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Letter

Search for the Chiral Magnetic Effect with charge-dependent azimuthal correlations in Xe–Xe collisions at $\sqrt{s_{\mathrm{NN}}} = 5.44$ TeV

ALICE Collaboration *

A B S T R A C T

Charge-dependent two- and three-particle correlations measured in Xe–Xe collisions at $\sqrt{s_{\mathrm{NN}}} = 5.44$ TeV are presented. Results are obtained for charged particles in the pseudorapidity range $|\eta| < 0.8$ and transverse momentum interval $0.2 \leq p_{\mathrm{T}} < 5.0$ GeV/c for different collision centralities. The three-particle correlator $\gamma_{\alpha\beta} \equiv \langle \cos(\varphi_\alpha + \varphi_\beta - 2\Psi_2) \rangle$, calculated for different combinations of charge sign α and β, is expected to be sensitive to the presence of the Chiral Magnetic Effect (CME). Its magnitude is similar to the one observed in Pb–Pb collisions in contrast to a smaller CME signal in Xe–Xe collisions than in Pb–Pb collisions predicted by Monte Carlo (MC) calculations including a magnetic field induced by the spectator protons. These observations point to a large non-CME contribution to the correlator. Furthermore, the charge dependence of $\gamma_{\alpha\beta}$ can be described by a blast wave model calculation that incorporates background effects and by the Anomalous Viscous Fluid Dynamics model with values of the CME signal consistent with zero. The Xe–Xe and Pb–Pb results are combined with the expected CME signal dependence on the system size from the MC calculations including a magnetic field to obtain the fraction of CME contribution in $\gamma_{\alpha\beta}$, f_{CME}. The CME fraction is compatible with zero for the 30% most central events in both systems and then becomes positive. This yields an upper limit of 2% (3%) and 25% (32%) at 95% (99.7%) confidence level for the CME signal contribution to $\gamma_{\alpha\beta}$ in the 0–70% Xe–Xe and Pb–Pb collisions, respectively.

https://www.sciencedirect.com/science/article/pii/S0370269324004209?via%3Dihub

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The charge-dependent correlations are measured using two- and three-particle correlators expressed

$$\delta_{\alpha\beta} \equiv \langle \cos(\varphi_\alpha - \varphi_\beta) \rangle$$

δ is dominated by background contributions, and δ is coupled with anisotropic flows

$$\gamma_{\alpha\beta} \equiv \langle \cos(\varphi_\alpha + \varphi_\beta - 2\Psi_{\rm RP}) \rangle$$

or

$$\gamma_{\alpha\beta} \equiv \langle \cos(\varphi_\alpha + \varphi_\beta - 2\Psi_2) \rangle$$

Same sign charged particles and Opposite sign charged particles

$$\Delta\delta_{\alpha\beta} \text{ and } \Delta\gamma_{\alpha\beta}$$

$$f_{\rm CME}$$ Fraction of CME

Compared results for XeXe at 5.44 TeV with PbPb at 5.02 TeV

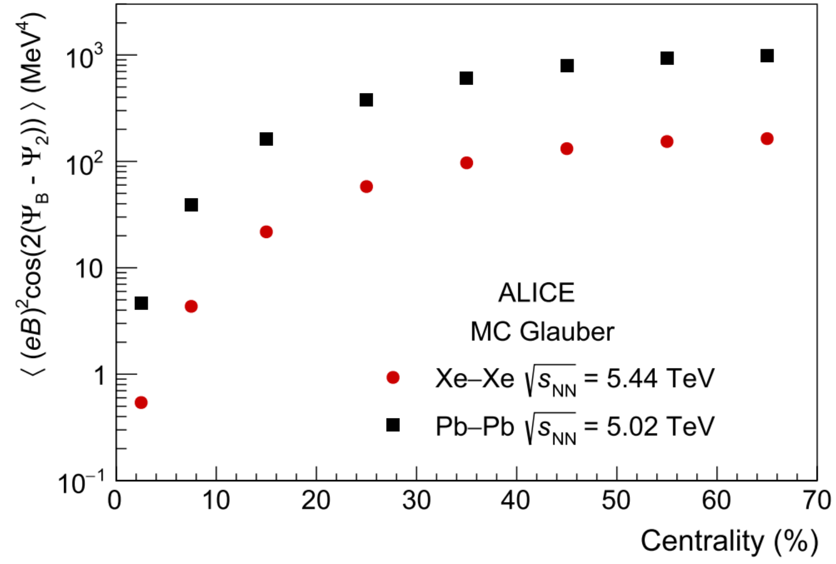


Fig. 5. The expected CME signal as a function of centrality from MC Glauber simulations for Xe–Xe and Pb–Pb collisions [73] (see text for details).

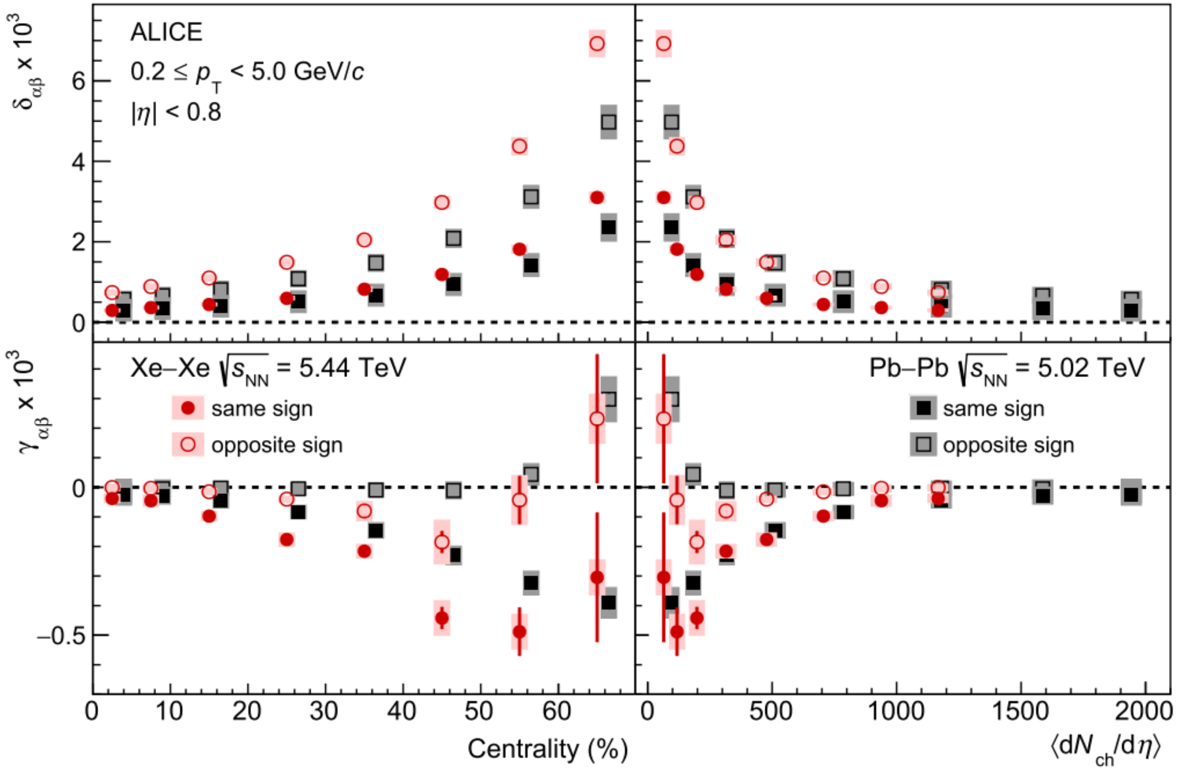


Fig. 1. The $\delta_{\alpha\beta}$ (top panels) and $\gamma_{\alpha\beta}$ (bottom panels) correlators as a function of centrality (left panels) and charged-particle density [65,66] (right panels) for pairs of particles with same (closed markers) and opposite (open markers) charges from Xe–Xe collisions at $\sqrt{s_{NN}} = 5.44$ TeV (red circles) compared to Pb–Pb collisions at $\sqrt{s_{NN}} = 5.02$ TeV (black squares) [42]. The Pb–Pb points are slightly shifted along the horizontal axis for better visibility in the left panels. Bars (boxes) denote statistical (systematic) uncertainties.

1. For $\delta_{\alpha\beta}$, the magnitude of the same- and opposite-charge pair correlations is positive and increases from central to peripheral collisions. In contrast to the CME expectation, the correlation for the opposite-charge pairs is stronger than for the same-charge combinations, indicating that background dominates these measurements.
2. For $\gamma_{\alpha\beta}$, the magnitude of opposite-charge pair correlations is close to zero within uncertainties for most of the centrality intervals, while it decreases from central to peripheral collisions becoming more negative for same-charge pairs. Thus, the correlation of opposite-charge pairs is weaker than for same-charge pairs. This ordering is compatible with a charge separation with respect to the reaction plane expected in the presence of the CME.

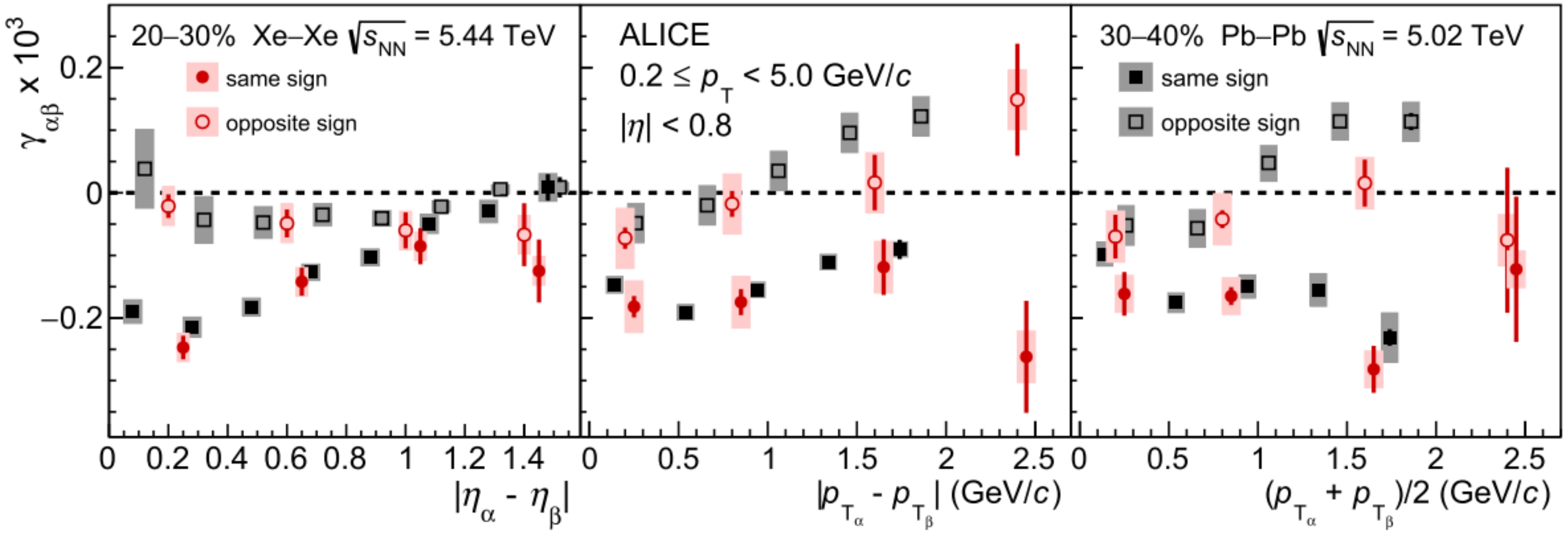
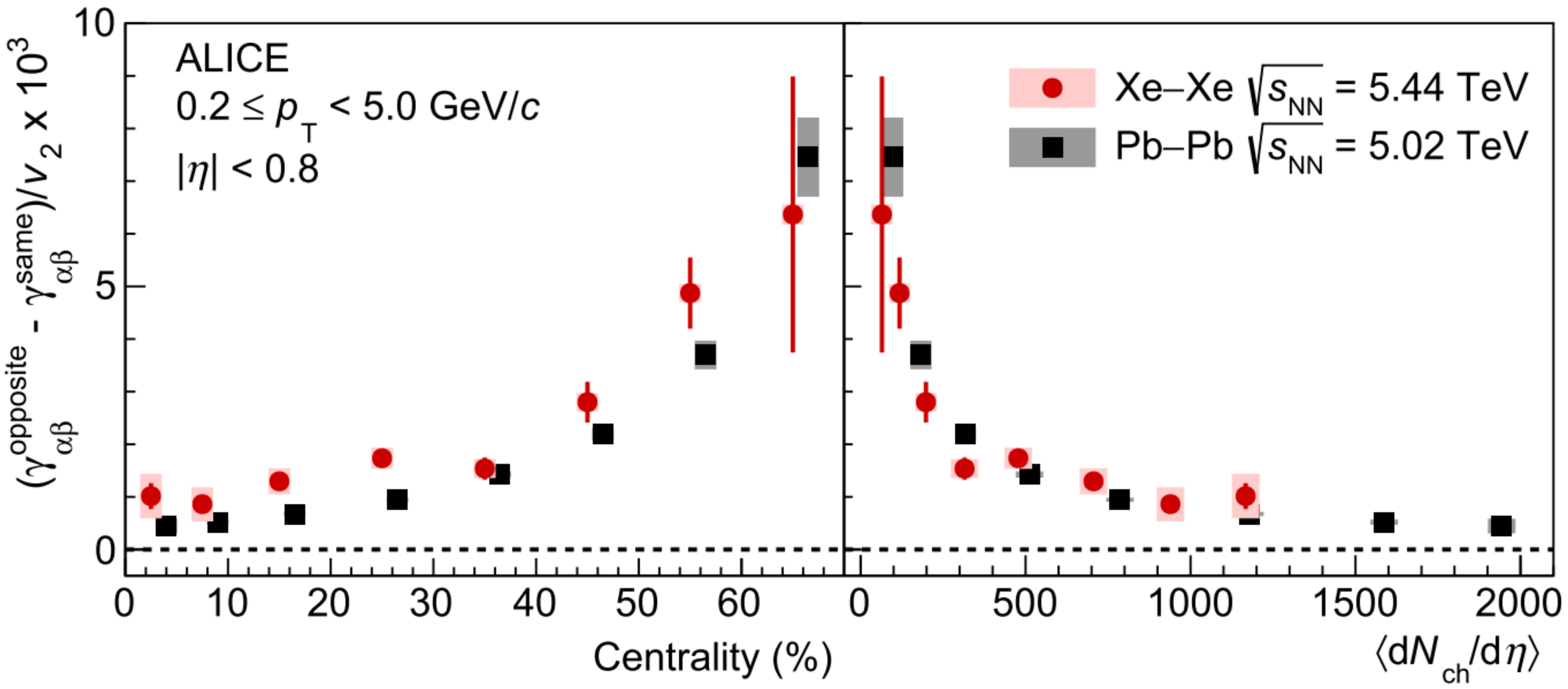


Fig. 2. The dependence of $\gamma_{\alpha\beta}$ on the pseudorapidity difference $|\eta_\alpha - \eta_\beta|$ (left panel), the transverse momentum difference $|p_{T_\alpha} - p_{T_\beta}|$ (middle panel), and the average transverse momentum $(p_{T_\alpha} + p_{T_\beta})/2$ (right panel) for pairs of particles with same (closed markers) and opposite (open markers) charges from 20–30% Xe–Xe collisions at $\sqrt{s_{NN}} = 5.44$ TeV (red circles) compared to results from 30–40% Pb–Pb collisions at $\sqrt{s_{NN}} = 5.02$ TeV (black squares) [42]. The Pb–Pb and Xe–Xe same-charge points are slightly shifted along the horizontal axis for better visibility in all panels. Bars (boxes) denote statistical (systematic) uncertainties.

1. The opposite-charge pair correlations from Xe–Xe collisions show a weak dependence on $\Delta\eta$ and $\langle p_T \rangle$, while they increase with increasing Δp_T of the pair. The correlations for the same-charge pairs do not exhibit any significant dependence on Δp_T and $\langle p_T \rangle$ within uncertainties.
2. correlations show a strong dependence on $\Delta\eta$ with a width of approximately one unit in pseudorapidity difference .
3. The Xe–Xe and Pb–Pb results are compatible within uncertainties demonstrating similar behaviour of this observable despite the differences in the magnetic field .



The value of $\Delta\gamma_{\alpha\beta}/v_2$ is positive for all centralities and its magnitude increases from central to peripheral collisions. Furthermore, it is slightly higher in Xe–Xe than Pb–Pb collisions in the 10–60% centrality interval. However, the Xe–Xe and Pb–Pb data points fall approximately onto the same curve when reported as a function of $\langle dN_{ch}/d\eta \rangle$

Assuming that both the CME signal and the background scale with $\mathrm{d}N_{ch}/\mathrm{d}\eta$, the charge dependence of $\gamma_{\alpha\beta}$ for the two collision systems can be expressed using a two-component approach

W.-T. Deng, X.-G. Huang, G.-L. Ma, G. Wang, Test the chiral magnetic effect with isobaric collisions, Phys. Rev. C 94 (2016) 041901, arXiv:1607.04697 [nucl-th]

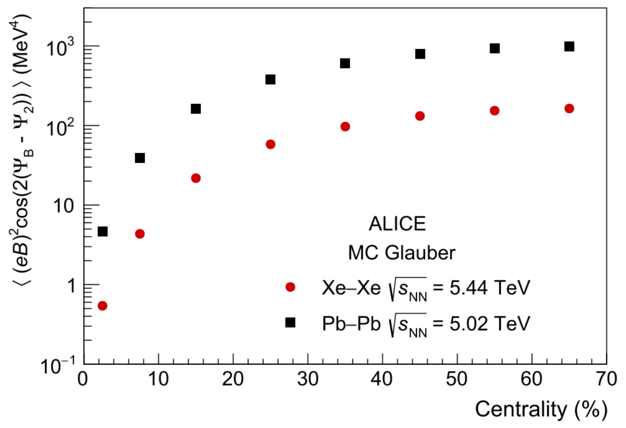


Fig. 5. The expected CME signal as a function of centrality from MC Glauber simulations for Xe–Xe and Pb–Pb collisions [73] (see text for details).

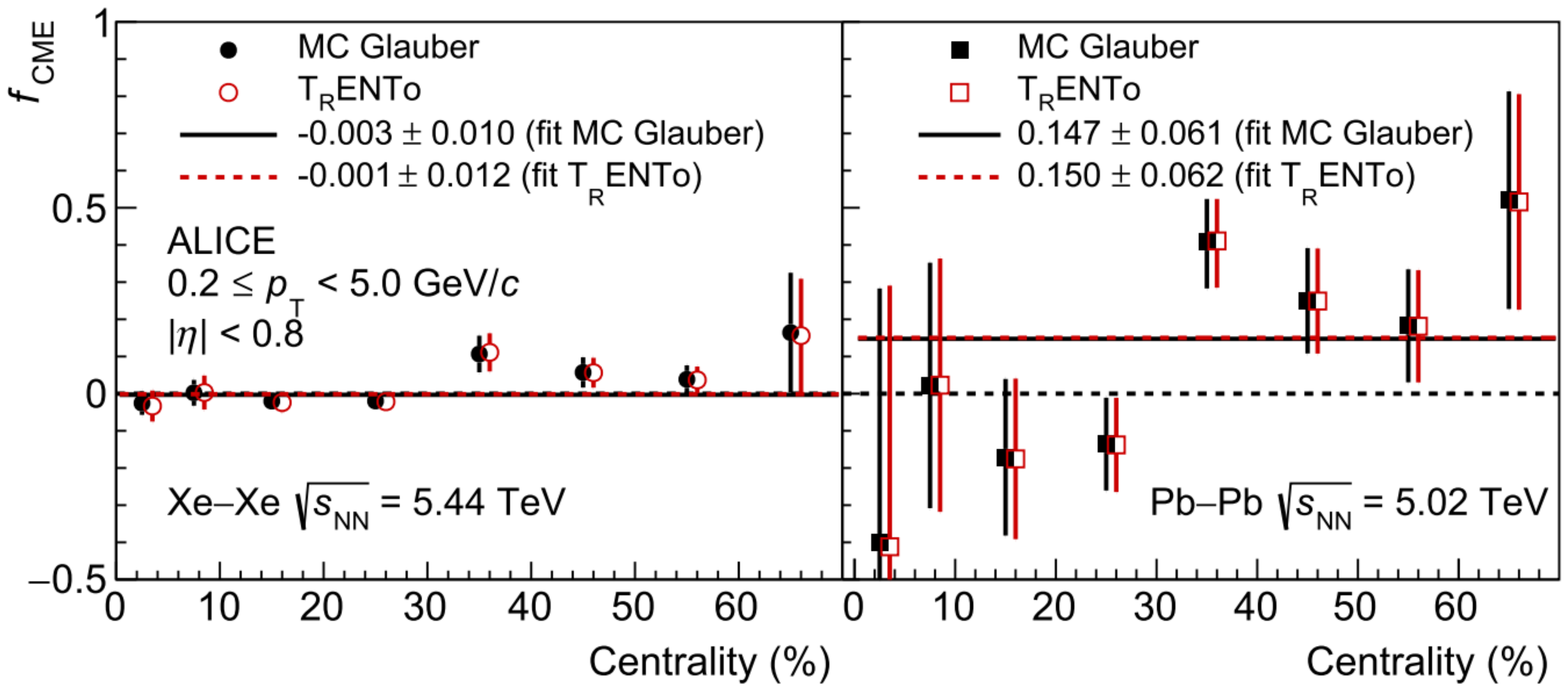
$$\Gamma^{\mathrm{Xe-Xe}} = sB^{\mathrm{Xe-Xe}} + bv_2^{\mathrm{Xe-Xe}},$$

$$\Gamma^{\mathrm{Pb-Pb}} = sB^{\mathrm{Pb-Pb}} + bv_2^{\mathrm{Pb-Pb}},$$

where $\Gamma \equiv \gamma_{\alpha\beta}\,\mathrm{d}N_{\mathrm{ch}}/\mathrm{d}\eta,\ B \equiv \langle (eB)^2\cos(2(\Psi_{\mathrm{B}} - \Psi_2))\rangle,$

The s and b parameters quantify the signal and background contributions, respectively,

$$f_{\mathrm{CME}} = \frac{sB}{sB + bv_2}.$$



1. The f_{CME} is compatible with zero up to 30% centrality in both systems
2. positive for midcentral and peripheral collisions with larger values in Pb–Pb than in Xe–Xe.
3. Fitting the data points in the centrality range 0–70% with a constant function neglecting any centrality dependence gives f_{CME} = -0.003 ± 0.010 (f_{CME} = -0.001 ± 0.012) and f_{CME} = 0.147 ± 0.061 (f_{CME} = 0.150 ± 0.062) for MC Glauber (T_RENTo) initial conditions in Xe–Xe and Pb–Pb collisions, respectively.
4. These results are consistent with zero CME fraction in Xe–Xe collisions and correspond to upper limits on f_{CME} of 2% (3%) and 25% (32%) at 95% (99.7%) confidence level for the 0–70% centrality interval in Xe–Xe and Pb–Pb collisions, respectively. The limits are estimated assuming Gaussian uncertainties.