Measurements of directed, elliptic, and triangular flow in Cu+Au collisions at $\sqrt{s_{NN}} = 200\text{GeV}^{\dagger}$

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In relativistic high-energy heavy-ion collisions, a hot and dense nuclear matter called quark-gluon plasma (QGP) is considered to exist. Until now several measurements and theoretical calculations have suggested the successful formation of QGP and the produced QGP is a nearly perfect fluid.

The measurements of the azimuthal anisotropies of particle emission is a strong tool to investigate the property of QGP. In relativistic heavy-ion collisions, the initial spatial anisotropy of the overlap region of the off-center nuclear-nuclear collisions is converted to an anisotropy in momentum space through the pressure gradient. Namely, azimuthal anisotropic flow originates from the initial spatial geometry and is considered to result from the hydrodynamic expansion of QGP. Thus, azimuthal anisotropy provides us with the initial spatial condition and the bulk property of QGP. The azimuthal anisotropic flow is expressed as the coefficients of the Fourier expansion series as follows,

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

where $v_n = \langle \cos(n(\phi - \Psi_n)) \rangle$(n=1,2,3,4...) is the magnitude of azimuthal anisotropy. ϕ is the azimuthal angle of each particle and Ψ_n called the n_{th} order Event Plane that is the azimuthal direction in which more particles are emitted. The first order coefficient is the magnitude of directed particle emission called Directed flow. In symmetric collision systems, the signal of Directed flow around the collision point is very small due to the symmetric interaction region. The second order coefficient is the magnitude of elliptical particle emission called Elliptic flow. So far the measurements of v_2 have been hardly studied in symmetric collision systems and concluded the viscosity η/s of QGP is small. The third harmonic coefficient is the magnitude of triangular particle emission called Triangular flow. v_3 originates from the initial nucleon fluctuation. The combined even and odd harmonic coefficients provide more stringent constraint on the initial condition and the viscosity of QGP than v_2 measurement alone.

In 2012, Cu and Au collisions were operated at RHIC. This was the first asymmetric heavy-ion collision for controling initial spatial geometry. In Cu+Au collisions systems, asymmetric initial conditions lead to an asymmetric pressure gradient and particle production for the Cu and Au side. The measurements of v_n in the Cu+Au collisions further constrain viscosity and initial conditions.

Figure 1 shows the sizable v_1 measured as the function of transverse momentum p_T for four multiplicity classes. The v_1 is measured with respect to the Cu spectator neutrons that do not participate in the collisions. In all multiplicity classes, high p_T particles that come from the Au nuclei are indicated by negative v_1.

Figures 2,3 illustrate v_2 and v_3 measured as functions of p_T compared to the hydrodynamical calculation. The event-by-event hydrodynamical calculation with two different viscosities reproduce v_2 and v_3 simultaneously.

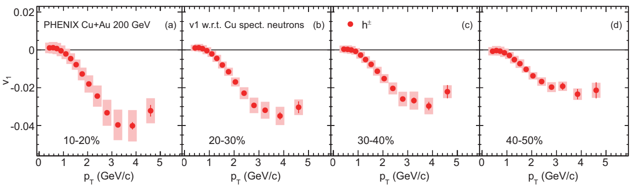

Fig. 1. $v_1(p_T)$ for four different multiplicity classes

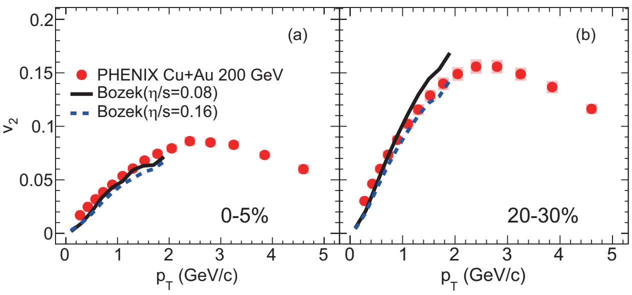

Fig. 2. $v_2(p_T)$ for two different multiplicity classes compared to hydrodynamical calculation

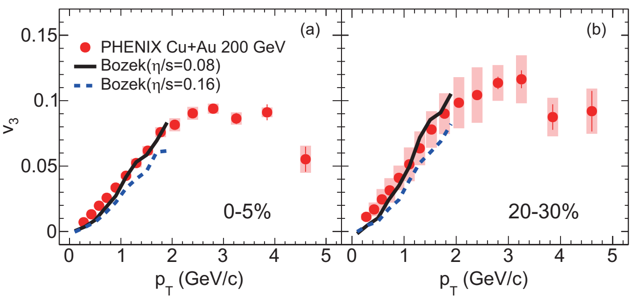

Fig. 3. $v_3(p_T)$ for 2 different multiplicity classes compared to hydrodynamical calculation

References

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