Heavy Quark Production in Large Rapidity in d+Au Collisions at RHIC

Ming Xiong Liu *

P-25, MS H846
Los Alamos National Laboratory
Los Alamos, NM 87545

Abstract

At RHIC energy, heavy flavor production in herding collisions is dominated by gluonic processes and so is a sensitive probe of the gluon structure function in the nucleon and its modification in nuclei. A study of heavy flavor production in p+p and d+Au collisions in various kinematic regions presents an opportunity to probe various cold nuclear medium effects: parton shadowing, color glass condensate, initial state energy loss, and coherent multiple scattering in final state interactions.

We study cold nuclear medium effects on open charm and J/ψ production in d+Au collisions with the PHENIX muon spectrometers at forward and backward rapidity $1.2 < |\eta| < 2.4$. The latest results are presented.

Key words: Heavy Quarks, d+Au Collisions, RHIC
PACS: 25.75 -q

1 Introduction

Heavy quarks are expected to be created from initial gluon interactions in herding collisions and are proposed to be ideal probes to study the hot and dense medium created in early heavy-ion collisions at RHIC. Heavy quark production in p+p interactions can be used to test and calibrate pQCD calculations, while measurements in d+Au collisions serve to quantify the not-well-known cold nuclear medium effects. This was the original motivation. However, it was quickly realized that physics in d+Au collisions is much rich

* for the PHENIX Collaboration.
Email address: mliu@lanl.gov (Ming Xiong Liu).

than we naively thought. The early data of high p_T light hadron production from BRAHMS and PHENIX experiments showed a significant suppression (enhancement) in particle yields in the forward (backward) rapidity region, here forward (backward) is define by the direction of deuteron (gold) going direction. The results are very different form the early conventional model calculations based on simple multiple scattering models with Glauber geometry, and have generated much interest and led to intense debate on the underlying physics of the forward rapidity processes in d+Au collisions at RHIC.

The initial formation of charm quark pairs from hard scattering is sensitive the incoming gluon distributions (thus any shadowing and anti-shadowing in gluon structure function in Au nucleus), and also the initial parton energy loss. In the final state, a J/ψ can be disassociated by interacting with the medium to form an open charm pair; for open charms, they can be affected by final state multiple scattering and energy loss.

Within the PHENIX muon arm acceptance, charm production in the forward rapidity is sensitive to possible gluon shadowing in Au nucleus at $x_{Au} \sim 0.01$, and in the backward rapidity, it is sensitive to possible gluon anti-shadowing in Au nucleus at $x_{Au} \sim 0.1$ [1].

2 The PHENIX Experiment

The PHENIX detector is designed for excellent lepton measurements [2]. At mid-rapidity, a Ring Image Cherenkov Detector and an electromagnetic calorimeters are used to identify electrons. In the forward and backward rapidities, the muon spectrometers are used to identify and measure high energy muons with high precision. One should note that in the PHENIX, open charm production is measured via inclusive non-photonic electrons and prompt muons, and one can't distinguish leptons from charm and beauty decays separately. It is generally expected that at low p_T, most of the leptons are from charm decays while at high p_T, majority of them are from beauty decays. J/ψ production is measured in the di-muon and di-electron channels in three rapidity ranges with the muon spectrometers and central arms, covering rapidity range of $1.2 < |\eta| < 2.4$ and $|\eta| < 0.35$, respectively.

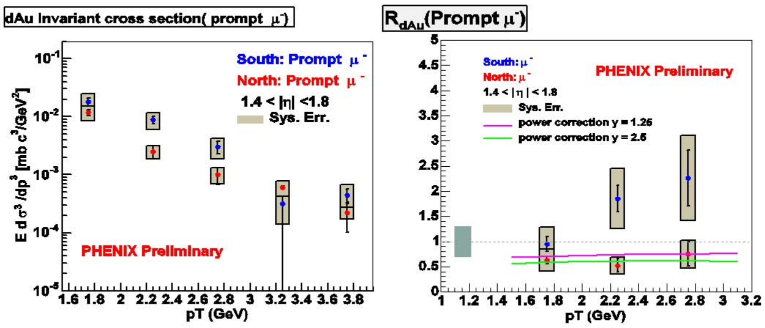

Fig. 1. Invariant p_T spectra (left) and nuclear modification factor of prompt muons (right) in d+Au collisions. The theoretical curves are from a power correction model at $\eta = 1.25$ and 2.5.

3 Charm Nuclear Modification Factor in d+Au collisions

The nuclear modification factor R_{dA} is used to quantify the cold nuclear medium effects,

$$R_{dA}(p_T, y) = \frac{\frac{d^2\sigma^{dA}}{dp_T dy}}{N_{coll}^{dA} \times \frac{d^2\sigma^{pp}}{dp_T dy}} \tag{1}$$

This comparison with p+p result is based on the assumption that the production of high p_T particles scales with the number of binary collisions N_{coll}^{dA} in the initial state, and $N_{coll}^{dA} \sim 7$ for minimum bias d+Au collisions estimated with Glauber Model. Without nuclear medium effects, $R_{dA} \equiv 1$.

PHENIX has measured open charm production via high pT non-photonic electrons and prompt muons. In the middle rapidity, $|\eta| < 0.35$, non-photonic electron p_T spectrum is measured. In the forward rapidity, the prompt muon yields are studied in both p+p and d+Au collisions. Figure 1 shows the nuclear modification factor R_{dAu} of prompt muons at forward and backward rapidities. Suppression is observed in the forward direction, which is consistent with CGC [3],recombination [4], and power correction pictures [5]. The enhancement at the backward direction needs more theoretical investigation. Anti-shadowing and final state recombination could lead to such enhancement, but there is no detailed calculation yet.

J/ψ production is also studied in the forward and backward directions, see Figure 2. A very similar suppression (enhancement) pattern is observed.

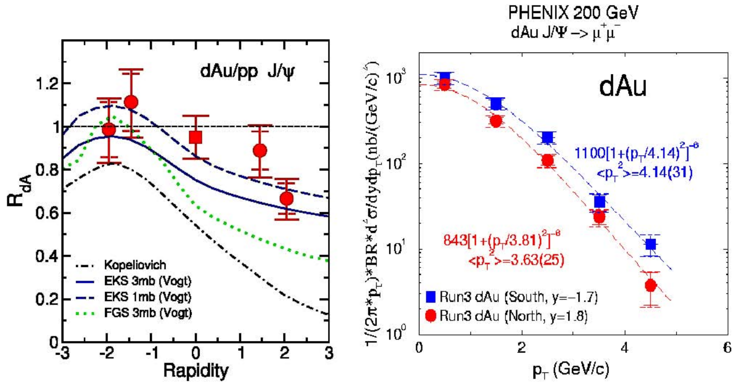

Fig. 2. Nuclear modification factor (left) and invariant p_T spectra of J/ψ (right) in d+Au collisions.

4 Summary and Outlook

We have observed a significant cold nuclear medium effect in forward and backward rapidity in both open heavy flavor and J/ψ production in d+Au collisions at 200 GeV/c. In both cases, a suppression in forward rapidity is observed. This is consistent with several calculations based on CGC,finial state recombination, initial state energy loss and power correction models. However, data are statistically limited to distinguish different models. In the backward rapidity, the observed enhancement needs more theoretical investigation. Anti-shadowing and recombination models could lead to such enhancement. More precise d+Au measurements are needed in the future to understand different cold nuclear medium effects in d+Au collisions.

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