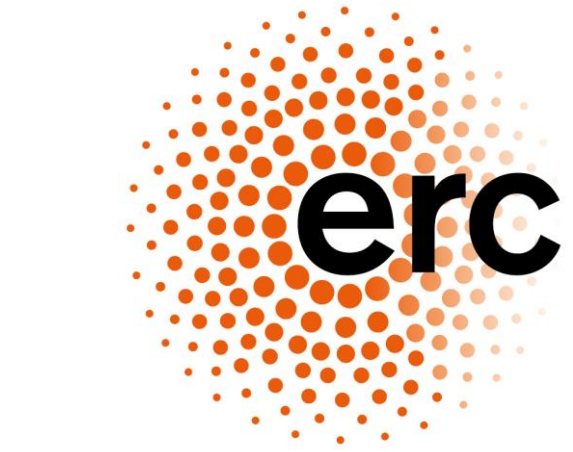# Multi-harmonic Correlations in ALICE

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Higher Order Symmetric Cumulants $SC(k,l,m)$

❖ Measurement of the genuine correlations between three and more flow amplitudes v_n using $SC(k,l,m)$

  • Information on the transport properties of QGP which cannot be obtained with one flow amplitude or $SC(m,n)$

  • Insights on the origins of the correlations between the flow amplitudes

❖ Comparison between the initial and final states using the Normalised Symmetric Cumulants $NSC(k,l,m)$

$$SC(k,l,m) = \langle v_k^2 v_l^2 v_m^2 \rangle - \langle v_k^2 v_l^2 \rangle \langle v_m^2 \rangle - \langle v_k^2 v_m^2 \rangle \langle v_l^2 \rangle$$
$$- \langle v_l^2 v_m^2 \rangle \langle v_k^2 \rangle + 2 \langle v_k^2 \rangle \langle v_l^2 \rangle \langle v_m^2 \rangle$$

$$NSC(k,l,m) = \frac{SC(k,l,m)}{\langle v_k^2 \rangle \langle v_l^2 \rangle \langle v_m^2 \rangle}$$

CM, A. Bilandzic, D. Karakoç, S.F. Taghavi, arXiv:1901.06968v2 [nucl-ex]

❖ See poster CD14: "Theoretical Framework for Multi-harmonic Correlations in Heavy-ion Collisions" (CM, A. Bilandzic, D. Karakoç, S.F. Taghavi)

Experimental Dataset

❖ $8 \cdot 10^7$ minimum-bias events from central and mid-central Pb-Pb collisions at $\sqrt{s_{NN}}$ = 2.76 TeV recorded by ALICE

❖ Estimation of the centrality with Silicon Pixel Detector (SPD)

❖ Reconstruction of the tracks with Time Projection Chamber (TPC) and Inner Tracking System (ITS)

Theoretical Models

iEBE-VISHNU

❖ Initial state obtained with **Monte Carlo Glauber**

❖ Flow from hydrodynamic evolution after 0.6 fm/c (η/s = 0.08)

EKRT

❖ Initial state obtained from the combination of perturbative QCD and saturation model

❖ Final state from solving the equation for viscous and ideal hydrodynamics

❖ Two sets of predictions: $\eta/s(T)$ = 0.2 and $\eta/s(T)$ = param1

H. Niemi, K.J. Eskola, R. Paatelainen, Phys. Rev. C93, 024907 (2016)

First Preliminary Results at $\sqrt{s_{NN}}$ = 2.76 TeV

❖ SC(2,3,4) non-zero in mid-central collisions ➔ **Presence of genuine correlations between the flow amplitudes v_2, v_3 and v_4**

❖ NSC(2,3,4) close to zero for MC-Glauber in the initial state and non-zero for iEBE-VISHNU in the final state ➔ **Development of the genuine 3-harmonic correlations during the collective evolution in the thermalized medium**

ALI-PREL-336679

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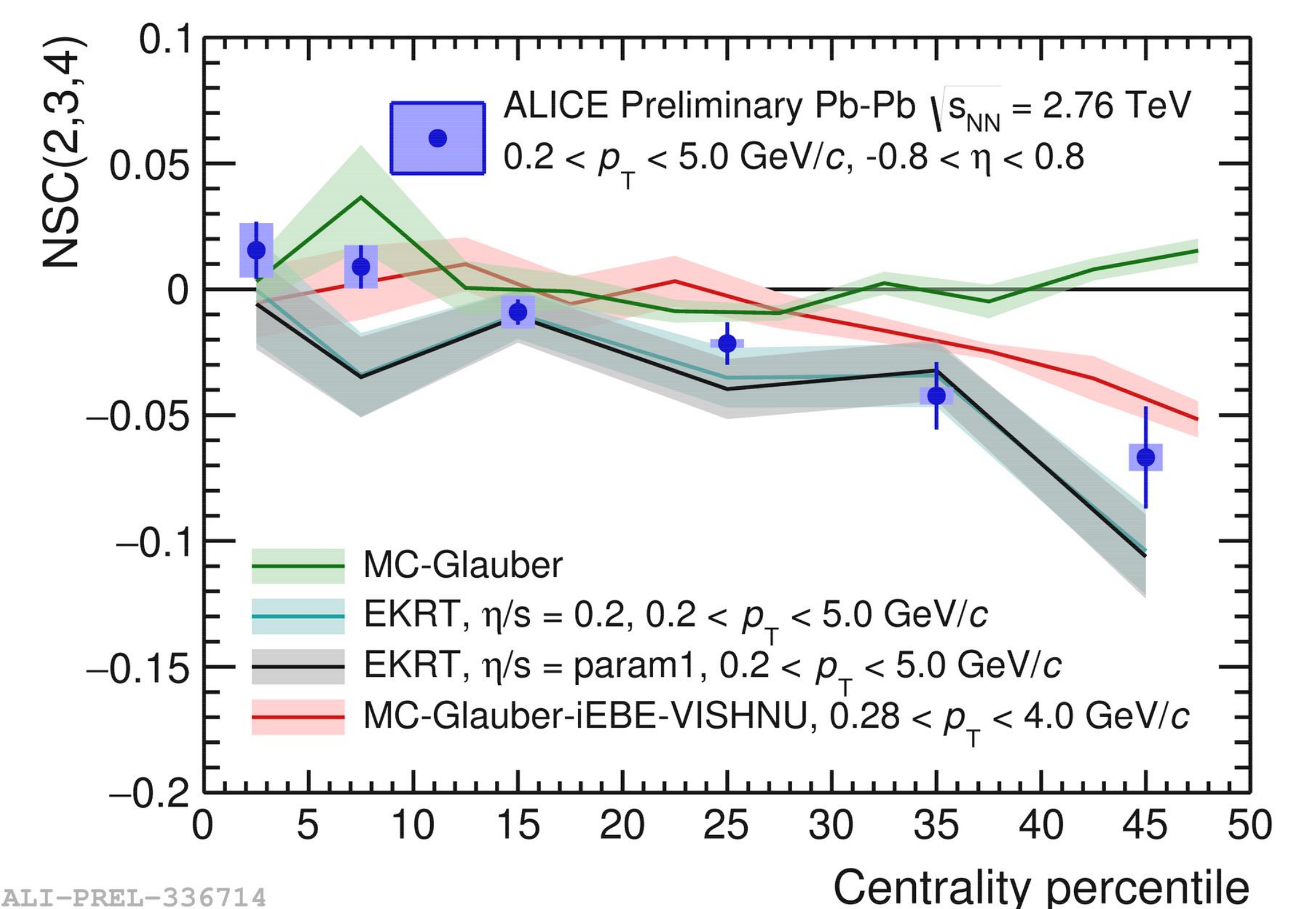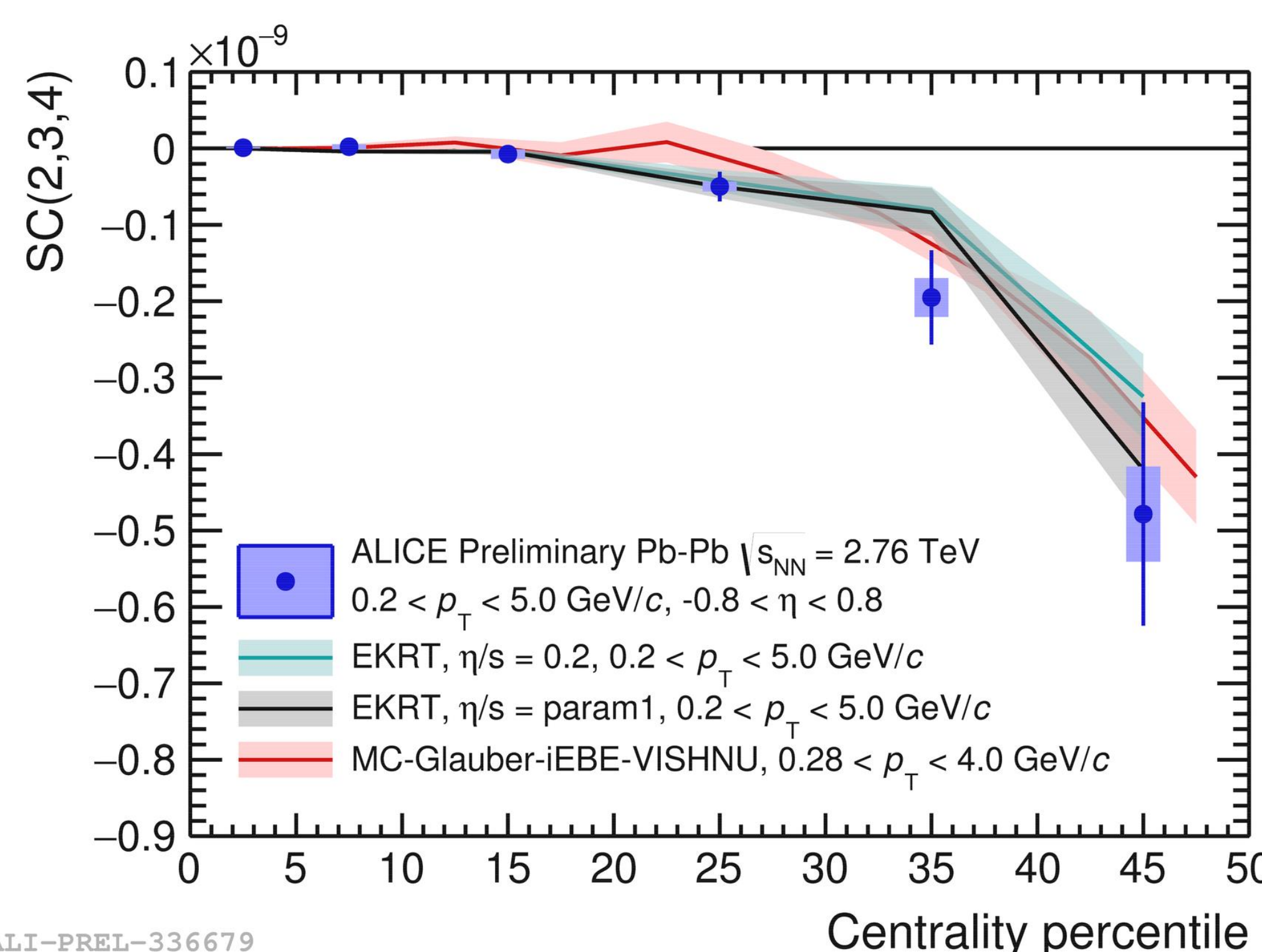
❖ In non-central collisions, trivial geometric correlations between flow amplitudes can exist due to the ellipsoidal shape of the volume of strongly interacting matter

  • All odd harmonics zero for an ideal elliptical initial state without fluctuations

  • Relations satisfied by the even harmonics: $\frac{v_4}{v_2^2} = \frac{3}{2} - \frac{1}{128}\epsilon^4 + O(\epsilon^6)$ and $\frac{v_6}{v_2^3} = \frac{5}{2} - \frac{15}{512}\epsilon^4 + O(\epsilon^6)$

❖ If origin of the correlations solely from the elliptic geometry: SC(4,2) non-zero and SC(2,3,4) zero as v_3 independent from v_2 and v_4

➔ **Not observed! Correlations between v_2, v_3 and v_4 not only to the initial elliptic geometry in non-central collisions**

Outlook

❖ New information on the origins of the correlations between flow amplitudes from the first preliminary results of SC(2,3,4) and NSC(2,3,4) in Pb-Pb collisions at $\sqrt{s_{NN}}$ = 2.76 TeV

  • First experimental confirmation of both geometric and non-geometric contributions to SC(4,2) demonstrated with $SC(k,l,m)$

❖ Great potential to learn more with the study of other combinations of flow amplitudes