Recent ATLAS Measurements of jets and electroweak bosons

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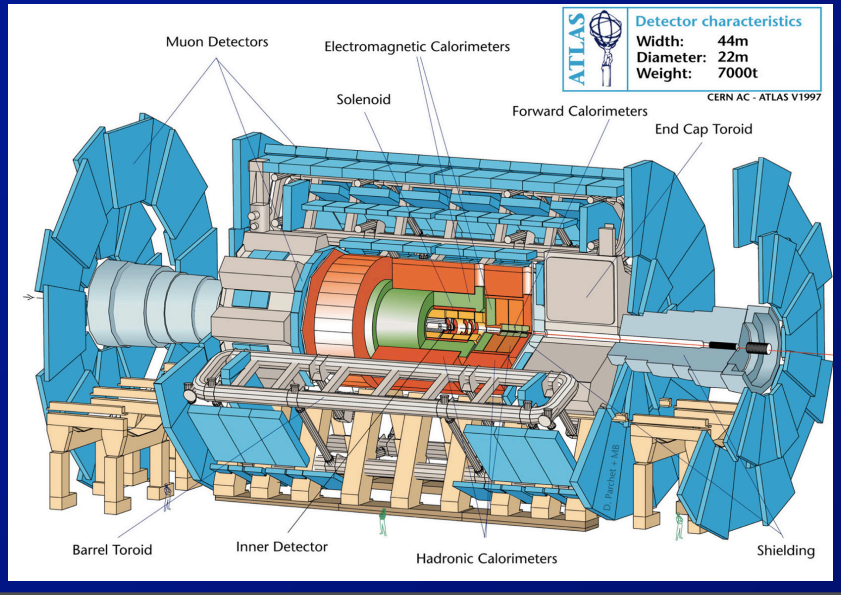
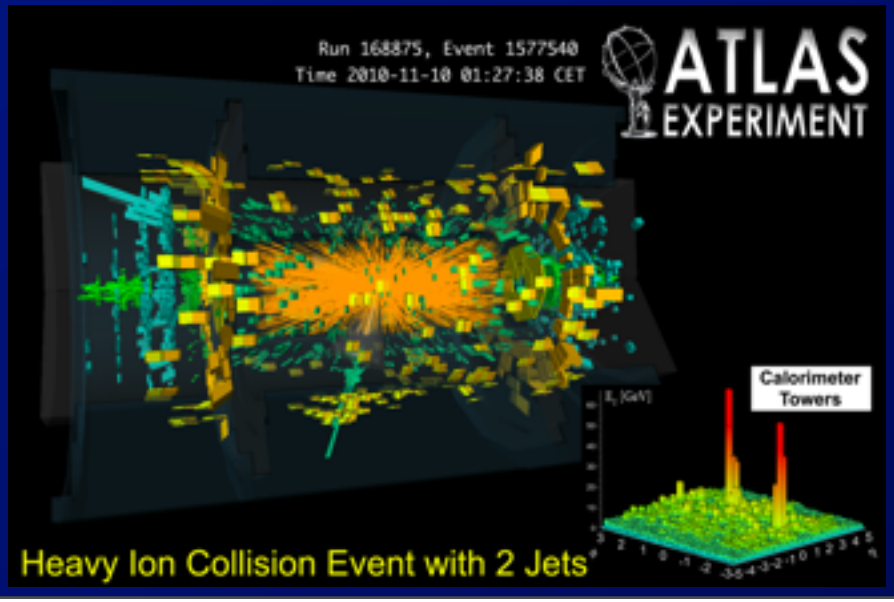
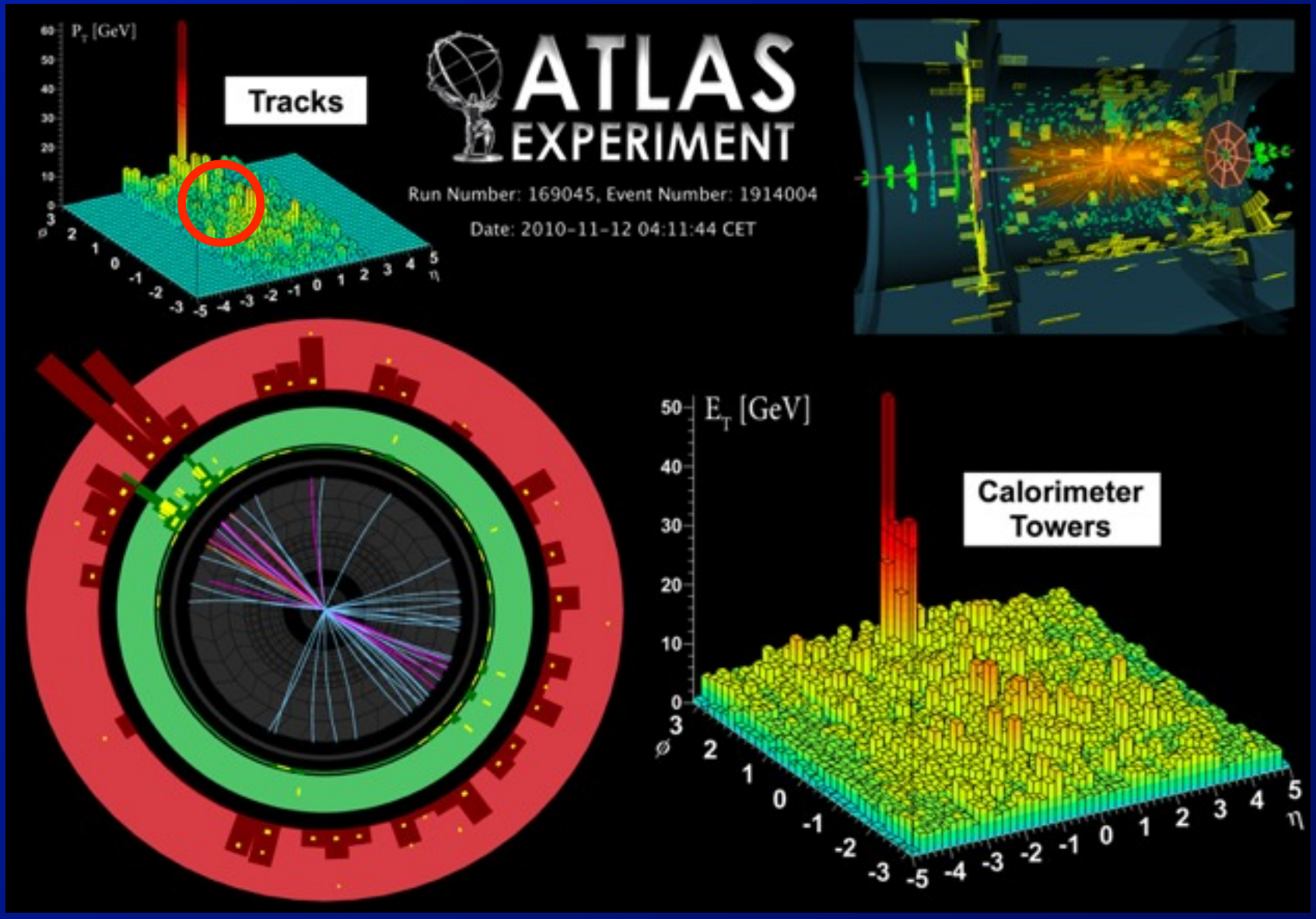




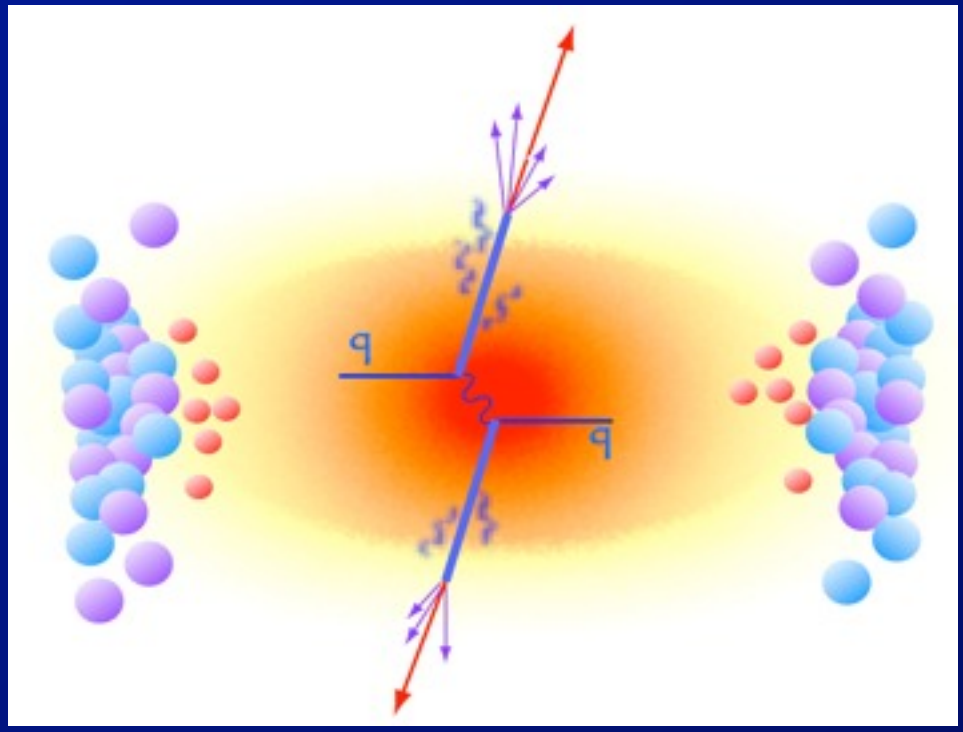
The beginning …



Probes differential quenching. Need other measurements to probe inclusive quenching.

Jet probes of the quark gluon plasma

- Use jets from hard scattering processes to directly probe the quark gluon plasma (QGP)

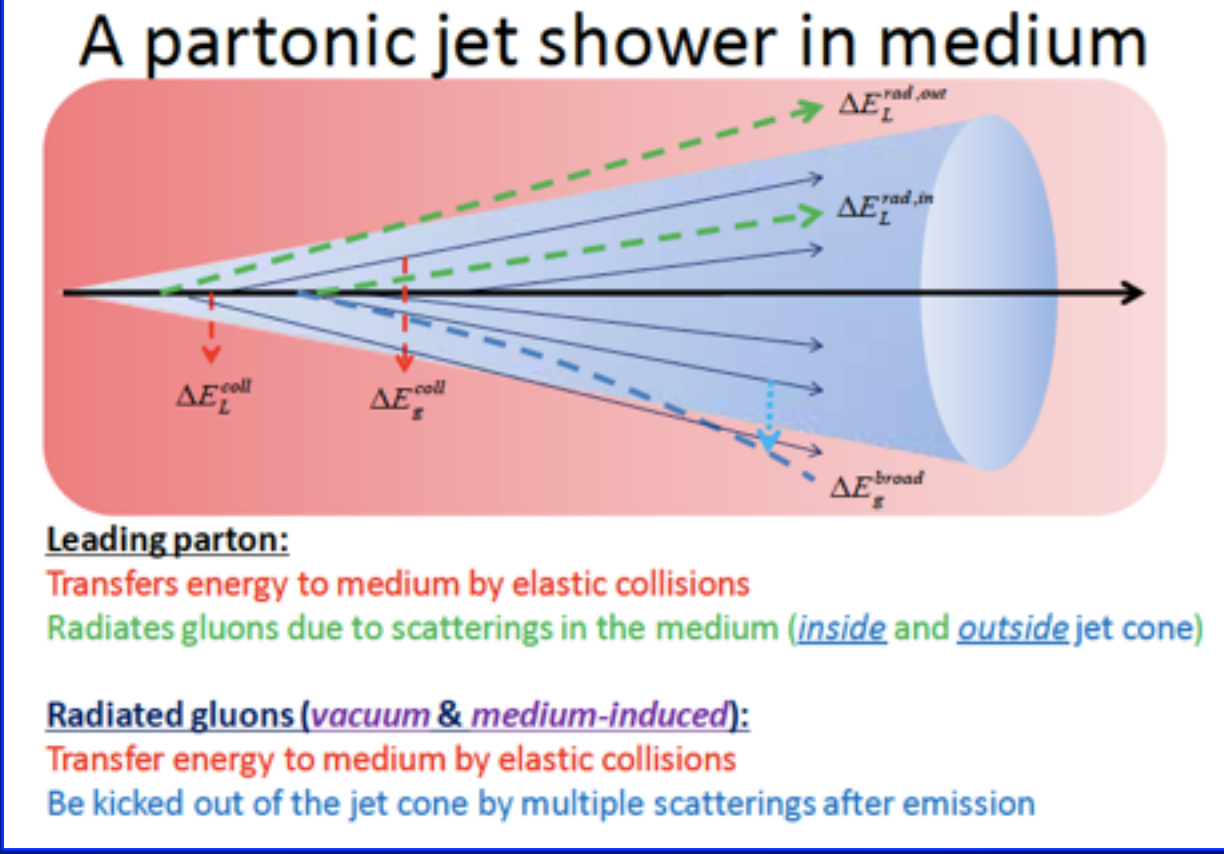


- Key experimental question:
  - How do parton showers in quark gluon plasma differ from those in vacuum?

    ⇒Remember: not all jets the same (q/g/c/b)
- Use vector bosons to calibrate rates

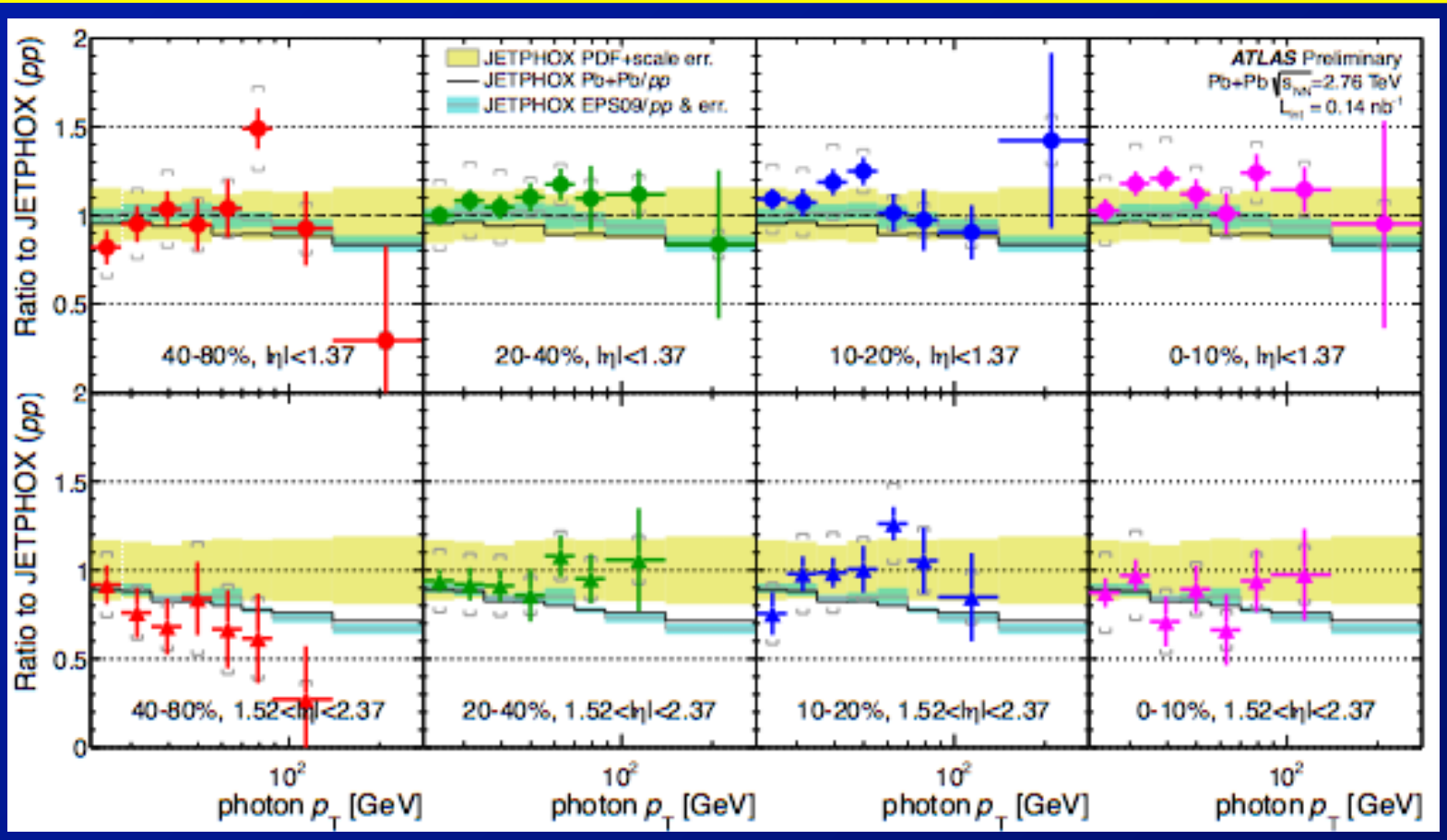
Jet probes of the quark gluon plasma (2)

Jet - QGP interactions schematically



- This is an intrinsically weakly coupled picture
- But flow measurements imply strong coupling at least for long (how long?) wavelengths
  - How confident are we that quenching is dominated by weakly coupled modes ("it works" is inadequate).

Pb+Pb photon yields



|η|<1.37

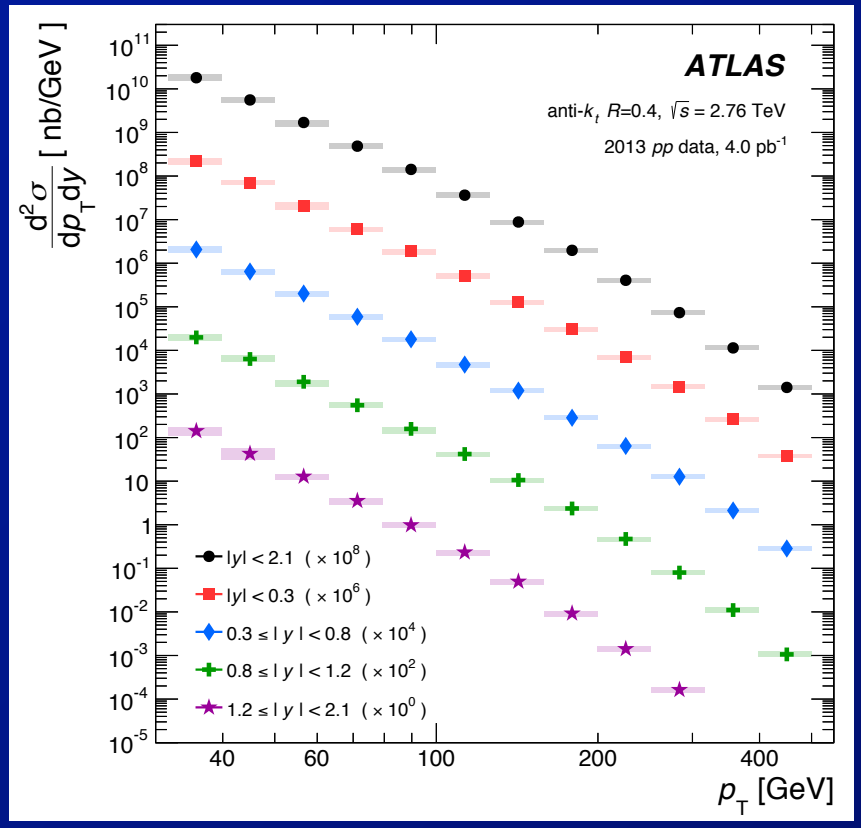
1.52<|η|<2.37

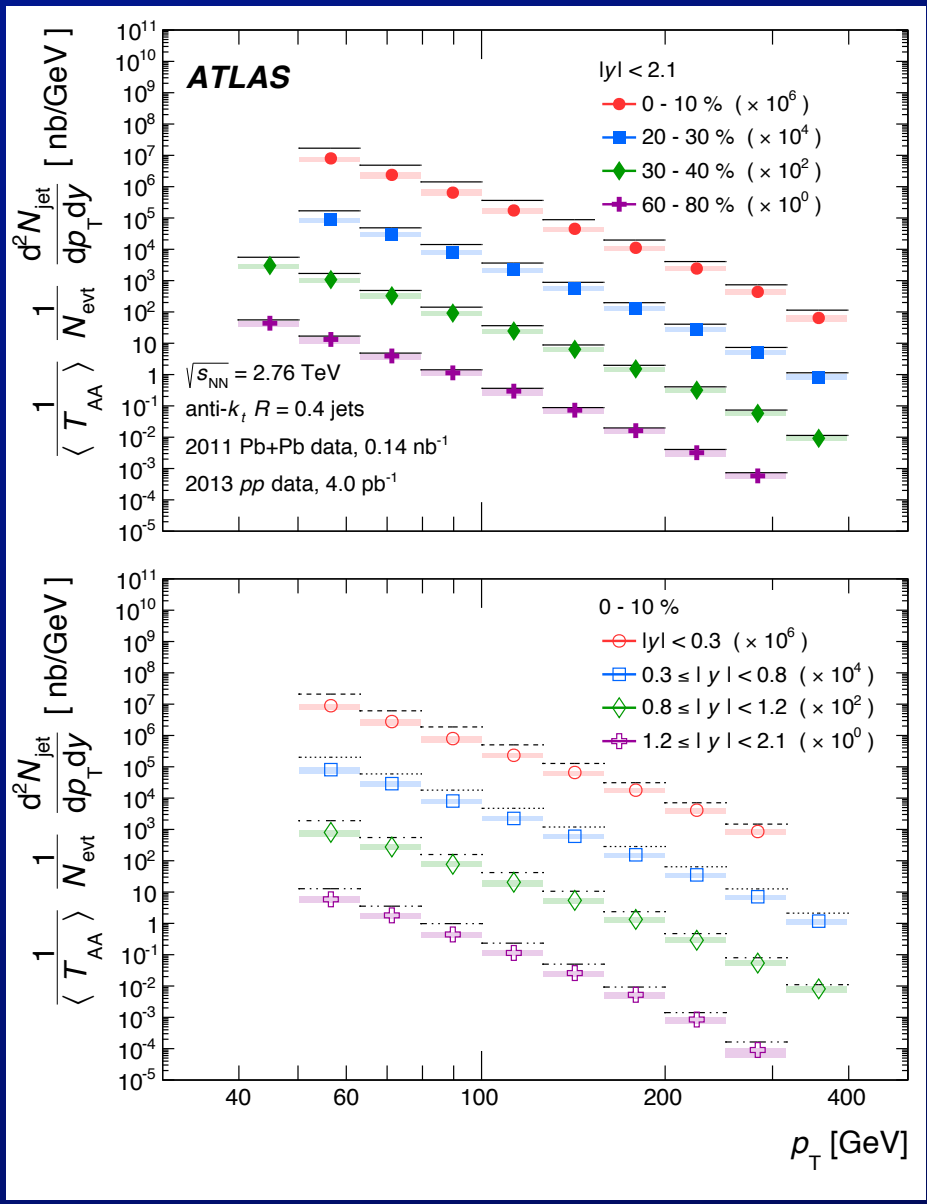
- Ratios of isolated, direct photon yields/T_{AA} to NLO pQCD calculation for p-p (JETPHOX1.3)
  - Also shown, JETPHOX for Pb+Pb: iso only, EPS09

⇒Hard scattering rates under control, but not yet sensitive to nuclear PDF effects in Pb+Pb

Jet spectra: p+p and Pb+Pb

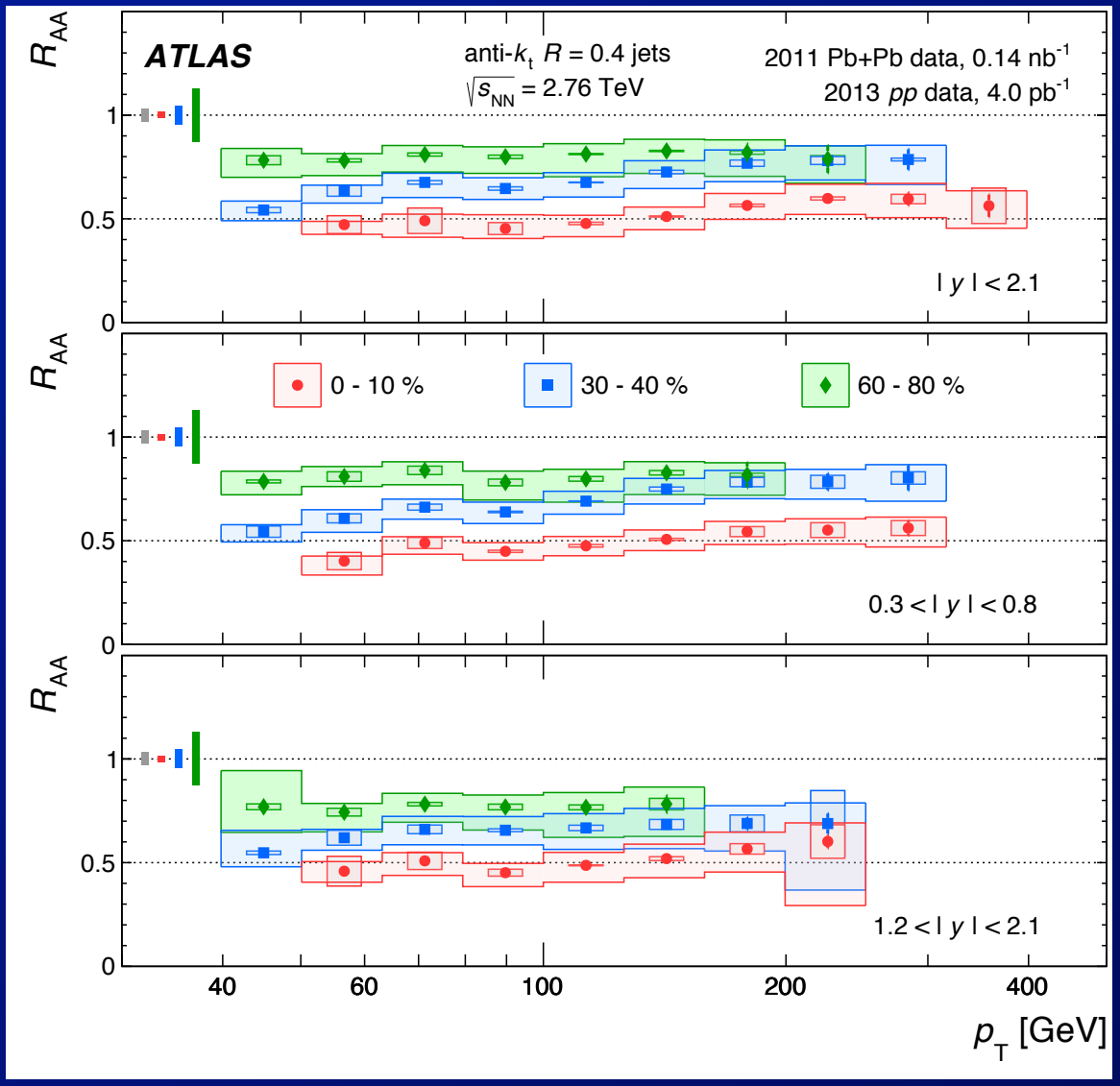
- **Absolutely normalized jet spectra:**
  - 2013 2.76 TeV p+p (left)
    - ⇒ cross-section
  - 2011 Pb+Pb (right)
    - ⇒per-event yields





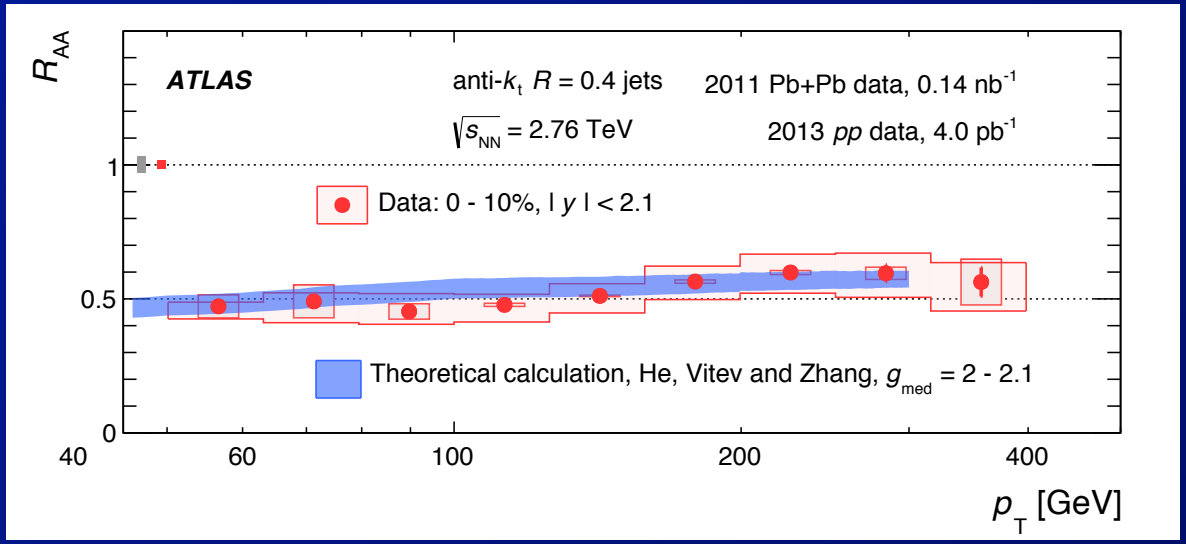
Jet R_{AA} : ATLAS preliminary for QM14

- R_{AA} vs p_T and y
  - in sub-set of measured centrality bins
    - ⇒Fully unfolded
- Observe
  - Factor of ~ 2 suppression up to jet p_T of 400 GeV
  - Slow increase with increasing jet p_T
    - ⇒May vary with centrality

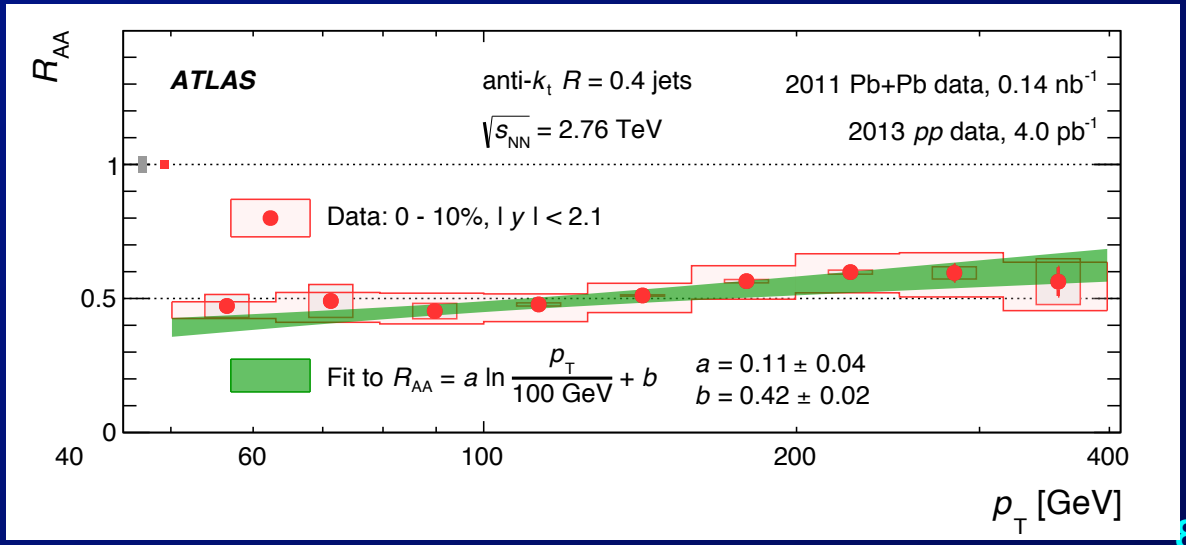


p_T dependence of R_{AA}

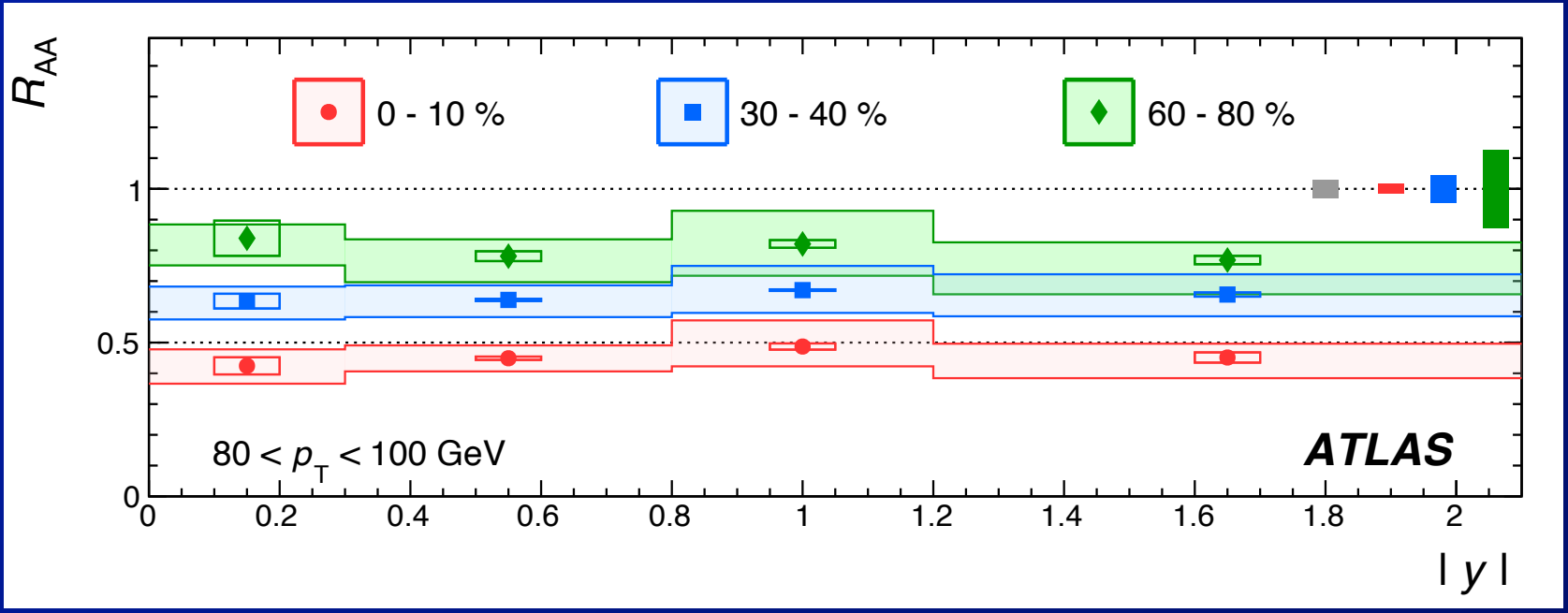
- Calculation by He et al gets correct slope for right amount of quenching



- Attempt to extract slope from data accounting for systematic uncertainties yields non-zero slope at 3σ significance

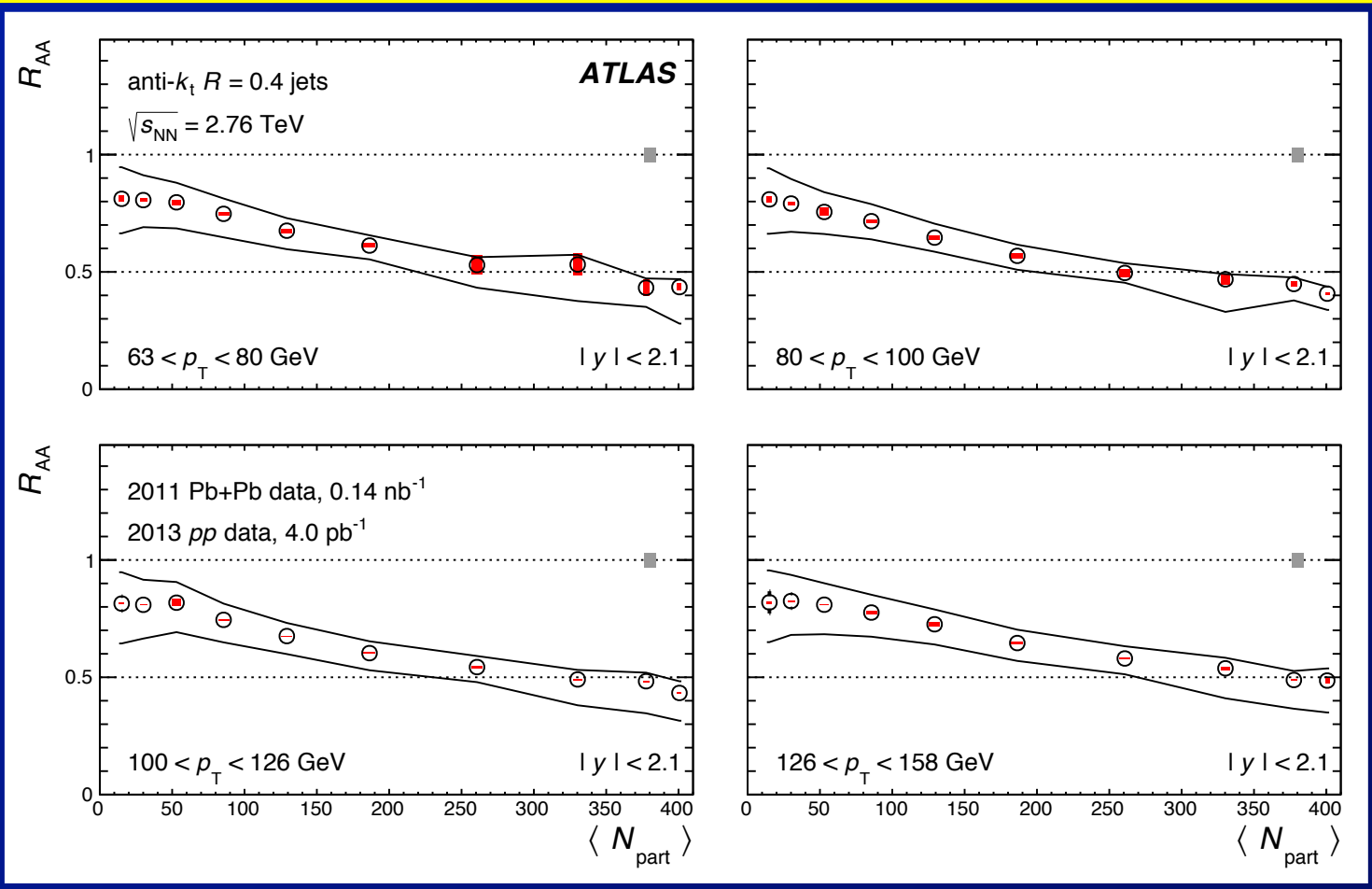


Jet R_{AA} vs centrality and y: ATLAS



- **No significant dependence on rapidity observed**
  - Even though both spectrum shape and quark/gluon fractions vary with y
    - ⇒Especially important to test expectations that gluon dE/dx ~ twice that of quarks
    - ⇒Need differential, more precise measurements of even single jet suppression to make progress

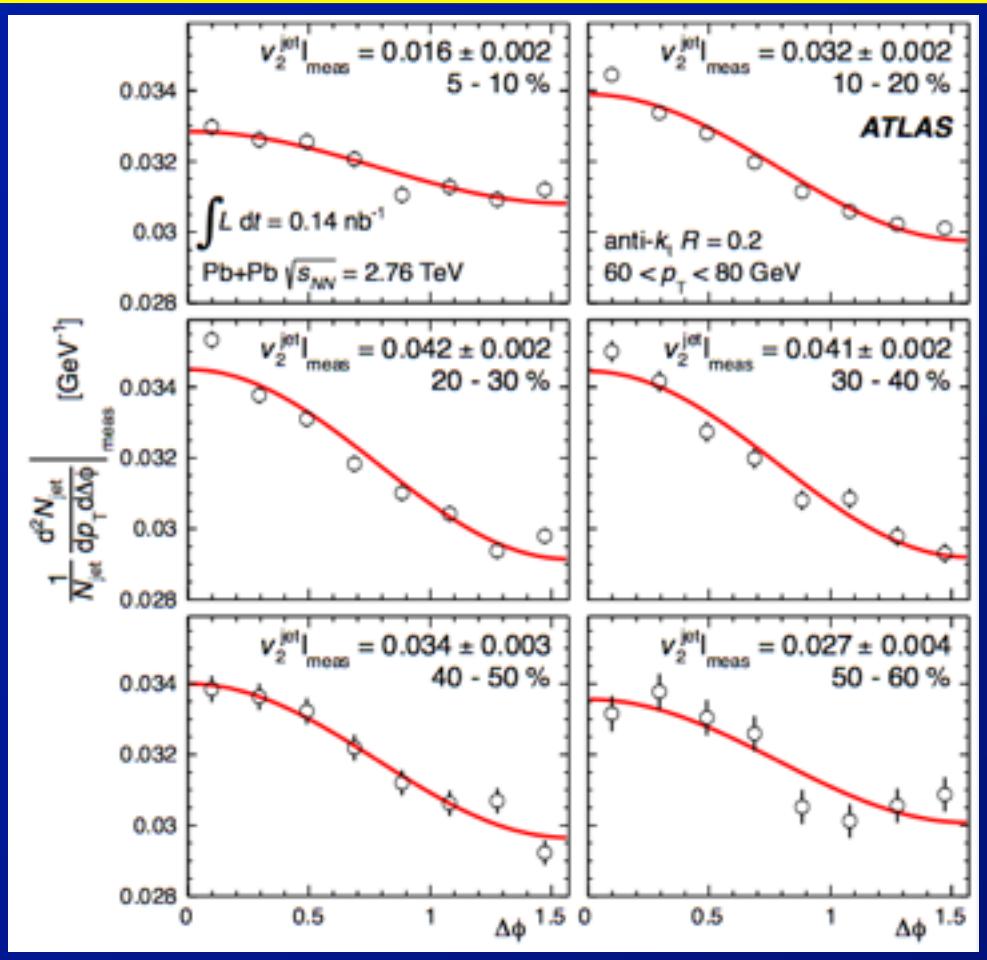
Centrality dependence

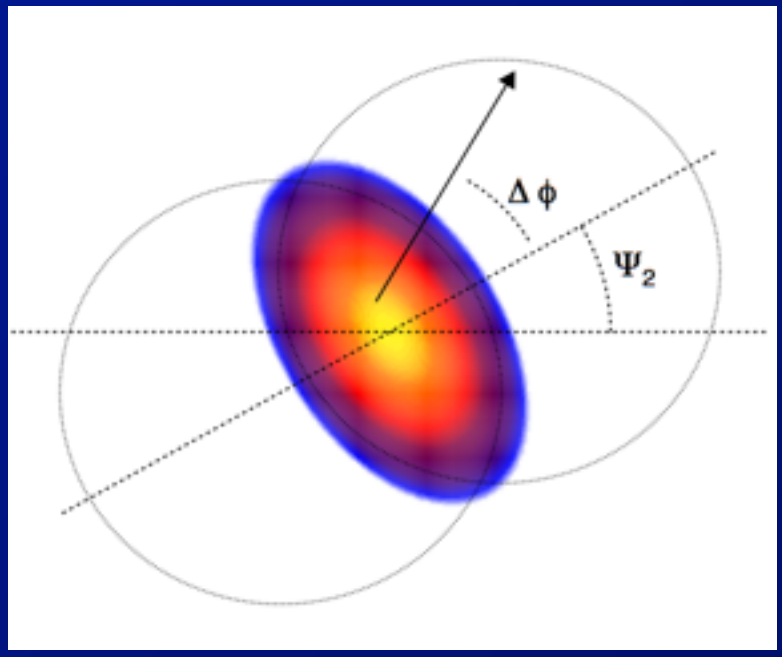


- **Variation of jet R_{AA} with centrality continues down to the most central 1% bin**
  - **Geometry? energy density/T?**

    ⇒ Need detailed quenching calculations.

Differential jet suppression



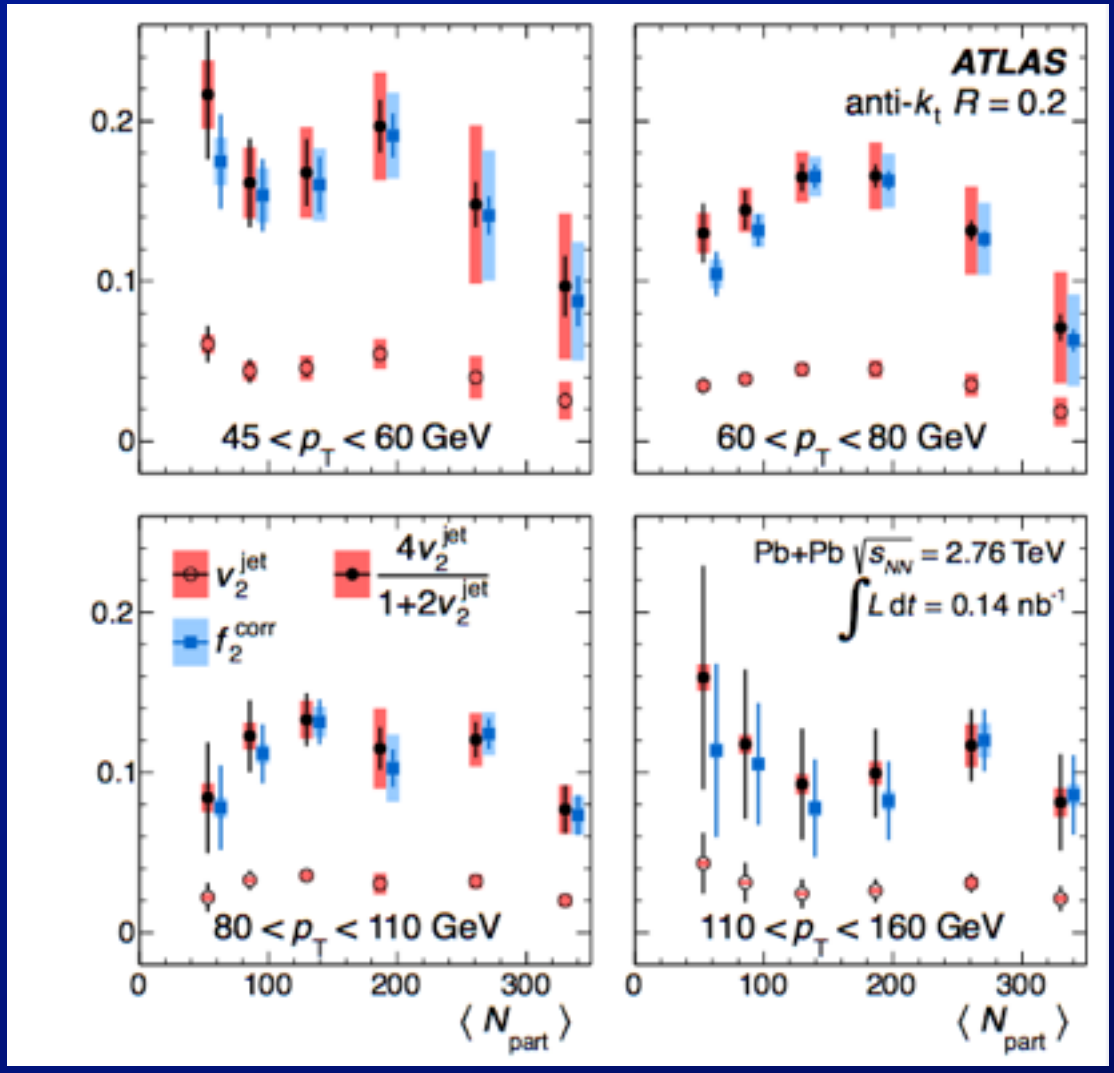


$$\frac{dN}{d\Delta\phi} \approx \left\langle \frac{dN}{d\Delta\phi} \right\rangle [1 + 2v_2 \cos(2\Delta\phi)]$$

- Use elliptic flow in underlying event to determine orientation of event plane for each event.
- Measure variation in jet yield as a function of relative angle, $\Delta\varphi = \varphi - \Psi_2$.

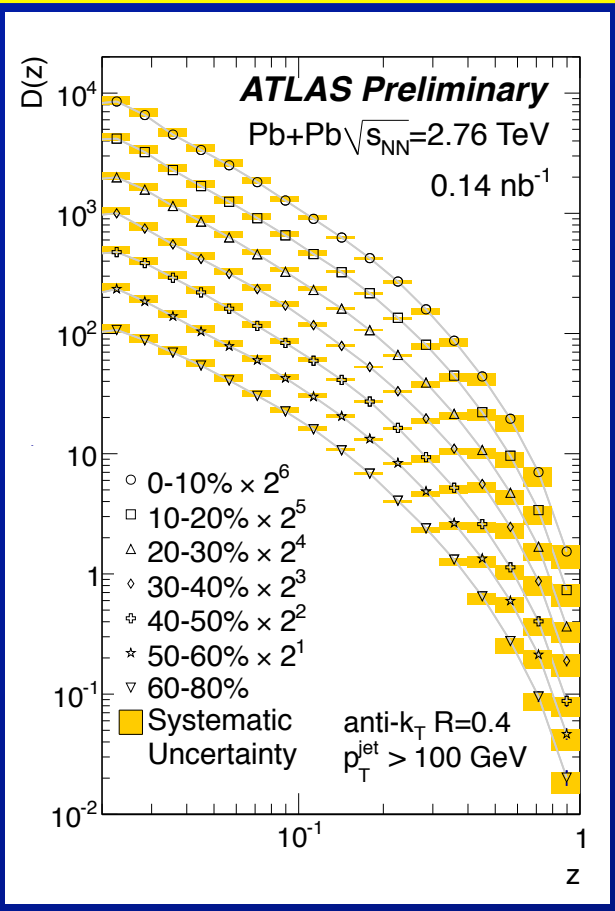
Differential jet suppression (2)

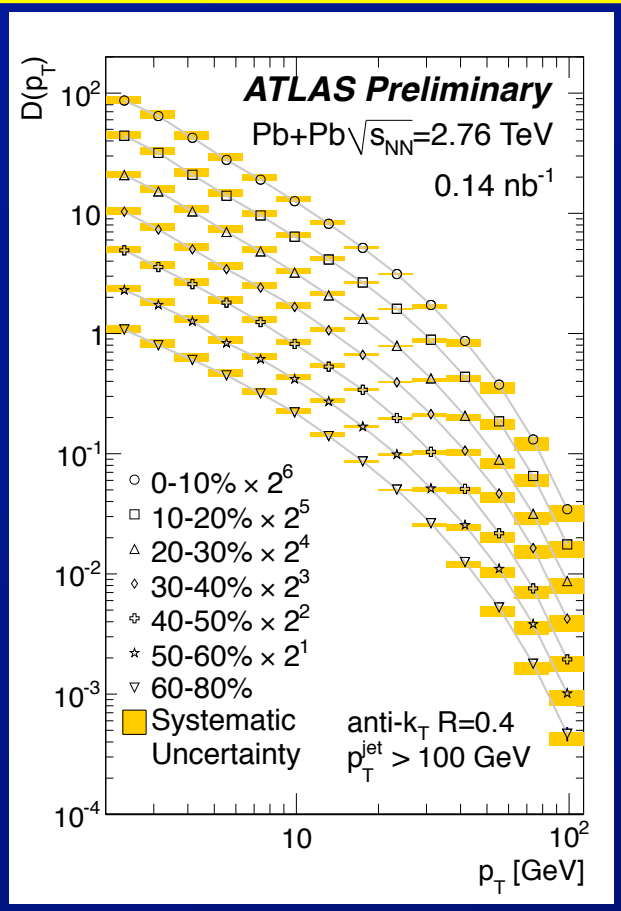
- Centrality dependence of
  - Jet v_2
  - Ratio of in-plane to out-of-plane jet yields
- Observe up to 20% change in jet yield with $\Delta\varphi$
  - ⇒Critical test of path length dependence of energy loss



- Next step: test for sensitivity of jet quenching to energy density fluctuations seen in v_n

Pb+Pb fragmentation functions: ATLAS





$$D(p_T) = \frac{1}{N_{jet}} \frac{dN_{chg}}{dp_T}$$

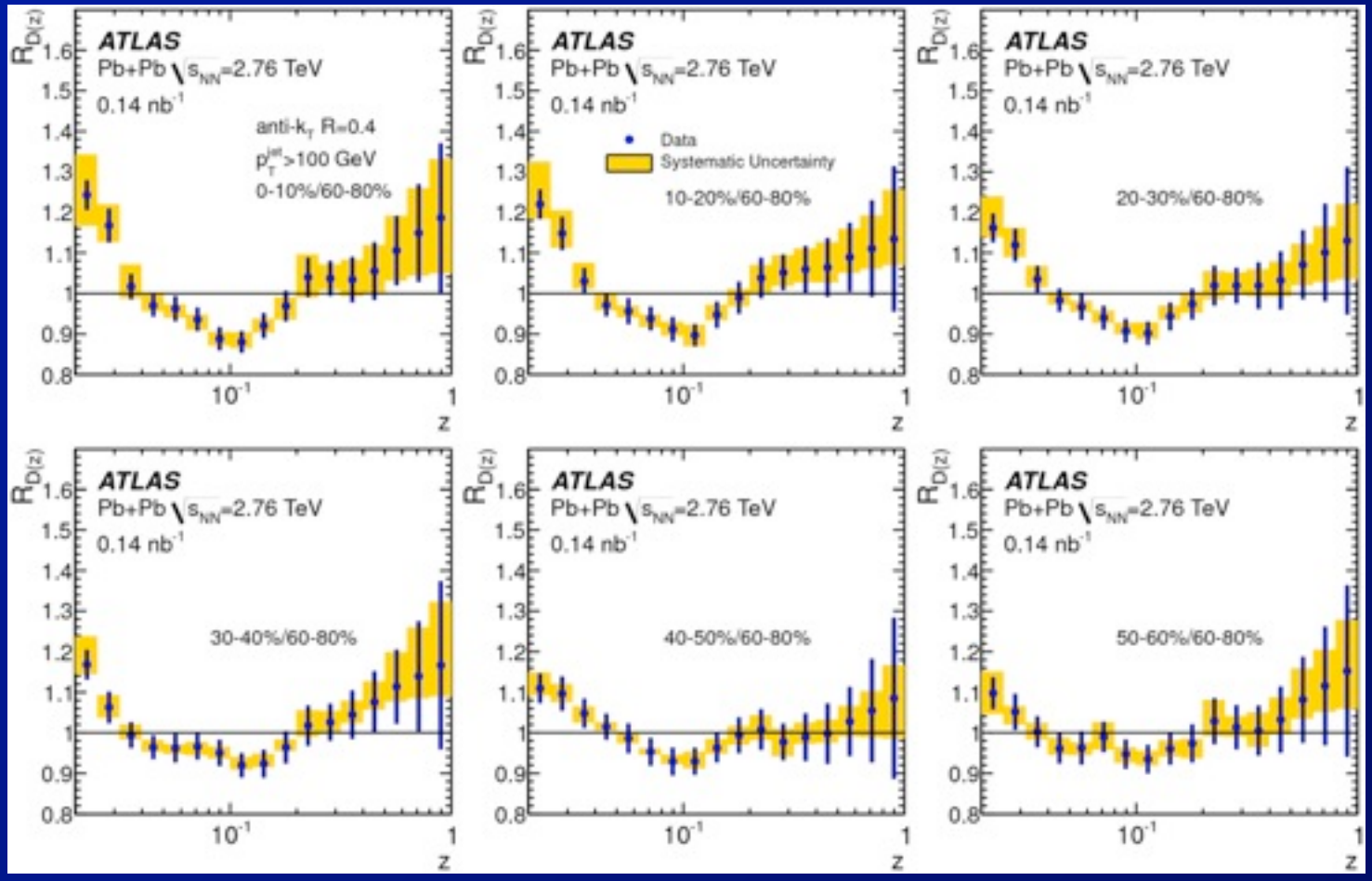
$$D(z) = \frac{1}{N_{jet}} \frac{dN_{chg}}{dz}$$

$$z = \vec{p}_{chg} \cdot \vec{p}_{jet} / |\vec{p}_{jet}|^2$$

- Distributions of charged-particle fragments in isolated R = 0.4, 0.3, 0.2 jets
  - Isolation avoids complications from nearby jets

⇒Evaluate ratios to observe quenching effects

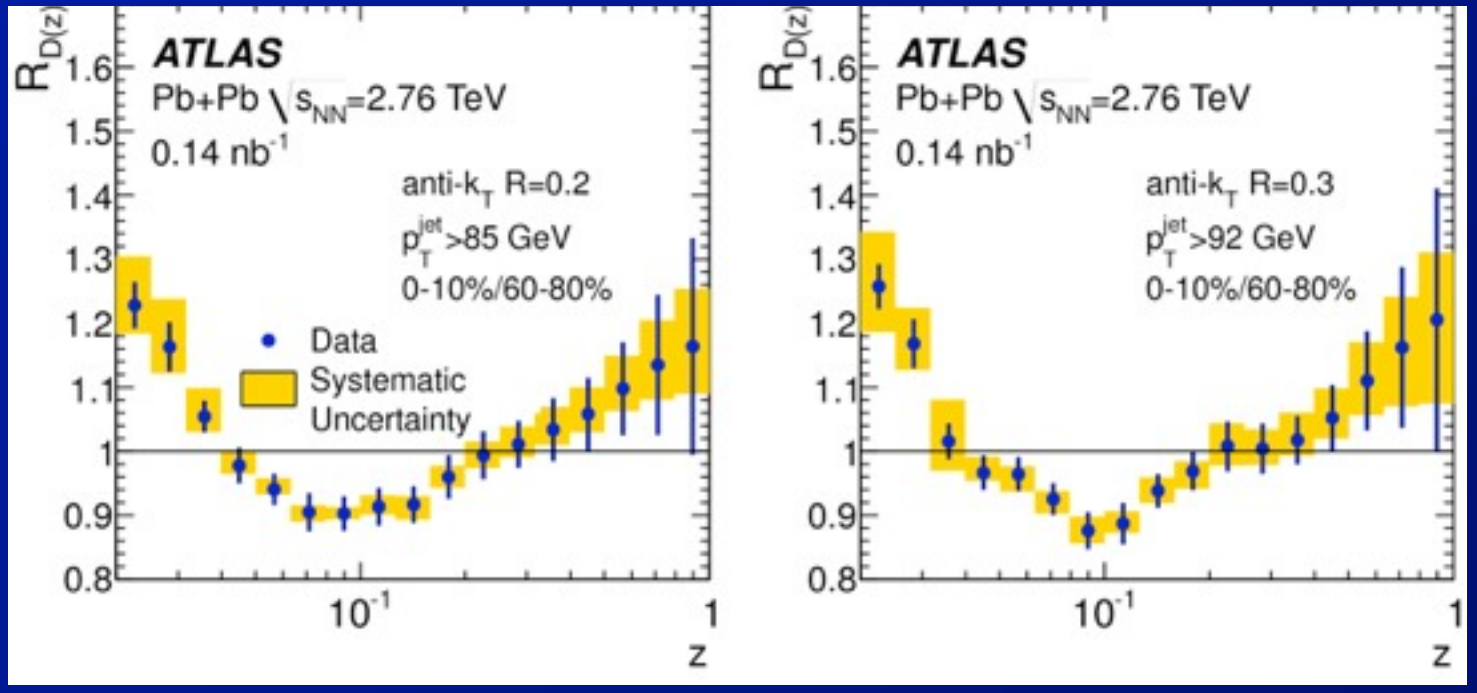
Pb+Pb modified jet fragmentation



- Observe modifications of parton showers / fragmentation functions

  ⇒Loss of fragments at intermediate z, excess at low z/p_T, possibly at high z as well.

Frag functions: interpretation?

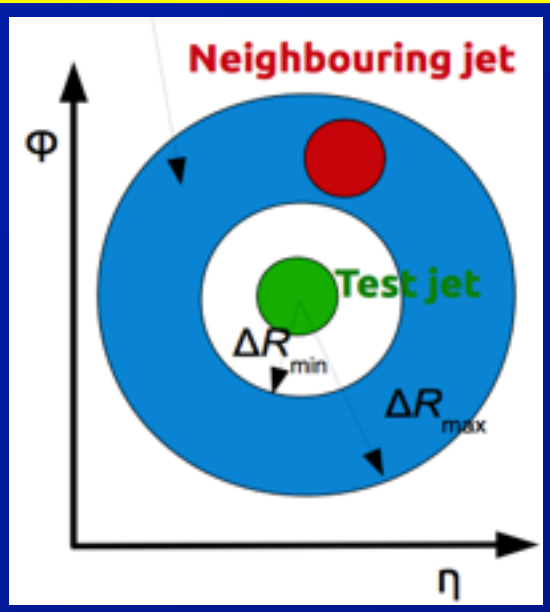


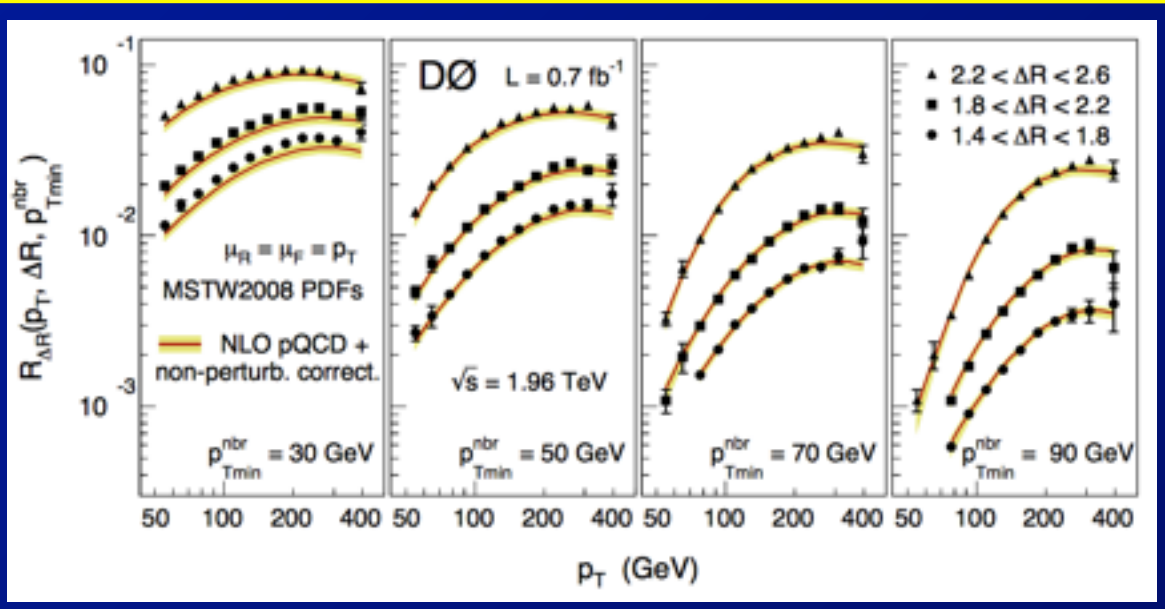
- How much if this is really medium modification of parton showers?
  - Versus (e.g.) different quark/gluon dE/dx?

    ⇒Hints that q/g is ~ enough.
- What is responsible for low-z excess?

  ⇒Hints from JEWEL that it's medium recoils.

Pb+Pb nearby jets, $R_{\Delta R}$

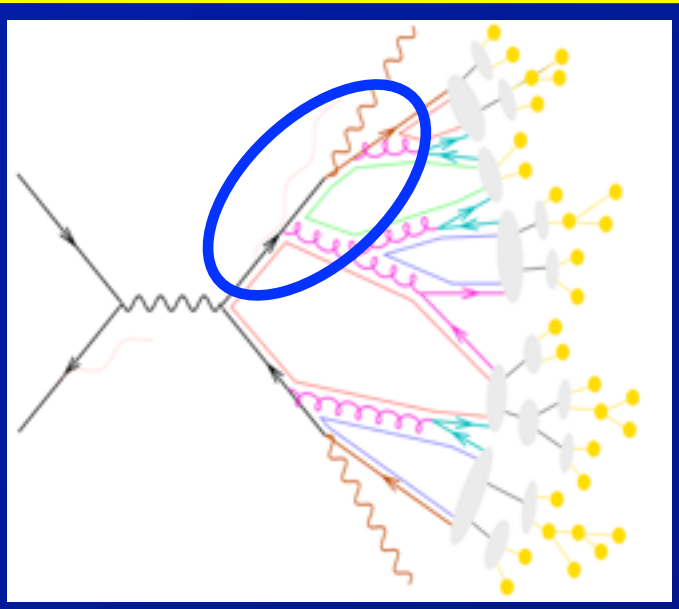


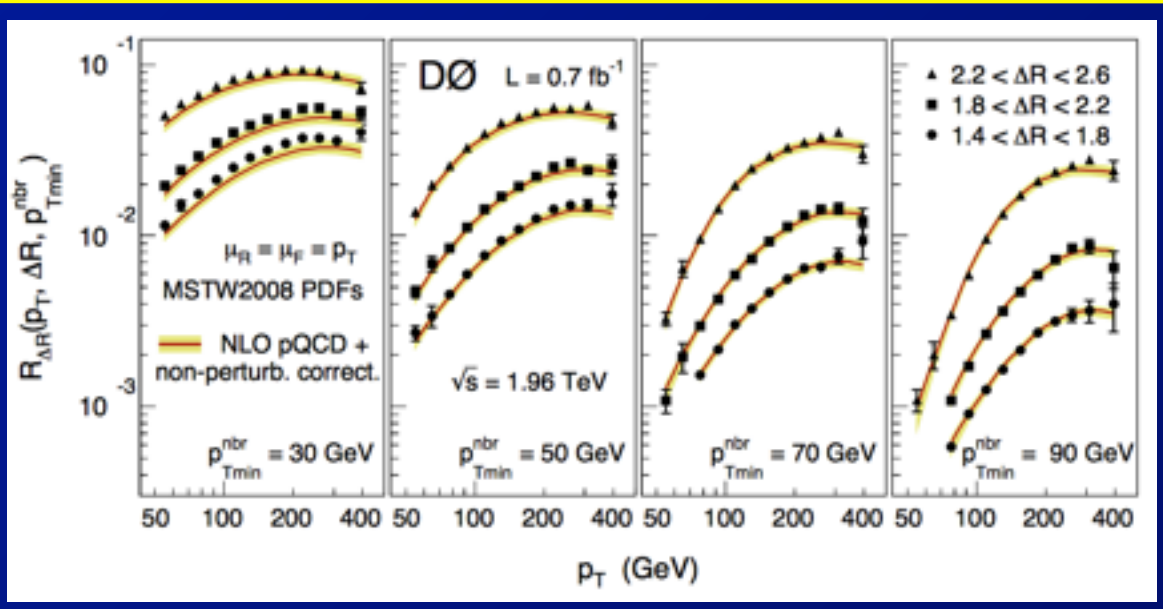


- 1st step in studying internal structure of parton showers
  - Measure conditional yield of "neighboring" (lower p_T) jets associated with "test" jet

    ⇒ In this analysis, over $0.8 < \Delta R < 1.6$ for $R = 0.4$

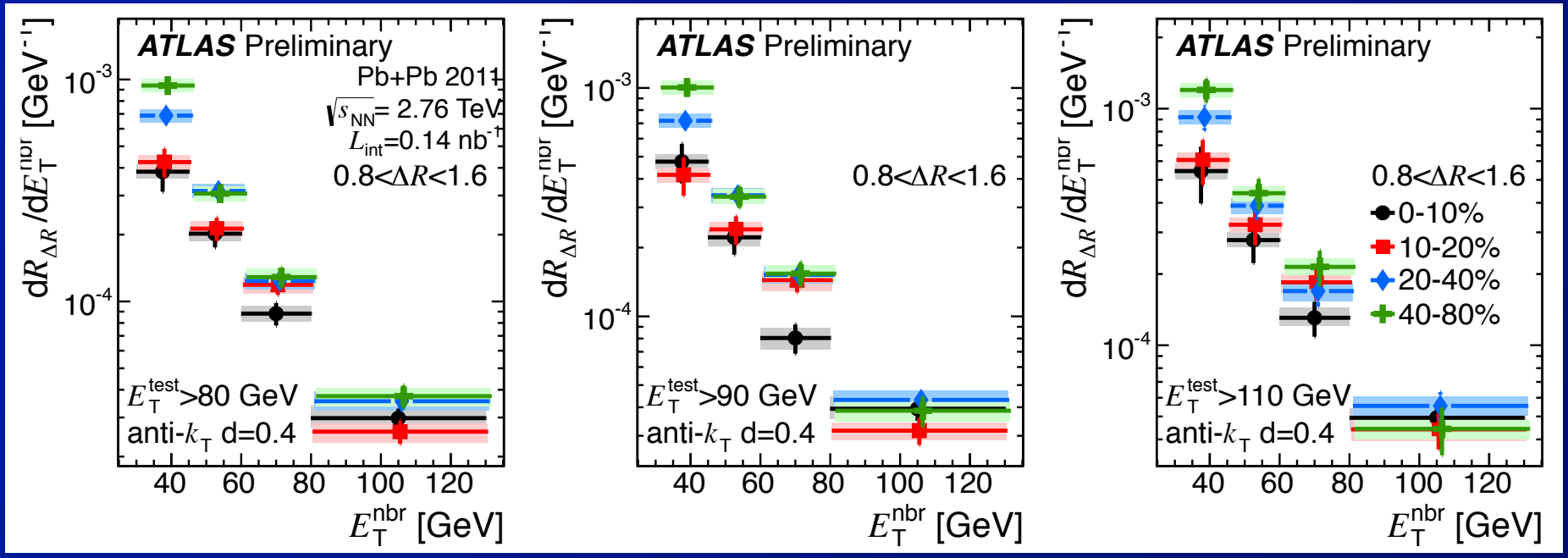
Pb+Pb nearby jets, $R_{\Delta R}$





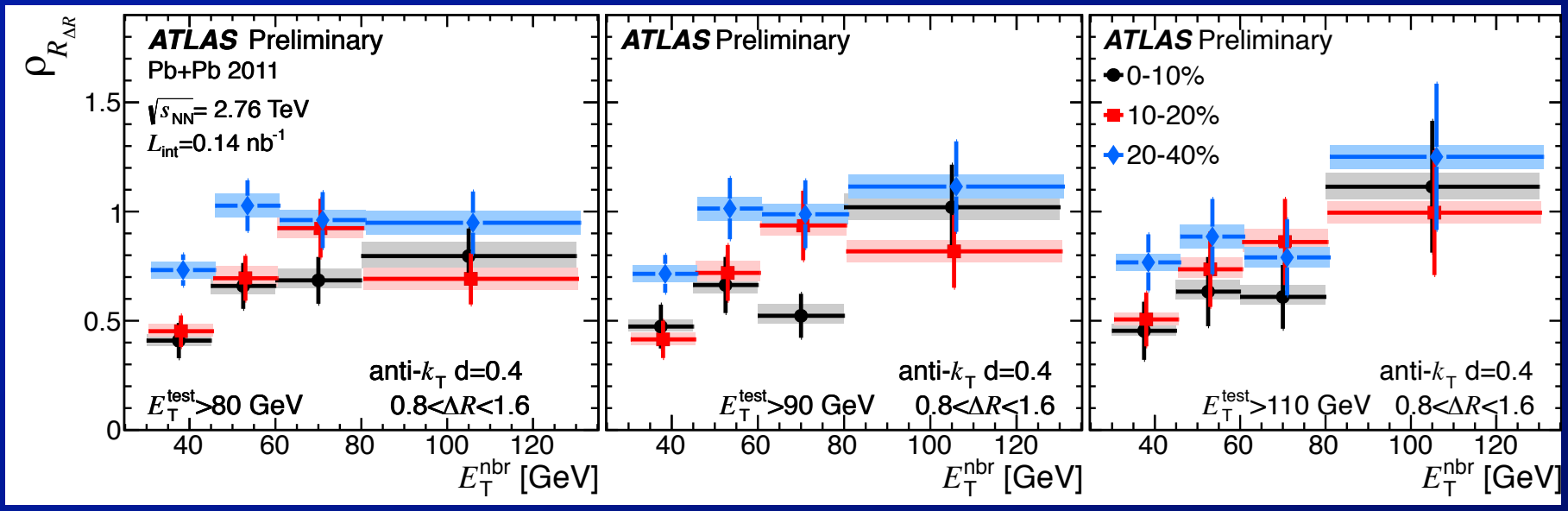
- 1st step in studying internal structure of parton showers
  - Measure conditional yield of "neighboring" (lower p_T) jets associated with "test" jet
    - ⇒ In this analysis, over $0.8 < \Delta R < 1.6$ for $R = 0.4$
  - Predominantly from parton shower (vs NLO)
    - ⇒ Mostly gluon jets but generator dependence …
    - ⇒ In p-p $R_{\Delta R}$ used for α_s measurement

$R_{\Delta R}$ vs neighboring jet p_T



- **Large reduction in $R_{\Delta R}$ between peripheral and central collisions**
  - Though spectrum of nearby jets is less steep than the inclusive jet spectrum
  - And the quenching of test jet should partially compensate the quenching of nearby jet.

$R_{\Delta R}$ central/peripheral ratios



- Take central / peripheral ratio of the $R_{\Delta R}$ values, plot vs neighboring jet p_T
  - surprising centrality dependence?
    - ⇒ little difference between 20-40% and 40-80%
  - Most of the "suppression" disappears for comparable test and neighboring jet p_T values
  - Need real calculation to interpret
- Influence of pre-equilibrium physics? too high k_T?

Summary / comments

- Jet suppression and fragmentation functions probe average quenching effects
  - quark/gluon differences/contributions?
  - when will be ready to start applying serious calculations to the data

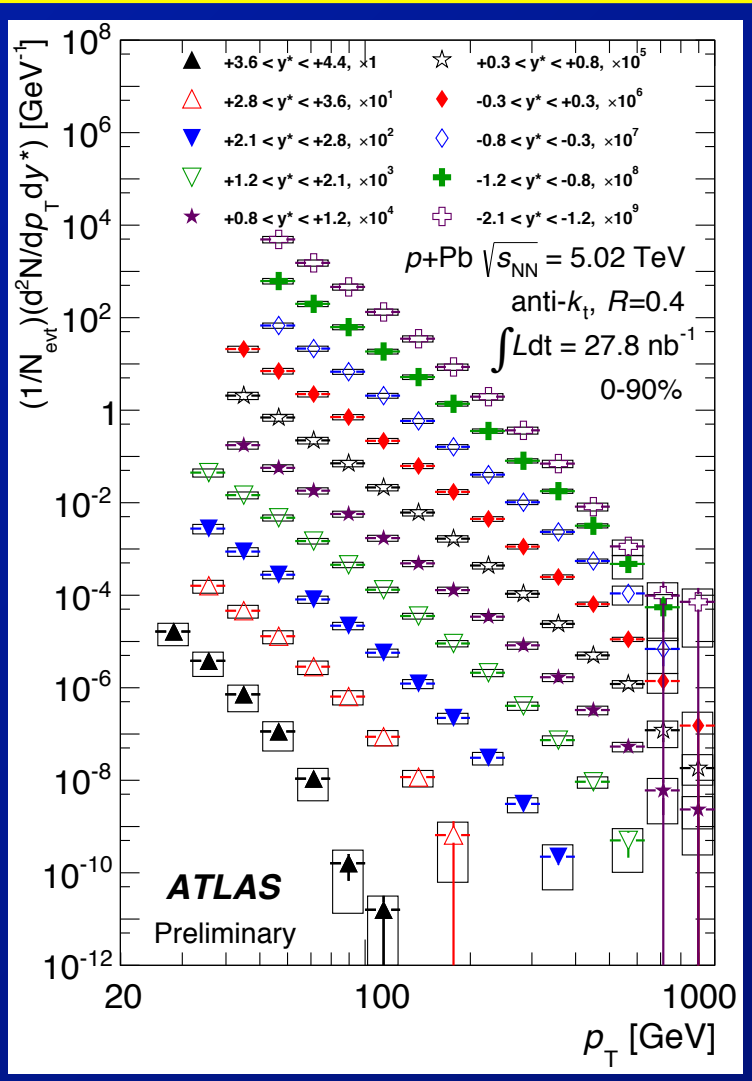
    ⇒with intent to test theory (first) and evaluate medium properties (second)
- Modulation of jet yield wrt elliptic plane
  - Important step in using jets to probe geometry

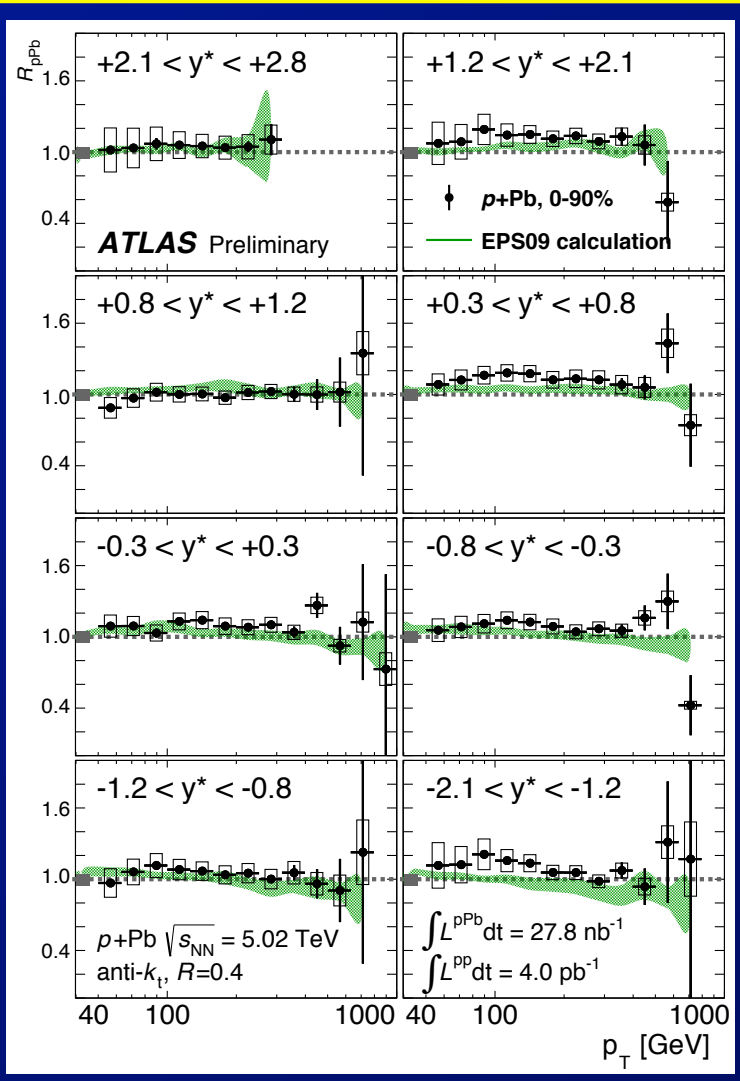
    ⇒ important to extend to higher v_n (Run 2)
- New results on multiple jets in parton showers
  - Another kind of multiple-parton correlation

    ⇒Test understanding of in-medium PS
- (where) Is there sensitivity to pre-equilibrium?

Backup

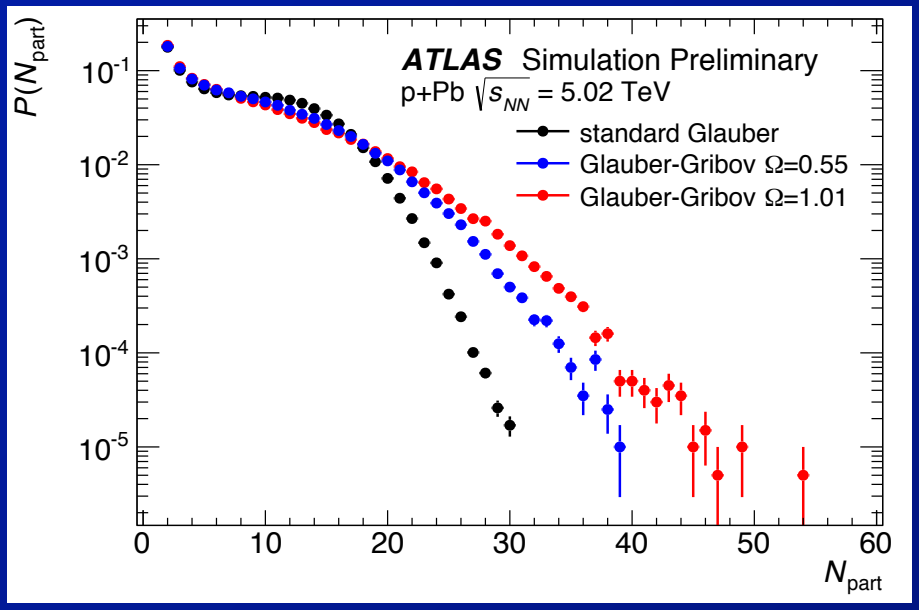
p+Pb Jet production: ATLAS

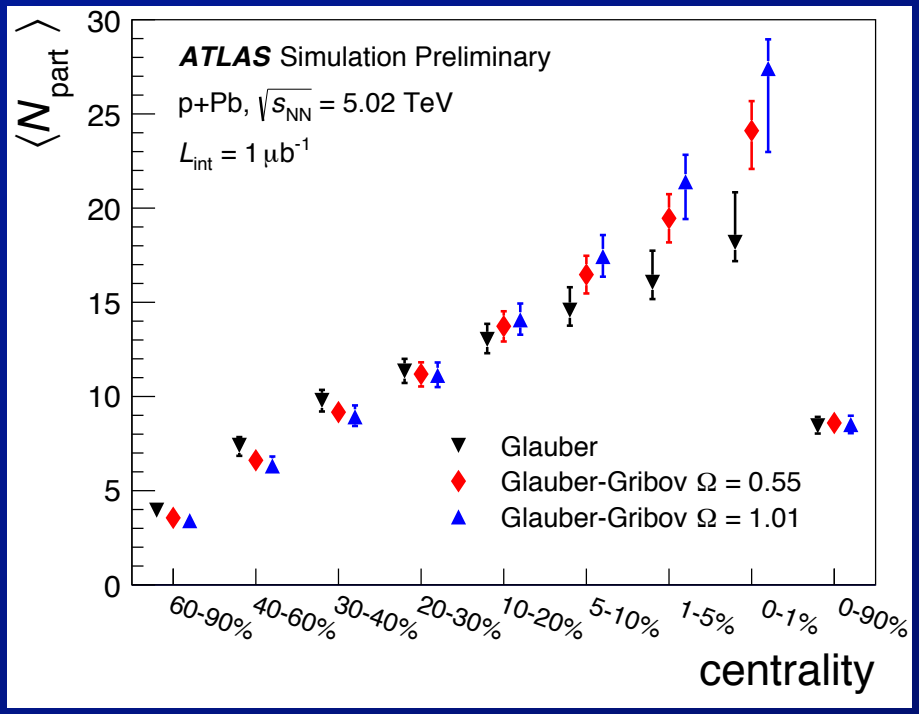


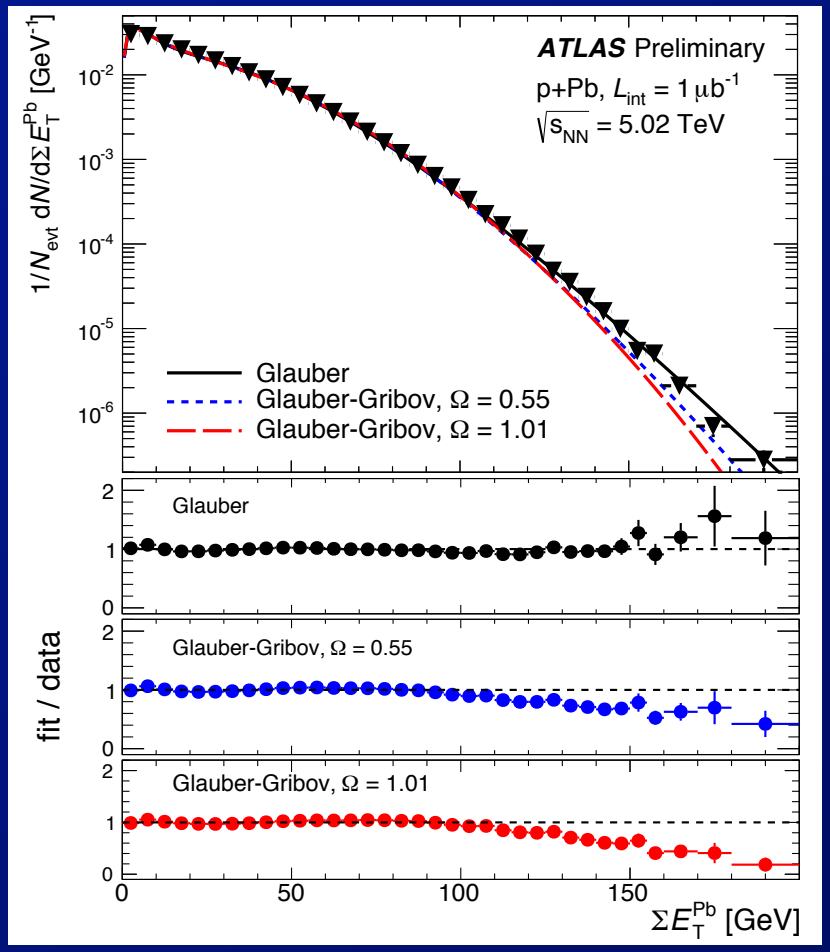


- ~ inclusive jet yields (left) and jet R_{pPb} (right)
  - ⇒using 2013 p-p reference for R_{pPb}
- R_{pPb} compared to pQCD w/ EPS09 (Armesto)

p+Pb Glauber(Gribov) analysis



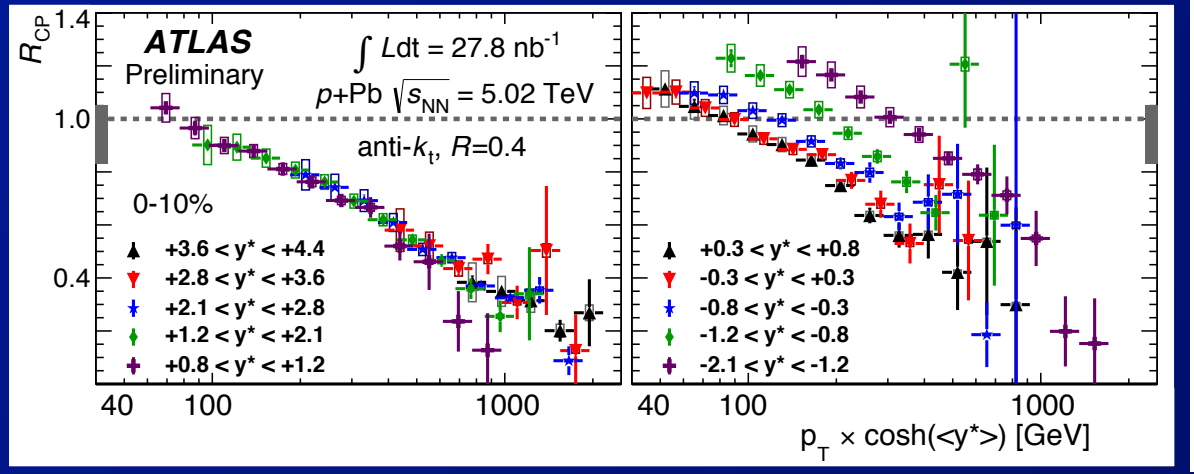


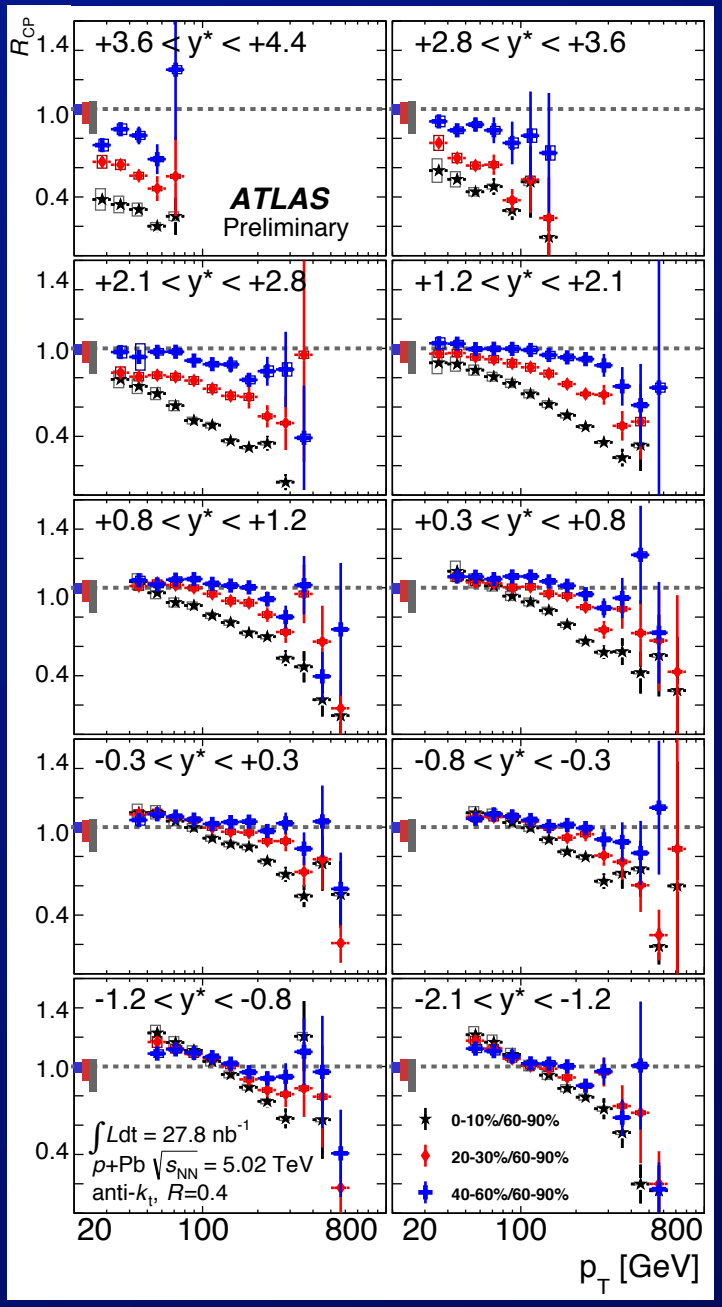


- **Evaluating implications of the Strikman *et al* Glauber-Gribov color fluctuations model for p+Pb centrality**

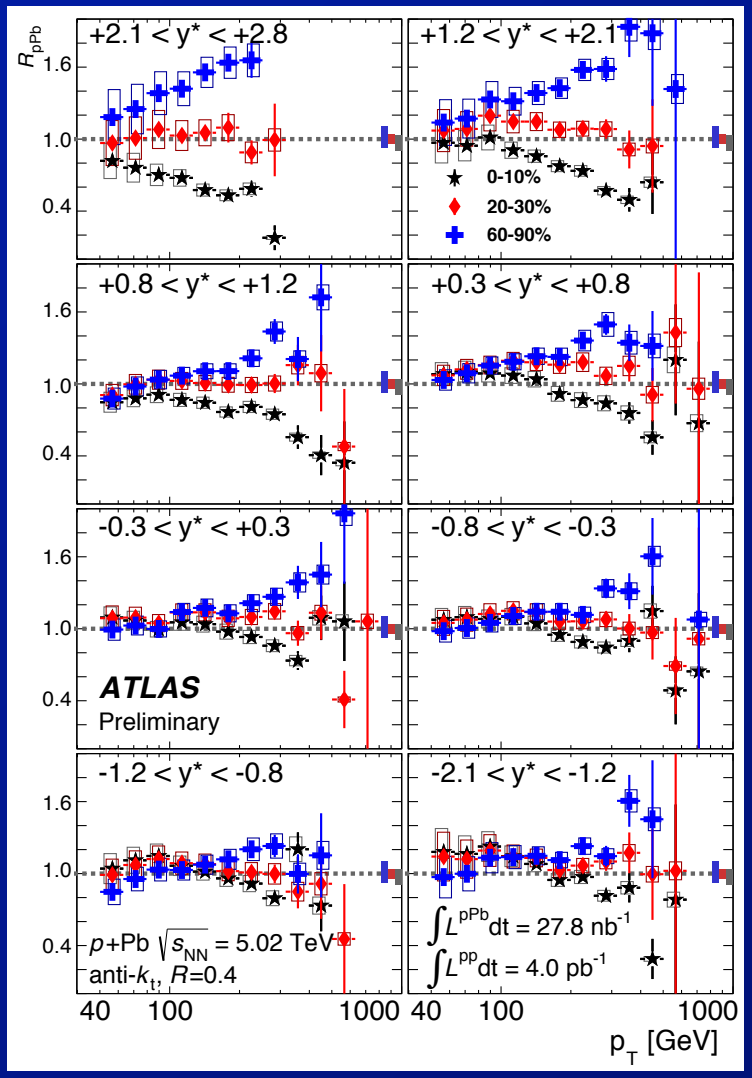
Jet R_{CP}, R_{pPb}

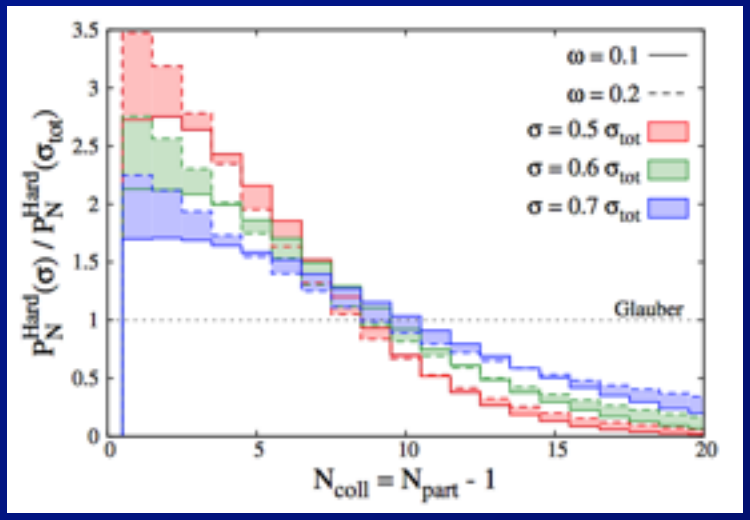
- As reported at Hard Probes
  - ATLAS observes a strong variation in jet yield with centrality at high p_T or forward rapidities
    - ⇒Scales with $p = p_T \times \cosh(y)$ in forward direction
    - ⇒Depends on x_p ?

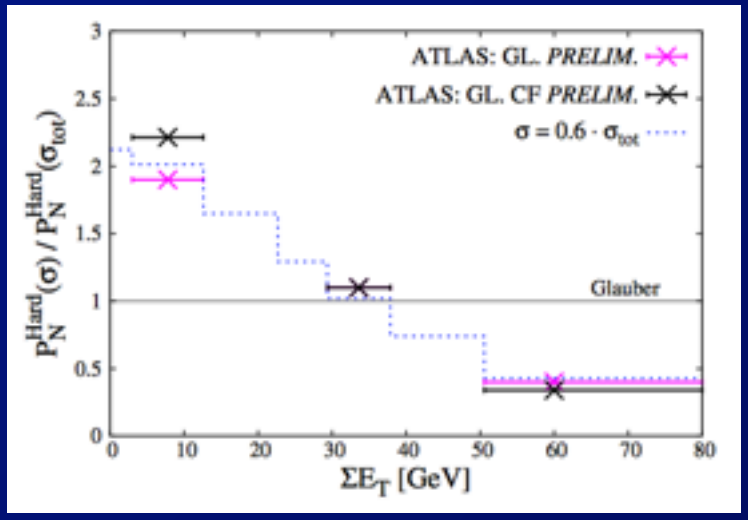




Coupling hard and soft physics







- **Undermines existing paradigm for centrality**

  ⇒**Need much more detailed description of geometry of p-p, p-A (A-A?) collisions**