Systematic study of elliptic and higher order harmonics by event plane method in Pb-Pb 2.76 TeV collisions at LHC-ALICE

Workshop on Particle Correlations and Femtoscopy
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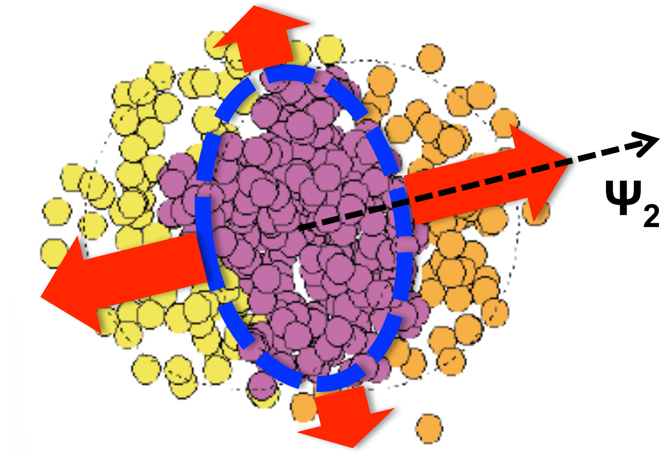
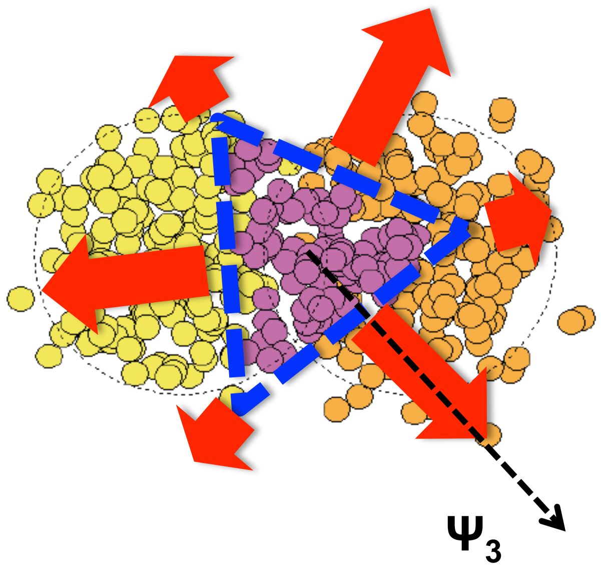
What's collective flow





Initial spatial anisotropy
eccentricity(n=2)
triangularity(n=3)
quadrangularity(n=4)
...

pressure gradient

Momentum space anisotropy

- n-th fourier coefficient of $dN/d(\varphi_{track}-\Psi_n)$ dist.

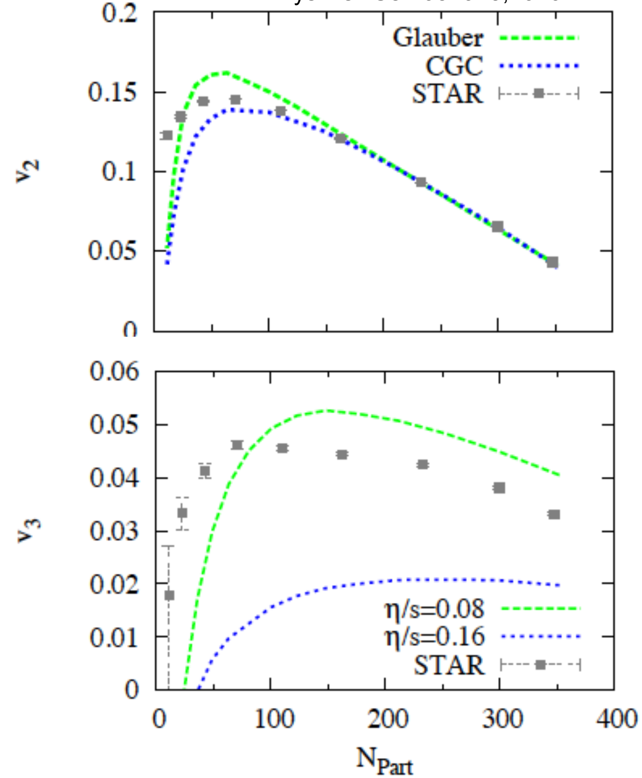
$$v_n = \langle cos(n(\phi - \Psi_n)) \rangle$$

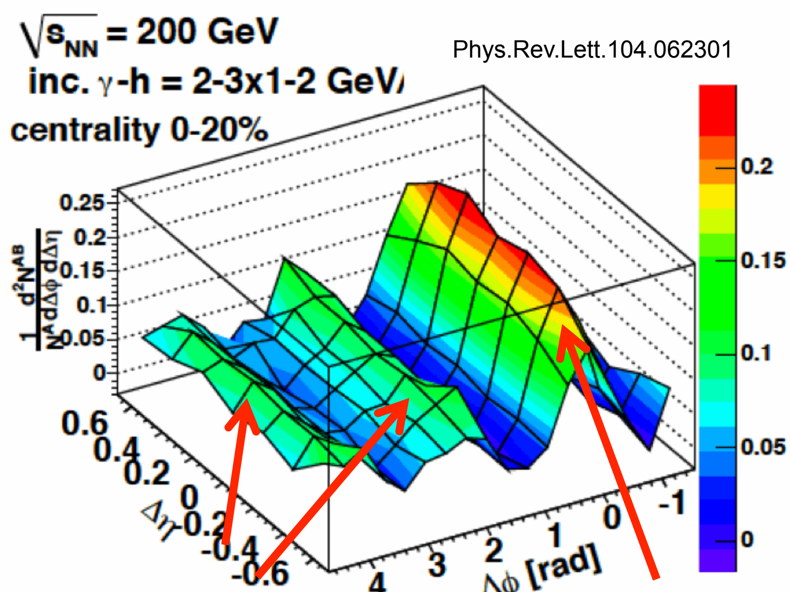
- **Sensitive probe for early stage of heavy ion collisions.**

Motivation

- How does collective flow manifest itself at LHC?
  - Constraints on η/s and initial condition (CGC/ Glauber).
  - Does quark number and KE_T scaling work at LHC ?
- Are ridge and mach cone like structure fully explained by higher order flow ?

Phys.Rev.C82:034913,2010

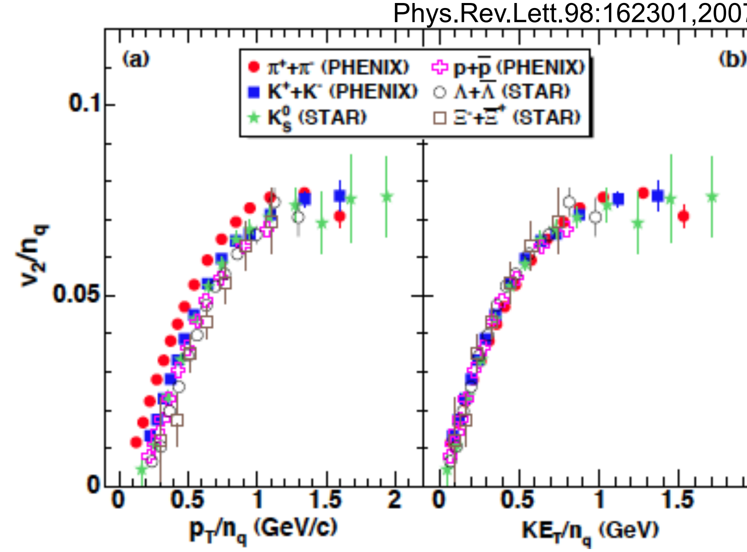




Mach cone like structure

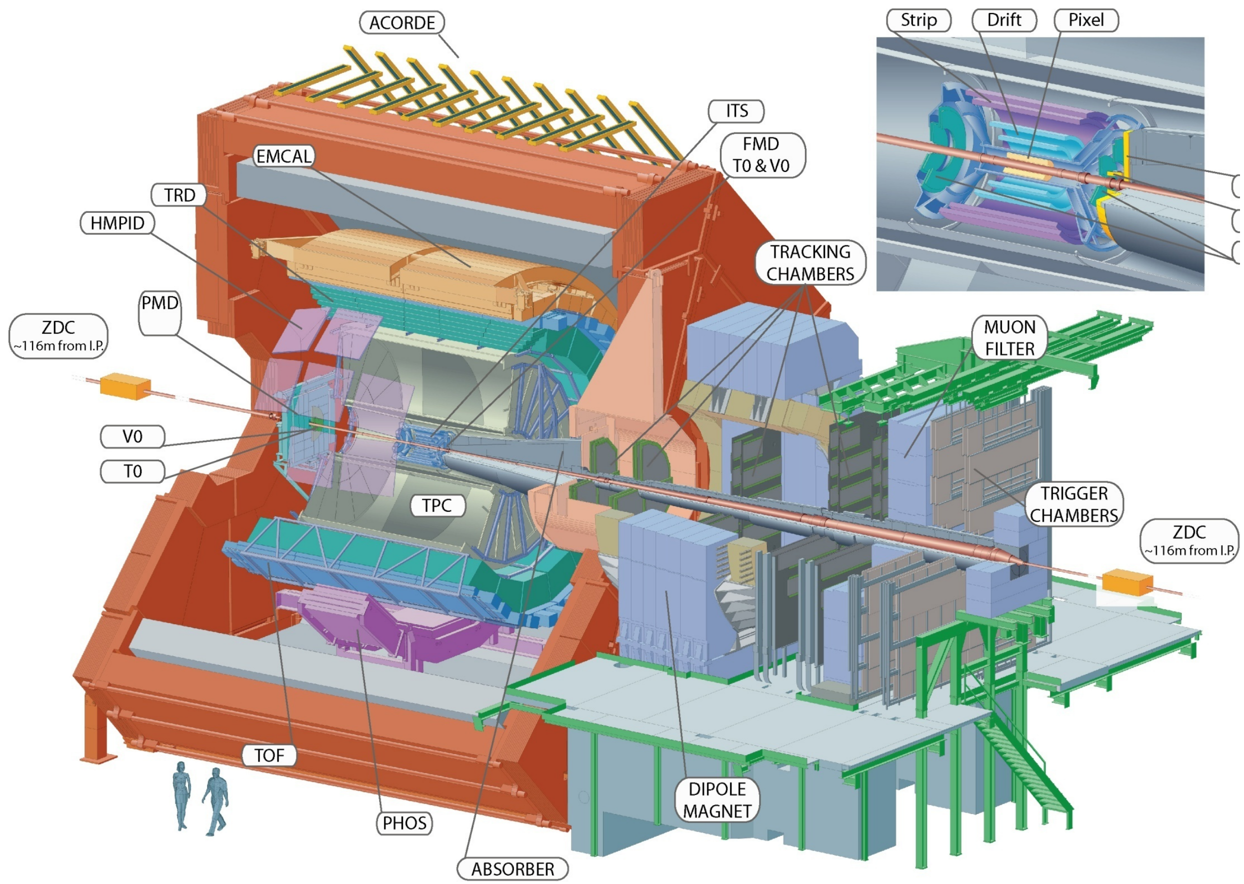
ridge

Phys.Rev.Lett.98:162301,2007



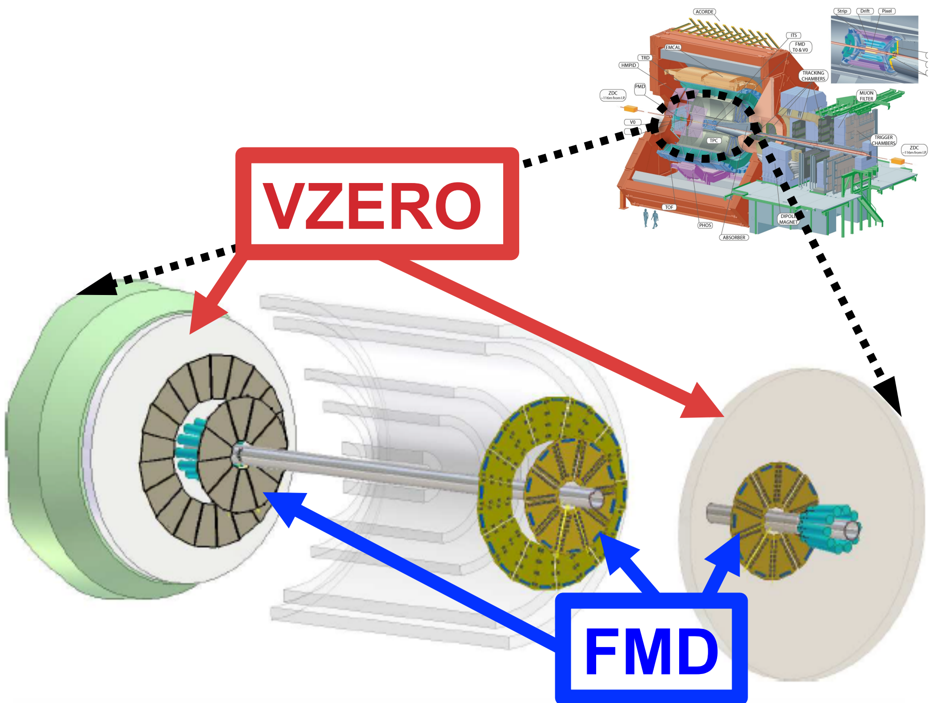
ALICE detector

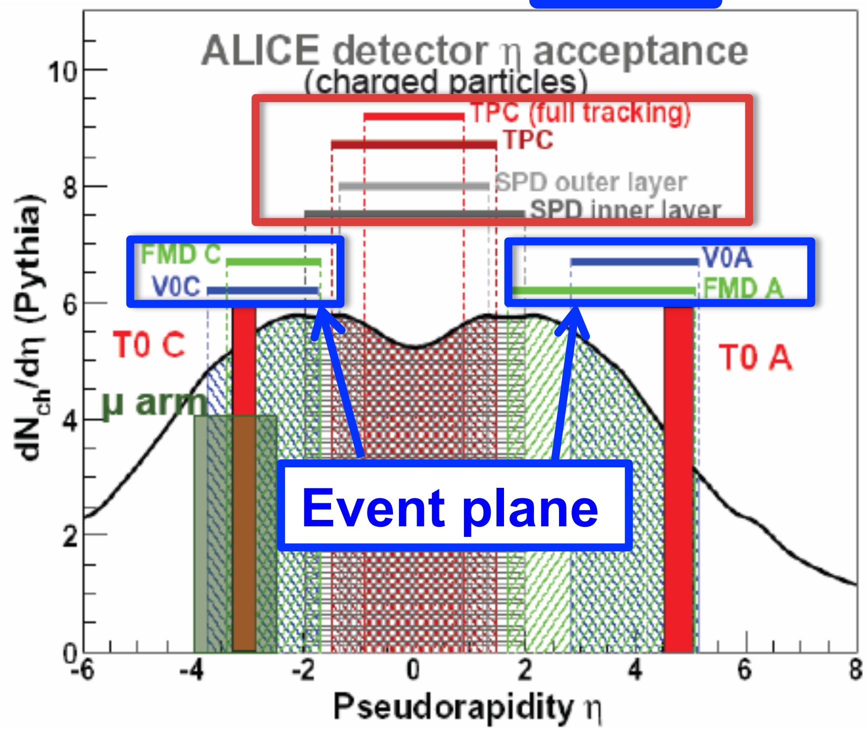
- **TPC & ITS**
  - Charged particle tracking
- **VZERO**
  - Scintillation counter.
  - Event trigger
  - Centrality determination
  - **E.P. determination**
- **FMD**
  - Silicon strip detector.
  - **E.P. determination**



ALICE detector

- In this analysis, **v_n at mid-rapidity** is measured using **Event Planes at forward rapidity**.
  - This introduce large rapidity gap to reduce non-flow bias on v_n measurement.
- **TPC & ITS**
  - $0<\Phi<2\pi$
  - $|\eta_{track}|<0.8$
- **VZERO**
  - $0<\Phi<2\pi$: Divided into 8 segments
  - $V0_A$: $2.8 < \eta < 5.1$
  - $V0_C$: $-3.7 < \eta < -1.7$
  - $\mathbf{0.9<|\eta_{track}-\eta_{VZERO}|<5.9}$
- **FMD**
  - $0<\Phi<2\pi$: Divided into 20 segments
  - FMD_A : $1.7 < \eta < 5.0$
  - FMD_C : $-3.4 < \eta < -1.7$
  - $\mathbf{0.9<|\eta_{track}-\eta_{FMD}|<5.8}$





v_n measurement by E.P. method

① Determine E.P. in sub event i : Ψ_n^i

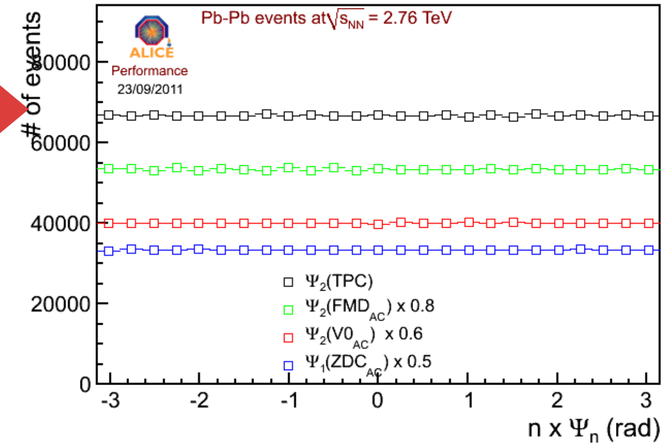
② Measure $v_n^{meas.}\{ EP_i \}$

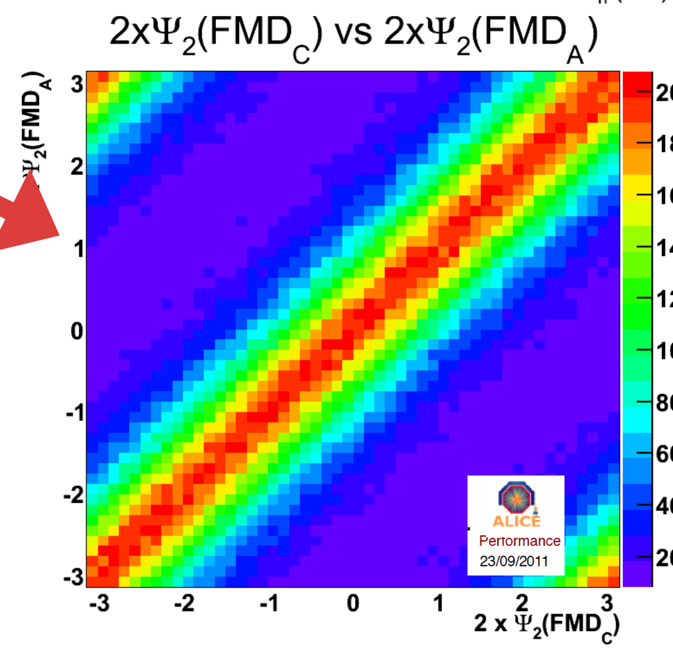
$$v_n^{meas.}\{ EP_i \} = \langle \cos(n(\varphi_{track} - \Psi_n^i)) \rangle$$

③ Extract $Res\{\Psi_n^i\}$ from <u>E.P. correlations</u>

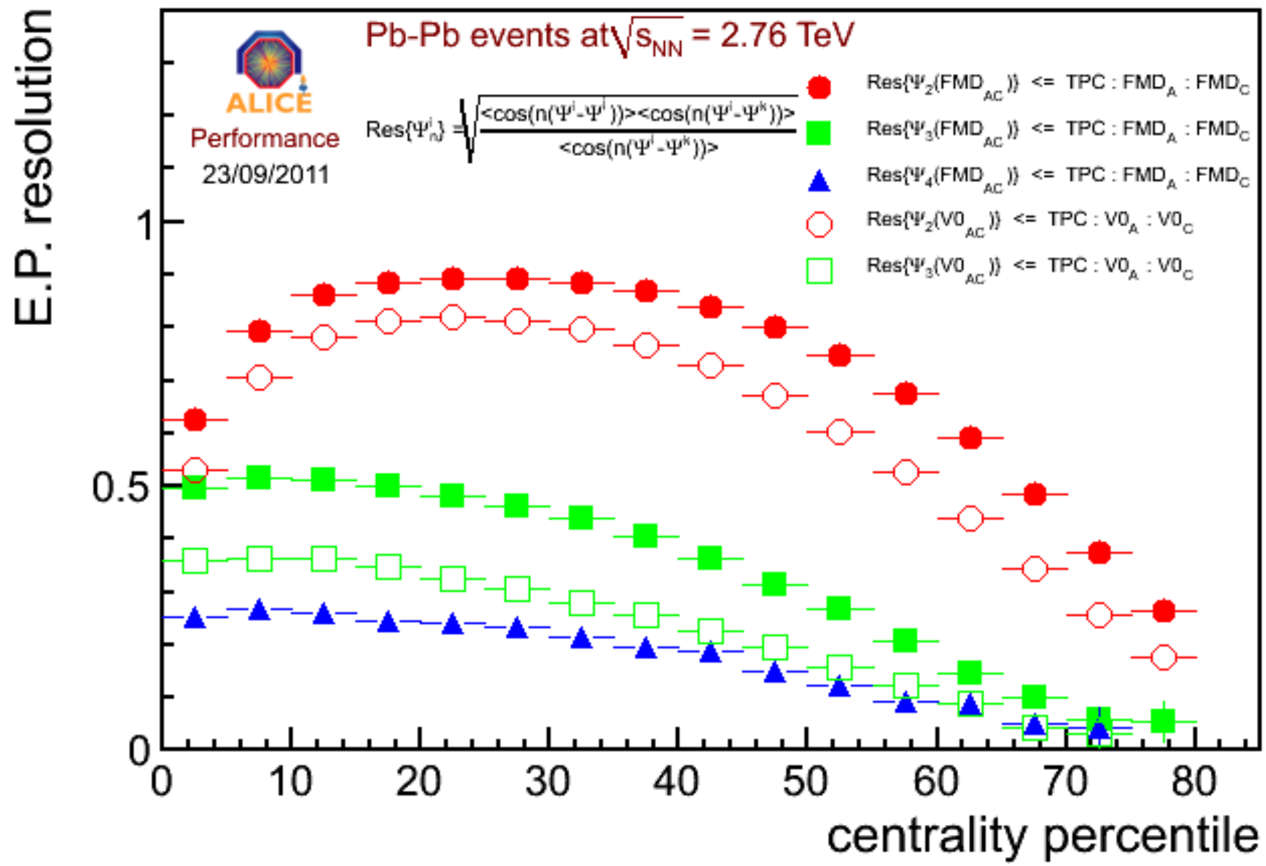
④ Correct $v_n^{meas.}\{ EP_i \}$ by E.P. resolution

$$v_n\{ EP_i \} = v_n^{meas.}\{ EP_i \} / Res\{\Psi_n^i\}$$





E.P. resolutions for n-th order plane

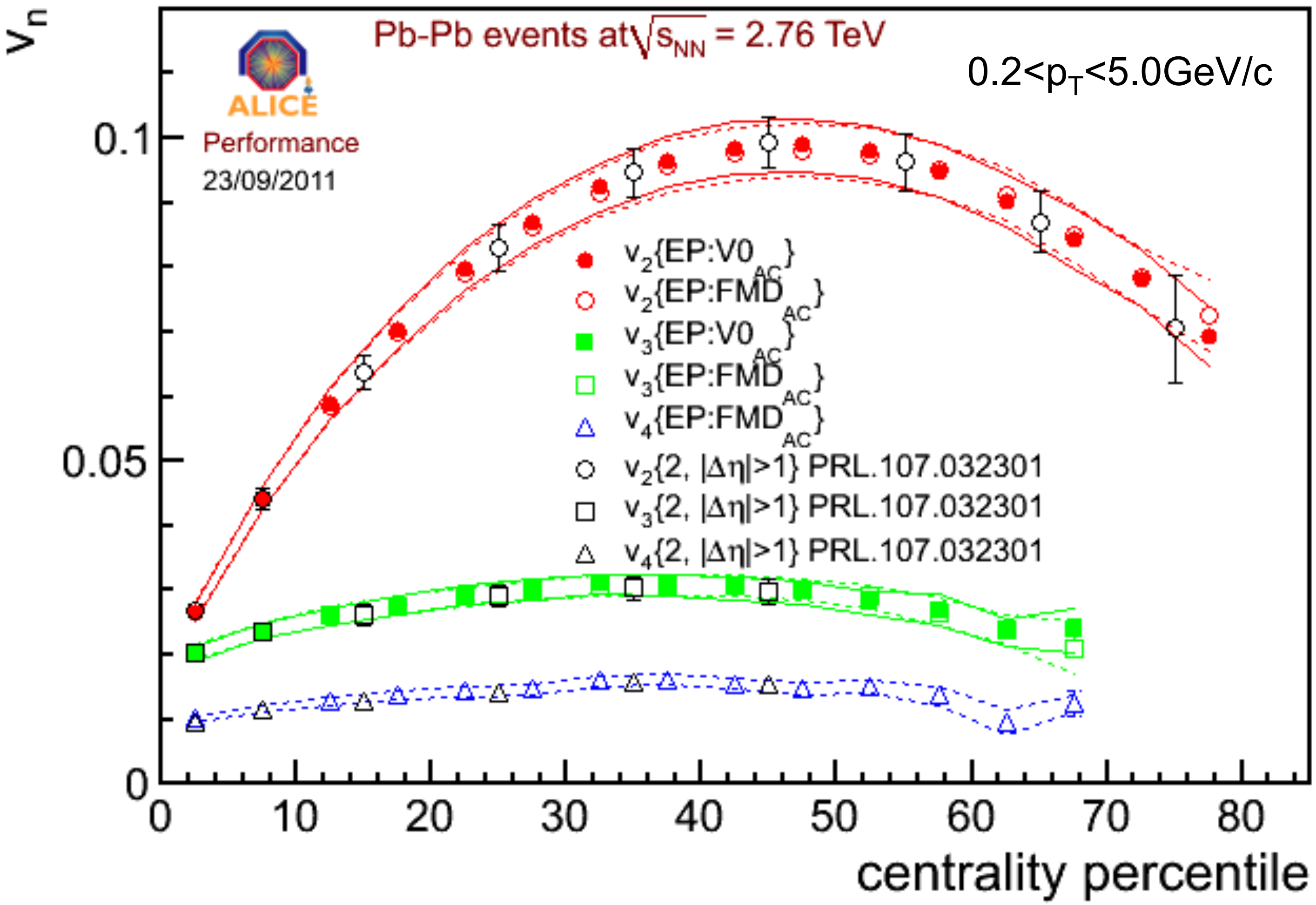


- E.P. resolutions are extracted by 3 sub event method.

$$\langle\cos\left(n(\Psi_n^i-\Psi_n^{True})\right)\rangle=\sqrt{\frac{\langle\cos\left(n(\Psi_n^i-\Psi_n^j)\right)\rangle\langle\cos\left(n(\Psi_n^i-\Psi_n^k)\right)\rangle}{\langle\cos\left(n(\Psi_n^j-\Psi_n^k)\right)\rangle}}$$

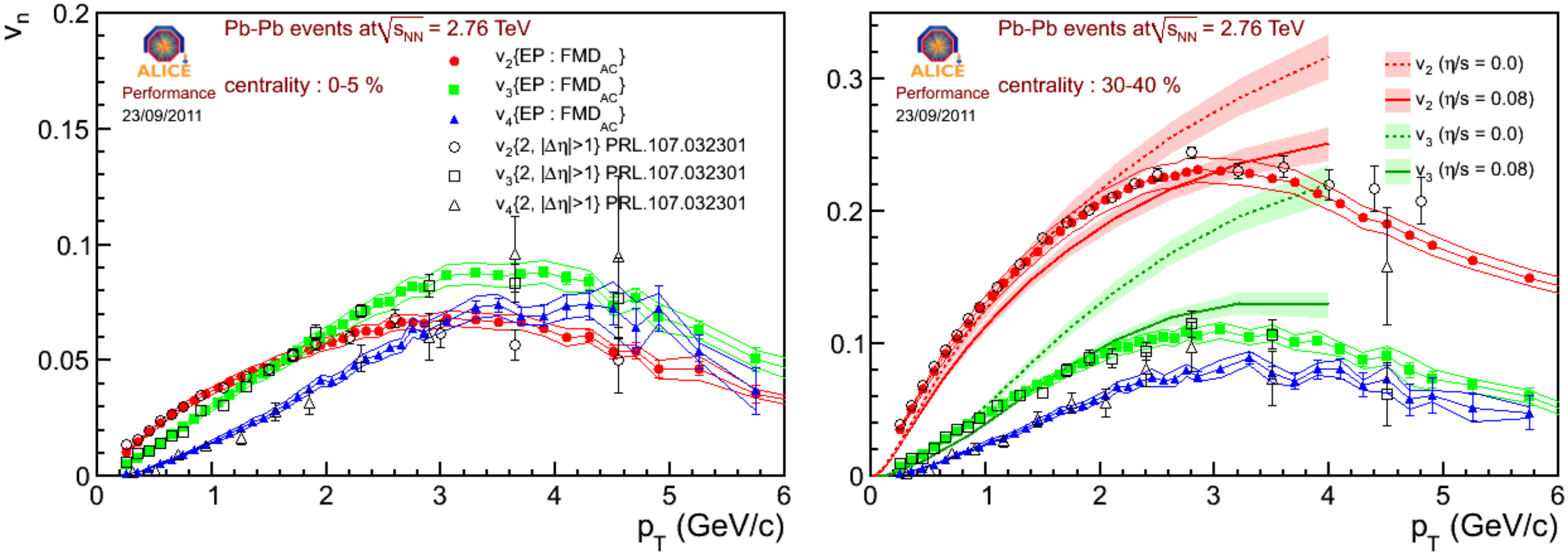
- These excellent resolutions allow us to measure v_2, v_3 and v_4 .

centrality dependence of v_n



- Results on $v_n\{EP\}$ (this analysis) and $v_n\{2,|\Delta\eta|>1\}$ (PRL, obtained from 2-part.corr. using TPC tracks) are fully consistent.
- v_3 and v_4 have a weak centrality dependence compared to v_2 .

p_T dependence of v_n



- Results on v_n{EP}(this analysis) and v_n{2,|Δη|<1}(PRL, obtained from 2-part.corr. using TPC tracks) are fully consistent.
- $v_3(v_4)$ is as large as v_2 at about 1.6 GeV/c (3.0 GeV/c) for 0-5% central
  - necessity to consider higher order flow for the study of di-hadron correlation especially for central collisions.

Summary & Outlook

- v_n (n=2,3,4) are measured using E.P. determined by forward detectors in Pb-Pb collisions at sqrt(s_{NN})=2.76 TeV with ALICE detector.
  - Results on v_n{E.P.} and v_n{2, |Δη|>1}) are fully consistent.
  - Centrality dependence of v_2, v_3 and v_4 .
    - v_3 and v_4 have a weak centrality dependence compared to v_2
  - p_T dependence of v_2, v_3 and v_4 .
    - v_3(v_4) is as large as v_2 at about 1.6 GeV/c (3.0 GeV/c) for 0-5% central
    - Comparison with hydro. predictions (Glauber initial condition)
      - η/s=0.08 favored with respect to ideal hydro.