

# PHENIX results on jets in d+Au

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*for the PHENIX Collaboration*

QM 2015

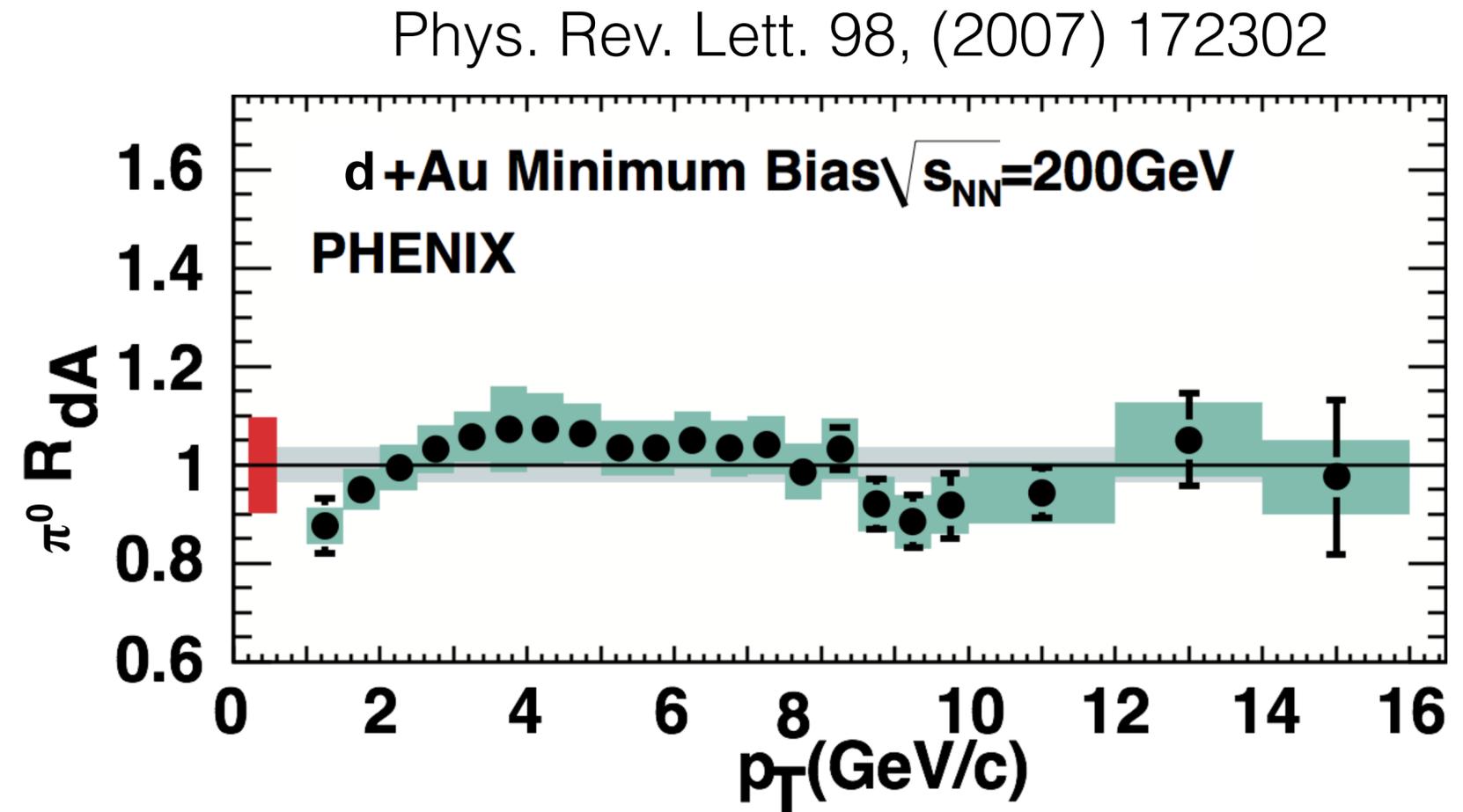
Kobe, Japan

Sept. 29<sup>th</sup>, 2015



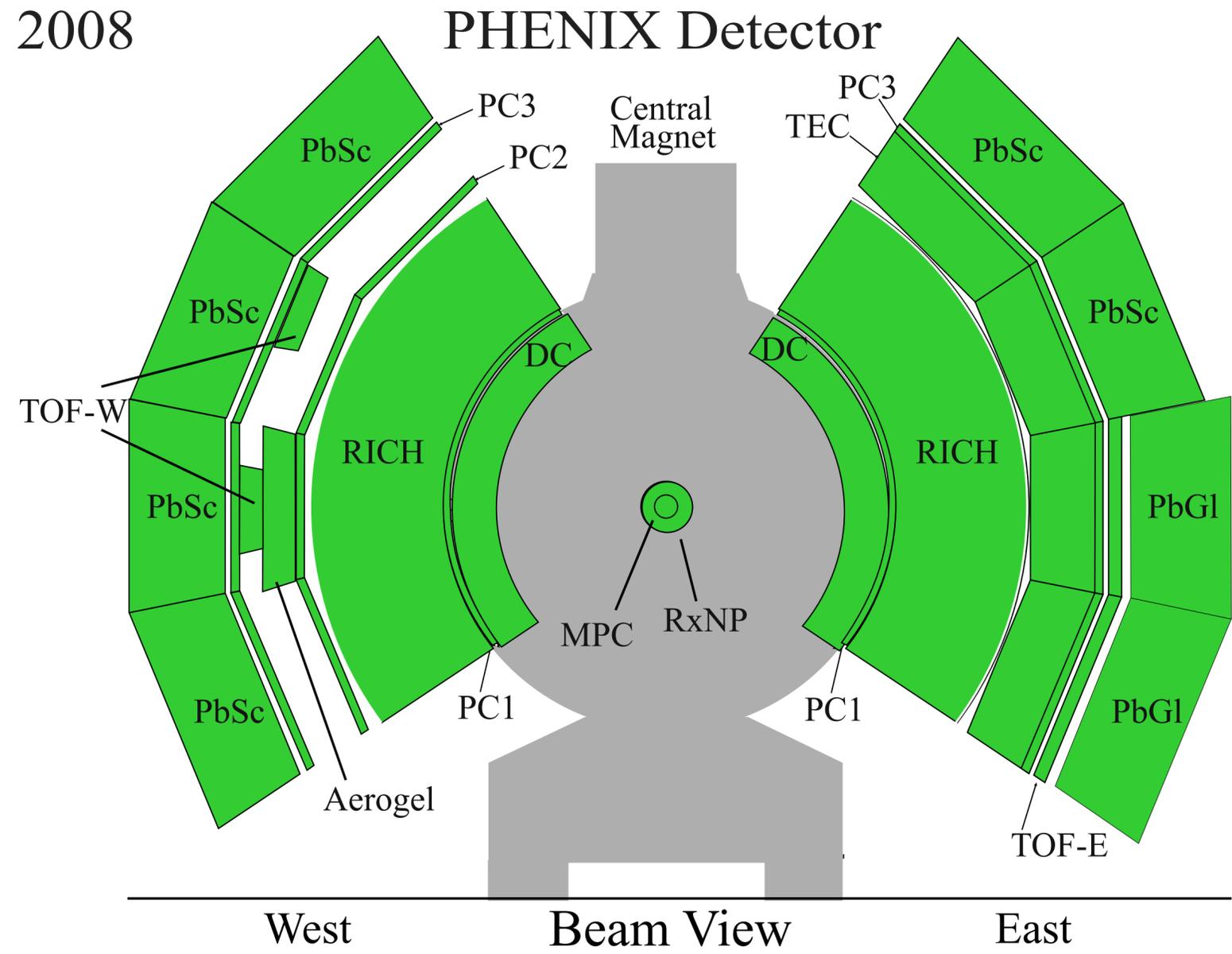
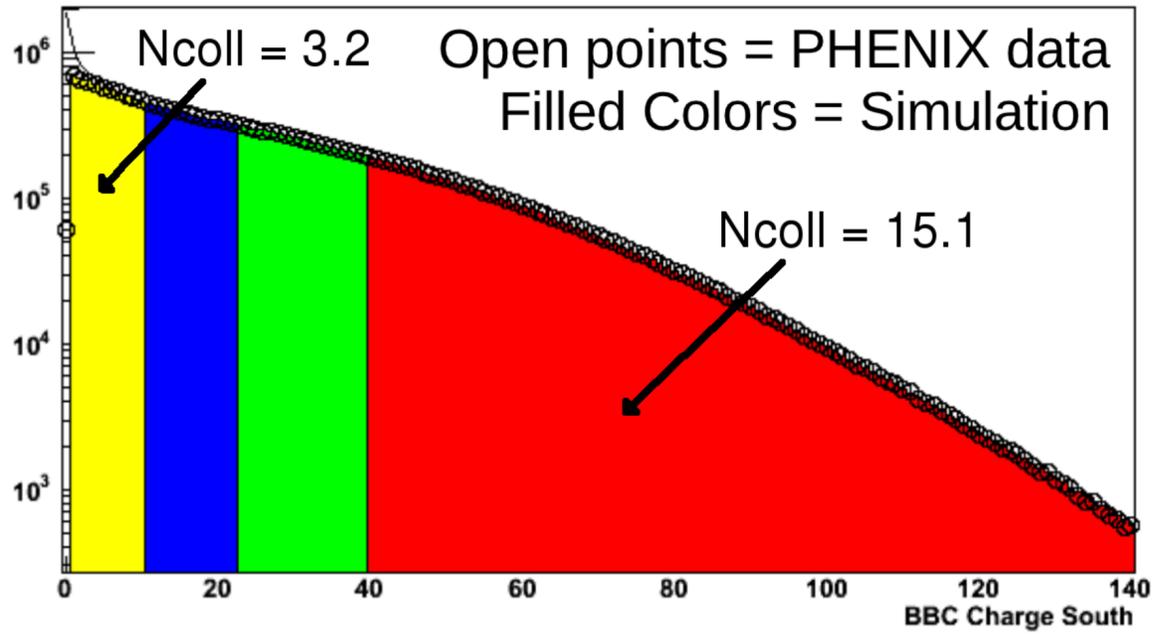
# hard probes in d+Au

- **Baseline for Au+Au**
  - important component in understanding observed HI suppression
- **probe cold nuclear matter effects**
  - sensitive to modification to nuclear PDFs
  - test of initial state energy loss estimates
- **are there medium effects in small systems?**
  - bulk observables show intriguing hints of medium in small systems



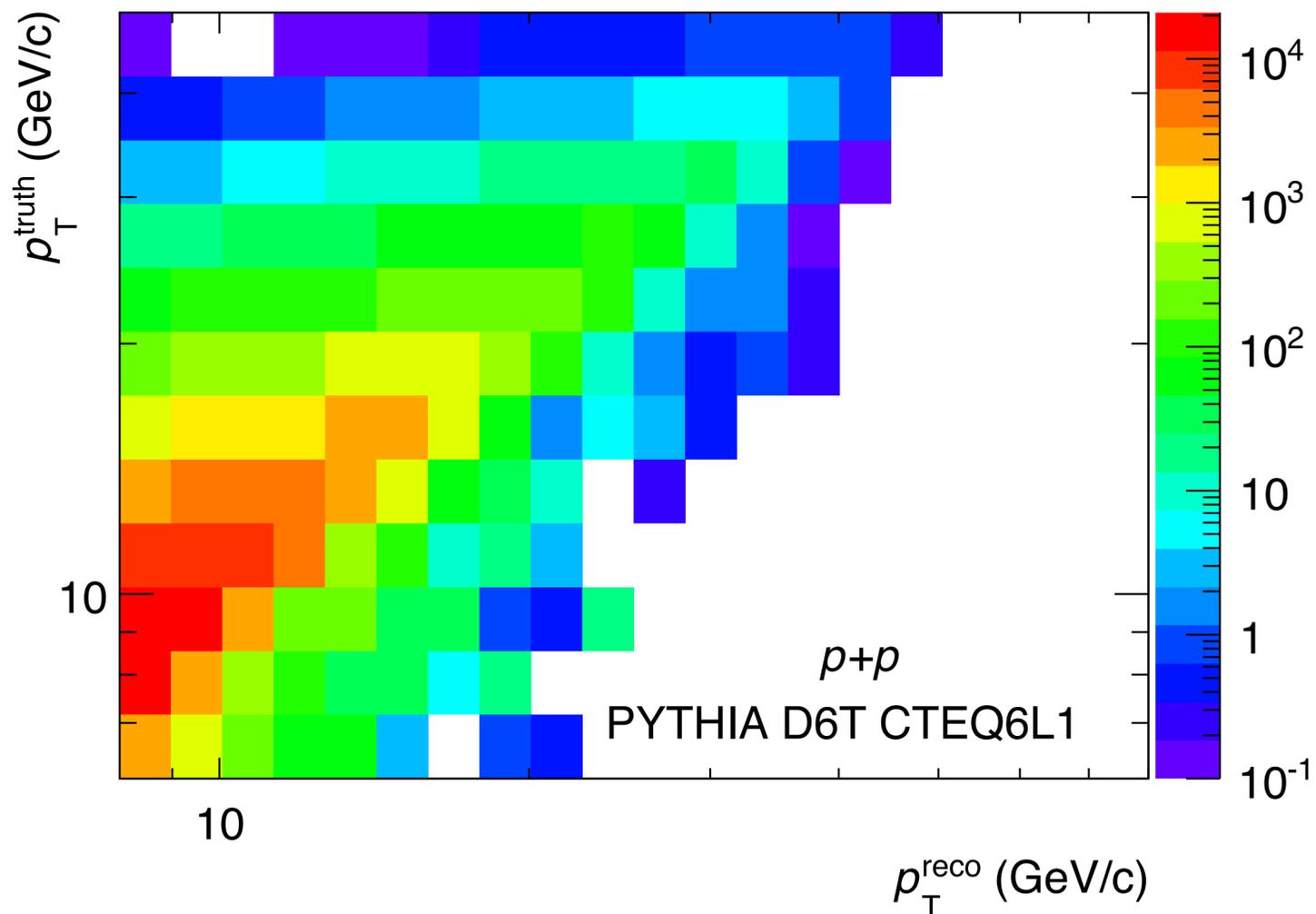
# Measuring jets in PHENIX

- **Jets reconstructed using central arm tracking + EMCal**
  - charged particles ( $h^\pm, e^\pm$ ) using DC + PC
  - neutral particles ( $\gamma, \pi^0, \eta$  / etc.) using EMCal
- **Centrality determined using Au-going beam-beam counter**



**central arms:  $|\eta| < 0.35, \Delta\phi = \pi$**   
**East arm only**

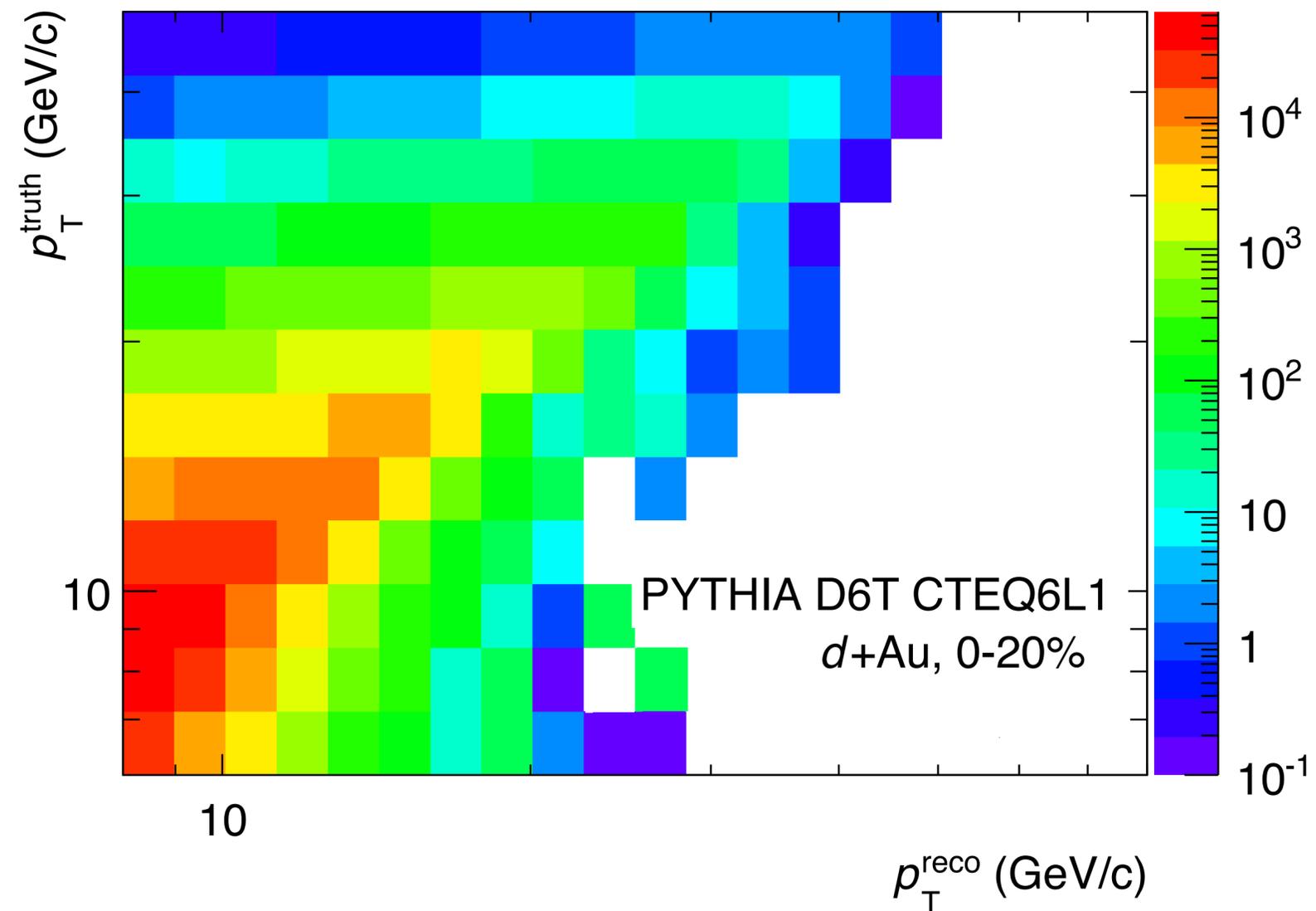
# Measuring jets in PHENIX



- 2008  $\sqrt{s} = 200$  GeV p+p and d+Au
- Jets reconstructed using anti- $k_T$   $R=0.3$ 
  - track  $p_T > 0.4$  GeV/c
  - cluster  $E > 0.4$  GeV
  - recovers ~65-70% of jet energy
- Jet-level cuts
  - particle multiplicity  $\geq 3$
  - charged fraction  $< 0.75$
  - jet axis to edge:  $\Delta\eta > 0.05$ ,  $\Delta\phi > \pi/64$
- careful control of acceptance
- detector effects corrected for using SVD unfolding procedure

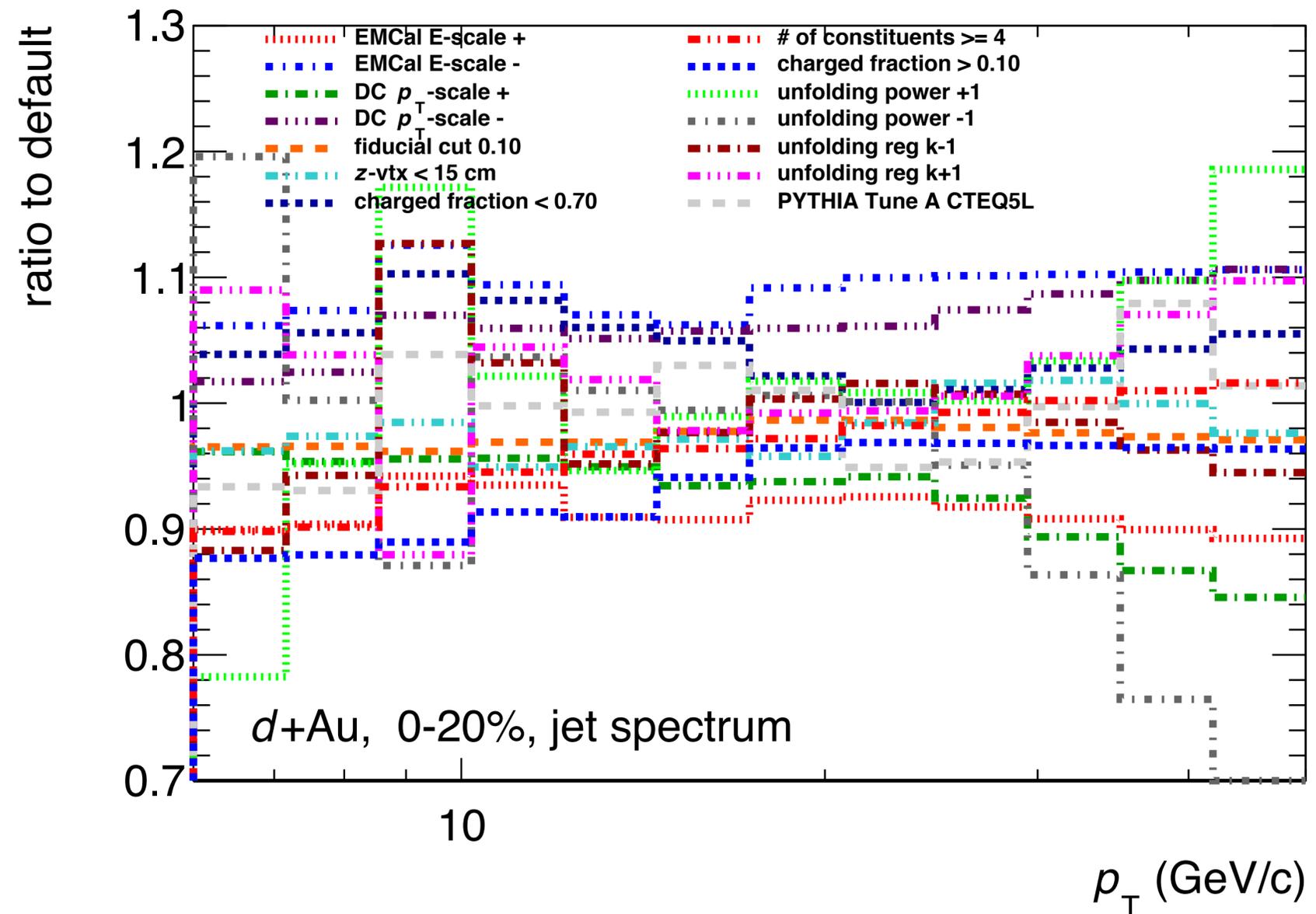
# Measuring jets in PHENIX

- **PYTHIA embedded in d+Au data to correct for underlying event**
  - $\langle p_T \rangle < 10\%$  of jet  $p_T$  at 20 GeV
  - fluctuations add  $\sim 1\%$  to resolution
- **Systematics determined by varying range of jet selection criteria, unfolding procedure and energy scale uncertainties**
  - many are common to p+p and d+Au and will cancel in  $R_{dA}$  and  $R_{CP}$



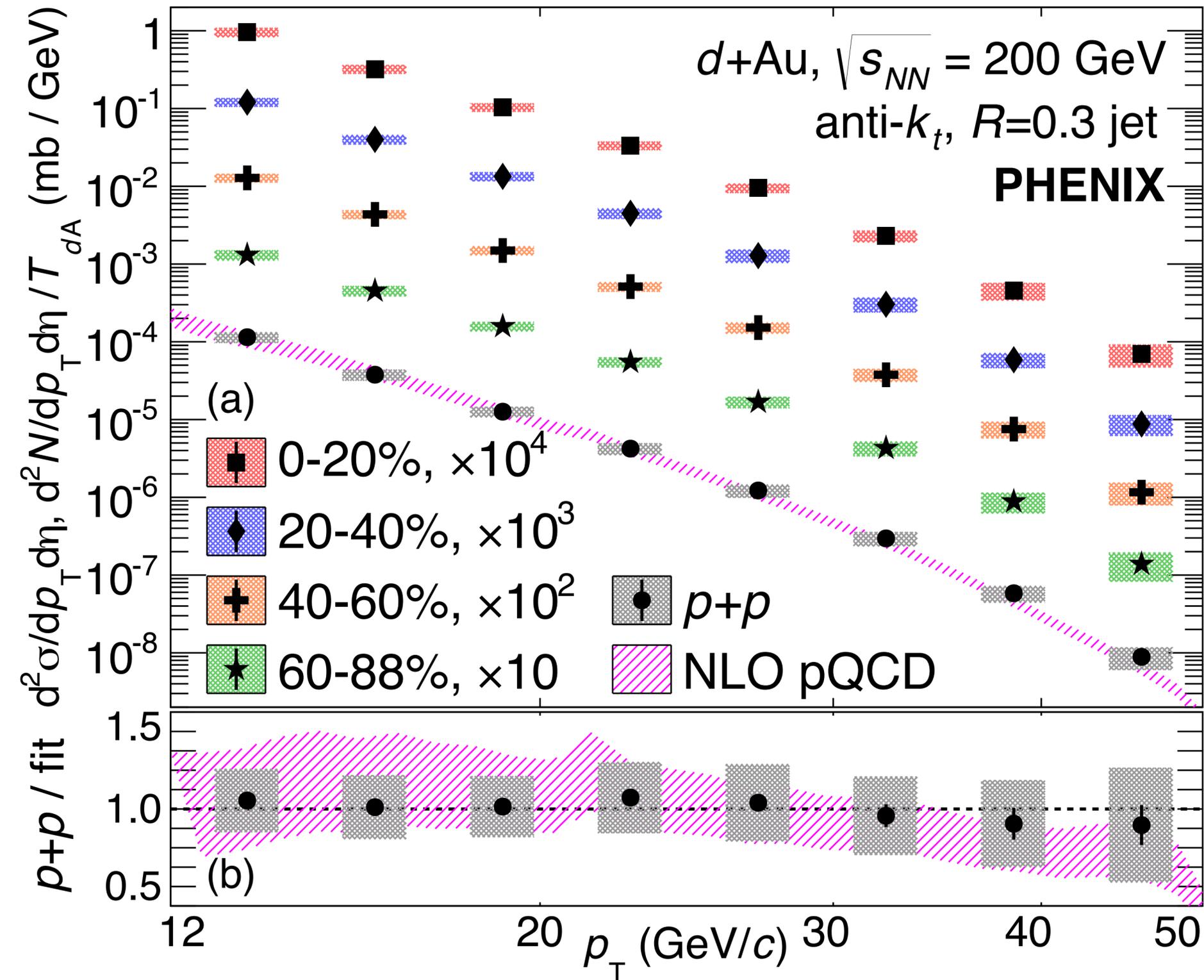
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# Inclusive jet yields

arXiv:1509.04657[nucl-ex]

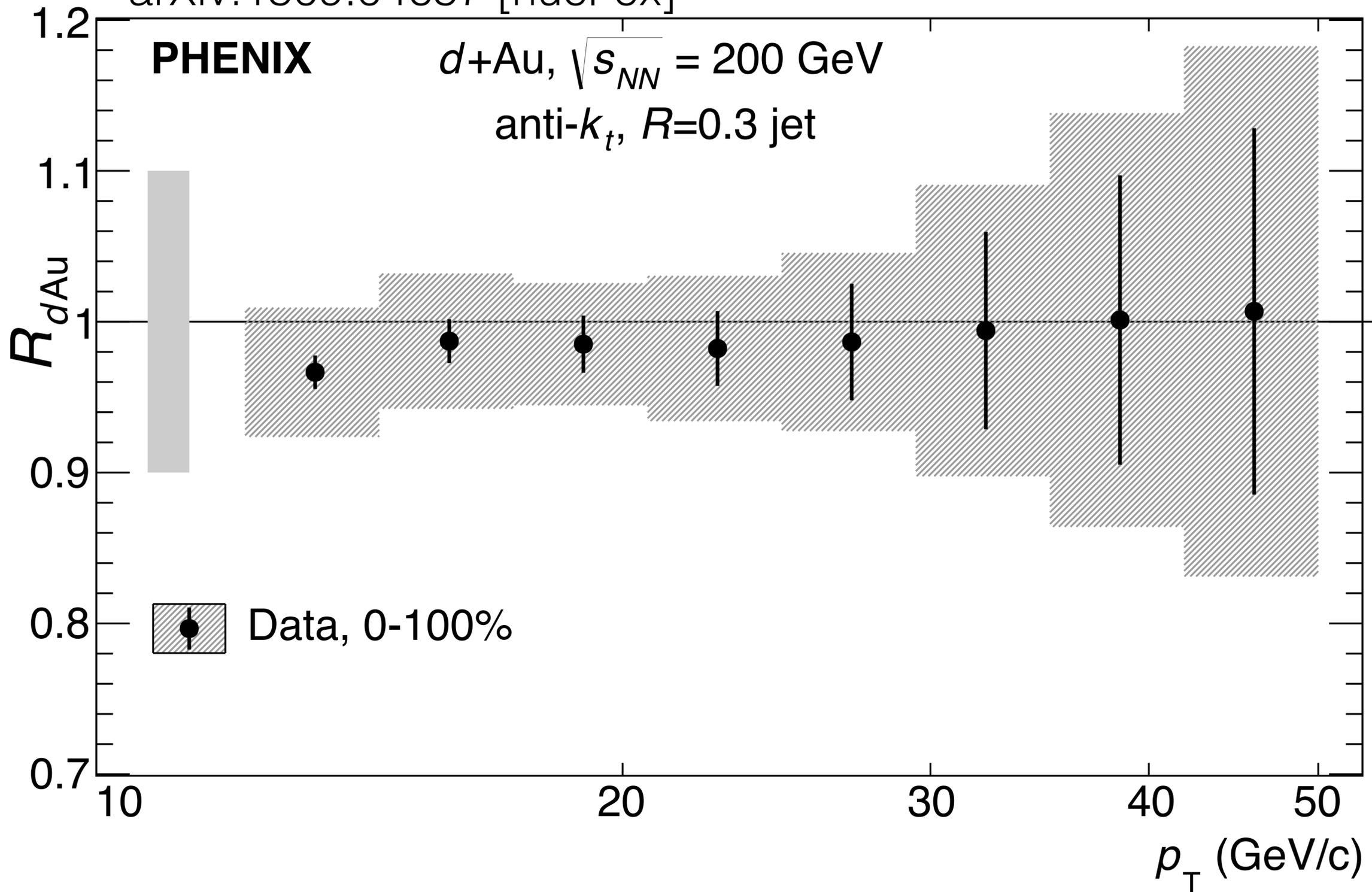


- first published jet results from PHENIX!

- spectra spanning large kinematic range

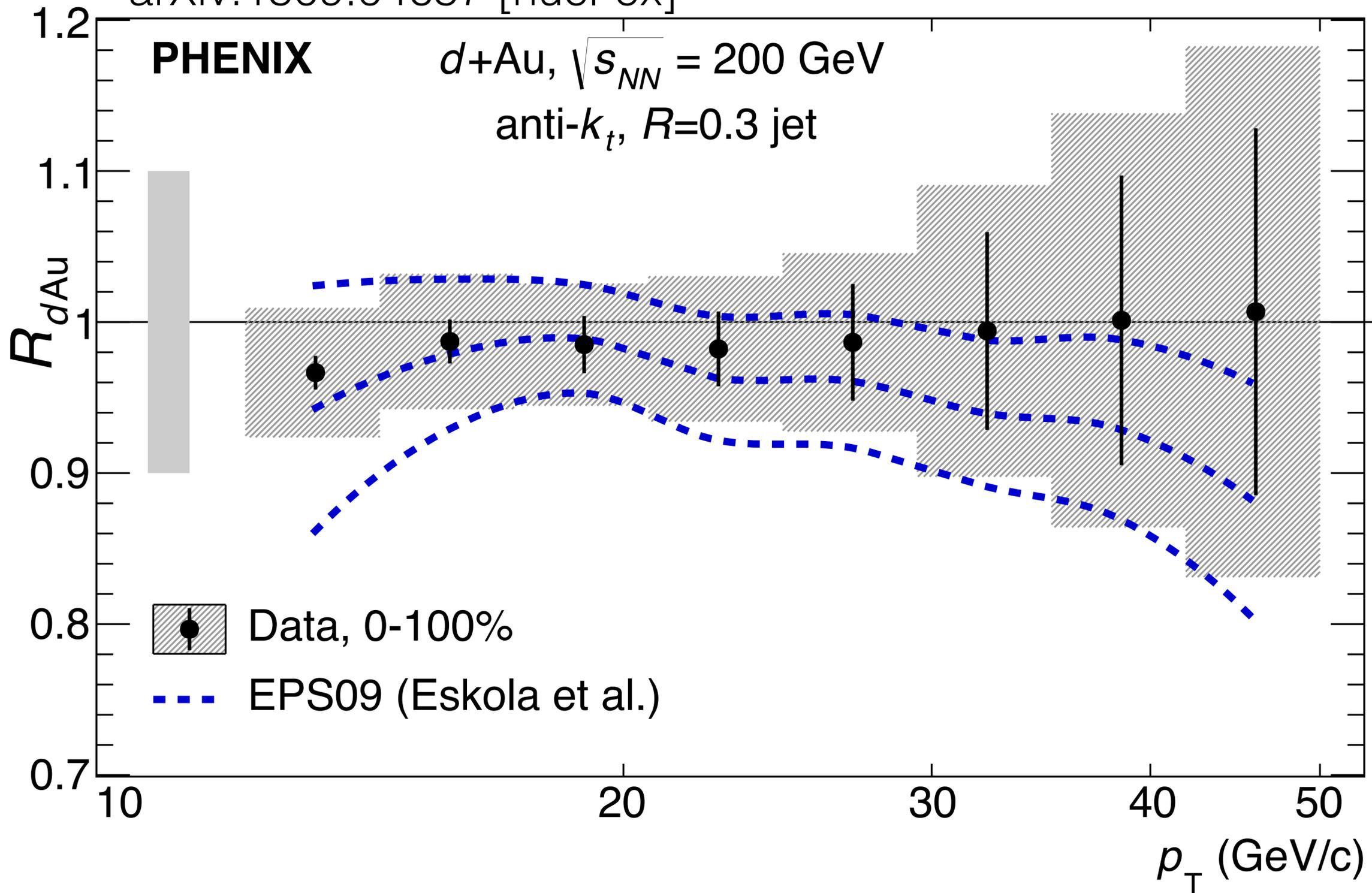
# Minimum bias d+Au jets

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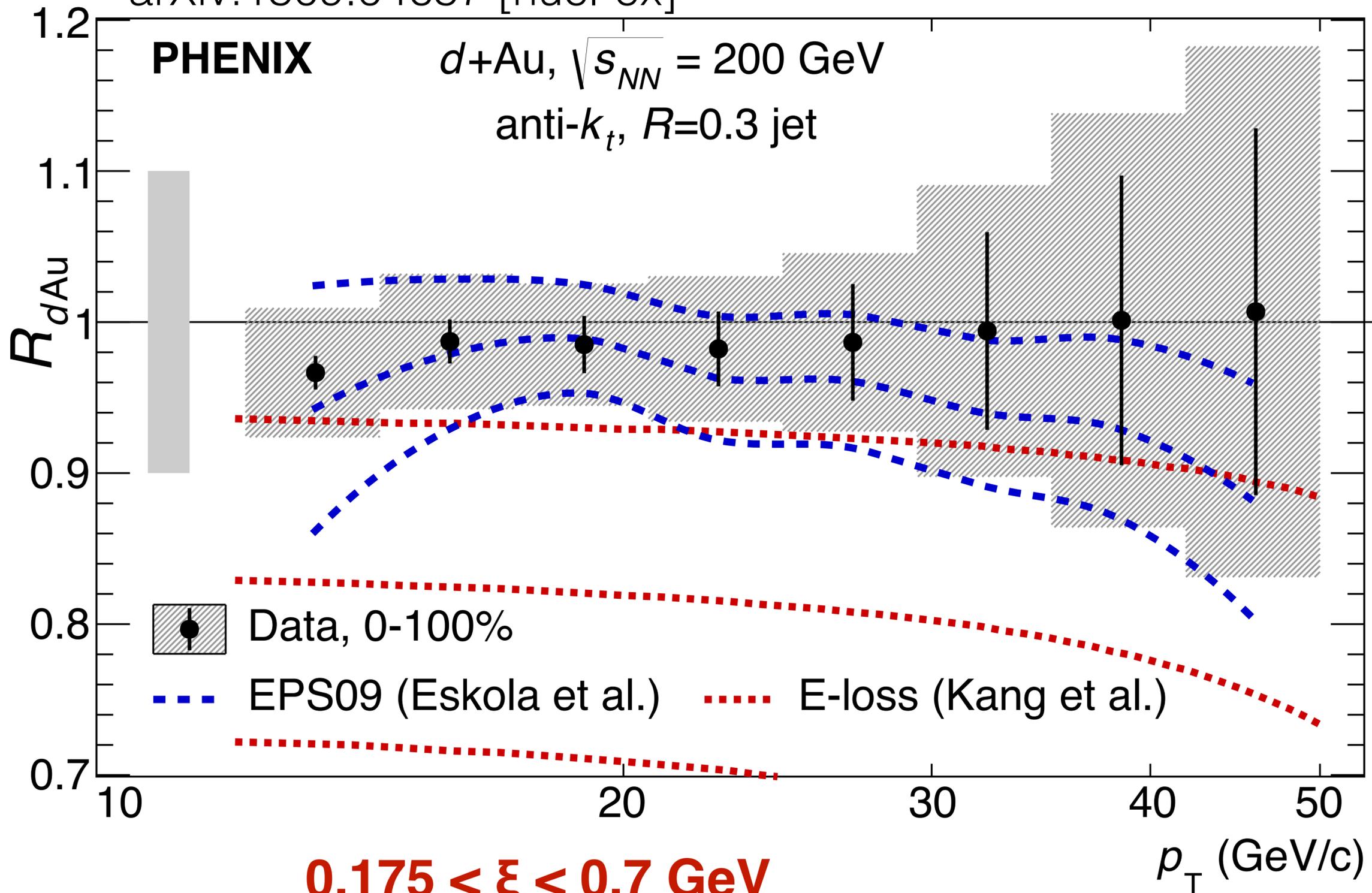
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consistent with nPDF  
calculations

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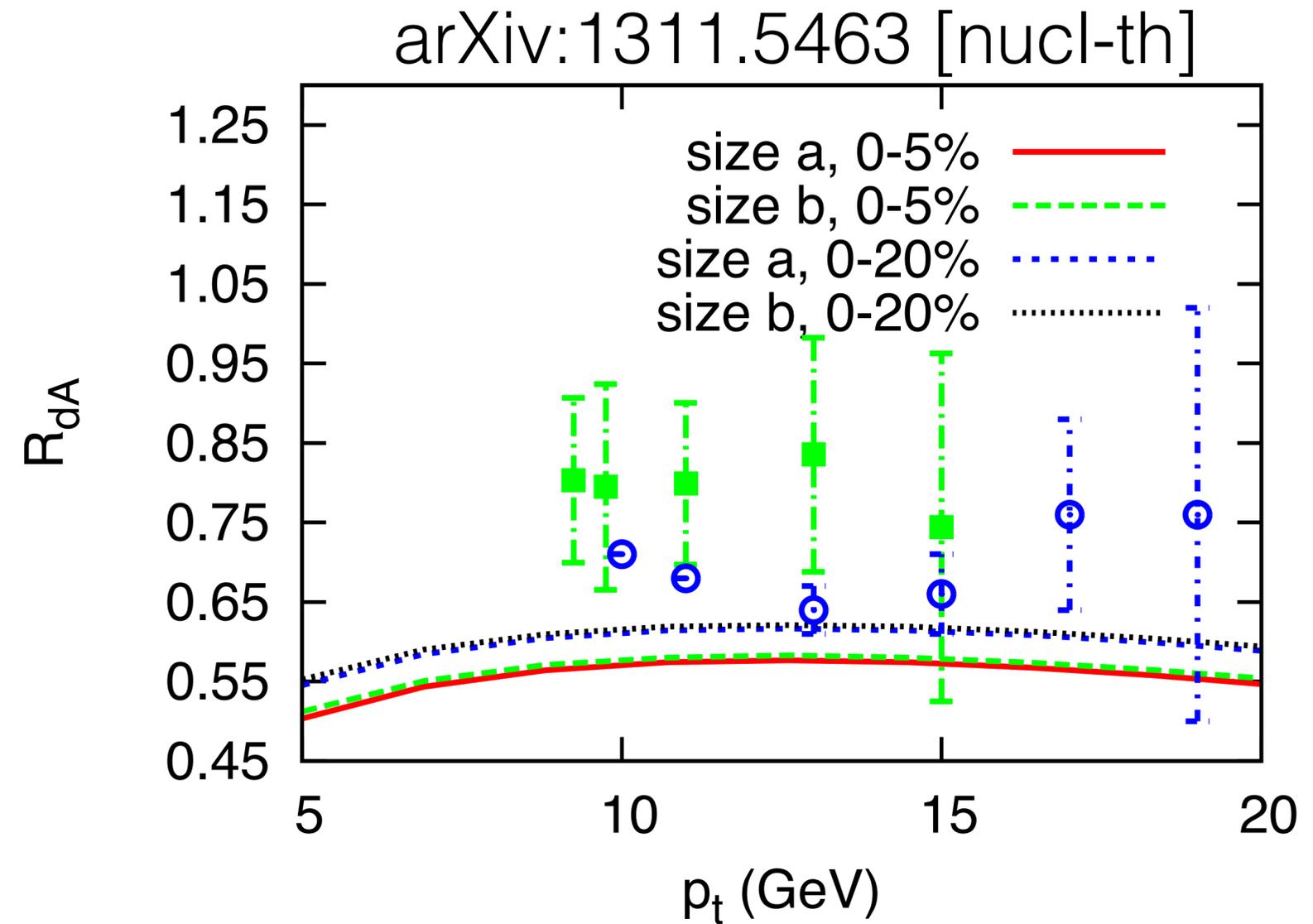
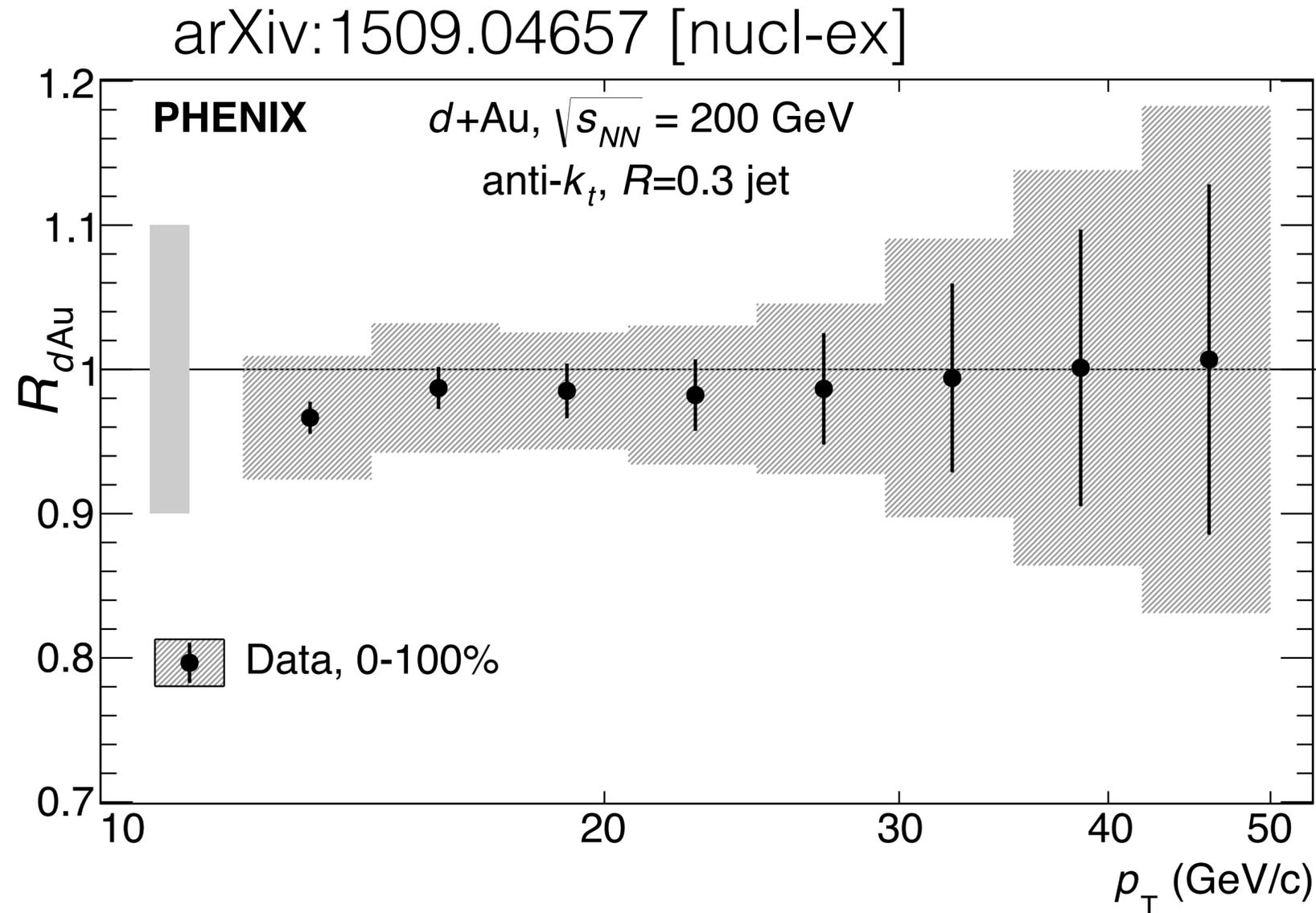


consistent with nPDF  
calculations

favors small momentum  
transfer within  
CNM E-loss calculations

**$0.175 < \xi < 0.7$  GeV**  
**( $\xi = p_T$  transfer per scattering)**

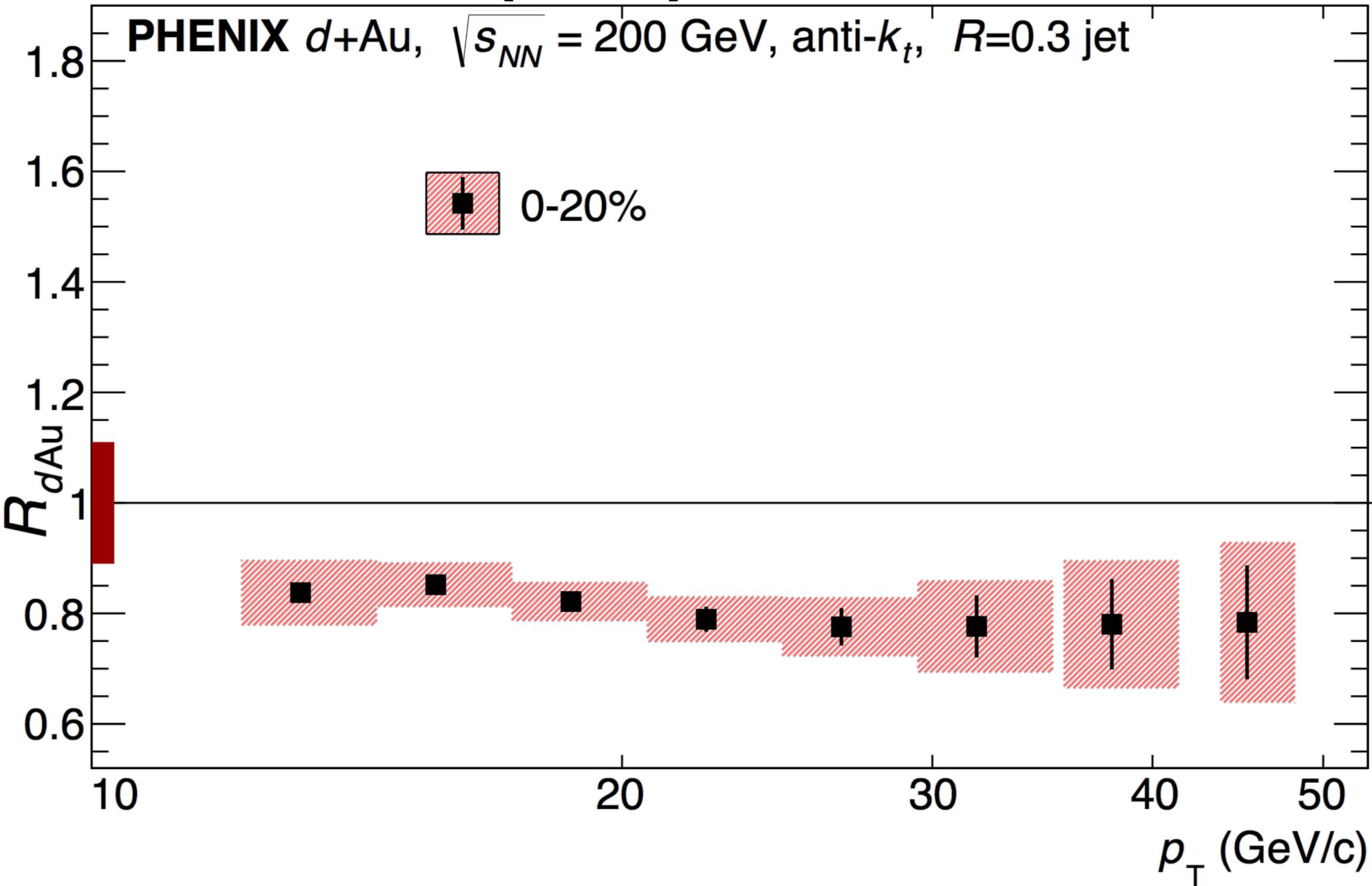
# room for hot medium effects?



- hot medium energy loss calculations for single hadrons show measurable suppression
  - need calculations for inclusive jets

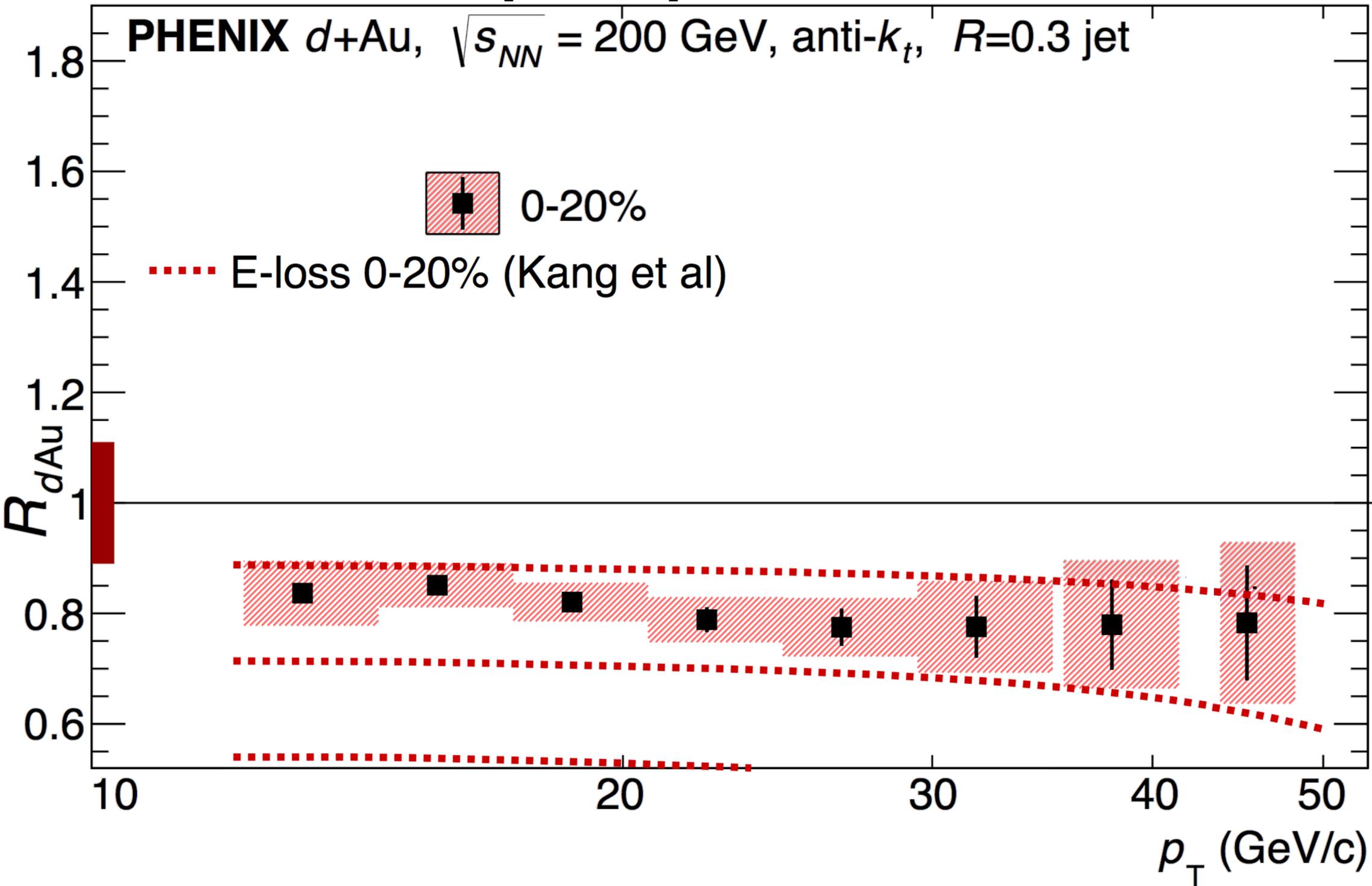
# Centrality dependence of jet modification

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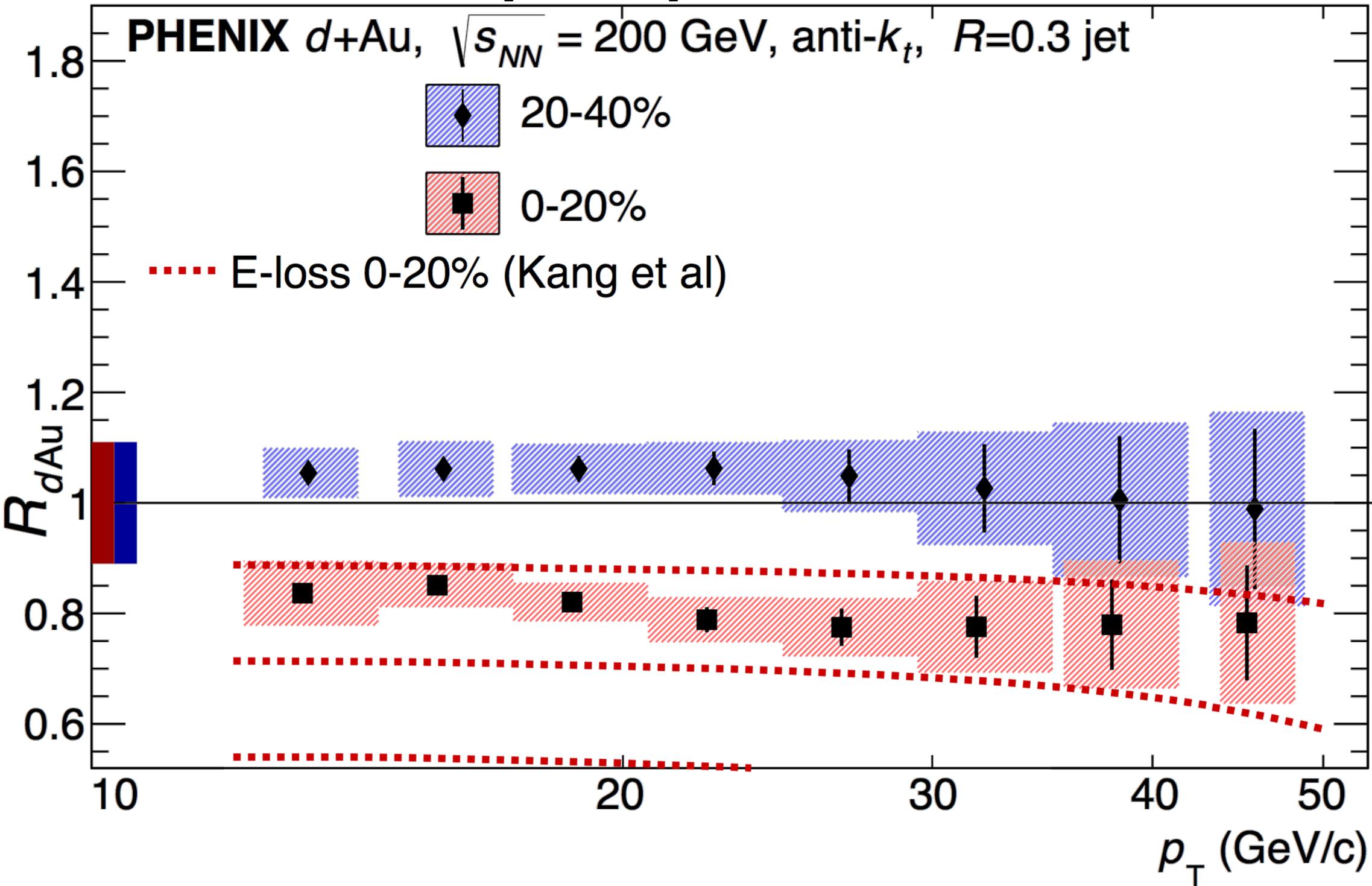
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- central  $d+Au$  shows suppression consistent with modest CNM E-loss

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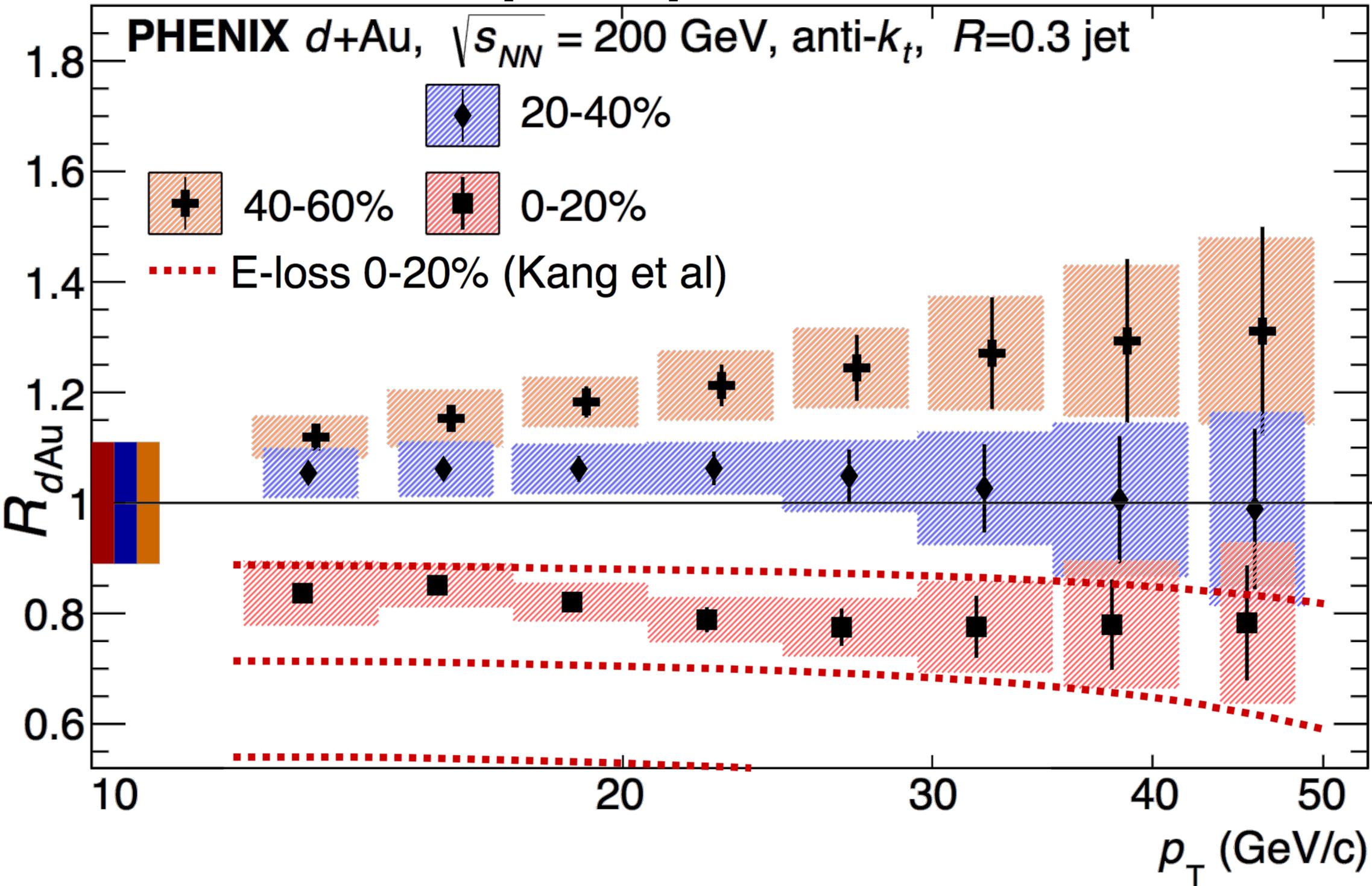
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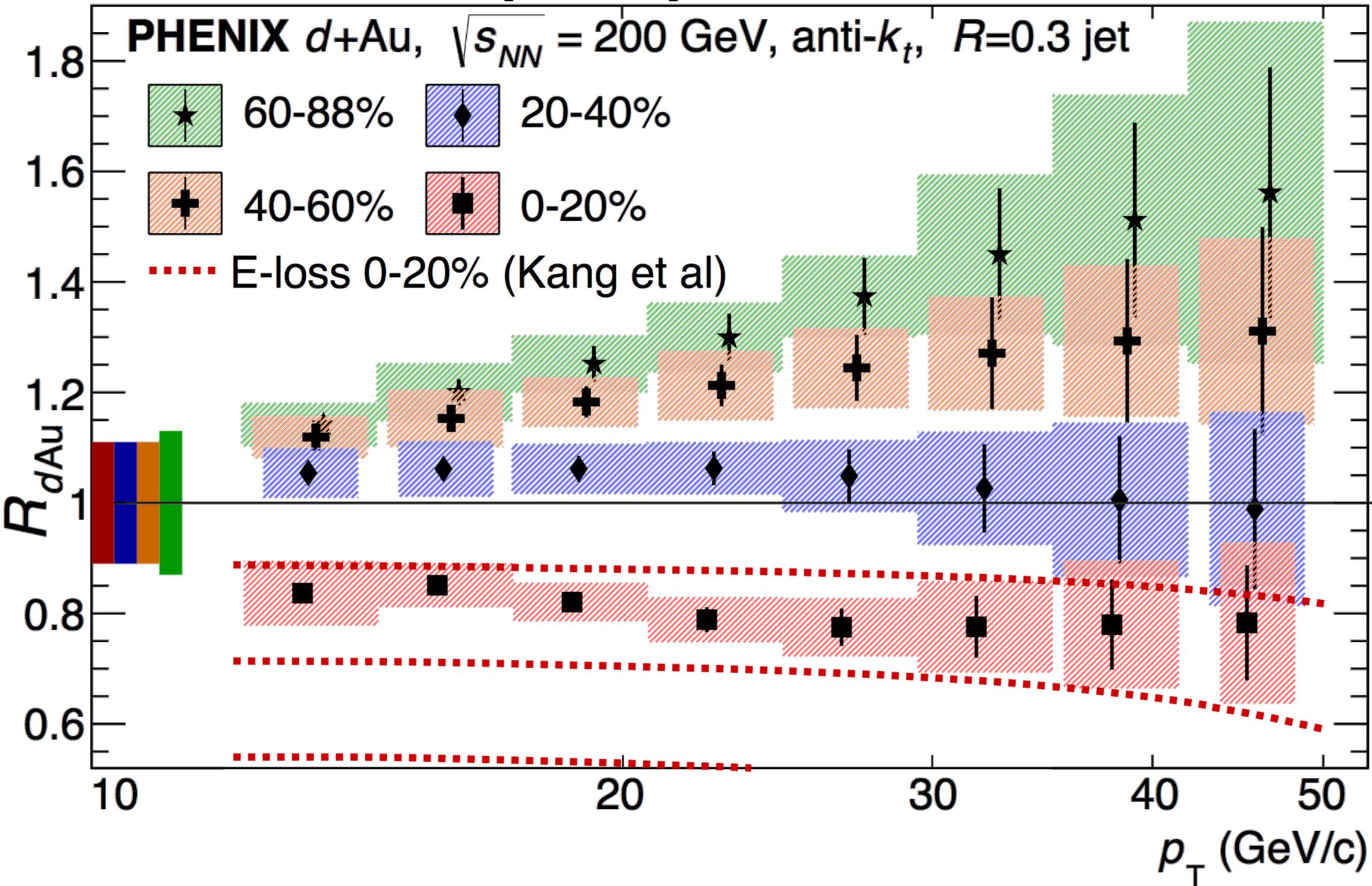
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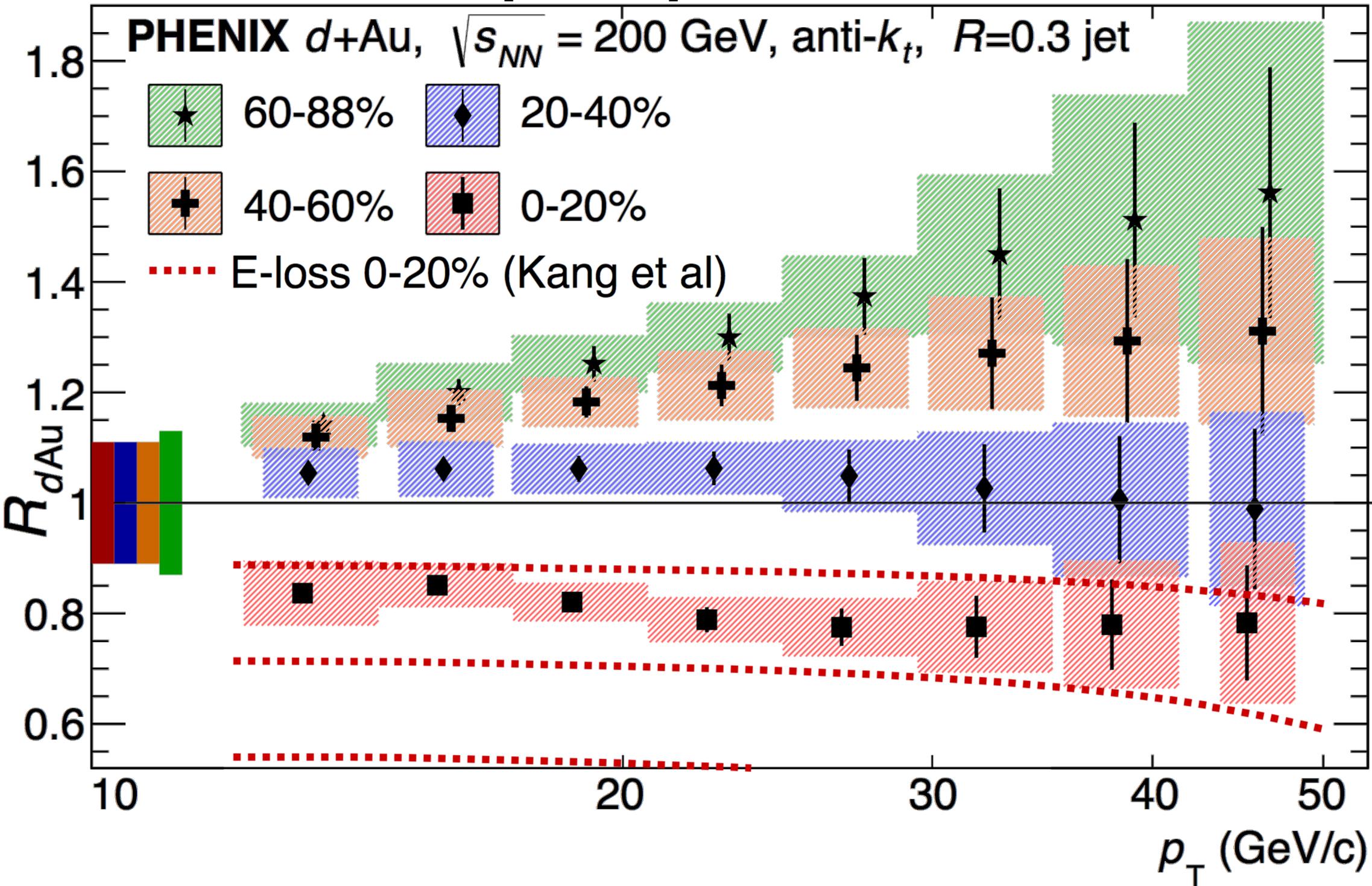
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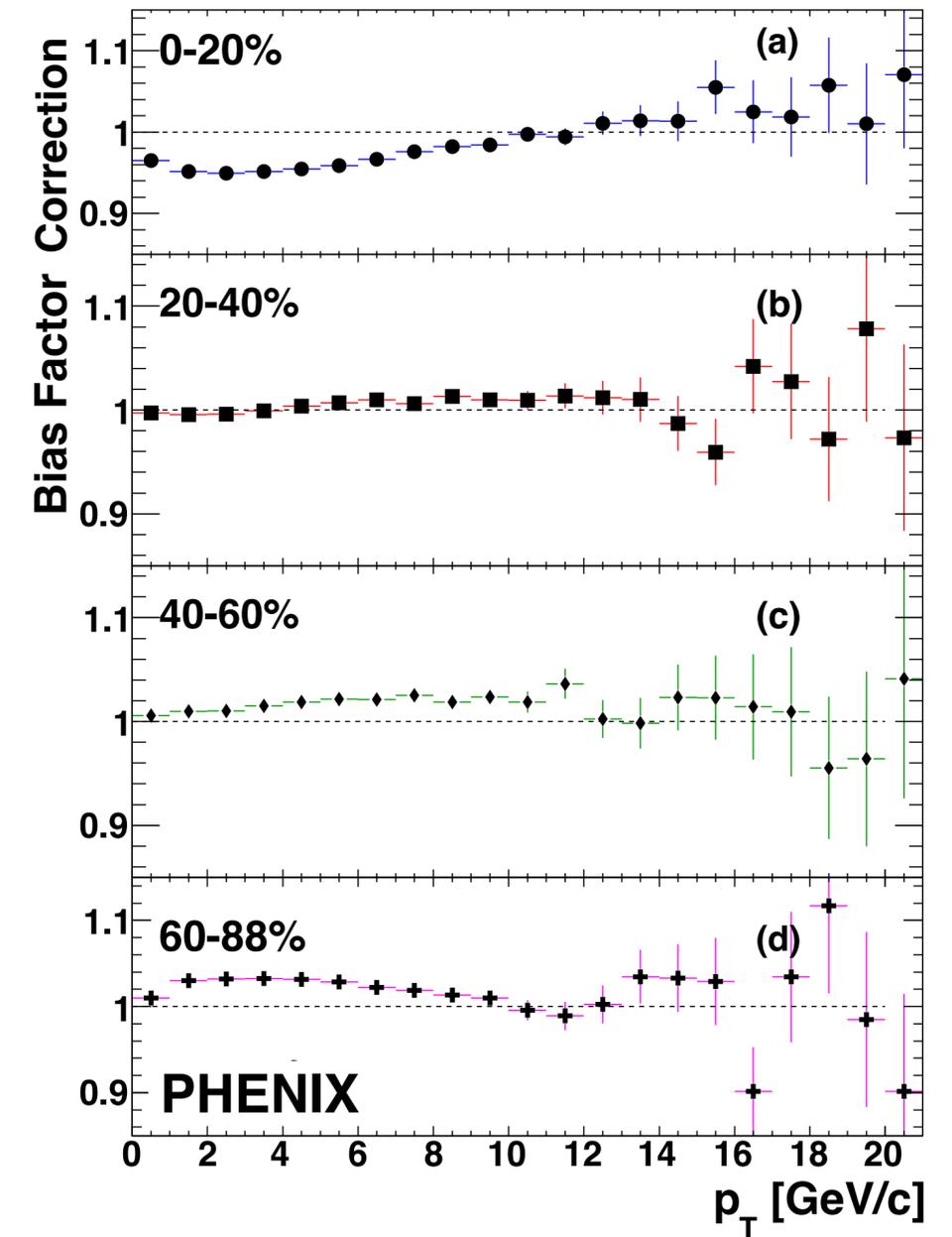
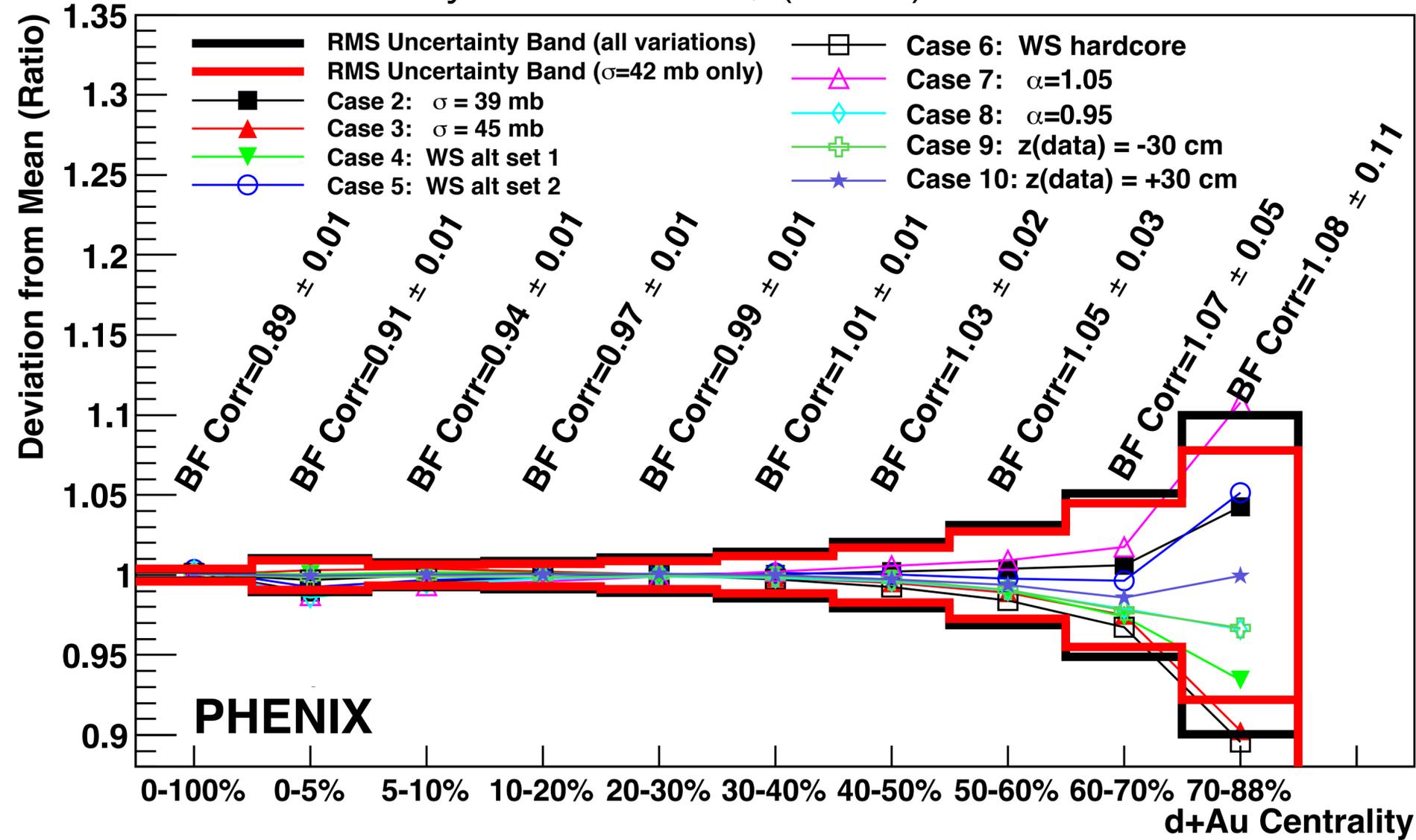
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- central  $d+Au$  shows suppression consistent with modest CNM E-loss
- enhancement seen in peripheral events presents a challenge
  - cannot be explained by trivial multiplicity bias in centrality determination

# Multiplicity bias effects

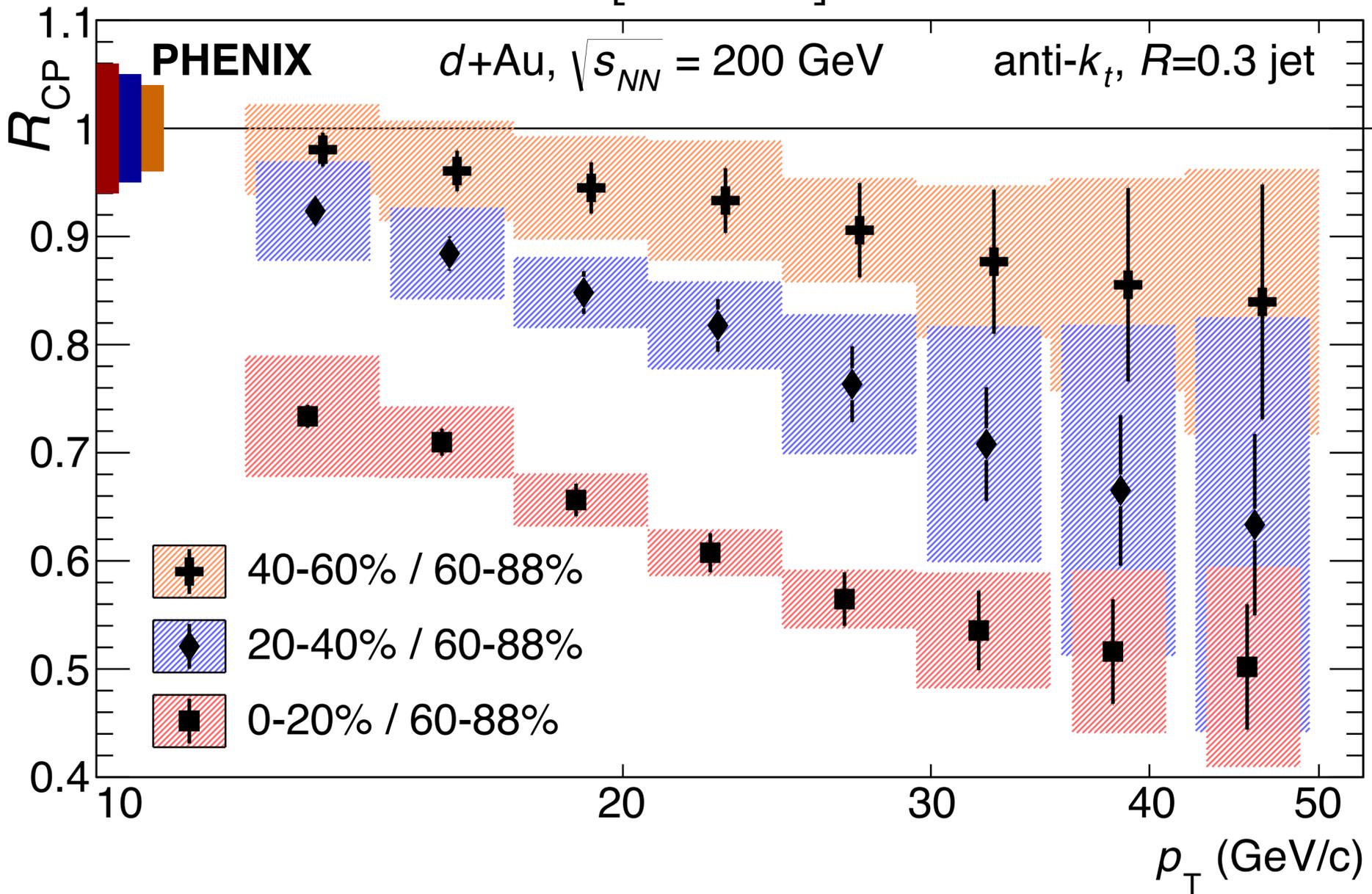
Phys. Rev. C 90, (2014) 034902



Auto-correlation bias effect studied by PHENIX using Glauber+NBD and HIJING

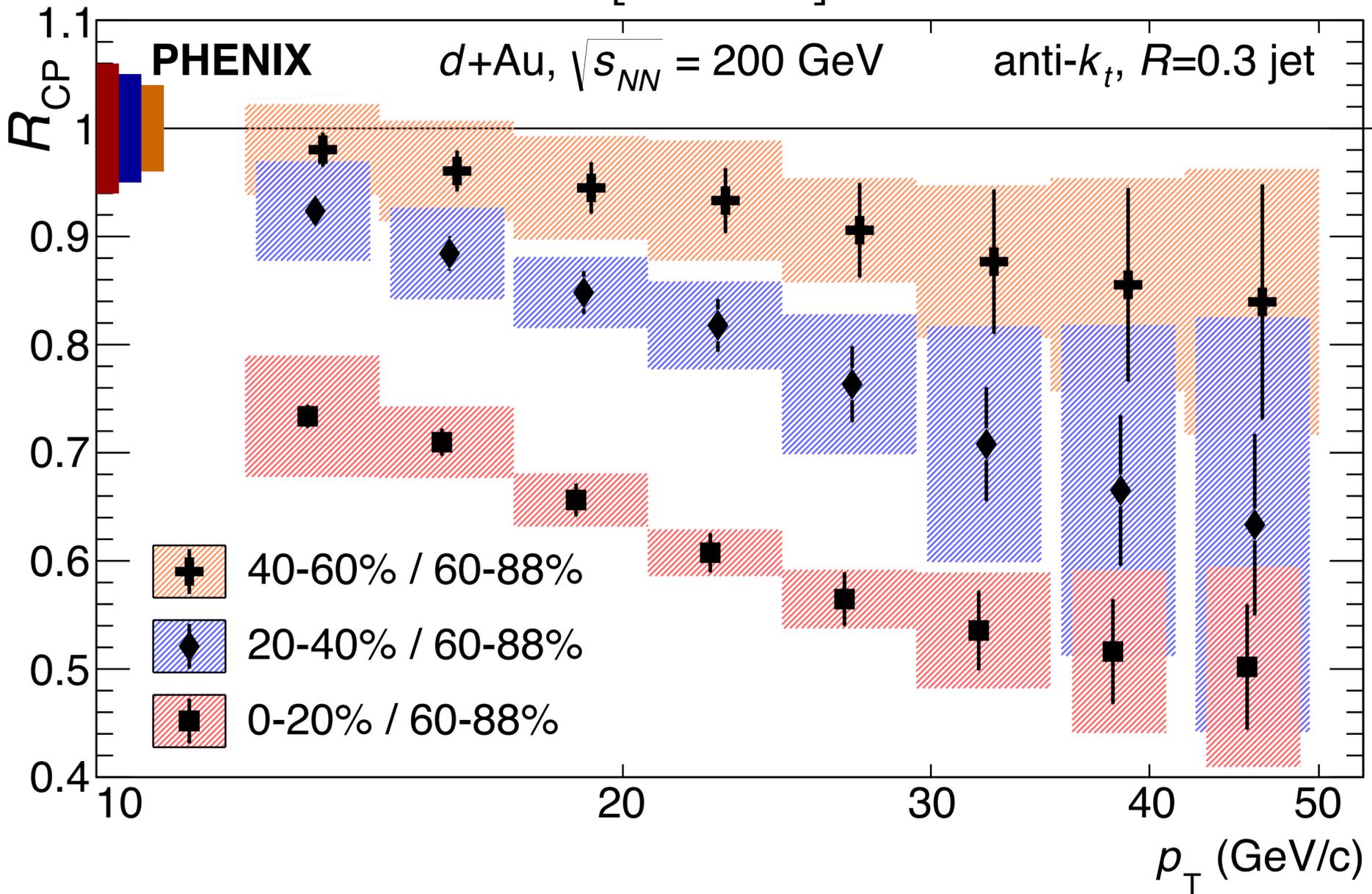
# relation to other systems

arXiv:1509.04657 [nucl-ex]

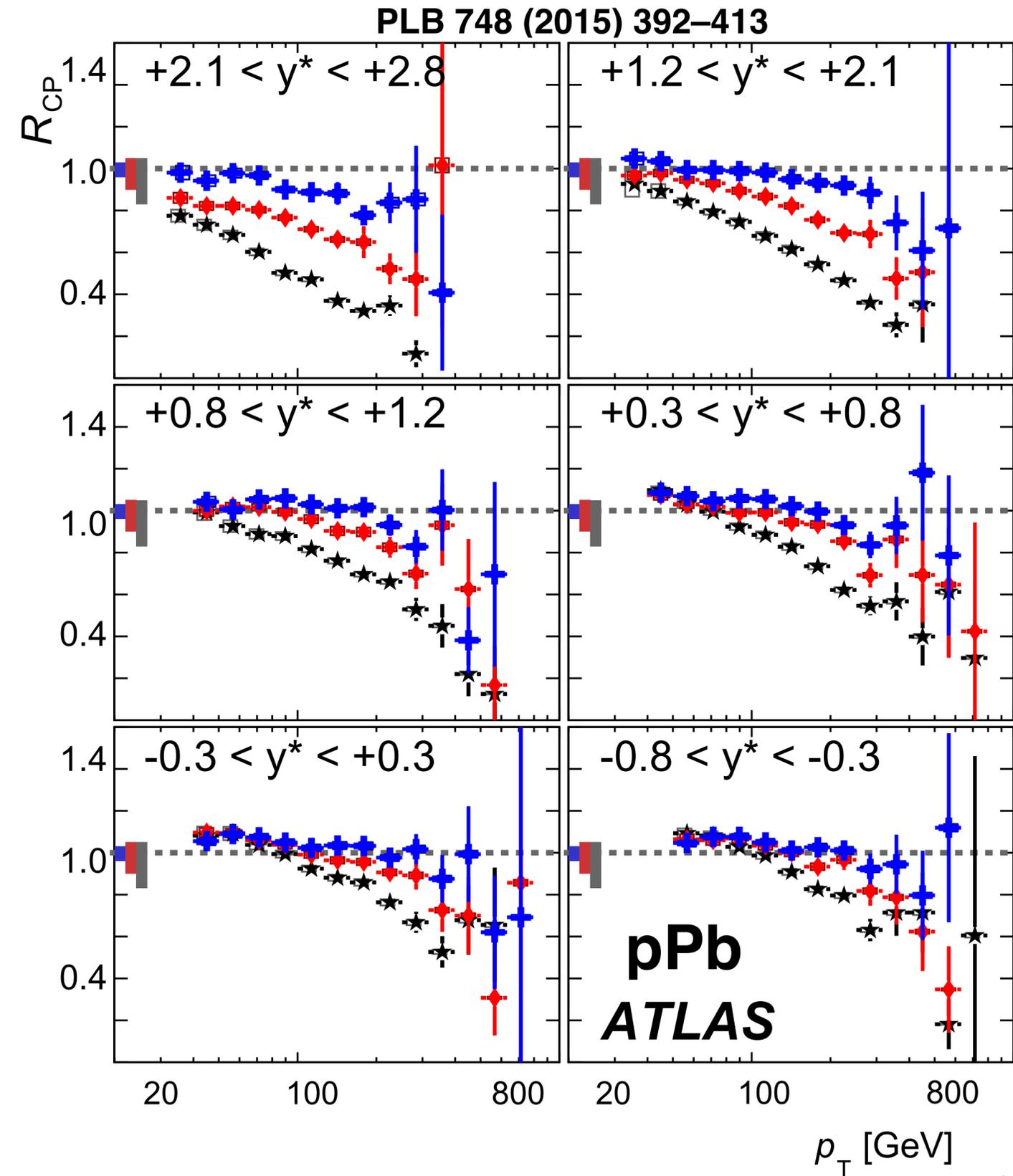


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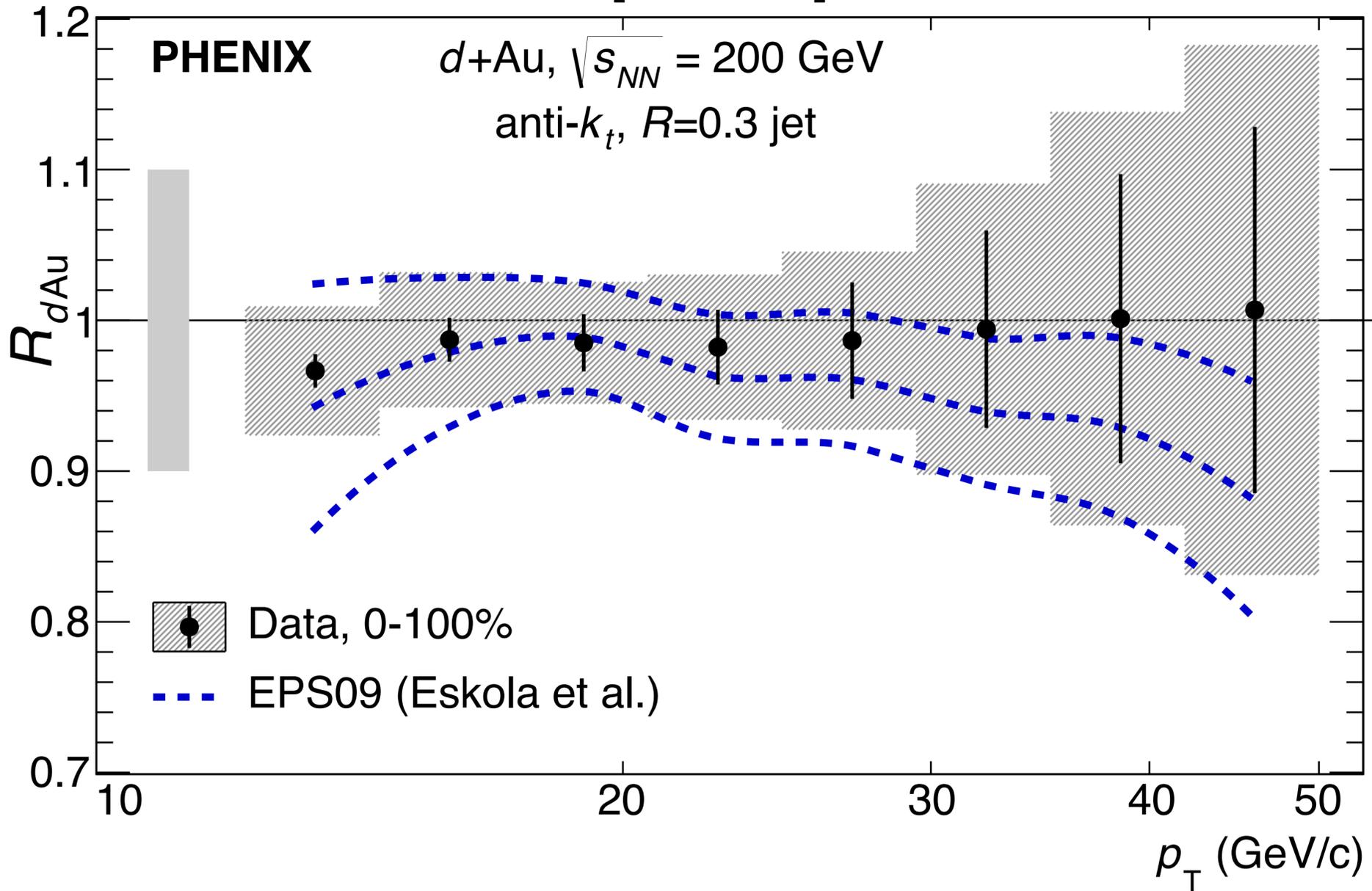


**similar trend seen at the LHC**

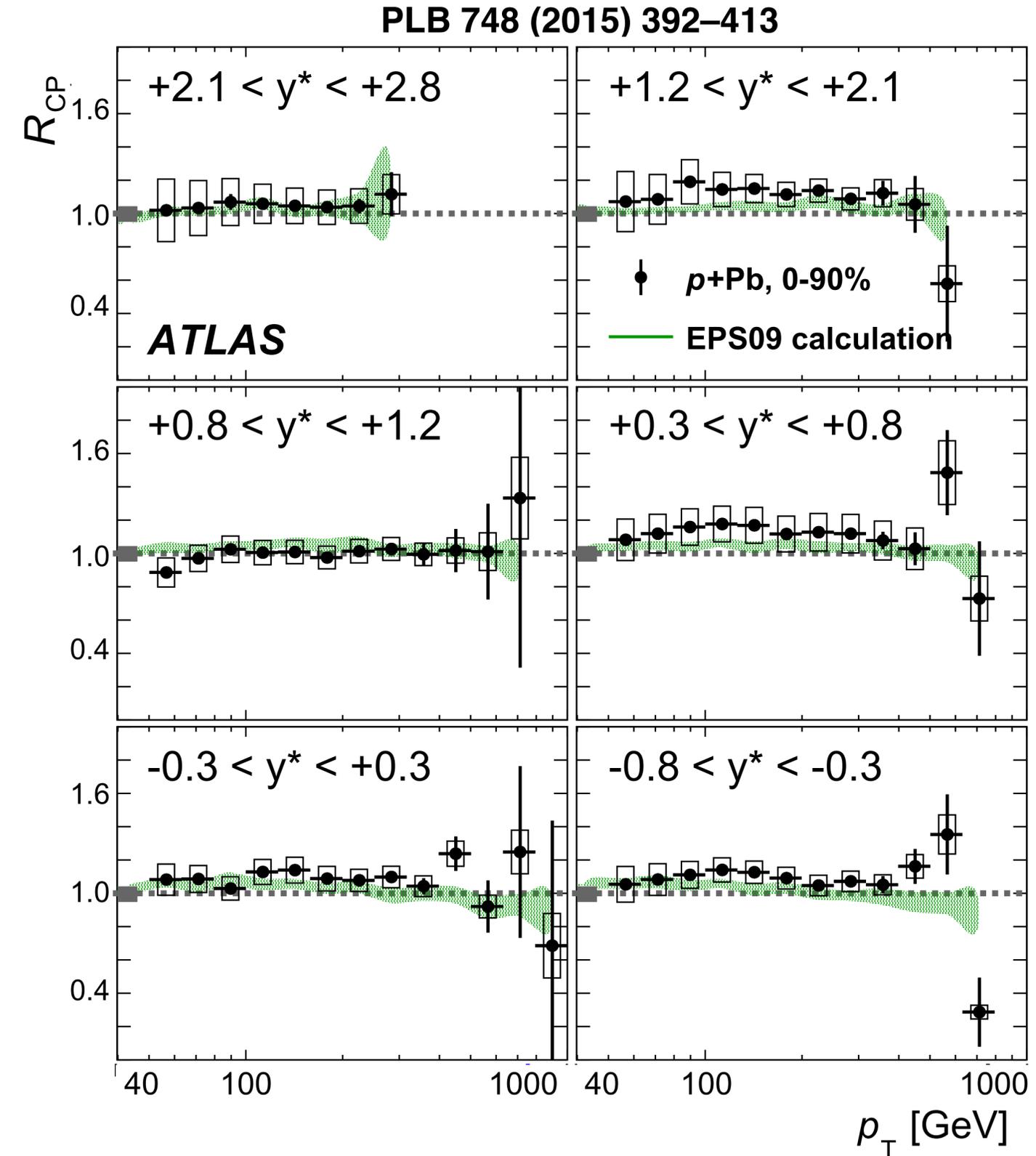


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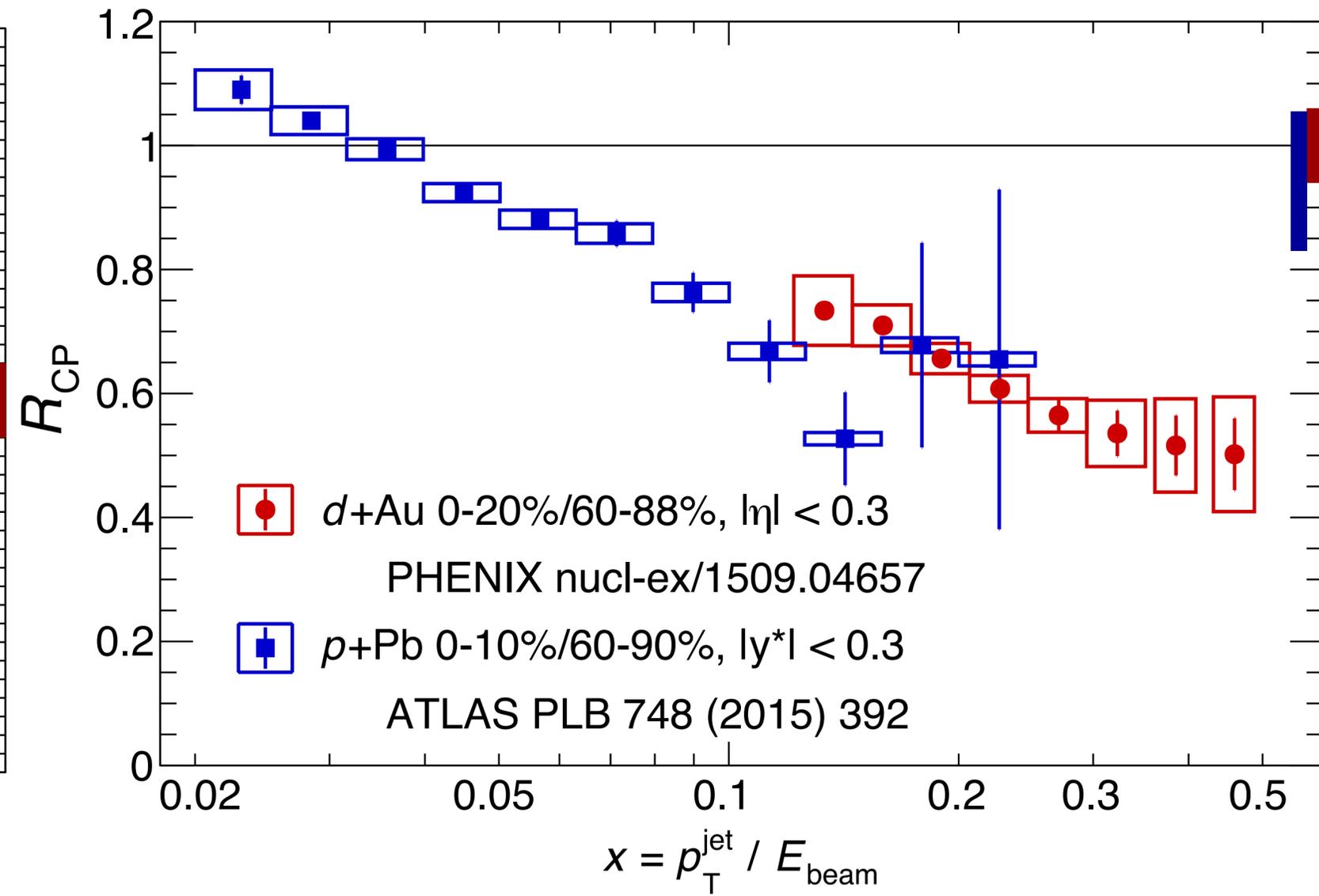
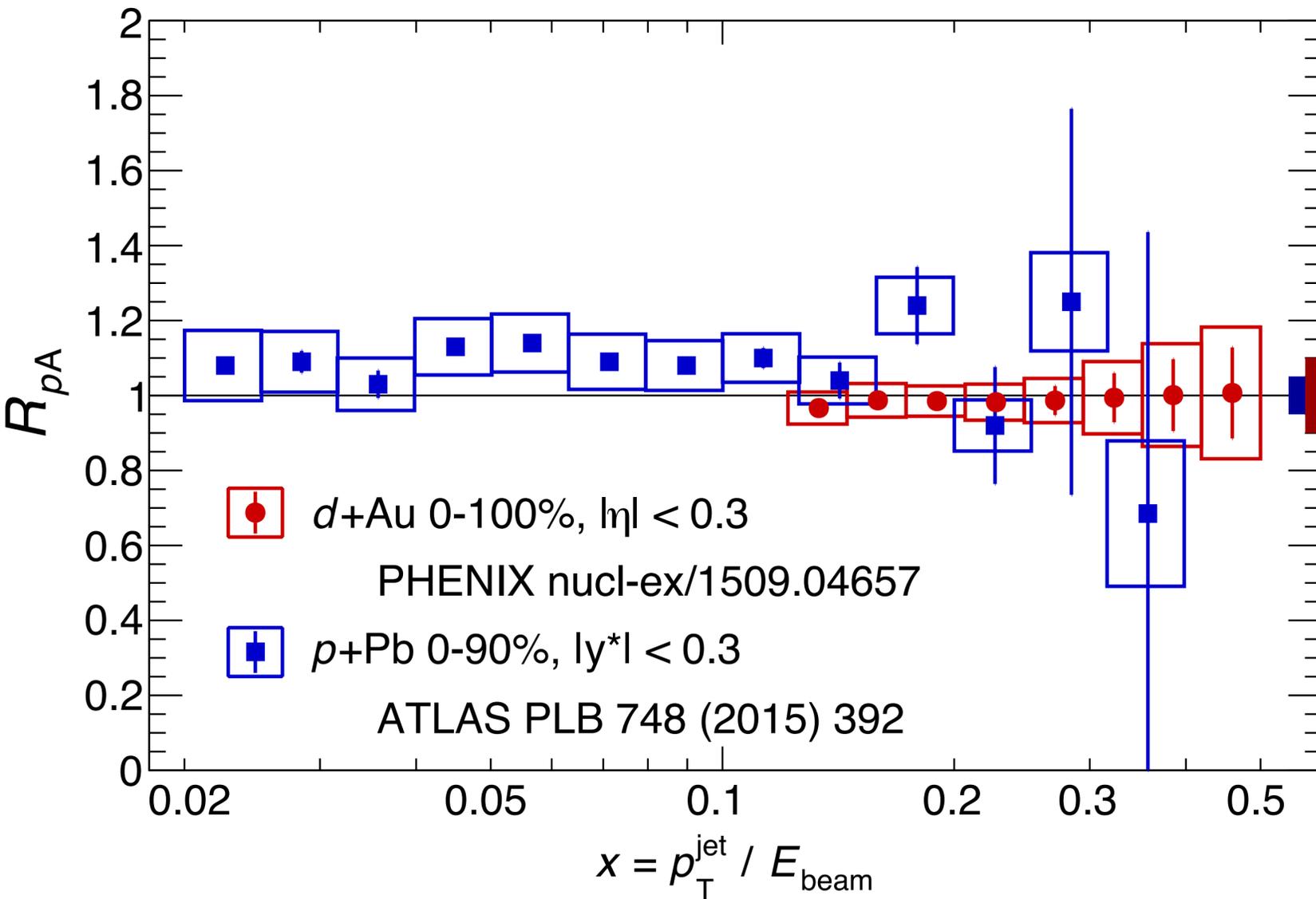
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**similar trend seen at the LHC**



# relation to other systems



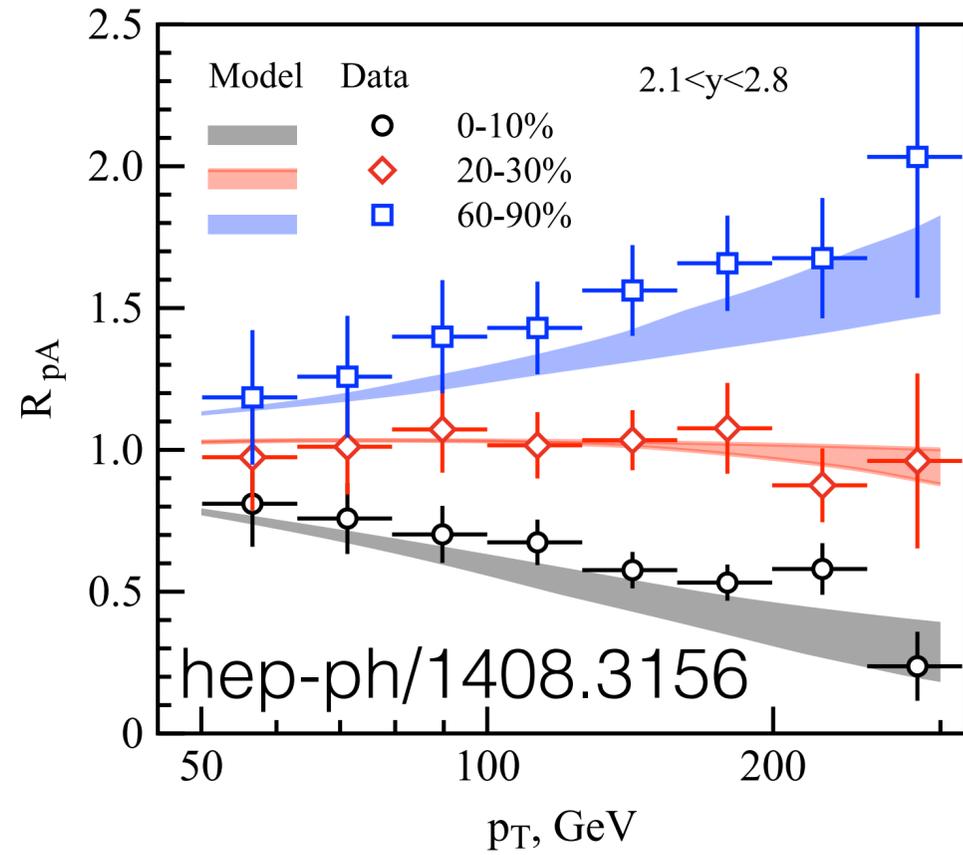
similar trend seen **in same x range** at the LHC  
 $\Rightarrow$  **similar initial state effect?**

# Need model calculations for d+Au!

proton color fluctuation models describe p+Pb data

presence of high-x jet  $\Rightarrow$

# Need model calculations for d+Au!

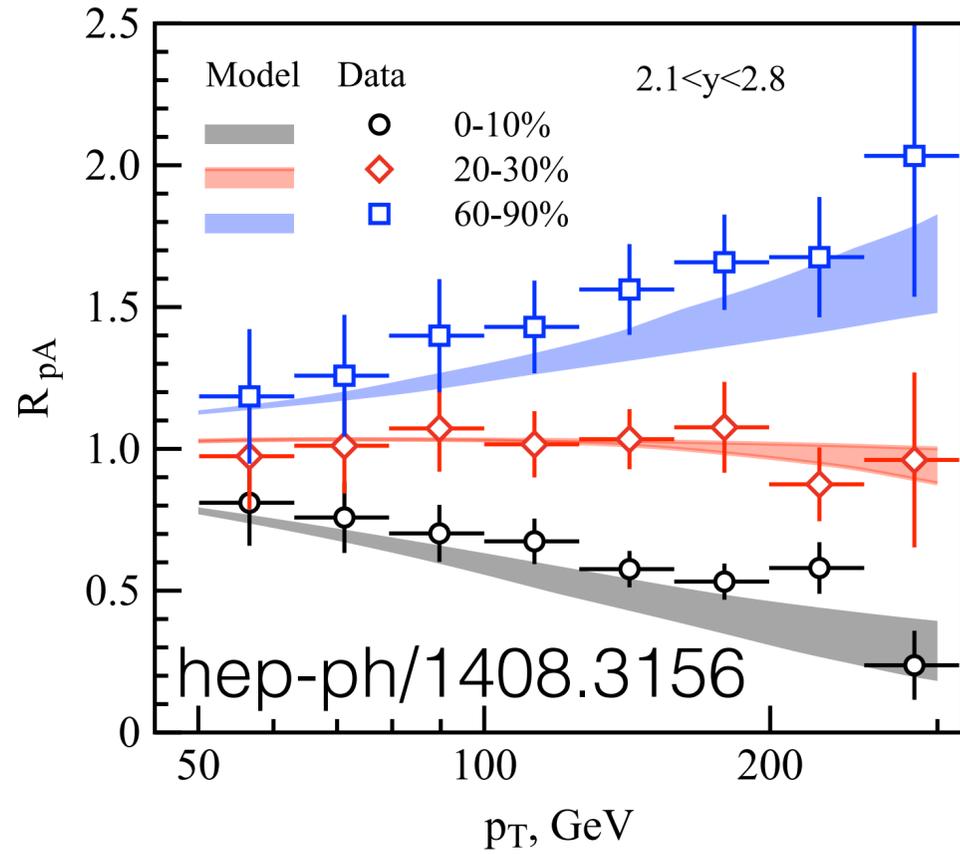


proton color fluctuation models describe p+Pb data

presence of high-x jet  $\Rightarrow$

$\downarrow$  soft particle production

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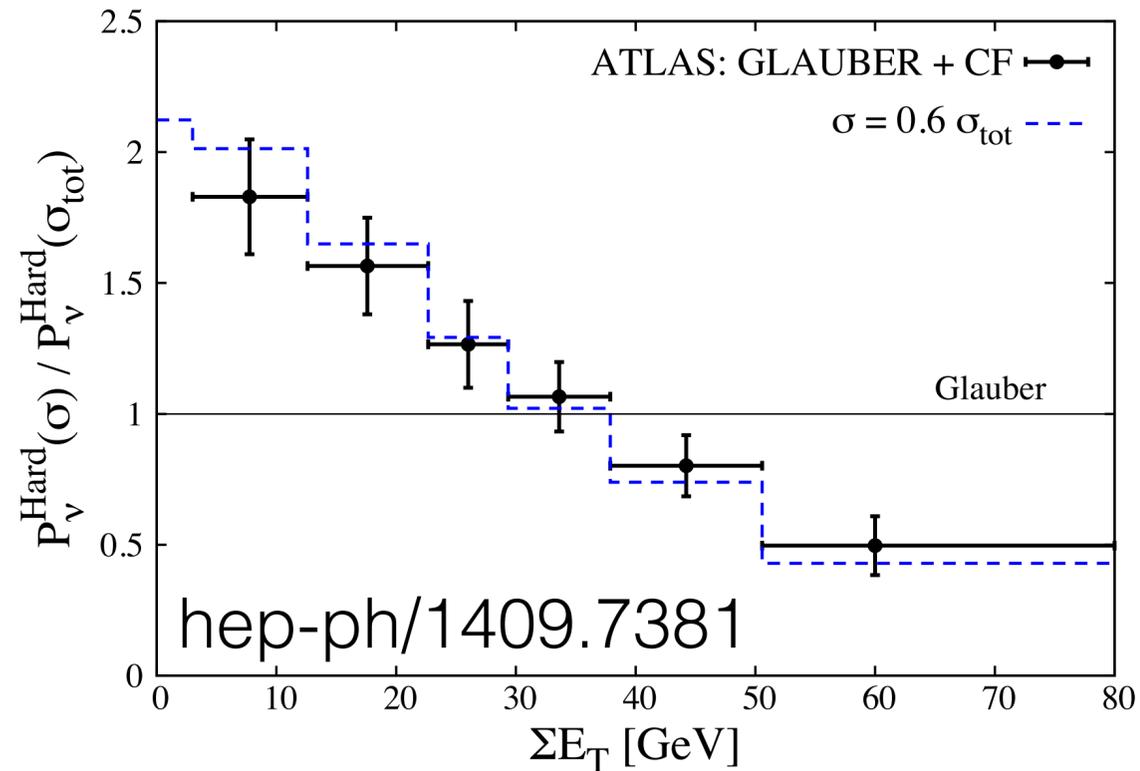


proton color fluctuation models describe p+Pb data

presence of high-x jet  $\Rightarrow$

↓ soft particle production

↓ # of collisions



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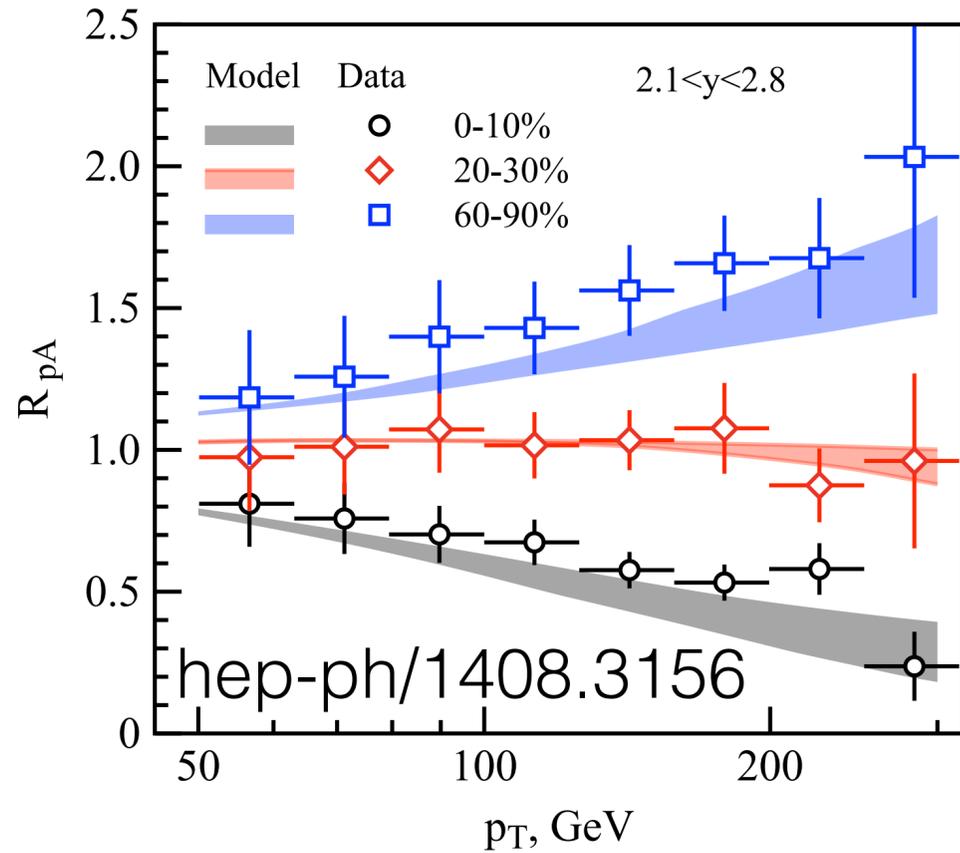
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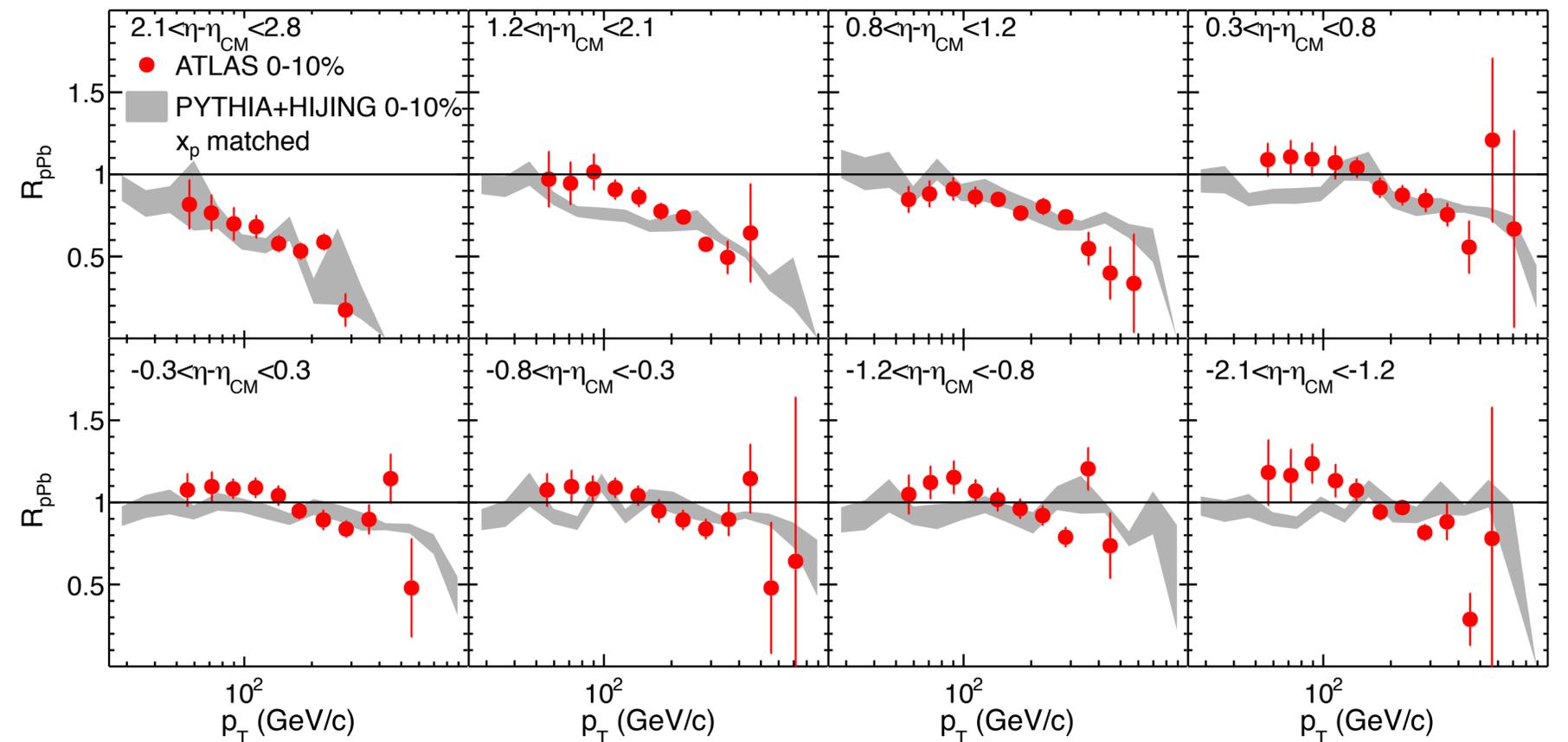
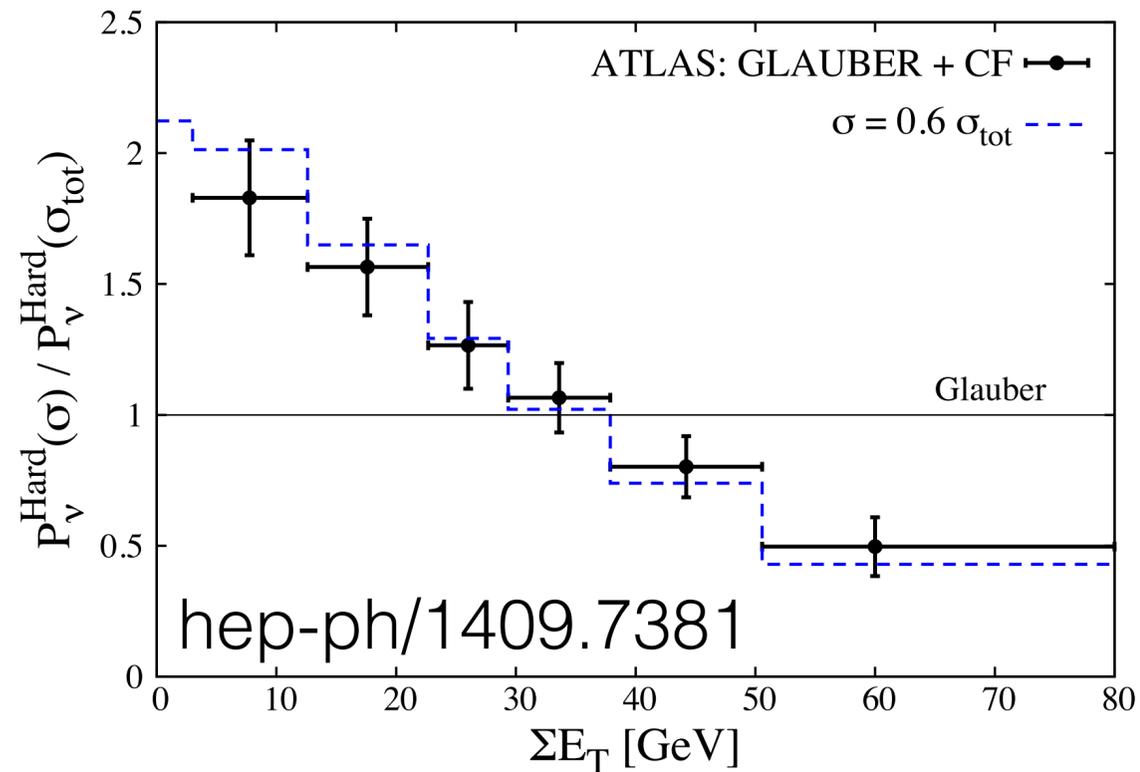
$\downarrow$  soft particle production

$\downarrow$  # of collisions

$\downarrow$  energy of proton

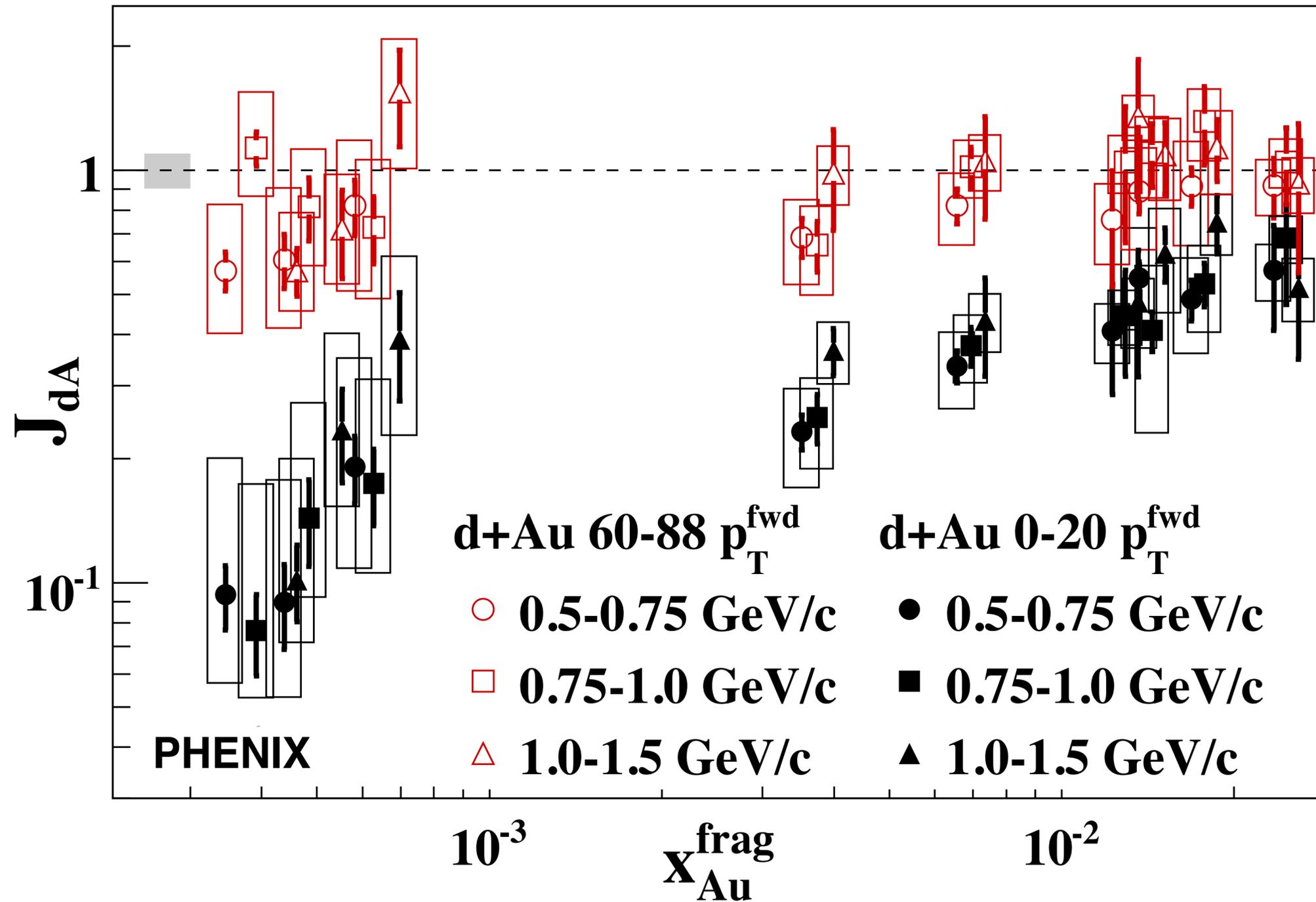


hep-ph/1502.02986



# low-x suppression revisited

Phys. Rev. Lett. 107, (2011)172301



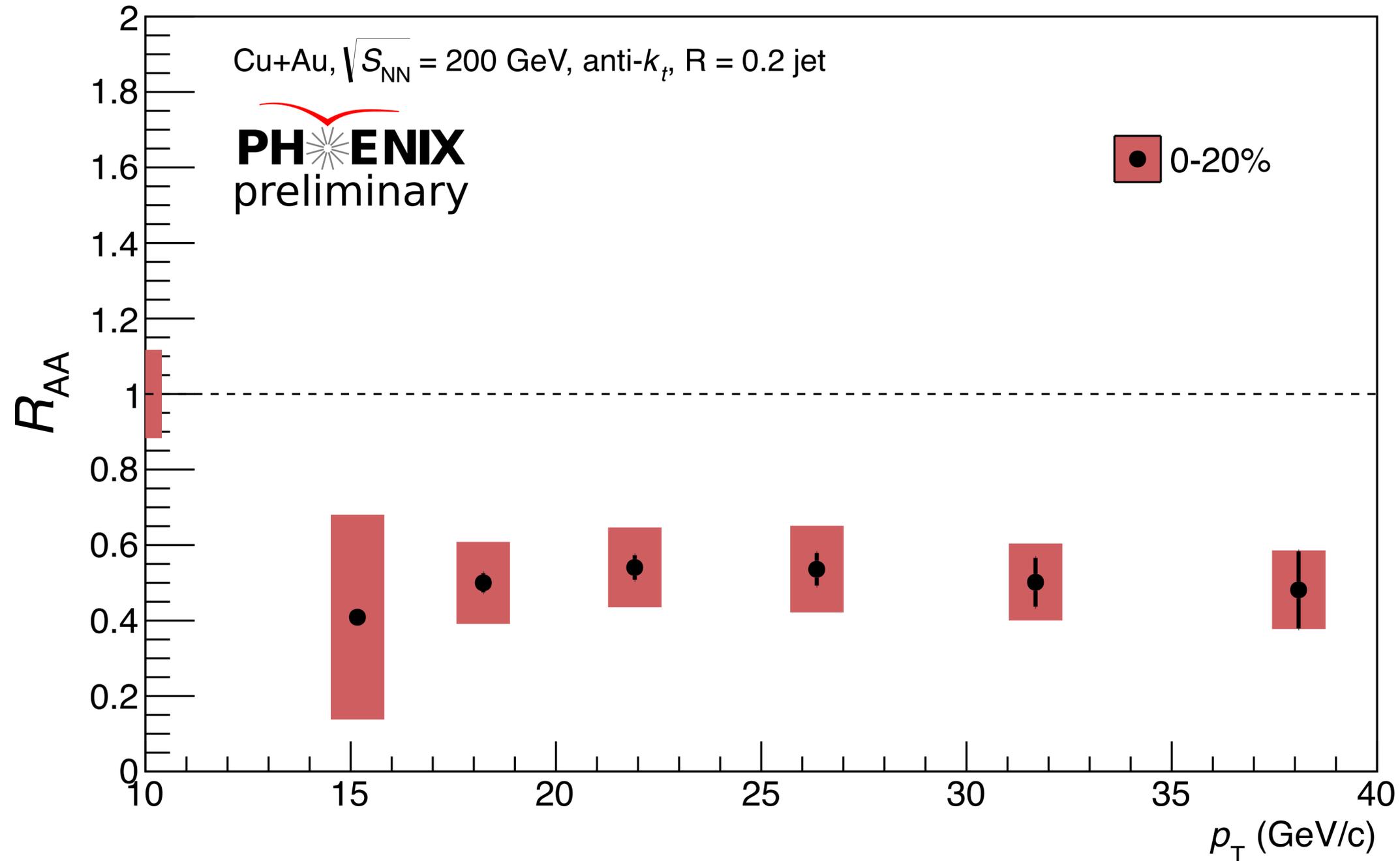
are we probing low-x in Au  
or high-x in d?

# Summary and Outlook

- **Hard probes in d+Au important part of full picture of both nuclear structure and potential medium effects**
- **Minimum bias  $R_{dA} = 1$** 
  - strong constraint on initial state effects over large kinematic range
- **Strong centrality dependence observed in  $R_{dA}$  of inclusive jets**
  - see poster #0421 by D. Perepelitsa
  - presents challenge to theorists
- **Future measurements of jets in p+Au, and He<sup>3</sup>+Au, can provide important tests of models attempting to explain observed centrality dependence through proton color fluctuations**

# jets in heavy ion collisions

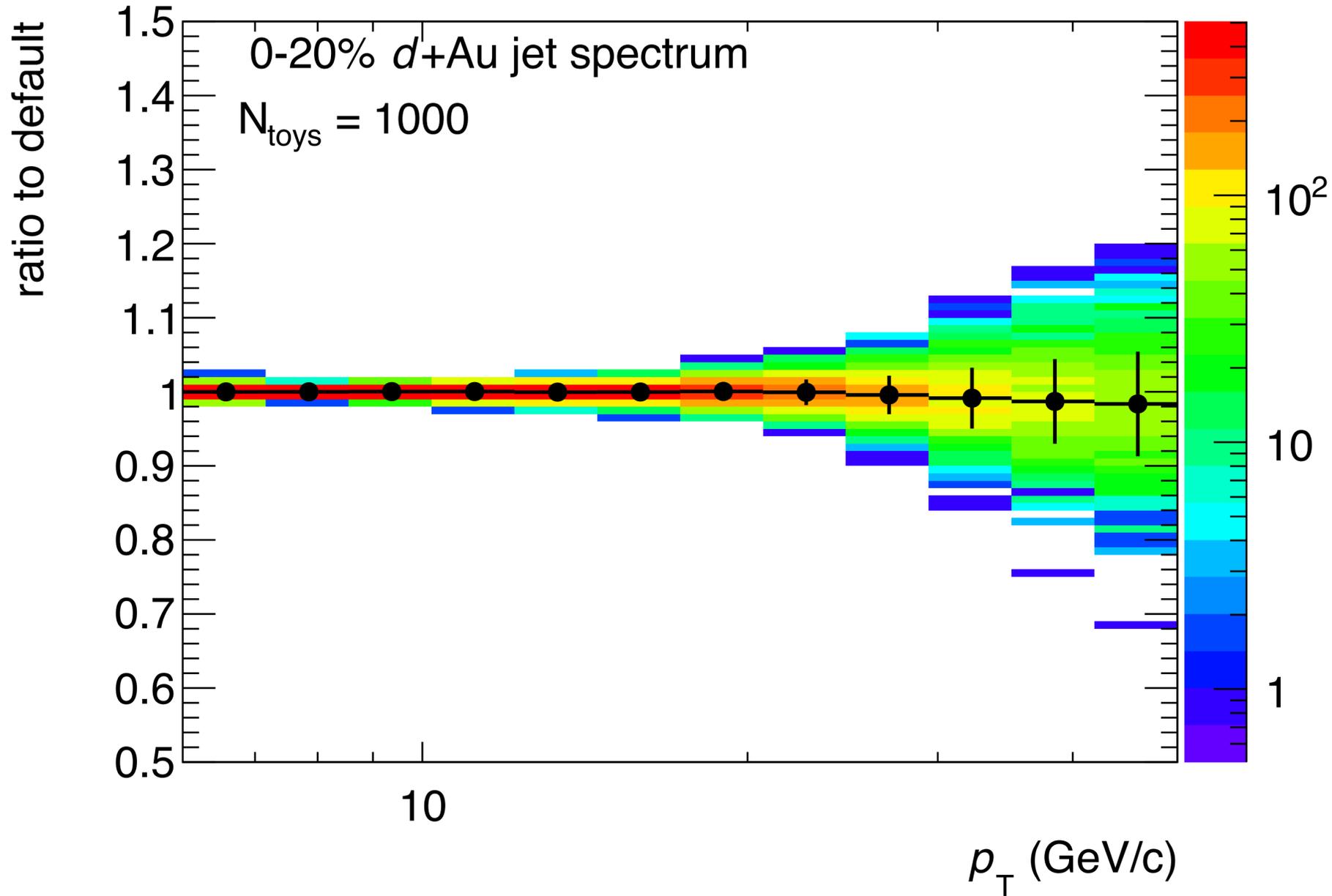
high- $p_T$  suppression  $\Rightarrow$  important QGP observable



**For detailed discussion of jets in heavy-ion collisions  
see talk by Arbin Timilsina - Sept. 29 @ 14:40**

Backup Slides

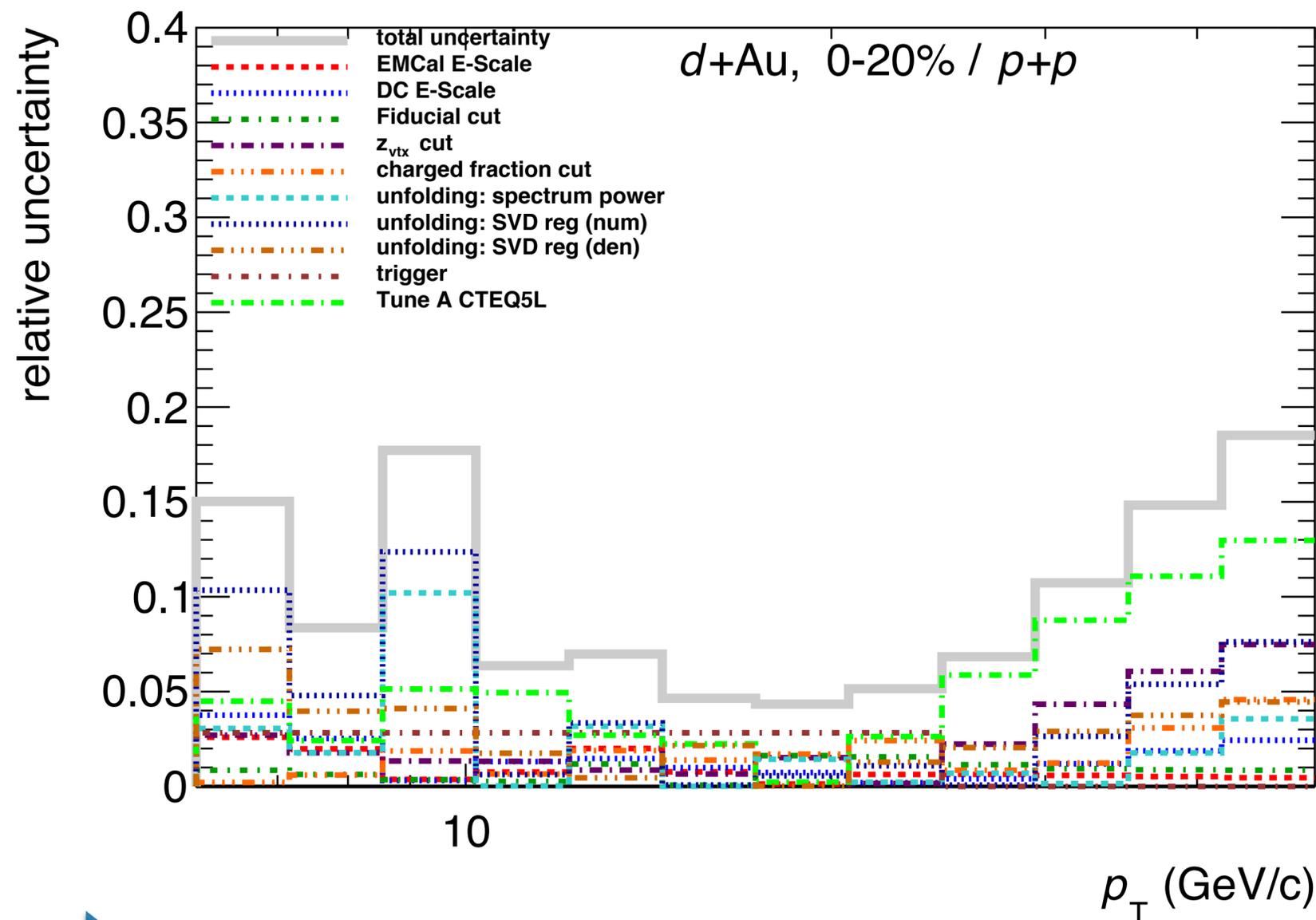
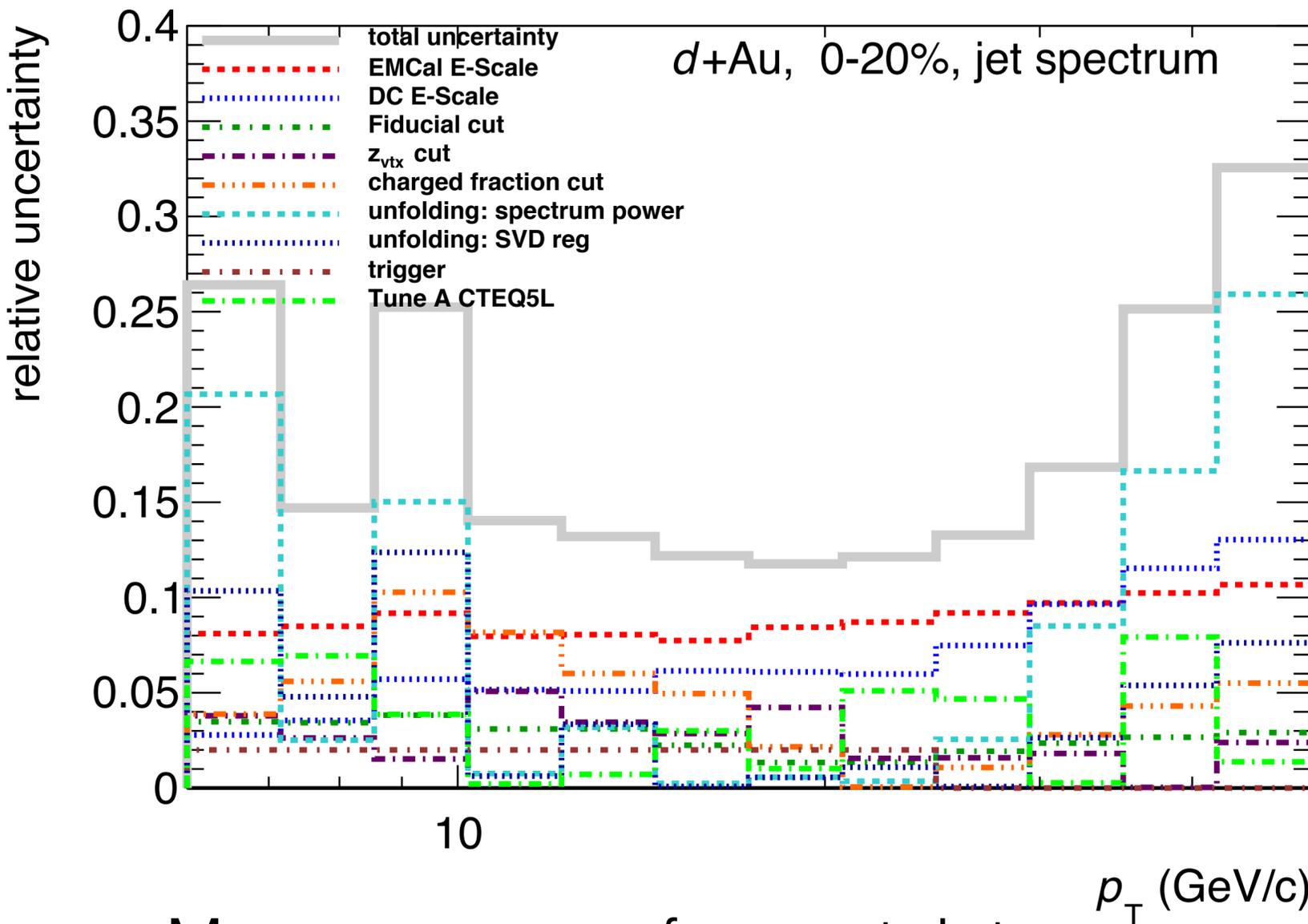
# Statistical uncertainties in unfolded spectra



## $10^3$ iterations on toy MC:

- sample Poisson distribution for range of counts in each  $p_{T,\text{reco}}$  bin
- redo unfolding with new reco-level spectrum

# Systematics in ratio

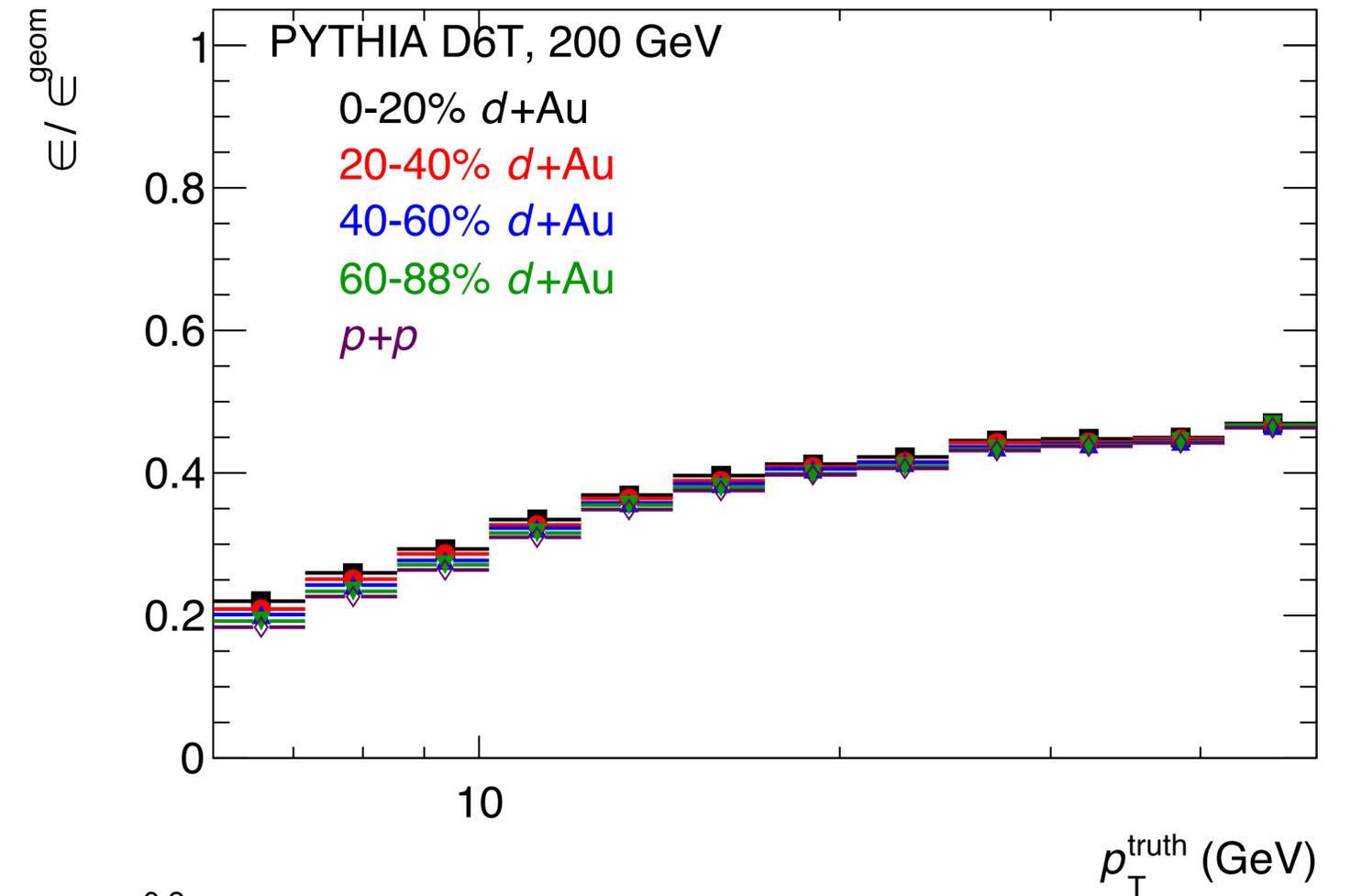
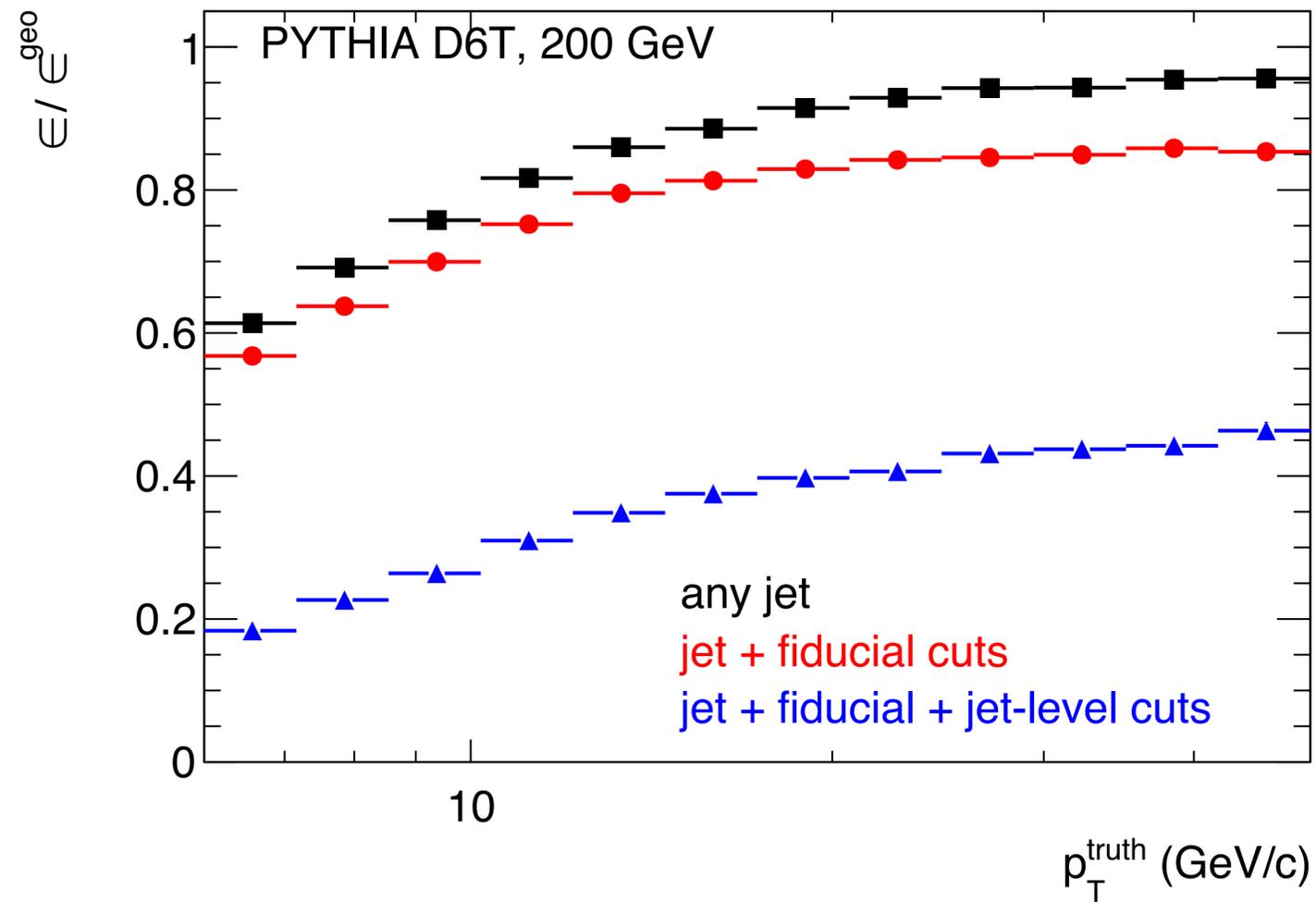


Many sources of uncertainty  
common to d+Au and p+p



cancel in ratio

# reconstruction efficiency



modest centrality dependence  
due to slight increase in  
efficiency from underlying  
event in central d+Au

