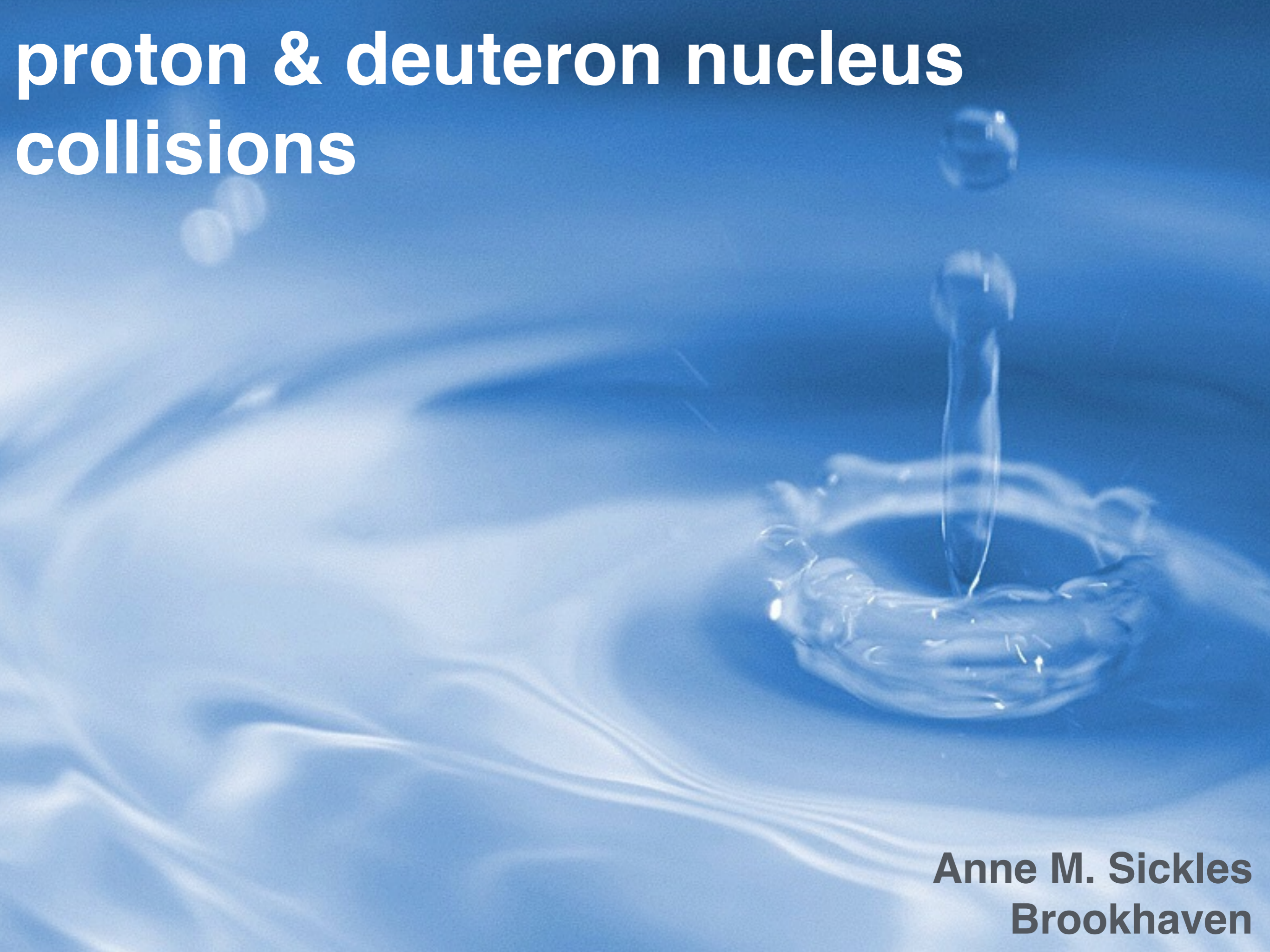


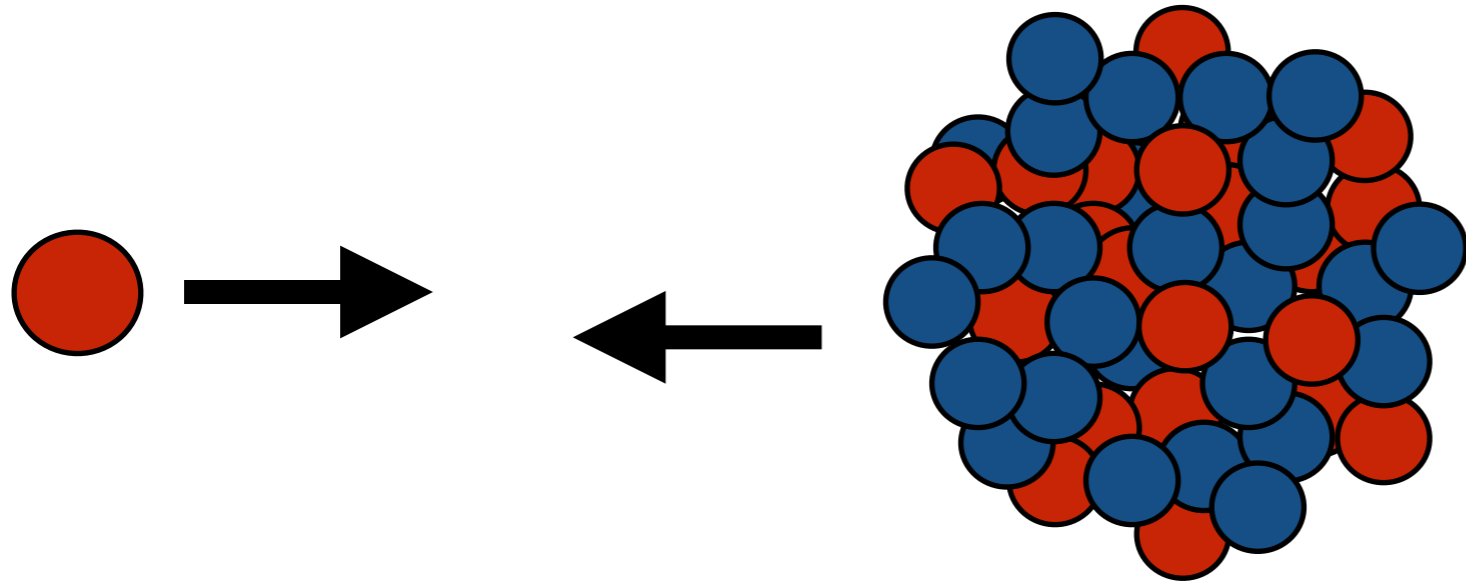
# proton & deuteron nucleus collisions



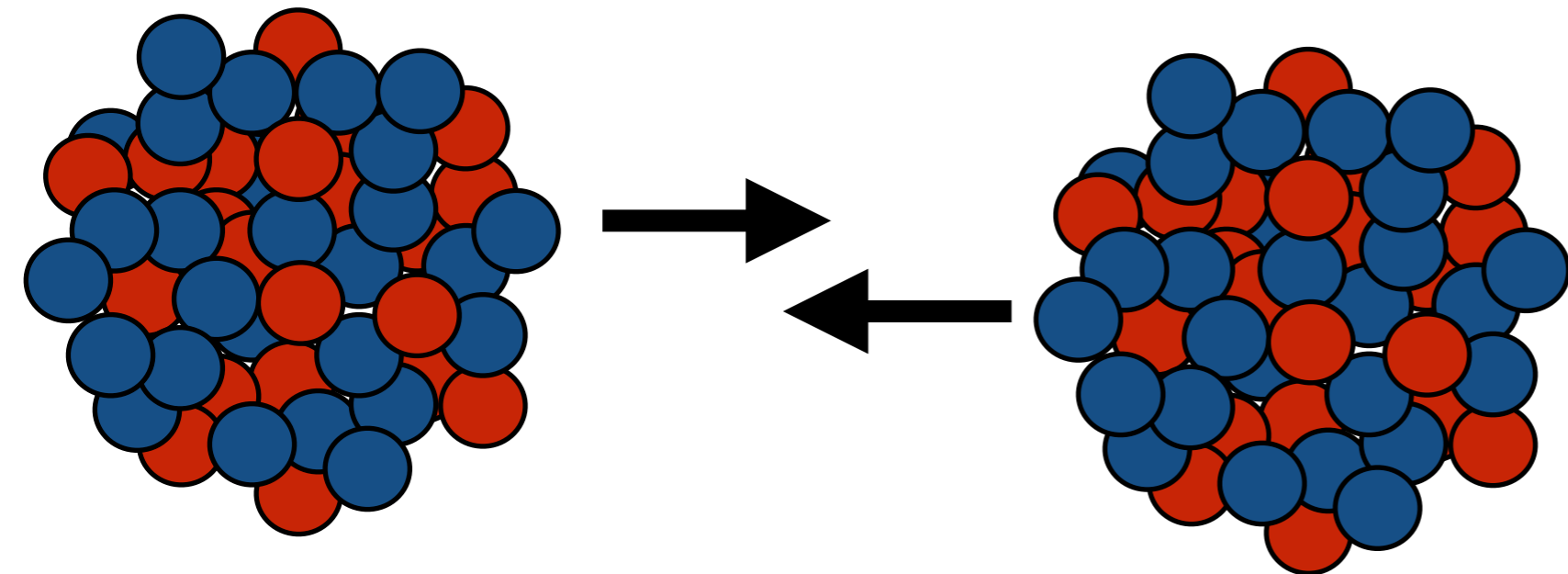
**Anne M. Sickles  
Brookhaven**

# why p+A collisions?

---



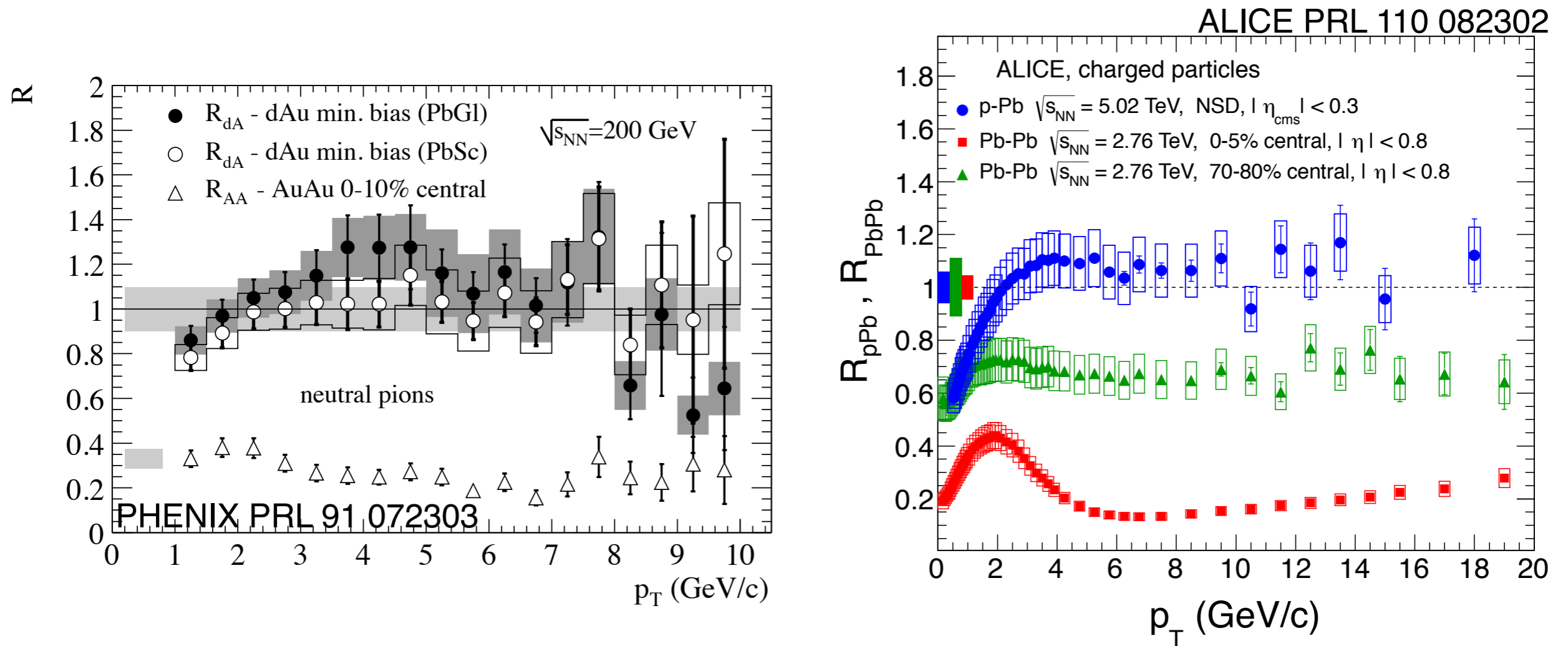
initial nuclei  
~~hot nuclear matter~~



hot nuclear matter  
created from initial  
nuclei

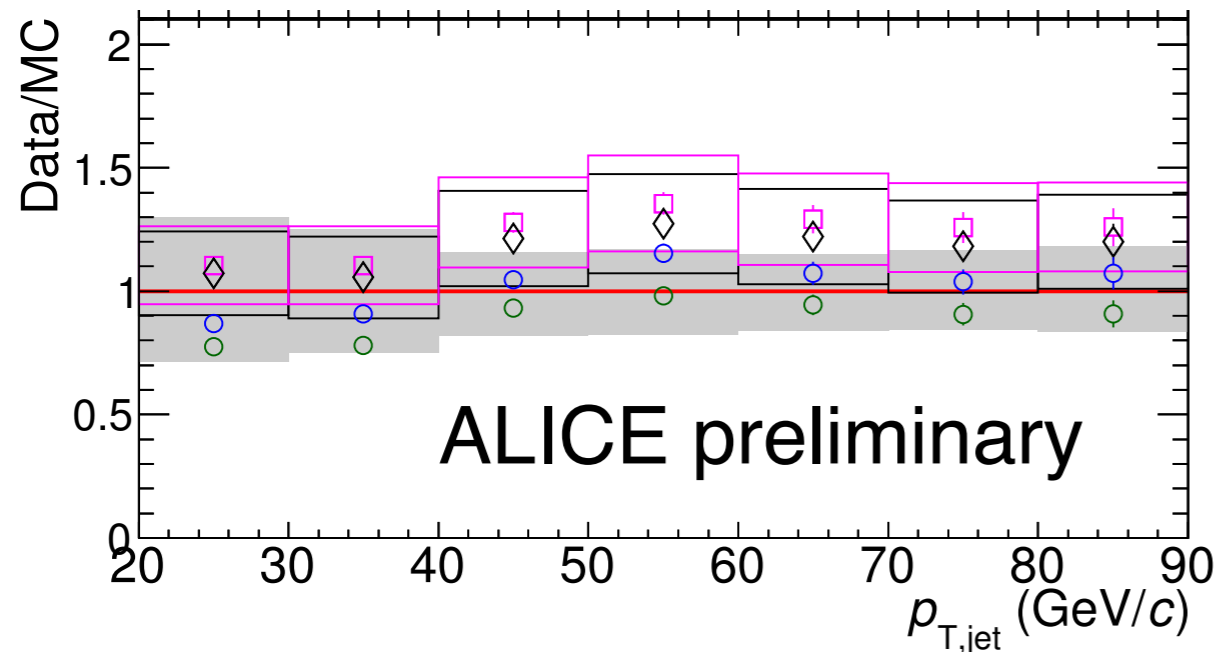
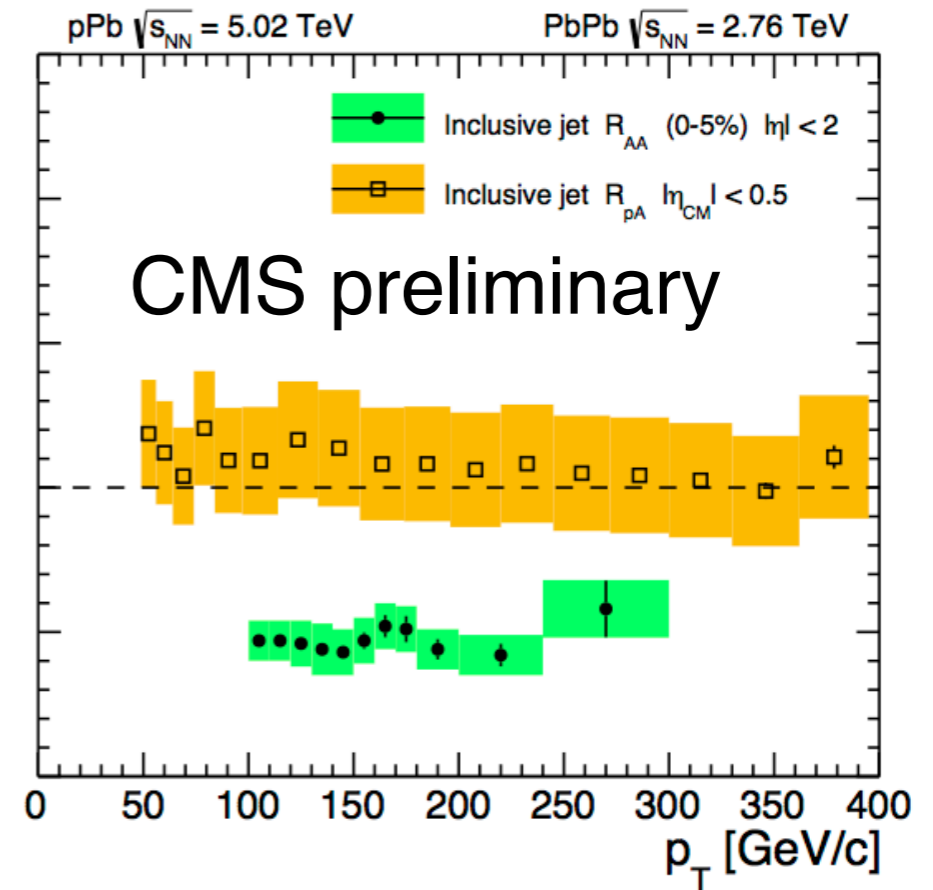
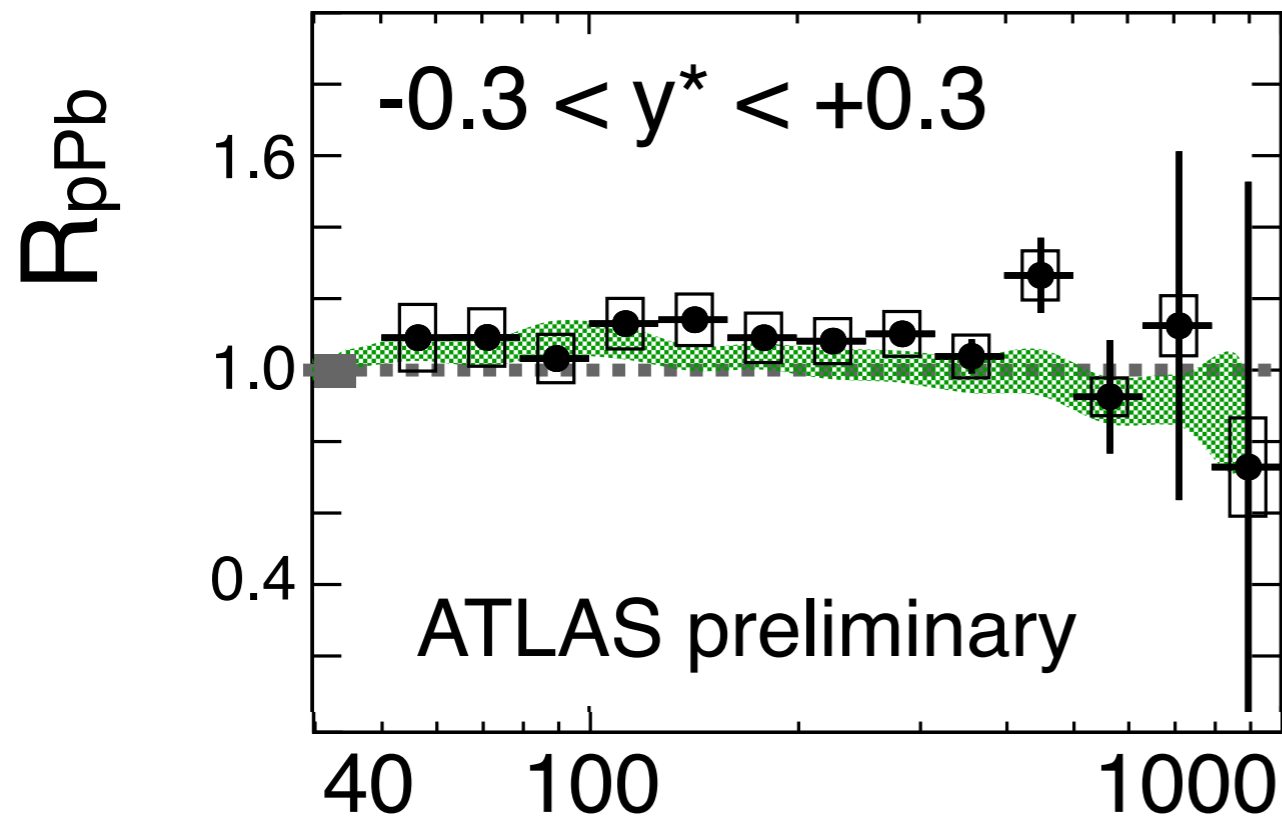


# hard probe rates



hard probe rates nearly unmodified from Ncoll scaling  
both in d+Au and p+Pb at midrapidity

# jets...new this Quark Matter



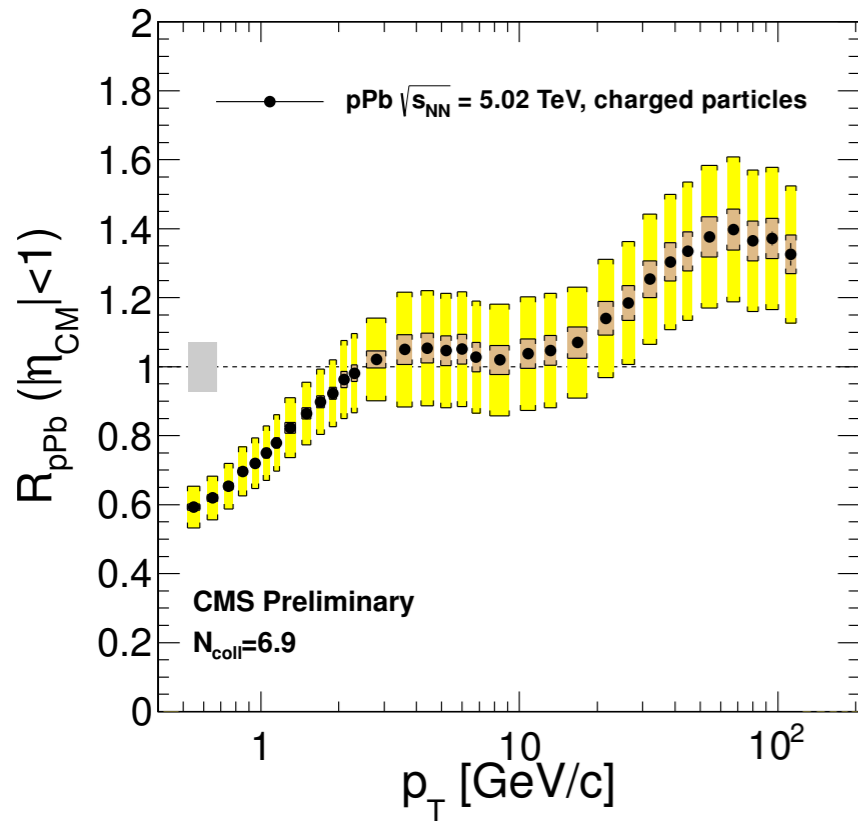
same conclusion from  
reconstructed jets at the  
LHC



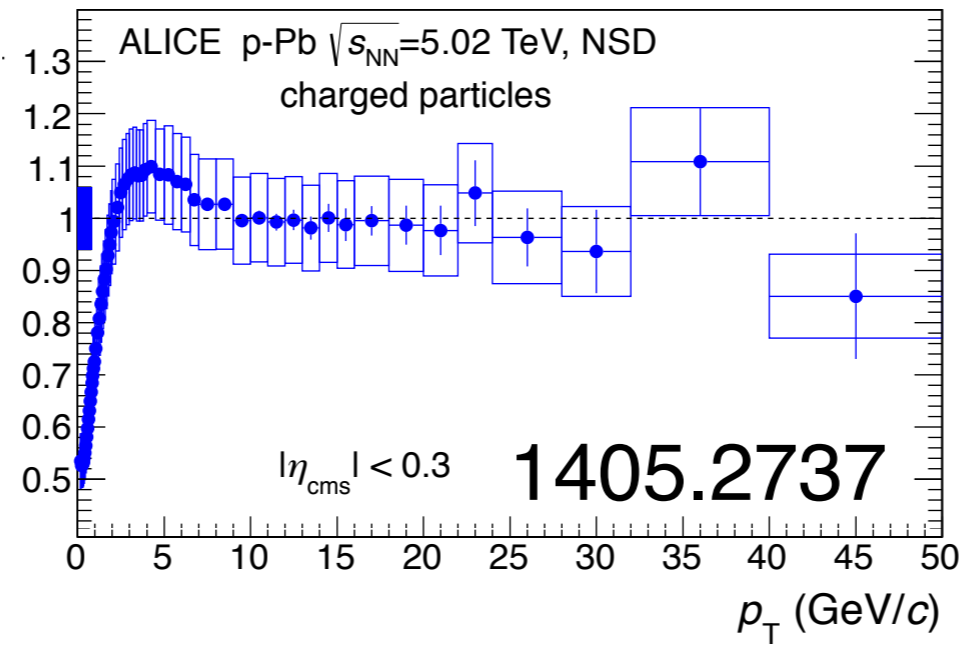
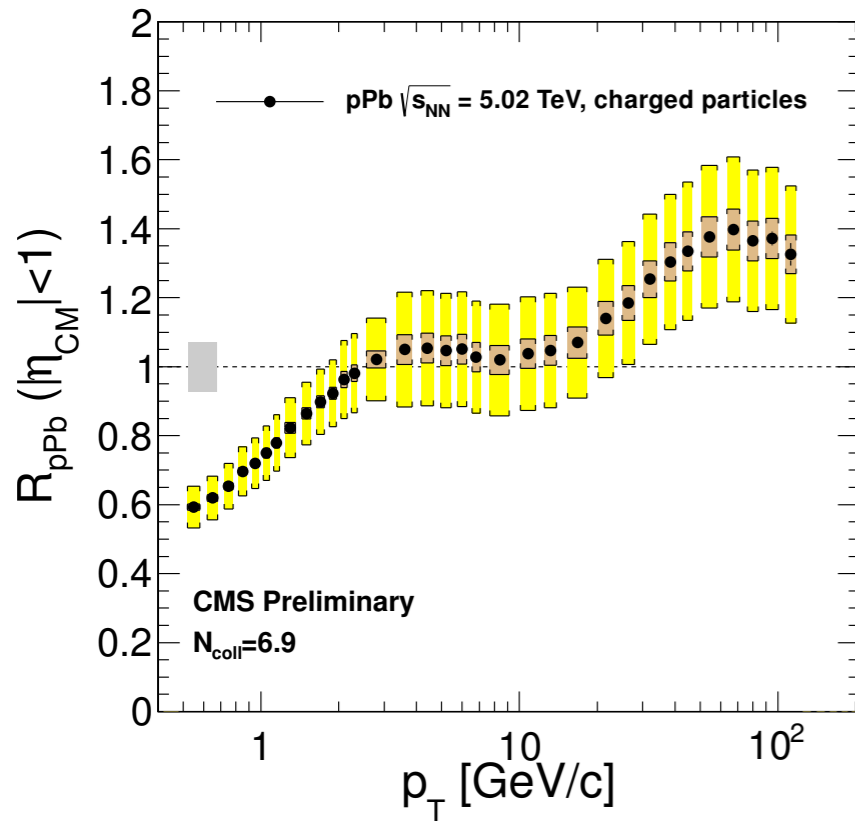
# charged particles...more interesting

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# charged particles...more interesting

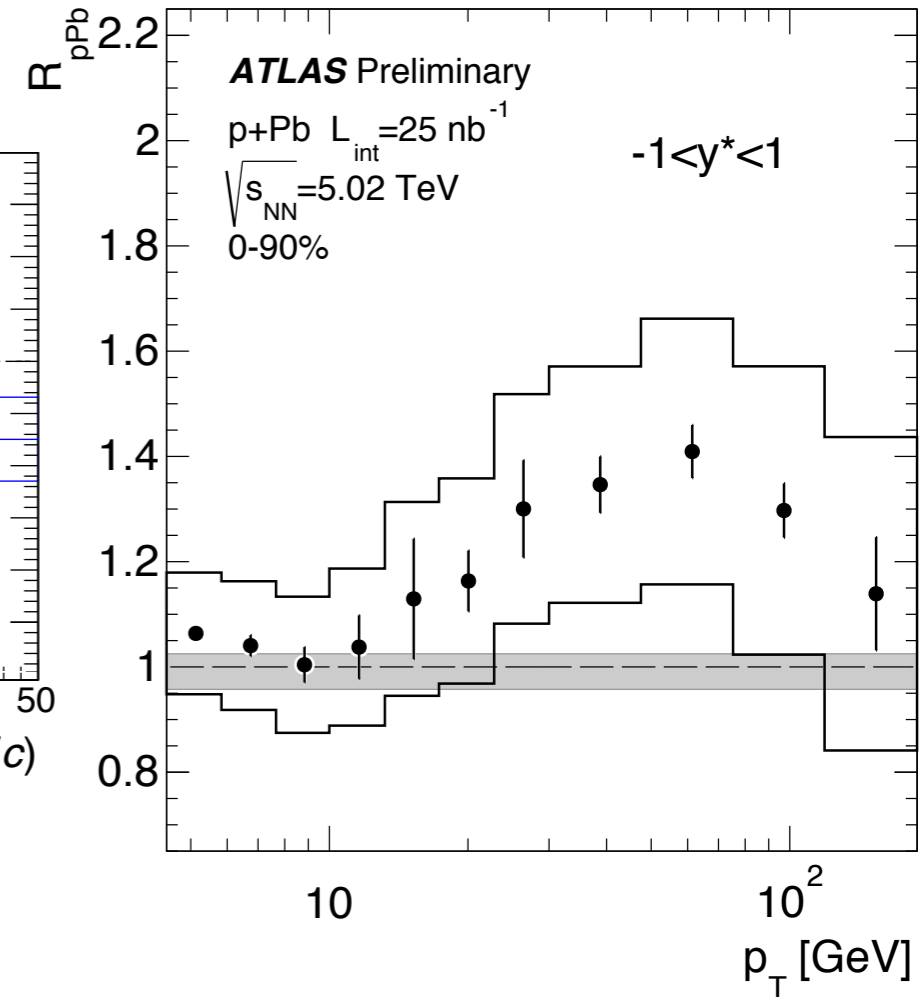
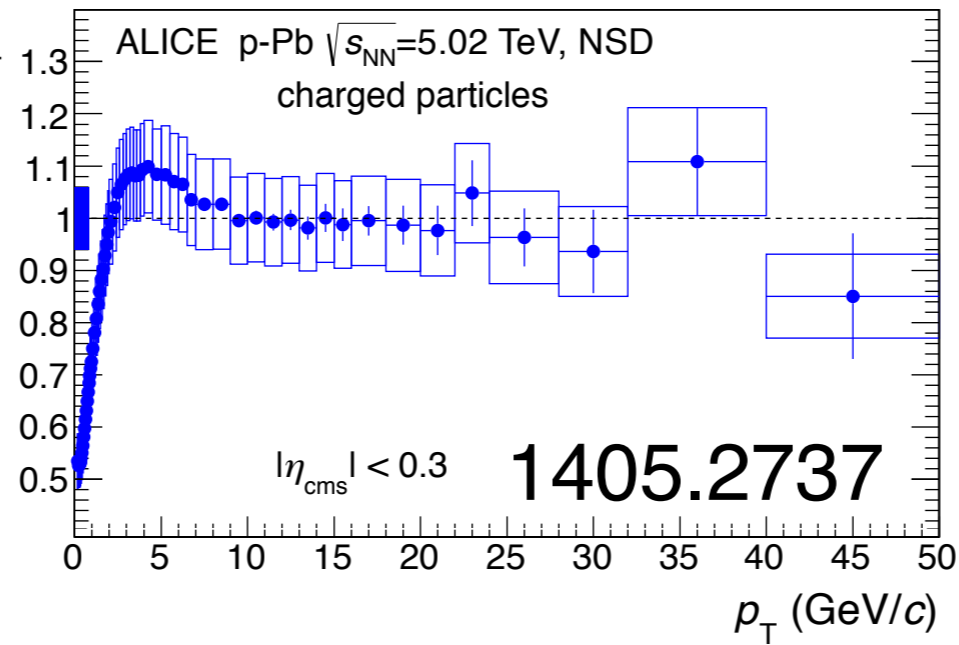
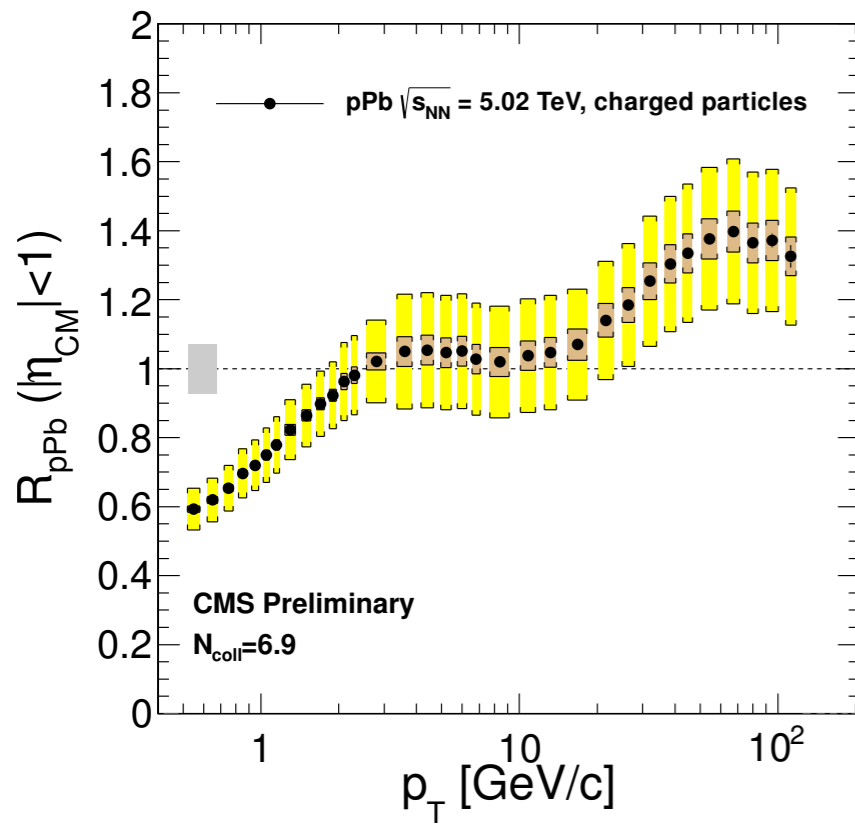


# charged particles...more interesting

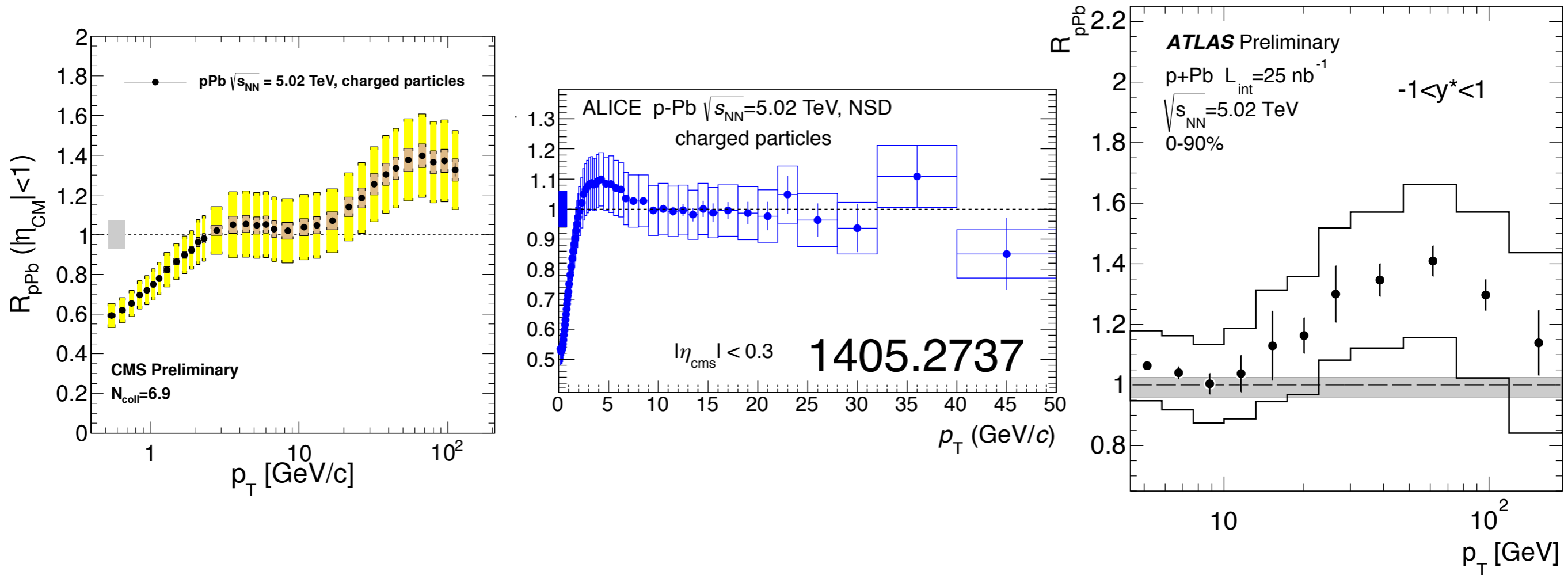




# charged particles...more interesting

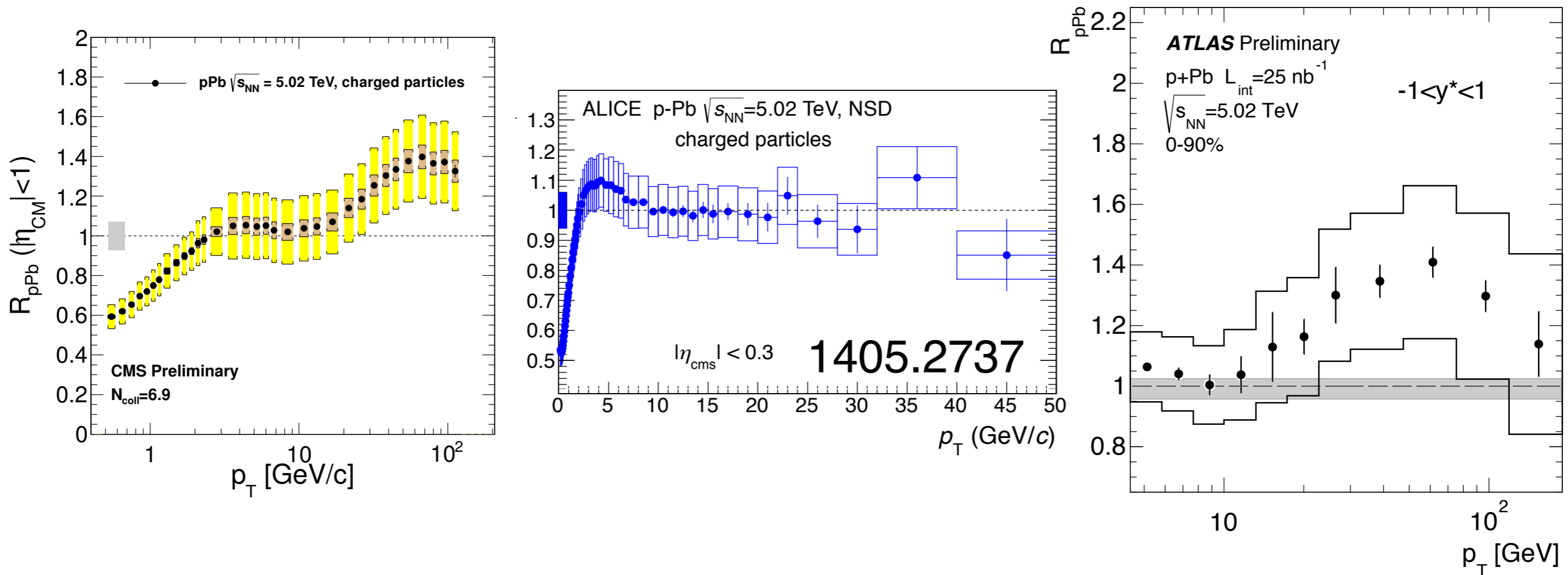


# charged particles...more interesting



- different impressions between CMS/ATLAS & ALICE data

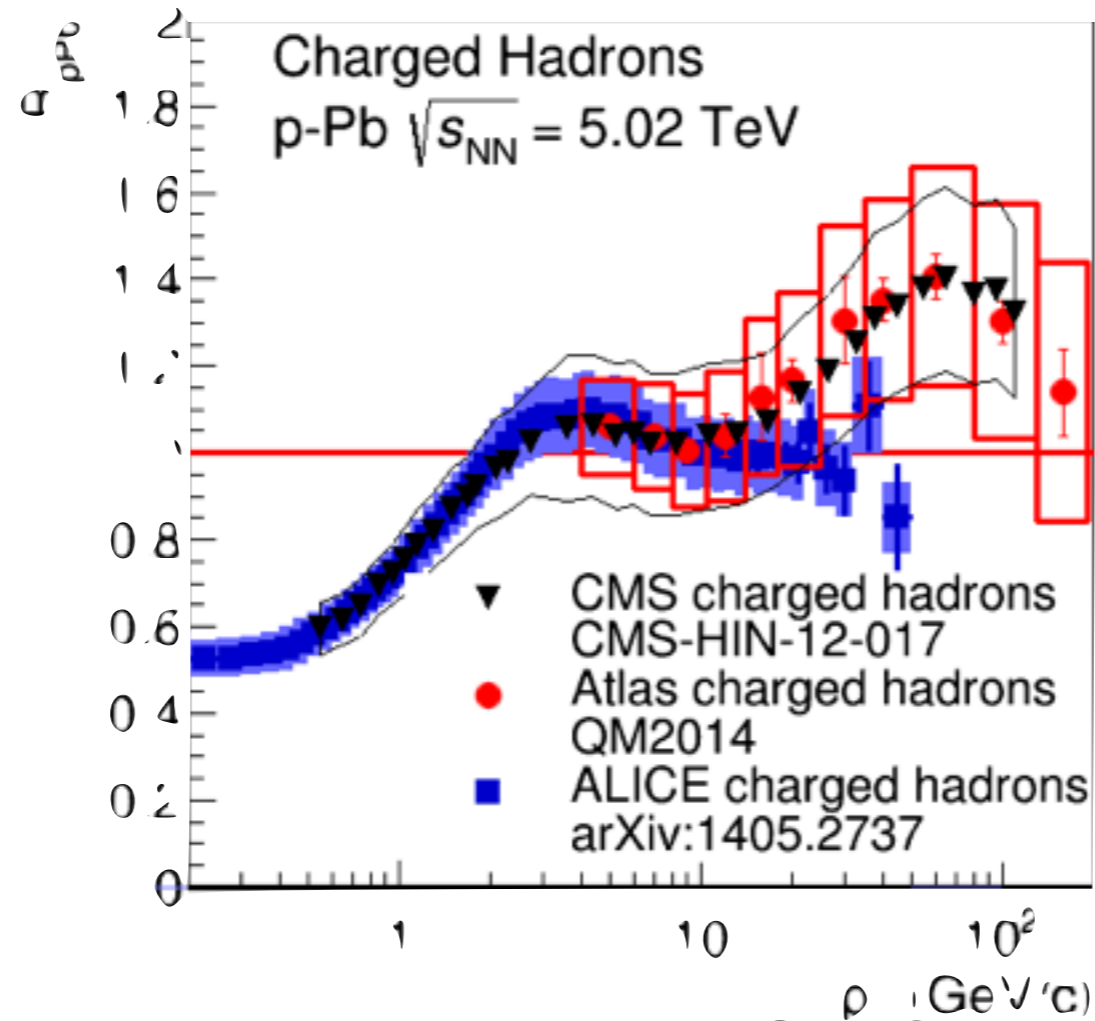
# charged particles...more interesting



- different impressions between CMS/ATLAS & ALICE data
- big caveat: no pp reference at 5TeV (will be wanted for HI reference anyway)!
- much of the difference ALICE/CMS difference is in the reference (see E. Appelt (CMS))

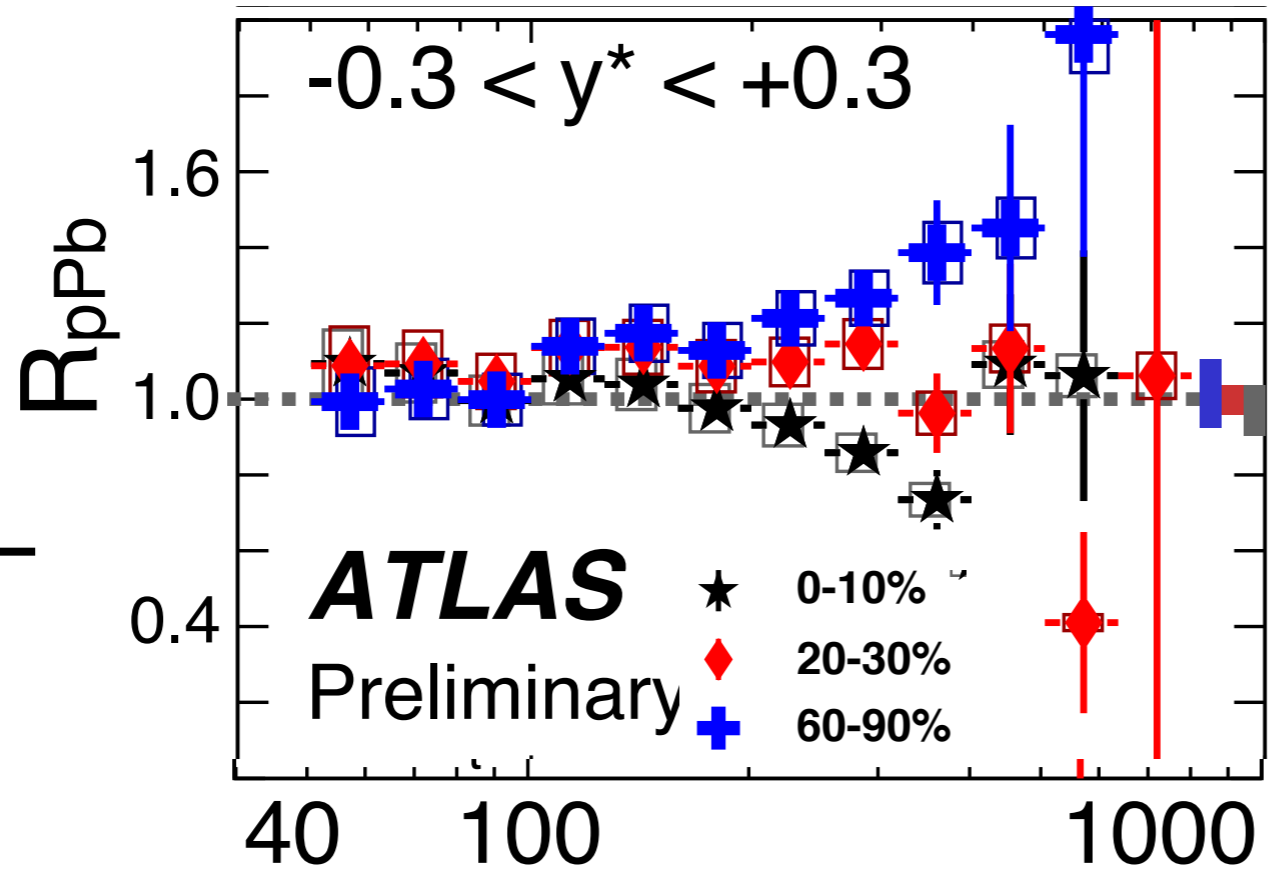
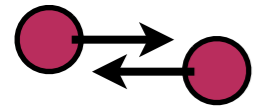
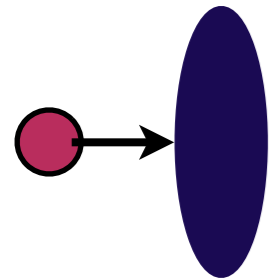


# charged particles...more interesting

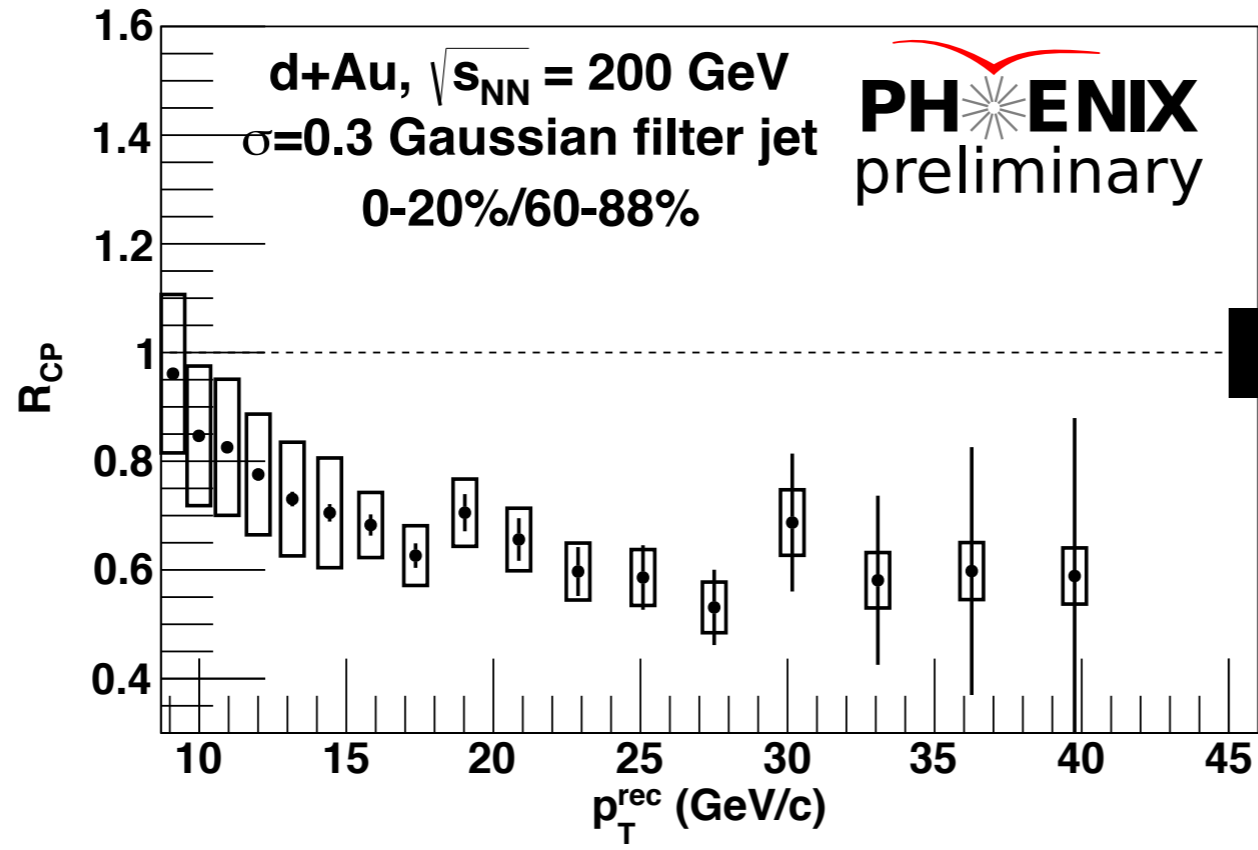
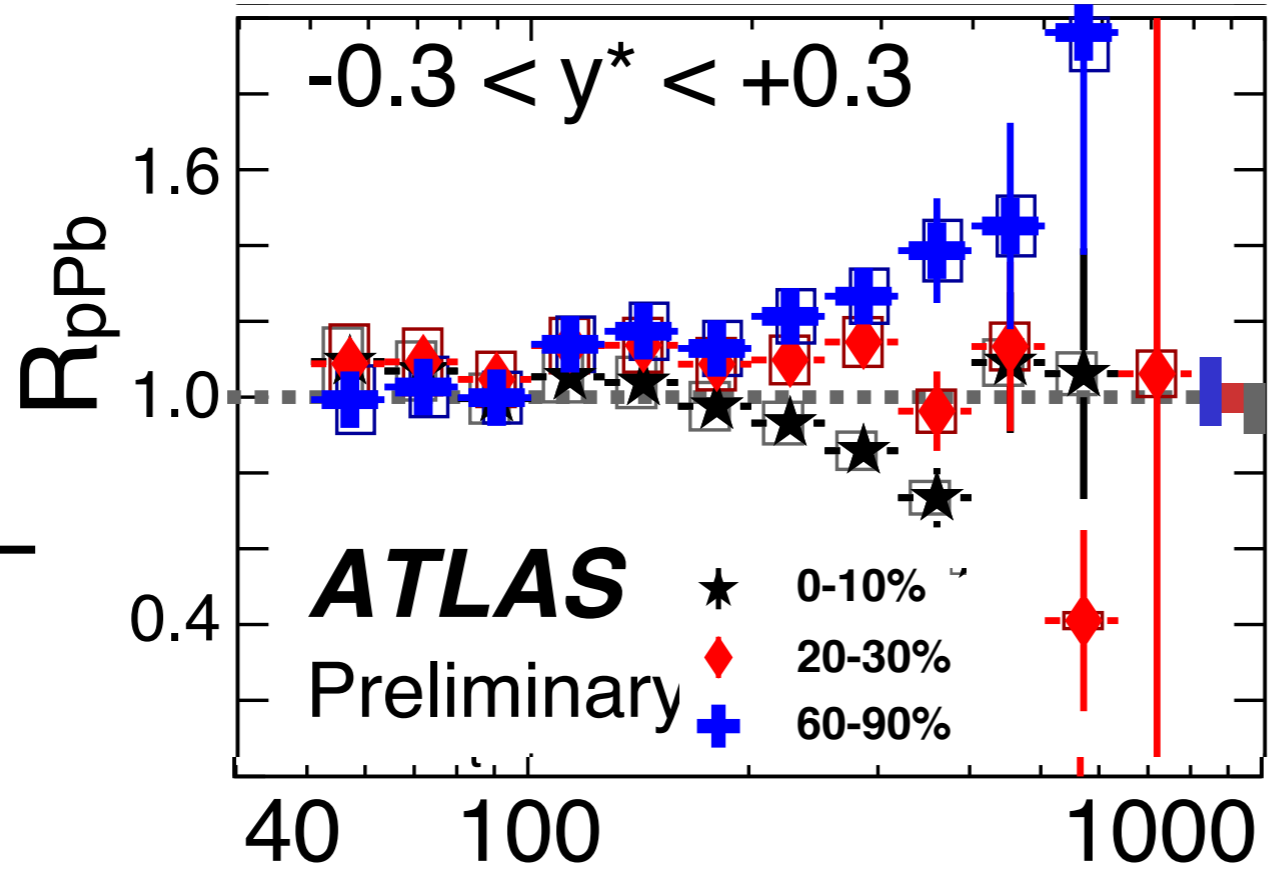
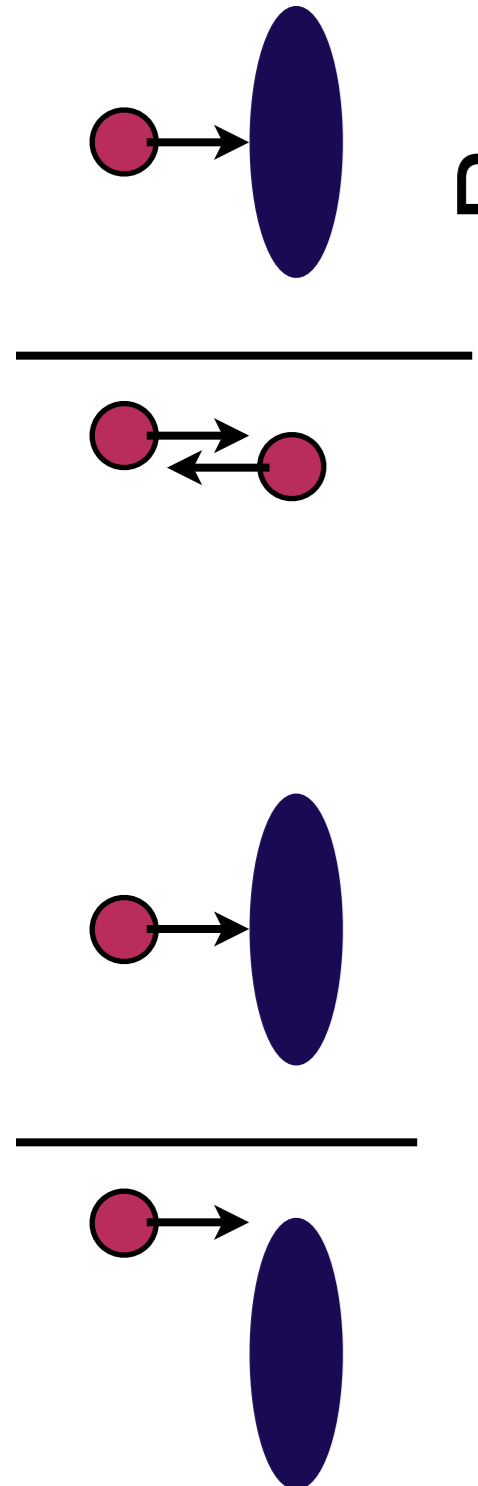


- different impressions between CMS/ATLAS & ALICE data
- big caveat: no pp reference at 5TeV (will be wanted for HI reference anyway)!
- much of the difference ALICE/CMS difference is in the reference (see E. Appelt (CMS))

# and centrality dependence?

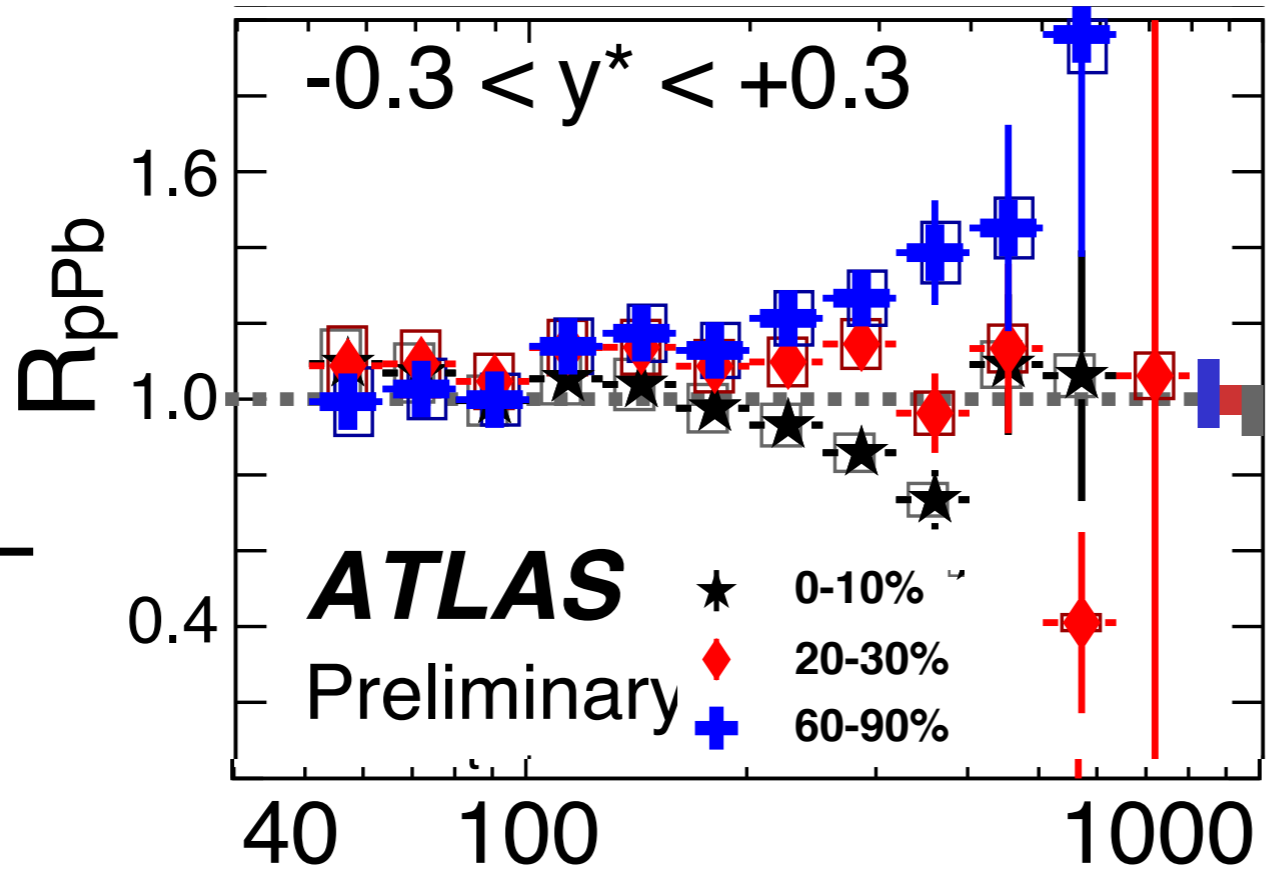
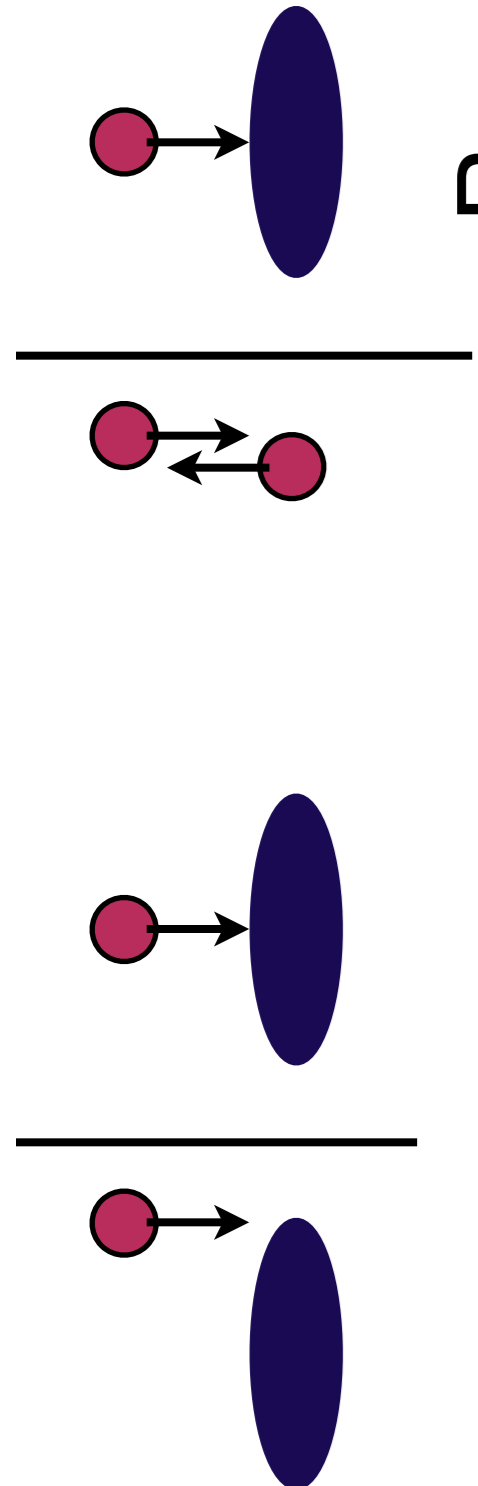


# and centrality dependence?

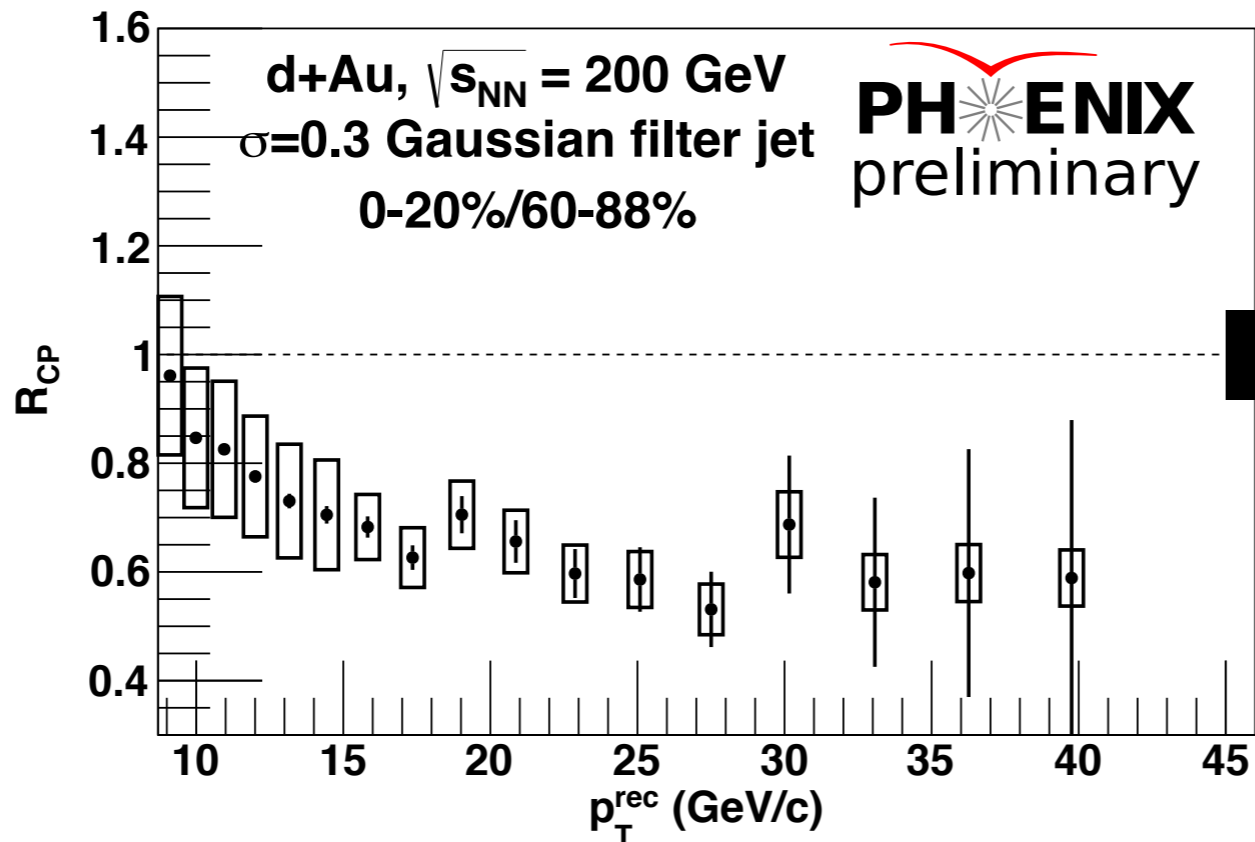




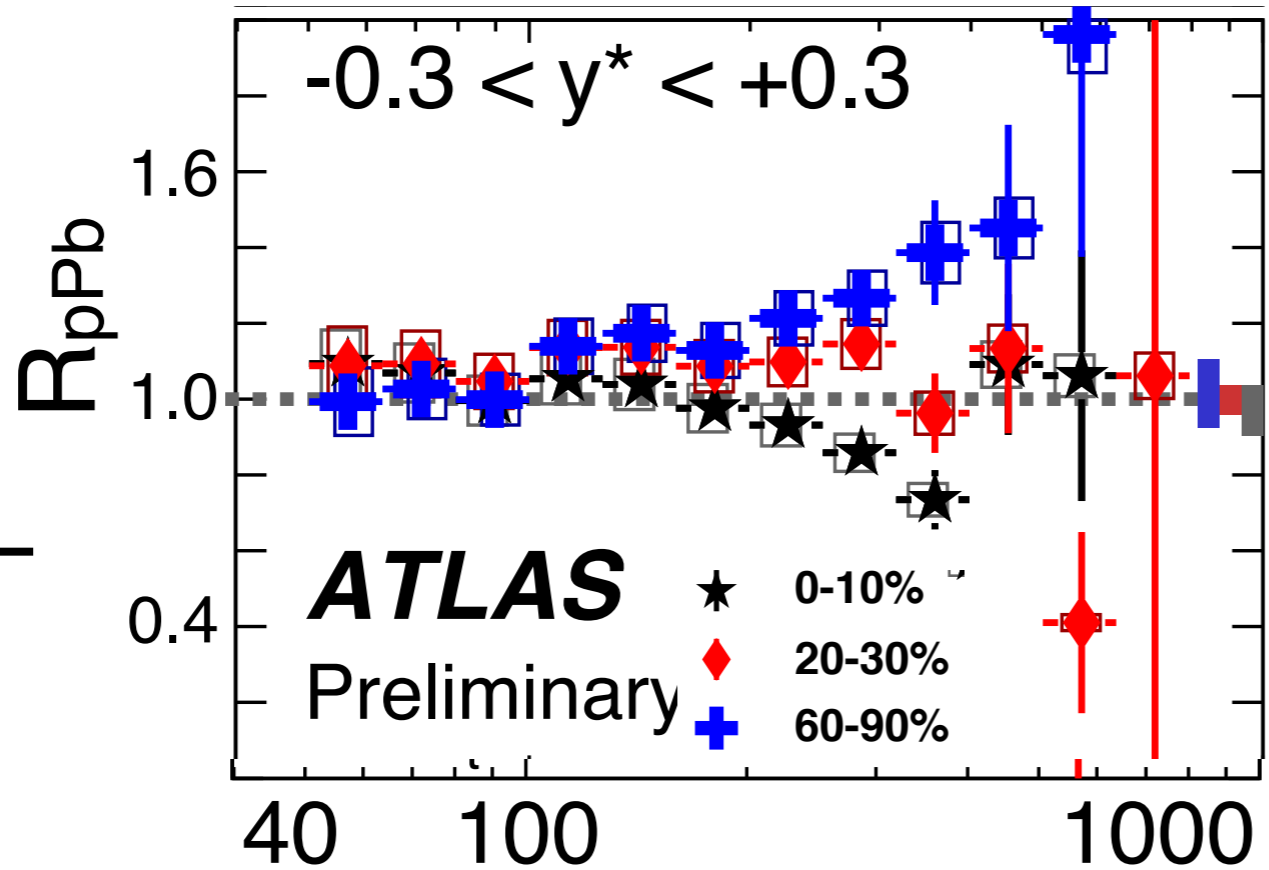
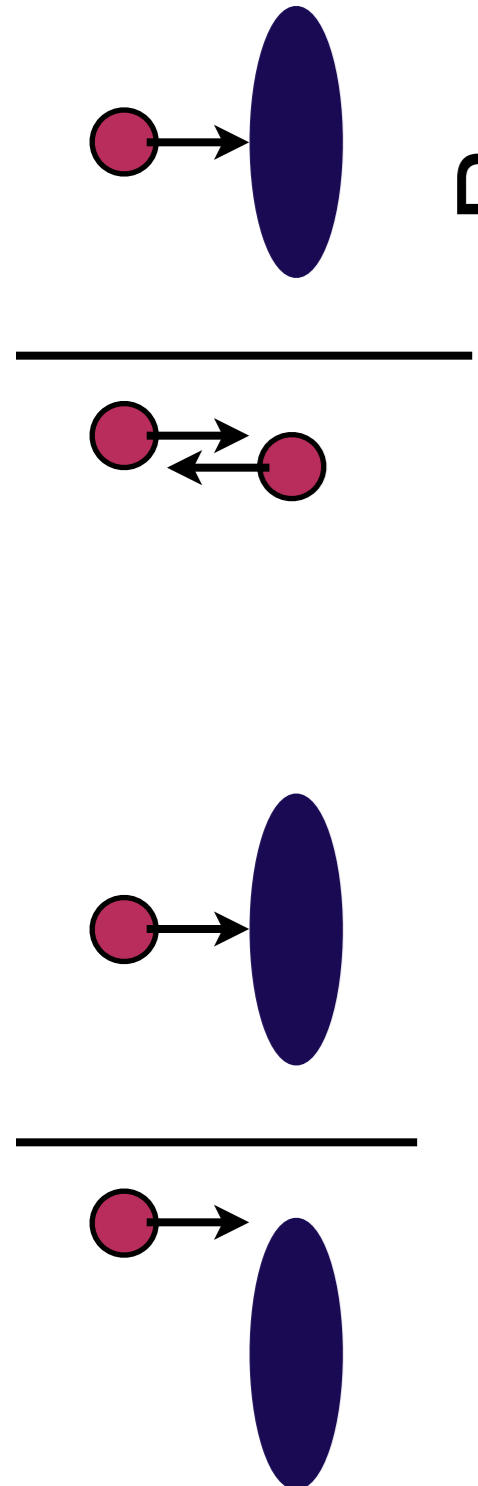
# and centrality dependence?



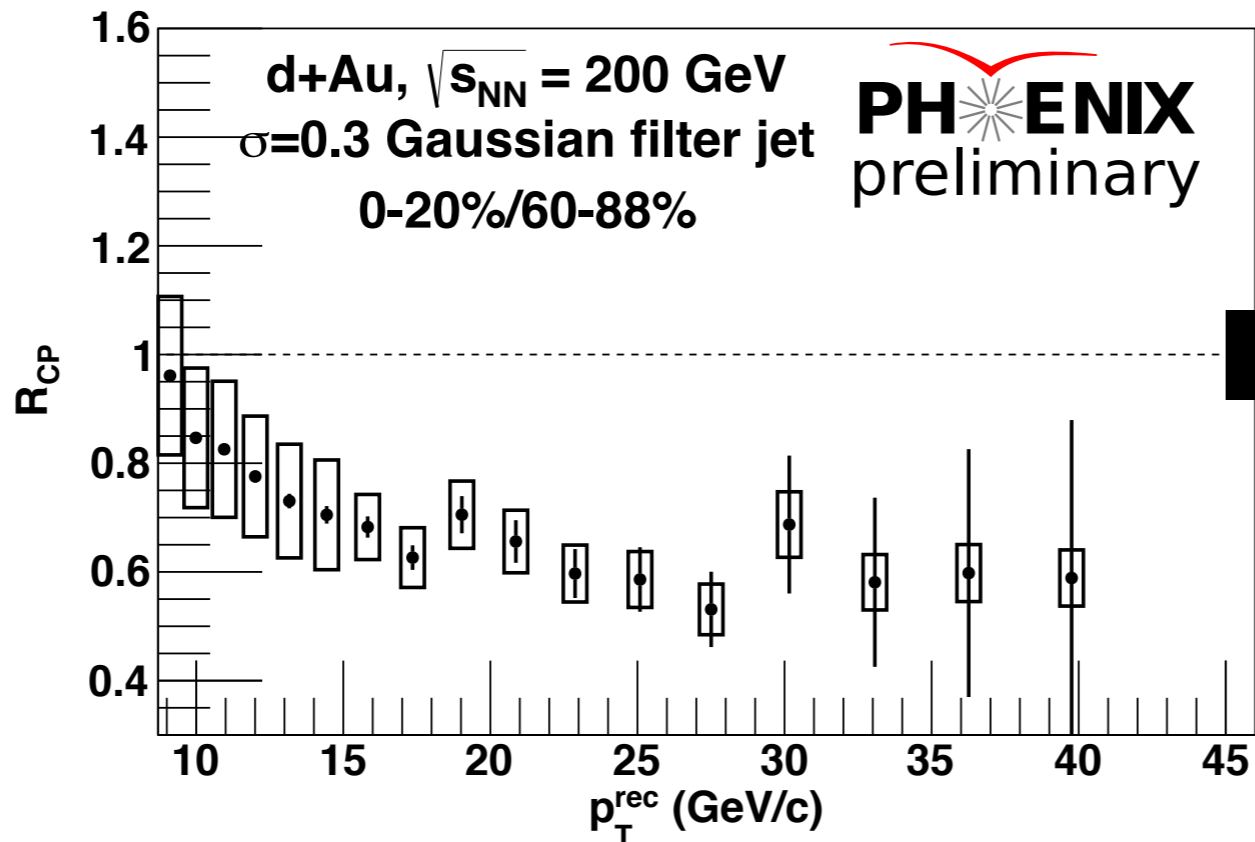
both suppression and enhancement hidden in min. bias RpA!



# and centrality dependence?

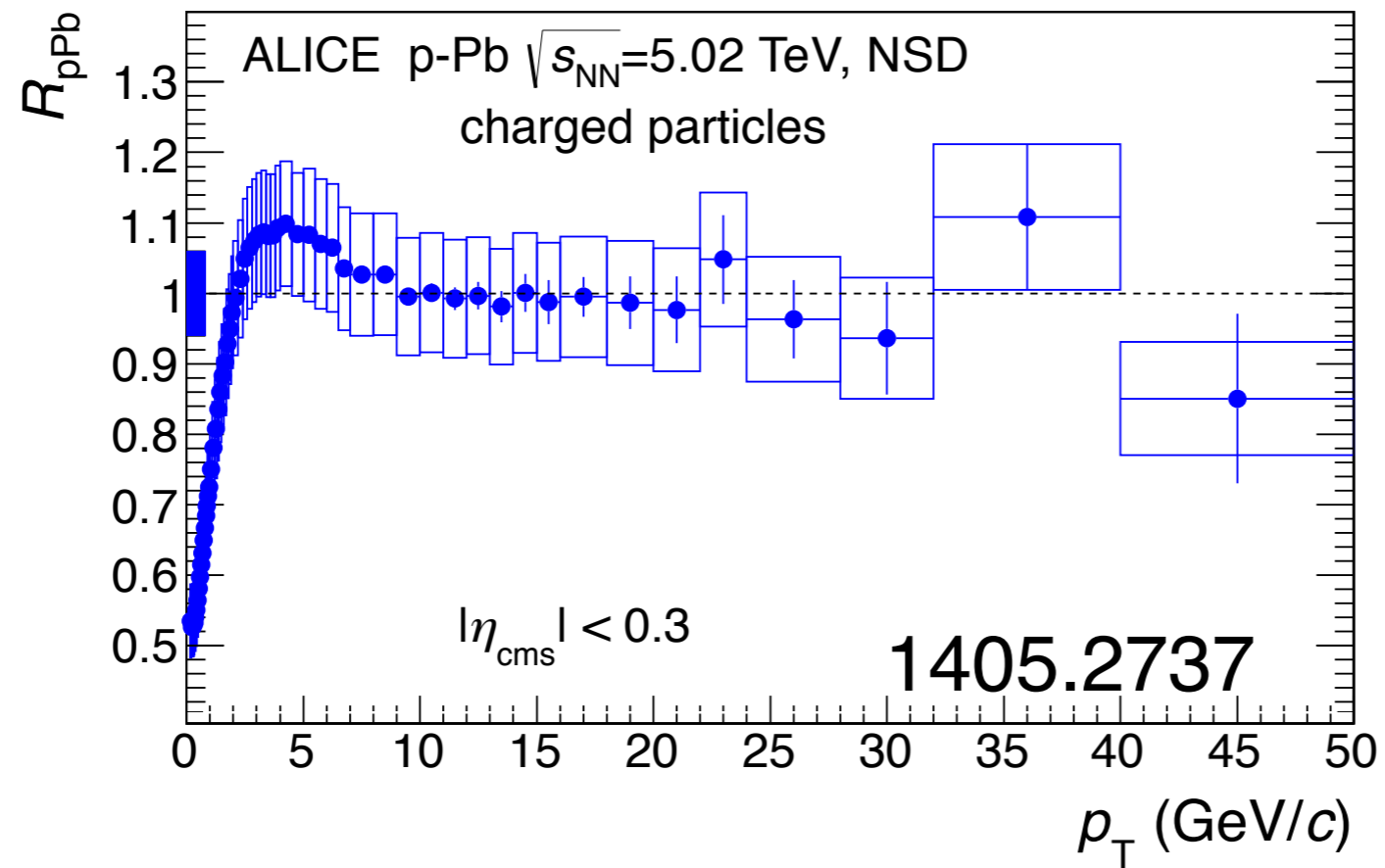


both suppression and enhancement hidden in min. bias RpA!

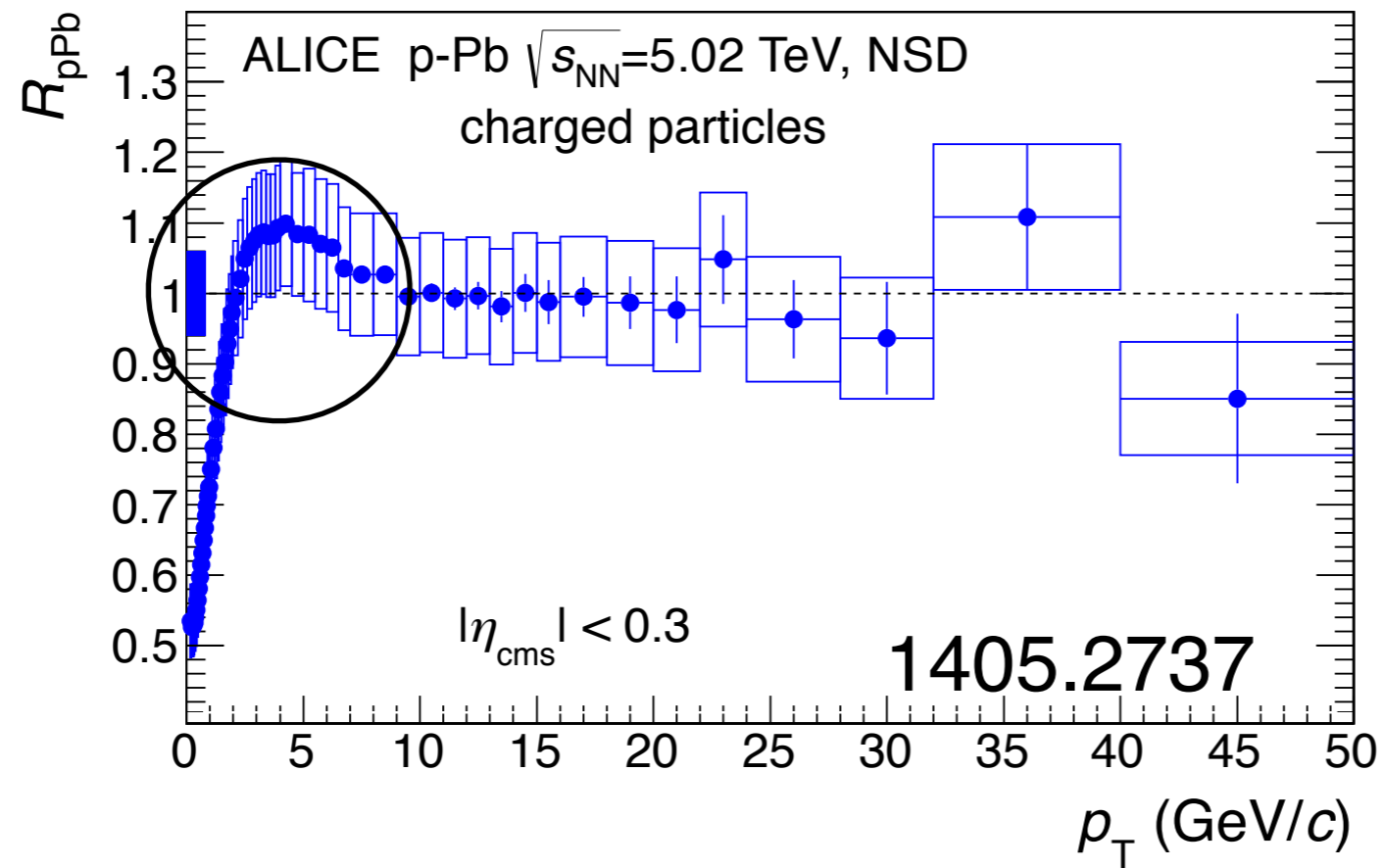


however, not necessarily the same story from ALICE

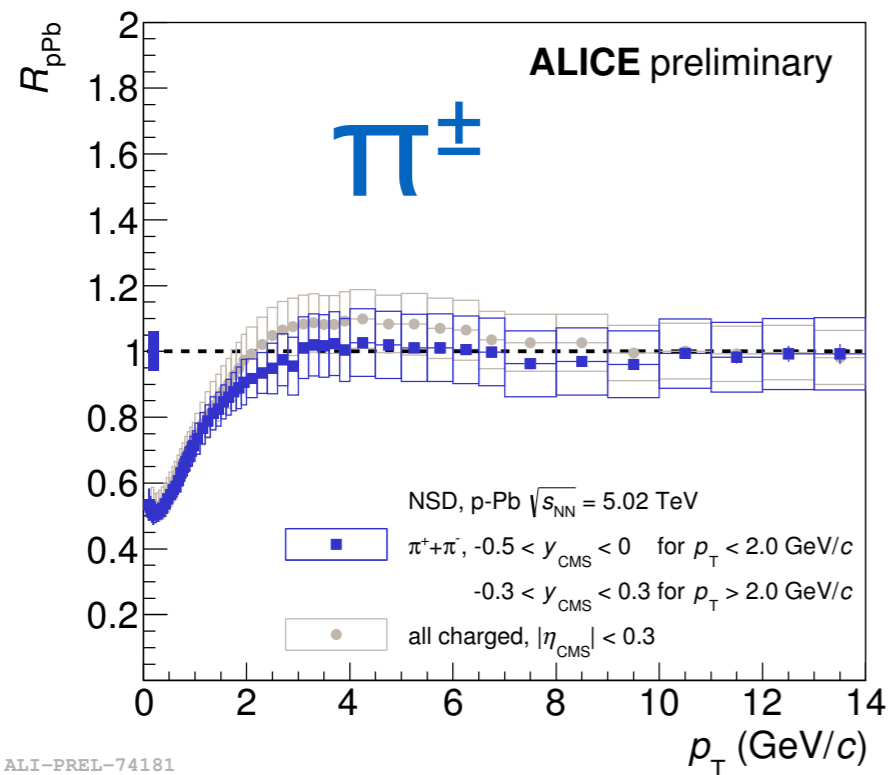
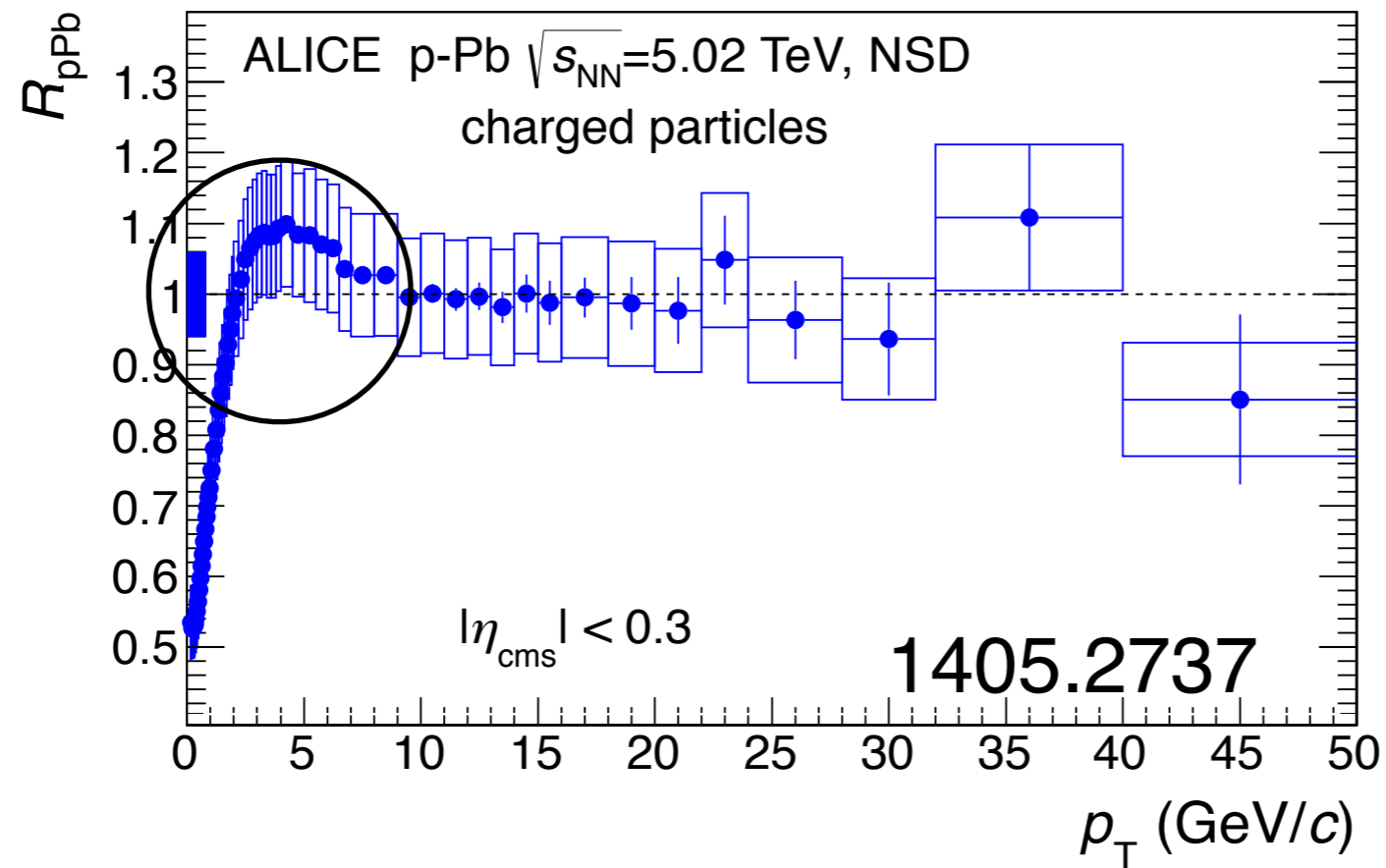
# moving down in $p_T$



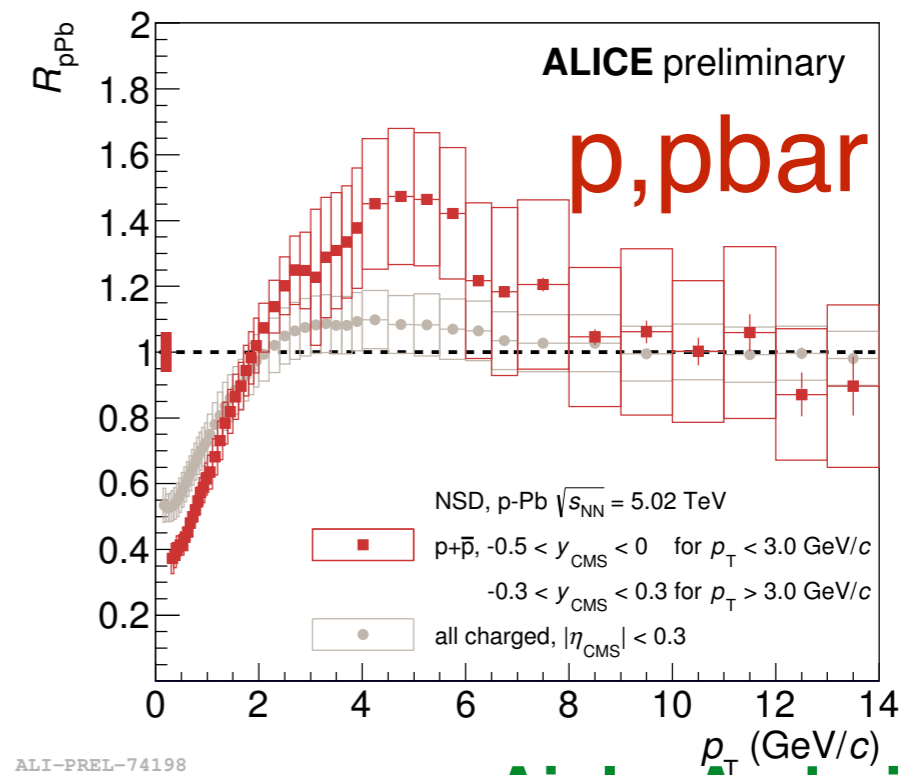
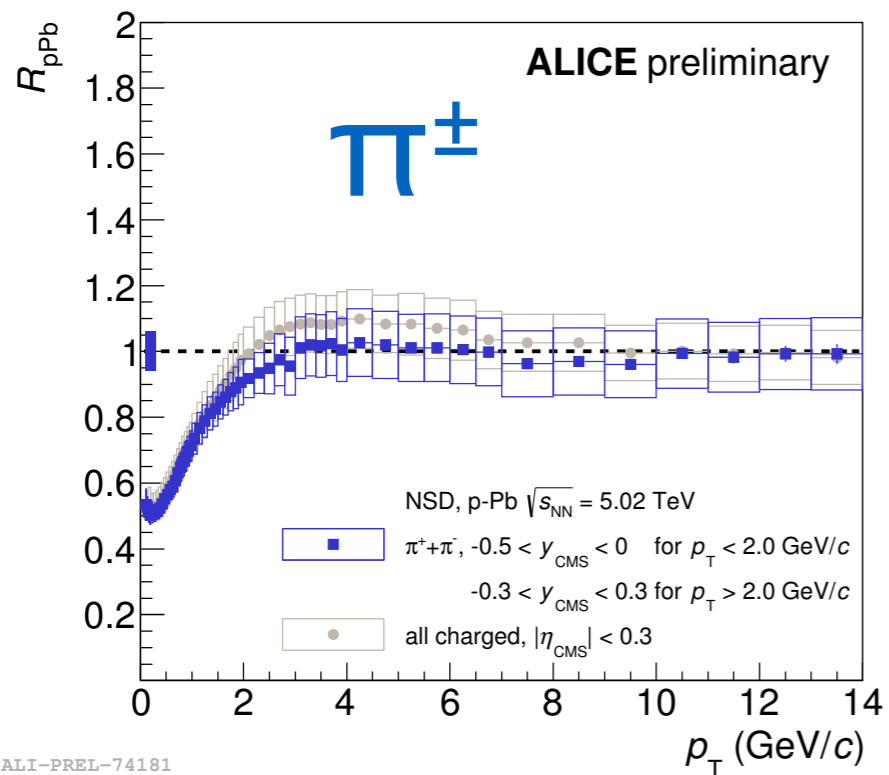
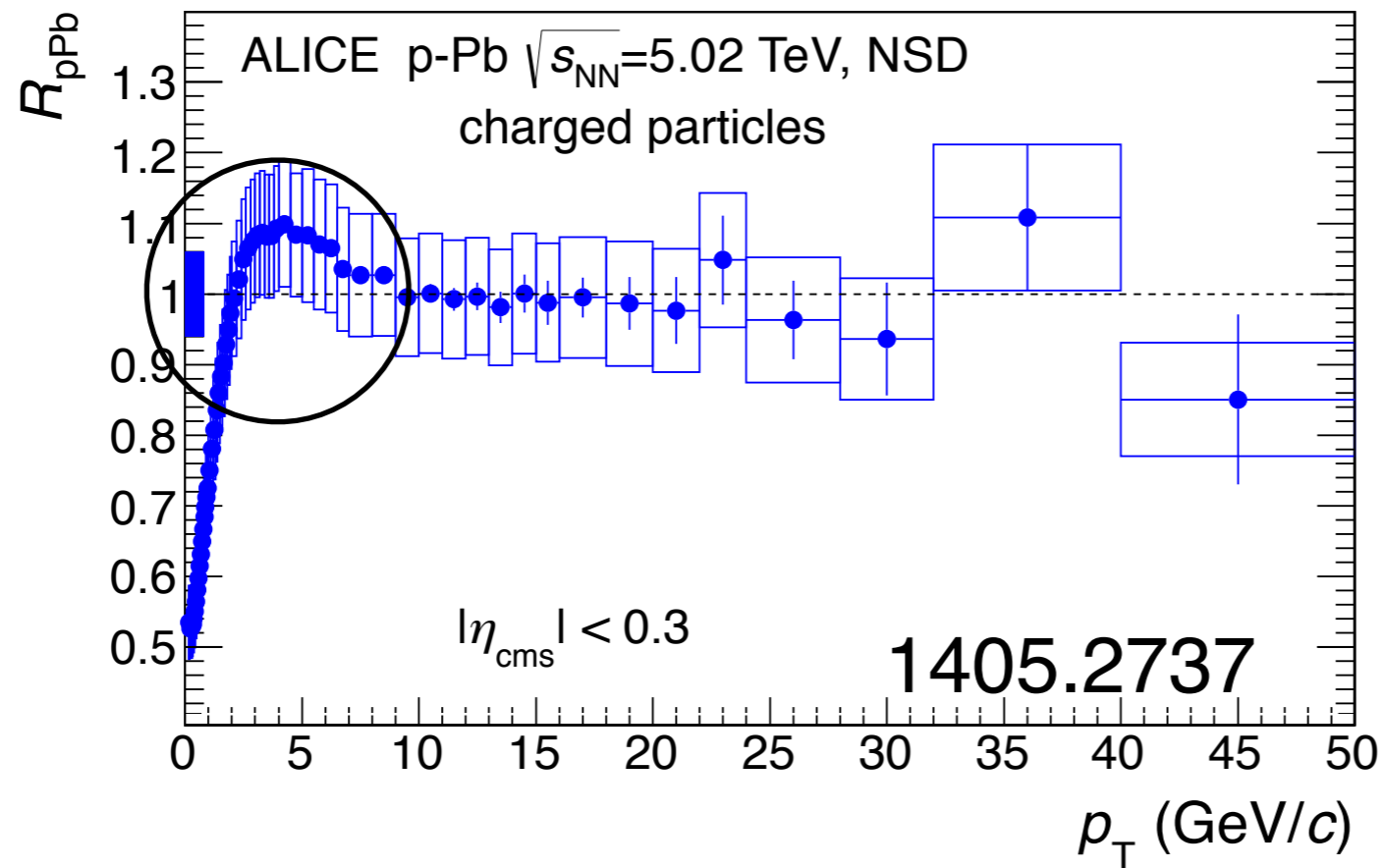
# moving down in $p_T$



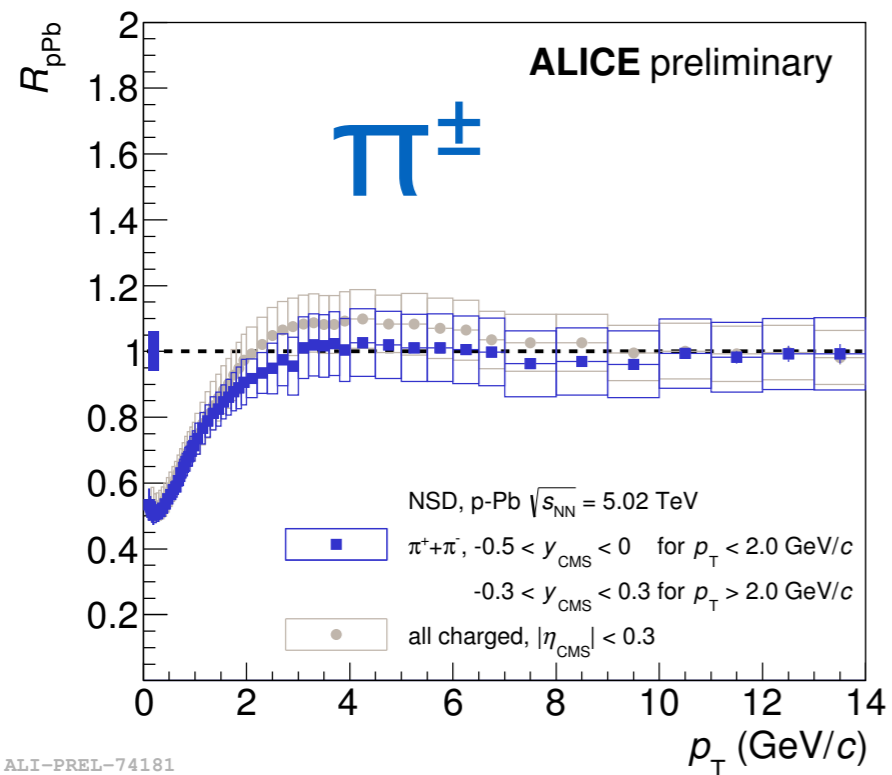
# moving down in $p_T$



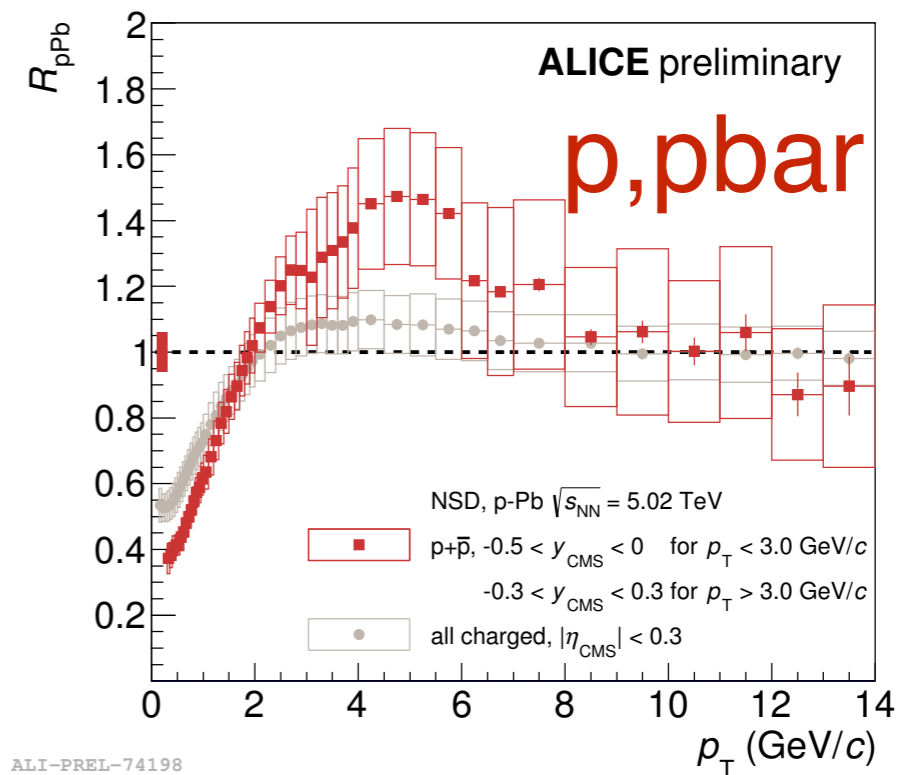
# moving down in $p_T$



# enhanced protons



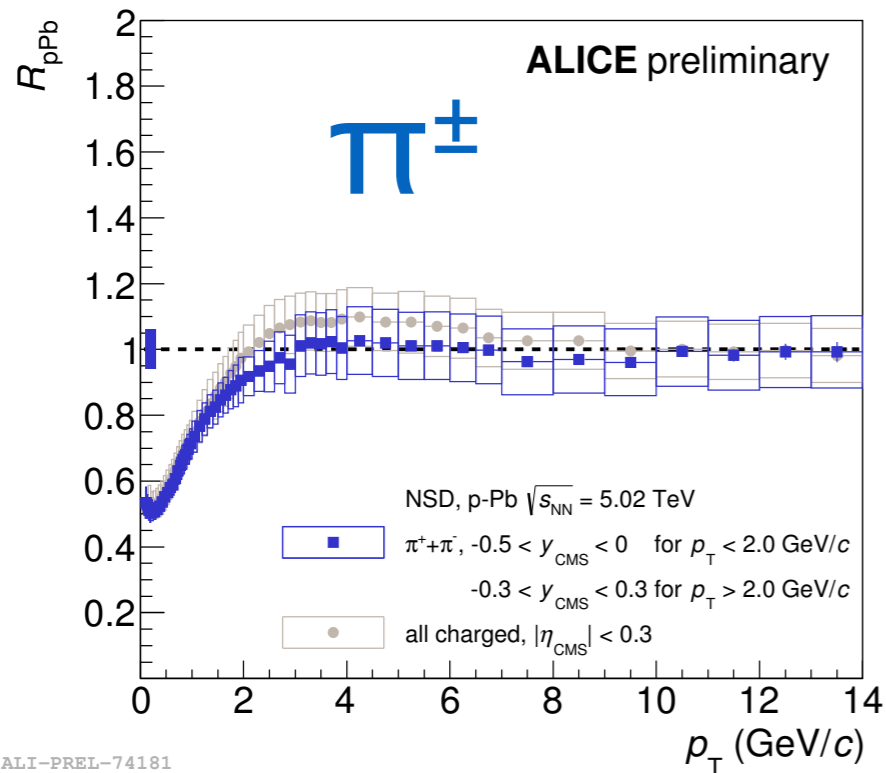
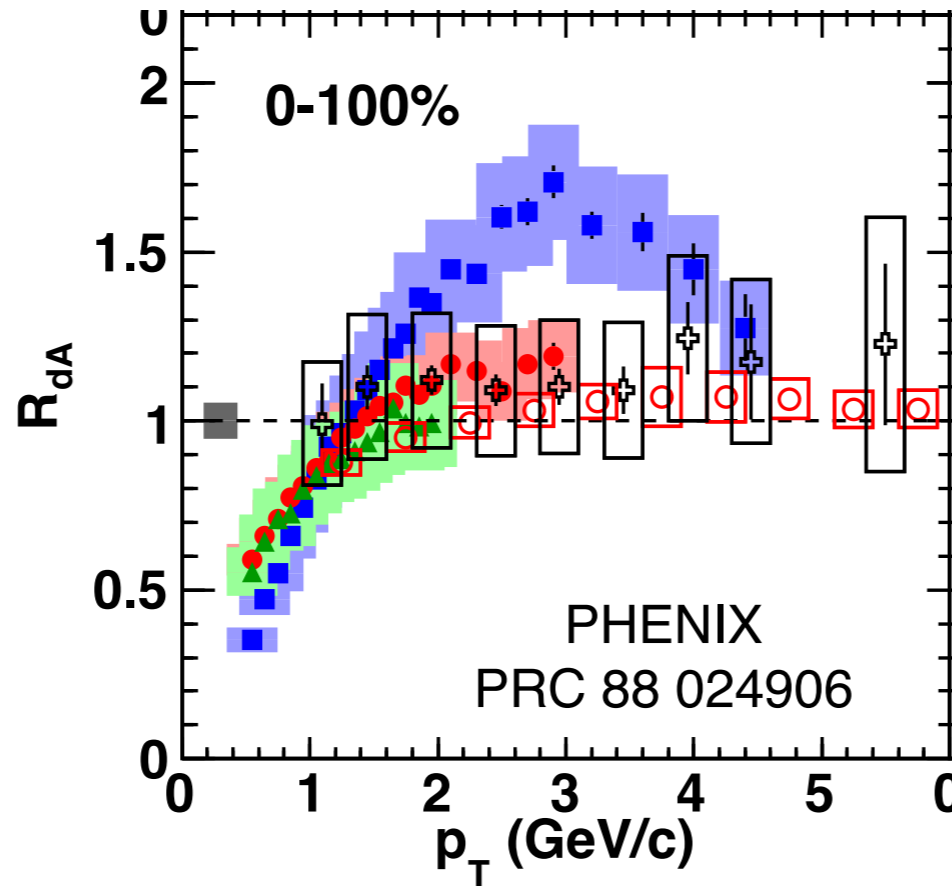
LHC  
p+Pb



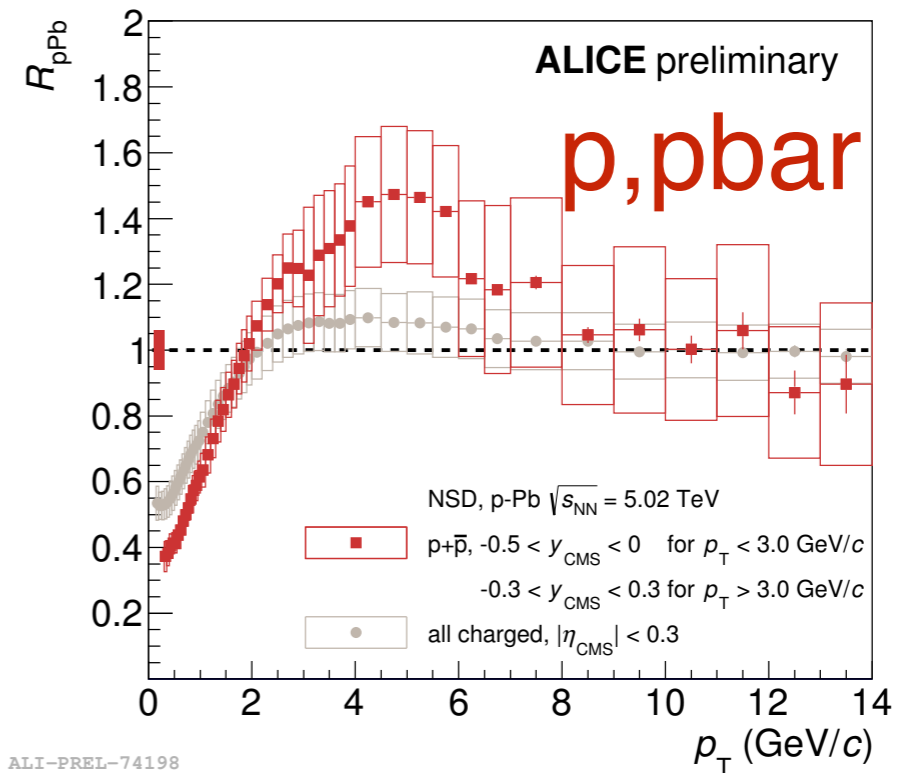


# enhanced protons

**RHIC  
d+Au**

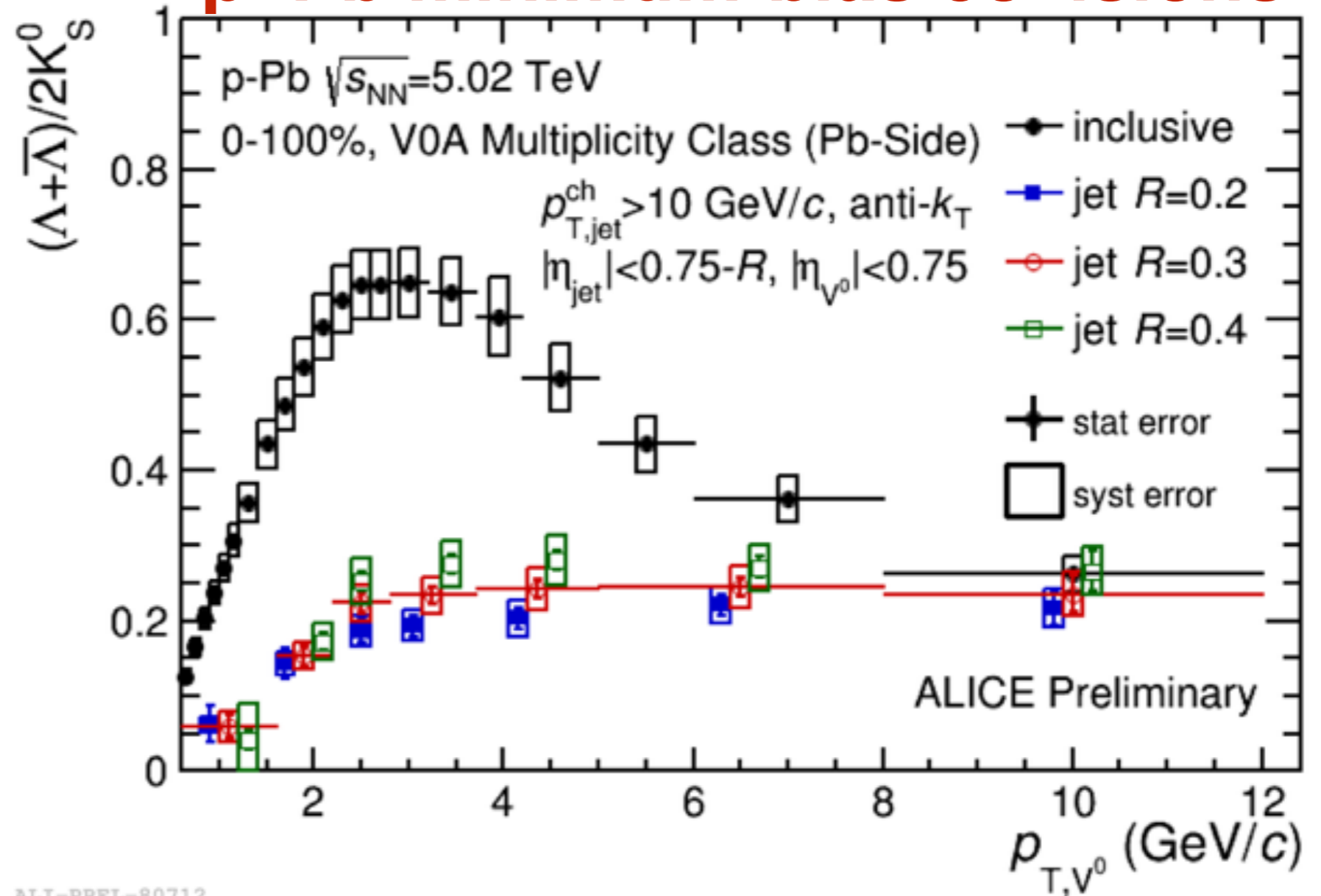


**LHC  
p+Pb**



# where are the enhanced baryons from?

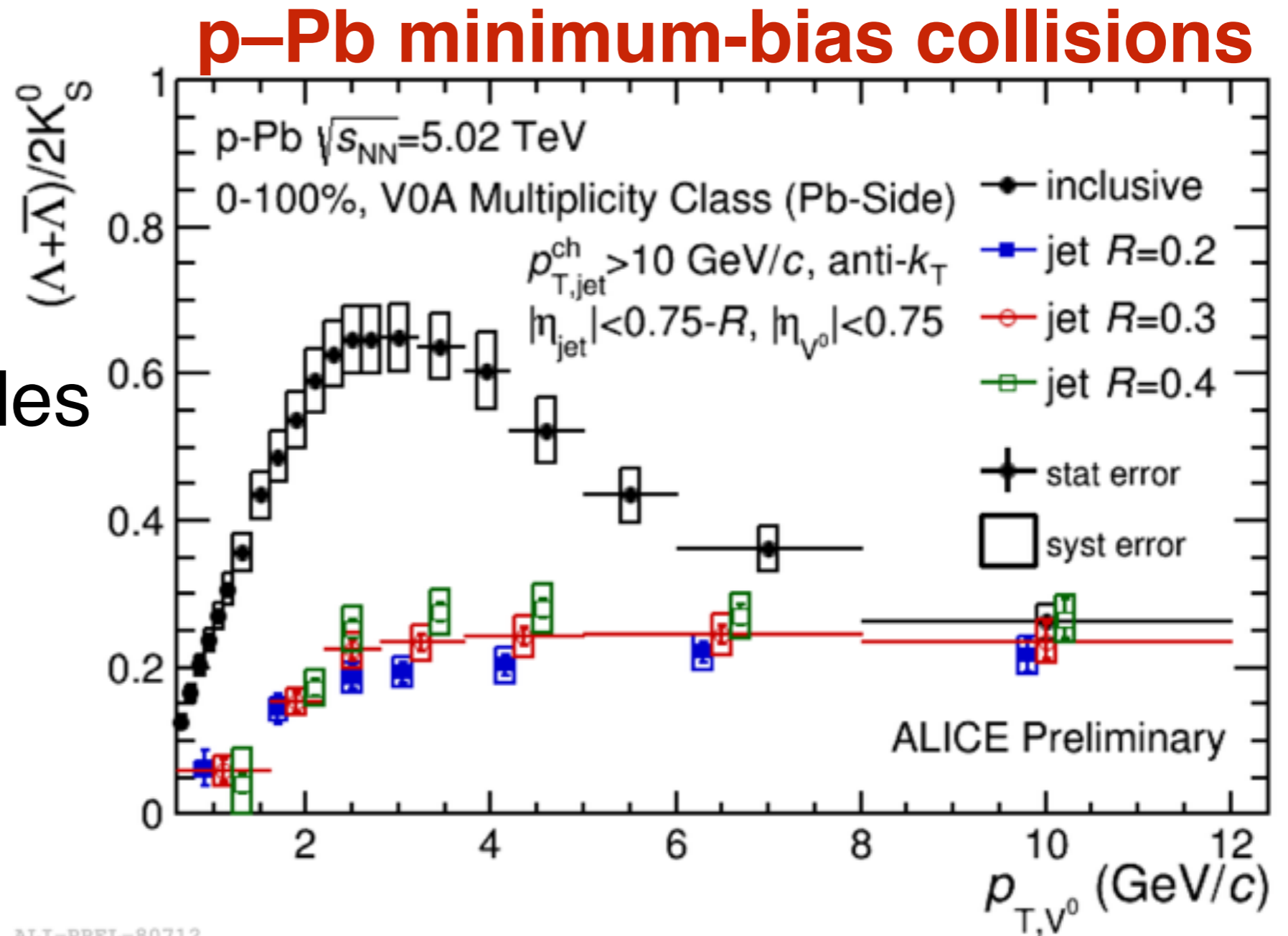
## p-Pb minimum-bias collisions



ALI-PREL-80712

# where are the enhanced baryons from?

inclusive particles



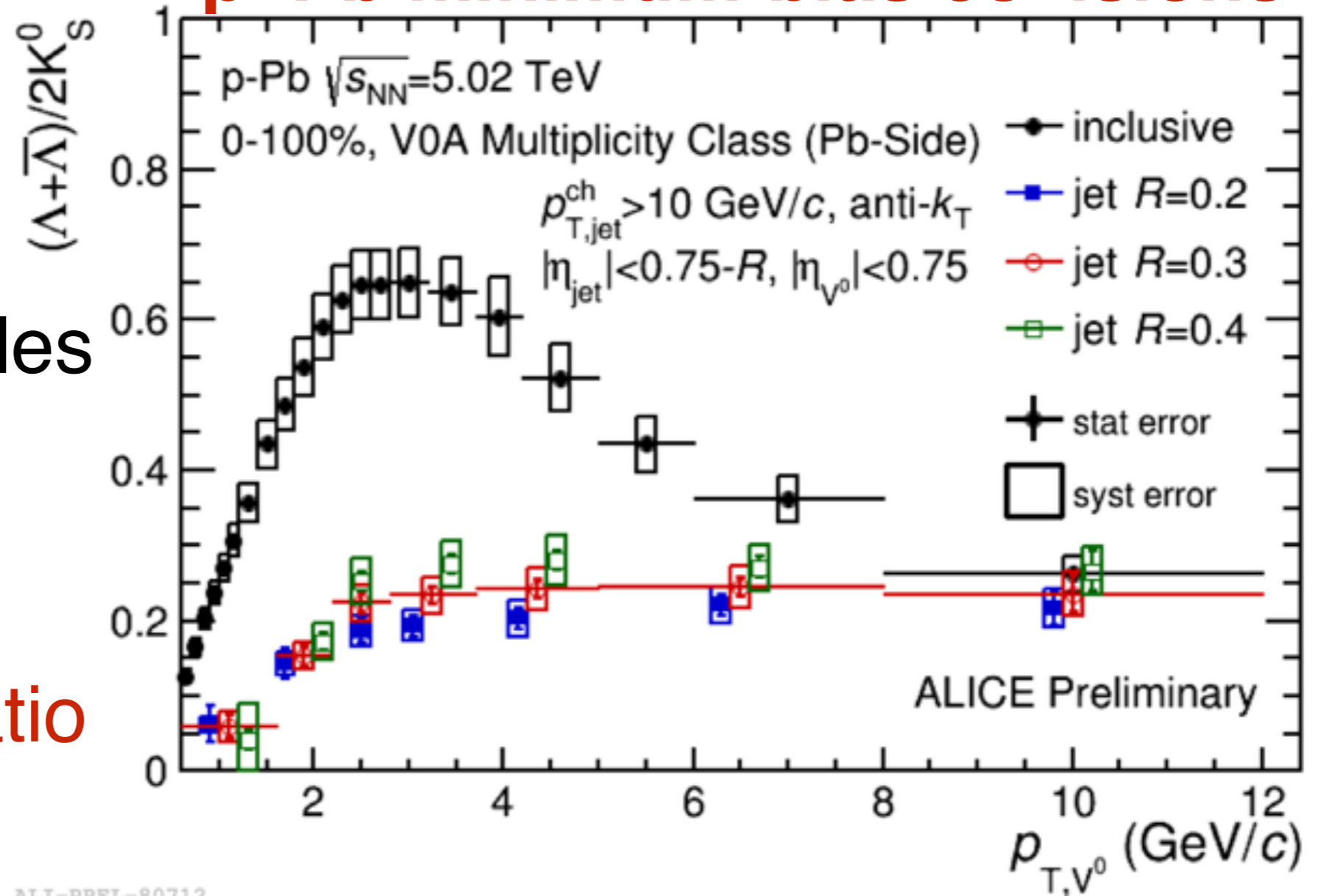
ALI-PREL-80712

# where are the enhanced baryons from?

inclusive particles

**jets:**  
PYTHIA-like ratio

## p-Pb minimum-bias collisions

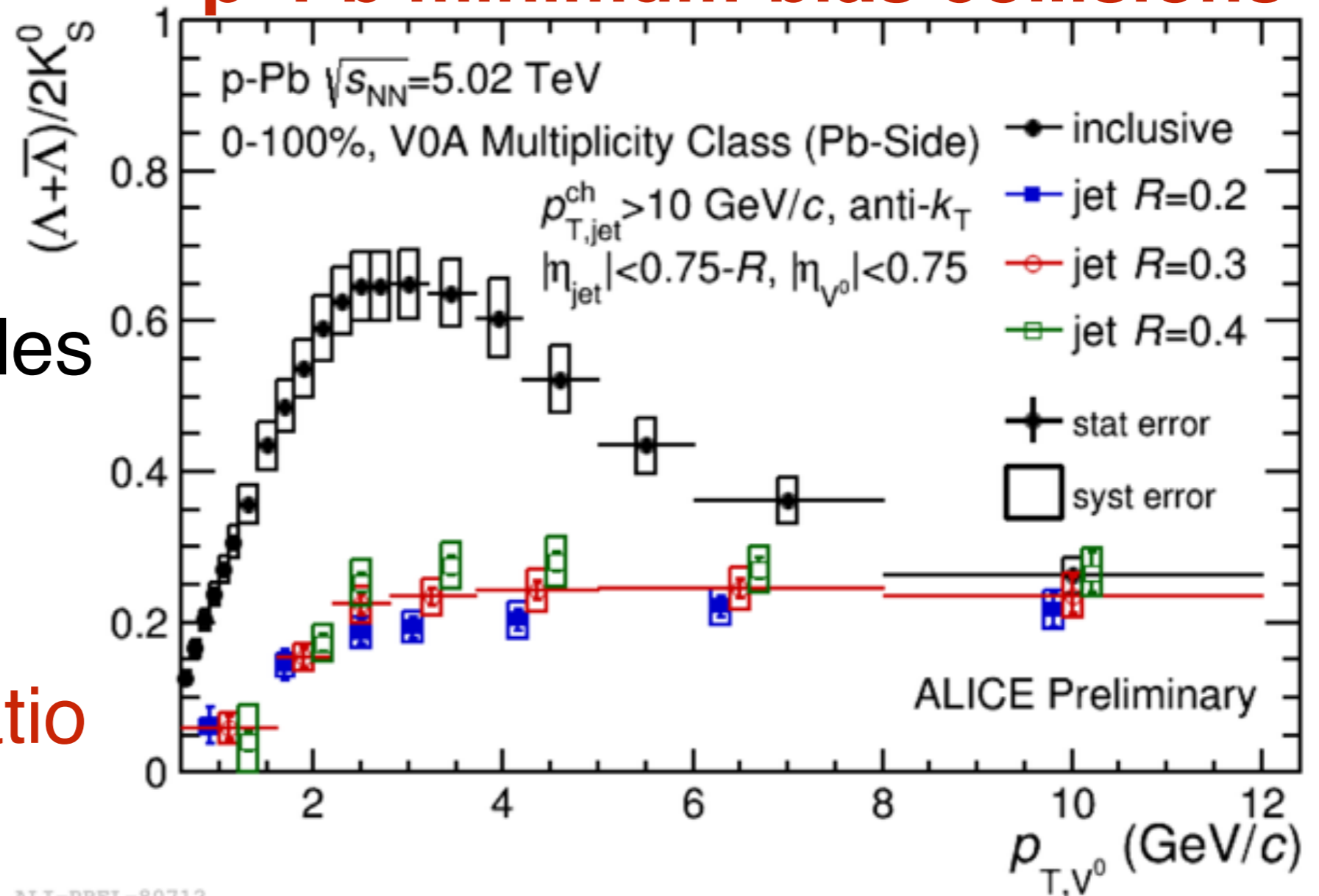


# where are the enhanced baryons from?

## p-Pb minimum-bias collisions

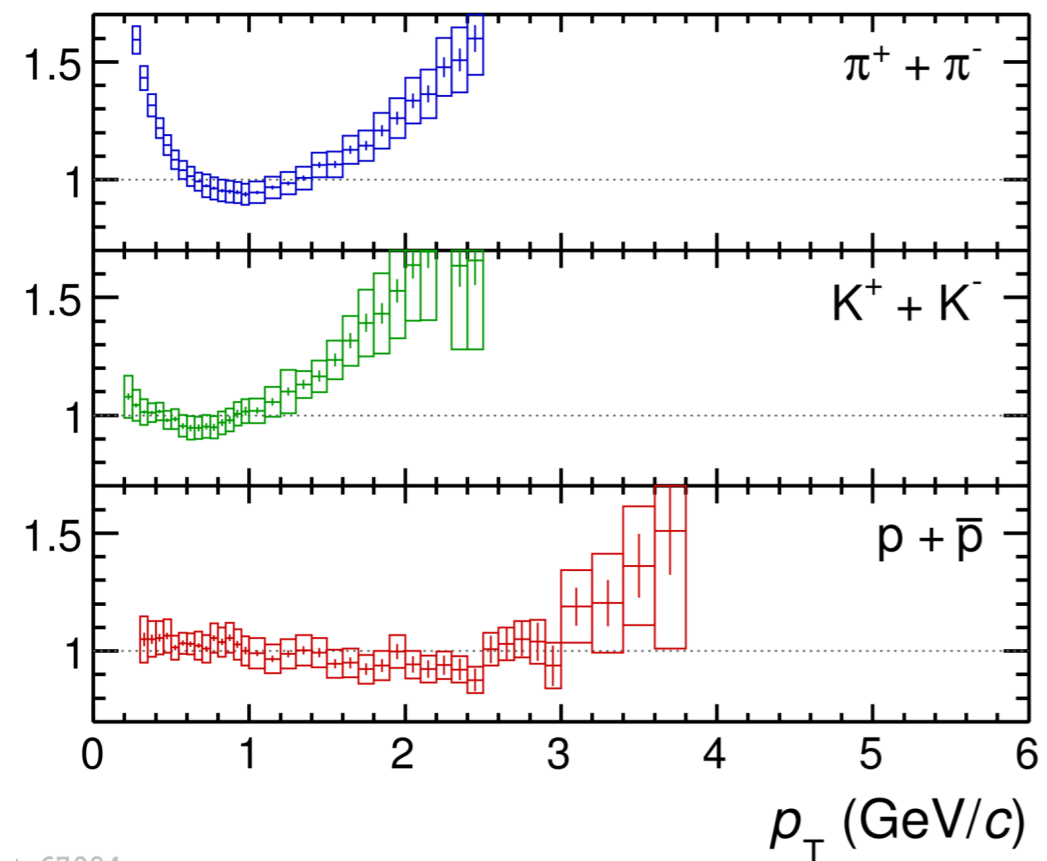
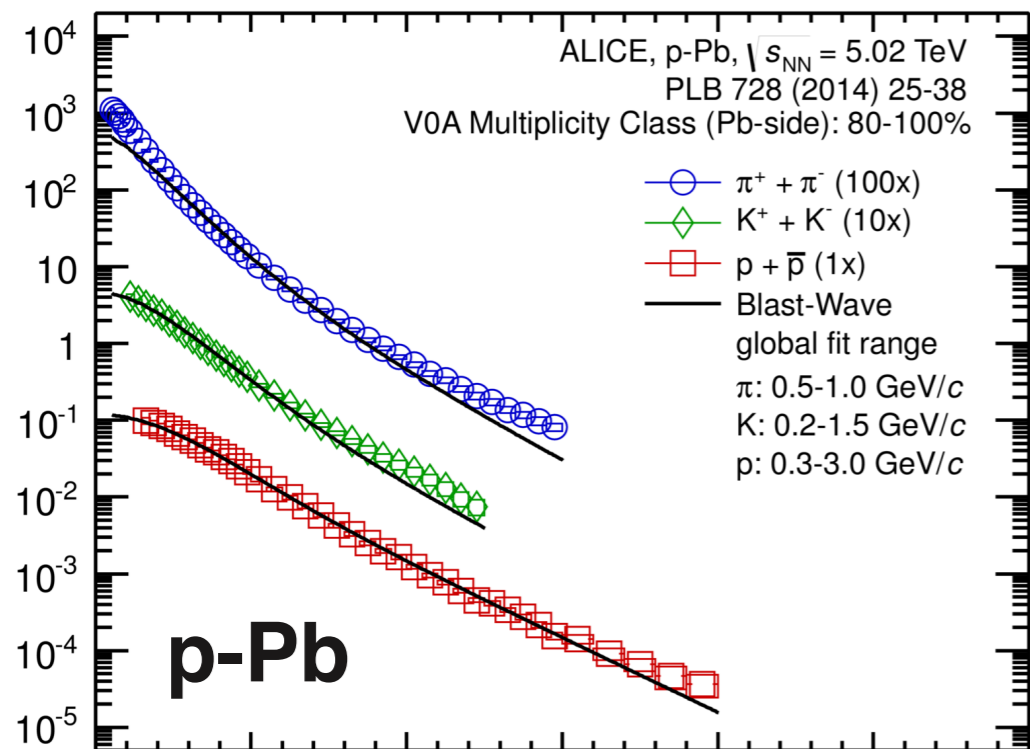
inclusive particles

**jets:**  
PYTHIA-like ratio



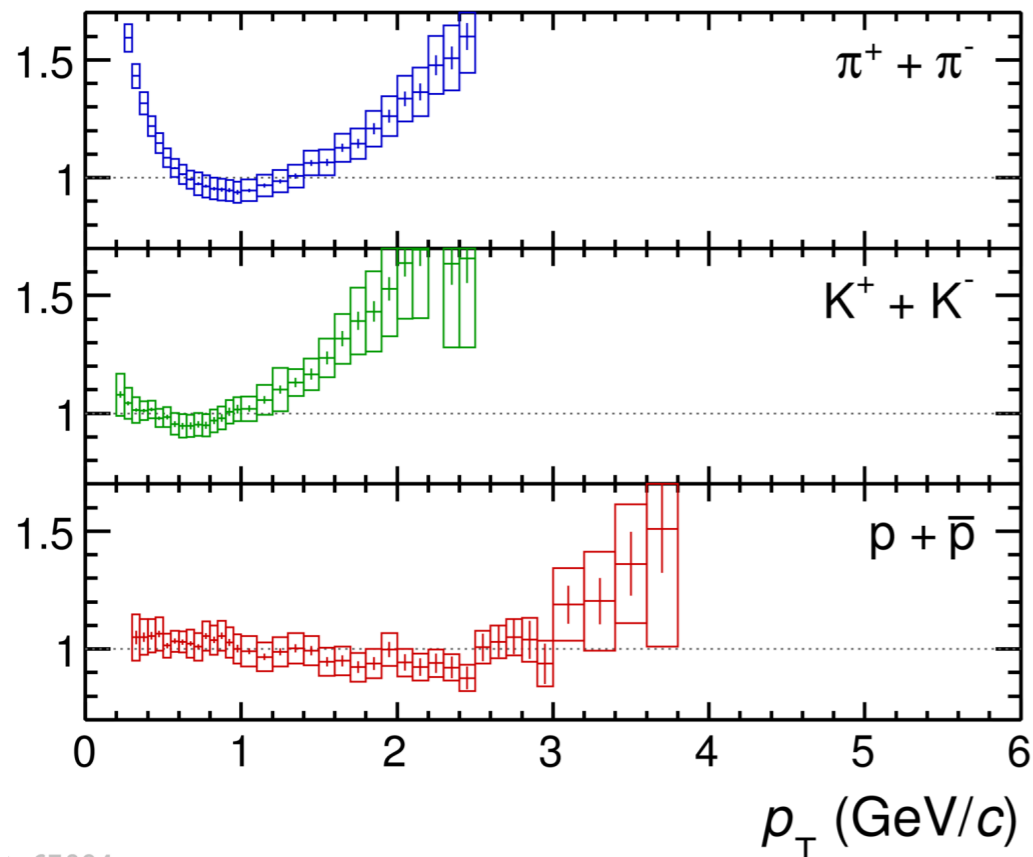
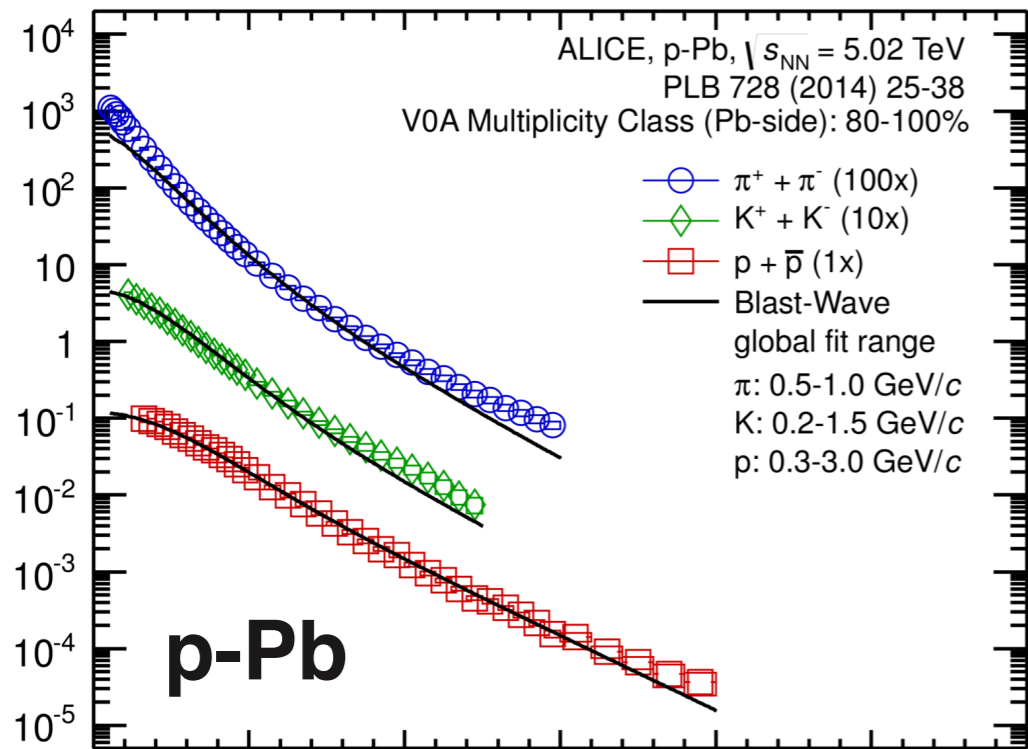
extra baryons don't seem to be in the jets...

# low $p_T$ spectra

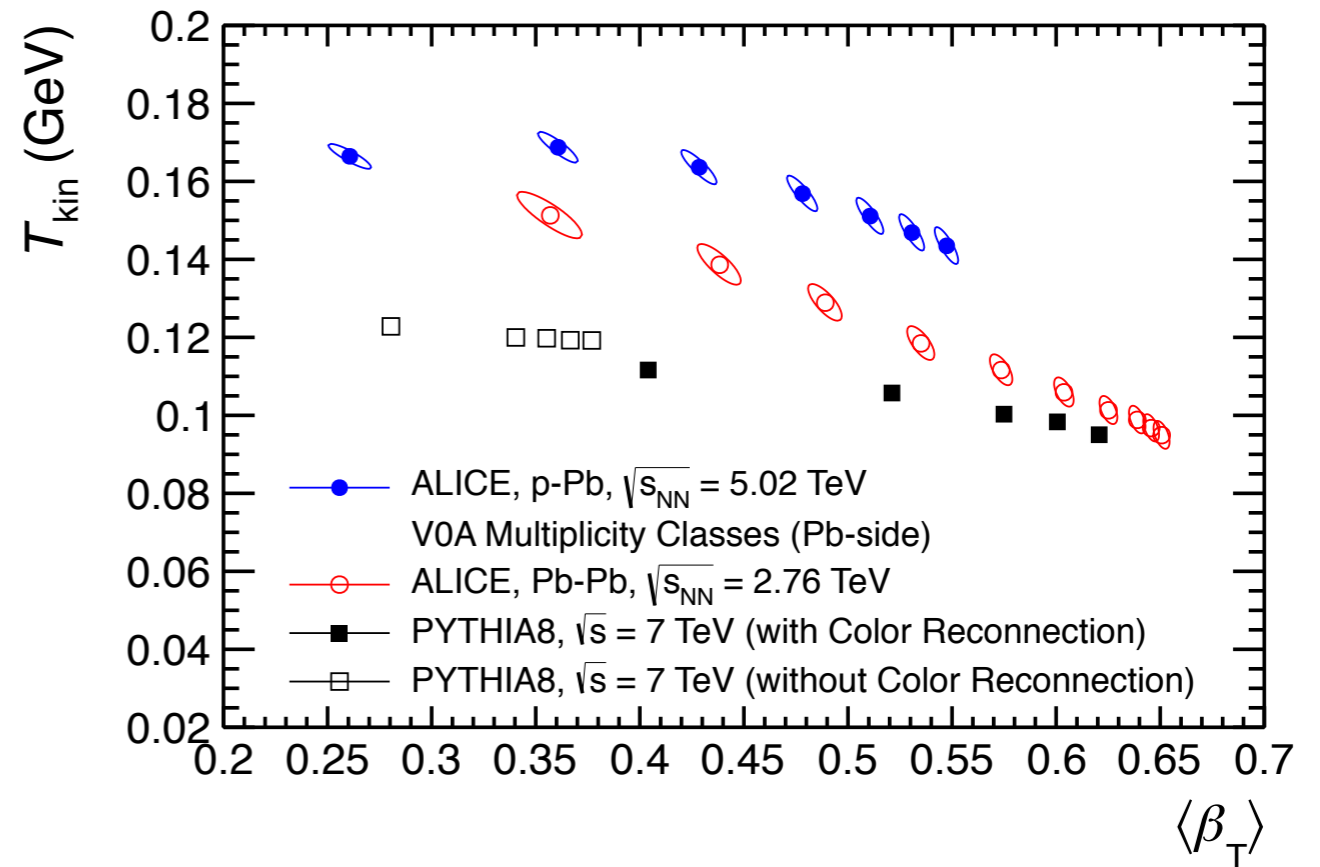


PLB 728 25 (2014)

# low $p_T$ spectra

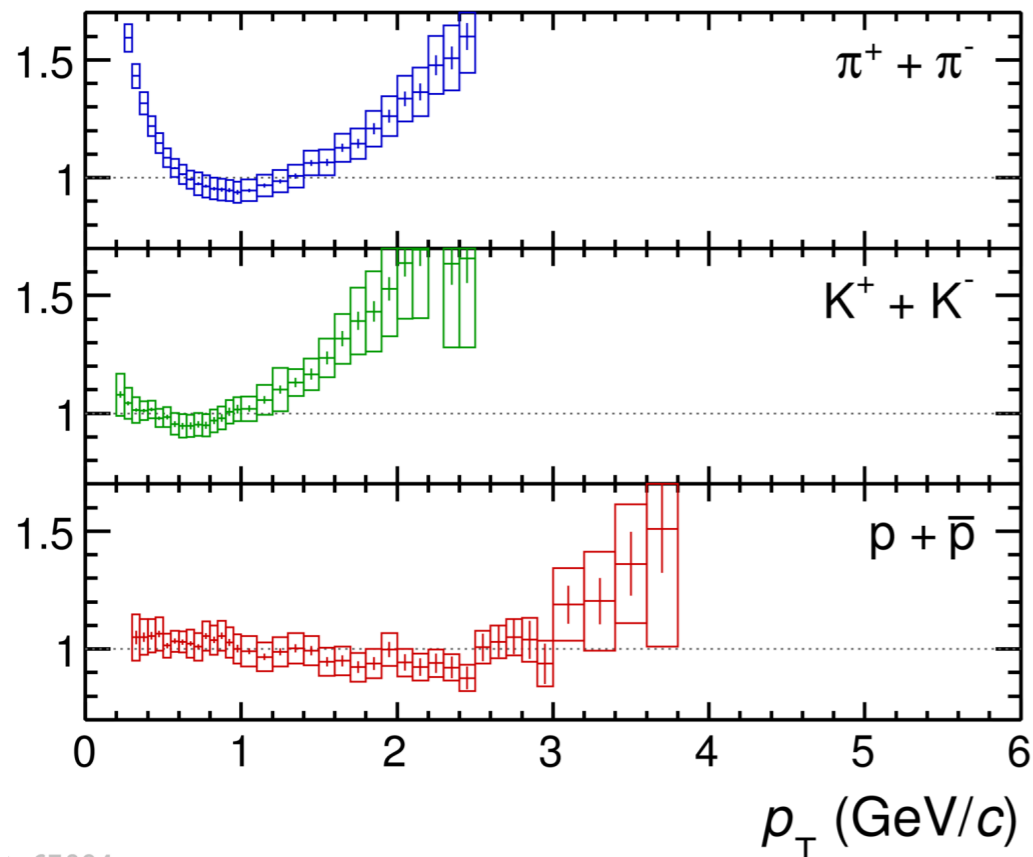
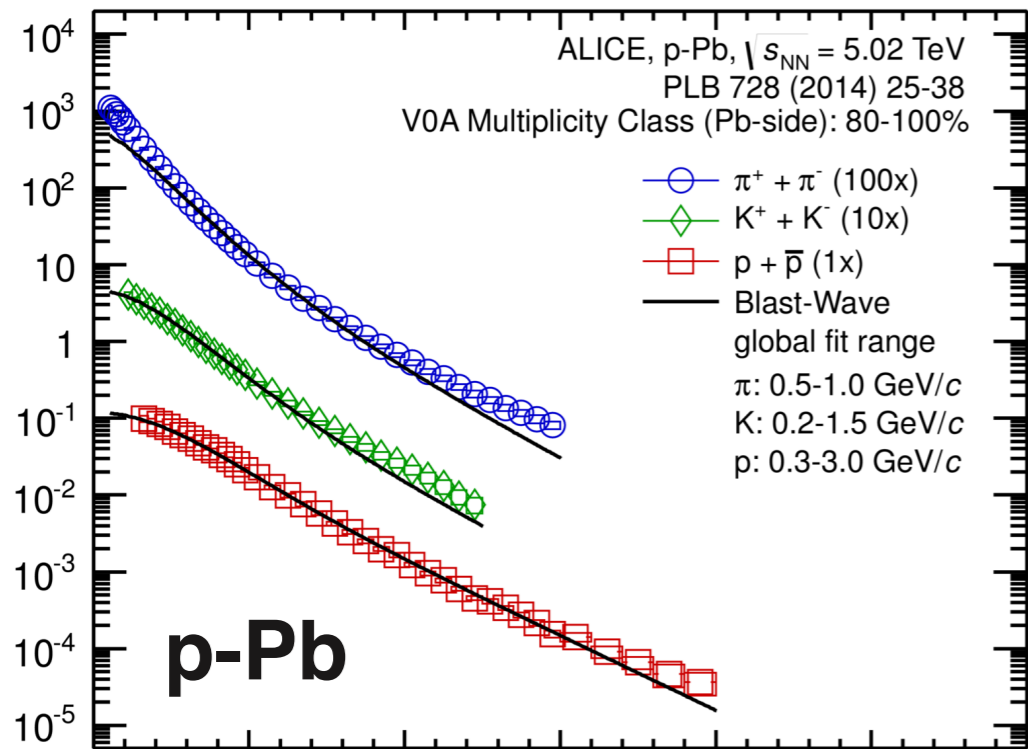


PLB 728 25 (2014)

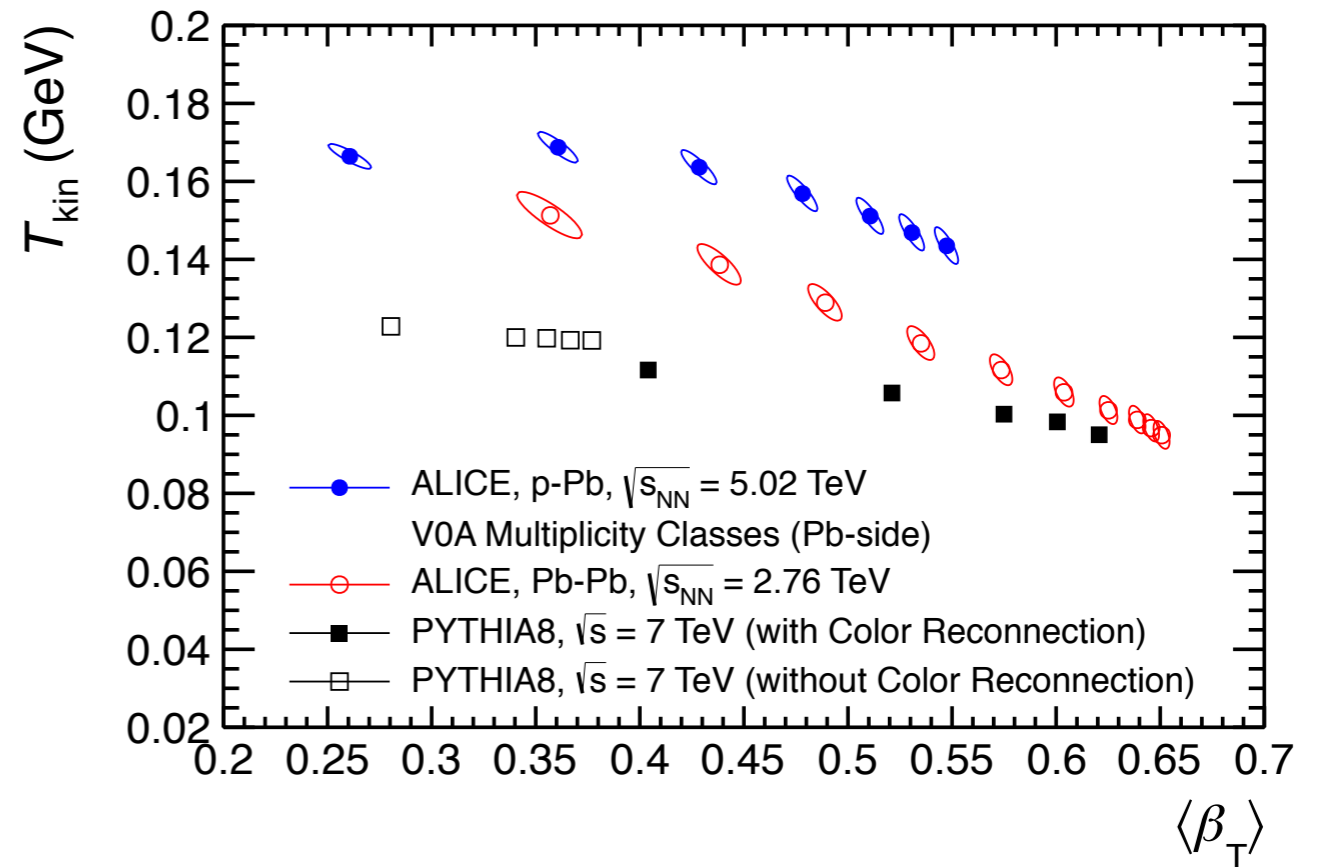




# low $p_T$ spectra

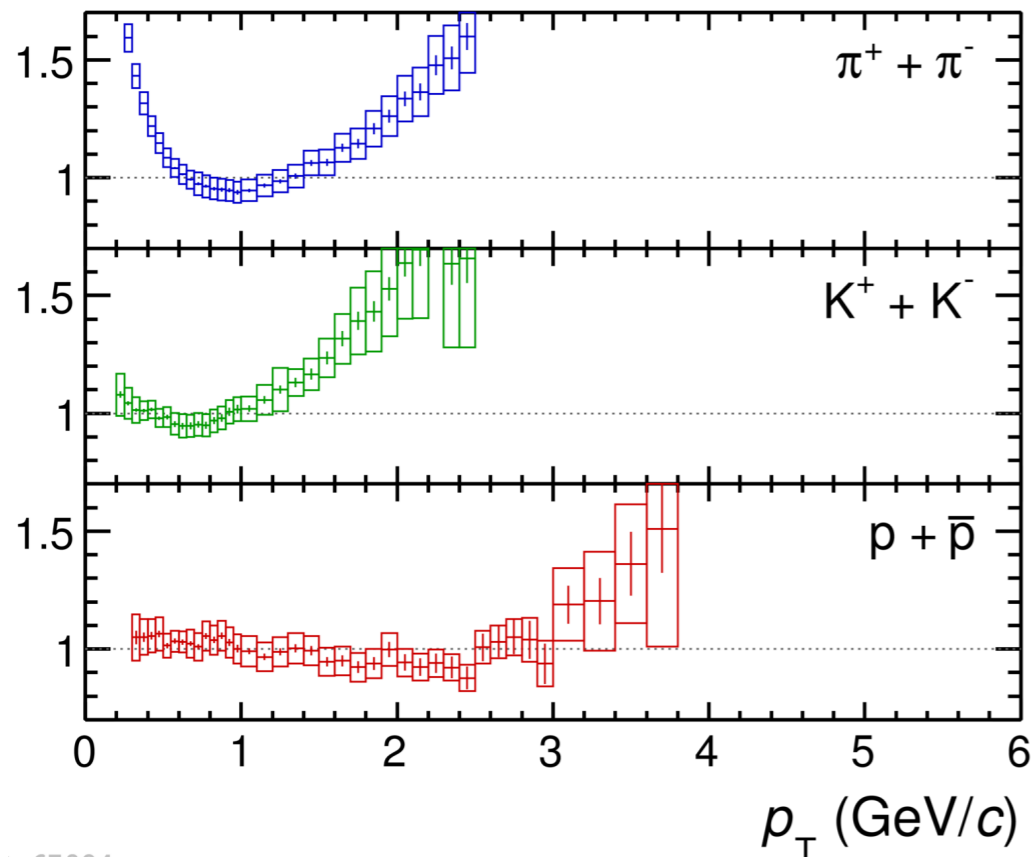
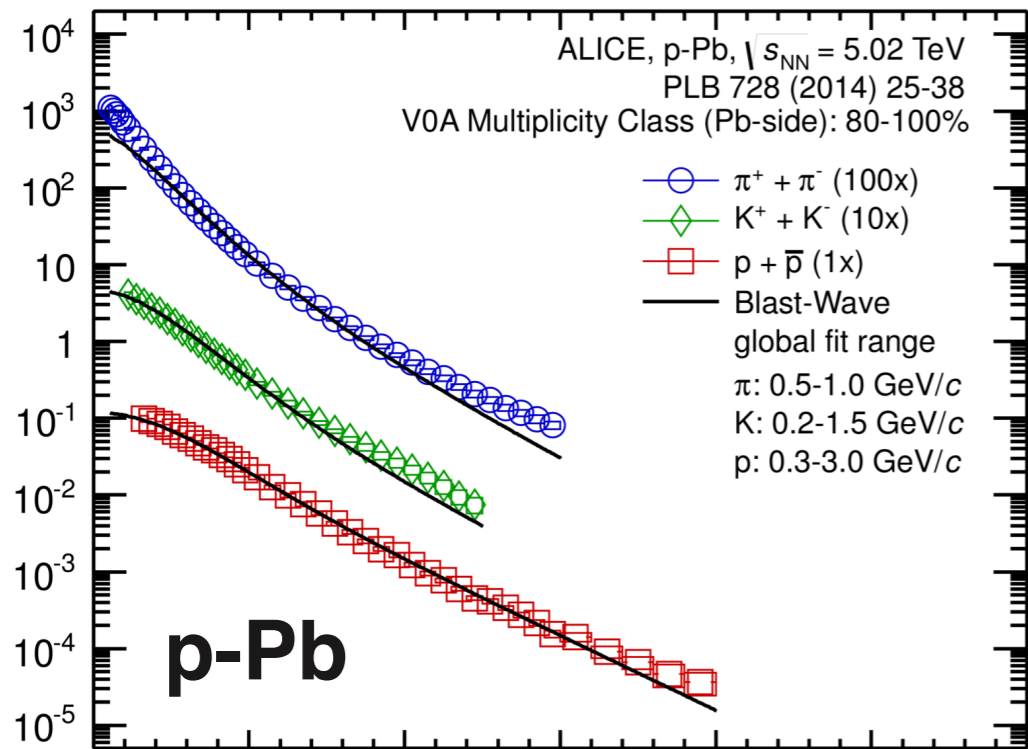


PLB 728 25 (2014)

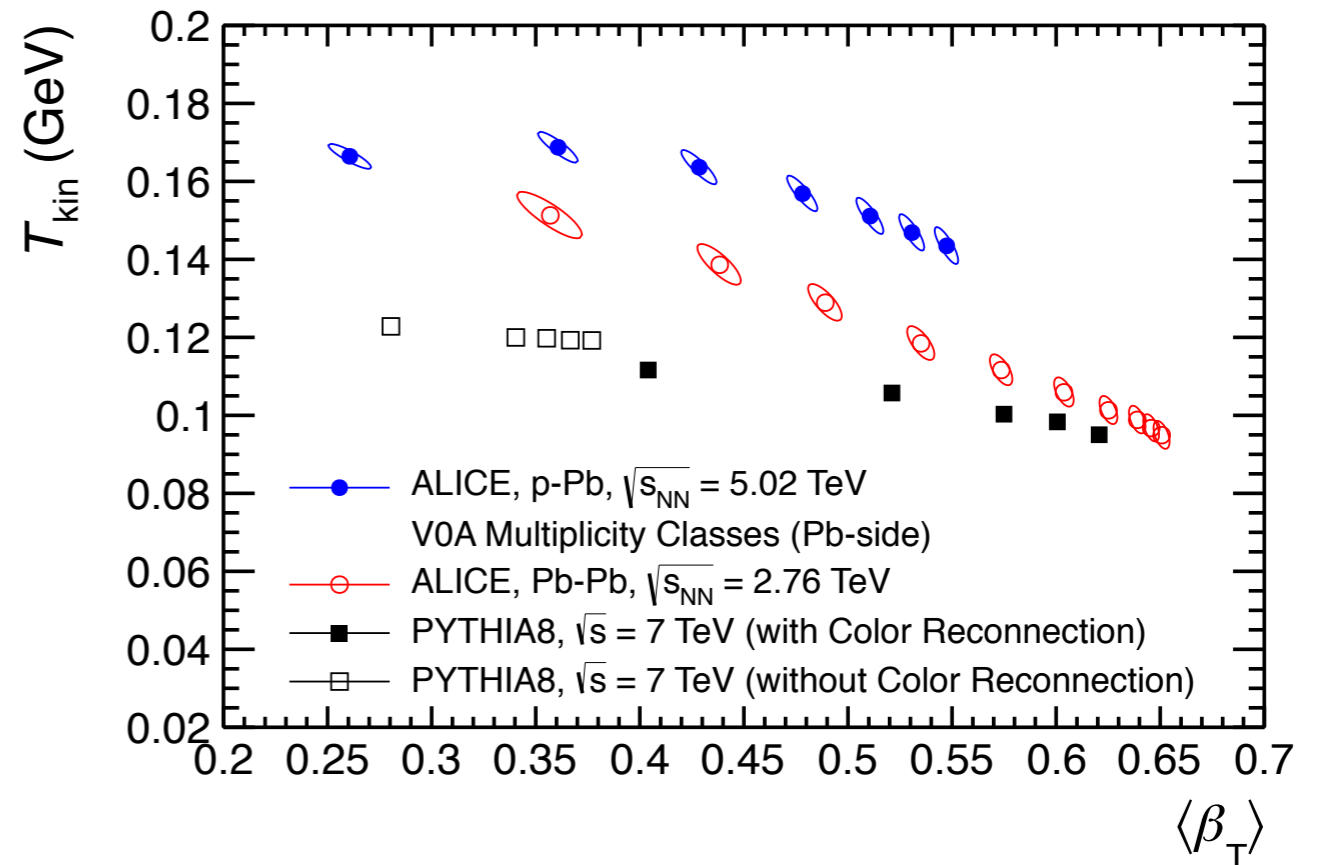


- **reasonably good description at RHIC and the LHC**

# low $p_T$ spectra



PLB 728 25 (2014)



- **reasonably good description at RHIC and the LHC**

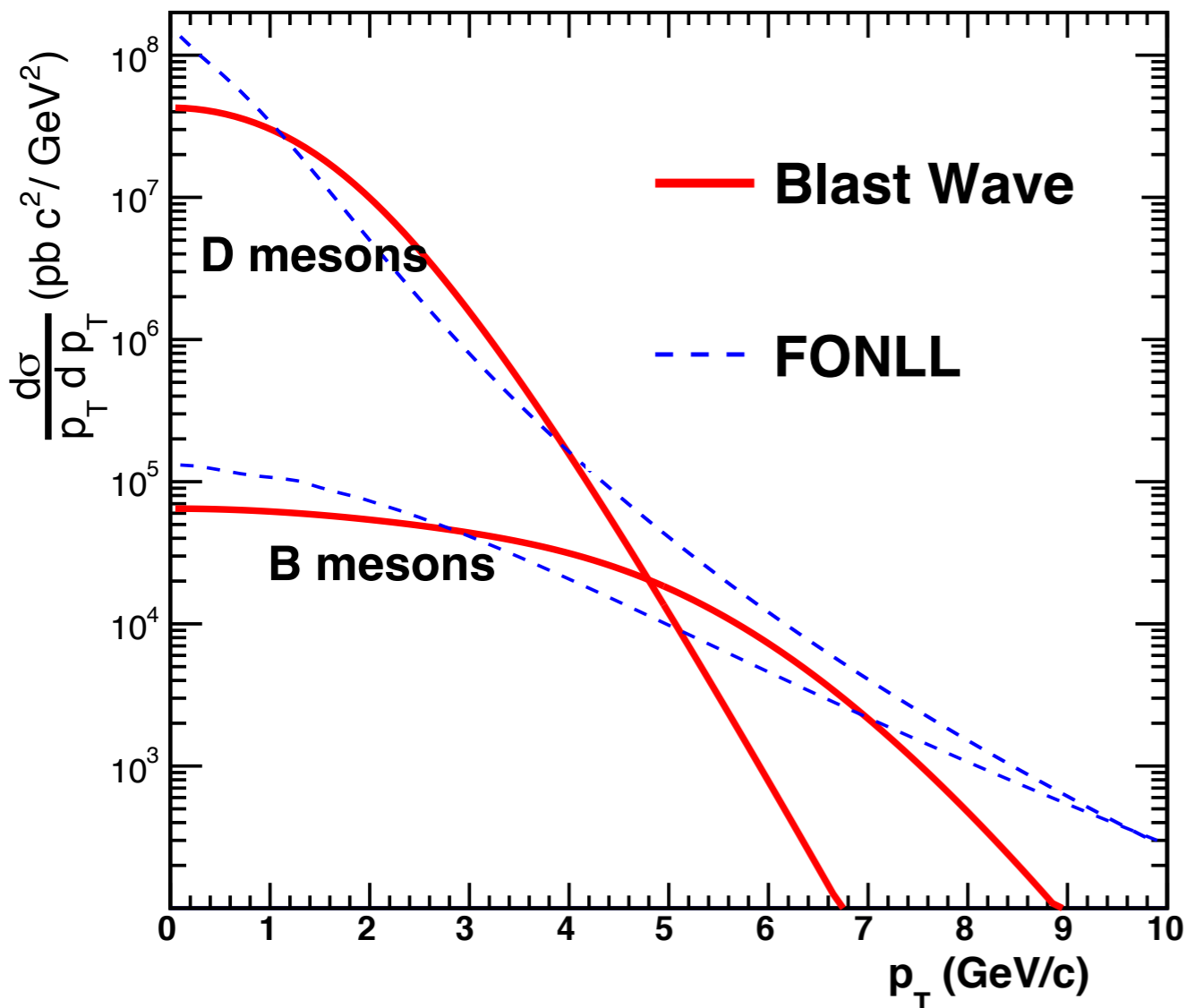
central d+Au:  
 simultaneous fit to  $\pi$ , K, p

$$\langle \beta \rangle = 0.46$$

$$T_{fo} = 139 \text{ MeV}$$

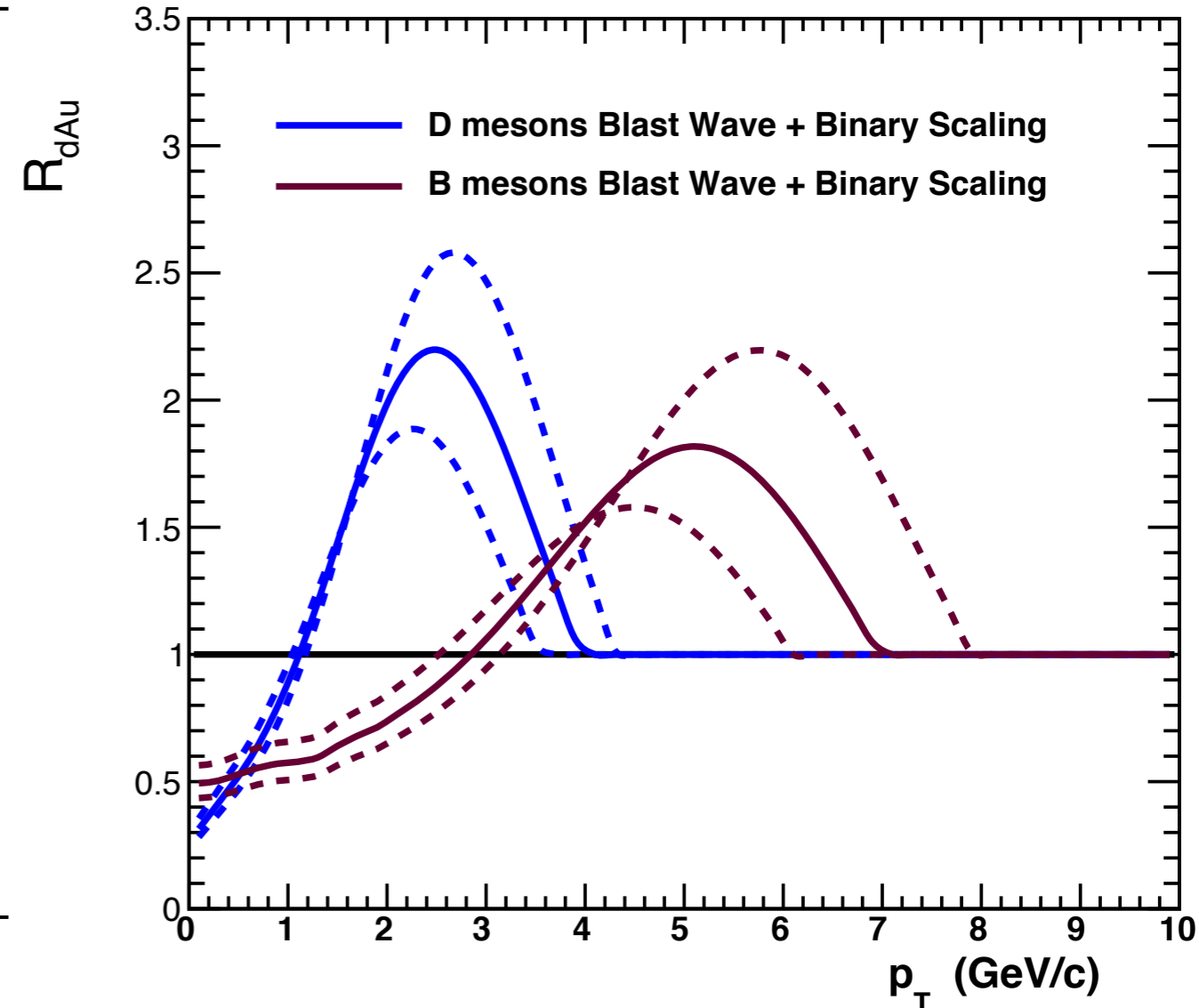
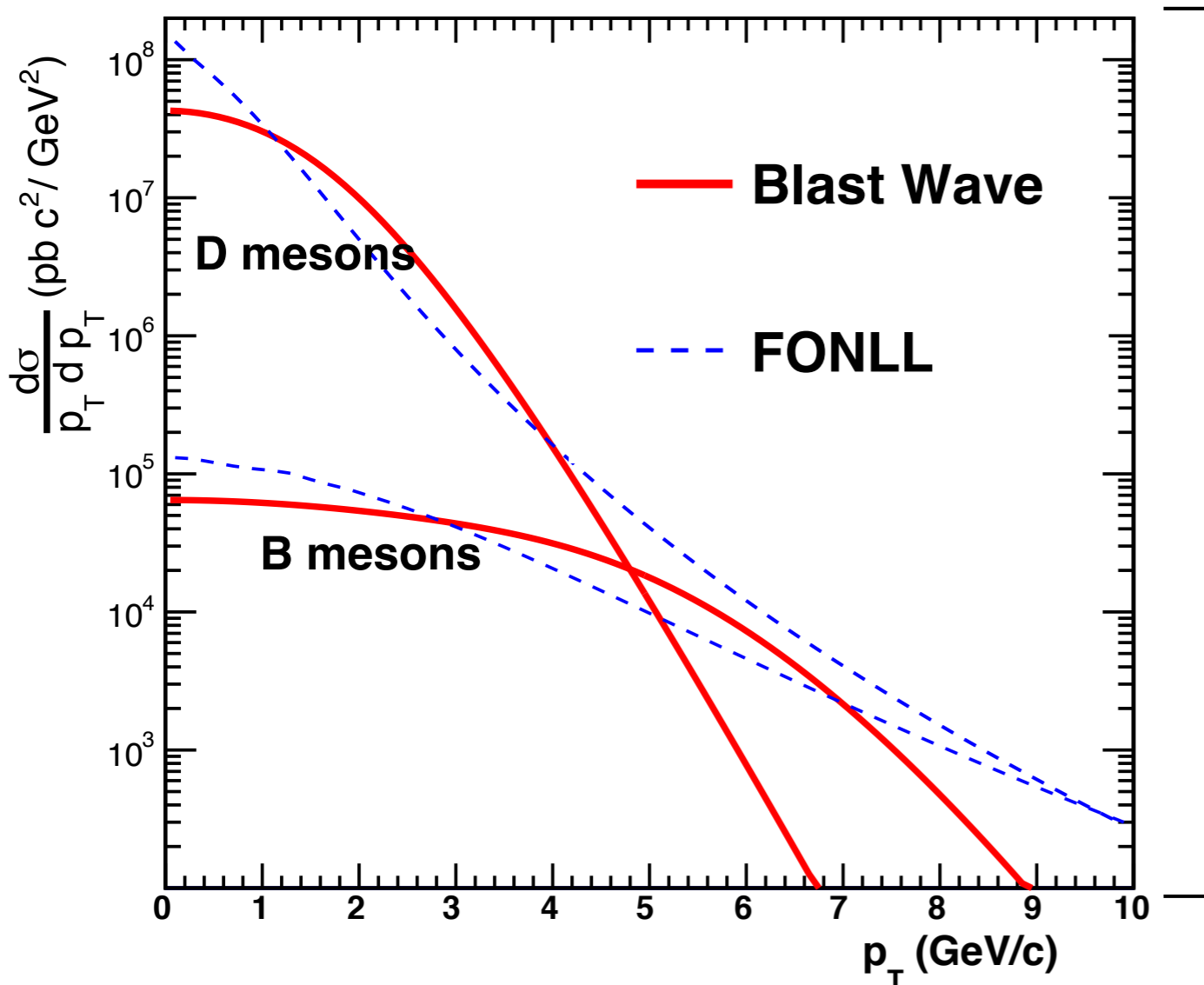
# what about heavy mesons?

expectations from Blast Wave for heavy mesons in d+Au

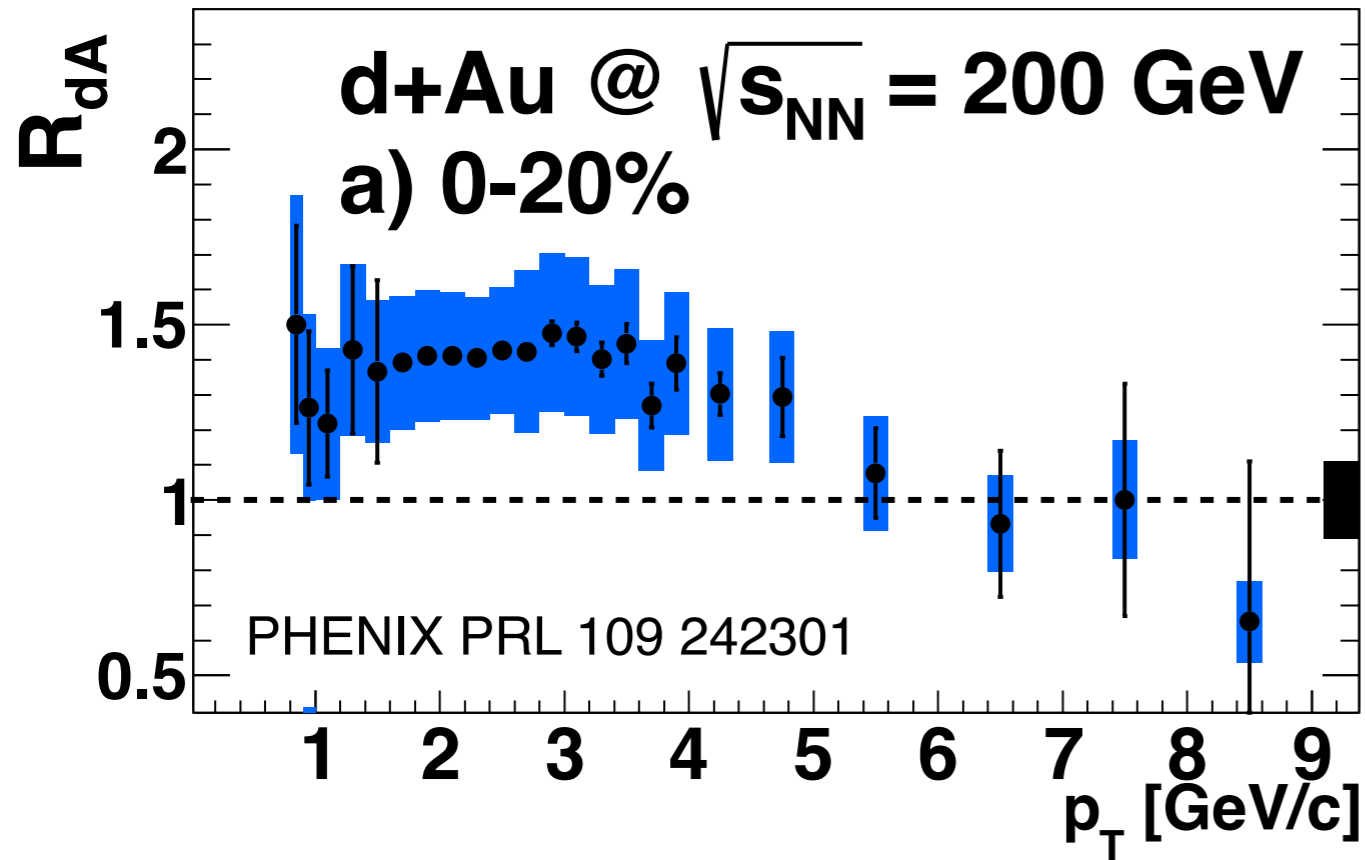


# what about heavy mesons?

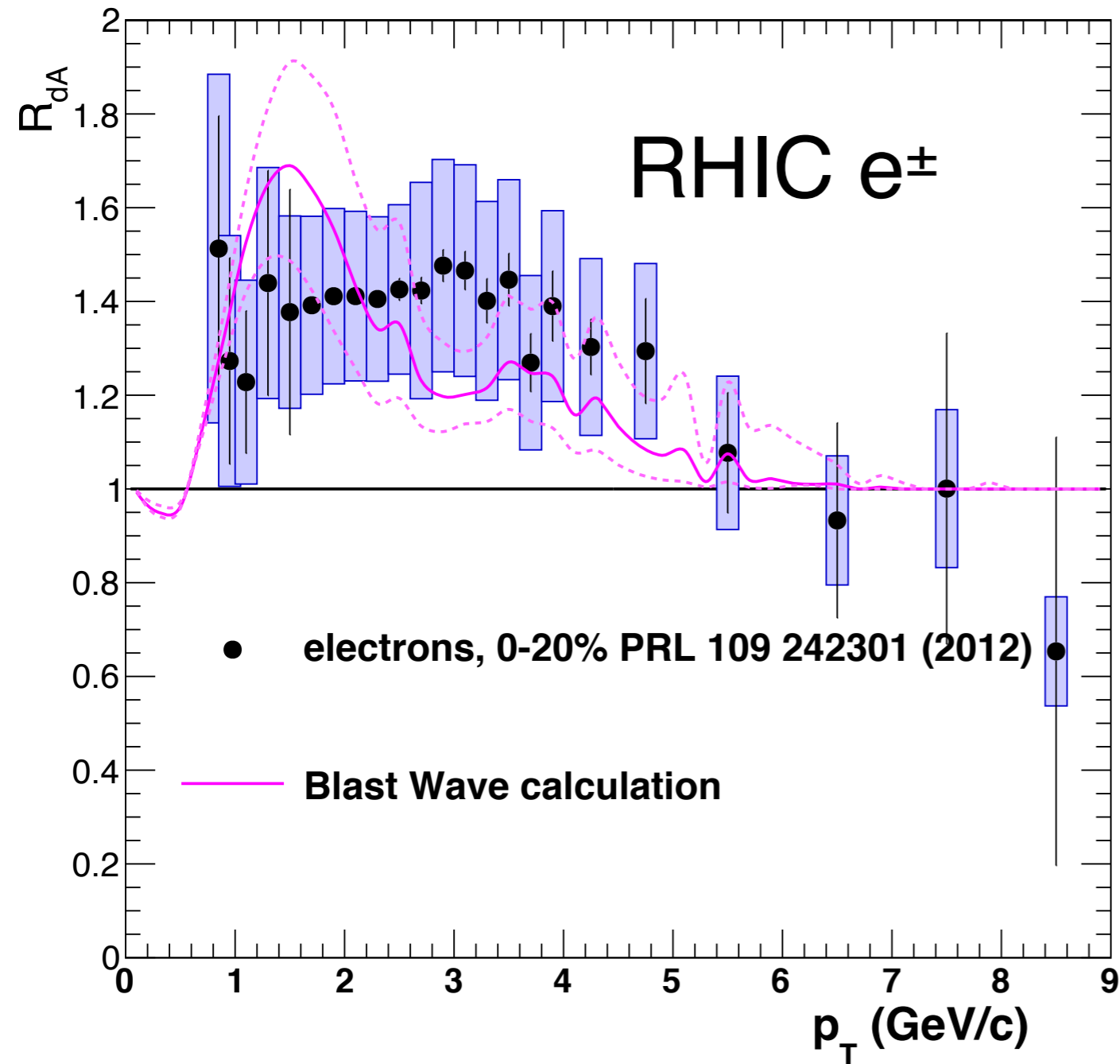
expectations from Blast Wave for heavy mesons in d+Au



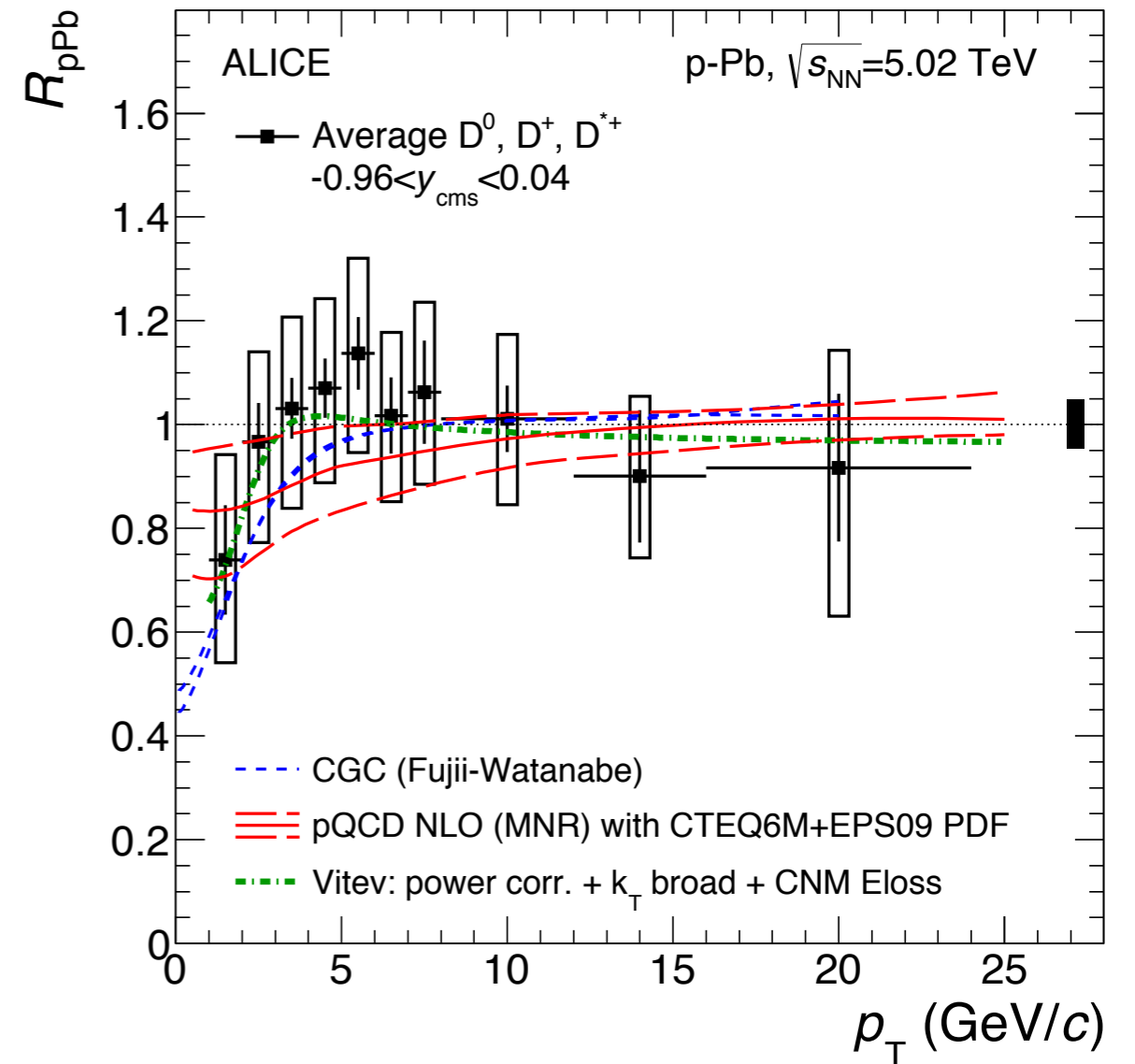
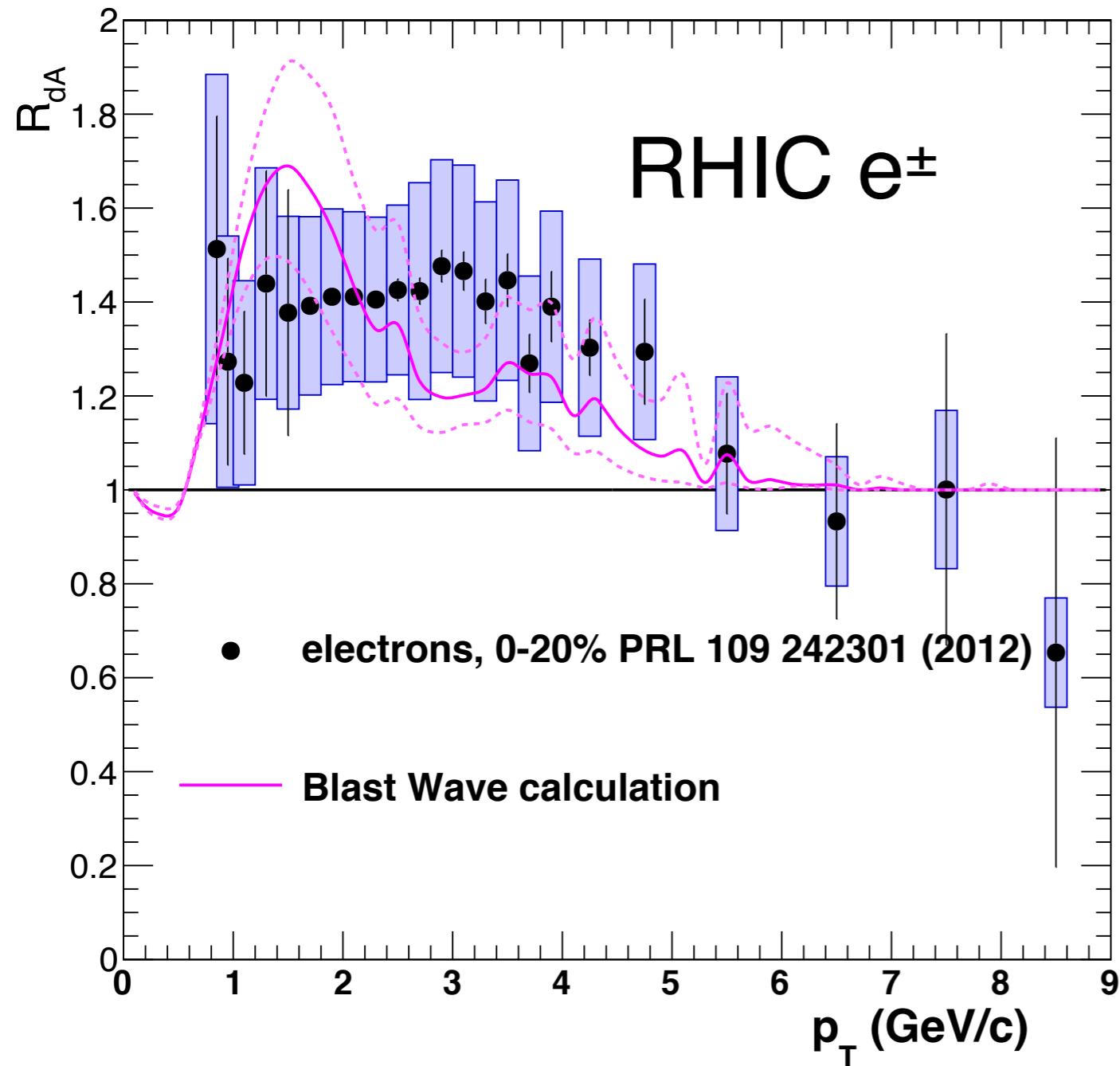
# what about heavy mesons?



# what about heavy mesons?

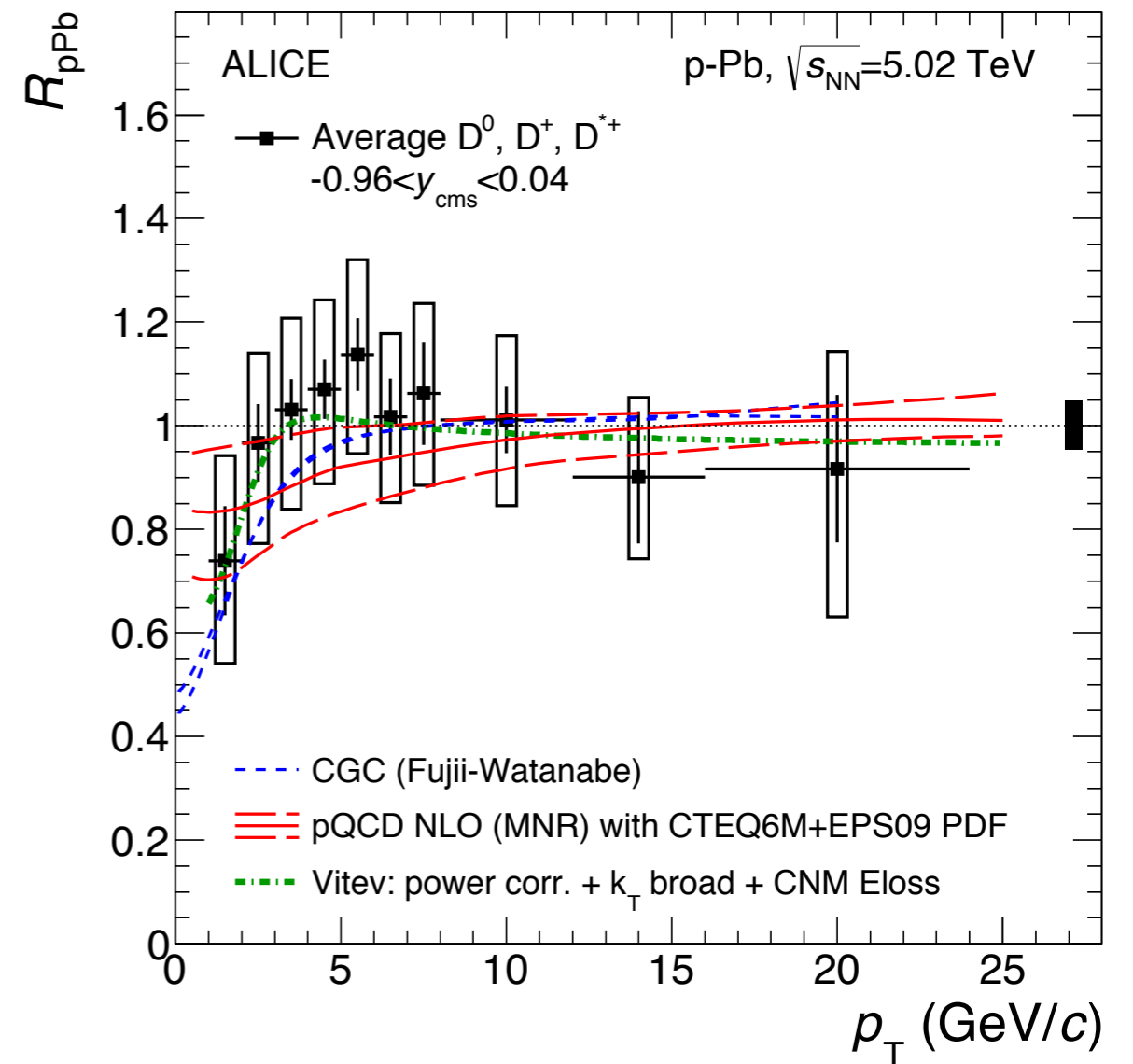
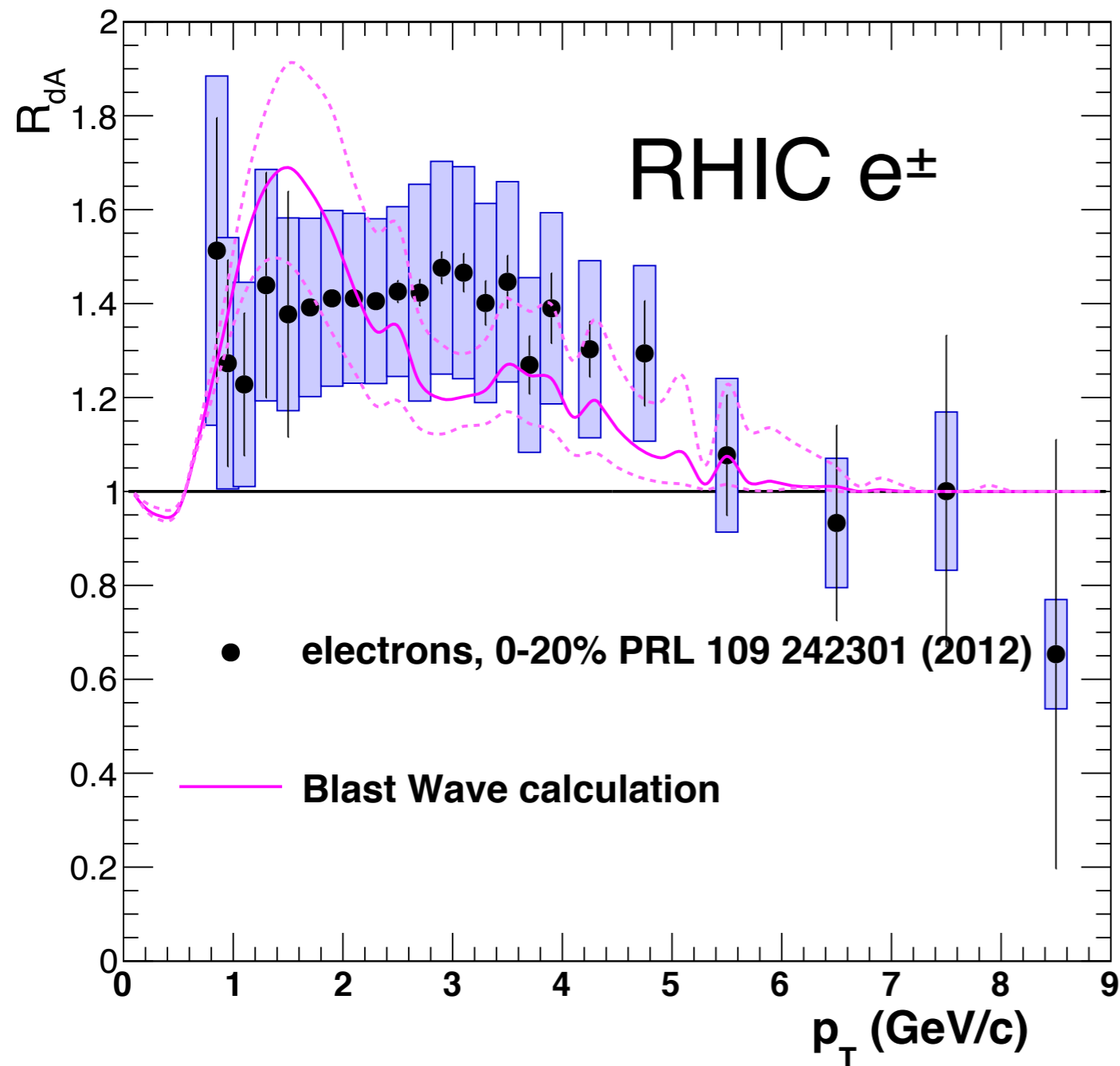


# what about heavy mesons?





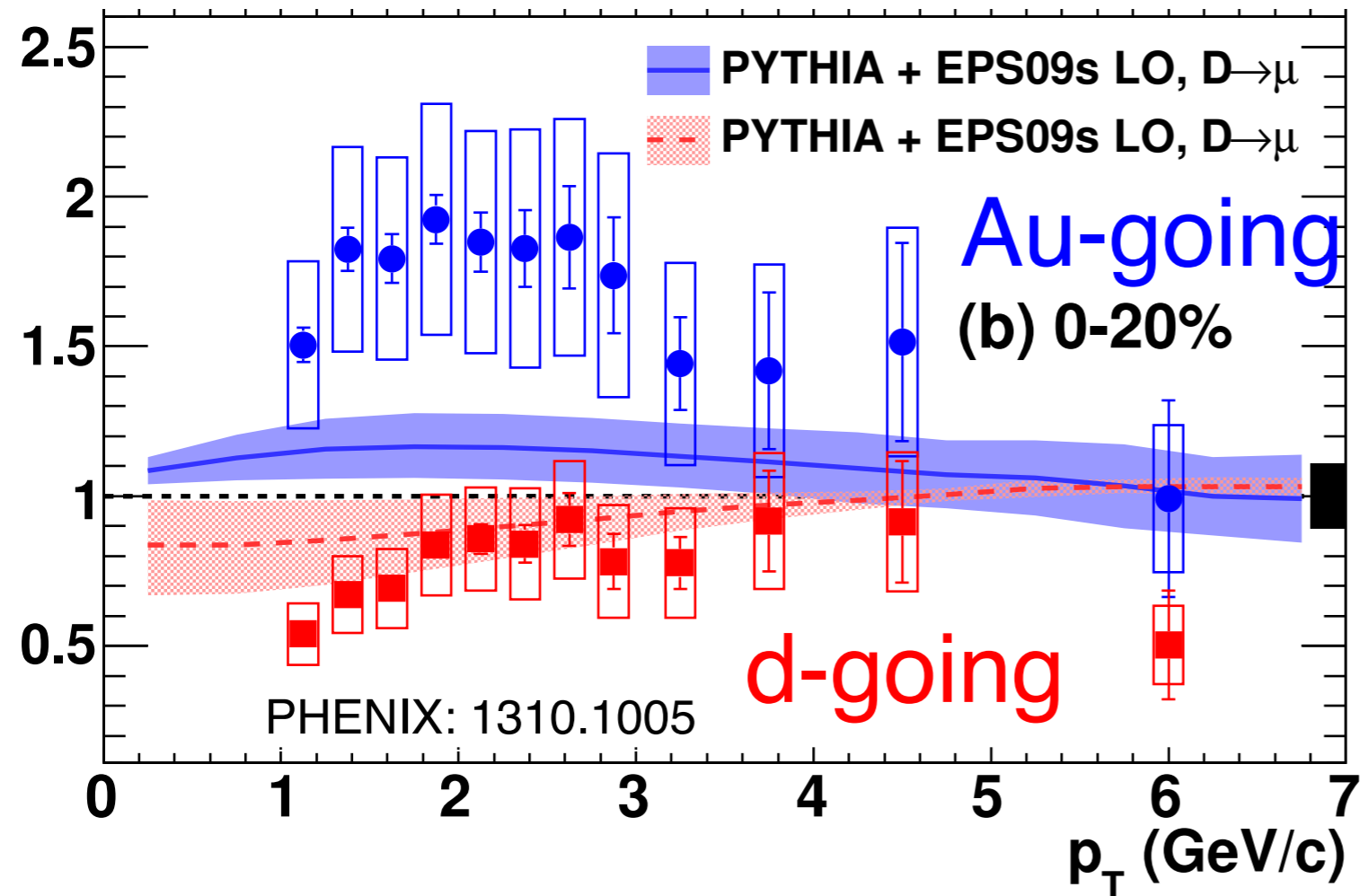
# what about heavy mesons?



a smaller effect at the LHC could be due to the harder initial spectrum

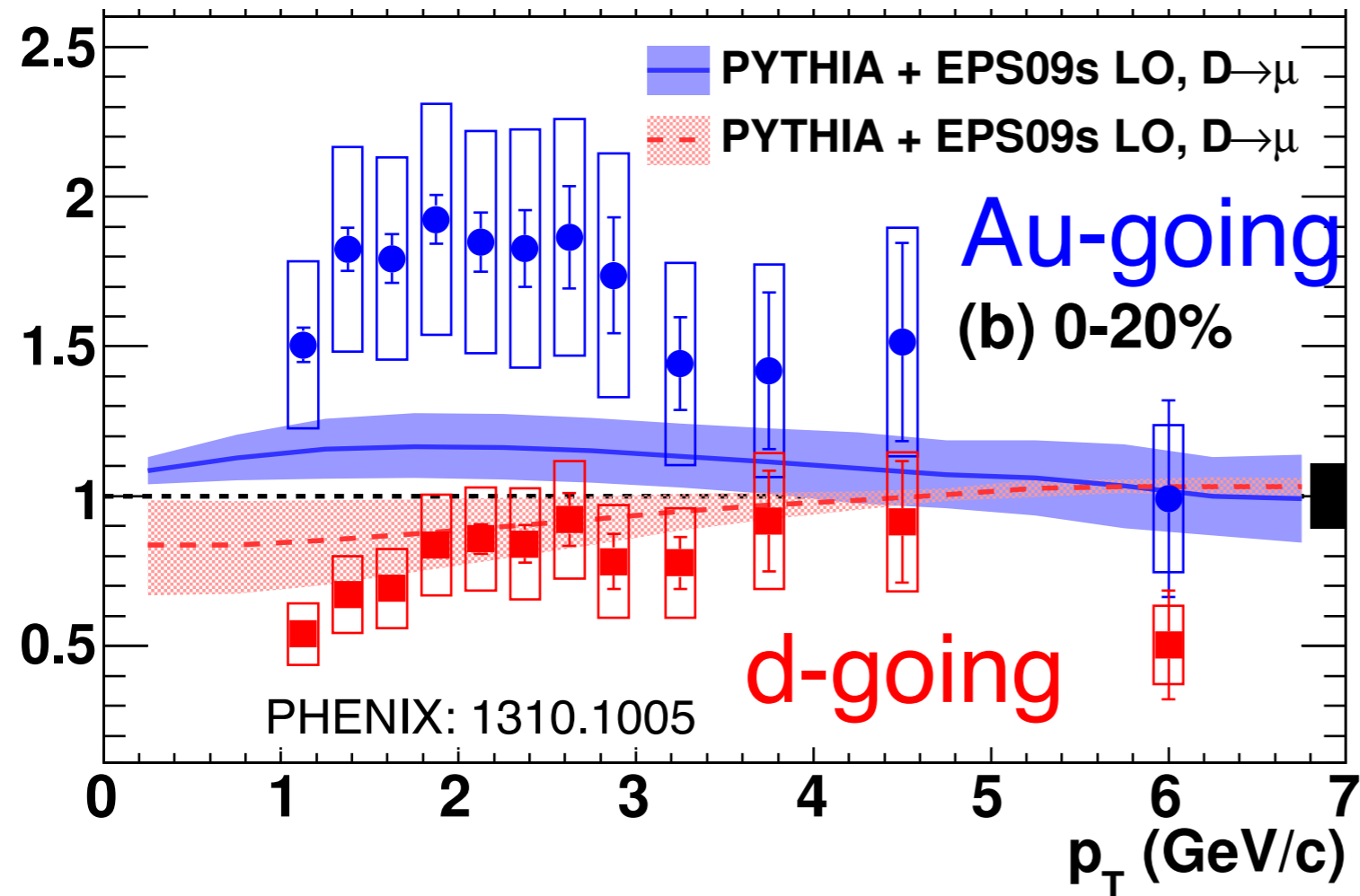
# away from midrapidity

$\mu: 1.4 < |\eta| < 2.0$



# away from midrapidity

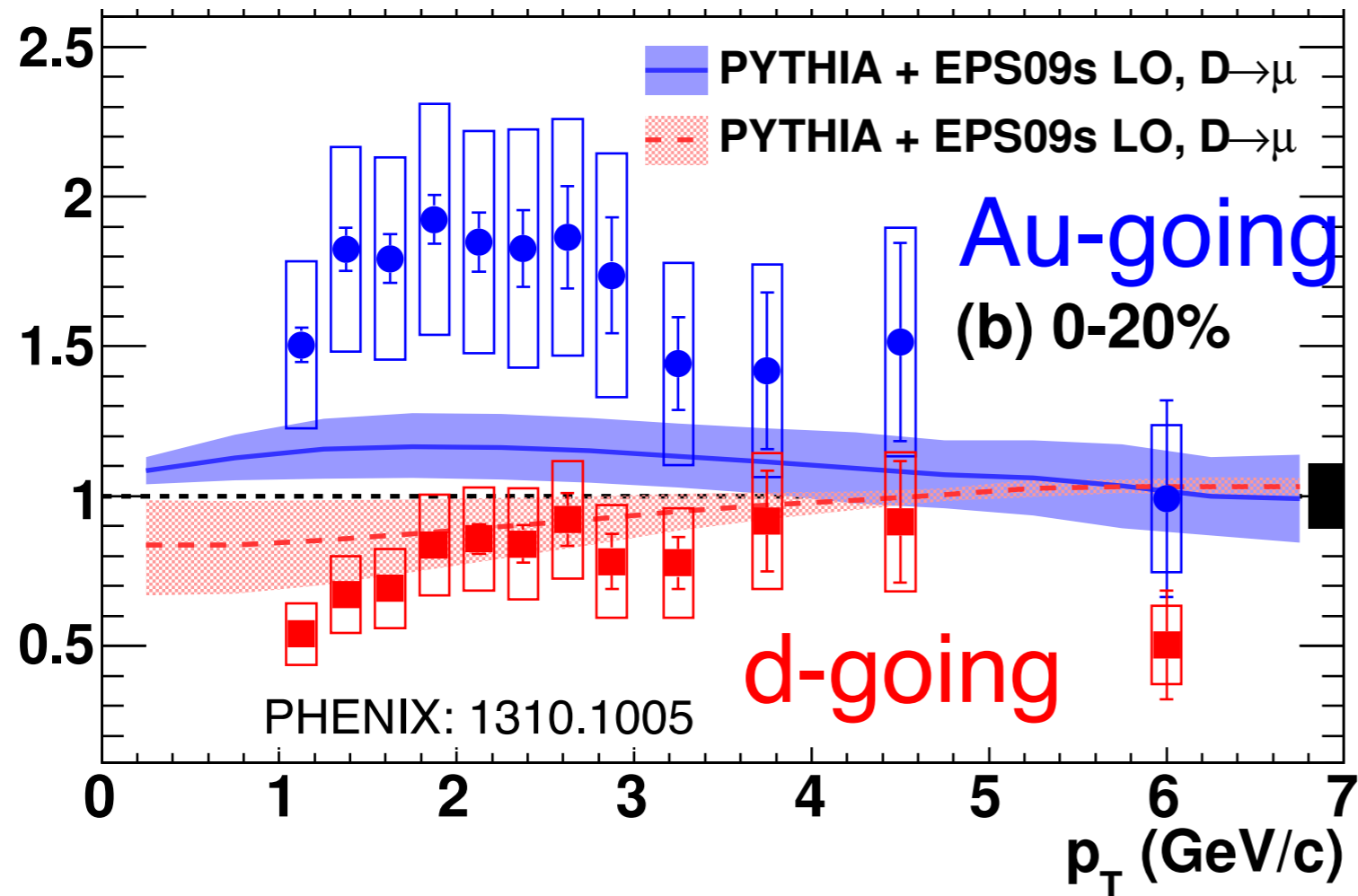
$\mu: 1.4 < |\eta| < 2.0$



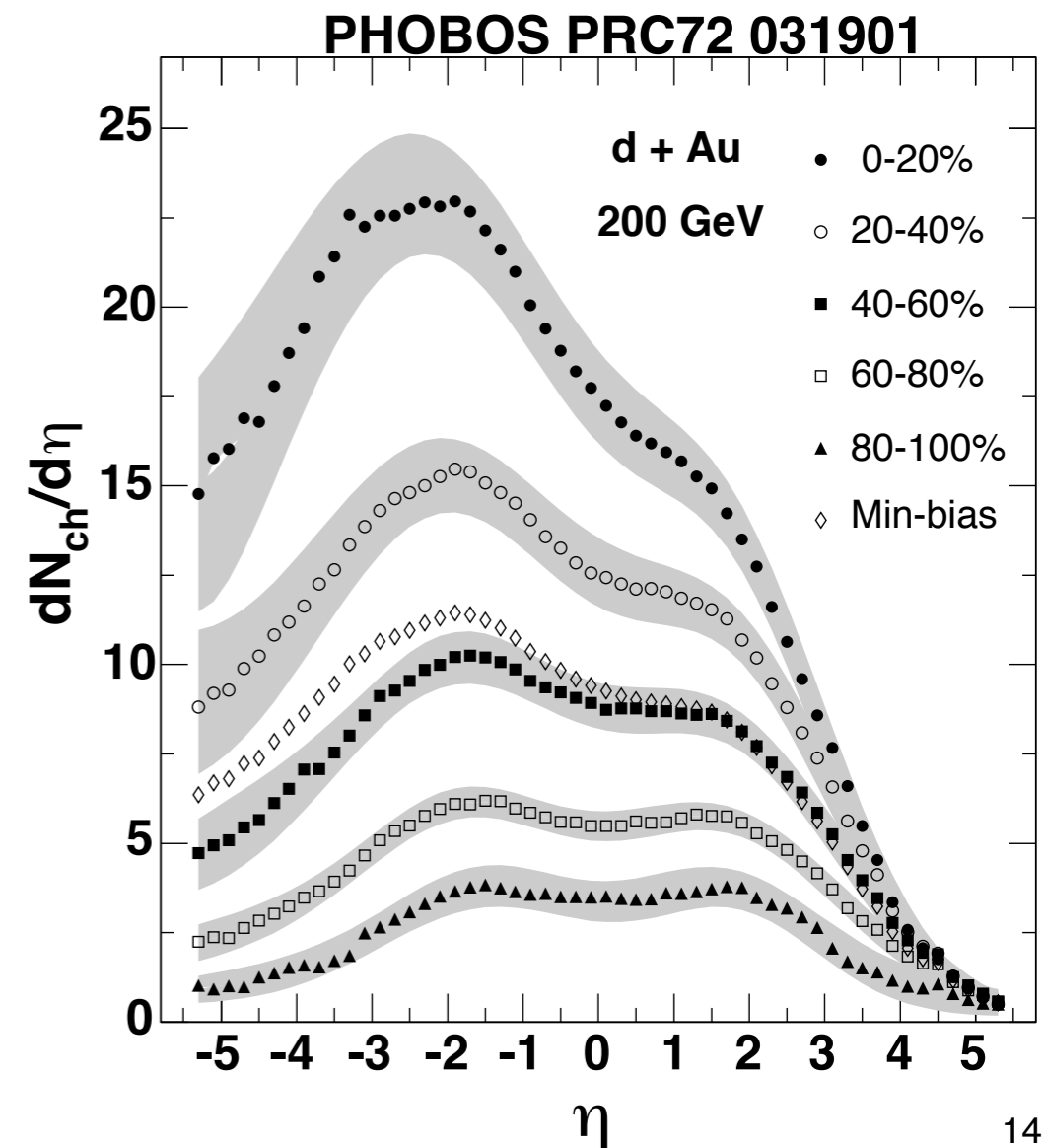
enhancement larger than EPS09

# away from midrapidity

$\mu: 1.4 < |\eta| < 2.0$

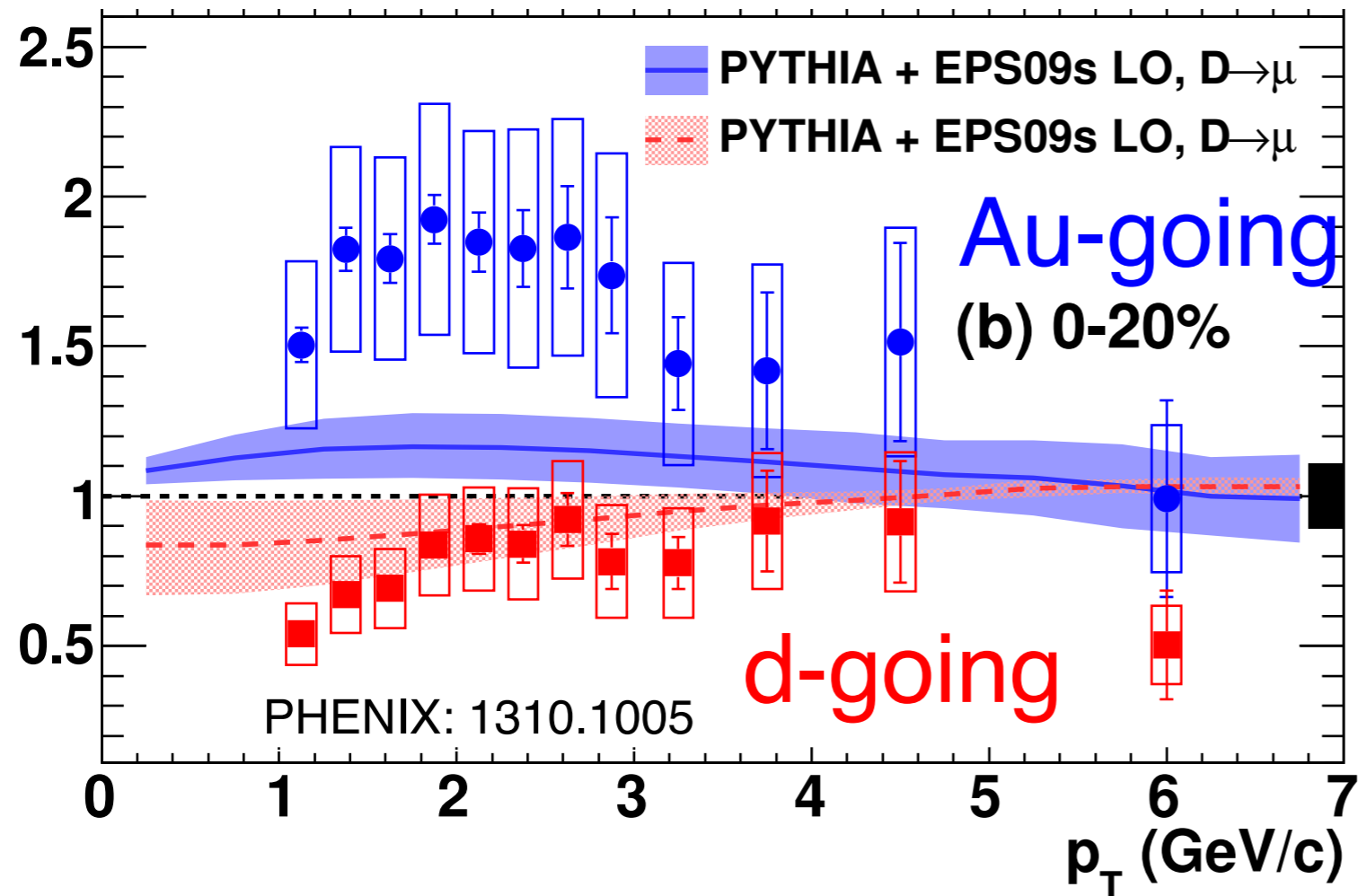


enhancement larger than EPS09

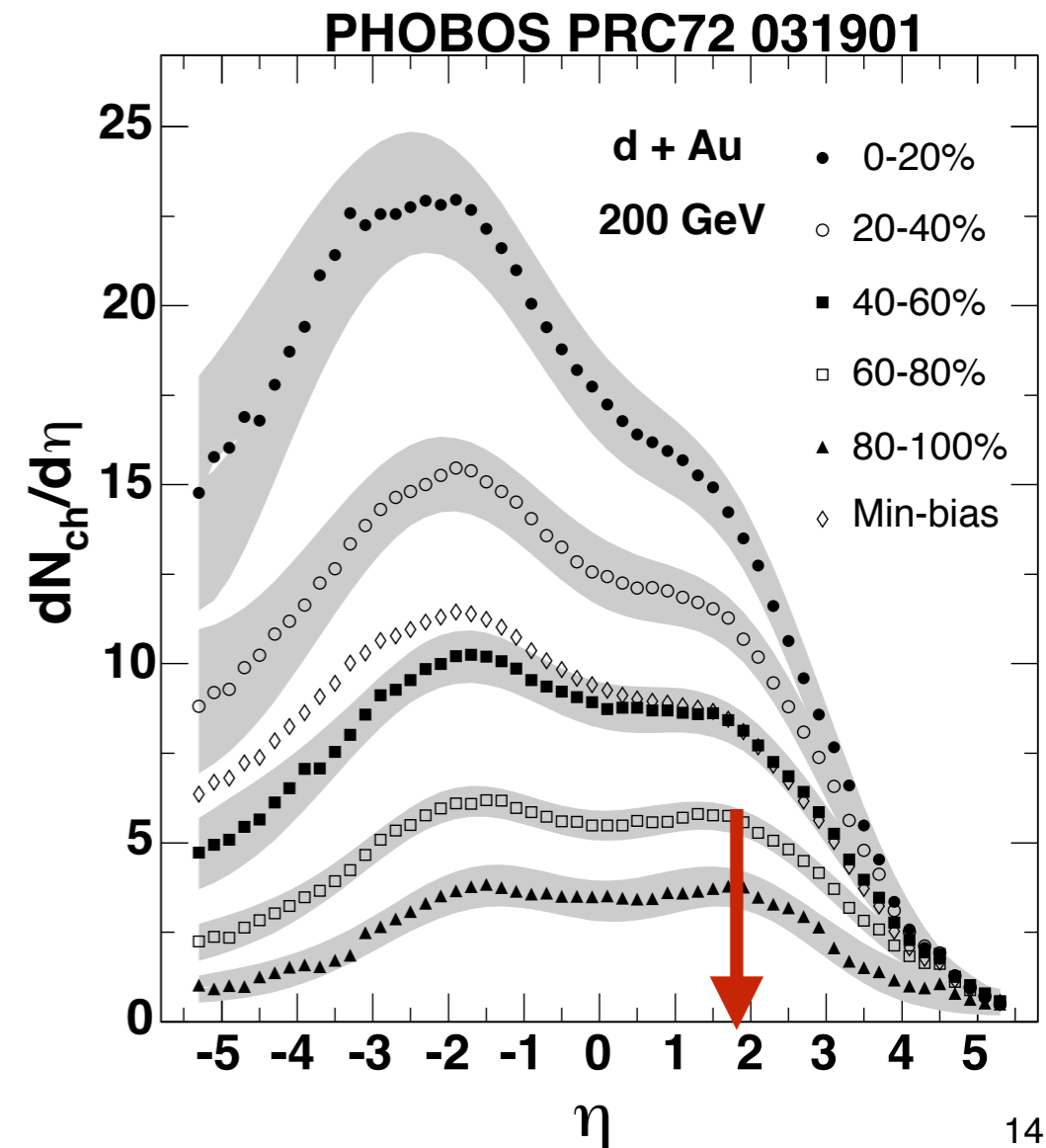


# away from midrapidity

$\mu: 1.4 < |\eta| < 2.0$

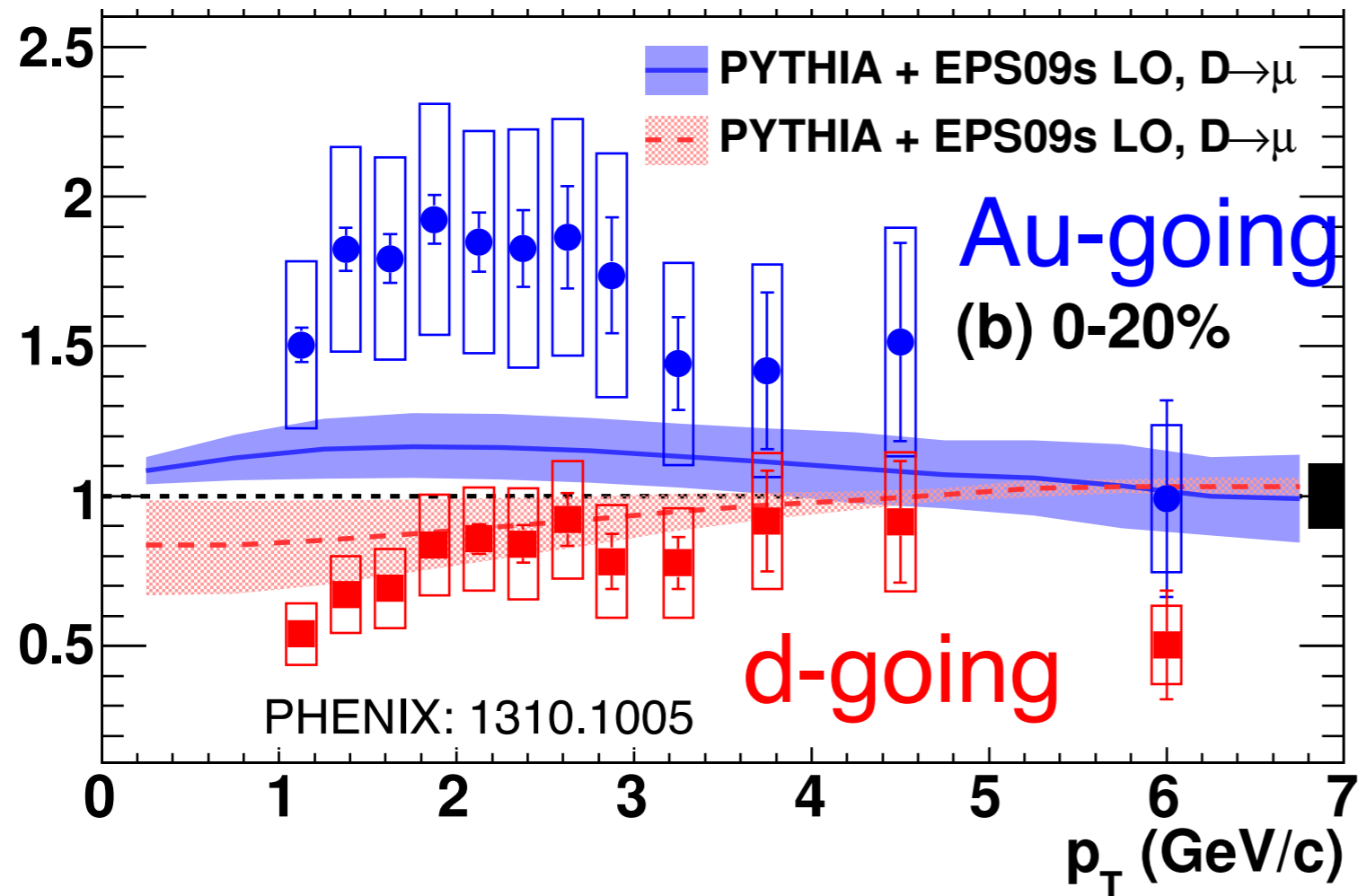


enhancement larger than EPS09

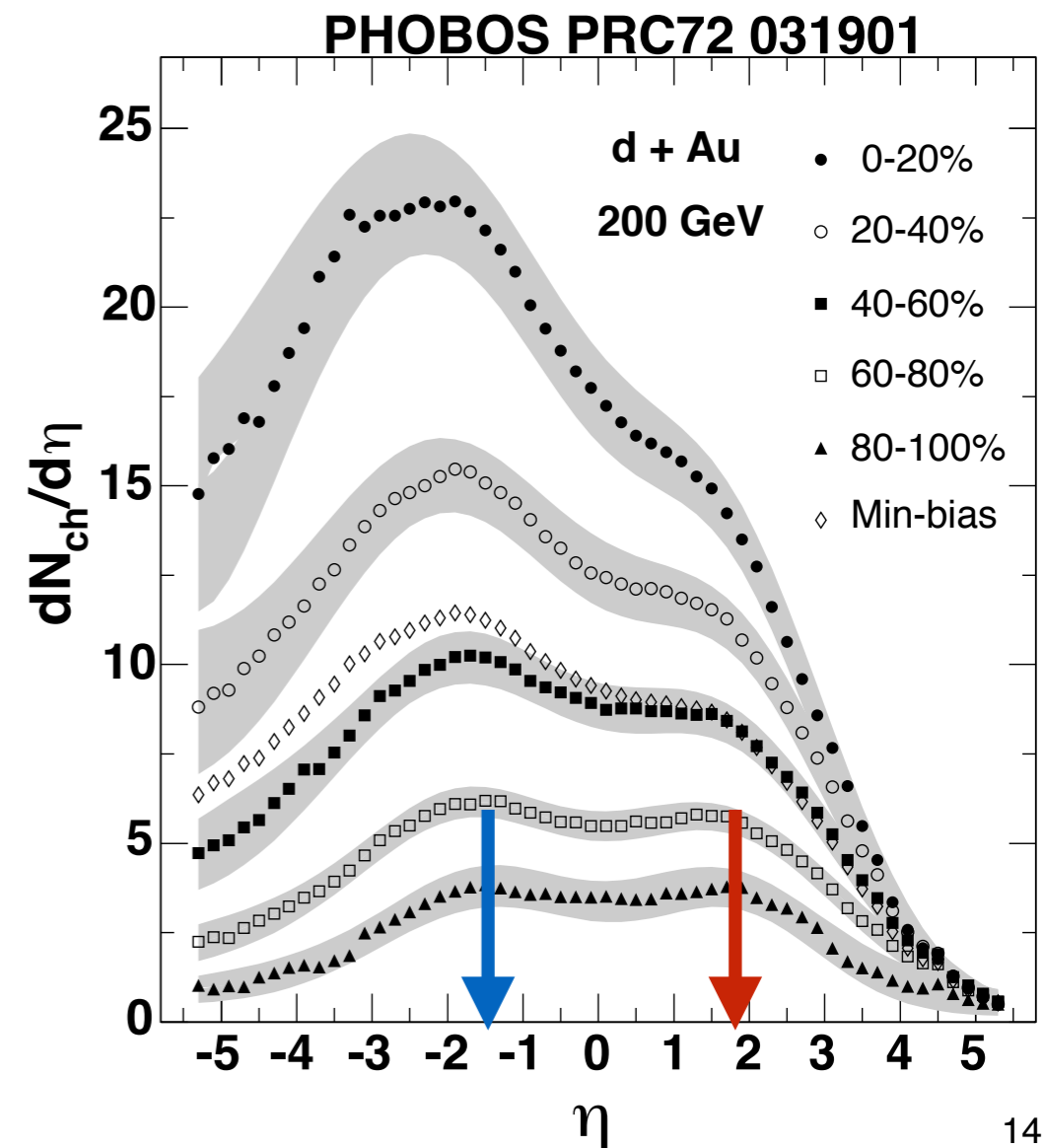


# away from midrapidity

$\mu: 1.4 < |\eta| < 2.0$

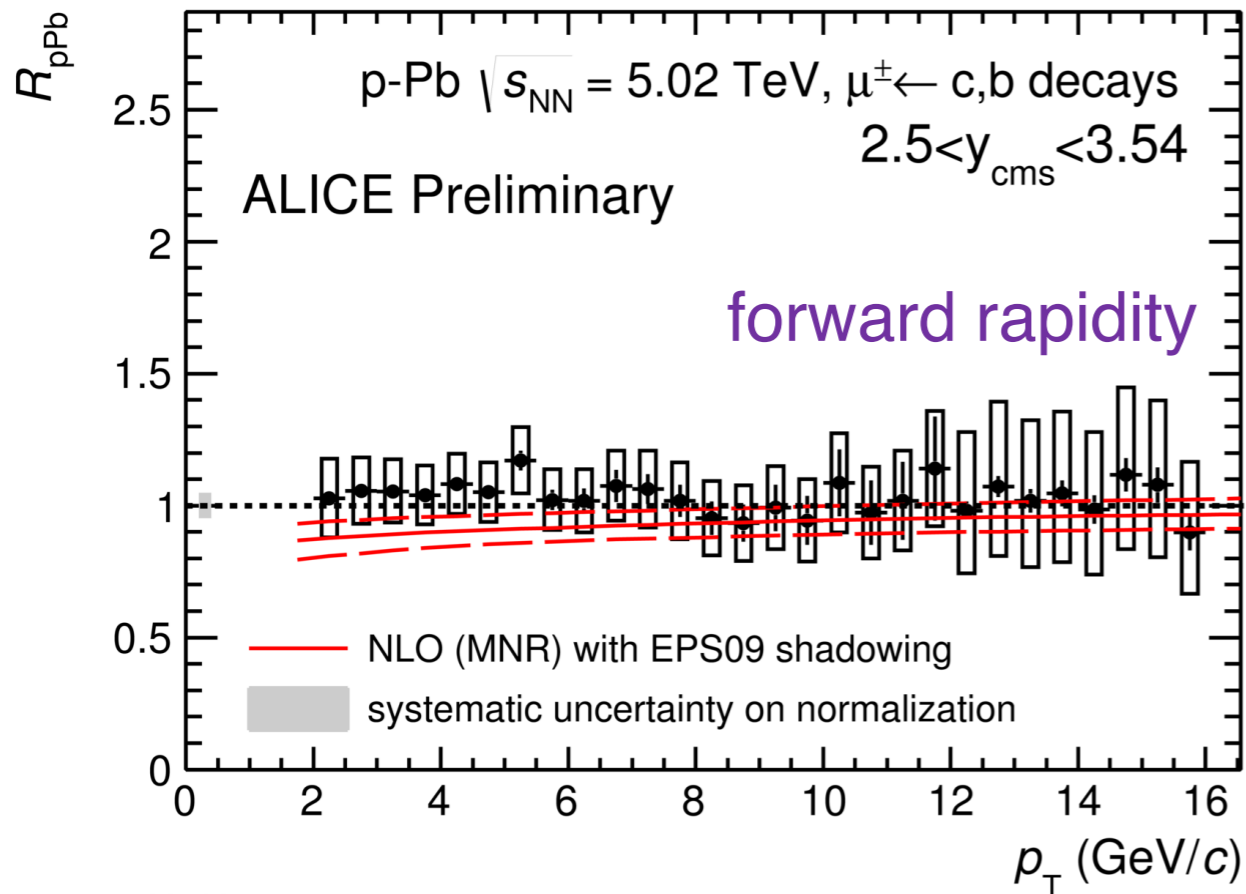


enhancement larger than EPS09



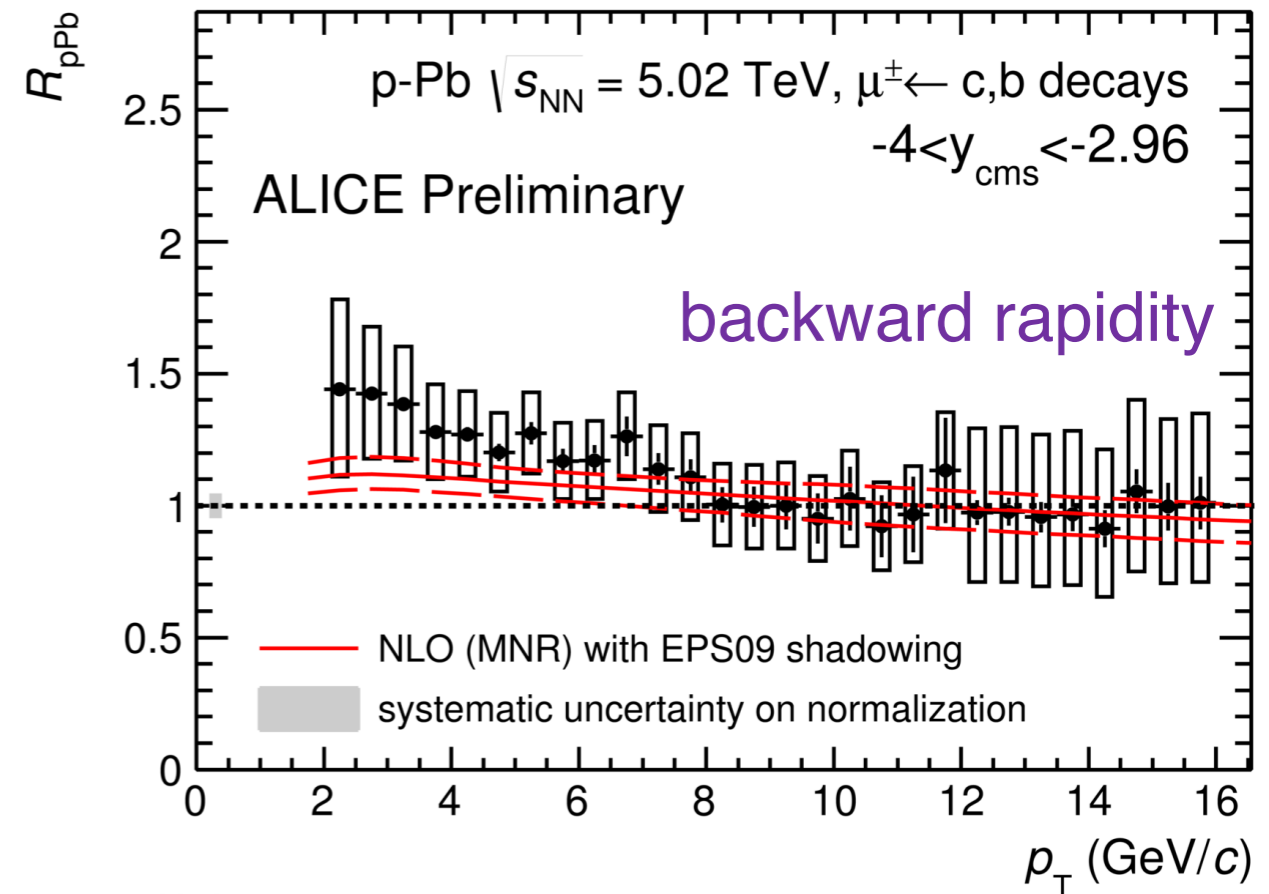
# away from midrapidity

p-going



LI-PREL-80422

Pb-going



ALI-PREL-80434

similar results from ALICE, perhaps slightly smaller  
A-going enhancement



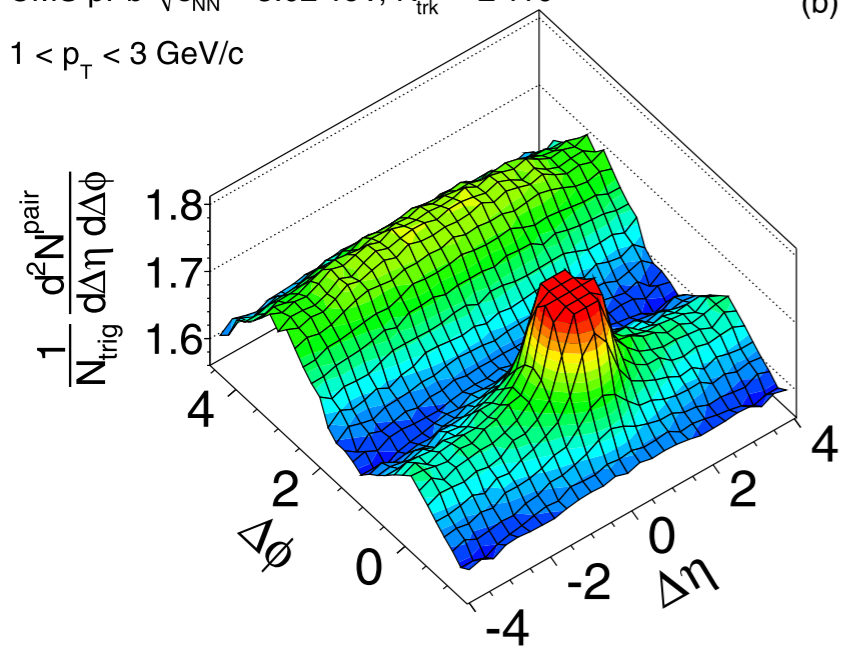
- 
- many features of identified particles at moderate and low  $p_T$  spectra are suggestive of what has been observed in A+A collisions at both RHIC and the LHC
  - how are these particles correlated with each other?

# angular correlations

---

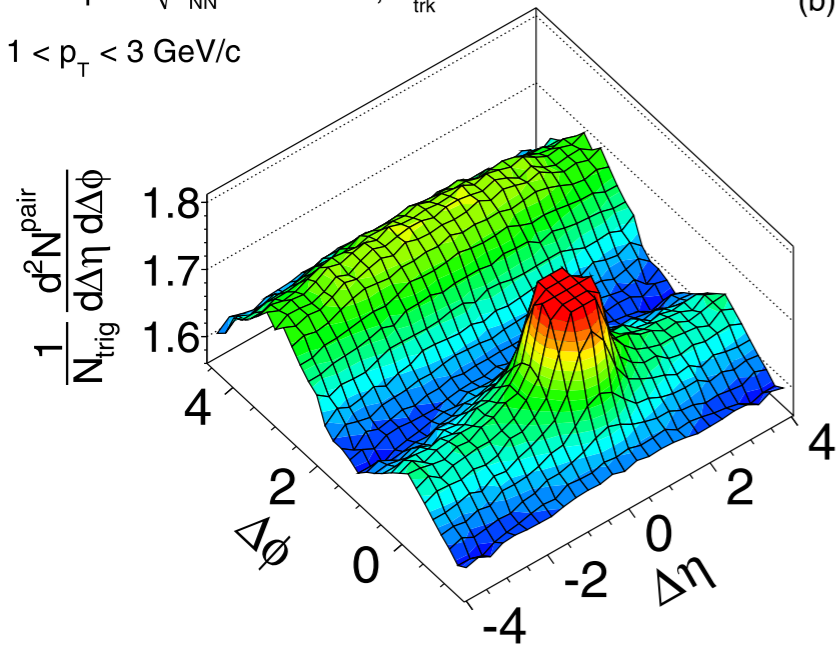
# angular correlations

CMS pPb  $\sqrt{s_{NN}} = 5.02$  TeV,  $N_{\text{trk}}^{\text{offline}} \geq 110$   
 $1 < p_T < 3$  GeV/c

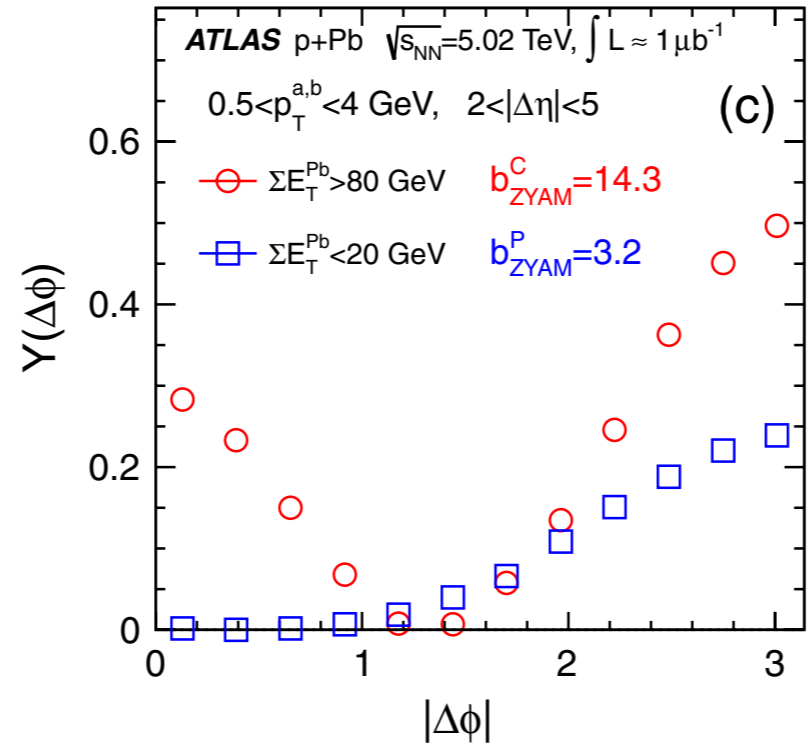


# angular correlations

CMS pPb  $\sqrt{s_{NN}} = 5.02$  TeV,  $N_{\text{trk}}^{\text{offline}} \geq 110$   
 $1 < p_T < 3$  GeV/c



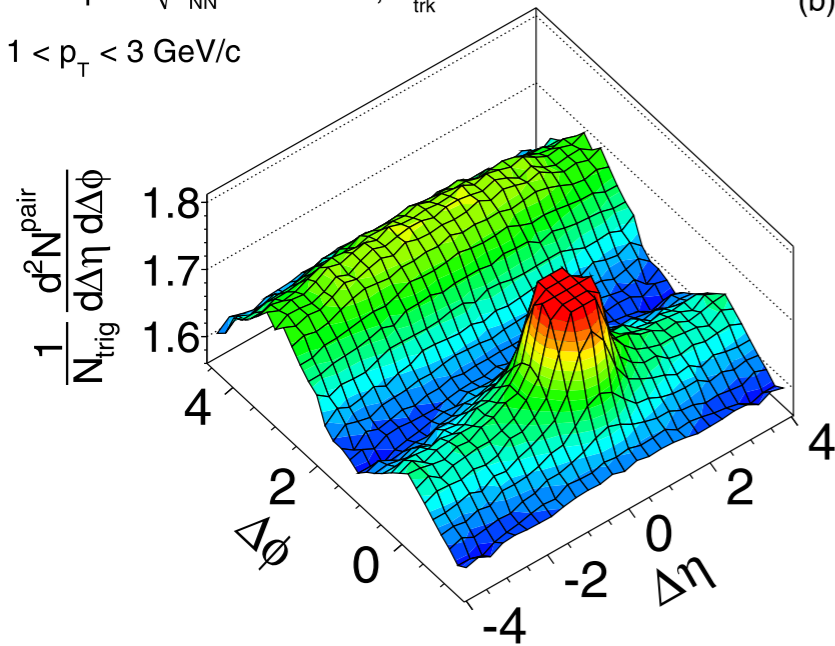
(b)



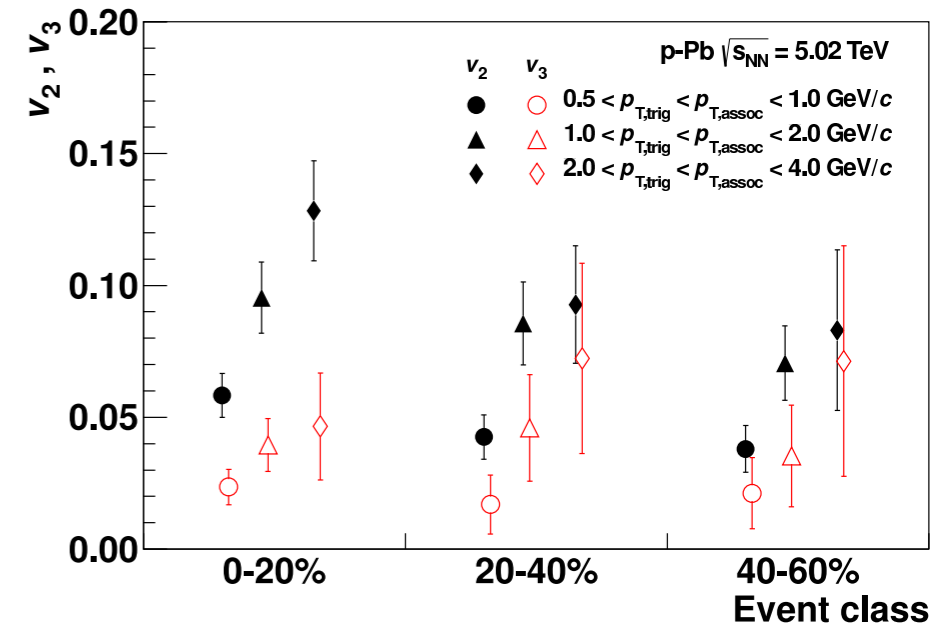
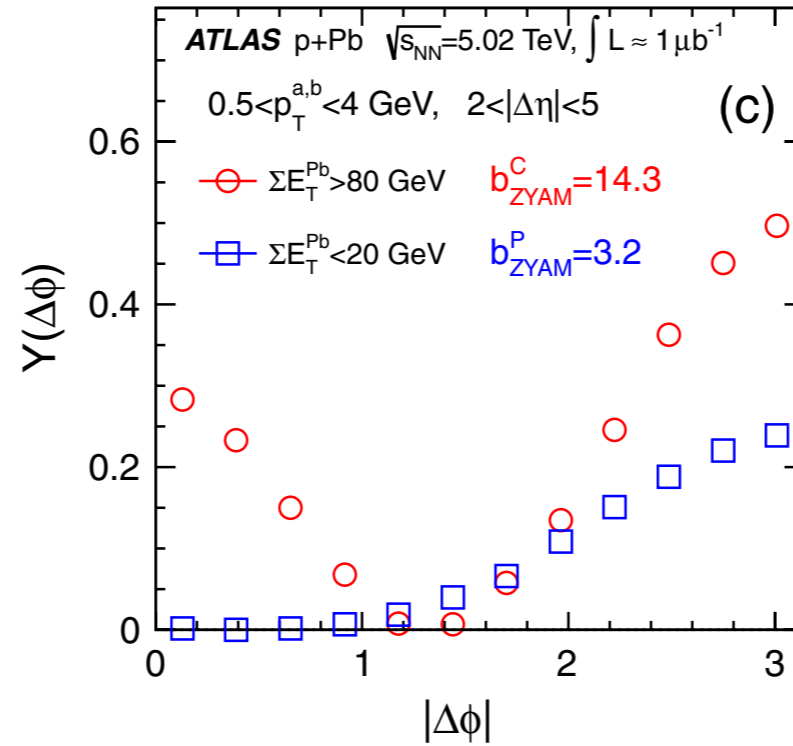
(c)

# angular correlations

CMS pPb  $\sqrt{s_{NN}} = 5.02$  TeV,  $N_{trk}^{offline} \geq 110$   
 $1 < p_T < 3$  GeV/c

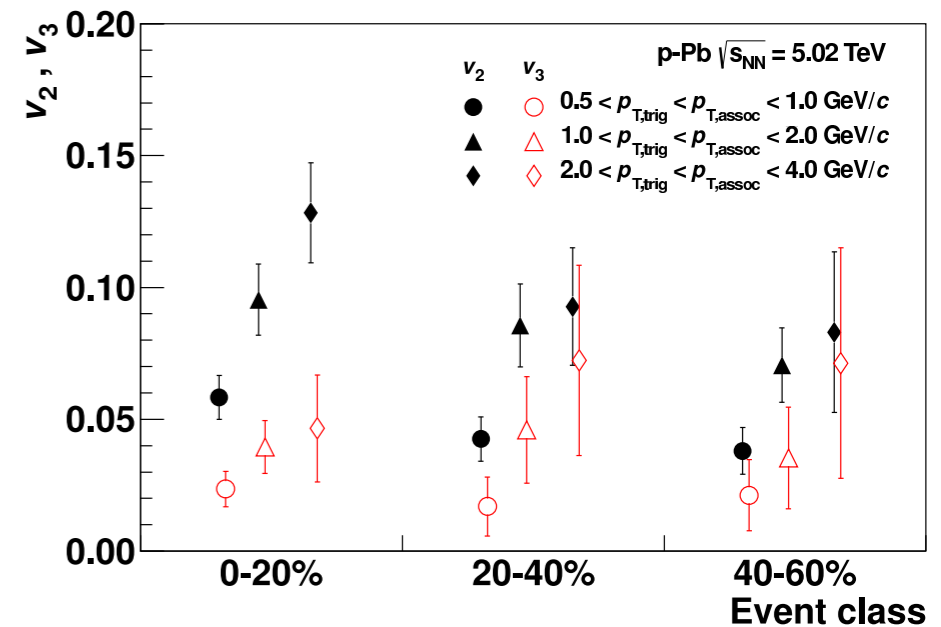
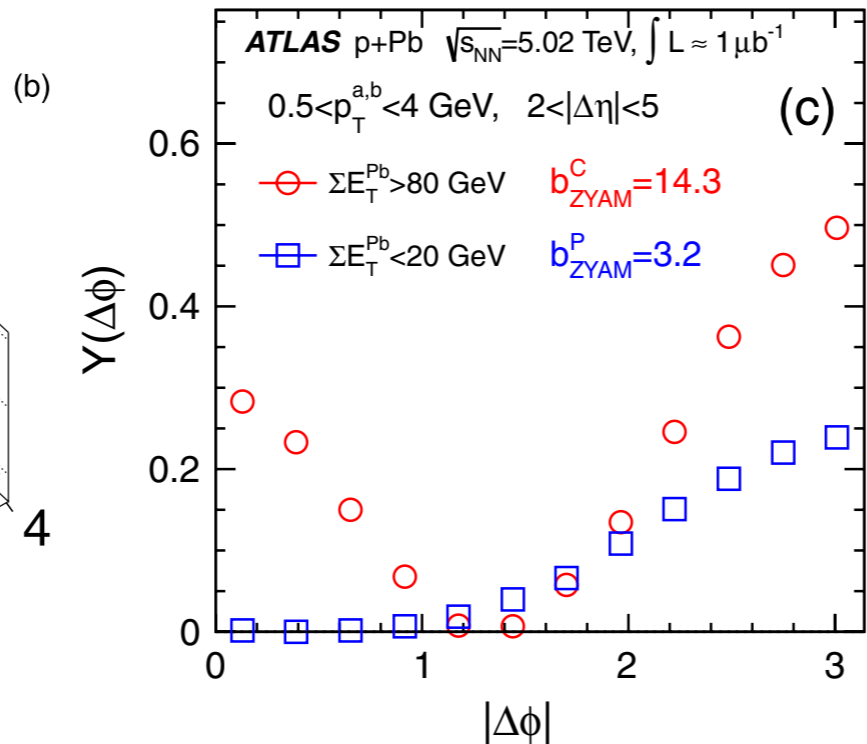
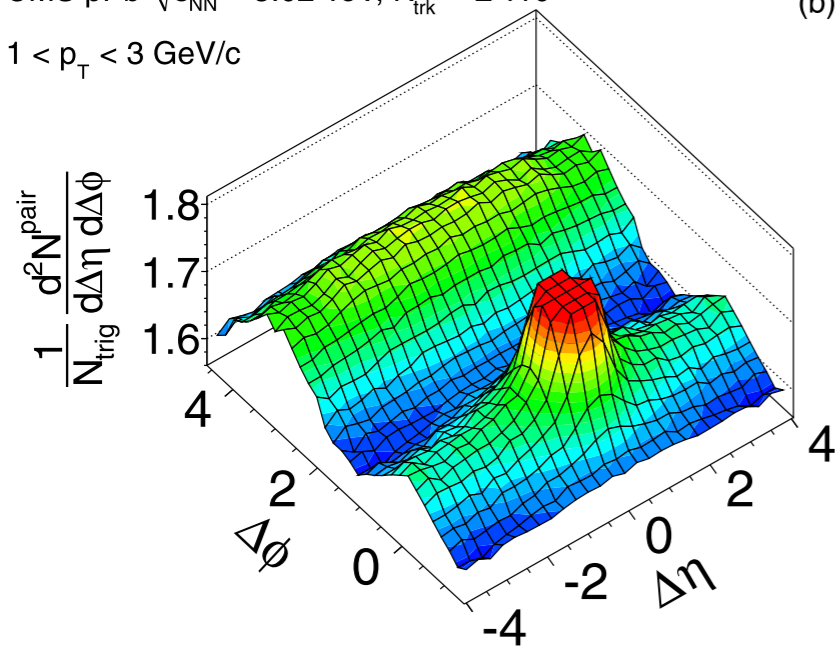


(b)



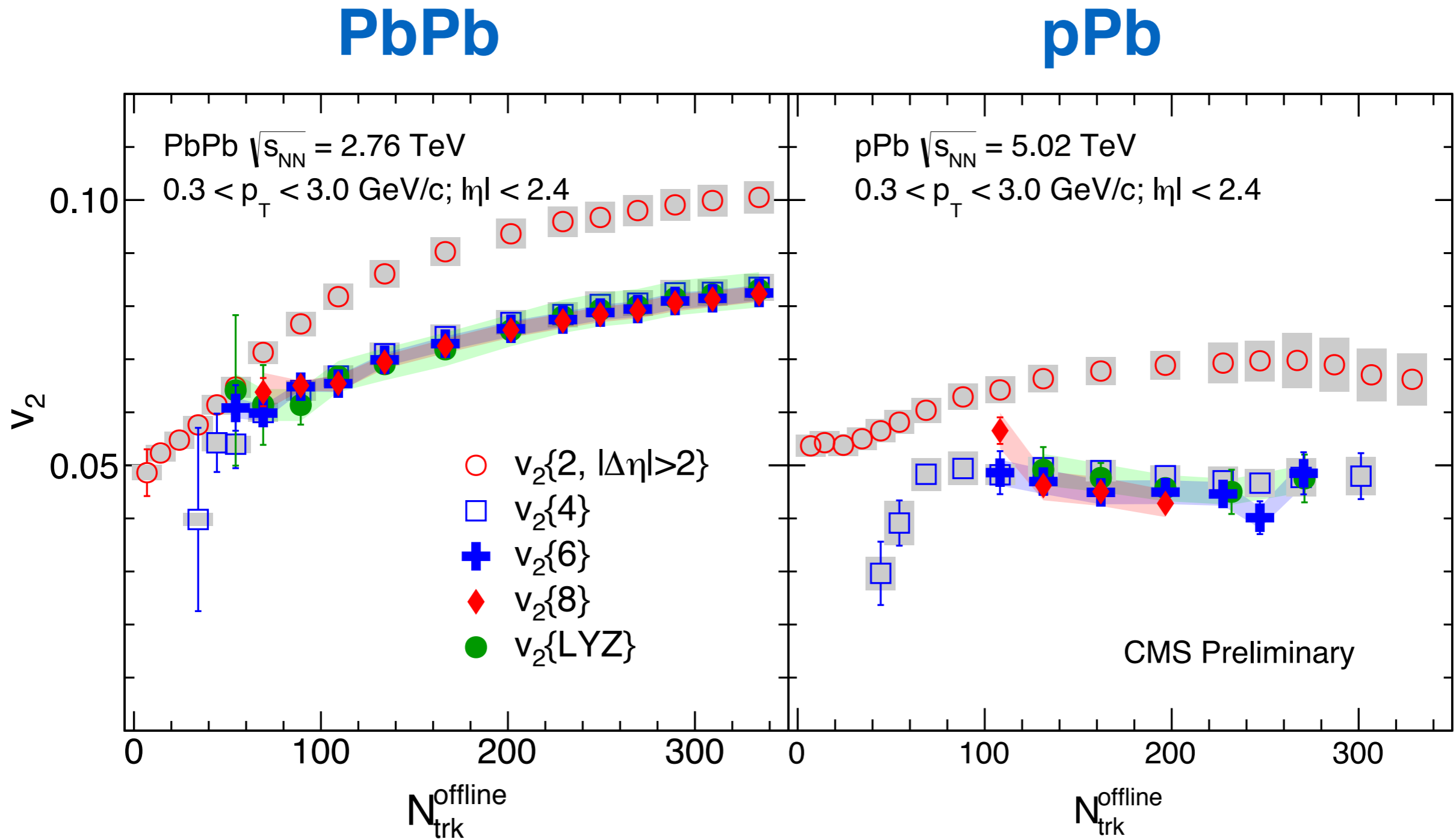
# angular correlations

CMS pPb  $\sqrt{s_{NN}} = 5.02$  TeV,  $N_{trk}^{offline} \geq 110$   
 $1 < p_T < 3$  GeV/c



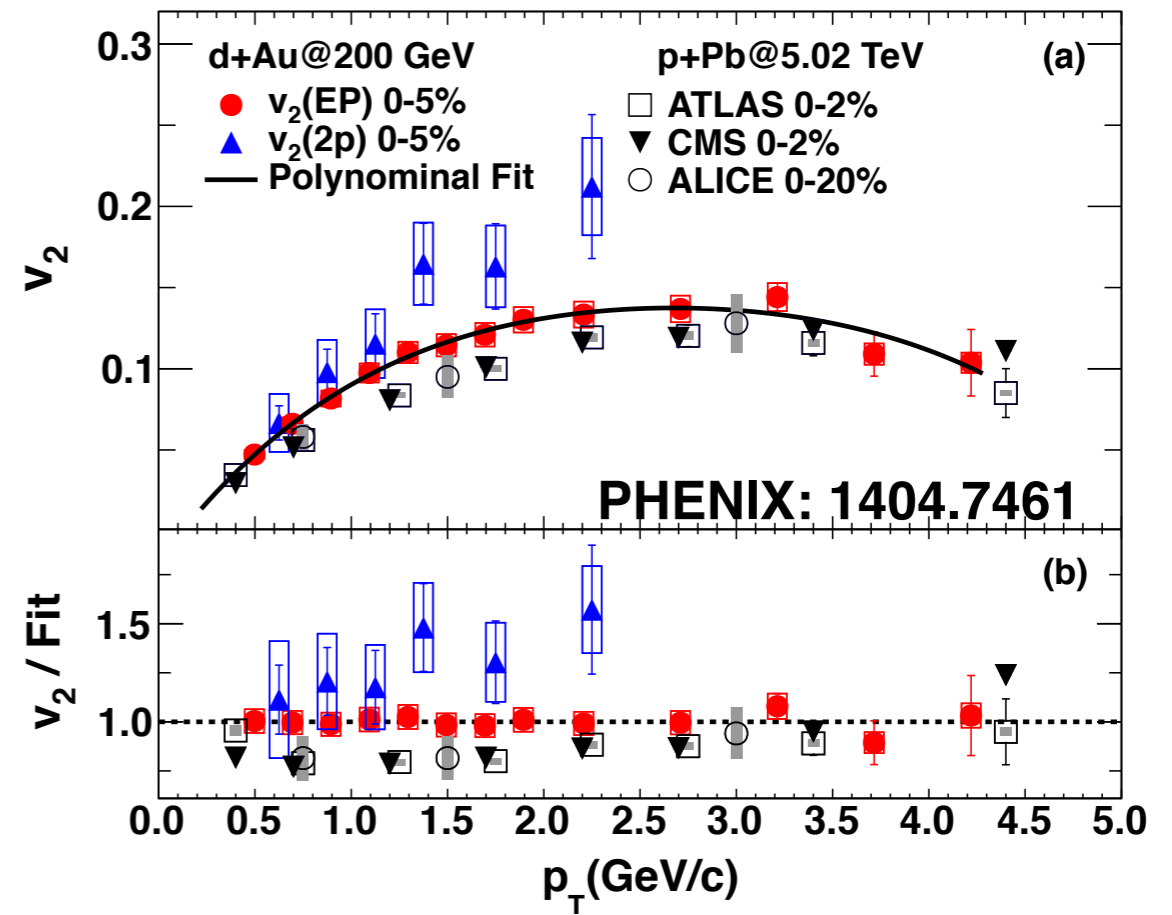
QM2014: wealth of new measurements  
 vigorous discussion about methods & interpretation  
 focus on methods,  $p_T$  reach, particle ID

# cumulants



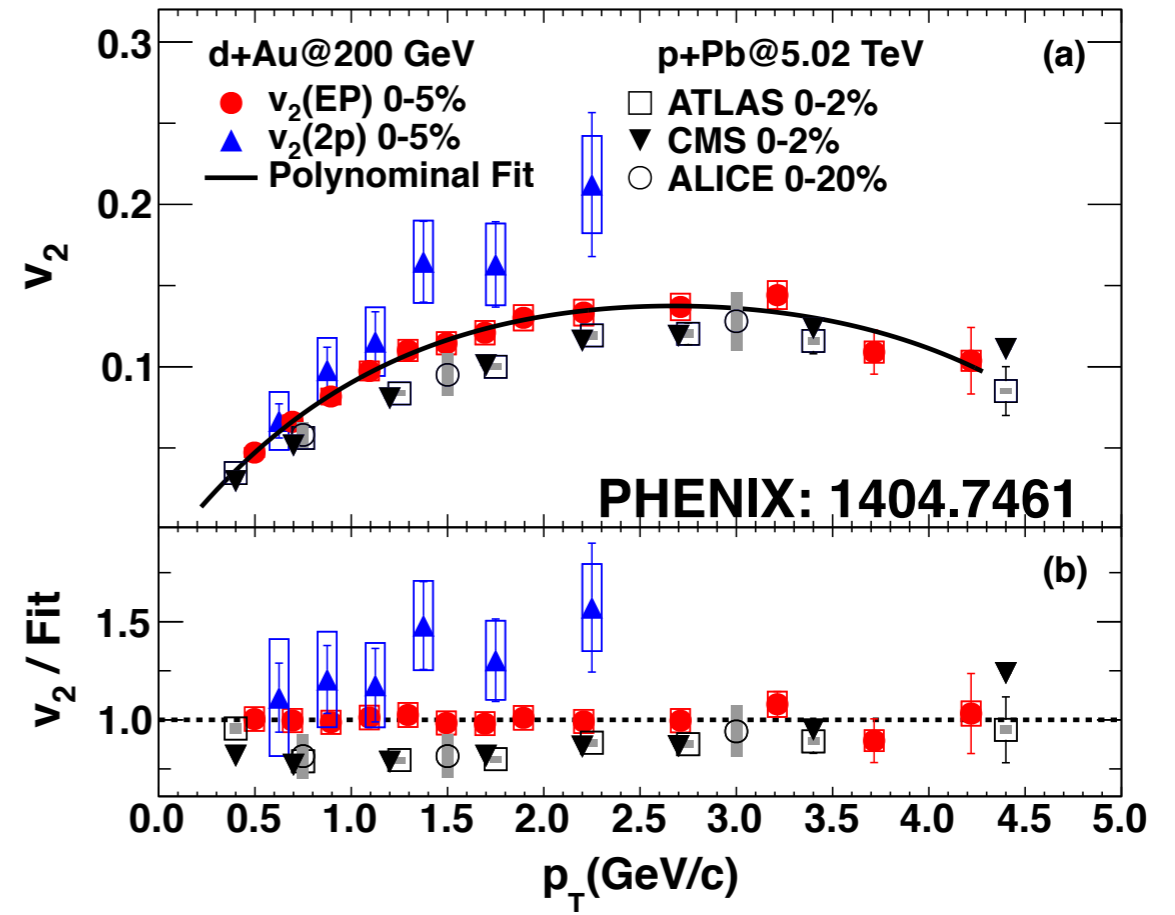
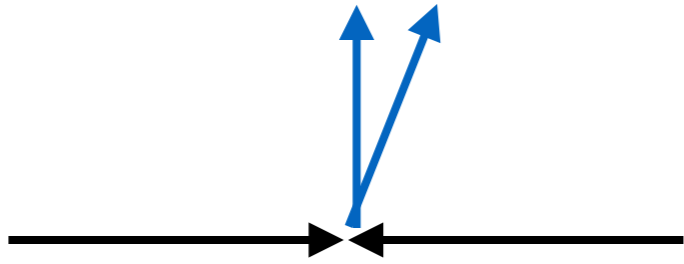
$v_2$  from cumulants smaller than 2-particle correlations  
no change in  $v_2$  for 4,6,8 part. cumulants

# $v_2$ @ RHIC

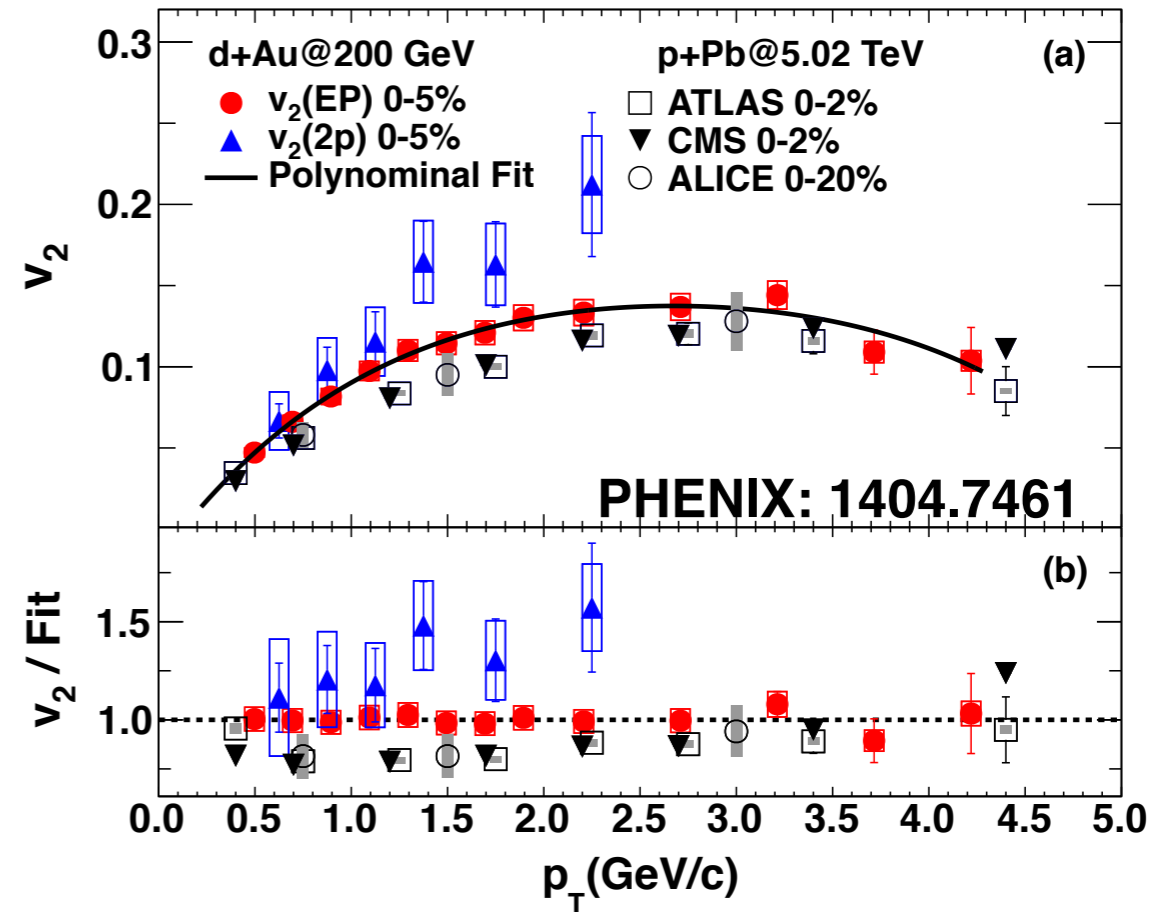
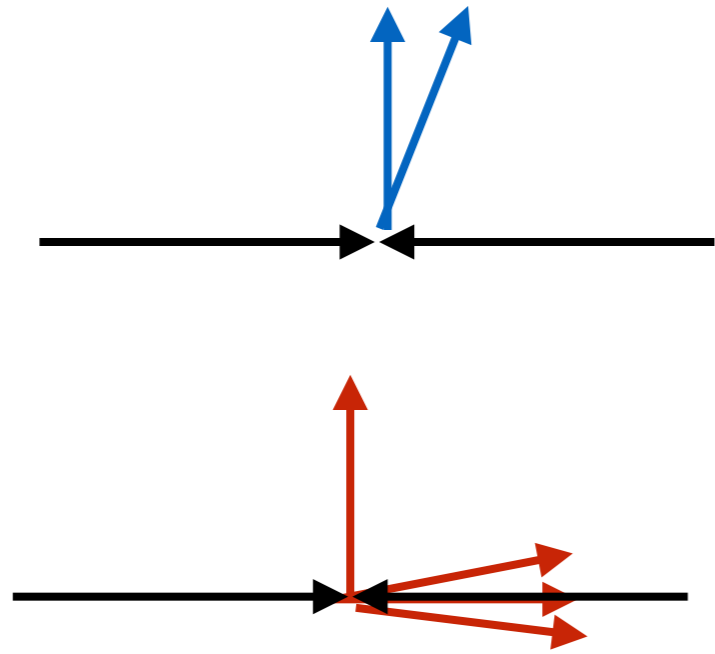




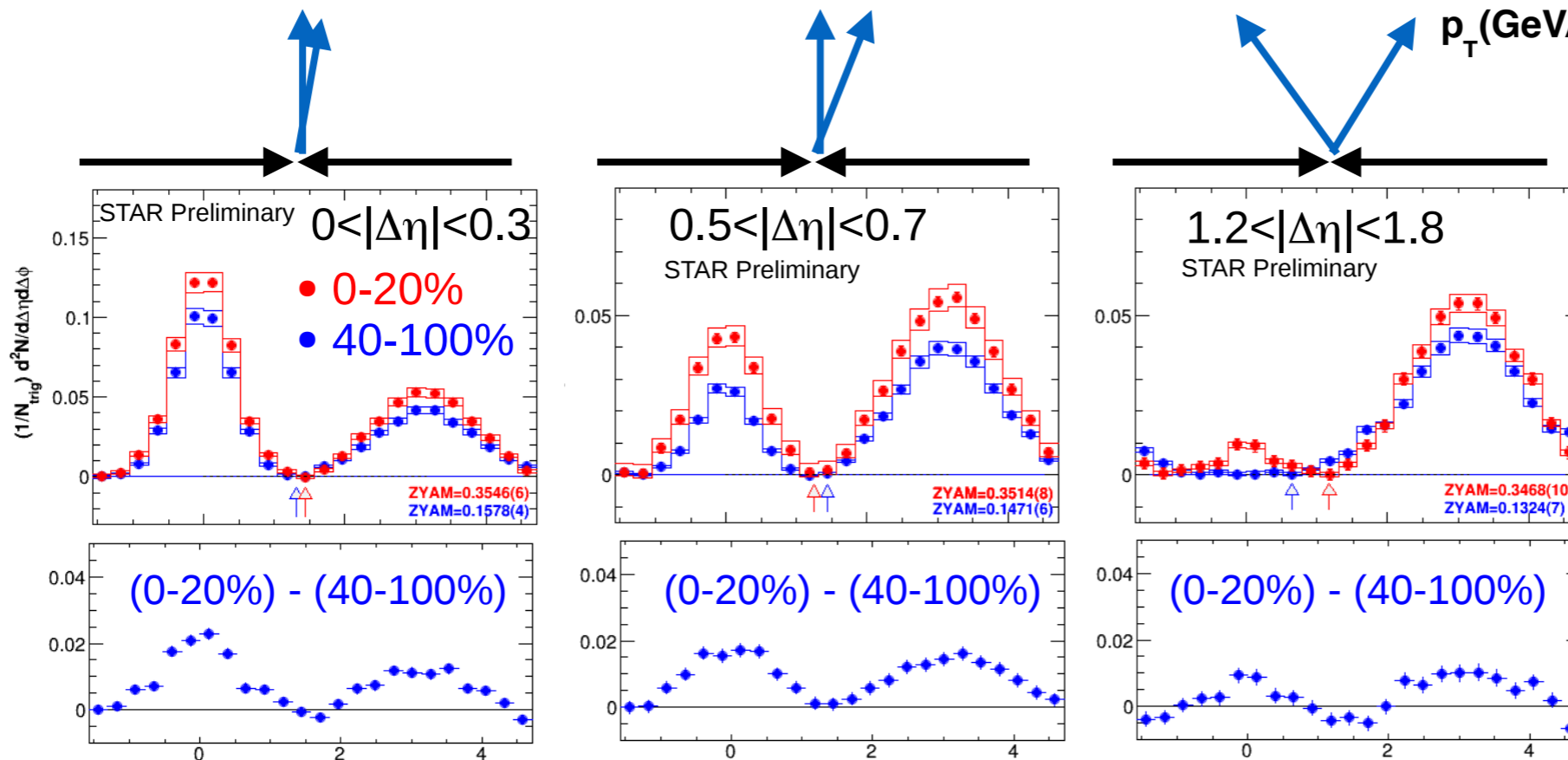
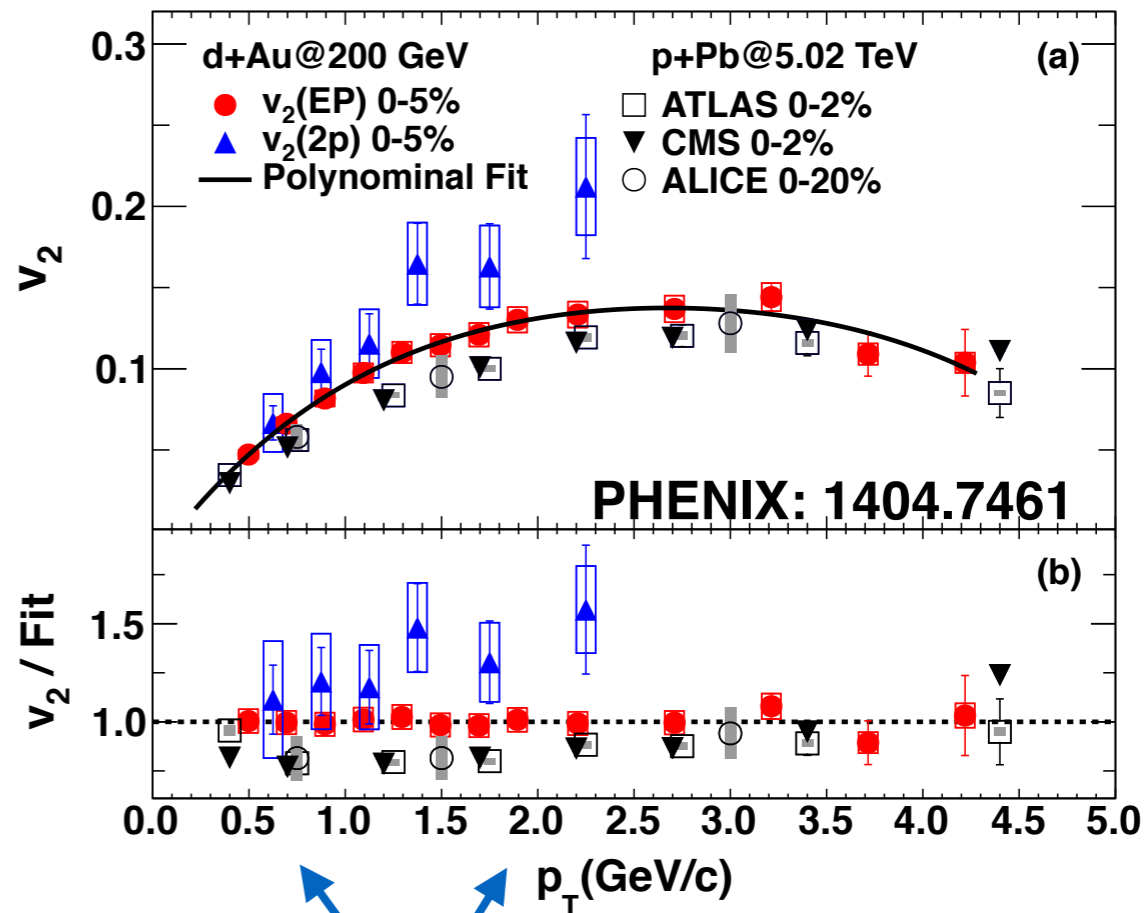
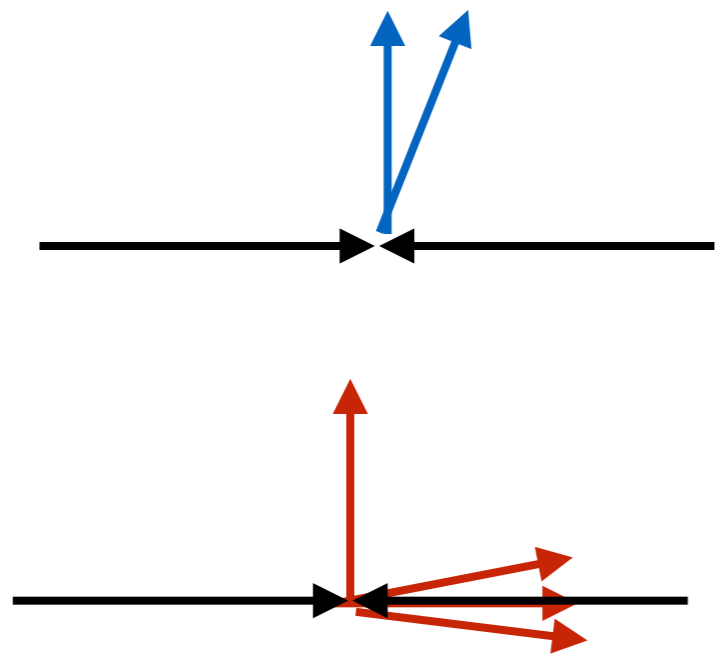
# $v_2$ @ RHIC



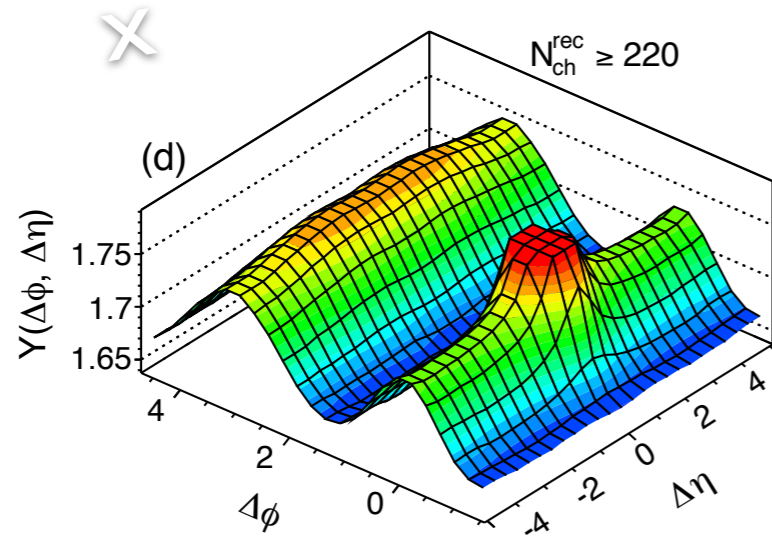
# $v_2$ @ RHIC



# v2 @ RHIC

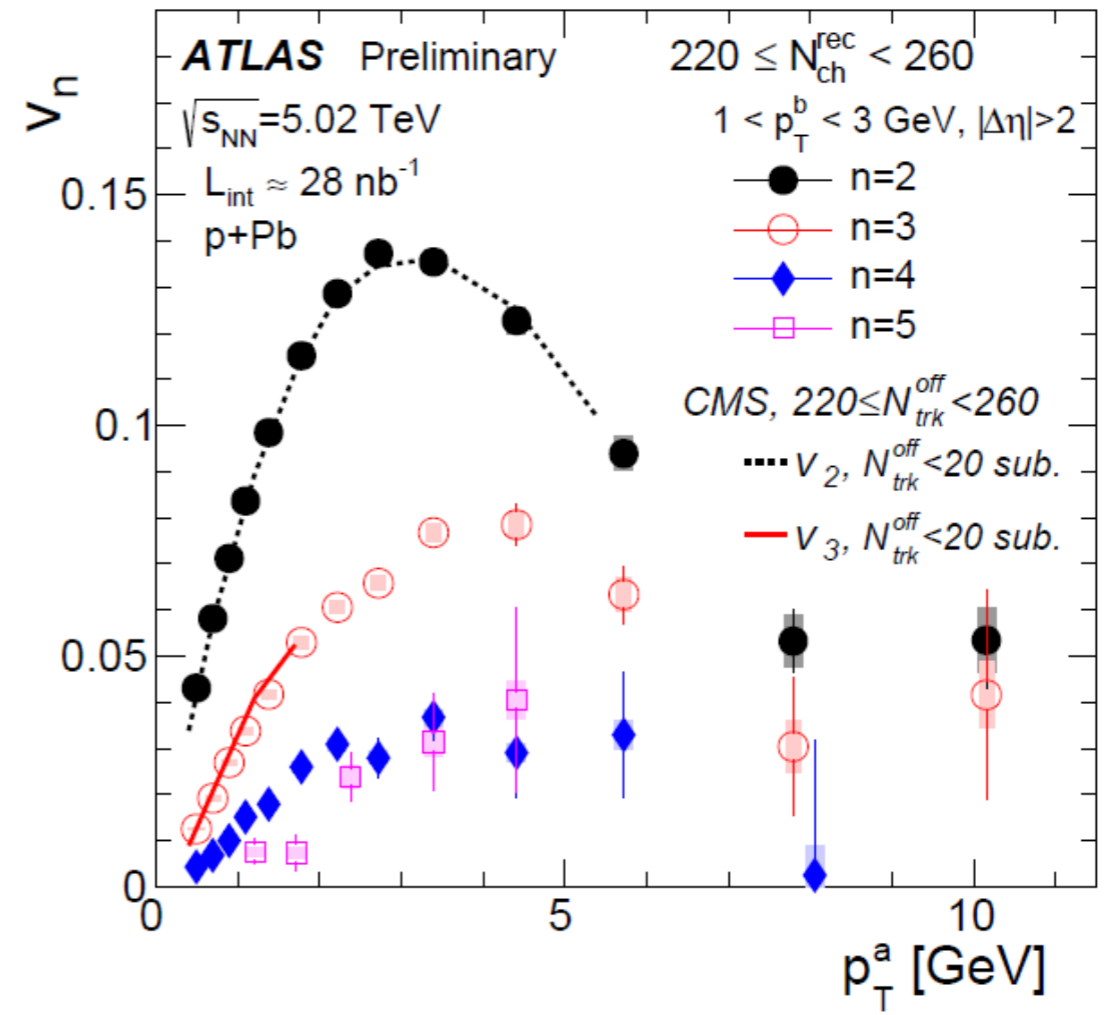
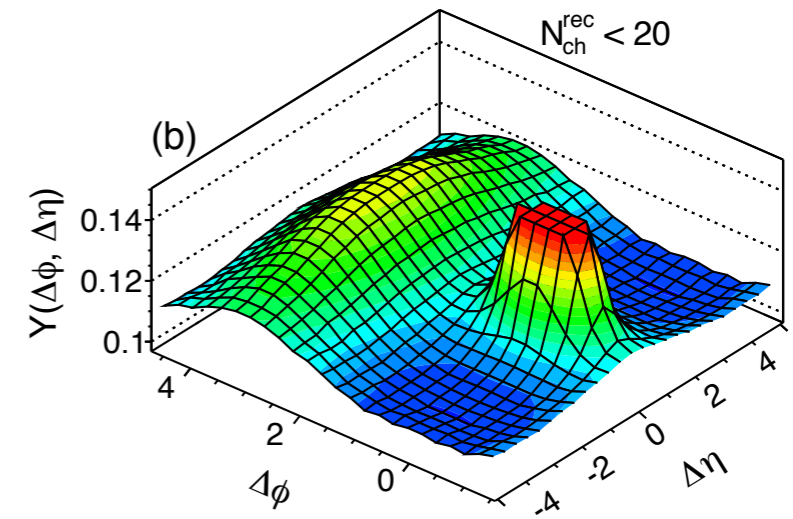


# recoil subtraction

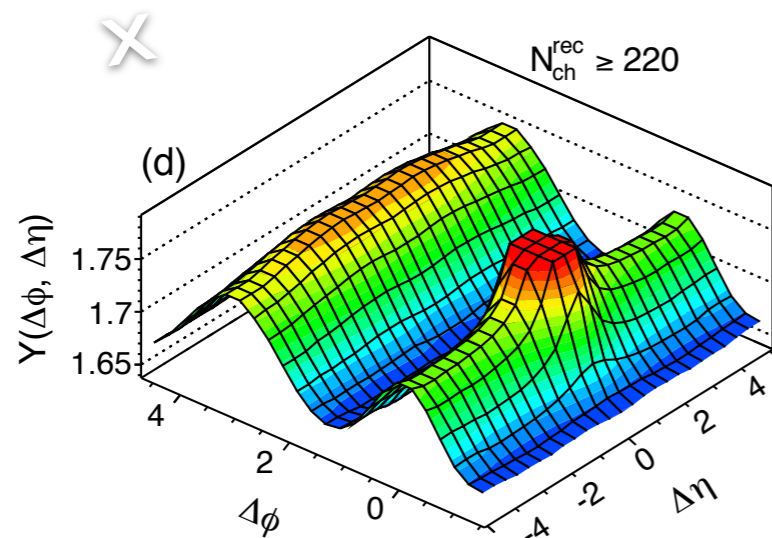


p+Pb  
**ATLAS Preliminary**  
 $\sqrt{s_{NN}} = 5.02 \text{ TeV}, L_{int} \approx 28 \text{ nb}^{-1}$   
 $1 < p_T^{a,b} < 3 \text{ GeV}$

—  $\propto$

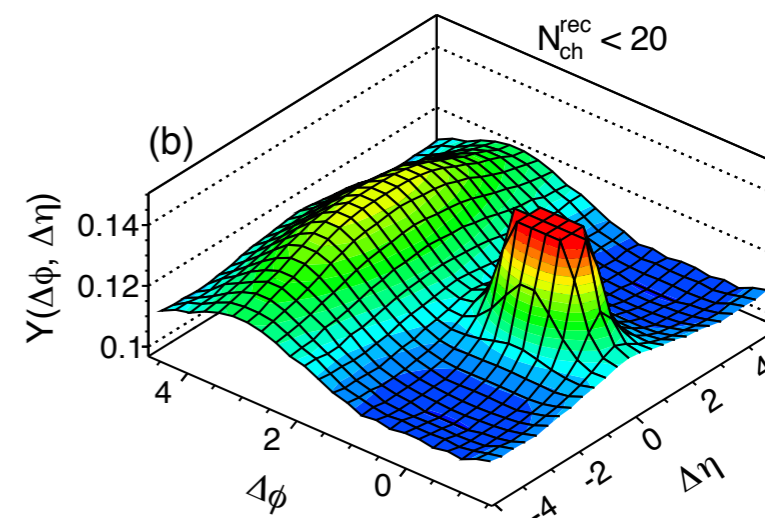


# recoil subtraction

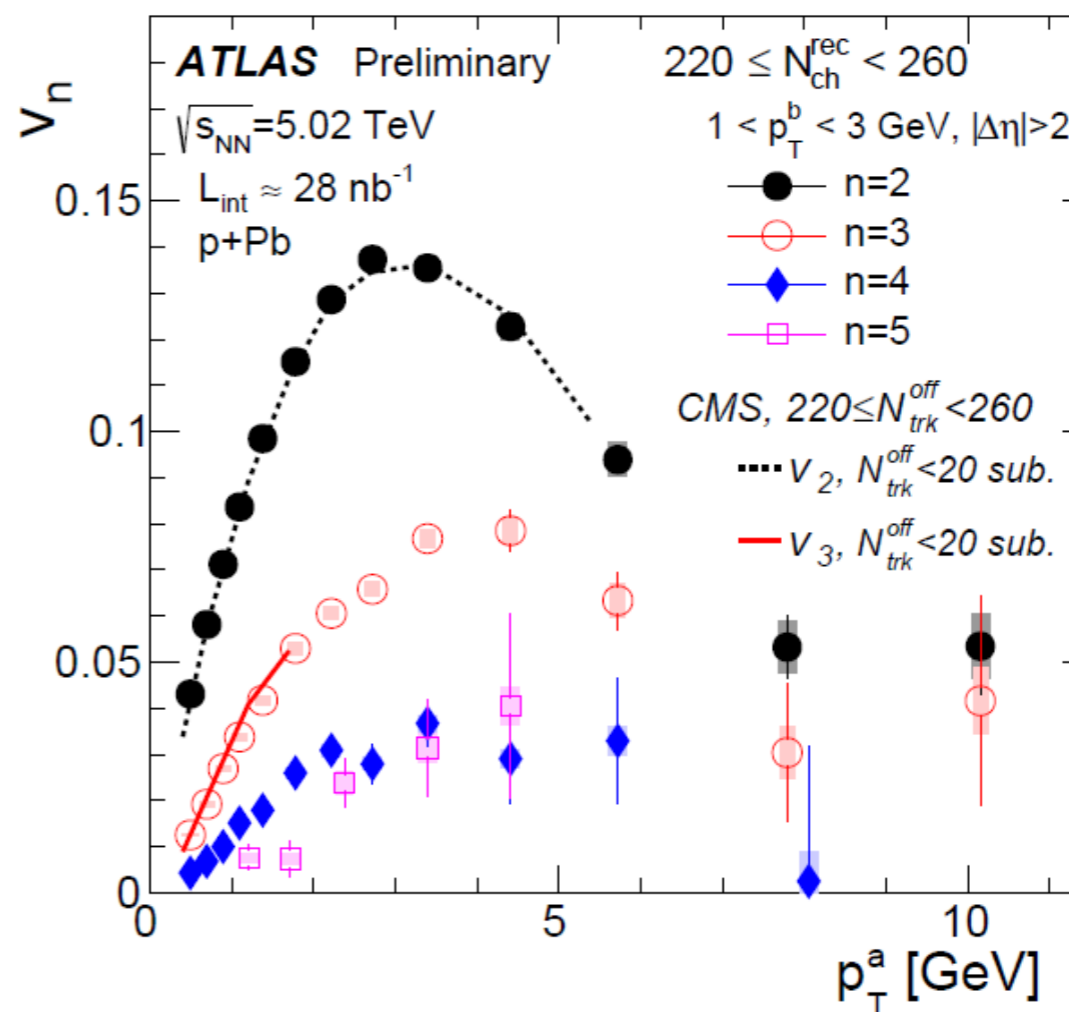


p+Pb  
**ATLAS** Preliminary  
 $\sqrt{s_{NN}}=5.02$  TeV,  $L_{int} \approx 28$  nb<sup>-1</sup>  
 $1 < p_T^{a,b} < 3$  GeV

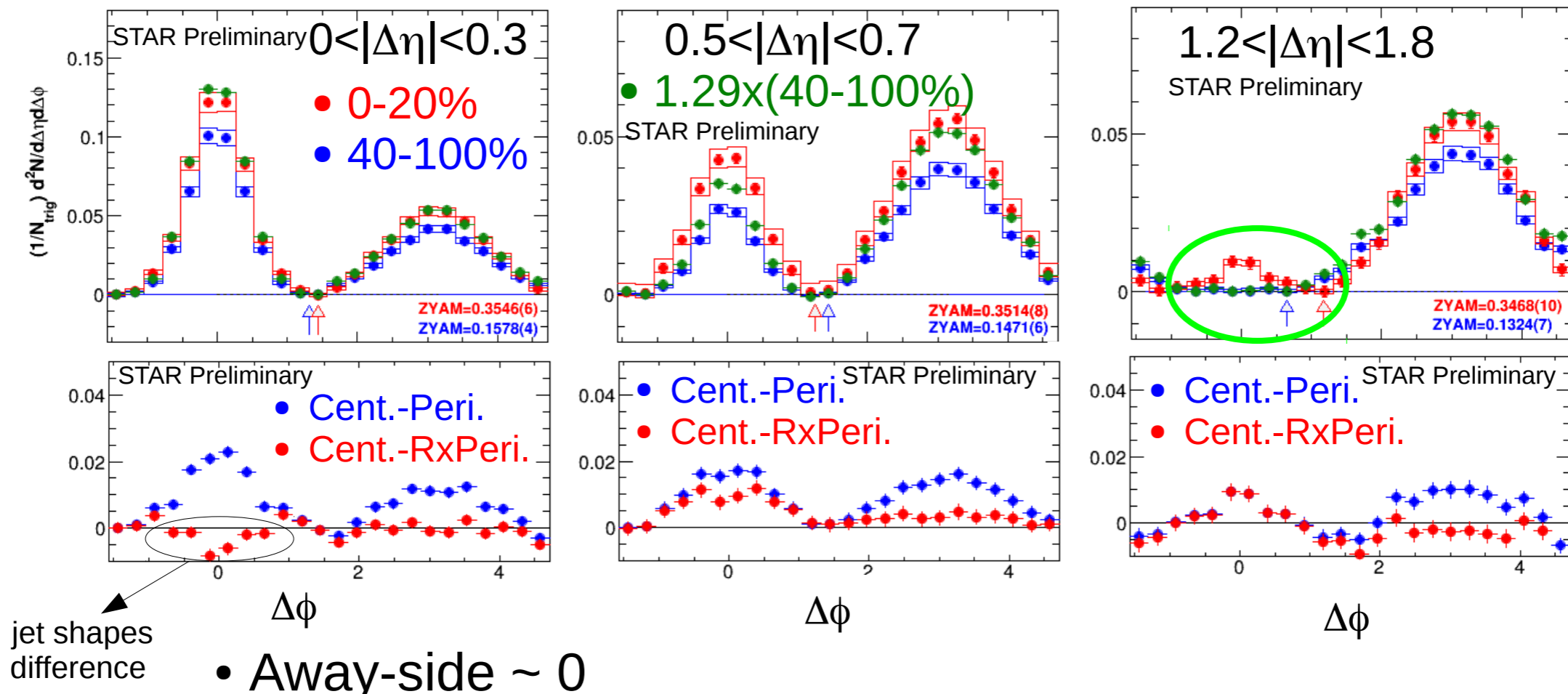
—  $\propto$



$\propto$  accounts for differences in the jets between peripheral and central, sizable effect at high  $p_T$

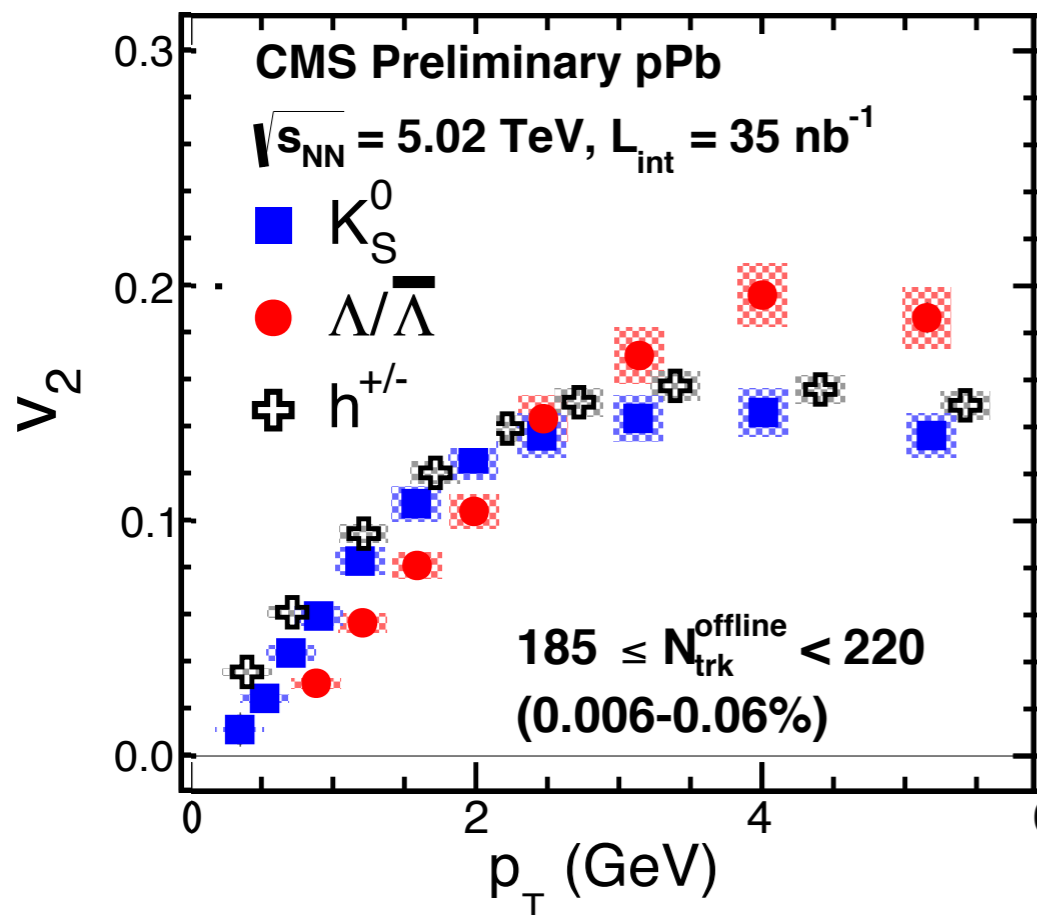
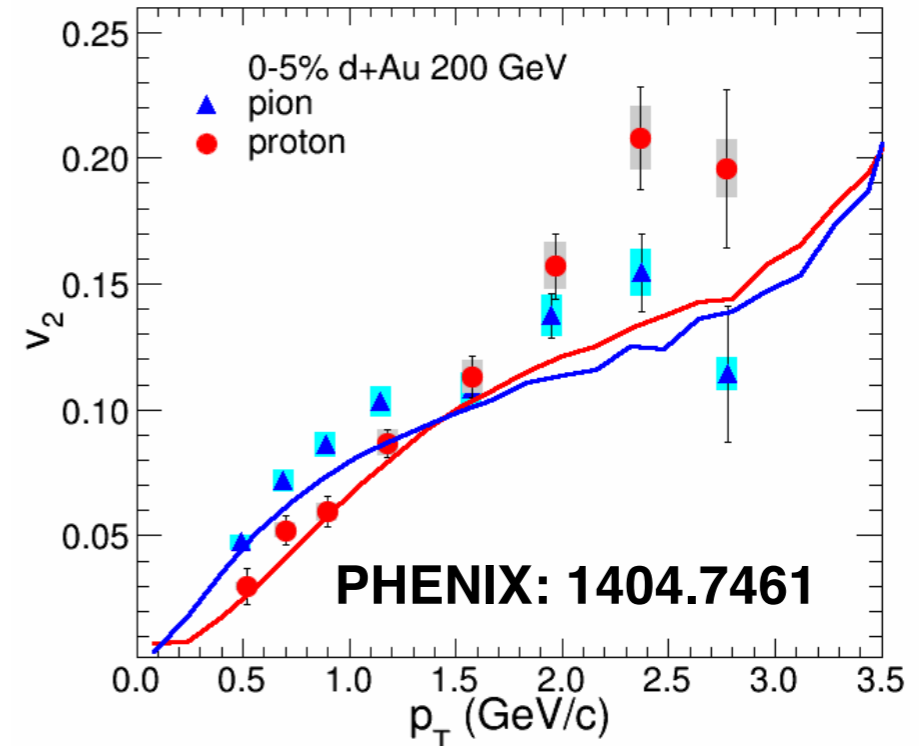
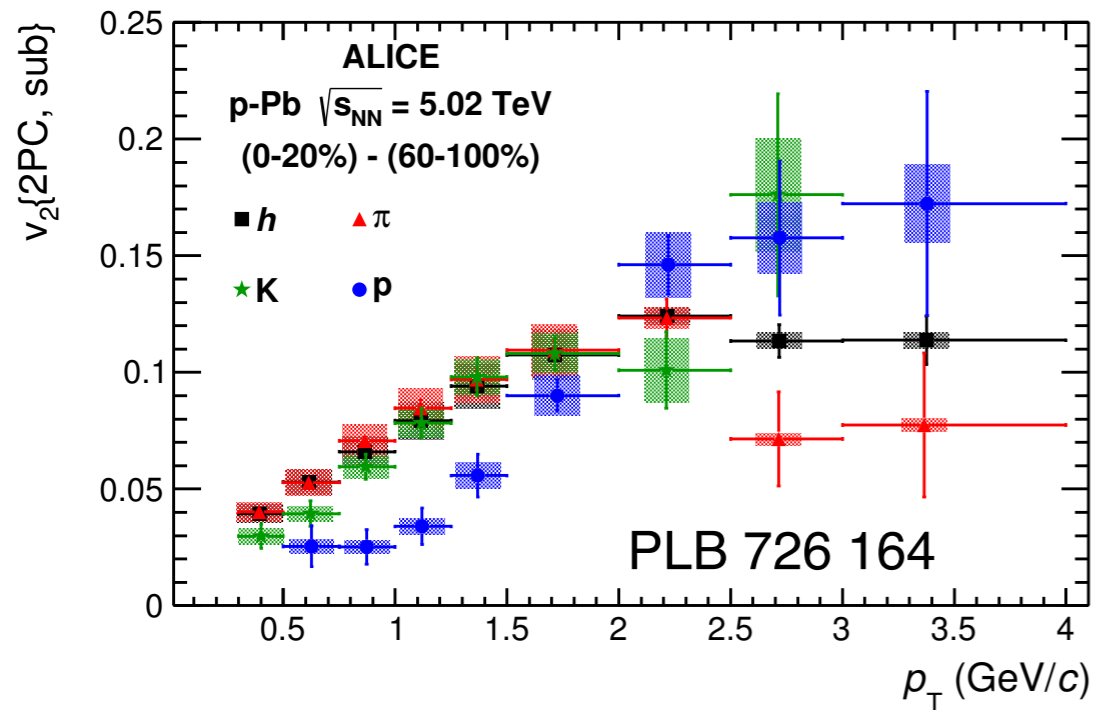


# recoil subtraction – STAR



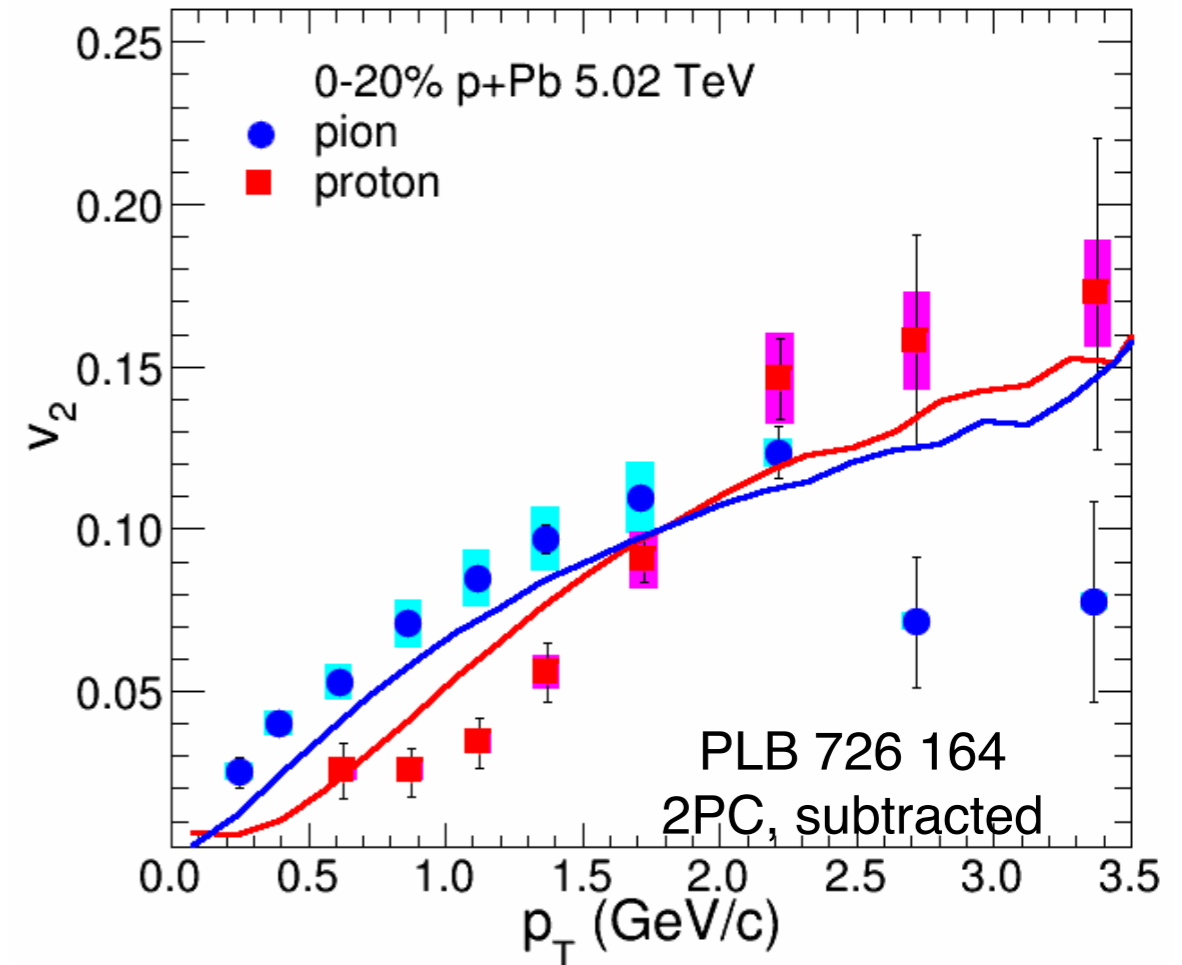
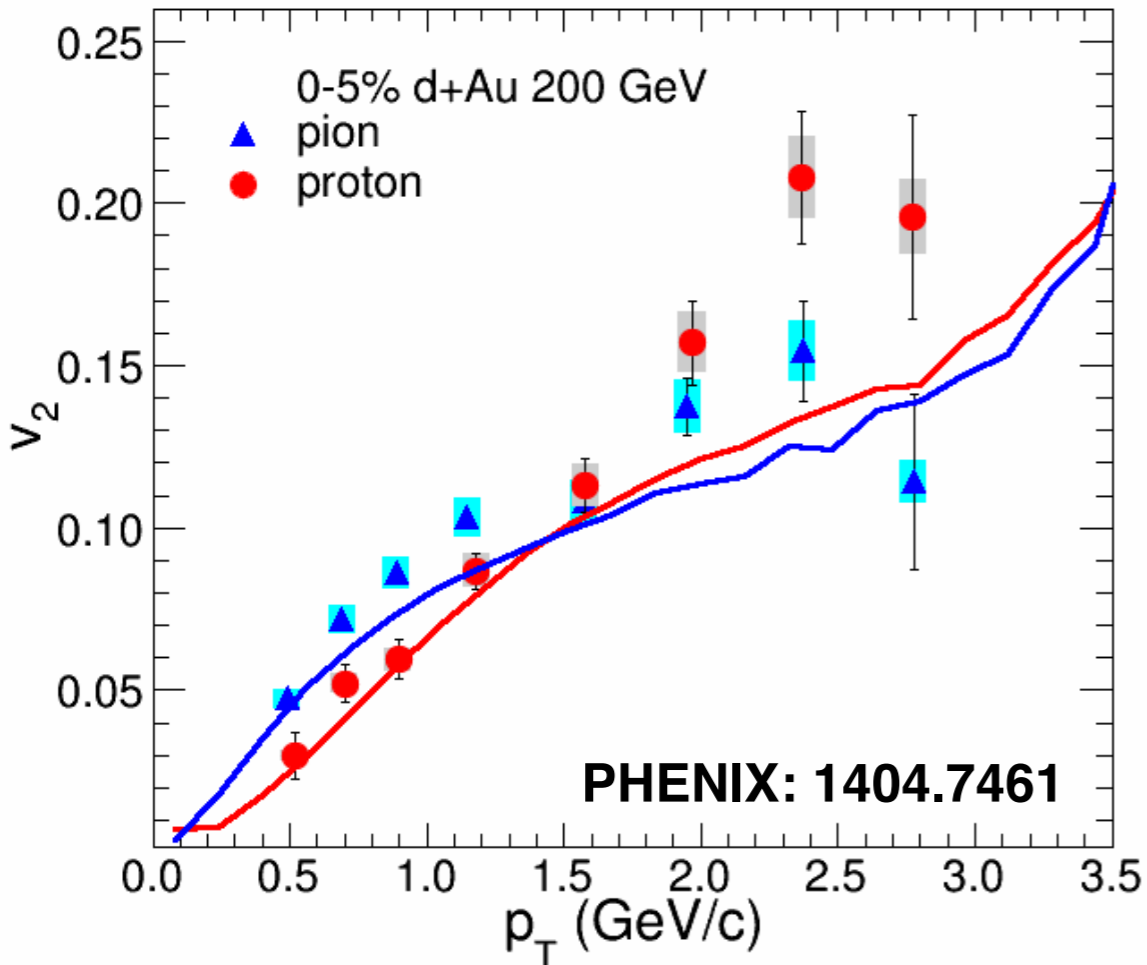
seems to make a bigger difference for STAR  
 many different details here (which matter!) great to see  
 centrality,  $p_T$ , etc dependence

# mass dependent flow



mass differences seen:  
lower  $v_2$  for heavier particles  
at low  $p_T$ , crossing at higher  
 $p_T$

# mass dependent flow



MC Glauber IC

$$\eta/s = 1/4\pi$$

$$\tau_0 = 0.5 \text{ fm/c}$$

$$T_f = 170 \text{ MeV}$$

cascade

calculations: P. Romatschke

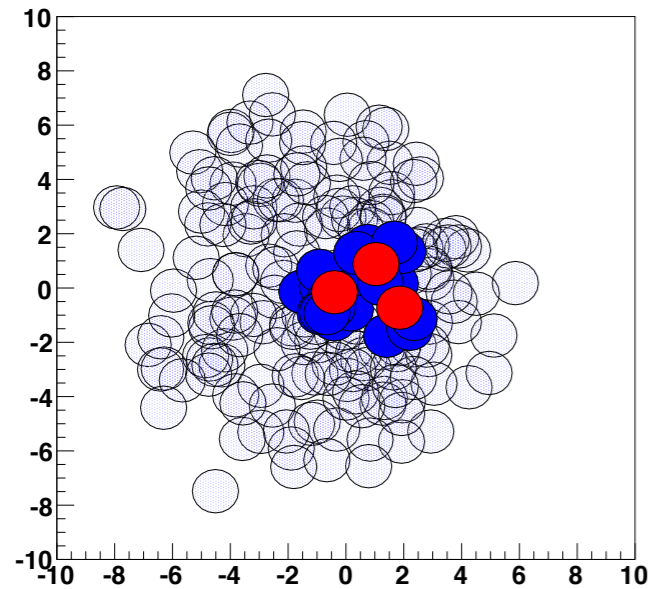
**what can we learn by the successes and failures of hydro calculations in these very small systems?**

Huang, Milano



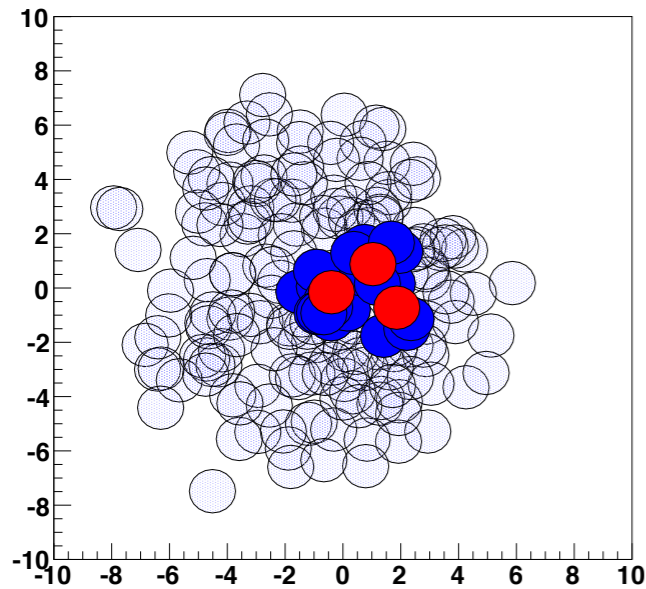
# ${}^3\text{He}+\text{Au}$ :

---



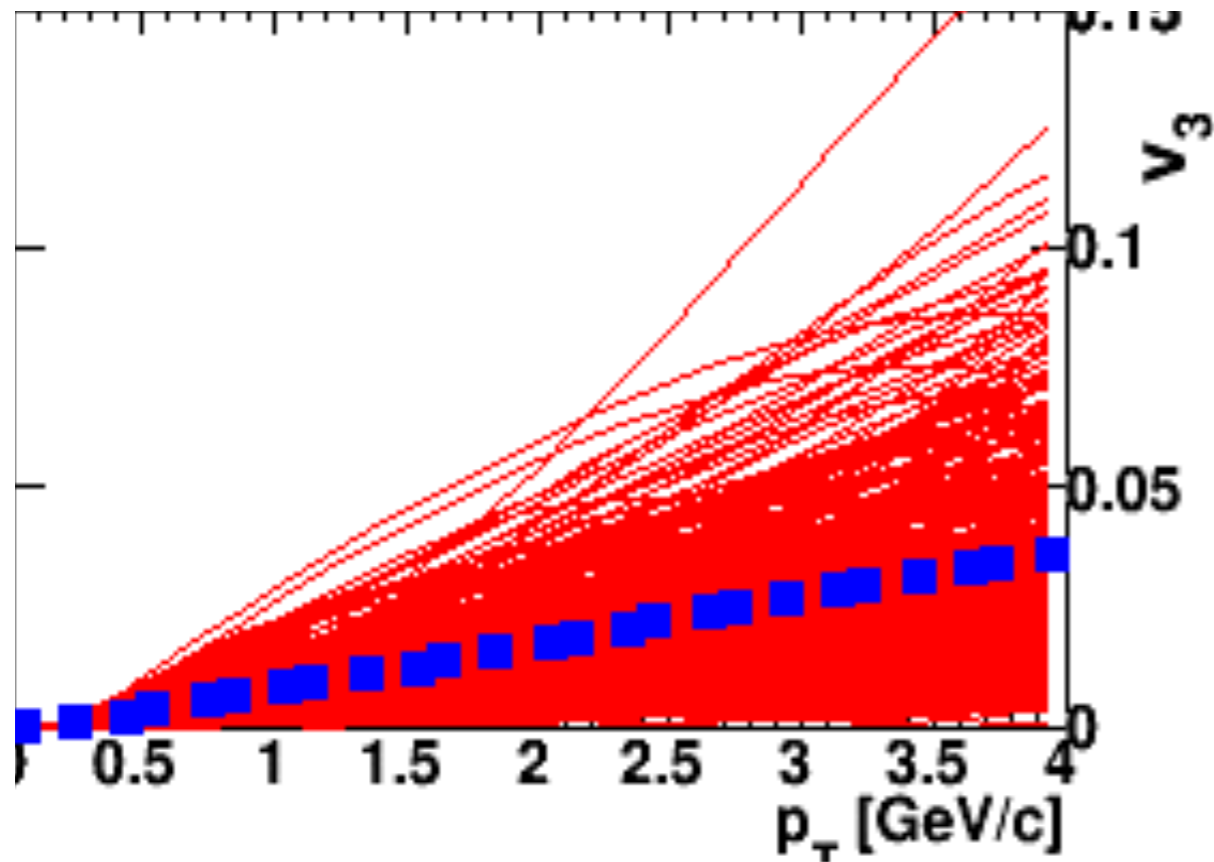
**${}^3\text{HeA}$ : variation of the system geometry**

# $^3\text{He}+\text{Au}$ :

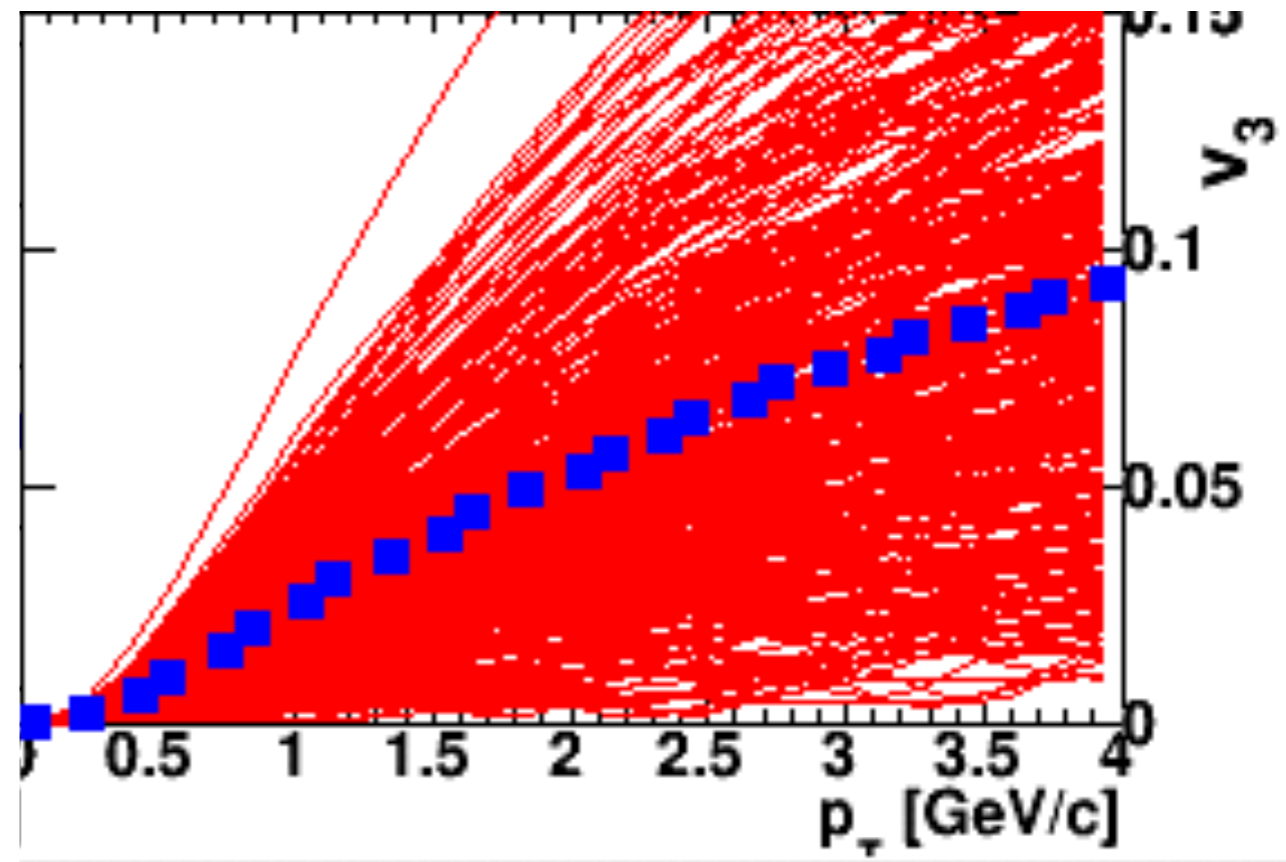


## $^3\text{HeA}$ : variation of the system geometry

5% most central



1% most central

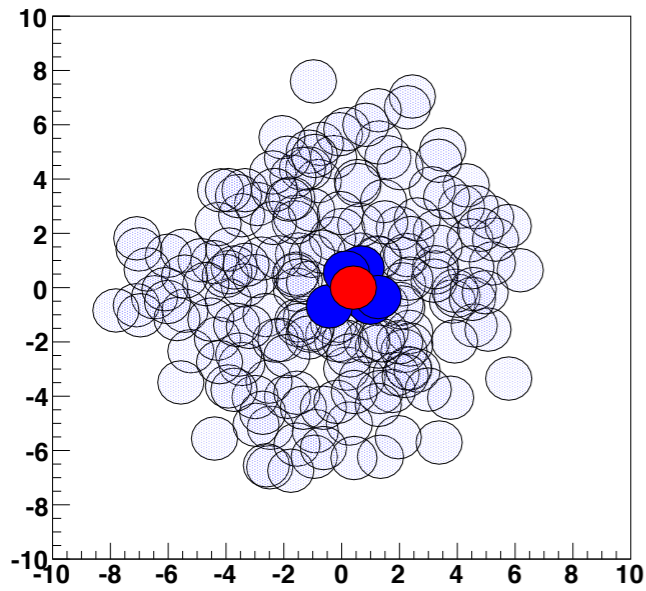


calculations: P. Romatschke (CD parallel), Nagle et al: 1312.4565

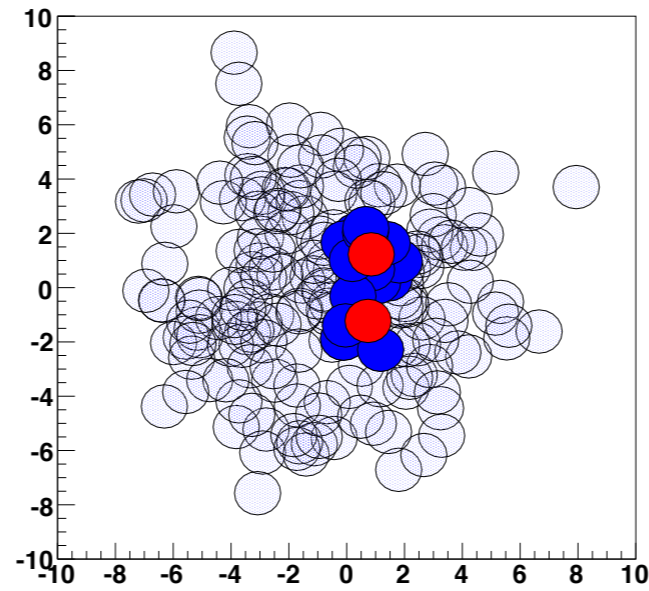
# linking geometry to correlations?

---

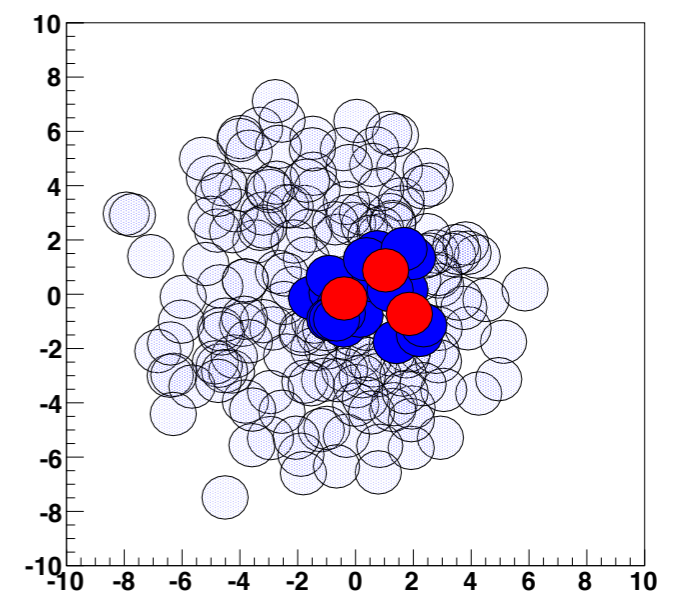
**pA**



**dA**



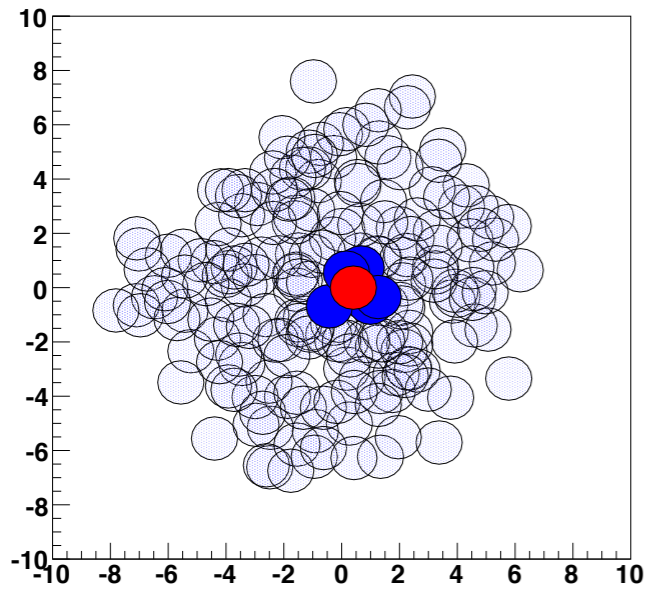
**<sup>3</sup>HeA**



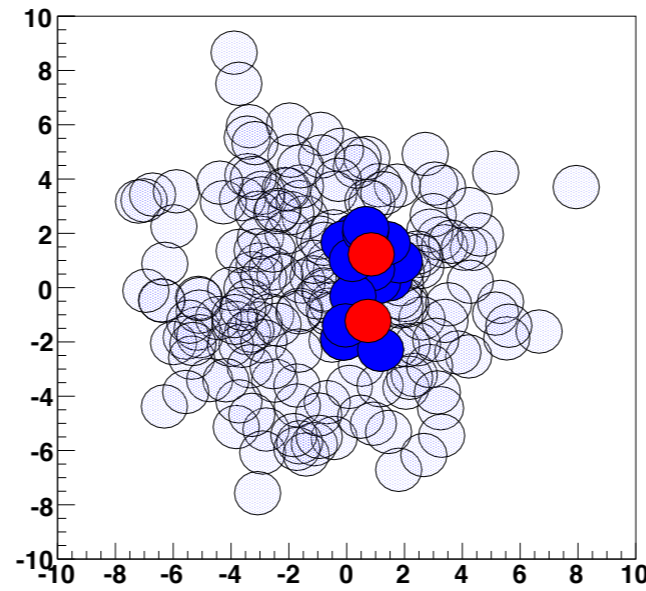
# linking geometry to correlations?

---

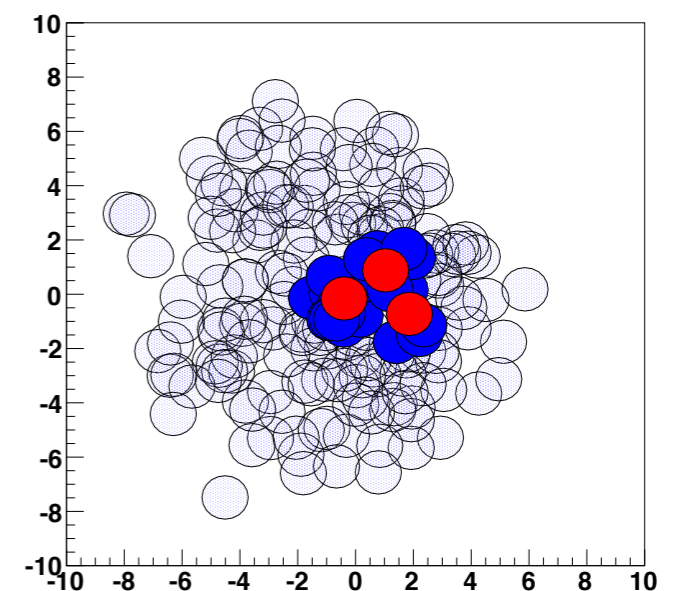
**pA**



**dA**

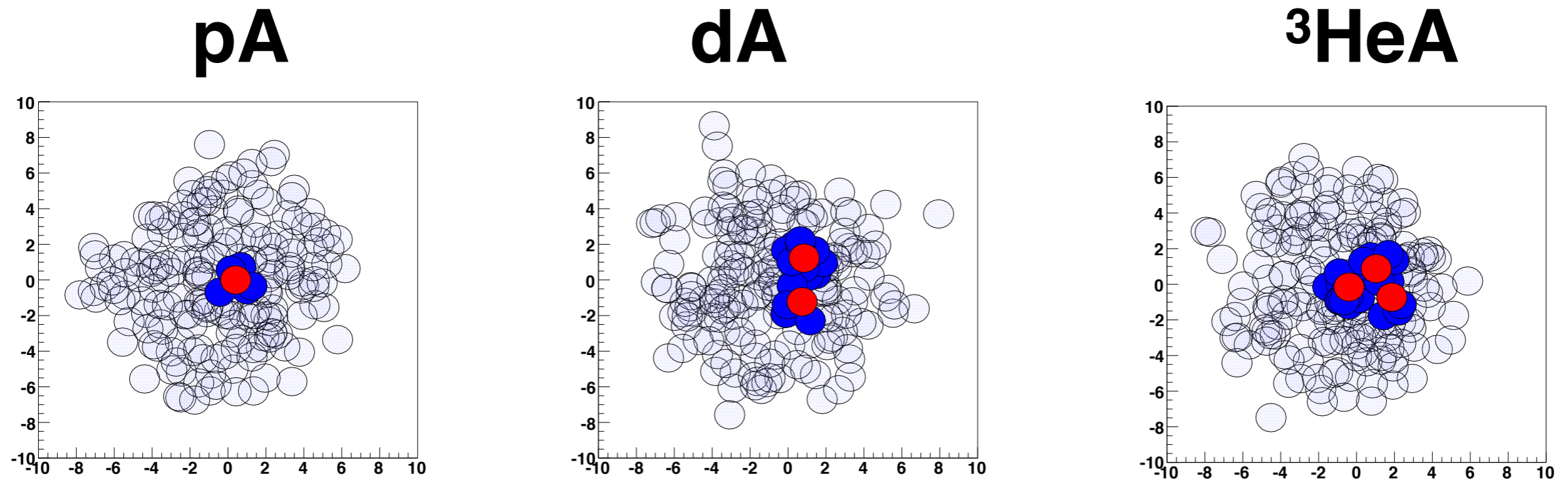


**<sup>3</sup>HeA**



looking forward to p+Au and <sup>3</sup>He+Au  
measurements at RHIC in the next year

# linking geometry to correlations?



looking forward to p+Au and <sup>3</sup>He+Au measurements at RHIC in the next year

in addition to new collision systems, detector upgrades to both STAR & PHENIX will provide big improvements on existing d+Au measurements (silicon, MTD, MPC-EX)



# flow in pA systems?

---

- the soft sector of pA shares a lot of features with AA
- that doesn't necessarily mean we have created mini-QGPs in pA systems
  - and if we have that doesn't necessarily mean that hydrodynamics is the only relevant physics
- however, if flow-like signals are so generic, how does that feed back into our understanding of AA collisions?

**For myself, it's a great time to be an experimentalist!**

# pA @ QM2014

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- huge surprises since Quark Matter 2012
- both for hard and soft physics
- a large fraction of the new results here are from pA
- **absolutely impossible to cover them all in 25 minutes!**
- p+Pb at the LHC has produced a wealth of very interesting measurements
- RHIC is looking forward to new data in pA very soon
- interactions between all the experimental collaborations and the theory community moving our understanding forward



XXIV QUARK MATTER  
DARMSTADT 2014

# acknowledgements

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- ALICE, ATLAS, CMS, PHENIX & STAR (especially the conveners) for providing the plots
- all the experimental parallel speakers for their clear presentations
- many, many people for their discussions



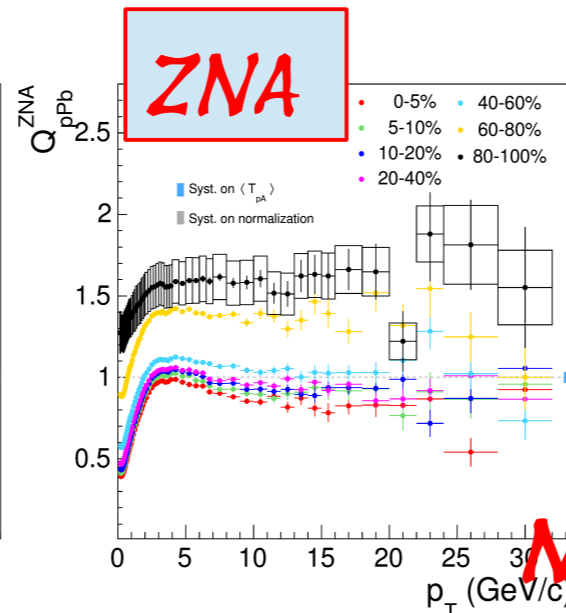
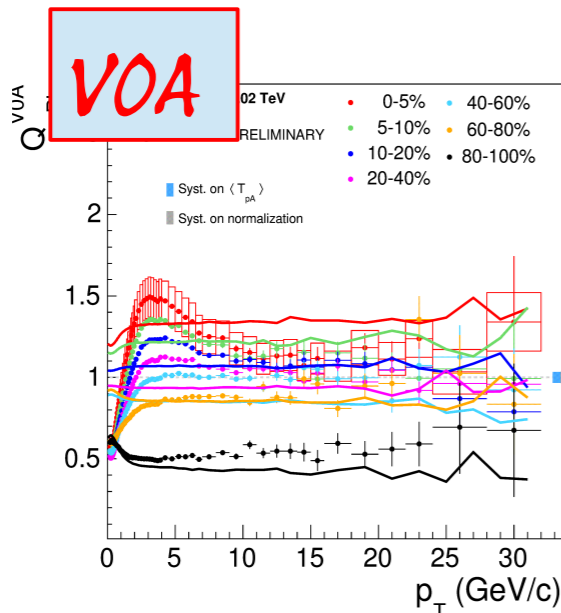
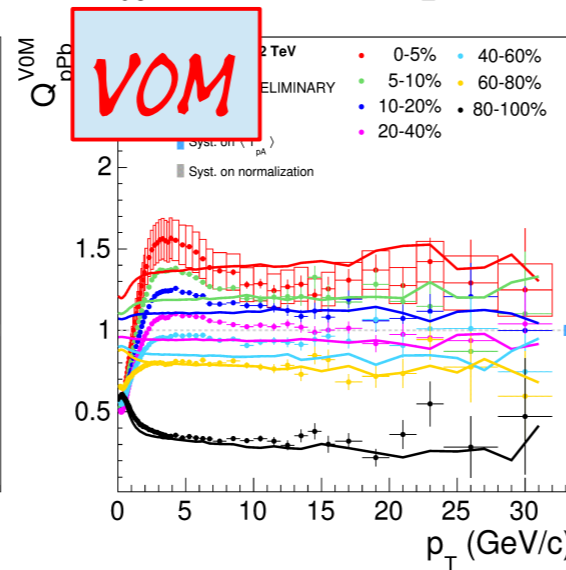
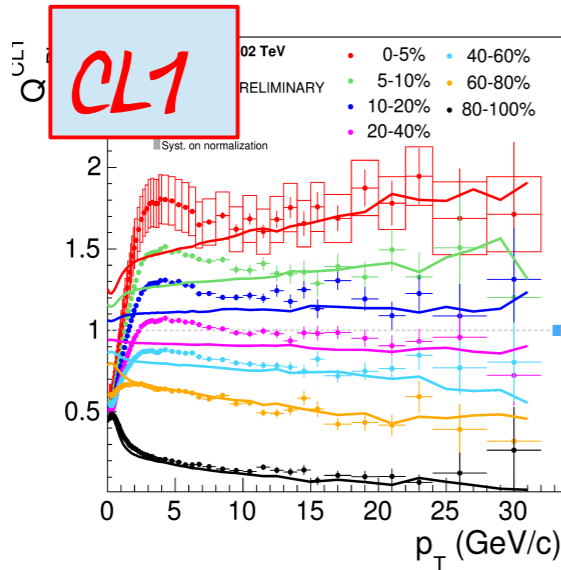
backups



# QpA

**CL1:** SPD cluster  $|\eta| < 1.4$   
**V0M:** V0A+C Mult.  $(-3.7 < \eta < -1.7, 2.8 < \eta < 5.1)$   
**V0A:** V0A Mult  $(2.8 < \eta < 5.1)$   
**ZNA:**  $0^\circ$  Neutron Energy

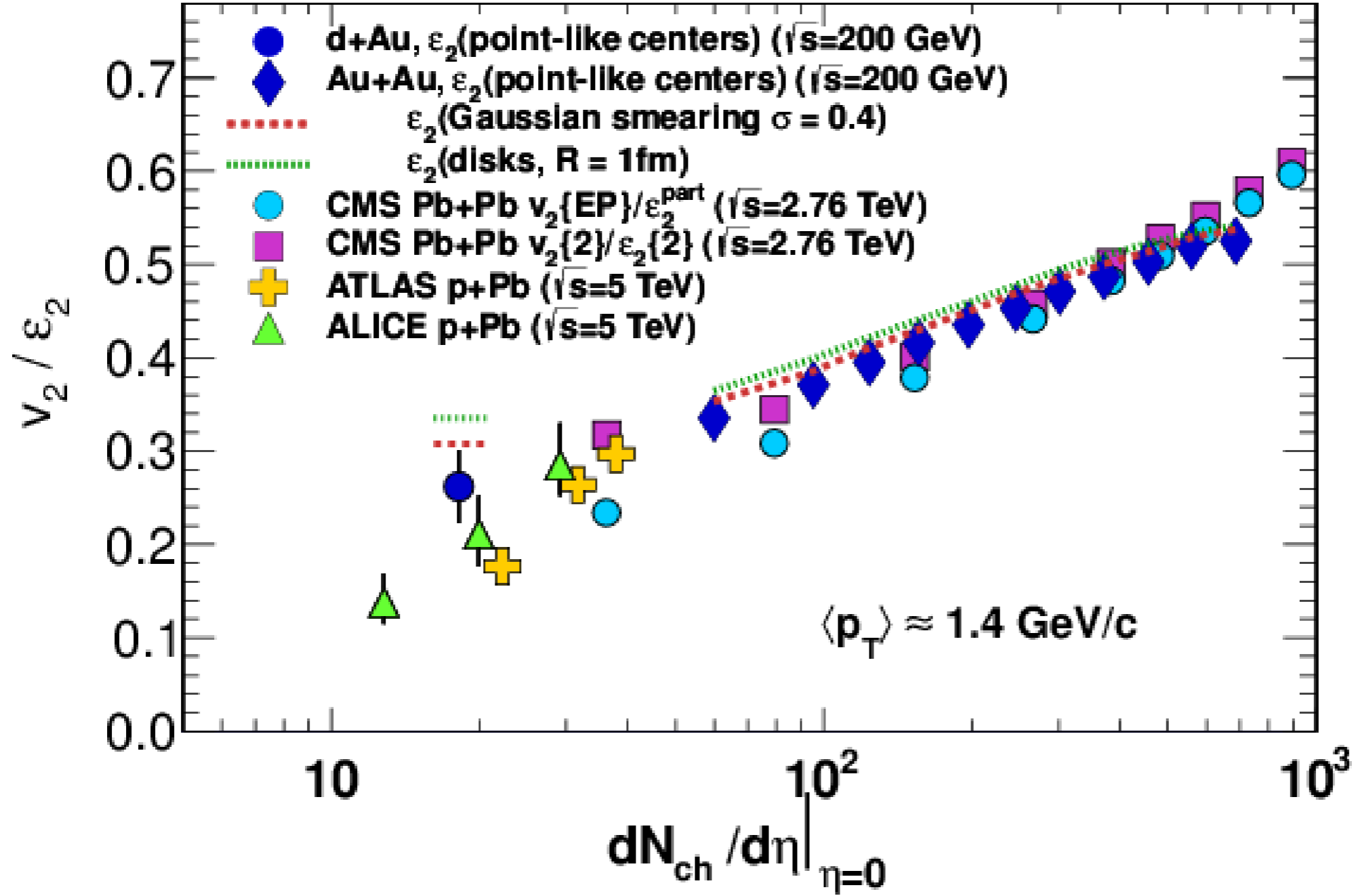
$$Q_{pA}(p_T; cent) = \frac{d N^{pA} / d p_T}{N_{coll}^{Glauber} d N^{pp} / d p_T} = \frac{d N^{pA} / d p_T}{T_{pA}^{Glauber} d \sigma^{pp} / d p_T} \neq 1$$



- $Q_{pPb}$  spread between centrality  
Reduces with increasing rapidity gap: CL1  $\rightarrow$  V0M  $\rightarrow$  V0A
- Negative slope in 80-100%  $\rightarrow$  "jet veto bias"  
Reduces in V0M and absent in V0A
- Good agreement with G-PYTHIA (Pythia + p-Pb Glauber MC)  
Worse in V0M and V0A
- Deviations at intermediate  $p_T$
- ZNA: spectra more similar high- $p_T$  values  $\rightarrow$  bias in  $N_{coll}$

**NEW!**

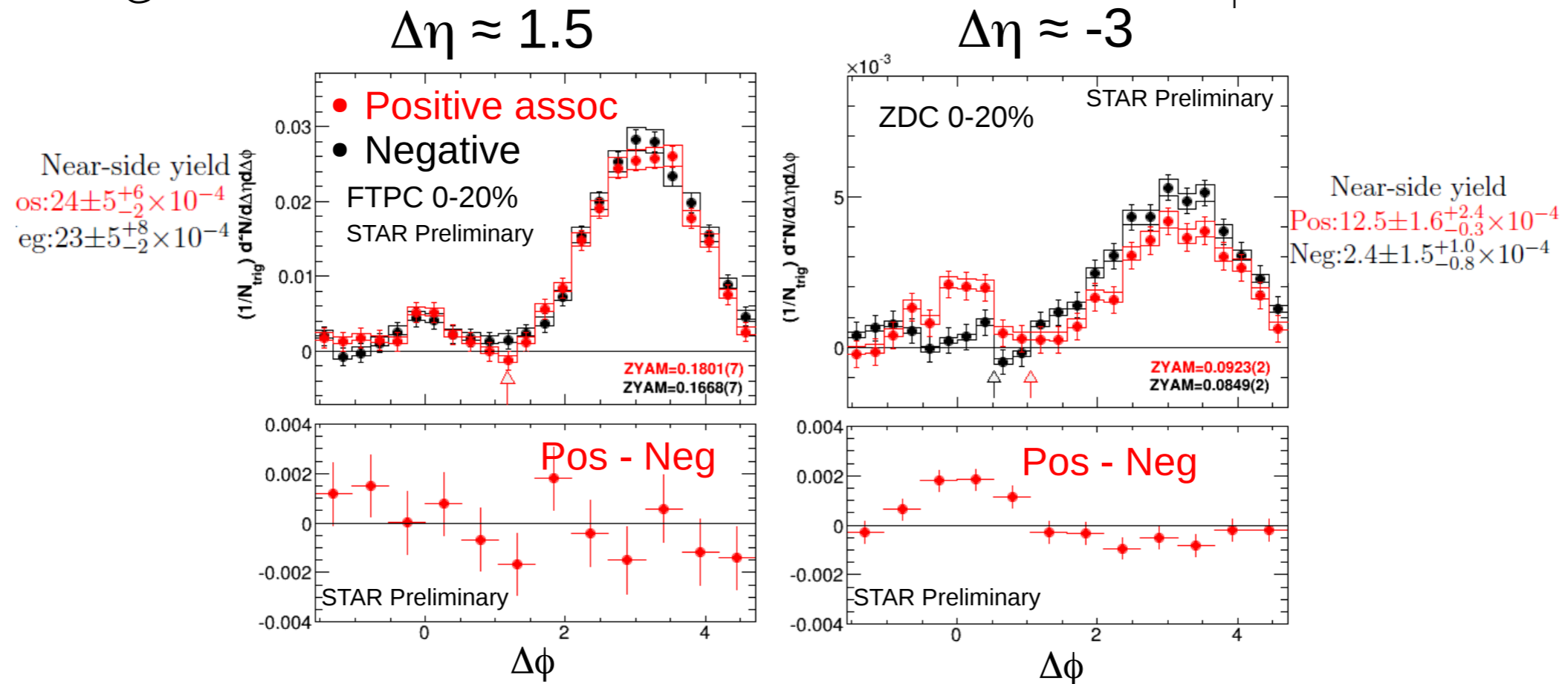
A. Toia



# Associated Particle: Positive vs Negative

d+Au@200 GeV

$p_T$ : [1,3]x[1,3] GeV/c



- $\Delta\eta \approx 1.5$ : No difference.
- $\Delta\eta \approx -3$  near-side: **positive** associated particles only  
 → **Transport protons?**



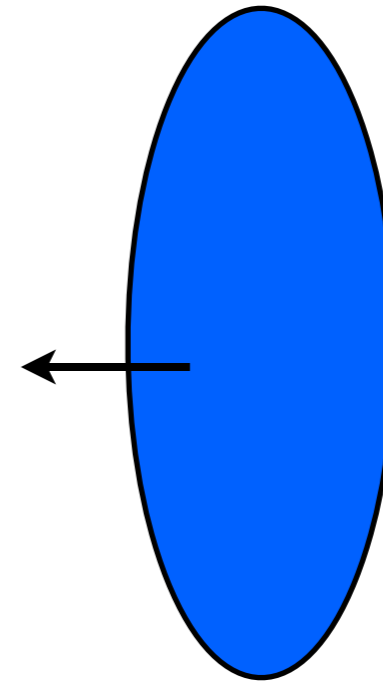
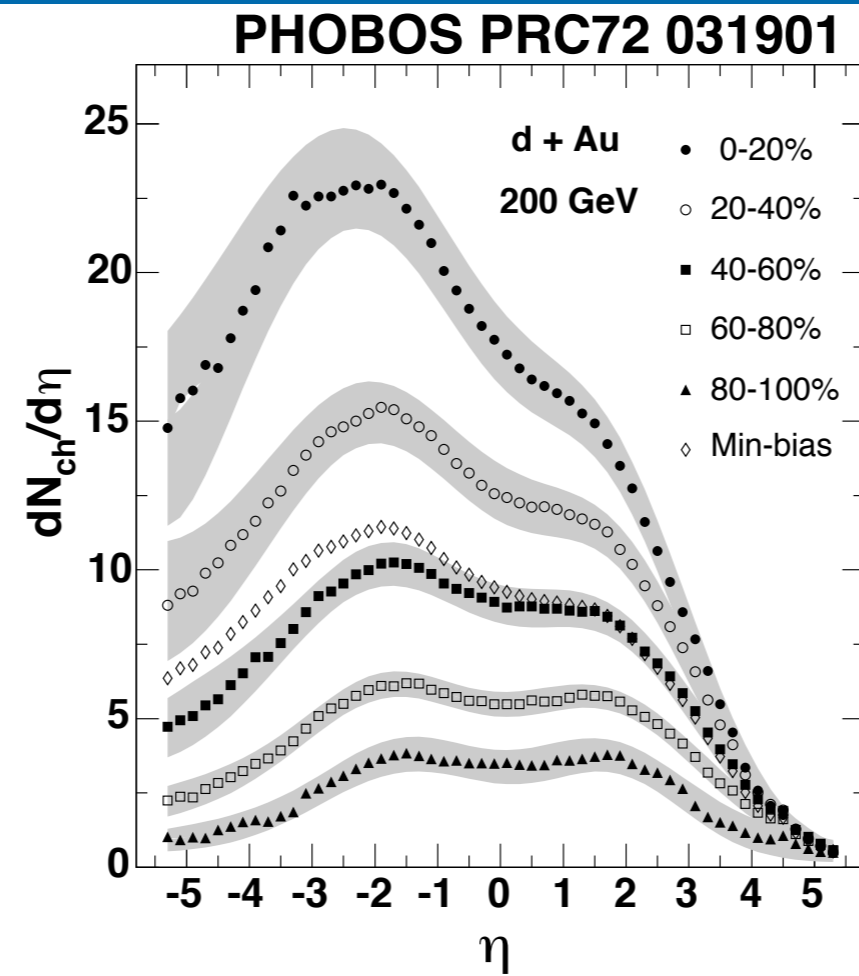
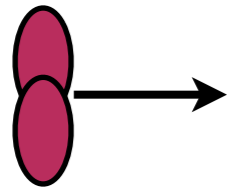
2014 May

Li Yi, Purdue University

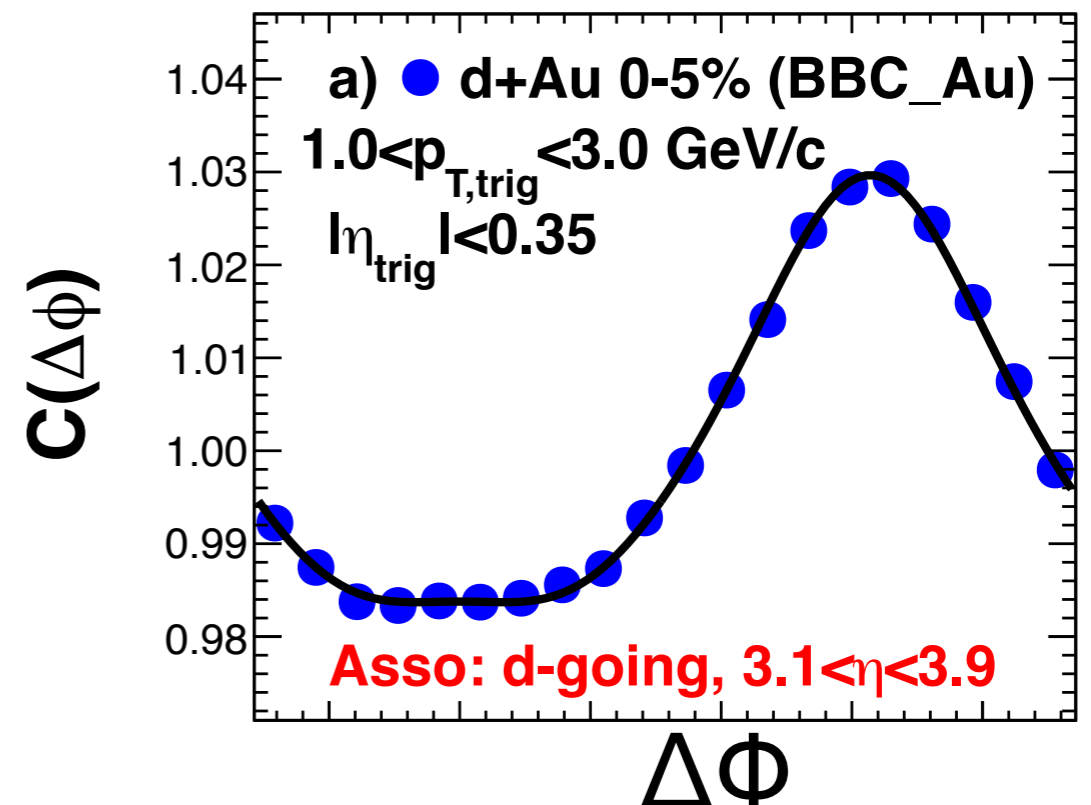
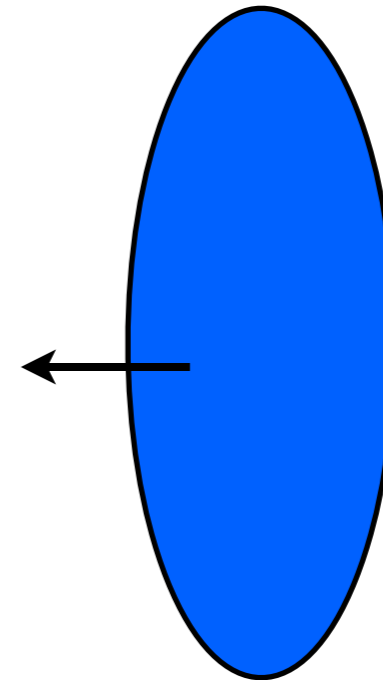
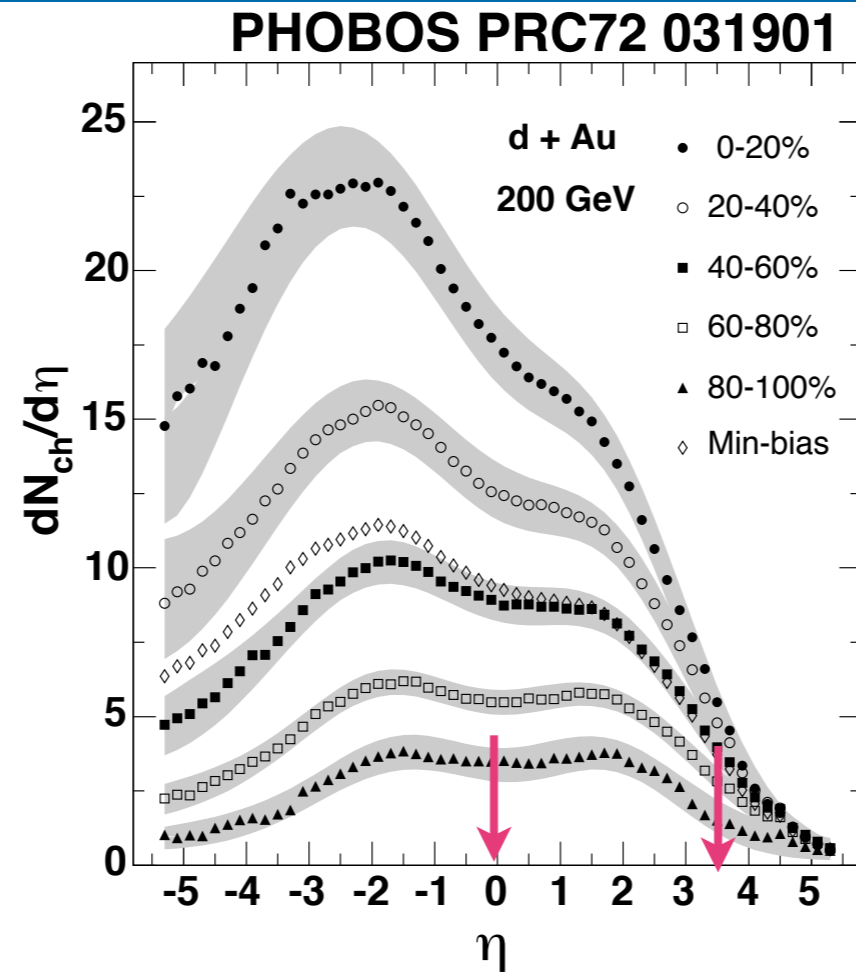
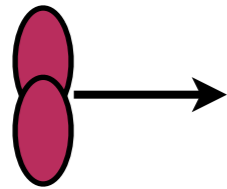
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what is the correlation between FTPC & ZDC centrality?

# long range correlations in dAu



# long range correlations in dAu



# long range correlations in dAu

