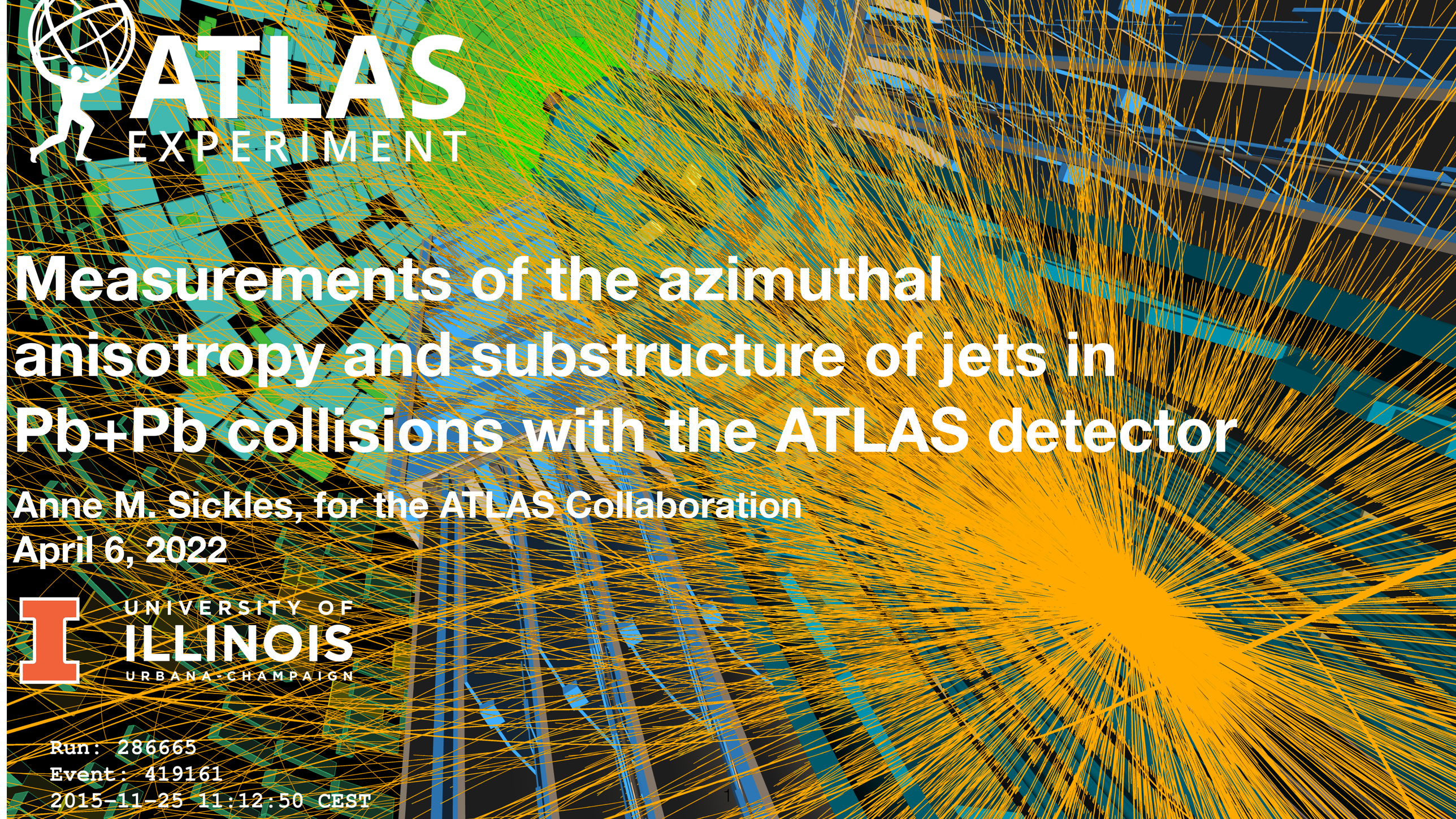
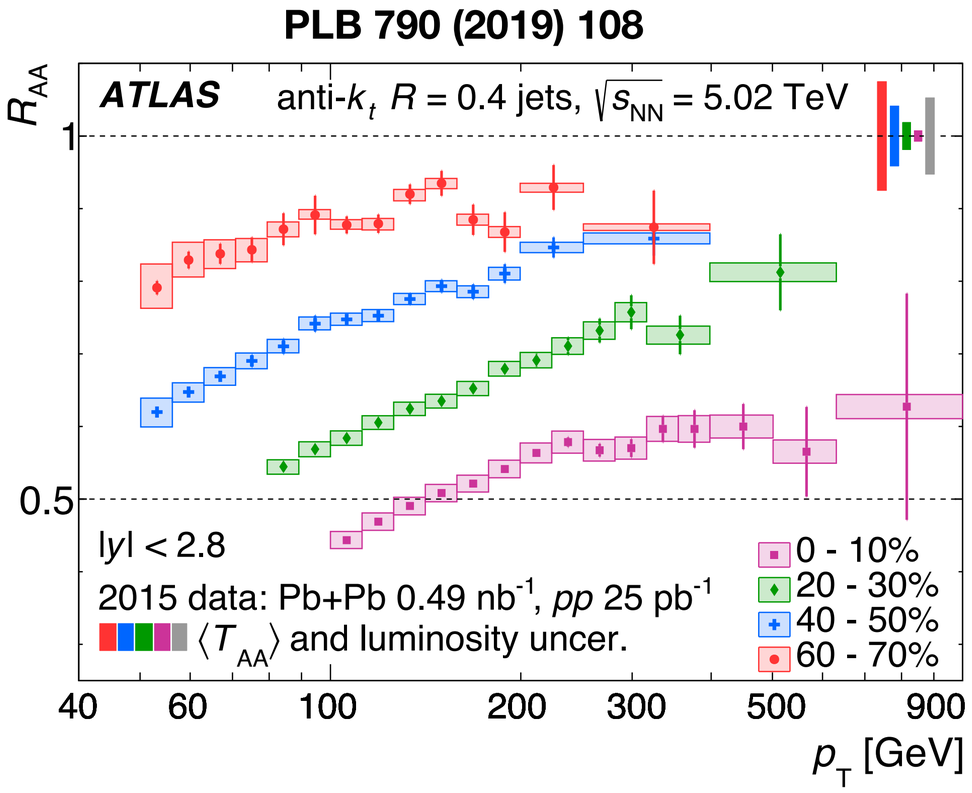


Measurements of the azimuthal anisotropy and substructure of jets in Pb+Pb collisions with the ATLAS detector

Anne M. Sickles, for the ATLAS Collaboration

April 6, 2022

UNIVERSITY OF ILLINOIS
URBANA-CHAMPAIGN



existing, precise, measurements of jet R_{AA} in PbPb collisions

how do we understand the observed suppression in terms of geometry & jet structure?

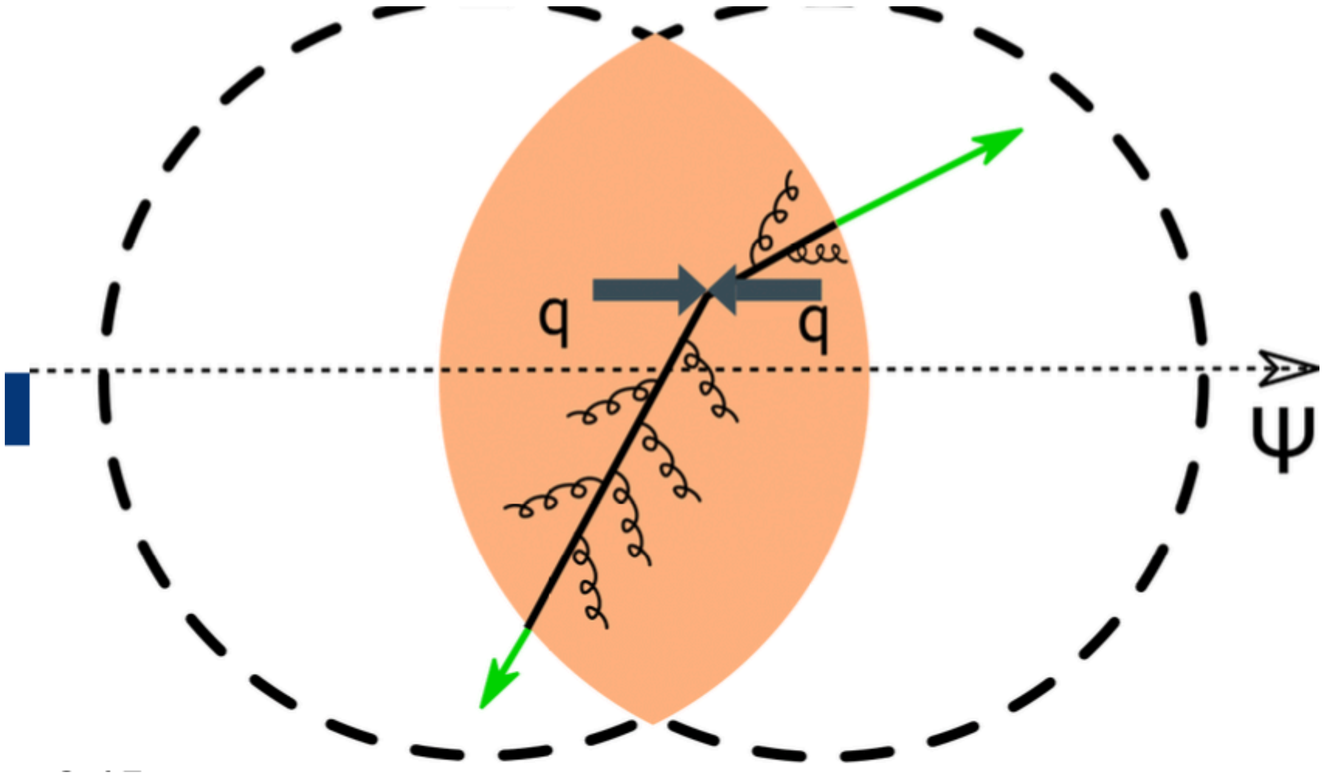
jet v_n

n > 2 & large kinematic reach

substructure dependent R_{AA}

absolutely normalized measurements to directly compare energy loss

jet v_n



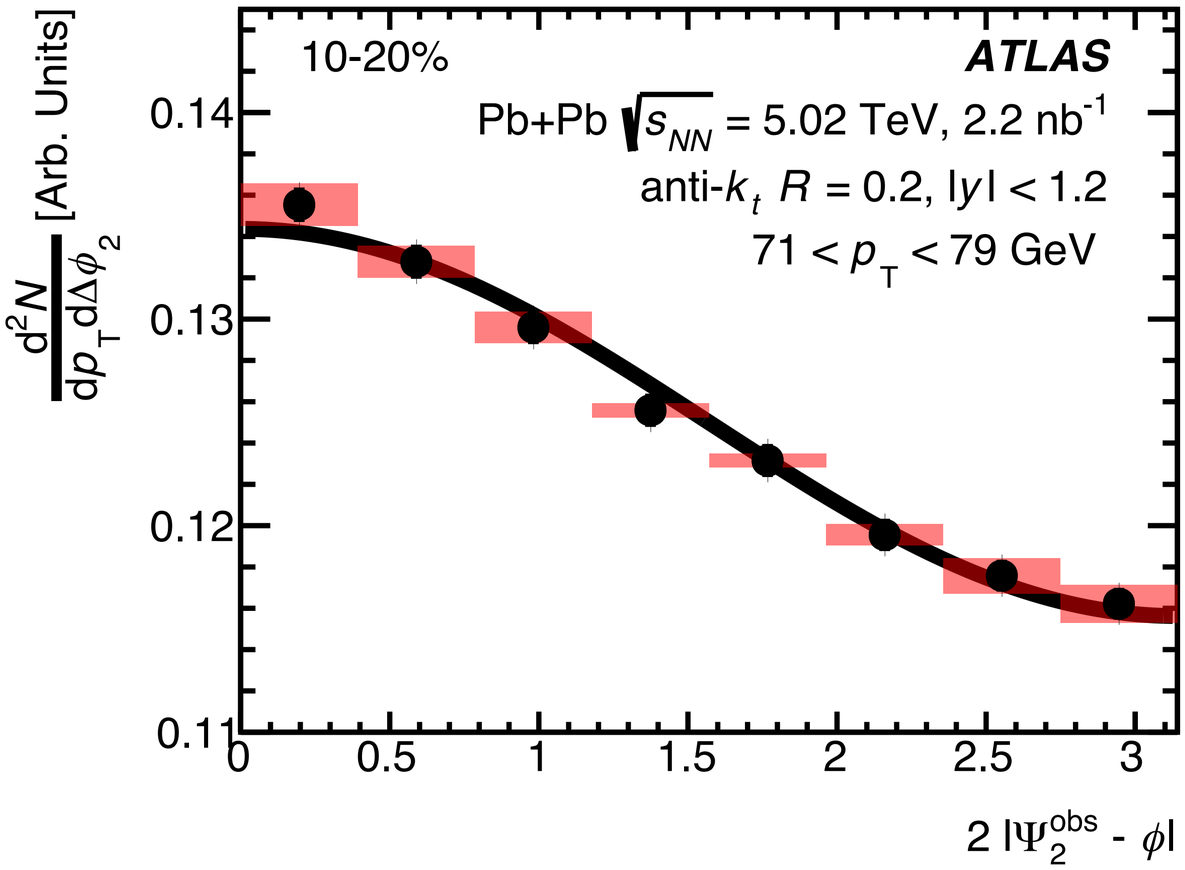
measurements of the jet rates as a function of 2, 3 & 4th order event planes

sensitive to the path length dependence of jet energy loss

accepted in PRC, 2111.06606

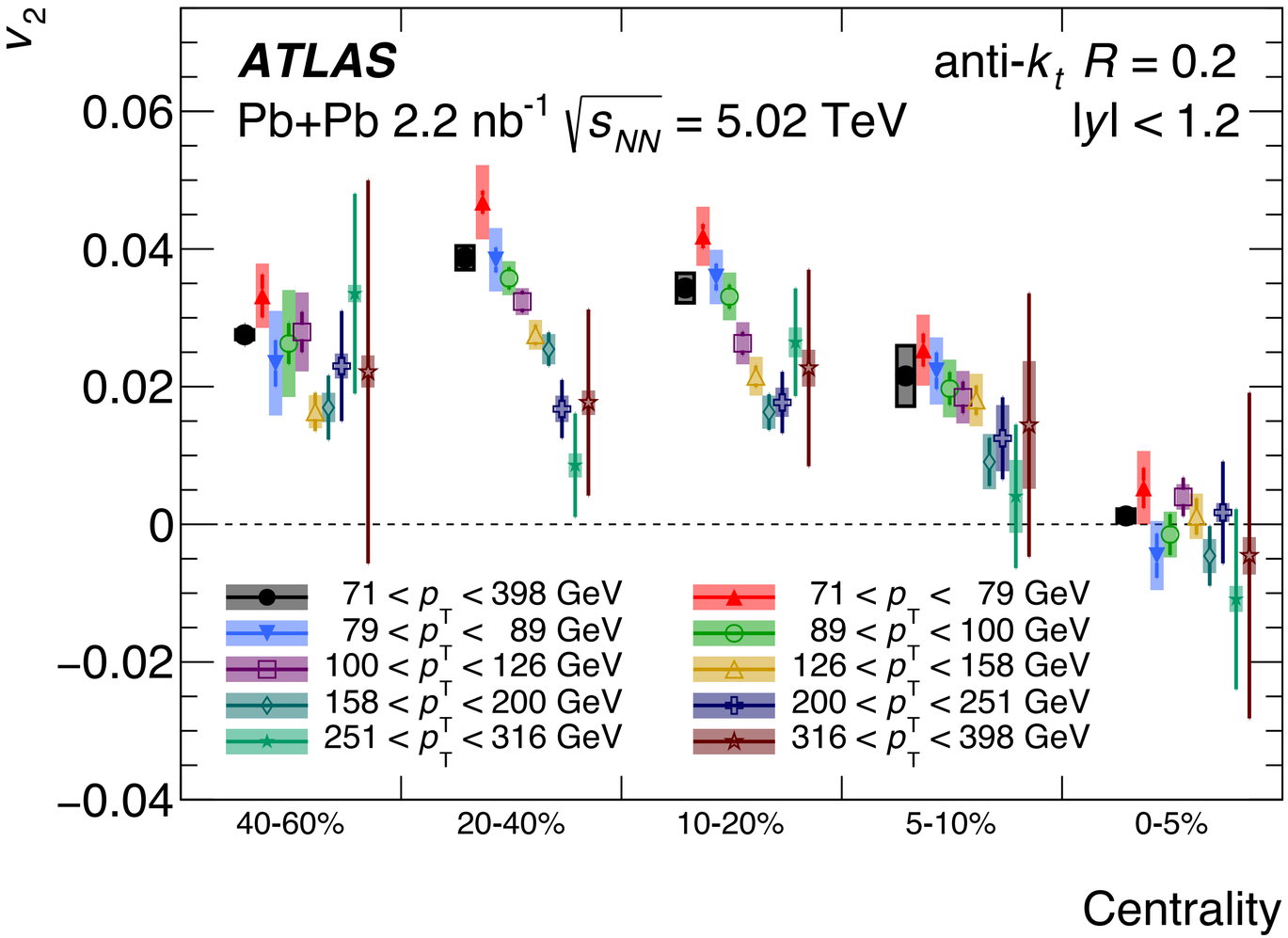
analysis procedure

- jet angle measured wrt event plane measured with $4.0 < |\eta| < 4.9$
  - reduces any bias on the event plane from the away side jet
- jet momentum is unfolded
- jet position resolution is greatly improved by using small R = 0.2 jets



2111.06606

jet v_2

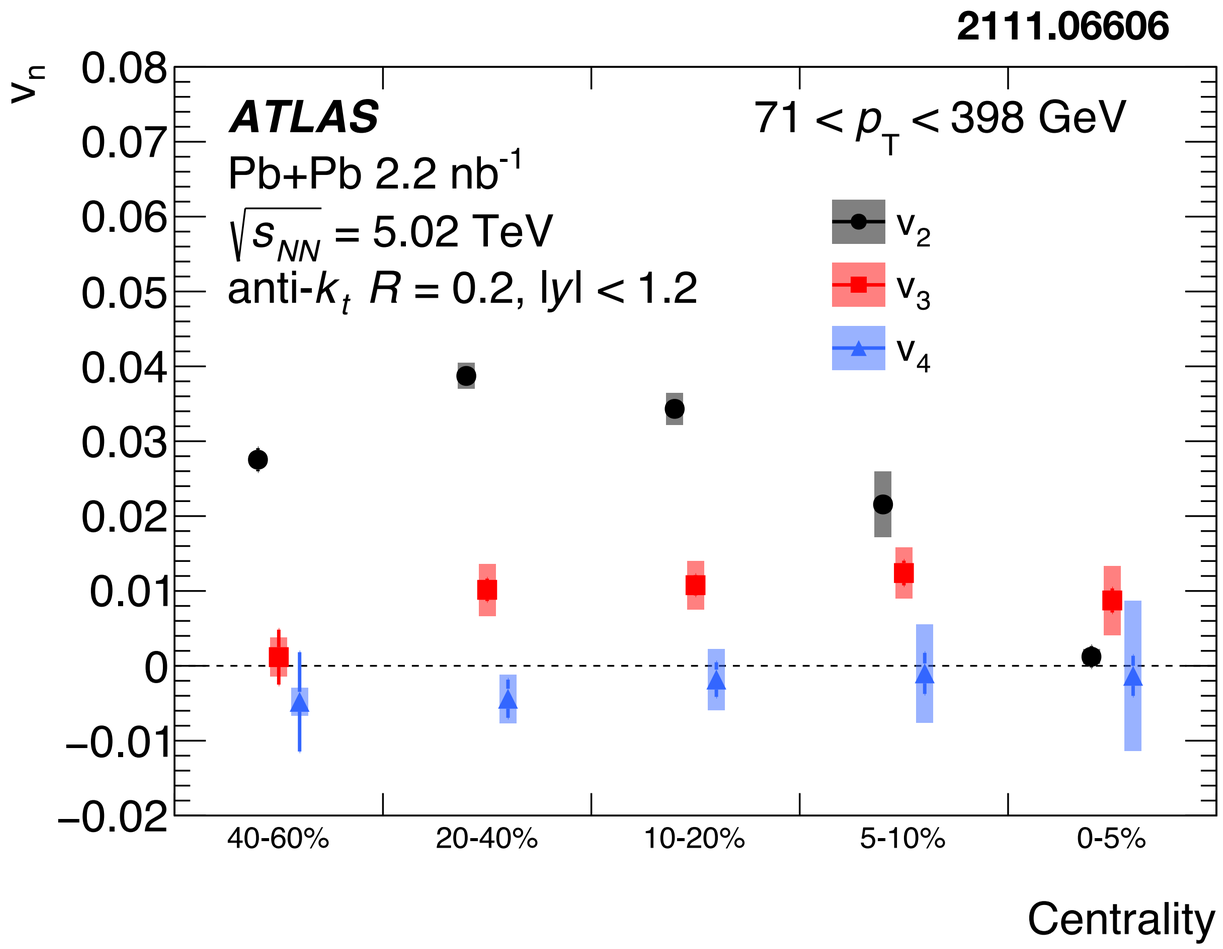


- $v_2 > 0$ observed for all but the most central collisions
- v_2 decreases with increasing p_T but remains > 0 in mid-central collisions up to at least 250 GeV

2111.06606

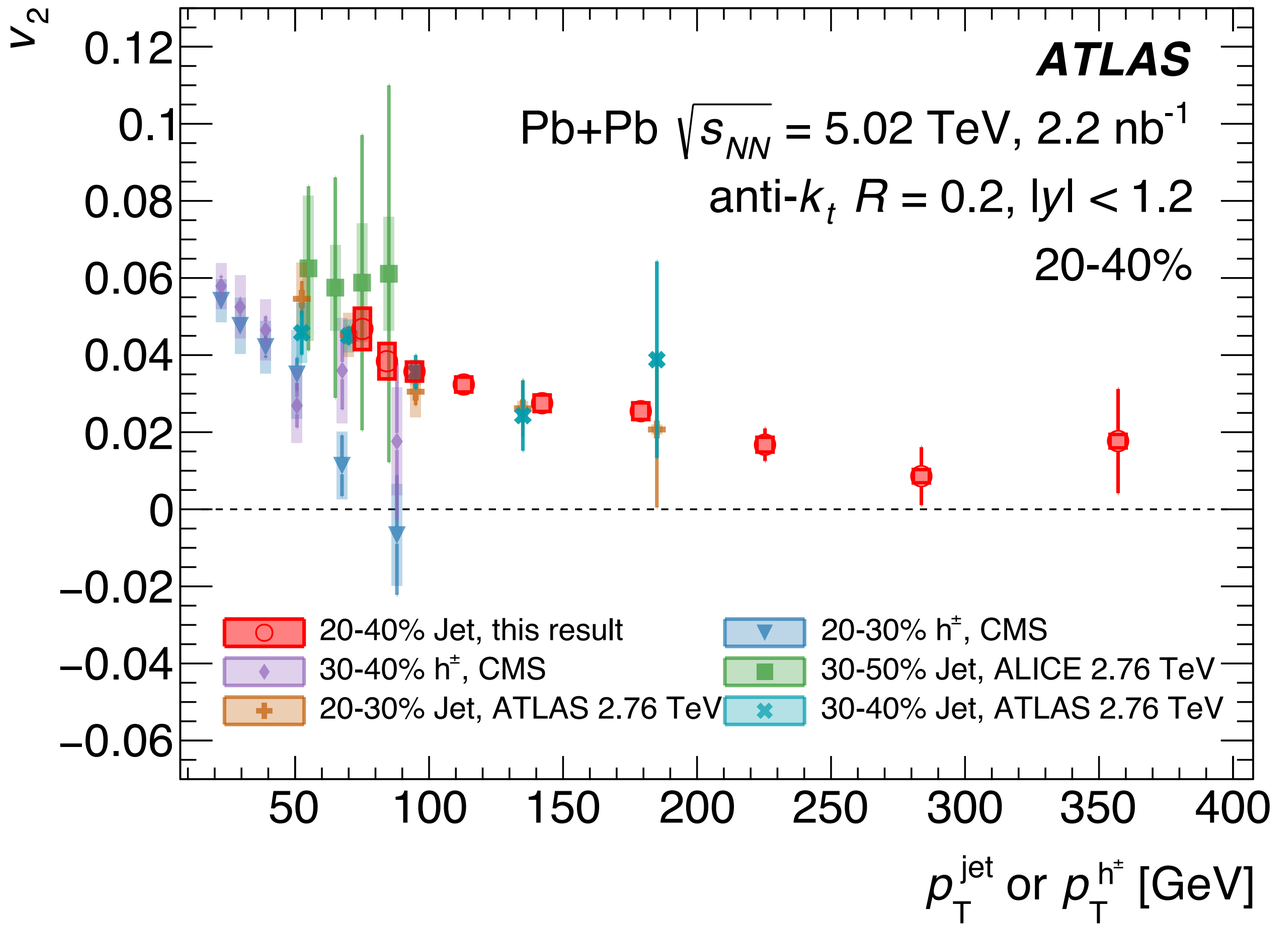
centrality dependence of jet v_n

- v_2 largest in mid-central collisions; consistent with 0 in the most central collisions
- v_3 ~1% for mid-central/central collisions
  - for both v_2 & v_3 the centrality dependence is similar to that of hydrodynamic vn which is driven by the initial collision geometry
  - suggests the same geometry plays a significant role in jet quenching
- v_4 consistent with 0
  - larger uncertainties from poor 4th order event plane resolution



comparison to previous measurements

- full Run 2 data & jets provide large increase in precision and kinematic range over 2.76 TeV results & charged hadron measurements



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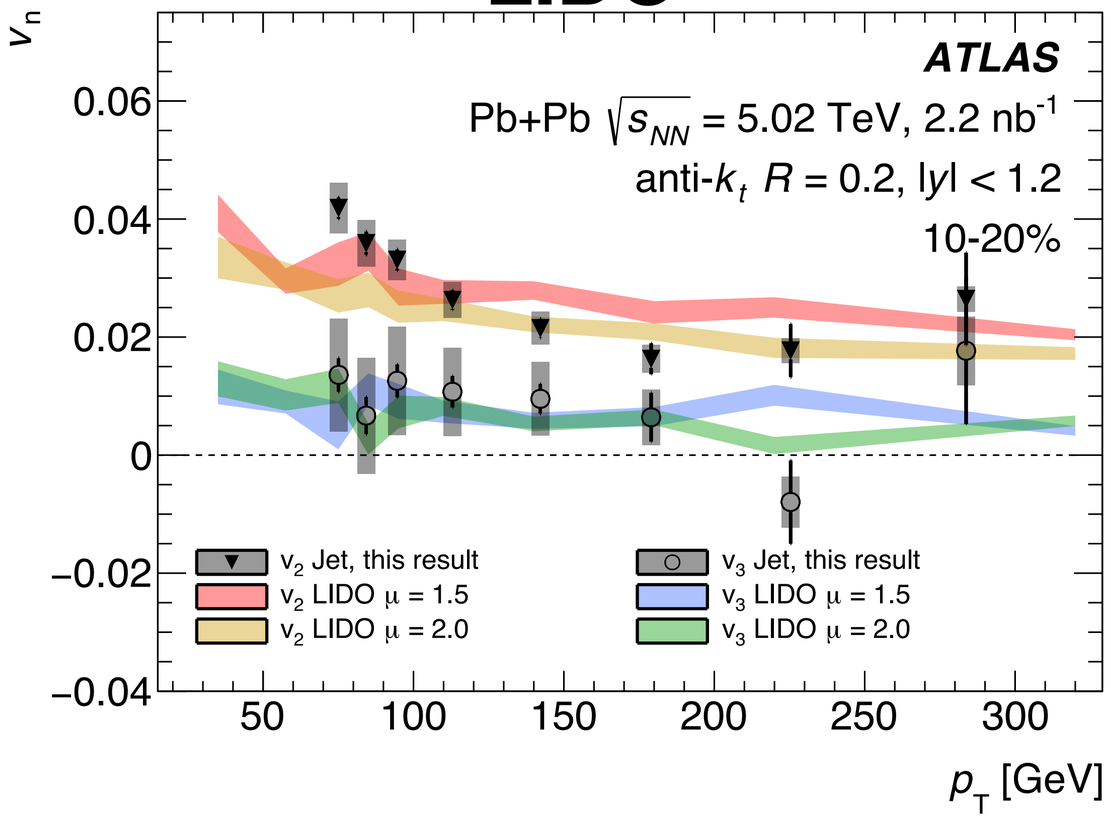
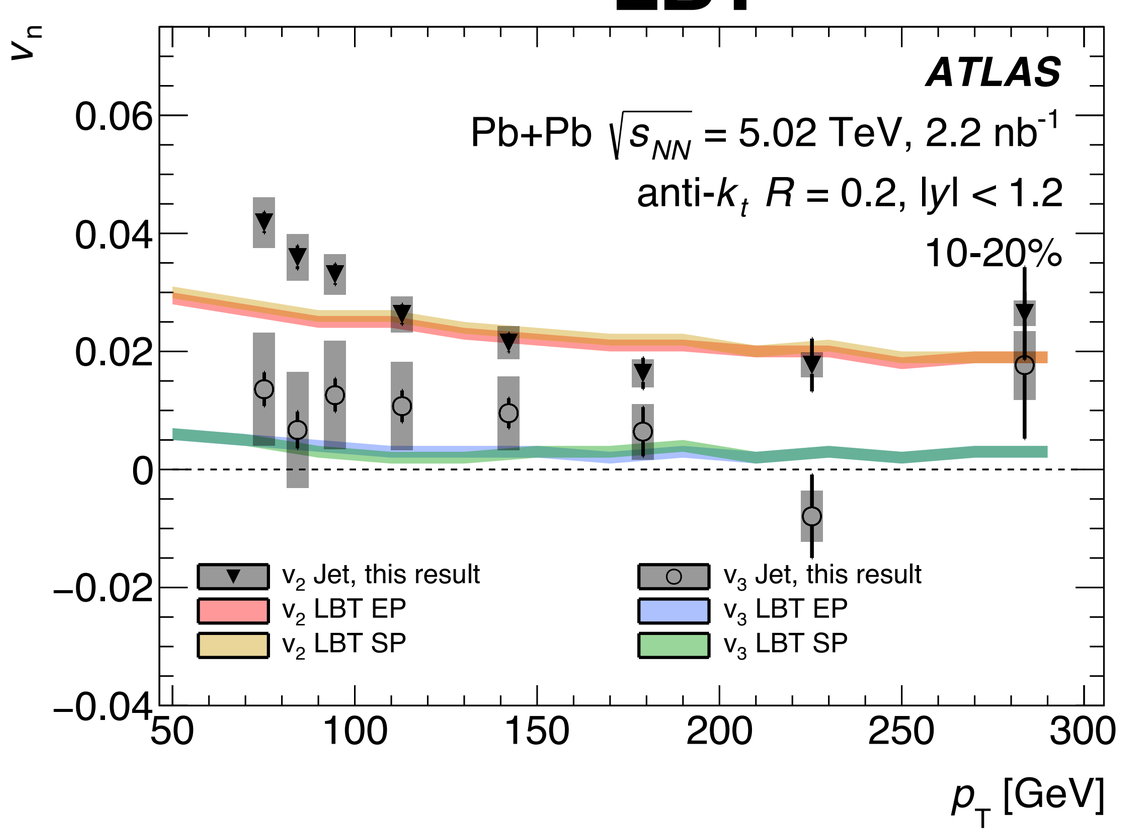
comparisons to theory

LIDO



LBT

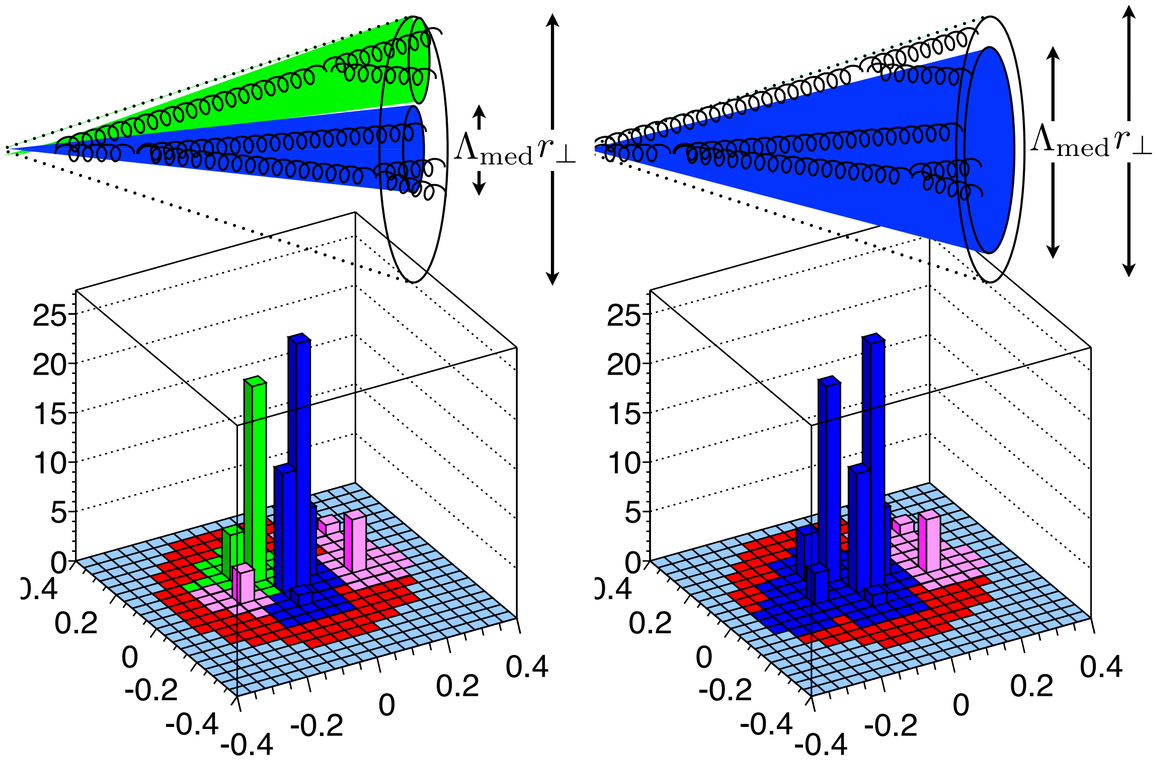


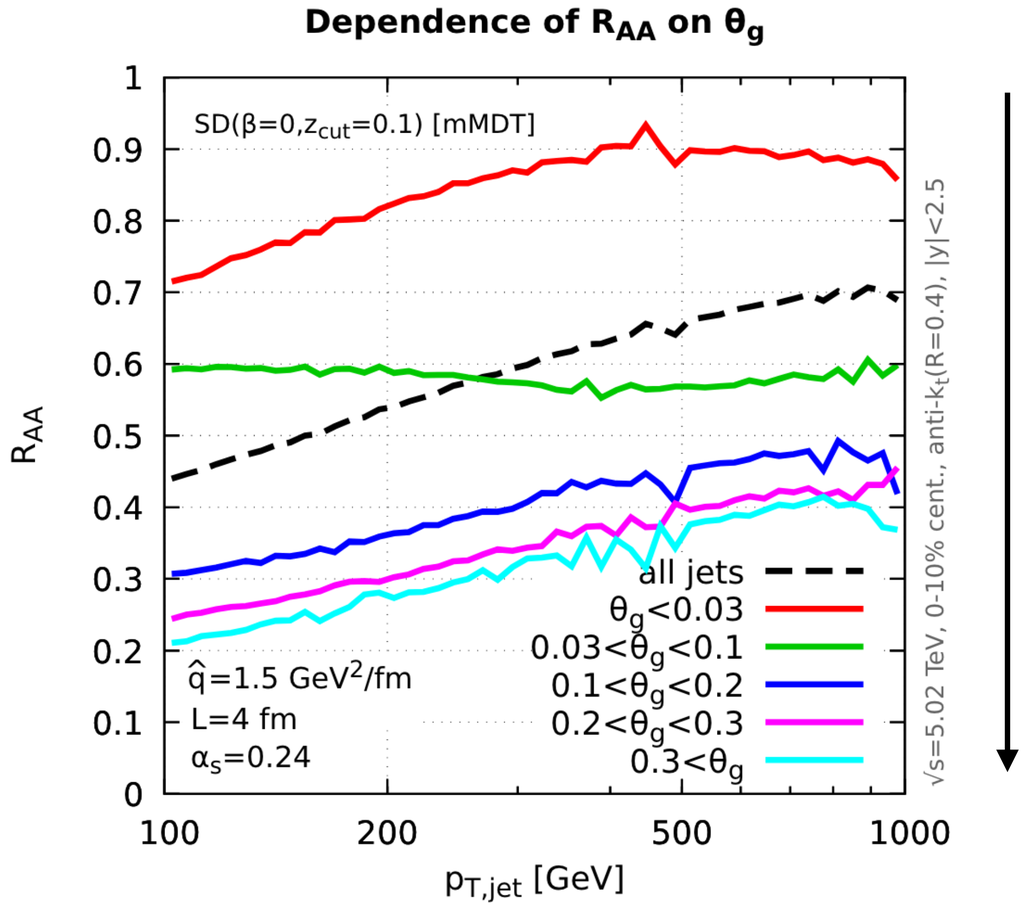
both LBT (1811.08975) and LIDO (2010.13680) get the size of the v_2 & v_3 well, except for the p_T dependence of the v_2 below ~100 GeV which is stronger in data than the models

2111.06606

substructure dependent R_{AA}

does RAA depend on the structure of the jet?





increasing distance between subjets

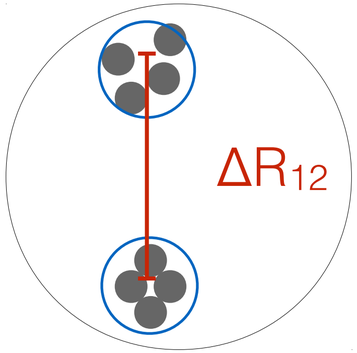
1210.7765 J. Casalderrey-Solana, Y. Mehtar-Tani, C. A. Salgado, K. Tywoniuk

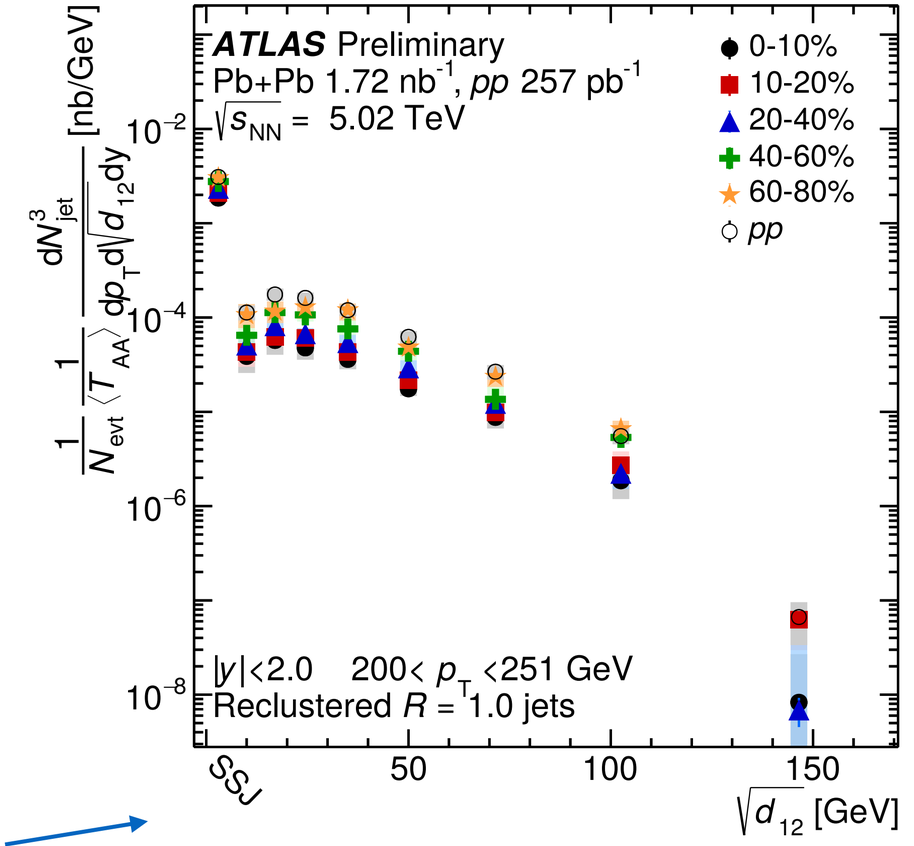
1907.04866 Caucal, Iancu, Soyez

large R jets

- R = 1.0 jets composed of R = 0.2 jets with p_T > 35 GeV
  - removes soft, diffuse energy from the jets

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





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

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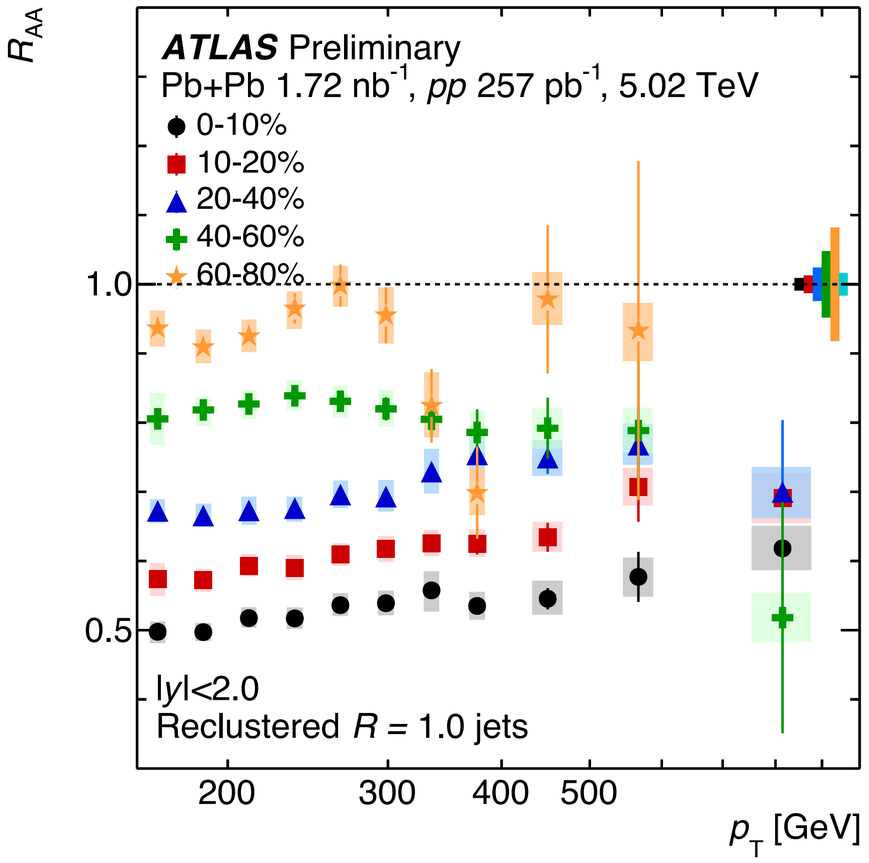
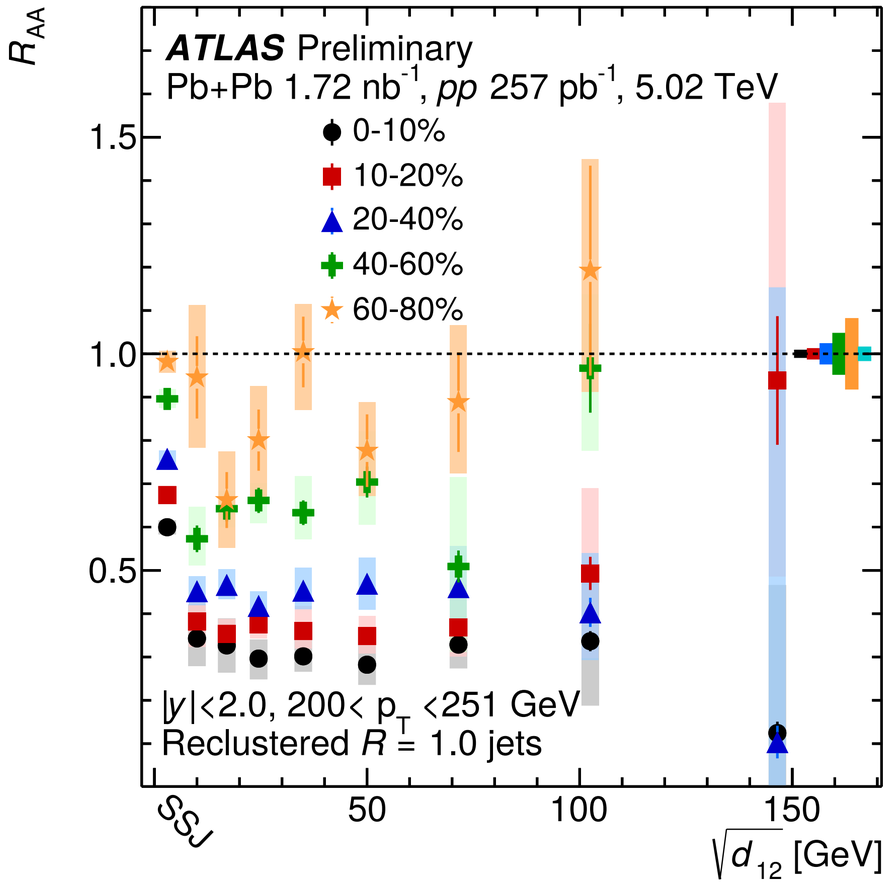
R_{AA} of these jets





R = 1.0 jets suppressed out to 800 GeV

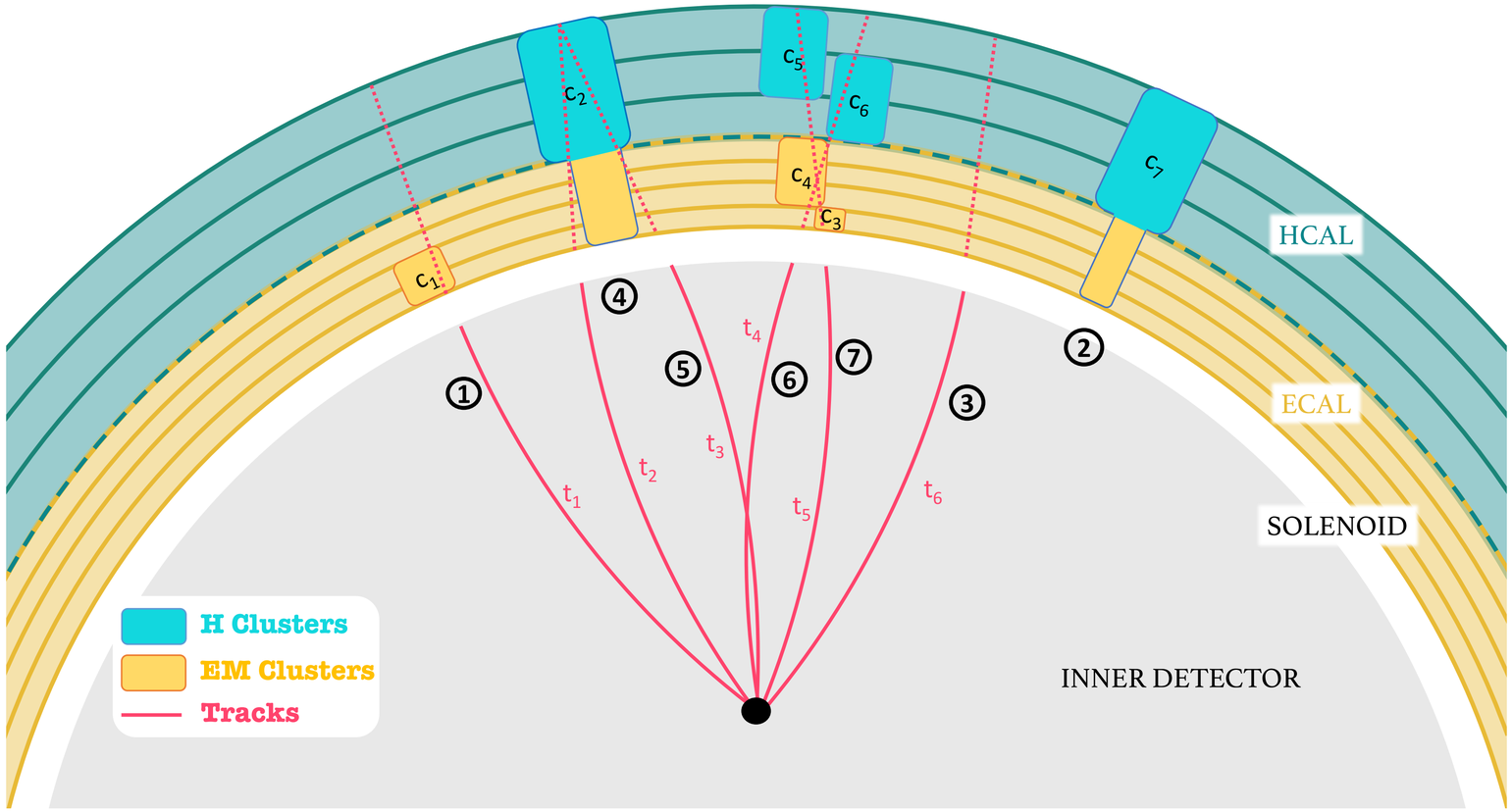
jets with a single sub-jet (SSJ) are less suppressed than those with >1 sub-jet

ATLAS-CONF-2019-056

track-calo clusters (TCCs)

TCCs use the tracks to improve the substructure performance of the clusters & *allow a closer look at small angles than is possible in the $\sqrt{d_{12}}$ measurement*

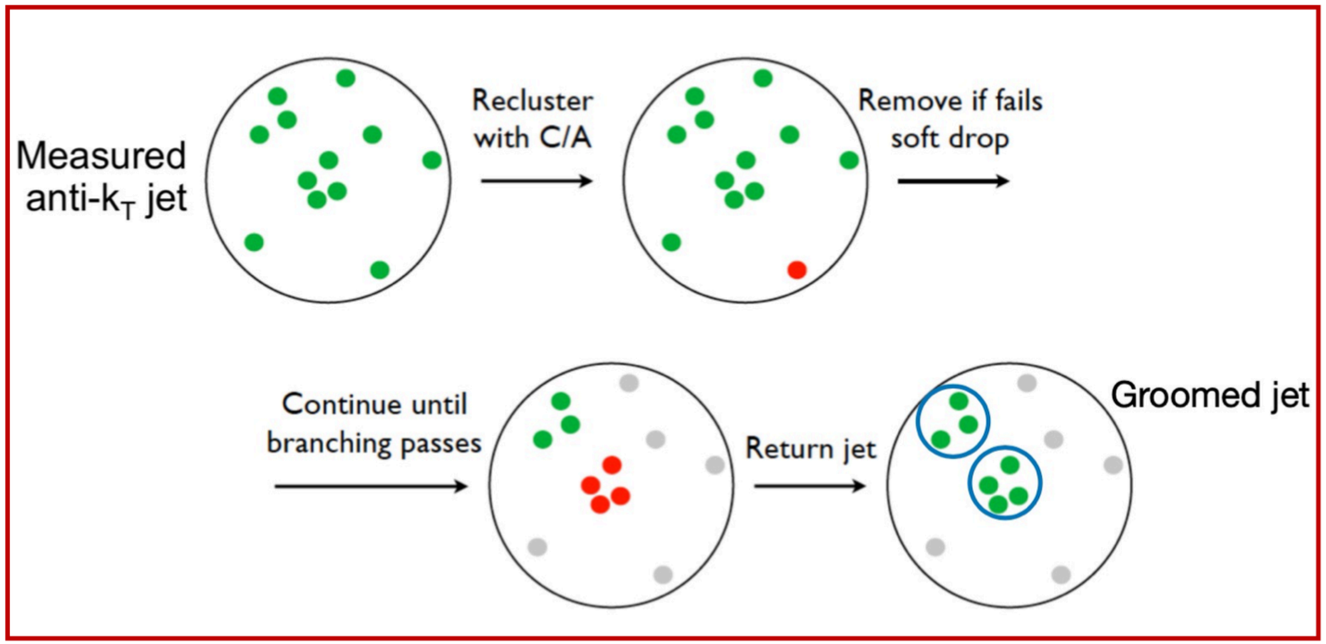
here TCCs with p_T > 4 GeV are used to reduce the effect of the underlying event
jets are the same calorimeter jets as in previous ATLAS HI measurements to allow for direct comparison to other measurements



ATL-PHYS-PUB-2017-015

analysis procedure

- Jets are reclustered with C/A algorithm and iteratively declustered till the subjets satisfy the Soft Drop (SD) condition
- jets are R = 0 calorimeter jets; substructure constituents are TCCs
  - r_g and jet p_T are unfolded using 2D Bayesian unfolding to the truth level

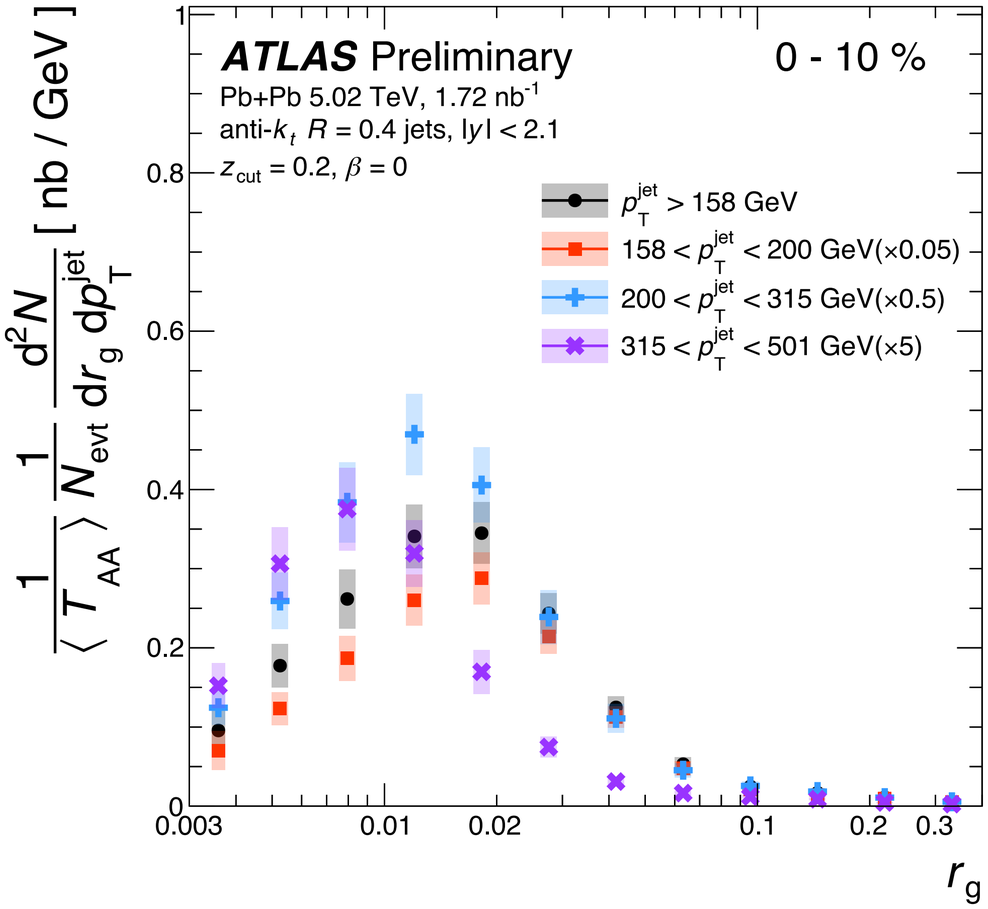


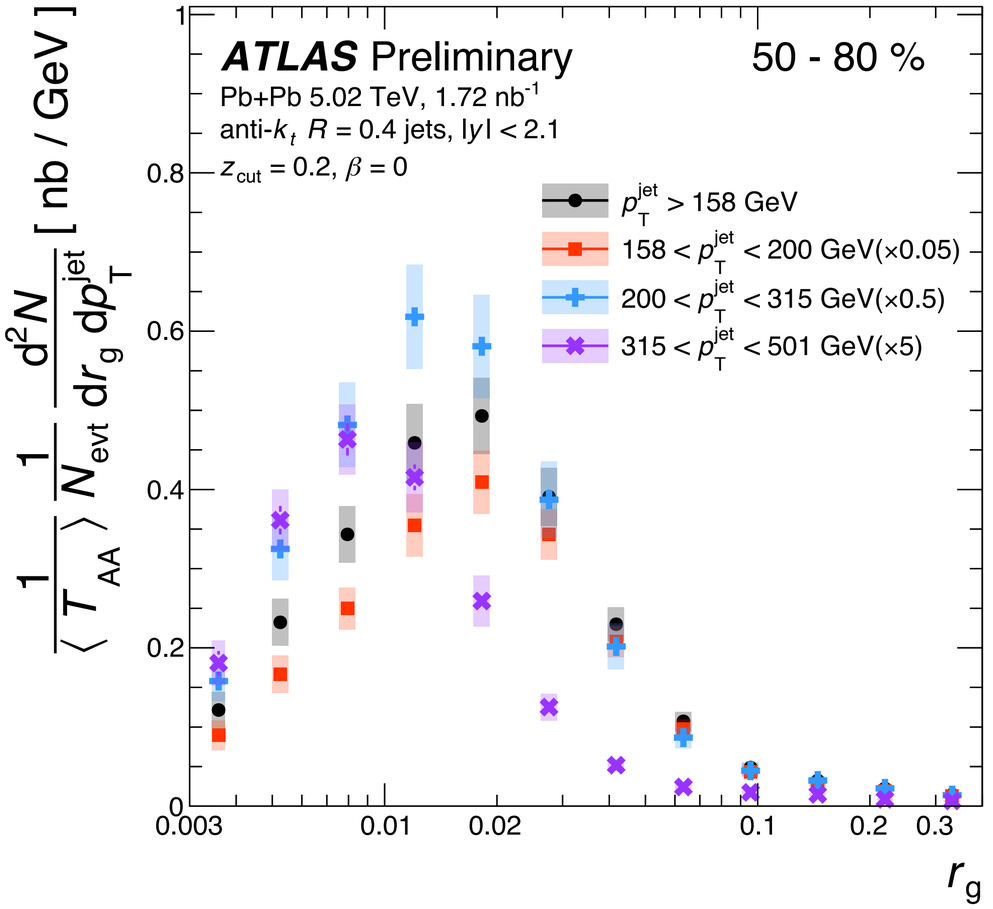
$$z_g = \frac{min(p_{T,i}, p_{T,j})}{p_{T,i} + p_{T,j}} > z_{cut} \left(\frac{\Delta R_{i,j}}{R} \right)^{\beta}$$

$$z_{cut} = 0.2 \qquad \beta = 0$$

$r_g = \Delta R_{i,j}$ **between the subjets satisfying the SD condition**

r_g distributions



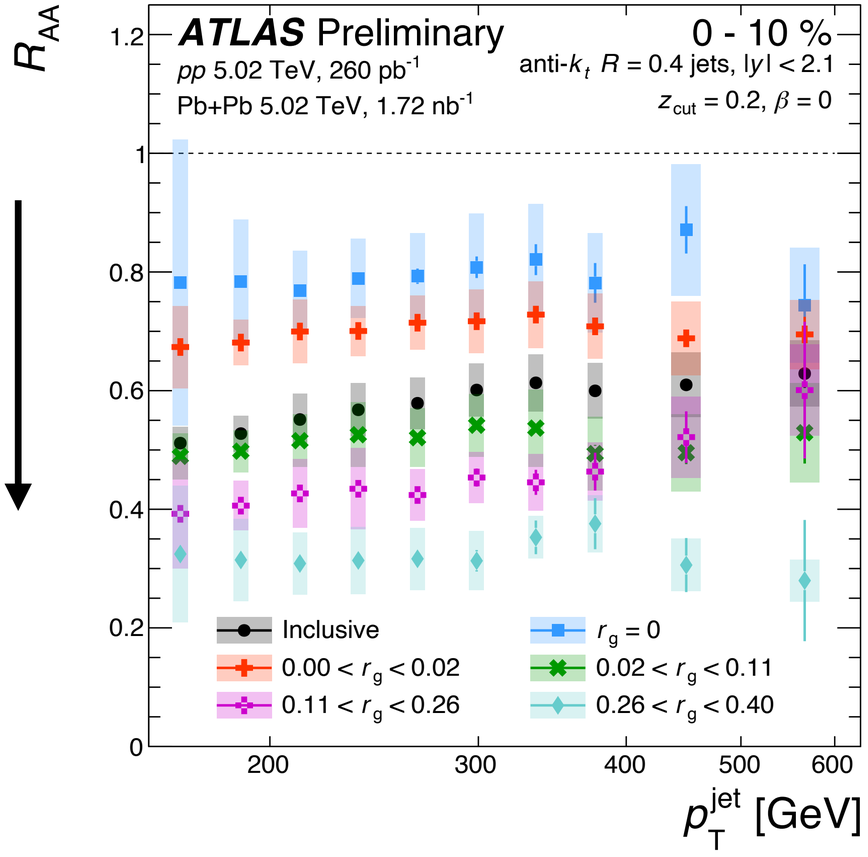


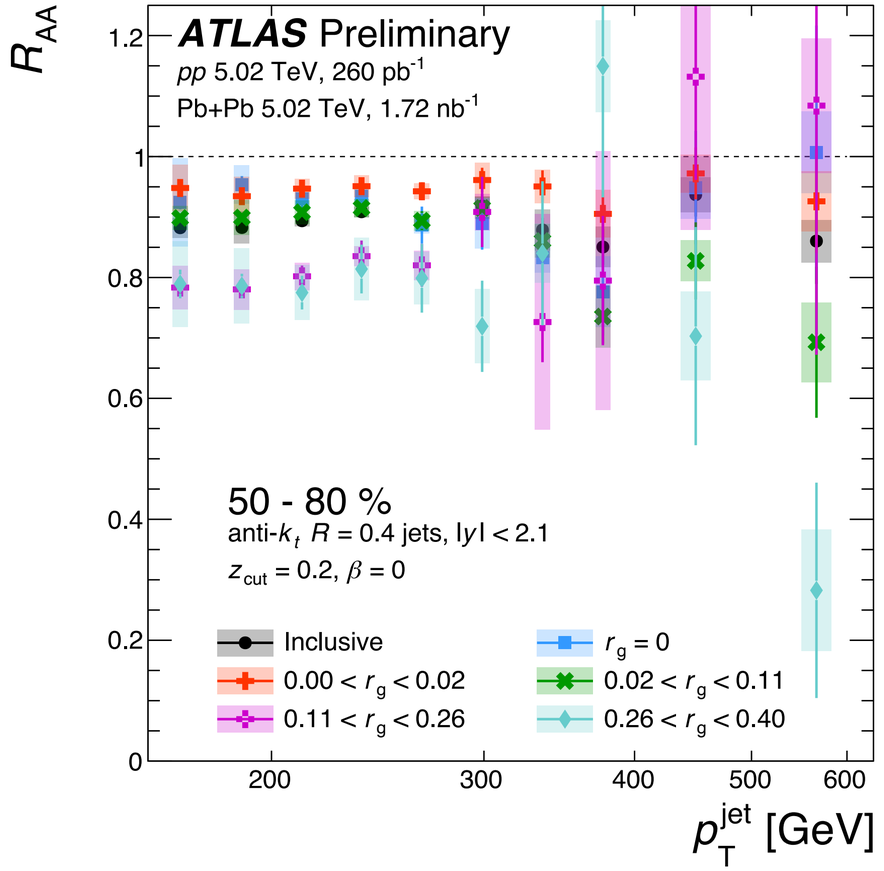
r_g distribution shape has jet p_T depedence but little centrality dependence

ATLAS-CONF-2022-026

r_g dependence of suppression

large r_g jets more suppressed





similar trends with r_g for all centralities

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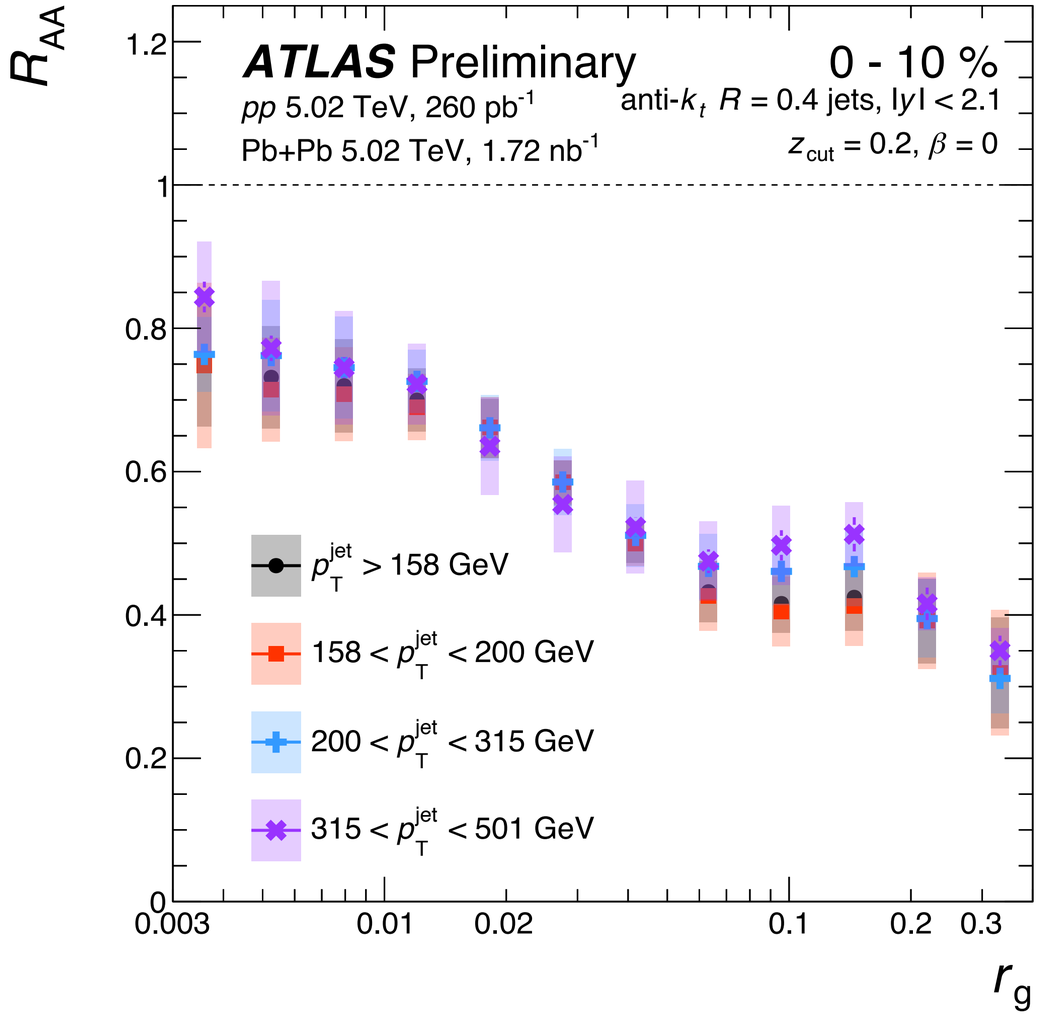
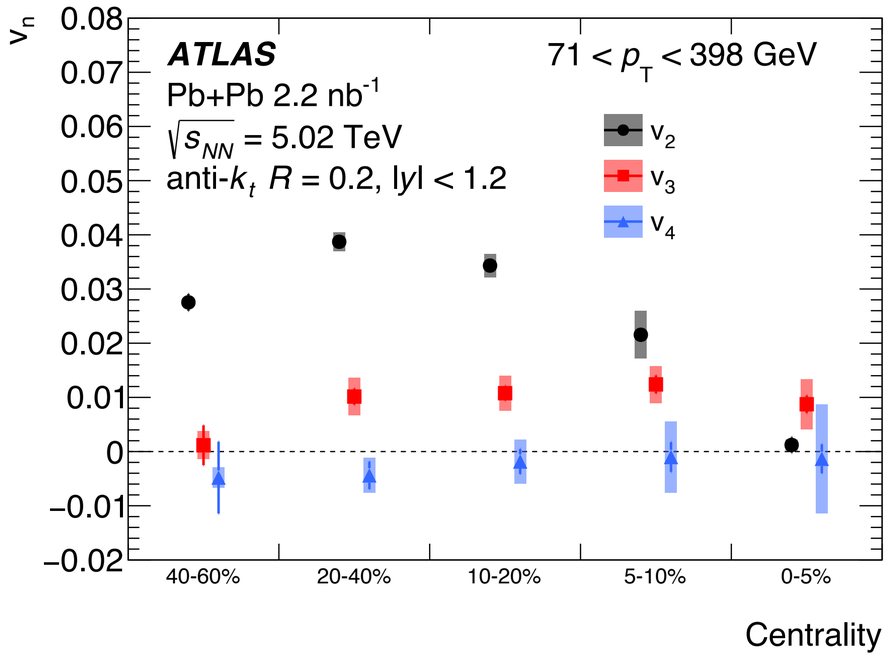
r_g dependence of suppression



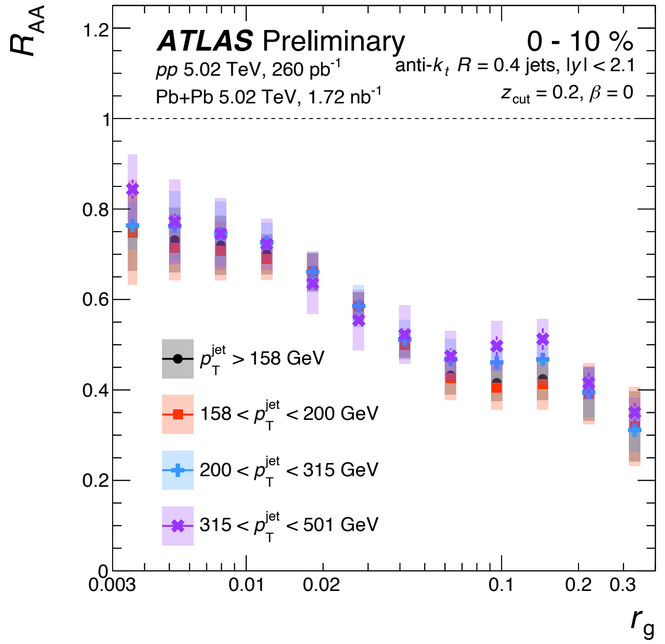
- clear r_g dependence to R_{AA}
- r_g, not jet p_T, determines the R_{AA}

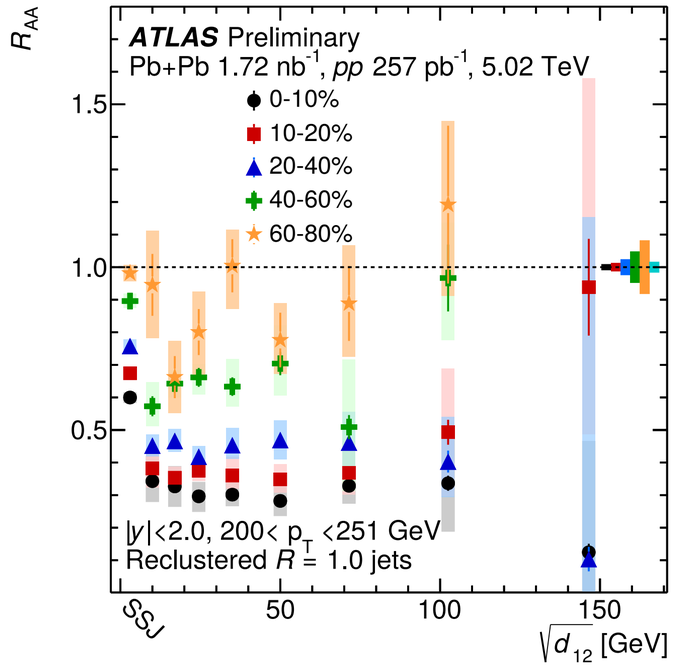
ATLAS-CONF-2022-026

summary



jet azimuthal anisotropies show path length dependence of jet quenching

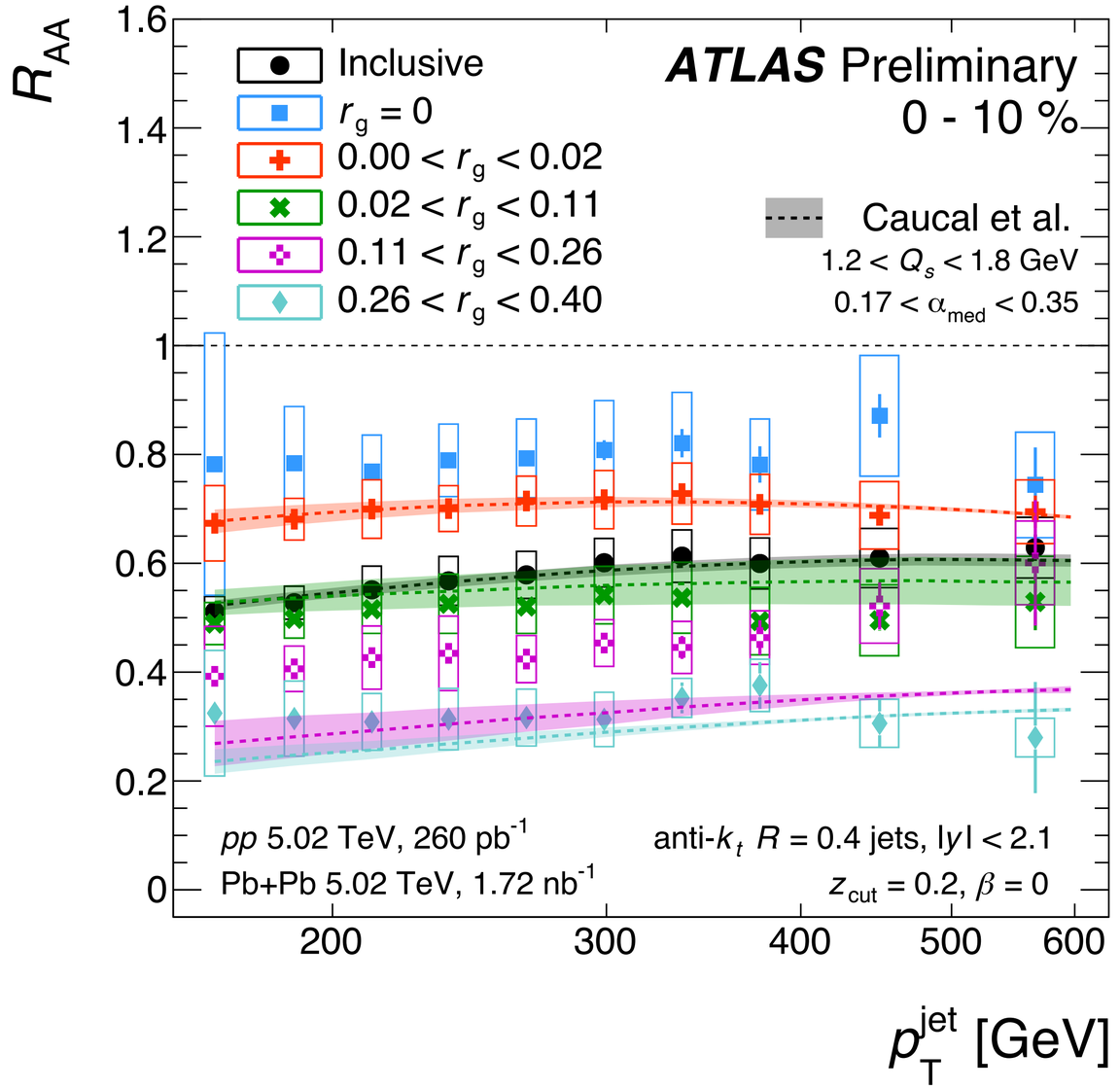




jet suppression shows strong r_g dependence within R = 0.4 jets

both geometry and substructure play a significant role in jet quenching

see all ATLAS Heavy Ion results here: https://twiki.cern.ch/twiki/bin/view/AtlasPublic/HeavyIonsPublicResults

backups

theory comparison