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Measurement of Charged Hadron Spectra in Au+Au Collision at $\sqrt{s_{NN}} = 62.4$ GeV at RHIC-PHENIX

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1. Introduction

In high energy heavy ion collisions at RHIC, a large excess in the yield of protons (anti-protons) over pion yield was found in the medium to high transverse momentum (p_T) region [1]. p/π ratios increase gradually up to 2.5 GeV/c and stay almost flat. Top values of p/π^+ is about 1 and $\bar{p}/\pi^-$ is about 0.8 in most central collisions. This phenomenon was not expected from a general picture of hadron production through the jet fragmentation process [2]. High p_T particles are generated from a hard process at an early time of collisions. Thus, it is believed that particles over 2 GeV/c of transverse momentum follow the fragmentation model. However a baryon excess has occurred around p_T 2 ~ 4 GeV/c range.

To explain this phenomenon, a new idea of particle generation has been proposed, which is called a quark recombination model [3,4]. In this model, a high-momentum parton picks up some other partons from the abundant source of hot and dense deconfined matter, and they form mesons and baryons. The numerical calculations show that the process favors the baryon production in the momentum range between 2 ~ 4 GeV/c.

It should be interesting to see the results at different collision energies, in order to investigate more deeply the hadron formation process. There is a low energy collision run at the PHENIX experiment $\sqrt{s_{NN}} = 62.4$ GeV in Run4.

2. Measurement of charged hadrons at PHENIX

The PHENIX detector has a pair of central-arm spectrometers, called as East-arm and West-arm, each of which covers mid-rapidity region from -0.35 to +0.35.

Measuring incoming particles to the beam axis is required to determine a centrality and vertex points. Beam-Beam Counter (BBC) and Zero Degree Counter (ZDC) are located at near the beam line and these devices measure the centrality and the vertex point in each collision. Drift Chamber (DC) serves as a device for particle tracking and momentum determination. Also Pad Chambers (PC) are located in each arms to rise a precision of tracking. Ring Imaging Cherenkov counter (RICH) and Electro Magnetic Calorimeter (EMC) are fully installed in each arms.

A main difference between West-arm and East-arm is that the West-arm has Aerogel Cherenkov Counter (ACC) and the East-arm has a Scintillation counter of Time of Flight (TOF). One of the scheme of particle identification (PID) is measuring particle momentum and time of flight,

thus TOF is used as PID device. Another technique for PID is measuring a correlation between a Cherenkov light yields and momentum. High p_T particles can be identified by the ACC with measuring Cherenkov light emissions.

In this analysis, the ACC is used as a PID device for pions, while the TOF is used for protons. Preliminary results of charged hadrons analysis by TOF can be seen in [5].

ACC is a new detector subsystem which was installed before Run-4. The performance is reported in [6].

3. Analysis

Figure 1. Particle identification range of pion and kaon for Aerogel Cherenkov counter.

38 M of minimum biased events were collected in the RUN4 Au+Au collisions at $\sqrt{s_{NN}} = 62.4$ GeV.

The centrality is distinguished in 4 centrality bins (0-10%, 10-30%, 30-60% and 60-83.7%) at this RUN period. Charge sum of BBC with corrections of multiplicity and vertex points are used to determine the centrality. However a basic technique to obtain a centrality which used at $\sqrt{s_{NN}} = 200$ GeV can't be applied for 62.4 GeV analysis, because energy deposit at the ZDC is too small to get a correlation between BBC and ZDC. Currently the most peripheral (60-83.7%) has some background events, therefore results of this centrality are not be shown. This centrality determination is commonly used among the PHENIX collaborations.

Tracking selections and the the PID method are explained in following. At First, all of charged tracks are measured by DC, and good qualified tracks are selected. Furthermore PC responses at projection points of tracks are checked and good tracks are selected. The particle identification has been done by ACC and EMC time-of-flight. Figure 1 shows a correlation between momentum and number of counted photo-electrons (p.e) at the ACC. Solid lines in Fig.1 are expected mean value of p.e for charged pion and kaon. Also dot-lines shows 2σ range from mean value for each particles. The range between 2σ lines are used for the PID selection. However an overlap region of pion and kaon above 3.5 GeV/c are exclude from charged pion analysis.

In order to determine the overall detector efficiency, single particle simulation data are generated. Total number of generated data are 4 M events. Collection factors for a detector inefficiency are calculated from the simulation data using a particle selection conditions same as the real data analysis.

4. Results

Figure 2. Charged pion spectra for each centrality.

Figure 2 shows charged pion invariant yield spectra for each centrality in Au+Au collisions at $\sqrt{s_{NN}} = 62.4$ GeV. Inverse triangles mean pion spectra measured by ACC and EMC. Also open circles mean pion spectra measured by TOF. ACC and TOF results are consistent up to 3.0 GeV/c with in each centrality. ACC can identify charged pions up to 4.5 GeV/c, however more detail study is needed to show more high p_T region.

p/π^+ and $\bar{p}/\pi^-$ ratios in three different centrality bins are shown in Fig. 3. In this case proton and anti-proton spectra are refer from a TOF analysis [5]. It is clearly seen from the figure that an excess of proton (anti-proton) yield over pion yield become prominent with increase of centrality.

The proton excess is consistent to $\sqrt{s_{NN}} = 200$ GeV data

Figure 3. p/π ratios for each centrality.

at the region above 2.5 GeV/c. One difference between 62.4 GeV and 200 GeV data is that 62.4 GeV data tend to start increasing from more lower p_T than 200 GeV/c. One of the main process around 1.5 GeV/c is a soft process for the hadron productions. Therefore to explain the difference of the proton excess in low p_T region, other effects such as a shadowing effect should be considered.

5. Summary

Charged pion invariant yield spectra were measured using Aerogel Counter in RUN4 PHENIX Au+Au collisions at $\sqrt{s_{NN}} = 62.4$ GeV. Combined with charged pion spectra and proton spectra which measured by TOF, p/π ratio were obtained. Proton excess was also clearly seen in $\sqrt{s_{NN}} = 62.4$ GeV Au+Au collision. More study for Aerogel analysis is needed to obtain more than 3.0 GeV p/π ratio.

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