Directed Flow of Charged Particles at Midrapidity Relative to the Spectator Plane in Pb-Pb Collisions at $\sqrt{s_{\rm NN}} = 2.76$ TeV

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The directed flow of charged particles at midrapidity is measured in Pb-Pb collisions at $\sqrt{s_{\rm NN}} =$ 2.76 TeV relative to the collision symmetry plane defined by the spectator nucleons. A negative slope of the rapidity-odd directed flow component with approximately 3 times smaller magnitude than found at the highest RHIC energy is observed. This suggests a smaller longitudinal tilt of the initial system and disfavors the strong fireball rotation predicted for the LHC energies. The rapidity-even directed flow component is measured for the first time with spectators and found to be independent of pseudorapidity with a sign change at transverse momenta p_T between 1.2 and 1.7 GeV/c. Combined with the observation of a vanishing rapidity-even p_T shift along the spectator deflection this is strong evidence for dipolelike initial density fluctuations in the overlap zone of the nuclei. Similar trends in the rapidity-even directed flow and the estimate from two-particle correlations at midrapidity, which is larger by about a factor of 40, indicate a weak correlation between fluctuating participant and spectator symmetry planes. These observations open new possibilities for investigation of the initial conditions in heavy-ion collisions with spectator nucleons.

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The goal of the heavy-ion program at the Large Hadron Collider (LHC) is to explore the properties of deconfined quark-gluon matter. Anisotropic transverse flow is sensitive to the early times of the collision, when the deconfined state of quarks and gluons is expected to dominate the collision dynamics (see reviews [1–3] and references therein), with a positive (in-plane) elliptic flow as first observed at the Alternating Gradient Synchrotron (AGS) [4,5]. A much stronger flow was subsequently measured at the Super Proton Synchrotron (SPS) [6], Relativistic Heavy Ion Collider (RHIC) [7–9], and recently at the LHC [10–12]. Elliptic flow at RHIC and the LHC is reproduced by hydrodynamic model calculations with a small value of the ratio of shear viscosity to entropy density [13–16]. Despite the success of hydrodynamics in describing the equilibrium phase of matter produced in a relativistic heavy-ion collision, there are still large theoretical uncertainties in determination of the initial conditions. Significant triangular flow measured recently at RHIC [17,18] and LHC [12,19,20] energies has demonstrated [21,22] that initial energy fluctuations play an important role in the development of the final momentum-space anisotropy of the distribution of produced particles.

The collision geometry is illustrated in Fig. 1, which depicts the participant overlap region and spectators as viewed in (a) the reaction plane and (b) the plane perpendicular to the beam. Figure 1(a) shows the projectile and target spectators repelled in the reaction (xz) plane from the center of the colliding system along the impact parameter (x) direction. An alternative scenario where spectators

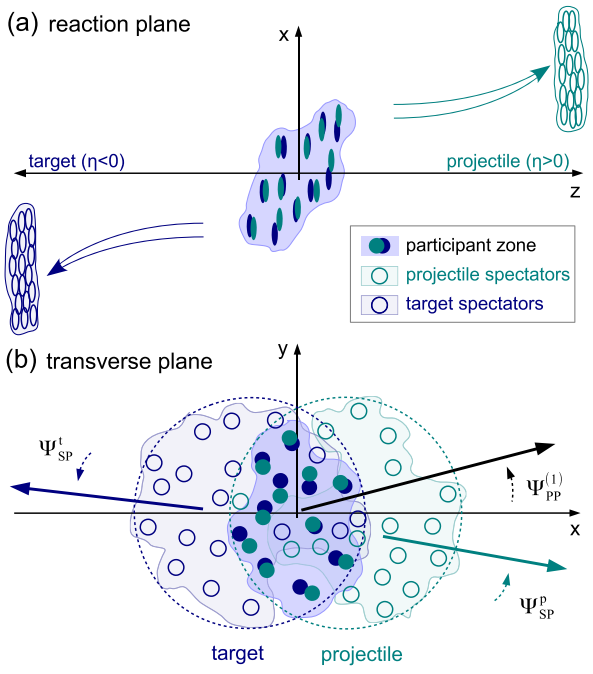

FIG. 1 (color online). Sketch of a noncentral heavy-ion collision. See text for description of the figure.

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