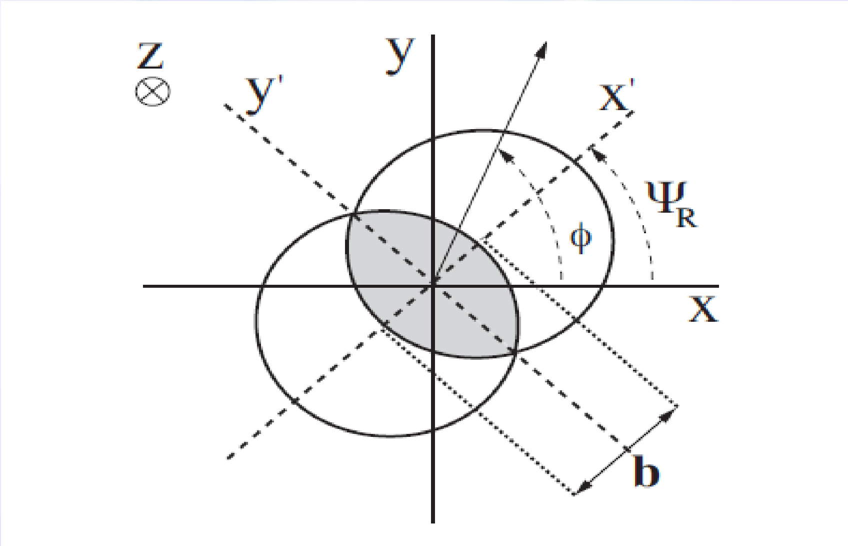
A simulation study of fluctuation effect on harmonic flow at FAIR Energy

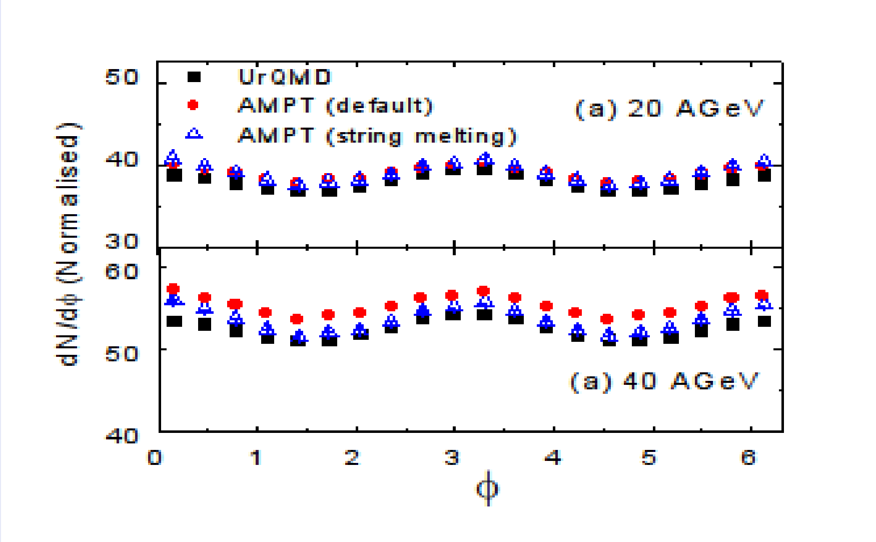
Soumya Sarkar
&
Amitabha Mukhopadhyay

University of North Bengal

International Conference on Matter under High Densities, 21 – 23 June 2016,
Sikkim Manipal Institute of Technology, Gangtok, Sikkim, India

Collective Flow





- Flow is – the nth Fourier coefficient v_n of the distributions of particle azimuthal angles with respect to the reaction plane.

$$\frac{dN}{d\phi} \propto 1 + 2\sum v_n \cos(n(\phi - \Psi)),$$

$$v_2 = \langle \cos(2(\phi - \Psi)) \rangle$$

The 2nd coefficient v_2 characterises the eccentricity of the particle distribution in momentum space.

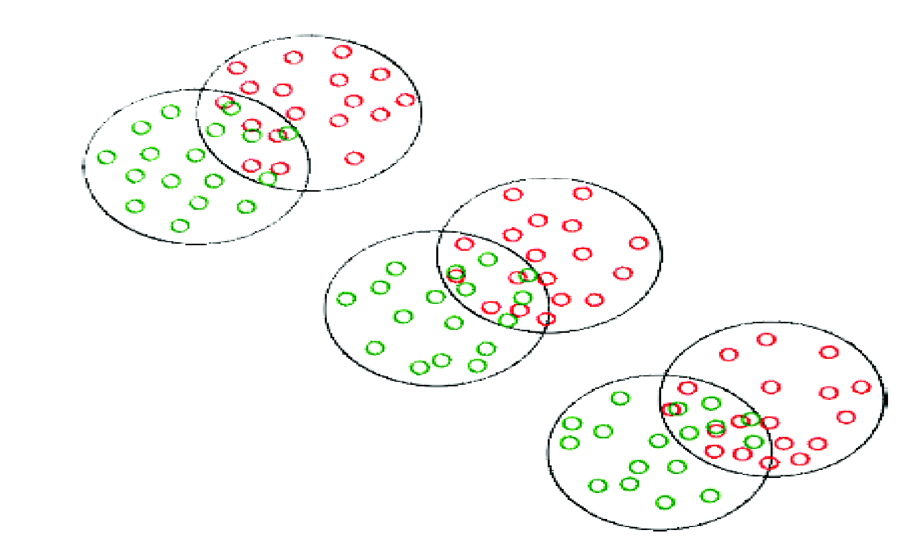
- The initial spatial anisotropy of the created system is quantified by the eccentricity :

$$\epsilon_{std} = \frac{\langle y^2 - x^2 \rangle}{\langle y^2 + x^2 \rangle}$$

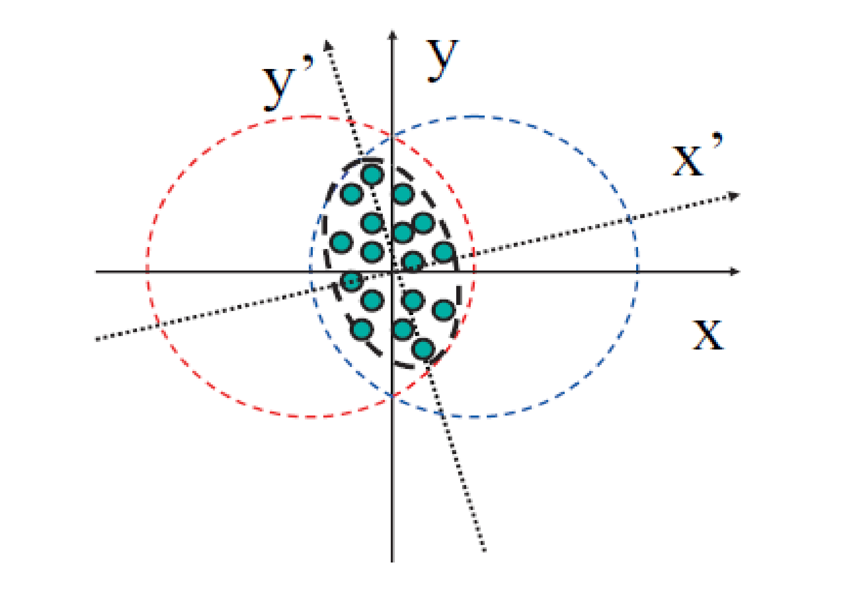
Reference:

- J.Y.Ollitrault, Phys.Rev.D 46, 229 (1992)
- S. A. Voloshin et.al. arXiv:0809.2949 [nucl-ex]

INTRODUCTION TO PARTICIPANT ECCENTRICITY



- **Two collisions are never identical**.In figure we have shown three collisions at **same impact parameter**.
- Initial spatial assymetry fluctuation leads to event by event fluctuation in anisotropic flow.

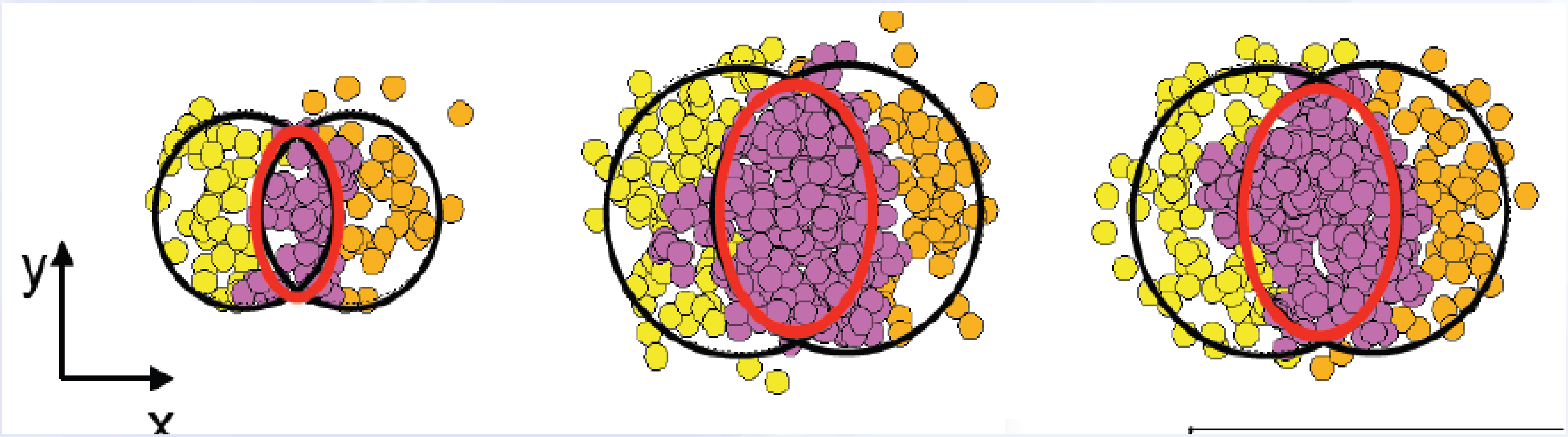


- One should define the eccentricity of initial spatial anisotropy in a proper way to take care of the event by event fluctuations.
- To accomodate the feature we define the eccentricity as :

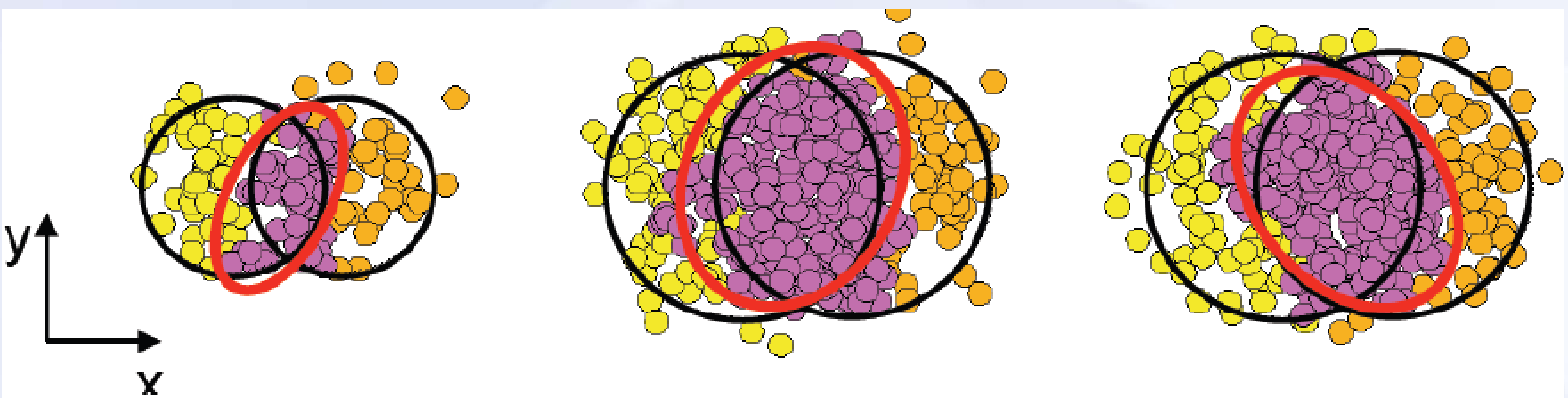
$$\epsilon_{part} = \frac{\langle y'^2 - x'^2 \rangle}{\langle y'^2 + x'^2 \rangle}$$

B.Alver *et.al*., Phys. Rev. Lett. 98, 242302(2007)

ECCENTRICITY (STANDARD)



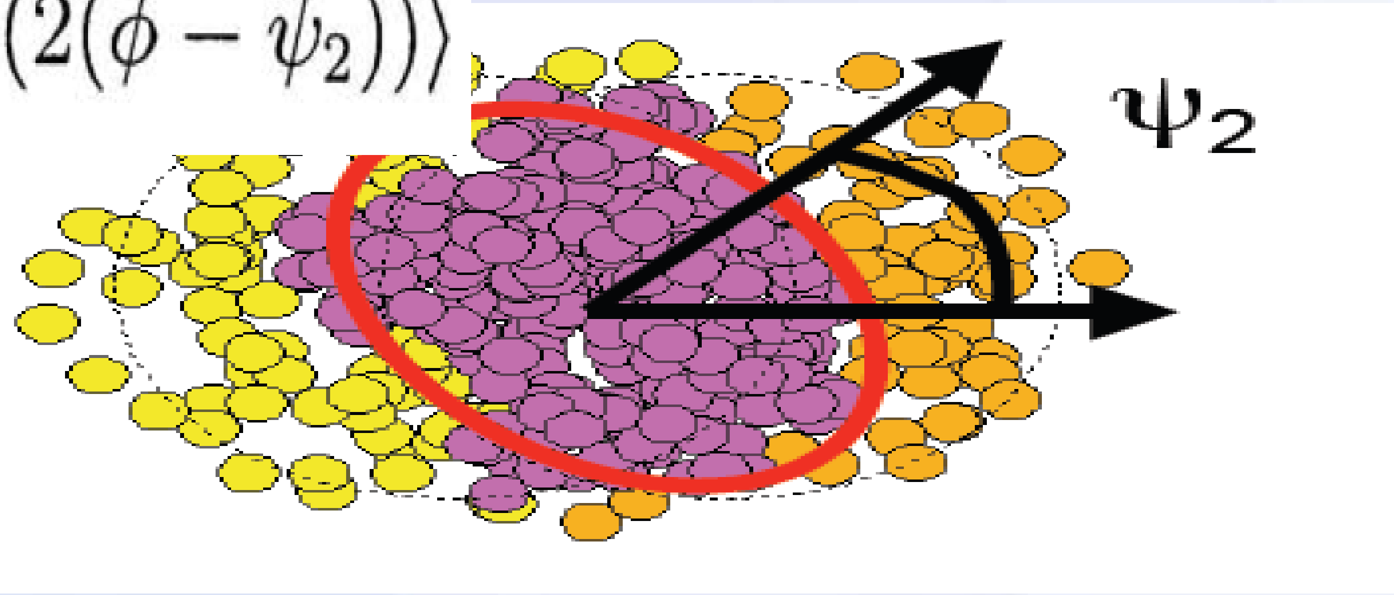
ECCENTRICITY (PARTICIPANT)



Courtesy: PHOBOS Collaboration

Participant eccentricity and elliptic flow

$$v_2 = \langle \cos(2(\phi - \psi_2)) \rangle$$



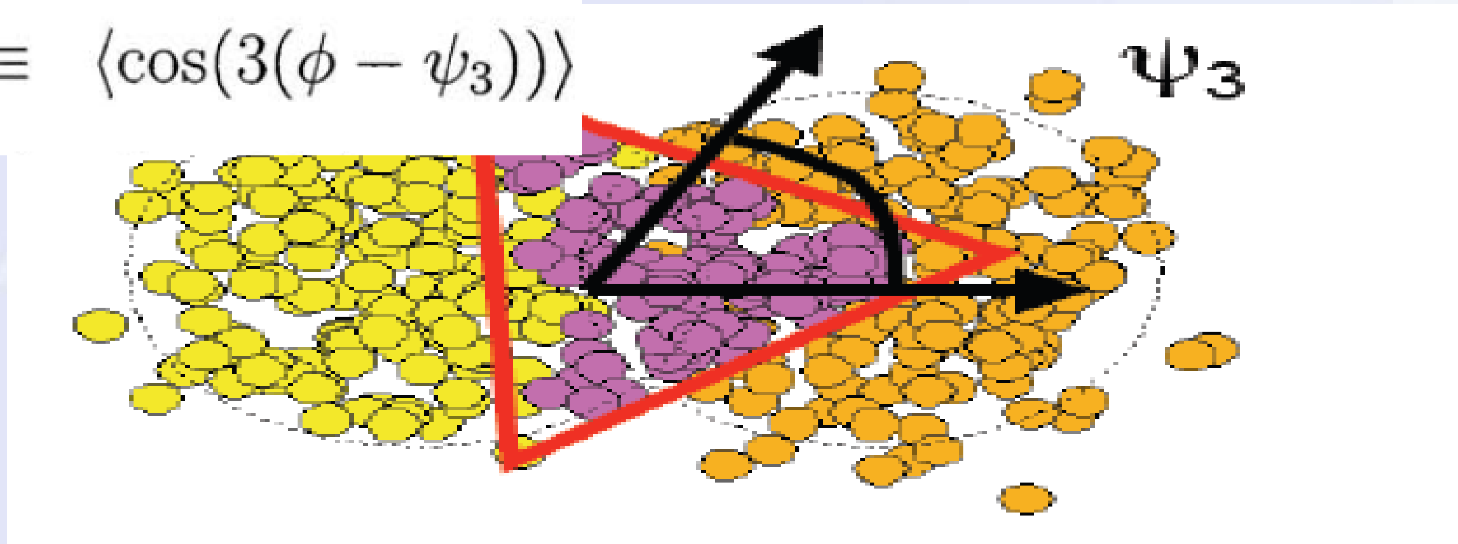
$$\varepsilon_2 = \frac{\sqrt{\langle r^2 \cos(2\phi_{\text{part}}) \rangle^2 + \langle r^2 \sin(2\phi_{\text{part}}) \rangle^2}}{\langle r^2 \rangle}$$

$$\psi_2 = \frac{\text{atan2}\left(\langle r^2 \sin(2\phi_{\text{part}}) \rangle , \langle r^2 \cos(2\phi_{\text{part}}) \rangle \right) + \pi}{2}$$

B. Alver *et.al*. Phys. Rev. C 81, 054905 (2010)

Participant triangularity and triangular flow

$$v_3 \equiv \langle \cos(3(\phi - \psi_3)) \rangle$$



$$\varepsilon_3 \equiv \frac{\sqrt{\langle r^2 \cos(3\phi_{\rm part}) \rangle^2 + \langle r^2 \sin(3\phi_{\rm part}) \rangle^2}}{\langle r^2 \rangle}$$

$$\psi_3 = \frac{\mathrm{atan2}\left(\langle r^2 \sin(3\phi_{\rm part}) \rangle, \langle r^2 \cos(3\phi_{\rm part}) \rangle\right) + \pi}{3}$$

B. Alver *et.al*. Phys. Rev. C 81, 054905 (2010)

Our Analysis

1. System : Au + Au

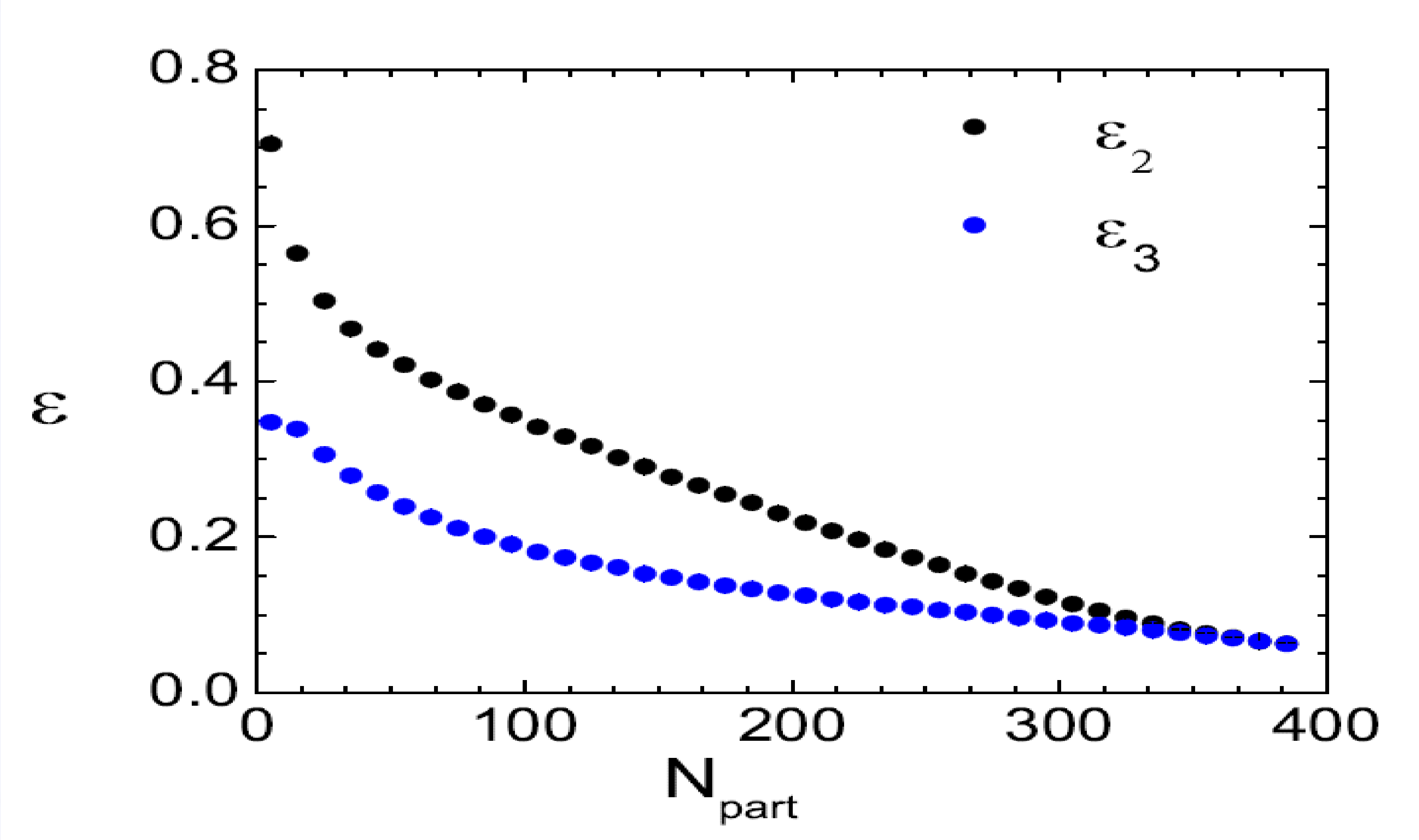
2. Energy : 30A GeV (lab)

3. Model : AMPT (String Melting)

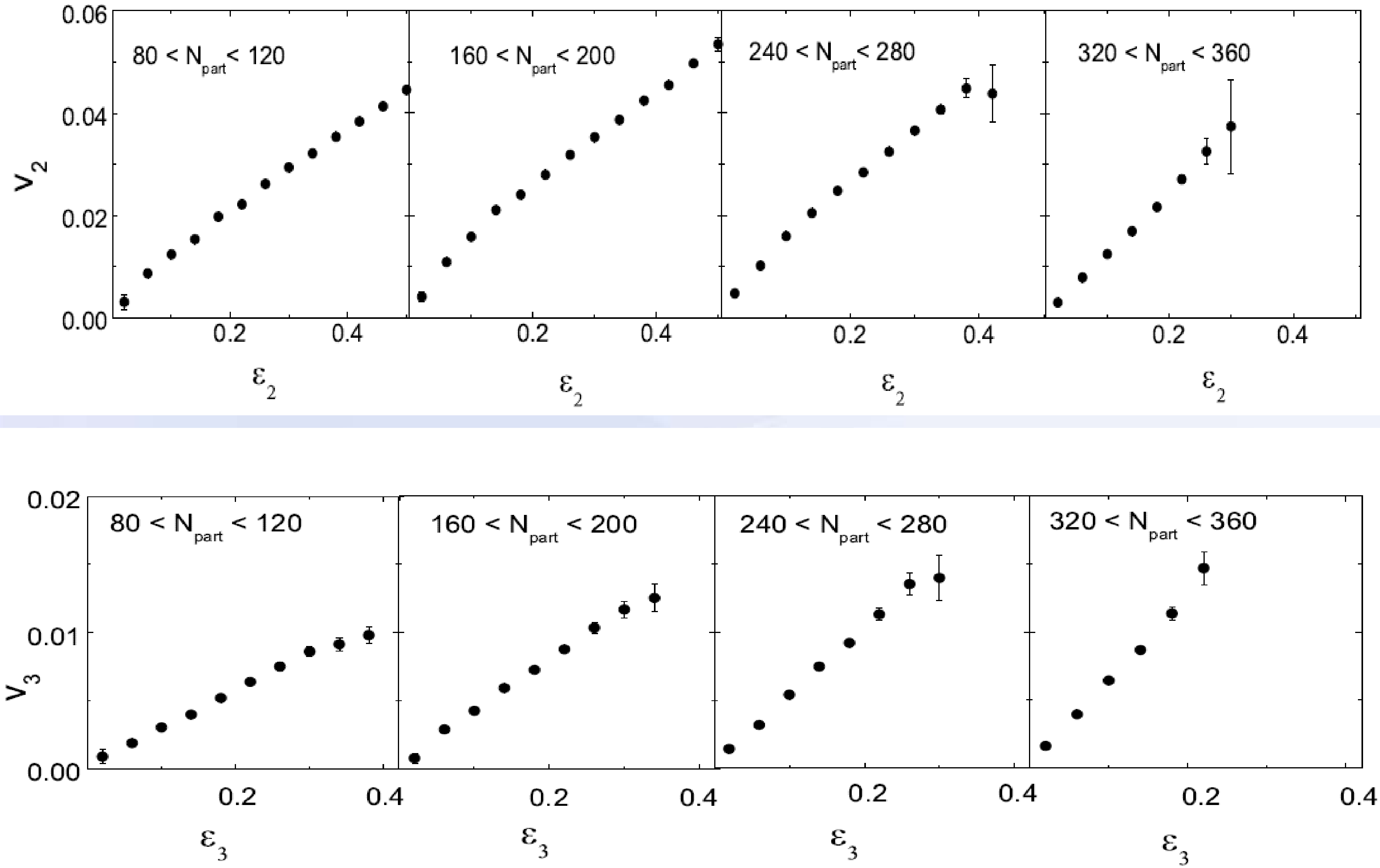
4. Statistics : 1 Million (minimum biased)

5. Parton scattering cross-section : 3, 6 and 10 mb

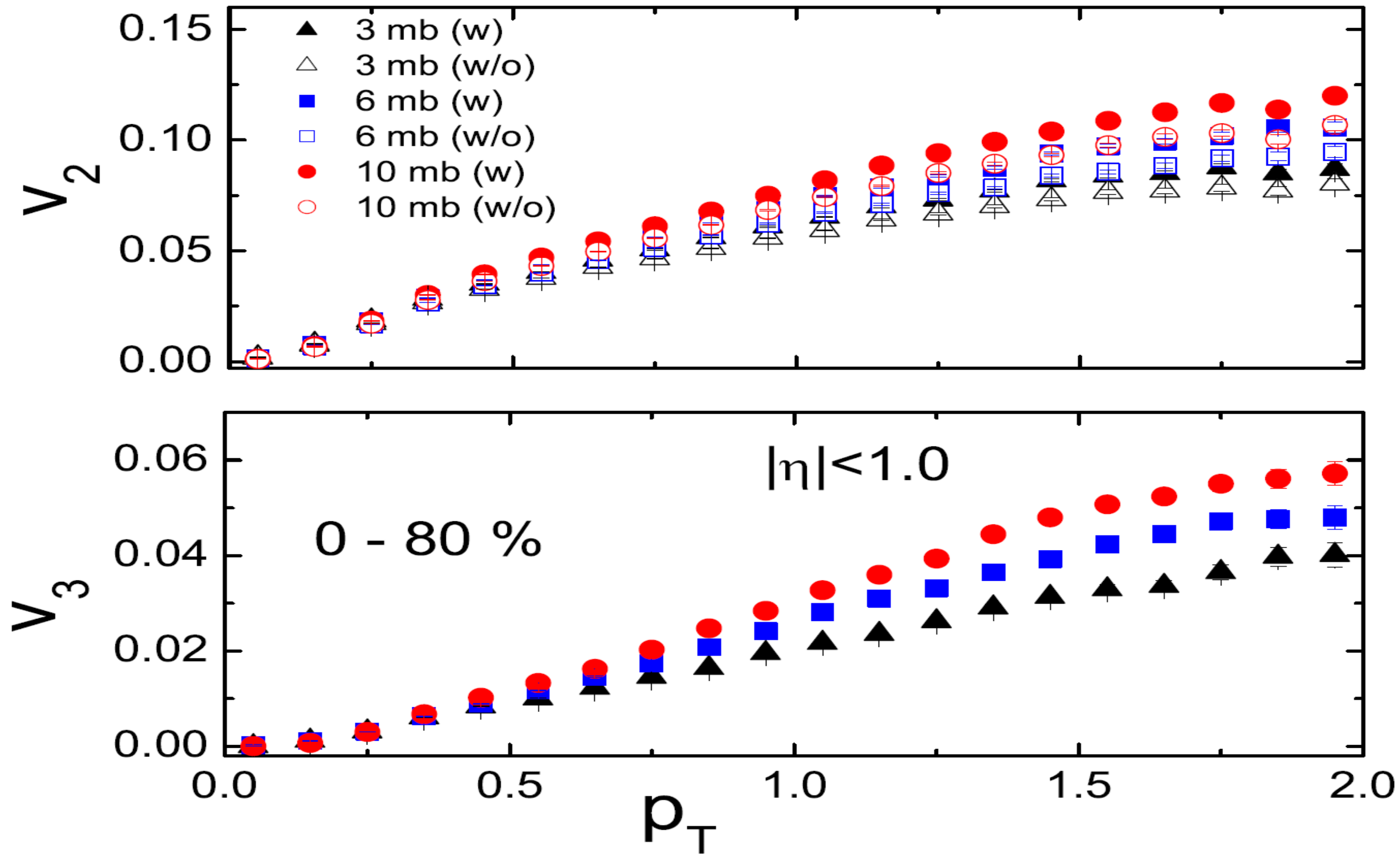
RESULTS



Eccentricity is larger than triangularity except in very central collisions



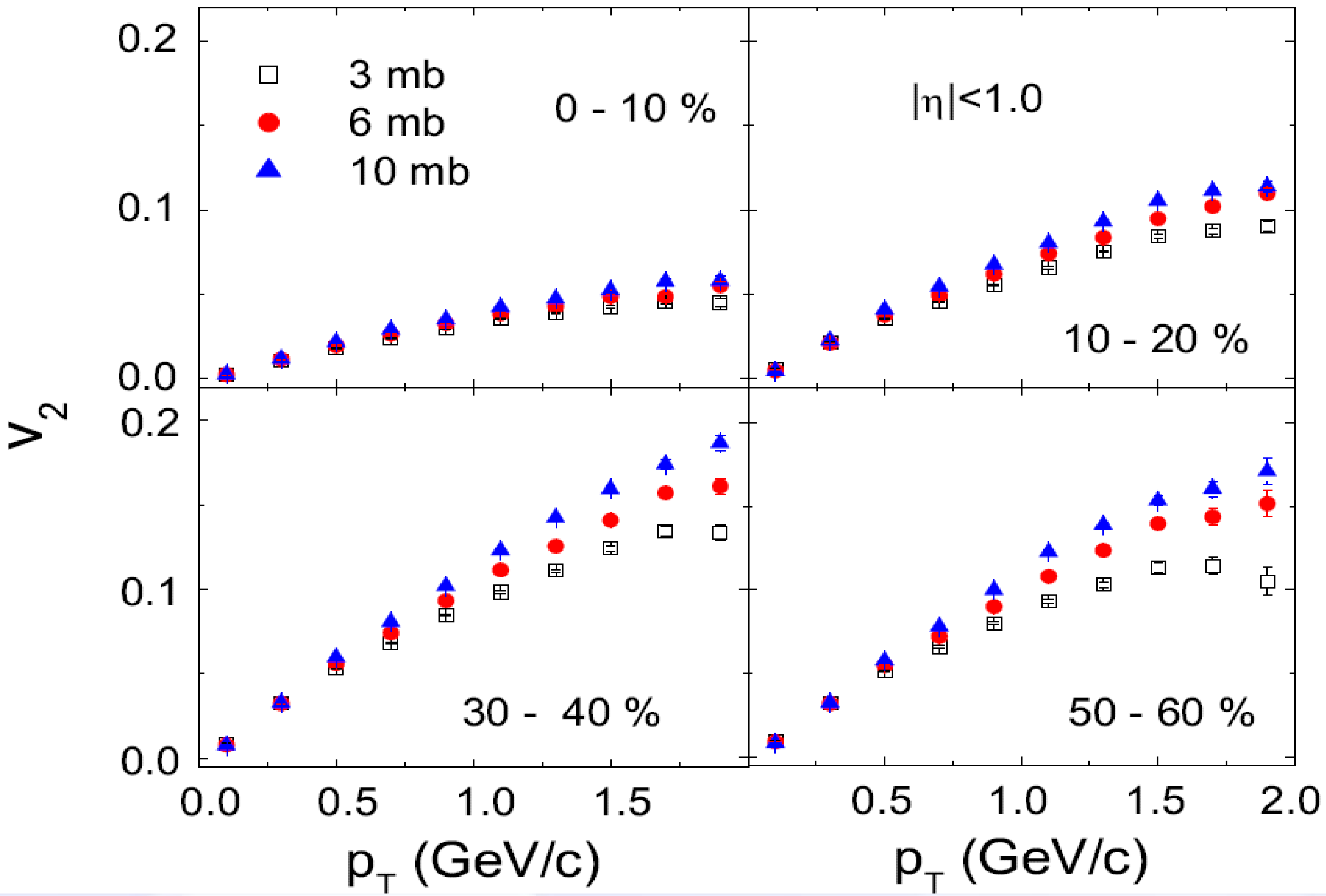
Conversion efficiency decreases with the order of harmonic flow



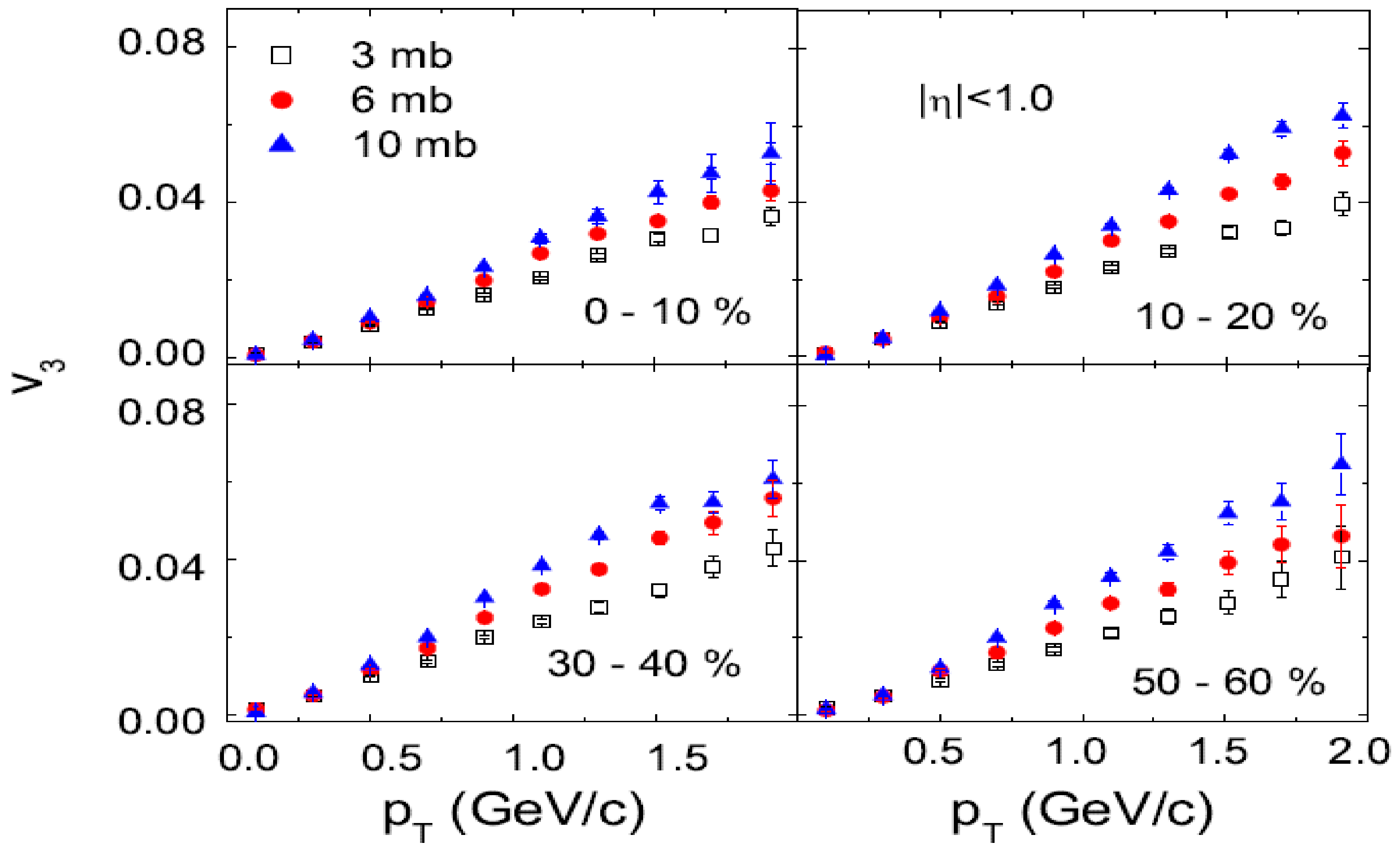
Overall similar trend as results at RHIC energies

L. X. Han *et.al*. Phys. Rev. C 84, 064907 (2011)

Centrality dependence of elliptic flow

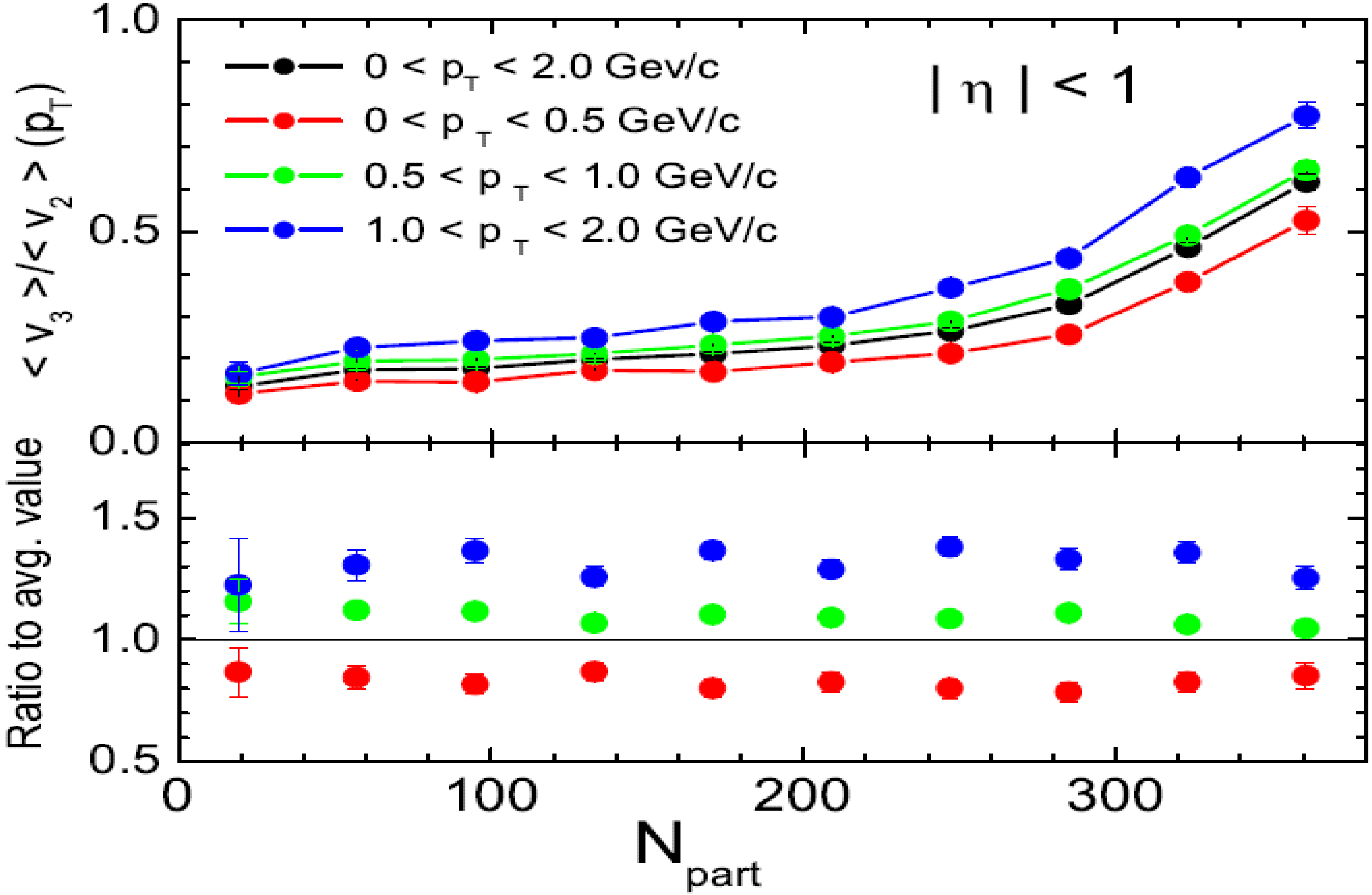


Centrality dependence of triangular flow



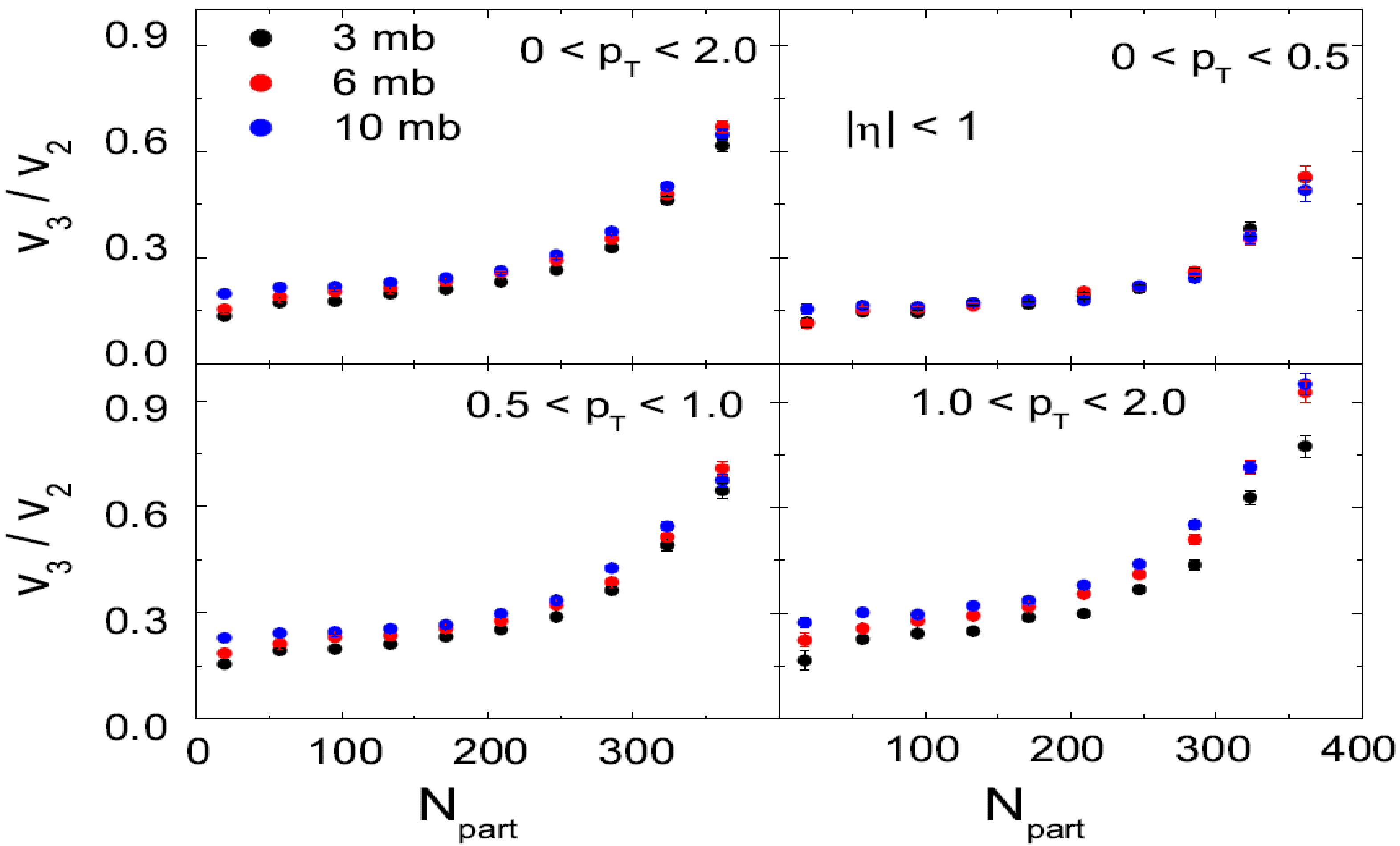
Triangular flow shows less centrality dependence than elliptic flow

Relative magnitude



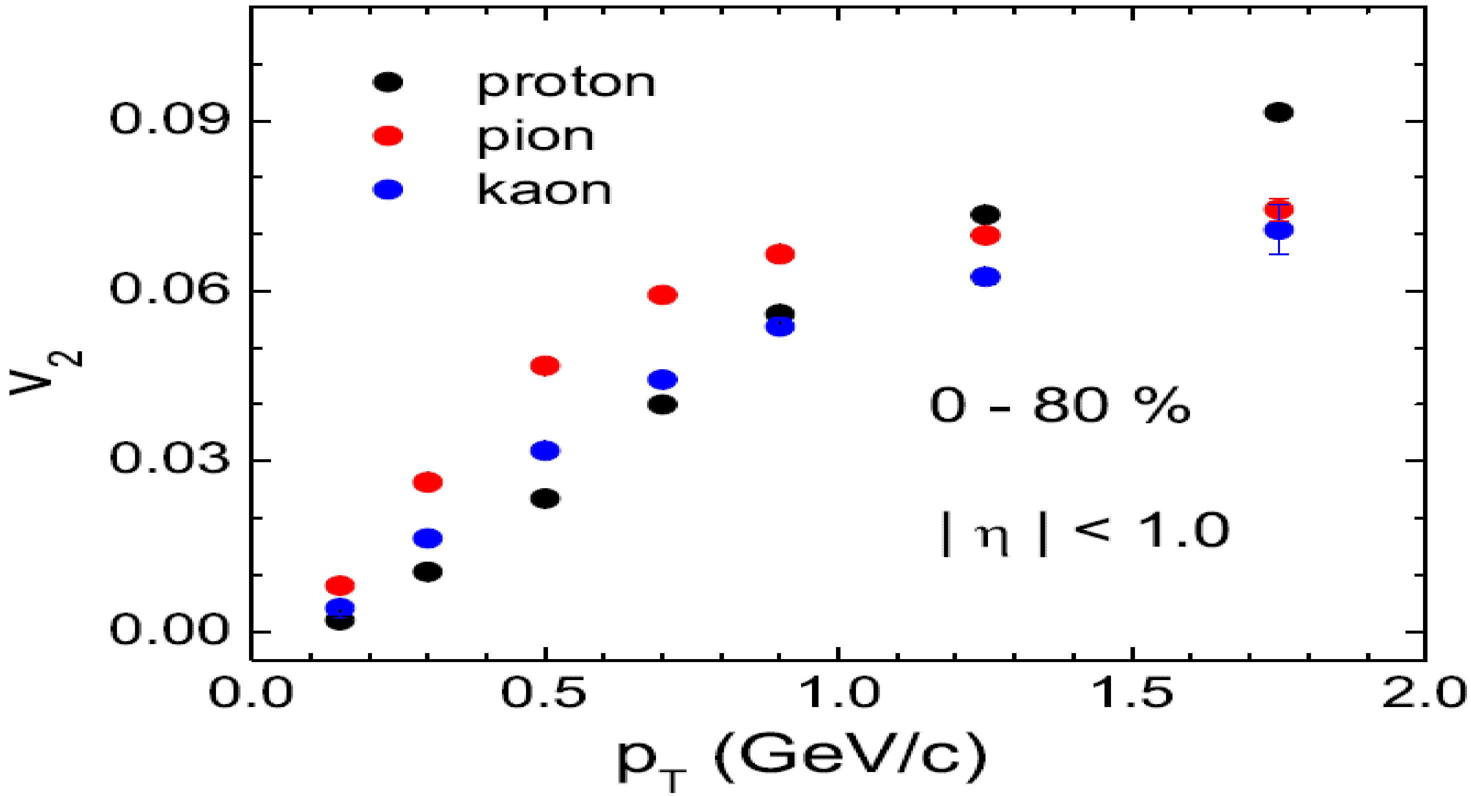
Relative strength of triangular flow increases with centrality and transverse momentum

Cross-section dependence of relative strength



Cross-section dependence is more pronounced at high transverse momentum

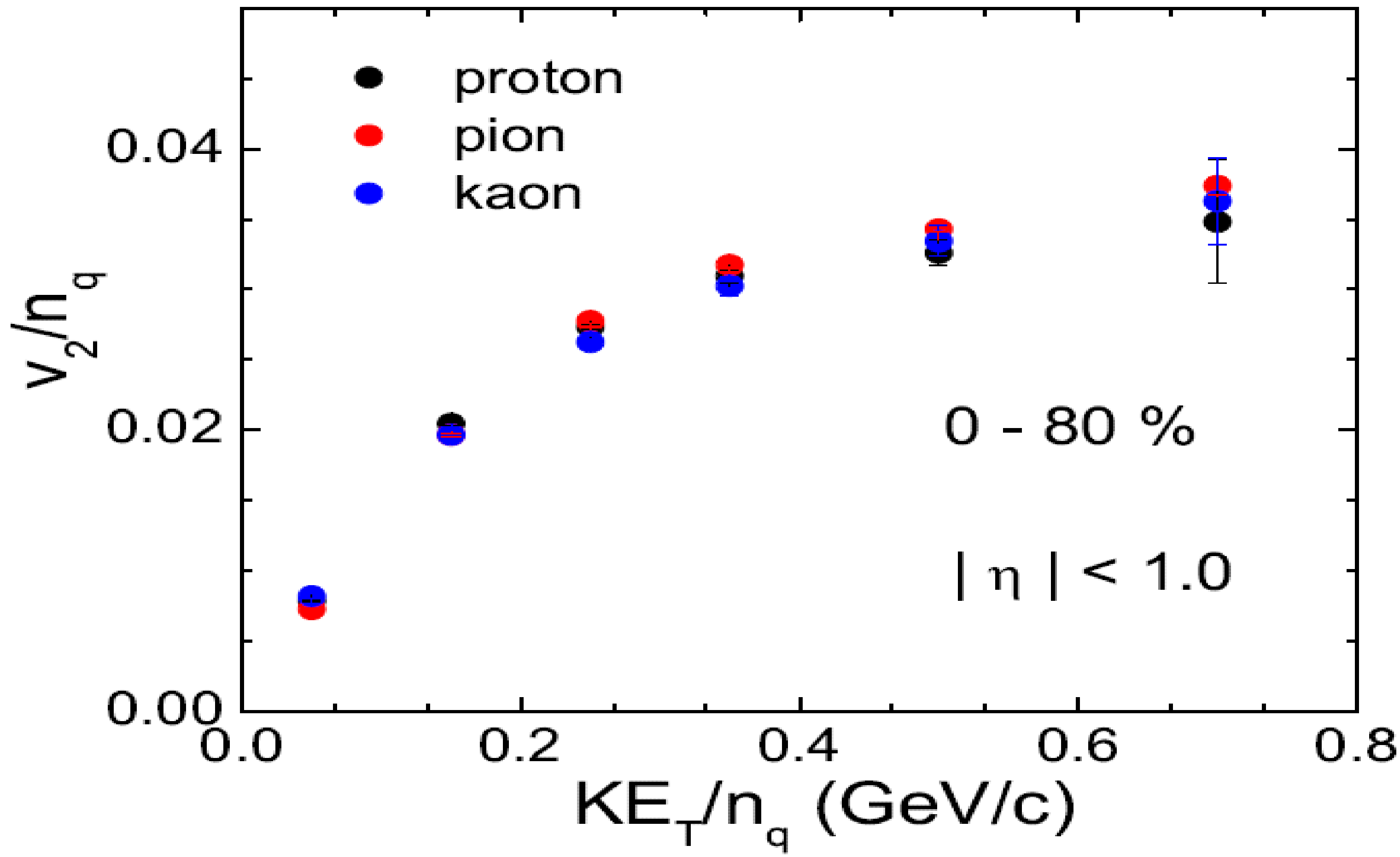
Species dependence of elliptic flow



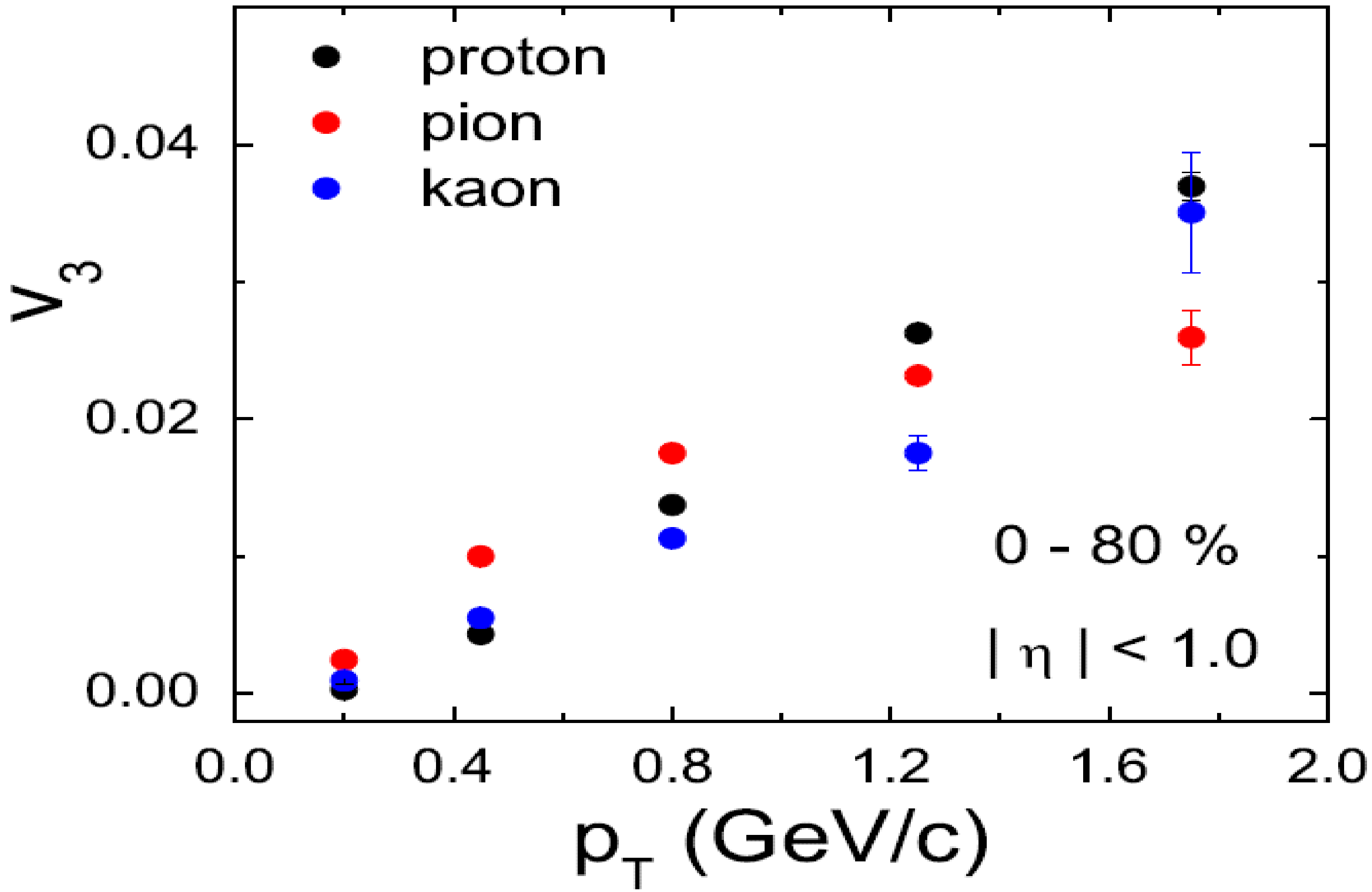
Mass ordering is revealed even after considering fluctuation

P.P.Bhaduri *et al*. Phys.Rev. C **81**, 034906 (2010)

Quark number scaling



Species dependence of triangular flow



Weak Mass ordering ?? L. X. Han et.al. Phys. Rev. C 84, 064907 (2011)

Conclusion

1. Elliptic and triangular flow analysis is performed with AMPT (string melting) simulated data at 30A GeV at three different (3, 6, 10 mb) parton scattering cross-section.

2. The flow systematics follow similar trend like other anaysis available in literature.

3. Centrality dependence of triangular flow is less than elliptic flow.

4. Relative strength of triangular flow increases with transverse momentum and also centrality.

5. Elliptic flow shows mass ordering and quark no. scaling even after considering initial fluctuations.

6. Mass ordering in triangular flow is weak in comparison to that at RHIC energies.

Future Plan

1. We intend to perform the same analysis using the cumulant method and compare them with our existing reaction plane results.

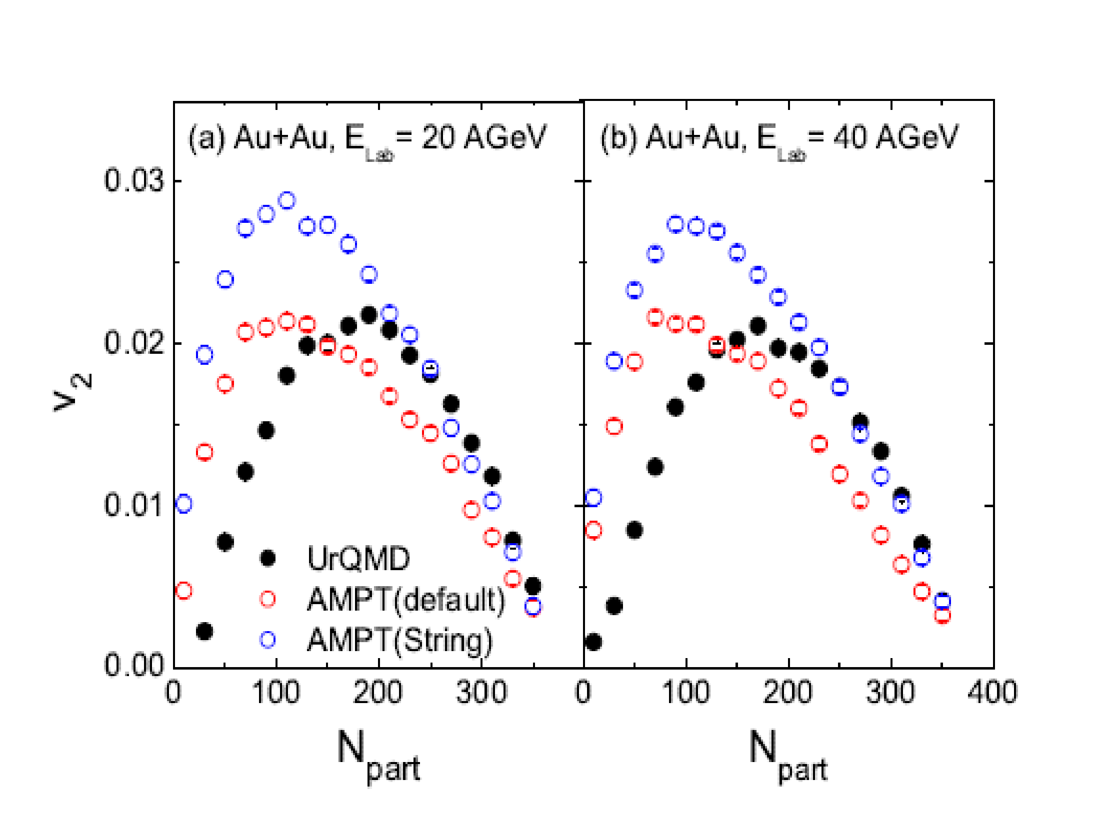
2. We will also deal with different colliding systems proposed for CBM – both symmetric (Au+Au or Ni+Ni) and asymmetric (Au+Ni) for a better understanding of the geometrical effects to collective flow.

3. We have also planned to perform different types of physics analysis related to collective flow over the entire energy range, that is, E_{lab}= 10 – 40A GeV.

THANK YOU

BACK UP

CENTRALITY DEPENDANCE OF ELLIPTIC FLOW AT 20 AGeV & 40 AGeV FROM DIFFERENT MODELS

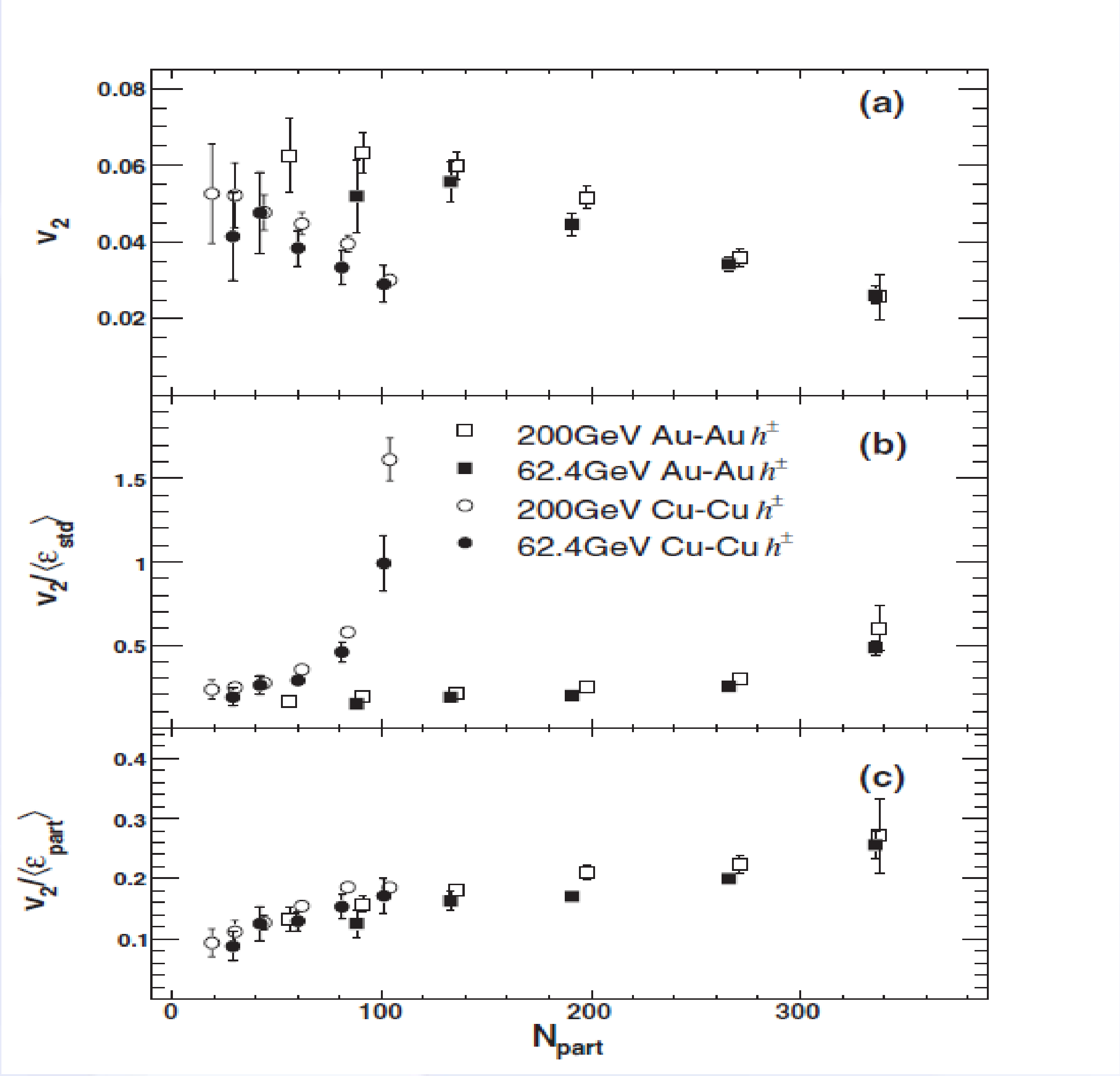


- v_2 hardly changes with energy.
- Models yield different v_2 values at same centality class for mid-central to peripheral collisions:
- v_2 values are nearly same in the central region having decreasing trend.
- The peak of v_2 data obtained from AMPT is found at lower N_{part} values in comparison to UrQMD.

Similar results were obtained at 200 GeV

Reference:

- Csernai et.al. Euro.Phys.J.A, **45**, 353 (2010)
- X. Zhu et.al. Phys. Rev. C **72**, 064911 (2005)



(a)
(b)
(c)
0.08
0.06
0.04
0.02
v_2
1.5
1
0.5
$v_2/\langle\varepsilon_{std}\rangle$
0.4
0.3
0.2
0.1
$v_2/\langle\varepsilon_{part}\rangle$
200GeV Au-Au $h^{\pm}$
62.4GeV Au-Au $h^{\pm}$
200GeV Cu-Cu $h^{\pm}$
62.4GeV Cu-Cu $h^{\pm}$
0
100
200
300
N_{part}