Overview of QM2014: Experimental Data in pA and dA

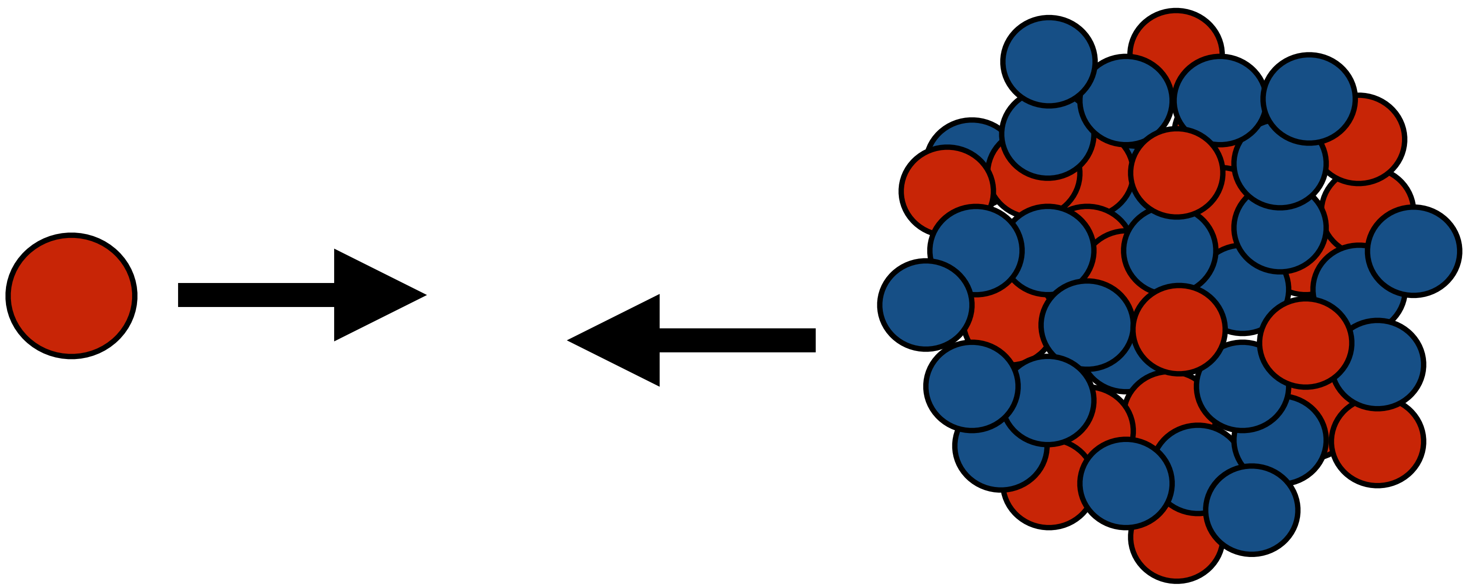
All materials are from the following presentations in QM2014

http://qm2014.gsi.de/

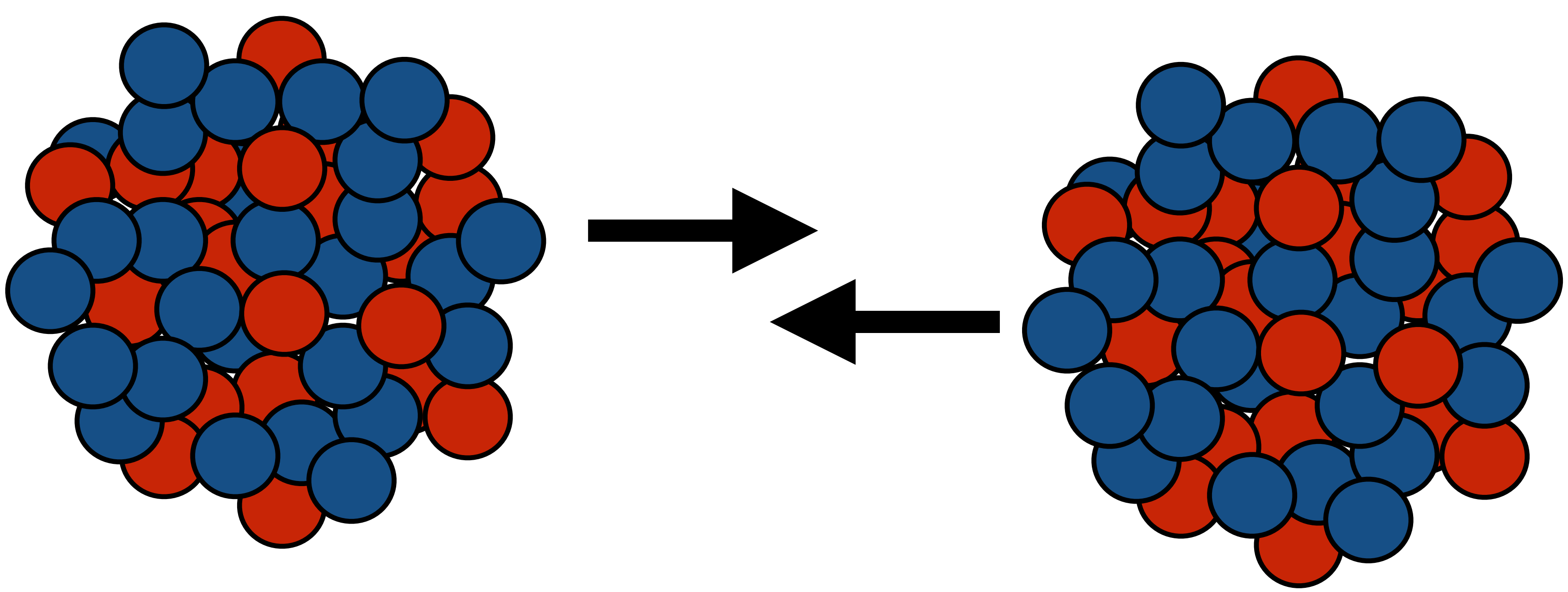
Thursday morning: Anne SICKLES

Monday afternoon: Li YI, Sanghoon Lim

why p+A collisions?

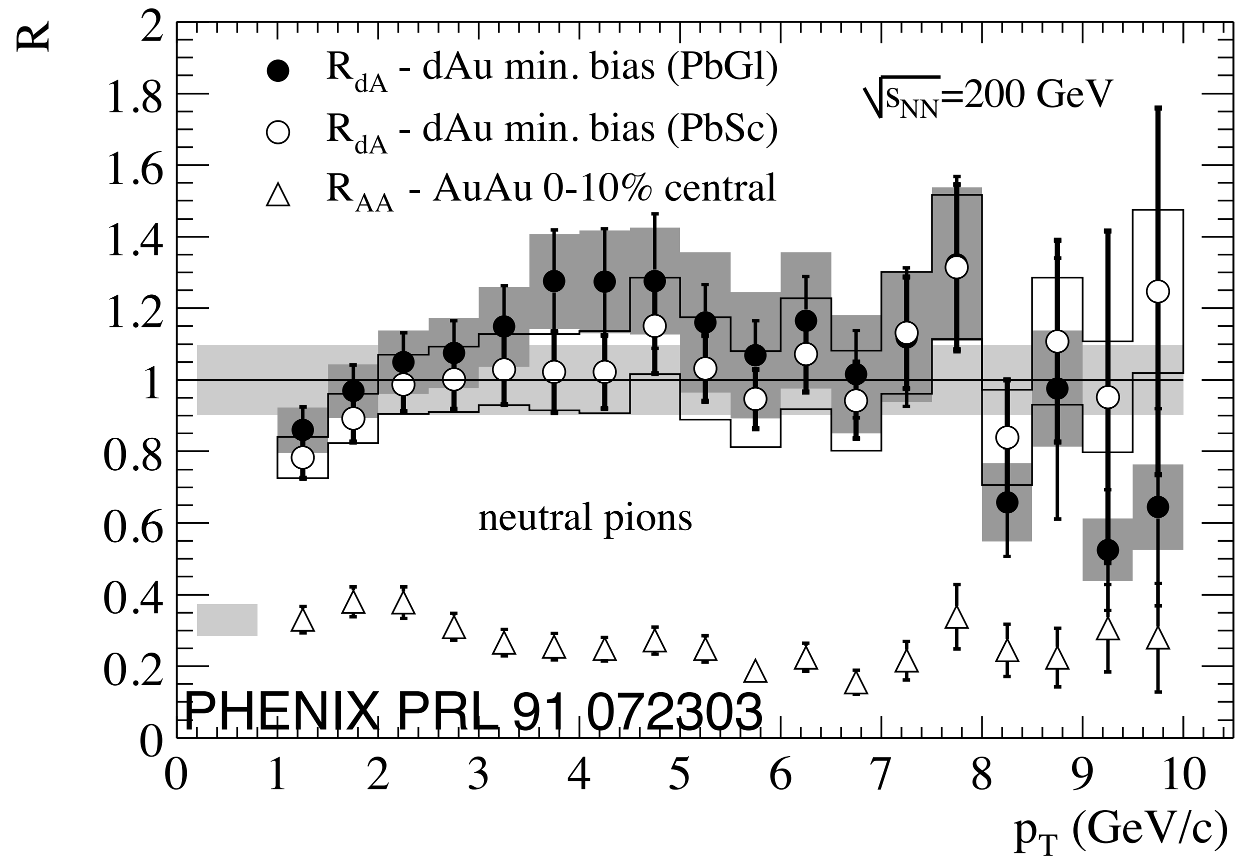


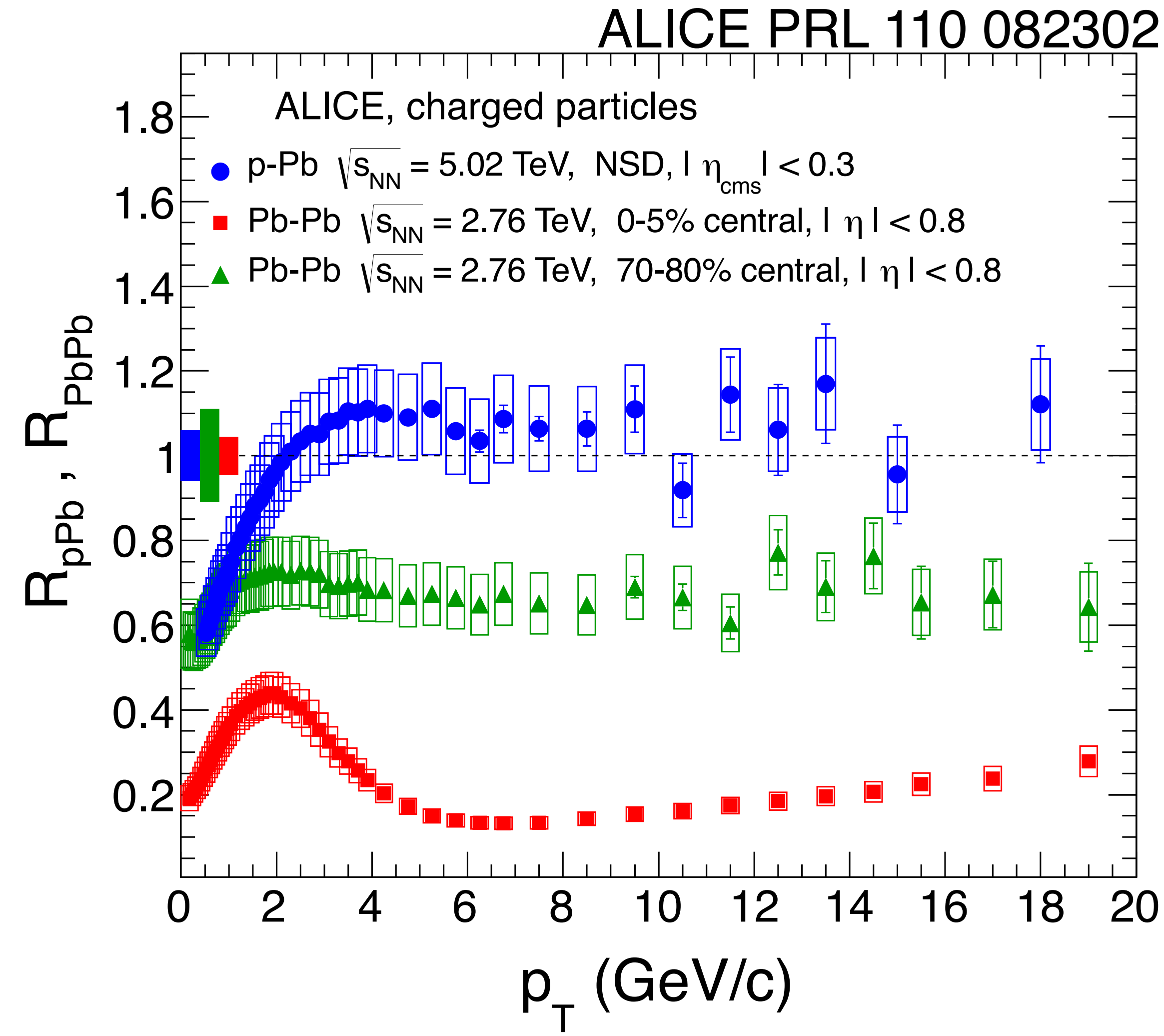
initial nuclei
~~hot nuclear matter~~



hot nuclear matter created from initial nuclei

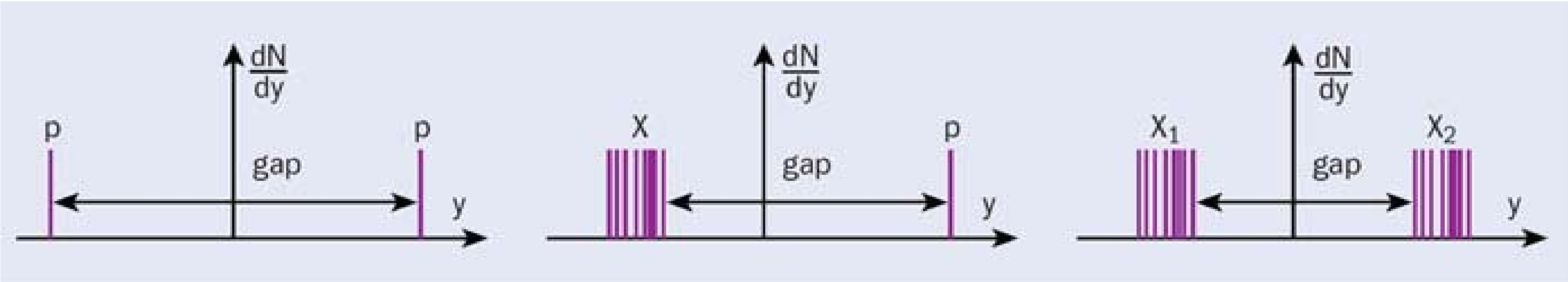
hard probe rates





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

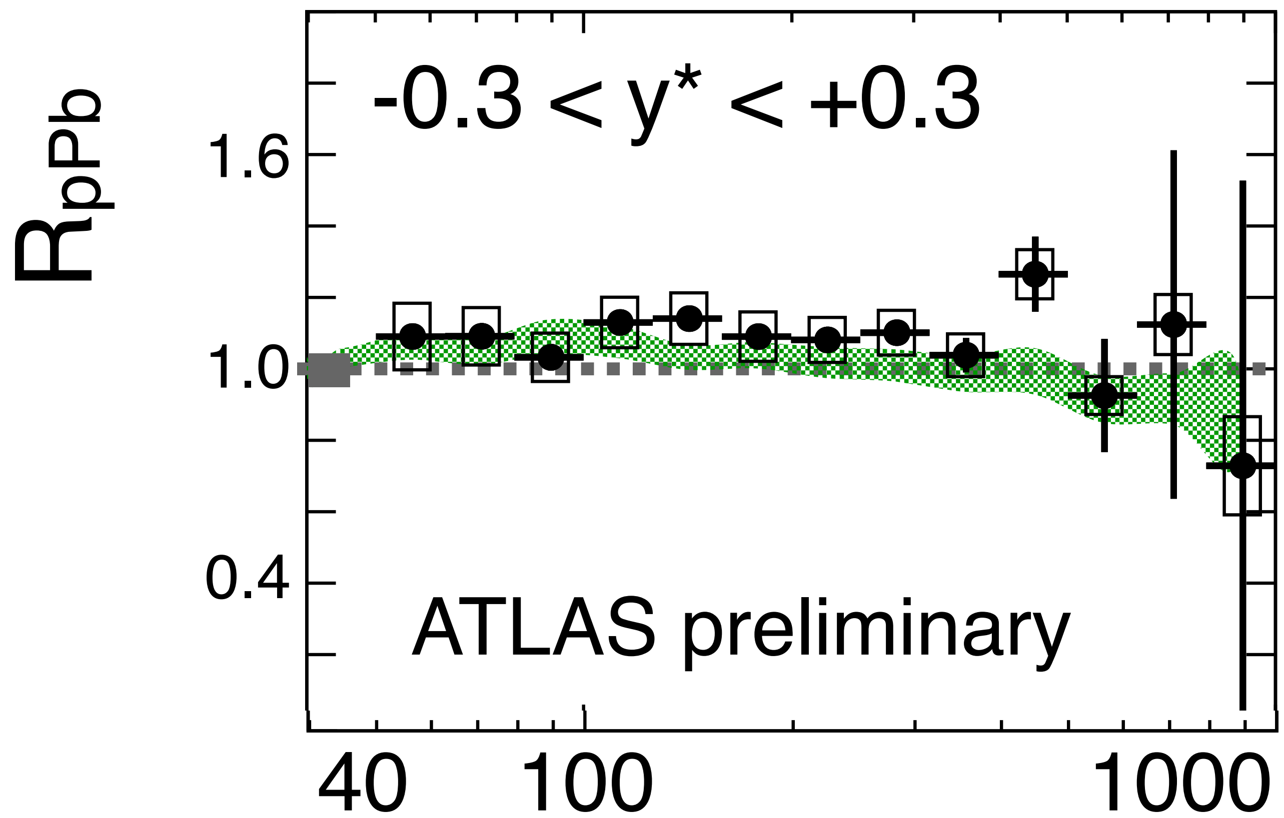
Non-single diffractive events

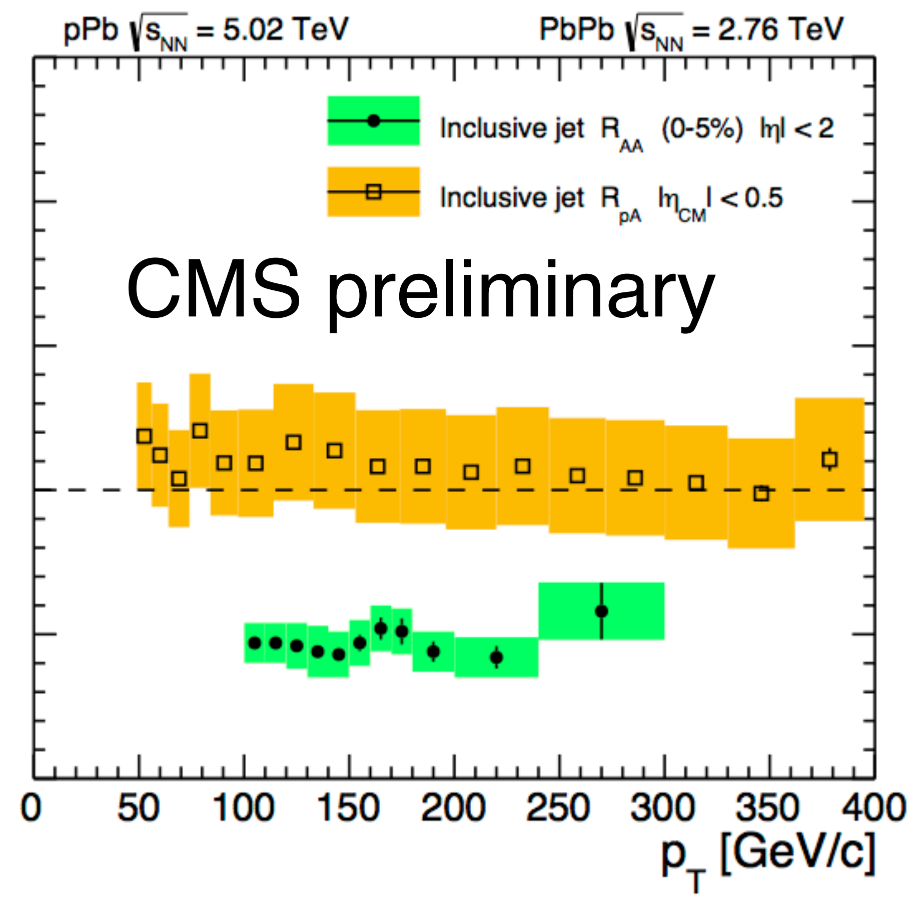


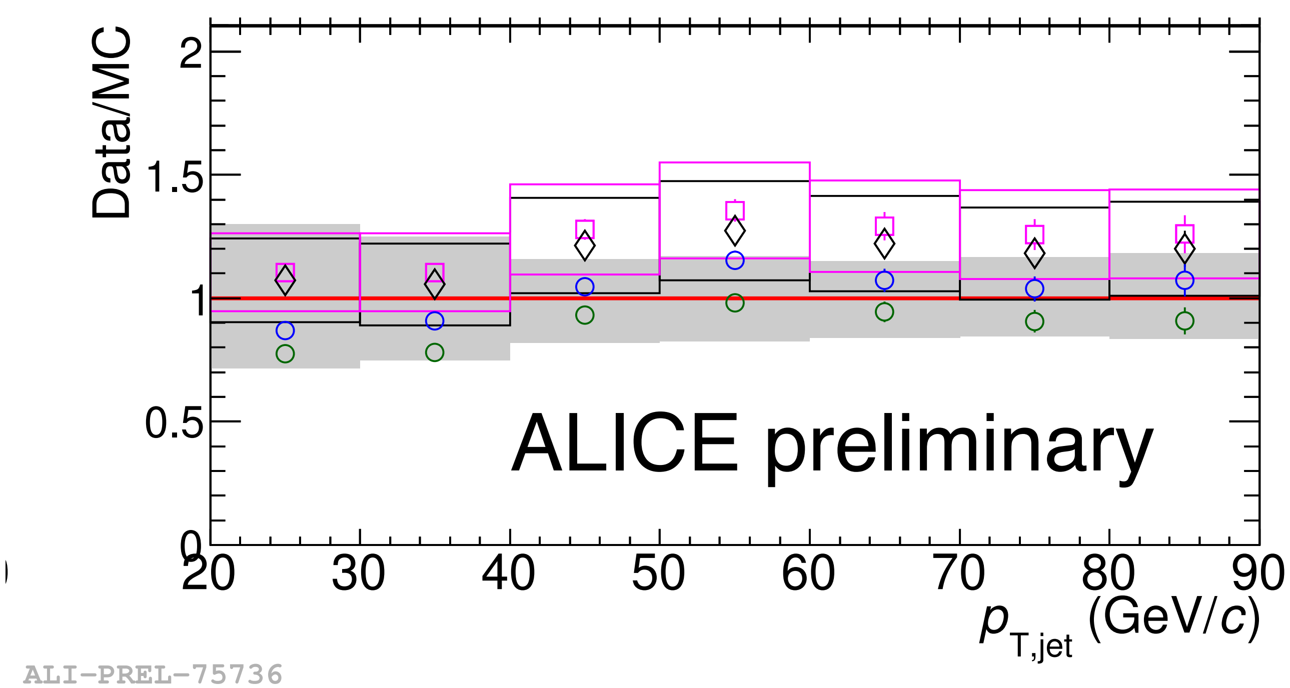
Elastic Single diffractive Double diffractive

- Diffractive reaction in particle physics: Exchange of pomeron that has the quantum numbers of vacuum leaving a large "rapidity gap"
- ALICE definition of SD: Diffracted mass M_X < 200 GeV/c^2 (non-diffractive protons escape the detector acceptance) with a large rapidity gap
  - DD: NSD with $\Delta\eta > 3$
- Experimental definition
  - SD-like: Only one side of the detector is active
  - NSD-like: Both sides of the detector are active
  - Normalizing the data to specific event class such as non-single diffractive or inelastic collisions: input for the model calculations to determine the number of binary collisions

jets…new this Quark Matter



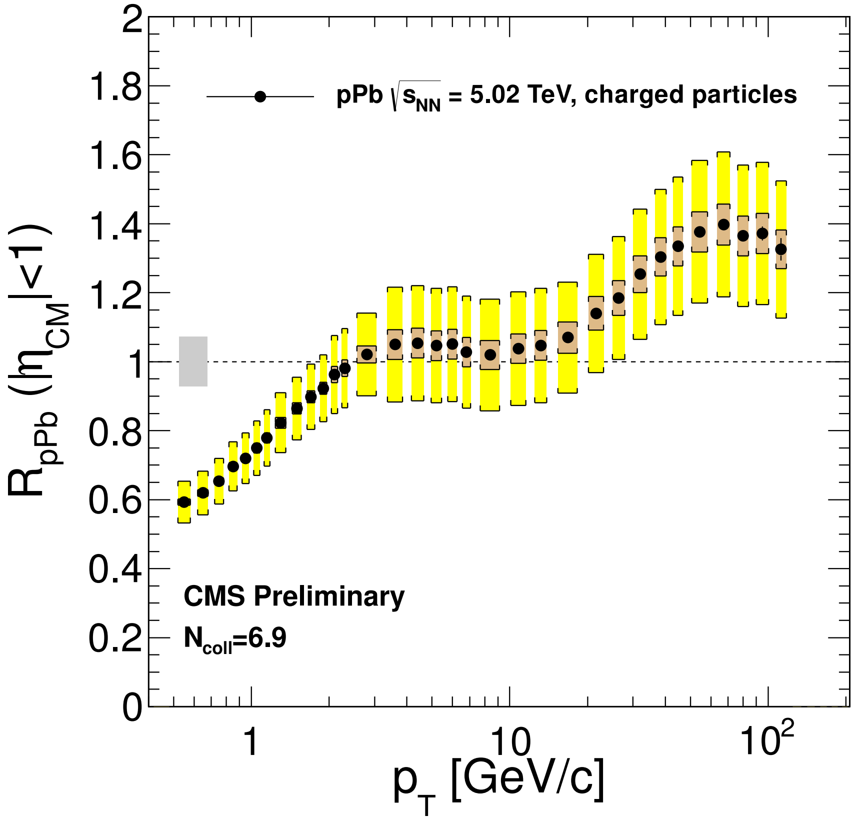


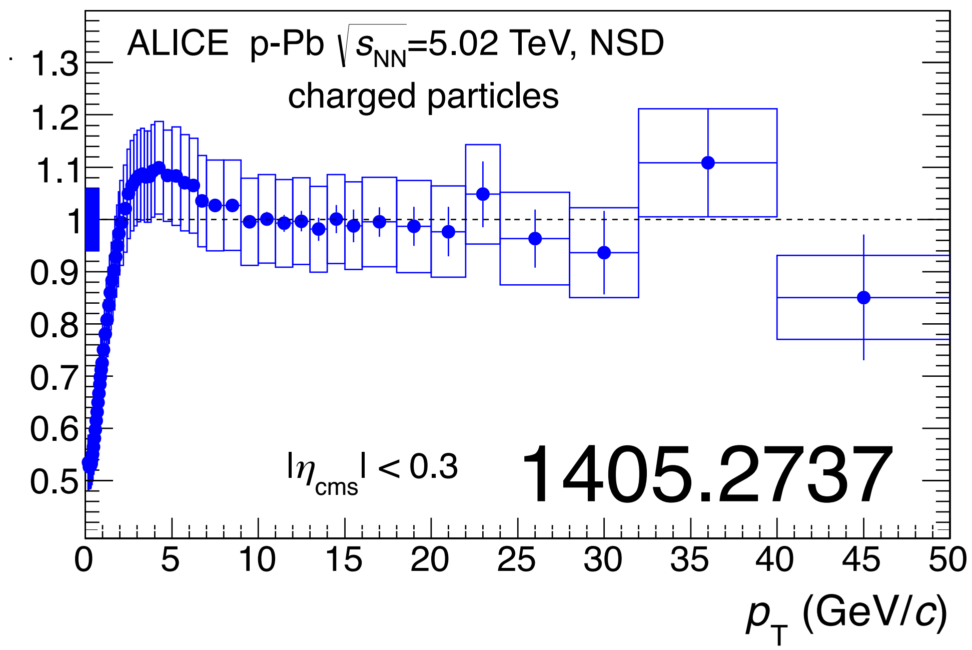


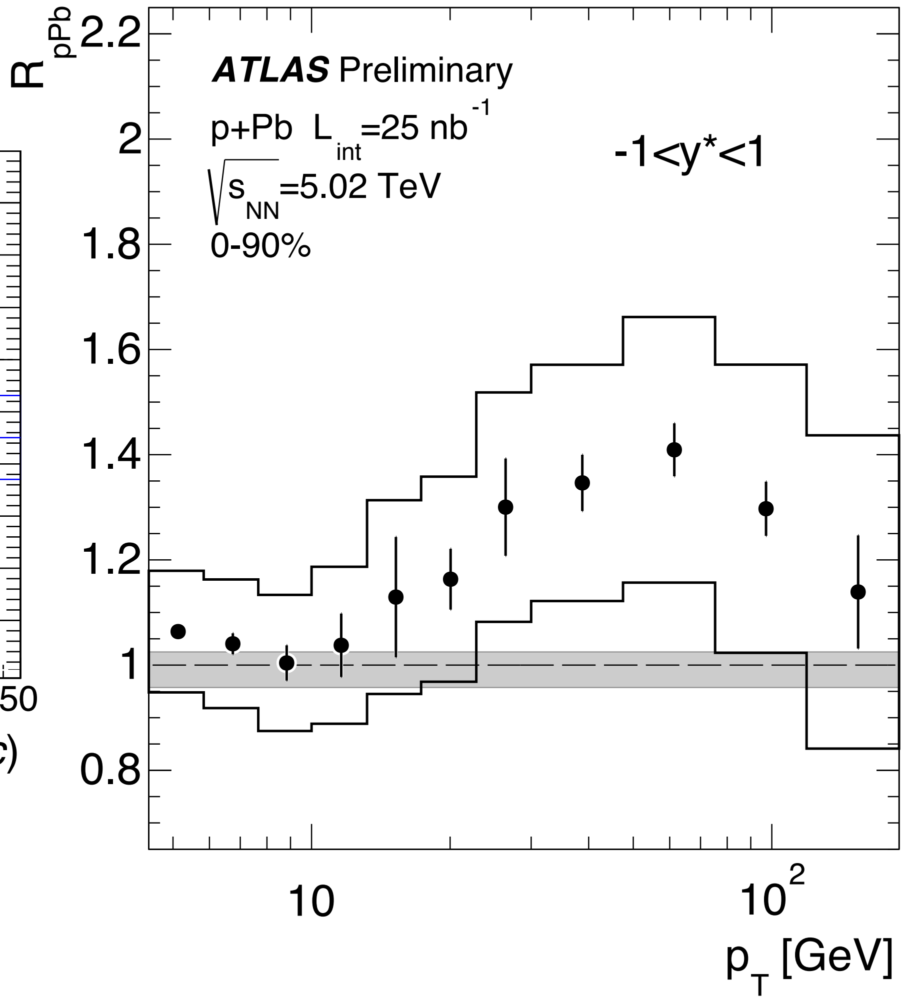
same conclusion from reconstructed jets at the LHC

Perepelitsa, Appelt, Aiola

charged particles…more interesting



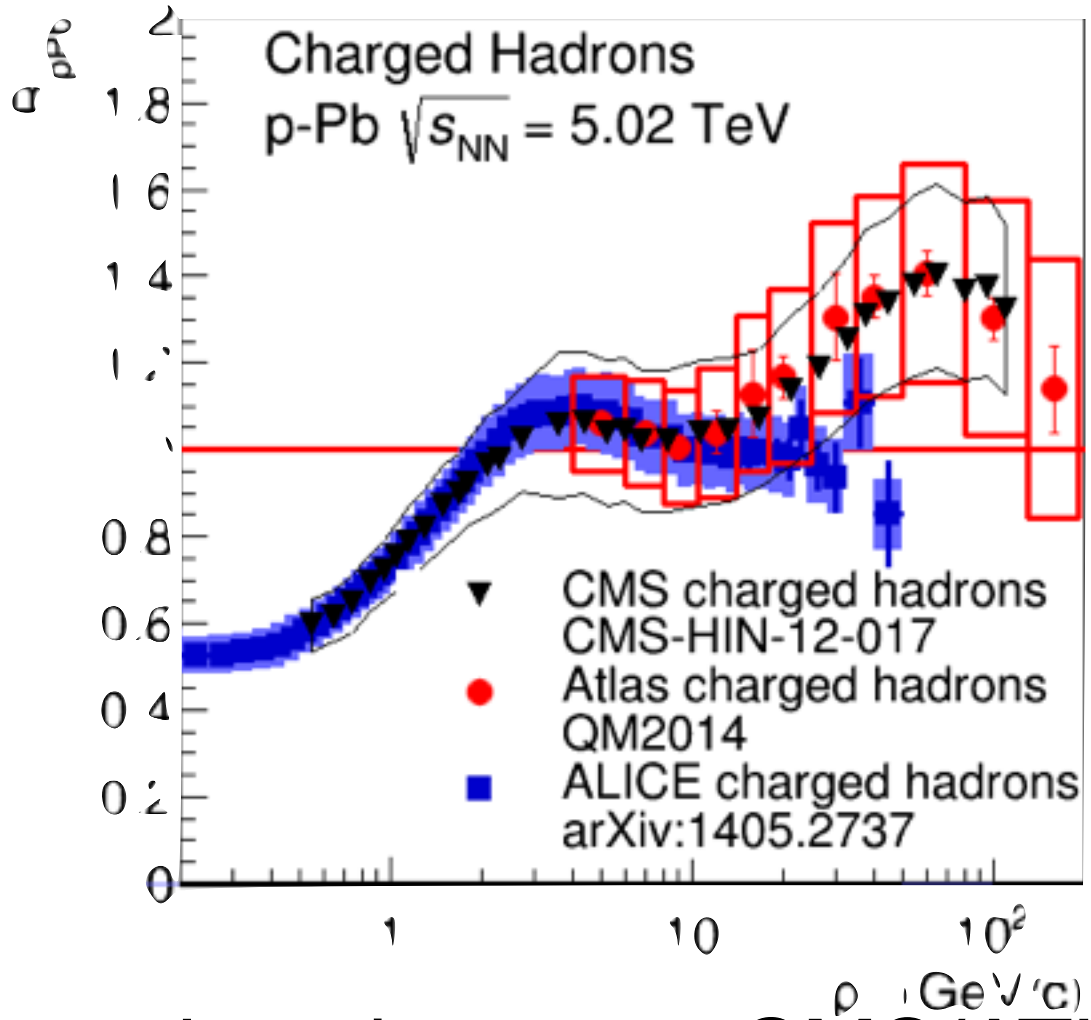




- different impressions between CMS/ATLAS & ALICE data
- big caveat: no pp reference at 5TeV (will be wanted for HI reference anyway)!
  - much of the difference ALICE/CMS difference is in the reference (see E. Appelt (CMS))

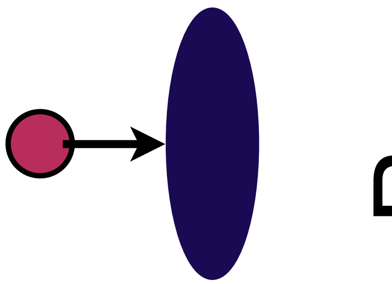
Appelt, Aiola, Balek

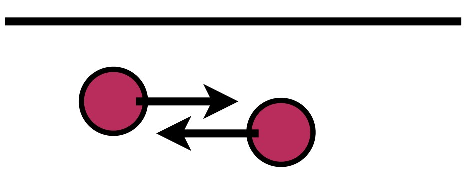
charged particles…more interesting

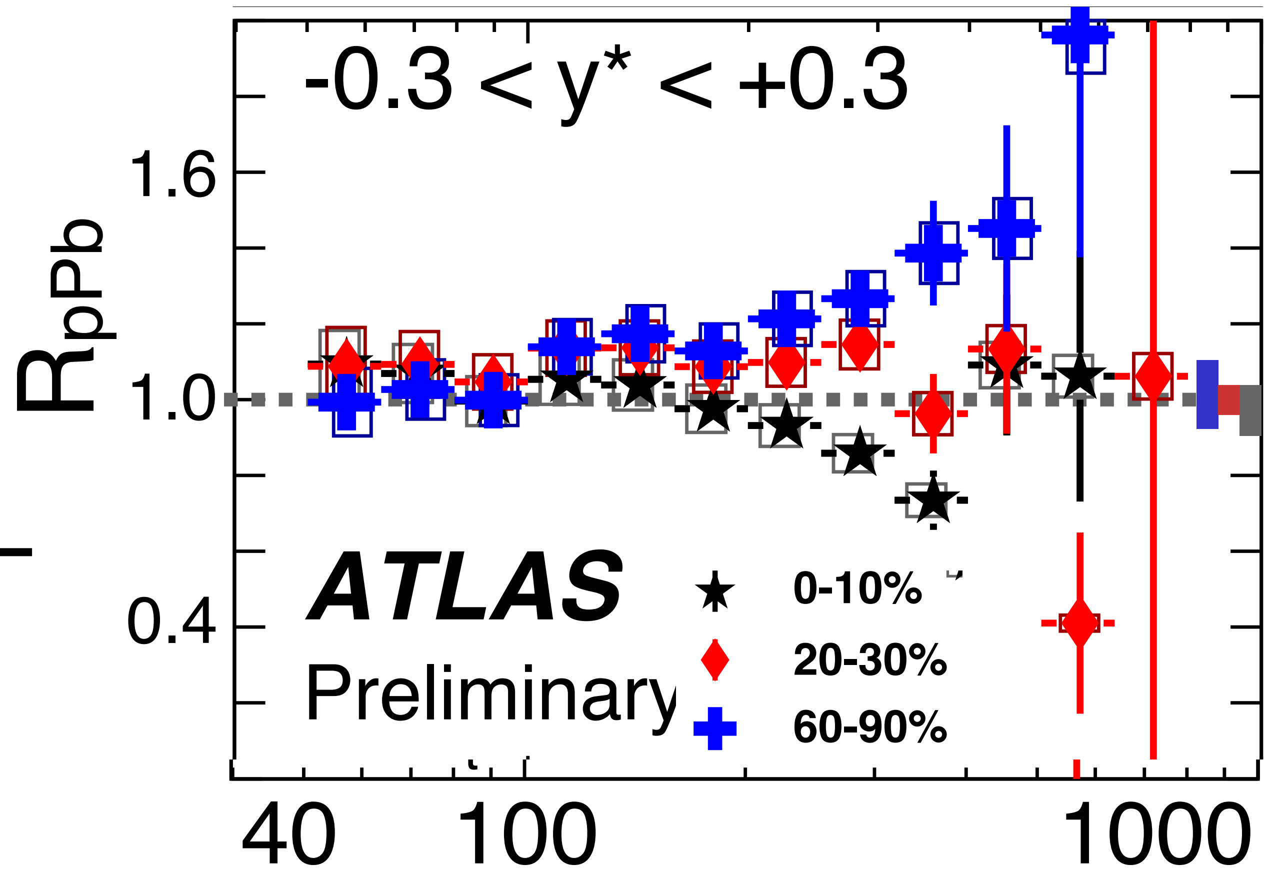


- different impressions between CMS/ATLAS & ALICE data
- big caveat: no pp reference at 5TeV (will be wanted for HI reference anyway)!
  - much of the difference ALICE/CMS difference is in the reference (see E. Appelt (CMS))

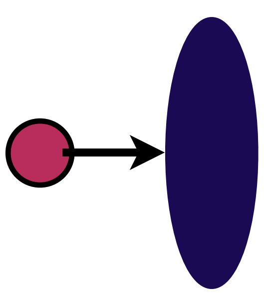
and centrality dependence?

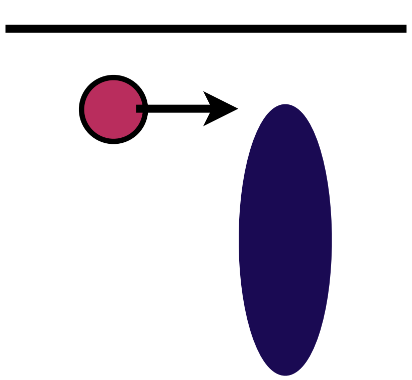


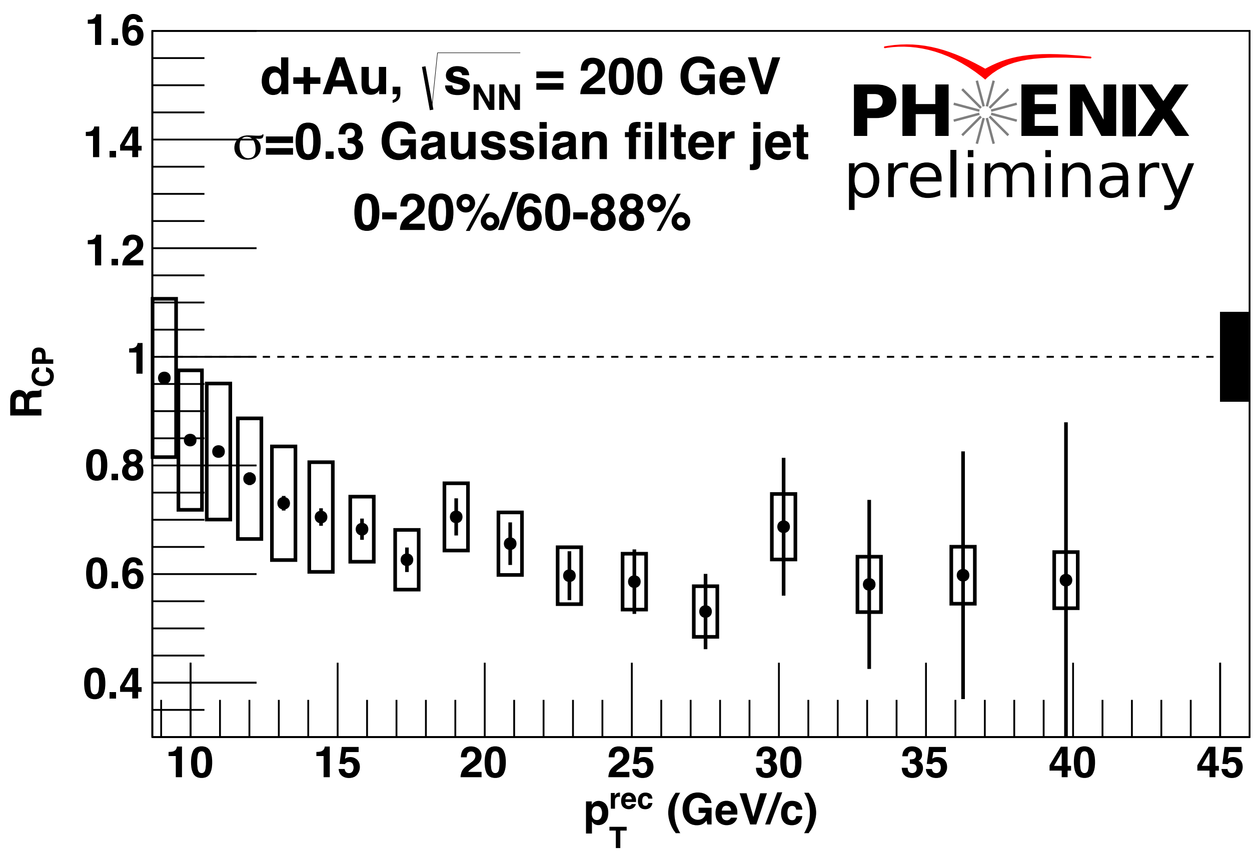




both suppression and enhancement hidden in min. bias RpA!



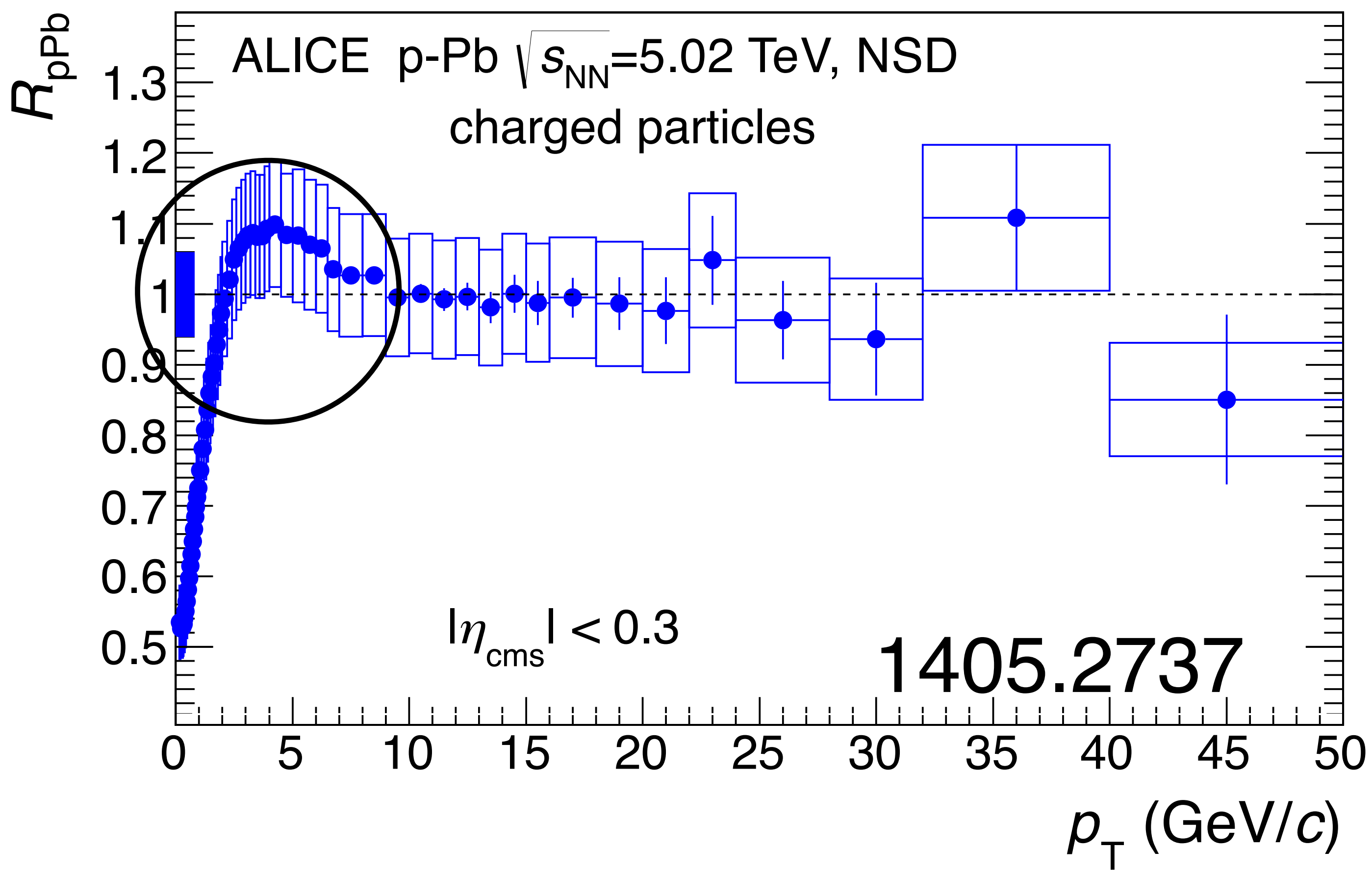


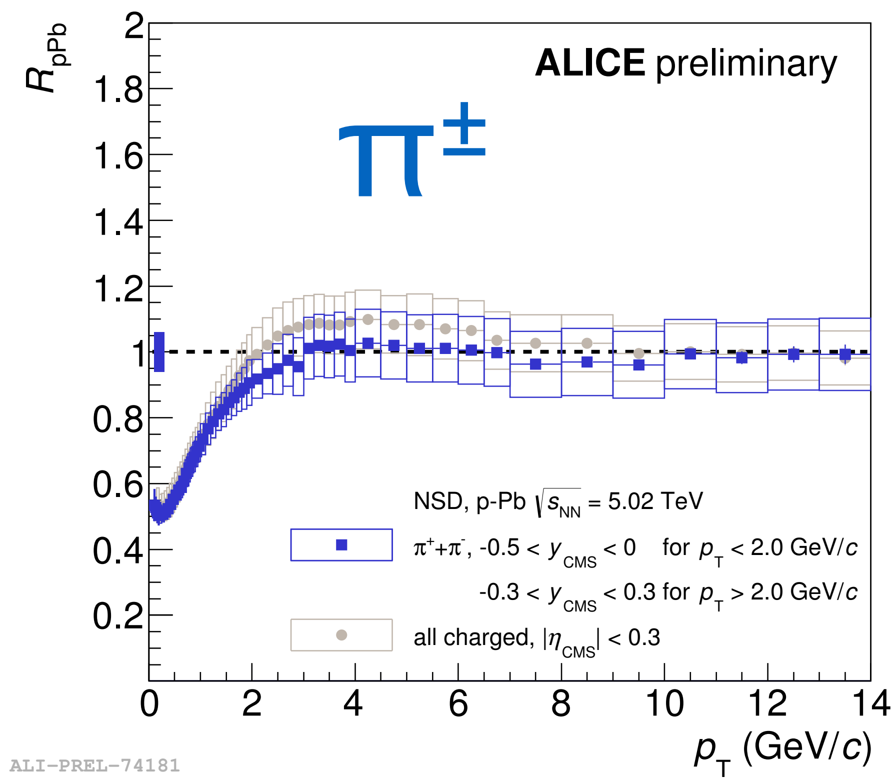


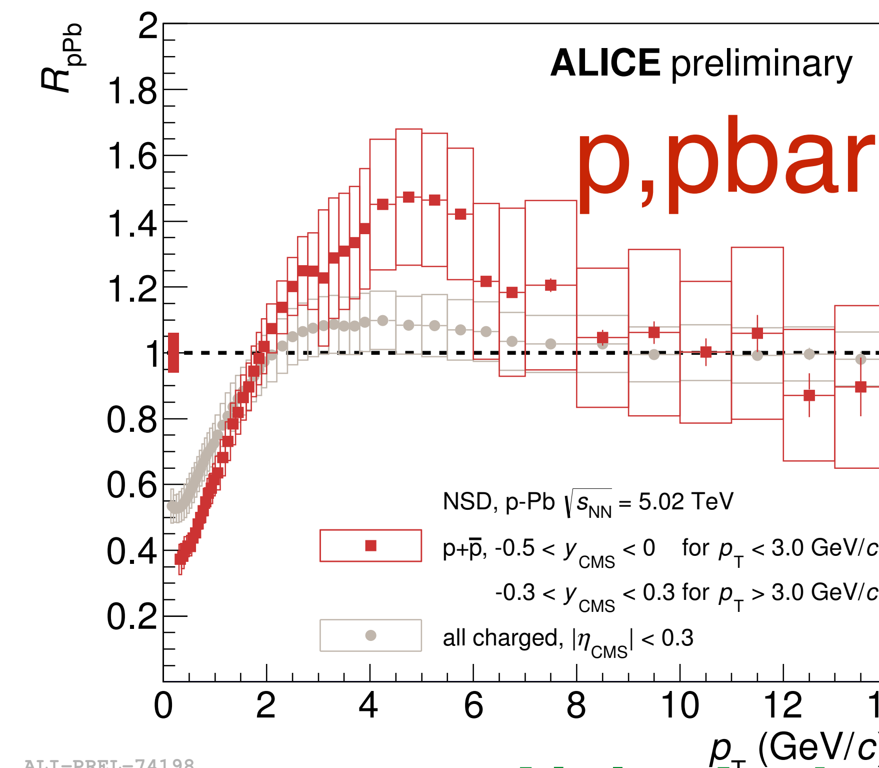
however, not necessarily the same story from ALICE

Perepelitsa, Campbell

moving down in p_T



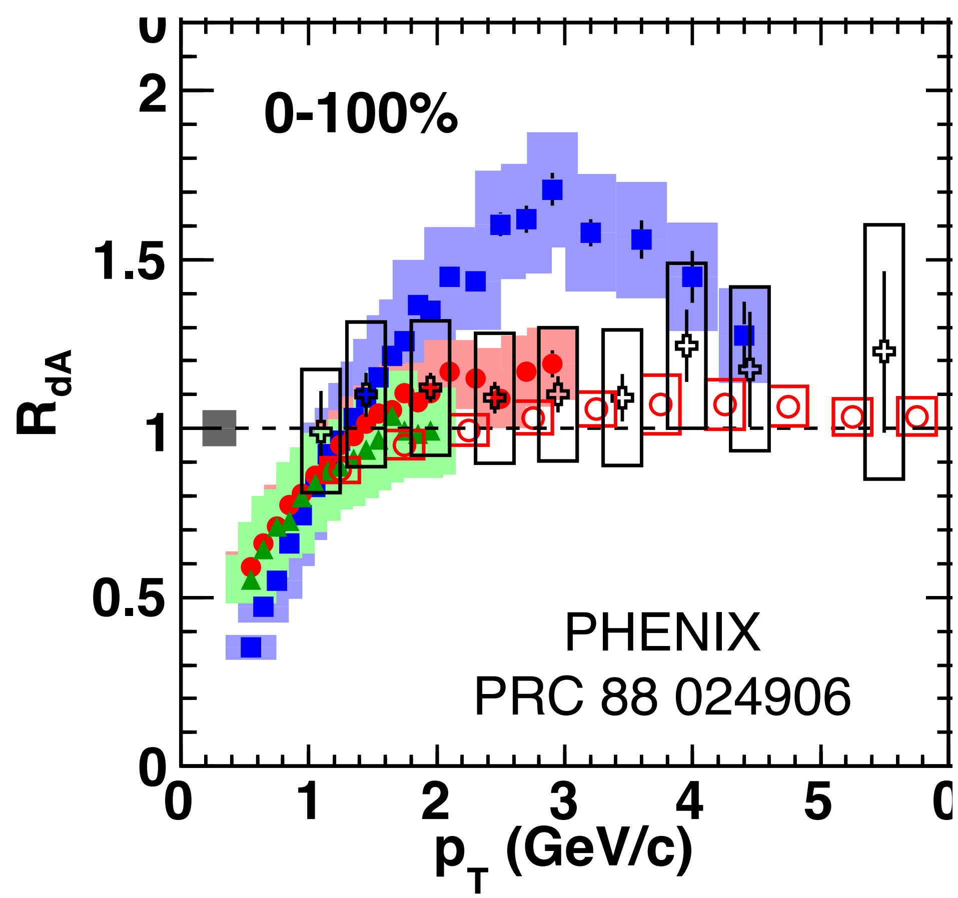


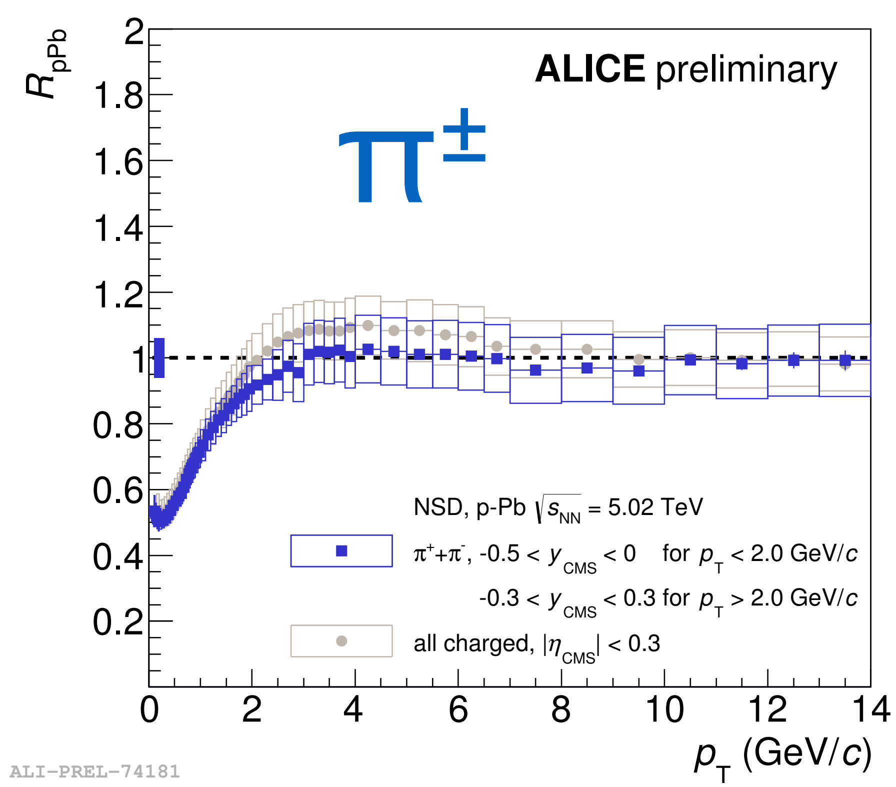


Aiola, Andrei

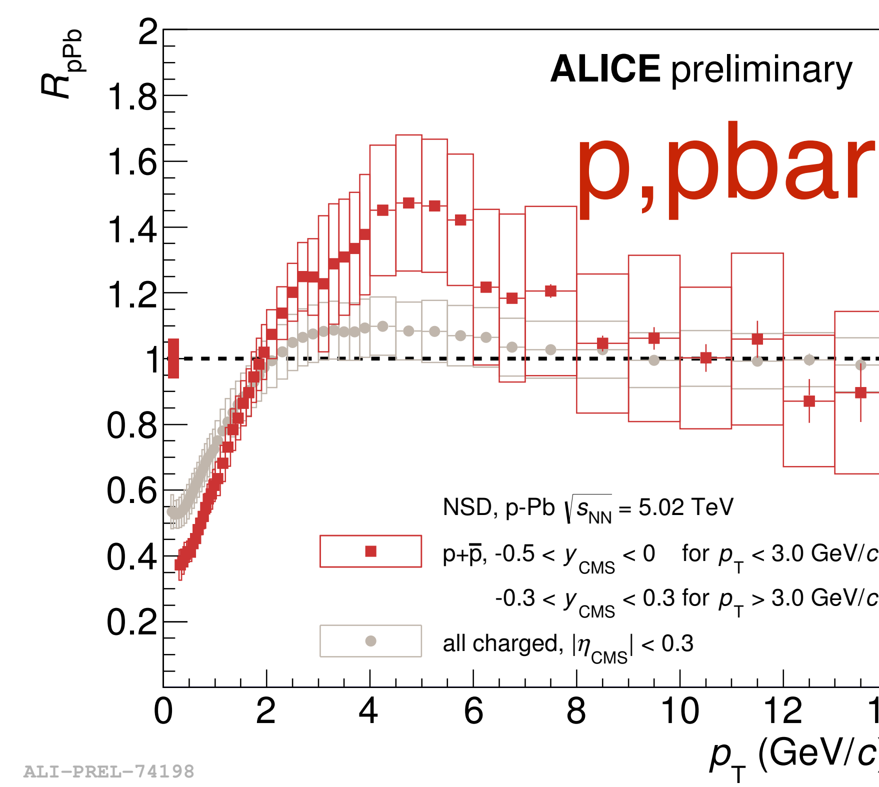
enhanced protons

RHIC d+Au





LHC p+Pb



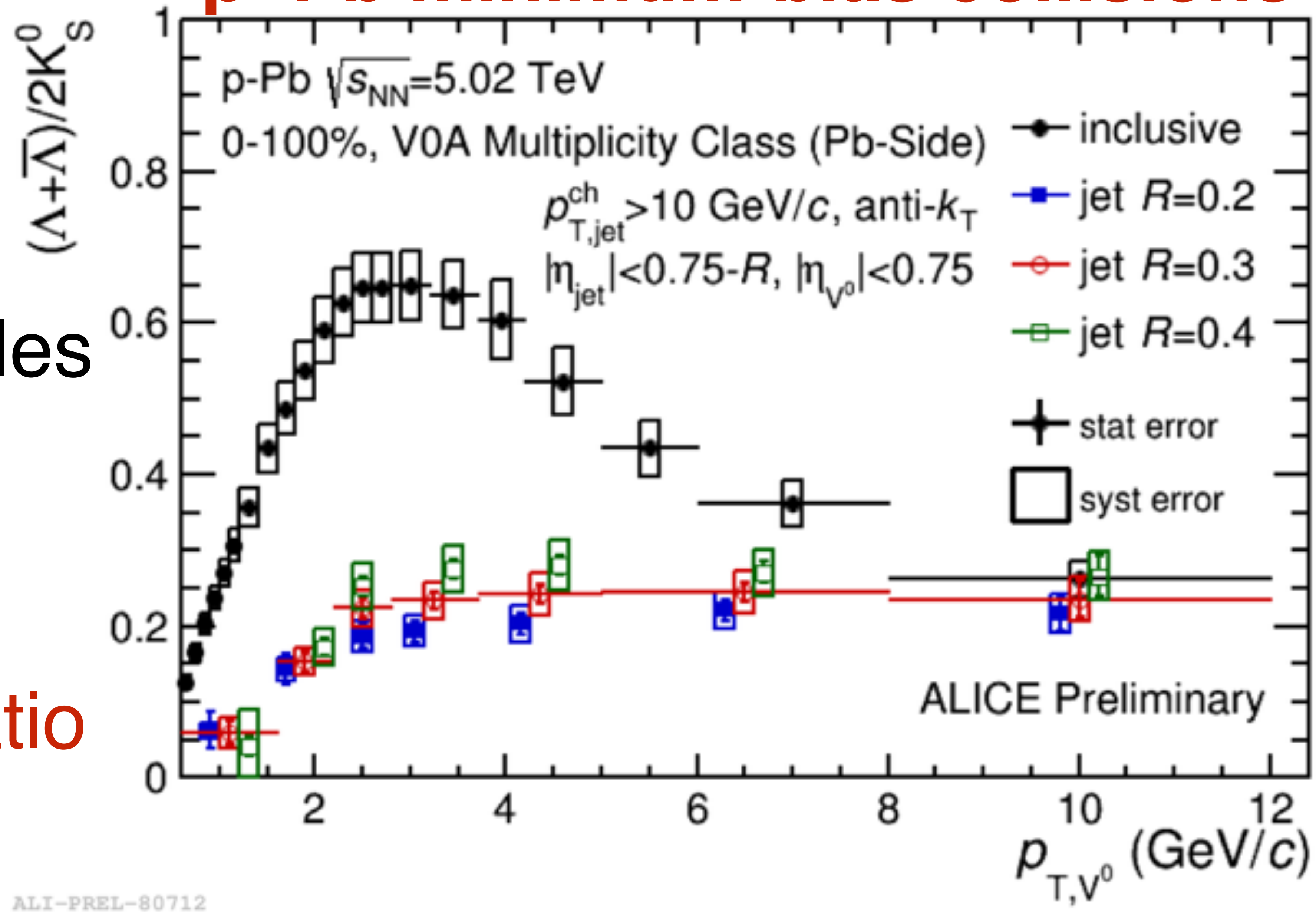
Campbell, Andrei

where are the enhanced baryons from?

p–Pb minimum-bias collisions

inclusive particles

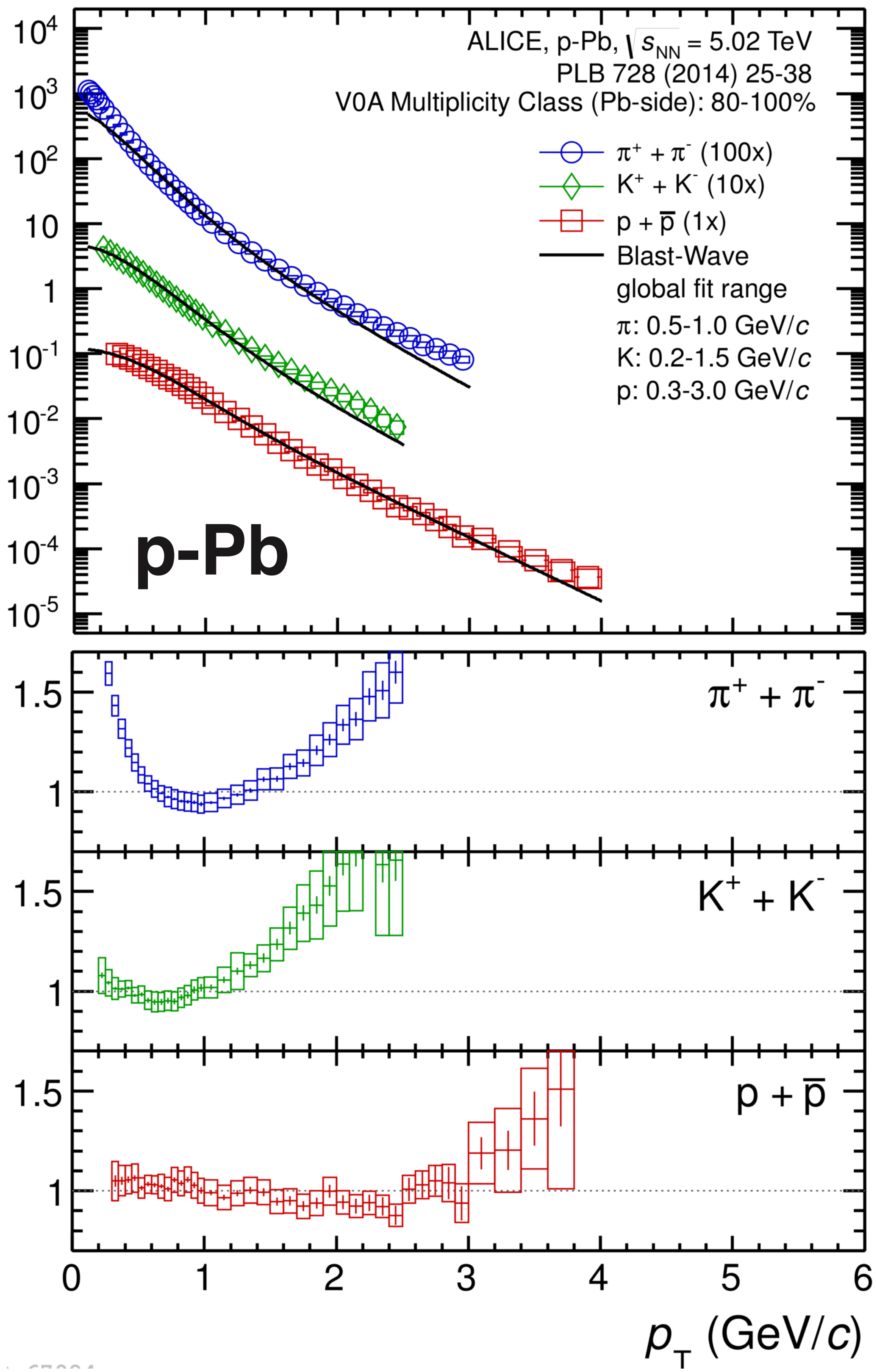
jets:
PYTHIA-like ratio



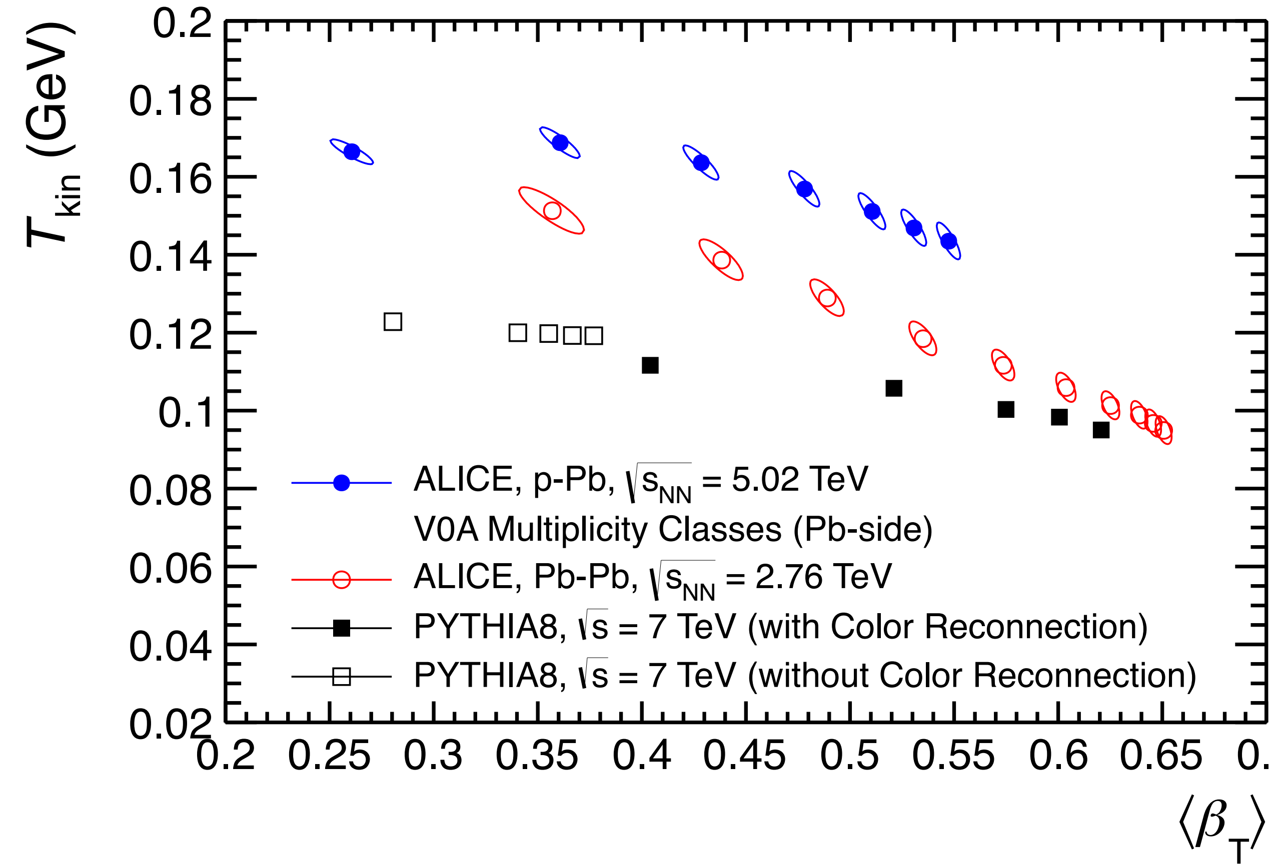
extra baryons don't seem to be in the jets…

Zhang

low p_T spectra



PLB 728 25 (2014)



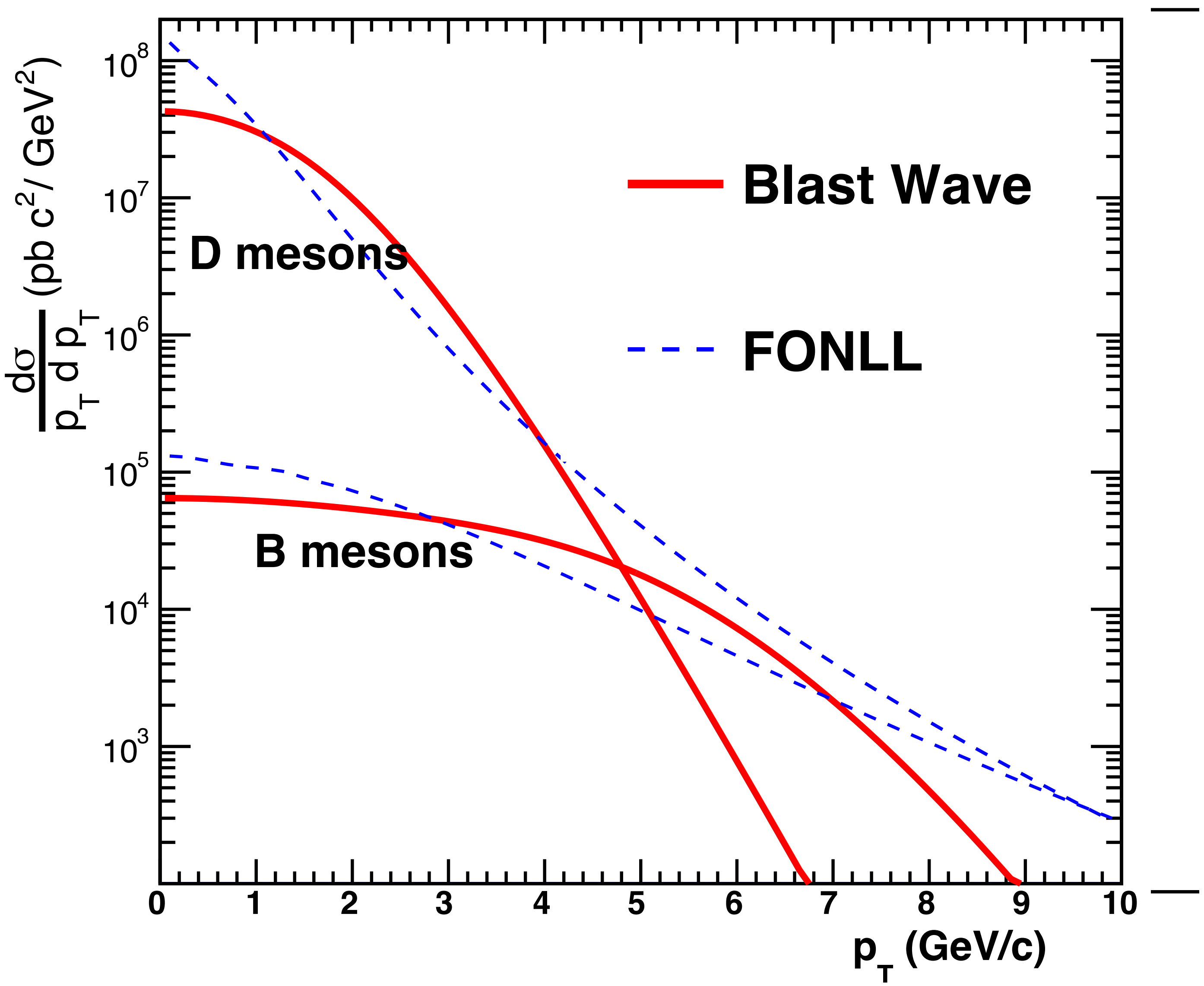
- **reasonably good description at RHIC and the LHC**

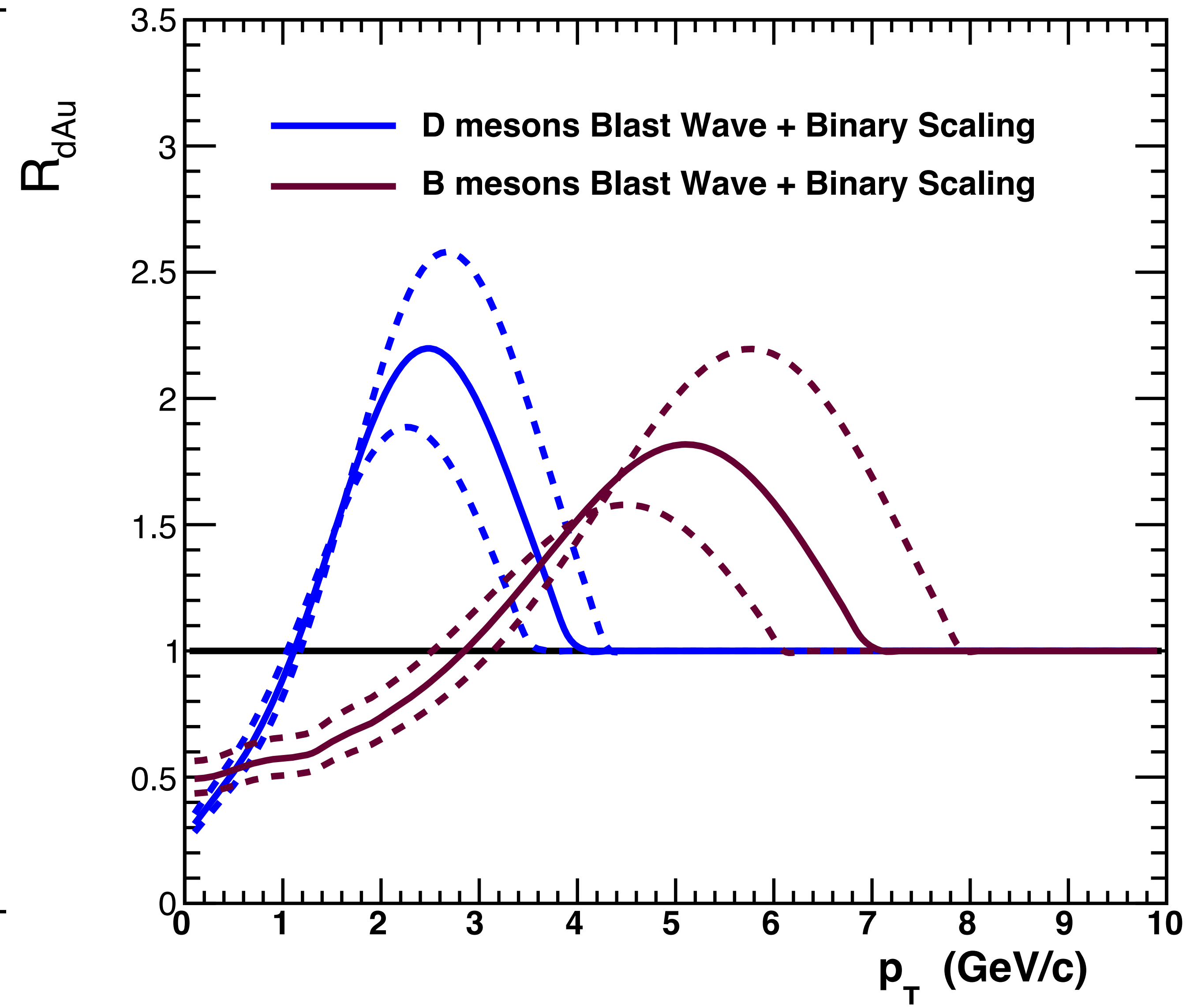
central d+Au:
simultaneous fit to π, K, p
<β> = 0.46
T_{fo} = 139MeV

Andrei

what about heavy mesons?

expectations from Blast Wave for heavy mesons in d+Au

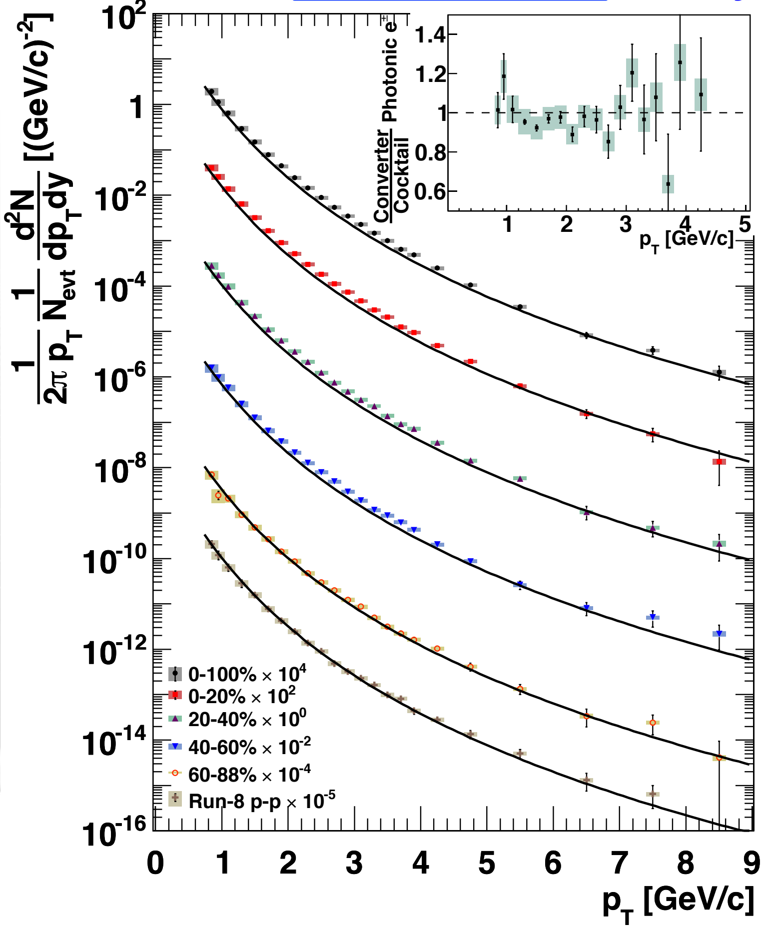




data: PHENIX PRL 109 242301
AMS: PLB 731 51 (2014)

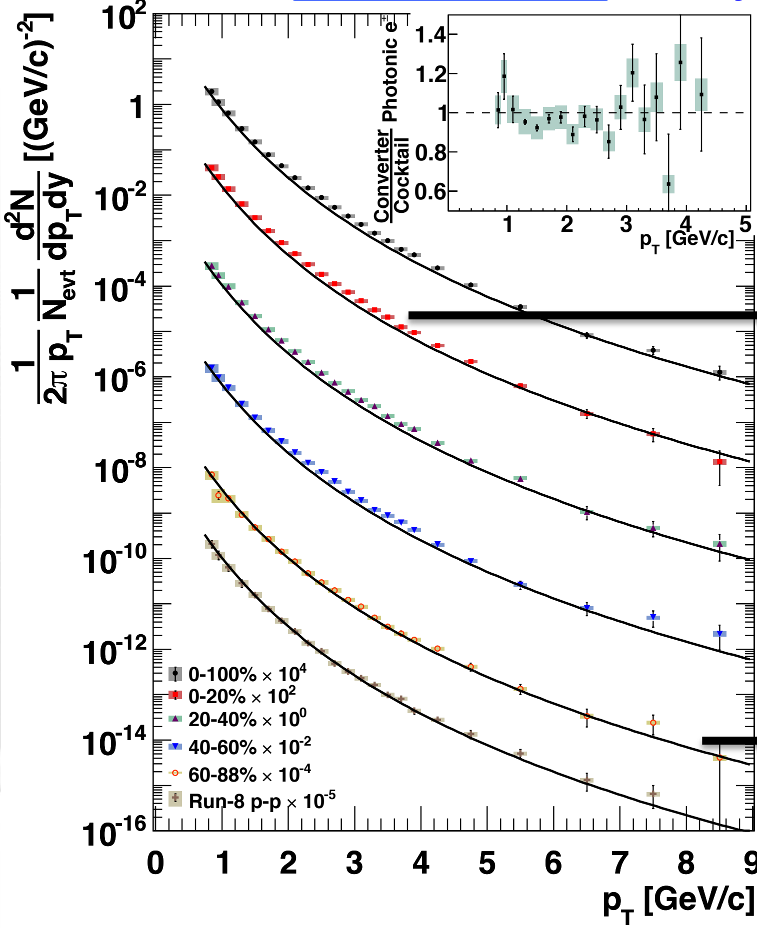
In d+Au collisions

Phys. Rev. Lett. 109, 242301 (2012)



In d+Au collisions

Phys. Rev. Lett. 109, 242301 (2012)

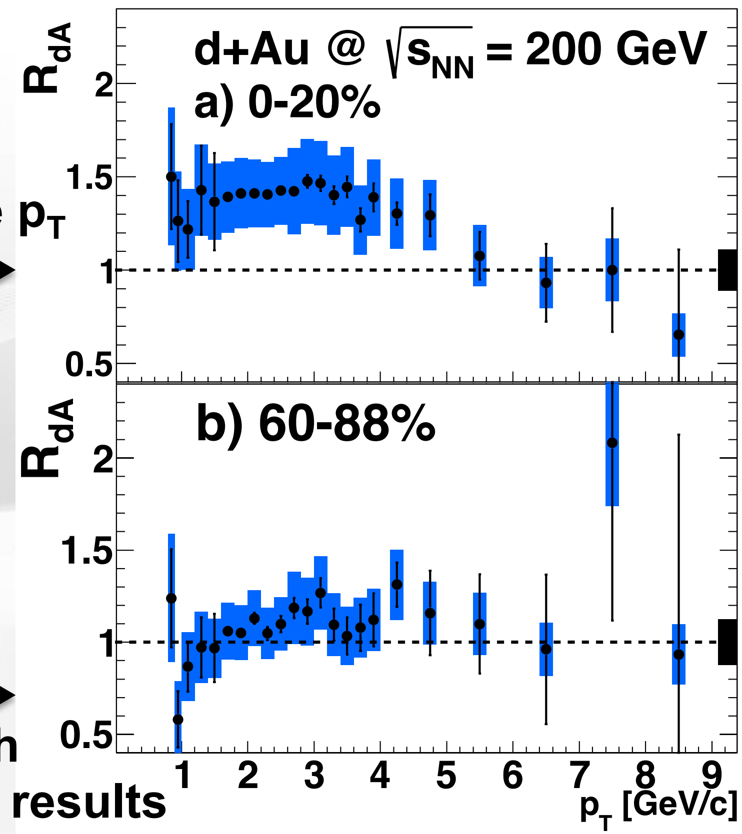


Enhancement at intermediate p_T

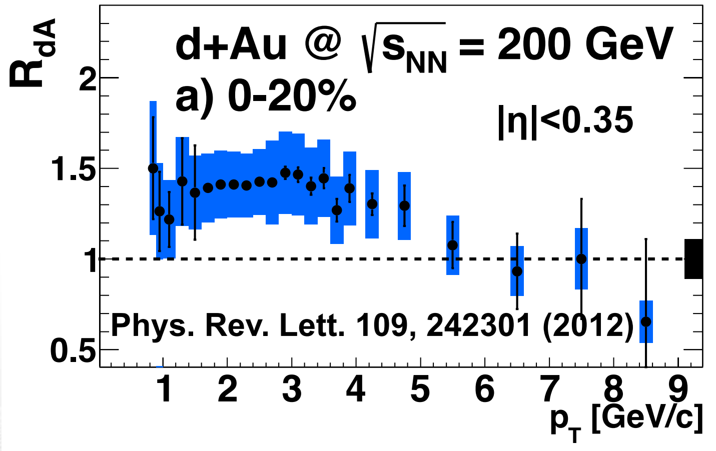
<Ncoll>≈15.1

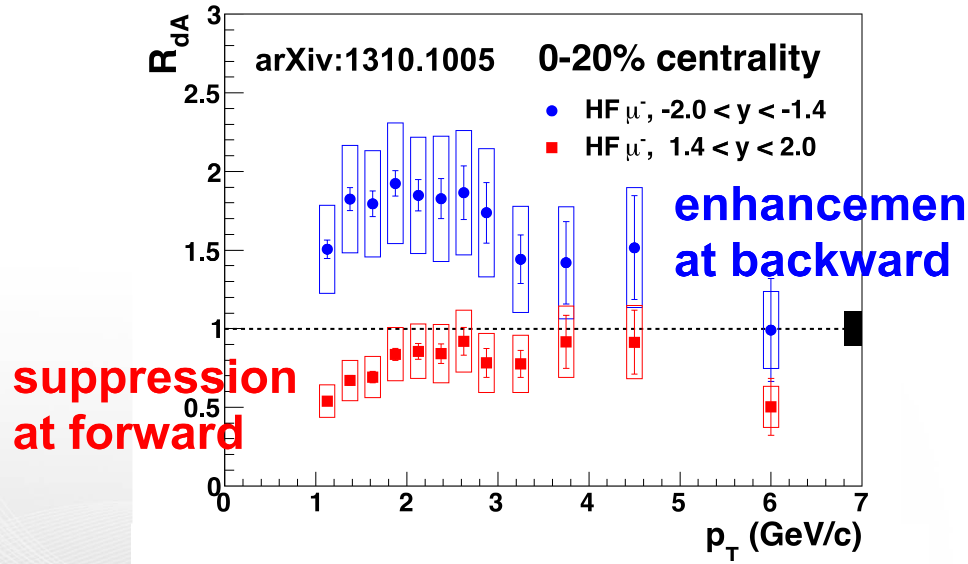
<Ncoll>≈3.2

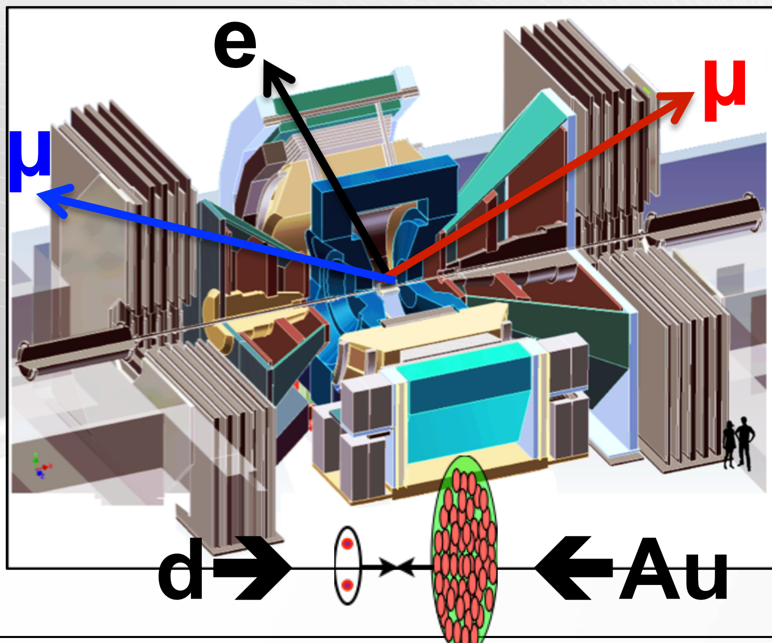
Consistent with the scaled p+p results

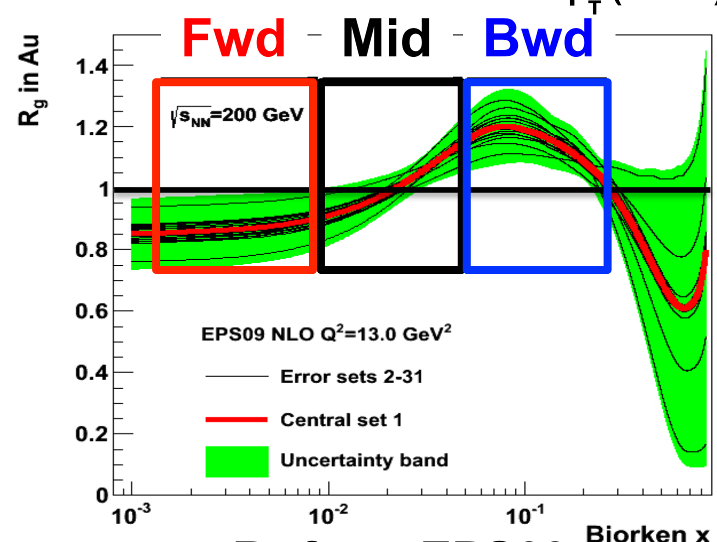


Rapidity expansion in d+Au



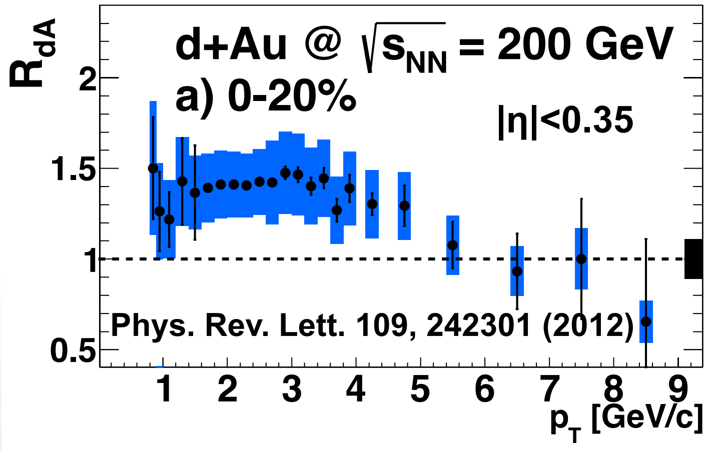


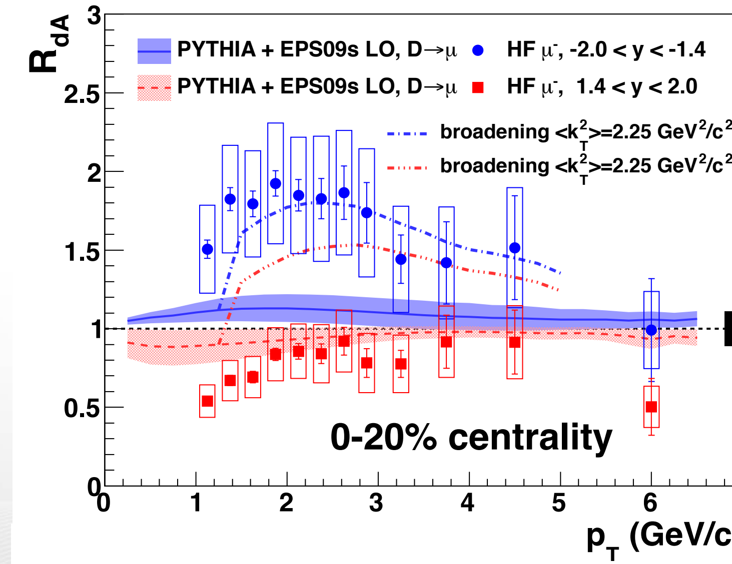


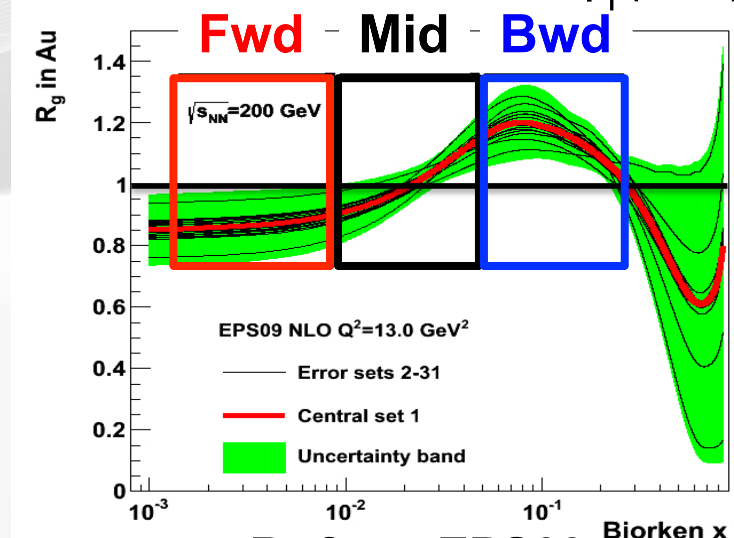


R_g from EPS09

Rapidity expansion in d+Au





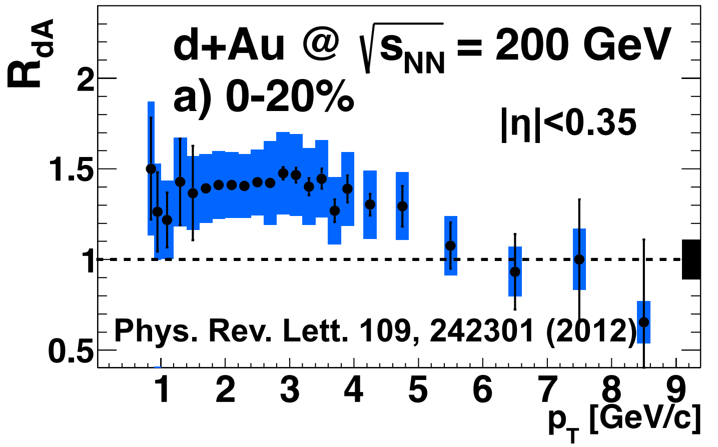


R_g from EPS09

Fail to reproduce the data at both rapidity simultaneously w/ combinations of initial-state effects!

- modification of nPDF
- initial k_T broadening

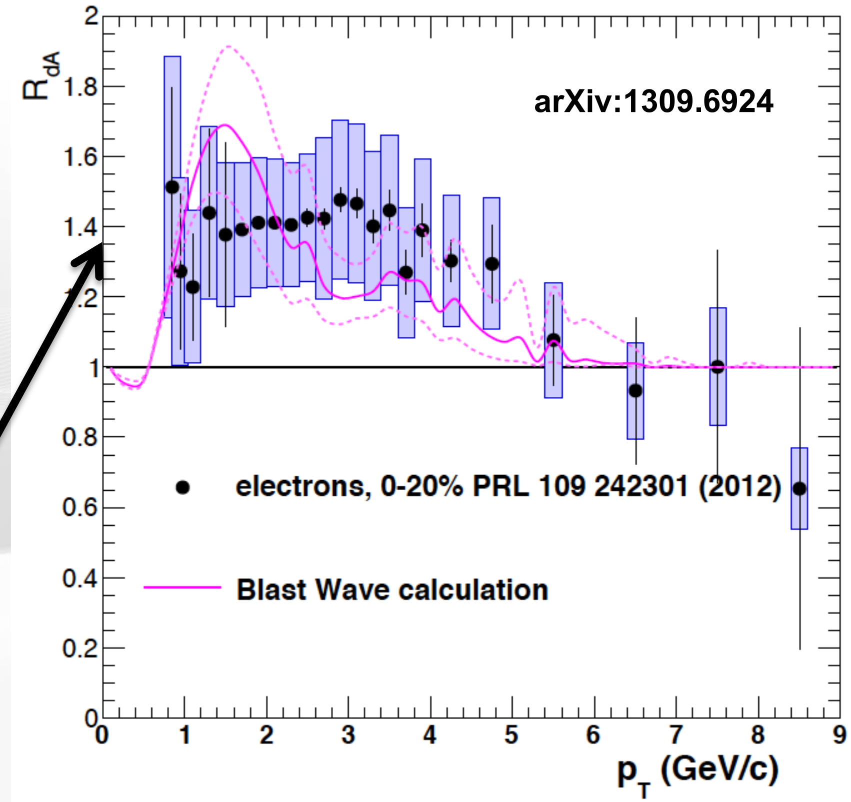
Enhancement in central d+Au



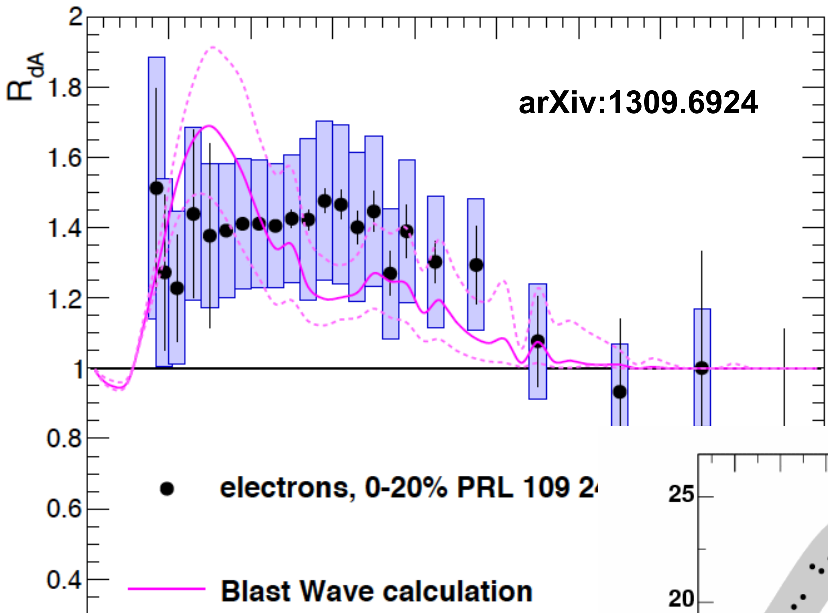
Cronin enhancement?

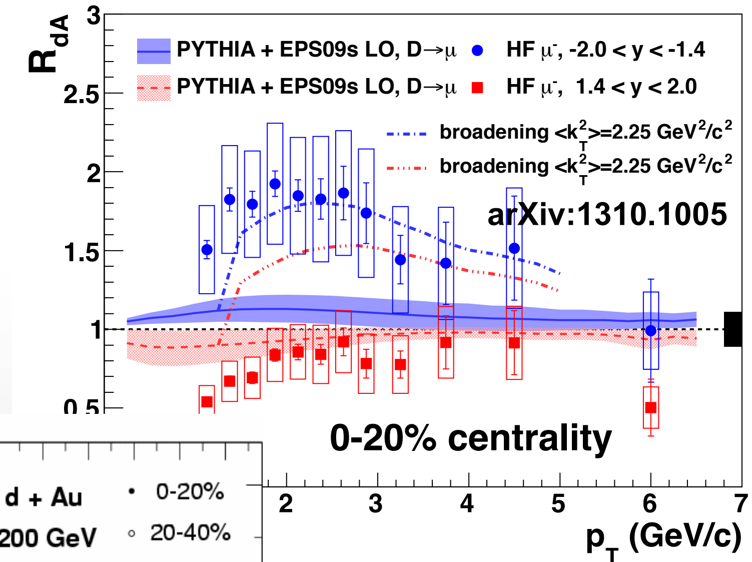
→initial p_T component due to multiple scattering of incoming partons

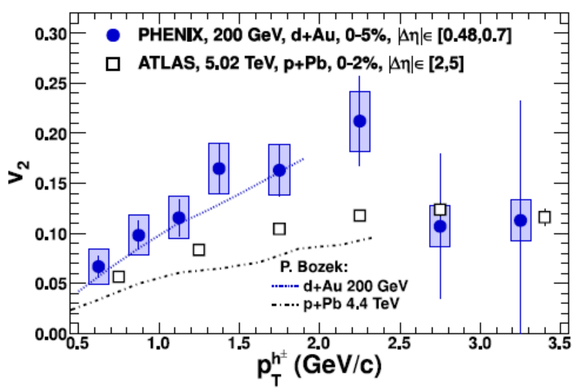
Radial flow qualitatively reproduces the data!!



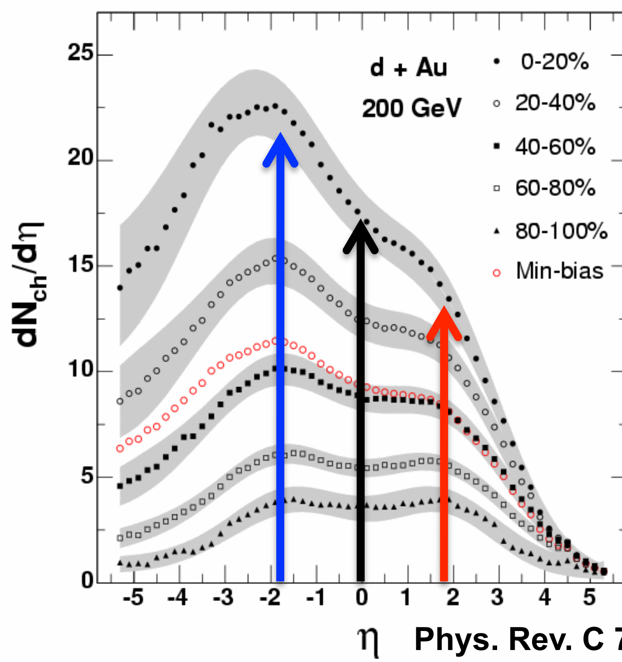
Hydrodynamic behavior?







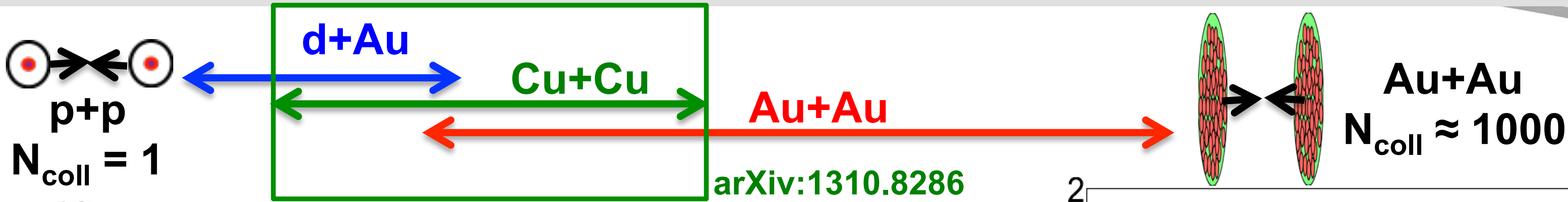
Phys. Rev. Lett. 111, 212301 (2013)

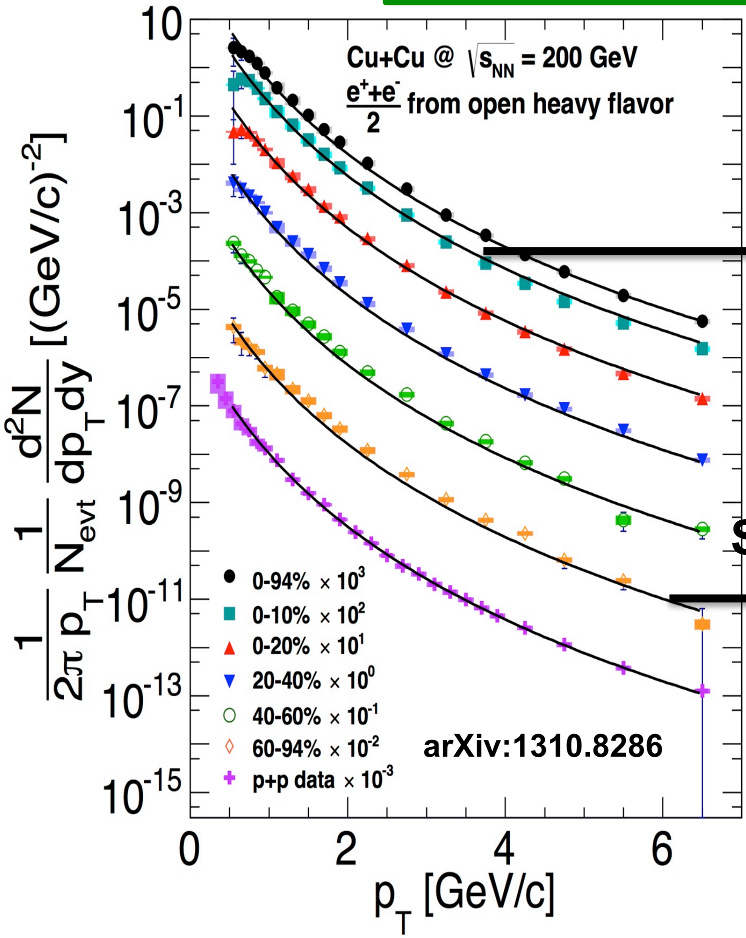


Phys. Rev. C 72, 031901 (2005)

Enhancement at mid- and backward rapidity possibly due to final-state interaction?

In Cu+Cu collisions



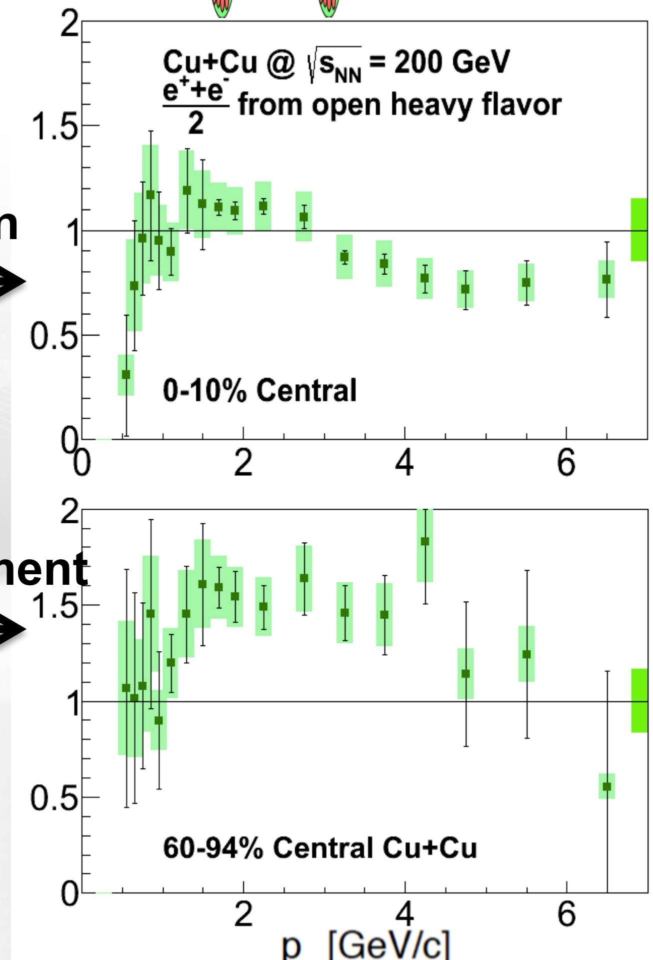


Slight suppression

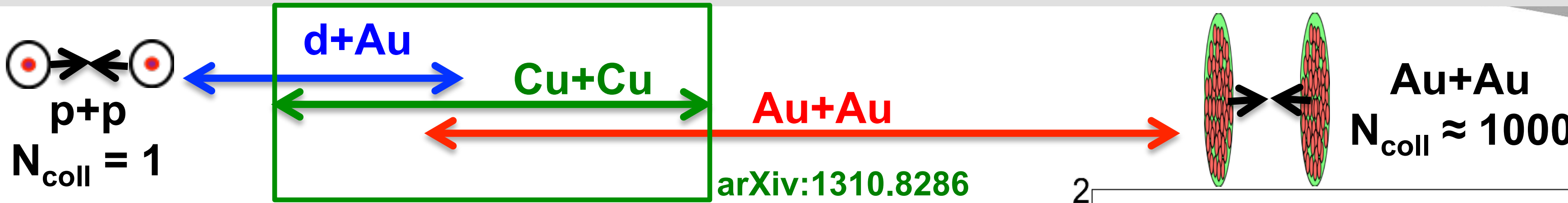
<Ncoll>≈182.7

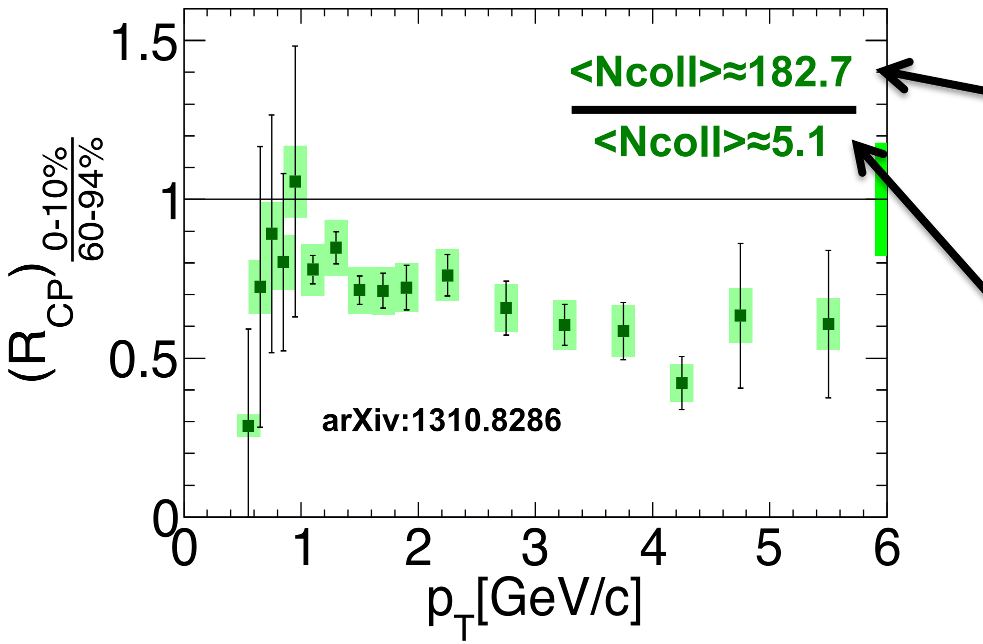
Significant enhancement

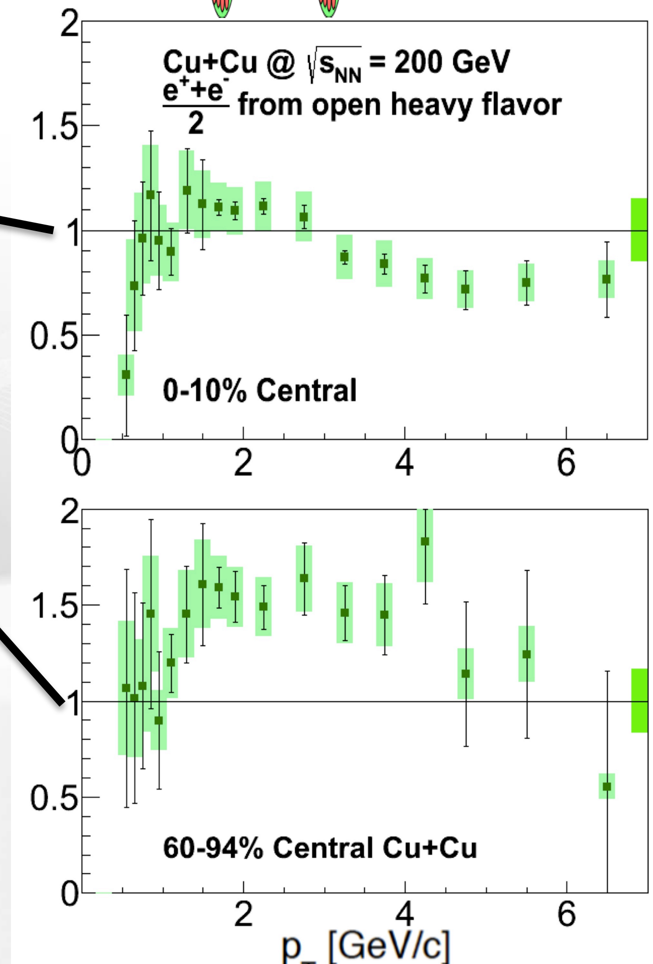
<Ncoll>≈5.1



In Cu+Cu collisions

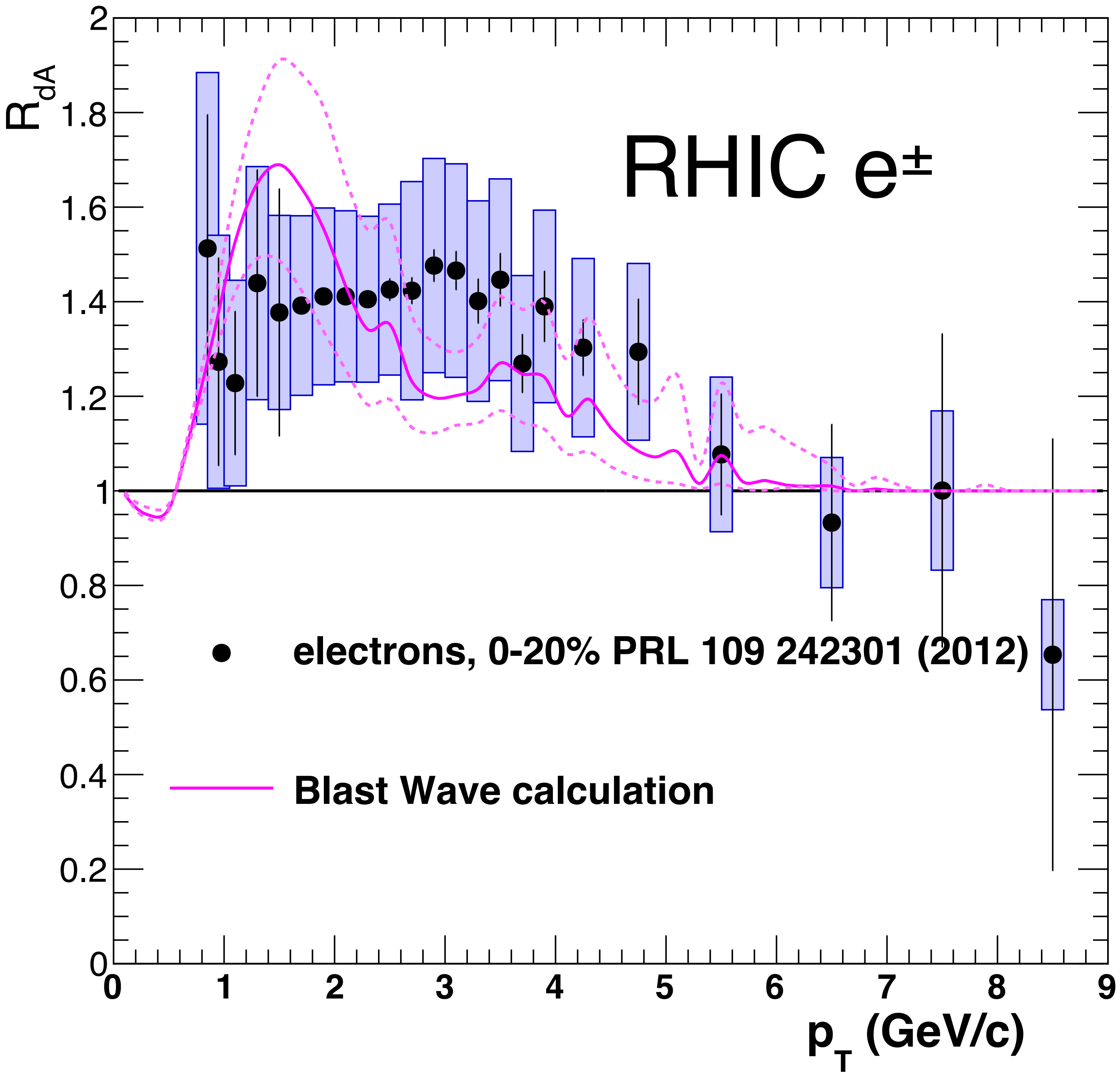


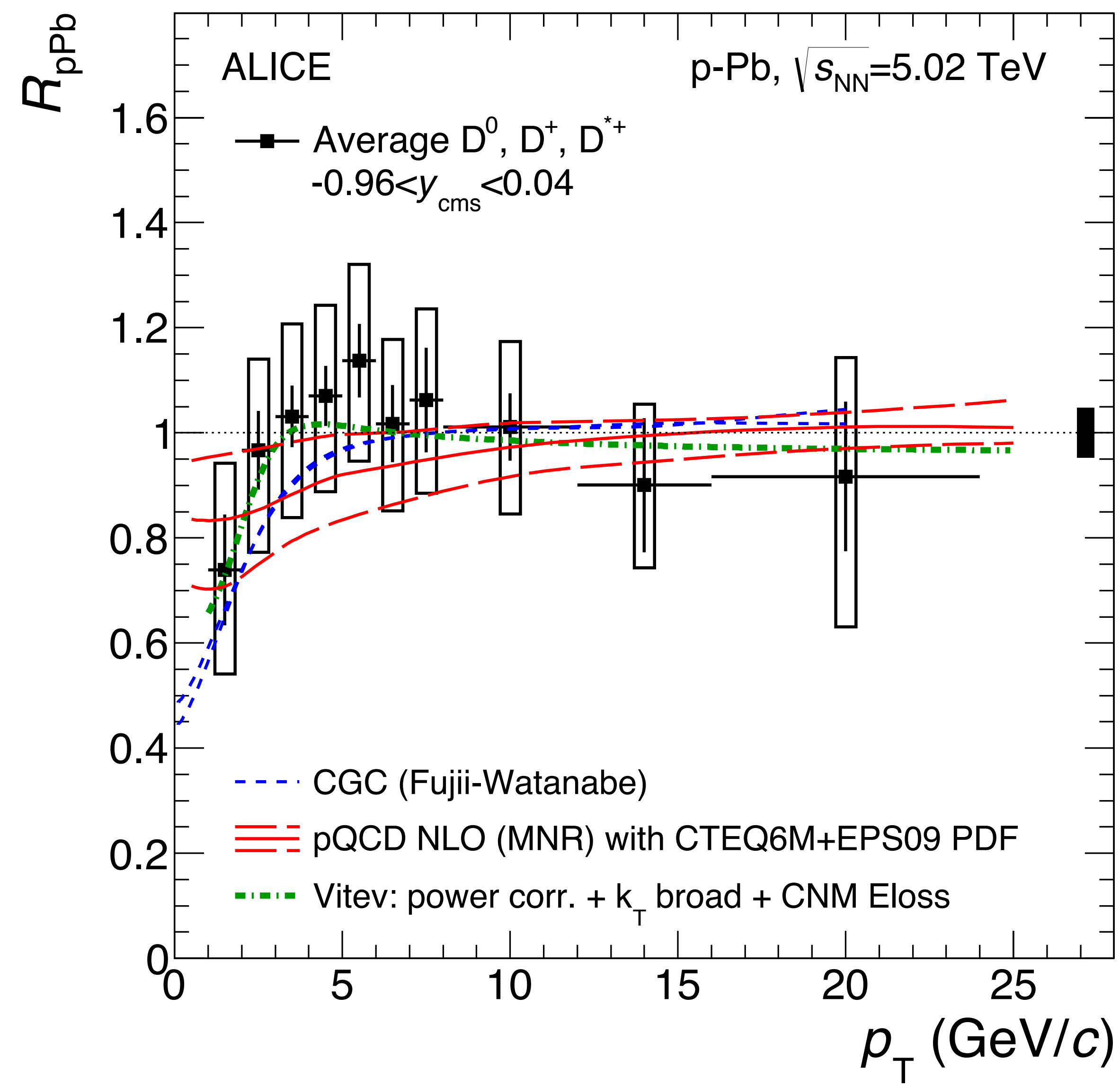




R_{CP} shows a significant suppression
→ hot nuclear matter effects are dominating in central Cu+Cu collisions

what about heavy mesons?



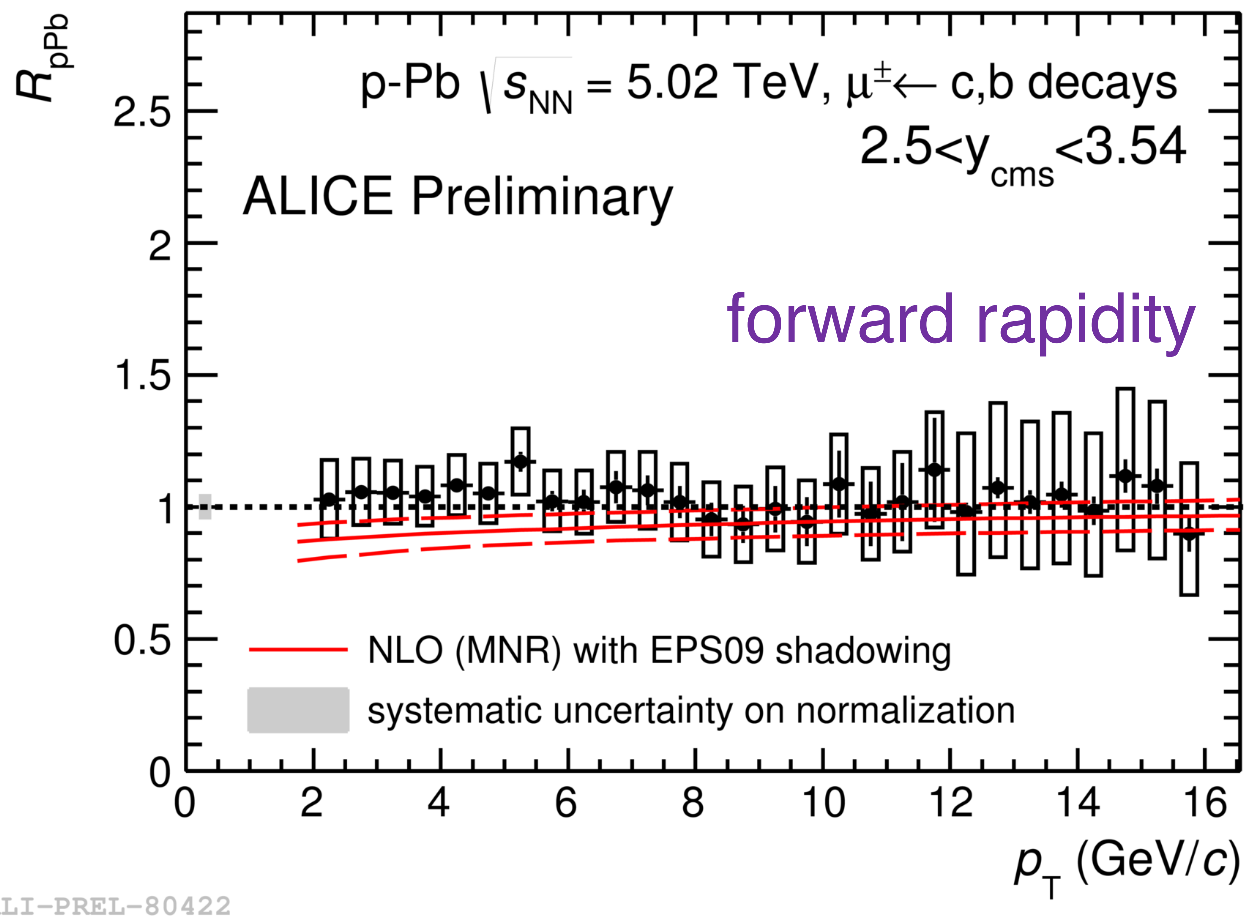


a smaller effect at the LHC could be due to the harder initial spectrum

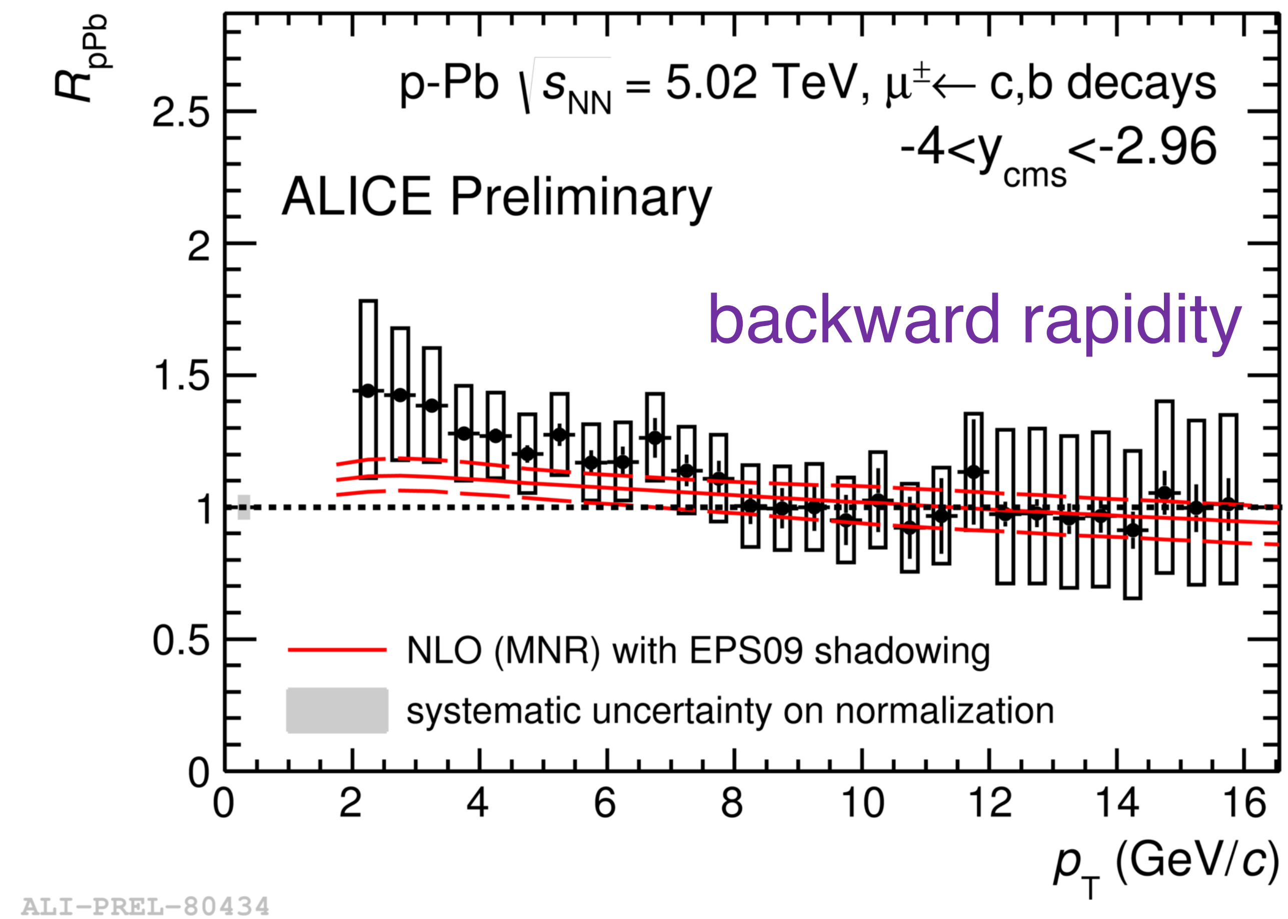
Lim, S. Li

away from midrapidity

p-going



Pb-going



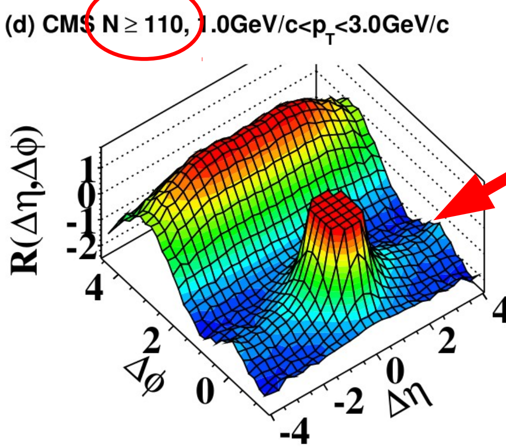
similar results from ALICE, perhaps slightly smaller A-going enhancement

S. Li

- 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?

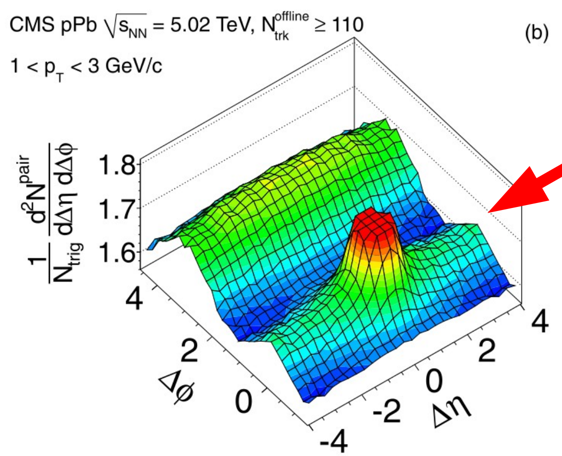
Ridge in p+p, p+Pb at LHC

CMS pp JHEP 09 (2010) 091

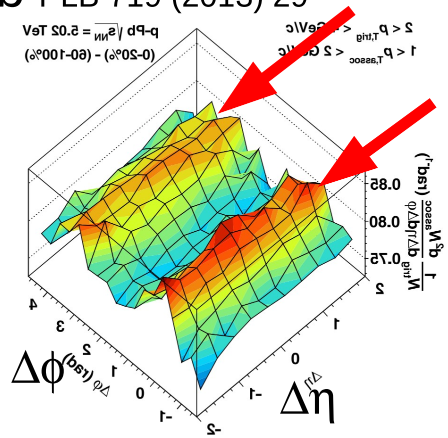


Near-side Ridge

CMS pPb PLB 718 (2013) 795

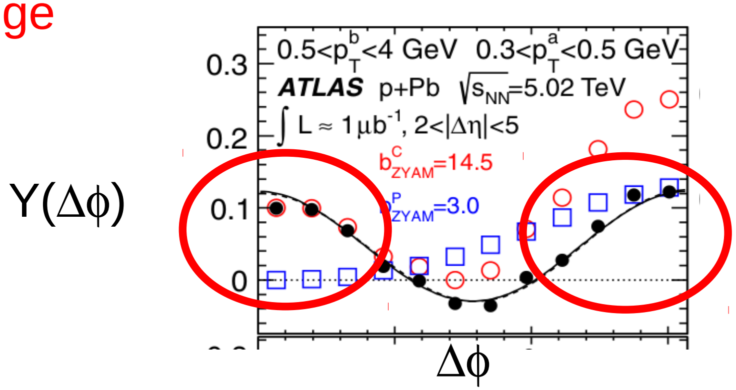


ALICE pPb PLB 719 (2013) 29



Double Ridge

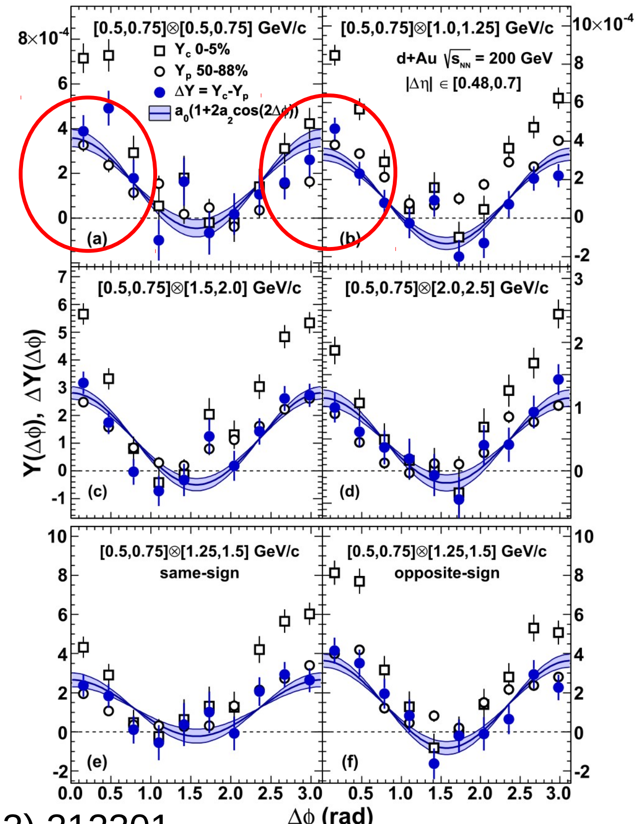
ATLAS pPb PRL 110 (2013) 182302



- Ridge observed in high-multiplicity pp and pPb events
- High-multi.－ low-multi. (for jets) → double ridge in pPb

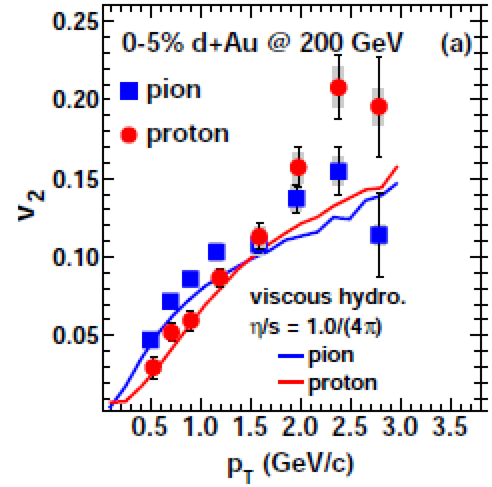
Ridge in d+Au at RHIC?

PHENIX d+Au Double Ridge



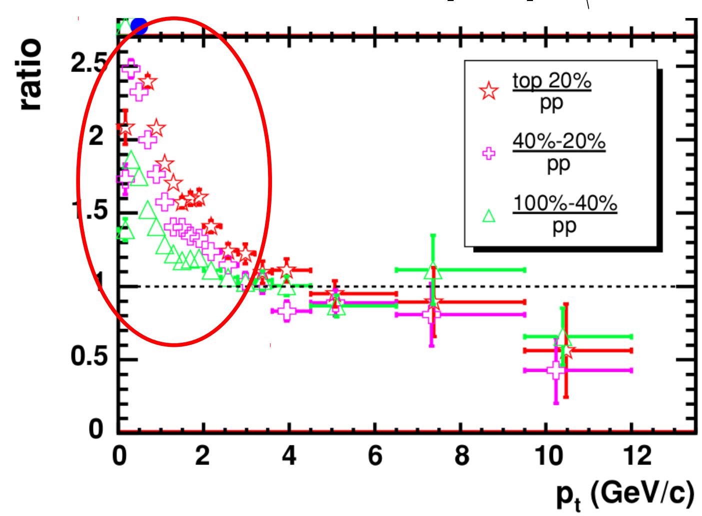
PRL 111 (2013) 212301

PHENIX d+Au Finite v_2



arXiv 1404.7461v1

STAR d+Au vs p+p $\left\langle \sum \cos\left(2\left(\varphi_{p_t} - \varphi_i\right)\right)\right\rangle$



PRC 72 (2005) 014904

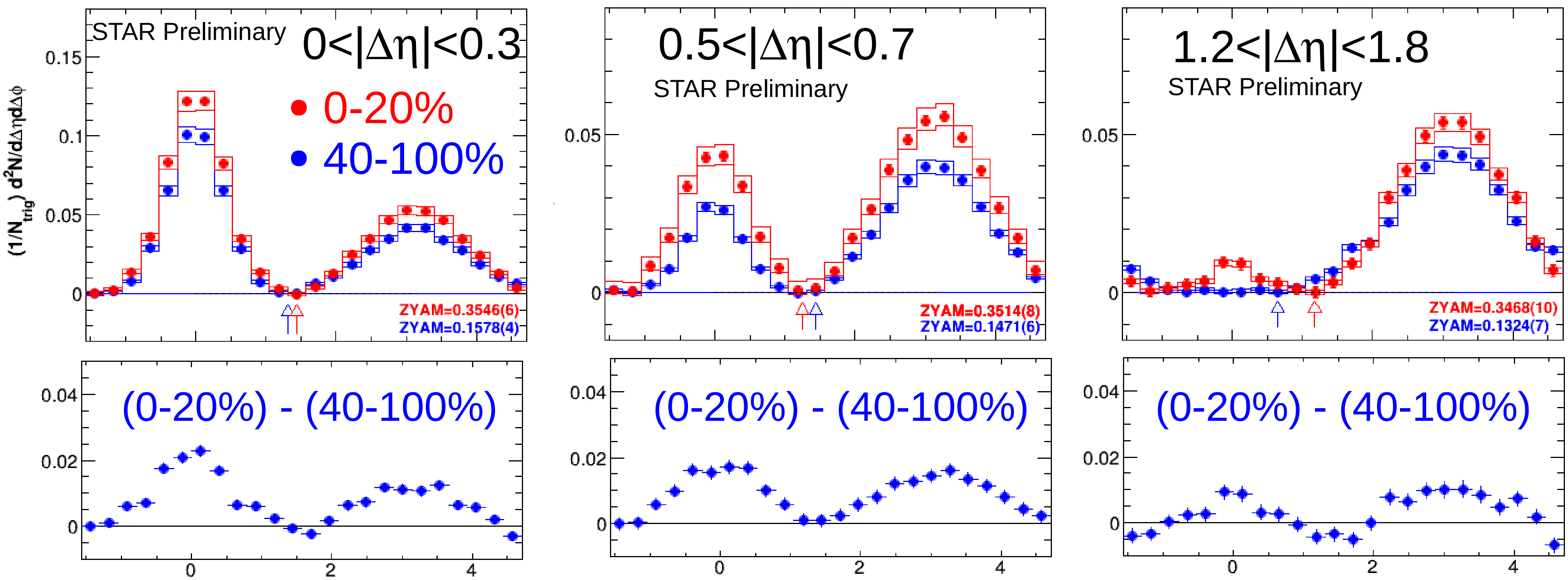
Physics mechanisms

- Hydro?
- CGC?

TPC-TPC Δϕ Correlations High- vs Low-mult.

d+Au@200 GeV

p_T: [1,3]x[1,3] GeV/*c*
FTPC Multiplicity

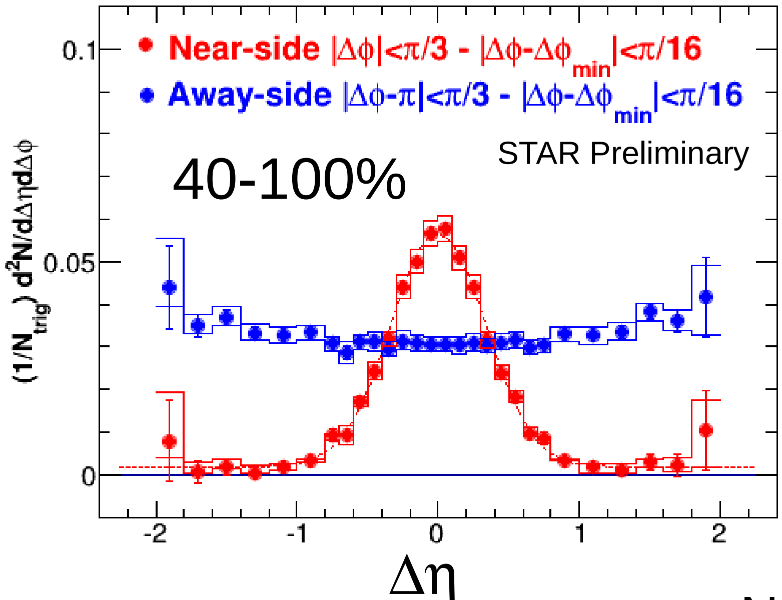


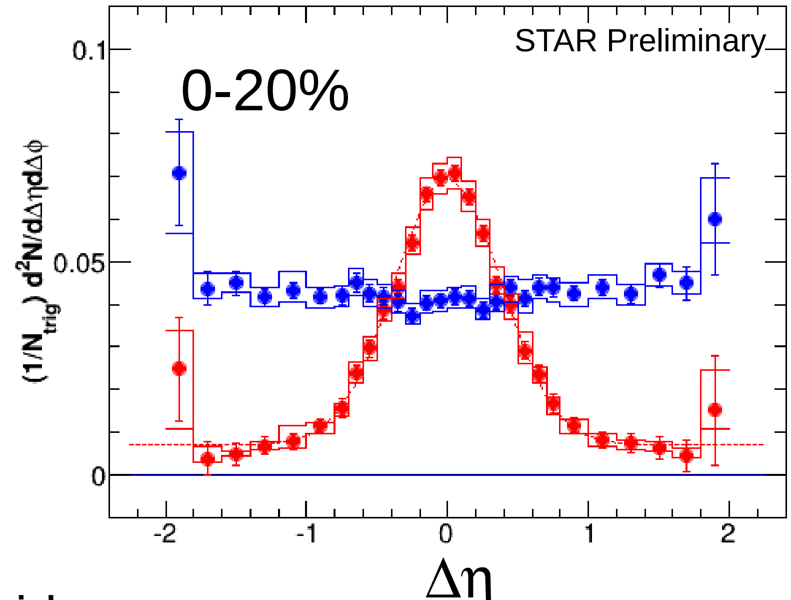
- high-mult. (cent.) > low-mult. (peri.) on both near-side and away-side.
- central - peripheral = “double ridge”

Near-side Ridge in High-multiplicity

d+Au@200 GeV

p_T: [1,3]x[1,3] GeV/*c*
FTPC Multiplicity





Near-side
Gaussian + Pedestal Fit

40-100%	0-20%	
Y = 0.0459(10)	Y = 0.0594(18)	Gaus. area
σ = 0.336(6)	σ = 0.382(9)	Gaus. width
Ped = 0.0019(4)	Ped = 0.0070(8)	Pedestal
χ^2/ndf = 19/25	χ^2/ndf = 19/25	

- Finite pedestal → Near-side Ridge
- Different jet shapes and yields between cent. and peri.
  → Multiplicity selection bias? Jet energy, fragmentation?

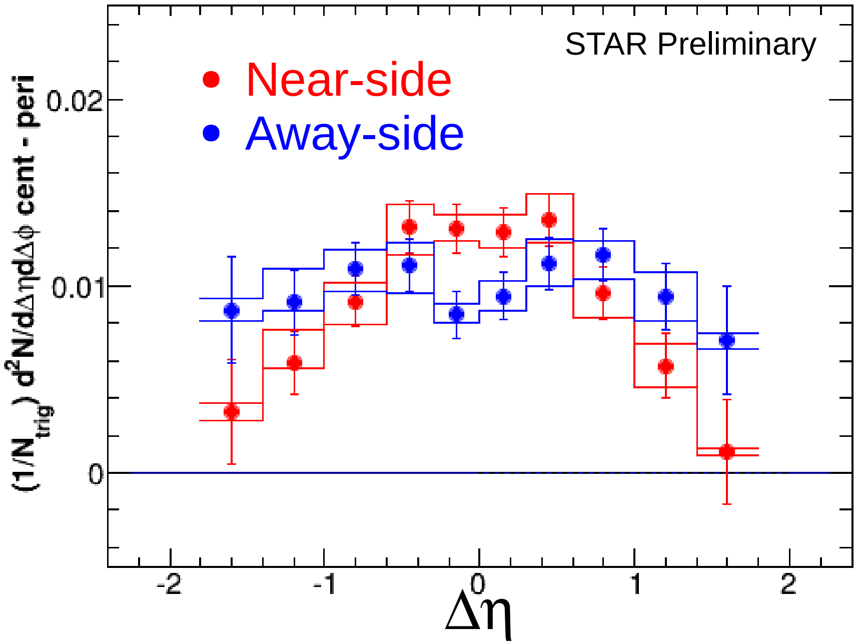
Away-side Ridge?

d+Au@200 GeV

p_T: [1,3]x[1,3] GeV/*c*
FTPC Multiplicity

(0-20%) - (40-100%)

- Cent. - peri. ≠ Cent. - Jets residual of jets



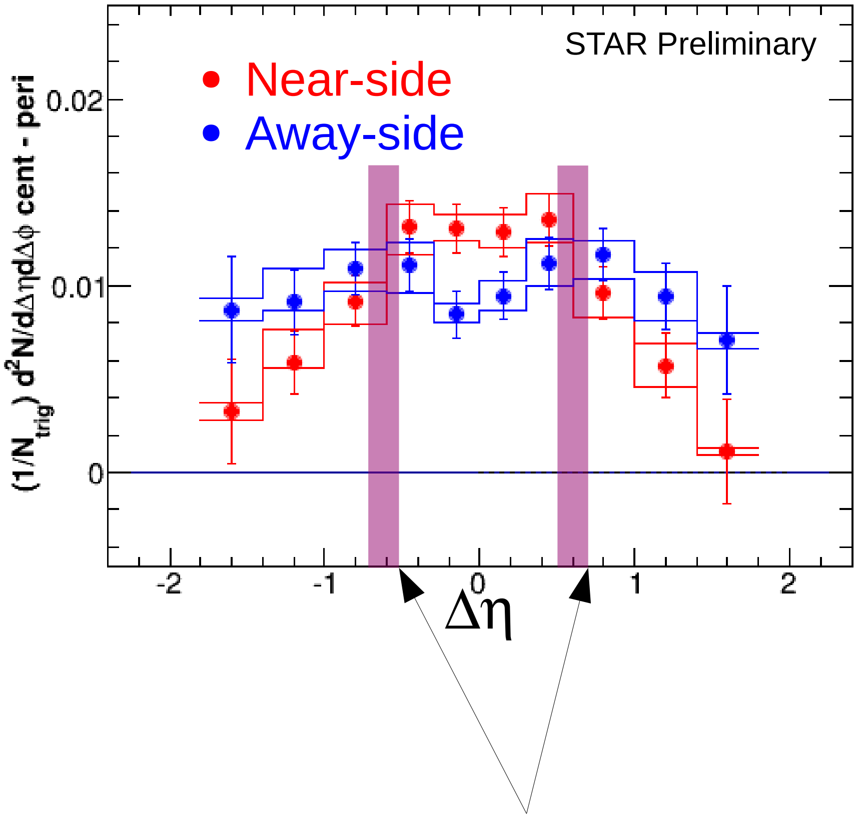
Away-side Ridge?

d+Au@200 GeV

p_T: [1,3]x[1,3] GeV/*c*
FTPC Multiplicity

- Cent. - peri. ≠ Cent. - Jets residual of jets

(0-20%) - (40-100%)



|Δη| used in PHENIX's paper
Same near-side and away-side
PRL 111 (2013) 212301

No Away-side Ridge

d+Au@200 GeV

p_T: [1,3]x[1,3] GeV/c
FTPC Multiplicity

Do first-order correction: same jet yield

Assume:

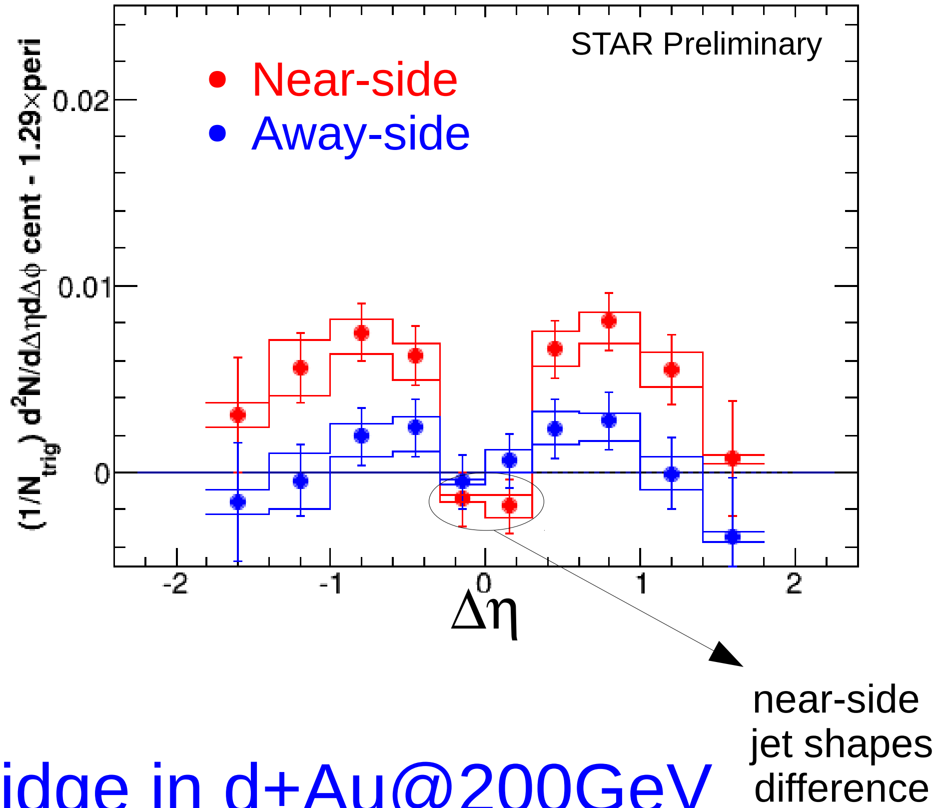
- Peri. correlation has jets only.
- Away-side jet yield $\propto$ near-side jet yield

$Y^{Cent.}$, $Y^{Peri.}$: near-side jet yields

R = $Y^{Cent.}$ / $Y^{Peri.}$ = 1.29±0.05
(Away-side ratio: 1.32±0.02)

Cent. - R×Peri≈ Cent. - Jets

(0-20%) - 1.29 x (40-100%)



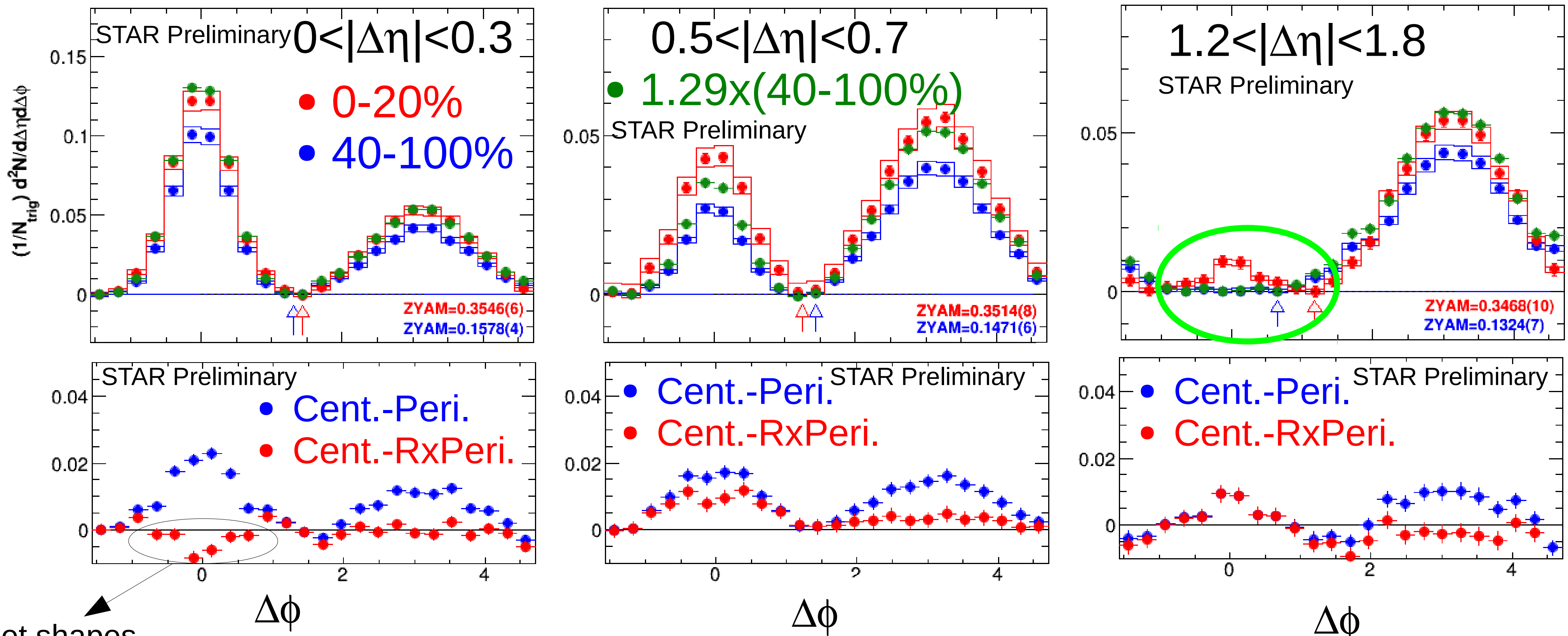
- Away-side ~ 0 → No Double Ridge in d+Au@200GeV

TPC-TPC Δϕ Correlations High- vs Low-mult.

d+Au@200 GeV

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

FTPC Multiplicity



jet shapes difference

- Away-side ~ 0
- Near-side: finite at Δη ≈ 1.5

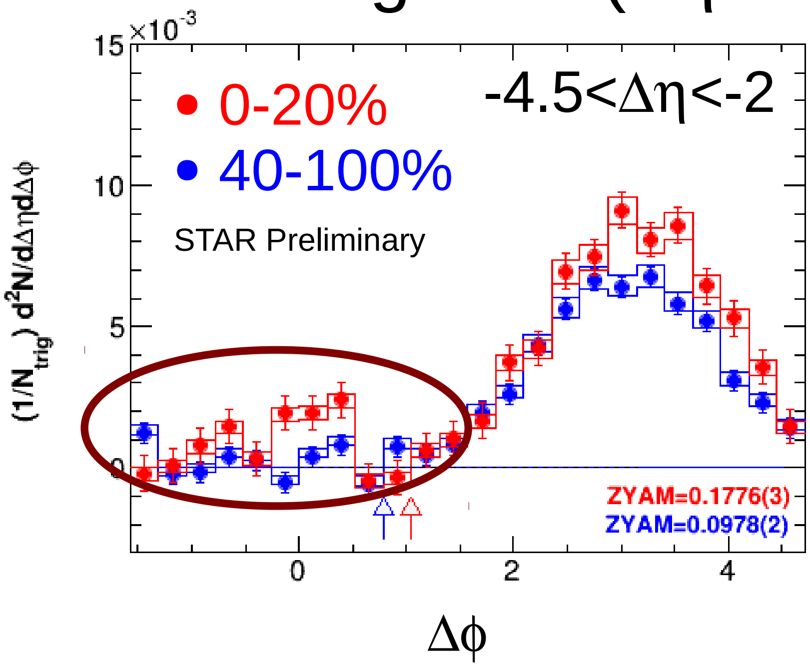
  → How about even larger |Δη| ≈ 3?

TPC-FTPC: High-. vs Low-multiplicity

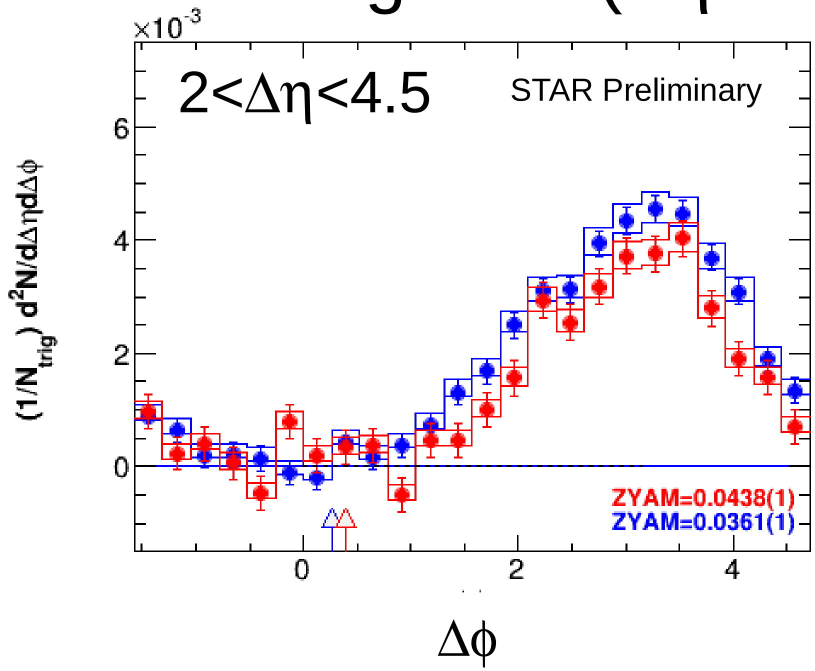
d+Au@200 GeV

p_T: [1,3]x[1,3] GeV/*c*
ZDC Energy

Au-Going Side ($\Delta\eta \approx -3$)



d-Going Side ($\Delta\eta \approx 3$)



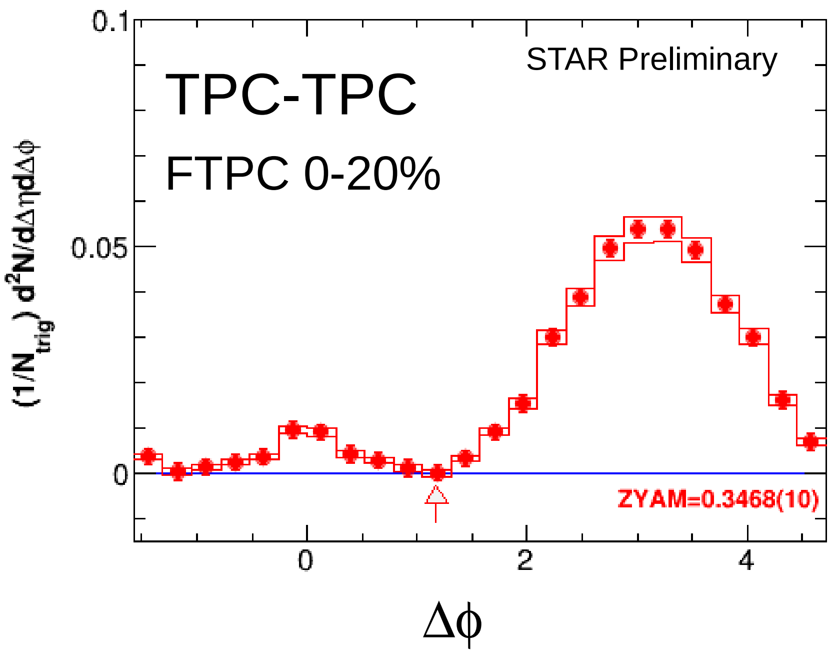
- Away-side: enhanced at Au-going side; depleted at d-side.
- Near-side: finite for FTPC Au-going side ($\Delta\eta \approx 3$) in high-multiplicity collisions.

Recap: Near-side in High-multiplicity

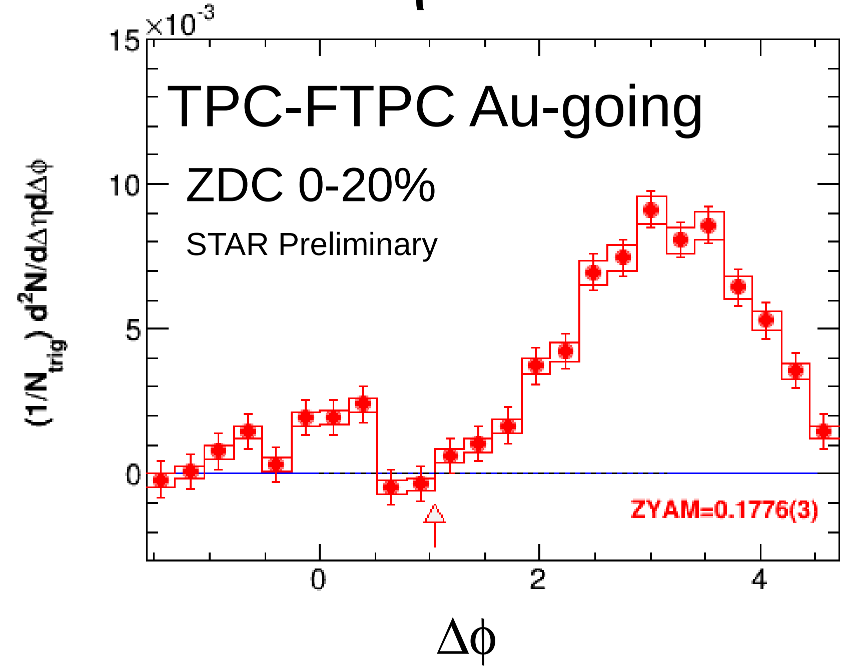
d+Au@200 GeV

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

$\Delta\eta \approx 1.5$



$\Delta\eta \approx -3$



- Long-range near-side correlations are observed in both TPC-TPC and TPC-FTPC
- What could be the the physics mechanism?
- Study charge combinations

Unlike-sign vs Like-sign

d+Au@200 GeV

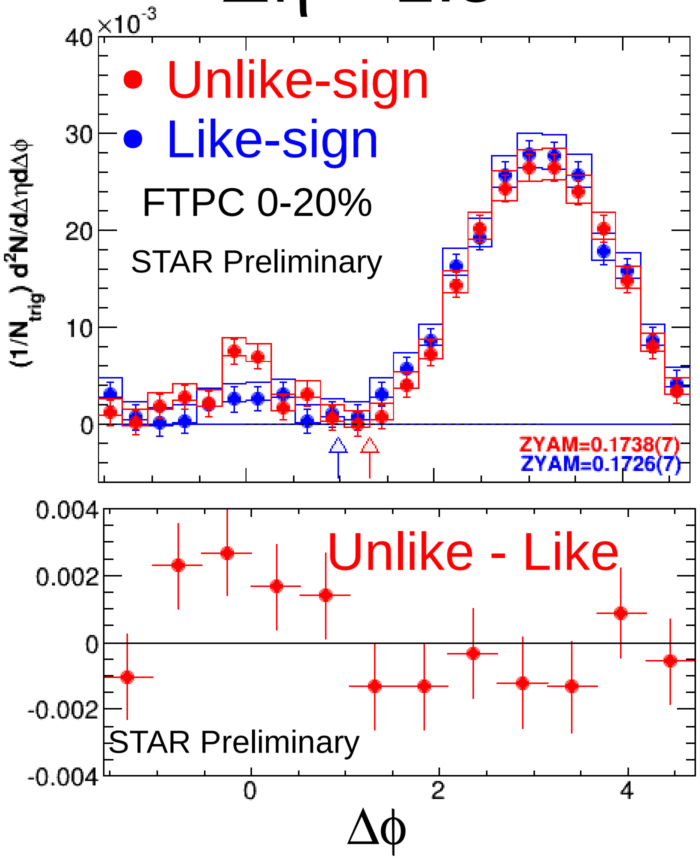
p_T: [1,3]x[1,3] GeV/c

Near-side yield

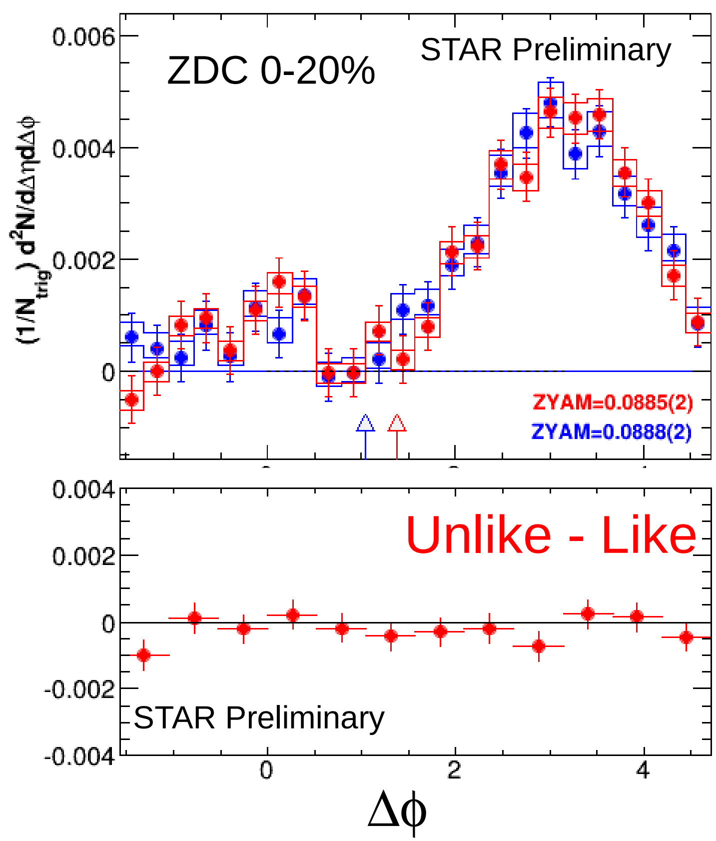
US: $35\pm5^{+14}_{-3}\times10^{-4}$

LS: $18\pm5^{+16}_{-2}\times10^{-4}$

$\Delta\eta \approx 1.5$



$\Delta\eta \approx -3$



Near-side yield

US: $7.6\pm1.5^{+1.6}_{-1.9}\times10^{-4}$

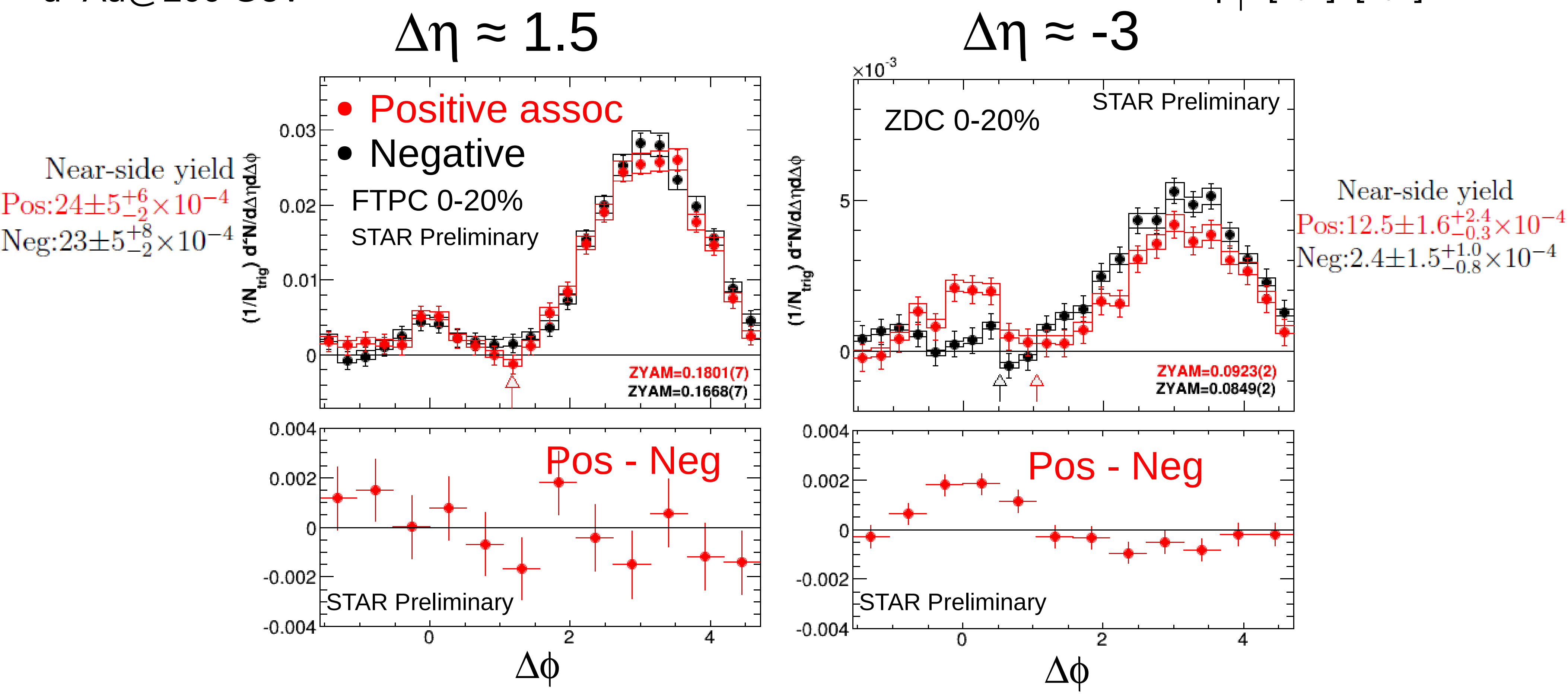
LS: $6.2\pm1.6^{+2.9}_{-1.5}\times10^{-4}$

- $\Delta\eta \approx 1.5$ near-side: unlike-sign > like-sign
  → Jet-like feature?
- $\Delta\eta \approx -3$: No difference.

Associated Particle: Positive vs Negative

d+Au@200 GeV

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

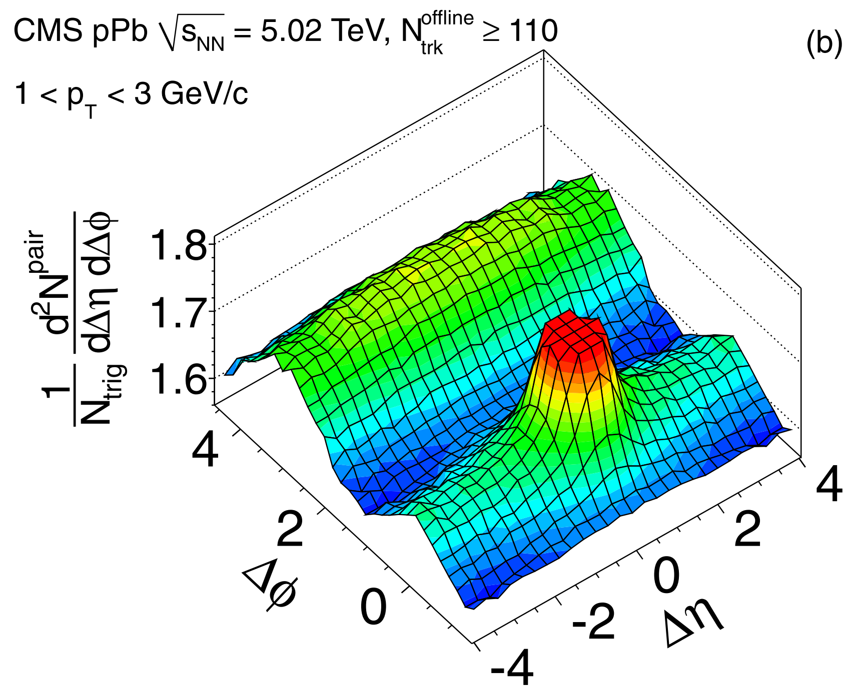


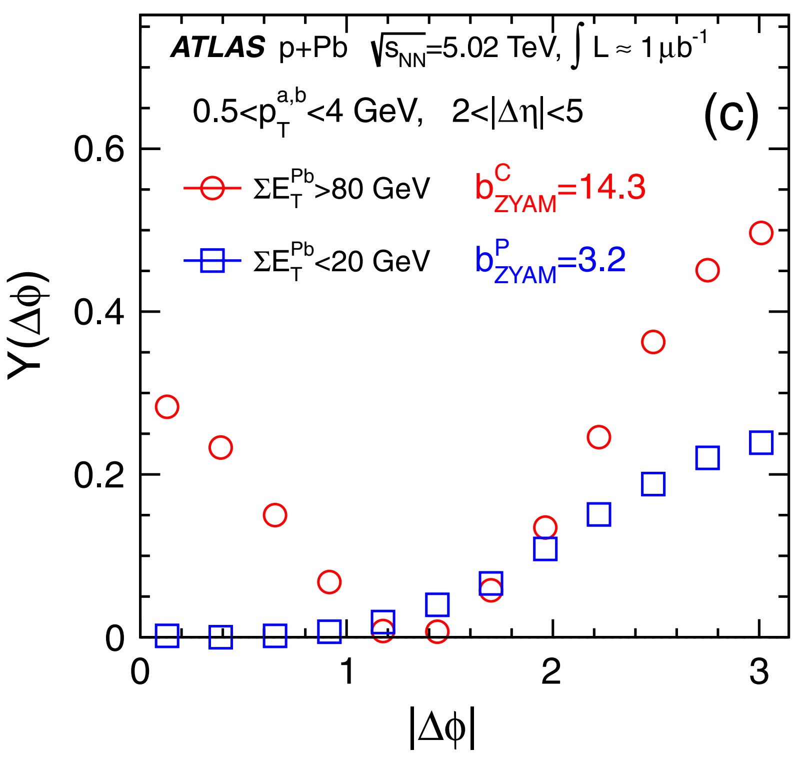
- Δη ≈ 1.5: No difference.
- Δη ≈ -3 near-side: positive associated particles only
  → Transport protons?

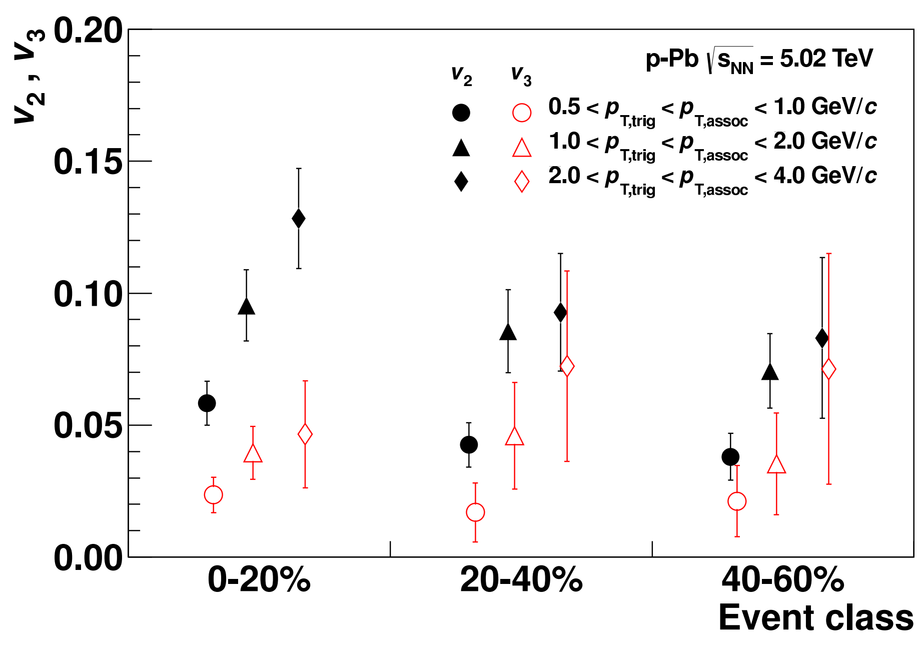
Summary for the correlation part

- Jets yield and shape difference observed in low- and high-multiplicity d+Au@200 GeV
- Away-side ~ 0 after jet difference corrected - No double ridge
- Finite near-side long-range correlations – Ridge observed by STAR.
  - $\Delta\eta$ ~ 1.5 : unlike-sign > like-sign → jet-like?
  - $\Delta\eta$ ~ -3: from positive associated particle only → transport protons?
- The near-side ridge may be due to physics mechanism other than flow. STAR does not observe elliptic flow in d+Au.

angular correlations







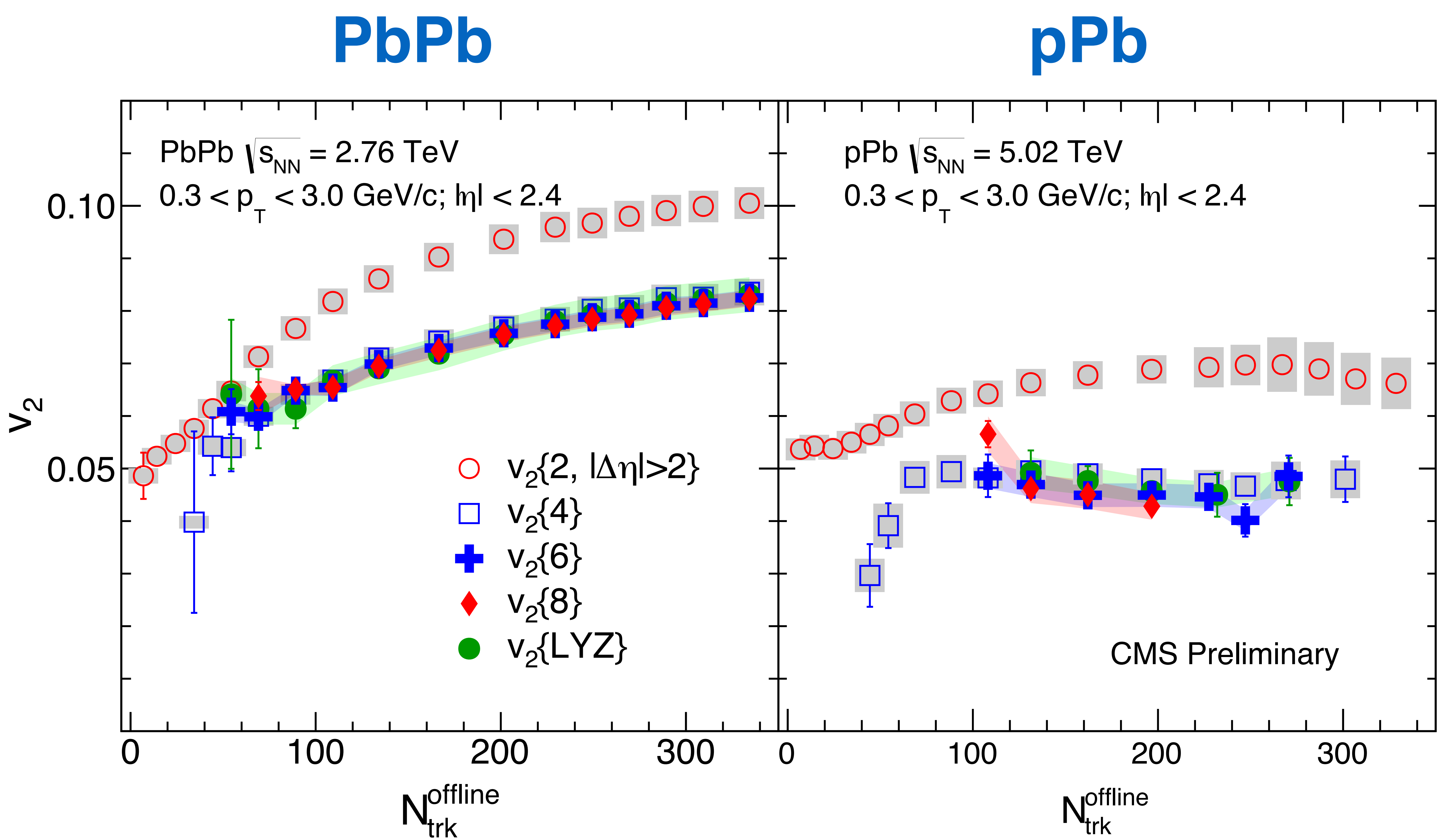
QM2014: wealth of new measurements

vigorous discussion about methods & interpretation

focus on methods, p_T reach, particle ID

CMS PLB 718 795 (2013)
ALICE PLB 719 29
ATLAS PRL 110 182302

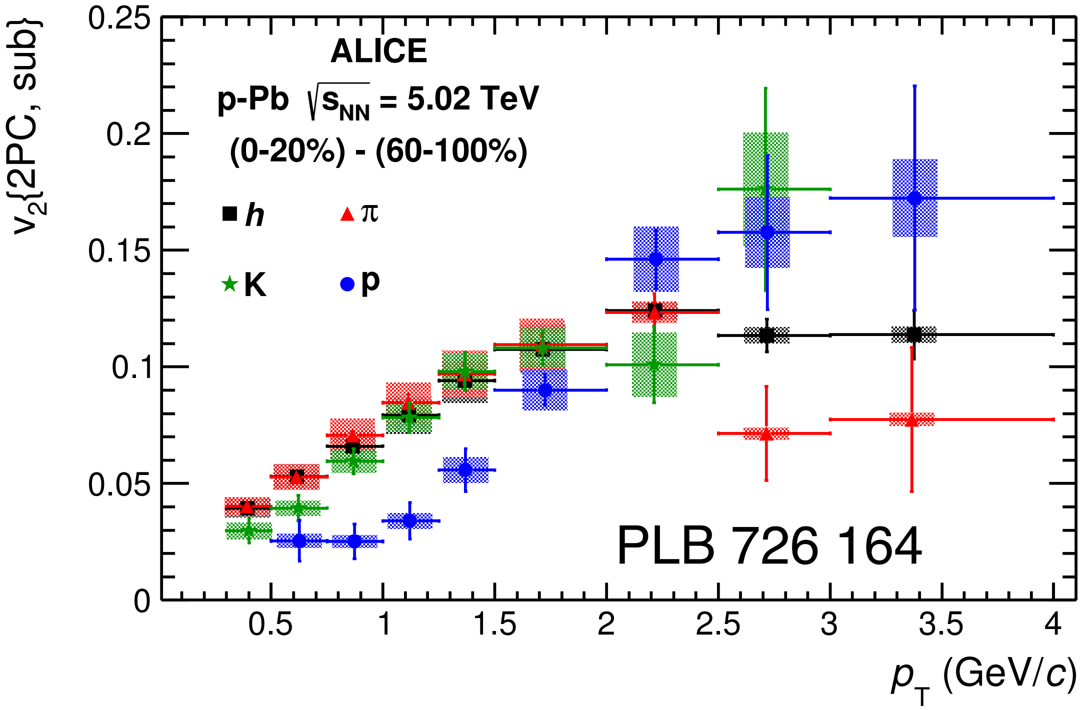
cumulants

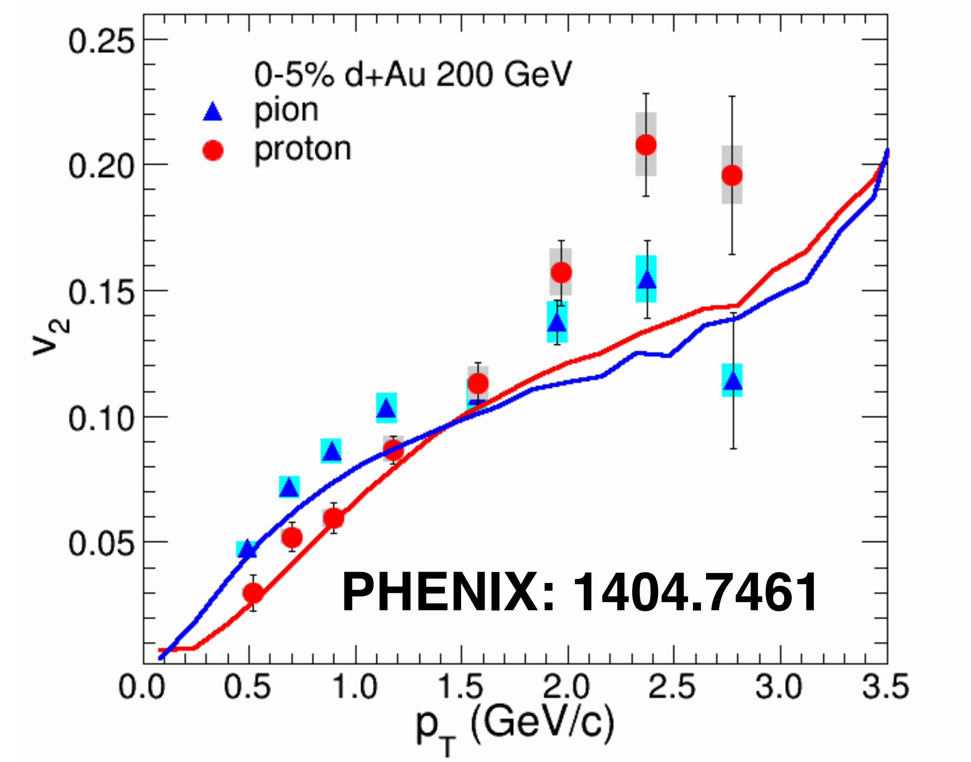


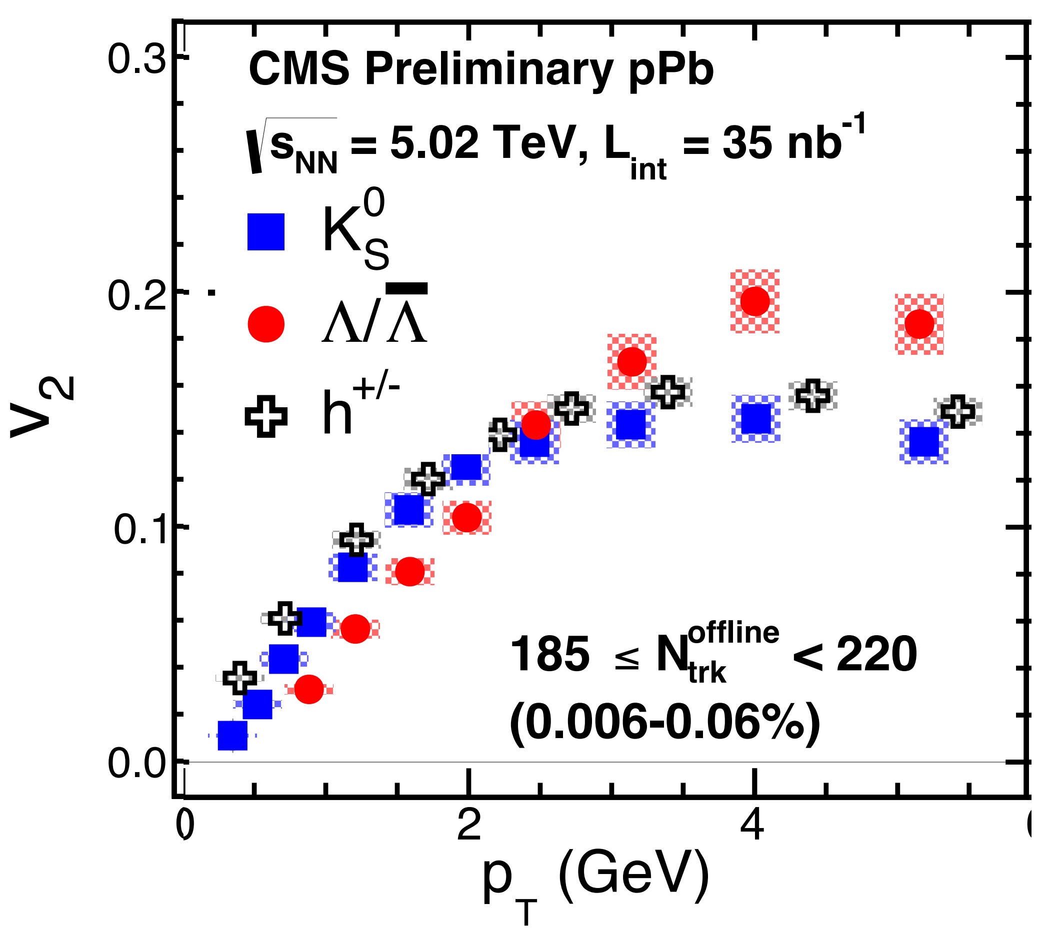
v2 from cumulants smaller than 2-particle correlations
no change in v2 for 4,6,8 part. cumulants

Wang

mass dependent flow



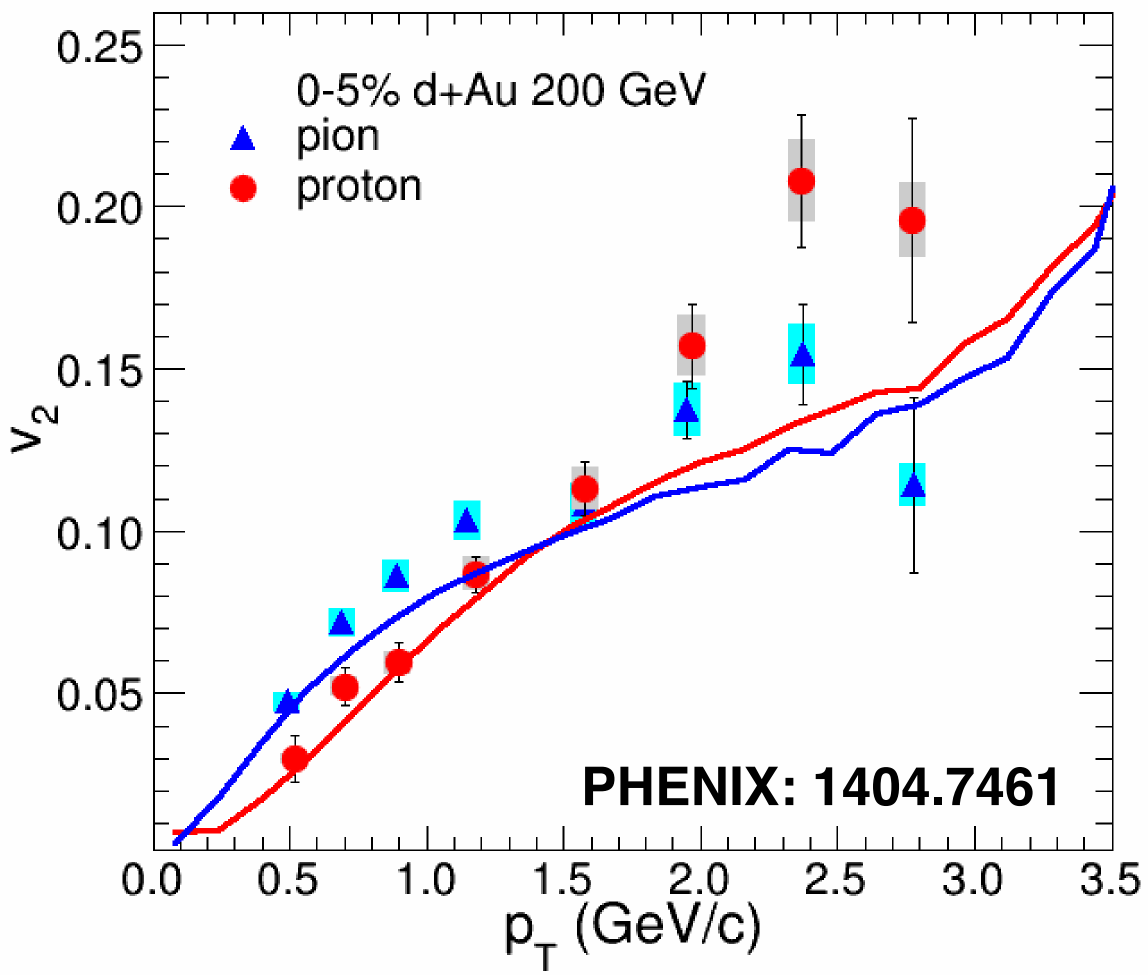


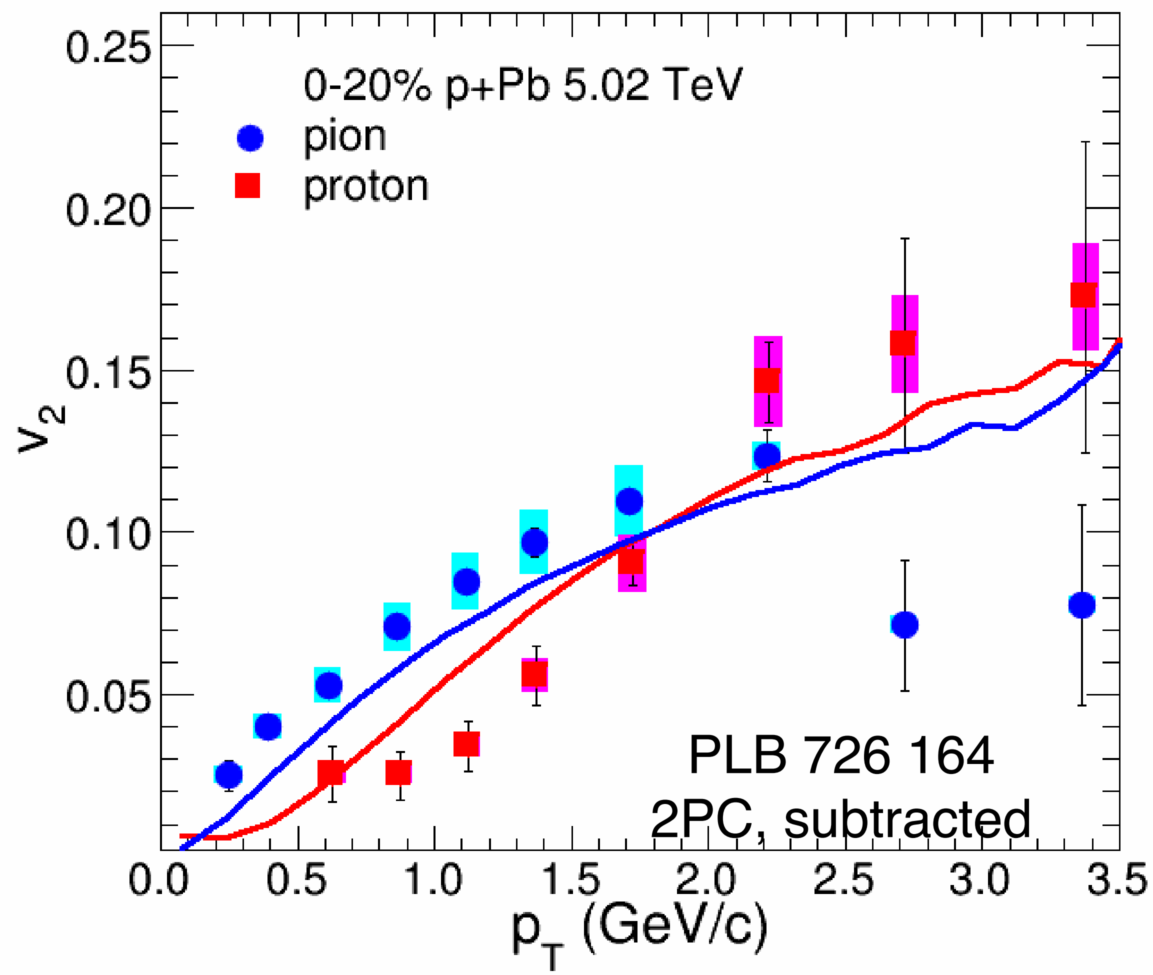


mass differences seen: lower v_2 for heavier particles at low p_T, crossing at higher p_T

Milano, Huang, Sharma

mass dependent flow





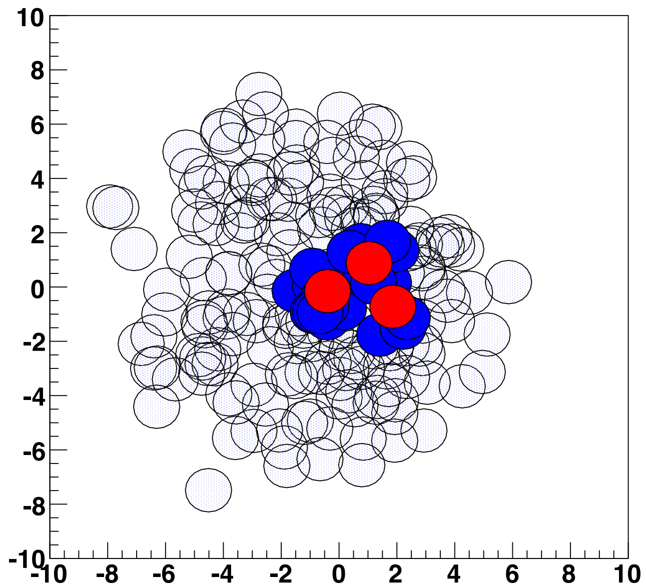
MC Glauber IC
$\eta/s = 1/4\pi$
$\tau_0 = 0.5$ fm/c
$T_f = 170$MeV
cascade

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

calculations: P. Romatschke

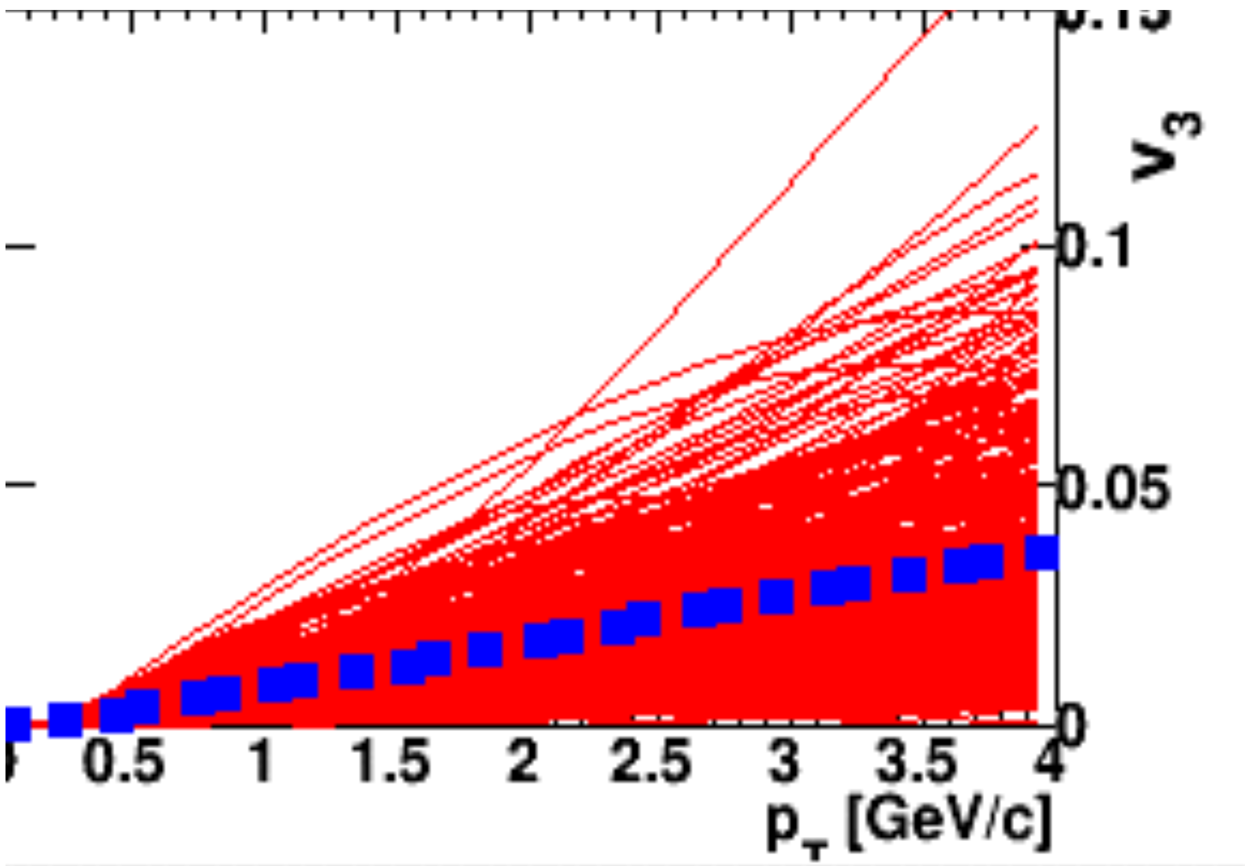
Huang, Milano

^{3}He+Au:

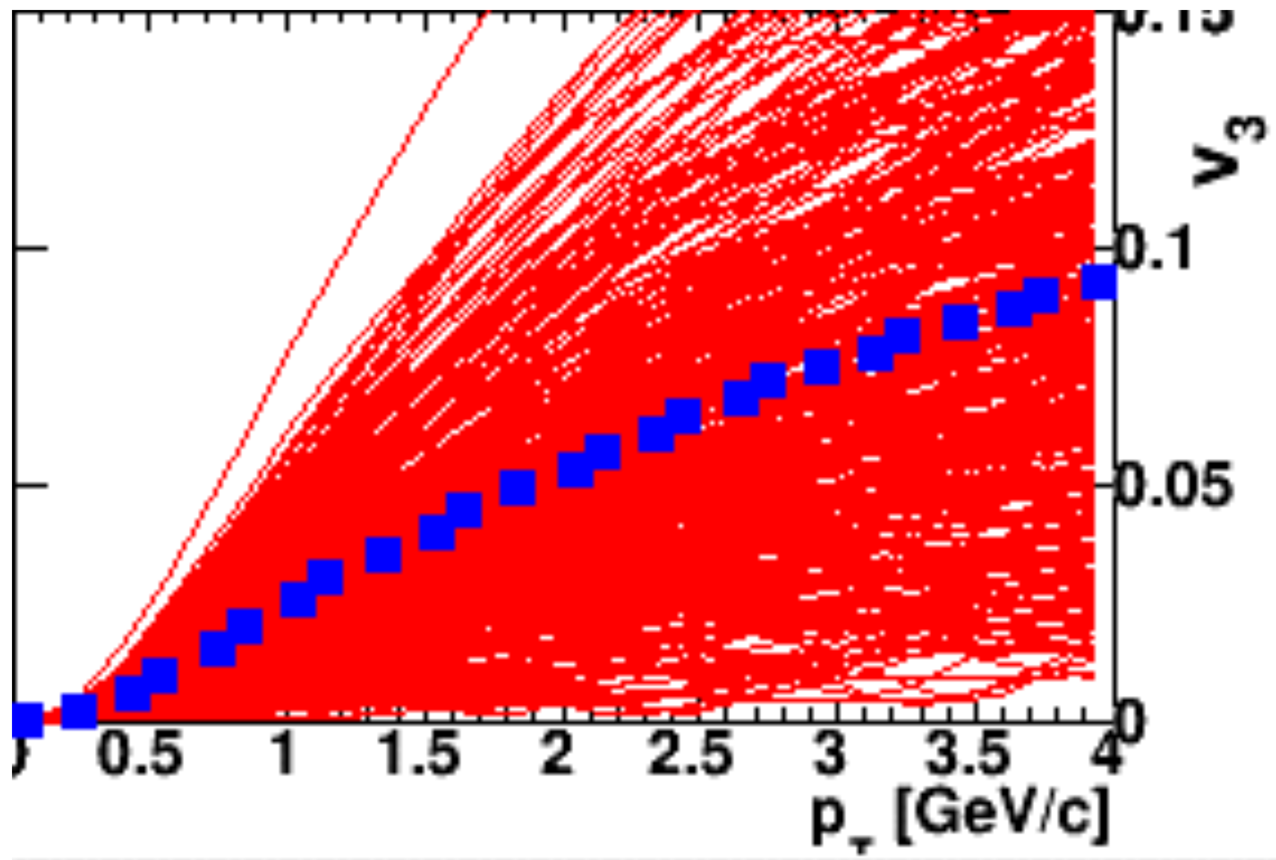


^{3}HeA: variation of the system geometry

5% most central



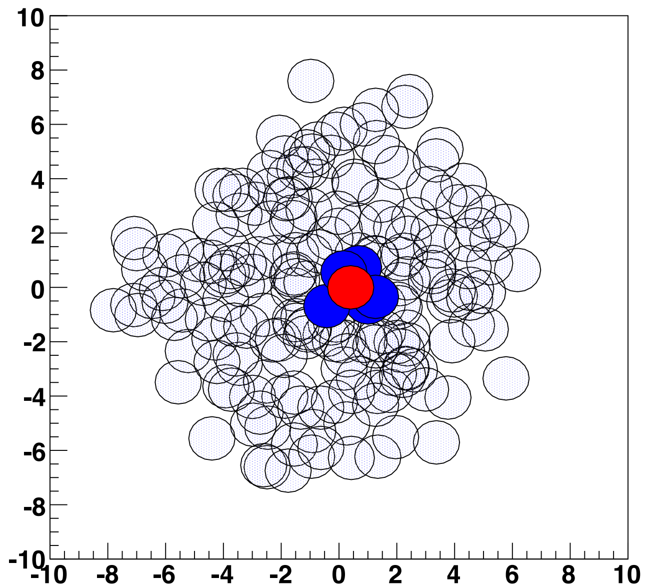
1% most central



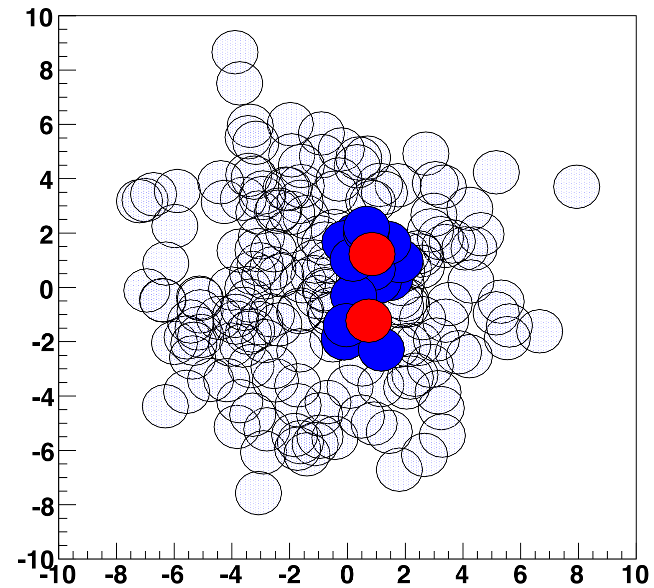
calculations: P. Romatschke (CD parallel), Nagle et al: 1312.4565

linking geometry to correlations?

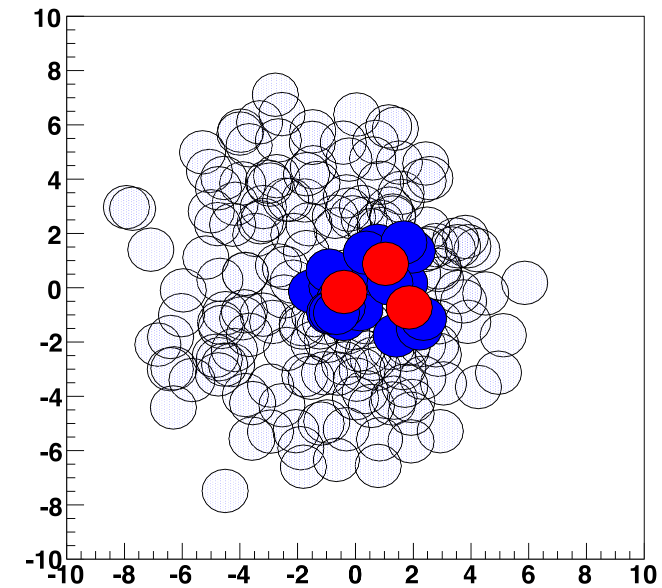
pA



dA



^{3}HeA



looking forward to p+Au and 3He+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)