

J/ ψ elliptic flow measurement in Pb-Pb collisions at 2.76 TeV at forward rapidity in the ALICE experiment

Laure Massacrier

On behalf of the ALICE Collaboration
SUBATECH, Nantes, France



Outline

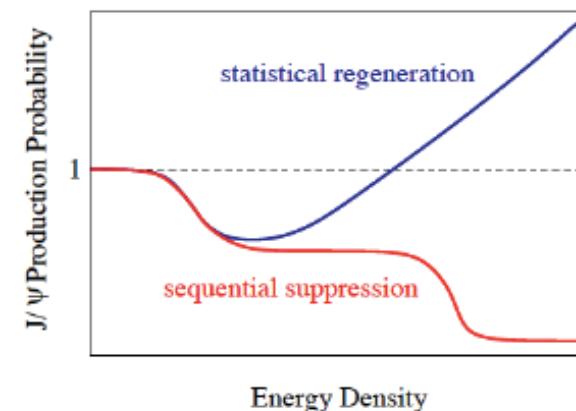
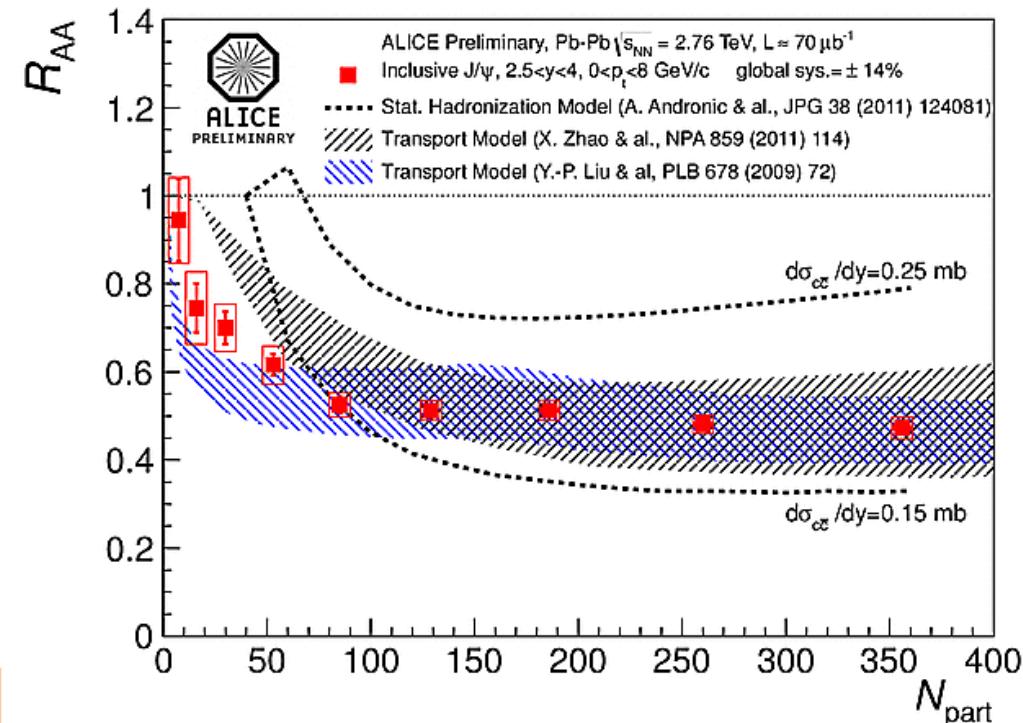
- Physics Motivations
- ALICE Setup
- Data analysis
 - Event plane method
 - The event plane determination and its resolution
 - Signal extraction
 - Observed v_2 extraction
 - Resolution of the event plane correction
 - Results
 - Centrality dependence of $J/\psi v_2$
 - p_t -differential $J/\psi v_2$
 - Comparison with STAR
 - Comparison with theory
- Outlook

Physics motivation

- ALICE J/ ψ R_{AA} measurement in Pb-Pb collisions at forward rapidity
 - R_{AA} larger than at SPS and RHIC in most central collisions (all p_t)
 - Weak centrality dependence
 - Statistical hadronization and transport models with regeneration mechanism can describe the data

New results on J/ ψ R_{AA} presented by Jens Wiechula this afternoon and in Christophe Suire talk on wednesday

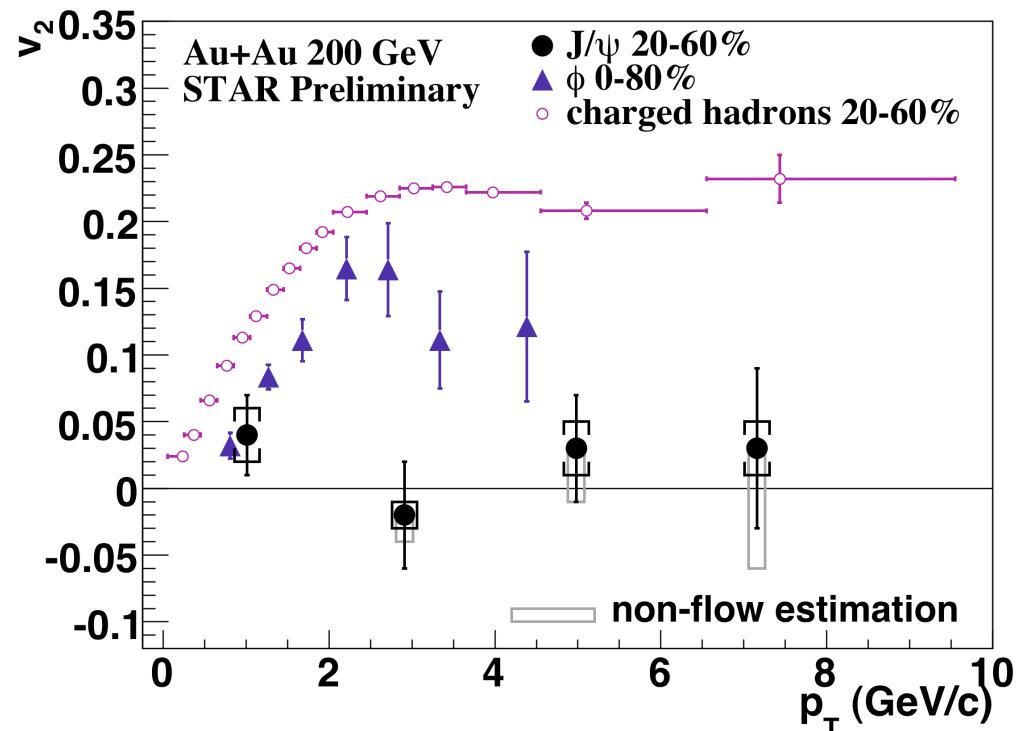
- At LHC energy, high charm quark density
- Role of regeneration in J/ ψ production mechanism?





Physics motivation

- J/ ψ elliptic flow measurement :
 - To learn about the fate of J/ ψ in the QGP
 - J/ ψ elliptic flow inherited from charmed quark that thermalize in QGP?
- J/ ψ elliptic flow compatible with zero within the uncertainties in all of the measured p_t ranges at RHIC energies
- J/ ψ production at RHIC dominated by charm quark recombination? This is disfavored by STAR. However models assuming regeneration at low p_t and primordial J/ ψ production at high p_t can describe the data



Zebo Tang (for the STAR Collaboration) 2011
J. Phys. G: Nucl. Part. Phys. 38 124107

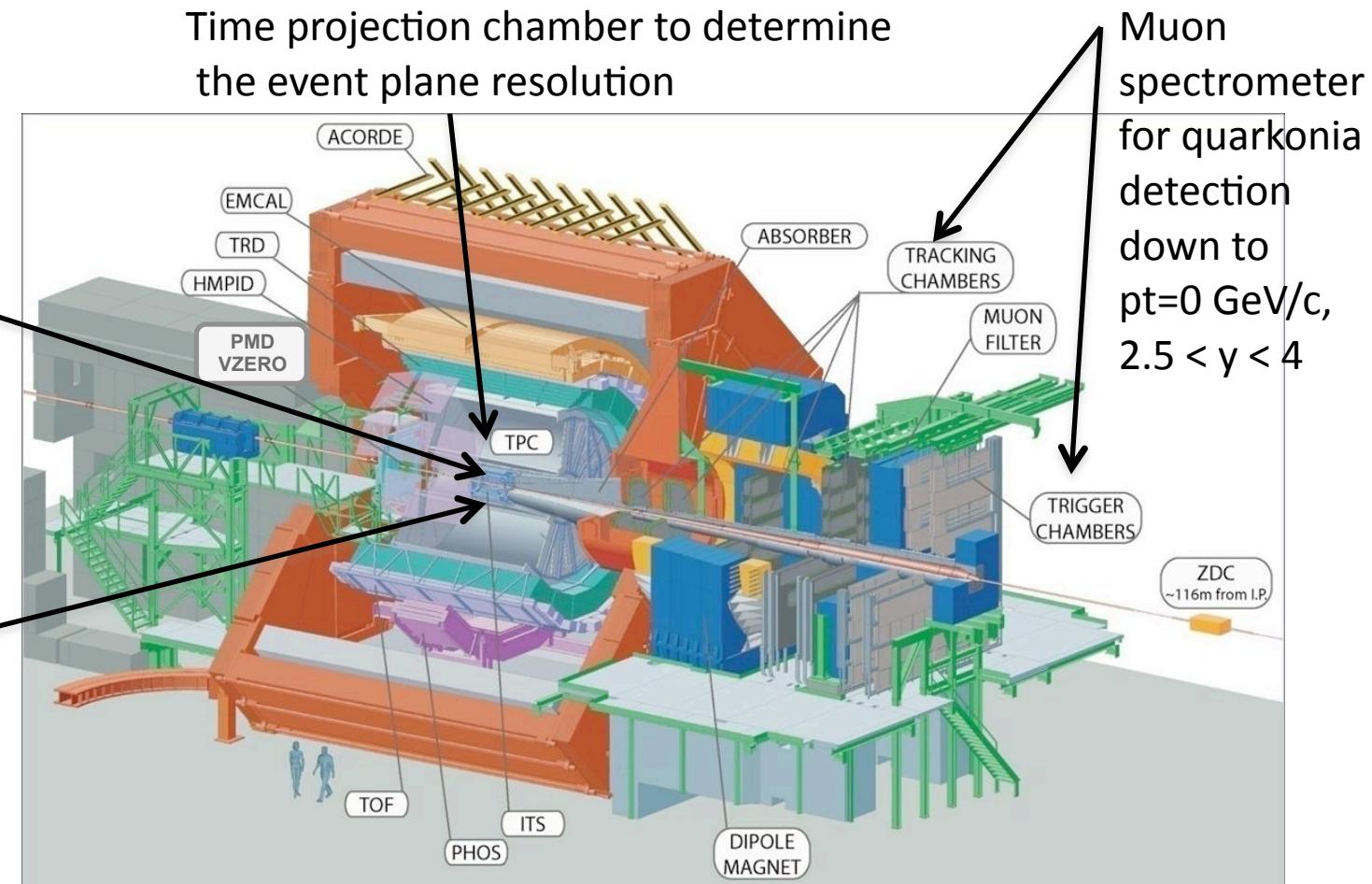


ALICE

ALICE Setup

VZERO
hodoscopes
to determine
the event
plane and the
centrality of
the collision.
Also used as
trigger

First layers of
the inner
tracking system
for vertex
determination



Minimum Bias trigger : Signal in VZEROA & VZEROC

$$L_{\text{int}} \approx 1 \mu\text{b}^{-1}$$

Dimuon trigger : MB trigger + 2 muon tracks above a p_t cut ($1 \text{ GeV}/c$)

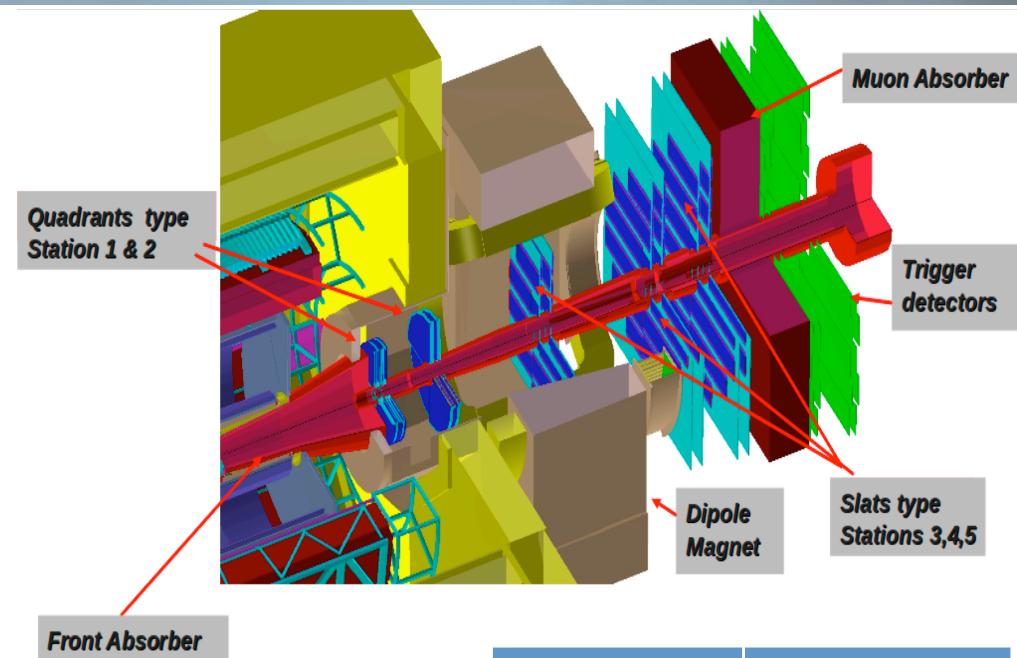
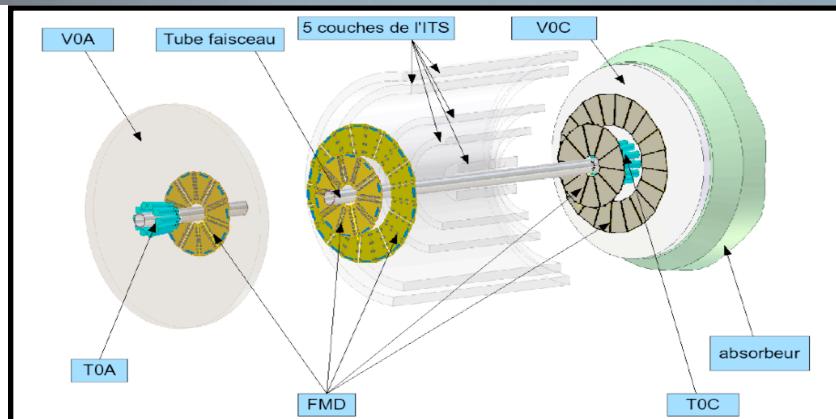
$$L_{\text{int}} \approx 70 \mu\text{b}^{-1}$$

Pb-Pb
collisions
2011



ALICE

ALICE Setup



- **VZERO detectors :**

- 2 arrays of 32 scintillators located on both side of the interaction point (VZEROA and VZEROC)
- Each array is divided into 4 rings of 8 scintillators
- VZEROC shares part of the acceptance of the muon spectrometer
- Pseudo-rapidity gap between VZEROA and muon spectrometer : 5.3 units

- **Muon spectrometer :**

- Pseudo-rapidity coverage : $-4 < \eta < -2.5$
- Muon track selection :
 - Both tracks reconstructed in the tracker matched a track in the muon trigger
 - Both tracks exit the front absorber within the angular acceptance of the spectrometer
 - Opposite sign dimuon within $2.5 < y < 4$

The Event plane method

- Azimuthal angle of the reaction plane estimated from the **observed event plane angle** determined from anisotropic flow itself
- Event flow vector \vec{Q} (2d vector in the transverse plane) :

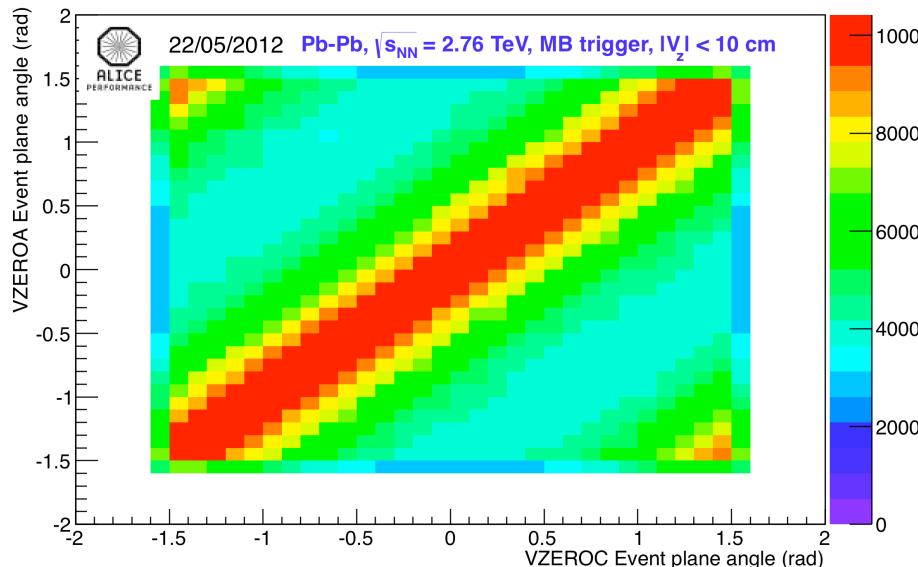
$$Q_{n,x} = \frac{\sum_{i=0}^{31} S_i \cos(n\phi_i)}{\sum_{i=0}^{31} S_i}$$

$$Q_{n,y} = \frac{\sum_{i=0}^{31} S_i \sin(n\phi_i)}{\sum_{i=0}^{31} S_i}$$

Where ϕ_i is the azimuthal angle of each scintillator array, n = 2 for elliptic flow and S_i is a weight proportional to the elliptic flow of the primary particles crossing the scintillator

- The **event plane angle** for the 2nd harmonic obtained with VZEROA detector is expressed as : $\Psi_{EP,2} = \frac{\arctan 2(Q_{2,y}, Q_{2,x})}{2}$
- The observed v_2 is the 2nd harmonic of the azimuthal distribution of particles with respect to the event plane : $v_2^{obs}(p_T, y) = <\cos[2(\phi_i - \Psi_{EP,2})]>$
- Finite multiplicity limits the estimation of the angle of the reaction plane, v_2 is then corrected by the **event plane resolution** : $v_2 = v_2^{obs}/R_2$

Flattening of the event plane azimuthal distribution



Flattening of the event plane azimuthal distribution needed to remove acceptance correlations from an imperfect detector

- First step : equalization of the signal from all the 64 VZERO channels (32 per hodoscope)

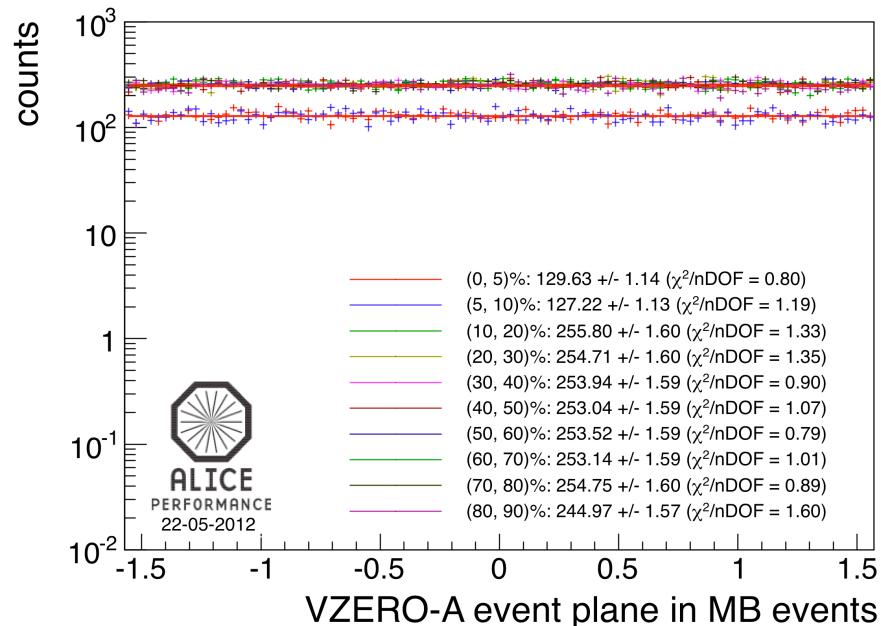
- Second step : Recentering, twisting and rescaling of VZERO event-plane cumulants

$$Q_{2,x} = \langle Q_{2,x} \rangle + A^+ [\cos 2\Psi_{EP,2} + \Lambda^+ \sin 2\Psi_{EP,2}]$$

$$Q_{2,y} = \langle Q_{2,y} \rangle + A^- [\cos 2\Psi_{EP,2} + \Lambda^- \sin 2\Psi_{EP,2}]$$

Parameters extracted from mean and RMS of $Q_{2,x}$, $Q_{2,y}$ and $Q_{2,x}Q_{2,y}$ distributions

- Last step : Remove residual fluctuations due to azimuthal segmentation of VZERO rings. Fourier flattening technique using one single parameter $\langle \sin 8\Psi_{EP,2} \rangle$



Signal extraction

J/ ψ signal extraction
performed in 6 $\Delta\phi$ bins where

$$\Delta\varphi = \phi_{\text{dimuon}} - \Psi_{\text{EP, 2}}$$

2 different functions used to describe the signal :

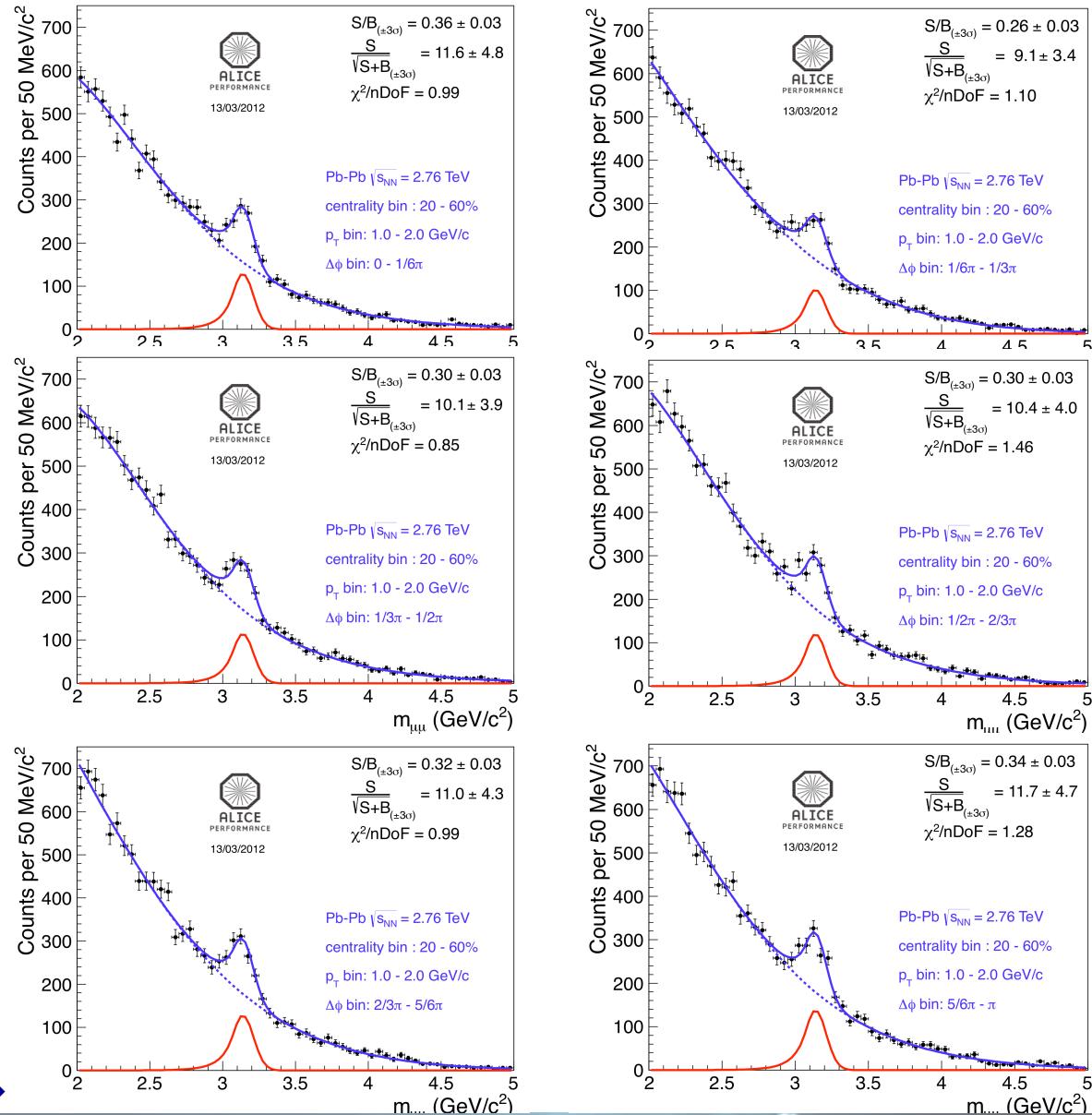
- a Crystal Ball function
- a Crystal Ball function with an additional tail on the right

2 different functions used to describe the background :

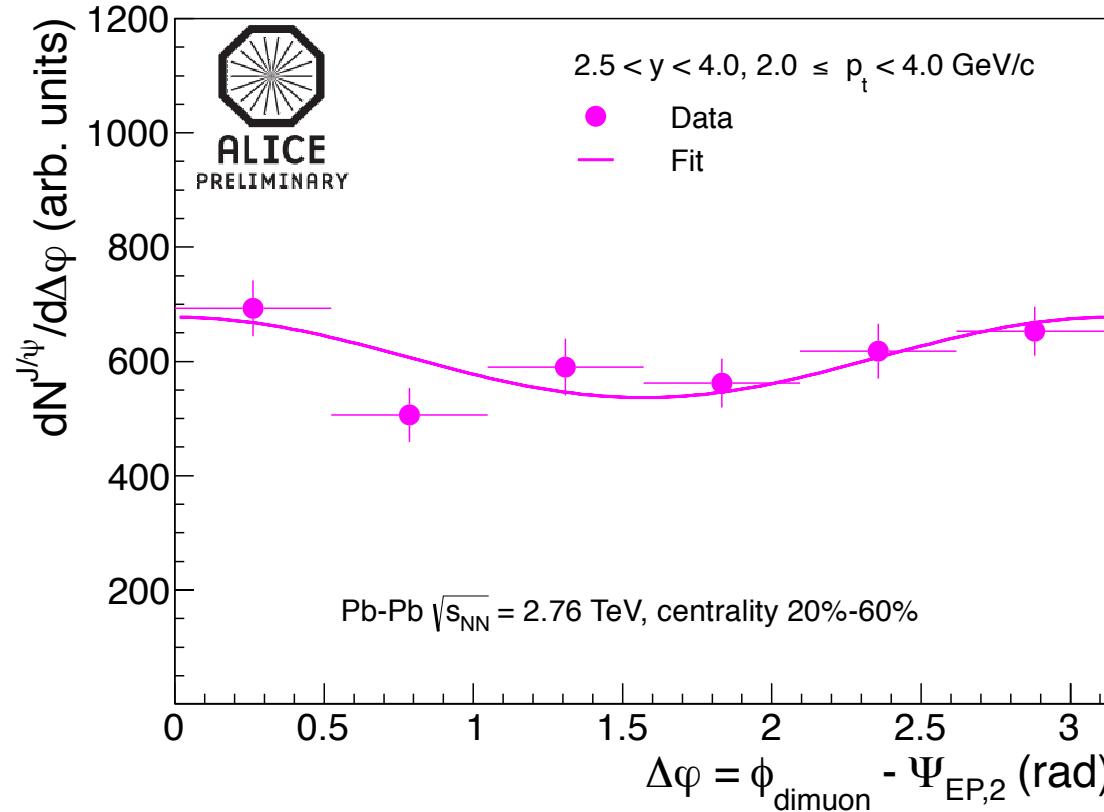
- a third order polynomial function
- a variable width gaussian

In addition, the fitting range and width of the Crystal ball are varied in order to evaluate systematic uncertainties from signal extraction

Crystal ball + variable width gaussian →



Observed v_2 extraction

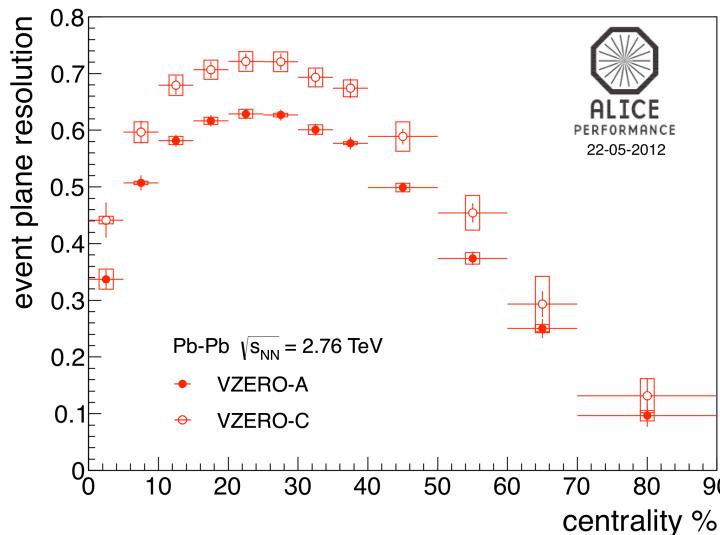


- Non corrected elliptic flow v_2^{obs} extracted from the fit of the distribution of the number of J/ψ in $6\Delta\varphi$ bins
- Extraction is performed for different bins in centrality and transverse momentum of the dimuon pair

$$\frac{dN_{J/\psi}}{d\Delta\varphi} = A \times \left[1 + 2 v_2^{obs} \cos(2[\phi_{\text{dimuon}} - \Psi_{EP,2}]) \right]$$

Event plane resolution

- 3 sub-events method to determine the resolution of the event plane given by VZEROA detector :
 - 3 independent detectors (TPC, VZEROA, VZEROC), with 3 different rapidity coverage and large η gap between the 3 sub-events



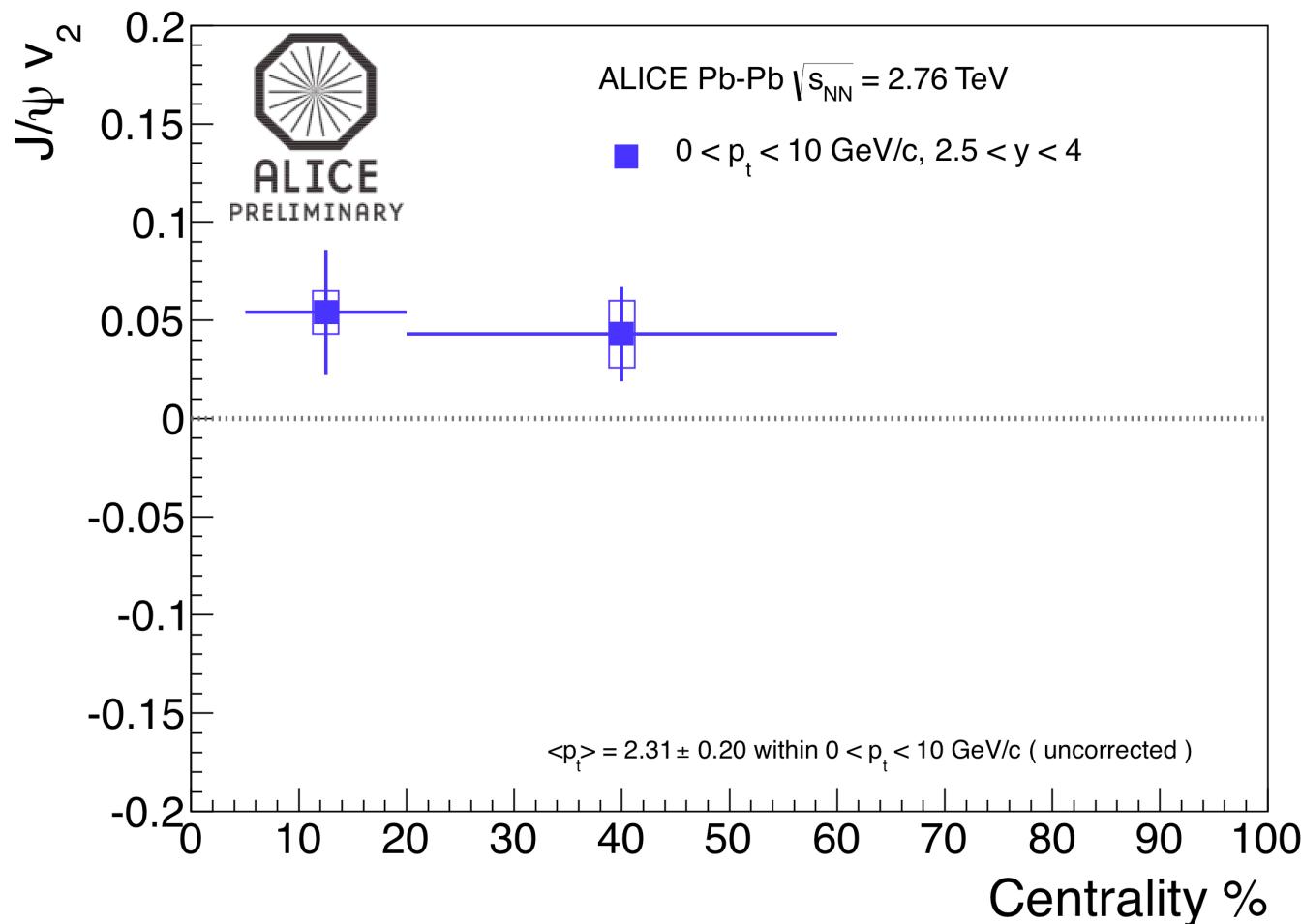
If the subevents are not “equal,” or if you have only correlations between particles in different windows, and the resolution in each window can be different, then one needs at least three windows to determine the event plane resolution in each of them. In this case, for example, the resolution in the first window is determined as [3,4]

$$\langle \cos[n(\Psi_m^a - \Psi_r)] \rangle = \sqrt{\frac{\langle \cos[n(\Psi_m^a - \Psi_m^b)] \rangle \langle \cos[n(\Psi_m^a - \Psi_m^c)] \rangle}{\langle \cos[n(\Psi_m^b - \Psi_m^c)] \rangle}}.$$

A. M. Poskanzer and S. A. Voloshin, Phys. Rev. C58, 1671

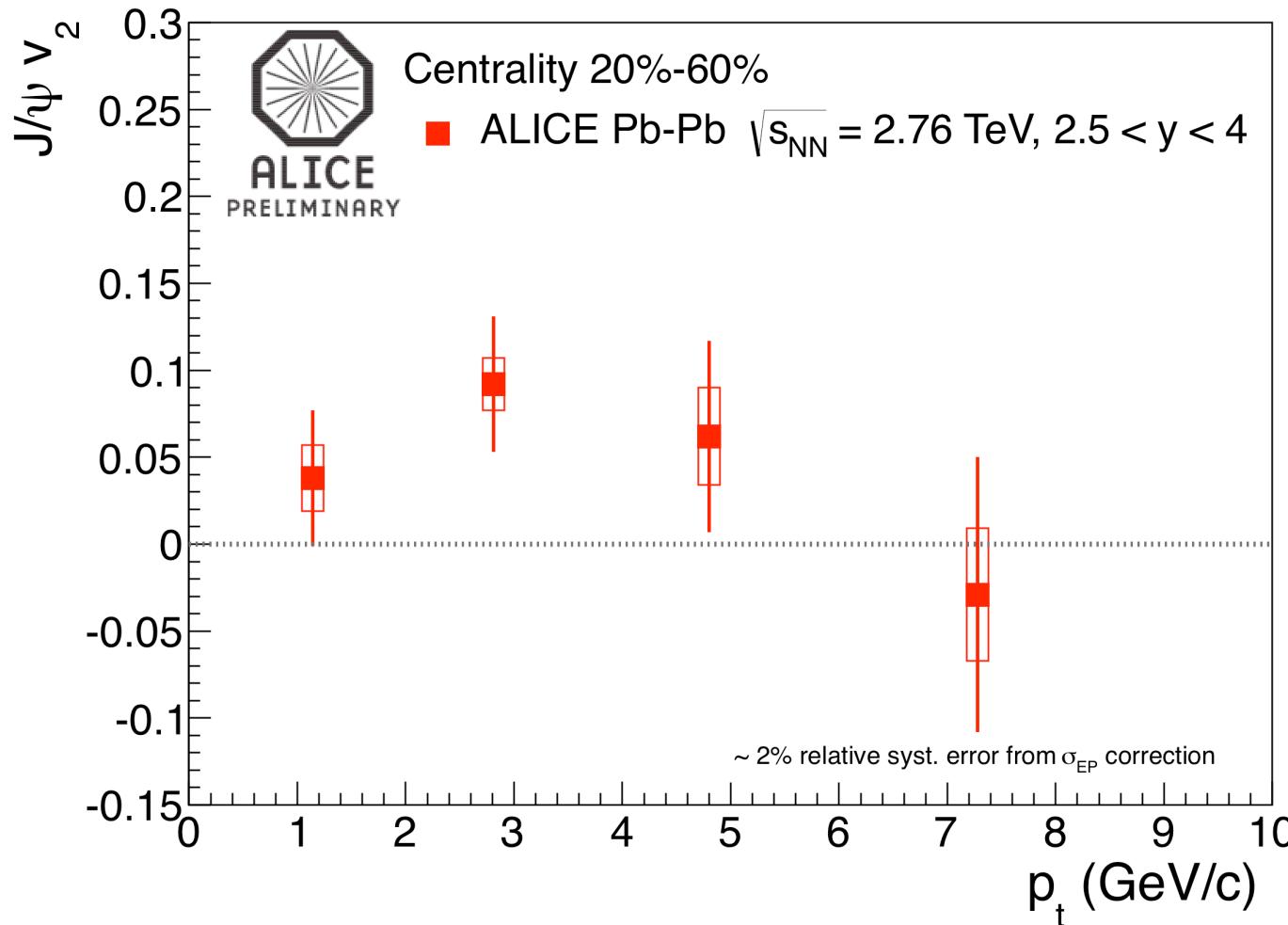
- Alternatively, a second set of 3 sub-events was used (VZEROA, inner ring of VZEROC, outer ring of VZEROC)
- VZEROA resolution obtained with these 2 sets of sub-event differs by 2% and this value is considered as a systematic uncertainty
- For wide centrality bins, the resolution obtained from narrow bins is weighted by the number of reconstructed J/ψ

Results : Centrality dependence of J/ ψ v_2



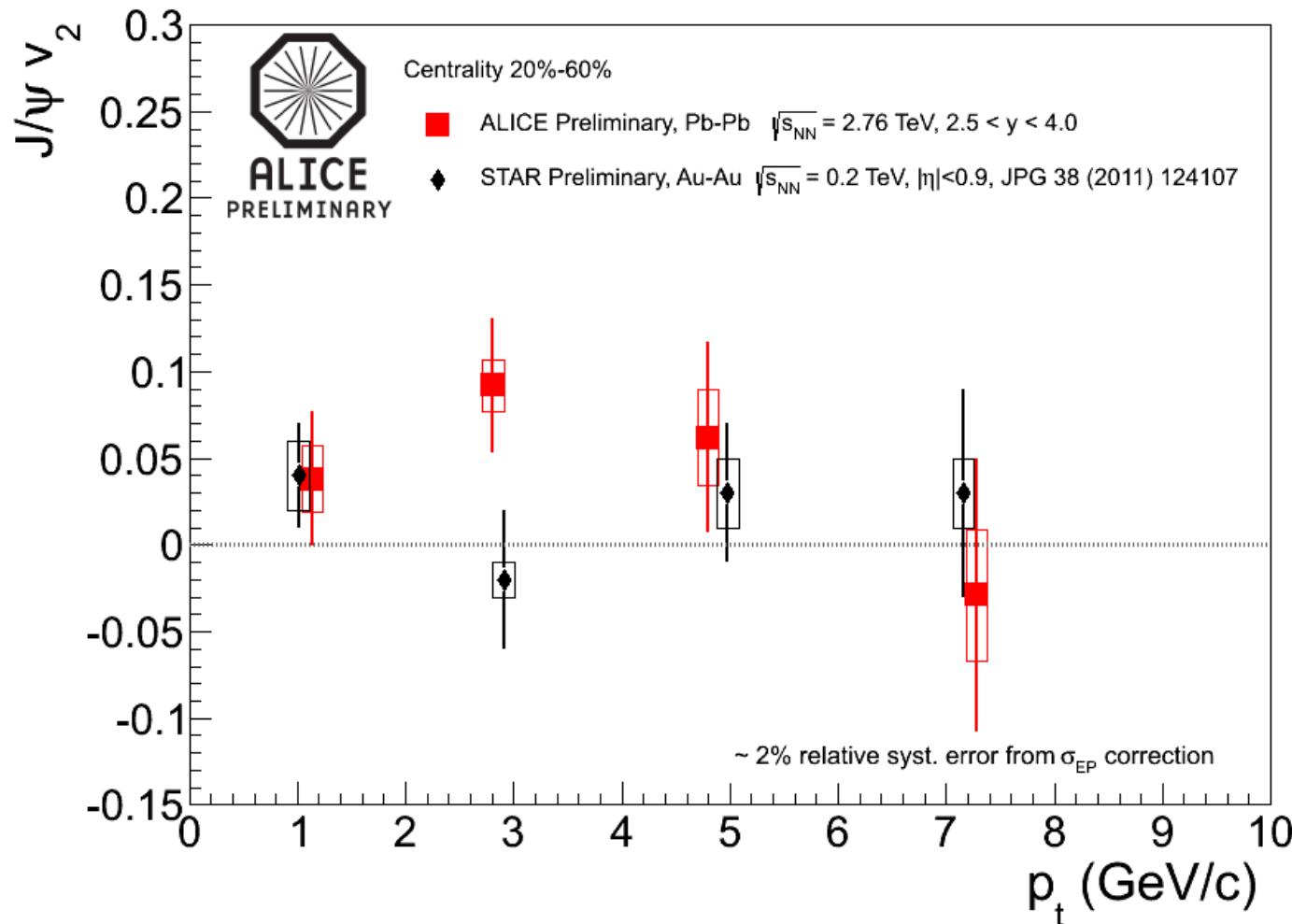
- Integrated J/ ψ elliptic flow measured in 2 centrality bins (5-20%, 20-60%)
- $< p_t > = 2.31 \pm 0.20$ GeV/c
- Hints for non zero elliptic flow

Results : p_T -differential $J/\psi v_2$



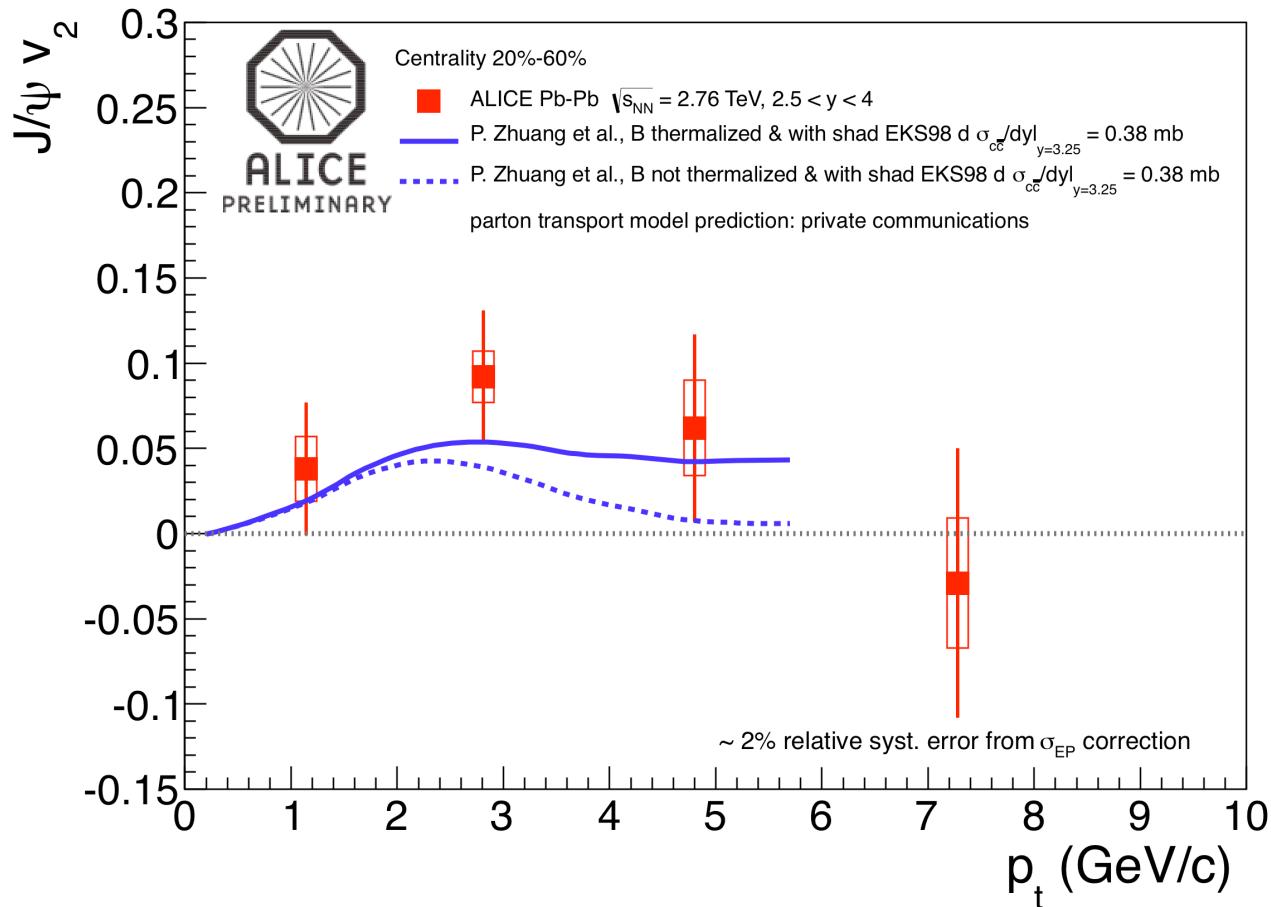
- Hints for non-zero $J/\psi v_2$ measured in the centrality range 20-60% and in the p_T range 2-4 GeV/c **with a significance of 2.2σ**
- Statistical error is dominant

p_T -differential $\text{J}/\psi v_2$ (comparison with STAR)



- Different behaviour observed between STAR and ALICE in the p_t range 2-4 GeV/c
(reminder : 2.2σ deviation from zero for ALICE $\text{J}/\psi v_2$ in that p_t bin)

p_T -differential $J/\psi v_2$ (comparison with theory)



- Parton transport model :
 - Charm production cross section : 0.38mb (between pp data and FONLL calculations)
 - Shadowing effects included
 - Thermalized or unthermalized b quark assumption
 - if unthermalized b quark \rightarrow small contribution to $J/\psi v_2$

- This model qualitatively describes the $J/\psi R_{AA}$ versus centrality and p_t

See talk by Jens Wiechula this afternoon and Christophe Suire plenary talk on wednesday

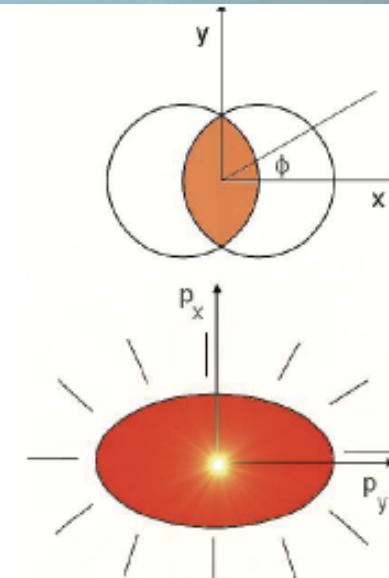
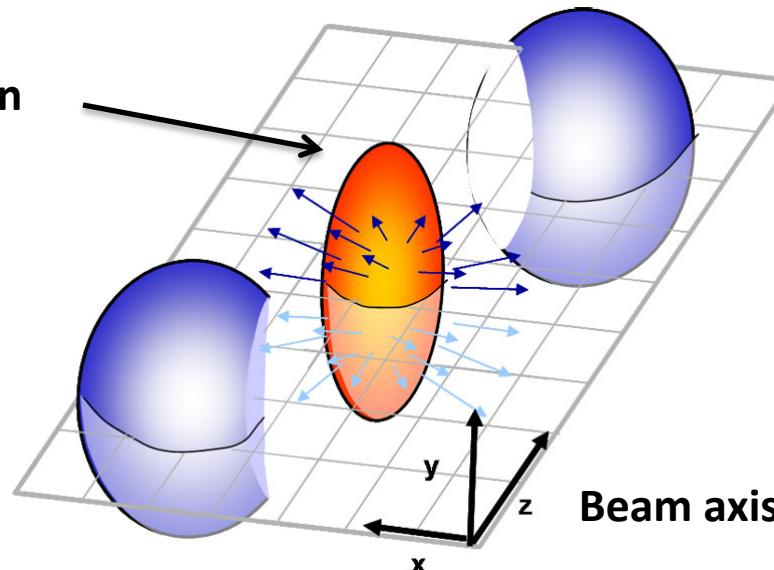
Conclusions and outlook

- First measurement of J/ψ elliptic flow at LHC : magnitude described by transport model ($c\bar{c}$ regeneration in QGP)
- Hints for non-zero $J/\psi v_2$ in semi-central Pb-Pb collisions ($\sqrt{s} = 2.76$ TeV), in the p_t range 2-4 GeV/c, with a significance of 2.2σ at forward rapidity with the ALICE detector
- Event plane method was used
 - v_2 measurement using other methods is under progress
 - $\cos(2\Delta\phi)$ versus invariant mass fitting
 - scalar product method
 - Gap correlation method
 - Lee Yang Zero method

Back up

Data analysis : The Event plane method

Reaction
plane



- Spatial anisotropy is converted via multiple collisions into an anisotropic momentum distribution
- Particle azimuthal distribution measured with respect to the reaction plane can be expanded in a **Fourier series** :

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

where $v_2 = <\cos[2(\phi_i - \Psi_{RP})]>$ quantifies **elliptic flow**