Charge asymmetry dependence of mean p_T in p-Pb and Pb-Pb collisions at $\sqrt{s_{NN}}$ = 5.02 TeV

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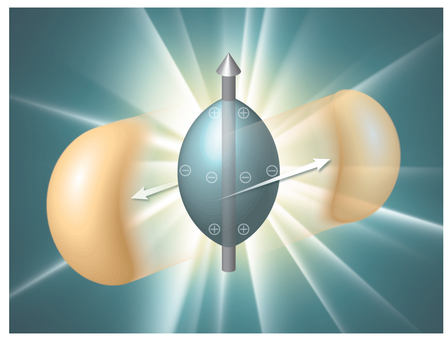
• Abstract

One of the novel anomalous chiral effects, the chiral magnetic wave (CMW), has been experimentally searched by the charge asymmetry (A_{ch}) dependence of elliptic flow (v_2) in recent years. The observed linear dependence between the A_{ch} and v_2 of the positively and negatively charged hadrons, however, still remains inconclusive owing to the existence of the background effects such as local charge conservation (LCC) entwined with the collectivity of the collision system. Here we present the simulation results of the mean transverse momentum (p_T) as a function of A_{ch} in p-Pb and Pb-Pb collisions at $\sqrt{s_{NN}}$ = 5.02 TeV. Such a study provides more insights into the search for CMW as well as the collective behavior of the Quark-Gluon Plasma (QGP).



• Definition

Charge asymmetry: $A_{ch} \equiv \frac{N^+ - N^-}{N^+ + N^-}$ Anisotropic flow: $\frac{dN}{d\varphi} \propto 1 + \sum_{n=1}^{\infty} 2v_n \cos[n(\varphi - \Psi_n)]$ with $v_n = \langle \cos[n(\varphi - \Psi_n)] \rangle$

• Motivation

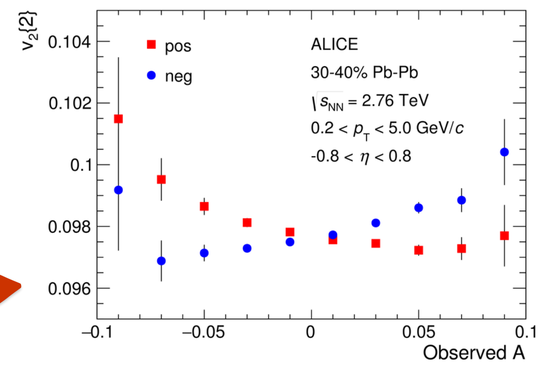
The **chiral magnetic wave** (CMW) [1], a collective excitation of the chiral magnetic effect (CME) and the chiral separation effect (CSE), has been theoretically proposed. By analogy with the electric dipole moment generated by the CME, the CMW could manifest itself in forming an electric quadrupole moment of the collision system, where the "poles" (out-of-plane) and the "equator" (in-plane) of the participant region respectively acquire additional positive or negative charges. Such a CMW-induced charge separation can be examined via **the A_{ch} dependence of v_2**, namely,

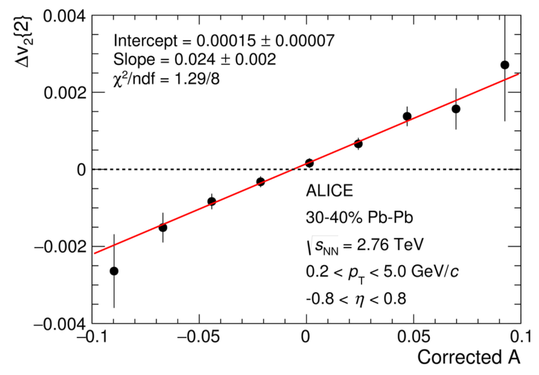
$$\Delta v_2 \equiv v_2^- - v_2^+ \simeq r A_{ch}$$

where the **slope parameter *r*** is used to quantify the strength of the quadrupole configuration. The experimental measurements have been reported by the ALICE [2], CMS [3] and STAR [4] collaborations at various collision energies and systems (right figure). A universal linear relation with the similar slope value ($r \sim 3\%$ at semi-central collisions) has been observed, seemingly matching the CMW expectation. On the other hand, the very similar slope surprisingly observed in p-Pb collisions indicates the existence of a common background. One of the main backgrounds is expected to be the **local charge conservation** (LCC) [5]. When convoluted with the characteristic dependence of v_2 on η and p_T, locally charge-conserved clusters originating from a fluid element or a resonance decay could be able to create a linear dependence between **the A_{ch} and the mean p_T**, i.e.,

$$\Delta \langle p_T \rangle \equiv \langle p_T^- \rangle - \langle p_T^+ \rangle \simeq r_{p_T} A_{ch}$$

where the r_{pT} is the slope between the Δp_T and A_{ch}. It is well known that v_2 has a strong dependence on the particle p_T. Therefore, the observed linear relationship between the p_T-integrated v_2 and A_{ch} is established.





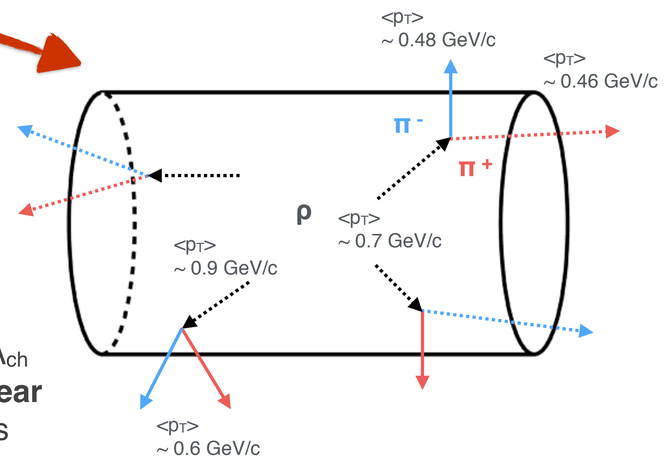
• ALICE experiment and the simulation

ALICE (A Large Ion Collider Experiment) is a major experiment at the LHC (Large Hadron Collider). ALICE detector is a multipurpose, large-acceptance detector, designed for the comprehensive study of the QGP created in the high energy collisions. The simulation framework of the ALICE experiment covers the simulation of primary collisions, the generation of the emerging particles and the transport of particles through the detector, etc. In this study, the events are simulated by the Monte Carlo generators HIJING [6] and DPMJET [7]. **HIJING** combines a QCD-inspired model of jet production using the Lund model for jet fragmentation. Hard or semi-hard parton scatterings with p_T of a few GeV are expected to dominate the collisions. **DPMJET** is an implementation of the two-component Dual Parton Model. It is based on the Gribov-Glauber approach and treats both soft and hard scattering processes in an unified way.

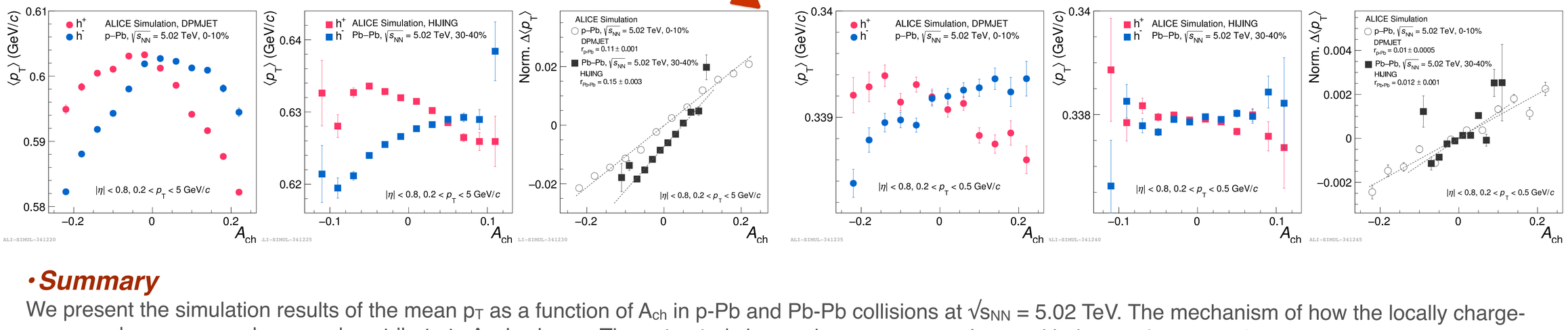
• Results and discussions

In the generated MC events, one can trace the locally charge-conserved pairs, i.e. ρ meson, and study how they decay and contribute to A_{ch}. As the right figure shown, those ρ mesons with relatively higher $\langle p_T \rangle$ (~0.9 GeV/c) tend to decay into π pairs with a smaller opening angle, so both of the daughters locate within the detector acceptance, leading to zero A_{ch}. Those ρ mesons with relatively lower $\langle p_T \rangle$ (~0.7 GeV/c) are apt to decay into π pairs with larger opening angle, only one of which can be experimentally measured, leading to the non-zero A_{ch}. In addition, the $\langle p_T \rangle$ of the daughters in the above two cases are also different. Due to such a mechanism, one can always find that

$$A_{ch} < 0 \Rightarrow \langle p_T \rangle^{\pi-} < \langle p_T \rangle^{\pi+} \qquad A_{ch} > 0 \Rightarrow \langle p_T \rangle^{\pi-} > \langle p_T \rangle^{\pi+}$$



Not only the resonance but all the primary particles are likely to be influenced by the LCC via the fluid element. The A_{ch} dependence of $\langle p_T \rangle$ in the MC events are presented in the figures below. Without invoking the charge separation, **clear linear dependences between $\langle p_T \rangle$ and A_{ch} can be seen**. The normalized slope value r_{pT} between $\Delta\langle p_T \rangle$ and A_{ch} is found to be **~0.11** for p-Pb collisions and **~0.15** for Pb-Pb collisions. Such values are well consistent with the ones reported by the CMS experiment (**~0.12**). One can narrow down the p_T coverage to reduce such a $\langle p_T \rangle$ - A_{ch} dependence. When changing the p_T upper limits from 5 to 0.5 GeV/c, the slopes get reduced to **~0.01** (by 1/10). Therefore, it is important to perform the measurements of v_2 at the narrow p_T range to eliminate the LCC effect as low as possible.



• Summary

We present the simulation results of the mean p_T as a function of A_{ch} in p-Pb and Pb-Pb collisions at $\sqrt{s_{NN}}$ = 5.02 TeV. The mechanism of how the locally charge-conserved resonances decay and contribute to A_{ch} is shown. The extracted slope values r_{pT} are consistent with the previous experimental measurement. Our study provides more insights into the search for CMW as well as the collective behavior of the QGP.

• Reference

[1] Phys. Rev. Lett. 107, 052303 (2011). **[2]** Rev. C 93, 044903 (2016). **[3]** ArXiv:1708.08901 [Nucl-Ex] (2017). **[4]** Phys. Rev. Lett. 114, 252302 (2015). **[5]** Physics Letters B 726, 239 (2013). **[6]** Phys. Rev. D 44, 3501 (1991). **[7]** http://sroesler.web.cern.ch/sroesler/dpmjet3.html

Acknowledgement

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