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Charge asymmetry dependence of anisotropic flow in pPb and PbPb collisions with the CMS experiment

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Abstract

In nucleus-nucleus collisions, the linear dependence found for the elliptic flow harmonic of both positive or negative charged particles as a function of event charge asymmetry is predicted by the phenomenon known as the Chiral Magnetic Wave (CMW) due to its induced electric quadrupole moment. Here, the event charge asymmetry $A_{\rm ch}$ is defined as $\frac{N_+ - N_-}{N_+ + N_-}$, where N_+ and N_- are the number of positive and negative charged particles, respectively. However, other scenarios are also possible and may provide alternative explanations for the experimental results. New measurements of elliptic (v_2) and triangular (v_3) flow for positive and negative charged particles as a function of $A_{\rm ch}$ in pPb and PbPb collisions at $\sqrt{s_{NN}}$ = 5.02 TeV are presented, using data collected by the CMS experiment during the LHC runs 1 and 2. The slopes and intercepts of the charged-dependent v_n harmonics vs. $A_{\rm ch}$ are directly compared for pPb and PbPb collisions with similar charged-particle multiplicities, where a strong CMW effect is not expected in very high multiplicity pPb events. Moreover, a comparison is made of the slope parameters between v_2 and v_3 harmonics normalized by the inclusive charge particle v_n in PbPb collisions as a function of centrality. These results provide a means to discriminate between the CMW and other scenarios such as local charge conservation as possible explanations for the observed charge dependent behavior.

Keywords: CMW, Chiral Magnetic Wave, LCC, local charge conservation, small systems, chiral magnetic effect

1. Introduction

In relativistic nucleus-nucleus collisions, the nonzero axial chemical potential, induced by the chiral anomaly with an imbalance of left- and right-handed quarks, can produce an electric current along the magnetic field that is produced by the spectator protons [1, 2, 3]. The phenomenon of electric charge separation along the axis of magnetic field is known as the chiral magnetic effect (CME) [1]. The chiral separation effect (CSE) is a similar process, where the chiralities can be separated along the magnetic field direction due to the presence of the electric charges. The CME and CSE together form a collective excitation, known as the chiral magnetic wave (CMW). The propagation of the CMW produces an electric quadrupole moment in the system, where additional positive (negative) charges are accumulated away from (close to) the reaction plane [4].

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It has been proposed that this electric quadrupole moment in the quark-gluon plasma fireball can induce an effect on the second-order azimuthal anisotropic coefficient (known as "elliptic flow", v_2) of the final-state particles, which then exhibits a negative (positive) correlation to event charge asymmetry, $A_{ch} \equiv \frac{N_+ - N_-}{N_+ + N_-}$, for positive- (negative-) charged particles [4]. Here, N_+ and N_- denote the number of positive- and negative-charged particles in each event. Therefore, the elliptic flow coefficients (v_2) of positive- and negative-charged particles show a linear dependence on A_{ch} as follows, $v_{2,\pm} = v_{2,\pm}^{base} \mp r A_{ch}$,where $v_{2,\pm}^{base}$ represents the $v_{2,\pm}$ value when $A_{ch} = 0$ and the r denotes the slope parameter.

The observed A_{ch} values must be corrected for the detector acceptance and tracking efficiency to arrive at the corrected true A_{ch} values. Based on Monte Carlo (MC) simulations, the detector effects can be modeled as a Gaussian smearing to the true A_{ch} distribution, with the smearing width determined from observed A_{ch} distribution at a given true A_{ch}. With observed A_{ch} distribution in the data and smearing width from MC simulations, a correlation between the observed and true A_{ch} value in the data is established, which shows a linear relation. The linear slope is extracted as the correction factor and applied to obtain the corrected A_{ch} values in each multiplicity or centrality range of the data.

Recent measurements of charge asymmetry dependence of $v_{2,\pm}$ in AA collisions made at the BNL's RHIC and the CERN's LHC provide evidence in line with the CMW mechanism [5, 6, 7]. However, the interpretation of the results still remains highly debated. For example, the local charge conservation effect has been shown to qualitatively explain the charge-dependent v_2 data as a function of event charge asymmetry [8], where the signal arises from the interplay of finite detector acceptance and the dependence of v_n on transverse momentum (p_T) for charged particles from decays of resonances, resulting in a correlation between p_T averaged v_n and A_{ch}.

This contribution presents the measurements of charge asymmetry dependence of v_2 coefficients in pPb collisions, and both v_2 and v_3 coefficients in PbPb collisions at $\sqrt{s_{NN}} = 5.02$ TeV, using data collected with the CMS detector at the LHC [9]. The CMW contribution to any charge asymmetry dependent v_n signal is expected to be very small in a pPb collision compared to a PbPb collision with similar event multiplicity. This is mainly due to the fact that the induced magnetic field in pPb is much reduced in strength, and most importantly, oriented randomly with respect to the event plane [10]. Furthermore, a direct comparison of A_{ch}-dependent v_2 and v_3 coefficients in PbPb collisions can provide important evidence to differentiate between the CMW and local charge conservation (LCC) mechanisms.

2. Results

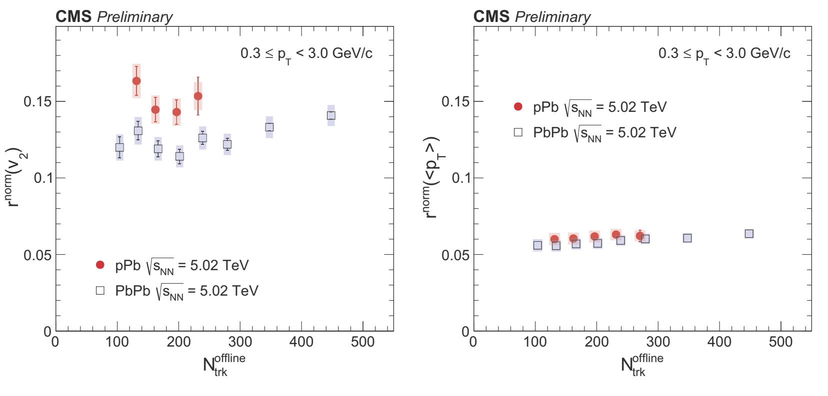

Fig. 1. The linear slope for v_2 (left) and $\langle p_T \rangle$ (right) parameters $r^{norm}(v_2)$ and $r^{norm}(\langle p_T \rangle)$ as a function of event multiplicity in pPb and PbPb collisions at $\sqrt{s_{NN}} = 5.02$ TeV. Statistical and systematic uncertainties are indicated by the error bars and shaded regions, respectively [11]