Chinese Physics C

Volume 48 Number 8 August 2024

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国内统一刊号：CN 11－5641/O4 国内邮发代号：2－522 定价：150.00 元

PARTICLE AND NUCLEAR ASTROPHYSICS AND COSMOLOGY

Applying deep learning technique to chiral magnetic wave search

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It is well known that in strong interaction the parity symmetry (left-right mirror symmetry) is conserved. However, Quantum ChromoDynamics (QCD), the fundamental quantum field theory of strong interaction, permits in its Lagrange terms which, while conserving parity on average, allow for local violations of parity. It has been proposed that heavy ion collisions offer a unique opportunity to detect these parity-violating fluctuations in strong interaction. In these collisions, heavy nuclei like gold and lead are colliding with each other at a speed near the speed of the light, creating drops of quark-gluon plasma (QGP). In QGP topological domains of unbalanced quark chirality (unequal number of left-handed and right-handed quarks) may be created due to collective gluon excitations. In addition, a strong magnetic field as large as 1018 Gauss may be generated at the collision volume from protons in the colliding beams. The coupling of the chirality imbalanced quarks and the magnetic field would yield a Chiral Magnetic Effect (CME) leading to a charge separation of the final state charged particles along the direction of the magnetic field. The CME creating a dipole moment which explicitly violates the parity symmetry. The time dependence of the CME could also lead to a Chiral Magnetic Wave (CMW). The CMW could induce a charge quadrupole distribution and result in differences in elliptic flows of positively and negatively charged pions. Experimental searches for these quark chirality effects have been a major scientific objective for heavy ion research programs at RHIC and LHC.

The experimental searches for the quark chirality effects of CME and CMW proved to be extremely challenging due to background contributions. In their work [1], Zhao and Huang proposed using neural networks to search for CMW signal independent of specific observables used previously in the experiments. They demonstrated that after training on simulated data containing CMW-like features, the neural network can reliably identify CMW events. They also assessed the robustness of the neural network approach using simulation data of different beam energies, types of colliding nuclei, and collision centralities. Zhao and Huang suggested a novel approach to experimentally search for the CMW. Similar approaches could be extended to search for other chiral effects such as chiral vortical effects and chiral vortical waves.

References

[1] Y. S. Zhao and X. G. Huang, Chin. Phys. C48, 084103 (2024), arXiv: 2407.00926 [nucl-th].