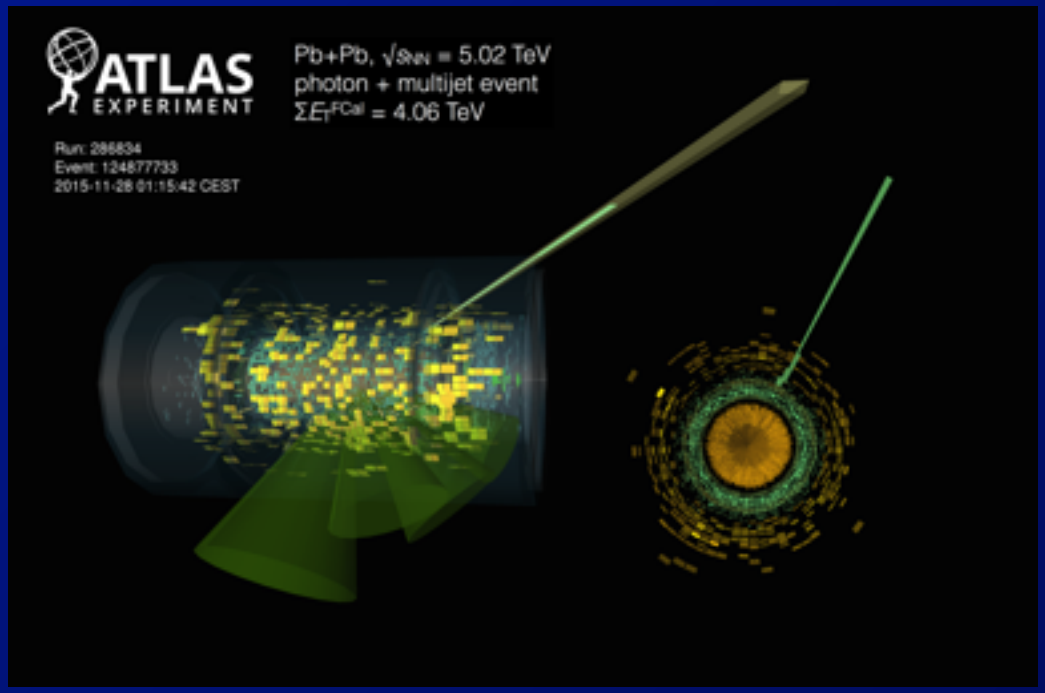
Gamma-jet correlations in 5.02 TeV Pb+Pb collisions by ATLAS

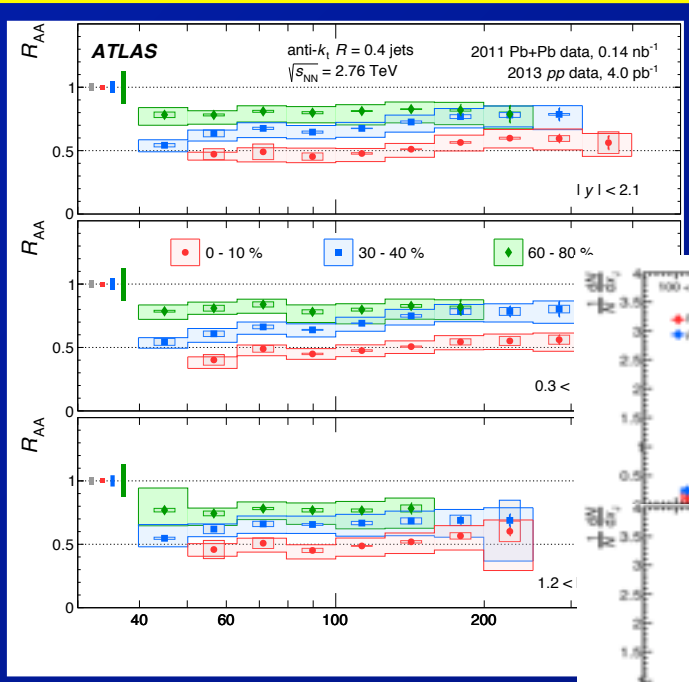
Prof. Brian A. Cole
for the ATLAS collaboration

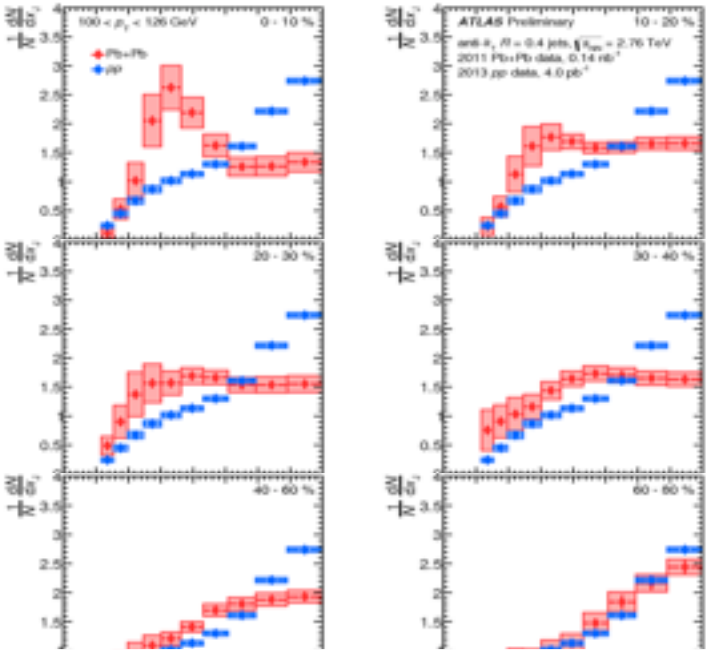
Hard Probes 2016 Conference
May 23, 2016

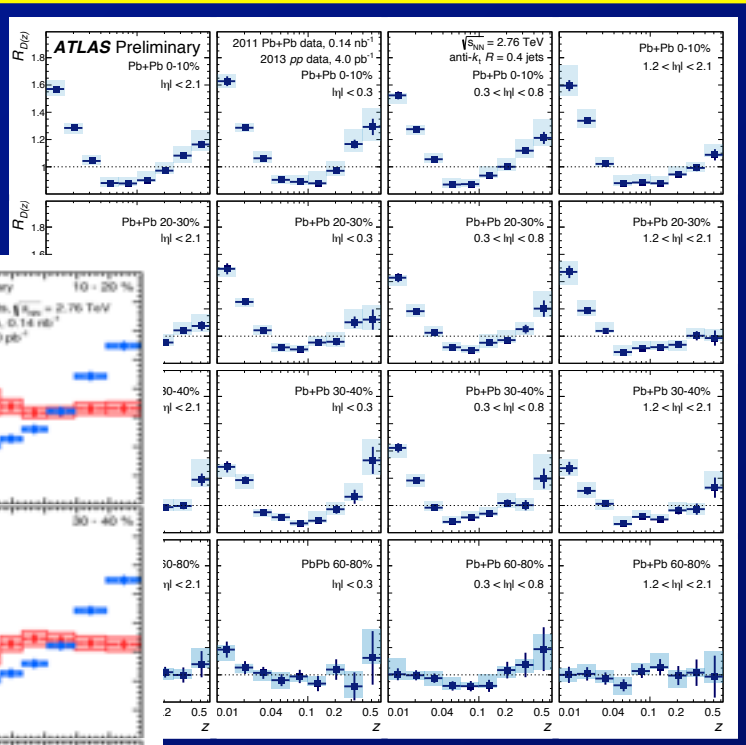


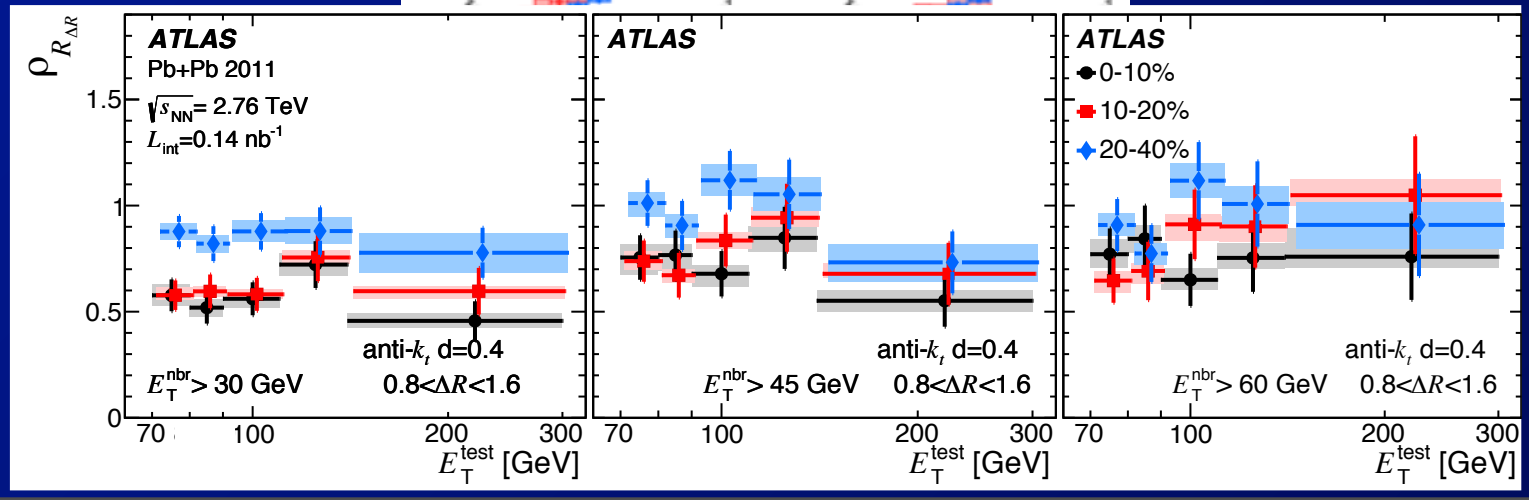
ATLAS-CONF-2016-110 (via https://twiki.cern.ch/twiki/bin/view/AtlasPublic)

ATLAS probes of jet quenching









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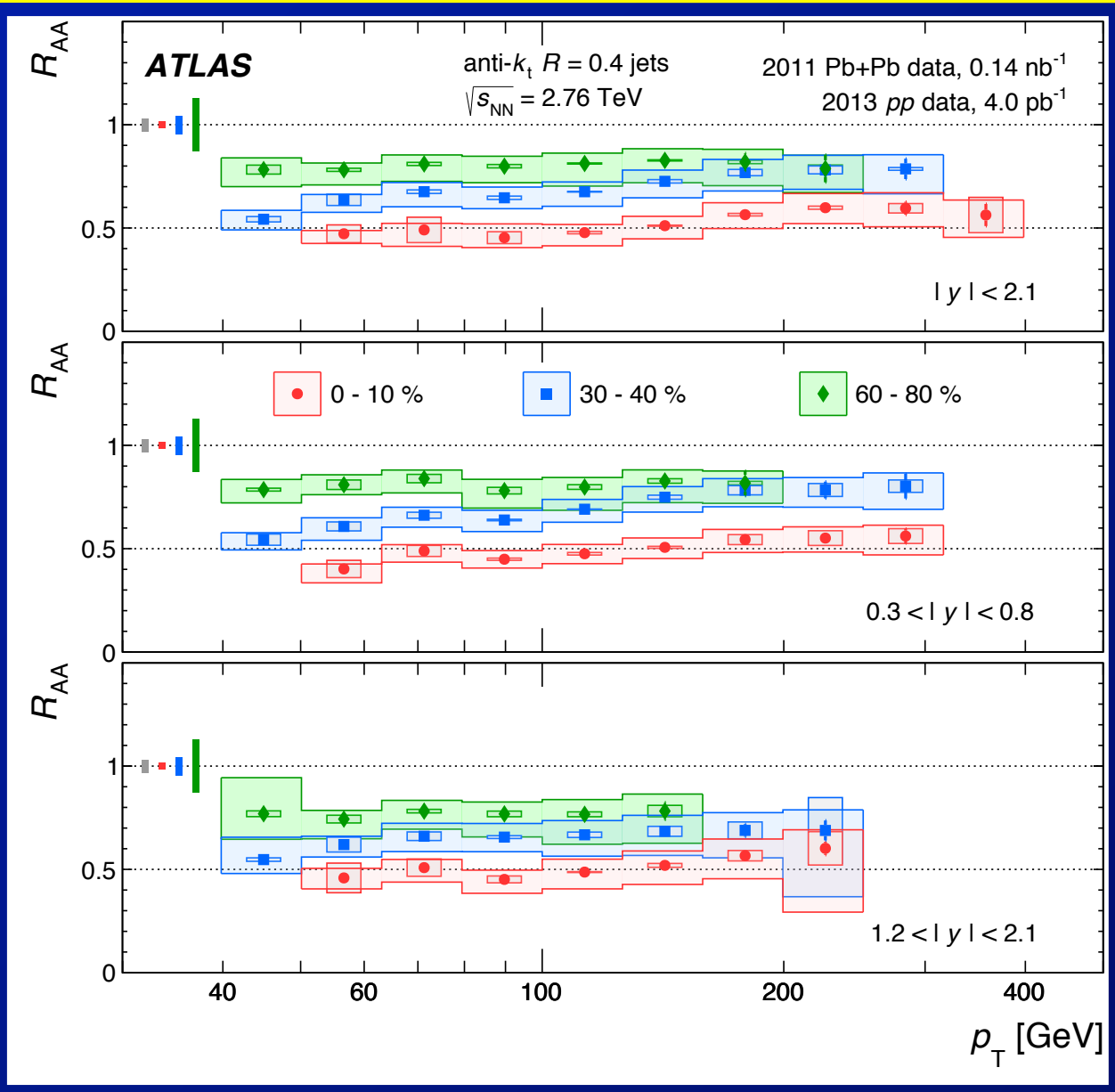
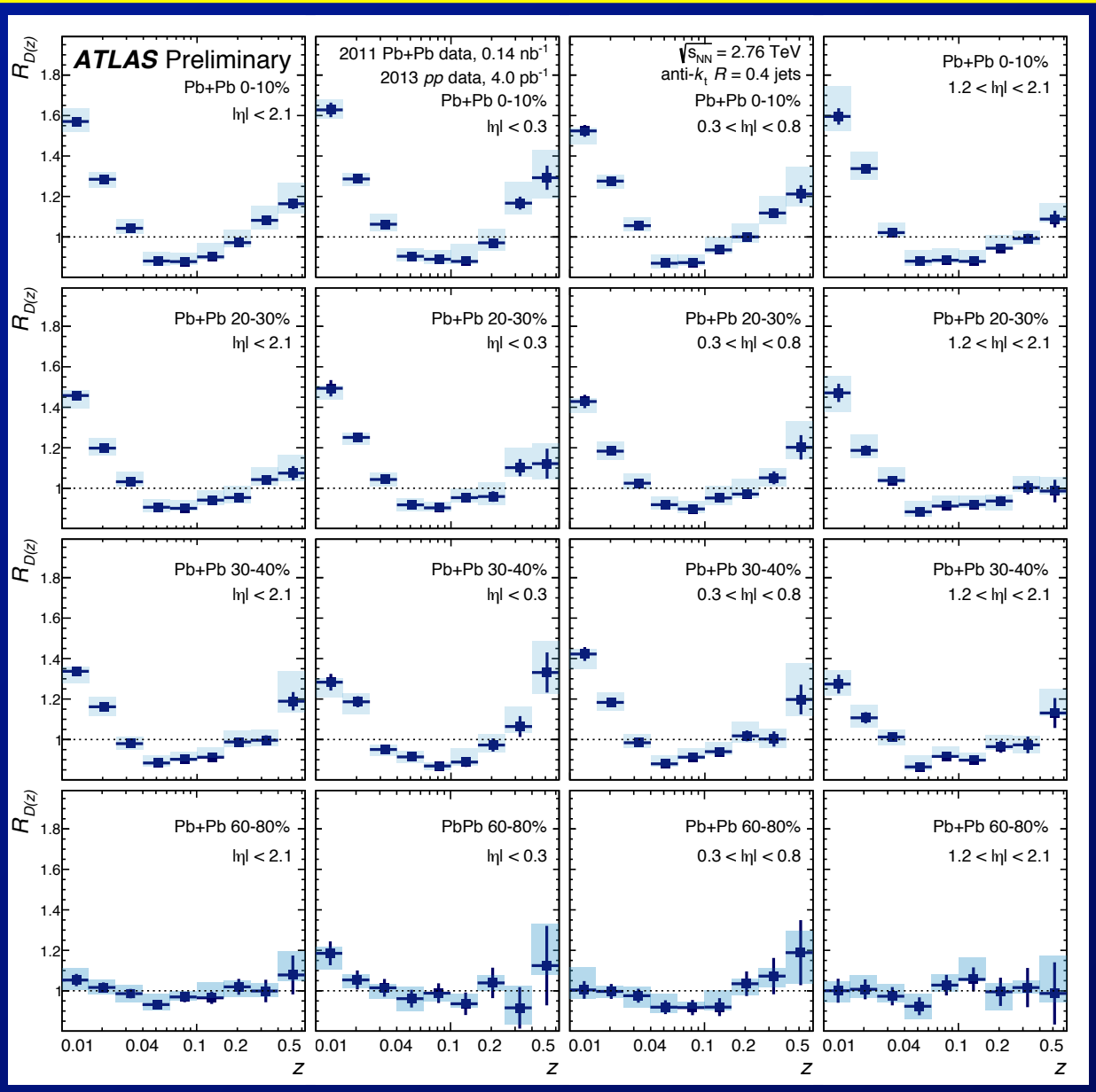


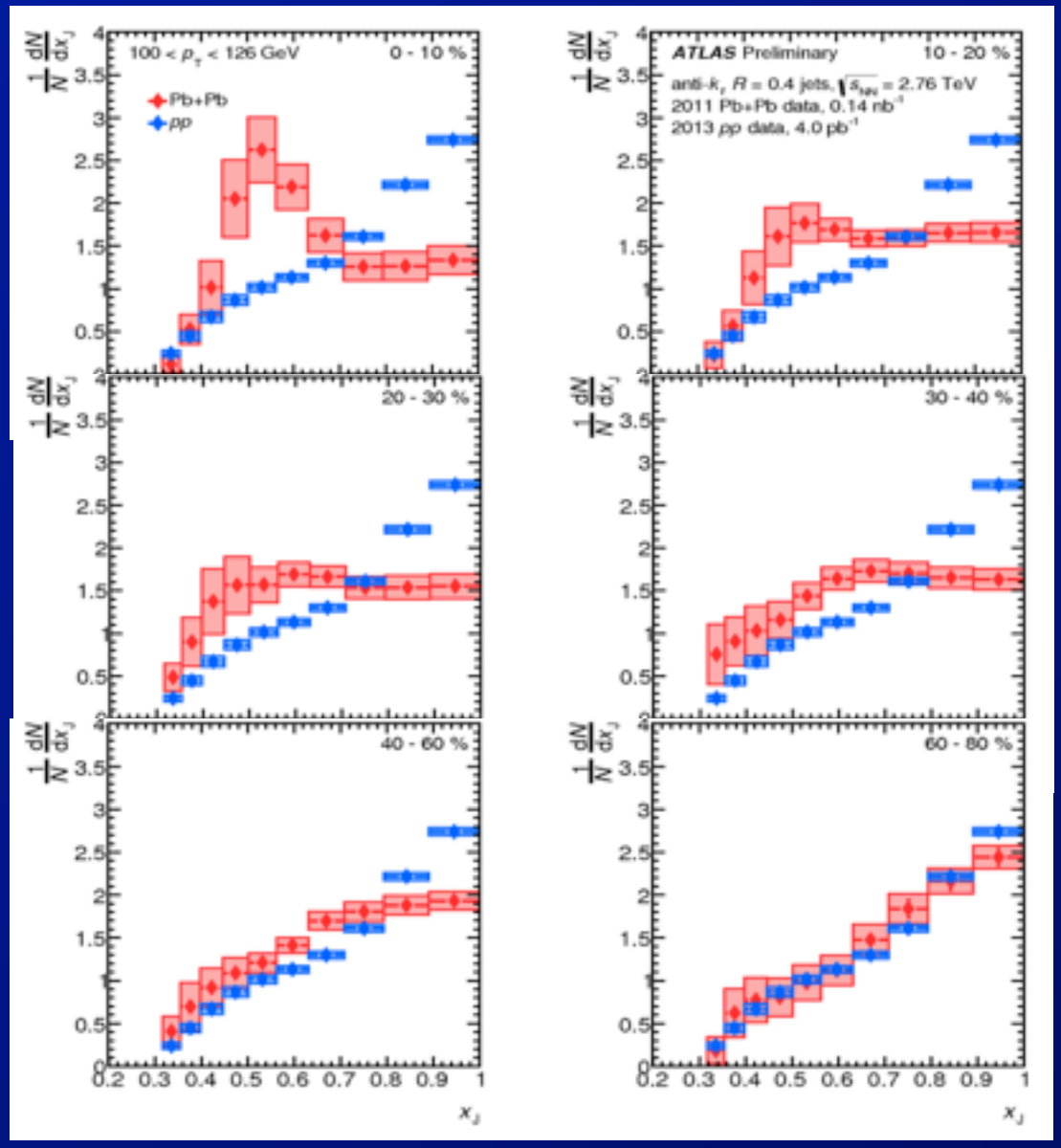
- Jet R_{AA}

ATLAS probes of jet quenching



- Modified jet fragmentation

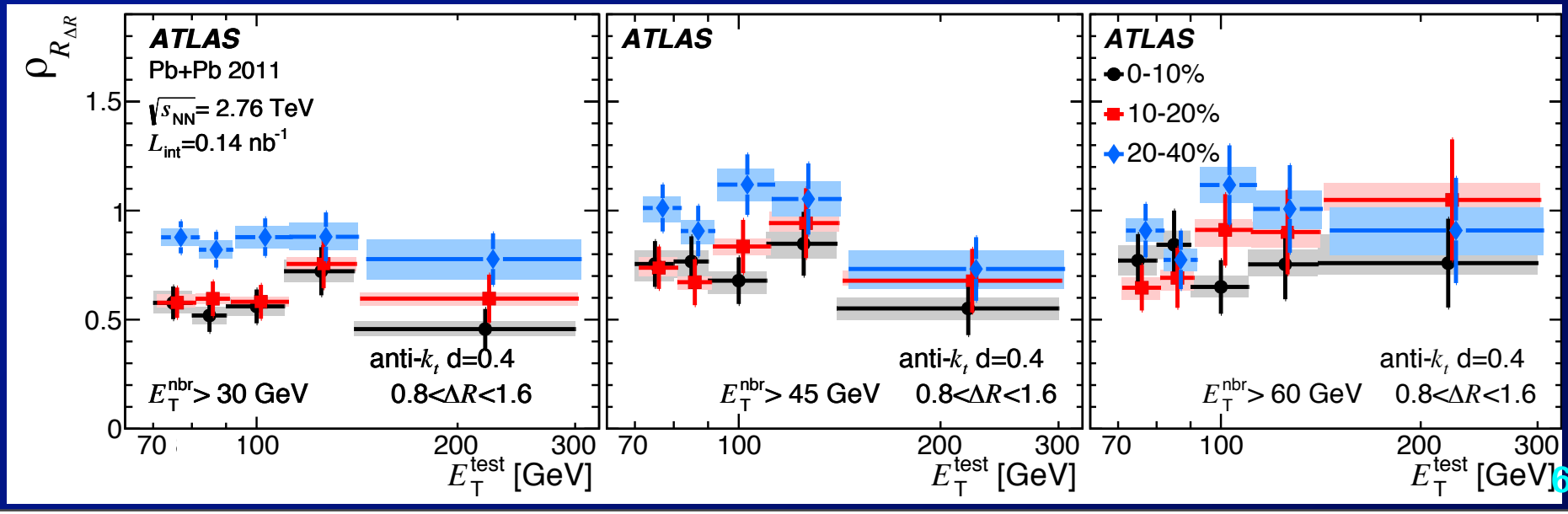
ATLAS probes of jet quenching



- Dijet asymmetry (unfolded)

ATLAS probes of jet quenching

- Small-angle jet pairs



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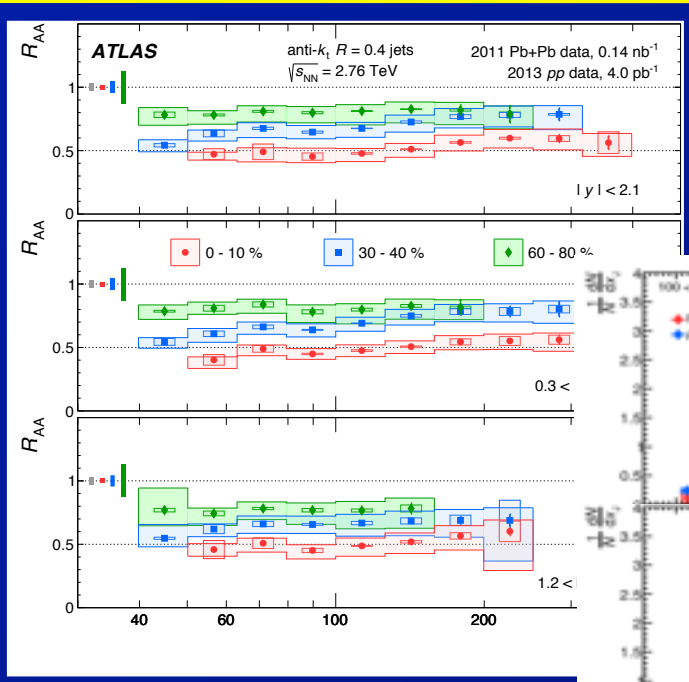
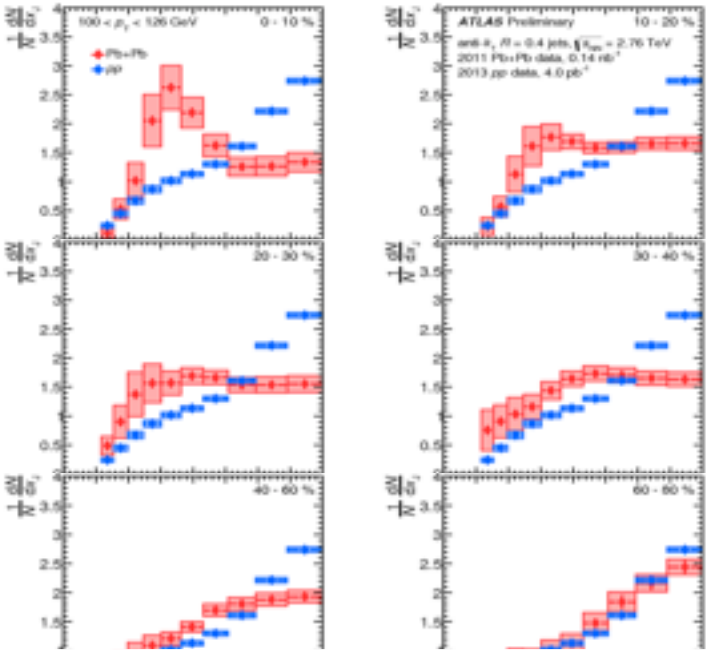
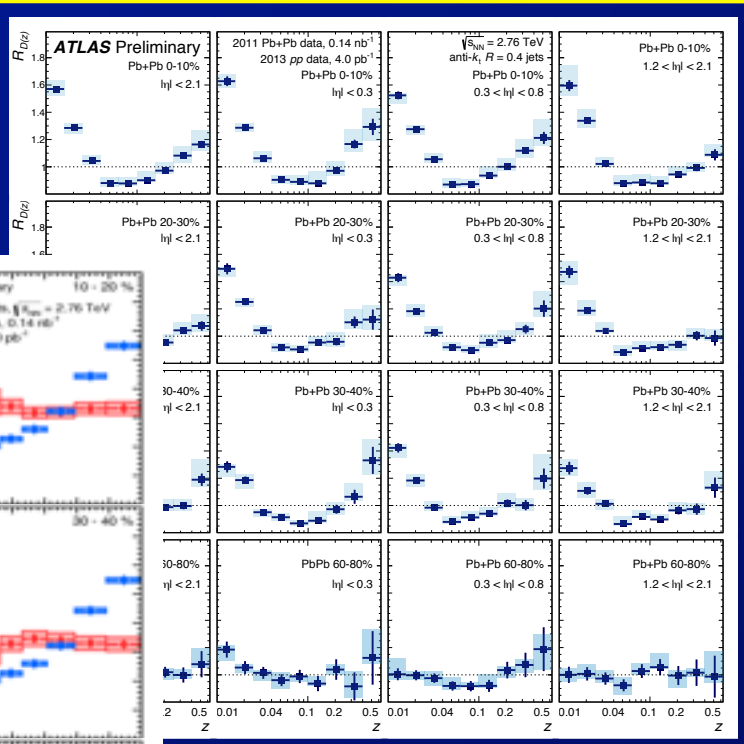
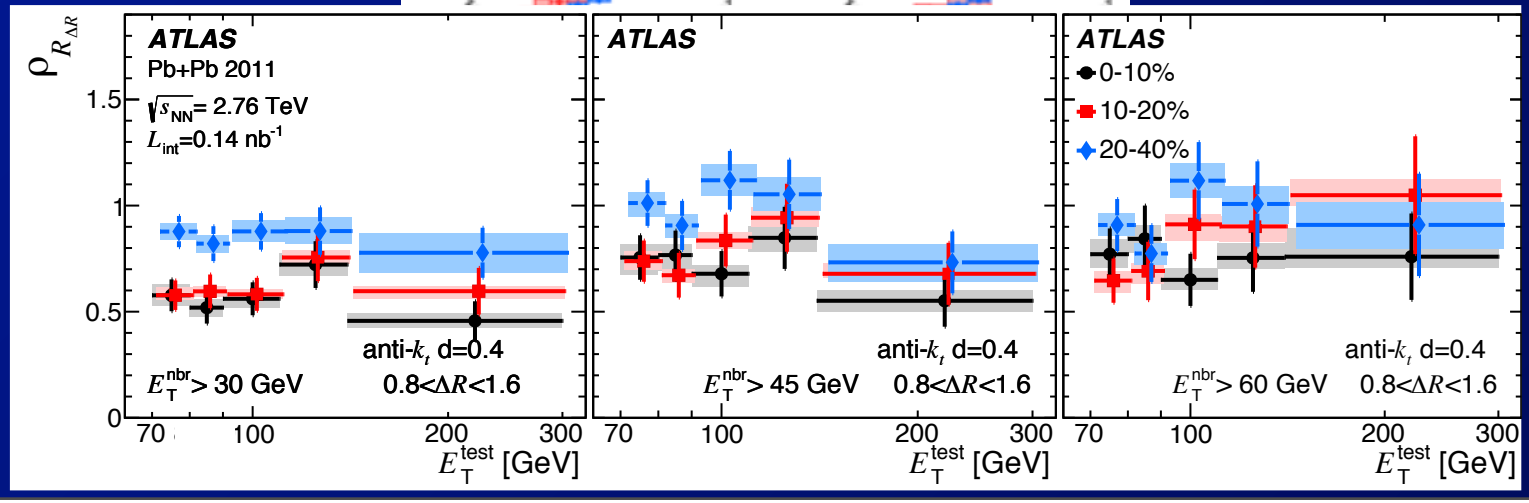
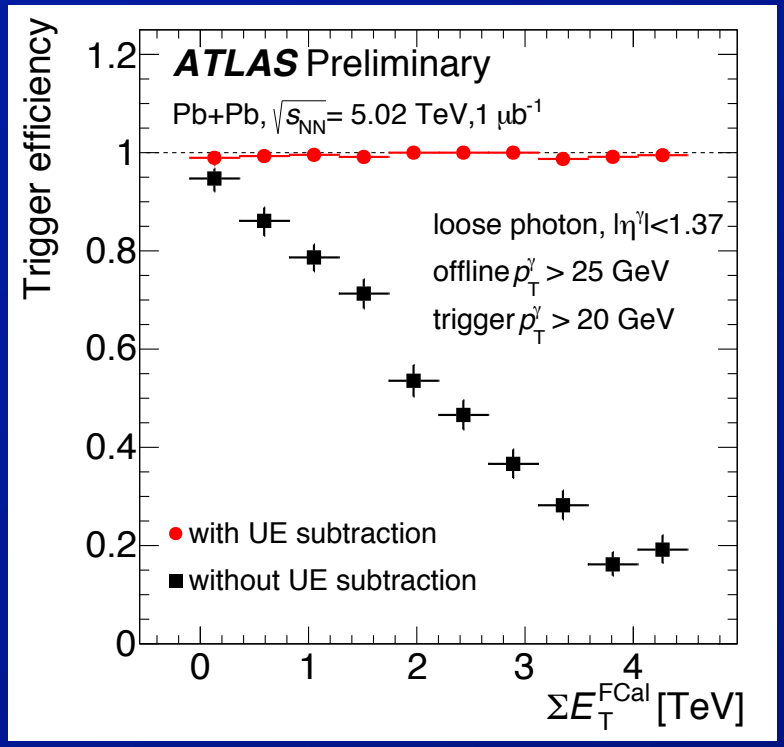


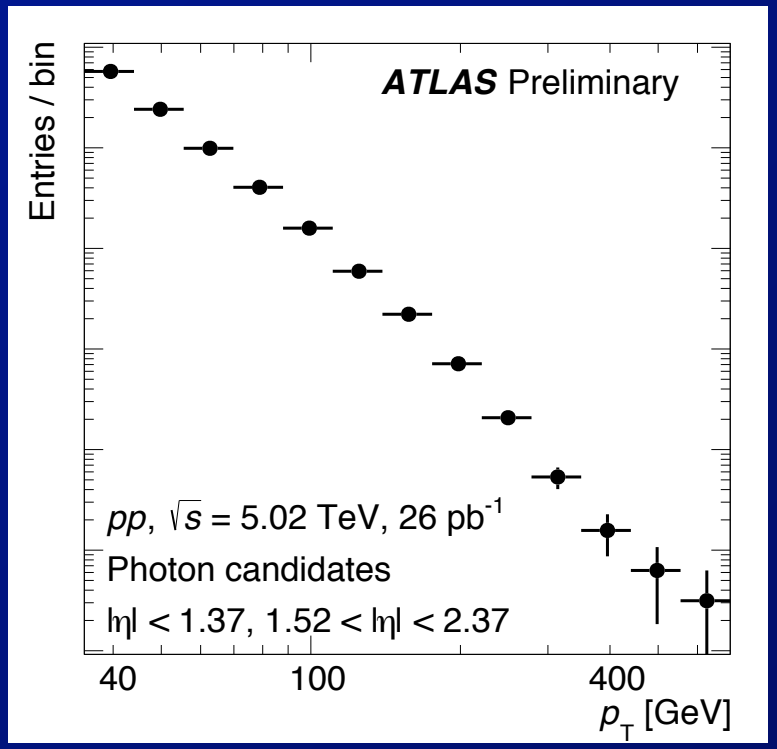






1st Run 2 Pb+Pb jet result: Gamma-Jet





- **Data collected in Nov. - Dec. 2015:**
  - $\sqrt{s_{NN}}$ = 5.02 TeV Pb+Pb, $\int \mathcal{L}dt$ = 0.52 nb^{-1}
  - $\sqrt{s}$ = 5.02 TeV pp, $\int \mathcal{L}dt$ = 26 pb^{-1}
- **Using photon triggers that sampled full luminosity**

  ⇒38 k photons with 60 < p_T < 150 in pp data

  ⇒29 k " " in Pb+Pb, 0-50%

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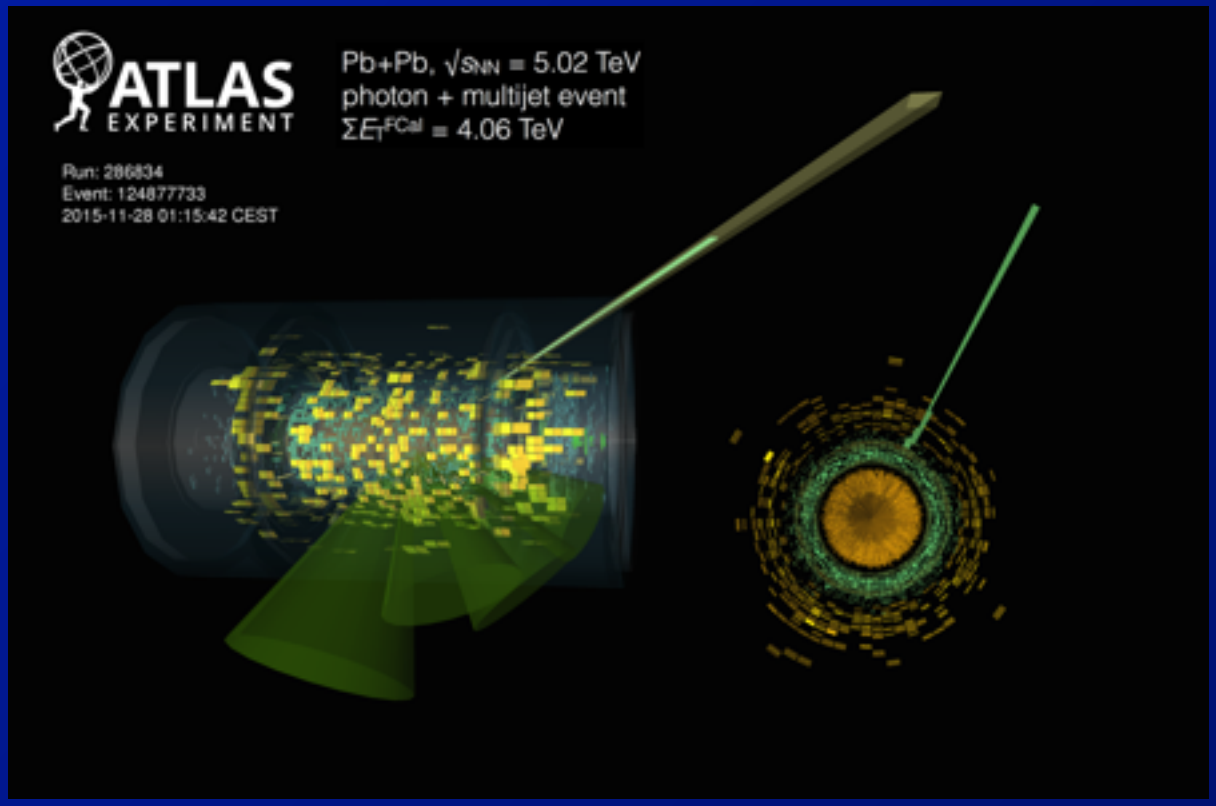

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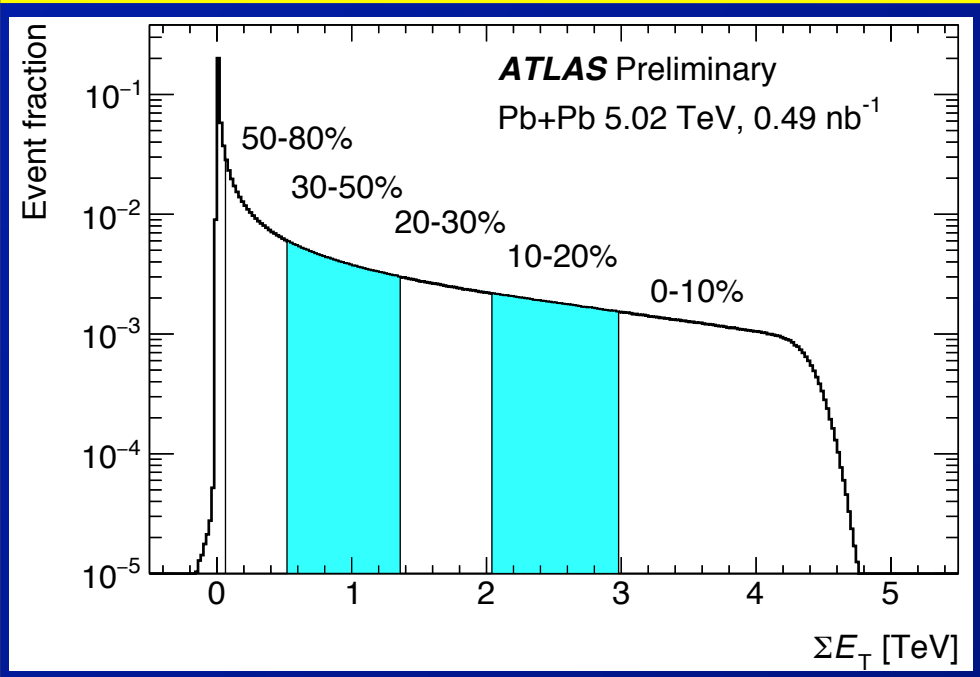
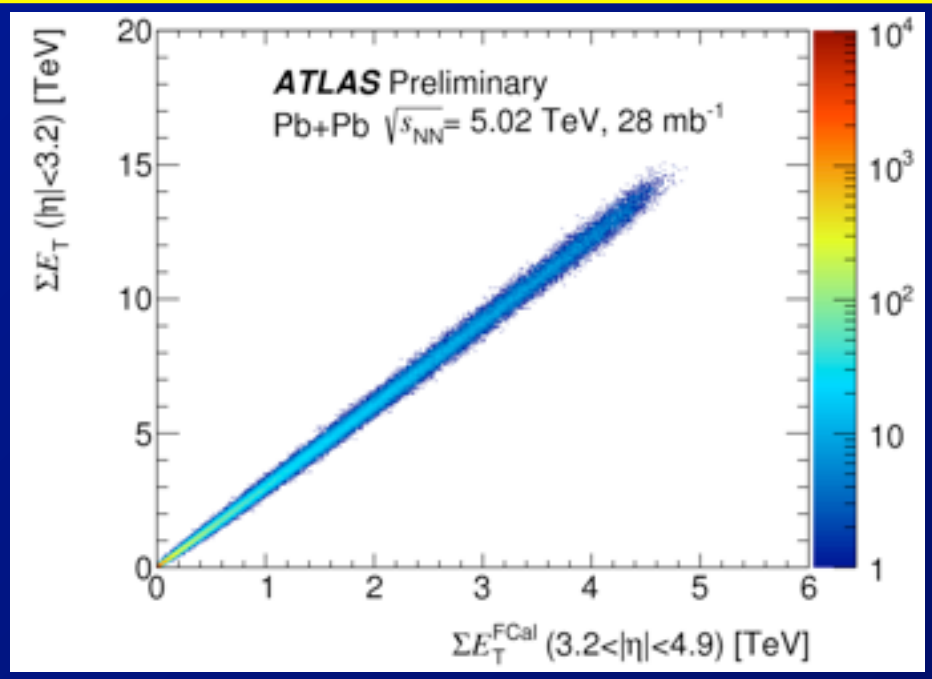
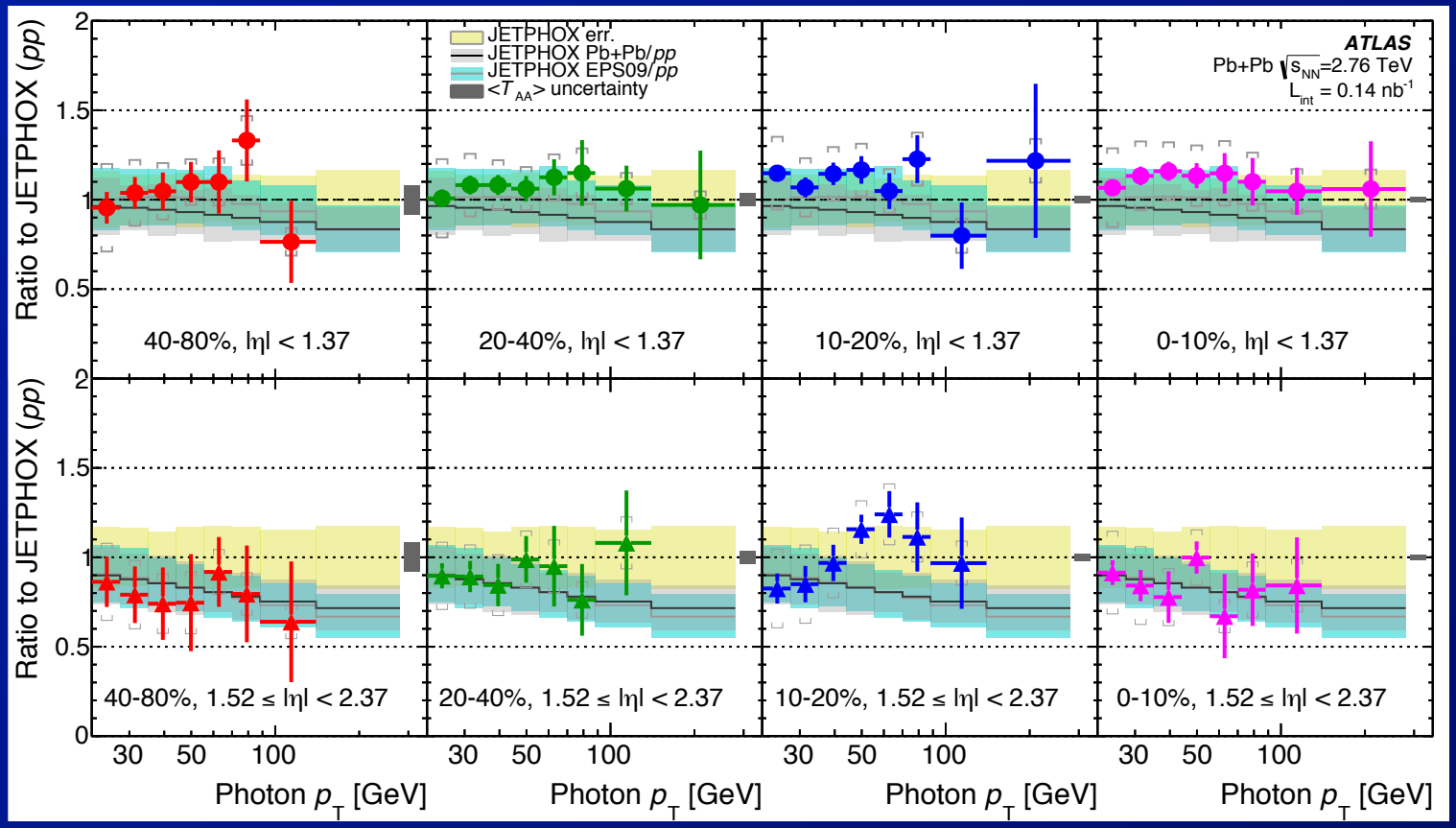
ATLAS 5.02 TeV Pb+Pb Data





- Usual centrality analysis using two-component model, but applied over 0-85% centrality range
  - ⇒Avoids complications with photo-nuclear, electromagnetic backgrounds in peripheral Pb+Pb
- For this analysis:
  - ⇒0-10%, 10-20%, 20-30%, 30-50% intervals

Prompt photons in 2.76 TeV Pb+Pb



- **ATLAS measurement of prompt, isolated photon production in 2.76 TeV Pb+Pb collisions**
  - compared to JETPHOX with & without isospin, EPS09
  - ⇒Good agreement when isospin included in Jetphox
  - ⇒Similar methods, systematics for Run 2 photon analysis

Photon identification

- Candidate photons obtained from clusters in EM calorimeter with shower shape cuts applied

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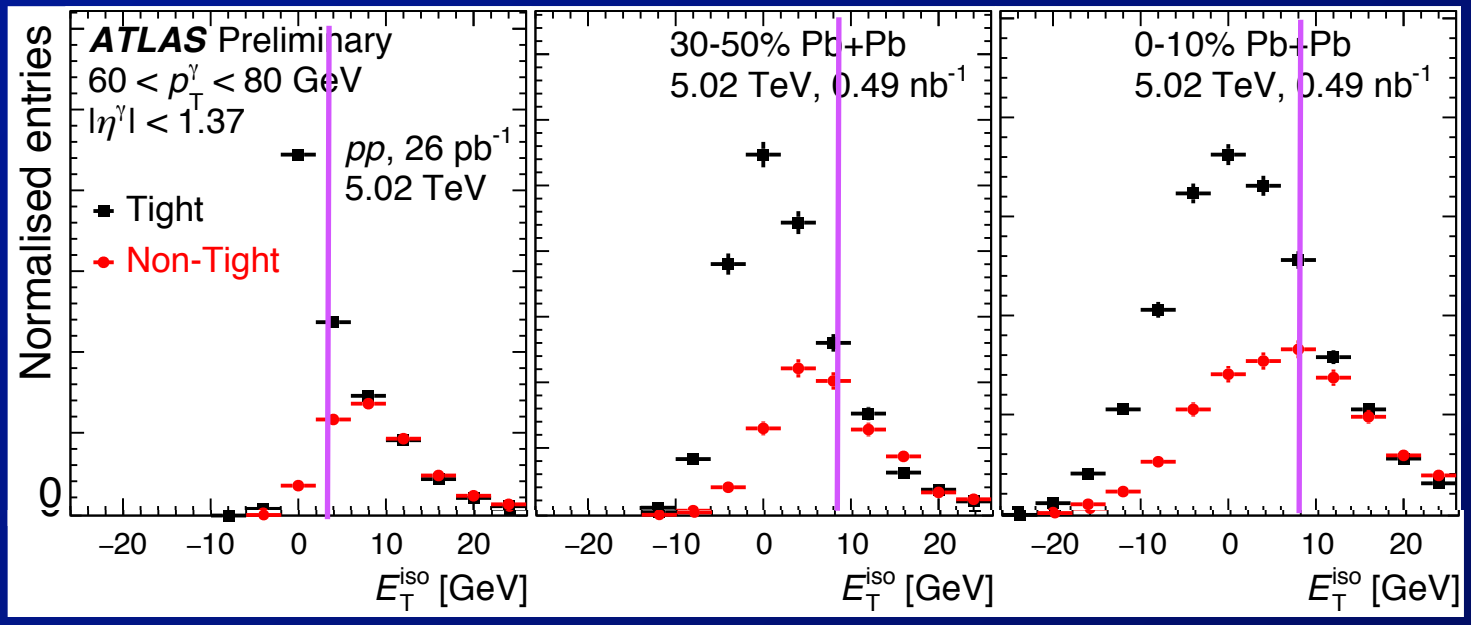
⇒Compare isolation distributions for clusters that pass "tight" and "non-tight" selections



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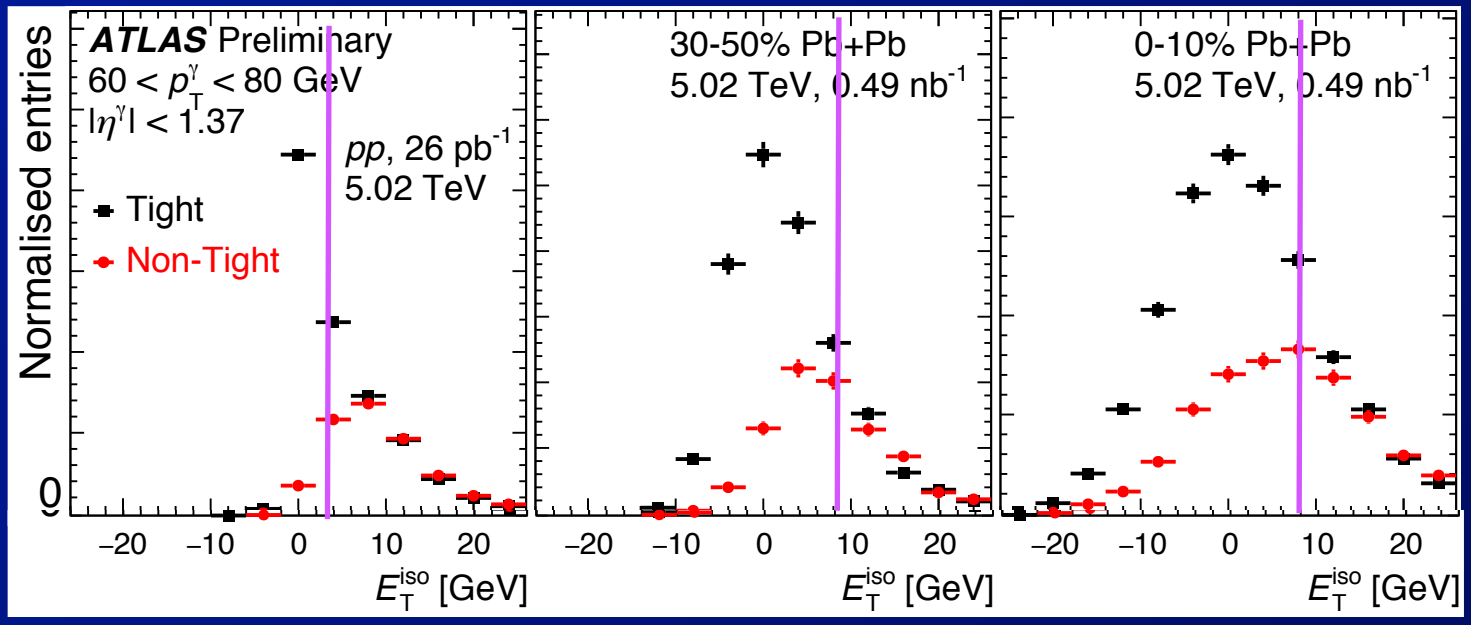


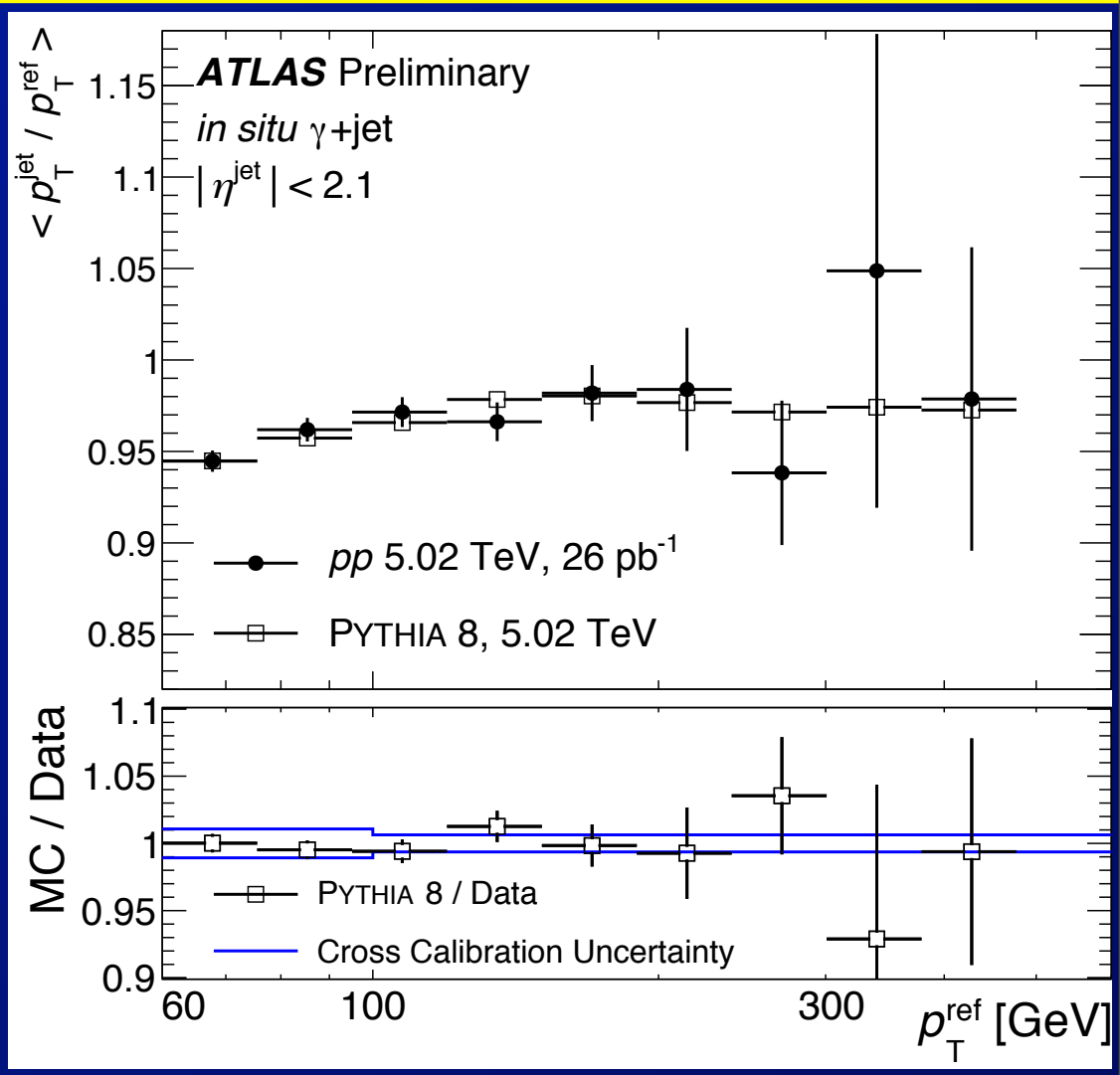
- Photon purity (data driven) >~ 70% in Pb+Pb data

⇒ subtracted using sideband method (below)

Gamma-Jet jet energy scale

- Heavy ion jet reconstruction energy scale:
  - Calibrated using 5.02 TeV pp MC

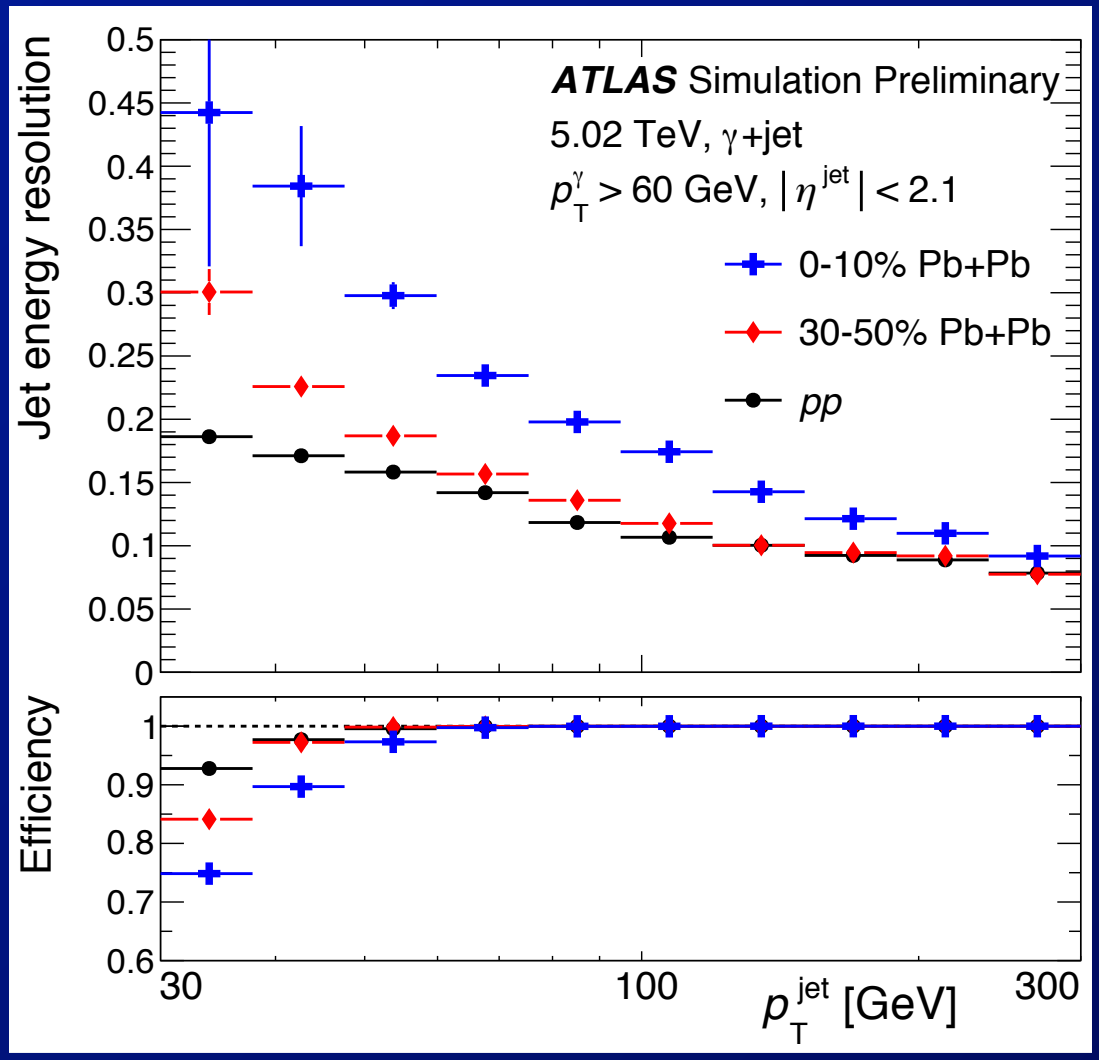
  ⇒POWHEG
- Apply 13 TeV pp "in-situ" correction
  - Corrects for data-MC differences
- Apply 5.02 - 13 TeV "cross-calibration"
  - transfer jet energy scale systematic uncertainties
- Test in 5.02 TeV pp data using gamma-jet events



Gamma-jet Jet performance

- MC: PYTHIA8 + data overlay evaluation of jet performance in γ-jet events
  - Jet energy resolution ↑ due to underlying event fluctuations
  - Jet efficiency ↓ due to increased JER

⇒ ~ entirely due to jets falling below minimum p_T cut



- Jets in gamma-jet events have p_T corrected for flavor-dependent JES offset (previous slide)

The measurement

- Measure γ-jet pT balance: $x_j \equiv p_{\mathrm{T}}^{\mathrm{jet}} / p_{\mathrm{T}}^{\gamma}$
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  - ⇒ 60–80 GeV, 80–100 GeV, 100–150 GeV
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- Using R = 0.4 anti-k_T jets
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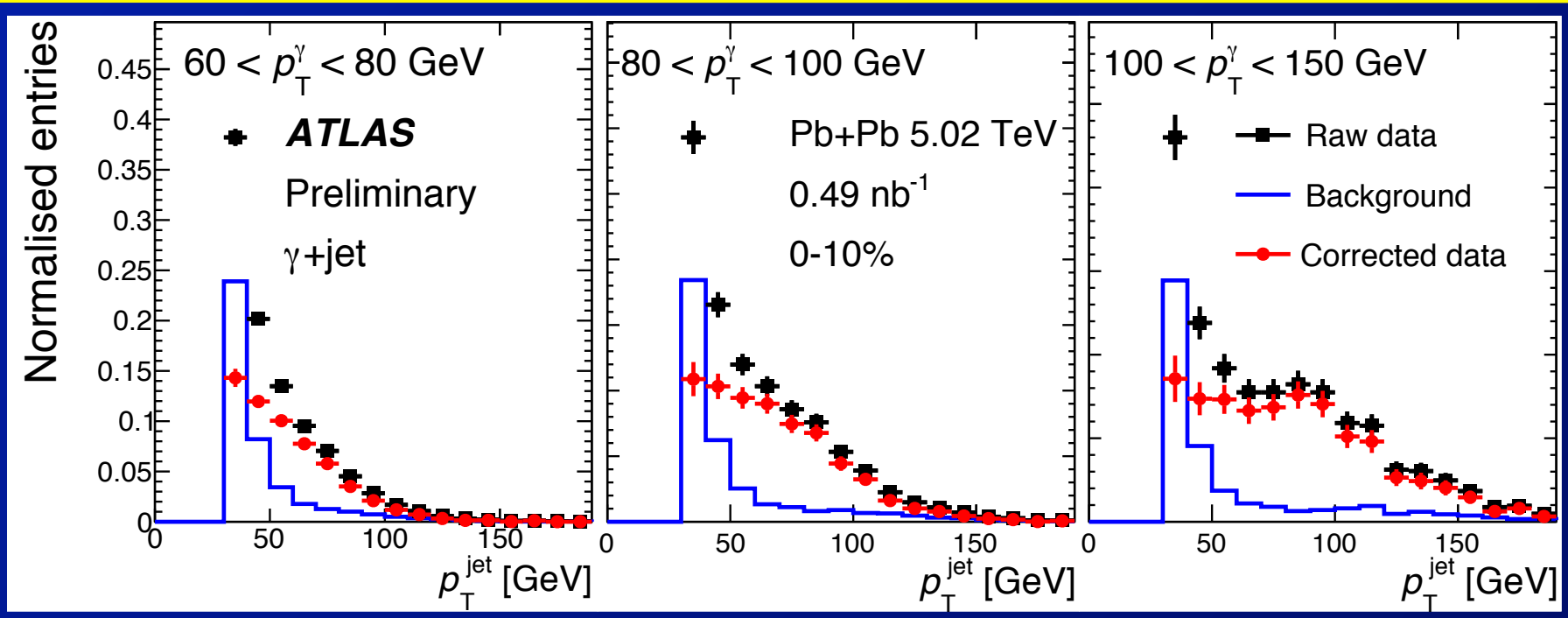
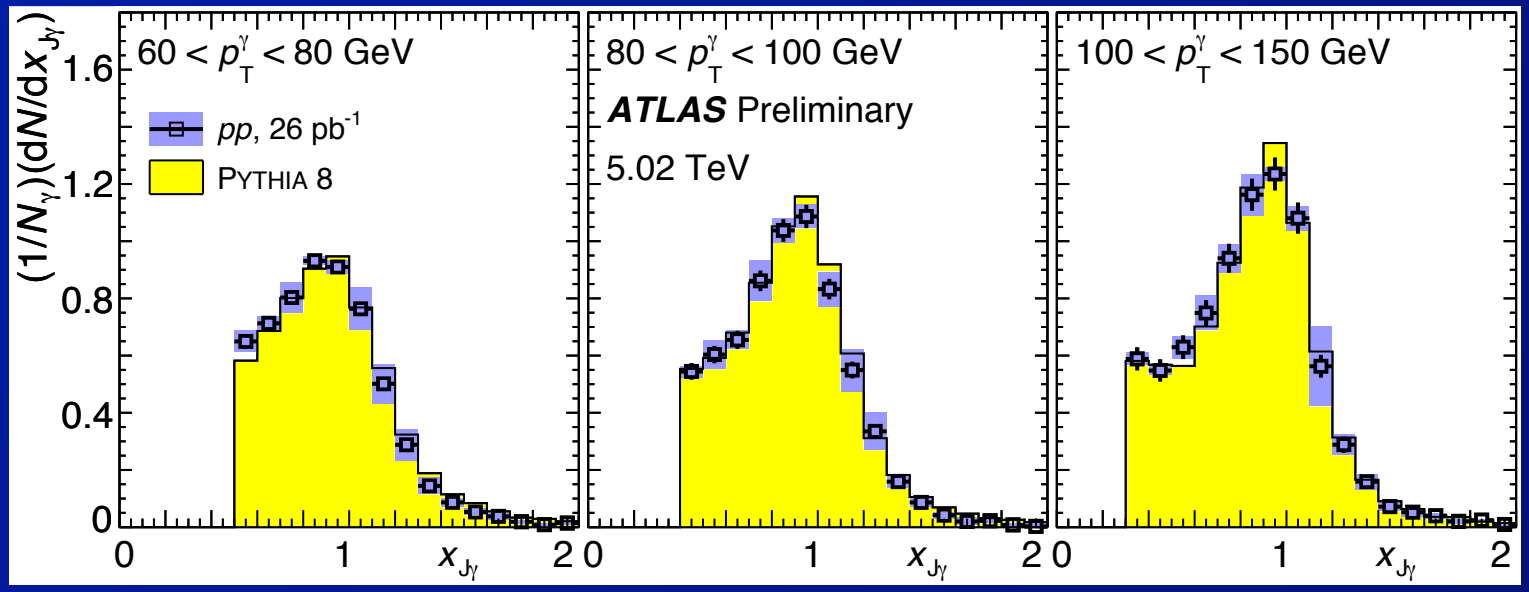
  - ⇒ $p_T^{jet} > 30$ GeV, $|\eta_{jet}| < 2.1$
- Inclusive measurement with Δφ selection
  - include all jets in γ-jet events
  - ⇒ straightforward combinatoric subtraction
  - For x_j measurement, require $\Delta\varphi > 7\pi/8$

Combinatoric subtraction



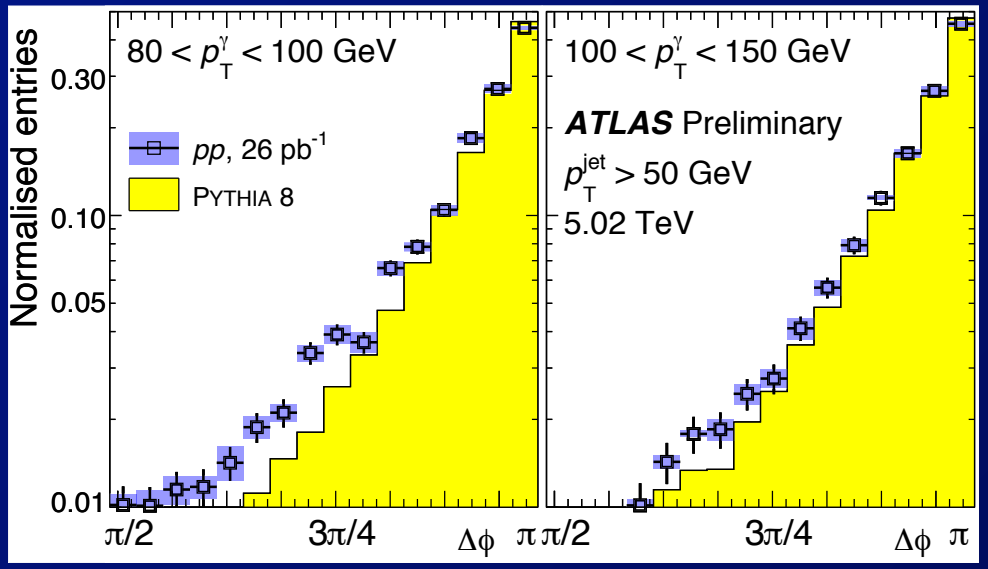
- **Multiple hard scattering + UE fluctuations produce jets uncorrelated with γ-jet hard scattering**
  - **Measure combinatoric rate using MC data overlay**
    - ⇒ **The underlying events are minimum-bias Pb+Pb**
  - **Subtract differentially in Δφ, p_T^{jet}**
- **Also subtract background pairs via photon sideband**
  - ⇒**Shown above: yield for Δφ > 7π/8**

Gamma-Jet in 5.02 TeV pp collisions



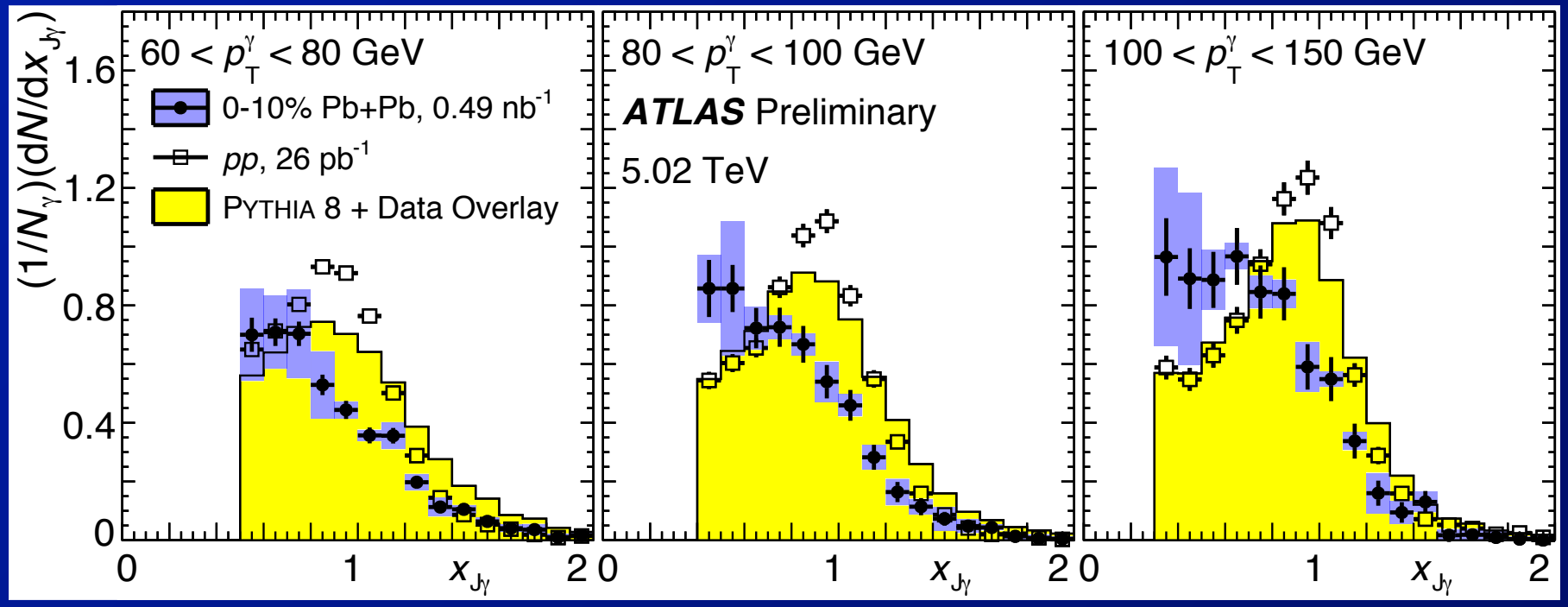
$\Delta\varphi > 7\pi/8$

- Comparing data (measured) to PYTHIA8 + GEANT (reconstructed)
  - ⇒Top: $1/N_\gamma\, dN/dx_j$
  - ⇒Bottom: $1/N_{pair}\, dN/d\,\Delta\varphi$



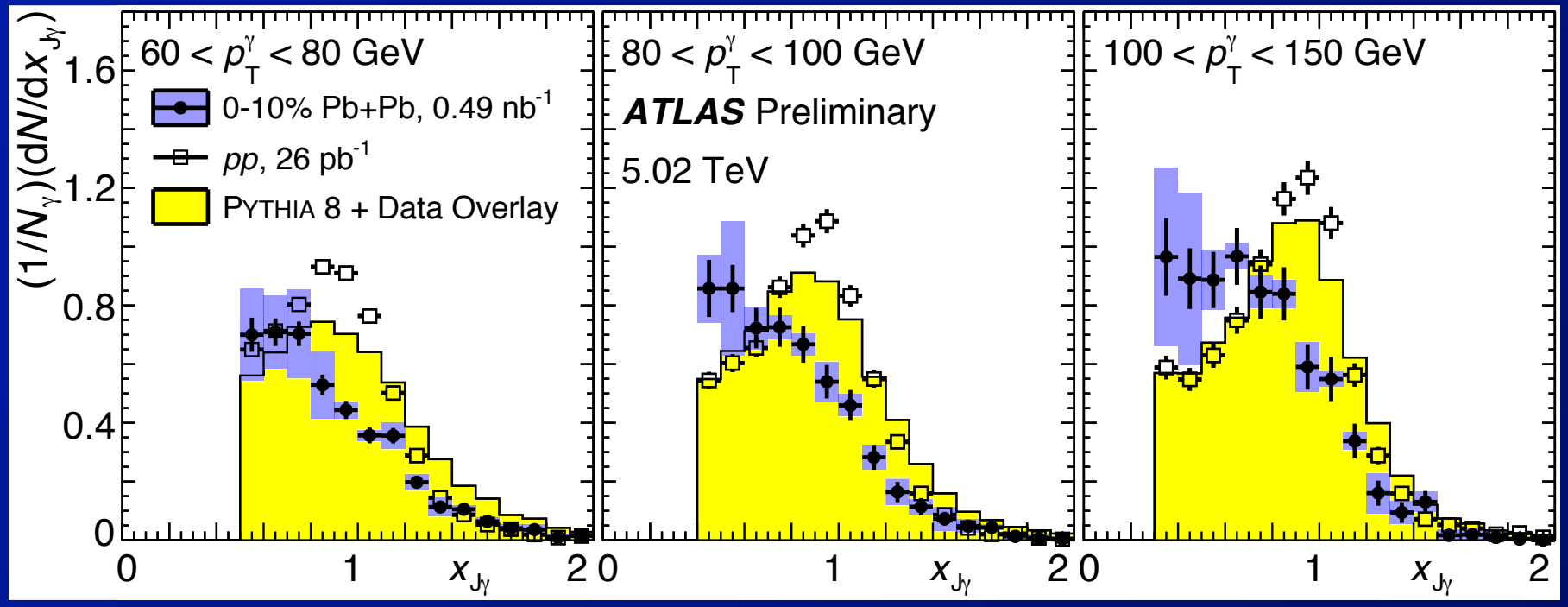
- Important: PYTHIA8 sample does not include frag. photon contribution

Gamma-Jet in 5.02 TeV Pb+Pb collisions



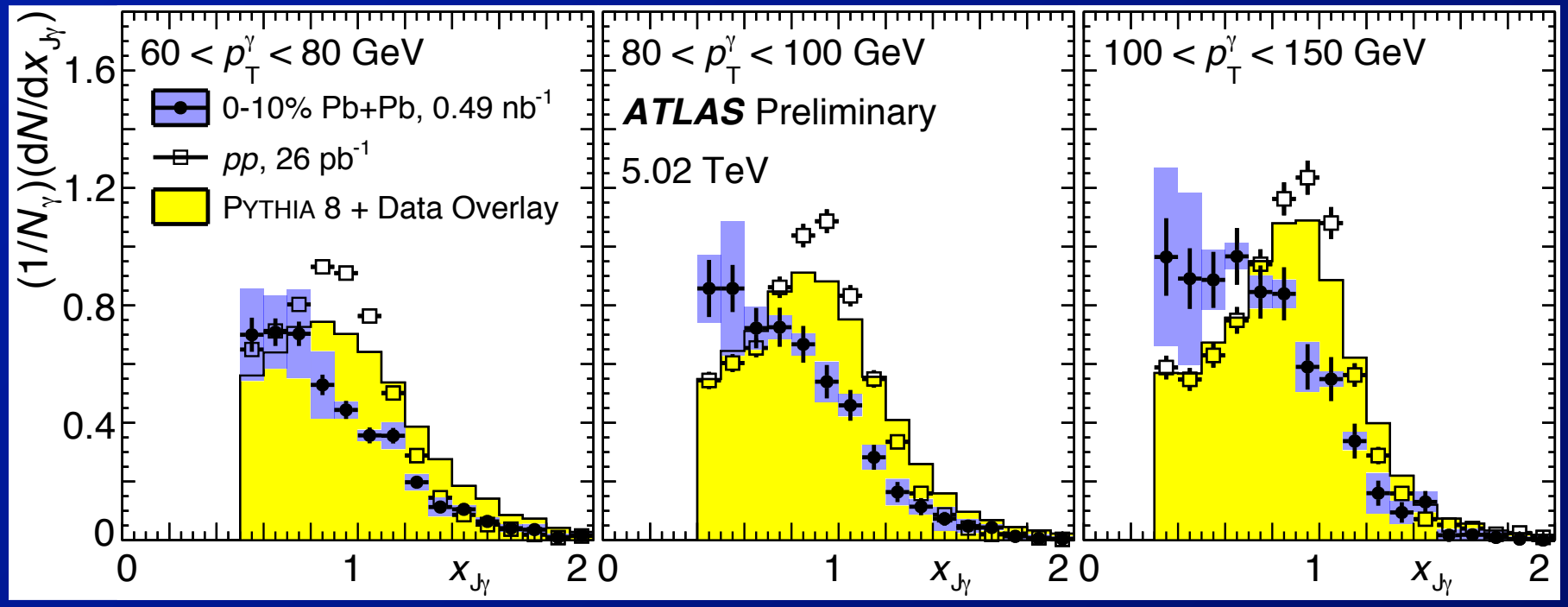
- **Start with 0-10% centrality bin:**
  - solid points in the figure
  - systematic uncertainties from:
    - ⇒Jet energy scale uncertainties (pp & Pb+Pb)
    - ⇒Jet energy resolution uncertainties
    - ⇒photon purity, combinatoric subtraction

Gamma-Jet in 5.02 TeV Pb+Pb collisions



- **Start with 0-10% centrality bin:**
  - Compare measured, background-subtracted $1/N\gamma\ dN/dx_j$ for inclusive pairs with $\Delta\varphi > 7\pi/8$.
  - to PYTHIA8+GEANT + Pb+Pb data overlay

Gamma-Jet in 5.02 TeV Pb+Pb collisions



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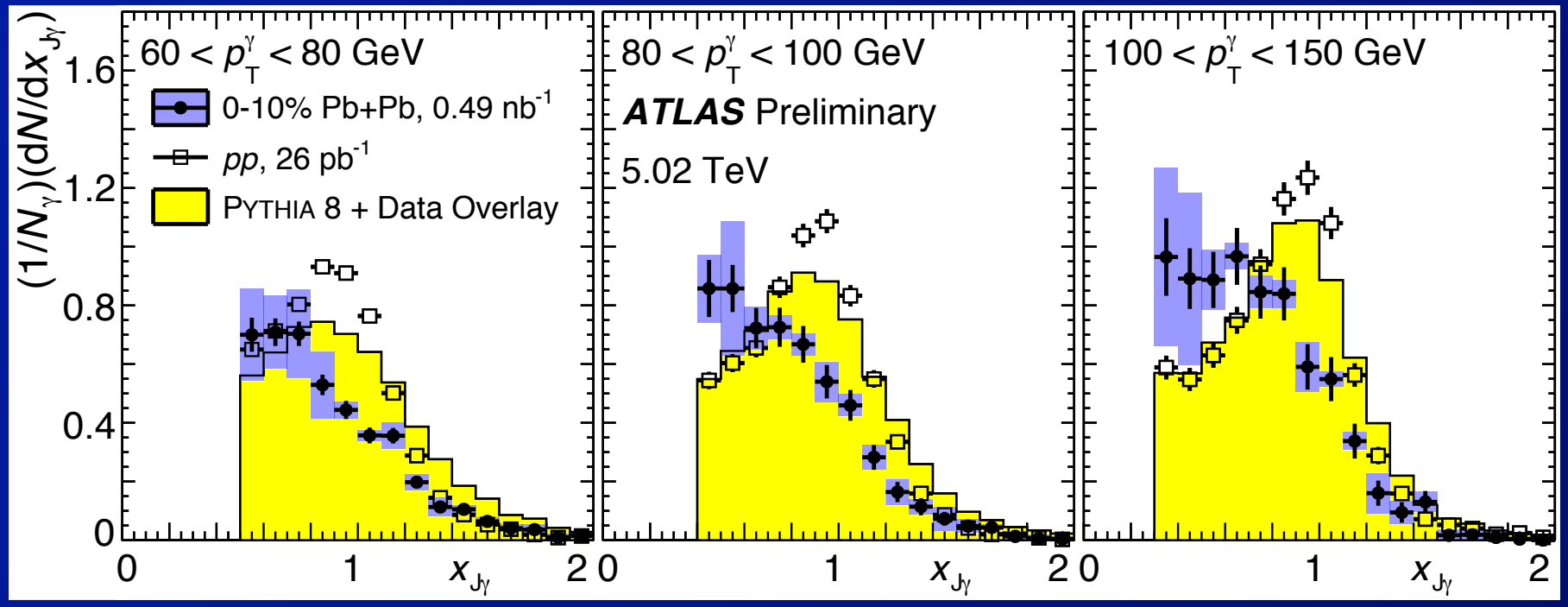

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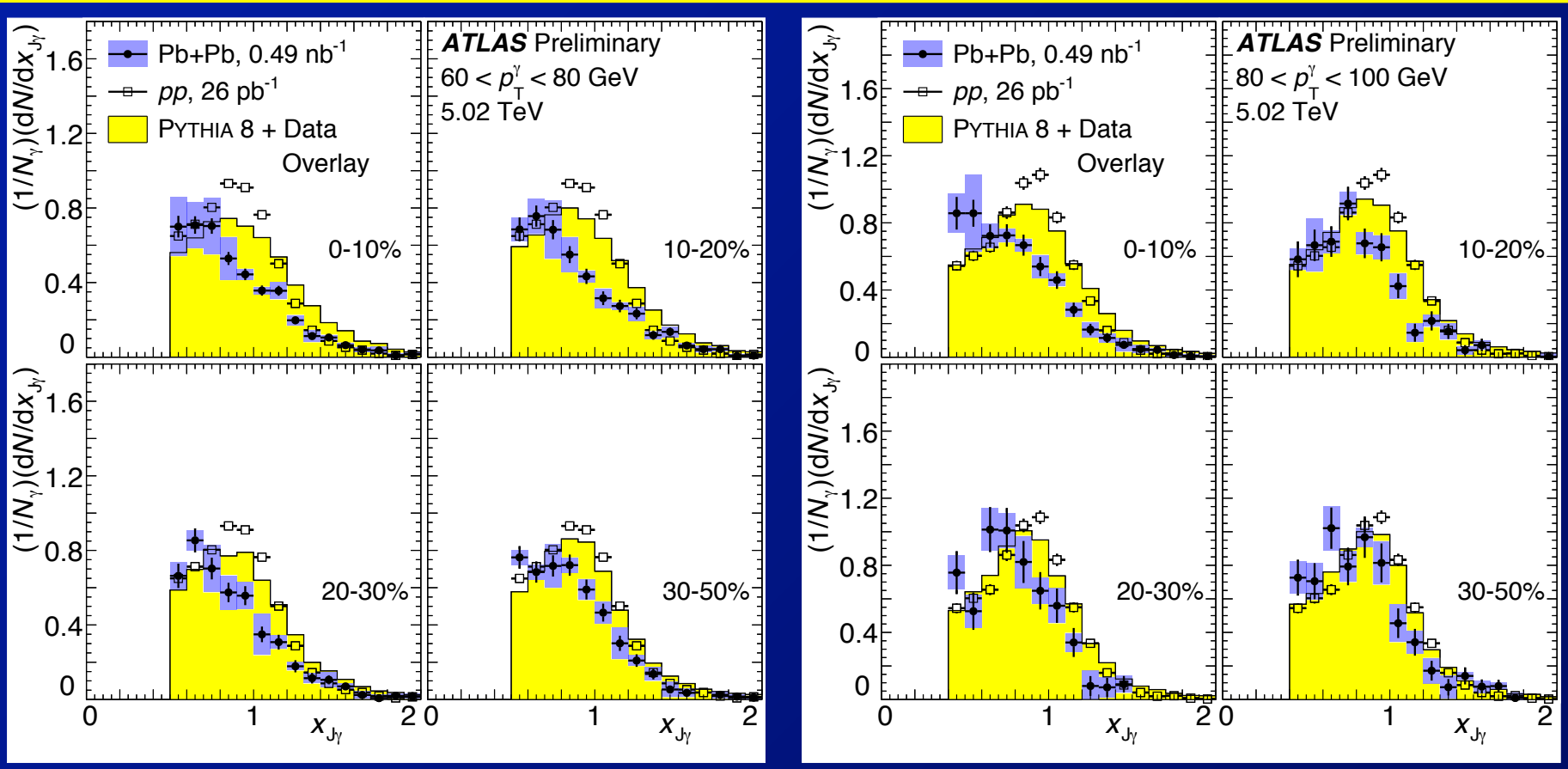
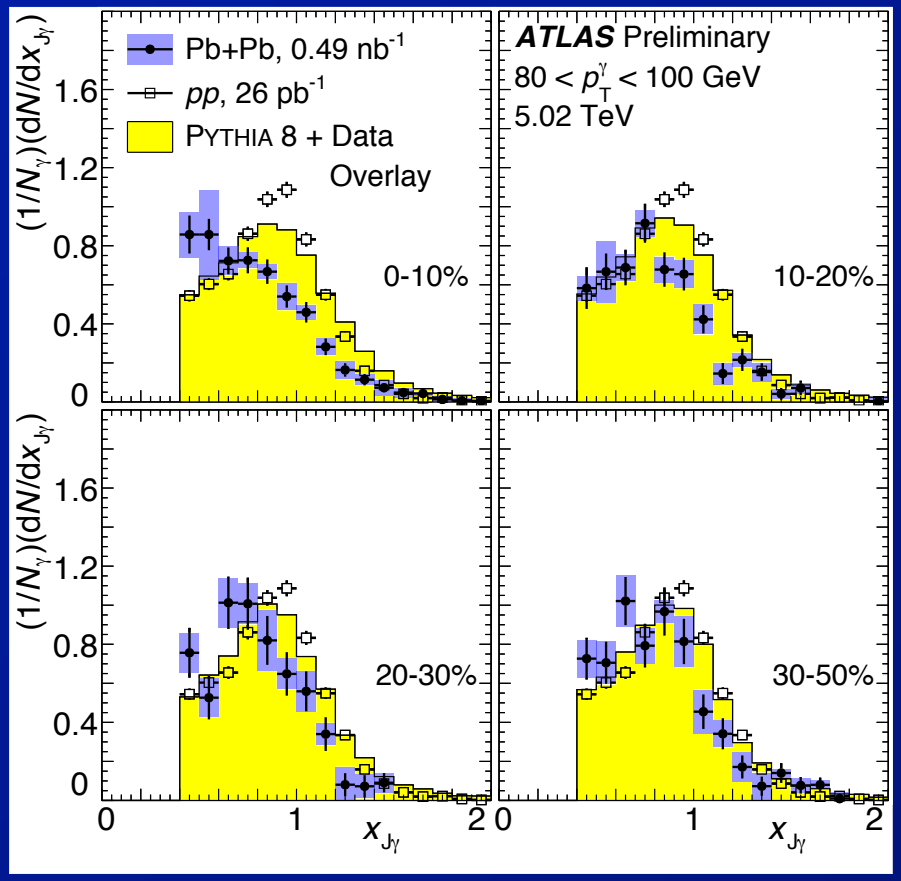
⇒See clear modification (downward shift) in central Pb+Pb due to energy loss of balance jets

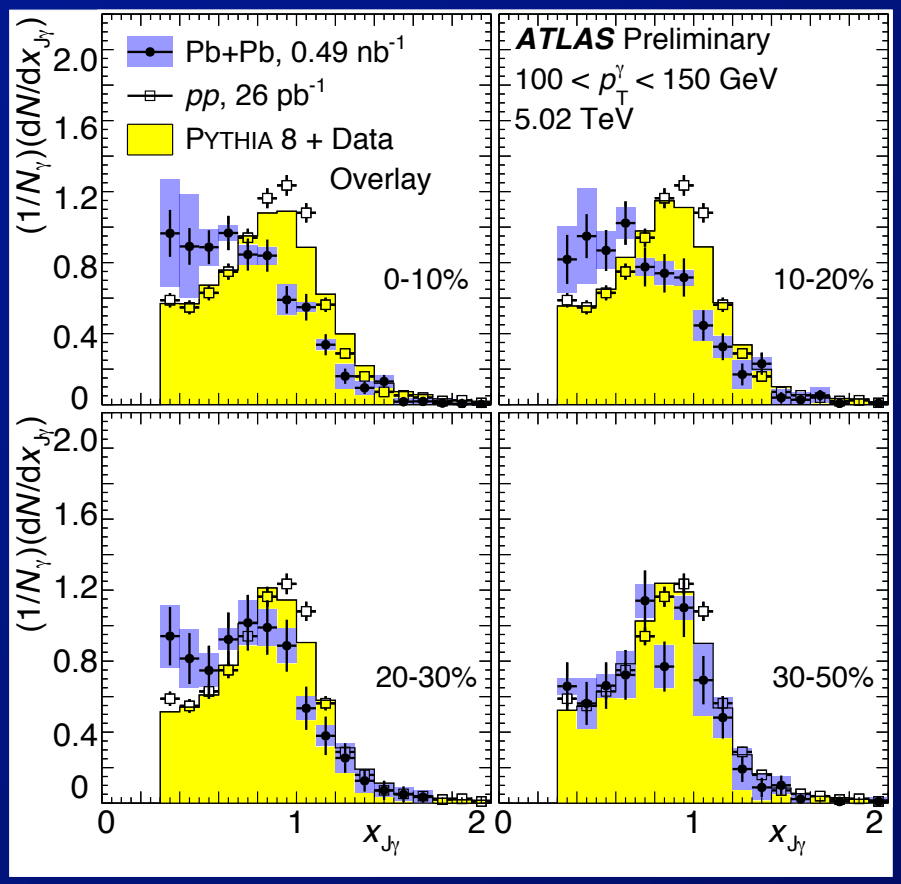
Gamma-Jet in 5.02 TeV Pb+Pb collisions



- Centrality dependence for two photon p_T ranges
  - Left: 60–80 GeV, right: 80–100 GeV
    - ⇒ Observe a smaller shift in less central collisions
    - ⇒ At higher p_T, can see evolving peak + lower x_j contribution

Gamma-Jet in 5.02 TeV Pb+Pb collisions





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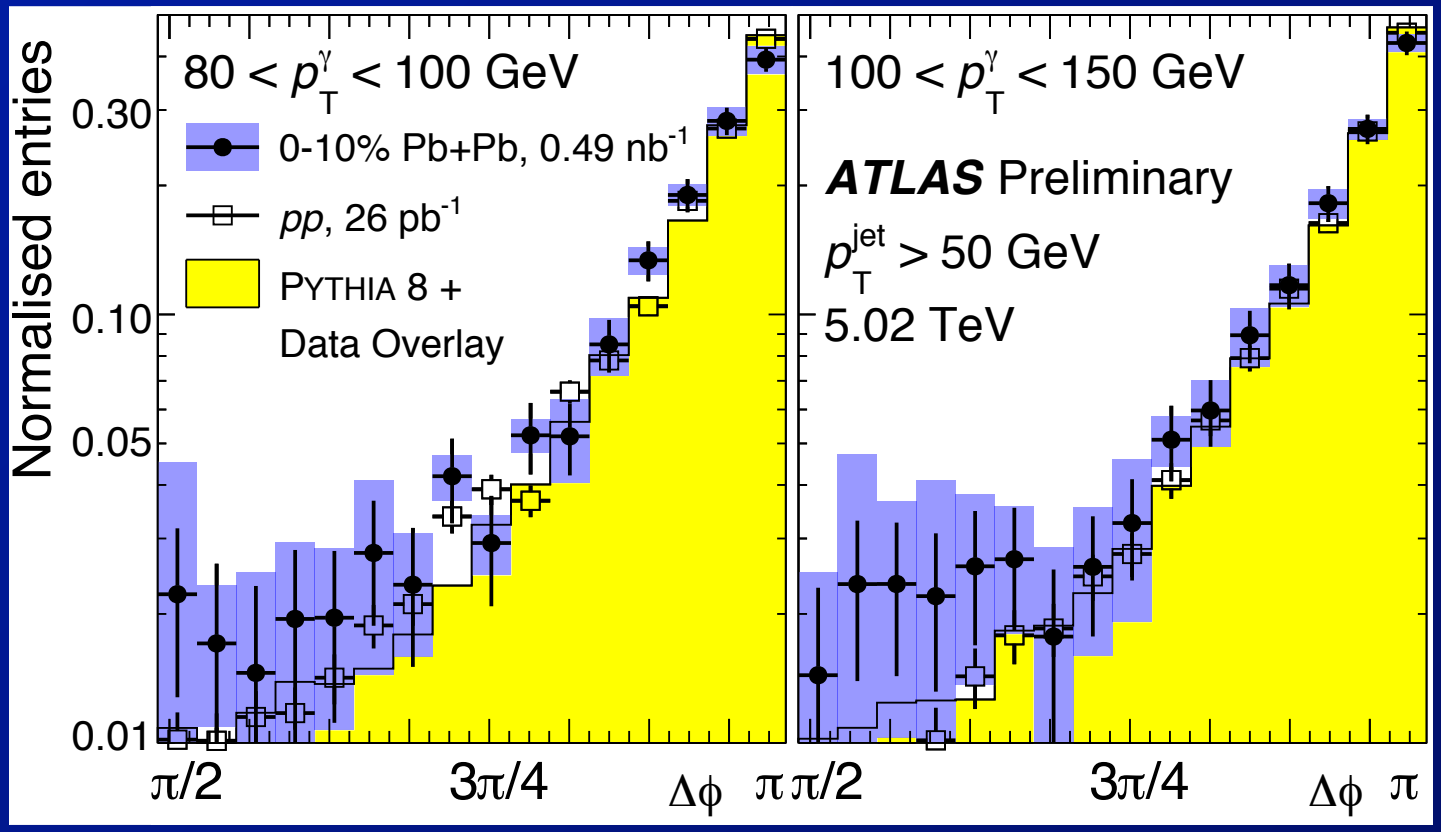

- Look at Δφ distribution for 0-10% centrality
  - p_T^{jet} > 50 GeV to limit combinatoric contribution
  - compare to PYTHIA8 + GEANT + data overlay, pp data

⇒same disagreement with PYTHIA8 as seen for pp

⇒agreement between 0-10% Pb+Pb and pp

Summary and Conclusions

- ATLAS has measured gamma-jet correlations in 5.02 TeV pp and Pb+Pb collisions
  - ⇒ $\int \mathcal{L} dt$ = 26 pb^{-1}, 0.52 nb^{-1}, respectively
- Jets reconstructed using anti-k_t with R = 0.4
  - ⇒ heavy ion jet algorithm with underlying event subtraction and v_2 flow correction
  - ⇒ full set of jet energy scale corrections and uncertainties propagated from 13 TeV pp data
- Measured distributions (no unfolding):
  - $1/N_\gamma \, dN/dx_j$ for $\Delta\varphi > 7\pi/8$ and $1/N_{pair} \, dN/d\Delta\varphi$
  - compared to PYTHI8 + GEANT + PbPb overlay
- See data-PYTHIA8 agreement for pp x_j distribution
  - ⇒ In Pb+Pb collisions see clear quenching effects
- See data-PYTHIA8 disagreement for pp $\Delta\varphi$ distribution
  - ⇒ Pb+Pb and pp $\Delta\varphi$ dist's agree within uncertainties