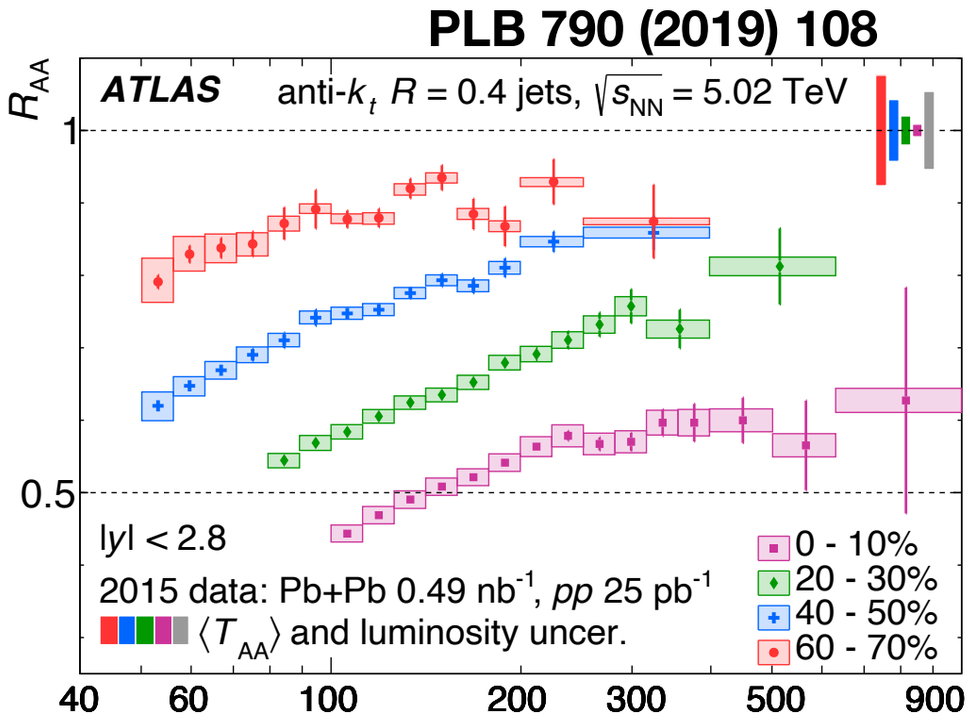
Measurement of jet structure and substructure in heavy ion collisions with ATLAS

Anne M. Sickles, for the ATLAS Collaboration

June 3, 2020

why study jet structure and sub-structure

- measure modifications of jet structure due to interactions with the QGP
  - include energy loss and medium response
- do jets with different structure lose energy differently?



experimentally

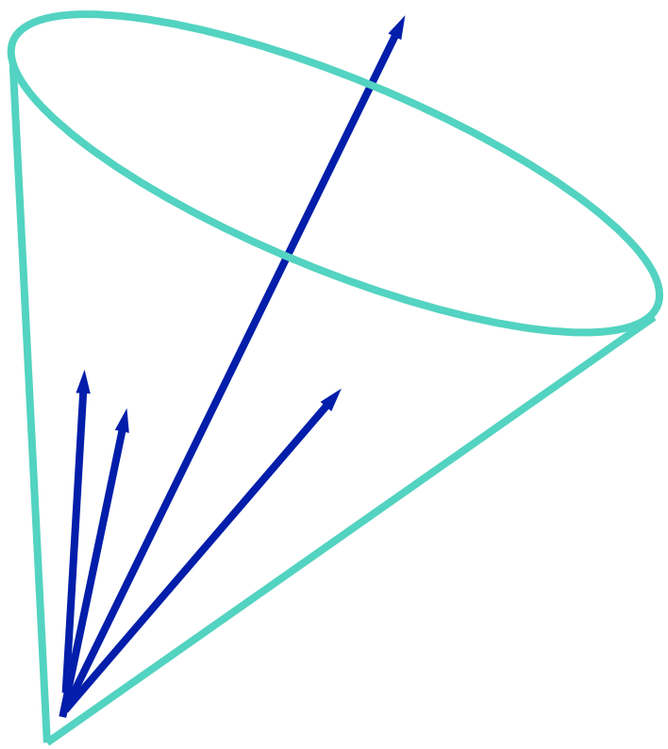
- detailed investigations of "standard" R = 0.4 jets
- measure the suppression of jets as a function of their structure

jet fragmentation

how do the particles in the jet carry its momentum?

$$D(z) \equiv \frac{1}{N_{\mathrm{jet}}} \frac{\mathrm{d}N_{\mathrm{ch}}}{\mathrm{d}z} \qquad D(p_{\mathrm{T}}) \equiv \frac{1}{N_{\mathrm{jet}}} \frac{dn_{\mathrm{ch}}}{dp_{\mathrm{T}}}$$

$$z \equiv p_{\mathrm{T}} \cos \Delta R \; / \; p_{\mathrm{T}}^{\mathrm{jet}}$$

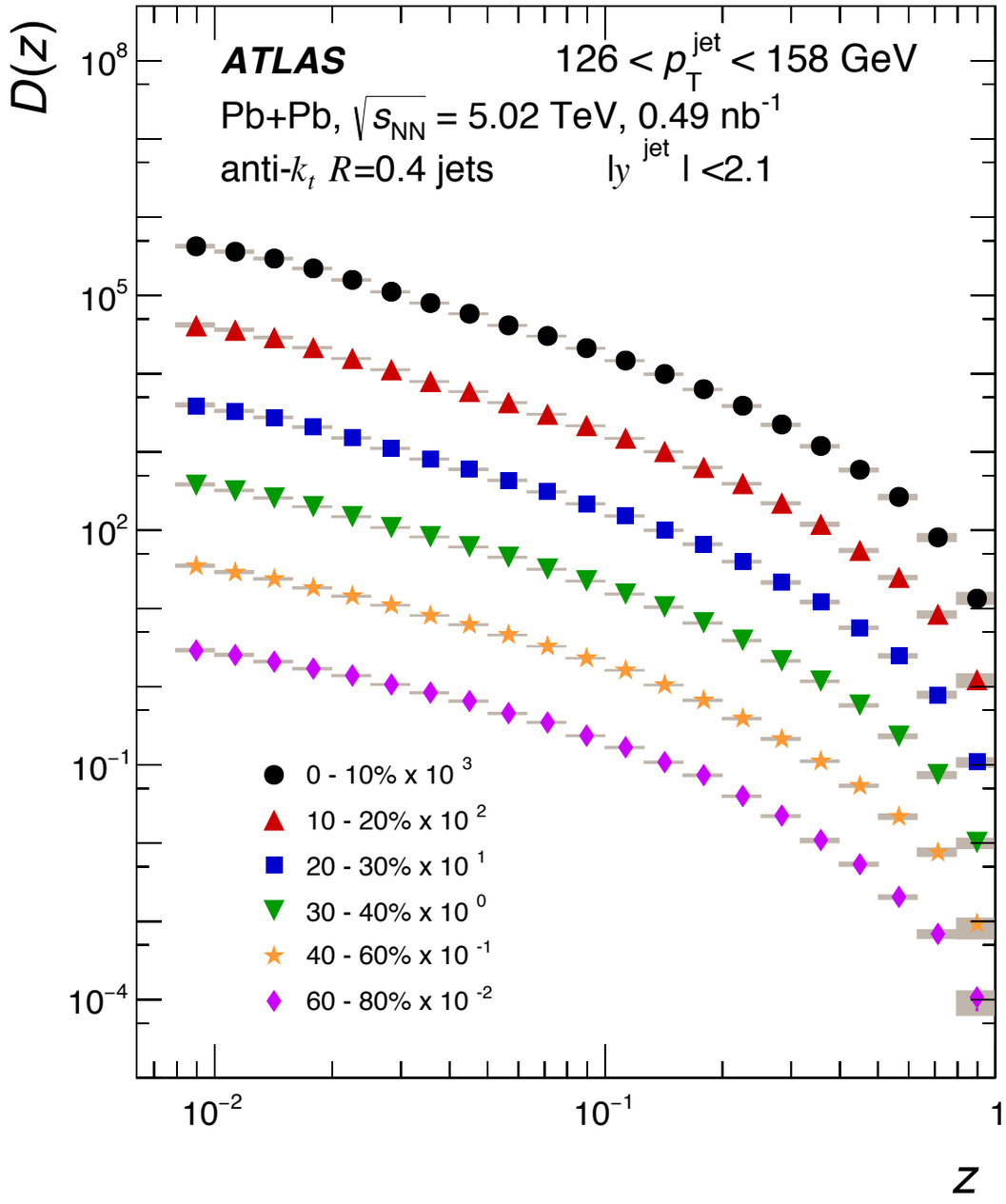


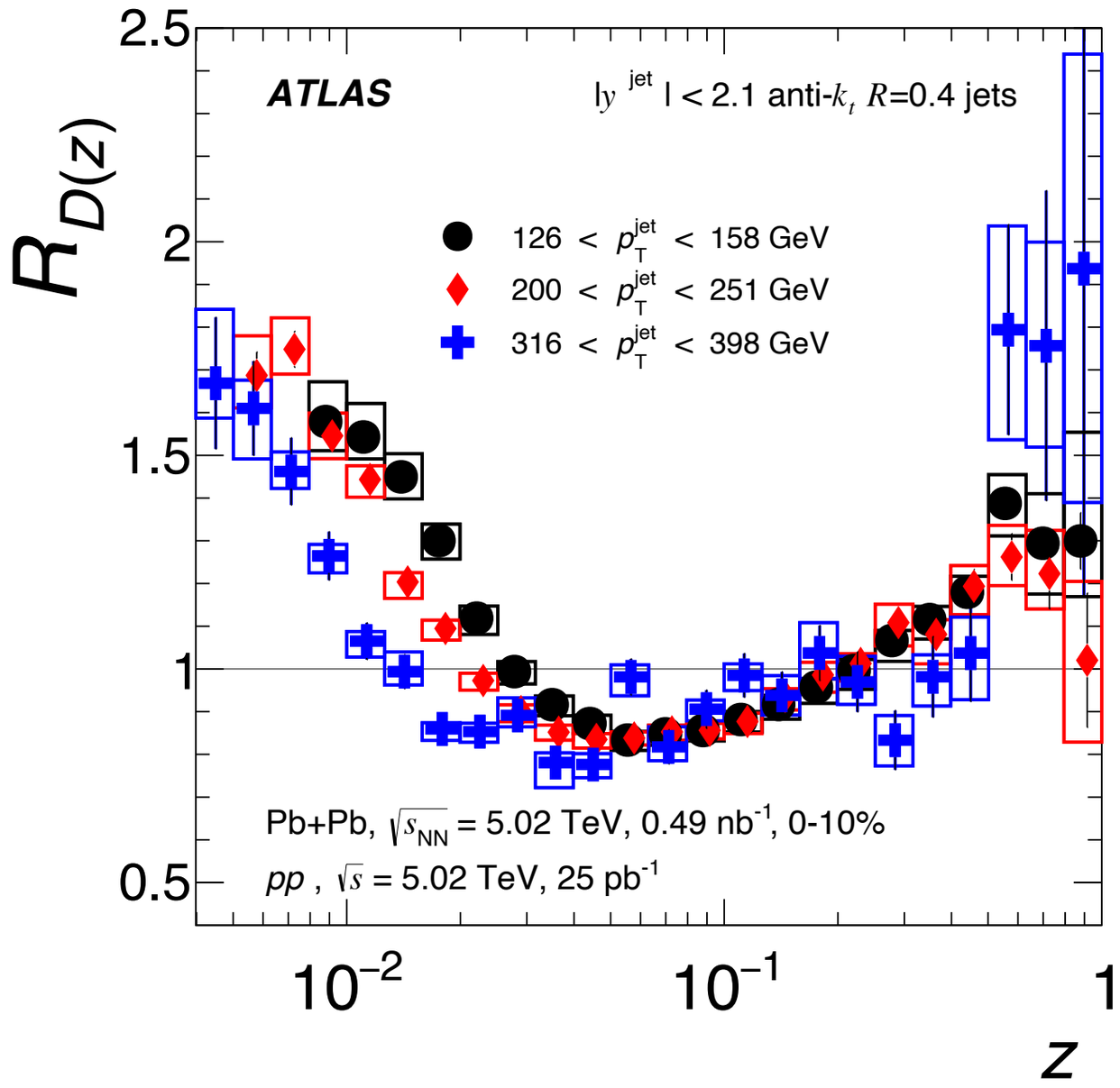
fragmentation functions in PbPb collisions

same quantity in PbPb collisions

after the jets have lost energy

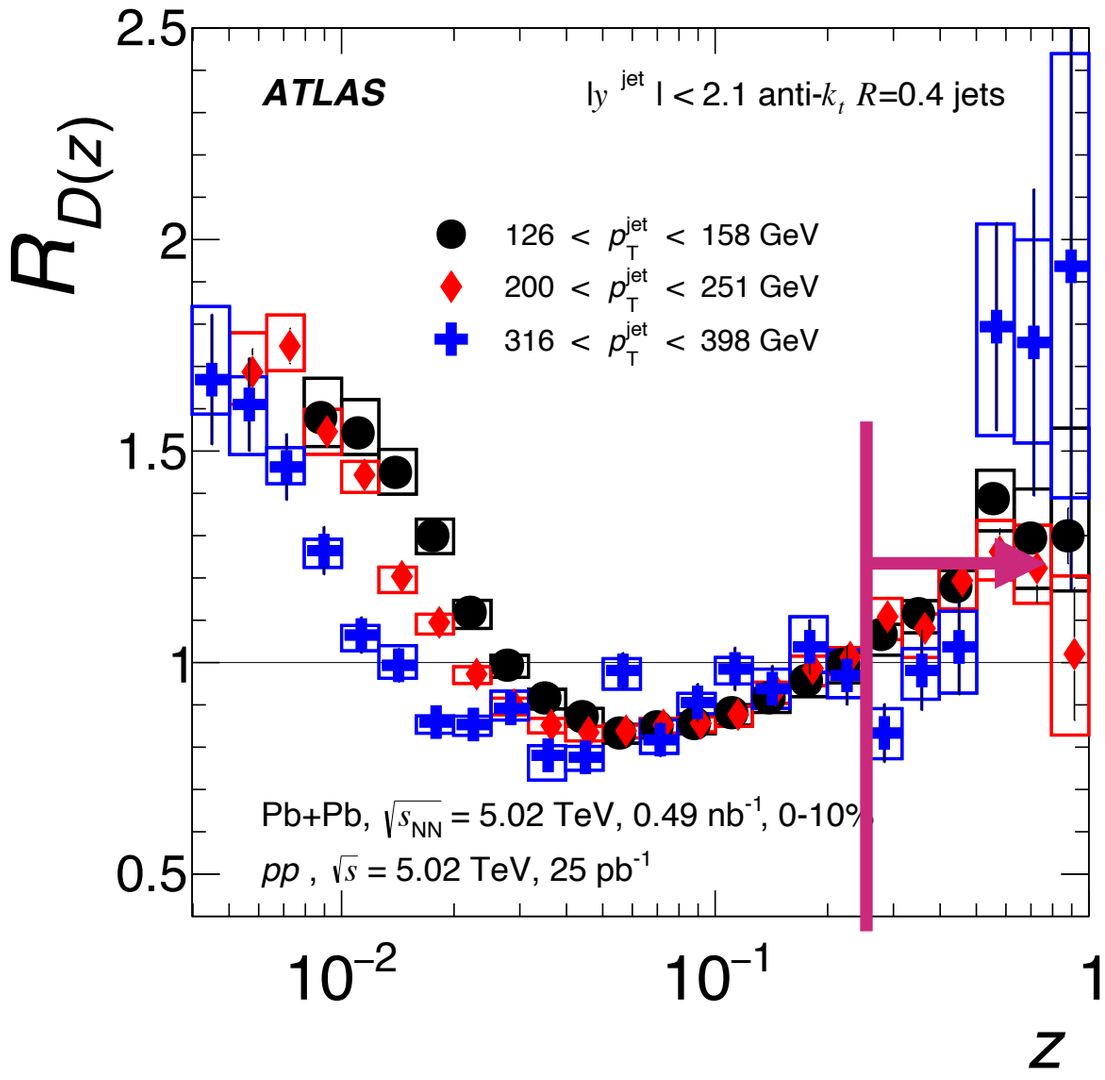
$$R_{D(z)} \equiv \frac{D(z)_{\mathrm{PbPb}}}{D(z)_{pp}}$$



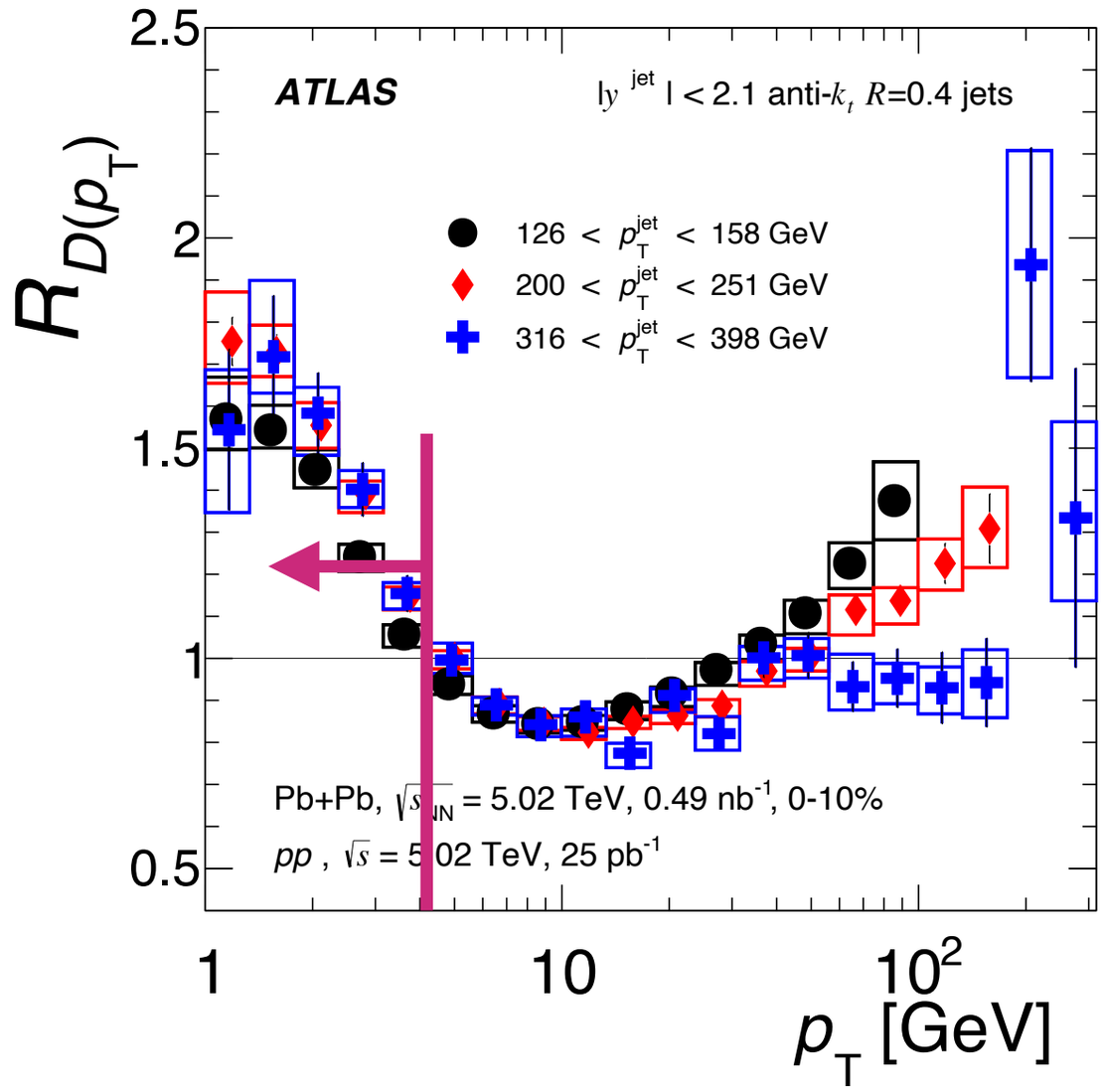


PRC98 (2018) 024908

fragmentation functions in z & p_T



high z scaling:
related to fragmentation?



low p_T scaling:
QGP scale?

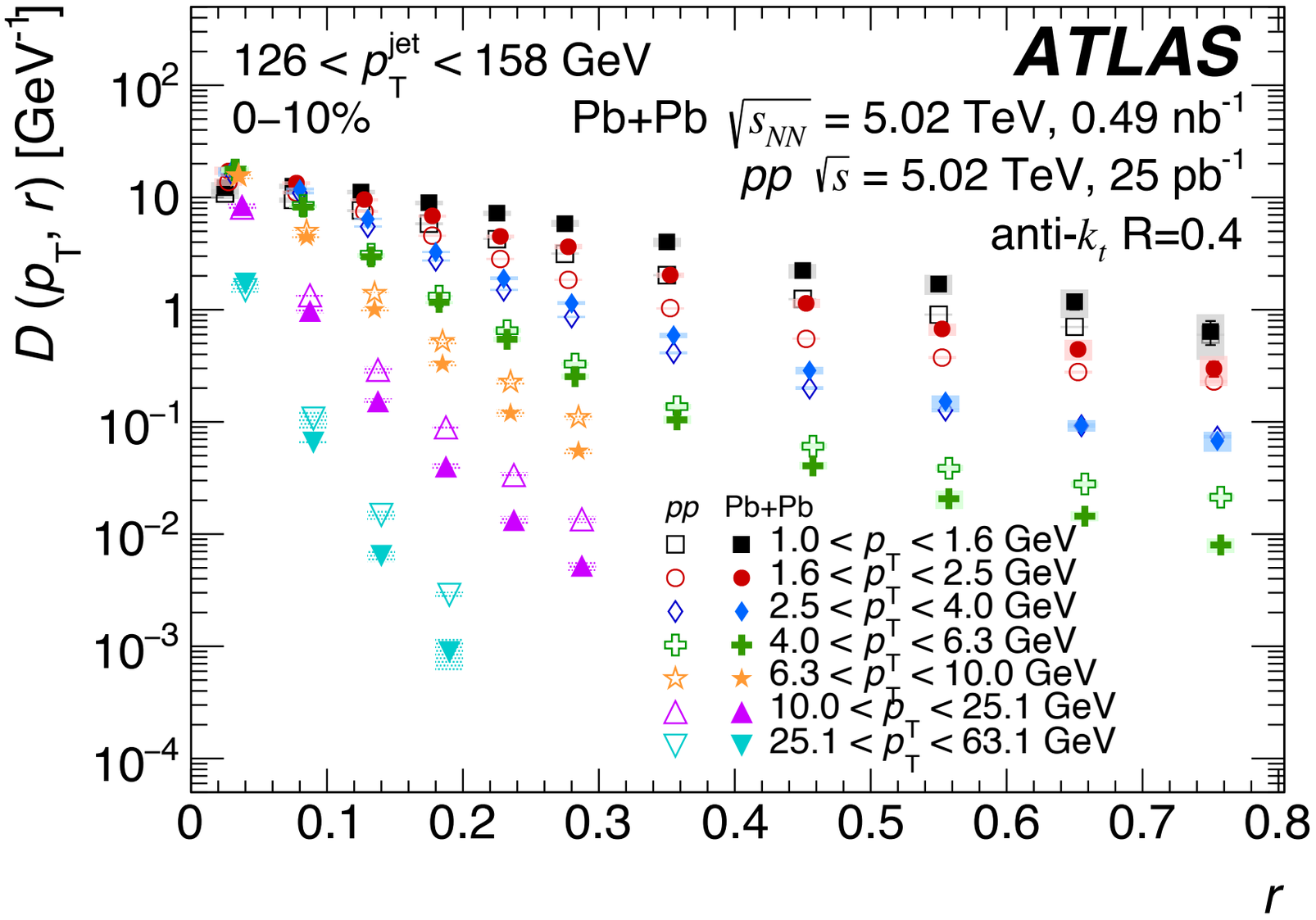
where are these particles wrt jet axis?

PRC98 (2018) 024908

angular and momentum dependence of jet particles

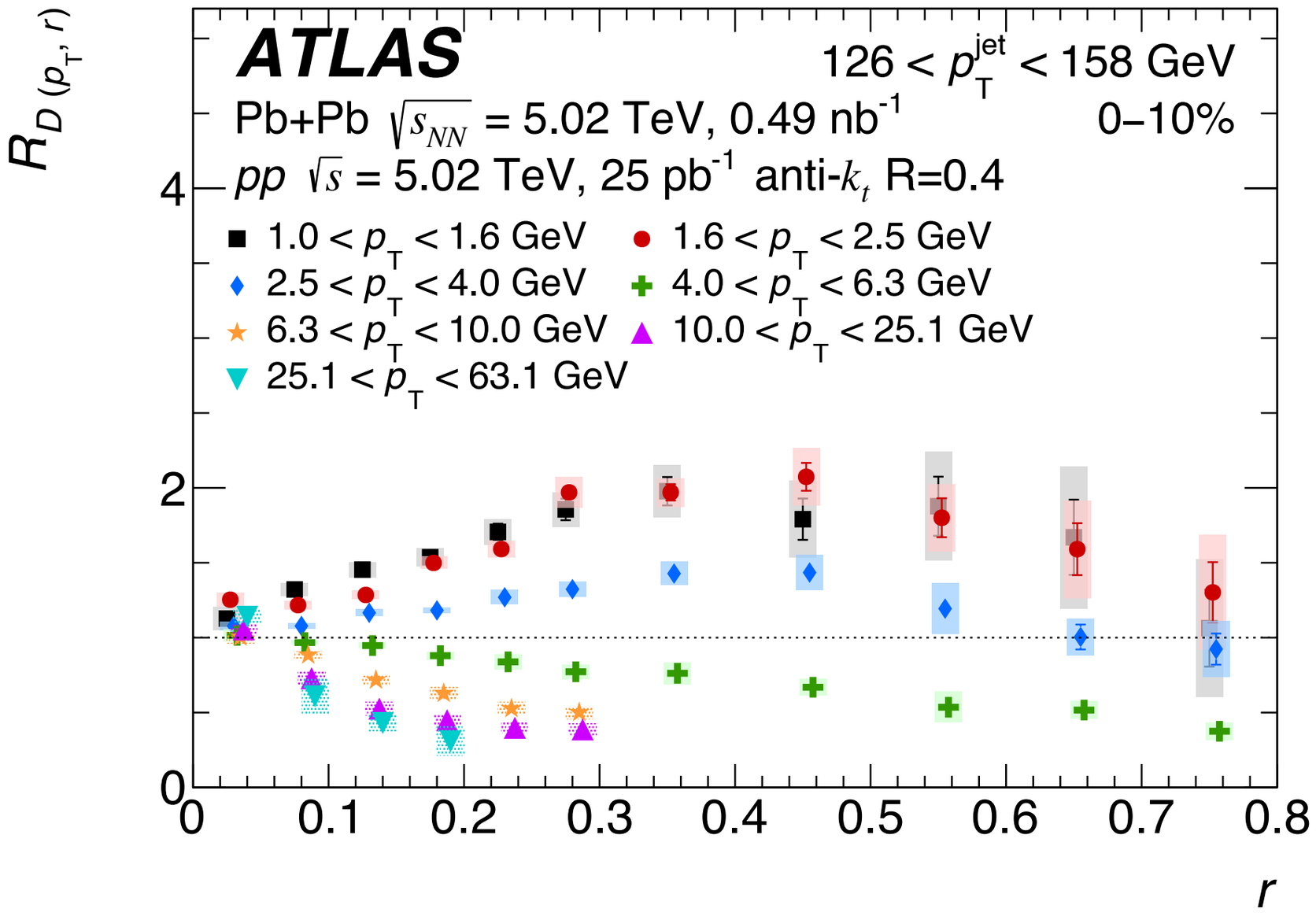
a 2D map of jet fragmentation

$$D(p_{\mathrm{T}}, r) = \frac{1}{N_{\mathrm{jet}}} \frac{1}{2\pi r\, dr} \frac{dn_{\mathrm{ch}}(p_{\mathrm{T}}, r)}{dp_{\mathrm{T}}}$$



PRC100 (2019) 064901

PbPb modifications versus r



$$R_{D(p_{\mathrm{T}},r)} = \frac{D(p_{\mathrm{T}},r)_{\mathrm{Pb+Pb}}}{D(p_{\mathrm{T}},r)_{pp}}$$

broadening:

$p_T \lesssim 4$ GeV

narrowing:

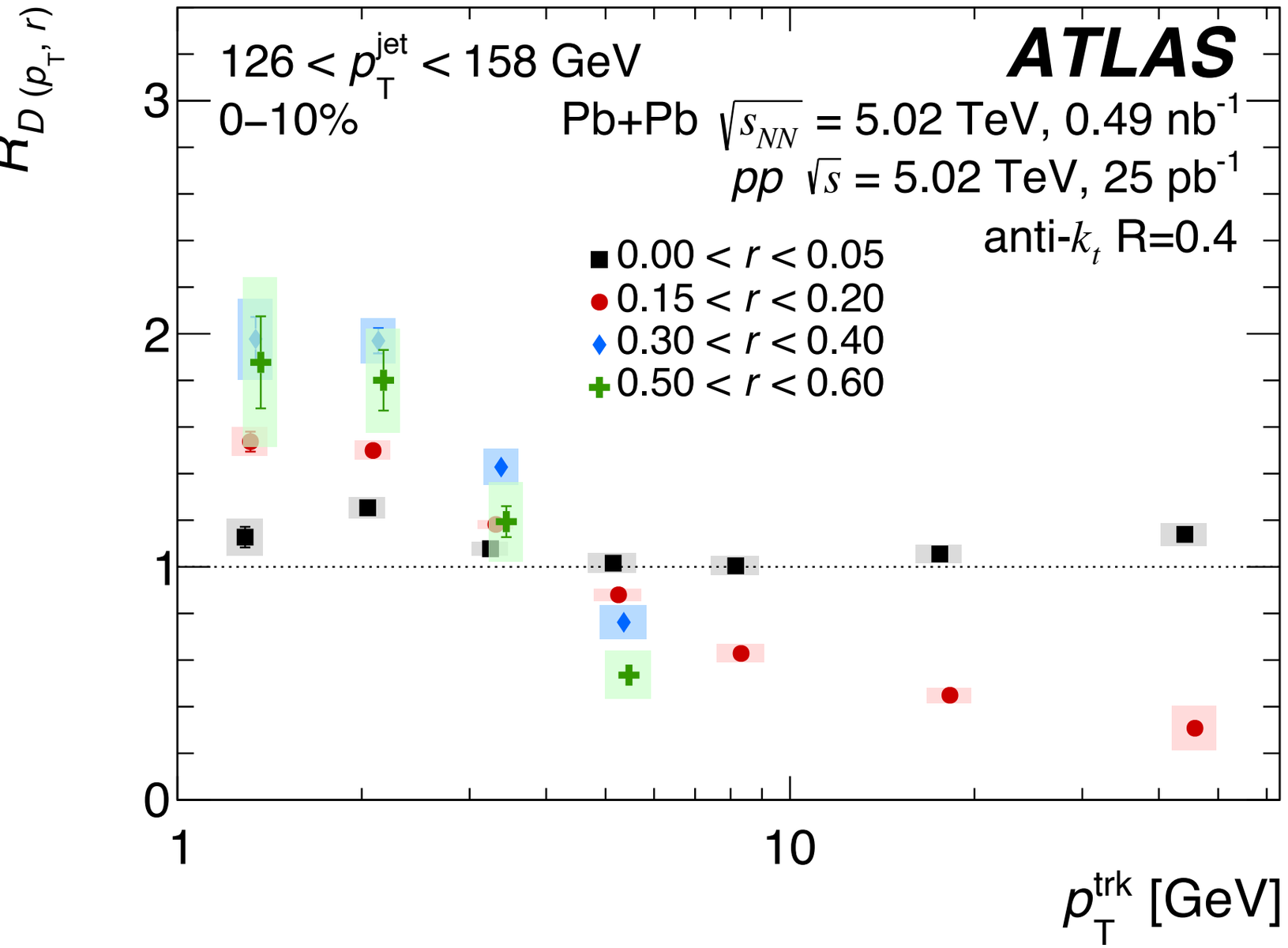
$p_T \gtrsim 4$ GeV

same 4 GeV scale as in the fragmentation functions

PRC100 (2019) 064901

PbPb modifications versus p_T

a different look at the same ratio



core: not much modification

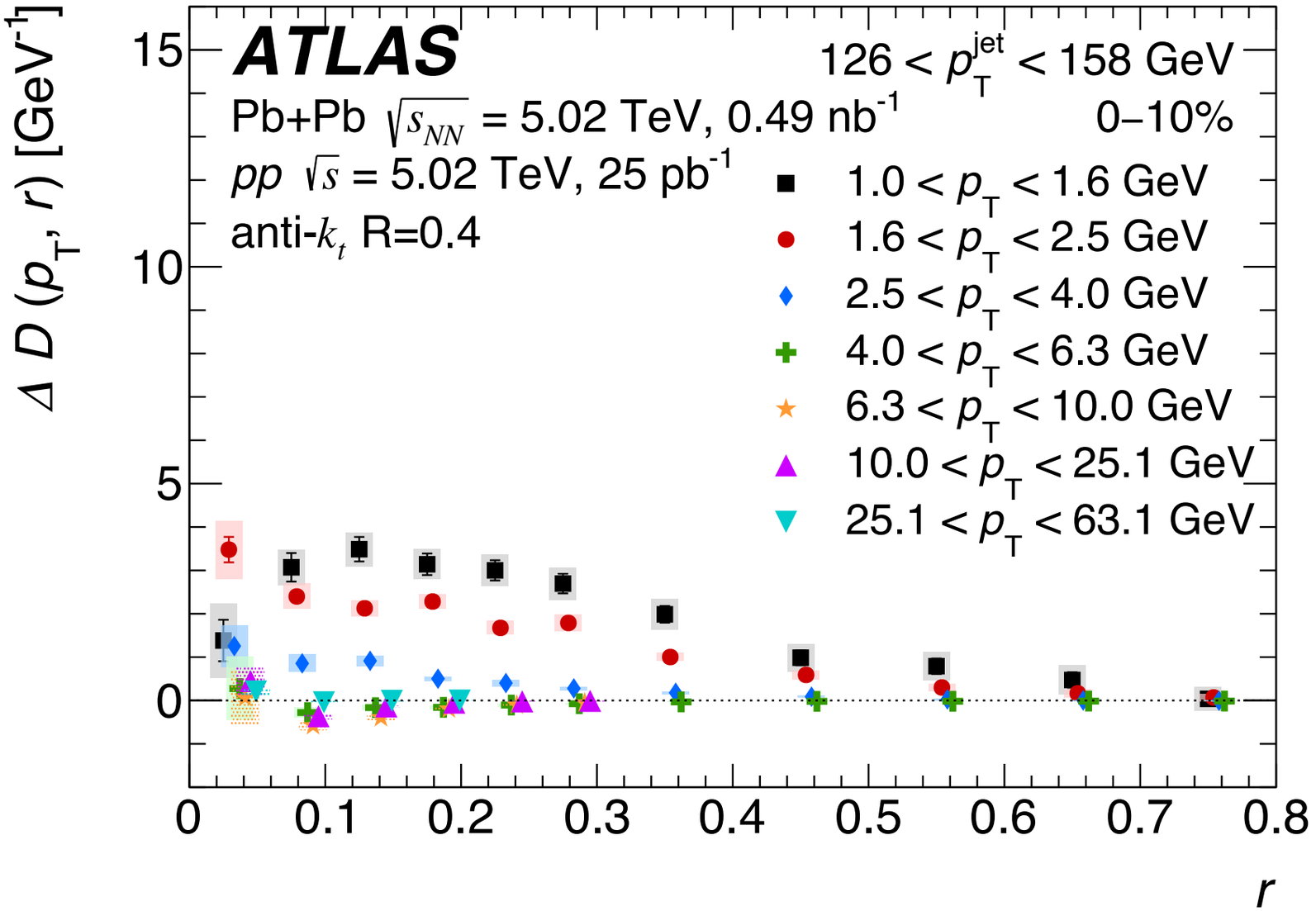
larger r: increasing modifications until ~the jet radius

PRC100 (2019) 064901

PbPb modifications versus r

in pp collisions most particles are near the jet axis so
looking at the difference (PbPb - pp) can be useful in addition to the ratio

$$\Delta D(p_{\mathrm{T}}, r) = D(p_{\mathrm{T}}, r)_{\mathrm{Pb+Pb}} - D(p_{\mathrm{T}}, r)_{pp}$$



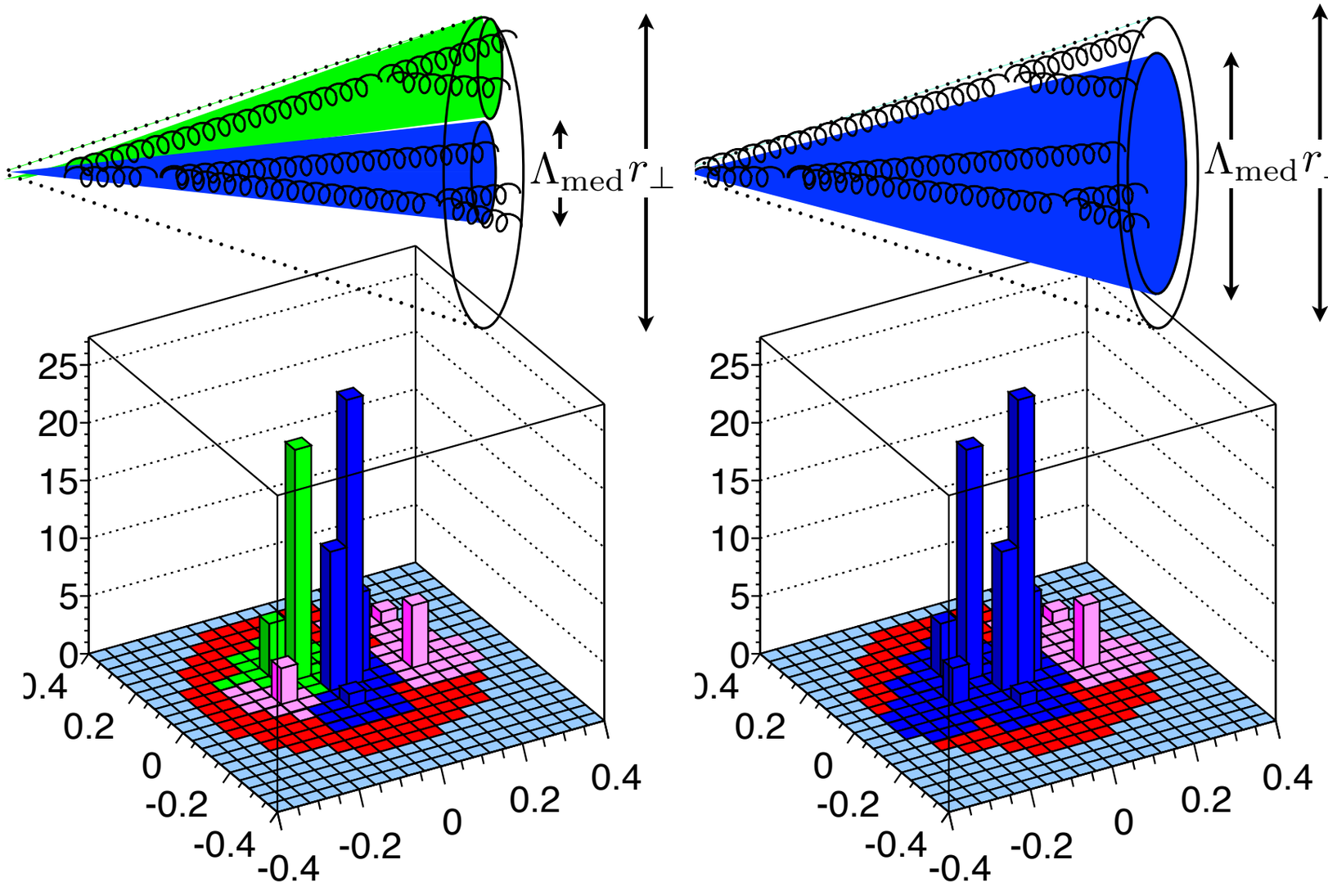
in PbPb collisions:
most of the "extra" particles are within the jet cone

PRC100 (2019) 064901

hard structure of jets at large angles

does jet suppression depend on the jet structure?

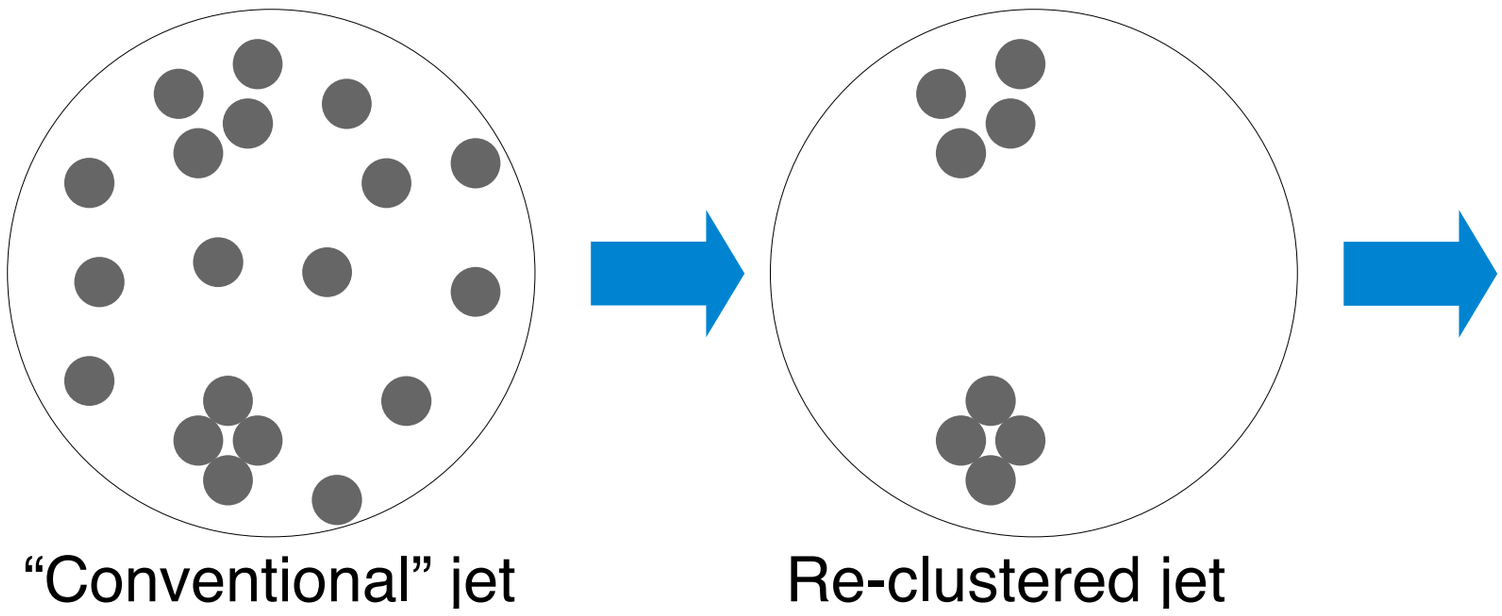
experimentally: look at jets with large R whose constituents are R =0.2 jets



1210.7765 J. Casalderrey-Solana, Y. Mehtar-Tani, C. A. Salgado, K. Tywoniuk

large R jets reconstructed from R = 0.2 jets

Cal. towers & UE subtraction → R=0.2 jets anti-k_t jets $p_T > 35$ GeV → re-clustering with anti-k_t R=1.0 → Sub-jets → re-clustering with k_t algorithm → Splitting scale $\sqrt{d_{12}}$



Different jets than the conventional R=1.0.

Trimming & 35 GeV threshold remove soft components.

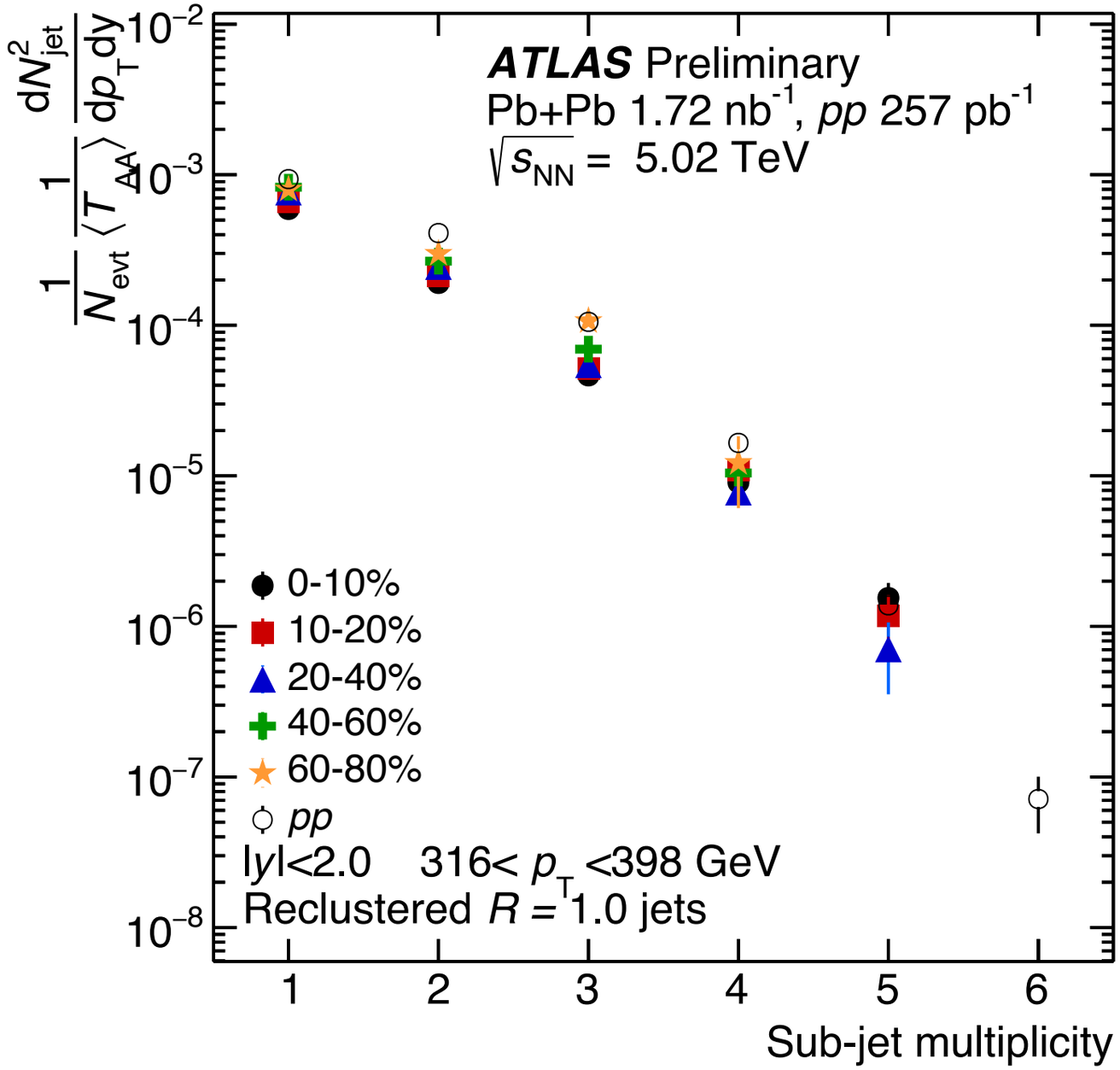
M. Rybar QM19

sub-jet distribution

most likely configuration:

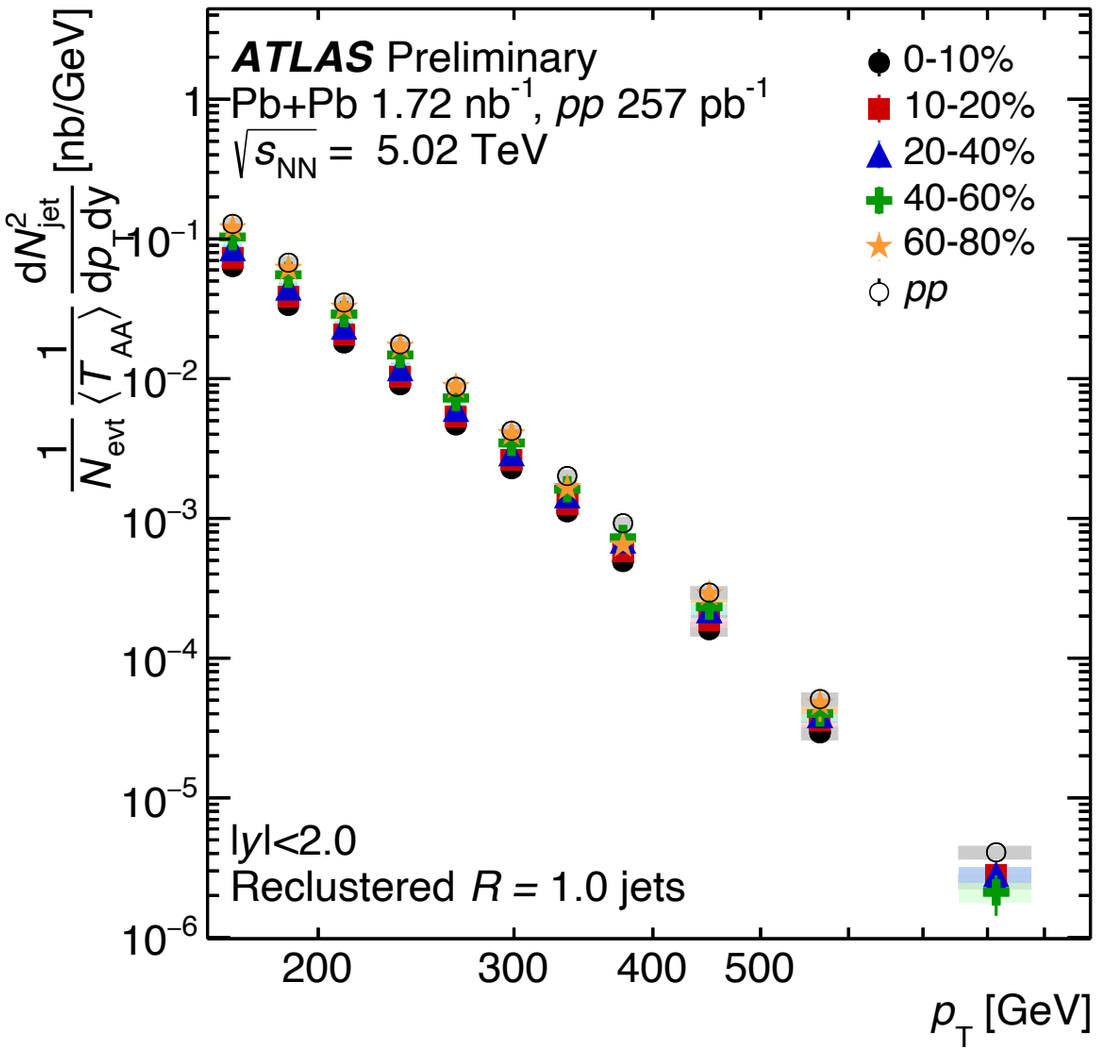
R = 1.0 jet made up of a single isolated R = 0.2 jet

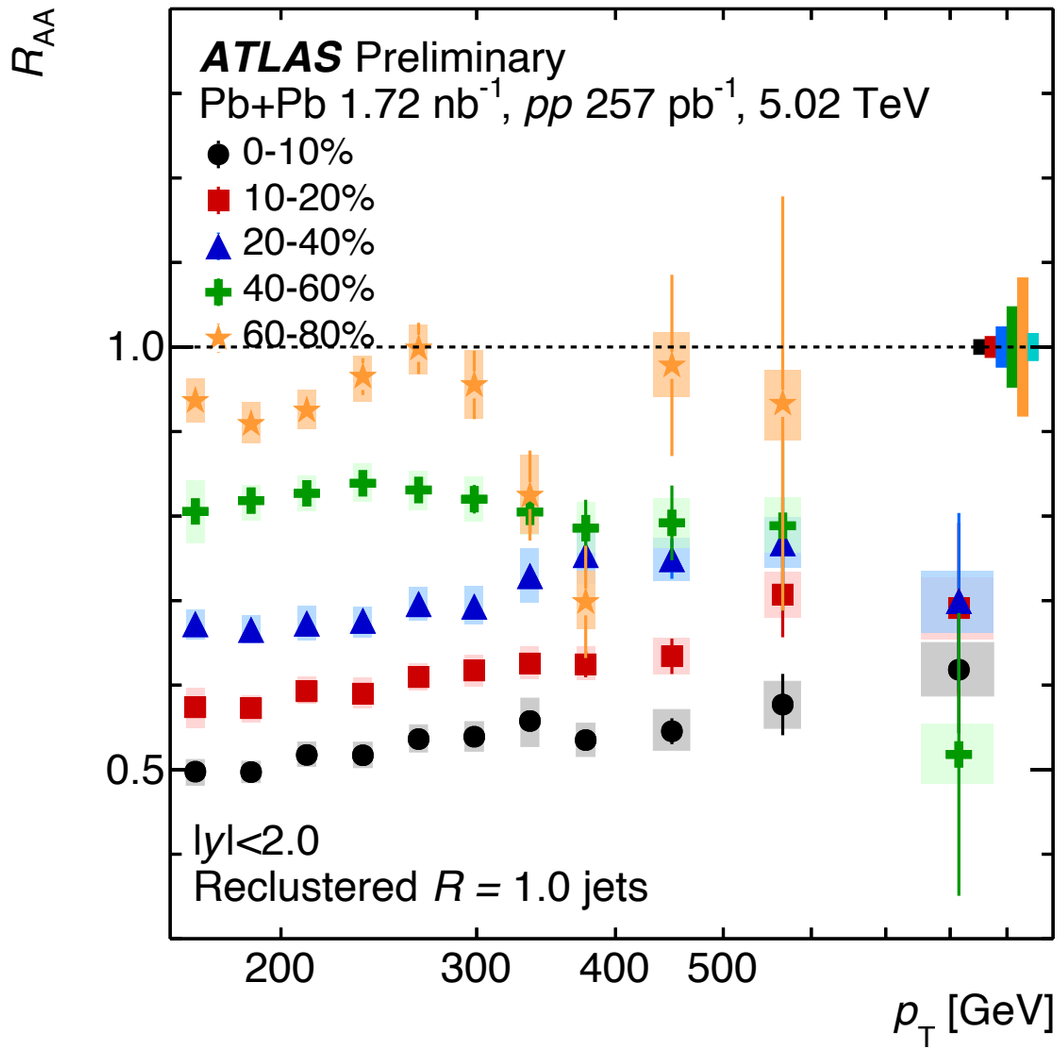
two-dimensional unfolding applied in $\sqrt{d_{12}}$ and jet p_T



ATLAS-CONF-2019-056

unfolded distribution of R =1.0 reclustered jets



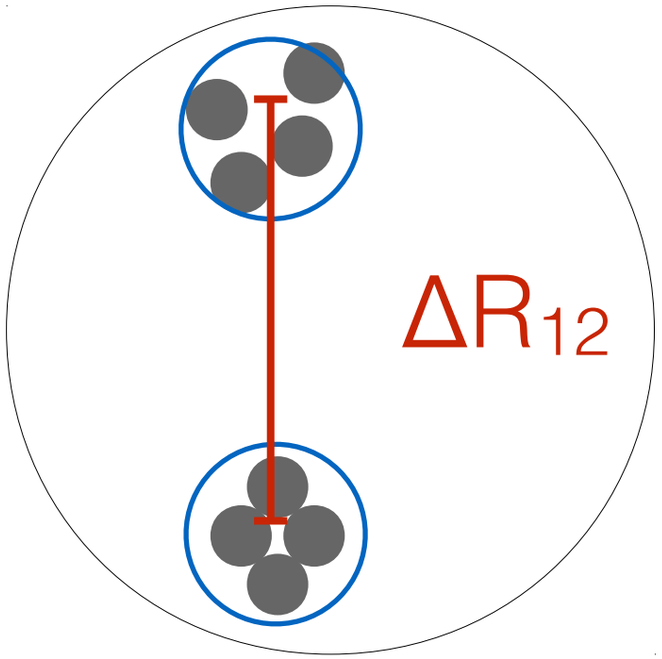


suppression of R = 1.0 jets out to 900 GeV!

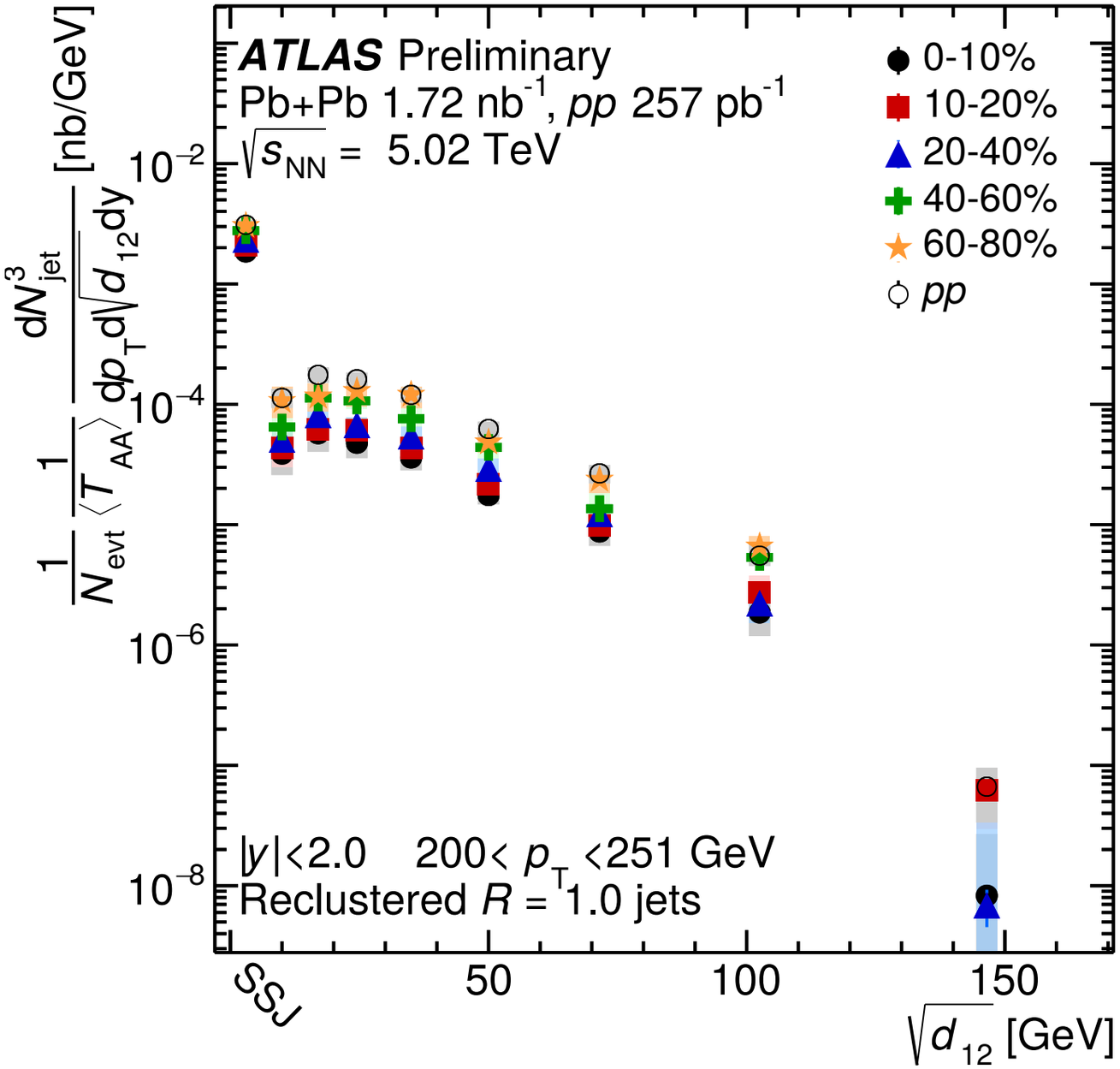
ATLAS-CONF-2019-056

absolutely normalized $\sqrt{d_{12}}$ distributions

$$\sqrt{d_{12}} = \min(p_{T1}, p_{T2}) \times \Delta R_{12}$$



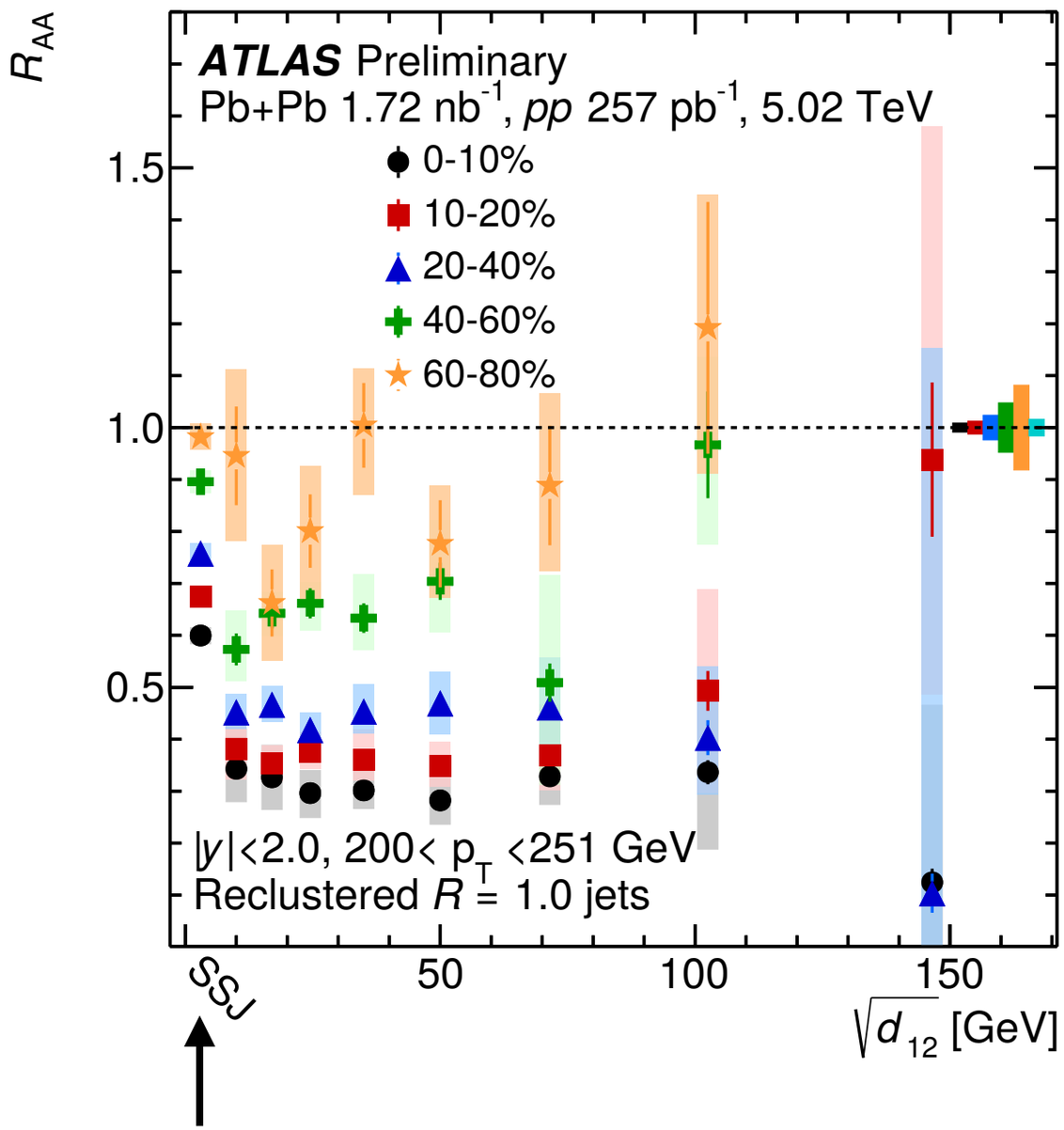
if there is only a single sub-jet (SSJ) → $\sqrt{d_{12}} = 0$



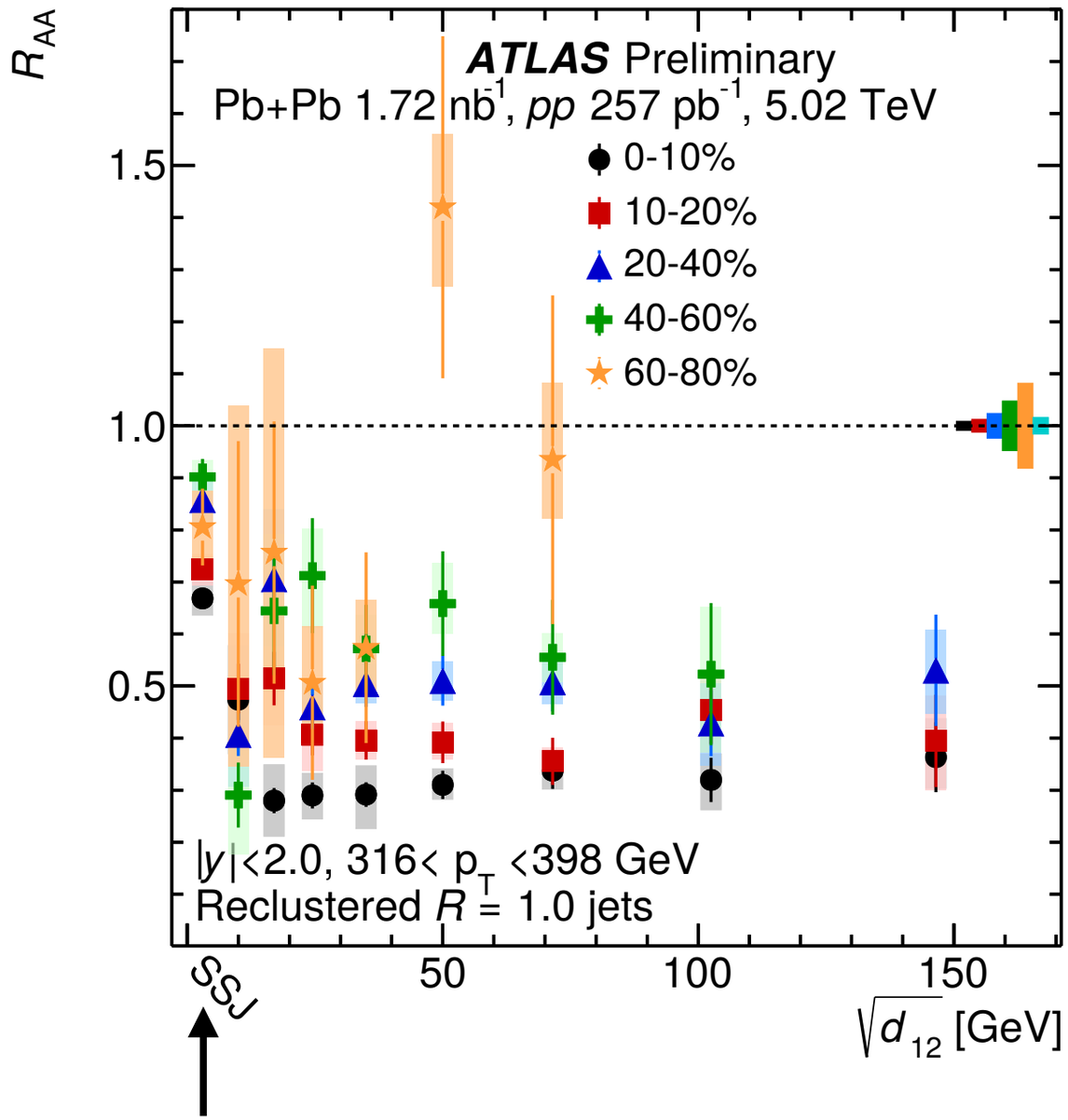
ATLAS-CONF-2019-056

R_{AA} versus $\sqrt{d_{12}}$

$200 < p_T < 251$ GeV



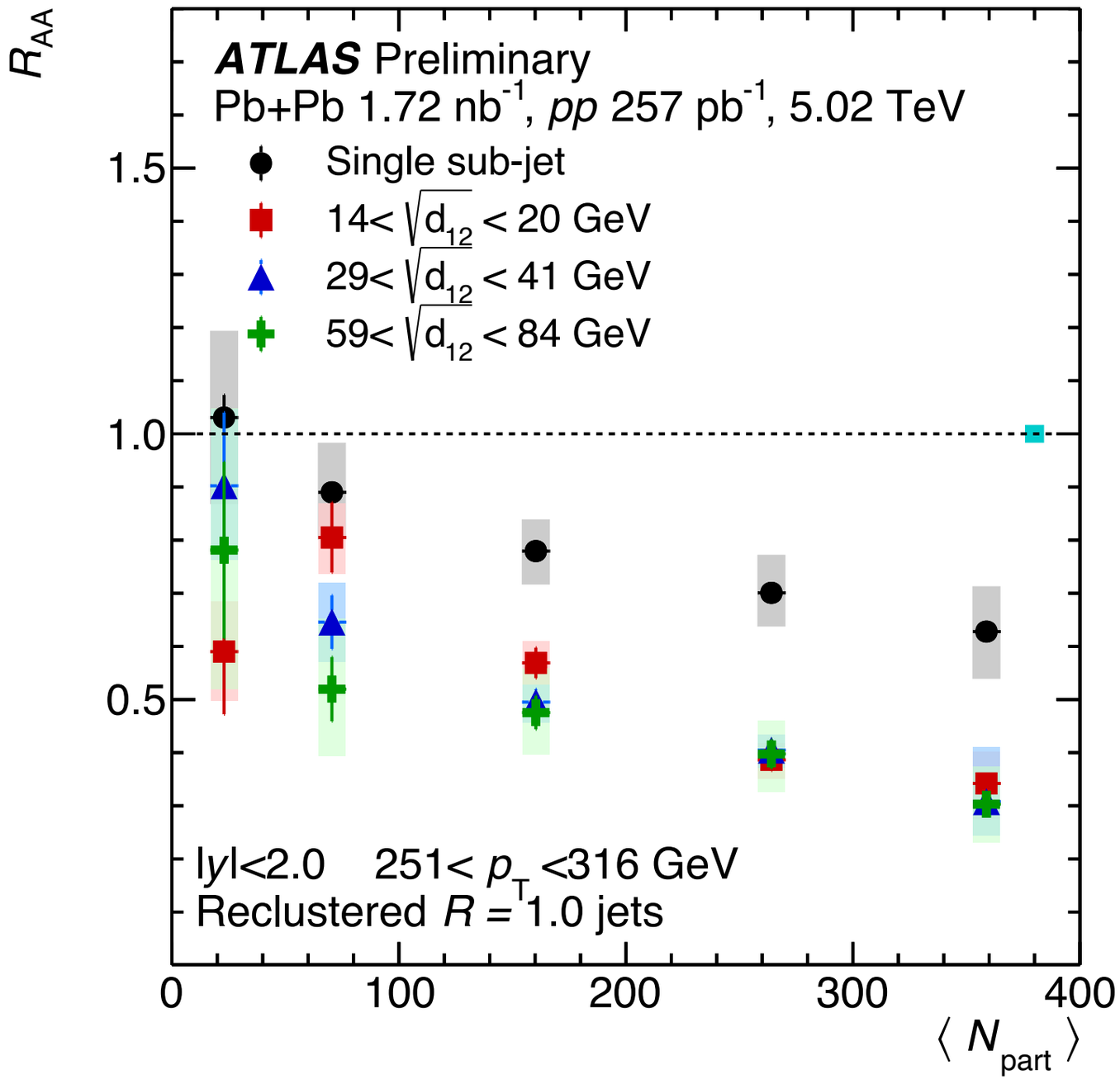
$316 < p_T < 398$ GeV



jets with a single sub-jet are less suppressed than those with >1 sub-jet

R_{AA} for $\sqrt{d_{12}}$ selections

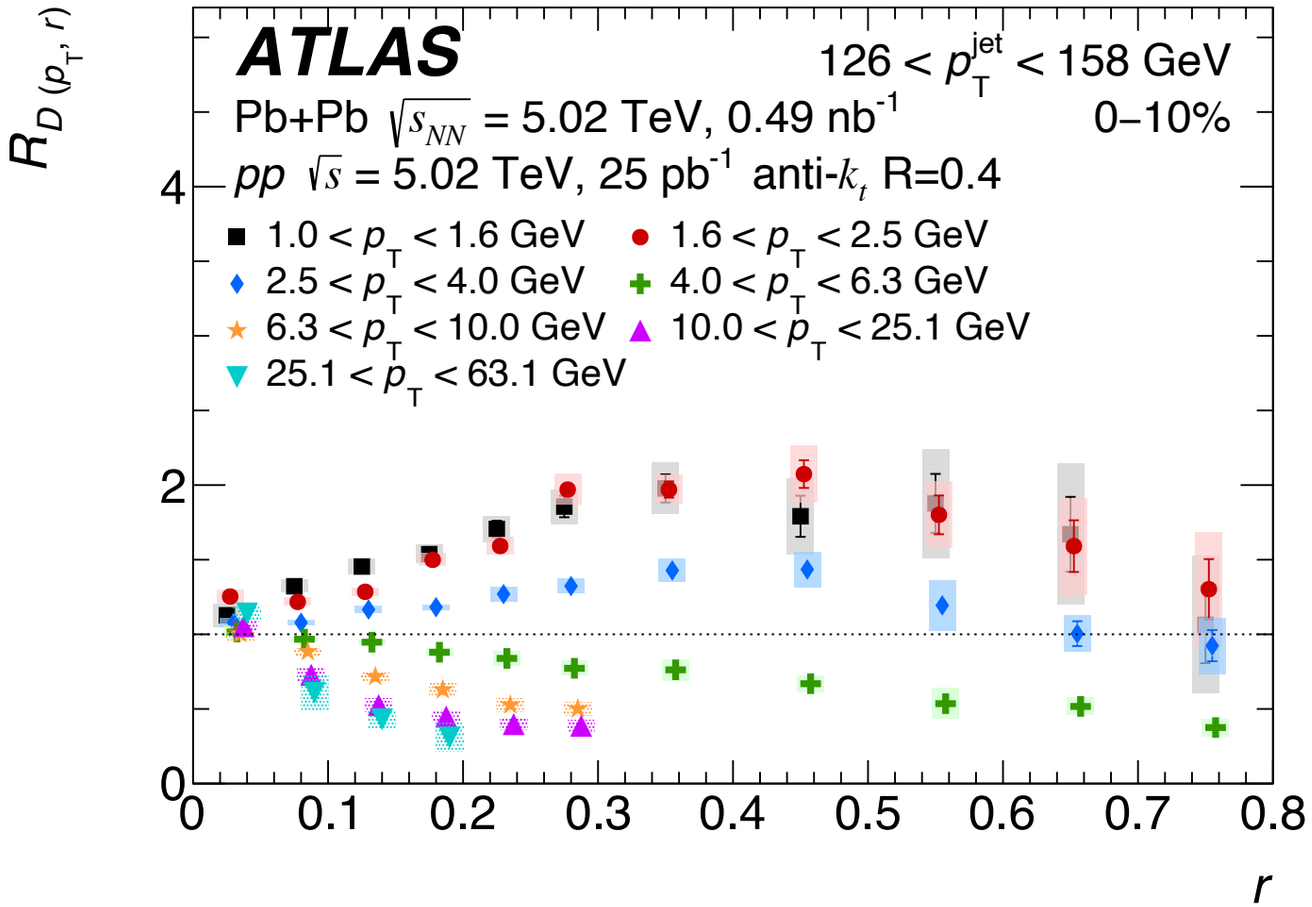
jets with a single sub-jet are less suppressed than those with >1 sub-jet

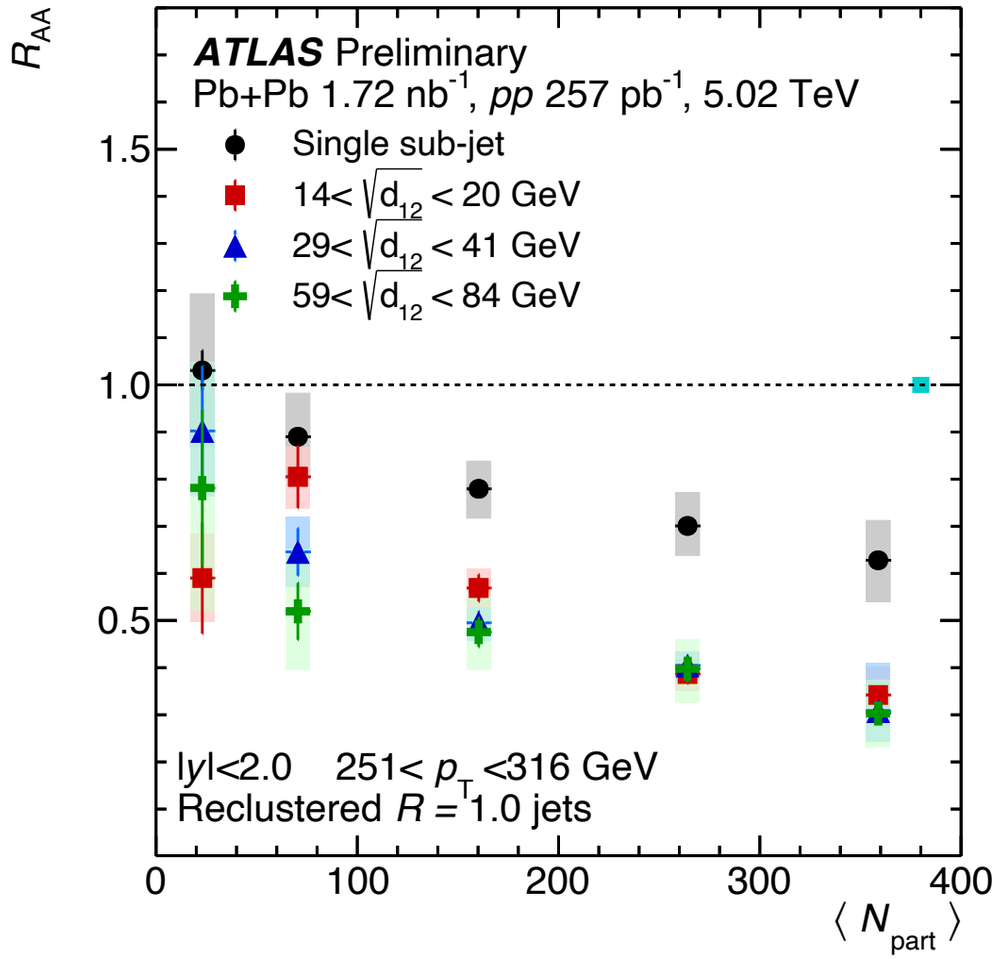


small $\sqrt{d_{12}}$ dependence for $\sqrt{d_{12}} > 0$ in central collisions

ATLAS-CONF-2019-056

summary



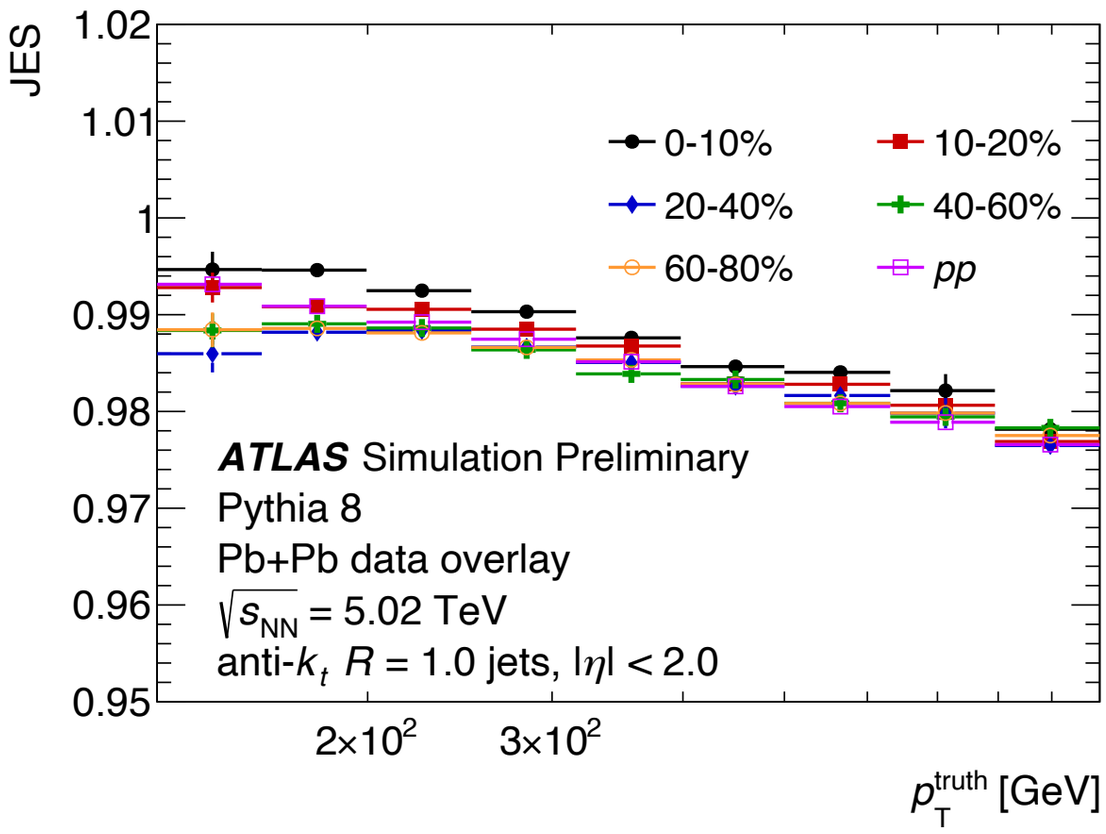


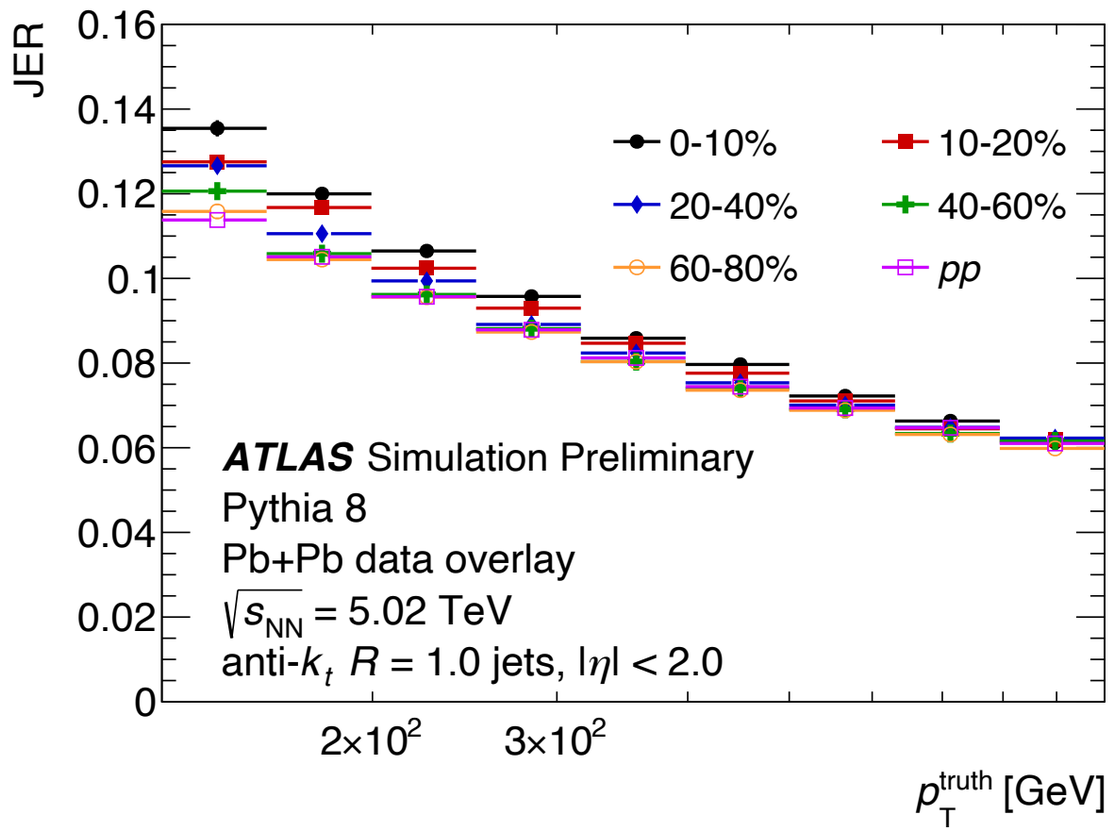
- structure of jet fragments is significantly modified in Pb+Pb, with a qualitative change at ~4 GeV
- reclustered R = 1.0 jets made up of a single sub-jet less quenched than those with multiple sub-jets

all ATLAS Heavy Ion Results: https://twiki.cern.ch/twiki/bin/view/AtlasPublic/HeavyIonsPublicResults

backups

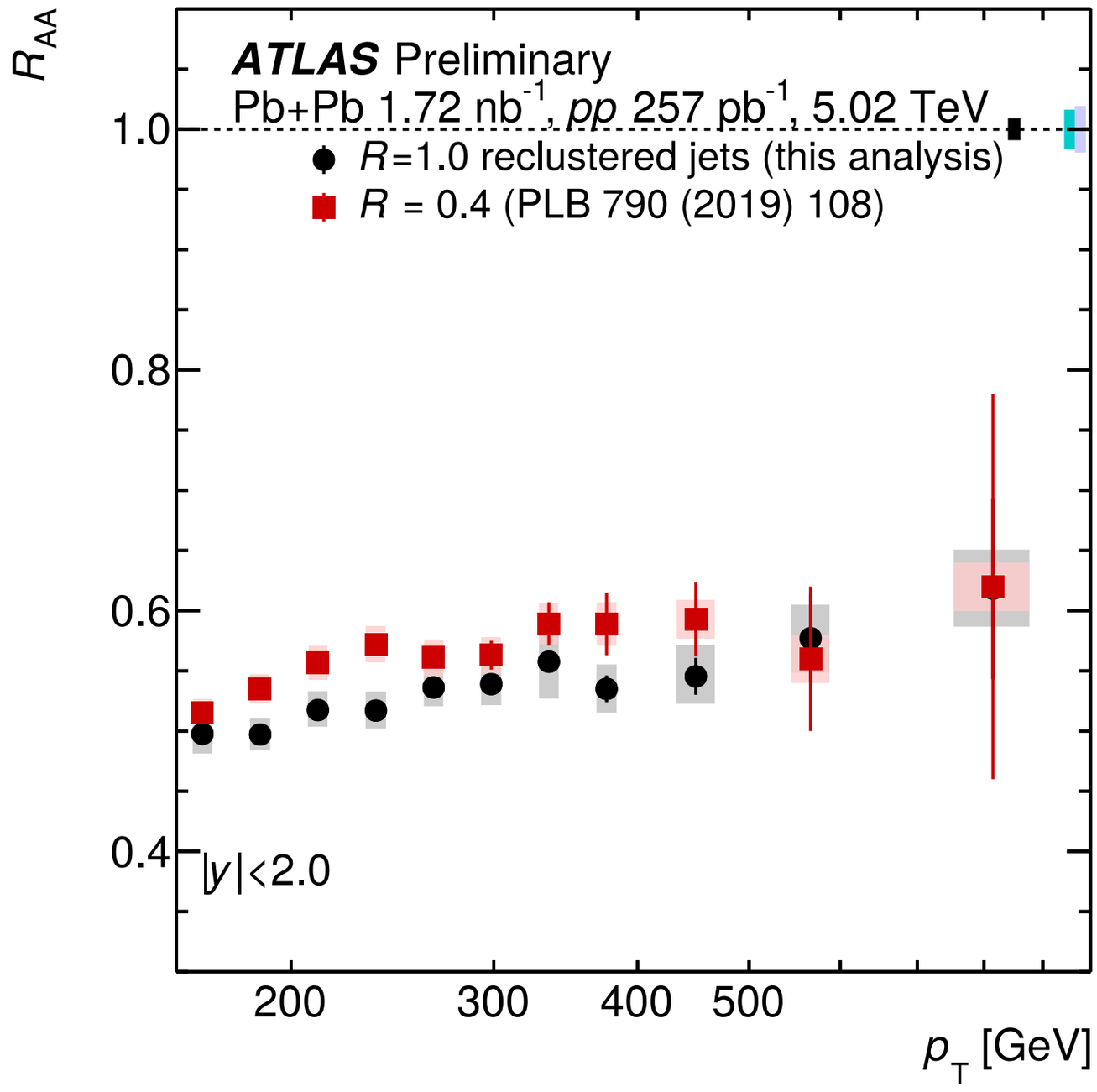
R = 1.0 JES/JER





ATLAS-CONF-2019-056

RAA comparison to anti-kt R = 0.4 jets



ATLAS-CONF-2019-056