HEAVY FLAVOR PRODUCTION IN STAR

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In this contribution, the STAR collaboration at RHIC reports on measurements related to heavy flavor production. We present results from D meson production, and from indirect reconstruction of heavy flavor via semi-leptonic decays, including low transverse momentum muons and the inclusive yield of non-photonic electrons. We focus on the non-photonic electrons, and present results over a broad range of transverse momenta ($1.2 < p_T < 10$ GeV/c) in p+p, d+Au, and Au+Au collisions at $\sqrt{s_{\rm NN}} = 200$ GeV. The non-photonic electron yield exhibits unexpectedly large suppression in central Au+Au collisions at high p_T, suggesting substantial heavy quark energy loss in hot QCD matter.

1. Introduction

In the study of relativistic heavy-ion collisions, one of the main goals is to create a system of deconfined quarks and gluons in the laboratory and to study its properties. In the experiments performed at the Relativistic Heavy Ion Collider (RHIC) the expectation is that the state formed in the collision of the nuclei will be the one described by high-temperature Quantum Chromodynamics (QCD), the Quark-Gluon Plasma (QGP). Recent experimental studies at RHIC have given evidence that the nuclear matter created in the highest energy collisions exhibits properties consistent with QGP production. In particular, it has been extablished that the matter produced is found to be extremely opaque to the passage of hard partons[1,2,3], which are believed to lose energy via gluon radiation in the dense medium before fragmenting into hadrons[4]. A better quantitative understanding of the partonic energy loss in the medium is one of the issues that need to

*http://www.star.bnl.gov/central/collaboration/authors/authorlist.php be addressed. The measurement of heavy quark (charm and bottom) production provides key tests of the parton energy loss mechanism [5]. Because of the large masses of charm and bottom quarks, they are produced almost exclusively by initial parton interactions, and their production can be calculated by perturbative QCD [6]. Calculations of heavy flavor cross-sections and spectra are available in next-to-leading-order for both p+p [6,7,8] and A+A collisions (including additional cold nuclear matter effects such as initial parton scattering and shadowing [8]). In this contribution, we summarize the current status of heavy flavor measurements by the STAR Collaboration and compare to theory.

2. Analysis and Results

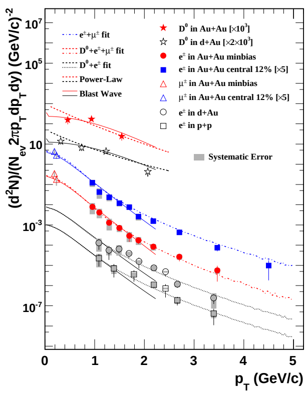

Figure 1. Open charm reconstruction summary: p_T distributions for D^0 mesons, for charm-decayed muons, and for non-photonic electrons from TOF.

The open charm analysis relies on a combinatoric reconstruction of the $D^0 \rightarrow K^-\pi^+$ (and c.c.) decay chain. The muons originating from charm decay at low p_T were analyzed by combining the energy loss (dE/dx) information from the TPC and the mass-square information from the TOF. The analysis of non-photonic electrons consists of three main steps: selection of a clean electron sample; subtraction of electron background arising from interactions in material and decays; and residual corrections of the signal yield. The electron identification was done using dE/dx + TOF information at low p_T, and dE/dx+ EMC information (matching of track momentum and electromagnetic energy) at high p_T. The analysis details and a discussion of the sources of uncertainty can be found elsewhere [9,12].

The measurements at low-p_T used for the estimation of the total charm cross section are shown in Fig. 1. Using a combined fit to the D^0, muon, and low-p_T non-photonic electron spectra, we obtain the mid-rapidity D^0 yield. We then extrapolate (assuming $\sigma_{D^0}/\sigma_{c\bar{c}} = 0.54 \pm 0.05$, and a factor of 4.7 ± 0.7 from mid-rapidity to full phase space) to estimate $\sigma_{c\bar{c}}^{NN}$ from the data[9]. We obtain values in the range 0.94–1.8 mb. The estimations agree for all datasets (as they should if binary-collision scaling holds). The overall magnitude of the cross-section is ~ 5 times larger than NLO calculations, and this discrepancy is under investigation.

Figure 2(left) shows the fully corrected non-photonic electron spectra. The dashed, dotted and solid lines correspond to pQCD predictions [8] for the electron spectra from semileptonic D and B mesons decays. A common normalization factor of 5.7, corresponding to the ratio between STAR measured charm cross section [9] and the FONLL cross section [8] is applied to the predicted electron spectra. The calculations describe the shape of the measured spectra rather well, although the uncertainties in the theory and the data do not allow for a precise determination of the region where bottom decays start to dominate. It appears, however, that the non-photonic electrons have a significant to dominant contribution from beauty decays at higher p_T. Figure 2(right) shows R_{AA} for non-photonic electrons as a function of p_T. The error bars correspond to the statistical uncertainties. The boxes represent the uncorrelated systematic uncertainties while the dashed area shows the overall normalization uncertainty. In Au+Au collisions, we observe an unexpectedly strong suppression increasing from peripheral to central collisions. For the 0-5% most central collisions, non-photonic electron production for $p_T > 3$ GeV/c is suppressed by a factor ~ 5 (similar to the one observed for inclusive hadrons [2], shown in grey box).

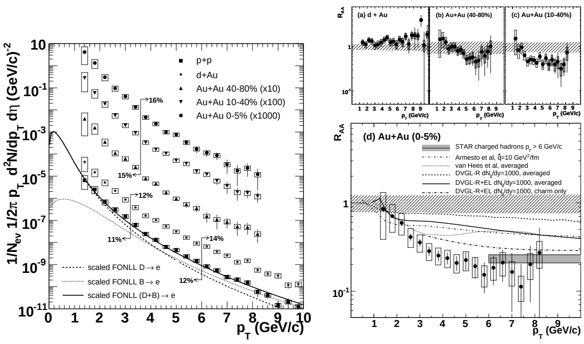

Figure 2. Left: Non-photonic electron spectra for p+p, d+Au, and Au+Au collisions at $\sqrt{s_{\rm NN}}$= 200 GeV. The dashed, dotted and solid lines correspond to scaled pQCD predictions (see text)for the electron spectra from semileptonic decays of D and B mesons. Right: The non-photonic electron nuclear modification factor, R_{AA}, for d+Au and Au+Au collisions at $\sqrt{s_{\rm NN}}$= 200 GeV. The error bars depict the statistical uncertainties.

Figure 2(right) also shows different theoretical predictions for suppression in central events. While all depicted calculations [13,14,15,16] are based on the ansatz that heavy quarks lose their energy due to final state interactions, the predictions differ in the processes and mechanisms taken into account. The main message is that all current models overpredict R_{AA} at high-p_T. It is important to note that in all calculations charm quarks are substantially more quenched than bottom quarks. The calculated R_{AA} for electrons solely from D decay describes the data rather well. It is the dominance of electrons from B decays for $p_T \gtrsim 4$ GeV/c that pushes the predicted R_{AA} to higher values. The question of whether or not this discrepancy indicates that the B dominance sets in at higher p_T remains open until we are experimentally able to disentangle B and D contributions.

3. Summary and Conclusions

We summarized the STAR results on heavy flavor production in heavy-ion collisions. We presented measurements on direct open heavy flavor production and on semileptonic (muon and electron) decays of open heavy flavor leading to an estimate of the charm cross section at RHIC energies. The nuclear modification factor of non-photonic electrons at high-p_T indicates an unexpectedly large suppression in central Au+Au collisions, consistent with substantial energy loss of heavy quarks in the medium. Although all the model calculations overpredict the data, it is important to keep in mind that there are significant uncertainties in the data as well as in the current calculations. These measurements provide constraints for models driving to a full understanding of the energy loss mechanisms, a fundamental milestone for the characterization of the medium properties.

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