Elliptic Flow From STAR

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Methods

$$\frac{dN}{d\phi} \sim 1 + 2v_1\cos(\phi - \psi_1) + 2v_2\cos(\phi - \psi_2) + \cdots$$

- Particles correlated with the event plane

$$v_n = \langle e^{in(\phi_i - \psi_n)} \rangle = \cos(n(\phi_i - \psi_n))$$

- Particles pair correlations

Both are based on two–particle correlations

$$v_n^2 = \langle e^{in(\phi_i - \phi_j)} \rangle_{i \neq j} = \cos(n(\phi_i - \phi_j))_{i \neq j}$$

- Four–particle correlations (cumulants)

$$-v_n^4 = \langle e^{in(\phi_1 + \phi_2 - \phi_3 - \phi_4)} \rangle - \langle e^{in(\phi_1 - \phi_3)} \rangle \langle e^{in(\phi_2 - \phi_4)} \rangle - \langle e^{in(\phi_1 - \phi_4)} \rangle \langle e^{in(\phi_2 - \phi_3)} \rangle$$

$$= \cos(n(\phi_1 + \phi_2 - \phi_3 - \phi_4)) - \cos(n(\phi_1 - \phi_3))\cos(n(\phi_2 - \phi_4)) - \cos(n(\phi_1 - \phi_4))\cos(n(\phi_2 - \phi_3))$$

Four–particle correlations
Motivation for cumulants

The correlation between two particles is

$$\langle u_{n,1} u_{n,2}^{*} \rangle \equiv \langle e^{in\phi_1} e^{-in\phi_2} \rangle = v_n^2 + \delta_n$$

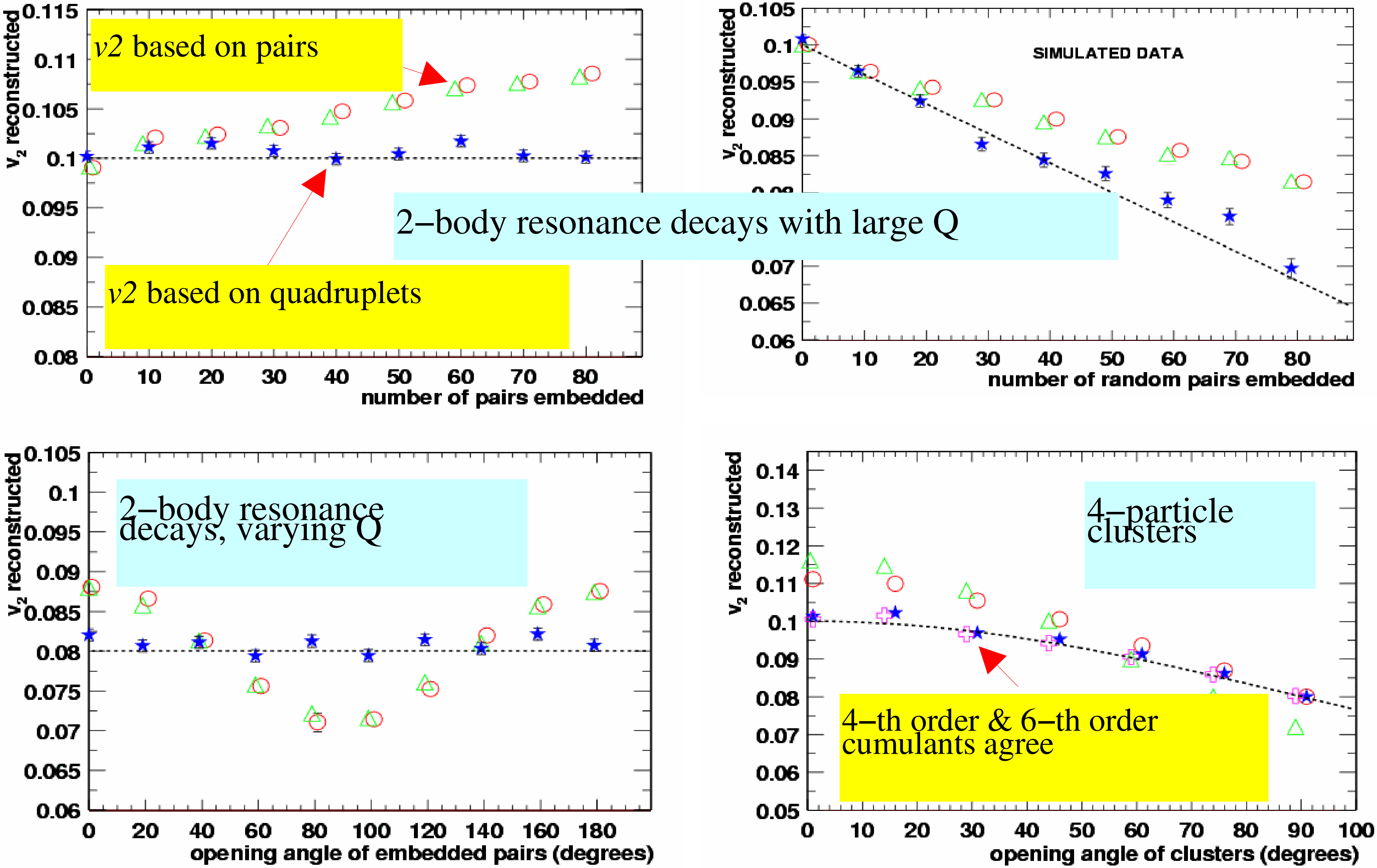
Correlating four particles, one gets

$$\langle u_{n,1} u_{n,2} u_{n,3}^{*} u_{n,4}^{*} \rangle = v_n^4 + 2 \cdot 2 \cdot v_n^2 \delta_n + 2\,\delta_n^2$$

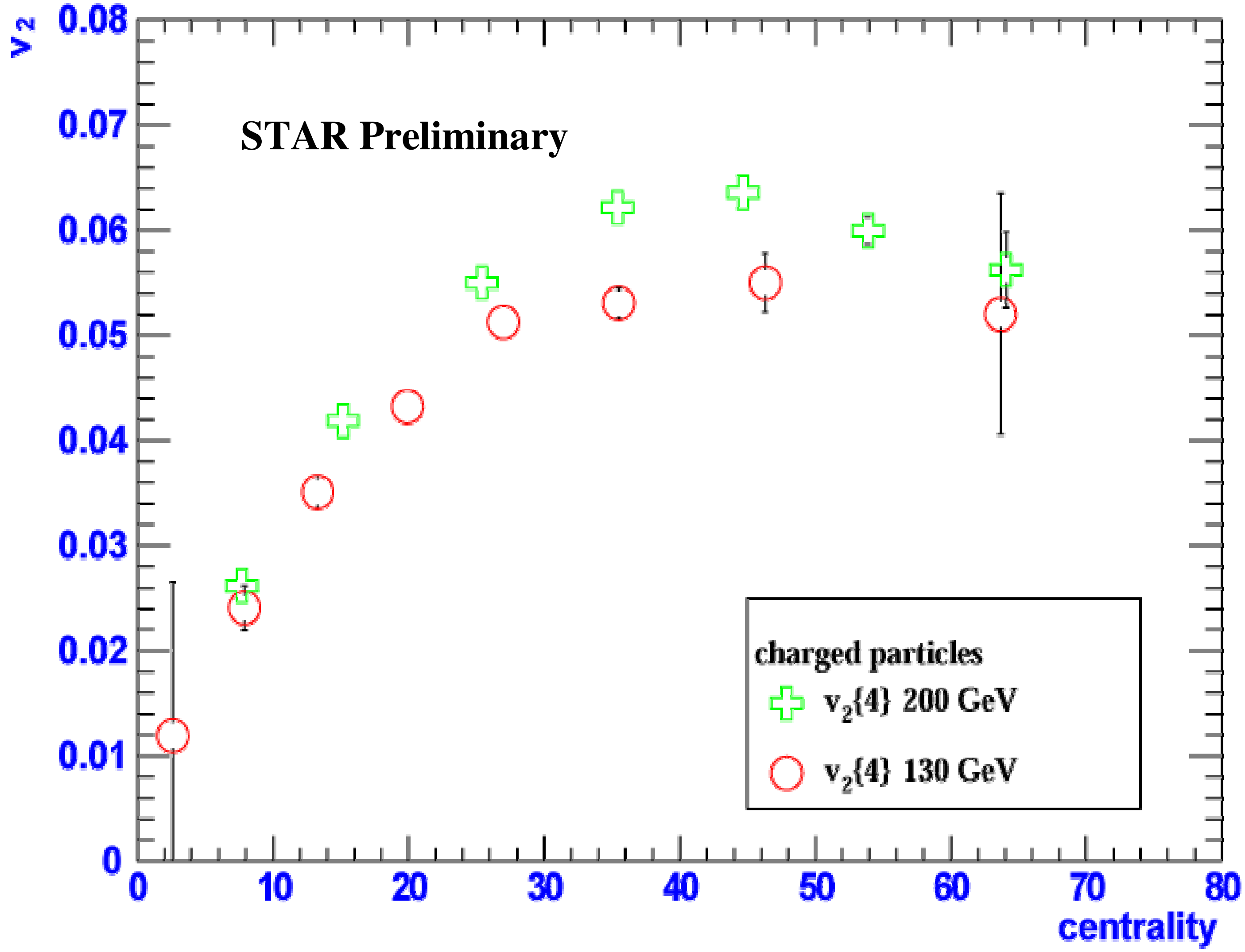
The nonflow term δ_n is thus canceled in the cumulant:

$$\langle\langle u_{n,1} u_{n,2} u_{n,3}^{*} u_{n,4}^{*} \rangle\rangle \equiv \langle u_{n,1} u_{n,2} u_{n,3}^{*} u_{n,4}^{*} \rangle - 2 \langle u_{n,1} u_{n,2}^{*} \rangle^2 = -v_n^4$$

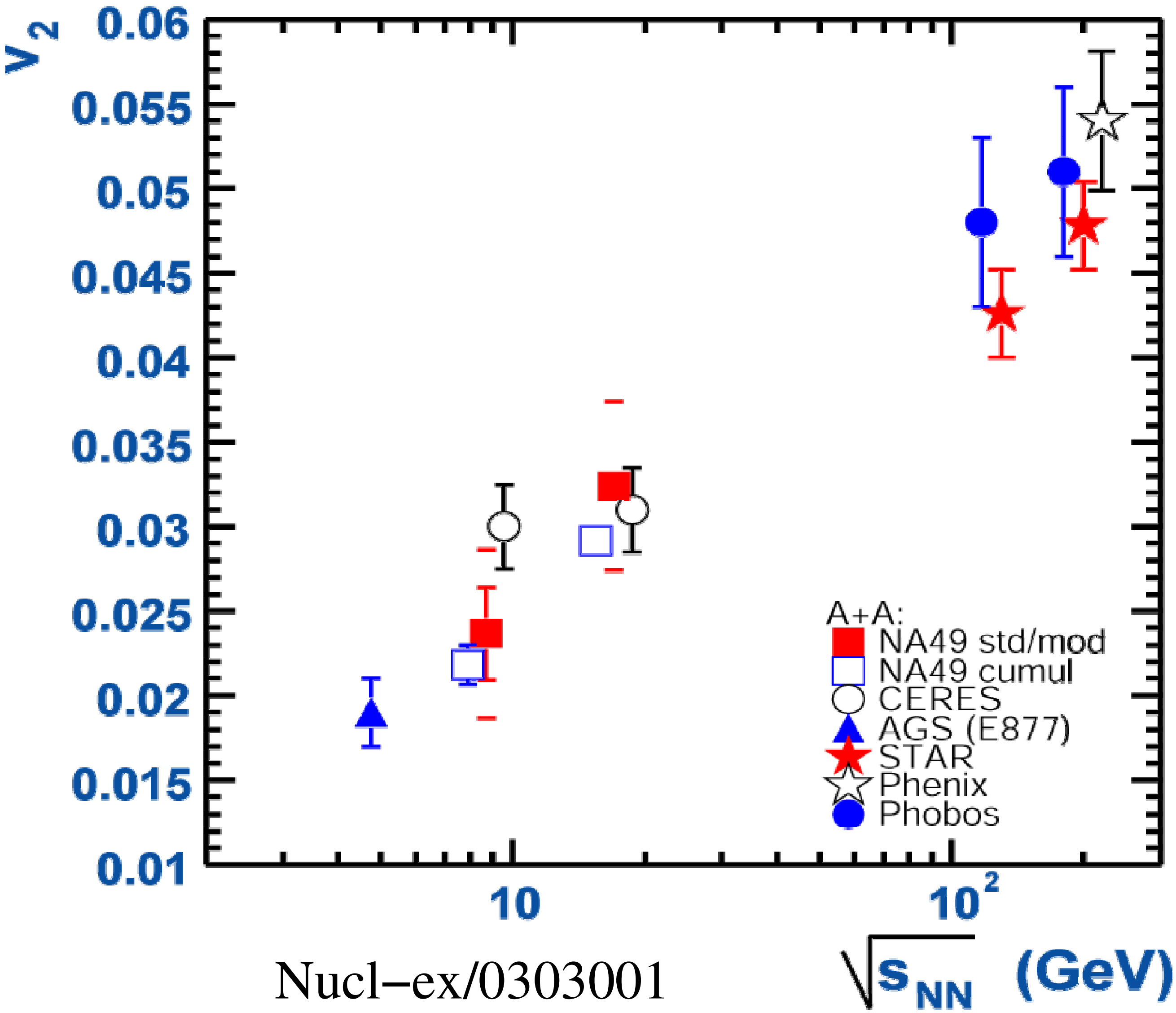
Four−particle correlations
Simulations



Comparing v2 for 130 and 200 GeV



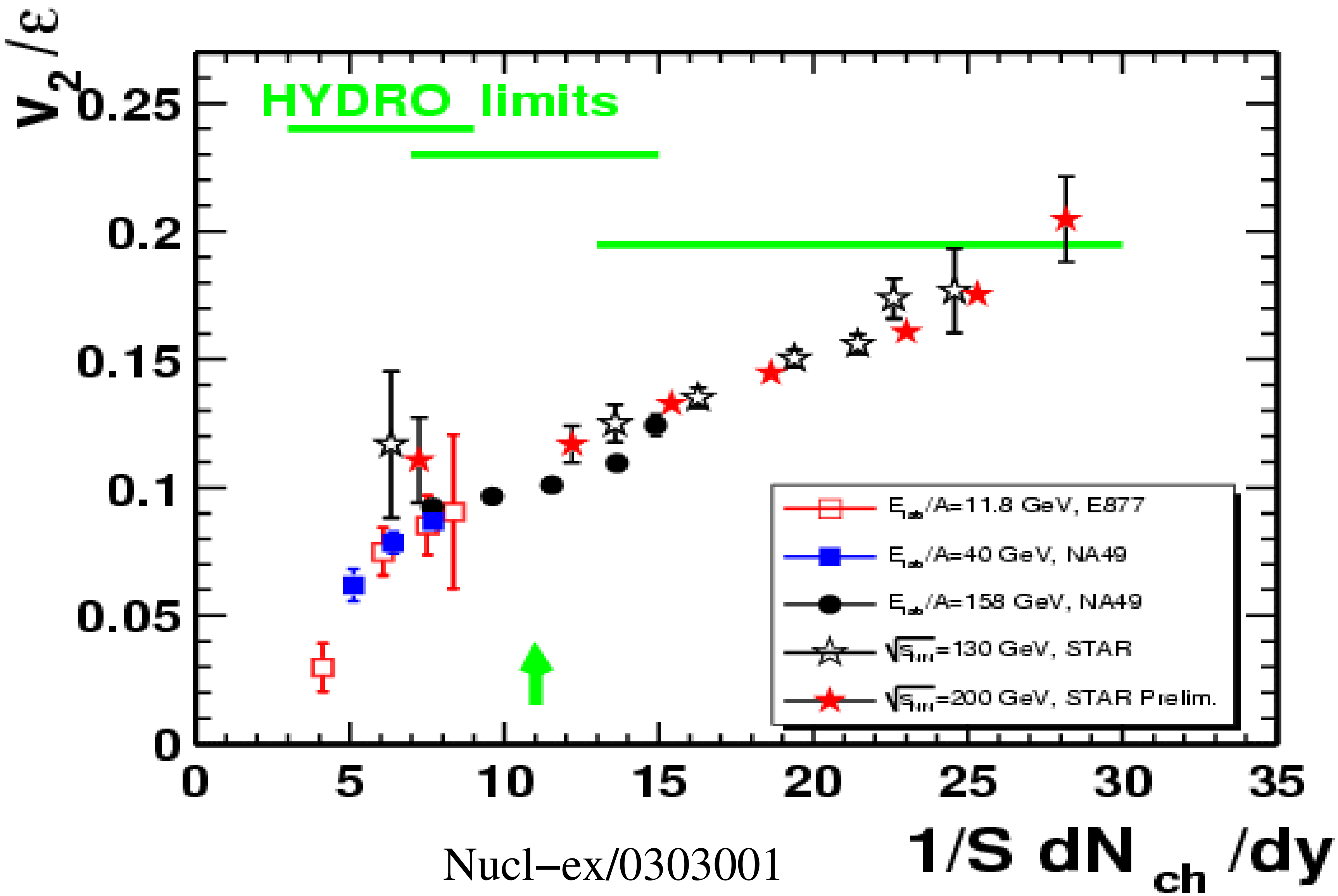
Elliptic flow; excitation function



Nucl–ex/0303001

Monotonically increases with the beam energy

Elliptic flow; Reaching Hydro limit?



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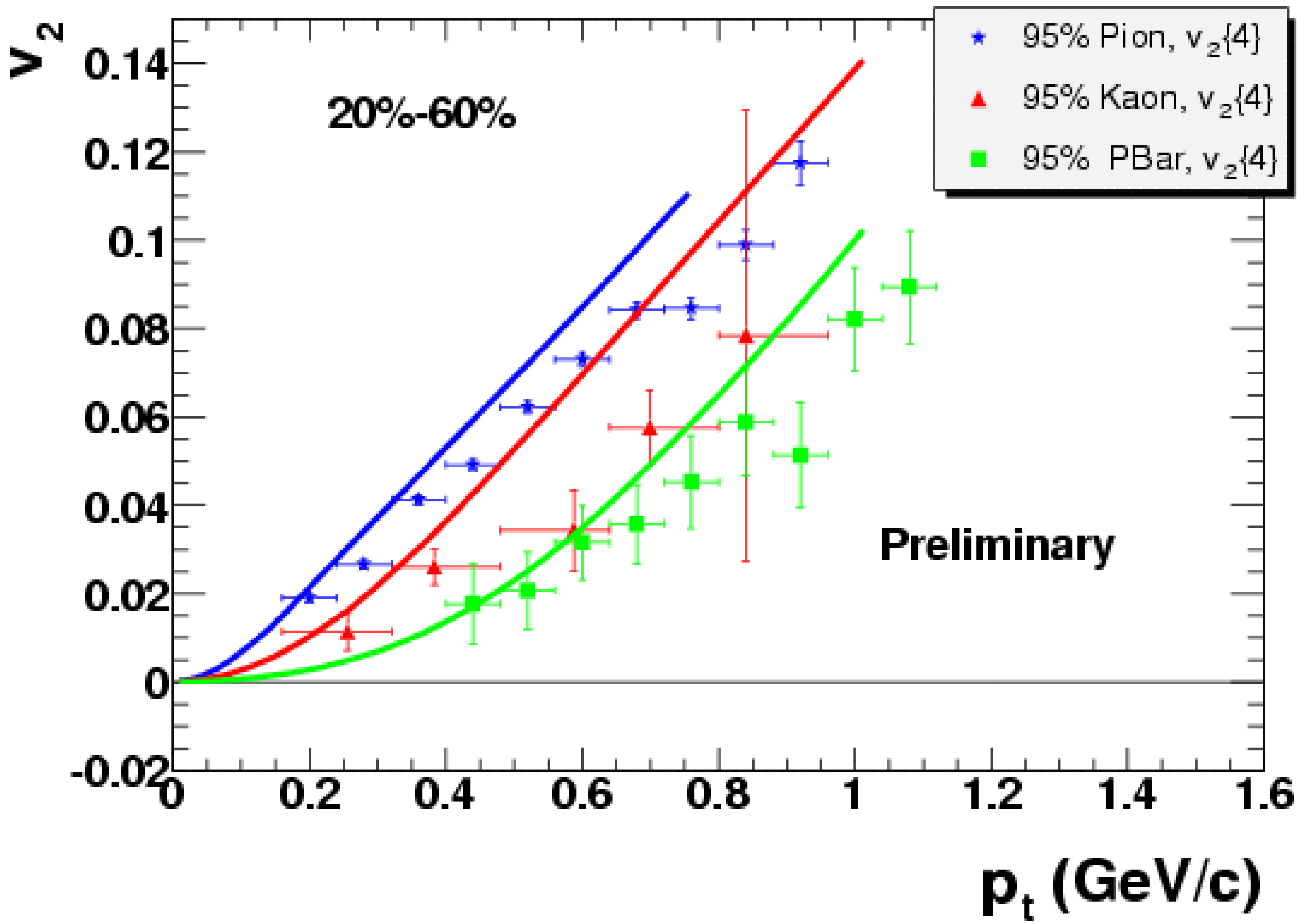
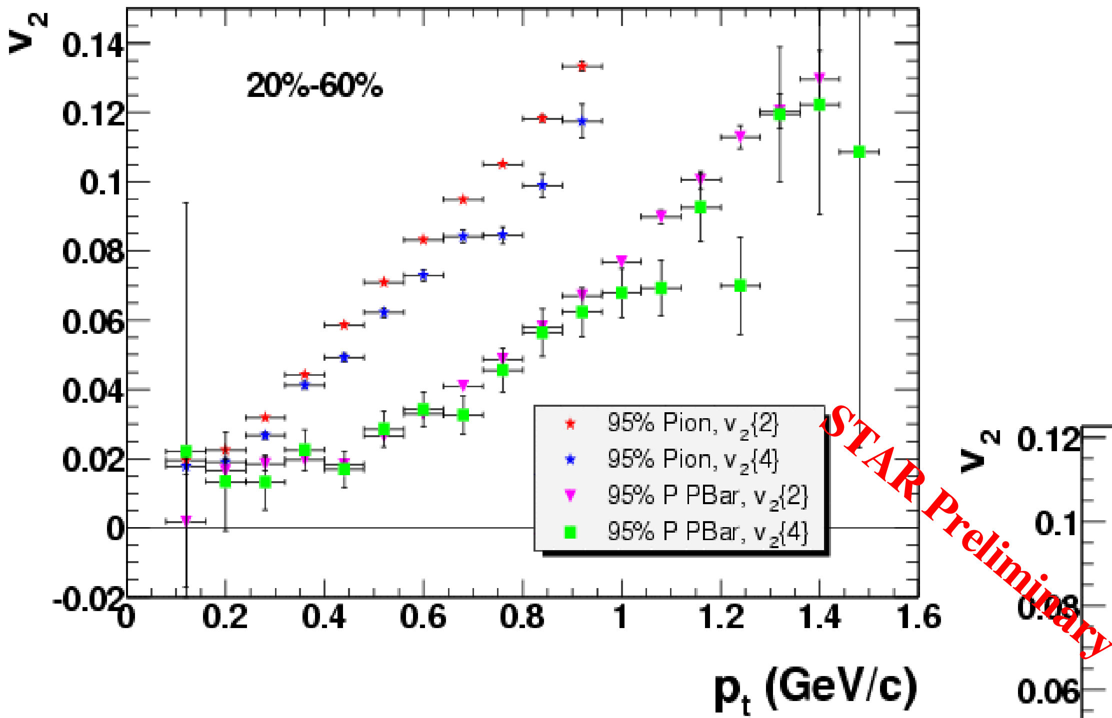
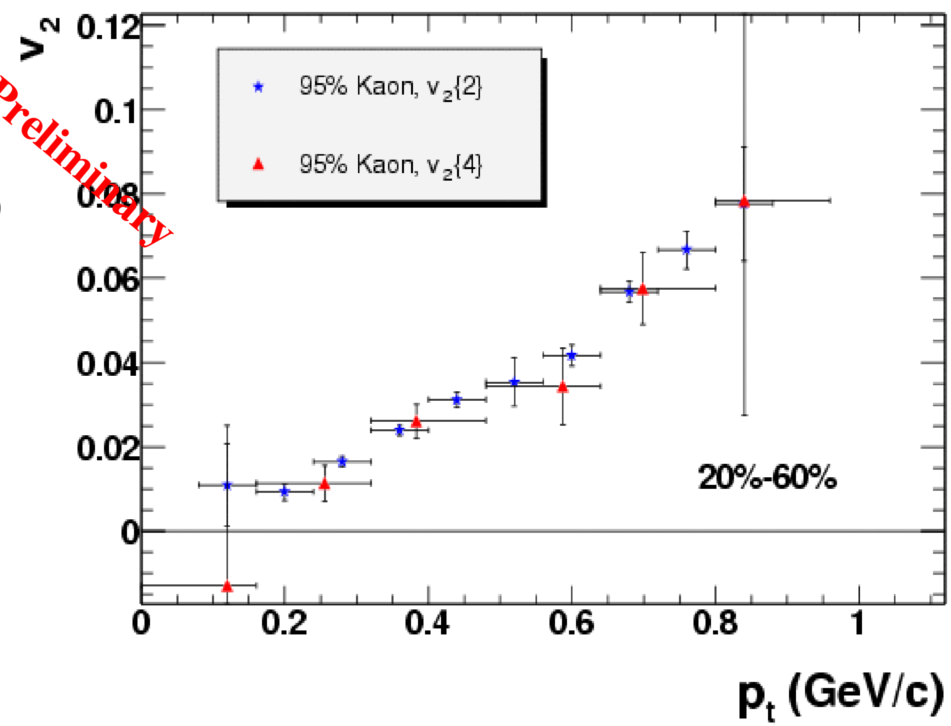
Elliptic Flow For Identified Particles



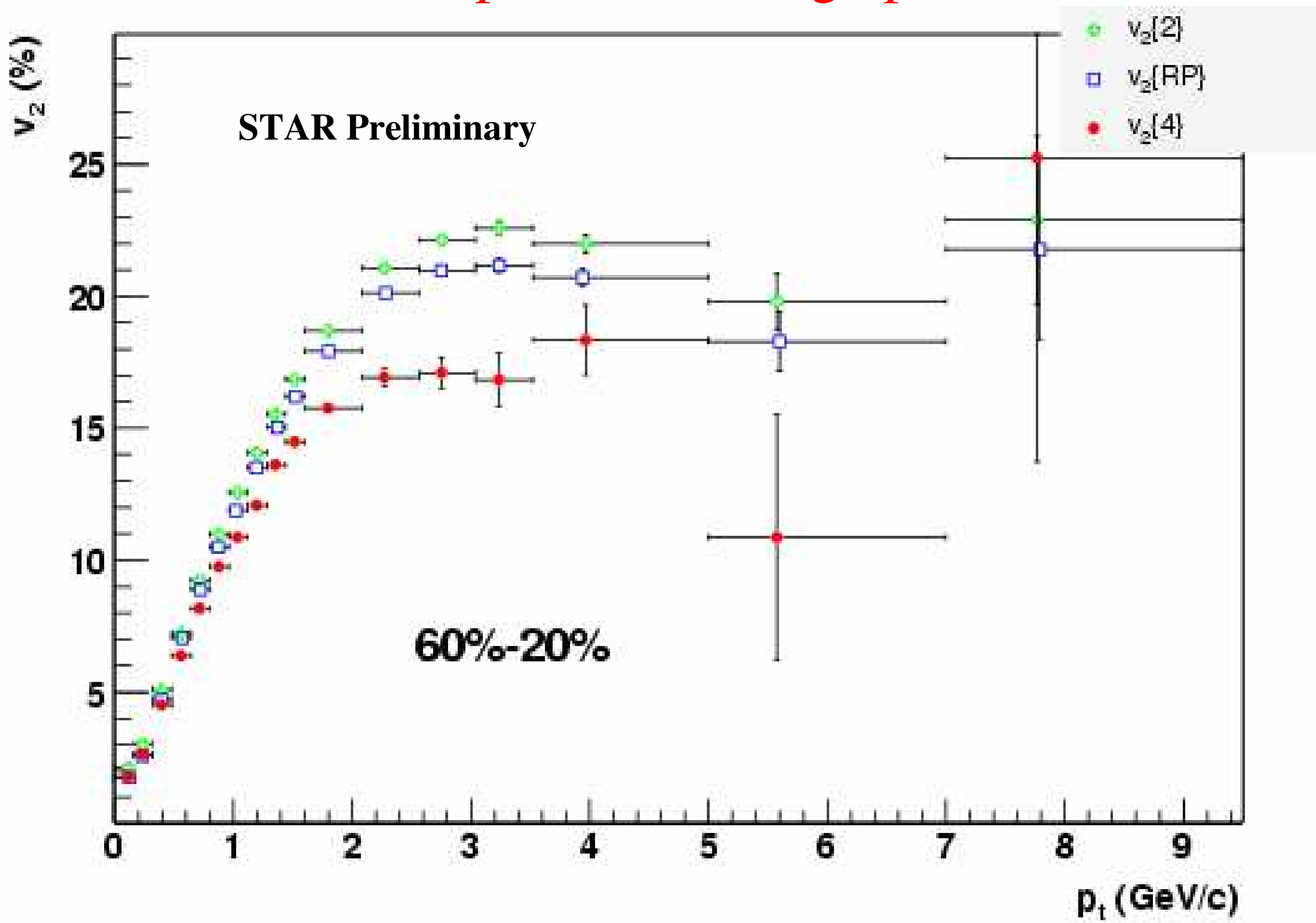
Non–flow in Identified Particles



At low pt, Non–flow effects are visible in pions, not clear in kaons and protons/anti–protons.

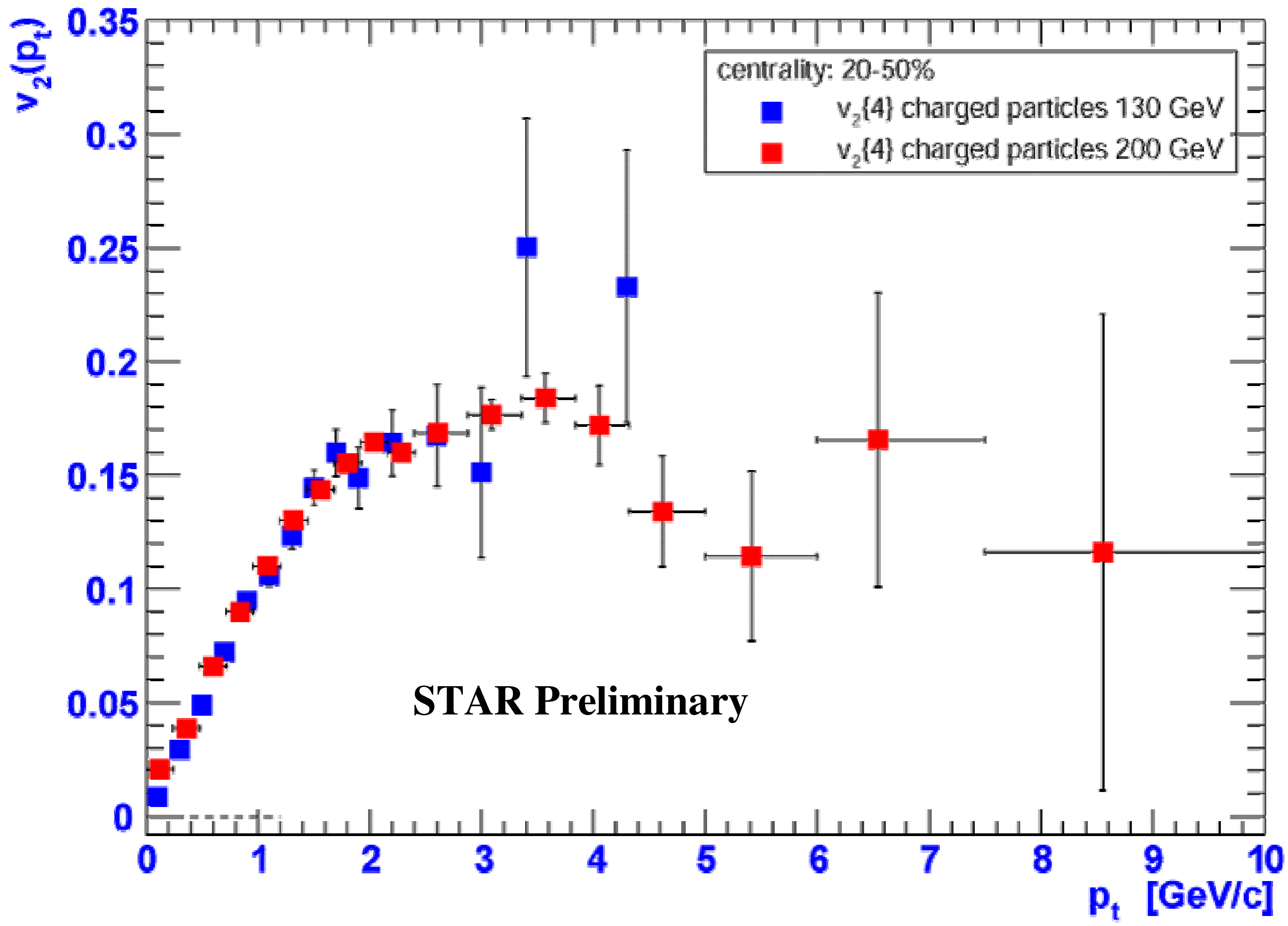


Elliptic Flow at high pt

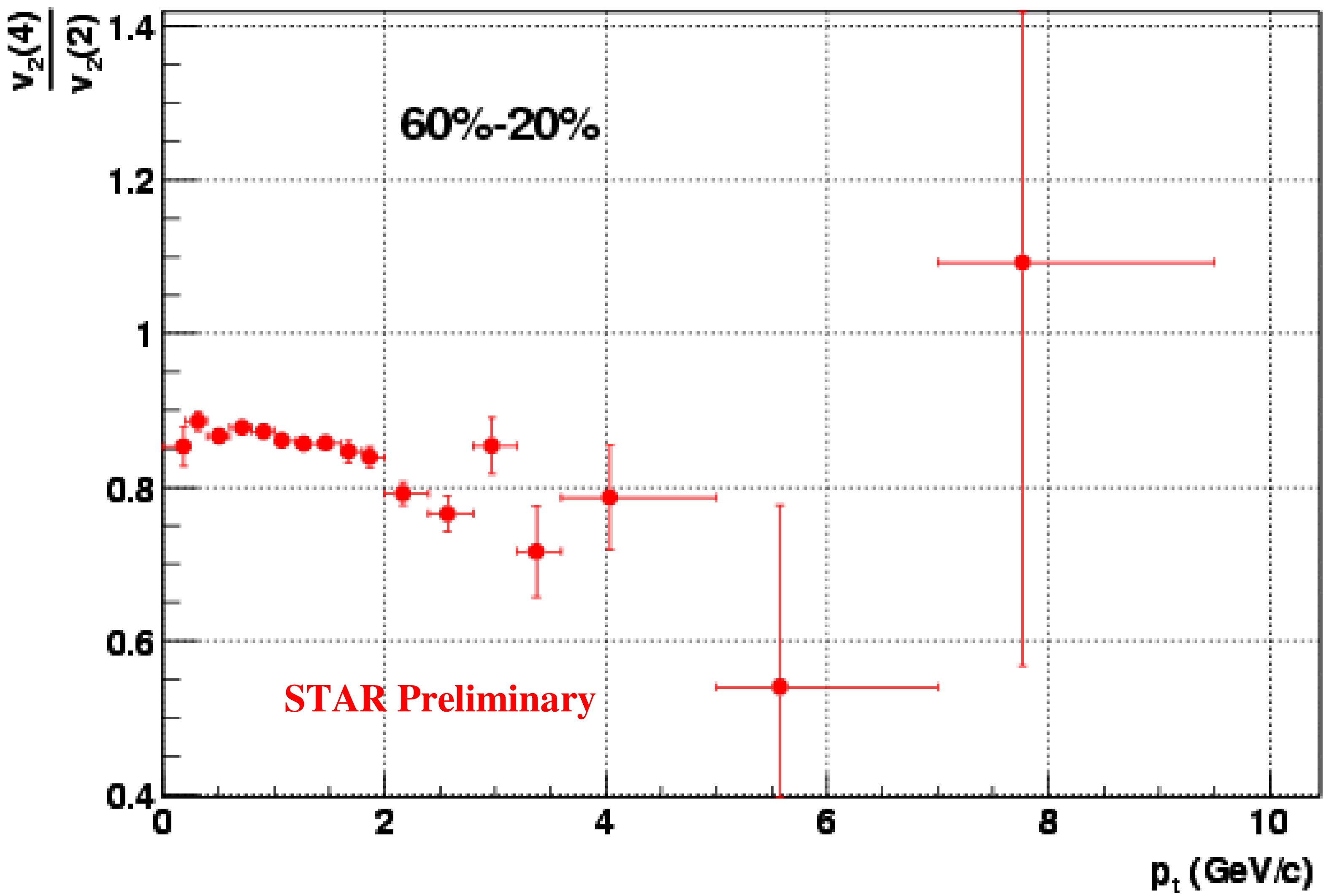


Sizable v2 up to 6 GeV/c in midcentral events

Elliptic Flow vs. pt (130 GeV Vs. 200 GeV)



Non–flow; pt dependence



Non–flow study at high pt (S. Voloshin)

$$\langle u_b Q^* \rangle = (v_b v_p + \delta_{bp}^{AA}) M^{AA}$$

$$\delta_{bp}^{AA} \approx \frac{\delta_{bp}^{pp}}{N_{coll}} \approx \frac{\delta_{bp}^{pp} M^{pp}}{M^{AA}}$$

$$Q = \sum_{i \in "pool"} u_i; \quad u_i = e^{i2\varphi_i}$$

v_b – Flow in a particular pt/eta "bin"

v_b – Average flow in the pt/eta region used to define RP (or "pool" of particles)

δ_{bp}^{pp} Azimuthal correlations in *pp*
($u_a u_b^*$, $u \equiv e^{i2\phi}$)

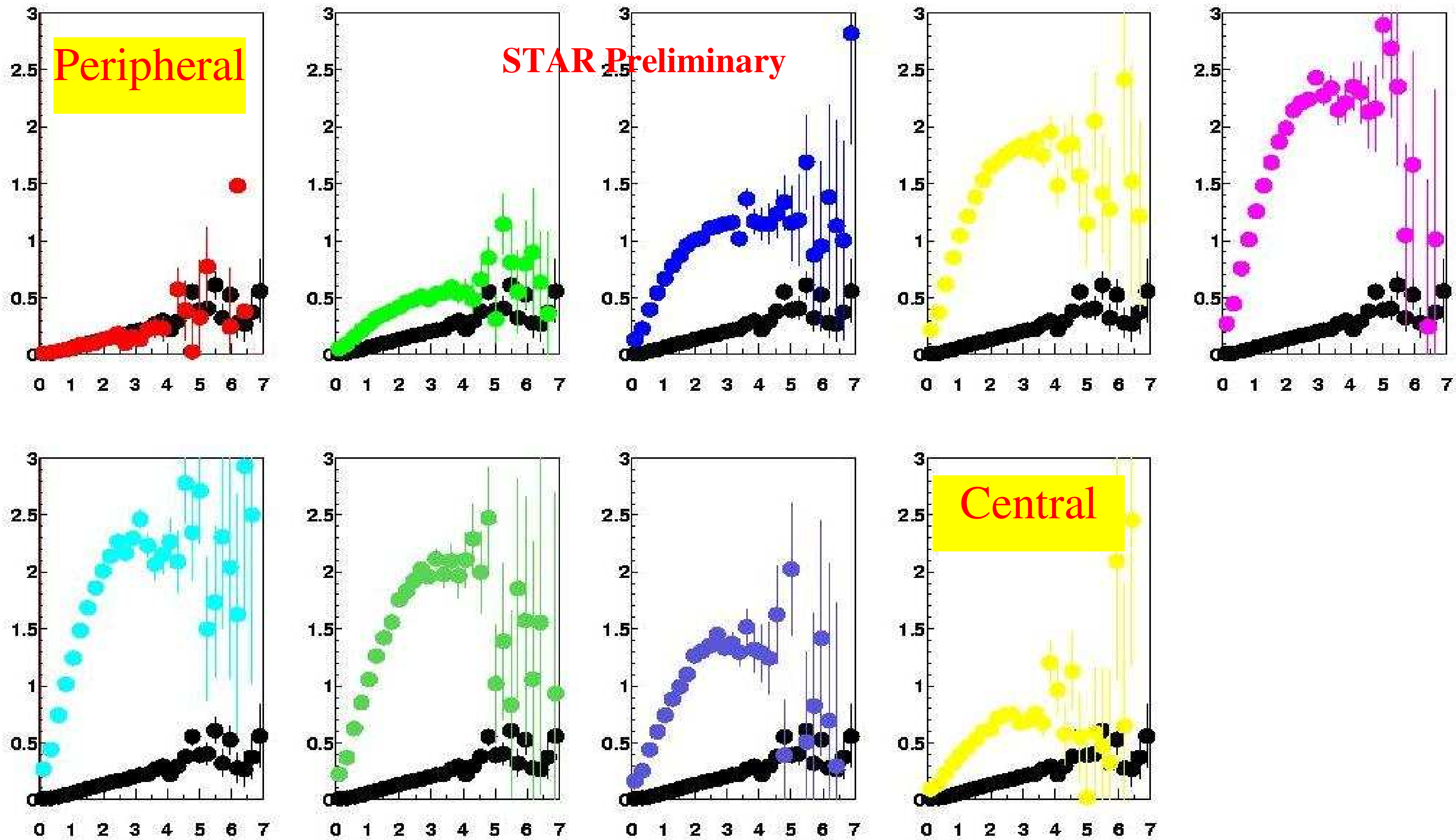
Then non–flow/flow contribution ratio in AA would be:

$$\frac{\delta_{bp}^{pp}}{N_{coll}} : v_2^2$$

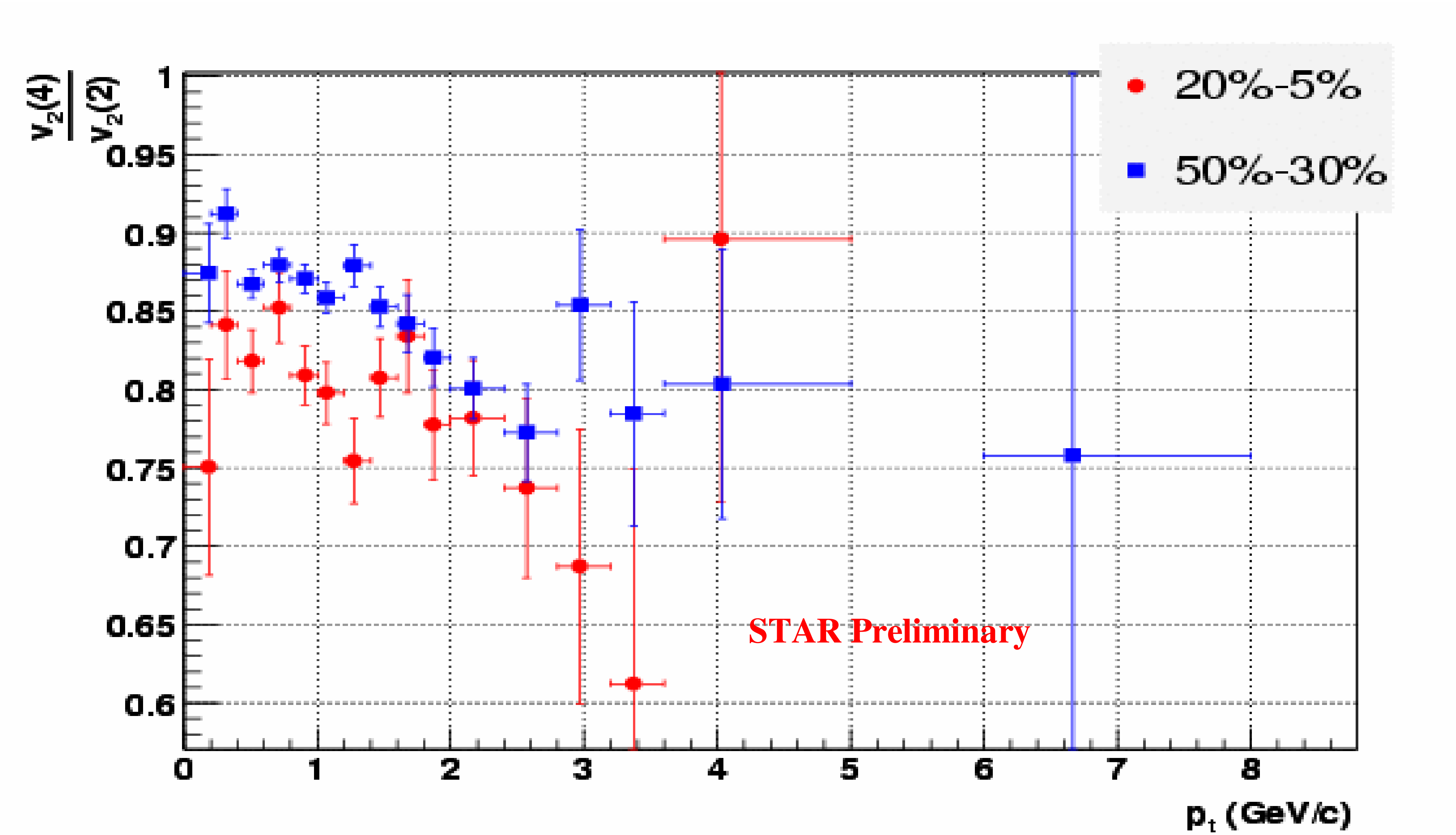
- Could be significant for peripheral ($Ncoll$ ~ 5, v ~ 0.08) or very central ($Ncoll$ ~ 200, v ~ 0.01) collisions

Non–flow study at high pt (S. Voloshin)

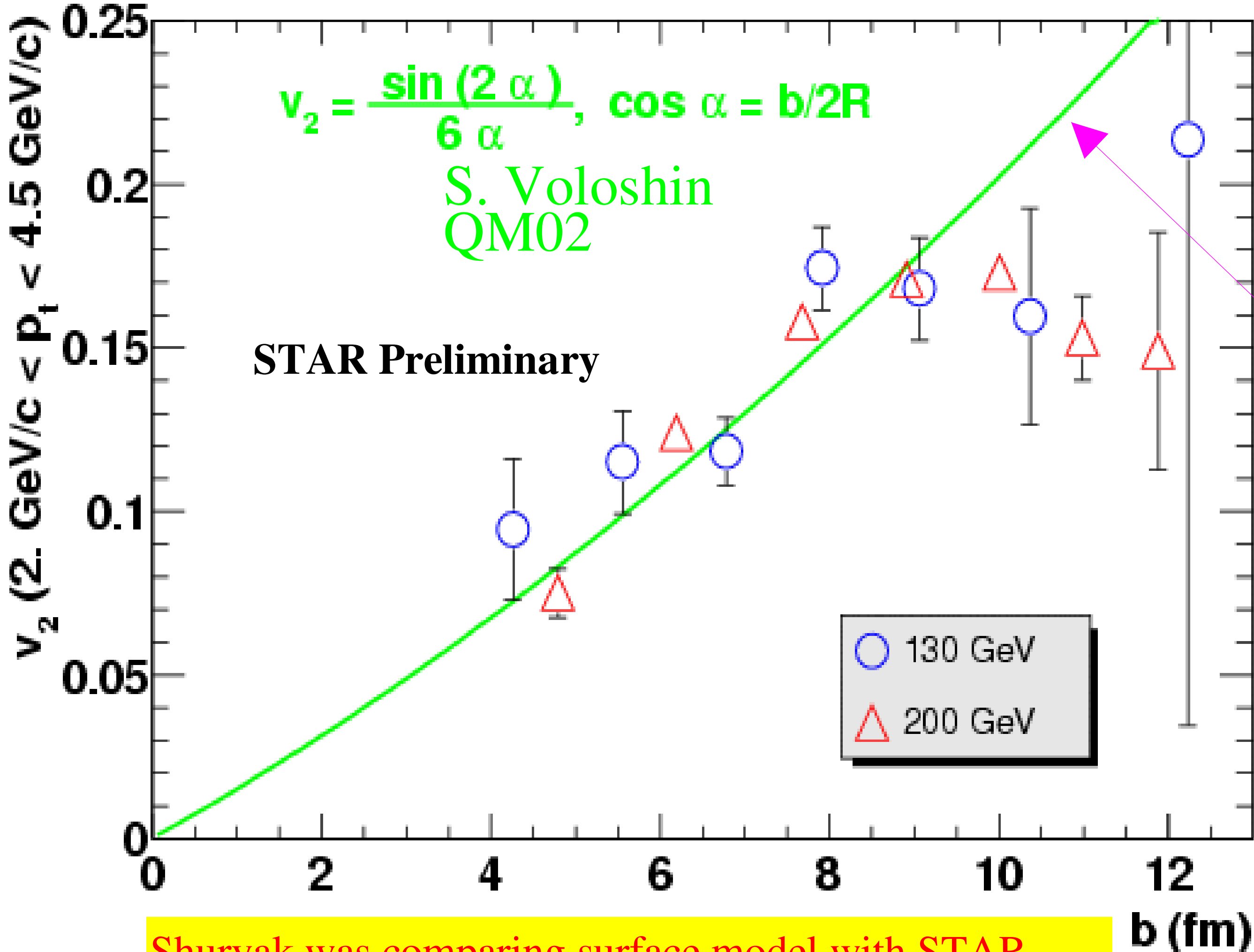
$$\langle u_b Q^* \rangle^{AA} \approx v_b v_p M^{AA} + \langle u_b Q^* \rangle^{pp}$$

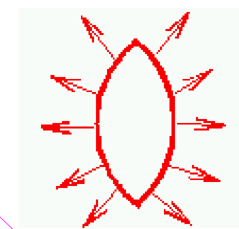


Non–flow at high pt; What does the data look like?



Geometric v2 ?

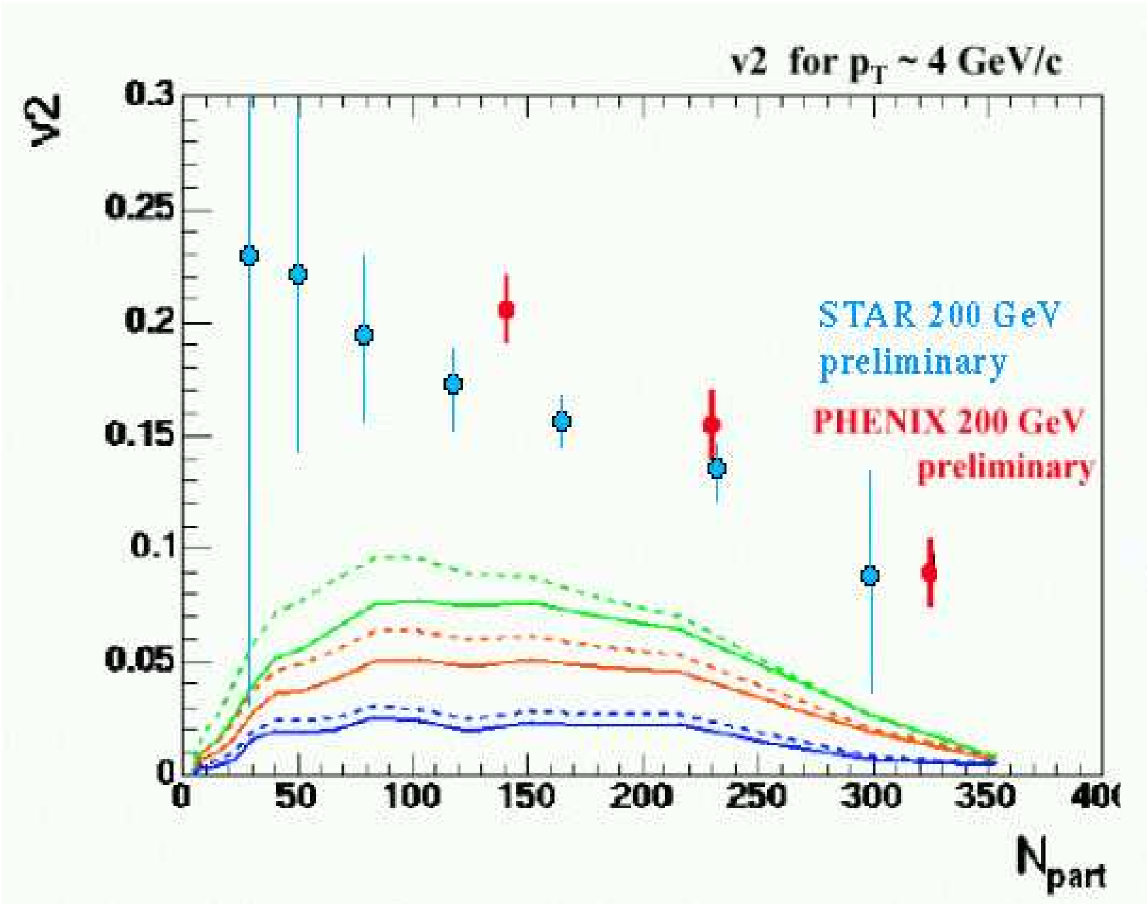




The curve was derived with the assumption of surface emission – an assumption of an extreme case though.

Shuryak was comparing surface model with STAR preliminary reaction plane v2, now with 4–th order cumulant v2, we do not see an inconsistence of v2 at high pt and surface emission from surface.

Geometric v2 ?



Normal nuclear absorption

$$I_1 = \int_0^\infty dl \; \rho(x,y)$$

Energy loss style absorption

$$I_2 = \int_0^\infty dl \; l \; \rho(x,y)$$

Absorption + expansion, $l_0 \sim 0.2$ fm

$$I_3 = \int_0^\infty dl \; \frac{l_0}{l_0 + l} \; \rho(x,y)$$

J. Jia & A. Drees, HIT talk in LBL.
STAR data added from 4–th order cumulant method.

V2 at high pt produced by a Woods–Saxon nuclear density profile is insufficient to match the data – what will happen at higher pt ?

Conclusions

- V2 scaled by eccentricity is proportional to 1/S dN/dy, and approaches pure Hydro limits for central events at 130/200 GeV.
- Sizable v2 up to 6 GeV/c in middle central events at 200 GeV.
- Non–flow at high pt might be big in peripheral and central events.
- V2 from (not so) high pt could be consistent with surface emission, but too big for energy loss inside a medium of profile of Woods–Saxon nuclear density.