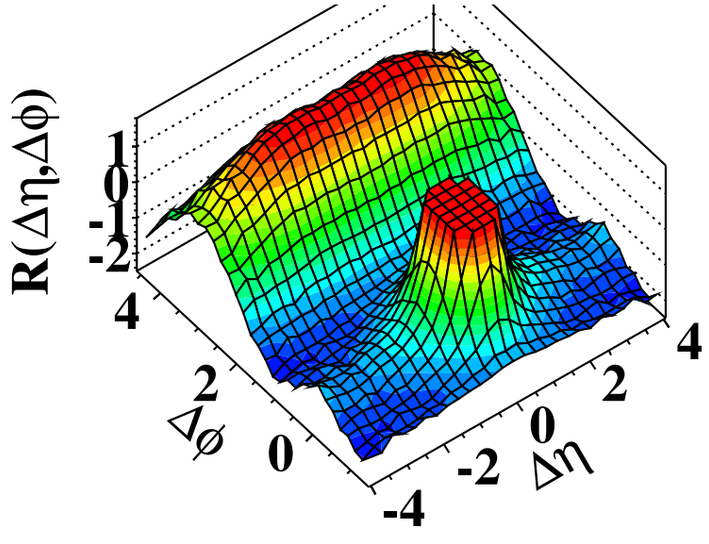
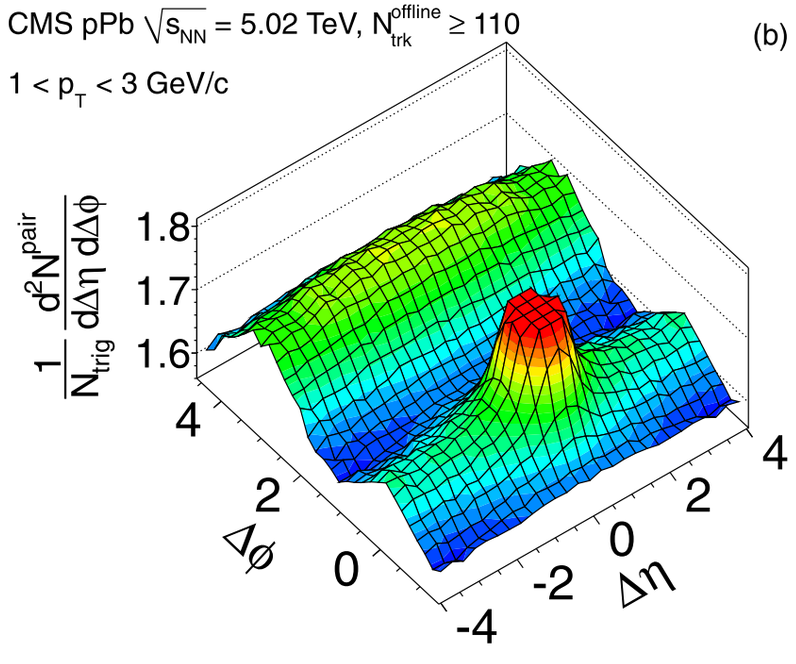
d+Au Hadron Correlation Measurements at PHENIX

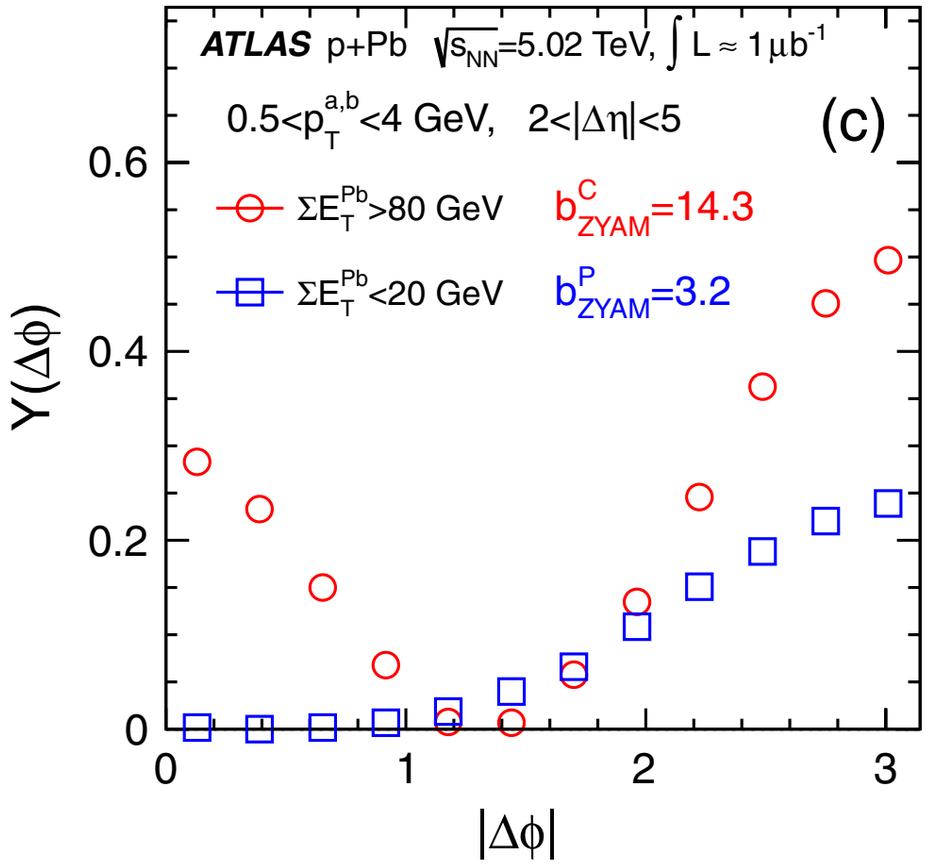
Anne Sickles for the PHENIX Collaboration

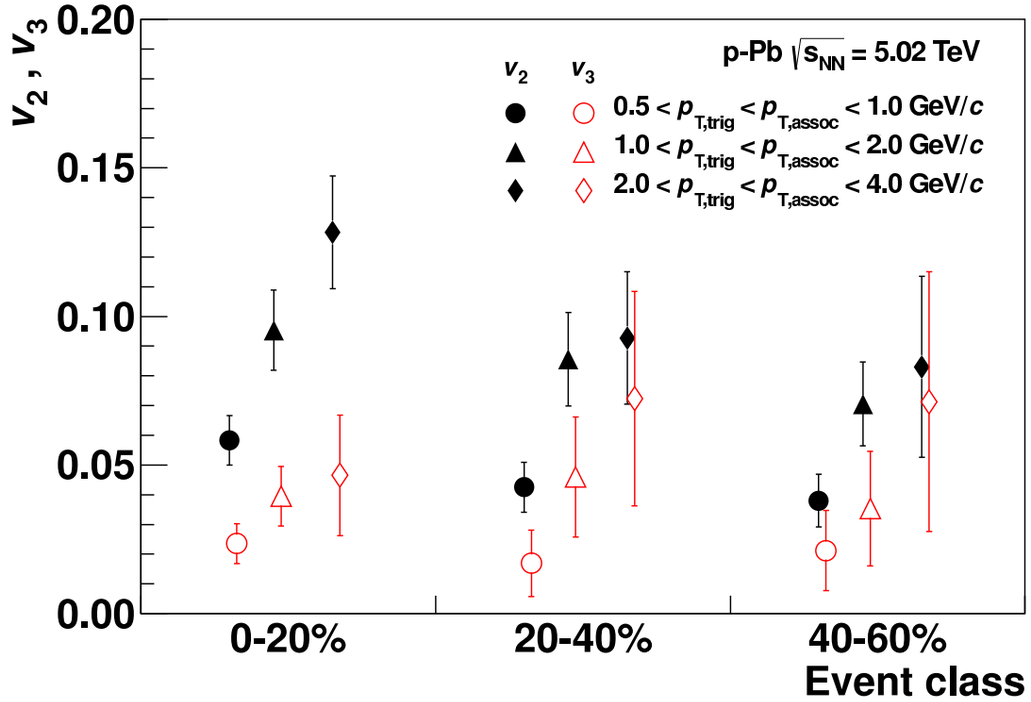
Brookhaven

pp & pPb ridges



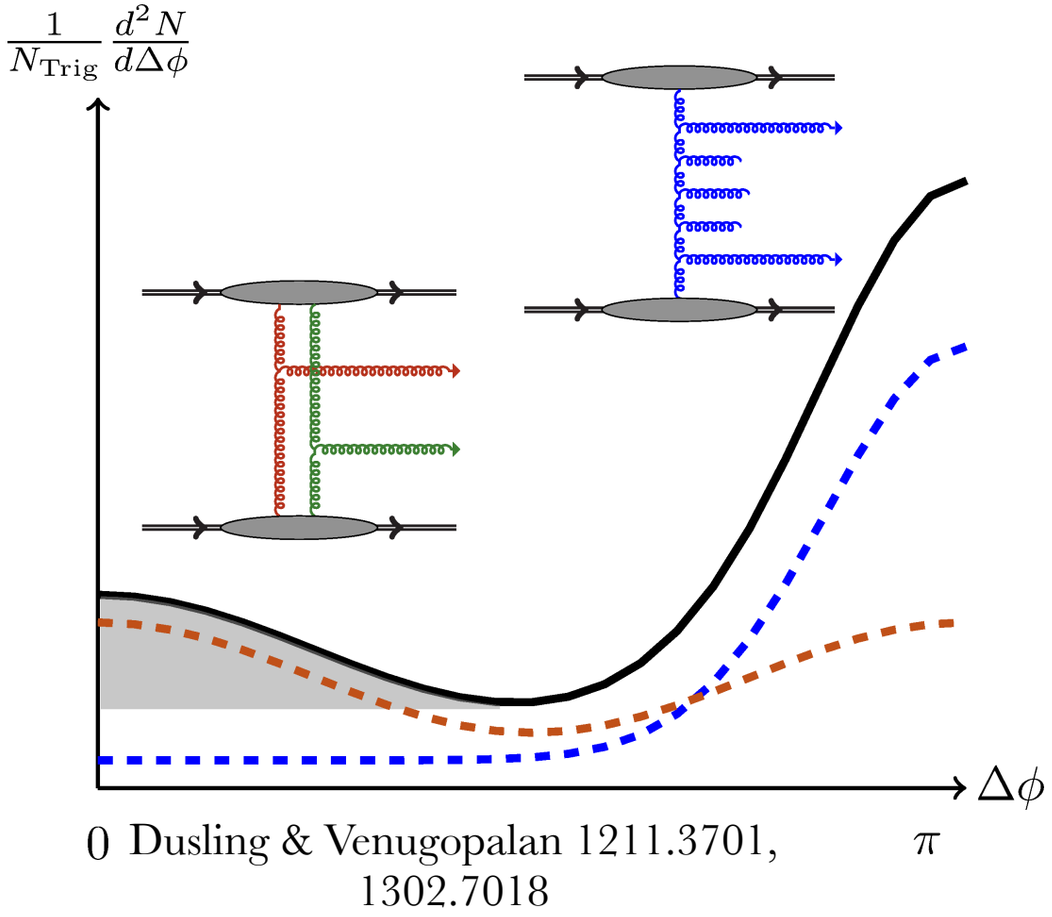




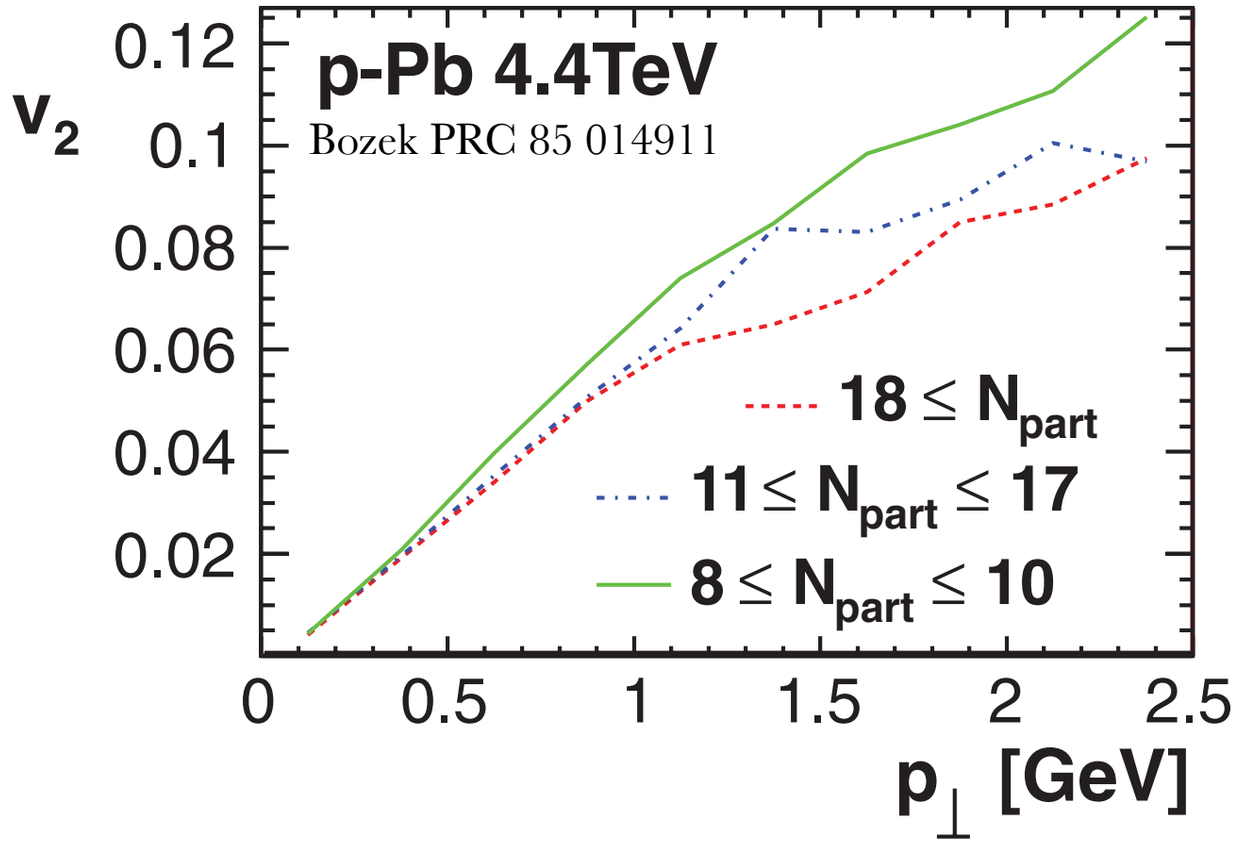


CMS PLB 718 795 (2013)
ALICE PLB 719 29
ATLAS PRL 110 182302

initial or final state effect?



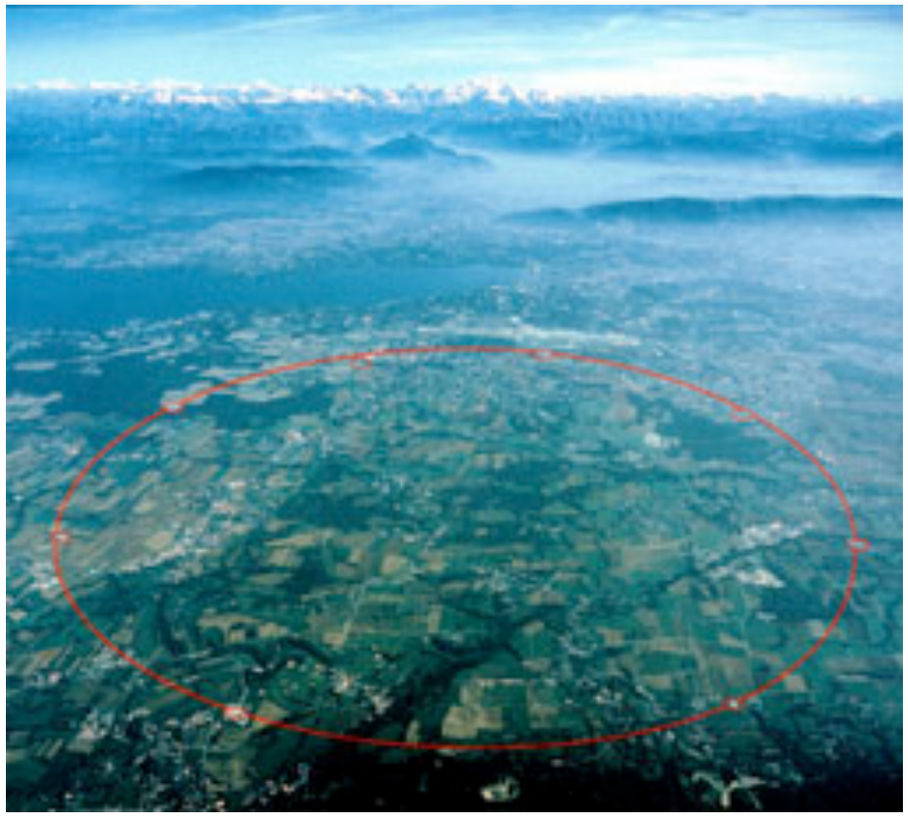
Dusling & Venugopalan 1211.3701, 1302.7018



CGC/Glasma

hydrodynamics

RHIC & LHC

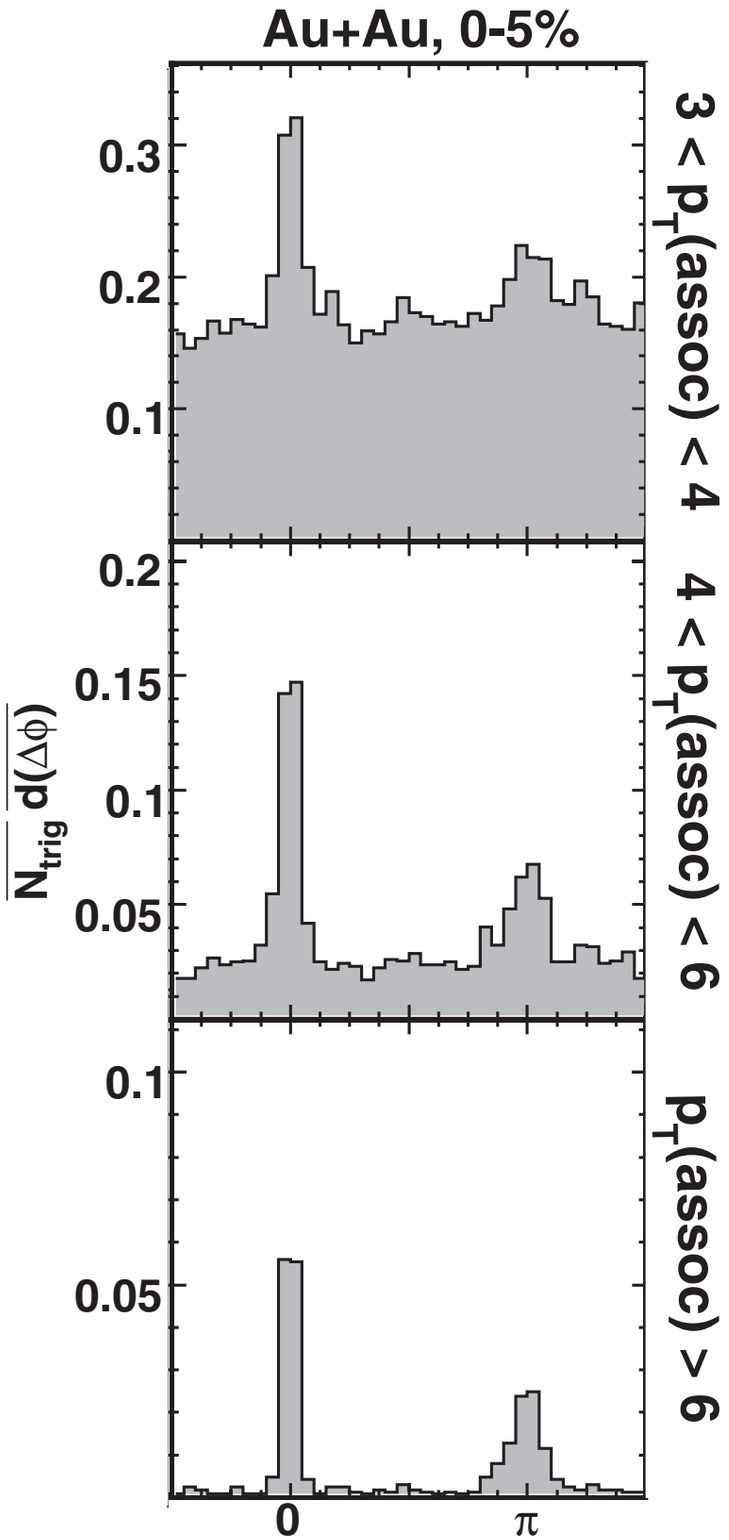


5.02TeV pPb

200GeV dAu

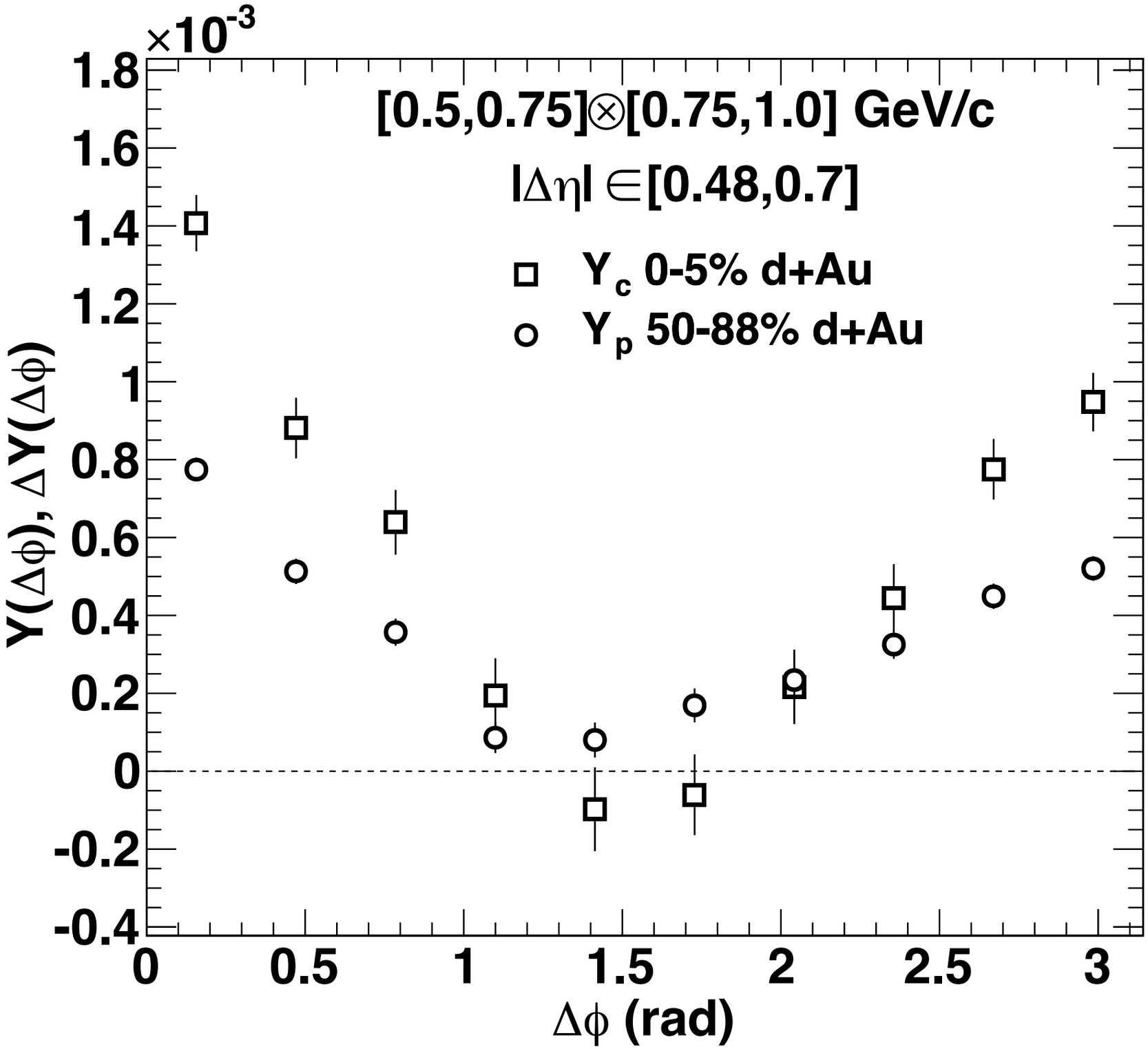
25x difference in collision energy
d-A vs p-A
large data sample already on tape

minimizing jet effect in PHENIX



- normal two particle correlations: look at as high p_T particles as possible
  - minimizes combinatoric background, maximizes jet correlations
- near side jets are a small $|\Delta\eta|$ correlation
  - keep one particle at very low p_T
    - maximize sensitivity to underlying event
  - select as large $|\Delta\eta|$ as possible ($|\eta| < 0.35$)
  - $0.48 < |\Delta\eta| < 0.7$

centrality dependence



central

peripheral

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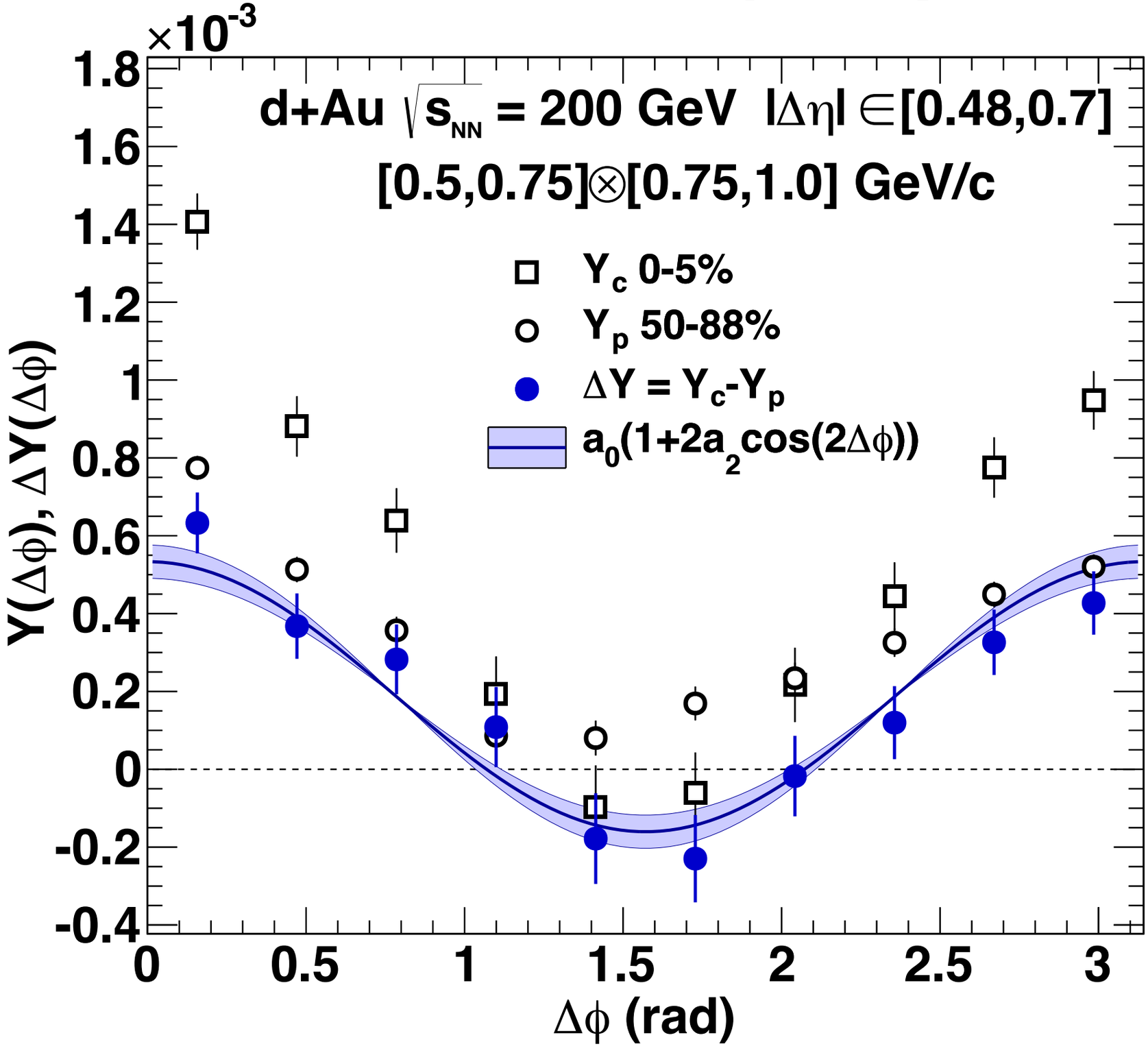
centrality dependence



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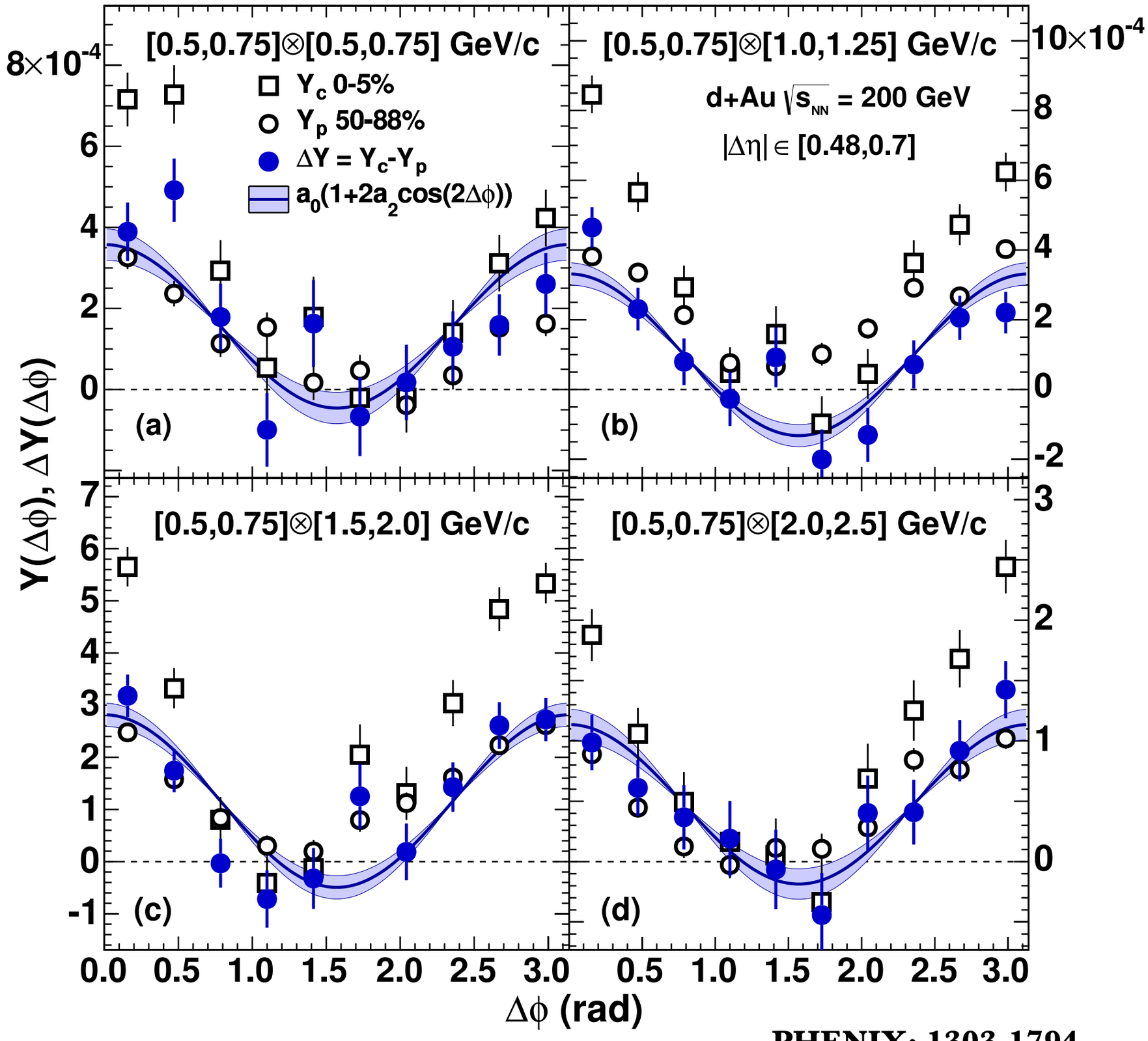
centrality dependence consistently described by cos2Δφ shape for many p_T bins



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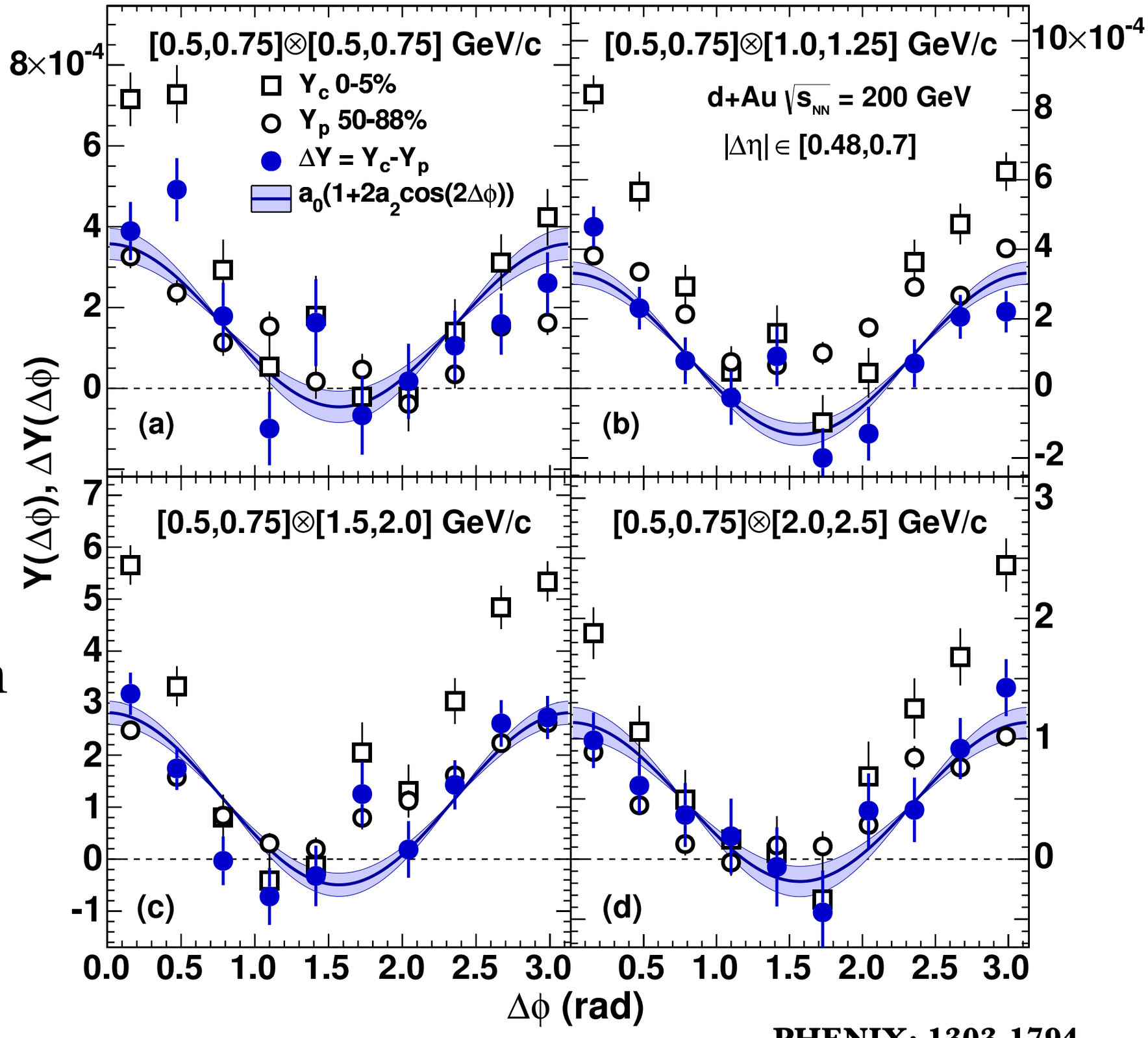
centrality dependence consistently described by cos2Δφ shape for many p_T bins

but is this just an artifact of the small $|\Delta\eta|$ acceptance?



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remaining jet effects?

issue: short range effects from centrality dependent jet modifications could modify near side correlations within small $|\Delta\eta|$

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- vary the minimum $|\Delta\eta|$ cut from 0.36 to 0.60
- look at the charge sign dependence:
  - jet correlations are enhanced for opposite sign pairs and suppressed for same sign pairs
- further studying with event generators
- look for truly long range correlations

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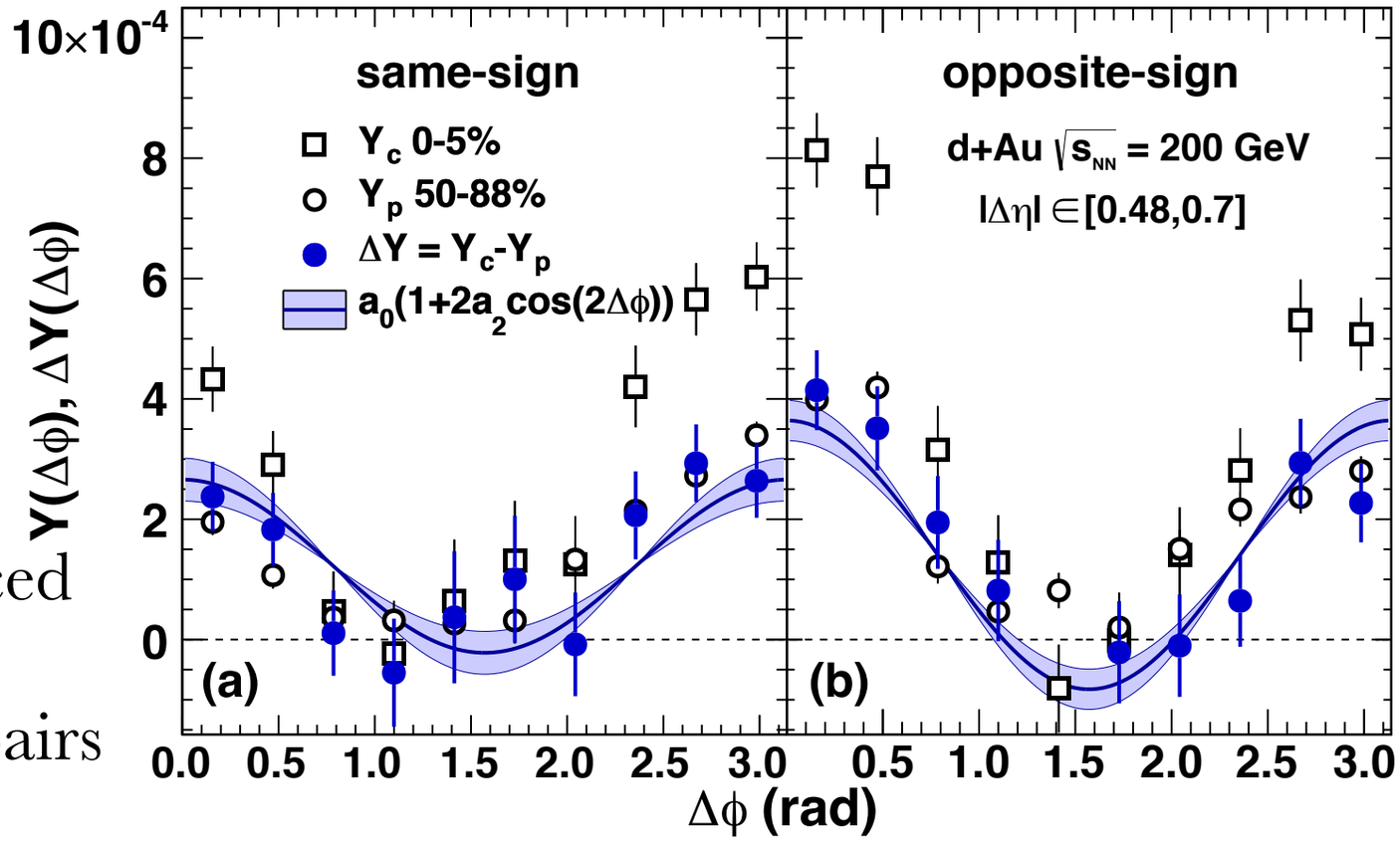

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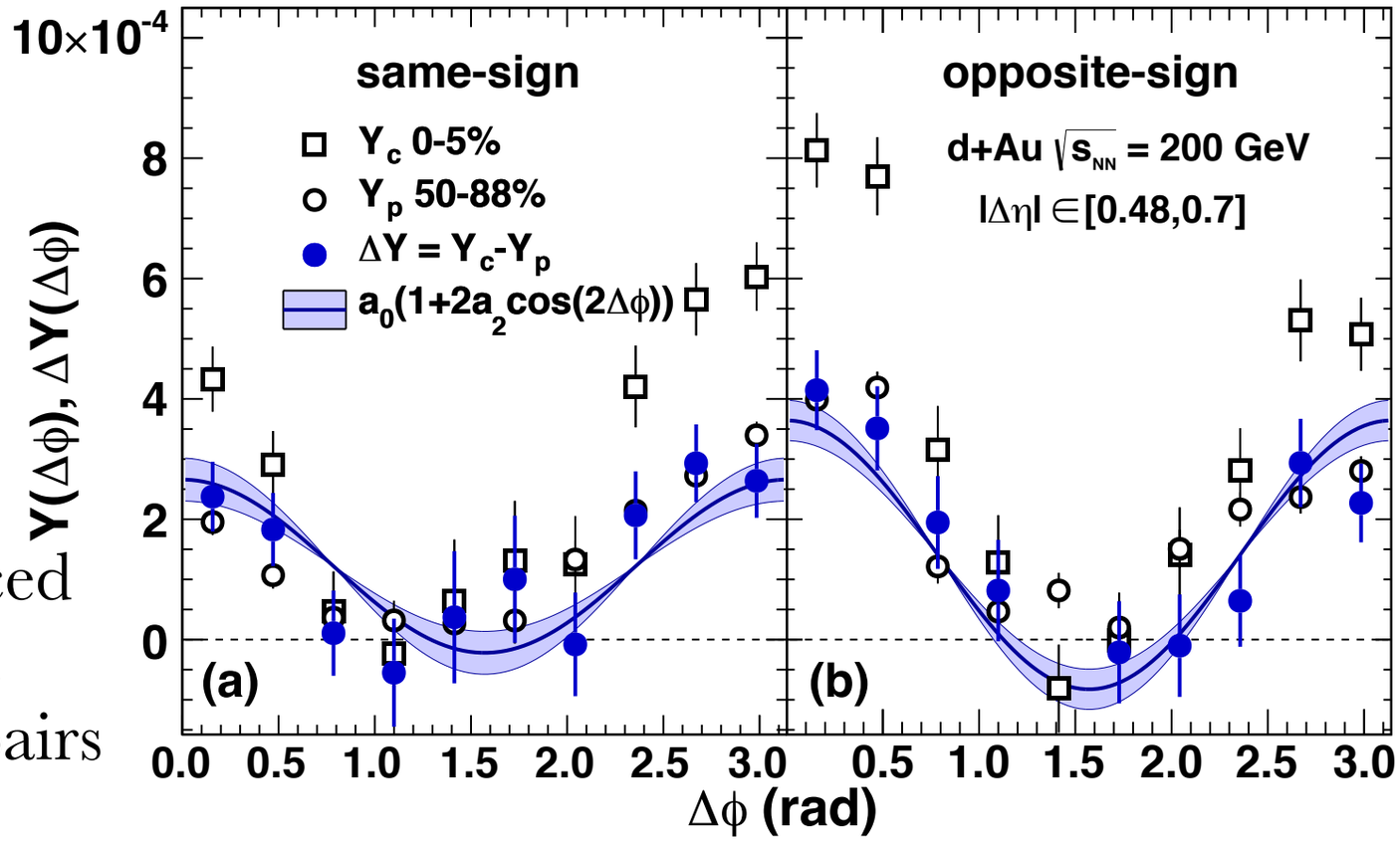

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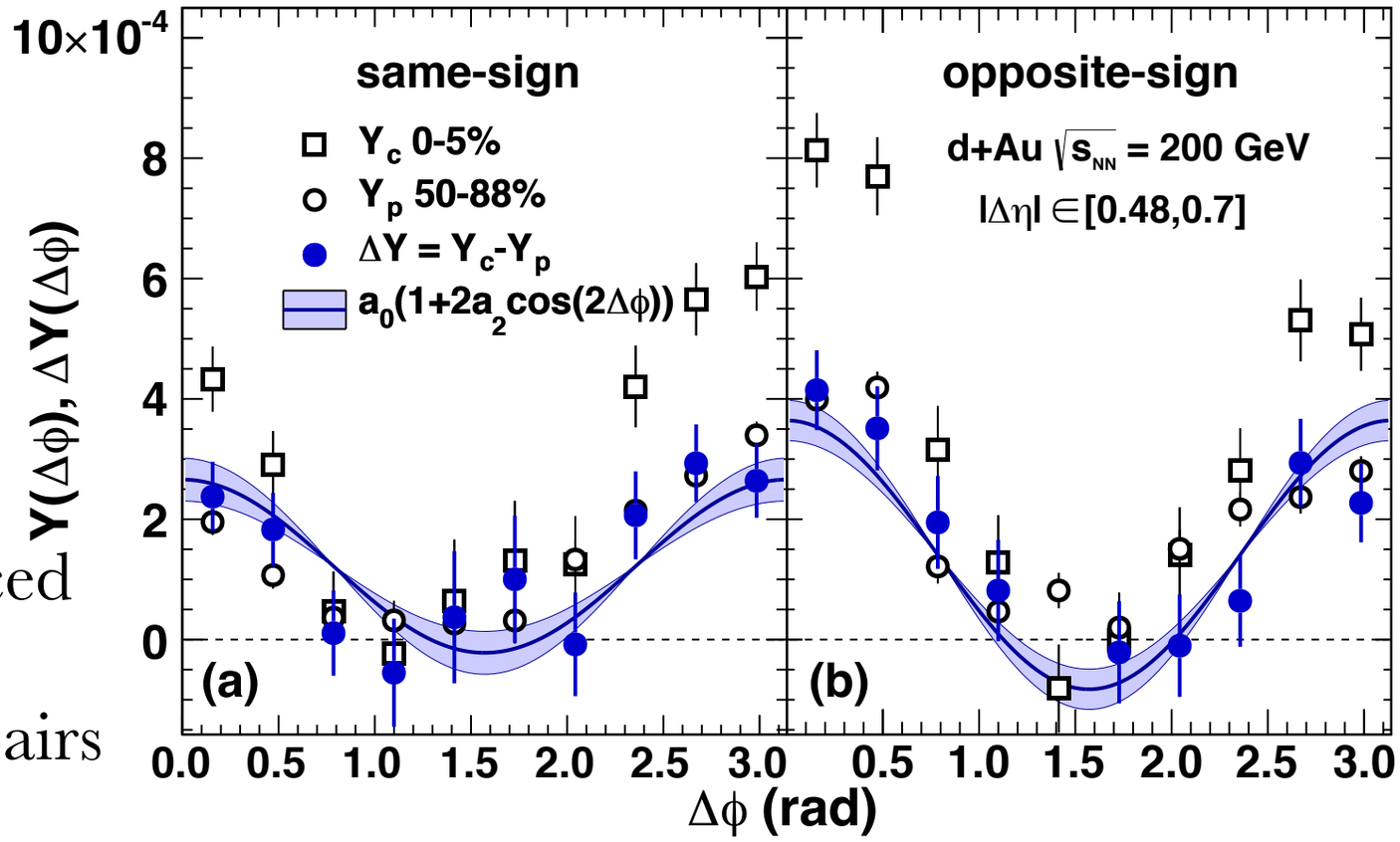

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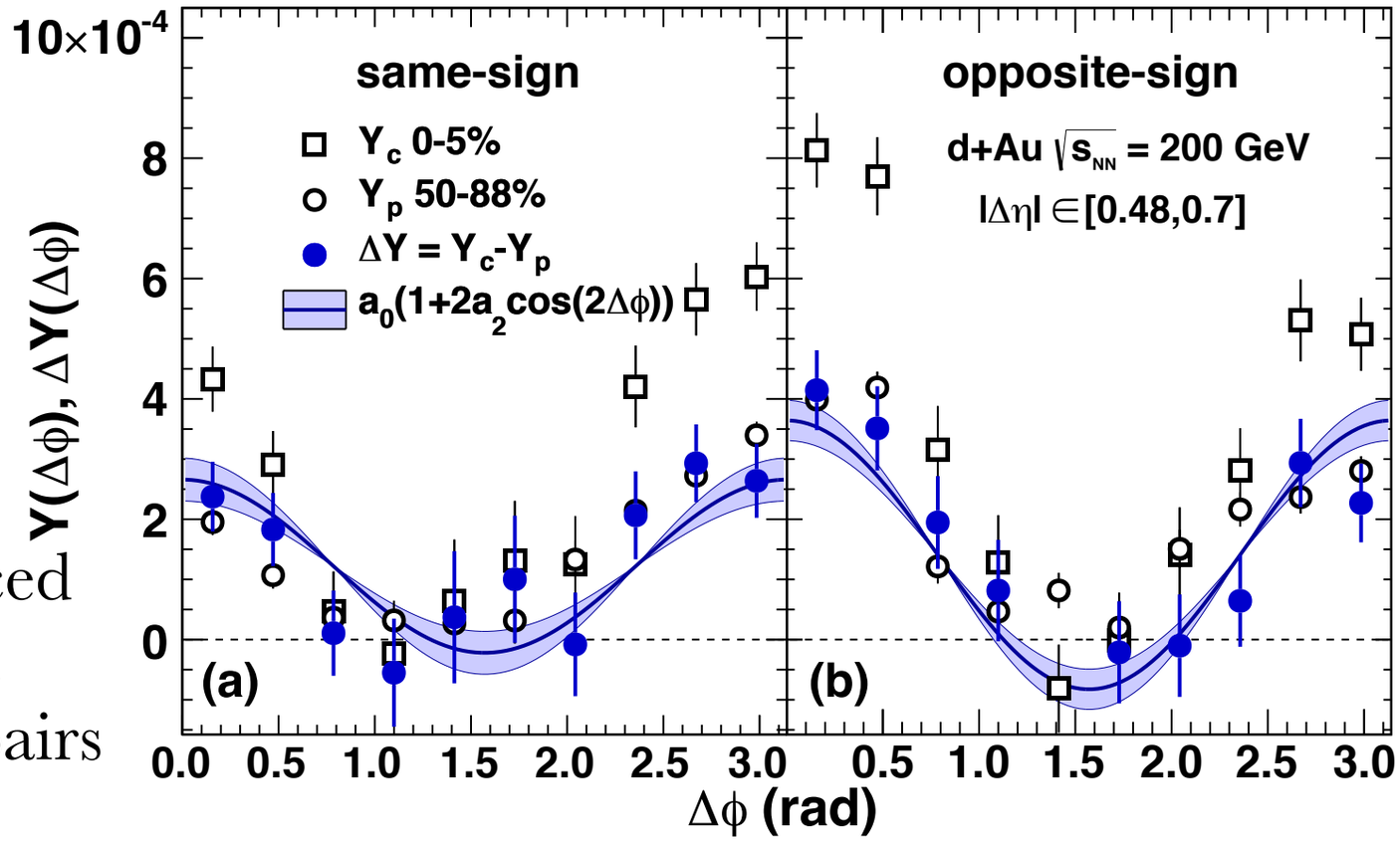
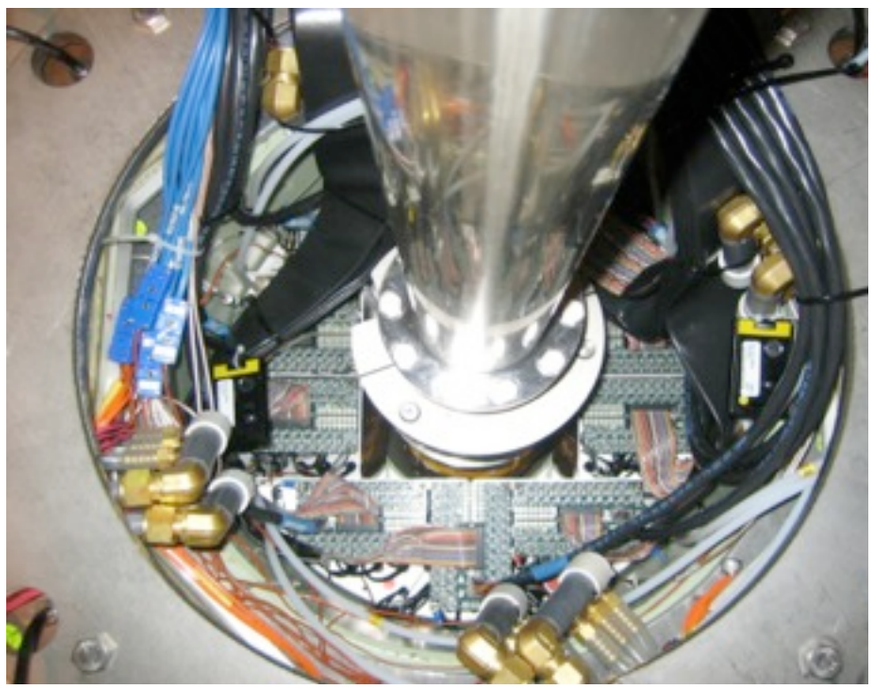


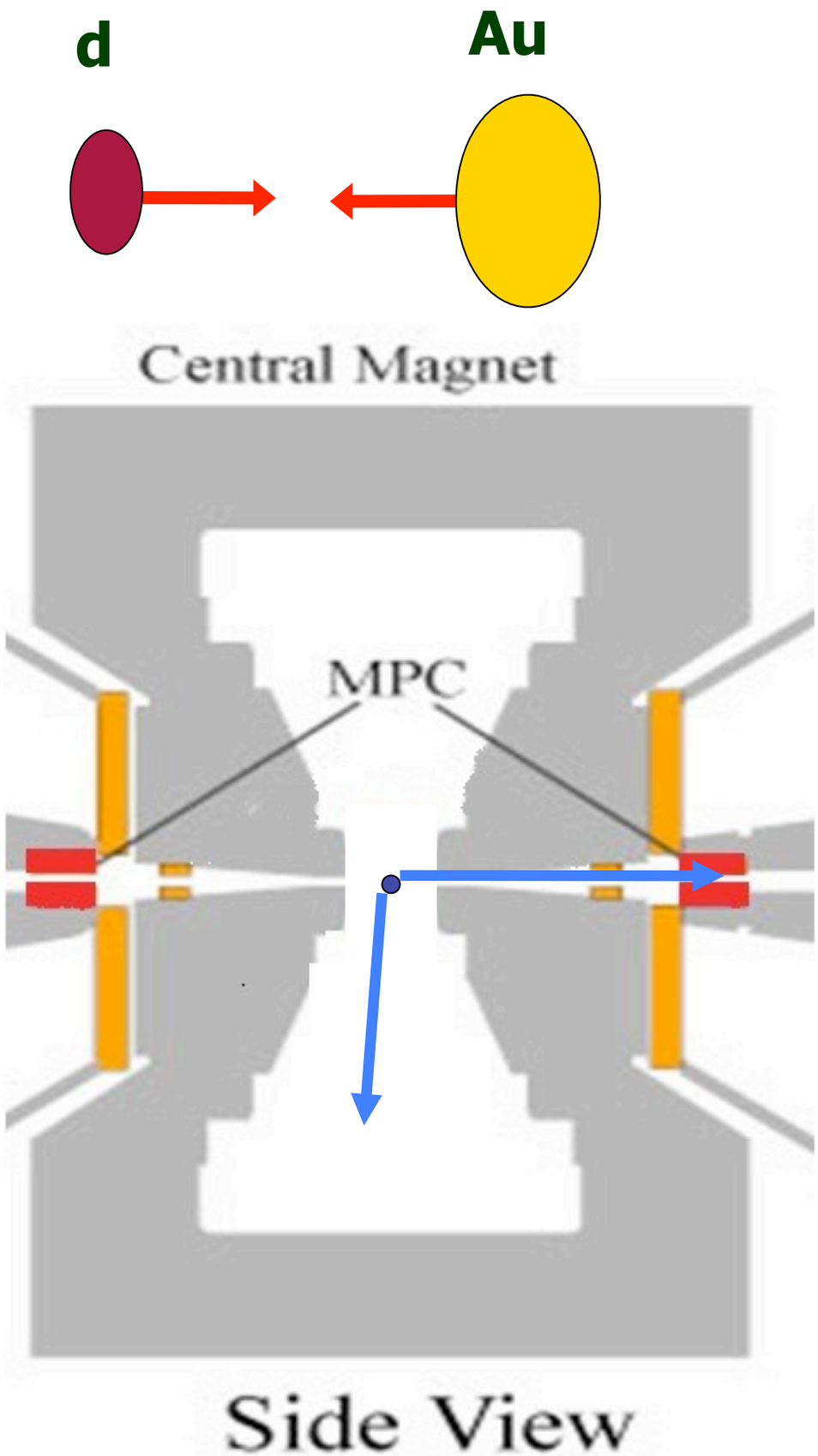
rapidity separated correlations

Muon Piston Calorimeters

both d-going & Au-going directions

$3 < |\eta| < 4$

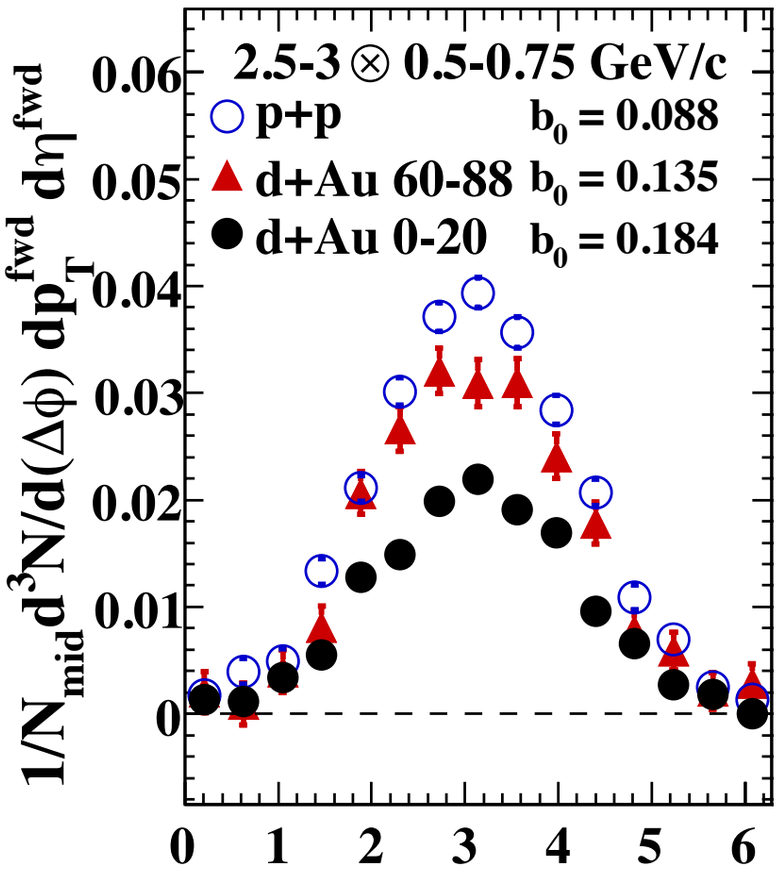




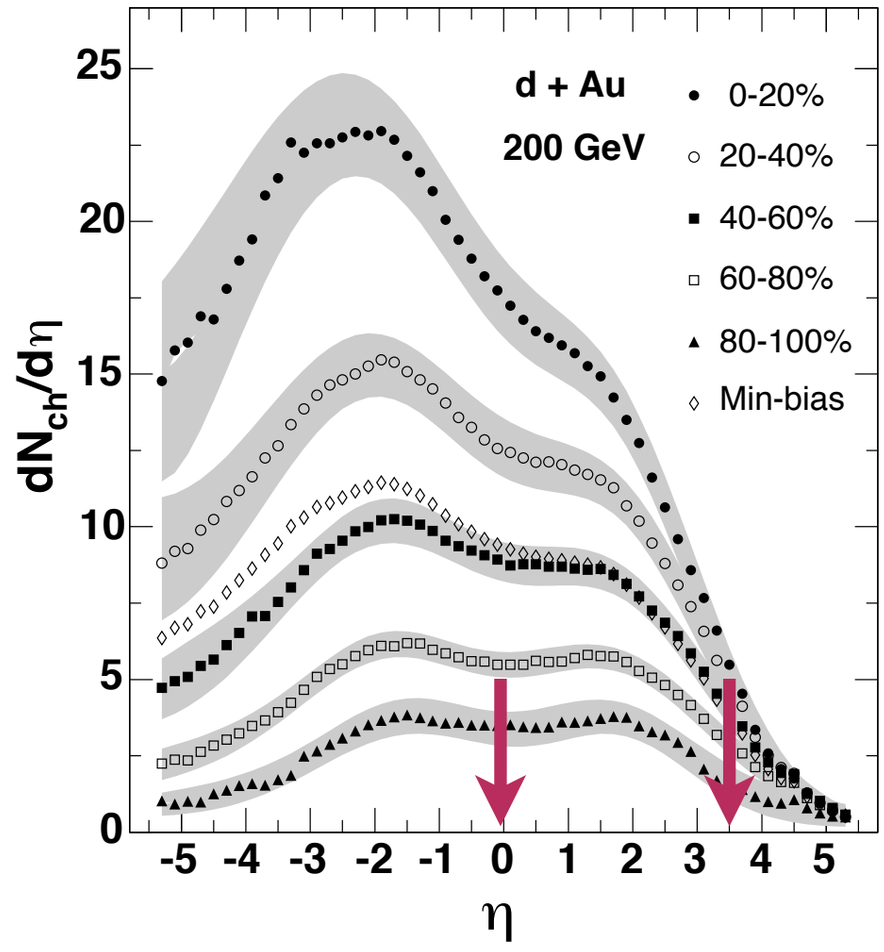
rapidity separated correlations

PRL 107, 172301 (2011) PHYSICAL REVIEW LETTERS week ending 21 OCTOBER 2011

Suppression of Back-to-Back Hadron Pairs at Forward Rapidity in d + Au Collisions at $\sqrt{s_{NN}} = 200$ GeV



PHOBOS PRC72 031901

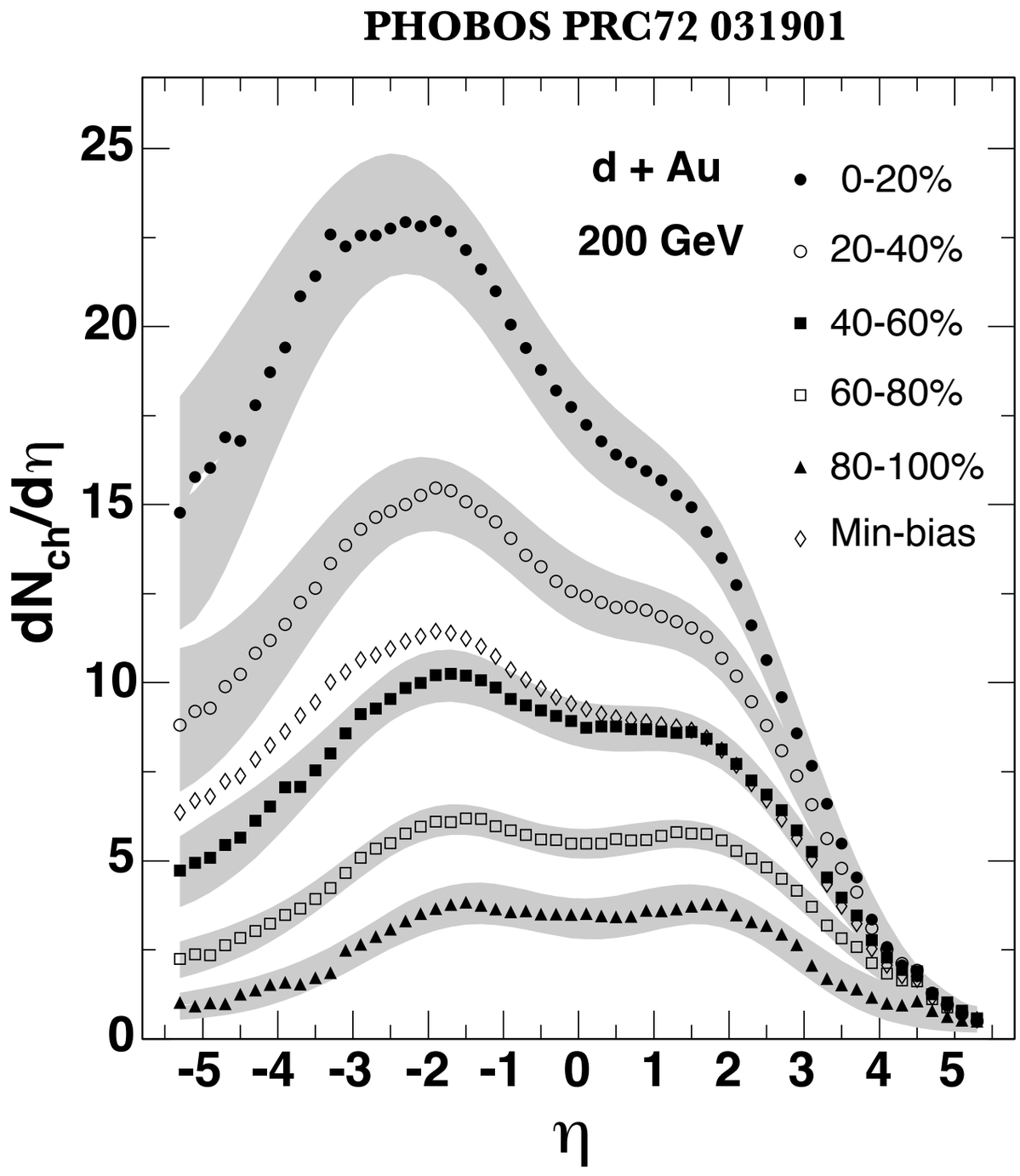


no evidence for long range correlation at $\Delta\phi \sim 0$

however, this is at relatively high p_T and with a particle in the d-going direction→not the most sensitive place to look...

extending forward/backward correlations

- very low E_T in MPC by using energy flow rather than reconstructed particles
  - sensitivity to bulk particles in calorimeter measurement
    - correlate with central arm: long range: $3 < |\Delta\eta| < 4$
- separate d-going and Au-going phenomena



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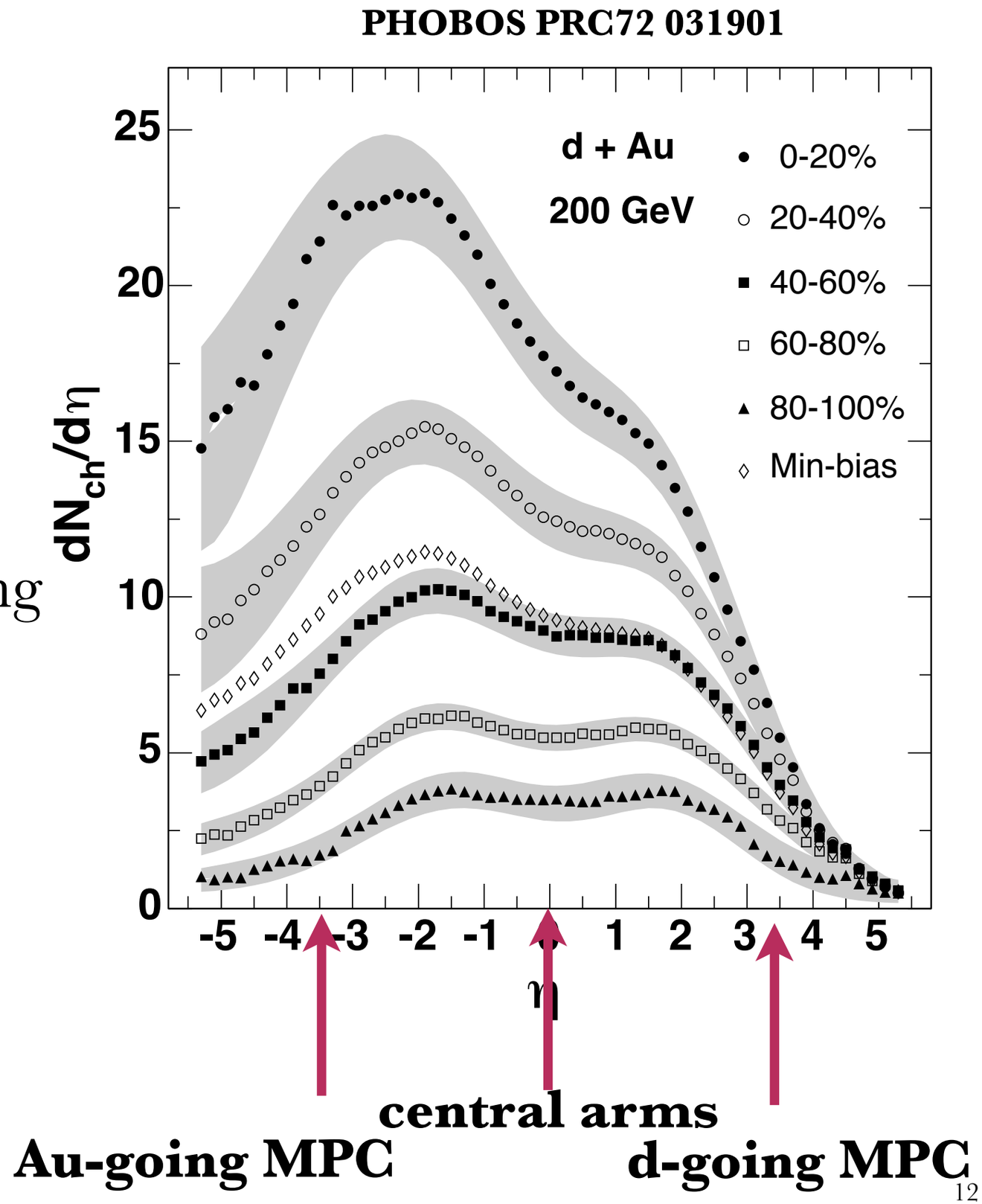
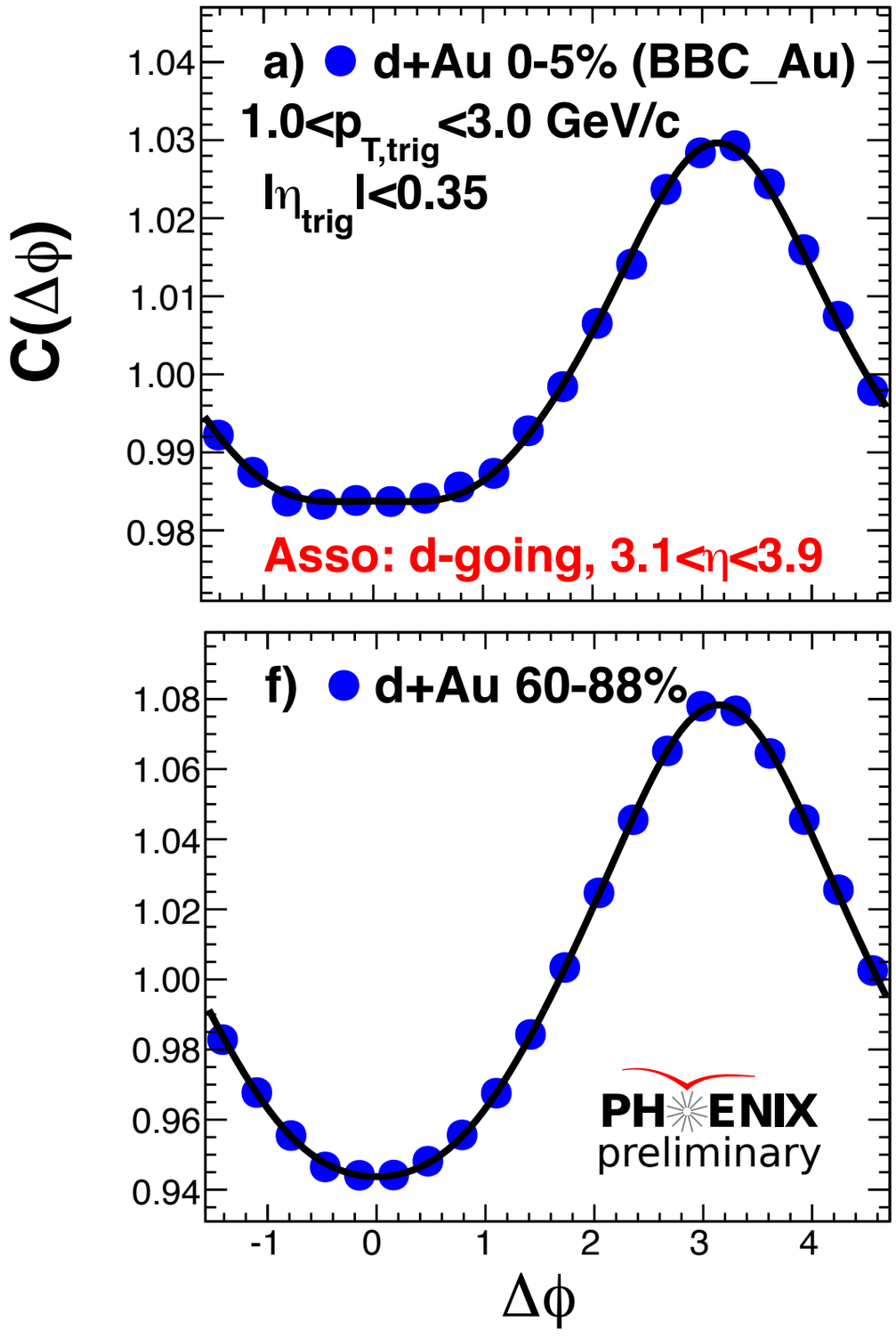
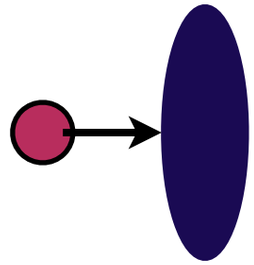
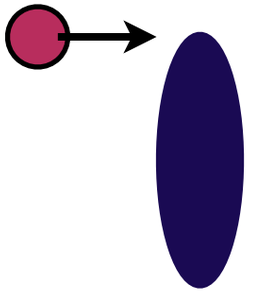
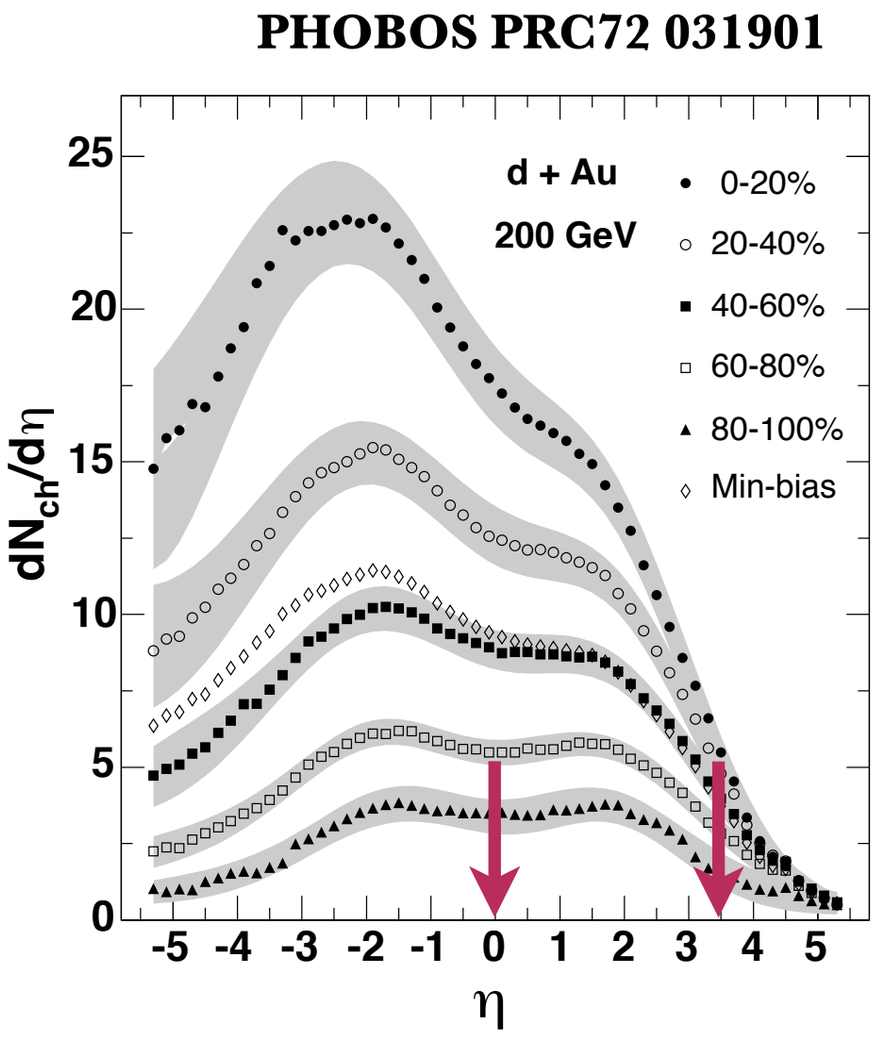


mid/d-going correlations



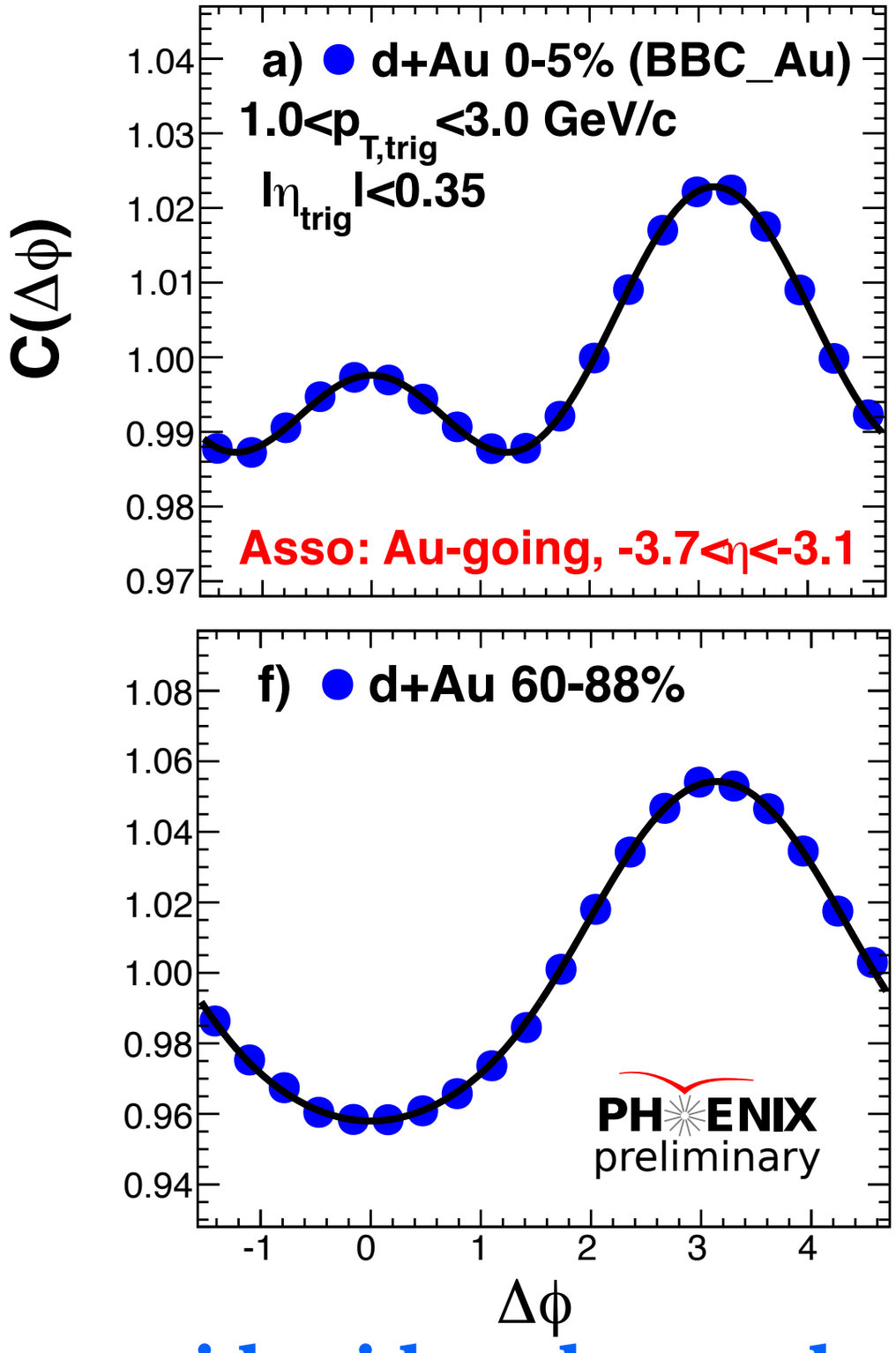


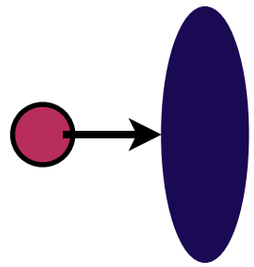


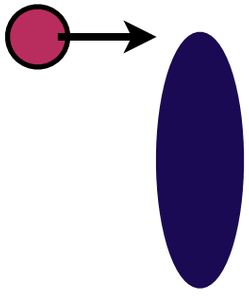


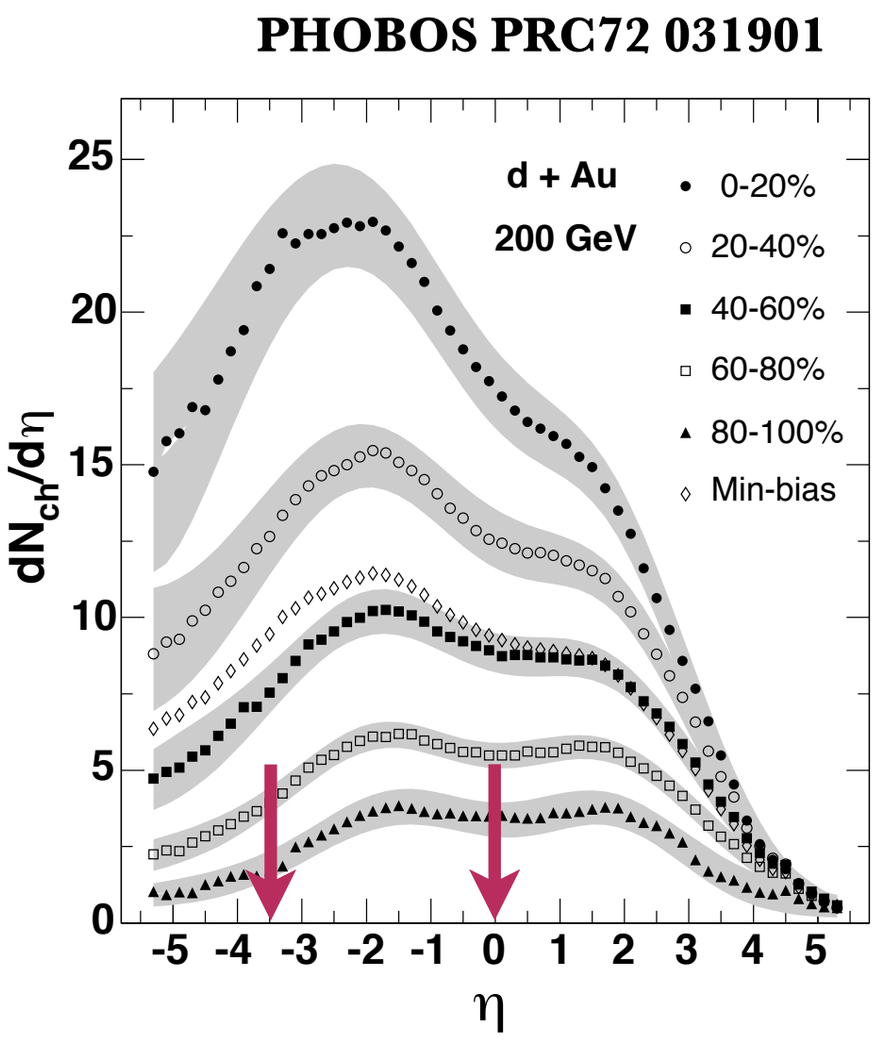
no small Δφ bump, some shape change with centrality

mid/Au-going correlations







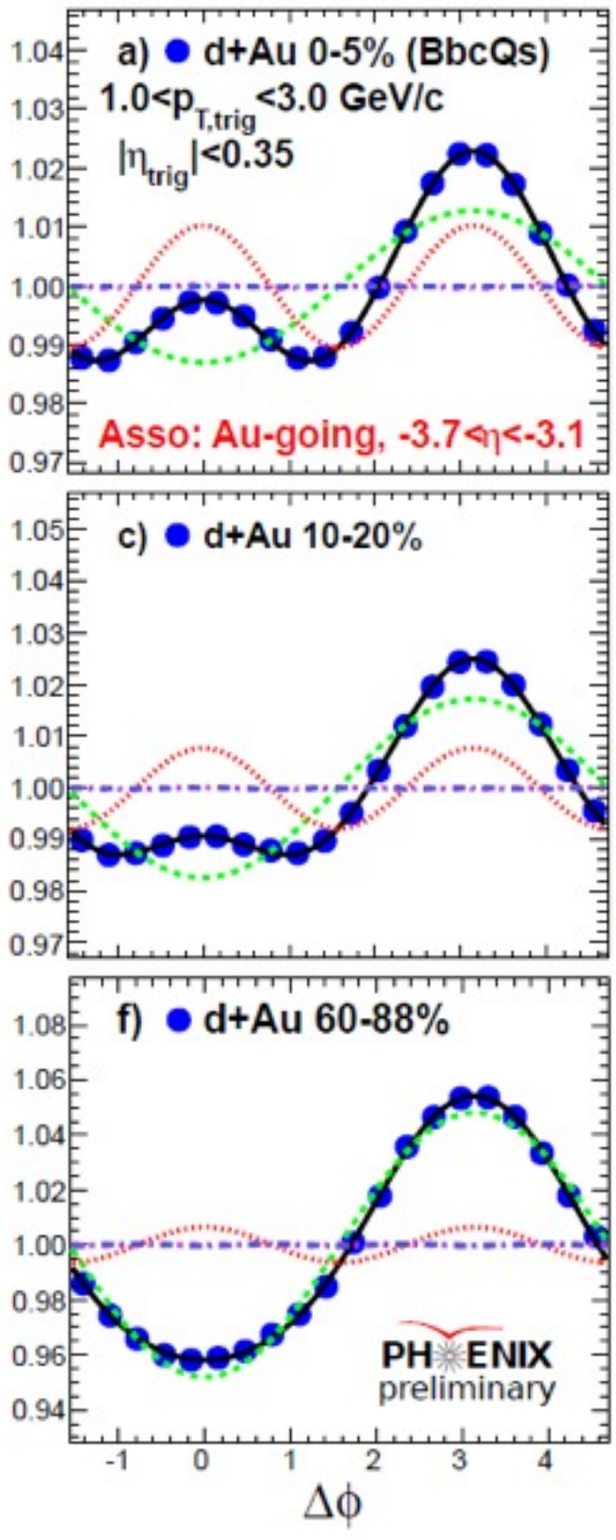


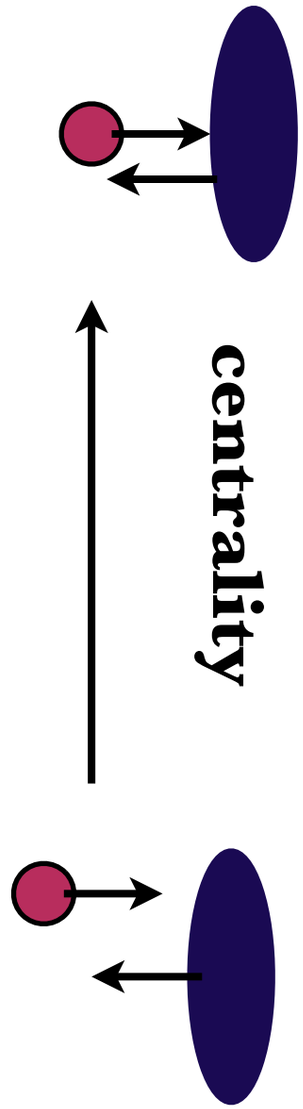
near side ridge observed at large Δη in central dAu collisions

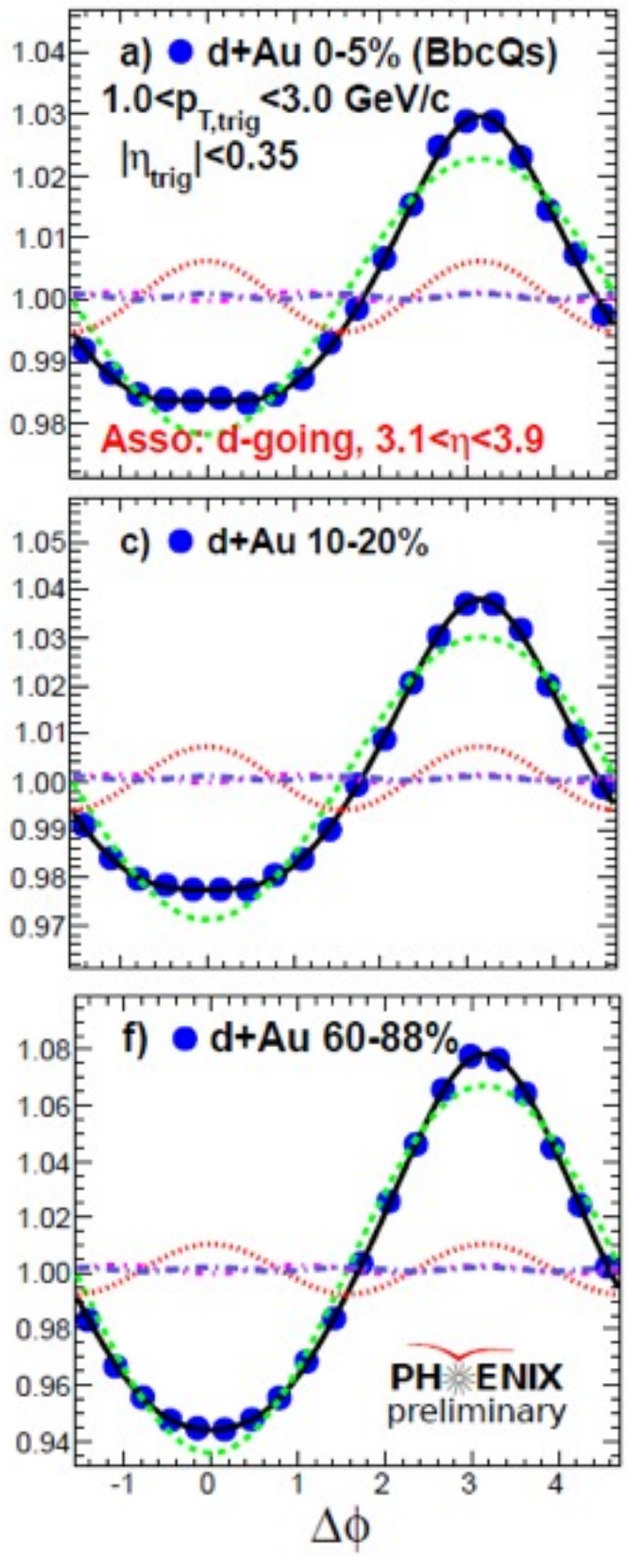
η dependence

Au-going

d-going



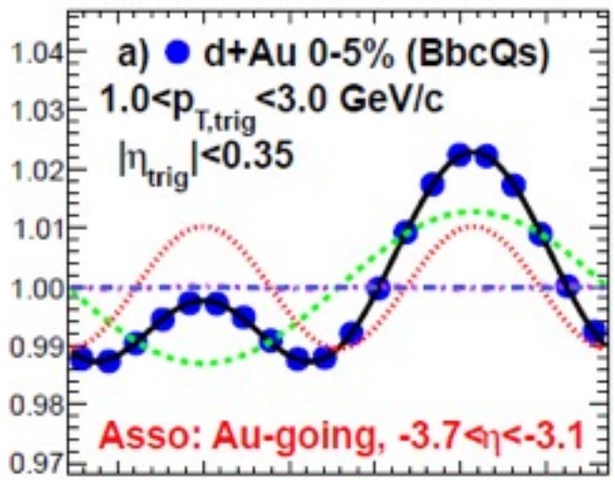


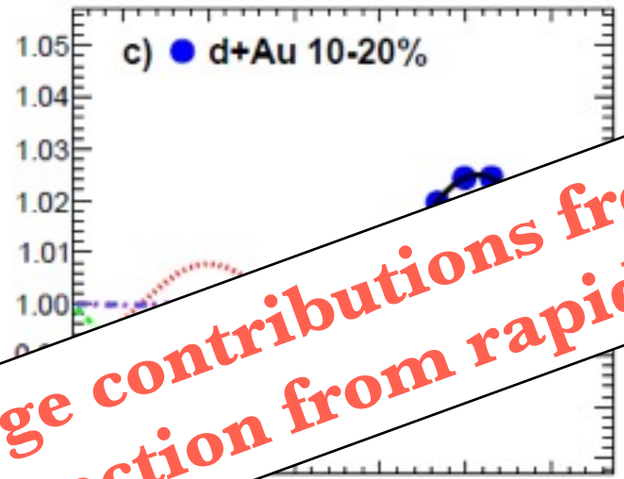


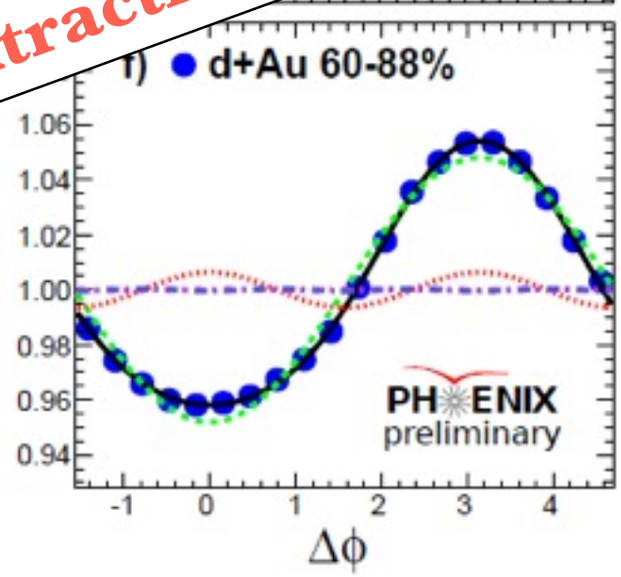
η dependence

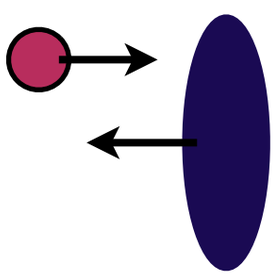
Au-going

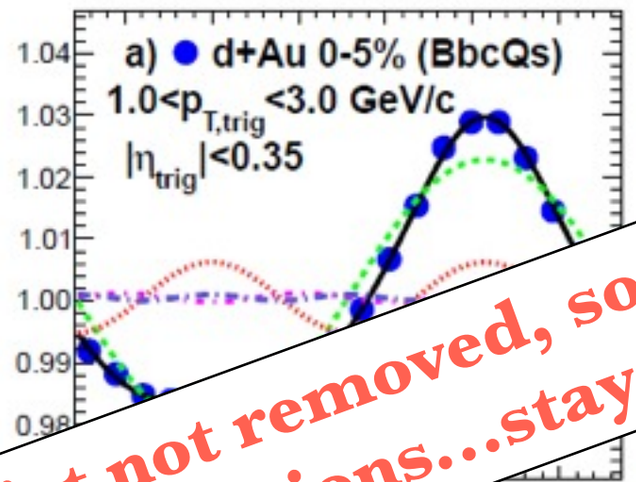
d-going

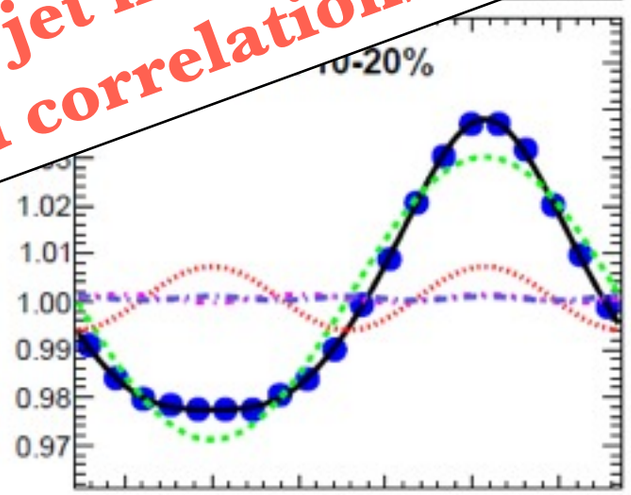


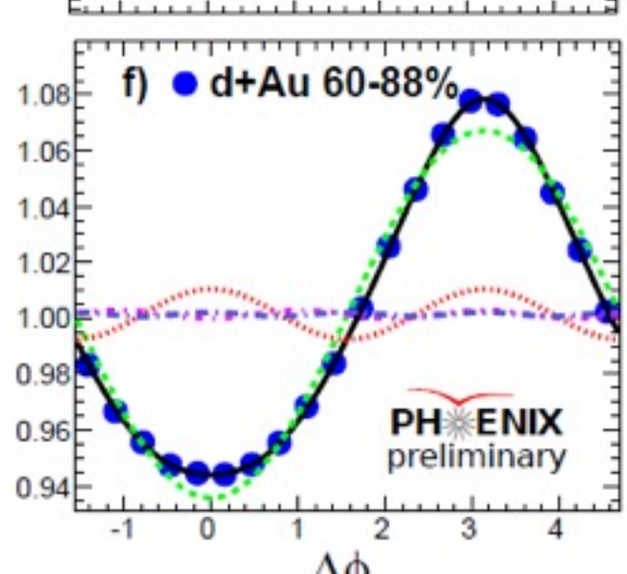






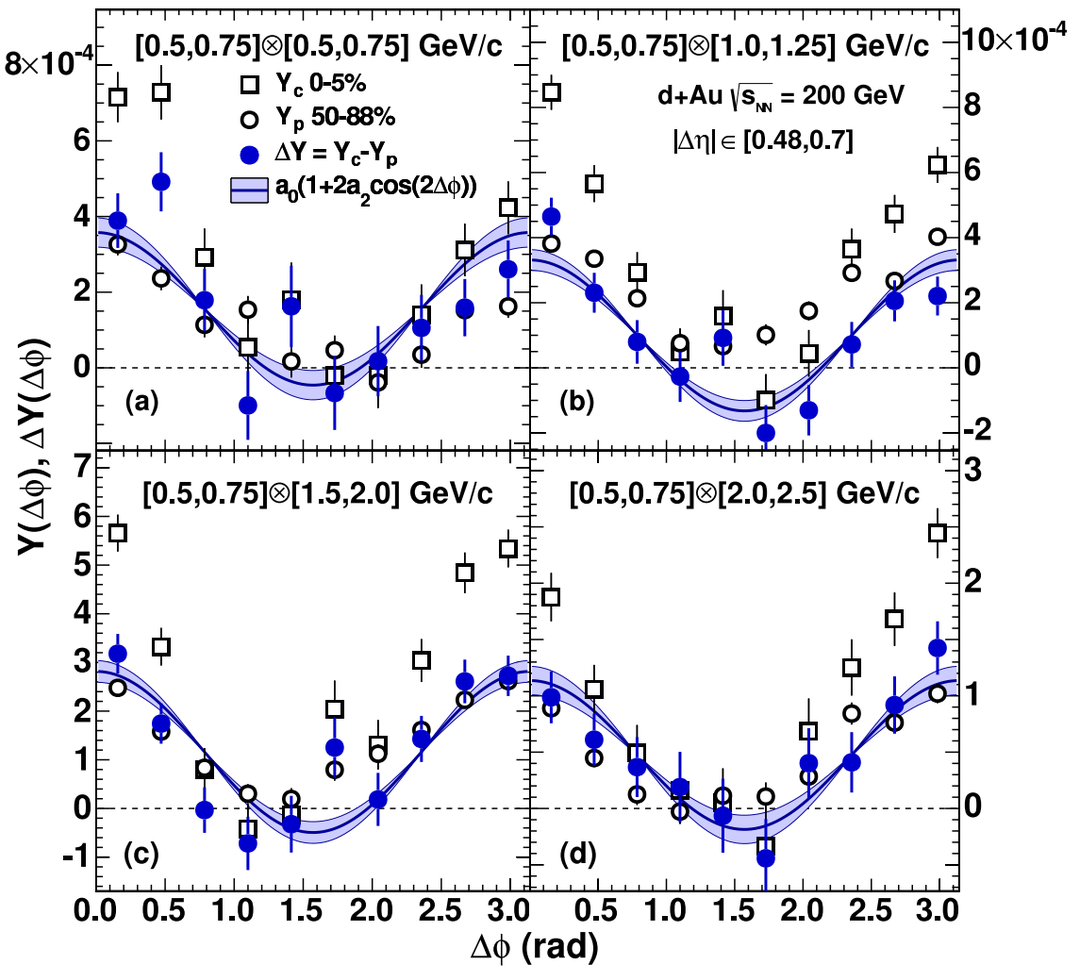


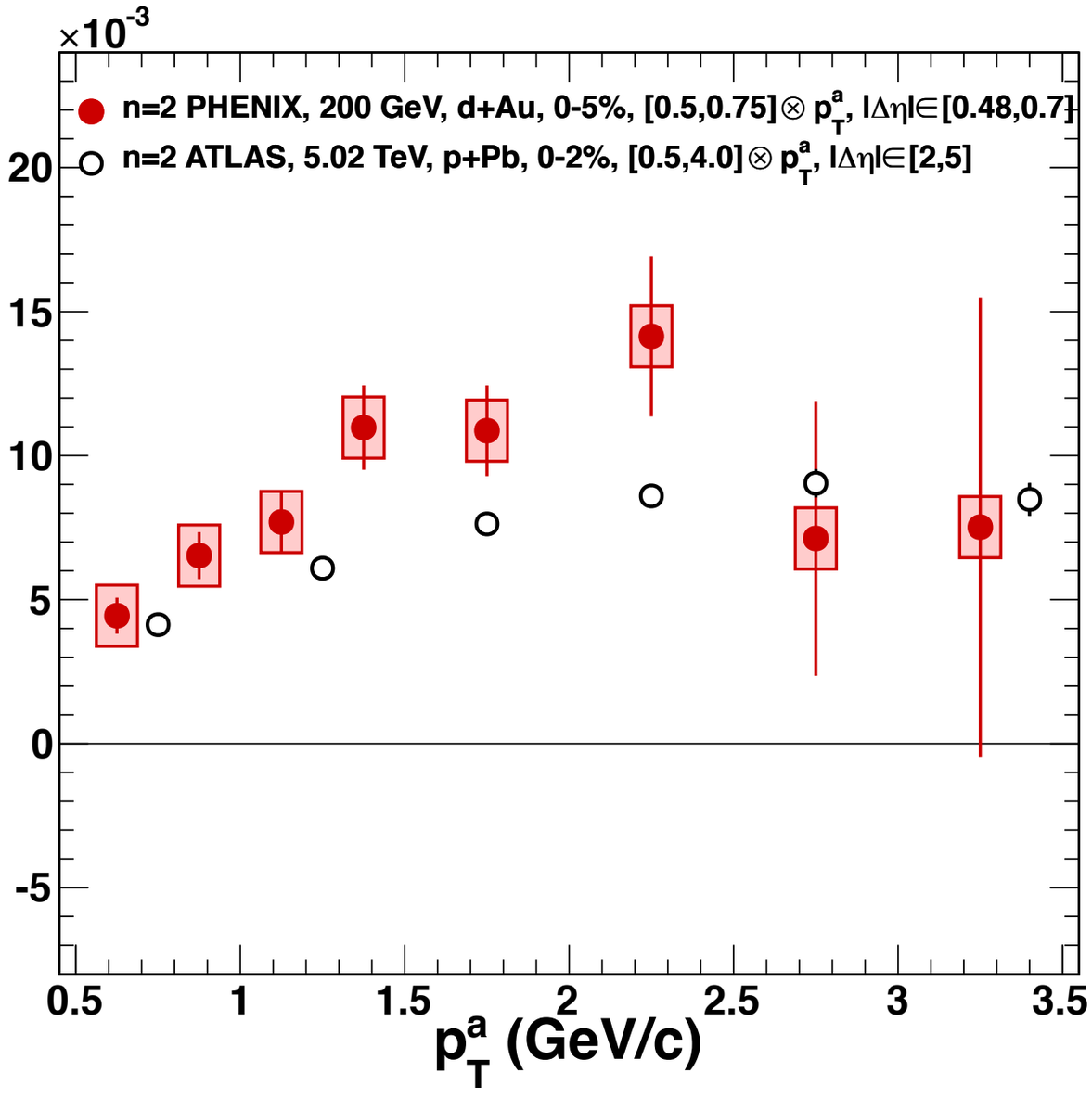




large contributions from away side jet not removed, so no v_N extraction from rapidity separated correlations…stay tuned!

back to mid-rapidity





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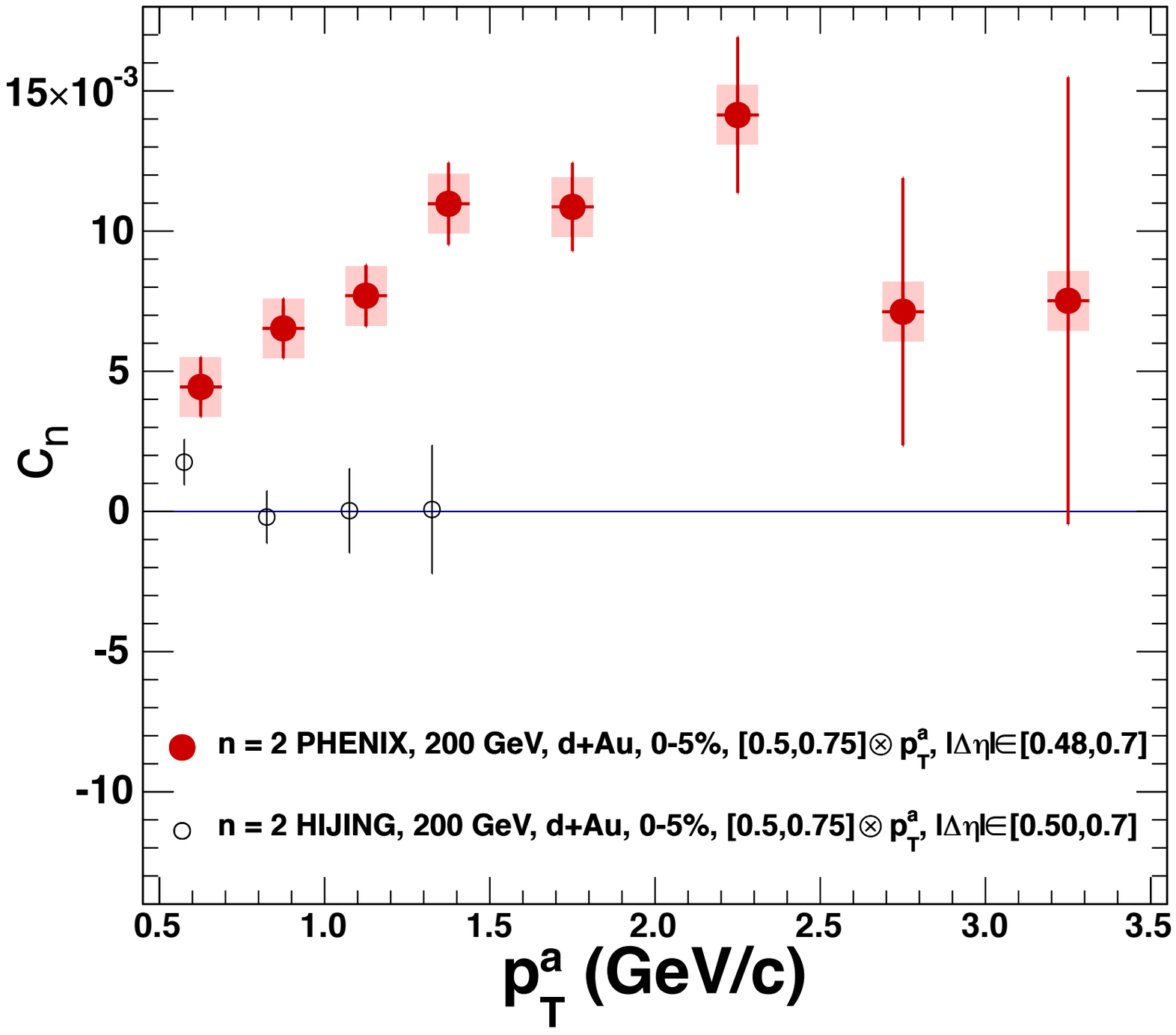
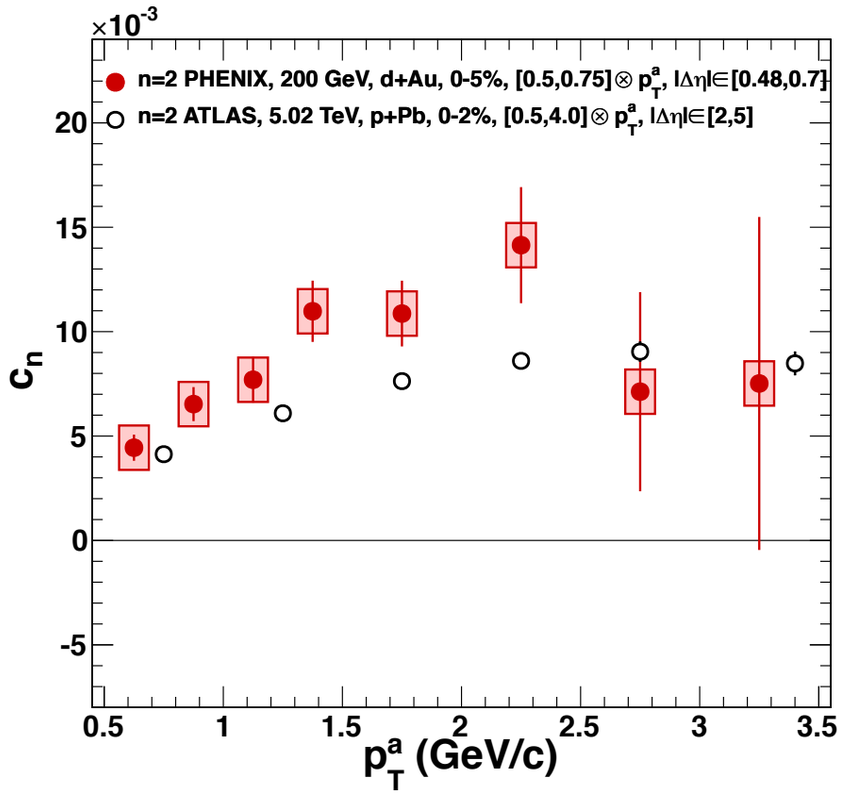
Hijing expectations?

- HIJING has no flow, no CGC
- perform the same study with HIJING as in the data

HIJING c_2 consistent with 0, much smaller than in data

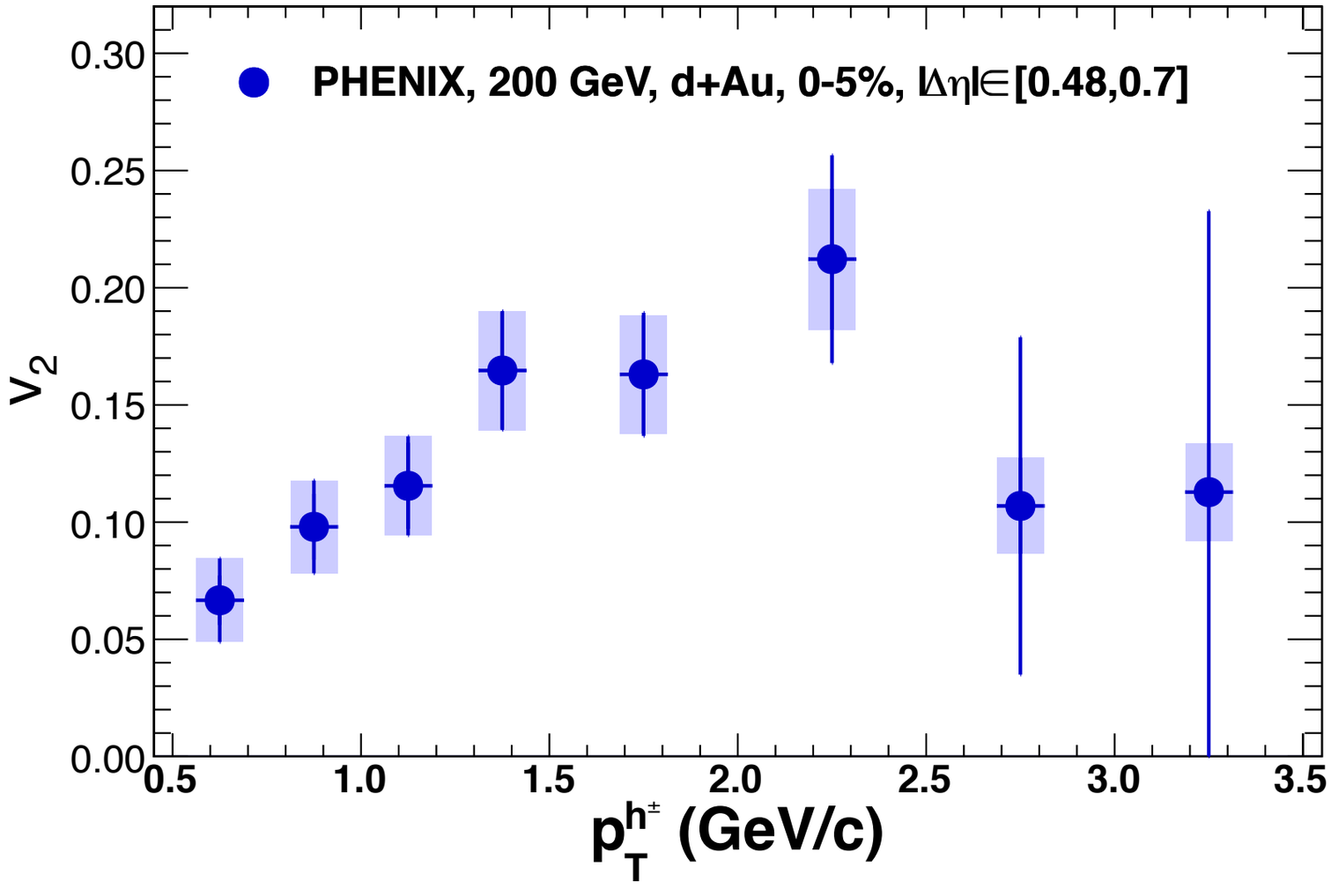


extract v_2 via factorization



$c2(p_{T,a},p_{T,b}) = v2(p_{T,a})v2(p_{T,b})$

→factorization assumption: two particle modulation is the product of the single particle anisotropies, no inconsistencies with this assumption found



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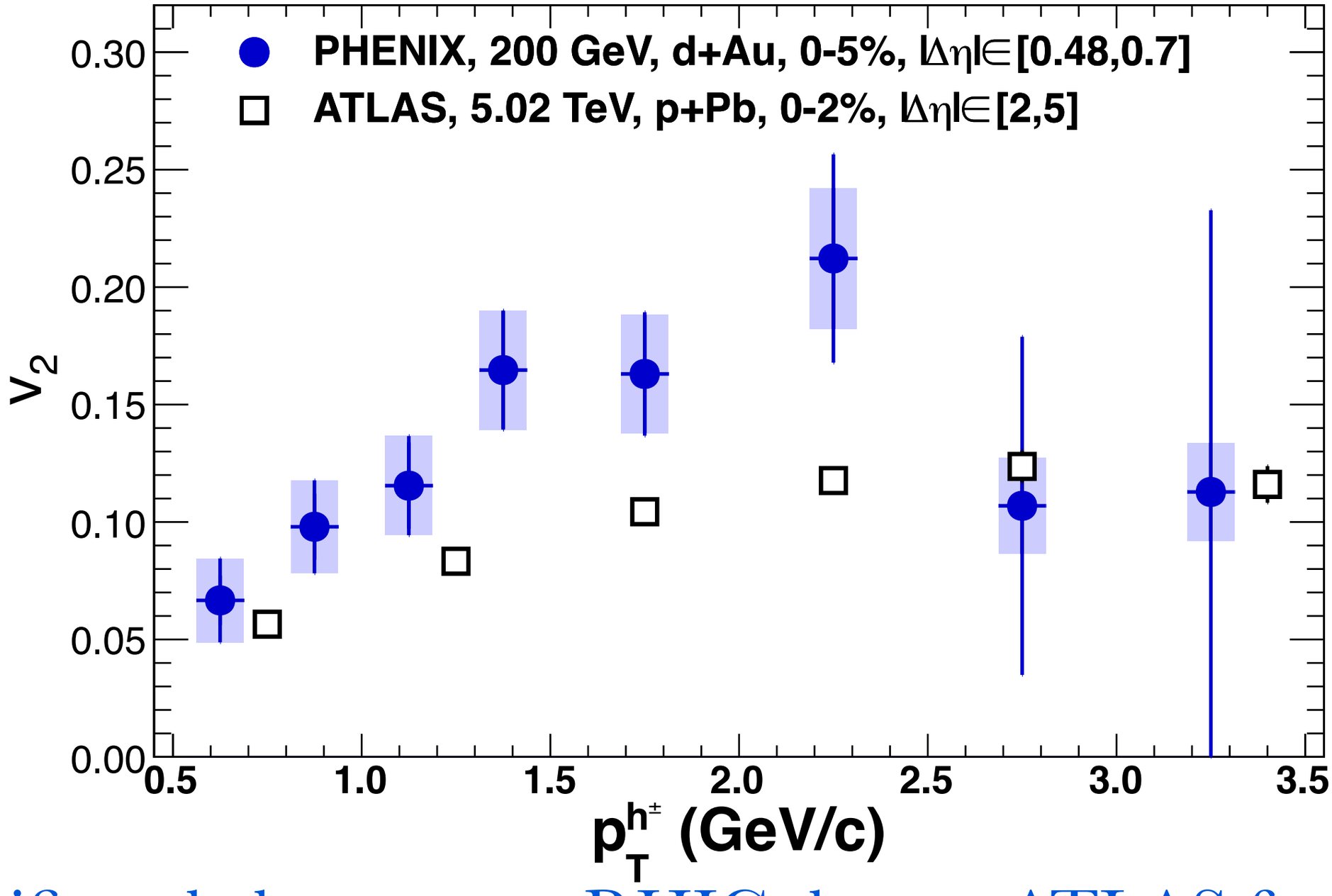
comparison with LHC results



significantly larger v_2 at RHIC than at ATLAS for similar centrality selection

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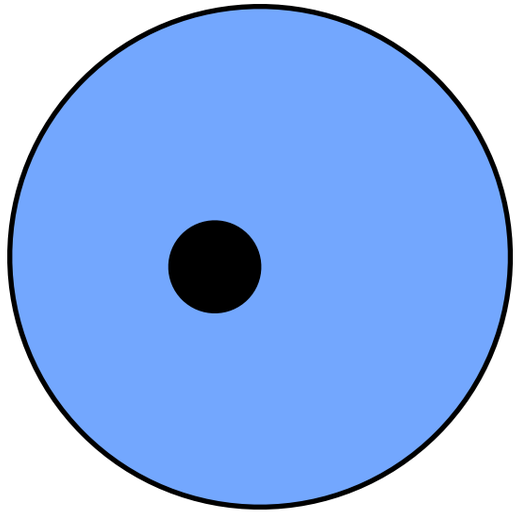
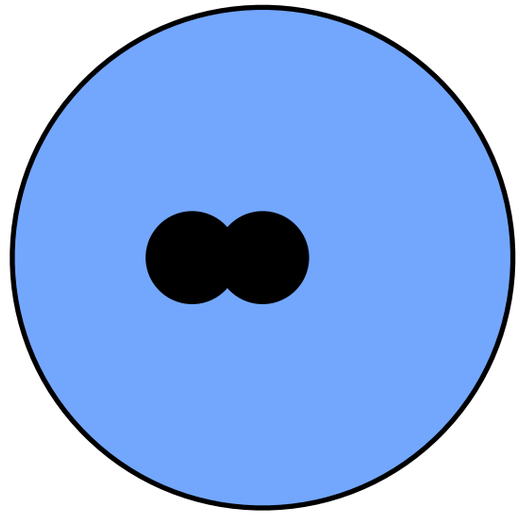
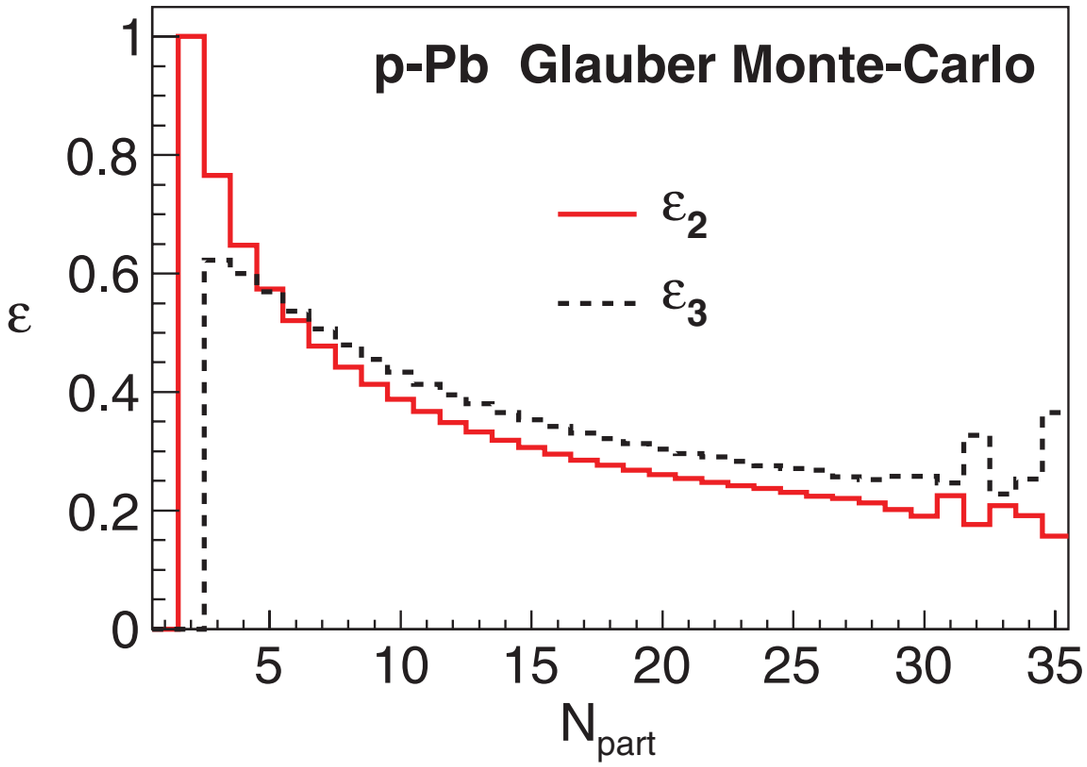
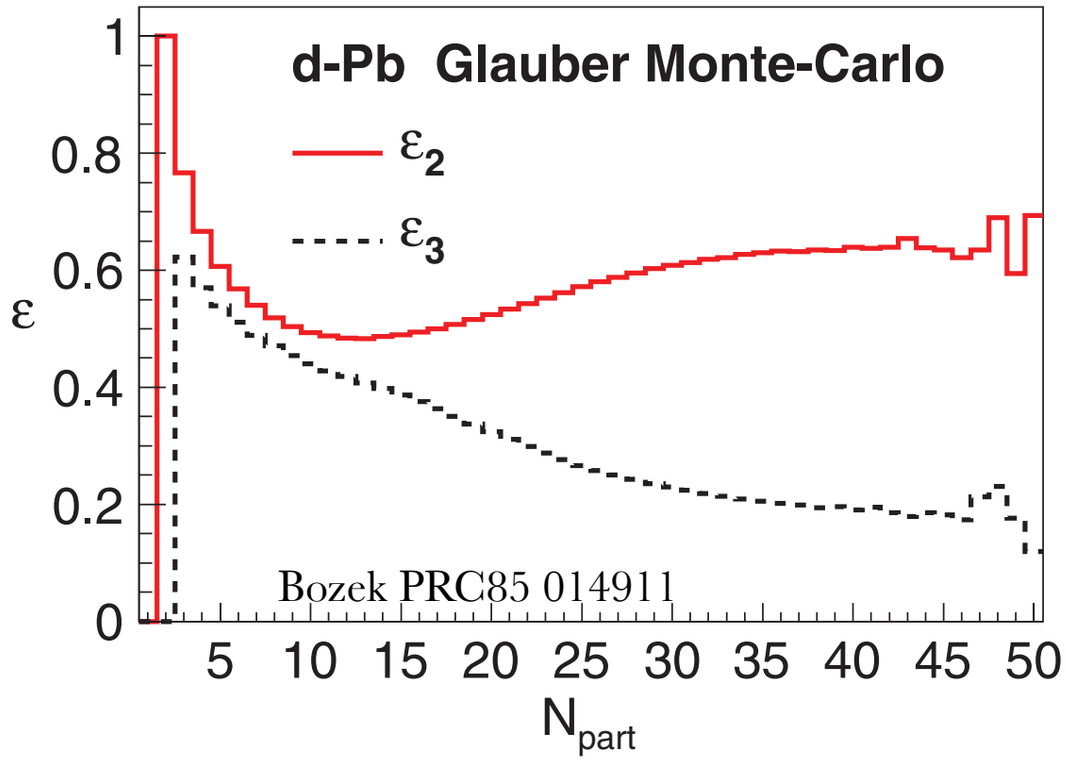
pPb vs dAu

pPb vs dAu

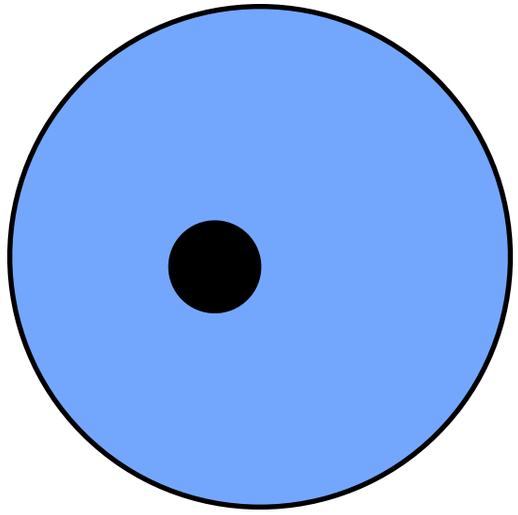


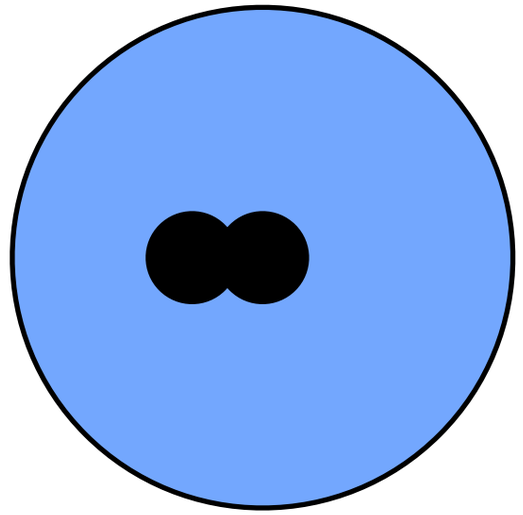


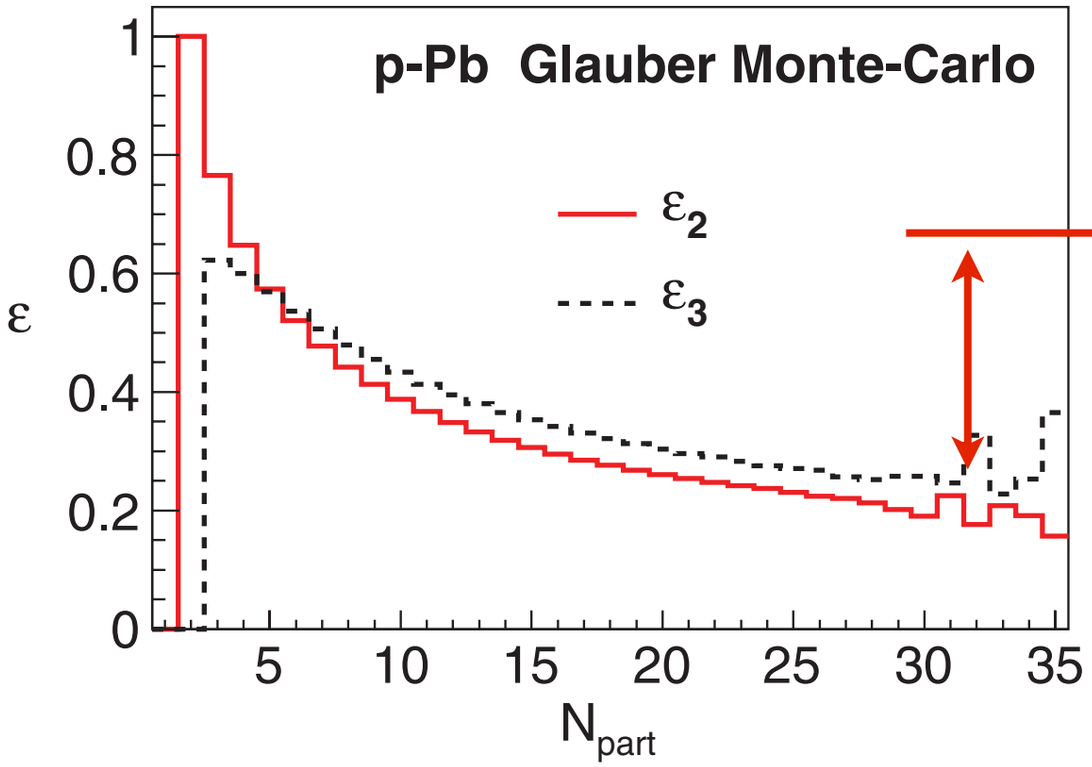

p-Pb Glauber Monte-Carlo
ε2
ε3
ε
Npart
0
0.2
0.4
0.6
0.8
1
5
10
15
20
25
30
35

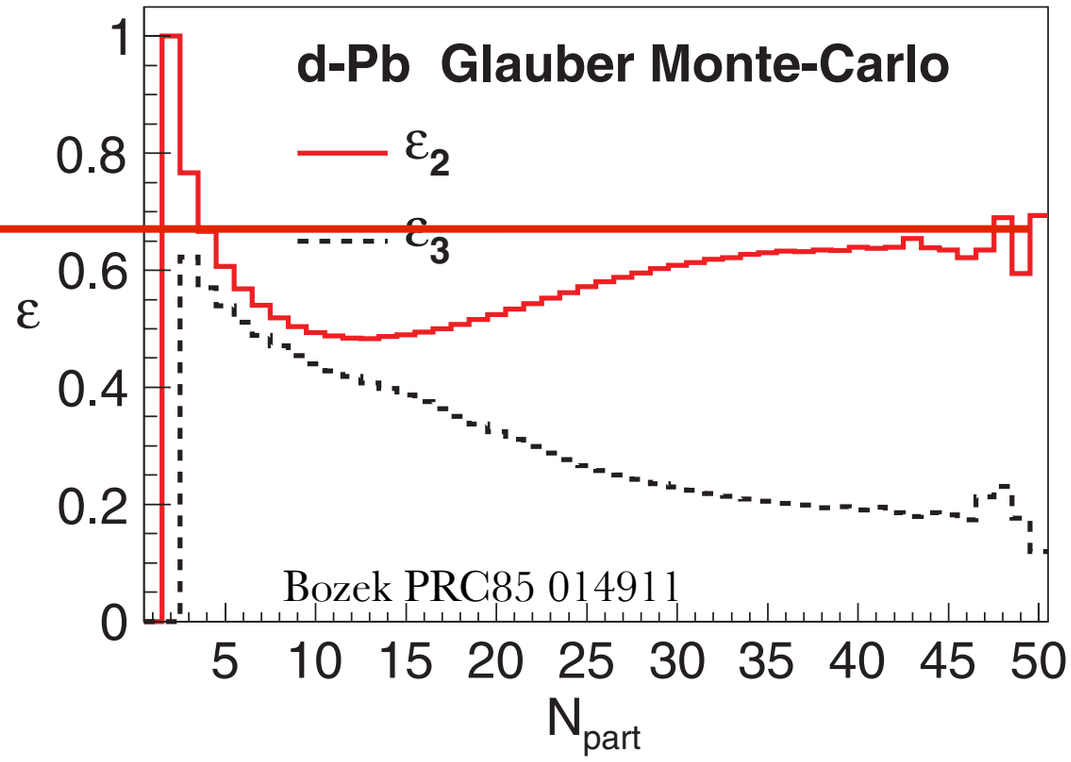

d-Pb Glauber Monte-Carlo
ε2
ε3
ε
Npart
Bozek PRC85 014911
0
0.2
0.4
0.6
0.8
1
5
10
15
20
25
30
35
40
45
50

pPb vs dAu



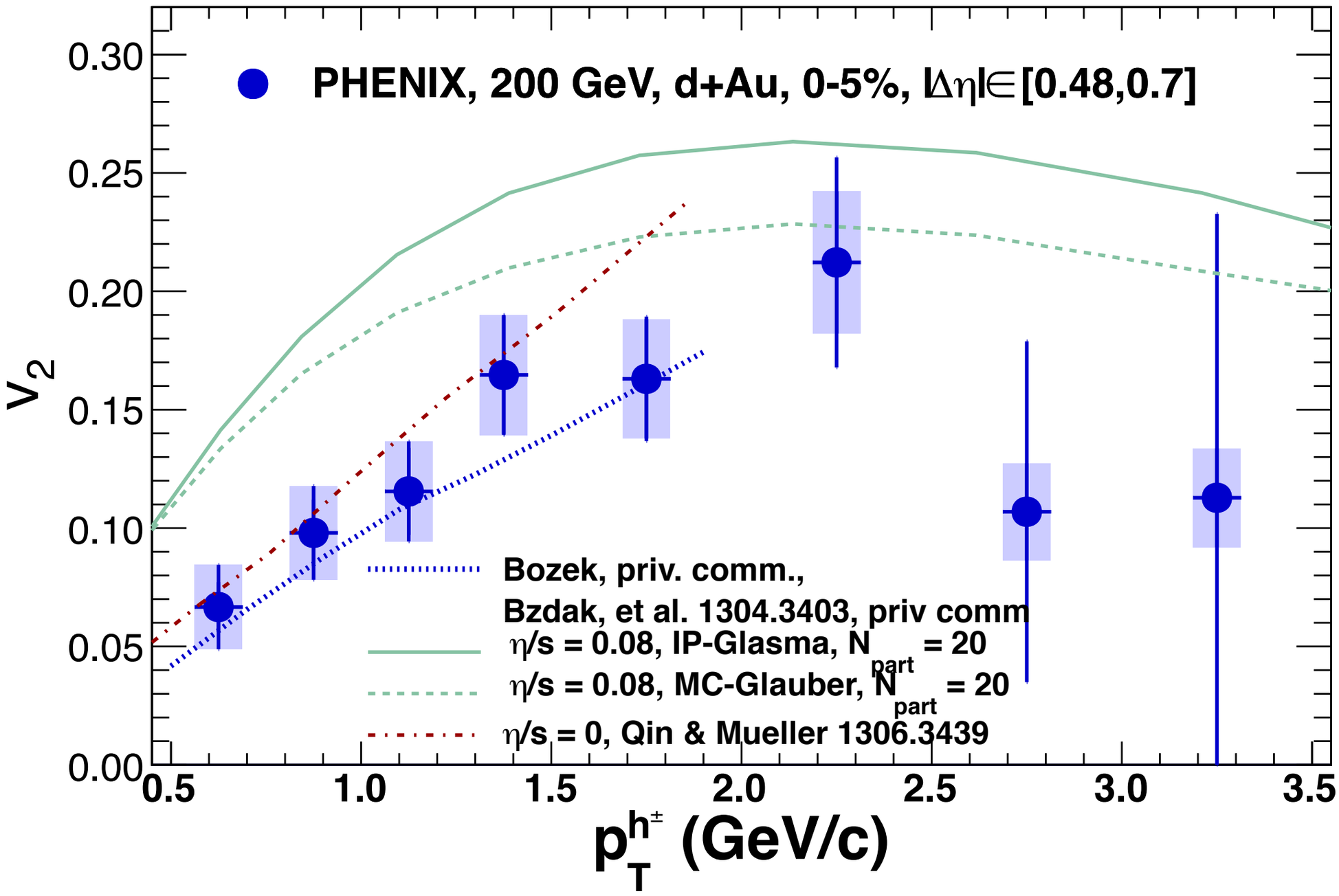






d+A central collisions have much larger ε_2 than p+A

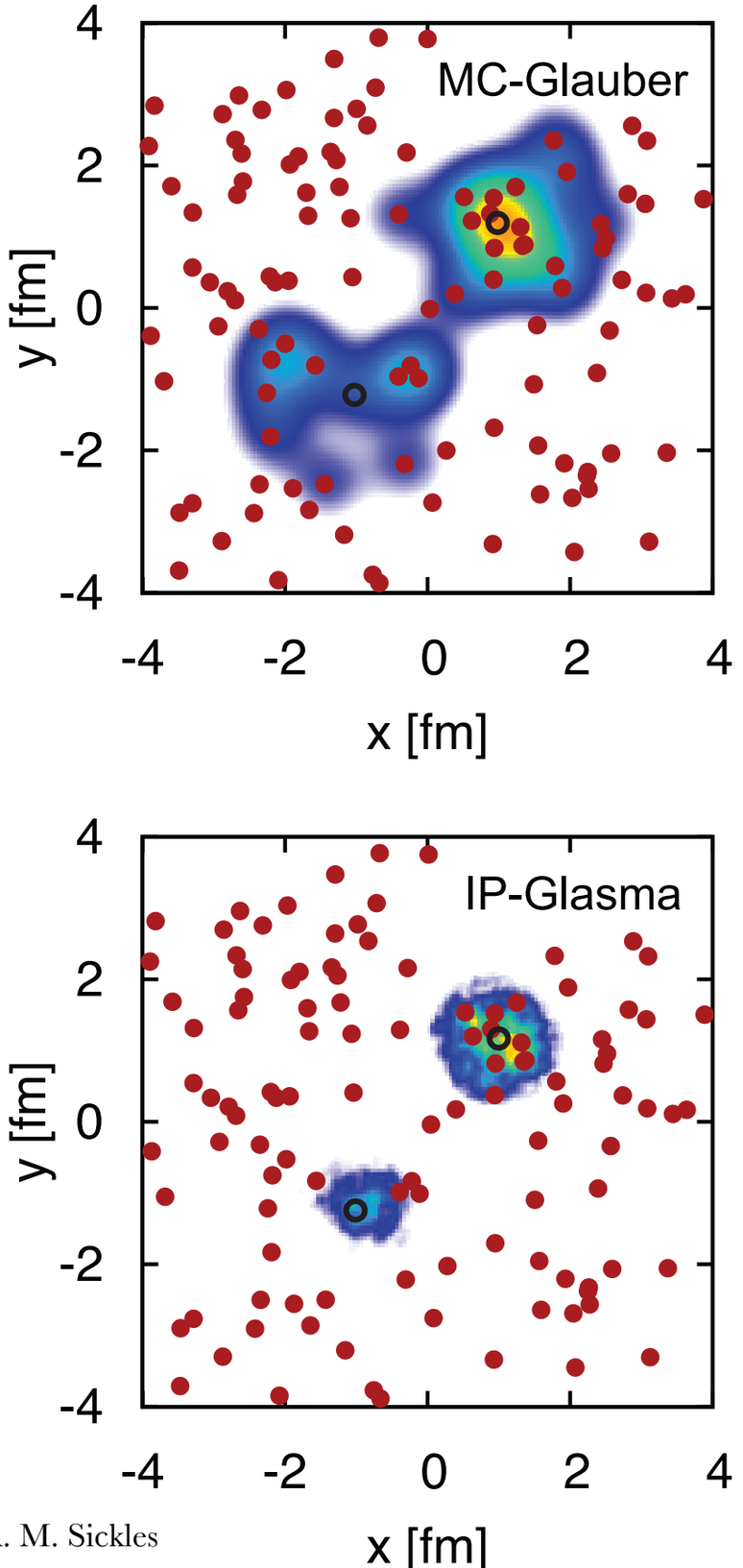
comparison to hydro calculations

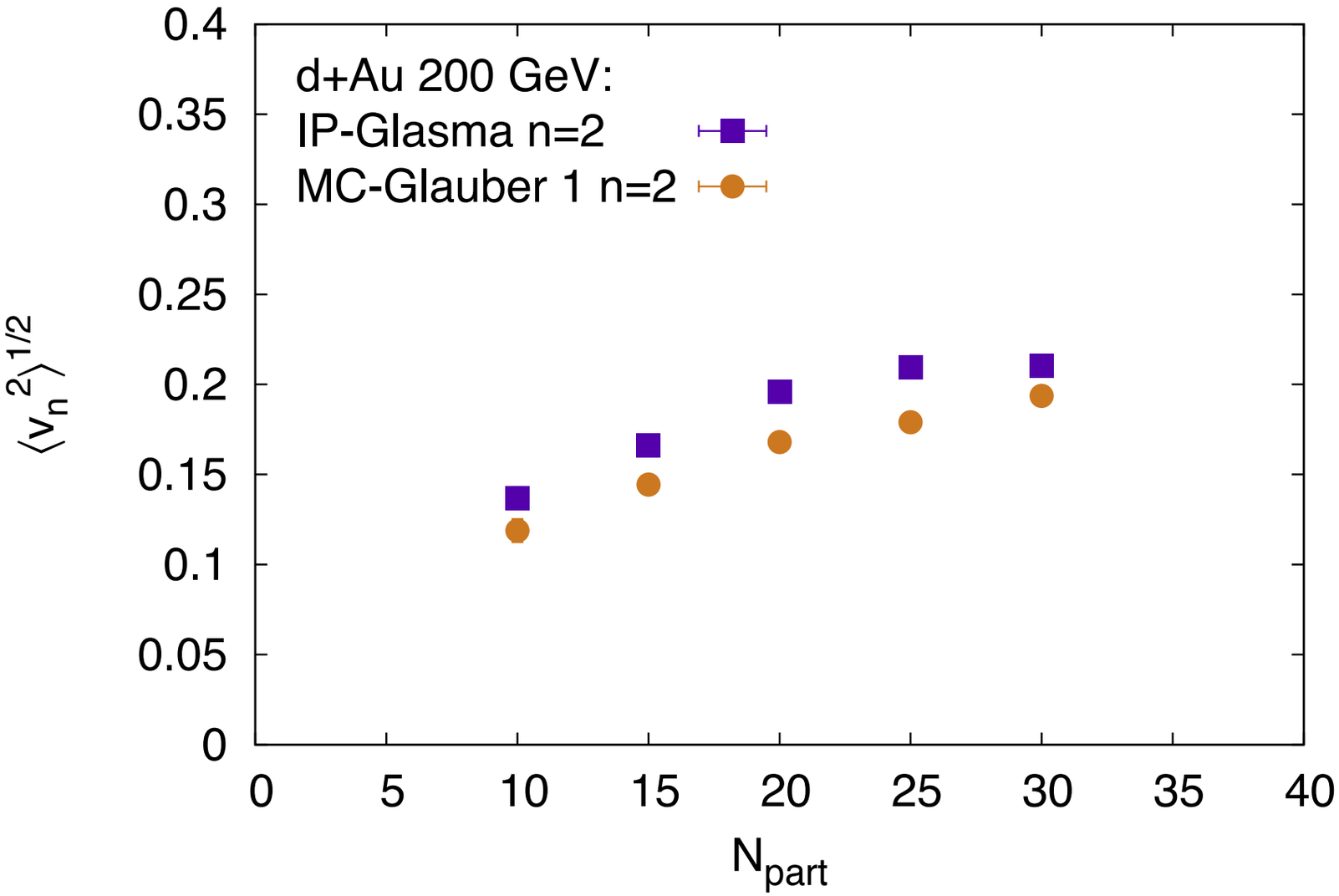


qualitative agreement with hydro calculations with $\eta/s \leq 0.08$

n.b. Bzdak et al calculations at fixed N_{part}

the shape of the initial state



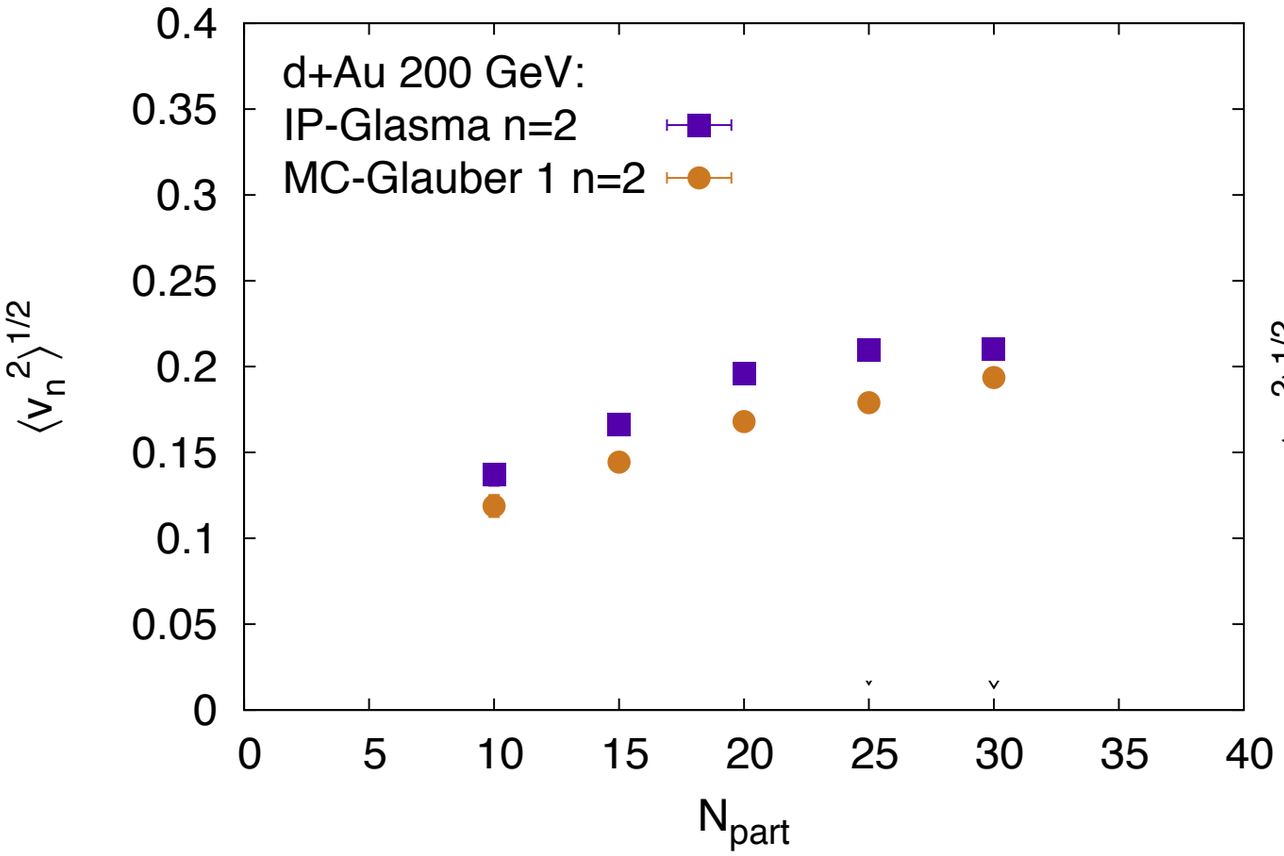


- **v2 naturally enhanced in dAu**
- **little dependence on initial state description--Glauber vs IP-Glasma**

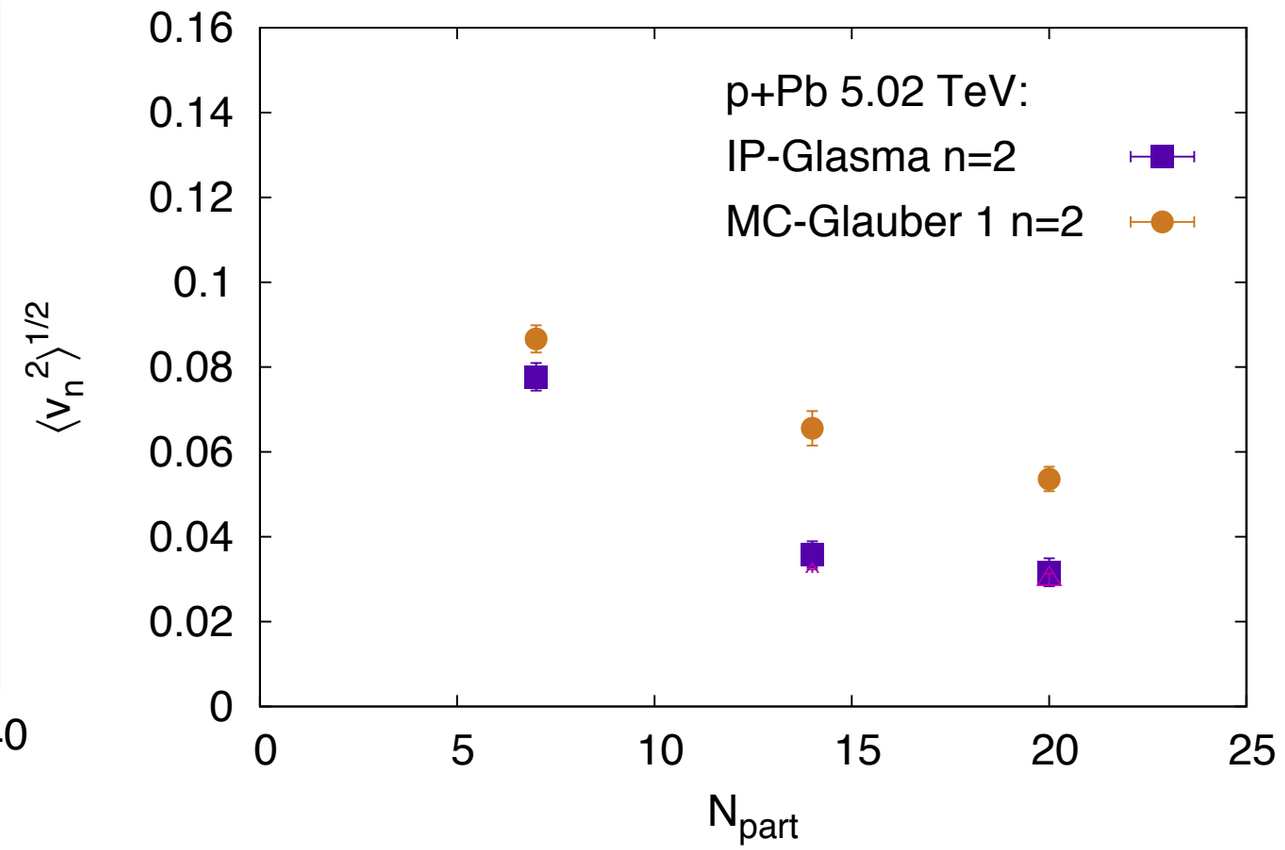
Bzdak et al: 1304.3403

d+Au compared to p+Pb

d+Au



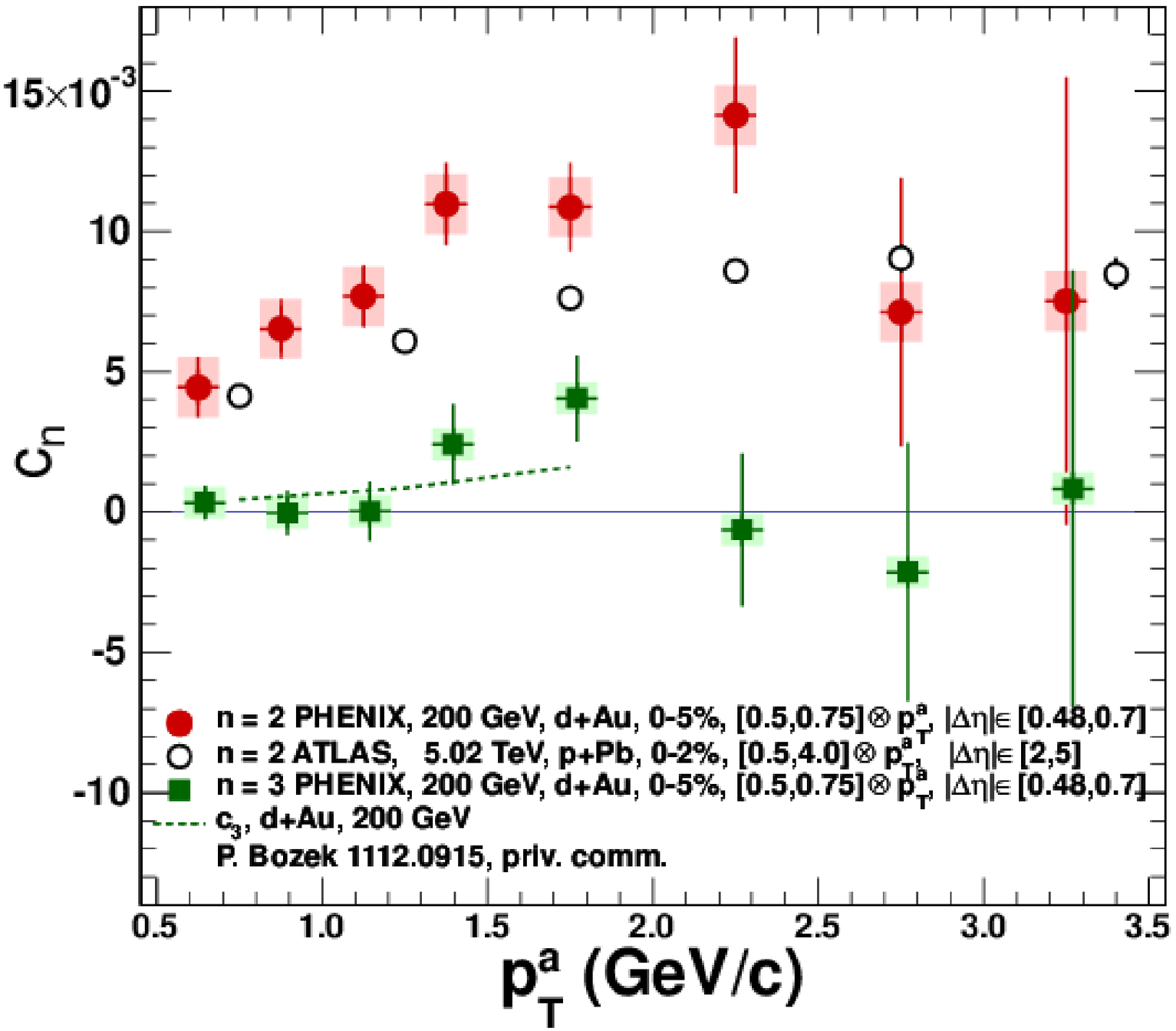
p+Pb



- d+Au:
  - larger v_2
  - smaller dependence on initial state description

Bzdak et al: 1304.3403

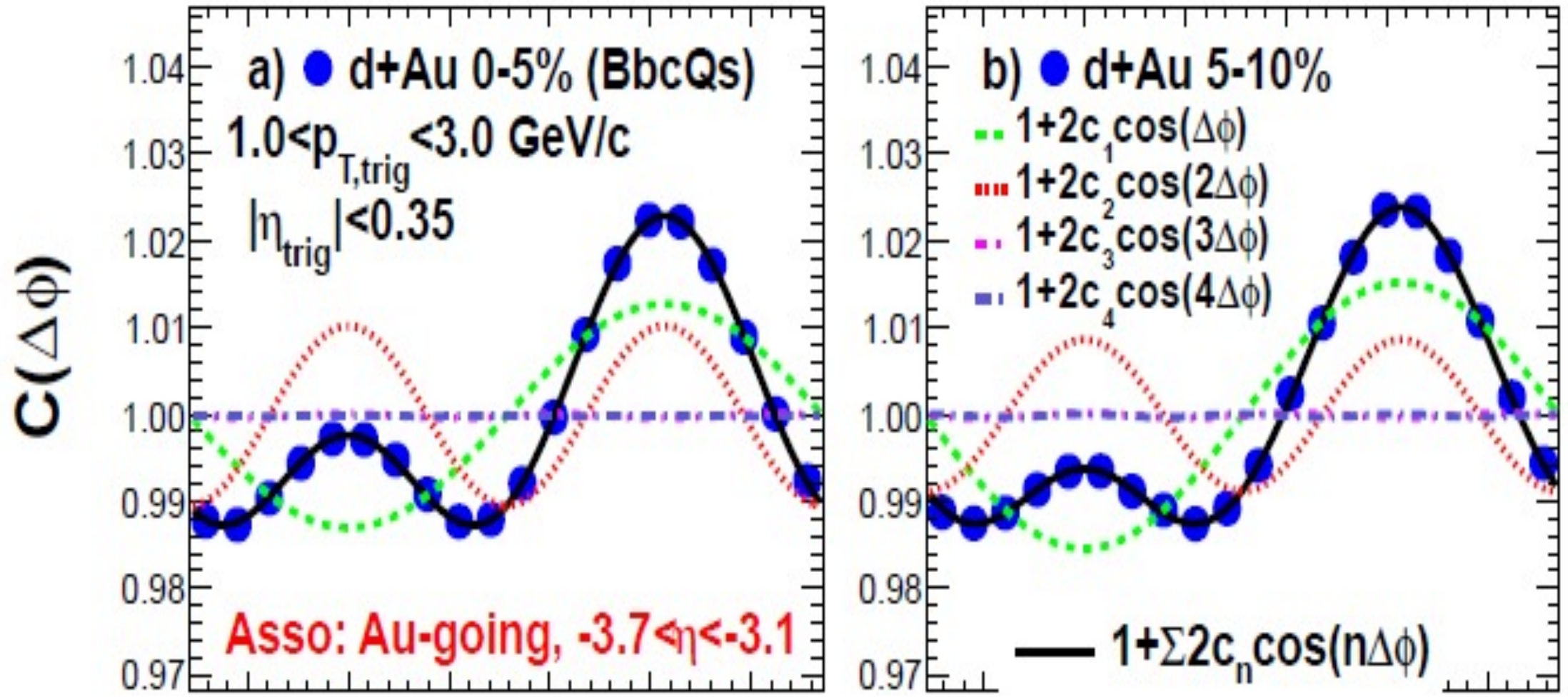
v_3 at RHIC?



no evidence for significant v3, consistent with hydro expectations

PHENIX: 1303.1794

v_3 at RHIC?

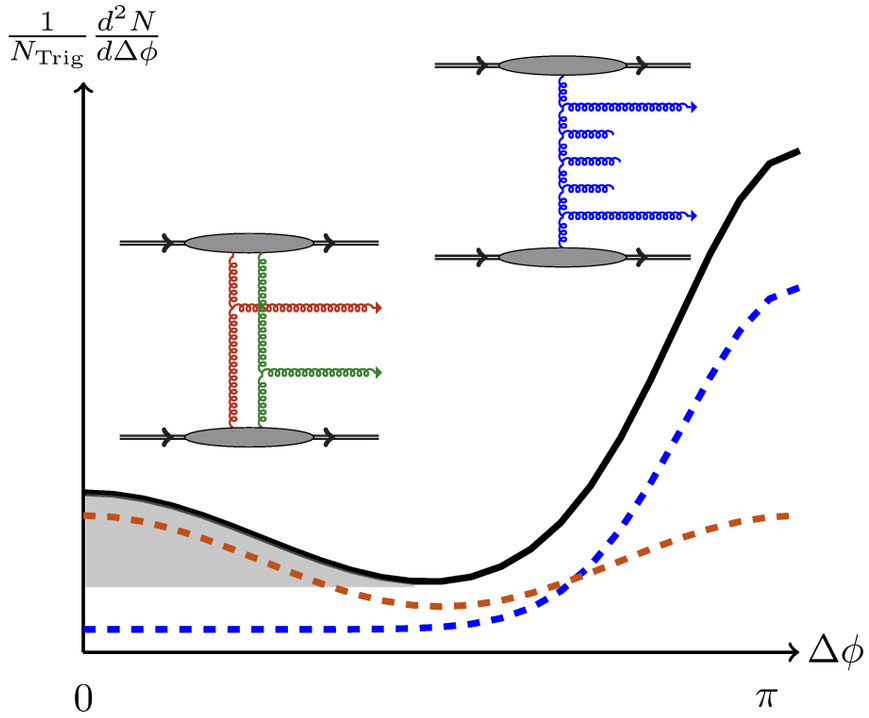


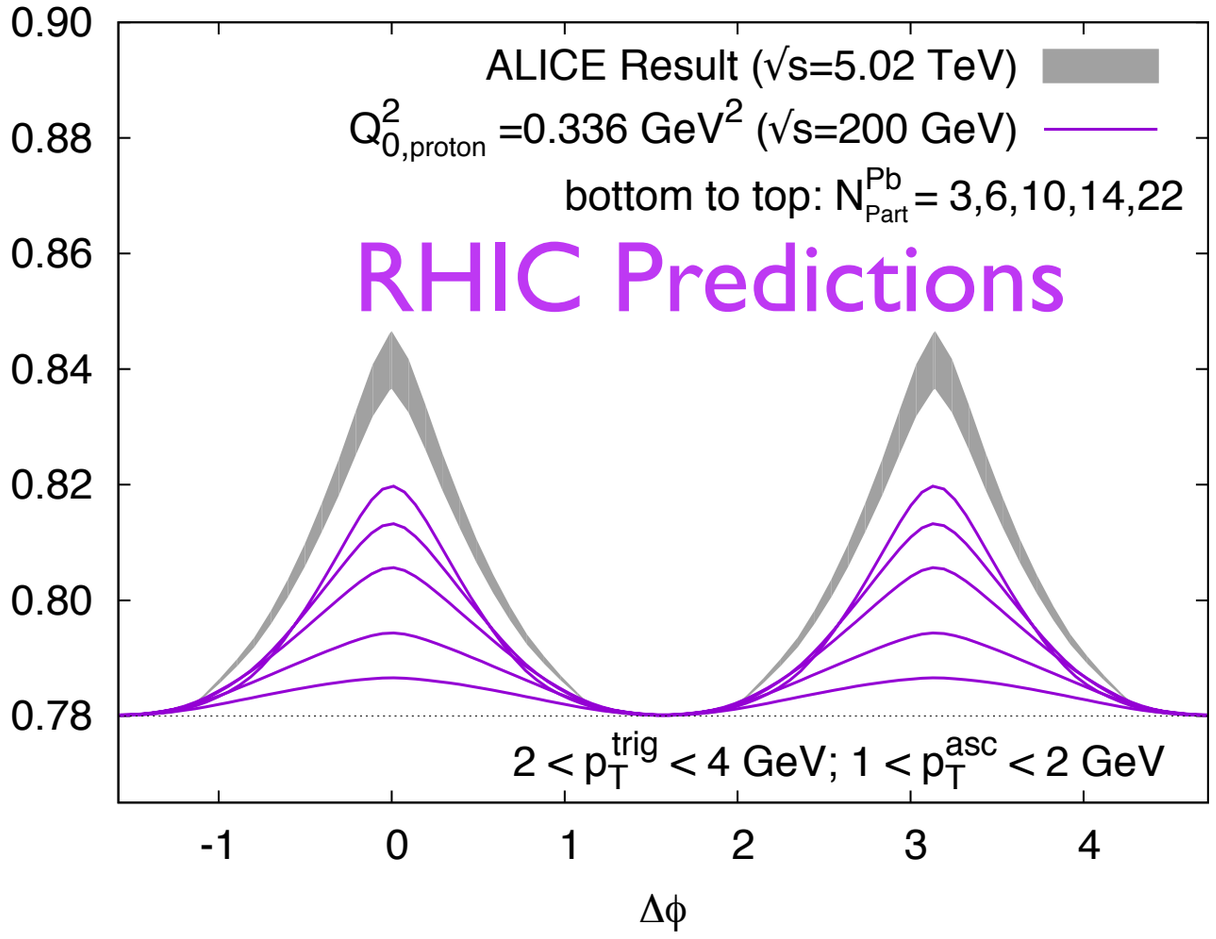
no significant c3 in Fourier decomposition of mid-forward correlations

PHENIX: 1303.1794

what about the CGC?

significant signal expected at RHIC!

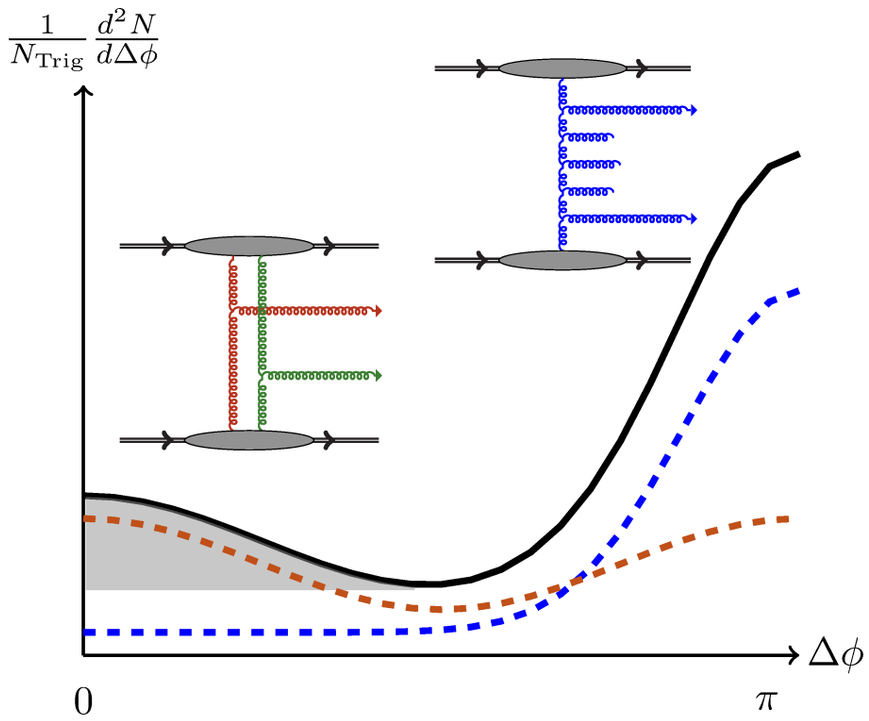


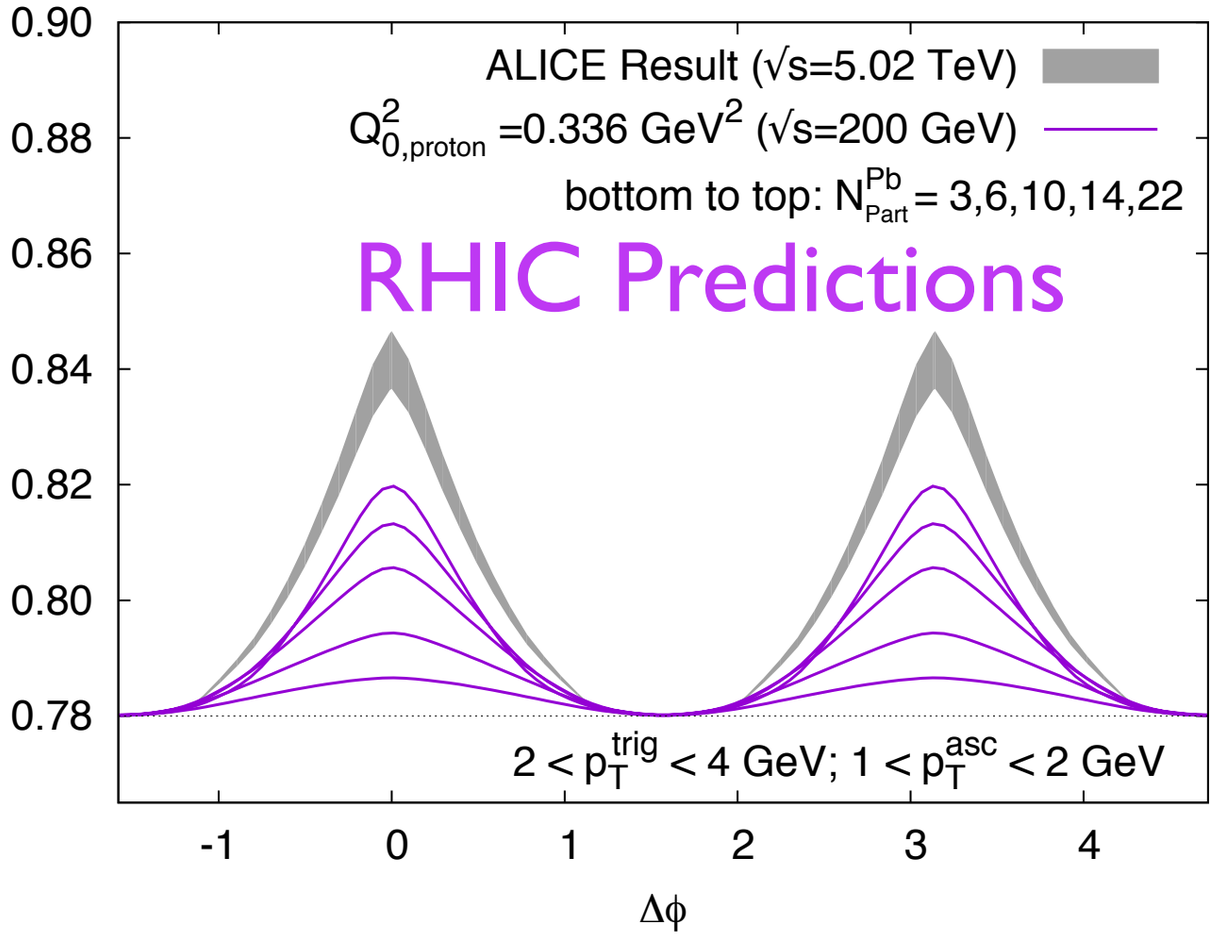


Dusling & Venugopalan 1211.3701, 1302.7018 & private comm.

what about the CGC?

significant signal expected at RHIC!

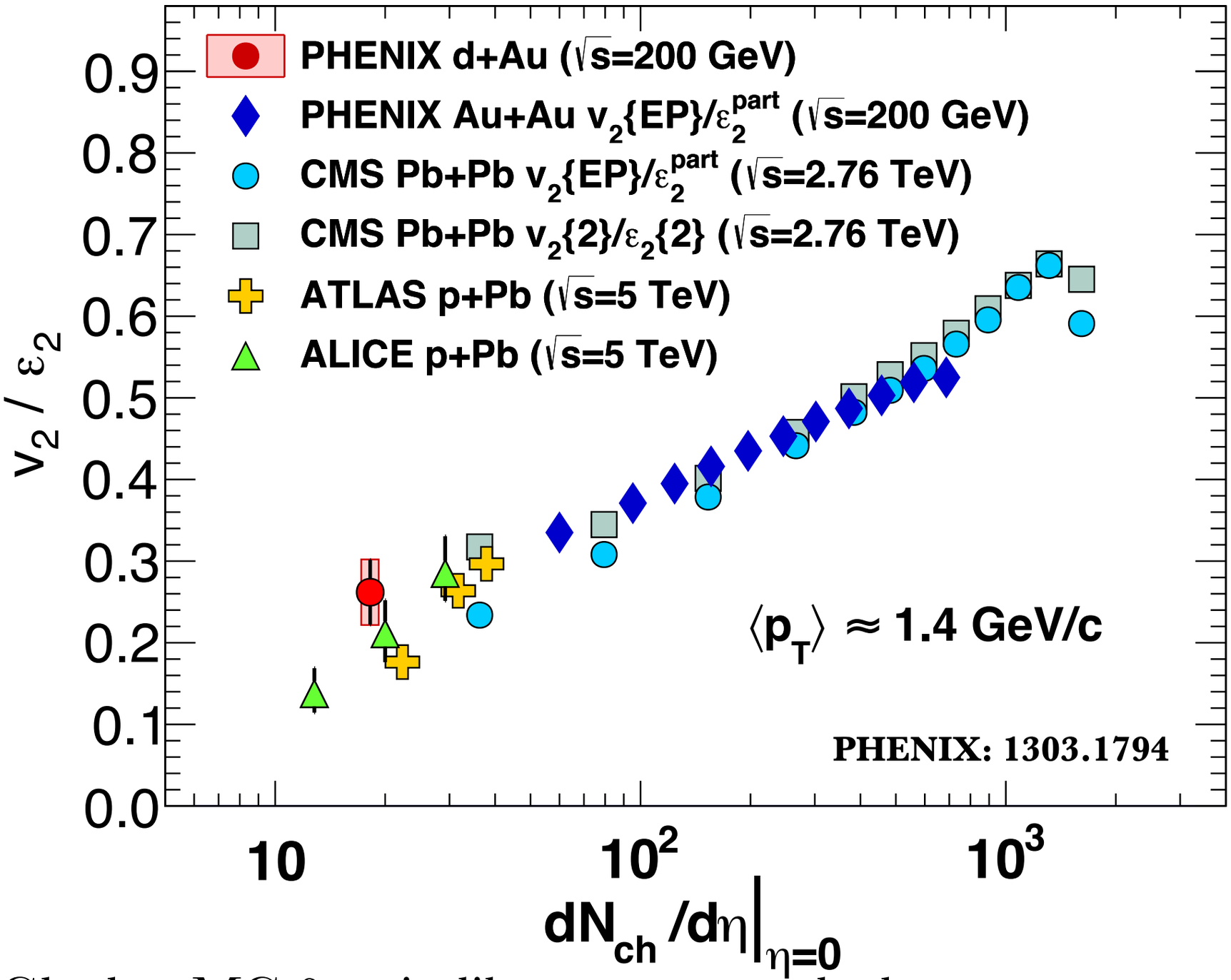




- smaller yield expected at RHIC compared to LHC
- Fourier coefficients aren't calculated for this model--working to compare to our data

Dusling & Venugopalan 1211.3701, 1302.7018 & private comm.

v_2/ε_2 vs multiplicity



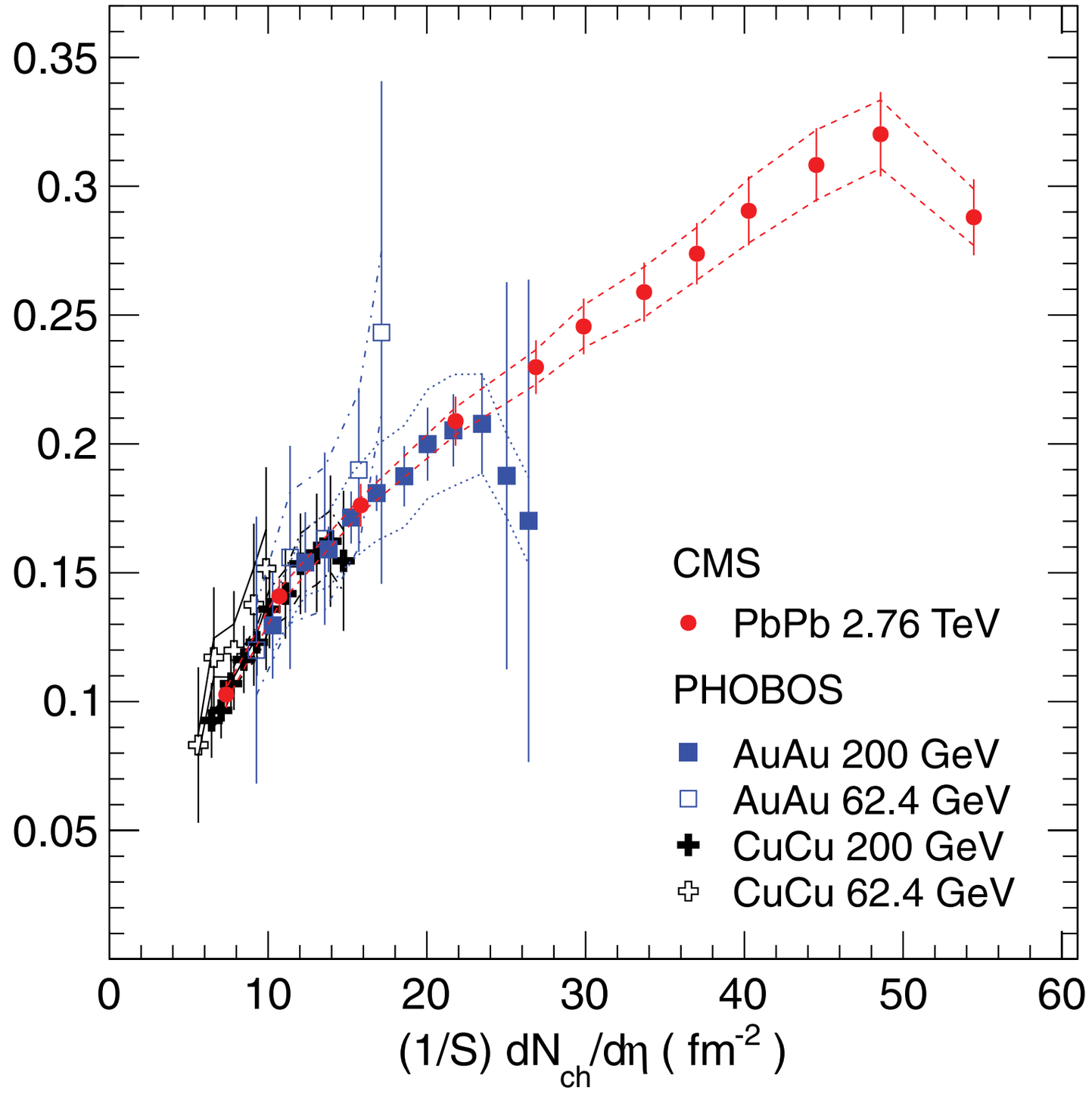
- Glauber MC & pointlike centers to calculate ε_2
- → approximate scaling of v_2/ε_2 with $dN/d\eta$

a common relationship between geometry and v_2?

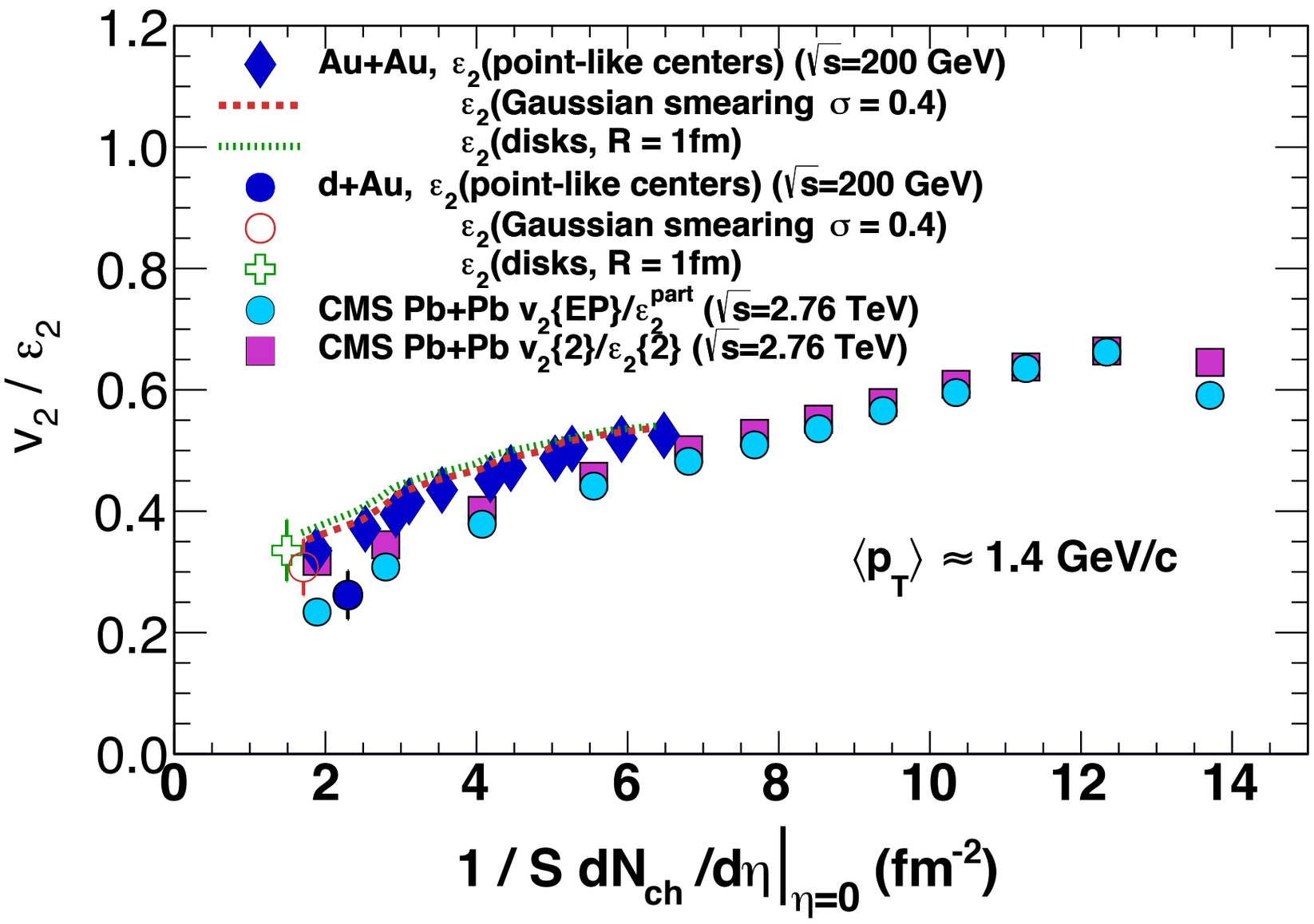
scaling with overlap area?

$$S = 4\pi\sqrt{\sigma_x^2\sigma_y^2 - \sigma_{xy}^2}$$

p_T integrated v_2 data found to scale in heavy ions with $1/S\ dN_{ch}/d\eta$ over wide collision energy



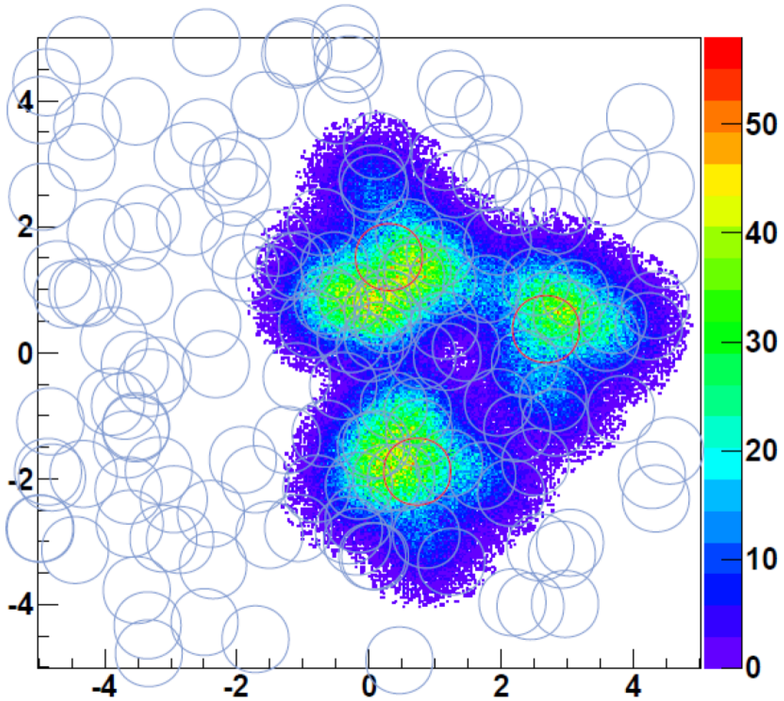
CMS PRC 87 014902



- approximate scaling with $1/S\ dN_{ch}/d\eta$
  - significant uncertainties due to nucleon representations in d+Au
  - n.b. not directly comparable to other 1/S plots, here v_2 at fixed p_T!

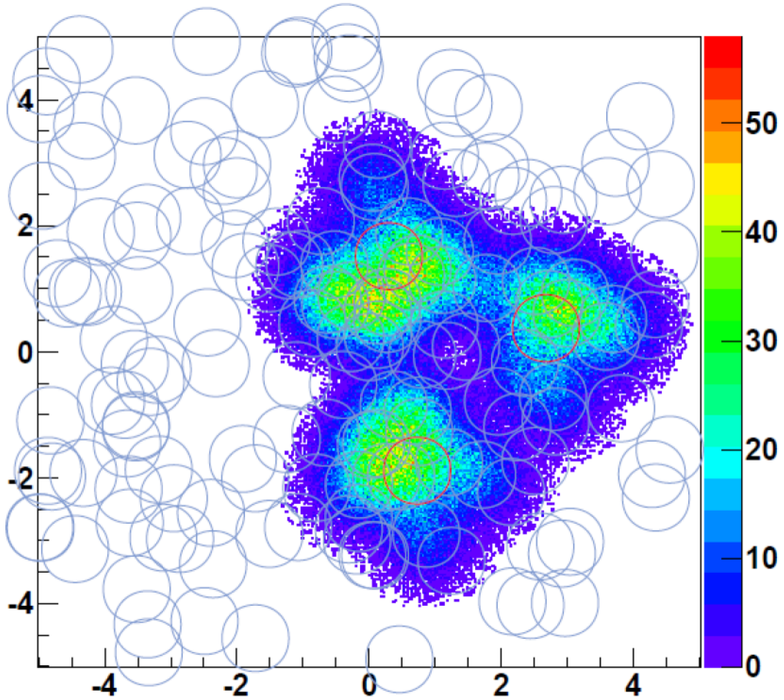
hydro or CGC?

He3 + Au



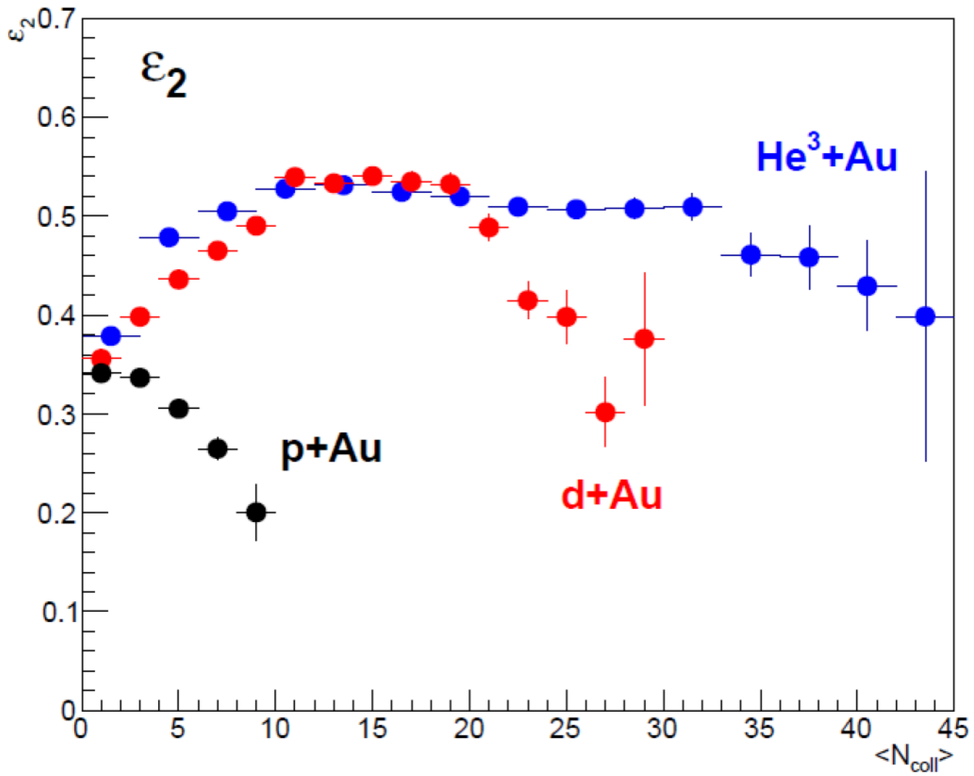
increase the triangularity of the initial state! what happens to v_3?

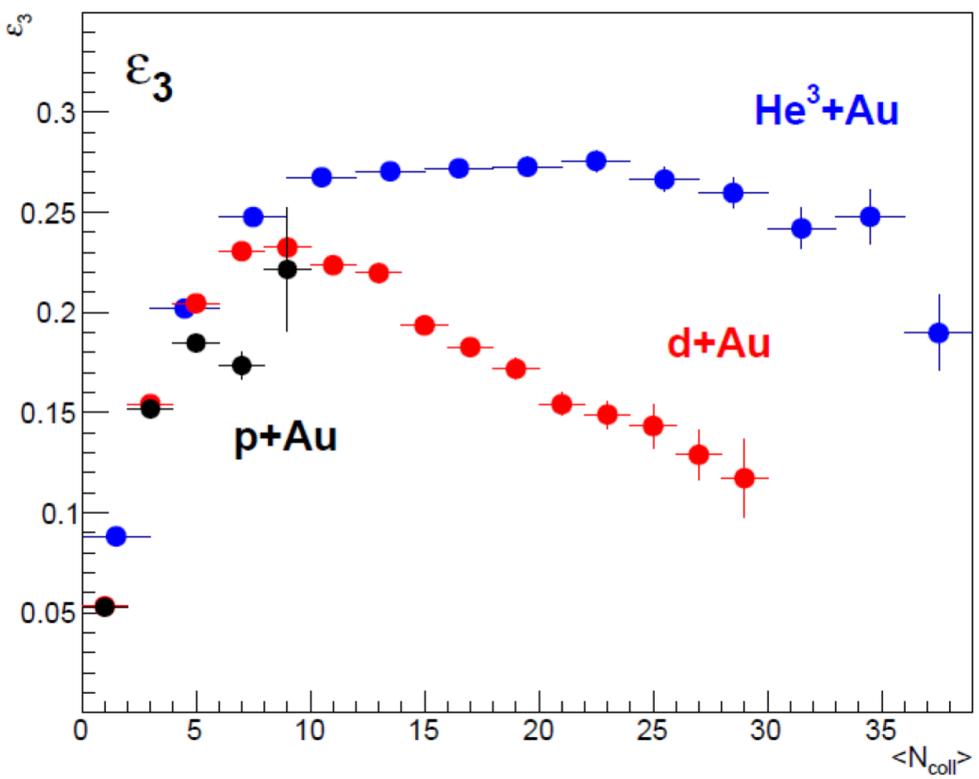
hydro or CGC?



increase the triangularity of the initial state! what happens to v_3?

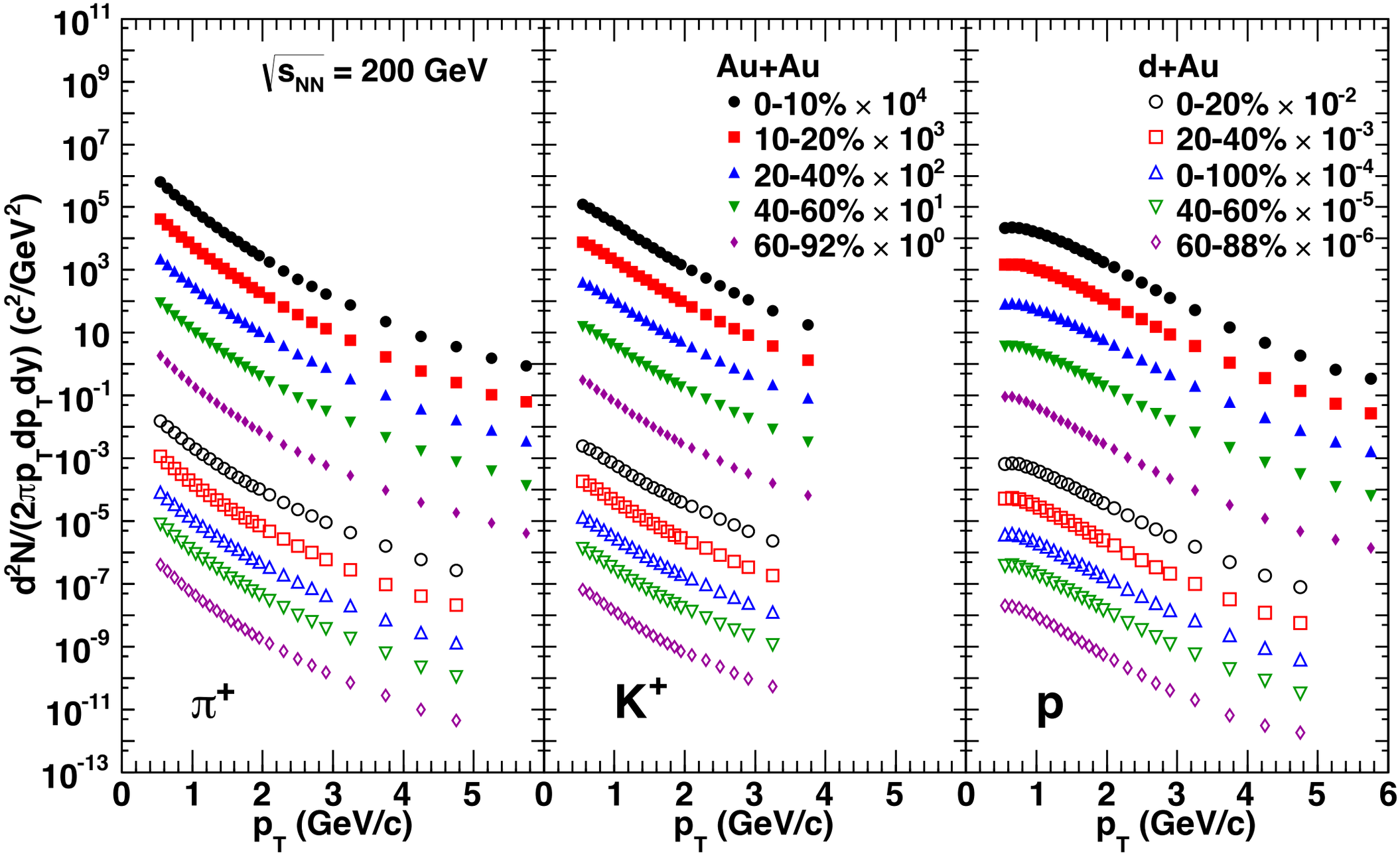
PHENIX requesting short d+Au & He^3+Au with increased acceptance relative to previous d+Au running (VTX/FVTX) to constrain geometry along with long p+Au running in 2015





exploit the versatility of RHIC!

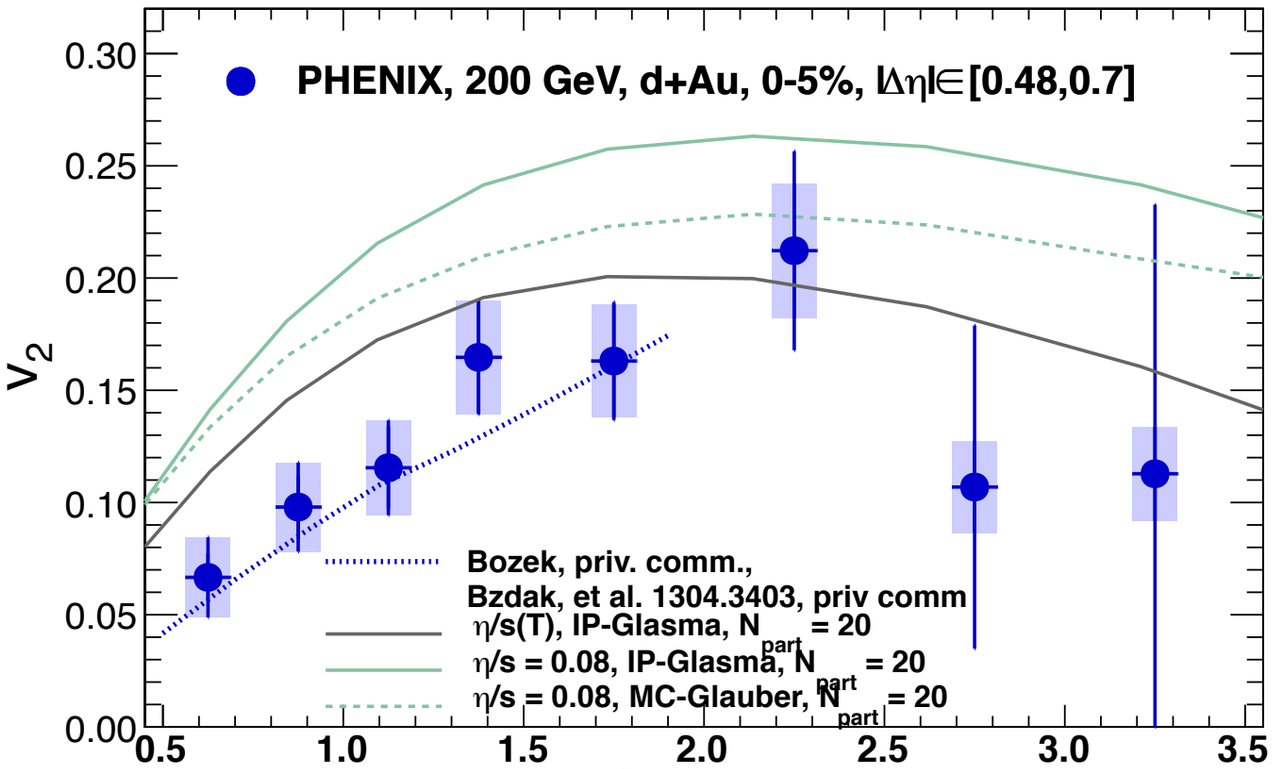
spectra in dAu

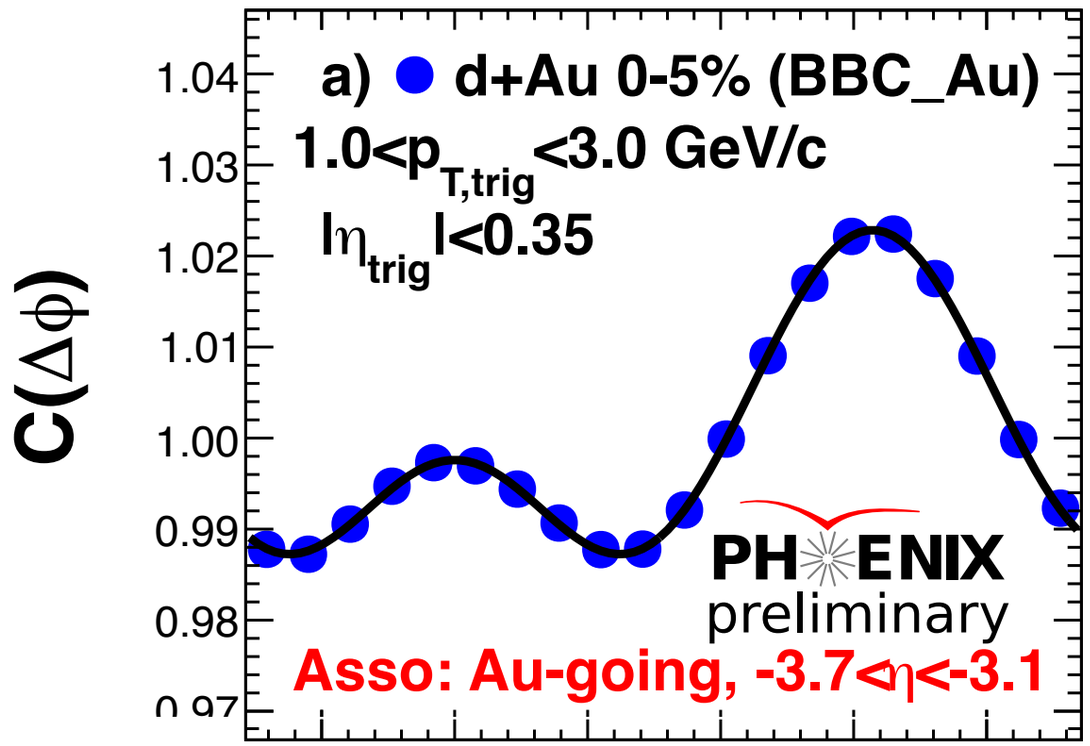


spectra should also be addressed by hydro calculations

PHENIX:1304.3410

conclusions



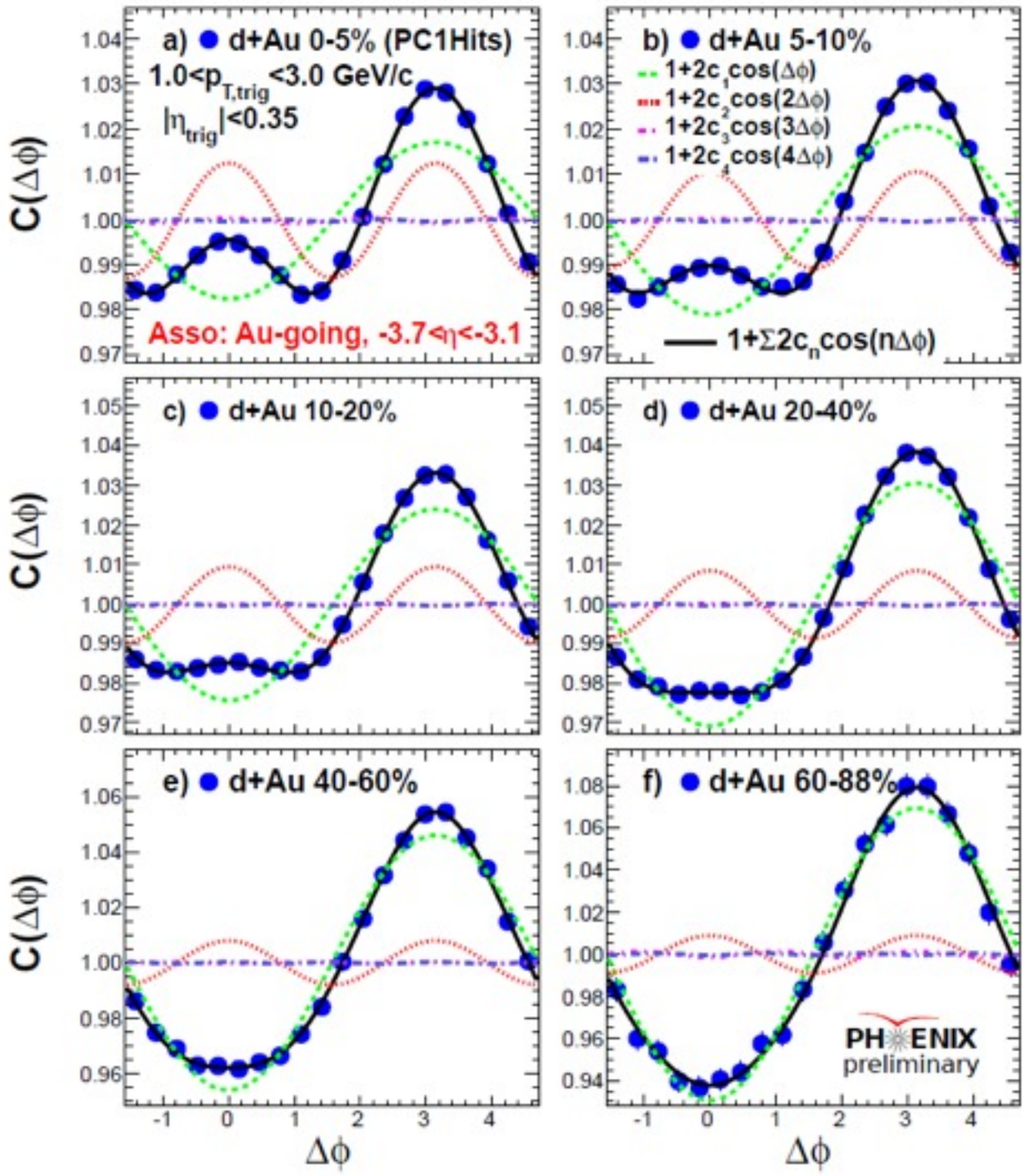


- ridge-like behavior seen at PHENIX at short and long range ($\Delta\eta > 3$) with large v_2 at midrapidity
- we're working to extend these measurements:
  - yields, $v_N(\eta)$, different collision systems (pA, dA, He^3A, peripheral heavy ions, asymmetric collisions...)
  - ...in order to understand what's going on in very small systems

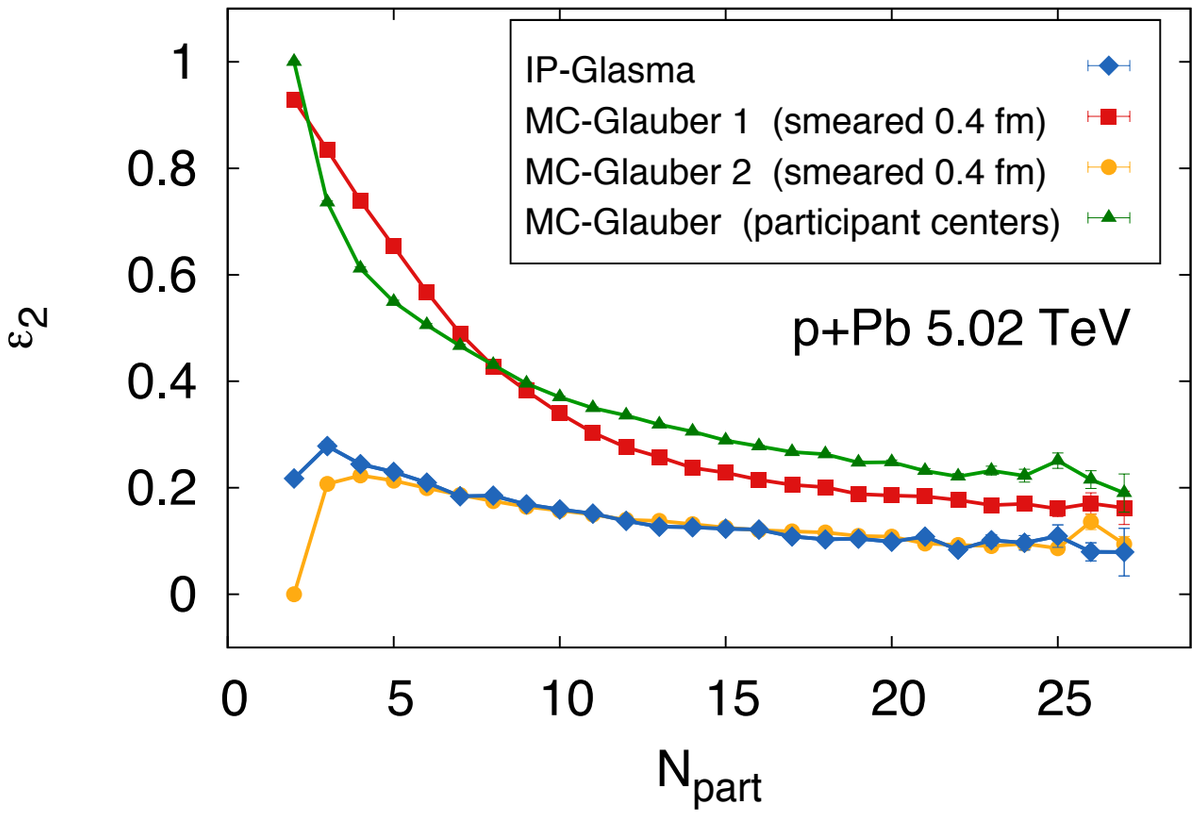
more on d+Au: John Chen 9/12 parallel session

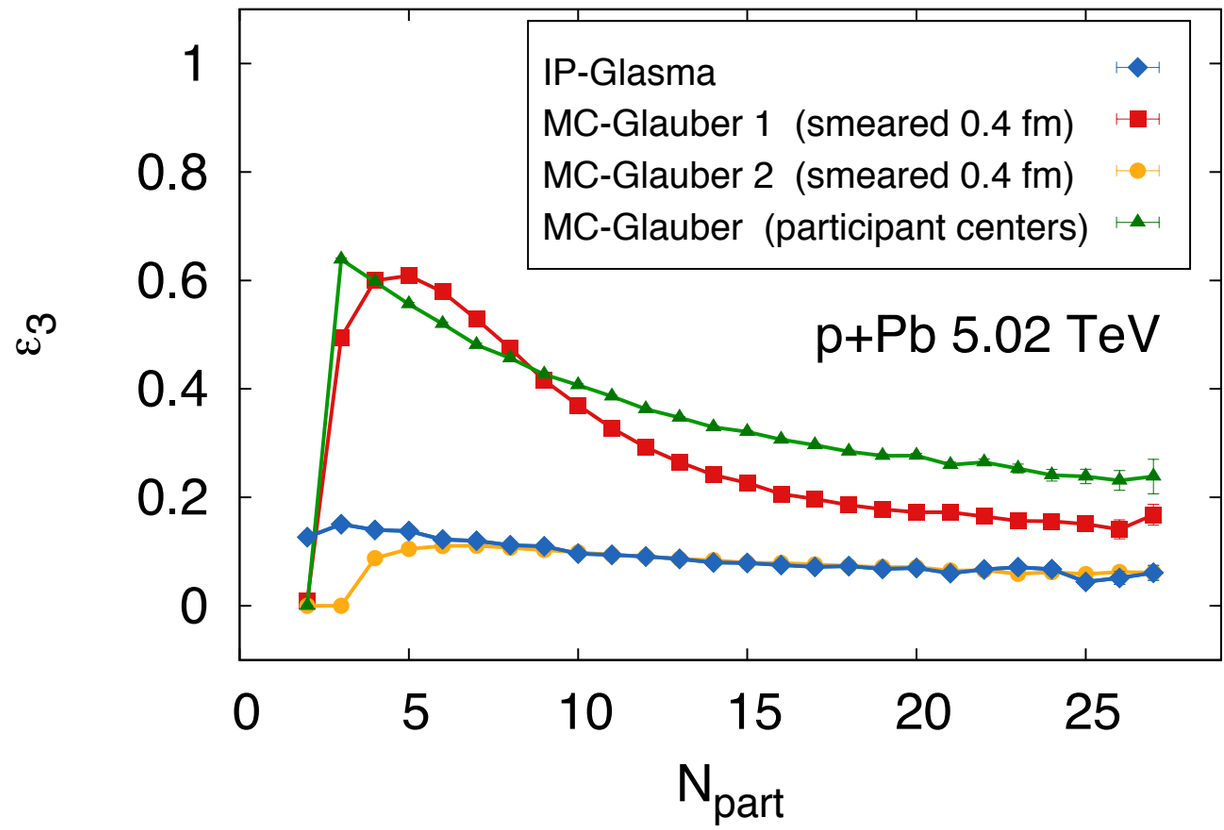
backups

- PHENIX dAu centrality determination by charge in Au-going BBC, which is in the same rapidity window as MPC: $3<\eta<4$
  - here determine the event centrality by number of PC1 hits (mid-rapidity)
    - some differences, but qualitative features remain unchanged



what is the eccentricity?



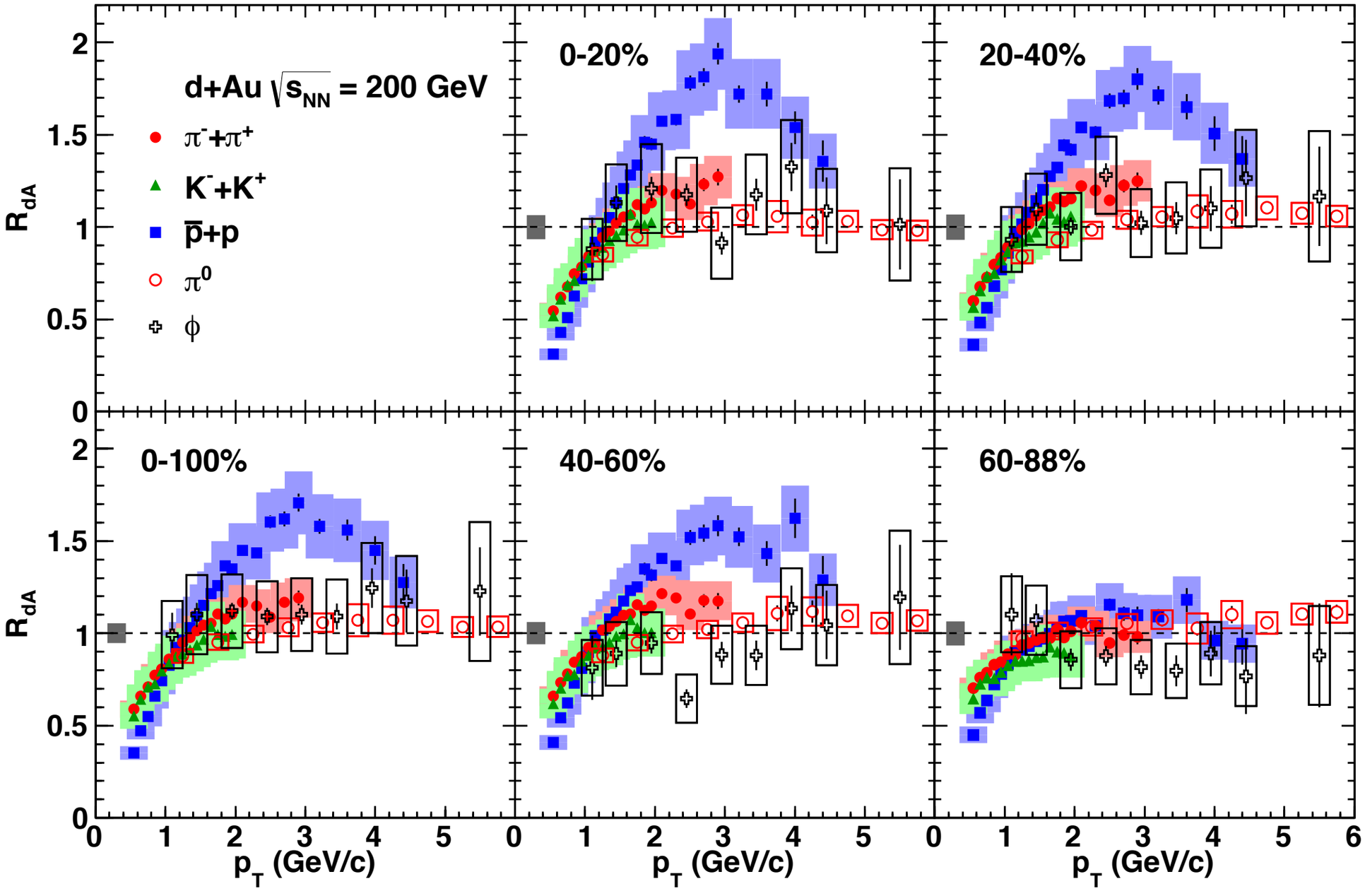


models can give very different eccentricities!

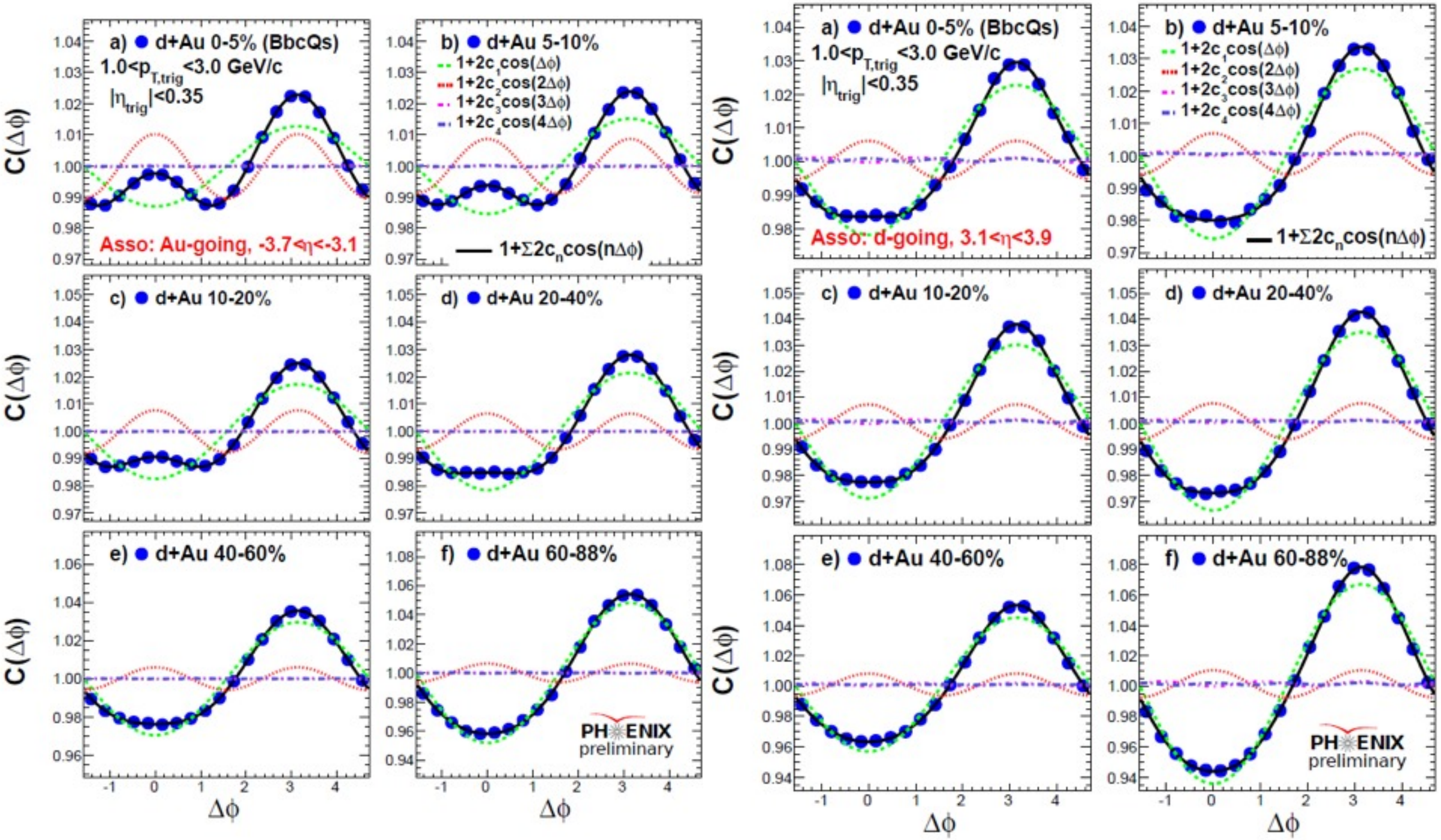
MC-Glauber 1 MC-Glauber 2

Bzdak et al: 1304.3403

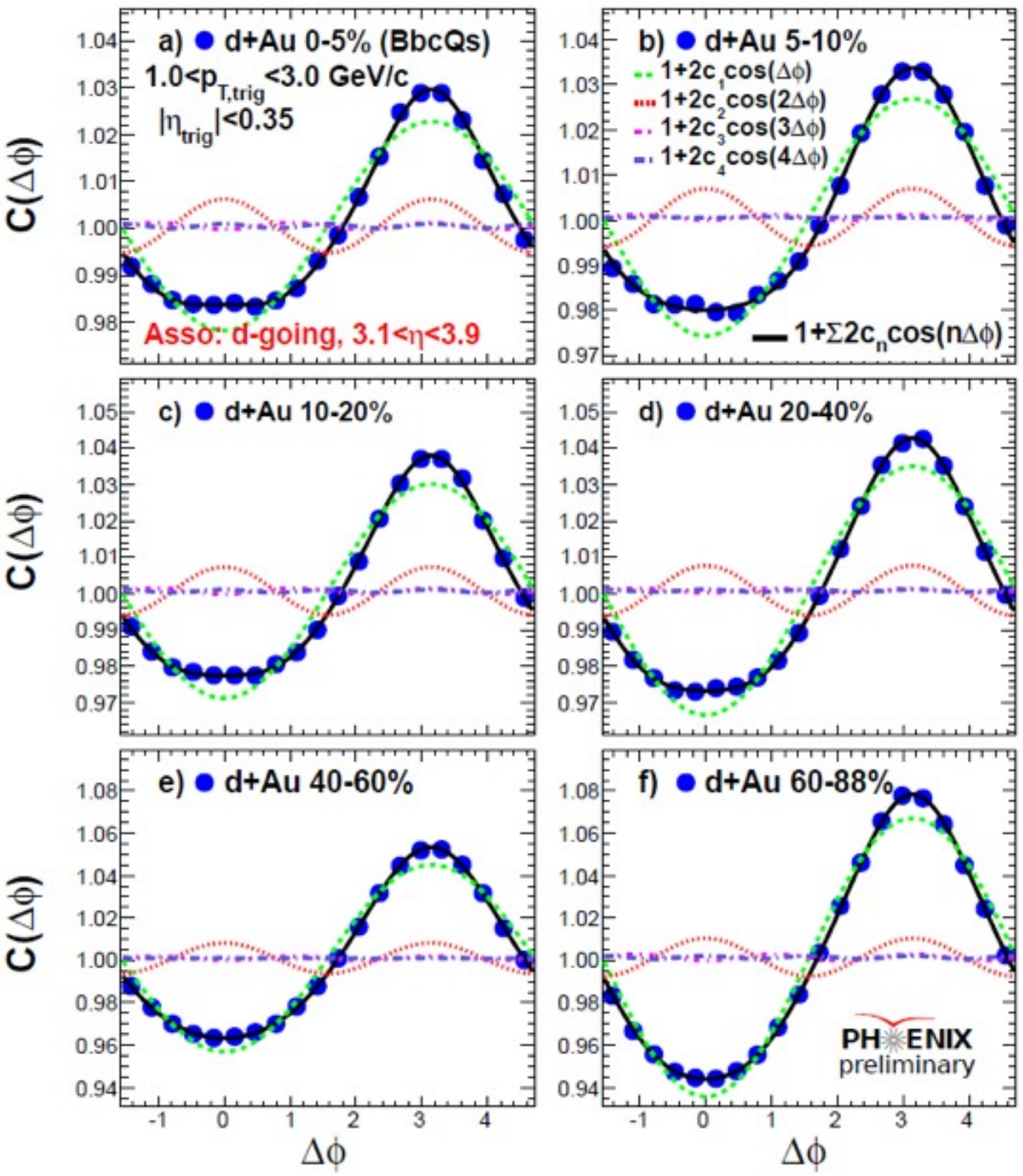
R_{dA}

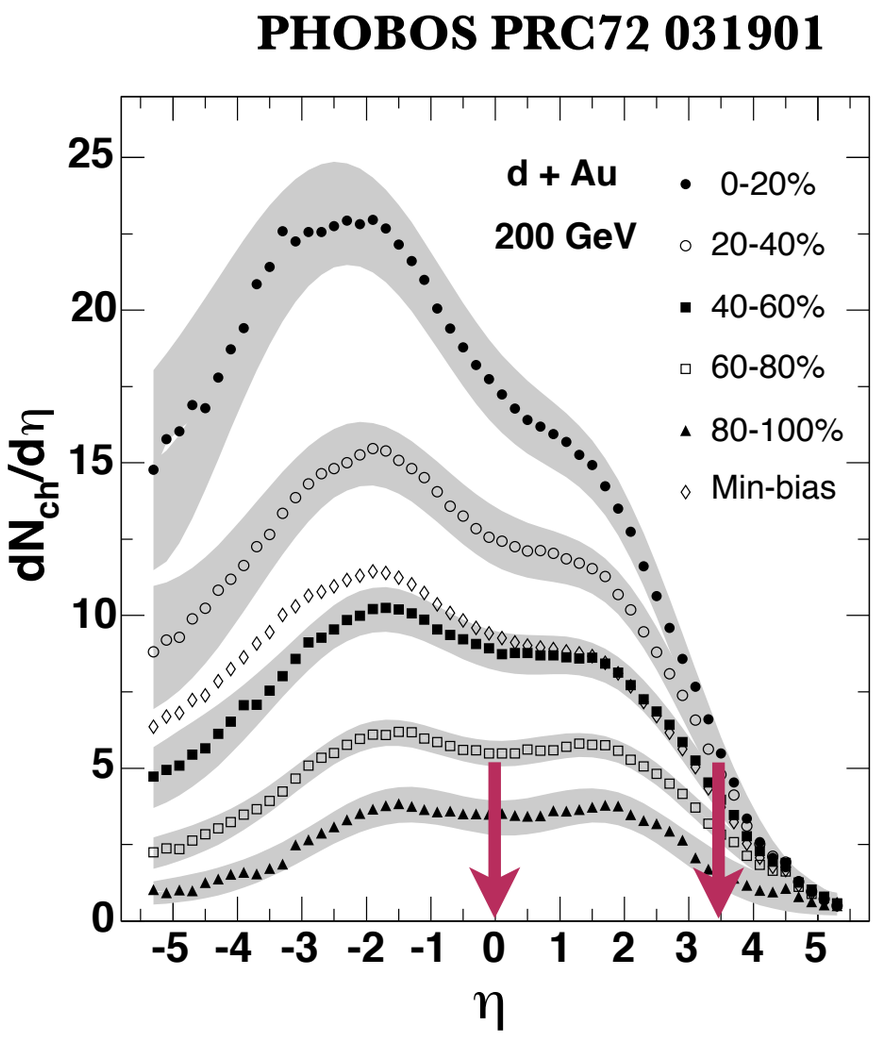


PHENIX:1304.3410


a) ● d+Au 0-5% (BbcQs)
1.0<p_T,trig<3.0 GeV/c
|η_trig|<0.35
Asso: Au-going, -3.7<η<-3.1
b) ● d+Au 5-10%
1+2c_1cos(Δφ)
1+2c_2cos(2Δφ)
1+2c_3cos(3Δφ)
1+2c_4cos(4Δφ)
1+Σ2c_ncos(nΔφ)
c) ● d+Au 10-20%
d) ● d+Au 20-40%
e) ● d+Au 40-60%
f) ● d+Au 60-88%
PHENIX
preliminary
C(Δφ)
Δφ
a) ● d+Au 0-5% (BbcQs)
1.0<p_T,trig<3.0 GeV/c
|η_trig|<0.35
Asso: d-going, 3.1<η<3.9
b) ● d+Au 5-10%
1+2c_1cos(Δφ)
1+2c_2cos(2Δφ)
1+2c_3cos(3Δφ)
1+2c_4cos(4Δφ)
1+Σ2c_ncos(nΔφ)
c) ● d+Au 10-20%
d) ● d+Au 20-40%
e) ● d+Au 40-60%
f) ● d+Au 60-88%
PHENIX
preliminary
C(Δφ)
Δφ

NEW! mid/d-going correlations

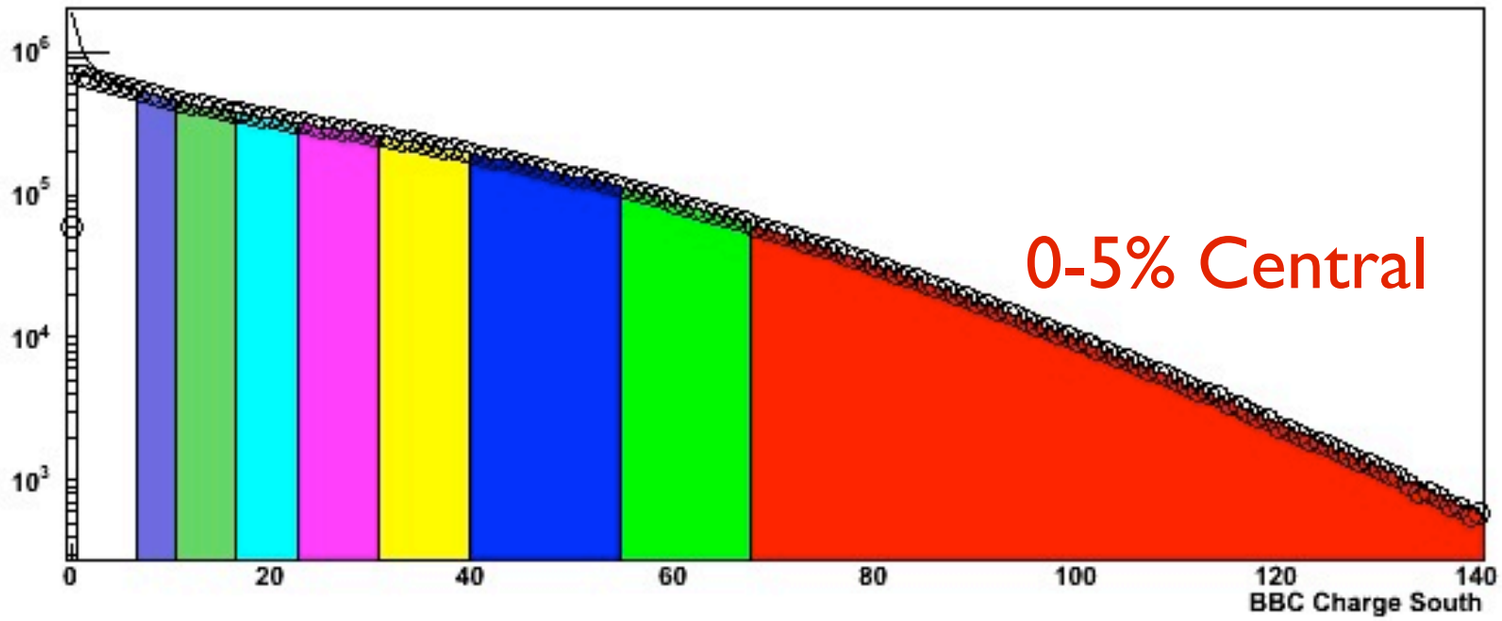


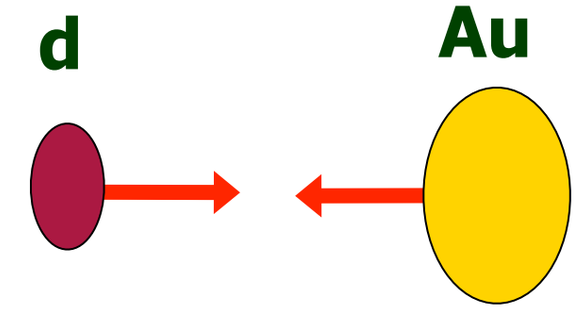


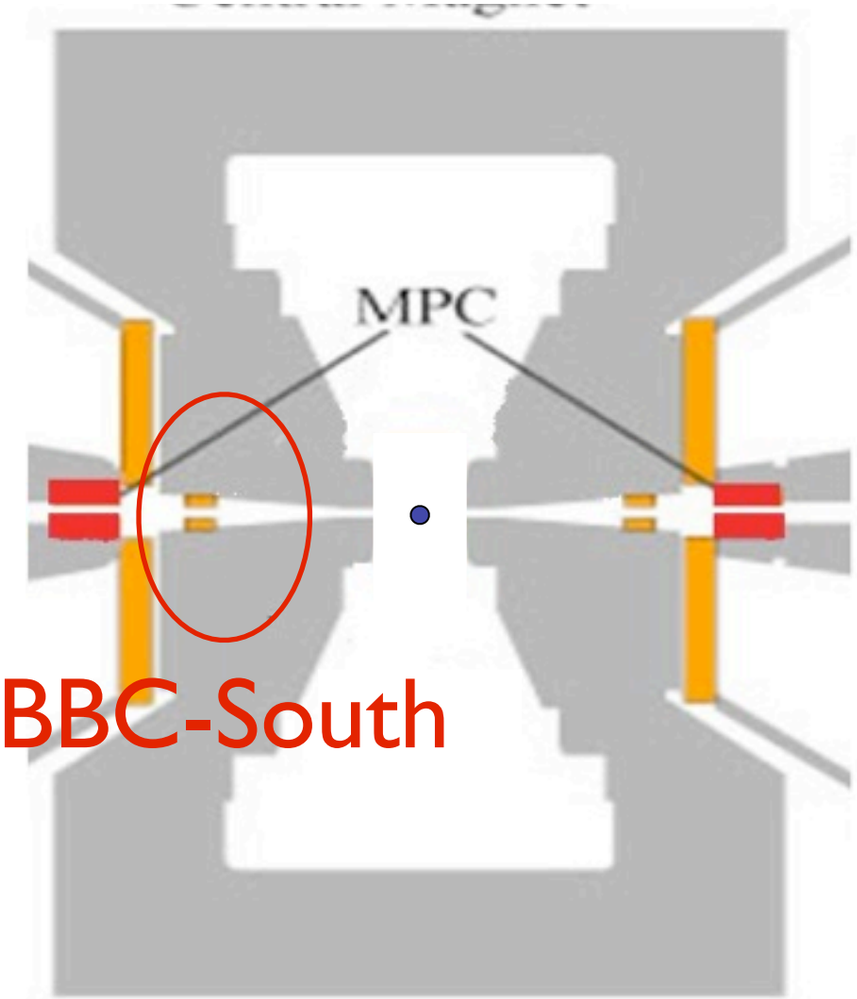
correlations between mid-rapidity particles & energy weighted towers in d-going MPC

no small Δφ bump, perhaps some v_2?

Centrality Selection







BBC Charge distribution well described by Glauber MC + negative binomial distribution