Measurement of semi electronic decay of heavy flavor mesons in d+Au collision at RHIC using PHENIX detector

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Abstract

The PHENIX detector at RHIC has measured single electron spectra from heavy flavor decays in p+p and Au+Au collisions at $\sqrt{S}_{NN}$=200 GeV. A strong suppression is observed compared to the binary scaling of p+p collisions for high p_T single electrons in Au+Au collisions providing evidence for strong medium effects. The motivation for measuring the single electron spectra from the decay of heavy flavor mesons in d+Au collisions from the 2008 RHIC run (Run8) is to determine parton distribution modifications, the Cronin effect and possible energy loss present in cold nuclear matter. These phenomena can mask hot nuclear matter effects and therefore must be understood in order to interpret the Au+Au results. The analysis is still in progress, but the latest results and technical details are being shown in the current paper.

Key words: Semi electronic decay, heavy flavor and PHENIX experiment

1. Introduction

PHENIX has measured single electron spectra from heavy flavor decays in Au+Au collisions at $\sqrt{S}_{NN}$=200 GeV [1]. A nuclear modification factors$R_{AA} << 1$ was observed at high p_T (p_T > 5 GeV/c) in this measurement which provided evidence for strong medium effects[1]. The measurement of heavy flavor production for p+p in PHENIX has also been measured[2] which provided the baseline for studying hot and dense matter effects in heavy ion reactions. Preliminary results obtained during the 2003 d+Au Run[3-4] has no indication of strong suppression but are inconclusive, specially at high p_T. Understanding of background and its subtraction from the data play crucial roles in the measurement of single electron spectra. The two main methods which get implemented in the measurement are: a) Cocktail Subtraction Method and b) Converter Subtraction Method. In this article the Cocktail subtraction method used for RUN08 (2007-08) has been discussed along with the work done so far for measuring single electron from 2007-08 PHENIX d+Au data at 200 GeV.

2. Electron measurement in PHENIX

Beam-Beam Counter (BBC), Ring Imaging Cherenkov Detector (RICH), Drift Chamber (DC), Pad Chamber1 (PC1), Pad Chamber2 (PC2) and Electromagnetic Calorimeter (EMCAL) together provides the electron measurement detectors. BBC provides the centrality and z vertex information along with minimum bias trigger. Electron ID cut and Electron trigger are being provided by EMCAL and RICH. Track reconstruction and momentum is provided by DC and PC1. Track energy measurement is being provided by EMCal. Keeping these in mind the ratio of parameters energy (E) and momentum (p) is important. For electrons this ratio is 1.0. Figure 1 shows the E/p distribution for 3.0$< p_T <$ 4.0 GeV. The peak at E/p=1.0 gives the electron number. E/p<1.0 has contribution from hadronic background. The Gaussian peak at E/p=1.0 gives the number of electrons in the p_T bin selected. In order to find out the number of electrons in different p_T bins E/p ratio has to be determined for each of the p_T bins. It is also important to determine the electron trigger efficiency. The trigger efficiency is determined for each one of the 8 sectors of the EMCal. Figure 2 shows the electron trigger efficiency for one of the sector of EMCAL. Figure 3 shows the single electron p_T distribution from 2007-08 PHENIX d+Au data. The blue one is from Electron Trigger Data (ERT) and red one is the Minimum Bias data (MB). The Y axis is an arbitrary unit as still acceptance and efficiency corrections has to be applied on these spectra which will eventually provide the invariant yield of single electron. Even though the trigger efficiency for one sector of EMCal approaches 100% as in Figure 2 it's not the case with other sectors of EMCal. That's the reason the ERT triggered data is lower than MB data in Figure 3. It is to be noted from these distribution that there is enough statistics at high p_T as well, something which was missing during the 2003 d+Au Run in RHIC.

3. Cocktail Method

In cocktail calculation, sources of electron are classified into two class i.e. photonic or non-photonic sources. The photonic sources are: i) Dalitz decays of light neutral mesons: π^0, η, η', ω and ϕ ii) Conversion of photons from decays of these light neutral mesons into material and iii) Conversion of direct photons, e.g. from quark gluon Compton scattering in material. The nonphotonic sources that gets implemented in cocktail generation are i) Weak kaon decays, referred as K_{e3} decays and ii) Virtual direct photons from initial hard scattering processes. The π^0 being the dominant electron source acts as a fundamental input for hadron decay generator. The first step is to parameterize the π^0 invariant yield or the cross section spectra. The π^0[5] and $\pi^{\pm}$[6] yields were measured by PHENIX in different collision centrality regimes. The next step is to determine the spectra of other light mesons based on the parameterization of π spectra and m_T scaling. According to m_T scaling the spectral shape of other light hadrons with mass m_h become similar to that of pion at high p_T under the assumption of universal spectrum in m_T=$\sqrt{(p_T^2+m_h^2)}$. The third step is to determine the other light mesons to π^0 ratio which is further scaled to the particle ratios with the values η/π^0=0.47±0.02[7], ρ/π^0=1.0±0.3[8], ω/π^0=0.94±0.08[8], η'/π^0=1.0±0.3[8], ϕ/π^0=0.40±0.12[8] by suitable weight factor. Only statistical errors are mentioned here. This weight factor is then used as input in EXODUS particle generator. In the low p_T region (p_T <4.5 GeV/c) spectrum has been fitted by the Hagedorn function $d\sigma/p_T dp_T$=A/(1+$p_T/\pi^0)^m$, in the high p_T region (p_T >4.5 GeV/c) spectrum was fitted by the modified power law function d$\sigma/p_T dp_T$=B/(0.2+$p_T)^n$ and both the functions were connected by using the Woods Saxon form, T(p_T)=1/[1+exp((p_T-t)/w)] in order to fit the complete spectrum of π^0 and $\pi^\pm$. The combined π^0 and $\pi^\pm$ data are then fitted according to the following modified Hagedorn parameterization: dσ/p_T=T(p_T)A/(1+$p_T/\pi^0)^m$+(1-T(p_T))(B/(0.2+$p_T)^n$). This has been done for different centrality bins (0-20%, 20-40%, 40-60% and 60-88% centrality). Once the parametrization of pion data has been done the spectra of other light mesons are being done by using m_T scaling. The other meson to pion ratio was calculated and then it was normalized in order to make the calculated ratio of the same order as that of the particle ratios from references [7] and [8]. The normalizing factor was used as an input to the EXODUS hadron decay generator which is used for generation of single electron cocktail. Figure 4 shows the single electron cocktail for minimum bias. The electron cocktail has been generated for different centrality bins (0-20%, 20-40%, 40-60%, 60-88%) as well by following the same procedure. Contributions from J/ψ, K_{e3}, Y has not been included yet and work is going on for inclusion of electron contributions from these mesons.

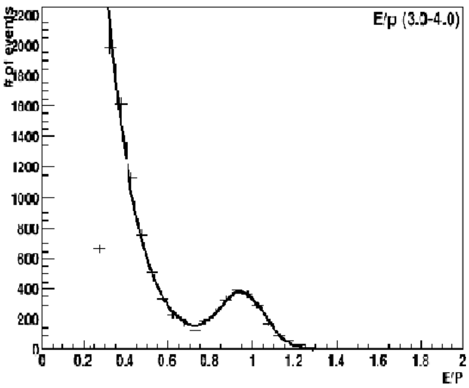

Fig. 1. E/p for 3.0< p_T <4.0 GeV.

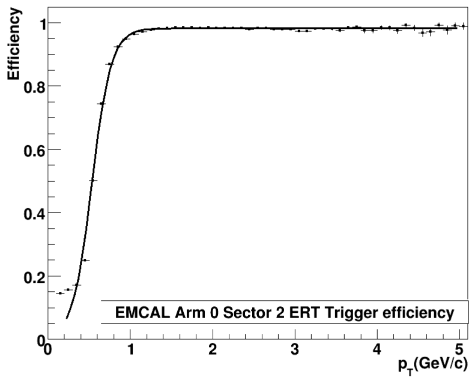

Fig. 2. Electron trig. efficiency for Arm0 Sec.2 of EMCal.

4. Heavy Flavor future in PHENIX

Currently for RHIC run 2010-11 Silicon Vertex tracker has been installed. It provides the coverage in the rapidities (|η| <1.0) and it is capable capable of directly identifying and distinguishing the charm and bottom decays in central arm of PHENIX by measuring the vertex displacement of single electrons. Construction of Forward Silicon Vertex Trackers (FVTX) with forward and backward rapidity coverage 1.2< |η| < 2.2 is underway and is planned to get installed during RHIC Run 12.

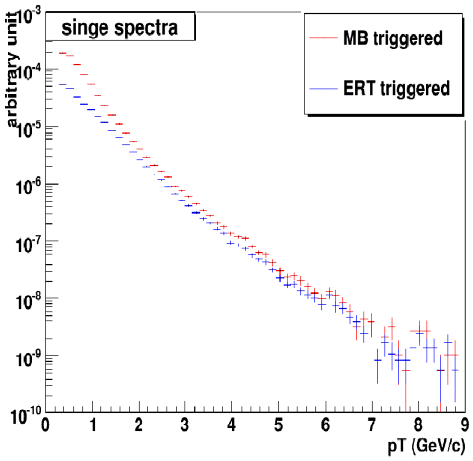

Fig. 3. Single electron spectra for MB and ERT data.

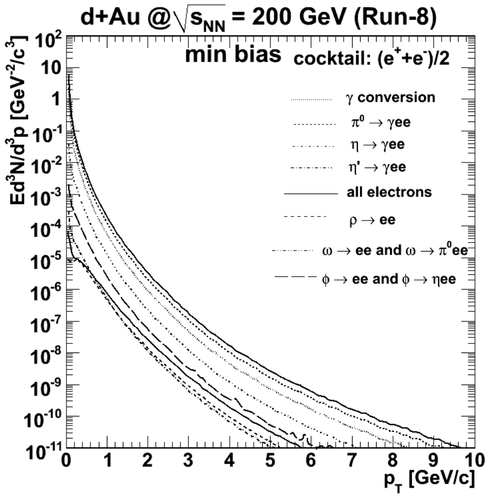

Fig. 4. Single e^- cocktail for Run8 d+Au in MB.

5. Conclusions

Heavy flavor is a promising probe to understand the nature of dense hot matter produced in RHIC collision. In order to account for cold nuclear effects the heavy flavor needs to be also studied in p+A or d+A collisions. So far the possibility of strong effects from cold nuclear matter at mid rapidity has been ruled out by preliminary results. PHENIX has thirty times more statistics from RHIC run 2008 compared to RHIC run 2003. The comparatively huge and much improved statistics for 2008 is helpful in detailed study of heavy flavor from semi-electronic decay of these heavy flavors giving more insights of cold nuclear matter, especially at high p_T. Work is in progress towards the measurement of the nuclear modification factor of semi-electronic decays from heavy flavor.

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