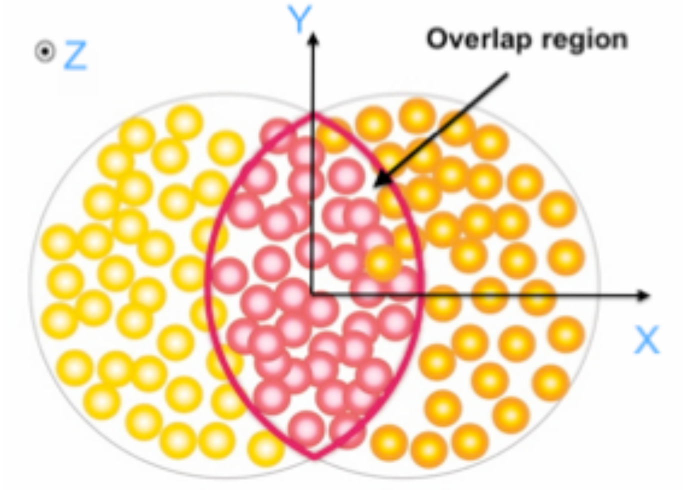
Higher harmonic flow of ϕ meson in STAR at RHIC

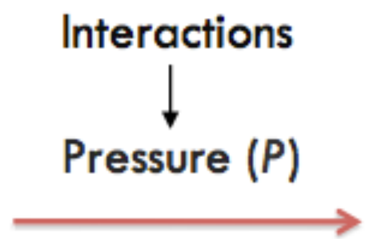
Mukesh Kumar Sharma (for the STAR Collaboration)
University of Jammu, Jammu, INDIA

OUTLINE:

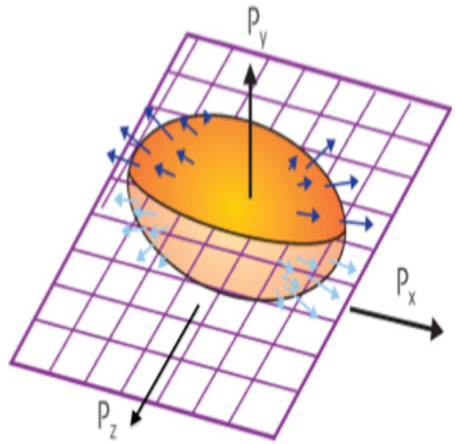
- ✓ Introduction and Motivation
- ✓ STAR Detector and Data set
- ✓ Analysis Method
- ✓ Results
- ✓ Summary

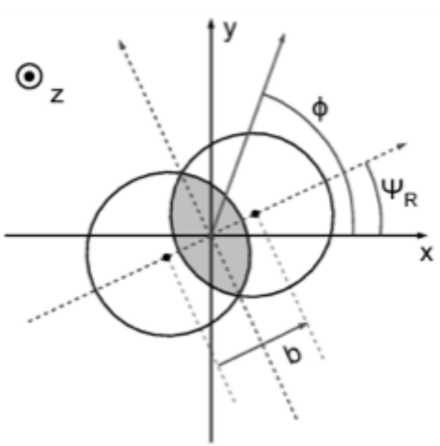
Introduction: Azimuthal anisotropy





$$y > x \longrightarrow \frac{\partial P}{\partial x} > \frac{\partial P}{\partial y}$$





$$\frac{dN}{d\phi} \propto \frac{1}{2\pi}\left[1+\sum_{n=1}^{\infty} 2v_n \cos(n(\phi-\psi_R))\right]$$

$$\phi = \tan^{-1}\left(\frac{p_y}{p_x}\right)$$

$$v_n = \langle \cos\left[n\left(\phi-\psi_R\right)\right]\rangle$$

- ψ_R is the azimuthal angle of the reaction plane (spanned by impact parameter and beam direction)
- v_2 , v_3 and v_4 are called elliptic, triangular and quadrangular flow

A. M. Poskanzer and S. A.Voloshin, Phys. Rev. C 58, 1671(1998).

Motivation

- ϕ meson has small hadronic interaction cross section. Thus ϕ meson v_n is less affected by later stage hadronic interaction. Hence ϕ meson is a clean probe to study the medium created in the early stage of collisions.
- The ratios between various harmonics can be used to understand the properties of the system created in heavy-ion collisions.

Coalescence Model

$$\frac{v_{4,M}(2p_T)}{v_{2,M}^2(2p_T)} \approx \frac{1}{4} + \frac{1}{2}\frac{v_{4,q}(p_T)}{v_{2,q}^2(p_T)}$$

Where $v_{n,q}(p_T) = k v_{2,q}^{n/2}(p_T)$

If k=1 $\frac{v_{4,M}(2p_T)}{v_{2,M}^2(2p_T)} \approx 0.75$

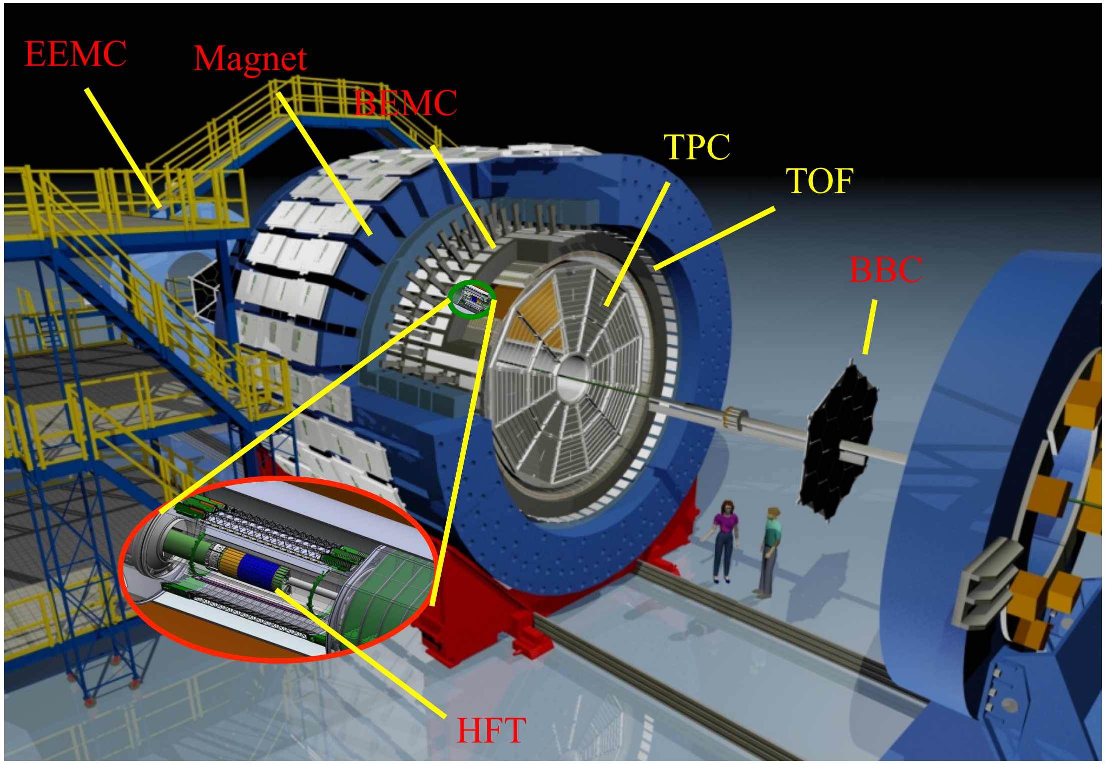
Hydro Model

$$\frac{v_4}{v_2^2} = 0.5$$

$\frac{v_3}{v_2}$ = Constant at high p_T

L. W. Chen et al., Phys. Rev. C 73, 044903 (2006).
J. Adams et al.(STAR Collabration), Nucl. Phys. A 757,102 (2005).
C. Lang et al., Eur. Phys. J. C 74 (2014) 2955.

STAR Experiment and Data Set



Magnetic field 0.5 Tesla
Full azimuthal coverage
$(0, 2\pi)$
$|\eta|<1.0$ for TPC and
$|\eta|<0.9$ for TOF

Data Set	Vertex Cut	Trigger	No. of events
AuAu 200 GeV (Run 11)	$|V_z|<$ 30 cm $|V_r|<$ 2 cm	MinBias	560 Million

Particle Identification with STAR TPC and TOF

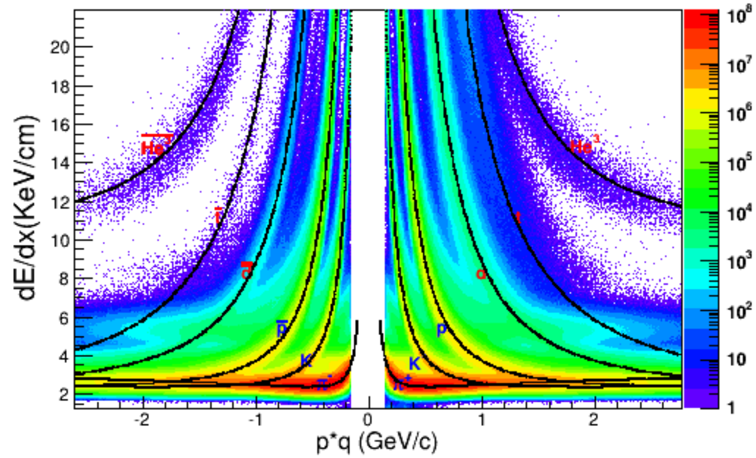
❑ TPC

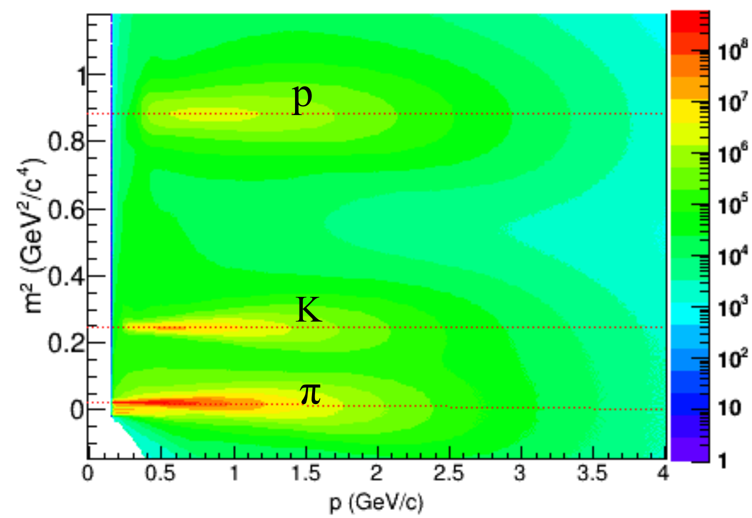
- Full azimuthal coverage (0, 2π)
- Identifies kaon upto p= 0.65 GeV/c
- **Bethe Bloch Formula**

$$-\left\langle \frac{dE}{dx} \right\rangle \sim A\left(1+\frac{m^2}{p^2}\right)$$

- Particle identifies using

$$N\sigma = \frac{1}{R}\times\log\left(\frac{dE/dx_{measured}}{dE/dx_{theory}}\right)$$





❑ TOF

- Full azimuthal coverage (0, 2π)
- Kaon can be identified upto p=1.6 GeV/c
- **Time of Flight**

$$\langle t \rangle = \frac{L}{\beta} \qquad \frac{1}{\beta} = \sqrt{1+\frac{m^2}{p^2}}$$

Hans Bichsel, NIM Phys Research A 562 (2006) 154–197.

Event Plane Resolution

- Event Plane defined as:

$$\Psi_n = \left(\tan^{-1}\left[\frac{\sum_i w_i \sin(n\phi_i)}{\sum_i w_i \cos(n\phi_i)} \right] \right) / n$$

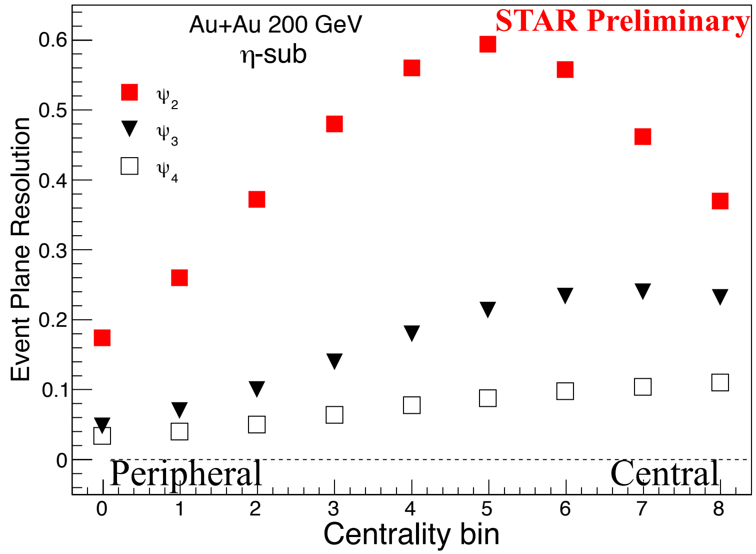
- Event Plane angle calculated in two different windows 'west' (η> 0.075) and 'east' (η< -0.075)

- Event Plane Resolution then given by:

$$R = \sqrt{< \cos[n(\Psi_n^{west} - \Psi_n^{east})] >}$$

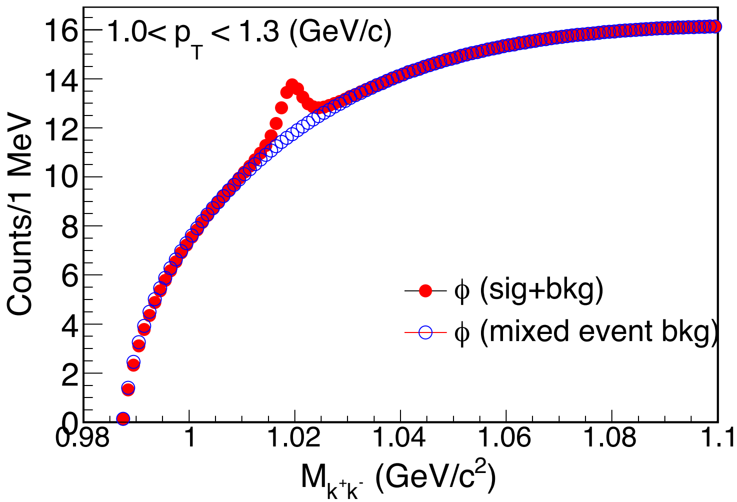
- event- by- event resolution correction

$$\langle v_n \rangle = \langle \frac{v_n^{obs.}}{R} \rangle$$

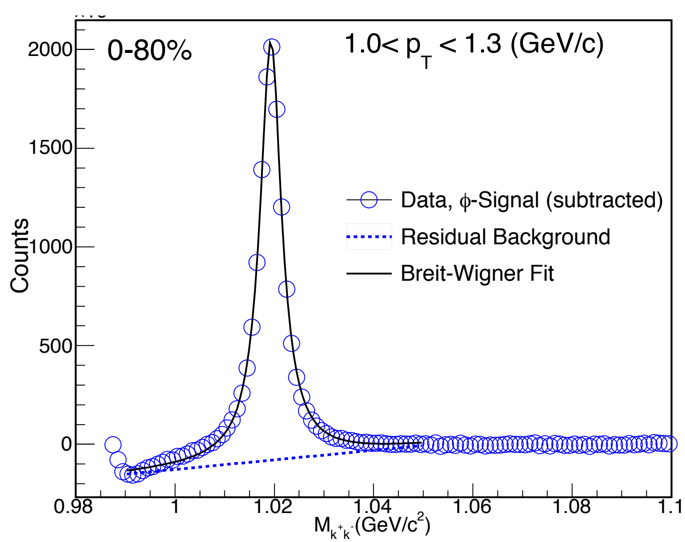


A.M. Poskanzer & Voloshin, Phys.Rev. C58 (1998).

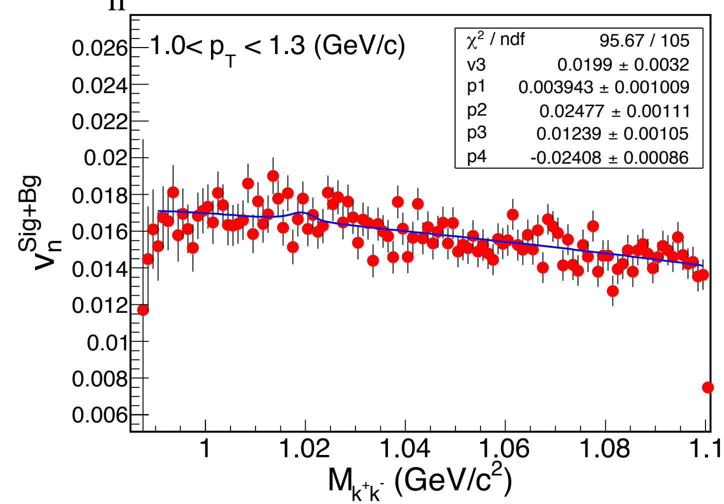
ϕ-meson signal extraction



- ϕ meson decay -> K^+K^-(B.R 48.9 %)
- Background reconstructed from mixed events
- ϕ signal is fitted with BW +1st order polynomial



v_n vs Invariant mass method

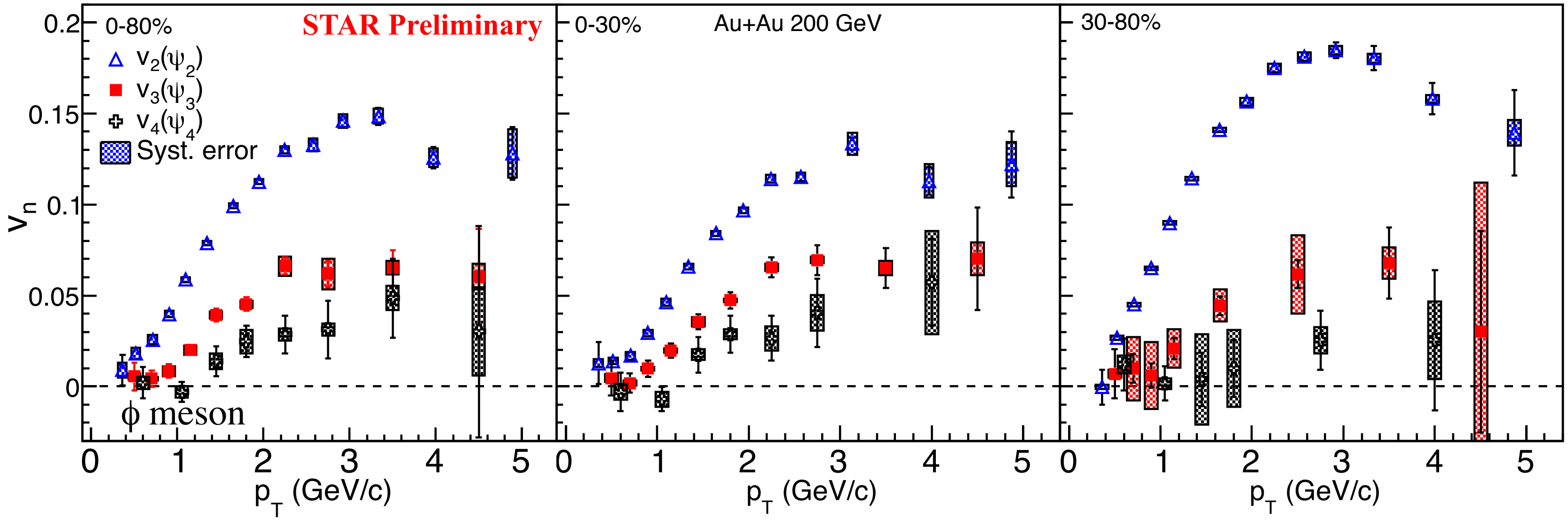


$$v_n^{Sig+Bg}(m_{inv}) = < \cos(n(\Phi - \Psi)) >$$

$$= v_n^{Sig} \cdot \frac{Sig}{Sig+Bg}(m_{inv}) + v_n^{Bg} \cdot \frac{Bg}{Sig+Bg}(m_{inv})$$

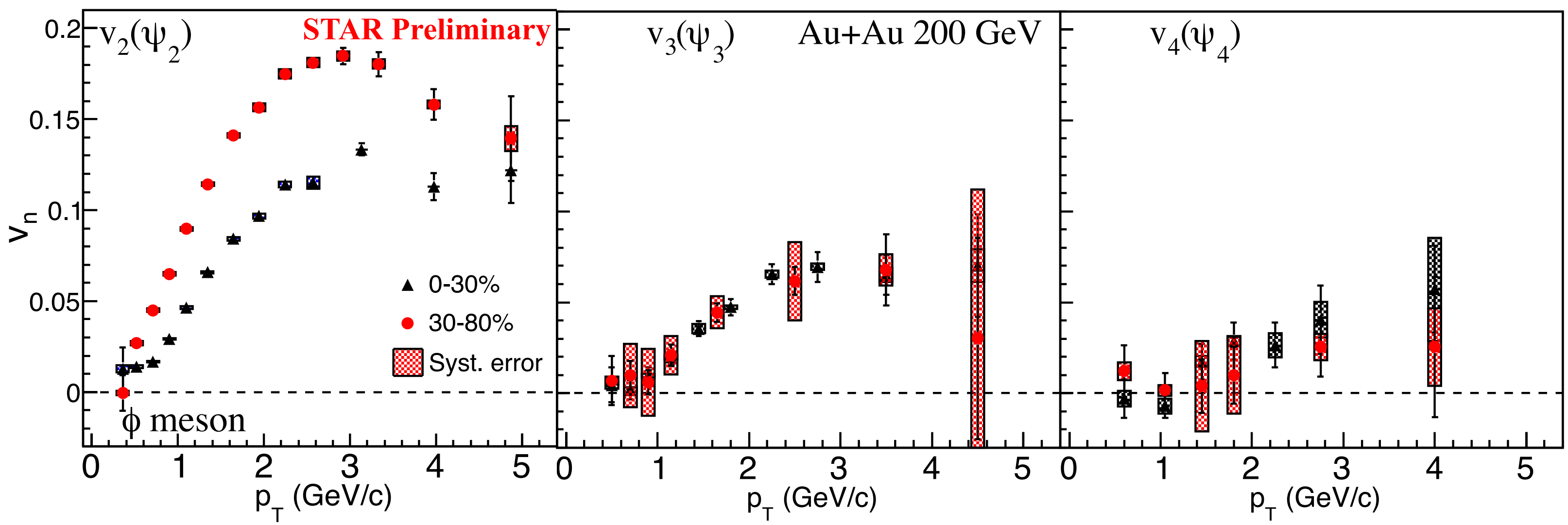
N. Borghini and J. Ollitrault Phys.Rev. C 70, 064905(2004).

v_2 , v_3 , v_4 of ϕ meson



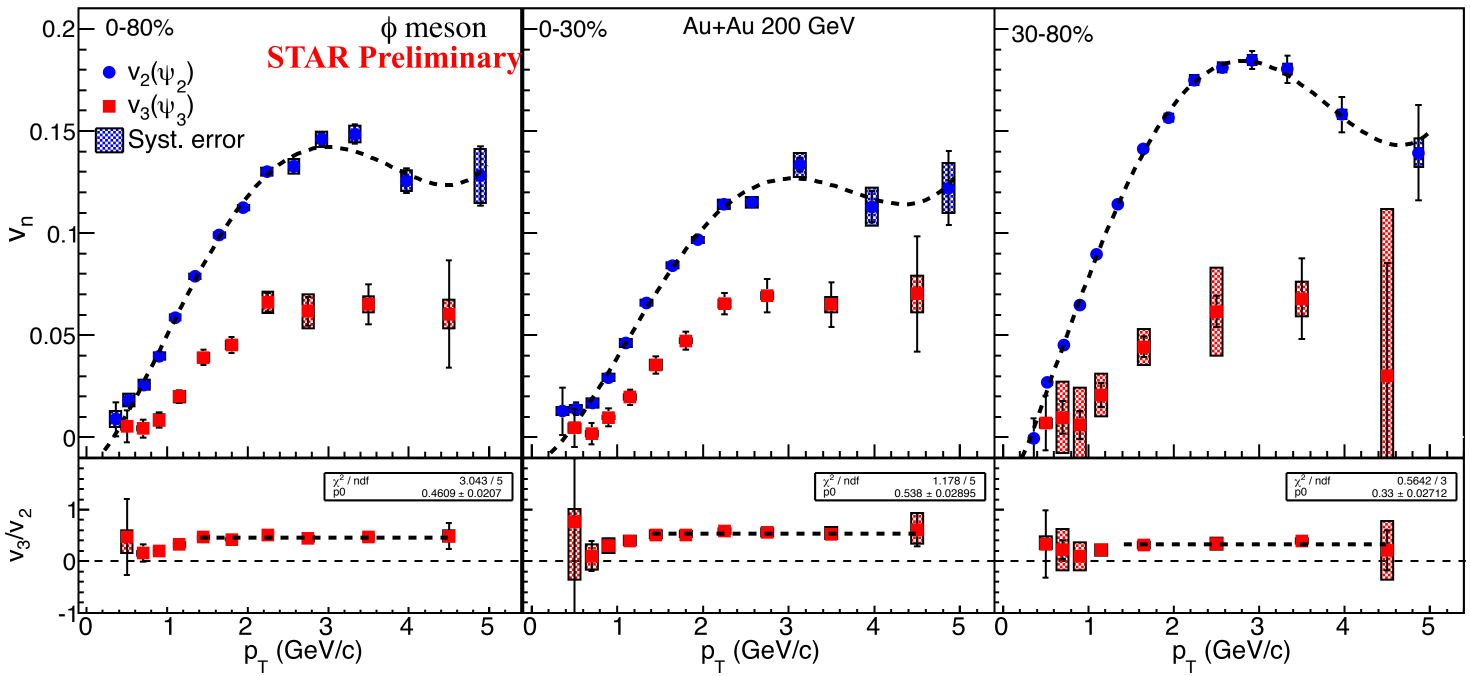
- The magnitude of $v_2(\psi_2)$ is greater than $v_3(\psi_3)$ and $v_4(\psi_4)$ for all centralities.
- v_n increases with p_T and has a maximum value in 2-3 GeV/c

v_n : Centrality dependence



- $v_2\,(\psi_2)$ shows strong centrality dependence
- No centrality dependence for $v_3(\psi_3)$ and $v_4(\psi_4)$ within statistical uncertainties

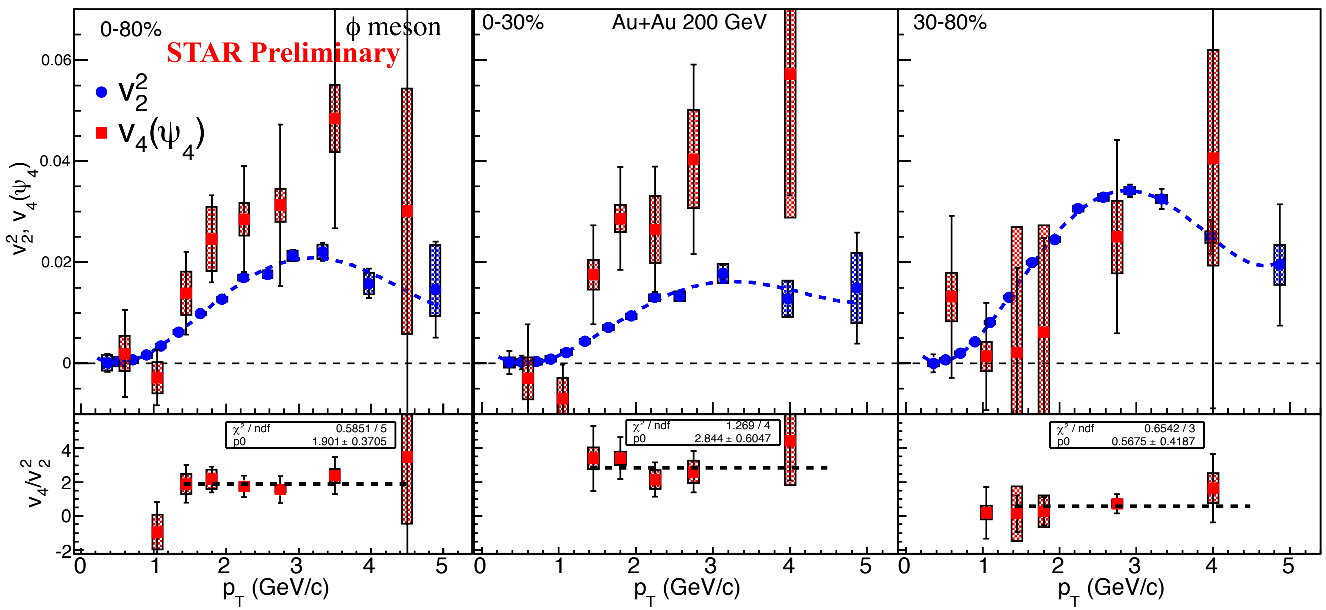
v_3/v_2 ratio



0-80%	0-30%	30-80%
v_3/v_2= 0.46+ -0.02	v_3/v_2= 0.53+- 0.02	v_3/v_2= 0.33+- 0.02

- v_3/v_2 ratio is constant for p_T>1.5 GeV/c

v_4/v_2^2 vs p_T



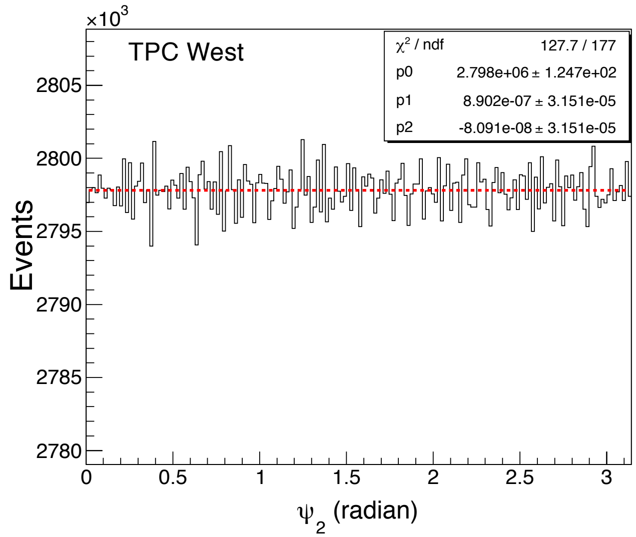
0-80%	0-30%	30-80%
$v_4(\psi_4)/v_2^2 = 1.90$ +- 0.37	$v_4(\psi_4)/v_2^2 = 2.84$ +- 0.60	$v_4(\psi_4)/v_2^2 = 0.56$ +- 0.42

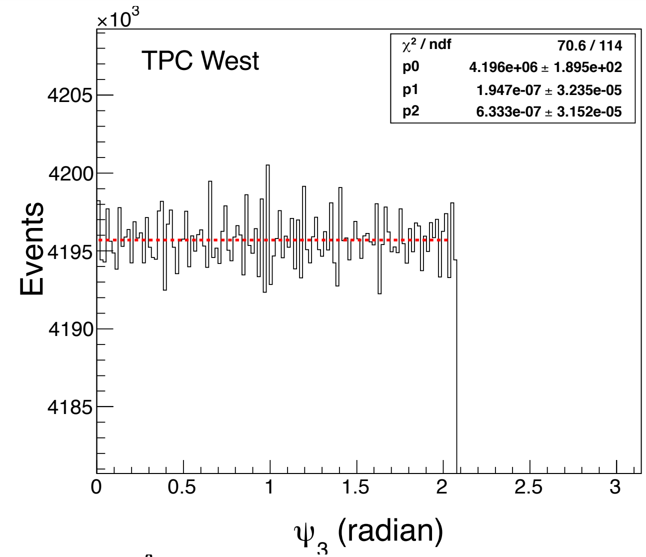
Summary

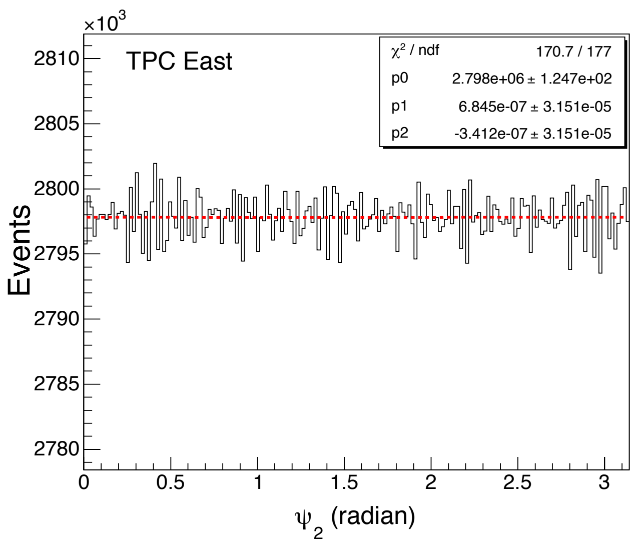
- We have presented $v_3(p_T)$ and $v_4(p_T)$ of ϕ meson in Au+Au collisions at $\sqrt{s_{NN}}$= 200 GeV
- v_n increases with p_T and has a maximum value in 2-3 GeV/c
- No centrality dependence for $v_3(\psi_3)$ and $v_4(\psi_4)$ within statistical uncertainties
- v_3/v_2 and $v_4(\psi_4)/v_2^2$ ratios are calculated in Au+Au collisions at $\sqrt{s_{NN}}$= 200 GeV
- v_3/v_2 ratio is constant for p_T>1.5 GeV/c

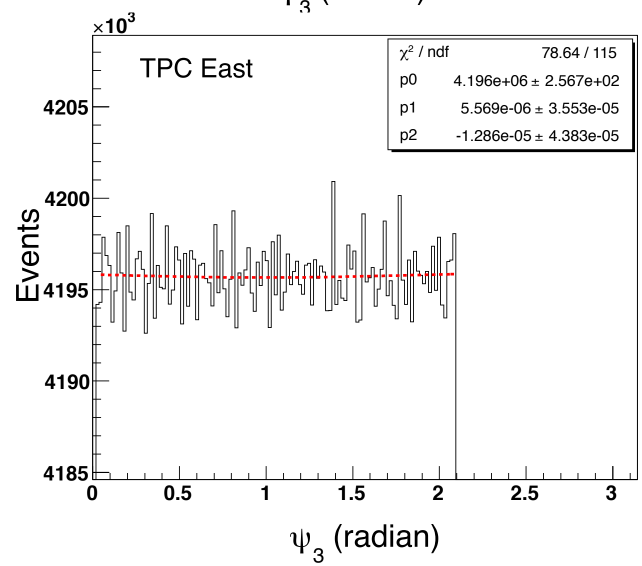
Thank you

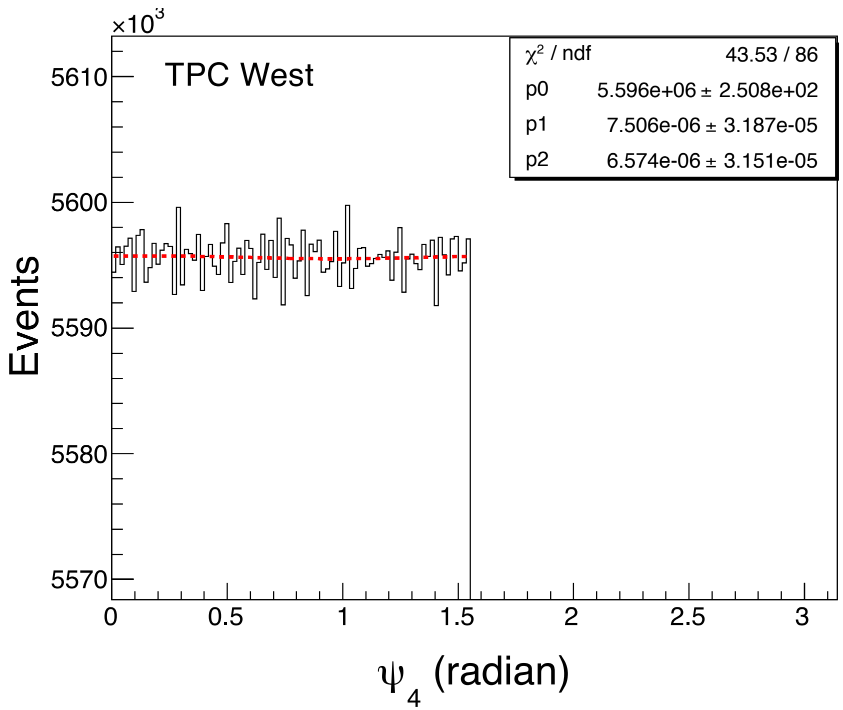
Back up Slides

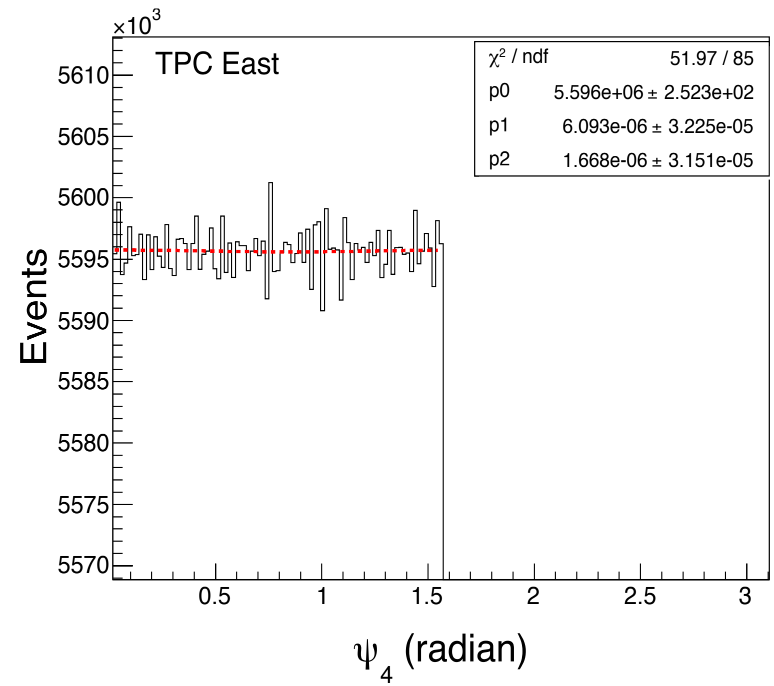












- Corrected by Recentre + Shift method
- Fitted with $p0*(1+p1*\cos[n\Psi_n] + p2*\sin[n\Psi_n])$
- η gap between east & west event plane is 0.1