Result of the energy scan program at RHIC-PHENIX

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1 Introduction

According to quantum chromodynamics, quarks and gluons are confined with strong forces in hadrons. It is expected that they are de-confined at a high temperature or high density[1,2]. This is called Quark Gluon Plasma (QGP), which may have existed in the early universe according to the big bang theory or in the core of a neutron star[3,4]. Experimentally, it is formed by relativistic heavy ion collision with a collider. The system geometry is elliptical at the first stage of a non-central collision. The geometrical anisotropy generates the asymmetry in the yield of particles as a function of the azimuthal angle with respect to the event plane of an event. The azimuthal anisotropy indicates an interaction with a short mean free path of partons in a hot dense medium. It also gives information about the initial state and its expansion, possibly through the QGP phase. The magnitude of azimuthal anisotropy of particle emission is measured as the second term of a Fourier series (v_2),

$$dN/d\phi = N(1 + 2v_2 \cos 2(\phi - \Psi)), \quad (1)$$

where N is number of the particle emissions, ϕ is azimuthal angle of the particle emission [rad], and Ψ is the event plane angle [rad].

2 Quark number scaling of hadron v_2

The measured large v_2 of hadrons is an indicator of the small mean free path in the hot dense medium and a hydrodynamic model with a low viscosity reproduces the collective behavior of the particles[5,6]. Meanwhile, the v_2 value scales with the constituent quark number and is independent of the particle mass. It indicates that the flow of hadrons is built up by the flow of quarks in the QGP according to the quark coalescence model. The v_2 of hadrons is the sum of the v_2 of combined partons in the quark coalescence model as follows,

$$v_2^{hadron}(p_T) = n v_2^{parton}(\frac{p_T}{n}), \quad (2)$$

where n is the number of partons in hadrons[7,8]. The experimental result of quark number scaling of v_2 suggests the quark level collectivity in the hot dense matter and the quark coalescence mechanism forms hadrons from quark matter via quark-gluon phase transition in the Au+Au $\sqrt{s_{NN}} = 200$ GeV collision at RHIC-PHENIX[9].

The study of v_2 with the energy scan of heavy ion collision may provide information about the threshold behavior of collision energy, if the quark number dependency is an indicator of a QGP phase. A new reaction plane detector was installed to measure the v_2 of hadrons with an enhanced event plane resolution at the RHIC-PHENIX experiment[10]. The higher resolution allows us to study v_2 at low energy collisions, which have low statistics of particles.

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3 Results of the energy scan program at RHIC-PHENIX

The v_2 of π^+ π^-, K^+, K^-, p, $\bar{p}$ and d were measured in the Au+Au $\sqrt{s_{NN}} = 39$ and 62 GeV collisions[11]. The number of constituent quark scaling of the v_2 of hadrons is mostly established in these energies (fig.1 shows the results of 39 GeV). Considering this as an indication of the QGP phase, the threshold energy of the QGP-hadron phase transition would be lower than $\sqrt{s_{NN}} = 39$ GeV. In contrast, particle (especially p) v_2 differs from anti-particle v_2 in these lower beam energy collisions. It could be given by interactions such as p-$\bar{p}$ annihilation in the high baryon density caused by the baryon stopping in the low energy collision.

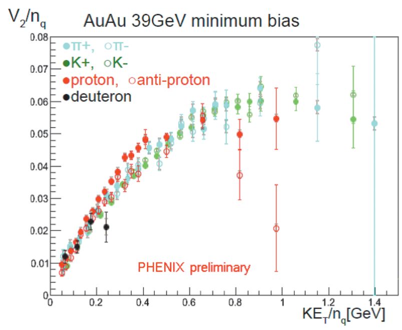

Fig. 1. The scaled hadron v_2 as a function of $KE_T = m_T - m$ with the number of constituents quarks in the Au+Au $\sqrt{s_{NN}} = 39$. The KE_T scale cancels the p_T shift by the collective behavior.

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