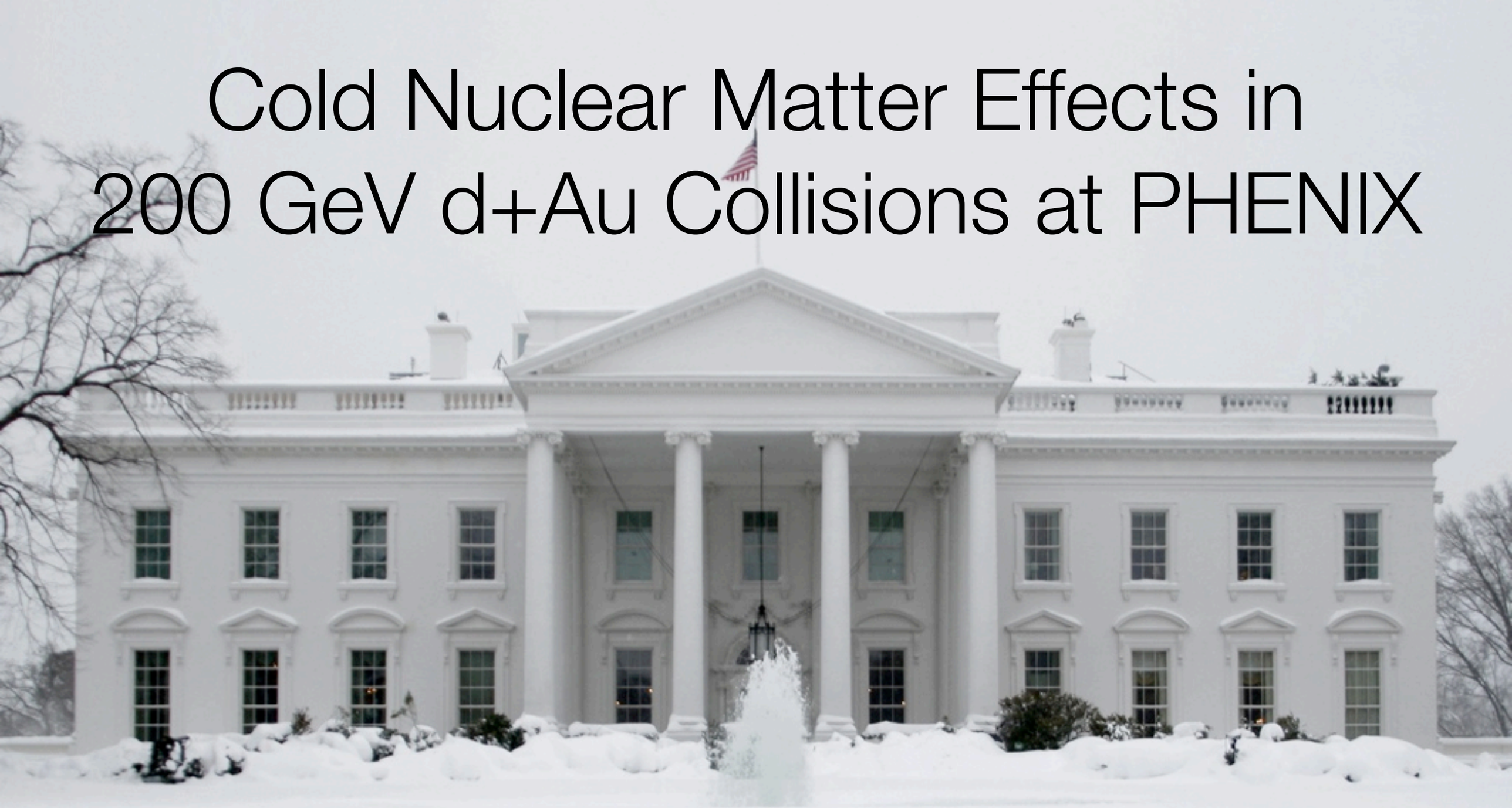
Cold Nuclear Matter Effects in 200 GeV d+Au Collisions at PHENIX



Baldo Sahlmueller (Stony Brook University), for the PHENIX collaboration

Stony Brook University

QM 12 QuarkMatter

PHENIX

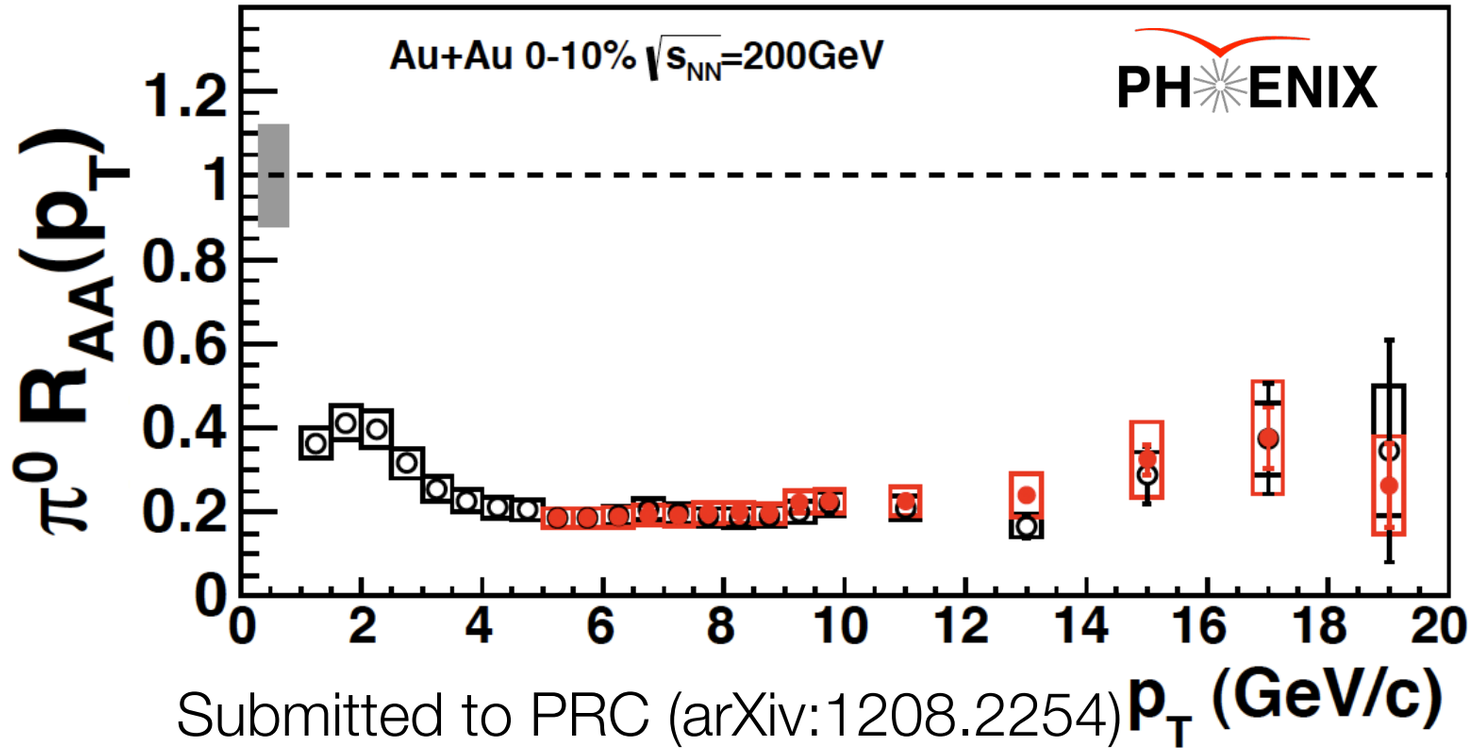
PHENIX Au+Au Measurements

- PHENIX observed strong suppression of light mesons such as π^0 in central Au+Au collisions

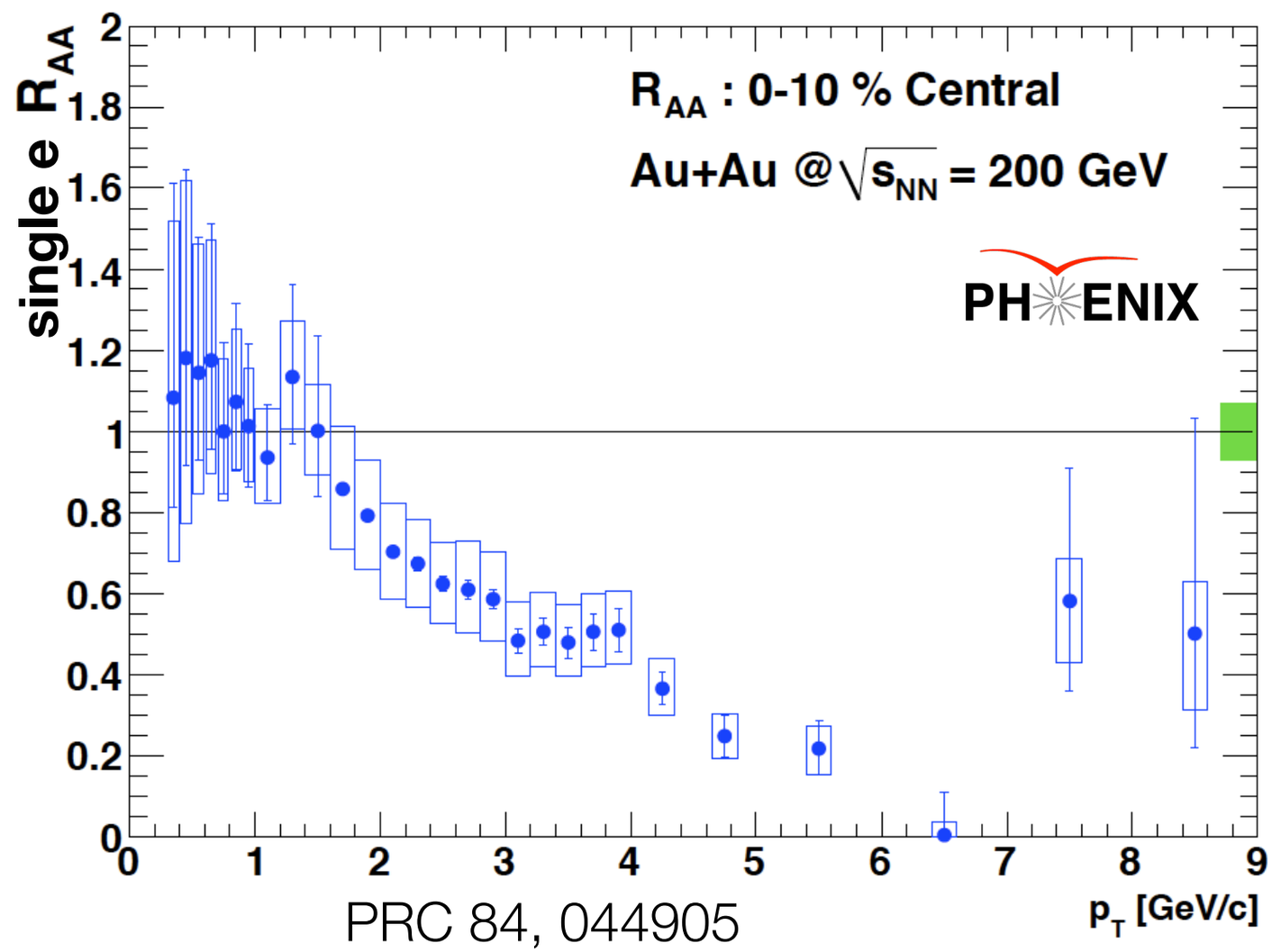
- At high p_T, single electrons from heavy quarks are also suppressed strongly

- The interpretation of these results requires - among others - an understanding of the initial state

- d+Au collisions are tool to study this initial state



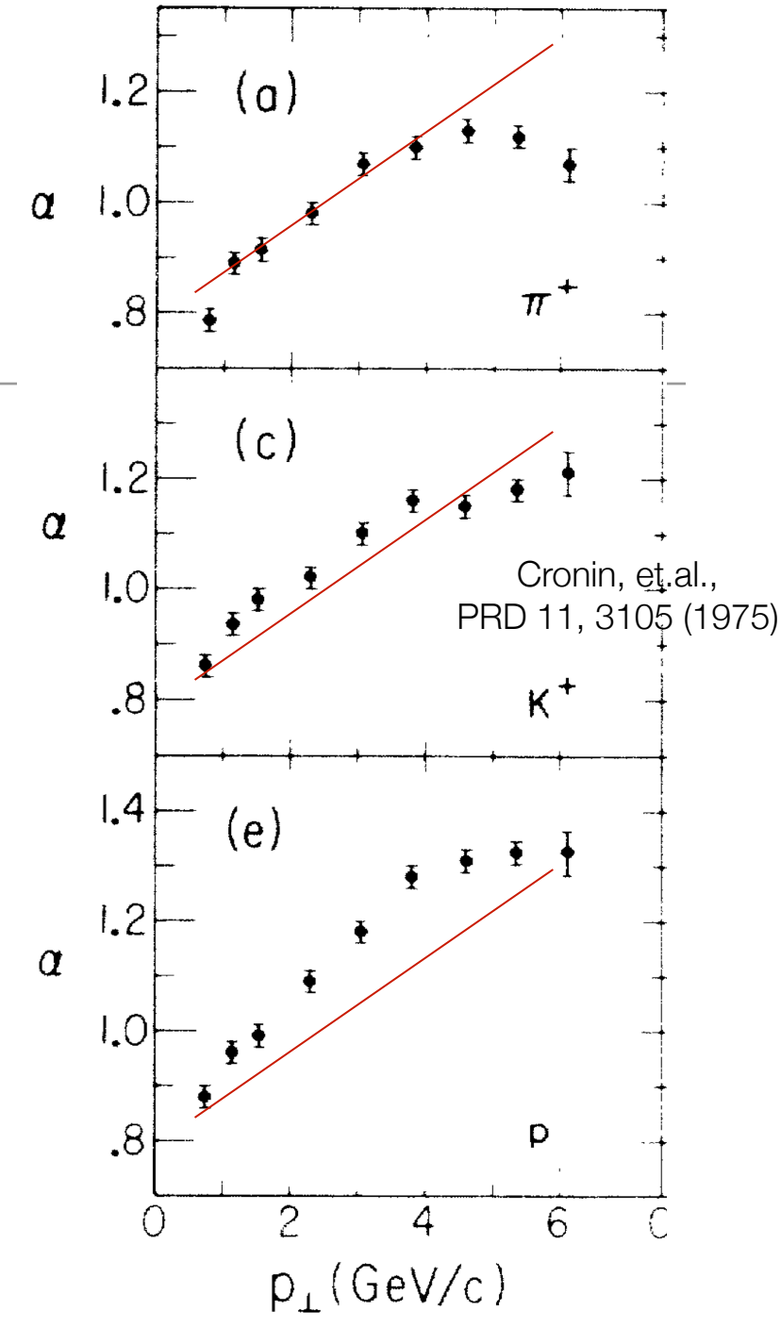
Submitted to PRC (arXiv:1208.2254)



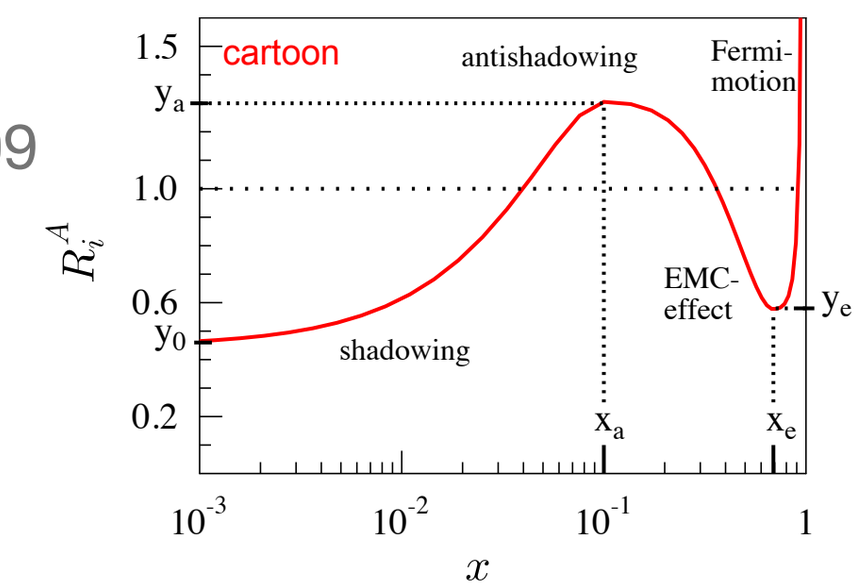
PRC 84, 044905

Cold nuclear matter effects

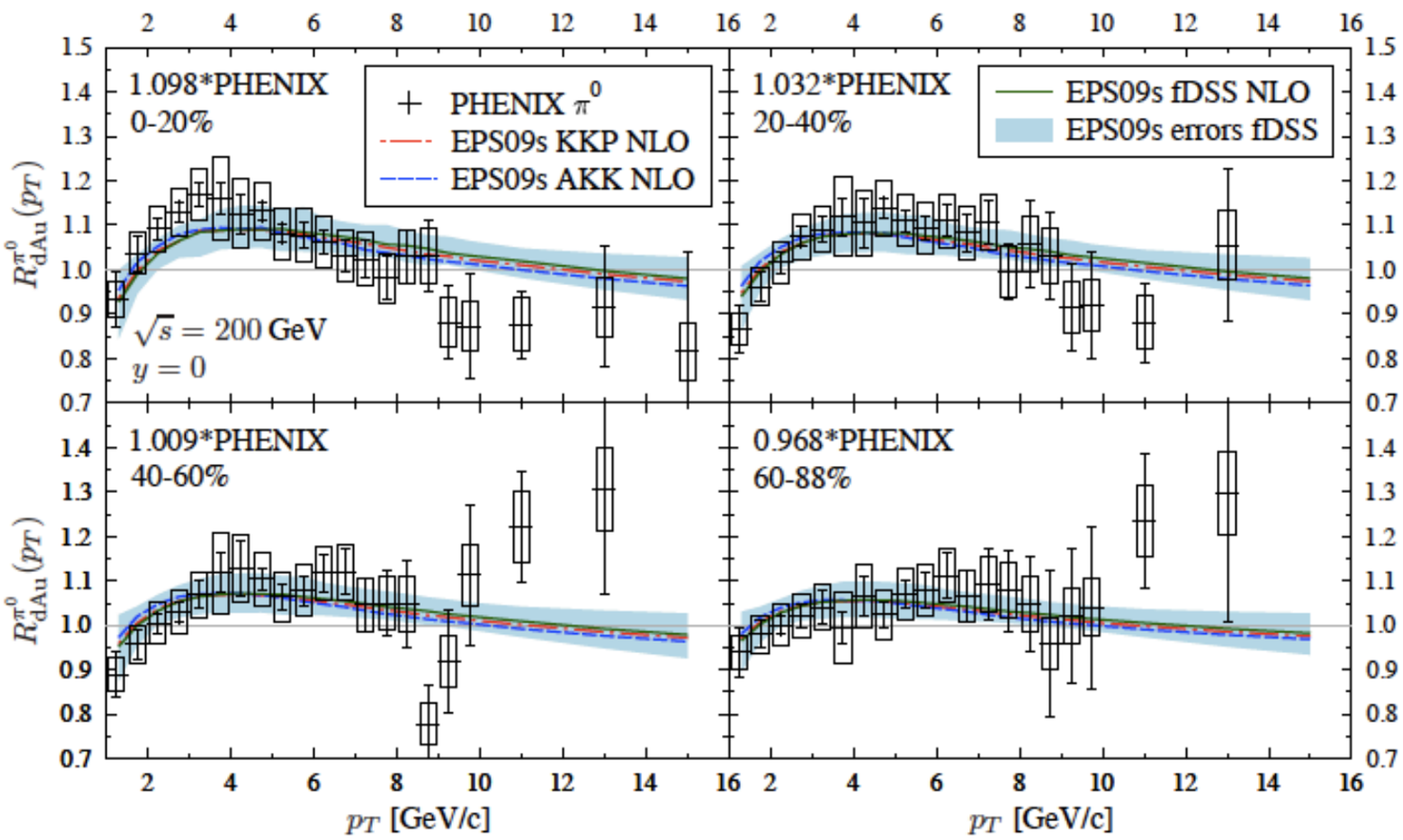
- Cronin enhancement
  - multiple scattering of partons in incoming nuclei
  - PID dependence at RHIC, higher enhancement for protons than pions
- Parton distributions modified in nuclei compared to protons
  - can lead to enhancement (anti-shadowing) or suppression (shadowing, EMC effect), depending on the x of the partons and the Q^2
  - Nuclear PDFs with uncertainties, such as EPS09
- Color glass condensate - mostly at forward rapidities, at very low x



Cronin, et.al., PRD 11, 3105 (1975)



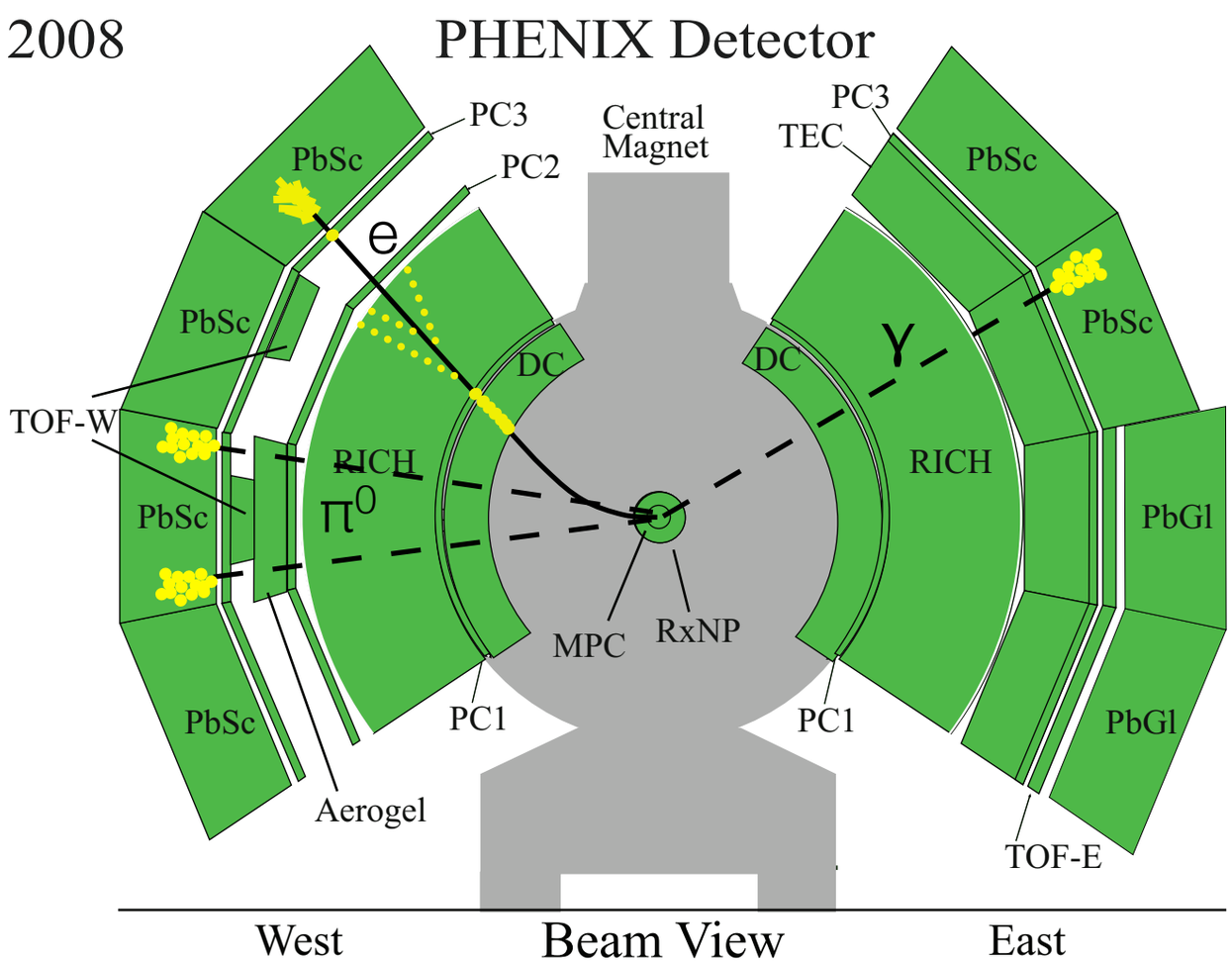
Centrality dependence of nuclear PDFs



arXiv:1205.5359

- Helenius, Eskola, et. al. published centrality dependent nuclear PDFs (arXiv:1205.5359)
- Compared to (2003) PHENIX π^0 R_{dA}
- Looks as if the curves agree with data (note that the data is scaled up/down within systematics, i.e. up to 9.8%)
- Limited significance of data at high p_T
- New data can help constraining these nPDFs

The PHENIX Experiment



- Versatile detector to measure rare probes
- Tracking detectors for charged particles, such as electrons and charged pions
- RICH allows electron ID
- Photon and electron energy measured with electromagnetic calorimeters
- Data taken in 2008 d+Au run are 30-fold increase compared to 2003

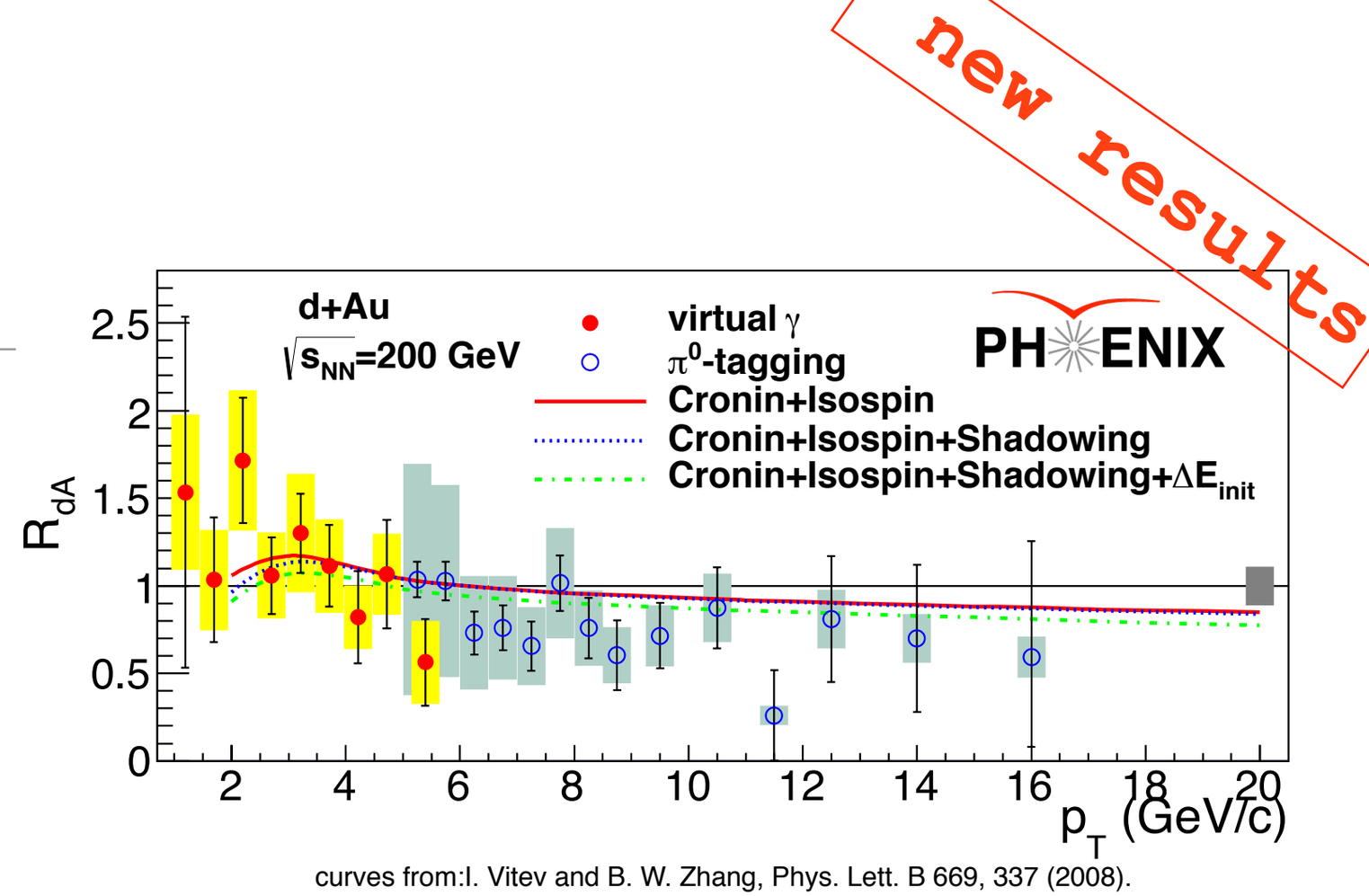
New results

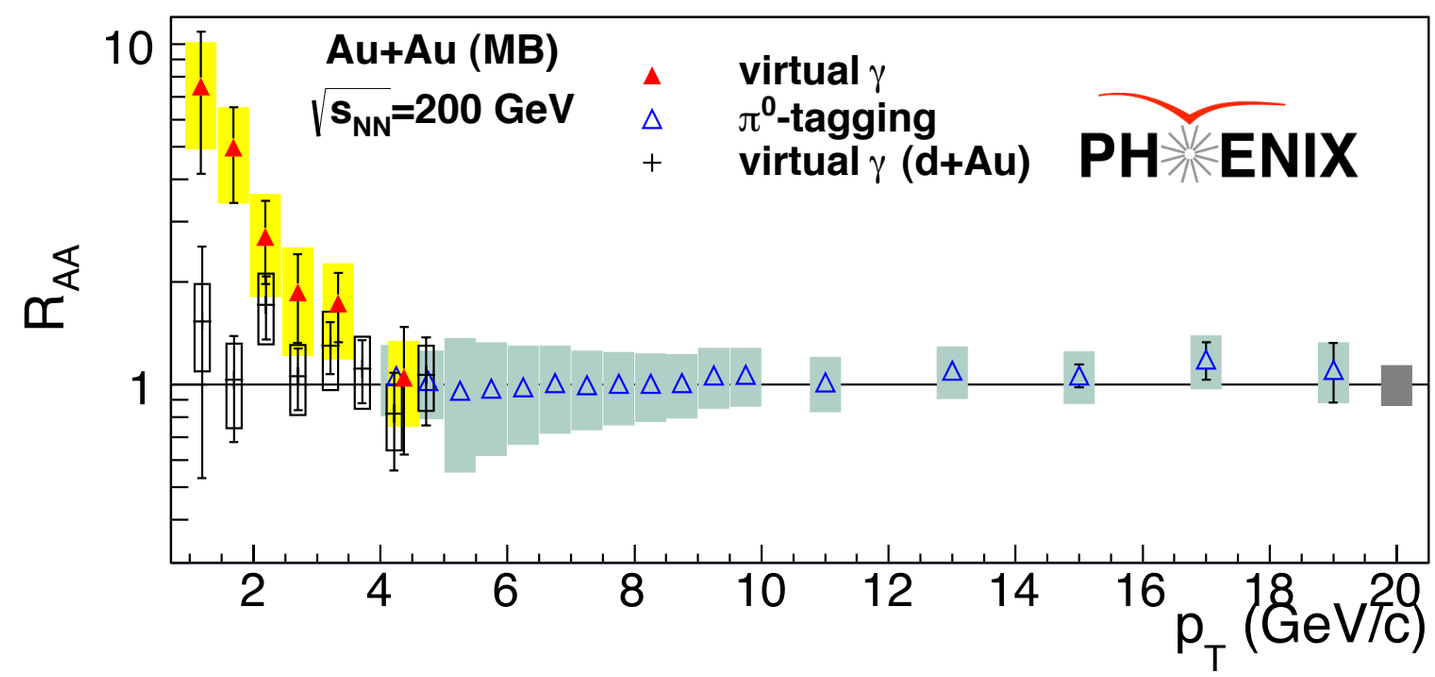
I will discuss the following

- direct photons (briefly)
- light mesons (π^0, η) and reconstructed jets
- single electrons from heavy flavor

The lightest: direct photons

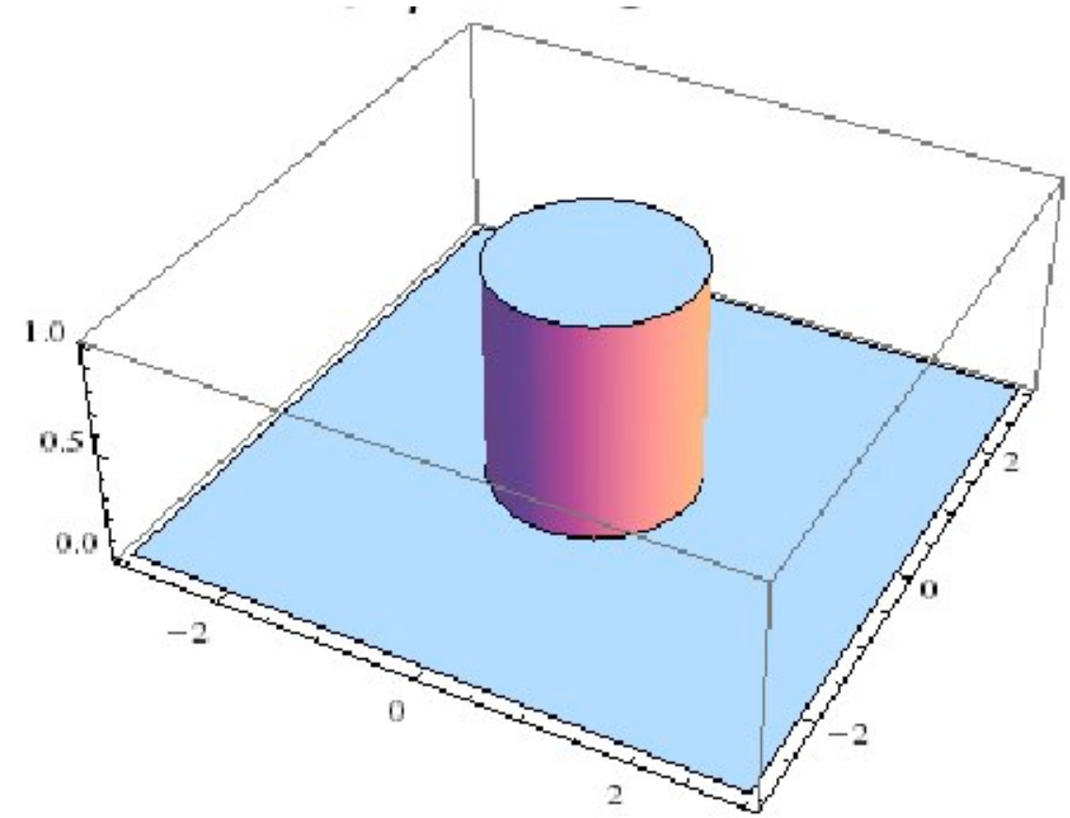
- Direct photons appear unmodified in d+Au
  - Possibly slight enhancement at low p_T
  - Theoretical models agree with data
  - data cannot (yet) distinguish between models
- Two different methods cover large p_T range
- Strong enhancement at low p_T in Au+Au final state effect





Submitted to PRL (arXiv:1208.1234)

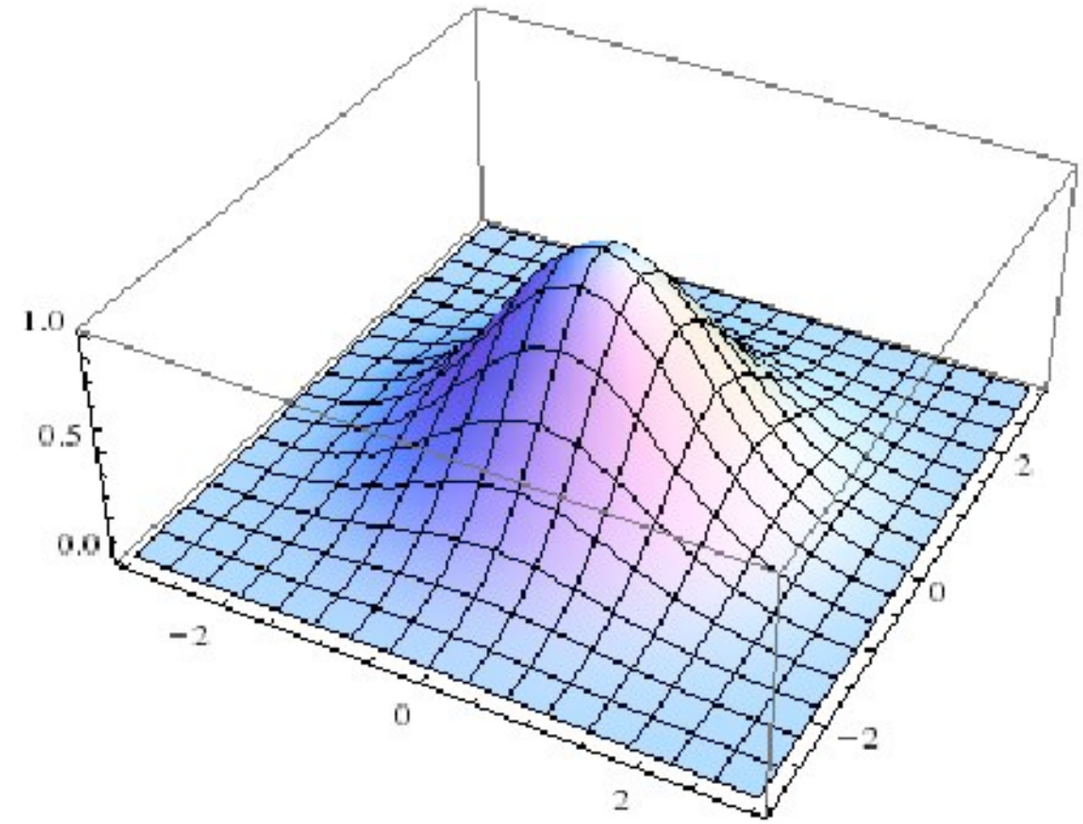
Measuring jets in PHENIX

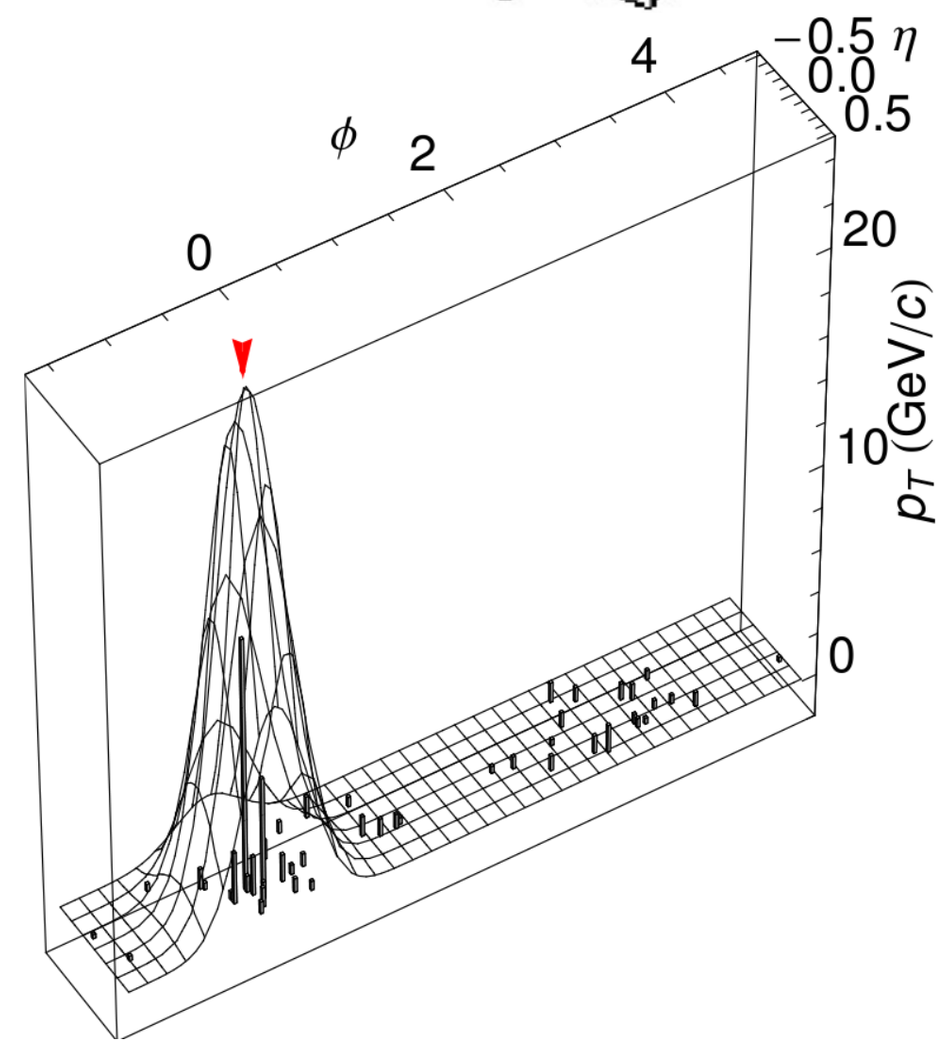


Poster by Dennis Perepelitsa

Measuring jets in PHENIX

- Gaussian filter algorithm
  - seedless, infrared and collinear safe, cone-like algorithm with Gaussian angular weighting (w.r.t. jet axis)
  - Developed for heavy-ion collisions, previously used in Cu+Cu and p+p at PHENIX
  - Focus on energetic core of jet, optimized S/B
- Small underlying event in d+Au, evaluated with embedding analysis
- Fake rate determined to be < 5% for jets with p_T > 9 GeV/c

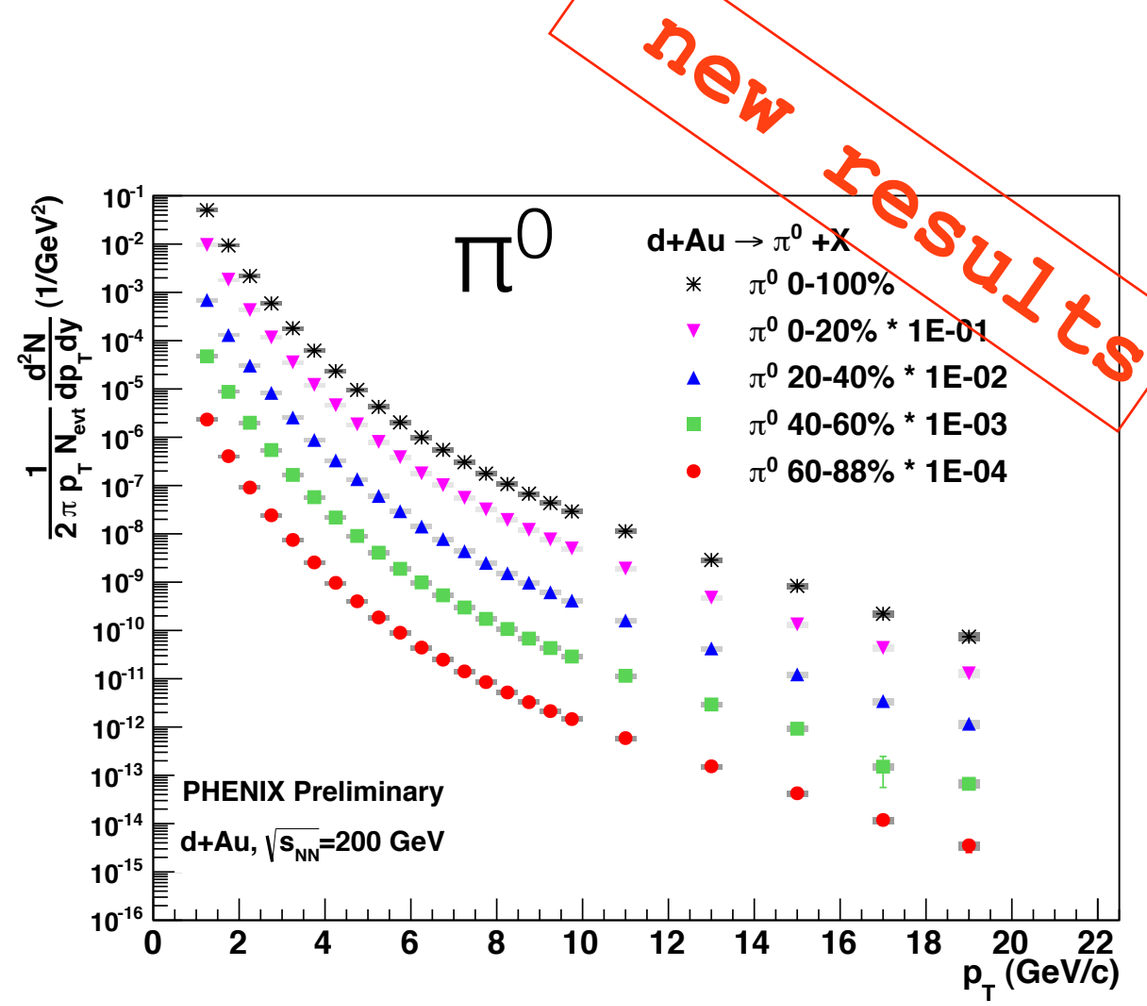


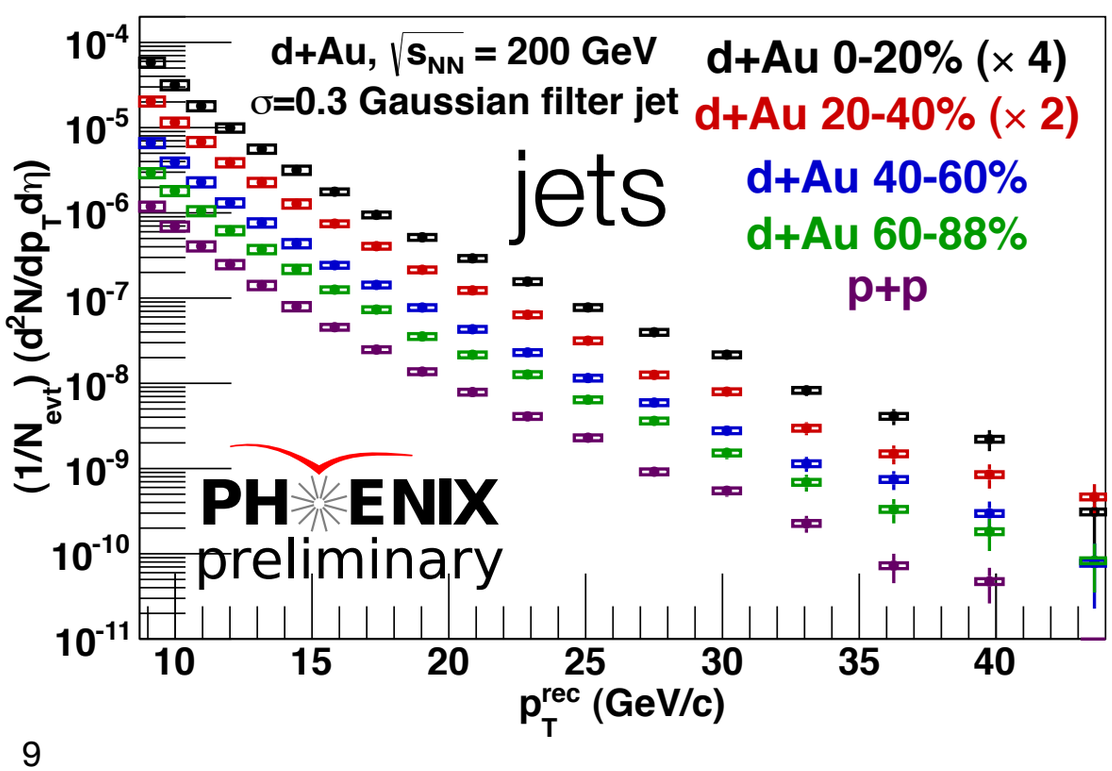


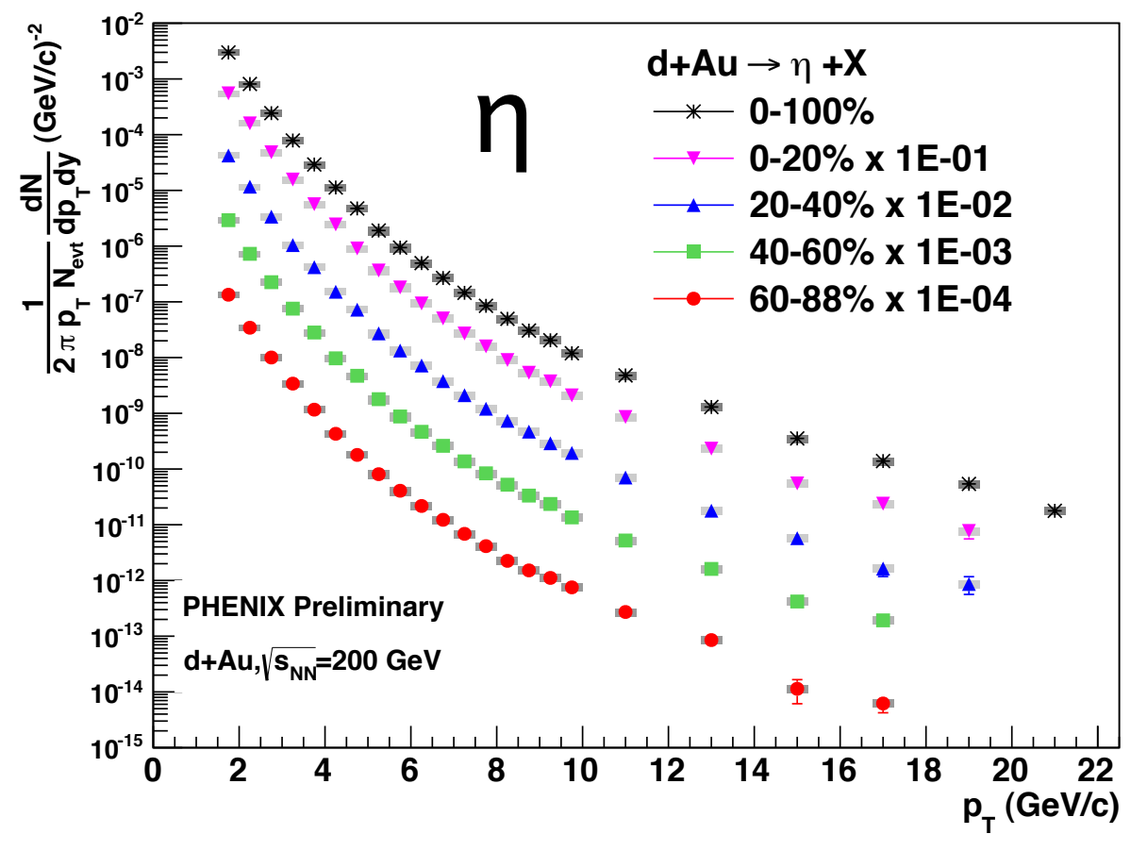
Poster by Dennis Perepelitsa

Light quarks and gluons: π^0, η, jets

- New results on π^0, η, and jets
  - π^0 now up to p_T=20 GeV/c
  - η up to p_T=22 GeV/c
  - jets up to p_T=45 GeV/c

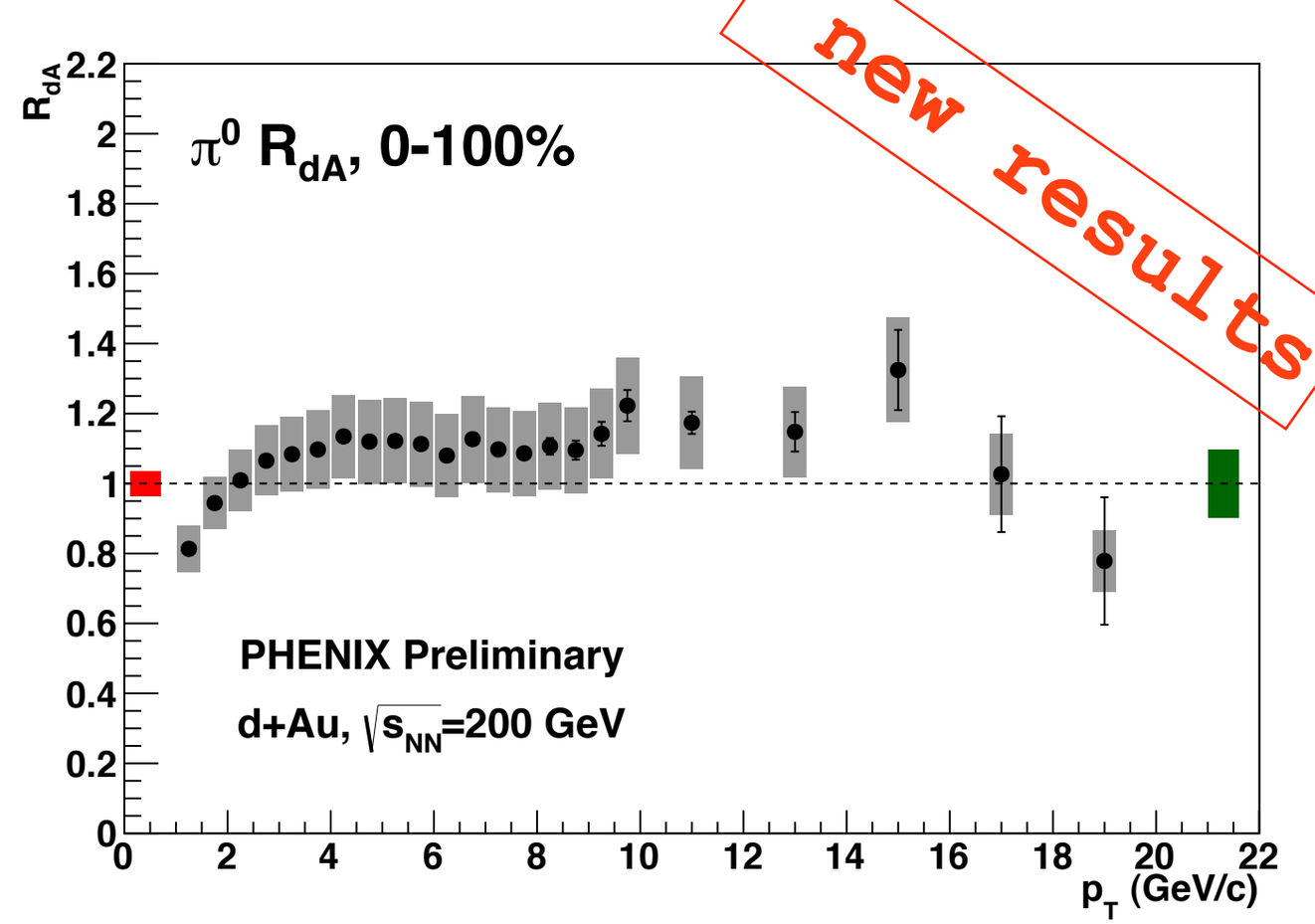


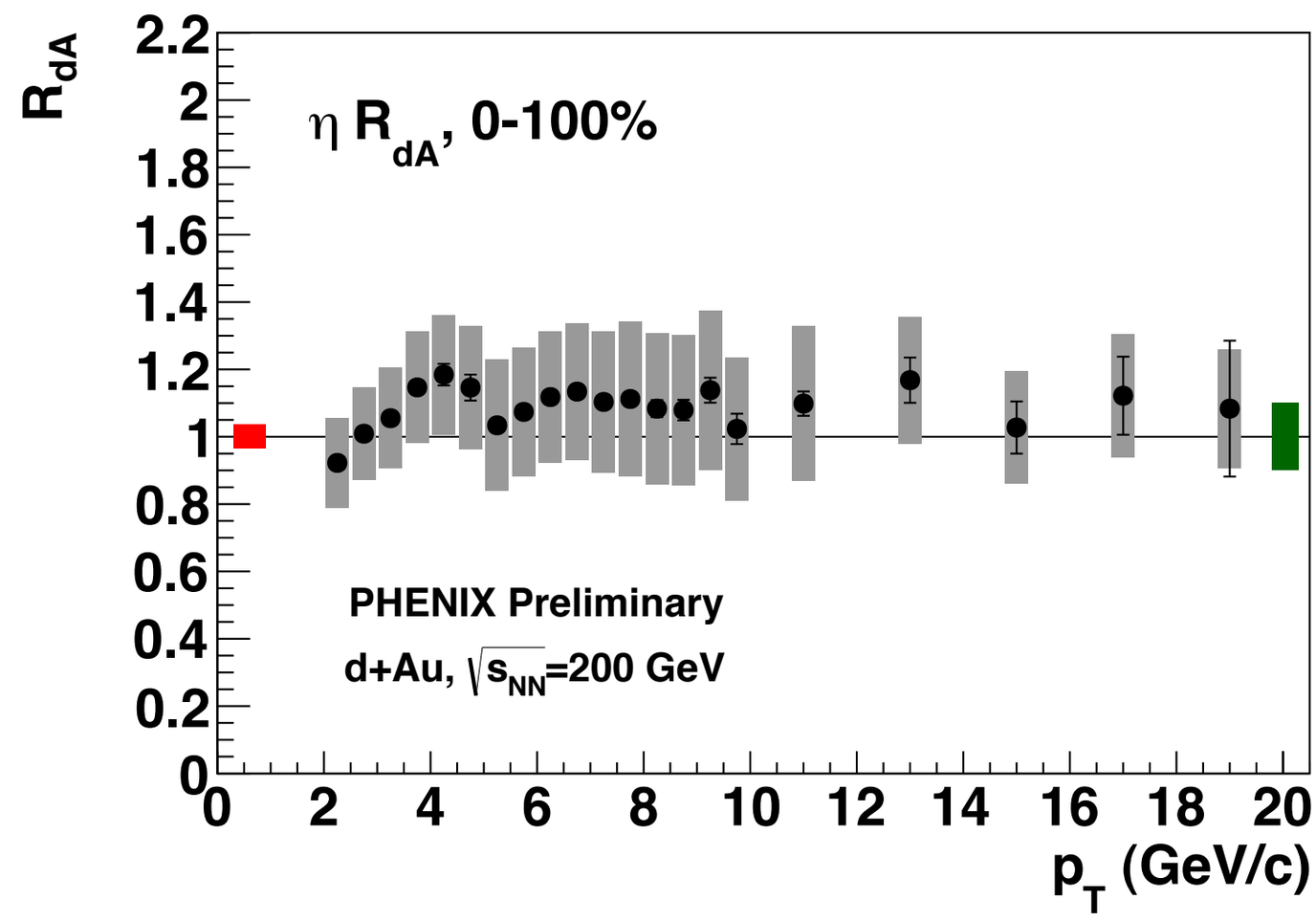




Modification?

- Looking at d+Au collisions without centrality selection: R_{dA} appears consistent with unity over the whole p_T range
  - Maybe slight enhancement for $p_T > 2$ GeV/c
- π^0 and η show the same behavior
  - Both π^0 and η have same system (and energy) dependence
- Suppression in Au+Au is final state effect (we knew that before)

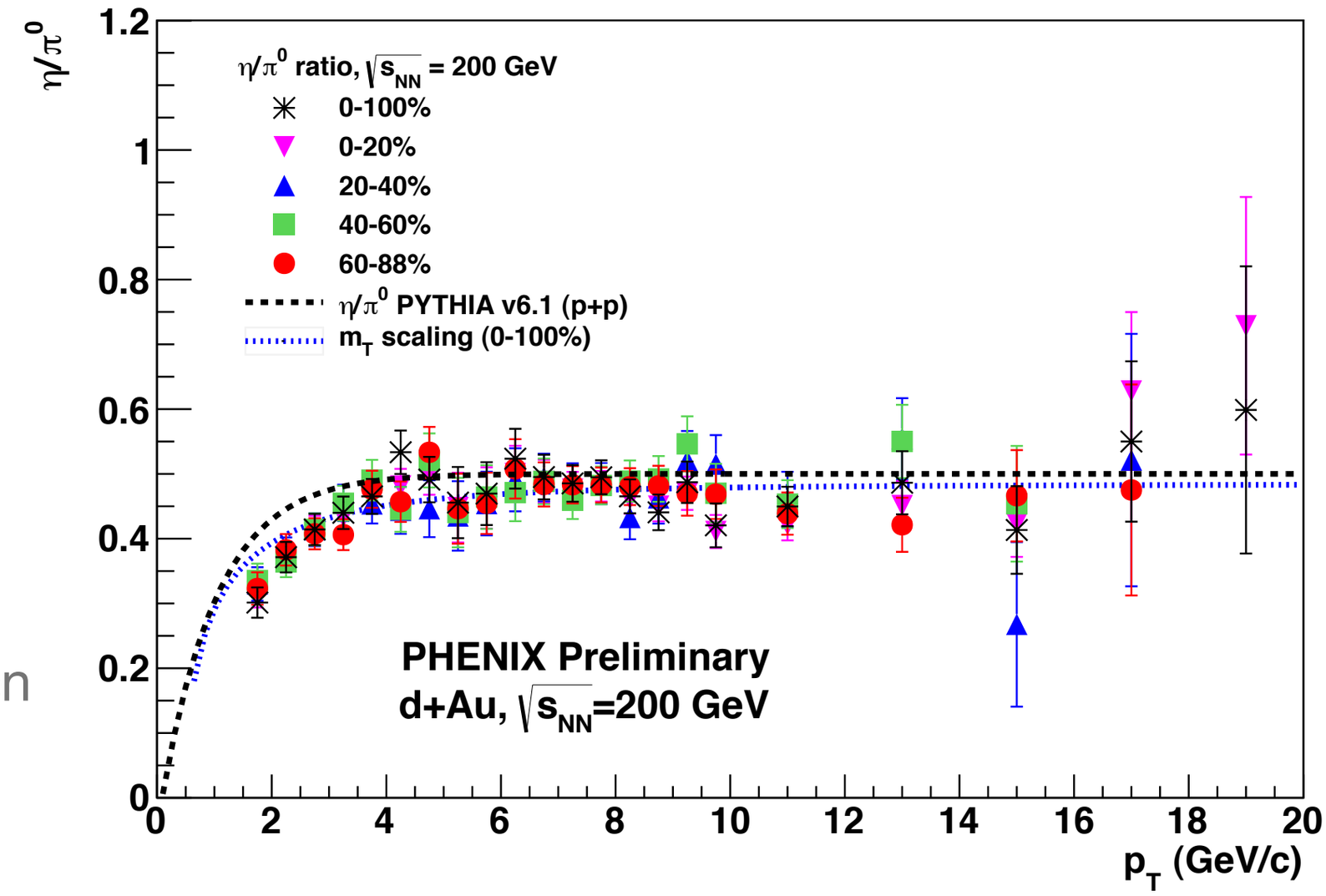




η/π^0 production ratio

new results

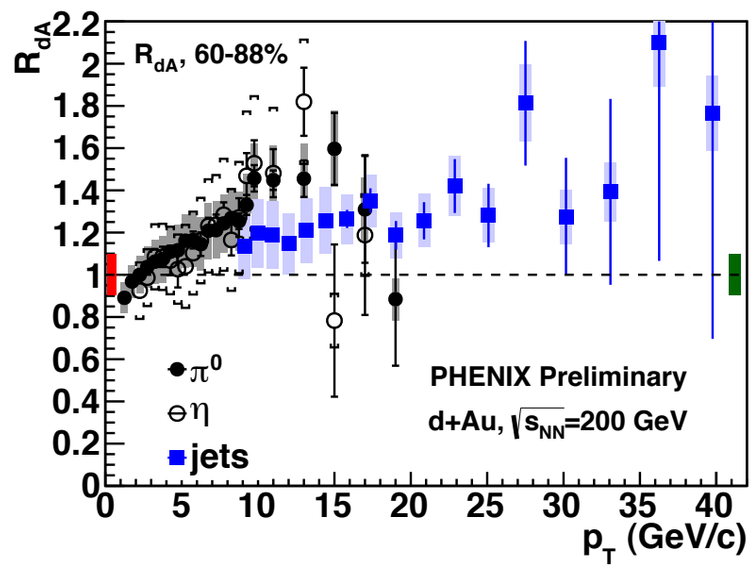
- There is no centrality dependence of the η/π^0 ratio
- At high pT, the ratio flattens out, at low pT, there is turn-on
  - Consistent with m_T scaling
  - m_T scaling factor between η and π^0 is ~0.48, which is consistent with measurement in p+p

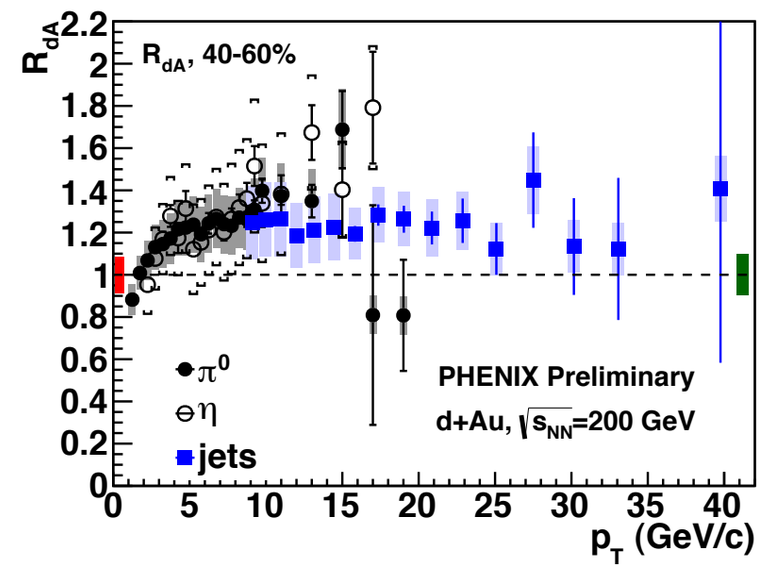


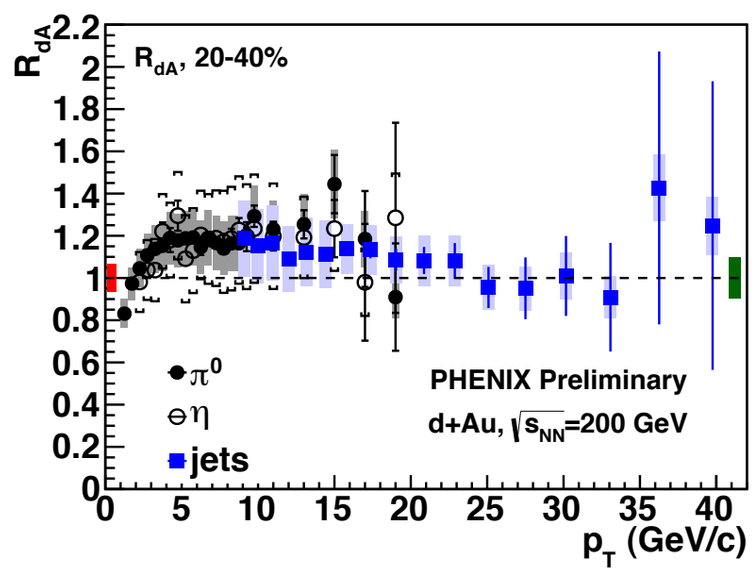
Centrality dependence

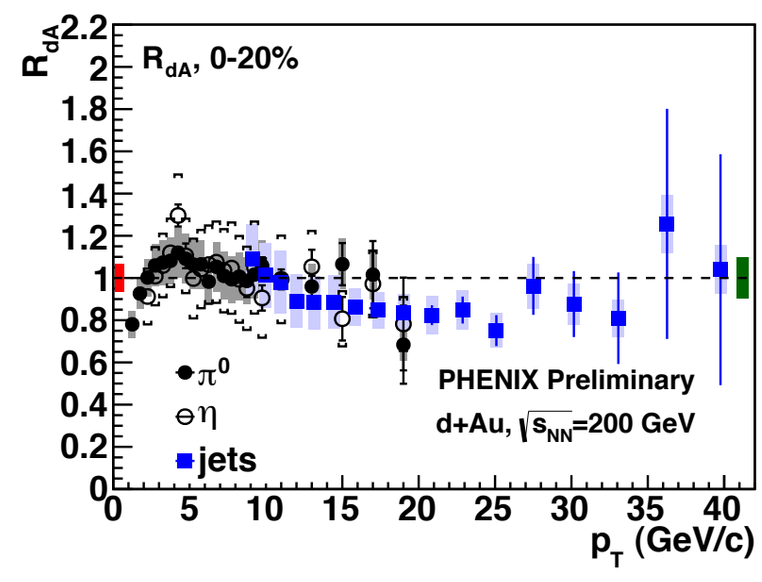
new results

- In all three channels, there is quite strong centrality dependence
- R_{dA} enhanced in peripheral, for π^0, η, and jets
- In central events, jets show some suppression (R_{dA}≈0.85) at high pT, π^0 and η show consistent behavior
- Though hints existed in old data, this is a surprise (comparison shown later)





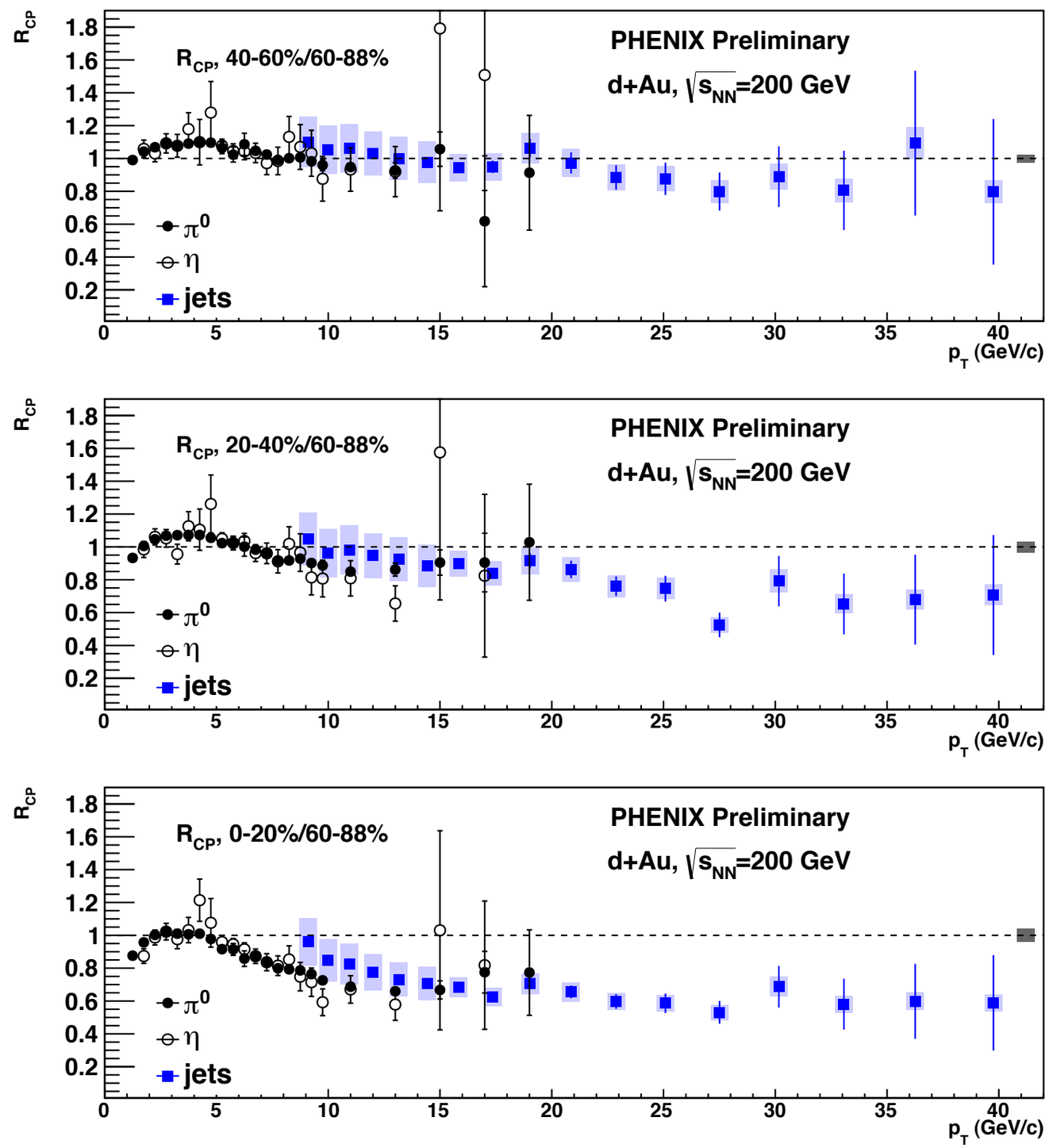




R_{CP}: another perspective of centrality dependence

new results

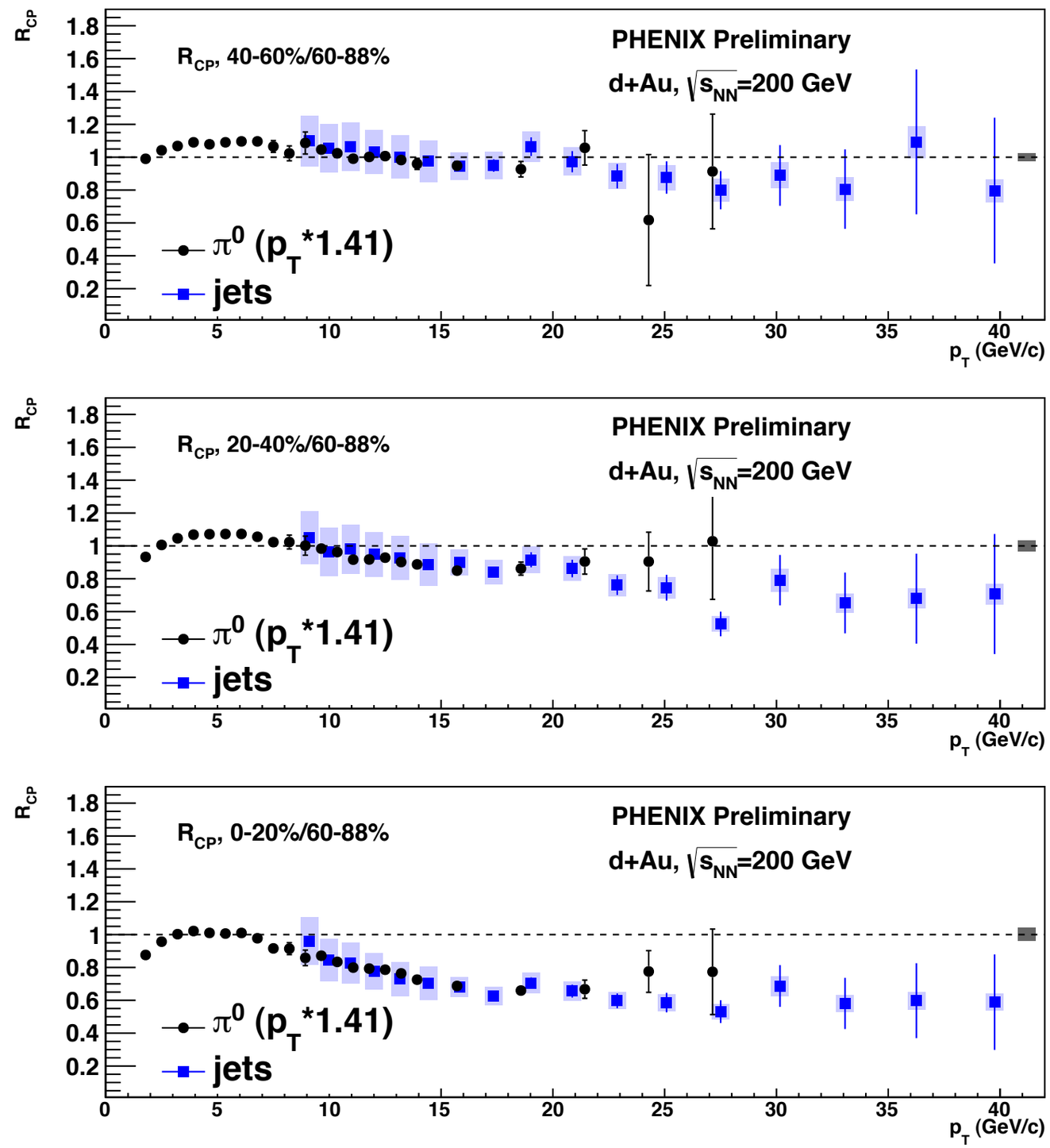
- R_{CP}, the ratio of the scaled yield in central divided by peripheral
  - Suppression of yield in central compared to peripheral collisions
  - Present in all three measurements



R_{CP}: another perspective of centrality dependence

new results

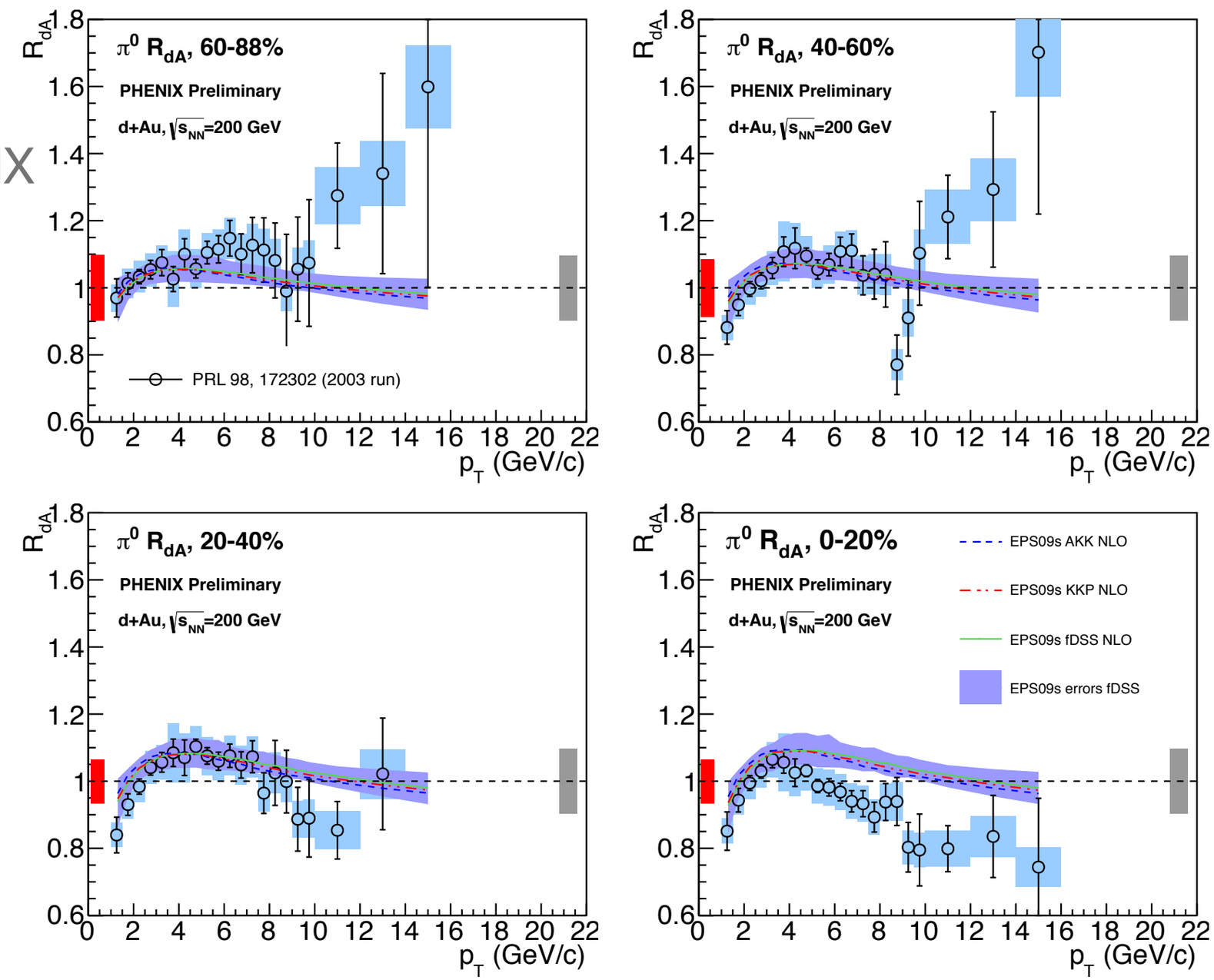
- R_{CP}, the ratio of the scaled yield in central divided by peripheral
  - Suppression of yield in central compared to peripheral collisions
  - Present in all three measurements
- Stretching the π^0 p_T with an empirical factor of 1/0.7
  - data align very well! Shape is the same after stretching
  - remember: high p_T hadrons are considered proxy for jets



EPS09s - does it describe the data?

- Does EPS09s explain the centrality dependence?
- n.b.: in their publication, PHENIX data were scaled up/down

2003 data

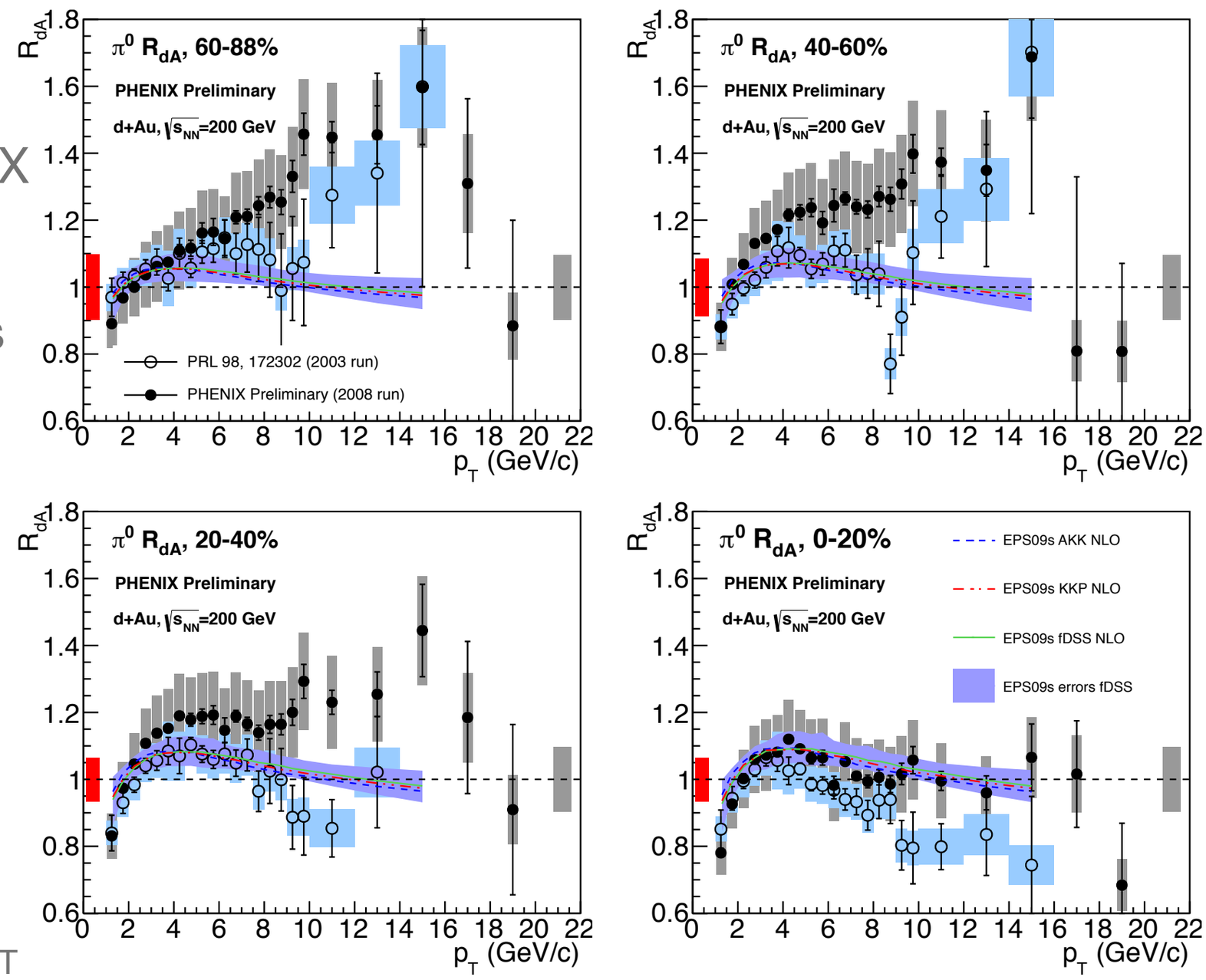


curves from arXiv:1205.5359

EPS09s - does it describe the data?

- Does EPS09s explain the centrality dependence?
- n.b.: in their publication, PHENIX data were scaled up/down
- Adding new data: EPS09s does not explain the centrality dependence!
  - reasonable agreement in central
  - however, does neither describe enhancement nor shape in peripheral
- insufficient constraint on high p_T from old data

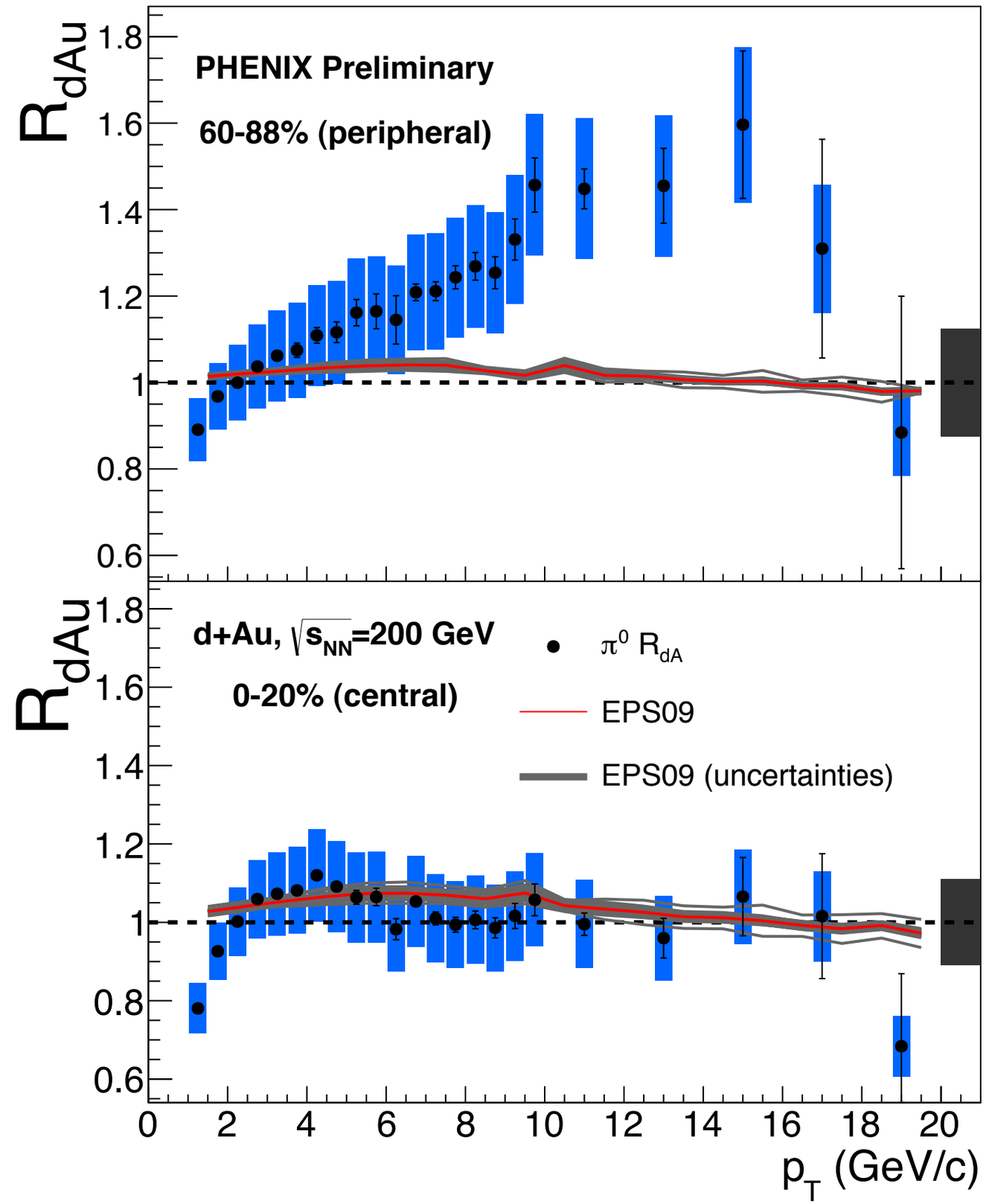
2003 and 2008 data



curves from arXiv:1205.5359

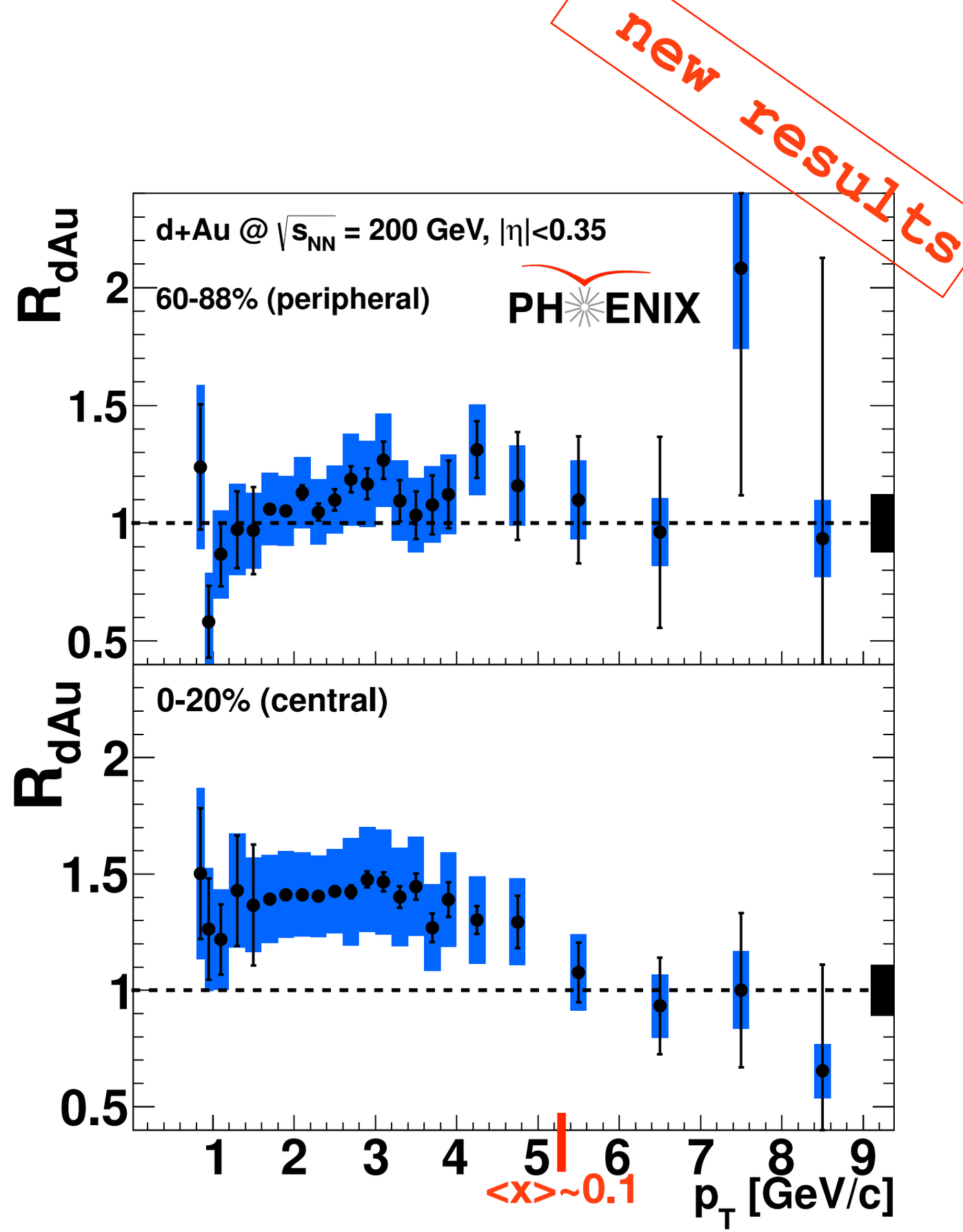
EPS09 with real PHENIX centrality

- Mapping centrality dependence as integrated longitudinal density through the nucleus, using EPS09 + Glauber MC + PYTHIA (x,Q^2)
- Using real PHENIX centrality distributions
- Leads also to only a weak centrality dependence
- Again, data is not matched in peripheral collisions
- It seems that T_A scaling does not work => different physics, beyond modified nPDFs



Heavy quarks

- Single electrons from heavy flavor decays
- Enhancement in central d+Au at intermediate p_T
  - Can this be Cronin enhancement?
  - Anti-shadowing is expected around <x>~0.1
- No suppression visible

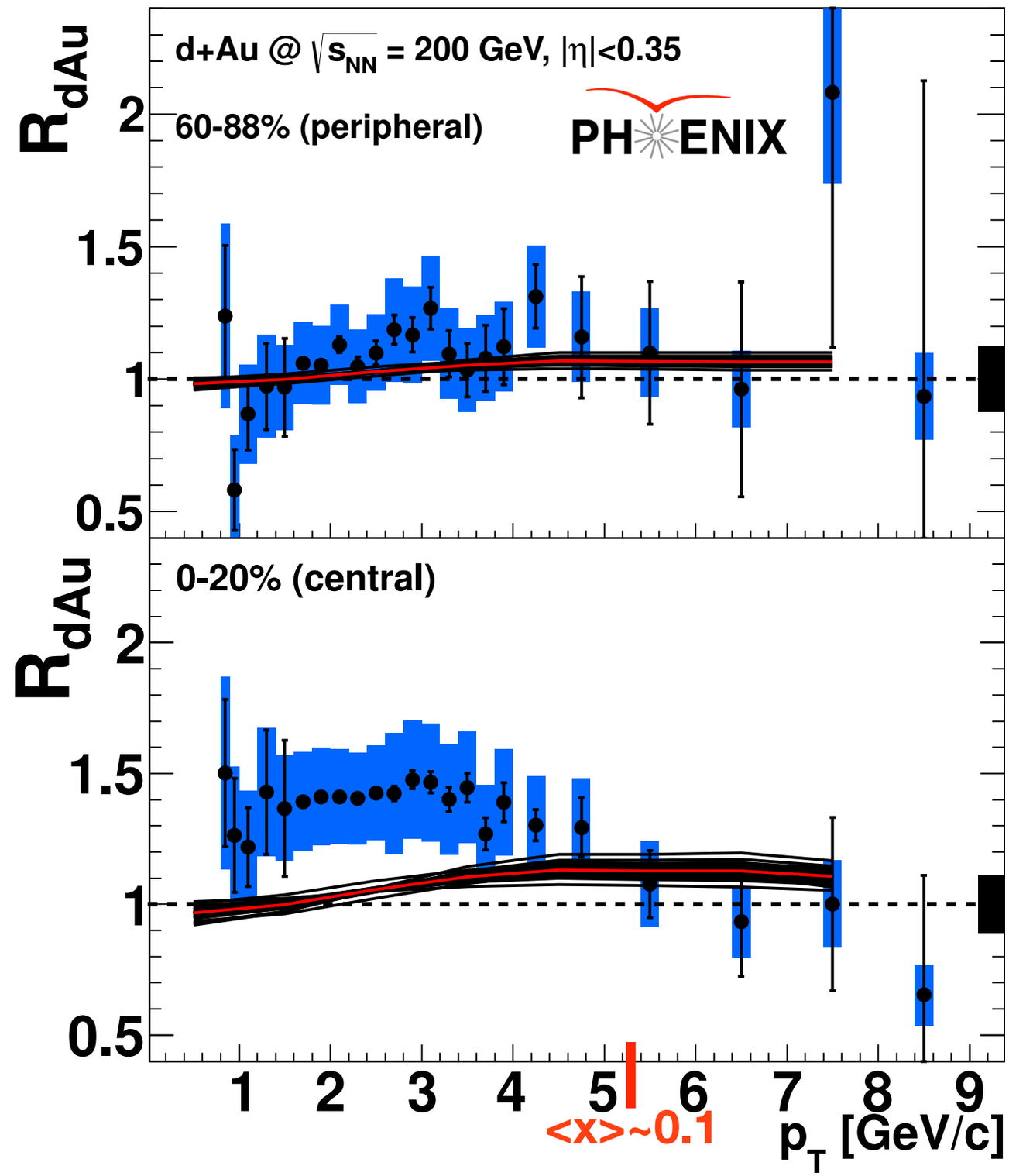


Submitted to PRL (arXiv:1208.1293)

Poster by Matt Durham

EPS09

- Comparison with EPS09, centrality dependence via integrated longitudinal density
- Works well in peripheral collisions
- Disagreement in enhancement region in central collisions
  - Calculation does not include Cronin enhancement!



Summary and outlook

- PHENIX measured centrality dependence of π^0, η, reconstructed jets, and electrons from heavy flavor, and minimum bias direct photons in d+Au
- Photons not modified, low p_T enhancement in Au+Au final state effect
- Quite strong centrality dependence of high p_T π^0, η, and jets with slight suppression in central and enhancement in peripheral collisions
  - EPS09 nuclear PDF does not describe this centrality dependence, are there additional mechanisms in peripheral d+Au?
- HF electrons enhanced at intermediate p_T in central collisions, not in peripheral
- Future: high statistics direct photon measurement with 2008 data
- Future detector upgrade (MPC-EX) will allow more precise measurements at forward rapidity

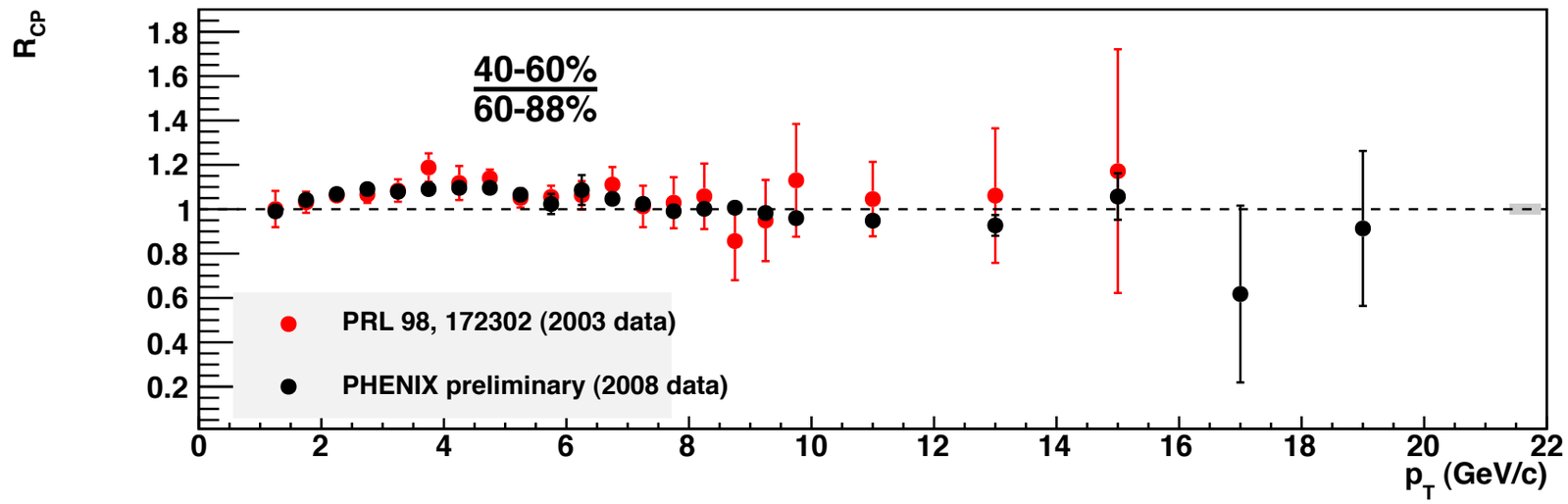
Related talks and posters

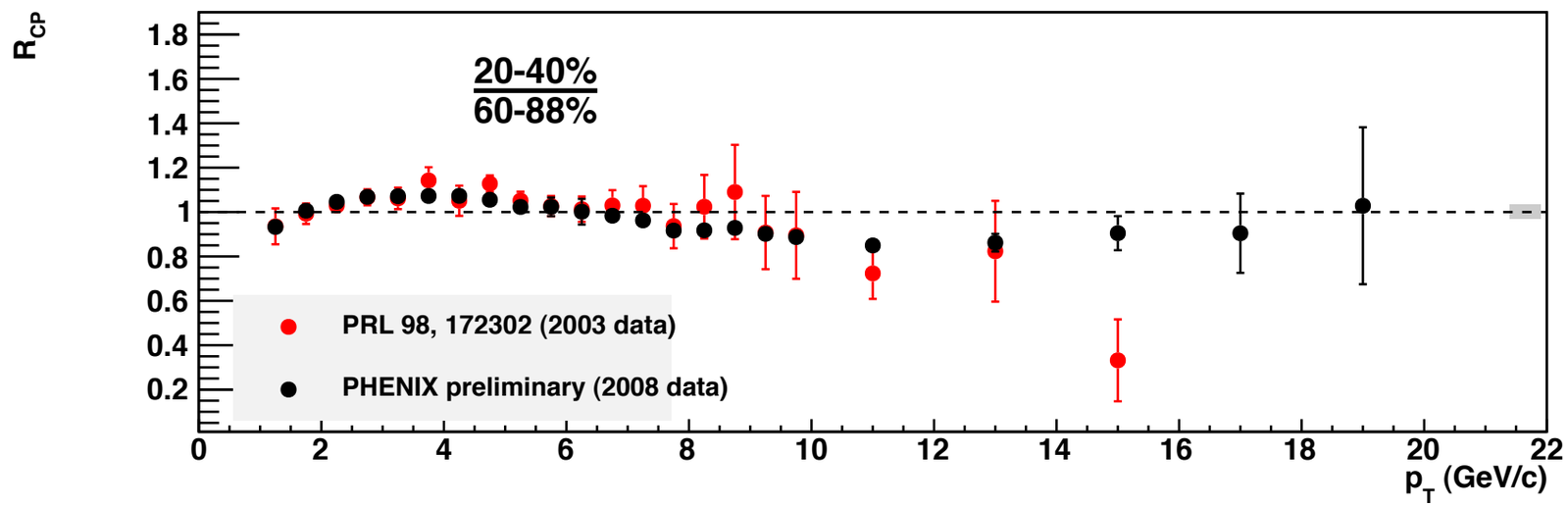
- Talks:
  - M. Wysocki (Monday plenary session, 15:05)
  - D. McGlinchey (Tuesday parallel 4 session, 15:15)
- Posters:
  - D. Perepelitsa
  - M. Durham

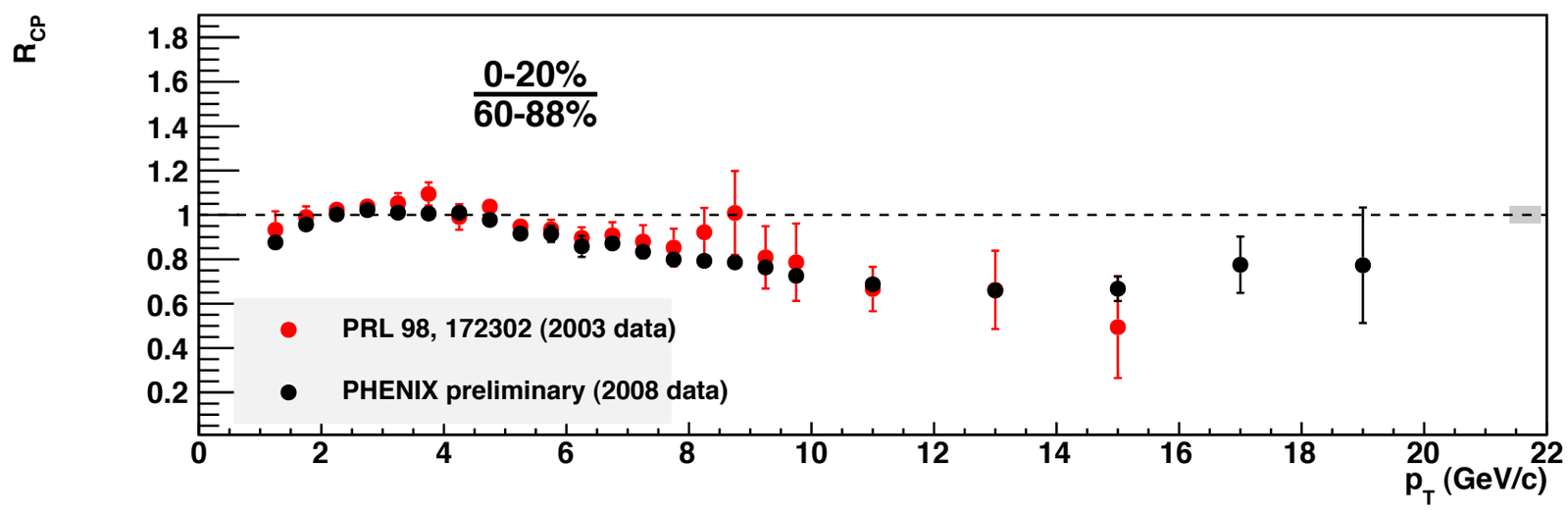
Backup

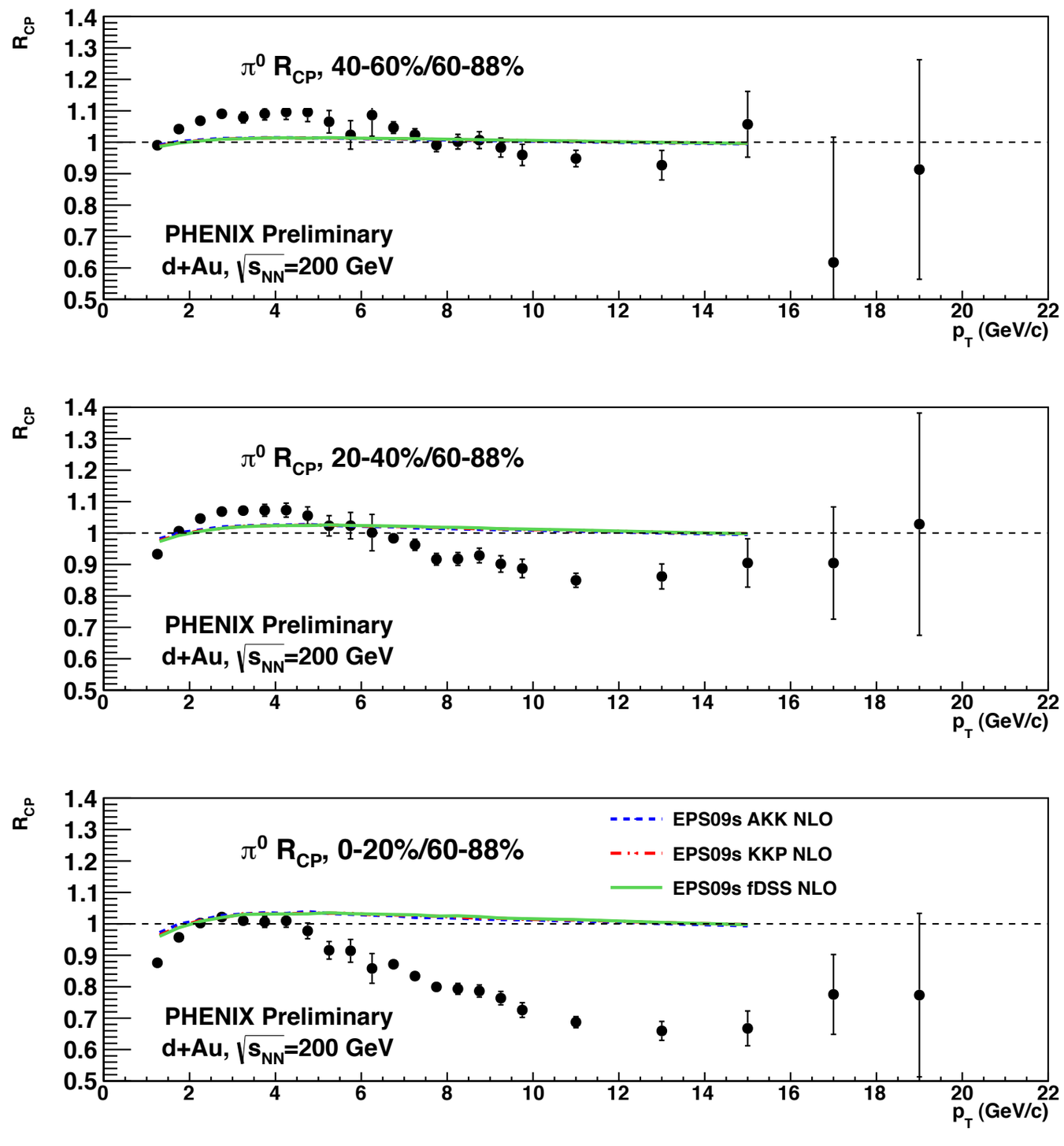
R_{CP} compared with the 2003 data

- They are the same
- Centrality dependence in d+Au is nothing new, but measured much more precise now







EPS09 - another look at the centrality dependence

- Calculating R_{CP} for EPS09s: does not predict a strong centrality dependence
- largest deviation from 1 for R_{CP} (from arXiv:1205.5359) at p_T~6 GeV/c when comparing central to peripheral
- No modification at high p_T in EPS09s, significant modification in PHENIX data