



Jet quenching studies with new jet substructure and suppression measurements in ATLAS

Martin Rybar

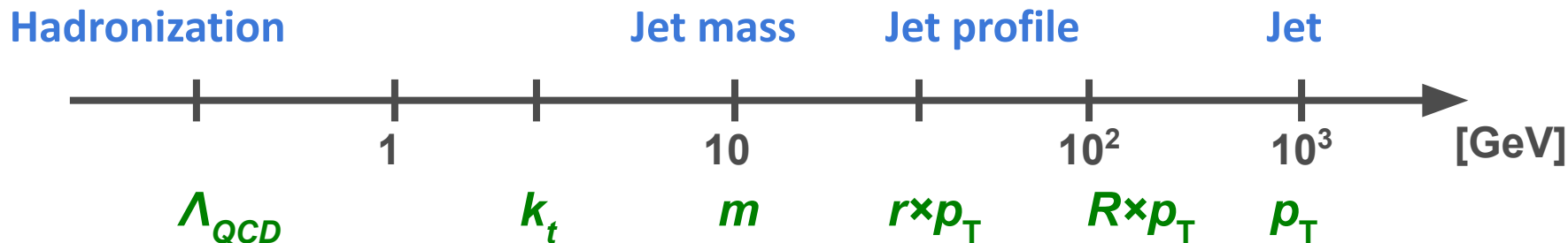
on behalf of ATLAS collaboration

Hard Probes 2023

28th March 2023

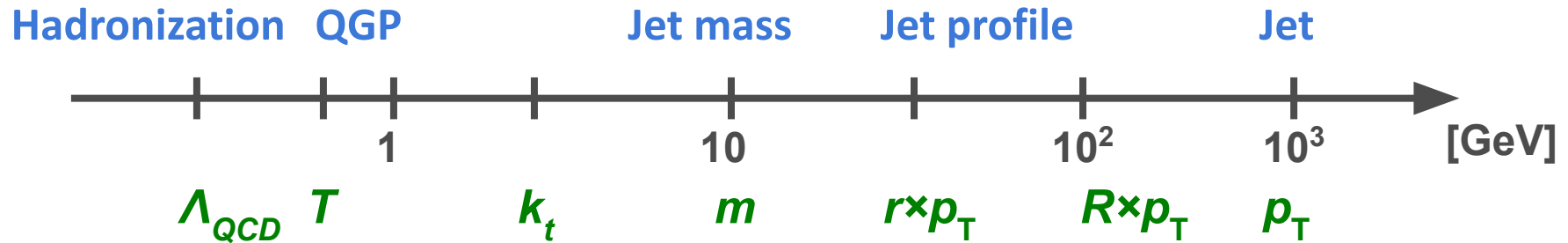
Why jet substructure?

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



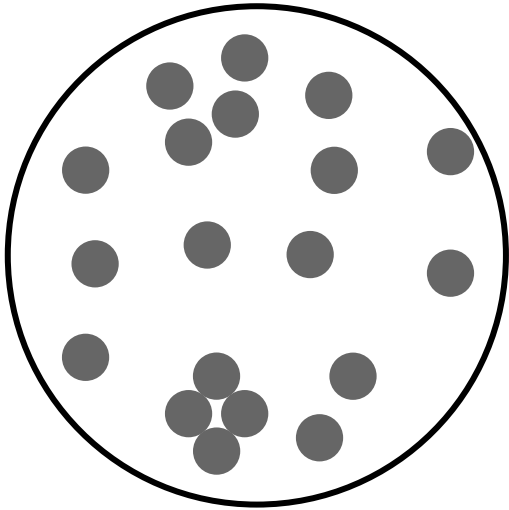
Why jet substructure in HI?

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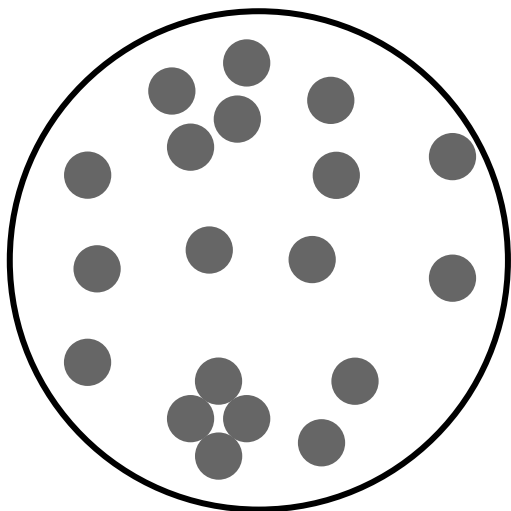
- We can use various jet substructure observables to probe different regimes.
 - What are the properties and degrees of freedom of QGP at length scales between point-like partons and hydrodynamic modes?
 - How does the color charge interact and lose energy?
 - What are the effective scales of the interactions determining the energy loss?

Jet definition & substructure

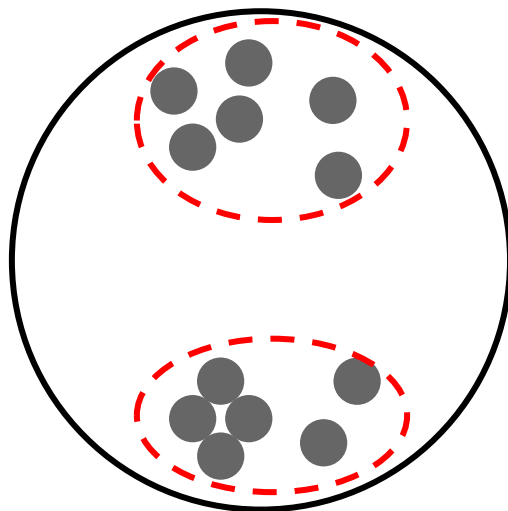


“Conventional” jet made of particles/tracks/towers/clusters

Jet definition & substructure



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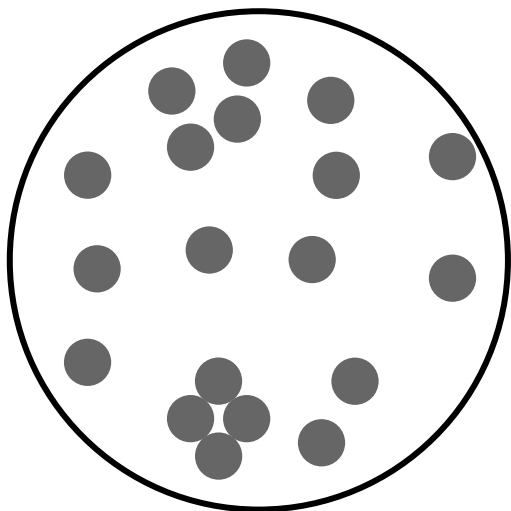


De-clustered & groomed jet with SoftDrop

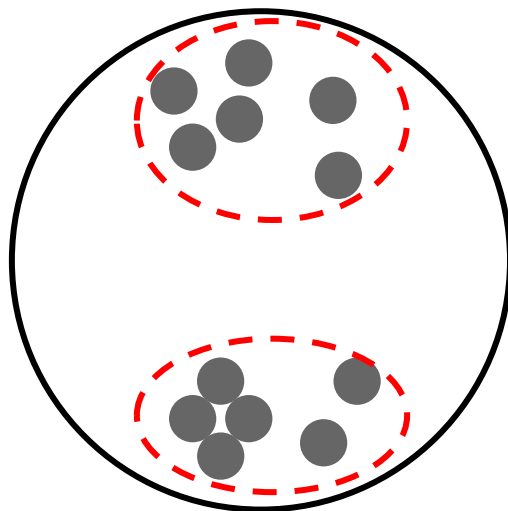
Focusing on hard substructure...

Declustering follow the splitting evolution; grooming parameters \leftrightarrow affects physics.

Jet definition & substructure

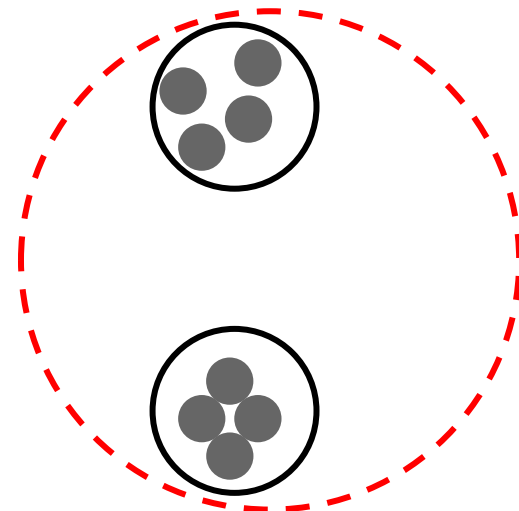


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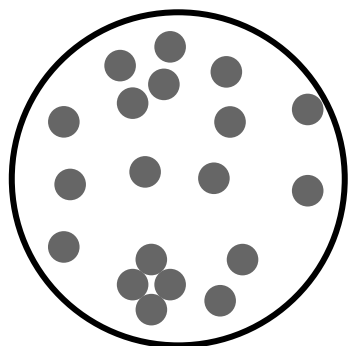
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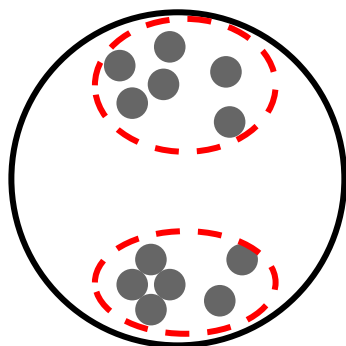
Re-clustered jet from smaller jets

Large-R jets designed for boosted W/Z/t; focus on hard structure; sub-jets.

Jet definition & substructure

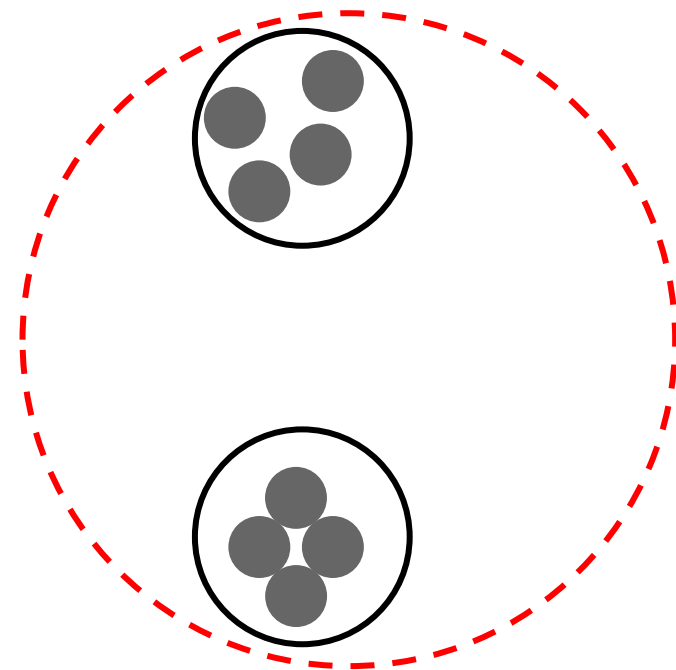


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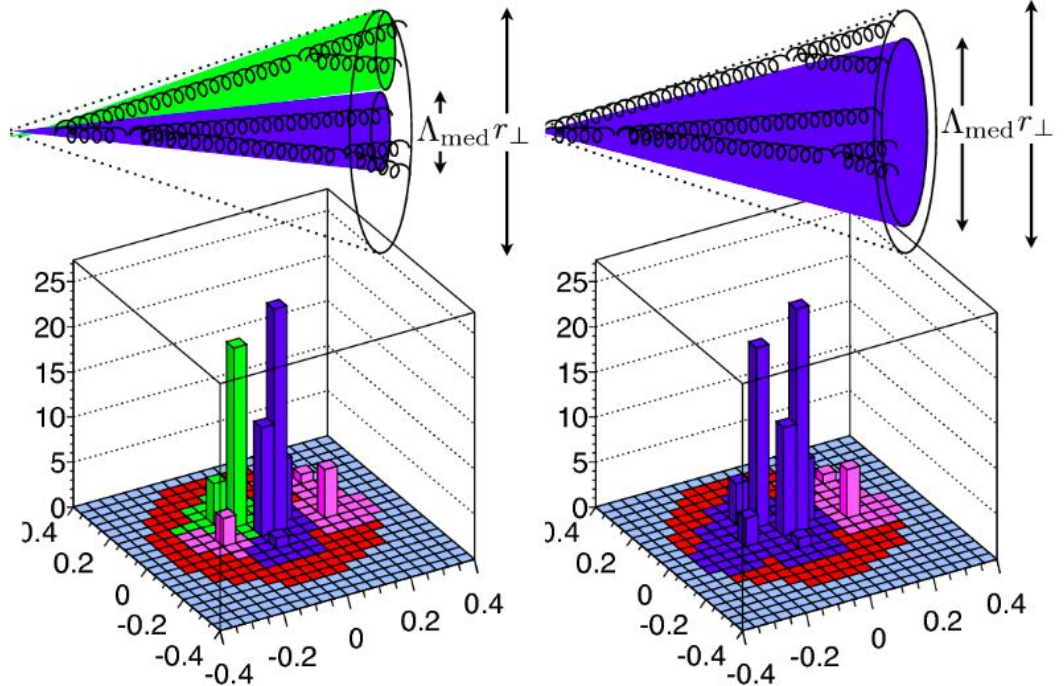
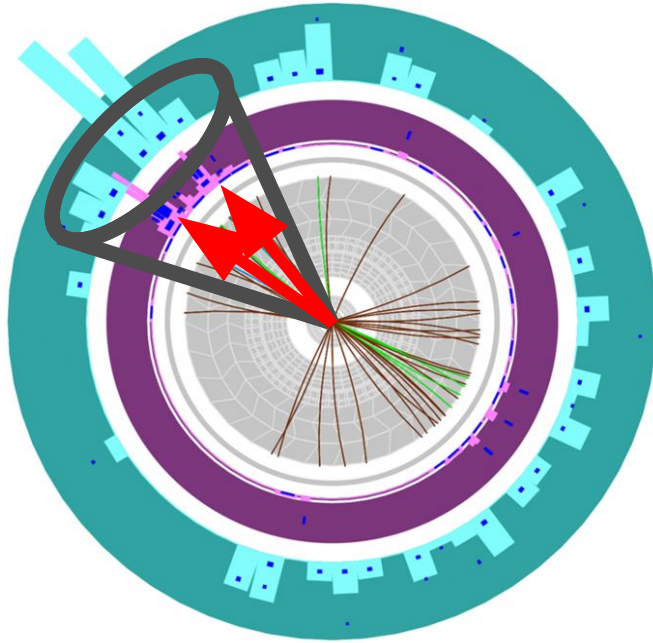
Substructure of $R=0.4$ jets
[arXiv:2211.11470](https://arxiv.org/abs/2211.11470)



Re-clustered jet from smaller jets

Substructure of $R=1.0$ jets
[arXiv:2301.05606](https://arxiv.org/abs/2301.05606)

Dependence of suppression on jet structure?

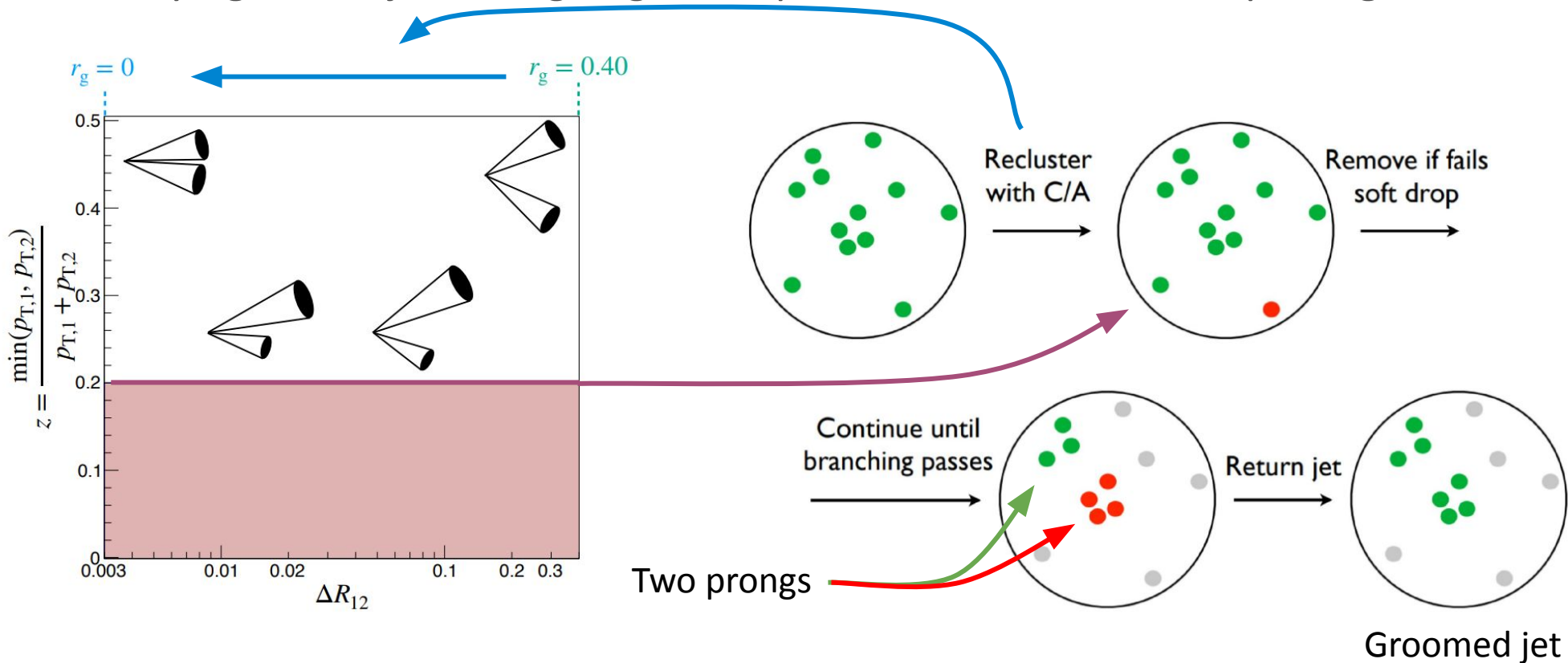


J. Casalderrey-Solana, Y. Mehtar-Tani, C. A. Salgado, K. Tywoniuk, Phys. Lett. B725 (2013) 357

Can be addressed by measurement of jet R_{AA} as a function of their sub-structure.

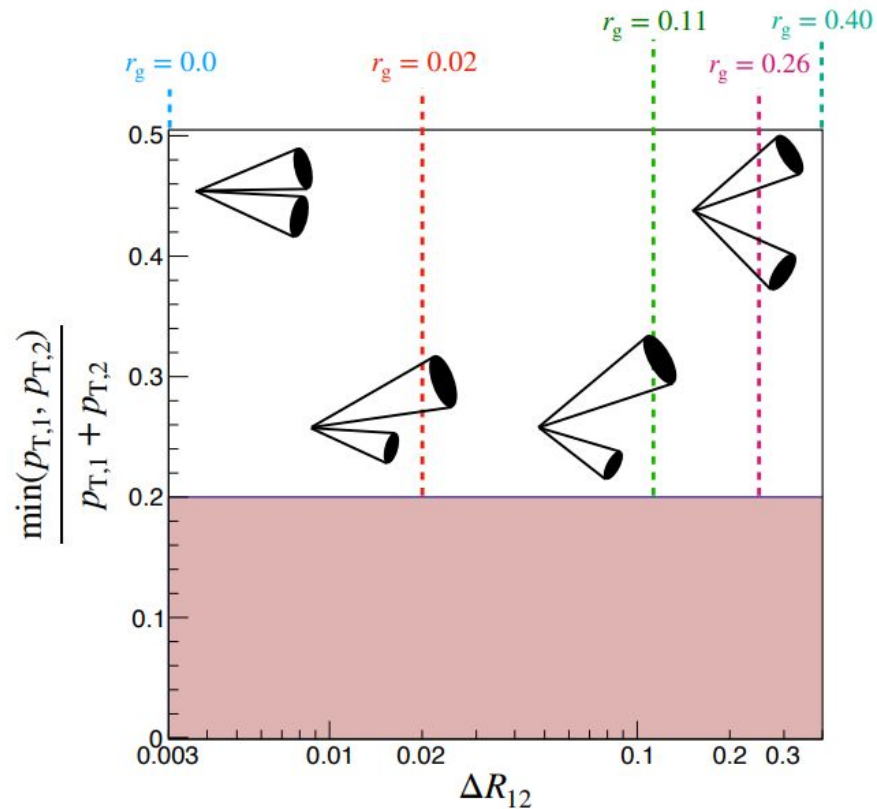
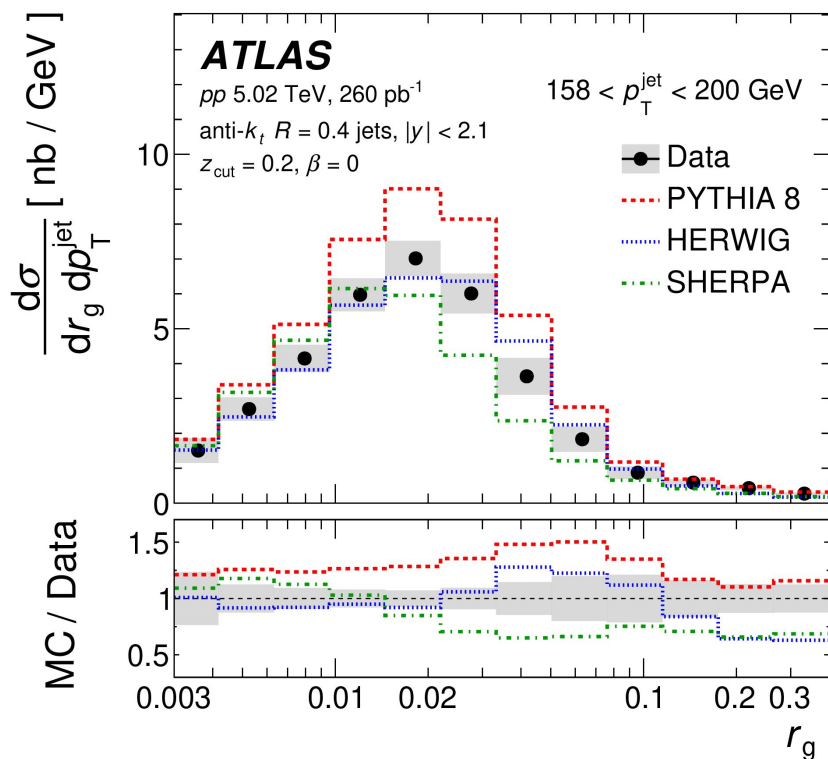
Classifying parton splittings with Soft-Drop

- Classifying $R = 0.4$ jets using angular separation of the hardest splitting



Classifying parton splittings with Soft-Drop

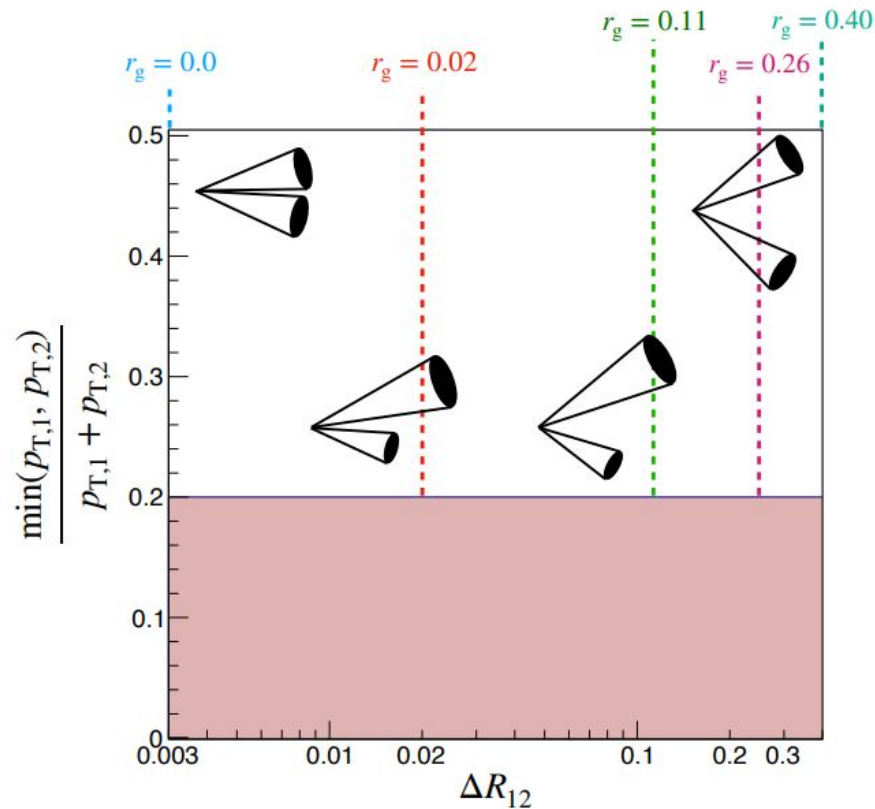
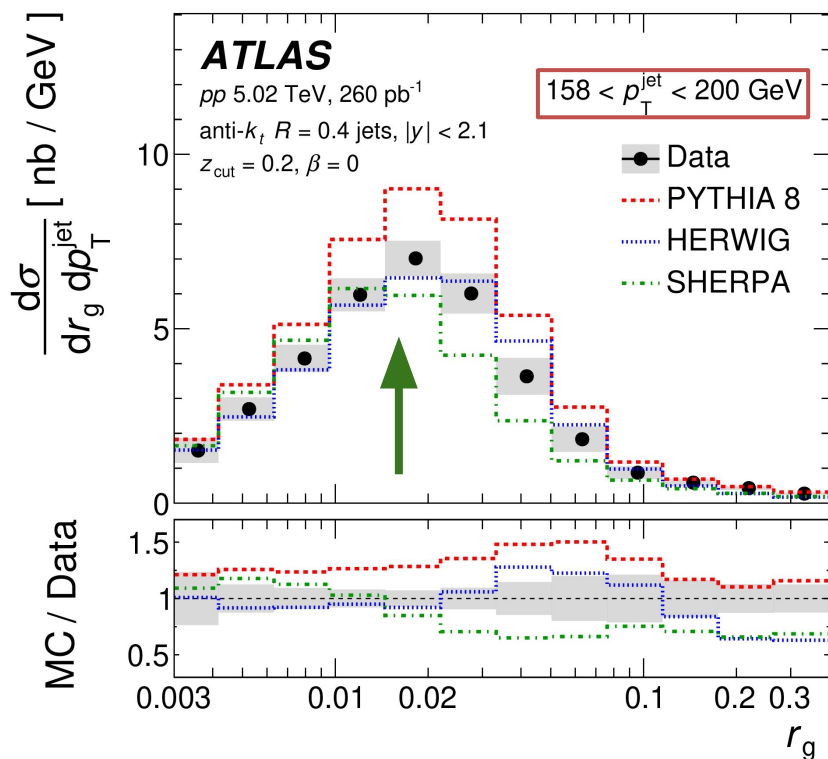
- Fully corrected & absolutely normalized cross-sections & yields.



Drawing by Dhanush Hangal

Classifying parton splittings with Soft-Drop

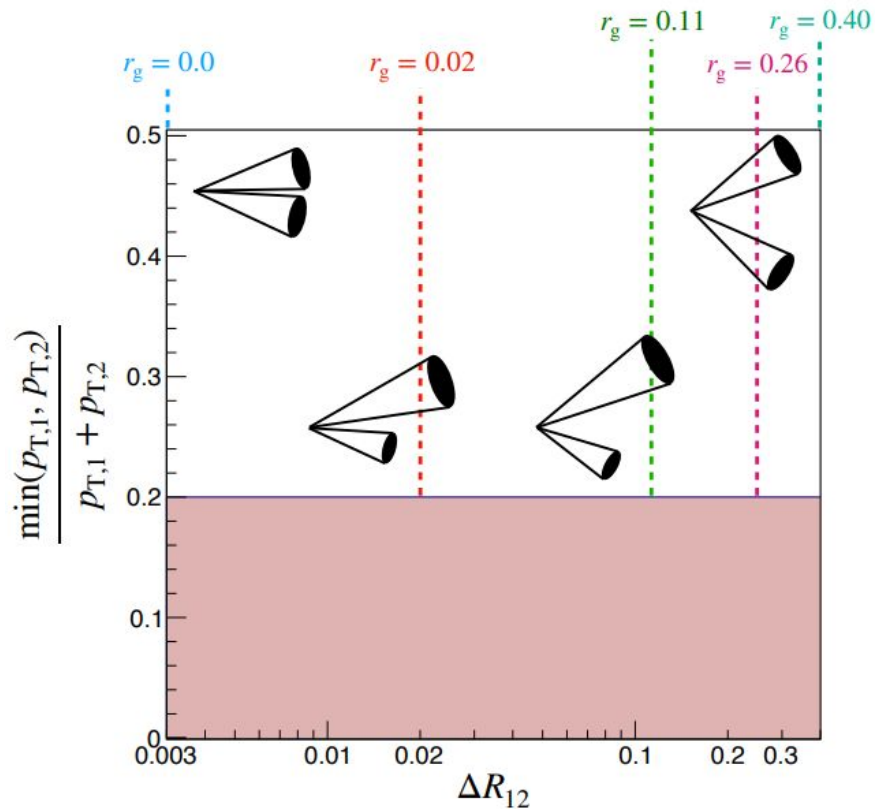
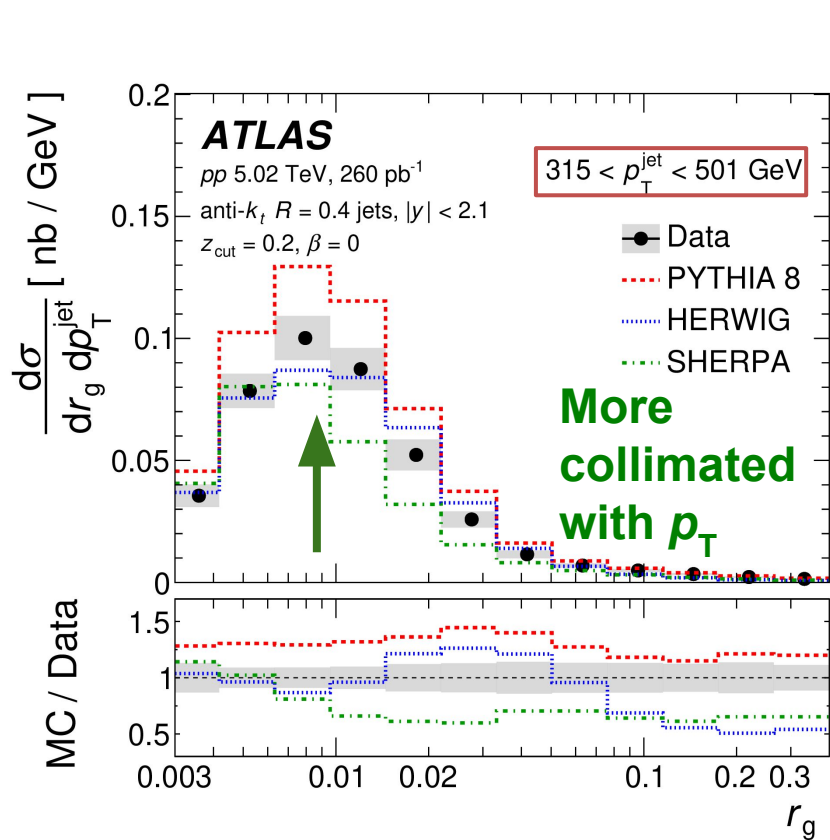
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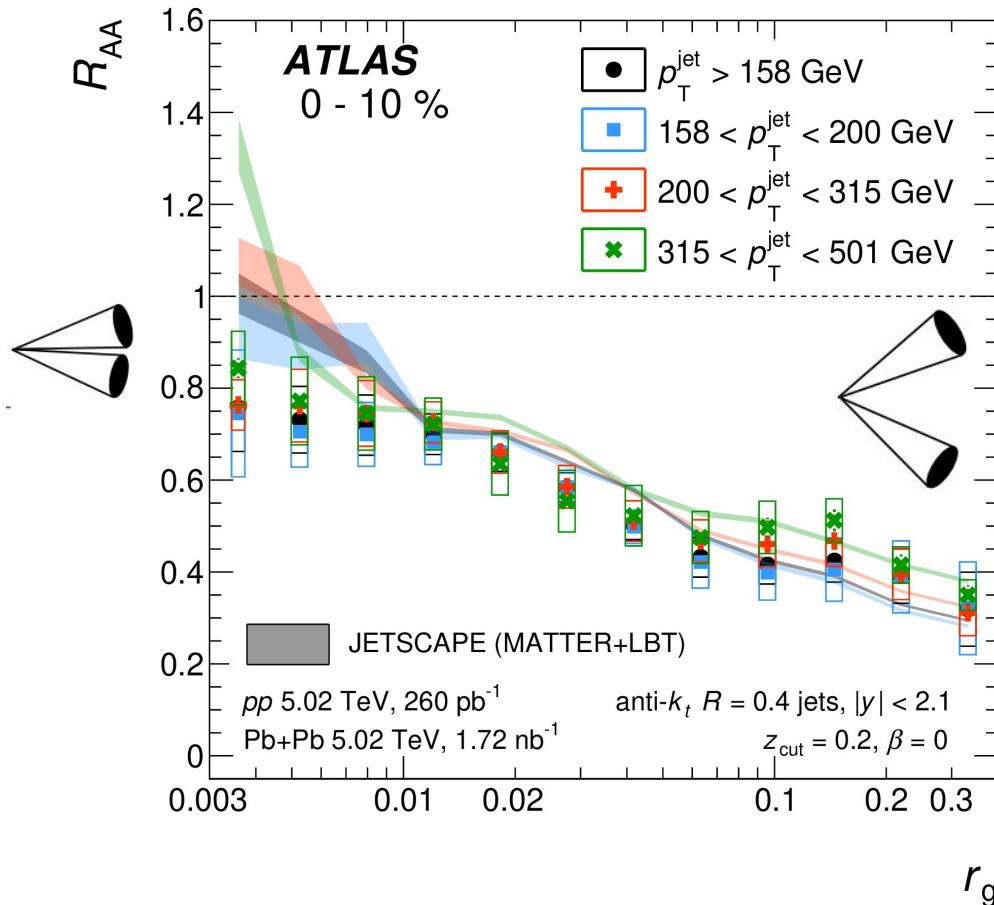
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Drawing by Dhanush Hangal

Suppression vs parton splittings

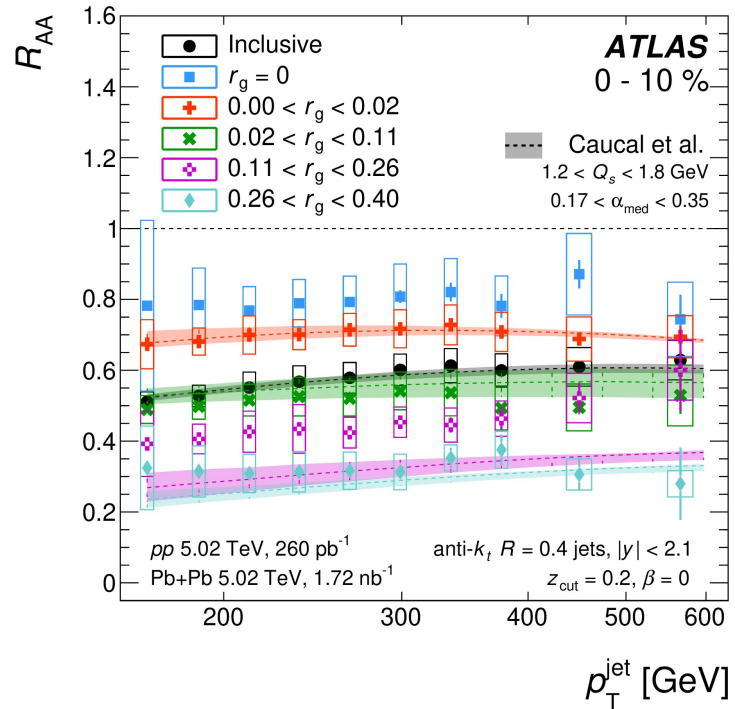


Strong dependence of jet suppression on r_g .

How can we understand the r_g vs p_T dependence?

Jet p_T dependence of the suppression

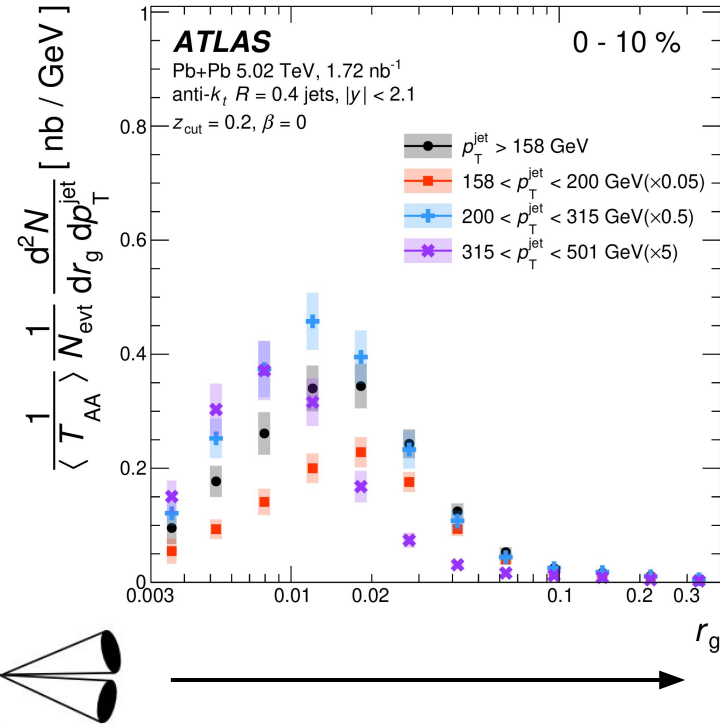
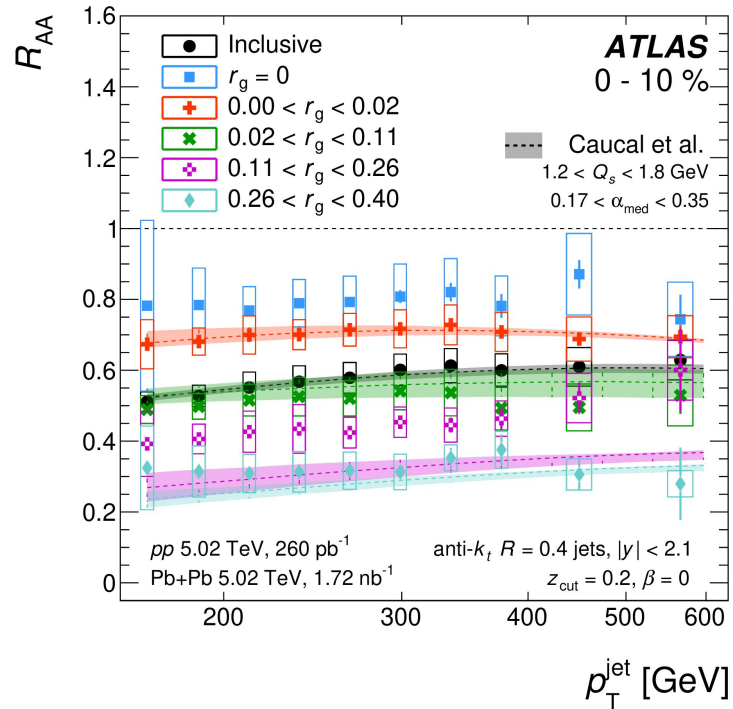
arXiv:2211.11470



Lack of p_T dependence of R_{AA} for jets with similar structure

Jet p_T dependence of the suppression

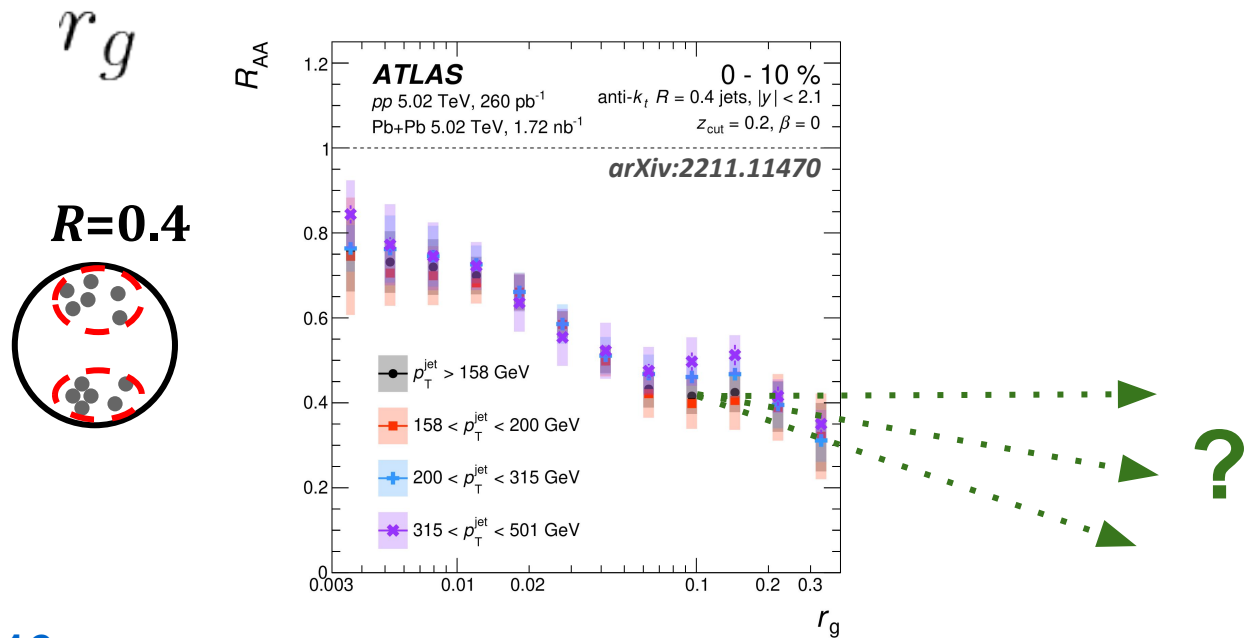
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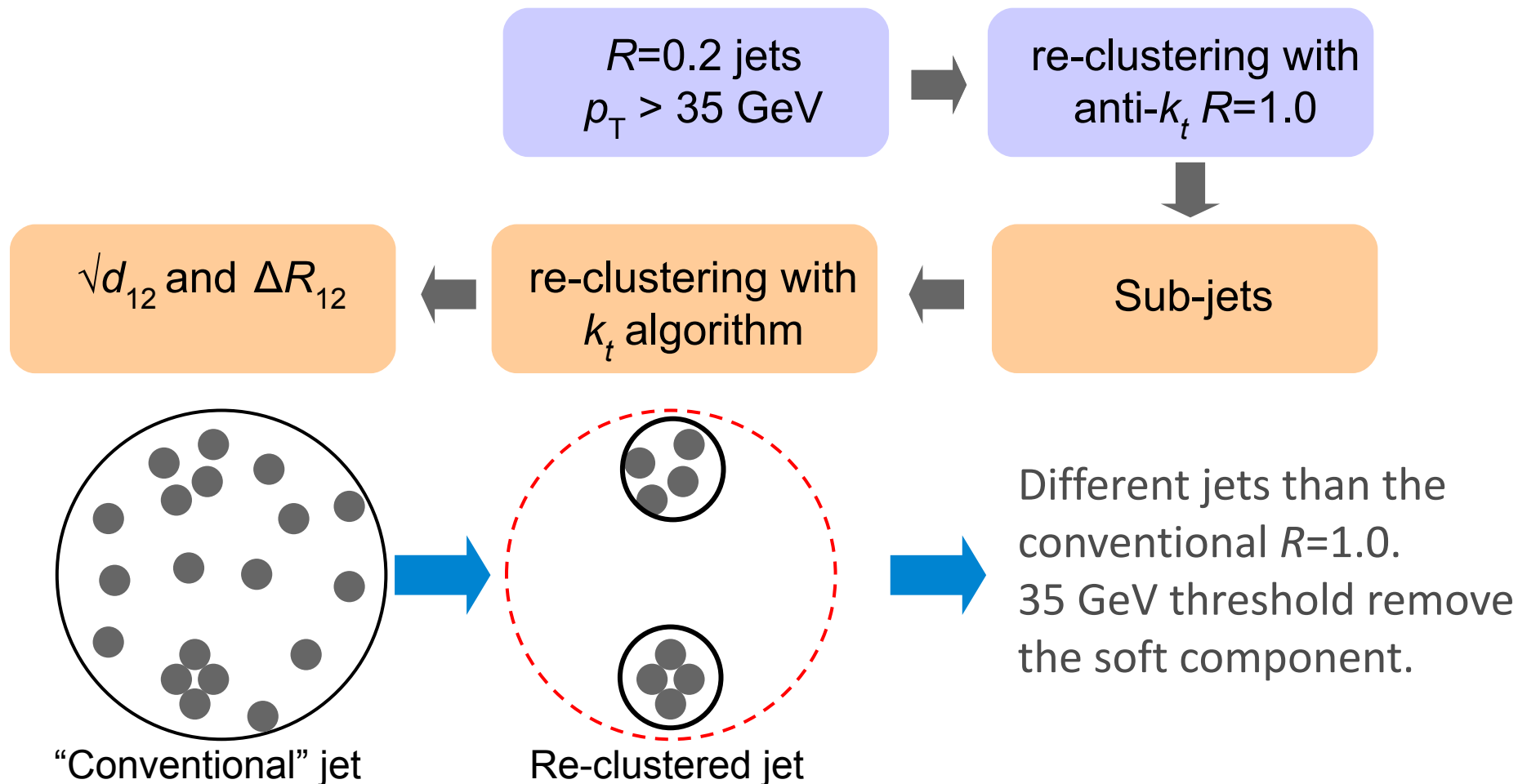
Lack of p_T dependence of R_{AA} for jets with similar structure + rise of inclusive $R_{AA} \Leftrightarrow p_T$ dependence to r_g .

Full picture: small & large jets

- Addressing transition from color-coherence to decoherence...



Re-clustered large- R jets

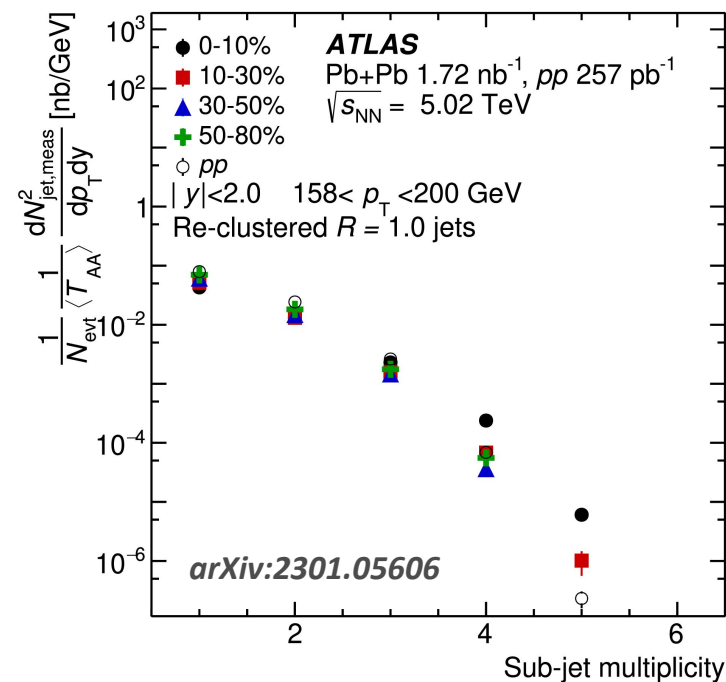


Observables and analysis procedure

- Measurement of yields of re-clustered $R=1.0$ jets as function of p_T , angular separation, and k_t splitting scale:

$$\Delta R_{12} = \sqrt{\Delta y_{12}^2 + \Delta \phi_{12}^2}, \quad \sqrt{d_{12}} = \min(p_{T1}, p_{T2}) \times \Delta R_{12}$$

- Jet suppression is evaluated using modification factor R_{AA} .



Raw sub-jet multiplicity

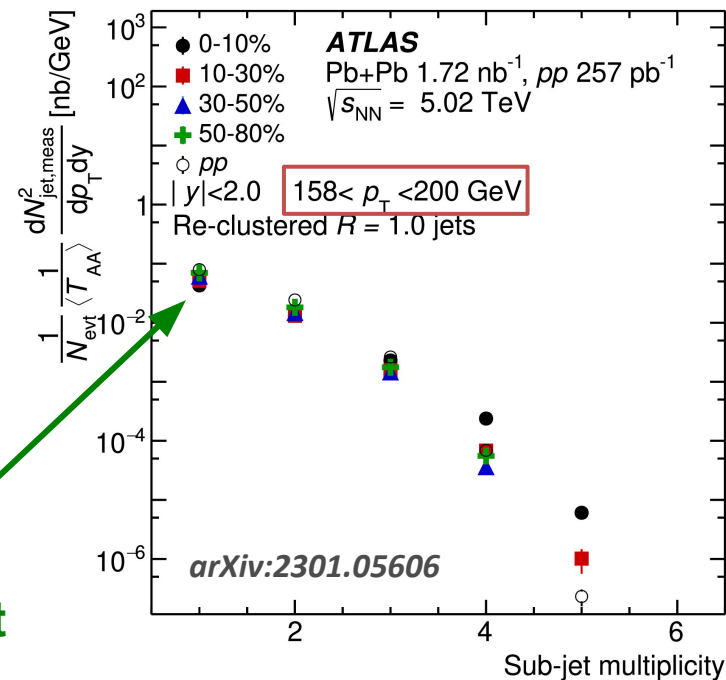
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Single sub-jet



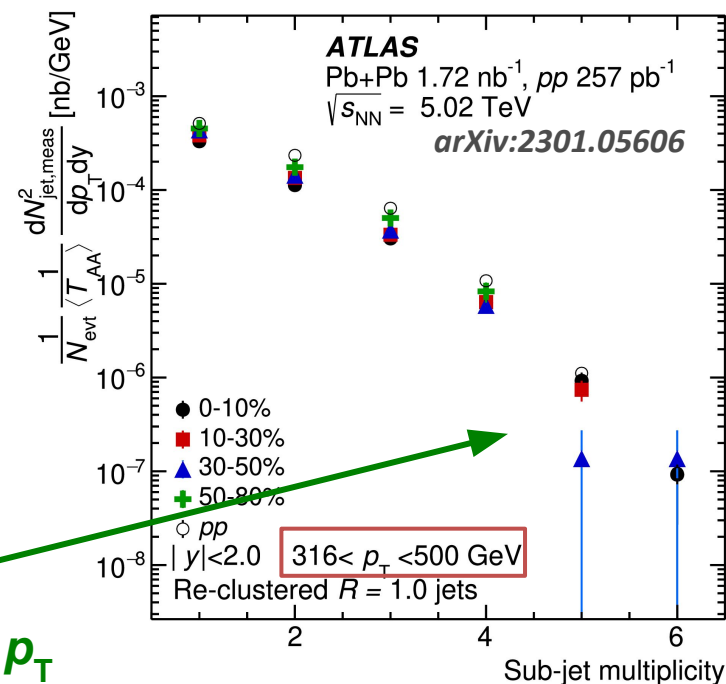
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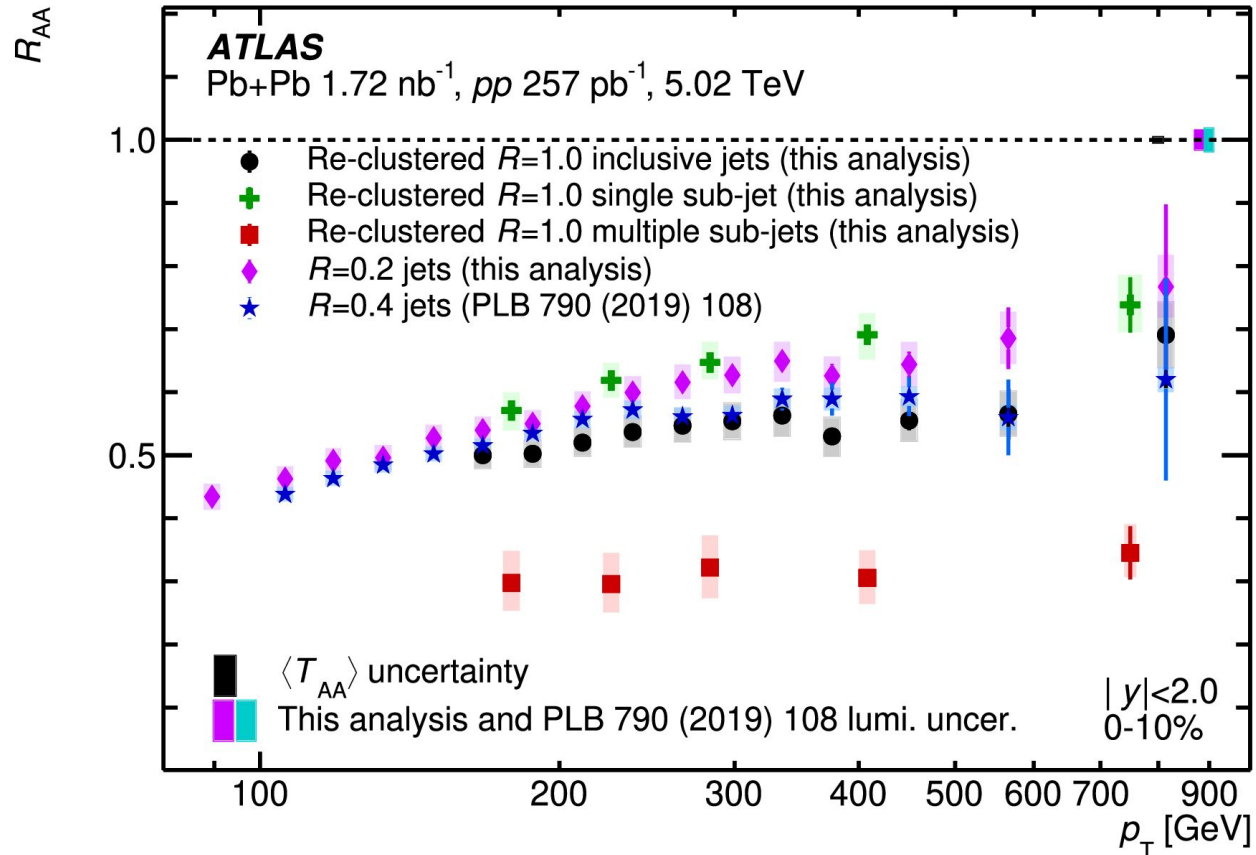
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Increasing
multiplicity with p_T

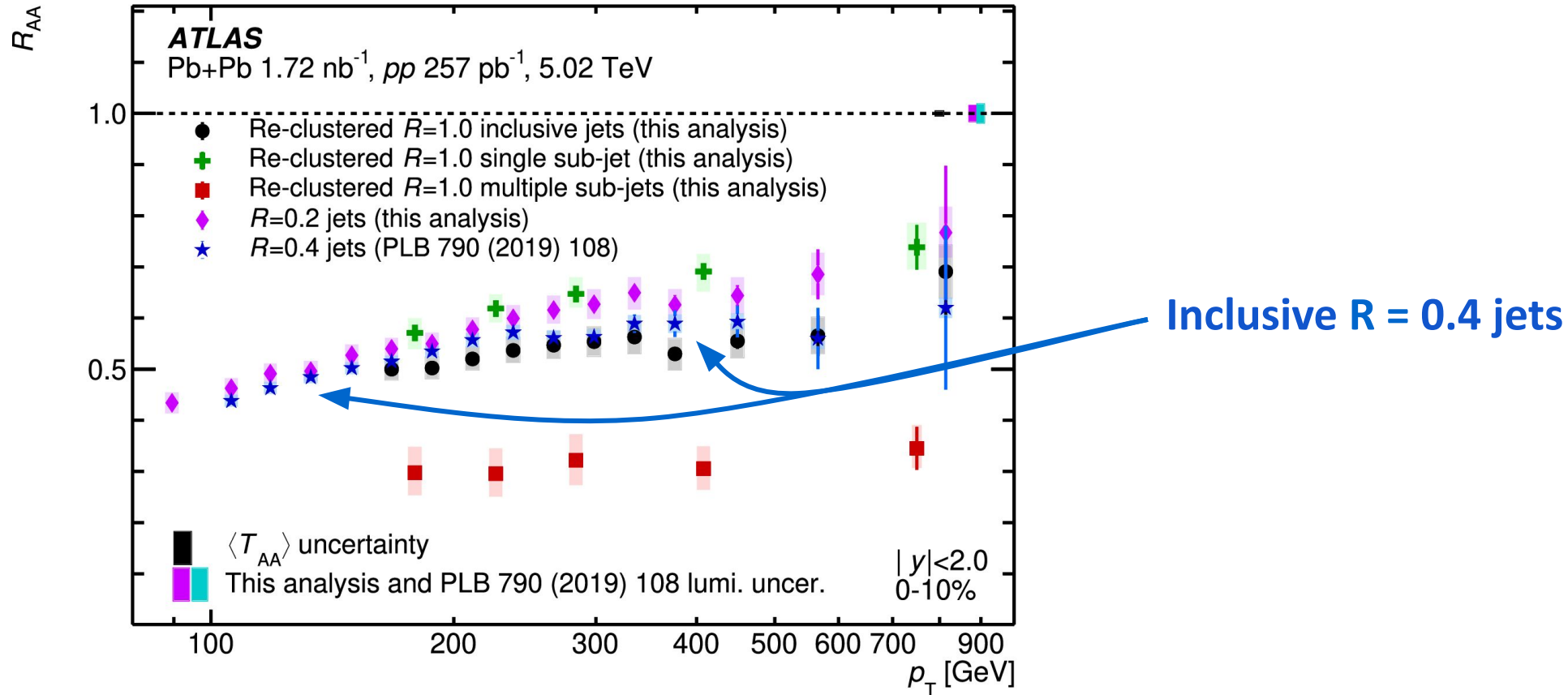
Raw sub-jet multiplicity

Jet suppression for different jet type

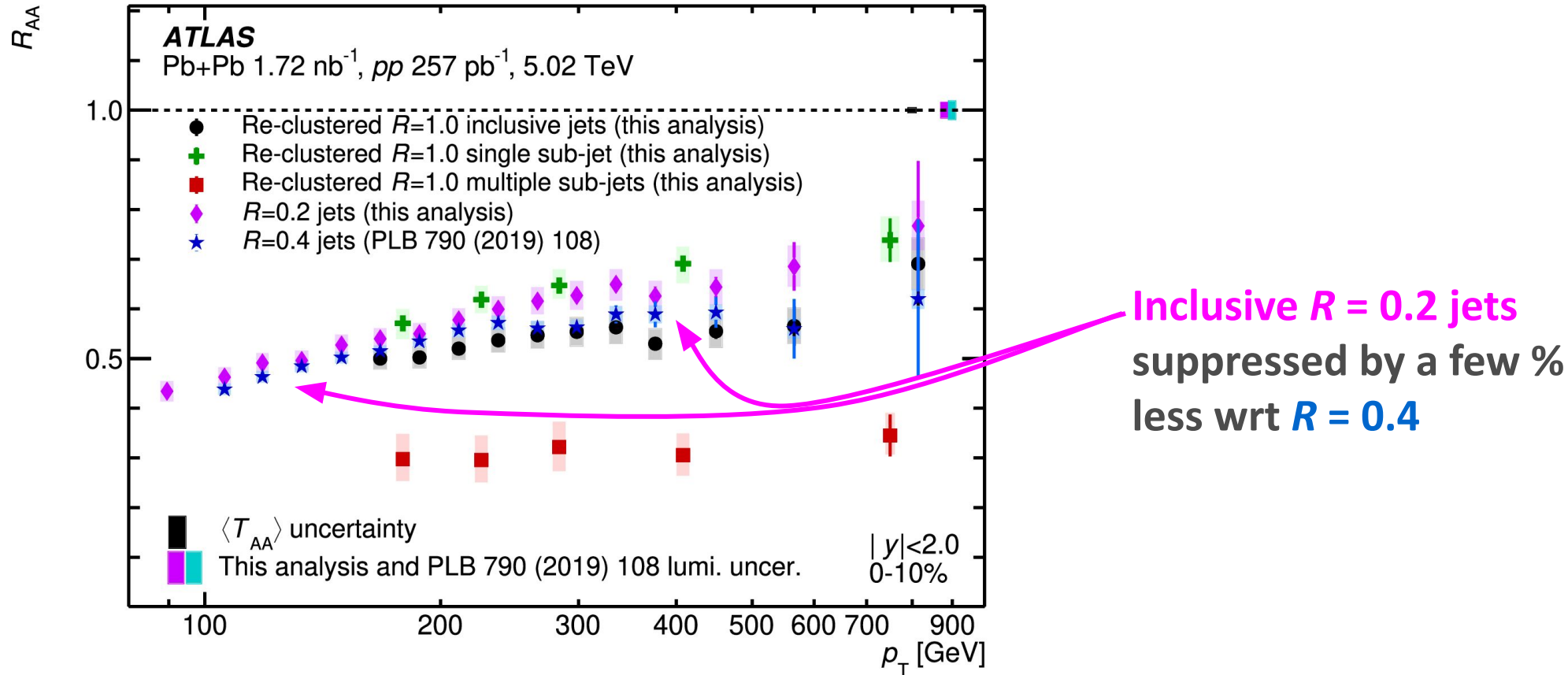


- Overall jets are suppressed in by factor ~ 2 (except red points) in central Pb+Pb.

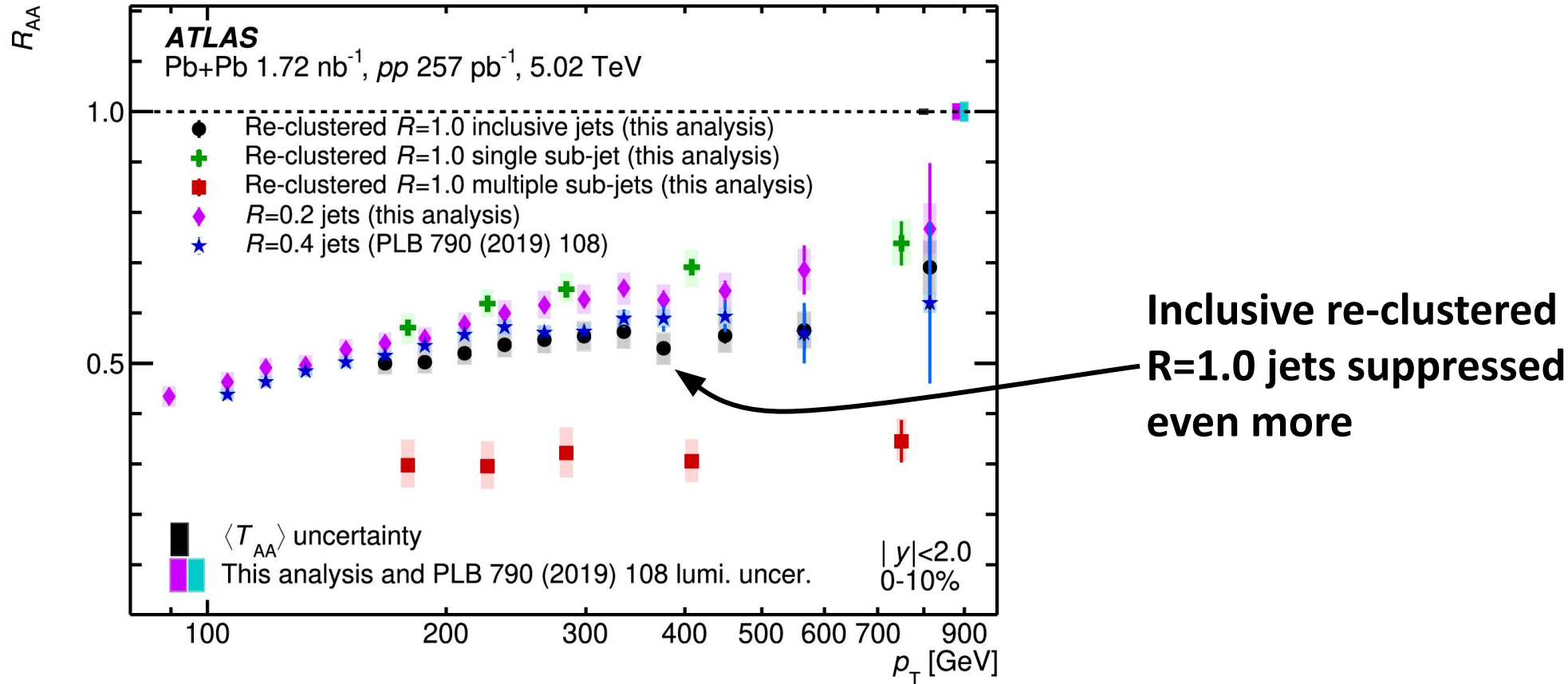
Jet suppression for different jet type



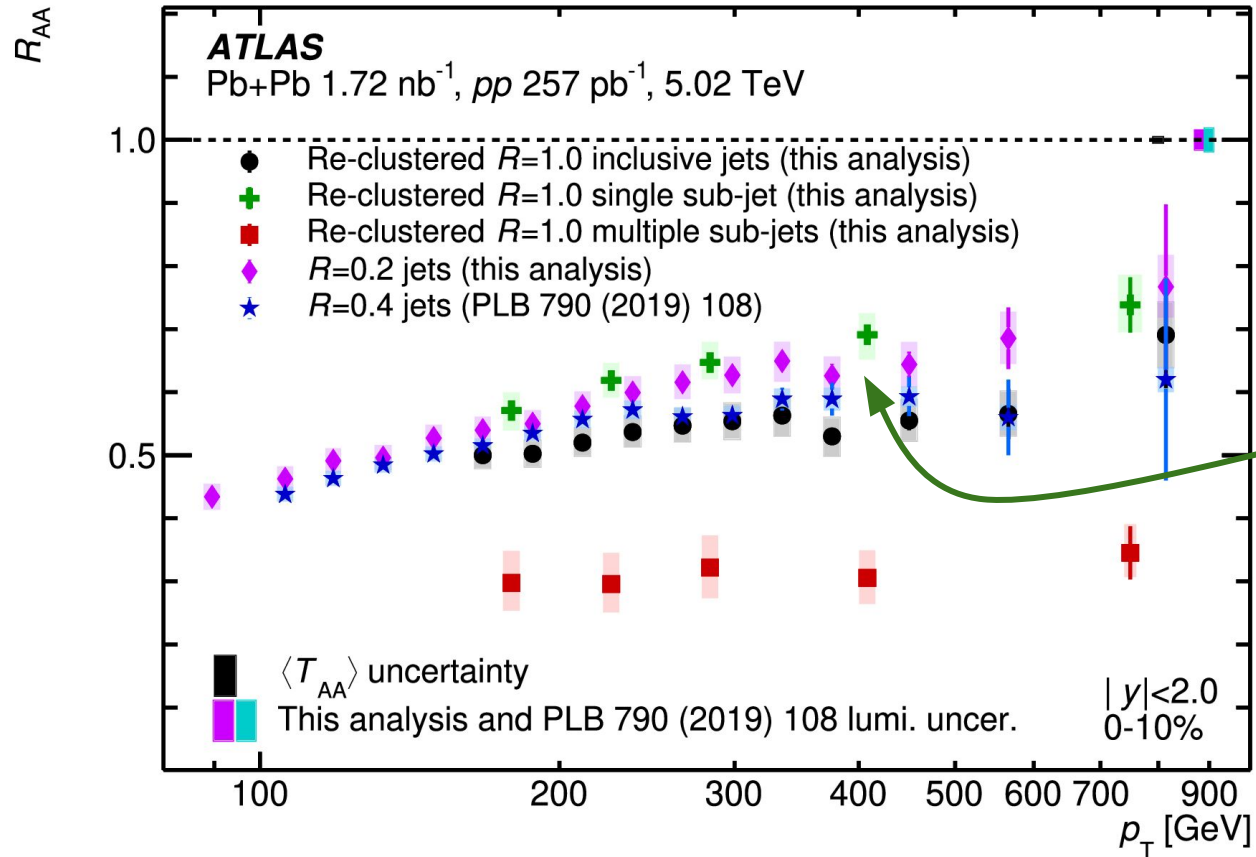
Jet suppression for different jet type



Jet suppression for different jet type

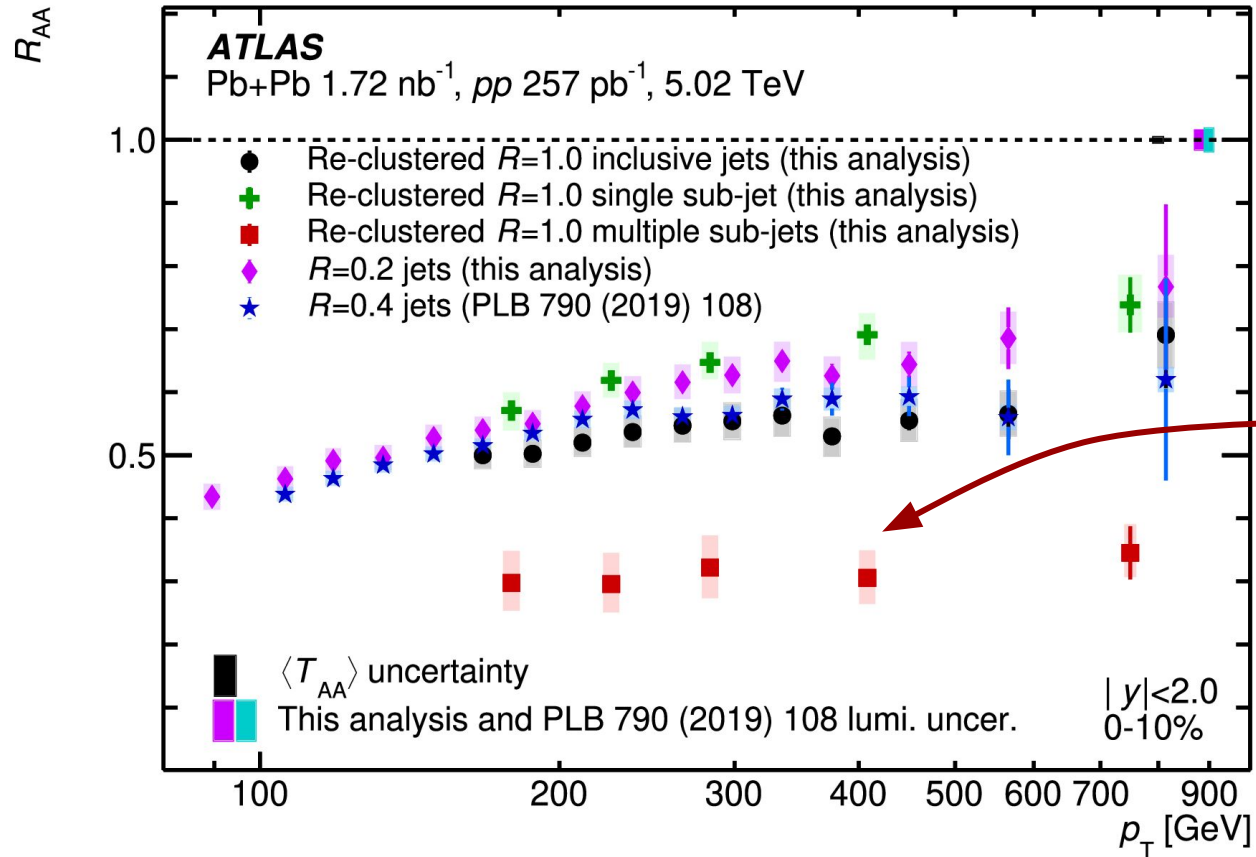


Jet suppression for different jet type



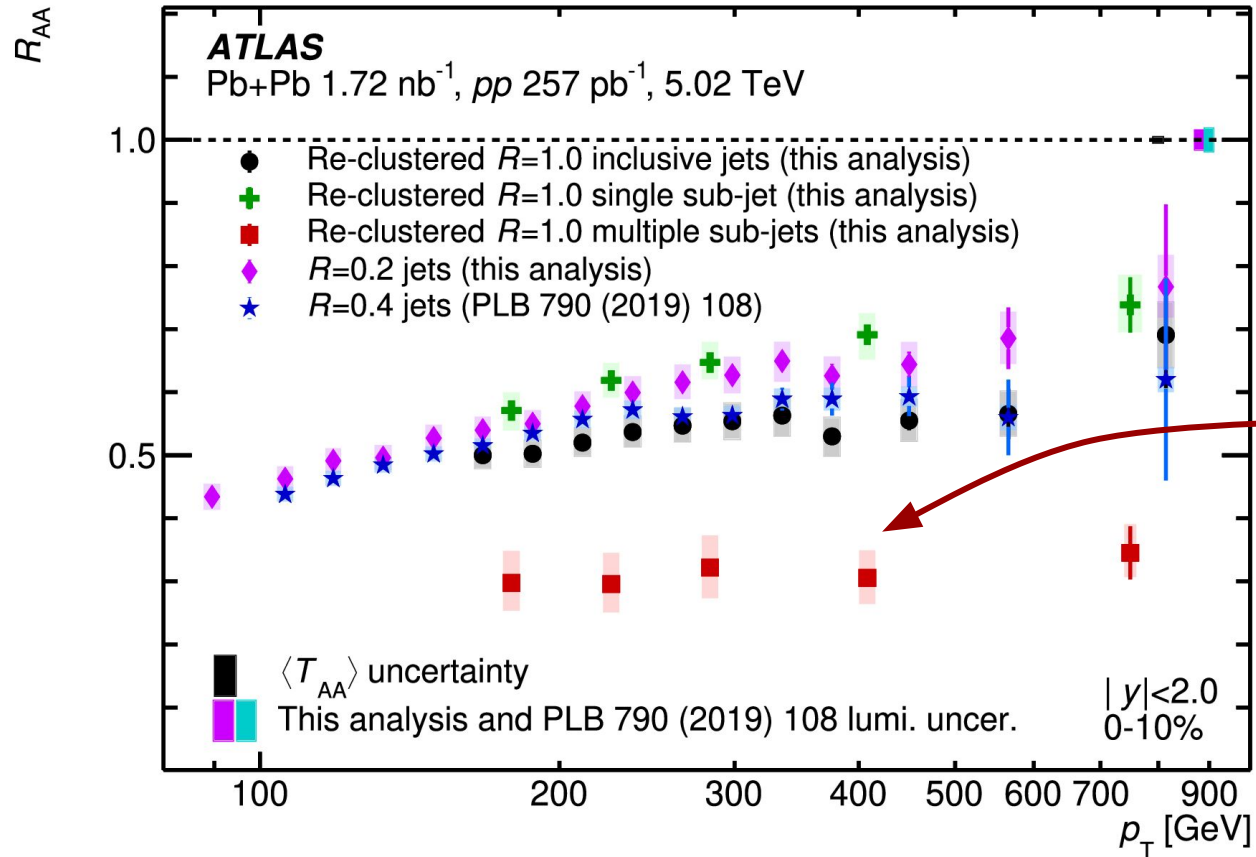
Two components:
single sub-jet $R=1.0$
suppressed the least

Jet suppression for different jet type



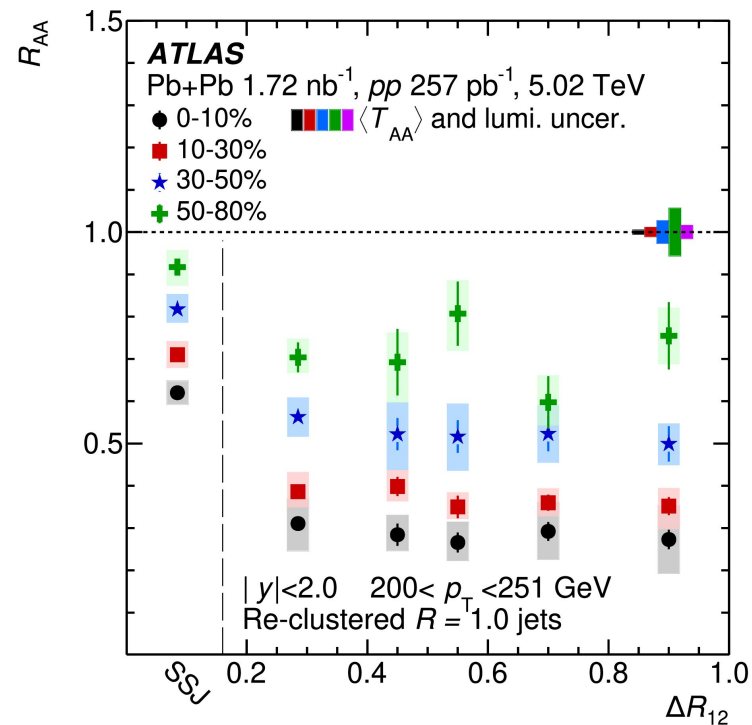
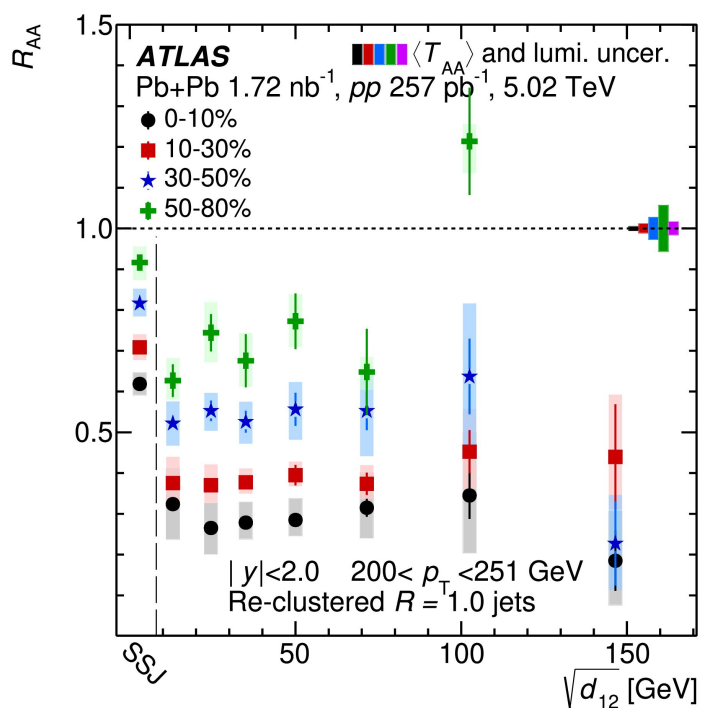
Two components:
multiple sub-jet $R=1.0$
suppressed of the largest
suppression

Jet suppression for different jet type



Two components:
multiple sub-jet $R=1.0$
flat $R_{AA} \Leftrightarrow$ increased
multiplicity with p_T &/||
different spectral shape

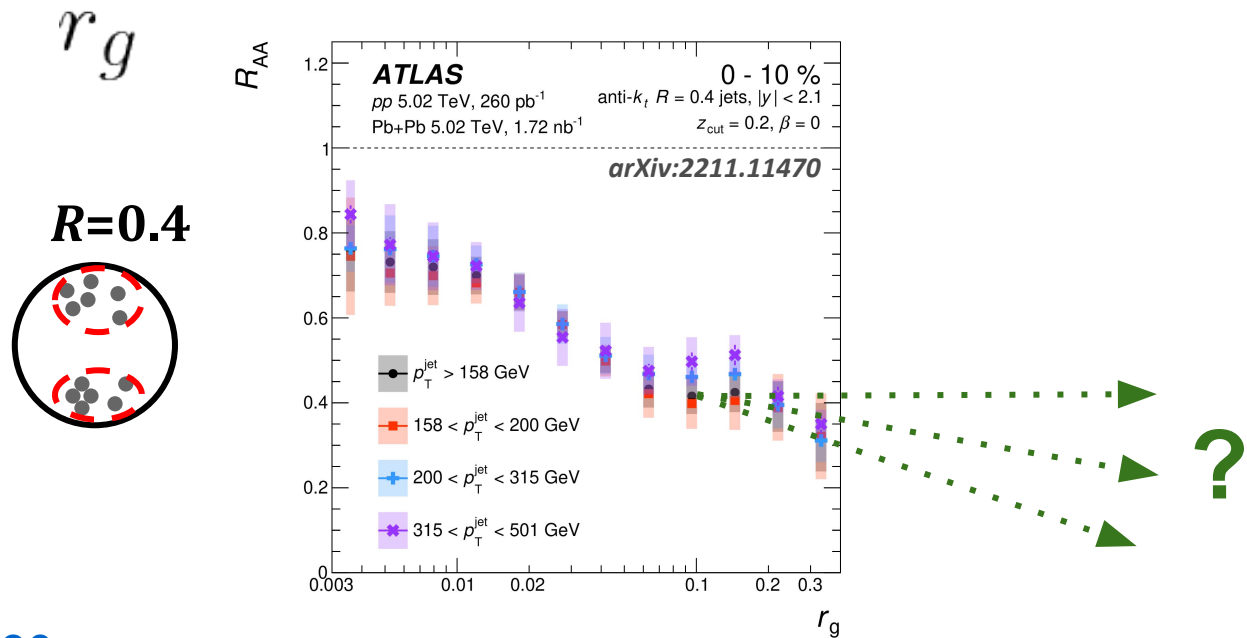
Re-clustered jets vs substructure



- The R_{AA} sharply decreases followed by flattening.
- Similar observation for suppression as function of angular separation.

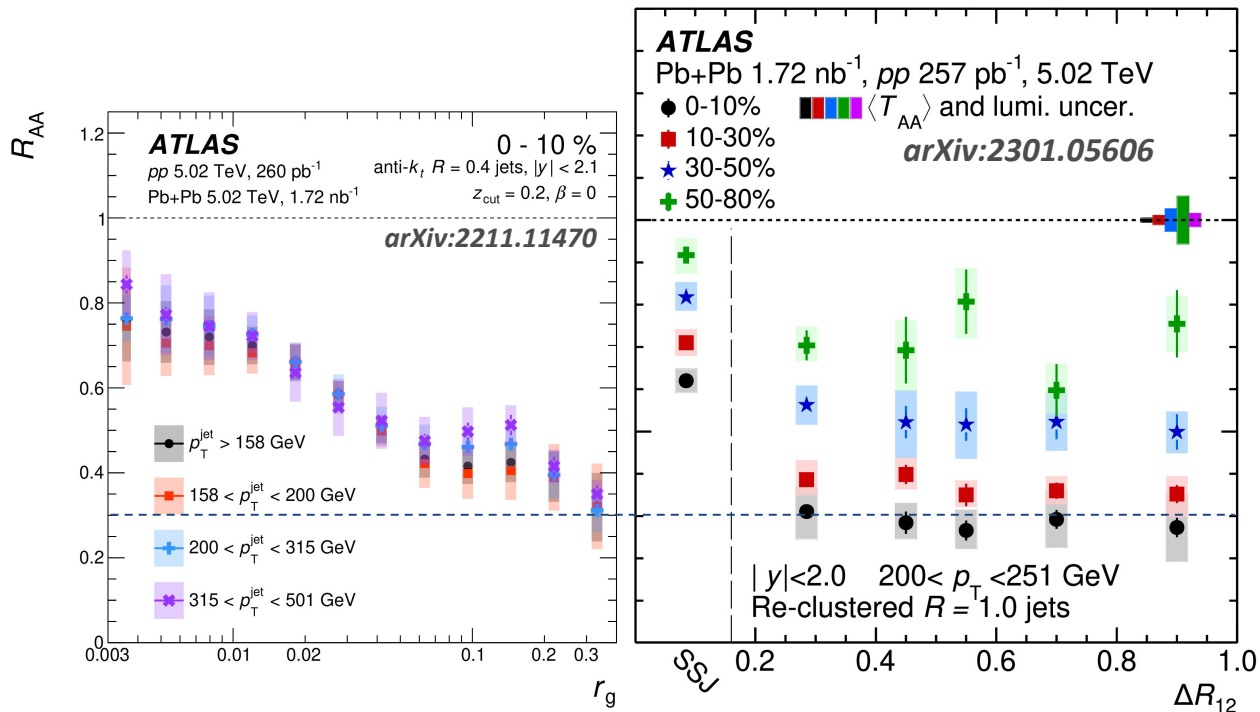
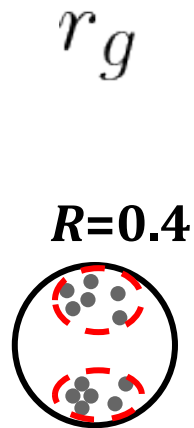
Full picture: small & large jets

- Addressing transition from color-coherence to decoherence...



Full picture: small & large jets

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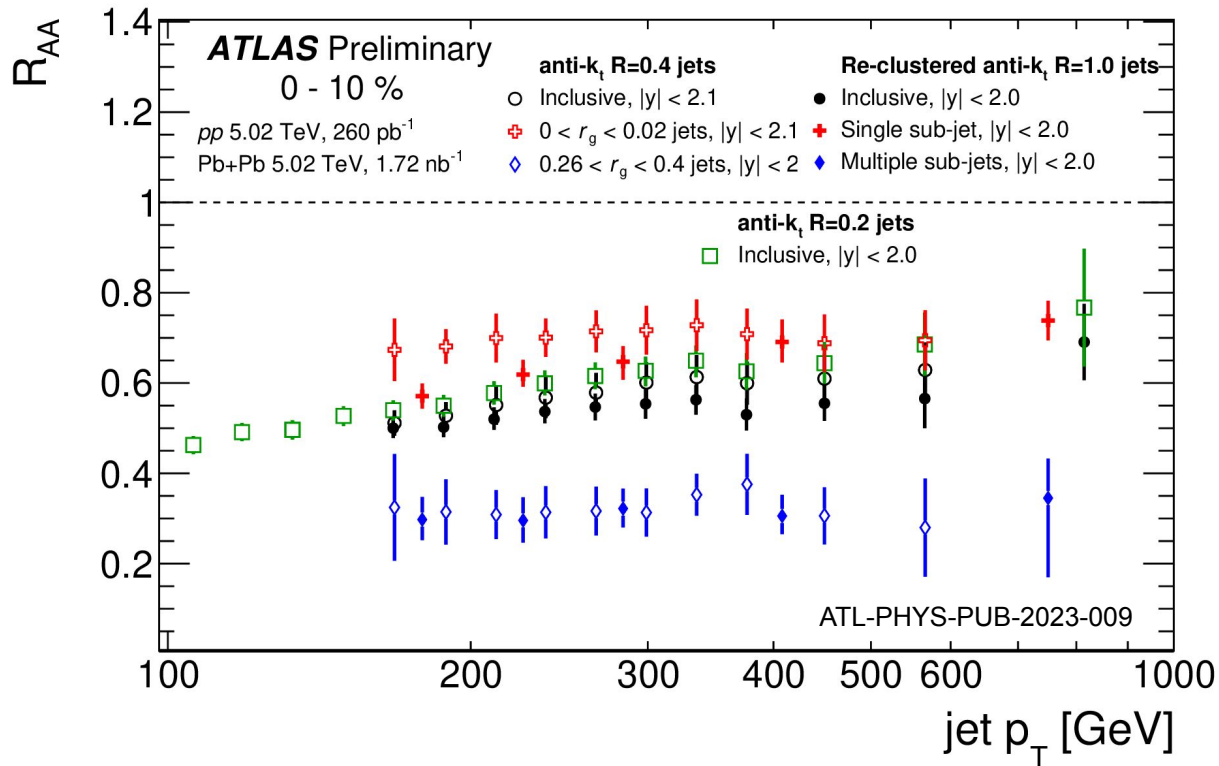


$$\Delta R_{12} = \sqrt{\Delta y_{12}^2 + \Delta \phi_{12}^2}$$

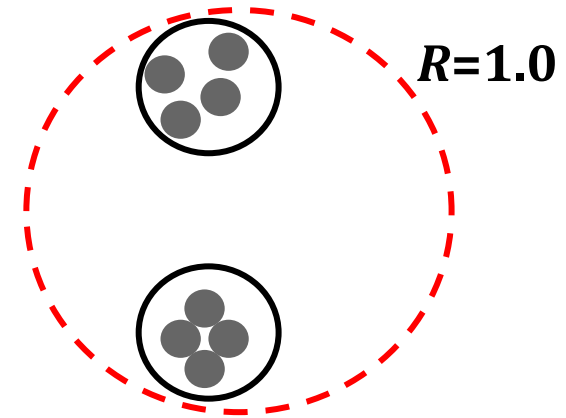
$R=1.0$

Full picture: small & large jets

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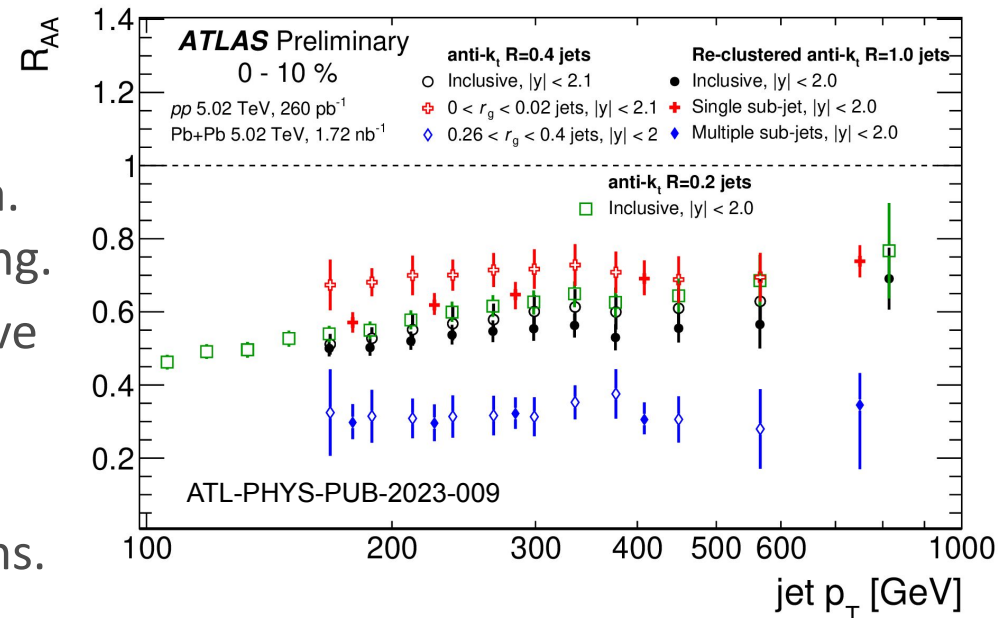


$$\Delta R_{12} = \sqrt{\Delta y_{12}^2 + \Delta \phi_{12}^2}$$



Summary

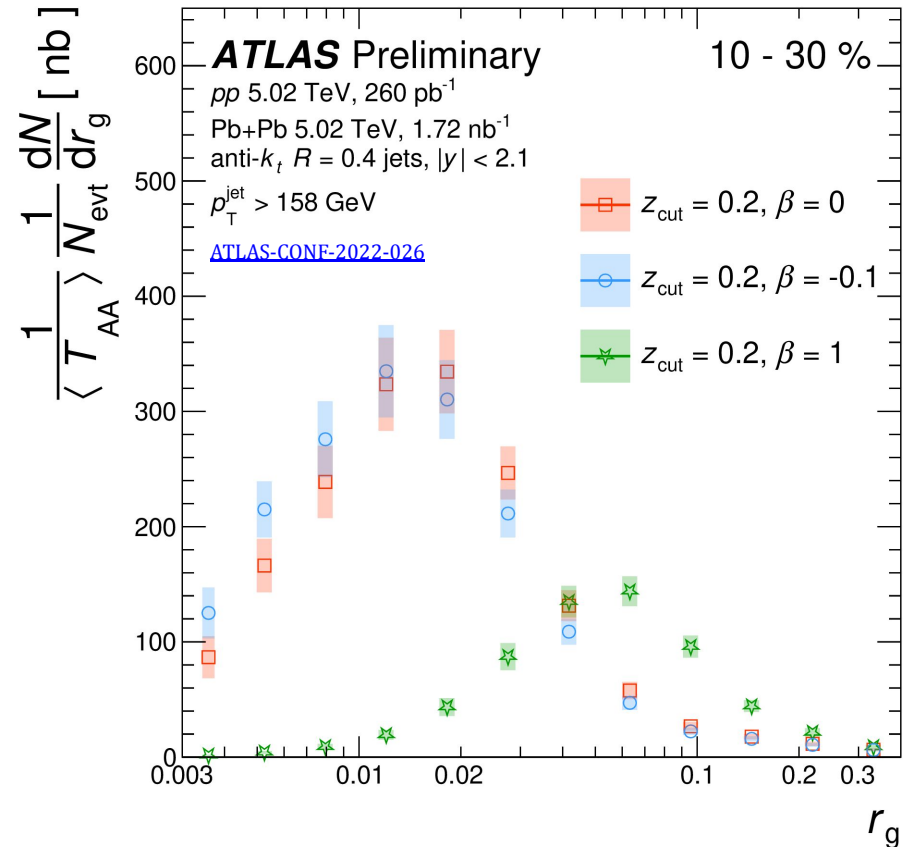
- Jet substructure in HI is a rapidly developing area
- Two new complementary measurement by ATLAS
 - Jet suppression depends significantly on jet substructure.
 - Probing role on angular scale from distance 0.003 up to 1.0 \Leftrightarrow should help addressing color coherence phenomena.
 - Testing role of p_T scale of hardest splitting.
 - Addresses the p_T dependence of inclusive suppression.
 - Run 3 data should allow similar measurements in photon-tagged systems.
- All data including yields & cross-section are [available](#).



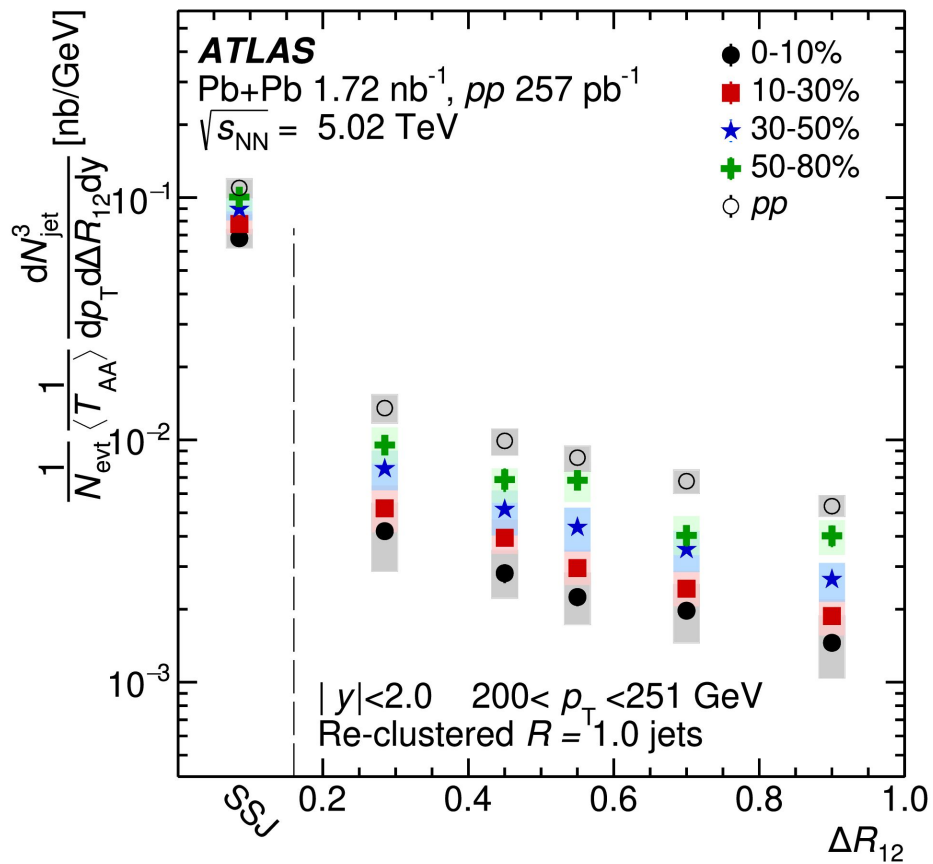
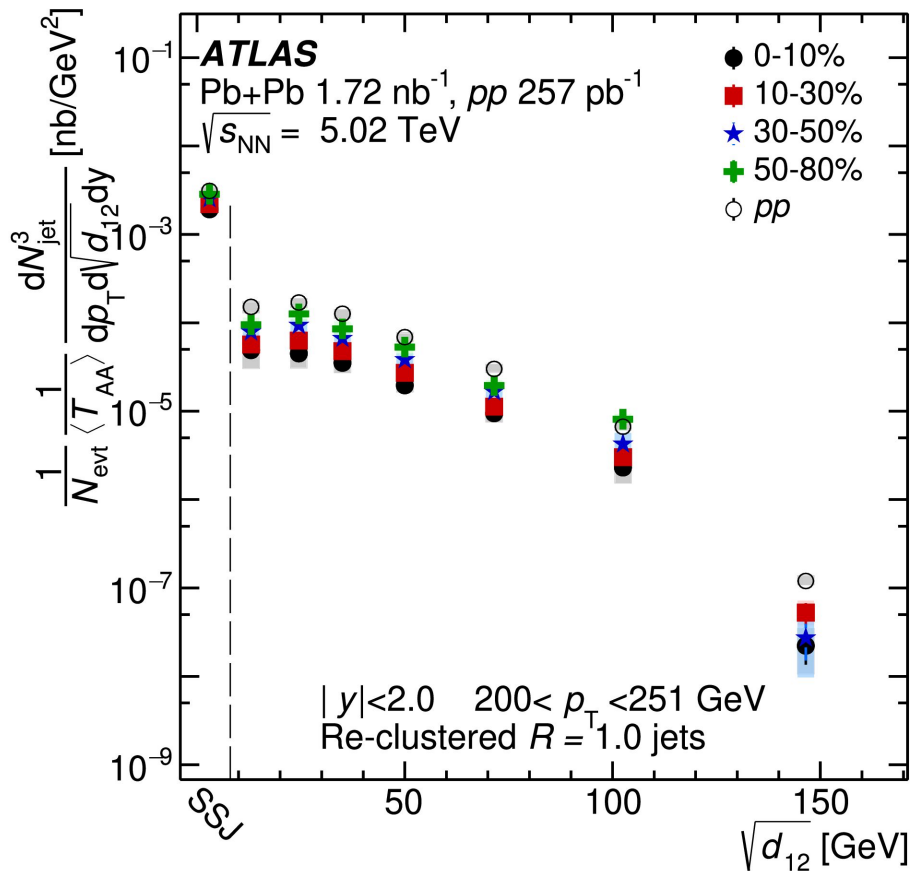
Backup

Challenges in jet structure measurements

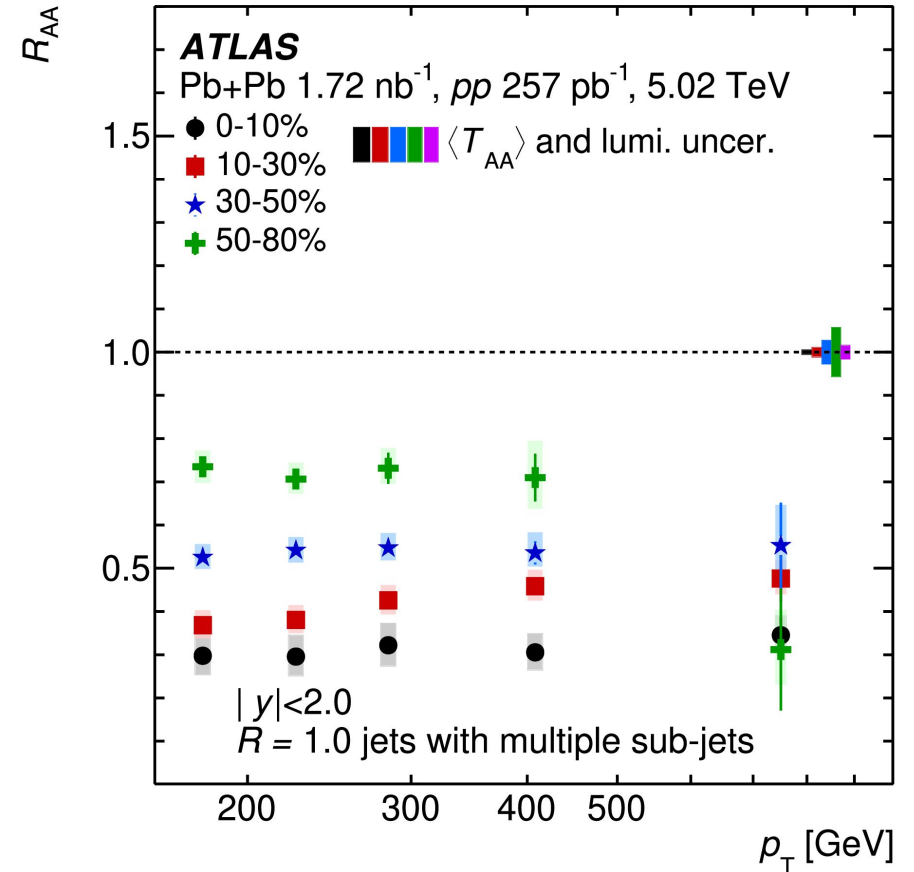
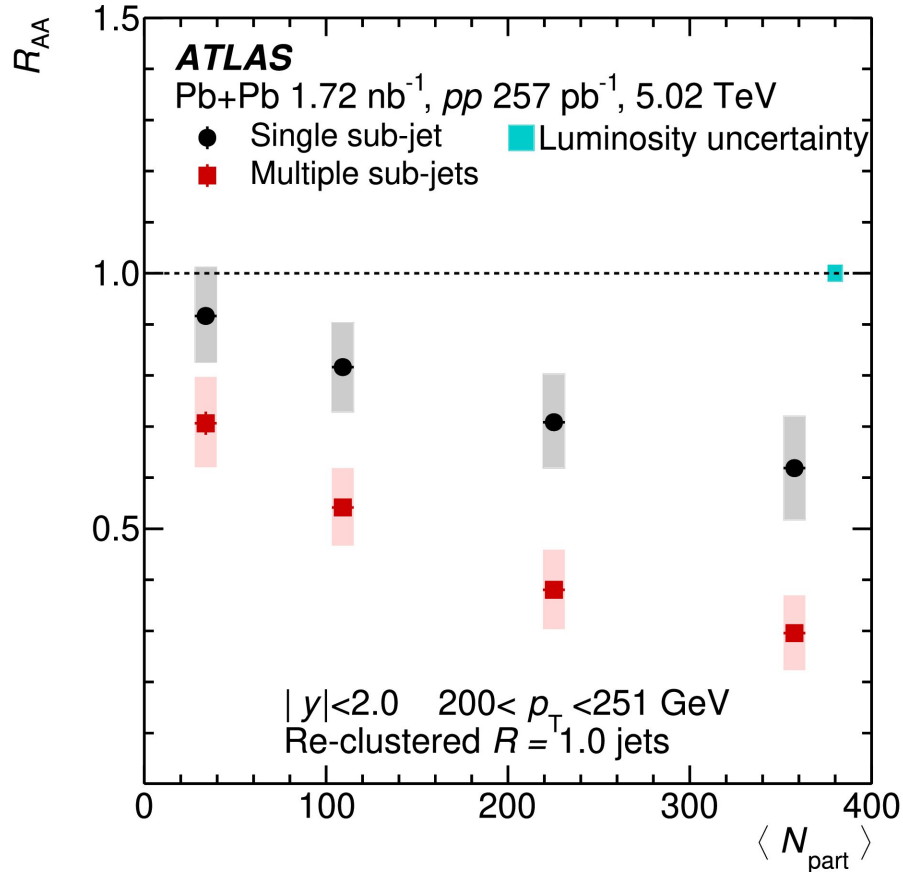
- Push towards larger phase space: lower energy and various/larger radius.
- Large UE contribution from soft particles.
- Combinatorial background from independent hard scatterings.
- For calorimetric measurement:
 - Jet energy calibration and uncertainties for every new jet “collection”.... different radius, subjects, and constituents.
- Role of ISR@FSR
- Choice of setting in grooming...
 - Sensitive to modeling and subtraction.
 - Need to understand biases we introduce.



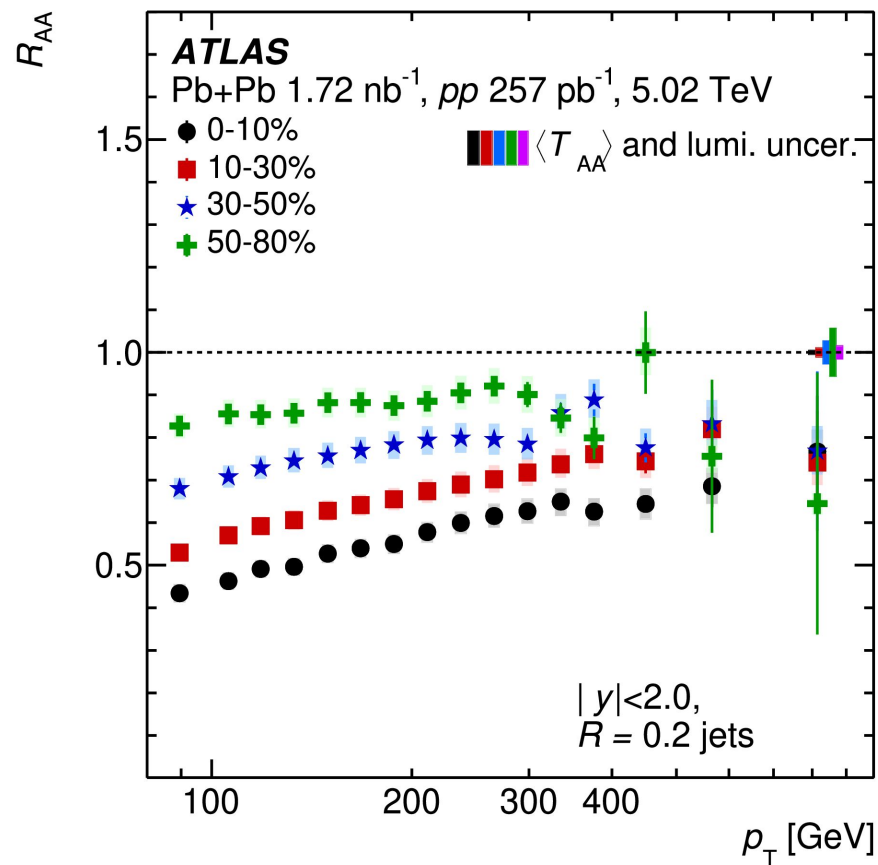
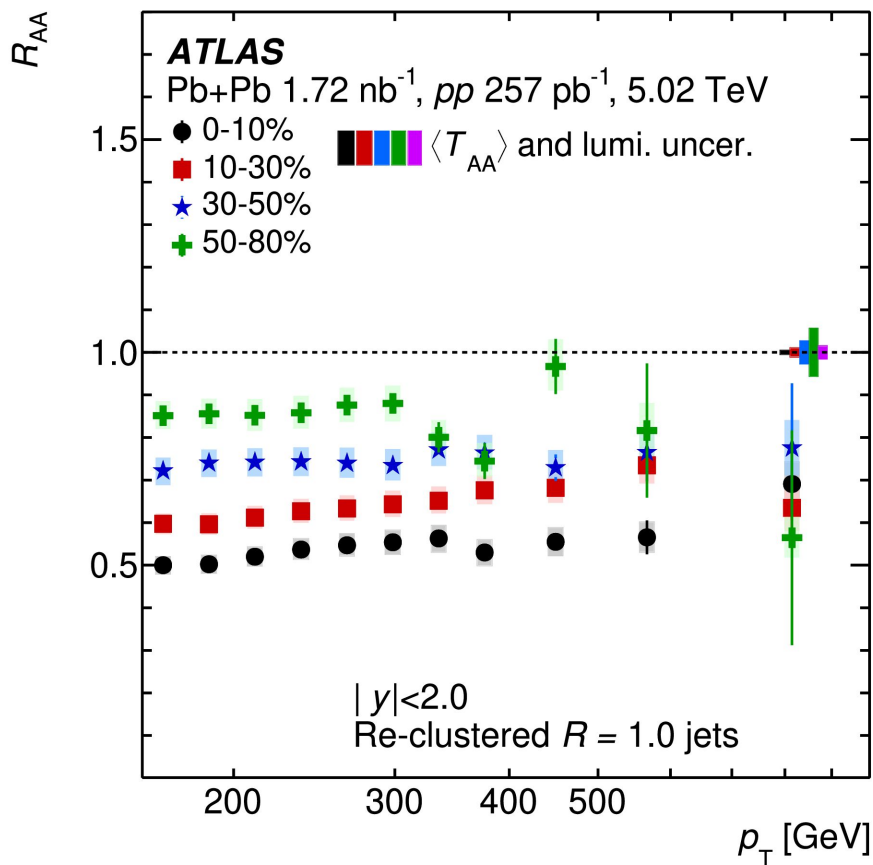
Splitting scale



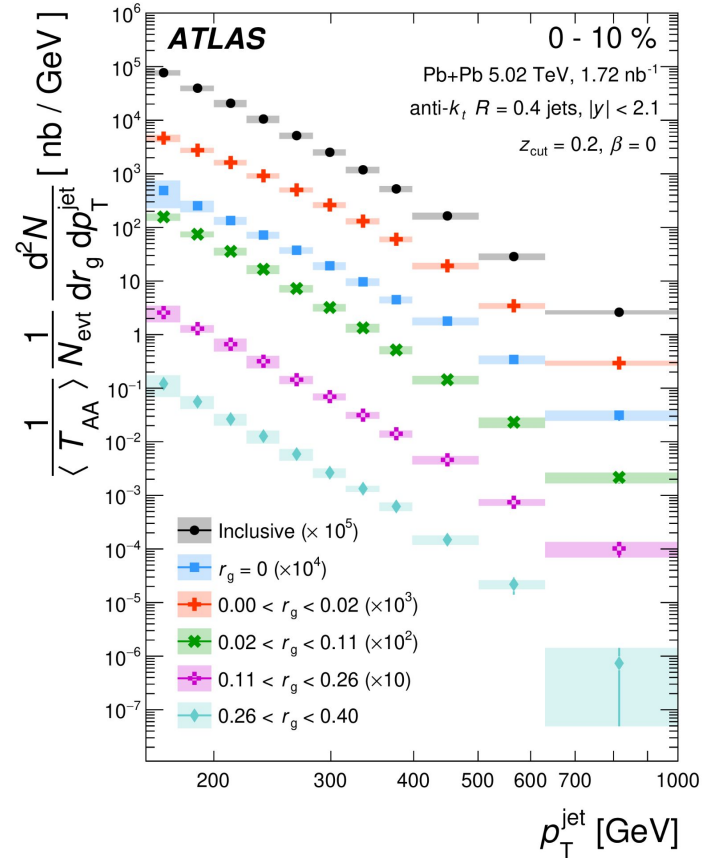
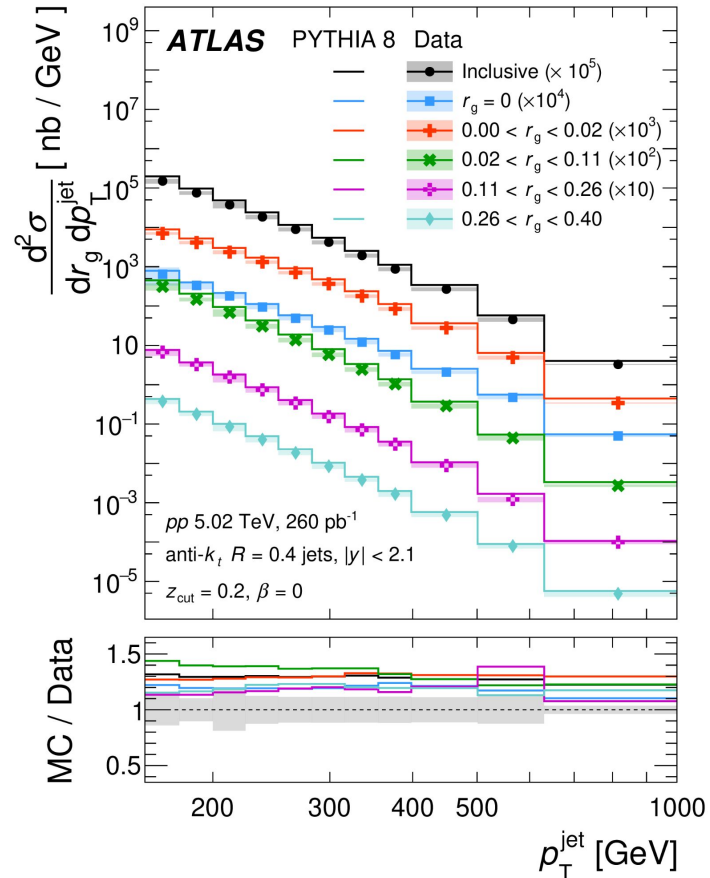
Clustered large-R jet RAA



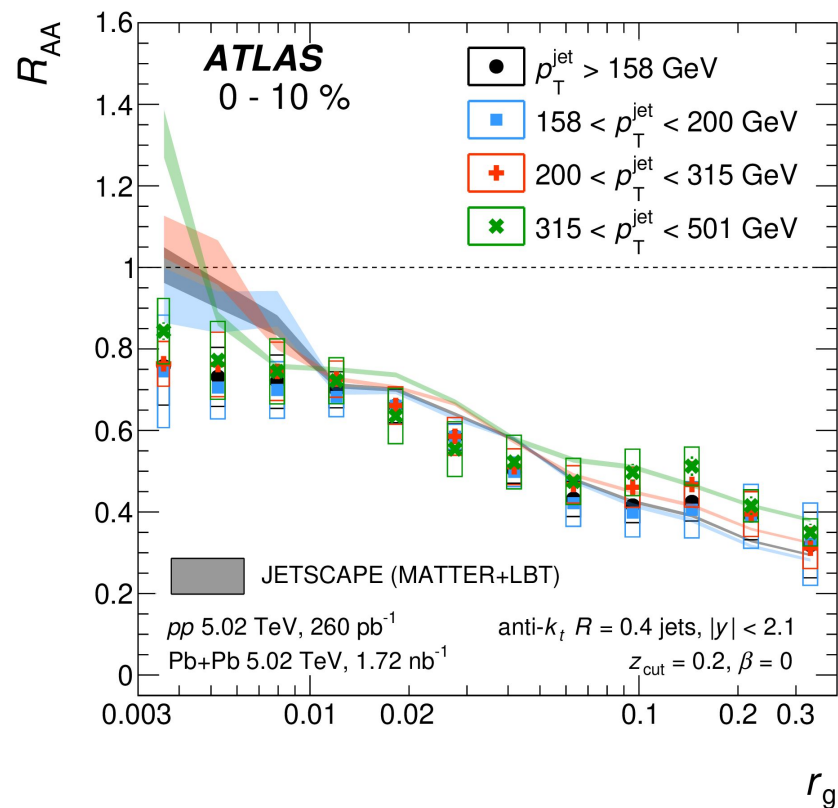
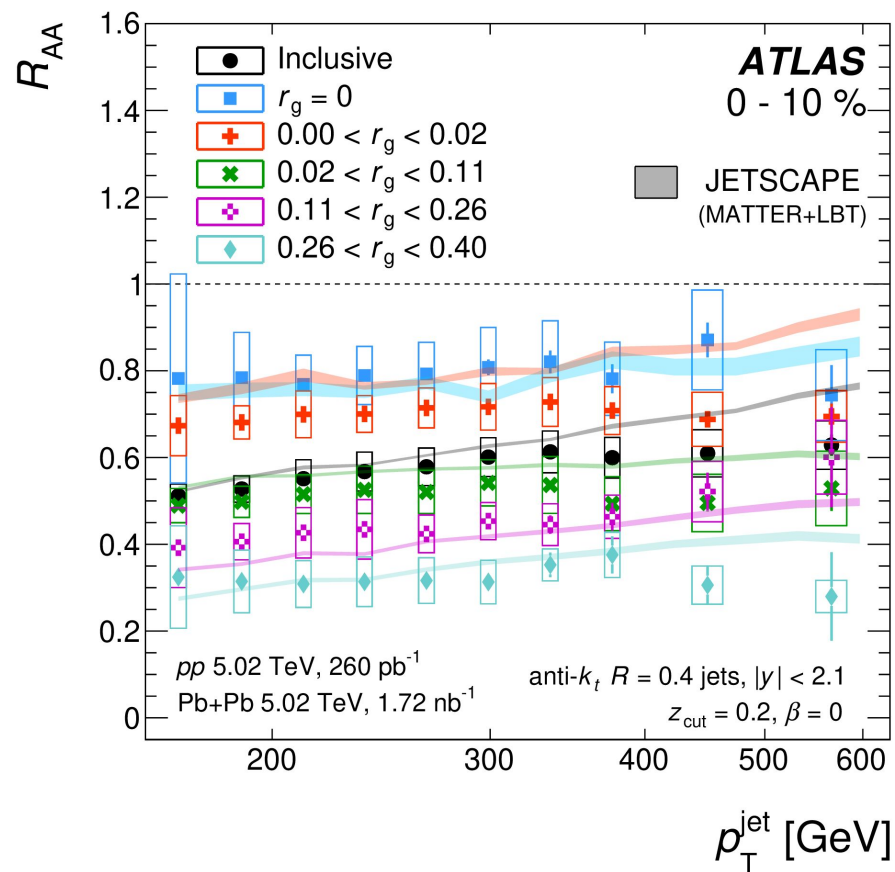
Inclusive je RAA



Additional material



Additional material



Additional material

