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Identified particle v_3 measurement at 200 GeV Au+Au collisions at RHIC-PHENIX experiment

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Higher order harmonics flow $v_{n,n\geq 3}$ is considered to be important because it is expected to be more sensitive to η/s than v_2. It has been known that identified particle v_2 has particle mass dependence in lower p_T region and different behavior in meson and baryon. Identified particle v_3 in Au+Au collisions at $\sqrt{s_{NN}}$ = 200GeV are presented. It is observed that identified particle v_3 has also mass dependence and different behavior in meson and beryon as same as in v_2. For the v_3, the number of constituent quark scaling as a function of KE_T/n_q doesn't work as good as observed in v_2. By comparison the experimental data and viscous hydrodynamics expansion, Glauber initial conditions and η/s=0.08 has found to describe the experimental data.

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1. Introduction

Quark-gluon plasma(QGP) study has been continued in Relativistic Heavy Ion Collider(RHIC) from 2000. It is known that emitted particles are not isotropic for azimuthal direction in each collistion. This is called the azimuthal anisotropy. This is sensitive to initial participant geometry, and η/s(the ratio of shear viscosity(η) to entropy density(s)) during QGP expansion. Measurement of azimuthal anisotropy is very important because it has early information in collisions, that is QGP information.

Ideal heavy ion that consists of an infinite number of nucleon and surface is smooth, always makes participant almond shape. And elliptic expansion of the almond shape give rise to v_2. But real heavy ion consists of a finite number of nucleon. So, initial participant geometry fluctuates, and this fluctuation makes higher order harmonics flow. And the higer order harmonics flow is expected to be more sensitive to η/s than v_2. Recently, higher order harmonics flow($v_{n,n\geq 3}$) is measured actively.

Charged particle $v_{2,3}$ has been measrued as a function of p_T for different centrality bins in Fig.1. Centrality dependence of v_2 and v_3 is found to be strong and weak, respectively. This indicates that v_3 is caused by initial participant fluctuation. Fig.2 shows comparison between v_2, v_3 and model calculations. It is known that v_2 is well described Glauber initial model and hydro-expansion with $4\pi\eta/s$=1, MC-KLN with $4\pi\eta/s$=2. v_3 can be described Glauber with $4\pi\eta/s$=1 better than MC-KLN with $4\pi\eta/s$. As seen above, v_3 study can be important for defining initial geometry calculation model and hydro-dynamic property η/s.

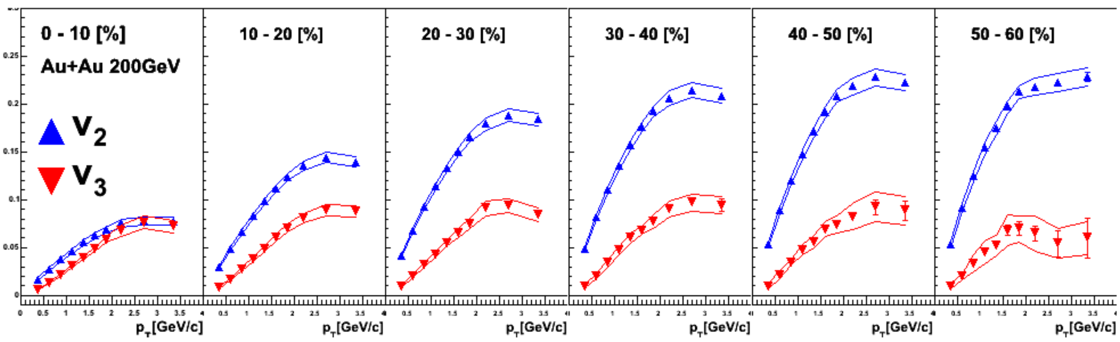

Figure 1: charged particle v_2 and v_3 versus p_T for 10% centrality bins[1]

It is known that v_2 as a function of p_T has different behavior for different particle species(Fig.3(left)). This provides us two important things. First, there is mass ordering in low p_T region, and this indicates that these can be described by hydrodynamics. Second, meson(pion and kaon) and baryon(proton) are different behavior, and difference between meson and baryon is number of constituent quarks. v_2 as a function of $KE_T(=\sqrt{m_0^2+p_T^2}-m_0)$ scaled by the number of constituent quarks is consistent with all particles(Fig.3(right)). This indicates that collective flow has been made in quark state(QGP).

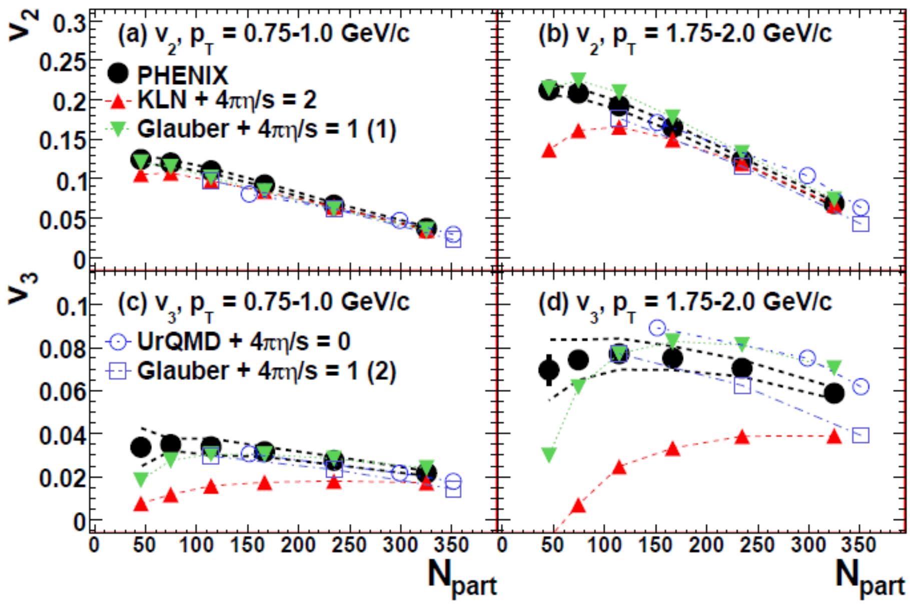

Figure 2: charged particle v_2 and v_3 versus N_{part} are compared with model calculations[1]

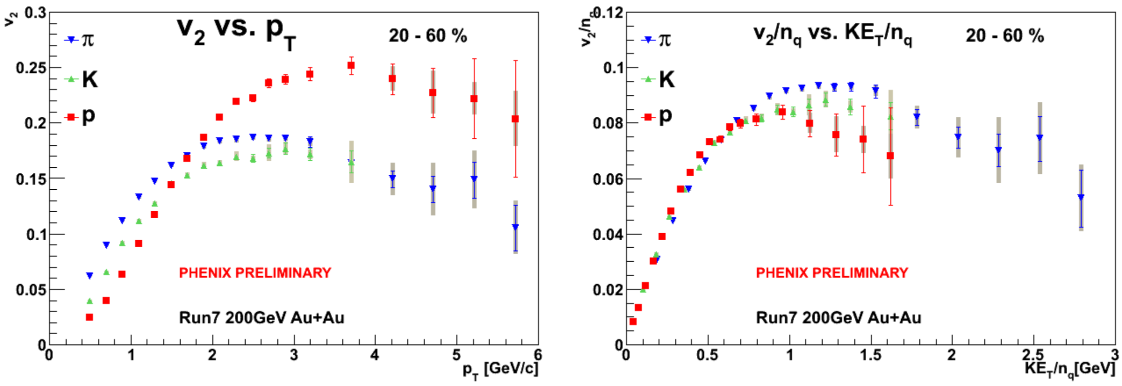

Figure 3: Identified particle v_2 for 20-60% centrality in Au+Au $\sqrt{s_{NN}}$=200GeV. As a function of p_T(left). Quark number scaling as a function of KE_T(right).

2. Data and method

The results presented are derived from Au+Au collisions obtaind during the 2007 RHIC runnning period. To measure the anisotropy, fourier series expansion is used for number of paricle in the azimuthal angle.

$$dN/d\phi = N_0[1+\sum 2v_n \cos\{n(\phi-\Psi_n)\}] \tag{2.1}$$

$$v_n = <\cos\{n(\phi-\Psi_n\}> \tag{2.2}$$

v_n is anisotropy signal, ϕ is azimuthal angle of particle measured by PHENIX Central Arm detectors and Ψ_n is n-th Event Plane. This v_n measurement using Event Plane method is called by Event Plane method. Ψ_n has been calculated by Reaction Plane detector(RxN) in this analysis. RxN has North(South) arms(up-down stream of beam) and both have two radial ring structures(Inner and Outer), coverage range in psudorapidity is that Inner is $1.5 < |\eta| < 2.8$ and Outer is $1.0 < |\eta| < 1.5$.

Fro measurement Ψ_n there are 3 steps: gain correction of each detector cell, re-centering of Q-vector and higher order fluttening. Because we cannot watch the participant shape directry, observed Event Plane($\Psi_{n,obs}$) is not true Event Plane($\Psi_{n,true}$). For extracting $v_{n,true}$, we have to use the following function.

$$v_{n,ture} = v_{n,obs}/\mathrm{Res}\{\Psi_n\} \tag{2.3}$$

$\mathrm{Res}\{\Psi_n\}$ indicates the resolution of $\Psi_{n,obs}$. In this analysis, resolution is estimated by correlating the Event Planes from two arms Reaction Plane detector up and down stream of the beam.

3. Result

Fig.4 shows the results of identified particle v_3 as a function of p_T and KE_T in mid-central(20-50% centrality). Mass ordering in v_3 has been observed in low p_T and v_3 of meson/baryon seems to be reversed at intermediate p_T, same as v_2.

The number of constituent quarks scaling has been tested for v_3 as a function of p_T and KE_T(Fig.5). $v_3(KE_T/n_q)$ scaling doesn't work as good as v_2. v_3 as a function of p_T/n_q seemes to be scaled better than KE_T/n_q.

Fig.6 shows predictions of identified particle v_3 as a function of p_T in central(0-5%) Au+Au collisions at RHIC, from viscous hydrodynamics. Upper groups are Glauber initial conditions and hydro-expansion with η/s=0.08 prediction, lowers are CGC with η/s=0.16. As a result of comparison between these predictions and result(Fig.4(left)), Glauber with η/s=0.08 works better. Although centrality bins are somewhat different, it can still be compared, because the centrality dependence of v_3 is known to be weak(Fig.1).

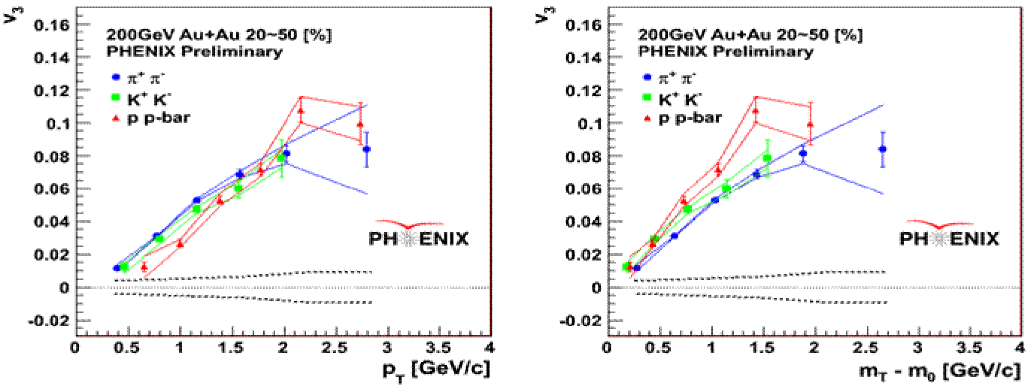

Figure 4: Identified particle v_3 in mid-central Au+Au collisions(20-50% centrality). Left figure : as a function of the transverse momentum, p_T. Right figure : as a function of the kinetic energy $m_T - m_0$.

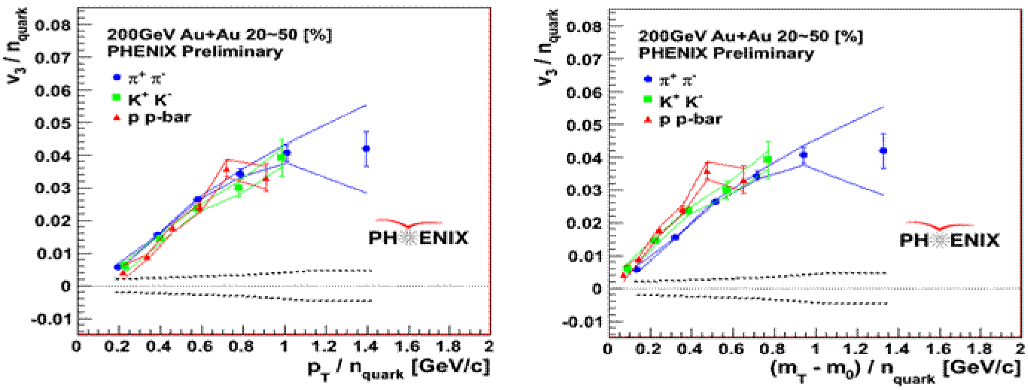

Figure 5: Identified particle v_3 is scaled by the number of constituent quarks in mid-central Au+Au collisions(20-50% centrality). Left figure : as a function of the transverse momentum per quark, p_T/n_q. Right figure : as a function of the kinetic energy per quark $(m_T - m_0)/n_q$.

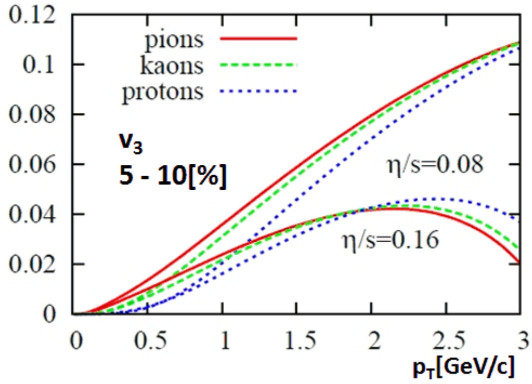

Figure 6: Hydrodynamic predictions of identified particle v_3 as a function of p_T in central(0-5%) Au+Au collisions at RHIC. Uppers are Glauber initial conditions and η/s=0.08. Lowers are CGC initial conditions with η/s=0.16.[2]

References

[1] A.Adare et al(PHENIX Collaboration) (2011) arXiv:1105.3928v1[nucl-ex]

[2] Burak Han Alver (2010) arXiv:1007.5469v2[nucl-th]