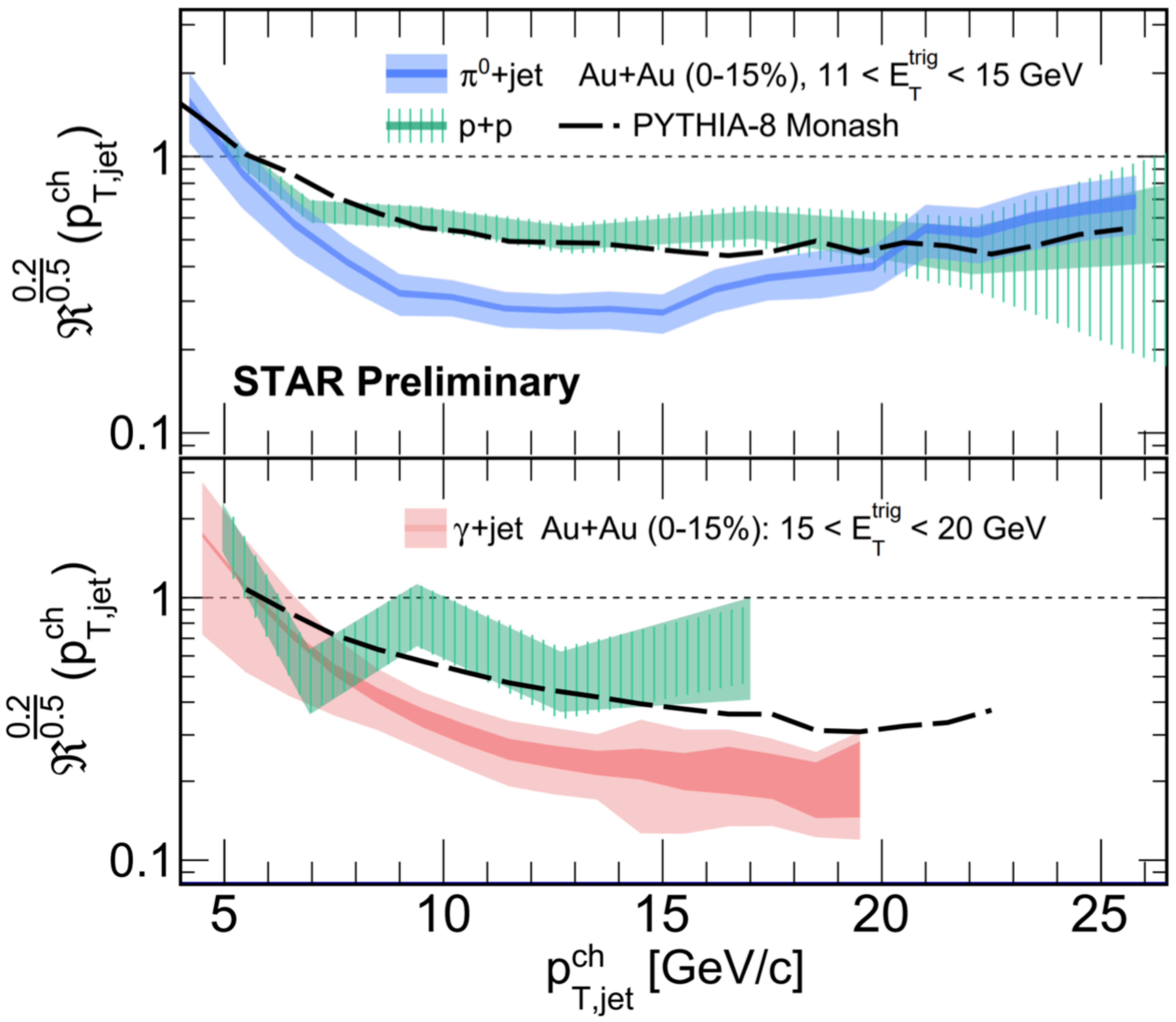
Large-R jets potentially select jets that were more "active"

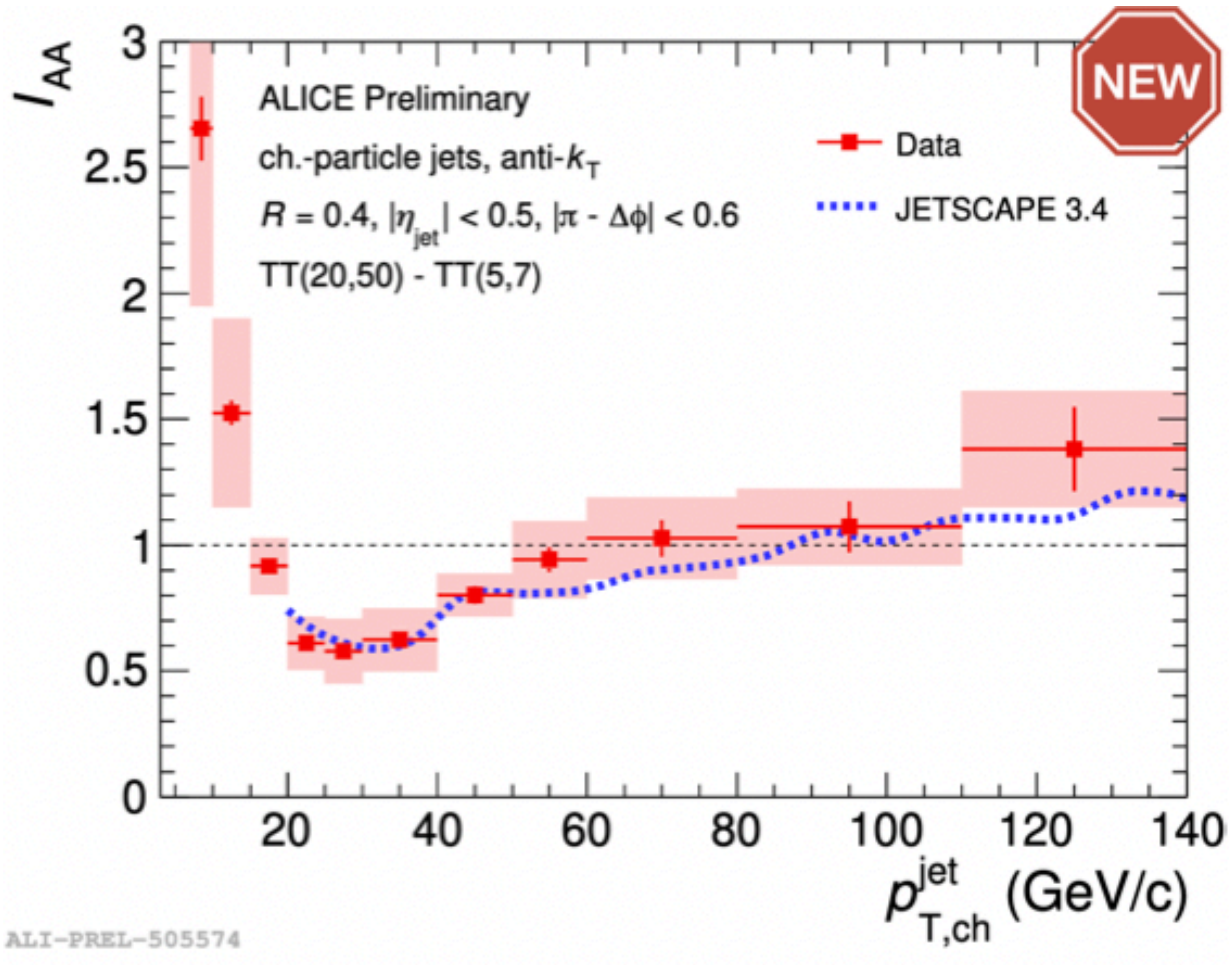
R = 0.6 jets appear more suppressed than R = 0.2 jets.

Hadrons recoiling from high-p_T trigger :

Coincidence measurements down to very low jet pt (STAR vs ALICE)

- *Derek Anderson's Talk*
- *Rey Cruz-Torres's Talk*

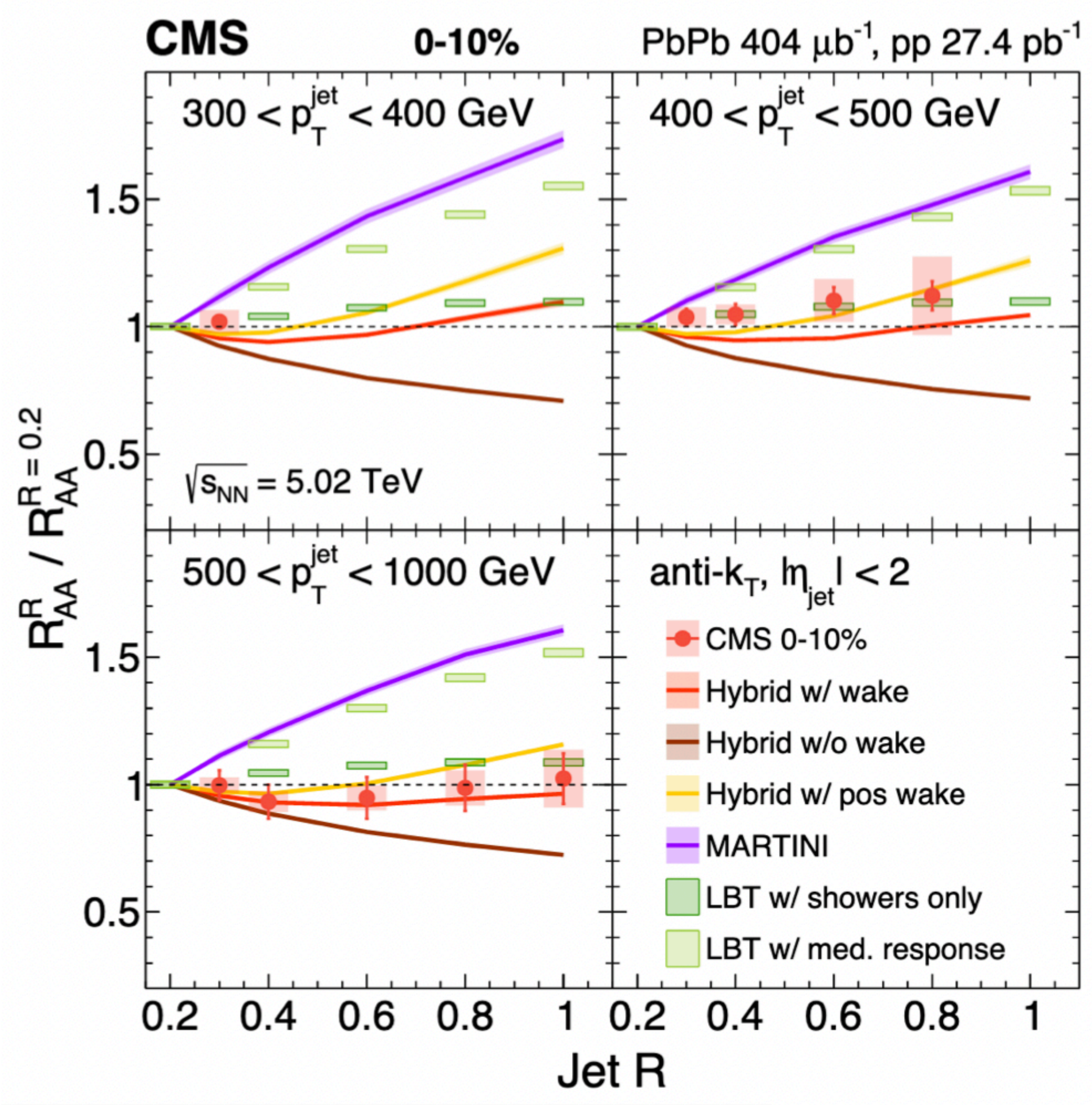


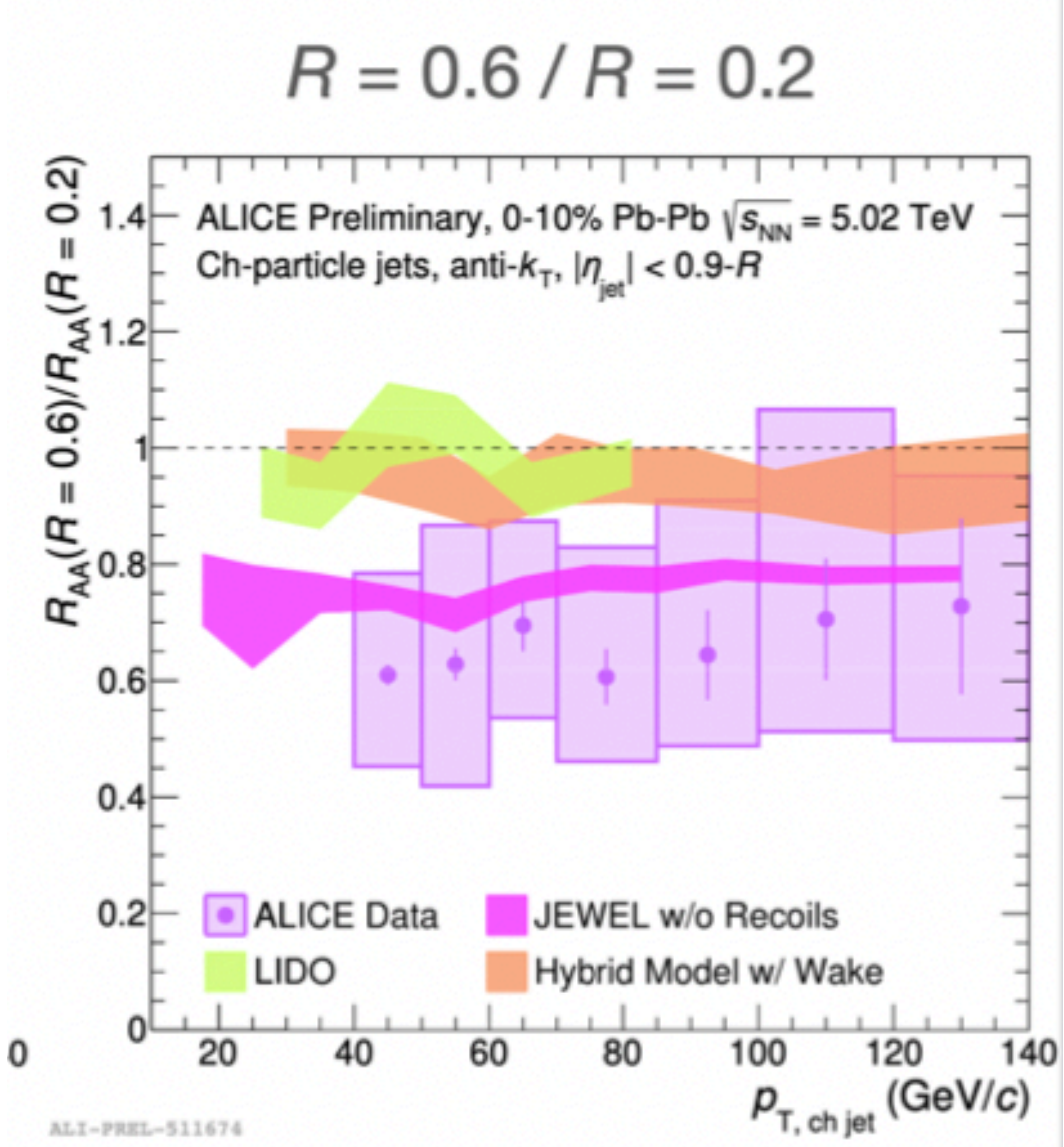


ALICE: Increase of correlated yield of very soft structures (pT,jet<20 GeV, R=0.4)

STAR: clear signature of intrajet broadening for similarly soft structures

Radial scan: CMS vs ALICE





▸ [Hannah Bossi's Talk]

No significant R dependence at high pT seen by CMS.

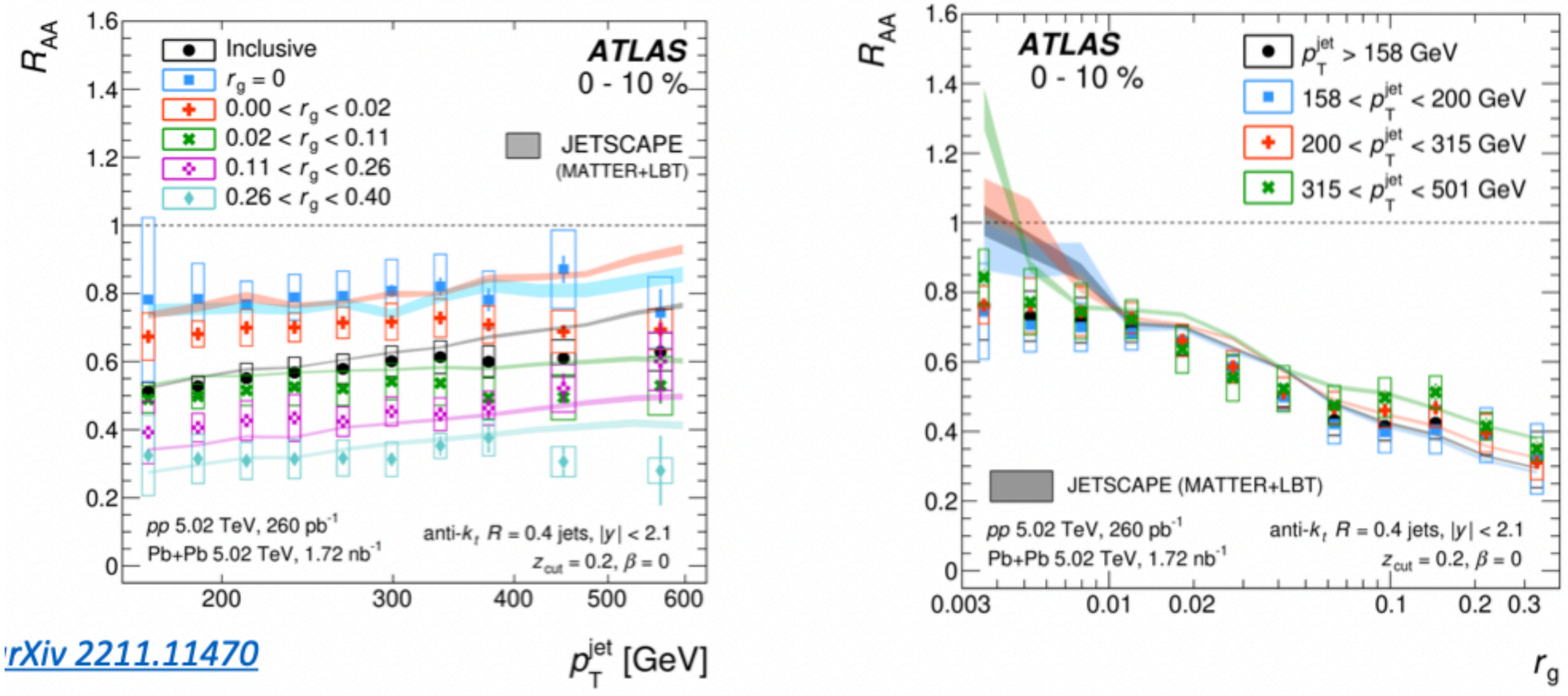
Relatively large uncertainties.

Models going in both directions.

Suppression: result of a) amount/how energy is redistributed and b) ability to recover it

ALICE results seem to indicate an incomplete balance between a) and b) as opposed to CMS results at higher jet p_Ts

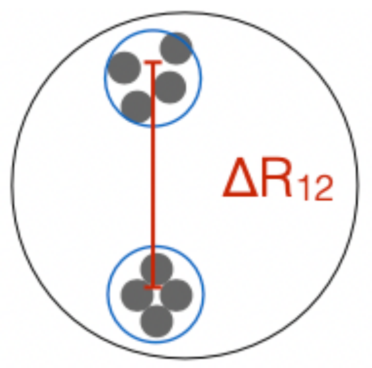
Jet substructure as a microscope:
Measurement of the azimuthal anisotropy and substructure of jets in Pb+Pb collisions with the ATLAS detector



[rXiv 2211.11470](arXiv 2211.11470)

ATLAS, arXiv 2211.11470

▸ *[Anne Sickles's Talk]()*



$r_g = \Delta R_{i,j}$ **between the subjets satisfying the SD condition**

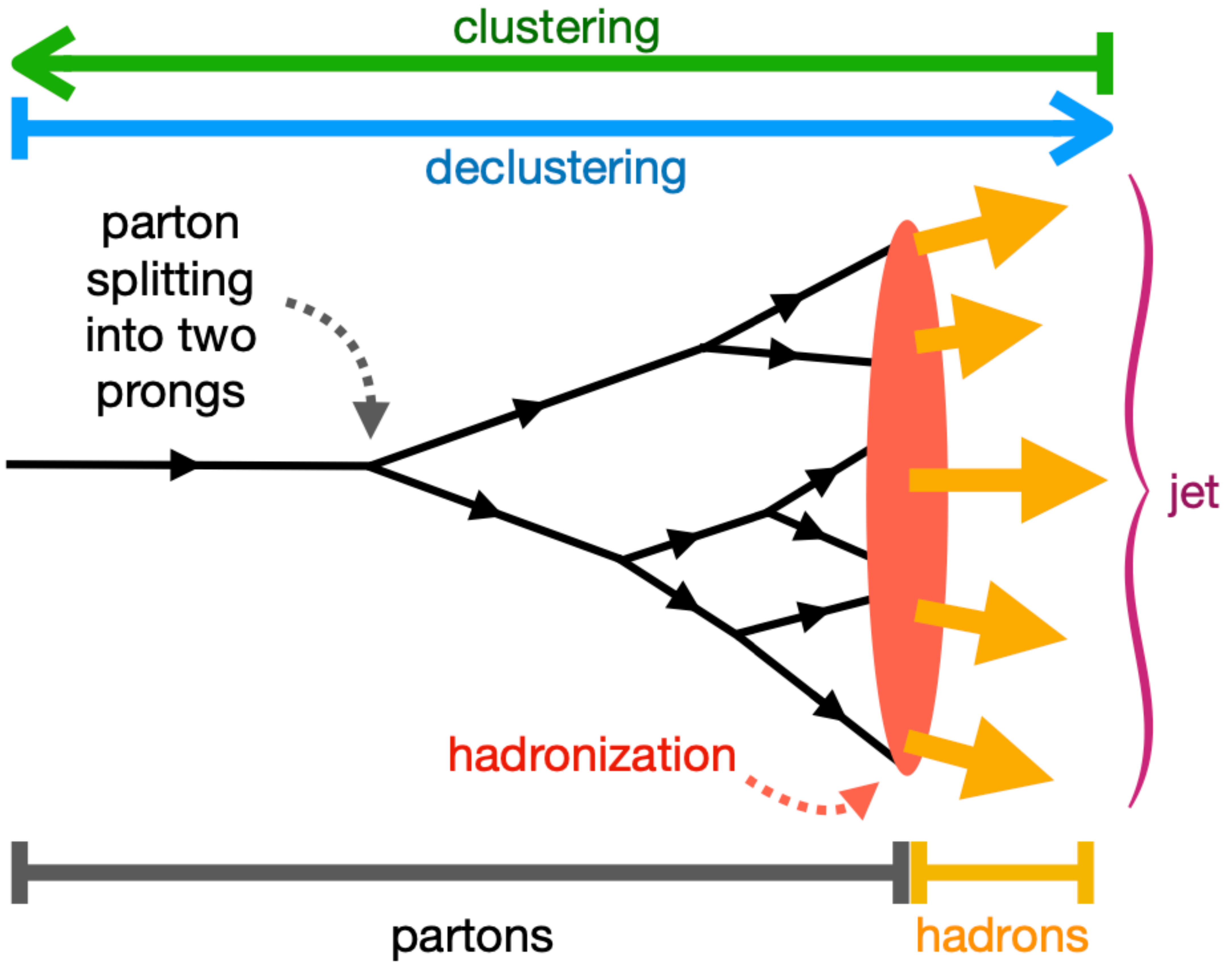
Jet suppression does not exhibit a strong variation with jet p_T but increases steeply with r_g:

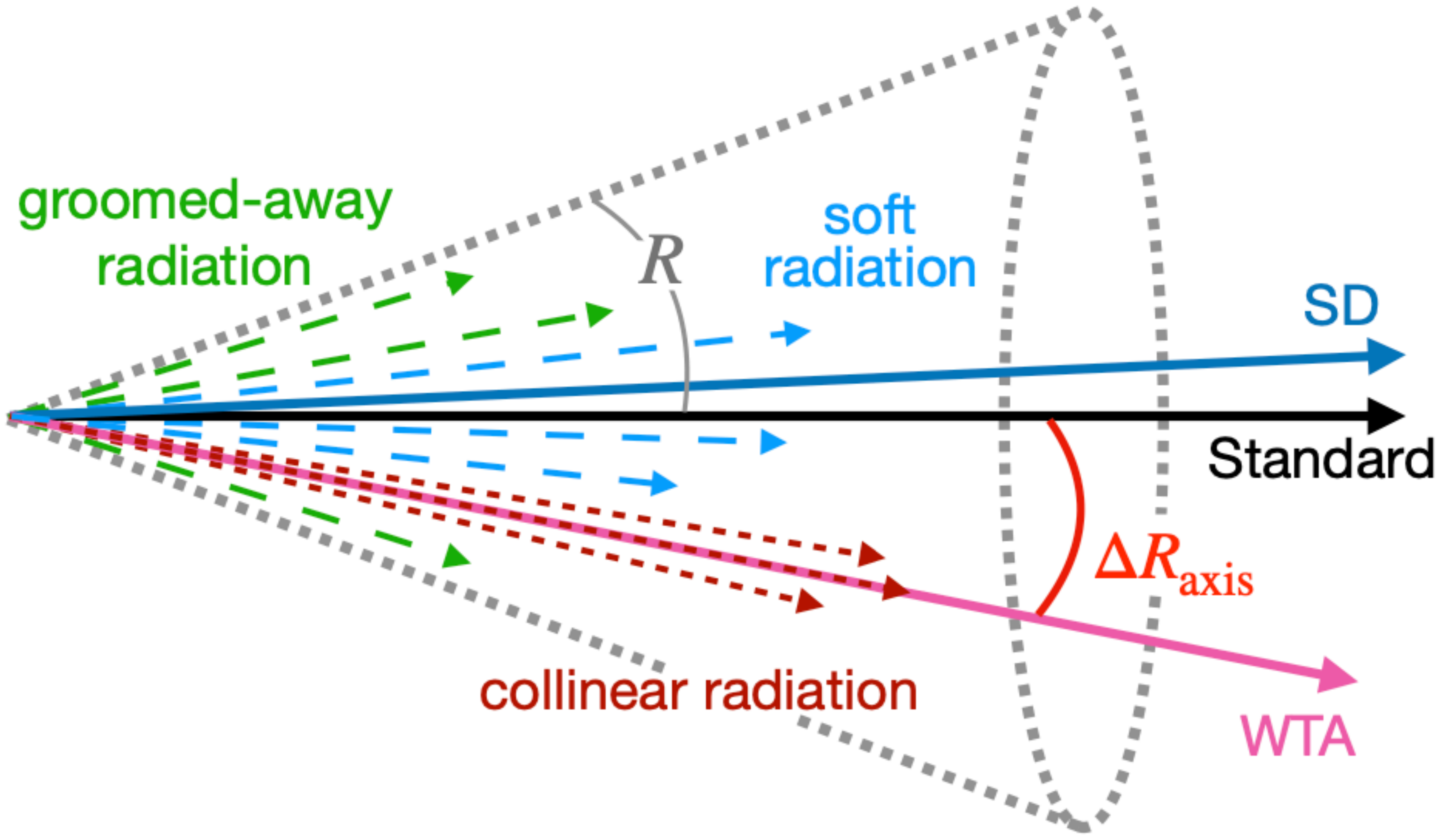
- consistent with a picture of jet quenching arising from coherence
- provides direct evidence in support of this approach

Angle between jet axes: substructure

Angular structure sensitive to effects of medium-induced gluon radiation and intra-jet pT broadening:

Understand interplay between QGP competing effects





Substructure observable: $\Delta R_{axis} = \sqrt{(y_2 - y_1)^2 + (\varphi_2 - \varphi_1)^2}$ between 2 axes

Angle between jet axes: substructure

Angular structure sensitive to effects of medium-induced gluon radiation and intra-jet pT broadening:

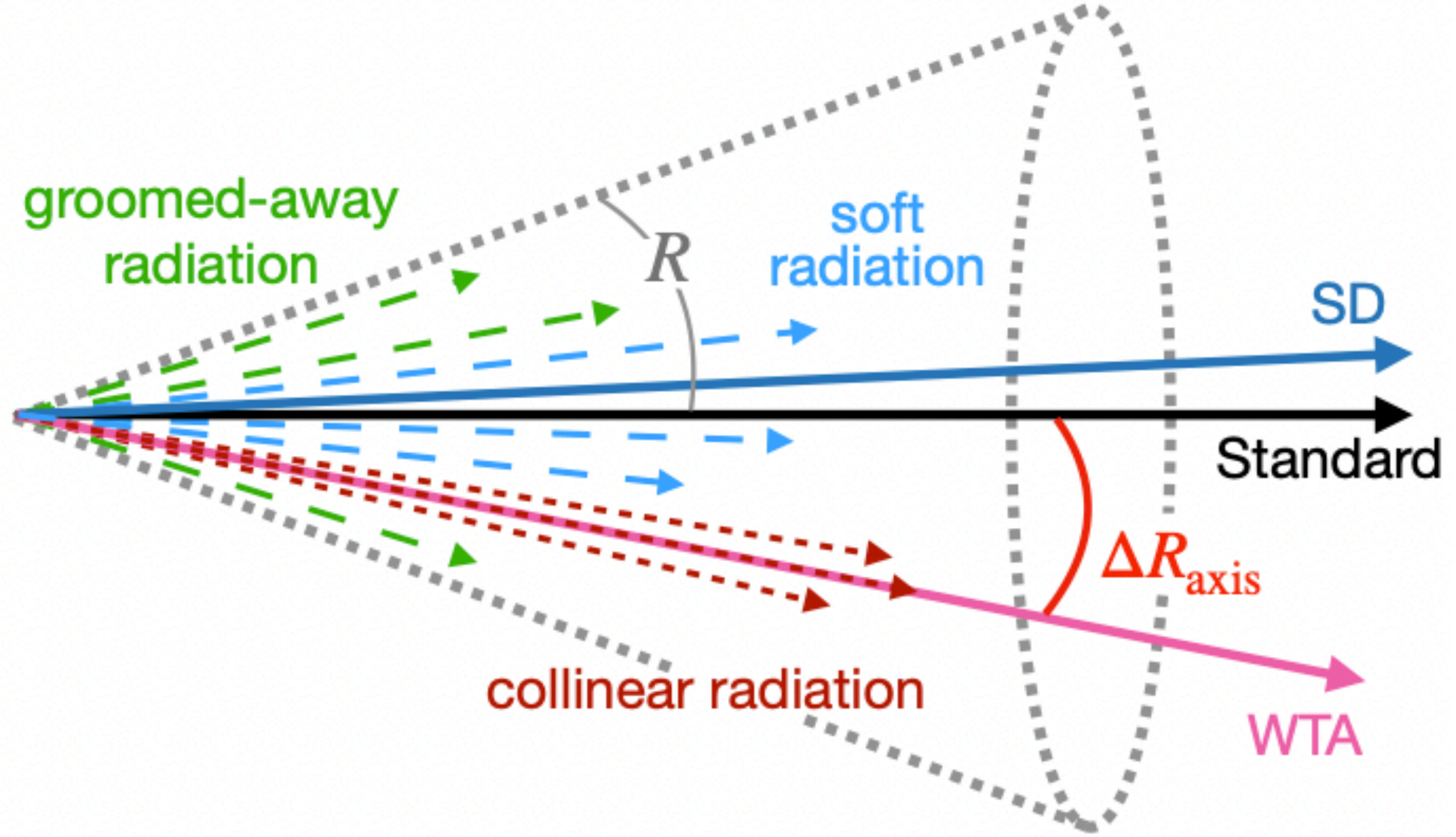
Understand interplay between QGP competing effects

P. Cal et al., JHEP 04 (2020) 211
ALICE, arXiv:2211.08928, JHEP In press
ALICE, arXiv:2303.13347

- **Standard axis:**
  coordinates in (y, φ) of jet clustered with anti-k_T algorithm and combined with E-Scheme

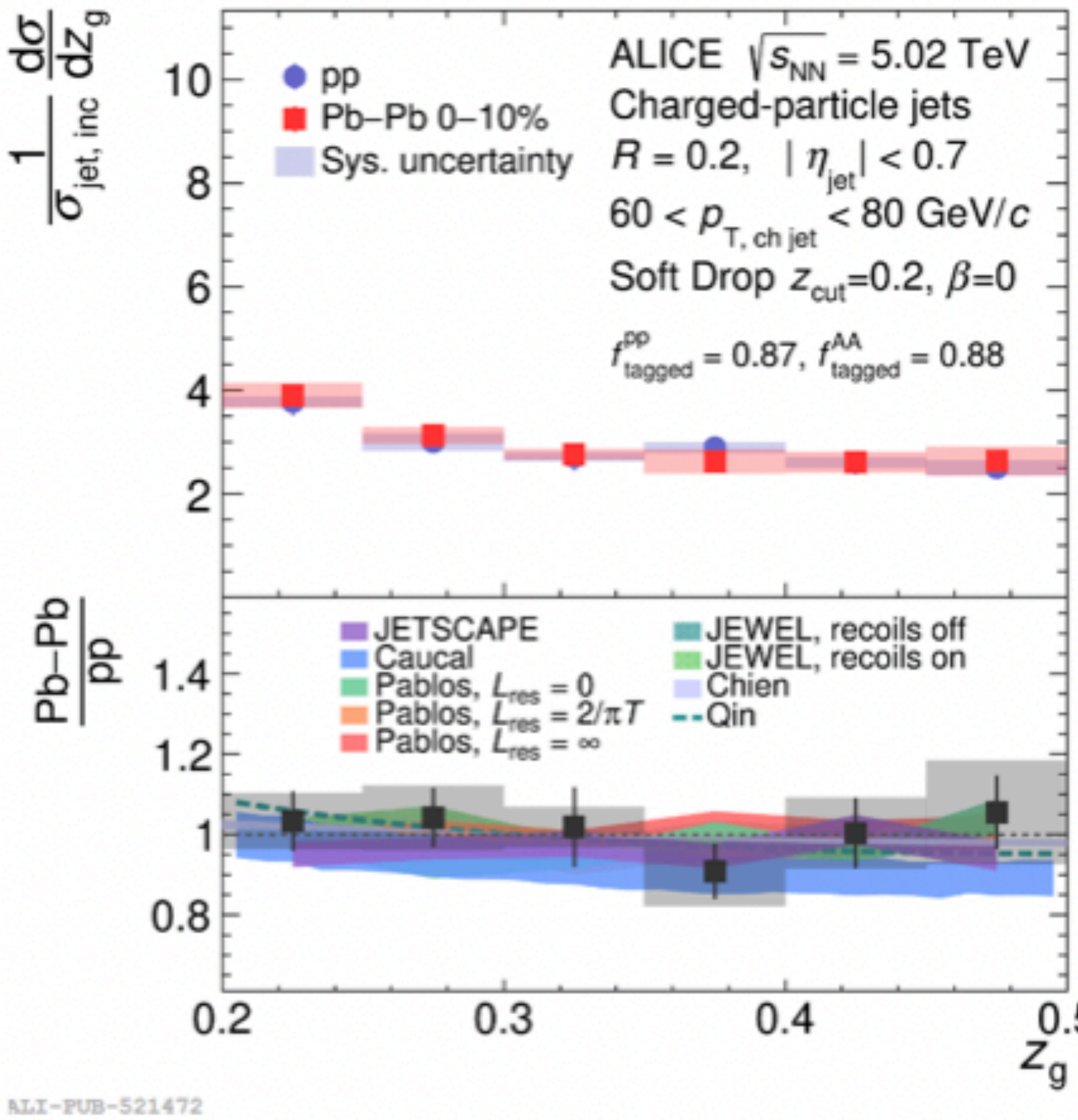
- **Groomed axis:**
  standard axis of groomed (with Soft Drop) jet

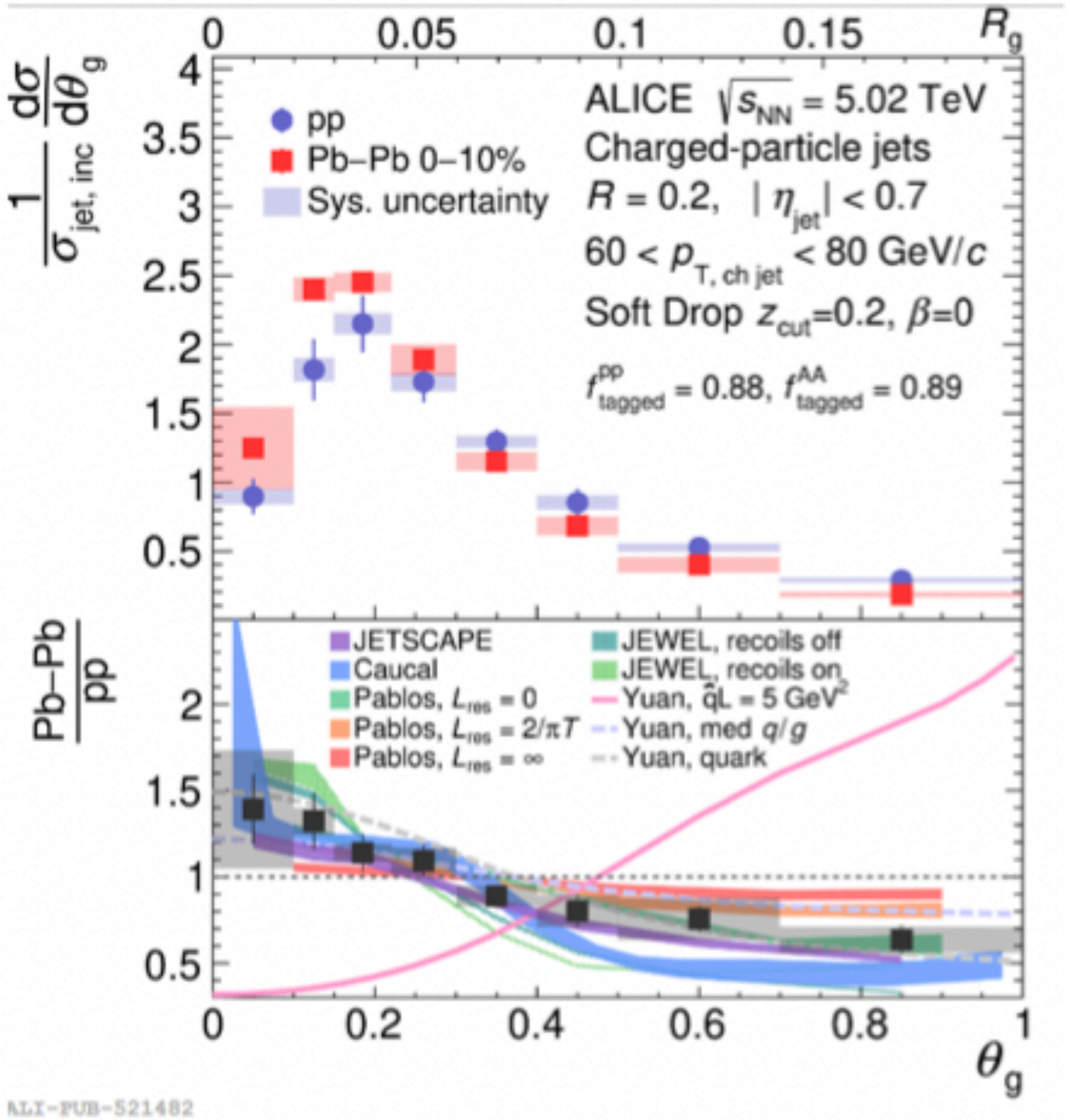
- **Winner-Takes-All (WTA) axis:**
  - recluster jet with CA algorithm
  - $2 \rightarrow 1$ prong combination by taking direction of harder prong and $p_{\mathrm{T,\,tot}} = p_{\mathrm{T,\,1}} + p_{\mathrm{T,\,2}}$
  - Resulting axis insensitive to soft radiation at leading power



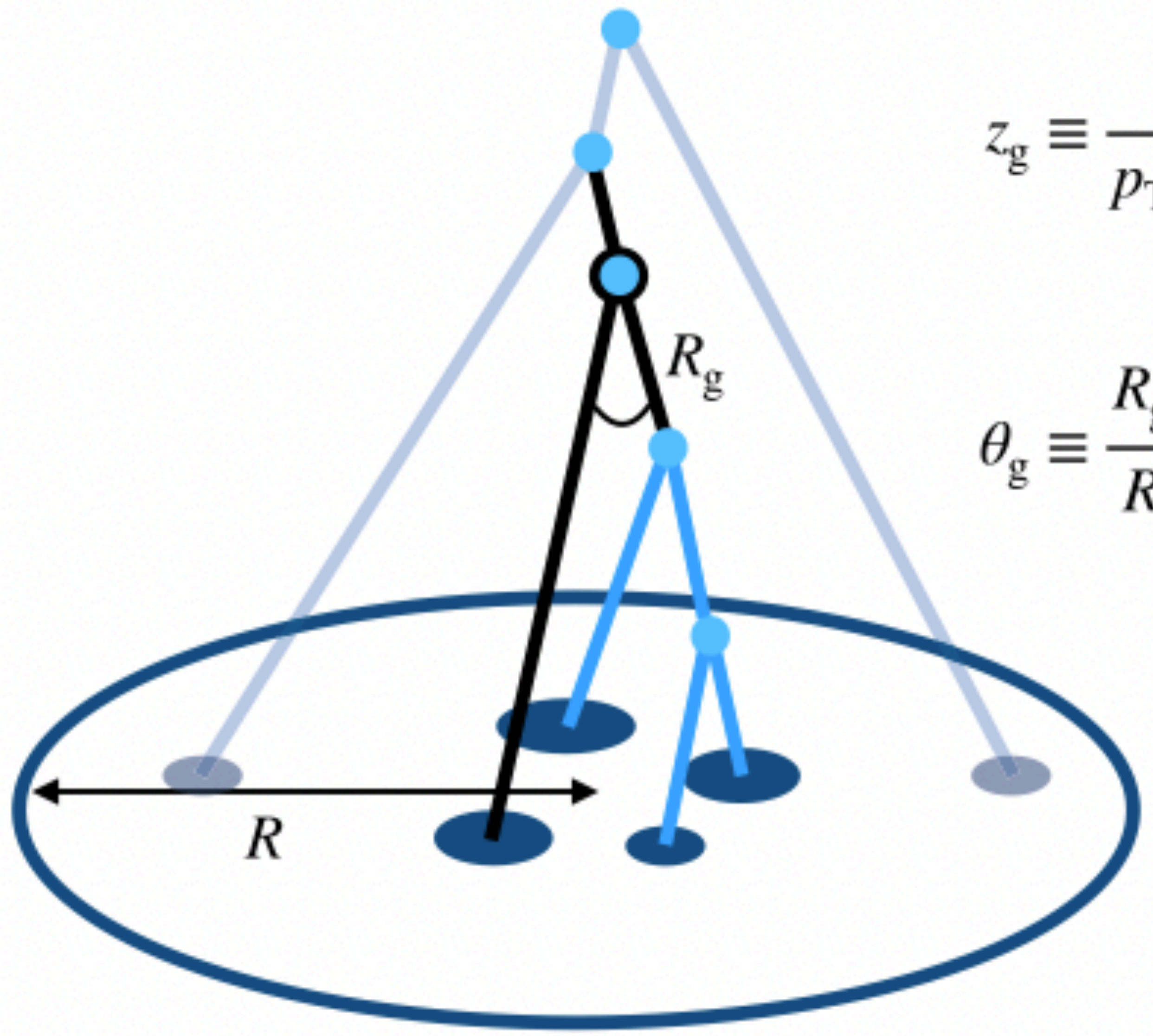
Substructure observable: $\Delta R_{axis} = \sqrt{(y_2 - y_1)^2 + (\varphi_2 - \varphi_1)^2}$ between 2 axes

Hannah Bossi's Talk





ALICE: *PRL* 128 (2022) 10, 102001



$$z_g \equiv \frac{p_{T,\mathrm{subleading}}}{p_{T,\mathrm{leading}} + p_{T,\mathrm{subleading}}}$$

$$\theta_g \equiv \frac{R_g}{R} \equiv \frac{\sqrt{\Delta y^2 + \Delta\varphi^2}}{R}$$

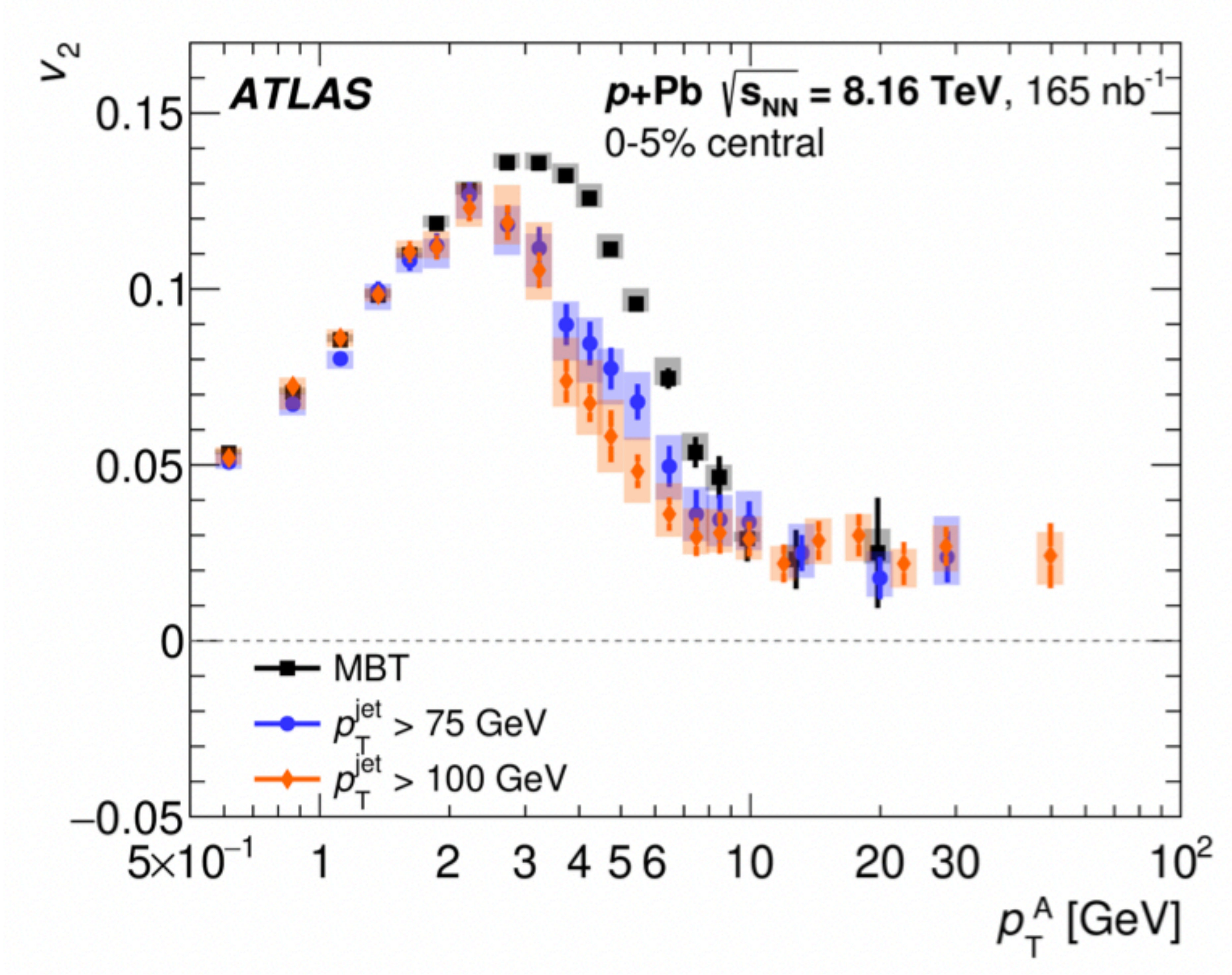
z_g: no modification

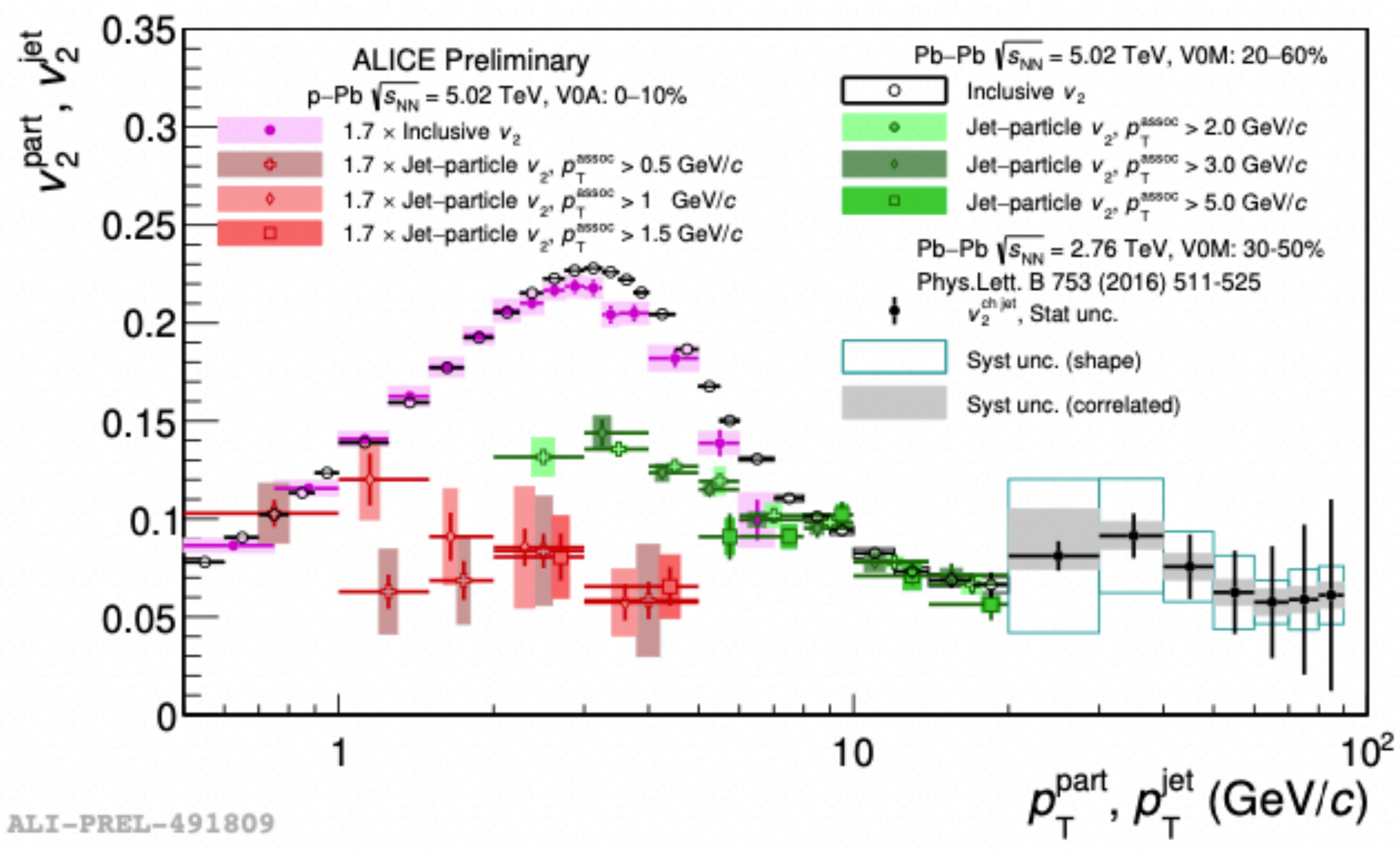
θ_g: narrowing in Pb-Pb compared to pp observed direct evidence of the modification of jet angular structure in QGP

Medium has resolving power for splittings (promotes narrow splittings, filters out wider subjets).

Jet quenching in small system

arXiv:2206.01138





No existing observations of quenching in p+Pb

- ATLAS: v_2 measurement show persisted v2 in p+Pb
- ALICE : v_2 of p-Pb and Pb-Pb have different magnitude but comparable.

Correlations between jet particles and the underlying event, no jet quenching!

- *Brian Cole's Talk HP23*
- *Christopher McGinn's Talk*
- *Caitie Beattie's Talk*

Exploring jet modification via γ-hadron and π^0-hadron correlations in Au+Au collisions at PHENIX

π^0- hadron: to explore lower momentum jets & fragments

- D_{AA} = ***difference of yields in AA and in pp***
- $D_{AA} > 0$ enhancement; $D_{AA} < 0$ suppression

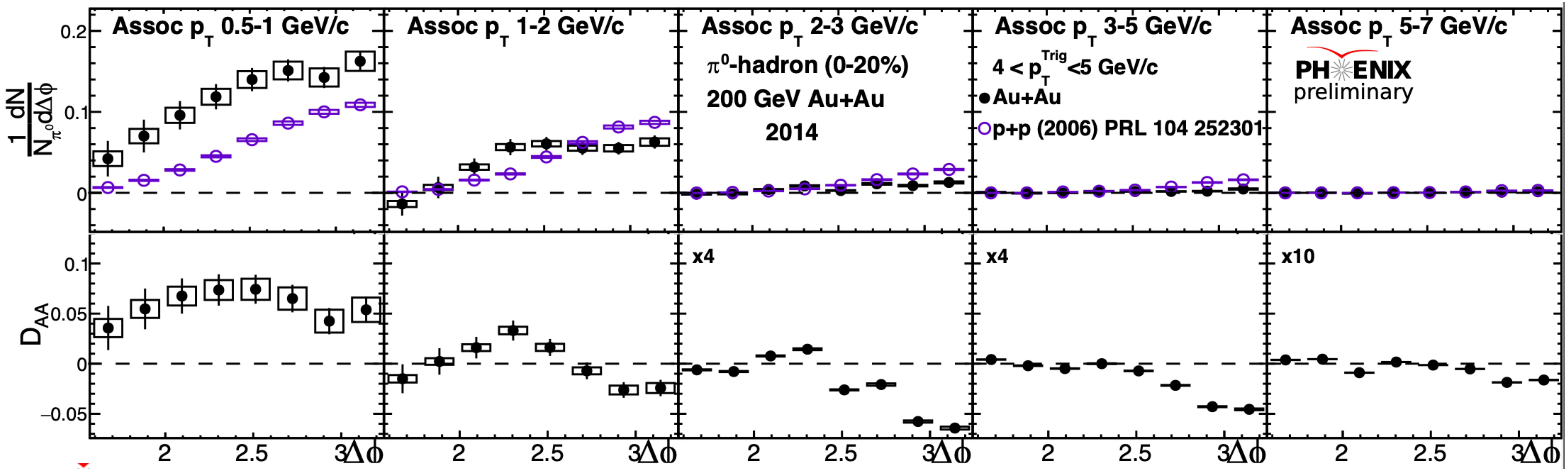
What is the dependence on hadron p_T?

Trigger pT: 4-5 GeV/c

- Transition from enhancement to suppression at higher hadron pT

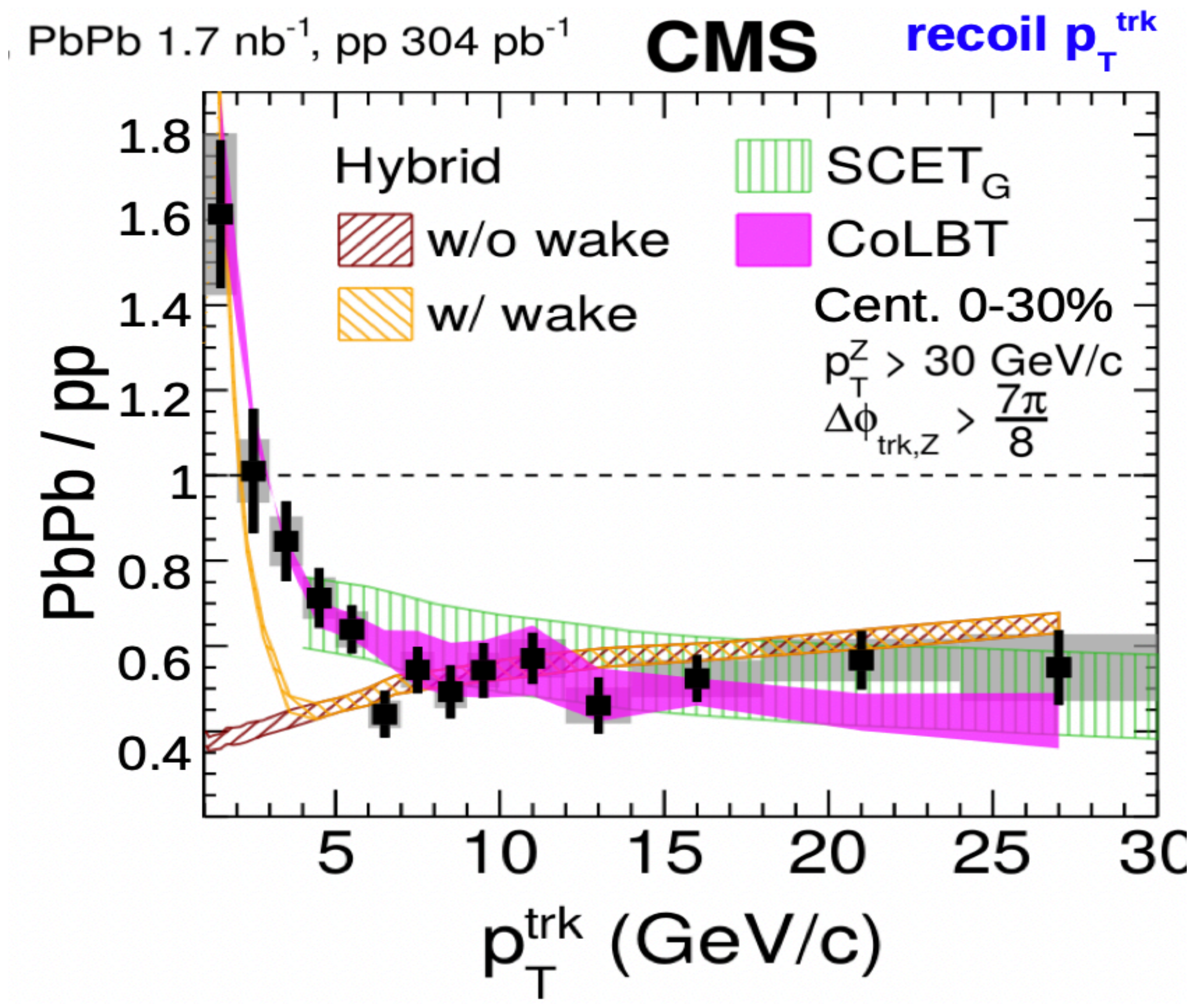
- $\gamma/Z + jet$ = way to measure parton medium interactions with jet FF

▸ Megan Connors's Talk

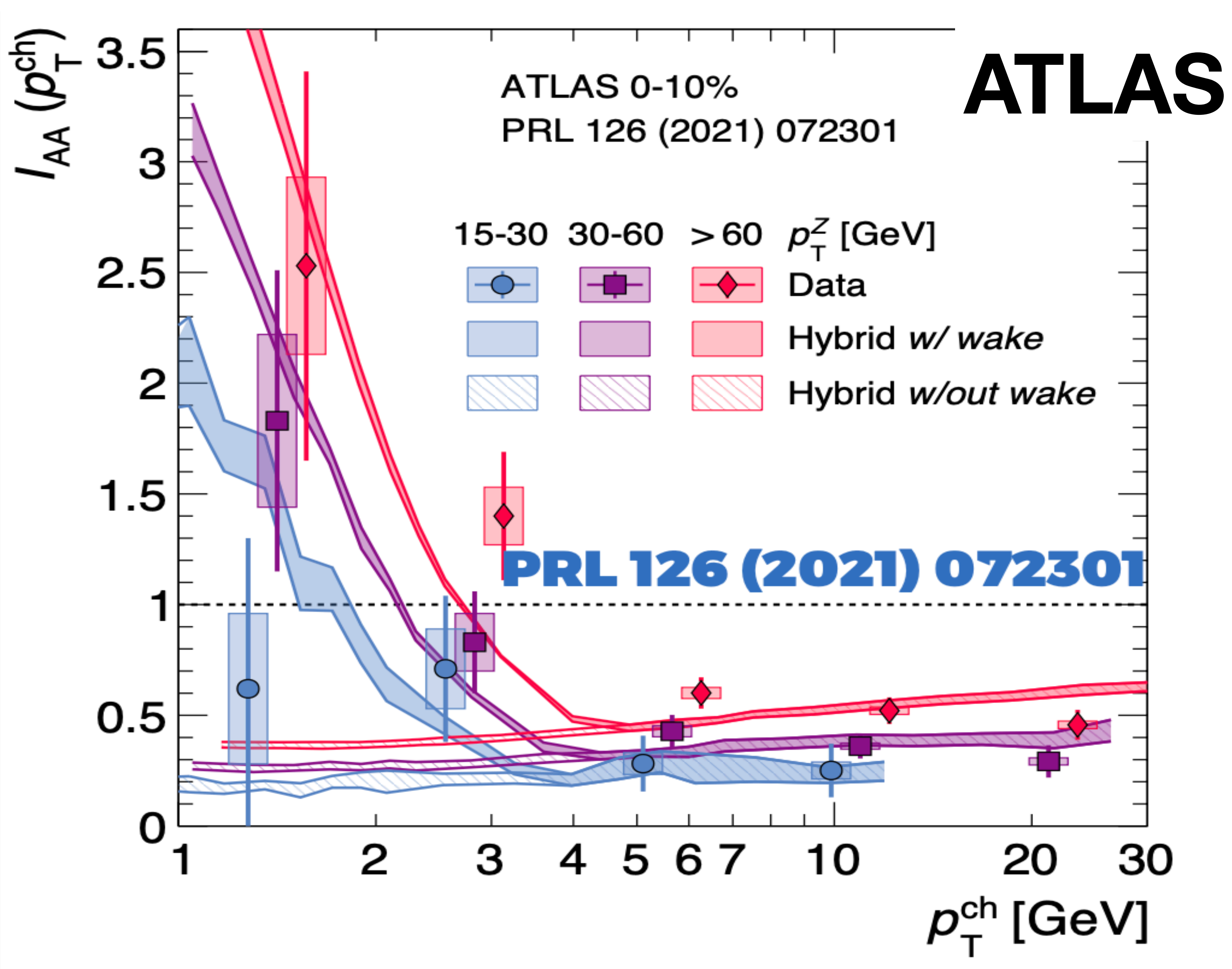


Hadrons recoiling from high-p_T trigger

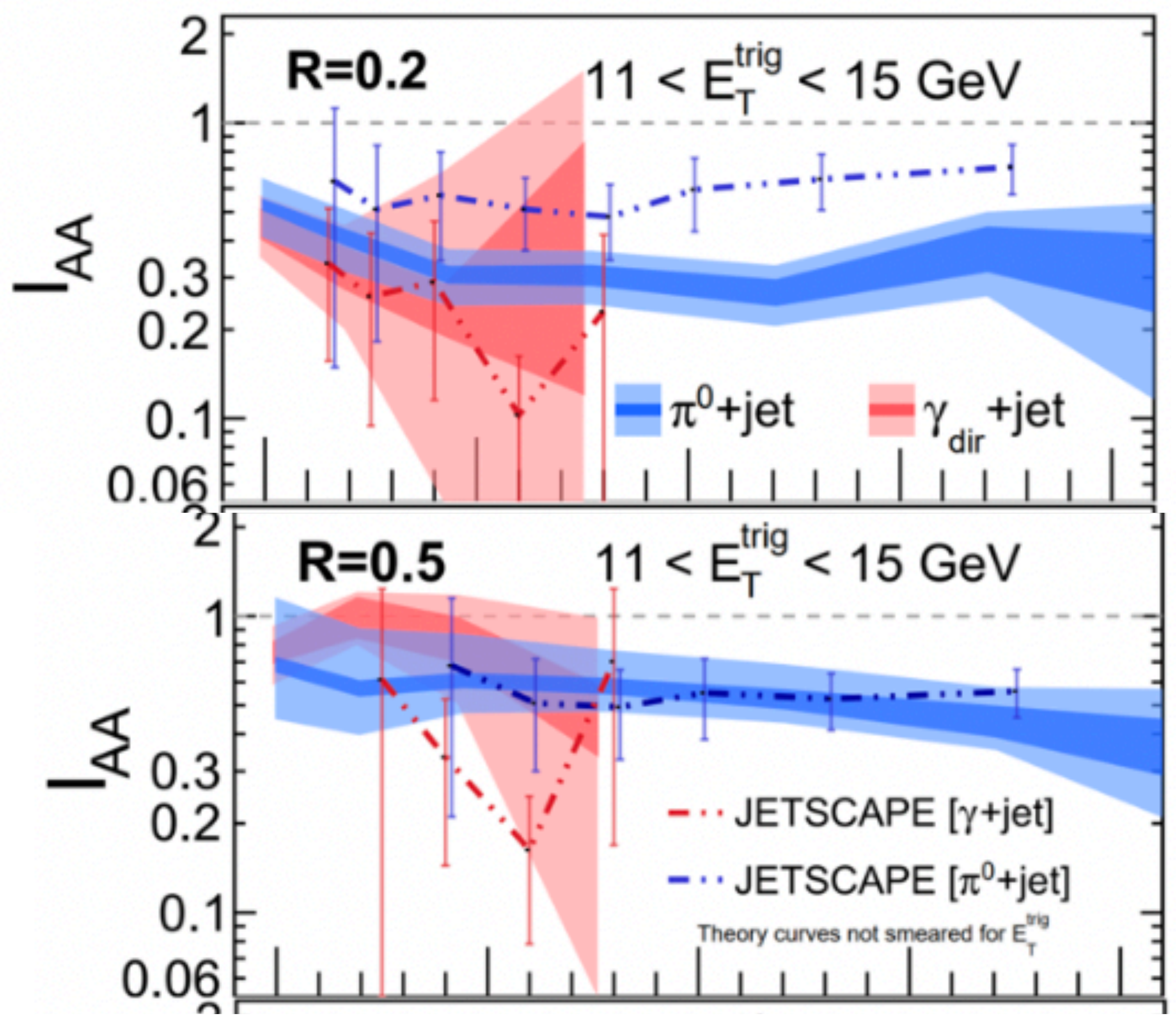
‣ Kaya Katar's Talk



‣ Christopher McGinn's Talk



‣ Derek Anderson's Talk



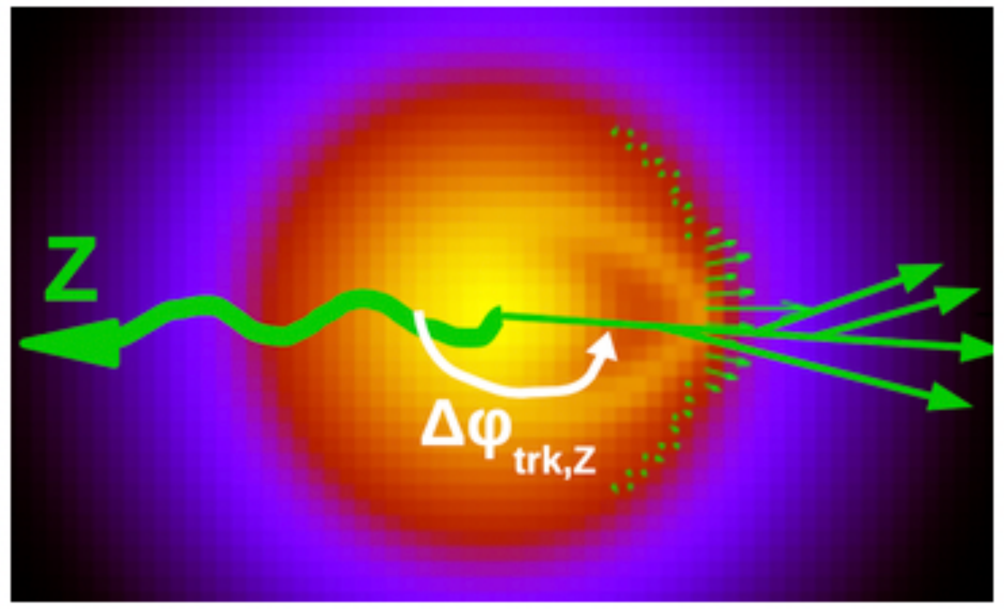
- SCETG: includes Glauber gluons into soft-collinear effective theory
- CoLBT: feeds quenched jet energy into hydrodynamics evolution

  Consistent with data both for low-p_T and high-p_T

- Hybrid model w/ wake qualitatively describes rising trend at low p_T

Hadrons recoiling from high-p_T trigger:

Z-boson tags for studying parton interactions



EW bosons tag the parton kinematics and flavour:

- way to understand medium response
- measure parton-medium interactions

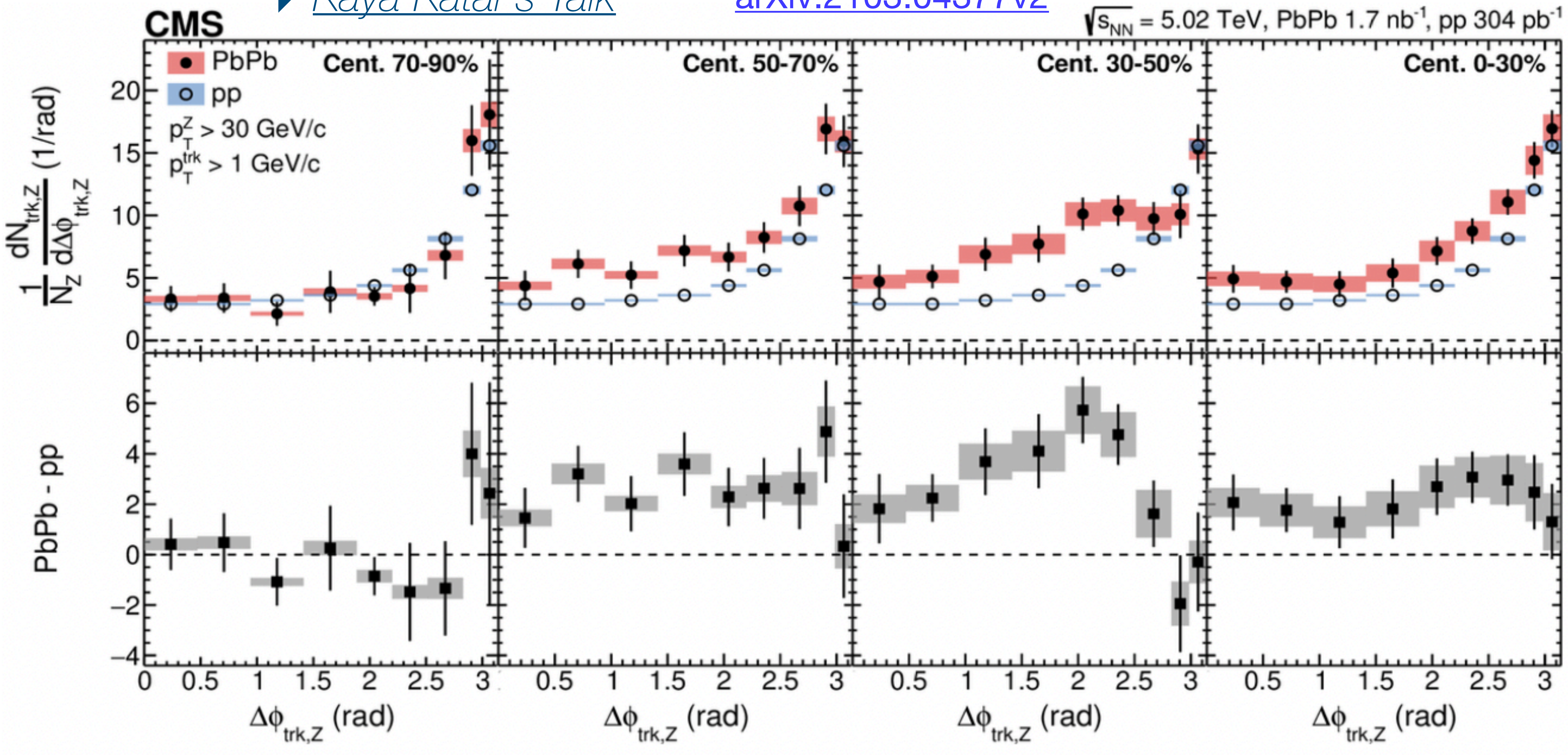
Angular correlations distributions $\Delta\varphi = (\varphi^{\gamma} - \varphi^{\mathrm{h}})$ reveal medium-induced modification of the away-side jet constituents

- Differences wrt pp

The excess observed in all bins could be caused by:

- medium response → jet excites the medium around it.
- medium modifications of partons

▸ Kaya Katar's Talk   arXiv:2103.04377v2

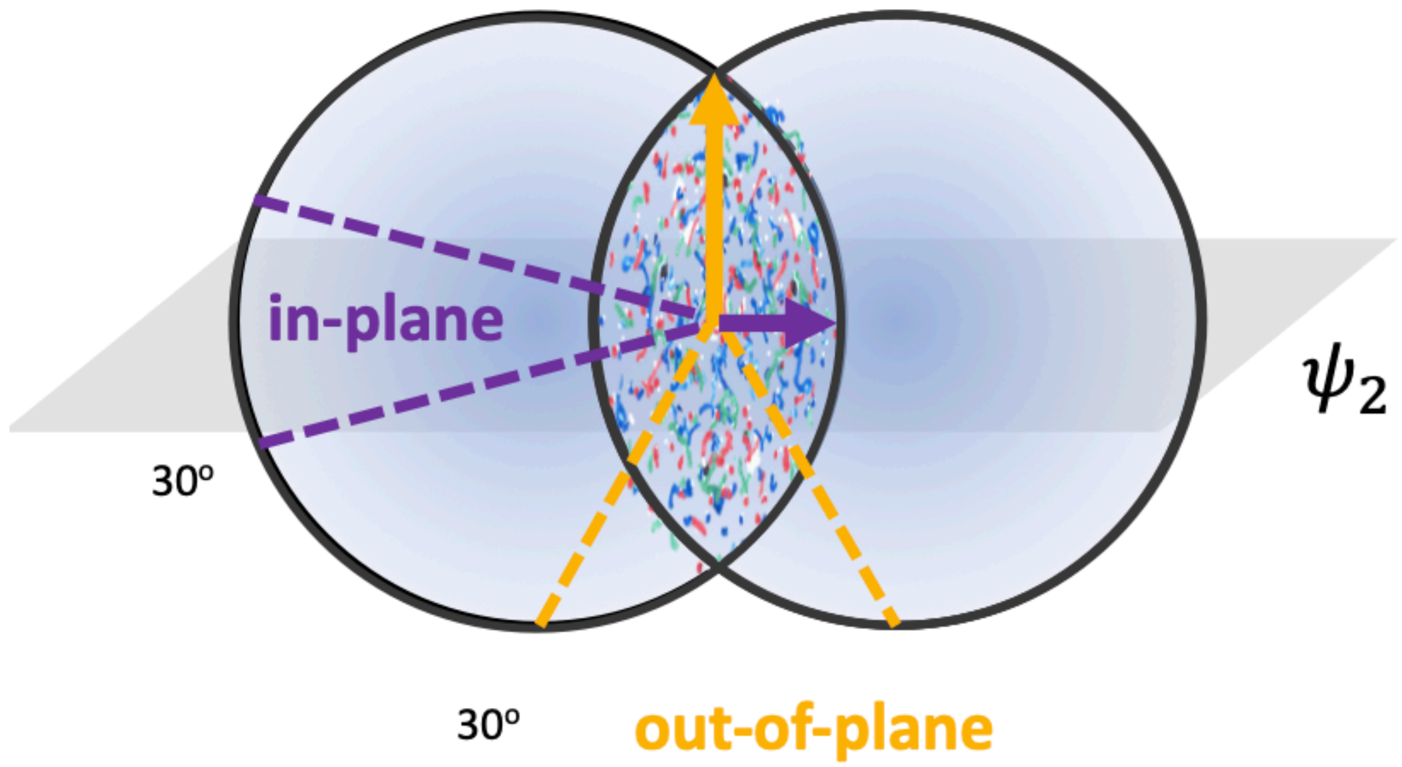


Centrality →

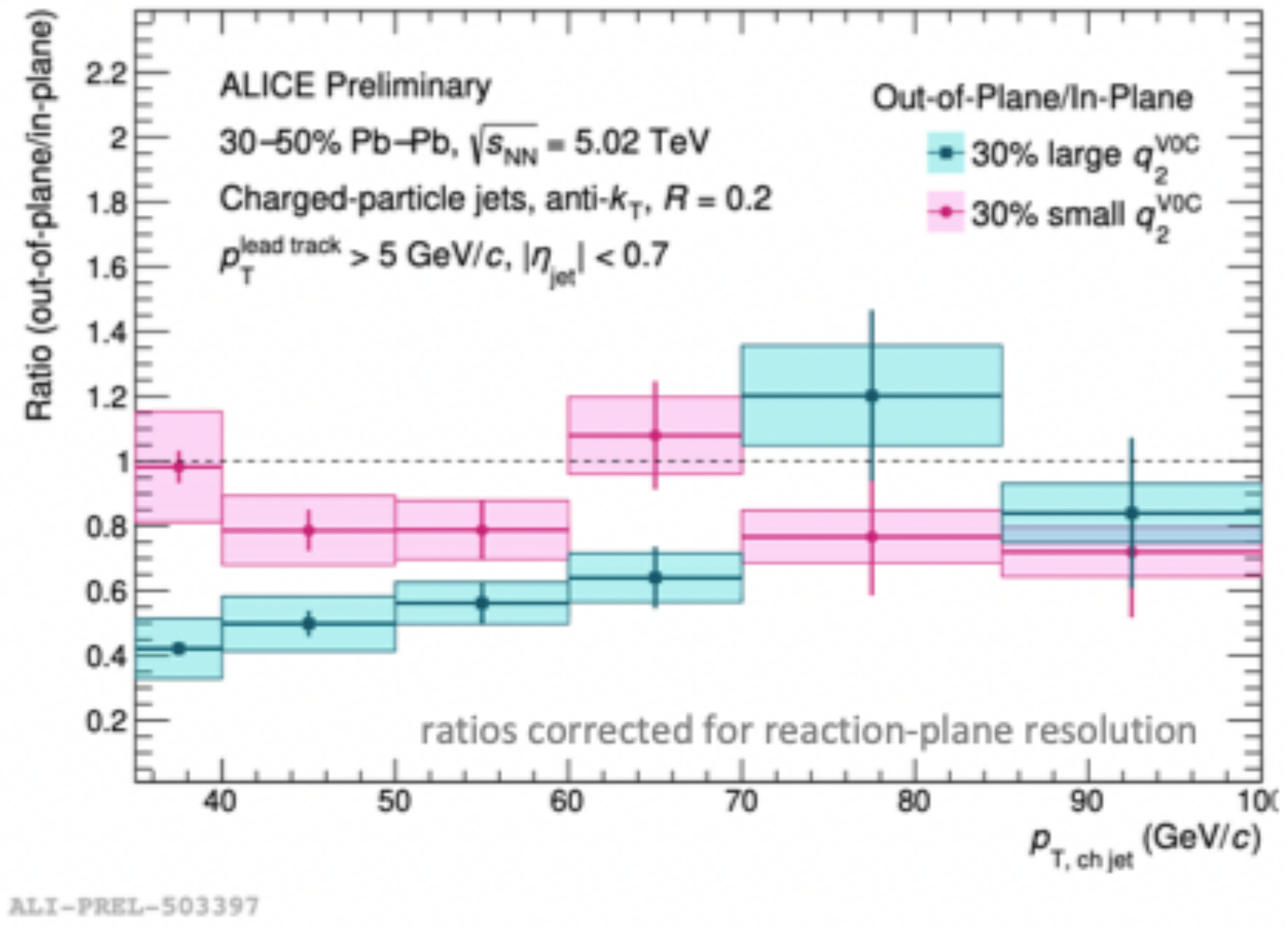
Jets lose energy due to QGP, related to path-length: radiative $\sim L^2$

Use ***Event plane angle***: in-plane axis shorter than out-of-plane

→ energy loss greater along the out-of-plane axis



- Caitie Beattie's Talk



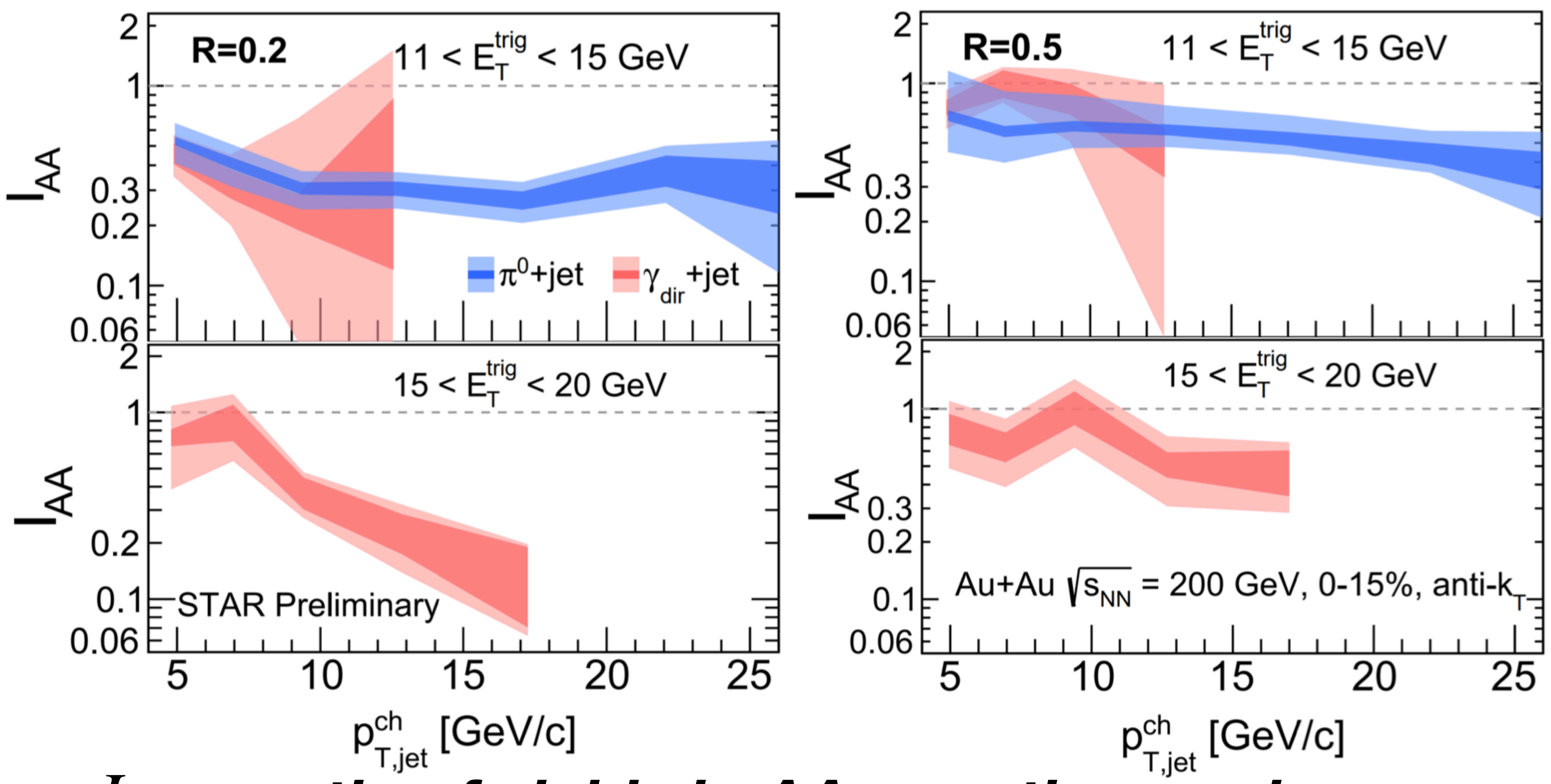
q^2 is related to the geometry of the overlapped region during collision: elliptical = large q^2

Selecting specific event shapes allows to maximize in plane and out of plane path length differences

Largest q^2 → more suppressed ratio of jet yields: stronger suppression out-of-plane

Hadrons recoiling from high-p_T trigger:

Medium modification with γ^{dir}+jet in p+p and Au+Au STAR



- γ^{dir}+ jet: valuable tool for quantifying the effects of jet quenching
- π^0+ jet: infos about the color factor and path length dependence of medium-induced energy loss
- differences between the recoil jet populations of the two triggers in their relative quark/gluon fraction and their mean path length

- I_{AA} = ***ratio of yields in AA over the one in pp***

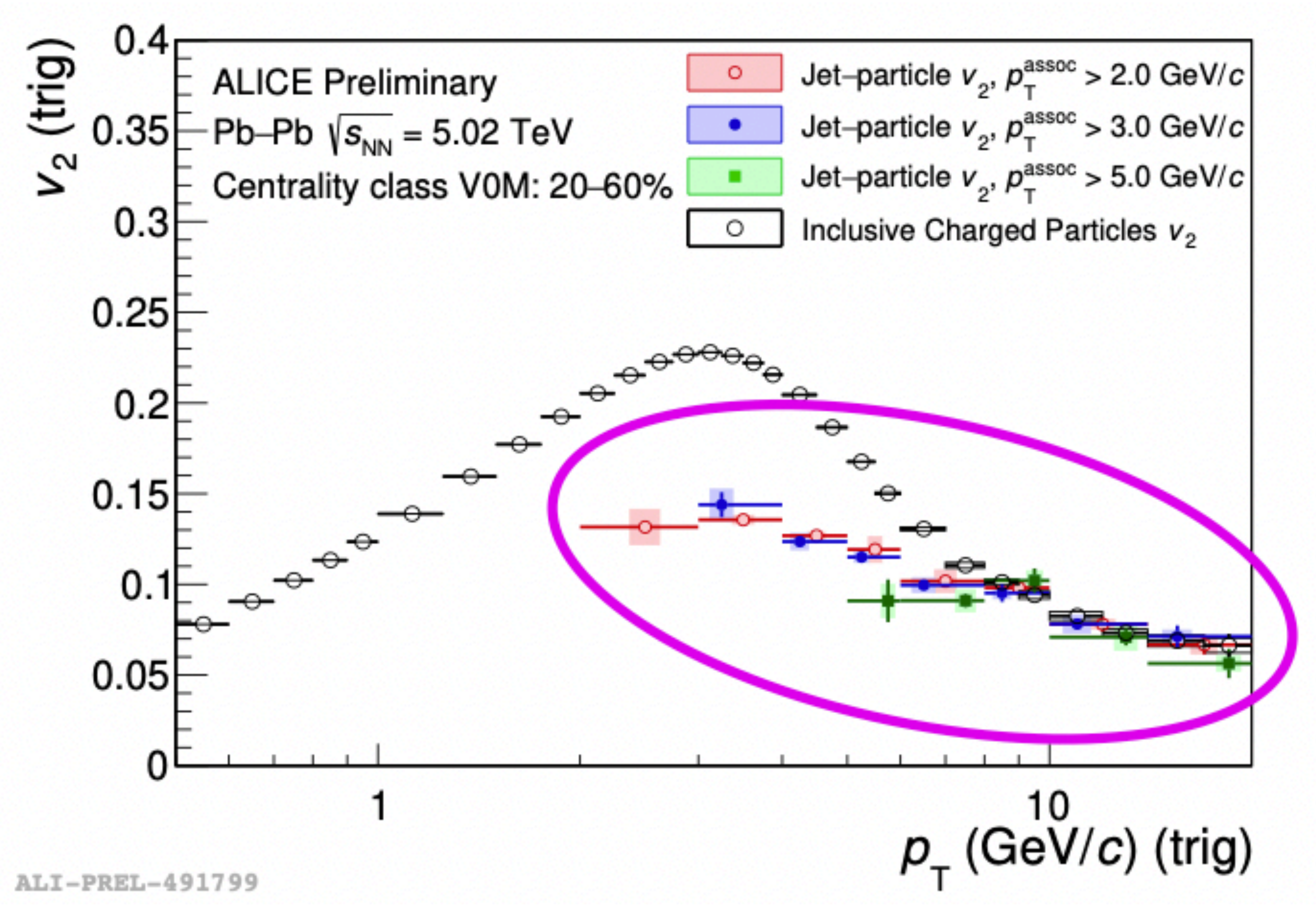
  observation of significant medium-induced intra-jet broadening: suppression wrt to p+p

- ***jet R dependence of suppression***

  $\boldsymbol{R = 0.2}$ more suppressed than 0.5 ⇒ Indication of energy redistributed to wide angles

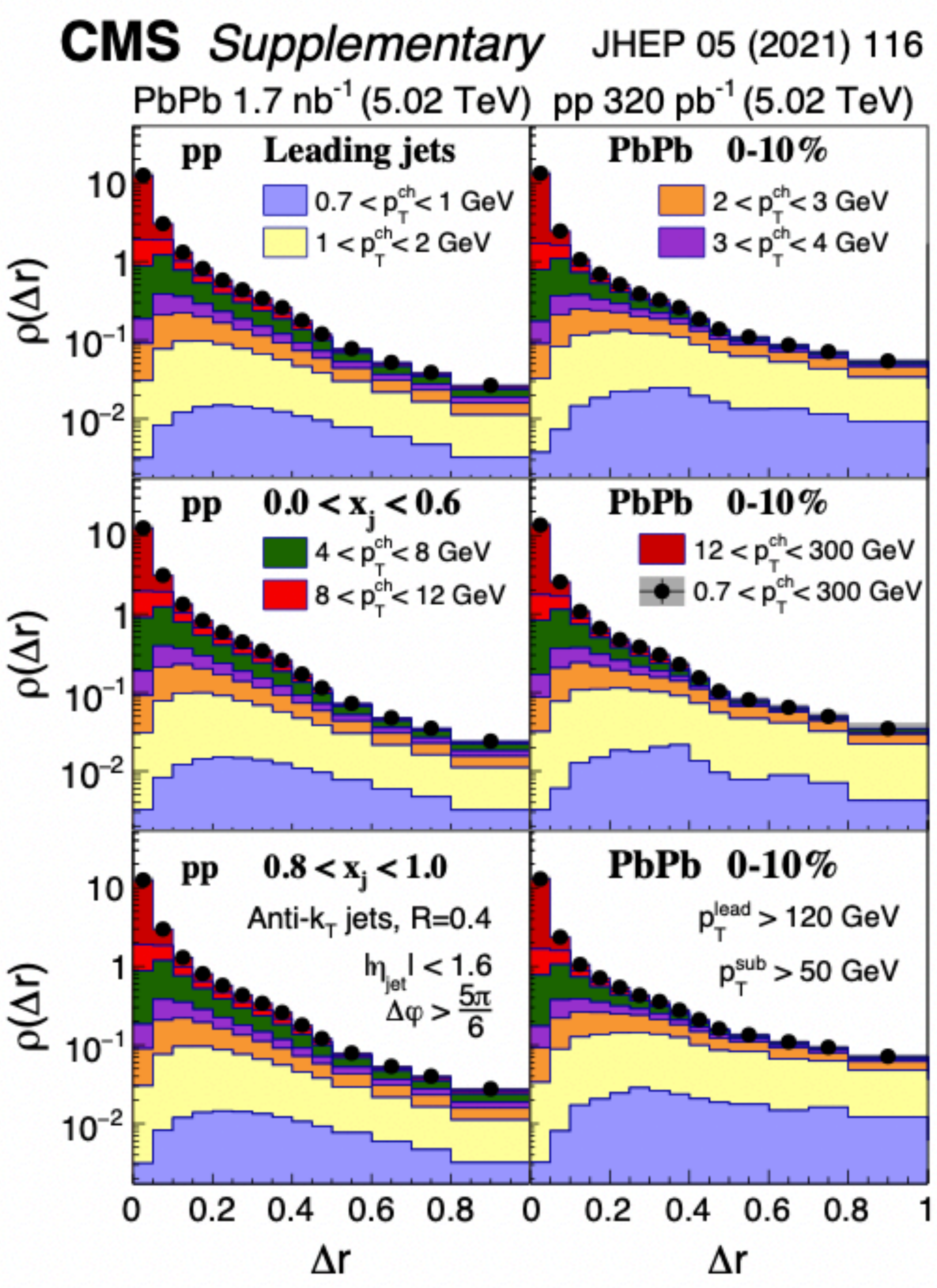
Geometry:

Caitie Beattie's Talk

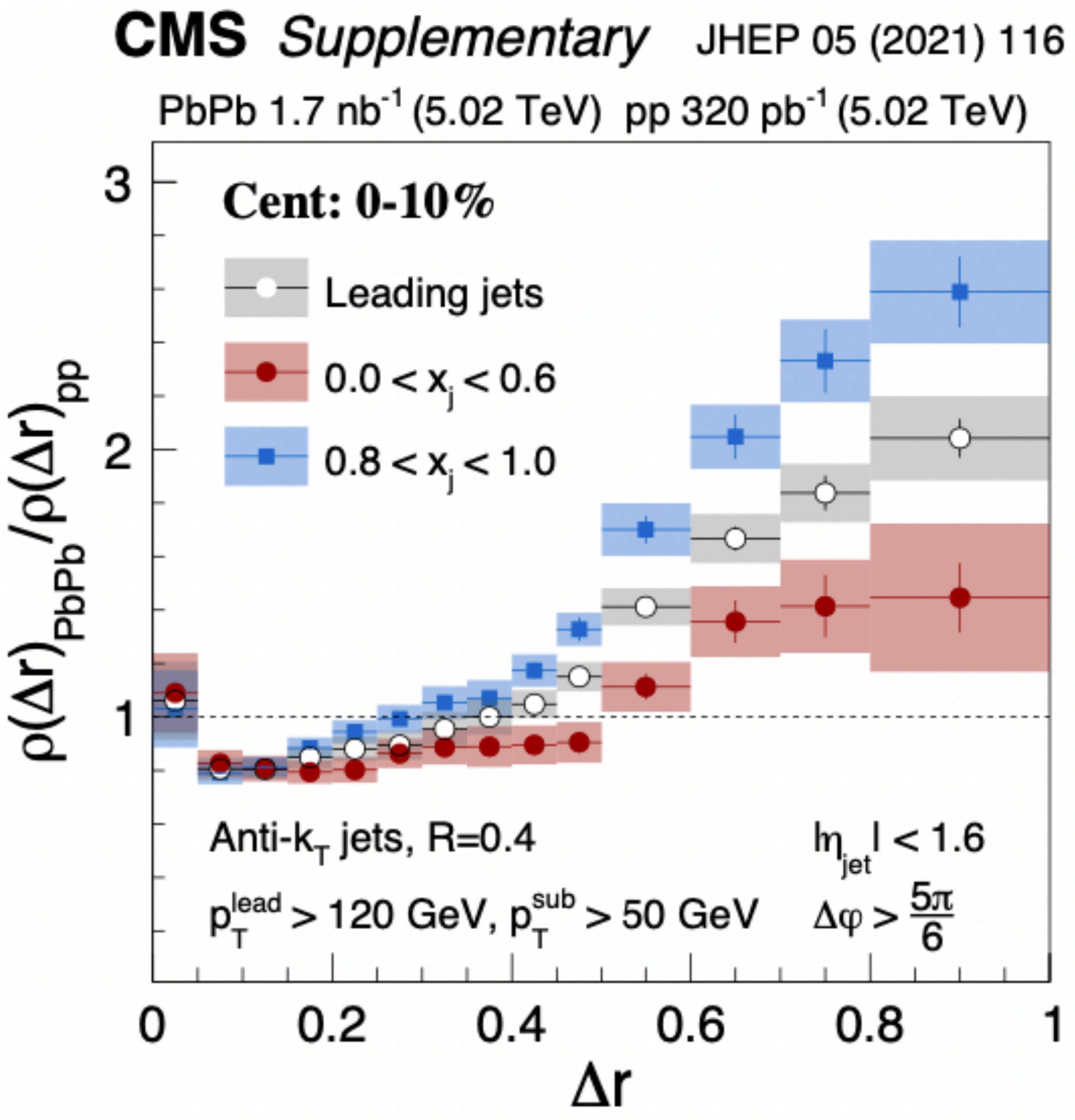


Non-zero v_2 is indicative of suppressed out-of-plane jet activity, consistent with path- length dependence.

Radial profile:



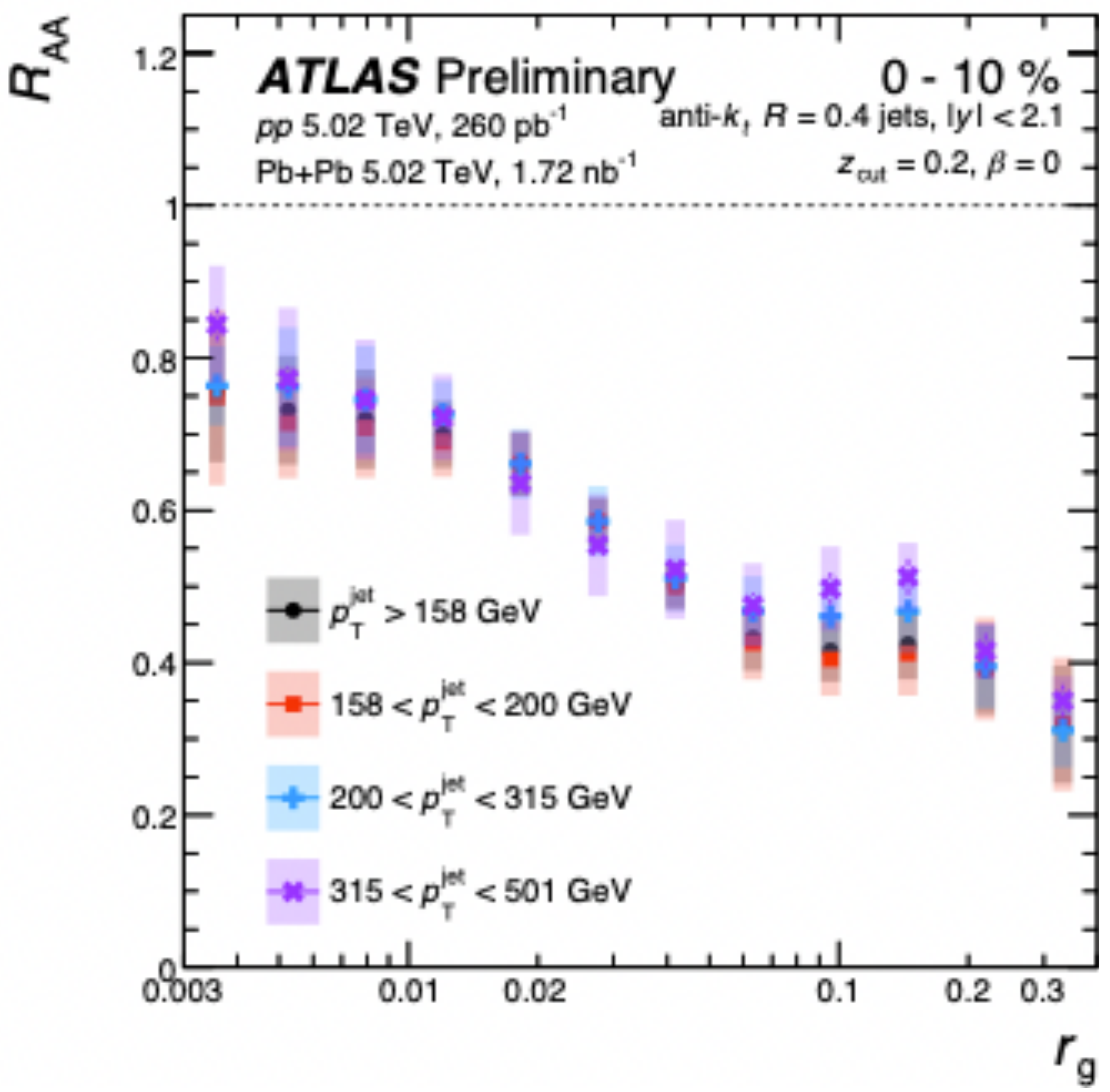
- [*Jussi Viinikainen's Talk*]



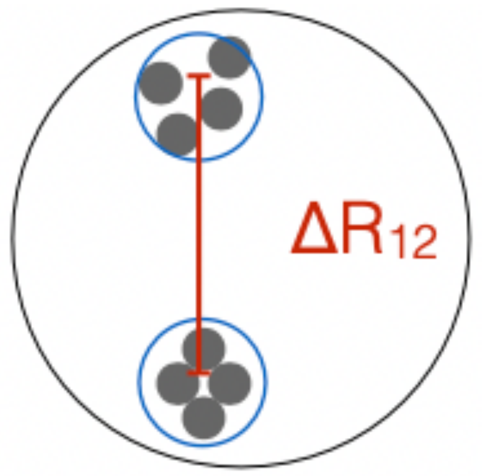
Leading jets: greatest modifications with respect to pp reference in balanced events

while the subleading jets are the most modified in unbalanced events. The results are consistent with a hypothesis that the unbalanced events are more surface biased, leading to the subleading jet going through a much larger distance in the plasma compared to the leading jet. However, one needs to take into account energy loss fluctuations before any conclusions can be drawn.

Substructure:



ATLAS-CONF-2022-026



$r_g = \Delta R_{i,j}$ **between the subjets satisfying the SD condition**

r_g radial scan = substructure of jets

Strong r_g dependence: ordering with respect to the splitting angle

the difference in the R_{AA} values is largest between jets having r_g values below or above 0.02,

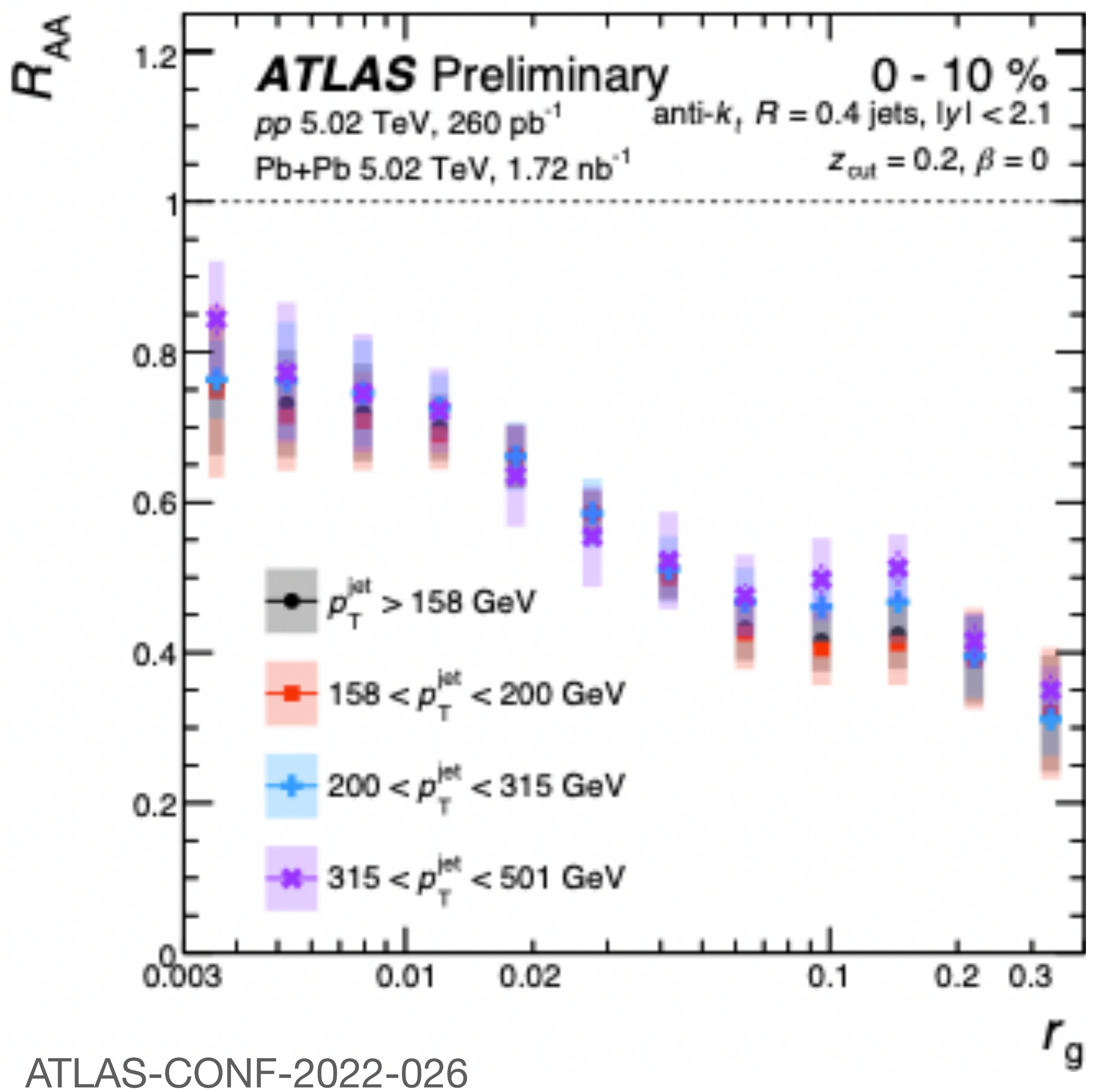
supporting a coherence picture of jet quenching

Lack of p_T dependence for R_{AA} for jets with similar structure + rise of inclusive R_{AA} ⇔ p_T dependence to r_g.

More quantitative comparison between experiments is needed.

arXiv:2211.11470

Substructure: Measurement of the azimuthal anisotropy and substructure of jets in Pb+Pb collisions with the ATLAS detector



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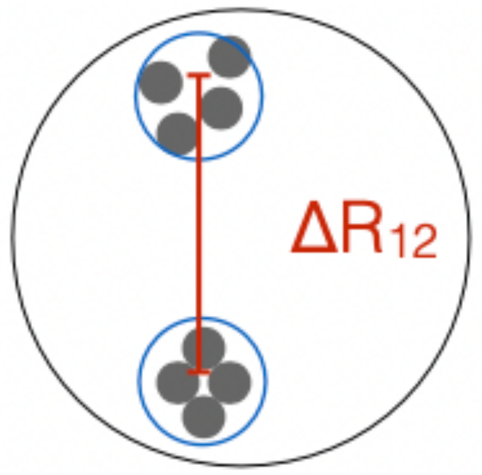


$r_g = \Delta R_{i,j}$ **between the subjets satisfying the SD condition**

Strong r_g dependence

Lack of p_T dependence for R_{AA} for jets with similar structure + rise of inclusive $R_{AA} \Leftrightarrow p_T$ dependence to r_g.

More quantitative comparison between experiments is needed.

Substructure plays a significant role in jet quenching

Both see larger jets more suppressed i.e. the jets are narrower

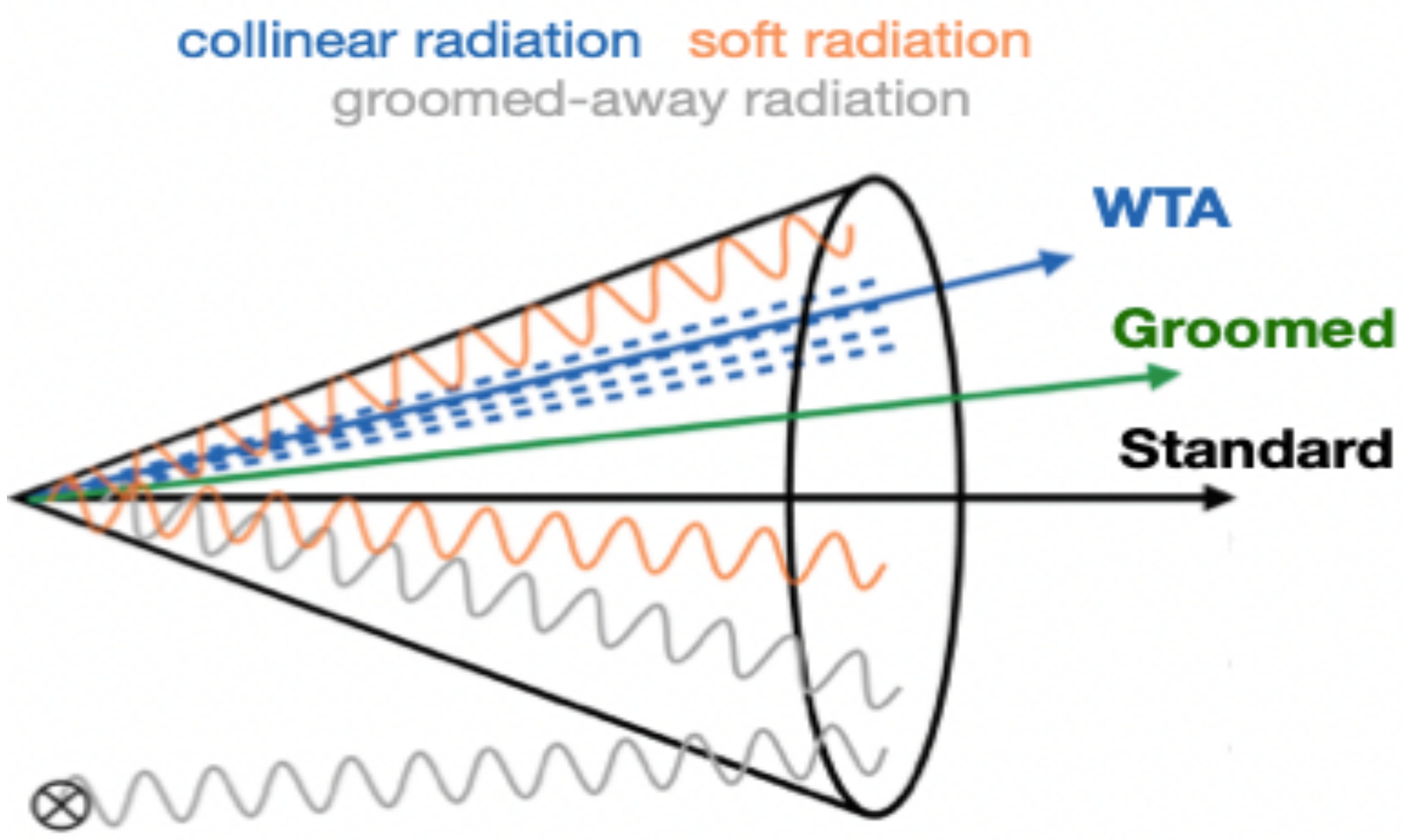
- Absolutely normalized → role of jet structure in the suppression pr

arXiv:2211.11470

Angle between jet axes: substructure

Angular structure sensitive to effects of medium-induced gluon radiation and intra-jet pT broadening:

Understand interplay between QGP competing effects



P. Cal et al., JHEP 04 (2020) 211

Angle between jets:

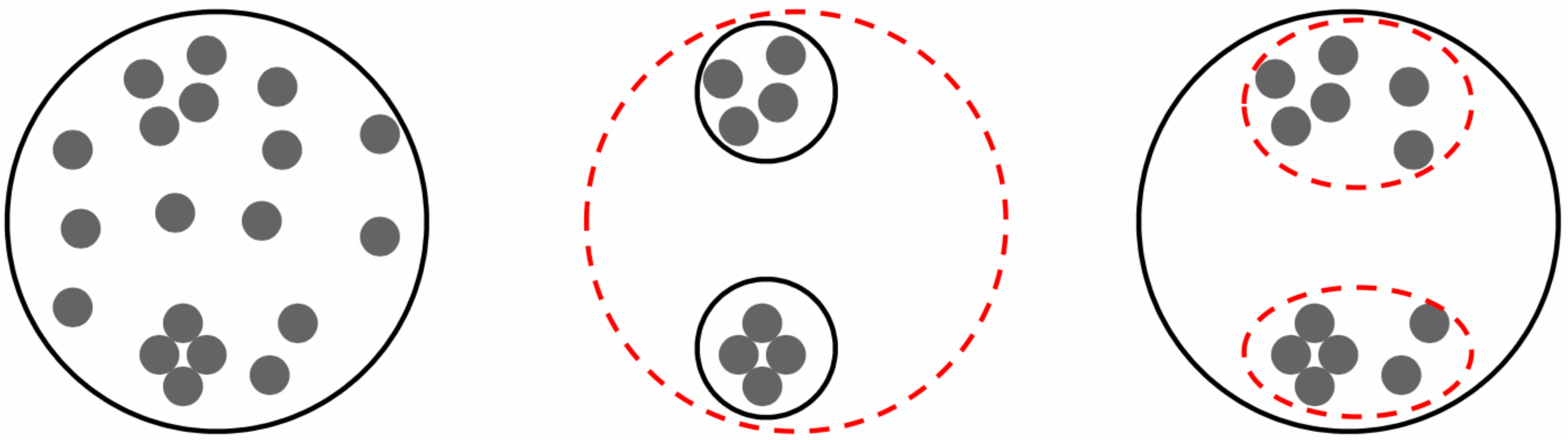
Standard Axis: anti-k_T jet with *E*-scheme recombination.

Groomed Axis: groom jets with Soft Drop (SD) algorithm

Winner Take All Axis (WTA): jet axis is given by its leading constituent

Substructure observable: $\Delta R_{axis} = \sqrt{(y_2 - y_1)^2 + (\varphi_2 - \varphi_1)^2}$ between 2 axes

Jets vocabulary



Conventional jet made of particles/tracks/clusters

Fragmentation functions, track-jet correlations and jet shapes

Re-clustered jet from smaller jets:

Large-R jets designed for boosted W/Z/t;

focus on hard structure; sub-jets

De-clustered & groomed jet:

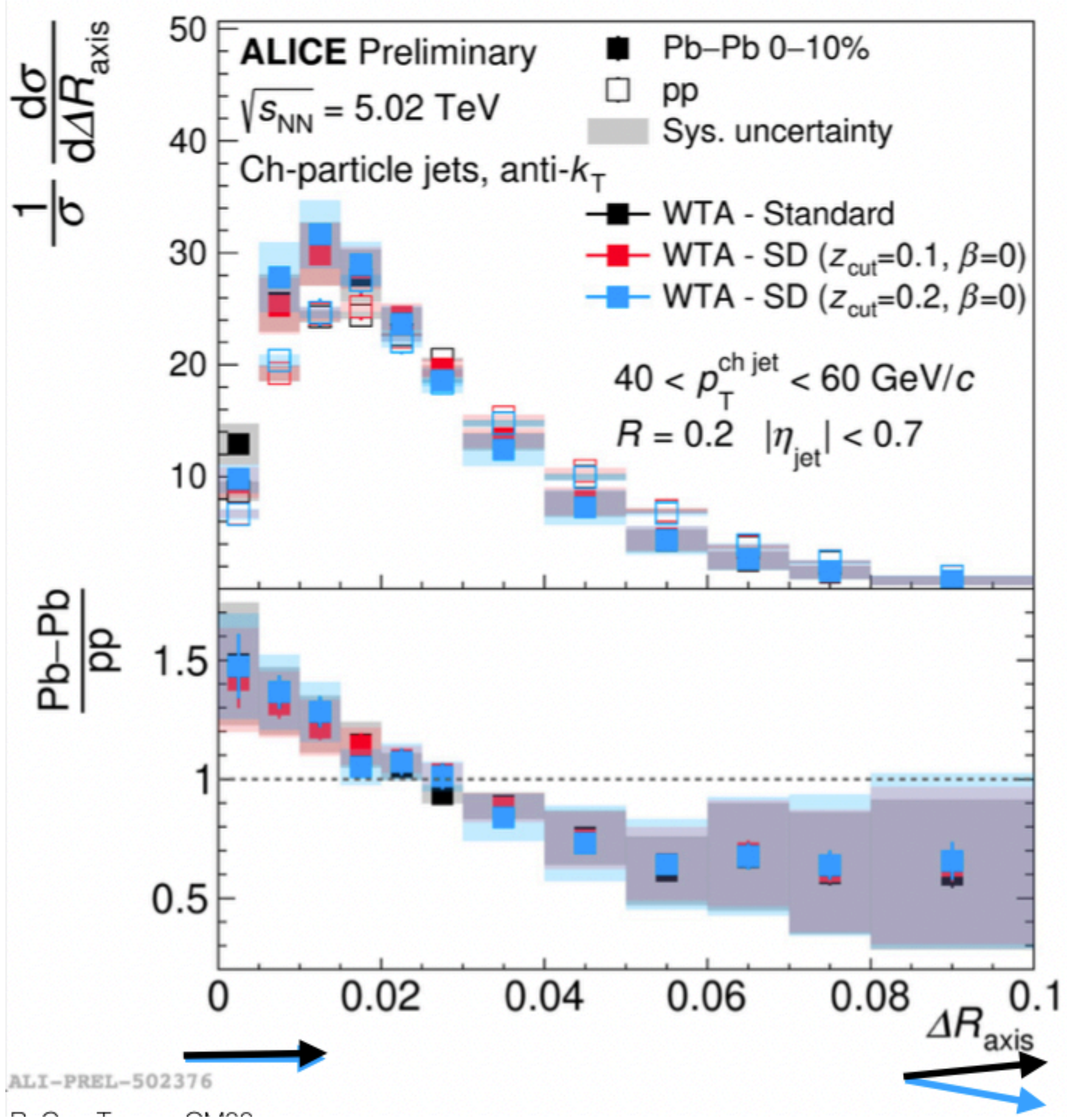
Large-scale structure;

grooming setting ⇔ affects physics

Angle between jet axes: substructure

‣ Rey Cruz-Torres's Talk

arXiv:2107.12984



Per-jet normalized → study the modification to radiation pattern

Angle between jet axis (groomed/ungroomed) and the direction of the hardest prong.

- Overall insensitivity to grooming:
  no change jet direction significantly
- Similar trend of narrowing as in other measurements