Identified charged hadron production in Pb-Pb collisions with event shape engineering

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Università degli Studi di Bari and INFN

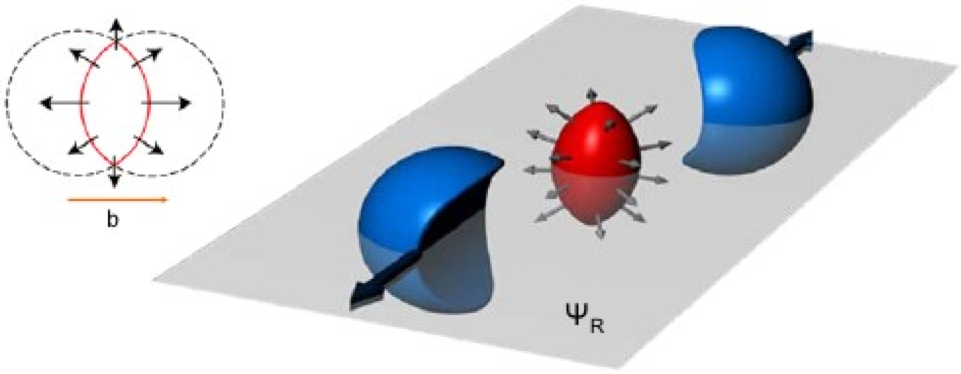
Outline

- Motivation
- The ALICE detector
- Event shape selection
- Unidentified charged particle v_2
- p_T spectra and particle identification
- Summary and outlook

Motivation

Study the effect of the initial geometry on final state observables

- Collision centrality
- Colliding nuclei of different size and shape (e.g. U-U collisions)



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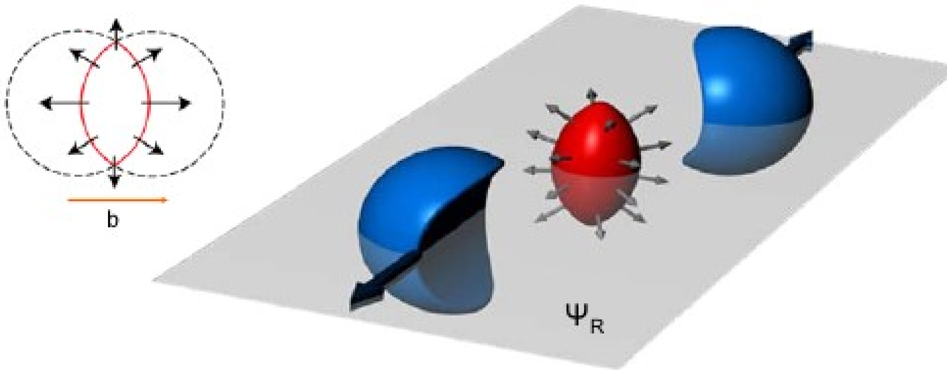
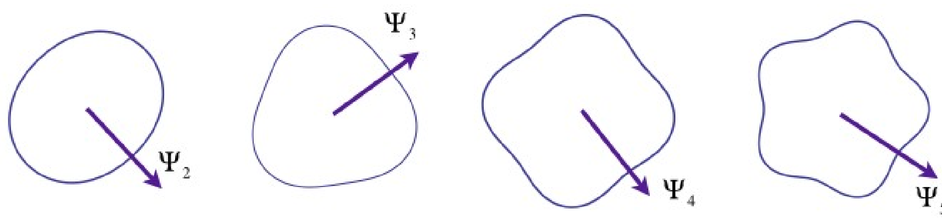


At fixed centrality: different initial shapes.



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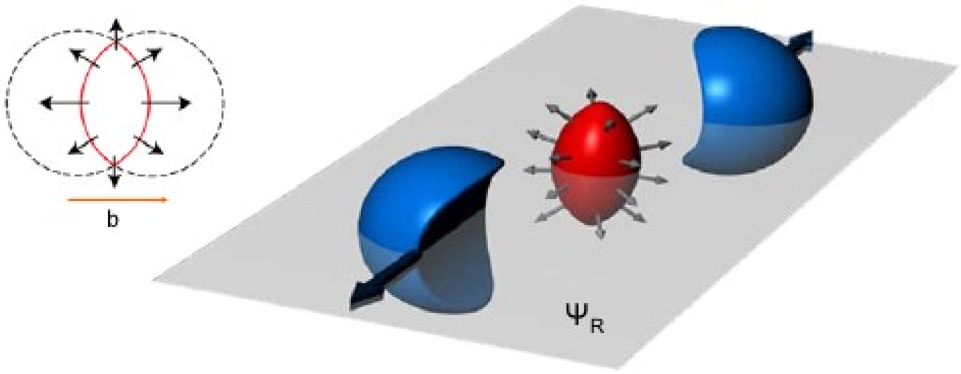

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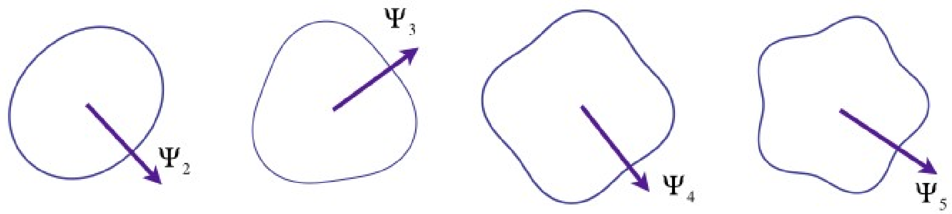
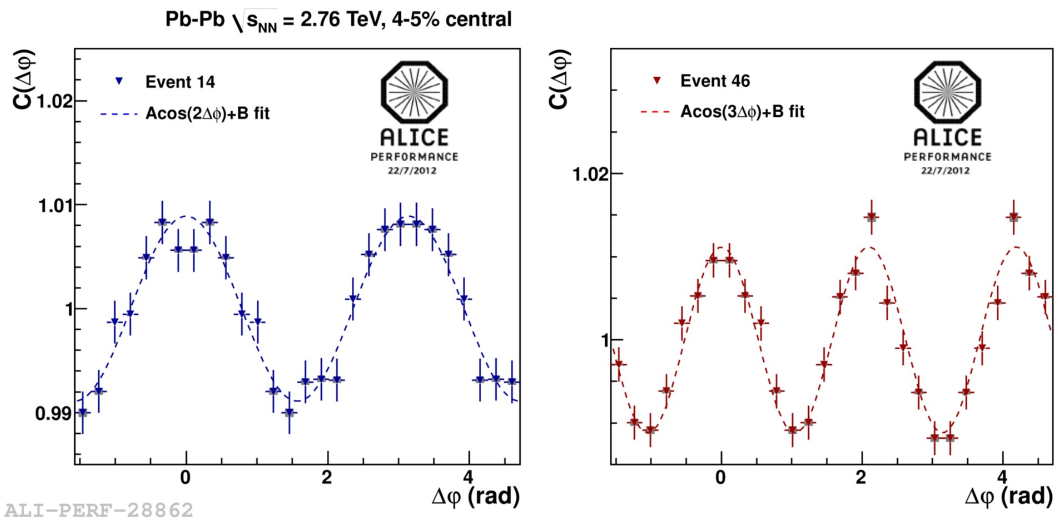


At fixed centrality, flow fluctuates → event selection based on flow



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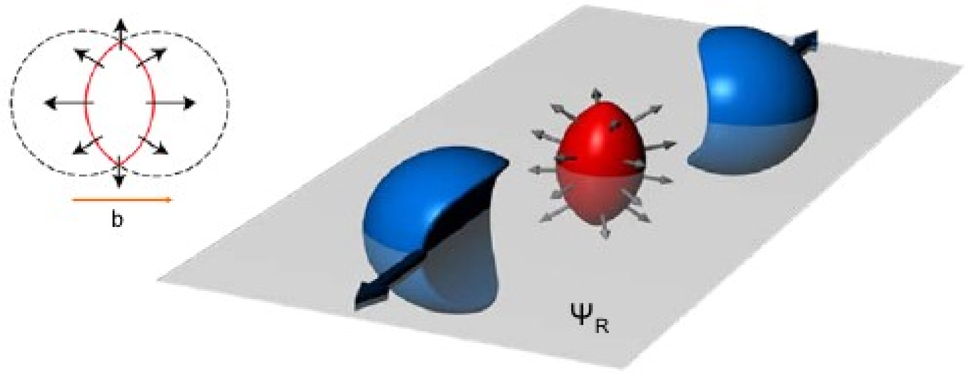

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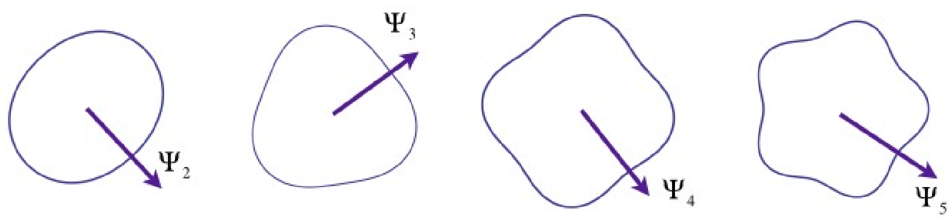

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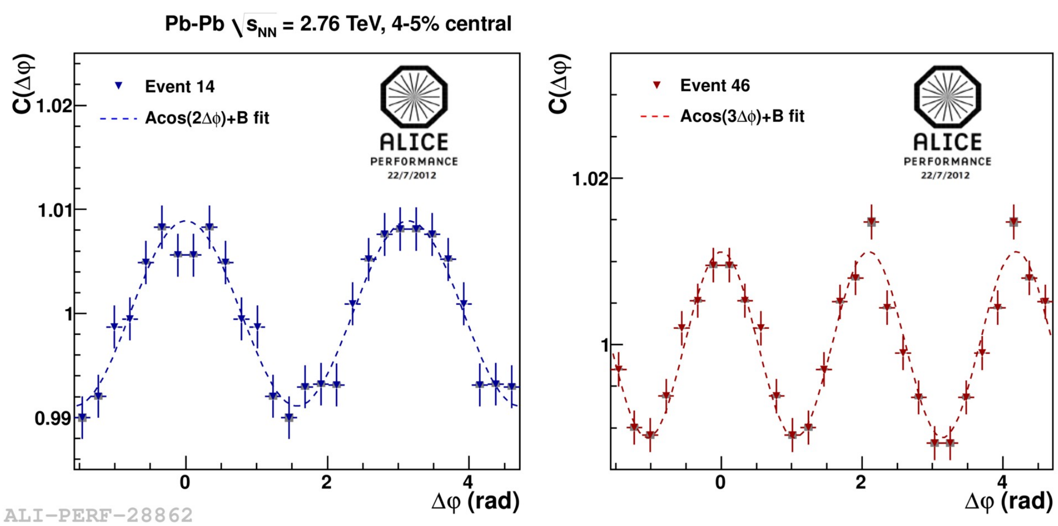
We can select events corresponding to nuclear collisions with different initial geometry configuration:

EVENT SHAPE ENGINEERING



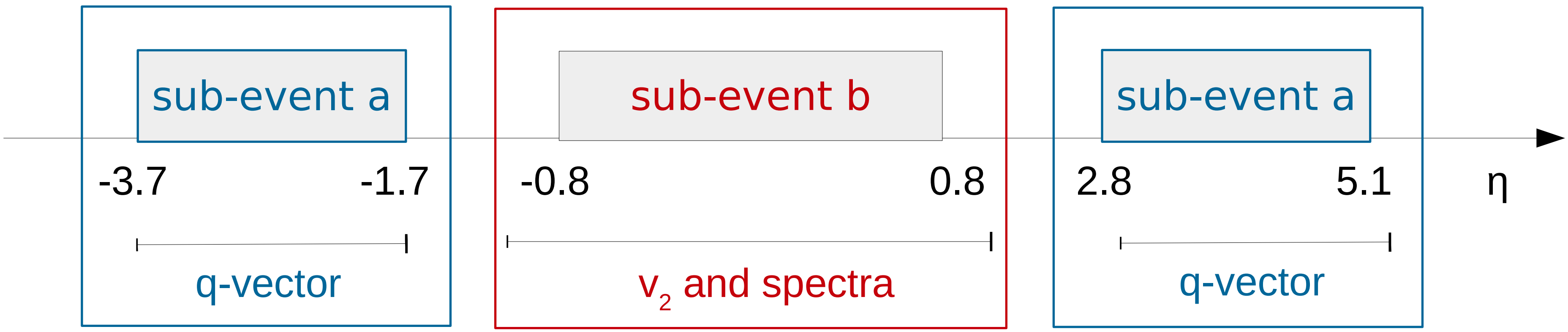
Schukraft et al, Phys.Lett. B719 (2013) 394-398

Event shape engineering

Event selection based on the magnitude of the **flow vector**

$$Q_{n,x} = \sum_i \cos(n\phi_i) \qquad Q_n = \{Q_{n,x}, iQ_{n,y}\}$$

$$Q_{n,y} = \sum_i \sin(n\phi_i) \qquad q_n = |Q_n| / \sqrt{M}$$



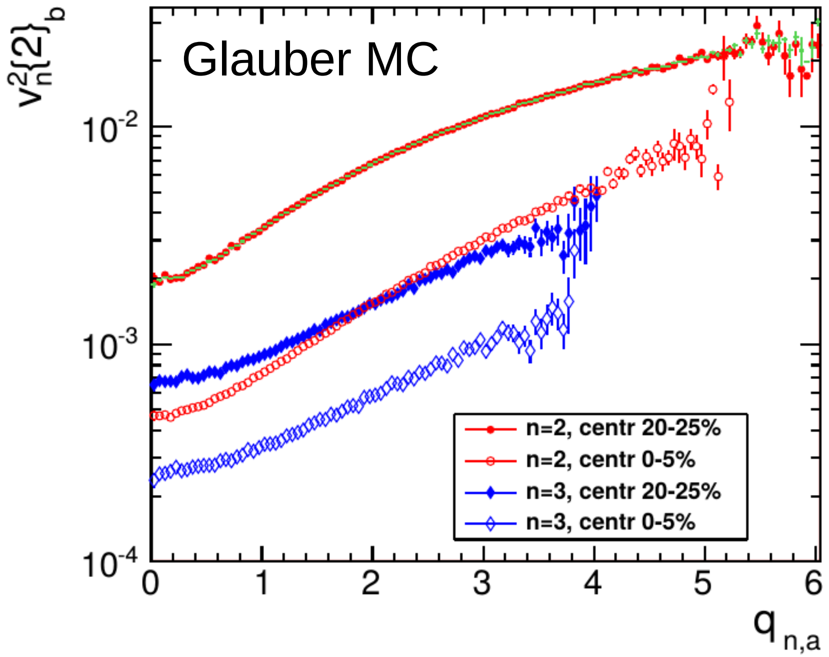
Need to avoid biases from non-flow: **sub-events with large pseudo-rapidity separation**

Measure q_2 in one independent sub-event for the event selection (sub-event a)

Study observables of interest in another pseudo-rapidity window (sub-event b)

ESE in MC

Schukraft et al, Phys.Lett. B719 (2013) 394-398



- q-vector evaluated in sub-event a, v_n^2 measured in sub-event b
- Large q_2 → larger v_2

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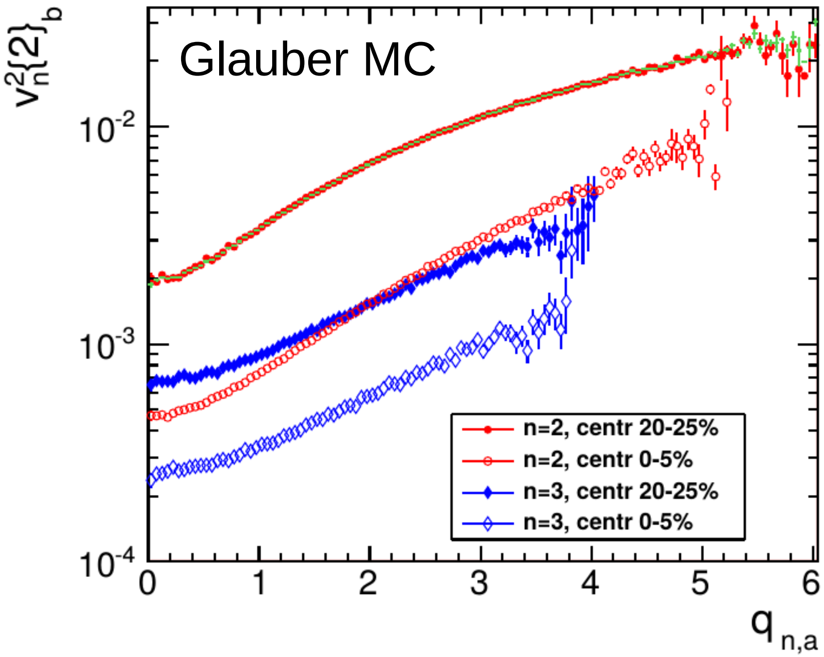

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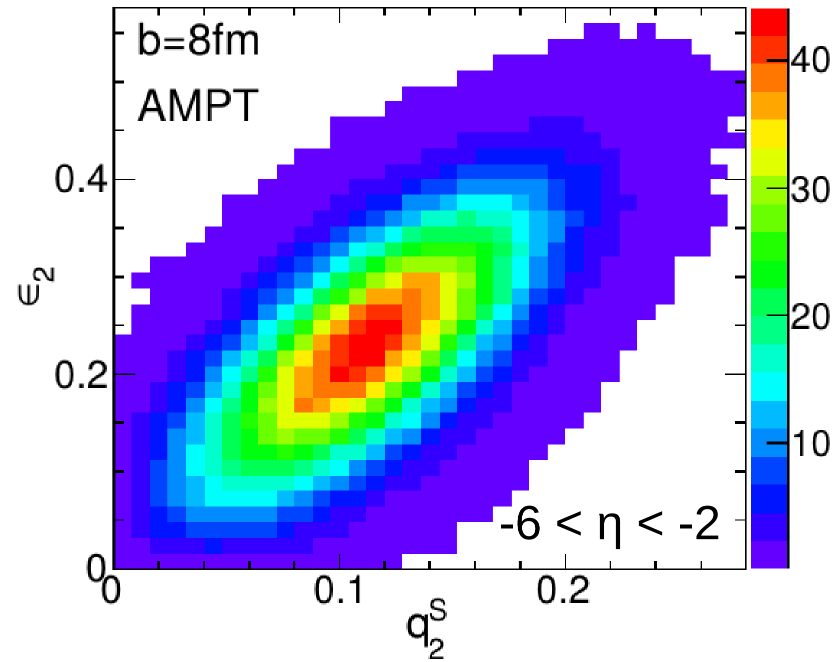
Huo et al, Phys.Rev. C90 (2014) 024910



- Strong positive correlation between eccentricity and q-vector
- $<\varepsilon_2>$ value is higher in 10% large q_2 sample

The shape of the initial geometry can be selected using the q-vector in the final state

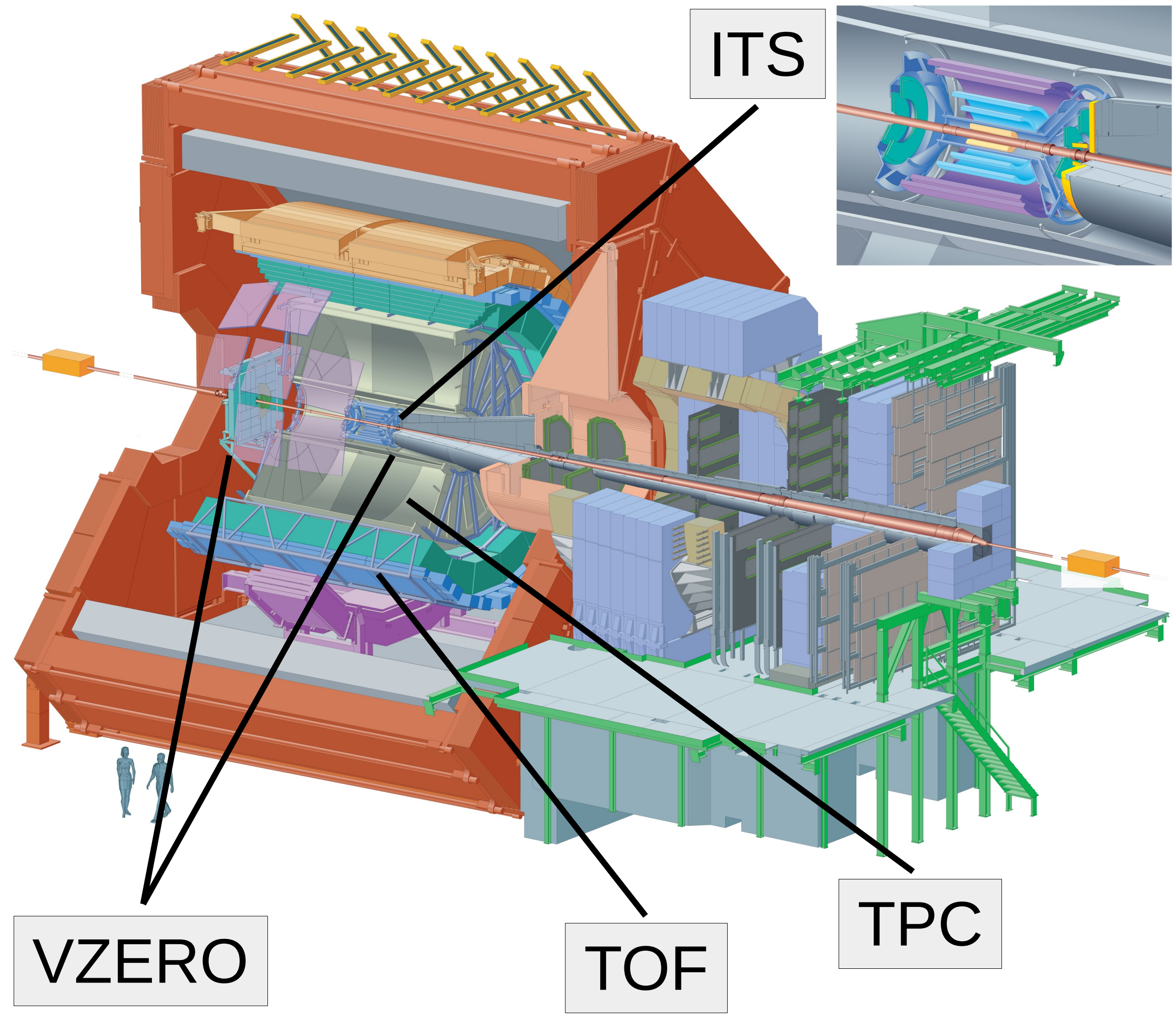
The ALICE detector

Inner Tracking System (ITS)
- Primary vertex reconstruction
- Combined ITS-TPC tracking

Time Projection Chamber (TPC)
- Main tracking system
- PID from energy loss in the gas

Time Of Flight (TOF)
- Tracks extrapolated from ITS-TPC
- PID from time of flight measurement

VZERO
- VZEROA ($2.8<\eta<5.1$)
- VZEROC ($-3.7<\eta<-1.7$)
- Trigger, centrality selection, event plane calculation



~10M minimum bias Pb-Pb events at $\sqrt{s_{NN}}$ = 2.76 TeV (2010 run) used for this analyisis.

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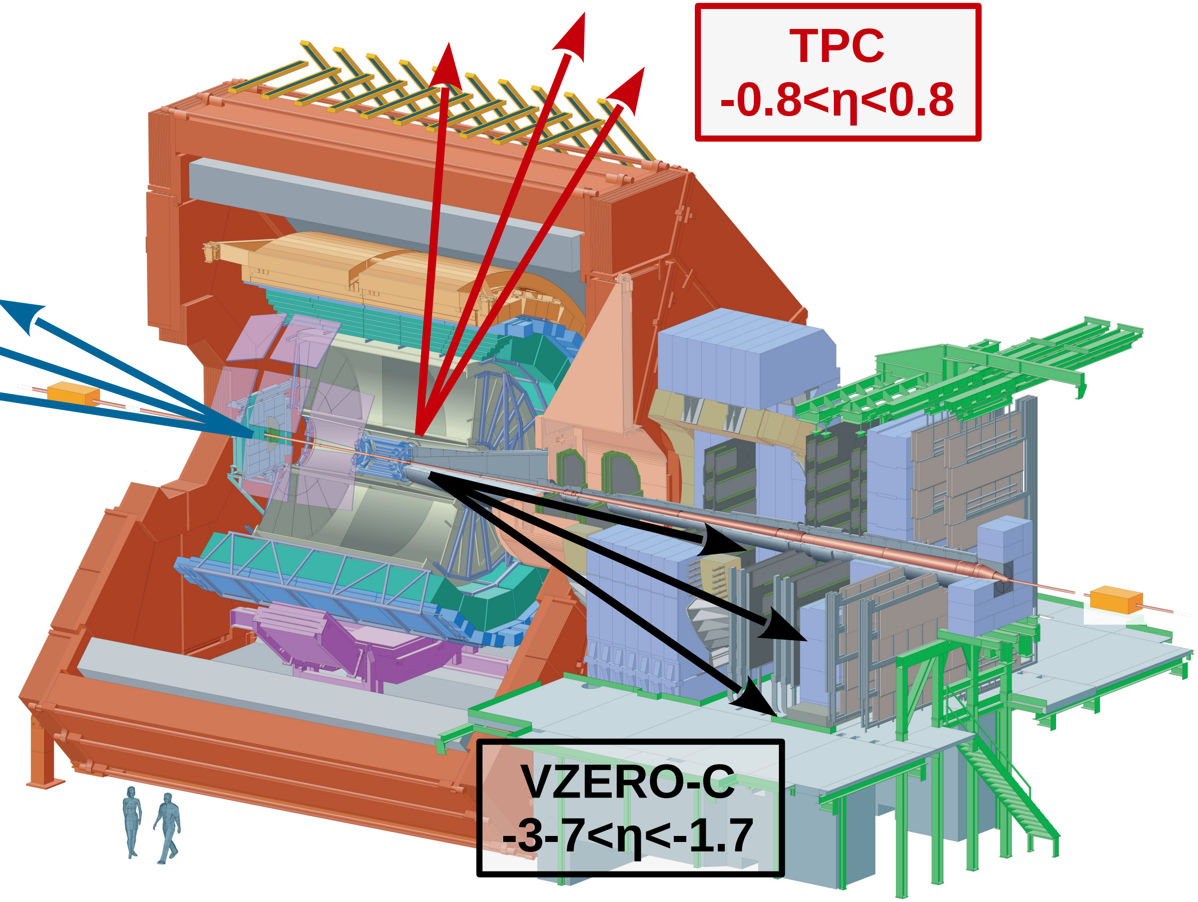

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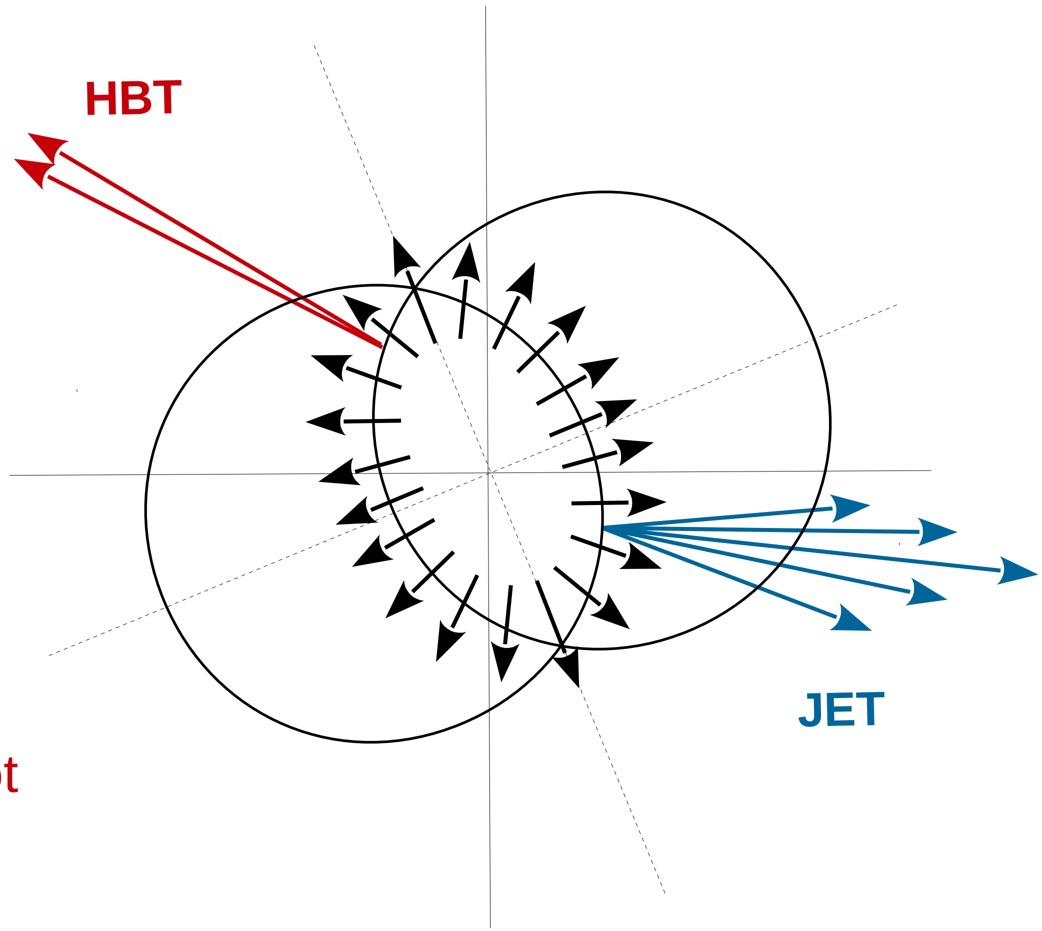
Non-flow contribution

Non-flow definition

contribution to v_n from azimuthal correlations between particles not due to their correlation with the reaction plane

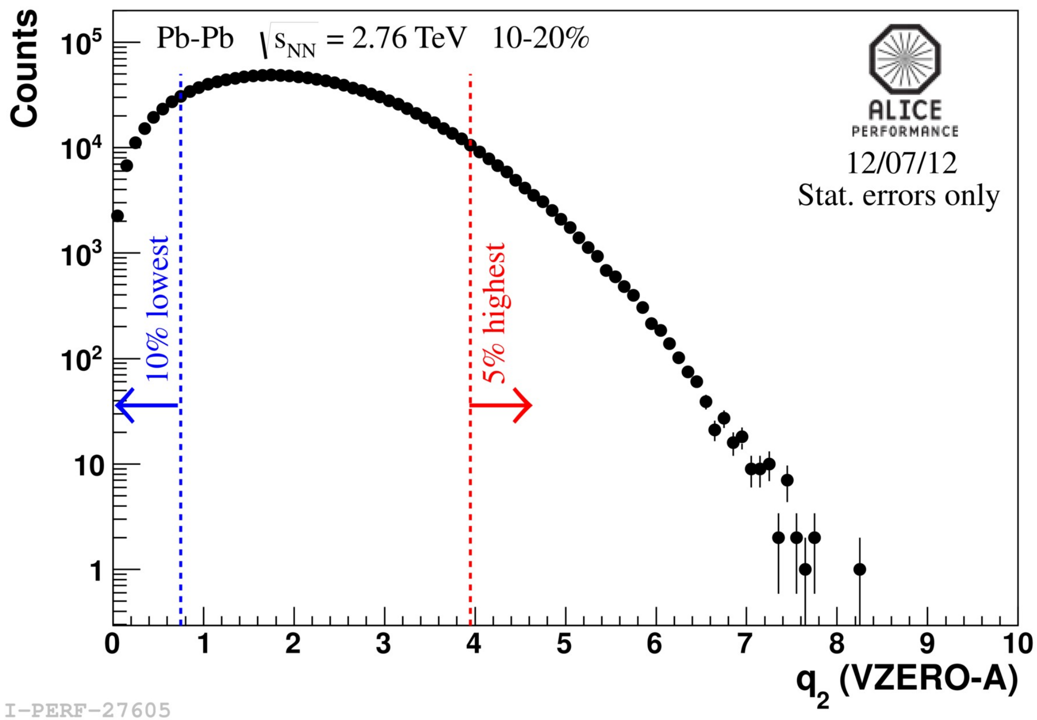
Examples

- HBT
- Resonances
- Jets
- …

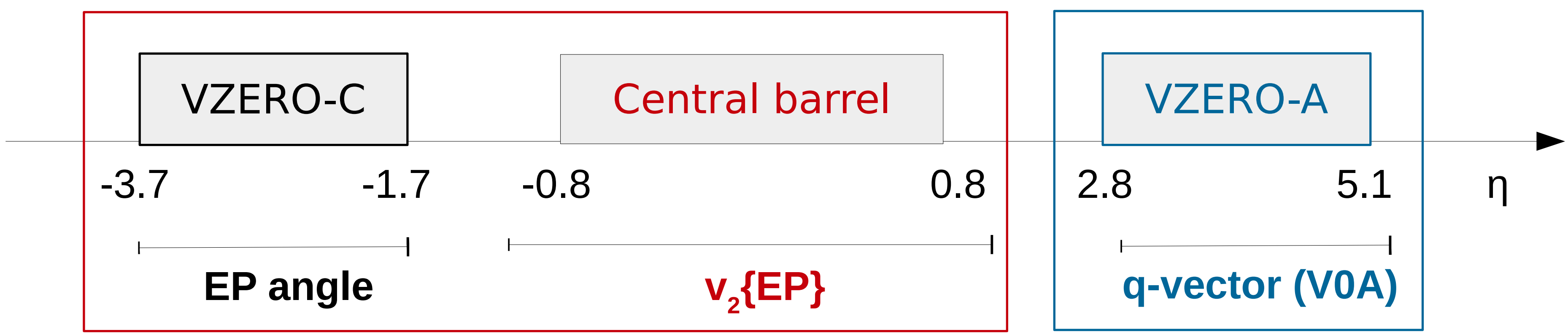


Large gap in pseudo-rapidity between sub-events suppresses correlations not related to the azimuthal asymmetry in the initial geometry

Elliptic flow with ESE: selection



- q-vector from VZERO-A ($2.8<\eta<5.1$)
- v_2 evaluated using tracks from TPC ($-0.8<\eta<0.8$) and event-plane from VZERO-C ($-3.7<\eta<-1.7$)
- Large $\Delta\eta$ separation between the three detectors → non-flow suppression



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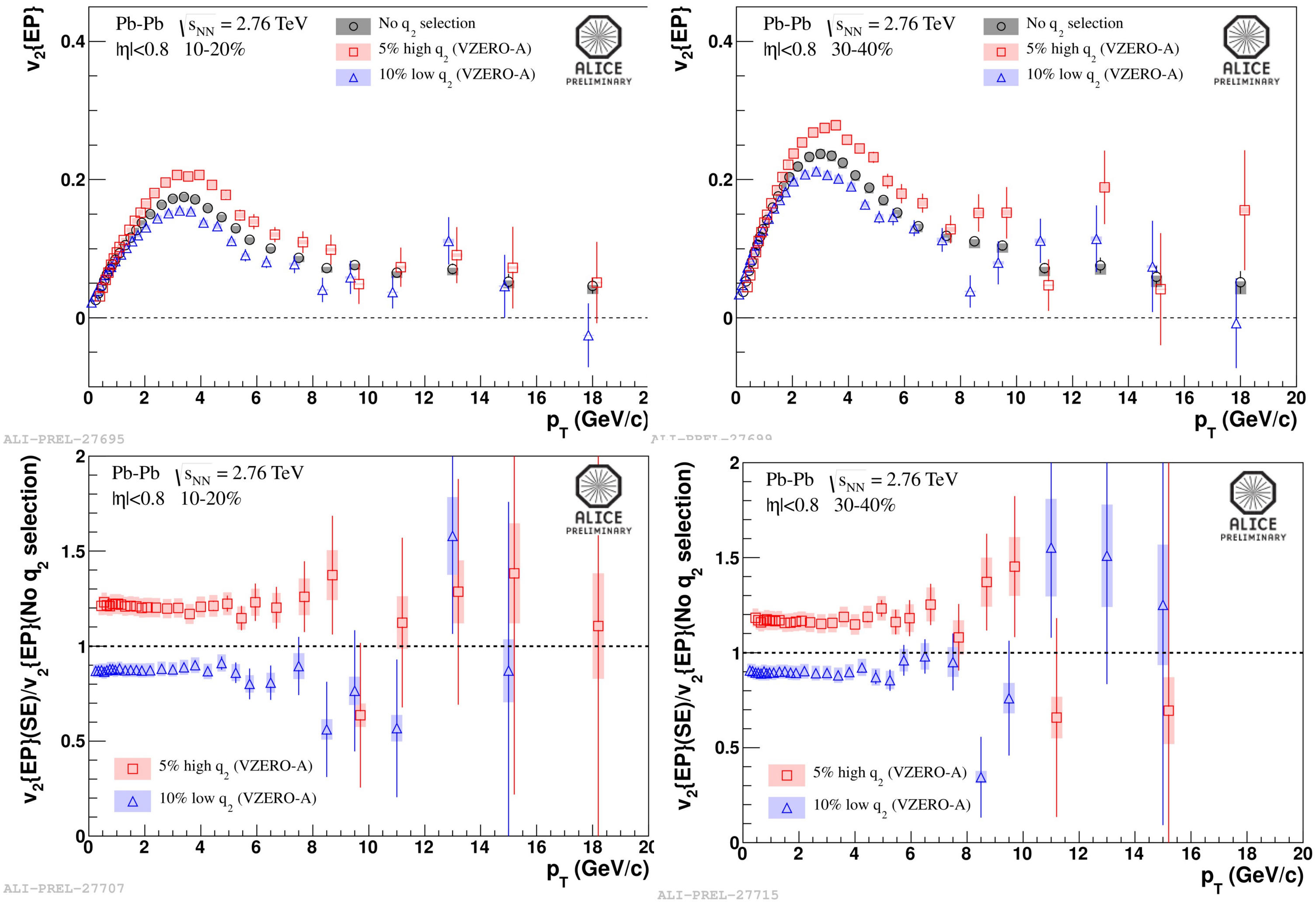


5% high q_2

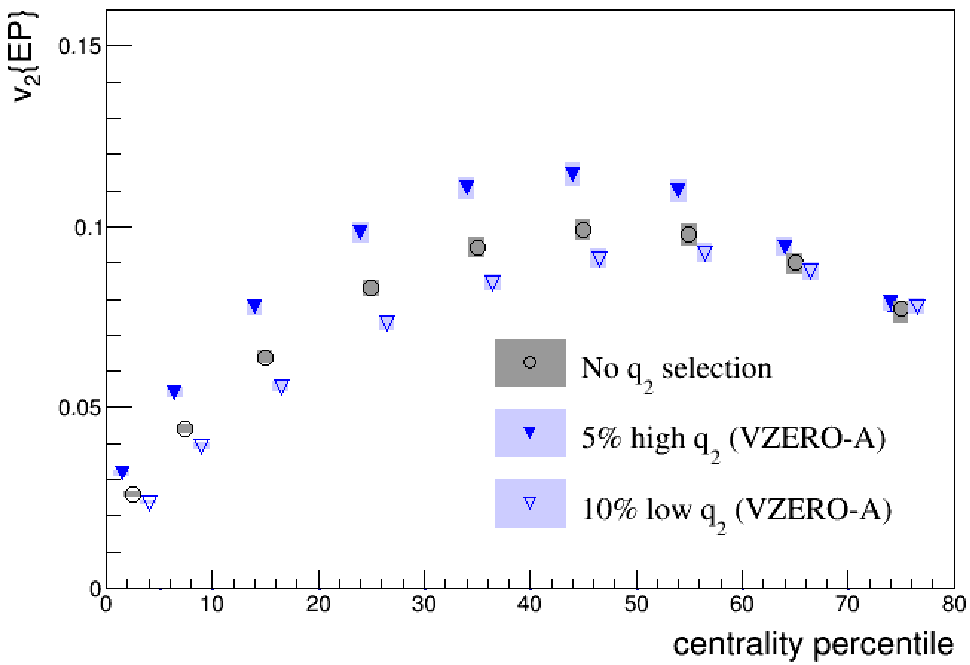
10% low q_2

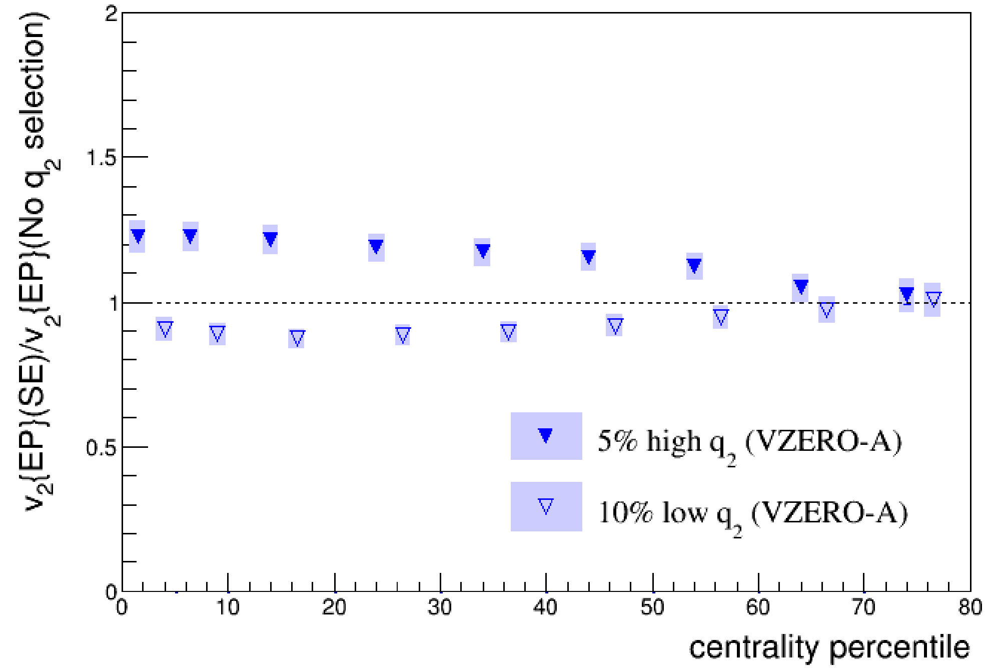
No q_2 selection

- q-vector from V0A (2.8<η<5.1)
- v_2 from TPC (-0.8<η<0.8)
- Event-plane from V0C (-3.7<η<-1.7)

- Event plane method used to evaluate v_2 (see backup)
- Ratios constant up to p_T = 6 Gev/c → similar flow fluctuations
- Smaller flow fluctuations effect for p_T > 6 Gev/c

Elliptic flow with ESE





- Integrated $v_2\{EP\}$ vs centrality percentile
- results for q_2 from VZERO-A (larger pseudo-rapidity gap)
- Method sensitivity to the event shape deteriorates for peripheral collisions

Spectra with ESE

Elliptic flow is related with the eccentricity of the collision: $v_2 \propto \epsilon_2$

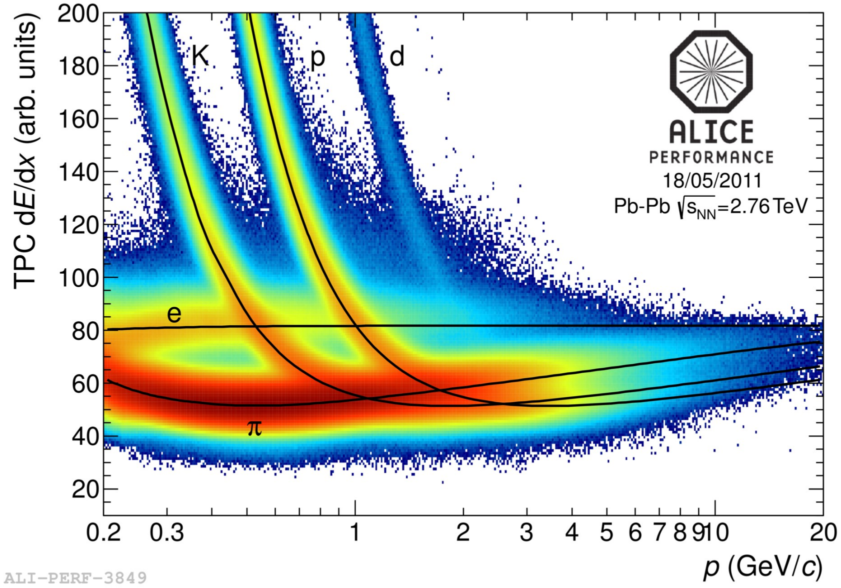
Understand connection between initial condition and hydro response

Event-shape selection: constraint initial condition (size and geometry of the collision fixed)

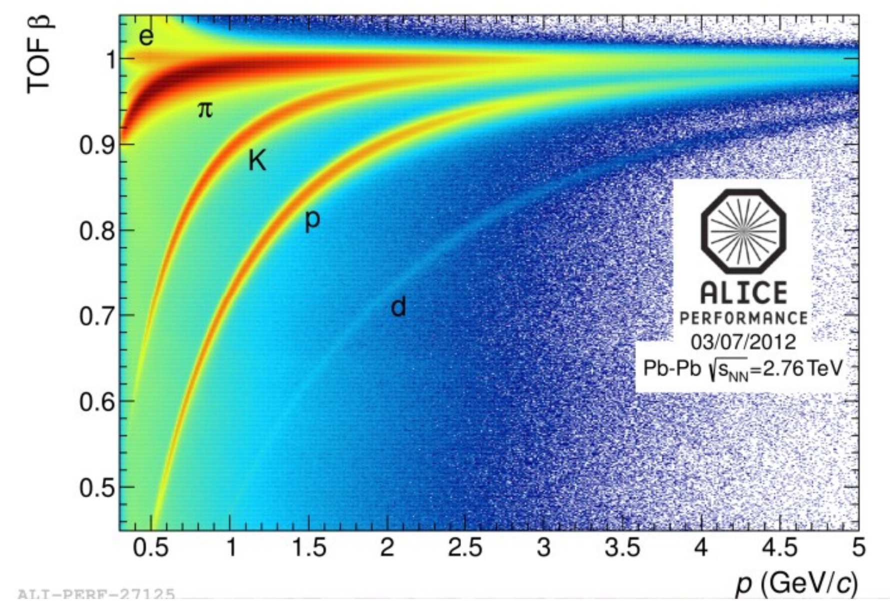
Analysis of transverse momentum spectra in event shaped event: correlation between radial and anisotropic flow?

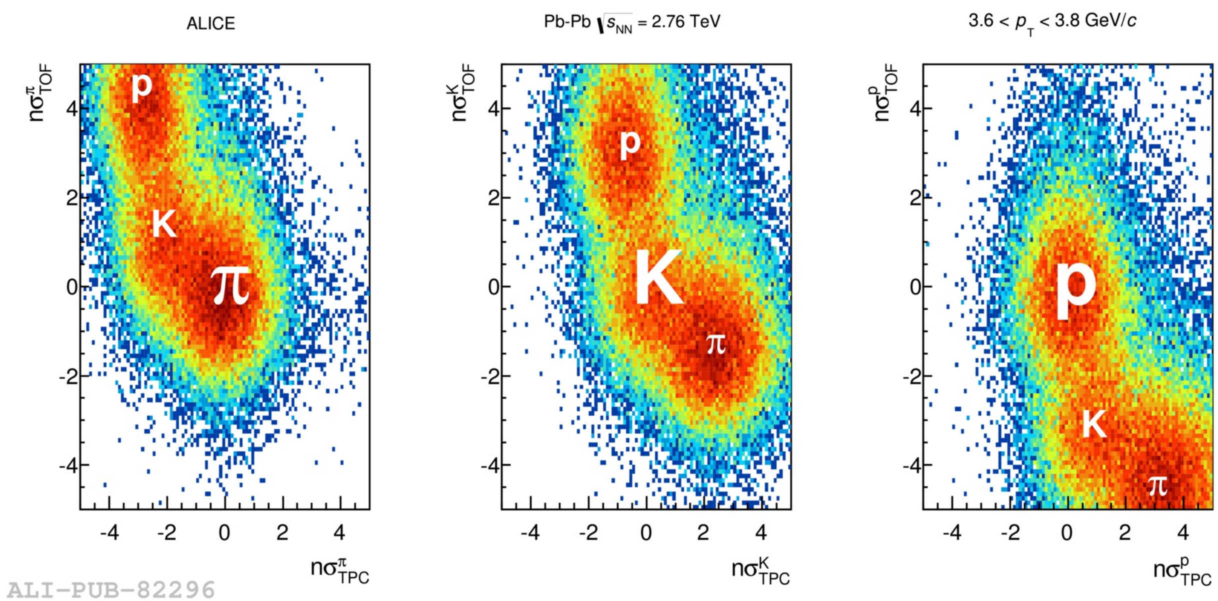
ALICE Particle IDentification

Time Projection Chamber



Time Of Flight



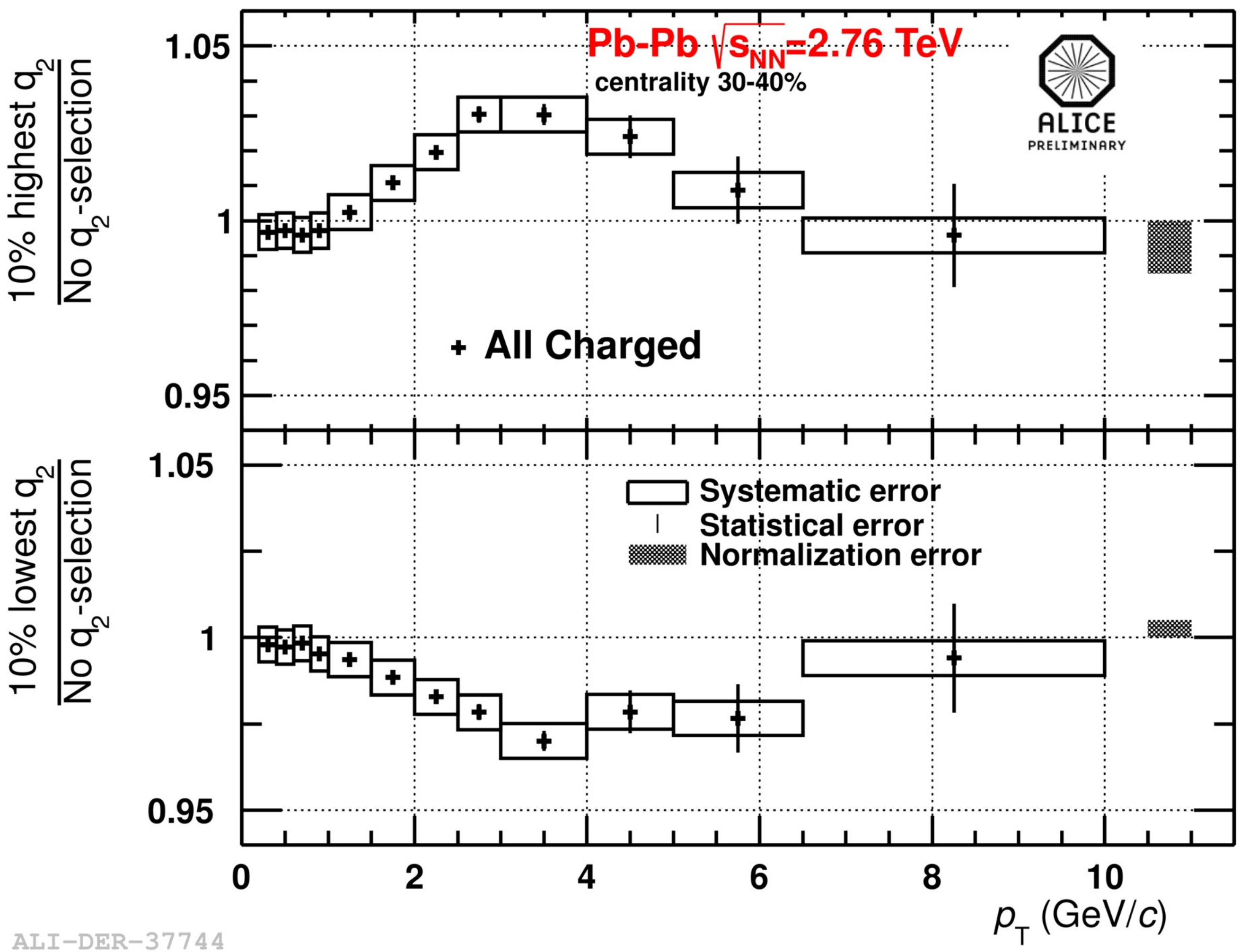


$$N^2_{\sigma,PID} = N^2_{\sigma,TPC} + N^2_{\sigma,TOF}$$

$$N^2_{\sigma,PID} < 3$$

$$N^2_{\sigma,PID} = N^2_{\sigma,TPC} \rightarrow p_T < 0.6 \text{ GeV/c}$$

Spectra with ESE



- Raw spectra used for the ratios: efficiency does not depend on q_2 selection
- Modification of the p_T-spectrum: large q_2 harder spectrum, opposite for small q_2
- Vanishing at high p_T: correlation related with hydrodynamics rather than with hard processes

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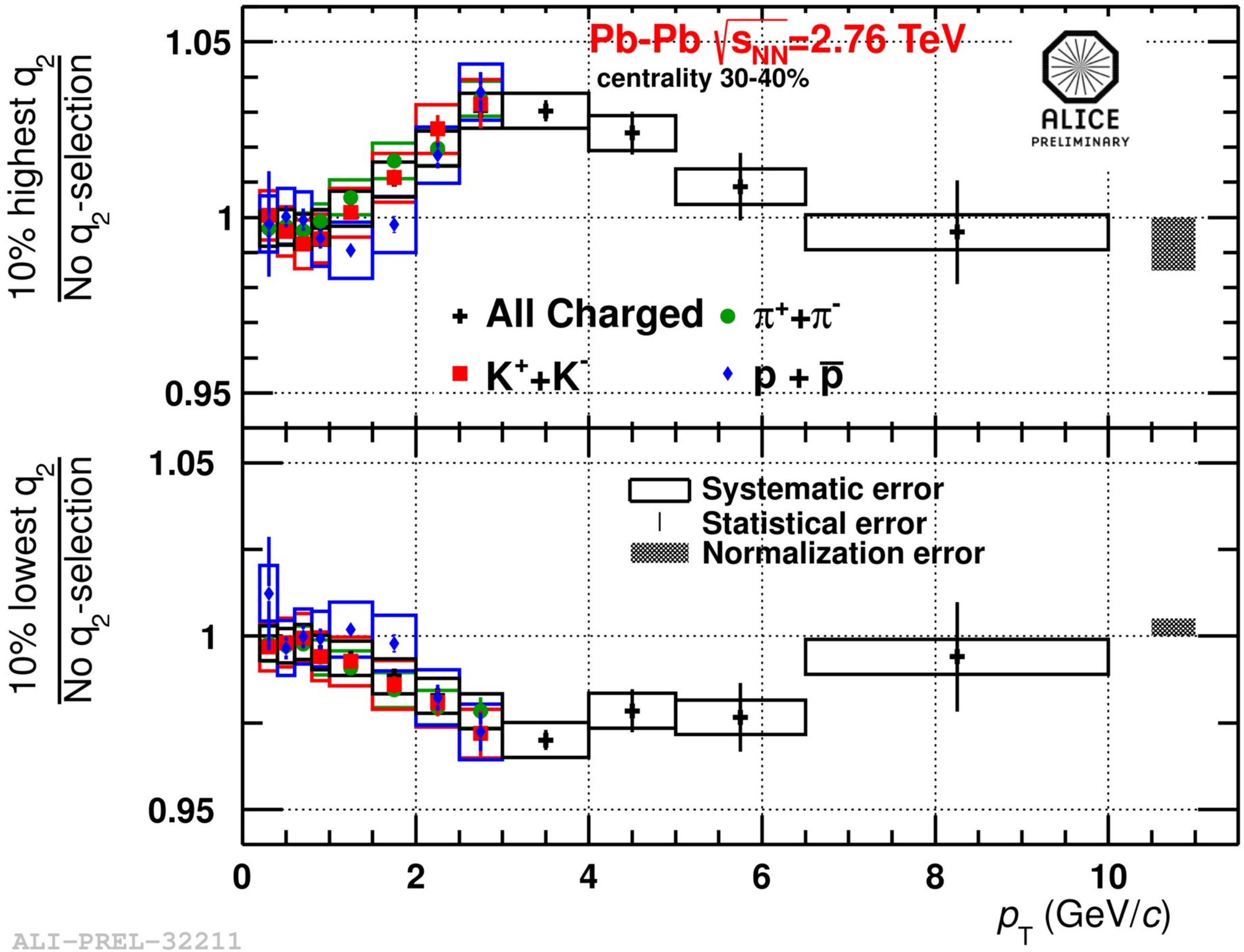

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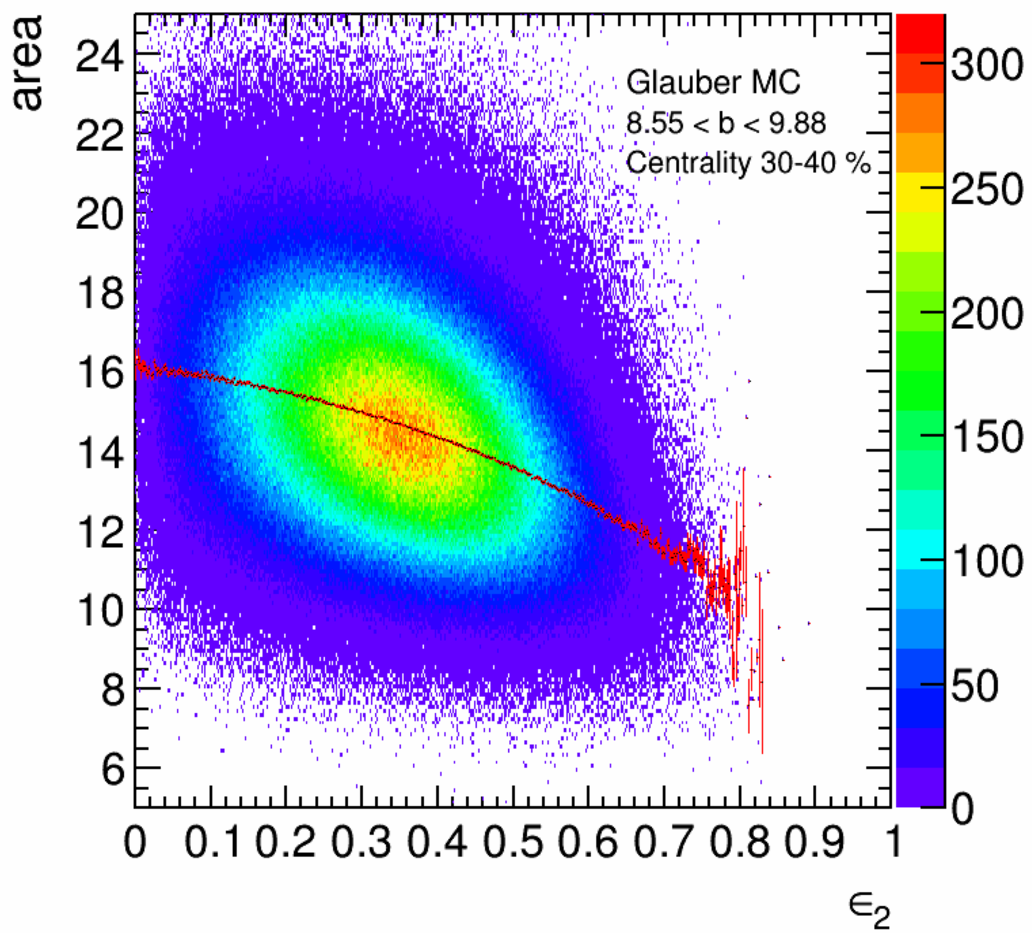
- same effect for all the particles
- hint of mass ordering?

Shape Fluctuation → Pressure Fluctuations (radial flow)?

Spectra ESE: Glauber MC



Effective area of the collision (wounded nucleons) vs eccentricity

Centrality 30-40 %

- Area and eccentricity are anti-correlated at fixed b_{imp} (centrality)
- Area inversely related to transverse density (N_{ch}/A): positive correlation between eccentricity and density.
- Large centrality bin → contribution of different size of the system

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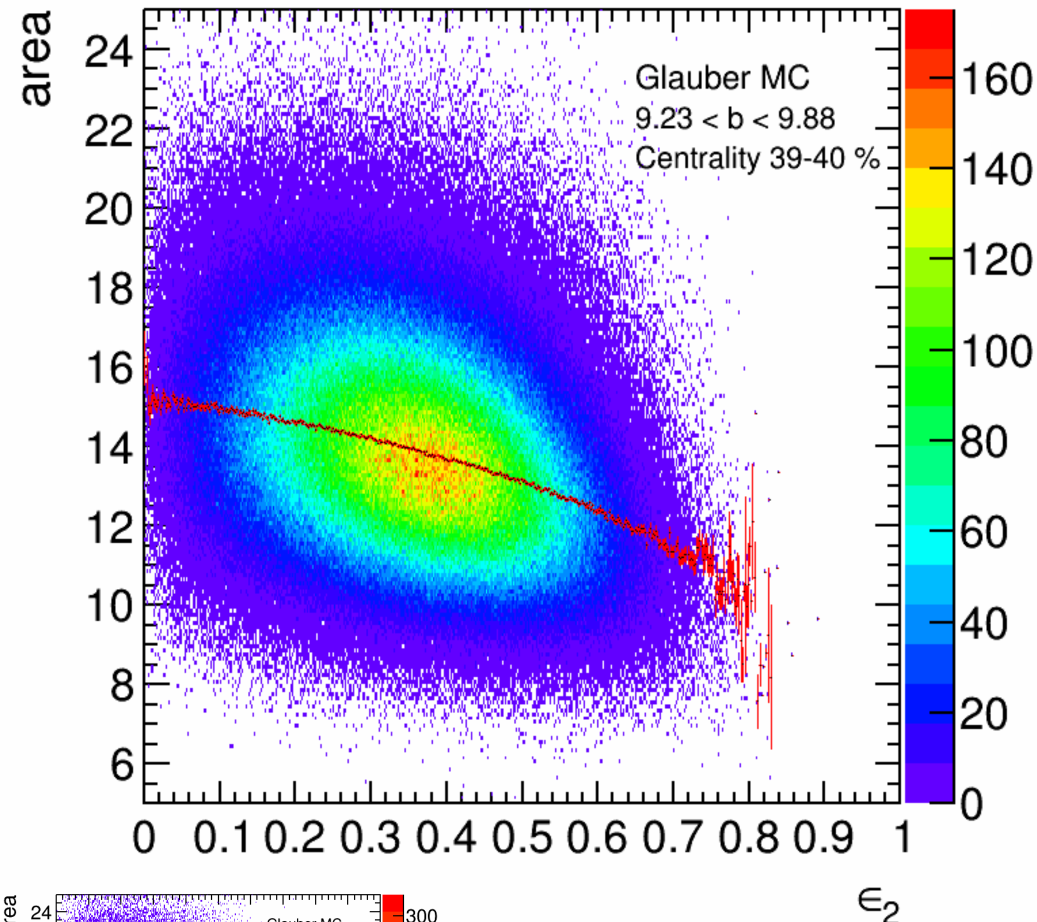

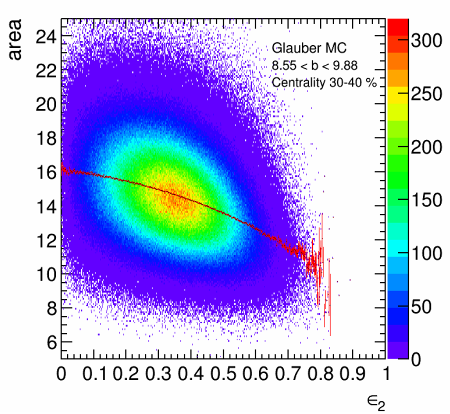

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- Correlation still present

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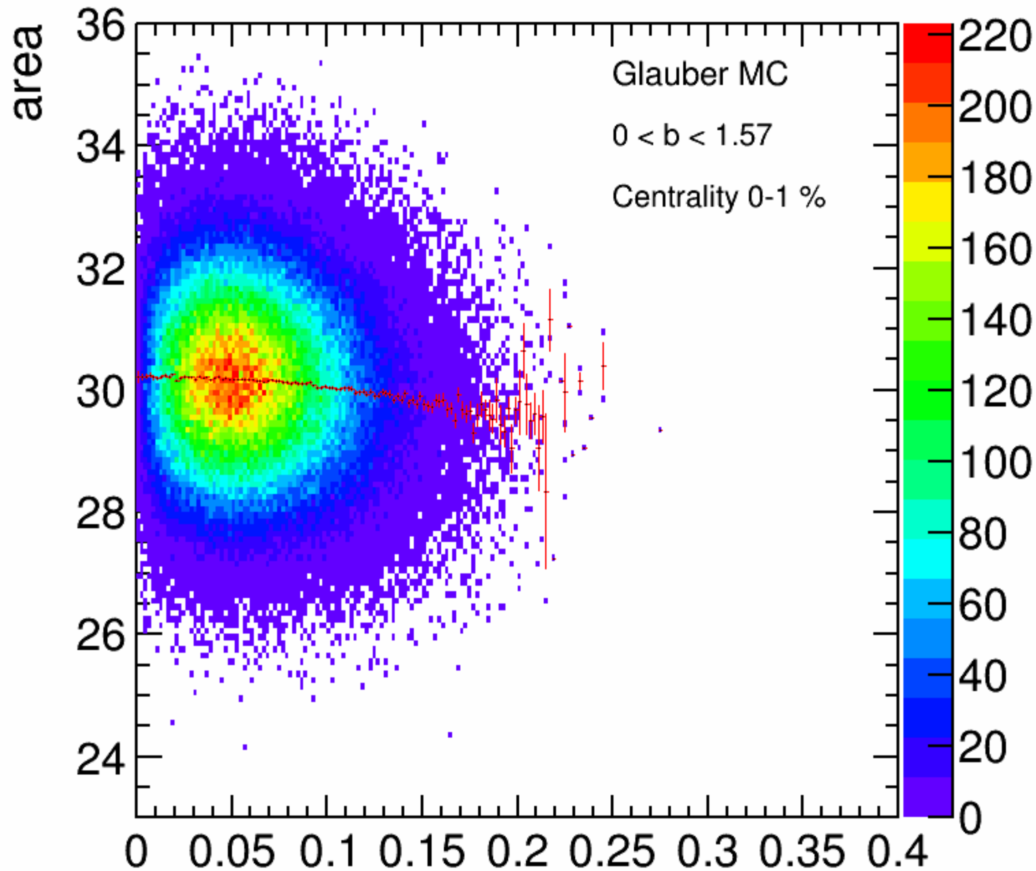

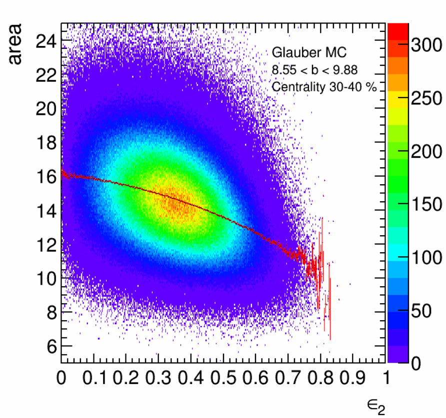

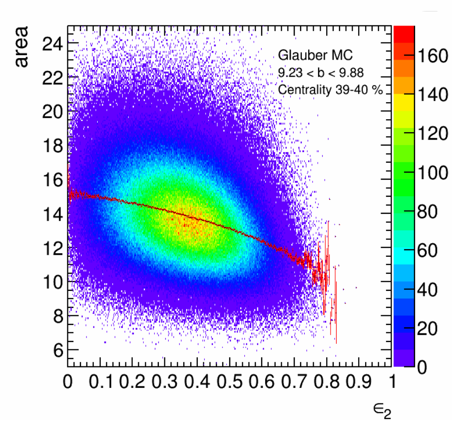

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<u>Centrality 39-40 %</u>

- Correlation still present

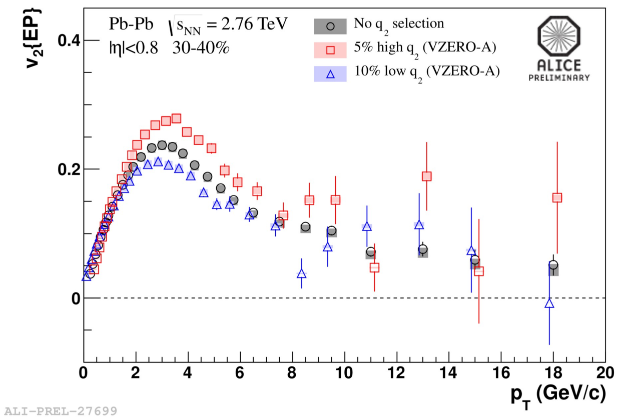
<u>Centrality 0-1 %</u>

- Weaker correlation between area and eccentricity

Summary and outlook

Summary

- q-vector allows the selection of events with larger or smaller elliptic flow than the average
- Event shape selection is sensitive to the pseudo-rapidity range used to evaluate the q-vector



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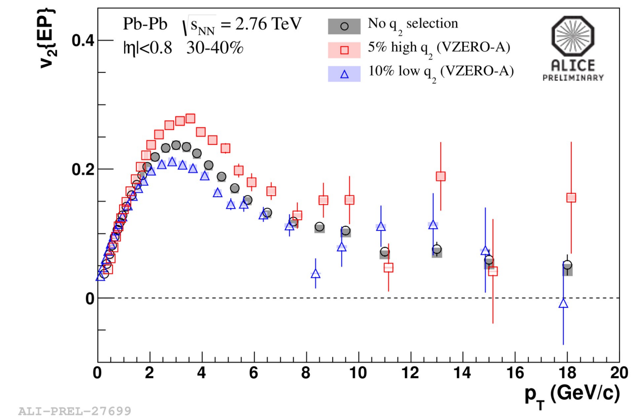
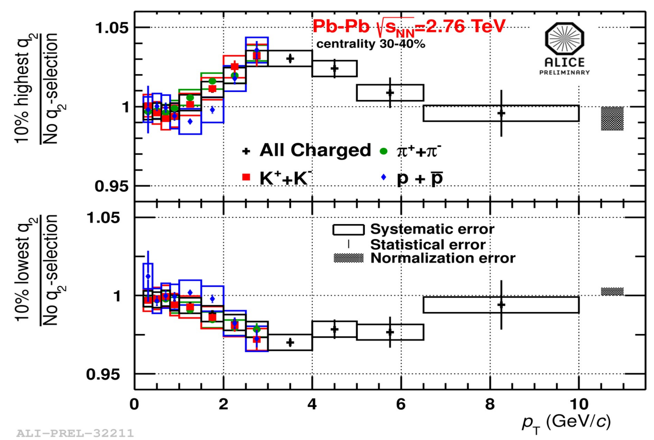
- Modification of the p_T spectrum in semi-central (30-40%) in the intermediate p_T region (from ~1 up to ~5 GeV/c) is observed.
- Hint of mass ordering in the region between ~1 up to ~3 GeV/c.





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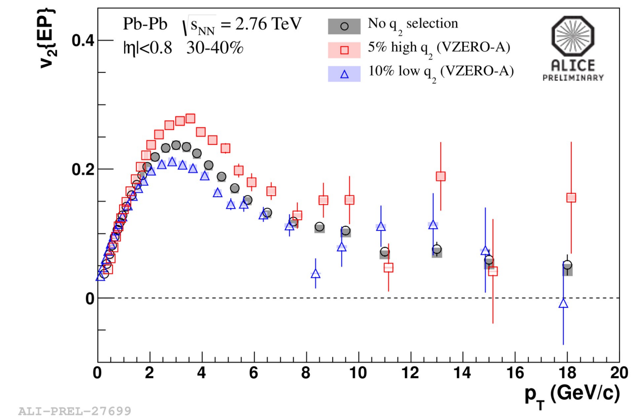
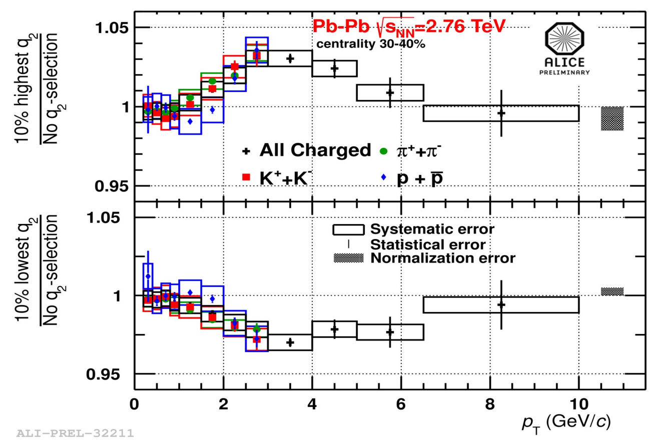




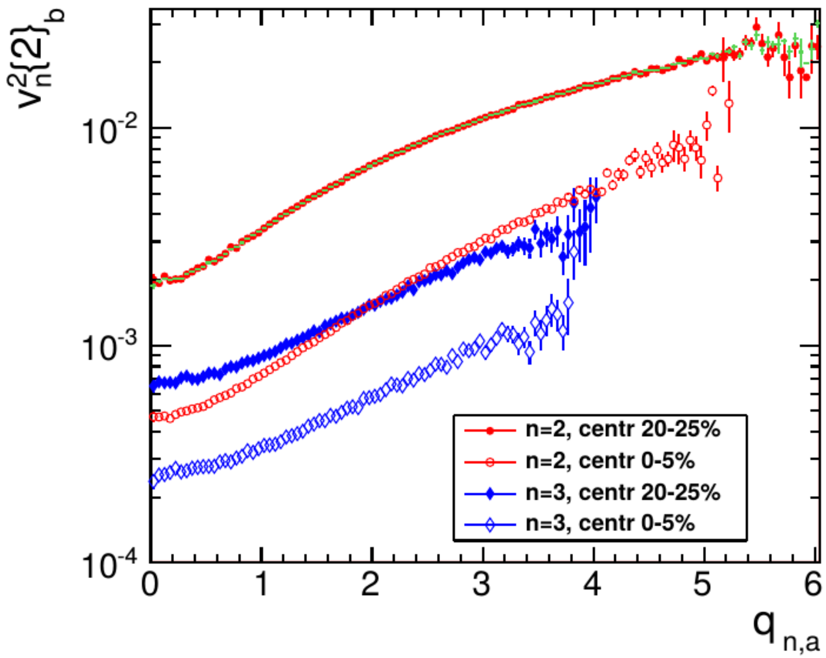
Analysis outlook

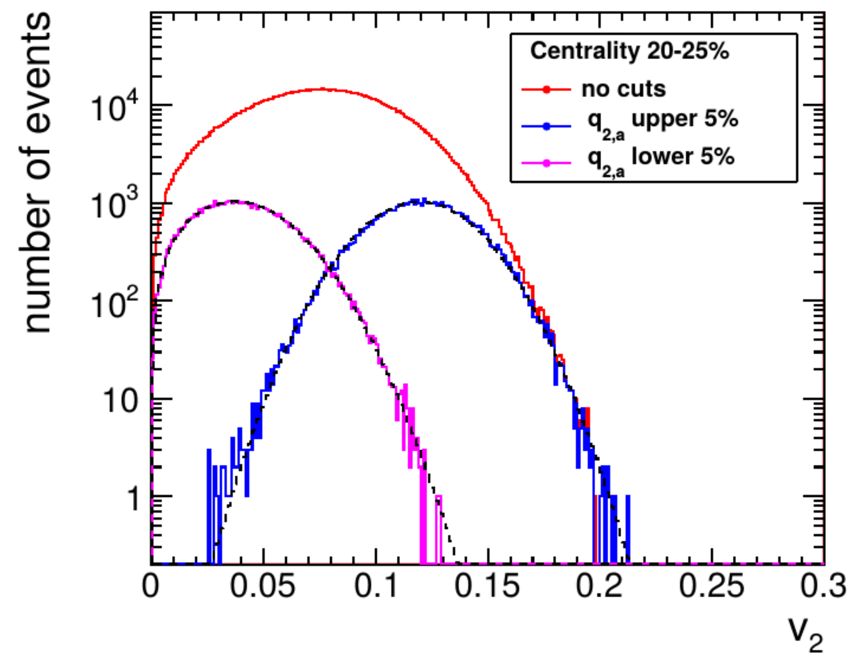
- q-vector calibration improvement
- Reduced systematic errors
- Extended PID range

Backup

ESE in MC

Schukraft et al, Phys.Lett. B719 (2013) 394-398



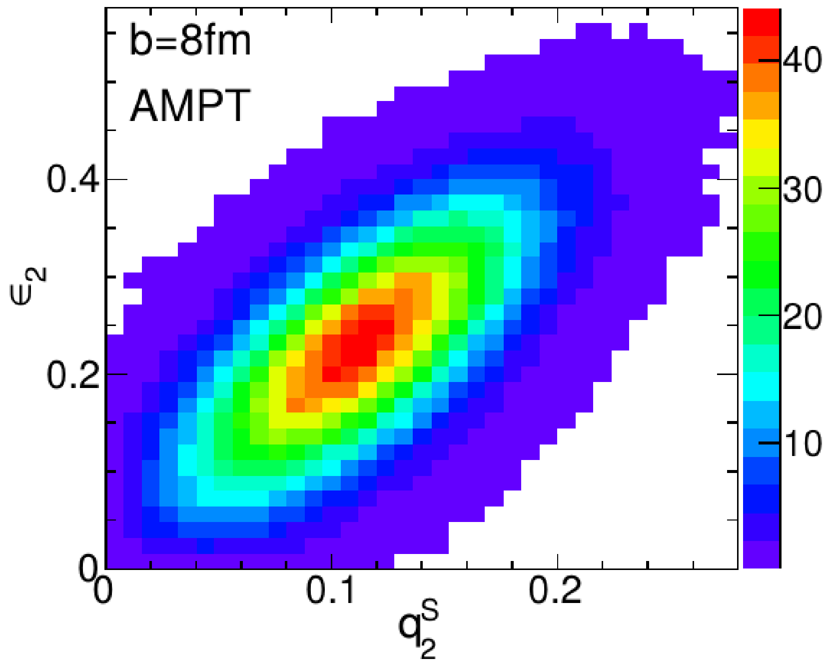


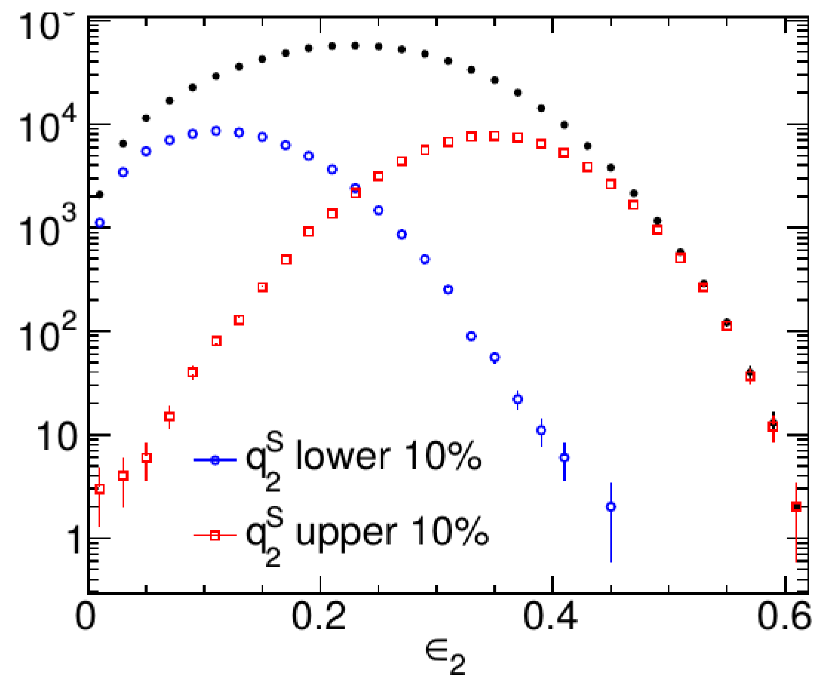
Simulation based on MC Glauber

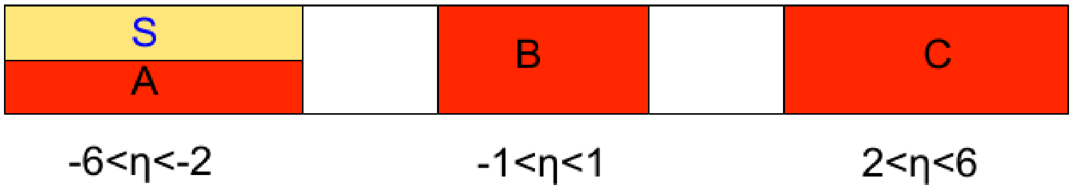
- q-vector evaluated in sub-event a, v_n^2 measured in sub-event b
- Multiplicity corresponding to Δη = 0.8 in Pb-Pb collisions at LHC
- Large q_2 → larger v_2

ESE in MC

Huo et al, Phys.Rev. C90 (2014) 024910





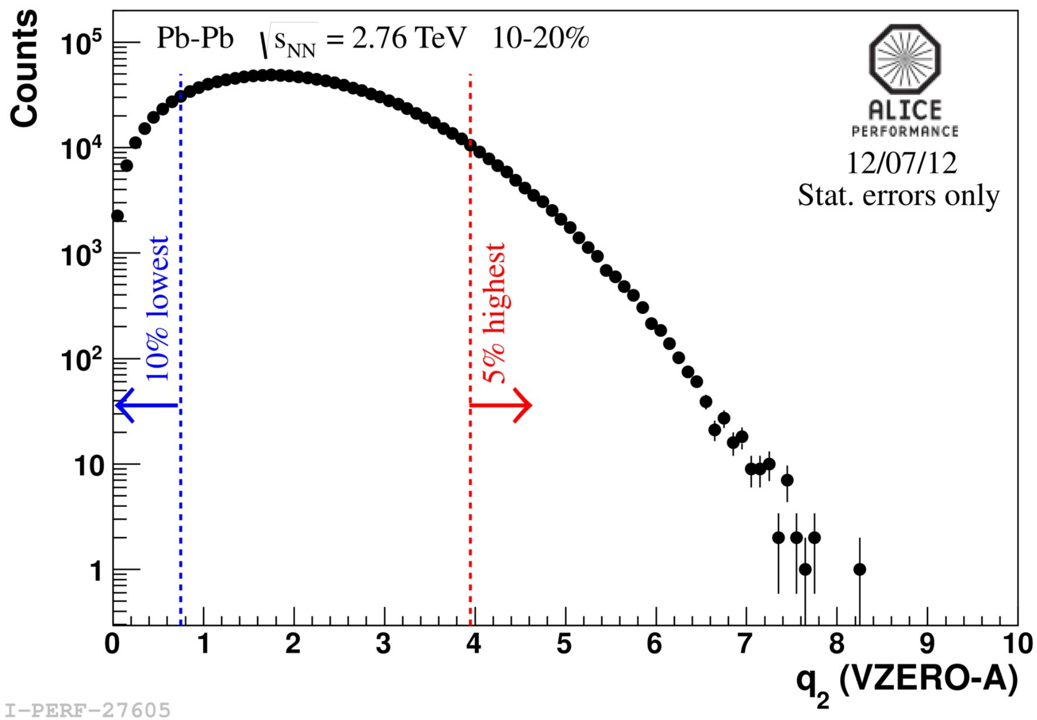


- Strong positive correlation between eccentricity and q-vector.
- $<\varepsilon_2>$ value is higher in 10% large q2 sample.
- The shape of the initial geometry can be selected using the q-vector in the final state.

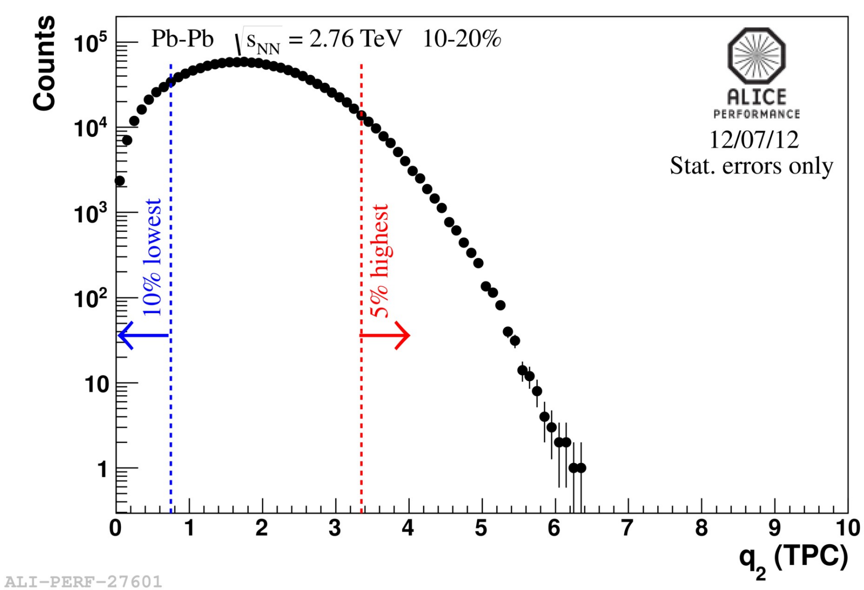
Event plane method

- Flow vectors calculation: $Q_{n,x} = \sum_i w_i \cos(n\phi_i)$ $\quad Q_{n,y} = \sum_i w_i \sin(n\phi_i)$
- Event plane angle calculation: $\psi_n = \left(\tan^{-1} \frac{\sum_i w_i \sin(n\phi_i)}{\sum_i w_i \cos(n\phi_i)} \right) / n$
- Flow coefficients: $v_n^{obs} = \langle \cos[n(\phi_i - \psi_n)] \rangle$
- Event plane resolution correction: $v_n = v_n^{obs} / R_n$ $\quad R_n = \langle \cos(n(\psi_n - \Psi_n)) \rangle$

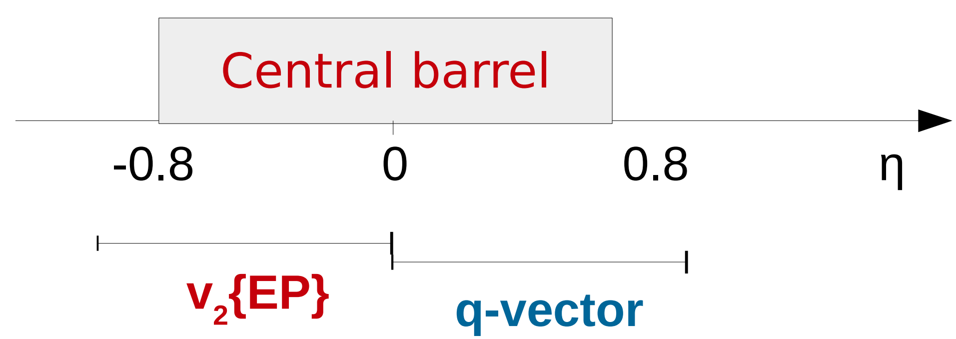
Elliptic flow with ESE: selection



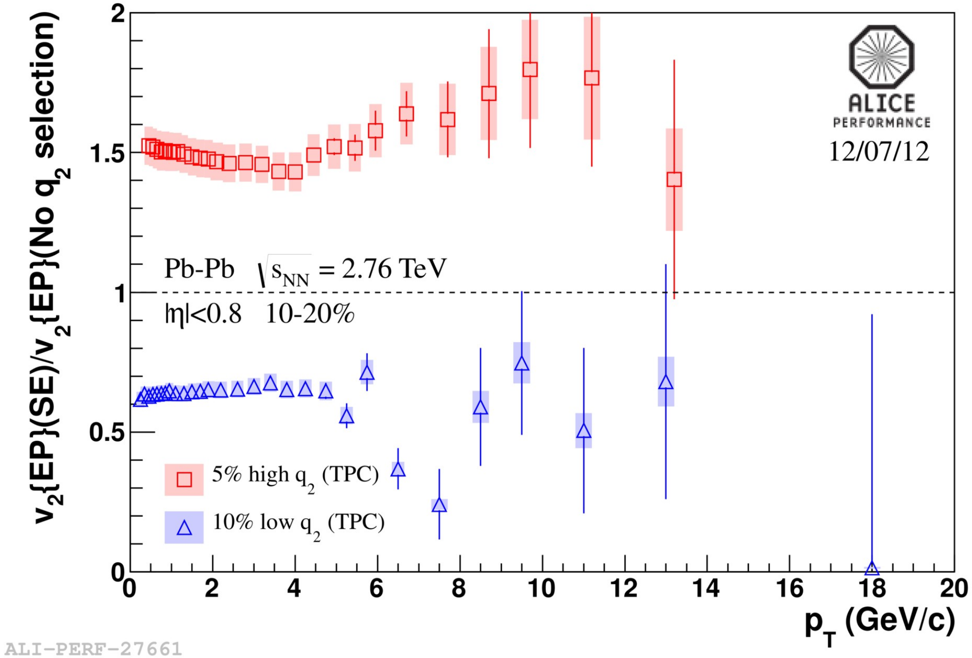
- q-vector from VZERO-A (2.8<η<5.1)
- v_2 evaluated using tracks from TPC (-0.8<η<0.8) and event-plane from VZERO-C (-3.7<η<-1.7)
- Large Δη separation between the three detectors → non-flow suppresion

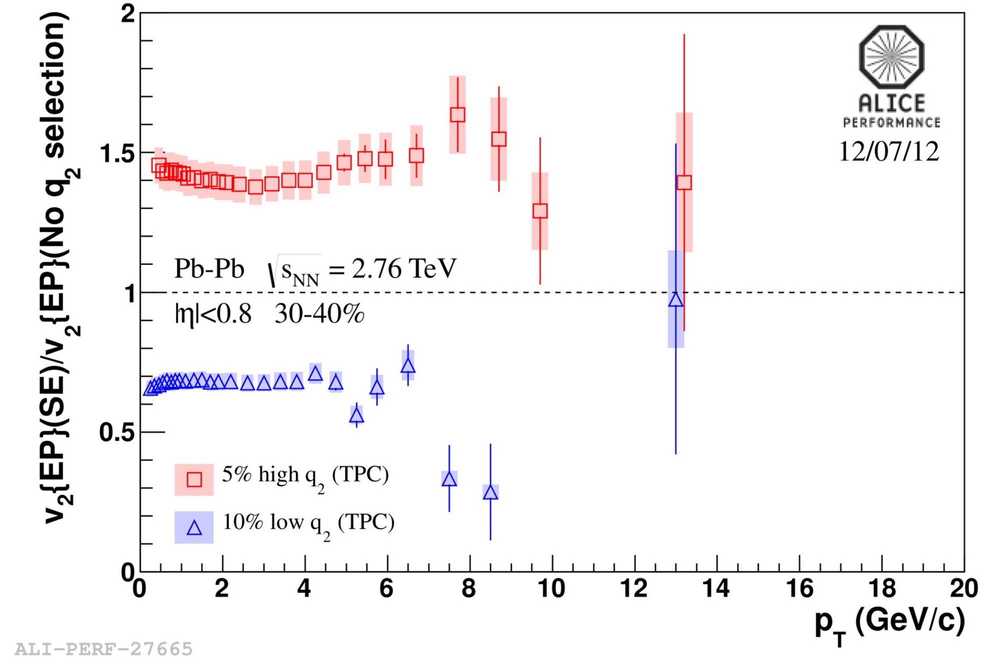


- q-vector from TPC (-0.8<η<0 or 0<η<0.8) and v_2 from the other TPC η window



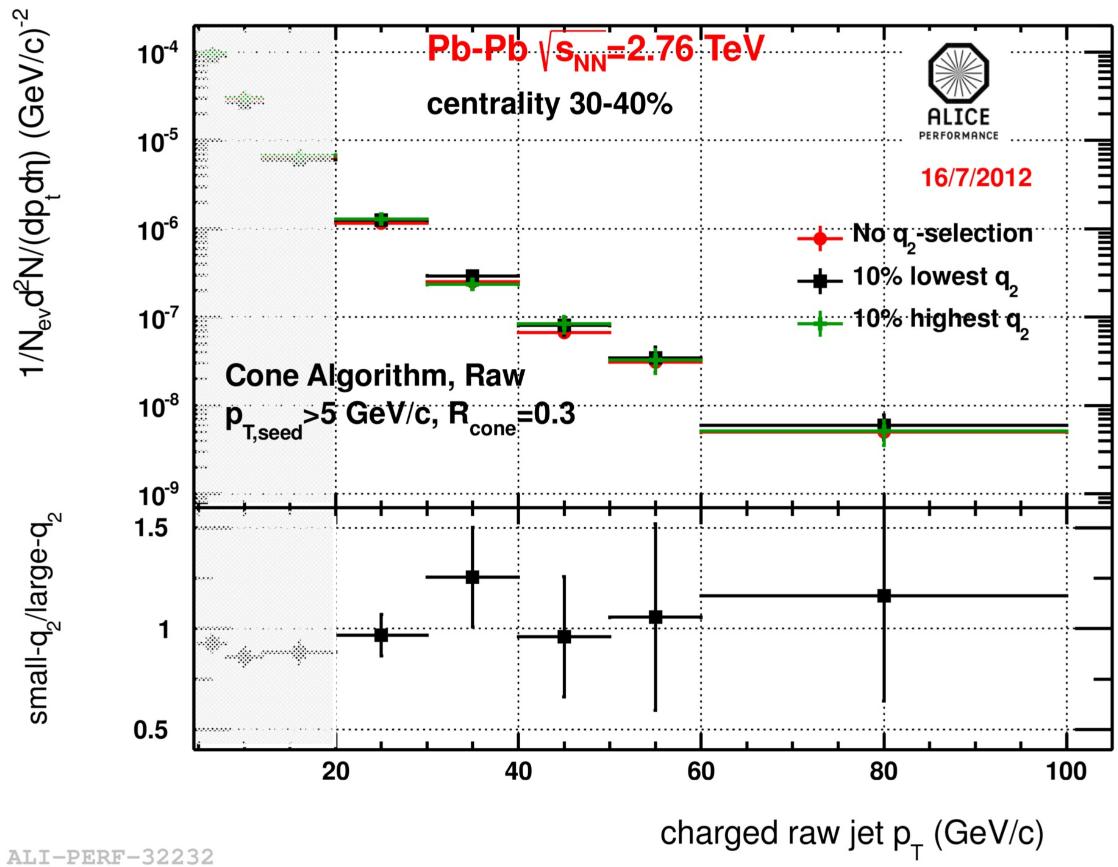
Elliptic flow with ESE





- q_2 from half TPC: -0.8<η<0 or 0<η<0.8
- v_2 evaluated using tracks from the other half of TPC (-0.8<η<0.8) and event-plane from VZERO
- Non flat ratios may be due to non-flow contributions

Spectra with ESE



Jet contamination

Background

- $P_{T,tot}$ = total pT in the event
- density = $p_{T,tot}$ / acceptance

Energy in a cone

- seed particle: (p_T>5GeV/c)
- $p_{T,sum}$ = sum of p_T in R<0.3
- area=$\pi \cdot R^2$
- $p_{T,jet}$= $p_{T,sum}$ - (density · area)

- method reliable only above ~20 GeV/c
- ratio is flat, “jet” contribution similar