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PHENIX results on charm and bottom quark yields in p+p and Au+Au collisions at $\sqrt{s_{NN}} = 200$ GeV

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PHENIX has measured electrons from heavy flavor decays at mid-rapidity $|y| < 0.35$ in a range of $1 < p_T < 7$ GeV/c. Separated charm and bottom yields are obtained by unfolding distance of closest approach distributions. Charm and bottom quark yields have been measured in p+p and Au+Au collisions obtained from the high luminosity RHIC runs taken in 2015 and 2014 respectively. The results in p+p collisions pose a tight constraint to the pQCD estimate of heavy flavor production. The nuclear modification of charm and bottom yields in Au+Au collisions can reveal how the energy that hadrons lose in the QGP medium depends on the quark mass, especially at low p_T. These proceedings report on the status of these measurements.

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1. Introduction

Heavy flavor quarks are a powerful probe of the Quark Gluon Plasma (QGP) at the Relativistic Heavy Ion Collider (RHIC), as at RHIC energies heavy flavor quarks, such as bottom and charm, are produced primarily in the initial hard scattering collisions. Due to this fact, heavy flavor quarks experience the full evolution of the collision system, and any modifications to heavy flavor quark yields in larger systems compared to p+p can provide valuable insight to the effects of the nuclear medium [1].

In hard scatterings that occur in p+p collisions it is possible to use perturbative Quantum Chromodynamics (pQCD) to calculate heavy flavor production. This can be done through Monte Carlo event generators such as PYTHIA, which uses leading order calculations to calculate particle generation. Additionally through the use of Fixed-Order plus Next-to-Leading-Log (FONLL) [2] it is possible to make more complete predictions on open heavy flavor production. The measurement of the fraction of heavy flavor electrons from bottom hadron decays in p+p collisions can be used to probe pQCD through comparison to FONLL calculations.

In heavy ion collisions PHENIX can probe properties of the interactions between quarks and the nuclear medium. This has been done through studying the yields of bottom and charm quarks in Au+Au collisions. By comparing the fraction of heavy flavor electrons from bottom hadron decays with calculations done using a Transport Matrix approach [3] insight can be gained on the coupling strength within the QGP. Additionally by studying the nuclear modification factor (R_{AA}) of separated bottom and charm quarks we can gain insights on the mass dependence of heavy-quark energy loss in the QGP.

2. Separated bottom and charm quark measurement in PHENIX

PHENIX measured electrons at mid rapidity $|\eta| < 0.35$ from the semi-leptonic decays of bottom and charm hadrons in both 0–10% central Au+Au and p+p events at $\sqrt{s_{NN}} = 200$ GeV. In the central arms of PHENIX electron candidates are identified through the combination of a ring imaging Cherenkov detector (RICH) as well as an energy/momentum. A schematic of the central arms in PHENIX can be seen in the left panel of Figure 1. This electron candidate sample is not a pure sample of electrons from heavy flavor decays but instead includes contributions from both photonic (such as π^0, η, and direct photons) and non-photonic sources (such as J/ψ and ke3). The contribution of each background electron source was constrained using a measurement of the fraction of photonic electrons in combination with an electron cocktail. The contributions to the electron candidate sample from each background source can be seen in the right panel of Figure 1.

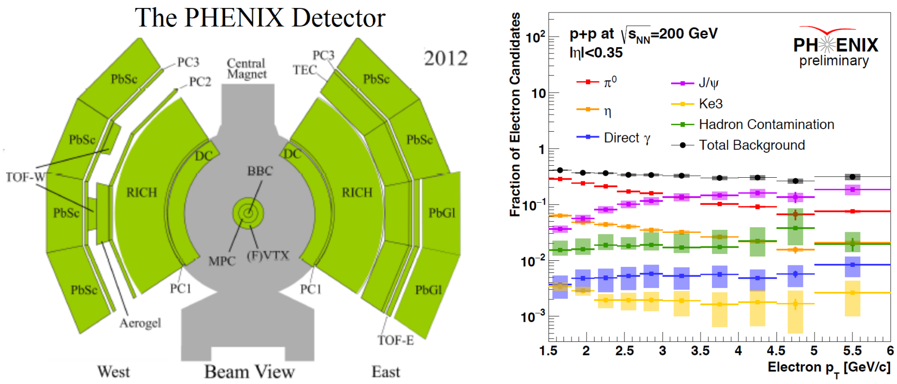

Figure 1: Left: A schematic view of PHENIX central arms.
Right: Fractional contributions to the measured electron sample for each considered source of background.

For each electron candidate the distance of closest approach in the transverse plane (DCA_T) was measured using the Silicon Vertex Tracker (VTX). The DCA_T allows PHENIX to distinguish between electrons from bottom, charm and the various background sources due to the differences in life time and decay kinematics, as seen in Figure 2.

The measurement of separated bottom and charm was done using Bayesian Inference Techniques to simultaneously take into account the measured electron DCA_T distributions and previously published inclusive heavy flavor electron yields. The details of this technique are discussed in Reference [4]. Using this procedure PHENIX was able to measure the heavy flavor electron differential cross-section for both electrons from bottom and charm hadron decays, as shown in Figure 2. It was observed that the extracted unfolding results are in good agreement within uncertainties with the measured electron DCA_T distribution and previously published inclusive heavy flavor electron differential cross-section.

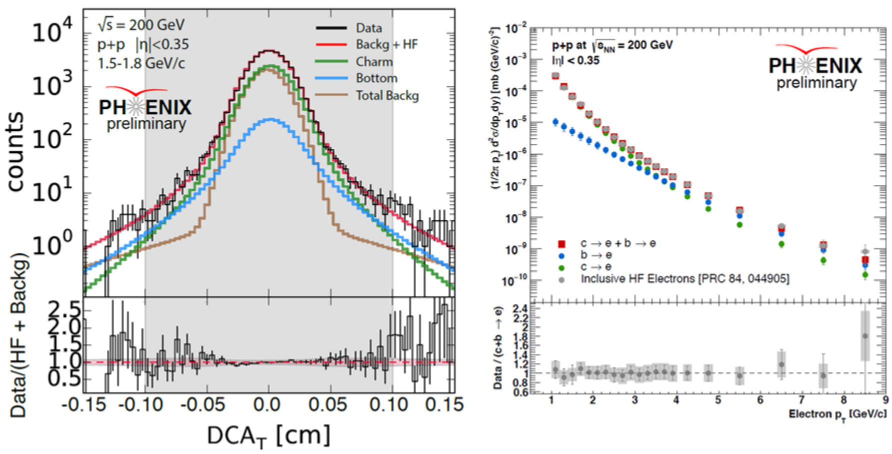

Figure 2: Left: The unfolded DCA_T distribution for electrons for bottom and charm overlaid with the background contributions and the measured electron candidate DCA_T distribution.
Right: Extracted bottom and charm electron invariant differential cross-section compared with the previously published inclusive heavy flavor measurement used as an input to the unfolding.

3. Results

The fraction of heavy flavor electrons which stem from b hadron decays (b-fraction) was extracted for both p+p and 0–10% central Au+Au collision systems between 1 and 9 GeV/c in electron transverse momentum, as shown in Figure 3. Through comparison to FONLL calculations it was seen in p+p that FONLL is able to accurately predict the relative contributions of bottom and charm electrons to within the uncertainty, extending the measurement to lower p_T than previously measured. In Au+Au systems it was seen through comparison with T-matrix calculations that the b-fraction is consistent with strong coupling in the QGP. Additionally, for $p_T > 5$ GeV/c the b-fraction is consistent with DGLV calculations [5] which contain both radiative and collisional sources of energy loss within the QGP.

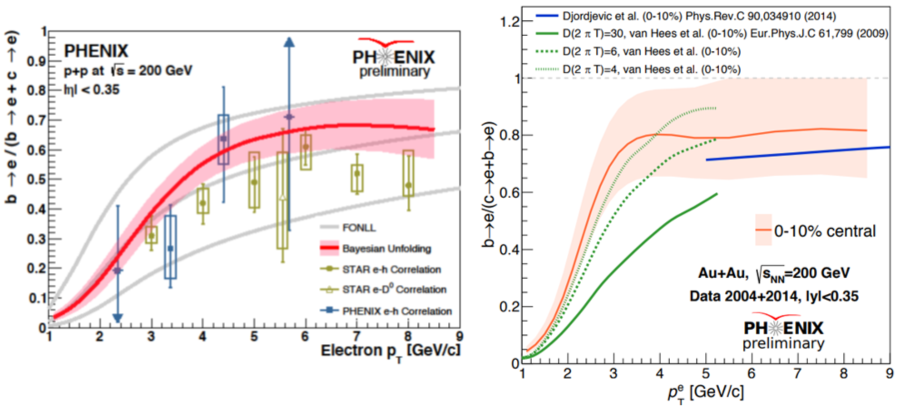

Figure 3: Left: The measured b-fraction for p+p collisions compared with FONLL calculations and previous measurements by STAR anad PHENIX.
Right: The measured b-fraction for Au+Au collisions compared with both T-matrix and DGLV calculations

Utilizing the measured bottom and charm electron yields measured using the unfolding in 0–10% central Au+Au collisions and combining them with previously published measurements in p+p from the STAR collaboration a preliminary R_{AA} measurement was done for both electrons from bottom and charm decays, as shown in Figure 4. In this measurement it is observed that electrons from bottom appear less suppressed than those from charm. This implies that there is a mass dependence to the energy loss experienced due to interactions within the QGP. For final publication this measurement will be updated with additional Au+Au statistics (fourfold increase) as well as the new p+p baseline measurement which extends down to 1 GeV/c in p_T. This will result in a R_{AA} measurement covering a larger range in p_T as well as with reduced uncertainties at mid and high p_T.

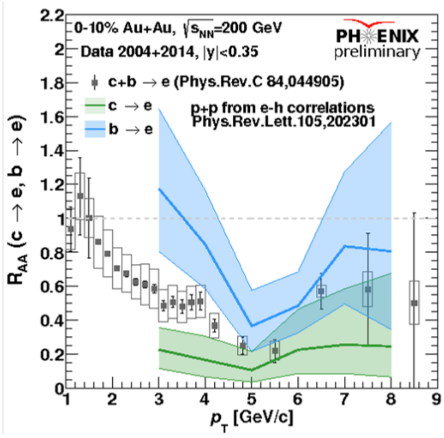

Figure 4: Nuclear modification factor R_{AA} measured for electrons from bottom and charm decays for 0–10% central Au+Au collisions using STAR electron-hadron correlation measurement for the p+p baseline.

4. Summary

PHENIX has made measurements of separated bottom and charm yields in both p+p and Au+Au collision systems. In p+p, through comparison of the b-fraction to FONLL calculations, it was observed that the relative production of bottom and charm electrons are consistent with pQCD down to 1 GeV/c in p_T. In Au+Au the b-fraction is consistent with a picture of strong coupling within the QGP at $p_T < 5$ GeV/c, and for $p_T > 5$ GeV/c it is consistent with DGLV calculations which contain both collisional and radiative energy loss. Utilizing the new p+p measurement of bottom and charm production, PHENIX will now be able to measure the R_{AA} of separated bottom and charm electrons down to 1 GeV/c in p_T, with reduced uncertainties at mid and high p_T.

References

[1] A. Adare *et al.,* (PHENIX) 2006 *Phys. Rev. Let.* **96** 032301

[2] M. Cacciari, M. Greco, and P. Nason, 1998 *J. High Energy Phys.* **05** 007

[3] V. Heese *et al.,* 2009 *Eur. Phys. J. C* **61** 799

[4] A. Adare *et al.,* (PHENIX) 2016 *Phys. Rev. C* **93** 034904

[5] Djordjevic *et al.,* 2014 *Phys. Rev. C* **90** 034910