Charged hadron elliptic and triangular flow in Cu+Au at $\sqrt{s_{NN}} = 200\text{GeV}$

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Quark-gluon-plasma (QGP) is considered to be a hot and dense nuclear matter which is a phase of matter in quantum chromodynamics. A QGP was created by colliding nuclei at the Relativistic Heavy Ion Collider (RHIC).

One of the strong evidence to prove the formation of QGP is that the low momentum particle production is anisotropic. Azimuthal anisotropy originates from initial spatial geometry. For low momentum particles, anisotropic collective flow is considered to result from the hydrodynamic expansion of QGP. Further the strength of azimuthal anisotropic flow has been used to determine the specific viscosity over entropy ratio ($\eta/s$) of QGP and the initial spatial condition by comparing it with the theoretical model. Thus measuring the azimuthal anisotropic flow is a good method to investigate the bulk property of QGP and the space time expansion mechanism.

The produced particle distribution is expressed as a Fourier expansion series as follows

$$\frac{dN}{d\phi} \propto 1 + \sum_{n=1}^{2} 2v_n \cos(n(\phi - \Psi_n))$$

where $v_n = \langle \cos(n(\phi - \Psi_n)) \rangle_n$ corresponds to the strength of anisotropic flow, $\phi$ is the azimuthal angle of the produced particle, $\Psi_n$ is the $n_{th}$ order event plane that is the average of all emitted particles angles. So far the $2_n$ order flow harmonic $v_2$ which is called elliptic flow has been studied in symmetric systems such as Au+Au, the $3_n$ order flow harmonic $v_3$ which is called triangular flow was not predicted to exist because initial geometry was considered to be symmetric. However recently, a large $v_3$ was measured at RHIC. The $v_3$ is assumed to have originated from the initial spatial fluctuation.

In 2012, a Cu+Au collision was performed at RHIC. In Cu+Au collisions, the initial spatial geometry is asymmetric. The pressure gradient is predicted to be different for the Au and Cu sides. Thus the different expansion at the Au and Cu sides will lead to the asymmetric emission of particles. The $v_n$ in the Cu+Au collision could help determine $\eta/s$ and the initial spatial condition.

Figure 1 illustrates the $N_{\text{part}}$ dependence of $v_2$ and $v_3$ for three collision systems. The system size dependence of $v_2$ is clearly seen. The $v_2$ values in Cu+Au collisions are between those in Au+Au and Cu+Cu data sets and $v_2$ in all systems increases as $N_{\text{part}}$ decreases, the difference of $v_2$ values between the different systems reduce with a decreasing $N_{\text{part}}$. The $N_{\text{part}}$ dependence of $v_2$ and $v_3$ could be expected from those of $2_n$ and $3_n$ order initial spatial anisotropies ($\epsilon_2$ and $\epsilon_3$). The $\epsilon_2$ and $\epsilon_3$ are calculated using a Glauber Monte Carlo simulation. Figure 2 illustrates comparison between $v_2$ and $v_3$ as a function of $p_T$ with event-by-event hydrodynamical calculation with $\eta/s$ for 20-30% centrality bin. In this hydrodynamical calculation, Glauber Monte Carlo simulations are employed as the initial spatial condition and 4$\pi/s = 1$ or 4$\pi/s = 2$ is used. The hydrodynamical calculation with 4$\pi/s = 1$ has better agreement with $v_2$ and $v_3$ at low $p_T$ than 4$\pi/s = 2$, whereas at high $p_T$ hydrodynamical calculation with 4$\pi/s = 2$ has better agreement with $v_2$ and $v_3$ than 4$\pi/s = 1$.

**References**