Recent (and some old) Results from PHENIX (and RHIC, LHC)

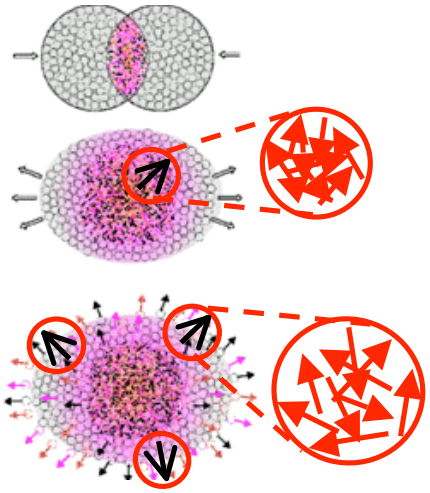
ShinIchi Esumi
Inst. of Physics
Univ. of Tsukuba

Contents

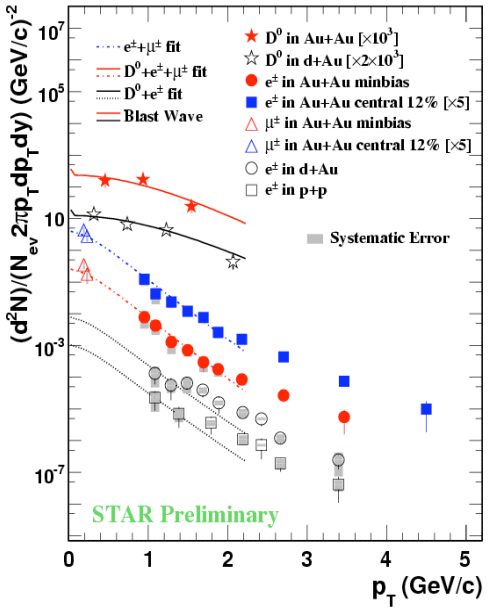
Bulk properties (Soft) : collective expansion effects
Energy loss (Hard) : high p_T / jet suppressions
Soft / Hard interplay : jet / bulk modification

Radial expansion

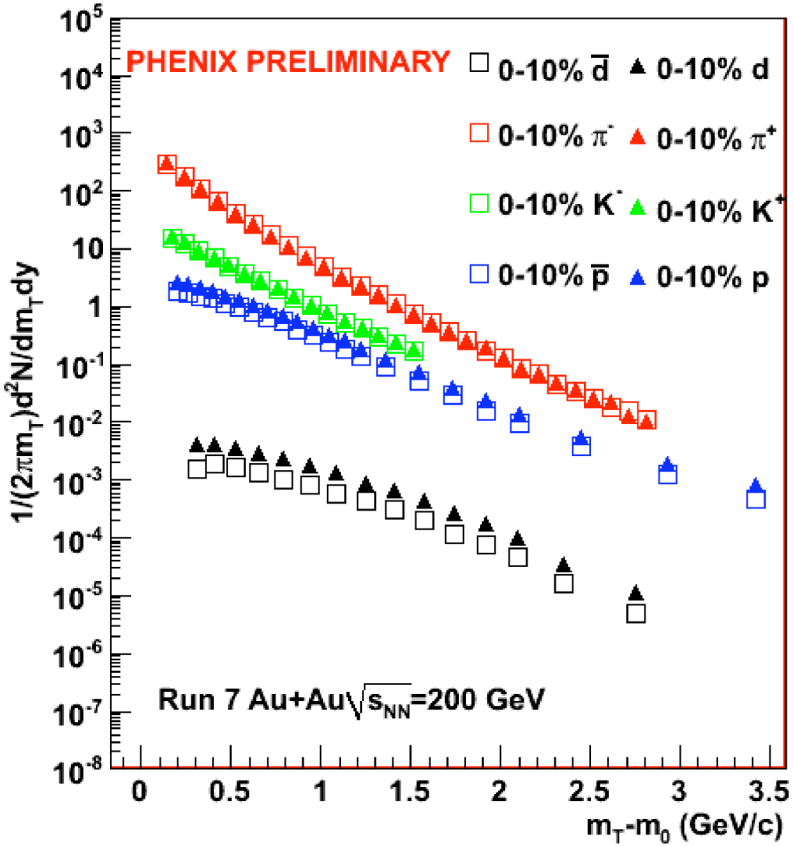
--- freeze-out time dependence ---

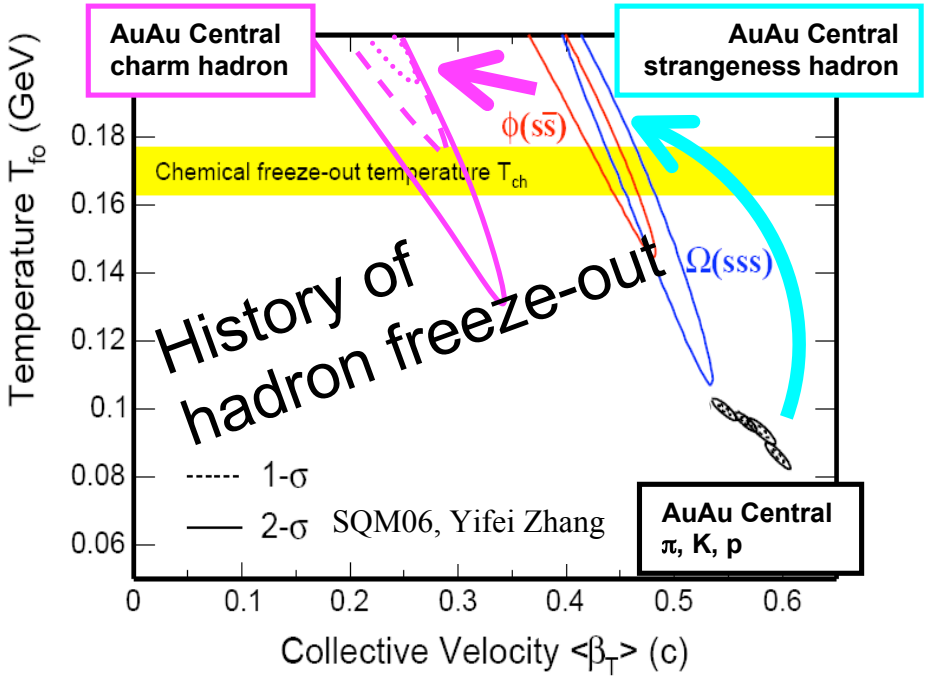


SQM06, Yifei Zhang



Hadron Spectra 0-10% Centrality

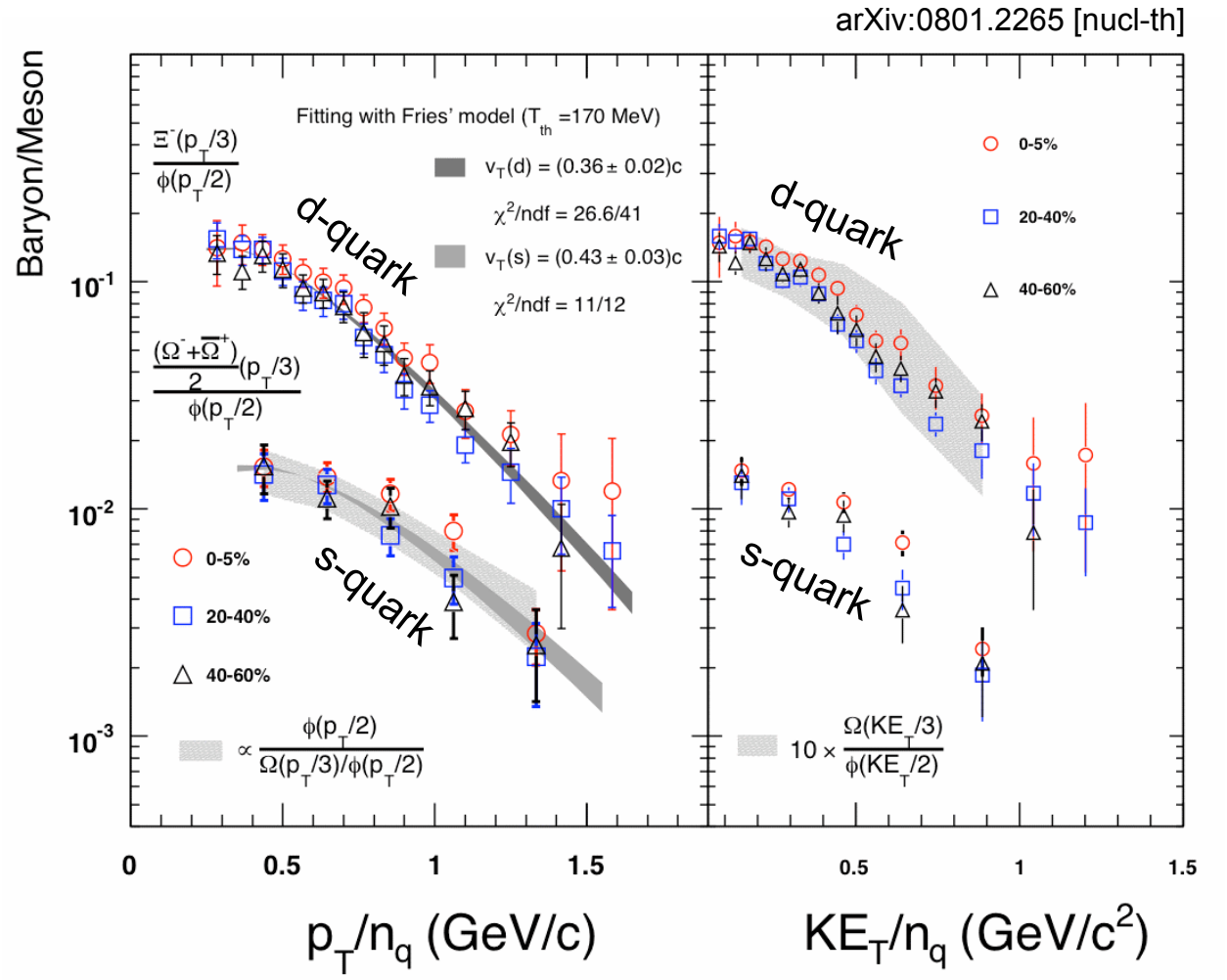


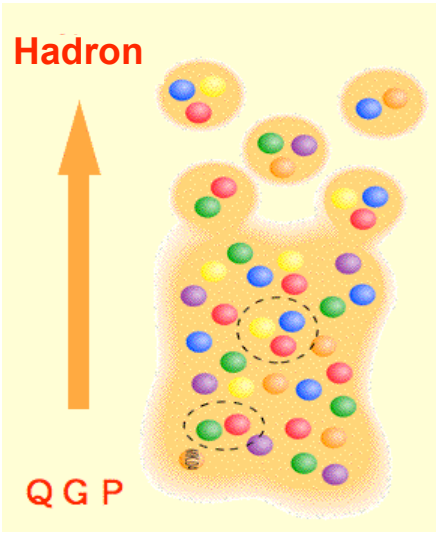


Quark momentum distribution

--- extracted from multi-strange hadron ratio ---

arXiv:0801.2265 [nucl-th]





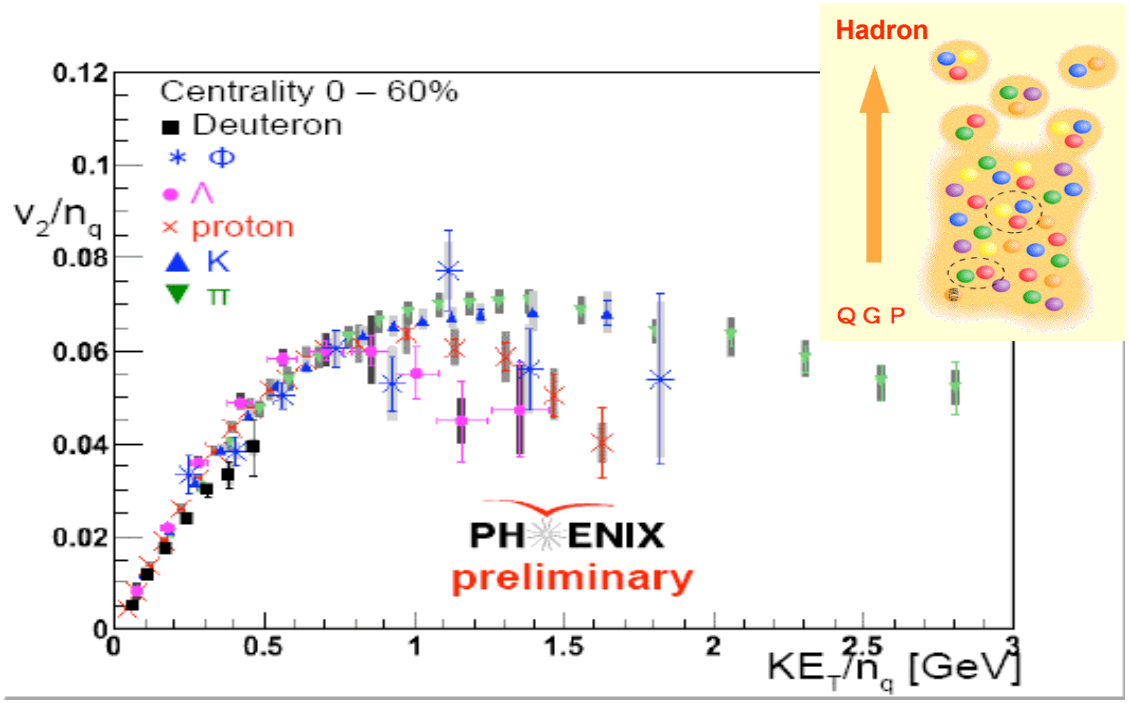
Collective radial expansion
-during the partonic phase
-before the hadronic phase

Quark coalescence or recombination mechanism for the hadronization

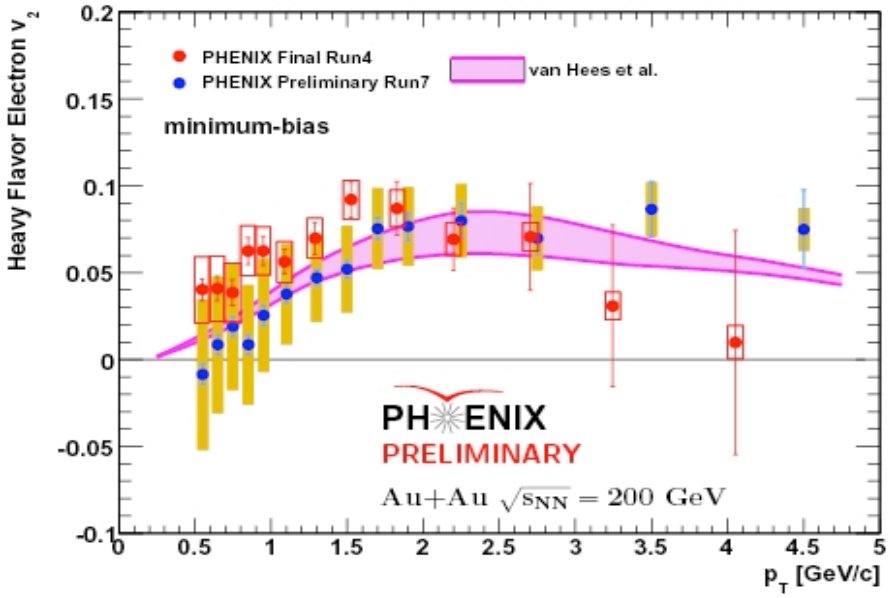
Partonic collectivity

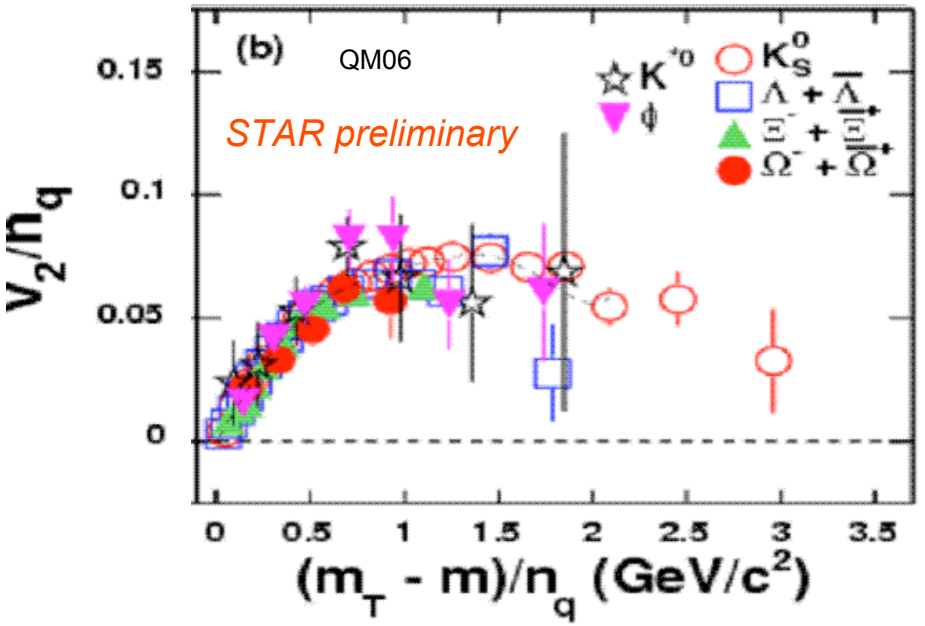
--- particle identified v_2 ---

Number of constituent quark scaling in hadron v_2 as well as multi-strange baryon v_2: v_2 is already established during the quark phase before the hadronization. This seems to be true even for heavy quark like charm.



QM08: A.Dion

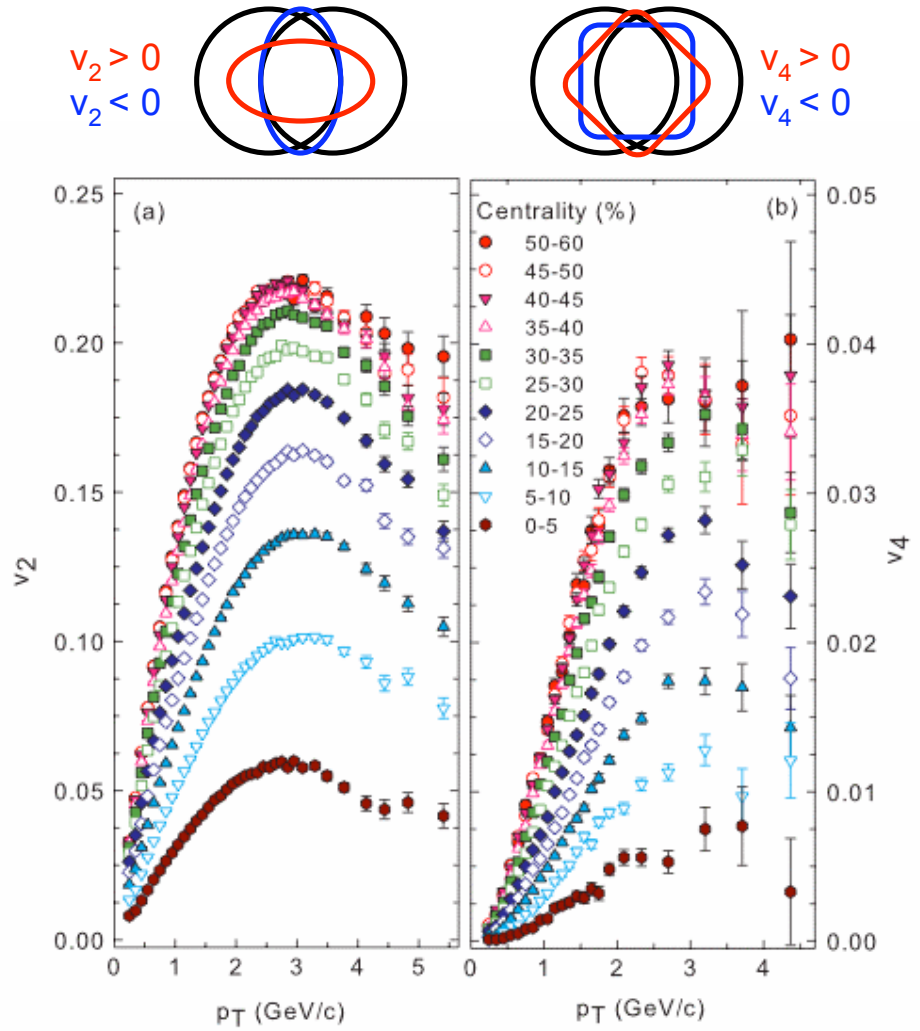


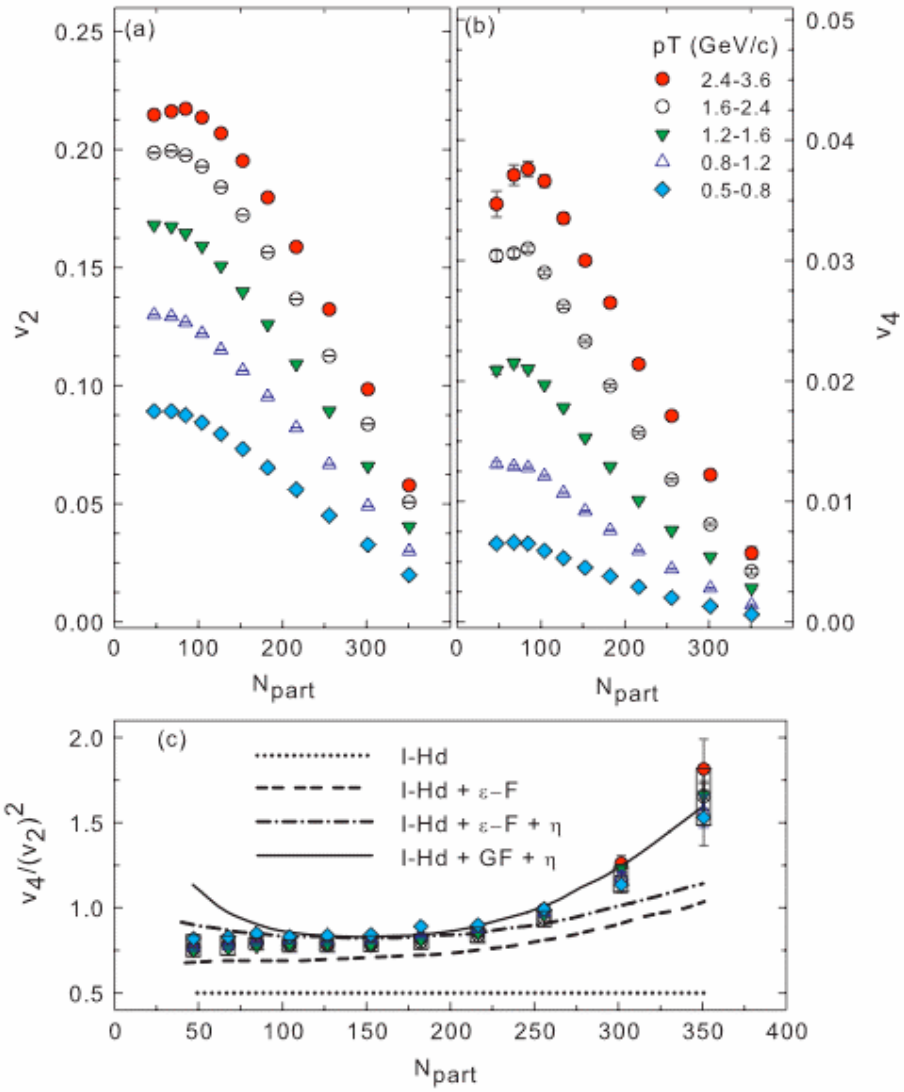


Higher order anisotropy v_4 vs v_2

--- relation with hydro expansion ---

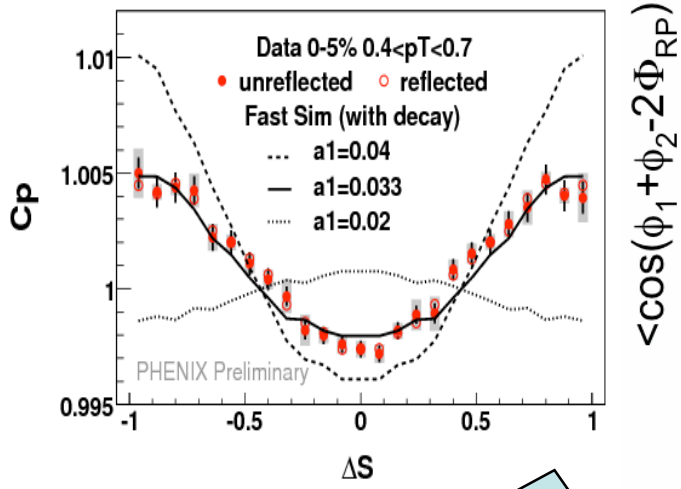
PRL105, 062301 (2010)



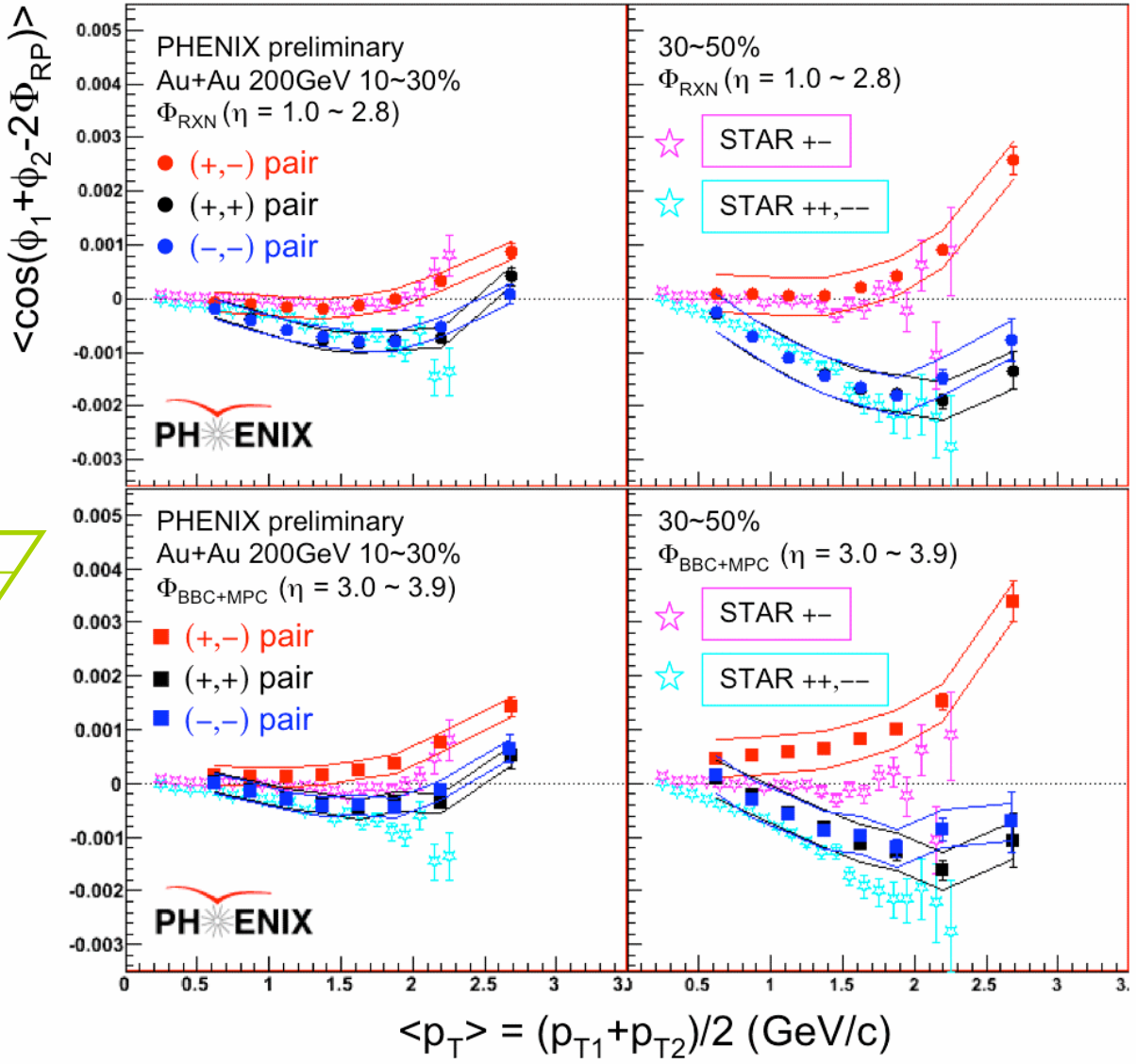


Parity violation signal

--- charge asymmetry w.r.t. R.P. ---



Fuqiang Wang,
this morning

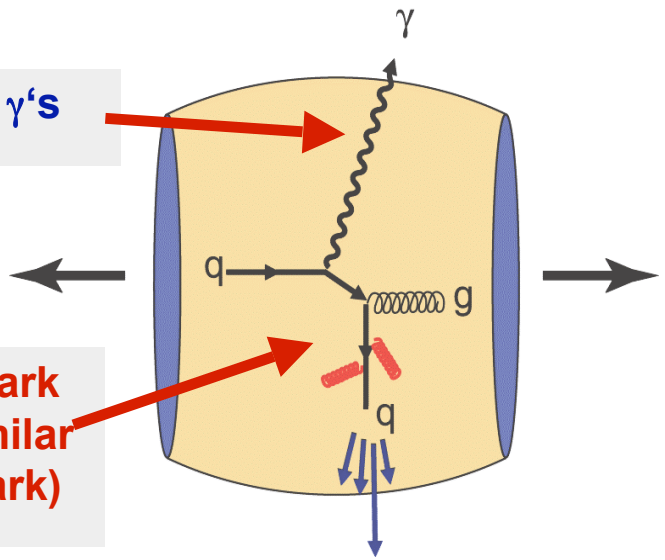


Jet quenching

--- energy loss of parton in QGP ---

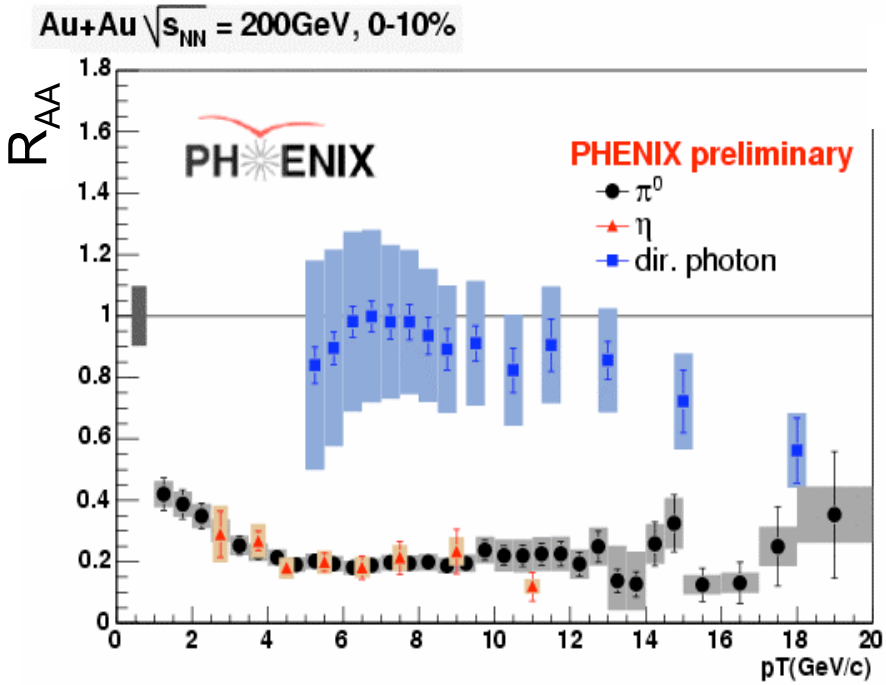
--- difference between hadron and direct photon ---

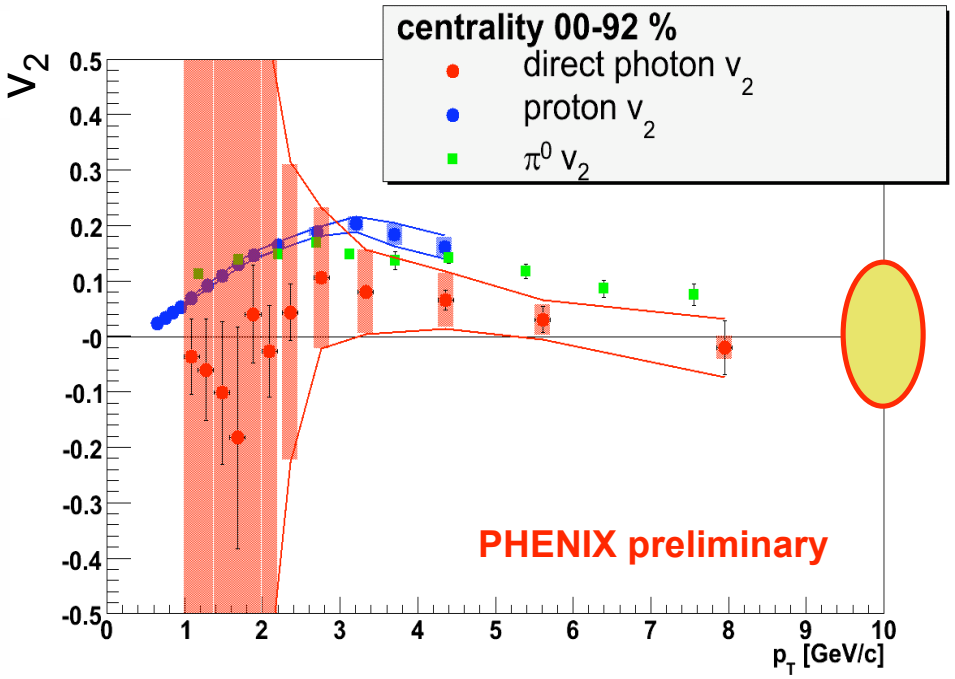
No energy loss for γ's



Energy loss for quark and gluon jets (similar even for heavy quark)

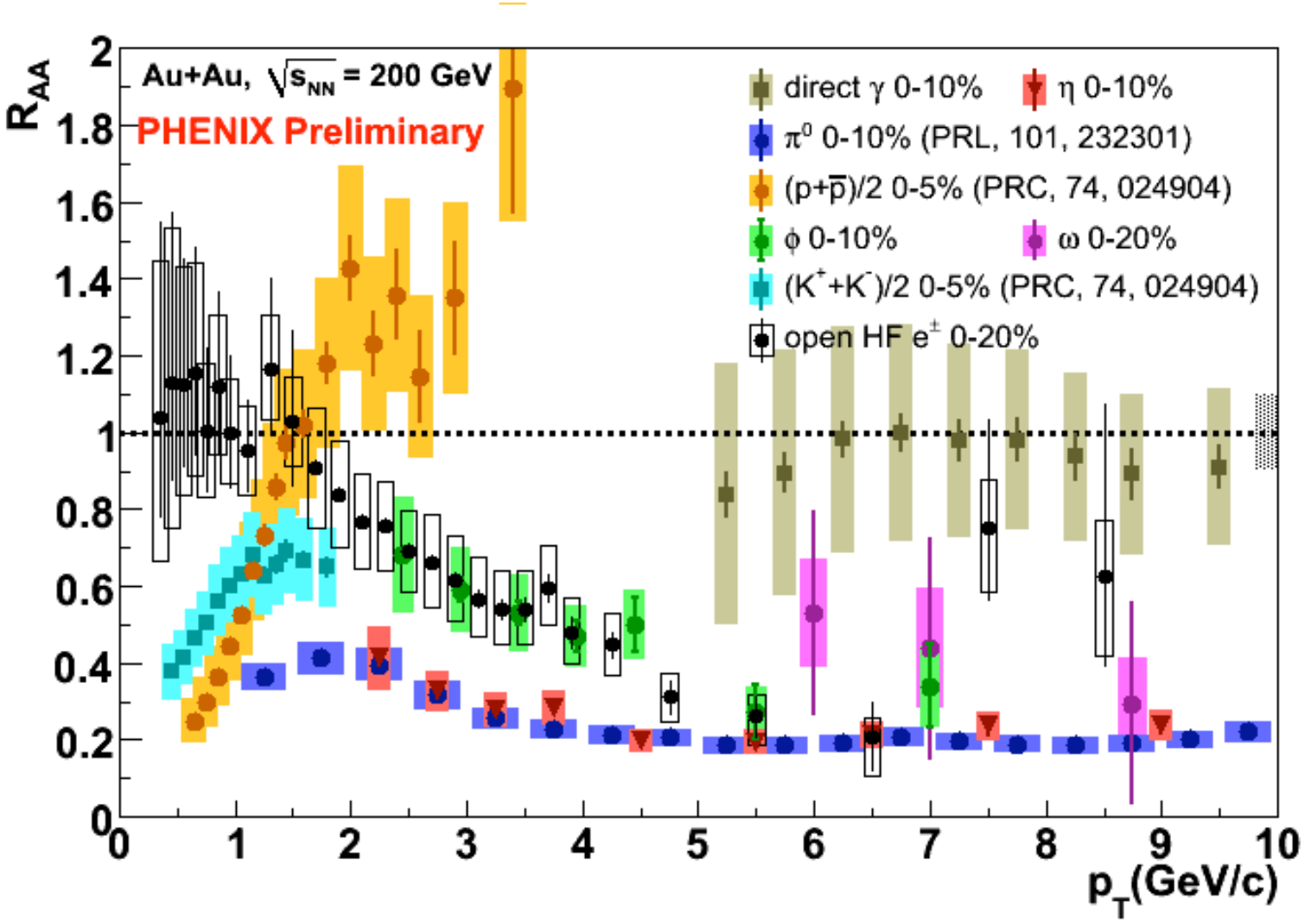
$$R_{AA} = \frac{\mathrm{Yield}_{AA} / \langle N_{\mathrm{binary}} \rangle_{AA}}{\mathrm{Yield}_{pp}}$$





Particle species dependence of suppression (R_{AA})

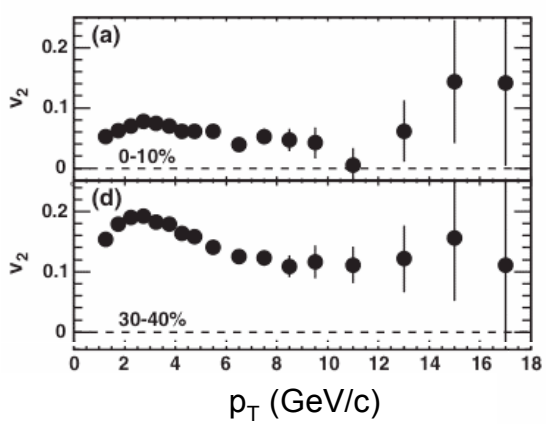
--- some quark flavor difference? ---

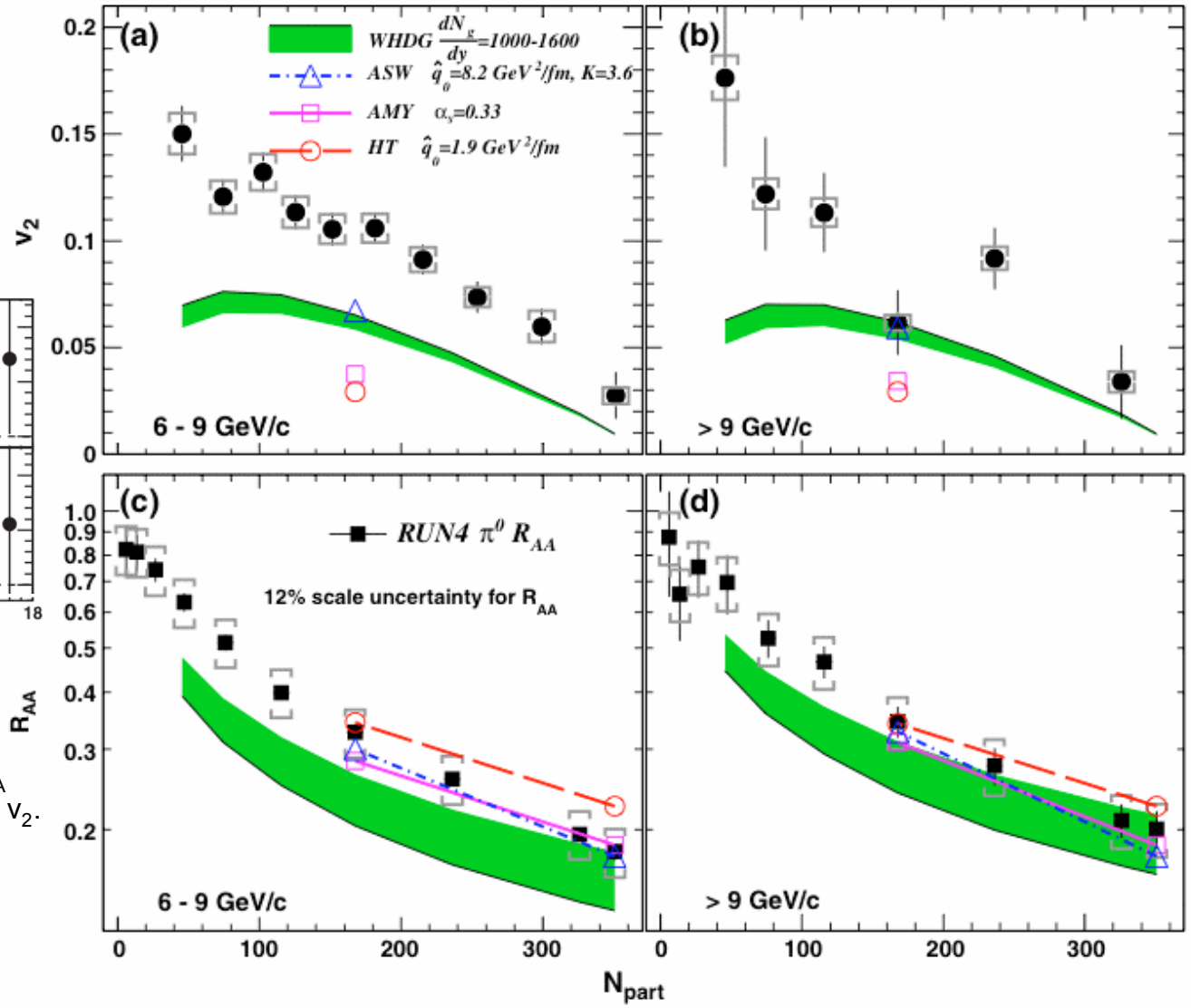


Understanding of high p_T π^0 v_2 and R_{AA} simultaneously

--- assumption of a common origin : energy loss ---

PRL105, 142301 (2010)



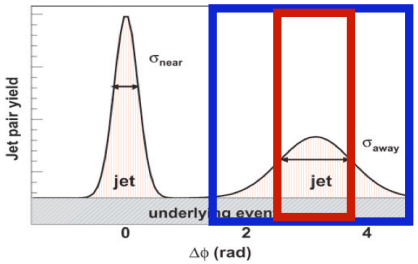


Models explaining measured R_{AA} do not usually explain measured v_2.

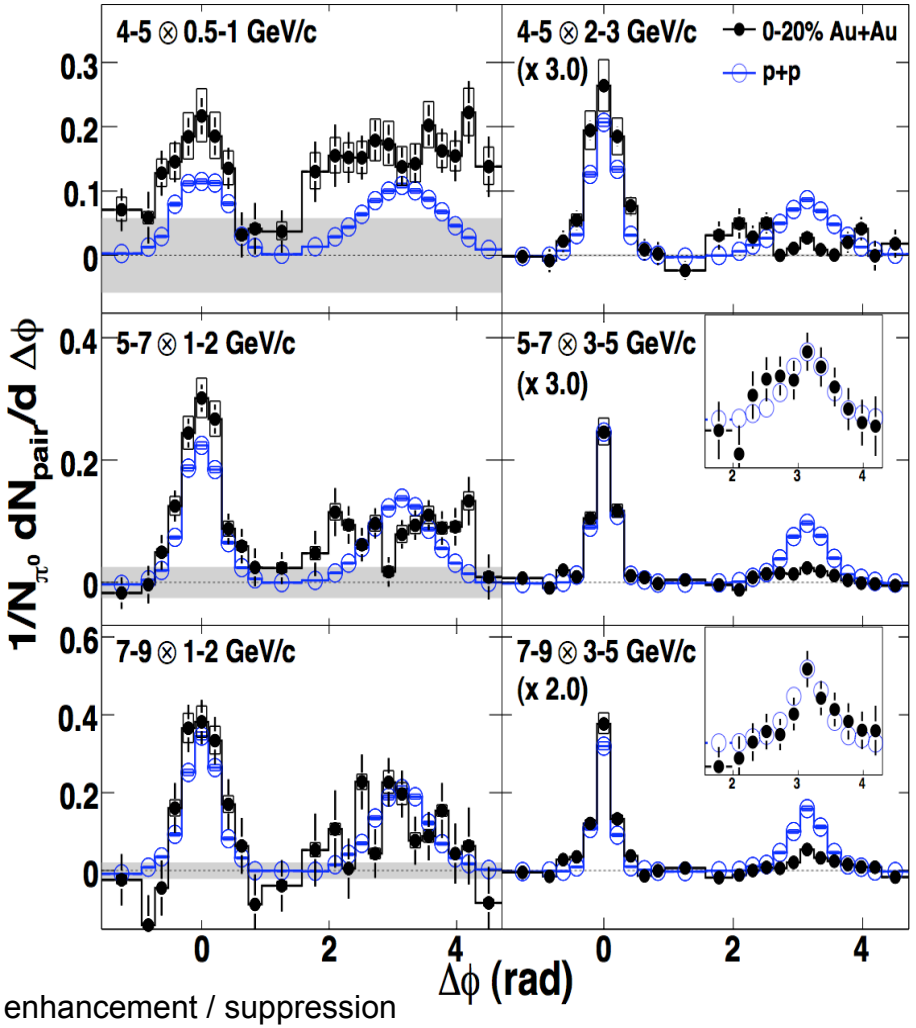
Jiangyong Jia, this afternoon

Two particle correlation (associate per trigger)

--- two different features at low/high p_T regions ---



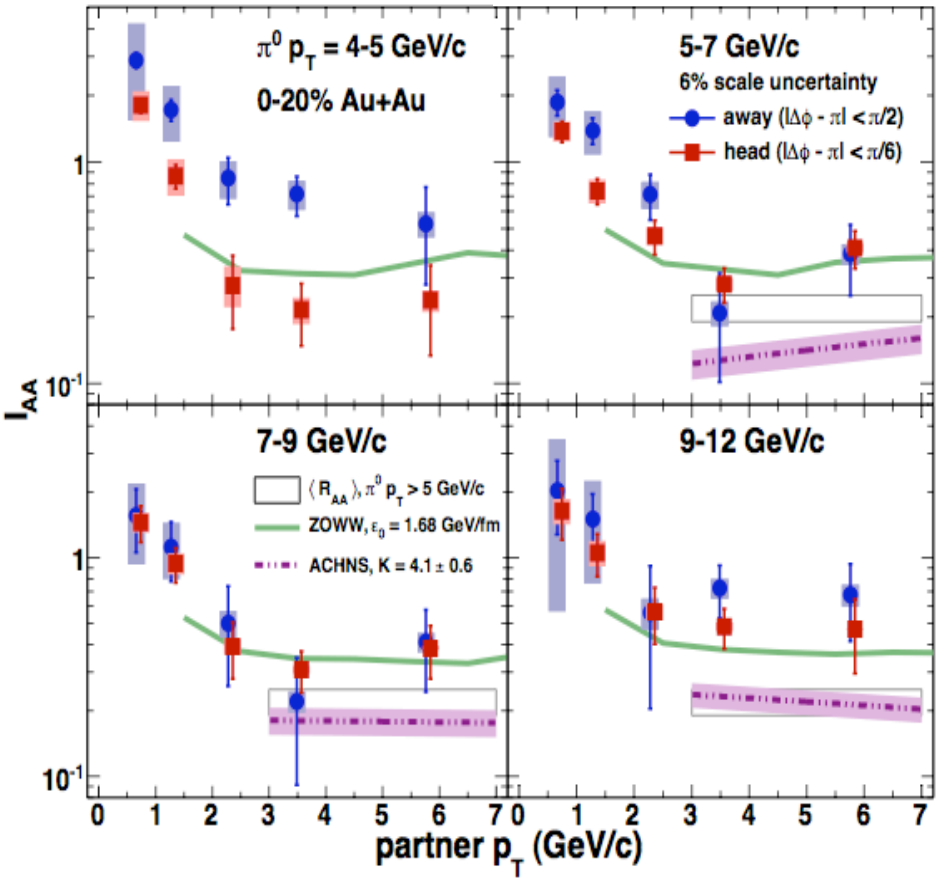
PRL104, 252301 (2010), arXiv:1002.1077



enhancement / suppression
broadening / un-modified shape

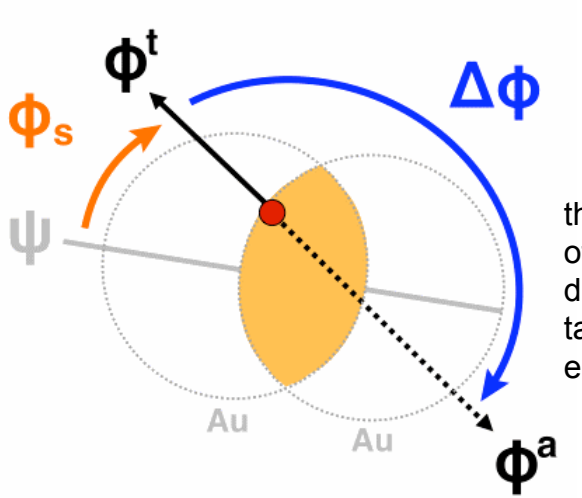
$$I_{AA} = \frac{(N^{ta}/N^{t})_{Au+Au}}{(N^{ta}/N^{t})_{p+p}}$$

I_{AA} is slightly higher than R_{AA}
less suppressed than singles
surface/tangential bias?

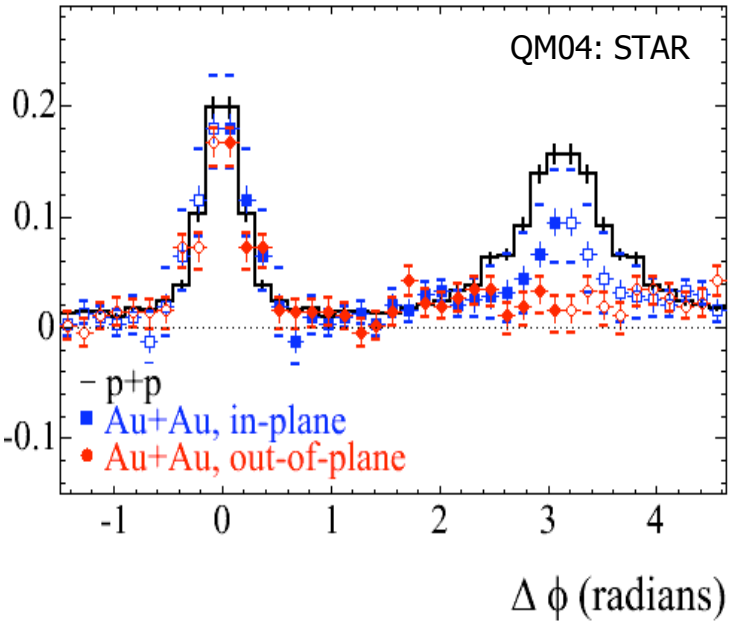


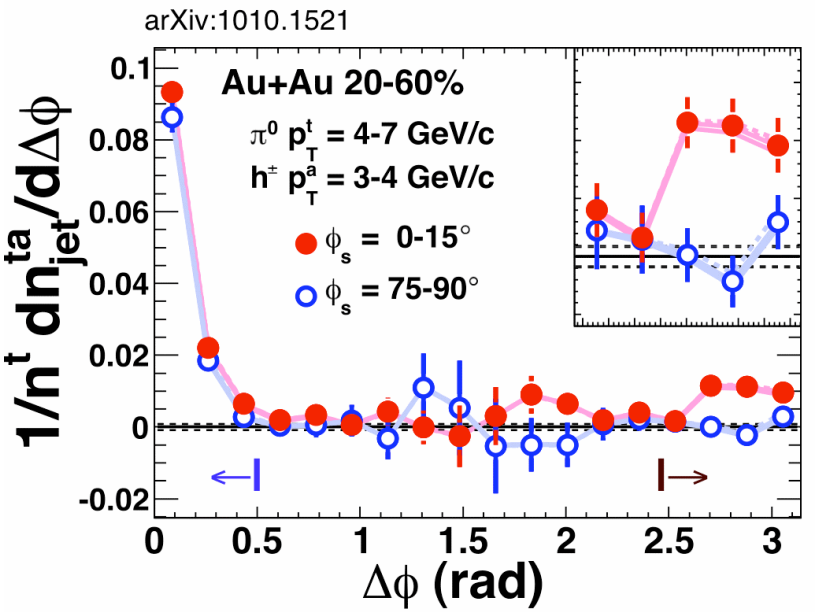
Reaction plane (path length) dependent energy loss

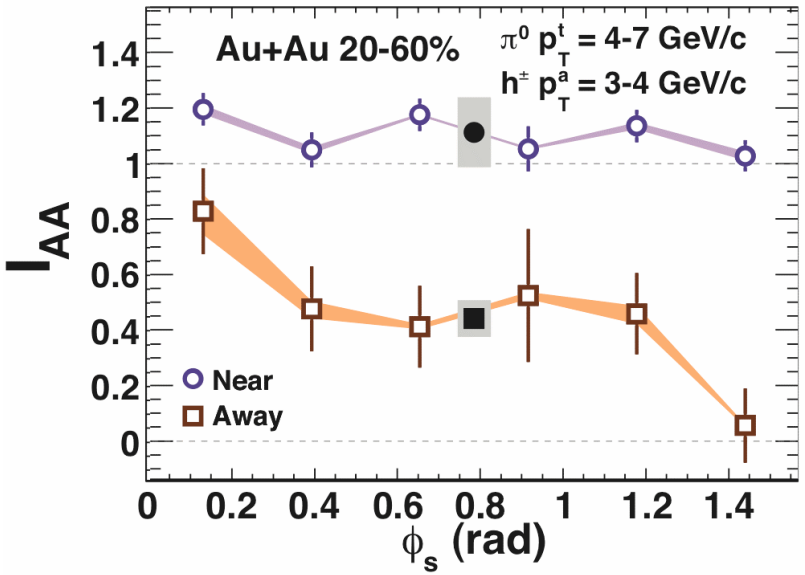
--- one of dominant sources of v_2 at high p_T ---



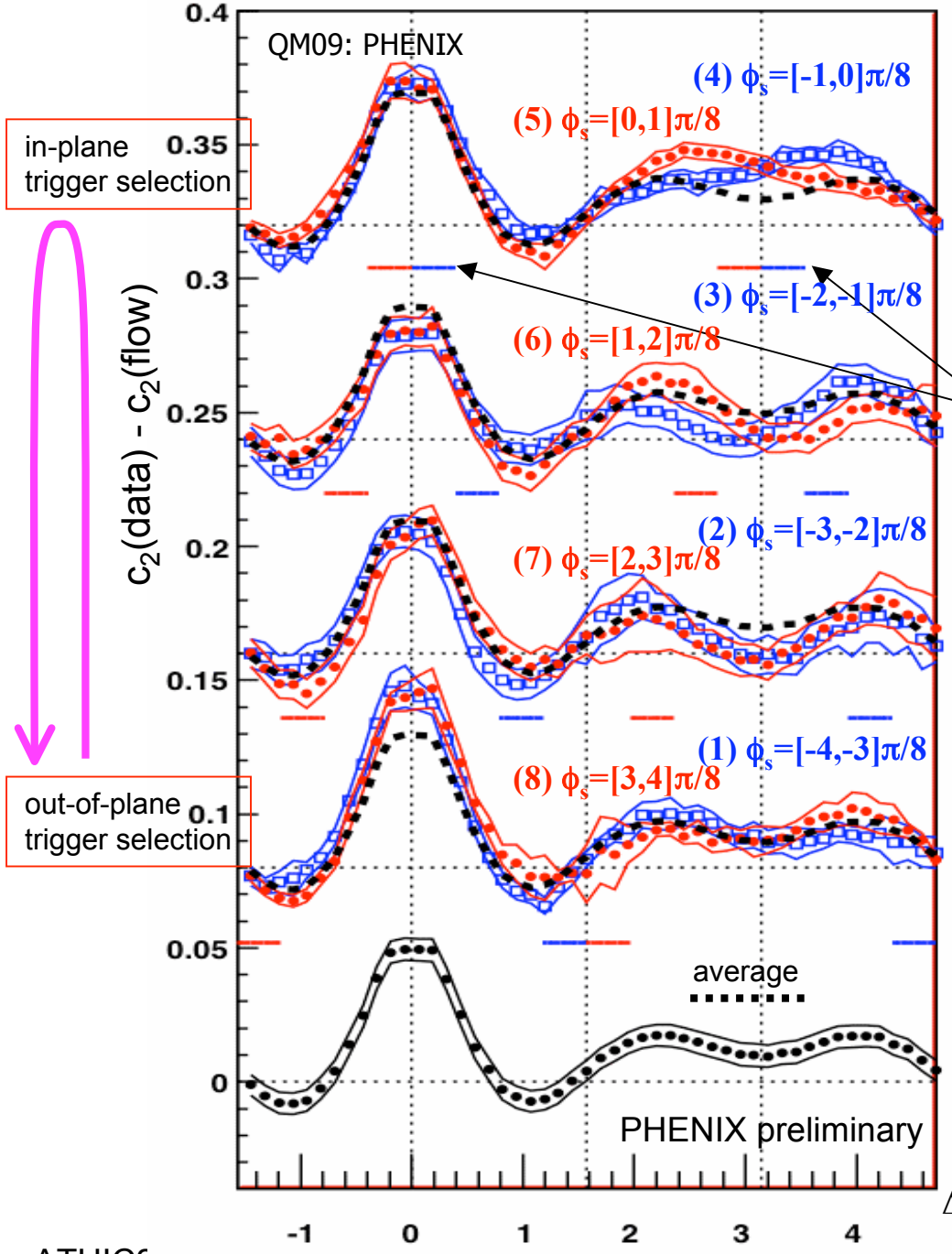
thickness dependence of penetration is more dominant than tangential surface emission.





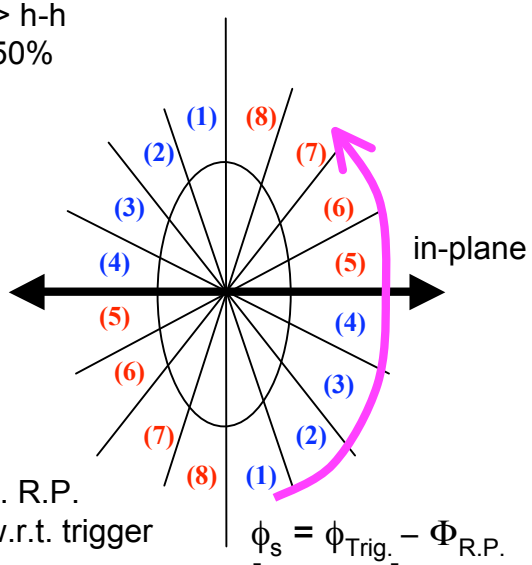


Geometrical dependence or effect from expansion?



200GeV Au+Au -> h-h
mid-central : 20-50%
p_T^{Trig}=2~4GeV/c
p_T^{Asso}=1~2GeV/c

in-plane associate regions

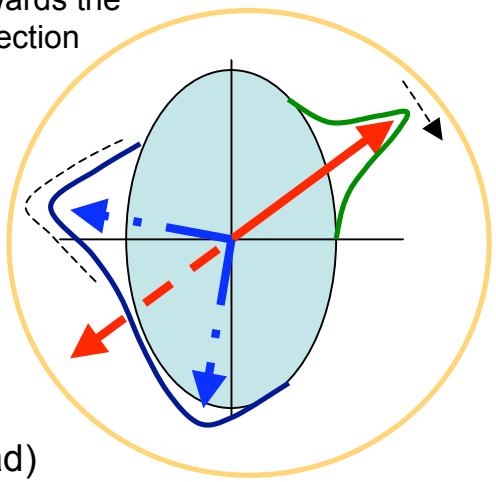


relatively lower p_T
left/right trigger w.r.t. R.P.
left/right associate w.r.t. trigger

$\phi_s = \phi_{Trig.} - \Phi_{R.P.}$
$[-\pi/2,\pi/2]$

strong preference of associate particle emission towards the in-plane (thinner) direction

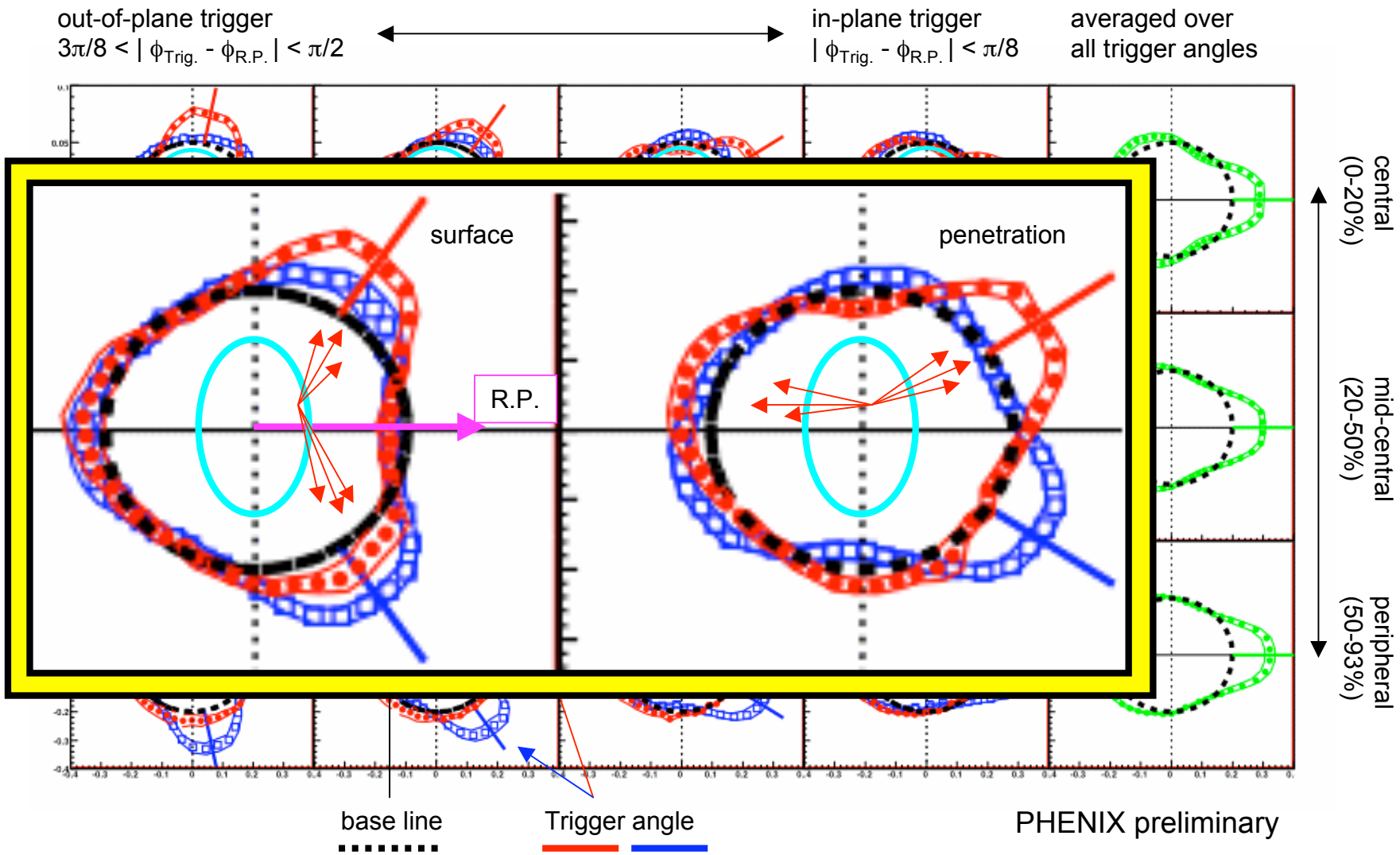
not significant but some reversed trend at out-of-plane



the same data in polar plots (R.P. is x axis)

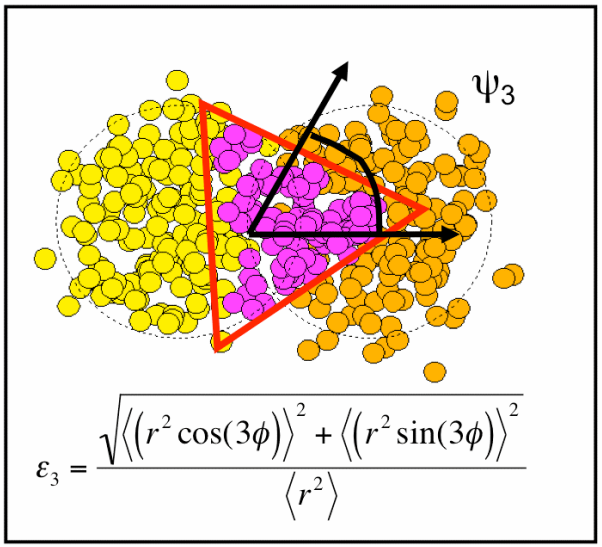
--- associate distribution for a given trigger direction ---

200GeV Au+Au -> h-h
(p_T^{Trig}=2~4GeV/c, p_T^{Asso}=1~2GeV/c)

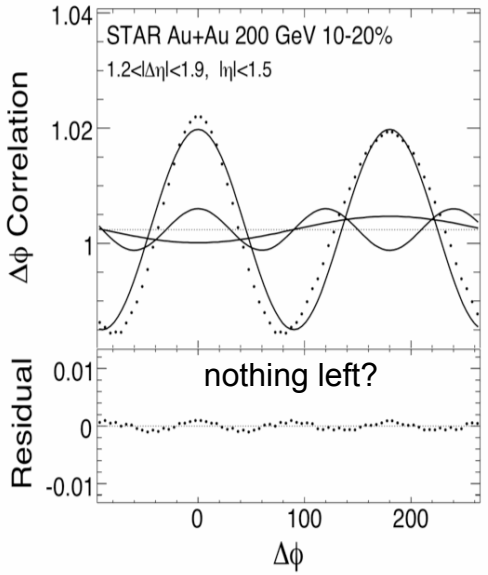


Burak Alver, GR, arXiv:1003.0194 (PRC 2010)

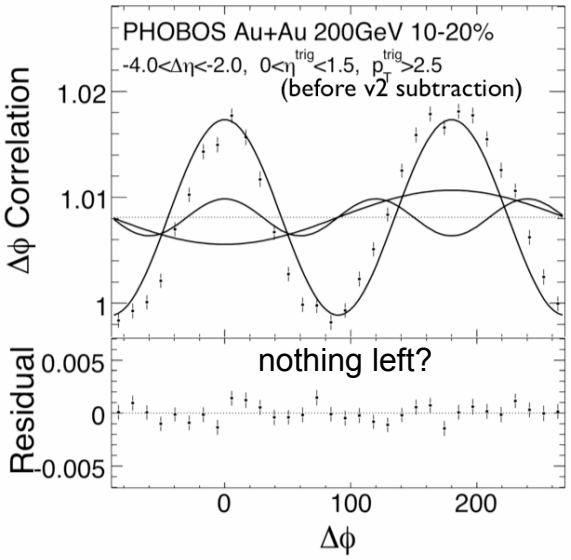
Participant Triangularity



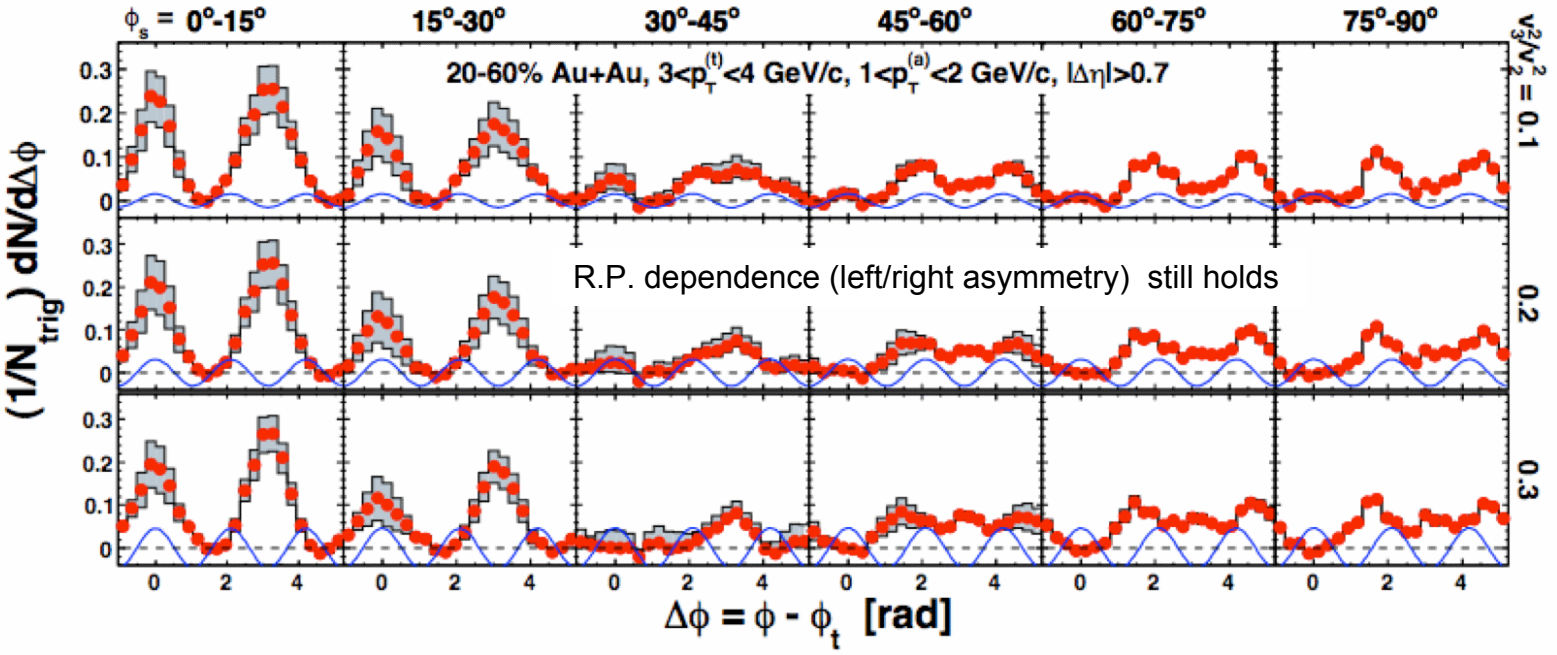
arXiv:0806.0513



PRL 104, 06230 (2010)

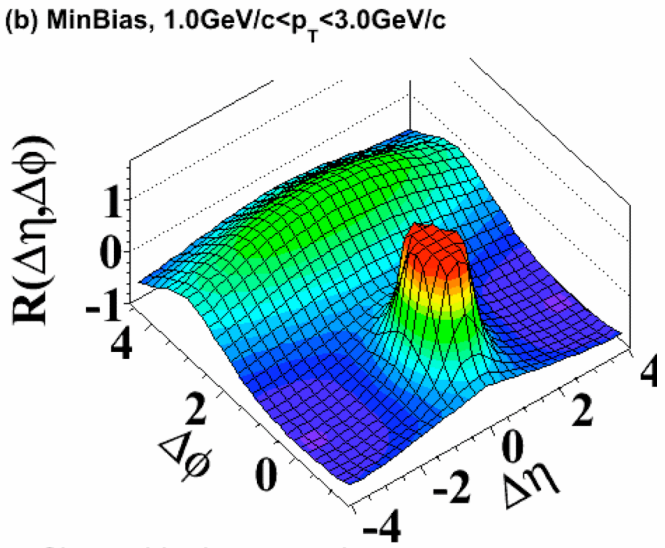


Hard Probe 2010, G. Roland



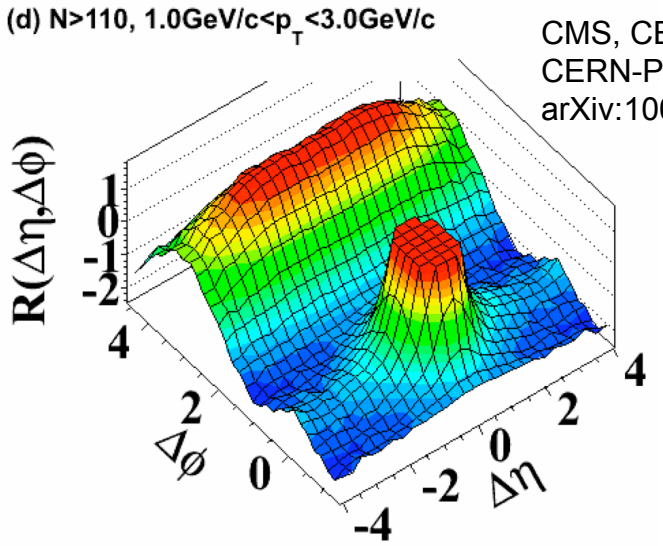
Ridge is seen at high multiplicity p+p(LHC)

MinBias



Charged hadron correlations
in CMS tracker ($|\eta| < 2.4$)

High multiplicity (N>110)

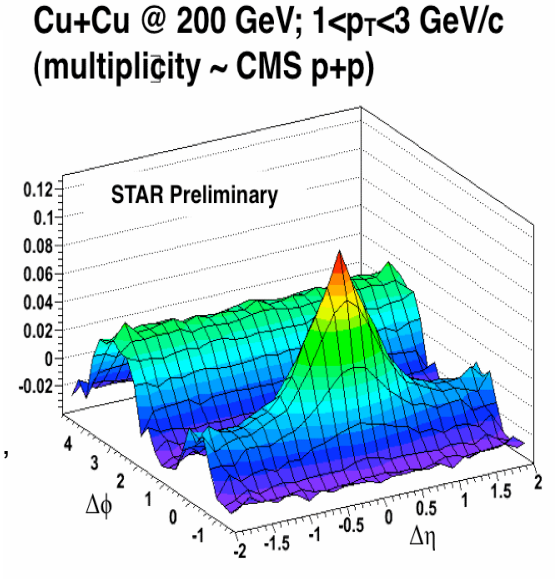


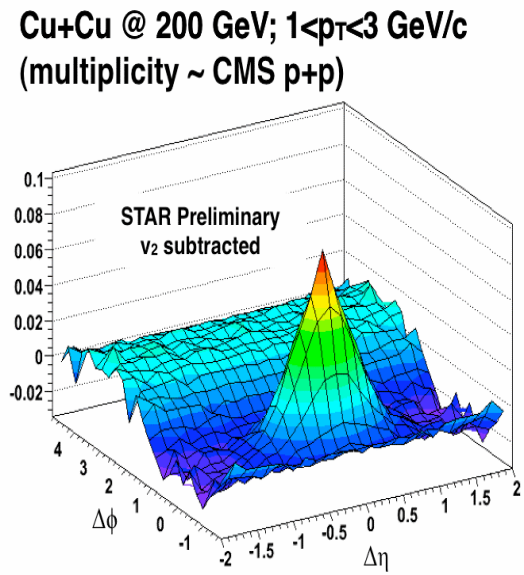
CMS, CERN Seminar, Sept. 21, 2010
CERN-PH-EP/2010-031
arXiv:1009.4122v1

long range correlation is also seen
at ISR, SppS, Fermi lab.
consistent with CGC picture?
what if there is v2 in p+p?

seen in Au+Au at RHIC, but not in Cu+Cu?
remember a large v_2 in Cu+Cu at RHIC
$\varepsilon_{STD} \sim \varepsilon_{part}$ (Au+Au)
$\varepsilon_{STD} << \varepsilon_{part}$ (Cu+Cu)

Hard Probe 2010,
J. Putschke



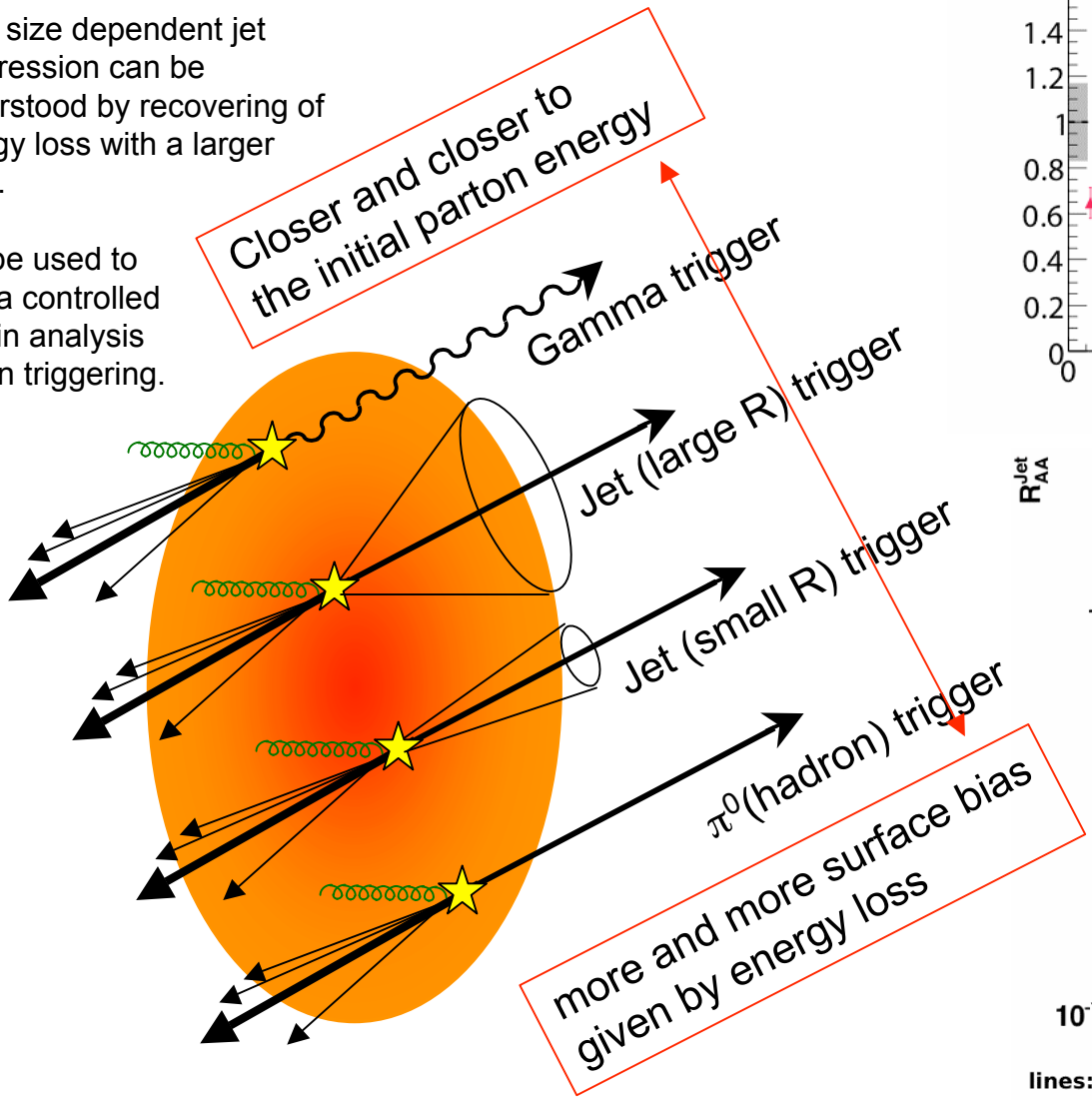


γ,Jet,π^0 - hadron correlation

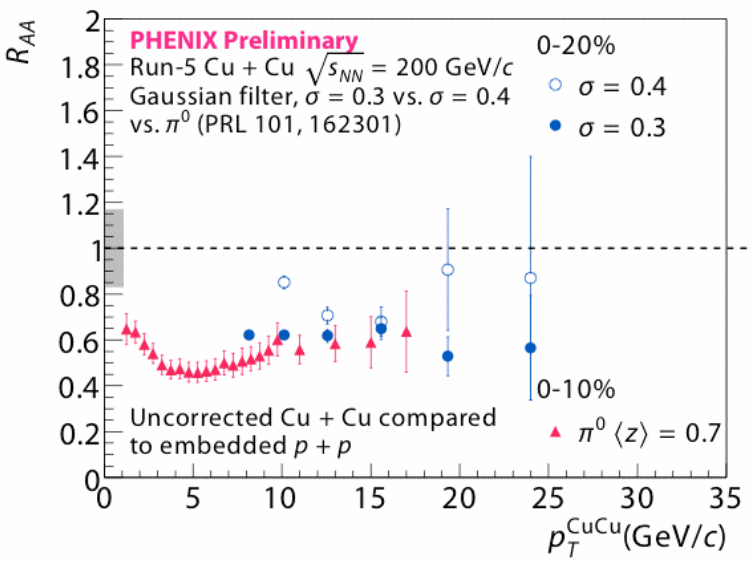
--- Comparisons are the most important! ---

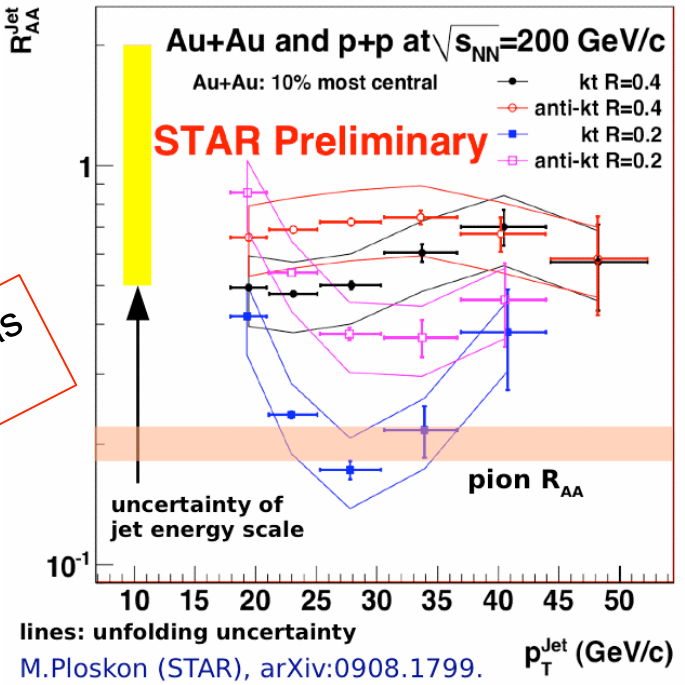
cone size dependent jet suppression can be understood by recovering of energy loss with a larger cone.

can be used to give a controlled bias in analysis and in triggering.

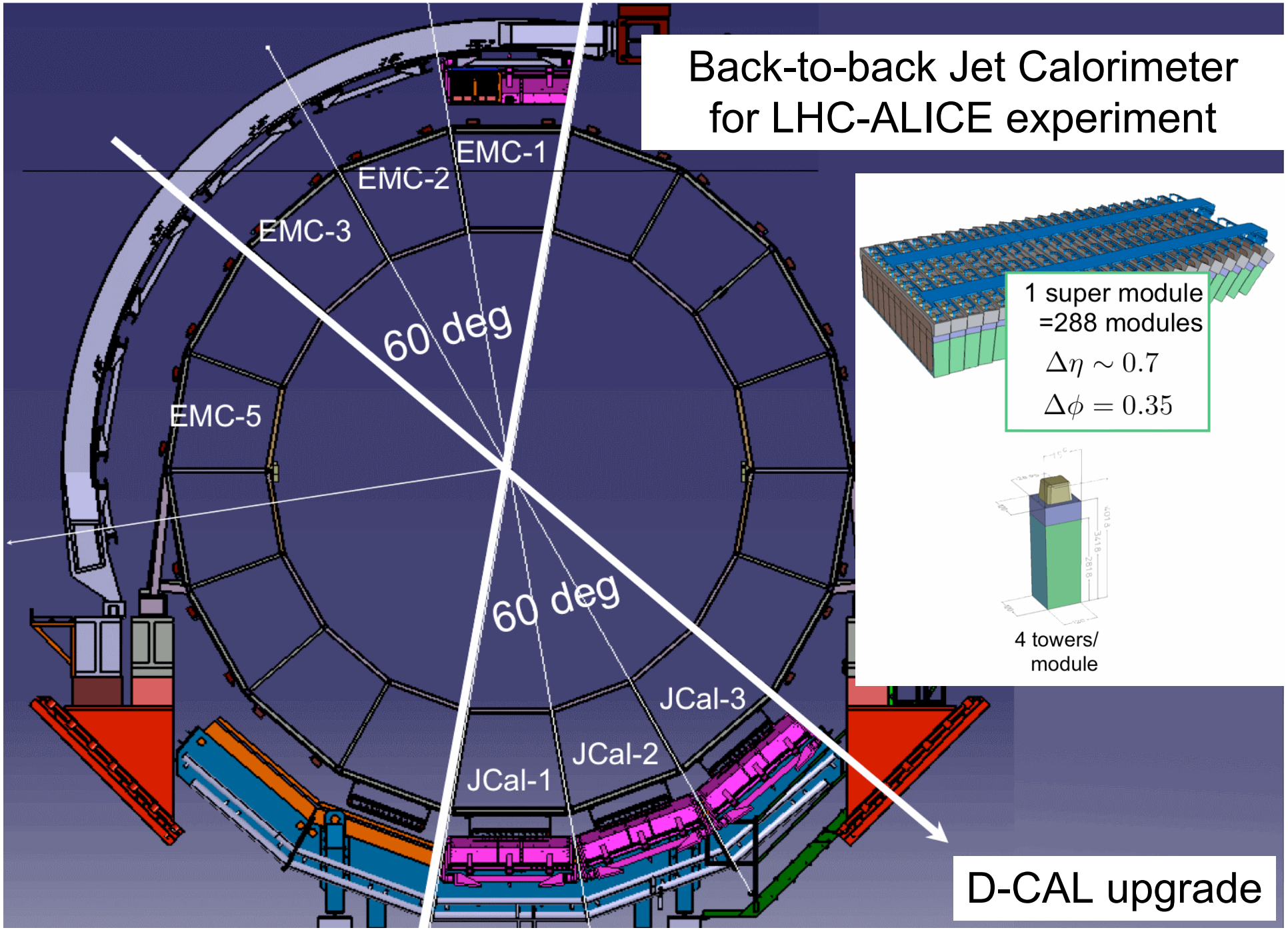


Hard Probe 2010, Yue Shi Lai





Back-to-back Jet Calorimeter for LHC-ALICE experiment



1 super module
=288 modules

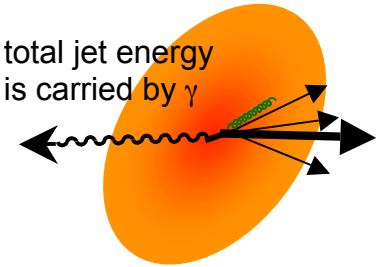
$\Delta\eta \sim 0.7$

$\Delta\phi = 0.35$

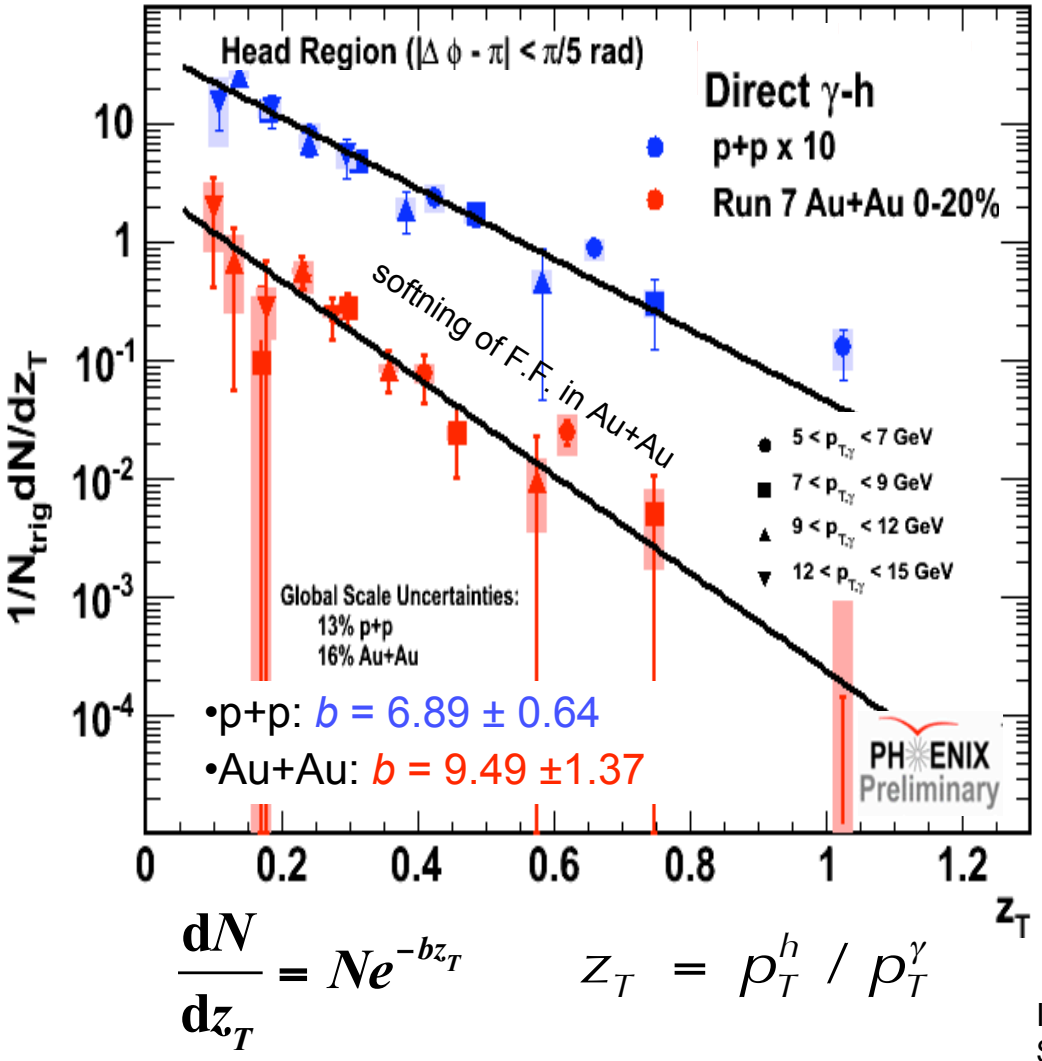
4 towers/
module

D-CAL upgrade

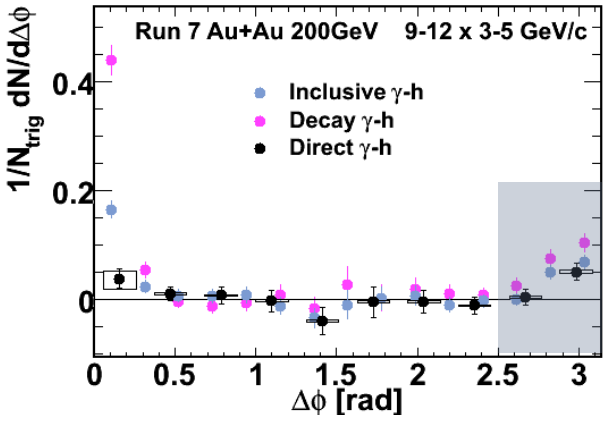
γ-Triggered Away-side Correlations: Jet Fragmentation Function in p+p and Au+Au

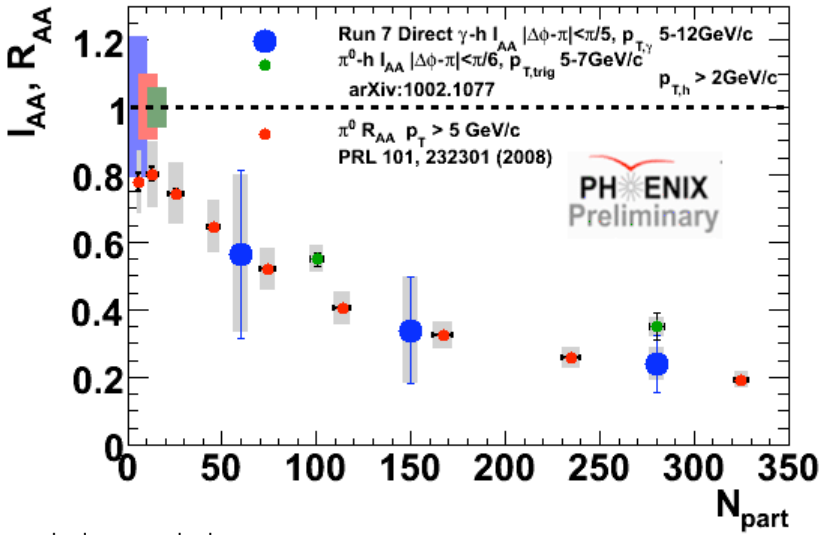


QM09 PHENIX



$$\frac{dN}{dz_T} = Ne^{-bz_T} \qquad z_T = p_T^h / p_T^\gamma$$

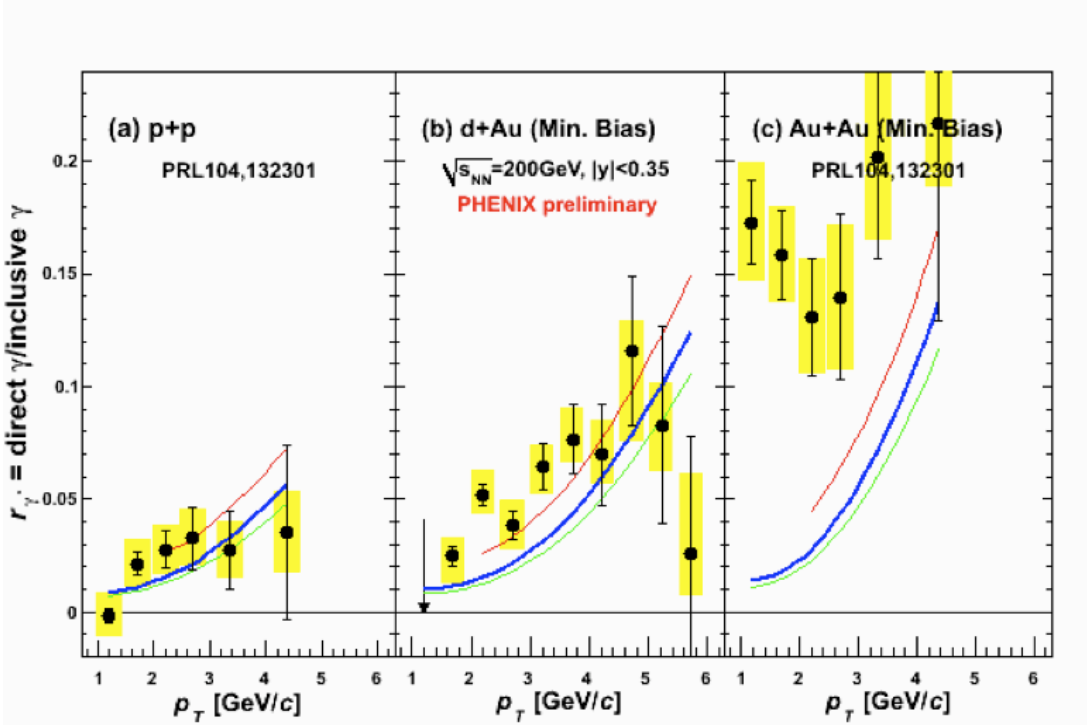




$I_{AA}^{\gamma\text{-had}} \sim R_{AA}^{\text{had}}$ is naively expected and confirmed.
Slightly higher $I_{AA}^{\pi 0\text{-had}}$ from surface/tangential bias.

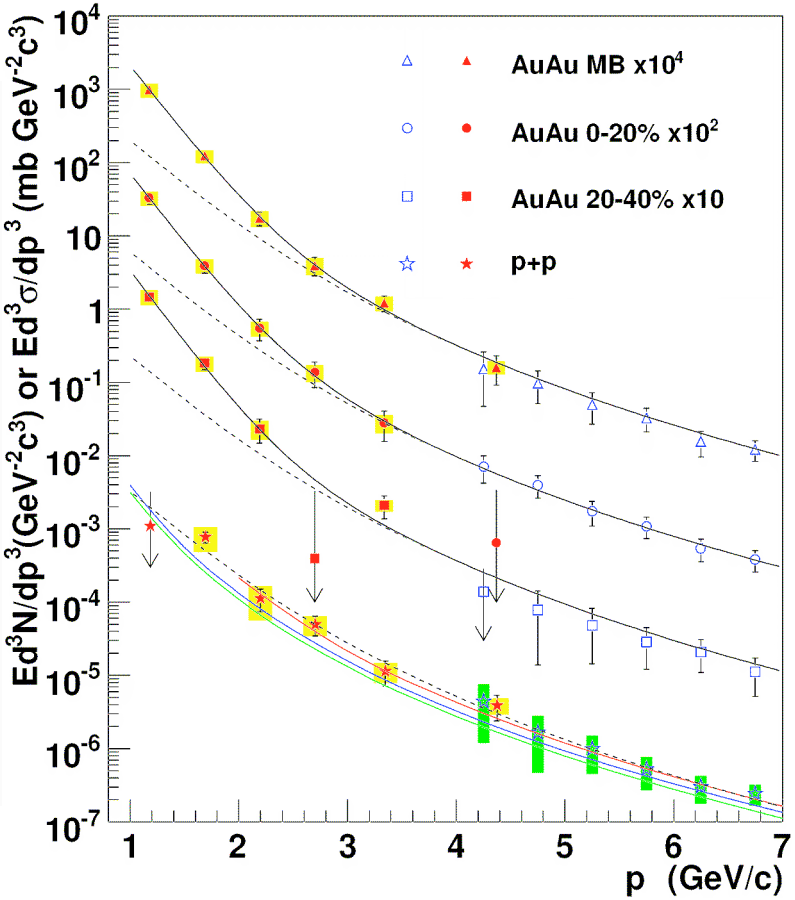
Direct photon at low p_T

--- path to the initial temperature ---
--- thermal photon radiation from QGP ---
--- v_2 of these photons for further tests ---



prompt photon production from initial binary collisions can explain the measured direct photon spectra at p+p and d+Au for entire p_T region and also at Au+Au for high p_T region, however not at mid-central to central Au+Au collisions especially for lower p_T region below 3GeV/c

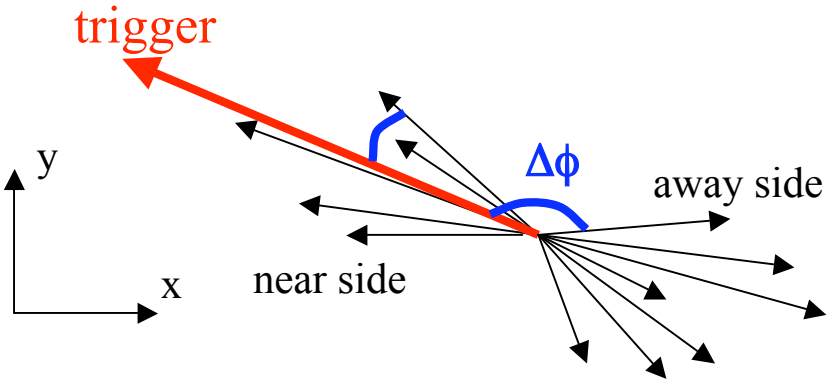
PRL104, 132301
arXiv:0804.4168v1

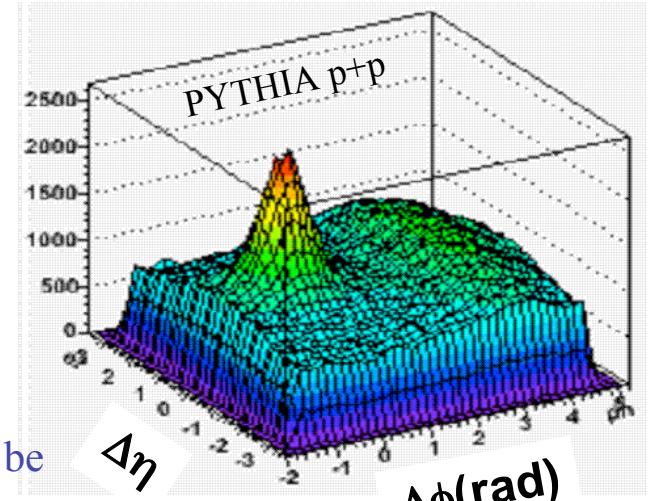


Slope parameter (0-20%):
T = (221 ± 23 ± 18) MeV
Various Hydro models:
$T_{Initial}$ = 300~600 MeV

Summary

* Transverse momentum distribution --- radial flow
* Elliptic and higher order event anisotropy --- elliptic flow
* Charge asymmetry --- possible parity violation
* High p_T/jet suppression R_{AA} and v_2 --- energy loss
* Jet modification via correlation --- feed back to bulk property
* Ridge, Mach-cone like structure vs triangular anisotropy
* Controlled biases with direct photon, jet and single hadron
* Initial temperature with thermal photon (and lepton pairs…)





(1) away side of a back-to-back(b-t-b) jet is wider in η than in ϕ

(2) If there are two parallel b-t-b jets, away side of one b-t-b jet can be near side of the another b-t-b jet.

(3) Suppression as well as modification of b-t-b jet would depend on relative angle w.r.t. almond geometry, we know this from v_2 measurement and believe this is the major source of v_2 at high p_T .

(4) Therefore, there should be inter b-t-b jets correlation give by the geometry from (3), this could make near side ridge like effect, especially if the effect (3) has shaper dependence than v_2(=cos2x).

(5) We always measure inclusive v_2, which includes the effect (3). Therefore any modification which could generates the elliptic anisotropy would be included in the measured v_2 .

(6) We subtract BG contribution with this v_2 from (5) by maximizing BG contribution assuming zero jet yield at minimum at any dϕ.

(7) If near and away side jets overlap each other, this subtraction underestimates the jet yield and can change the extracted jet shape.

(8) If you extract angular dependence of jet w.r.t. R.P., the results will easily be affected by the choice of v_2 from (5).