Jet suppression @ ATLAS

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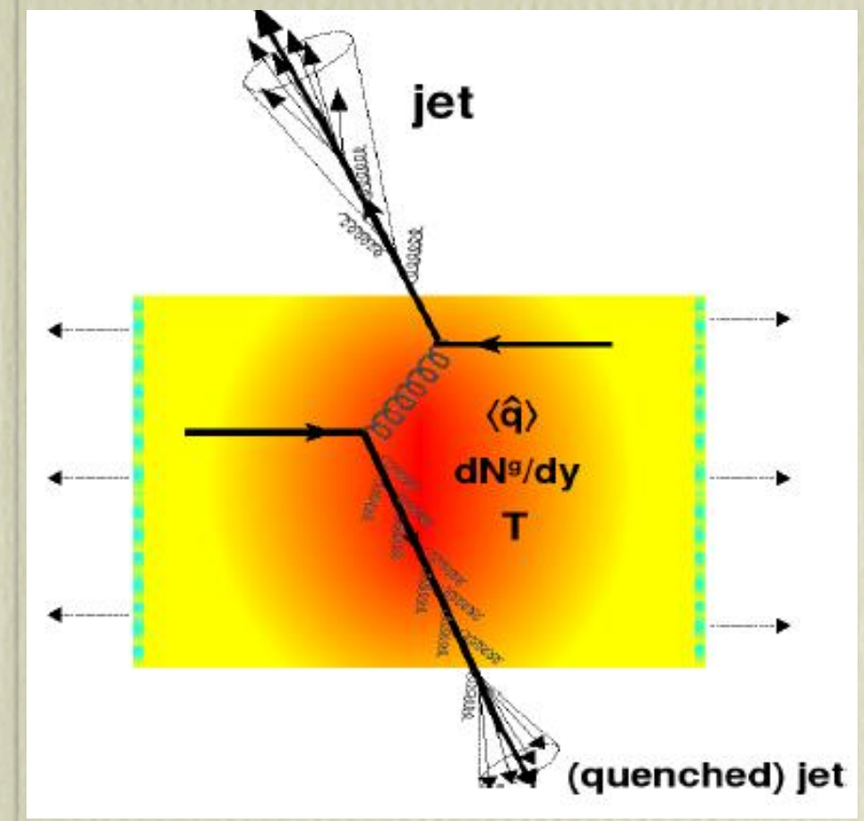
Mini-workshop on Heavy Ion collisions

Copenhagen 7-9 November 2011

Parton energy loss

How does a QCD medium at extreme color-charge density and temperature modify parton showering ?

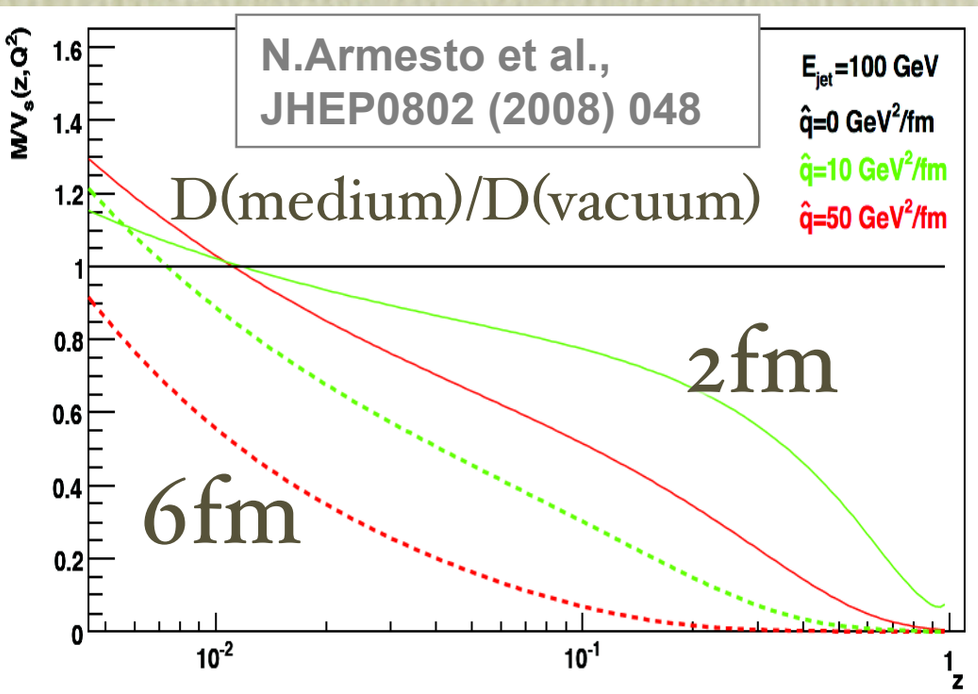
Plots in this presentation from
ATLAS-CONF-2011-075
Martin Spousta: ISMD2011 slides
CMS PAS HIN-11-004

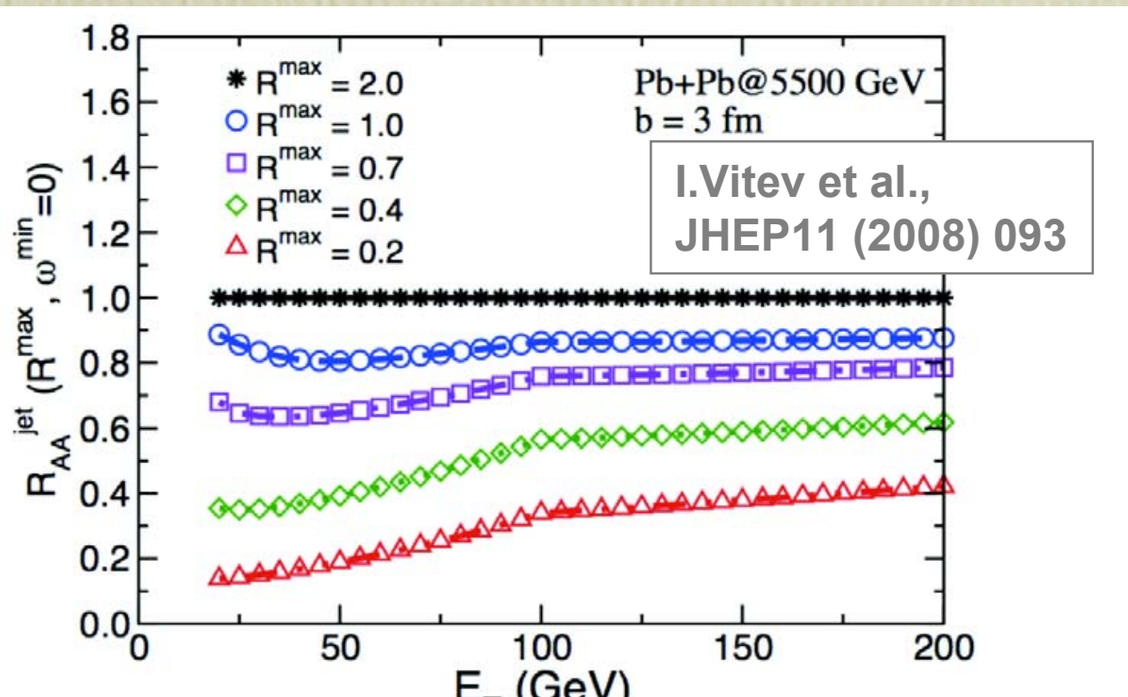


Questions on Quenching:

- Does the medium modify average di-jet properties?
- Does the medium affect the inclusive jet yield?
- Does it modify the fragmentation function, $D(z,k_T)$, in the cone?
- To where and to what is the lost energy dissipated?

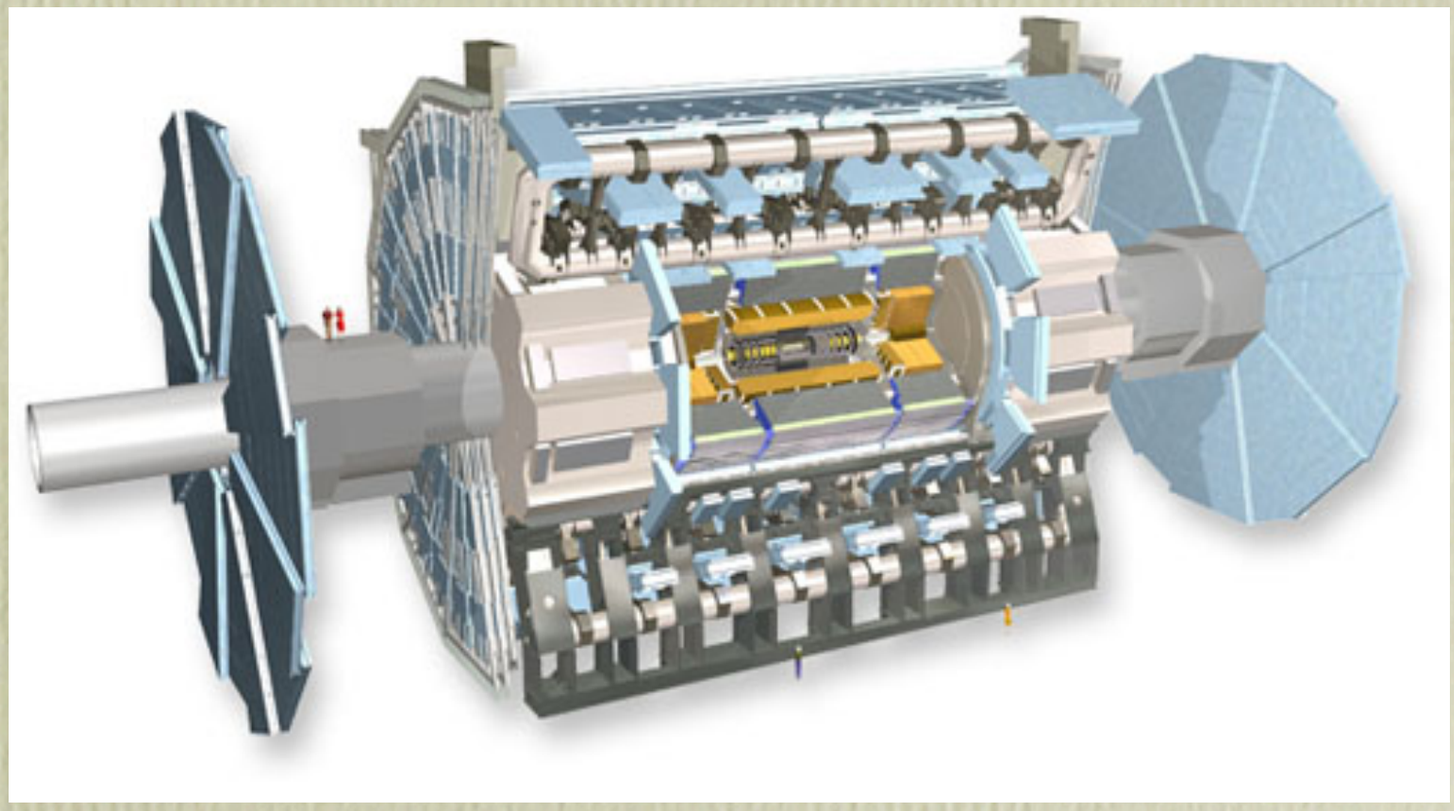
Some pre-LHC calculations of radiative energy loss:





ATLAS and Pb+Pb

LHC Pb+Pb collision data from fall 2010. Selected 7 mub^{-1} at 2.76 TeV per nucleon using minimum bias triggers.

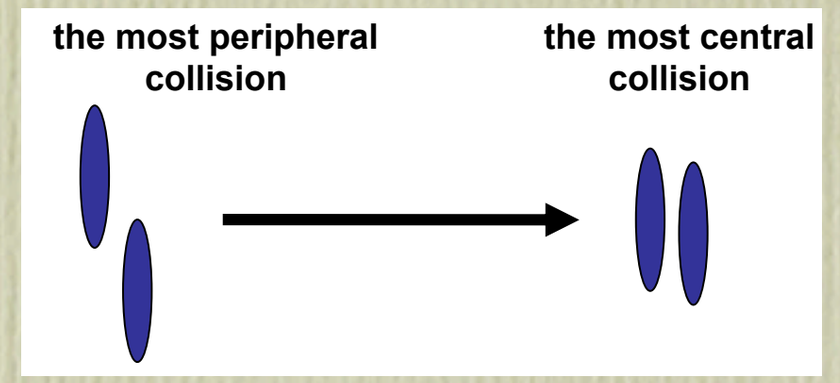


Complete hadronic and electromagnetic calorimeter coverage within |eta|<4.9

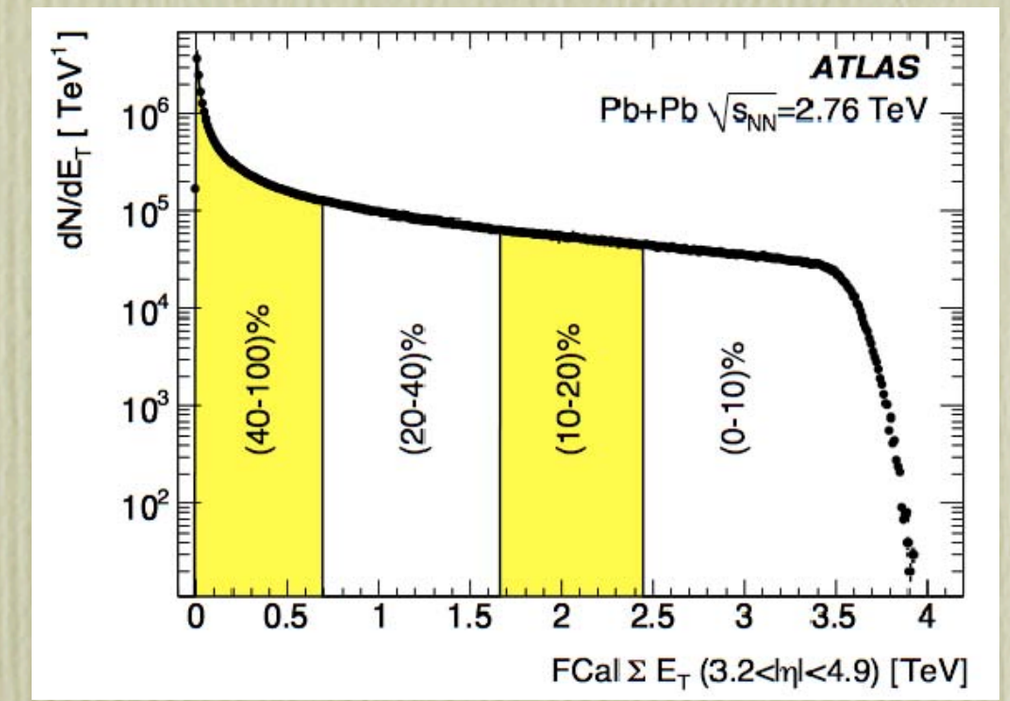
Complete high pT muon coverage within |eta|<2.7

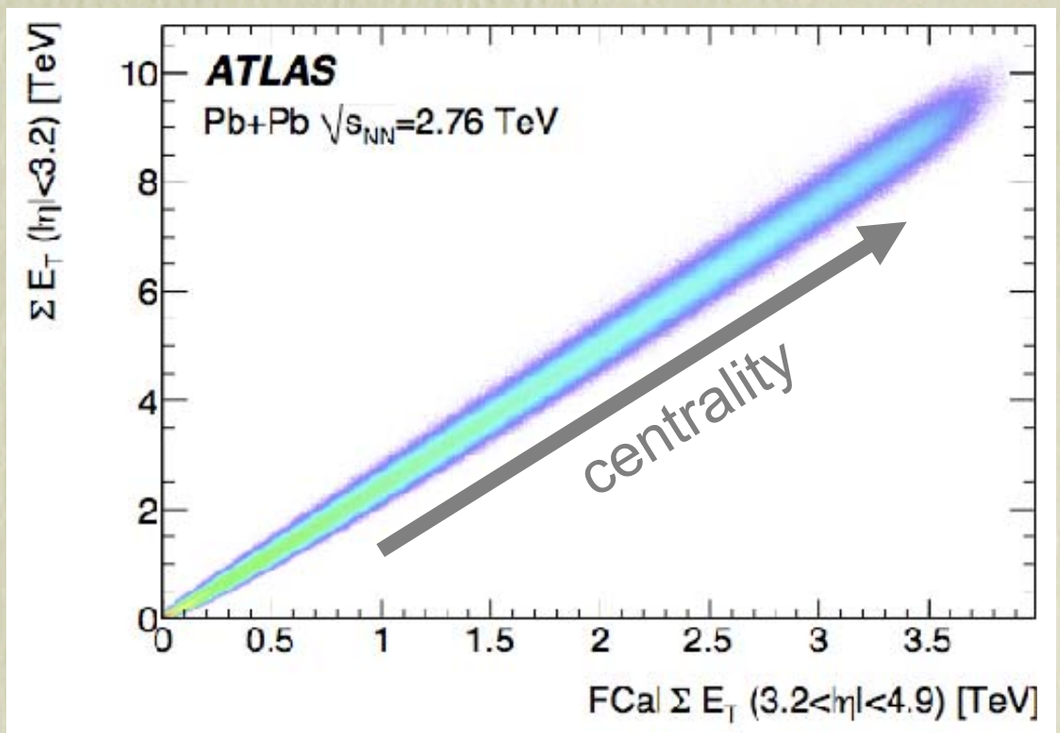
Precision tracking detector coverage for pT>100-500 MeV within |eta|<2.5

Centrality definition



Use total ET in the forward calorimeters covering 3.2 < |eta| < 4.9 as an estimator. This is a good estimator which is not biased by the jet measurements at |eta|<2.8.



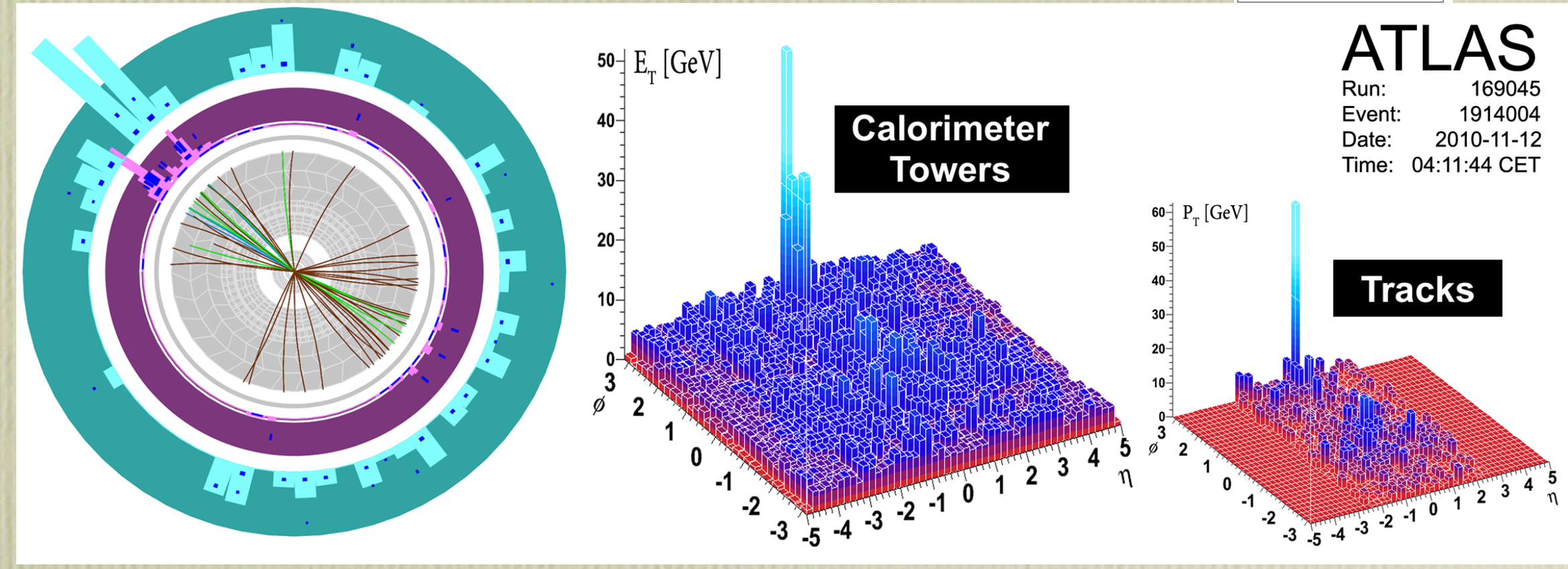


Jet reconstruction

- Use anti-k_T algorithm with R=0.2 and 0.4
- Input are Deta x Dphi = 0.1 x 0.1 calorimeter towers
- Subtract <E_T>, the non-jet energy, in each Deta=0.1 layer and each event (procedure checked by MC).
- Retain jets with E_{T1} > 100 GeV (R=0.4) or E_{T1} > 50 GeV (R=0.2), and for di-jet studies E_{T2} > 25 GeV, all within |eta|<2.8 .
- Repeat procedure on 7 TeV p+p events and simulated HIJING+PYTHIA+GEANT Pb+Pb events tuned to match underlying event fluctuations in data.

Dijet asymmetry

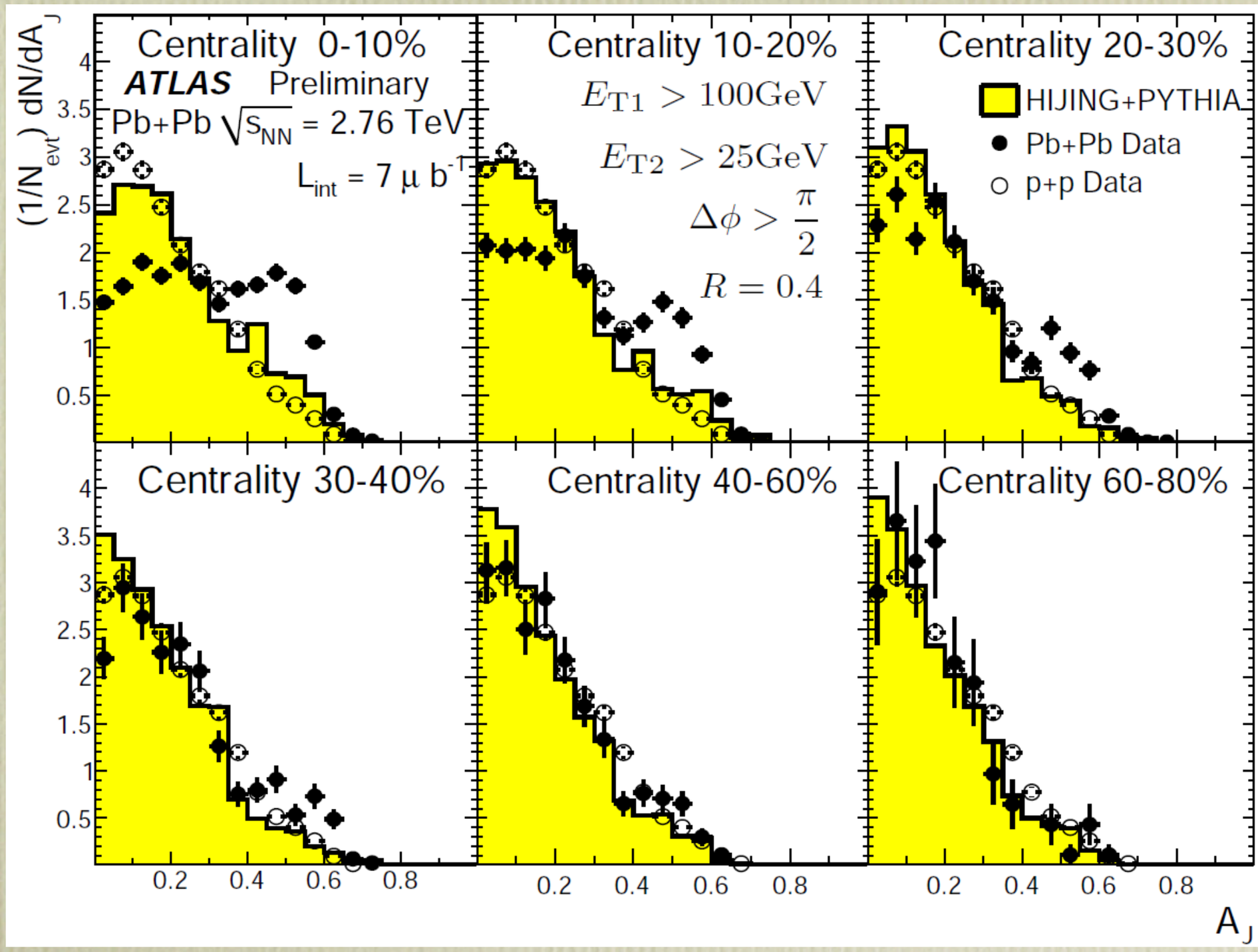
original result using L~1.7 μb^{-1}: **Phys. Rev. Let. 105, 252303**



An asymmetry, quantified as $A= (E_{T1}-E_{T2})/(E_{T1}+E_{T2})$, develops in head-on Pb+Pb collisions as opposed to p+p collisions.

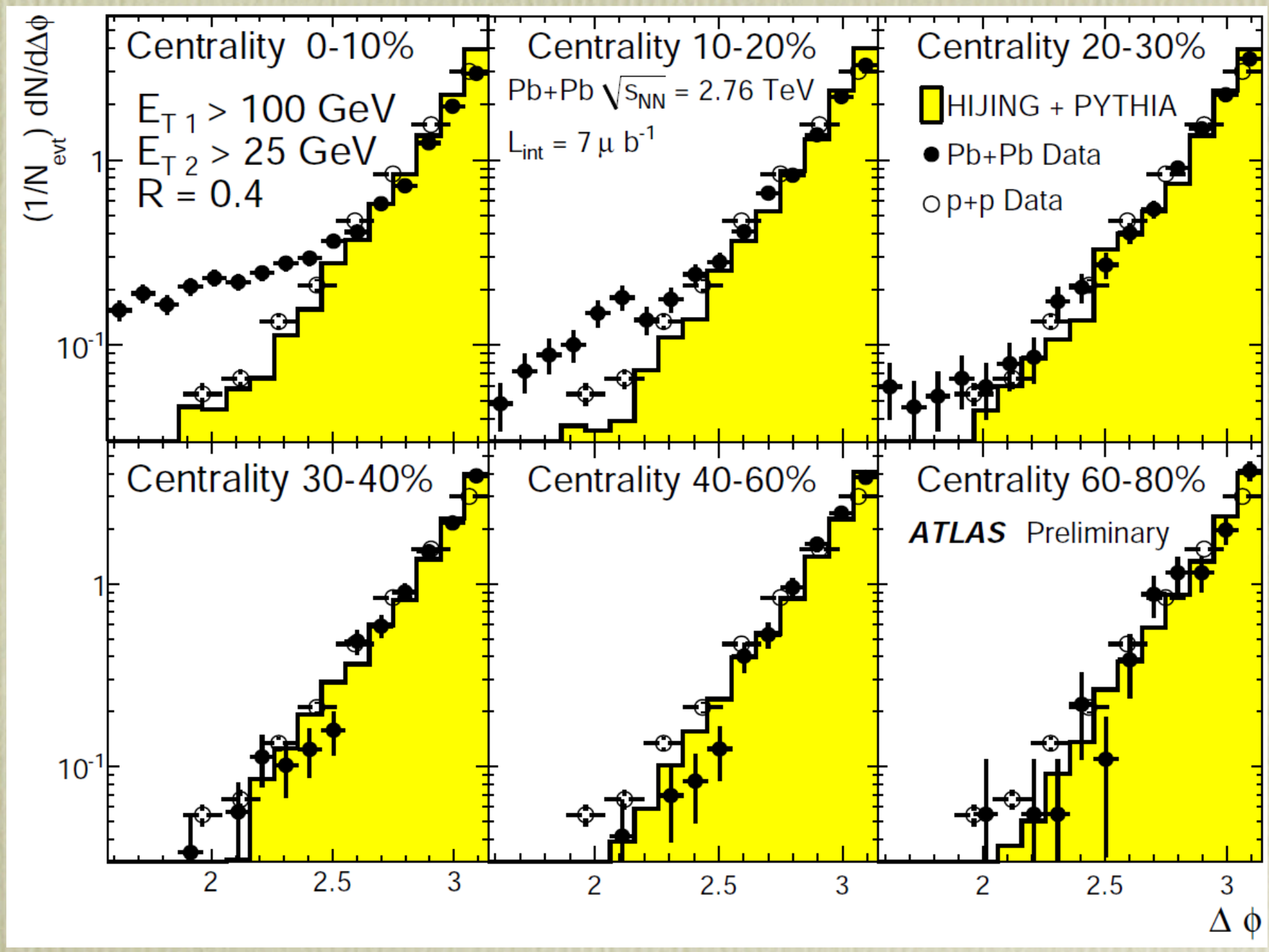
The azimuthal dijet correlation (peak at $|phi_1-phi_2| = pi$) is retained as in p+p collisions.

Di-jet asymmetry



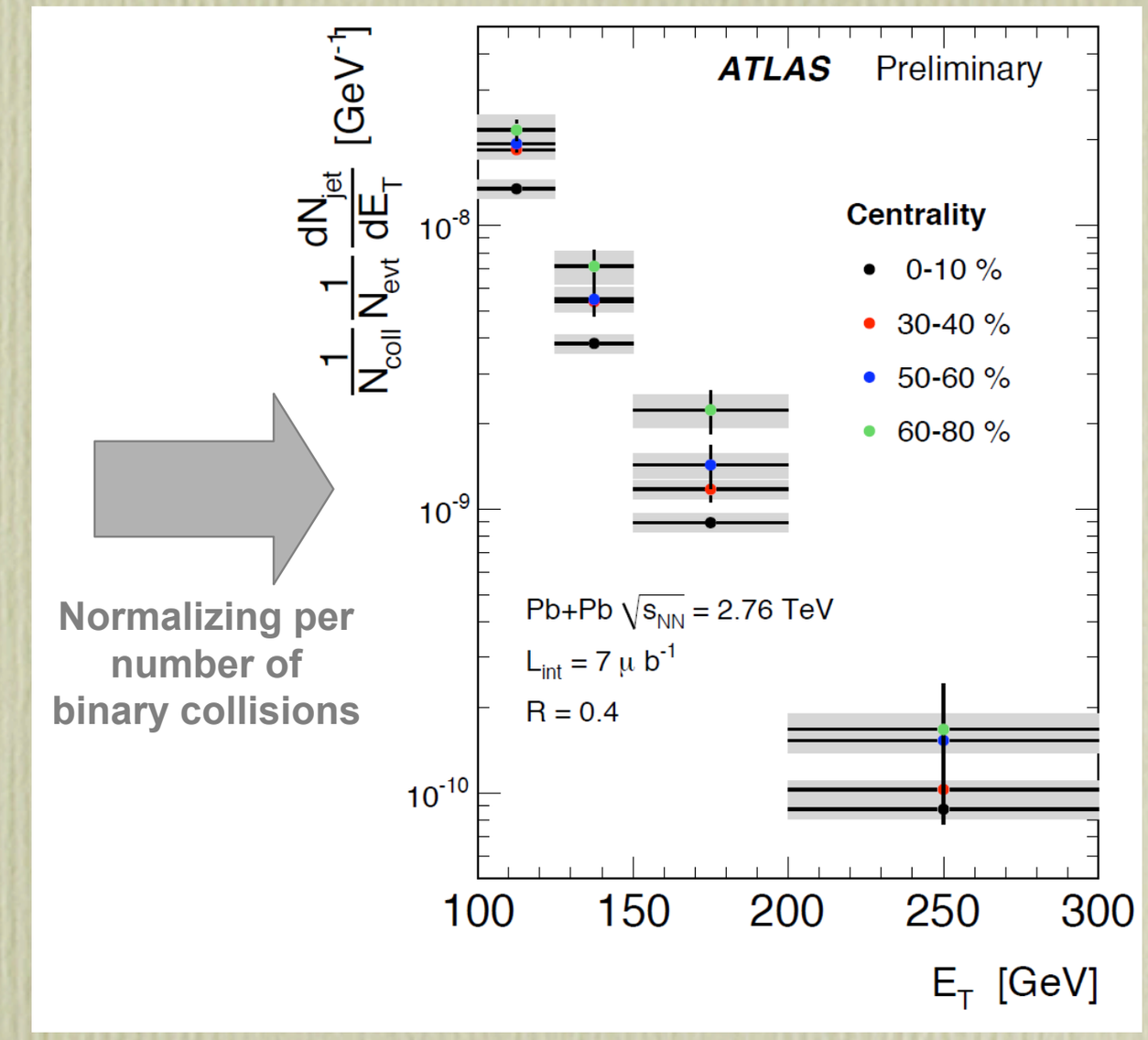
Asymmetry grows with centrality. Same picture for R=0.2.

Dijet azimuthal correlations

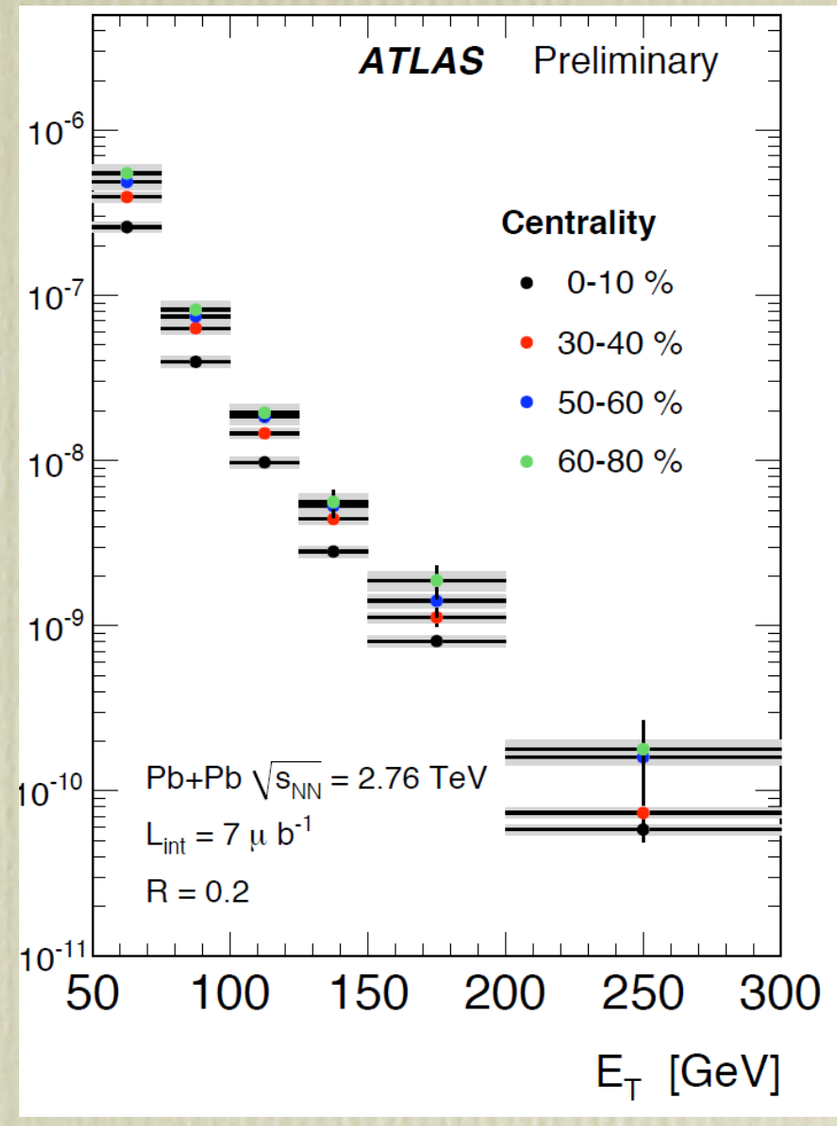


(Small pollution from combinatorics in very central events. Absent for R=0.2)

Inclusive jet yield

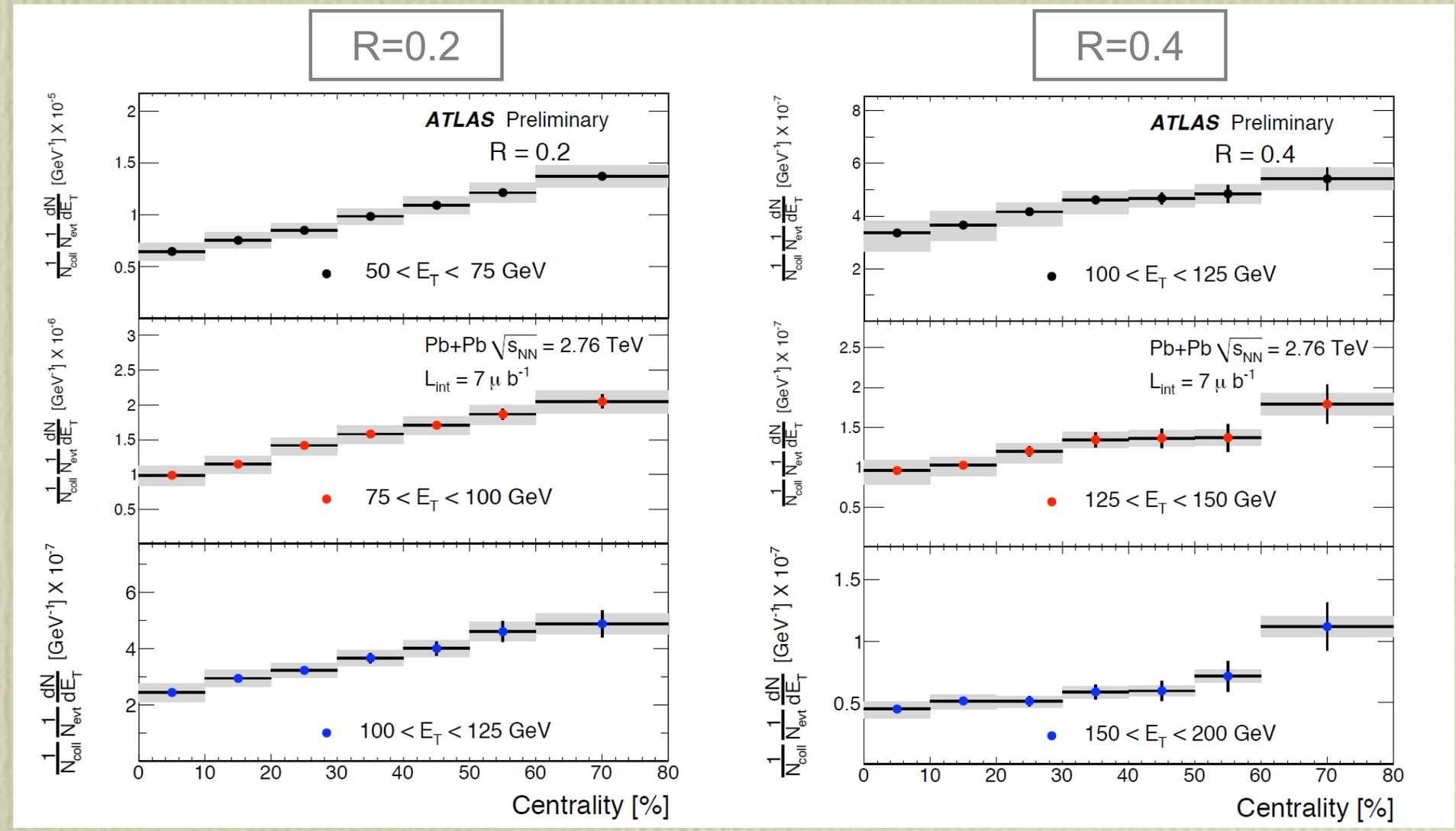


Normalizing per number of binary collisions



Main sys: JES (22%), Ncoll (8-12%) (greatly helped by W, Z measurements)
Main message: Jet yields per binary collision are reduced for central collisions.

Centrality dependence

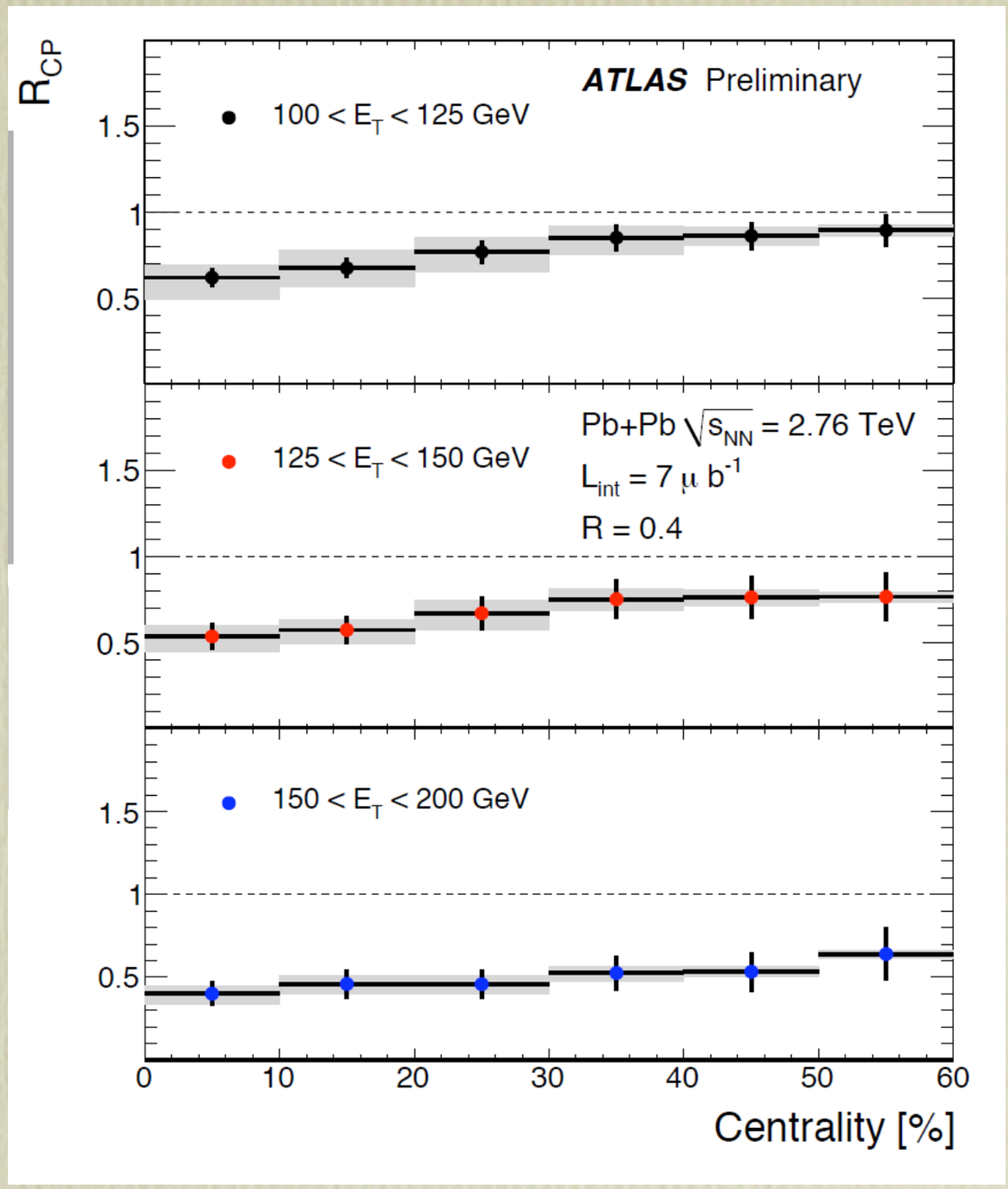


Nuclear modification factor decreases with centrality, about a factor of two at all energies for both jet cones.

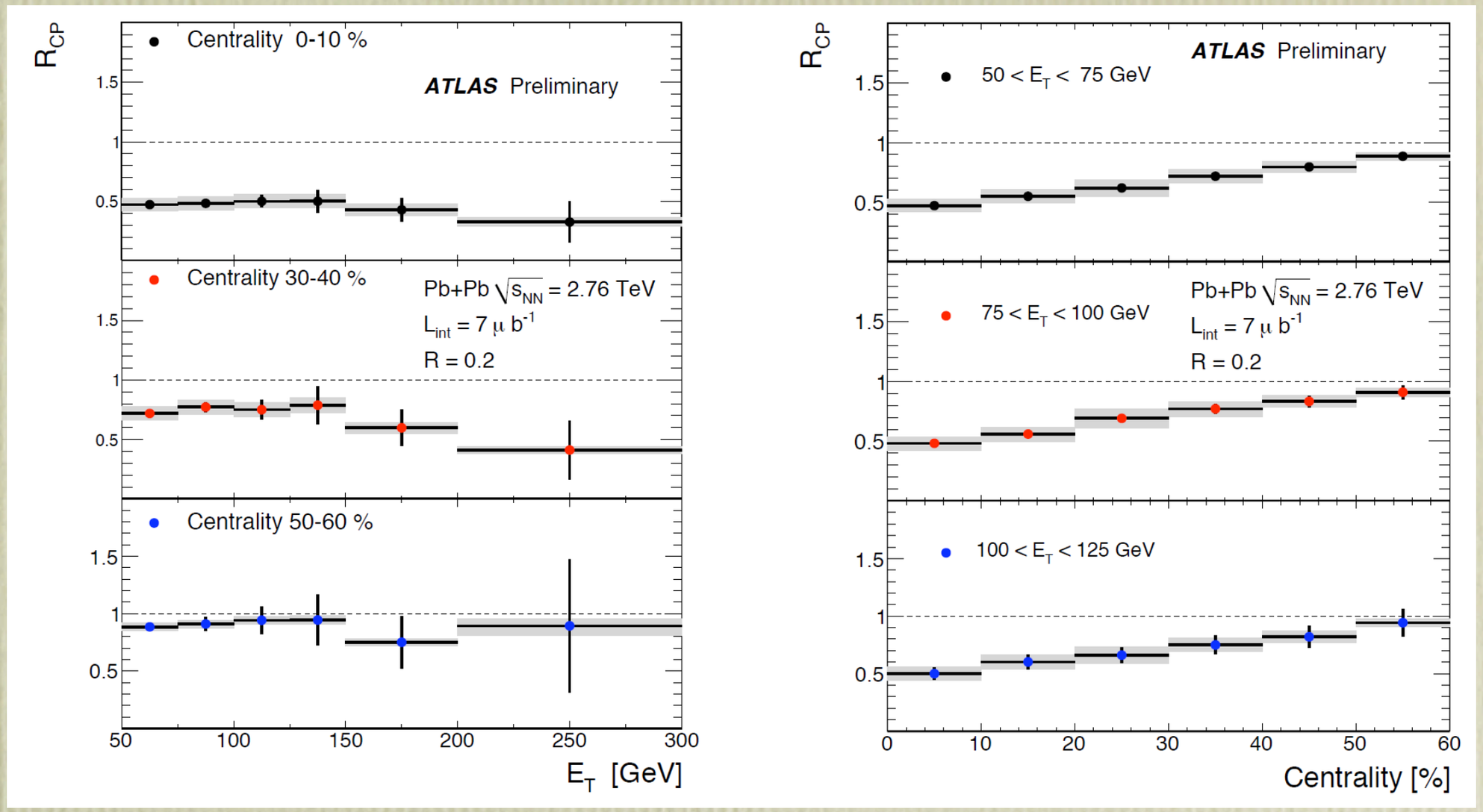
Central to peripheral jet ratio

The ratio of central to peripheral (60-80%) avoids some correlated systematics.

Again we see a suppression by about a factor of two for central collisions in the inclusive jet yield per NN independent of energy.



Central to peripheral R=0.2



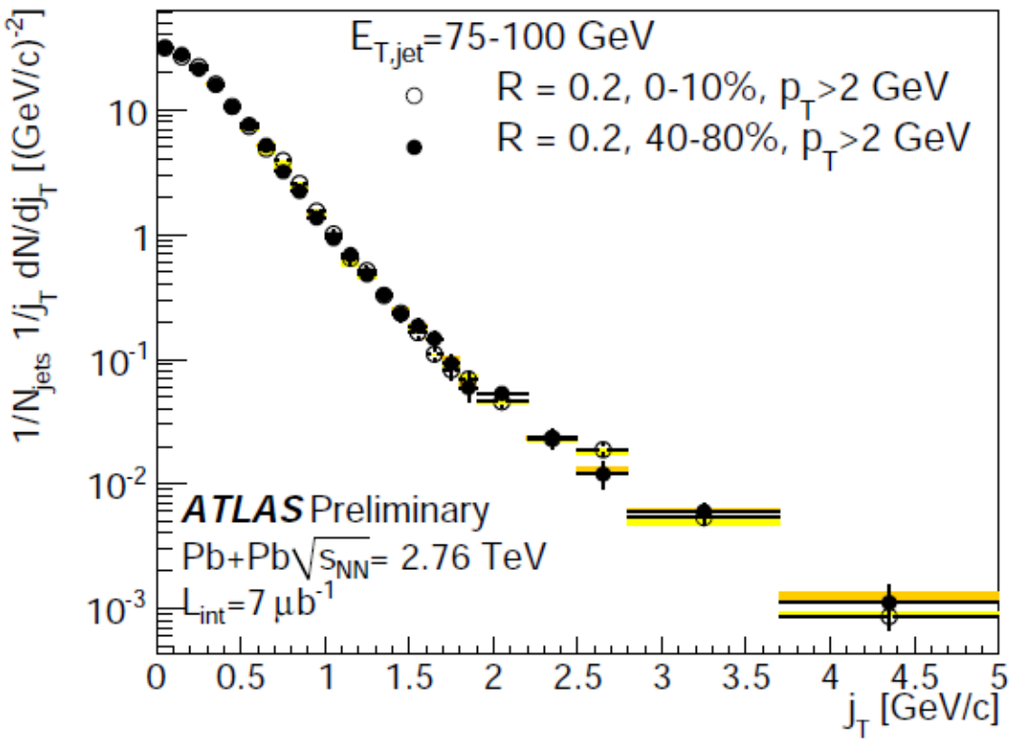
Same picture for R=0.2 => enlarging to R=0.4 *does not* recover the lost energy. This energy must be found other places!

There is no significant energy dependence of the suppression.

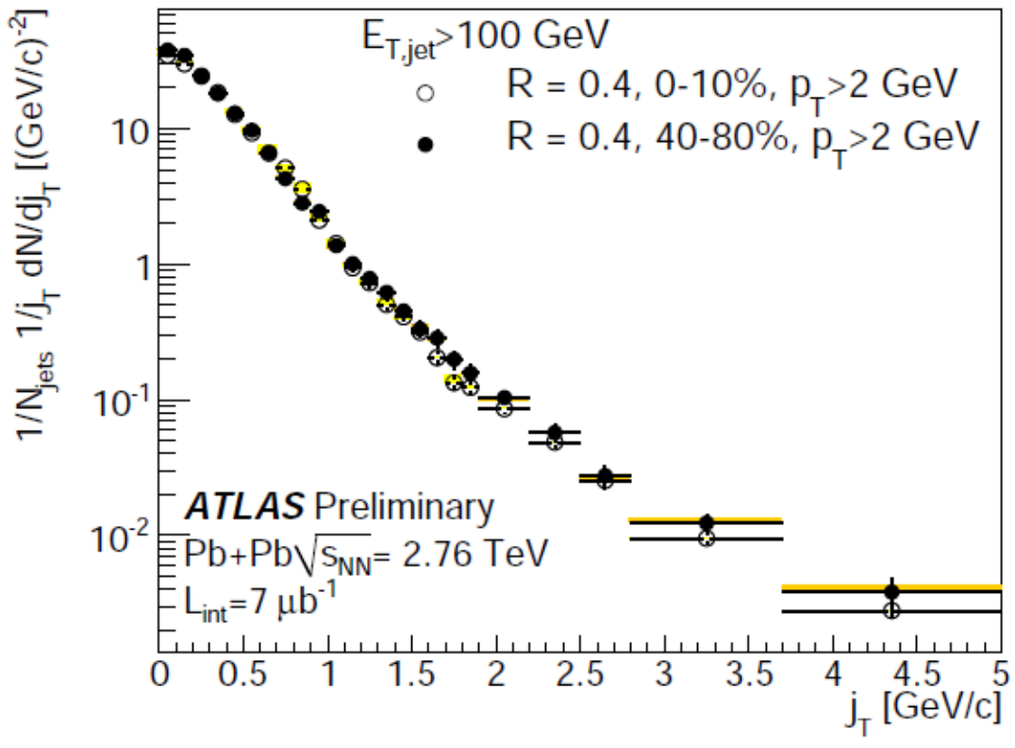
Jet transverse structure

$$j_T = p_T^{had} \sin \Delta R$$
$$\Delta R = \sqrt{\Delta\eta^2 + \Delta\phi^2}$$

R=0.2



R=0.4

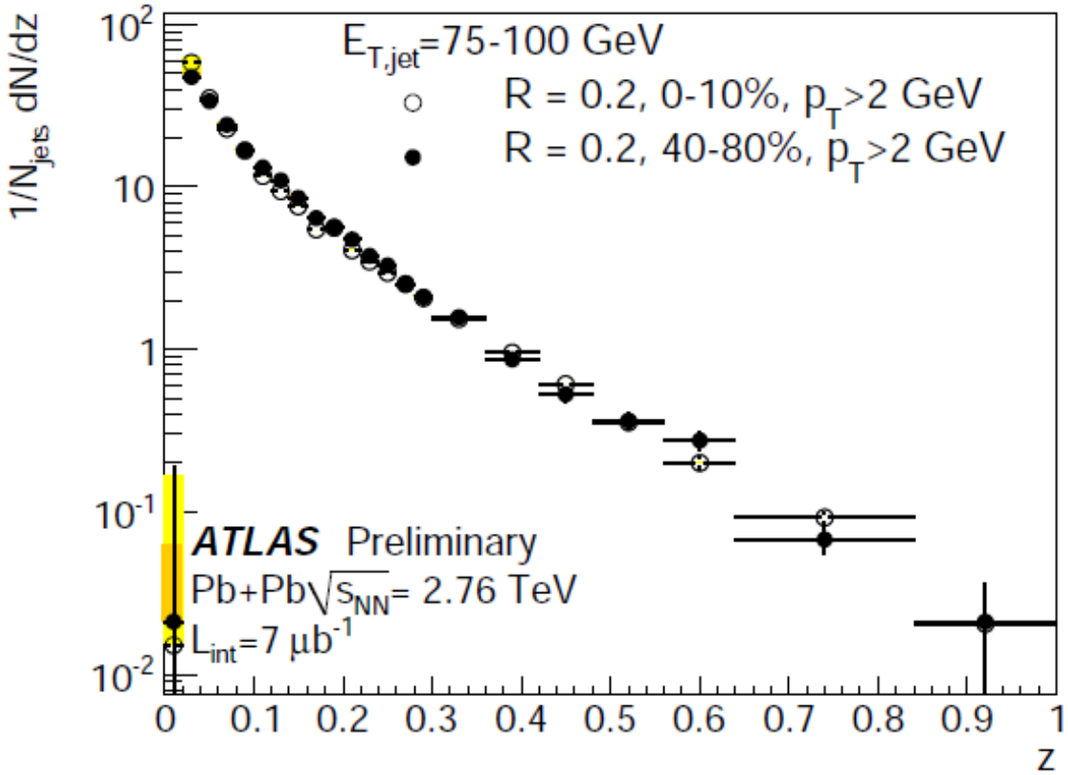


Charged tracks with p_T > 2 GeV in inclusive jets.
UE subtracted.
No jet broadening with centrality seen!

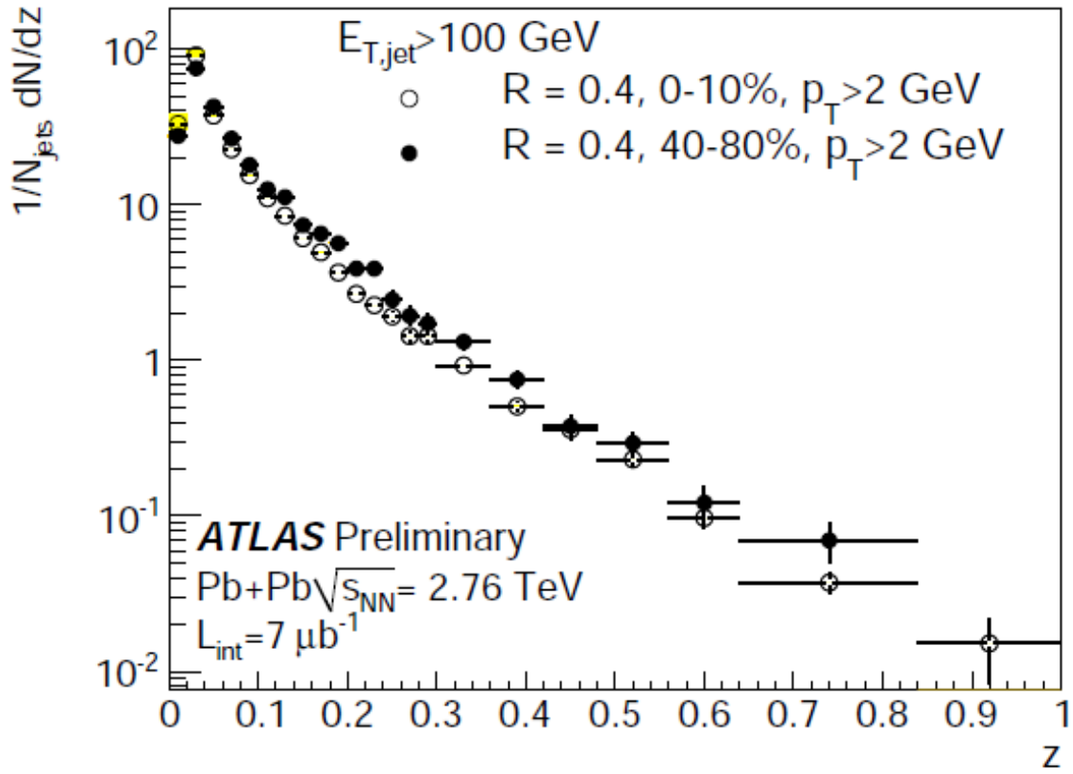
Longitudinal jet structure

$$z = p_T^{had} / E_T \cos \Delta R$$
$$\Delta R = \sqrt{\Delta\eta^2 + \Delta\phi^2}$$

R=0.2



R=0.4

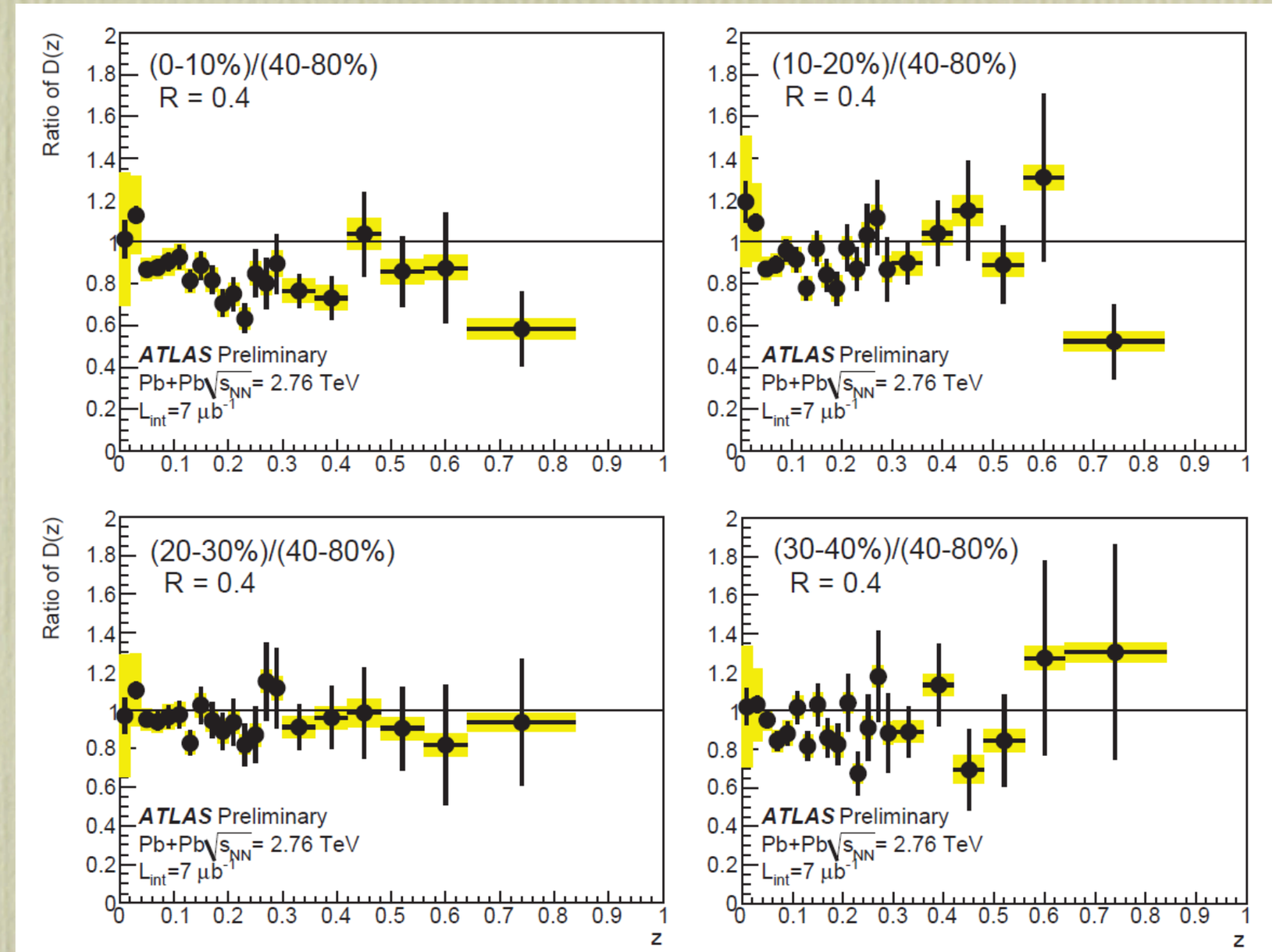


No strong centrality dependence in z neither.

(UE subtracted. Correction for JER for R=0.4.)

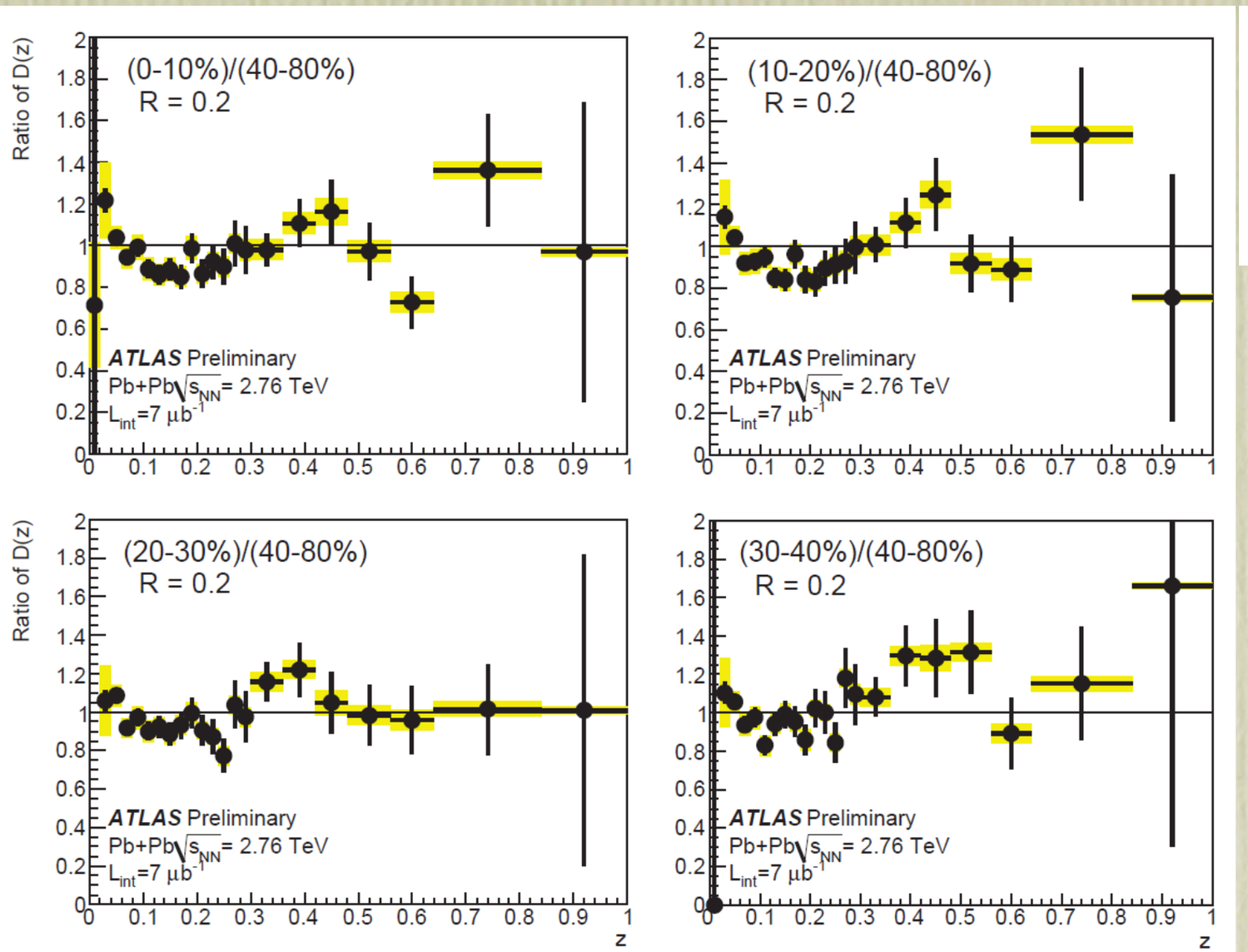
Central over peripheral longitudinal structure

$$z = p_T^{had}/E_T \cos\Delta R$$
$$\Delta R = \sqrt{\Delta\eta^2 + \Delta\phi^2}$$



Only weak (at most 20%) change of fragmentation function with centrality!

Central over peripheral longitudinal structure

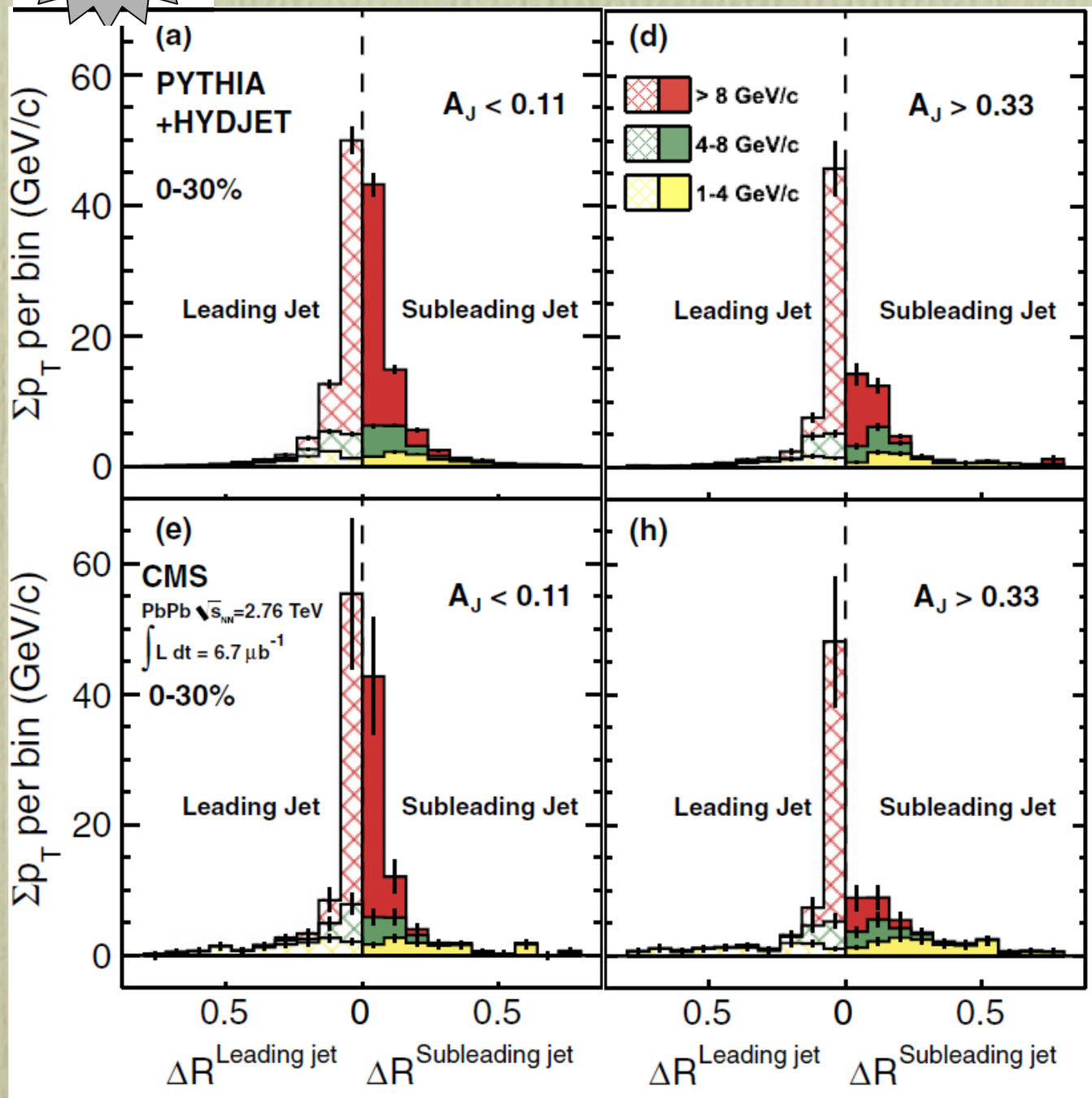


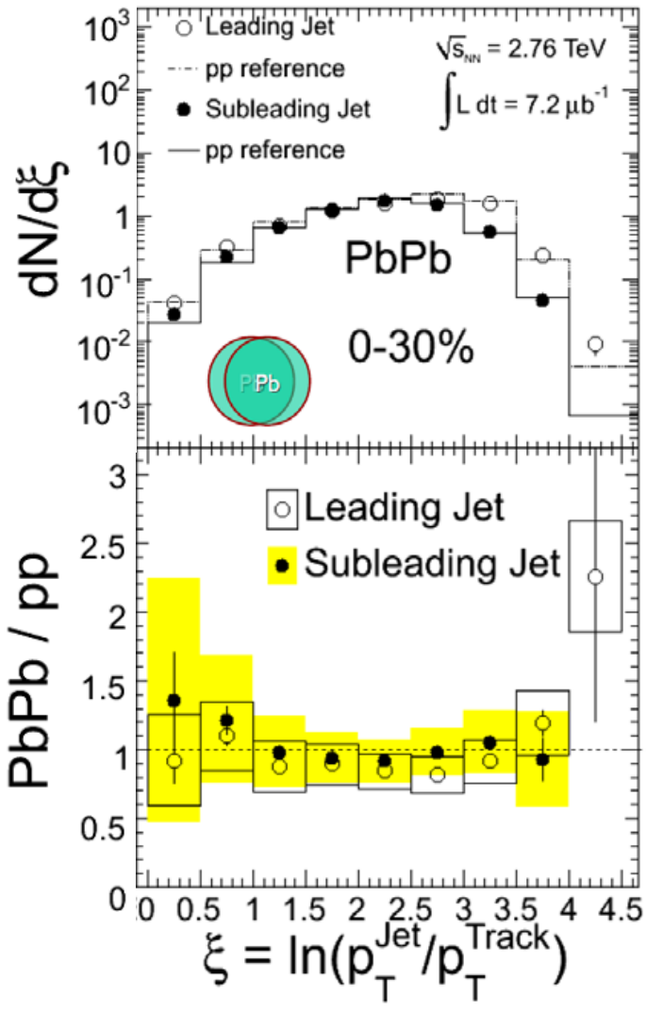
R=0.2

E_T=75-100 GeV

Also very weak change with centrality for R=0.2 jets!

Jet fragmentation in CMS

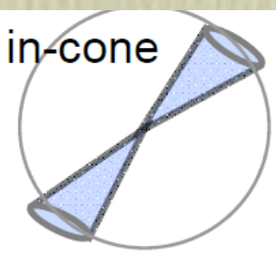


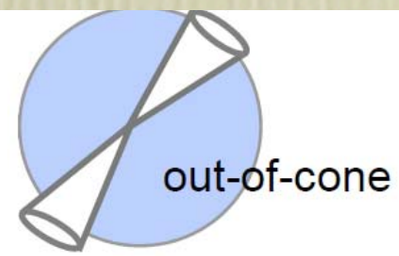


Results obtained by CMS for leading and subleading jets → No strong modification of jet fragmentation.

CMS results on overall balance

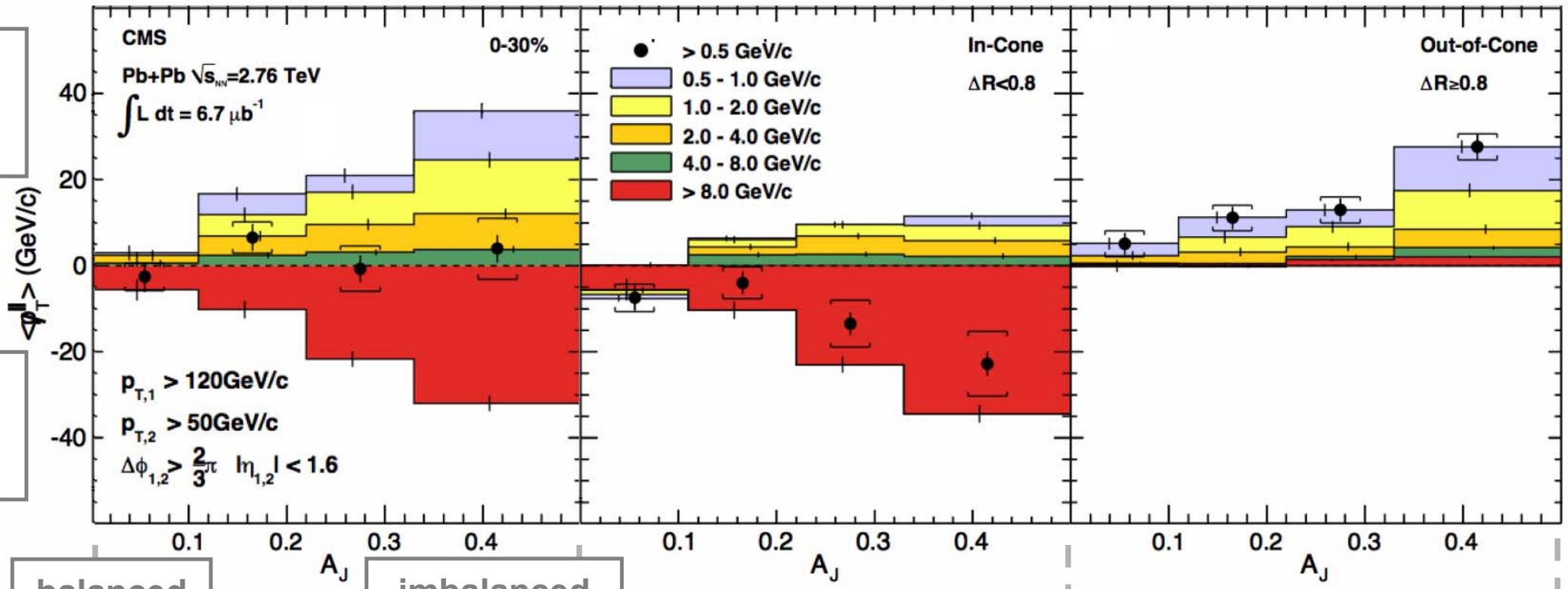
$$\not{p}_{\mathrm{T}}^{\parallel} = \sum_{\text{Tracks}} -p_{\mathrm{T}}^{\text{Track}} \cos\left(\phi_{\text{Track}} - \phi_{\text{Leading Jet}}\right)$$





excess away from leading jet

excess towards leading jet



balanced

imbalanced

When including low p_T particles momentum is balanced

Particles in-cone: large momentum imbalance as already seen

Particles out-of-cone: low p_T particles are balancing the event

Summary

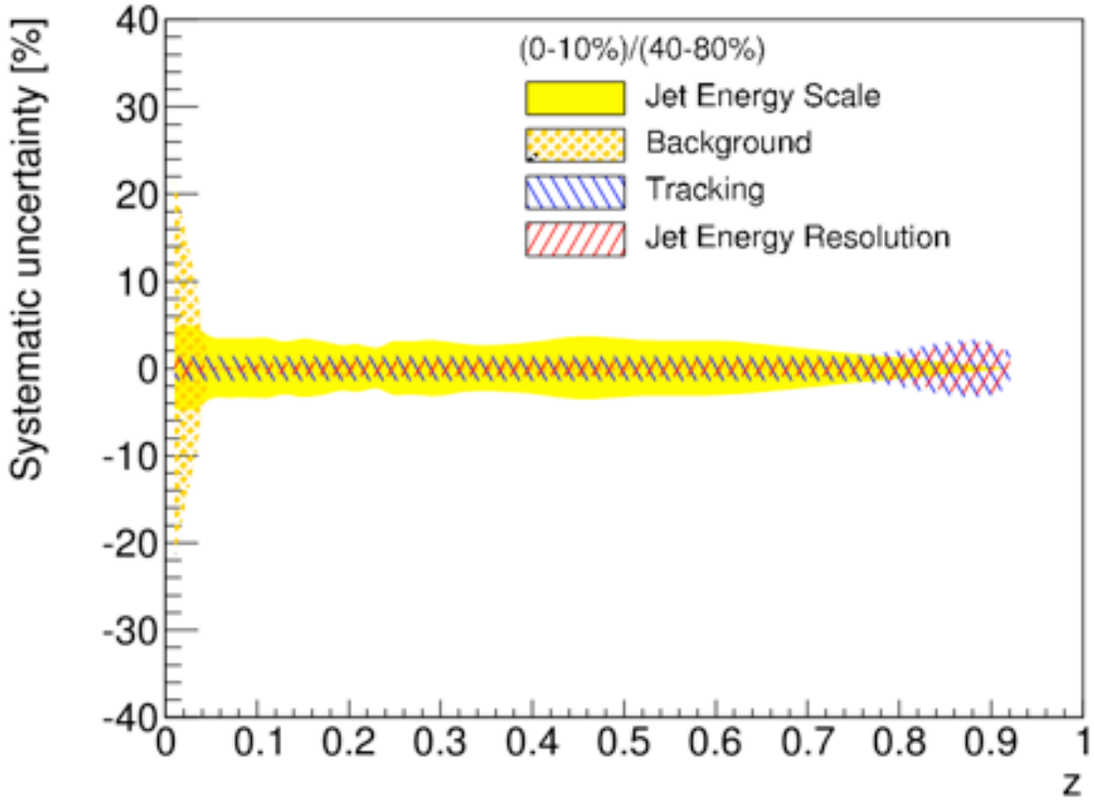
- Parton energy loss has been seen from the energy asymmetry in di-jet events and the inclusive jet suppression in central Pb+Pb collisions.

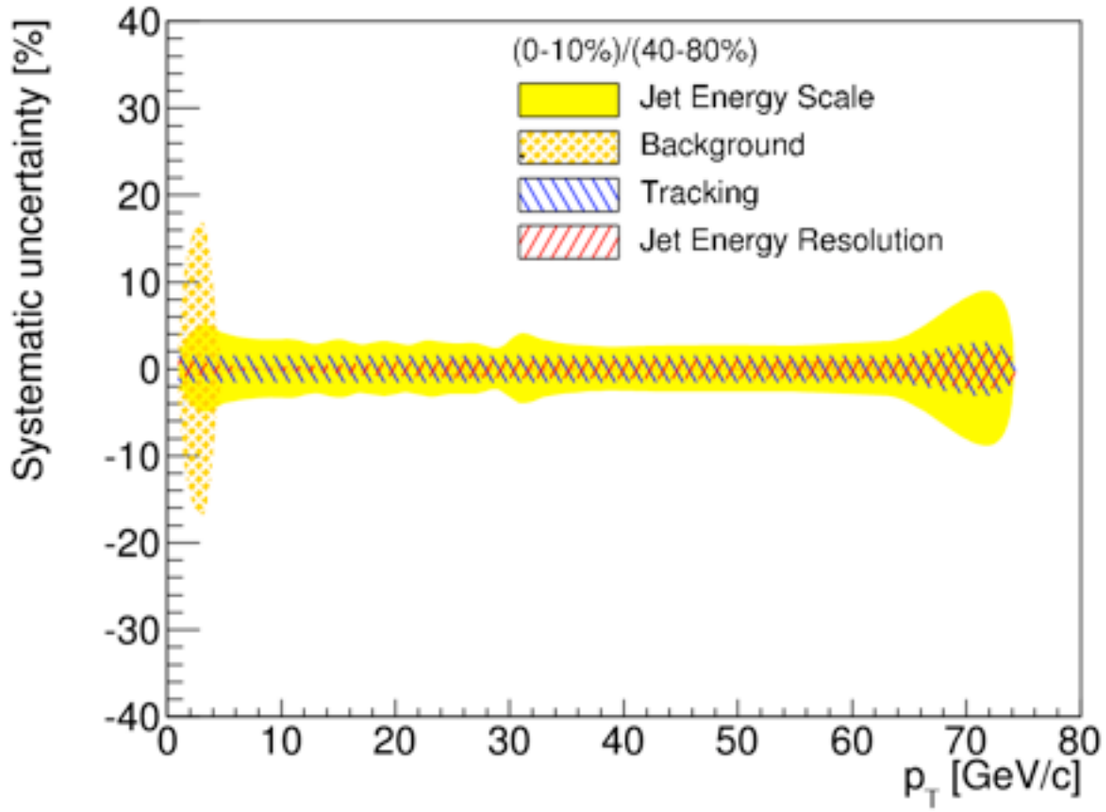
- Little or no dependence of suppression factor on jet energy at the 100 GeV scale. Same for R=0.4 and R=0.2.

- No change in di-jet azimuth correlations from pp to PbPb.

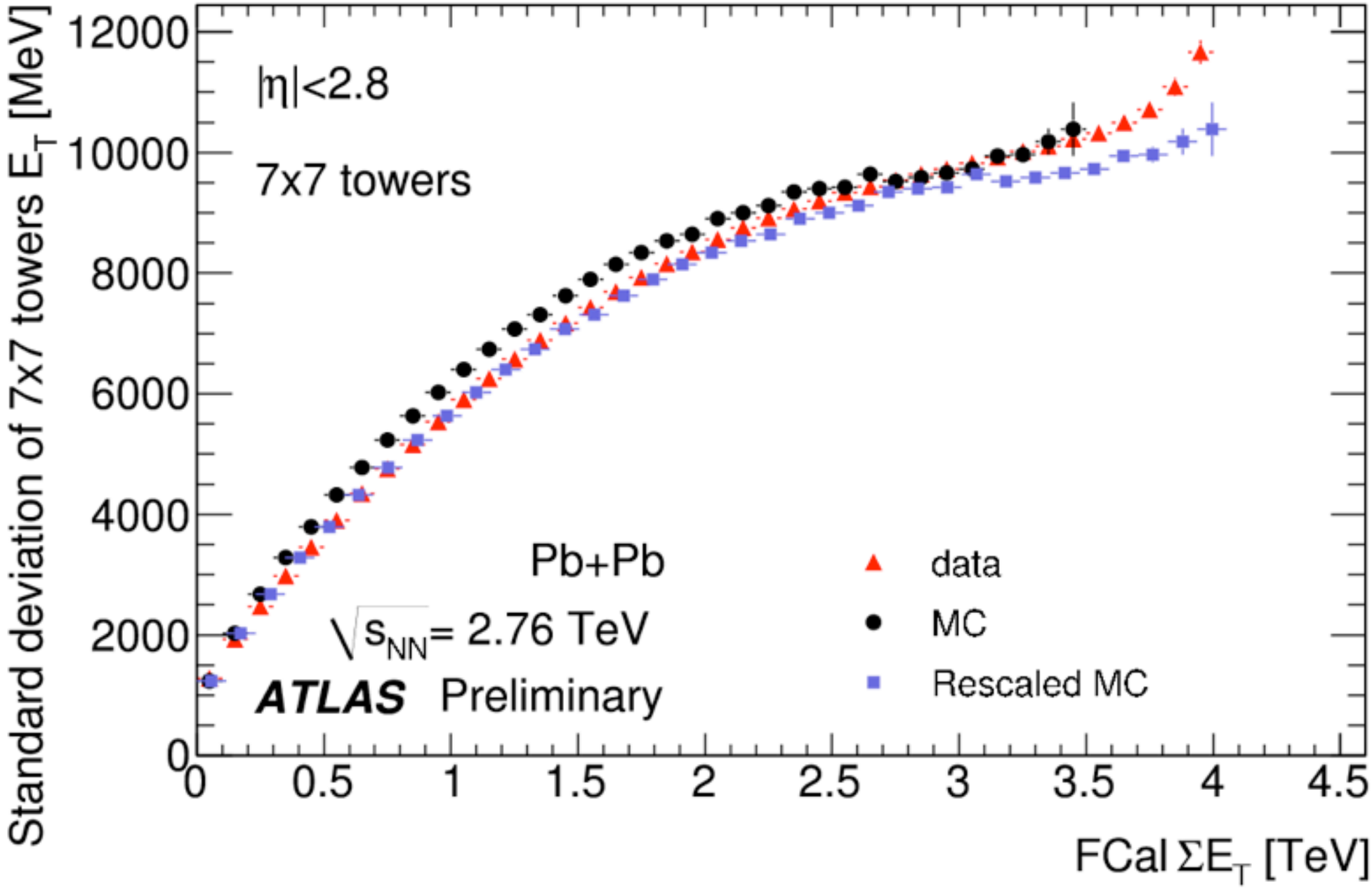
- Little - if any - modification of jet fragmentation, transversely or longitudinally. A jet is a jet!

Backup: Rcp systematics

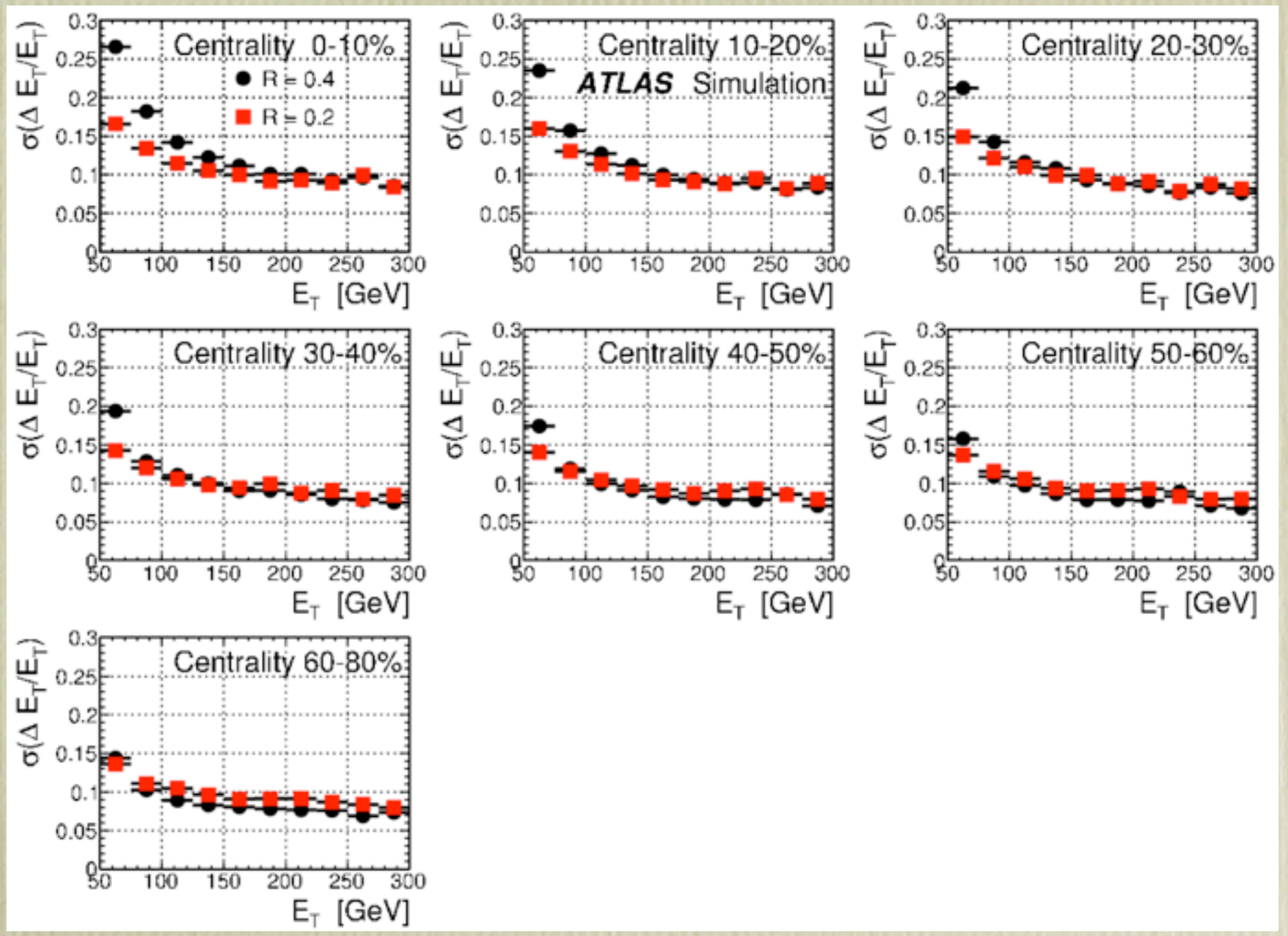




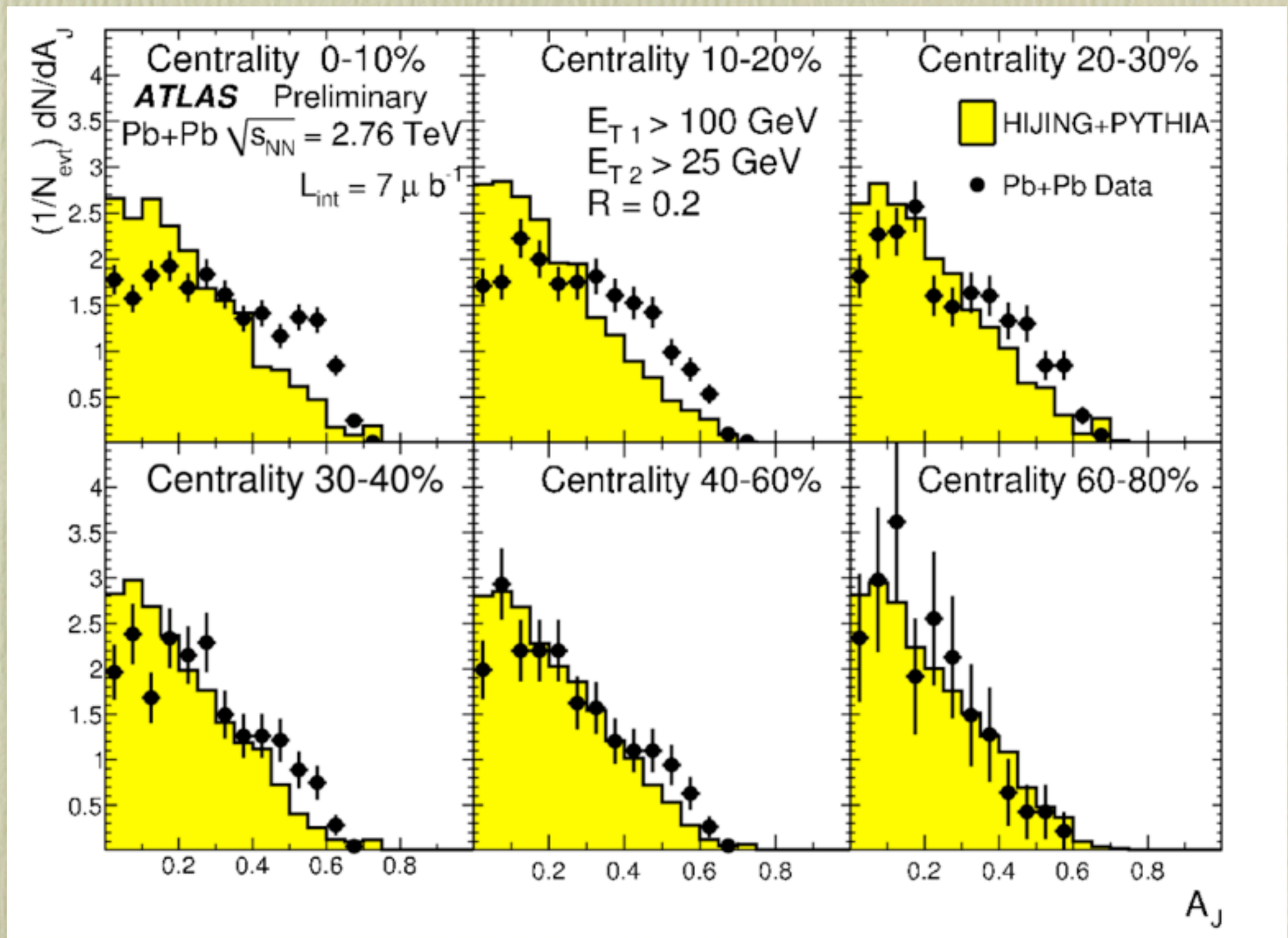
Backup: Corrections to MC



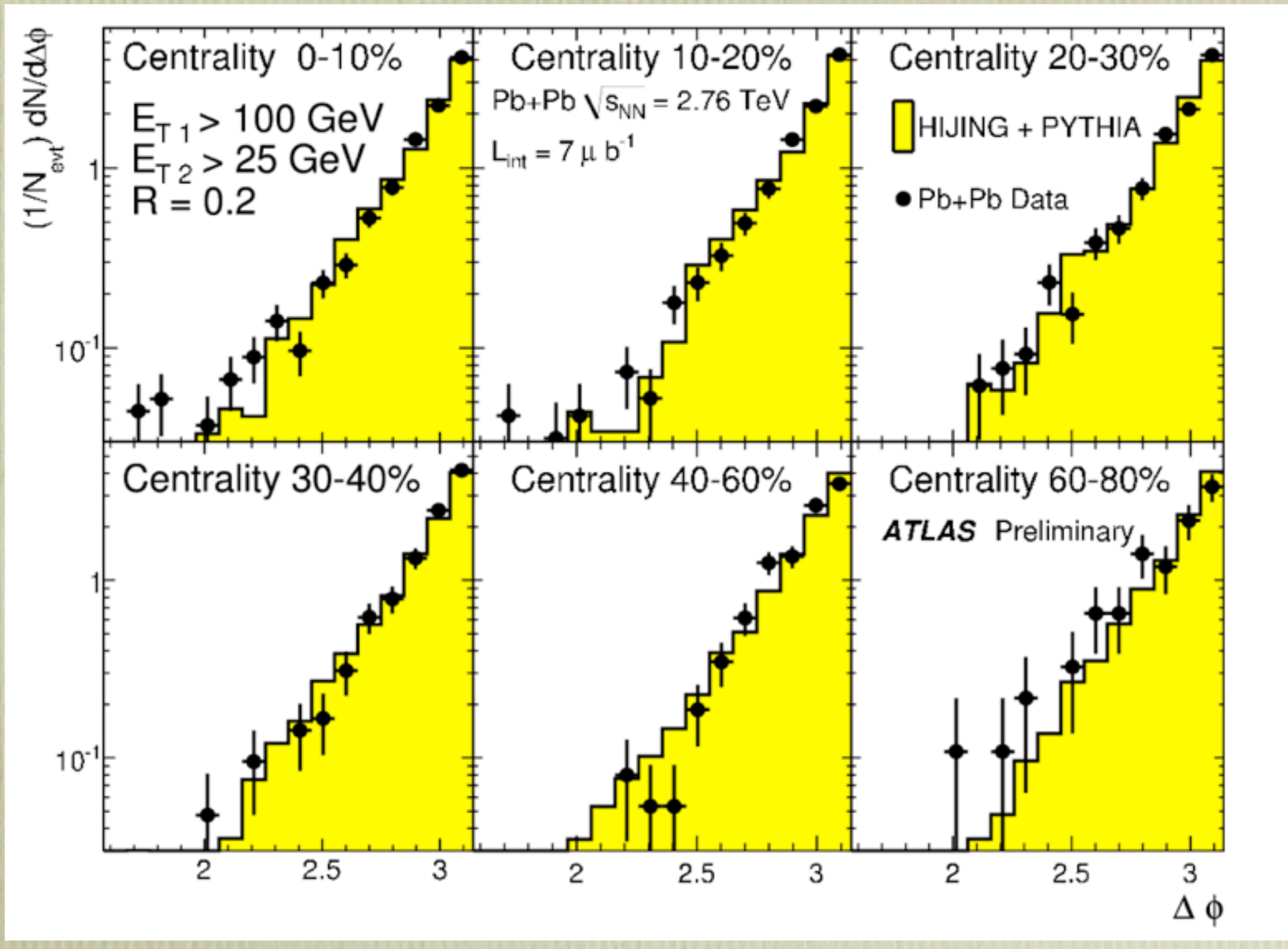
Backup: Jet energy resolution



Backup: Aj for R=0.2



Backup: Dphi for R=0.2



Backup: Aj(ET1) for R=0.2