Vol. 5 (2012) *Acta Physica Polonica B Proceedings Supplement* No 2

SINGLE ELECTRON ANALYSIS OF PHENIX Cu+Cu COLLISIONS AT CENTER-OF-MASS ENERGY 200 GeV PER NUCLEON PAIR*

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(Received December 27, 2011)

Analysis of single electrons created in $\sqrt{s_{NN}} = 200$ GeV Cu+Cu collisions at the PHENIX experiment at RHIC can reveal the influence of the medium on heavy flavor particles created in such collisions. Heavy flavor single electron spectra are presented after use of a cocktail background subtraction, as well as a cross-check using a converter to find photonic background. Comparisons of the nuclear modification factor to d+Au and Au+Au collisions of similar $N_{\rm coll}$ are done.

DOI:10.5506/APhysPolBSupp.5.285
PACS numbers: 12.38.Mh, 25.75.–q, 13.20.Fc

1. Motivation

Heavy flavor is an important probe of the medium generated in a heavy-ion collision. Charm and bottom quarks are generated in the initial stages of the collisions in gluon fusion reactions. We can study the interaction of heavy flavor with the nuclear medium via observables such as the nuclear modification factor, R_{AA}, and collective flow via event anisotropy.

PHENIX has previously measured the single electron spectra in $\sqrt{s_{NN}} = 200$ GeV p+p [2] and Au+Au [3] collisions. These previous results have shown that the heavy flavor electron spectrum is suppressed at higher $p_{\rm T}$ in the Au+Au system relative to p+p. This suppression is of roughly the same magnitude as that of lighter species.

* Presented at the Conference "Strangeness in Quark Matter 2011", Kraków, Poland, September 18–24, 2011.

2. Experimental method

Data is collected from the two central arms of the PHENIX at RHIC experiment [1]. The detectors included are the Drift Chamber, Pad Chambers, Ring Imaging Cherenkov Counter (RICH), and Electromagnetic Calorimetry. Momentum is measured via track geometry in the detector's magnetic field through use of hits in the drift chamber and pad chambers. Energy measurement in the calorimeter is used to help in separating electrons from hadronic background. Cherenkov ring shape is used as well in order to identify electron candidates. Note that hadrons with a momentum of less than 5 GeV do not create hits in the (RICH), allowing for further differentiation.

2.1. Background cocktail

The primary sources of background are photonic conversions and π^0 Dalitz decays. Various other light mesons contribute also to the total background (η, $\eta^{'}$, ρ, ω, ϕ, and K_{e3}). A cocktail method is used to describe the background (shown in Fig. 1). In the lower p_{T} range (up to 5 GeV/c), the $\pi^0 \rightarrow \gamma ee$ decay is the most significant contribution. The neutral and charged pion spectra from Run 5 200 GeV Cu+Cu collisions are fit to obtain their form. Then, the high-p_{T} ratios are used in combination with m_{t} scaling in order to obtain the spectra of the other species. These spectra are assumed to be described by modified Hagedorn functions

$$E\frac{d^3N}{d^3E} = \frac{c}{\left(e^{-ap_{\mathrm{T}}-bp_{\mathrm{T}}^2} + \frac{p_{\mathrm{T}}}{p^0}\right)^n}\,, \tag{1}$$

where p_{T} is the parent particle transverse momentum and a, b, c, p_0, and n are constants.

In order to calculate the contribution of weak K_{e3} decays ($K^0 \rightarrow \pi^{\pm}e^{\mp}\nu_e$ and $K^{\pm} \rightarrow \pi^0 e^{\mp}\nu_e$) to the electron cocktail, the charged and neutral kaon distributions in 200 GeV Cu+Cu collisions are fit and the resulting distribution is put through a full detector simulation in order to recreate the spectrum. Since these kaons have large displaced vertices (the charged kaon has a $c\tau$ of 3.712 meters and the K^0_{L} of 15.34 meters), only electrons from K_{e3} decays of very low momenta will leave tracks which can be mistaken for coming from the primary vertex. Simulation shows that the K_{e3} distribution quickly becomes negligible as the momentum increases, contributing less than 1% of the yield above $p_{\mathrm{T}} = 1.0$ GeV/c.

Photonic conversion electrons are one of the major sources of contamination. These occur within the material of the detector. The number of conversions depends on the number of radiation lengths photons must traverse. Most photons below 5 GeV/c come from the decay $\pi^0 \rightarrow \gamma\gamma$. To

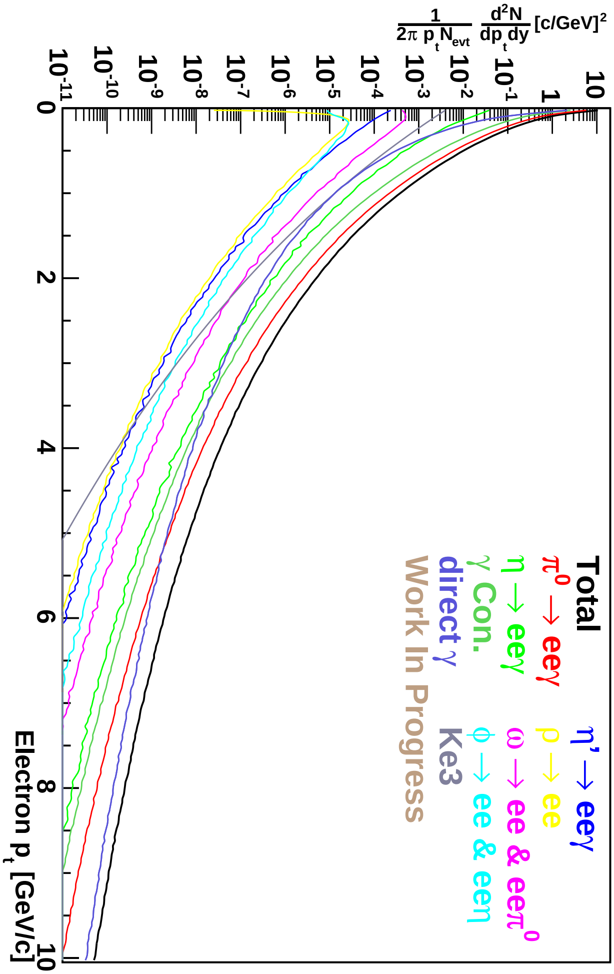


Fig. 1. Electron cocktail for minimum bias Cu+Cu collisions at $\sqrt{s_{NN}} = 200\,\text{GeV}$.

estimate the photonic electron spectrum in cocktail, the decays $\pi^0 \to \gamma\gamma$ and $\pi^0 \to \gamma e^+e^-$ were simulated for the complete detector setup. The ratio of electrons from $\pi^0 \to \gamma\gamma$ over $\pi^0 \to \gamma e^+e^-$ allows a conversions coefficient to be calculated as a function of p_{T}.

Another source of photonic electrons are direct virtual photons. The NLO prediction can be scaled by number of collisions to the Cu+Cu system or the PHENIX direct photon spectrum in Cu+Cu can be fit directly. The current analysis uses the former method, but a cross-check will be done with the latter. With the direct photon spectrum, it is possible to calculate the kinematics of the resulting electron conversions.

2.2. Converter cross-check

During the data collection period a brass cylinder of known radiation length was placed inside the PHENIX detector, surrounding the beam pipe. 182 million minimum bias events were taken using the converter compared to 871 million without.

Non-converter electrons are defined as a sum of photonic plus non-photonic contributions

$$N^{\text{converter}-\text{out}} = N^{\gamma} + N^{\text{non}-\gamma}\,. \tag{2}$$

The converter has two effects: the number of photonic electrons is boosted by a factor R_γ due to the addition of converter material and there is also a small attentuation, ϵ, of non-photonic electrons due to the presence of the said material

$$N^{\text{converter}-\text{in}} = R_\gamma N^{\gamma} + (1-\epsilon) N^{\text{non}-\gamma}\,. \tag{3}$$

The previous two equations can be solved for photonic and non-photonic electrons in terms of experimental measurements N^{γ} and $N^{\text{non}-\gamma}$ and known quantities, R_γ and ϵ

$$N^{\text{non}-\gamma} = \frac{R_\gamma N^{\text{converter}-\text{out}} - N^{\text{converter}-\text{in}}}{R_\gamma - 1 + \epsilon}\,, \tag{4}$$

$$N^{\gamma} = \frac{N^{\text{converter}-\text{in}} - (1-\epsilon) N^{\text{converter}-\text{out}}}{R_\gamma - 1 + \epsilon}\,. \tag{5}$$

3. Results

Converter results are largely consistent with those measured via cocktail. Because of the relationship of photonic electrons to other sources of background in the cocktail via the ratio of $\frac{\pi^0 \to \gamma\gamma}{\pi^0 \to \gamma e^+ e^-}$, the converter check also helps to verify the full cocktail.

By subtracting out the contaminants via the cocktail method, a spectrum of electrons from decays of charm and beauty mesons is generated. This is shown in figure 2. By dividing the spectrum in $\sqrt{s_{NN}} = 200$ GeV Cu+Cu by the proton–proton spectrum, a R_{AA} distribution is generated which shows the nuclear effects of the Cu+Cu system. By separation it into centrality bins, the Cu+Cu system can be compared with Au+Au (Fig. 3 (a)) and d+Au (Fig. 3 (b) and Fig. 3 (c)). Centrality bins are selected for comparison in order to match the number of nucleon–nucleon collisions (N_{coll}) in a given system and to see if there is a smooth transition into larger collisions from d+Au through Cu+Cu into Au+Au. As one can see, central $\sqrt{s_{NN}} = 200$ GeV Cu+Cu collisions (0 to 20% centrality) are consistent with

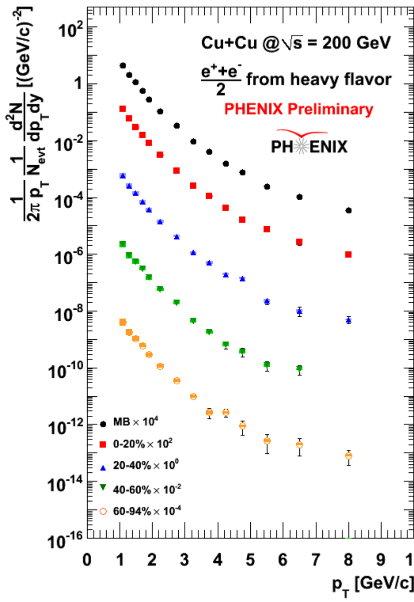
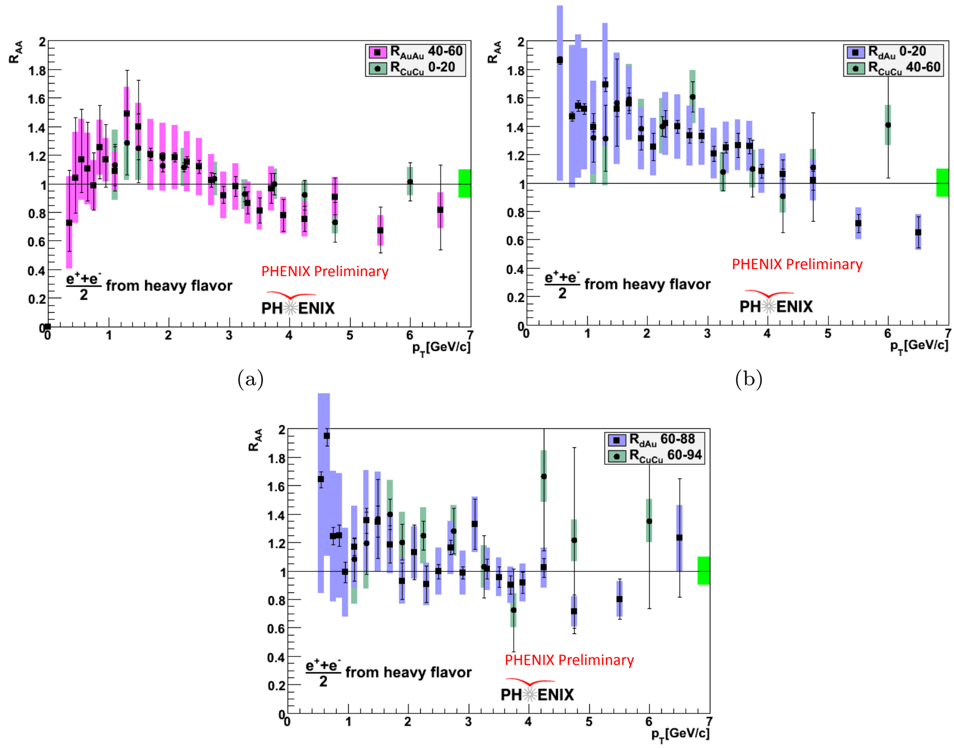


Fig. 2. Heavy flavor electron spectra in $\sqrt{s_{NN}} = 200\,\text{GeV}$ Cu+Cu collisions for various centrality bins. These results are from the cocktail method.

mid-peripheral $\sqrt{s_{NN}} = 200\,\text{GeV}$ Au+Au collisions (40 to 60% centrality). More peripheral $\sqrt{s_{NN}} = 200\,\text{GeV}$ Cu+Cu collisions (40 to 60% centrality) are consistent with central $\sqrt{s_{NN}} = 200\,\text{GeV}$ d+Au collisions (0 to 20% centrality) and there is also agreement in the most peripheral collisions of both systems (60 to 80% centrality Cu+Cu *vs.* 80 to 94% centrality d+Au).



(a) (b)

(c)

Fig. 3. (a) Comparison of R_{AA} at centrality 0 to 20% Cu+Cu ($N_{\rm coll} = 151.8$) to 40 to 60% Au+Au ($N_{\rm coll} = 90.65$). (b) Comparison of R_{AA} at centrality 40 to 60% Cu+Cu ($N_{\rm coll} = 22.3$) to 0 to 20% d+Au ($N_{\rm coll} = 15.1$). (c) Comparison of R_{AA} at centrality 80 to 94% Cu+Cu ($N_{\rm coll} = 5.1$) to 60 to 80% d+Au ($N_{\rm coll} = 3.2$).

4. Conclusions

PHENIX has successfully measured the electron spectrum from the decays of charm and bottom mesons in $\sqrt{s_{NN}} = 200$ GeV Cu+Cu collisions via a cocktail background subtraction method. The converter method verifies the consistency of the cocktail. Preliminary results indicate that the heavy flavor electron spectra in $\sqrt{s_{NN}} = 200$ GeV Cu+Cu are not highly suppressed at higher transverse momenta, in contrast with the central Au+Au system at 200 GeV but are similar to peripheral Au+Au collisions of similar $N_{\rm coll}$.

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