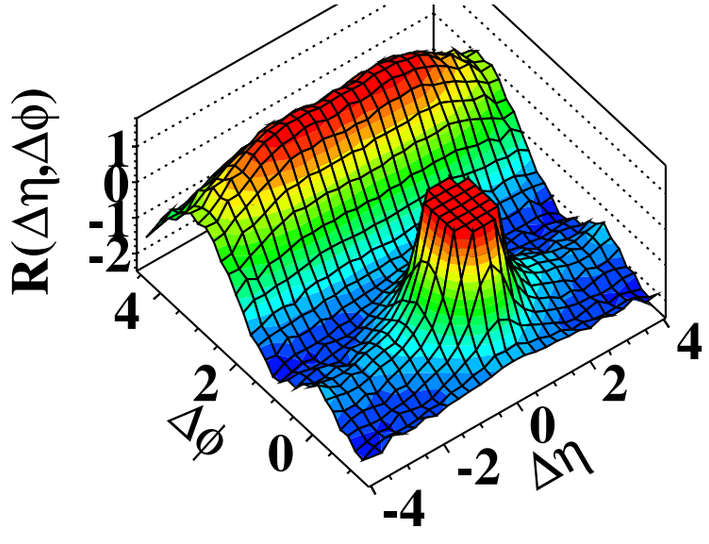
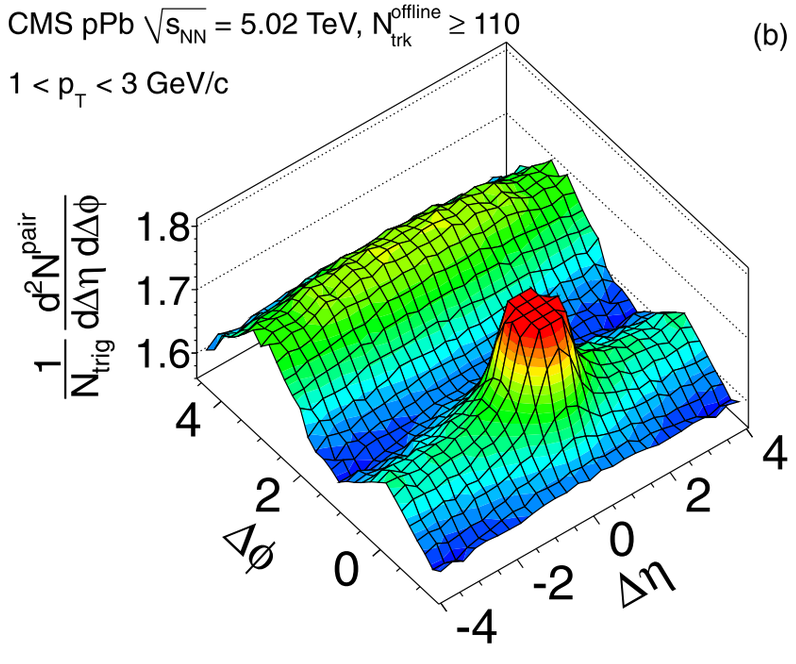
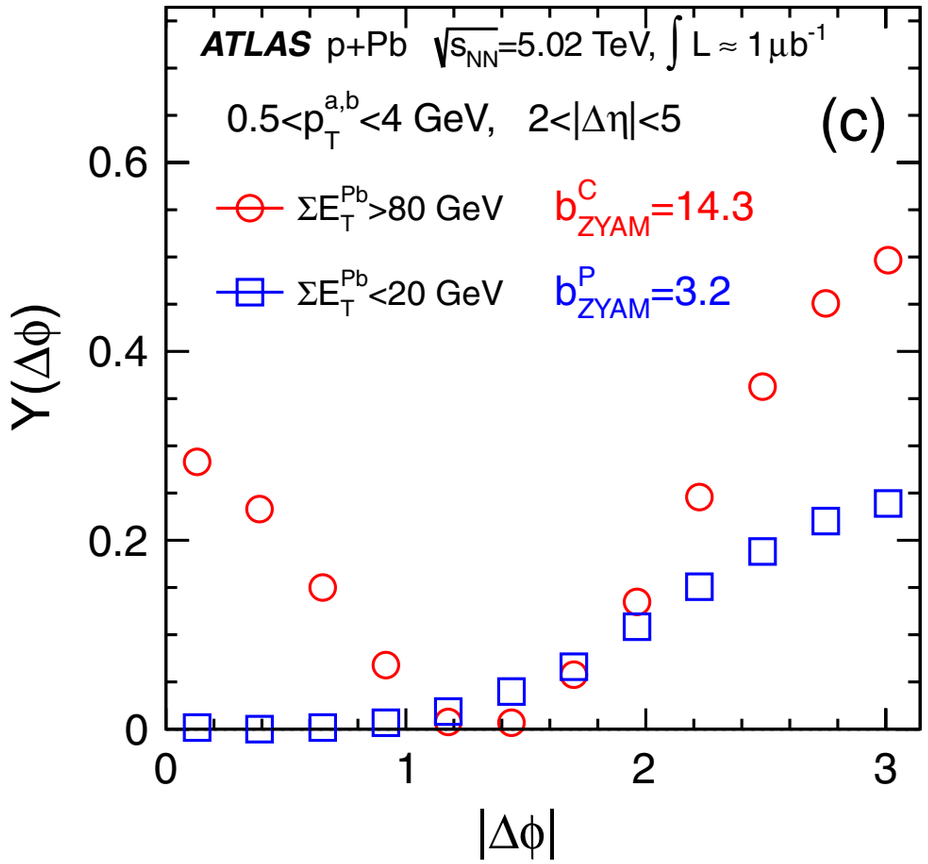
d+Au Hadron Correlation Measurements at PHENIX

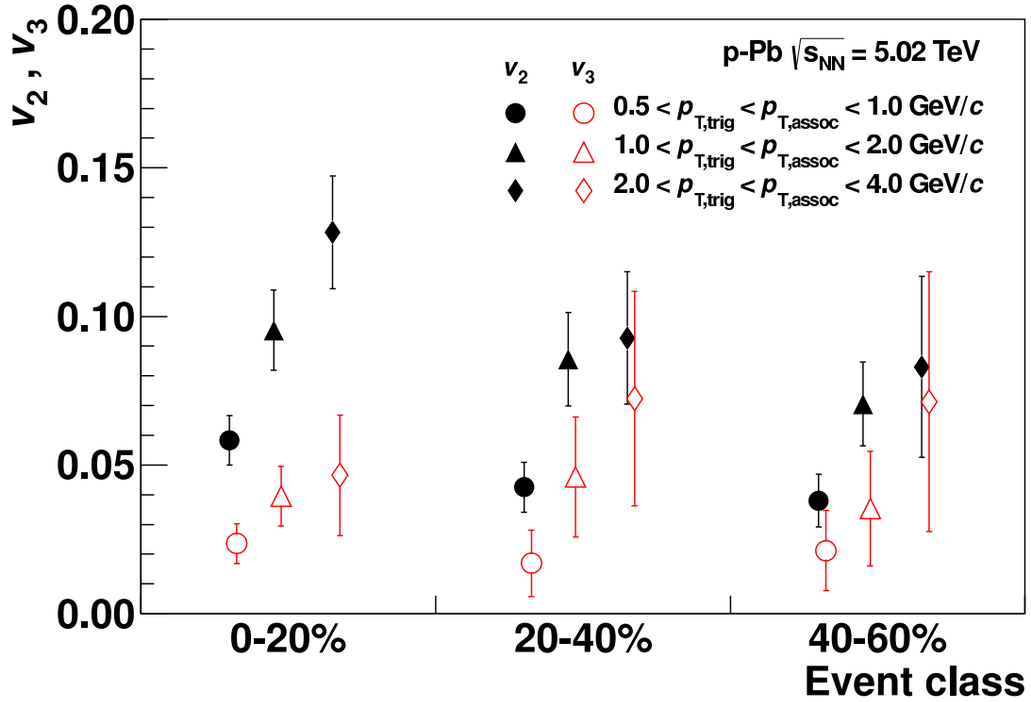
Anne Sickles for the PHENIX Collaboration
BNL

pp & pPb ridges



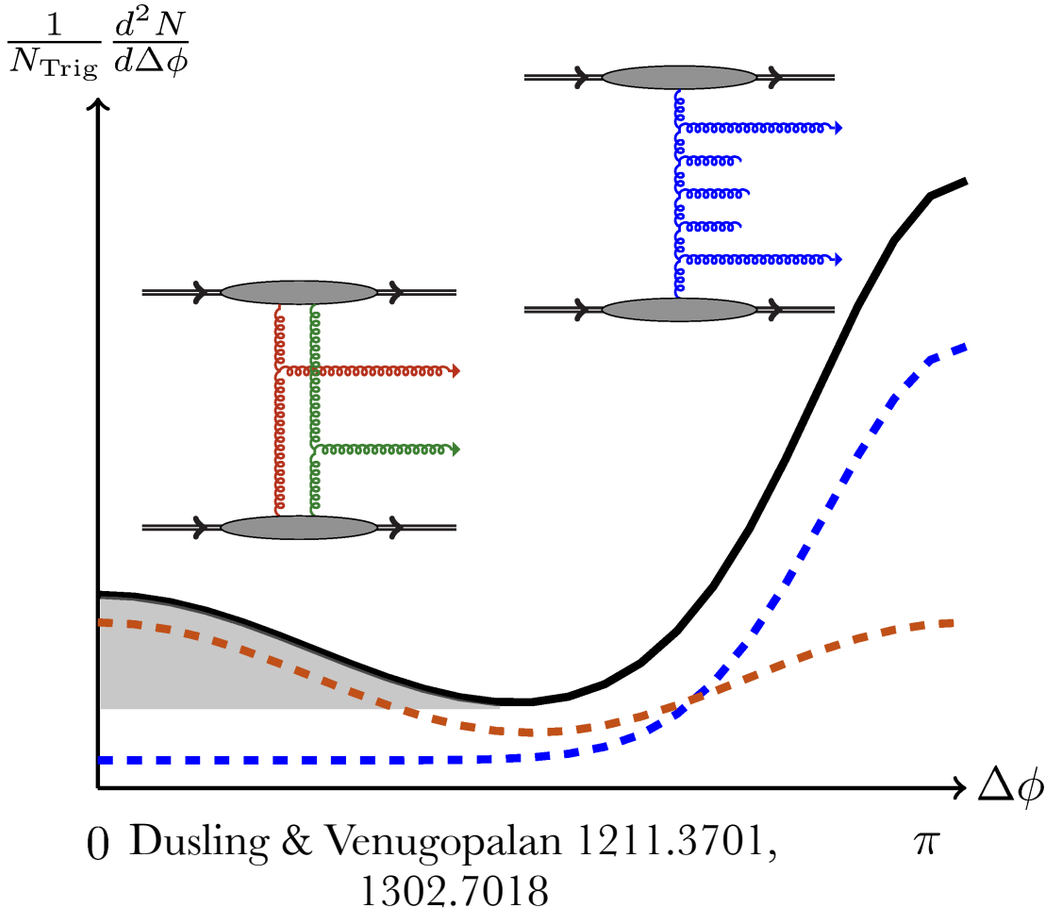




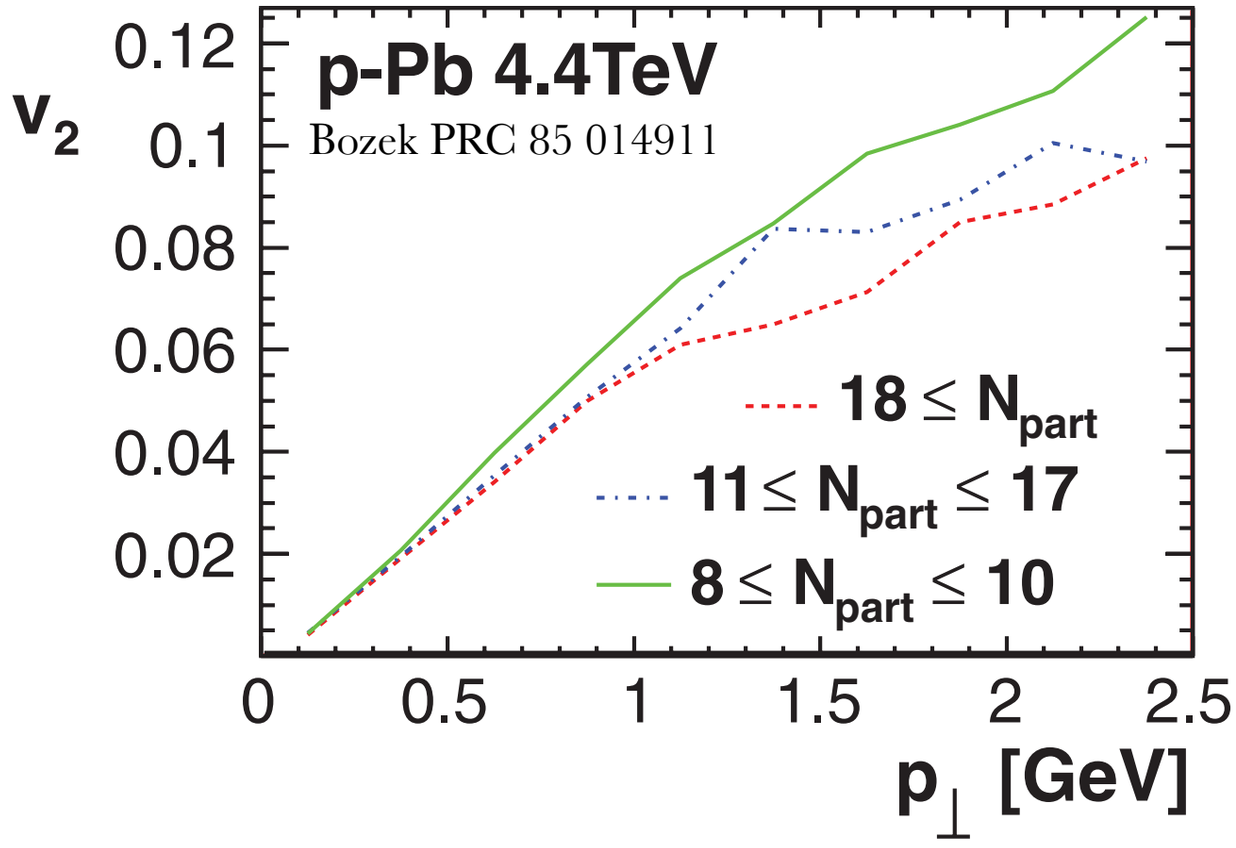


CMS PLB 718 795 (2013)
ALICE PLB 719 29
ATLAS PRL 110 182302

initial or final state effect?



Dusling & Venugopalan 1211.3701, 1302.7018



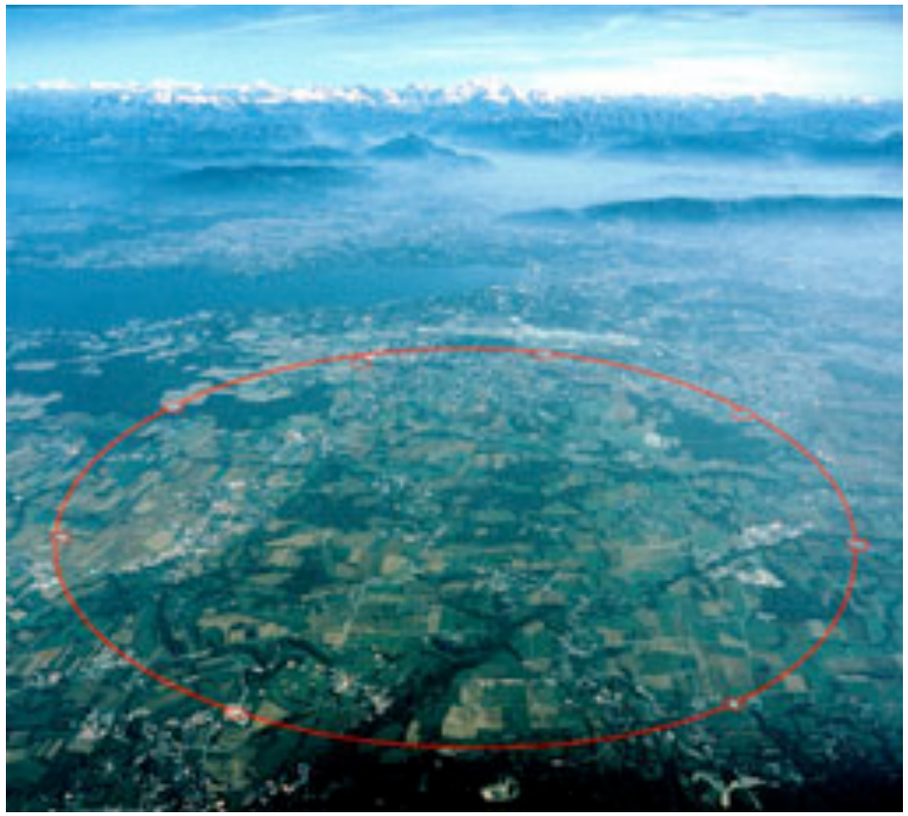
CGC/Glasma

hydrodynamics

watching from RHIC...

slide from Peter Steinberg JQRL 4/13

RHIC & LHC



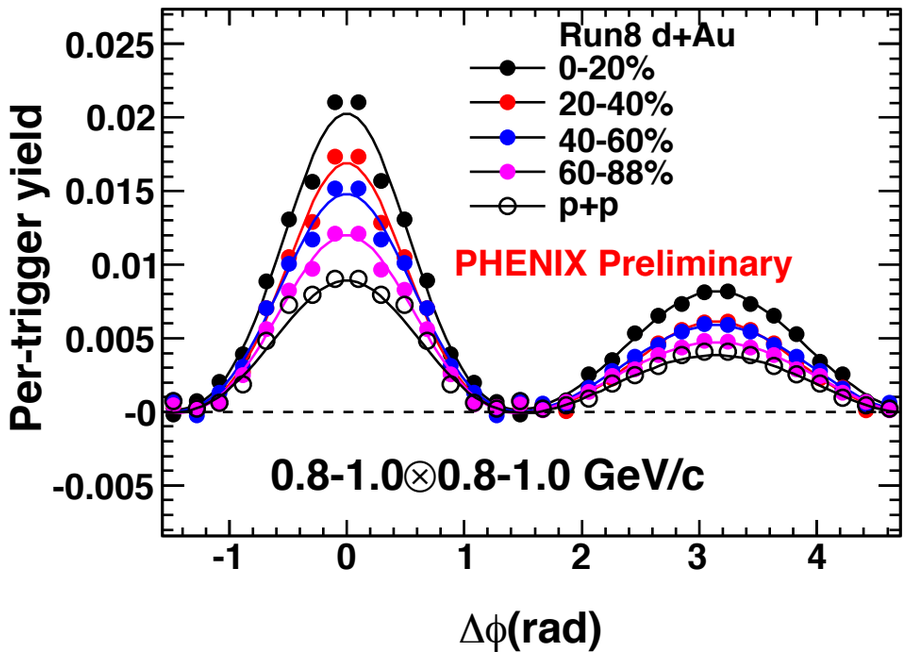
5.02TeV pPb

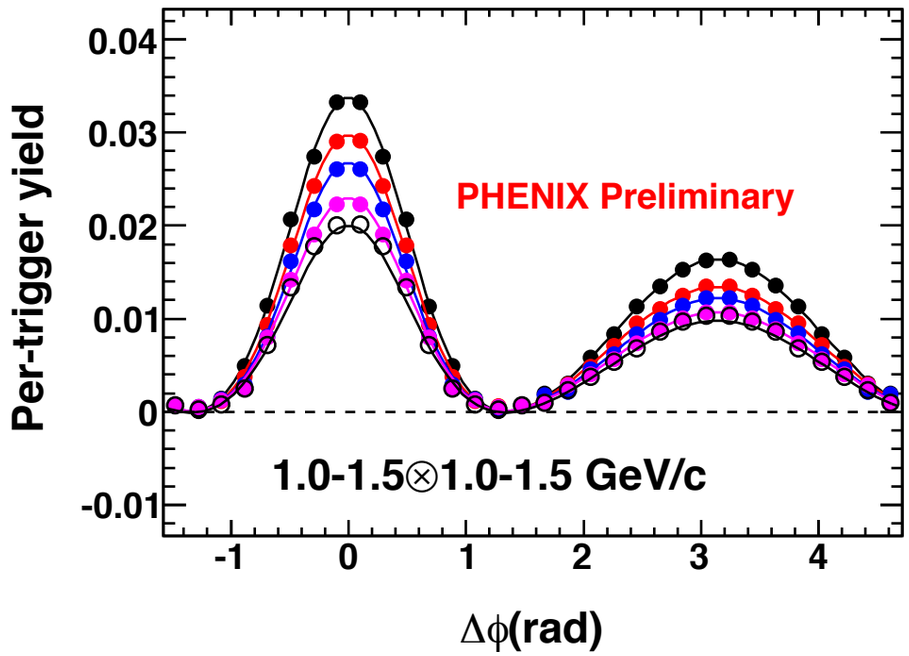
200GeV dAu

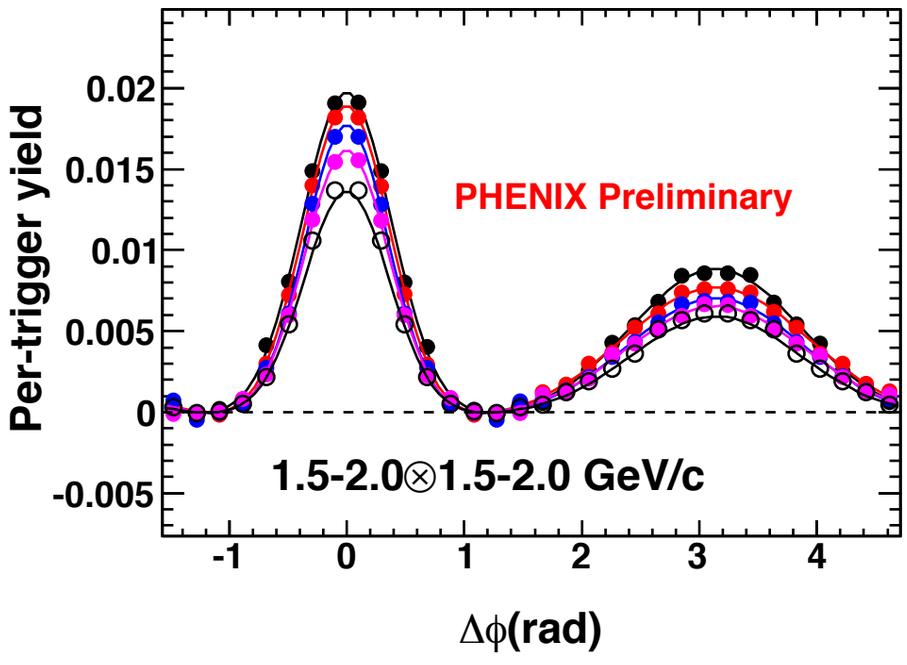
25x difference in collision energy
d-A vs p-A
large data sample already on tape

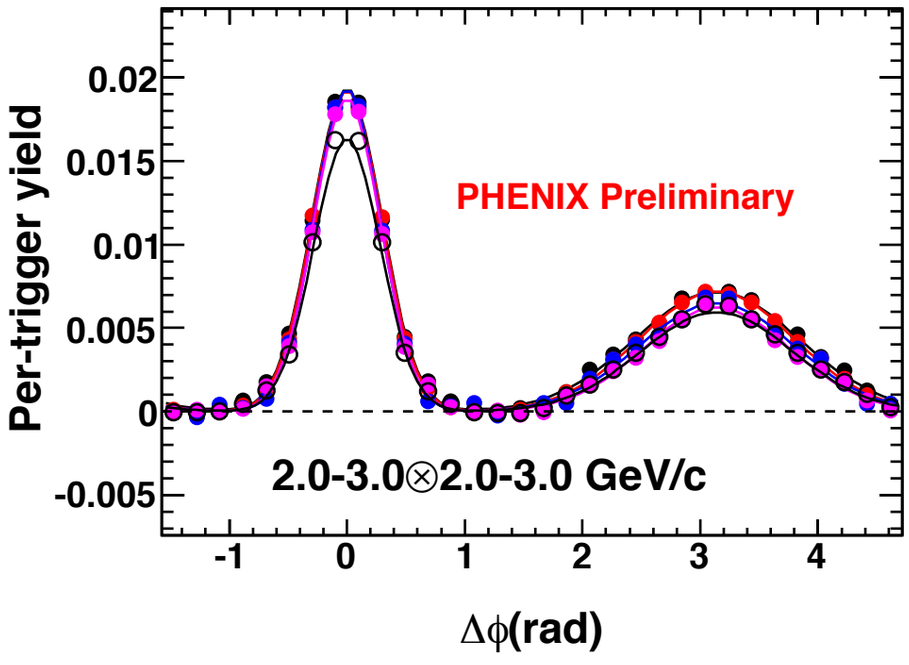
what do we already know?

from Quark Matter 2009 poster... $|\eta| < 0.35$





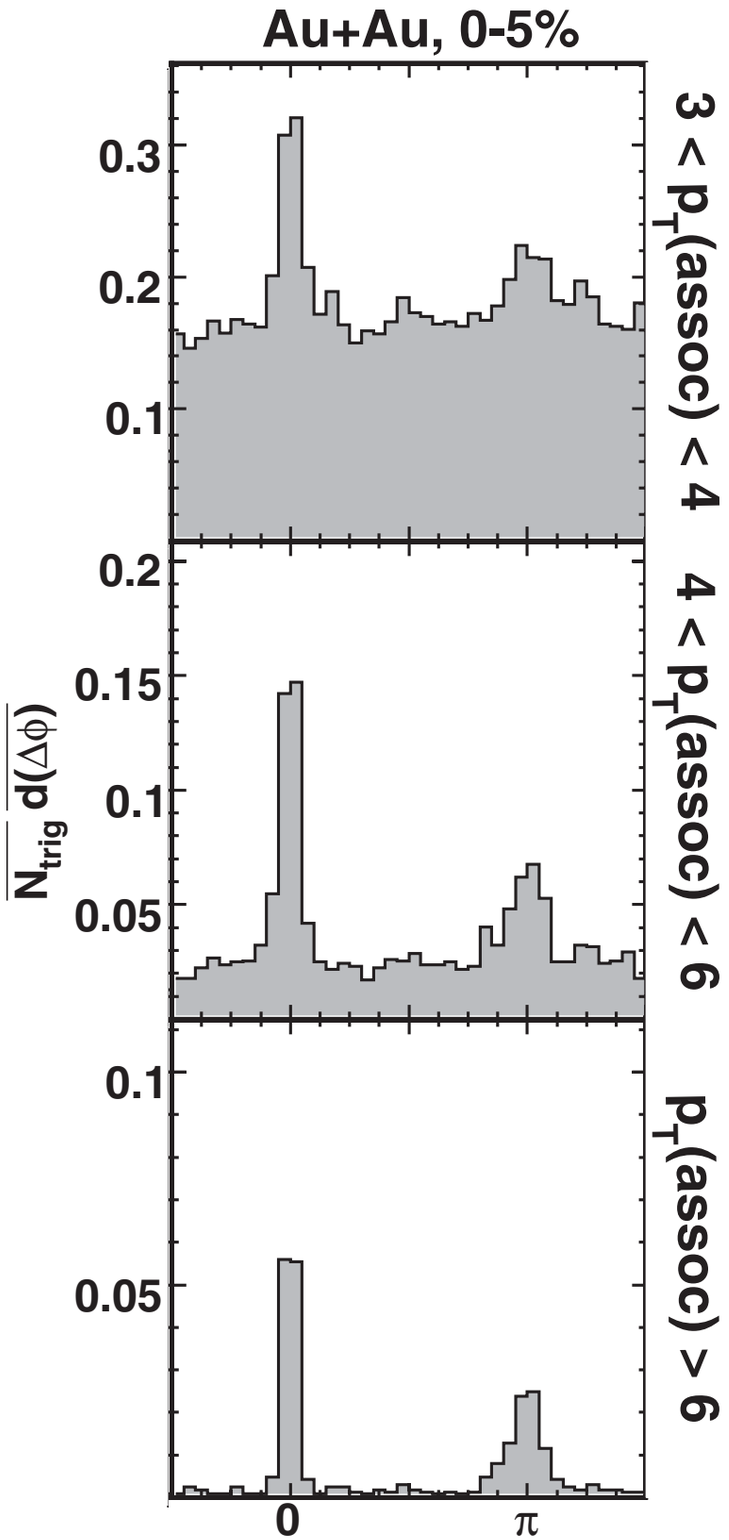




centrality dependent low p_T excess yield on both near and away side

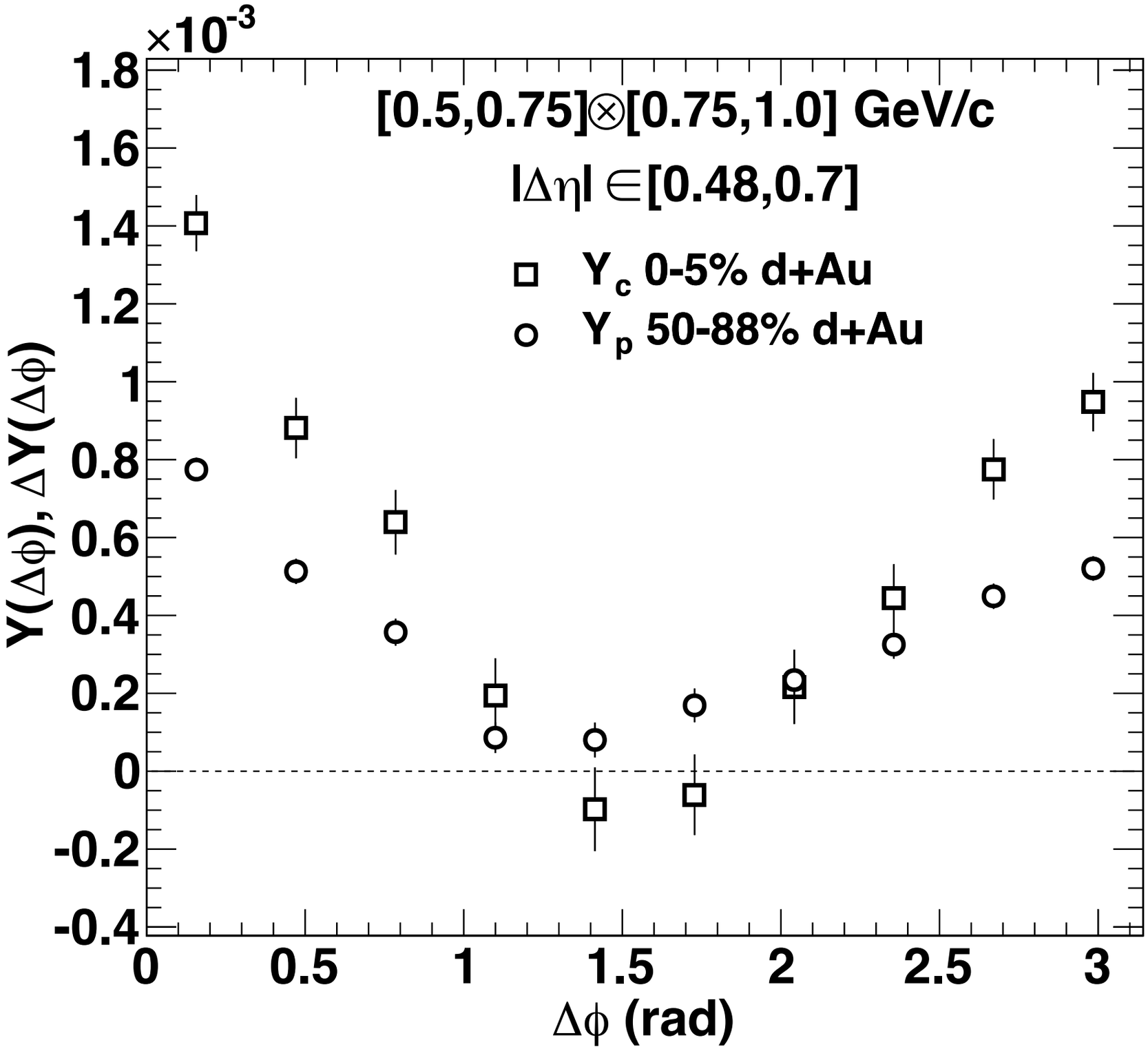
Jia: 0906.3776

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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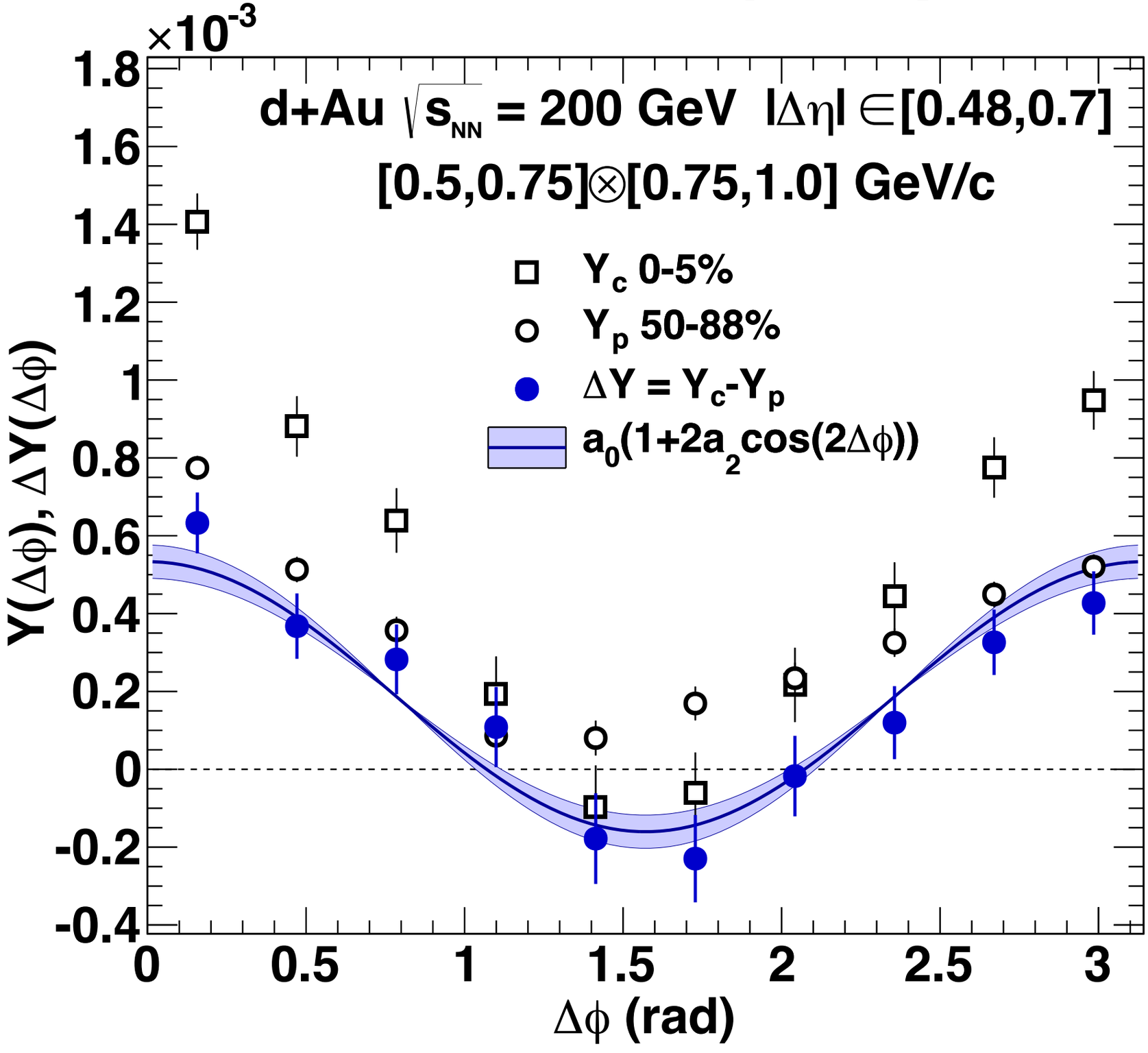
centrality dependence



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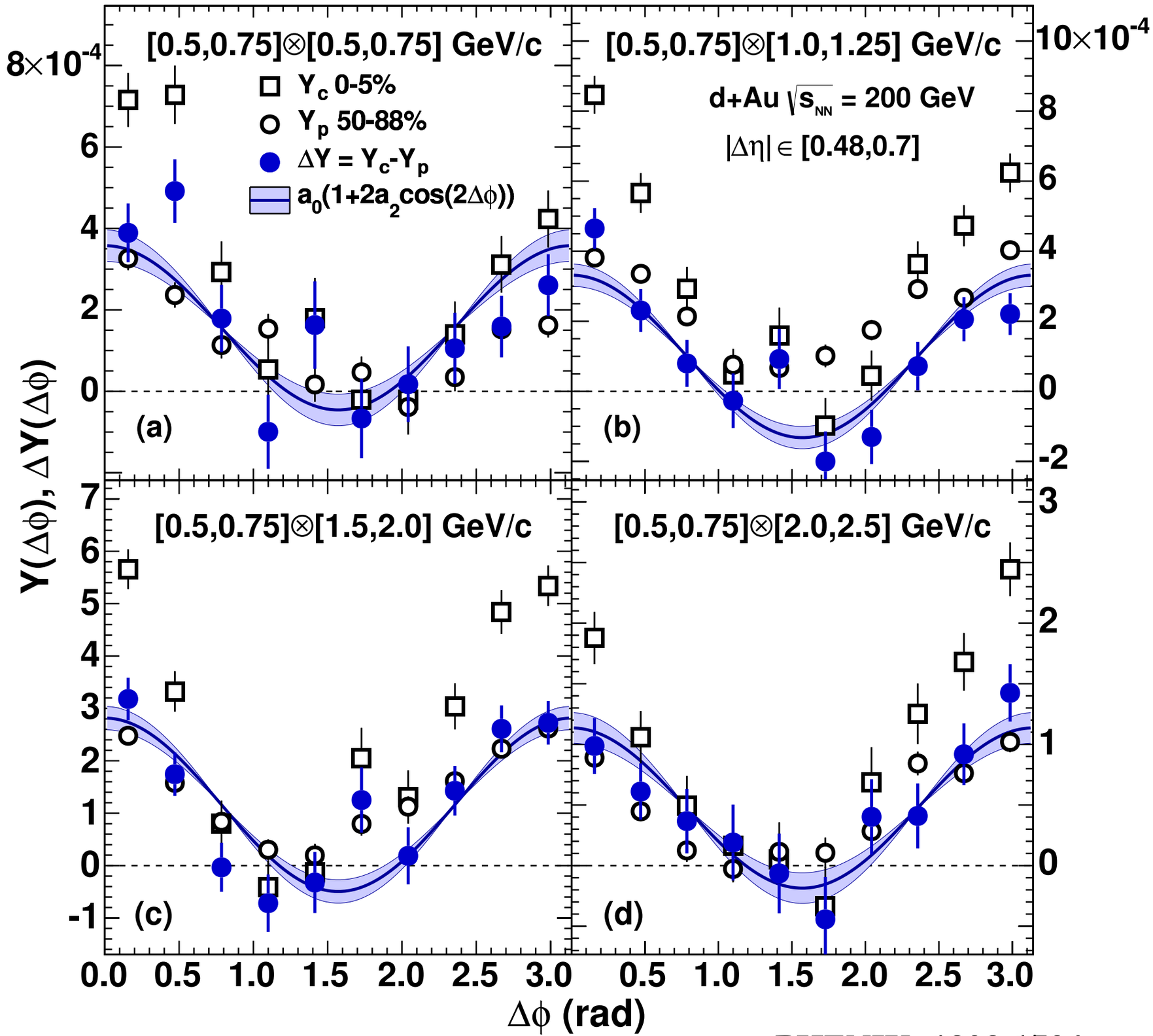
centrality dependence consistently described by cos2Δφ shape



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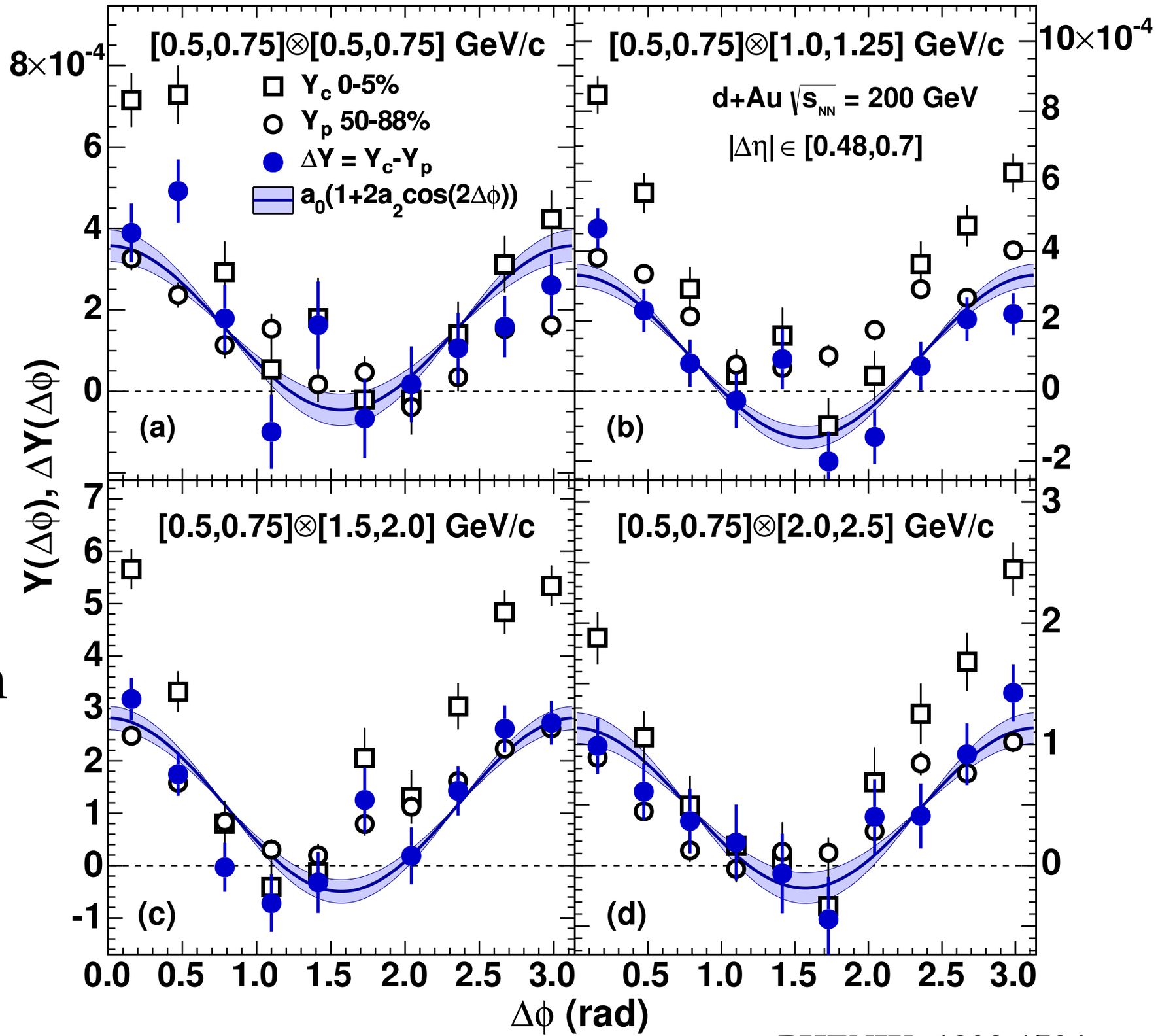
centrality dependence consistently described by cos2Δφ shape

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



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
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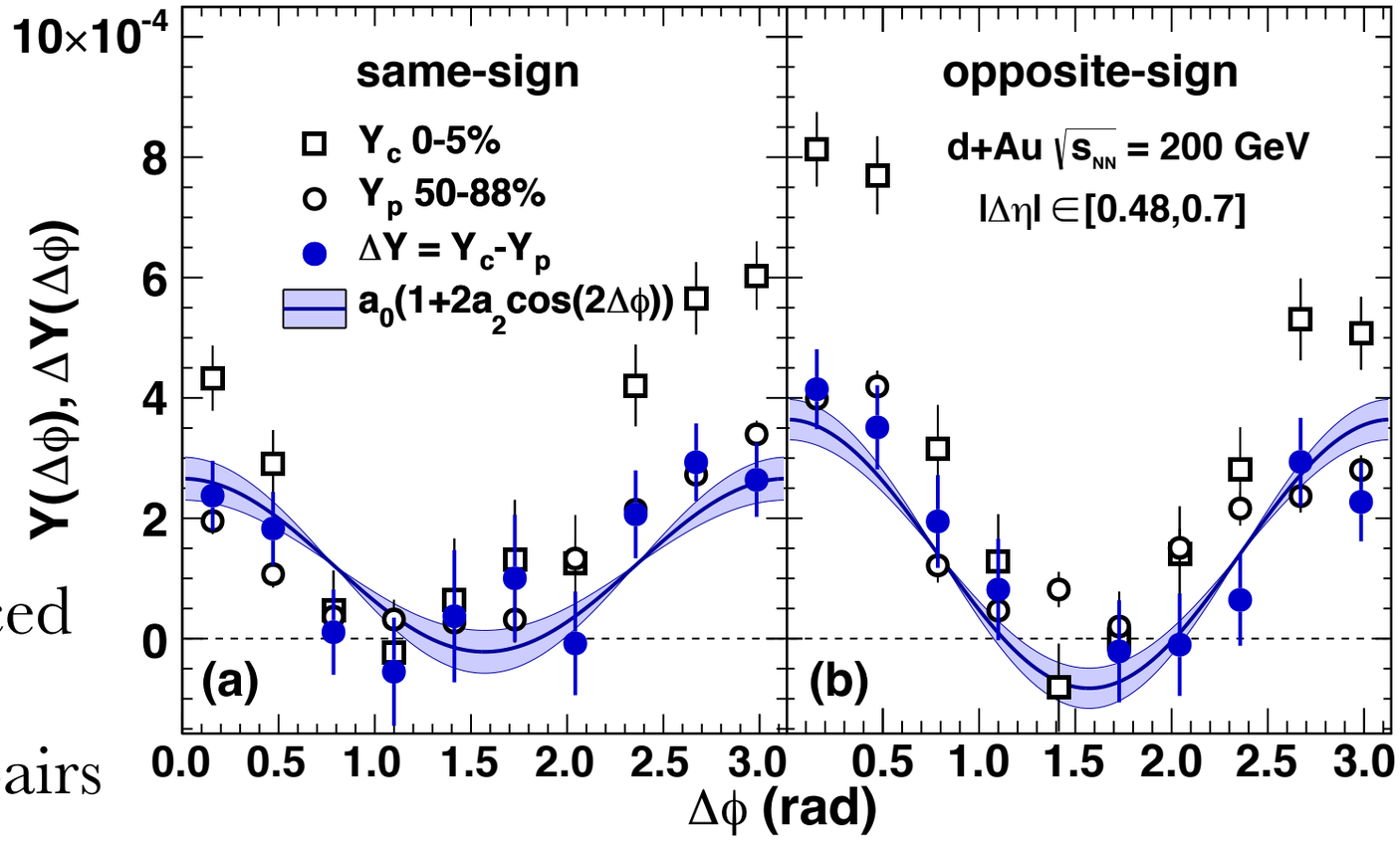

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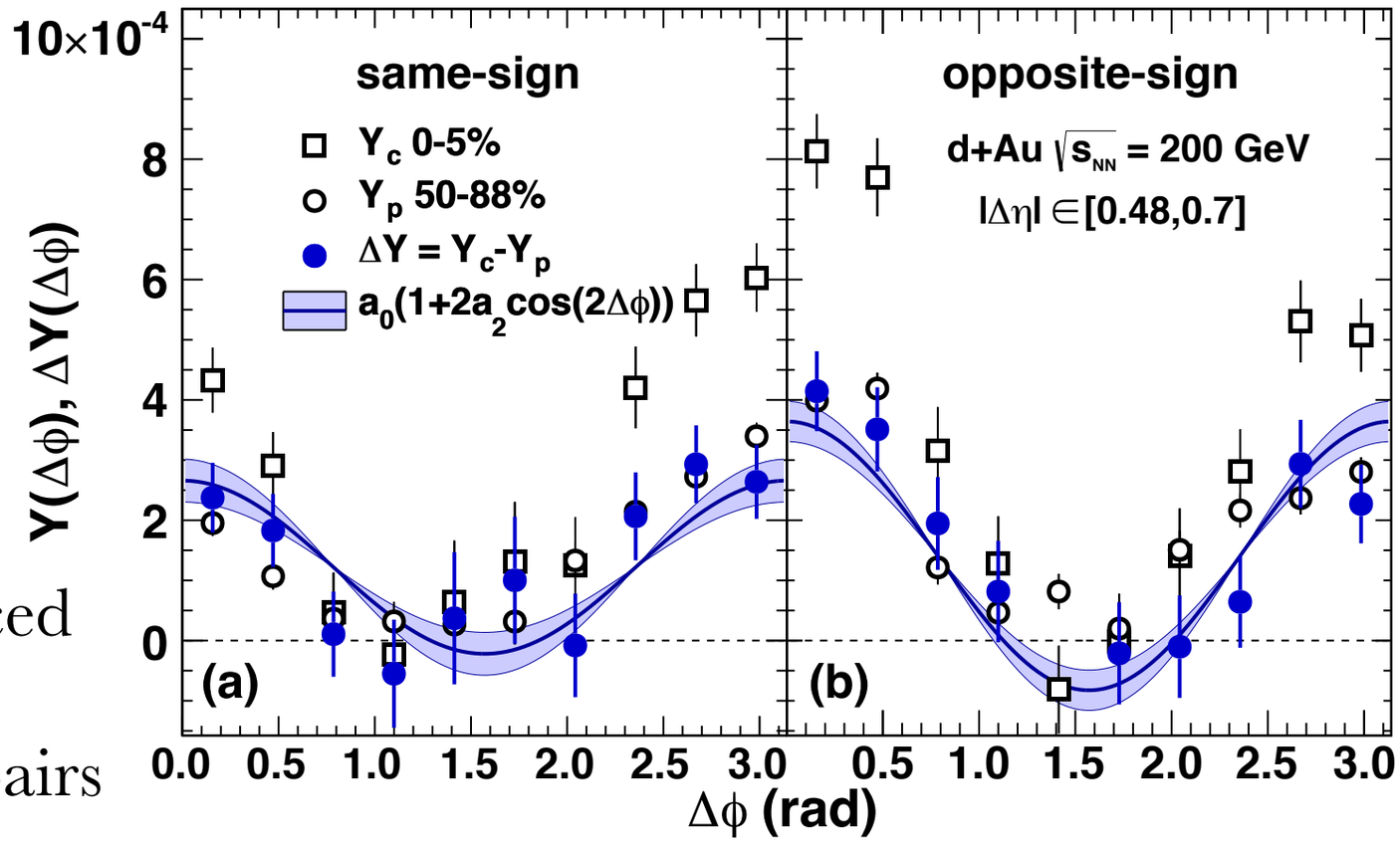

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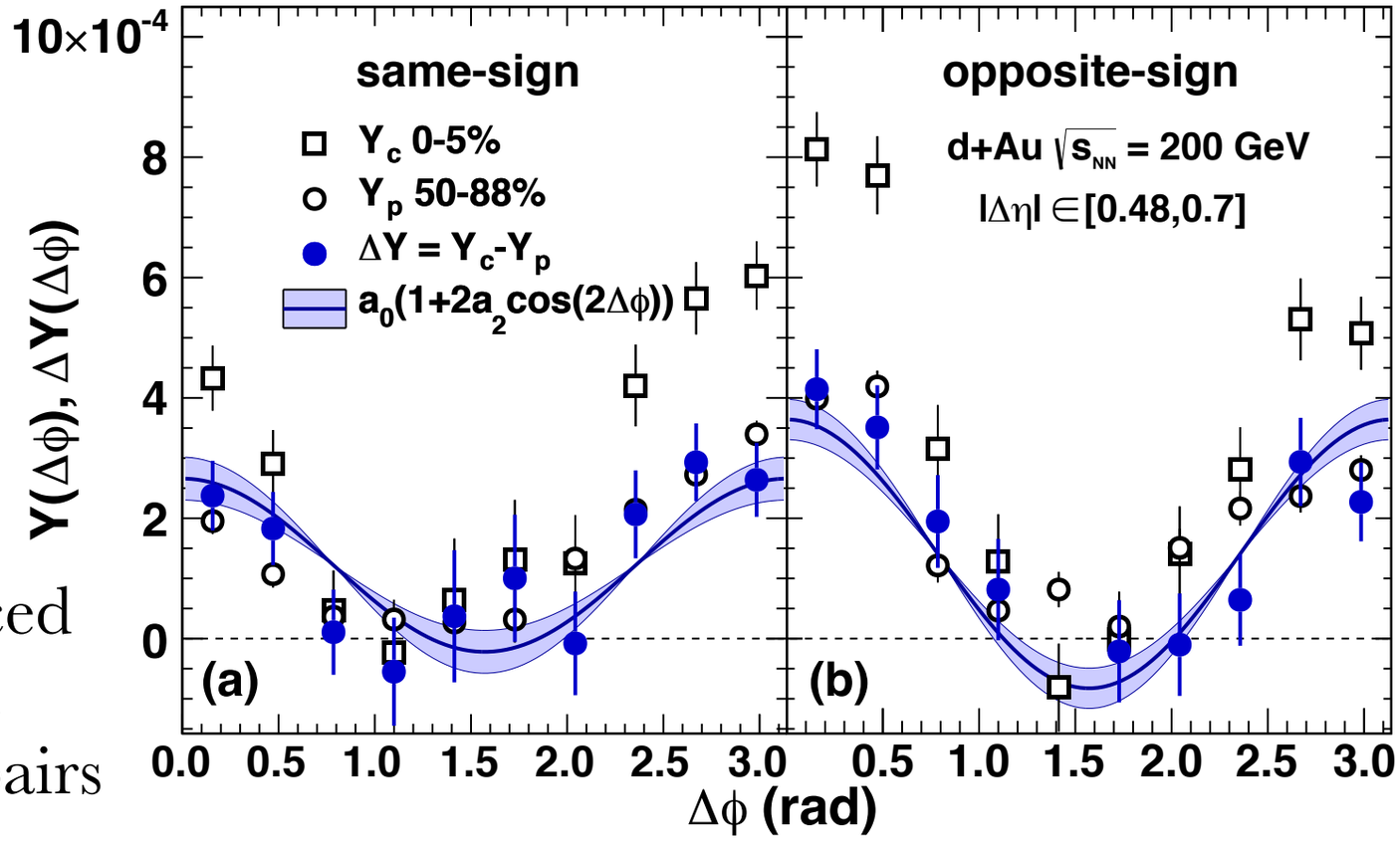

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- in progress: further studying with event generators
- New!: look for long range correlations

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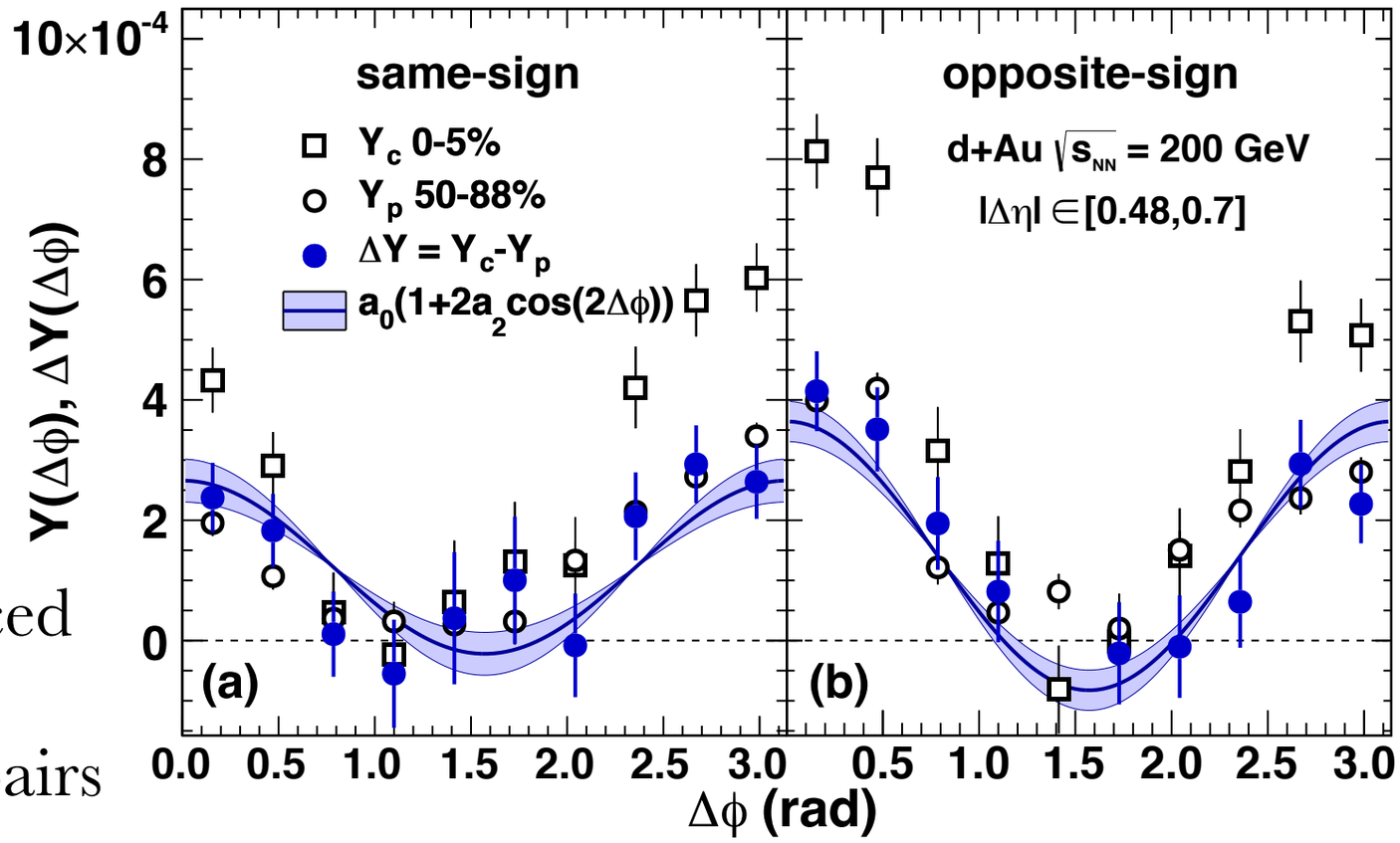
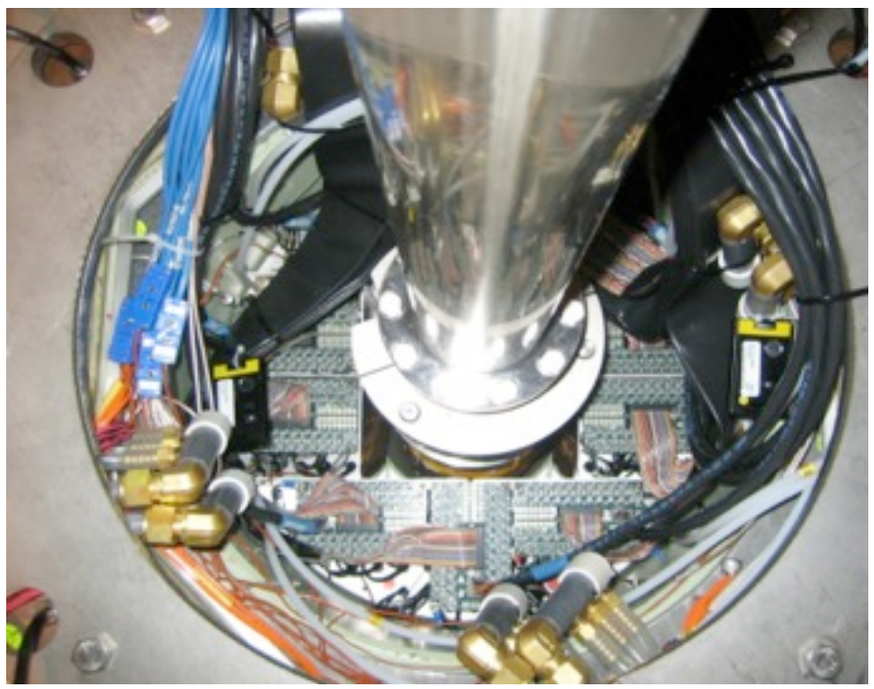


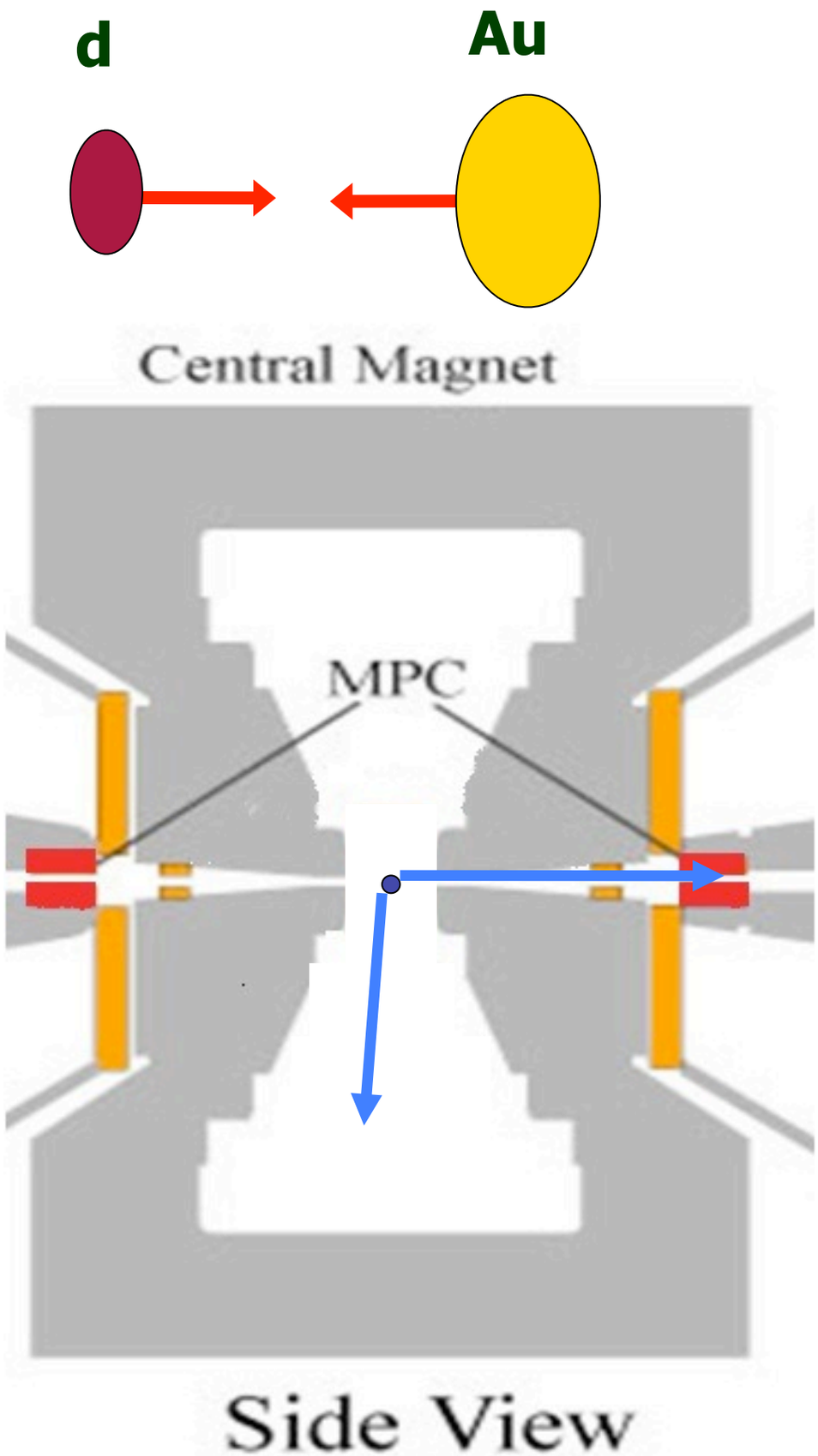
rapidity separated correlations

Muon Piston Calorimeters

both d-going & Au-going directions

$3 < |\eta| < 4$

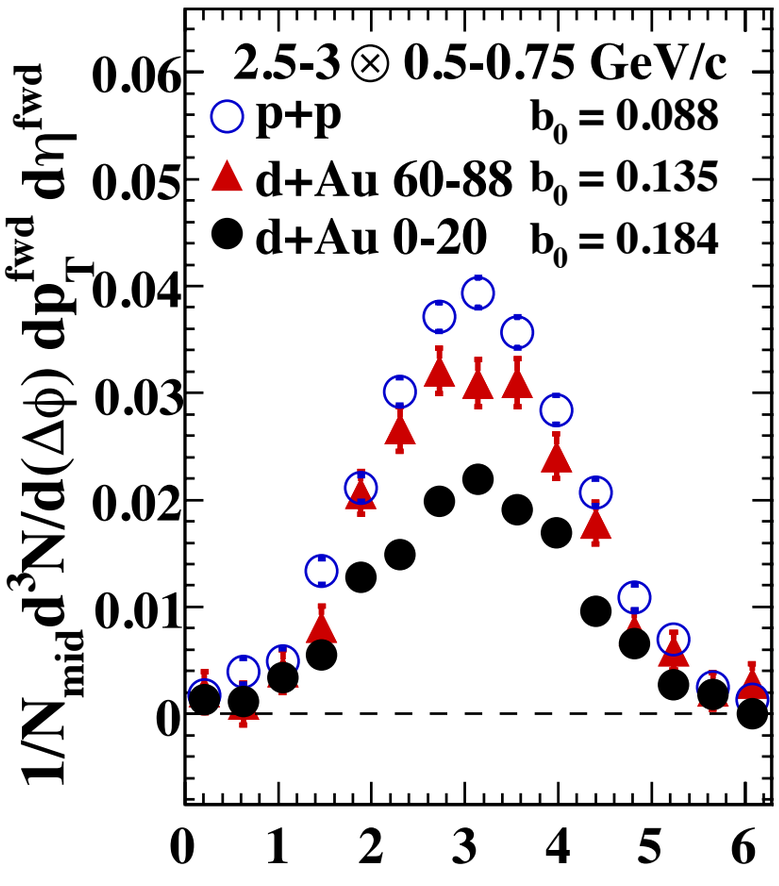




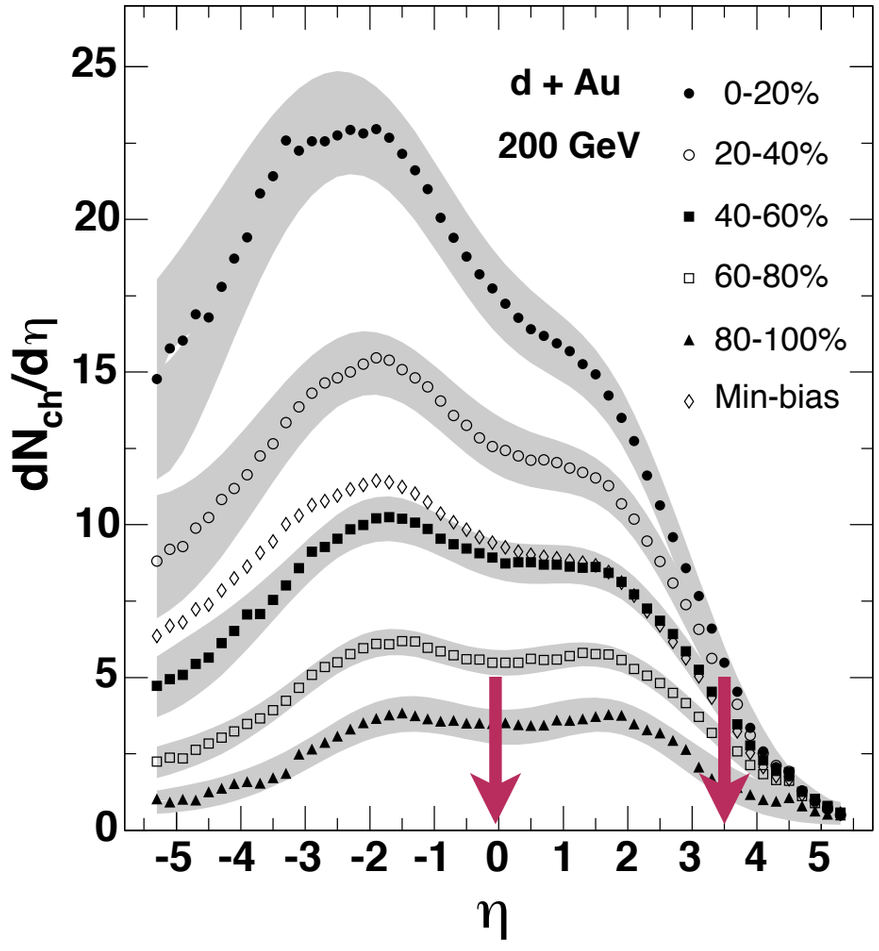
rapidity separated correlations

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



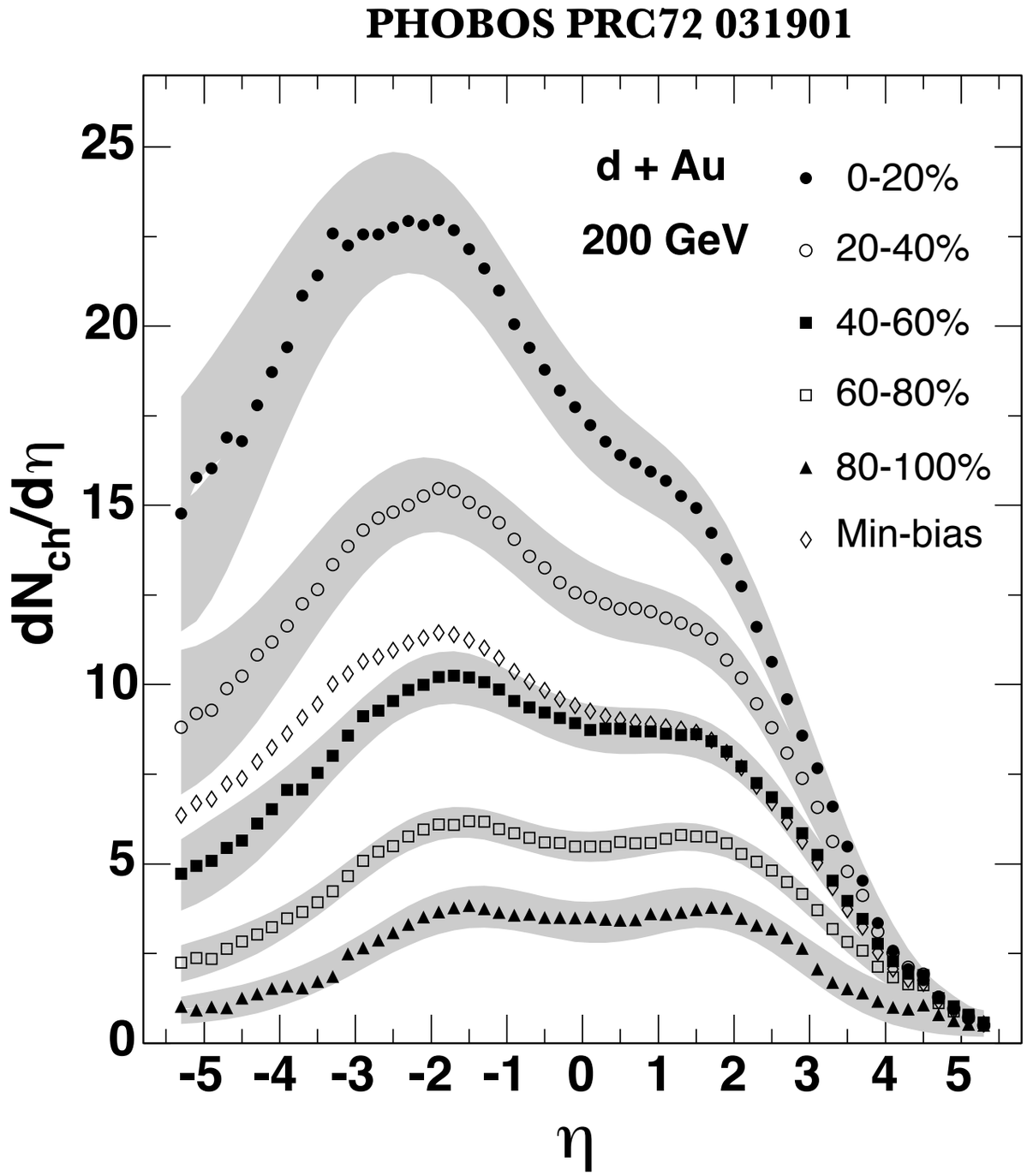
no evidence for long range correlation at $\Delta\phi \sim 0$

however, this is at relatively high p_T and only 0-20% central→not the most sensitive place to look...

extending forward/backward correlations

NEW! Shengli Huang

- 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: lon range: $3 < |\Delta\eta| < 4$
- separate d-going and Au-going phenomena



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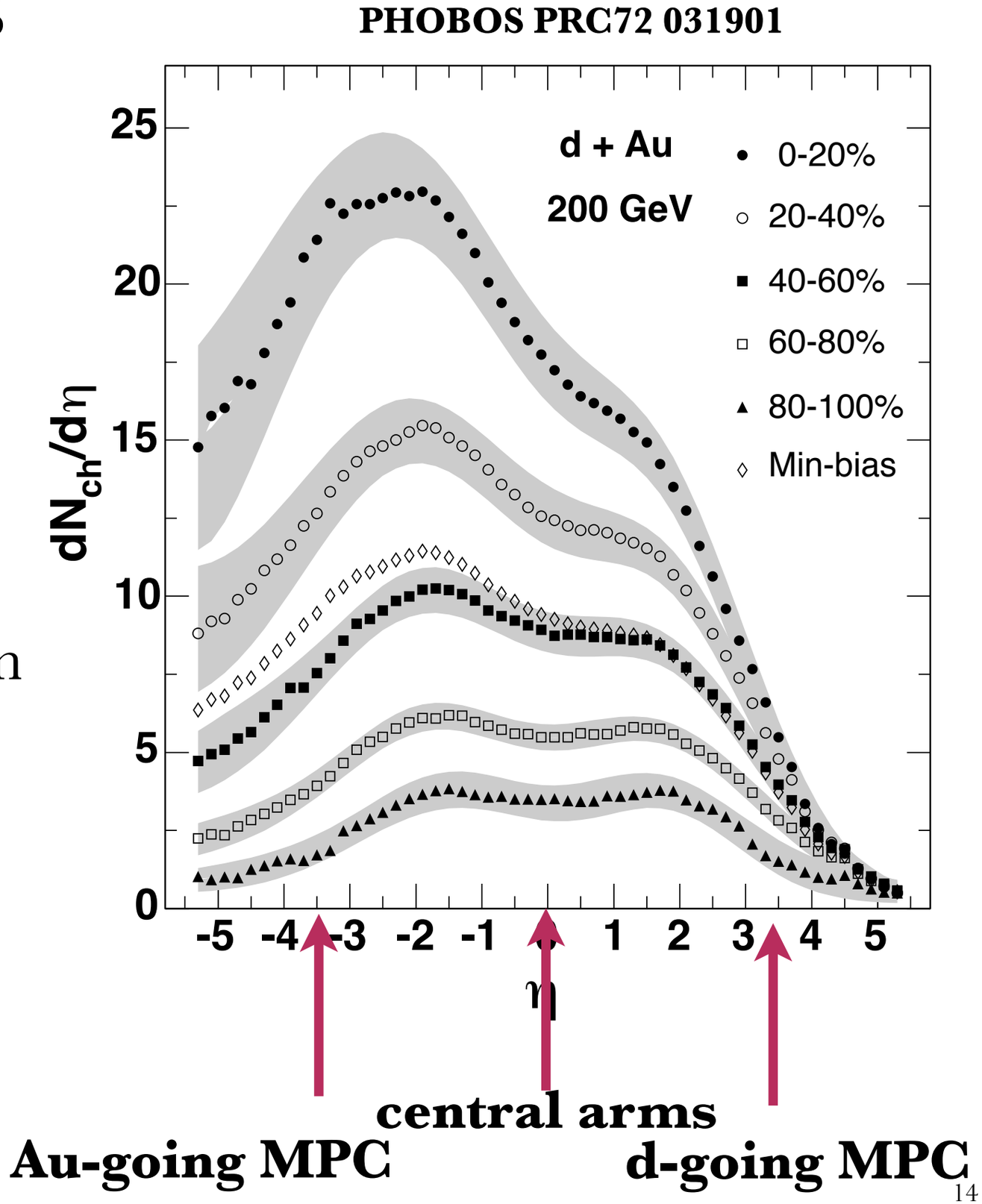
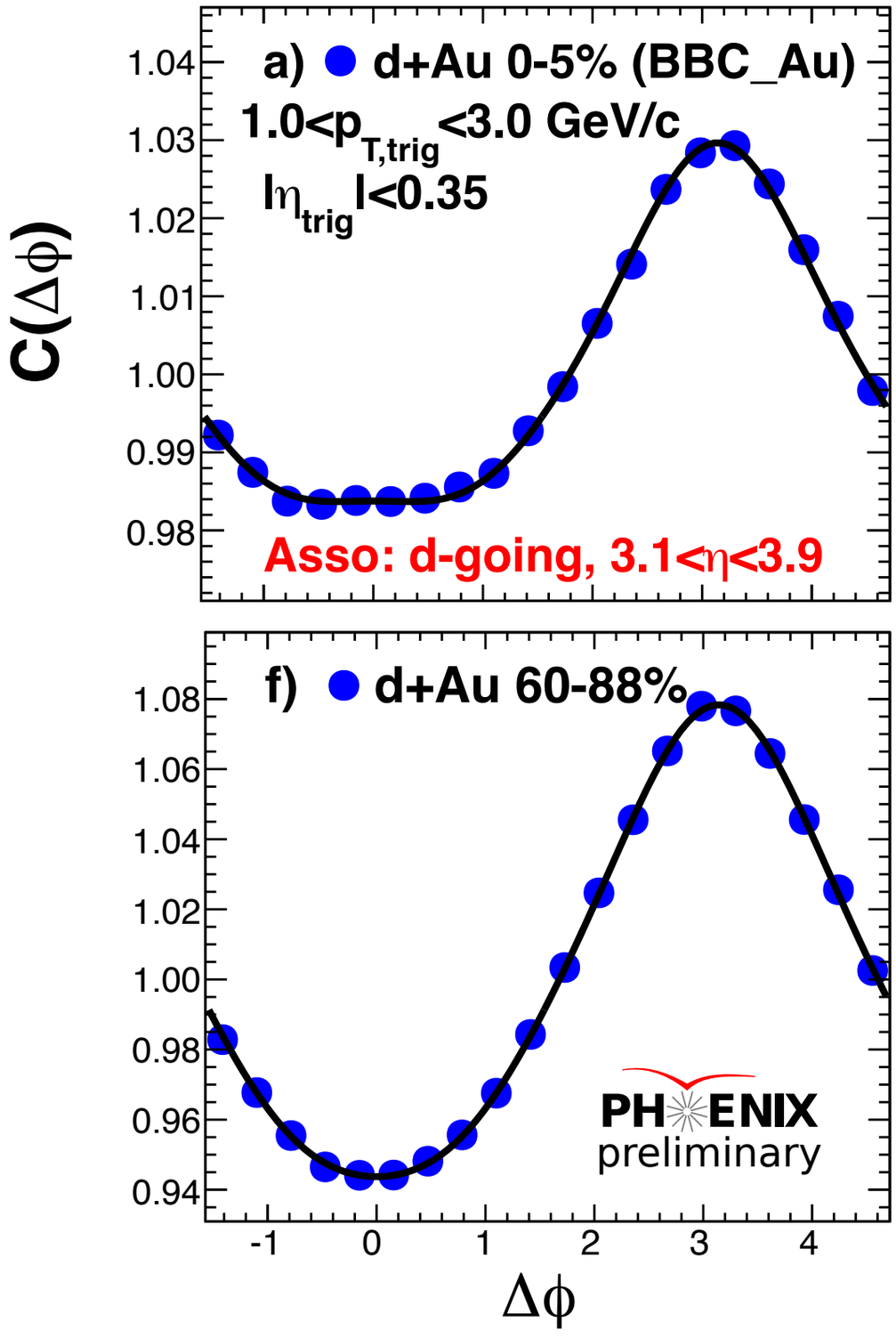
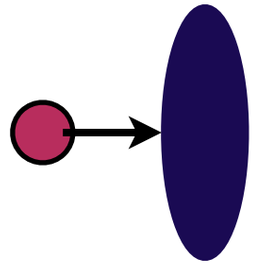
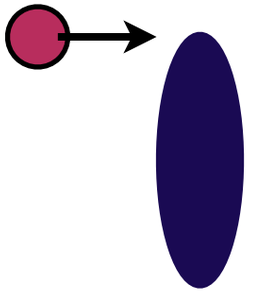


NEW! mid/d-going correlations







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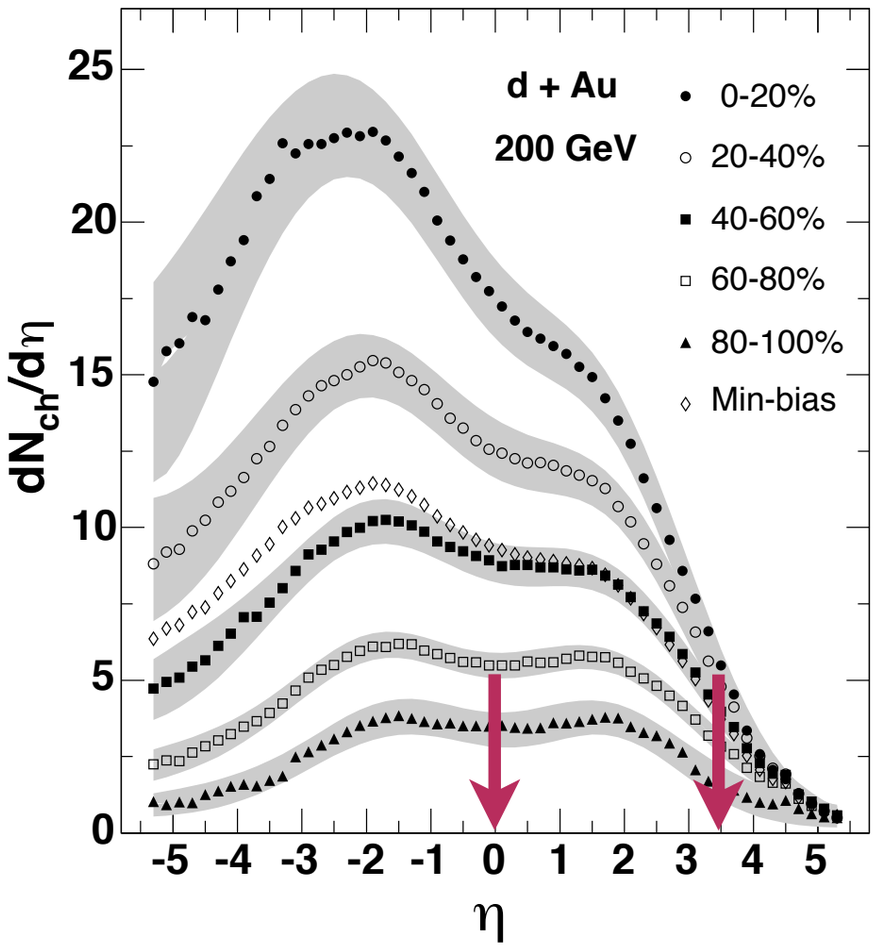
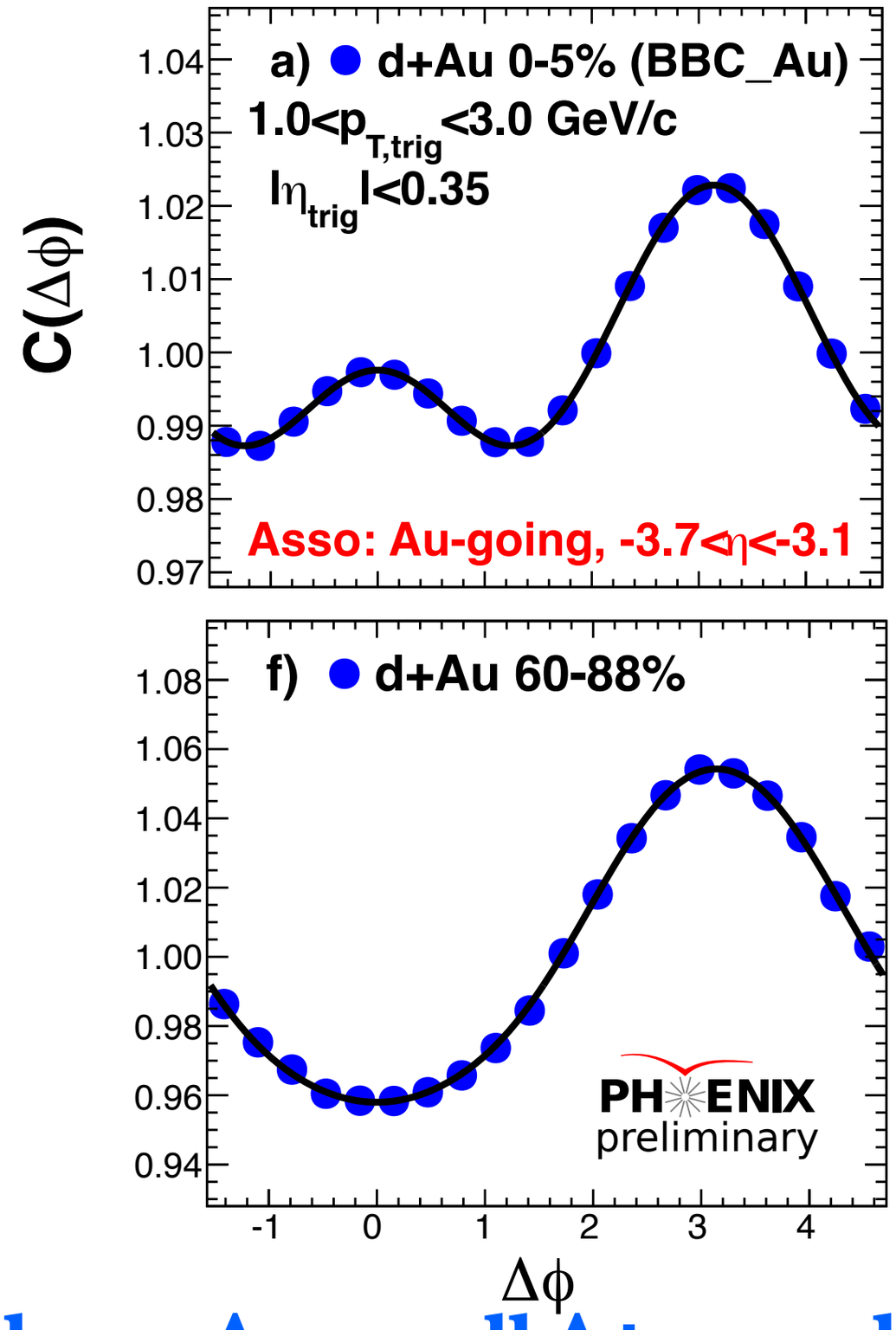
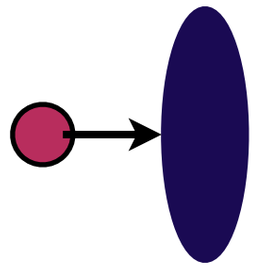
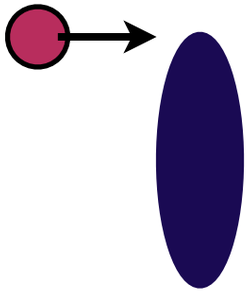


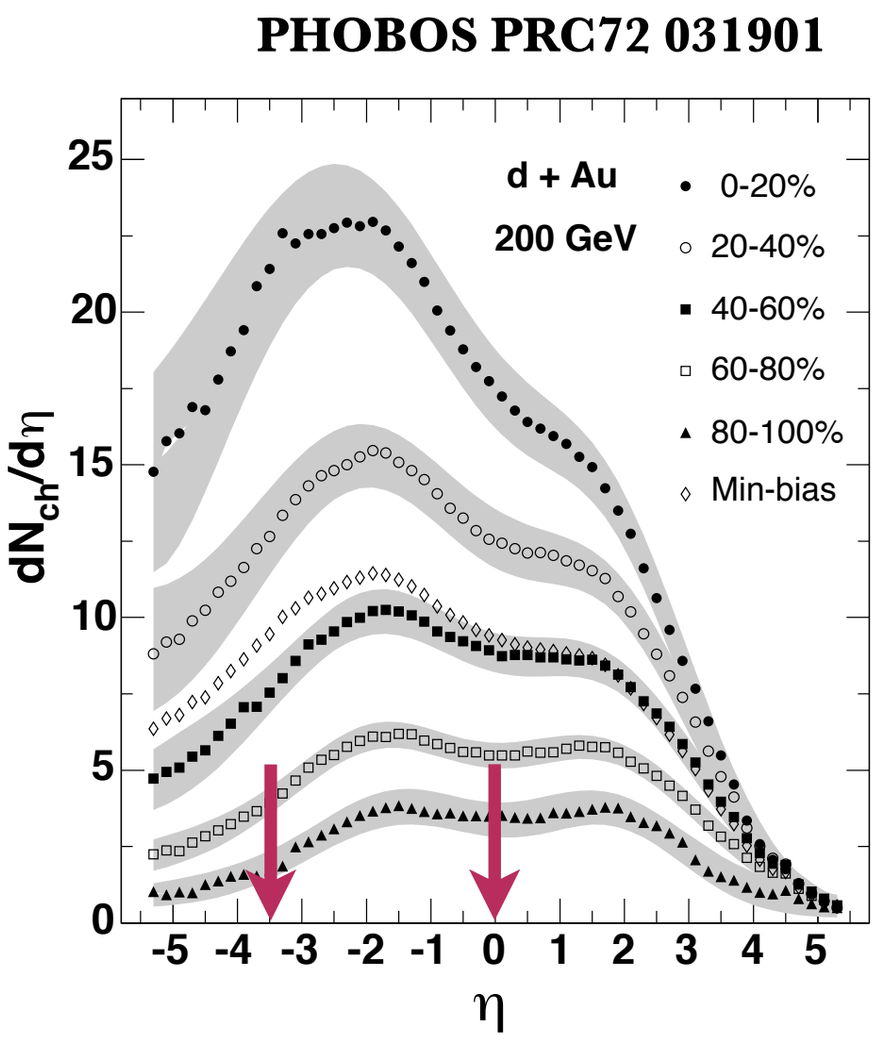
no small Δφ bump, some shape change

NEW! mid/Au-going correlations



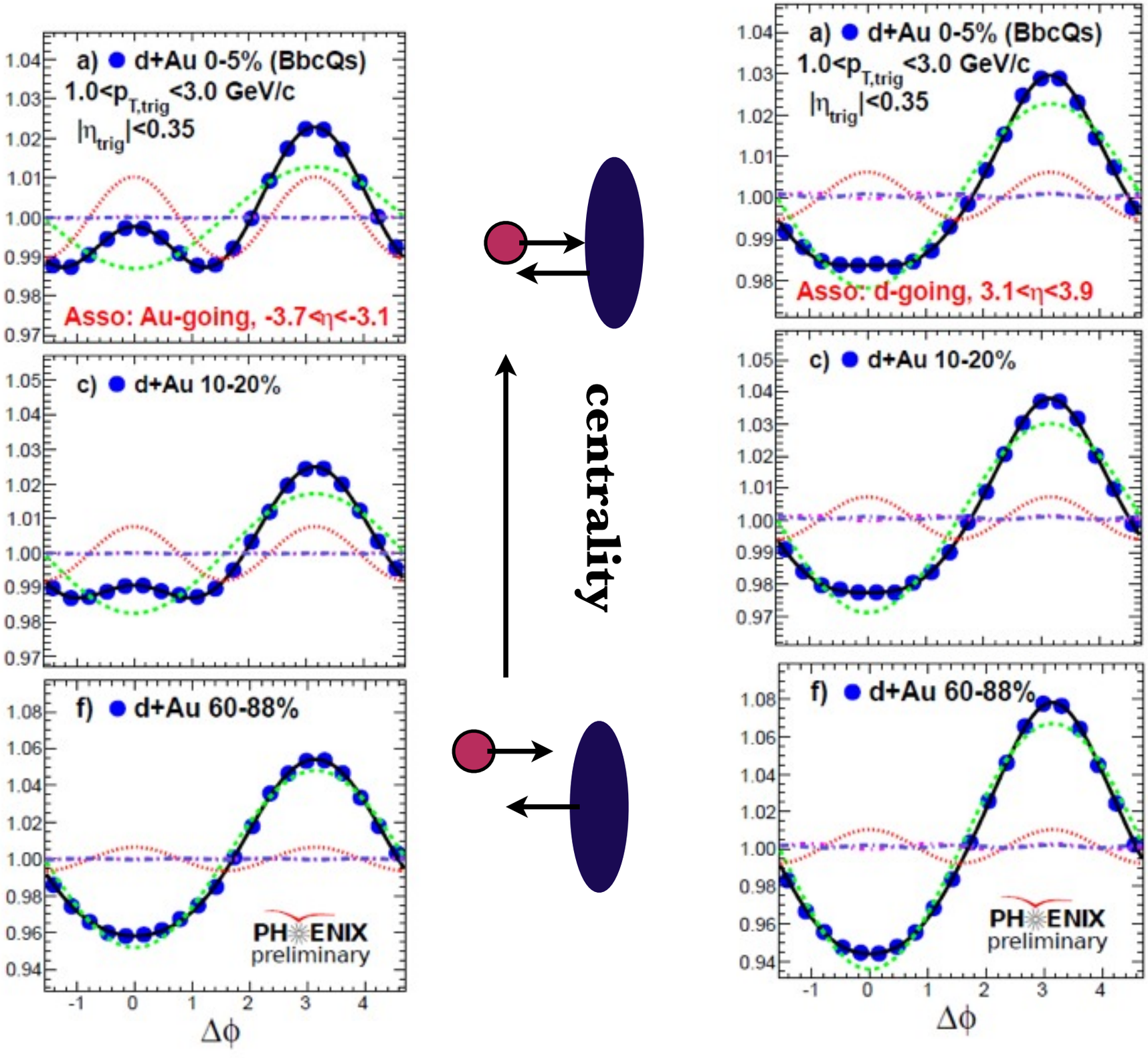




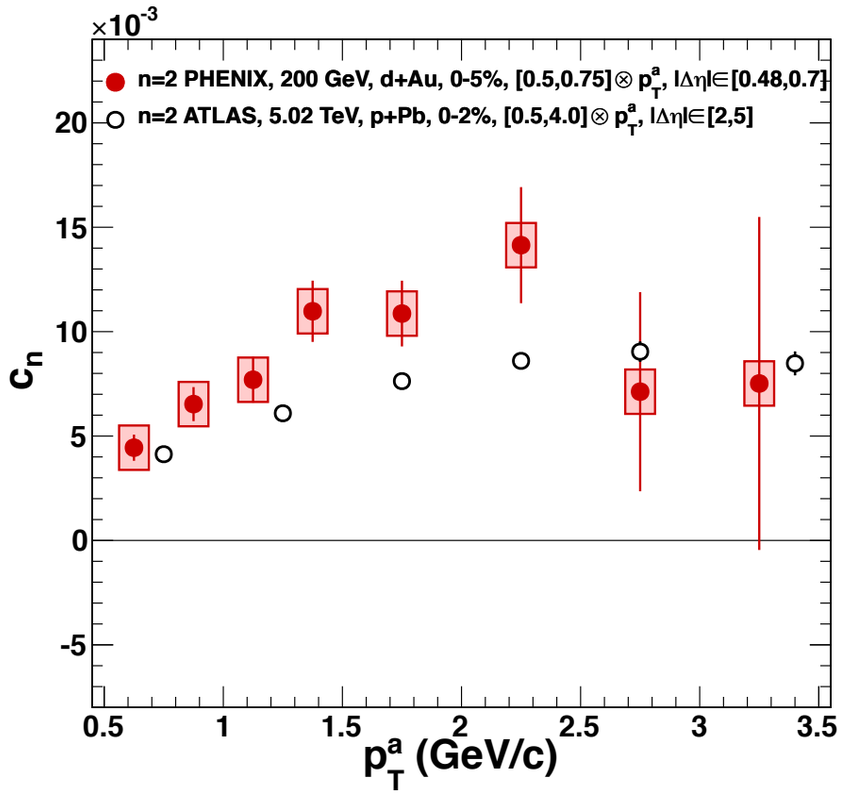


large Δη small Δφ correlations in central dAu collisions

NEW! mid/Au-going correlations

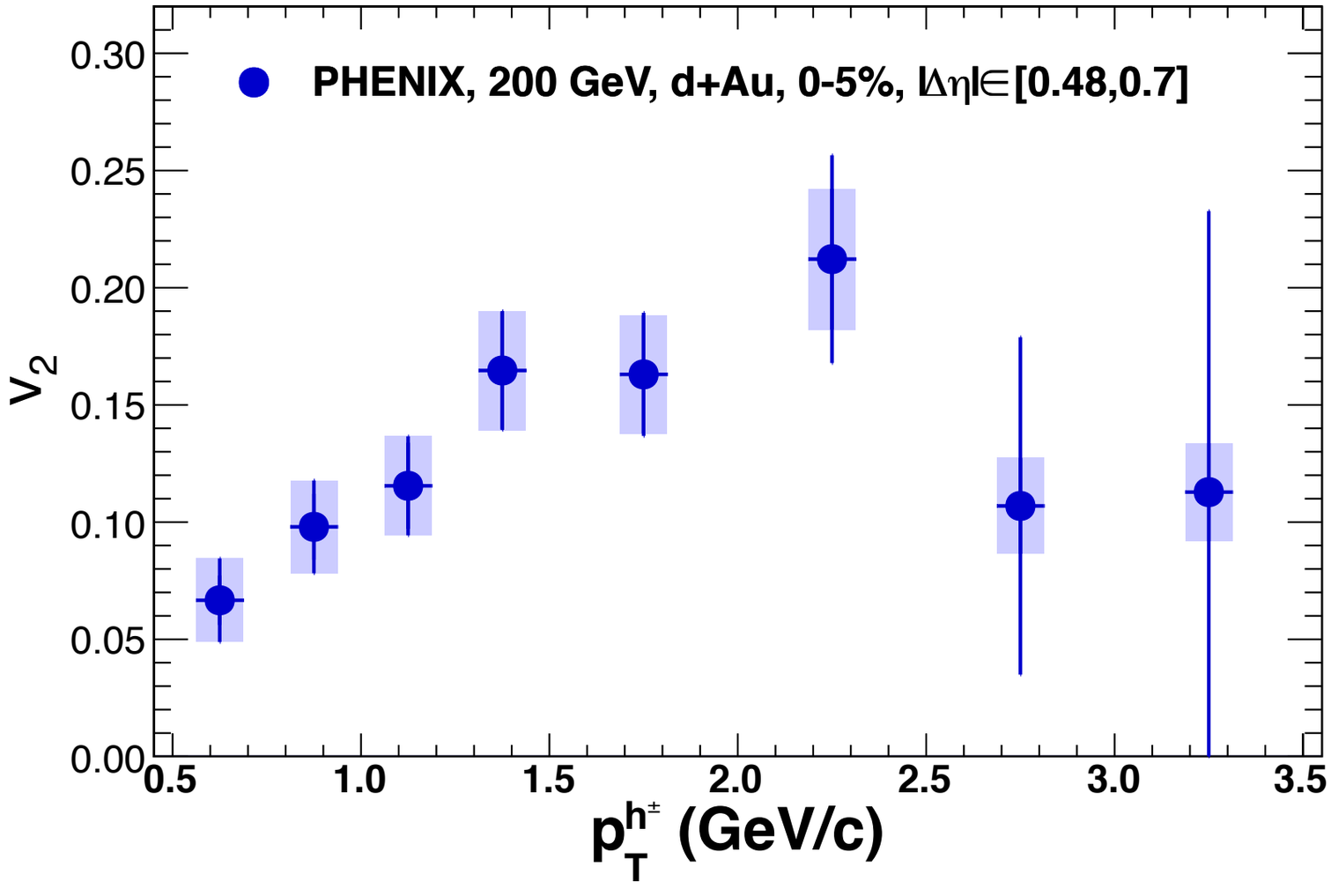


getting quantitative...



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

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



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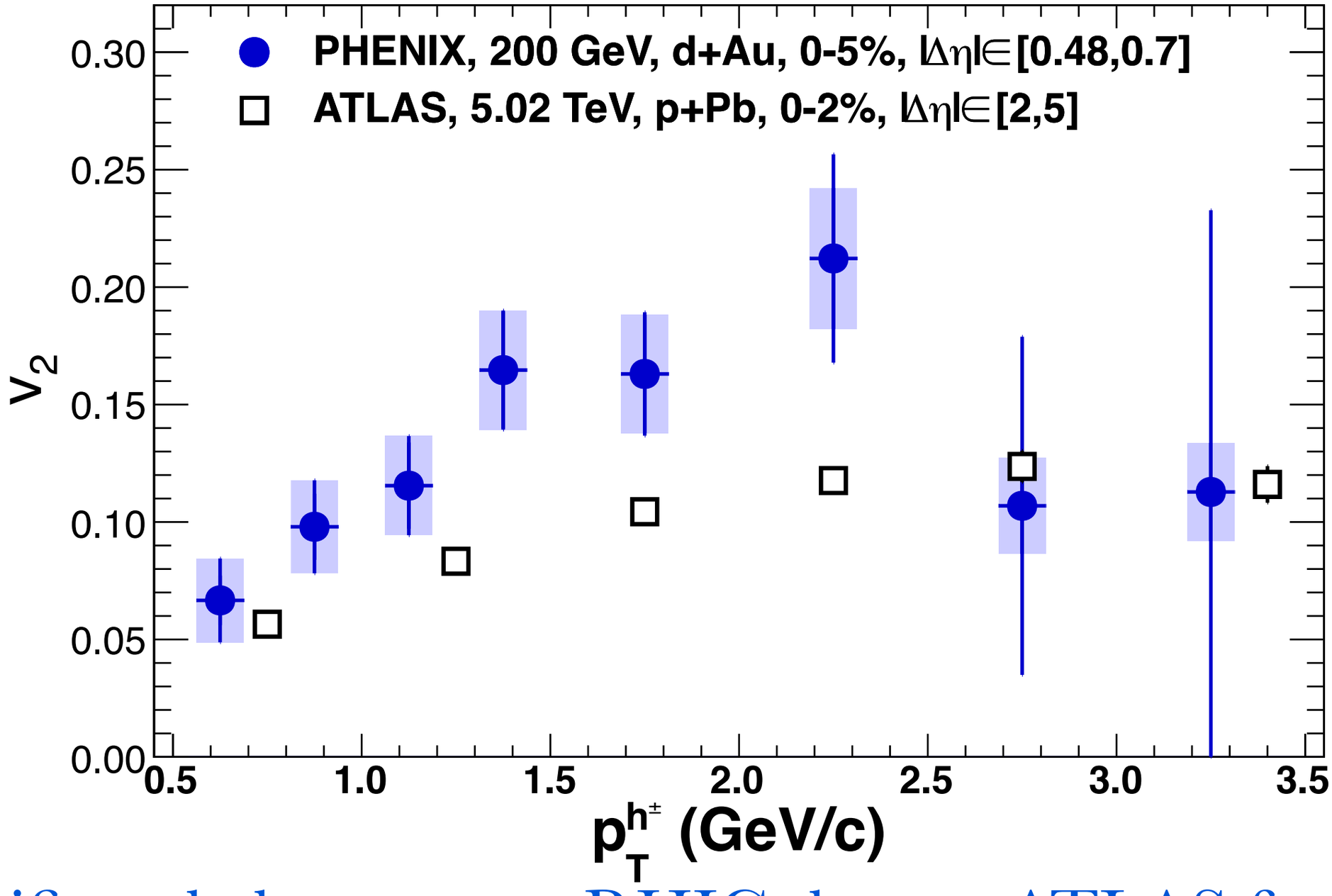
comparison with LHC results



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

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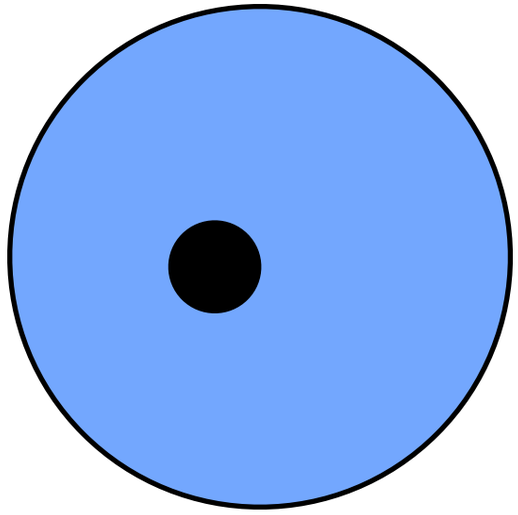
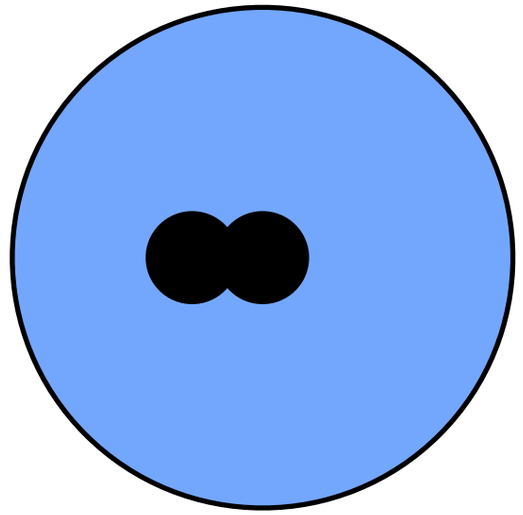
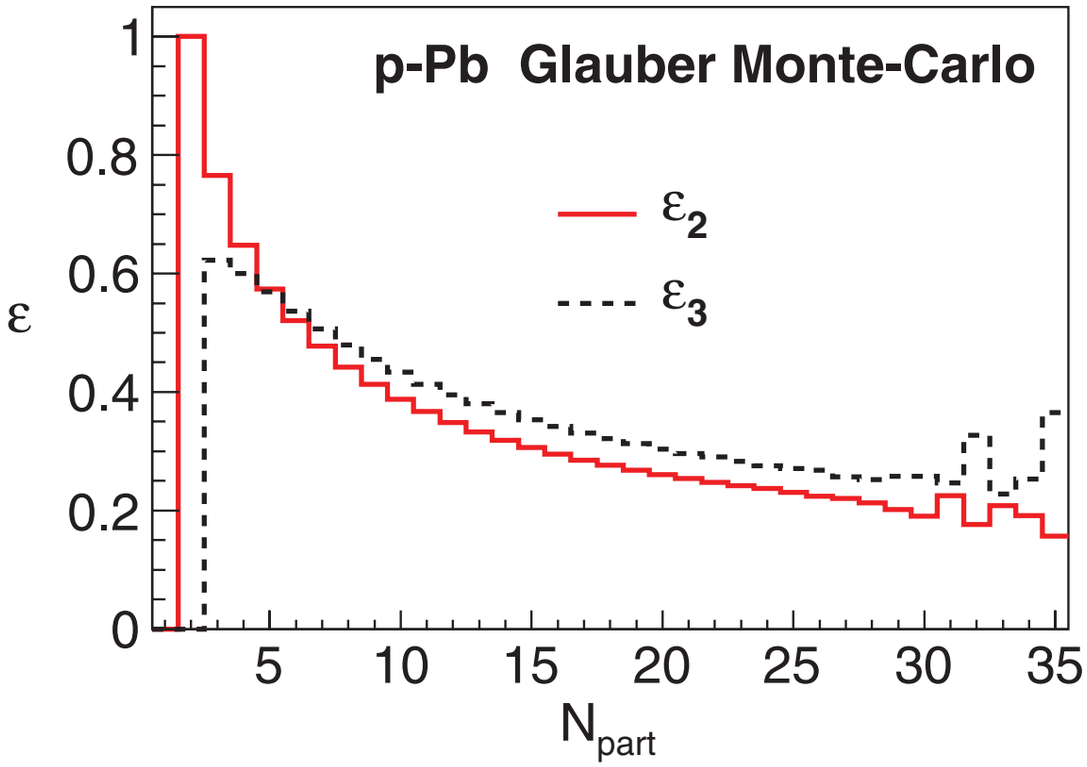
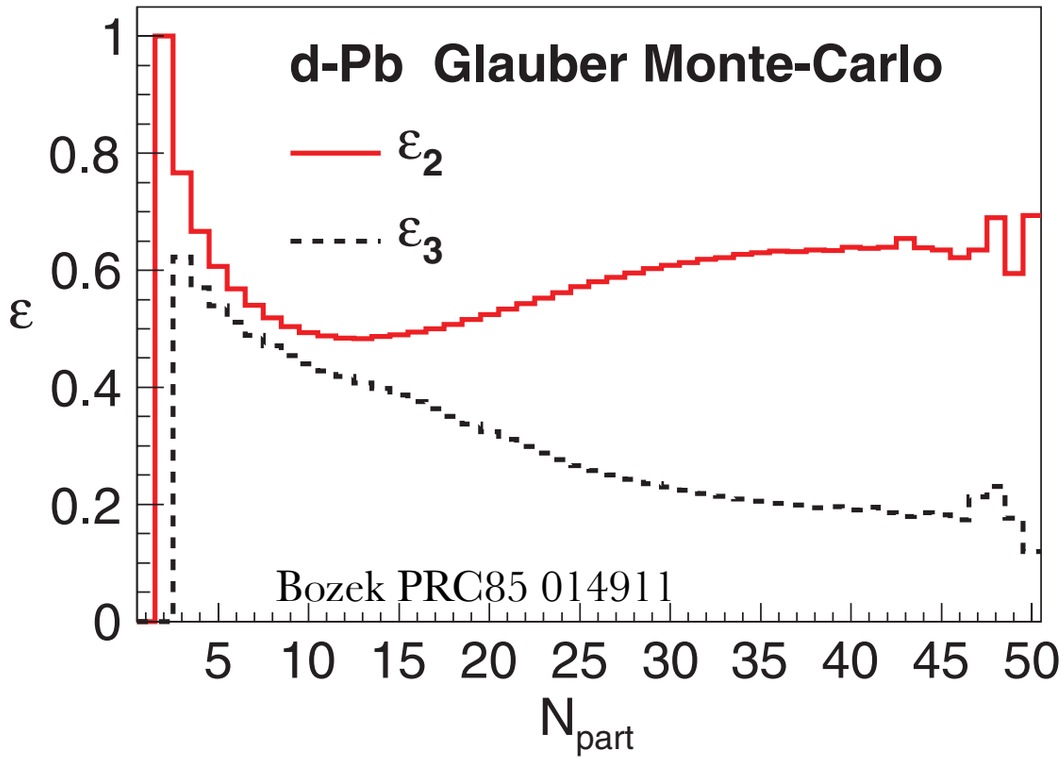
pPb vs dAu

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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ε2
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Bozek PRC85 014911
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0.6
0.8
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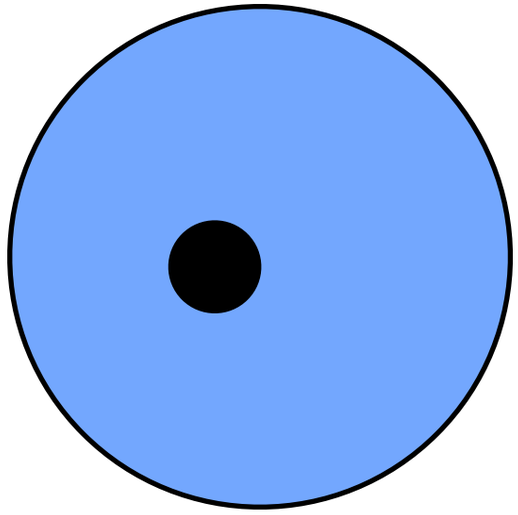
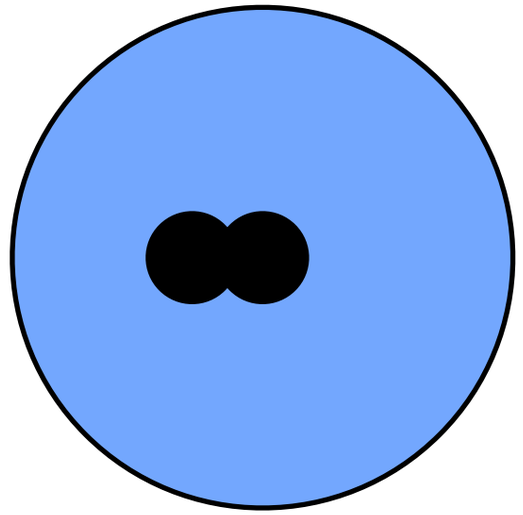
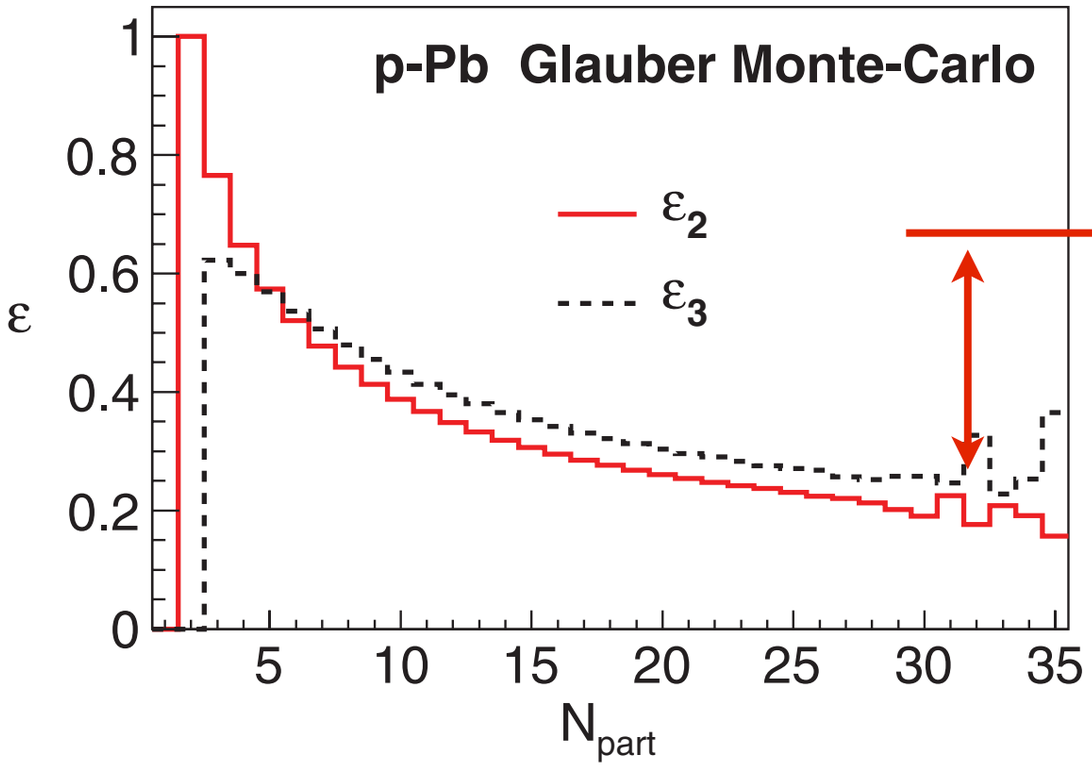
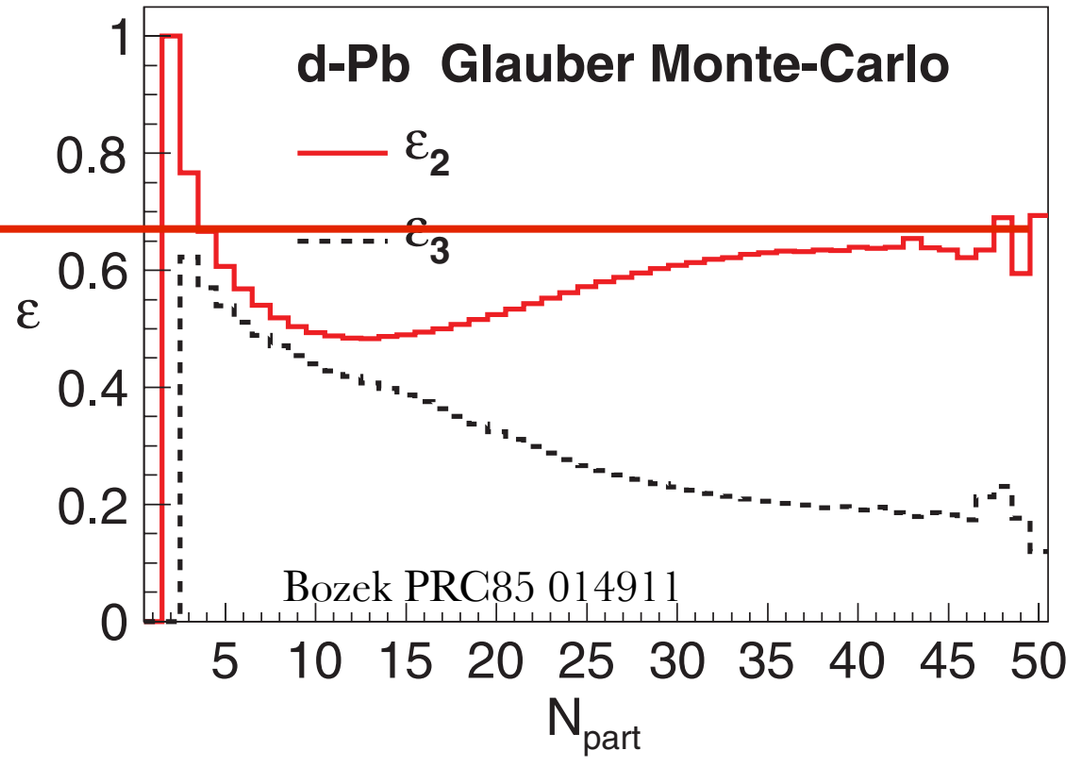
5
10
15
20
25
30
35
40
45
50

pPb vs dAu



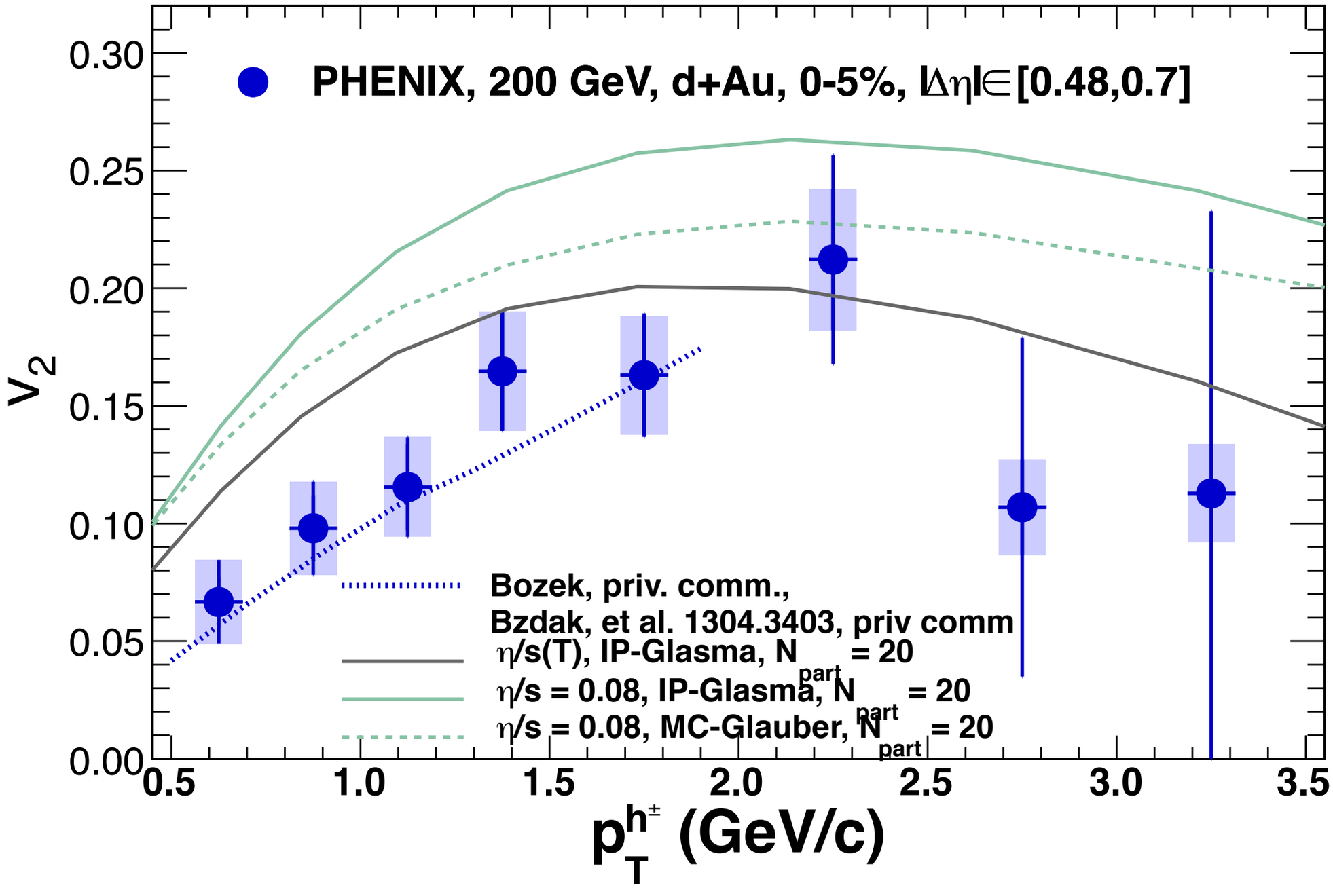






d+A central collisions have much larger ε_2 than p+A

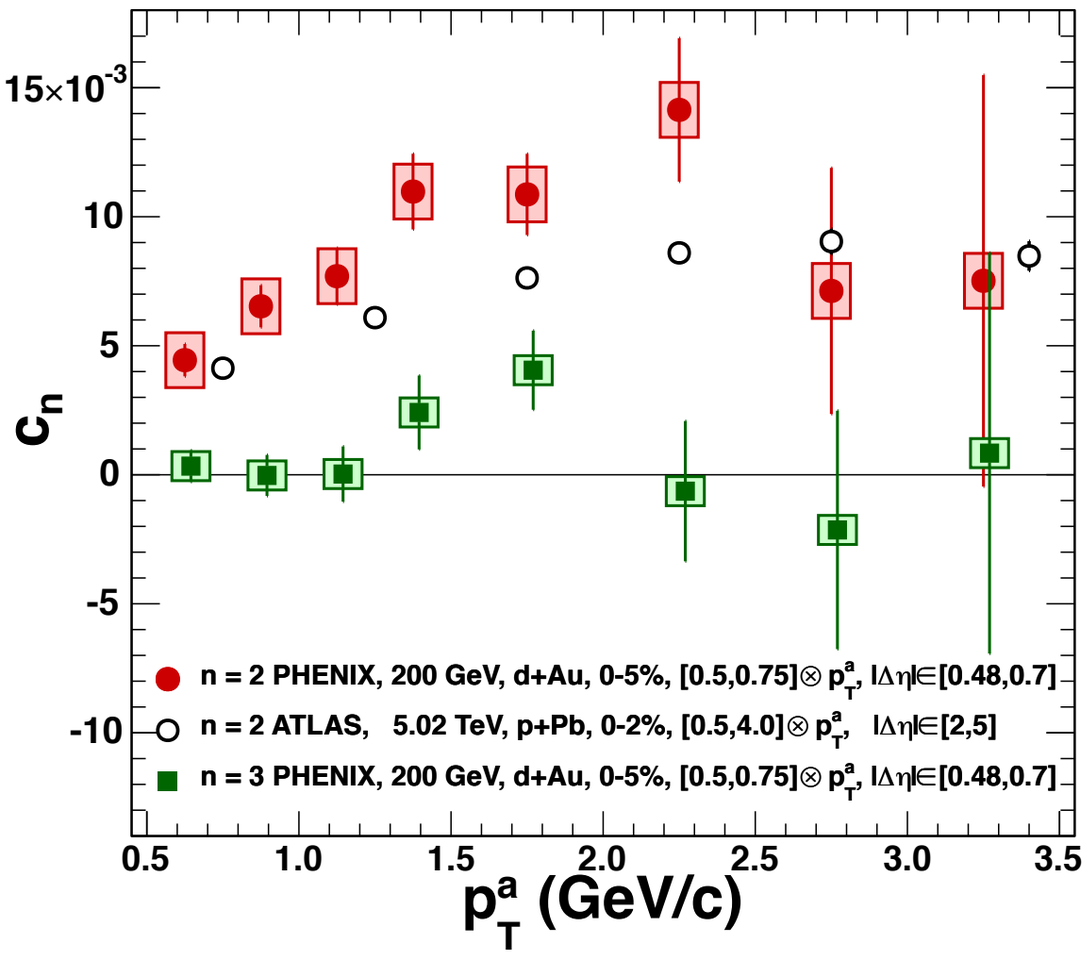
comparison to hydro calculations



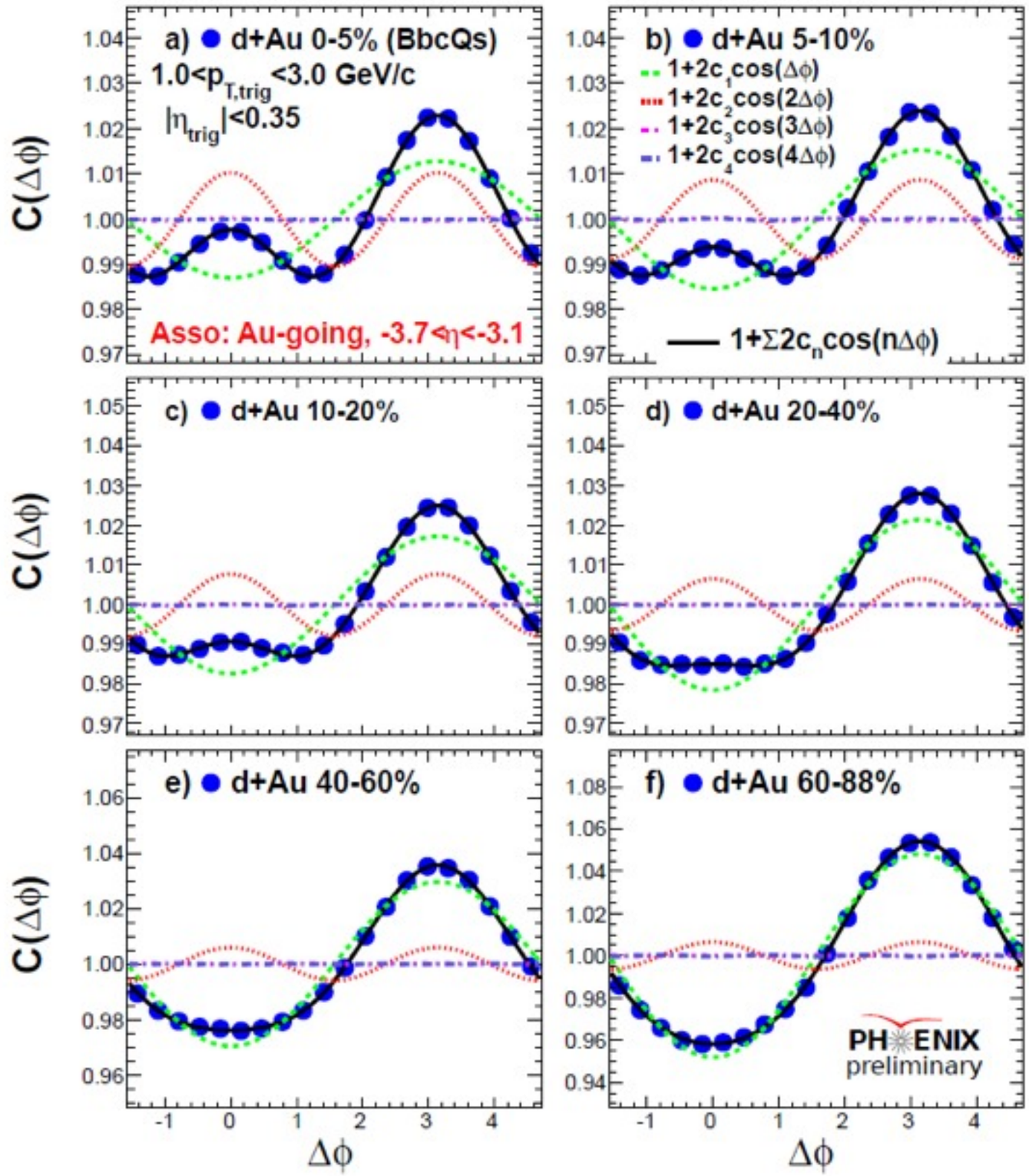
good qualitative agreement with hydro calculations

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

v_3 at RHIC?



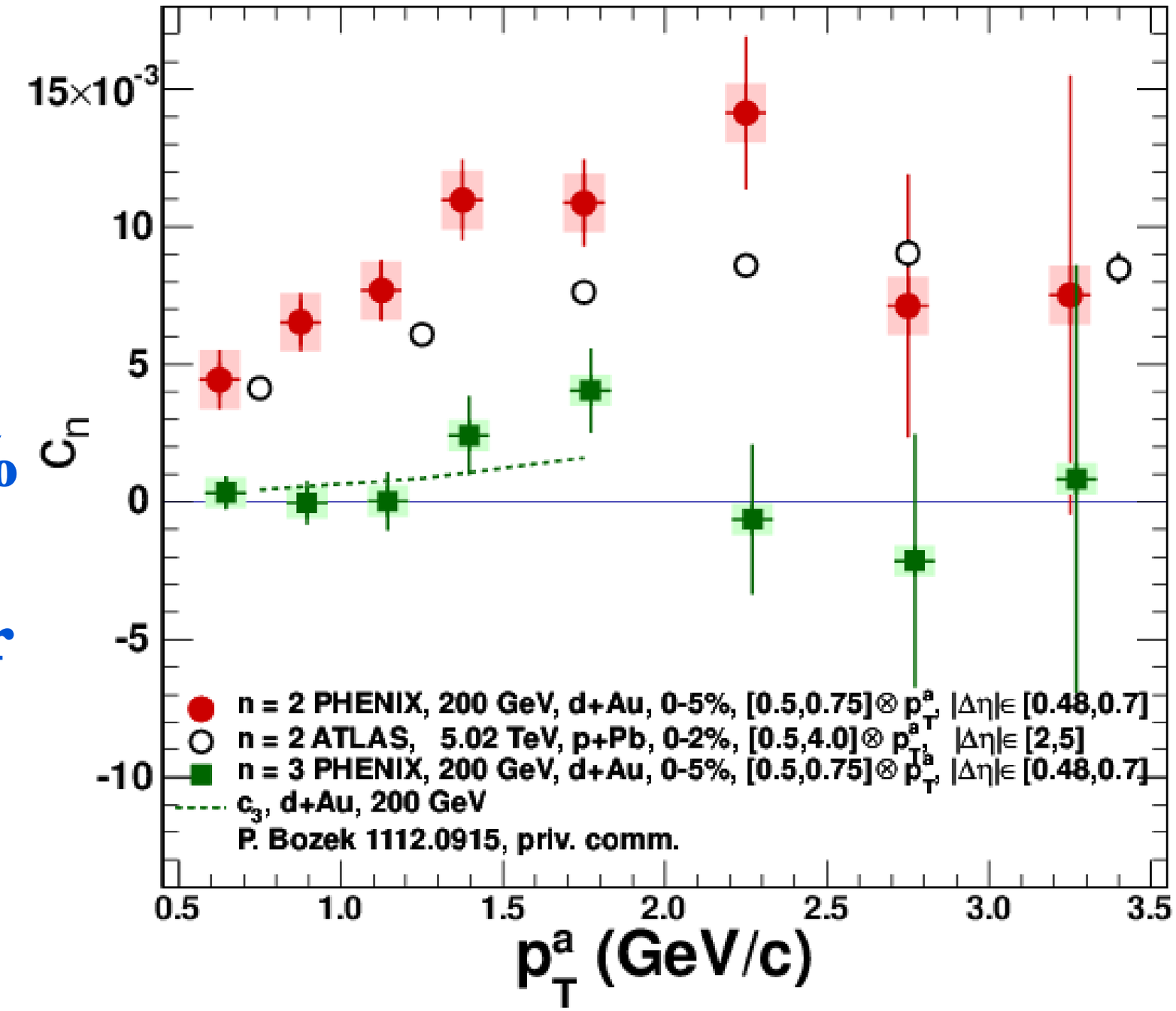
no evidence for significant v_3



PHENIX: 1303.1794

what v_3 might be expected?

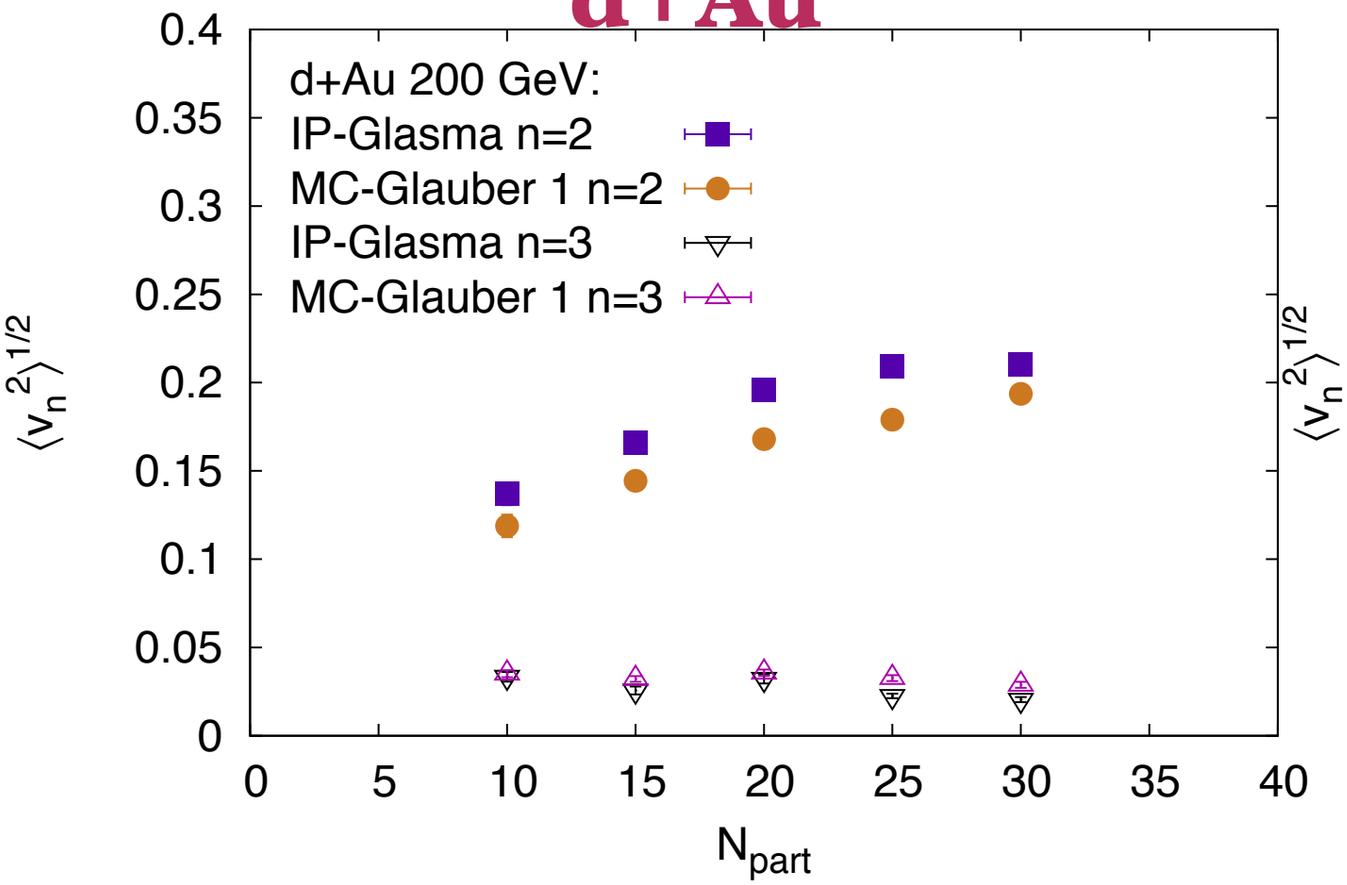
Bozek finds $v_3 < 5\%$ at $p_T = 2$GeV/c, consistent with our c_3 values

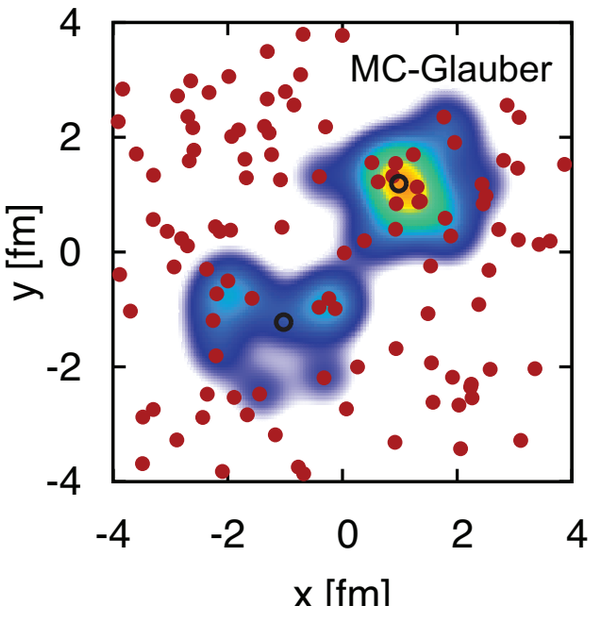


PHENIX: 1303.1794

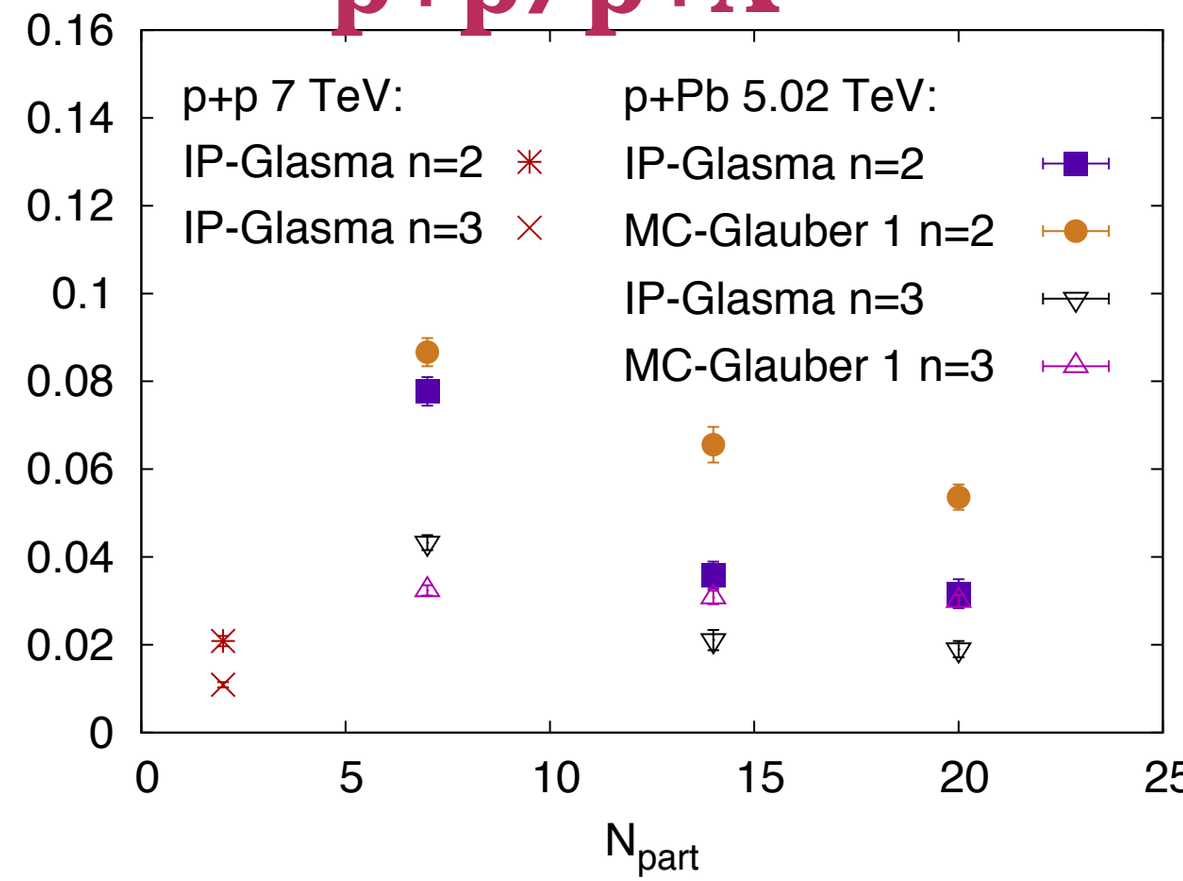
v_2 vs. v_3 in hydrodynamics

d+Au





p+p/p+A



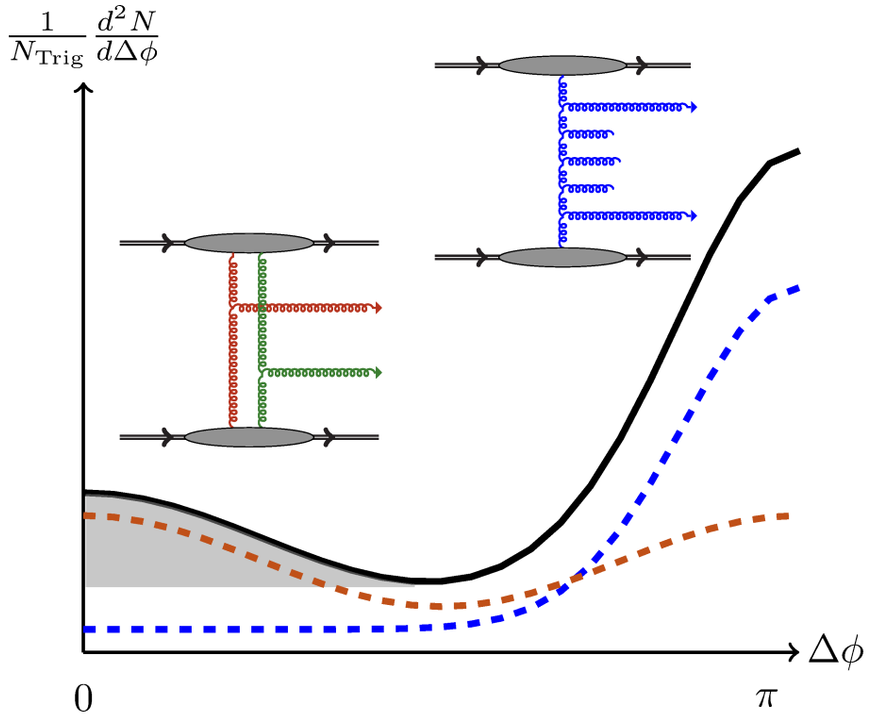
depends on system and model of initial state

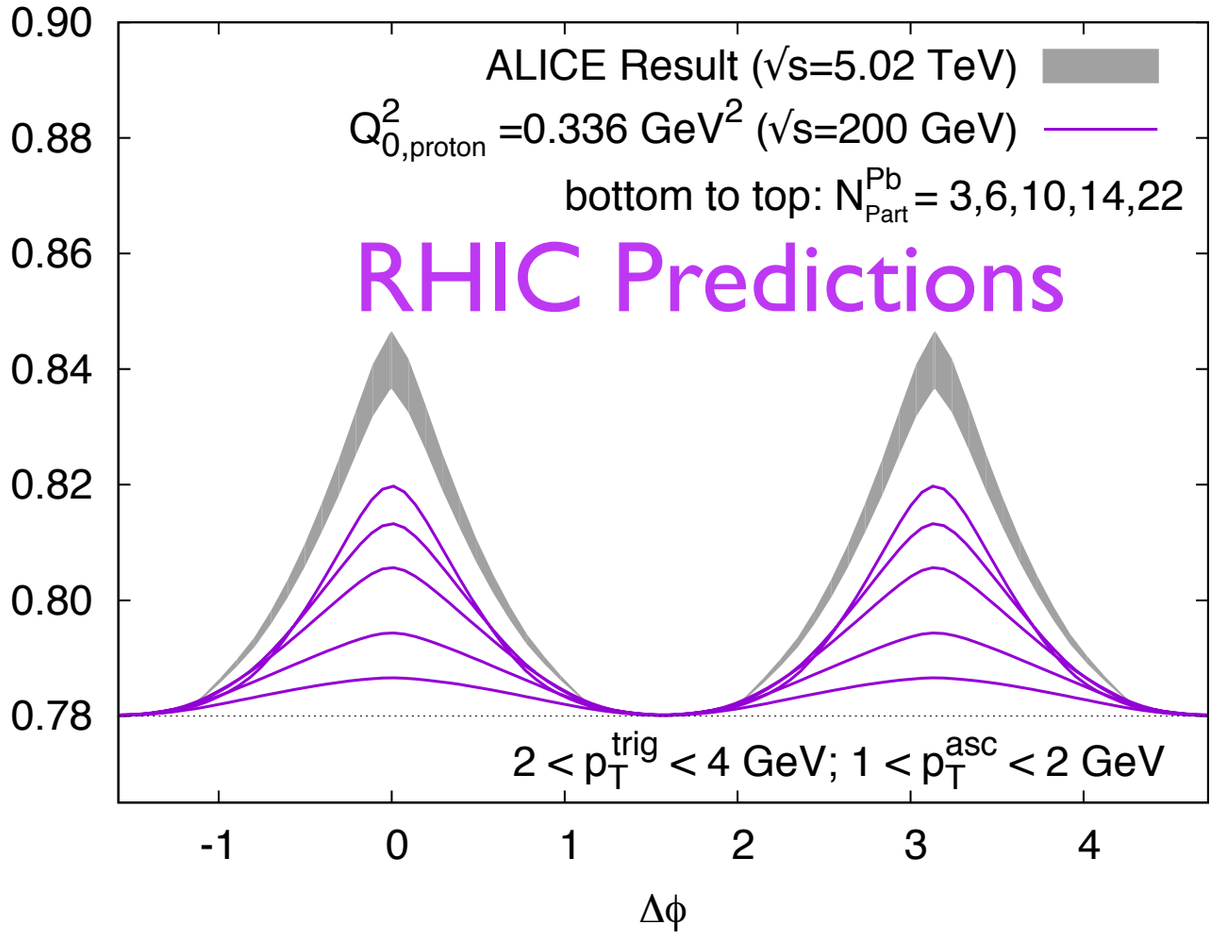
- **v2/v3 much larger in dAu than in pPb**

Bzdak et al: 1304.3403

what about the CGC?

significant signal expected at RHIC!

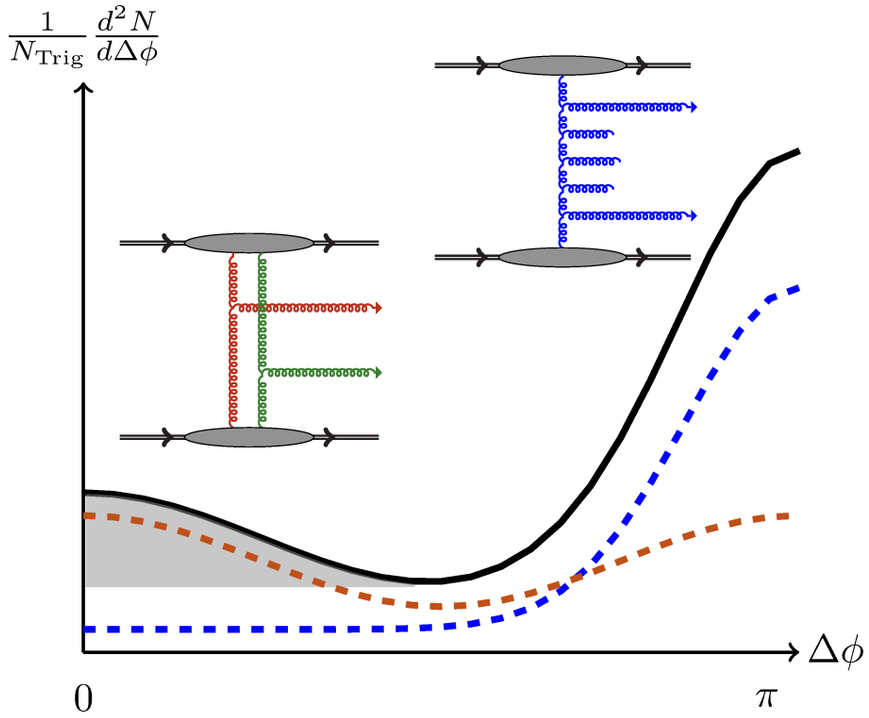


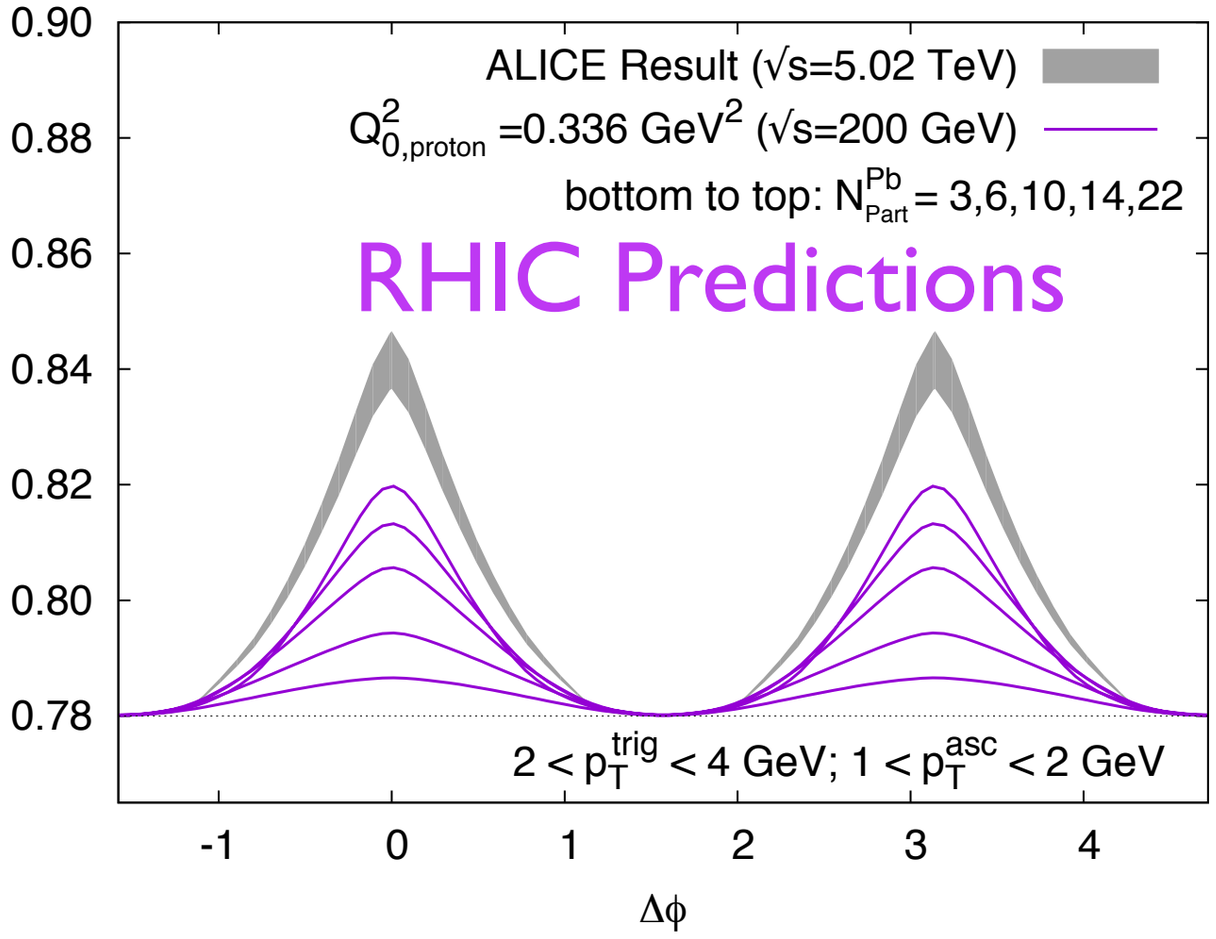


Dusling & Venugopalan 1211.3701, 1302.7018 & private comm.

what about the CGC?

significant signal expected at RHIC!

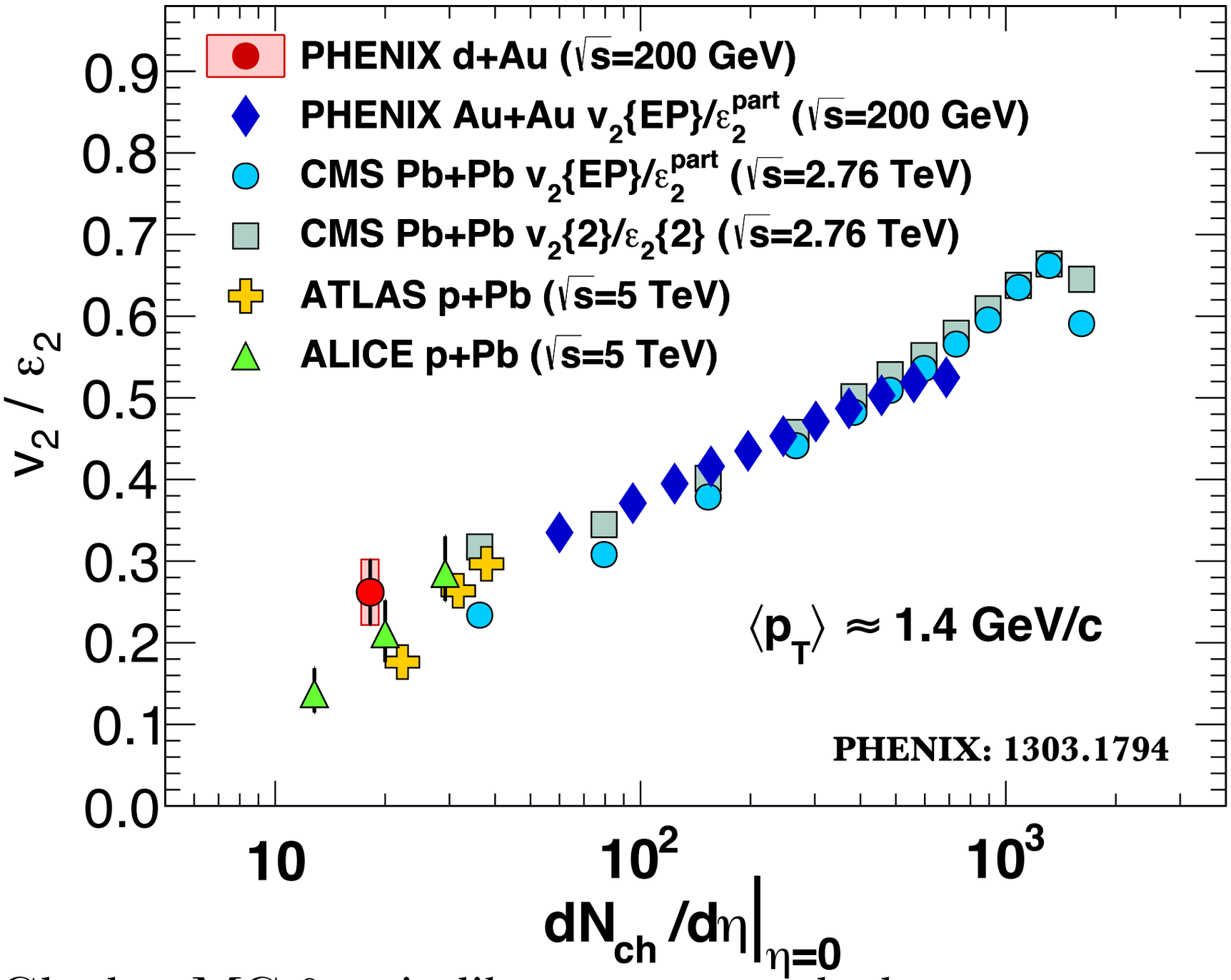




- smaller yield expected at RHIC compared to LHC
- Fourier coefficients aren't calculated for this model--working to compare to our data

Dusling & Venugopalan 1211.3701, 1302.7018 & private comm.

v_2/ε_2 vs multiplicity

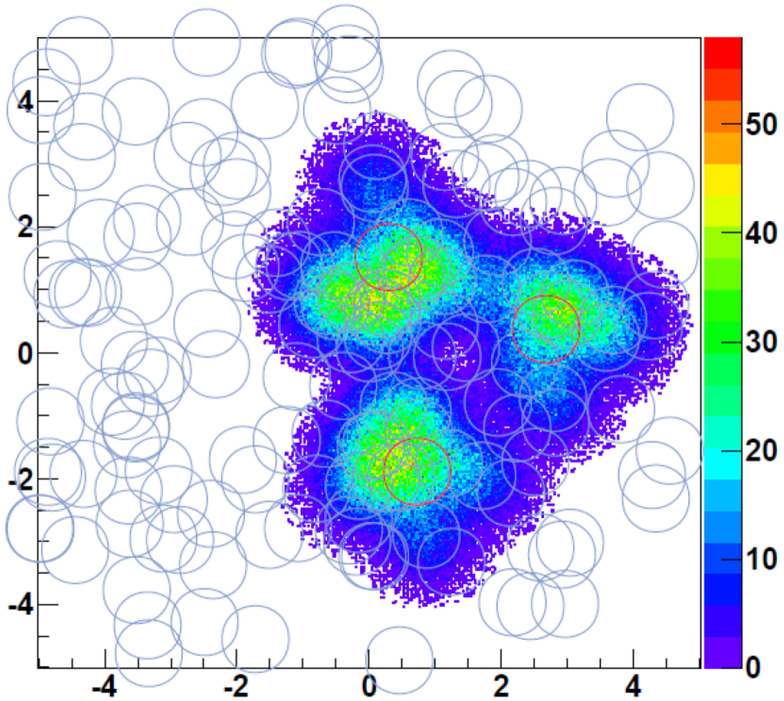


- Glauber MC & pointlike centers to calculate ε_2
- → approximate scaling of v_2/ε_2 with $dN/d\eta$

a common relationship between geometry and v_2?

hydro or CGC?

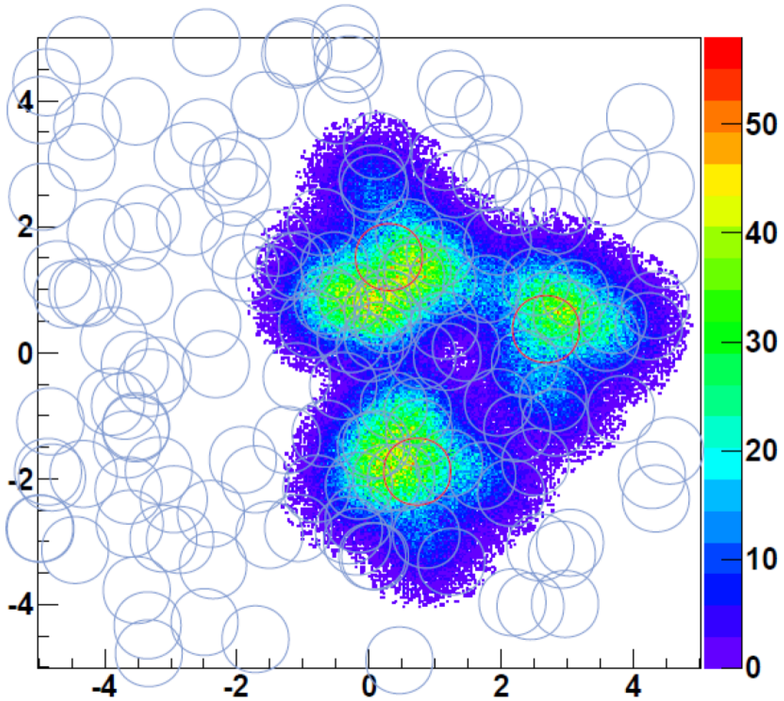
He3 + Au



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

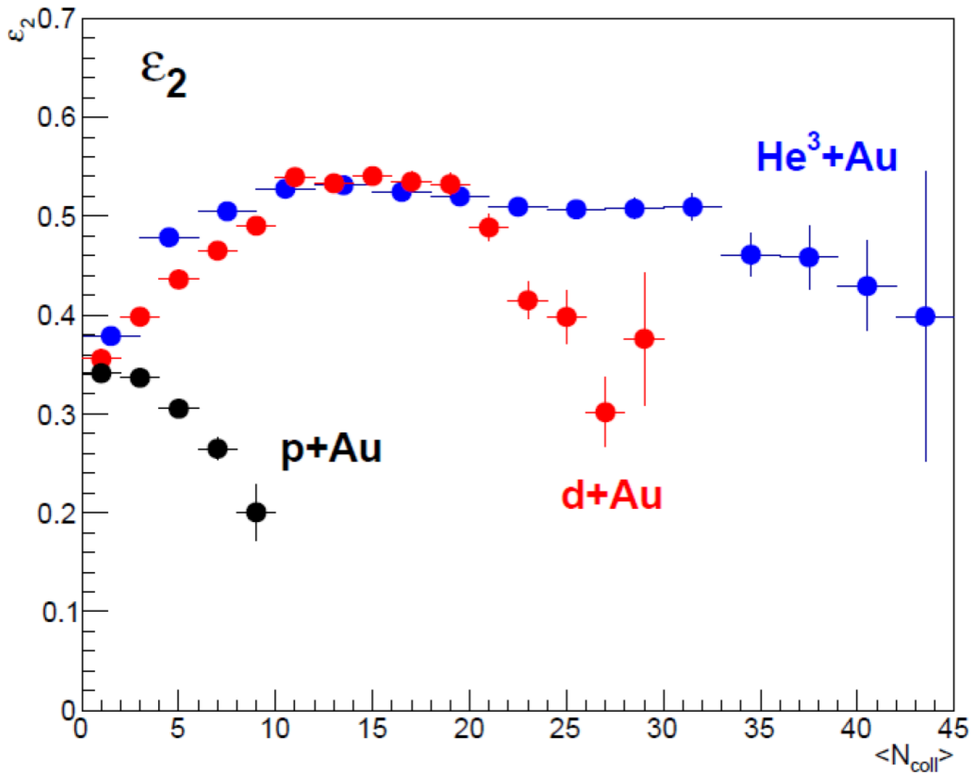
hydro or CGC?

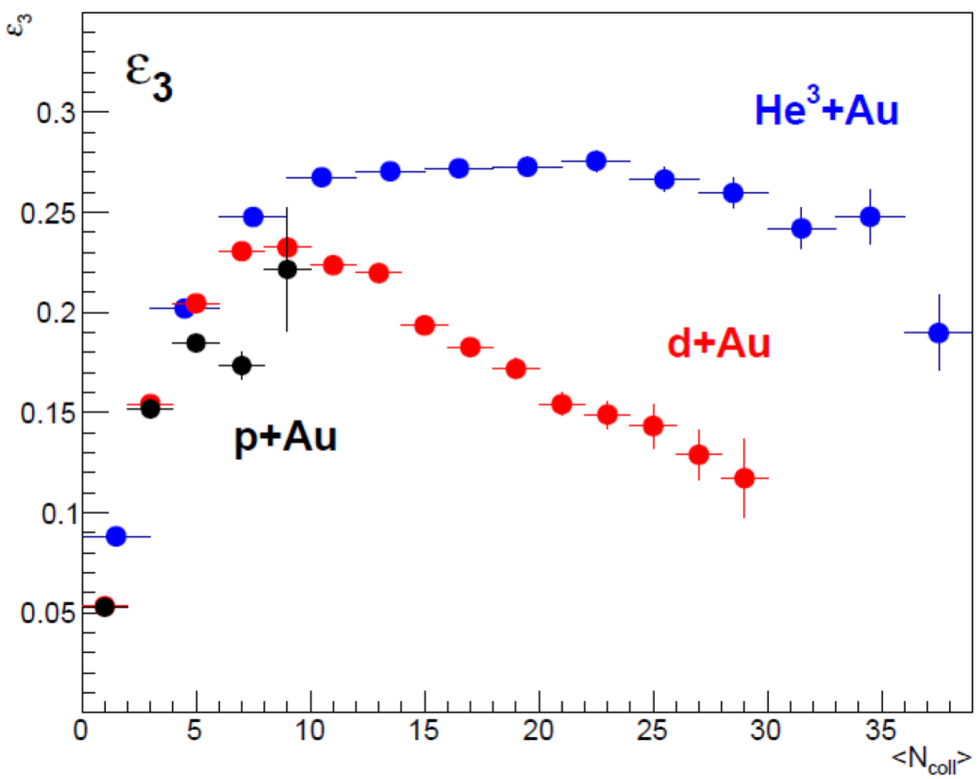
He3 + Au



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

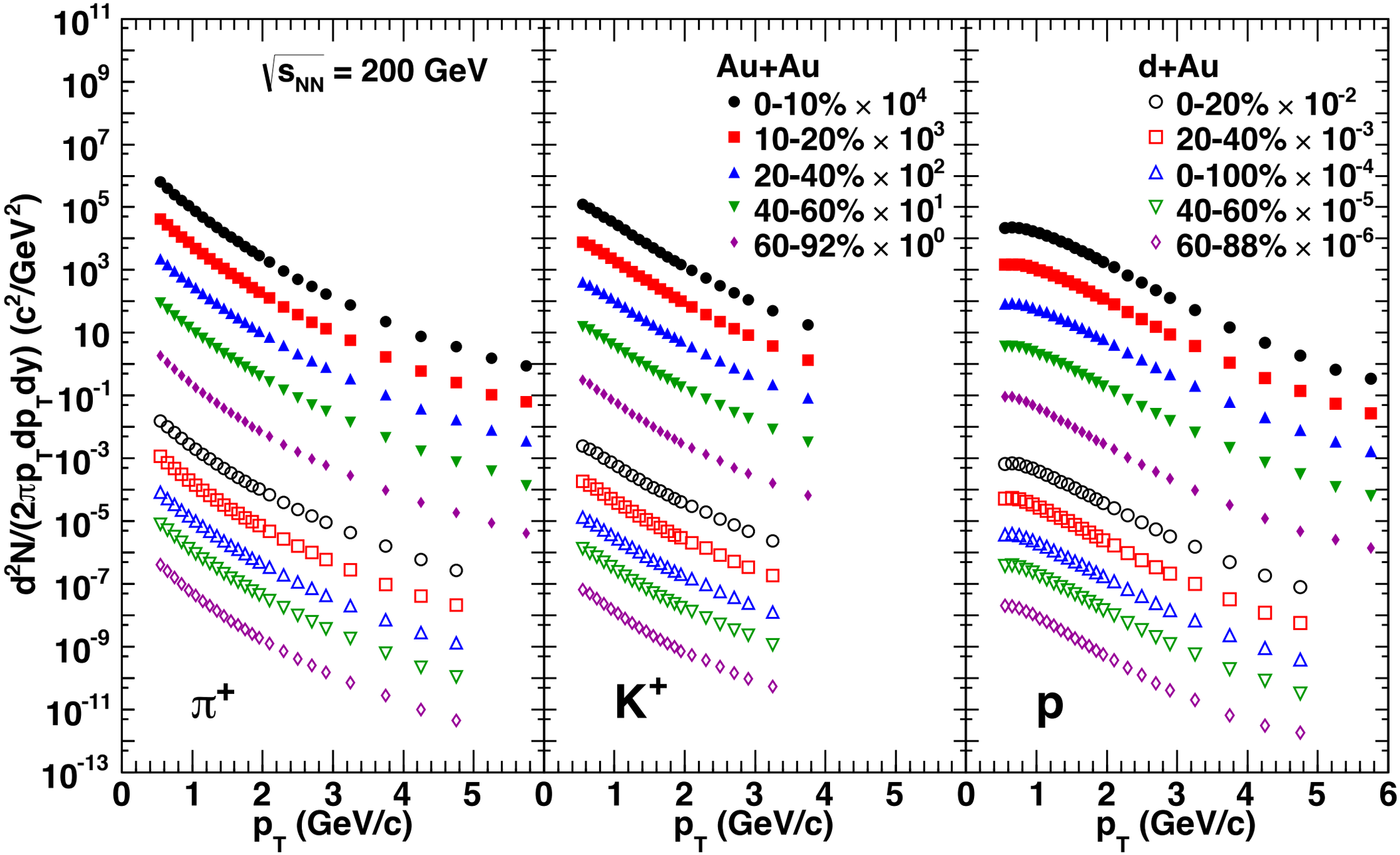
PHENIX requesting short d+Au & He^3+Au with increased acceptance relative to previous d+Au running (VTX/FVTX) to constrain geometry along with long p+Au running in 2015





exploit the versatility of RHIC!

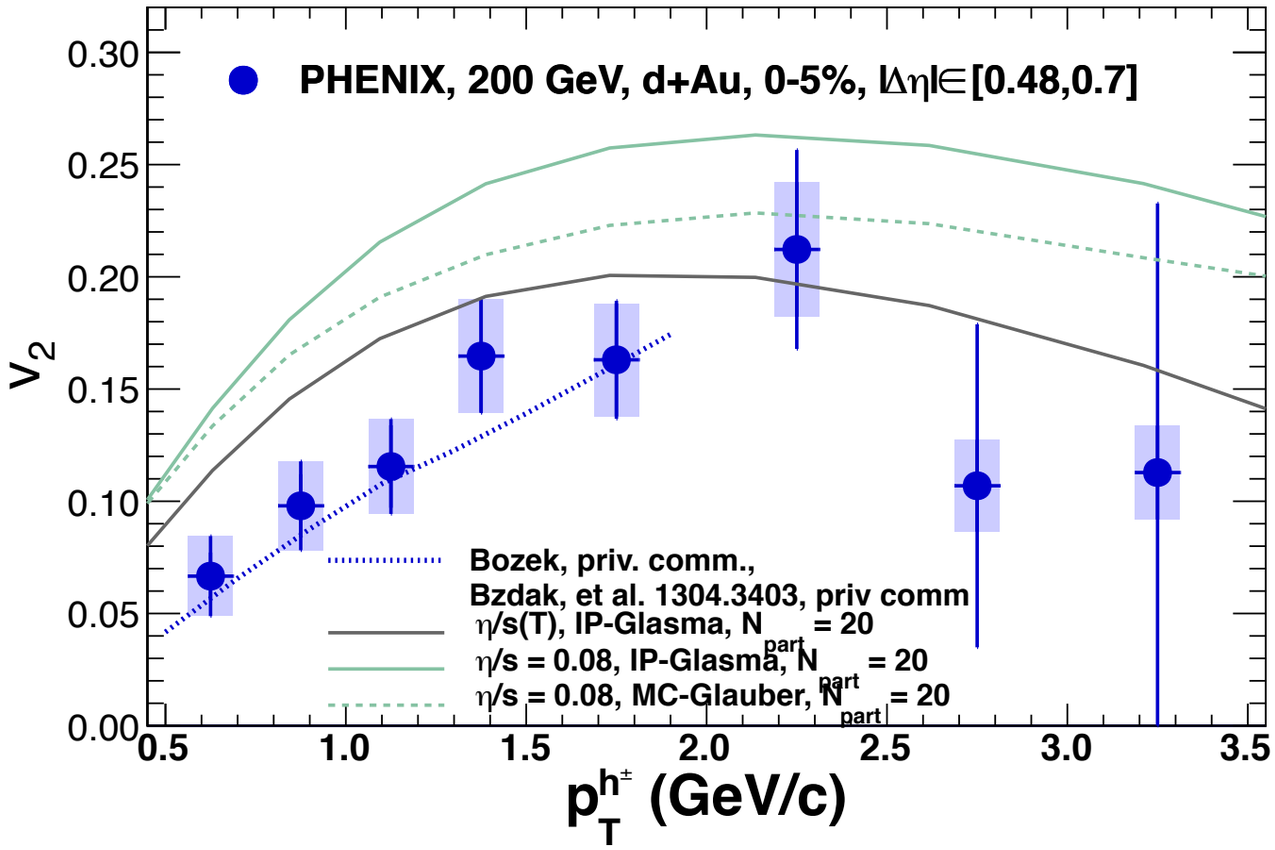
spectra in dAu

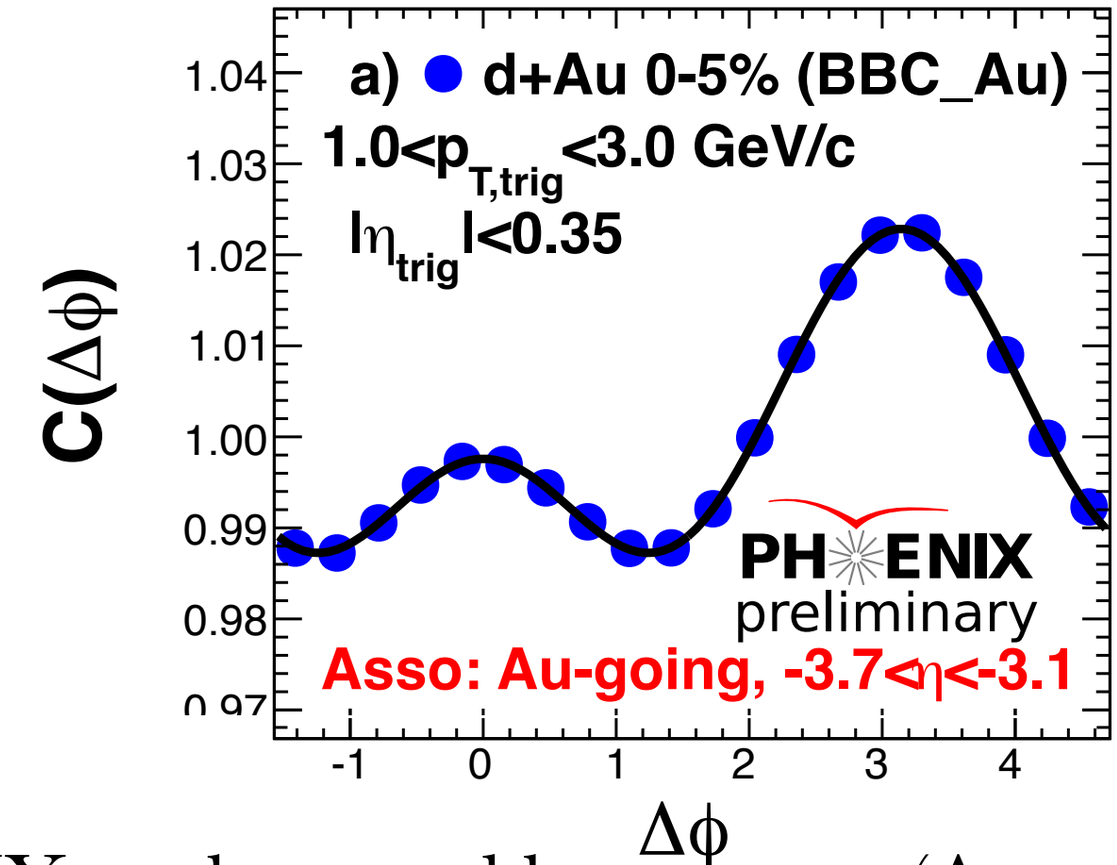


spectra should also be addressed by hydro calculations

PHENIX:1304.3410

conclusions

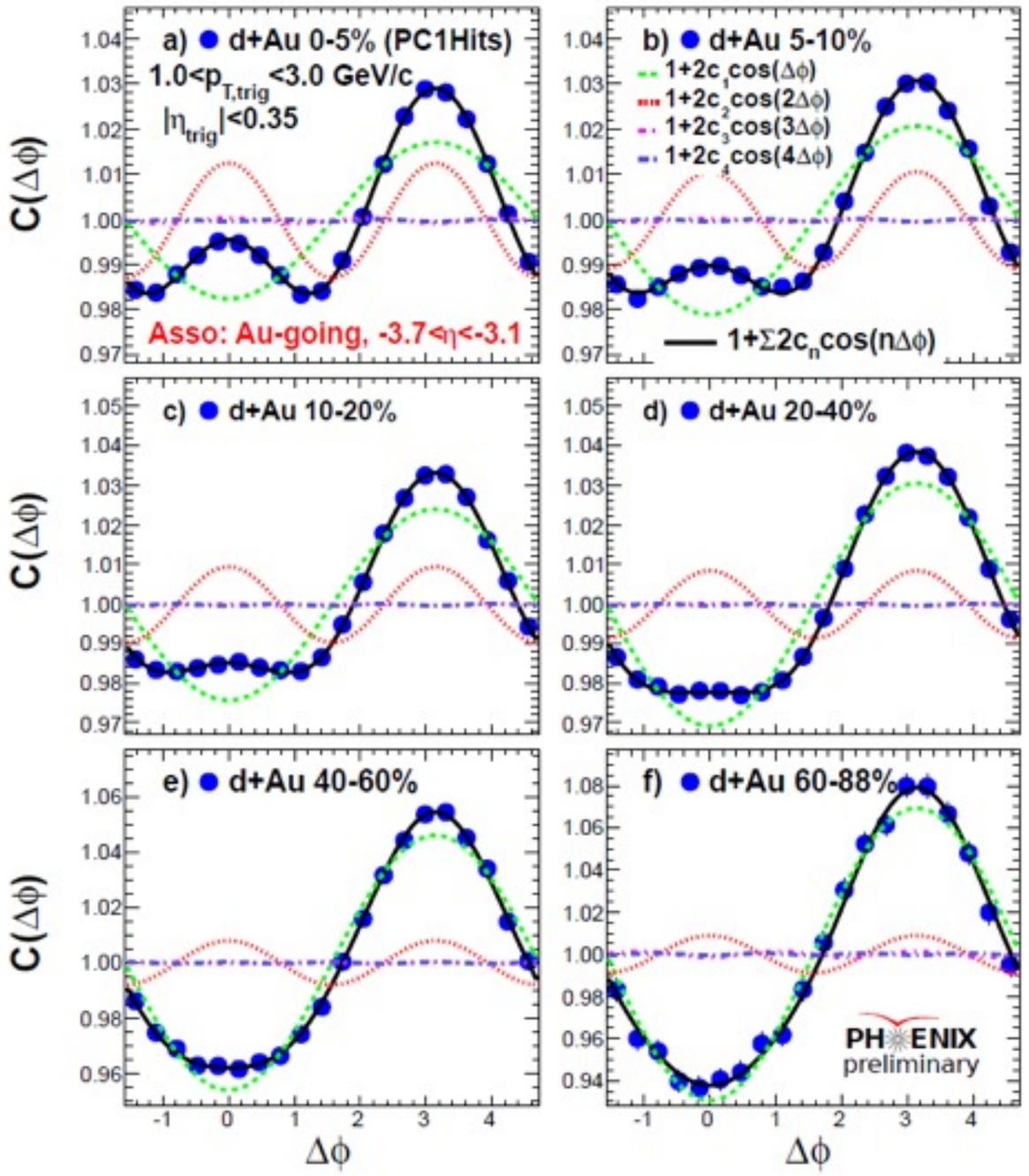




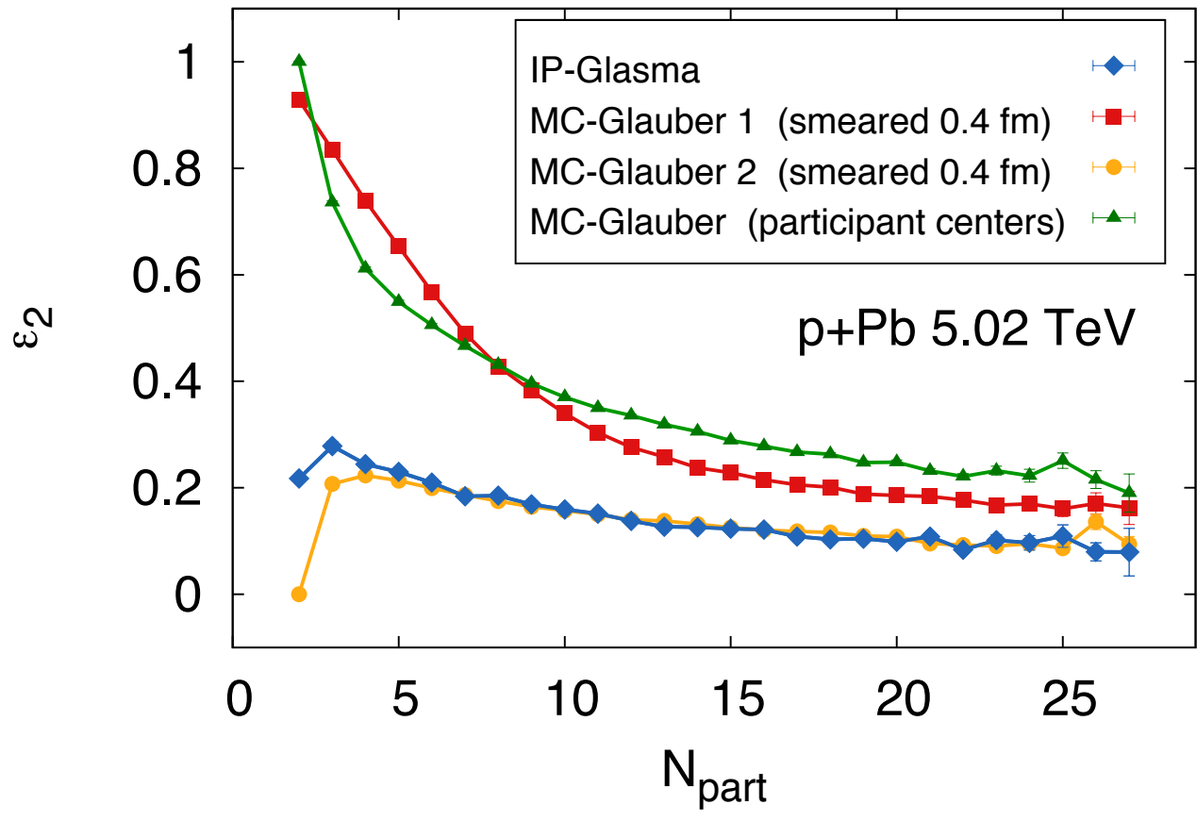
- ridge-like behavior seen at PHENIX at short and long range ($\Delta\eta > 3$) with large v_2 at midrapidity
- we look forward to extending these measurements:
  - yields, $v_N(\eta)$, different collision systems (pA, dA, He^3A, peripheral heavy ions, asymmetric collisions...)
  - ...in order to understand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

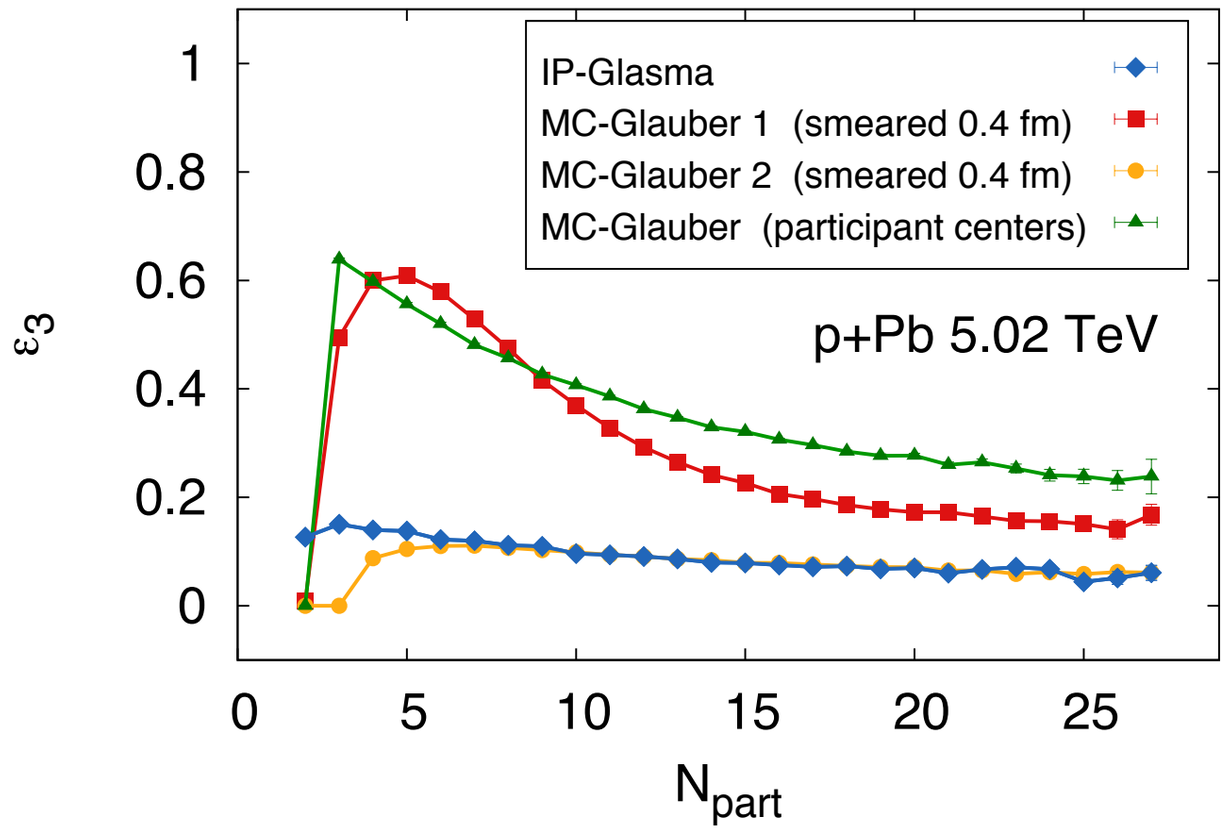
backups

- 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

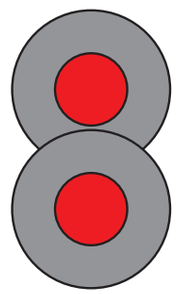


what is the eccentricity?

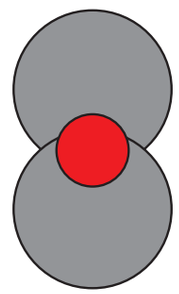




models can give very different eccentricities!



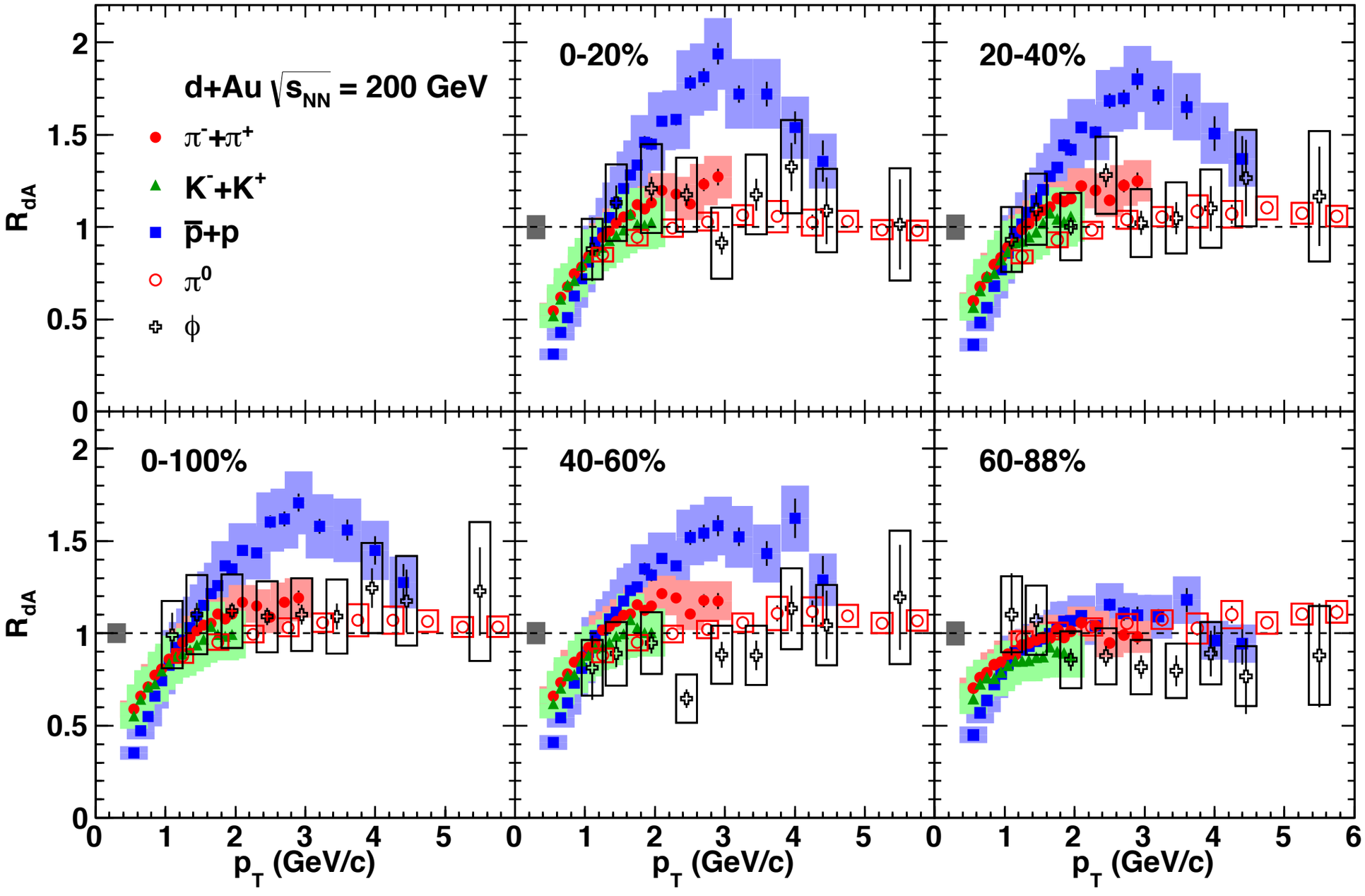
MC-Glauber 1



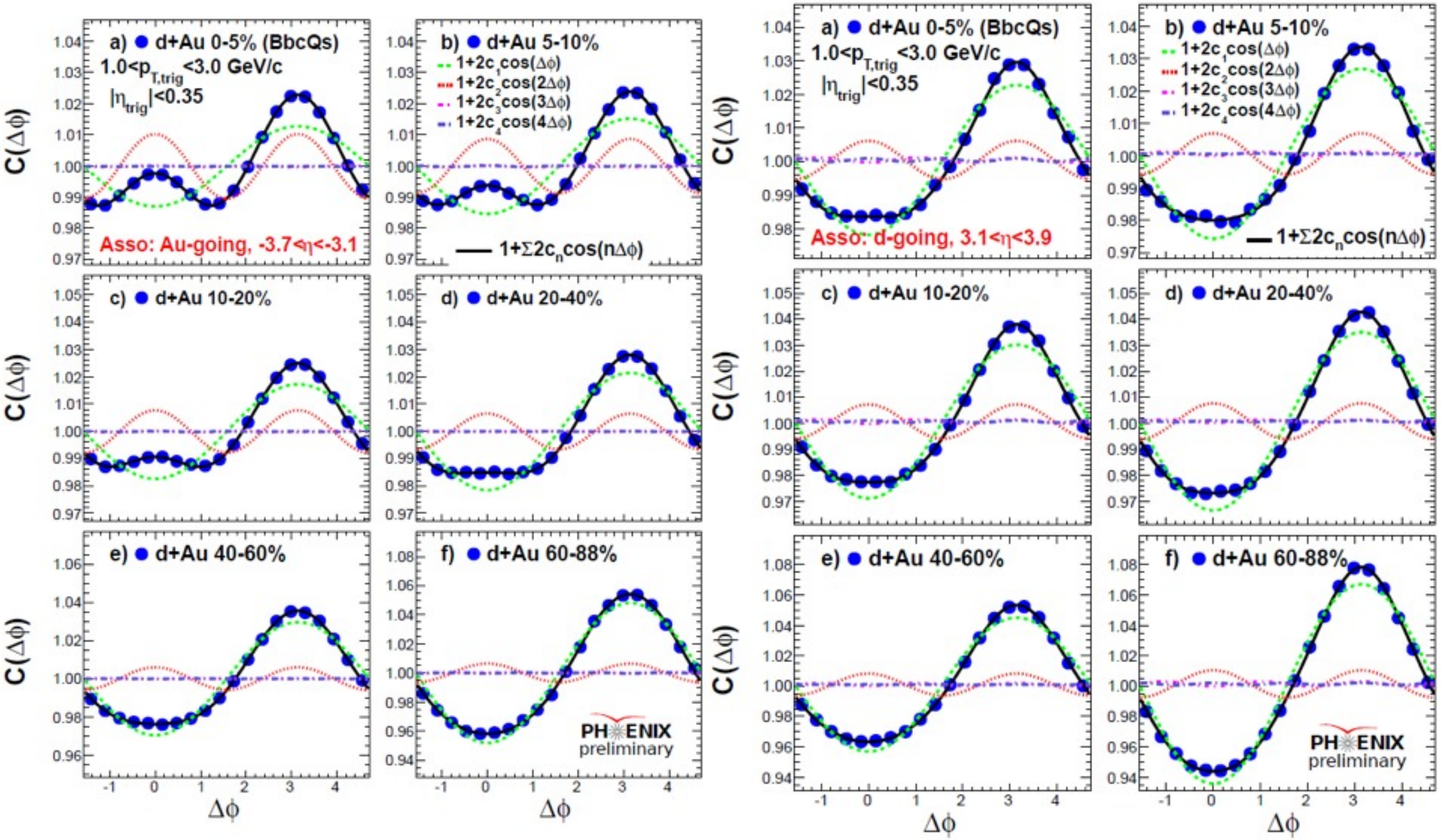
MC-Glauber 2

Bzdak et al: 1304.3403

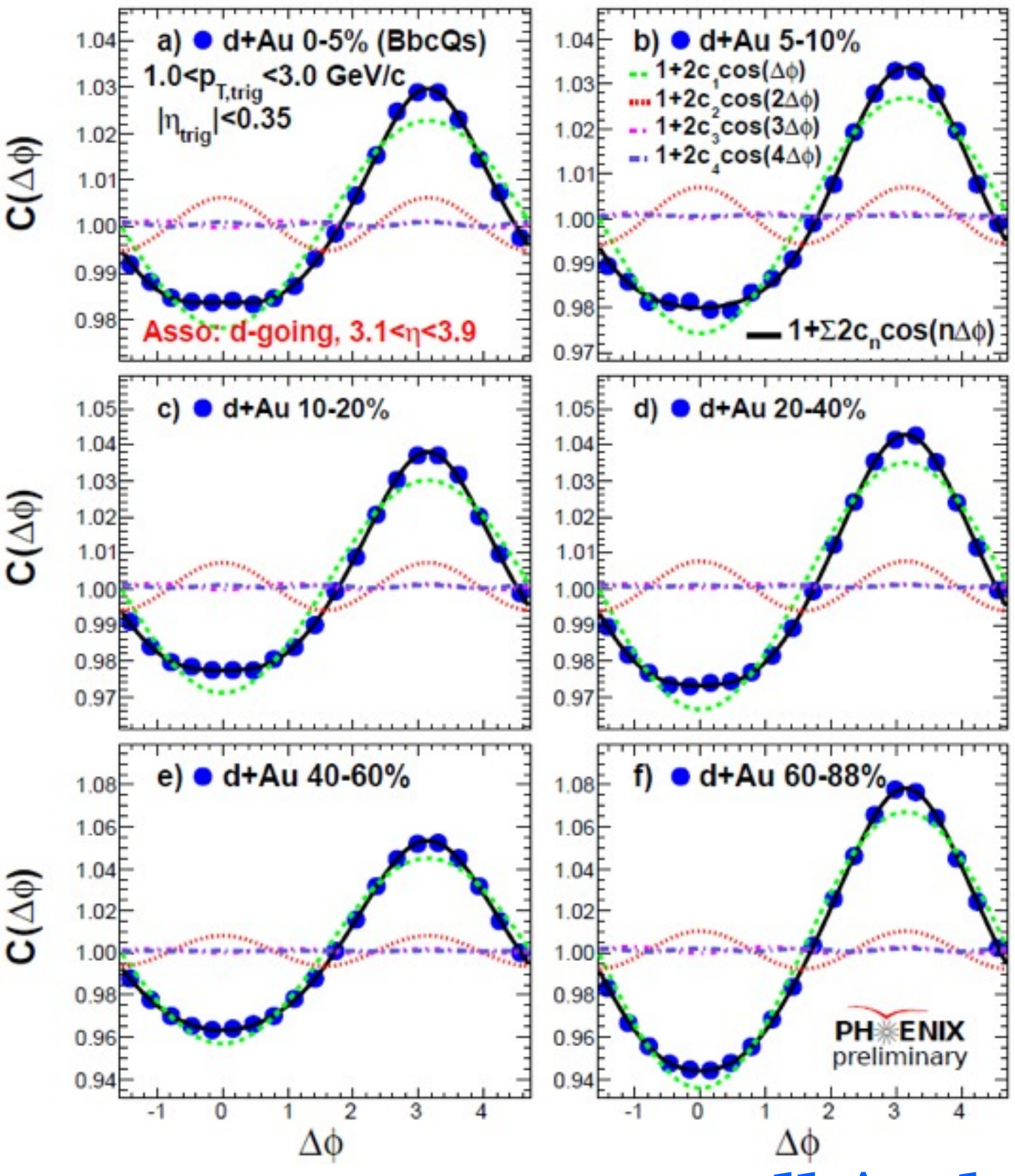
R_{dA}

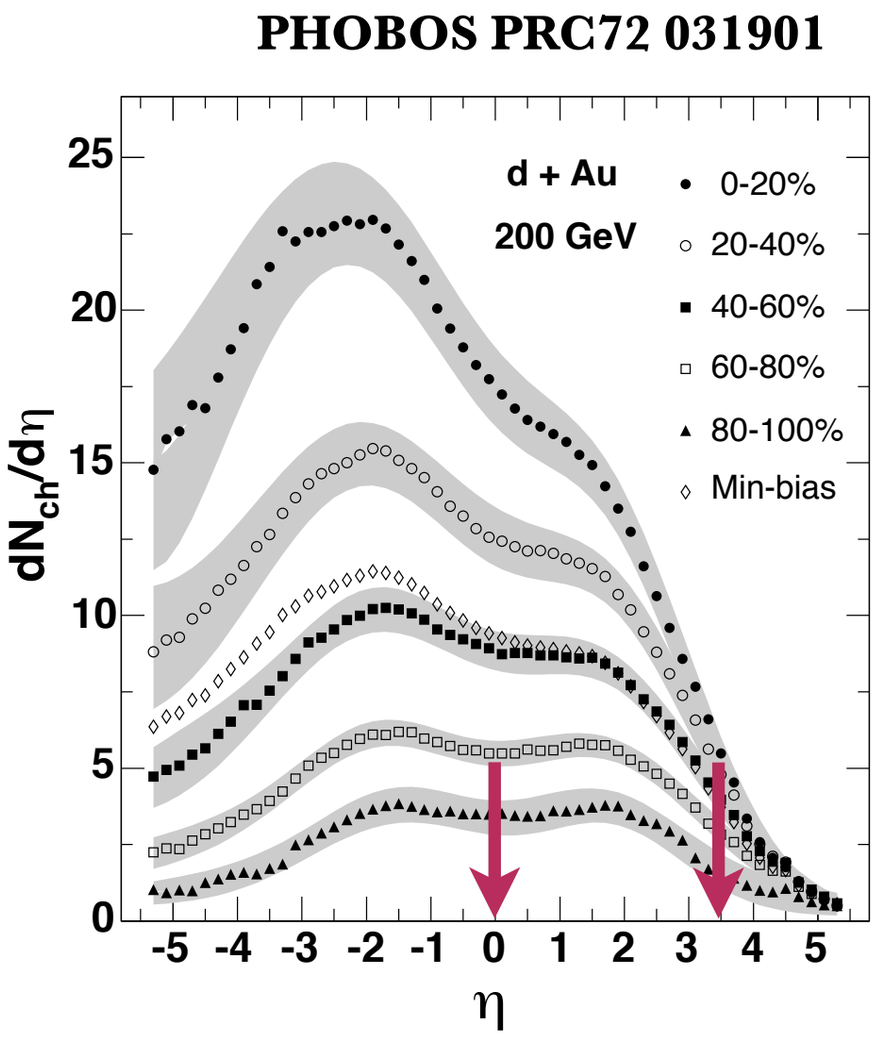


PHENIX:1304.3410


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

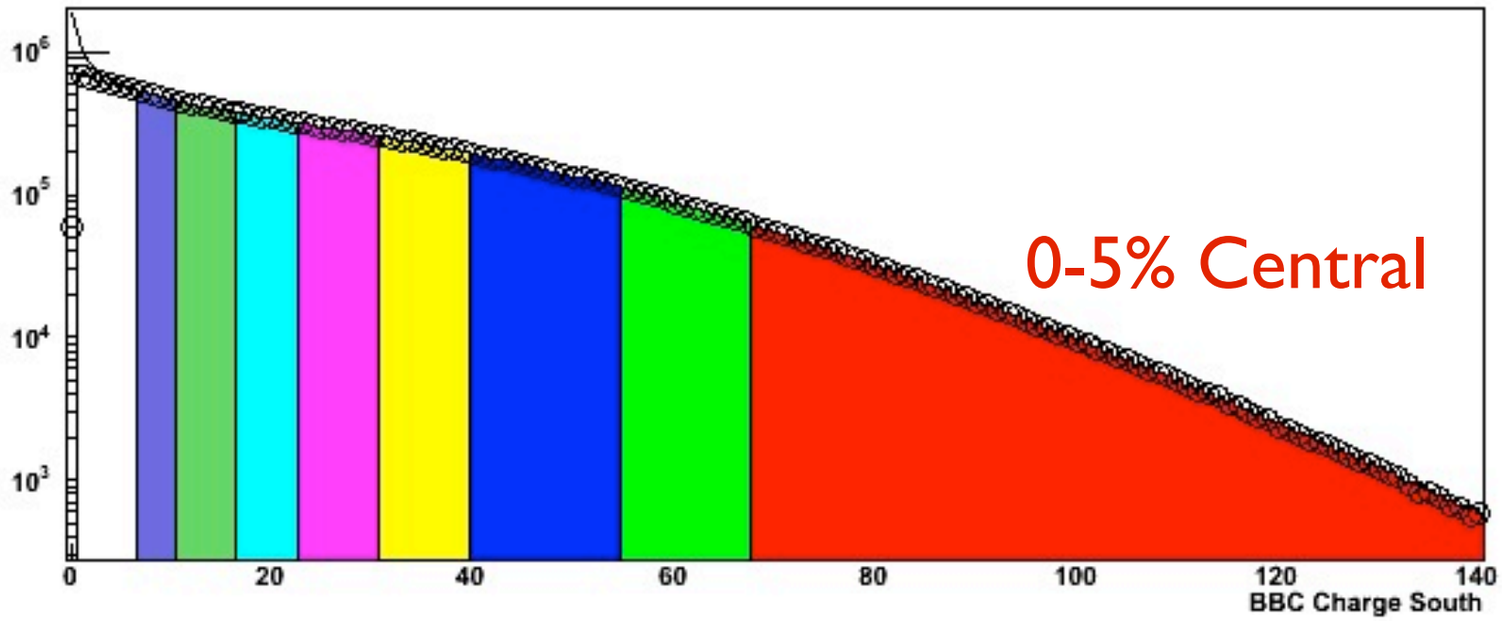


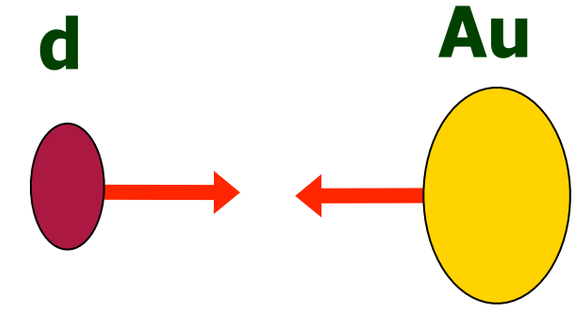


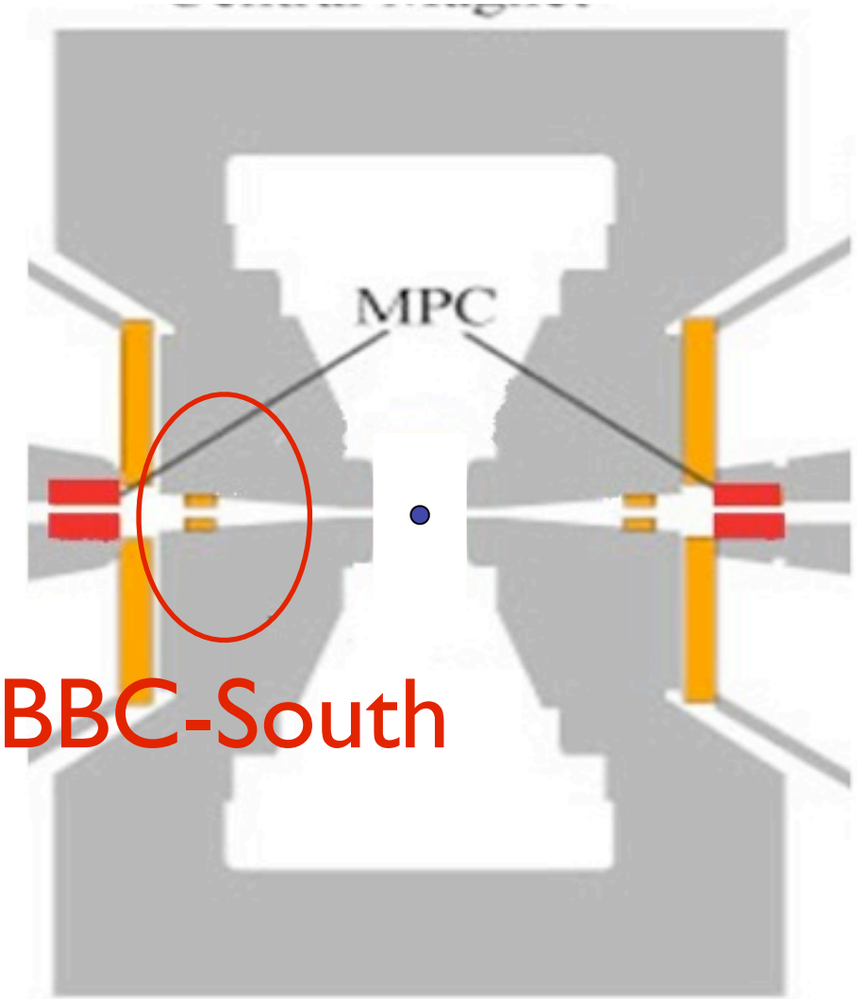
correlations between mid-rapidity particles & energy weighted towers in d-going MPC

no small Δφ bump, perhaps some v_2?

Centrality Selection







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