Inclusive jet production in ultrarelativistic proton-nucleus collisions

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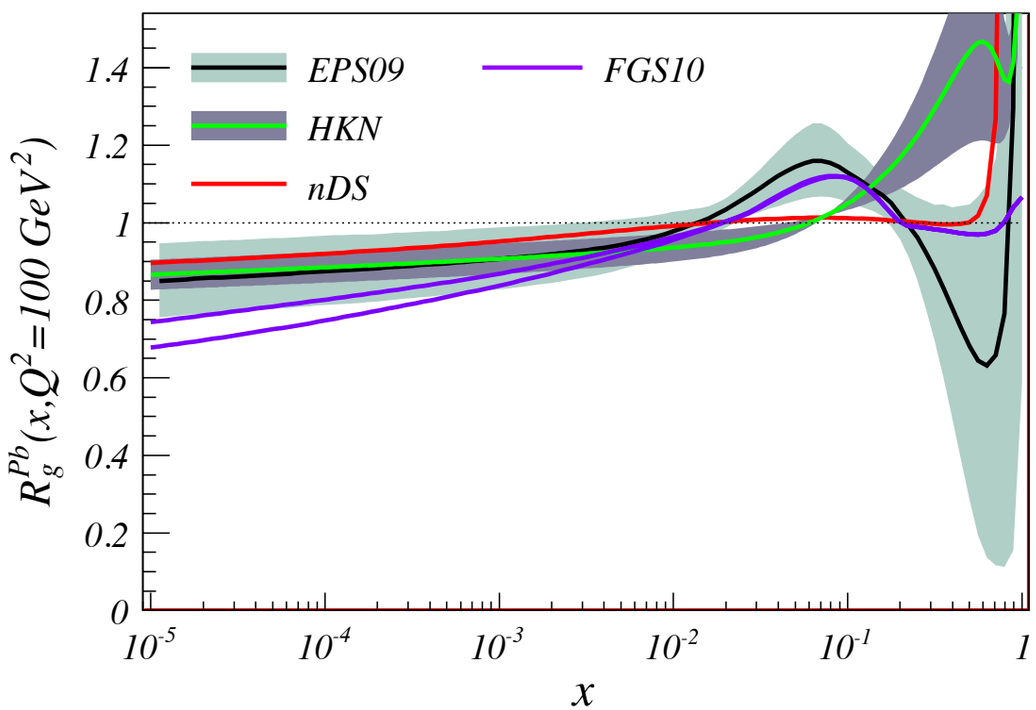
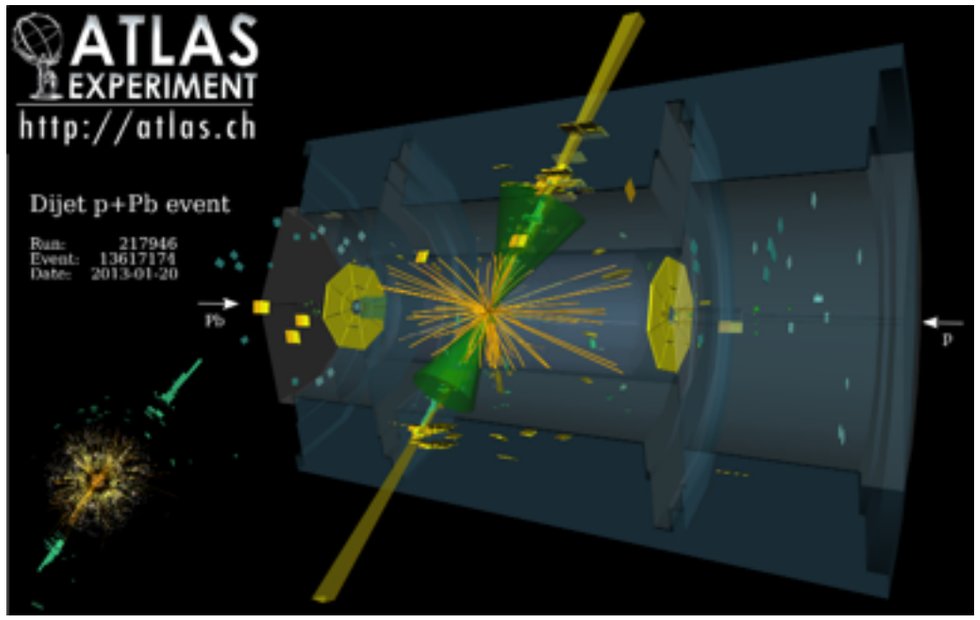
How are parton densities modified in the high density nucleus?

- Goal: map out the partonic landscape of the nucleus



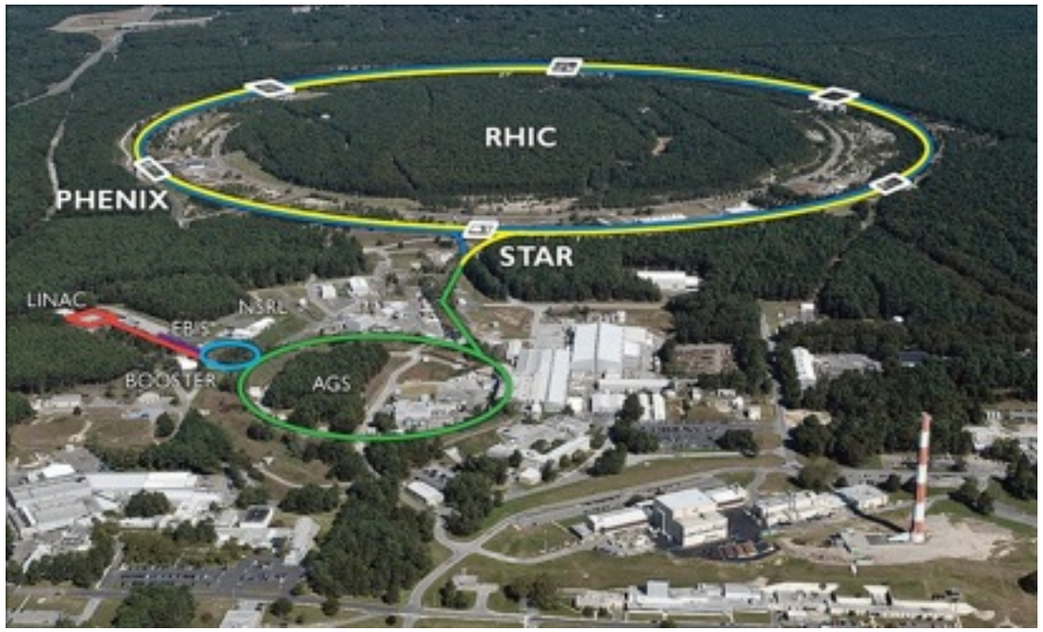
Salgado et al., hep-ph/1105.3919
example of different
nuclear PDF sets



Dijet event in *p*+Pb collision,
January 2013 @ the LHC

- Full jets offer access to a huge (x, Q^2) kinematic range
  - and better relationship with underlying parton-parton kinematics

Relativistic Heavy Ion Collider @ BNL

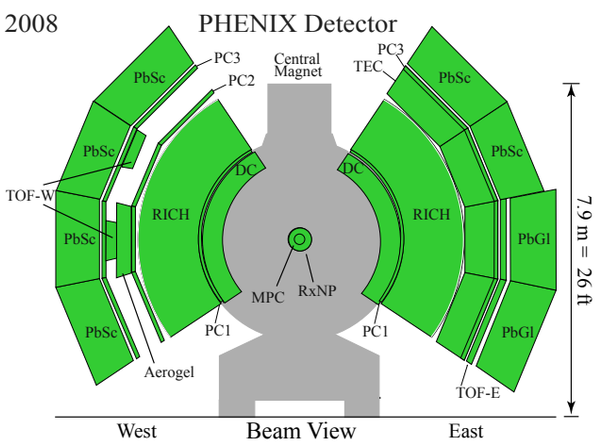


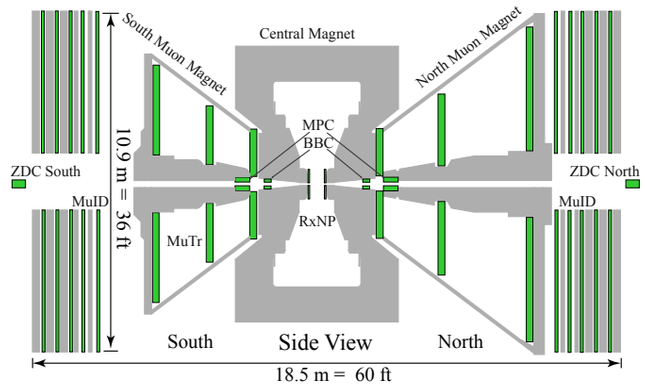
- 2008 data-taking
- 238 nb^{-1} of *d*+Au data
- 19 pb^{-1} of *pp* data
  - both at $\sqrt{s_{NN}}$ = 200 GeV

Large Hadron Collider @ CERN

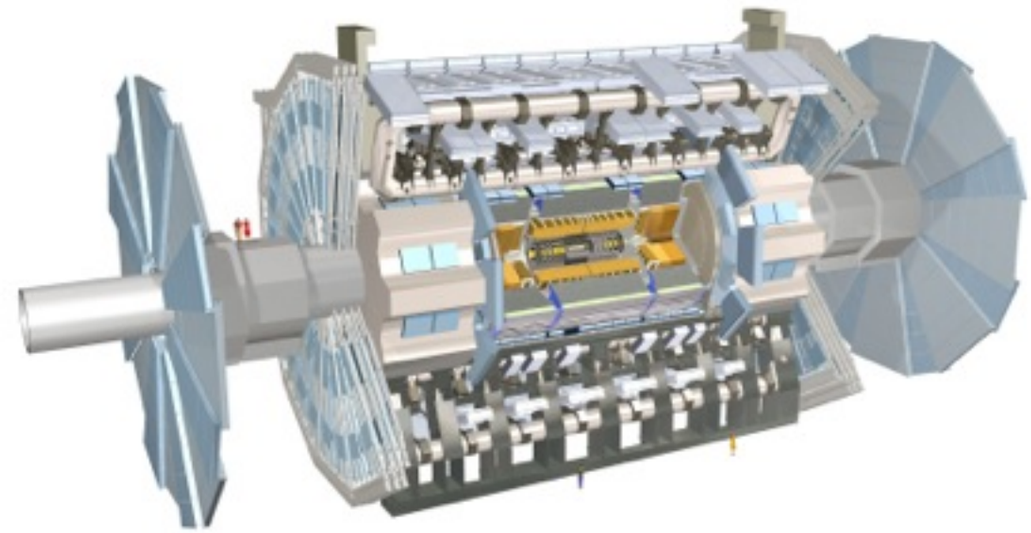
- 2013 data-taking
- 28 nb^{-1} of *p*+Pb data
  - $\sqrt{s_{NN}}$ = 5.02 TeV
  - COM shift of Δy = 0.465
- 4.0 pb^{-1} of *pp* data @ 2.76 TeV
  - $\sqrt{s}$ = 2.76 TeV

PHENIX Experiment @ RHIC





ATLAS Experiment @ LHC

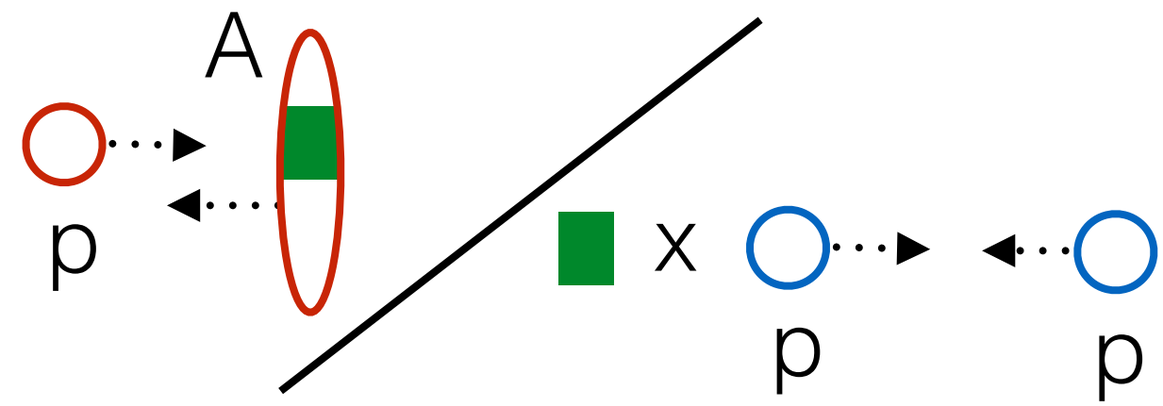


- Electromagnetic calorimeter + drift chamber
  - $|\eta| < 0.35$, $\Delta\phi = \pi/2 * 2$ Arms
- Hardware EMCal-based trigger
- Centrality determined in Au-going beam-beam counter
  - $2.1 < \eta < 3.8$
- Gaussian filter algorithm, $\sigma=0.3$

- Hadronic calorimeter
  - $|\eta| < 4.9$, $\Delta\phi = 2\pi$
- High-level software trigger
- Centrality determined in Pb-going FCal
  - $3.2 < \eta < 4.9$
- anti-k_T algorithm, R=0.4

Nuclear modification factors

$$R_{dAu} \text{ or } R_{pPb} = \frac{(1/N_{evt})\, d^2N/dp_T dy}{\langle T_{pA}\rangle\, d^2\sigma/dp_T dy}$$



double differential per-event yield — RHIC: corrected for underlying event effects; LHC: corrected for all detector effects

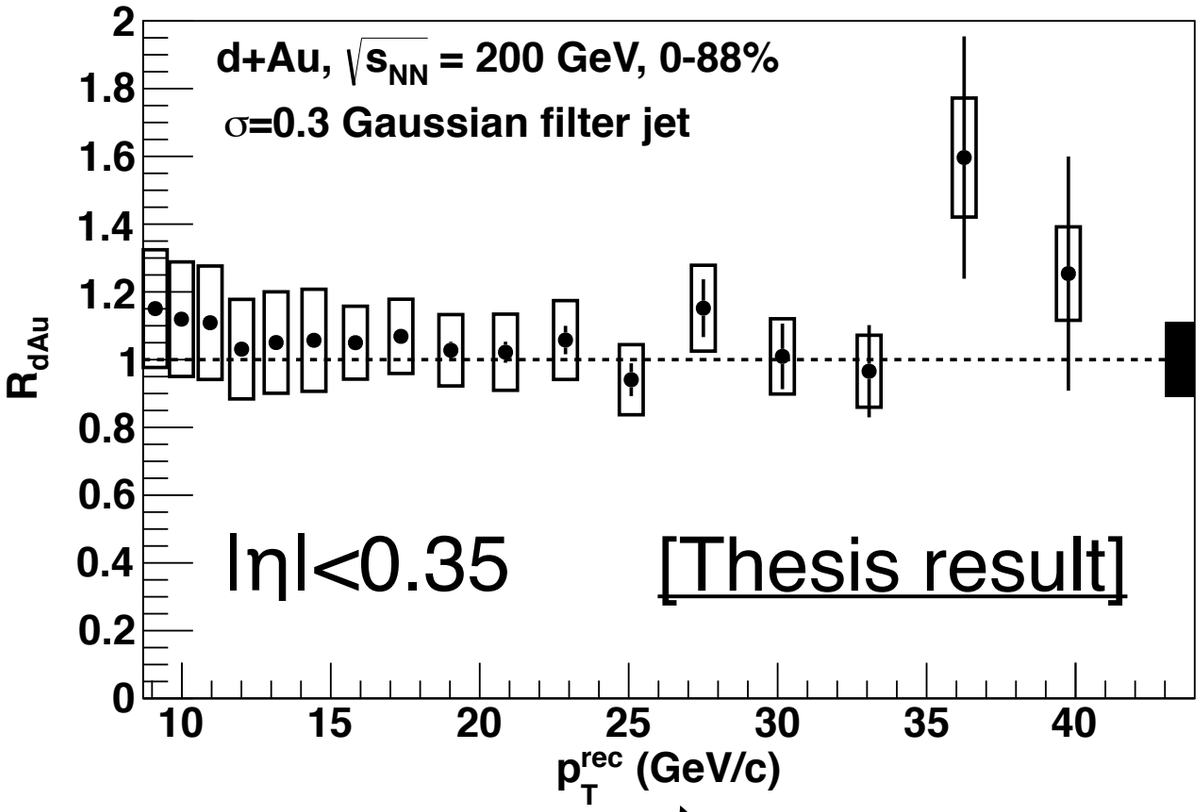
pp cross-section — RHIC: 200 GeV *pp* data from same Run; LHC: 2.76 TeV *pp* data from same period & x_T scaled to 5.02 TeV

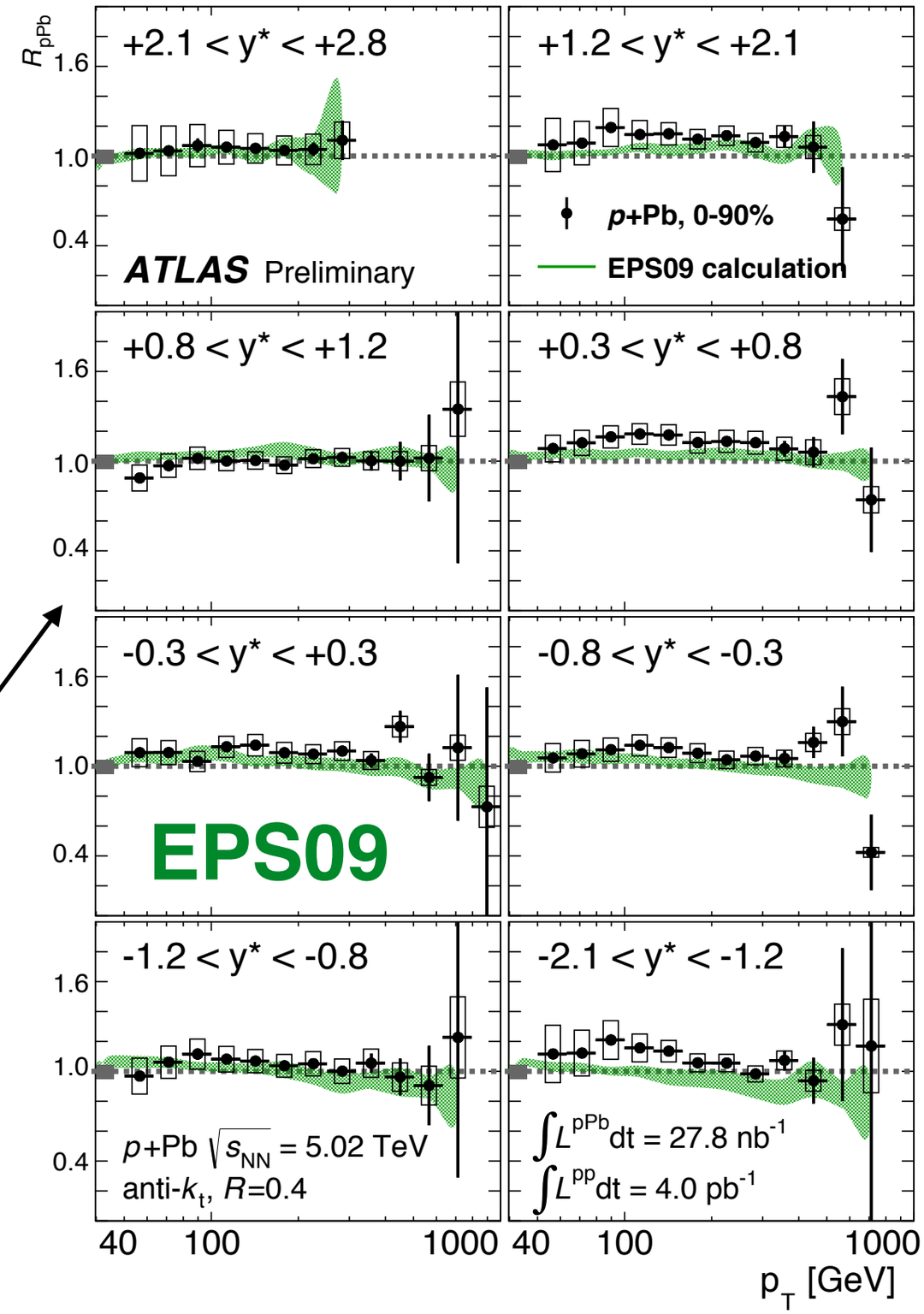
nuclear thickness function — For minimum bias collisions,

$$\langle T_{pA}\rangle = \langle N_{coll}\rangle / \sigma_{NN} = \begin{cases} 7.59 / 42 \text{ mb at RHIC} \\ 7.47 / 70 \text{ mb at LHC} \end{cases}$$

In the absence of nuclear effects, $R_{dAu} = R_{pPb} = 1$

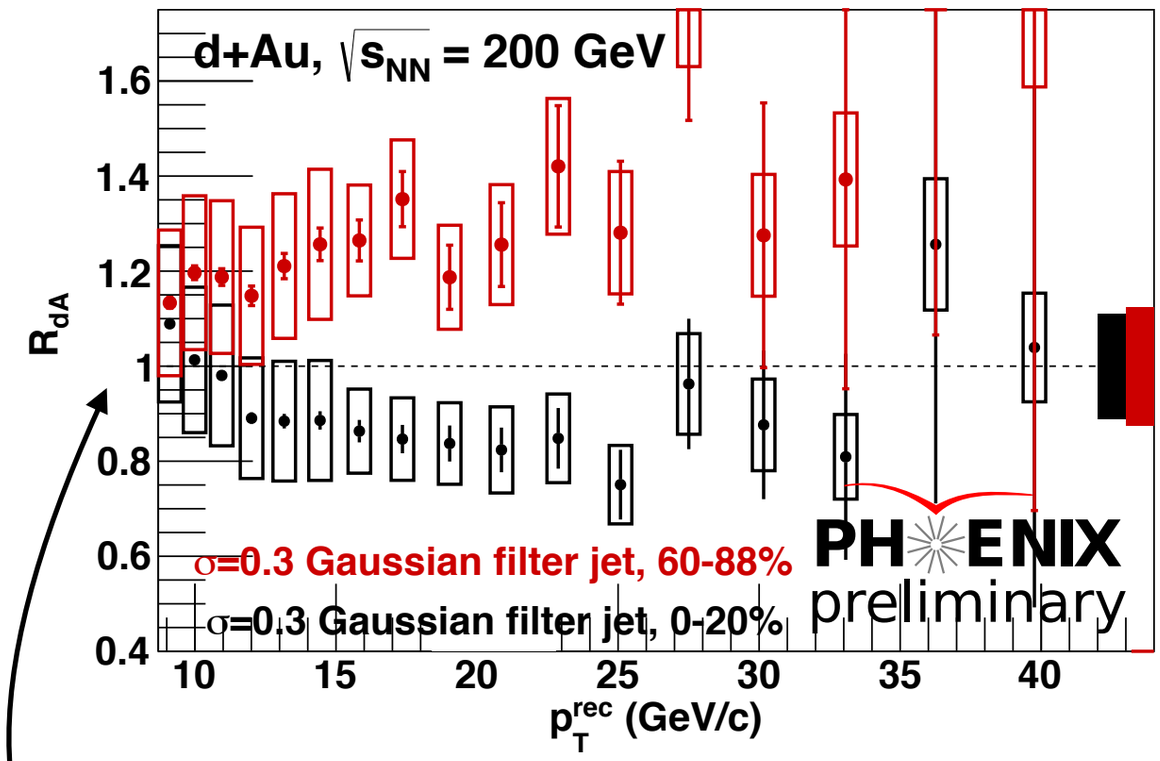
Minimum bias *p*/*d*+A collisions

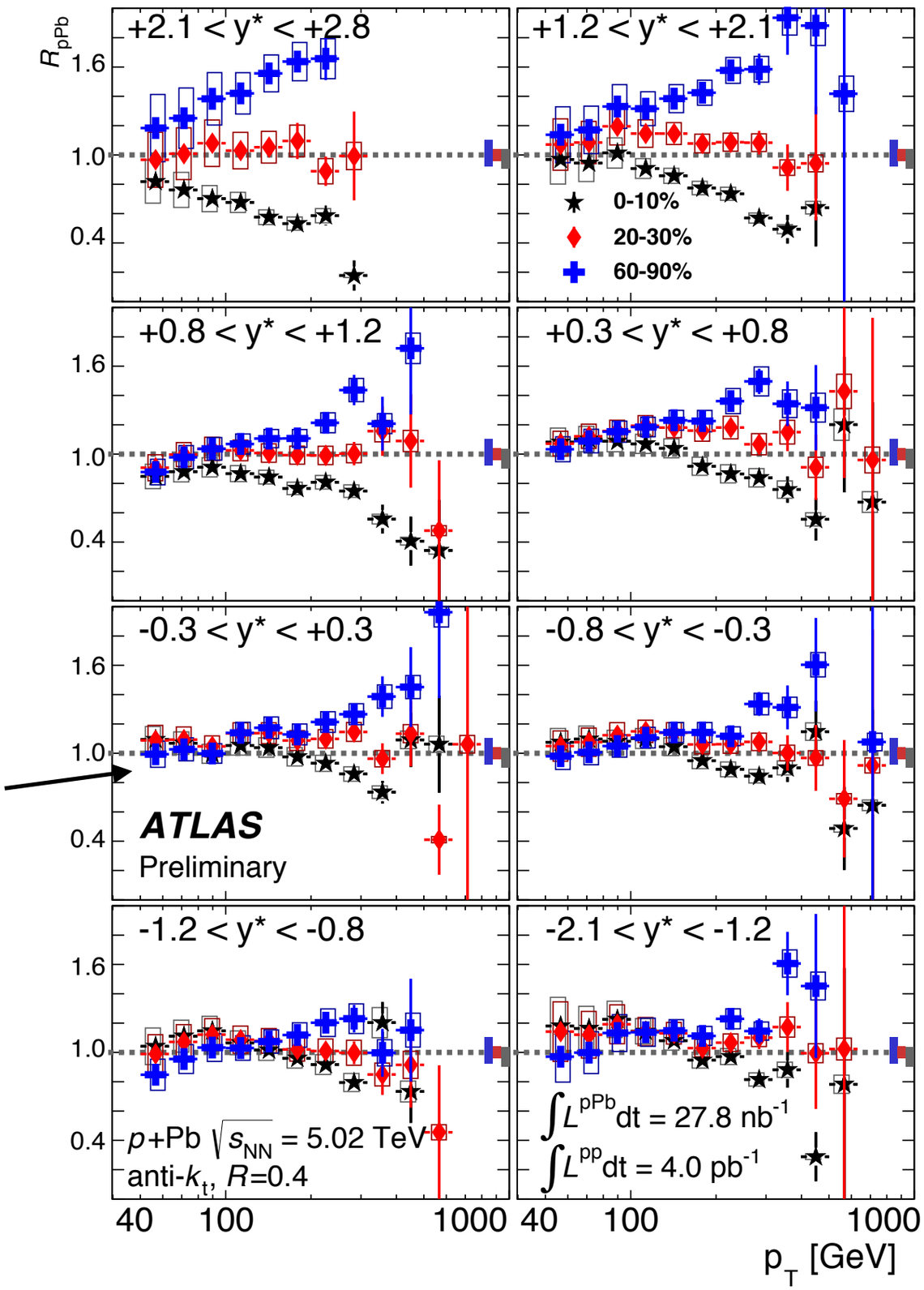




- Minimum bias <u>*d*+Au</u> and <u>*p*+Pb</u>
  - over a wide kinematic range
  - jet rates are in line with (or only slightly above) the geometric expectation

Centrality dependence of jet production

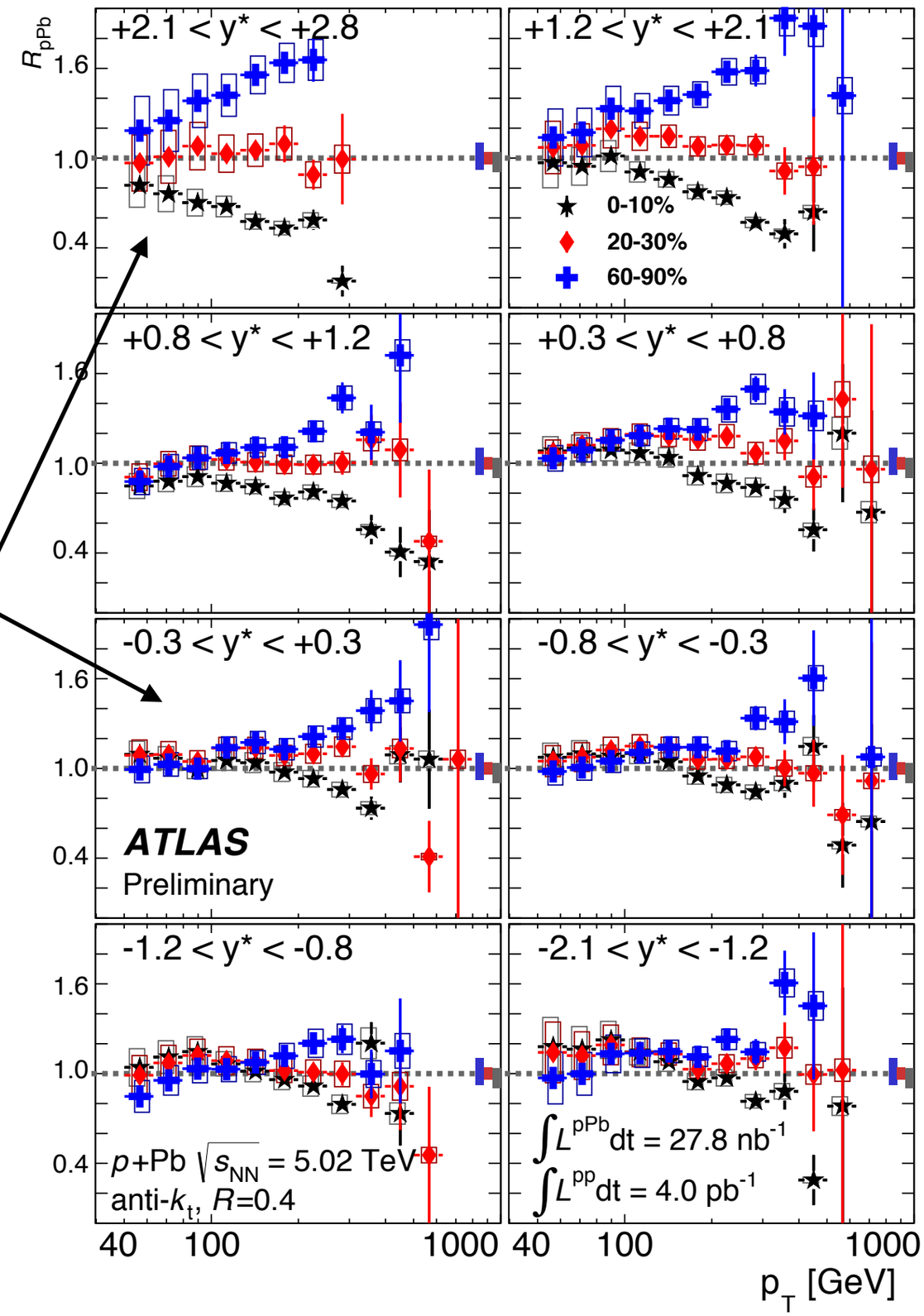




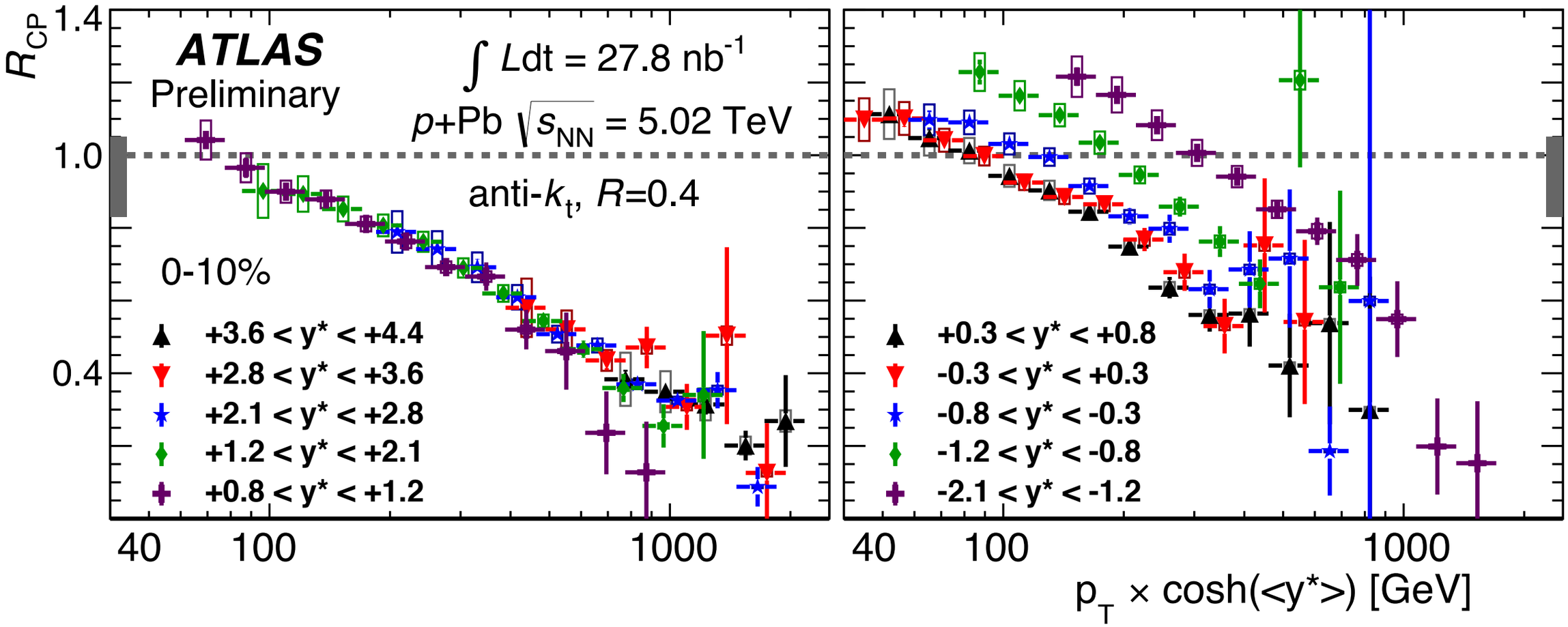
- Centrality-dependent spectra
  - geometric scaling at <u>intermediate</u> p_T
- Unexpected "splitting" at high p_T
  - suppression in central collisions
  - enhancement in peripheral collisions

Centrality dependence of jet production

- At mid-rapidity,
  - modest, high-p_T effect
- At forward rapidities,
  - large effect, starting at much lower p_T
- <u>How do we understand the rapidity dependence?</u>



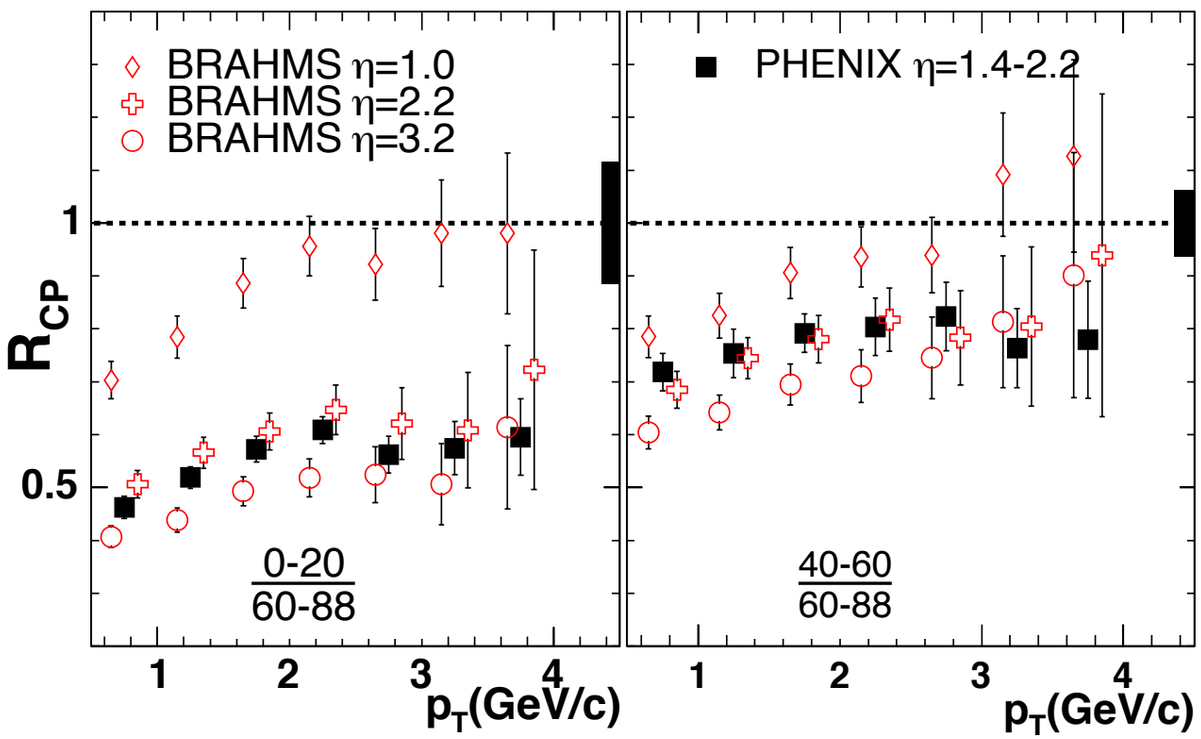
Rapidity dependence



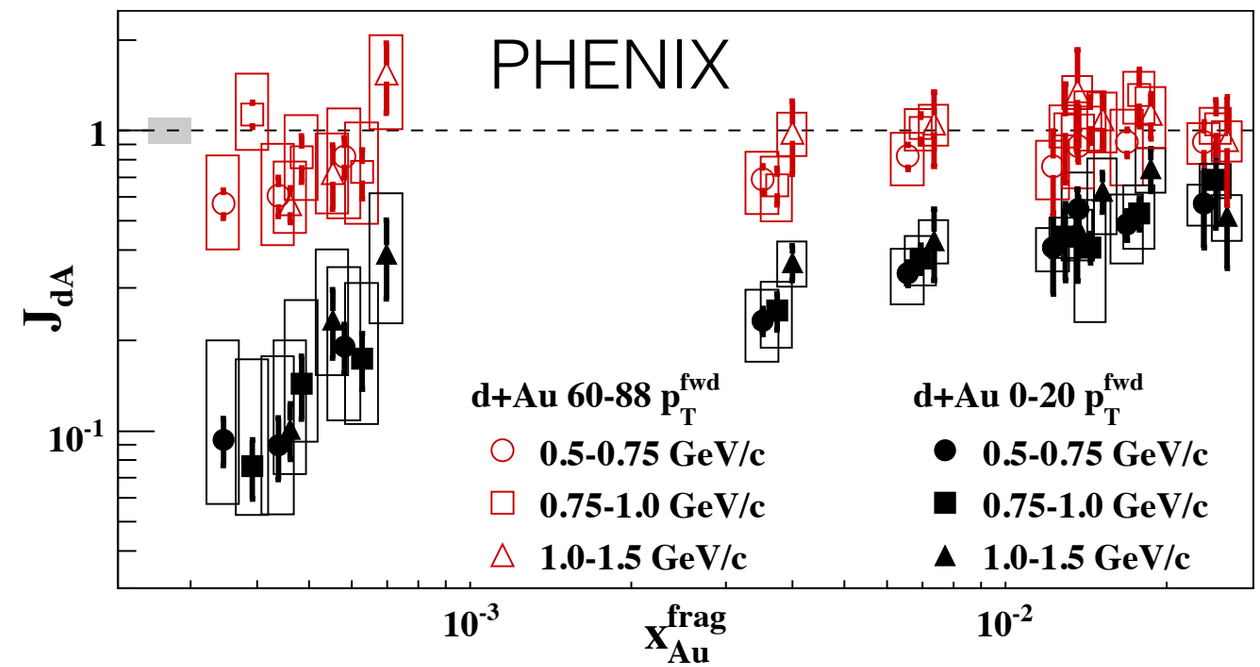
- Plot the R_{CP} vs. the <u>total jet energy p</u>
  - R_{CP} at forward & mid-rapidity falls along a common curve
- Modifications at all y have a <u>simple kinematic dependence</u>
- Centrality dependence of jet production at <u>high-p_T & y = 0</u> and <u>low-p_T & y ≫ 0</u> are connected!

Implications for existing data

PRL 94 082302 (2005) **hadron R_{CP}**



PRL 107 172301 (2011) **di-hadron J_{dA}**



- Strong centrality dependence observed in forward *d*+Au
  - *b*-dependent shadowing or saturation?
  - or a different phenomenon entirely?
    - one related to the high-p_T modifications at mid-rapidity?
- There are surely implications for forward *p*+Au in 2015 as well!