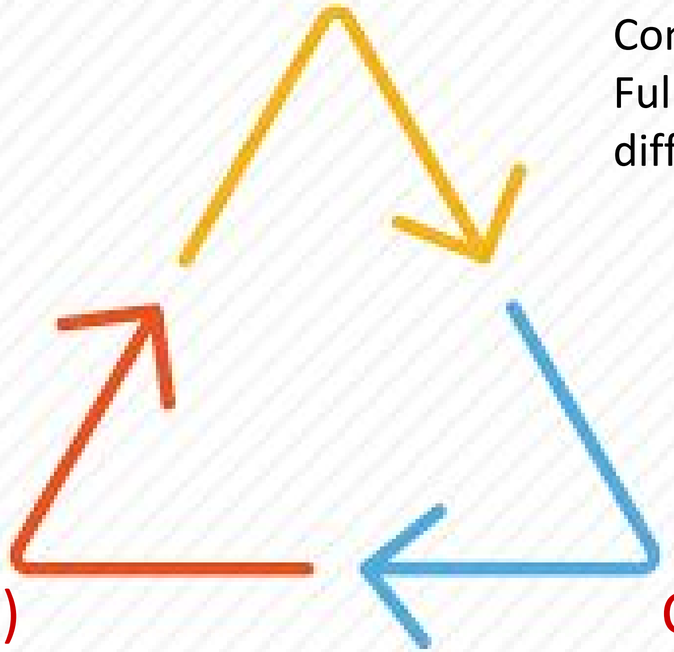
Can we learn something about the medium using jet substructure?

Jet width, mass, pTD, longitudinal and radial profile, zg, Mg, tau2/tau1, neighbouring jets

Complications for interpretation:
Full vs track jets, different kinematic ranges, different R, different constituent cutoffs….

Measurements



Models (MC)

JEWEL,QPYTHIA,MATTER
MARTINI,PYQUEN, HYBRID,...

Calculations

BDMPS, AMY, GLV, HT, SCET, LBT, AdS/CFT ...

Progress
Interplay
Asymptotic regimes where problem simplifies: grooming, kinematic regimes?

Measurements

- Do we know how the internal structure of a jet is modified by the medium?

  Yes, collimation of core + broadening at large R

- Do we need to know better?
  To answer billion $ question YES
  We don’t have a complete theory model describing features of data and we do have multiple incomplete models that we need to discriminate

- How?

  Can grooming and substructure techniques help?

Theory ideas

- 2 main regimes: strong vs weakly coupling between jet and medium
- Weak/pQCD approach: multiple soft vs single semi-hard emissions
- Which combination of observables can discriminate?
- How do we test specific theory ingredient? eg. color coherence?

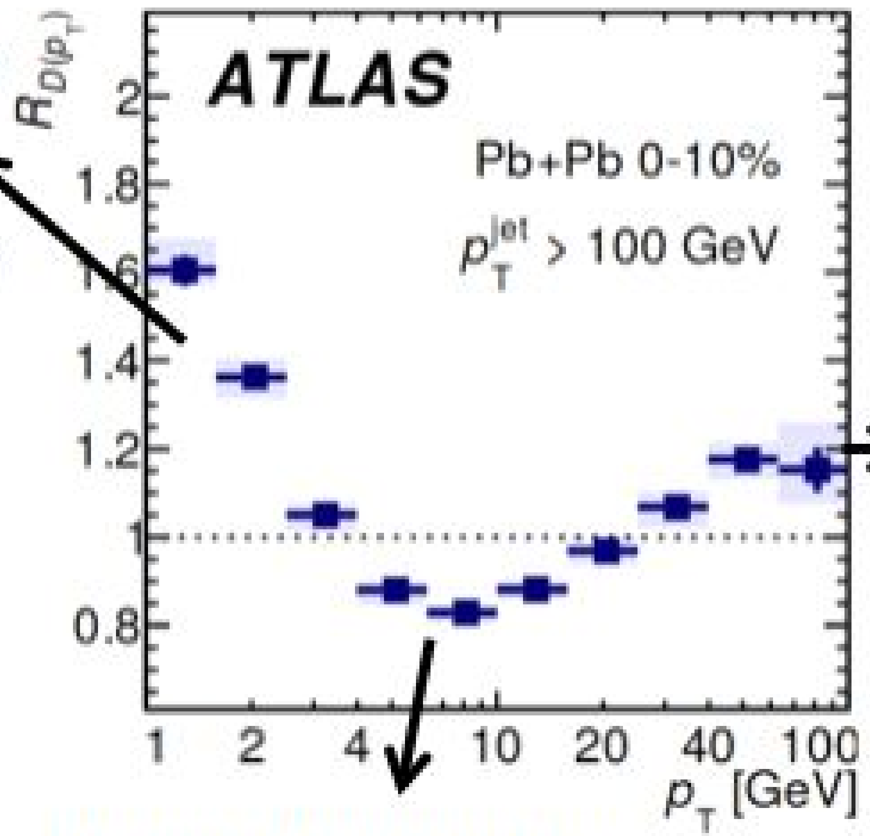
Plots

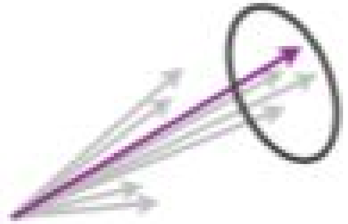
Fragmentation function

Longitudinal distribution of particles in jet

More soft particles due to interaction with medium

1-2 additional particles
~2 GeV additional energy





Similar amount of particles, but ~2 GeV more energy

Consistent with quenching difference of quark and gluon jets [M. Spousta HP16]

Suppression at intermediate p_T

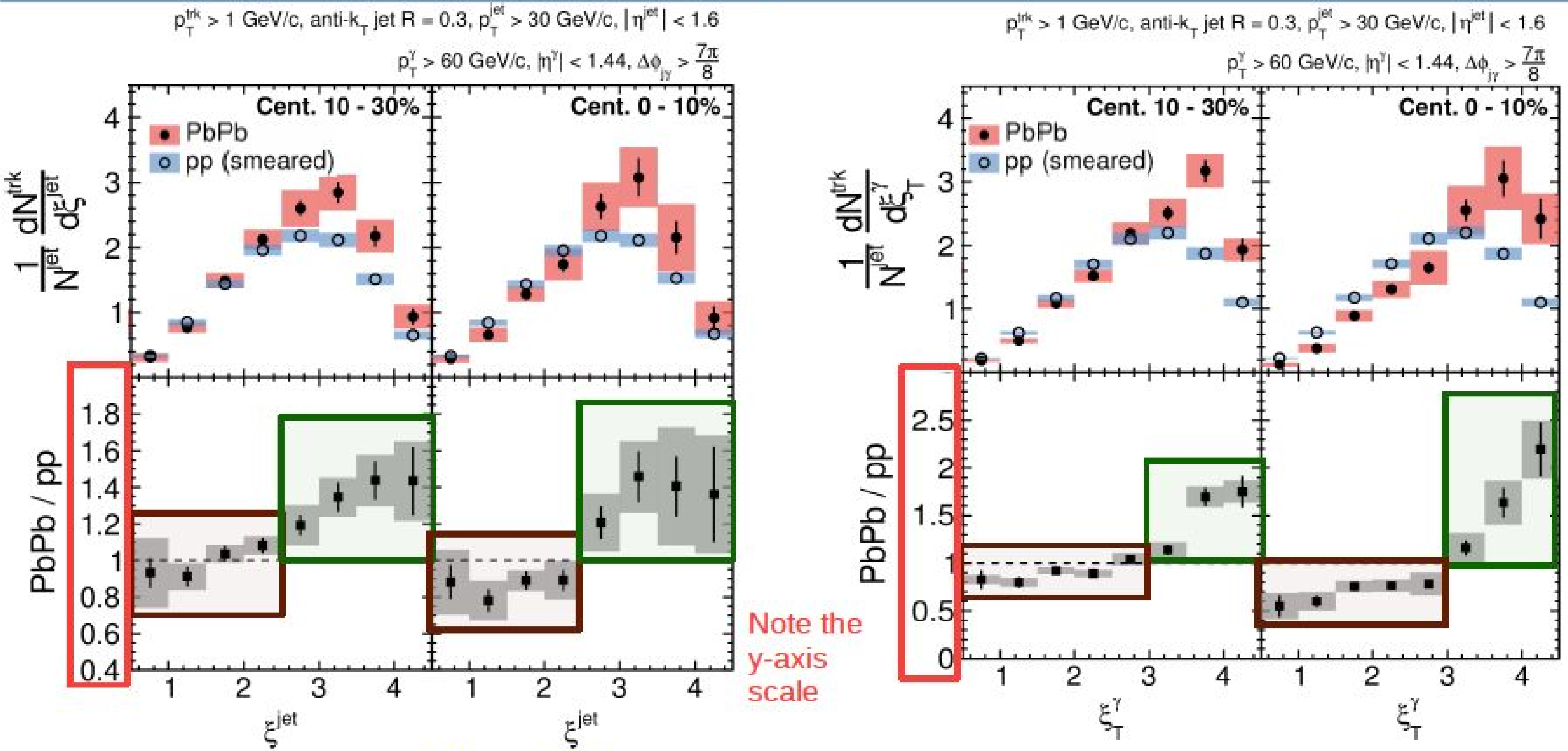
On average, 0.5 particle less
~4 GeV missing

Final run1 result
ATLAS arXiv:1702.00674

Radim Slovak Tue. 2.2
Martin Spousta Tue. 3.4

Results - ξ^{jet} vs ξ_T^{γ}

CMS-PAS HIN-16-014



ξ^{jet} and ξ_T^{γ} are **measured together for the first time**.

ξ^{jet}

- Based on reconstructed jet energy (energy after quenching)
- Jets are tagged by photon.
- General shift to left compared to ξ_T^{γ}
  - Out-of-cone radiation, photon+>1 jet , quenching in PbPb

ξ_T^{γ}

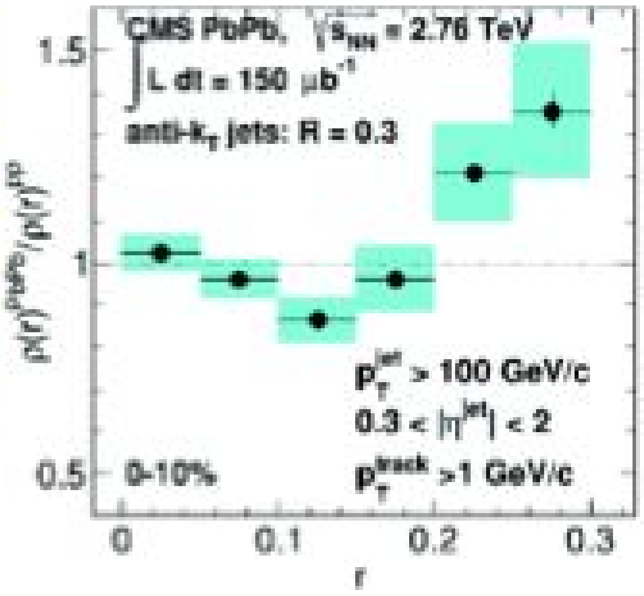
- Based on initial parton energy
- Modification is relatively stronger.
- Centrality dependence is more clear.

Jet shapes: measurements

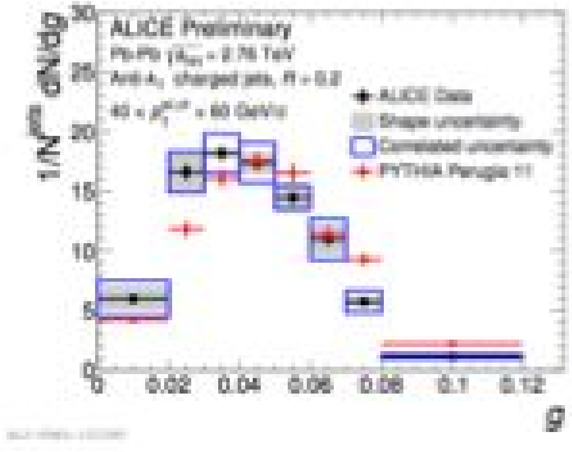
Probing the angular and momentum scale of the quenched jets

Radial profile

CMS PLB 730 (2014) 243

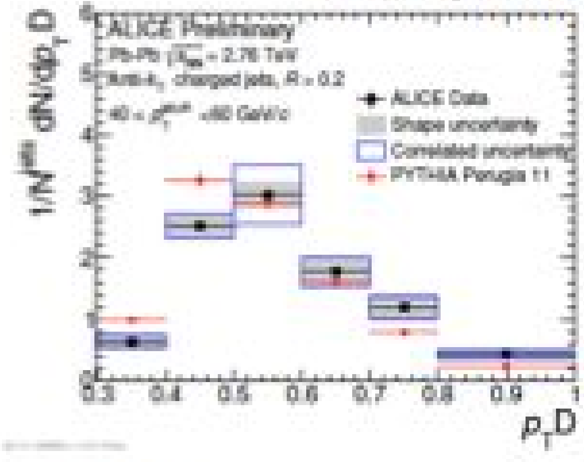


Jet width
girth



p_T-dispersion
p_TD

ALICE QM 2015



Small jets: R=0.2

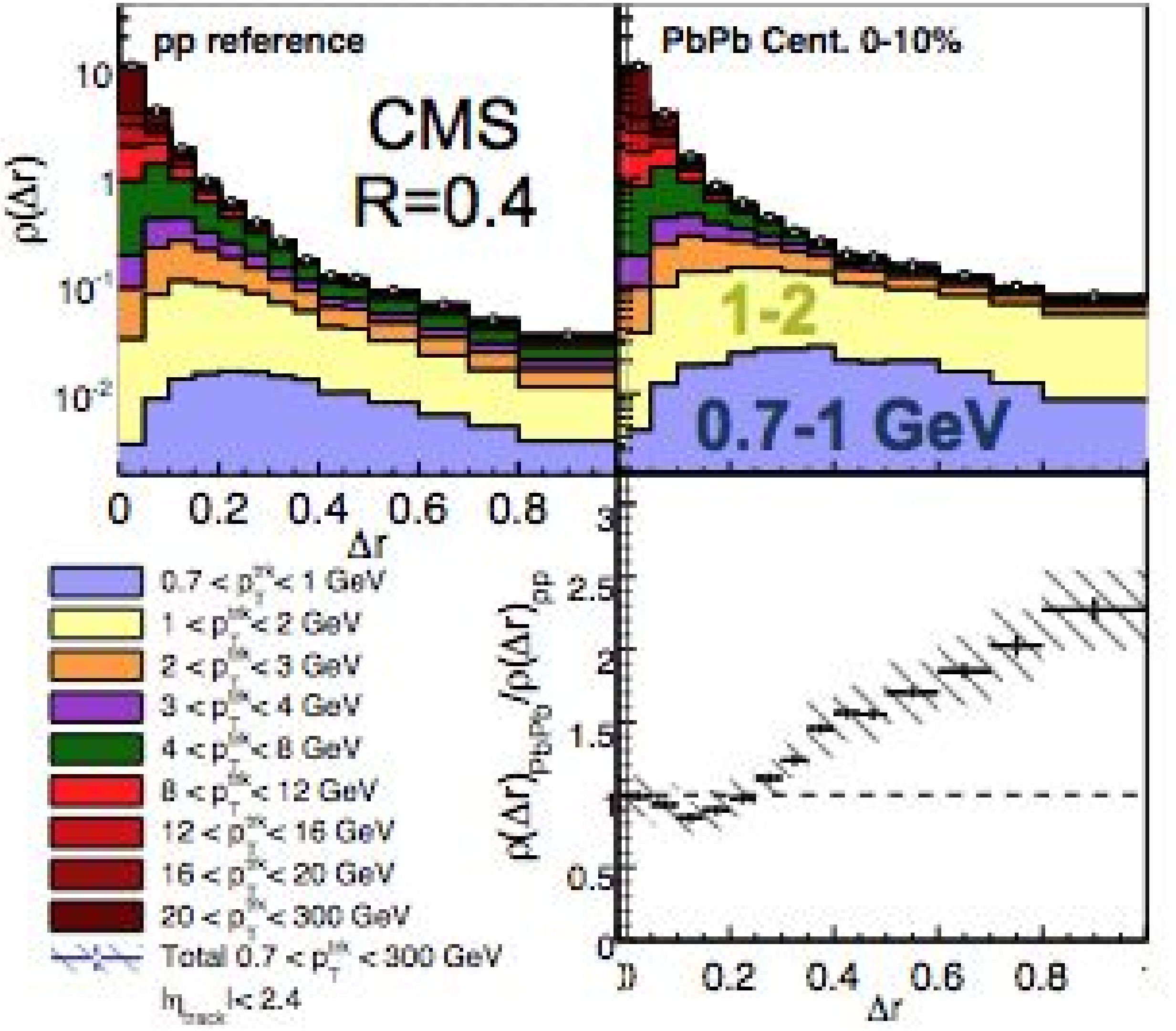
Event-averaged observable

Jet-by-jet observables

All measurements show a narrowing of the core of the jet

Radial profile

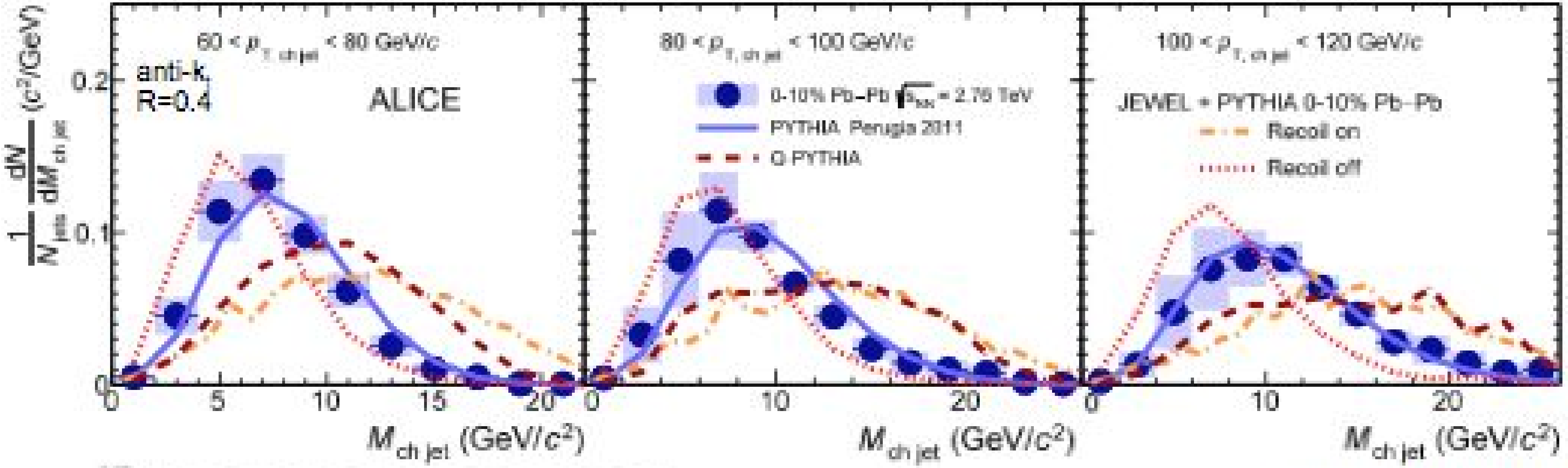
CMS PAS HIN-16-020



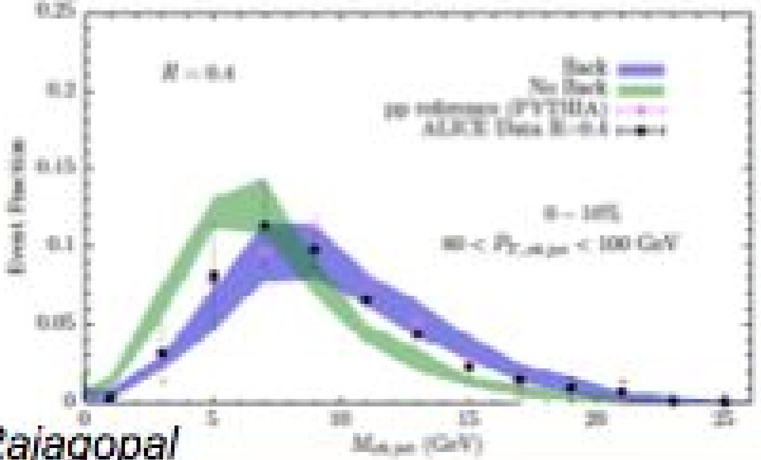
Event-averaged observable

Jet mass

Small mass: collimated jet, small number of constituents. Low virtuality
Large mass: broad jet, large number of constituents. High virtuality



arXiv:1702.00804



K. Rajagopal

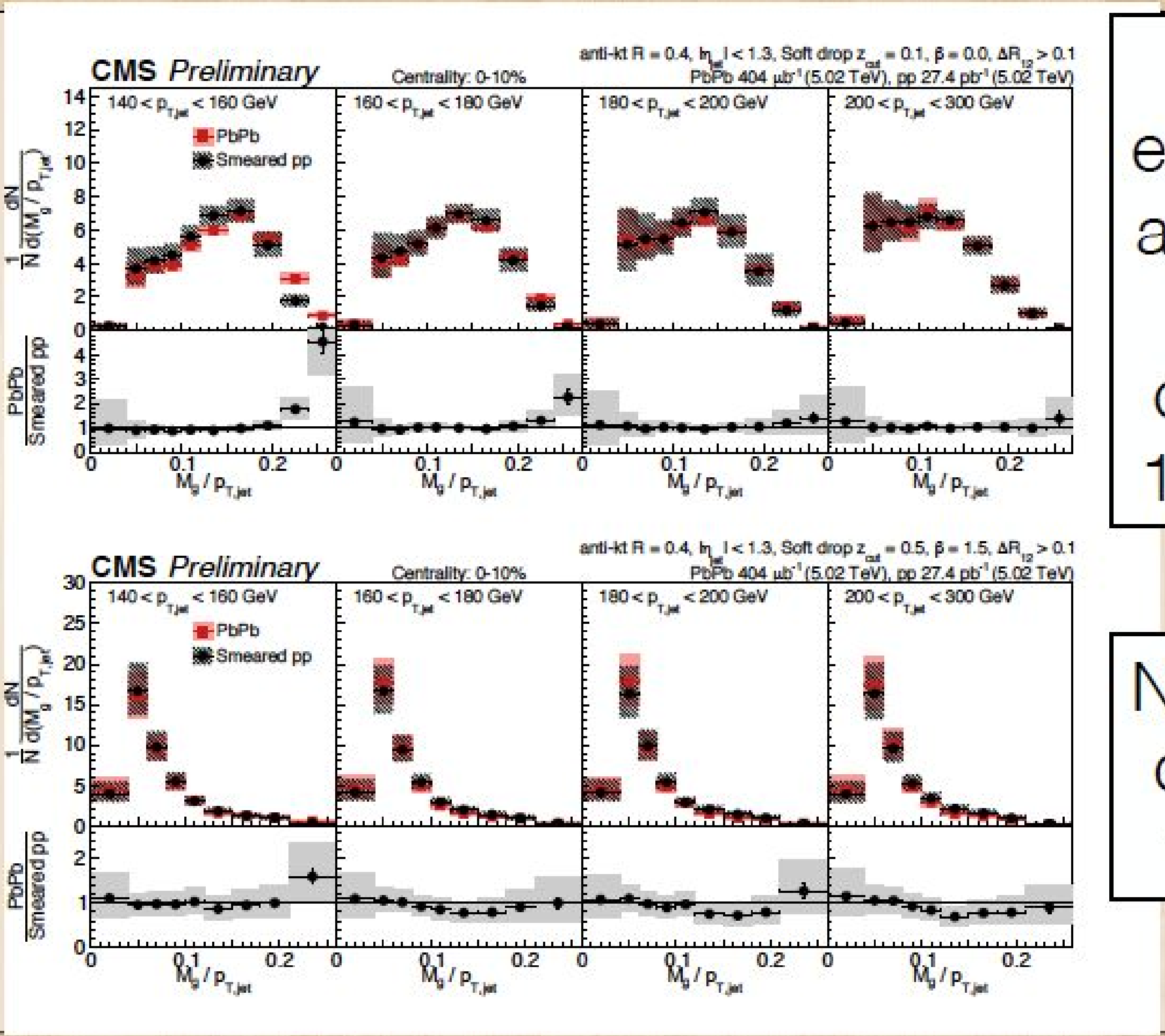
Data looks like PYTHIA
No modification?

Competing effects from energy loss and medium response in JEWEL and Hybrid model. [see also D. Pablos talk]

Mg

(0.1, 0.0)

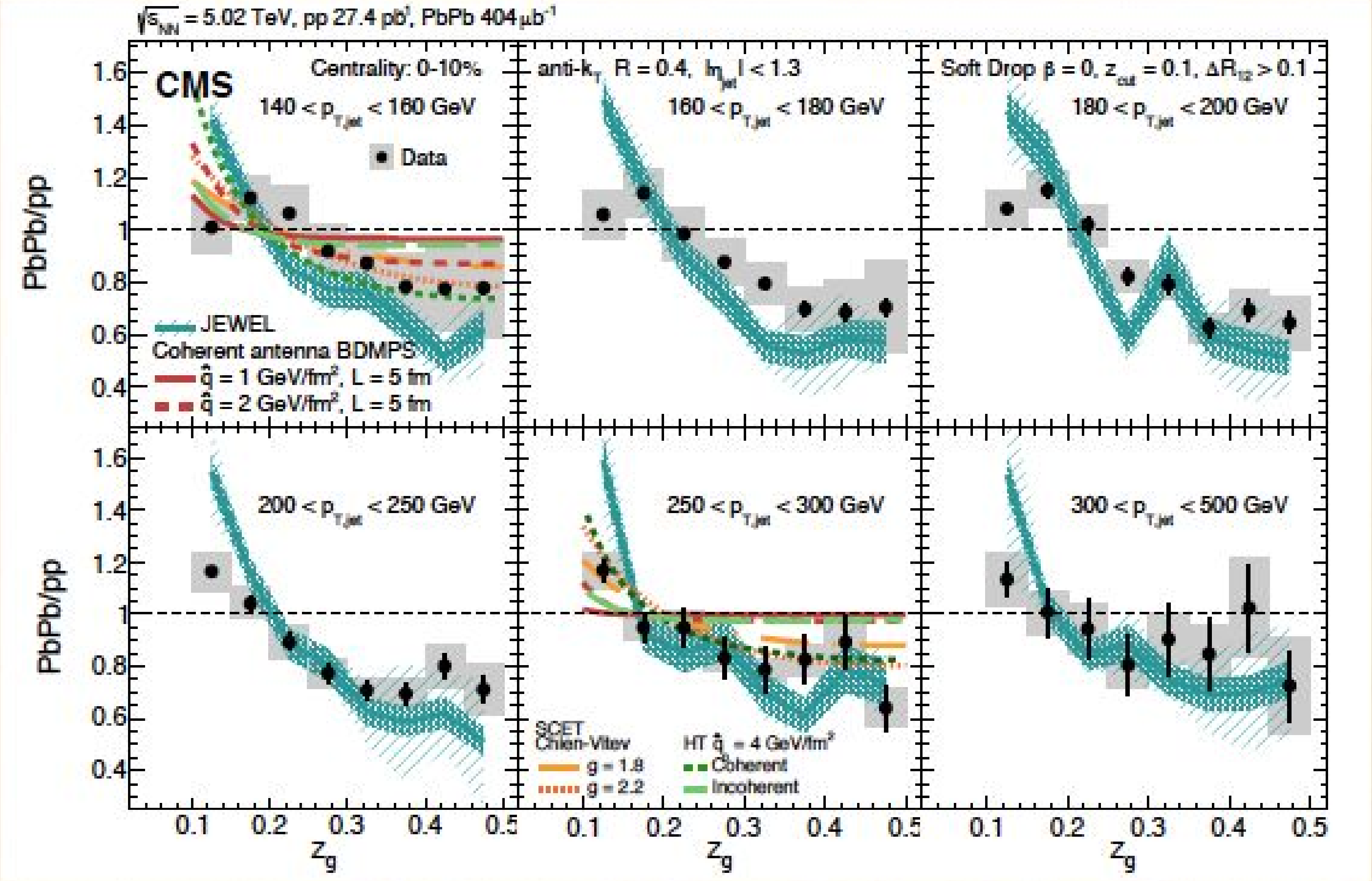
(0.5, 1.5)



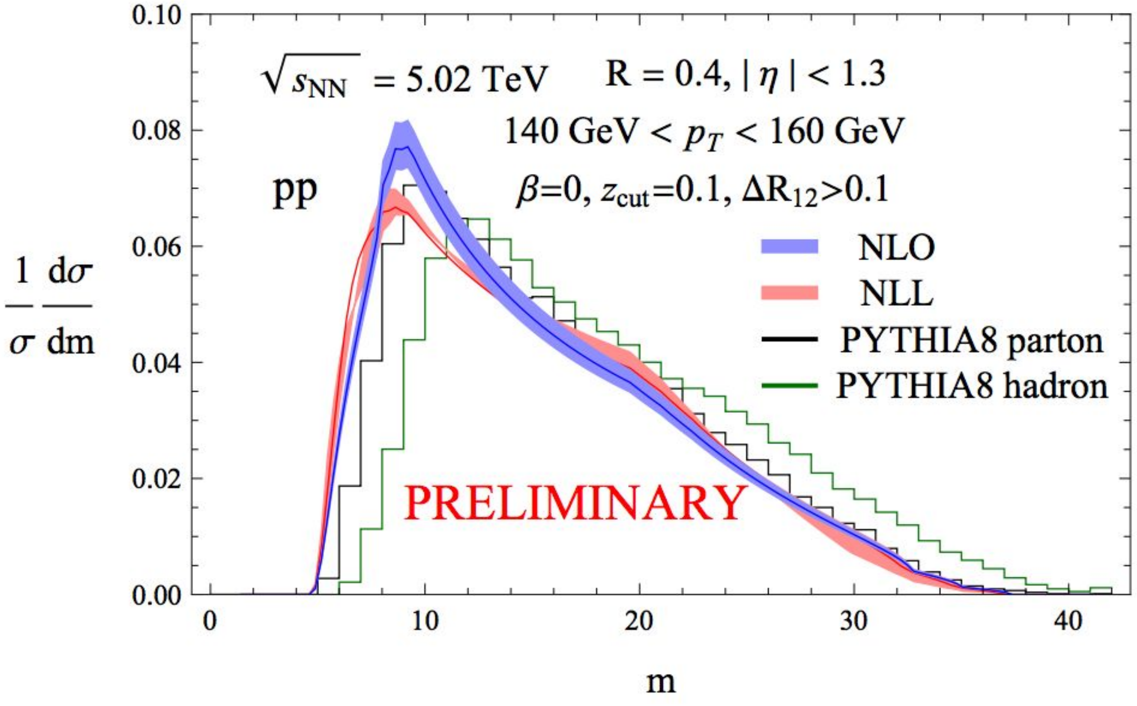
Relative enhancement at large mass in central collisions for 140-160 GeV

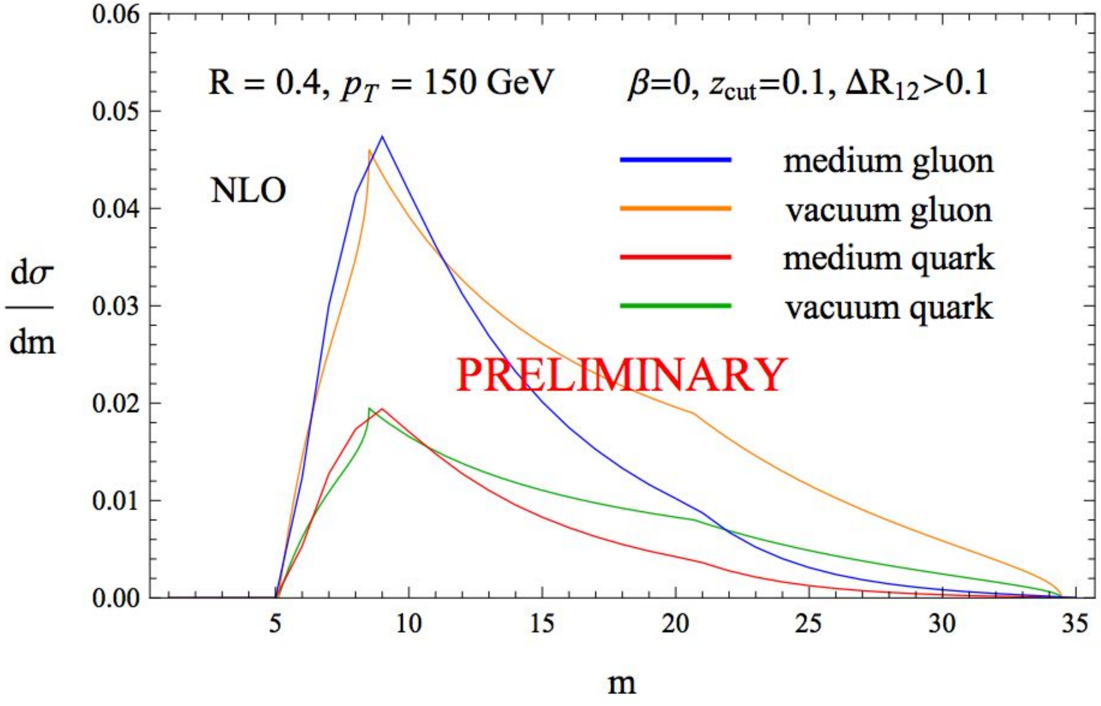
No significant deviation for the jet core

zg vs models



JEWEL generator **Soft collinear effective theory: modified gluon splitting function**
Multiple medium-induced gluon bremsstrahlung (coherent) **Highest twist calculation**

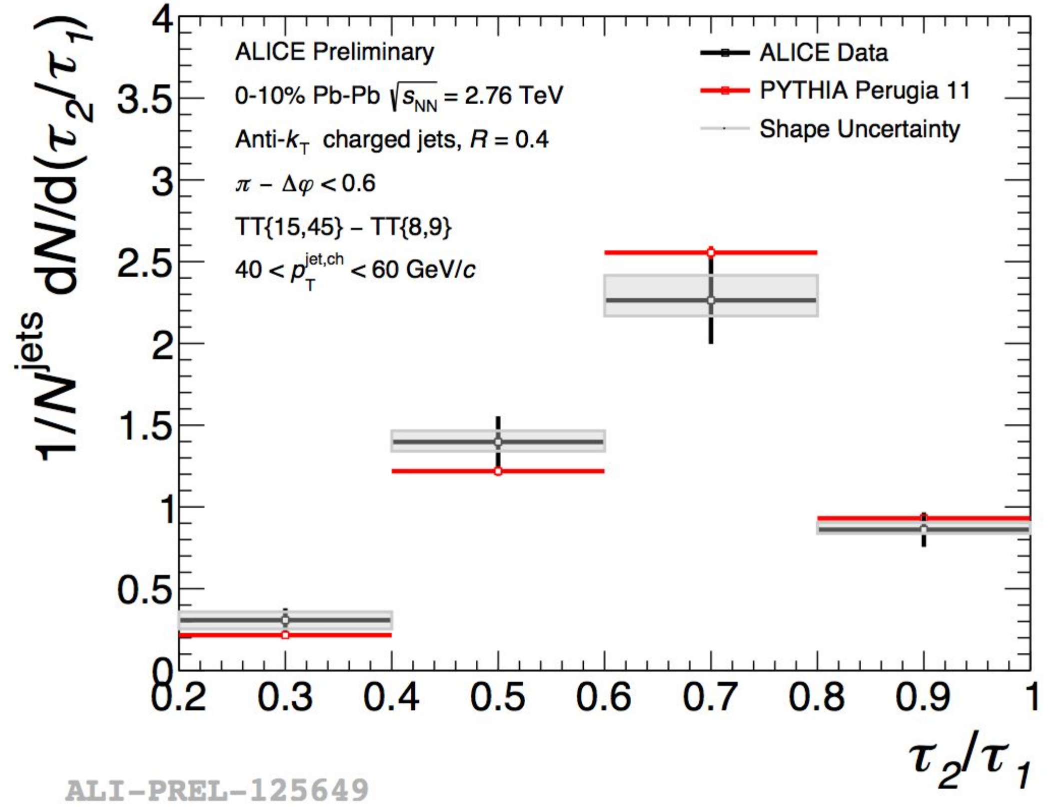




- The $\Delta R_{12} > 0.1$ cut cuts out the Sudakov peak and eliminates the quark/gluon difference
- The lower and upper limits of jet mass are essentially dictated by kinematics. r_g and jet mass are highly correlated
- The medium lowest-order perturbative contribution enhances the small mass region
- Hard splitting can "shield" inner soft radiations from being soft-dropped
- Soft contributions (anything softer: modification of subjets, pp smearing, etc) and hadronization effects are still under examination

Fully Corrected Recoil Jet Shape in Pb-Pb

Data mean = 0.652±0.011 (stat)
PYTHIA mean = 0.670±0.002 (stat)

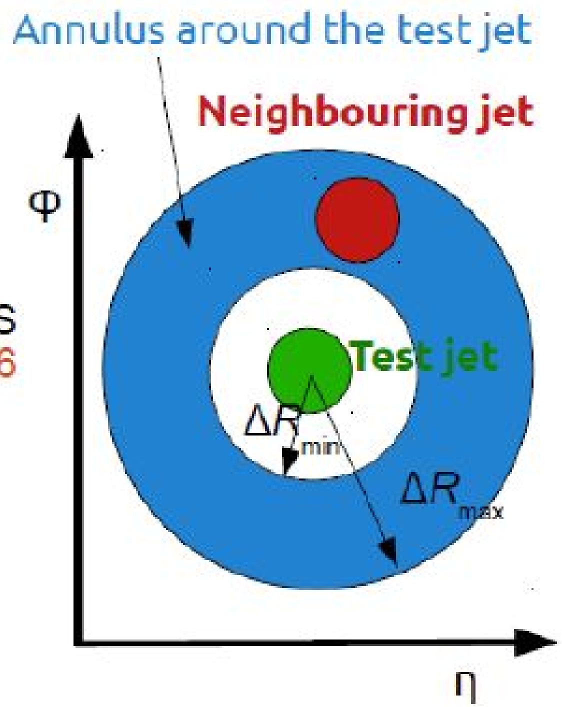


In addition to the systematic variations done in pp, the Pb-Pb analysis also considers the uncertainties due to:

- The choice of the subtraction method.
- The uncertainty due to the EP bias induced by the trigger track.

- Alignment of radiation relative to the two k_T axes is similar in Pb-Pb and PYTHIA
- Full correction of ΔR ongoing.

Neighbouring jets

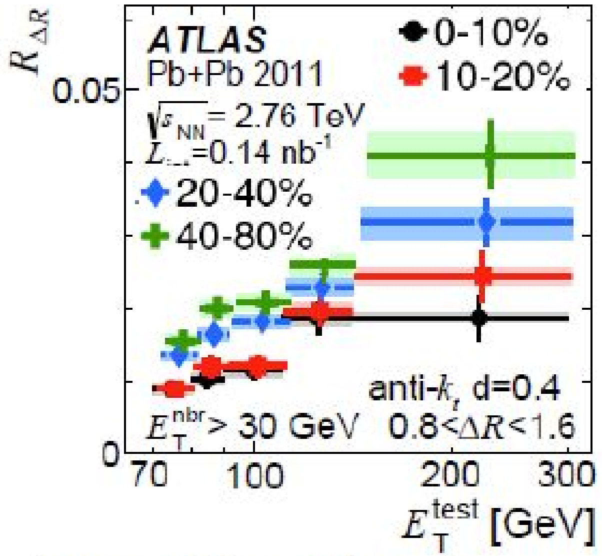


Observable: rate of neighbouring jets next to a test jet with given E_T^{test}

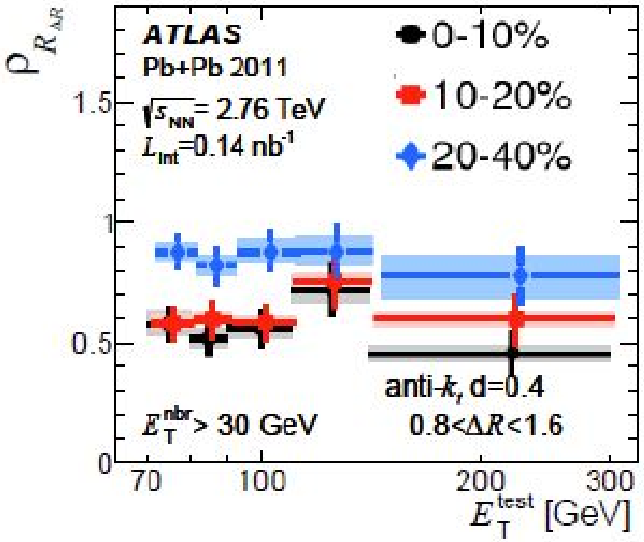
ATLAS
arXiv:1506.08656

$$R_{\Delta R} = \frac{1}{\mathrm{d}N_{\mathrm{jet}}^{\mathrm{test}}/\mathrm{d}E_{\mathrm{T}}^{\mathrm{test}}} \sum_{i=1}^{N_{\mathrm{jet}}^{\mathrm{test}}} \frac{\mathrm{d}N_{\mathrm{jet},i}^{\mathrm{nbr}}}{\mathrm{d}E_{\mathrm{T}}^{\mathrm{test}}}(E_{\mathrm{T}}^{\mathrm{test}}, E_{\mathrm{T,min}}^{\mathrm{nbr}}, \Delta R)$$

Rate of neighbouring jets



Central to peripheral ratio vs E_T^{nbr}



Neighbouring jets at large angle and large E

- Correlation between 2nd and 3rd leading jet in the event
- Independent shower evolution
- Common geometry → same path length

Possible extensions: small angle correlations, sub-jets