J/ψ azimuthal anisotropy in Au+Au collisions at 200 GeV

Zhao Feng[1,2] (For the STAR collaboration)

1.Brookhaven National Lab

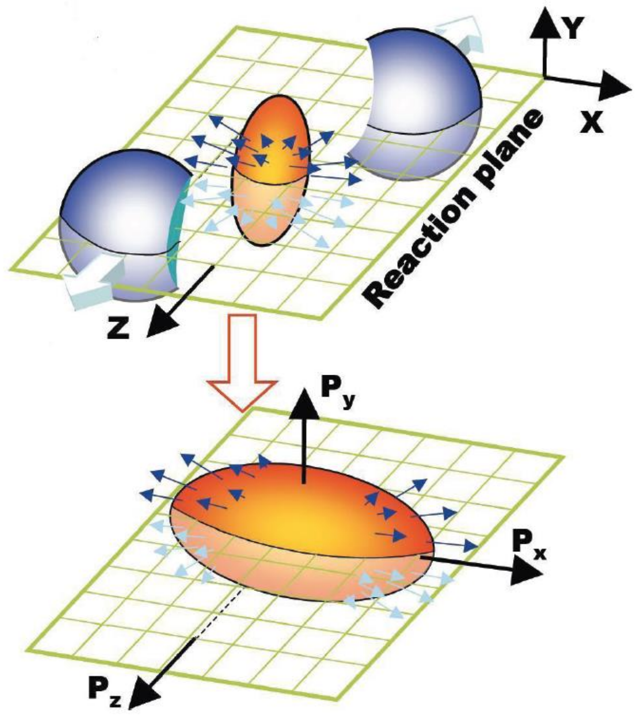
2.Central China Normal University

Flow

- The anisotropy in the initial spatial space will be transferred into the anisotropy in the momentum space, which can be described by Fourier series:

$$E\frac{d^3N}{d^3p} = \frac{1}{2\pi}\frac{d^2N}{p_T dp_T dy}\{1 + \sum_{n=1}^{\infty} 2v_n \cos[n(\varphi - \Psi_{RP})]\}$$

- v_n is the n_{th} harmonic coefficient, which is used for a quantitative characterization of the event anisotropy.
- v_1 is referred to directed flow while v_2 is called elliptic flow.
- Ψ_{RP} is the reaction plane angle, which is defined by the vector of the impact parameter and the beam direction, can not be directly measured. But it can be estimated from the particle's azimuthal distribution.



$$\Psi = 0.5 * arctan\frac{\sum q_y}{\sum q_x}$$

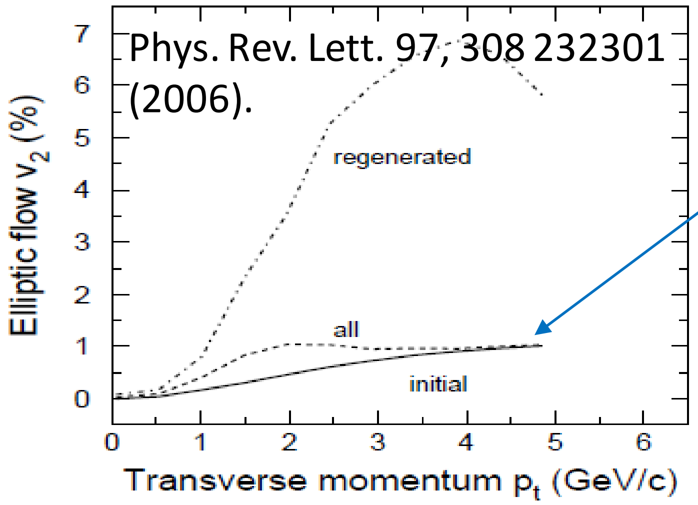
$$q_x = \cos(2 * \varphi);$$
$$q_y = \sin(2 * \varphi);$$

Motivation : charm quark production

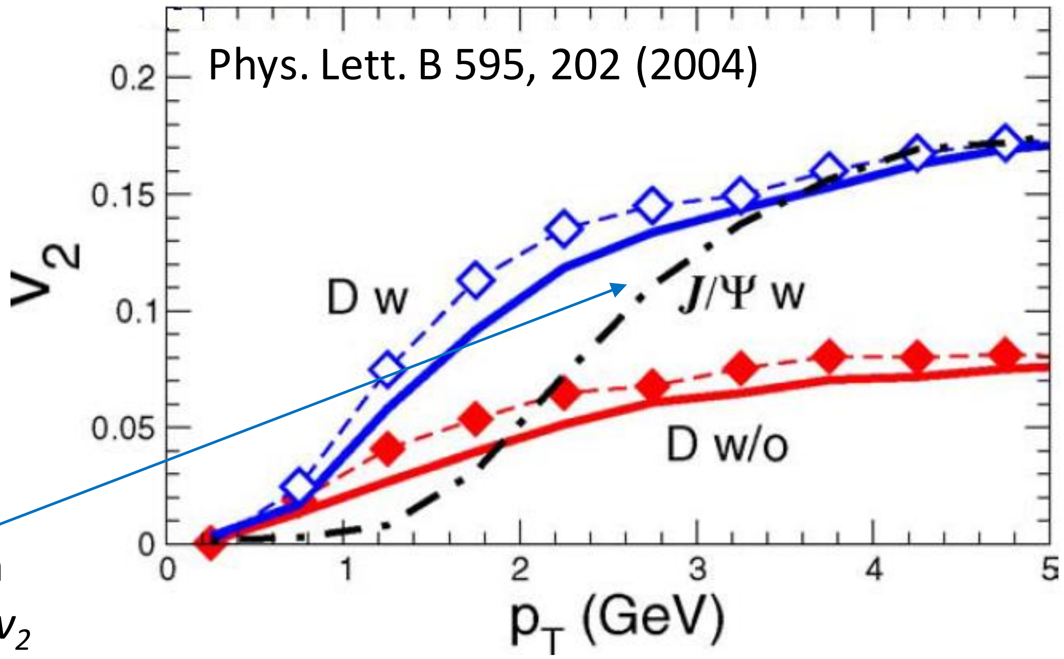
➢ Why study charm quark production in relativistic heavy-ion collisions ?

- Large mass : More difficult to thermalize than light quarks. If charm quarks have sizable collective motion, light partons must be well thermalized.
- Produced in the early stage : Useful for understanding the dynamics responsible for fast thermalization at RHIC.
- Less influenced by late evolution : Carry relatively clean information from early stage.

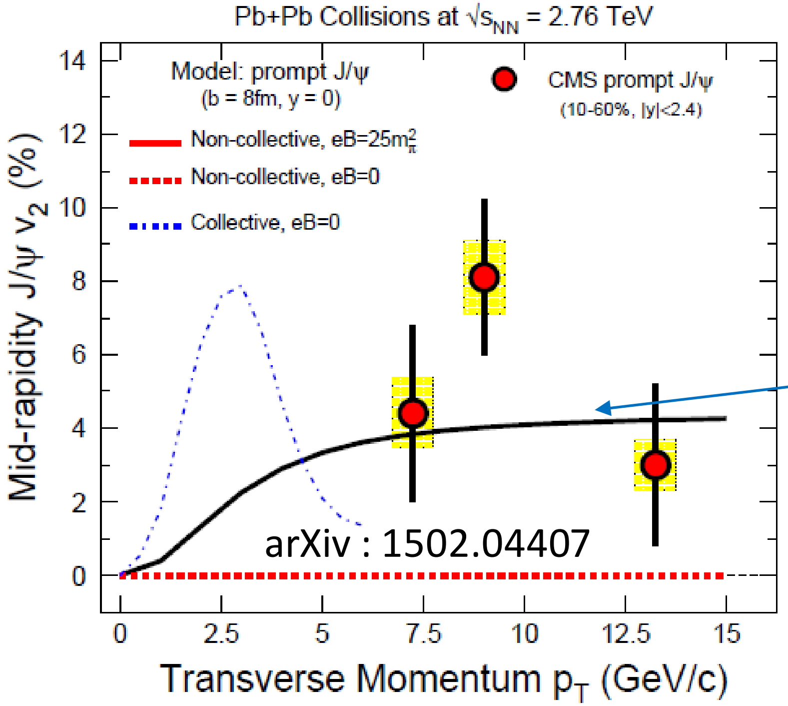
Motivation : J/ψ elliptic flow



Direct pQCD production + leakage effect give limited v_2



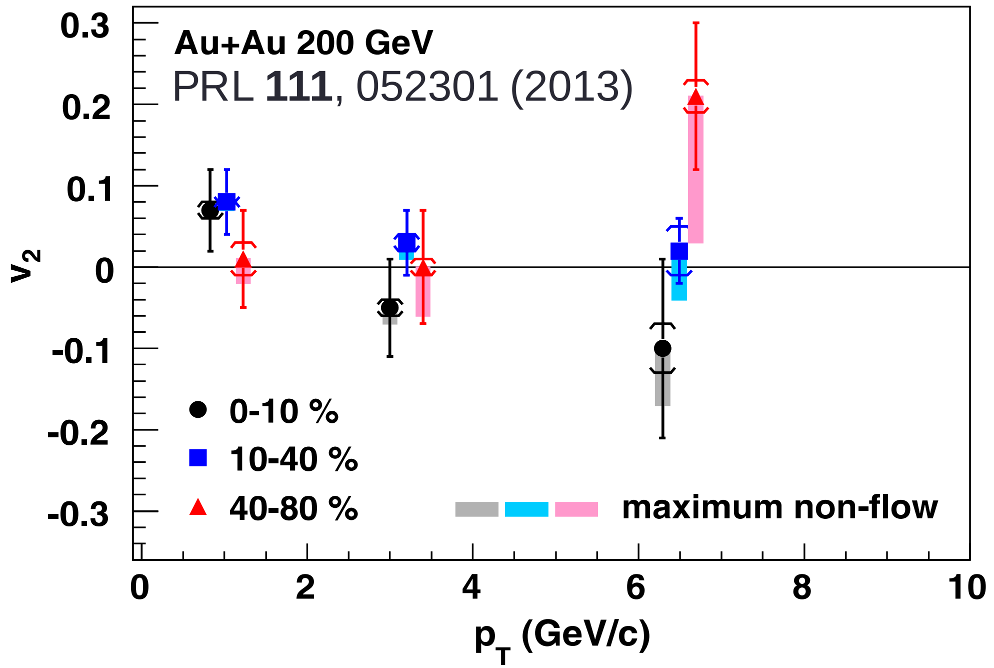
coalescence of thermalized charm quarks gives large v_2



External magnetic field gives finite v_2

- Different magnitudes and p_T dependence from different production mechanisms.
- Can be used to infer the relative contribution from different sources.
- Unique probe for testing production mechanisms and useful for constraining models.

STAR published results



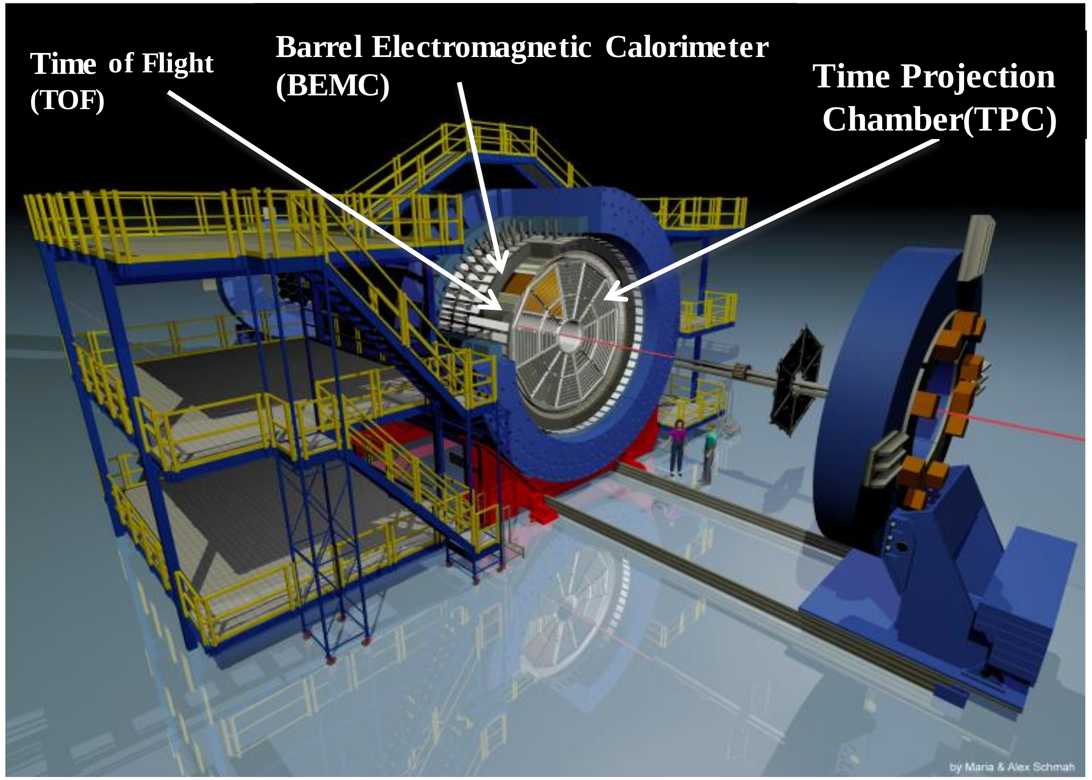
- Datasets used
  - Run10 Au + Au 200 GeV
  - Min.Bias 360M
  - Central 270M
  - High E_T trigger (BEMC) 170M
- J/ψ v_2 is consistent with zero when p_T > 2 GeV/c in Au+Au 200GeV collisions.
- Large statistical uncertainty

- Since the publication, more data have been taken in year 2011(statistics comparable to 2010) and 2014 (~10 times statistics of 2010).
- With these datasets we can reduce the statistical uncertainty and make a stronger conclusion.

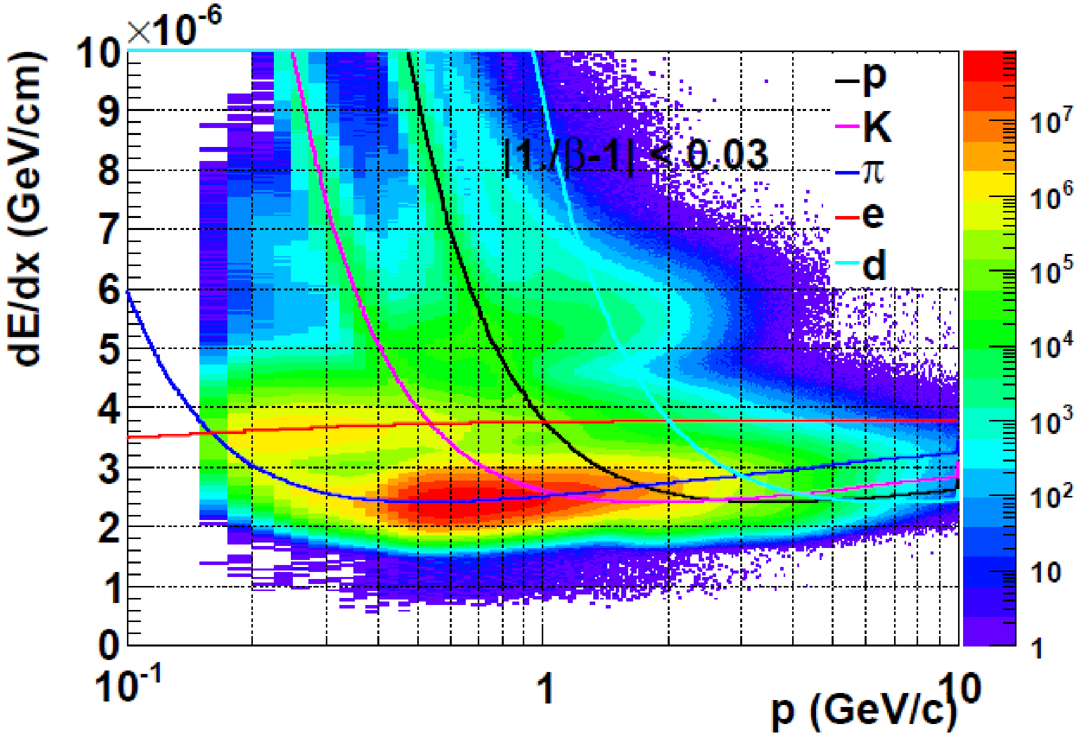
STAR detector

The Solenoidal Tracker at RHIC (STAR) is one of the two large experiments operating at RHIC.

- Large acceptance(2π azimuthal angle coverage).
- Excellent particle identification capabilities.
- Ideal for measuring flow and event-by-event correlations/fluctuations.



Electron PID



Good separation between electrons and pions

Electron PID

- **Event level cut :**

Centrality : 0-80%;

|VertexZ|< 30 cm;

- **Track quality cut :**

nHitsFit >20; nHitsDedx >15;

ratio >0.52 ; dca <1 cm;

p >1.2 GeV/c;

Electron-pair	momentum	The satisfaction of any of the three conditions below		
		TPC+BEMC	TPC+TOF	TPC+BEMC+TOF
daughter1	p>1.4 GeV/c	0.3<pc/E<1.5 -0.6< $n\sigma_{\{electron\}}$ <3 p>1.5 GeV/c BEMC energy>0.5	|1-1/β|<0.03 -0.3< $n\sigma_{\{electron\}}$ <3	0.3<pc/E<1.5 -1.0< $n\sigma_{\{electron\}}$ <3 |1-1/β|<0.03
daughter2	p>1.2 GeV/c			

$$n\sigma = \frac{1}{\sigma_{\{\frac{dE}{dx}\}}} \ln \frac{dE/dx_{measured}}{dE/dx_{theorical}}$$

Flattening of the event plane distribution

To correct for the TPC efficiency loss, a recentering factor needs to be generated.

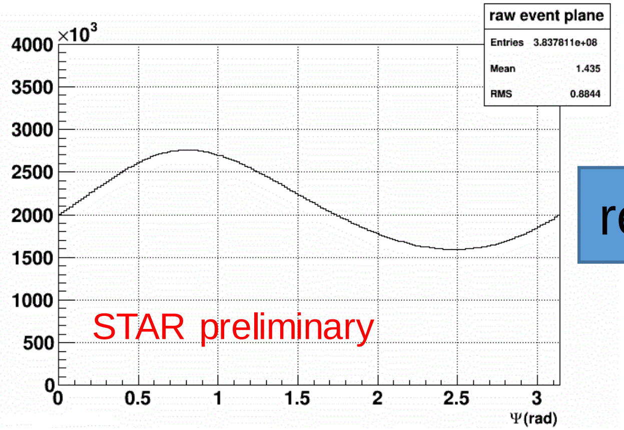
1. $Q_x = \frac{\sum_{i=1}^{n} q_x^i}{n}$, $Q_y = \frac{\sum_{i=1}^{n} q_y^i}{n}$ .The calculation is performed separately for different run day, centrality, pseudorapidity and vertex position along the beam direction.

2. Define
$$q_y' = q_y - Q_y$$
$$q_x' = q_x - Q_x$$

3. Obtain event plane angle:
$$\Psi = 0.5 * arctan\frac{\sum q_y'}{\sum q_x'}$$

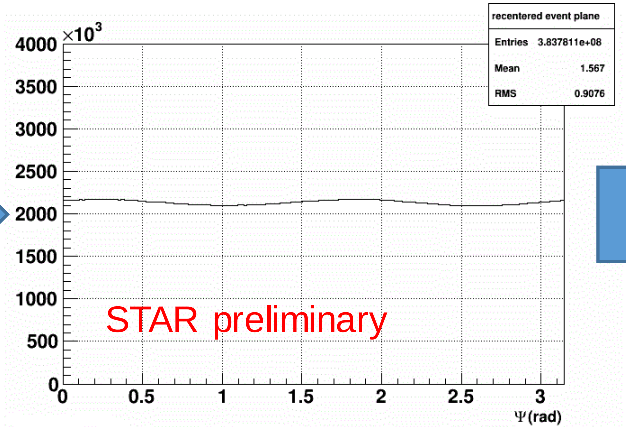
4. Further flatten the event plane distribution by shift method. (Phys. Rev. C 56, 3254 (1997)).

Event plane distributions



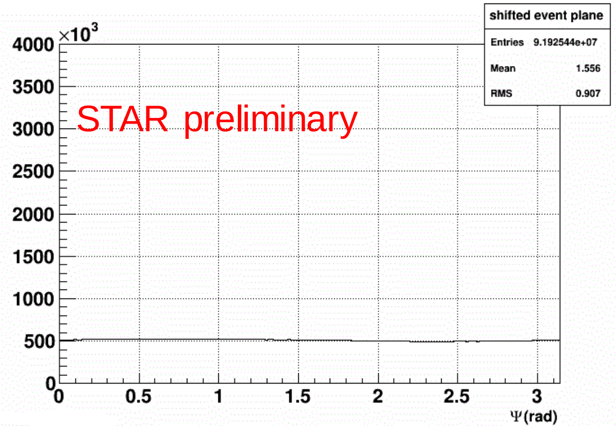
raw event plane

recenter



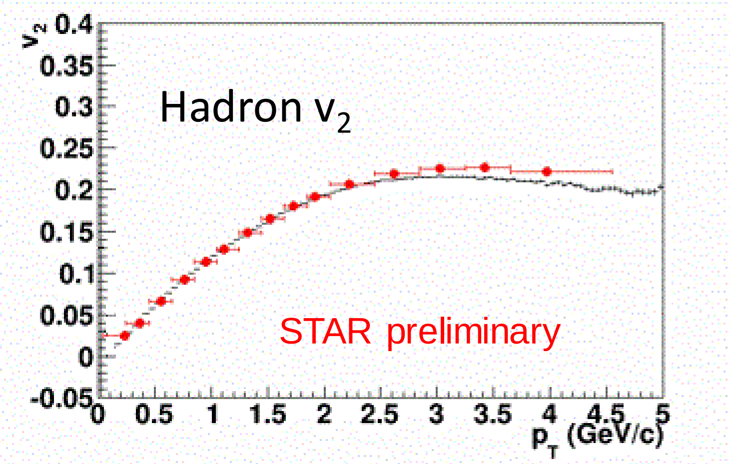
recentered event plane

shift



shifted event plane

The charged hadron v_2 we obtained with the flattened event plane is consistent with previous STAR publication.

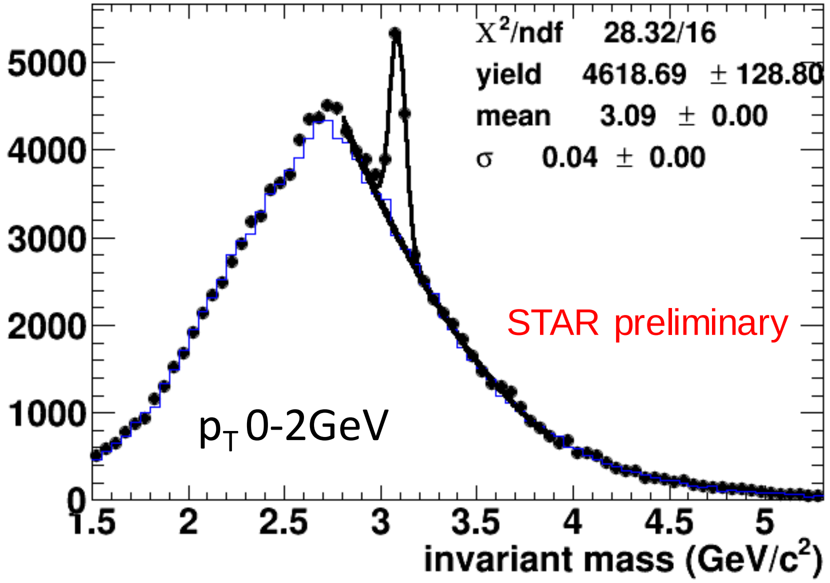


using 20-60% minbias events

Red points are from STAR publication (Phys. Rev. Lett. 93, 252301 (2004))

J/ψ yield extraction

- The unlike-sign m_{inv} distribution is fitted with a Gaussian on top of a polynomial background :



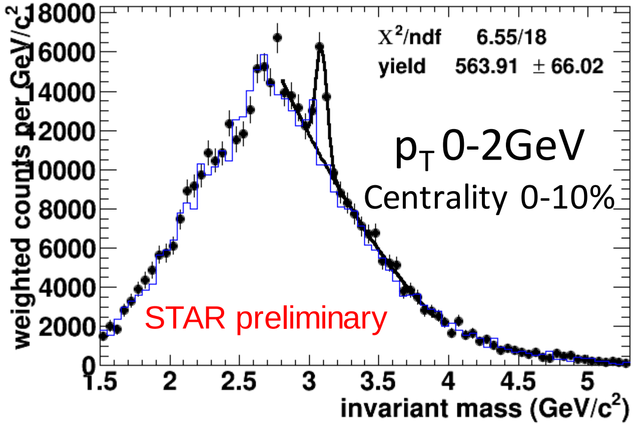
Solid dots : unlike-sign electron pairs
Blue line : same-sign electron pairs

$$y = ([1] + [2]x + [3]x^2) + \left(\frac{[4]}{[5]\sqrt{2\pi}} e^{-\frac{(x-[6])^2}{2[5]^2}}\right)$$

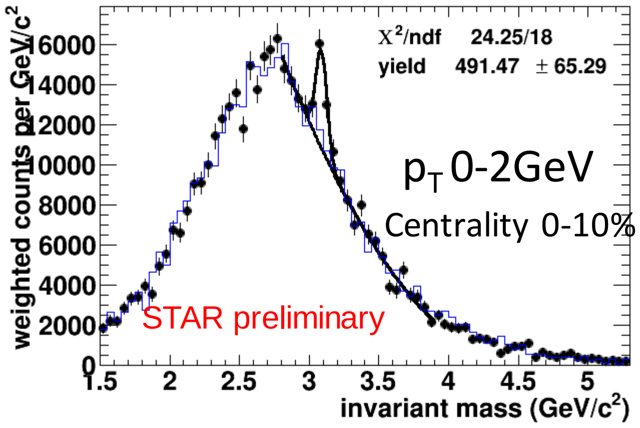
Background :Polynomial

Signal : Gaussian

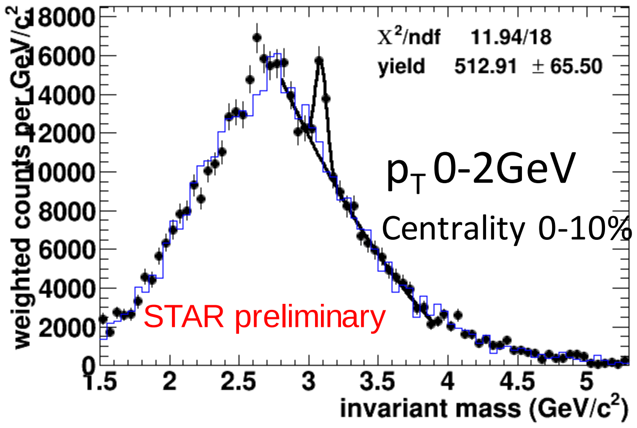
J/ψ yield in different $(\varphi - \Psi)$ bins



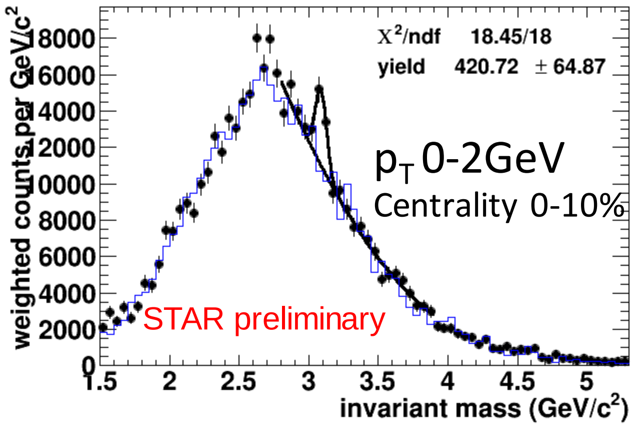
$\left[0, \frac{\pi}{10}\right]$



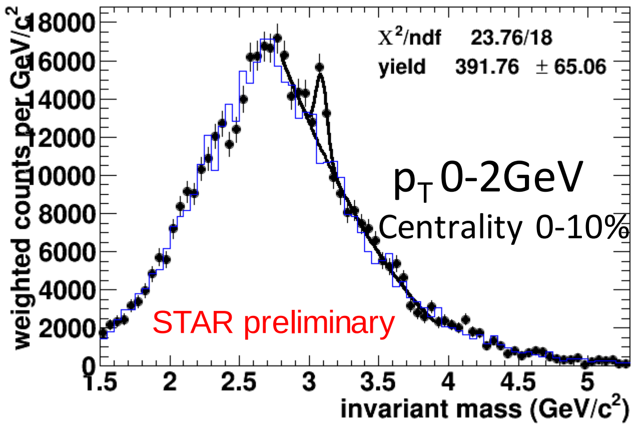
$\left[\frac{\pi}{10}, \frac{2\pi}{10}\right]$



$\left[\frac{2\pi}{10}, \frac{3\pi}{10}\right]$



$\left[\frac{3\pi}{10}, \frac{4\pi}{10}\right]$



$\left[\frac{4\pi}{10}, \frac{5\pi}{10}\right]$

V_2 Fitting Process

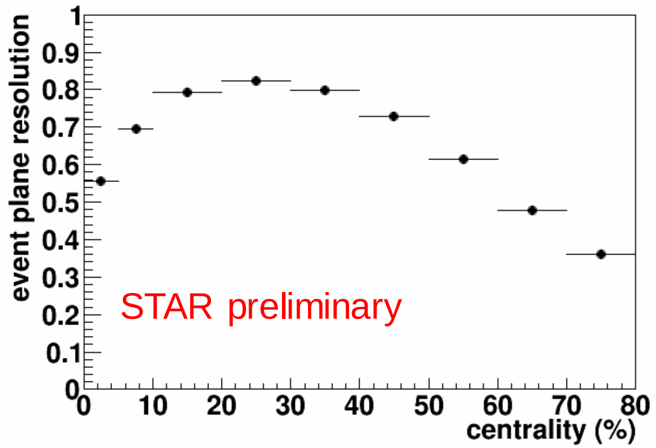
- With the yield as a function of $\varphi - \Psi$ obtained, the observed v_2 can be extracted by fitting with the following formula:

$$y = N[1 + 2v_2^{observed} * cos2(\varphi - \Psi)]$$

- The final v_2 need to be scaled by mean inverse event plane resolution.

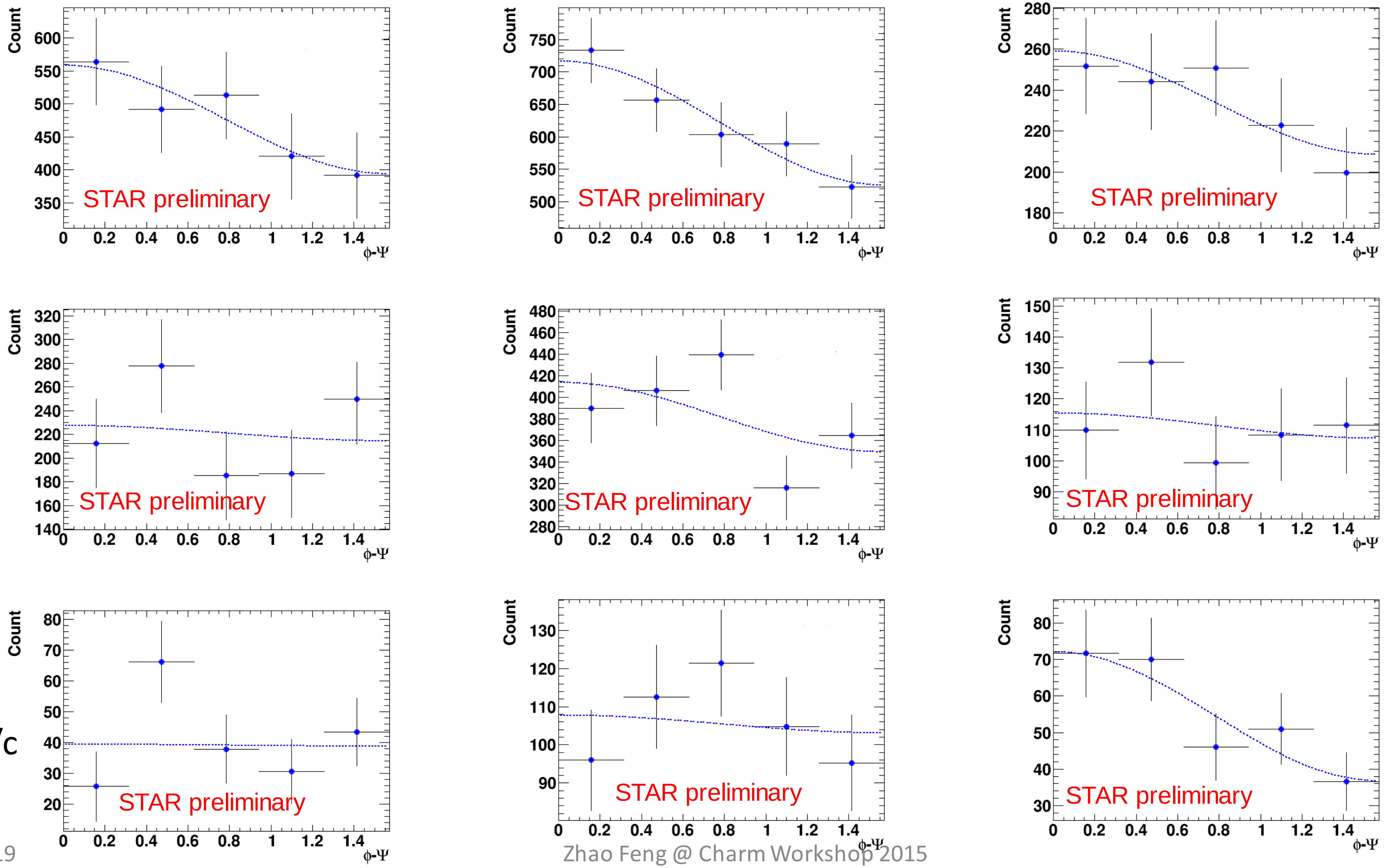
$$v_n = v_n^{obs,R}/R$$

The event plane resolution is derived by studying the correlation between two sub-events.(Poskanzer and Voloshin, Phys.Rev.C58:1671-1678,1998)

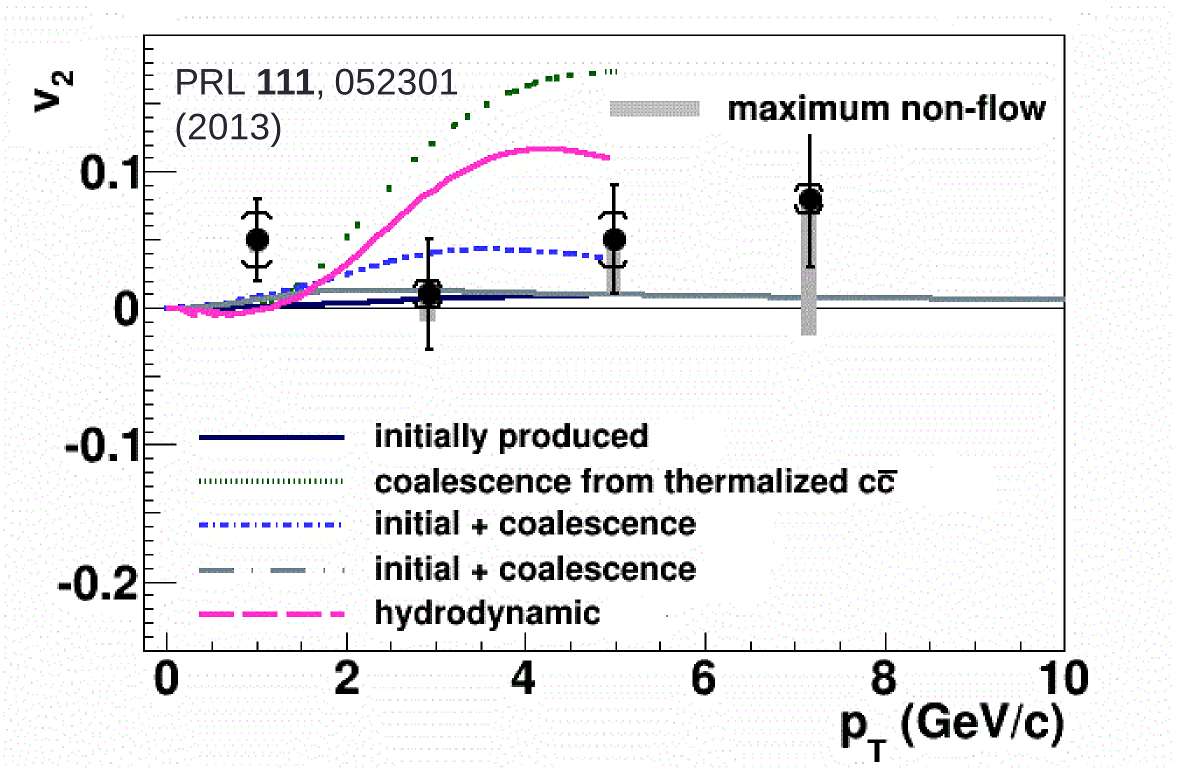


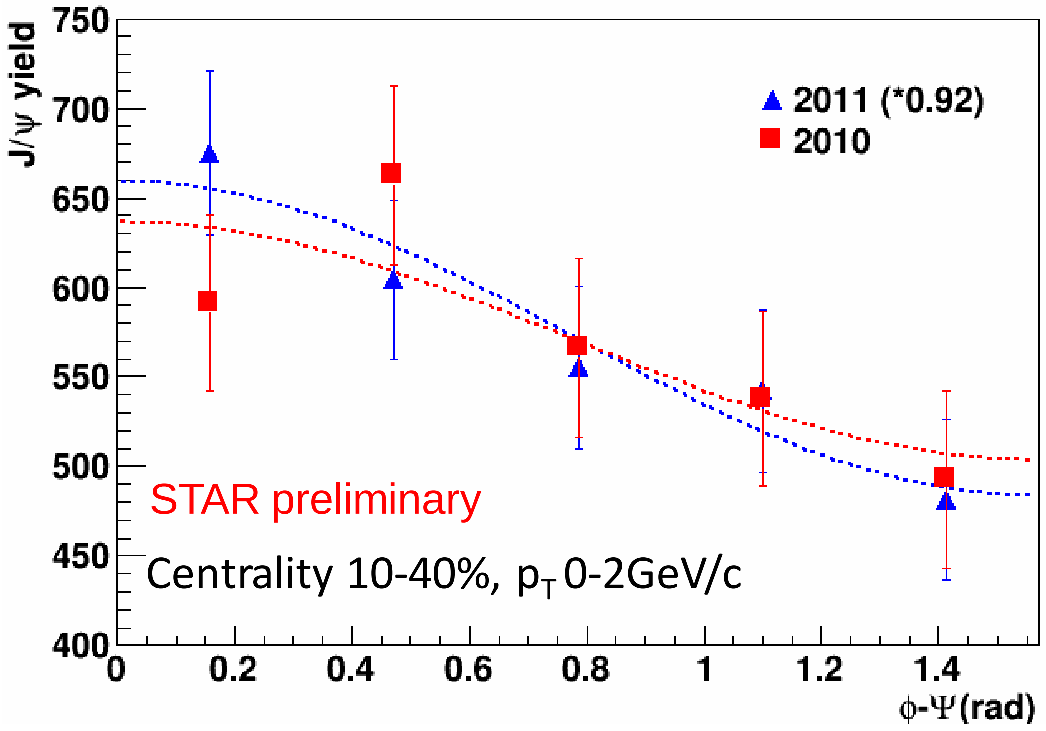
Azimuthal distribution

	0-10%	10-40%	40-80%
0-2 GeV/c			
2-5 GeV/c			
5-10 GeV/c			



Azimuthal distribution, compared to 2010





Conclusion

- From our published result, the measured J/ψ elliptic flow is consistent with zero within errors for transverse momentum between 2 and 10 GeV/c. Our measurement suggests that J/ψ with relatively large transverse momenta are not dominantly produced by coalescence from thermalized charm quarks, when comparing to model calculations.
- We are analyzing data from year 2011, the new analysis shows that the azimuthal distribution of J/ψ is consistent with our previous result. The extraction of final v_2 and the investigation of systematic uncertainties is ongoing.