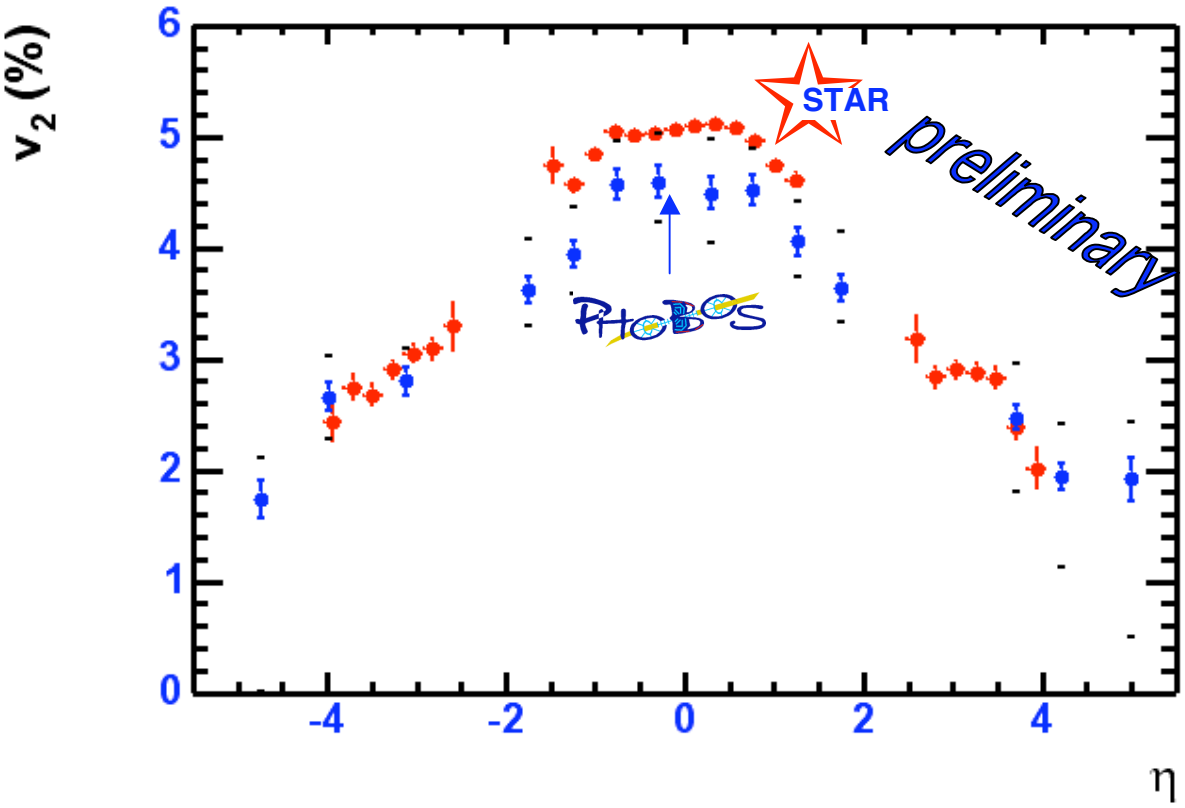
Azimuthal Anisotropy: The Higher Harmonics

Art Poskanzer

v_2 in the FTPC



200 GeV

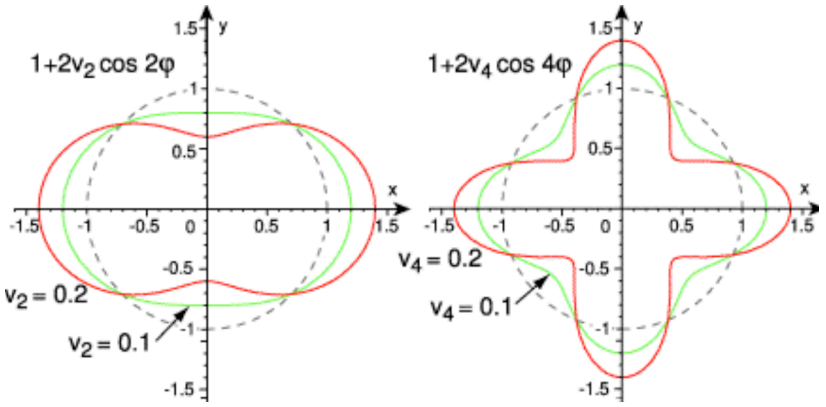
- **Event plane determination in TPC**
- **v_2 signal drops by about a factor of 1.8 from mid-rapidity to = 3**
- **PHOBOS fall off confirmed**

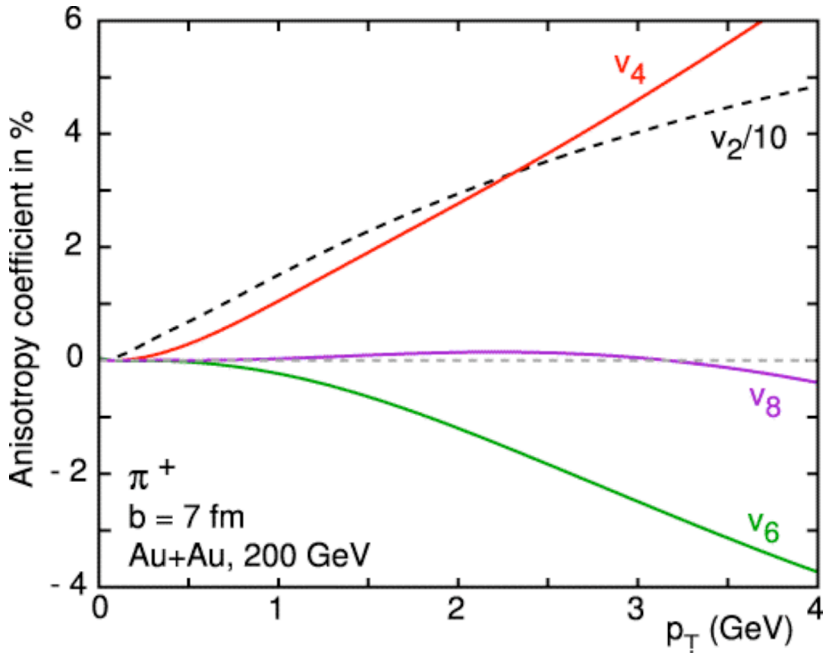
Search for higher harmonics

- Long History
  - Voloshin at CERES
  - Me and Voloshin with NA49 data
- Large, and decreasing slowly with harmonic number
- Probably all non-flow effects
- Except Voloshin and Zhang at AGS
  - E877: PRL 73, 2532 (1994)
  - Q distribution method

Peter Kolb

- v_4 - a small, but sensitive observable for heavy ion collisions: PRC 68, 031902(R)
  - Strong potential to constrain model calculations and carries valuable information on the dynamical evolution of the system
  - Magnitude, and even the sign, sensitive to initial conditions of hydro

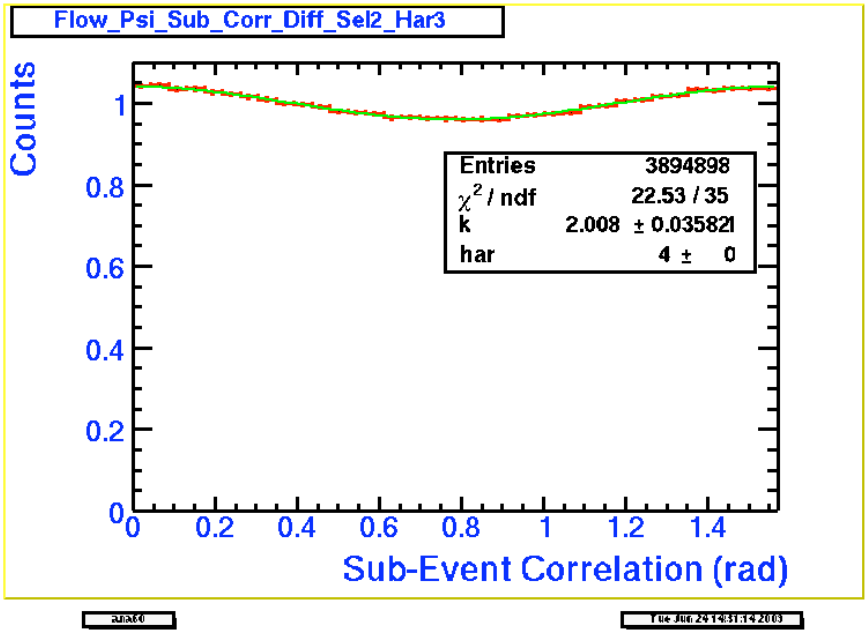




v_2 determines the reaction plane

- v_1 (Aihong Tang), v_4 v_6 and v_8 using **second** harmonic particles
- Possible because v_2 is so large at RHIC and event plane resolution is so good in STAR

4^{th} harmonic of one subevent relative to 2^{nd} harmonic of other subevent:
v_4 positive



Terminology

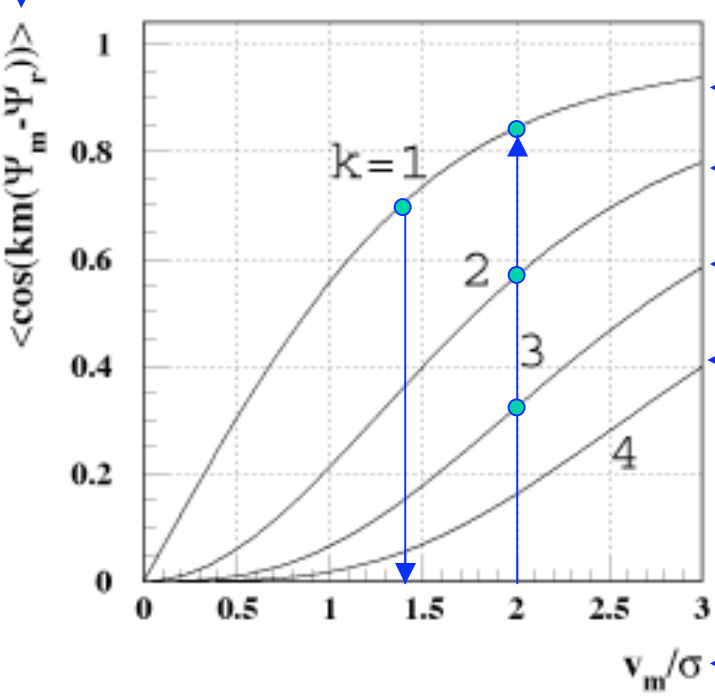
- n = harmonic number
- Old
  - v_n = harmonic order n with respect to event plane of same order
  - $v_n\{N\}$ = N-particle cumulant for v_n
- Addition
  - $v_n\{EP_2\}$ = harmonic order n with respect to event plane of order 2

Method

- **Described in methods paper:**
  - **Poskanzer and Voloshin, Phys. Rev. C 58, 1671 (1998)**

Square-root of subevent correlation

$$v = \frac{v_{observed}}{resolution}$$



← Same harmonic

← V_4 vs. 2nd

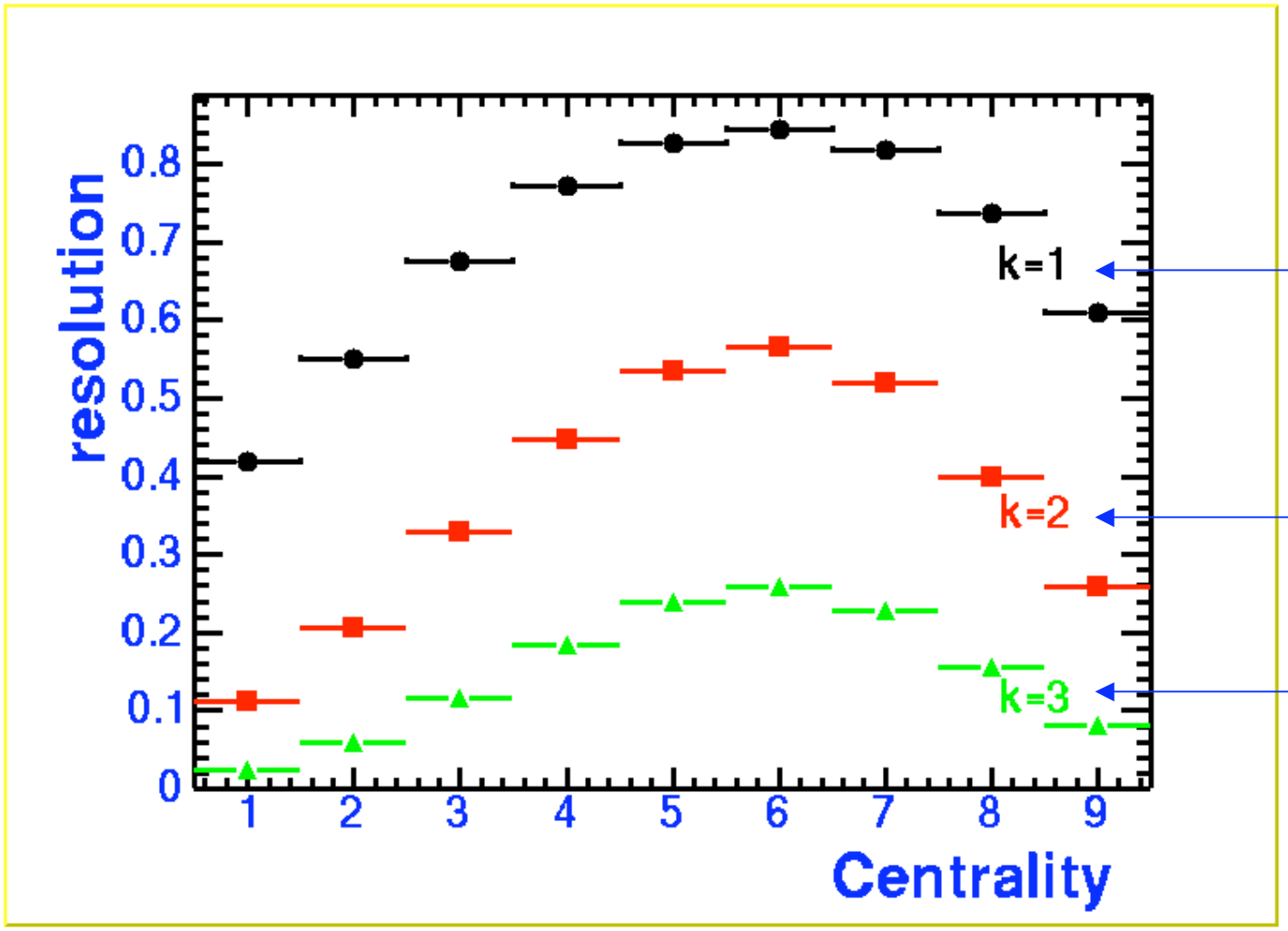
← V_6 vs. 2nd

← V_8 vs. 2nd

← Signal to fluctuation noise

STAR

Resolution

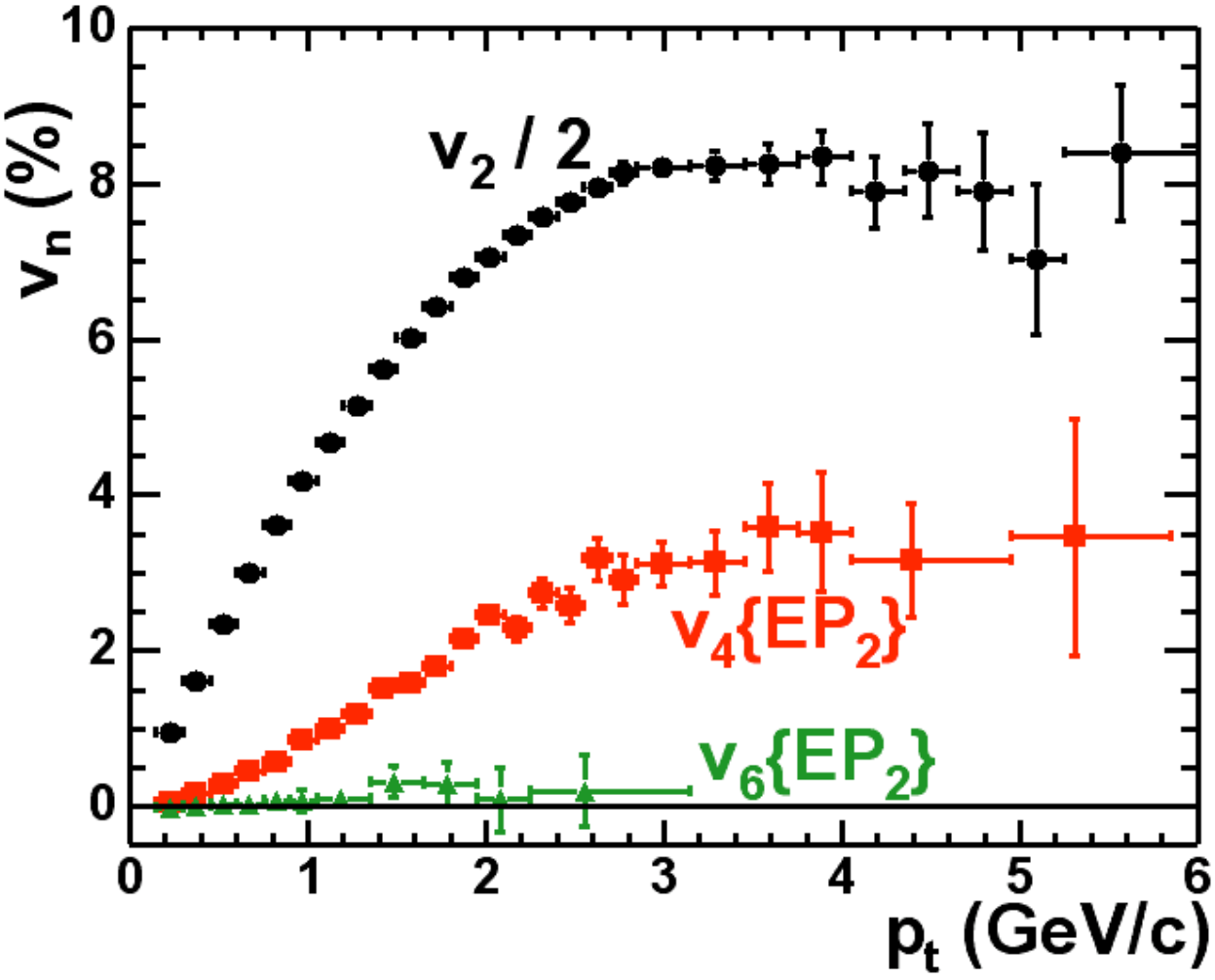


For v_2

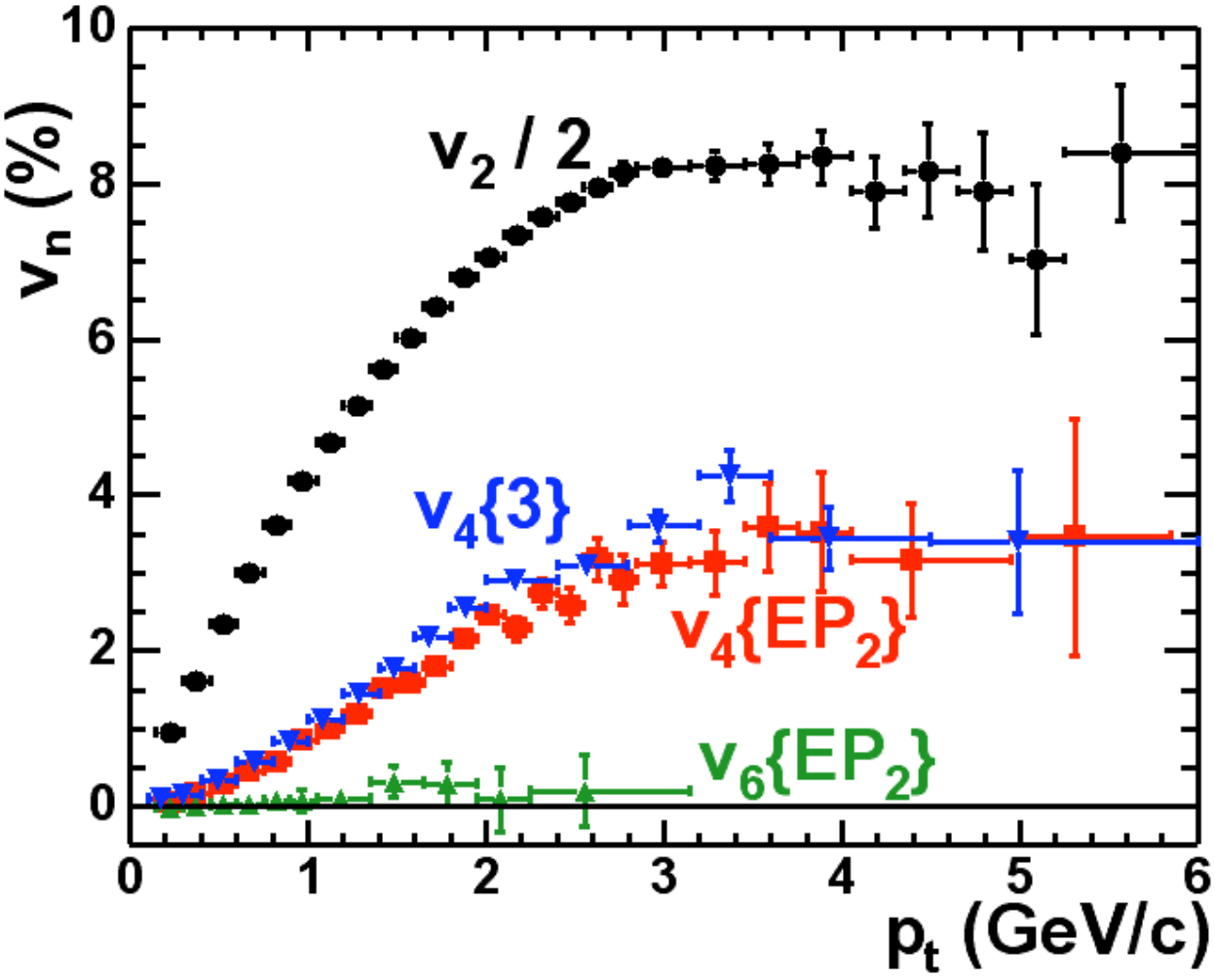
For v_4

For v_6

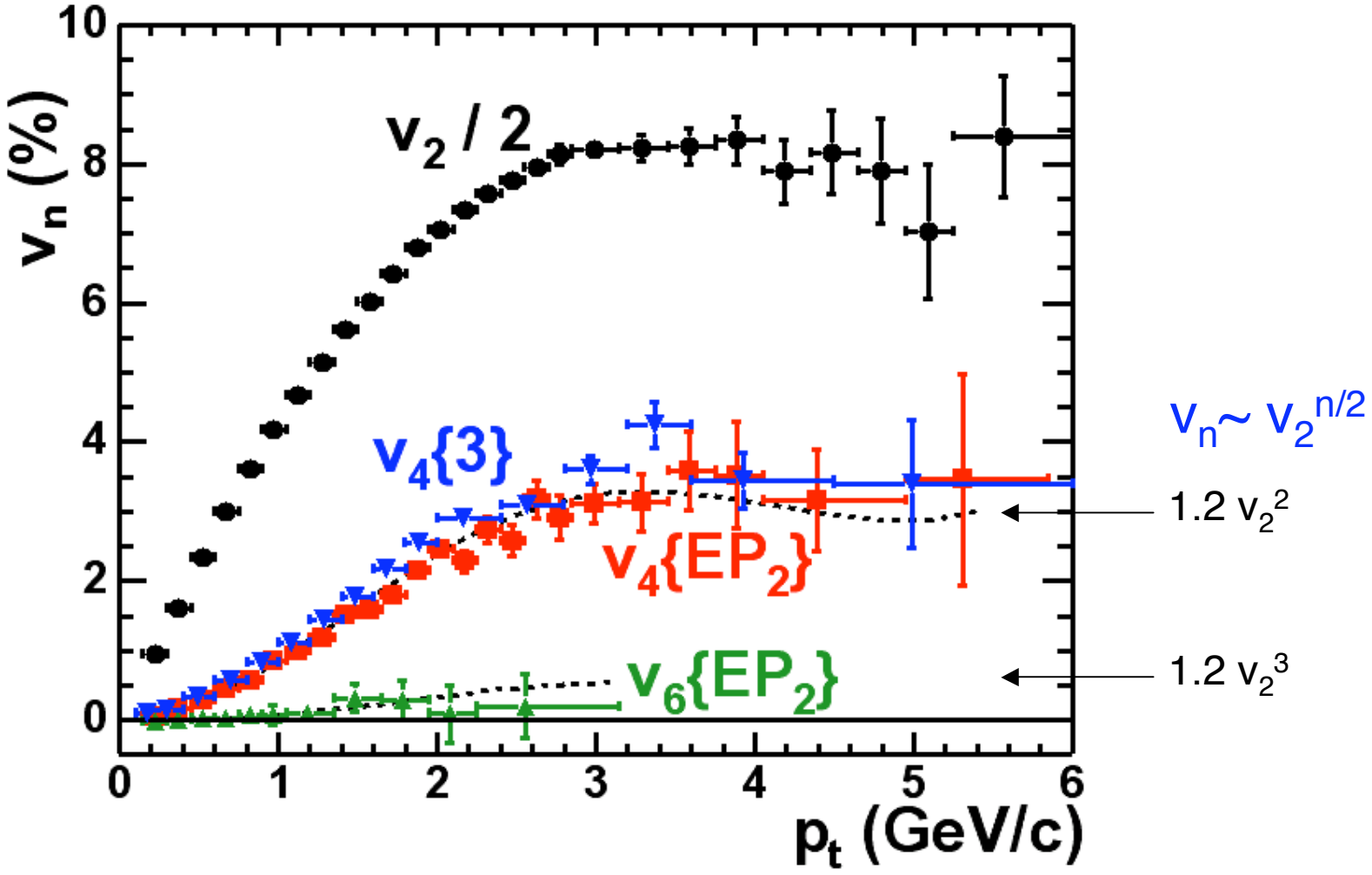
$v_4(p_t)$



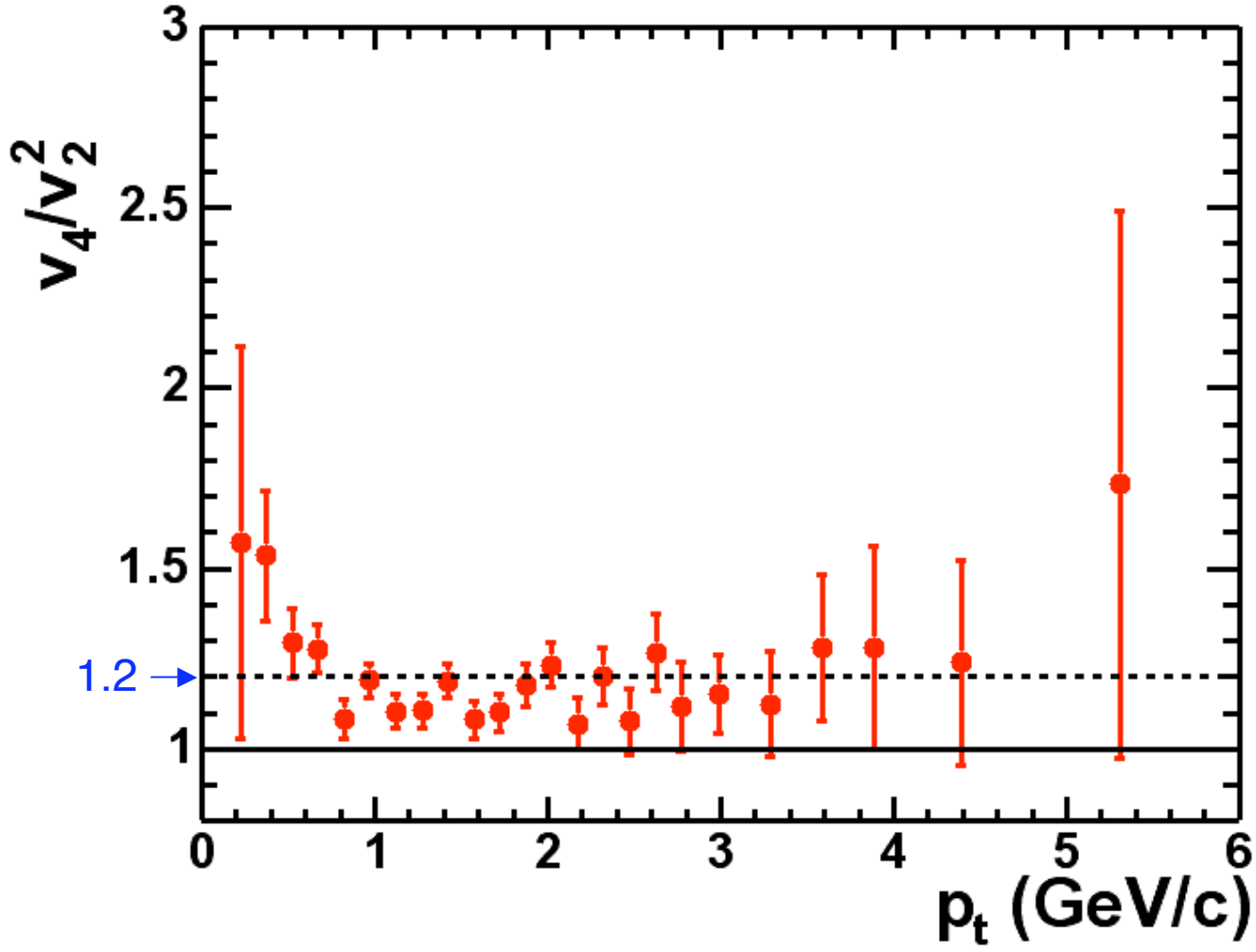
$v_4(p_t)$



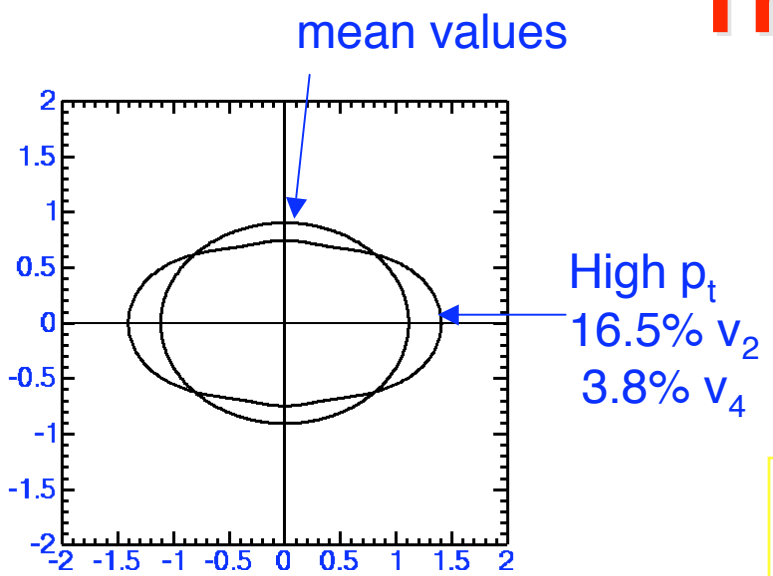
$v_4(p_t)$

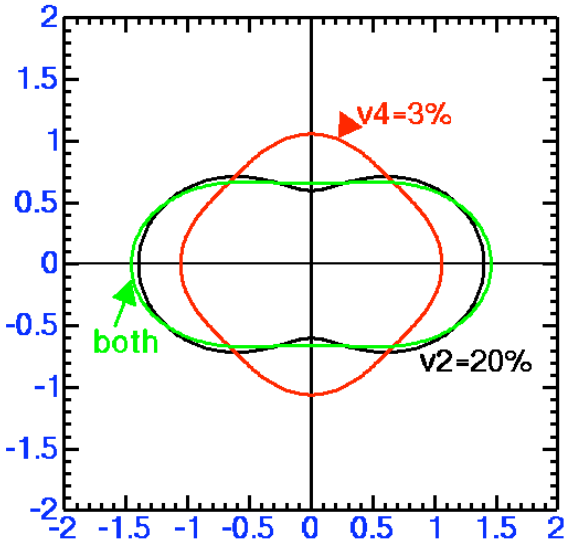

10
8
6
4
2
0
v_n (%)
v_2 / 2
$v_4\{3\}$
$v_4\{EP_2\}$
$v_6\{EP_2\}$
0
1
2
3
4
5
6
p_t (GeV/c)
$v_n \sim v_2^{n/2}$
1.2 v_2^2
1.2 v_2^3

$v_4(p_t)$ Scaling

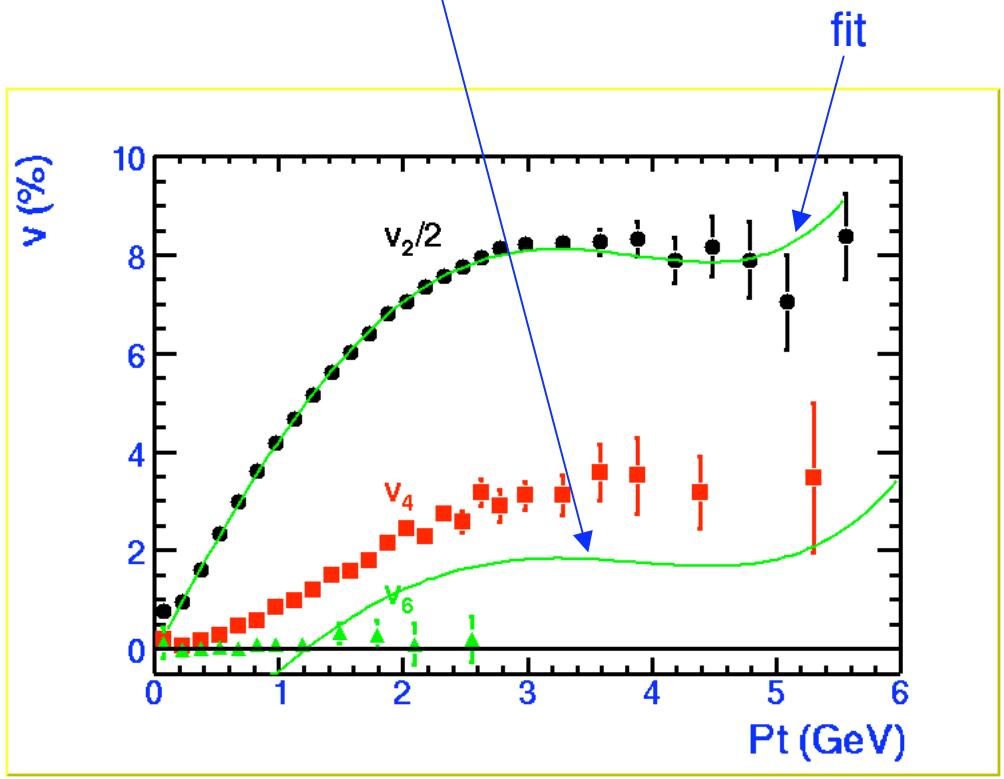


The Waist

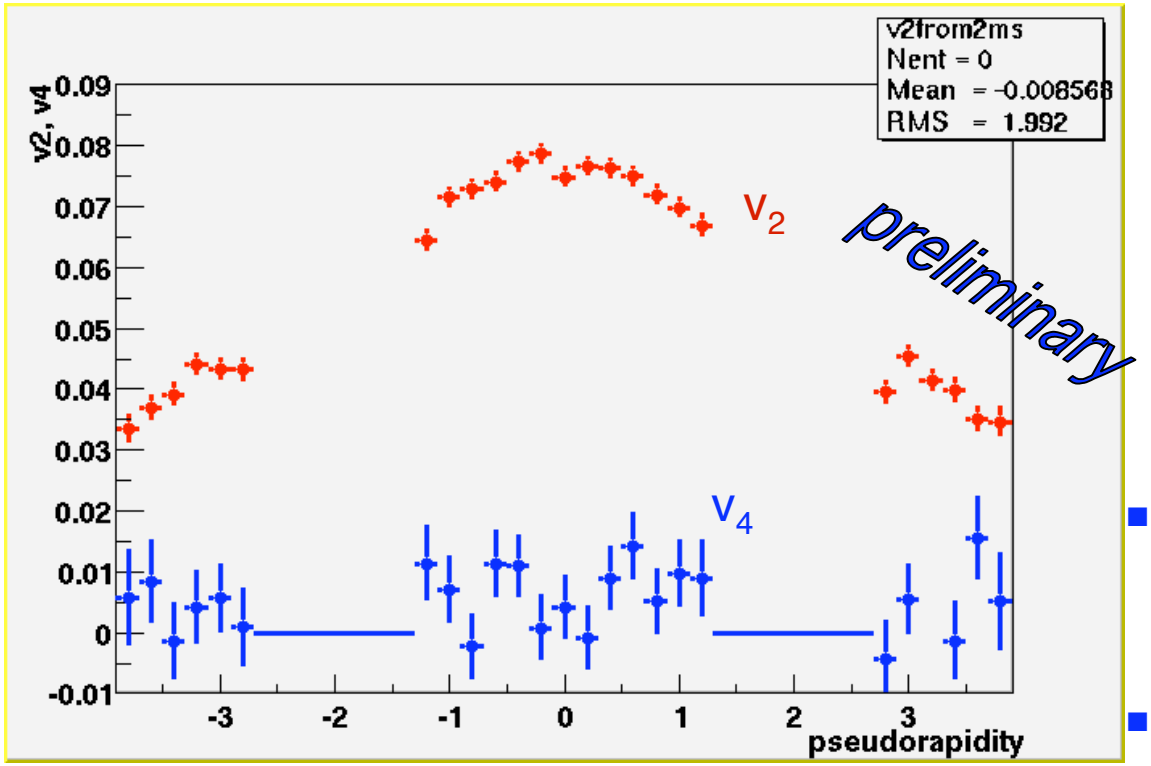




- **Kolb no waist:**
  - $v_4 = (10 * v_2 - 1) / 34$

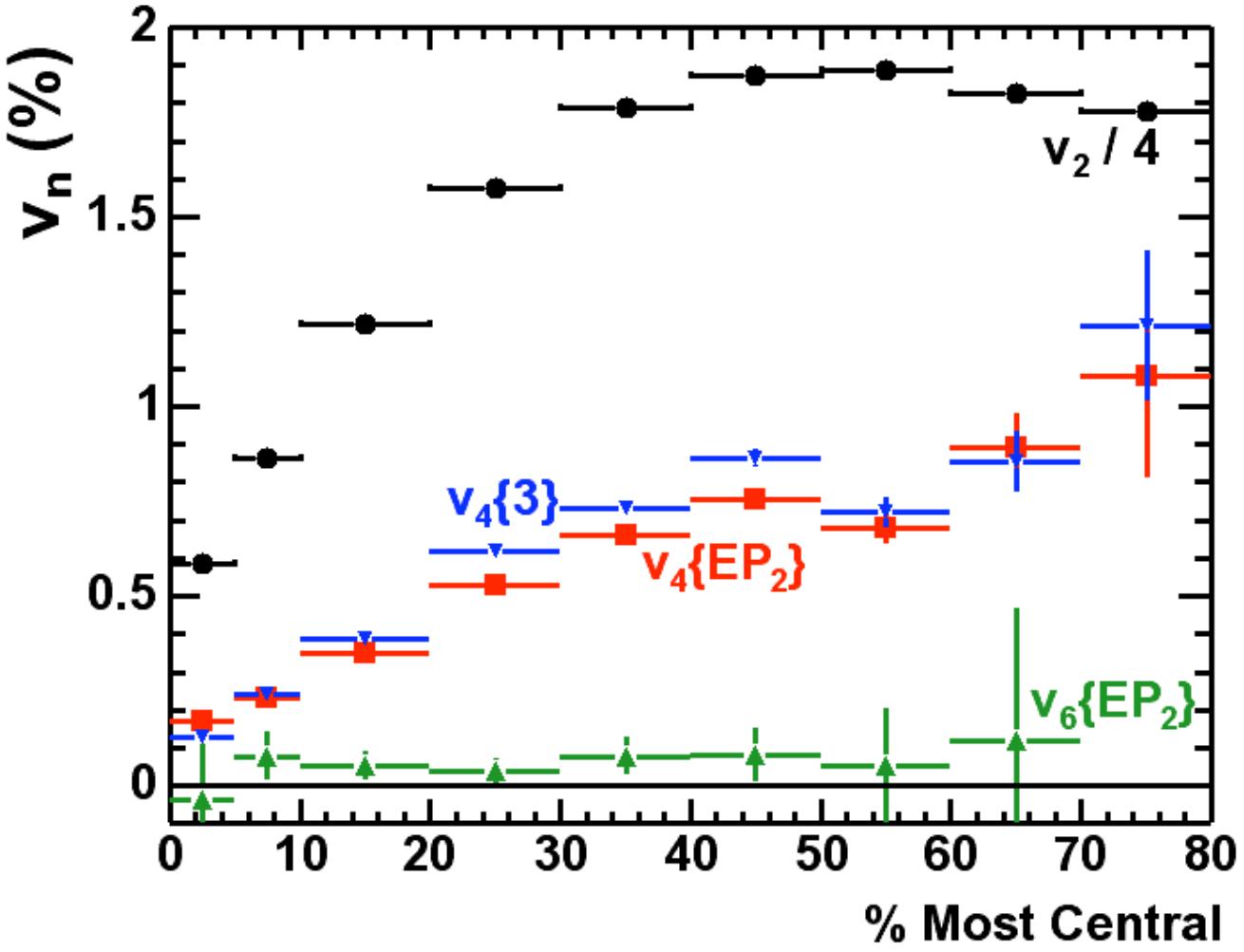


$v_4\{EP_2\}$ in the FTPC



- v_4 with respect to the 2nd harmonic event plane in the TPC
- Signal in the FTPCs consistent with 0 (0.03 ± 0.06)% with two sigma upper limit of 0.15%
- Drop of v_4 from TPC to FTPC faster than for v_2

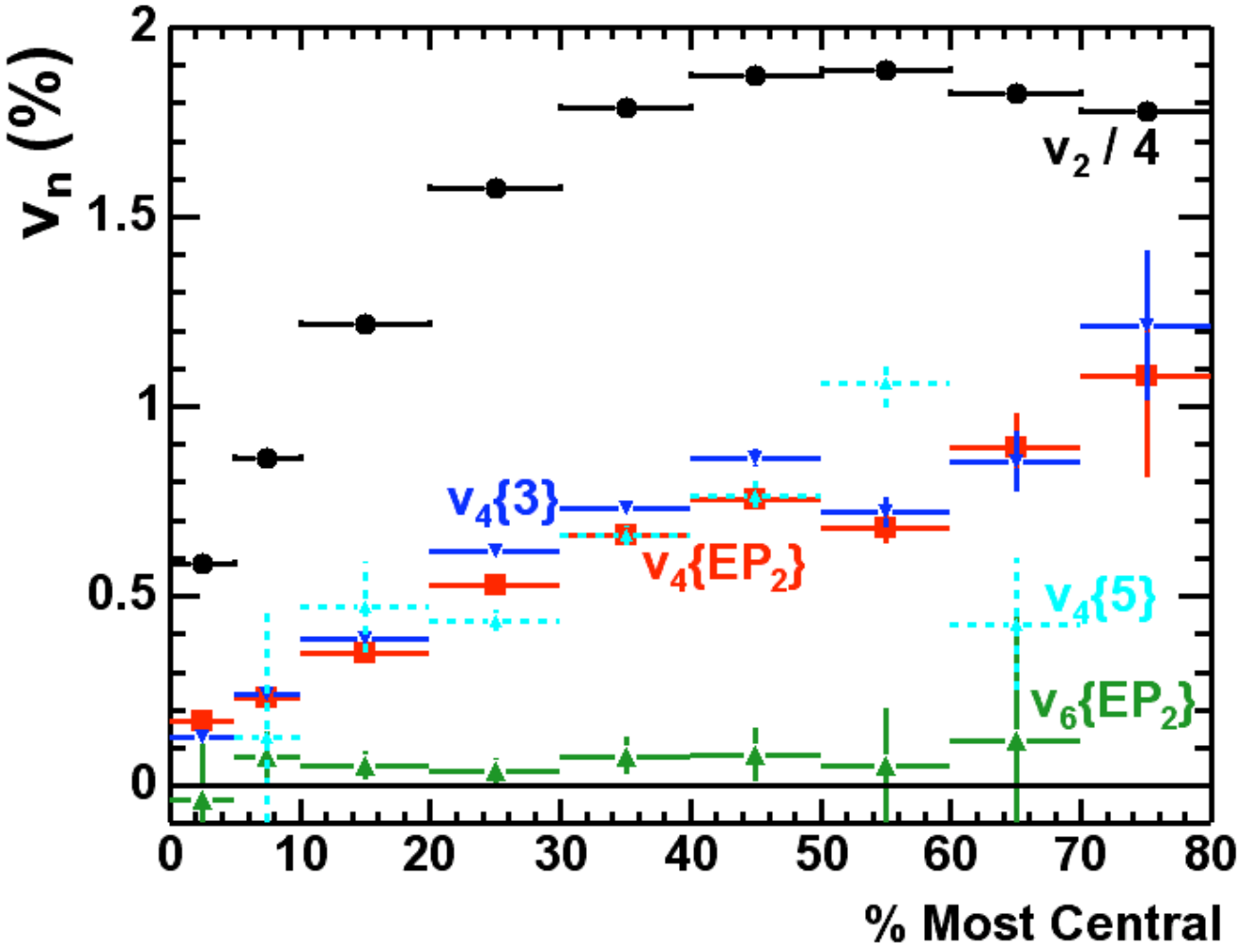
v_4(centrality)



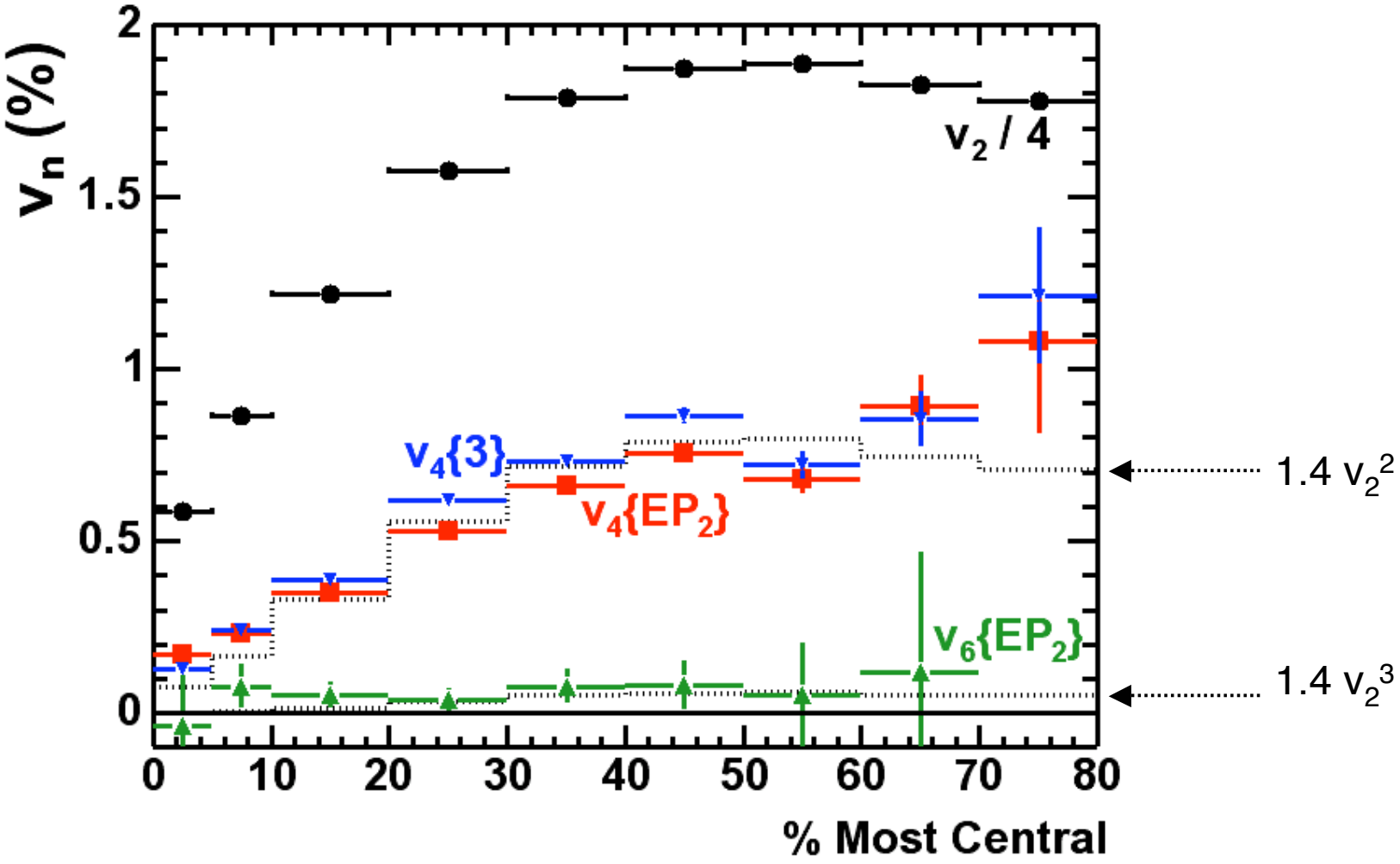
Poskanzer and Tang

STAR

v_4(centrality)



v_4(centrality)

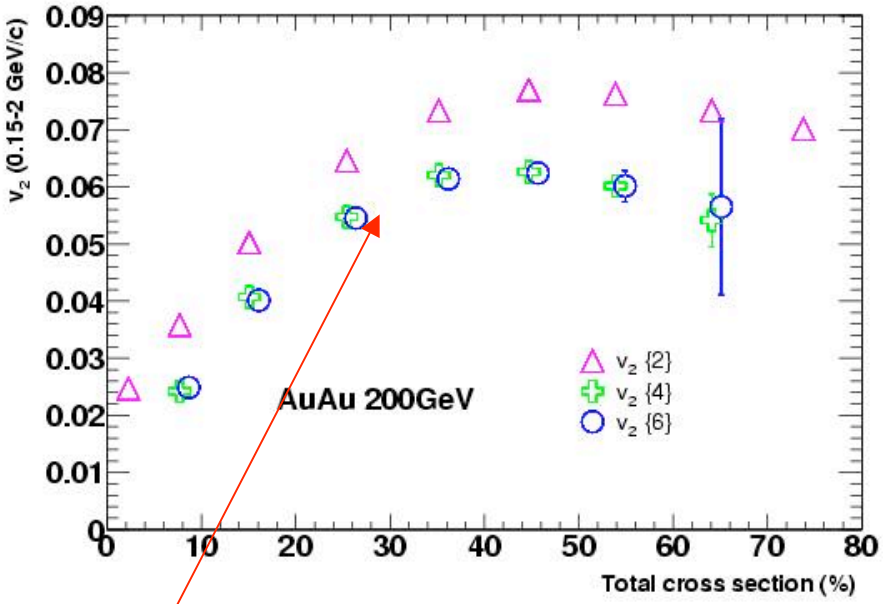


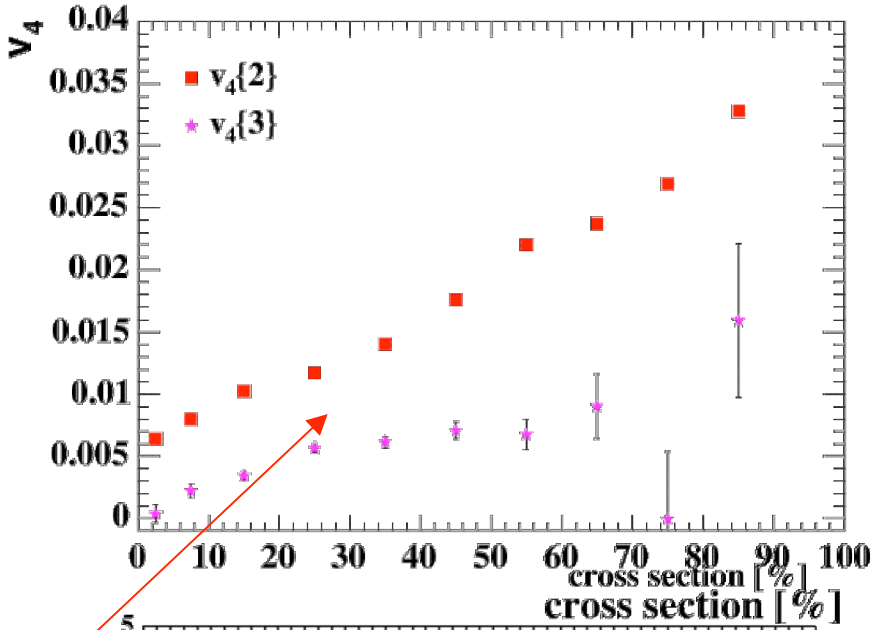
v triply integrated
in MTPC

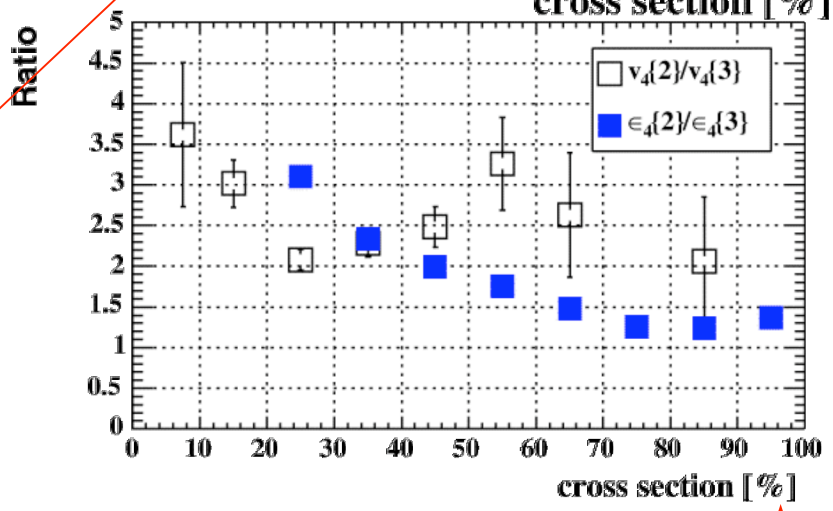
v	%
2	5.18 +/- 0.005
4	0.44 +/- 0.009
6	0.043 +/- 0.037
8	-0.06 +/- 0.14

Two sigma upper limit is 0.1%

Non-flow and/or Fluctuations







For v_2, about 20% reduction from $v_2\{2\}$ to $v_2\{4\}$

For v_4, up to a factor 3 difference!

Snellings and Voloshin

STAR

Conclusions

- v_4 compared to v_2
  - Integrated, a factor of 12 smaller
  - v_2^2 scaling
- v_6
  - Probably another factor of 10 smaller
  - Consistent with v_2^3 scaling
- Hydro, sensitive to initial conditions
  - v_4 fits very well
  - v_6 is zero instead of negative from hydro
- Waist
  - v_4 larger than needed to remove the waist
- $v_4\{EP_4\}$
  - 3x high because of either fluctuations or nonflow