Open Charm Production in $\sqrt{s_{NN}}$=200 GeV Au+Au Collisions at STAR

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We present first results on D^0 meson production via direct reconstruction of its hadronic decay channel $D^0 \to K\pi$ in minimum bias Au+Au collisions at $\sqrt{s_{NN}}$=200 GeV with p_T up to ∼3 GeV/c. Single electron[2] spectra with 1< p_T <4 GeV/c from the charm semi-leptonic decays are also analyzed from the same data set. The charm production total cross-section per nucleon-nucleon collision is measured to be 1.11±0.08(stat.)±0.42(sys.) mb in minimum bias Au+Au collisions, which is consistent with the N_{bin} scaling compared to d+Au collisions. The nuclear modification factors of the single electrons in minimum bias and 0-20% Au+Au collisions are significantly below unity at 1< p_T <4 GeV/c.

1. Introduction

Due to their large masses, charm quarks provide a unique tool to probe the partonic matter created in relativistic heavy-ion collisions. Charm quarks are produced in the early stages of high-energy heavy-ion collisions [1] and their charm total cross-section follows the number of binary collision (N_{bin}) scaling from $p+p$, d+Au to Au+Au collisions at RHIC energies. Theoretical calculations [2,3] have shown that the charm quarks interacting with surrounding partons in the medium could change their properties, such as the p_T shape, etc. Notably, charm quarks are believed to lose less energy compared to light quarks in the partonic matter due to the so-called "dead-cone" effect [4–6]. Thus, measurements of the D mesons together with the charm-hadron decayed single electrons - their p_T distributions and nuclear modification factors - will be vital to interpret the physics in relativistic heavy-ion collisions.

2. Analysis and Results

The data used for this analysis were taken with the STAR experiment during the $\sqrt{s_{NN}}$=200 GeV Au+Au run in 2004 at RHIC. A minimum bias Au+Au collision trigger was defined by requiring coincidences between two zero degree calorimeters. A total of 13.3 and 7.6 million minimum bias triggered Au+Au collision events are used for the D^0 reconstruction and the Time-of-Flight (TOF) single electron analysis, respectively. For the centrality dependence study of the single electrons, the minimum bias event sample is subdivided into three centrality bins: 0-20%, 20-40% and 40-80%.

[*]For the full list of STAR authors and acknowledgements, see appendix 'Collaboration' of this volume.
[2]The word "electron" refers to electron/positron throughout these proceedings.

The low p_T (< 3 GeV/c) D^0 mesons were reconstructed through their decay $D^0 \rightarrow K^-\pi^+$ ($\bar{D}^0 \rightarrow K^+\pi^-$) with a branching ratio of 3.83%. Analysis details can be found in Ref. [7]. Panel (a) of Fig. 1 shows the invariant mass distributions of kaon-pion pairs after mixed-event background subtraction (solid circles) and an additional linear residual background subtraction (open circles). The solid circle distributions are then fit with a Gaussian plus a linear function to extrapolate the signal of the D^0 meson. After the fit, the D^0 mass and width is found to be 1868±1 MeV/c^2 and 6±2 MeV/c^2, respectively. Three other D^0 signals are also observed in different p_T bins: $0.2< p_T <0.7$ GeV/c, $0.7< p_T <1.2$ GeV/c and $1.2< p_T <2$ GeV/c.

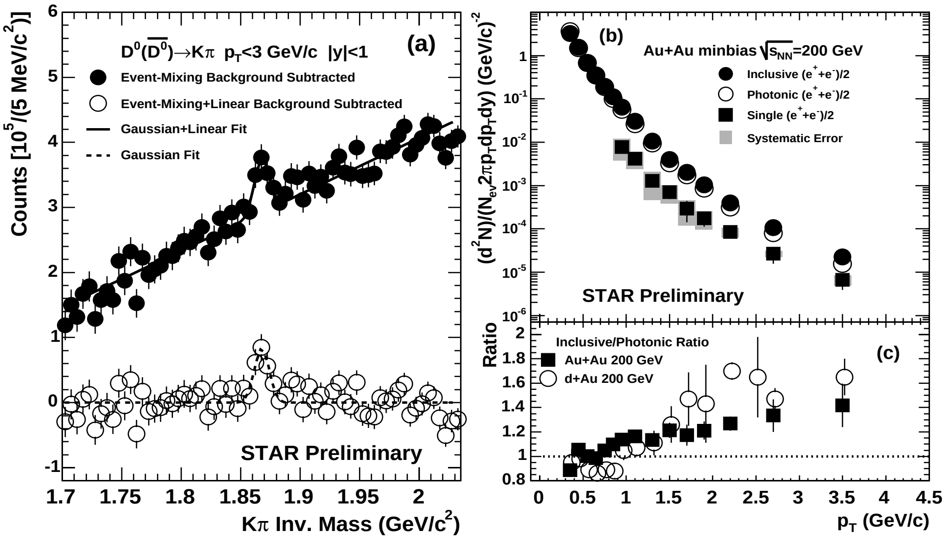

Figure 1. (a) Invariant mass distributions of kaon-pion pairs after mixed-event background subtraction (solid circles) and an additional linear residual background subtraction (open circles). (b) p_T distributions for inclusive (solid circles), photonic (open circles), and single (solid squares) electrons. (c) The ratio of inclusive electrons to the photonic backgrounds in minimum bias Au+Au (solid squares) and d+Au (open circles) collisions.

By using the combined information from the STAR TPC and TOF detectors, electrons can be identified and measured. Detailed analysis for the inclusive, photonic and single electron reconstruction can be found in Ref. [7]. Their p_T spectra are shown in panel (b) of Fig. 1. Panel (c) of Fig. 1 shows the ratio of inclusive electrons to the photonic backgrounds as a function of p_T. A significant excess is observed at $p_T >1$ GeV/c that is expected to be dominated by electrons from semi-leptonic decays of charm-hadrons.

Panel (a) of Fig. 2 shows the p_T distributions of D^0 and single electrons in minimum bias Au+Au, d+Au and $p + p$ collisions at $\sqrt{s_{NN}}$=200 GeV. Using a combined fit applied to both, directly reconstructed D^0 and the single electron distribution in Au+Au collisions, the mid-rapidity D^0 yield is then obtained and converted to the charm total cross-section per nucleon-nucleon collision ($\sigma_{c\bar{c}}^{NN}$) following the method addressed in

Ref. [7]. $\sigma_{c\bar{c}}^{NN}$ is measured to be 1.11±0.08(stat.)±0.42(sys.) mb from minimum bias Au+Au collisions which is comparable to $\sigma_{c\bar{c}}^{NN}$=1.4±0.2±0.2 mb in minimum bias d+Au collisions at $\sqrt{s_{NN}}$=200 GeV. Thus the charm total cross-section roughly follows the N_{bin} scaling from d+Au to Au+Au collisions which supports the conjecture that charm quarks are produced at early stages in relativistic heavy-ion collisions.

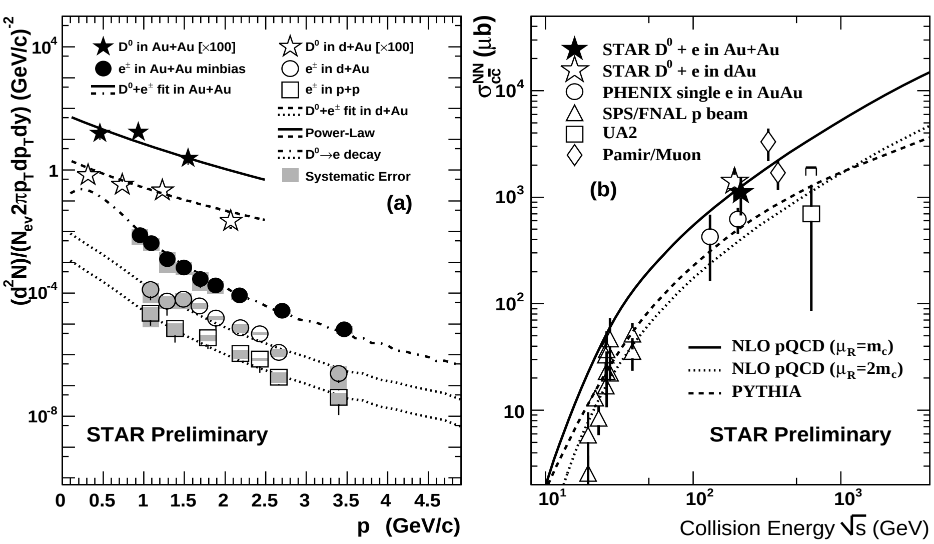

Figure 2. (a) p_T distributions of D^0 in Au+Au (filled stars) and d+Au (open stars) collisions and single electrons in Au+Au (solid circles), d+Au (open circles) and $p+p$ (open squares) collisions. (b) The $c\bar{c}$ cross-section per nucleon-nucleon collision vs. the collision energy.

The D^0 R_{AA} (star symbols in Panel (b) of Fig. 3) are calculated by dividing the D^0 data points in minimum bias Au+Au collisions by the power-law fit results of the D^0 p_T spectrum in d+Au collisions scaled by N_{bin}. The single electron p_T spectra are also measured in three collision centralities in Au+Au collisions: 0-20%, 20-40% and 40-80%, shown in Panel (a) of Fig. 3 and compared to the $D^0 \rightarrow e^{\pm}$ decayed shape in d+Au collisions scaled by N_{bin}. The spectra in minimum bias and 0-20% Au+Au collisions significantly deviate from the curves. The single electron R_{AA} in minimum bias and 0-20% central Au+Au collisions can then be calculated by dividing the corresponding data points by their referring curves, shown as solid circles and squares in Panel (b) of Fig. 3, respectively. The single electron R_{AA} in both minimum bias and 0-20% central Au+Au collisions is observed to be significantly below unity at 1< p_T <4 GeV/c and is consistent with theoretical predictions in [6] by considering charm quark radiation energy loss with $\hat{q}$=14 GeV/c^2/fm indicating that the charm p_T spectra must have been modified by the hot and dense medium in relativistic heavy-ion collisions.

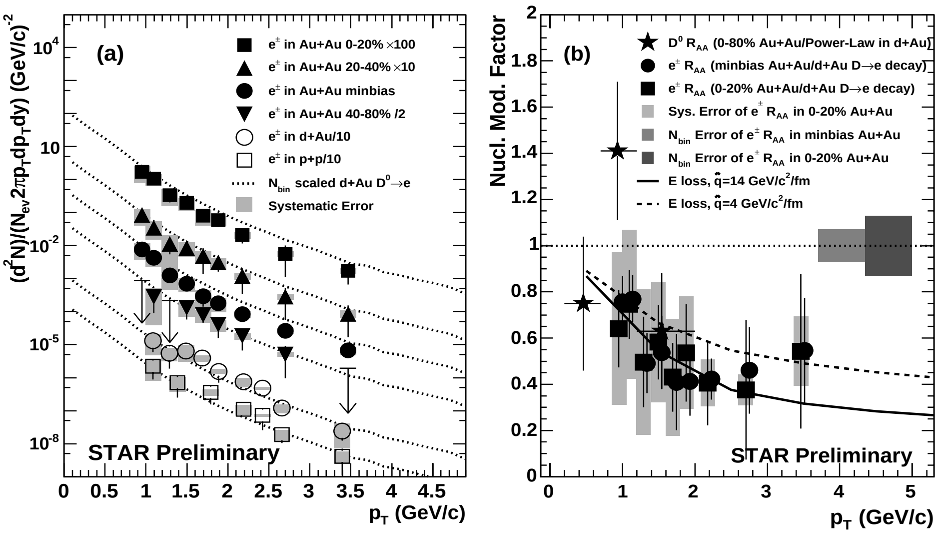

Figure 3. (a) Single electron p_T distributions from minimum bias Au+Au (solid circles), 0-20% (solid squares), 20-40% (upward triangles) and 40-80% (downward triangles) centralities of Au+Au collisions, d+Au (open circles) and $p + p$ (open squares) collisions. (b) Nuclear modification factors for D^0 (stars) and single electrons (circles and squares). Solid and dashed curves are theoretical predictions for single electron R_{AA} in [6] with different parameter settings.

3. Conclusions

In conclusion, the D^0 and the non-photonic single electron p_T distributions are measured in Au+Au collisions at $\sqrt{s_{NN}}$=200 GeV at STAR. Within the present statistical and systematic errors, the charm total cross-section per nucleon-nucleon collision is consistent with N_{bin} scaling from d+Au to Au+Au collisions indicating the charm quarks are mostly produced in early stages at relativistic heavy-ion collisions. The single electron nuclear modification factors in 0-20% centrality and minimum bias Au+Au collisions are measured to be significantly below unity at 1< p_T <4 GeV/c. Therefore we conclude that the charm p_T spectra are indeed modified by the hot and dense medium in relativistic heavy-ion collisions at RHIC energies.

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