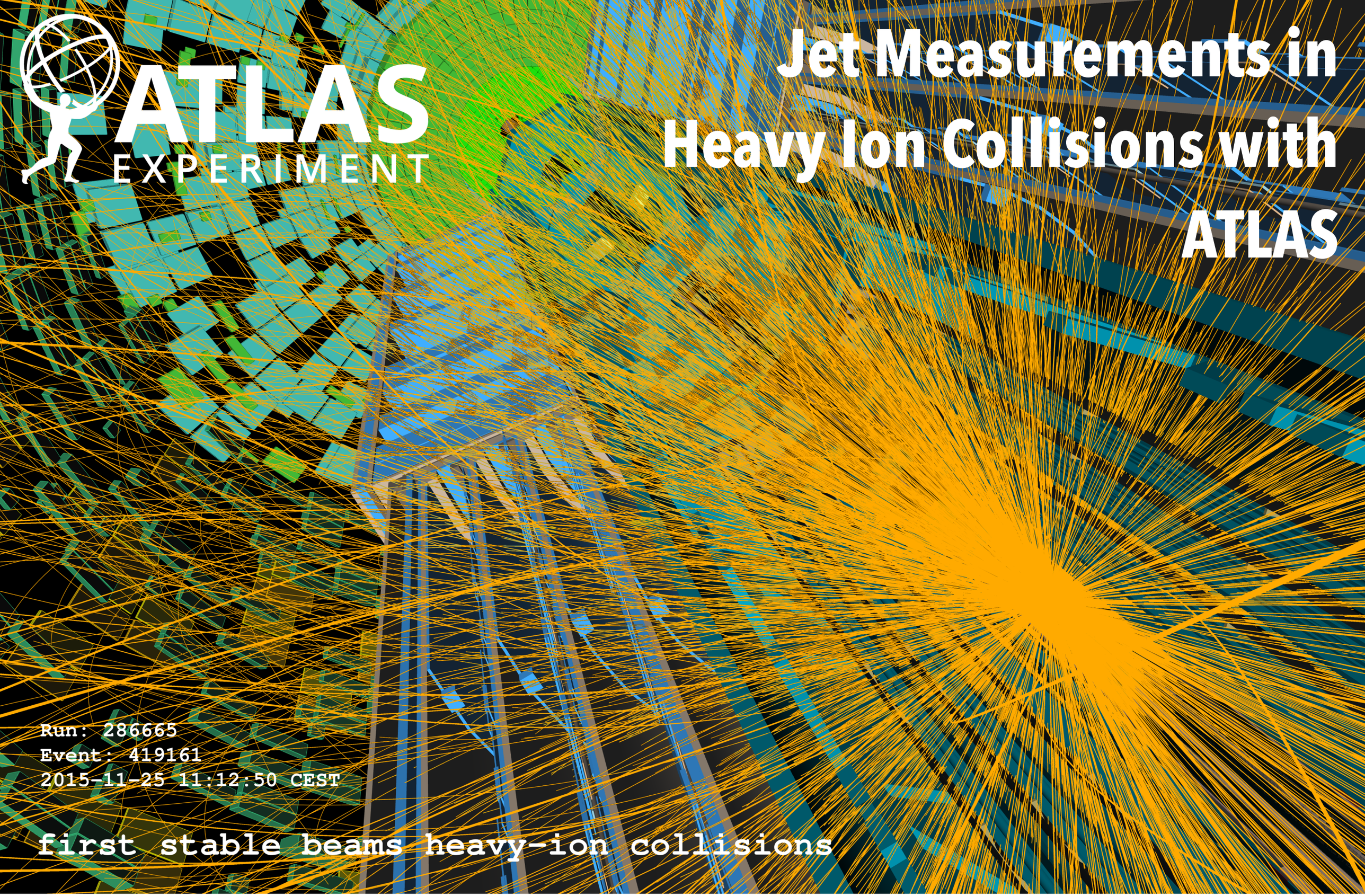
Jet Measurements in Heavy Ion Collisions with ATLAS

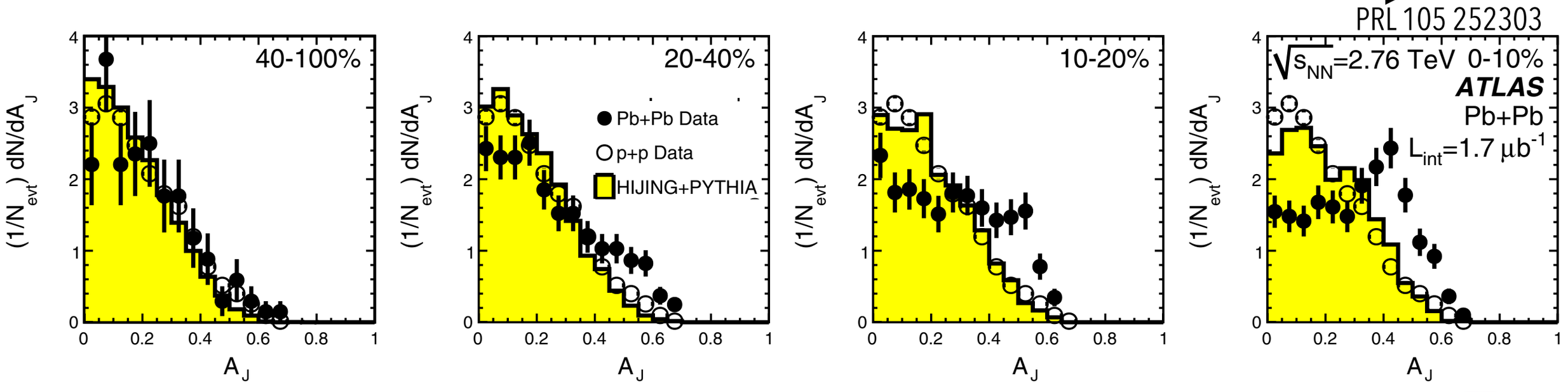


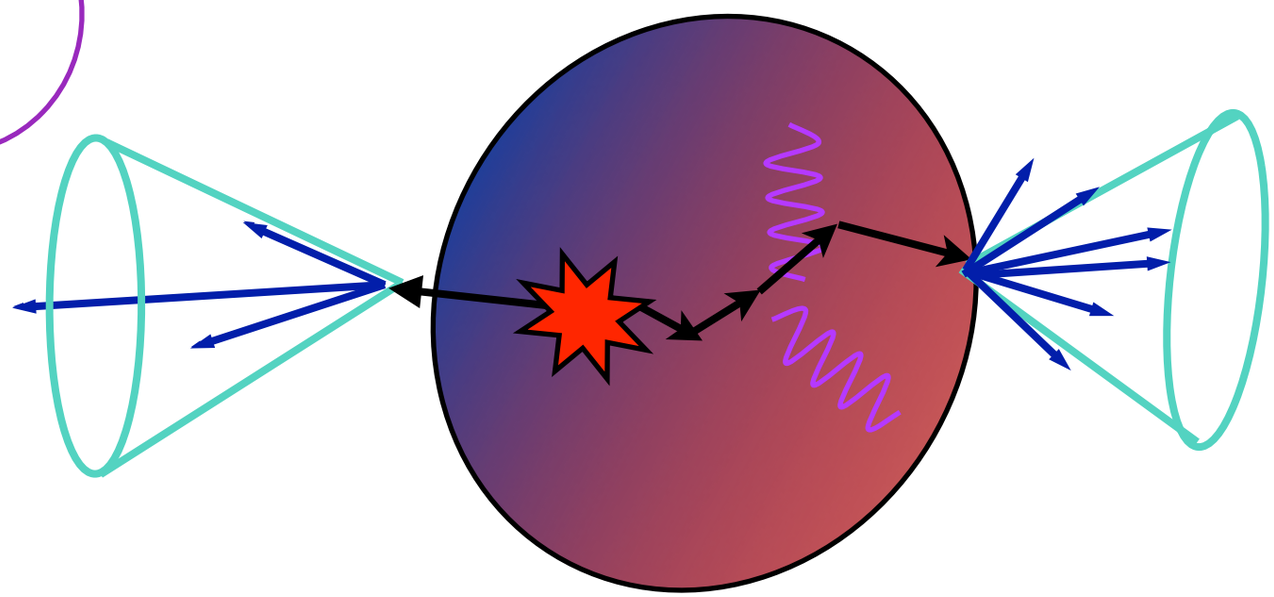
Anne M. Sickles, for the ATLAS Collaboration

January 28, 2018

jets in PbPb collisions

more central collisions

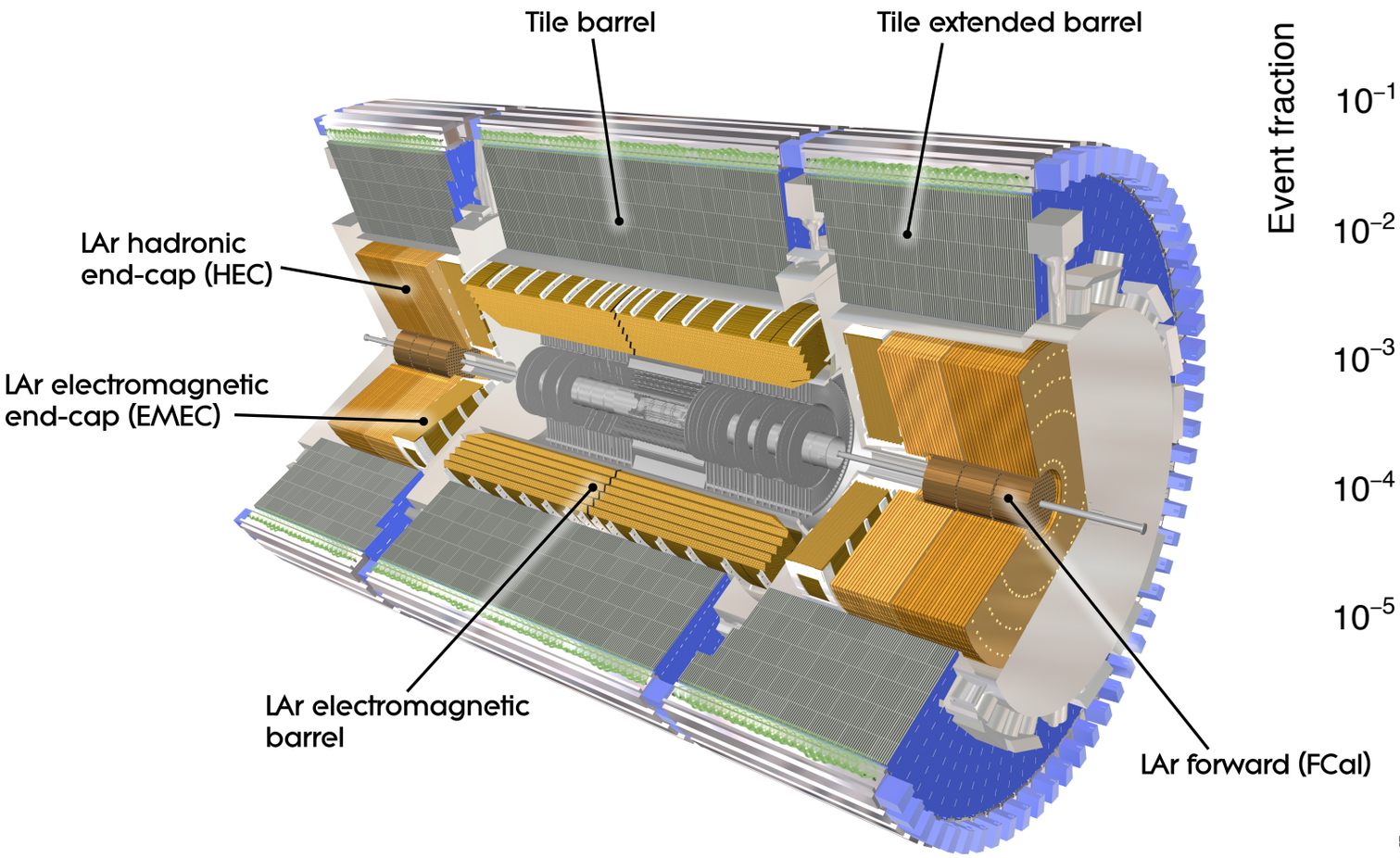


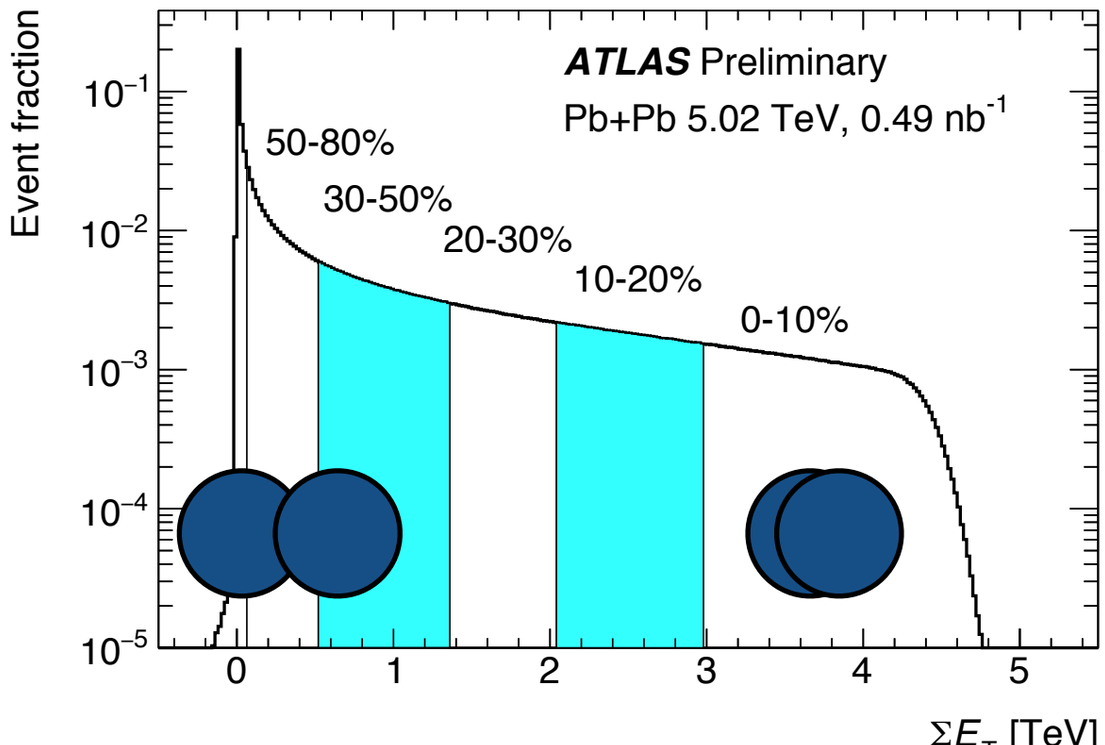


what happens to jets as they pass through the quark-gluon plasma?

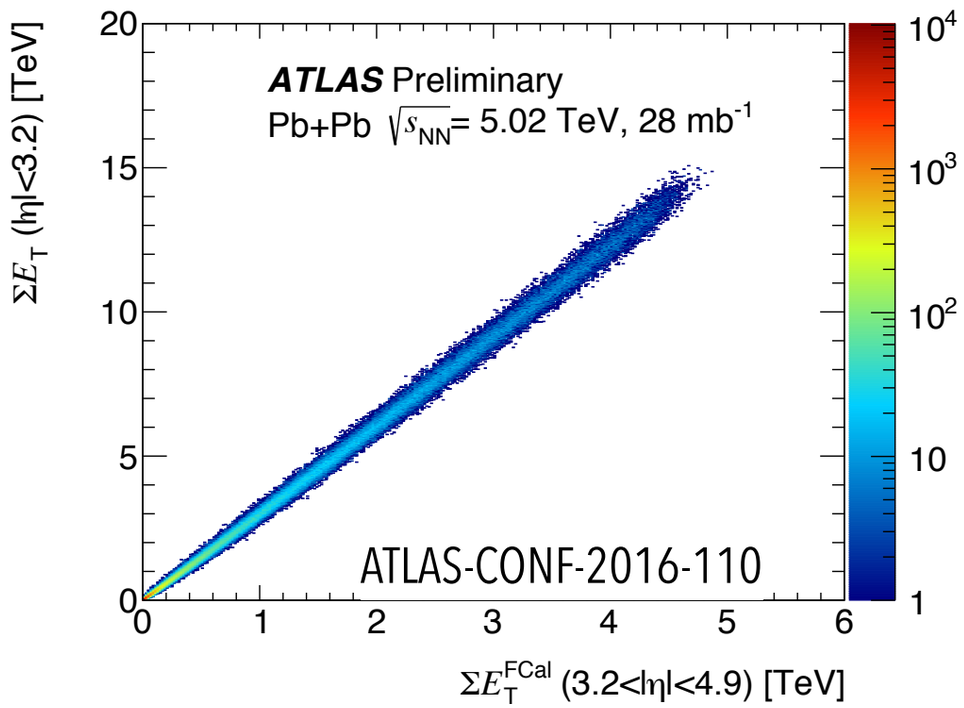
what does that tell us about the properties of the QGP?

event classification: centrality

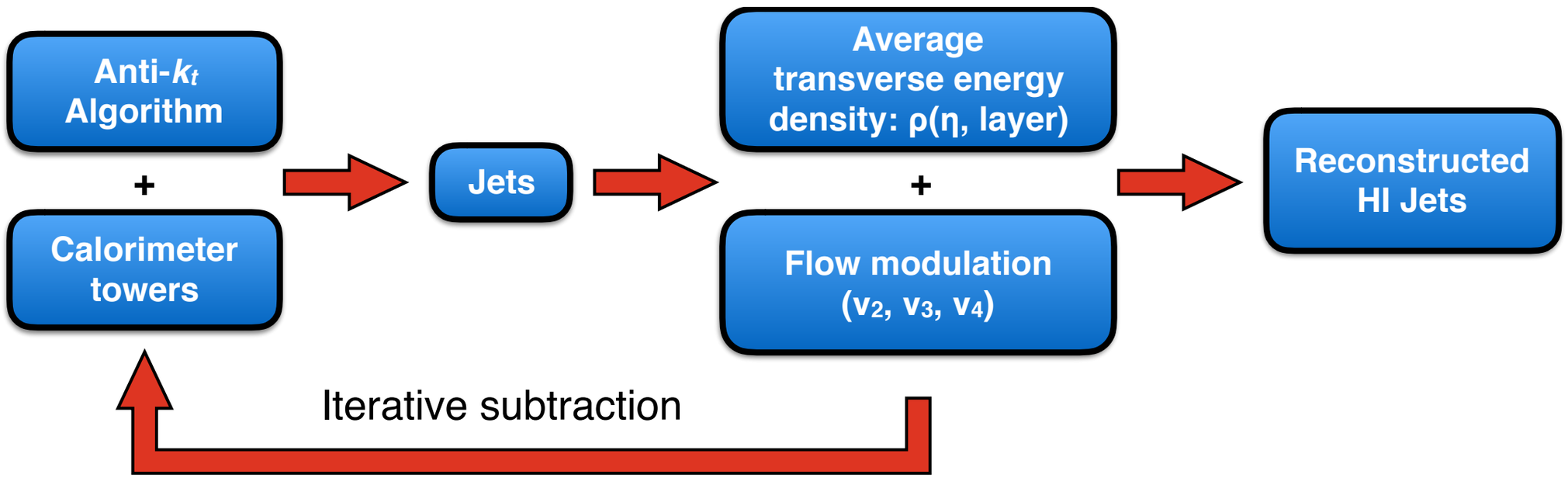




idea: FCal ΣE_T is correlated with collision impact parameter



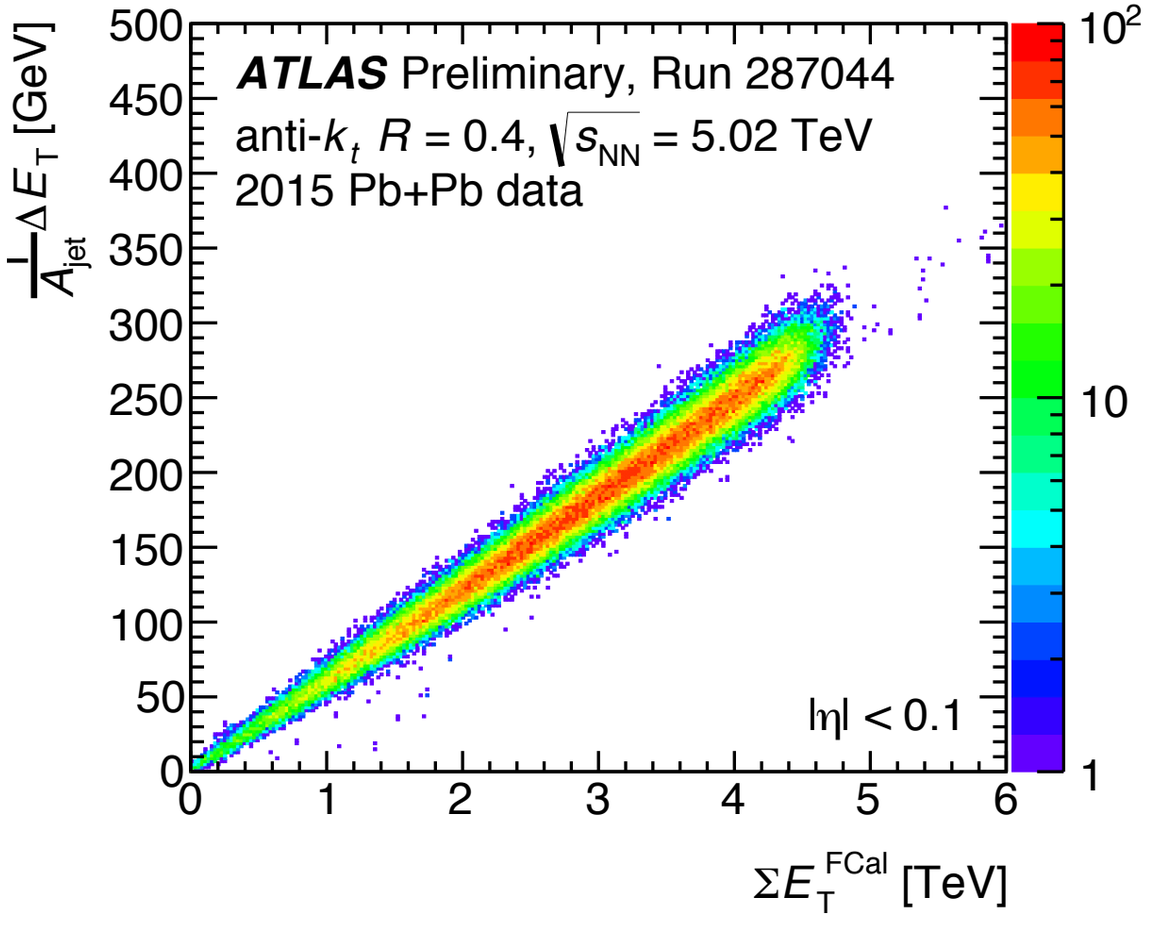
jet reconstruction in heavy ion collisions in ATLAS



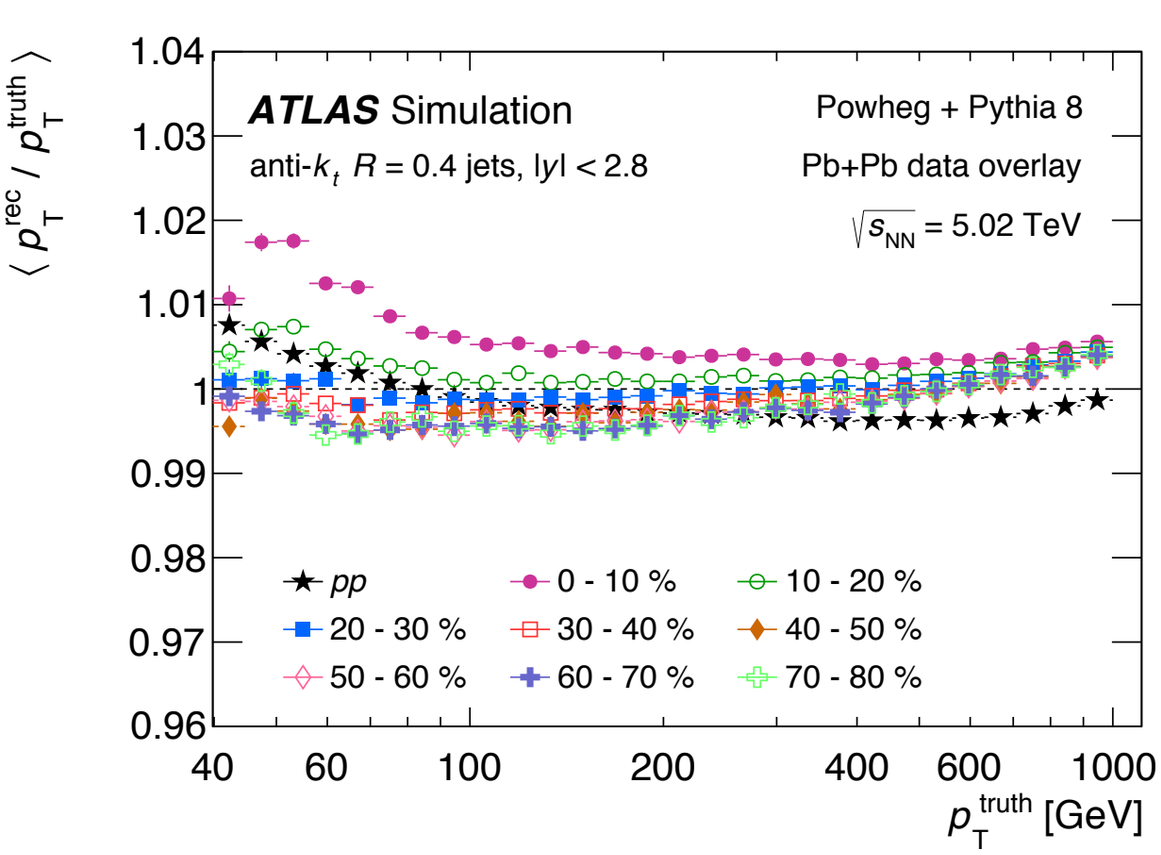
jet constituents: 0.1x0.1 calorimeter towers in ηxφ

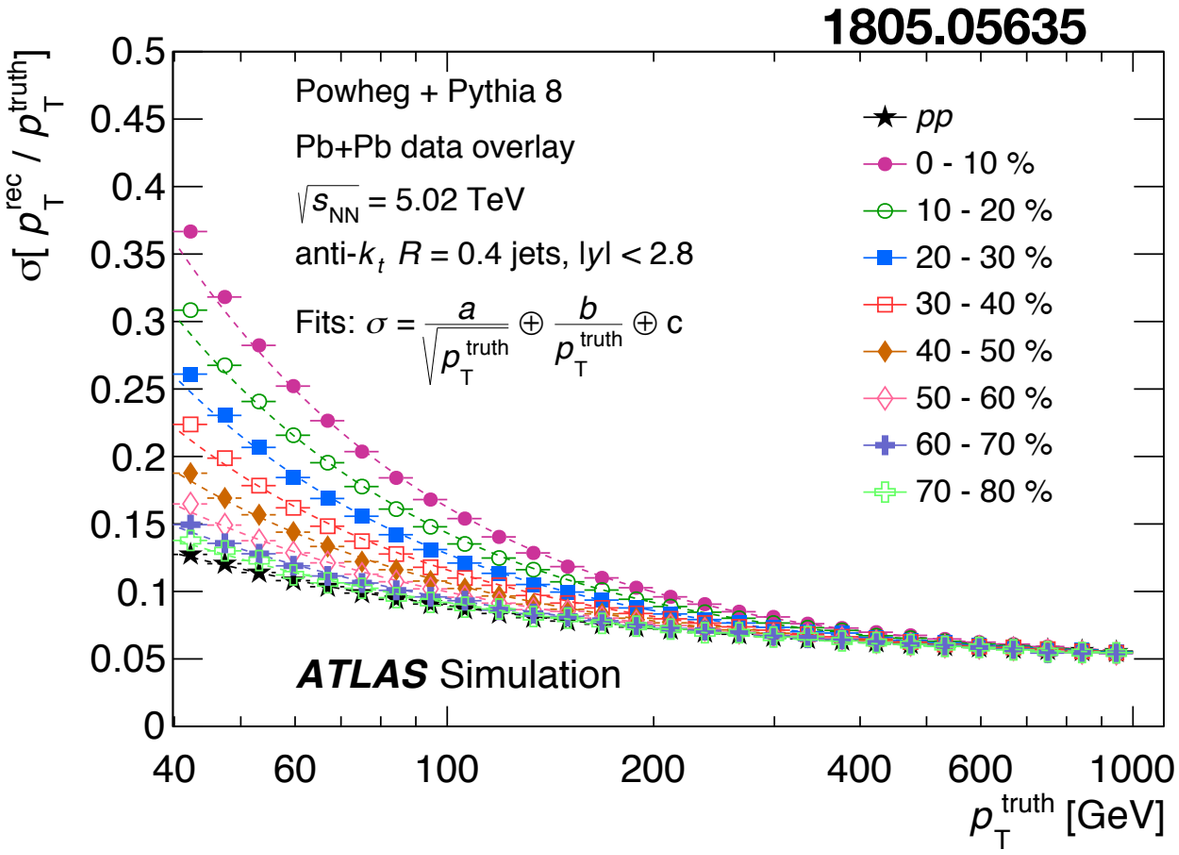
large UE: R = 0.4 jet → A_{jet} = 0.5

subtract up to 150 GeV from jet energy



jet performance



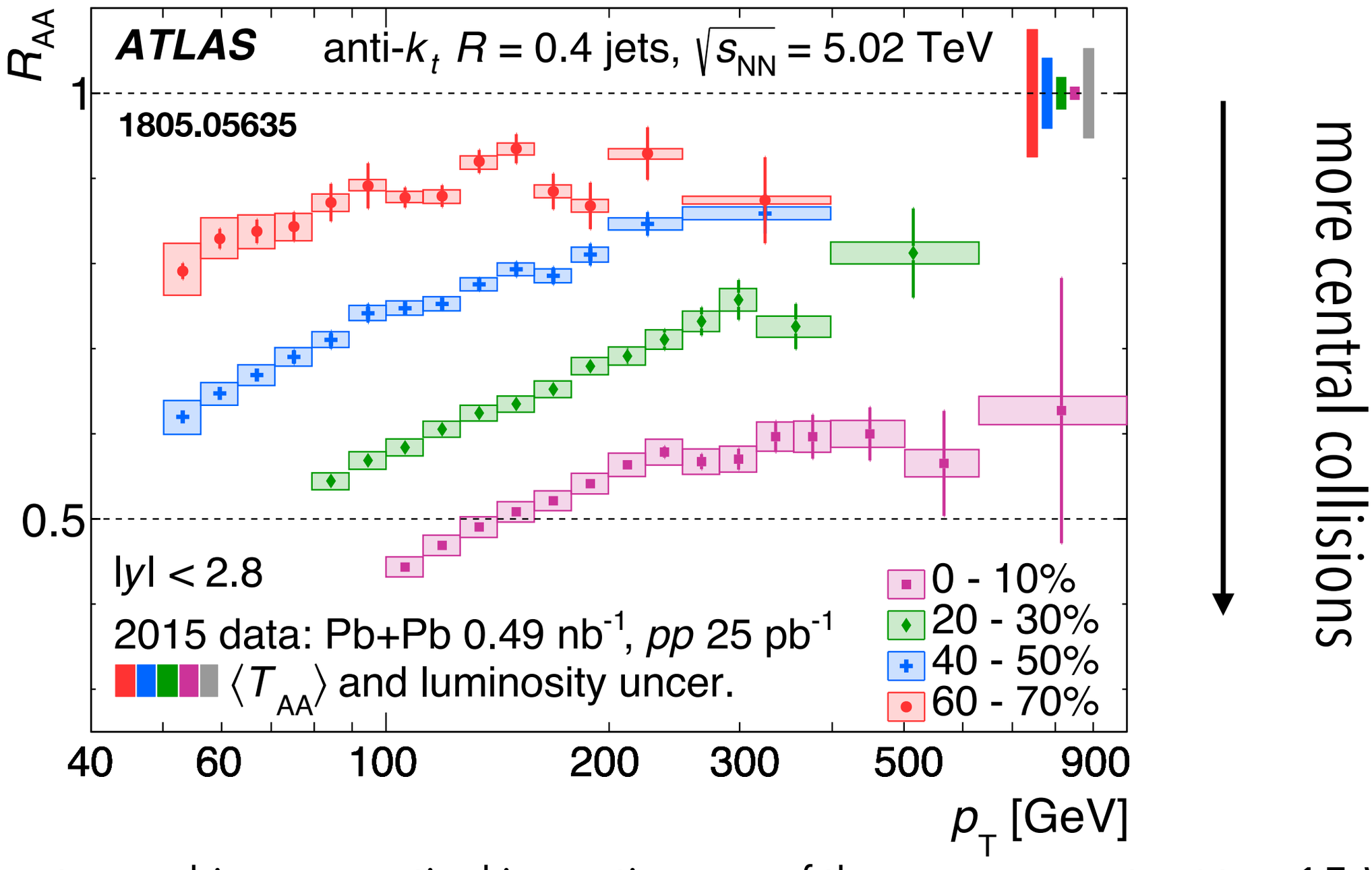


- **Jet Energy Scale**: ~1% centrality dependence above 100 GeV
- **Jet Energy Resolution**: degraded in central collisions wrt pp due to underlying event fluctuations

jet quenching

R_{AA} = number of jets in PbPb collisions/ pp collisions scaled by nuclear thickness function

$R_{AA} = 1 \rightarrow$ jets in PbPb collisions like pp collisions

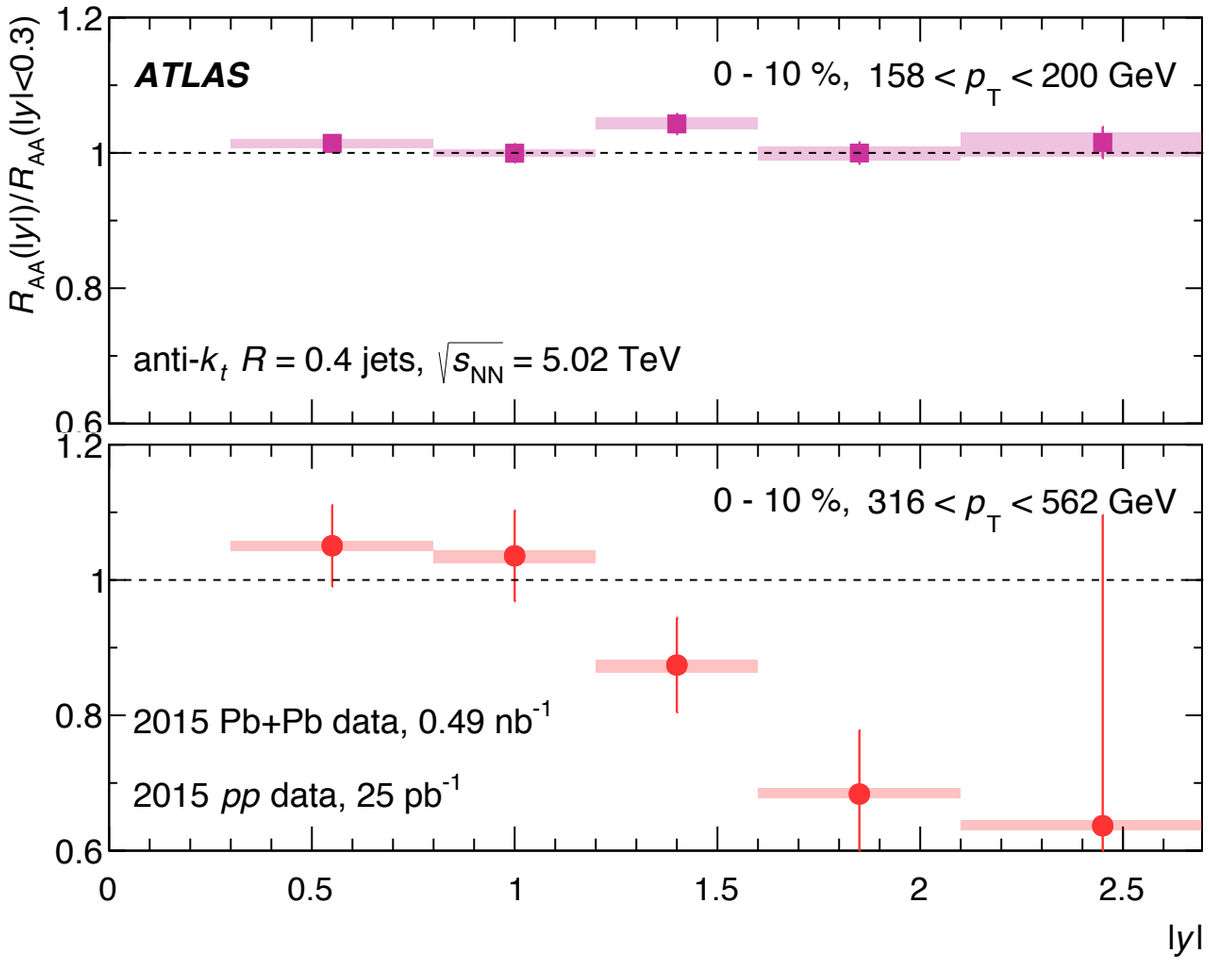


significant quenching over entire kinematic range of the measurement out to ~1 TeV

rapidity dependence of R_{AA}

- why rapidity?
  - fraction of quark jets increases with |y| at fixed jet p_T
  - quarks jets should lose less energy than gluon jets
    - **increase RAA with |y|**
- jet p_T spectra become steeper with increasing |y|
  - **decrease RAA with |y|**

1805.05635



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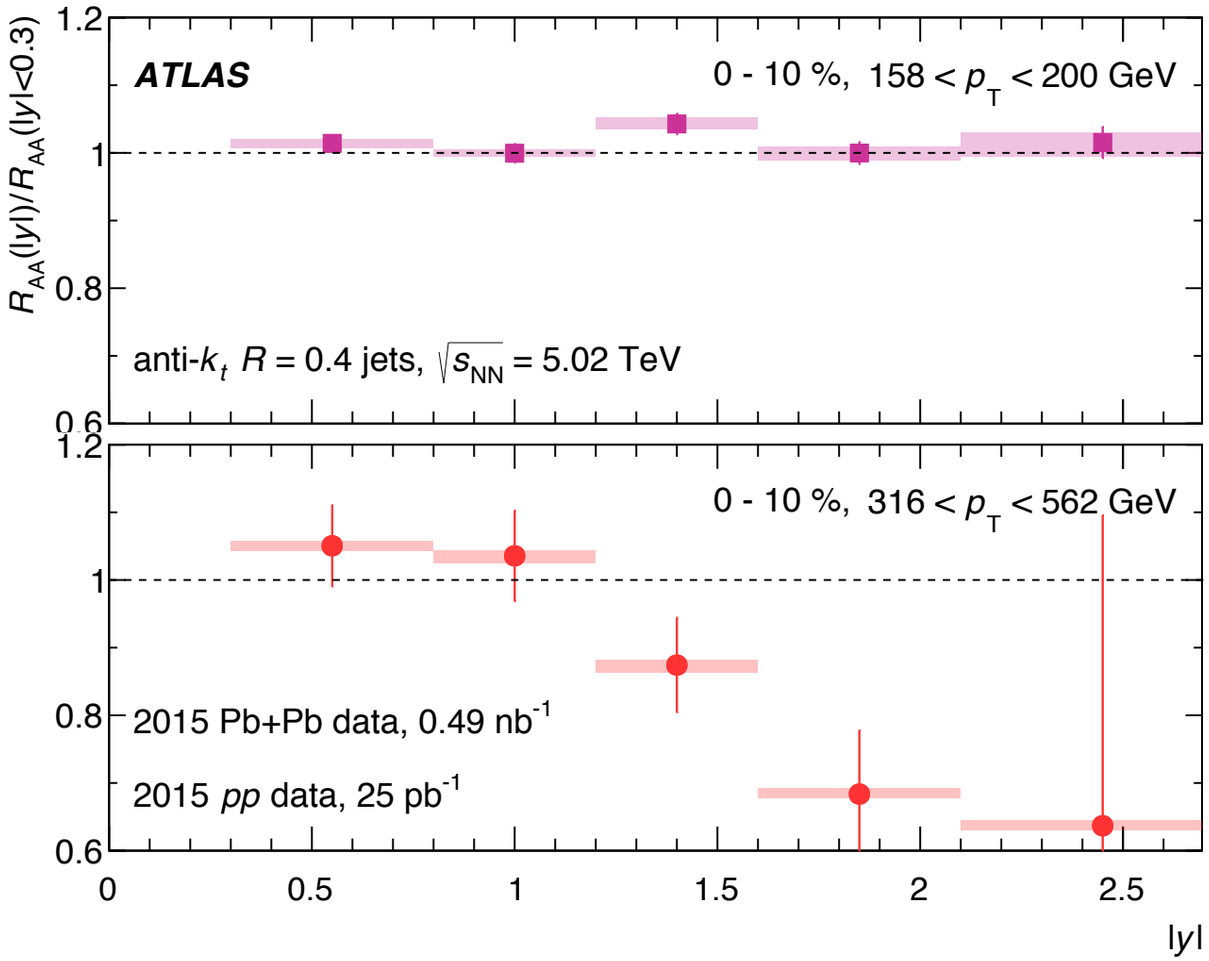
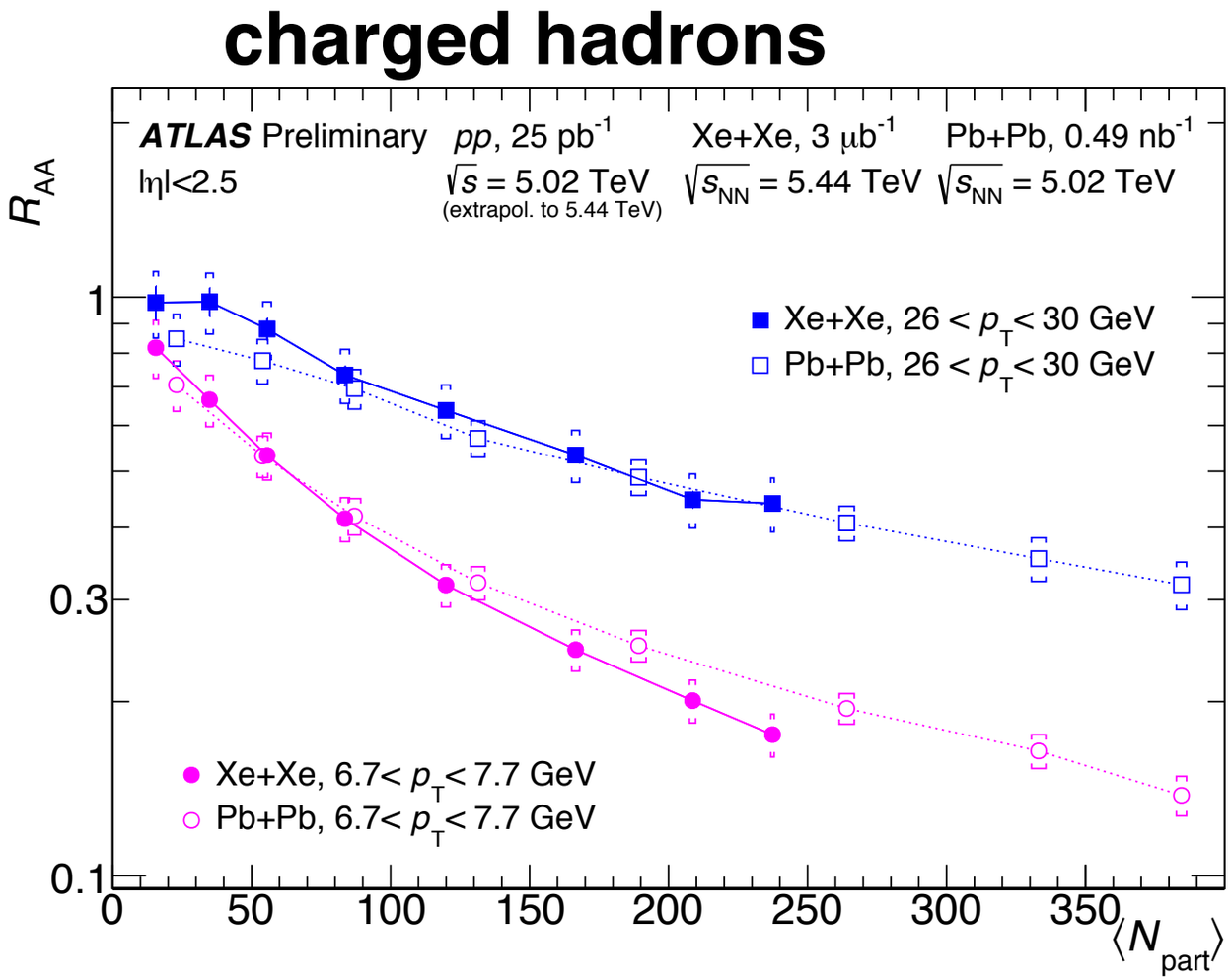
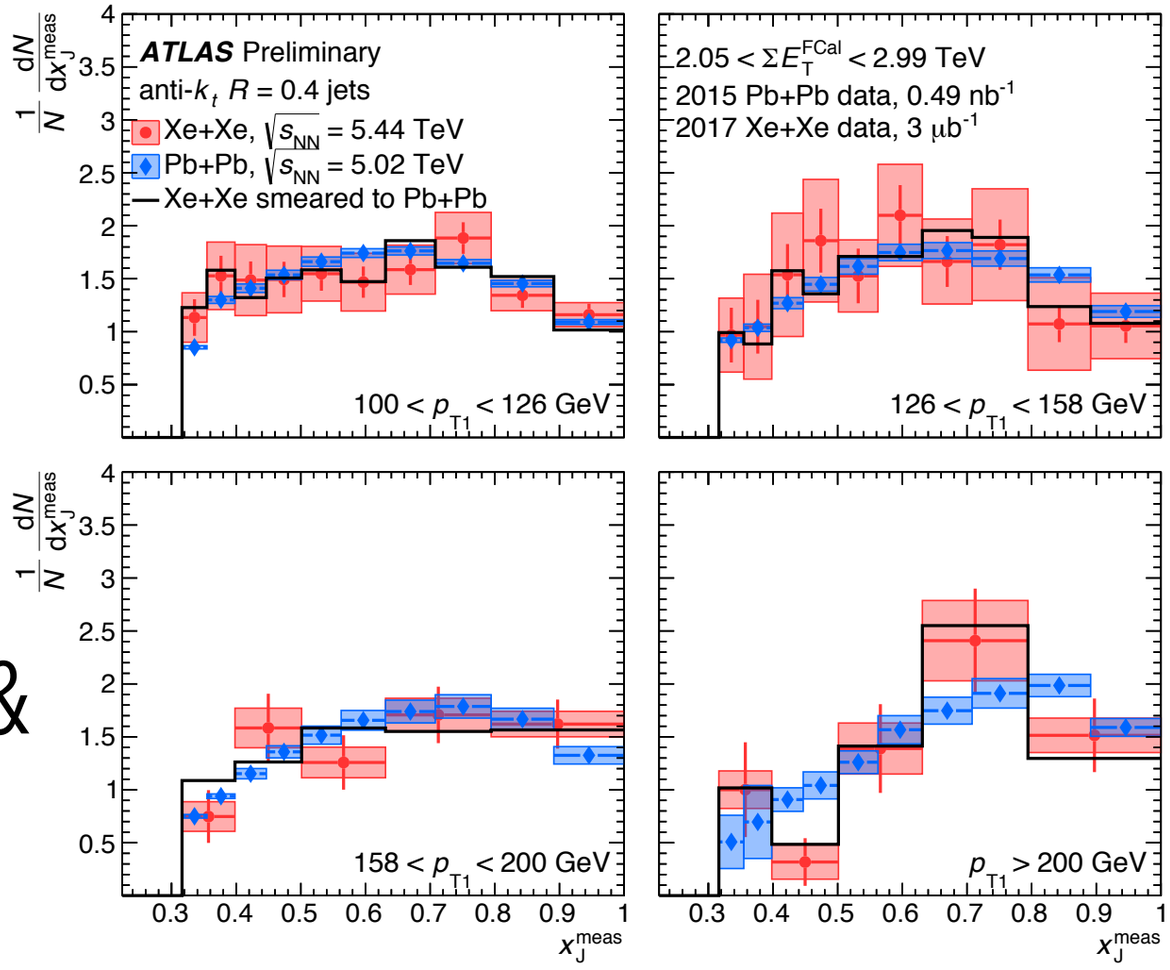


p_{Tjet} > 316 GeV: the effects of the steeper spectra dominate the measurement

XeXe–a first look at lighter ions



XeXe collisions provide a first look at the collision system dependence at the LHC



first results show that the jet modifications are consistent in XeXe & PbPb at the same system size

large uncertainties for Npart < ~50

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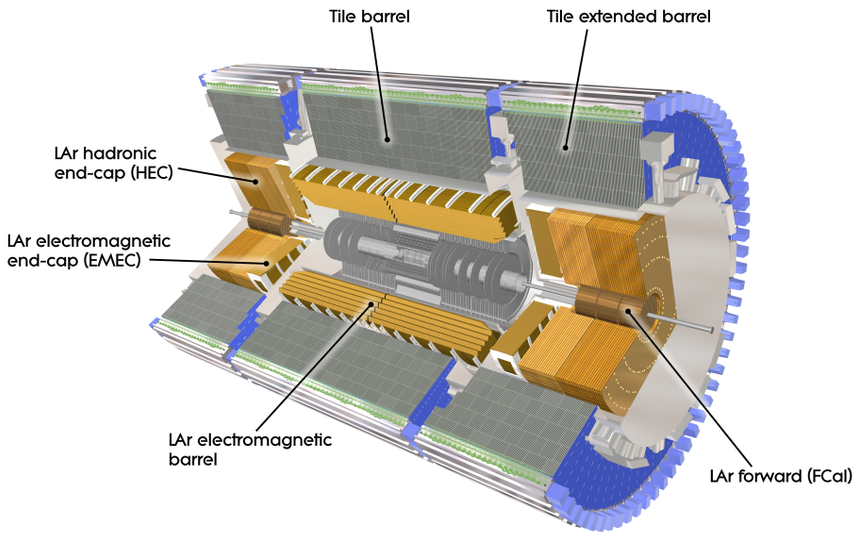
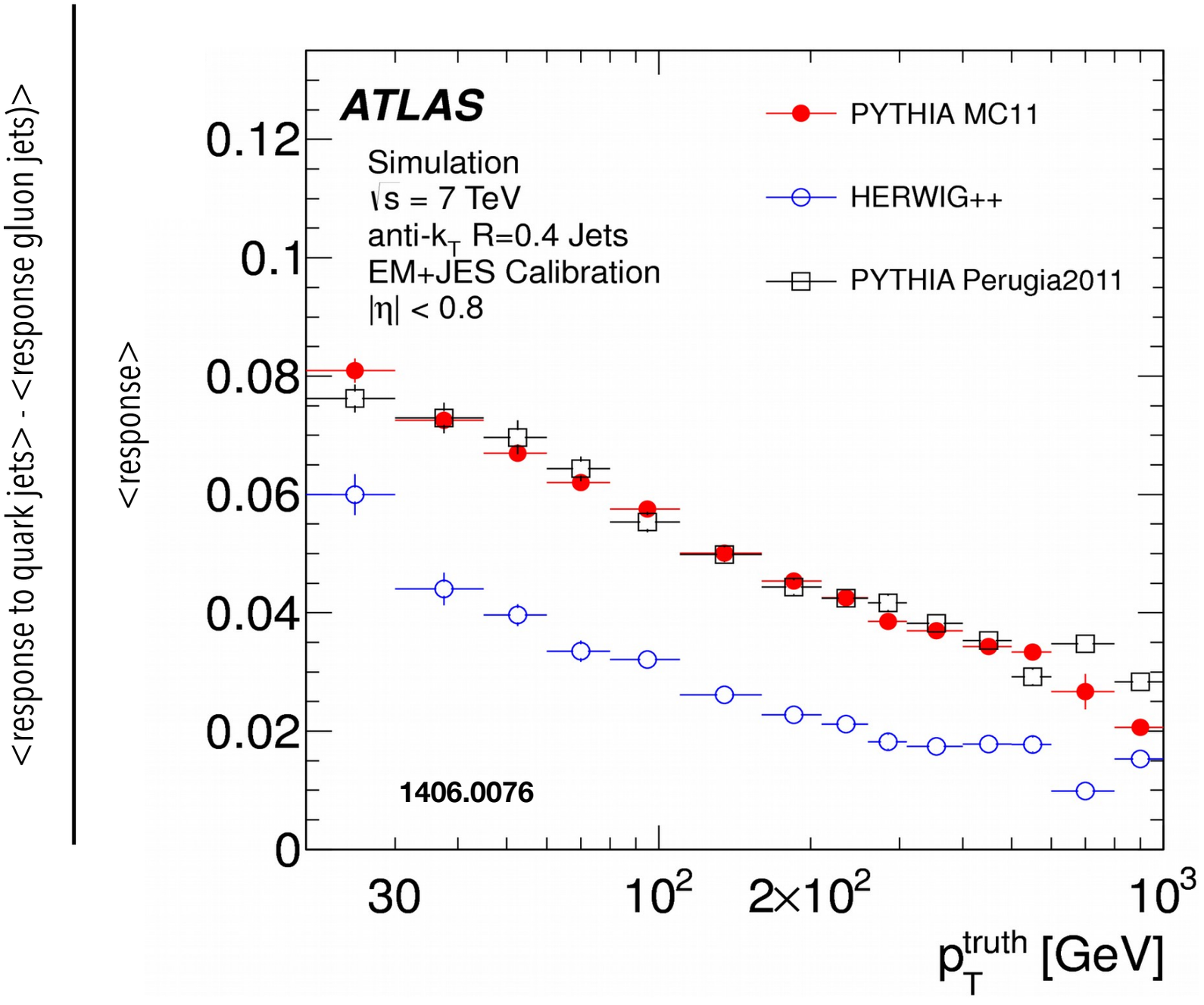
what about the structure of the jets in PbPb collisions?

calorimeter response to light jets





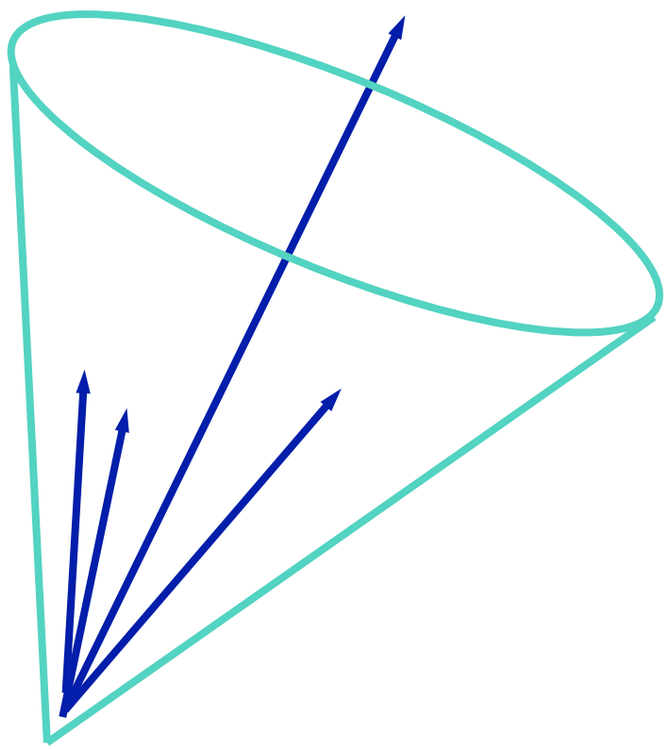
different calorimeter **response** to quark and gluon jets,
also different between PYTHIA & HERWIG

jet fragmentation

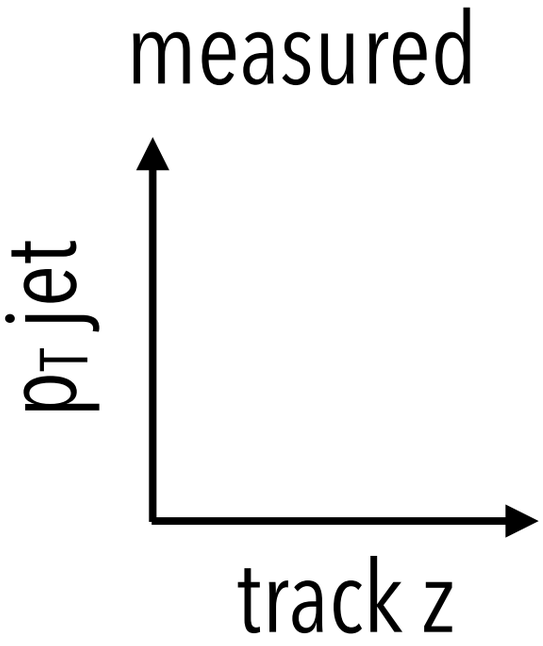
how do the particles in the jet carry its momentum?

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

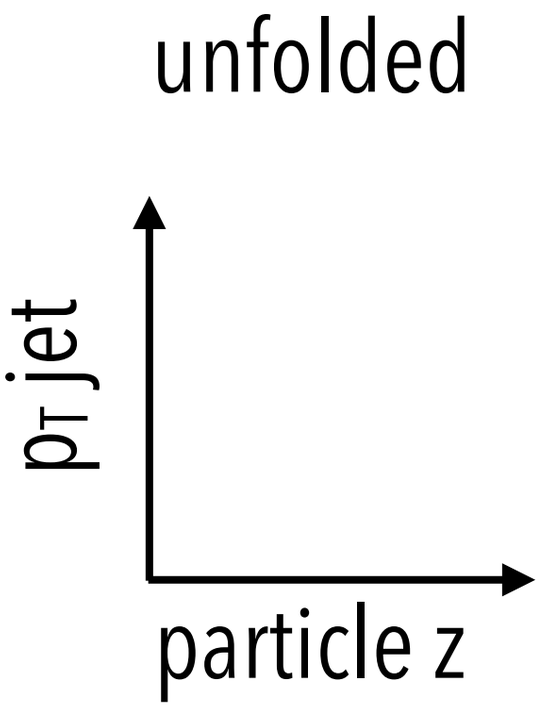
$$z \equiv p_{\mathrm{T}} \cos \Delta R \; / \; p_{\mathrm{T}}^{\mathrm{jet}}$$



unfolding for fragmentation functions



response matrix in $p_{T,meas}$, $p_{T,true}$, z_{meas}, z_{true}



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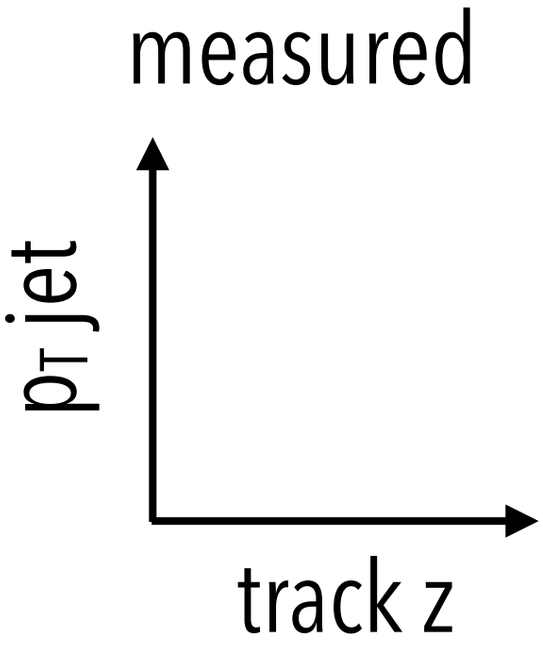
unfolding for fragmentation functions



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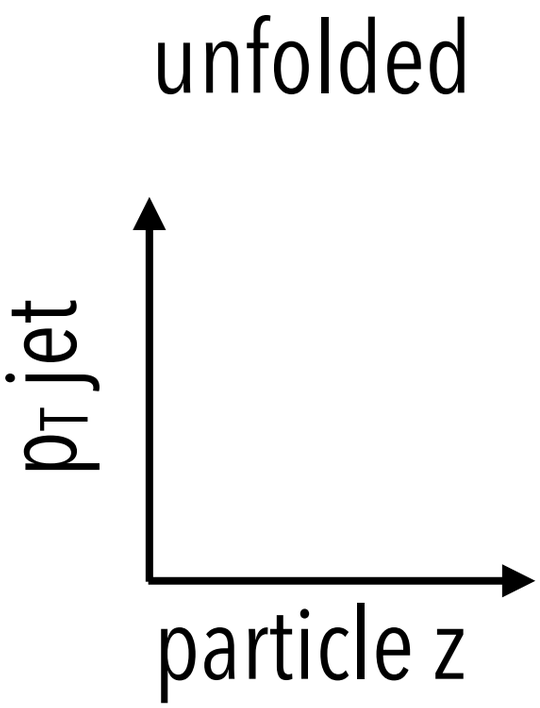

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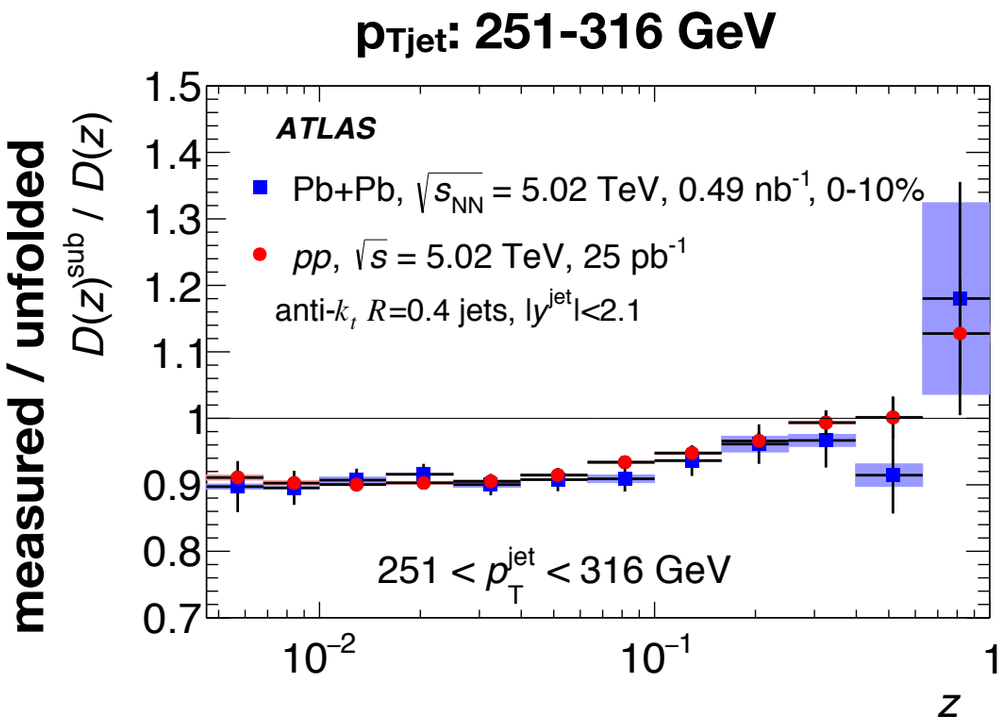
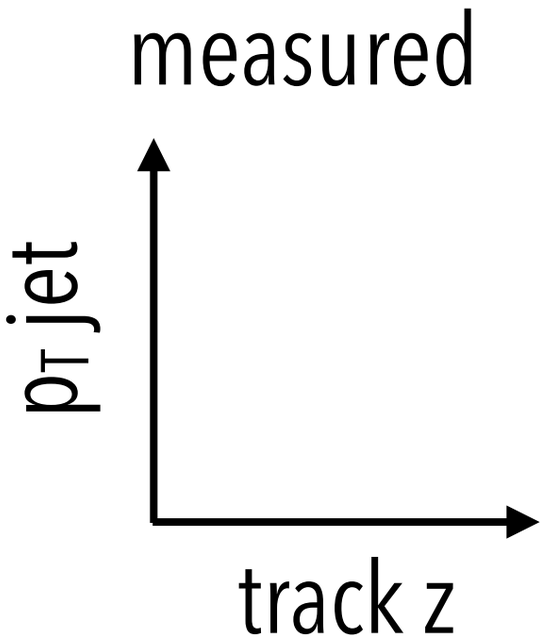
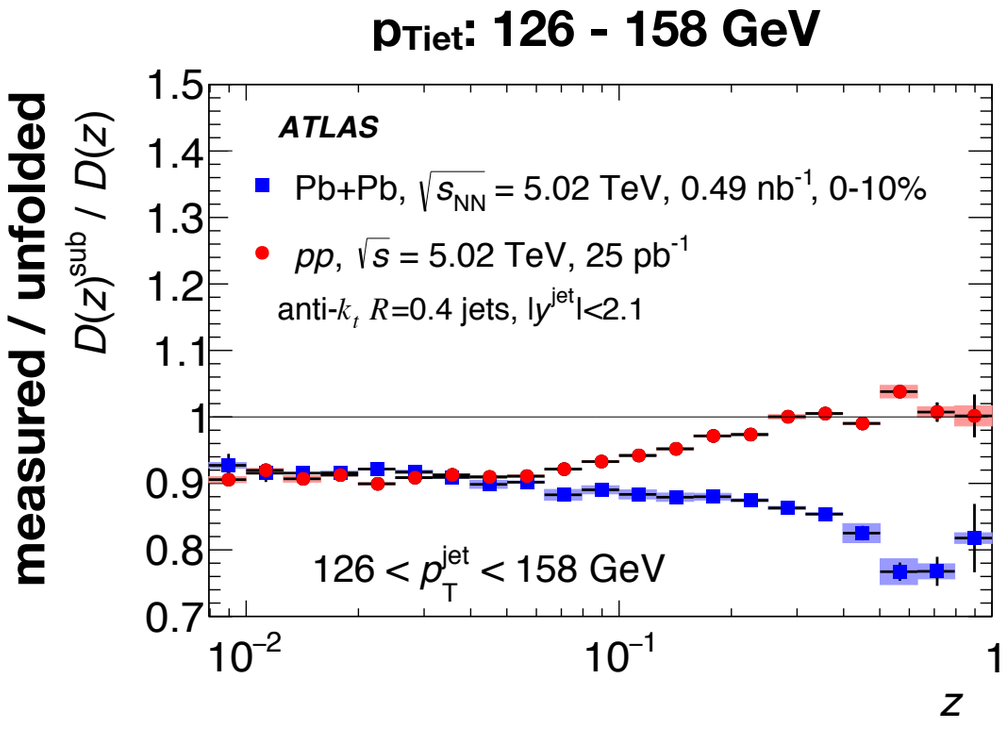


small UE effect
similar unfolding change in pp & PbPb

unfolding for fragmentation functions

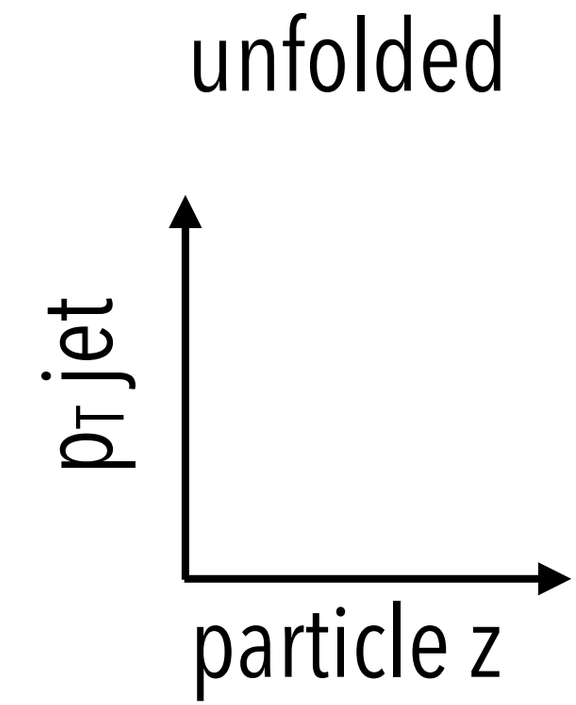


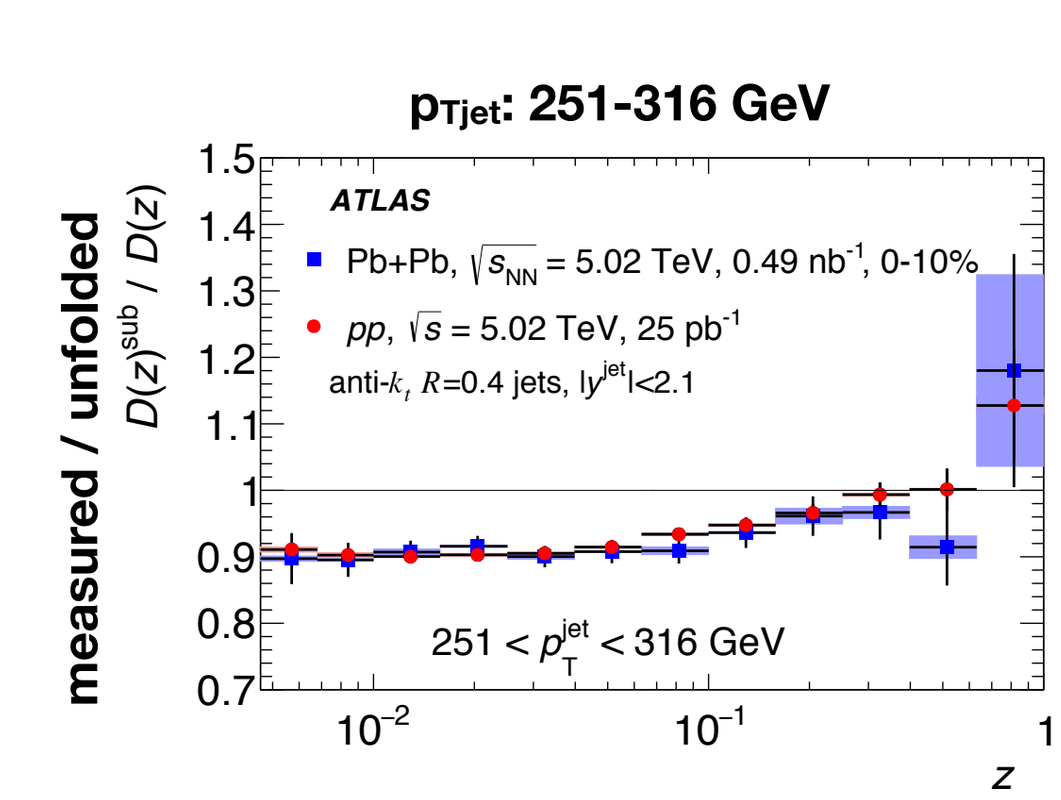


large centrality dependence to JER due to UE fluctuations

biggest effect at high z due to steepness of the fragmentation functions at z~1

response matrix in $p_{T,meas}$, $p_{T,true}$, z_{meas}, z_{true}





small UE effect
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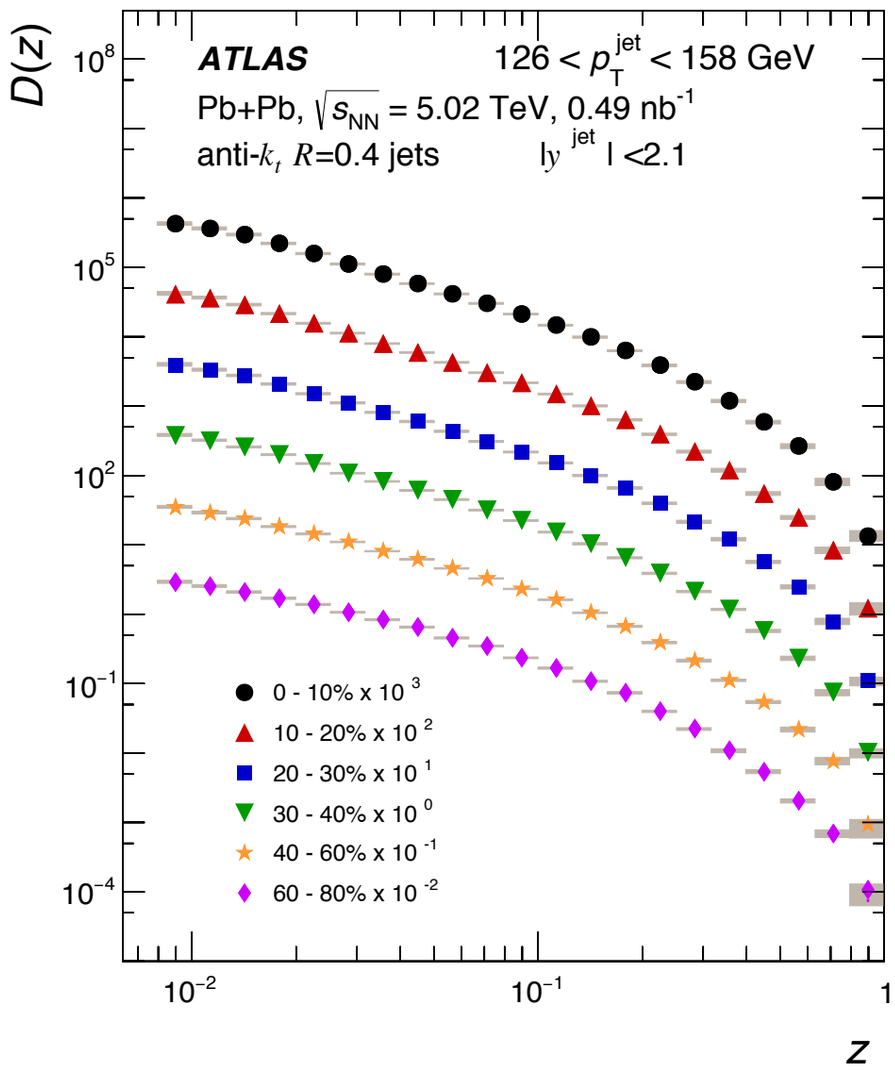
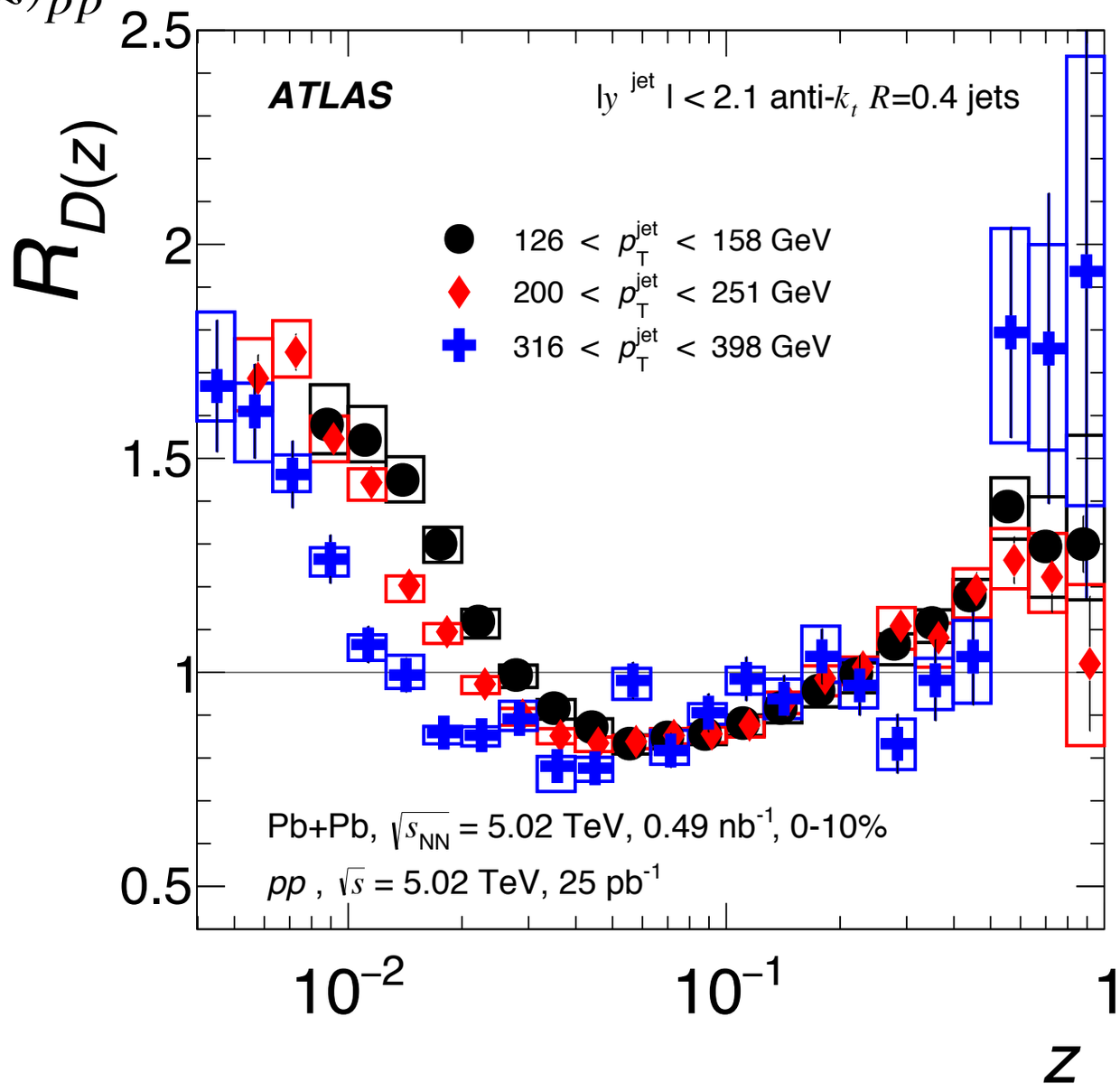
fragmentation functions in PbPb collisions

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





observe centrality and jet p_T dependent modifications to fragmentation functions in PbPb collisions

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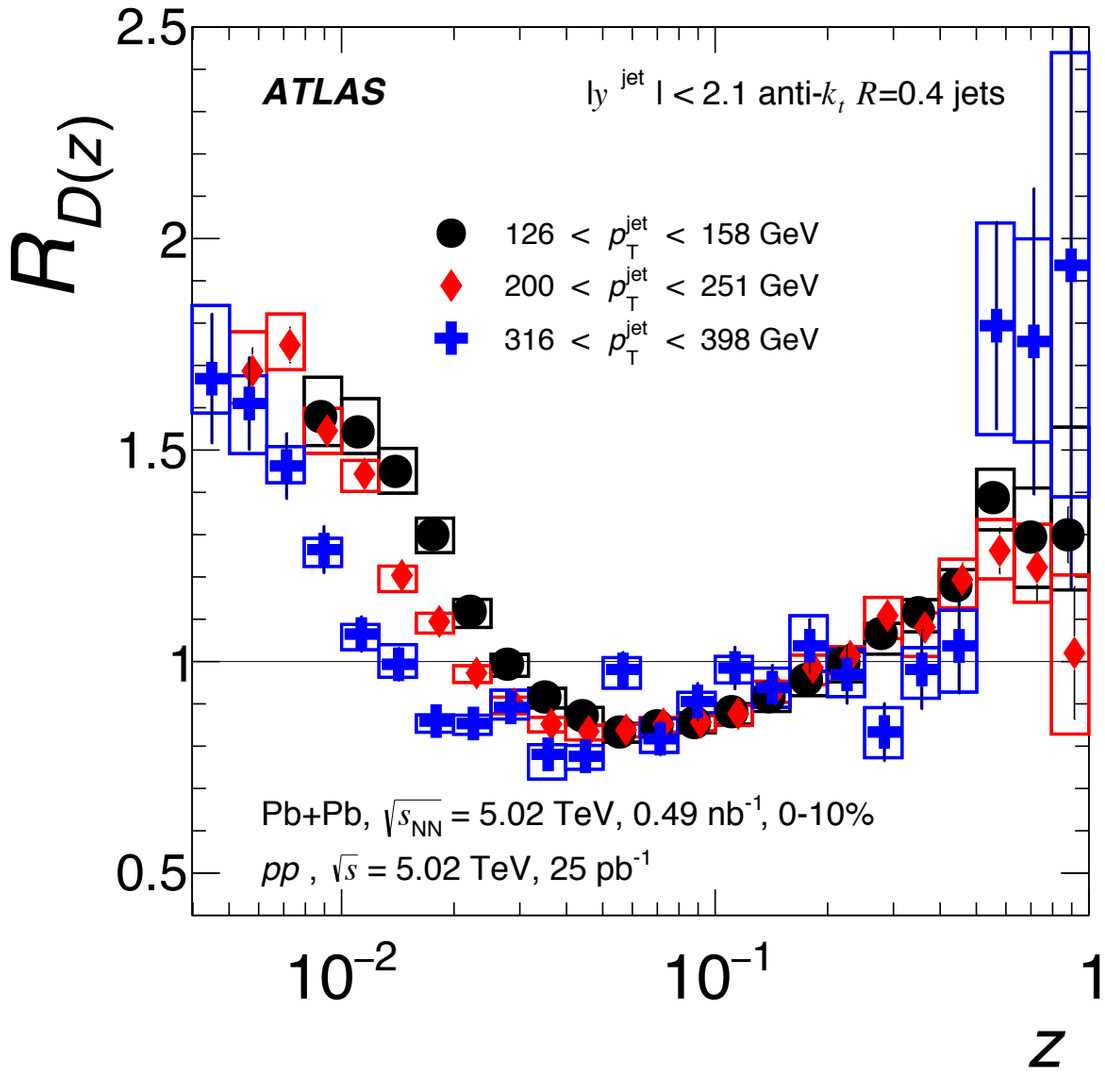
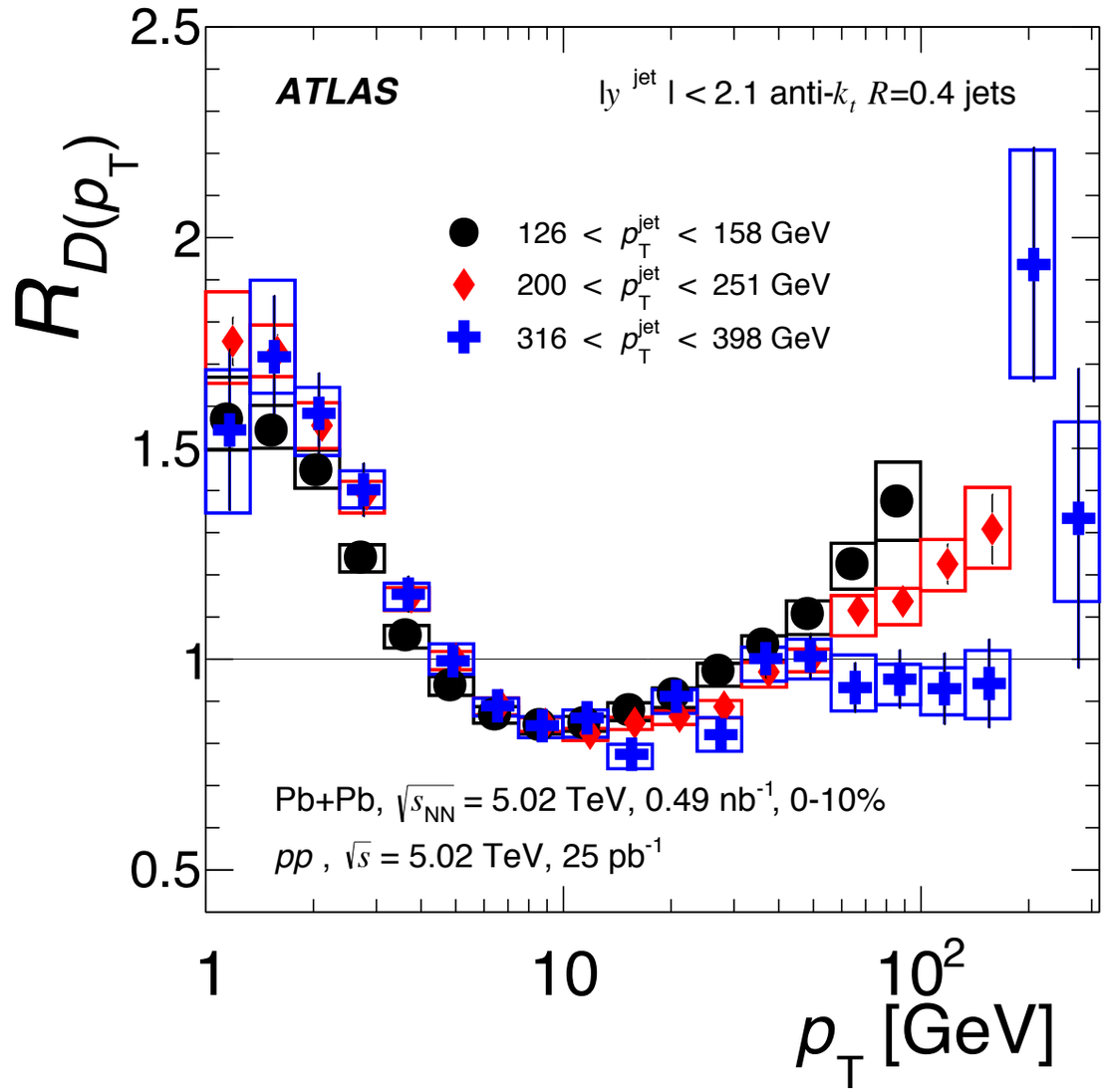
fragmentation functions in z & p_T





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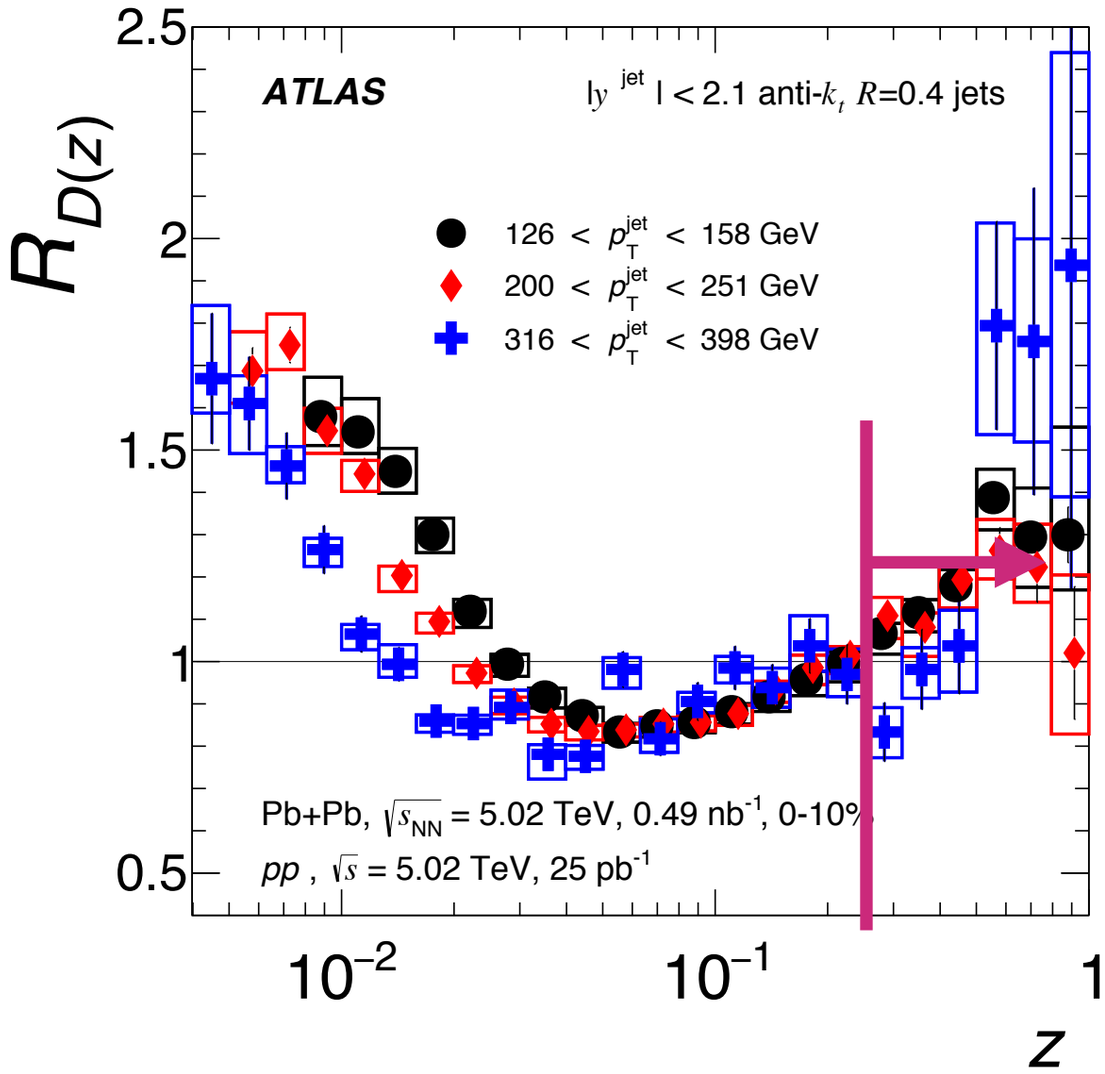
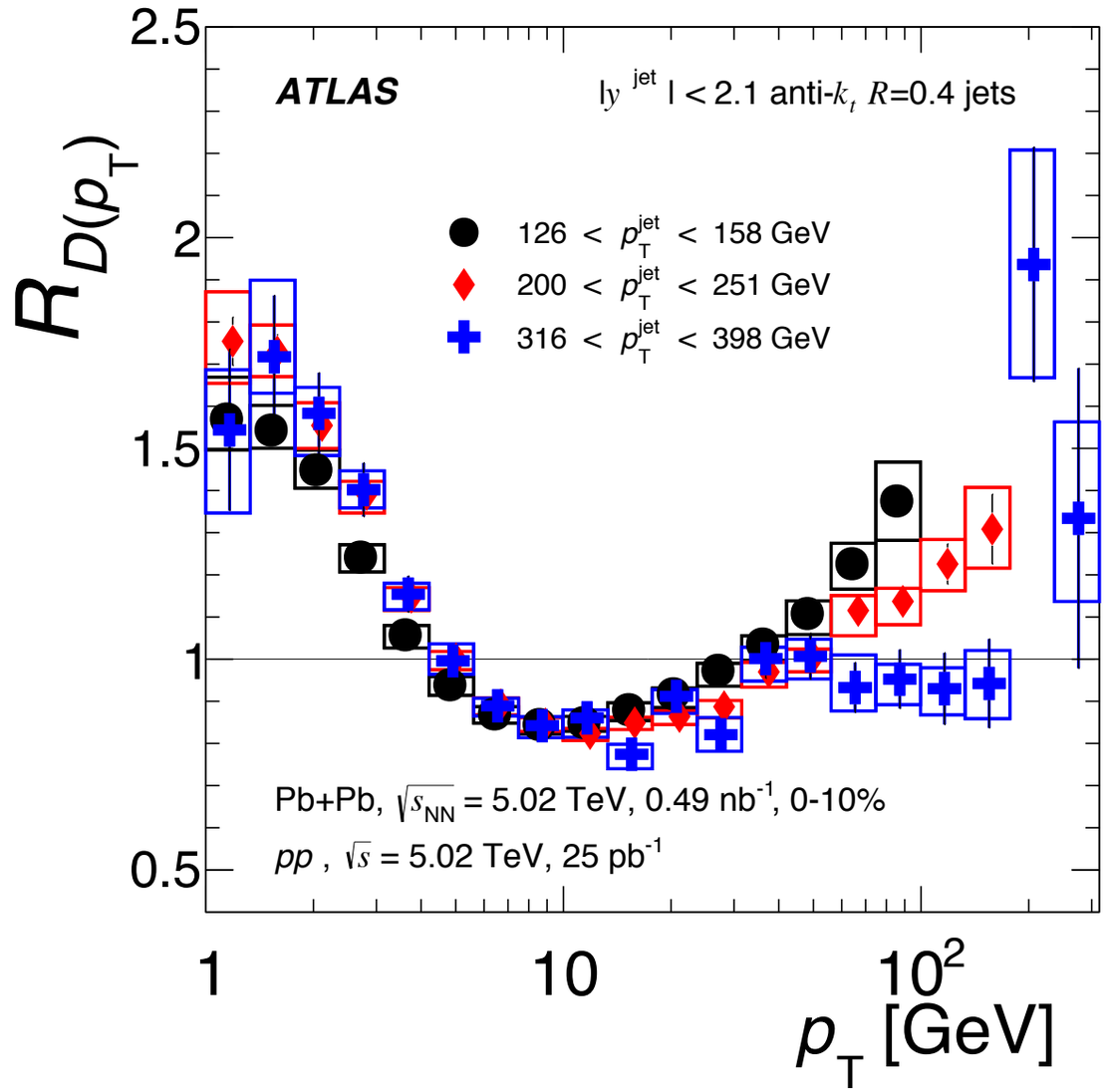
fragmentation functions in z & p_T





high z scaling:
related to fragmentation?

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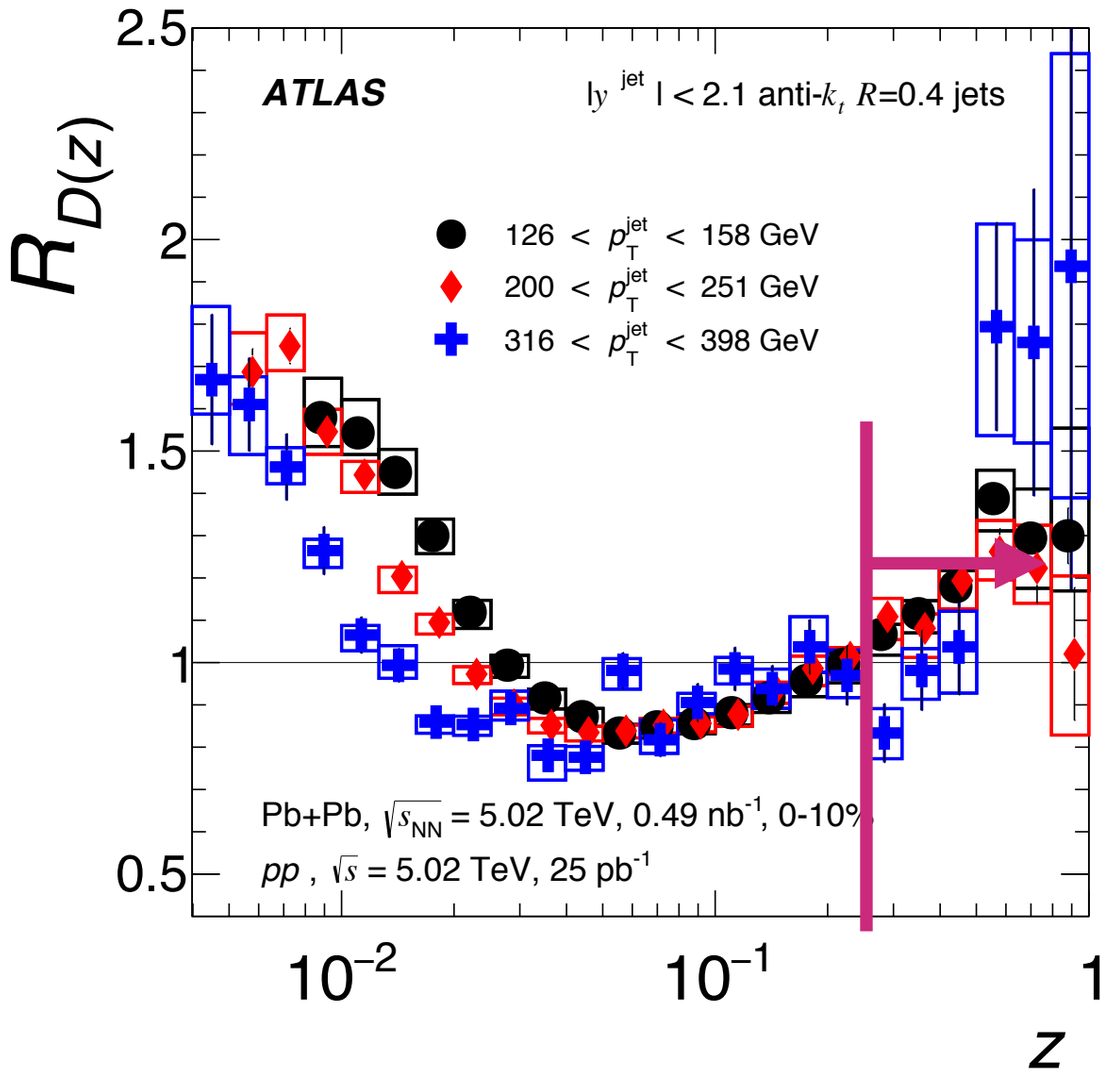
fragmentation functions in z & p_T



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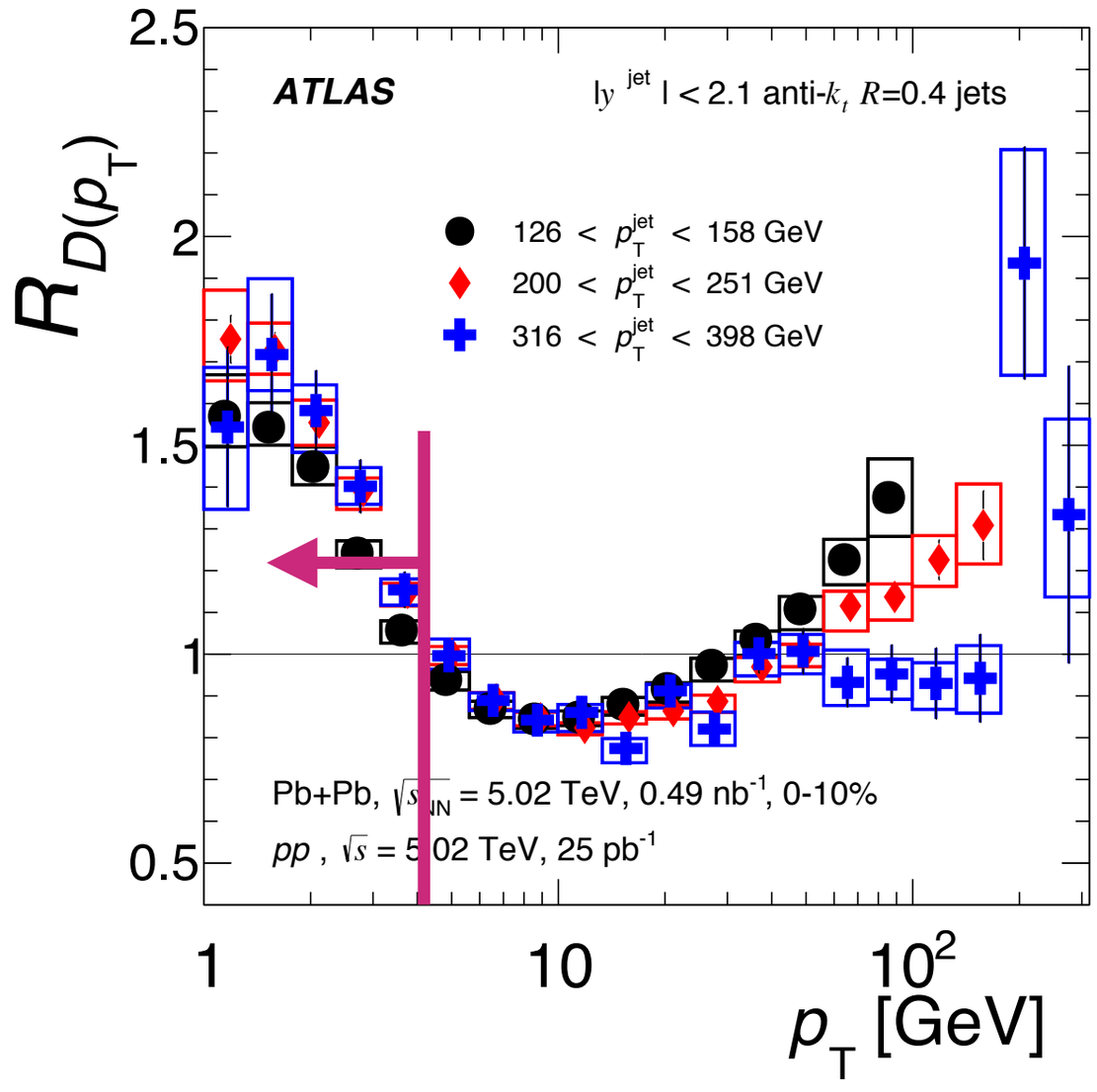

low p_T scaling:
QGP scale?

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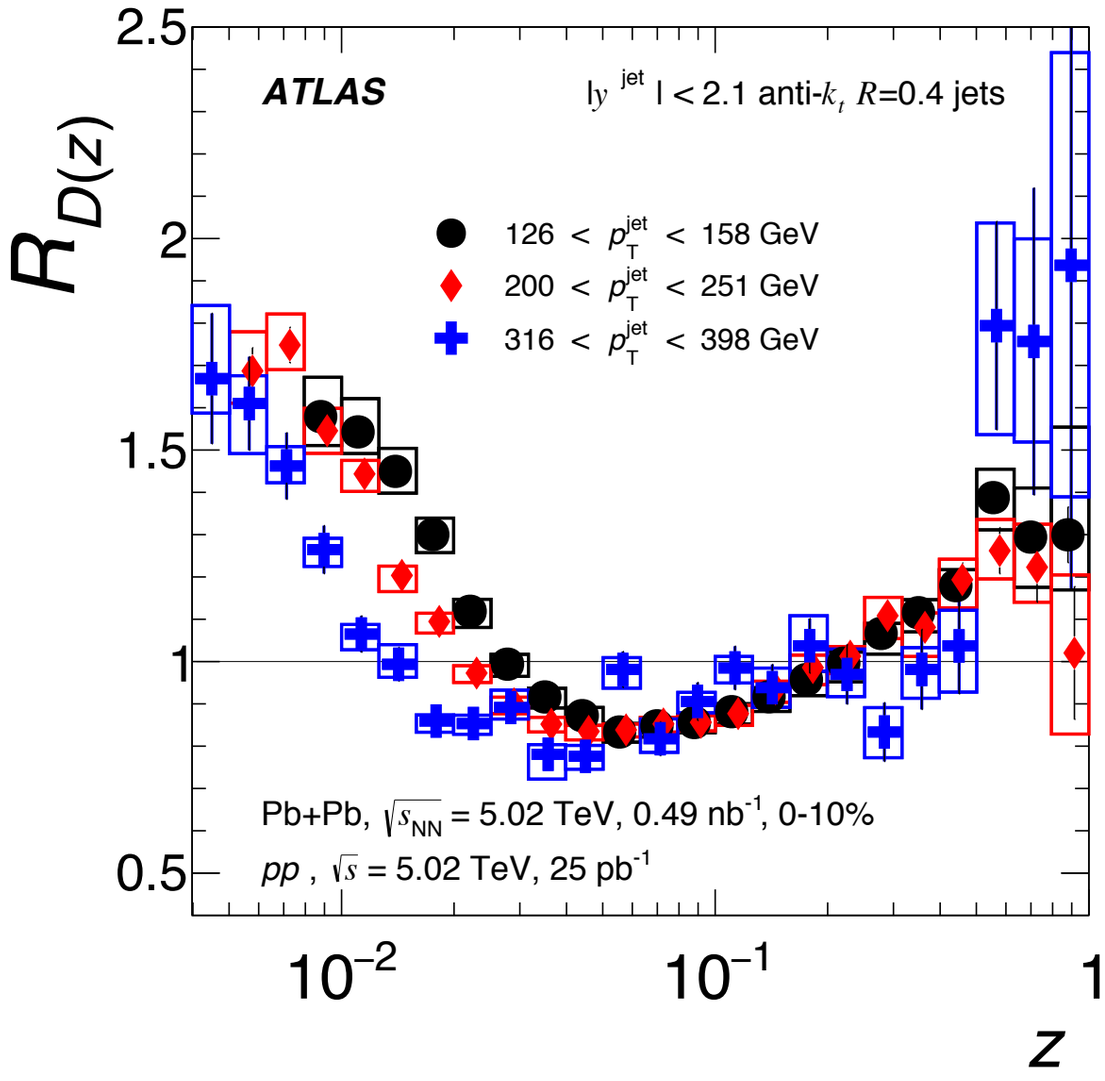
fragmentation functions in z & p_T



consistent $R_{D(z)}$ for unfolded results *due to* unfolding changing as a function of p_T jet

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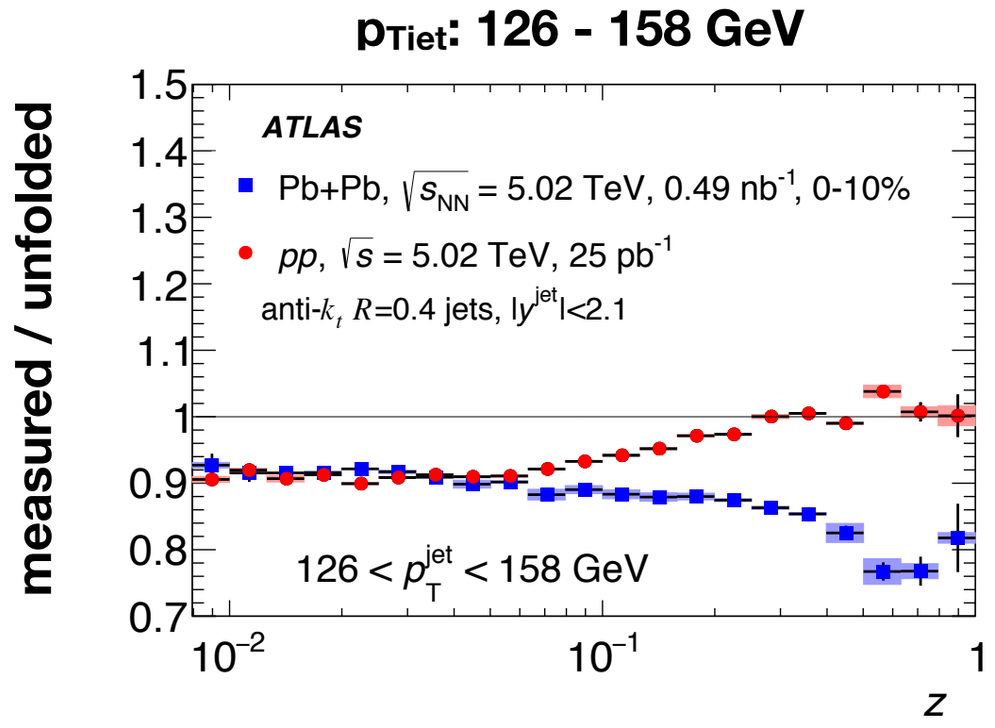
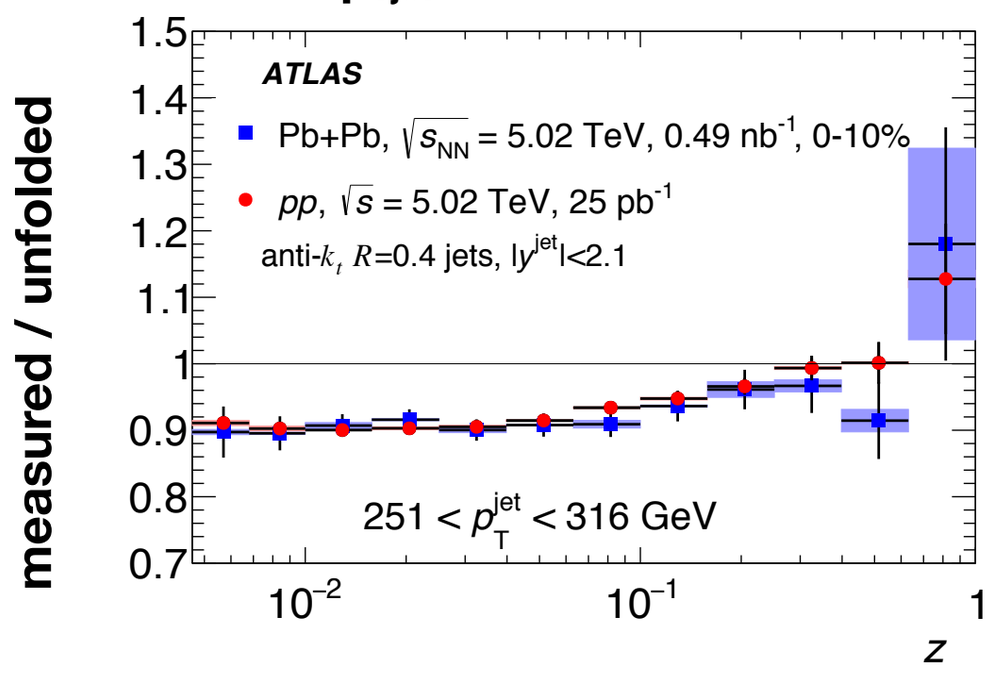


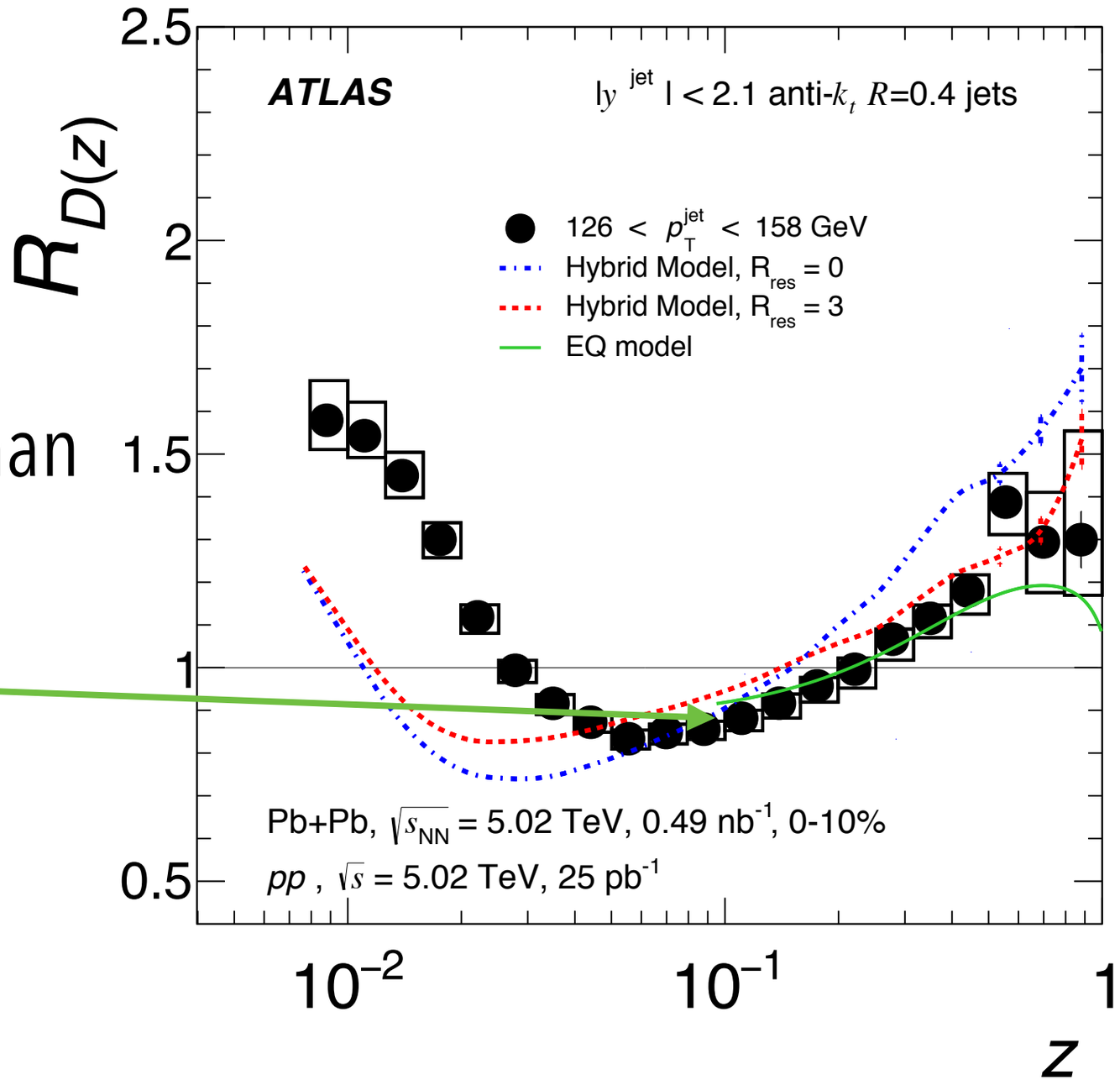


high z excess

Interpreting Single Jet Measurements in Pb+Pb Collisions at the LHC

Martin Spousta[a], Brian Cole[b] 1504.05169

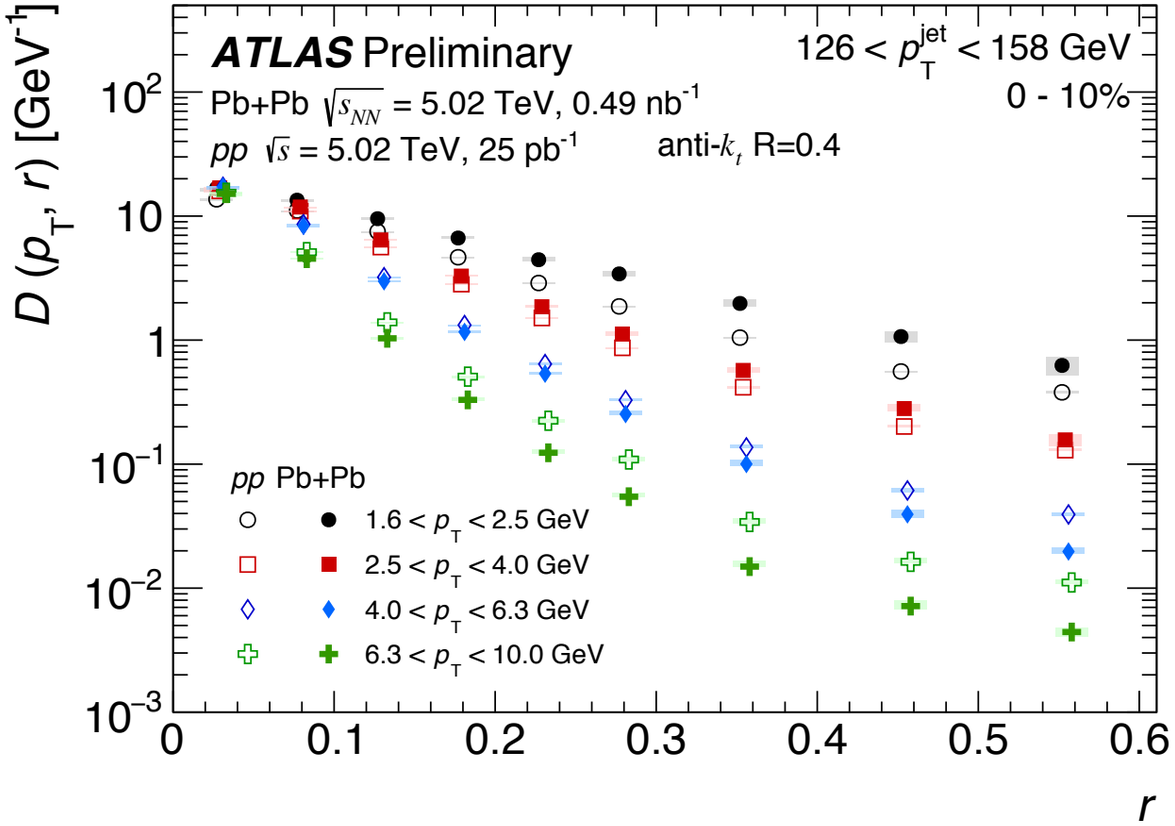
larger energy loss for gluons than quarks followed by pythia fragmentation

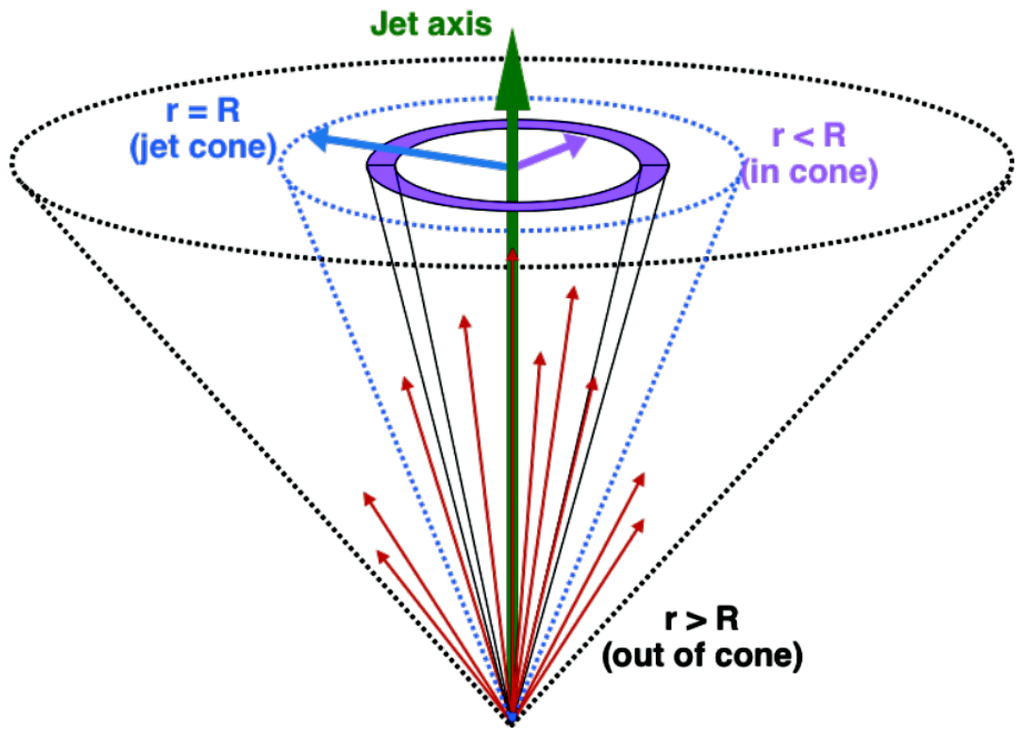


jet fragmentation (II)

where are the particles i*n and around* the jet?

$$D(p_{\mathrm{T}}, r) = \frac{1}{N_{\mathrm{jet}}} \frac{1}{2\pi r} \frac{\mathrm{d}^2 n_{\mathrm{ch}}(r)}{\mathrm{d}r \mathrm{d}p_{\mathrm{T}}}$$





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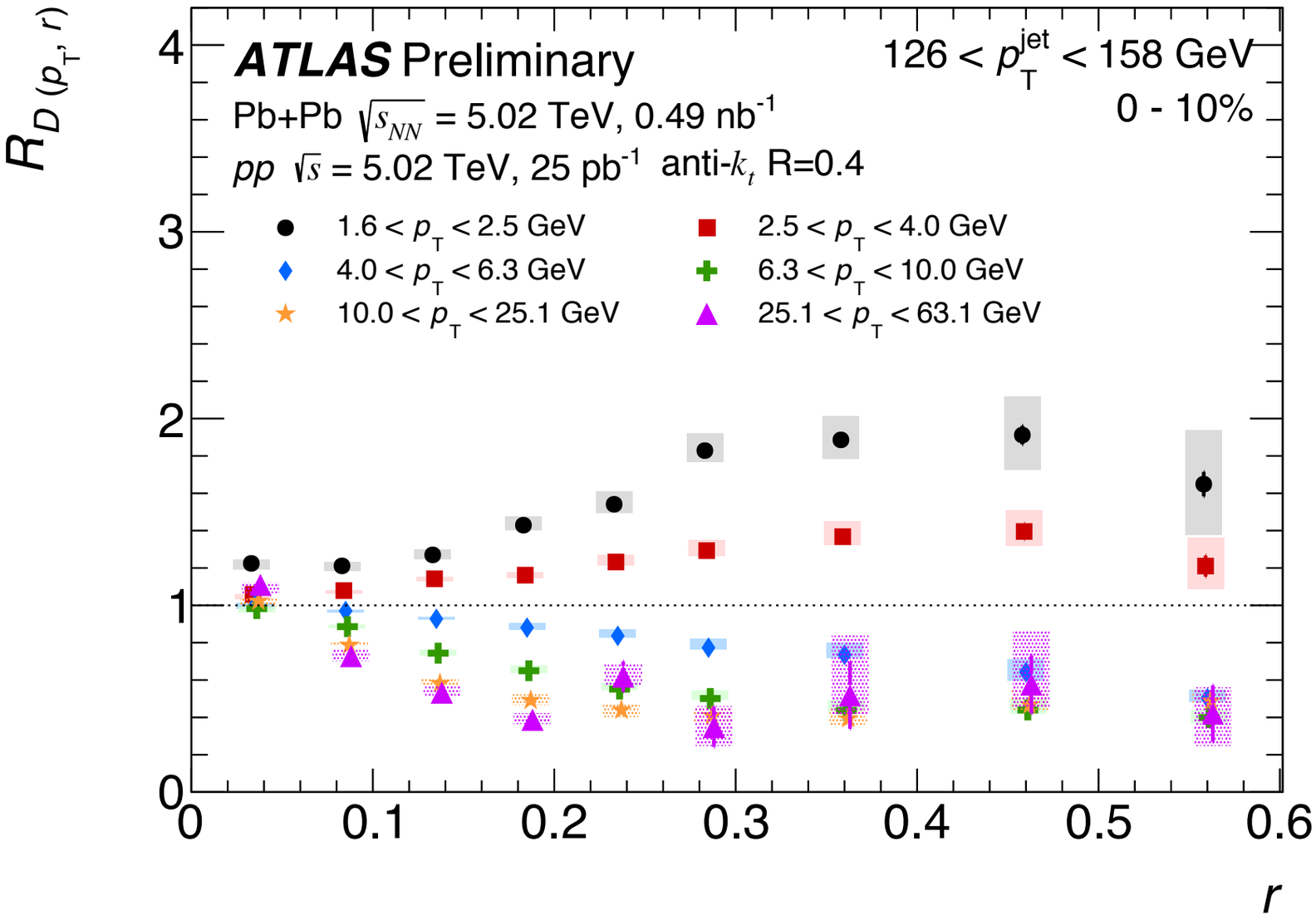
radial dependence of low p_T particles



$p_T < 4$ GeV: broader angular distribution in PbPb

$p_T > 4$ GeV: narrower angular distribution in PbPb

modifications grow with radius within the jet cone

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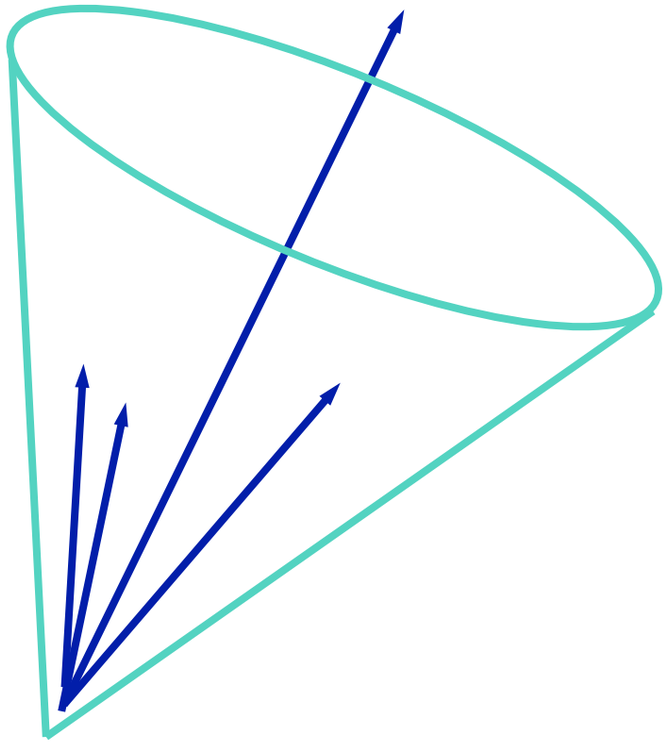
why jet mass in PbPb collisions?



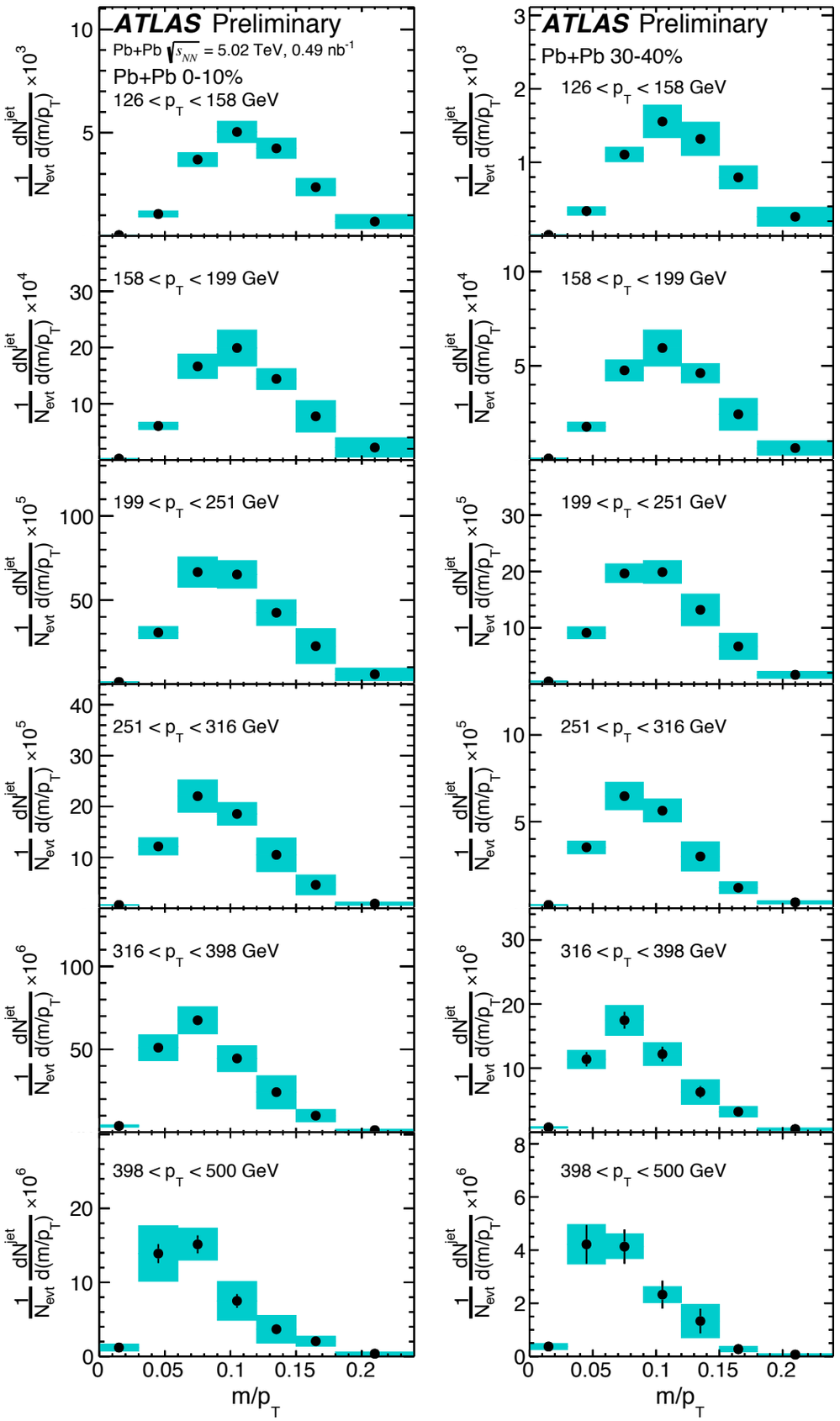
m/p_T related to the angular width of the jet

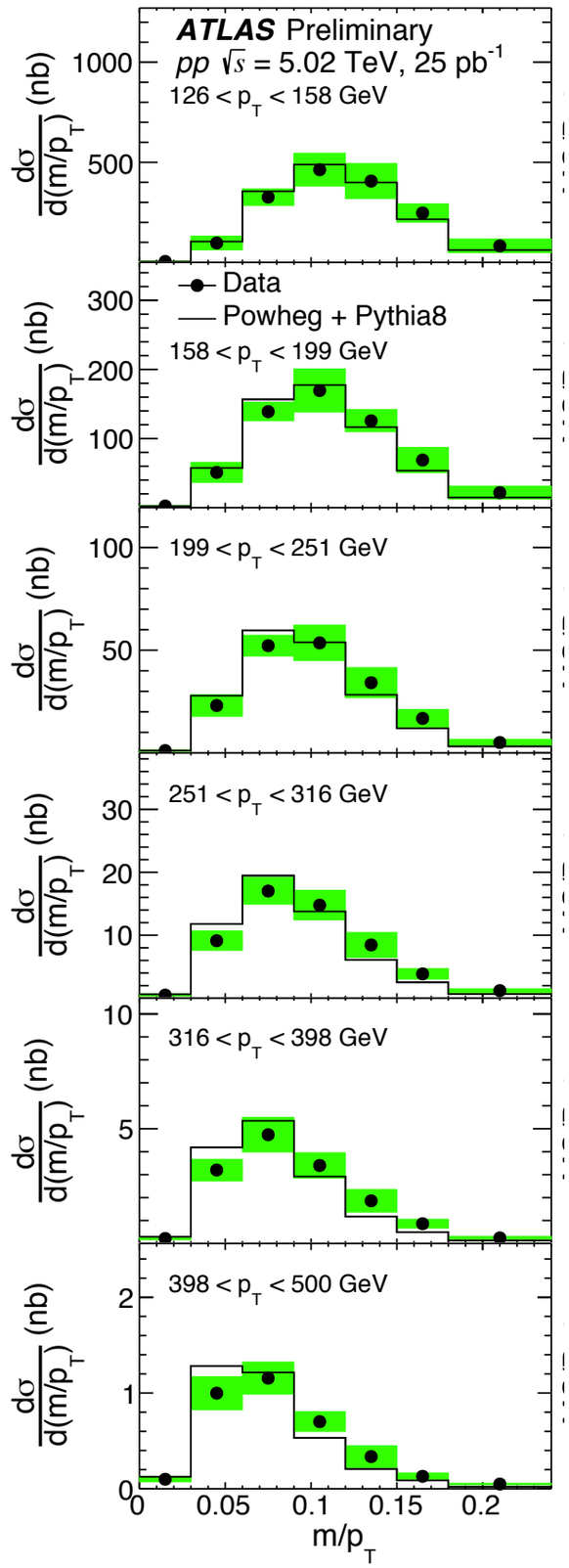
physics question: how are the parton showers resolved by the QGP?

experimental question: how does R_{AA} depend on m/p_T?

m/p_T distributions: PbPb & pp collisions

$R = 0.4$ anti-k_t jets





measurement over wide kinematic and centrality range

jet constituents
0.1x0.1 towers
no soft drop

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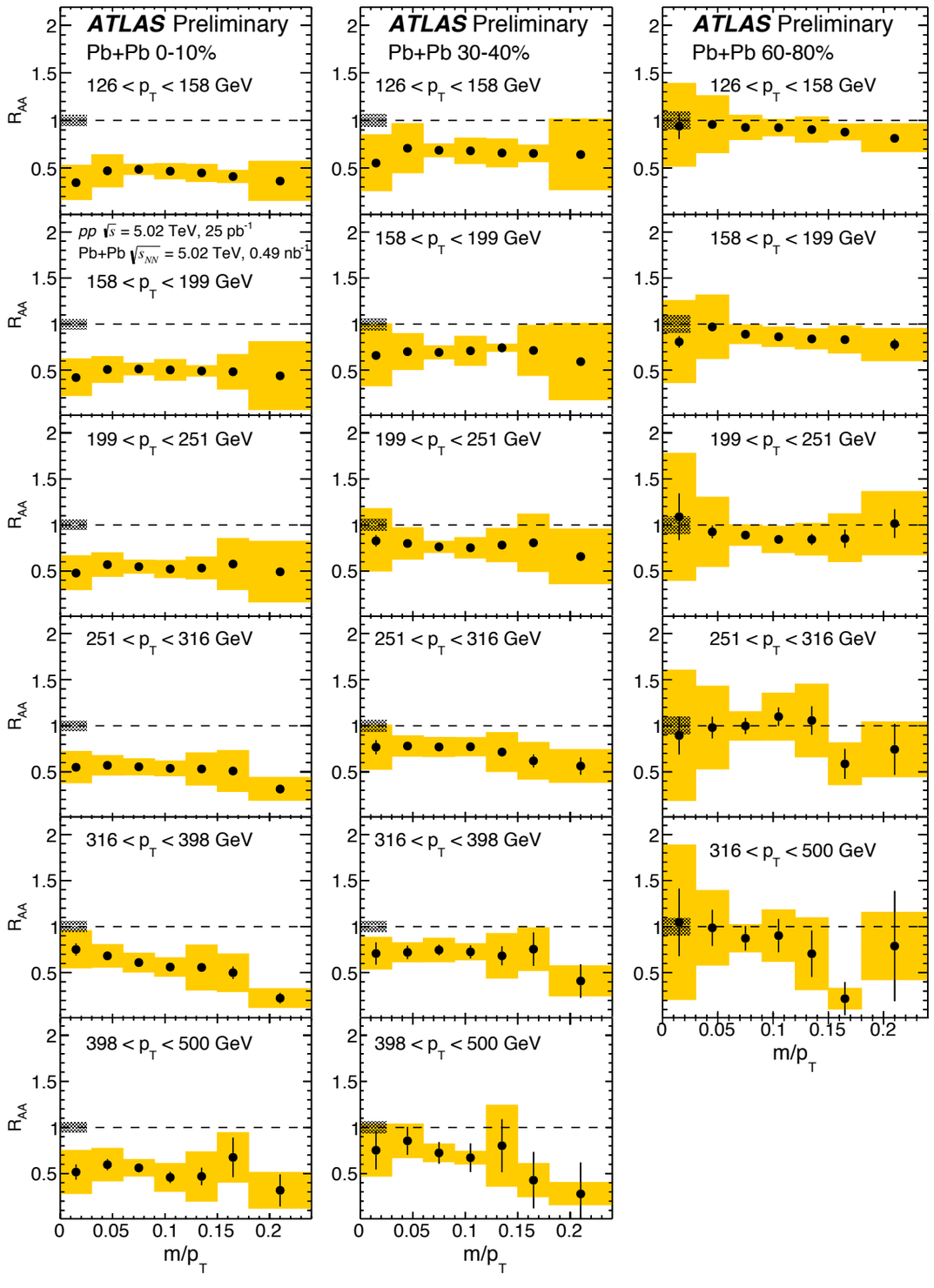
R_{AA} as a function of m/p_T

R = 0.4 anti-k_t jets



- over a wide kinematic & centrality range, no significant modification to m/p_T observed
- experimental goals:
  - reducing the systematic uncertainties
- also: rapidity dependence to change the quark/gluon fractions

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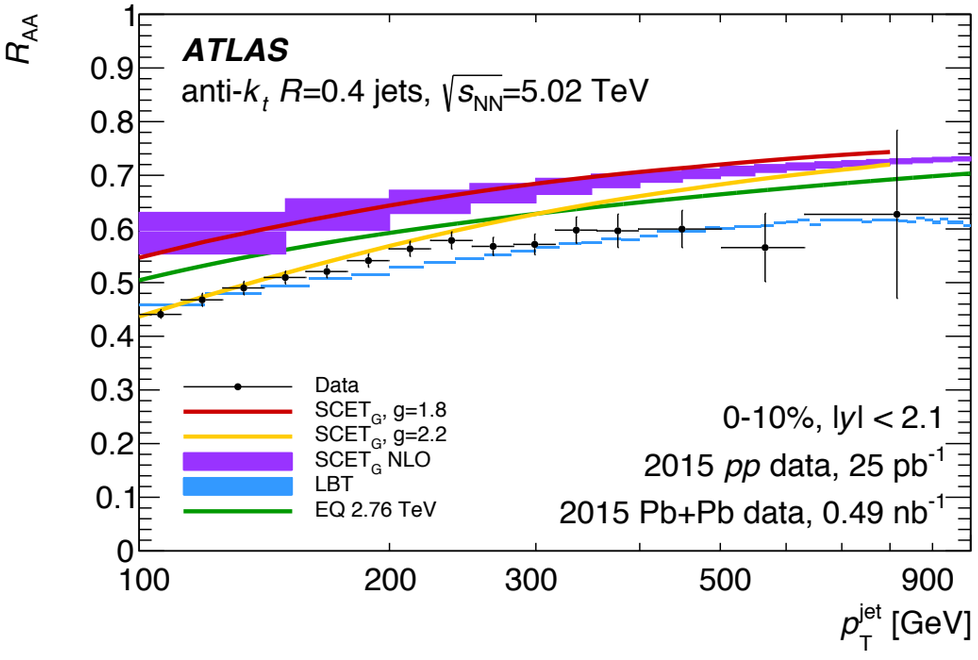
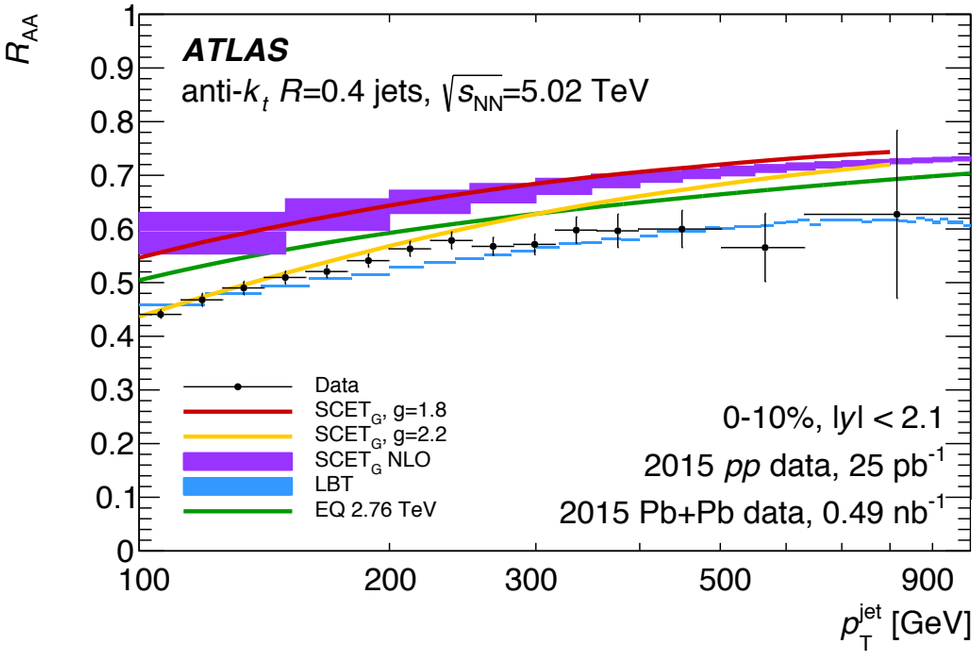
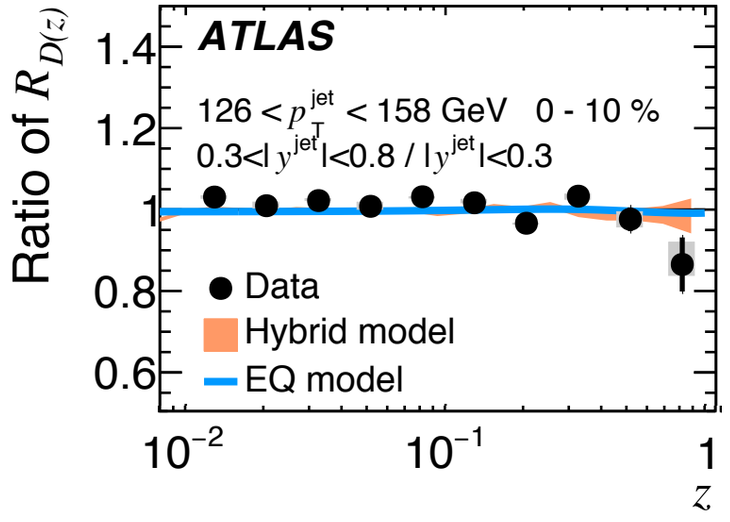
some theory comparisons

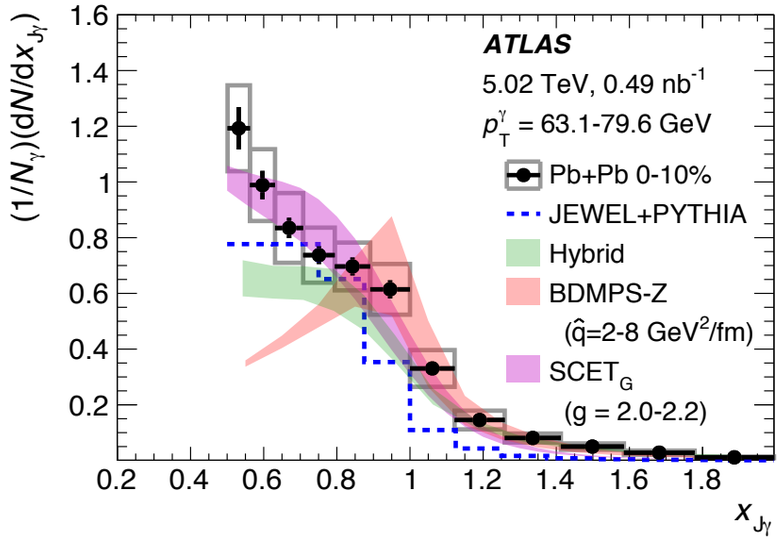
some theory comparisons

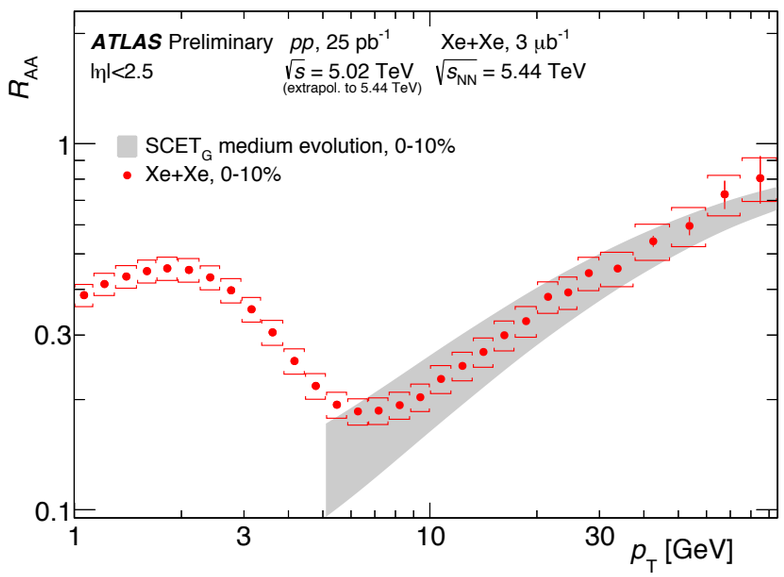


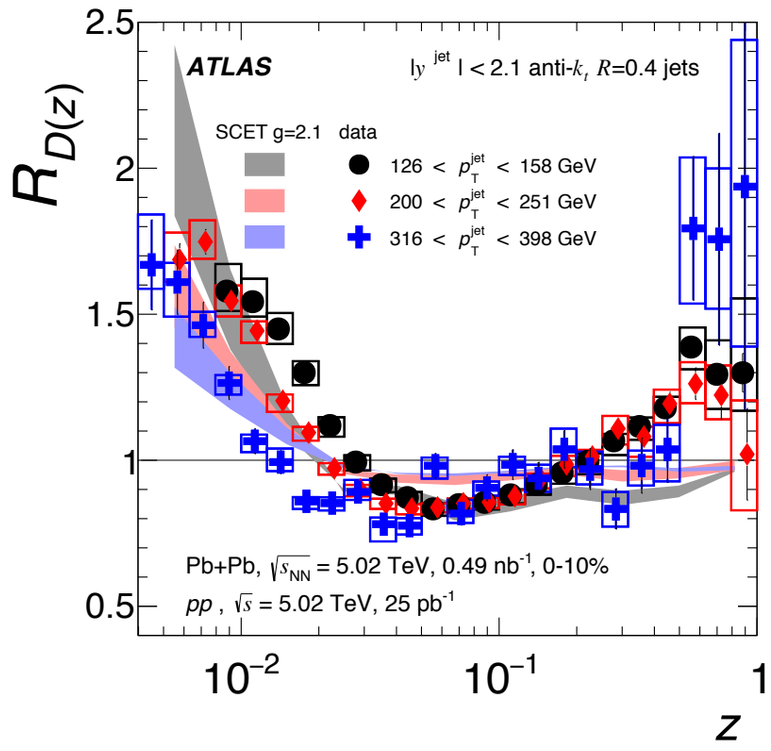
some theory comparisons



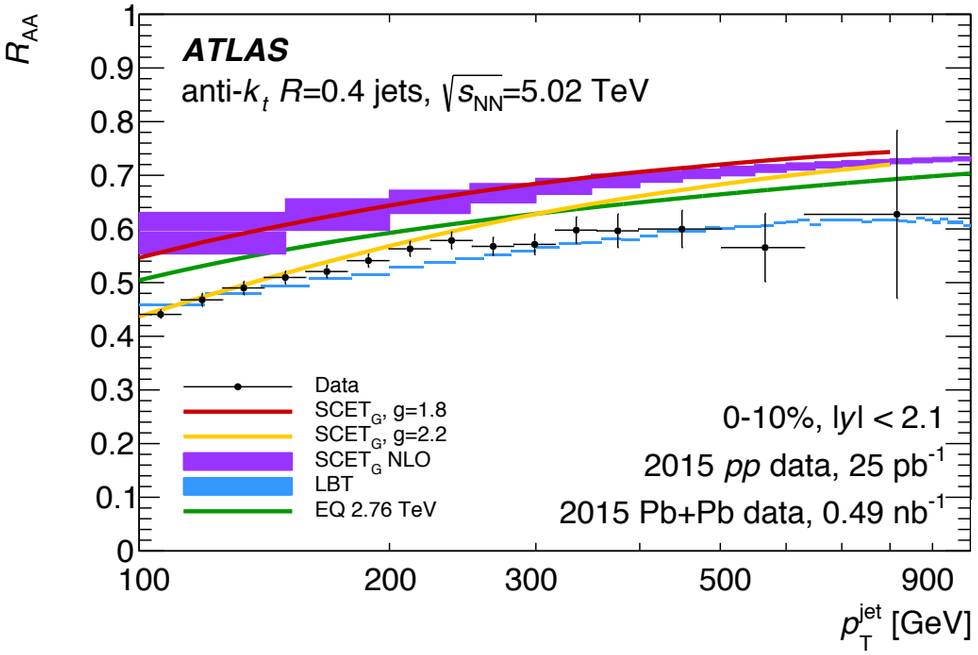


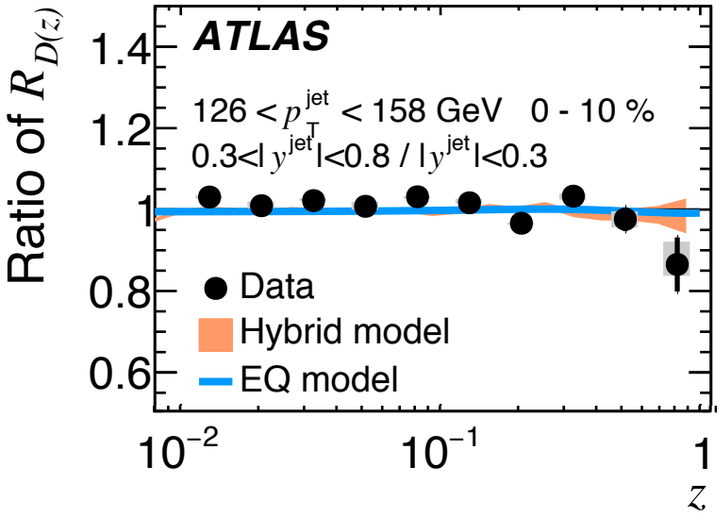


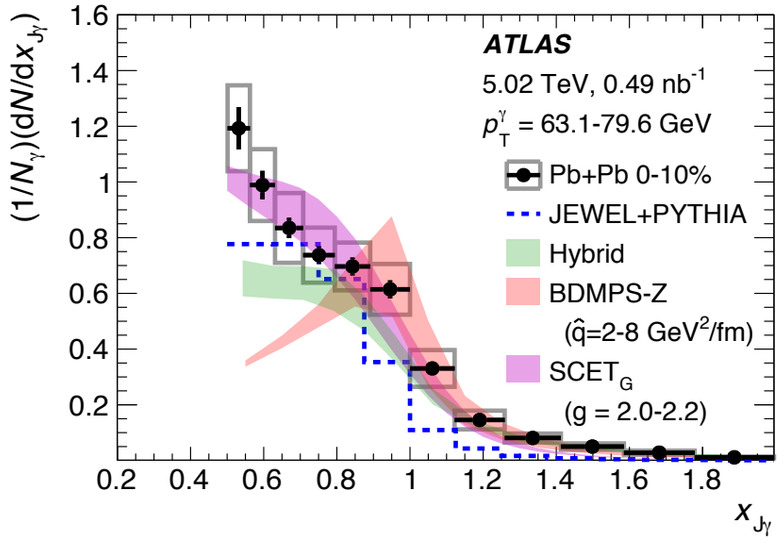


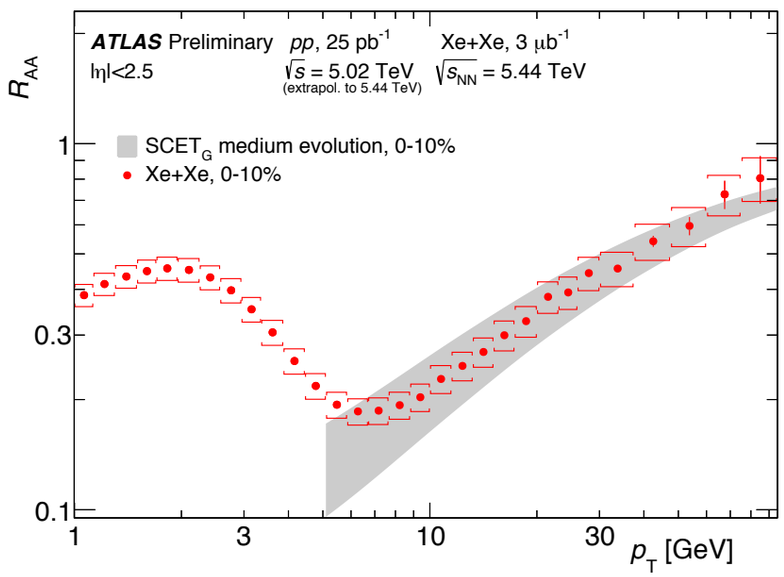


some theory comparisons

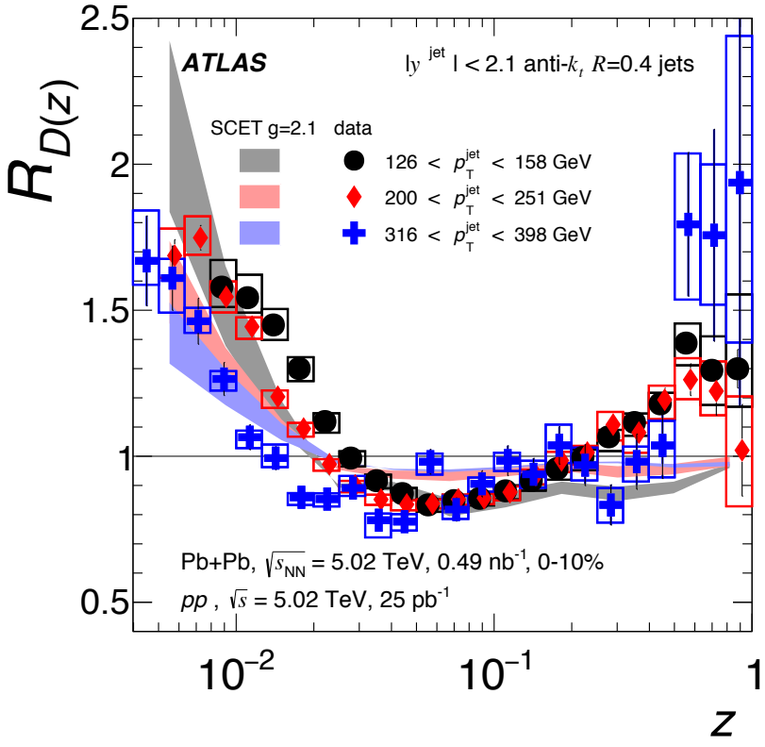








jet R_{AA} not well described by any model which provided calculations, but FF, γ-jet and charged particles can be described–*what do we learn from this?*



summary

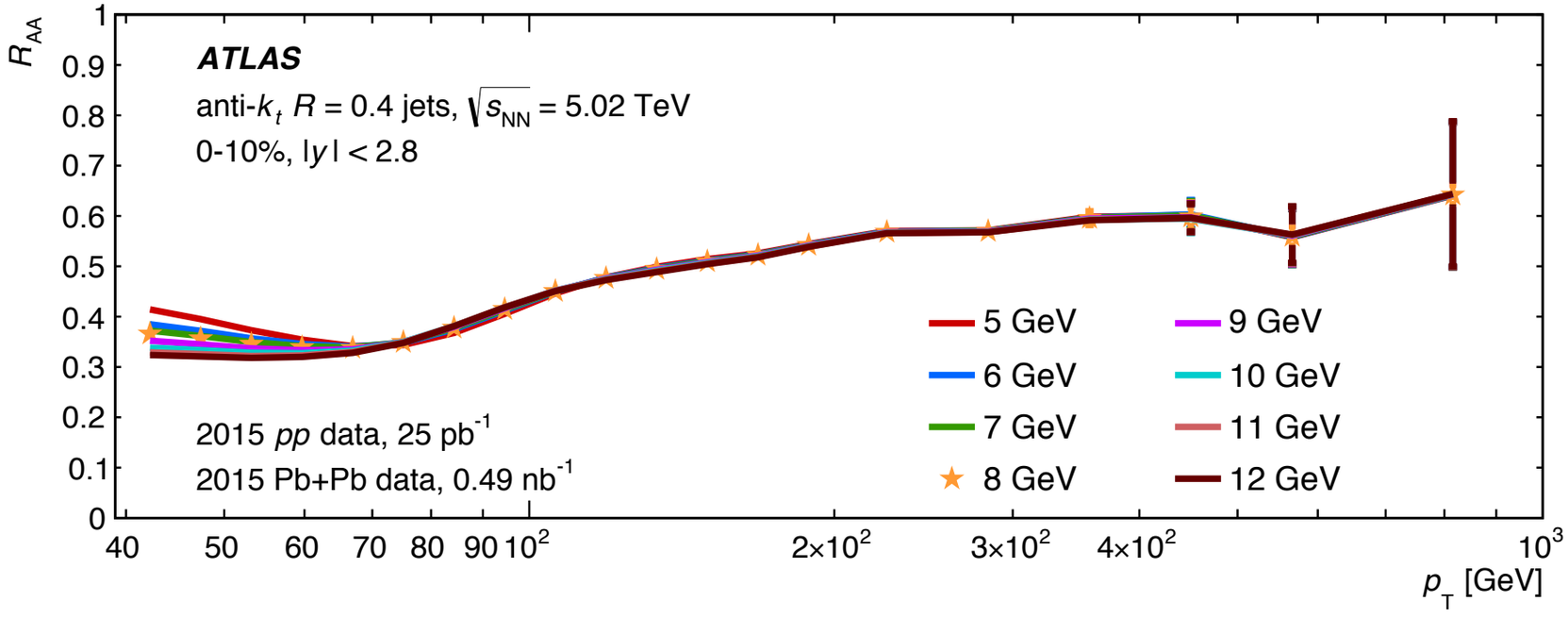
- ATLAS has many complementary results designed to constrain the physics of jet quenching
  - focus on unfolded results which allow comparisons across observables and to models
    - many model calculations available already
    - focus on systematic measurements as a function of jet p_T and rapidity
    - I've only flashed the photon-jet results (see Dennis Perepelitsa's talk) but they are a key part of the ATLAS program
    - what are the most important measurements to move make with the 2018 data to constraint the physics of jet quenching?
- full results: https://twiki.cern.ch/twiki/bin/view/AtlasPublic/HeavyIonsPublicResults

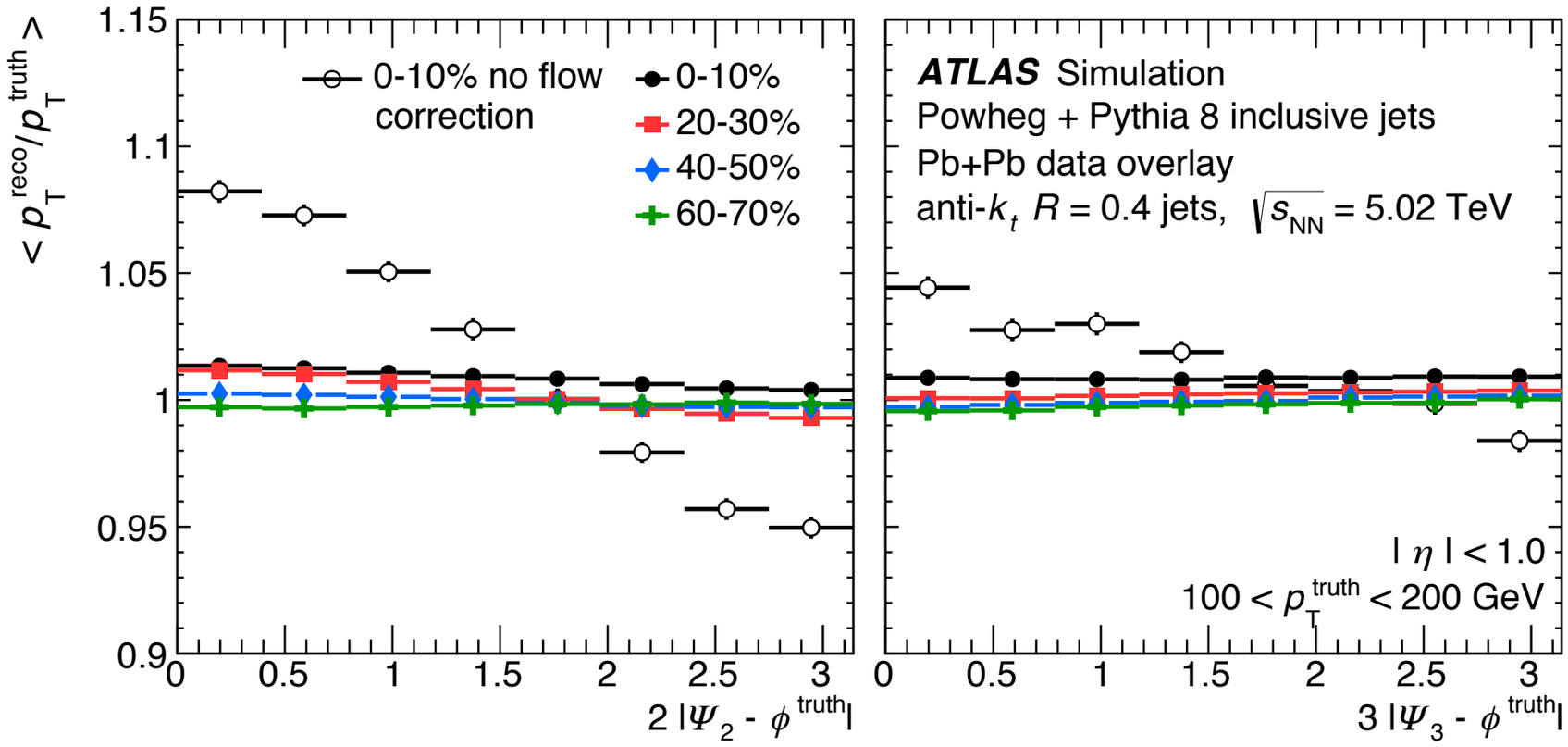
looking forward to extending these measurements with the 2018 data!

backup

flow effects on JES & fake jet rejection

1805.05635



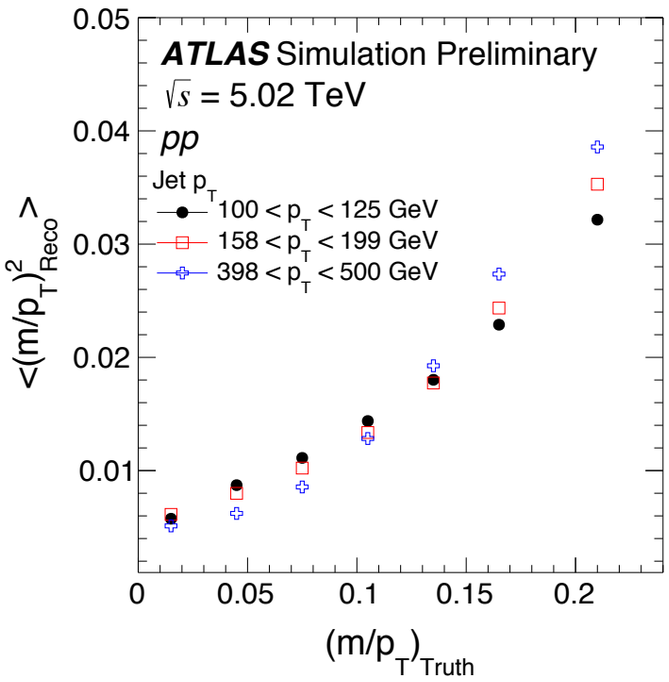


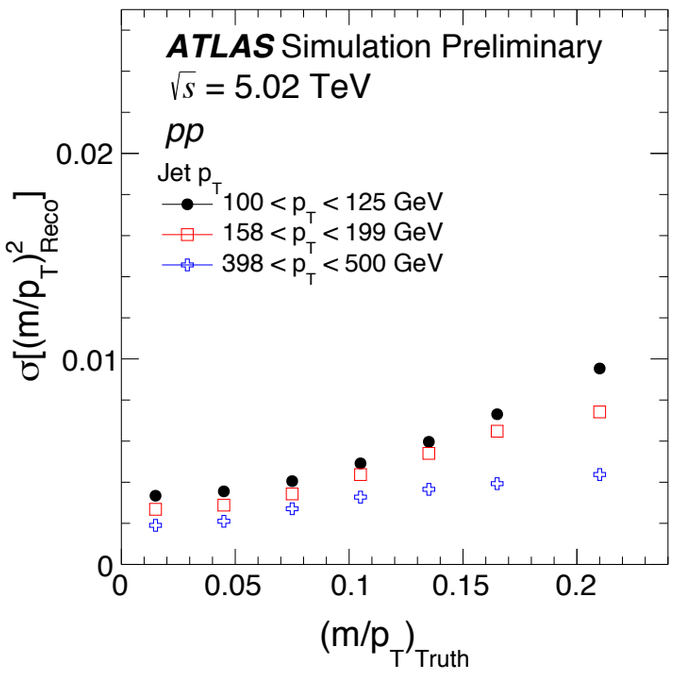
jet mass performance

$R = 0.4$ anti-k_t jets

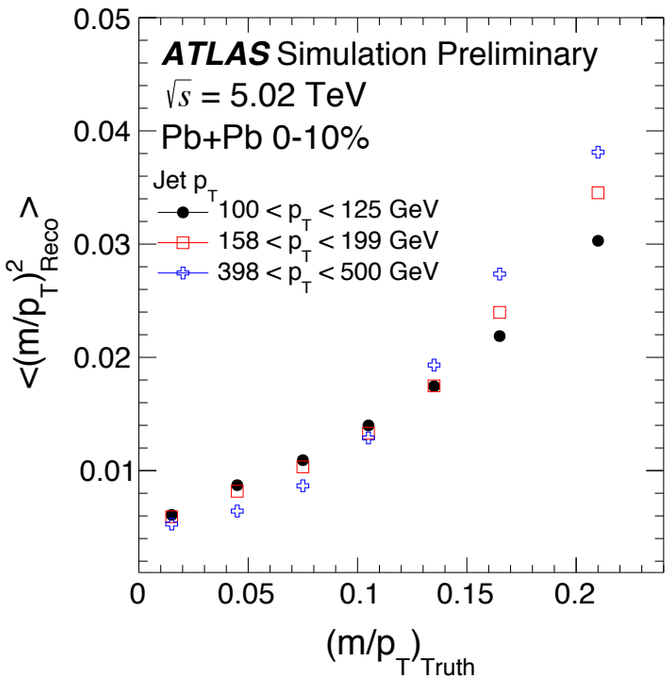
- jet mass scale (JMS): approximately independent of centrality
- jet mass resolution (JMR): increases in central collisions and at low jet p_T
  - expected from worse JER/ UE in this region

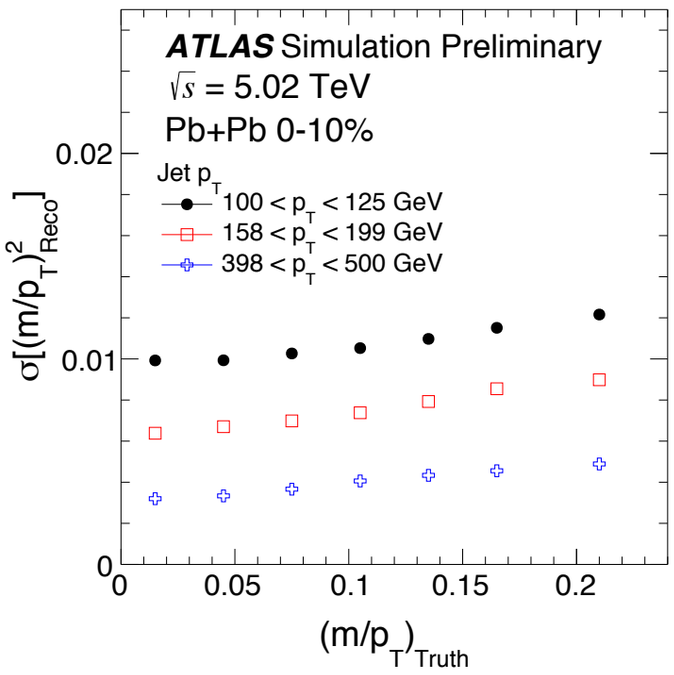
pp collisions





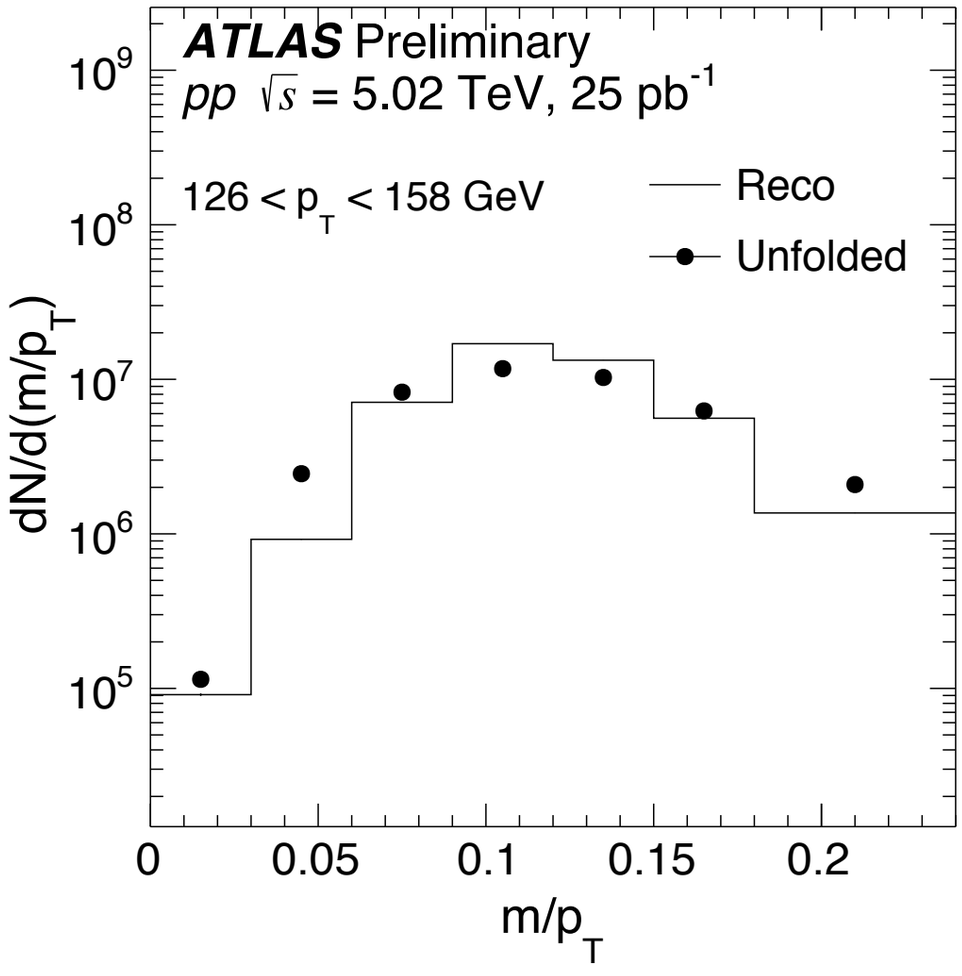
PbPb collisions

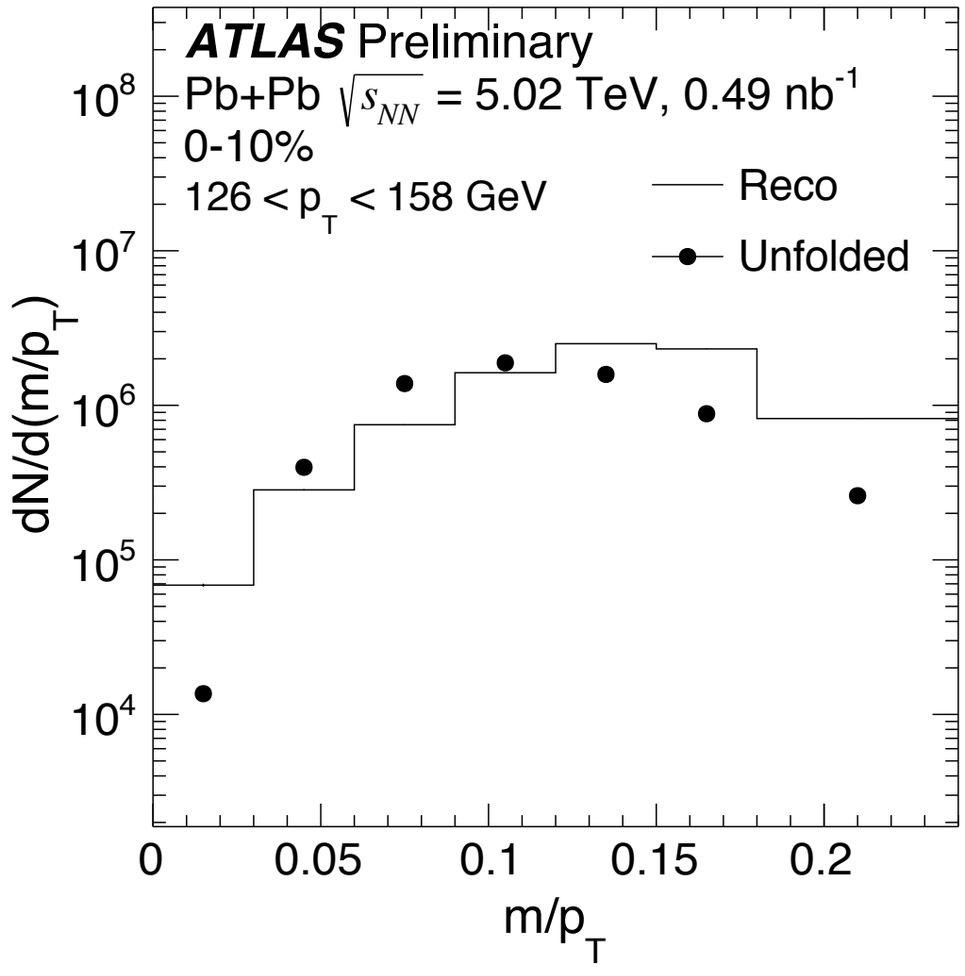




ATLAS-CONF-2018-014

unfolding





two dimensional Bayesian unfolding in m/p_T and p_T to correct for JMS and resolution effects

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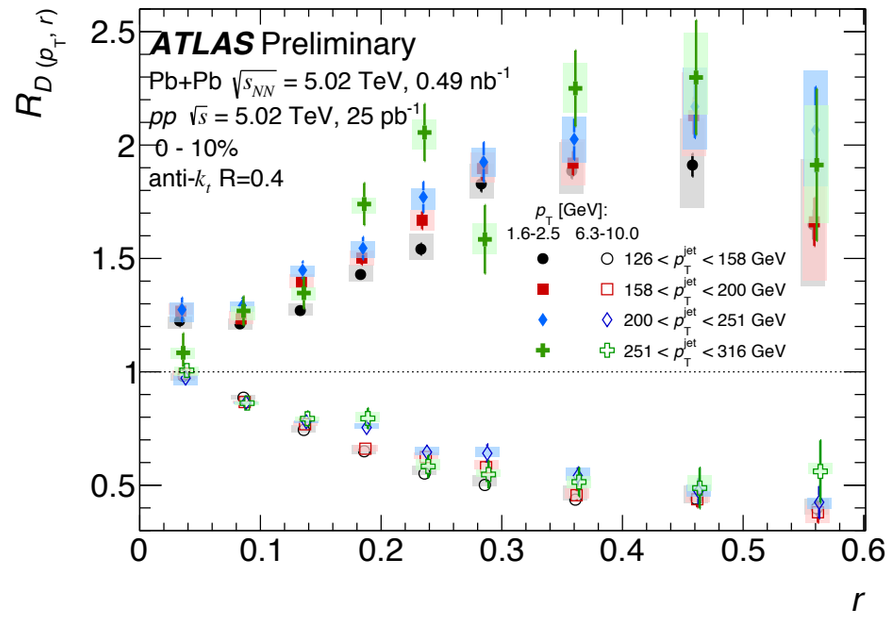
ATLAS Preliminary
Pb+Pb $\sqrt{s_{NN}}$ = 5.02 TeV, 0.49 nb^{-1}
pp $\sqrt{s}$ = 5.02 TeV, 25 pb^{-1}
0 - 10%
anti-k_t R=0.4
p_T [GeV]:
1.6-2.5 6.3-10.0
126 < p_T^{jet} < 158 GeV
158 < p_T^{jet} < 200 GeV
200 < p_T^{jet} < 251 GeV
251 < p_T^{jet} < 316 GeV
$R_{D\,(p_T,\,r)}$
2.5
2
1.5
1
0.5
0
0.1
0.2
0.3
0.4
0.5
0.6
r