Directed Flow v_1 and the Sign of Elliptic Flow v_2

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The two Forward TPCs (FTPCs [1]) of the STAR experiment [2] extend the pseudorapidity coverage of STAR into the region $2.5 < |\eta| < 4.0$. During RHIC run 2 about 70 thousand Au+Au collisions at a center of mass energy of $\sqrt{s_{NN}} = 200$ GeV were taken with both FTPCs and the STAR TPC [3].

The first measurement of directed flow at RHIC [4] showed that while $v_1(\eta)$ is close to zero at mid-rapidities, the signal rises to a couple of percent near pseudorapidity $|\eta| \approx 4$. From this observation it became clear that the STAR TPC sitting at mid-rapidity has very good capabilities to measure elliptic flow, while the Forward TPCs allow to measure directed flow. In order to utilize the method of Fourier decomposition and suppress non-flow contributions at the same time, we measure v_1 using a mixed harmonic technique: We determine the first order reaction plane Ψ_1 in the FTPCs and the second order reaction plane Ψ_2 in the TPC. Using the recently proposed notation (see [4]) we denote this measurement as

$$v_1\{\mathrm{EP1,EP2}\} = \frac{\left\langle \cos\left(\phi + \Psi_1^{\mathrm{FTPC}} - 2\Psi_2^{\mathrm{TPC}}\right)\right\rangle}{\sqrt{\left\langle \cos\left(\Psi_1^{\mathrm{FTPC_1}} + \Psi_1^{\mathrm{FTPC_2}} - 2\Psi_2^{\mathrm{TPC}}\right)\right\rangle \cdot \mathrm{Res}(\Psi_2^{\mathrm{TPC}})}},$$

where

$$\mathrm{Res}(\Psi_2^{\mathrm{TPC}}) := \langle \cos 2(\Psi_2 - \Psi_{\mathrm{RP}})\rangle$$

represents the resolution of the second order event plane measured in the TPC.

As shown in Fig. 1, the results are in reasonable agreement with the published measurement obtained by the three-particle cumulant method $v_1\{3\}$.

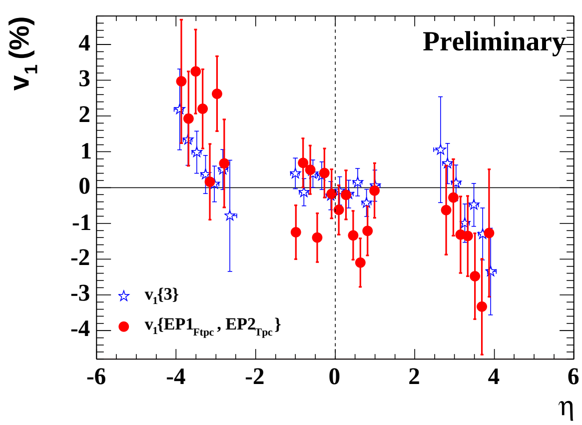

FIG. 1: Directed flow as a function of pseudorapidity. The measurements of $v_1\{\mathrm{EP1,EP2}\}$ (red circles; centrality 20–60%) agree within the errors with the published results of $v_1\{3\}$ (centrality 10–70%) [4].

This new method provides an elegant tool to measure the sign of v_2, which was assumed to be positive but had not yet been determined at RHIC energies. One of the quantities involved in the measurement of $v_1\{\mathrm{EP1,EP2}\}$ is proportional to the product of the integrated values of v_1^2 and v_2. Applying the proper factors for weights and multiplicities [5] leads to

$$v_1^2 \cdot v_2 = \left(\frac{4}{\pi}\right)^{\frac{3}{2}} \sqrt{\prod_d \frac{1}{M_d} \frac{\langle w_d^2\rangle}{\langle w_d\rangle^2}} \cdot \left\langle \cos\left(\Psi_1^{\mathrm{FTPC_1}} + \Psi_1^{\mathrm{FTPC_2}} - 2\Psi_2^{\mathrm{TPC}}\right)\right\rangle,$$

where the index d represents the three detectors used in the analysis: $\mathrm{FTPC_1}$, $\mathrm{FTPC_2}$, and TPC. For each centrality class M_d denotes the corresponding multiplicities and w_d are the applied weights (η-weighting for Ψ_1 and p_T-weighting for Ψ_2). Since v_1^2 is always positive, the sign of $v_1^2 \cdot v_2$ determines the sign of v_2.

Averaged over centralities 20–60% we measure $v_1^2 \cdot v_2$ in Fig. 2 to be $(2.34 \pm 0.98) \cdot 10^{-5}$. In this region the expected non-flow contributions are much smaller than for the most central and peripheral centrality bins. Therefore the sign of v_2 is determined to be positive: *In-plane* elliptic flow is confirmed.

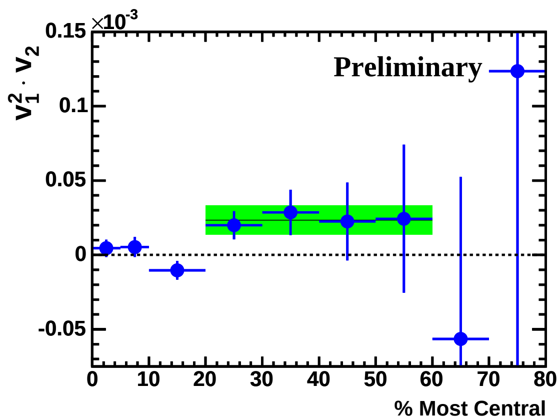

FIG. 2: The product of v_1^2 and v_2. Since the mean value of this quantity, averaged over centralities 20–60%, is $(2.34 \pm 0.98) \cdot 10^{-5}$, elliptic flow is measured to be *in-plane*.

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