Inclusive Photon Flow in 2.76 TeV Pb-Pb Collisions at ALICE forward rapidity

Anitha Nyatha

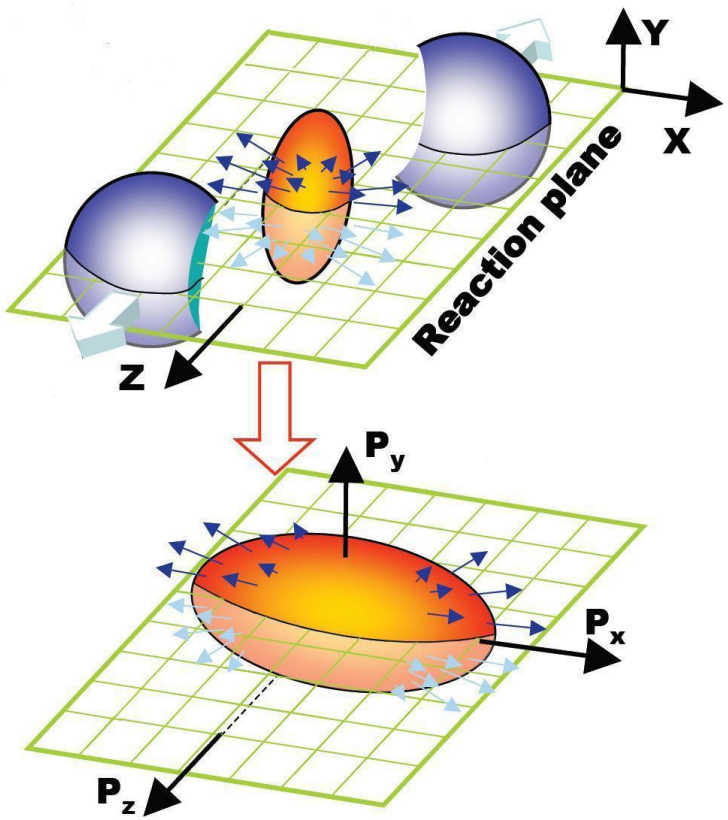
ALICE meet 27-28 April 2013

outline….

- Motivation
- Photon Multiplicity Detector
- Analysis procedure
- Photon Flow Results from Event Plane method
- Estimation of $v_2(\pi^0)$
- Systematic uncertainties
- Scalar Product method
- Summary

Anisotropic Flow

$$E\frac{d^3N}{d^3P} = \frac{1}{2\pi}\frac{d^2N}{p_t dp_t dy}\left(1+\sum_{n=1}^{\infty} 2v_n \cos[n(\phi-\psi_n)]\right)$$



$$v_n \equiv \left\langle \cos n(\phi-\psi_n) \right\rangle$$

spatial anisotropy → ε_n

momentum anisotropy → v_n

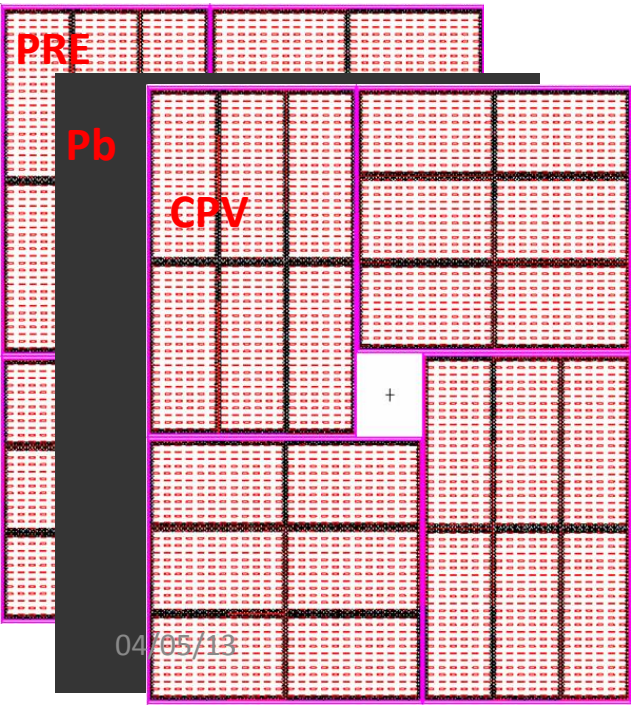
Photon Multiplicity Detector

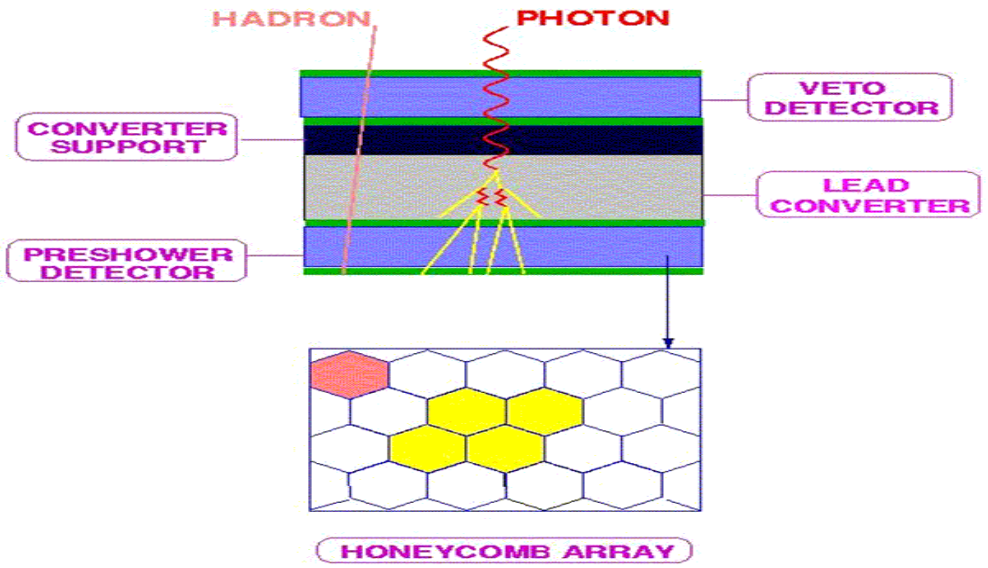
The charged hadron passing through PMD in general deposits energy like MIP in both planes.

Photon do not deposits any energy in CPV but deposits large signal in number of cells in Preshower plane.

So the cell number and signal strength are used for photon hadron discrimination

- Cell depth : 0.5 cm
- Cell cross-section : 0.23 cm^2
- Total no. of cells : 76800×2 (as installed)
- Distance from IP : 367.5 cm (as installed)
- Coverage : 2.3 to 3.9 in η
- Sensitive medium : Gas (Ar +CO_2 in the ratio 70:30)





Experimental Methods to Calculate Flow

- Event Plane Method:
  - Calculate Flow Vector, $Q = (Q_x, Q_y)$: $Q_{n,x} = \sum_i w_i \cos(n\phi_i)$ $Q_{n,y} = \sum_i w_i \sin(n\phi_i)$
  - Event plane angle: $\psi_n = \frac{1}{n}\tan^{-1}\left(\frac{Q_{n,y}}{Q_{n,x}}\right)$
  - Observed nth harmonic flow: $v_n^{obs} = \langle \cos[n(\phi - \psi_n)] \rangle$
  - Event Plane Resolution: $R_n = \langle \cos n(\psi_n - \Phi_n) \rangle$
  - Flow Coefficients: $v_n = \frac{v_n^{obs}}{R_n}$
- Scalar product Method:

$$u = e^{i2\phi_i} \quad v_2\{SP\} = \frac{\left\langle \left\langle u \bullet \frac{Q^*}{M_Q} \right\rangle_p \right\rangle_e}{\sqrt{\left\langle \frac{Q_A}{M_A} \bullet \frac{Q_B^*}{M_B} \right\rangle_e}}$$

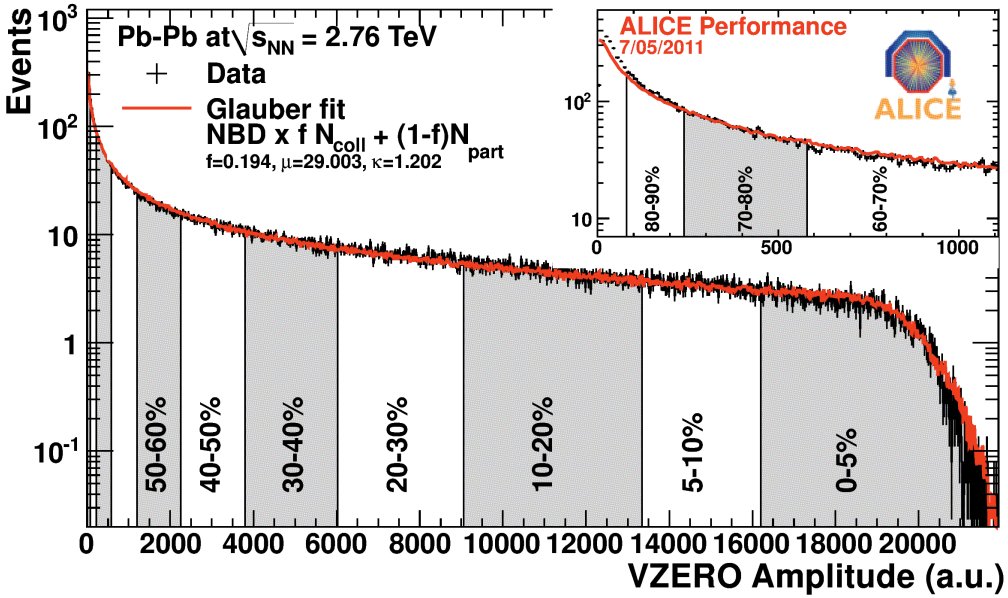
Event Selection

- Data: 2.76TeV Pb-Pb collisions, LHC10h period ESDs
- Event Selection: 11M with Minimum Bias physics selection(0-80%)

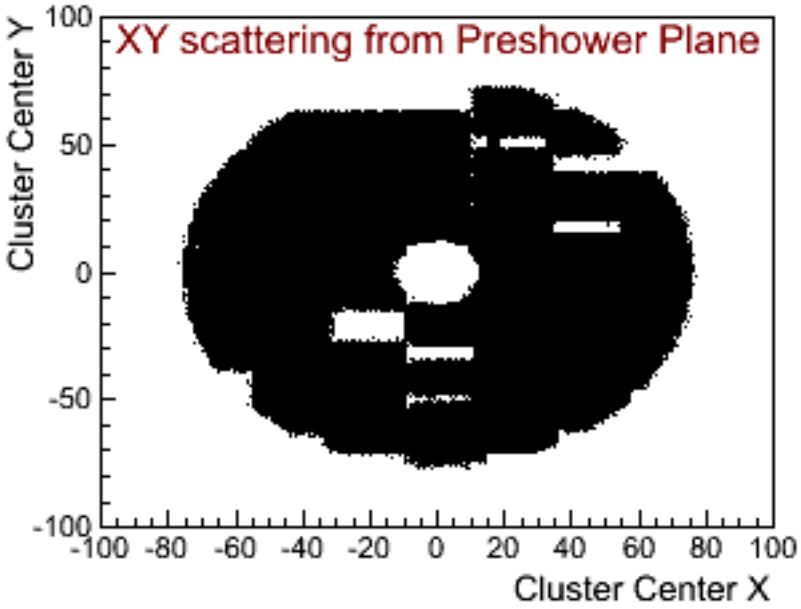
  Abs(Zvertex) <10 cm
- Track Selection:

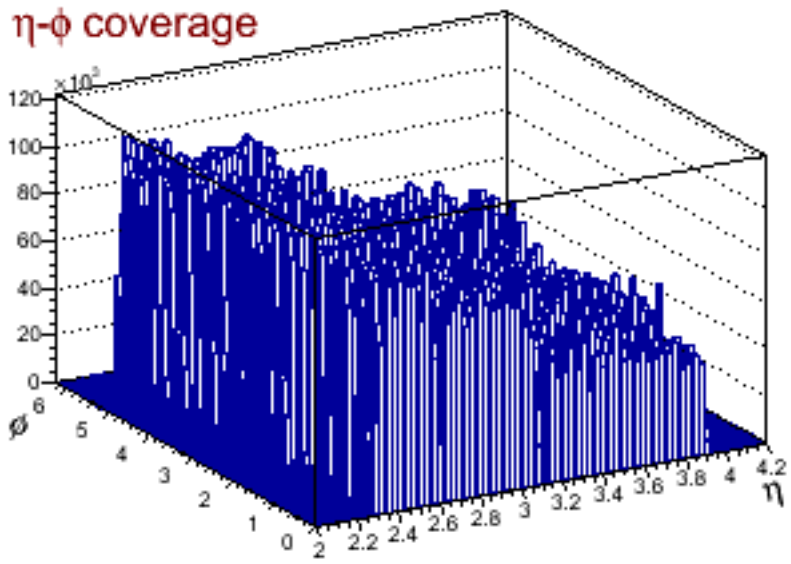
  Pseudorapidity Range: $|\eta| < 0.8$ for TPC (EP), $2.3 < |\eta| < 3.9$ for PMD (flow)

  P_T Range: $0.2 < P_T < 20$ Gev/c for EP
- Centrality selection : VZERO detector multiplicity fitted with Glauber model



PMD Coverage





Analysis Procedure

1) Calculated Event plane from TPC in each centrality bin

2) Correlating the azimuthal distributions of photons from PMD w.r.t TPC Event Plane, flow components $v_n\{\psi_n\}$ are calculated in each centrality bin.

$$v_n^{obs} = \langle \cos[n(\phi - \psi_n)] \rangle$$

these should be corrected with Resolution of each centrality $v_n = \frac{v_n^{obs}}{R_n}$

3) Event plane Resolution: Two-sub events with η-gap: 0.4

Left sub(ψ_{nA}):η (-0.2, -0.8); Right sub(ψ_{nB}): η (0.2, 0.8)}. For nth order flow component resolution:

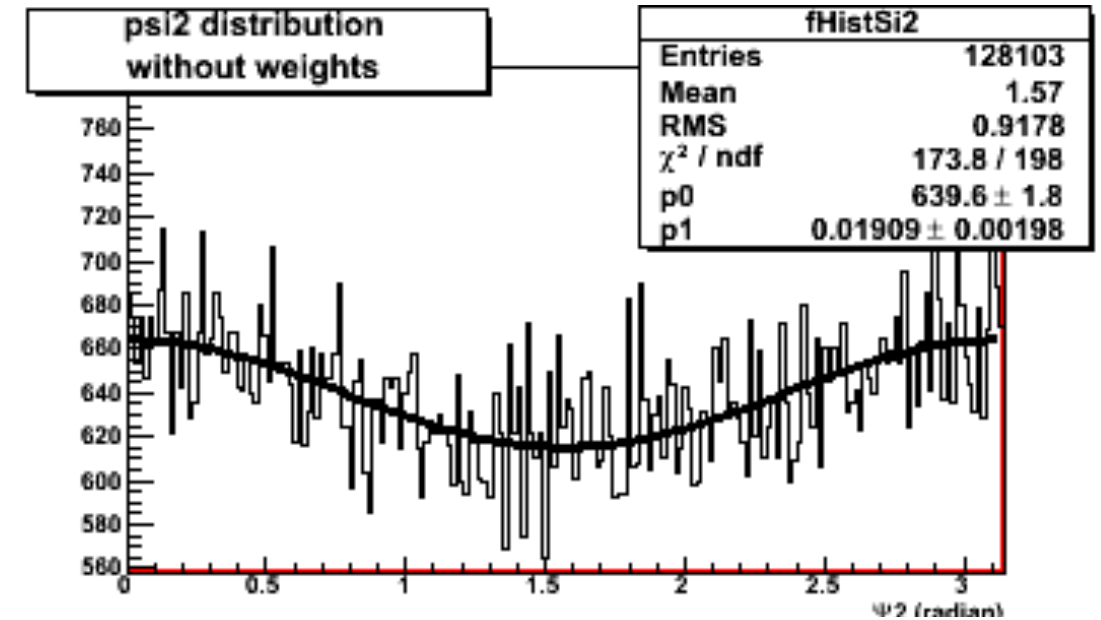
$$R_{n,sub} = R_n = \sqrt{\langle \cos n(\Psi_{nA} - \Psi_{nB}) \rangle}$$

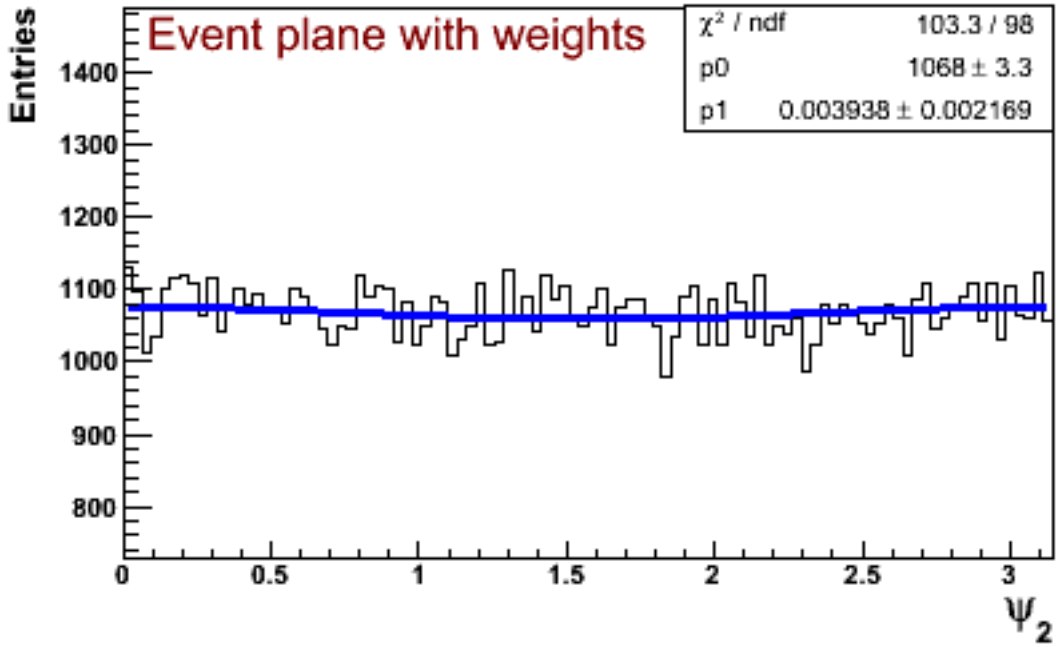
$$\langle \cos(km(\psi_m - \psi_r)) \rangle = \frac{\sqrt{\pi}}{2\sqrt{2}} \chi_m \exp(\chi_m^2/4) \left[I_{\frac{k-1}{2}}(\chi_m^2/4) + I_{\frac{k+1}{2}}(\chi_m^2/4) \right]$$

Ref:A. M. Poskanzer and S. A. Voloshin, 'Methods for analyzing anisotropic flow in relativistic nuclear collisions', Phys. Rev. C no. CS6346 (1998).

4) Each nth order flow component in each centrality bin is then corrected with corresponding nth order resolution in that bin.

Event plane before and after adding weights

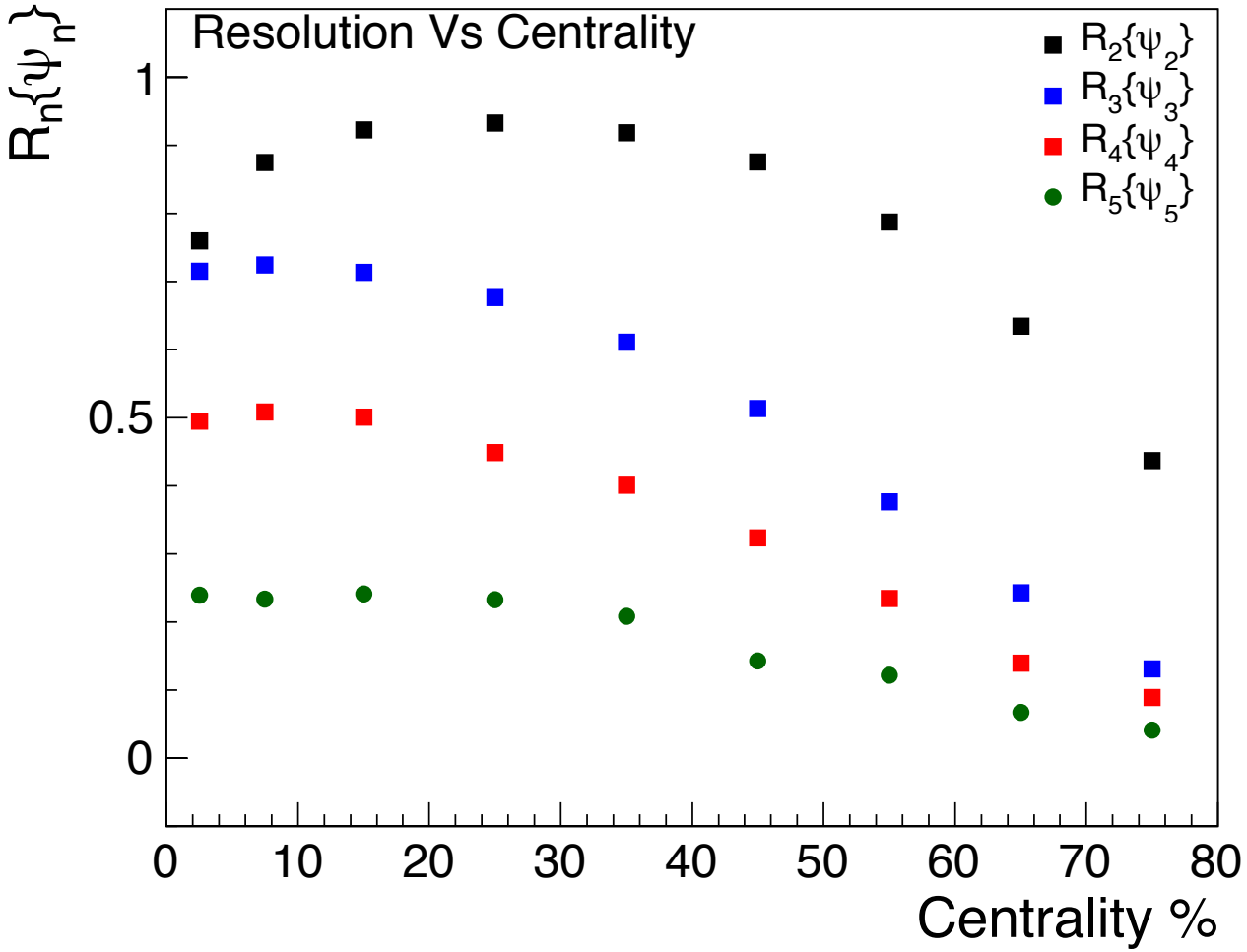




Full Event Plane Resolution Vs Centrality

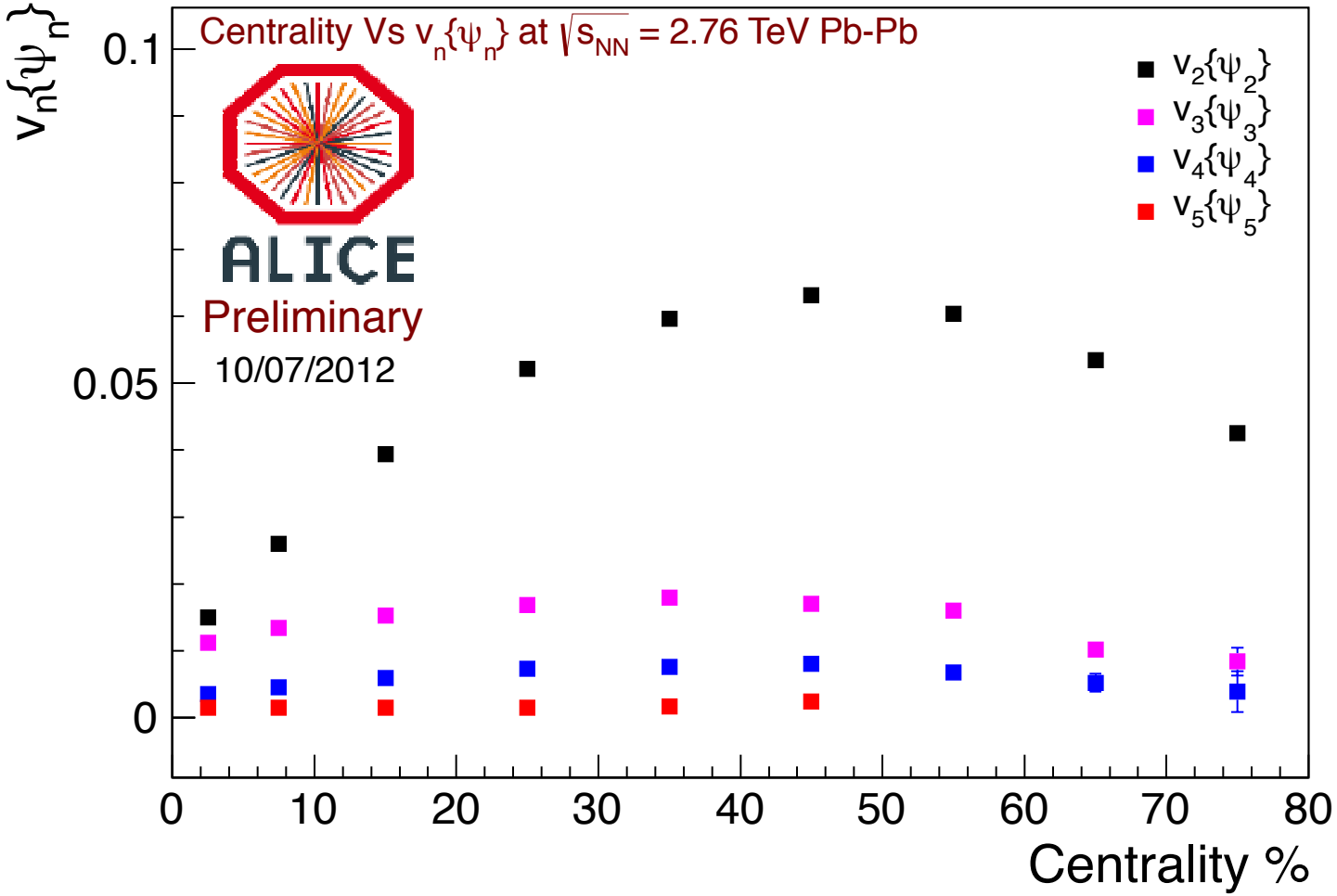
$$R_{n,sub} = \sqrt{\langle \cos n(\Psi_{nA} - \Psi_{nB}) \rangle}$$

$$\langle \cos(km(\psi_m - \psi_r)) \rangle = \frac{\sqrt{\pi}}{2\sqrt{2}} \chi_m \exp(\chi_m^2/4) \left[I_{\frac{k-1}{2}}(\chi_m^2/4) + I_{\frac{k+1}{2}}(\chi_m^2/4) \right]$$

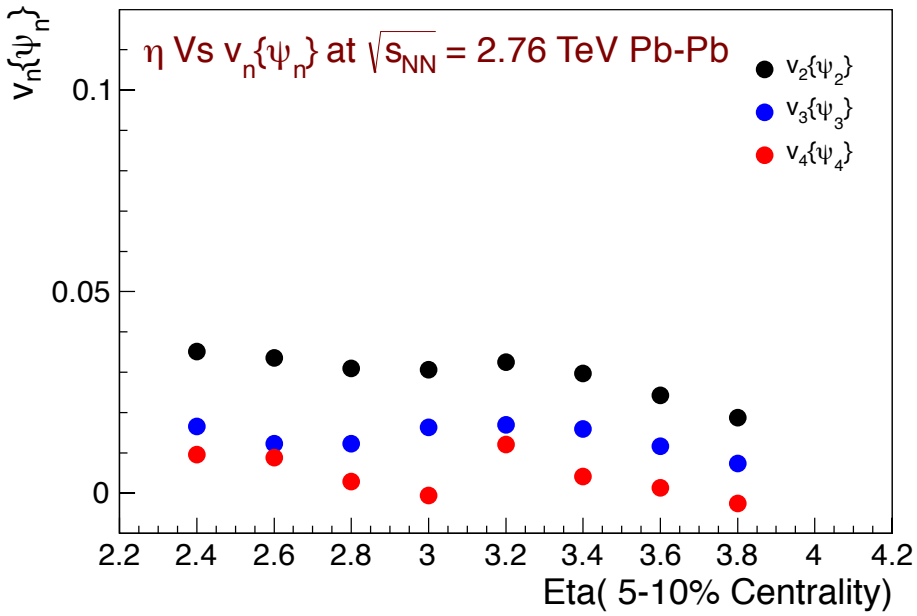


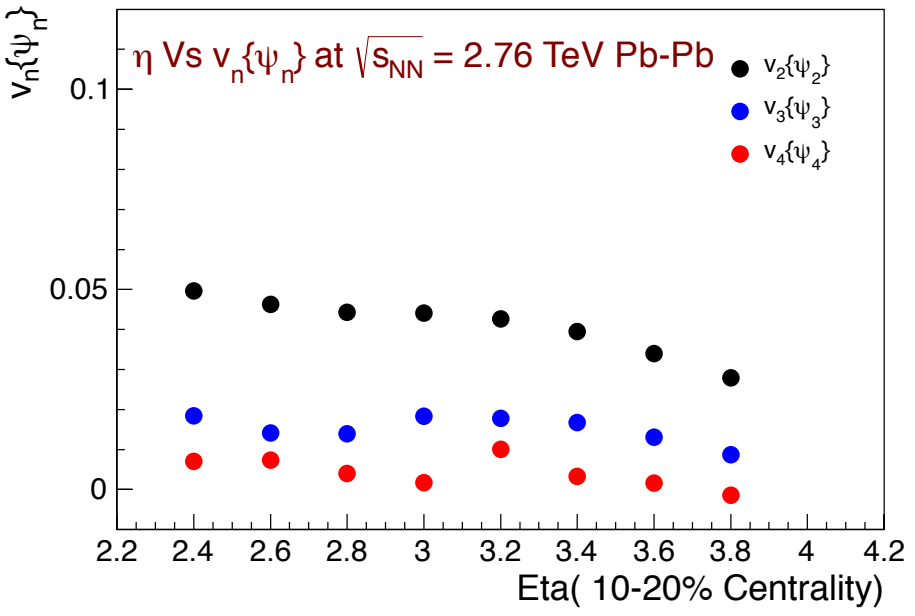
$v_n(\gamma)$ from PMD with centrality

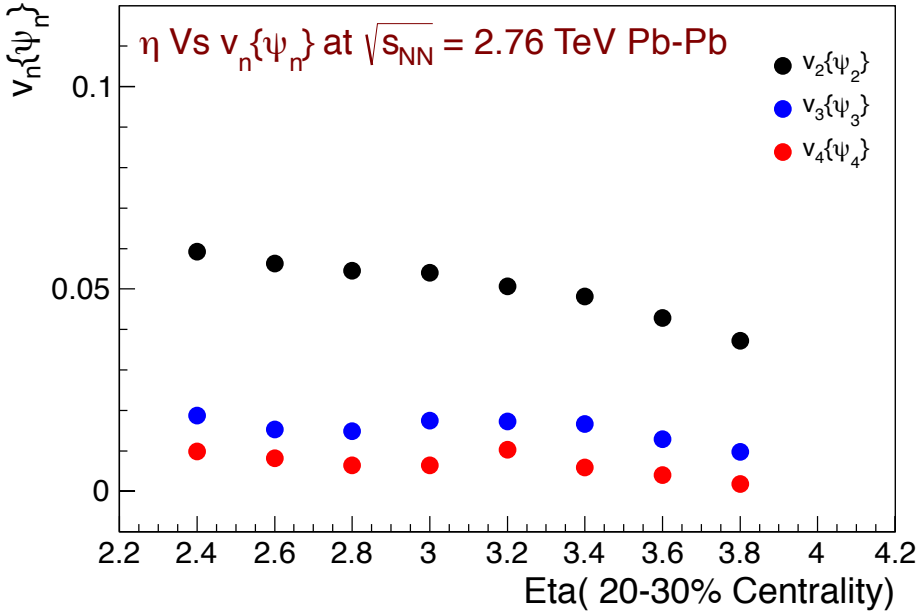
η: 2.3-3.9
Ncell >2 adc>6MIP
Full event Resolution

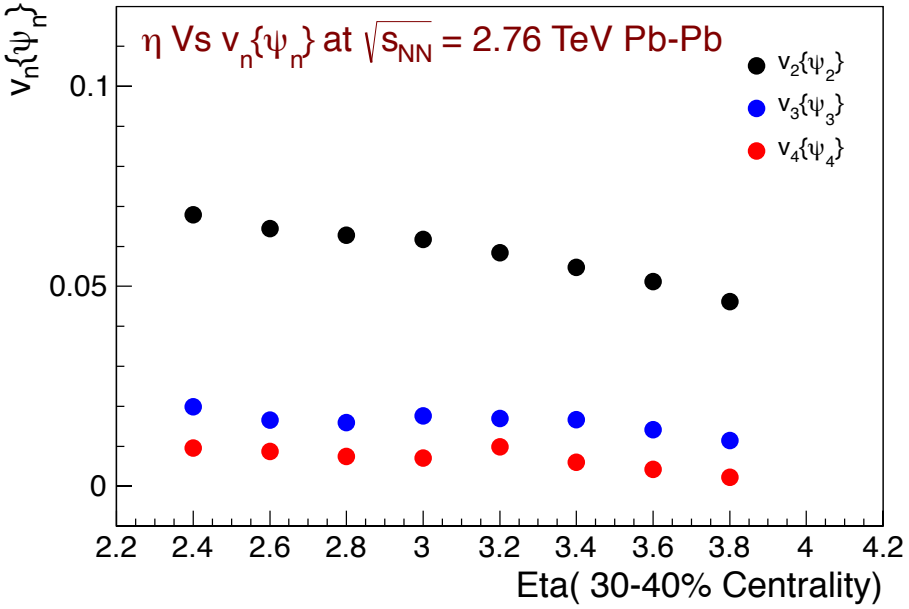


$v_n(\gamma)$ from PMD with Eta

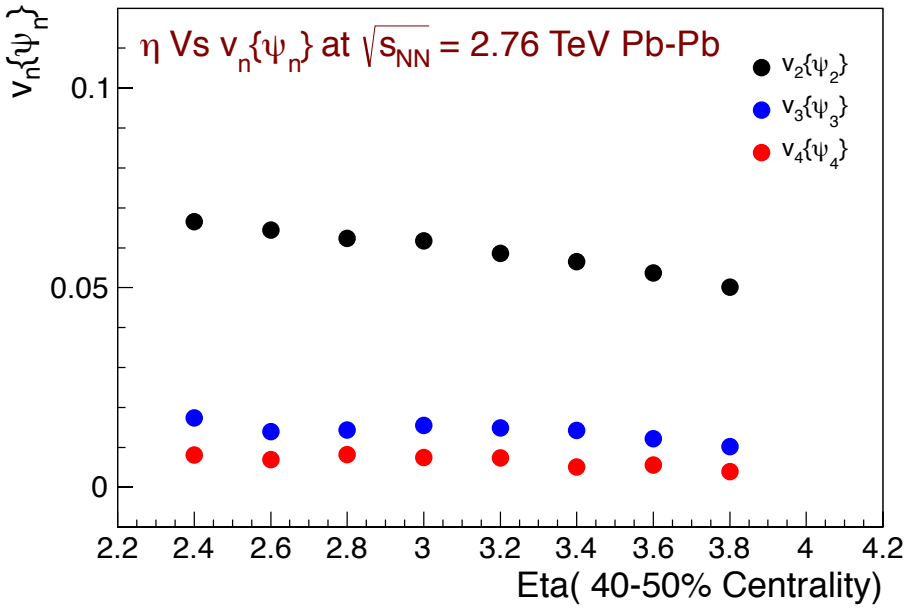


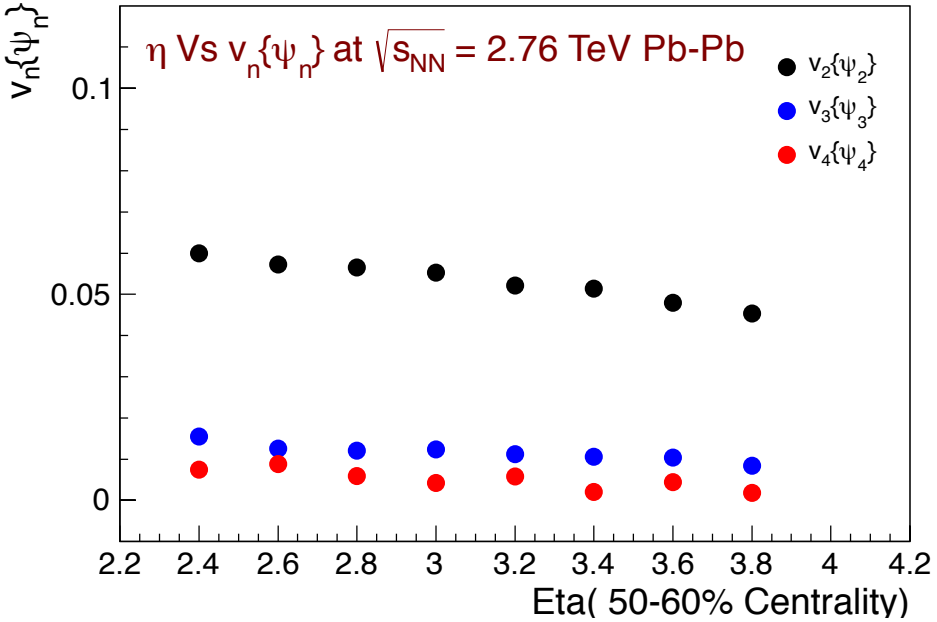


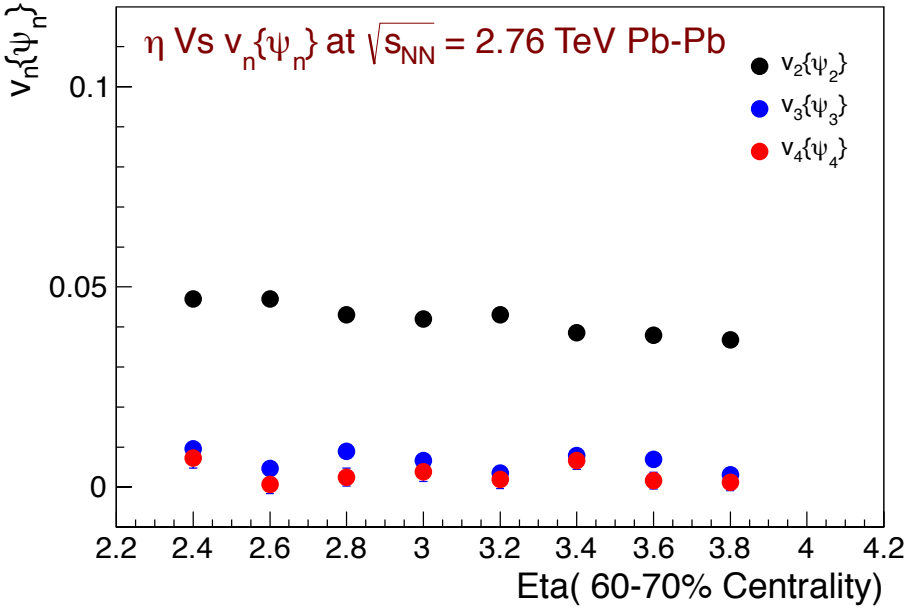


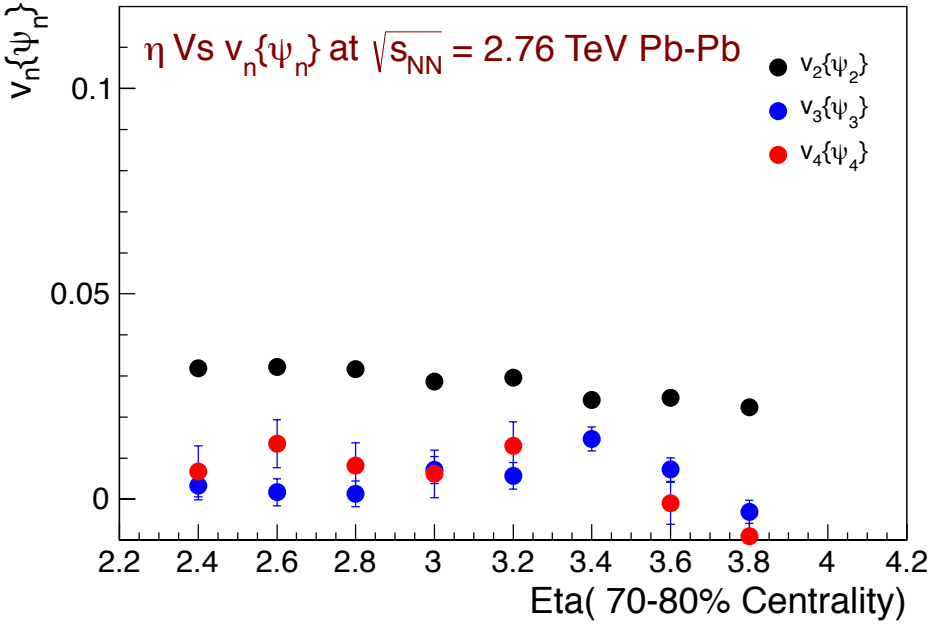


$v_n(\gamma)$ from PMD with Eta

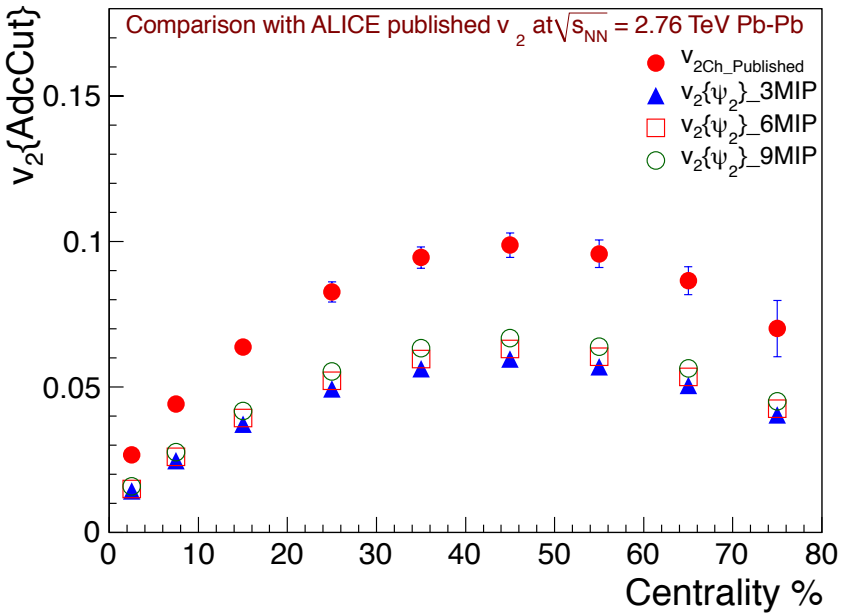


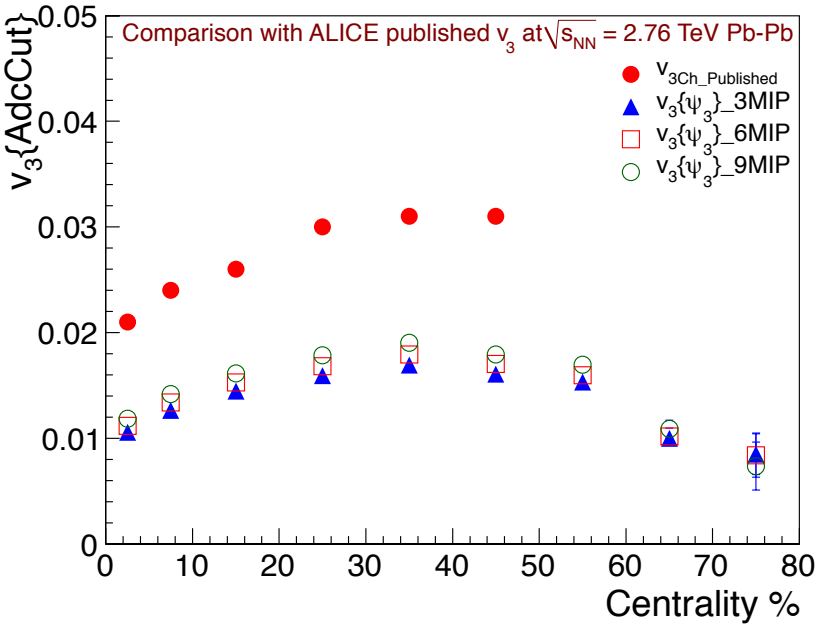


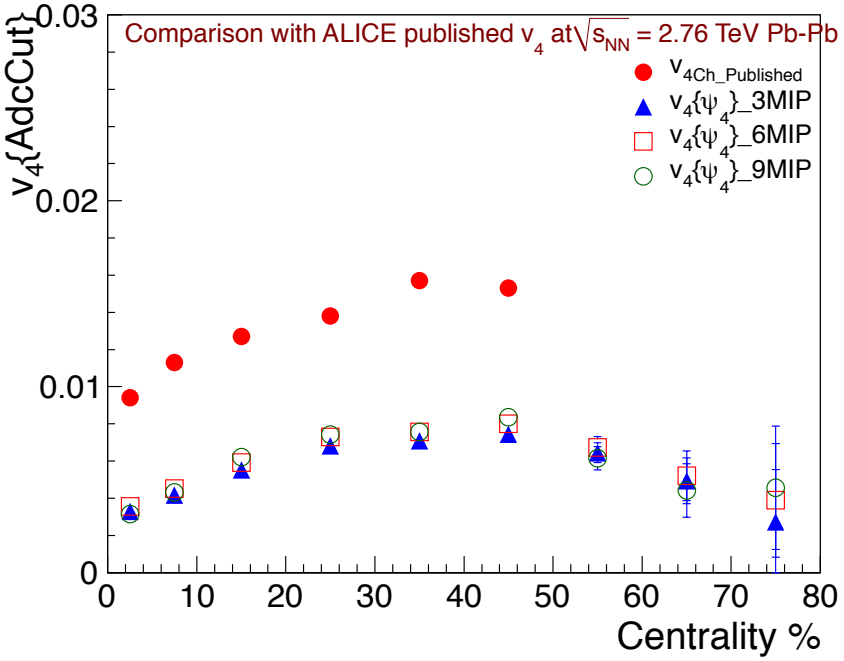




Photon v_n Compared with Charged particle v_n







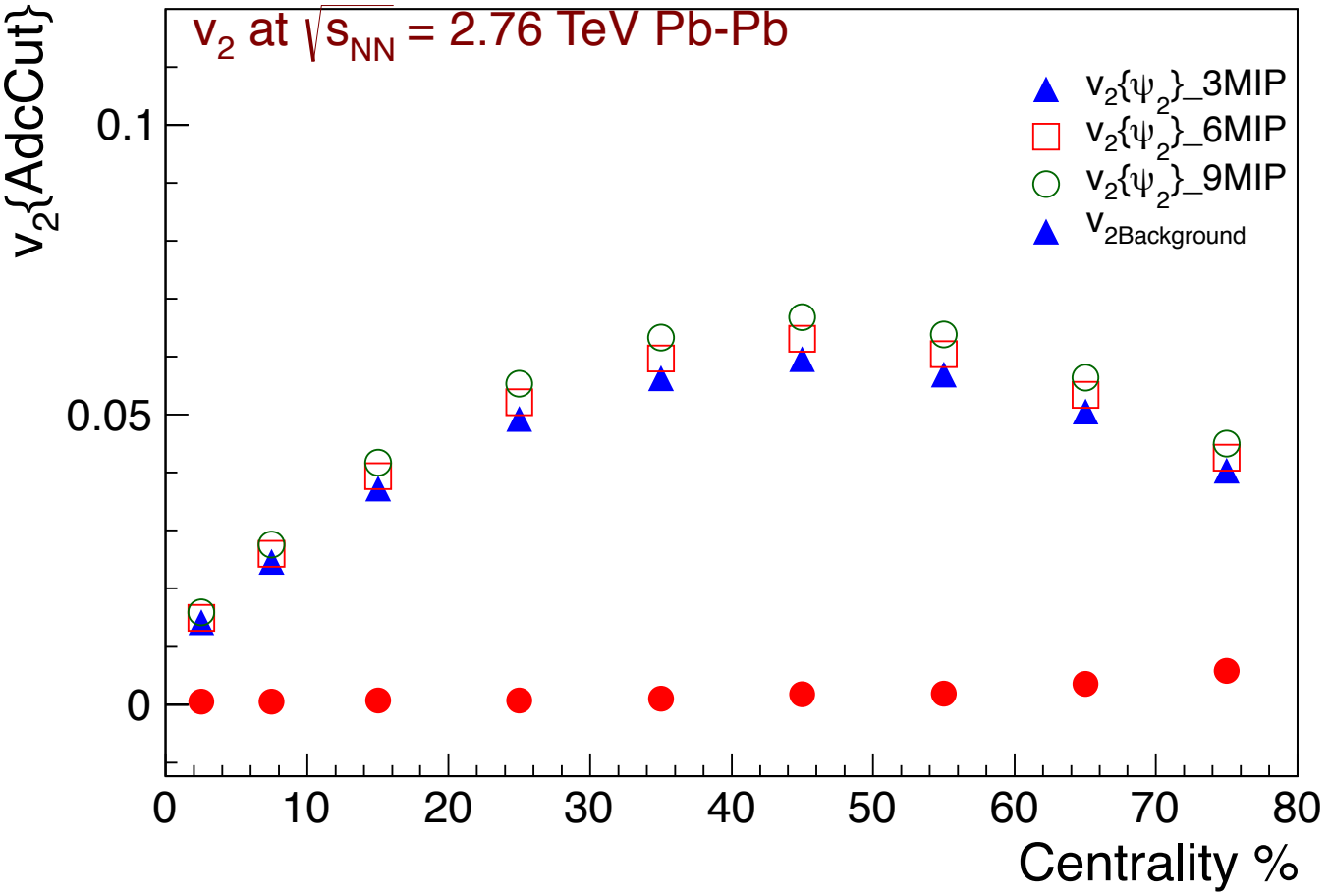
Ref: K. Aamodt et. al. , ''Higher Harmonic Anisotropic Flow Measurements of Charged Particles in Pb-Pb collisions at $\sqrt{S_{NN}}$=2.76 TeV ", Phys. Rev. Lett. 107, 032301 (2011), for ALICE collaboration

Systematic error calculations

- Background flow from HIJING with no flow.
- Error due to photon selection cuts.
- Detector effects from AMPT data.
- Effect of Material in front of PMD with 7% increased material budget.

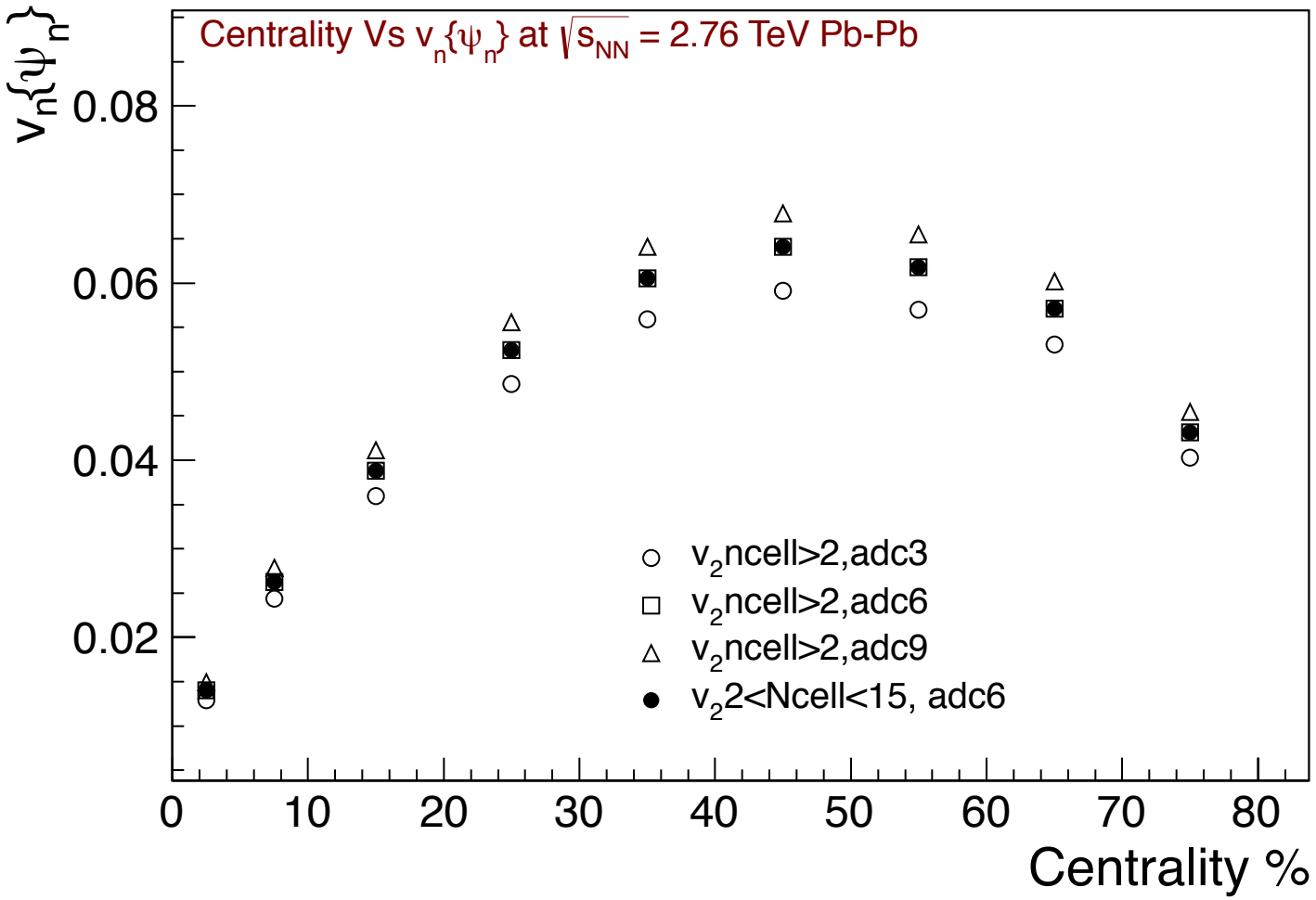
Background $v_2(\gamma)$ study from MC (HIJING+GEANT, No FLOW)

- Data: /alice/sim/LHC11a10b_bis
- Run #:138442, 138469, 138533, 138534, 138578, 138579.
- #Events: 157K (MB)
- Centrality Selection: V0 Detector



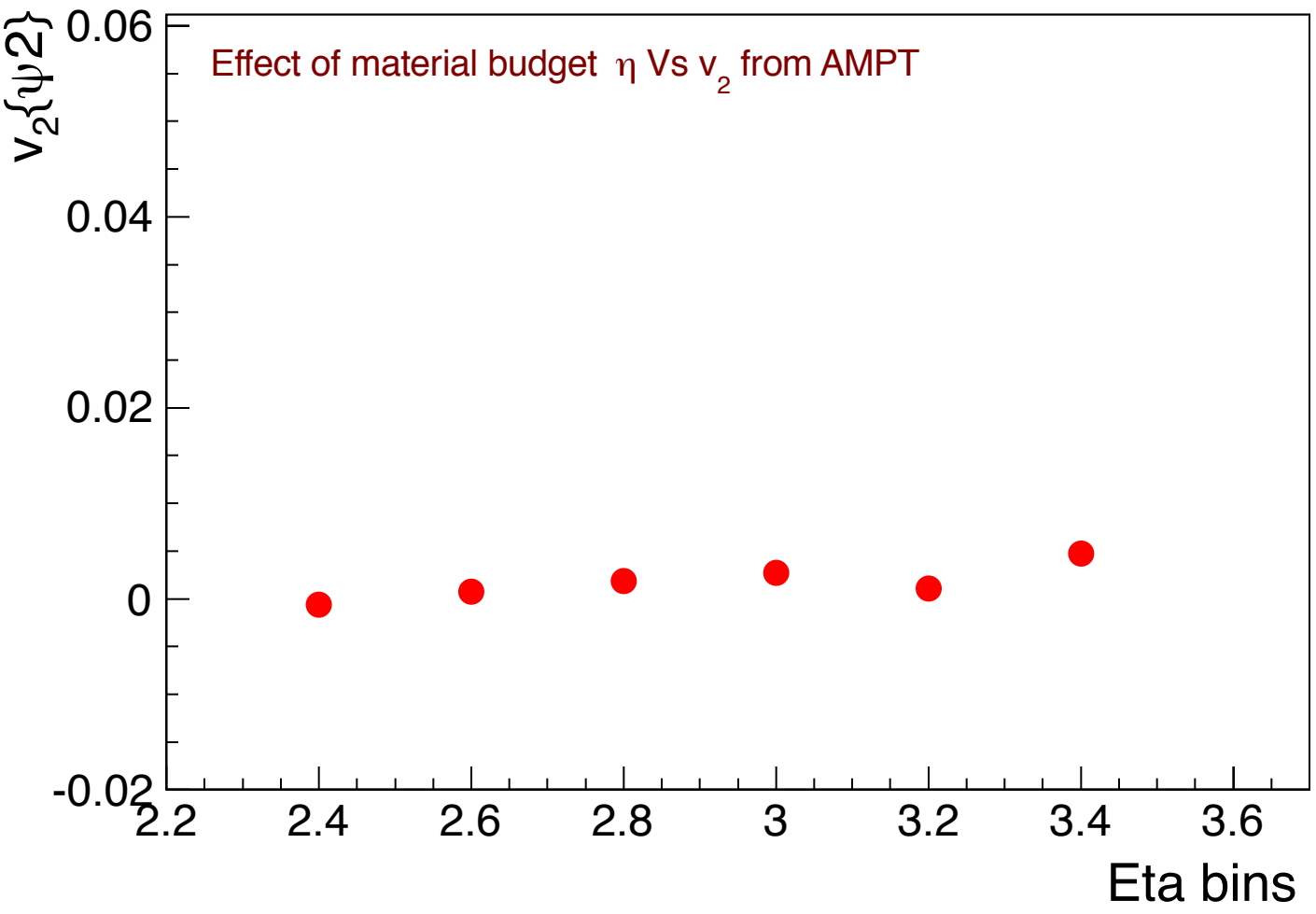
Error in $v_2(\gamma)$ (with ADC and Ncell cuts)

- Data: /alice/data/LHC10h



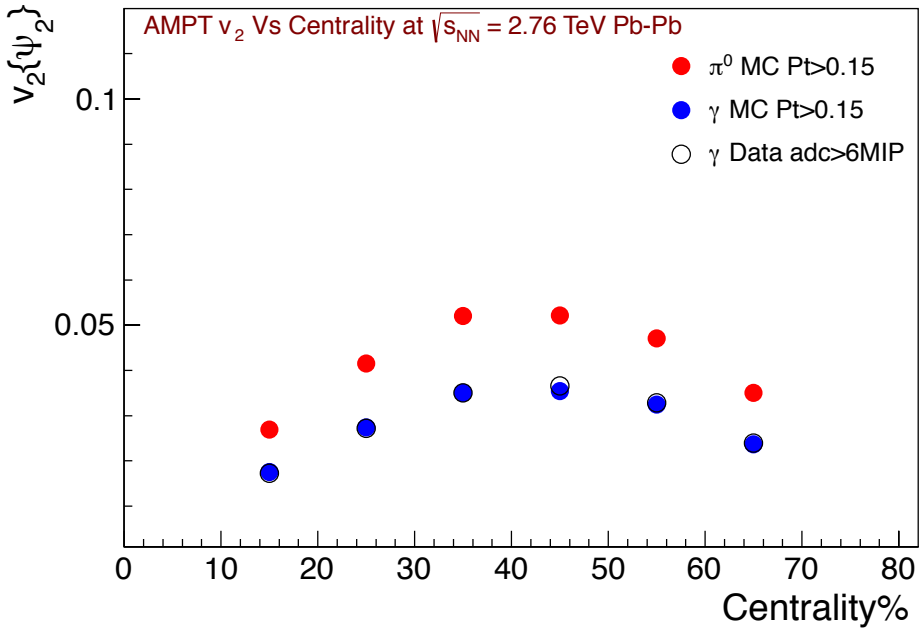
Eta Vs $v_2(\gamma)$ (+7% material budget, No FLOW)

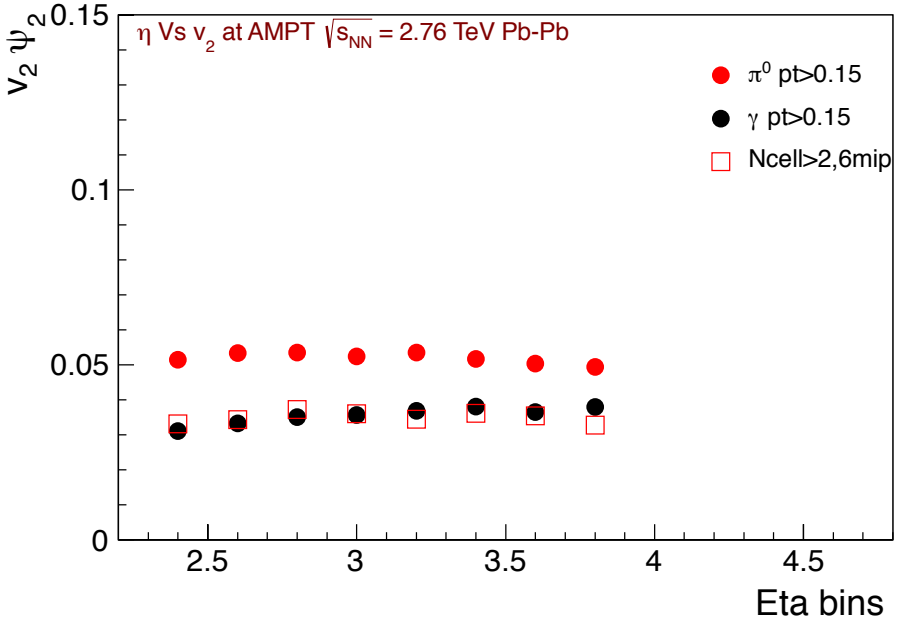
DATA:/alice/sim/LHC10h4, Run# 137161



Eta Vs $v_2(\gamma)$ (before and after GEANT)

- Data: /alice/sim/2012/LHC12a11a to /alice/sim/2012/LHC12a11i
- Run #:137686, 138534, 138653, 139038, 139437.
- #Events: 157K (MB)
- Ncell>2, ADC>6MIP





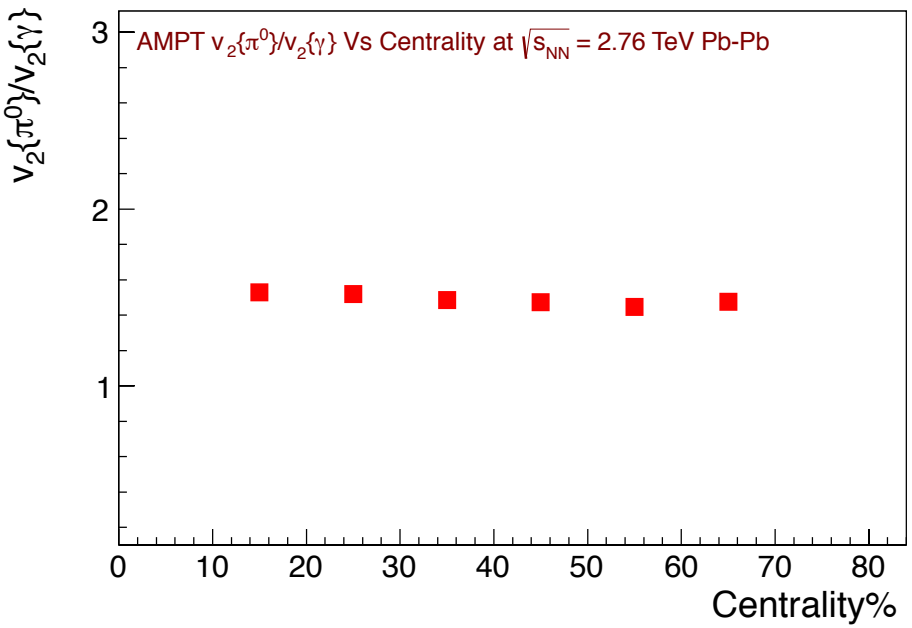
Summary

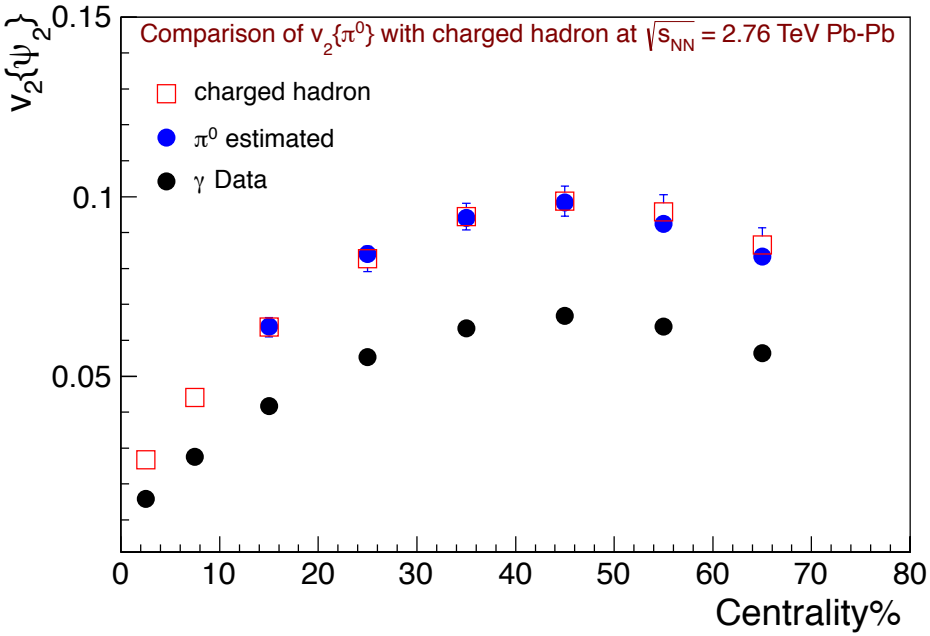
- Studied centrality and pseudorapidity dependence of photon flow components v_2, v_3, v_4 and v_5 from PMD using eventplane method and compared with ALICE published charged particle flow values.

Systematic uncertainties:

Centrality %	Background	ADC/Ncell cut	Detector Effect	Material Effect	Total Systematic error
0-5	3.10317	11.2755		9.8	15.25
5-10	1.84791	11.3681	1.81682	9.8	15.23
10-20	1.80068	11.2675	0.757258	9.8	15.06
20-30	1.34051	11.5478	0.11347	9.8	15.20
30-40	1.74231	11.7931	3.36386	9.8	15.80
40-50	2.82824	11.4323	0.96561	9.8	15.35
50-60	3.03487	11.5117	1.06387	9.8	15.45
60-70	6.74645	11.071		9.8	16.25

Estimation of pion (π^0) v_2

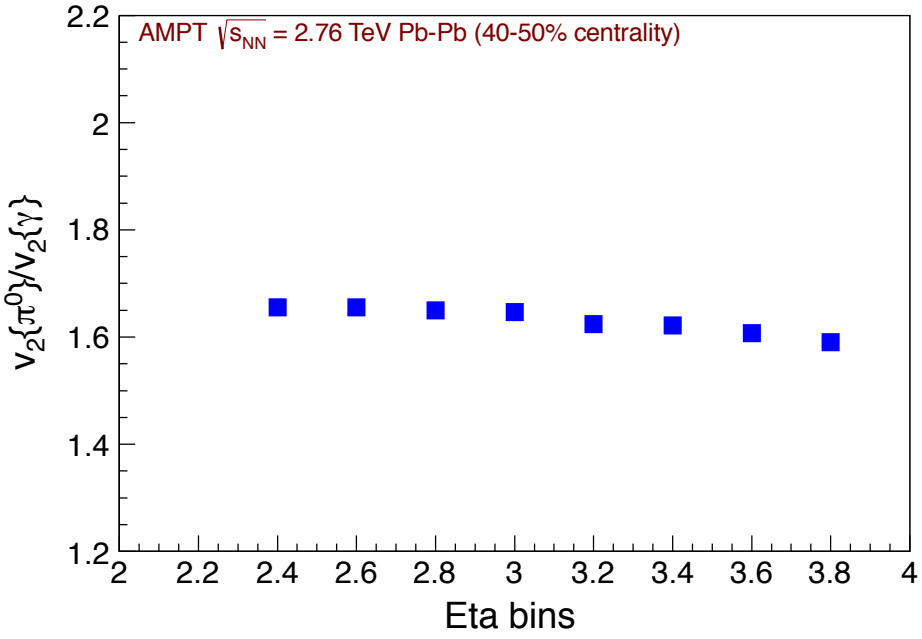


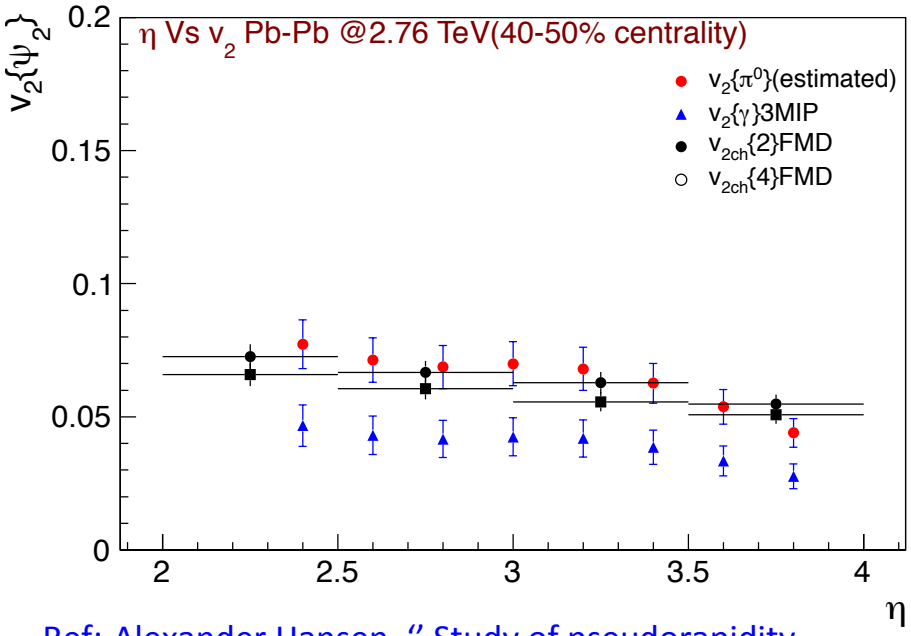


- $v_2^{obs}(\gamma)$ and $v_2^{obs}(\pi^0)$ obtained from AMPT
- $v_2^{Estimated}(\pi^0) = v_2^{data}(\gamma)$ X $\{ v_2^{obs}(\pi^0) / v_2^{obs}(\gamma)\}$

AMPT

Estimation of pion(π^0) v_2



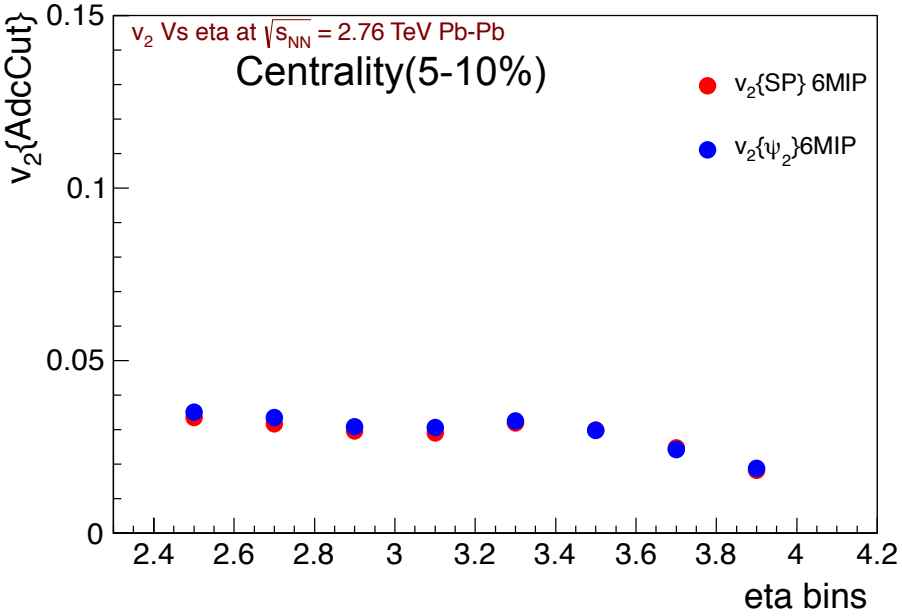


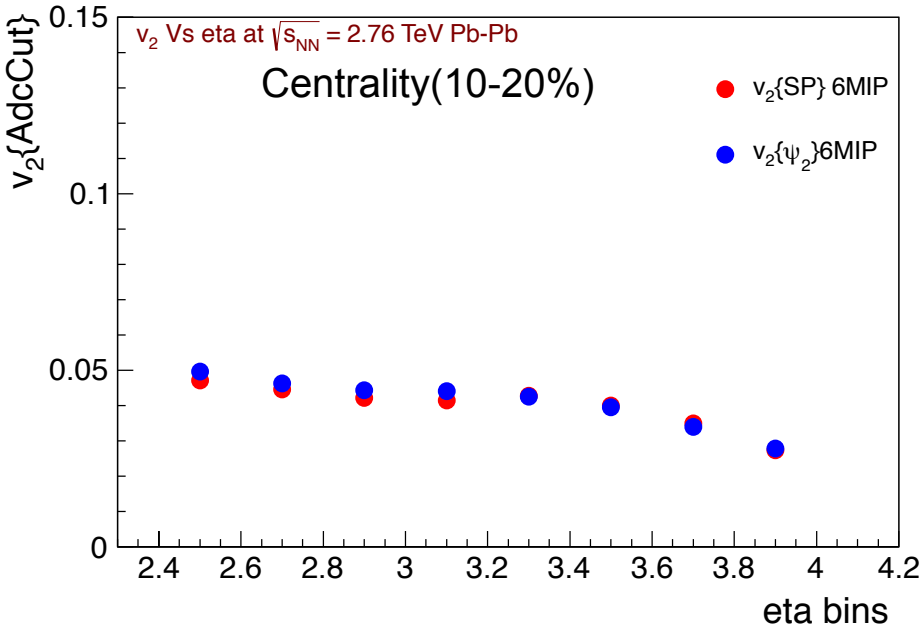
Ref: Alexander Hansen, " Study of pseudorapidity dependence of the anisotropic flow with ALICE at the LHC", Phys. Rev. Lett. 107, 032301 (2011), for ALICE collaboration

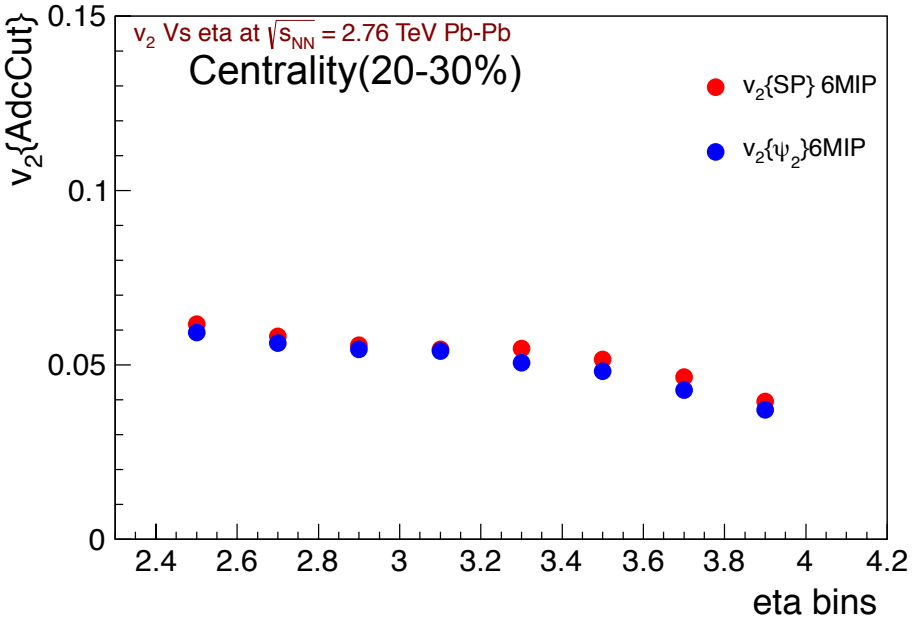
- $v_2^{\text{Estimated}}(\pi^0)$ is compared with charged particle v_2 from FMD(p_T>0).
- Estimated value seems to be higher

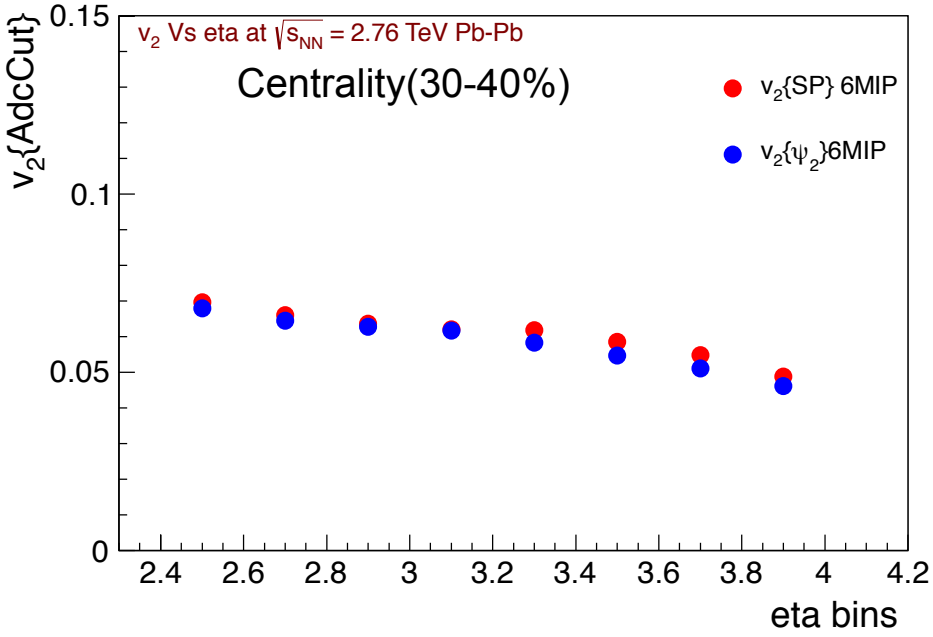
Comparison with Scalar Product method

v_2 vs Eta (in different centrality bins)

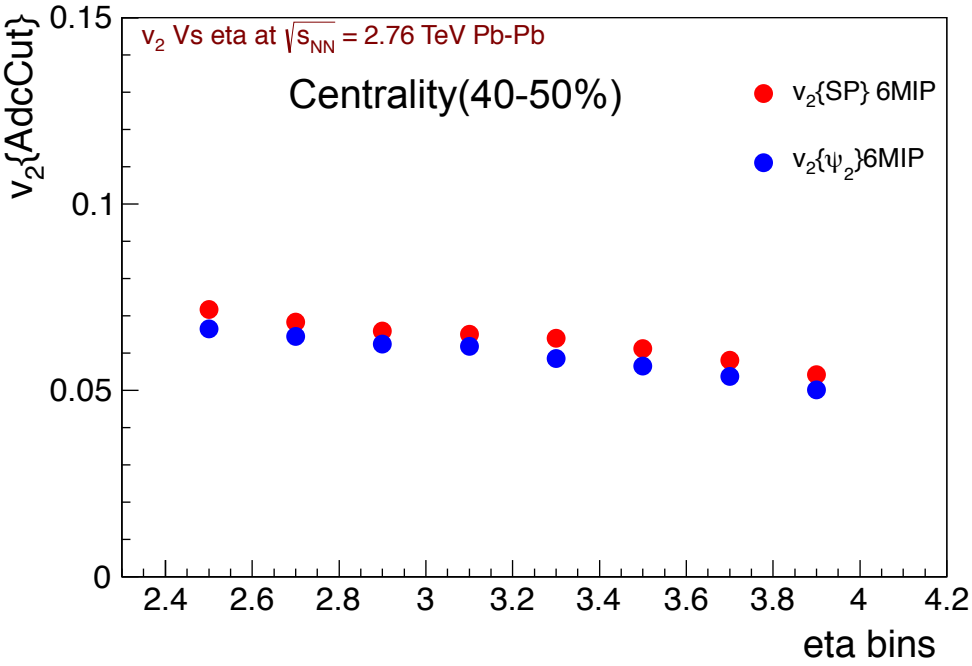


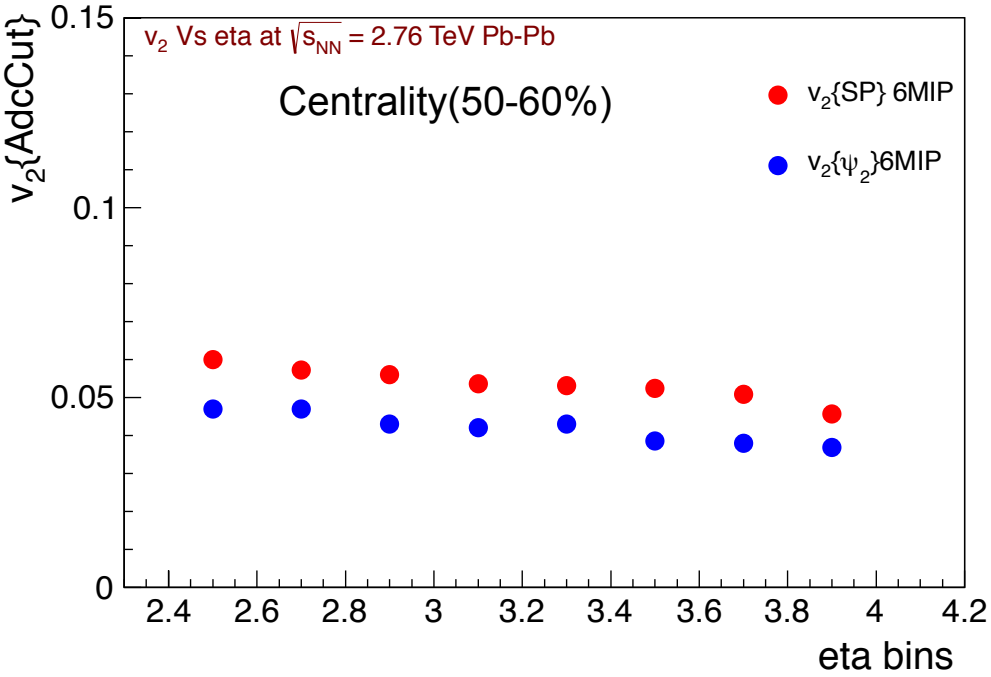




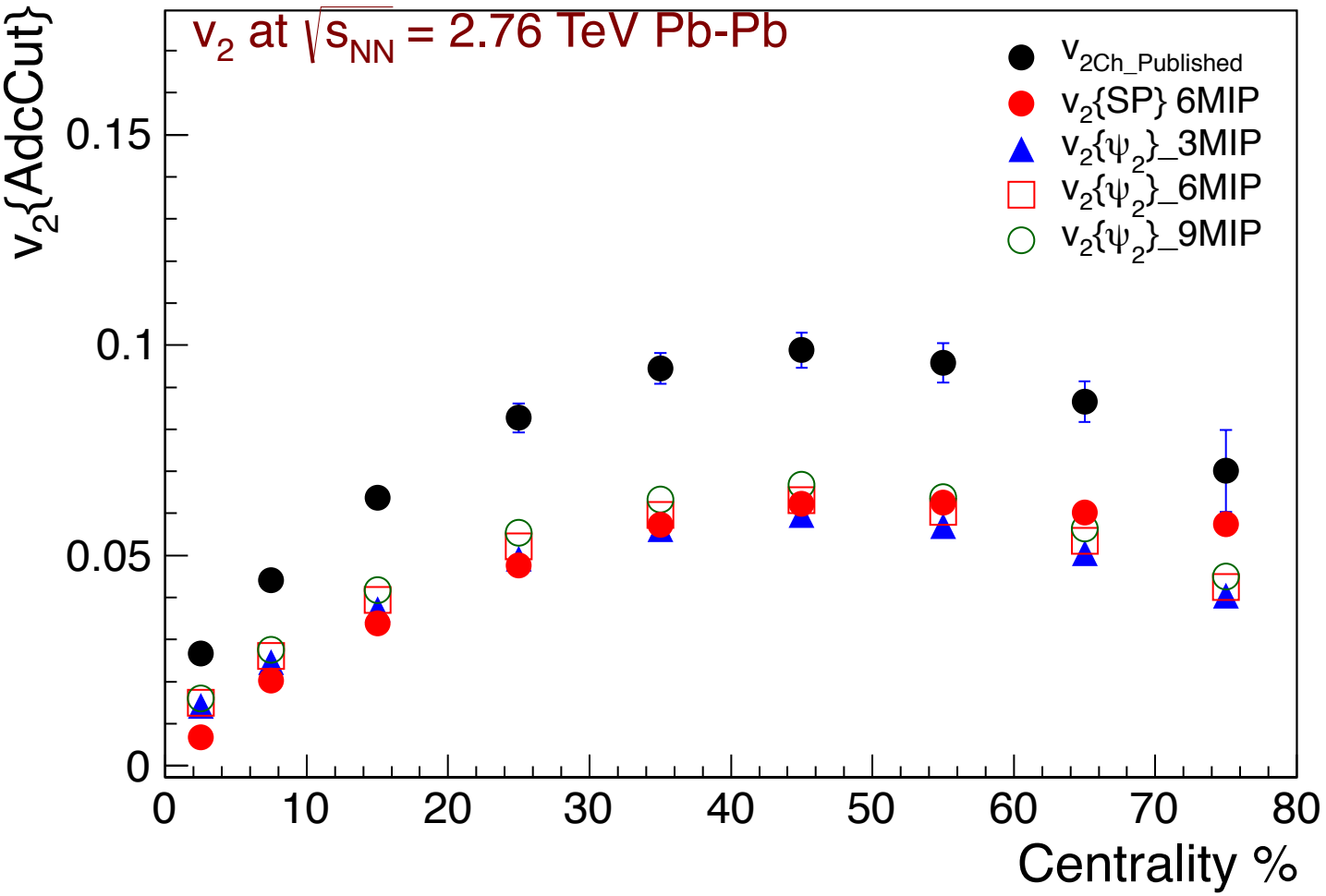


v_2 vs Eta (in different centrality bins)

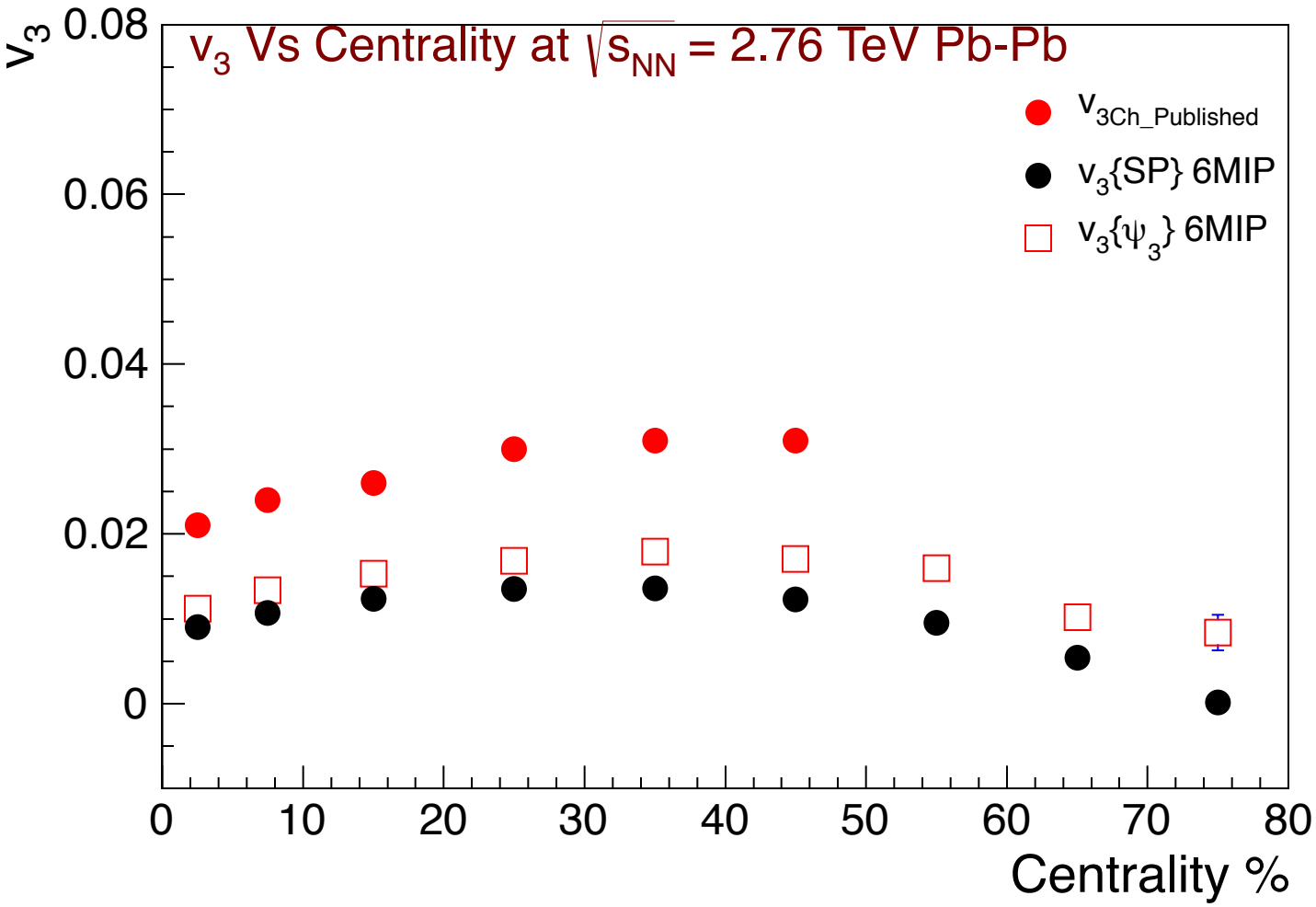




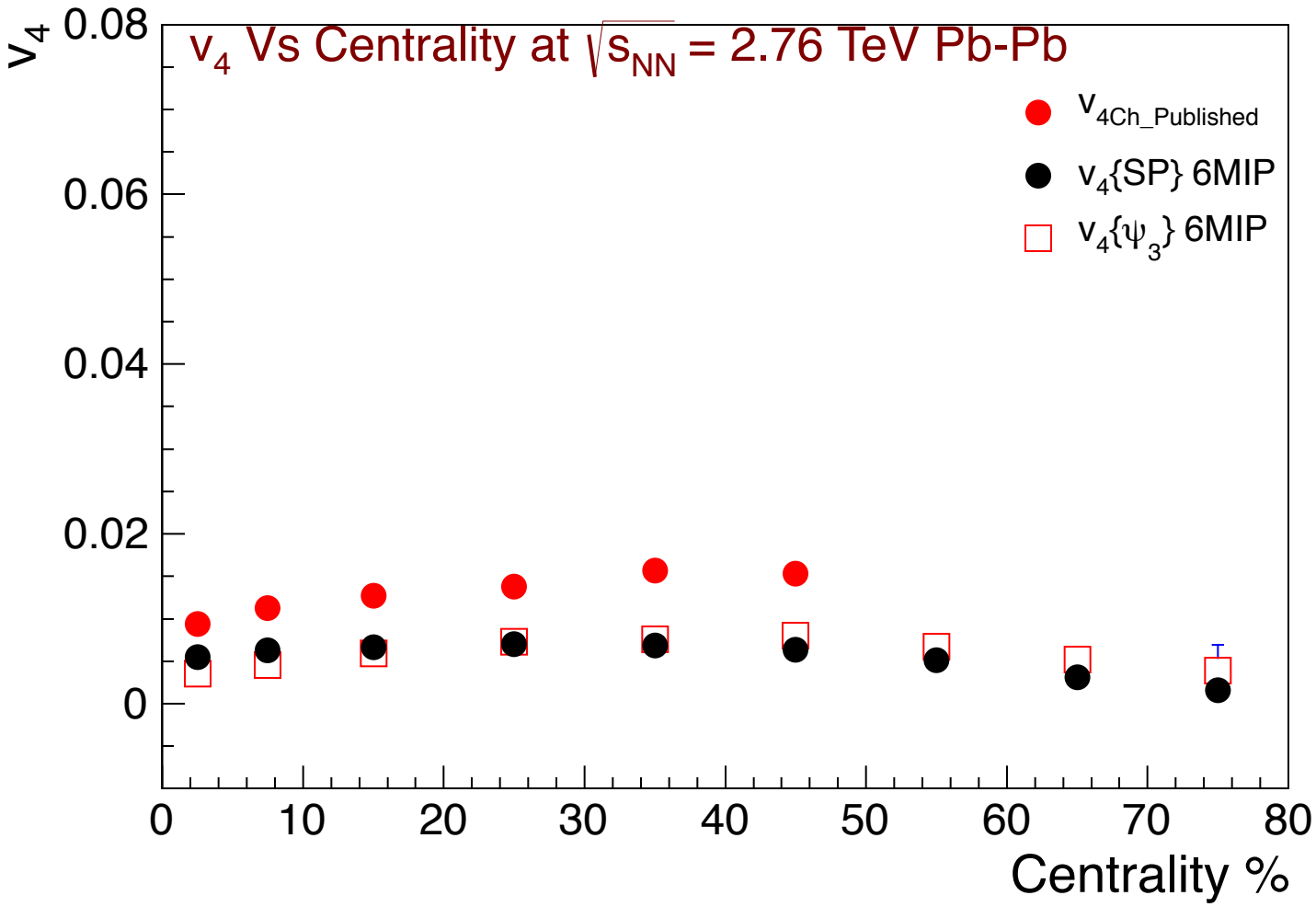
v_2 vs centrality



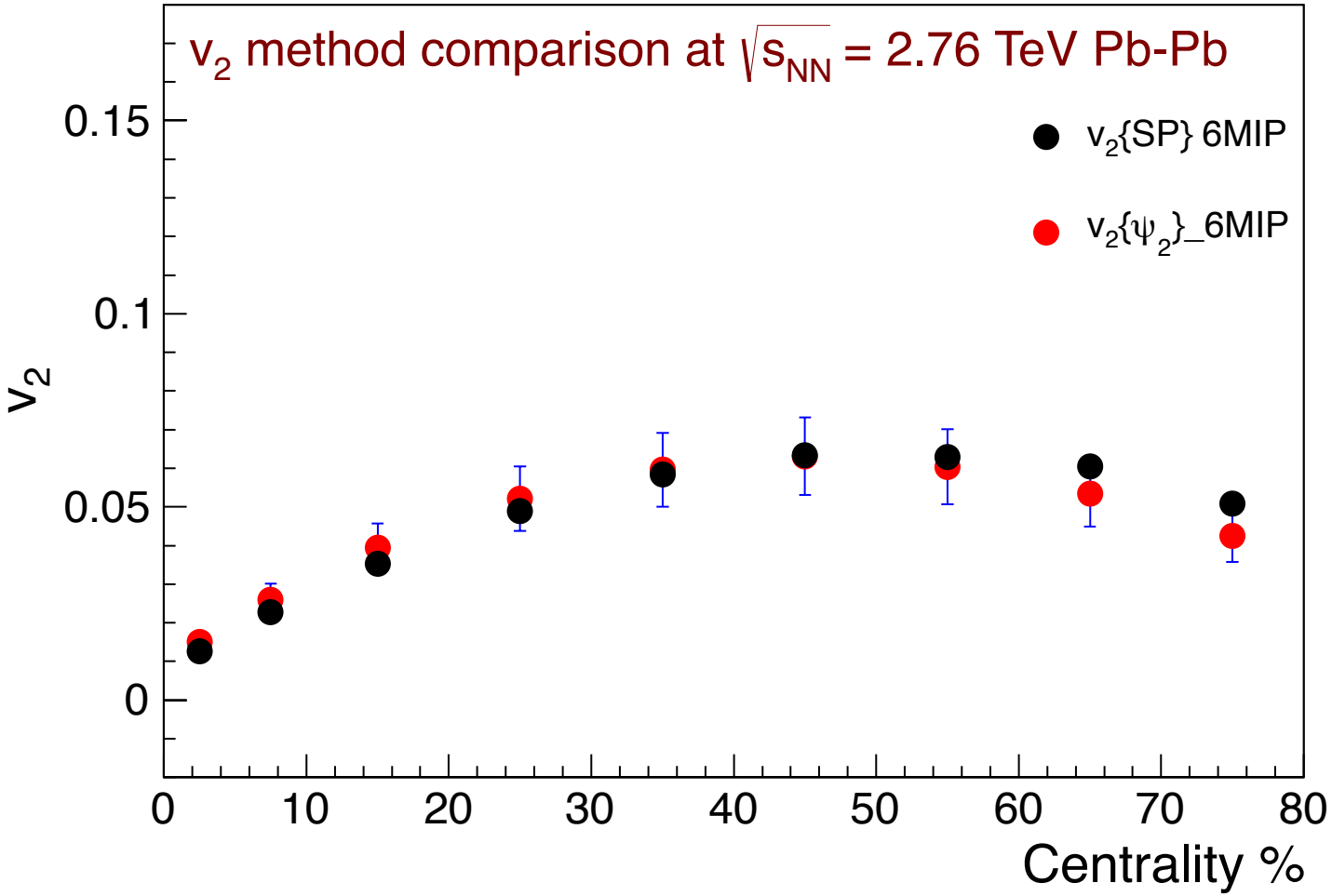
v_3 vs centrality



v_4 vs centrality



v_2 vs centrality



Summary

- Centrality and pseudorapidity dependence of photon flow components v_2, v_3, v_4 from PMD are studied systematically and results are compared with ALICE published charged particle flow results at mid-rapidity.

- Estimated v_2 of π^0 using photon v_2 from PMD is compared with charged particle v_2 from ALICE.

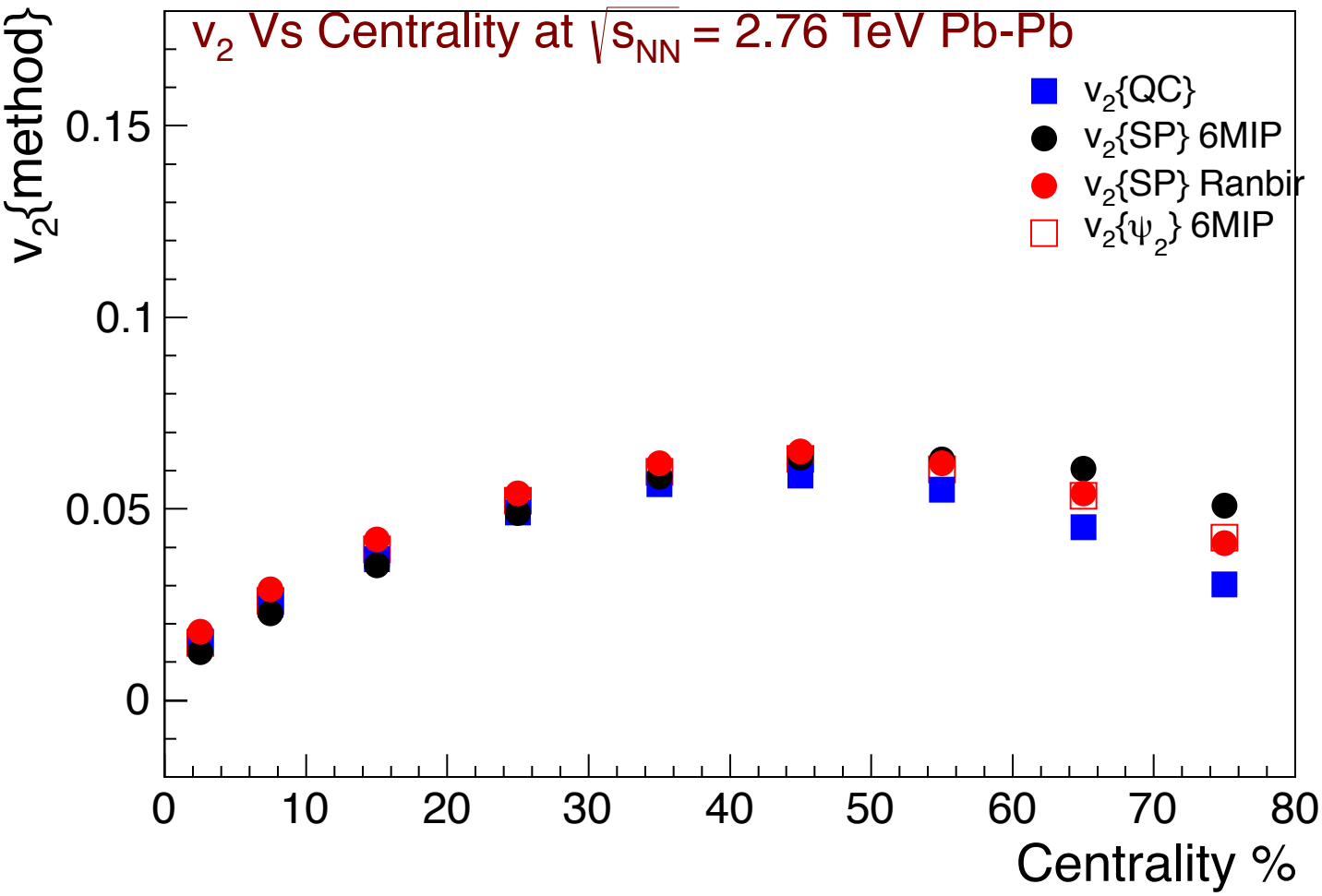
Systematic uncertainties:

- $v_{2background}$ background flow
- Uncertainties due to different photon selection cut
- Uncertainties due to detector effects
- Uncertainties due to material effect

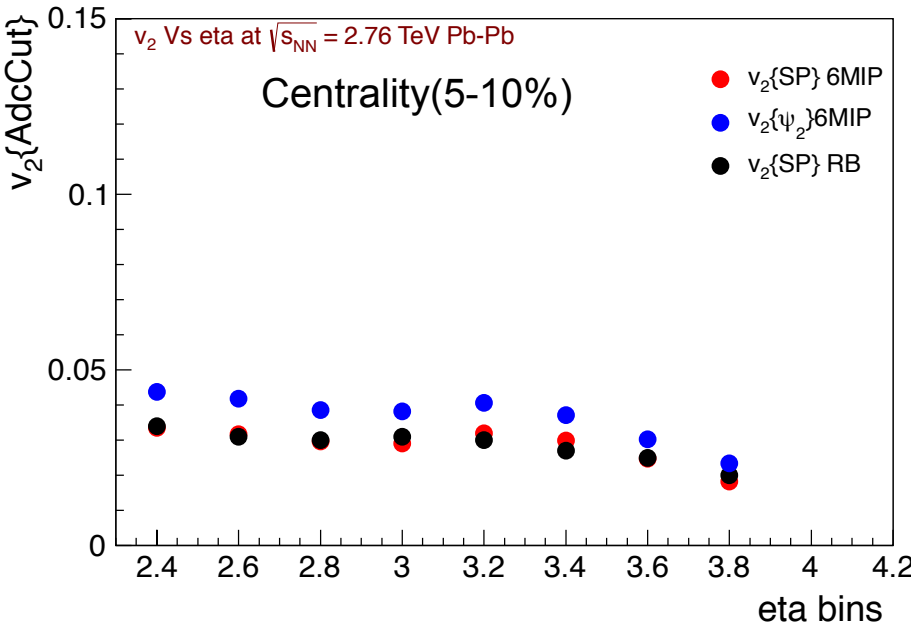
- The event plane results are compared with scalar product method results.

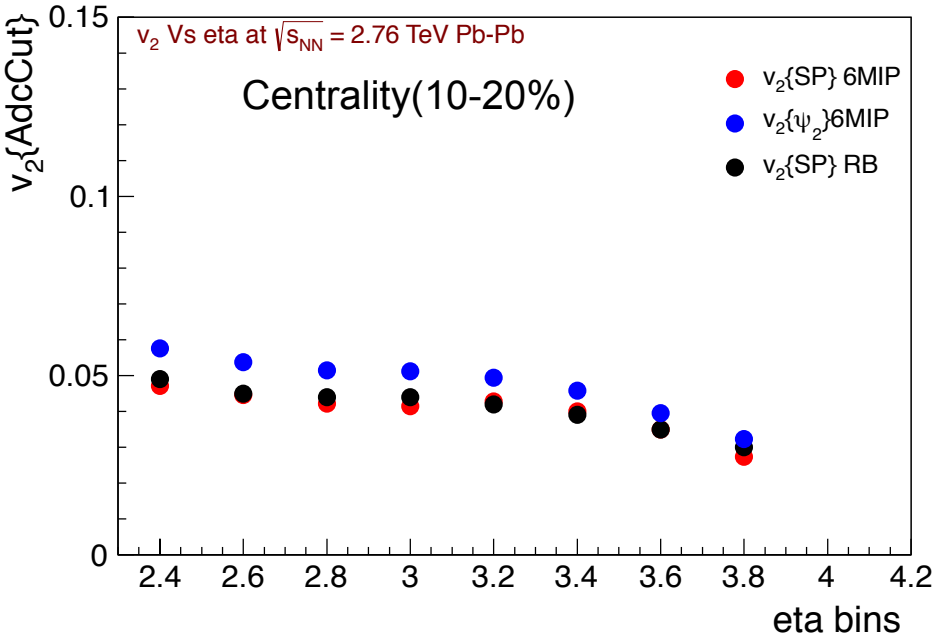
BACK UP SLIDES

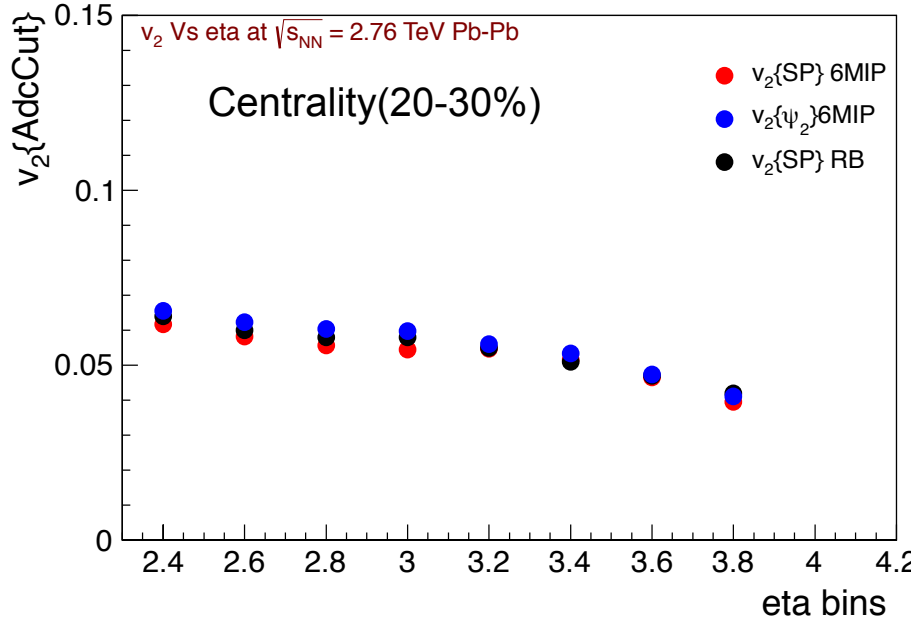
v_2 vs centrality

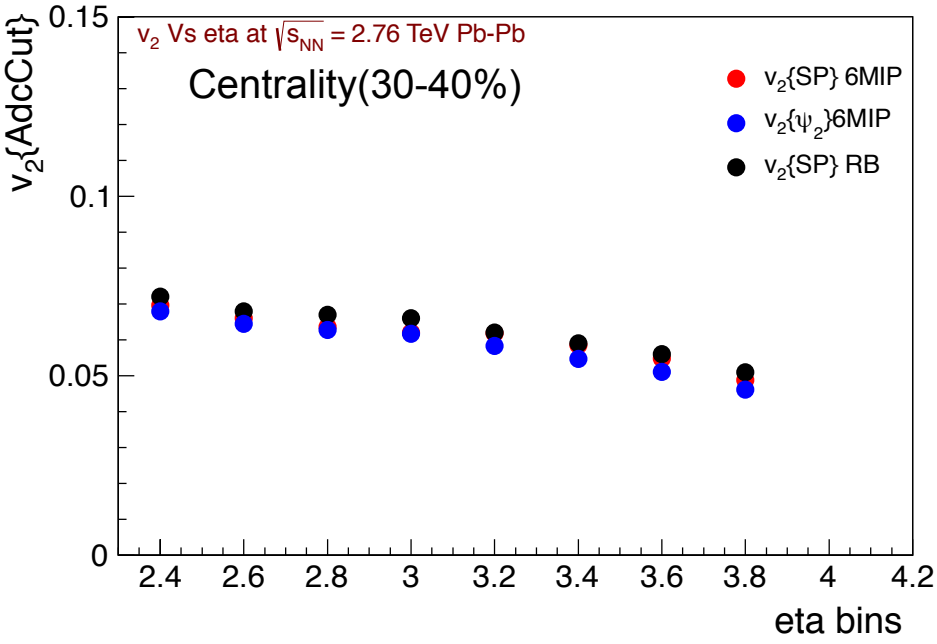


v_2 vs Eta (in different centrality bins)

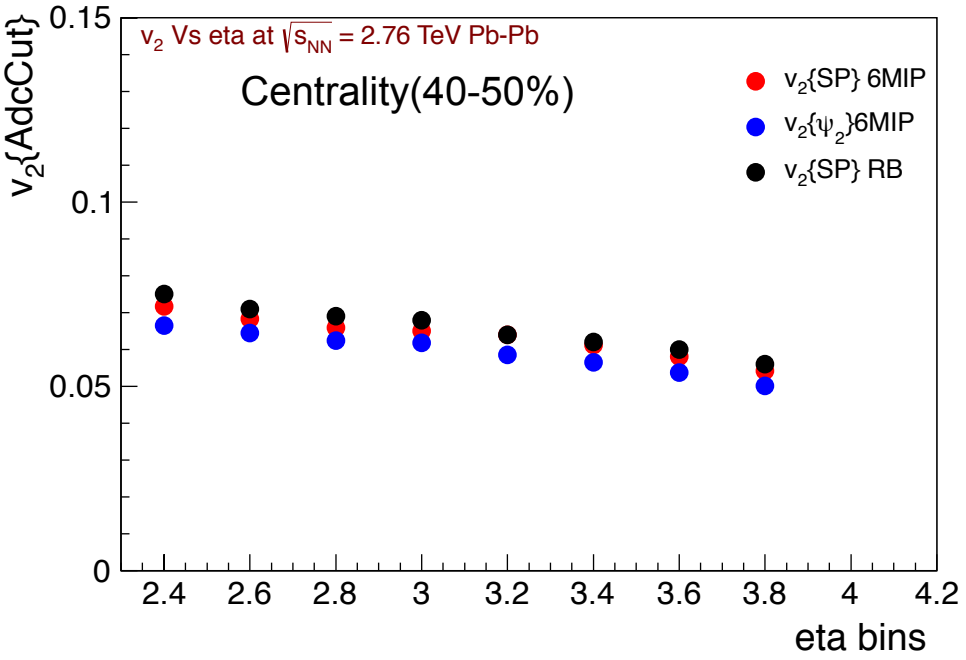


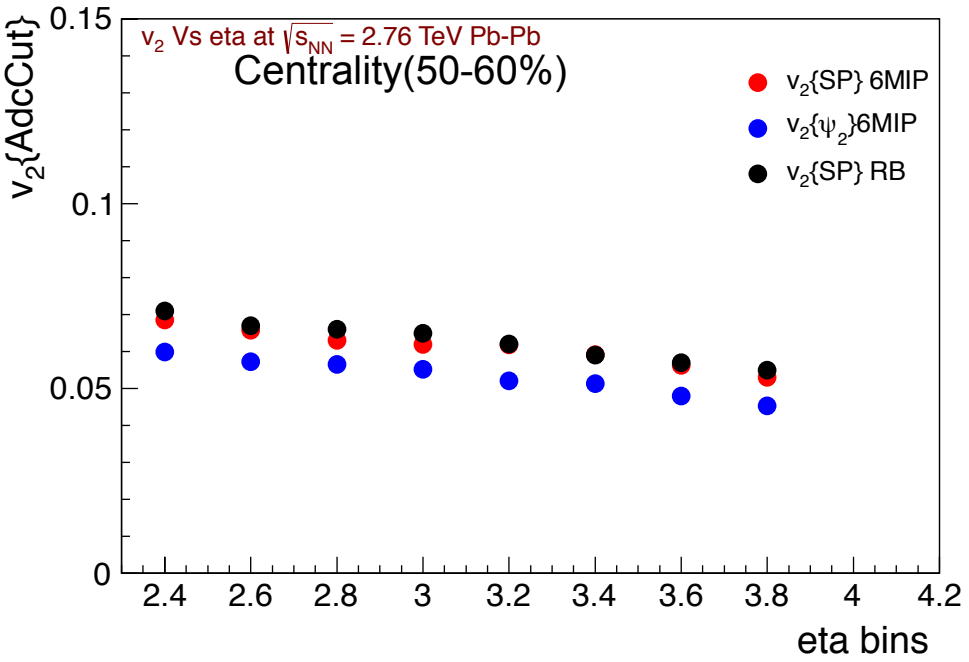




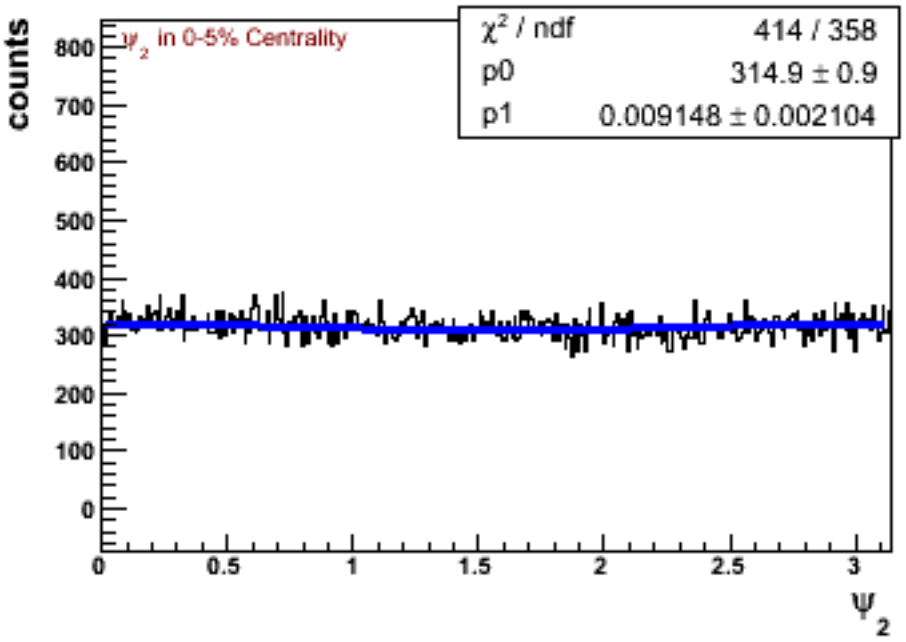


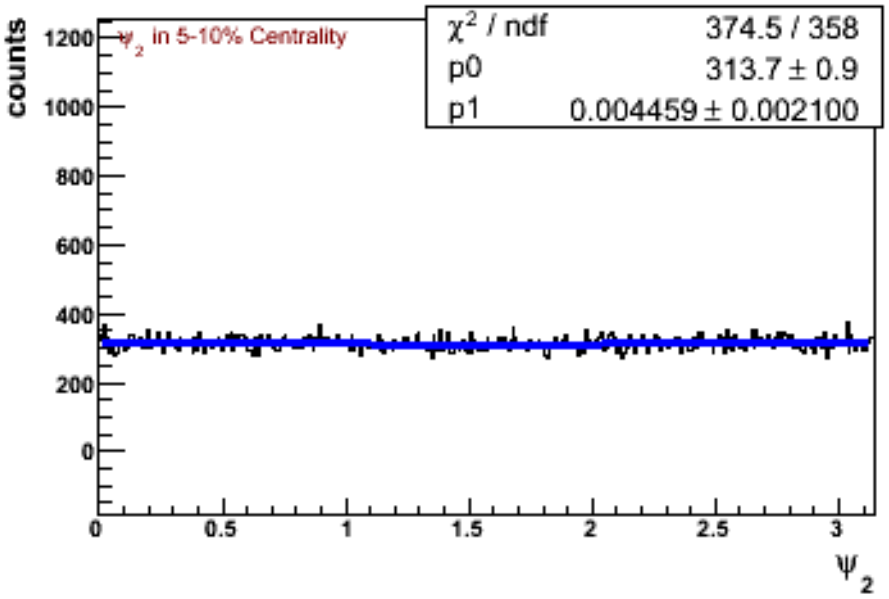
v_2 vs Eta (in different centrality bins)

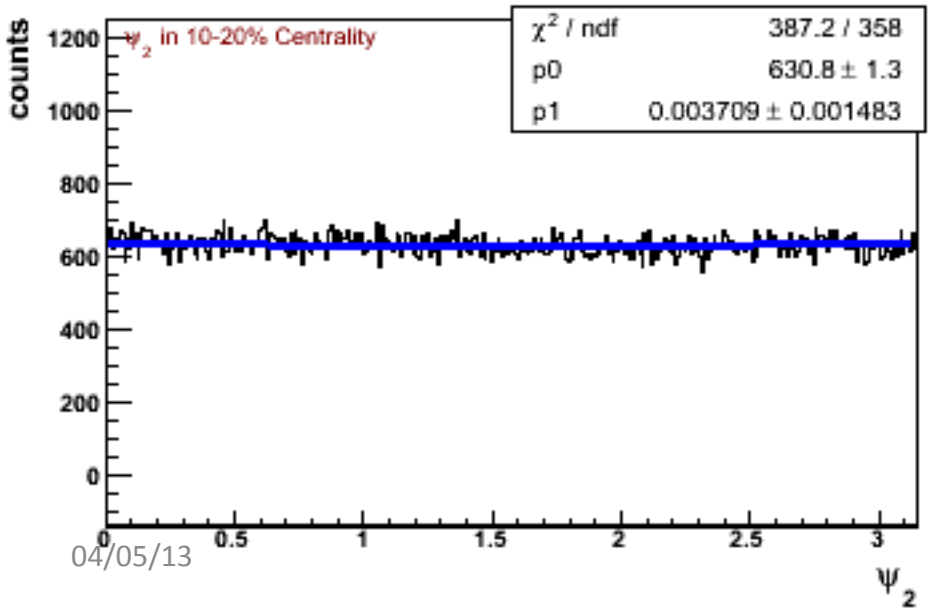


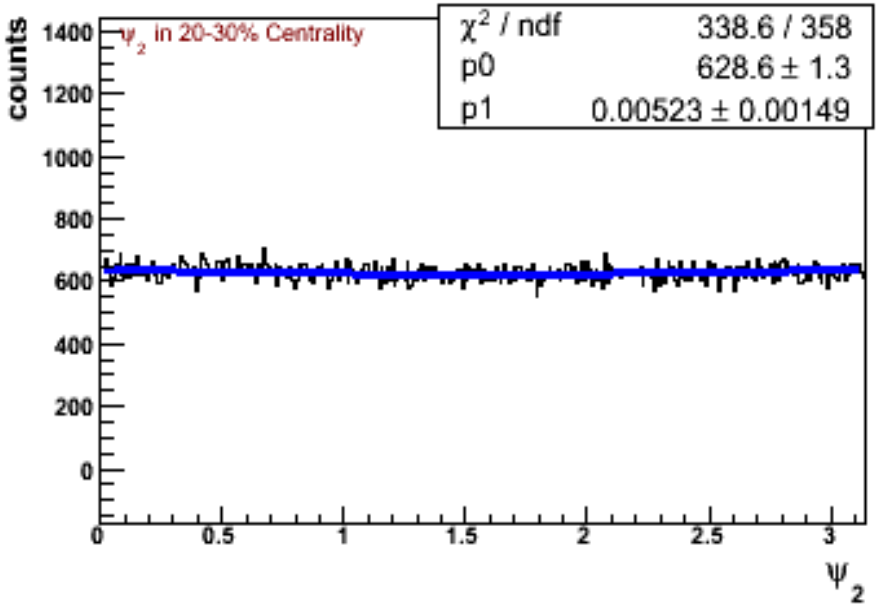


Reaction planes in Centrality bins

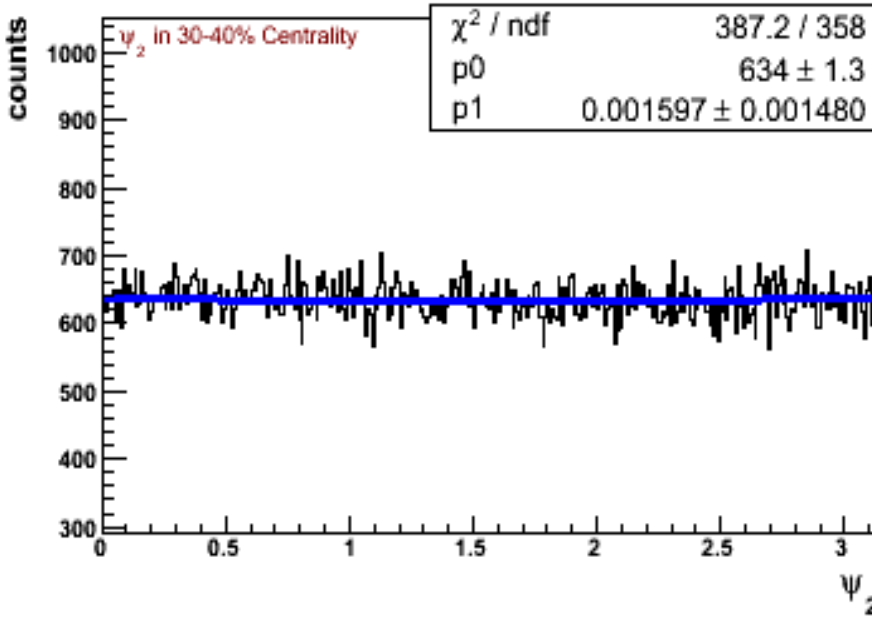


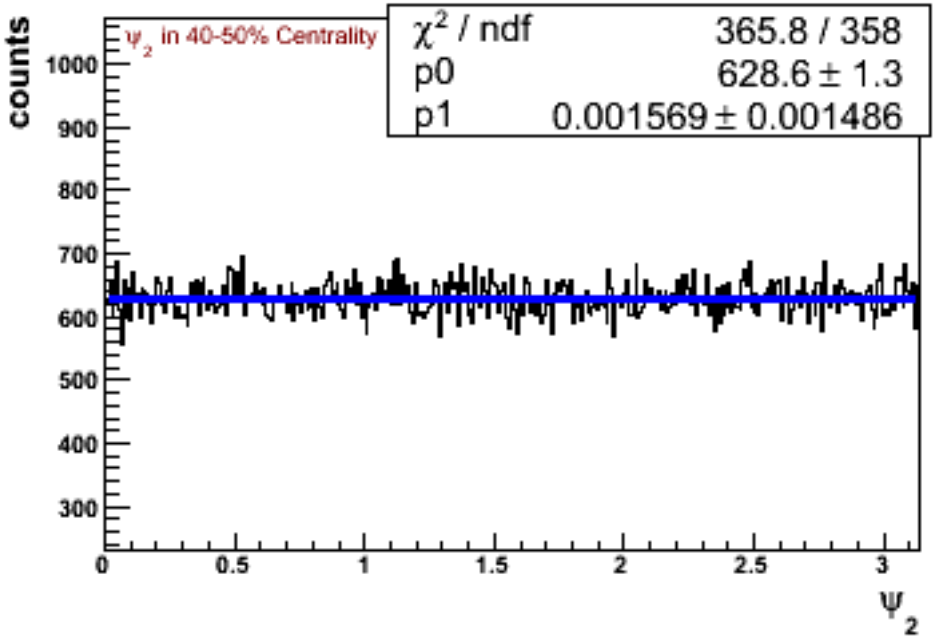


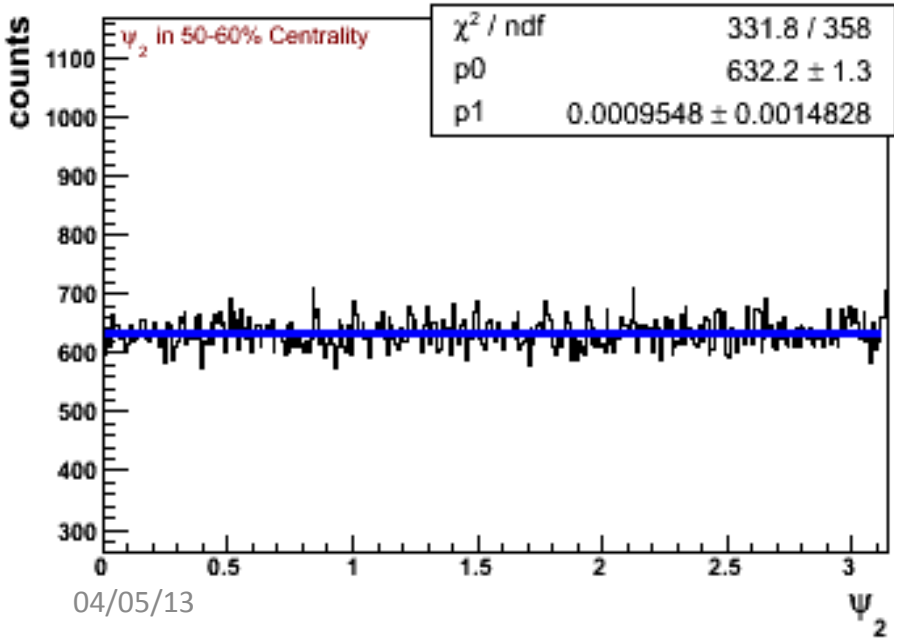


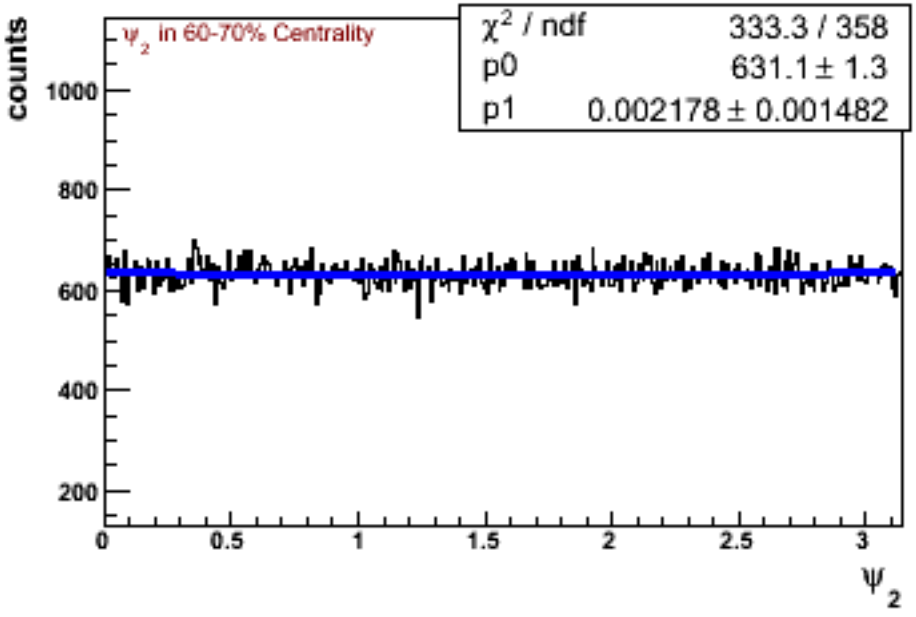


Reaction planes in Centrality bins









Reaction planes in Centrality bins