New results on the parton mass and color-charge dependence of jet quenching with ATLAS

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QUARK MATTER KRAKÓW 2022

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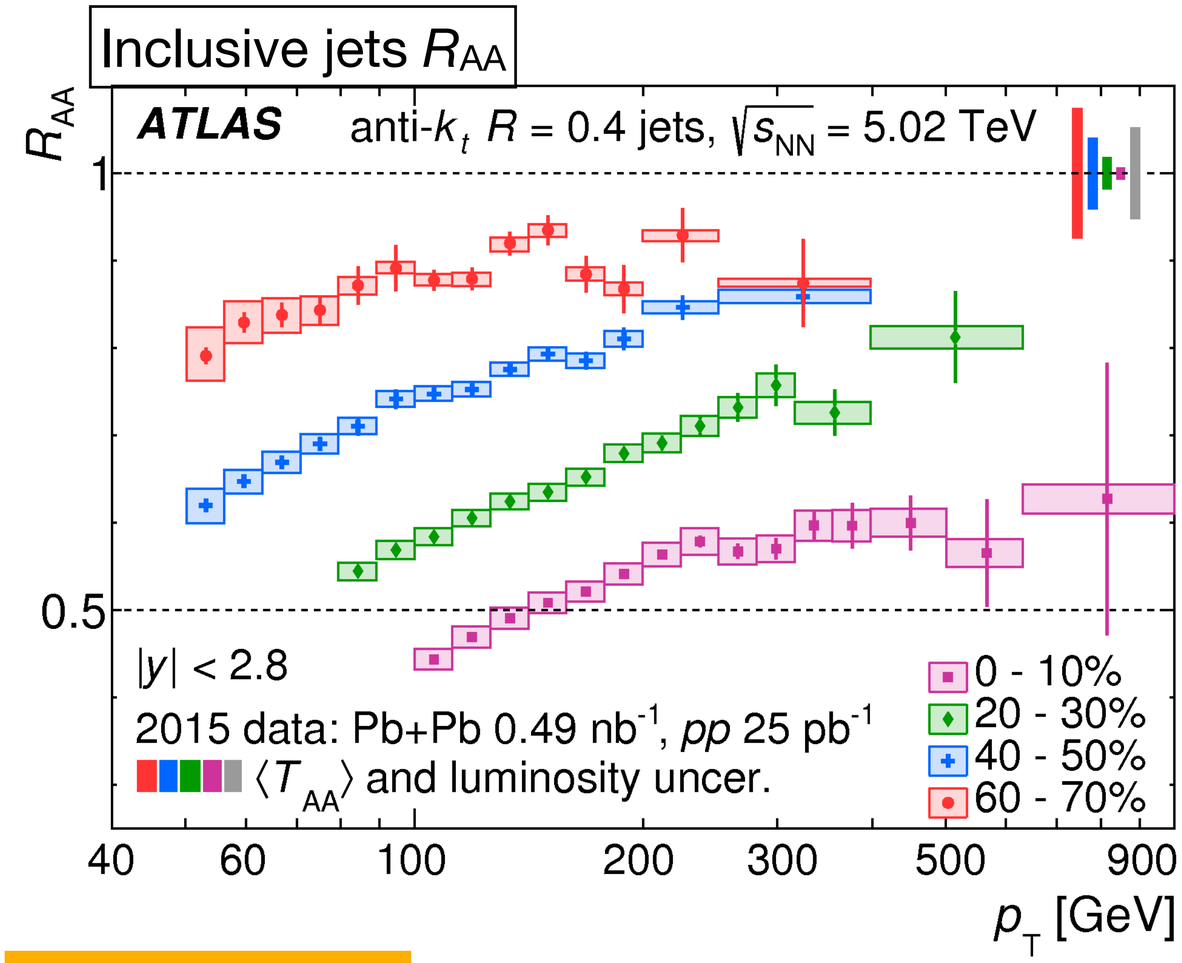
Flavor dependence in medium induced Energy loss

Jets are known to lose energy when going through the Quark-Gluon-Plasma



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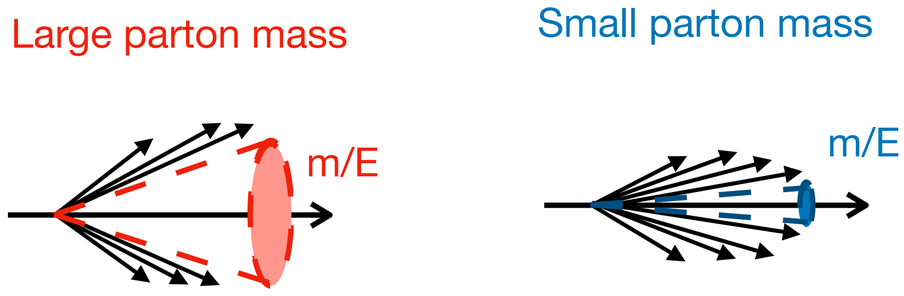
- Color-charge dependence

QCD suggest, gluons are more likely to radiate than quarks

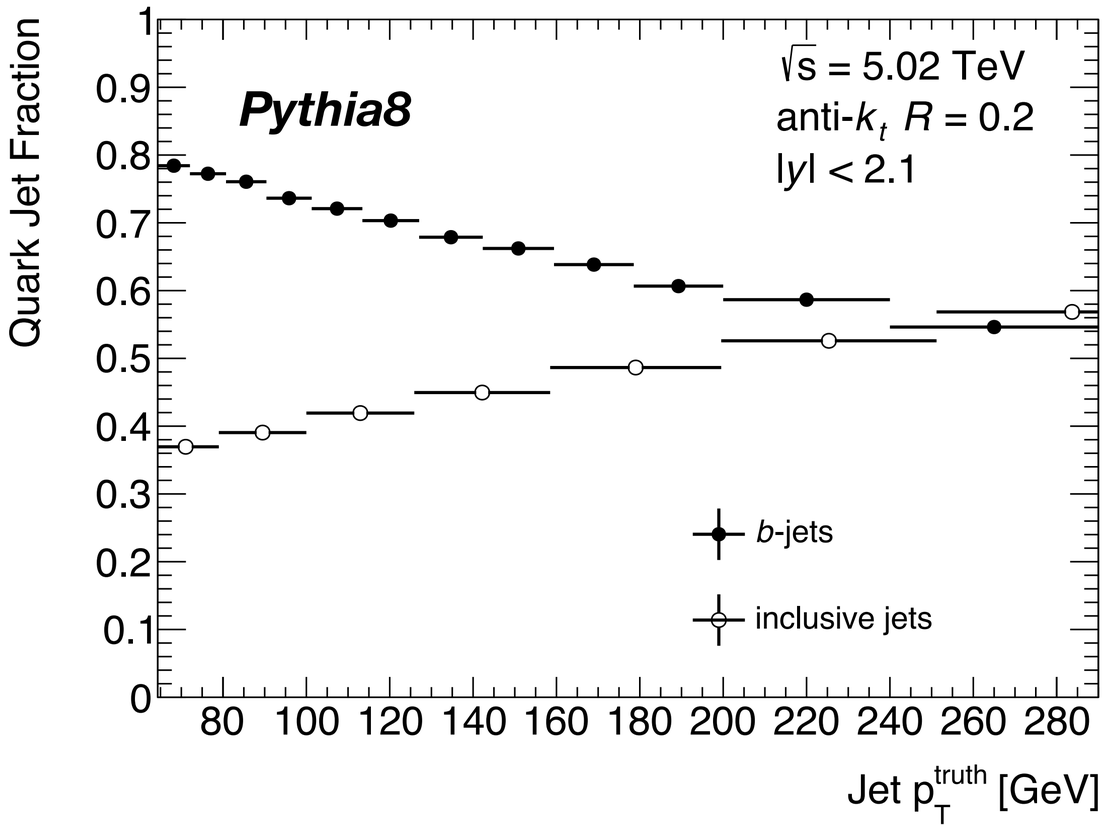
- Mass dependence expected due to “dead-cone effect”



Radiation is suppressed in θ < m/E

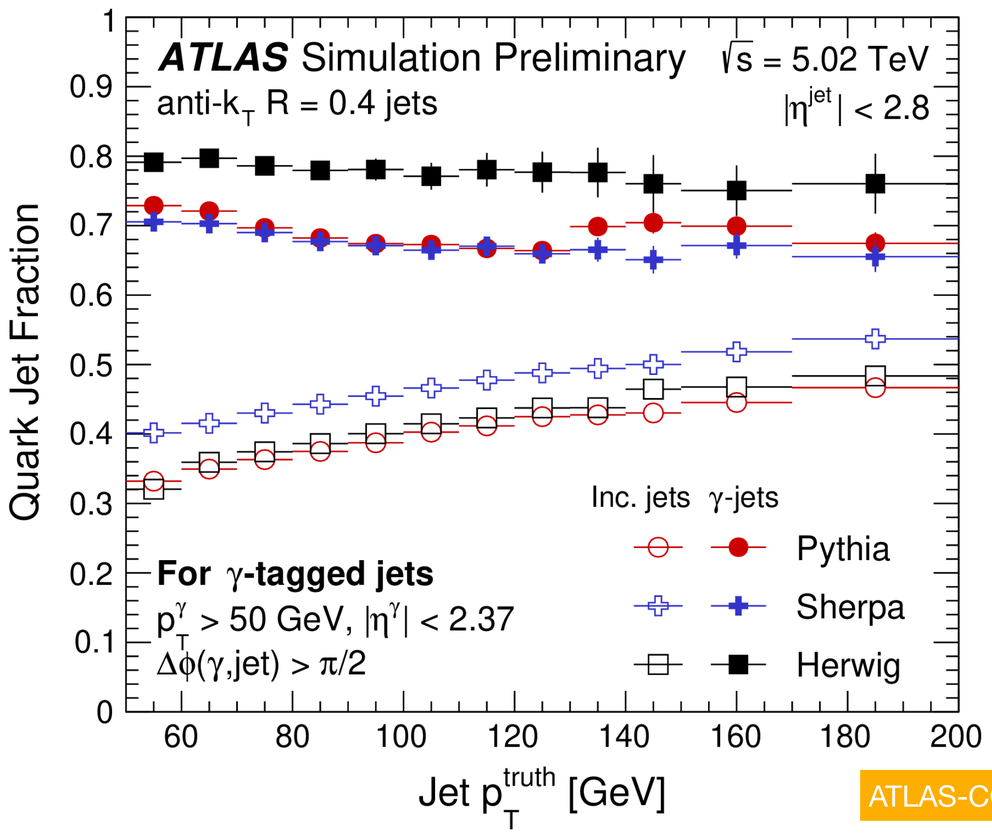
In this talk, two **new** ATLAS measurements

***b*-jets** vs inclusive jets



Sensitive to color-charge and parton mass

γ-tagged jets vs inclusive jets



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Sensitive to color-charge

***b*-jets** from semi-leptonic decays

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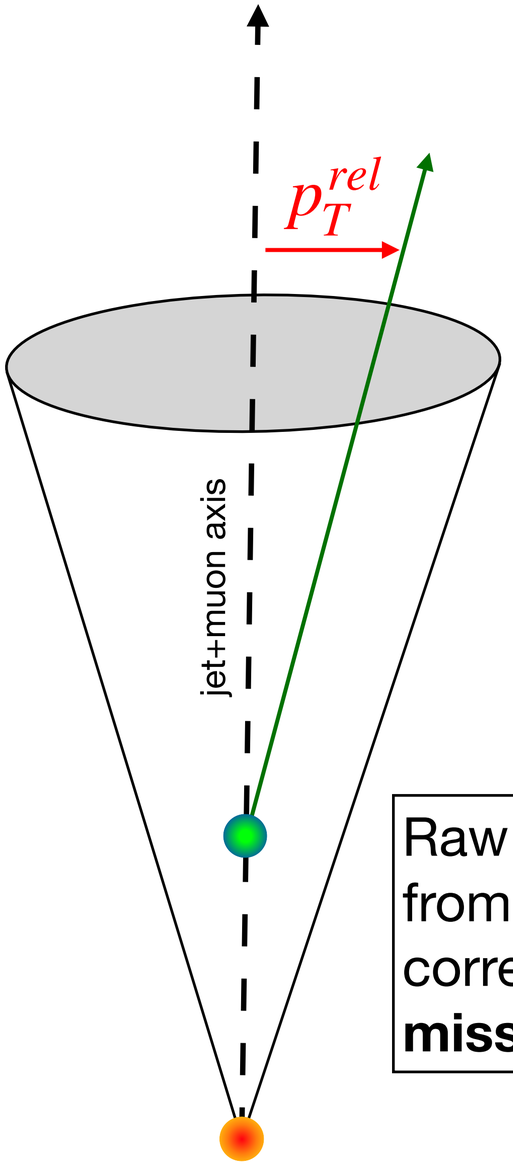


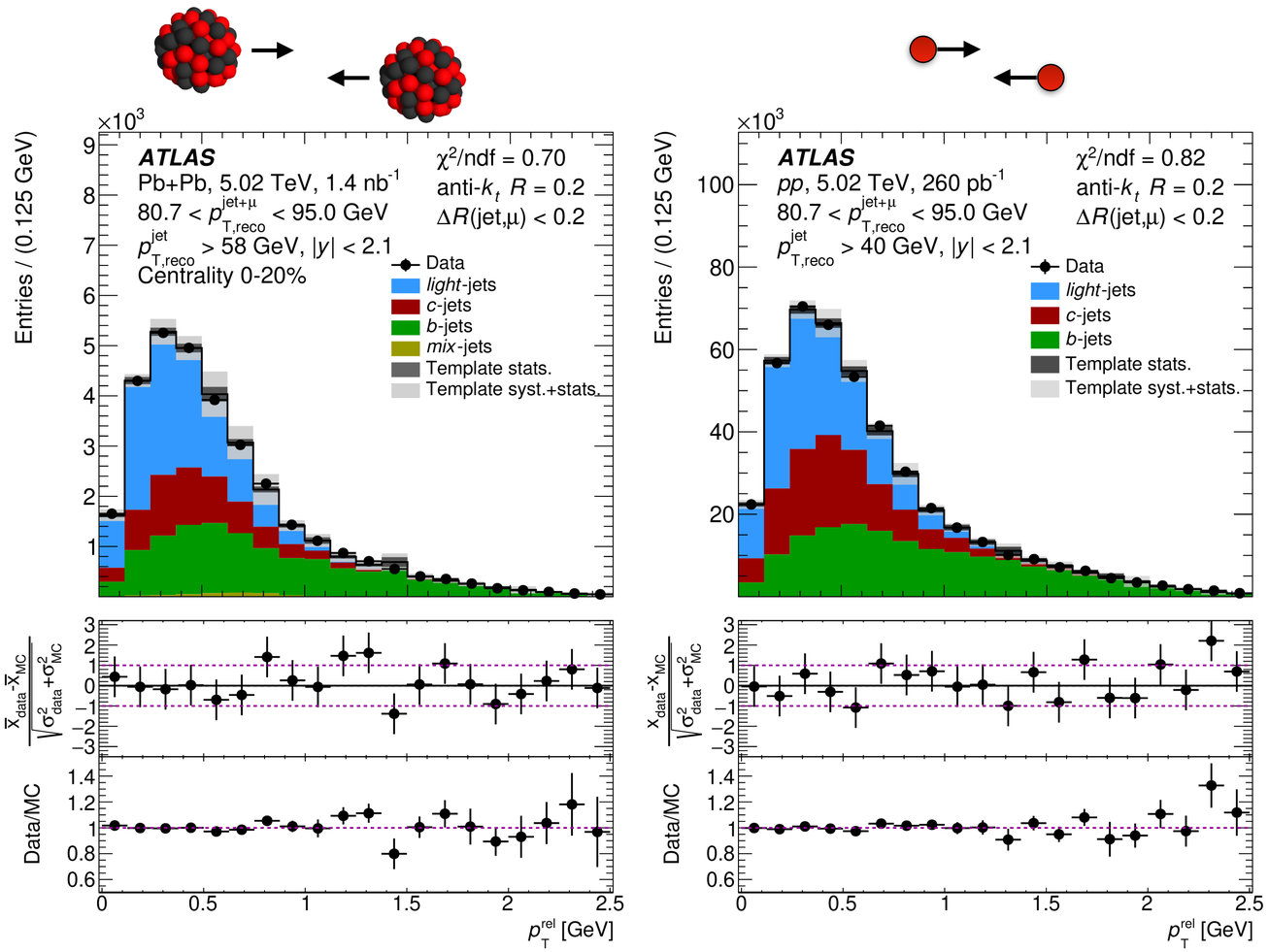
b-fraction estimated using template fit method on muon p_T-rel distribution

$$p_T^{rel} = ||\vec{p}_\mu \times \vec{u}||, \; where \; \vec{u} = \frac{\vec{p}_{jet+\mu}}{||\vec{p}_{jet+\mu}||} \; is \; the \; jet + \mu \; axis$$

Muon selection:

- Muon p_T > 4 GeV
- ΔR(jet,muon) < R

Raw *b*-jet spectra obtained from fit is **unfolded** to correct detector effects and **missing neutrino energy**



b-jets vs inclusive jets in *pp* collisions

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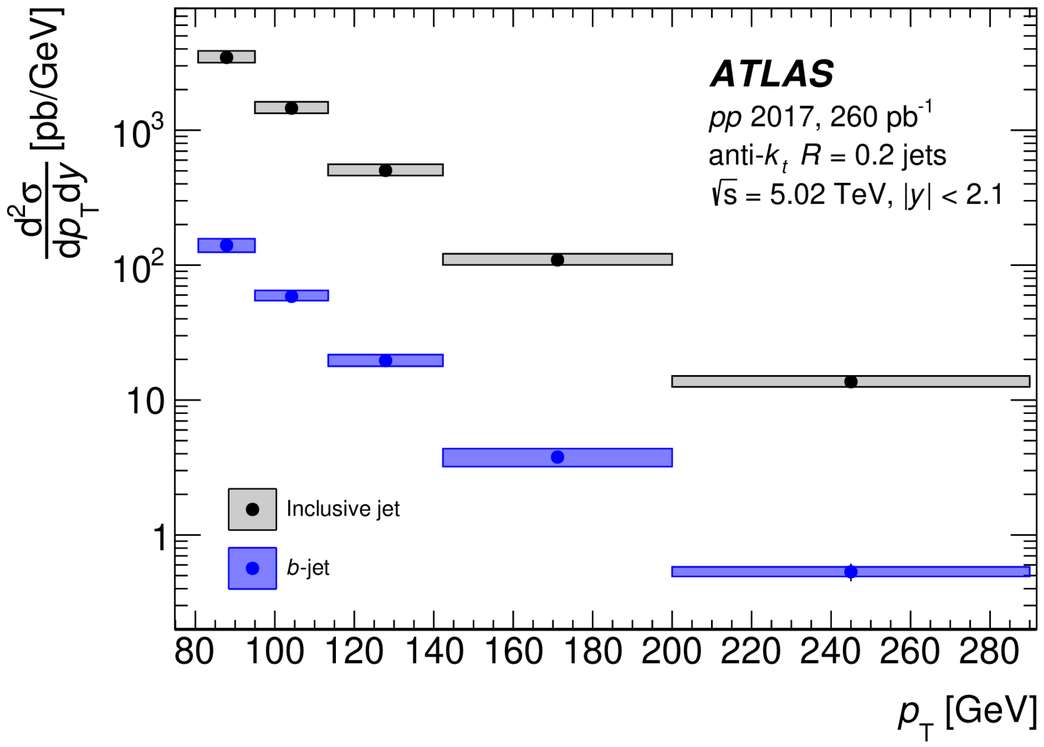

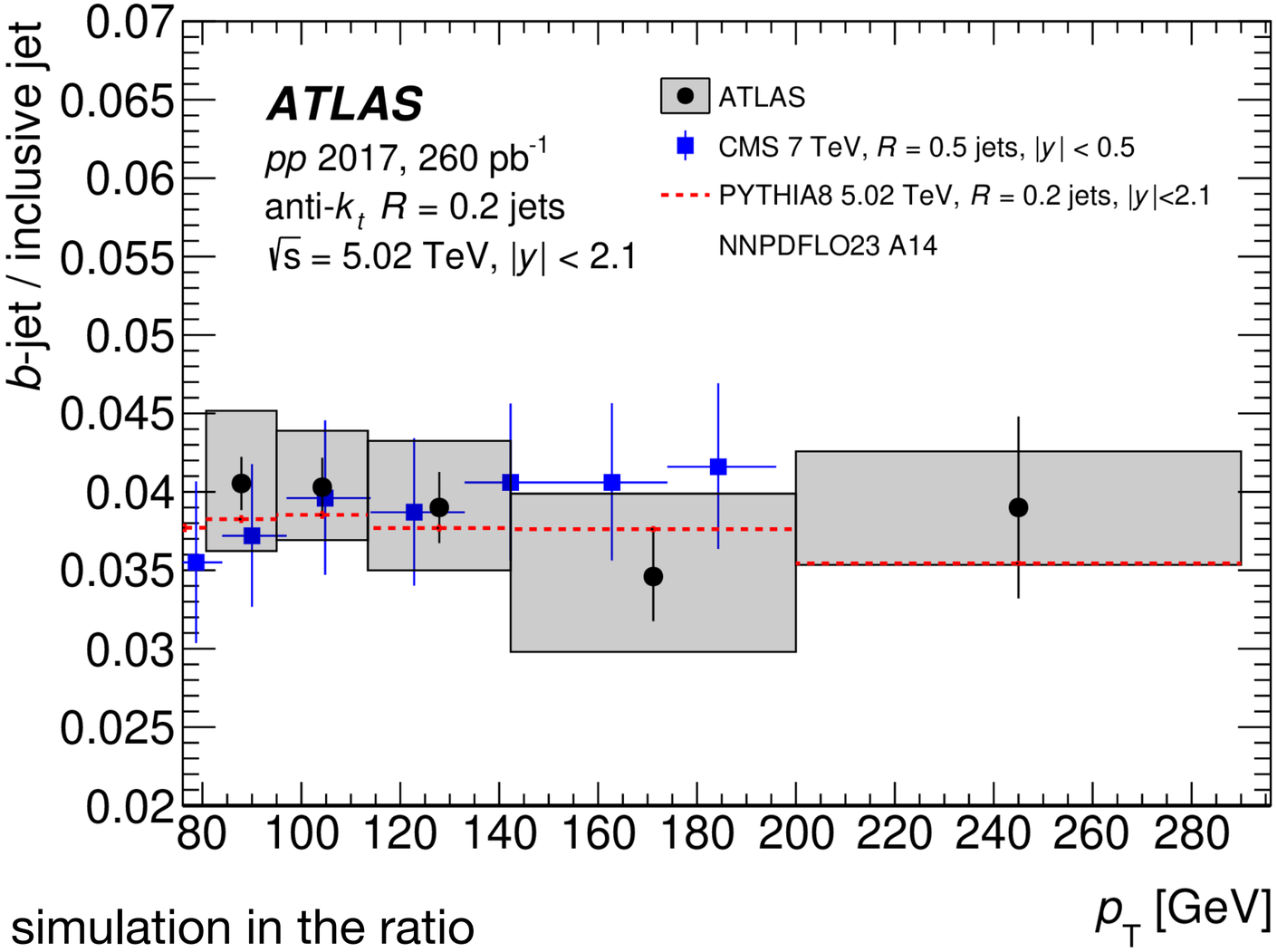

b-jet to inclusive R=0.2 cross-section ratio:

- Good agreement found between data and simulation in the ratio
- Comparison to CMS results consistent within errors
- Ratio consistent with flat withing uncertainties, relevant R_{AA} modification interpretation

***b*-jets vs inclusive jets** in Pb+Pb collisions

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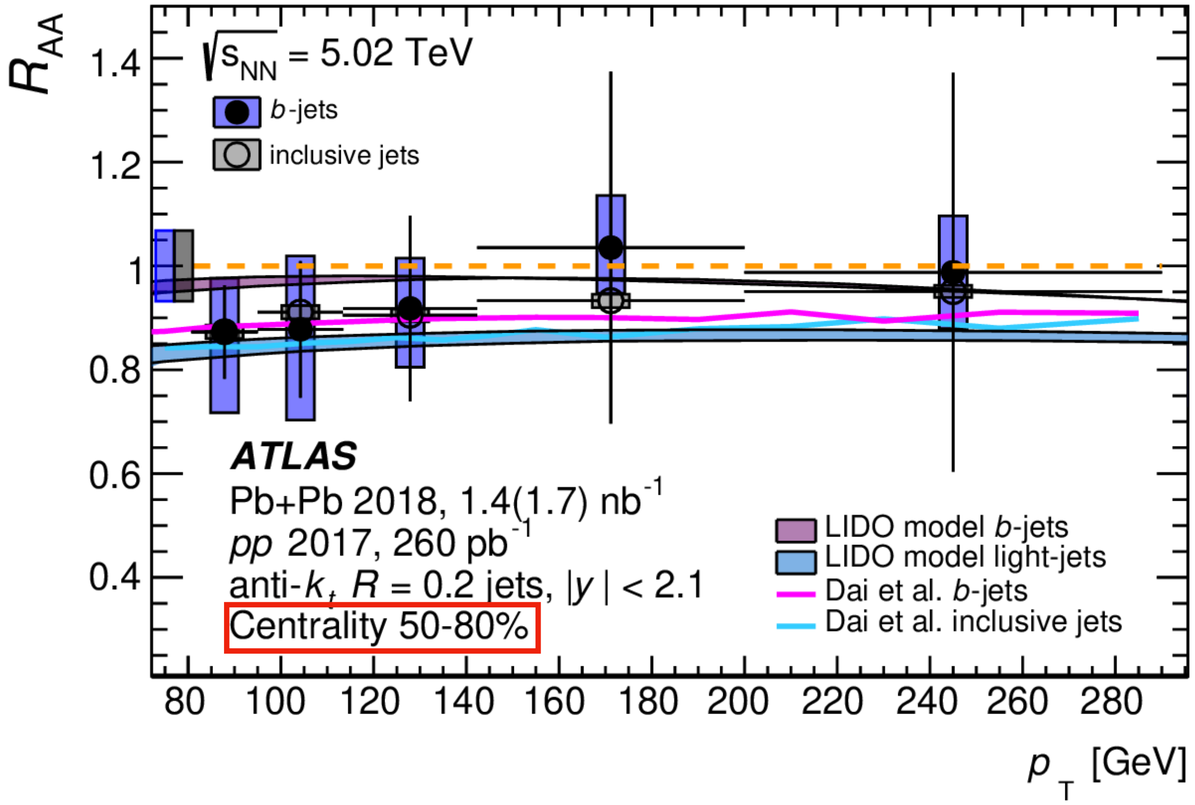

Nuclear modification factor, R_{AA}, measured for *b*-jets and inclusive jets:

- **Similar suppression in peripheral collisions**
- *b*-jet found to be less suppressed than inclusive jets in central collisions
- Both calculations capture the R_{AA} difference
- LIDO calculations reproduce well the measured R_{AA}

***b*-jets vs inclusive jets** in Pb+Pb collisions

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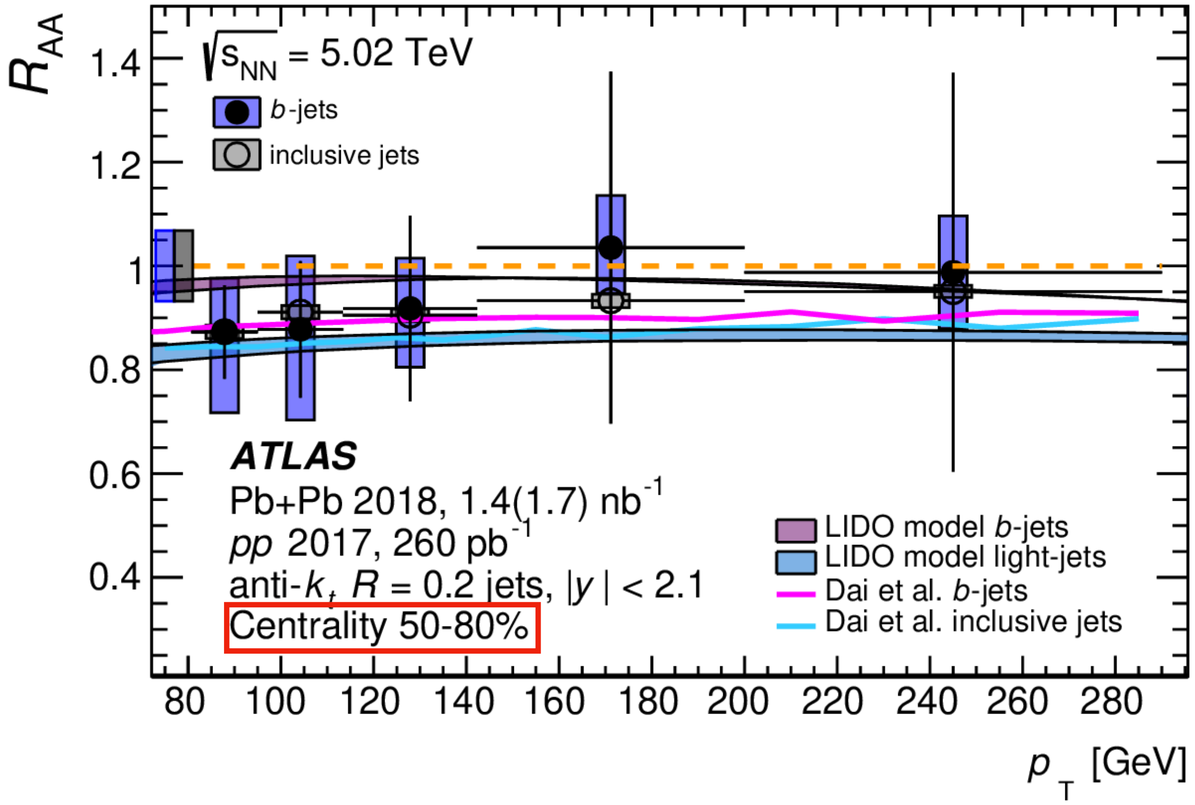

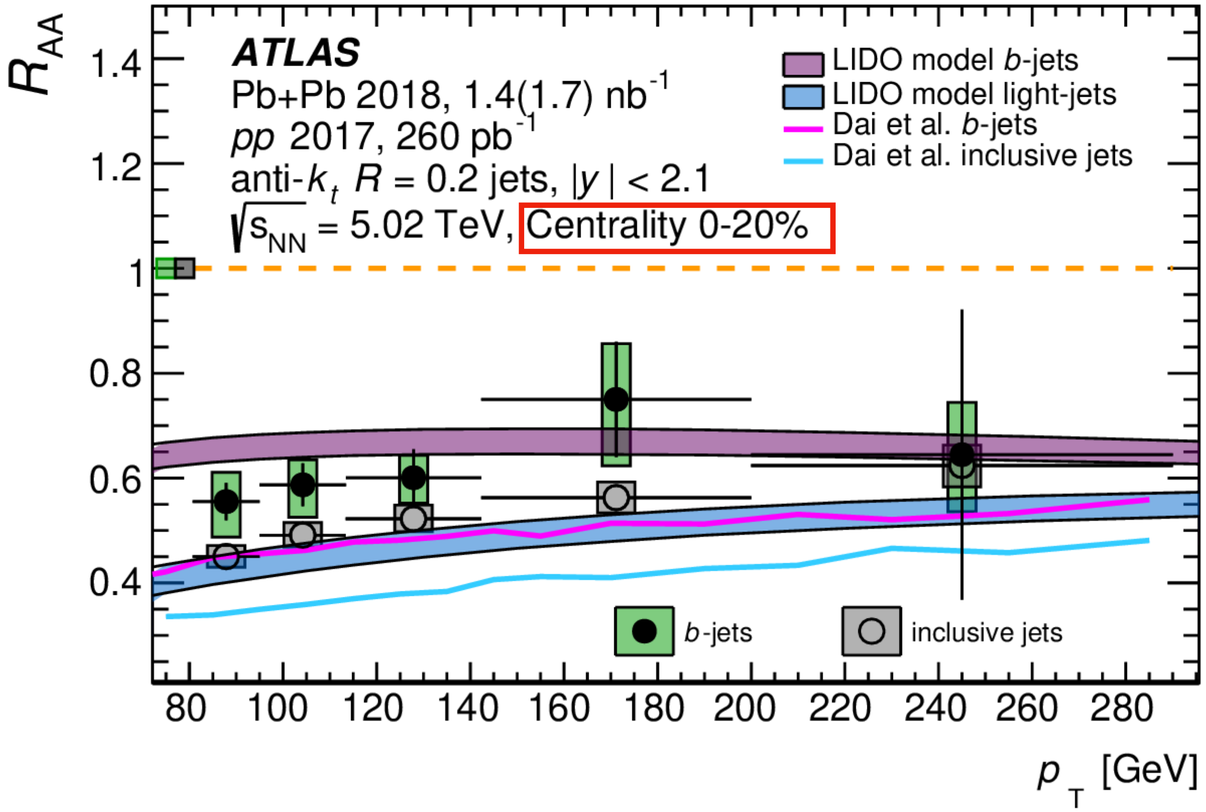

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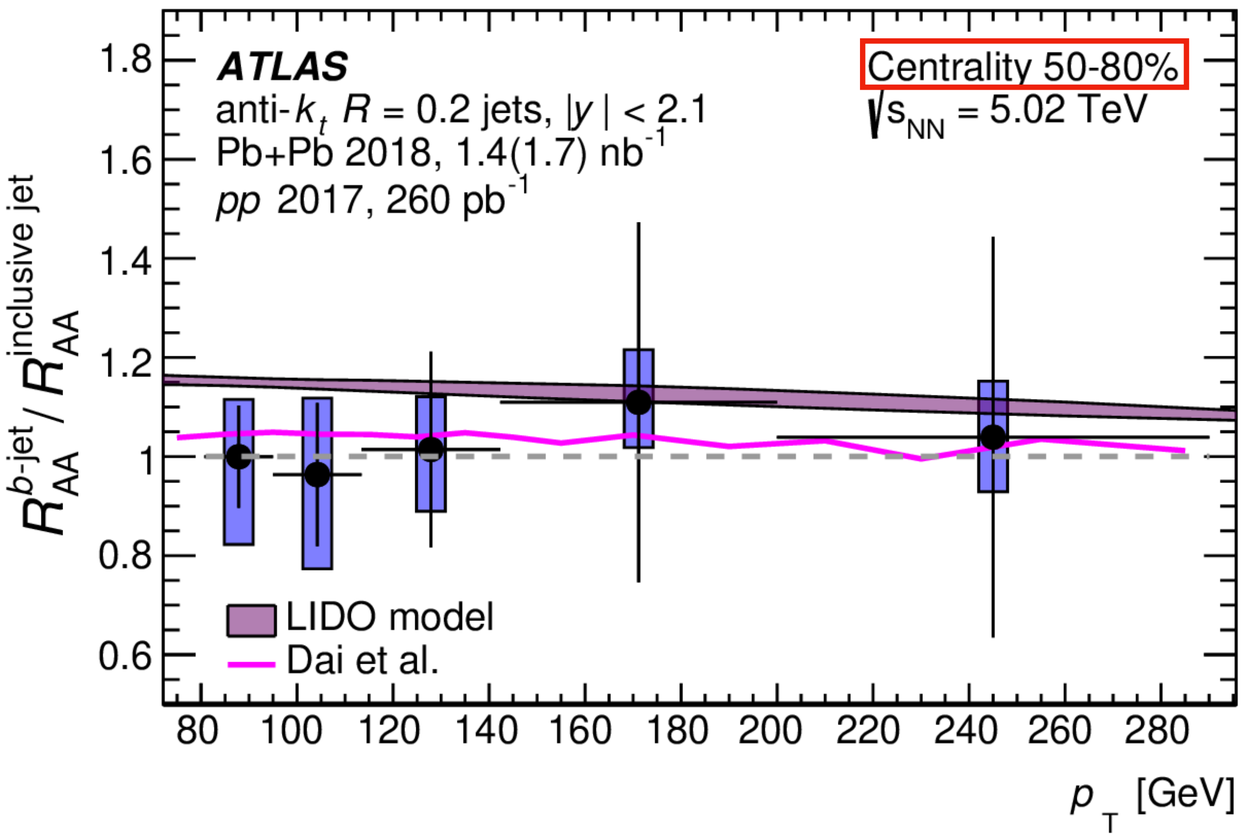

Ratio of nuclear modification factor, R_{AA}, between *b*-jets and inclusive jets:

- Smaller systematic uncertainties than R_{AA}, systematic uncertainties which are shared cancels in ratio
- Ratio **consistent with unity in peripheral** and ~20% above unity in central collisions
- Dai et al, calculations reproduce well R_{AA} ratio

***b*-jets vs inclusive jets** in Pb+Pb collisions

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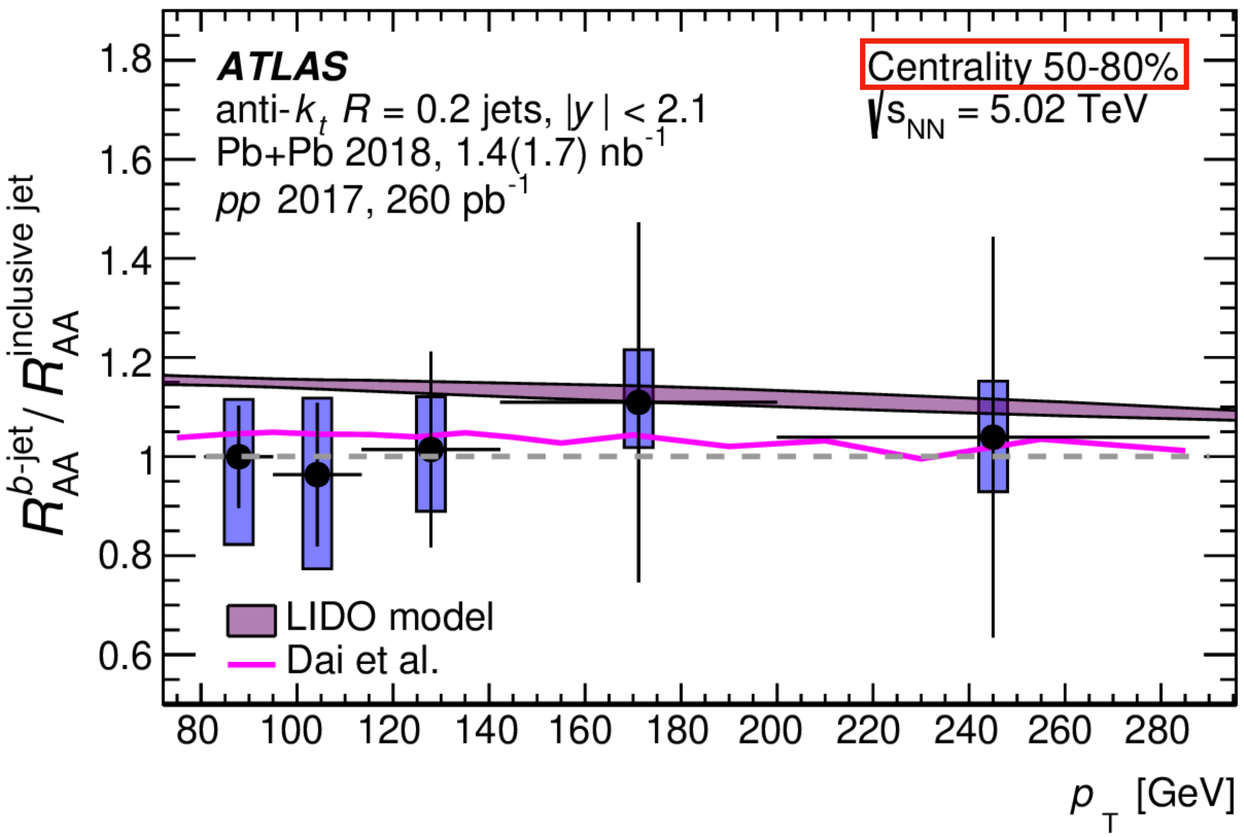

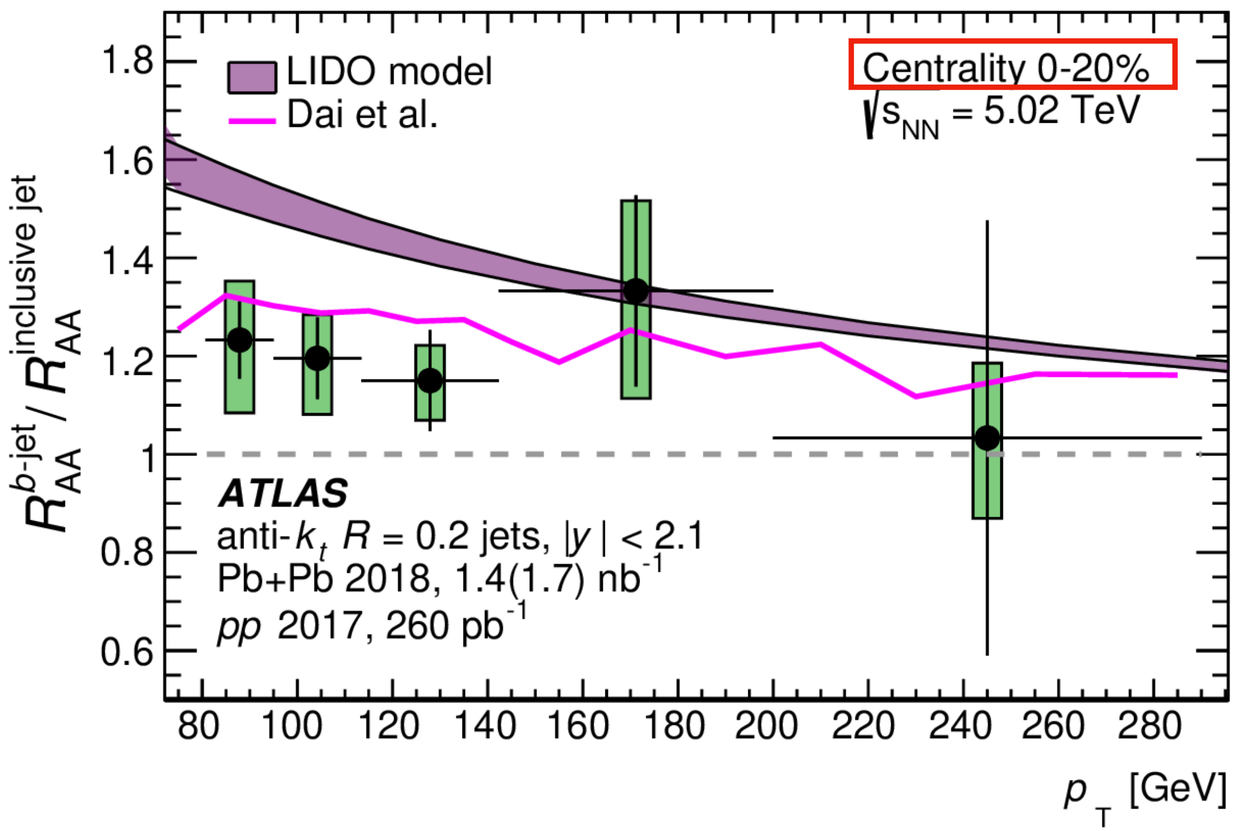

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Isolating color-charge effects

We have studied how mass can modify quenching

***b*-jets** vs inclusive jets

Sensitive to color-charge and parton mass

Now, can we ask the same question about color-charge?

γ-tagged jets vs inclusive jets

Sensitive to color-charge

γ-tagged jets analysis

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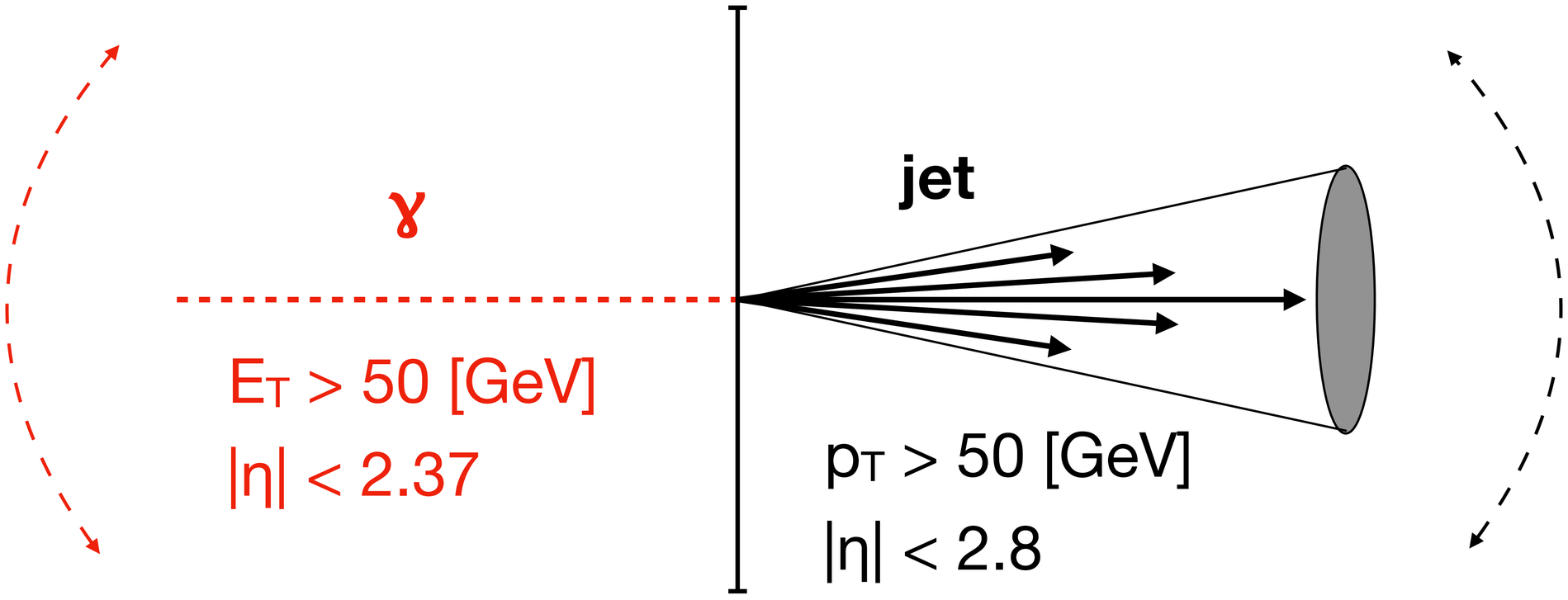
$\Delta\phi(\gamma,\text{jet}) > \pi/2$



- Combinatorial background removed
- Correction for background photons using photon purity
- 2D unfolding in γ and jet momentum
  - Corrects for resolutions, efficiency

γ-tagged jets *pp* cross-section

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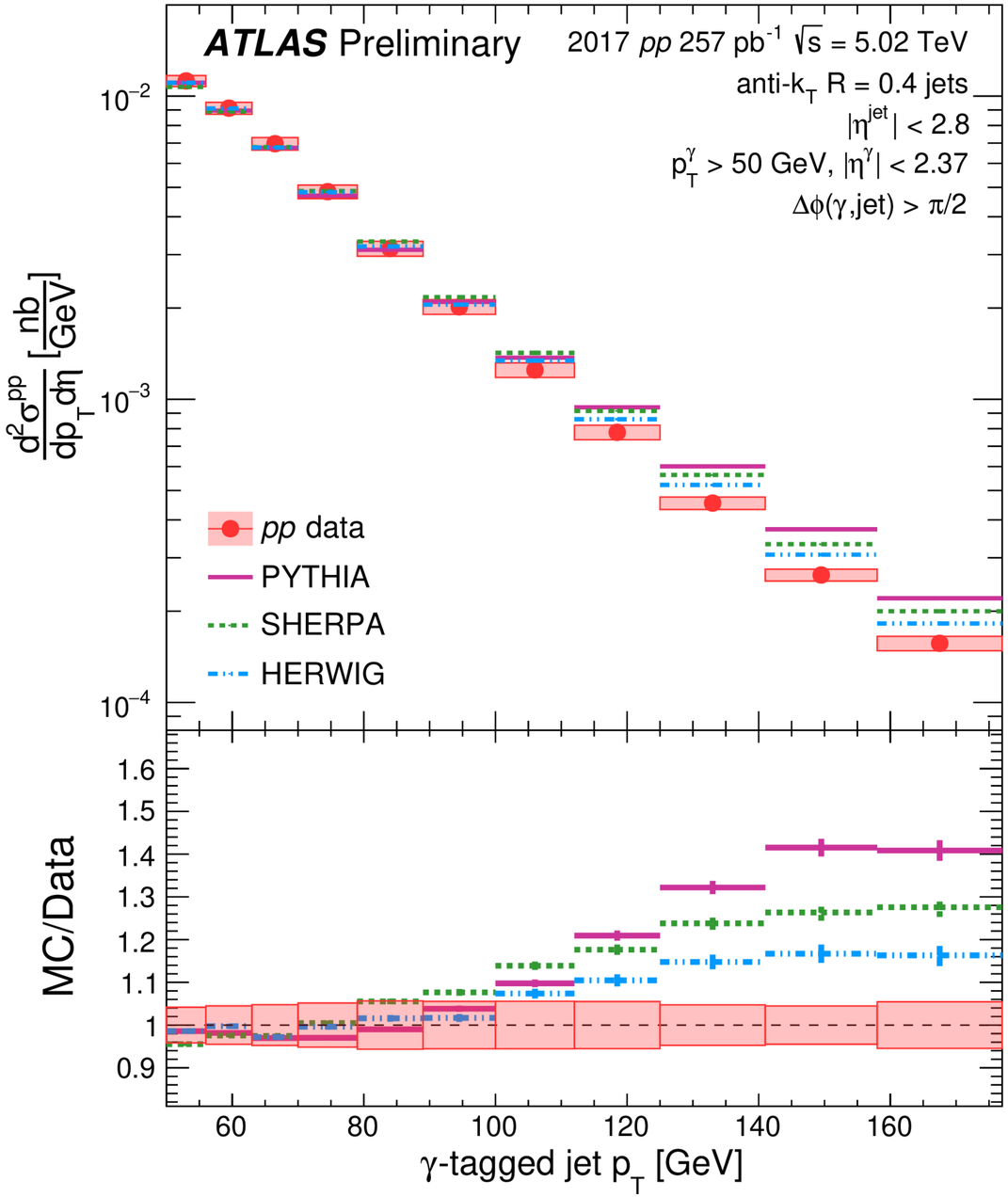

- γ-tagged jets cross-section measured for Jet R = 0.4 in *pp* collisions
- **Fully unfolded** results, γ-*tagged jets* p_T > 50 GeV
- Results are compared against generators
  - Good agreement up to 100 GeV
  - Data spectra steeper than MC for p_T > 100 GeV
    - Sensitive to multijet topology, fragmentation photon contribution
    - Opportunity to improve modeling

γ-tagged jets vs inclusive jets in *pp* and Pb+Pb collisions

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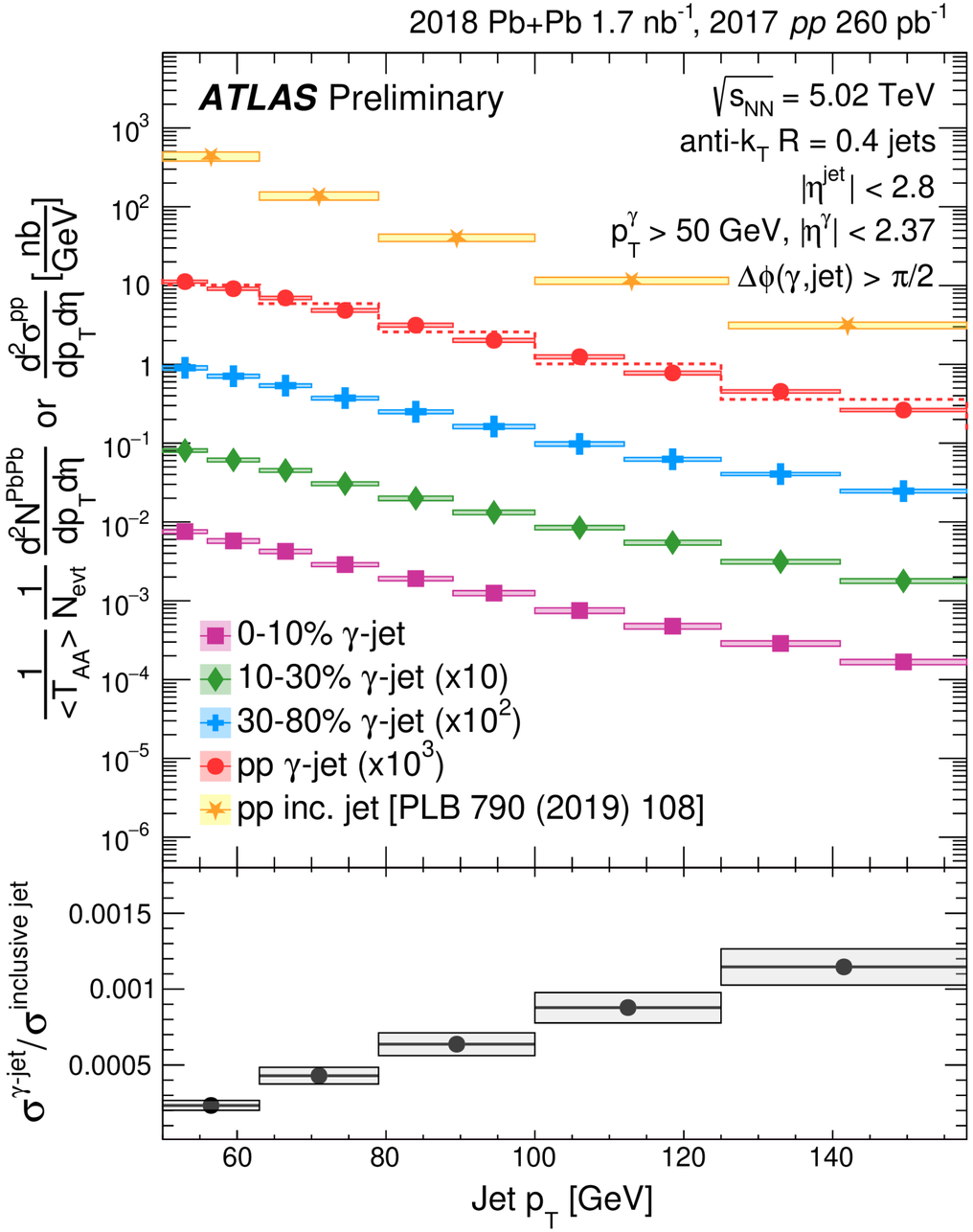

γ-tagged jets measured for three centralities classes in Pb+Pb data

γ-tagged jets to inclusive *R*=0.4 cross-section ratio:

- Relevant for R_{AA} modification interpretation
  - Inclusive jet spectra steeper than γ-tagged jets —> less suppression for γ-tagged jets
  - Isospin/nPDF effect also plays an important role —> larger suppression for γ-tagged jets
  - The two effects are expected to have similar magnitude but opposite sign

Inclusive jets from *PLB 790 (2019) 108*

γ-tagged jets vs inclusive jets in Pb+Pb collisions

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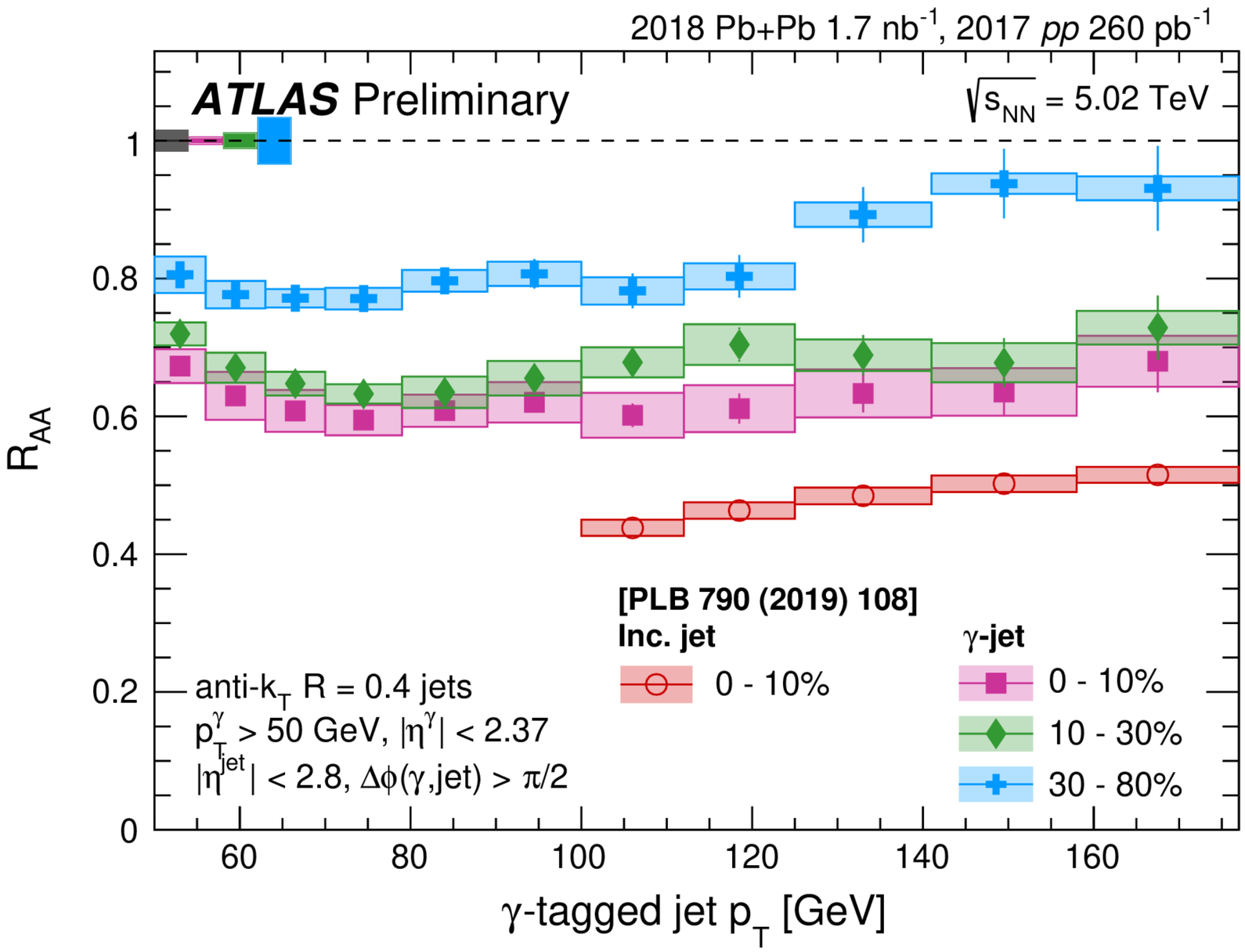

Nuclear modification factor, R_{AA}, measured for γ-tagged jets and inclusive jets from *PLB 790 (2019) 108*:

- γ-tagged jets R_{AA} measured for three centrality classes, central R_{AA} more suppressed than peripheral
- γ-tagged jets (quark-jet dominant) **found to be less suppressed** than inclusive (gluon-jet dominant) jets in central collisions

γ-tagged jets vs inclusive jets in Pb+Pb collisions

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Central collisions nuclear modification factor, R_{AA}, of **inclusive jets**, γ-tagged jets, and ratio:

- **Inclusive jets R_{AA}**, is well modeled by theoretical calculations

γ-tagged jets vs inclusive jets in Pb+Pb collisions

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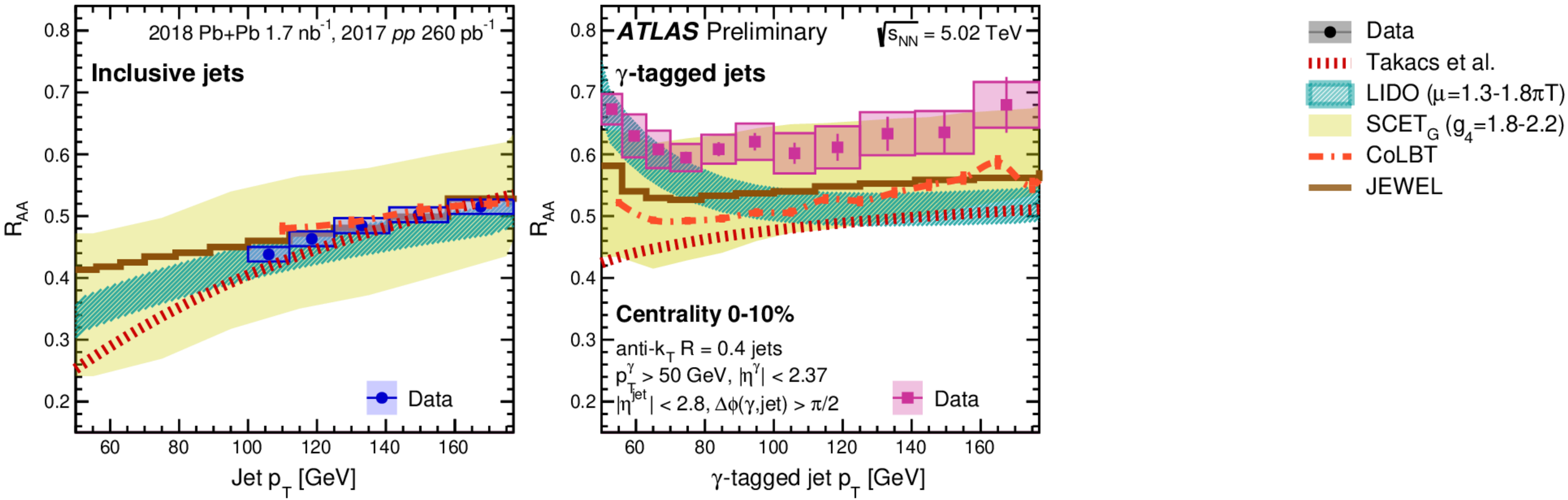

Central collisions nuclear modification factor, R_{AA}, of inclusive jets, **γ-tagged jets**, and ratio:

- Inclusive jets R_{AA}, is well modeled by theoretical calculations
- **γ-tagged jets R_{AA}**, in general, under-estimated by theoretical calculations
- SCET$_G$ reproduces both, this results could help constrain the parameter space

γ-tagged jets vs inclusive jets in Pb+Pb collisions

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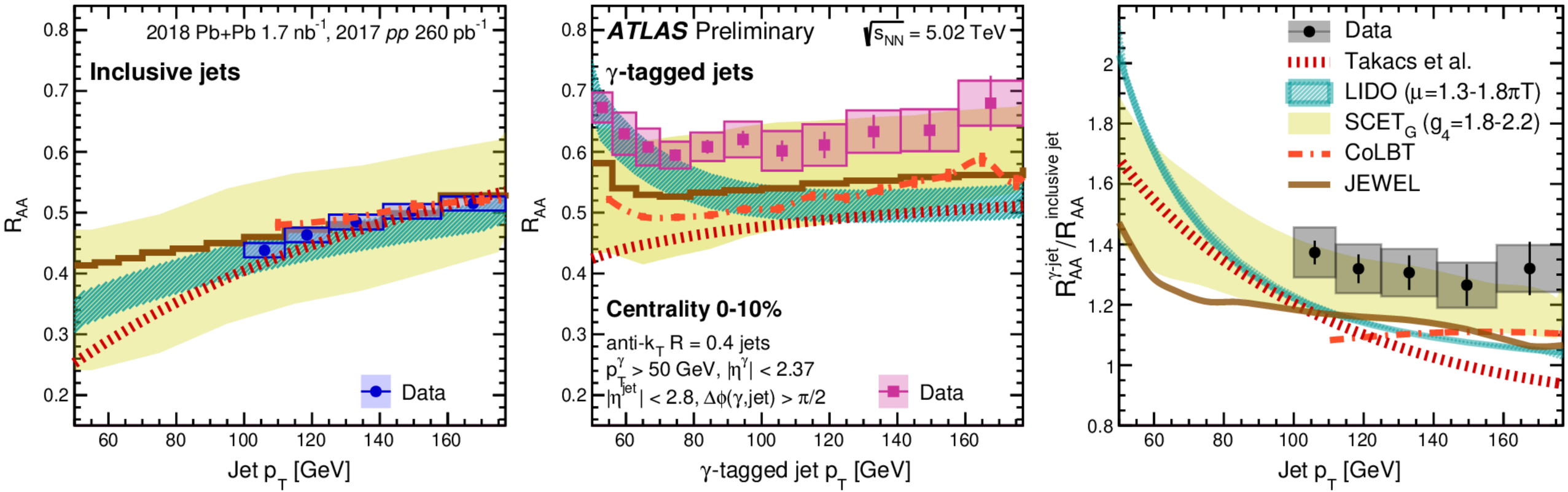

Central collisions nuclear modification factor, R_{AA}, of inclusive jets, γ-tagged jets, and **ratio**:

- Inclusive jets R_{AA}, is well modeled by theoretical calculations
- γ-tagged jets R_{AA}, in general, under-estimated by theoretical calculations
- $SCET_G$ reproduces both, this results could help constrain the parameter space
- **R_{AA} ratio ~30% above unity in central collisions**

Summary

Evidence of mass and color-charge energy loss dependence find by **ATLAS**

- ***b*-jet** R_{AA} central collisions were found to be **less suppressed than inclusive jets for the first time**
- **γ-tagged jets** R_{AA}, dominated by quark-jets, presented for the first time, **found to be less suppressed than inclusive jets**

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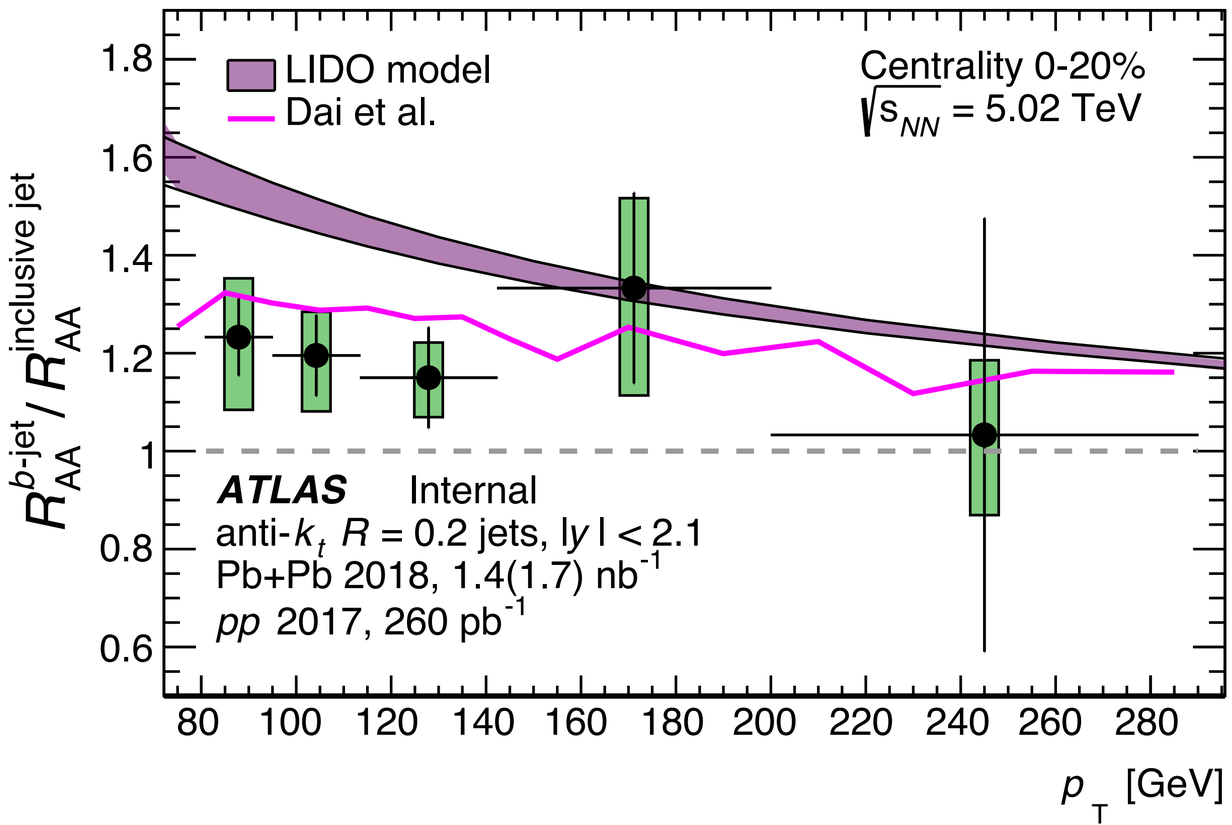
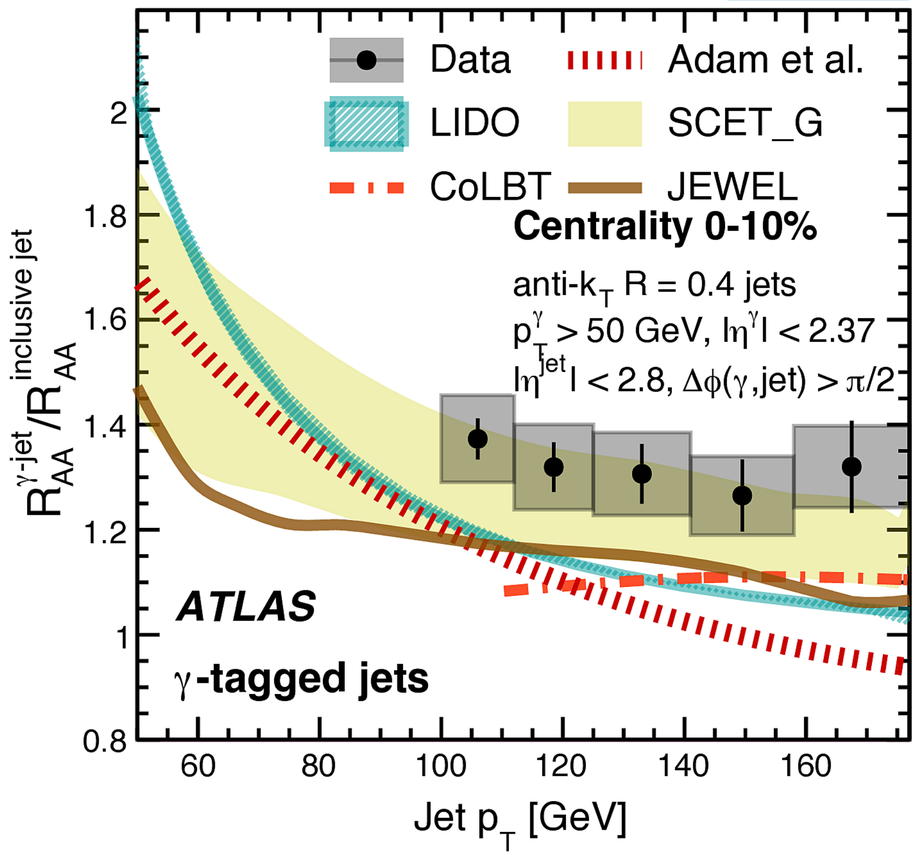
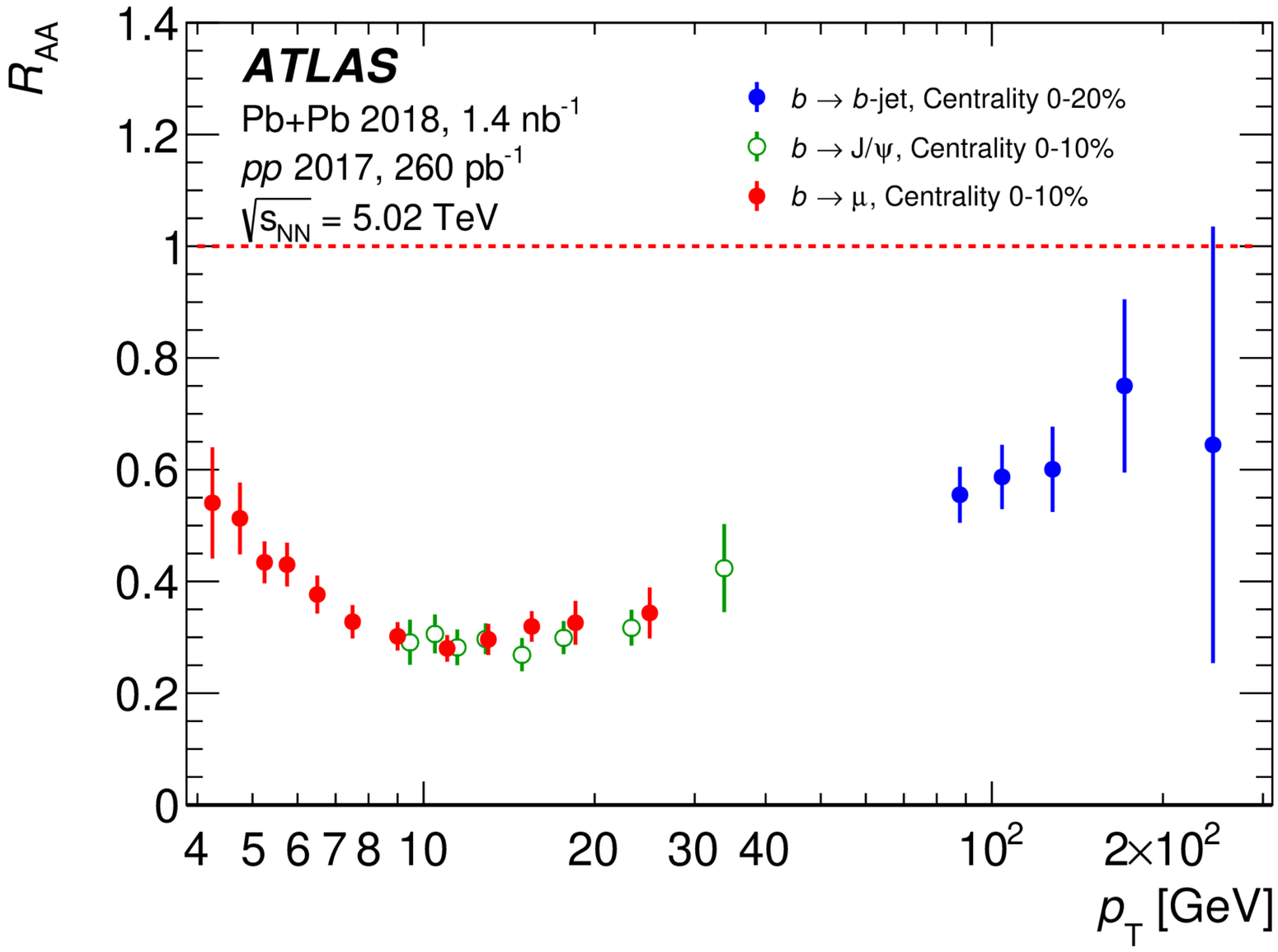




Thank you!

more results at: https://twiki.cern.ch/twiki/bin/view/AtlasPublic/HeavyIonsPublicResults



New and more precise results coming for **RUN3 data!**

Additional slides

***b*-jets** muon fragmentation

https://atlas.web.cern.ch/Atlas/GROUPS/PHYSICS/PAPERS/HION-2018-24/

p_T-rel is sensitive to muon momentum modeling

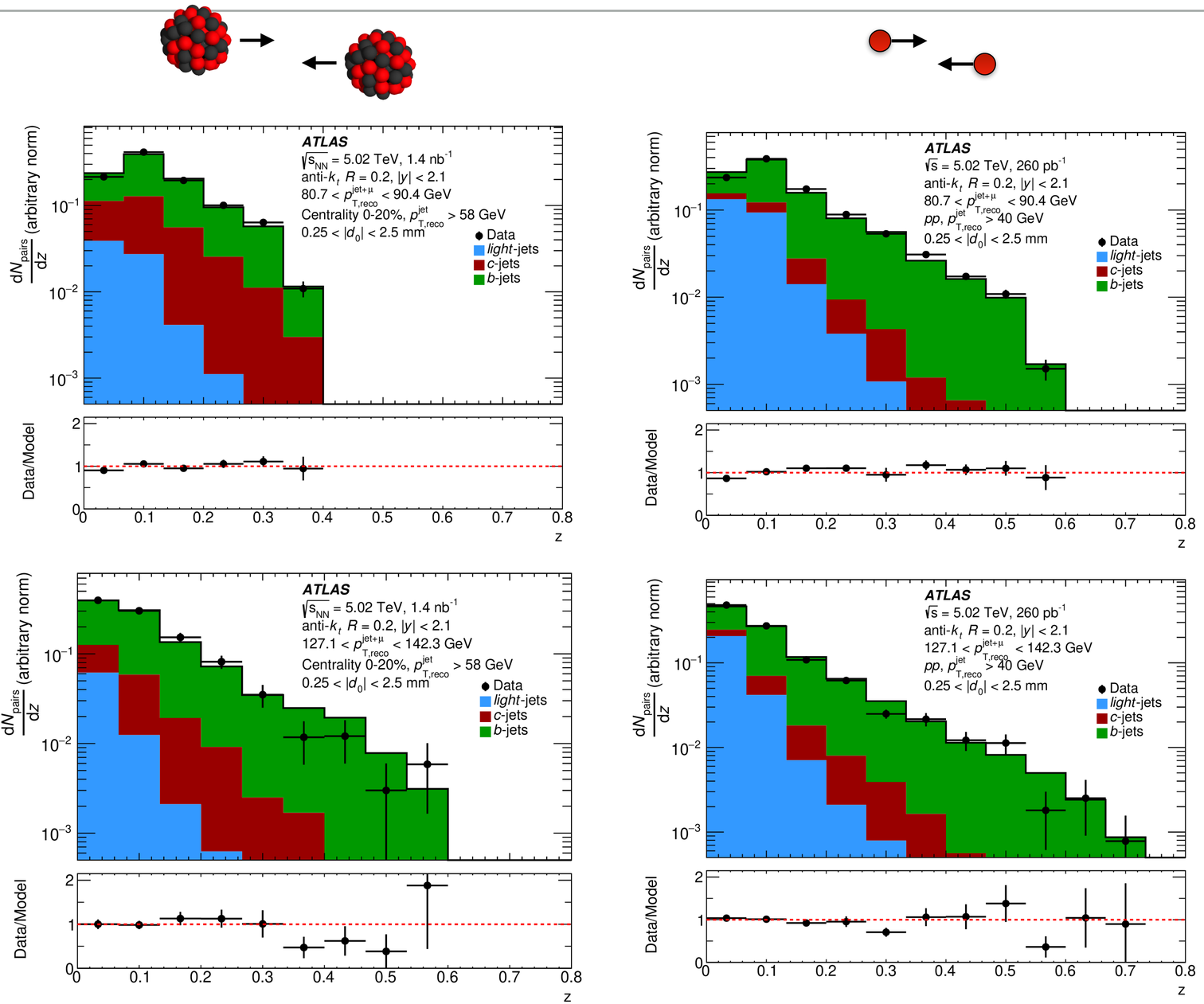
Independent test on muon fragmentation function, “z”, using measured flavor-fractions

$$z = p_T^{\mu} cos(\theta) / p_T^{jet+\mu}$$

The muon momentum distribution is well reproduced by PYTHIA8

PYTHIA8 setting:

- **A14** (ATLAS-PHYS-PUB-2014-021)
- **NNPDF23LO** (arXiv:1207.1303)



***b*-jets** *pp* cross-section

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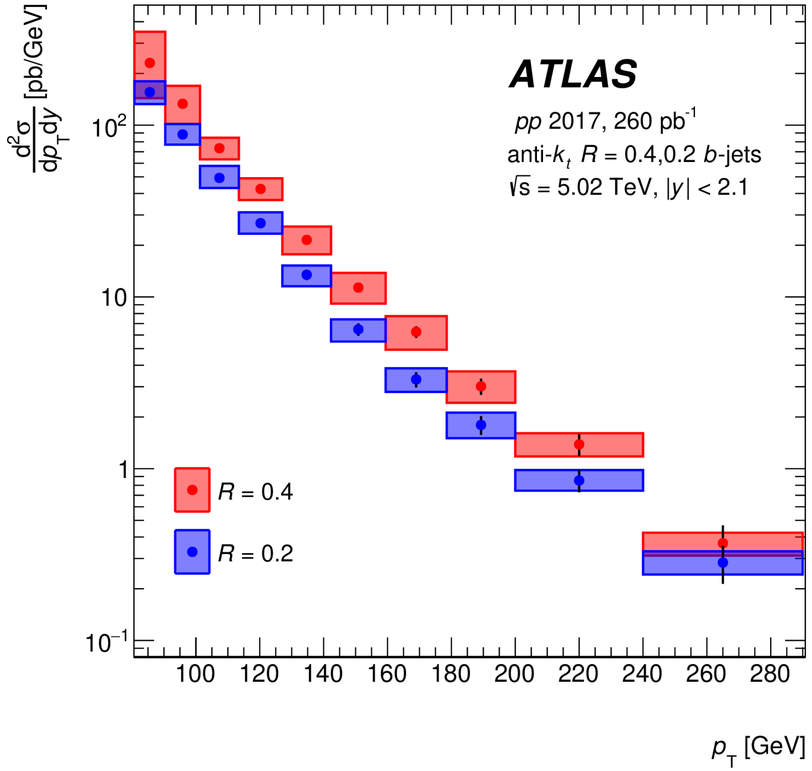

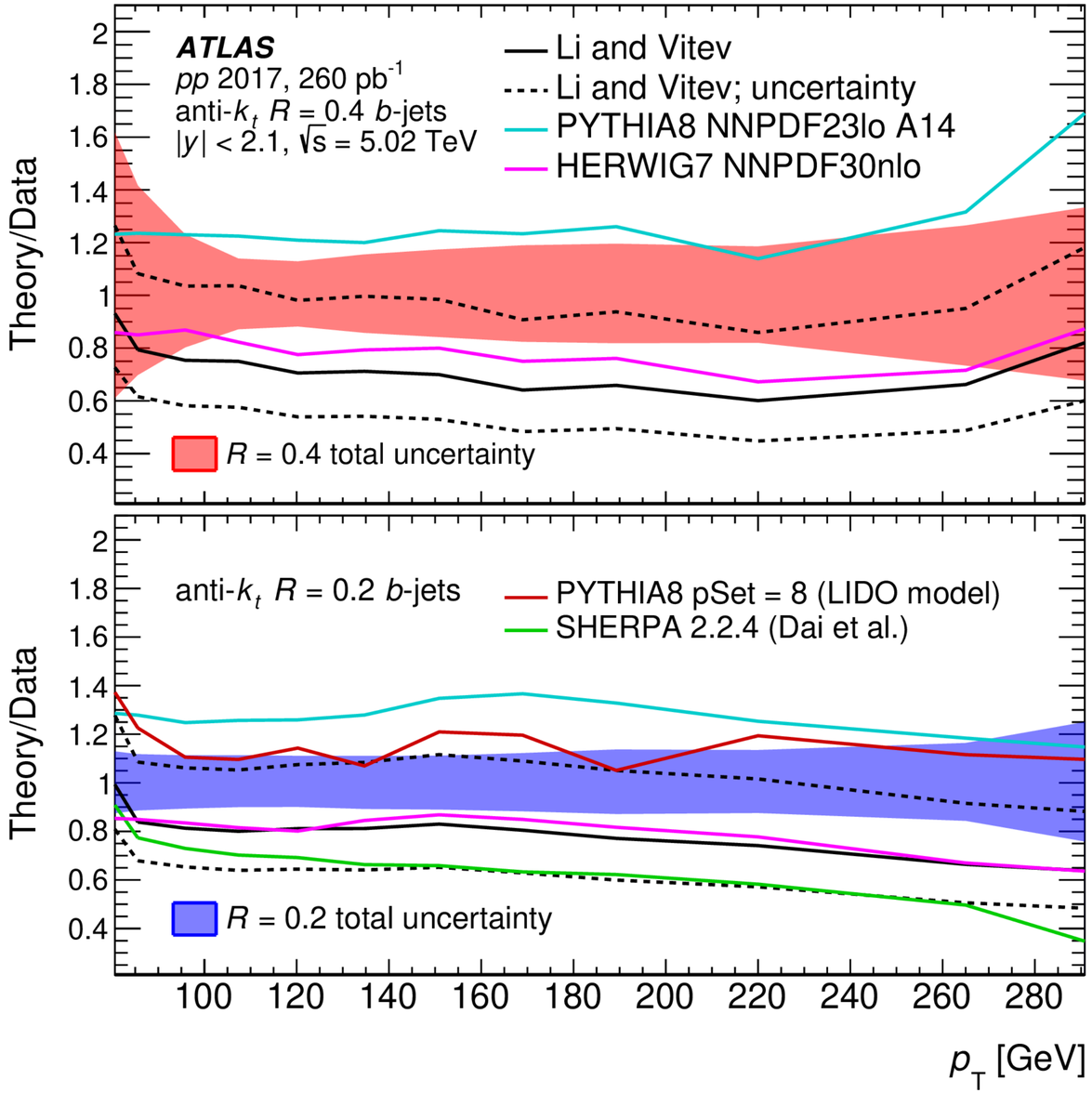

- *b*-jet cross-section measured for Jet R = 0.2, and 0.4 in *pp* collisions
- **Fully unfolded** results include neutrino energy, ***b*-jet p_T range: 80-250 GeV**
- Results are compared against generators and theoretical calculations

b-jets R_{AA} CMS comparison

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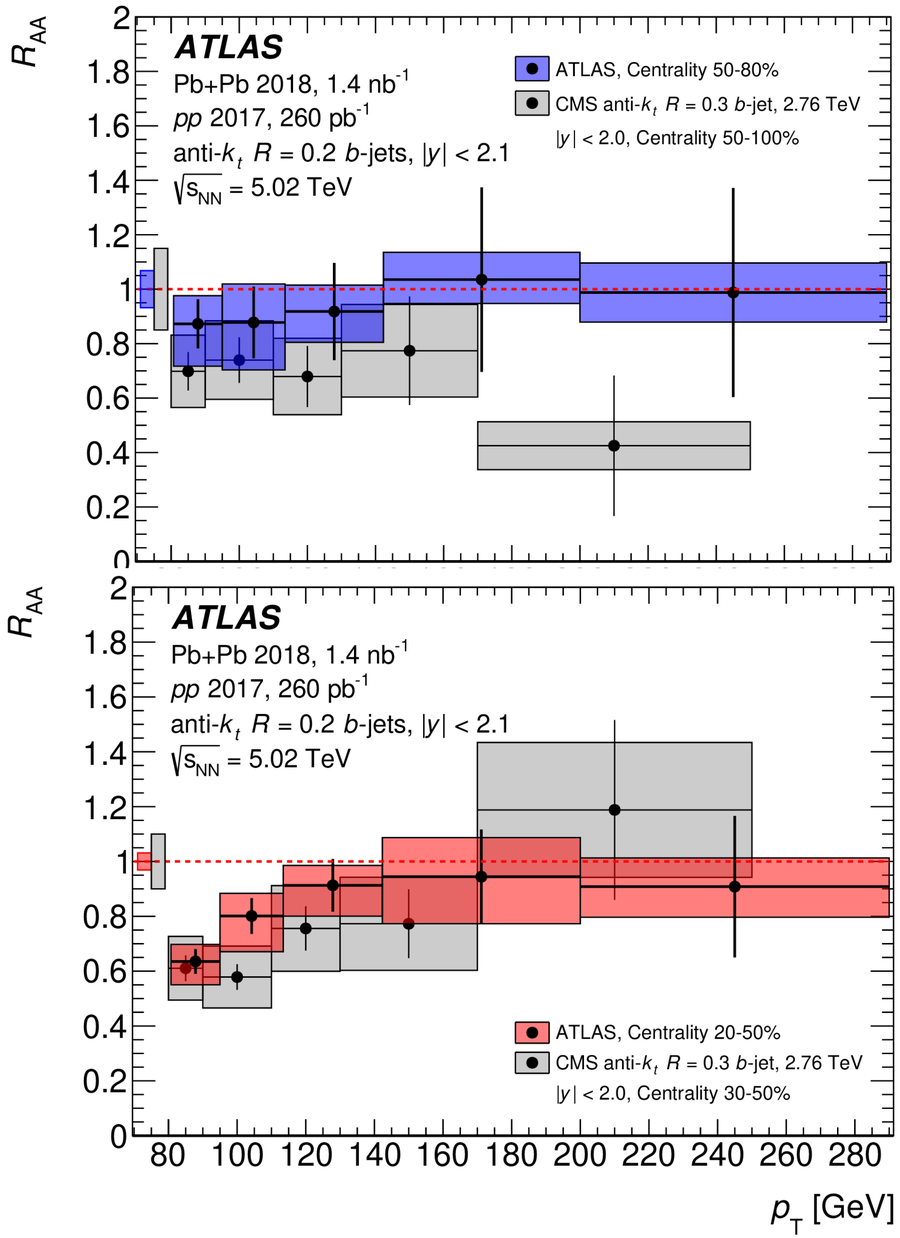

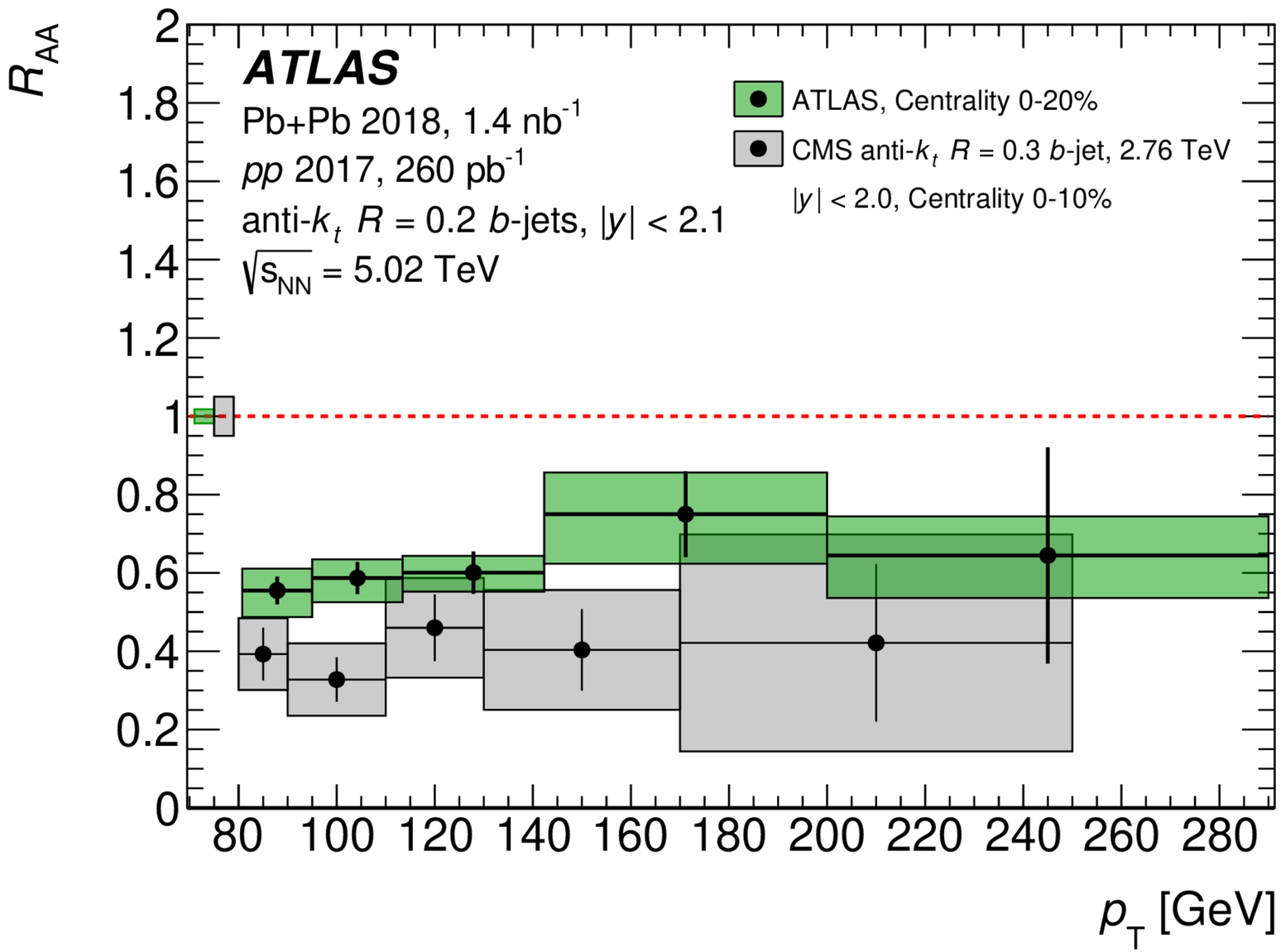

***b*-jets** *systematics*

https://atlas.web.cern.ch/Atlas/GROUPS/PHYSICS/PAPERS/HION-2018-24/