Available online at www.sciencedirect.com

ScienceDirect

Nuclear Physics A 967 (2017) 744–747

NUCLEAR PHYSICS A

www.elsevier.com/locate/nuclphysa

Charge-dependent azimuthal correlations in pPb collisions with CMS experiment

Zhoudunming Tu, on behalf of the CMS Collaboration

Physics & Astronomy MS-61, Rice University, Houston, US, 77005

Abstract

Charge-dependent azimuthal correlations relative to the event plane in AA collisions have been suggested as providing evidence for the chiral magnetic effect (CME) caused by local strong parity violation. However, the observation of the CME remains inconclusive because of several possible sources of background correlations that may account for part or all of the observed signals. This talk will present the first application of three-particle, charge-dependent azimuthal correlation analysis in proton-nucleus collisions, using pPb data collected with the CMS experiment at the LHC at $\sqrt{s_{NN}}$ = 5.02 TeV. The differences found in comparing same and opposite sign correlations are studied as a function of event multiplicity and the pseudorapidity gap between two of the particles detected in the CMS tracker detector. After selecting events with comparable charge-particle multiplicities, the results for pPb collisions are found to be similar to those for PbPb collisions collected at the same collision energy. With a reduced magnetic field strength and a random field orientation in high multiplicity pPb events, the CME contribution to any charge separation signal is expected to be much smaller than found in peripheral PbPb events. These results pose a challenge for the interpretation of charge-dependent azimuthal correlations in heavy ion collisions in terms of the chiral magnetic effect.

Keywords: heavy ion physics, small systems, chiral magnetic effect, local parity violation

1. Introduction

In relativistic heavy ion collisions, the extremely high temperature of Quark-Gluon-Plasma (QGP) with chiral symmetry restored, produces gluon fields that generates nontrivial topological configuration. The interaction between the quarks and these configurations can result in an imbalance of left- and right-handed quarks, where parity will be violated in strong interactions [1, 2, 3, 4]. As two relativistic heavy ions pass by each other, a very strong magnetic field can be induced by the spectator protons. Due to the chirality imbalance and the magnetic field, an electric current will be generated along the magnetic field direction. As a result, particles will have a preference of emitting along or opposite to the magnetic field direction, which translates into a charge separation effect for the final-state particles with respect to the reaction plane, known as "chiral magnetic effect" (CME).

In the past decade, measurements of charge separation in heavy ion collisions have been attempted by the STAR experiment from RHIC and the ALICE experiment from the LHC, where significant charge separation

Email address: zt7@rice.edu (Zhoudunming Tu, on behalf of the CMS Collaboration)

http://dx.doi.org/10.1016/j.nuclphysa.2017.05.089

signal has been observed in terms of the three-particle correlator [5]. The results are consistent with CME expectations. However, this observable is also largely affected by various of backgrounds. For reaction plane independent sources, i.e., back-to-back jets and momentum conservation, can dominate the three-particle correlators for events with low multiplicities [21]. These sources of backgrounds can be suppressed by taking the difference between opposite and same sign, where charge-independent part of the correlation is largely removed. Moreover, there are reaction plane related backgrounds that are charge-dependent, which can contribute to the three-particle correlator [6, 7], i.e., local charge conservation effect coupled with an elliptic flow (v_2). Therefore, the interpretation of the current results still remains inconclusive to date, despite significant amount of efforts from both experimental and theoretical sides have been carried out.

In recent years, CMS has reported that the flow-like behavior and its collective nature in high-multiplicity pp and pPb collisions have been established, in terms of radial flow and final-state azimuthal anisotropy correlations, which are similar to that in AA collisions [8, 9, 10, 11, 12, 13, 14, 15, 16]. In high-multiplicity pPb collisions, the magnetic field is expected to be smaller compared to noncentral PbPb collisions at the same center-of-mass energy. Moreover, due to its initial-state fluctuations in high-multiplicity pPb collisions, the magnetic field direction has almost no correlation with respect to the 2nd-order event-plane angle [17]. These two expectations has been studied using MC simulation [18]. Therefore, as the three-particle correlator is essentially a measure of the charge separation with respect to the event-plane, the charge separation signal is expected to be much smaller in pPb collisions than in PbPb collisions. In this paper, the recent results of charged-dependent correlation study in pPb collisions using the CMS detector [19] are presented, which can be found in Ref. [18].

2. Results

In Fig. 1, the same (SS) and opposite sign (OS) three-particle correlator, as a function of pseudorapidity difference between particle α and β, are shown for multiplicity range $185 \leq N_{\text{trk}}^{\text{offline}} < 220$ in pPb (a) and PbPb (b) collisions. The pPb results have both particle c reconstructed from Pb- and p-going side, which indicates a different magnitude for OS and SS. This could be related to the nonflow effect or charged-independent part of the correlator associated with Pb- and p-going side, since the difference between OS and SS remains the same. The significant signal in pPb collisions and similarity between pPb and PbPb collisions, as not expected in CME interpretation, strongly suggest the measured correlation are not related to the CME but some other common background correlations.

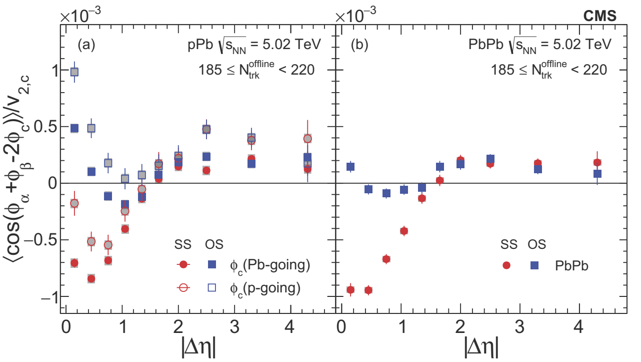

Fig. 1. The same (SS) and opposite sign (OS) three-particle correlator as a function of $\Delta\eta \equiv |\eta_\alpha - \eta_\beta|$ for $185 \leq N_{\text{trk}}^{\text{offline}} < 220$ in (a) pPb and (b) PbPb collisions at $\sqrt{s_{NN}} = 5.02$ TeV. The pPb results obtained with particle c in Pb-going (solid markers) and Pp-going (open markers) sides are shown separately [18]. Statistical and systematic uncertainties are indicated by the error bars and shaded regions, respectively.

In Fig. 2 (left), the integrated results ($|\eta_\alpha - \eta_\beta| < 1.6$) of SS and OS three-particle correlator as a function of $N_{\mathrm{trk}}^{\mathrm{offline}}$ are shown in pPb and PbPb collisions at $\sqrt{s_{NN}} = 5.02$ TeV. In Fig. 2 (right), the SS and OS three-particle correlator as a function of centrality are shown for CMS, ALICE, and STAR at center-of-mass energy of 5.02, 2.76, and 0.2 TeV, respectively. Not only OS and SS three-particle correlator are similar between pPb and PbPb collisions at $\sqrt{s_{NN}} = 5.02$ TeV, but also similar among different energies from different experiments. The strikingly similar magnitude between pPb and PbPb collisions, among different center-of-mass energies, again indicates that the dominant contribution of the signal is not related to the CME.

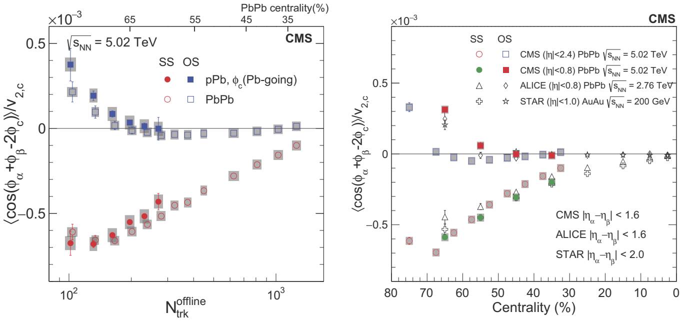

Fig. 2. Left: the same sign (SS) and opposite sign (OS) three-particle correlator averaged over $|\eta_\alpha - \eta_\beta| < 1.6$ as a function of $N_{\mathrm{trk}}^{\mathrm{offline}}$ in pPb and PbPb collisions at $\sqrt{s_{NN}} = 5.02$ TeV are shown [18]. Right: the same sign (SS) and opposite sign (OS) three-particle correlator averaged over $|\eta_\alpha - \eta_\beta| < 1.6$ as a function of centrality is presented in PbPb collisions at $\sqrt{s_{NN}} = 5.02$ TeV from CMS with $|\eta| < 2.4$ and $|\eta| < 0.8$, at $\sqrt{s_{NN}} = 2.76$ TeV from ALICE [20], and in AuAu collisions at $\sqrt{s_{NN}} = 0.2$ TeV from STAR [21]. The bars (boxes) represent statistical (systematic) point-by-point uncertainties.

In order to extract the charged-dependent part of the three-particle correlator, the difference between OS and SS is obtained for both pPb and PbPb collisions. In Fig. 3 (a), the OS-SS three-particle correlator is shown as function of $|\eta_\alpha - \eta_\beta|$ for multiplicity range $185 \leq N_{\mathrm{trk}}^{\mathrm{offline}} < 220$ in pPb and PbPb collisions. In Fig. 3 (b), the OS-SS three-particle correlator is shown as function of $N_{\mathrm{trk}}^{\mathrm{offline}}$, integrated over $|\eta_\alpha - \eta_\beta| < 1.6$. For all results shown in Fig. 3, the charged-dependent part of the three-particle correlator shows almost identical magnitude, indicating the underlying physics mechanism is not related to the CME.

3. Summary

In summary, the three-paritcle correlator of same and opposite sign particles with respect to the second-order event plane have been measured in pPb and PbPb collisions at $\sqrt{s_{NN}} = 5.02$ TeV by the CMS experiment at the LHC. The correlation is extracted as functions of particle pseudorapidity difference and charged-particle multiplicity of the event. The charged-dependent part of the three-particle correlator, difference between opposite and same sign particles, as functions of pseudorapidity difference and multiplicity is found to agree between pPb and PbPb collisions, indicating a common underlying mechanism that produces the measured correlation.

References

[1] T. D. Lee, A theory of spontaneous *T* violation, Phys. Rev. D 8 (1973) 1226. doi:10.1103/PhysRevD.8.1226.
[2] T. D. Lee, G. C. Wick, Vacuum stability and vacuum excitation in a spin-0 field theory, Phys. Rev. D 9 (1974) 2291. doi:10.1103/PhysRevD.9.2291.
[3] P. D. Morley, I. A. Schmidt, Strong p, cp, t violations in heavy-ion collisions, Z. Phys. C 26 (1985) 627. doi:10.1007/BF01551807.
[4] D. Kharzeev, R. D. Pisarski, M. H. G. Tytgat, Possibility of spontaneous parity violation in hot QCD, Phys. Rev. Lett. 81 (1998) 512. arXiv:hep-ph/9804221, doi:10.1103/PhysRevLett.81.512.

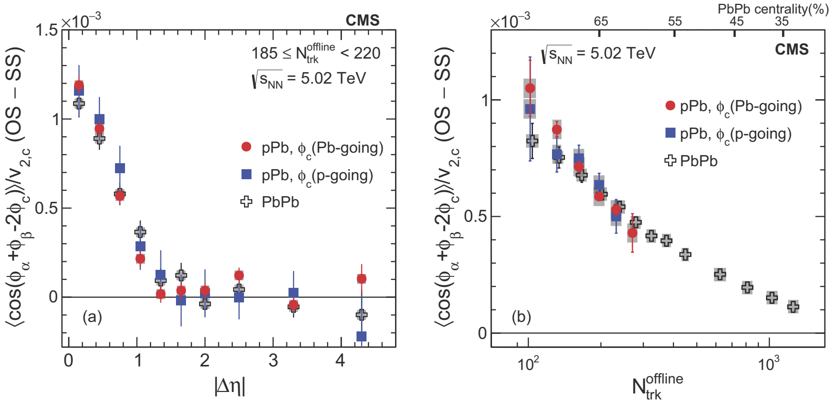

Fig. 3. The difference of the opposite sign (OS) and same sign (SS) three-particle correlators (a) as a function of $|\eta_\alpha - \eta_\beta|$ for 185 ≤ $N_{trk}^{offline}$ < 220 and (b) as a function of $N_{trk}^{offline}$, averaged over $|\eta_\alpha - \eta_\beta| < 1.6$, in pPb and PbPb collisions at $\sqrt{s_{NN}}$ = 5.02 TeV. The pPb results are obtained with particle *c* from Pb- and Pp-going sides separately [18]. Statistical and systematic uncertainties are indicated by the error bars and shaded regions, respectively.

[5] S. A. Voloshin, Parity violation in hot QCD: How to detect it, Phys. Rev. C 70 (2004) 057901. arXiv:hep-ph/0406311, doi:10.1103/PhysRevC.70.057901.

[6] A. Bzdak, V. Koch, J. Liao, Charge-Dependent Correlations in Relativistic Heavy Ion Collisions and the Chiral Magnetic Effect, Lect. Notes Phys. 871 (2013) 503–536. arXiv:1207.7327.

[7] S. Schlichting, S. Pratt, Charge conservation at energies available at the BNL Relativistic Heavy Ion Collider and contributions to local parity violation observables, Phys. Rev. C 83 (2011) 014913. arXiv:1009.4283, doi:10.1103/PhysRevC.83.014913.

[8] V. Khachatryan, et al., Multiplicity and rapidity dependence of strange hadron production in pp, pPb, and PbPb collisions at the LHC, Phys. Lett. B 768 (2017) 103. arXiv:1605.06699, doi:10.1016/j.physletb.2017.01.075.

[9] V. Khachatryan, et al., Observation of long-range, near-side angular correlations in proton-proton collisions at the LHC, JHEP 09 (2010) 091. arXiv:1009.4122, doi:10.1007/JHEP09(2010)091.

[10] S. Chatrchyan, et al., Observation of long-range, near-side angular correlations in pPb collisions at the LHC, Phys. Lett. B 718 (2013) 795. arXiv:1210.5482, doi:10.1016/j.physletb.2012.11.025.

[11] V. Khachatryan, et al., Long-range two-particle correlations of strange hadrons with charged particles in pPb and PbPb collisions at LHC energies, Phys. Lett. B 742 (2015) 200. arXiv:1409.3392, doi:10.1016/j.physletb.2015.01.034.

[12] S. Chatrchyan, et al., Multiplicity and transverse momentum dependence of two- and four-particle correlations in pPb and PbPb collisions, Phys. Lett. B 724 (2013) 213. arXiv:1305.0609, doi:10.1016/j.physletb.2013.06.028.

[13] V. Khachatryan, et al., Evidence for collective multiparticle correlations in ppb collisions, Phys. Rev. Lett. 115 (2015) 012301. arXiv:1502.05382, doi:10.1103/PhysRevLett.115.012301.

[14] K. Dusling, W. Li, B. Schenke, Novel collective phenomena in high-energy proton-proton and proton-nucleus collisions, Int. J. Mod. Phys. E 25 (2016) 1630002. arXiv:1509.07939, doi:10.1142/S0218301316300022.

[15] V. Khachatryan, et al., Evidence for collectivity in pp collisions at the LHC, Phys. Lett. B 765 (2017) 193. arXiv:1606.06198, doi:10.1016/j.physletb.2016.12.009.

[16] V. Khachatryan, et al., Measurement of long-range near-side two-particle angular correlations in pp collisions at $\sqrt{s}$ = 13 tev, Phys. Rev. Lett. 116 (2016) 172302. arXiv:1510.03068, doi:10.1103/PhysRevLett.116.172302.

[17] 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, doi:10.1103/PhysRevC.94.041901.

[18] V. Khachatryan, et al., Observation of charge-dependent azimuthal correlations in pPb collisions and its implication for the search for the chiral magnetic effect, Phys. Rev. Lett. 118 (12) (2017) 122301. arXiv:1610.00263, doi:10.1103/PhysRevLett.118.122301.

[19] S. Chatrchyan, et al., The CMS experiment at the CERN LHC, JINST 3 (2008) S08004. doi:10.1088/1748-0221/3/08/S08004.

[20] B. Abelev, et al., Charge separation relative to the reaction plane in Pb-Pb collisions at $\sqrt{s_{NN}}$ = 2.76 TeV, Phys. Rev. Lett. 110 (2013) 012301. arXiv:1207.0900, doi:10.1103/PhysRevLett.110.012301.

[21] B. I. Abelev, et al., Observation of charge-dependent azimuthal correlations and possible local strong parity violation in heavy-ion collisions, Phys. Rev. C 81 (2010) 054908. arXiv:0909.1717, doi:10.1103/PhysRevC.81.054908.