Azimuthal anisotropy in high-energy heavy-ion collisions at RHIC energies

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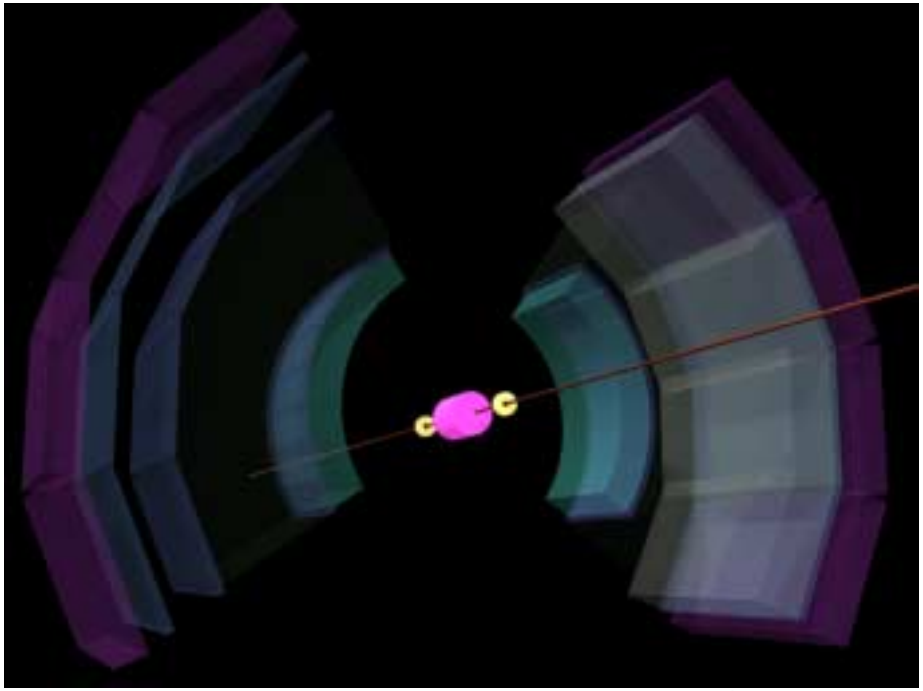
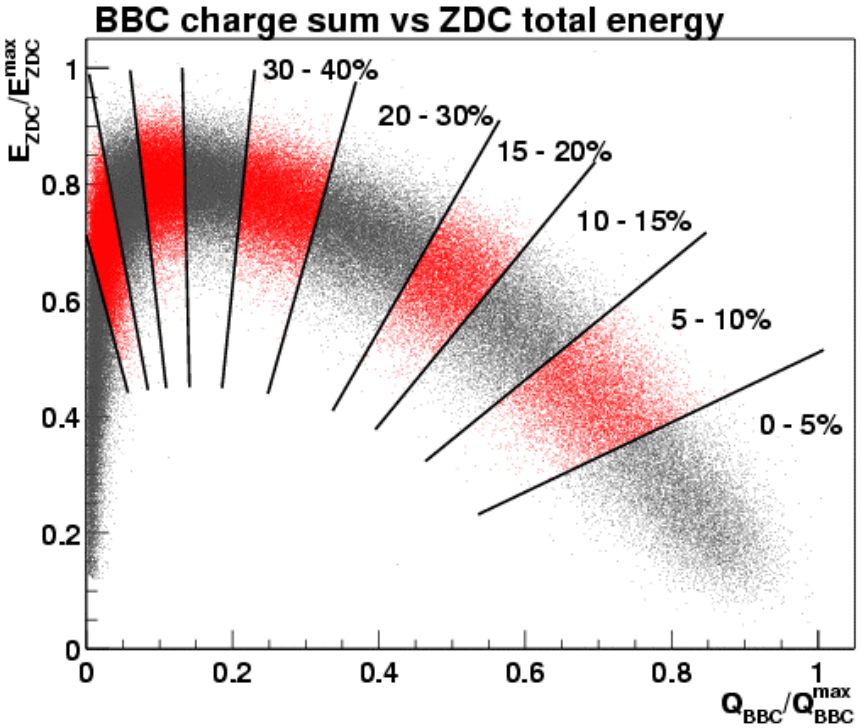
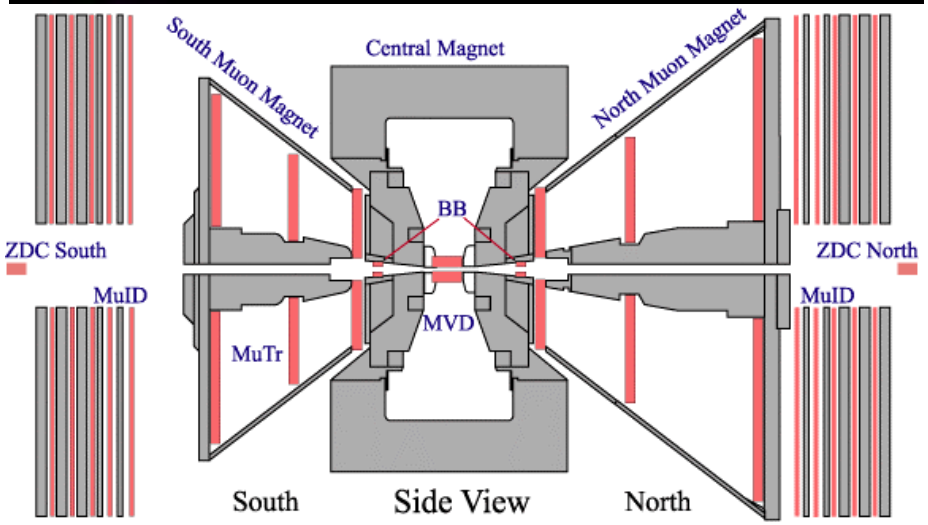
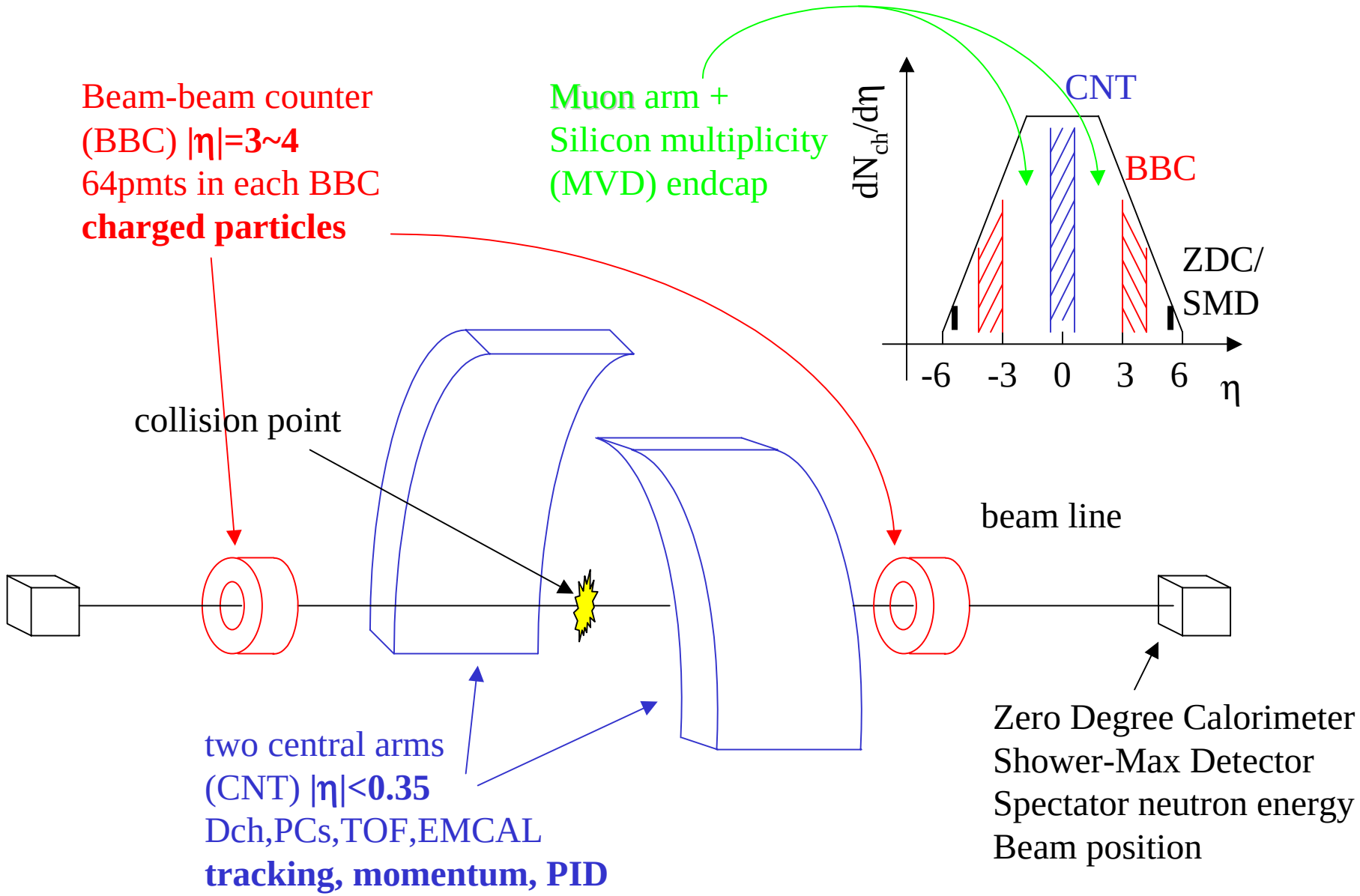
Flow measurements at PHENIX
Charged particle v1 and v2
Identified hadron v2
Charm and photon v2
Origin of v2 and non-flow

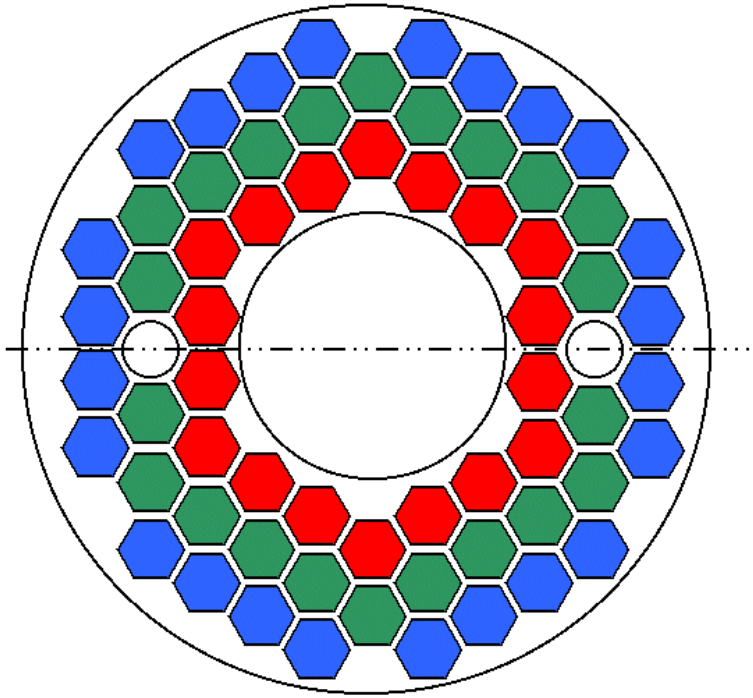
BBC/ZDC : centrality
Dch/PC1,2,3 : tracking
Tof : hadron PID
Rich : electron PID
Emcal : electron/photon PID





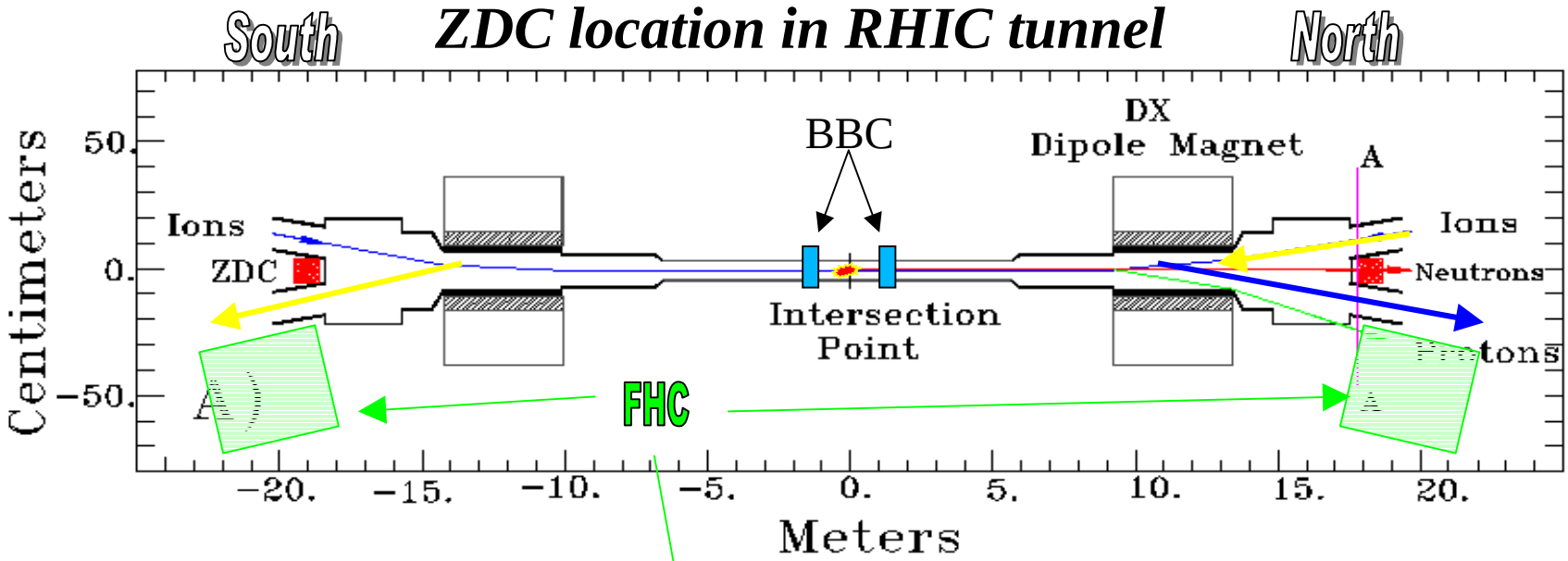



Beam-beam counter
(BBC) |η|=3~4
64pmts in each BBC
charged particles
Muon arm +
Silicon multiplicity
(MVD) endcap
dN_ch/dη
CNT
BBC
ZDC/
SMD
-6
-3
0
3
6
η
collision point
beam line
two central arms
(CNT) |η|<0.35
Dch,PCs,TOF,EMCAL
tracking, momentum, PID
Zero Degree Calorimeter
Shower-Max Detector
Spectator neutron energy
Beam position



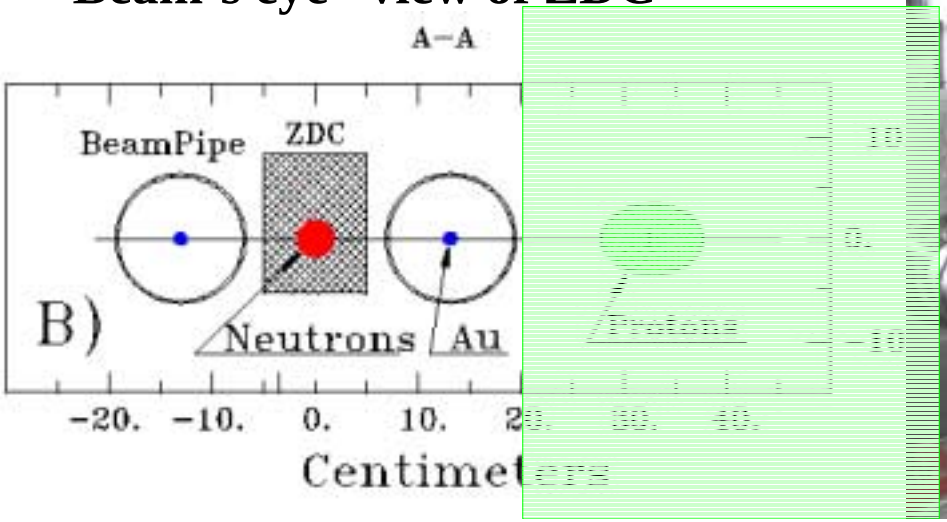
MIP calibration for each pmt
Ring gain correction
Average sin/cos shift correction
removing 4 special pmts
Normalized sumx/y distribution correction
Conventional flattering (shifting angle) correction

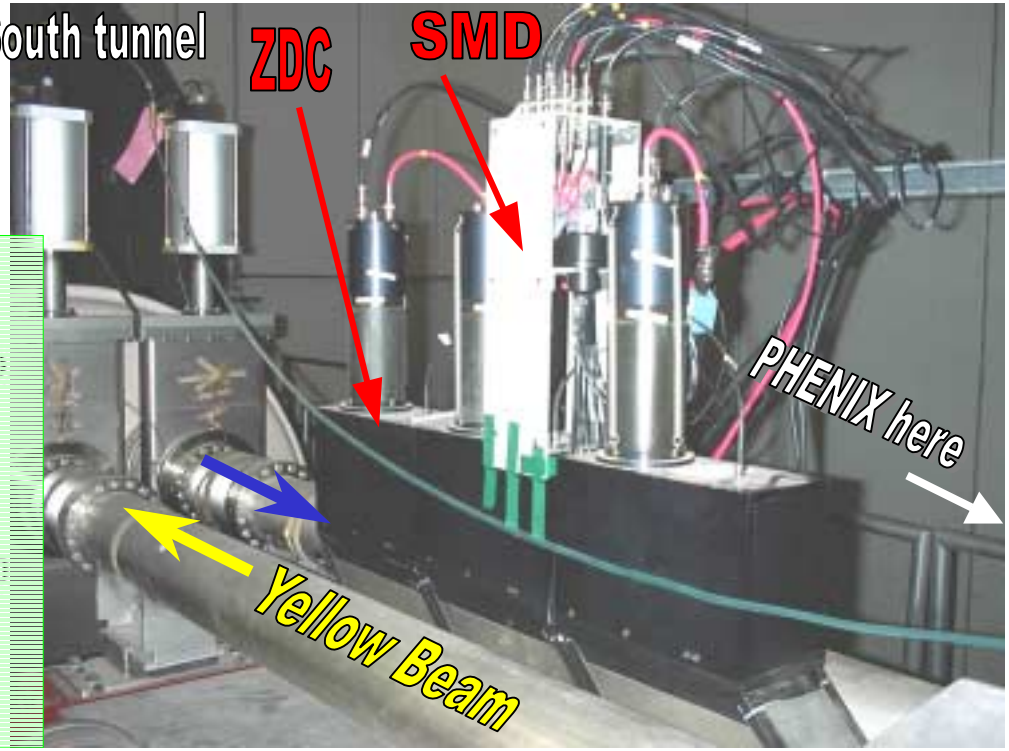
ZDC location in RHIC tunnel



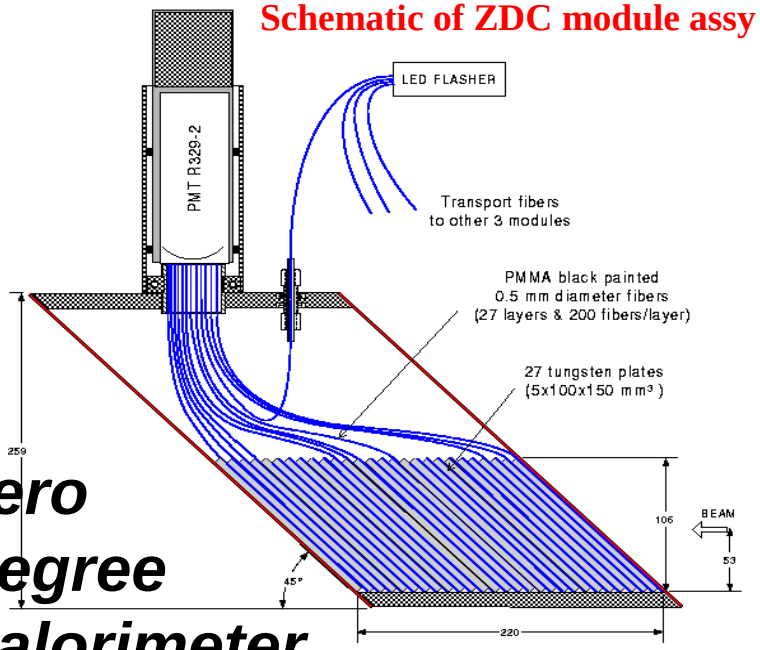
ZDC – Zero Degree Calorimeter
BBC – Beam Beam Counters
FHC – Forward Hadron Calorimeter

"Beam's eye" view of ZDC



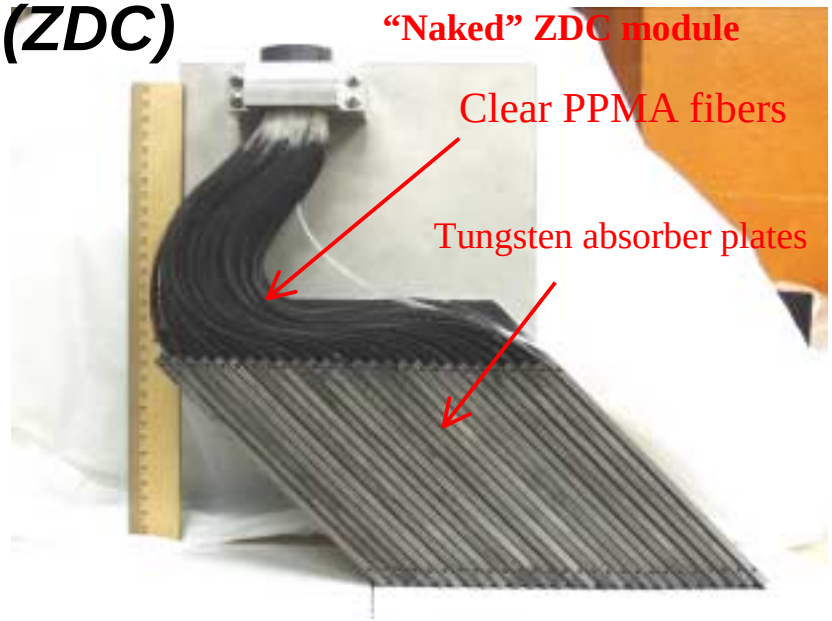


Schematic of ZDC module assy

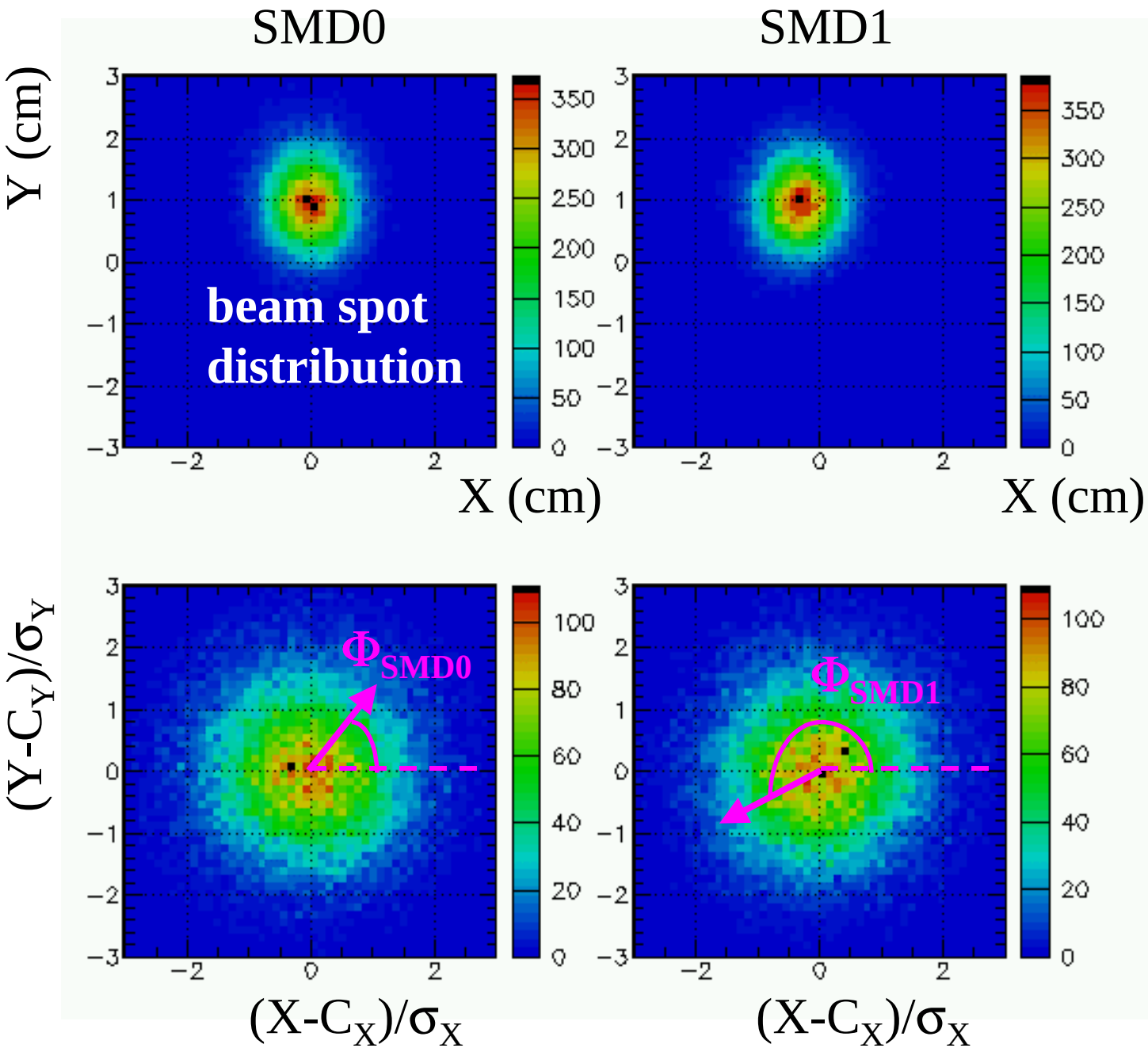


Zero Degree Calorimeter (ZDC)

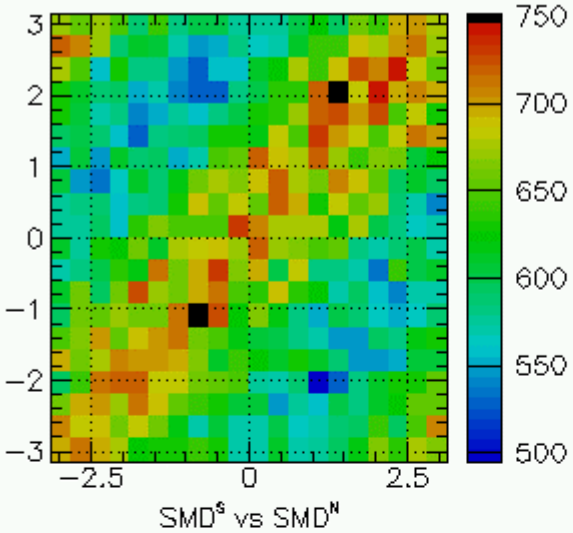
"Naked" ZDC module



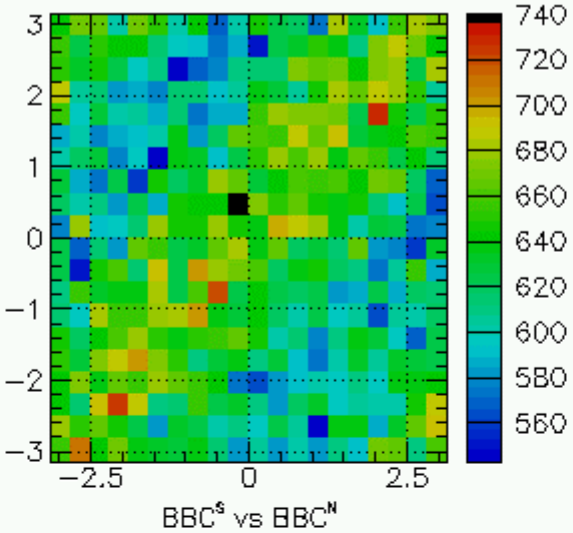
Shower Maximum Detector (SMD)


SMD0
SMD1
Y (cm)
beam spot distribution
X (cm)
X (cm)
$(Y-C_Y)/\sigma_Y$
Φ_{SMD0}
Φ_{SMD1}
$(X-C_X)/\sigma_X$
$(X-C_X)/\sigma_X$

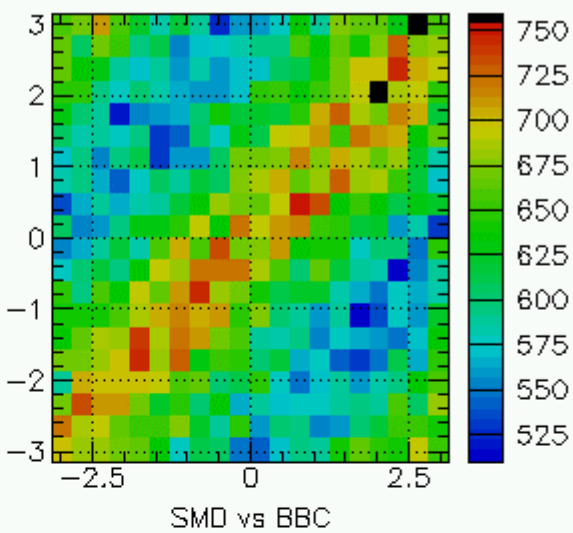
$\Phi_{SMD1}-\pi$ vs Φ_{SMD2}



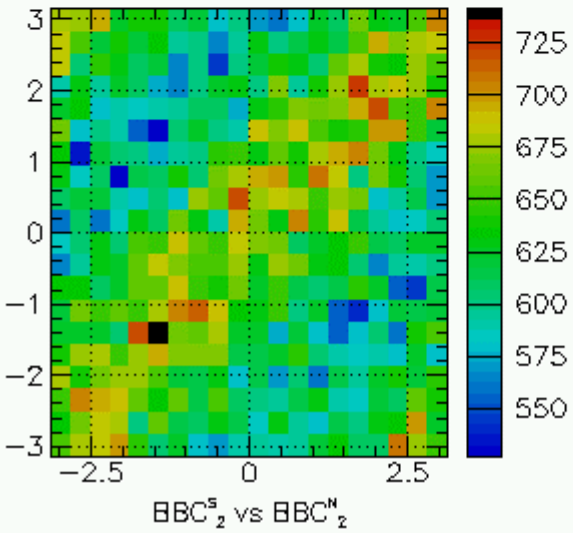
$\Phi_{BBC1}-\pi$ vs Φ_{BBC2}



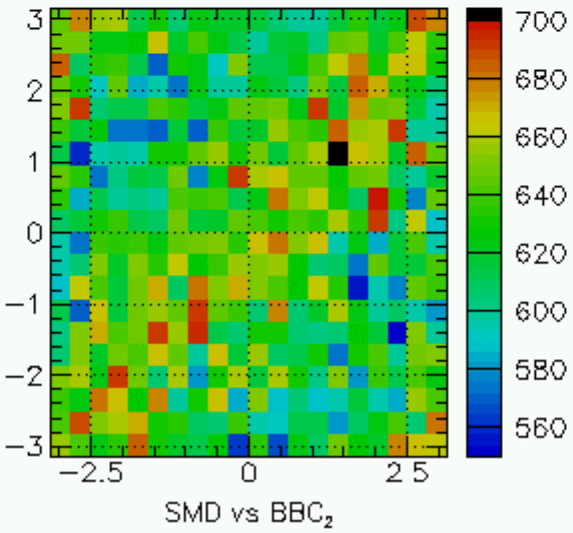
Φ_{SMD} vs $\Phi_{BBC}-\pi$

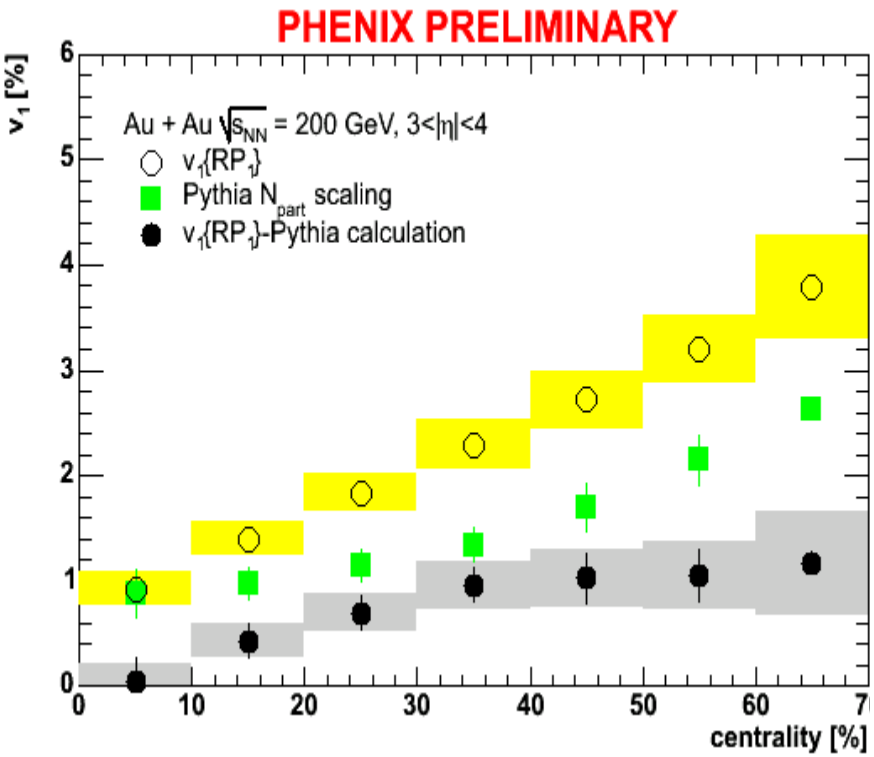


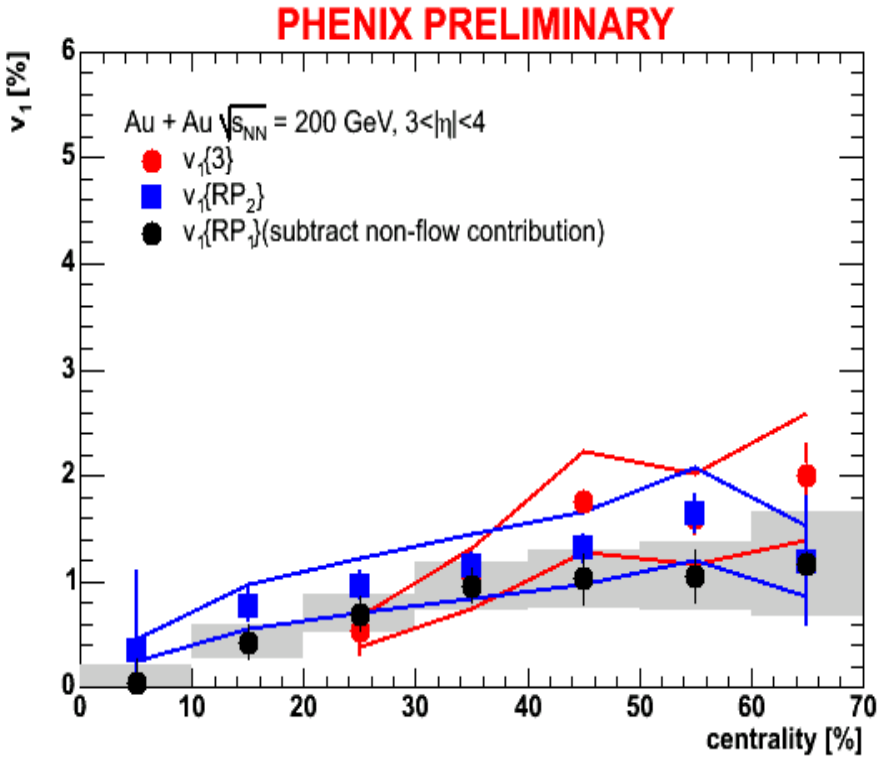
Φ^2_{BBC1} vs Φ^2_{BBC2}

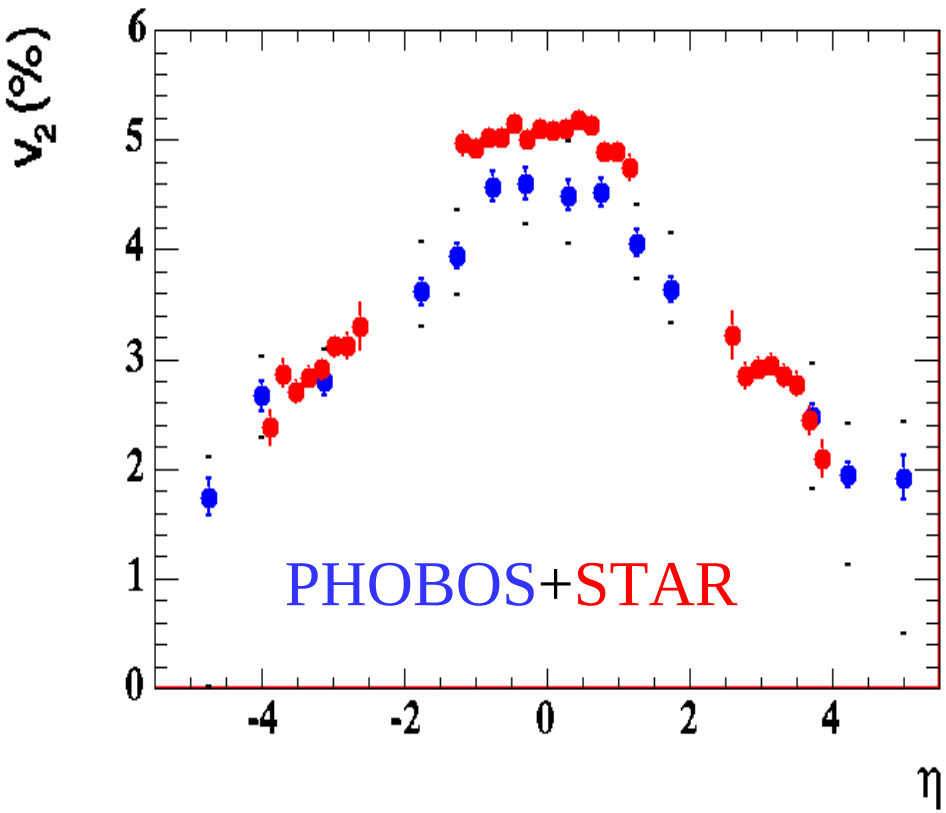


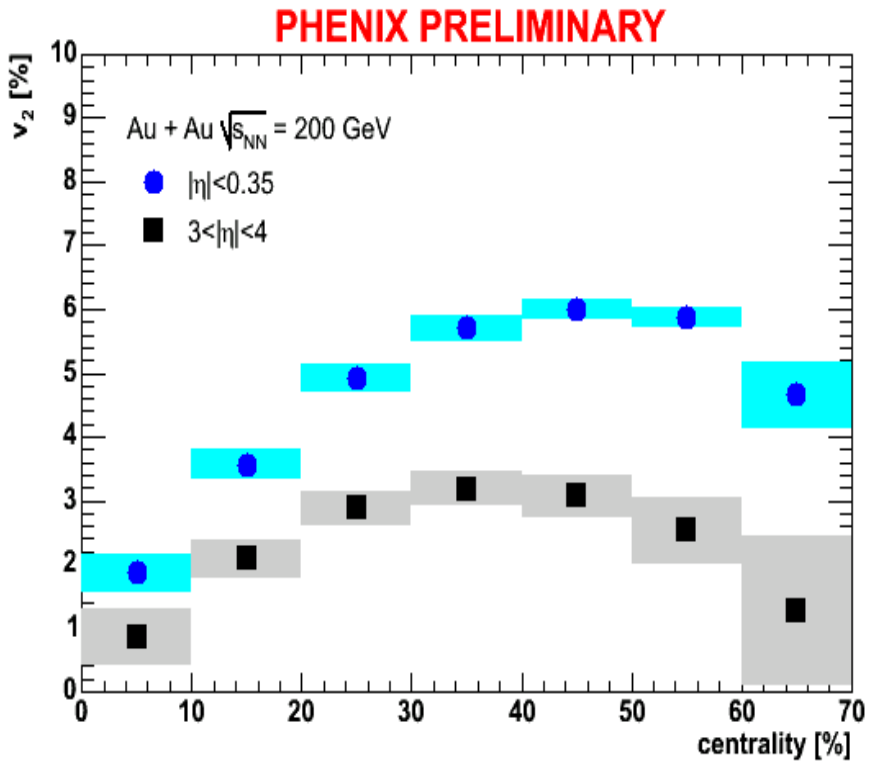
Φ_{SMD} vs Φ^2_{BBC}

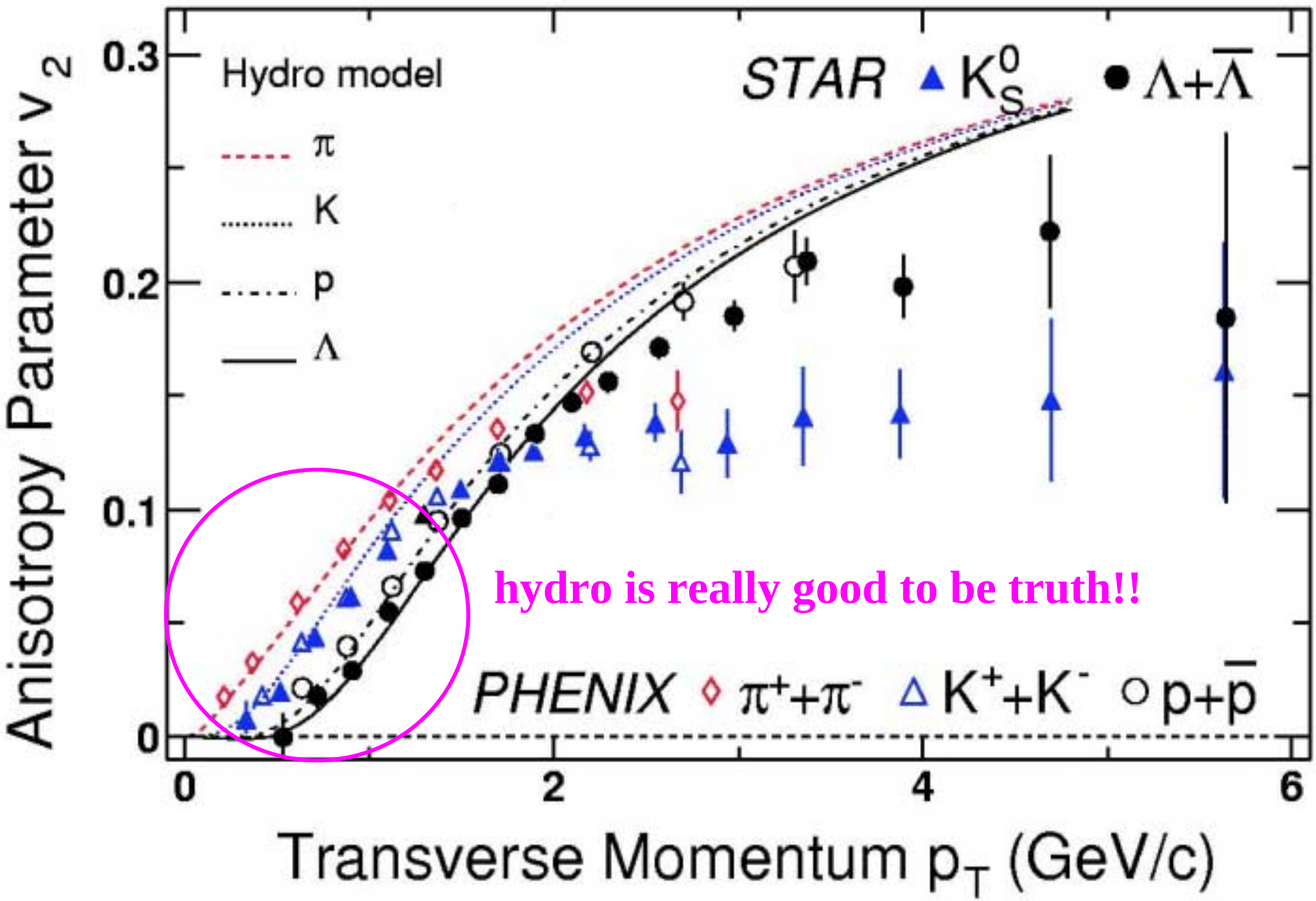



PHENIX PRELIMINARY
Au + Au √sNN = 200 GeV, 3<|η|<4
v1{RP1}
Pythia Npart scaling
v1{RP1}-Pythia calculation
v1 [%]
centrality [%]

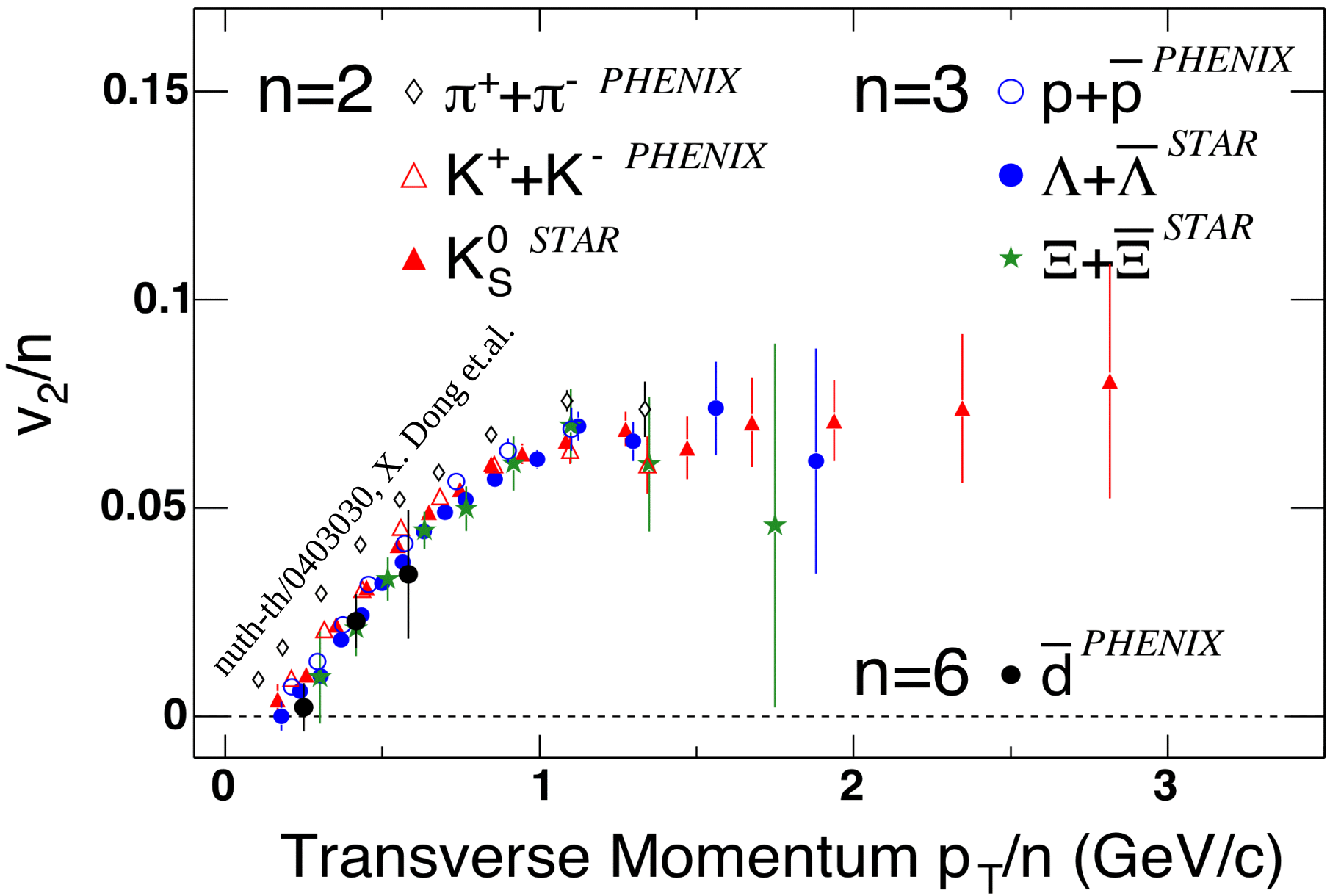

PHENIX PRELIMINARY
Au + Au √sNN = 200 GeV, 3<|η|<4
v1{3}
v1{RP2}
v1{RP1}(subtract non-flow contribution)
v1 [%]
centrality [%]


v_2 (%)
PHOBOS+STAR
η

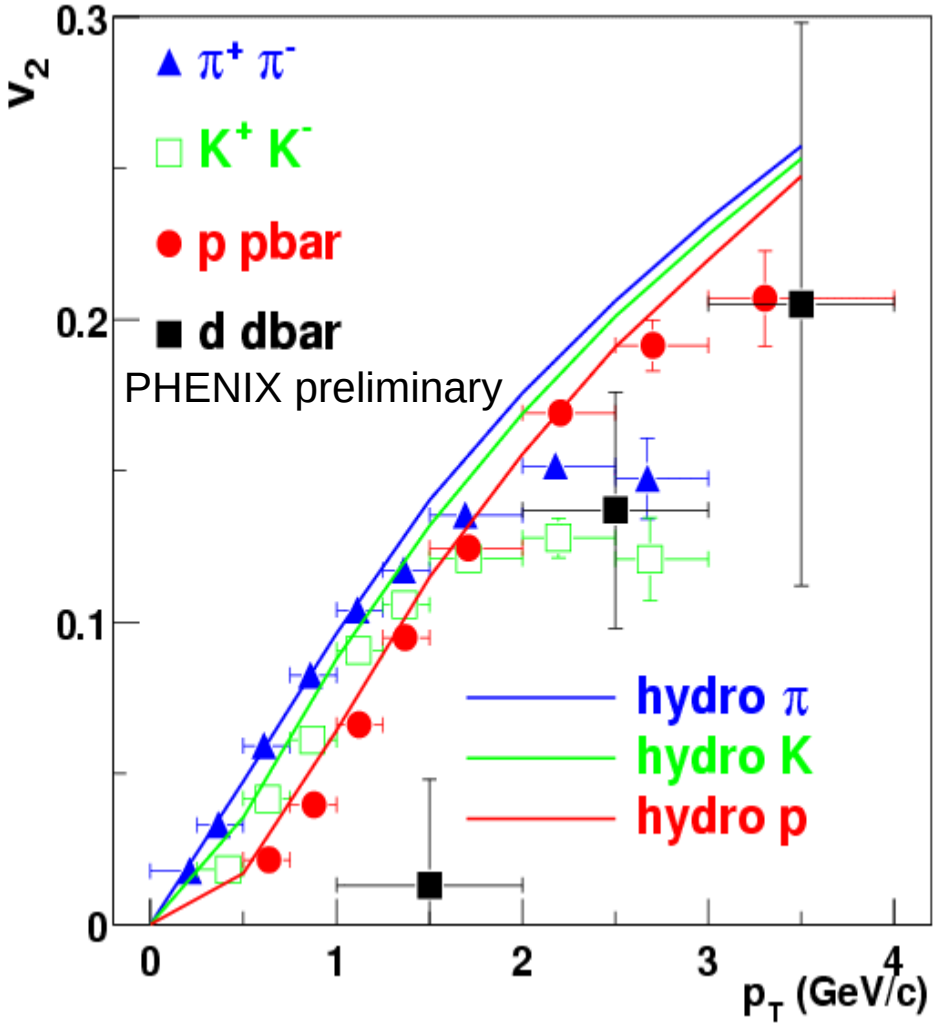

PHENIX PRELIMINARY
v_2 [%]
Au + Au $\sqrt{s_{NN}}$ = 200 GeV
|η|<0.35
3<|η|<4
centrality [%]

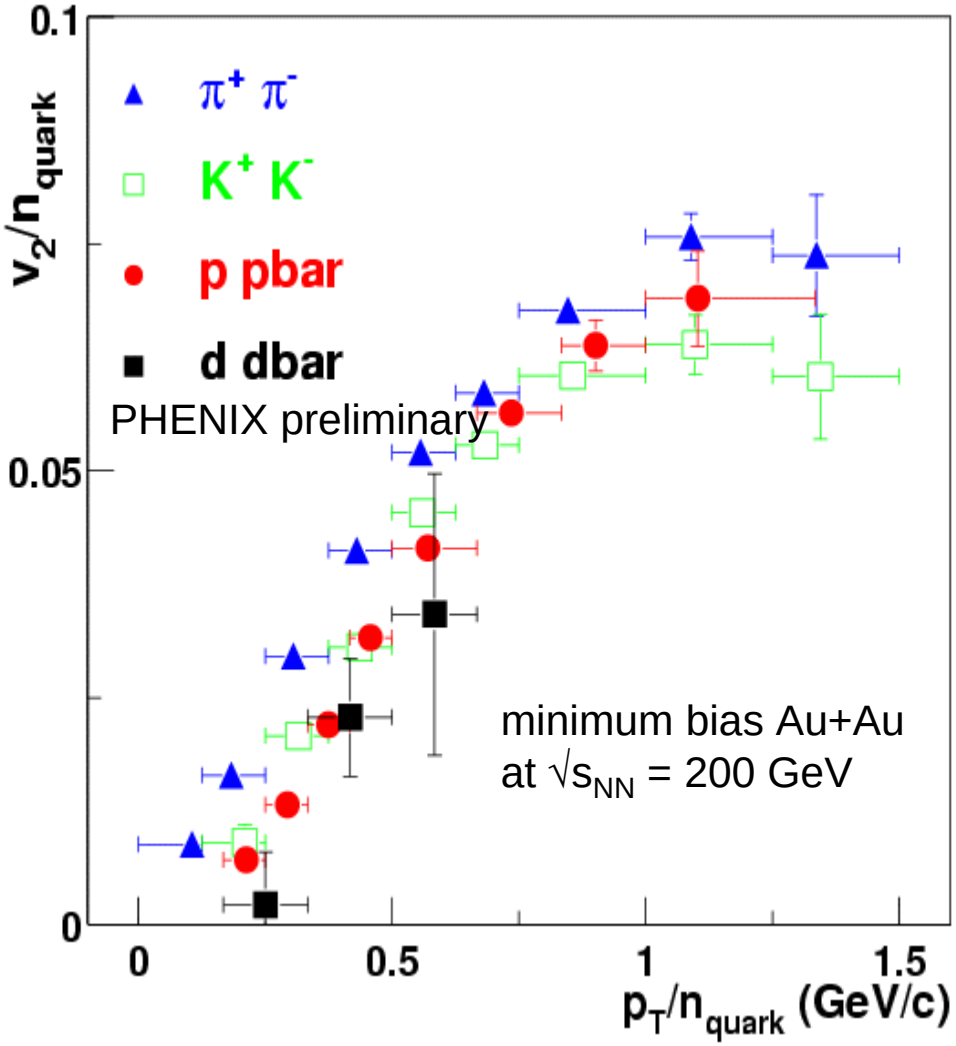


hydro is really good to be truth!!

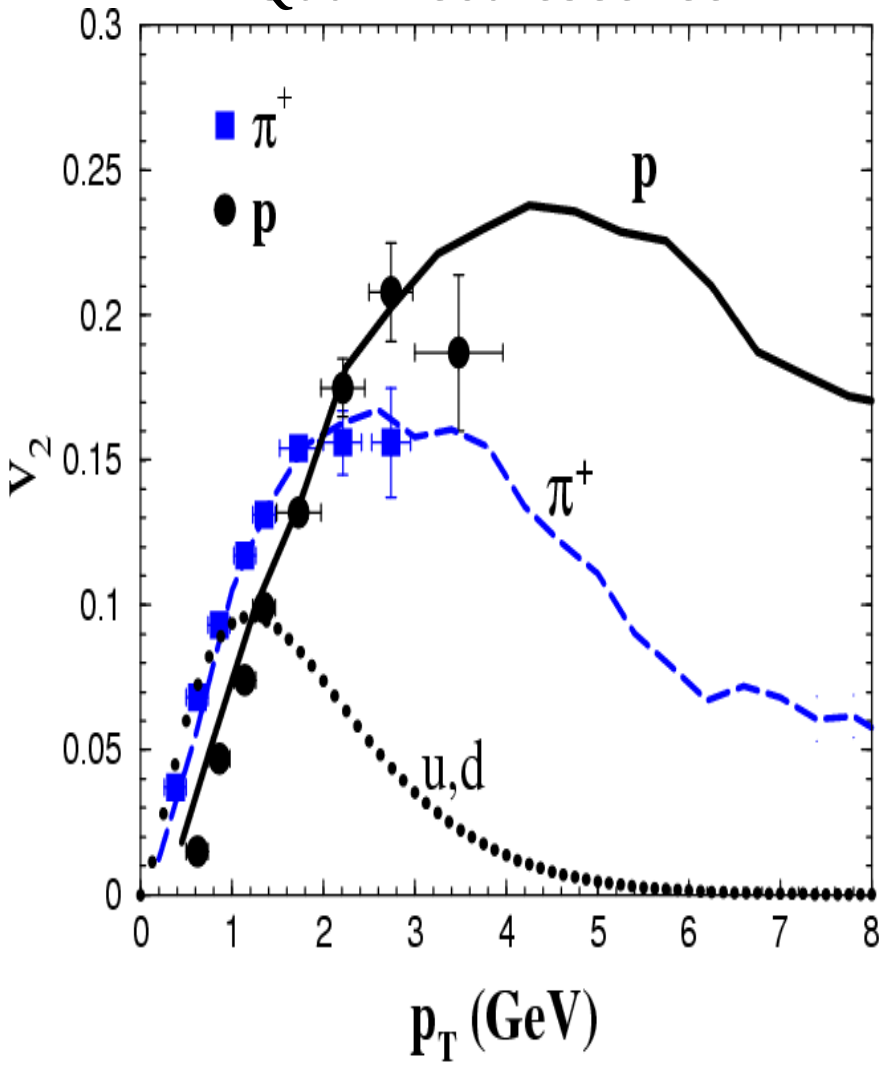

n=2
π+π- PHENIX
K+K- PHENIX
K0S STAR
n=3
p+p̄ PHENIX
Λ+Λ̄ STAR
Ξ+Ξ̄ STAR
n=6
d̄ PHENIX
nuth-th/0403030, X. Dong et.al.
v2/n
0.15
0.1
0.05
0
0
1
2
3
Transverse Momentum pT/n (GeV/c)

quark flow + hadron flow

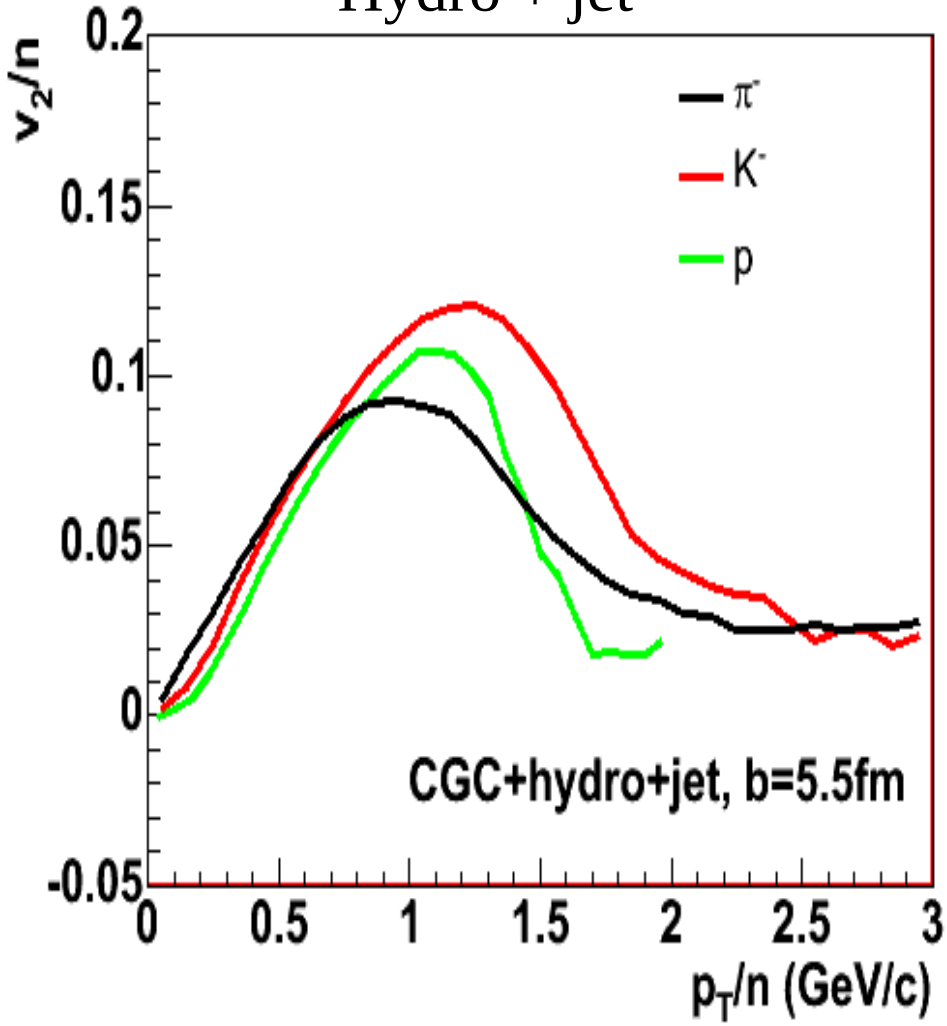




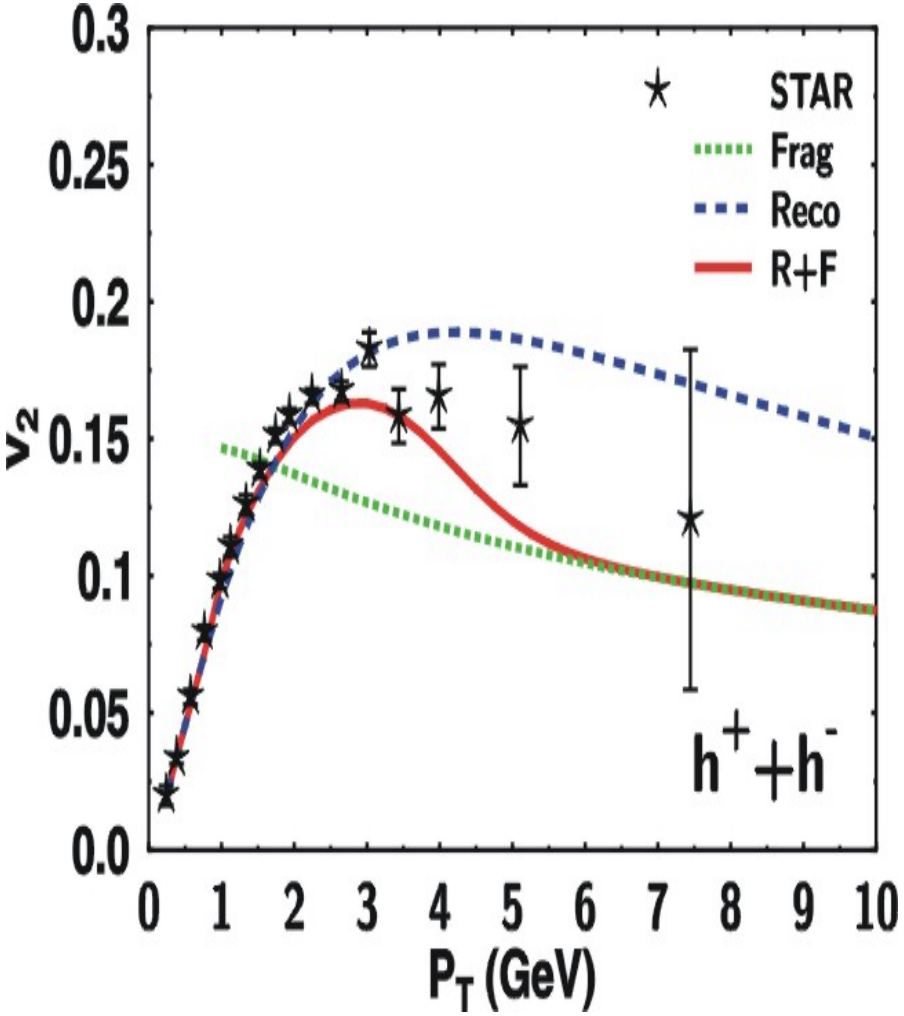
Quark coalescence

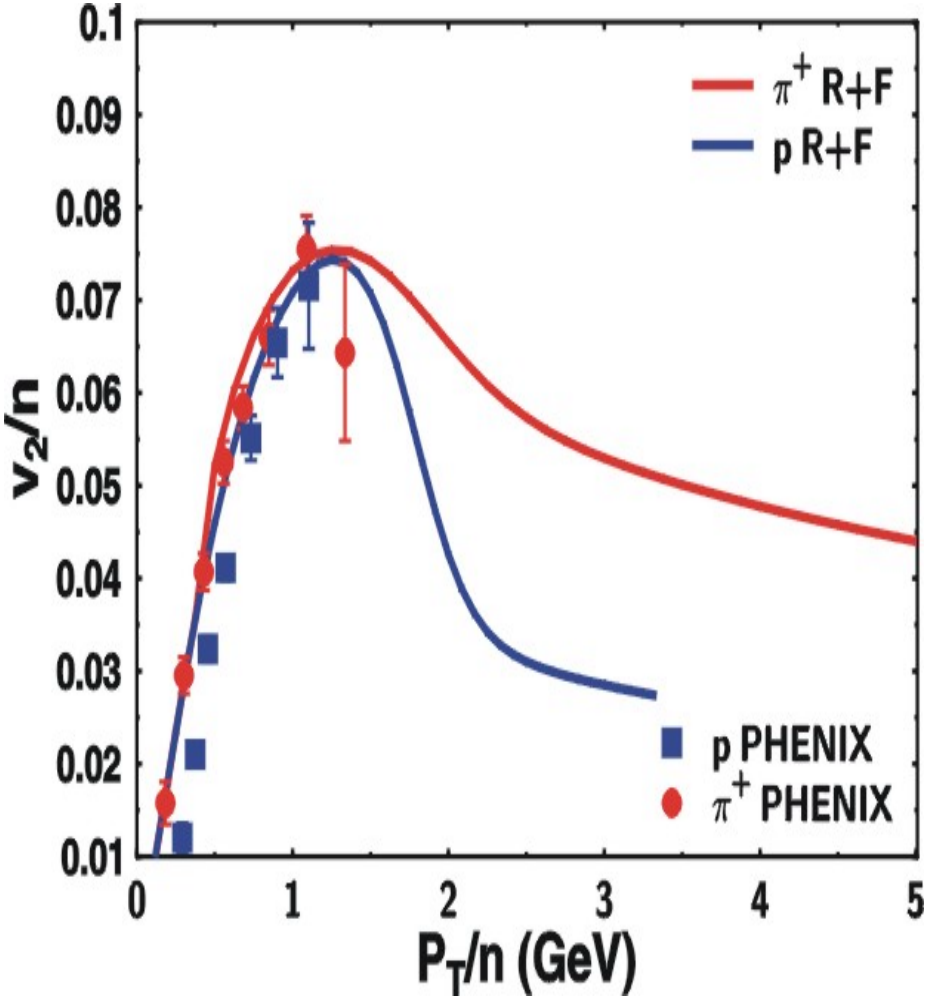


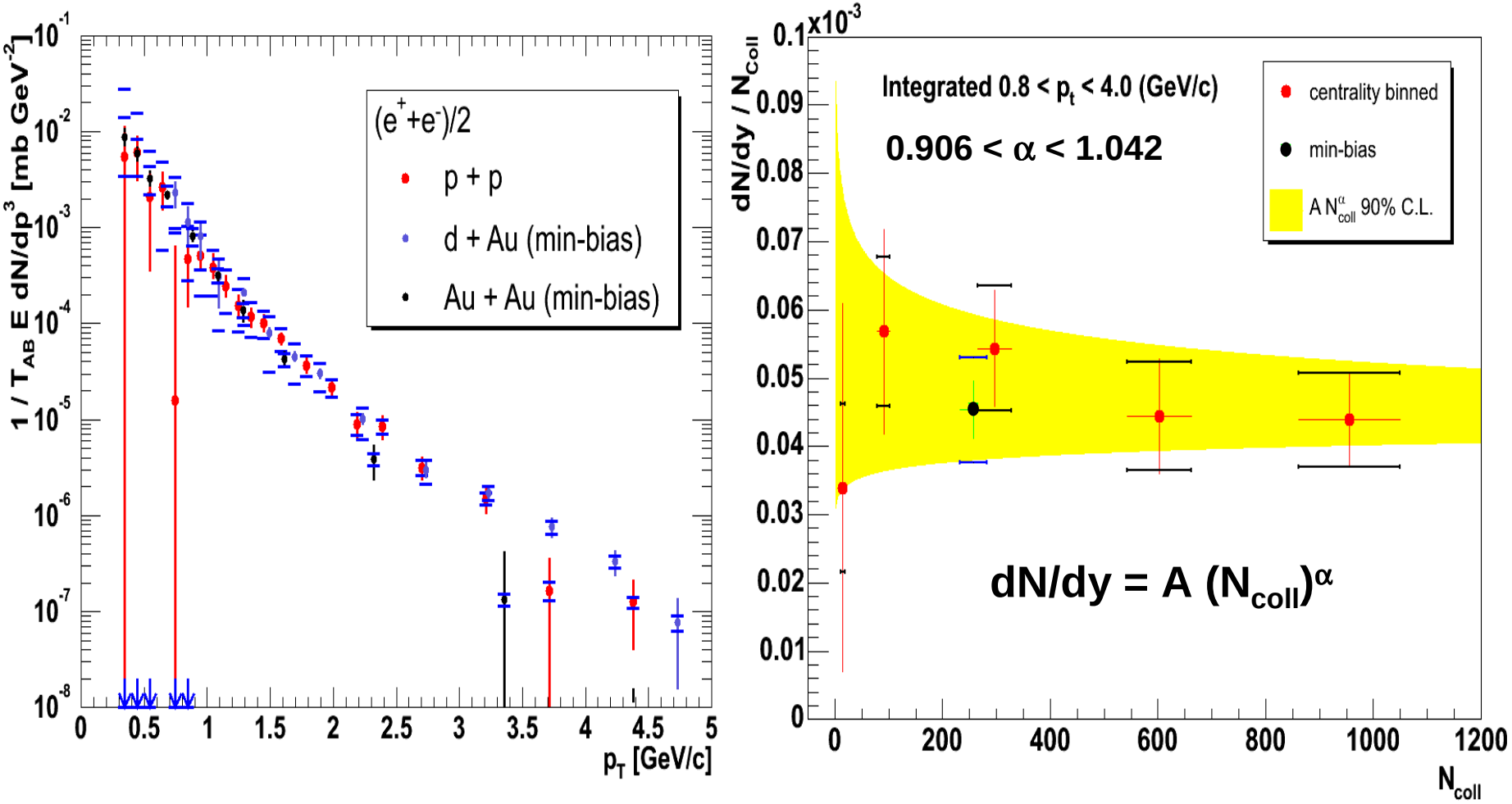
Hydro + jet

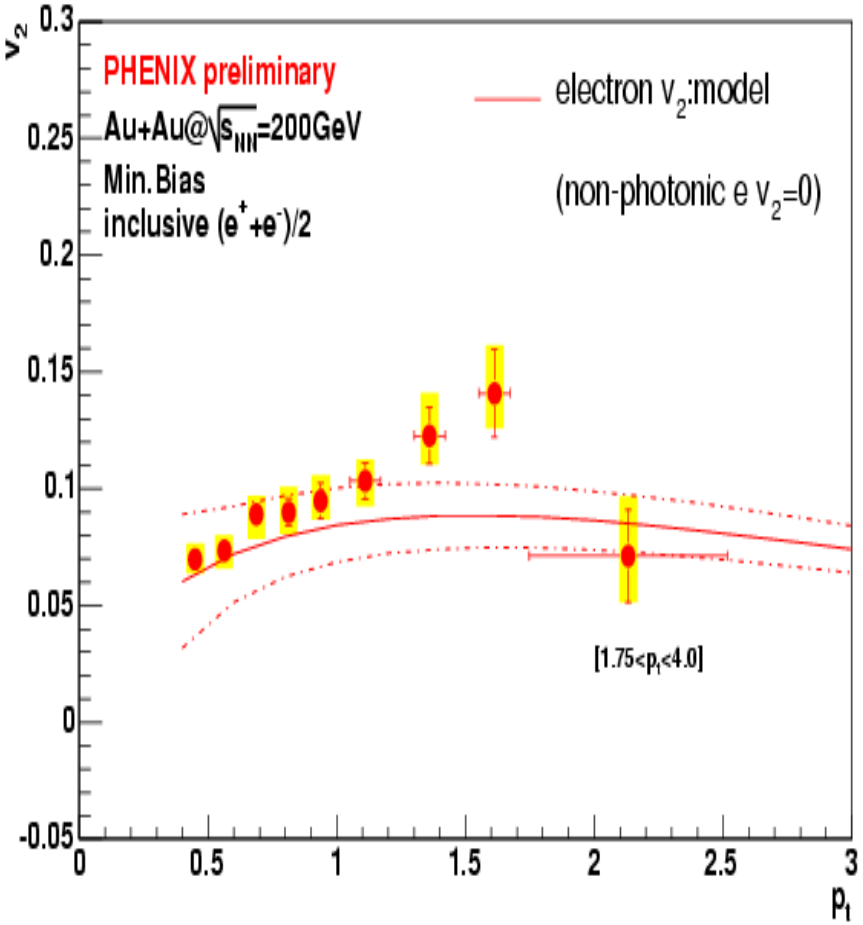


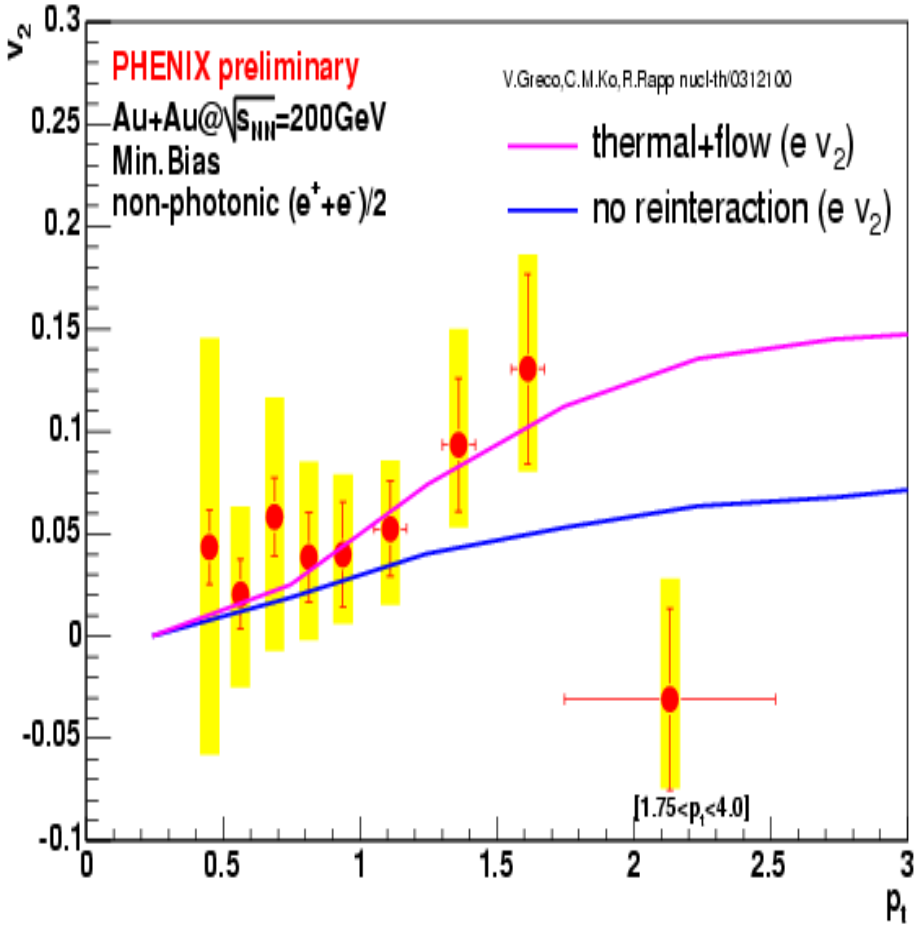
Recombination (quark coalescence) + fragmentation (jet)

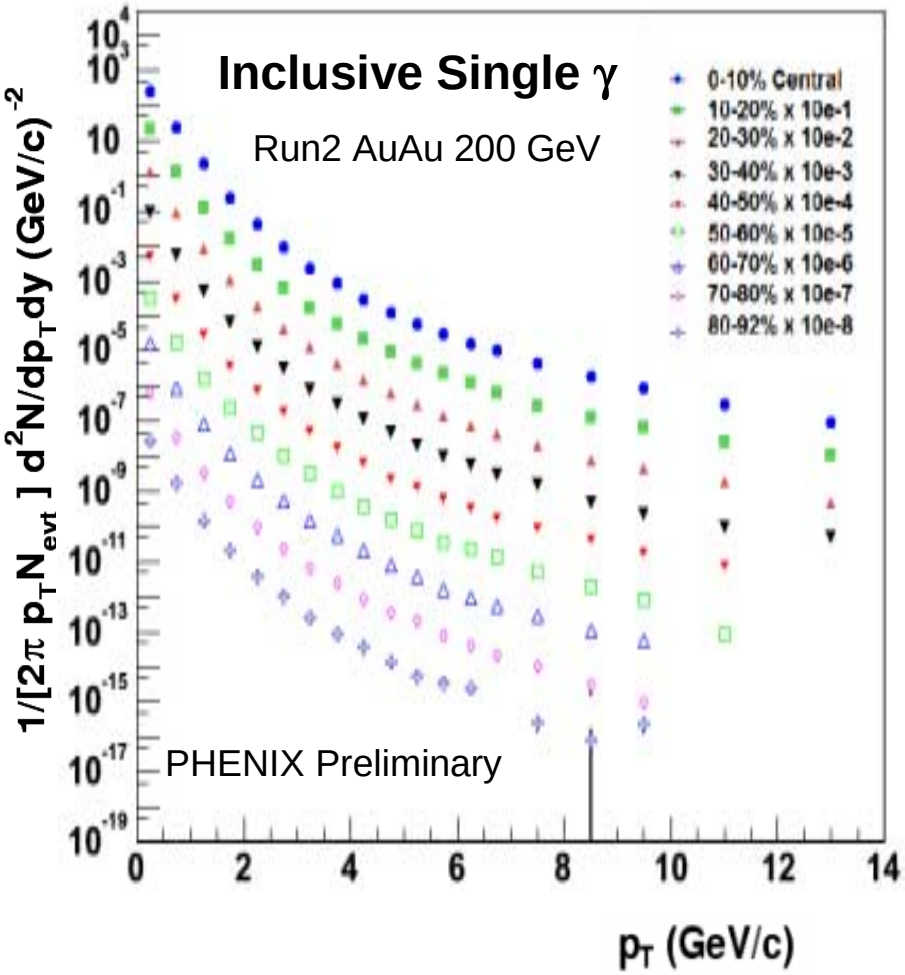


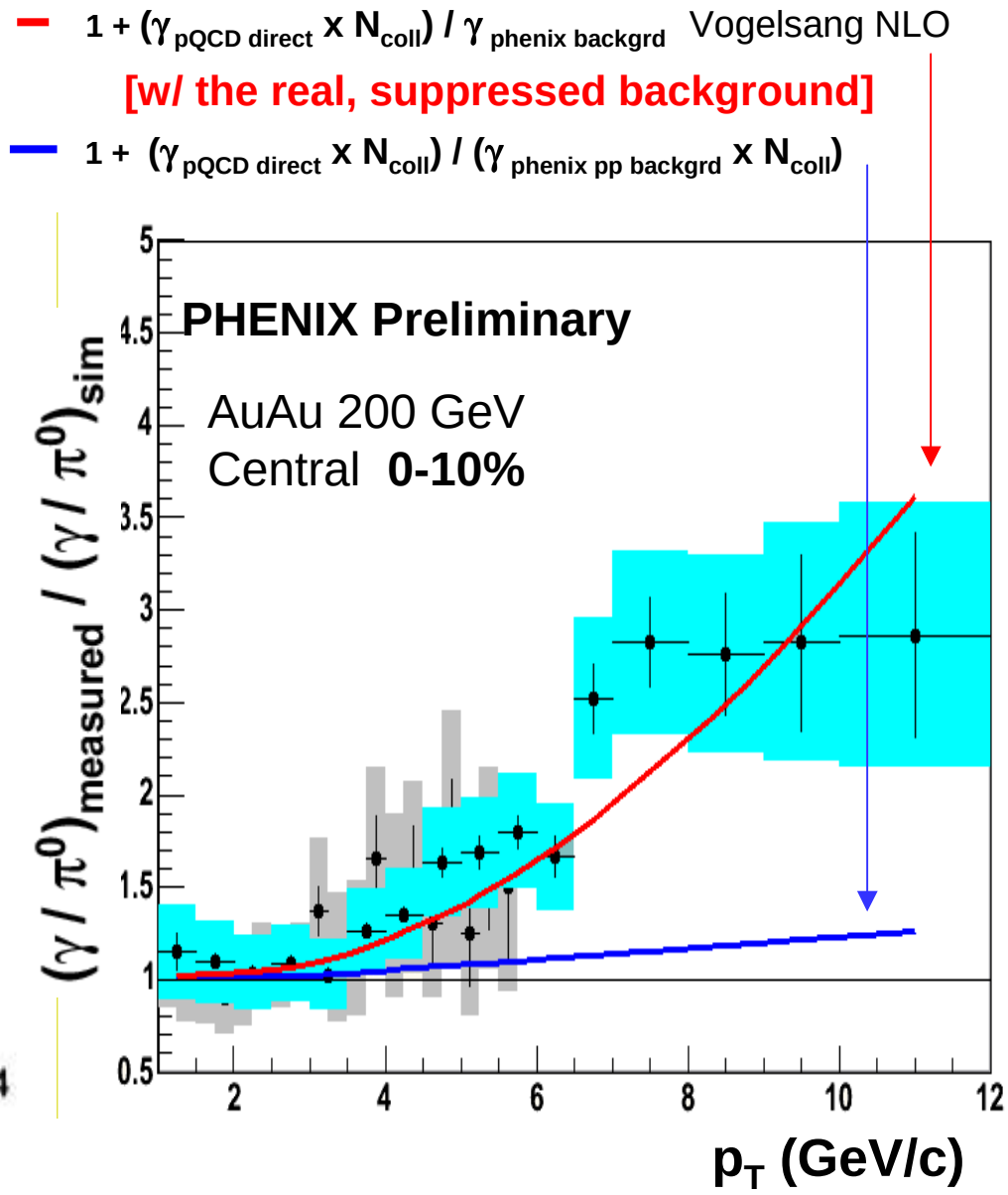



(e+ + e-)/2
p + p
d + Au (min-bias)
Au + Au (min-bias)
1 / T_AB E dN/dp^3 [mb GeV^-2]
p_T [GeV/c]
Integrated 0.8 < p_t < 4.0 (GeV/c)
0.906 < α < 1.042
centrality binned
min-bias
A N_coll^α 90% C.L.
dN/dy = A (N_coll)^α
dN/dy / N_coll
x10^-3
N_coll


PHENIX preliminary
Au+Au@$\sqrt{s_{NN}}$=200GeV
Min. Bias
inclusive $(e^+ + e^-)/2$
electron v_2:model
(non-photonic e v_2=0)
[1.75<p_t<4.0]
v_2
p_t

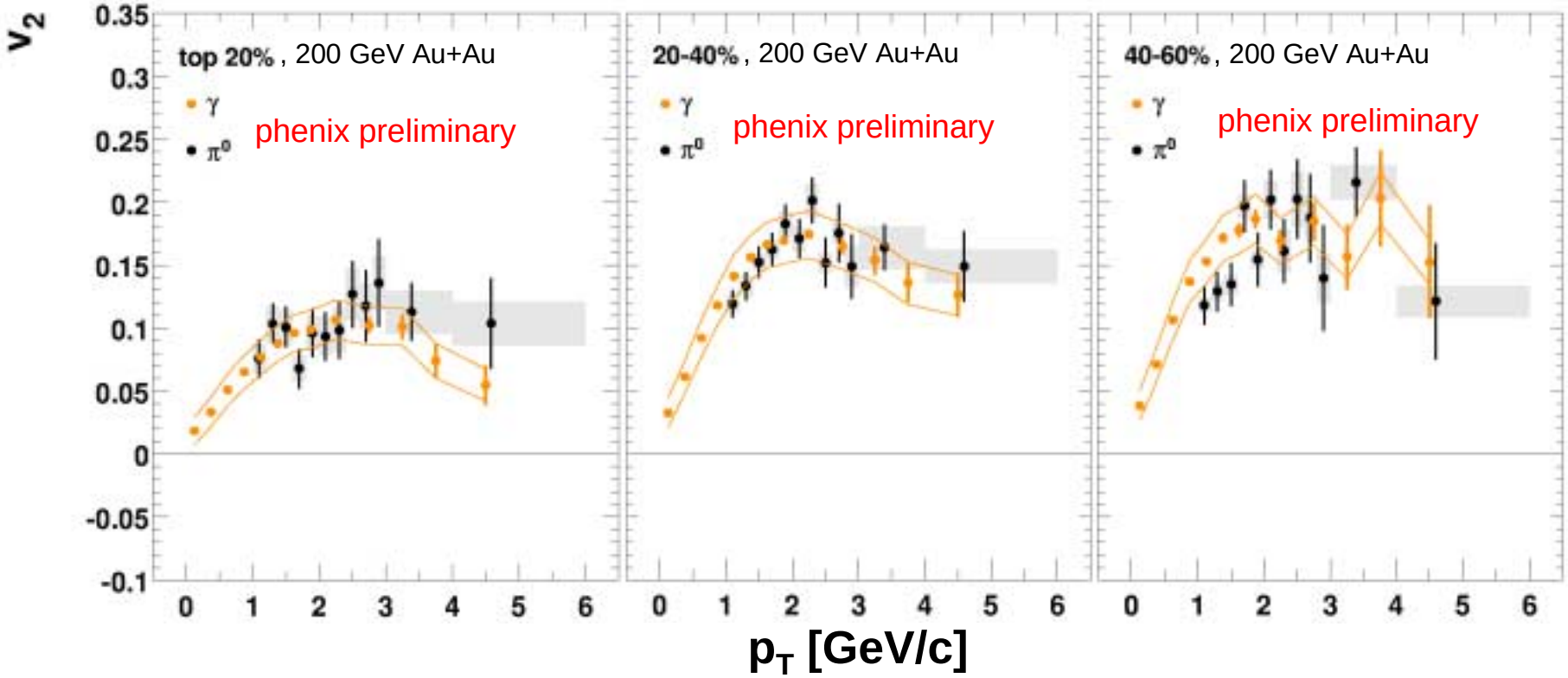

PHENIX preliminary
Au+Au@$\sqrt{s_{NN}}$=200GeV
Min. Bias
non-photonic $(e^+ + e^-)/2$
V.Greco,C.M.Ko,R.Rapp nucl-th/0312100
thermal+flow (e v_2)
no reinteraction (e v_2)
[1.75<p_t<4.0]
v_2
p_t

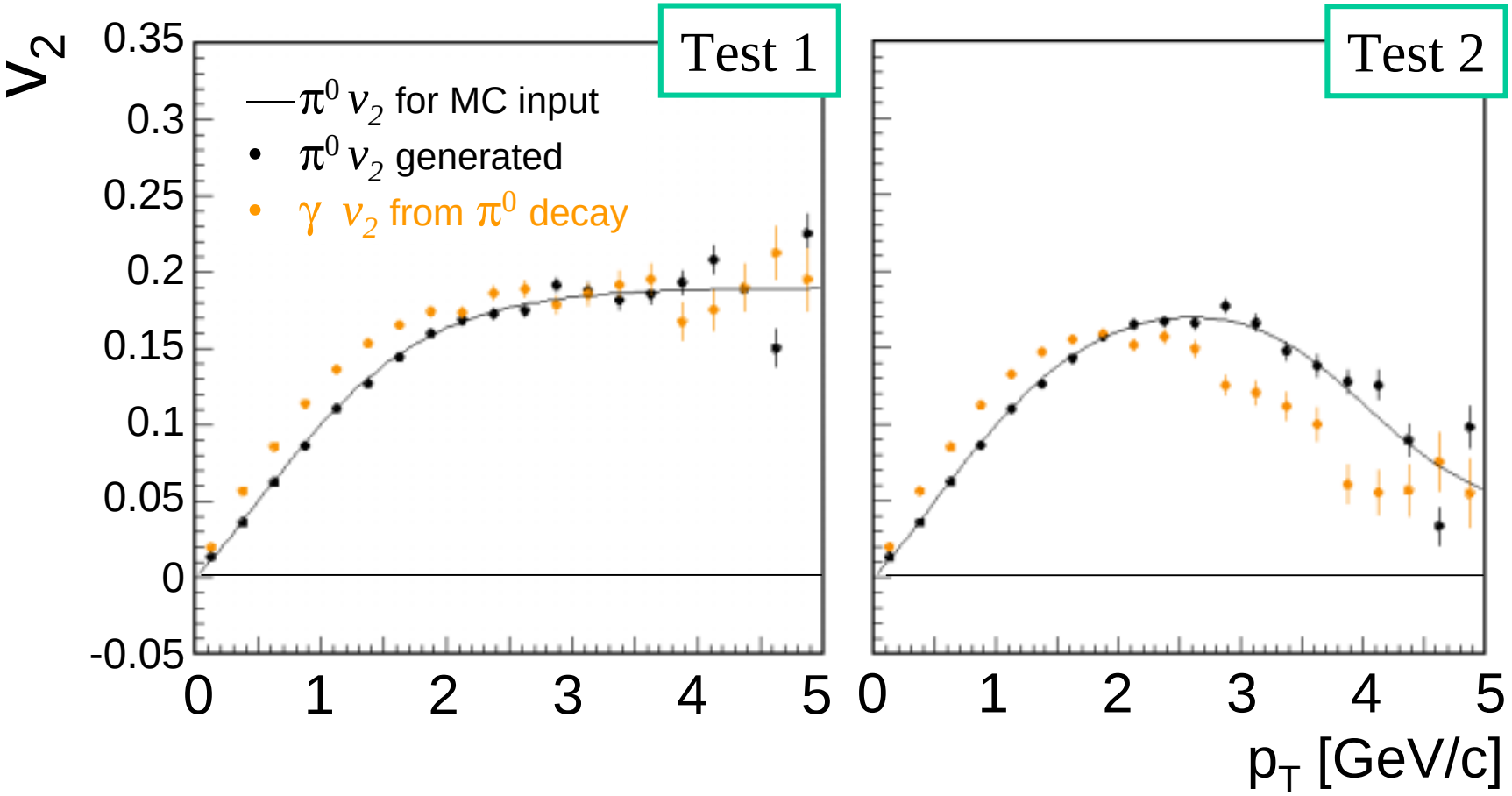

Inclusive Single γ
Run2 AuAu 200 GeV
0-10% Central
10-20% x 10e-1
20-30% x 10e-2
30-40% x 10e-3
40-50% x 10e-4
50-60% x 10e-5
60-70% x 10e-6
70-80% x 10e-7
80-92% x 10e-8
PHENIX Preliminary
1/[2π p_T N_evt] d^2N/dp_T dy (GeV/c)^-2
p_T (GeV/c)

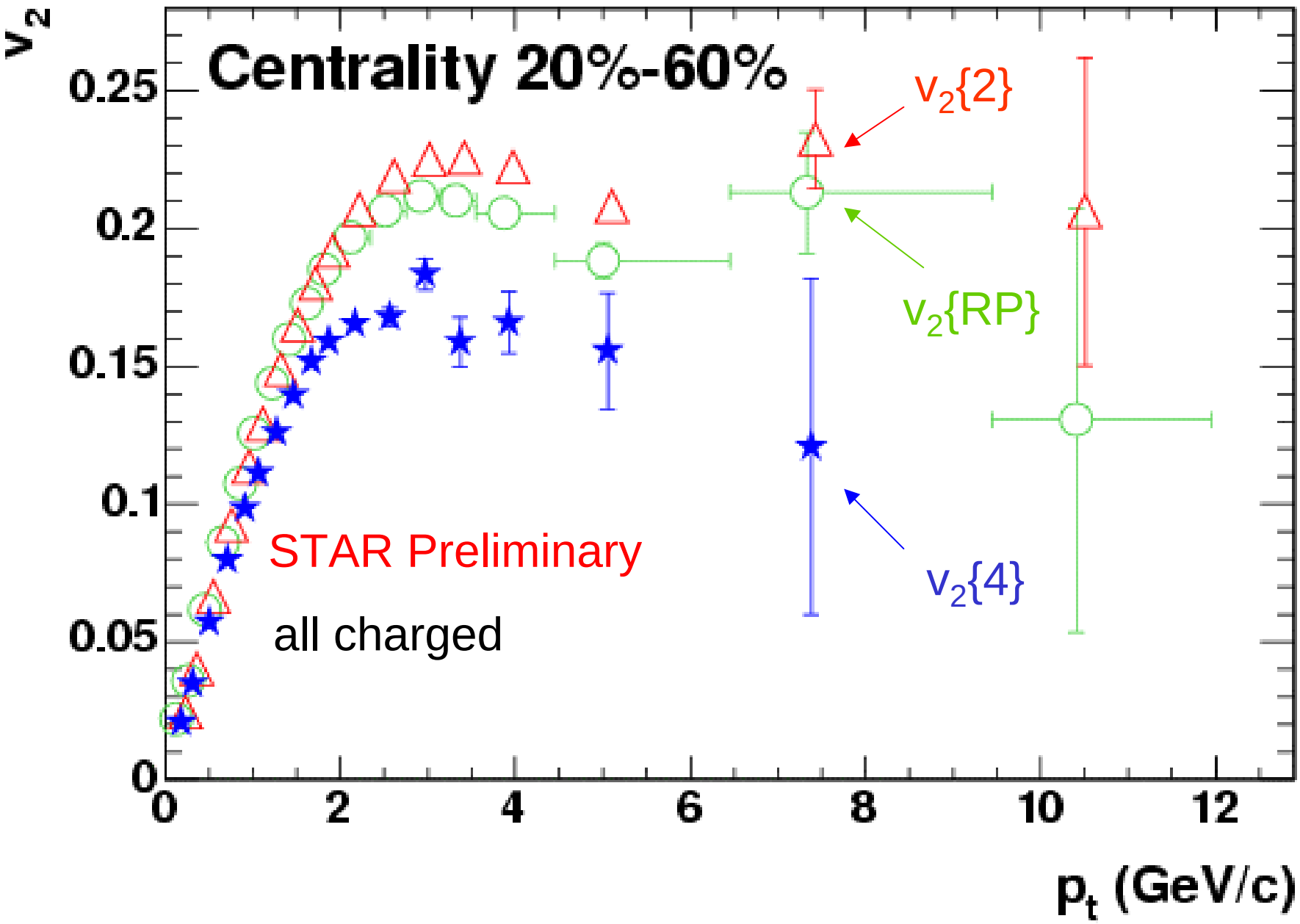

1 + (γ pQCD direct x N_coll) / γ phenix backgrd
Vogelsang NLO
[w/ the real, suppressed background]
1 + (γ pQCD direct x N_coll) / (γ phenix pp backgrd x N_coll)
PHENIX Preliminary
AuAu 200 GeV
Central 0-10%
(γ / π^0)_measured / (γ / π^0)_sim
p_T (GeV/c)

Note :
Inclusive photon = including all of the decay effect from hadrons

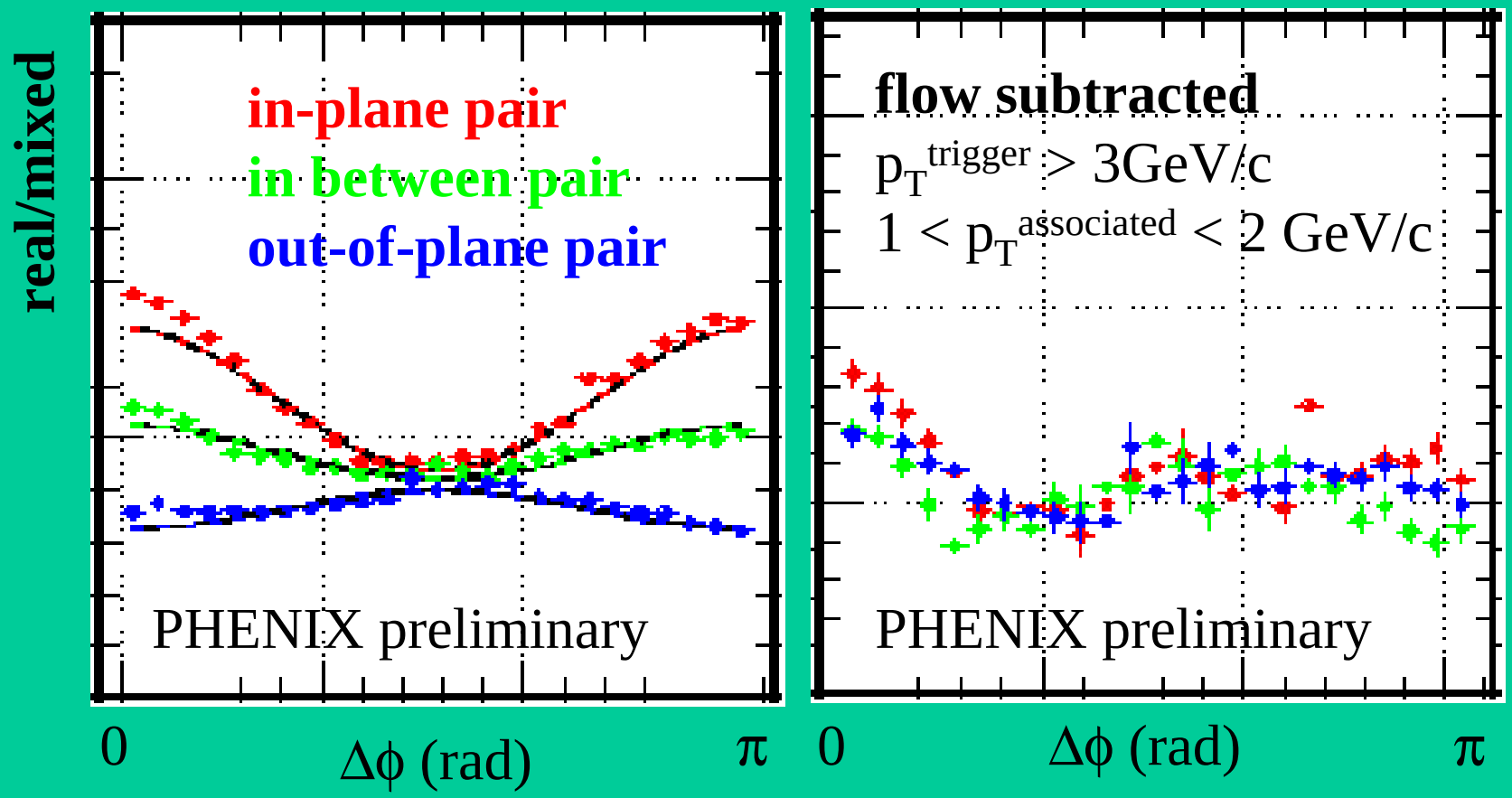
vertical bar : stat. error
curves, gray box : sys. error




Test 1
Test 2
v_2
π^0 v_2 for MC input
π^0 v_2 generated
γ v_2 from π^0 decay
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
-0.05
0
1
2
3
4
5
p_T [GeV/c]


Centrality 20%-60%
v_2
0.25
0.2
0.15
0.1
0.05
0
0
2
4
6
8
10
12
p_t (GeV/c)
$v_2\{2\}$
$v_2\{RP\}$
$v_2\{4\}$
STAR Preliminary
all charged

three curves are fixed by measured v2 and resolution → coalescence of jet-fragmentation one of the source of v2



Summary

Flow measurements at PHENIX
Charged particle v1 and v2
Identified hadron v2
Charm and photon v2
Origin of v2 and non-flow