Single leptons from heavy-flavor decays at RHIC

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Inclusive transverse momentum spectra of single electrons from Au+Au collisions have been measured at $\sqrt{s_{NN}} = 130$ GeV and 200 GeV at midrapidity by the PHENIX experiment at RHIC. After subtraction of background from photon conversions and light hadron decays, the spectra appear consistent with semileptonic decays of charmed particles.

1. Introduction

Particles carrying heavy flavor, *i.e.* charm or beauty quarks, are an important probe of the hot and dense medium created in high energy heavy-ion collisions. Heavy-flavor production proceeds mainly via gluon-gluon fusion in the collision's earliest stage, thus being sensitive to the initial gluon density [1,2] and to nuclear effects, such as shadowing. While propagating through the dense medium which could be in a deconfined state, quarks can lose energy by gluon radiation [3,4]. This might lead to a softening of final state particle spectra. Furthermore, heavy-flavor measurements provide an important baseline for the study of quarkonium suppression, which is a proposed signal of deconfinement [5].

The direct reconstruction of heavy-flavor decays, *e.g.* $D^0 \to K^-\pi^+$, is difficult in the high-multiplicity environment of a heavy-ion collision. An alternative is to determine the contributions from semileptonic heavy-flavor decays, *e.g.* $D \to eK\nu$, to single lepton and lepton pair spectra. PHENIX follows this approach in the analysis of single electrons, $(e^+ + e^-)/2$, measured in Au+Au collisions at $\sqrt{s_{NN}} = 130$ GeV [6] and 200 GeV.

2. Experiment and Analysis

The data used for this analysis were recorded by the PHENIX east-arm spectrometer ($\Delta\phi = 90^\circ$ in azimuth, $|\eta| < 0.35$ in pseudorapidity) which is described in detail elsewhere [7]. The electron measurement employs a multitude of subdetectors [6]. Beam-beam counters and zero-degree calorimeters provide the minimum bias trigger, measure the vertex position, and are used for centrality selection. Charged particle tracks are reconstructed with drift chambers and a layer of pad chambers. Electron identification is performed with ring imaging Cerenkov detectors and electromagnetic calorimeters. The raw spectra are corrected for geometrical acceptance, reconstruction and particle-identification efficiency, and for the multiplicity dependent efficiency loss due to detector occupancy.

*for the full PHENIX Collaboration author list and acknowledgements, see Appendix "Collaborations" of this volume.

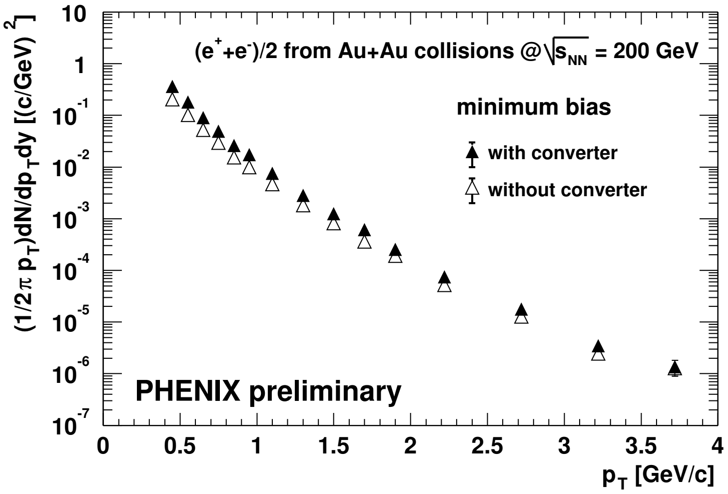

Figure 1: Invariant p_T spectra of electrons from minimum bias Au+Au collisions at $\sqrt{s_{NN}} = 200$ GeV measured in PHENIX without and with the additional photon converter installed.

The resulting invariant p_T distribution of electrons, measured from about $5.6M$ minimum bias Au+Au collisions, is shown in Fig. 1. The main sources contributing to the electron spectra can be divided into two categories[2], *photonic* sources, *i.e.* conversion of photons in material in PHENIX and Dalitz decays of light mesons, and *non-photonic* sources, *i.e.* semileptonic decays of heavy flavor. To separate these from each other as described below, a data set of about $3.2M$ minimum bias Au+Au collisions was used where a photon converter was added to the standard PHENIX setup. The converter, a thin brass tube with a radius of 29 cm, was installed in the center of PHENIX with the cylinder axis aligned with the beam line. The p_T distribution of electrons from the converter run is compared with the distribution measured without converter in Fig. 1. At low p_T the converter roughly doubles the electron yield. Since the spectral shapes of electrons from Dalitz decays and from photon conversions are almost identical one would expect the two spectra in Fig. 1 to exhibit the same shape if all electrons were from photonic sources only. The fact that the spectra approach each other at high p_T indicates the presence of a non-photonic source.

The non-photonic electron spectra are calculated in three steps. First, the spectra of electrons originating from photon conversions in the converter itself are obtained by subtracting the spectra measured without converter from those measured with converter. The result is corrected for the difference in material between the standard PHENIX setup and the setup with converter. Taking into account the relative contribution from Dalitz decays, the spectra of electrons from photonic sources in the standard setup are calculated from the pure conversion electron spectra in the second step. Finally, the spectra of electrons from non-photonic sources are obtained by subtracting the resulting electron spectra from photonic sources from the electron spectra measured in the standard setup.

3. Results and Discussion

The spectra of electrons from non-photonic sources in minimum bias Au+Au collisions at $\sqrt{s_{NN}} = 200$ GeV are shown in Fig. 2 together with the corresponding spectra from 130 GeV [6]. Note that the two data sets have been determined with two complementary methods with different systematic uncertainties, *i.e.* the converter method at 200 GeV and a cocktail subtraction method at 130 GeV. The curves in Fig. 2 correspond to predictions

[2] The contribution from other sources, *e.g.* vector meson decays, is only marginal.

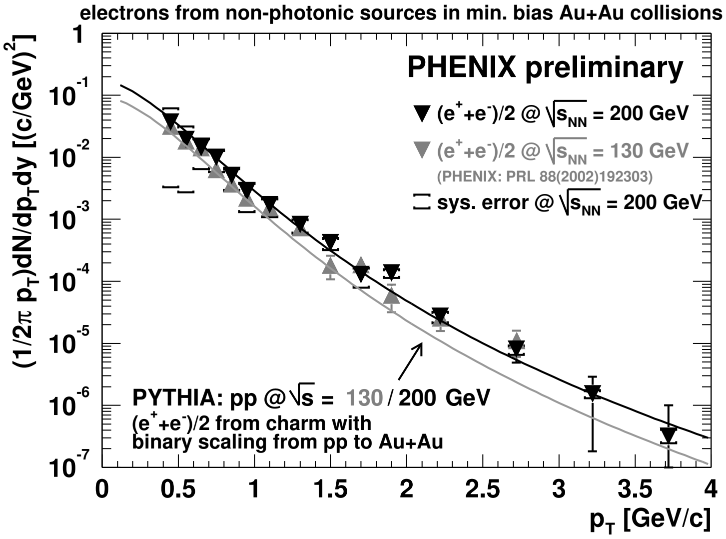

Figure 2: Invariant p_T spectra of electrons from non-photonic sources in minimum bias Au+Au collisions at $\sqrt{s_{NN}}$ = 200 GeV and $\sqrt{s_{NN}}$ = 130 GeV compared with the expected contributions from semileptonic open charm decays.

of electron spectra from semileptonic charm decays as calculated with PYTHIA for *pp* collisions scaled to Au+Au collisions using the number of binary collisions which are determined from a Glauber model calculation. The PYTHIA parameters have been tuned such that charm data from SPS and FNAL as well as single electron data from ISR are well described [6]. The charm production cross section $\sigma_{c\bar{c}}$ in *pp* collisions from this PYTHIA calculation is 330 μb at $\sqrt{s}$ = 130 GeV and 650 μb at 200 GeV. The electron yields and the spectral shapes are in reasonable agreement with the expectation from charm decays.

It is important to study the centrality dependence of these electron spectra since any medium effect is expected to be more pronounced in more central collisions. The centrality dependence is addressed in Fig. 3 which shows the comparison of the non-photonic electron p_T spectra measured in Au+Au collisions at $\sqrt{s_{NN}}$ = 200 GeV with the expectation from charm decays for four different centrality selections, ranging from 0% - 10% (most central) to 40% - 70% (most peripheral) of the total inelastic Au+Au cross section. Again, the *pp* PYTHIA calculation has been scaled to Au+Au using the number of binary collisions which increases by more than a factor of ten going from the most peripheral to the most central collisions. Although the uncertainties are quite large, the agreement between data and expectation is reasonable for all centrality selections.

4. Summary and Outlook

The spectra of electrons from non-photonic sources measured in Au+Au collisions at $\sqrt{s_{NN}}$ = 130 GeV and 200 GeV are consistent with the expectation from semileptonic charm decays as determined by *pp* PYTHIA calculations scaled to Au+Au using the number of binary collisions. At present, this is the only observable measured at RHIC obeying binary scaling within the experimental uncertainties. At SPS, the NA50 Collaboration inferred an enhancement of the charm yield by a factor of about three in Pb+Pb collisions compared to binary collision scaled *pp* measurement [8]. We do not observe such a large effect at RHIC. In central Au+Au collisions at RHIC, a suppression of high p_T hadron yields by a factor of 3-4 was reported relative to binary scaling [9,10]. We do not observe such a large effect in the electron spectra from non-photonic sources. This could reflect a smaller energy loss of charm compared to light quarks, c.f. [4]. For the $\sqrt{s_{NN}}$ = 200 GeV data, both the statistical and the systematic uncertainties can still be reduced signifi-

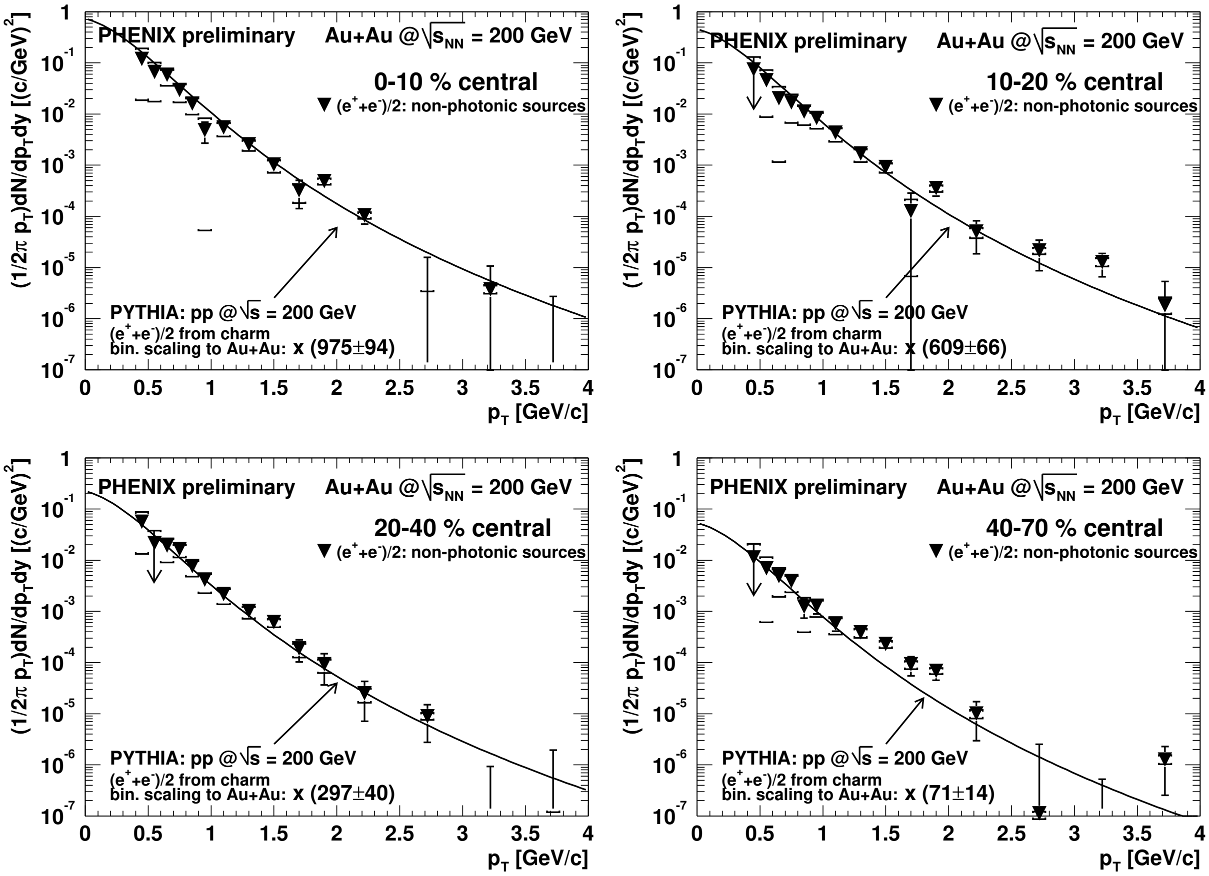

Figure 3. Invariant p_T spectra of electrons from non-photonic sources in Au+Au collisions at $\sqrt{s_{NN}} = 200$ GeV compared with the expected contributions from semileptonic open charm decays for four different centrality selections.

cantly, allowing for a more quantitative assessment of heavy-flavor production at RHIC. In particular, the analysis of the *pp* data at $\sqrt{s} = 200$ GeV will provide an actual measurement as baseline for the search for eventual medium effects instead of the PYTHIA prediction, thus reducing the model dependence of the interpretation significantly.

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