Constraining the color-charge dependence of parton-medium interactions with photon-tagged jet R_{AA} in Pb+Pb at 5.02 TeV with the ATLAS detector

ATLAS EXPERIMENT

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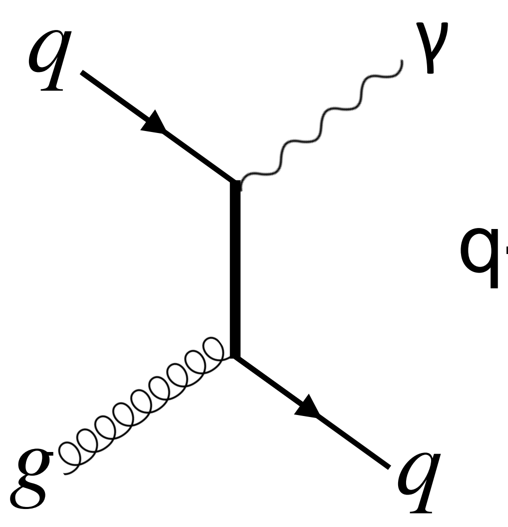
Quark Matter 2022 - the 29th International Conference on Ultra-relativistic Nucleus-Nucleus Collisions
4-10 April 2022, Krakow, Poland

Photon-tagged Jets vs. Inclusive Jets

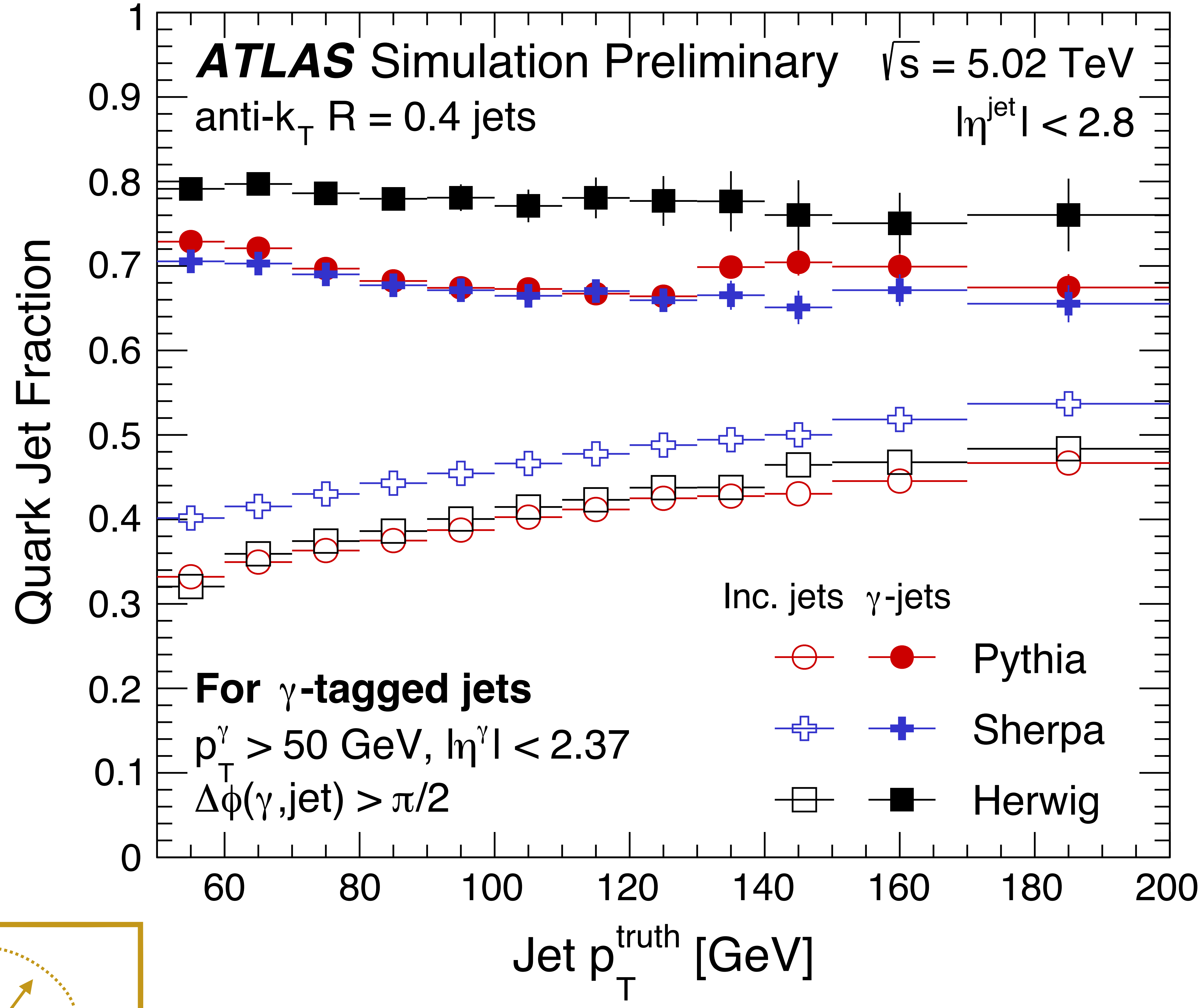
- **Photon-tagged jets** - jets produced in prompt photon (*pp*→γ+jet+X) producing events are largely produced by Compton scattering
  → quark-initiated jet dominant events

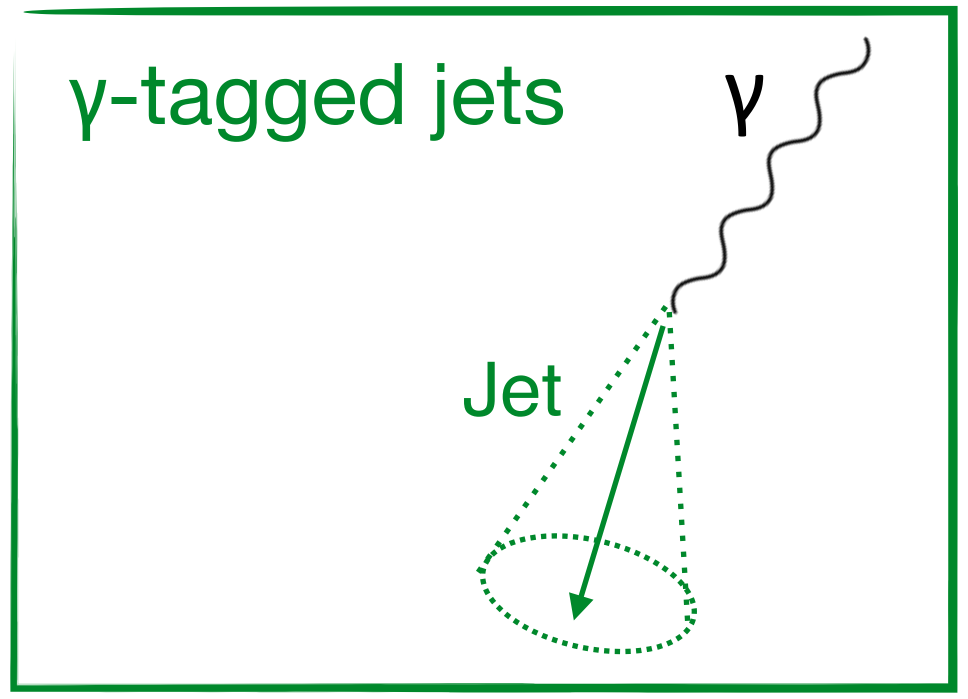


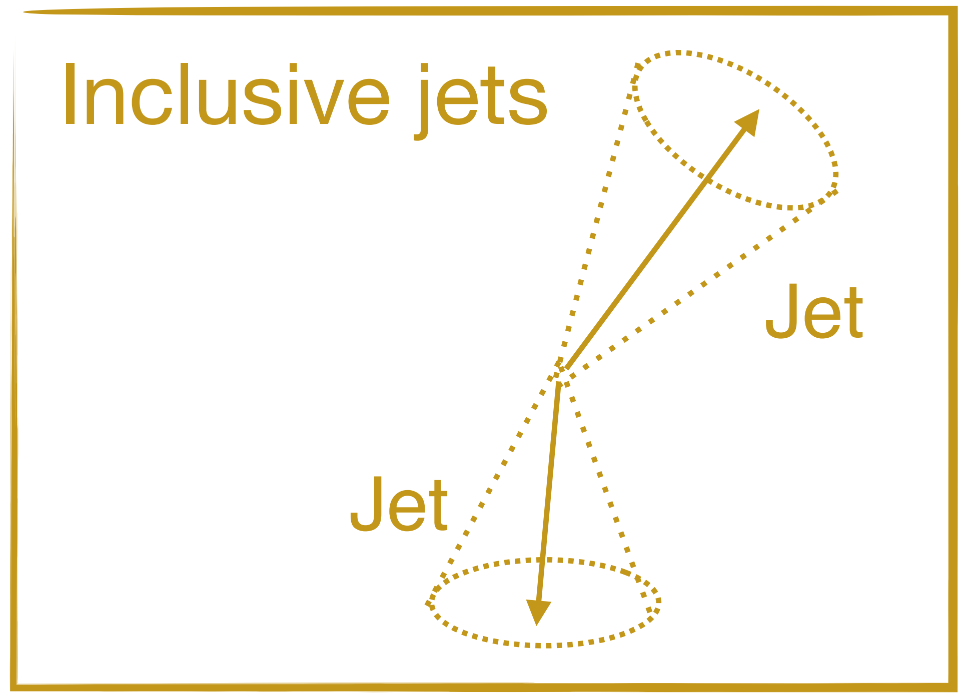
q-g Compton scattering

* note) colorless photons are not significantly modified by the QGP

- **Inclusive jets** - gluon-initiated jet dominant events
- Comparing **photon-tagged jet R_{AA}** and **inclusive jet R_{AA}**, one can see sensitivity to **color charge**







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Cross section

- Cross section for γ-tagged jets found out to be harder than that for inclusive jets
  - ➡ One needs to consider the **difference in p_T spectrum** between γ-tagged jets and inclusive jets when comparing R_{AA} of the two
- At p_T < ~100 GeV, MC generators (**Pythia**, **Sherpa**, **Herwig**) are compatible with the data within uncertainties
- At p_T > ~100 GeV, generators have higher cross section than the data
  - ➡ If theory predictions use one of these MC generators, one needs to consider the **difference in p_T spectrum** between the data and predictions

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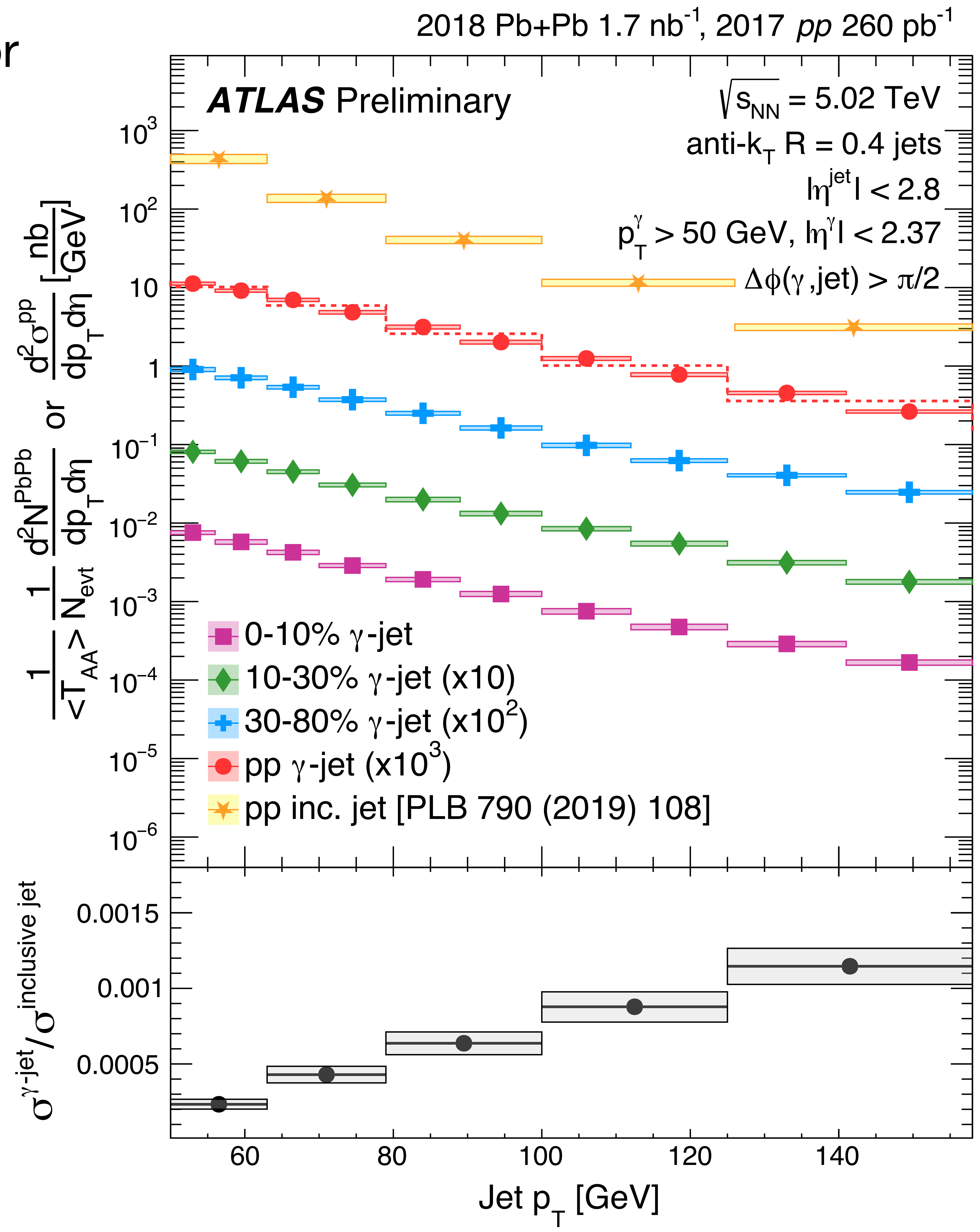
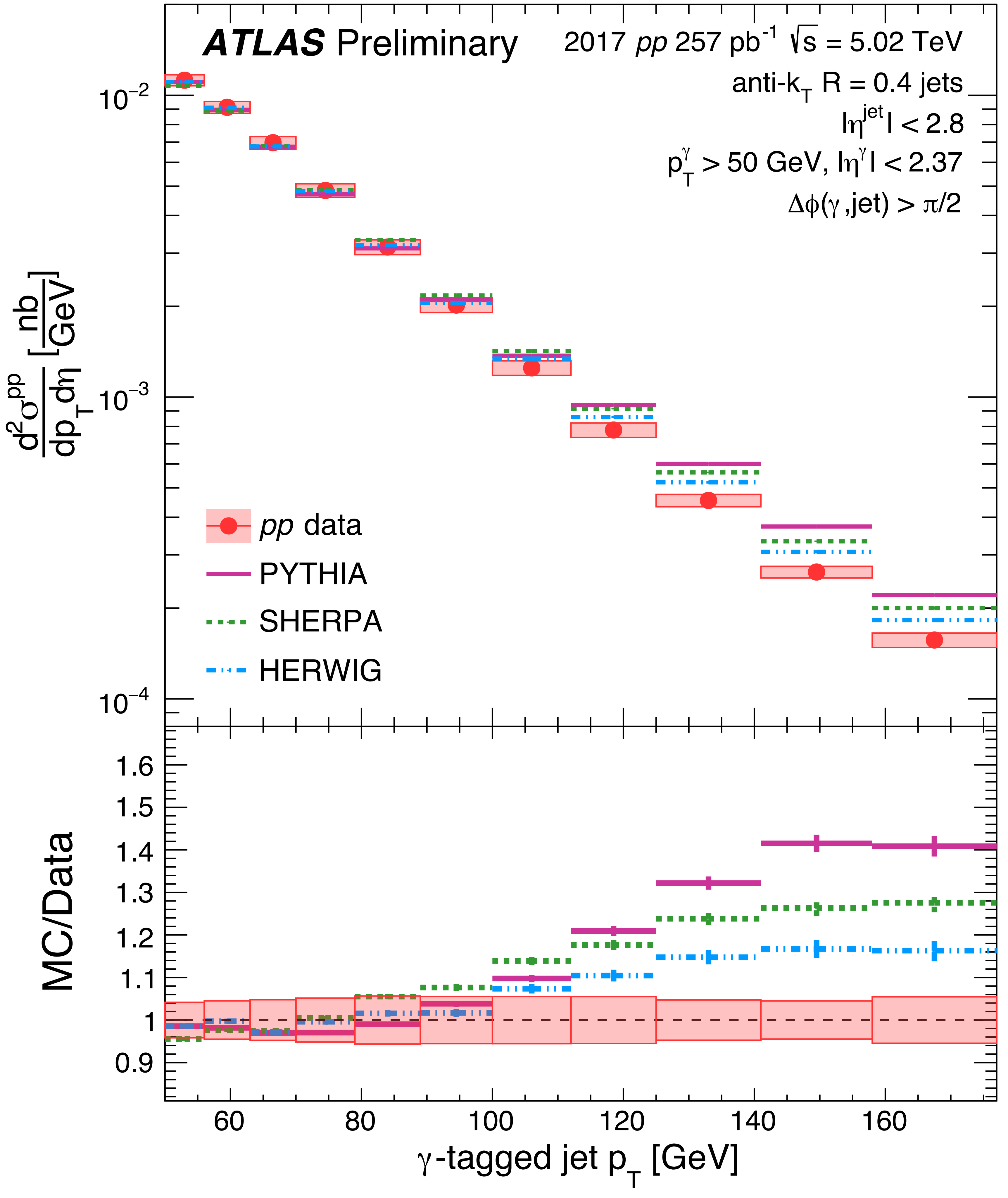




γ-tagged Jet R_{AA}

- R_{AA} shows centrality ordering (e.g. more suppression in 0-10%, less suppression in 30-80%)
- At $p_T > 80$ GeV, slowly rising trend similar to that of inclusive jets
- At $p_T < 80$ GeV, decreasing trend because of photon p_T threshold of 50 GeV

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

1) p_T^{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

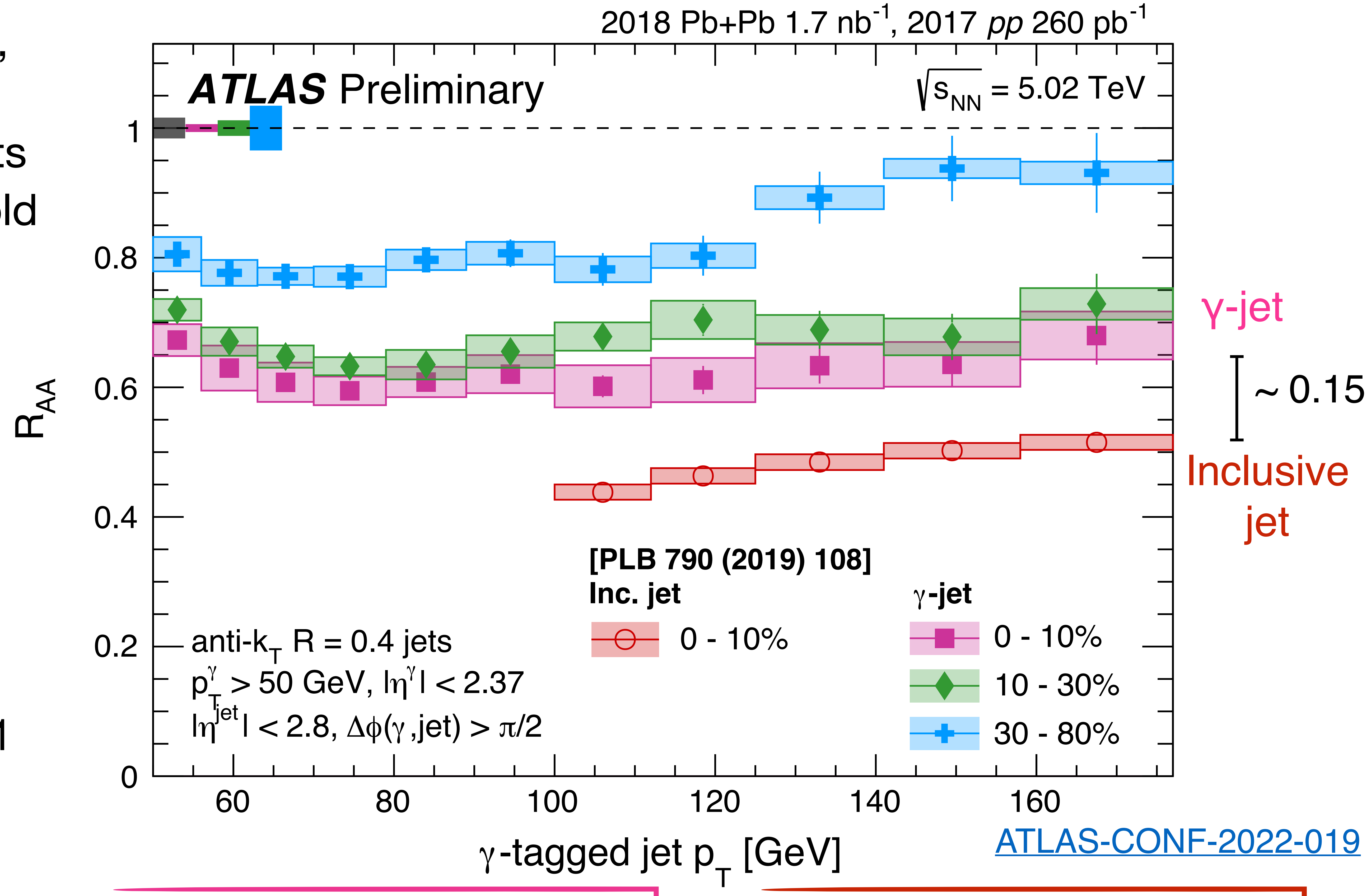
2) Isospin and nPDF effect

- 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_T

➡ **These two effects** are expected to have **opposite sign** and **similar magnitude**

- R_{AA} 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**



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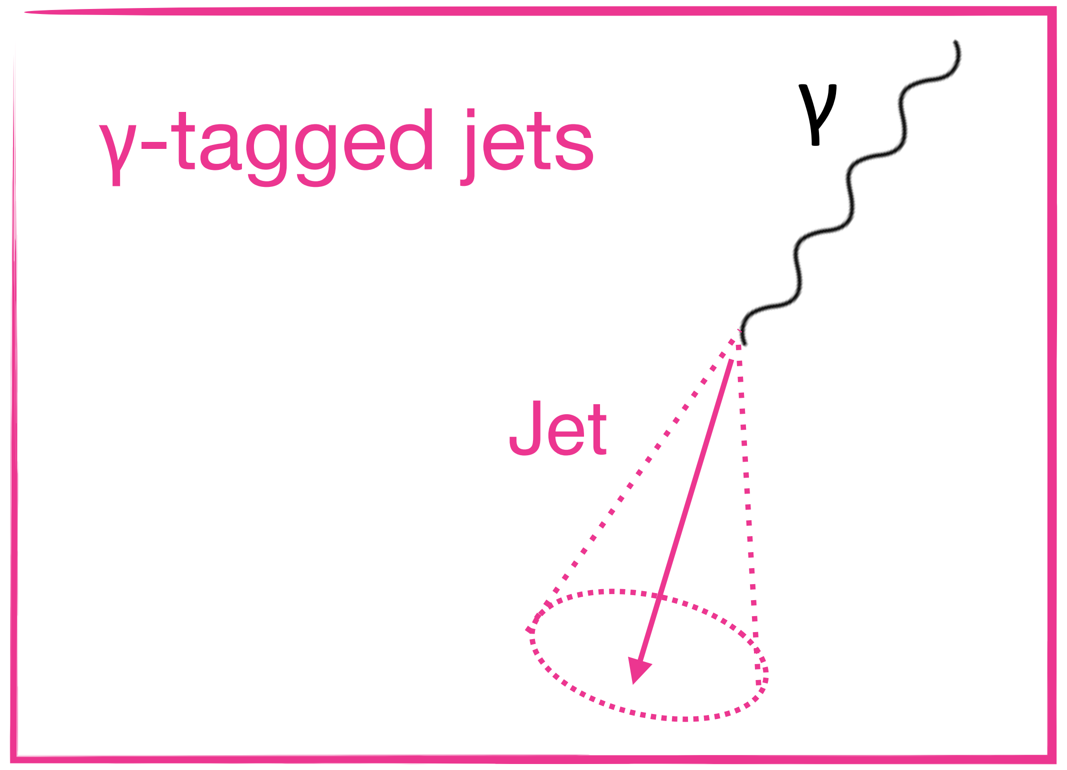
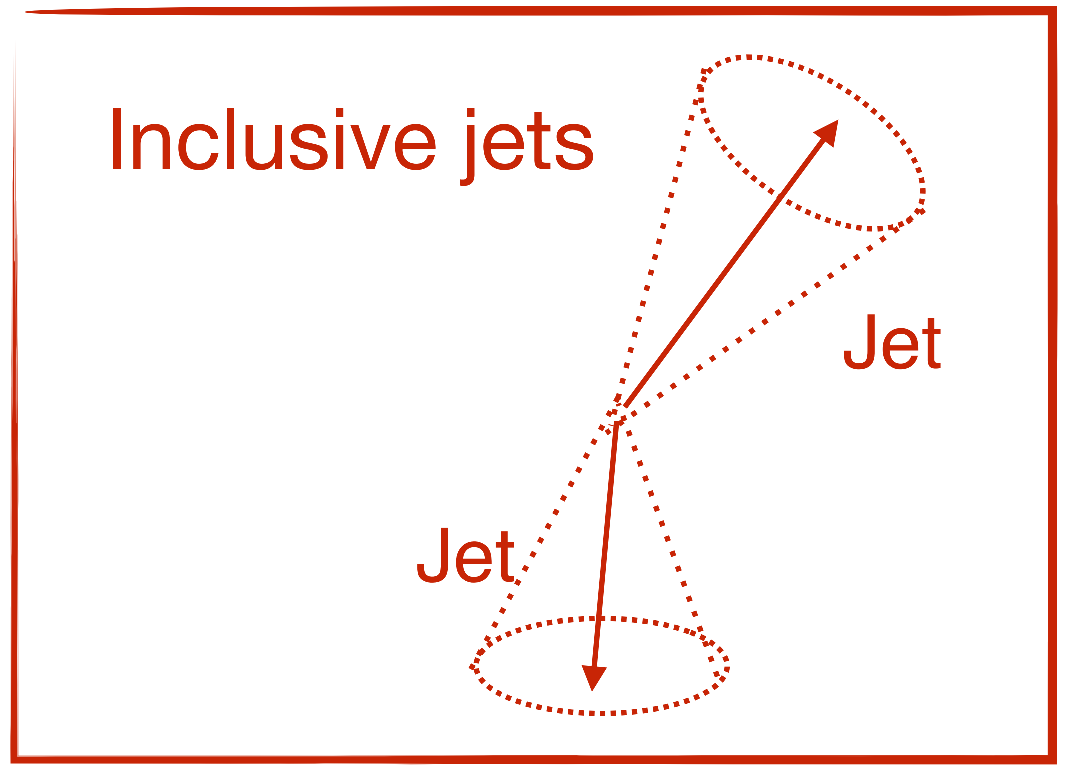
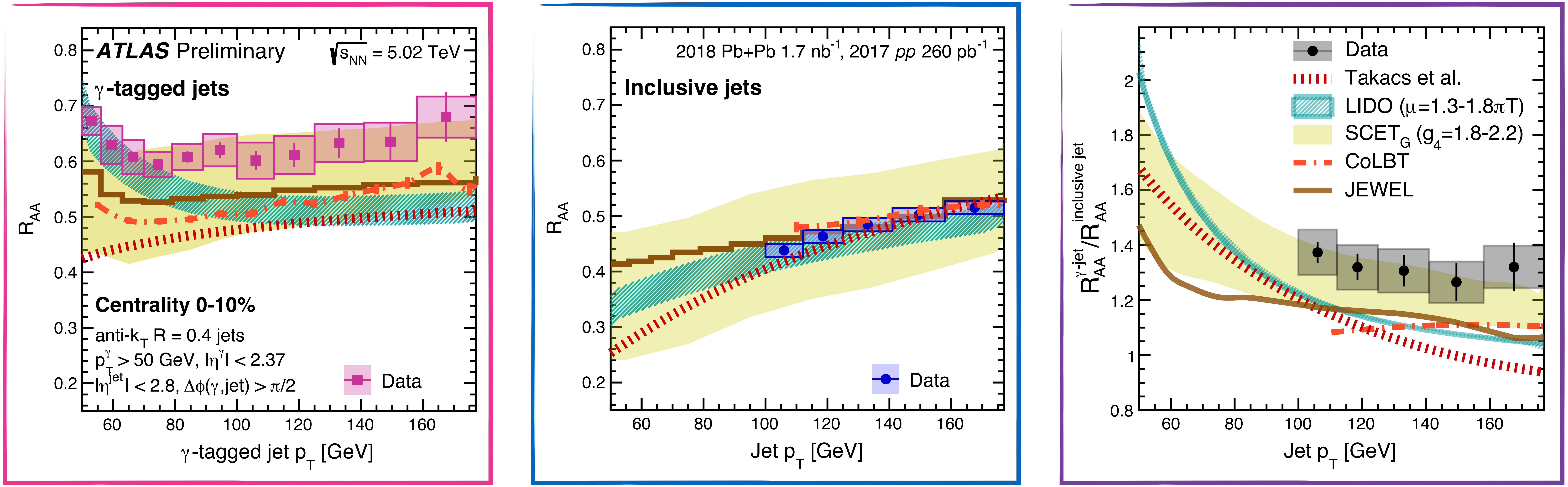




Theory Comparison



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- **For** **inclusive jets**, all calculations describe the inclusive jet data well
  ← it may arise from tuning free parameters to this previously available dataset
- **For** **γ-tagged jets**, the data are generally higher than the predictions, but are compatible with the SCET$_G$ calculation using a lower value of g
- **The ratio of the R_{AA} between γ-tagged jets and inclusive jets**, $R_{AA}^{\gamma-\text{jet}}/R_{AA}^{\text{inclusive jet}}$
  - mostly above unity evolving with p_T
  - compatible with the SCET$_G$ calculation within uncertainties
  ➡ **possibility to provide new constraints on the color charge dependence of energy loss in models**

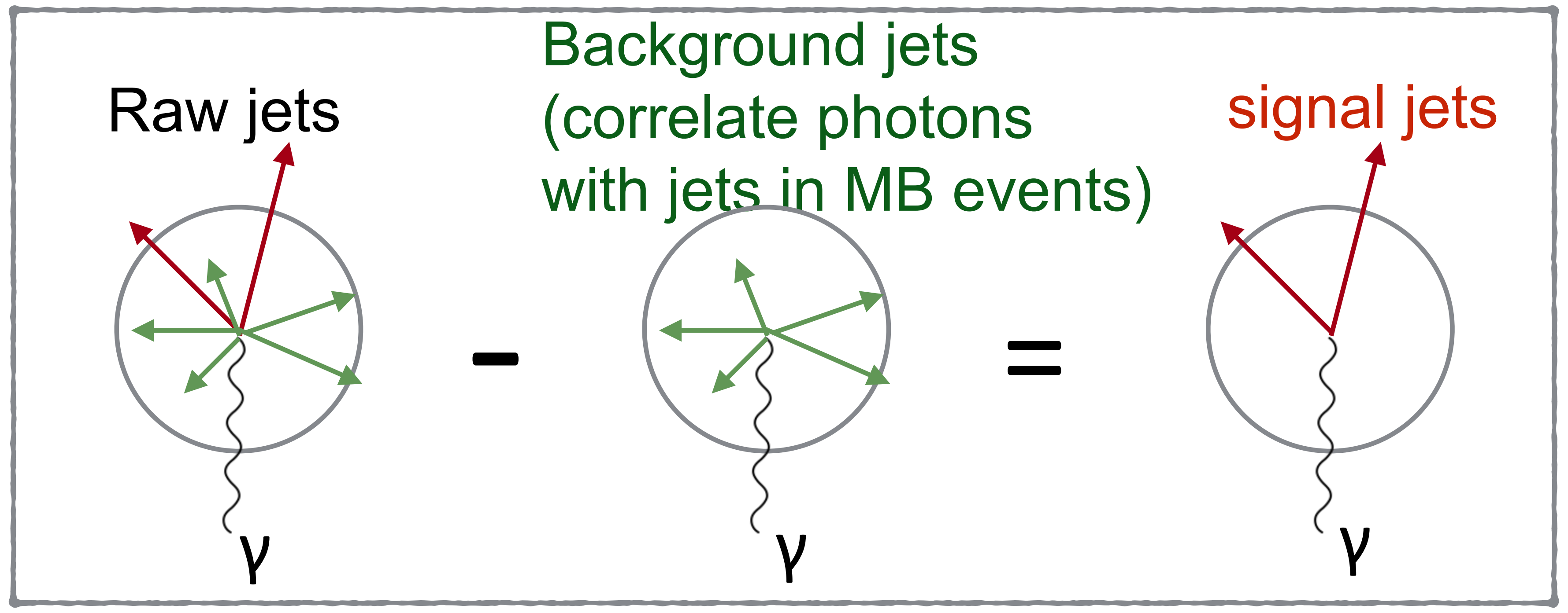
BACK UP

Analysis Selections

- **Photon triggers** used for p_T > 20 GeV (35 GeV) for Pb+Pb (pp) collisions
- Centrality bins: 0-10%, 10-30%, 30-80%
  - Centrality is characterized by the sum of the transverse energy in the forward calorimeters (ΣE_T^{FCal})
- **MC simulations** for pp collisions (including both direct and fragmentation photon processes)
  - **Pythia8** with the A14 tune and NNPDF 2.3 LO PDF set
  - **Sherpa** with the NNPDF 3.0 NNLO PDF set
  - **Herwig** with the MMHT2014lo PDF set
- MC simulations for Pb+Pb collisions: the generated events are overlaid at the hit level with a sample of minimum-bias Pb+Pb data events
- Photons:
  - p_T > **50** GeV/c (for the unfolding underflow, p_T > **40** GeV/c is used)
  - $|\eta| < 1.37$, $1.52 < |\eta| < 2.37$
  - Identification using the "tight" shower shape cuts
  - Isolation condition of $E_T^{iso} <$ **3** GeV
    - $E_T^{iso} \equiv$ the sum of the transverse energy in calorimeter cells within $\Delta R < 0.3$ not including the photon itself
    - E_T^{iso} is corrected for p_T and centrality to have a high (~90%) efficiency
- Jets:
  - Anti-k_T **R=0.4**
  - p_T > **50** GeV/c (for the unfolding underflow, p_T > **40** GeV is used)
  - $|\eta| < 2.8$
  - all jets with $\Delta\phi(\gamma,\text{jet}) >$ **π/2**

Analysis Procedure

- **1) Subtract combinatoric background in jet p_T (event mixing technique)**
  - subtract combinatoric contribution by correlating signal photons to jets in minimum-bias Pb+Pb events



- **2) Subtract jets correlated with non-signal photon (photon purity correction)**
  - $O_{rawPhoton} = O_{sigPhoton}$ * purity + $O_{bkgPhoton}$ * (1-purity)
    - O_x is per-photon jet yield tagged with x photon (x = raw, signal and background photons)
    - purity is estimated using the data-driven double sideband method (Ref. JHEP 08 (2016) 005)

- **3) Unfold for jet p_T and photon p_T (2D) to correct for bin-to-bin migration arising from the finite detector resolution**
  - The iterative Bayesian method is used with the RooUnfold software package (Ref. arXiv: 1105.1160)
  - The unfolding procedure also accounts for the finite reconstruction and selection efficiency of photons

- **4) R_{AA}**

Systematic Uncertainties

Photon-related uncertainties

1. Energy scale
2. Energy resolution
3. Efficiency
4. Purity

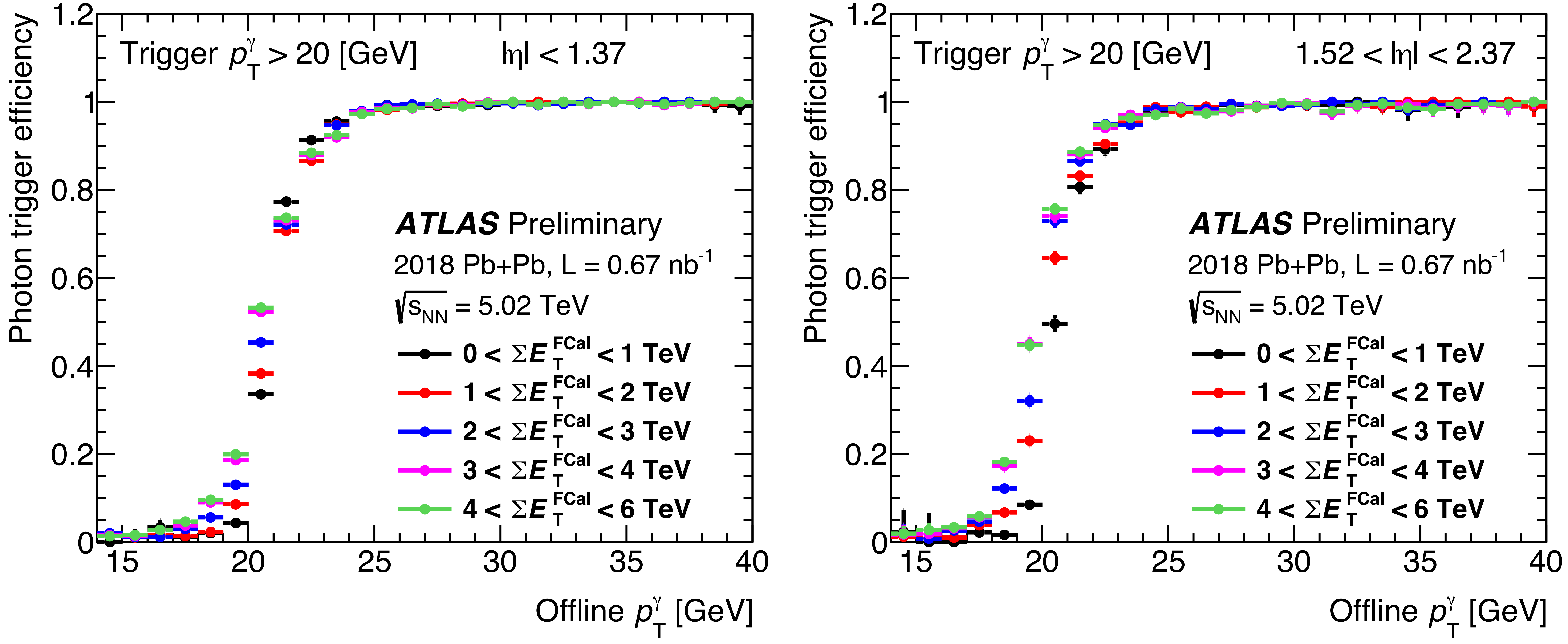
Jet-related uncertainties

5. Energy scale
6. Energy resolution

7. Unfolding
8. Combinatoric background subtraction
9. Global uncertainty (T_{AA} and luminosity)

- The individual uncertainties are added in quadrature to determine the full uncertainties
- For both cross-section and R_{AA} measurements, the jet energy scale uncertainties are dominant in almost the entire phase space

Trigger Efficiency



- Photon triggers are used for the analysis
- The offline photon selections (>40 GeV) are far above the online threshold of the trigger (>20 GeV)
  → the triggers are more than 99% efficient in this region

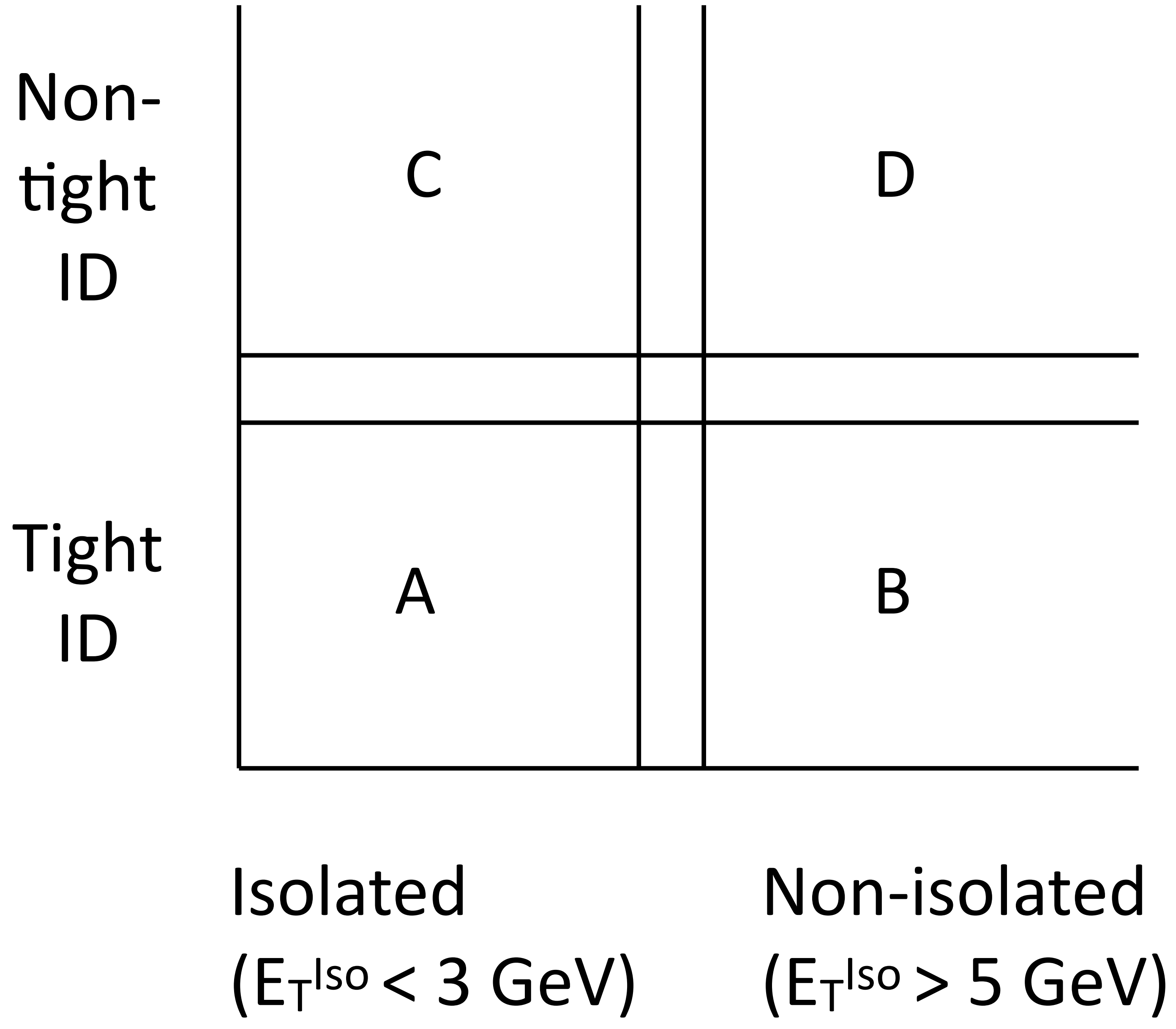
- Purity is estimated with double-sideband data-driven method
  - signal leakage factor ($f^{i,MC}$) obtained from MC

Double-sideband method

$$N^{A,data}_{signal} = N^{A,data} - \left(\left(N^{B,data} - f^{B,MC} N^{A,data}_{signal} \right) \cdot \frac{\left(N^{C,data} - f^{C,MC} N^{A,data}_{signal} \right)}{\left(N^{D,data} - f^{D,MC} N^{A,data}_{signal} \right)} \right)$$

$$\text{, where } f^{i,MC} = N^{i,MC}_{signal} / N^{A,MC}_{signal}$$

- Photon Purity
  - estimated in each p_T and centrality bins
  - a minimum of ≈ 75% in central Pb+Pb events at the lowest p_T values
  - increases quickly with p_T



Inclusive Jet R_{AA}

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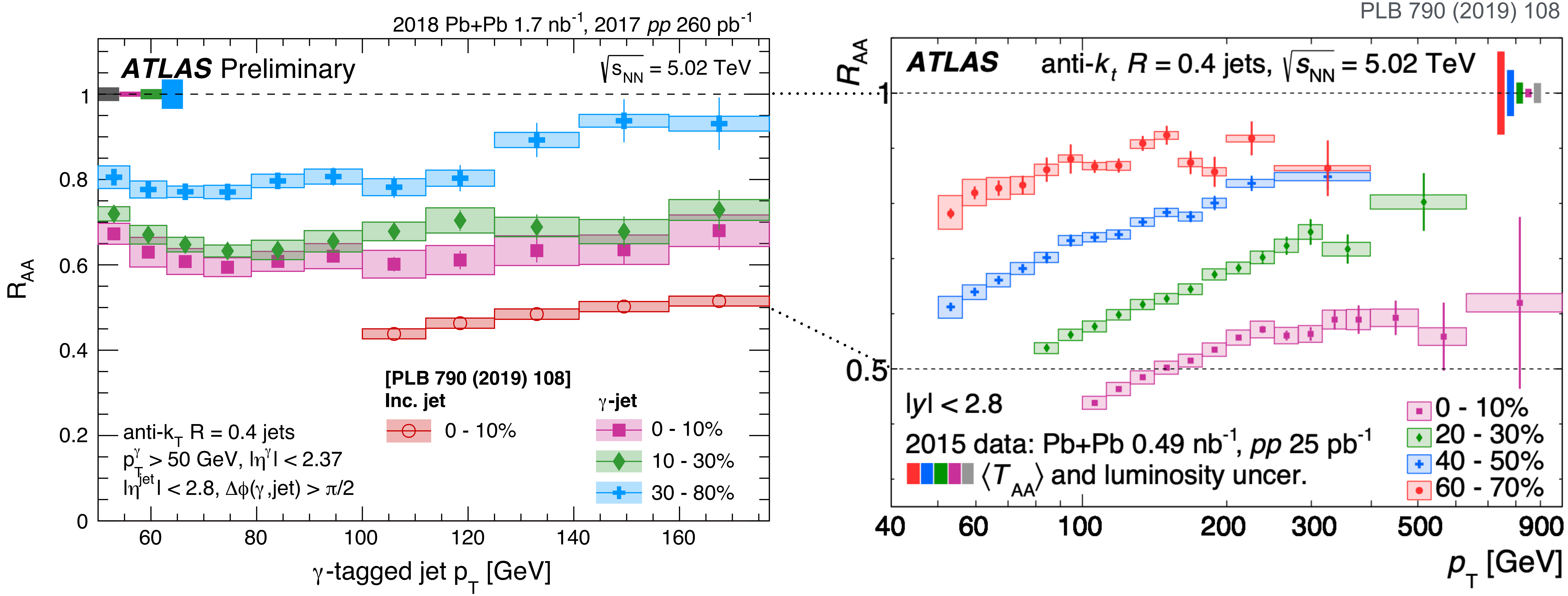

- Inclusive jets are more suppressed than γ-tagged jets across centrality