LHC–ALICE実験におけるソフトな指針で見るQGP
QGP through soft probes at LHC-ALICE

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A Large Ion Collider Experiment

European Organisation for Nuclear Research

筑波大学
University of Tsukuba

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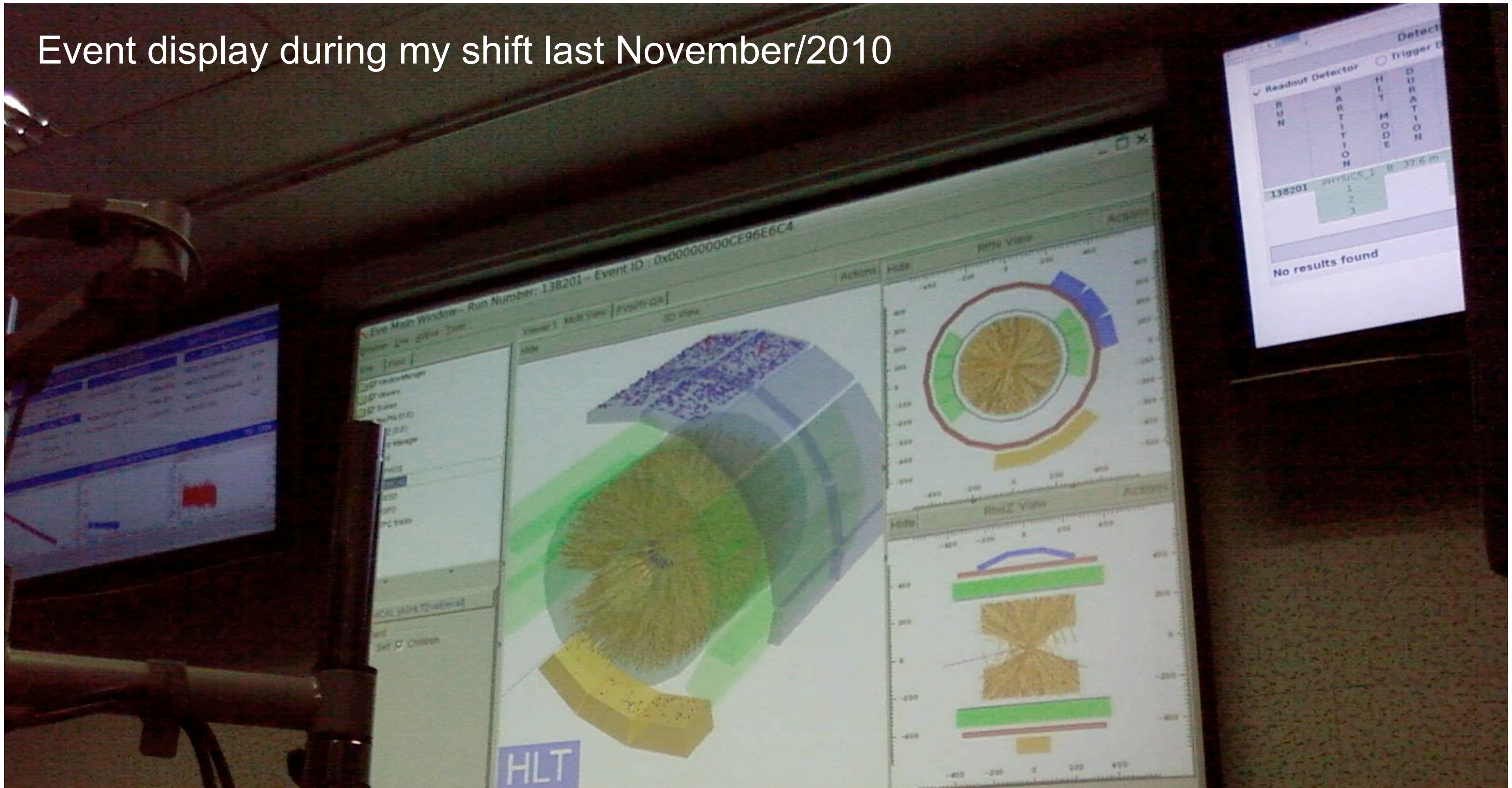
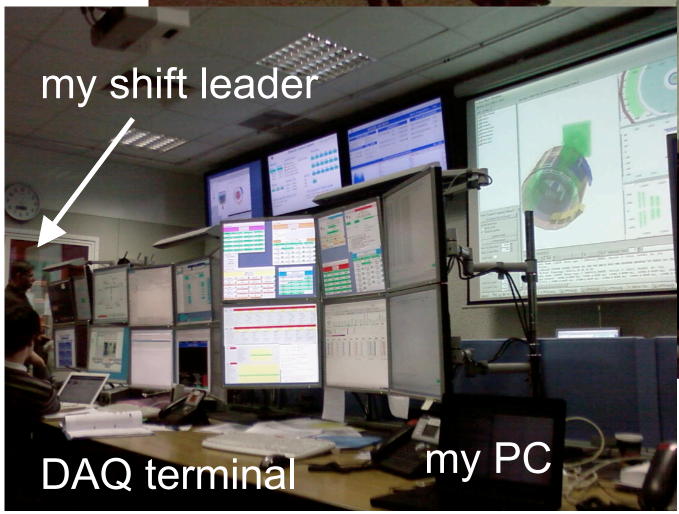
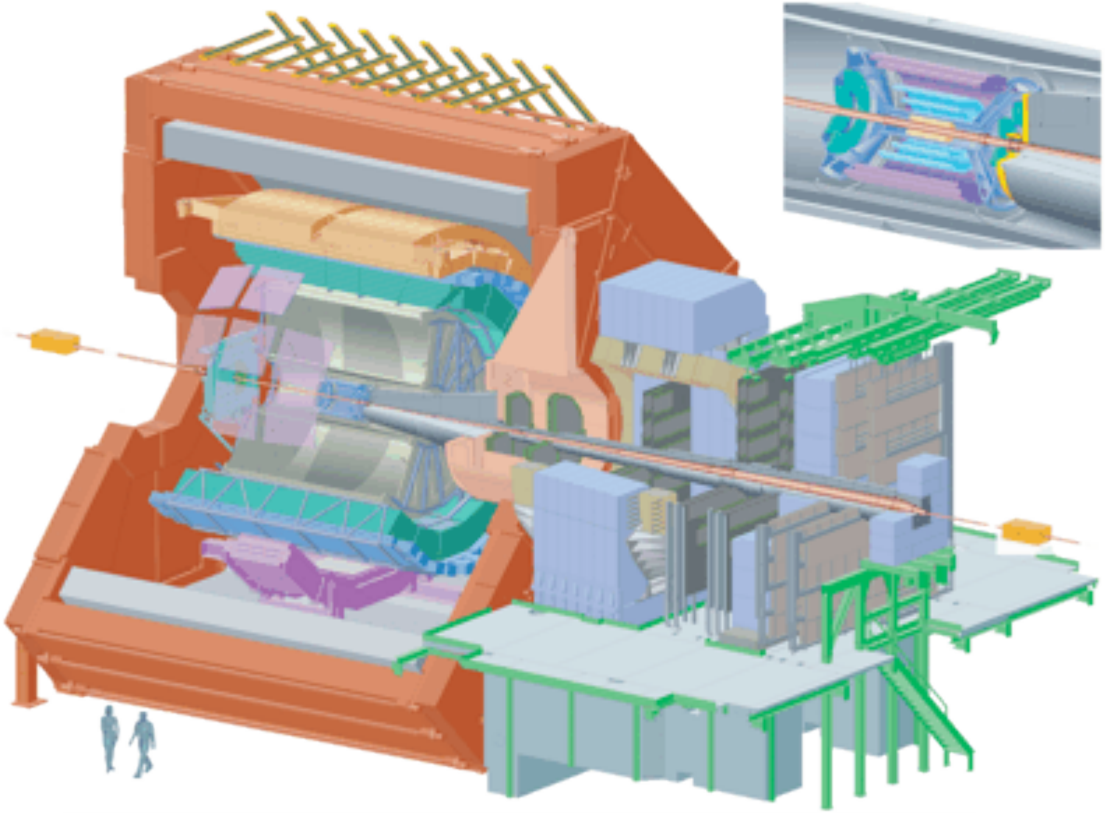
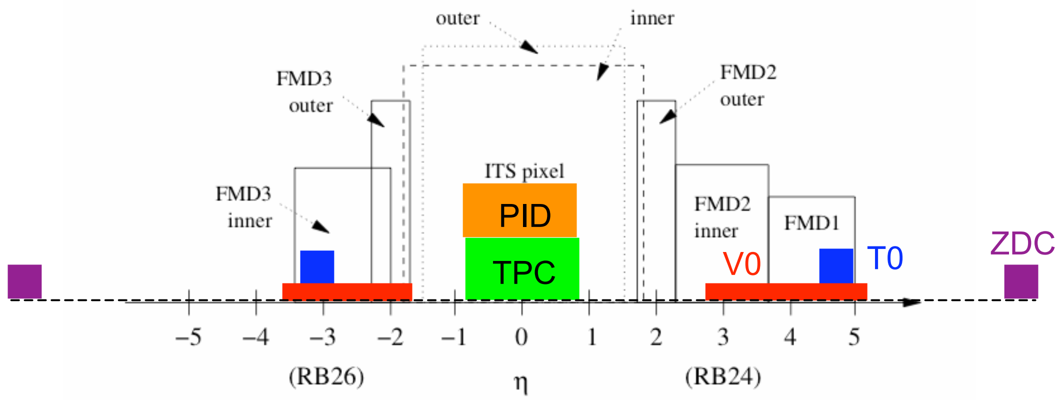
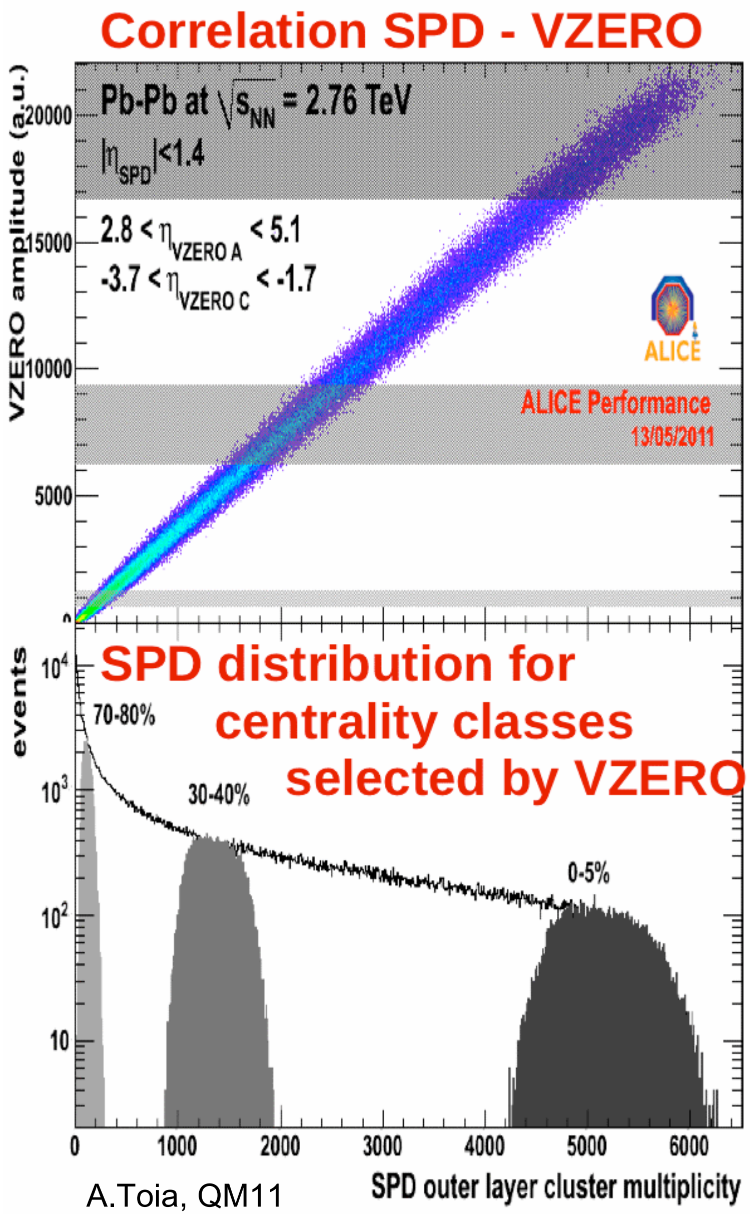

Event display during my shift last November/2010
HLT
ALICE


my shift leader
DAQ terminal
my PC


It was a nice winter day at CERN.

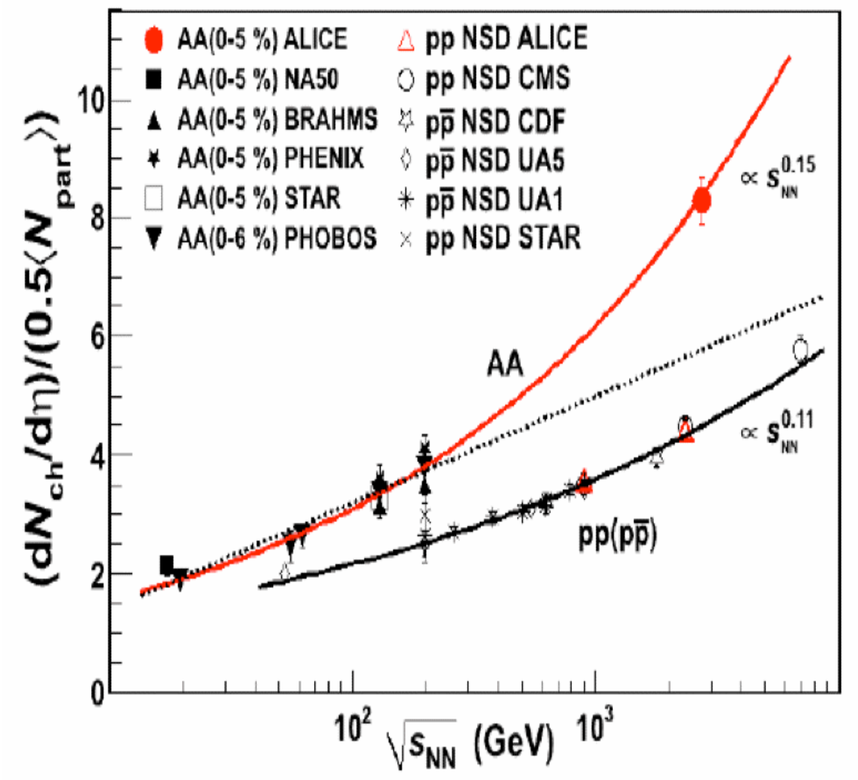


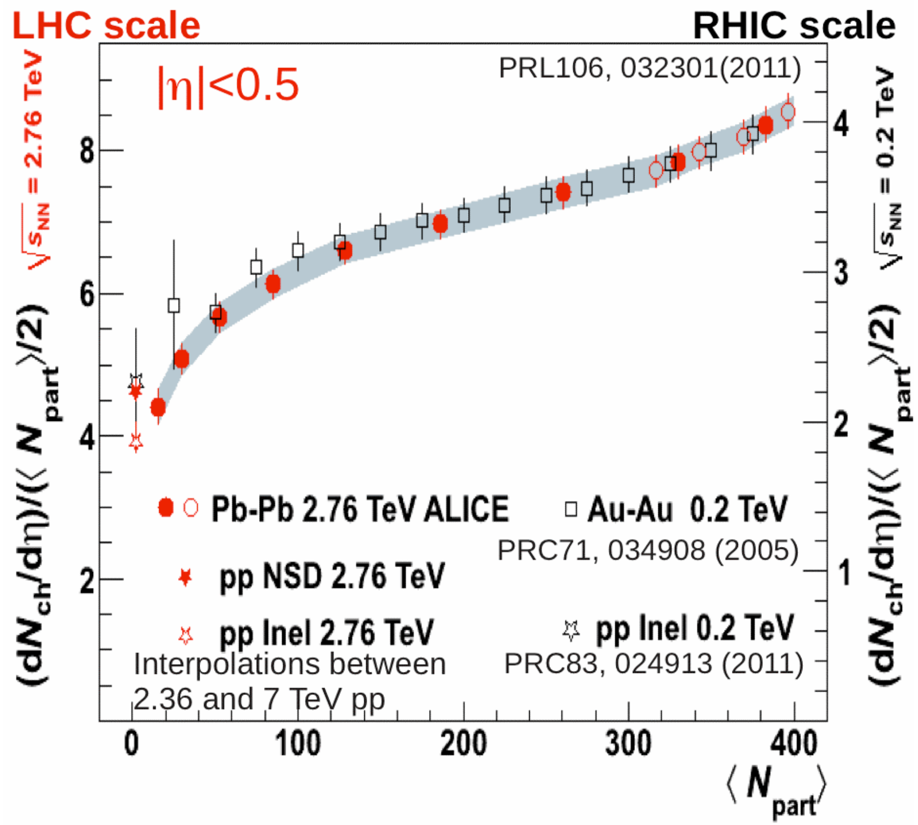

outer
inner
FMD3
outer
FMD2
outer
ITS pixel
PID
TPC
FMD3
inner
FMD2
inner
FMD1
V0
T0
ZDC
−5 −4 −3 −2 −1 0 1 2 3 4 5
(RB26)
η
(RB24)


Correlation SPD - VZERO
Pb-Pb at $\sqrt{s_{NN}}$ = 2.76 TeV
$|\eta_{SPD}|$<1.4
2.8 < $\eta_{VZERO\ A}$ < 5.1
-3.7 < $\eta_{VZERO\ C}$ < -1.7
ALICE
ALICE Performance
13/05/2011
VZERO amplitude (a.u.)
20000
15000
10000
5000
SPD distribution for
centrality classes
selected by VZERO
events
70-80%
30-40%
0-5%
10^4
10^3
10^2
10
0 1000 2000 3000 4000 5000 6000
A.Toia, QM11
SPD outer layer cluster multiplicity

Multiplicity in A+A at the highest possible energy

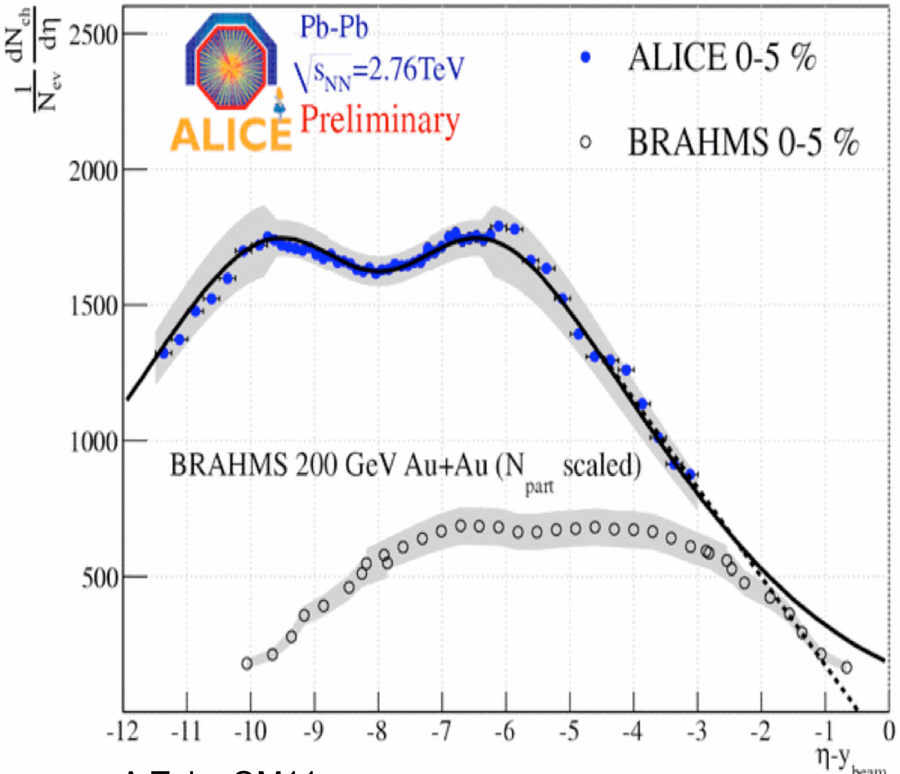
PRL105, 252301 (2010)





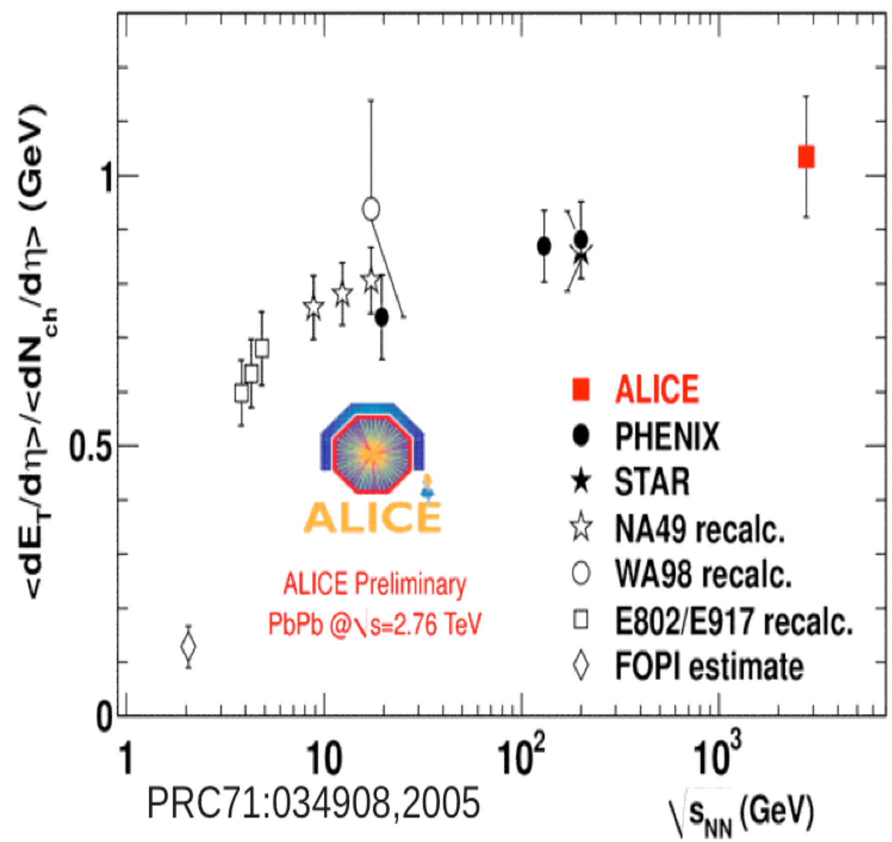
factor of ~2 increase with similar N_{part} dependence

dN_{ch}/dh distribution and E_T/N_{ch}



A.Toia, QM11

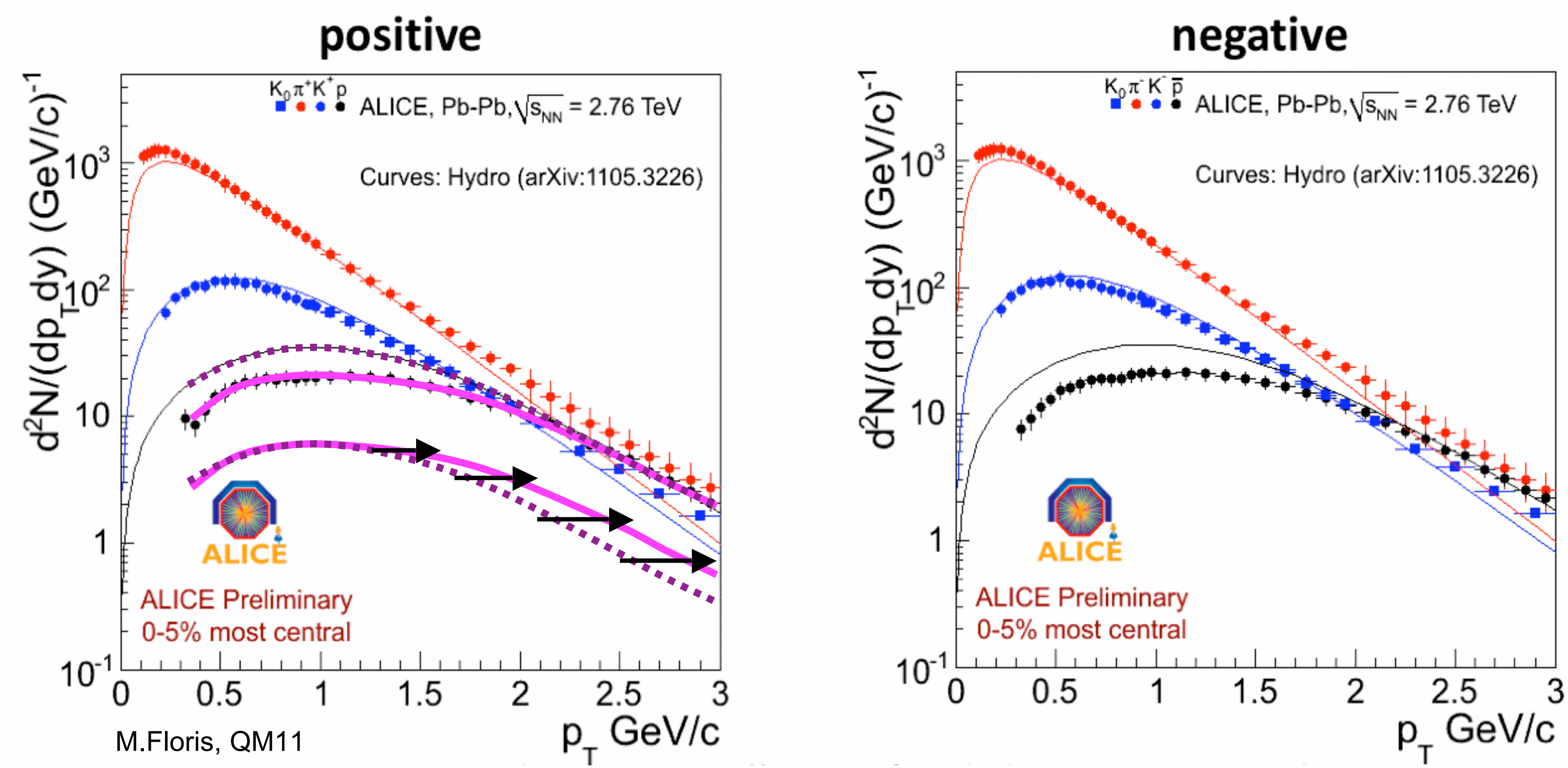
longitudinal scaling holds



PRC71:034908,2005

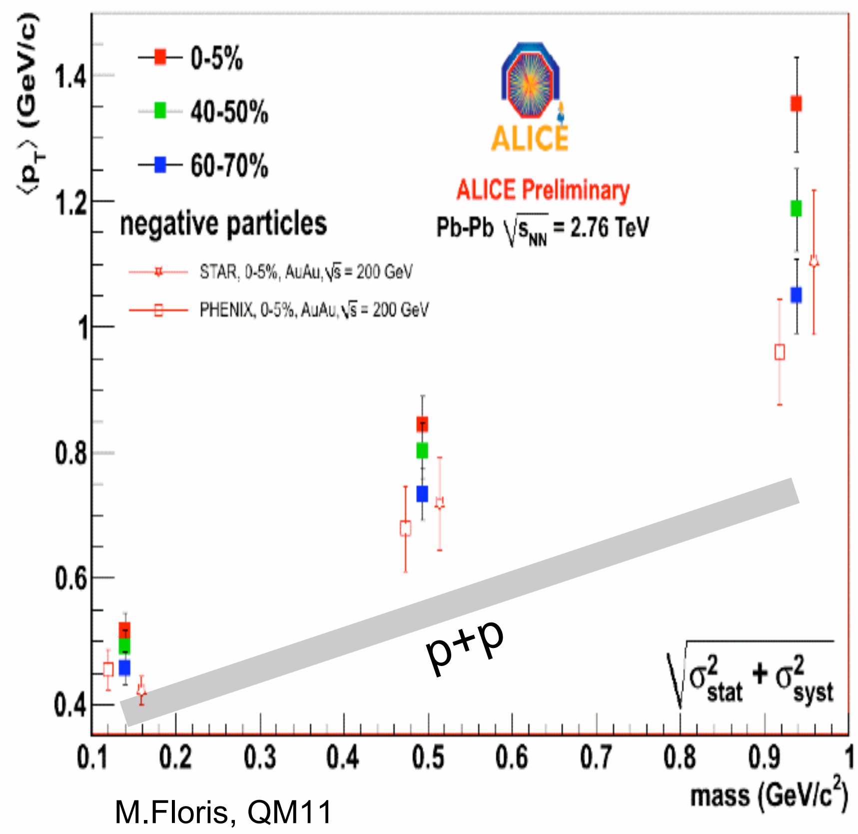
increases with sqrt(s_{NN})

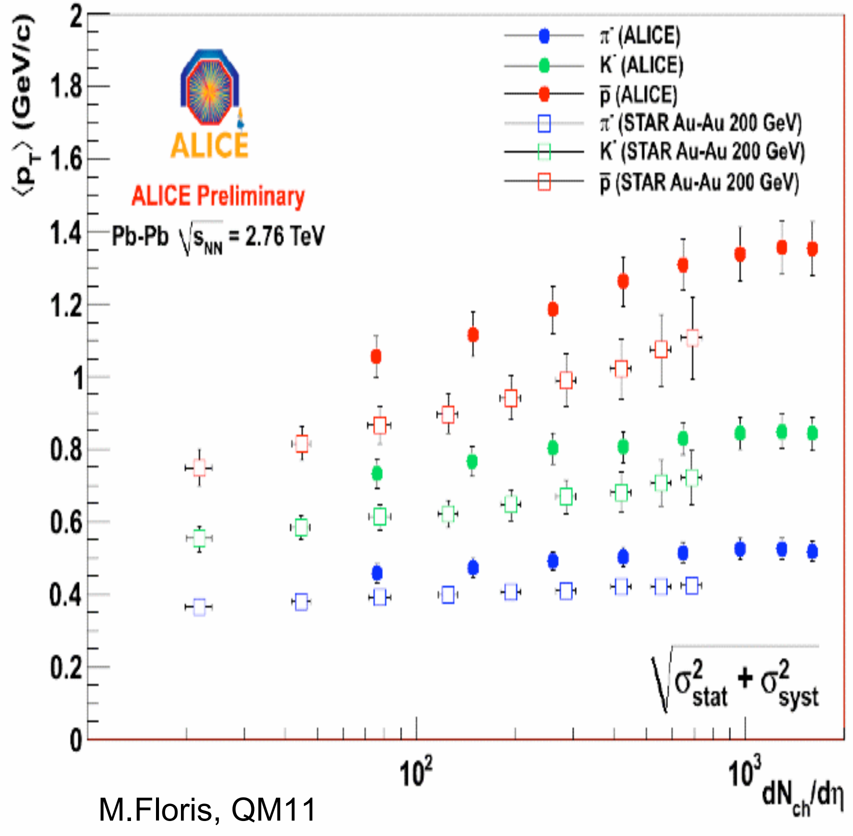
Particle identified p_T distribution



larger p_T shift for heavier particles
larger radial flow than in this hydro model

Particle mass and N_{part} dependence of $<p_T>$

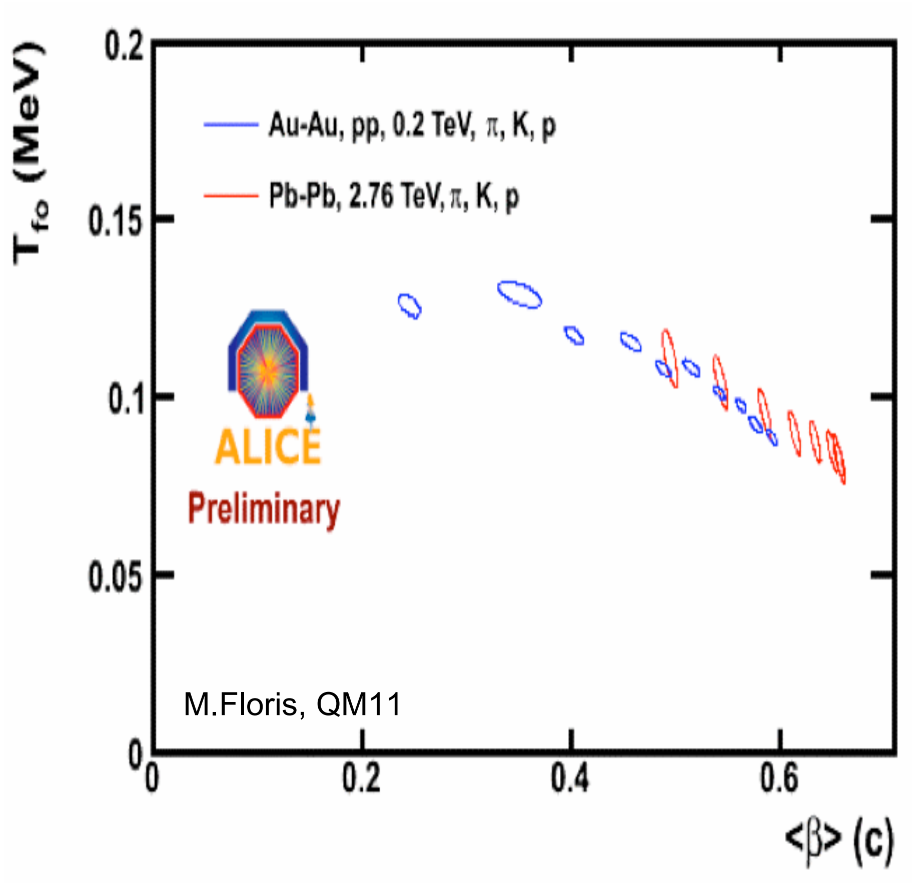




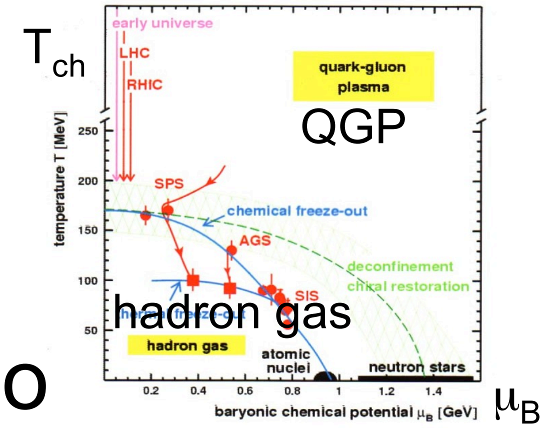
increased radial flow than at RHIC
and as a function of centrality

Blast wave fitting

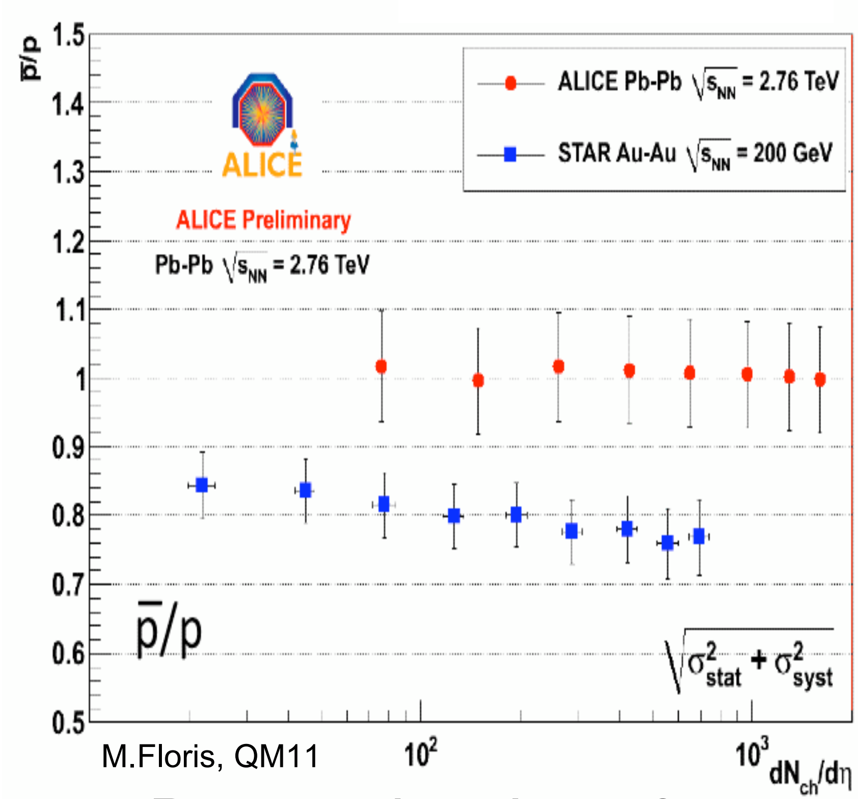
(hydro-dynamical model based fitting function)



larger expansion at LHC with similar freeze-out T_{fo}

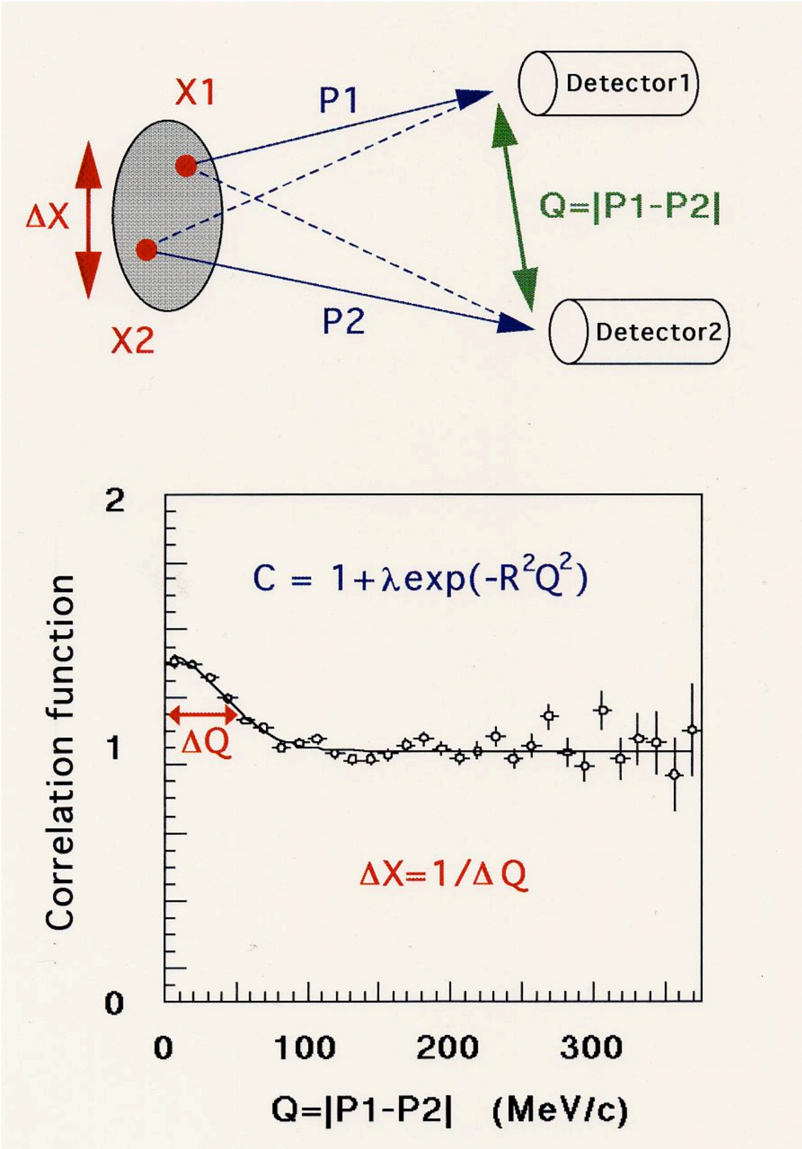


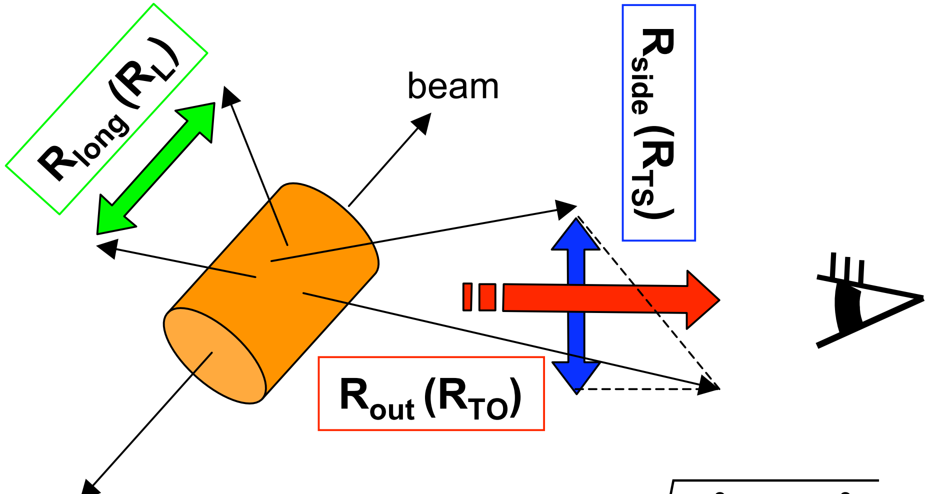
$\bar{p}$ / p ratio



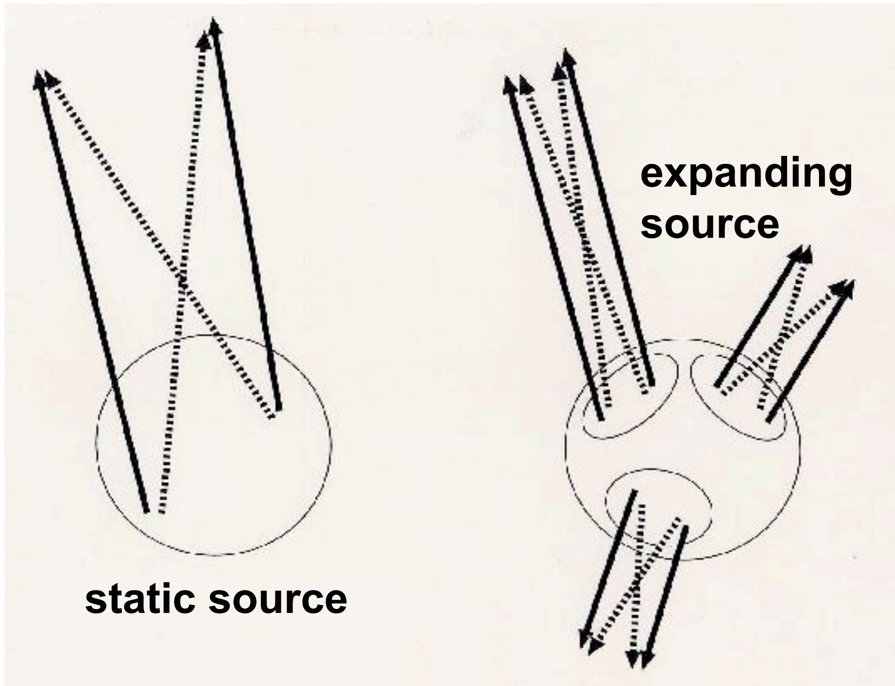
Baryon density ~ 0

HBT interferometry

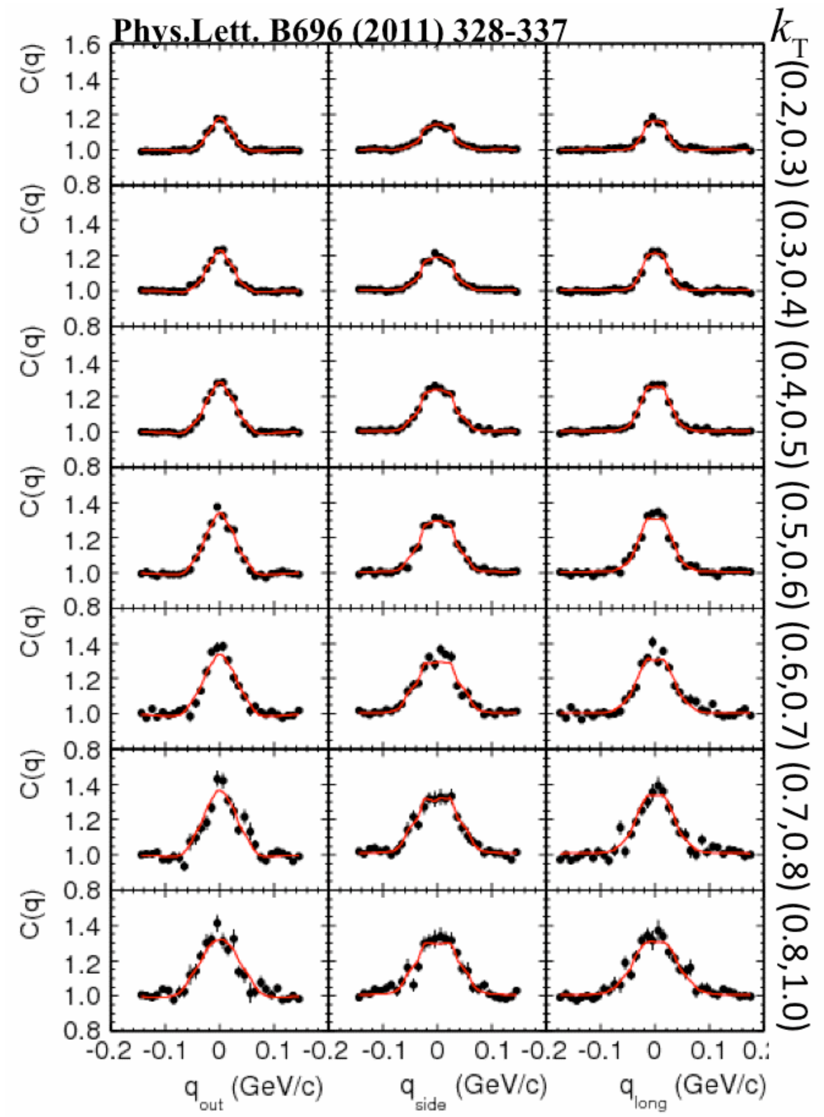


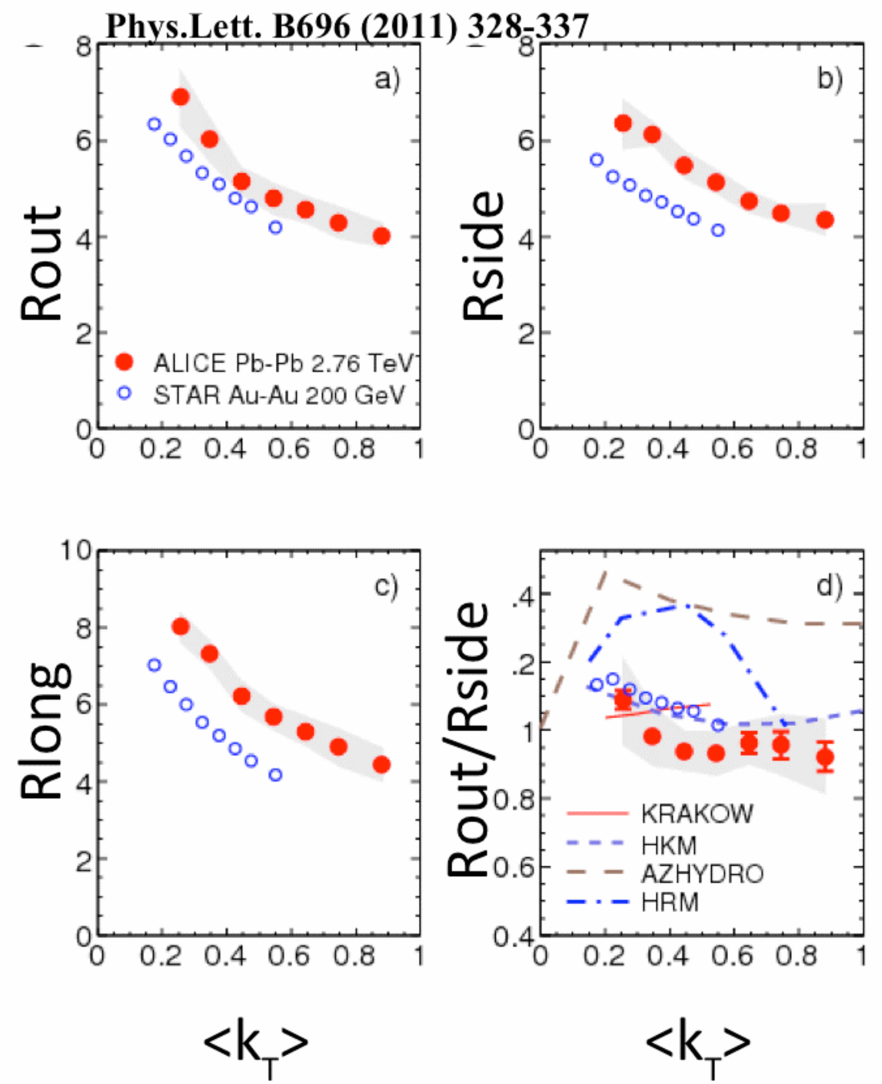


duration time $\Delta\tau = \sqrt{R_{TO}^2 - R_{TS}^2} / \beta$

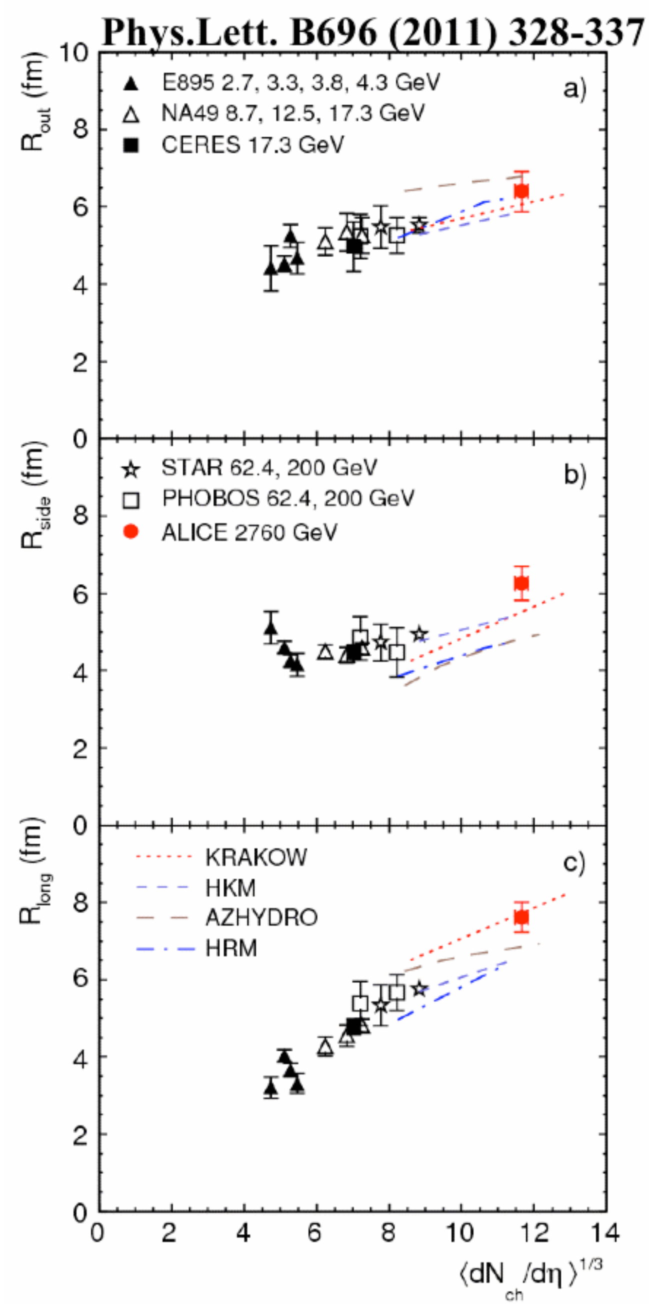


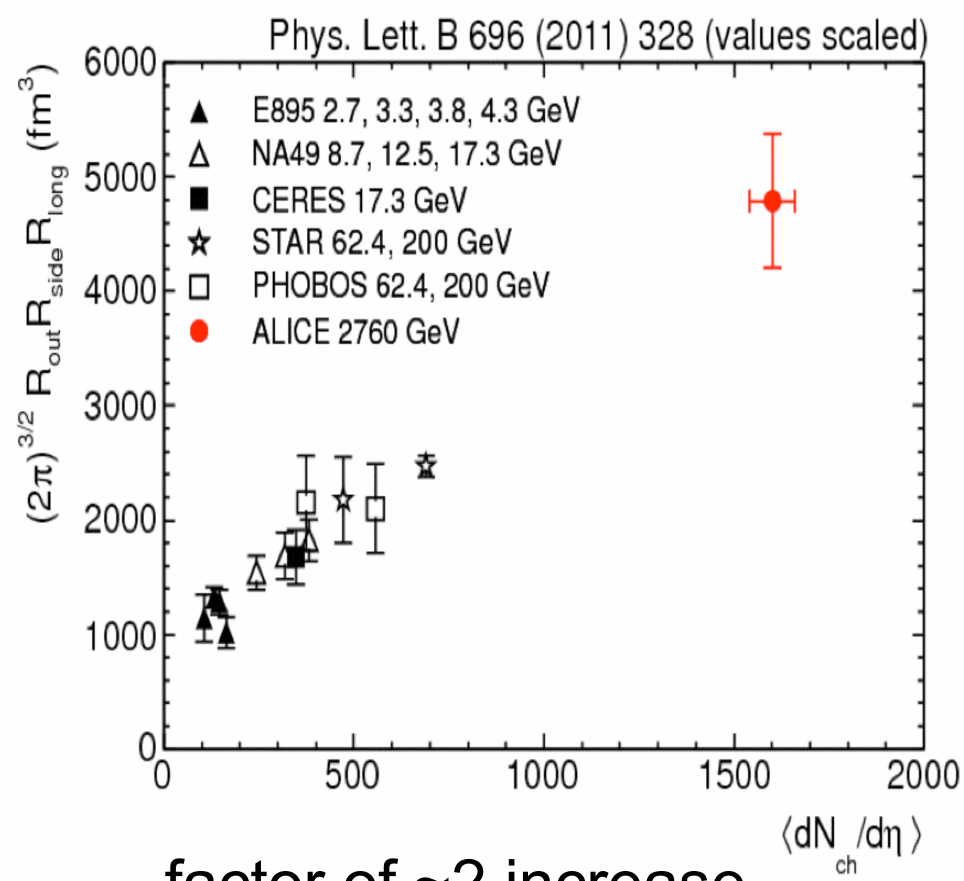
Similar k_T dependence from extended and expanding source





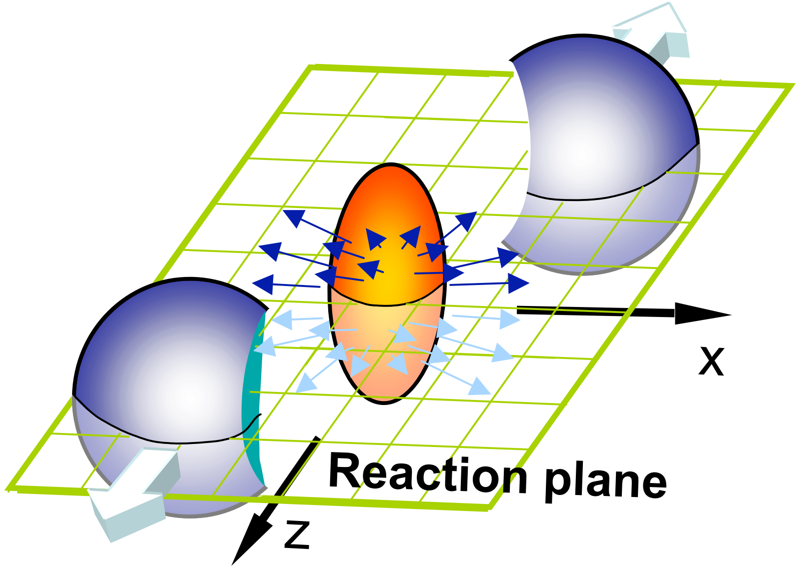
Beam energy dependence of 3D source size

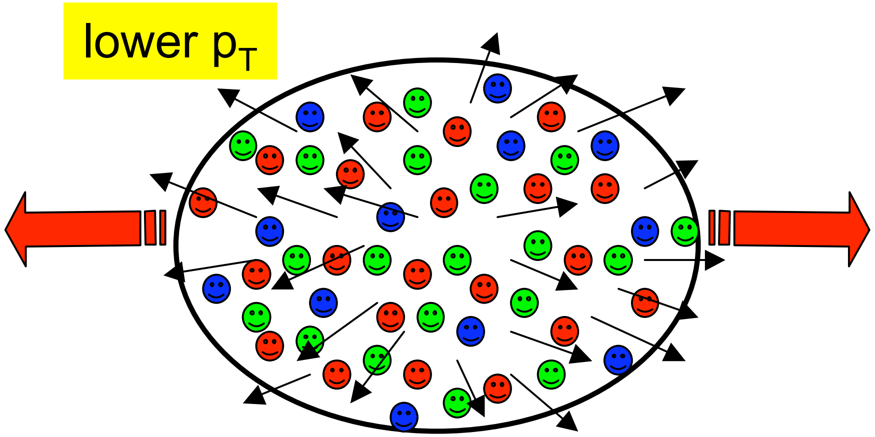




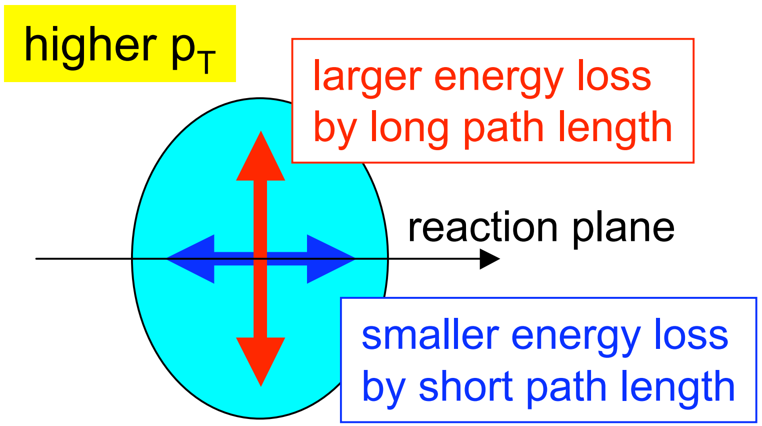
factor of ~2 increase
in source volume

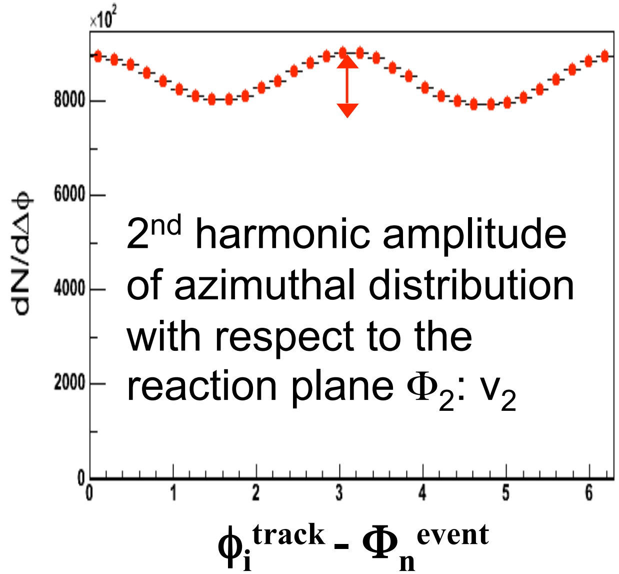
Elliptic flow (elliptic event anisotropy) : v_2



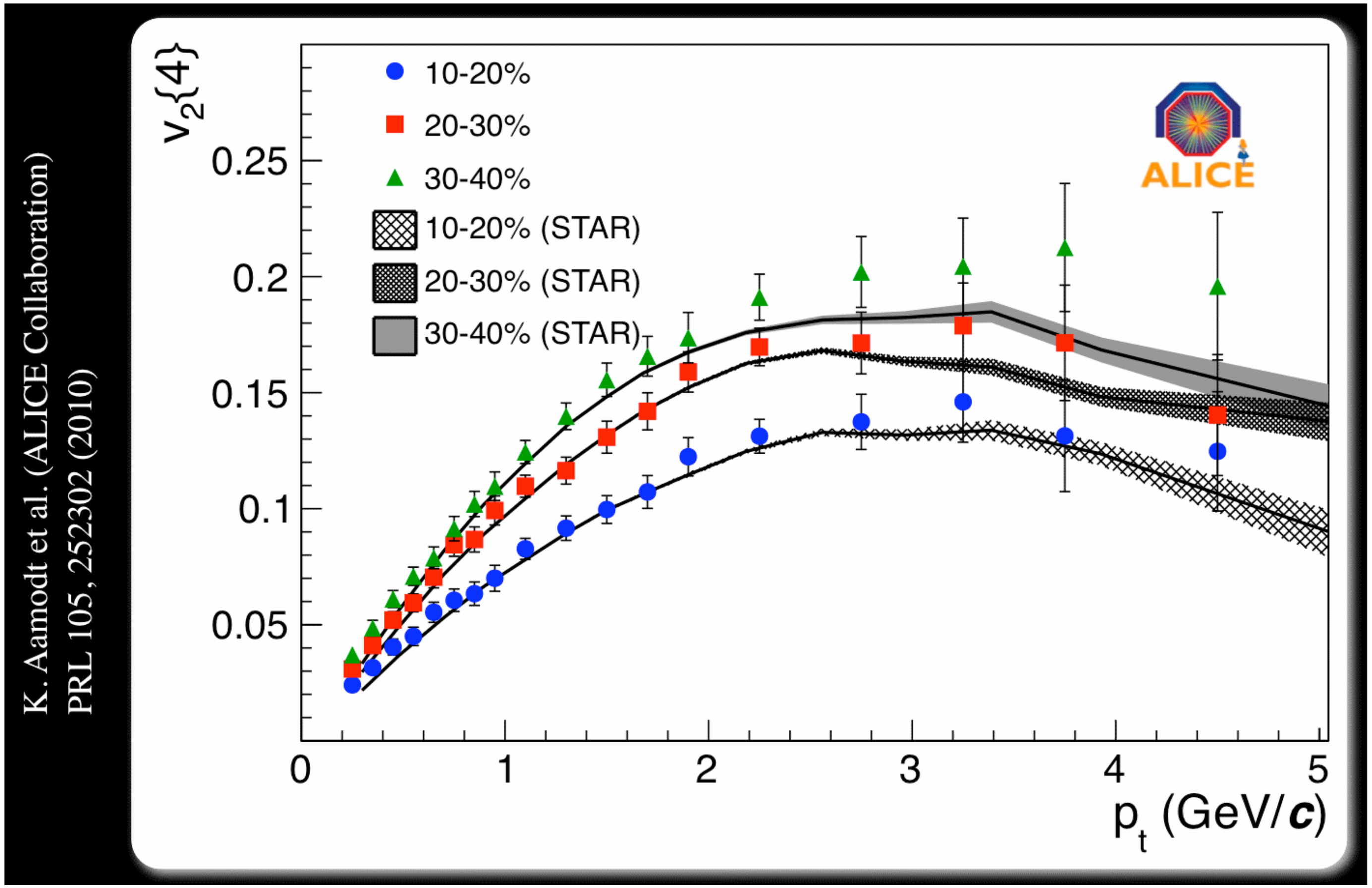


Hydro-dynamical expansion



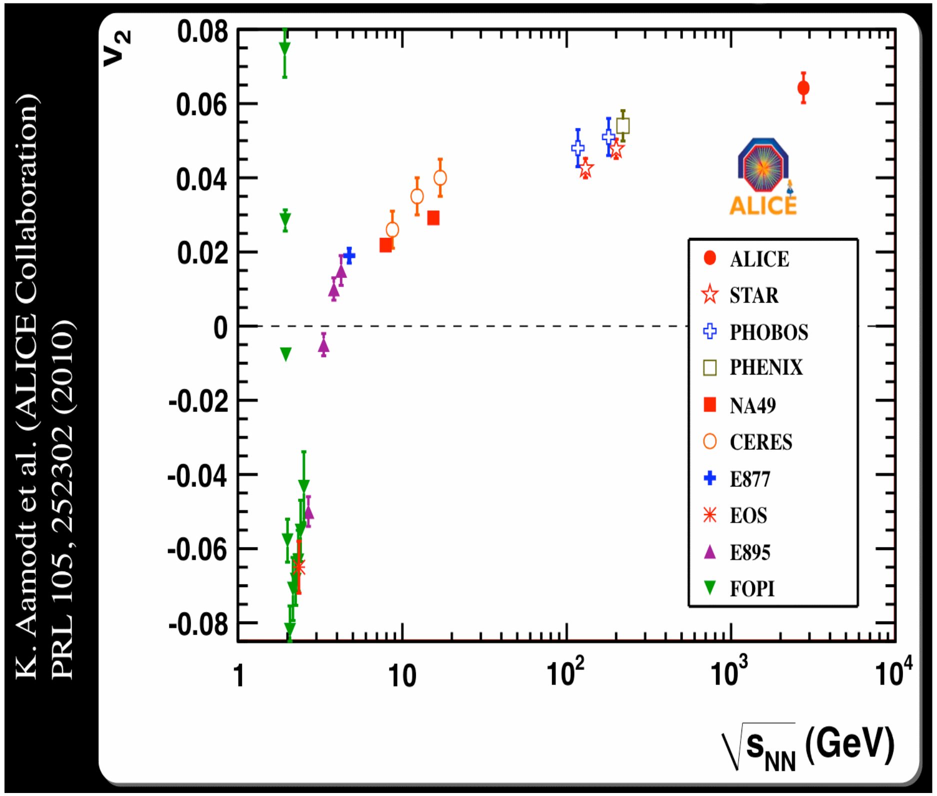


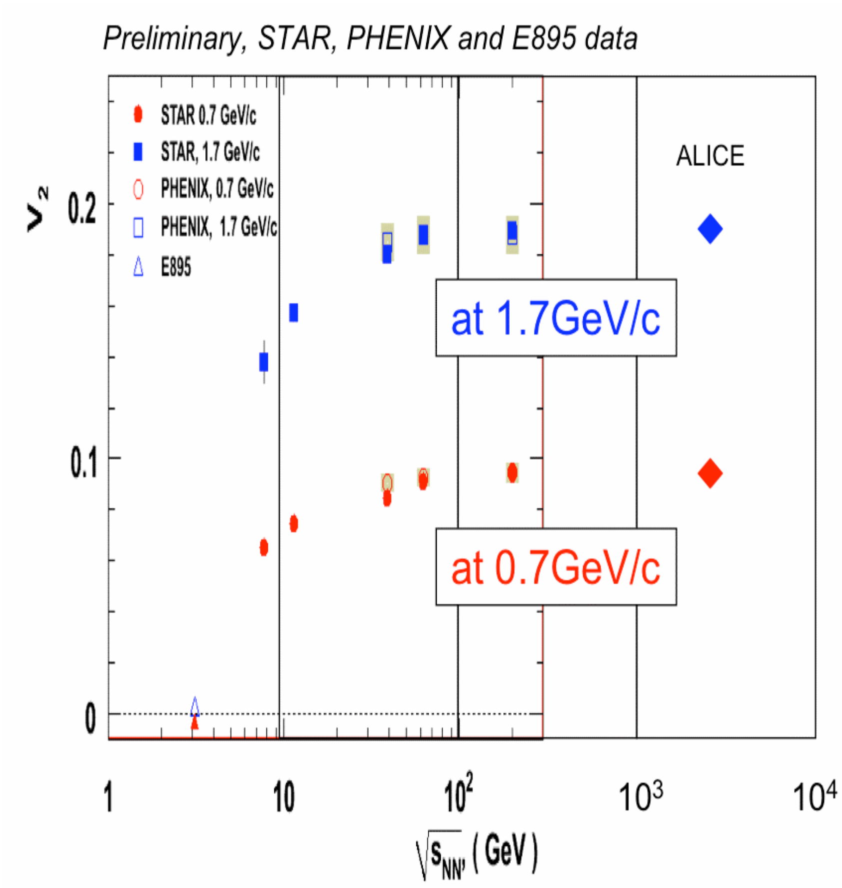
v_2 vs p_T comparison between RHIC and LHC



similar hydro-dynamic properties

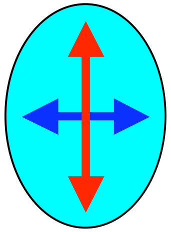
Beam energy dependence of $\langle v_2 \rangle$ and $v_2(p_T)$



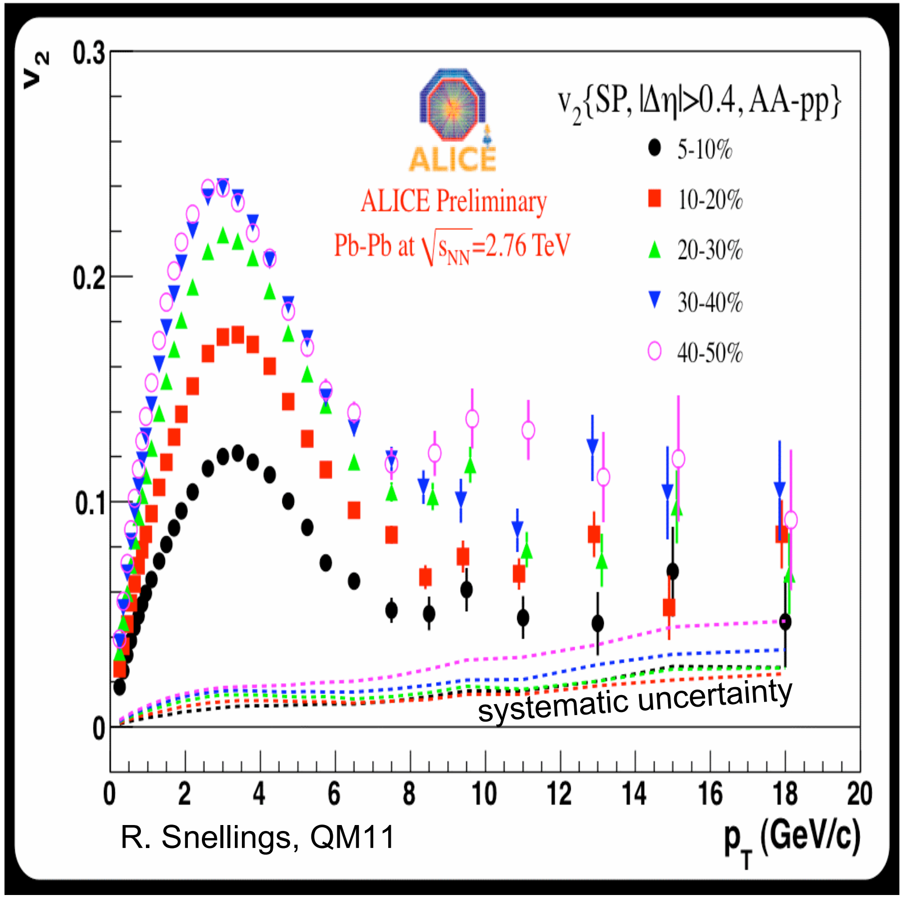


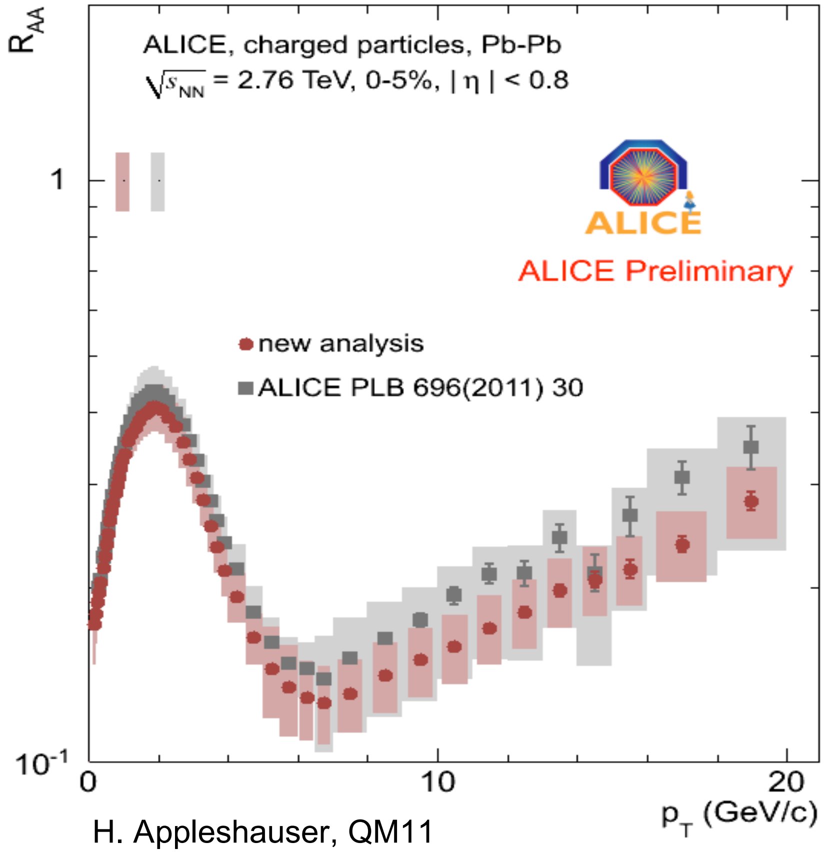
$\langle v_2 \rangle$ still increases with $\langle p_T \rangle$

$v_2(p_T)$ saturates



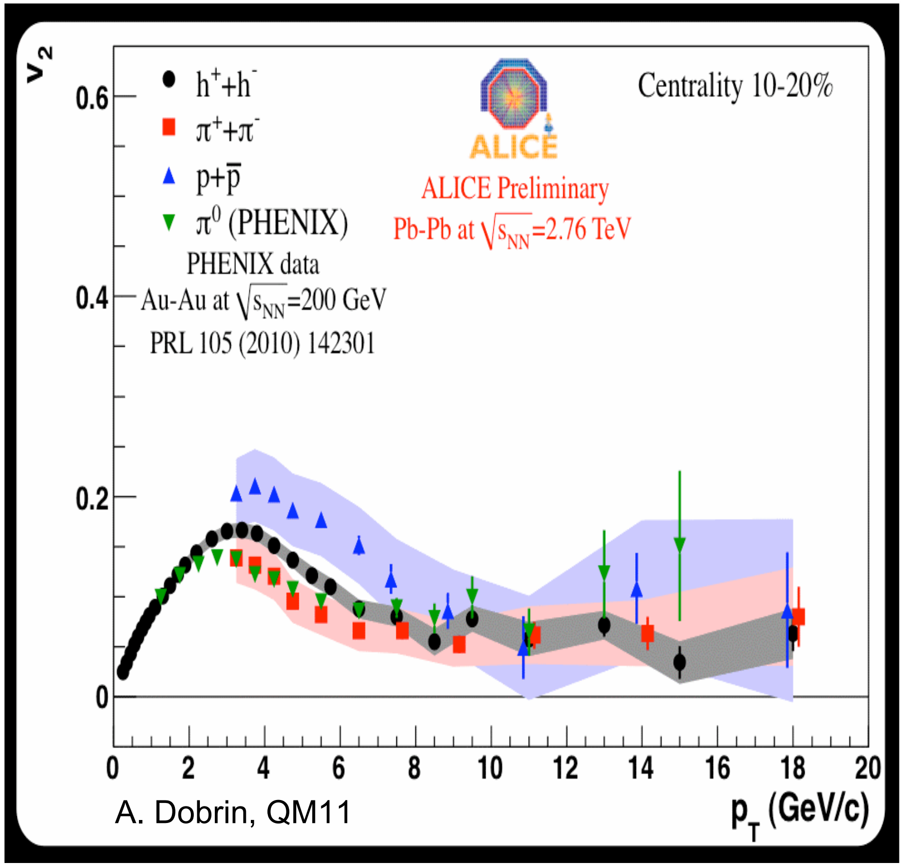
v_2 and R_{AA} at higher p_T region

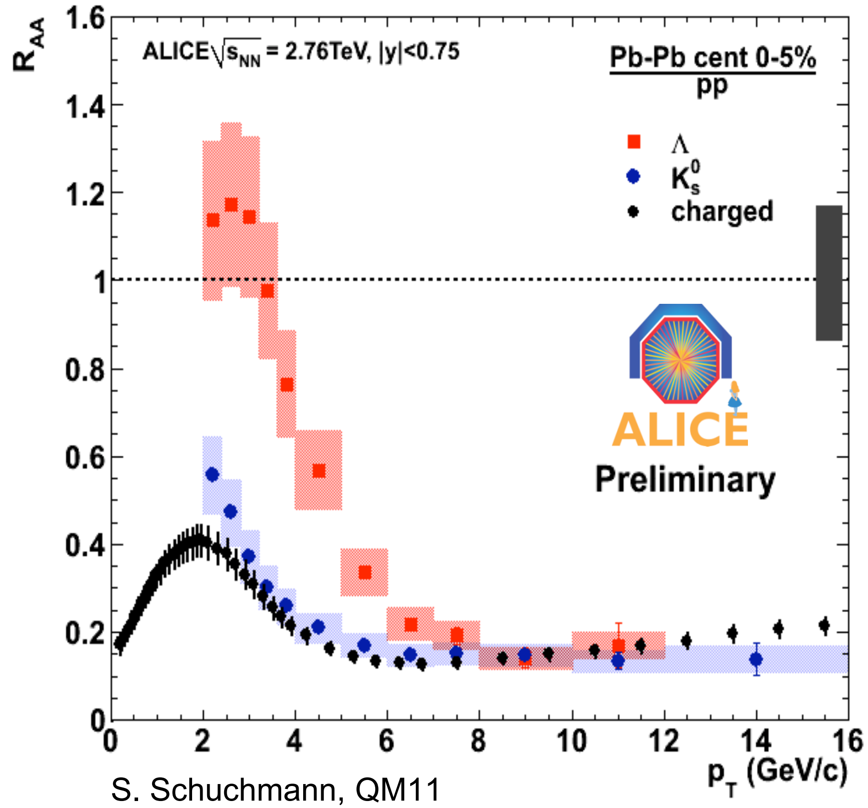




v_2 from suppression dominance given by path length

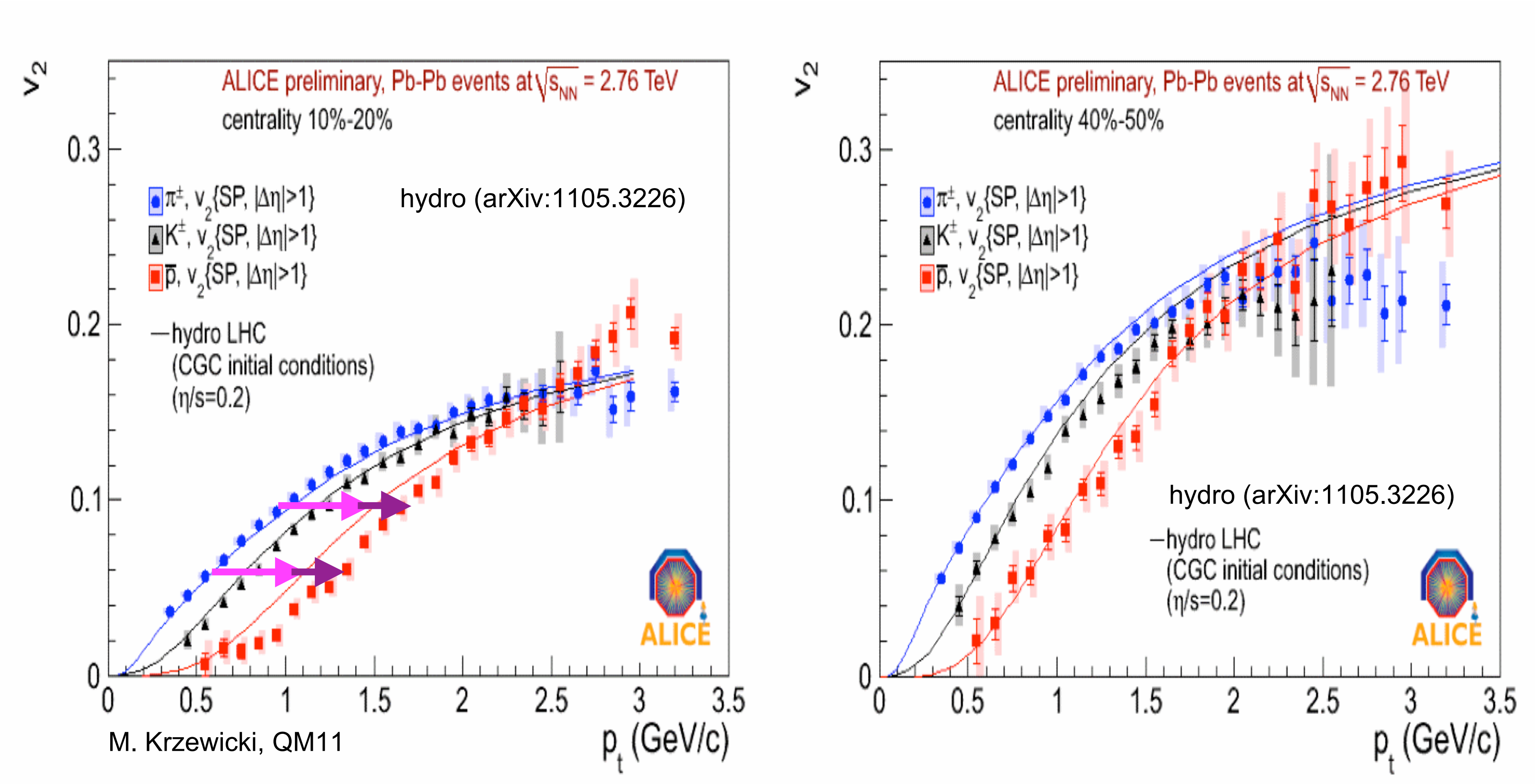
Particle identified v_2 and R_{AA} at higher p_T





particle dependence seems to be vanished at higher p_T

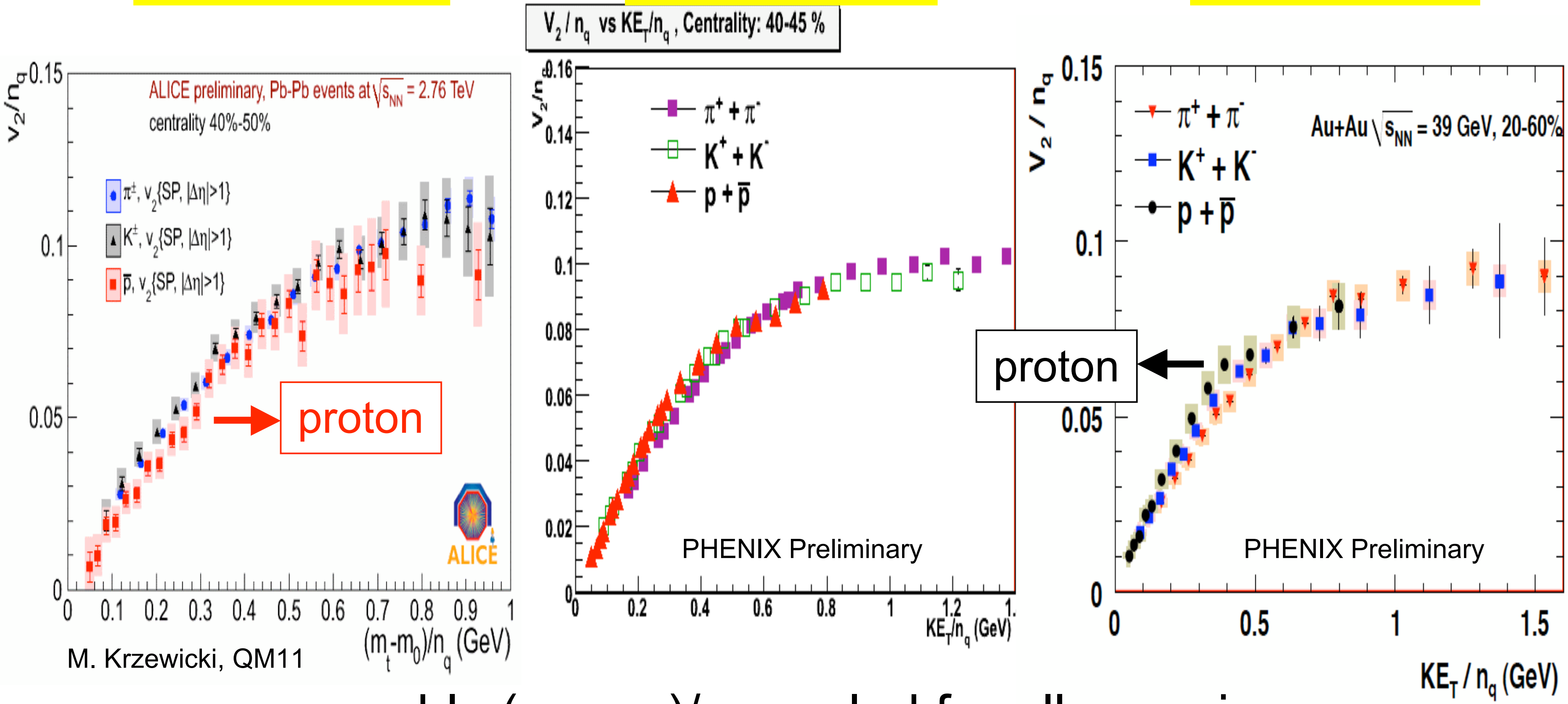
Particle identified v_2 at lower p_T



larger mass-splitting + familiar Baryon/Meson difference
larger radial flow in central collisions than in this hydro model

Small deviations in $(m_T\text{-}m_0)/n_q$ scaled v_2

Pb+Pb 2.76TeV | Au+Au 200GeV | Au+Au 39GeV

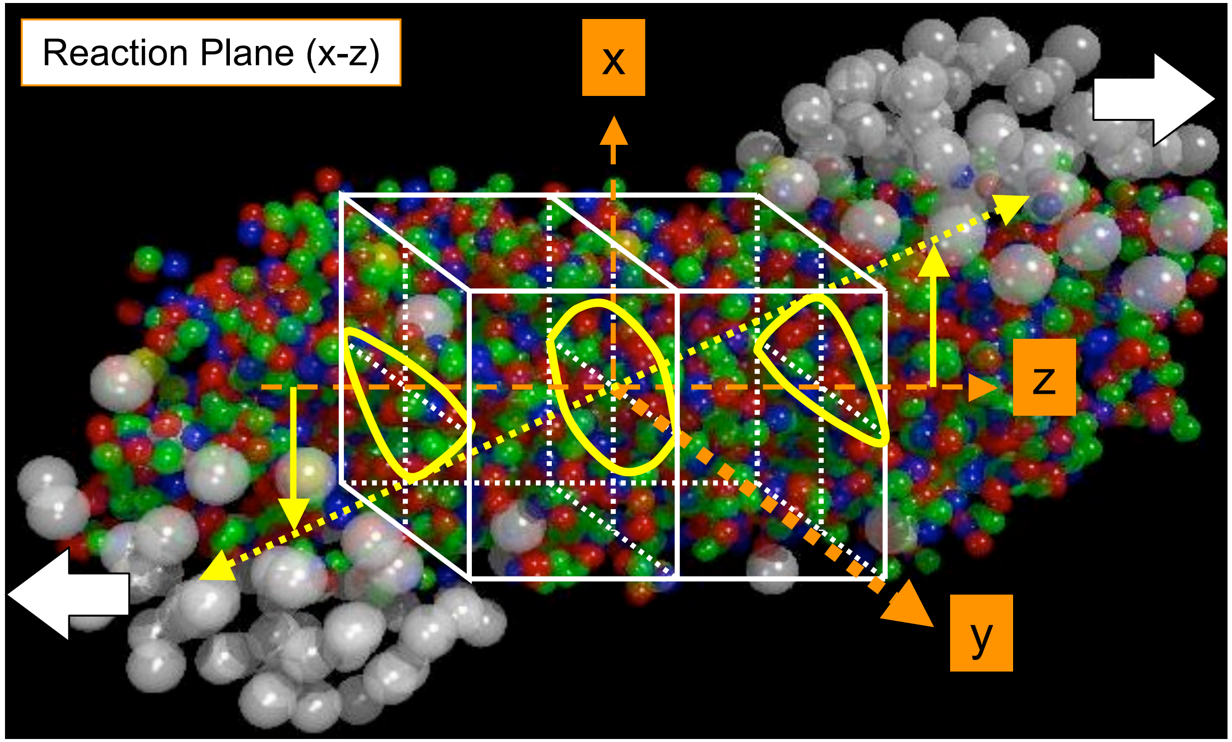


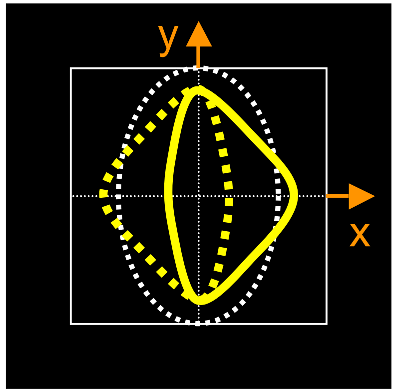
roughly $(m_T\text{-}m_0)/n_q$ scaled for all energies

larger p_T shift for heavier particles

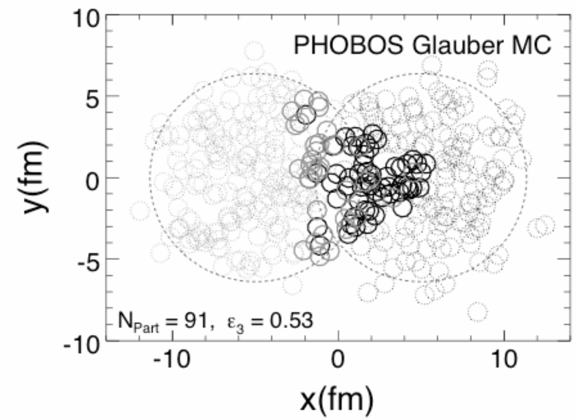
radial flow increases with energy

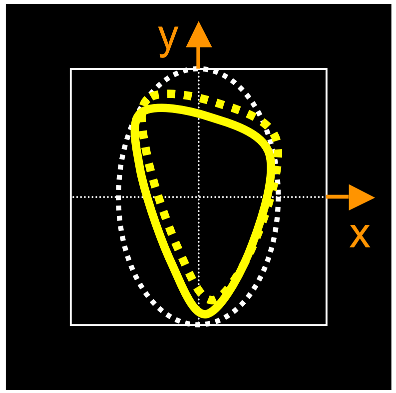
v_3 and Initial Fluctuation





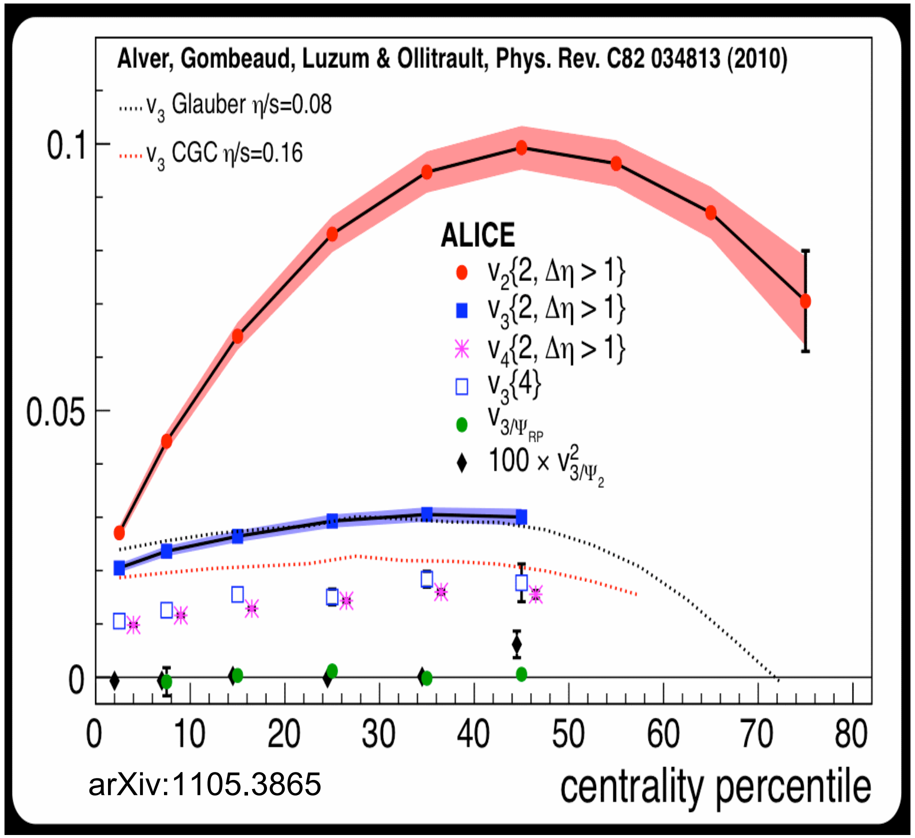
arXiv:1003.0194

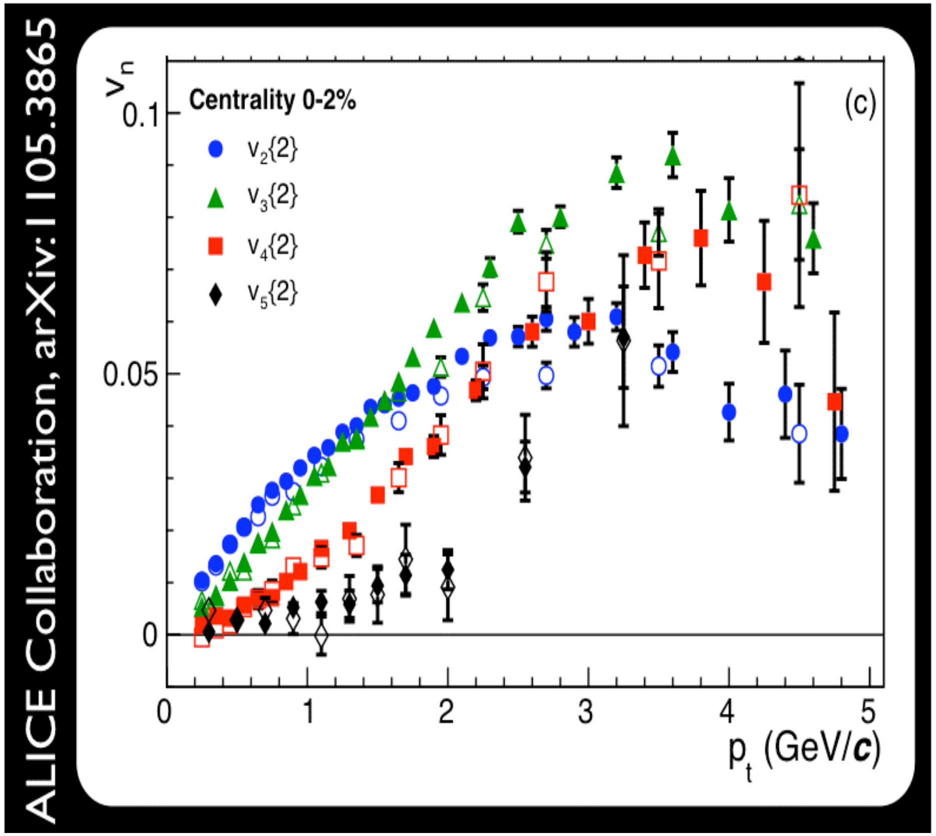




black-disk --> sign-flipping v_3
initial fluctuation --> no-sign-flipping v_3
similar effects for all the higher moments v_n

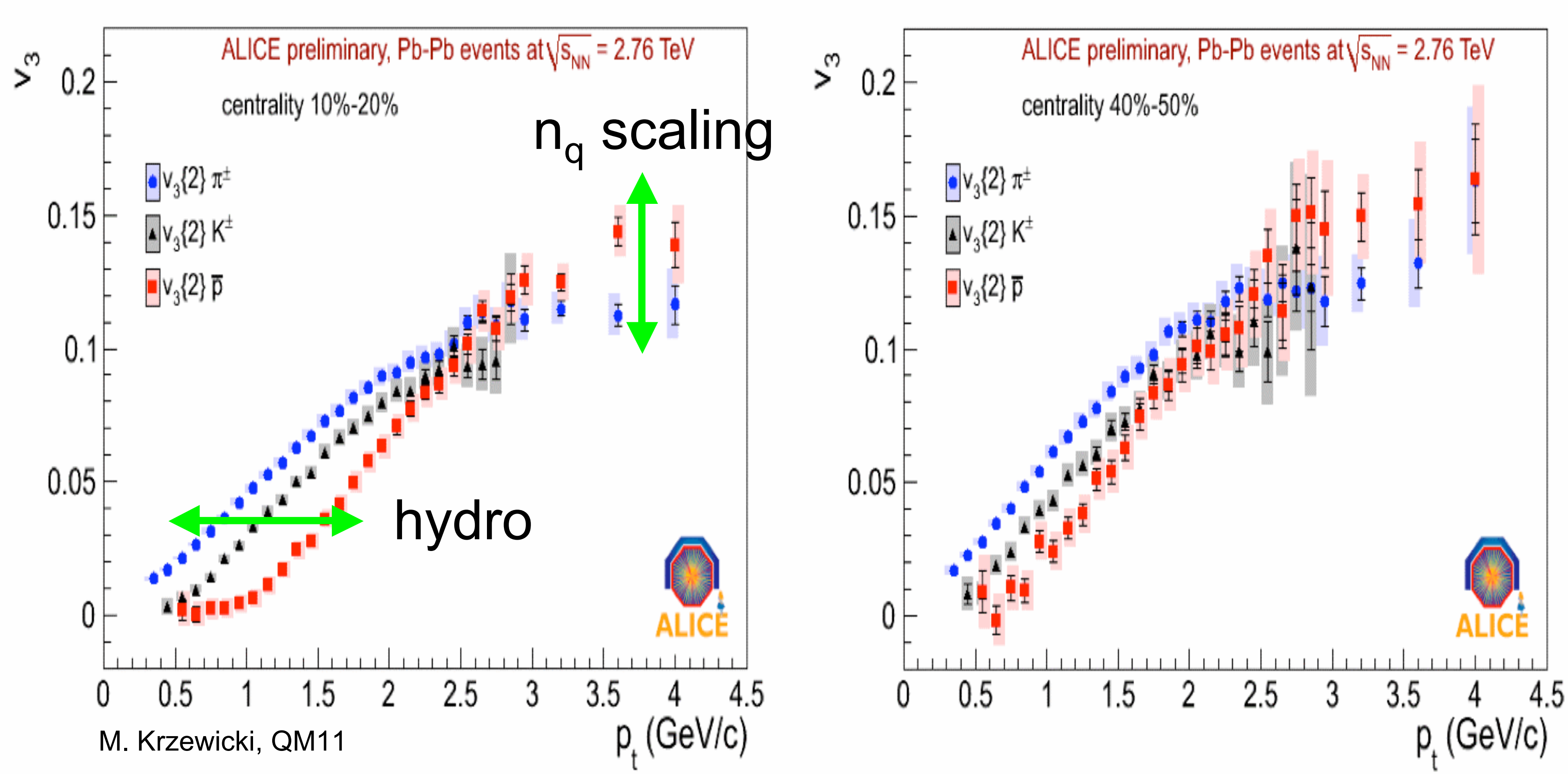
Centrality and p_T dependence of v_n





almost zero signal for sign-flipping v_3 (some small signal at RHIC-PHENIX)
significant non-sign-flipping v_3, v_4 at central and higher p_T
smaller centrality dependence for v_3, v_4 than for v_2

Particle identified v_3



M. Krzewicki, QM11

hydro : similar mass-splitting at lower p_T

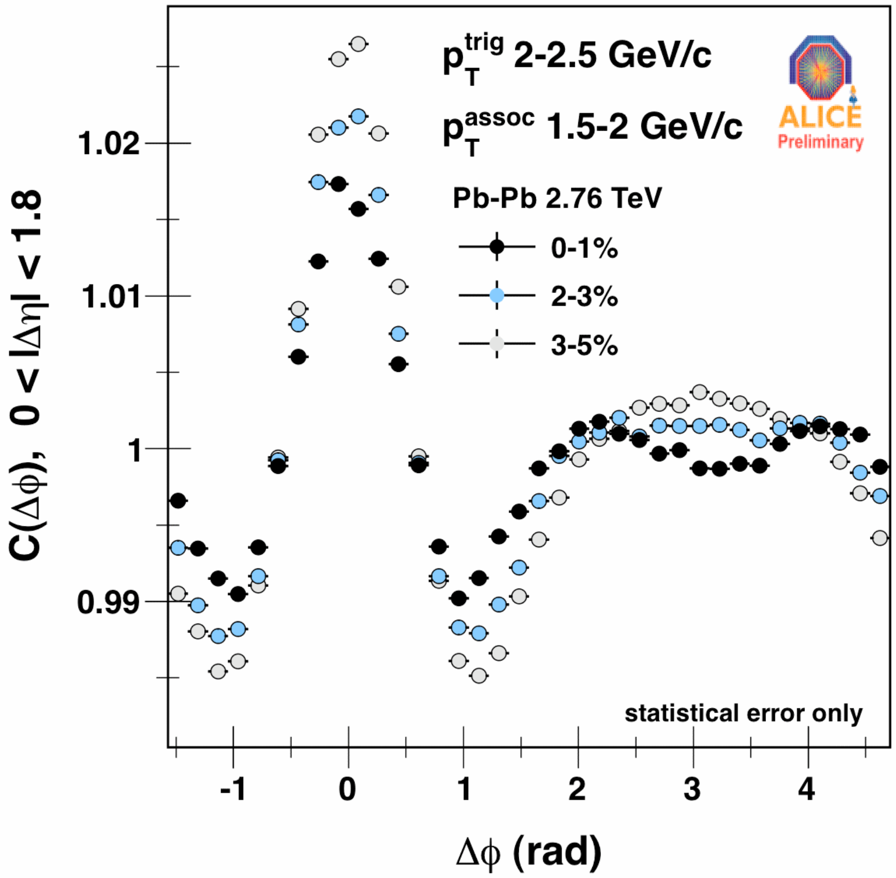
n_q scaling : similar Baryon / Meson difference at higher p_T

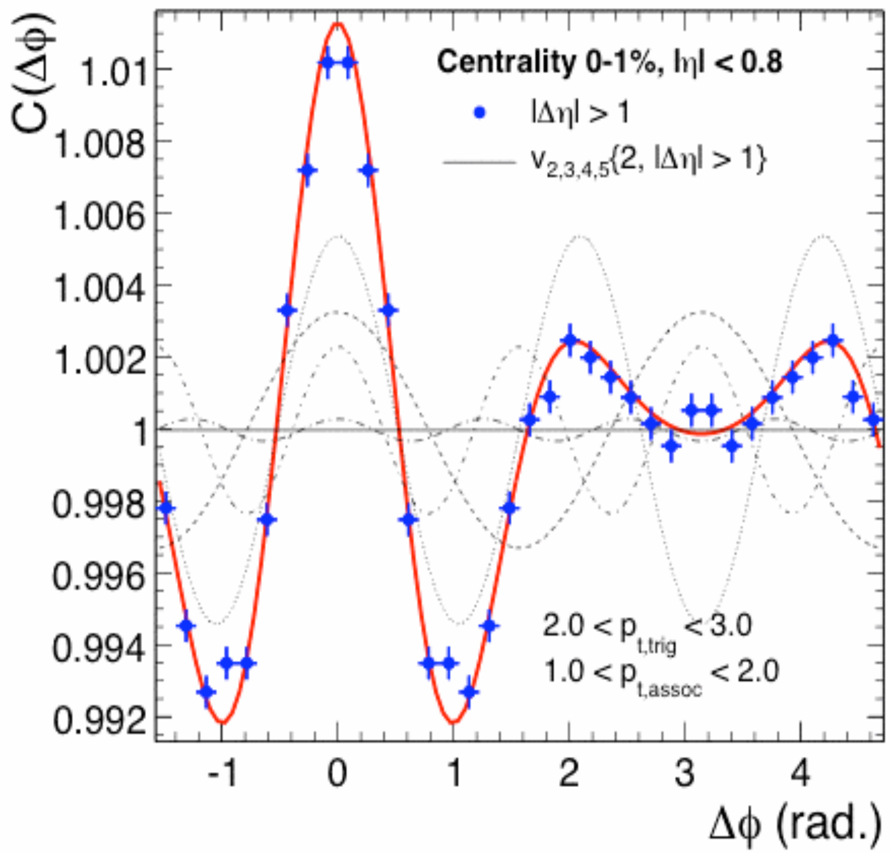
The KE_T/n_q scaling for v_3 is also not as good as for v_2

2-particle azimuthal correlation function

--- flow un-subtracted C_2 ---

A. Adare, QM11 arXiv:1105.3865

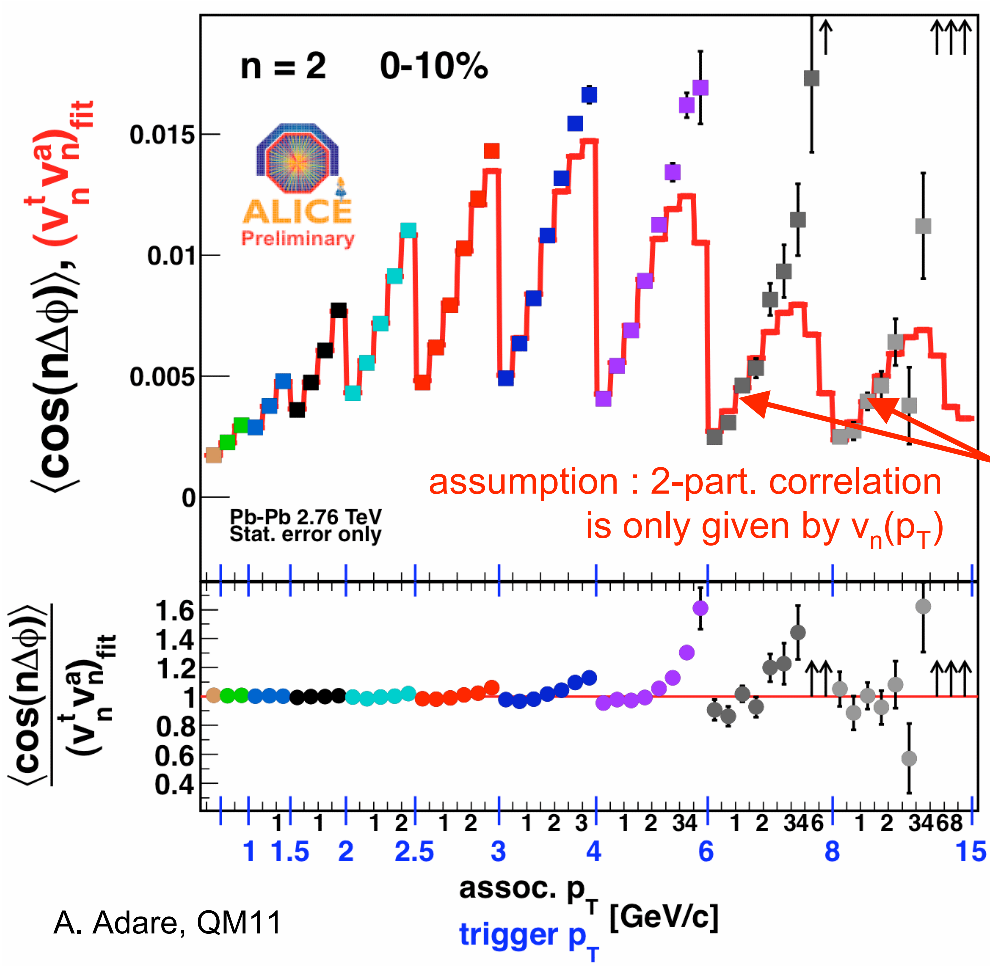




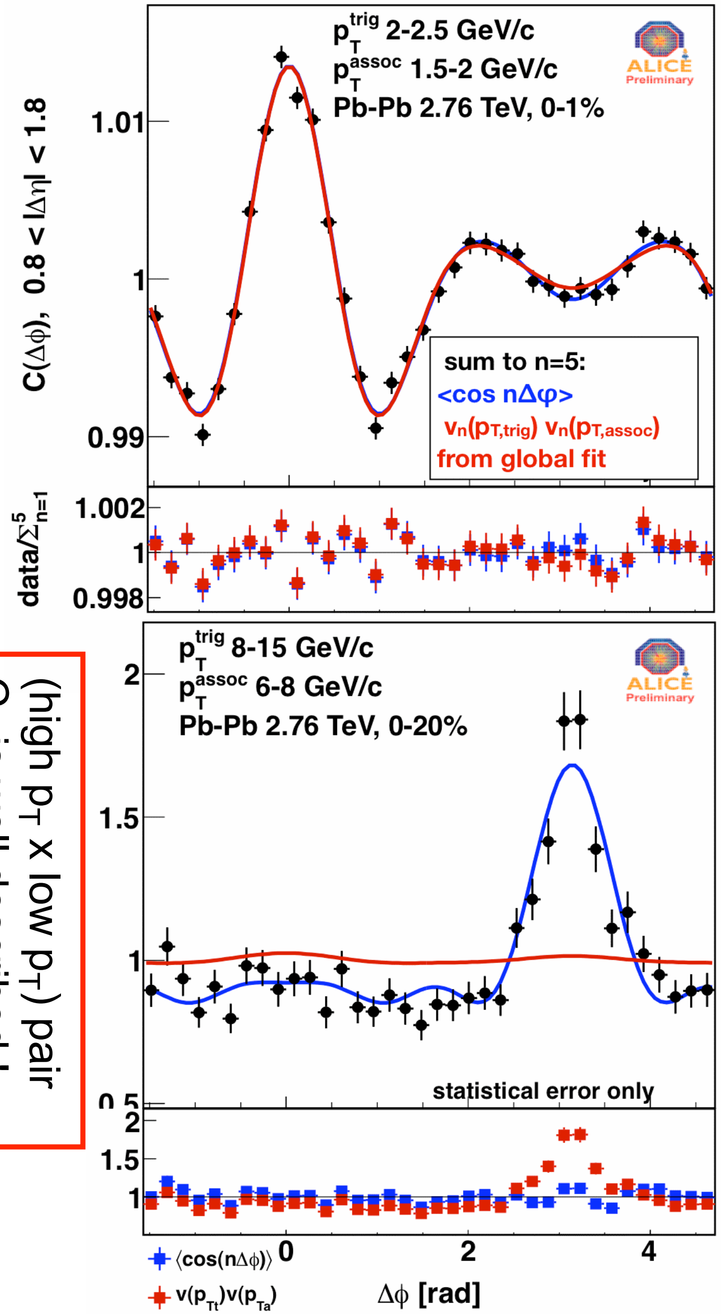
rapidity separated C_2 is well described by $v_{2,3,4,5}$
as naturally expected because of $v_n\{2, |\Delta\eta|>1\}$

($v_n^{trig.}$ x $v_n^{asso.}$) global fit

with various p_T (trig. x asso.) combinations
describes the C_2 shape well at lower p_T

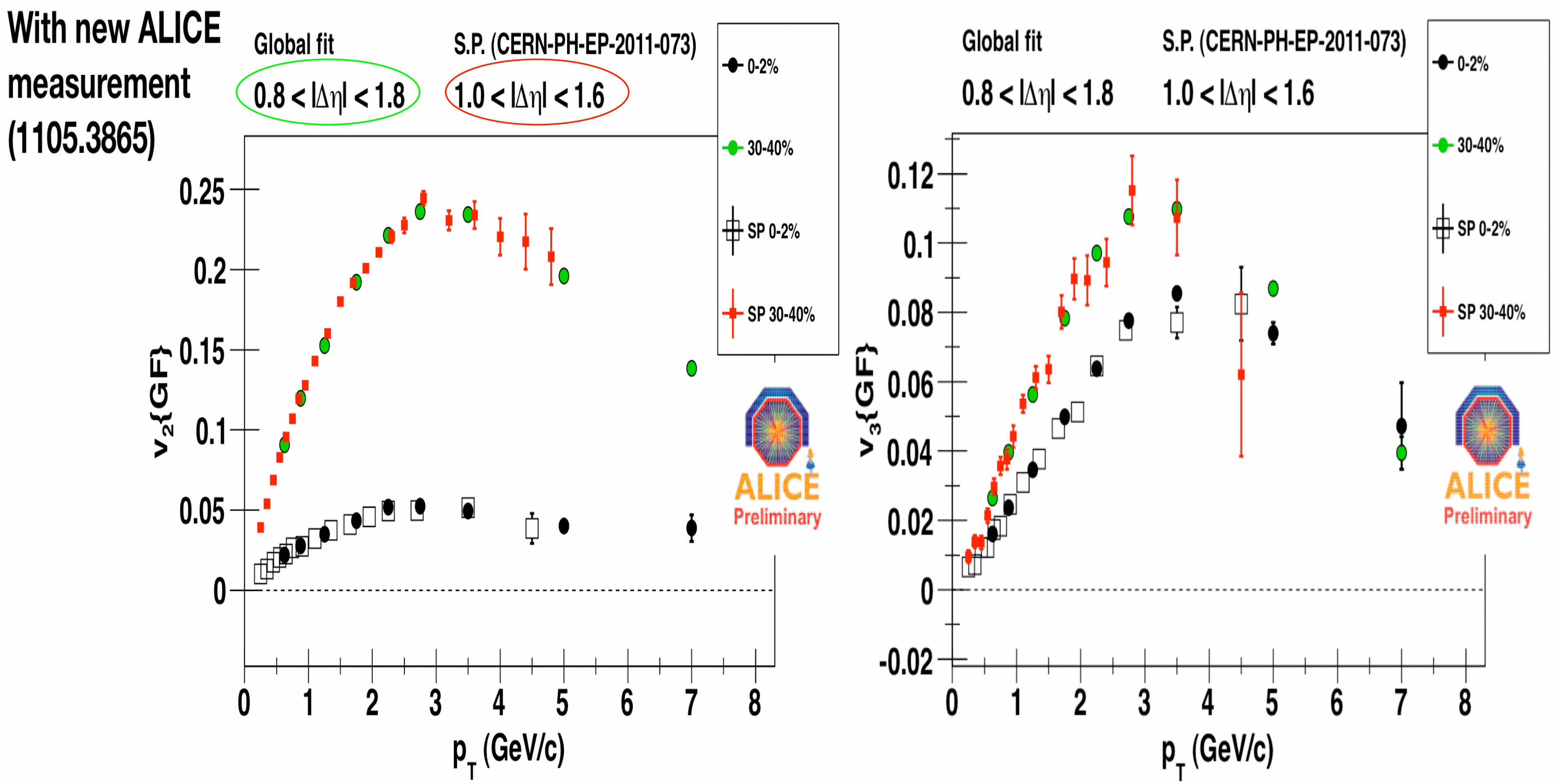


(high p_T x low p_T) pair
C_2 is well described !



$v_n\{C_2 \text{ global fit}\} \sim v_n\{2, |\Delta\eta|>1\}$

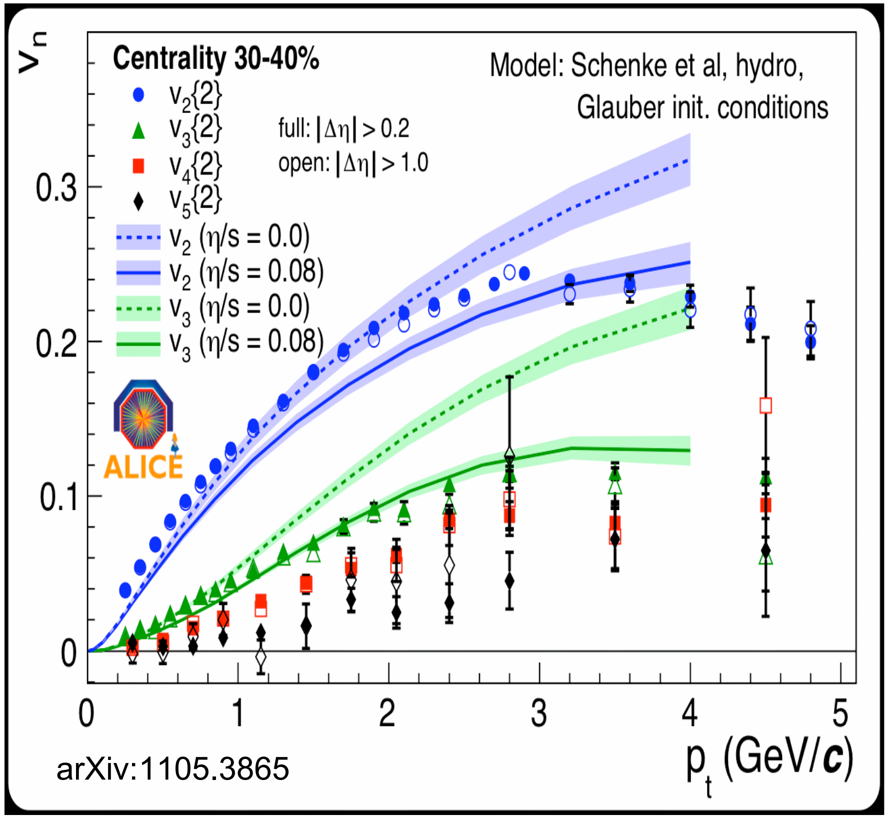
A. Adare, QM11

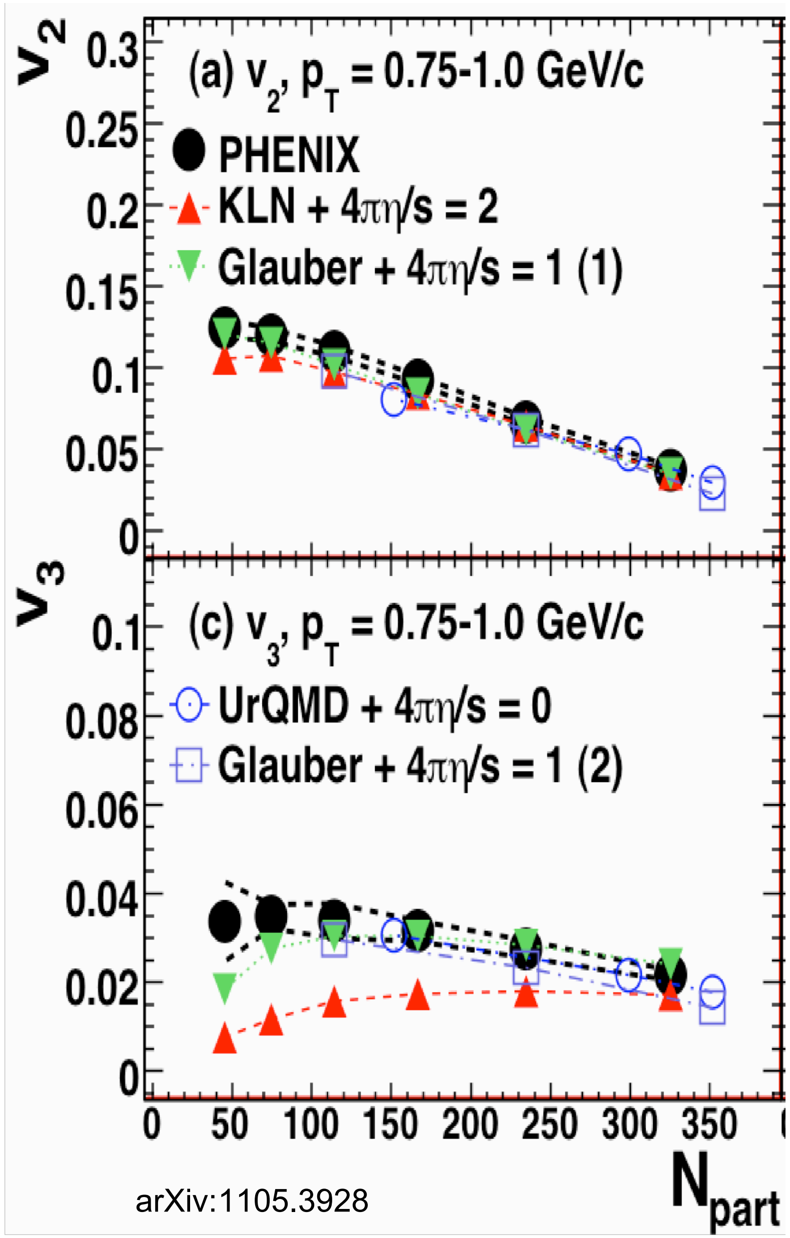


good agreement of v_n even towards higher p_T
coming from (low x high) p_T combinations in C_2

init. fluc. : Glauber / CGC

hydro. η/s : Large / Small





Summary

2.76TeV Pb+Pb collisions are measured in LHC-ALICE

- factor of 2 in charged particle multiplicity $dN_{ch}/d\eta$
- factor of 2 in freeze-out volume from HBT
- net-Baryron free region in the phase diagram
- increased and pronounced radial flow in several cases
- similar hydro properties compared with RHIC
- initial fluctuation and hydro-expansion drive the v_n
- discrimination power on initial geometry and viscosity

Back-up

PRC82.034913

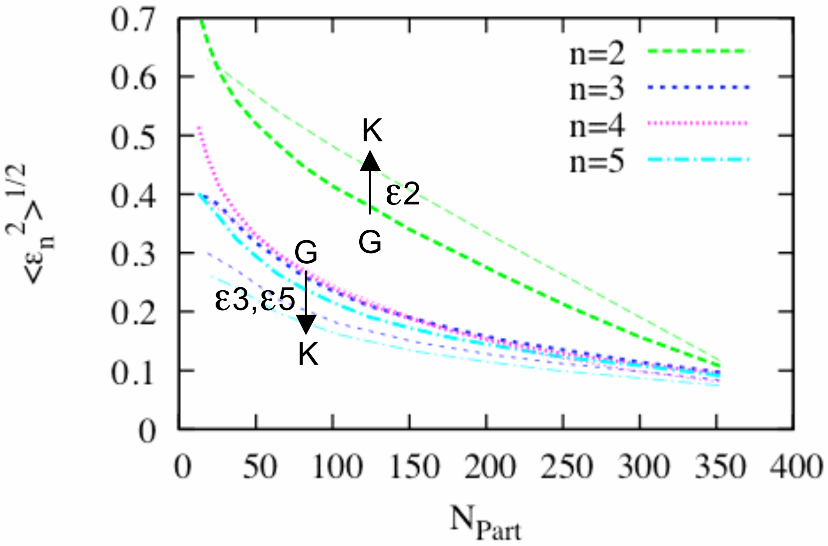


FIG. 7: (Color online) Root mean square eccentricities $\varepsilon_n^{\rm rms}$ for $n = 2, 3, 4, 5$ for Au-Au collisions at 200 GeV per nucleon, versus the number of participant nucleons $N_{\rm Part}$. $N_{\rm Part}$ is used as a measure of the centrality in nucleus-nucleus collisions: it is largest for central collisions, with zero impact parameter [53]. Thick lines: Monte-Carlo Glauber model [50]; Thin lines: Monte-Carlo KLN model [52].

arXiv:1104.0650

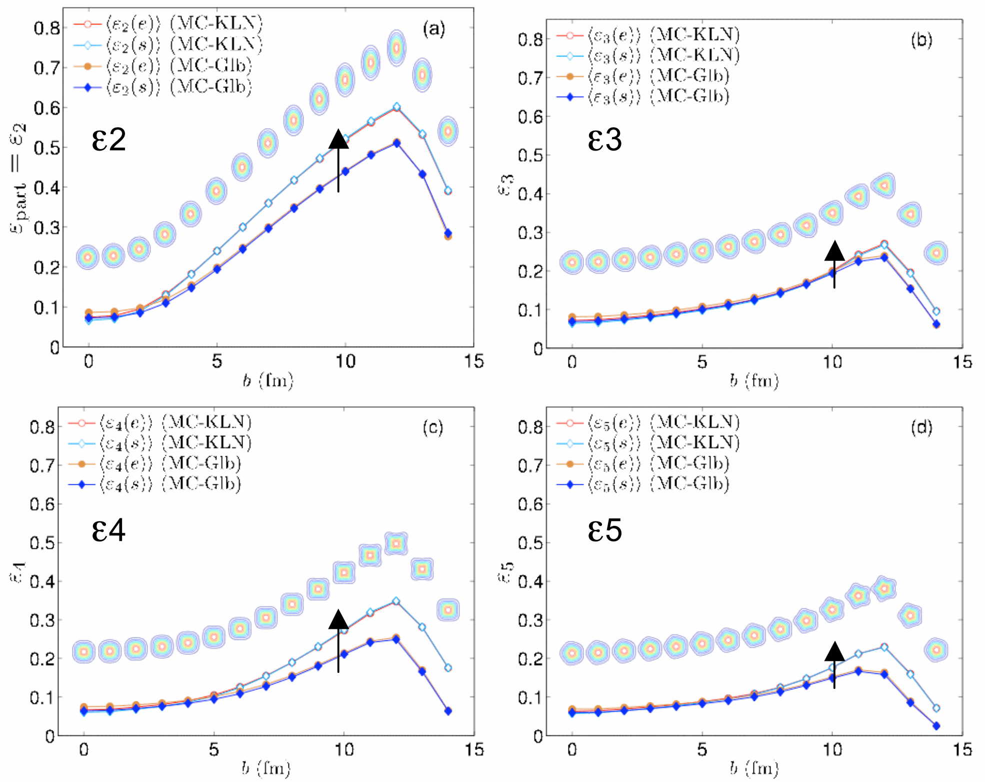


FIG. 5: (Color online) Harmonic eccentricity coefficients $\varepsilon_2 = \varepsilon_{\rm part}$ (a), ε_3 (b), ε_4 (c) and ε_4 (d) as functions of impact parameter, calculated from the MC-Glauber (filled symbols, solid lines) and MC-KLN models (open symbols, dashed lines), using the energy density (circles) or entropy density (triangles) as weight function. The contour plots illustrate deformed Gaussian profiles $e(r,\phi) = e_0 \exp\left[-\frac{r^2}{2\rho^2}\left(1+\varepsilon_n \cos(n\phi)\right)\right]$, with eccentricity $\varepsilon_n(e)$ taken from the MC-KLN model at the corrsponding impact parameter.

arXiv:1108.1714

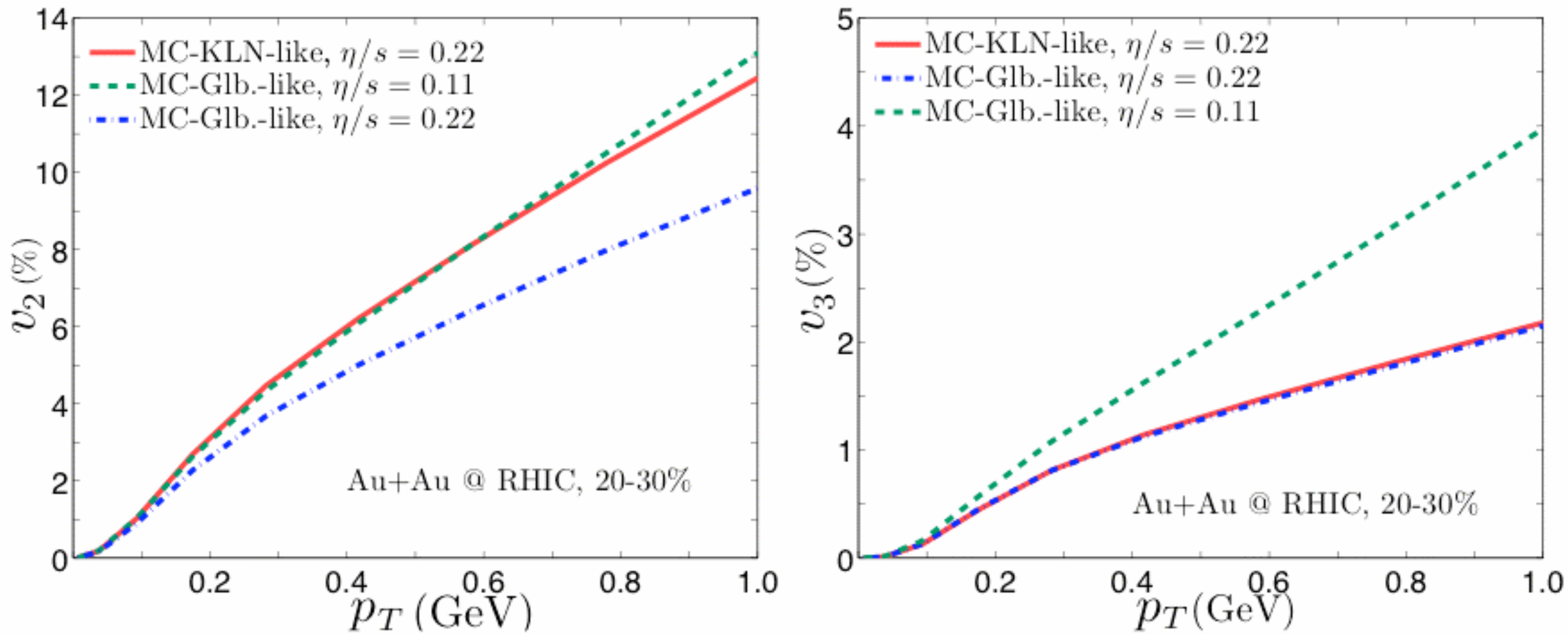
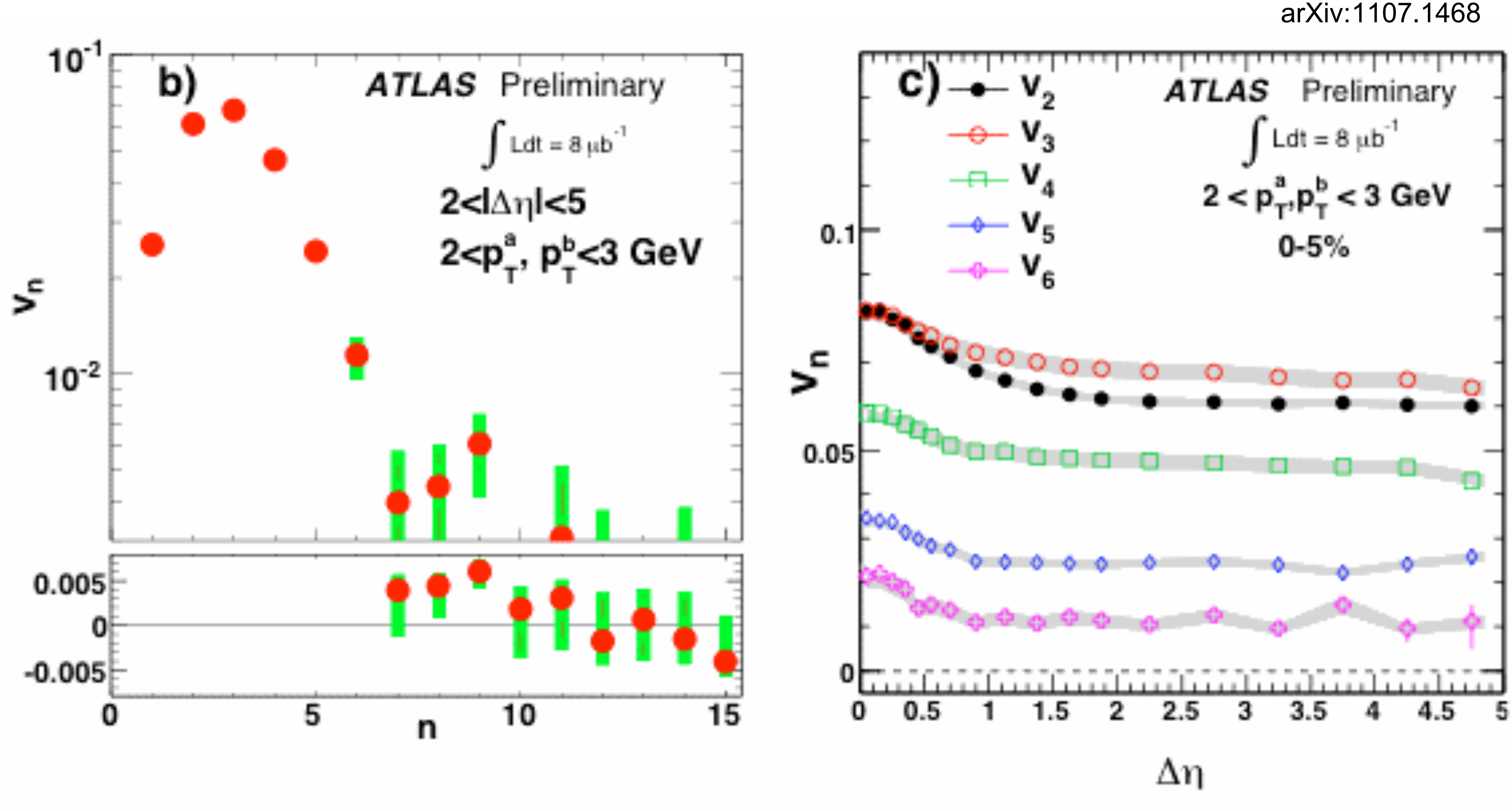


FIGURE 2. Differential $v_2(p_T)$ (left) and $v_3(p_T)$ (right) from viscous hydrodynamics using MC-Glauber-like and MC-KLN-like initial conditions and different values for η/s (see text for discussion).

Fig. 2 shows differential $v_{2,3}(p_T)$ curves resulting from the viscous hydrodynamic evolution of these initial conditions. The solid and dashed curves in the left panel show that, in order to obtain the same $v_2(p_T)$ for MC-KLN-like and MC-Glauber like initial conditions, the fluid must be twice as viscous for the former than for the latter. The right panel shows that, with η/s chosen to produce the same v_2, MC-Glauber-like and MC-KLN-like initial conditions produce dramatically different v_3, with the one from MC-KLN-like initialization being much smaller. Conversely, if η/s is tuned to produce the same v_3, MC-Glauber-like and MC-KLN-like initial conditions require the same value of η/s (solid and dash-dotted lines in the right panel), which then leads to dramatically different v_2 values for the different initial conditions (see corresponding lines in the left panel). These conclusions agree qualitatively with corresponding statements made in Refs. [5, 6].

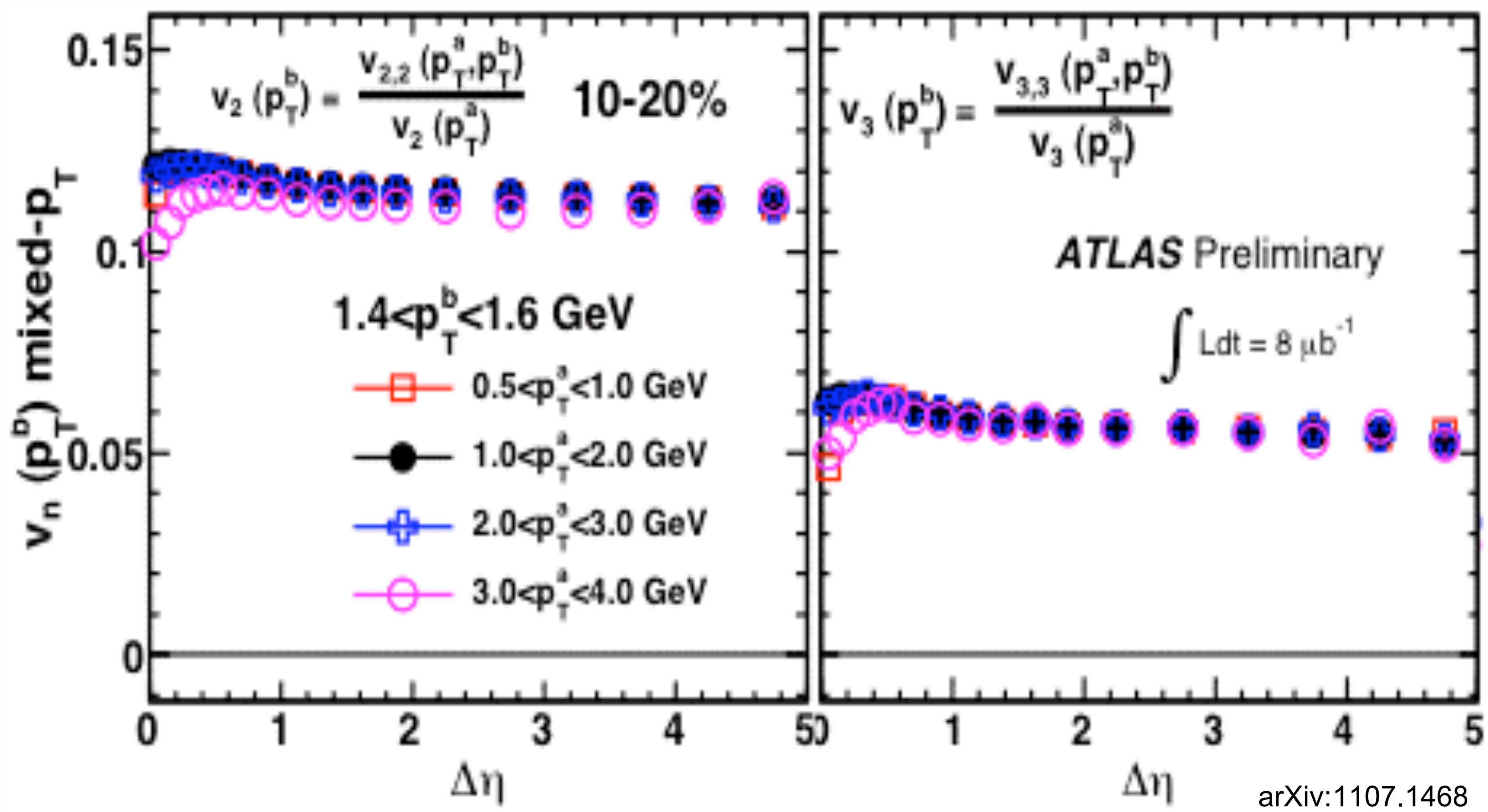
$|\Delta\eta|$ dependence of v_n from LHC-ATLAS

arXiv:1107.1468

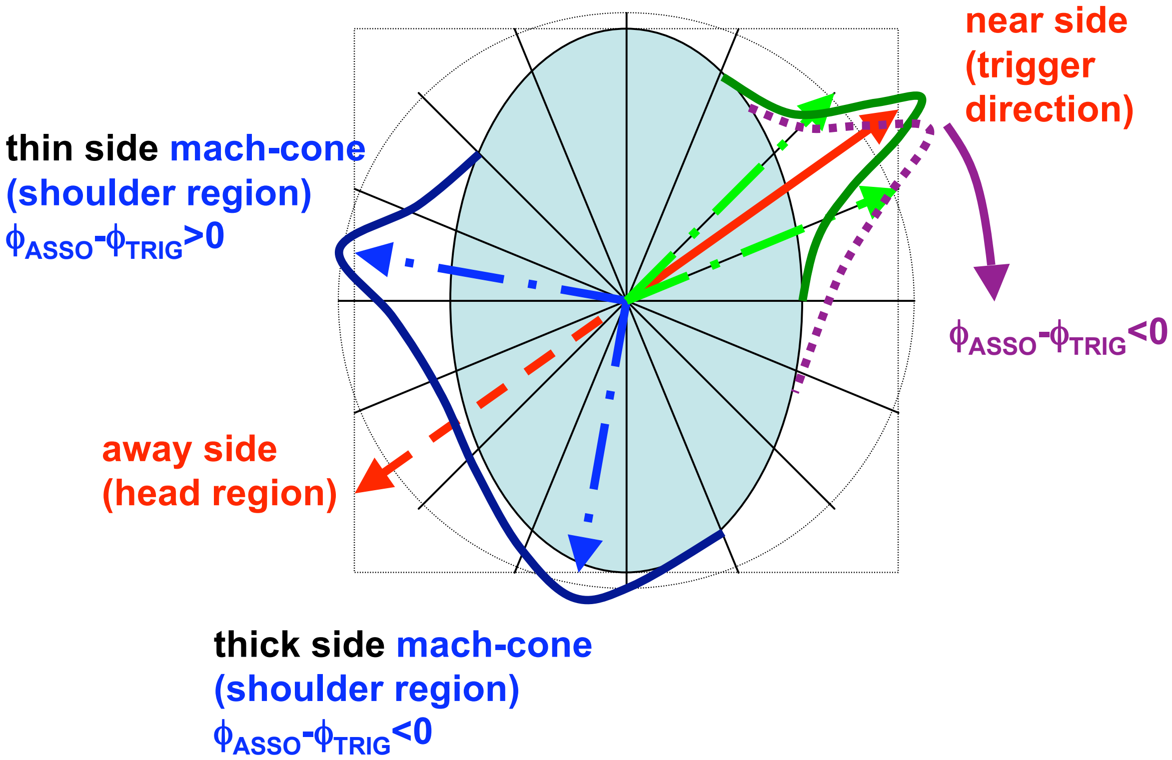


$|\Delta\eta|$ dependence of ($v_n^{trig.}$ x $v_n^{asso.}$)

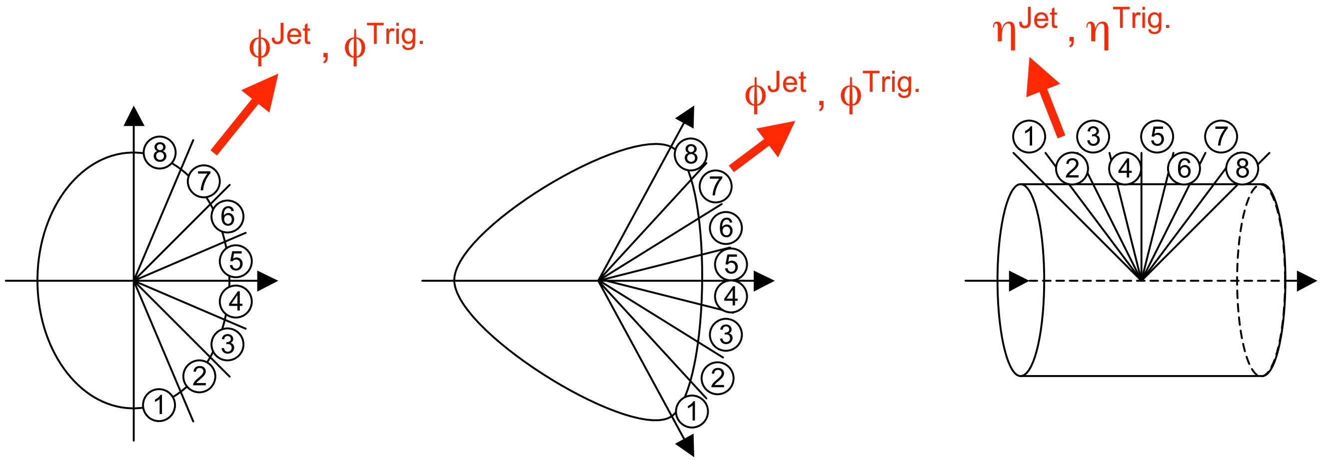
with $v_n\{C_2$ global fit$\}$, which they call v_n factorization in ATLAS



Probe the transverse geometry and/or dynamics
with trigger angle selected 2-particle correlation



jet, di-jet and multi-particle correlation with various conditions



Observed left/right asymmetry remains after “the usual/normal” v_3 subtraction.

200GeV Au+Au -> h-h
(p_T^{Trig}=2~4, p_T^{Asso}=1~2GeV/c)
$v_2(v_4\{\Phi_2\})$-only subtraction
PHENIX preliminary

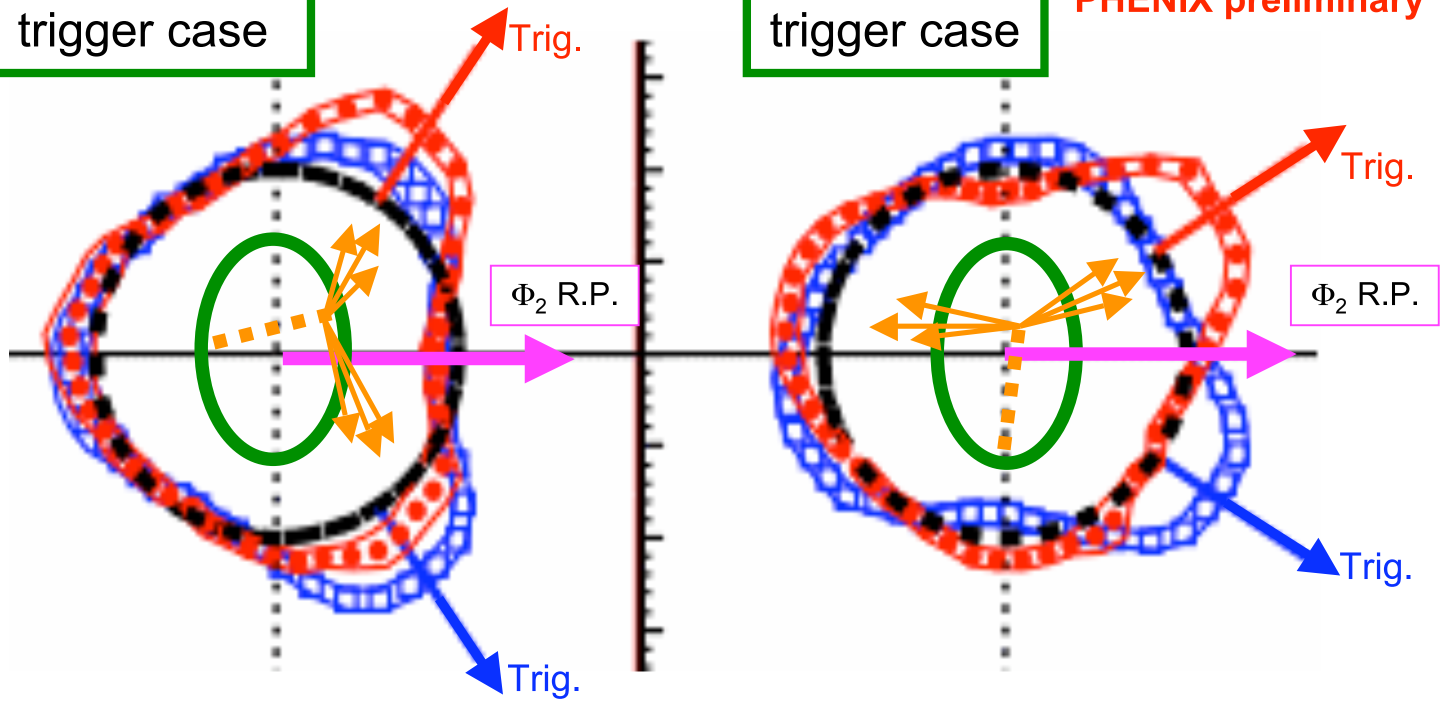
Trigger angle selection w.r.t. Φ_2 separately for left(up) / right(down)

Trigger angle selected 2-part. corr. data are plotted in polar coordinate by rotating Φ_2 R.P. angle as X-axis.

Flow subtracted yield is shown radially with base line. ■■■■■■

out-of-plane trigger case

in-plane trigger case

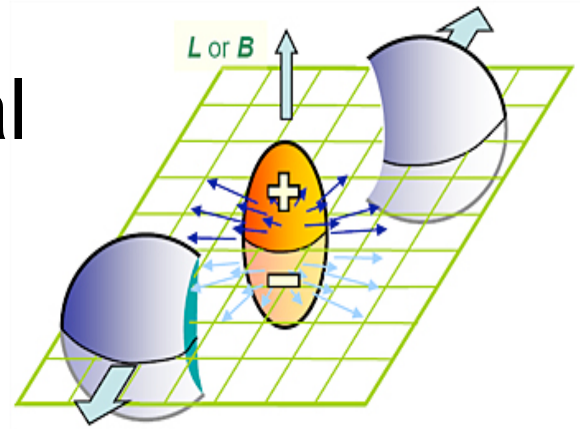


surface dominance

penetration dominance

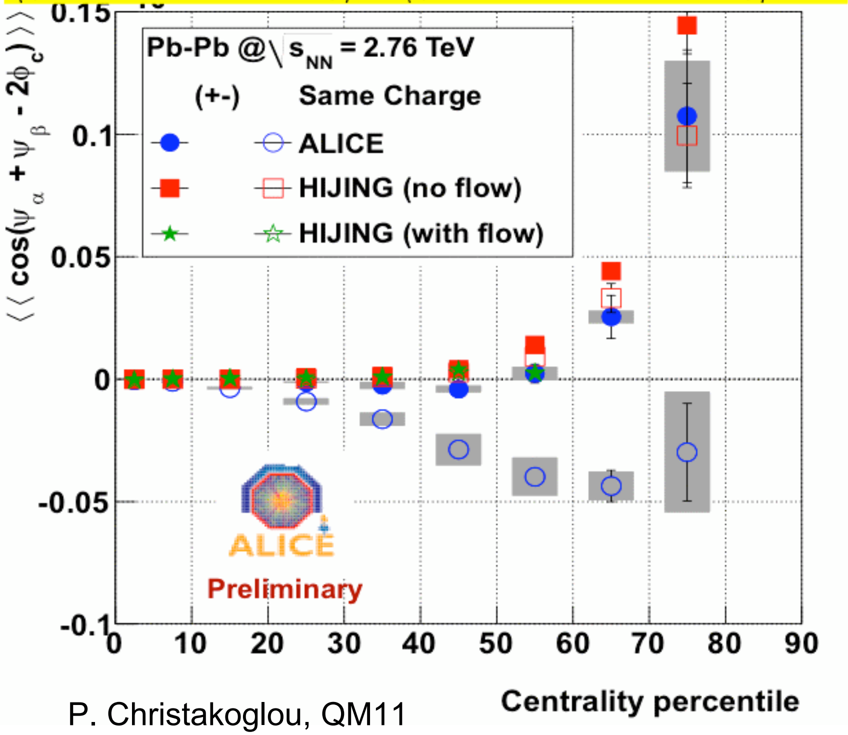
Two competing processes seen

Possible charge asymmetry signal from Local Parity Violation



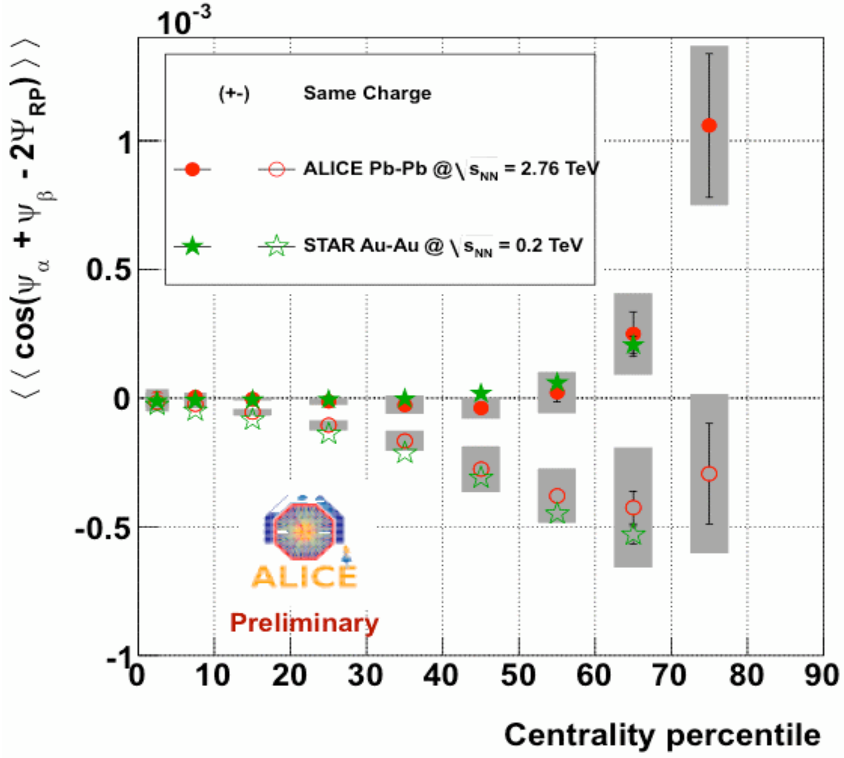
S. A. Voloshin, Phys. Rev. C **70**, 057901 (2004).

$$\left\langle\left\langle \cos(\psi_a + \psi_b - 2\phi_c) \right\rangle\right\rangle = \left\langle\left\langle \cos(\psi_a + \psi_b - 2\Psi_{RP}) \right\rangle\right\rangle \; v_{2,c}$$

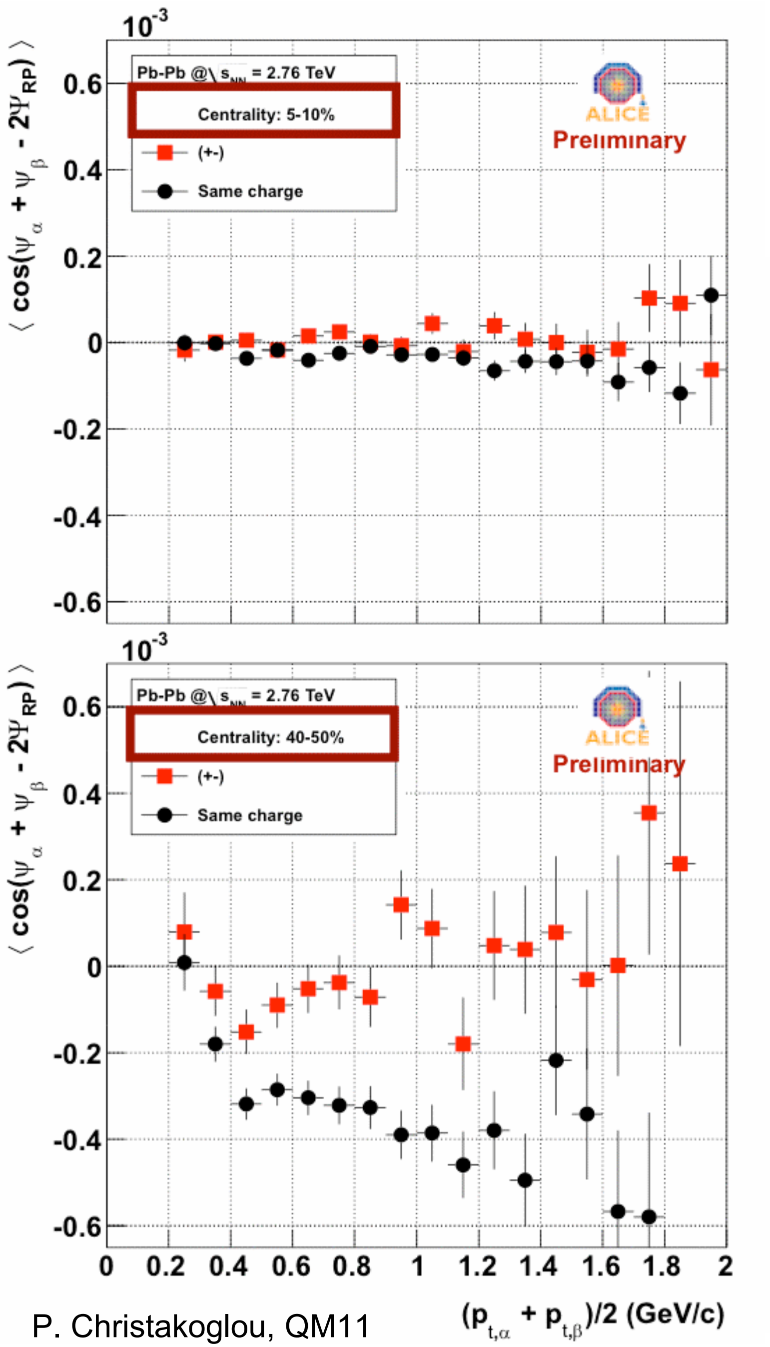


P. Christakoglou, QM11

STAR Collaboration: Phys. Rev. Lett. **81**, 251601 (2009)
STAR Collaboration: Phys. Rev. **C81**, 054908 (2010)



p_T dependence of the observed asymmetry signal



P. Christakoglou, QM11