Novel Measurements of Dijet Quenching with ATLAS

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On behalf of the ATLAS Collaboration

Dijets as probes of energy loss

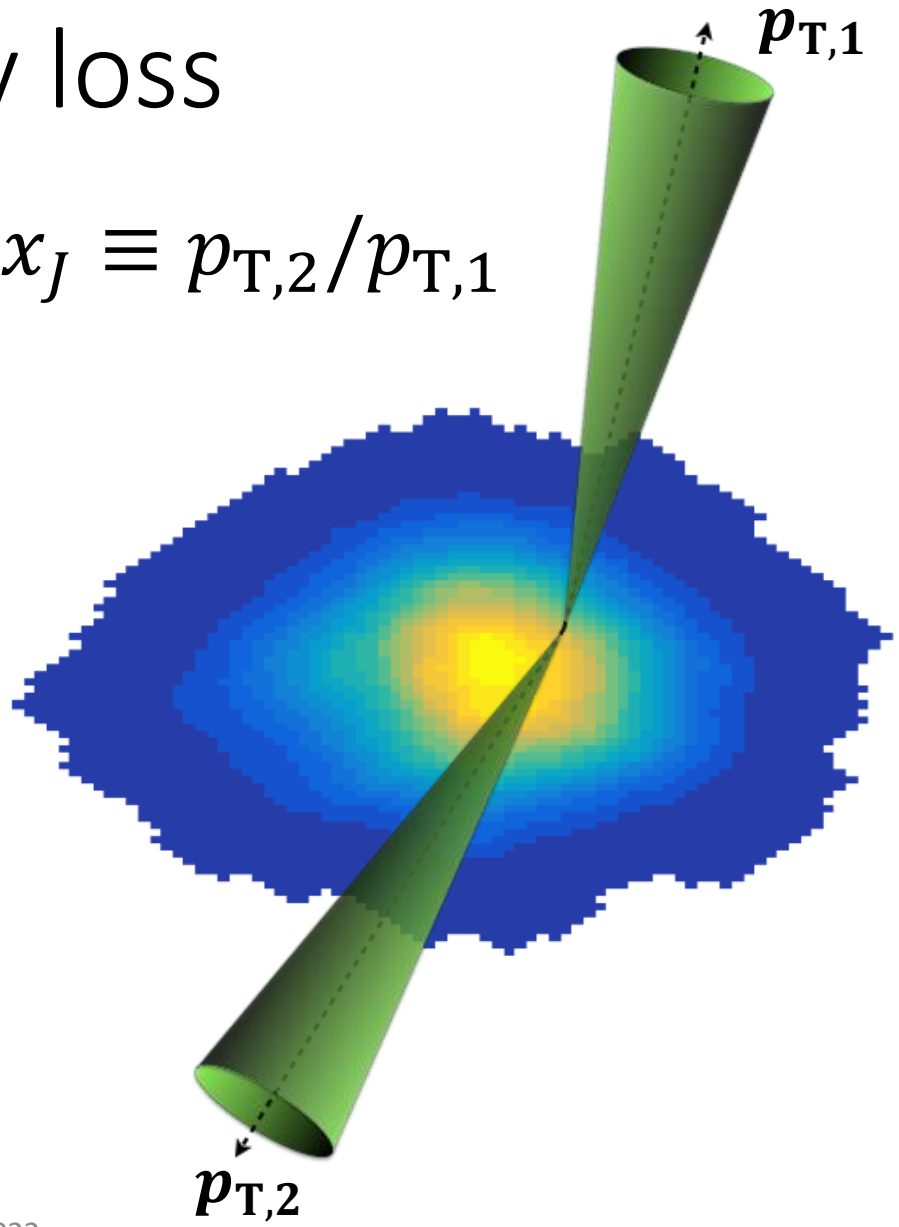
$$x_J \equiv p_{\mathrm{T},2}/p_{\mathrm{T},1}$$

Back-to-back jet pairs provide access to asymmetric energy loss

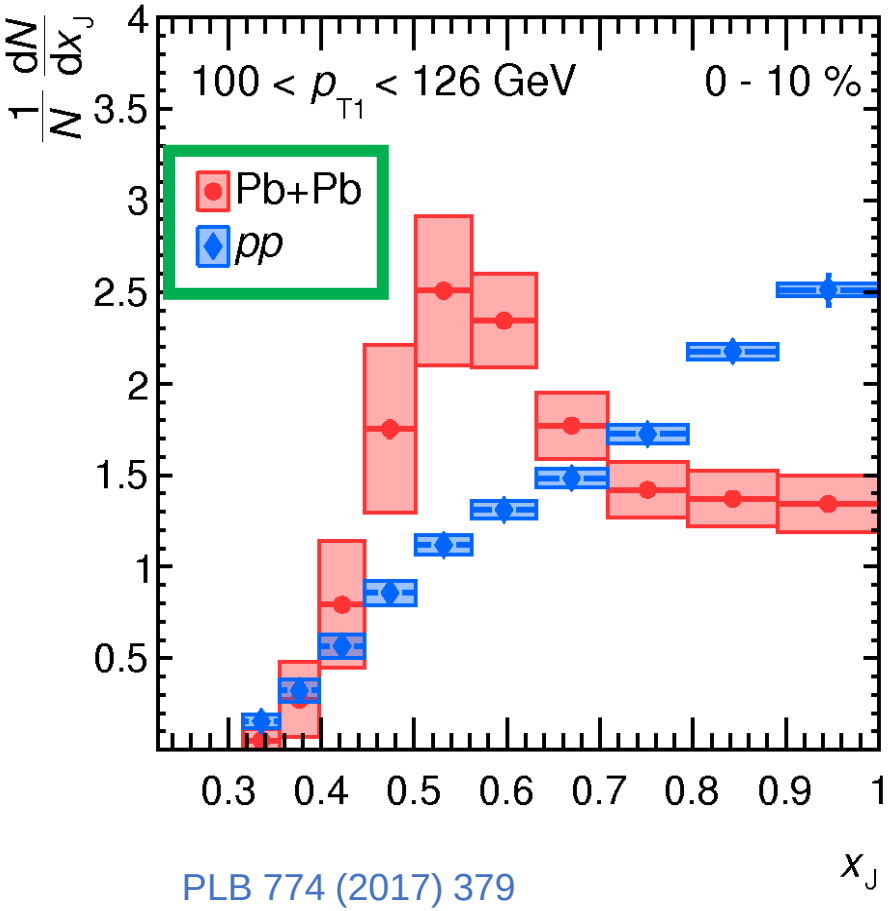
Can provide constraint on the contributions from:

- Path length dependent energy loss
- Energy loss fluctuations

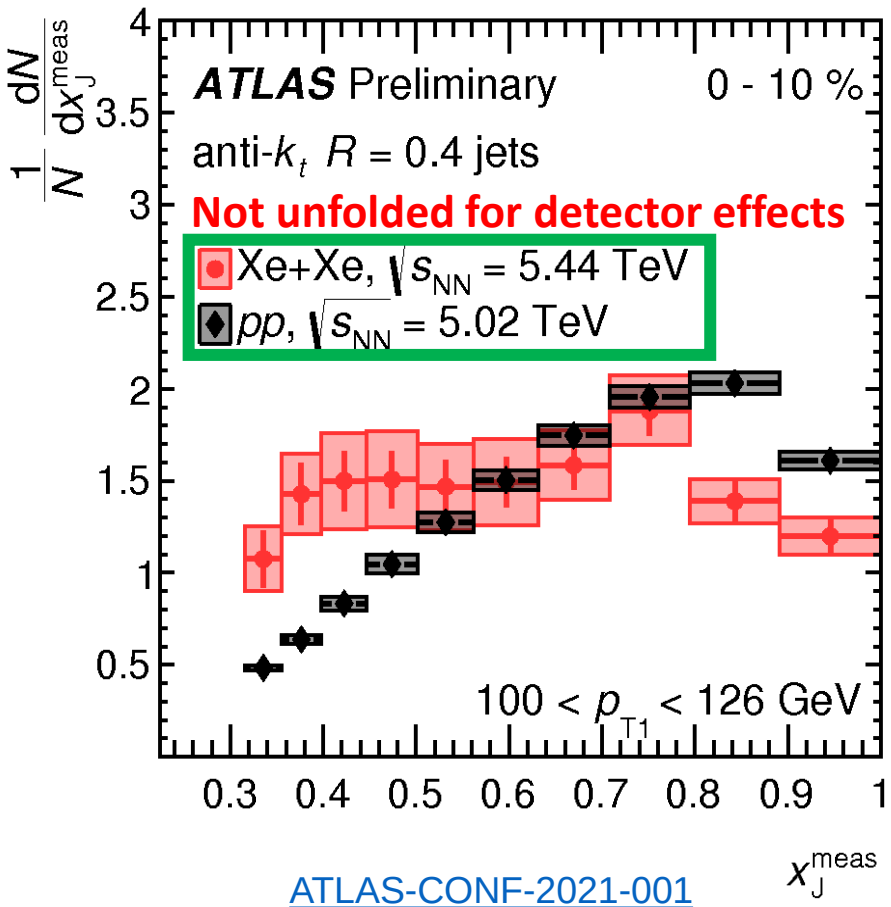
Provide enhanced sensitivity to small amounts of jet quenching



Previous ATLAS results of dijet balance



PLB 774 (2017) 379
(see also: PRL 105(2010) 252303)



ATLAS-CONF-2021-001

Modifications of the x_J **shape** are measured in both Pb+Pb and Xe+Xe

In central Pb+Pb a peak structure is observed at intermediate x_J

➢A persistent challenge for the theory community

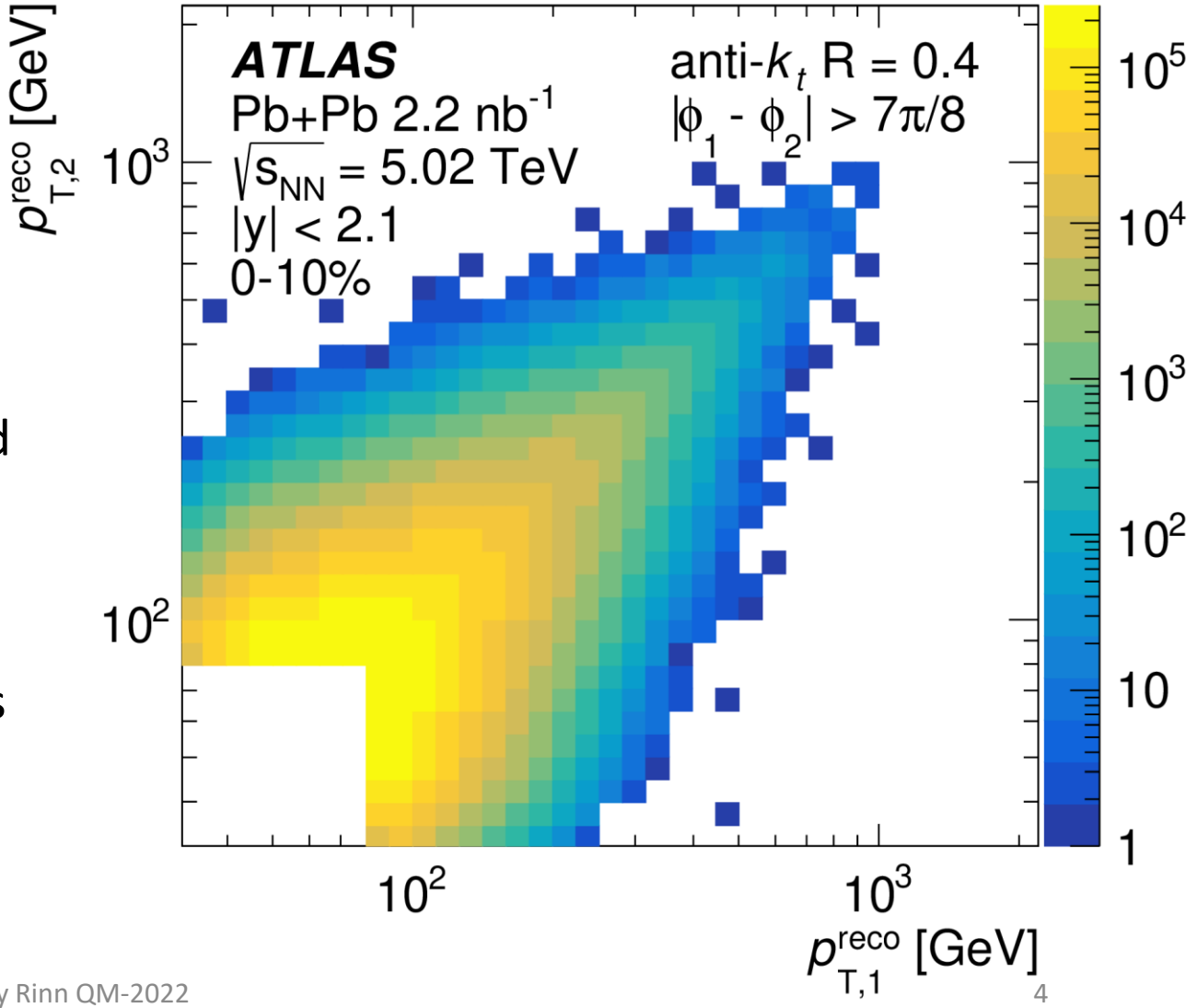
Dijet analysis overview:

Two-dimensional $(p_{\mathrm{T},1}, p_{\mathrm{T},2})$ distributions are measured for the leading dijet pair

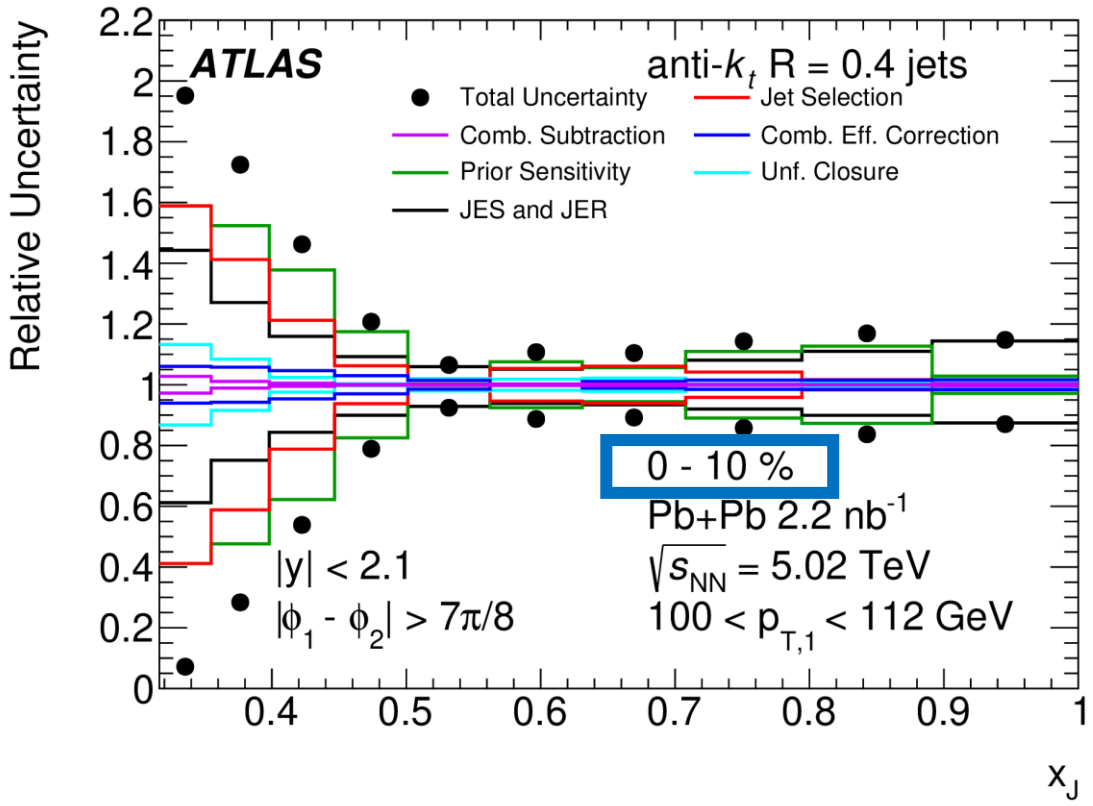
- $\Delta\phi_{1,2} > \frac{7\pi}{8}$
- $|\eta| < 2.1$

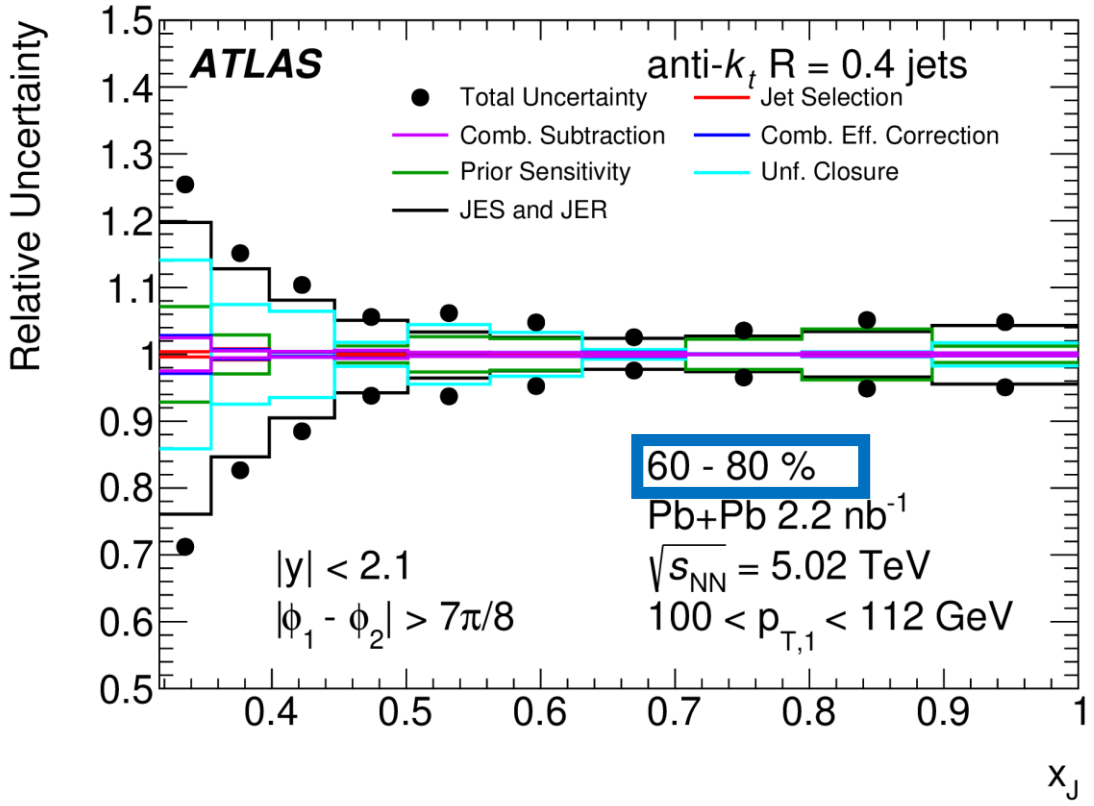
Corrected for combinatoric dijets, then unfolded for detector effects using 2D Bayesian unfolding

Unfolded $\frac{dN_{pair}}{dp_{T,1}dp_{T,2}}$ distribution projected across selections of $p_{\mathrm{T},1}$ to extract $\frac{dN}{dx_J}$ distributions



Uncertainties on per dijet pair x_J distributions





In central events the uncertainties are driven by unfolding

In peripheral events the uncertainty from the jet energy scale and resolution are dominant

Dijet x_J observables

Per dijet pair normalized x_J distributions: $\frac{1}{N_{pair}}\frac{dN_{pair}}{dx_J}$

- Enables direct comparison of the x_J shape across centrality in Pb+Pb and in *pp*

Never Before Measured

Absolutely normalized x_J distributions: $\frac{1}{N_{evt}\langle T_{AA}\rangle}\frac{dN_{pair}}{dx_J}$

- Enables evaluation of the dijet per event yields as a function of x_J
- Provides insight into the dynamics of dijet energy loss

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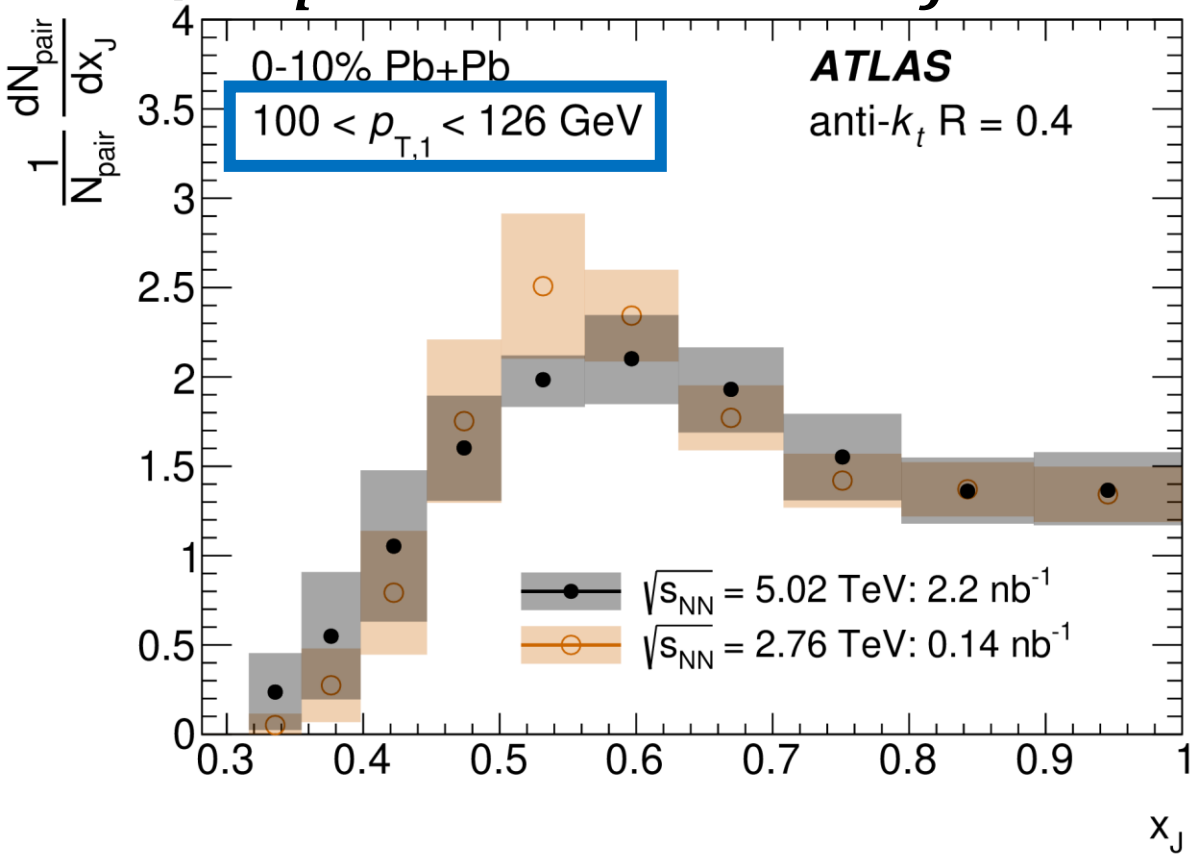
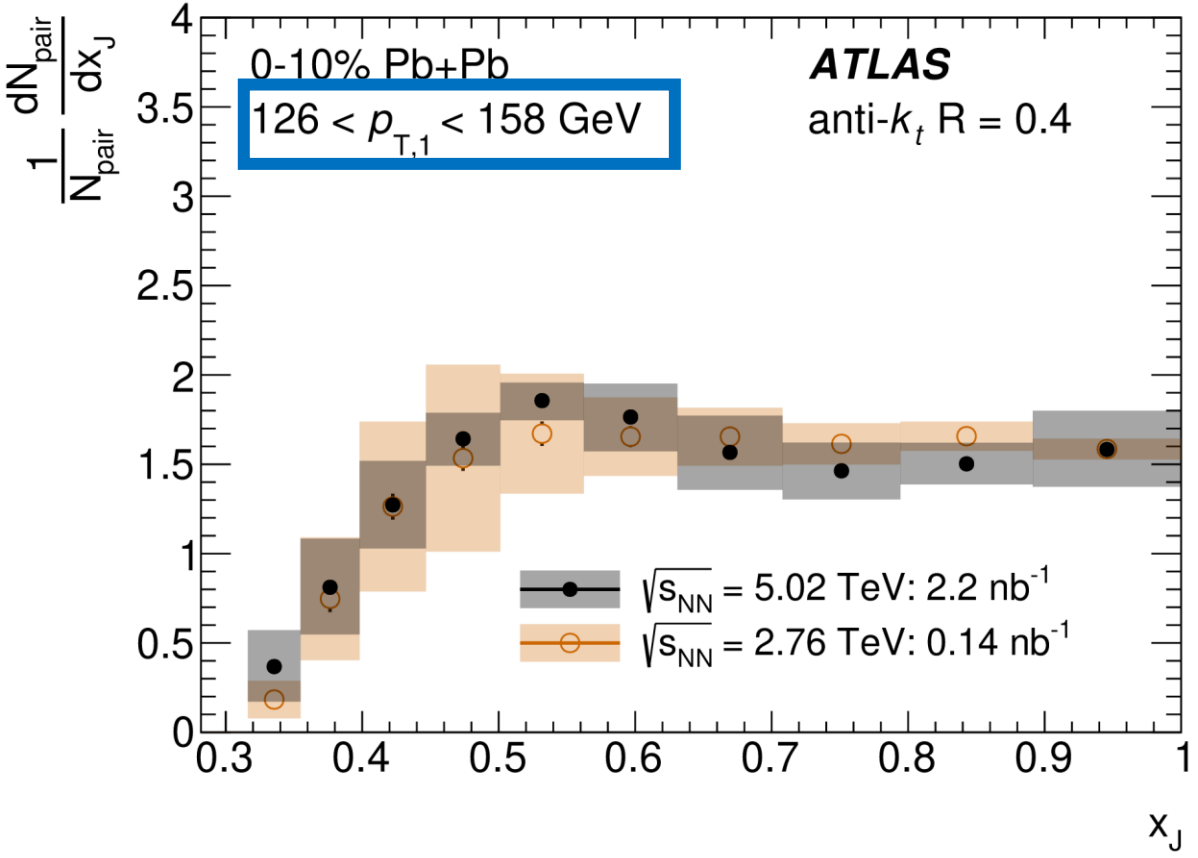
$1/N_{pair}\ dN_{pair}/dx_J$ distributions

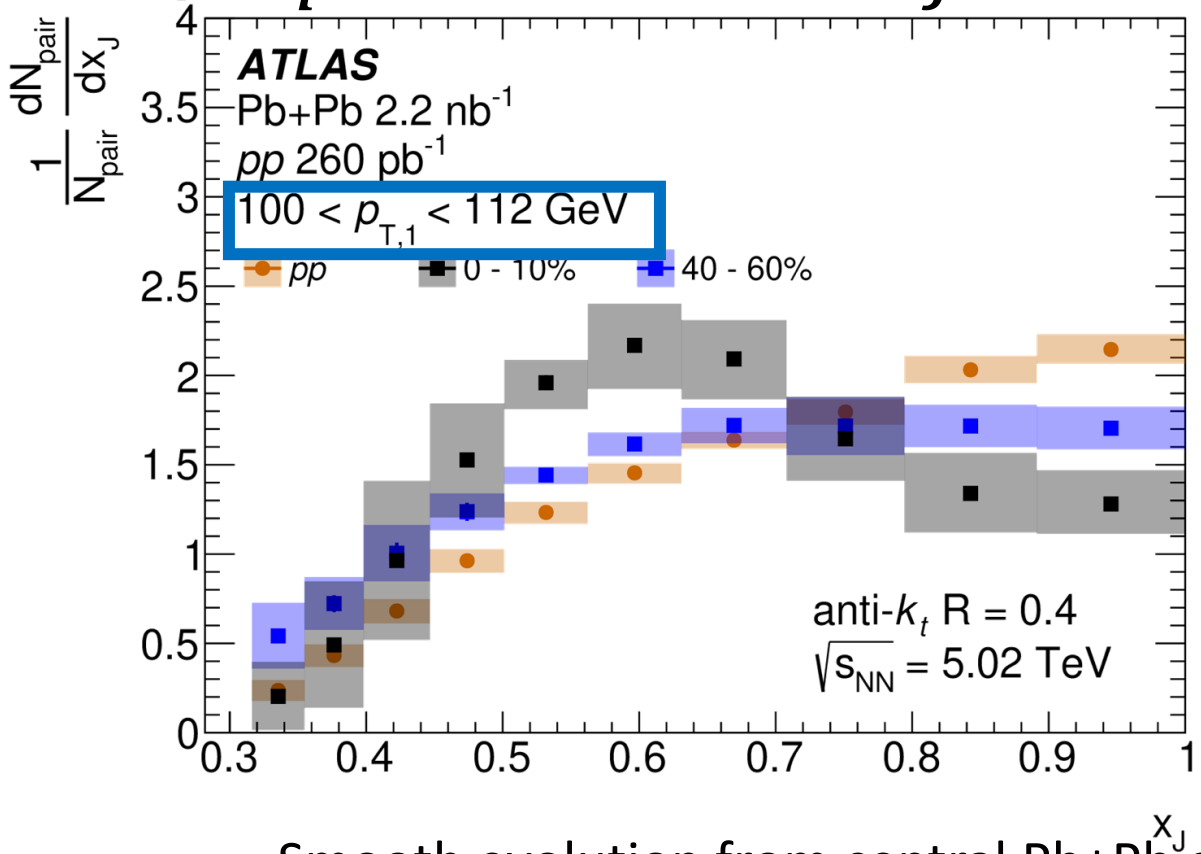


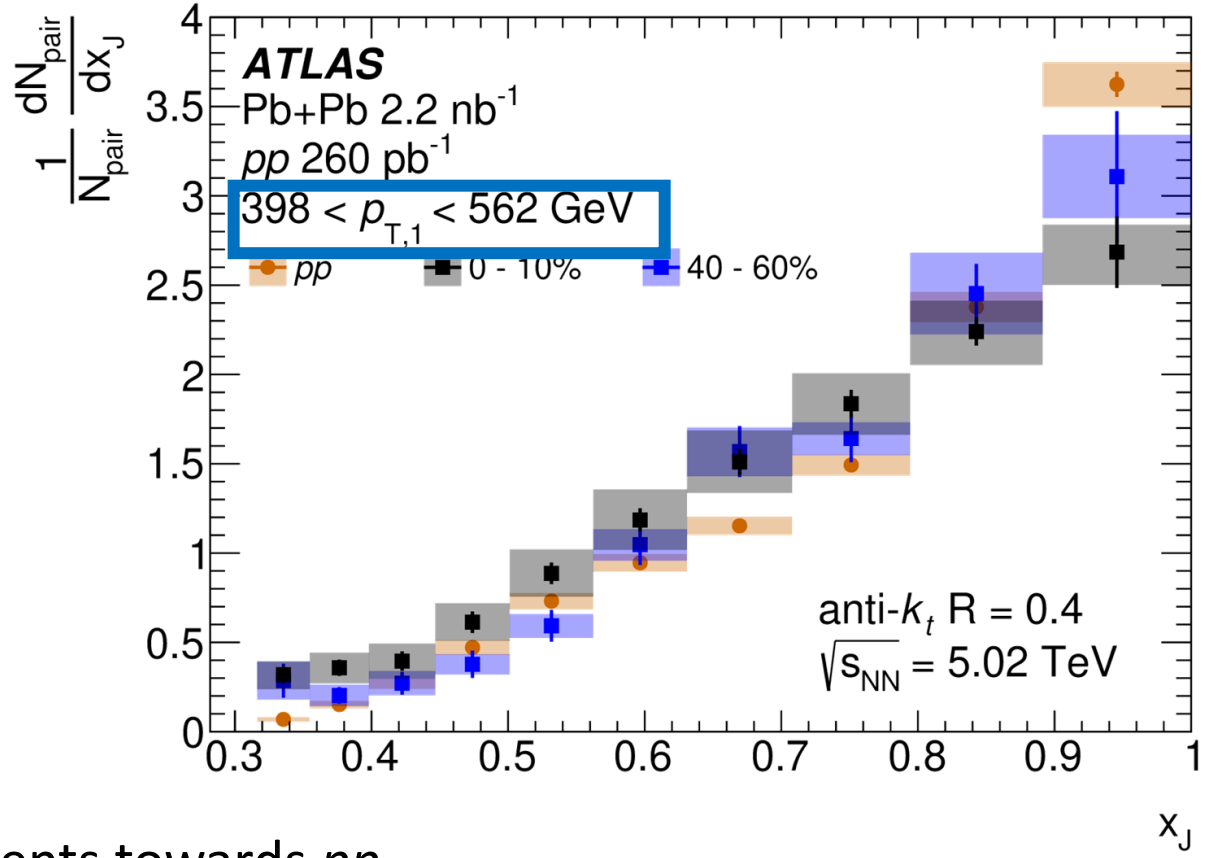


Data consistent with previous results measured in $\sqrt{s_{NN}} = 2.76$ TeV collisions

- Peak observed at intermediate x_J at low $p_{T,1}$ in central events, although milder

$1/N_{pair}\ dN_{pair}/dx_J$ distributions

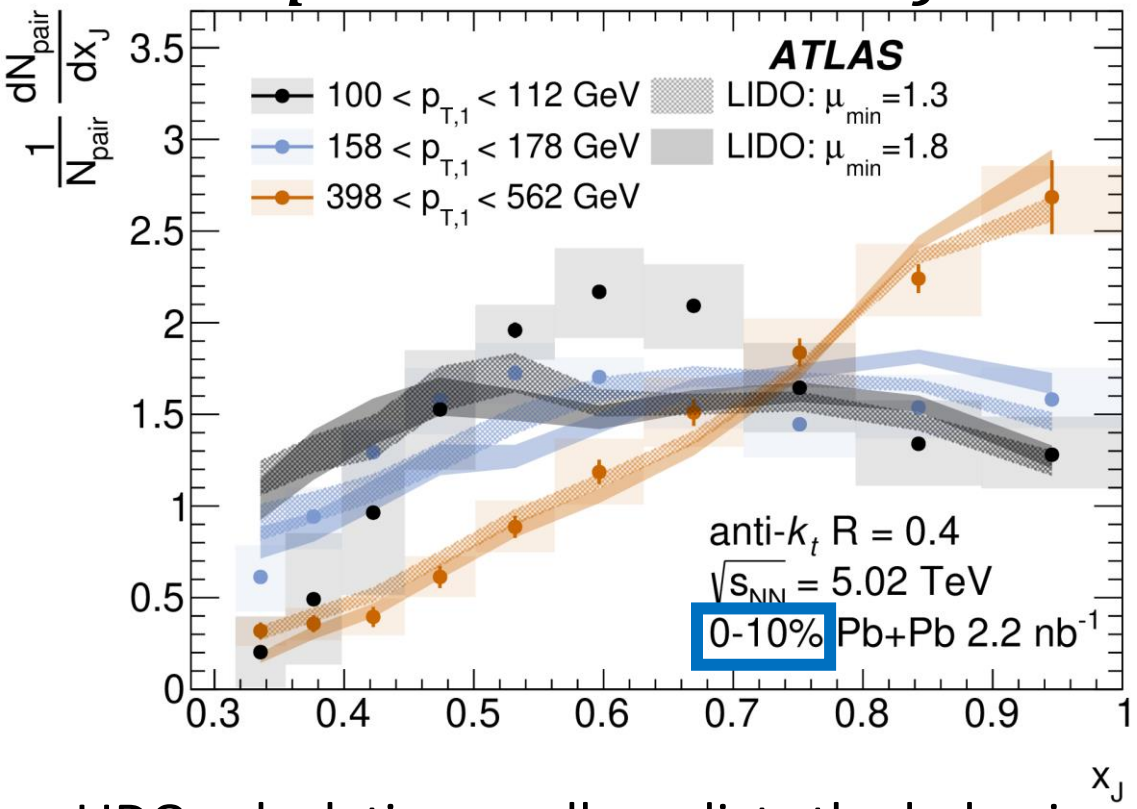


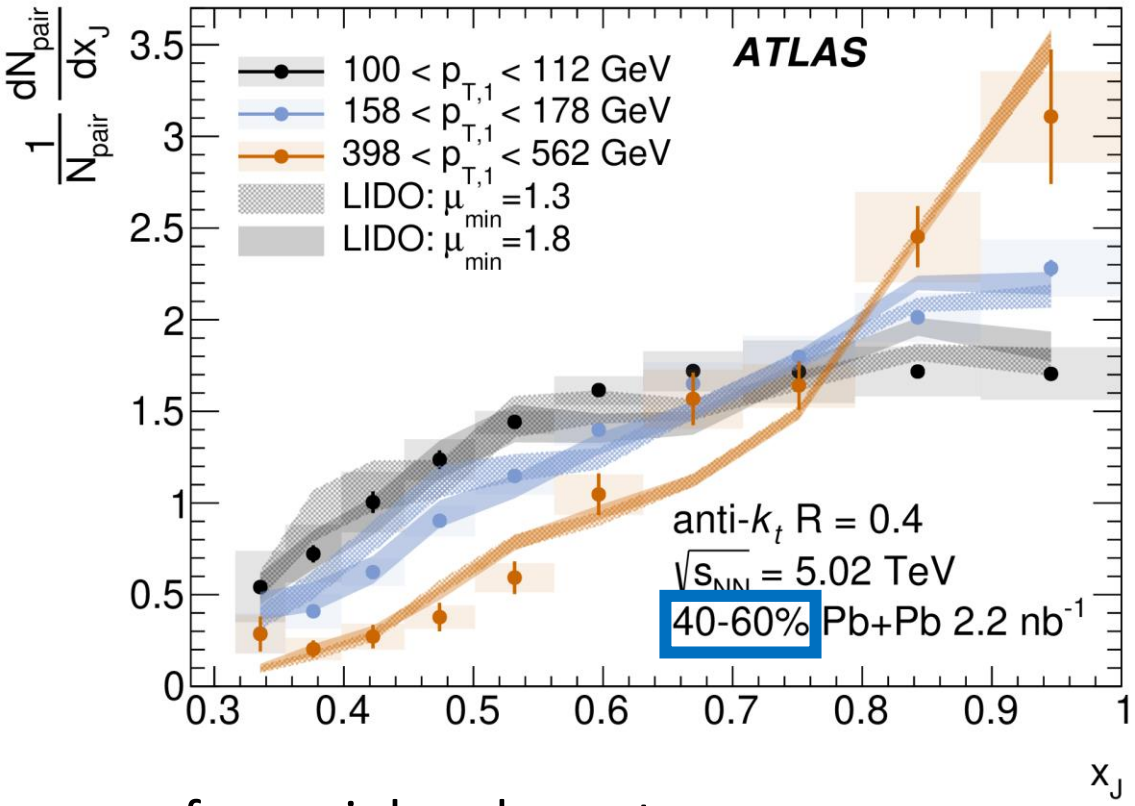


Smooth evolution from central Pb+Pb events towards *pp*

Significant modifications from *pp* collisions observed even at the highest $p_{\mathrm{T},1}$

$1/N_{pair}\ dN_{pair}/dx_J$: Comparison with theory





LIDO calculations well predicts the behavior across $p_{\mathrm{T},1}$ for peripheral events

- Reproduces the x_J shape for intermediate and high $p_{\mathrm{T},1}$ in central events

LIDO does not reproduce the peak observed at intermediate x_J at low $p_{\mathrm{T},1}$

Dijet x_J observables

Per dijet pair normalized x_J distributions: $\frac{1}{N_{pair}}\frac{dN_{pair}}{dx_J}$

- Enables direct comparison of the x_J shape across centrality in Pb+Pb and in *pp*

Never Before Measured

Absolutely normalized x_J distributions: $\frac{1}{N_{evt}\langle T_{AA}\rangle}\frac{dN_{pair}}{dx_J}$

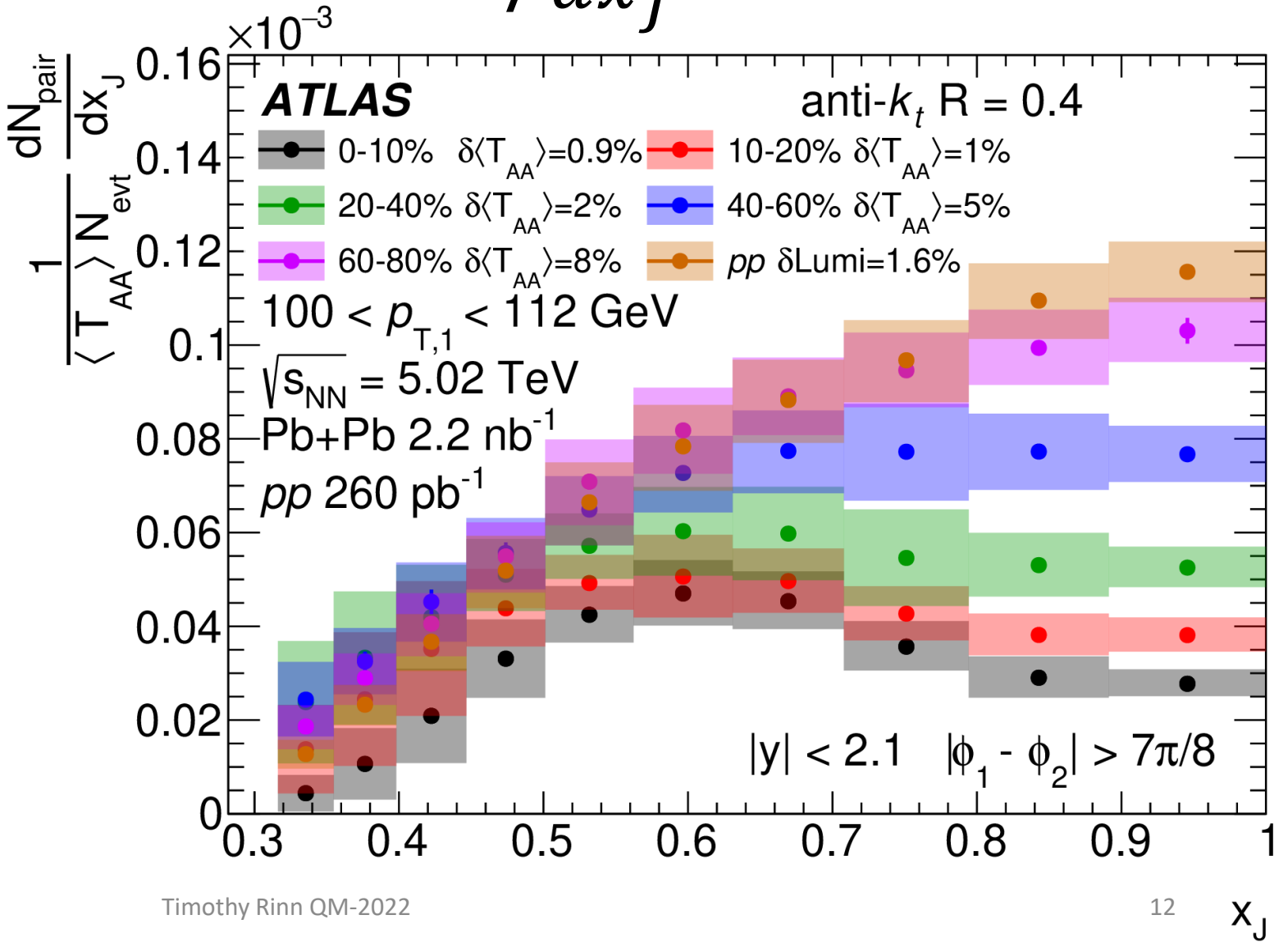
- Enables evaluation of the dijet per event yields as a function of x_J
- Provides insight into the dynamics of dijet energy loss

Absolutely normalized dN_{pair}/dx_J

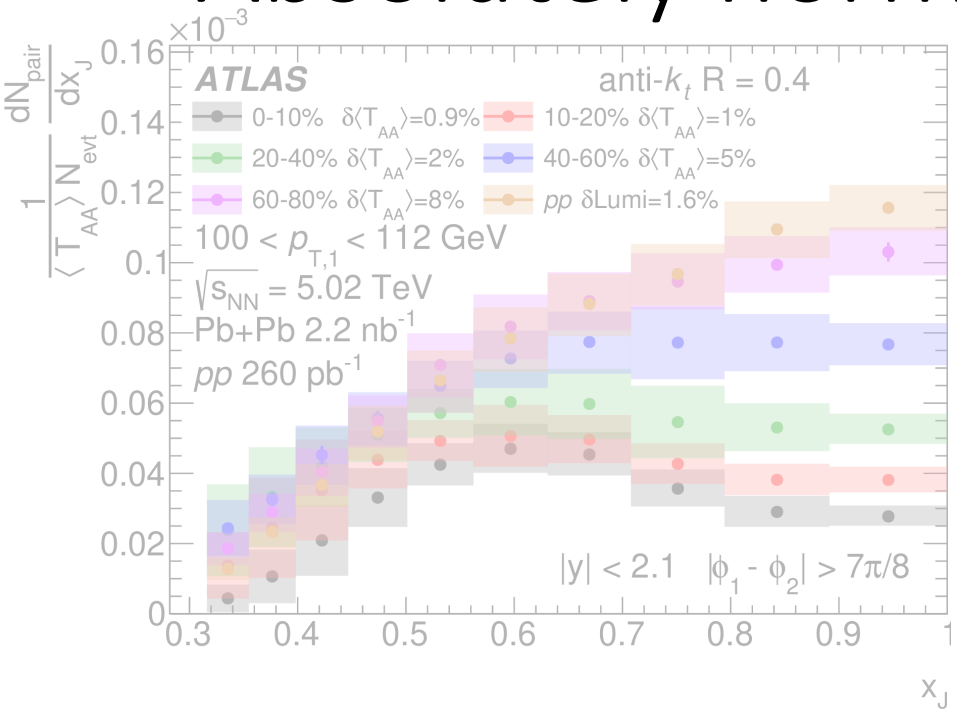
Using a $\frac{1}{\langle T_{AA} \rangle N_{evt}}$ normalization enables the study of dijet yields as a function of x_J

The peak structure observed at intermediate x_J stems from the favorable suppression of symmetric dijets

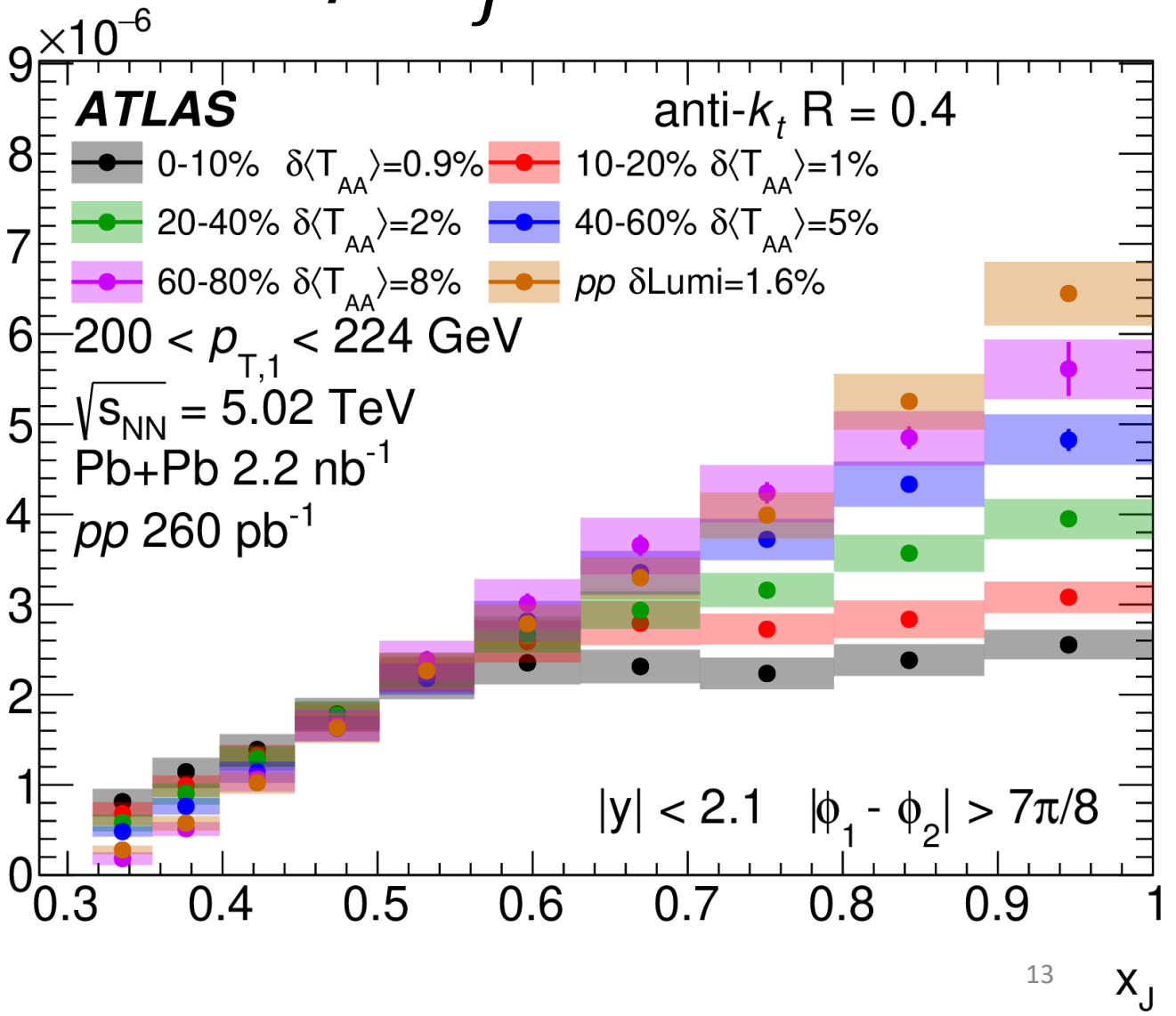
- No evidence for enhancement over *pp* of intermediate x_J



Absolutely normalized dN_{pair}/dx_J

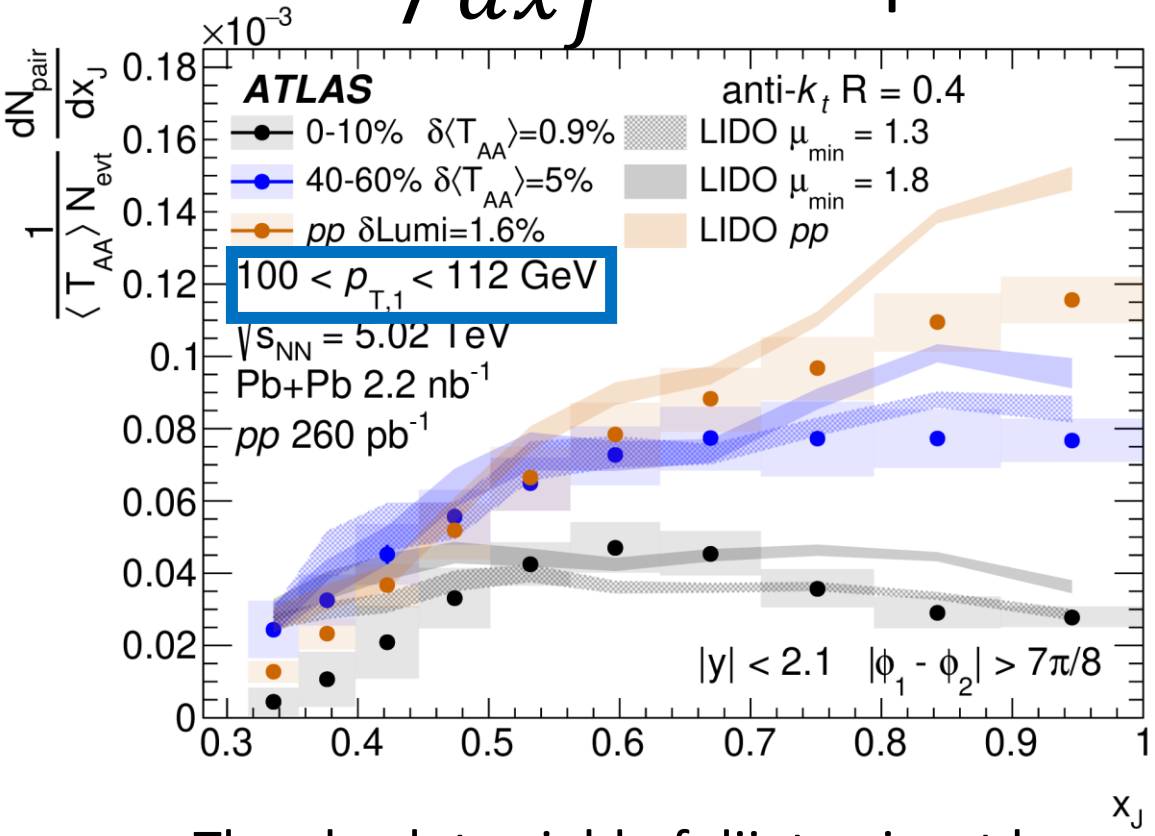


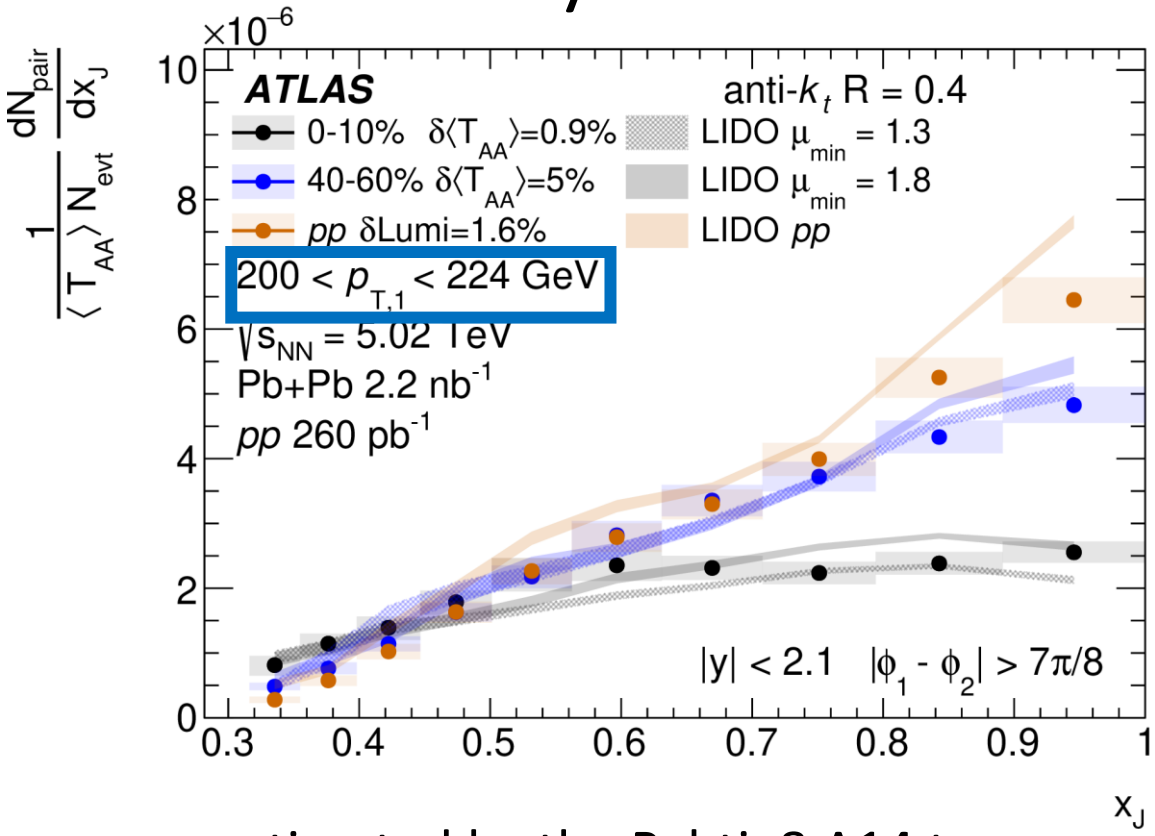
$\frac{1}{\langle T_{AA}\rangle} \frac{dN_{pair}}{dx_J}$



The systematic suppression of symmetric dijets persists with increasing $p_{\mathrm{T},1}$

dN_{pair}/dx_J: Comparison with theory





The absolute yield of dijet pairs at low $p_{T,1}$ are overestimated by the Pyhtia8 A14 tune with CTEQL1 PDF used in LIDO

LIDO qualitatively predicts the depletion of symmetric dijets observed across $p_{T,1}$

Dijet nuclear modification factor: R_{AA}^{pair}

$R_{AA}^{pair}(\boldsymbol{p_{T,1}})$ quantifies the suppression of the **leading jet** in a dijet

$$R_{\mathrm{AA}}^{\mathrm{pair}}(\boldsymbol{p_{T,1}}) = \frac{\frac{1}{\langle T_{AA}\rangle N_{evt}^{AA}} \int_{0.32\times \boldsymbol{p_{T,1}}}^{\boldsymbol{p_{T,1}}} \frac{d^2 N_{pair}^{AA}}{dp_{T,1}dp_{T,2}} \boldsymbol{dp_{T,2}}}{\frac{1}{L_{pp}} \int_{0.32\times \boldsymbol{p_{T,1}}}^{\boldsymbol{p_{T,1}}} \frac{d^2 N_{pair}^{pp}}{dp_{T,1}dp_{T,2}} \boldsymbol{dp_{T,2}}}$$

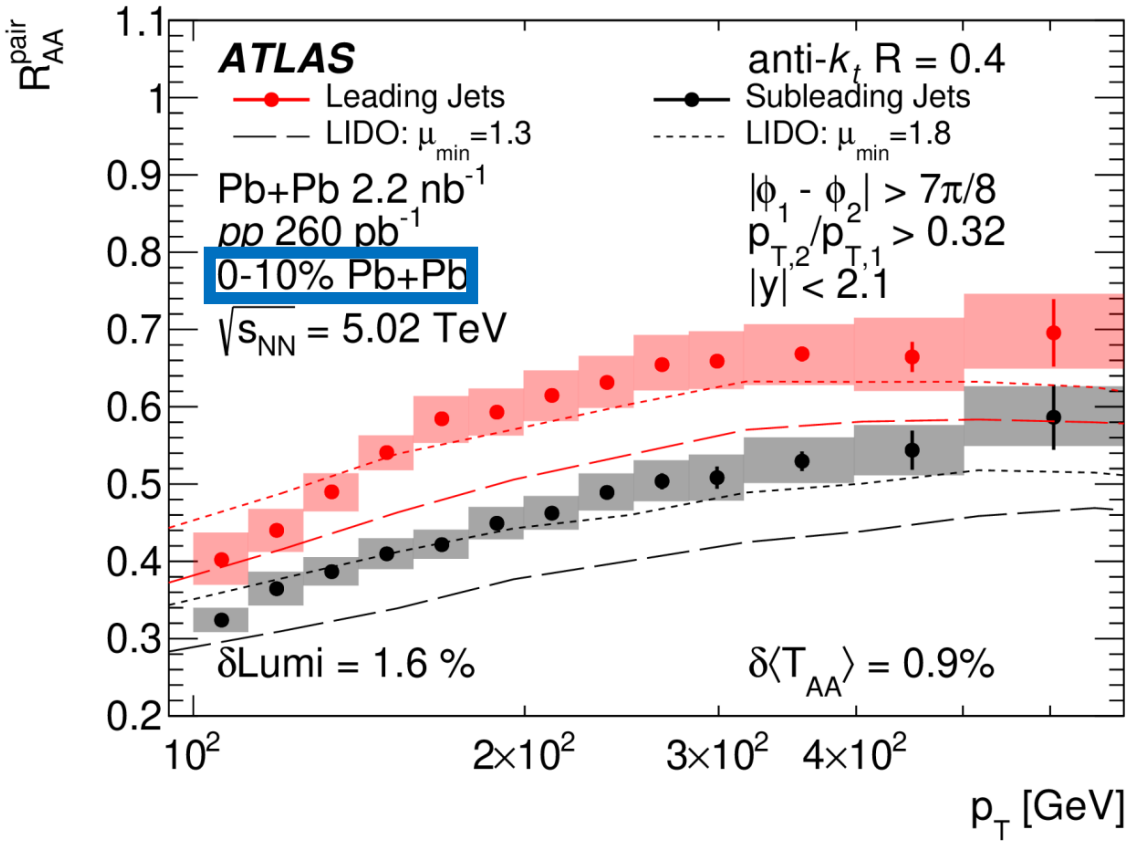
$R_{AA}^{pair}(\boldsymbol{p_{T,2}})$ quantifies the suppression of the **subleading jet** in a dijet

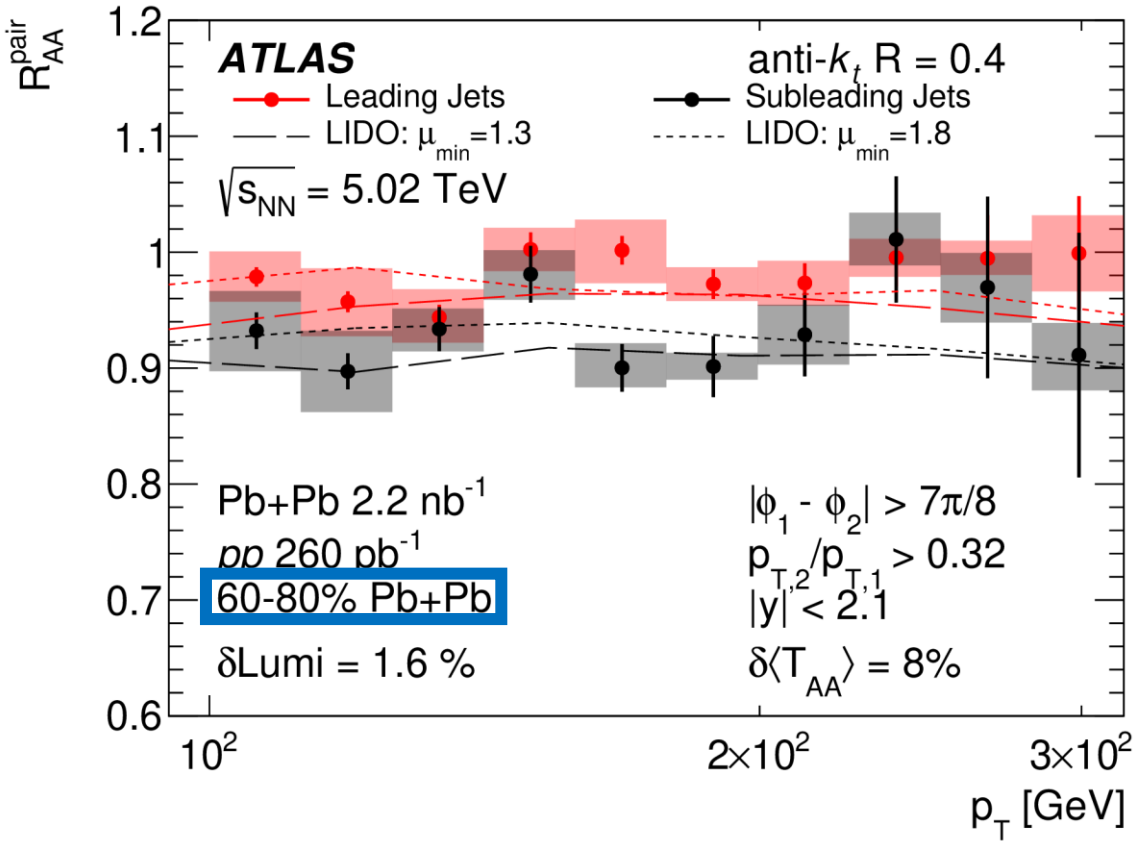
$$R_{\mathrm{AA}}^{\mathrm{pair}}(\boldsymbol{p_{T,2}}) = \frac{\frac{1}{\langle T_{AA}\rangle N_{evt}^{AA}} \int_{\boldsymbol{p_{T,2}}}^{\boldsymbol{p_{T,2}}/0.32} \frac{d^2 N_{pair}^{AA}}{dp_{T,1}dp_{T,2}} \boldsymbol{dp_{T,1}}}{\frac{1}{L_{pp}} \int_{\boldsymbol{p_{T,2}}}^{\boldsymbol{p_{T,2}}/0.32} \frac{d^2 N_{pair}^{pp}}{dp_{T,1}dp_{T,2}} \boldsymbol{dp_{T,1}}}$$

Dijet threshold condition of $\frac{\boldsymbol{p_{T,2}}}{\boldsymbol{p_{T,1}}} > 0.32$

$\frac{\boldsymbol{p_{T,2}}}{\boldsymbol{p_{T,1}}} > 0.32$ 

$R_{AA}^{pair}(p_{\mathrm{T},1})$ and $R_{AA}^{pair}(p_{\mathrm{T},2})$





In peripheral Pb+Pb no significant suppression is observed for leading jets

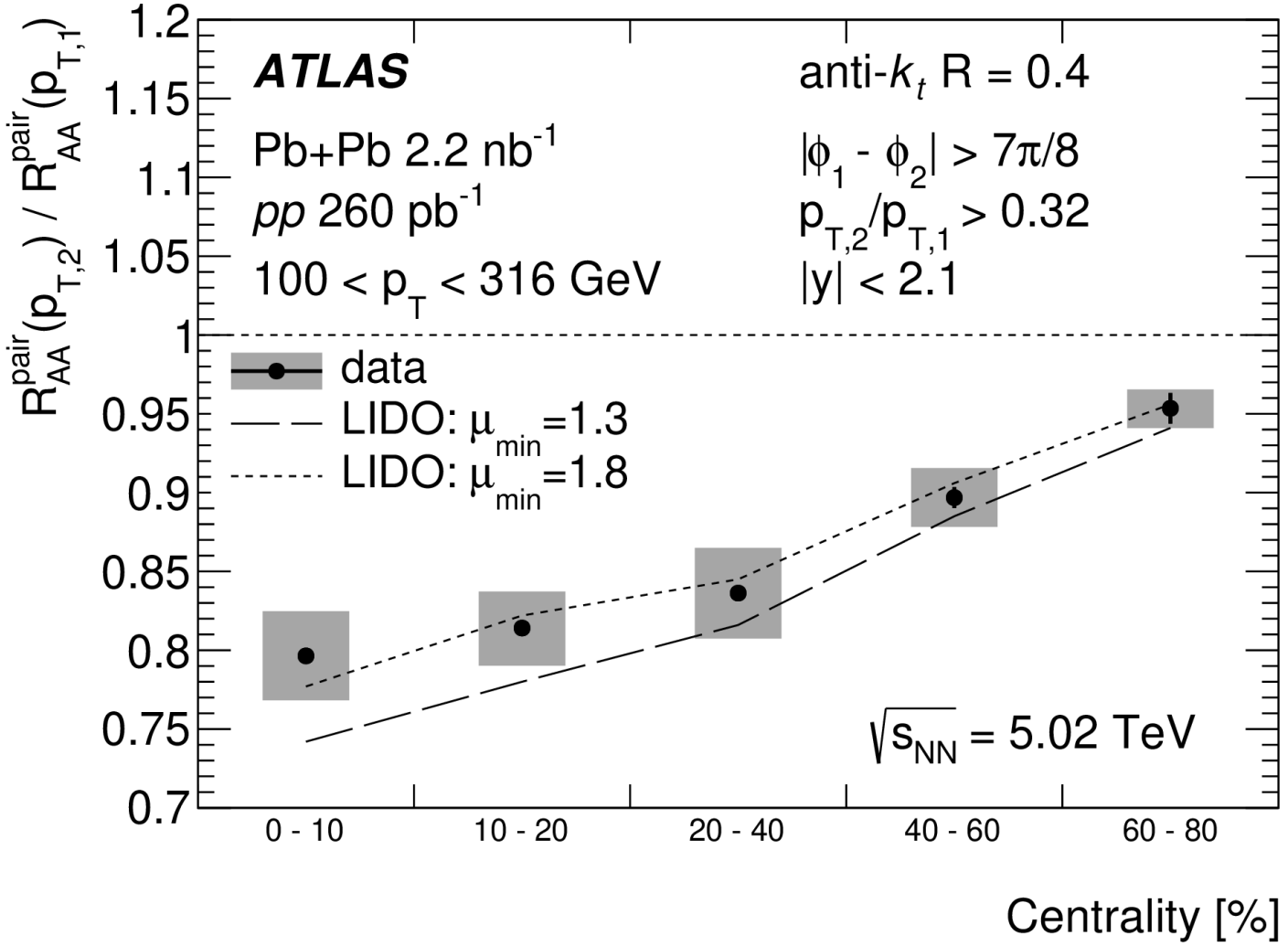
Across centrality and p_T a relative suppression of subleading to leading jets is observed

$R_{AA}^{pair}(p_{\mathrm{T},2}) \,/\, R_{AA}^{pair}(p_{\mathrm{T},1})$

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

- 3σ significant relative suppression observed in peripheral Pb+Pb

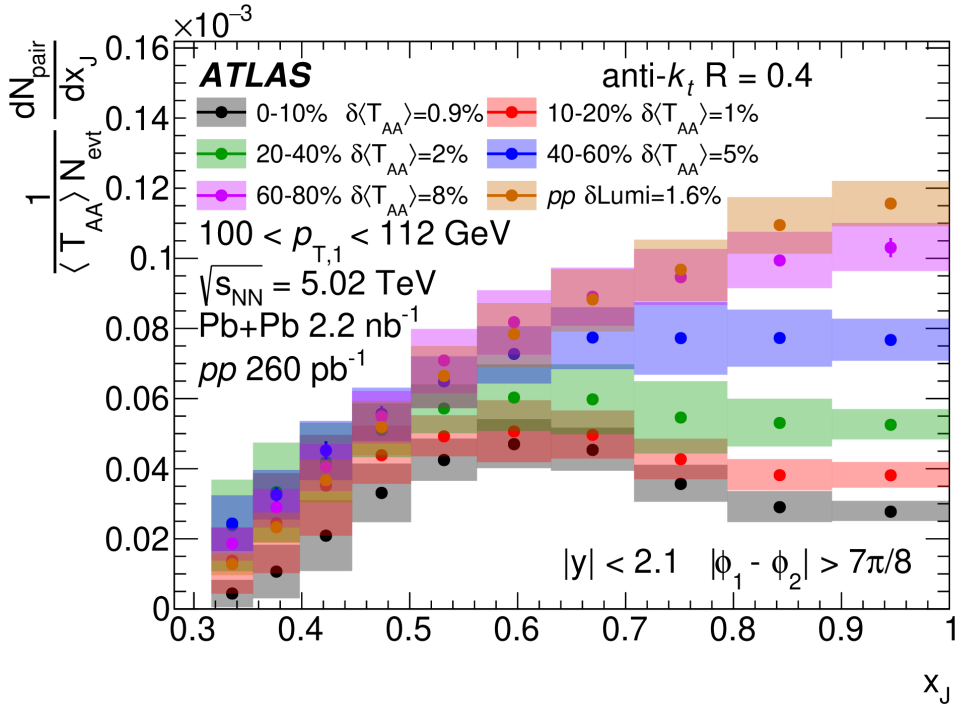
LIDO calculations with a $\mu_{min} = 1.8$ well reproduces the measurement

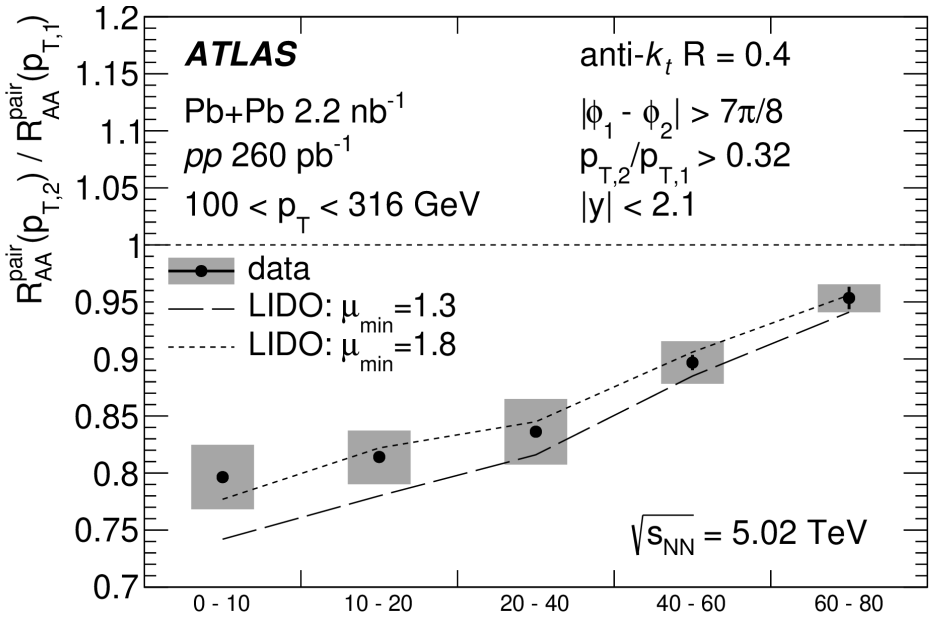


Summary

Novel measurements of dijets in Pb+Pb collisions have been presented

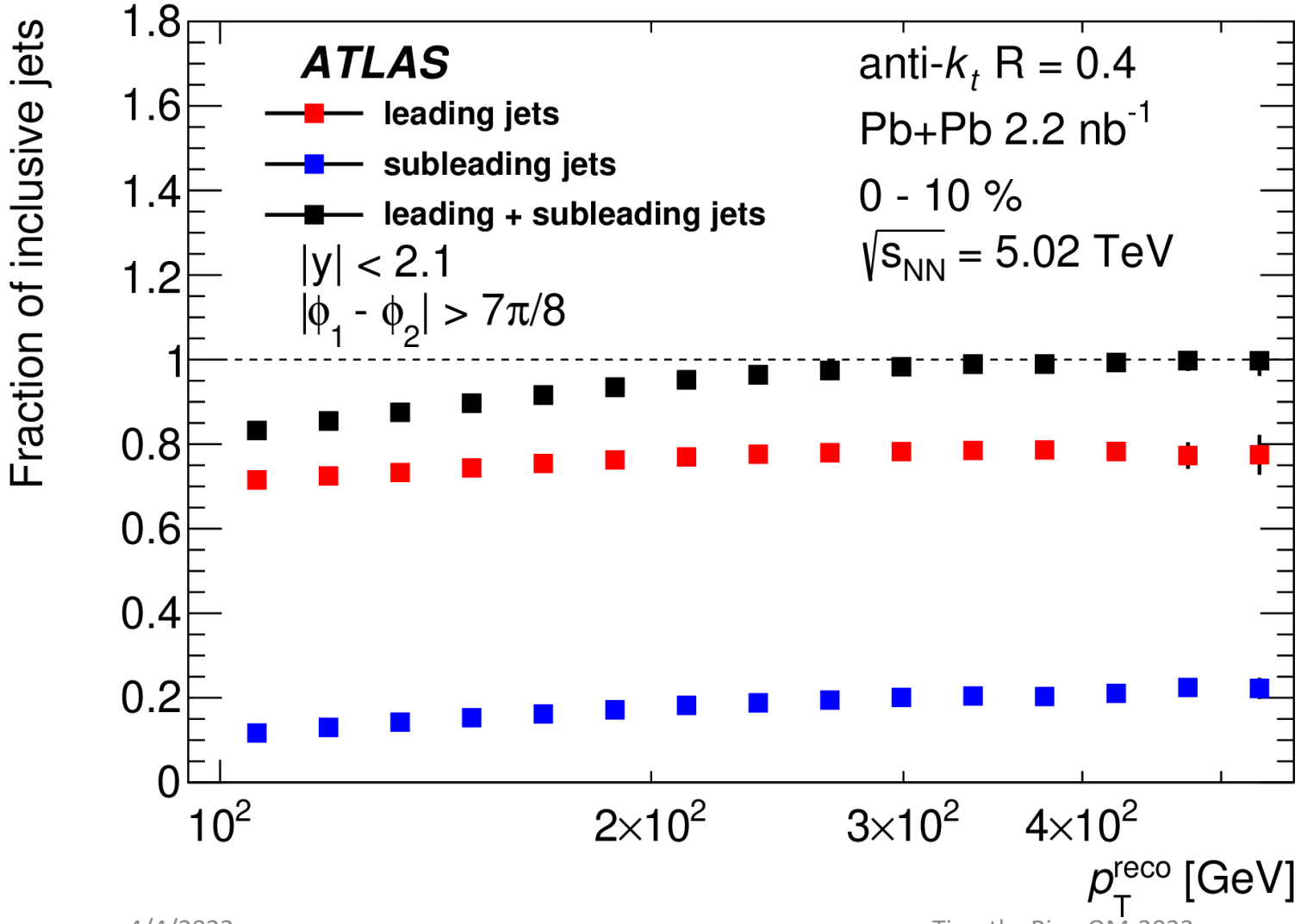
- Measurements of the absolutely normalized x_J distributions provide evidence of preferable depletion of balanced dijets
- Measurements of $R_{AA}^{pair}(p_{T,1})$ and $R_{AA}^{pair}(p_{T,2})$ quantify the suppression of leading and subleading jets
- A 3σ suppression of subleading jets to leading jets is observed in peripheral Pb+Pb





backups

Dijet fraction of inclusive jets

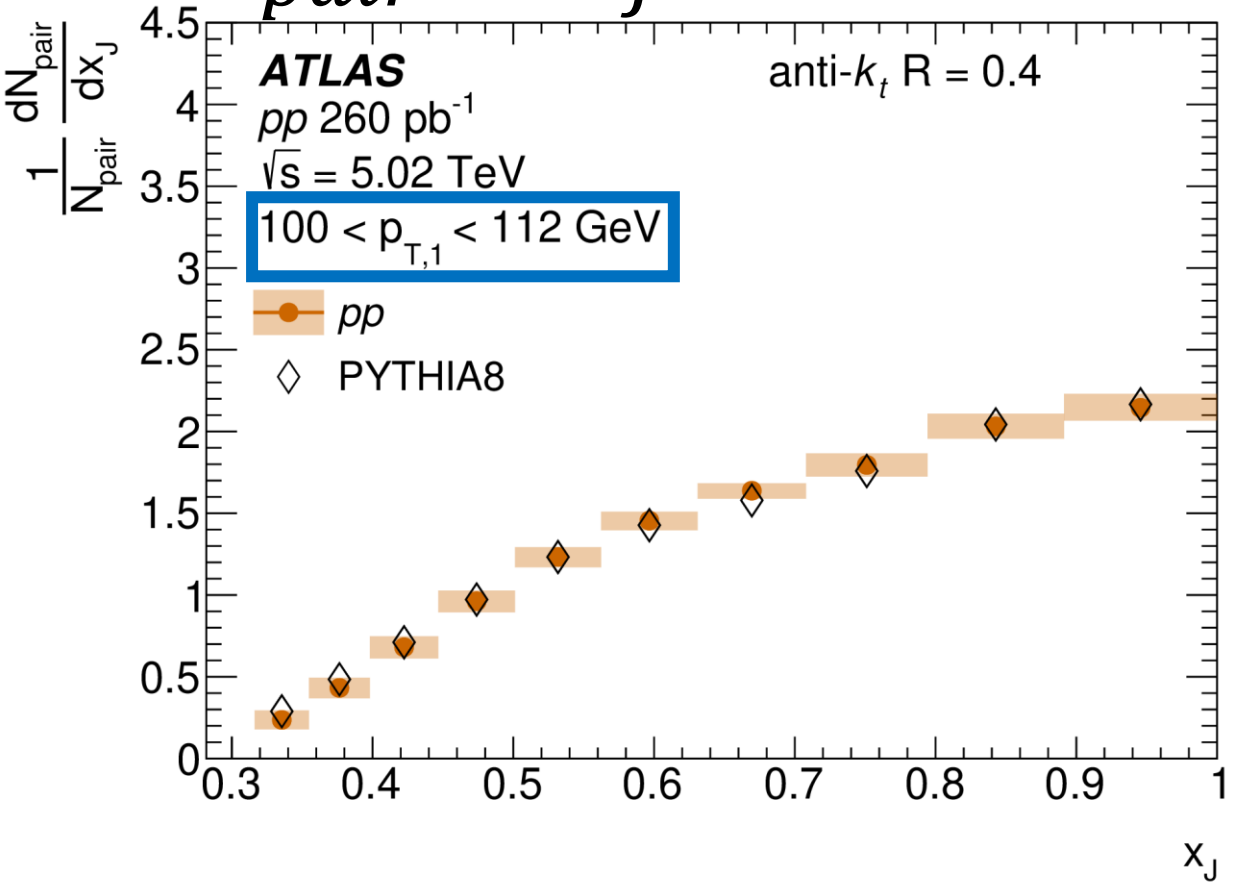


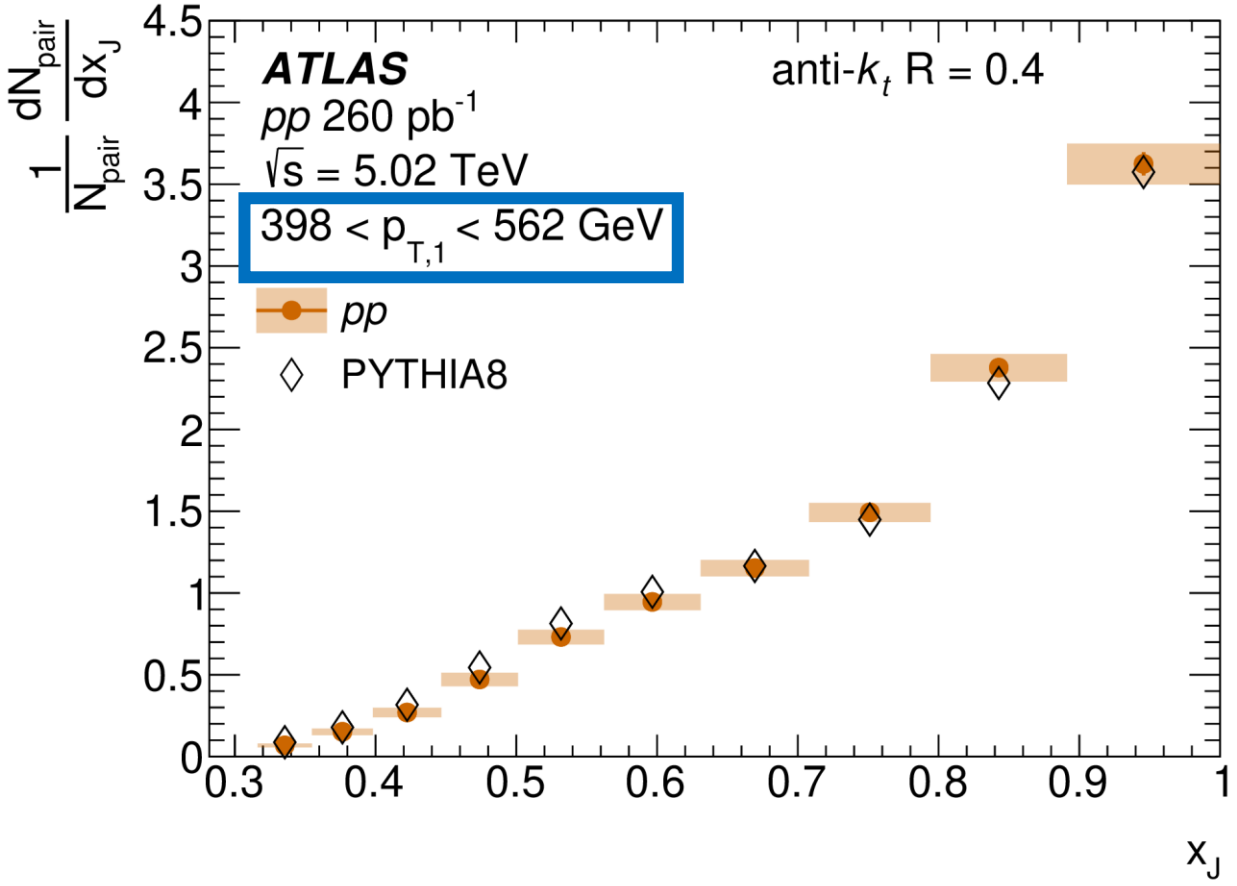
Measured fractions of inclusive jets which are part of the leading **dijet**, the **leading jet** of the dijet, or the **subleading** jet of the dijet

At 100 GeV: 83% of inclusive jets are part of the leading dijet

- Over 95% for $p_T^{reco} > 200$ GeV

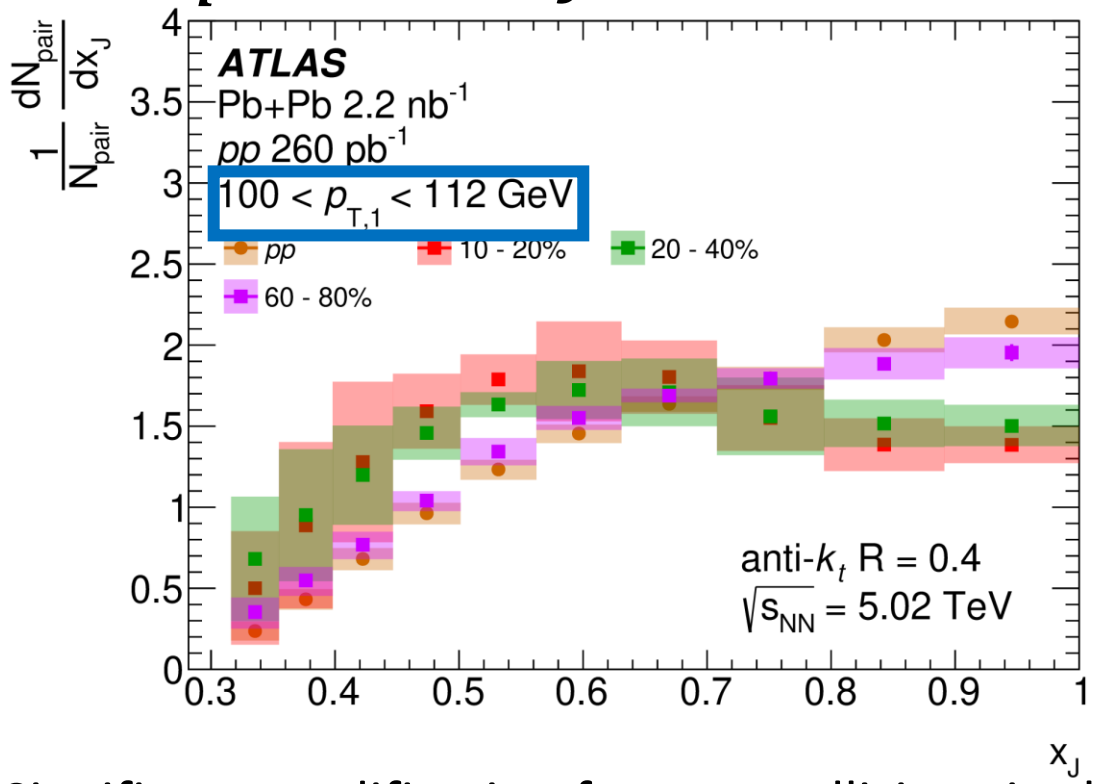
$\frac{1}{N_{pair}}\frac{dN_{pair}}{dx_J}$ pythia comparison

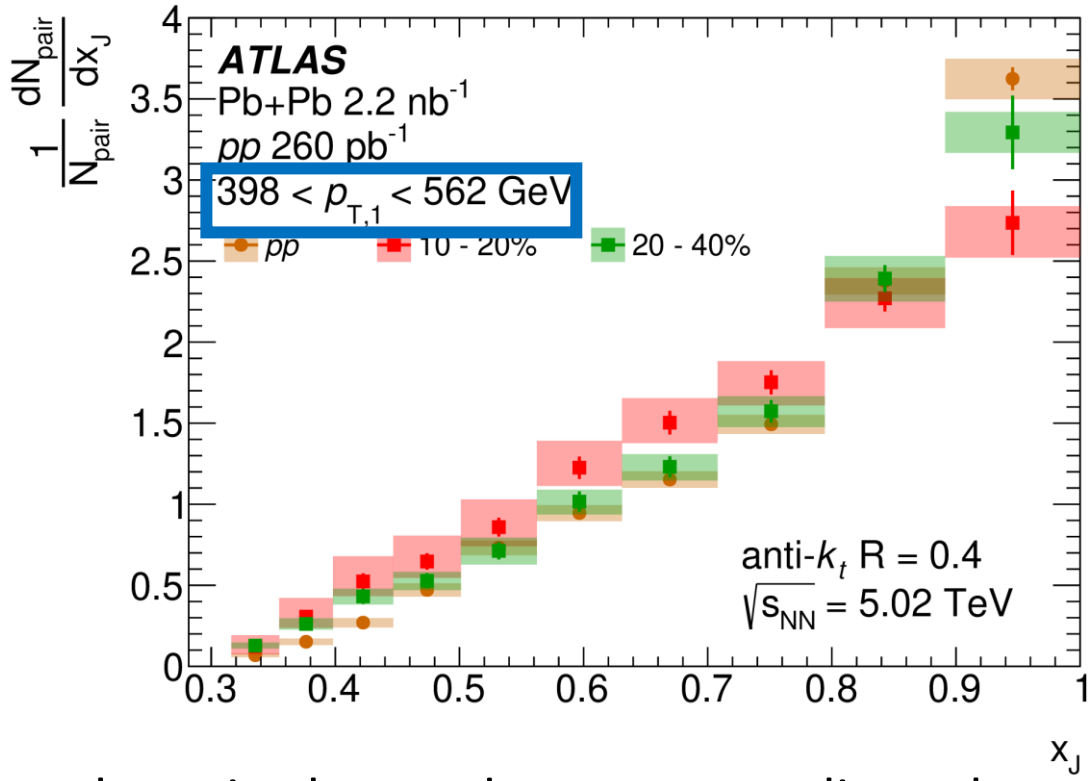




Pythia8 using the A14 tune with NNPDF23LO PDFs well reproduces the shape of the x_J distribution in *pp* collisions across $p_{\mathrm{T},1}$

$\frac{1}{N_{pair}}\frac{dN_{pair}}{dx_J}$ additional centrality intervals



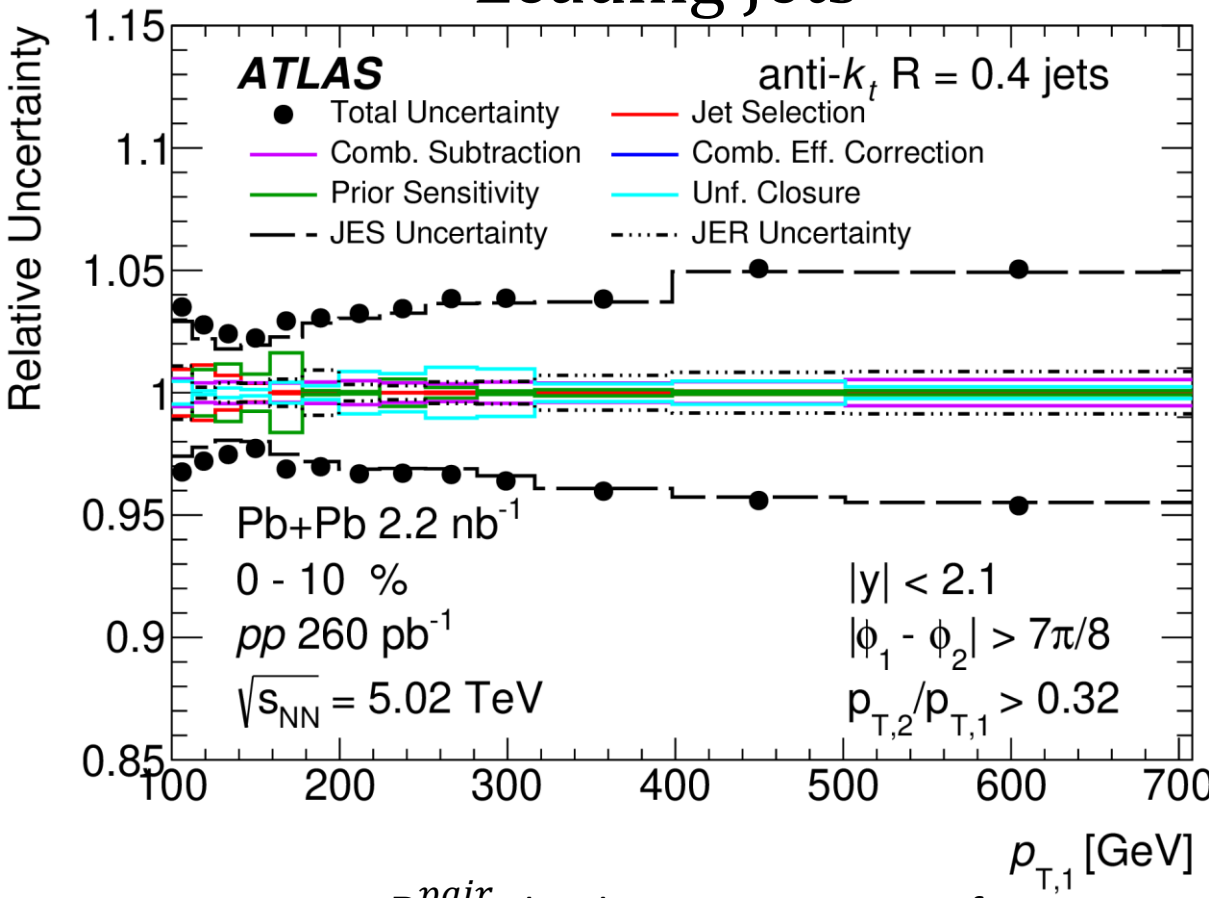


Significant modification from *pp* collisions in the x_J shape is observed across centrality at low $p_{\mathrm{T},1}$

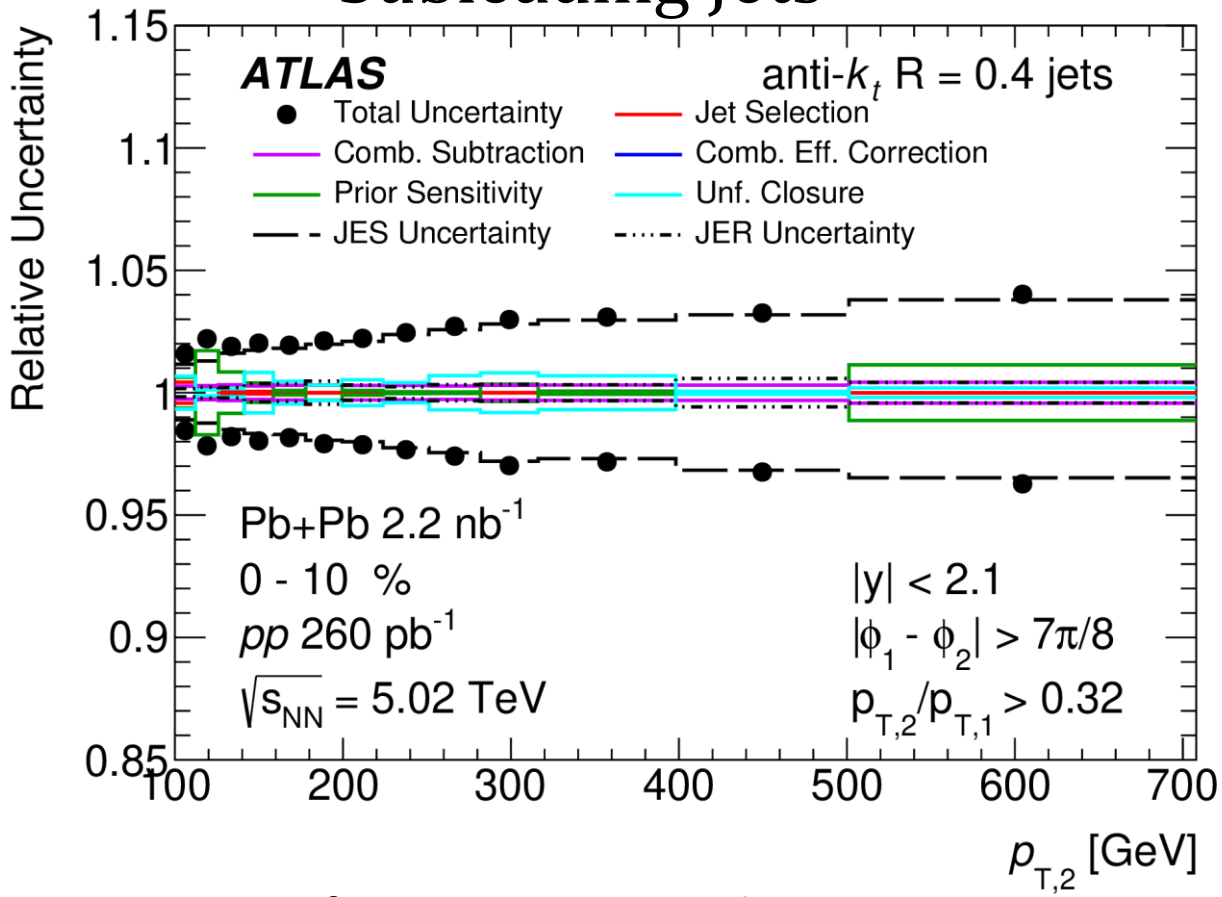
Notable deviations from *pp* is observed up through 60% central Pb+Pb events for 398 < $p_{\mathrm{T},1}$ < 562 GeV

Systematic uncertainties for R_{AA}^{pair}

Leading Jets

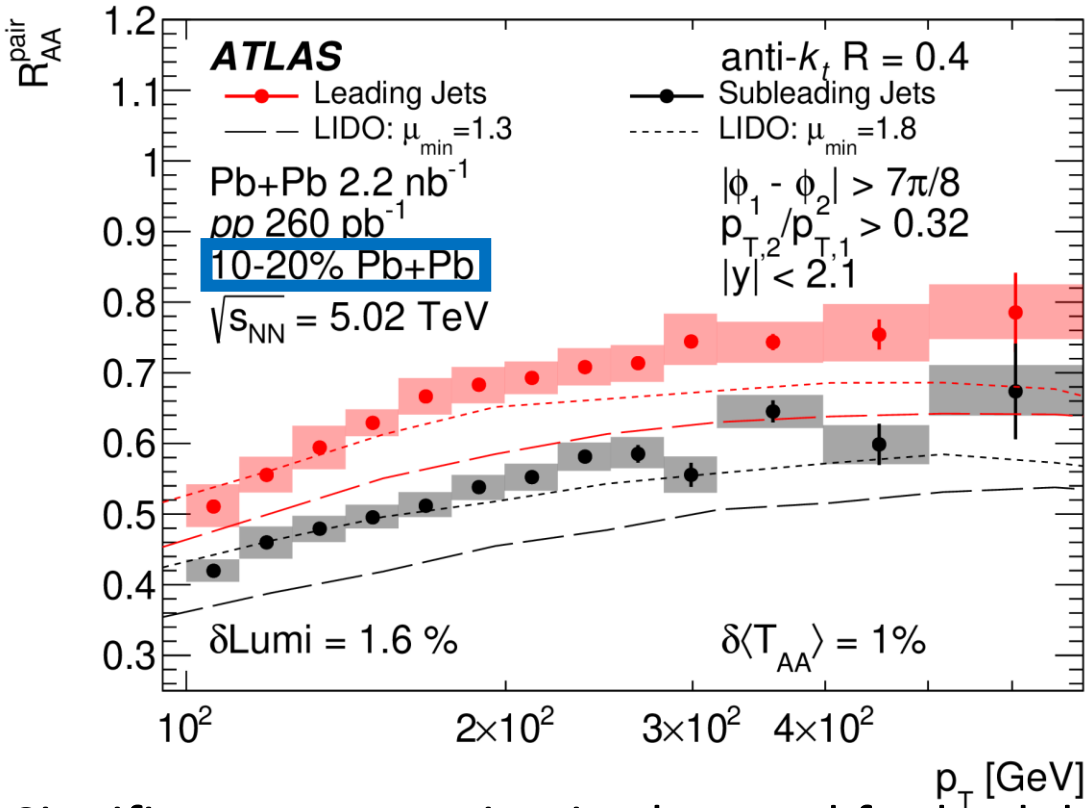


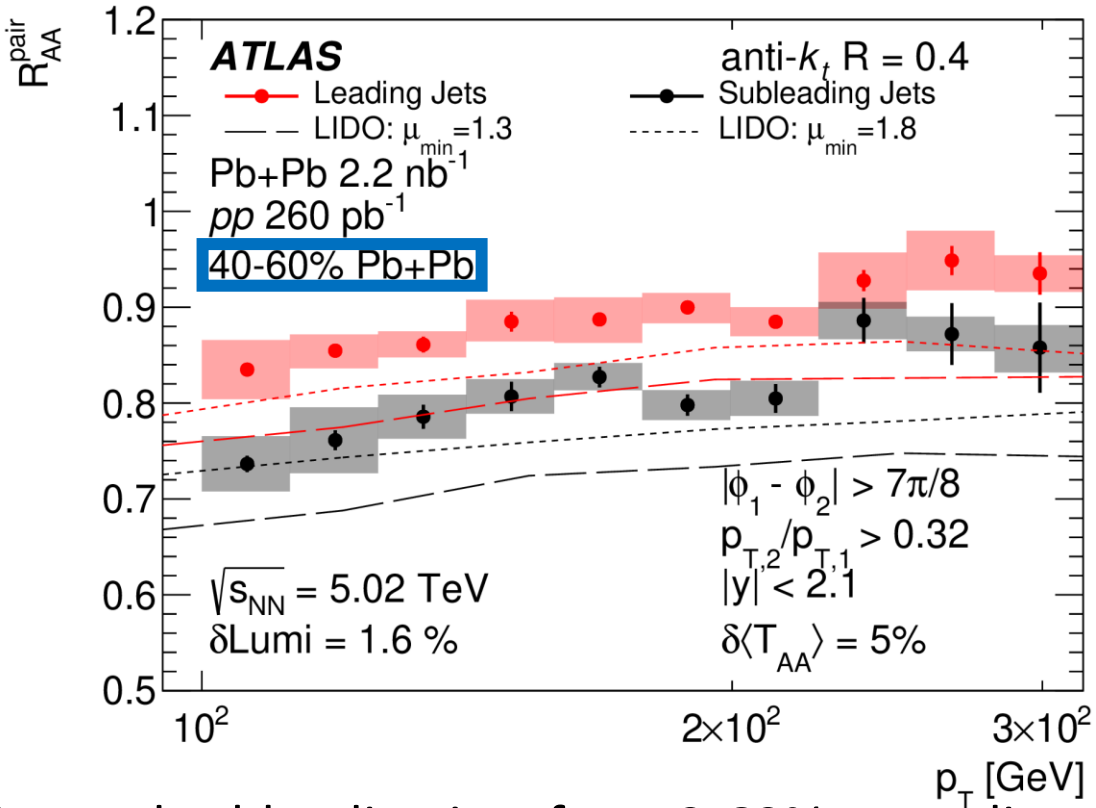
Subleading Jets



For R_{AA}^{pair} the dominant sources of systematic uncertainty stem from uncertainty on the JES

R_{AA}^{Pair} additional centrality selections



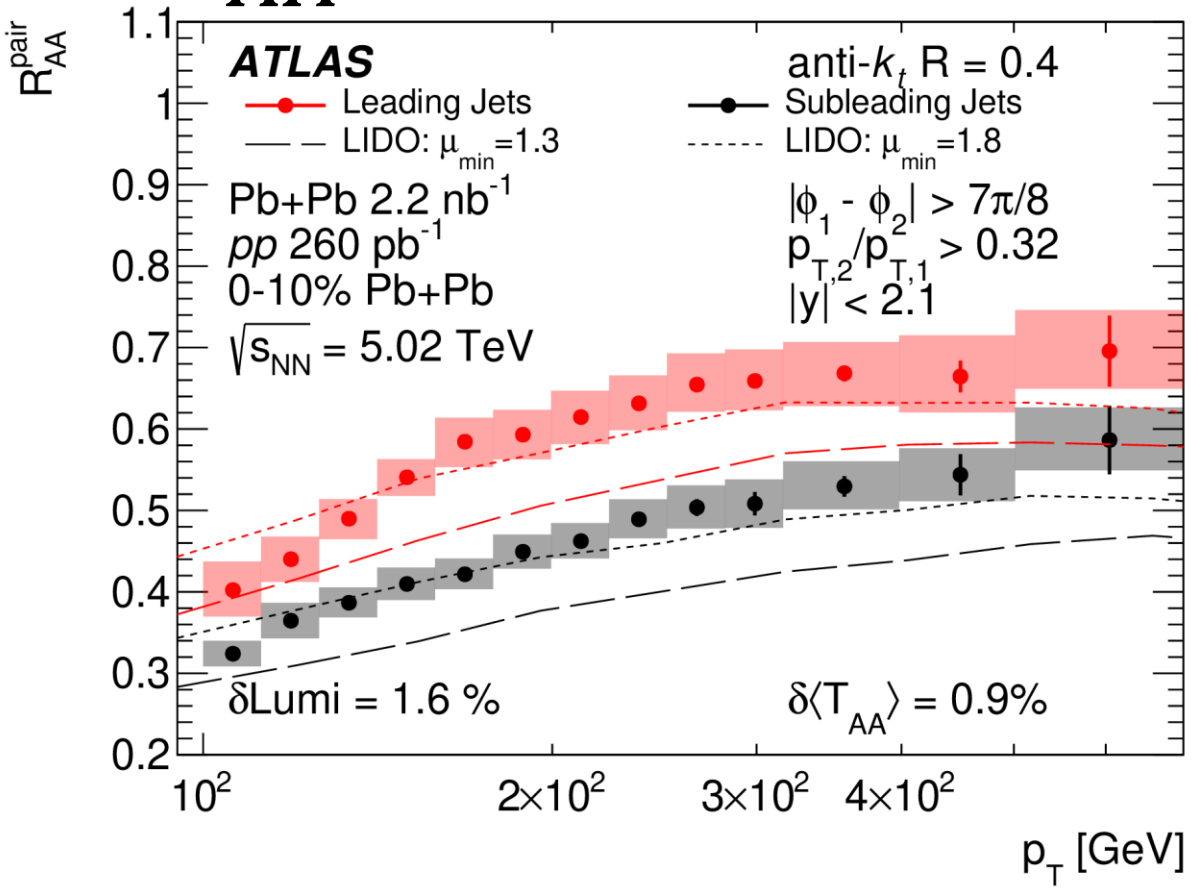


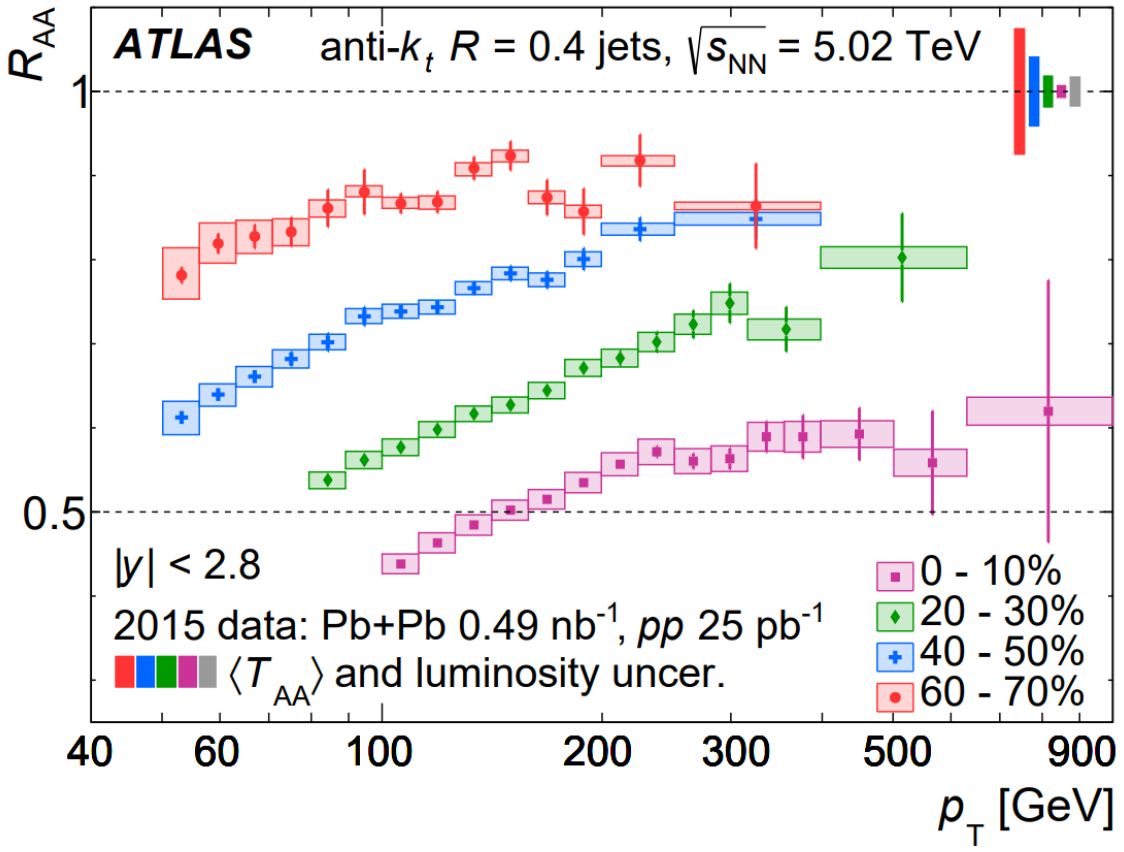
Significant suppression is observed for both leading and subleading jets from 0-60% centrality

Subleading jets are systematically suppressed relative to leading jets across all measured p_T

R_{AA}^{pair} and inclusive jets R_{AA}

https://arxiv.org/pdf/1805.05635.pdf





The inclusive jet R_{AA} above 150 GeV is bracketed by the $R_{AA}^{pair}(p_{T,1})$ and $R_{AA}^{pair}(p_{T,2})$

- Below 150 GeV the inclusive jet R_{AA} is consistent with the $R_{AA}^{pair}(p_{T,1})$