Search for Chiral Magnetic Wave (CMW) with ALICE at the LHC

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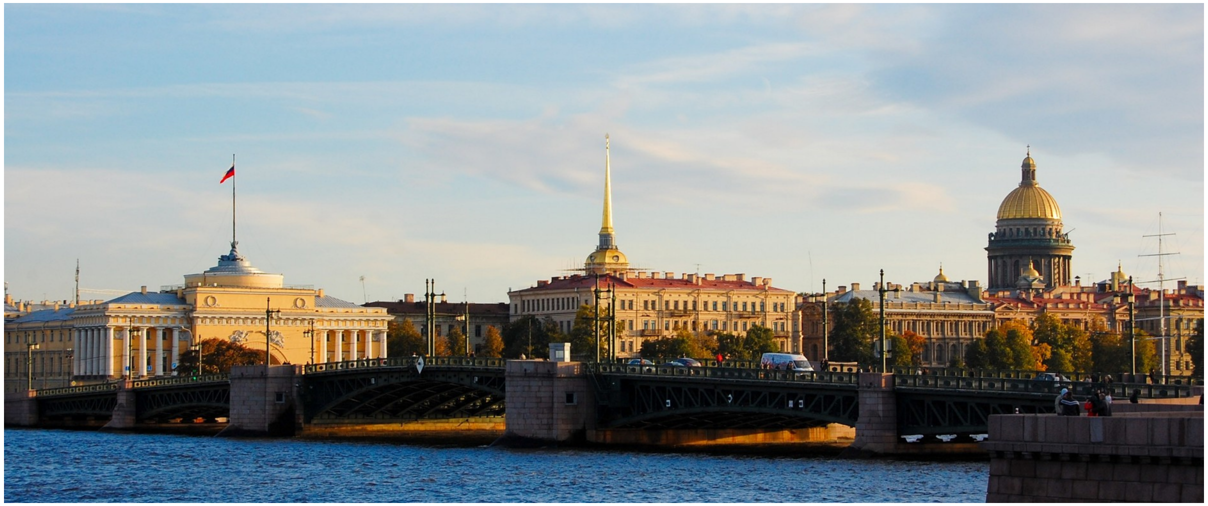
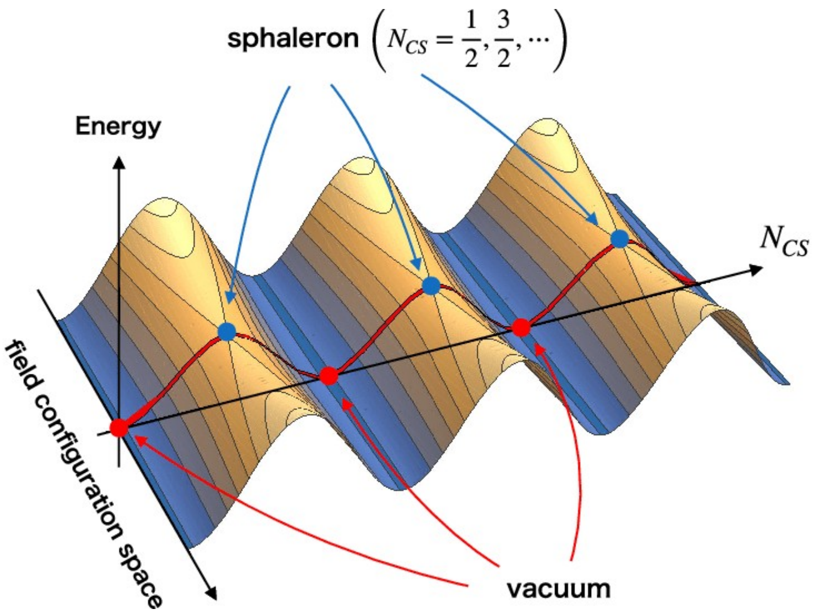
Outline:

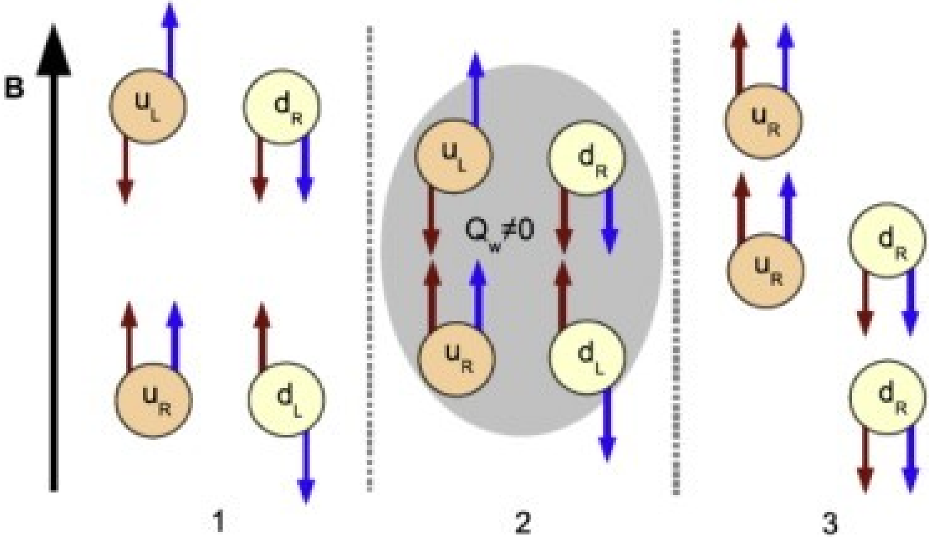
- Motivation
- Experimental observable
- ALICE detectors
- Analysed data, event and track cuts
- Results
- Summary and outlook

LXXI International Conference NUCLEUS – 2021



Motivation





- QCD vacuum: degenerate
- Generates chirality imbalance:

$$N_L^f - N_R^f = 2Q_W$$

- Axial and vector currents
- Induces **parity odd domains**

Chiral Magnetic Effect (CME): $j_V = \frac{N_c e}{2\pi^2}\mu_A B$

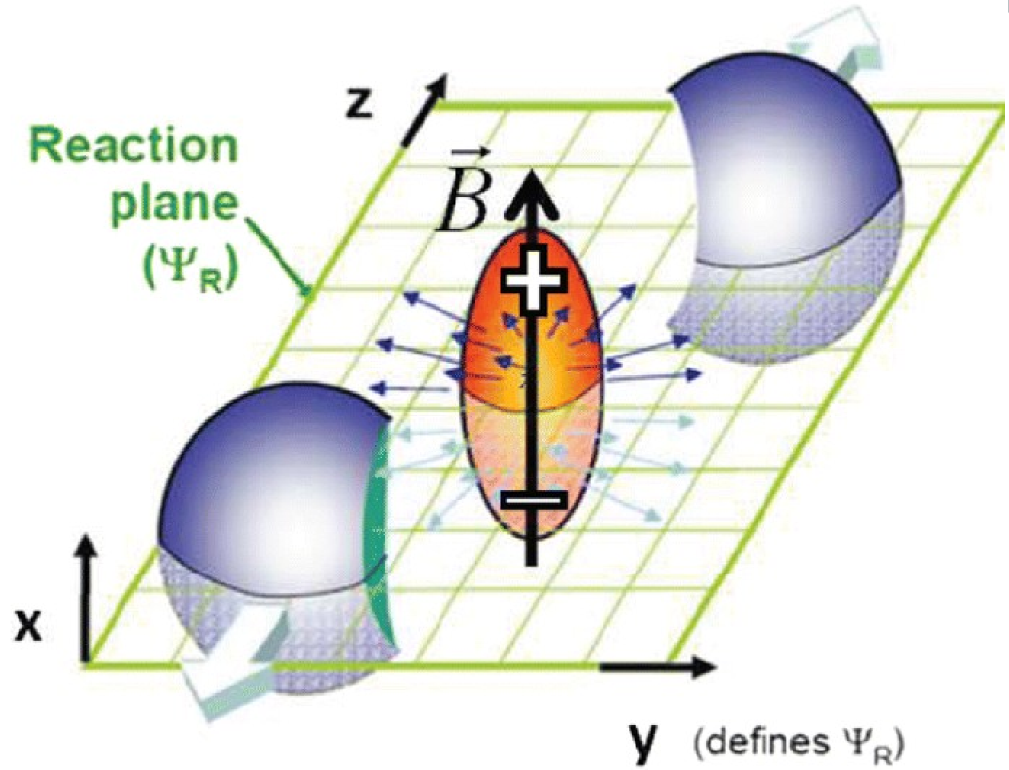
Chiral Separation Effect (CSE): $j_A = \frac{N_c e}{2\pi^2}\mu_V B$

Chiral Magnetic Wave: CME + CSE

[1] Phys.Rev.Lett. 81 (1998) 512-515
[2] Phys.Rev.D. 101 (2020) 096014

Heavy-ion collisions

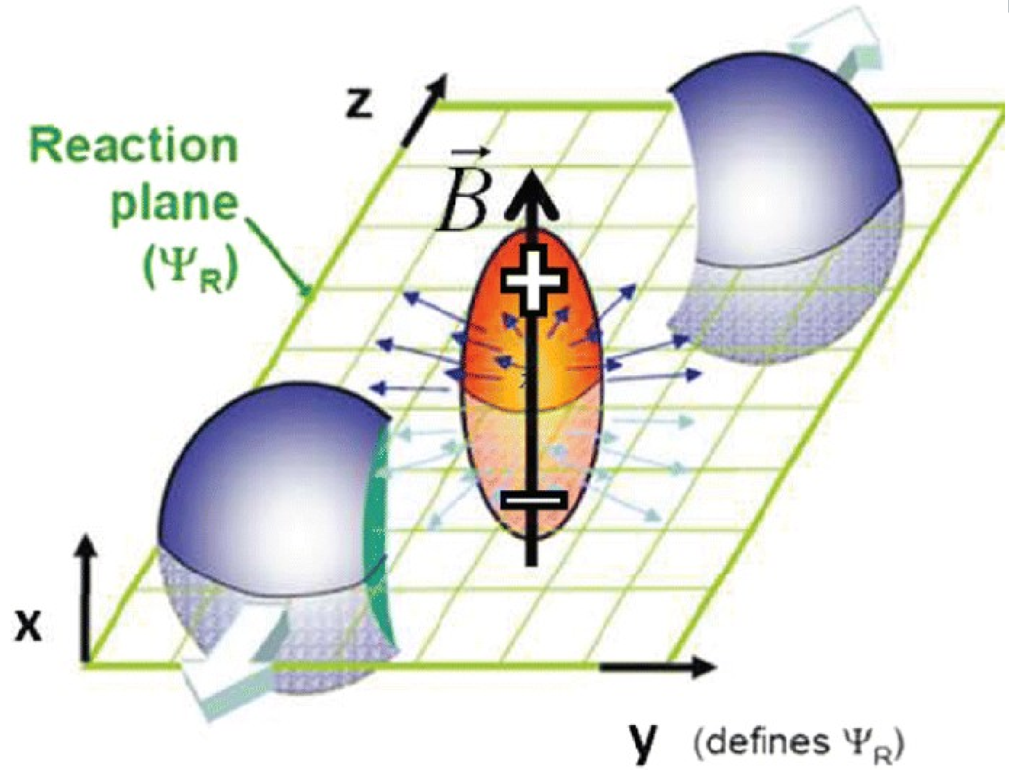
- ☞ Chiral symmetry restoration



Phys.Rev.Lett. 81 (1998) 512-515

Heavy-ion collisions

- ☞ Chiral symmetry restoration
- ☞ Deconfinement



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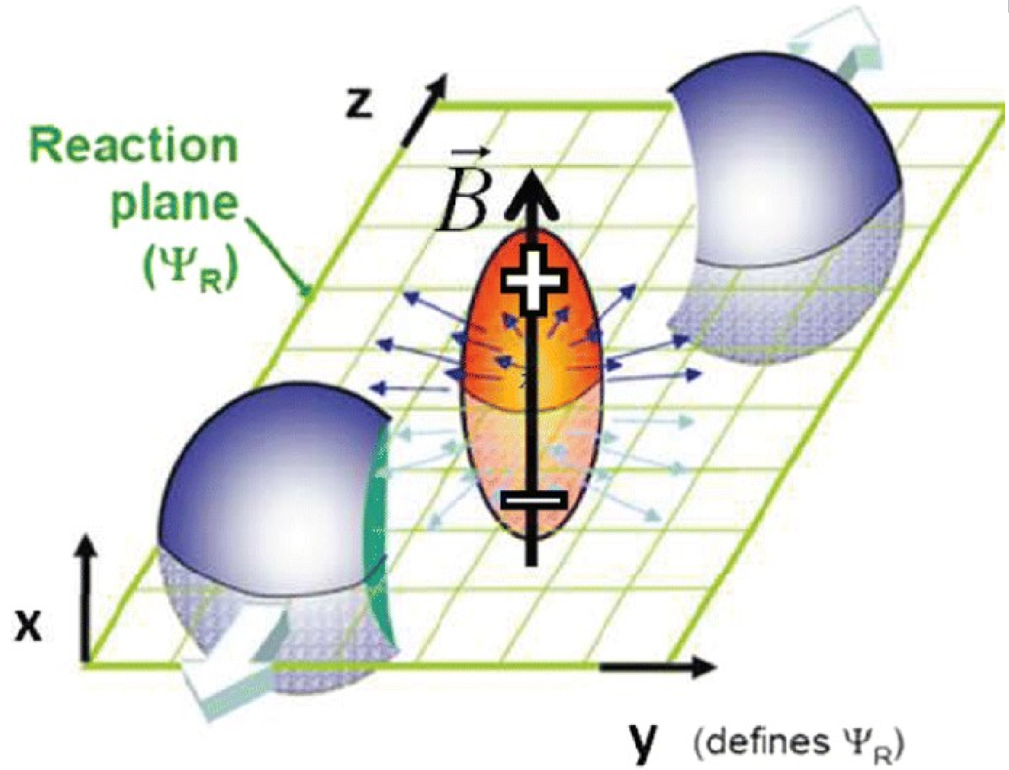
Heavy-ion collisions

- ☞ Chiral symmetry restoration
- ☞ Deconfinement
- ☞ QCD vacuum transitions



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Heavy-ion collisions

- ☞ Chiral symmetry restoration
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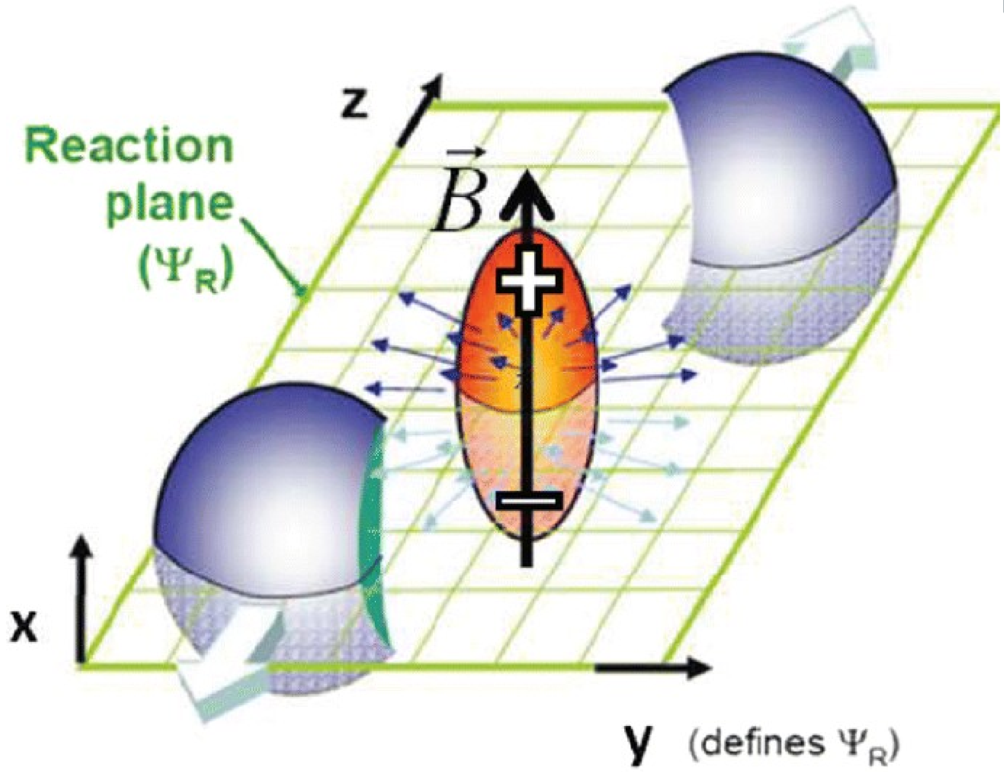
- ☞ Extremely strong magnetic field (~10^{15} T)



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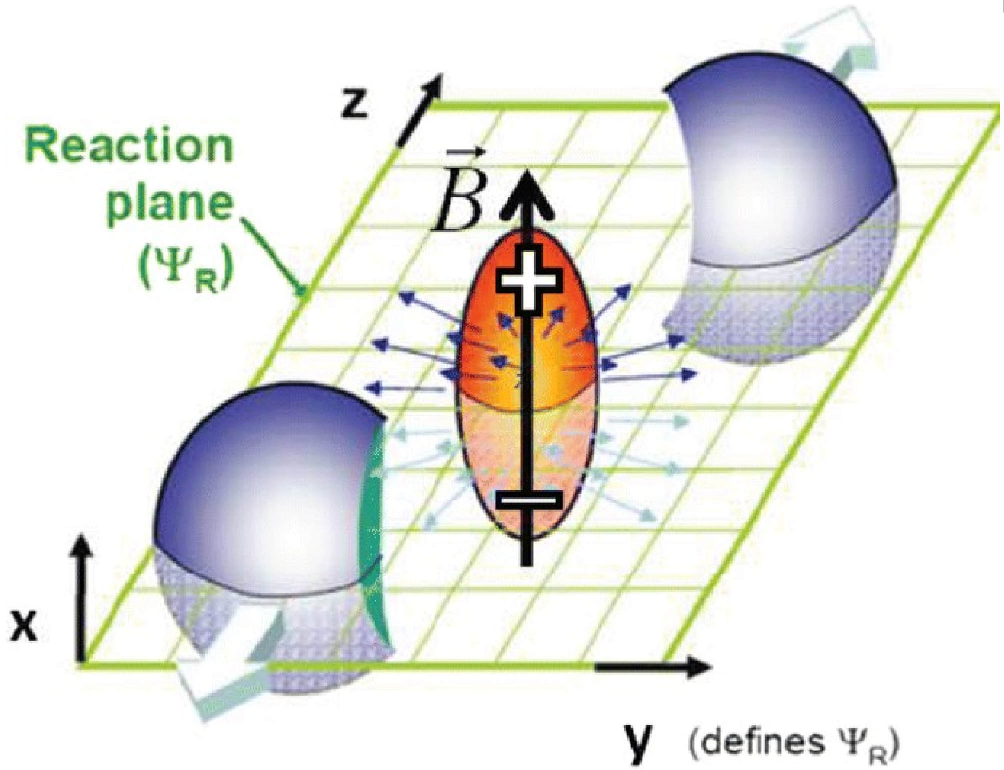
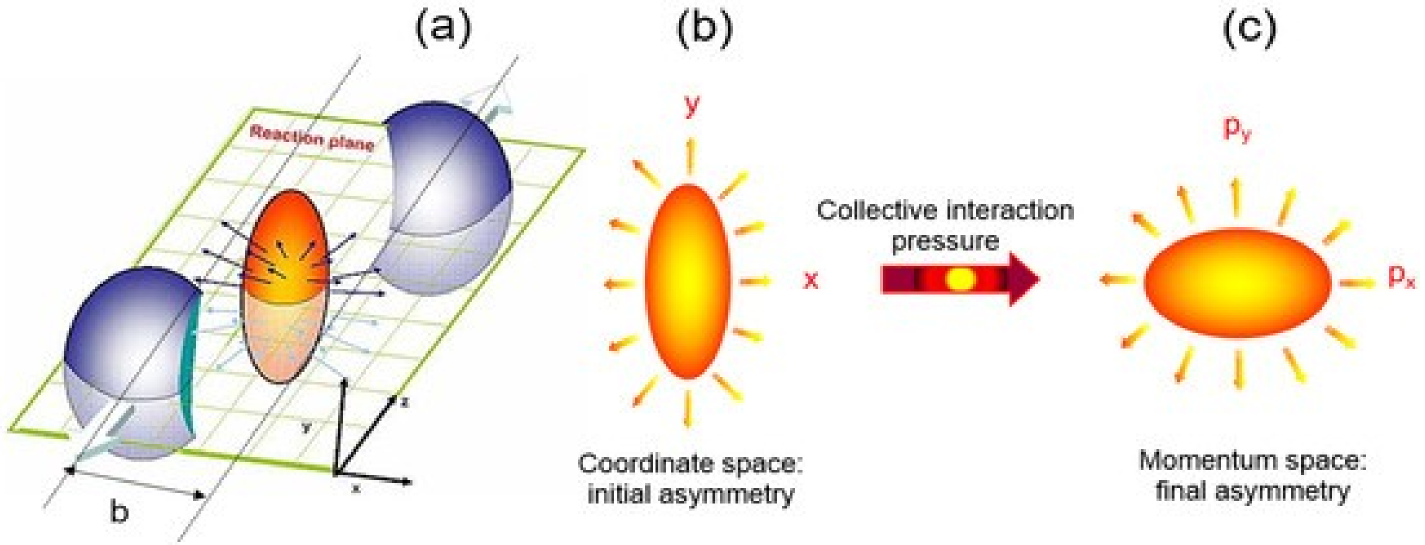


All the necessary conditions are possible to be achieved in heavy-ion collisions

Phys.Rev.Lett. 81 (1998) 512-515

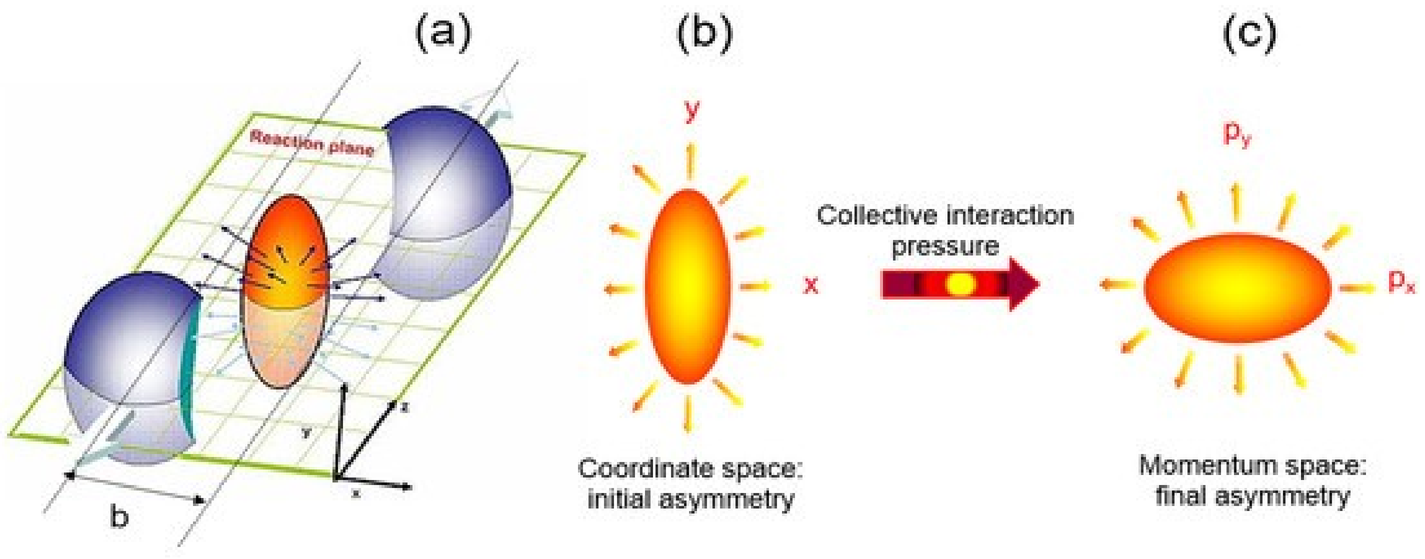
Anisotropic flow



☞ Spatial anisotropy ⟶ momentum anisotropy

Phys.Rev.D 48 (1993) 1132-1139

Anisotropic flow



- Spatial anisotropy → momentum anisotropy
- Characterised by:

$$E\frac{d^3N}{d^3p}=\frac{d^2N}{2\pi p_T dp_T dy}\left(1+\Sigma 2 v_n \cos\left[n\left(\varphi-\Psi_{n,R}\right)\right]\right)$$

Fourier coefficients

Phys.Rev.D 48 (1993) 1132-1139

Observables

☞ Charge dependent elliptic flow

$$v_2^{h^\pm} = v_2 \mp r \frac{A_{ch}}{2} \qquad A_{ch} = \frac{N^+ - N^-}{N^+ + N^-}$$ [1],

☞ **CMW observable**: $r^{Norm}_{\Delta v_2} = \frac{d\left(\frac{\Delta v_2}{\langle v_2 \rangle}\right)}{d\,A_{ch}}$

Normalised slope ,

$$\Delta v_2 = v_2^{h^-} - v_2^{h^+} \qquad \langle v_2 \rangle = \frac{v_2^{h^-} + v_2^{h^+}}{2}$$

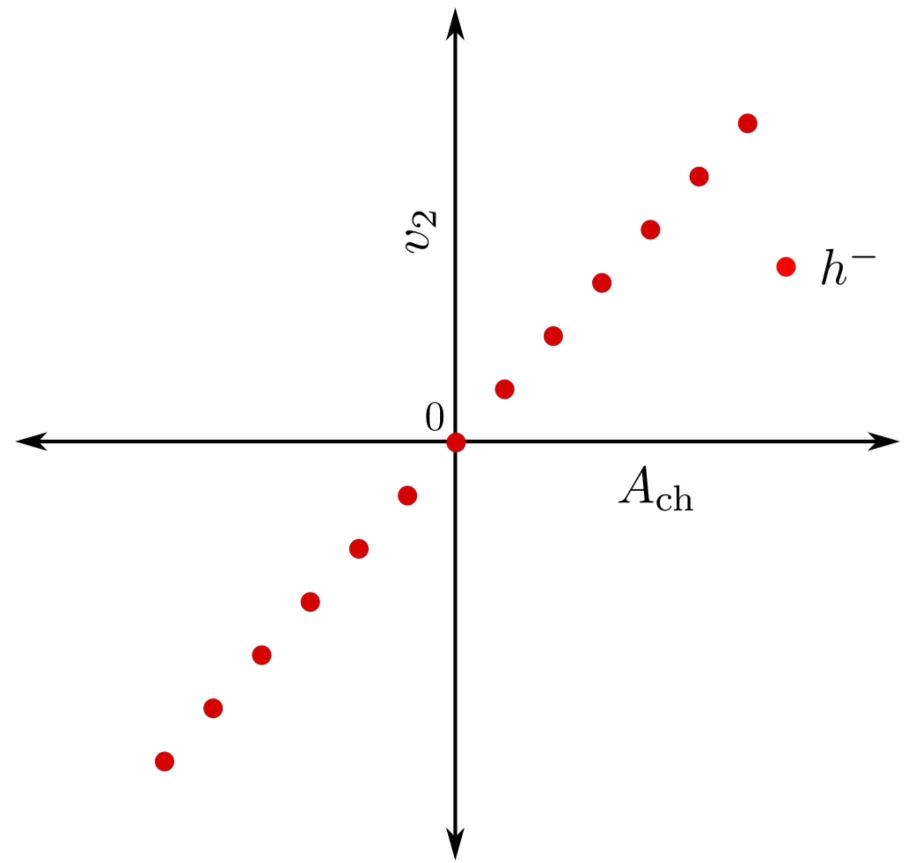
☞ **Possible background**:
Local charge conservation (LCC)

- Probe the background:
Similar measurement with v_3

☞ **Signal**:

- $r^{Norm}_{\Delta v_2} > 0$
- $r^{Norm}_{\Delta v_2} > r^{Norm}_{\Delta v_3}$

For illustration purpose



[1] Phys.Rev.Lett. 107 (2011) 052303
[2] Phys.Rev.C 100 (2019) 6, 064908
[3] Phys. Rev. C 103 (2021) 034906

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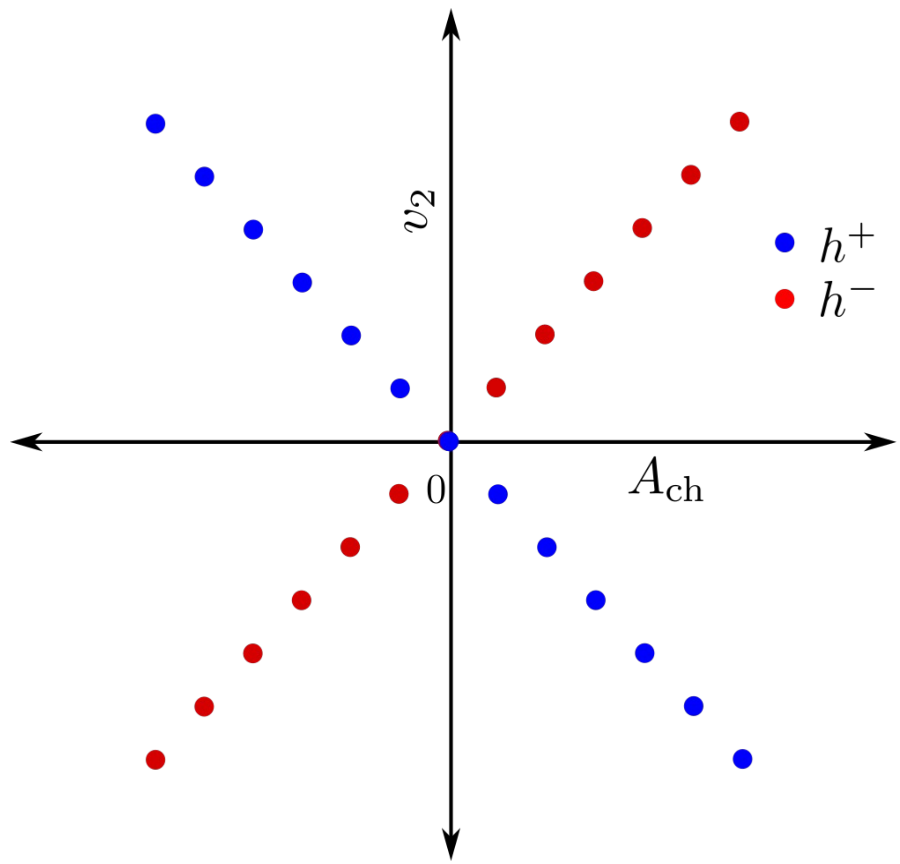

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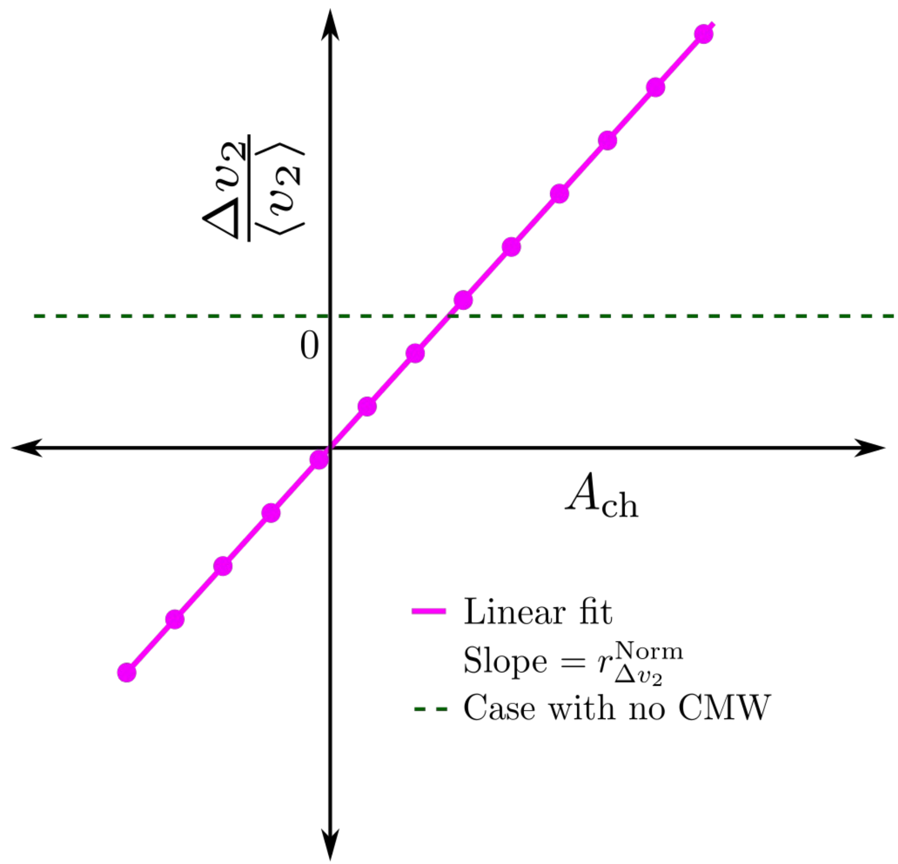

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ALICE detectors

Creator:cairo 1.14.6 (http://cairographi
CreationDate:Mon Mar 6 15:35:55 2017
CreationDate:Mon Mar 6 15:35:55 2017
LanguageLevel:3

V0

TPC

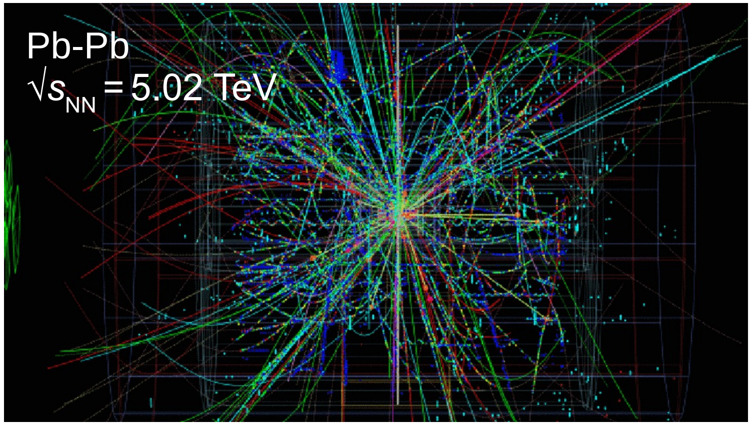
Time Projection Chamber (TPC): ($|\eta| < 0.9$)

- ☞Primary vertex and tracking
- ☞Momentum measurement
- ☞PID through dE/dx

V0: V0A ($2.8 < \eta < 5.1$) & V0C ($-3.7 < \eta < -1.7$)

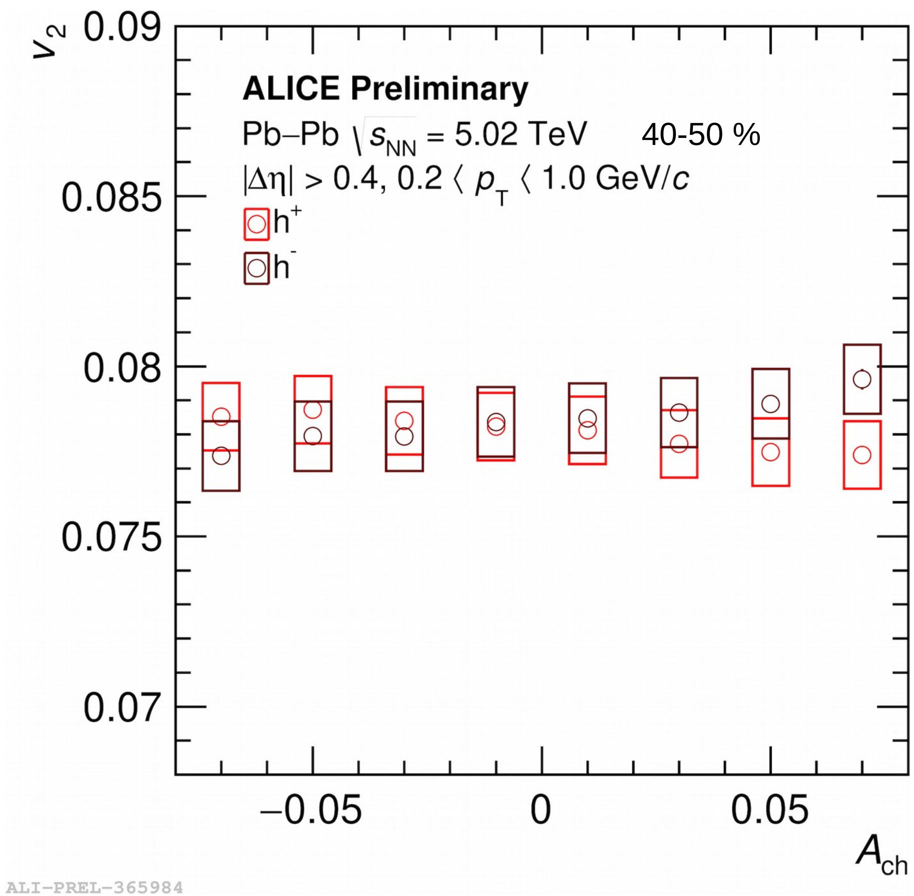
- ☞Trigger, centrality

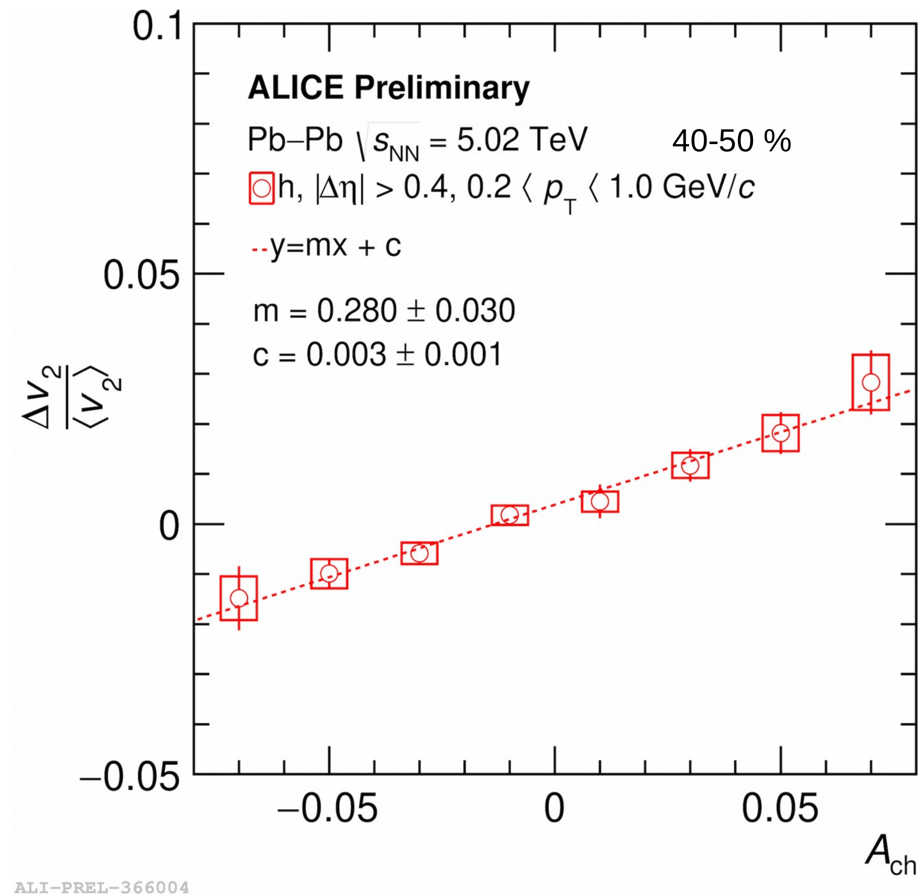
Analysis details



No. of events	~45x10^6
Kinematic range	$\lvert\eta\rvert$<0.8 0.2<p_T<0.5 GeV/c (pions) 0.2<p_T<1.0 GeV/c (hadrons)
Non flow suppression	$\lvert\Delta\eta\rvert$ > 0.4 between subevents
Charge asymmetry (A_{ch})	0.2<p_T<10 GeV/c, $\lvert\eta\rvert$<0.8, 10 uniform bins (-0.1 to 0.1)
Centrality (%)	0 - 80

Elliptic flow (v_2) vs charge asymmetry (A_{ch})



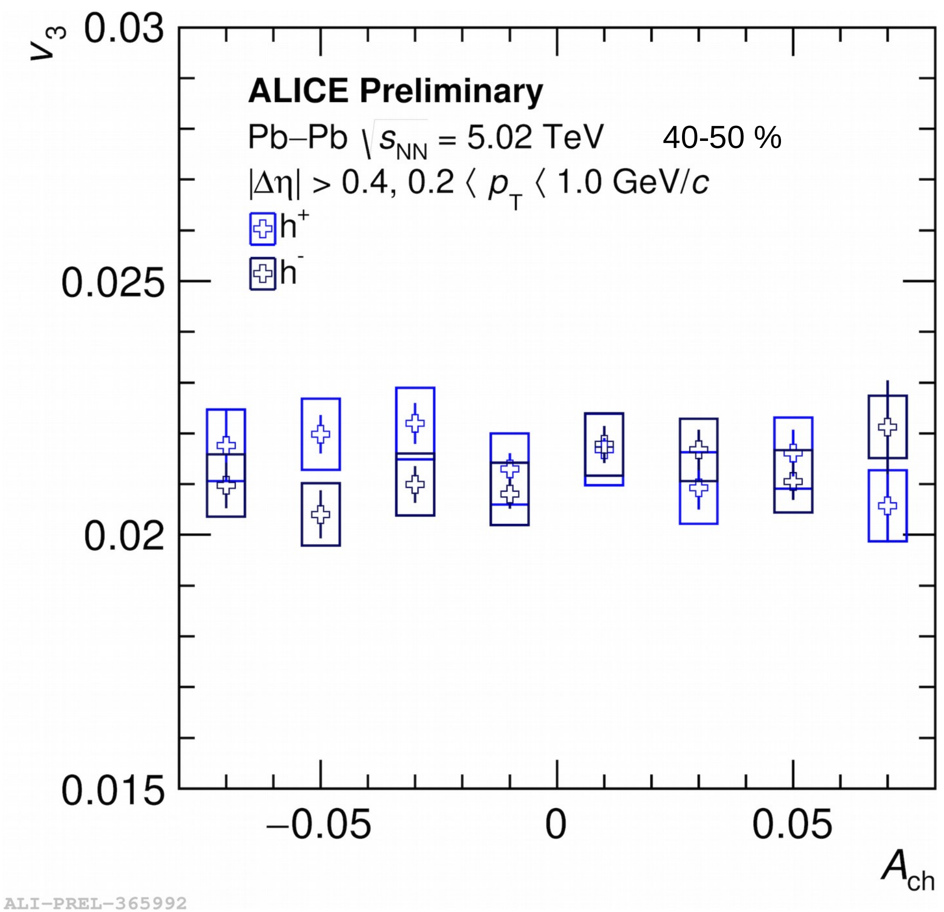


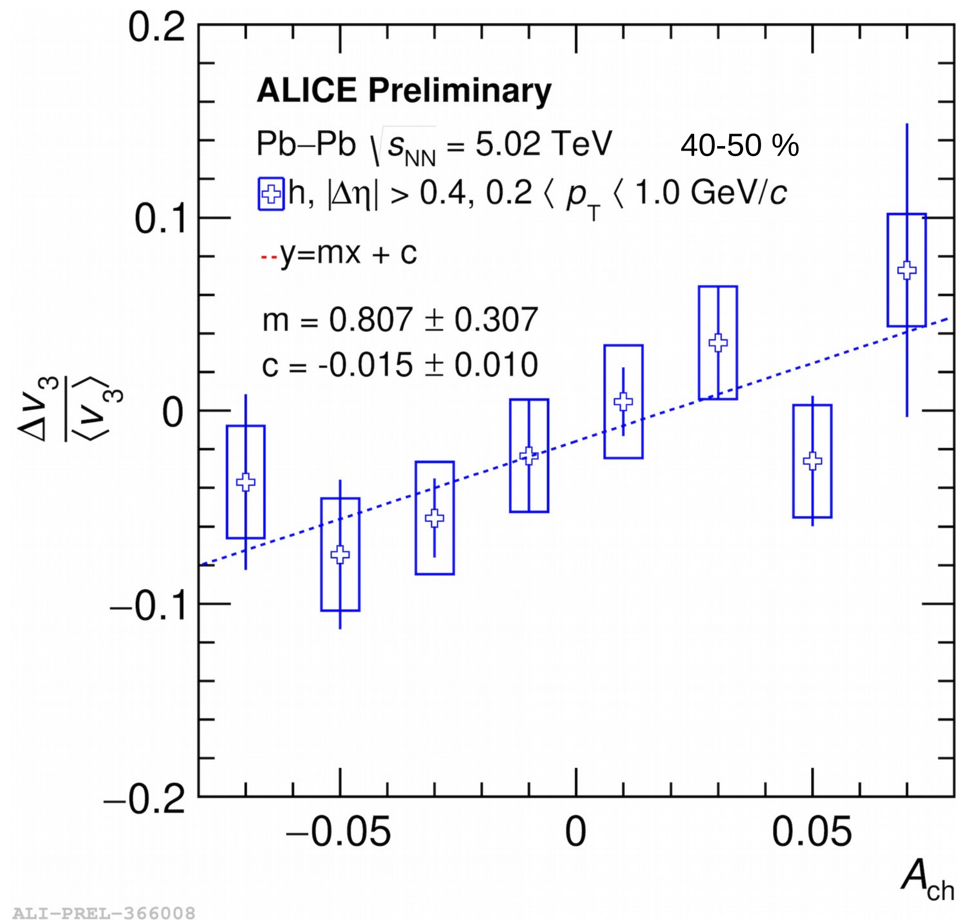
☞ Finite $r^{Norm}_{\Delta v_2}$ is observed

$$r^{Norm}_{\Delta v_n} = \frac{d\left(\frac{\Delta v_n}{\langle v_n \rangle}\right)}{d\,A_{ch}}$$

$$A_{ch} = \frac{N^+ - N^-}{N^+ + N^-}$$

Triangular flow (v_3) vs charge asymmetry (A_{ch})





☞ Finite $r^{Norm}_{\Delta v_3}$ is observed

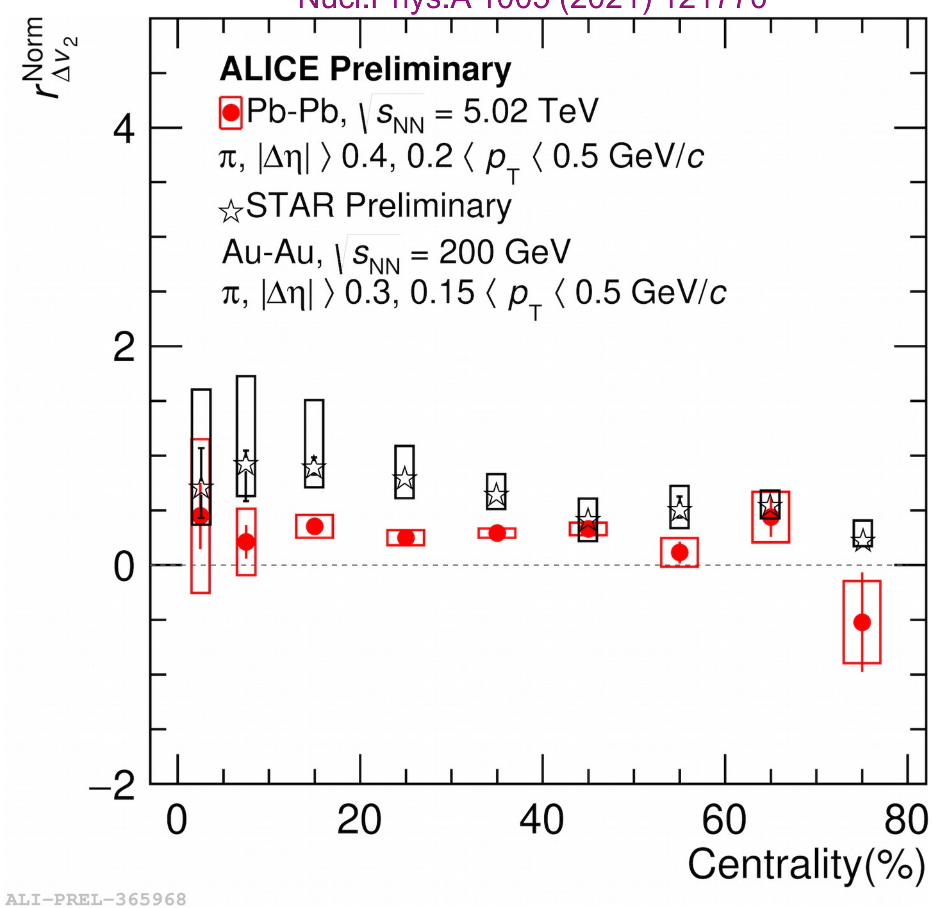
$$r^{Norm}_{\Delta v_n} = \frac{d\left(\frac{\Delta v_n}{\langle v_n \rangle}\right)}{d A_{ch}}$$

$$A_{ch} = \frac{N^+ - N^-}{N^+ + N^-}$$

Comparison of $r^{Norm}_{\Delta v_2}$ in ALICE to STAR and CMS

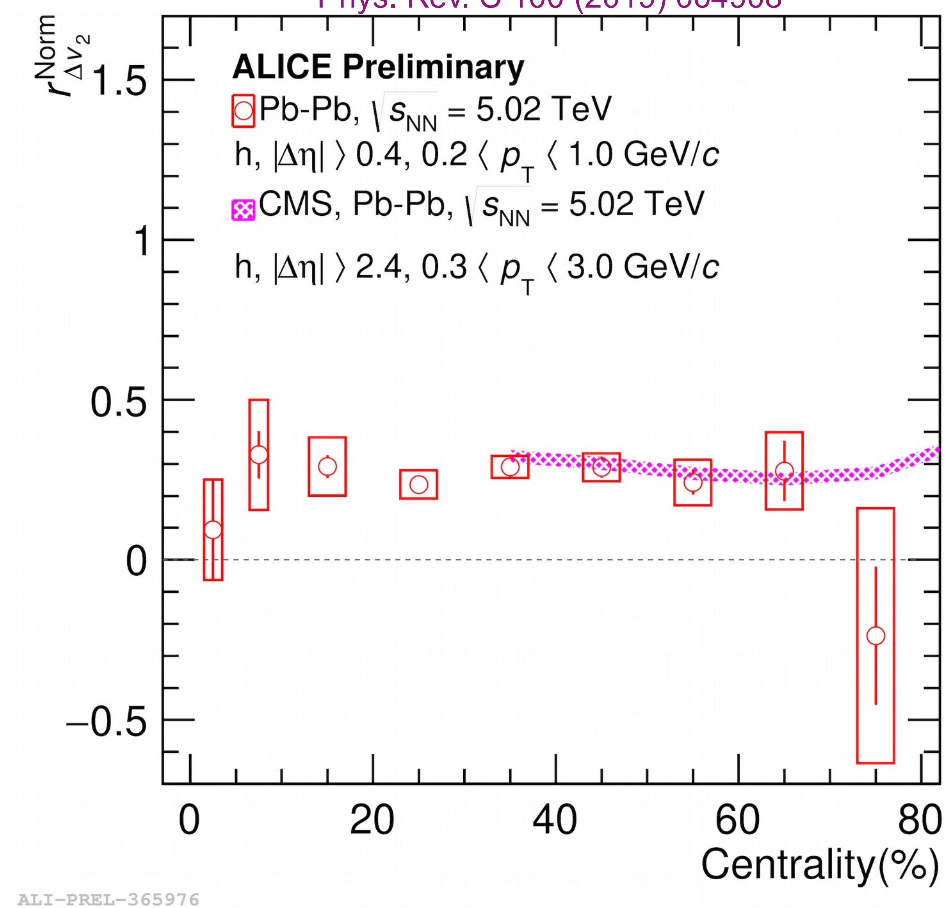
STAR

Nucl.Phys.A 1005 (2021) 121770



CMS

Phys. Rev. C 100 (2019) 064908



- ☞ $r^{Norm}_{\Delta v_2}$ h(ALICE) $\approx r^{Norm}_{\Delta v_2}$ h(CMS), but note different p_T ranges
- ☞ $r^{Norm}_{\Delta v_2}$ π(ALICE) $< r^{Norm}_{\Delta v_2}$ π(STAR)

Comparison of $r^{Norm}_{\Delta v_3}$ in ALICE to STAR and CMS

STAR

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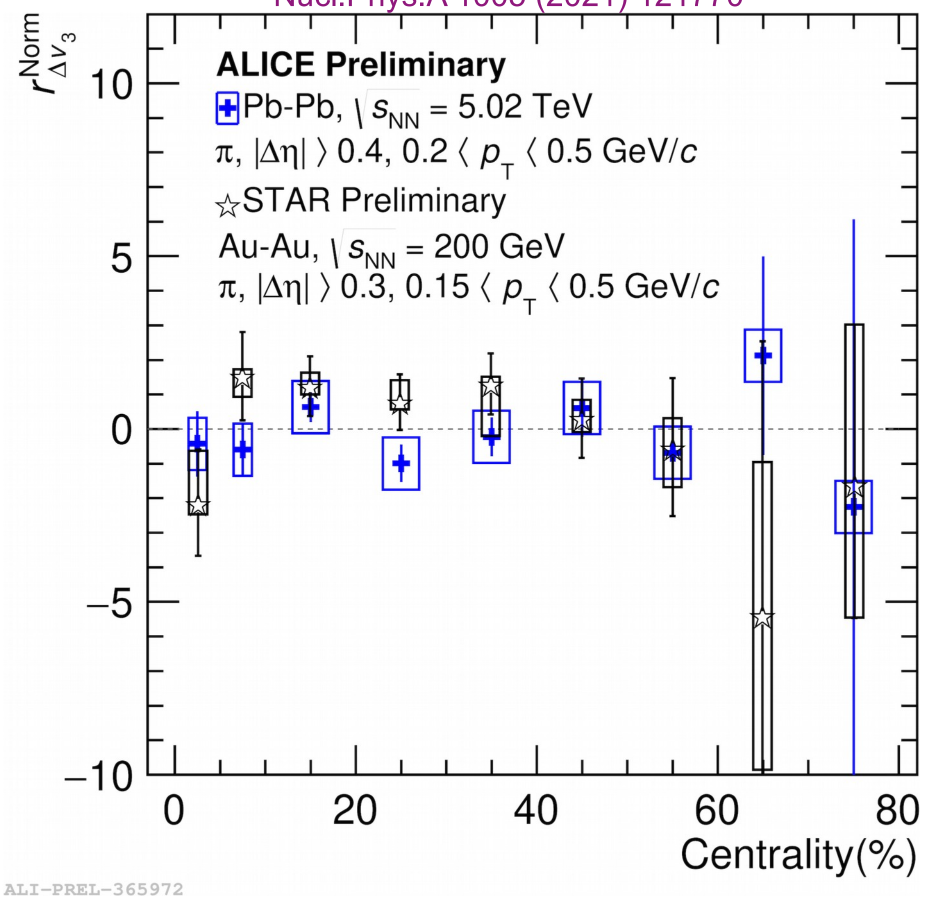

CMS

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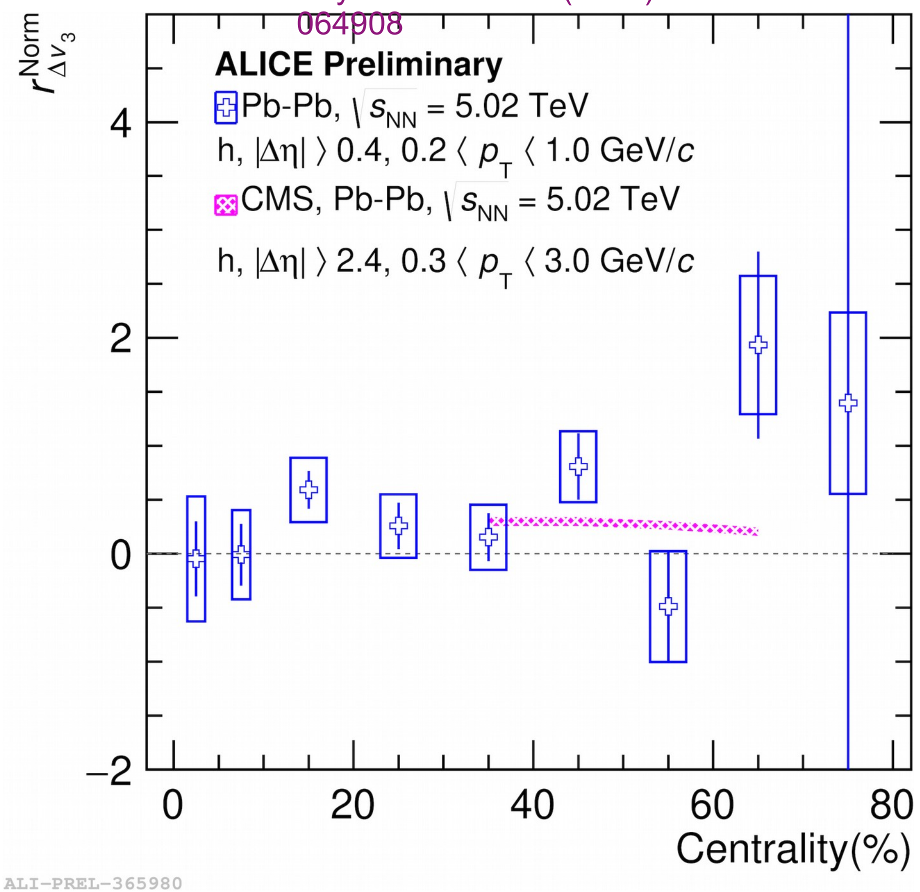
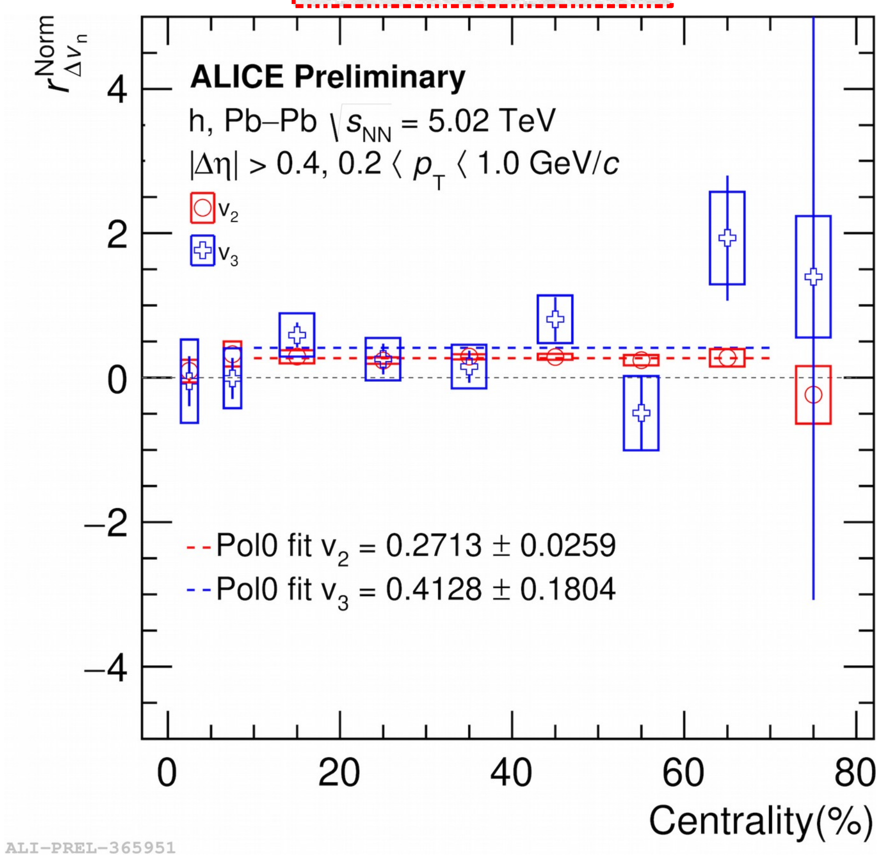


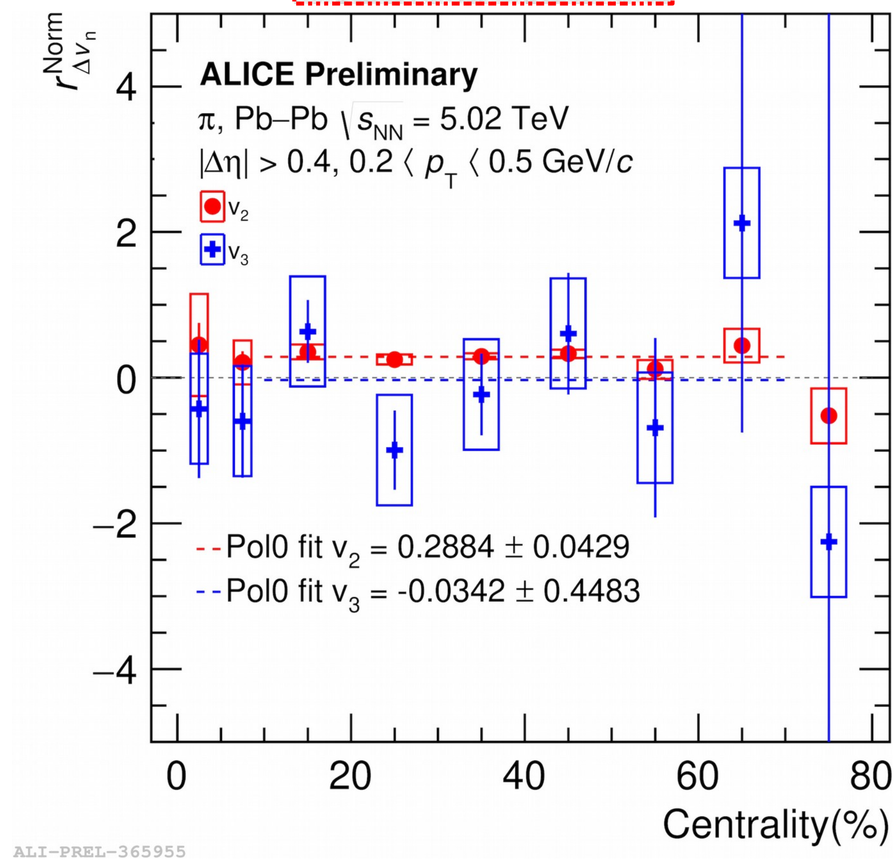
☞ No observed discrepancies in $r^{Norm}_{\Delta v_3}$ between ALICE, STAR and CMS, but uncertainties are large

Centrality dependence of $r^{Norm}_{\Delta v_n}$

Hadrons

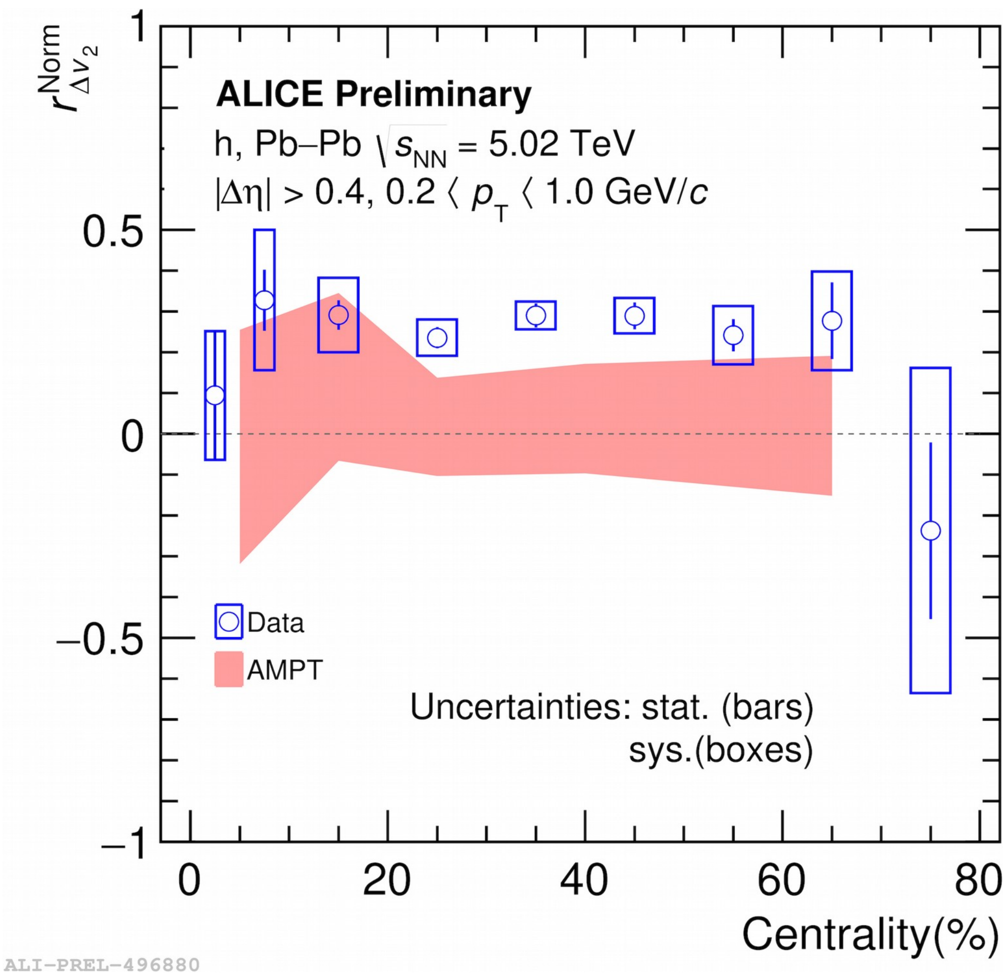


Pions



- ☞ $r^{Norm}_{\Delta v_3}$ has large uncertainties
- ☞ $r^{Norm}_{\Delta v_2}$ is compatible with $r^{Norm}_{\Delta v_3}$ for both hadrons and pions
- ☞ Background dominates the signal

Comparison of $r^{Norm}_{\Delta v_2}$ with AMPT model



☞ AMPT: No CMW and violation of charge conservation -> Slope consistent with zero

Summary

- First measurement of normalised Δv_2 and Δv_3 slope of charged hadrons and pions in Pb-Pb collisions in ALICE.
- $r^{Norm}_{\Delta v_2} > 0$ but compatible with $r^{Norm}_{\Delta v_3}$ indicates that background dominates the signal
- $r^{Norm}_{\Delta v_3}$ has large uncertainties
- $r^{Norm}_{\Delta v_2}$ (ALICE) ≈ $r^{Norm}_{\Delta v_2}$ (CMS)
- $r^{Norm}_{\Delta v_2}$ (ALICE) < $r^{Norm}_{\Delta v_2}$ (STAR)
- $r^{Norm}_{\Delta v_3}$ (ALICE) ≈ $r^{Norm}_{\Delta v_3}$ (CMS) ≈ $r^{Norm}_{\Delta v_3}$ (STAR)
- $r^{Norm}_{\Delta v_2}$ consistent with zero from AMPT model

Outlook

- Analysis ongoing in high statistics data taken in 2018

THANK YOU