A Case for the Chiral Magnetic Effect in mid-peripheral Au-Au Collisions $\sqrt{s_{NN}}=200$ GeV.
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Abstract

The Chiral Magnetic Effect (CME) is predicted for mid-peripheral Au-Au collisions $\sqrt{s_{NN}}=200$ GeV at RHIC. However many backgrounds can give signals that make the measurement hard to interpret. The STAR experiment has made a measurement that makes it possible to separate out the background from the signal. An event shape analysis is the key for controlling the effects of Transverse Momentum Conservation (TMC) in the Au-Au collisions. LHC Pb-Pb collision $\sqrt{s_{NN}}=2.76$ TeV has made event plane measurements from which we calculate the CME and make predictions about what the event shape analysis should give.

1 Introduction

Topological configurations should occur in the hot Quantum Chromodynamic (QCD) vacuum of the Quark-Gluon Plasma (QGP) which can be created in heavy ion collisions. These topological configurations form domains of local strong parity violation (P-odd domains) in the hot QCD matter through the so-called sphaleron transitions. The domains might be detected using the Chiral Magnetic Effect (CME)[1] where the strong external (electrodynamic) magnetic field at the early stage of a (non-central) collision, through the sphaleron transitions induces a charge separation along the direction of the magnetic field which is perpendicular to the reaction plane. Such an out of plane charge separation, however, varies its orientation from event to event, either parallel or anti-parallel to the magnetic field (sphaleron or antisphaleron). Also the magnetic field can be up or down with respect to the reaction plane depending if the ions pass in a clockwise or anti-clockwise manner. Any P-odd observable will vanish and only the variance of such observable may be detected.

The STAR collaboration[2] has published a measurement of charge particle azimuthal correlations consistent with CME expectations. In Ref.[3] and used by STAR the CME can be indirectly approached through a two-particle azimuthal correlation given by

$$\gamma = \langle \cos(\phi_1 + \phi_2 - 2\Psi_{RP}) \rangle = \langle \cos(\phi_1 - \Psi_{RP})\cos(\phi_2 - \Psi_{RP}) \rangle - \langle \sin(\phi_1 - \Psi_{RP})\sin(\phi_2 - \Psi_{RP}) \rangle,$$

(1)

where $\Psi_{RP}$, $\phi_1$, $\phi_2$ denote the azimuthal angles of the reaction plane, produced particle 1, and produced particle 2. This two particle azimuthal correlation measures the difference between the in plane and out of plane projected azimuthal correlation. If we would rotate all events such that $\Psi_{RP} = 0.0$, then $\gamma$ would become

$$\gamma = \langle \cos(\phi_1 + \phi_2) \rangle = \langle \cos(\phi_1)\cos(\phi_2) \rangle - \langle \sin(\phi_1)\sin(\phi_2) \rangle.$$  

(2)
The CME predicts that $\gamma > 0$ for opposite sign-pairs and $\gamma < 0$ for same sign-pairs. There are other two particle azimuthal correlation effects that can depend on the reaction plane driven by elliptic flow even though the underlying correlation may be independent of the reaction plane. These backgrounds are summarized in Ref.[4]. It was pointed in Ref.[4] that the $\phi$ difference correlation ($\delta$) which is independent of the reaction plane gives a constraint on the CME and backgrounds.

$$
\delta = \langle \cos(\phi_1 - \phi_2) \rangle = \langle \cos(\phi_1)\cos(\phi_2) \rangle + \langle \sin(\phi_1)\sin(\phi_2) \rangle.
$$

In Ref.[4] Transverse Momentum Conservation (TMC) is derived and demonstrated that if there is no other correlation in the data except elliptic flow TMC will give a negative $\langle \cos(\phi_1 + \phi_2 - 2\Psi_{RP}) \rangle$ ($\gamma$) which is $v_2$ smaller than $\langle \cos(\phi_1 - \phi_2) \rangle$ ($\delta$). $\delta$ is a negative number given by TMC and scales as $1/N$ ($N$ is the number of particles). Depending on other correlations the connection between $\gamma$ and $\delta$ could be larger than $v_2$. Also in Ref.[4] Local Charge Conservation (LCC) is another important background and the details of LCC is found in Ref.[5]. The authors of Ref.[5] point out that for same sign pairs LCC should give a small negative sign, while for opposite sign pairs LCC should give a large positive correlation. Using the same coupling effect to the reaction plane as TMC, one should expect $\langle \cos(\phi_1 + \phi_2 - 2\Psi_{RP})_{++} \rangle$ ($\gamma$) equal $v_2$ times $\langle \cos(\phi_1 - \phi_2)_{++} \rangle$ ($\delta$) for the LCC.

Ref.[1] has pointed out that P-odd domains on the surface of the fireball omit same charge sign particles in the direction of the magnetic field. The particles that escape the surface would be of the same sign while the charge particles moving in the opposite direction would be of opposite sign. These particles would run into the fireball and be thermalized and lose their direction (quenched). This effect makes it hard to know what the CME should give for opposite sign pairs. Also when one considers opposite sign pairs the LCC effect is much stronger than the TMC effect making $\delta$ a large positive number. When we scale down by the expected $v_2$ to obtain $\gamma$ we obtain a larger positive number which is bigger than what is measured. $\delta$ (2.0) times $v_2$ (.06) equals $\gamma$ (.12) where the measured value of $\gamma$ is .06. We need some additional negative .06 from some other source. Minijet quenching can increase the $\langle \sin(\phi_1)\sin(\phi_2) \rangle$ term because there is more quenching out of plane than in plane. This could account for a reduction of .06. I think it is clear that having three important effects plus two quenching effects makes the opposite sign very hard to make an analysis. On the other hand LCC, minijets and CME quenching for the same sign can be considered unimportant.

The paper is organized in the following manner:

Sec. 1 is the introduction to correlations. Sec. 2 is an analysis of the same sign data. Sec. 3 LHC analysis and predictions. Sec. 4 presents the summary and discussion.

2 Same Sign Analysis

In performing the same charge sign analysis we will assume that only TMC and CME amplitudes are present in the Au-Au $\sqrt{s_{NN}}=200$ GeV data. We will use $\langle \cos(\phi_1 + \phi_2 - 2\Psi_{RP}) \rangle$ ($\gamma$) and $\langle \cos(\phi_1 - \phi_2) \rangle$ ($\delta$) of Ref.[2] in our analysis. Figure 1 is the $\gamma$ measurement of
STAR while Figure 2 is the $\delta$ measurement. We can separate the Transverse Momentum Conservation (TMC) effect in the Au-Au collisions using a STAR event shape analysis. For 20-40% centrality half of the tracks of the TPC are used in order to determine the reaction plane. The other tracks are used to calculate $\langle \cos(\phi_1 + \phi_2 - 2\Psi_{RP}) \rangle$ (\gamma) for same and opposite sign. Also $\langle \cos2(\phi - \Psi_{RP}) \rangle$ ($v_2$) is calculated for these tracks. The $v_2$ measures the shape of each subevent. For positive $v_2$ we have more tracks in plane, while for negative $v_2$ we will have more tracks out of plane. The value for TMC in the correlator $\gamma$ should be zero when $v_2$ is zero. The value should be negative when $v_2$ is positive and positive when $v_2$ is negative. On the other hand the CME should not depend on the event shape ($v_2$) but only on the collision geometry which is given by the centrality. Thus the magnetic field and the charge separation is a constant offset.

In Figure 3 the results are plotted from the STAR analysis which used correlators that are proportional to $-\gamma$. Ref.[4] used measurements from Ref.[2] for centrality range 50% to 60% because this should give the best measurement signal to errors. The value for $\langle \cos(\phi_1 + \phi_2 - 2\Psi_{RP}) \rangle$ (\gamma) is $-0.00045 \pm 0.00005$ and $\langle \cos(\phi_1 - \phi_2) \rangle$ (\delta) is $-0.00038 \pm 0.00010$. $v_2$ is 0.06 and from Figure 3 assuming that the data for the same charge sign will be proportional to the centrality range 50% to 60%, we can determine the ratio of pure CME to $\gamma$ at measured $\langle \cos2(\phi - \Psi_{RP}) \rangle = 0.0$ and $\langle \cos2(\phi - \Psi_{RP}) \rangle = 0.06$. Figure 3 gives a ratio of $0.60 \pm 0.15$.

2.1 Fit Model

The fit model that we will use assumes that the three experimental values $\gamma$, $\delta$ and the ratio for the centrality range 50% to 60% can be fitted by three equations.

\[
\gamma = \langle \cos(\phi_1 + \phi_2) \rangle = \text{CME} + \text{ScaleT} * \text{TMC}. \tag{4}
\]

\[
\delta = \langle \cos(\phi_1 - \phi_2) \rangle = \text{TMC} - \text{ScaleM} * \text{CME}. \tag{5}
\]

\[
\text{ratio} = \frac{\text{CME}}{\gamma} = \frac{\text{CME}}{\text{CME} + \text{ScaleT} * \text{TMC}}. \tag{6}
\]

Where ScaleT is the faction of the TMC which is measure as part of $\delta$ as translated to $\gamma$ and ScaleM is the faction of the CME which is measure as part of $\gamma$ as translated to $\delta$. From the above equations we have three equations and four unknowns.

2.2 In Plane and Out of Plane

Equation 2 and equation 3 show how $\gamma$ and $\delta$ can be broken up into an in plane term $\langle \cos(\phi_1)\cos(\phi_2) \rangle$ and an out of plane term $\langle \sin(\phi_1)\sin(\phi_2) \rangle$. If we would make a simple assumption that the in plane $\langle \cos(\phi_1)\cos(\phi_2) \rangle$ is equal to the TMC value and that the out of plane $\langle \sin(\phi_1)\sin(\phi_2) \rangle$ is equal to the CME value, one can fit the equation 4 and equation 5 with ScaleT and ScaleM equal 1.0. TMC is equal to $-0.00041$ and the CME is equal to $-0.00004$, but the ratio is only $0.09$ which is way off. Let us consider the behavior of the CME term. Let us look at the pure CME case. Equation 4 becomes

\[
\langle \cos(\phi_1)\cos(\phi_2) \rangle - \langle \sin(\phi_1)\sin(\phi_2) \rangle = \text{CME}, \tag{7}
\]
Figure 1: (Color) (Solid points) $\langle \cos(\phi_1 + \phi_2 - 2\Psi_{RP}) \rangle$ (γ) calculated for Au-Au $\sqrt{s_{NN}}=200$ GeV events data acceptance cuts of $0.15 < p_t < 2$ GeV/c and $|\eta| < 1.0$. Event generators HIJING used the same input and acceptance cuts with and without an elliptic flow afterburner. Also generators URQMD and MEVSIM where used. Blue symbols mark opposite charge correlations, and red are same charge. For MEVSIM, HIJING, and URQMD points the true reaction plane from the generated event was used for $\Psi_{RP}$. Thick, solid lighter-colored lines represent possible non-reaction-plane-dependent contribution from many-particle clusters, as estimated by HIJING and discussed in Sec. VIIA of Ref.[2].
Figure 2: (Color) $\langle \cos(\phi_1 - \phi_2) \rangle$ ($\delta$) calculated for Au-Au $\sqrt{s_{NN}}=200$ GeV events data acceptance cuts of $0.15 < p_t < 2$ GeV/c and $|\eta| < 1.0$. We show different charge combinations and forward full magnetic field (FF) and reverse full magnetic field (RFF) configurations. The data points corresponding to different charge and field configurations are slightly shifted in the horizontal direction with respect to each other for clarity. The error bars are statistical. Also shown are model predictions described in Sec. VII of Ref.[2].
Figure 3: The charge correlation difference $\langle A_{UD}^2 \rangle - \langle A_{LR}^2 \rangle$ and $\langle A_+A_- \rangle_{UD} - \langle A_+A_- \rangle_{LR}$ which is proportional to $-\gamma$ for the same sign pairs (squares) and opposite sign pairs (dots) under the selection of soft particles low-$p_t$ ($p_t < 2$ GeV/c) is plotted as a function of azimuthal anisotropy shape of the sub-events.
while equation 5 becomes

\[ \langle \cos(\phi_1)\cos(\phi_2) \rangle + \langle \sin(\phi_1)\sin(\phi_2) \rangle = -\text{ScaleM} \ast \text{CME}. \quad (8) \]

\( \langle \cos(\phi_1)\cos(\phi_2) \rangle \) and \( \langle \sin(\phi_1)\sin(\phi_2) \rangle \) can be written as

\[ 2\langle \cos(\phi_1)\cos(\phi_2) \rangle = (\text{CME} - \text{ScaleM} \ast \text{CME}), \quad (9) \]

and

\[ 2\langle \sin(\phi_1)\sin(\phi_2) \rangle = -(\text{CME} + \text{ScaleM} \ast \text{CME}). \quad (10) \]

We know that CME is left right symmetric therefore \( \langle \cos(\phi_1)\cos(\phi_2) \rangle \) term equation is zero thus

\[ 0.0 = (\text{CME} - \text{ScaleM} \ast \text{CME}), \quad (11) \]

or \( \text{ScaleM} = 1.0 \). This is true in general.

### 2.3 Final Fit

We have seen in the last subsection that in general \( \text{ScaleM} = 1.0 \) thus equation 4 through 6 becomes

\[ \gamma = \langle \cos(\phi_1 + \phi_2) \rangle = \text{CME} + \text{ScaleT} \ast \text{TMC}. \quad (12) \]

\[ \delta = \langle \cos(\phi_1 - \phi_2) \rangle = \text{TMC} - \text{CME}. \quad (13) \]

\[ \text{ratio} = \frac{\text{CME}}{\gamma} = \frac{\text{CME}}{\text{CME} + \text{ScaleT} \ast \text{TMC}}. \quad (14) \]

We now have three equations and three unknowns. After doing the fit we obtain Table I.

**Table I.** Fit parameters and errors.

| parameters | value     | errors       |
|------------|-----------|--------------|
| CME        | -.0002625 | +.0000638    |
| TMC        | -.0006460 | +.0001195    |
| ScaleT     | .2836     | +.1601       |

Ref.[4] made a prediction that ScaleT should be equal to \( v_2 \) or 0.06. However there must be some other correlation of same sign charge pairs which makes the effect four times bigger. Ref.[6] showed that there is a suppression of near side same sign charge pairs created by the strong chromo-electric fields inside the glasma flux tubes generated by the color glass initial state of the Au-Au collisions. This suppression greatly increases the negative TMC effect between back to back particles of the same charge sign.
3 LHC Analysis and Predictions

At the LHC the ALICE experiment has made measurements like STAR but on Pb-Pb at √s_{NN}=2.76 TeV. We will again performing a same charge sign analysis using \( \langle \cos(\phi_1 + \phi_2 - 2\Psi_{RP}) \rangle (\gamma) \) and \( \langle \cos(\phi_1 - \phi_2) \rangle (\delta) \). Figure 4 is the \( \gamma \) measurement of ALICE while Figure 5 is the \( \delta \) measurement. Since LHC is at such a higher energy hard scattering or jets play a larger role. Let us initially assume that only jets and CME are present in the data.

Again the fit model will use the centrality range 50% to 60% for the LH C. The value for \( \langle \cos(\phi_1 + \phi_2 - 2\Psi_{RP}) \rangle \) (\( \gamma \)) is -.0004 and \( \langle \cos(\phi_1 - \phi_2) \rangle \) (\( \delta \)) is .00125. The \( v_2 \) value for this data is .105. We break up the \( \gamma \) and \( \delta \) into an in plane term \( \langle \cos(\phi_1)\cos(\phi_2) \rangle \) and an out of plane term \( \langle \sin(\phi_1)\sin(\phi_2) \rangle \).

\[
\langle \cos(\phi_1)\cos(\phi_2) \rangle = 0.000425, \tag{15}
\]

and

\[
\langle \sin(\phi_1)\sin(\phi_2) \rangle = 0.000825. \tag{16}
\]

3.1 Jets and CME

Using Ref.[4] as applied to jets, we can write

\[
\gamma = \langle \cos(\phi_1 + \phi_2) \rangle = v_2 \text{Jet}. \tag{17}
\]

\[
\delta = \langle \cos(\phi_1 - \phi_2) \rangle = \text{Jet}. \tag{18}
\]

Thus solving for \( \langle \cos(\phi_1)\cos(\phi_2) \rangle \), we have

\[
\langle \cos(\phi_1)\cos(\phi_2) \rangle = 0.5(1 + v_2) \text{Jet} = .000425, \tag{19}
\]

and

\[
\langle \sin(\phi_1)\sin(\phi_2) \rangle = 0.5(1 - v_2) \text{Jet} + \text{CME} = .000825. \tag{20}
\]

The Jet = .0007692 and CME = -.00048 which is bigger than the RHIC value of -.00026.

3.2 TMC at the LHC

We need to add Transverse Momentum Conservation (TMC) to the LHC Pb-Pb same charge sign analysis. At first let us assume that scaling is not the same as for jets and could differ from \( v_2 \). We can rewrite equations 19 and 20 as

\[
\langle \cos(\phi_1)\cos(\phi_2) \rangle = 0.5(1 + v_2) \text{Jet} - 0.5(1 + \text{ScaleT}) \text{TMC} = .000425, \tag{21}
\]

and

\[
\langle \sin(\phi_1)\sin(\phi_2) \rangle = 0.5(1 - v_2) \text{Jet} - 0.5(1 - \text{ScaleT}) \text{TMC} + \text{CME} = .000825. \tag{22}
\]
Figure 4: The centrality dependence of the integrated three-particle correlator $\langle \cos(\phi_\alpha + \phi_\beta - 2\Psi_{RP}) \rangle$ measured with four independent methods: the cumulant method using TPC tracks; the event plane estimation using the TPC, using the ZDC, or using the VZERO detectors. The correlation between same charge pairs and opposite charge pairs are indicted on the figure.
Figure 5: The centrality dependence of the integrated two-particle correlator $\langle cos(\phi_\alpha - \phi_\beta) \rangle$ (δ) measured by ALICE (close symbols) and STAR (open symbols). The correlation between same charge pairs and opposite charge pairs are indicted on the figure.
The TMC value can be written in terms of the Jet value using equation 21.

\[
TMC = \frac{0.5(1 + v_2)\text{Jet} - 0.000425}{0.5(1 + \text{ScaleT})}.
\]  

(23)

TMC is a negative correlation and in equation 21 and 22 this negative sign has been taken into account making the TMC term of these equations positive. From equation 23 if TMC = 0.0 then Jet = .0007692. If we increase Jet then TMC will increase. How large is the Jet term in the LHC data? In the next subsection we use the opposite charge sign pairs in order to estimate the value of Jet and TMC.

### 3.3 Opposite Sign Data and the TMC

We can use the opposite charge sign data for centrality range 50% to 60% from Figure 4 and Figure 5. The value for \( \langle \cos(\phi_1 + \phi_2) \rangle \) (\( \gamma \)) is 0.0 and \( \langle \cos(\phi_1 - \phi_2) \rangle \) (\( \delta \)) is .0033. We break up the \( \gamma \) and \( \delta \) into an in plane term \( \langle \cos(\phi_1)\cos(\phi_2) \rangle \) and an out of plane term \( \langle \sin(\phi_1)\sin(\phi_2) \rangle \) and obtain

\[
\langle \cos(\phi_1)\cos(\phi_2) \rangle = (1 + v_2)\text{Jet} - 0.5(1 + v_2)TMC = .00165.
\]  

(24)

Note that for ScaleT we have used \( v_2 \) because for the opposite sign pairs there is no local suppression of near side pairs which increases the negative TMC effect between back to back particles. Also the 0.5 factor in front of the Jet term is gone. This doubling of the Jet term come from the fact that in p-p the opposite sign correlation for jets is twice the same sign correlation.

### 3.4 LHC Predictions

In the last two subsections we have determined two equations and two unknowns, namely the Jet term and the TMC term in equation 23 and equation 24. First let us consider the case where \( v_2 \) is .105 and ScaleT = \( v_2 \). From these two equations one gets Jet = .002217 and TMC = .001448. When we substitute these values into equation 22 the CME value is -.00048. This value is the same as determined in the the first LHC subsection where there was no TMC term.

What would an analysis of event shape give at the LHC? Like in the STAR event shape analysis we use half of the tracks of the TPC in order to determine the reaction plane. The other tracks are used to calculate \( \langle \cos(\phi_1 + \phi_2 - 2\Psi_{RP}) \rangle \) (\( \gamma \)) for same sign. Also \( \langle \cos(\phi - \Psi_{RP}) \rangle \) (\( v_2 \)) is also calculated for these same tracks. The \( v_2 \) measures the shape of each subevent. For positive \( v_2 \) we have more tracks in plane, while for negative \( v_2 \) we will have more tracks out of plane. The value for Jet plus TMC in the correlator \( -\gamma \) should be zero when \( v_2 \) is zero. The value of Jet plus TMC should be positive when \( v_2 \) is positive and negative when \( v_2 \) is negative. We have plotted Figure 3 again adding a solid line which is proportional to \( -\gamma \) that would be measured at ALICE if ScaleT is equal to \( v_2 \) (Figure 6). The slope of the solid line is negative instead of positive like it is at RHIC. The difference in sign comes from the positive value of \( \langle \cos(\phi_1 - \phi_2) \rangle \) (\( \delta \)) at LHC while at RHIC it is negative.
The effect of the TMC term in the $\gamma$ correlator was determined at RHIC and was four times larger than $v_2$. The same suppression of near side same sign charge pairs which is created by the strong chromo-electric fields inside the glasma flux tubes generated by the color glass initial state of the Pb-Pb collisions maybe at work. This suppression could greatly increases the negative TMC effect between back to back particles of the same charge sign. We do not know how strong this effect is at the LHC, but if we use the same value of ScaleT measured at RHIC ScaleT = .2836, then Jet = .002040 and TMC = .001094. When we substitute these values into equation 22 the CME value is -.000304. Again we can predict on Figure 6 (this time a dashed line) what should be measured at ALICE if ScaleT is equal to .2836. The slope of the dashed line has the same value as the solid line except it has the opposite sign. This slope is not as extreme as at RHIC. The slope is flatter than at RHIC because of a cancellation by the Jet term scaled down by $v_2$ (.105) with the TMC term scaled by ScaleT (.2836). At RHIC there is no Jet term.

4 Summary and Discussion

We have shown in this manuscript that The Chiral Magnetic Effect (CME) is consistent with the correlation analysis for same sign charge pairs done by the STAR experiment on mid-peripheral Au-Au Collisions $\sqrt{s_{NN}}=200$ GeV. There are backgrounds present which can give signals that make the CME measurement hard to interpret. The STAR experiment has made a measurement that makes it possible to separate out the background from the signal for the same sign charge pairs. For the same sign charge pairs the Transverse Momentum Conservation (TMC) term is the only major background and it will vary with the shape of particle production characterized by $\langle \cos(2(\phi - \Psi_{RP})) \rangle (v_2)$. The $v_2$ measures the shape of each event. For positive $v_2$ we have more tracks in plane, while for negative $v_2$ we will have more tracks out of plane. The value for TMC in the correlator $\langle \cos(\phi_1 + \phi_2 - 2\Psi_{RP}) \rangle (\gamma)$ should be zero when $v_2$ is zero. The value should be negative when $v_2$ is positive and positive when $v_2$ is negative. Thus through this event shape analysis one can measure the CME.

We have made a fit to same charge pairs correlations at a centrality value of 50-60% using equations 12-14. We have determined that at this centrality for Au-Au Collisions $\sqrt{s_{NN}}=200$ GeV the value of CME is -.0002625 +.0000638 -.0000845. The TMC is two and half times bigger and of the same sign. The CME is a flow of charge out of the reaction driven by the magnetic field. This flow causes a charge separation and should be measurable. We can define in an event by event manner an in plane and out of plane charge separation

$$\Delta Q_{\text{IN}} = (N_{+}^{L} - N_{-}^{L}) - (N_{+}^{R} - N_{-}^{R})$$  \hspace{1cm} (25)$$

and

$$\Delta Q_{\text{OUT}} = (N_{+}^{T} - N_{-}^{T}) - (N_{+}^{B} - N_{-}^{B}).$$  \hspace{1cm} (26)$$

If there is a flow of charge out of plane then $\Delta Q_{\text{OUT}}$ should be wider than the in plane $\Delta Q_{\text{IN}}$. For centrality 40-50% we show the $\Delta Q$ distributions (see Figure 7). In this Figure we also show that the rms difference between out of plane and in plane divided by the average rms of the two distributions. The fact that this difference is positive and not consistent with any
Figure 6: The STAR charge correlation difference $\langle A_{UD}^2 \rangle - \langle A_{LR}^2 \rangle$ and $\langle A_+ A_- \rangle_{UD} - \langle A_+ A_- \rangle_{LR}$ which is proportional to $-\gamma$ for the same sign pairs (squares) and opposite sign pairs (dots) under the selection of soft particles low-$p_t$ ($p_t < 2$ GeV/c) is plotted as a function of azimuthal anisotropy shape of the sub-events. The solid line is a prediction of what would be measured at the LHC if the ScaleT is equal to $v_2$ (.105). The dash is a prediction of what would be measured at the LHC if the ScaleT is equal to what it was at RHIC (.2836).
known background other than CME, we conclude that the CME is the best and simplest explanation of the data.

With the success of the RHIC Au-Au $\sqrt{s_{NN}}=200$ GeV CME measurement we considered the LHC Pb-Pb $\sqrt{s_{NN}}=2.76$ TeV measurements. First we find that $\langle \cos(\phi_1 - \phi_2) \rangle (\delta)$ as measured by ALICE for the same charge sign pairs has changed sign. We assume that this is because of the importance of hard scattering or jets playing a greater role. By adding a jet term we are able to determine the amount of CME for the same 50-60% centrality. The value of CME is a little less than twice the value measured at RHIC $-0.00048$ to $-0.00030$. We can also make a prediction for the shape dependence of the event shape analysis if it is done at ALICE using their TPC (see Figure 6). This event shape analysis is a very important test of our approach to the same charge sign correlation data. However if the TMC effects scales like it did at RHIC the sign of the event shape correlation slope sign will be the same as at
RHIC but of a smaller value. If this prediction is false then our analysis is false. One should note the lower range of the CME value falls with in the range of the RHIC result. One must also make the $\Delta Q$ measurements. The width of $\Delta Q_{\text{OUT}}$ must continue to be larger than $\Delta Q_{\text{IN}}$.

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