$D_s^{\pm}$ meson production in Au+Au collisions at $\sqrt{s_{\rm NN}} =$ 200 GeV in STAR

Long Zhou (for the STAR collaboration)

#96 Jinzai road, University of Science and Technology of China, Hefei, Anhui, China

E-mail: zhoulong@mail.ustc.edu.cn

Abstract. In this article, we report the measurements of the nuclear modification factor (R_{AA}) and elliptic flow (v_2) for $D_s^{\pm}$ in Au+Au collisions at $\sqrt{s_{\rm NN}} = 200$ GeV from the STAR experiment. These results are compared with the results of other open charm mesons to study the hadronization mechanism of the charm quarks and disentangle the transport properties of quark-gluon plasma and hadronic phase [1]. We found that the nuclear modification factor for D_s are systematically higher than unity and D^0 R_{AA}. The ratio of D_s/D^0 for 10-40% central Au+Au collisions is also higher than that in p+p collisions as predicted by PYTHIA. The D_s/D^0 ratio is also compared to that in Pb+Pb collisions at $\sqrt{s_{\rm NN}} = 2.76$ TeV measured by the ALICE experiment. Our results indicate an enhancement of D_s meson production in Au+Au collisions.

1. Introduction

Heavy quarks are a unique probe to study the medium produced in ultra-relativistic heavy-ion collisions. Because of the large masses, their production is dominated by initial hard scatterings and is well described by perturbative QCD (pQCD) [2]. In particular the D_s(c$\bar{\rm s}$/$\bar{\rm c}$s) production in heavy-ion collisions is expected to be affected by both the strangeness enhancement and the primordial charm quark production. The modifications of D_s meson spectrum and its elliptic flow(v_2) in ultra-relativistic heavy-ion collisions are identified as a quantitative probe of key properties of the hot nuclear medium [1]. Theoretical calculations predict a remarkable enhancement of the D_s meson production as the result of a strong charm quark coupling to the Quark-Gluon Plasma (QGP) and subsequent recombination with equilibrated strange quarks when compared to non-strange D mesons [1]. Like multi-strange hadrons, D_s mesons are expected to freeze out at pseudo-critical temperature (T_{pc}), while the non-strange D meson picks up significant additional v_2 during the hadronic phase. Therefore, the elliptic flow of D_s meson is considered to be a better measure of the partonic contribution to the charm hadron v_2 than that of D^0 or $D^{\pm}$ [1].

The Heavy Flavor Tracker (HFT), installed at the STAR experiment since 2014, is designed to extend STAR's capability of measuring open charm mesons via the topological reconstruction of displaced decay vertices. The HFT detector consists of 4 layers of silicon detectors. The outer layer is the Silicon Strip Detector (SSD). The Intermediate Silicon Tracker (IST), consisting of one layer of single-sided strips, is located inside the SSD. Two layers of the Silicon Pixel Detector (PXL) are inside the IST. The PXL detectors have the resolution necessary for a precise measurement of the displaced vertices. The track pointing resolution of the HFT detector is about 46 μm for kaons at 750 MeV/c [3].

2. Data Analysis

About 750 million minimum bias events taken during the 2014 Au+Au run at $\sqrt{s_{\rm NN}} = 200$ GeV by the STAR experiment were used in this analysis. The identification of daughter particles was done at mid-rapidity $|y| < 1$ using the Time Projection Chamber (TPC) and the Time-of-Flight (TOF) detector. The HFT detector is used to reconstruct the decay vertices. We reconstruct D_s meson through the hadronic decay channel: $D_s \to \phi(1020) + \pi \to K^+ + K^- + \pi$, whose branching ratio is $(2.27 \pm 0.08)\%$. Topological and kinematic cuts are applied to reduce the combinatorial background. Figure 1 shows the reconstructed D_s signal for 0-80% centrality.

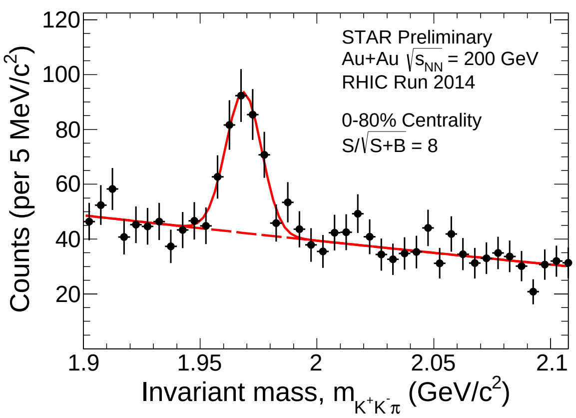

Figure 1. (Color online) The invariant mass distribution for D_s meson in 0-80% central Au+Au collisions at $\sqrt{s_{\rm NN}} = 200$ GeV

3. Physics Results

The invariant yield of D_s (average yield of D_s^+ and D_s^-) are calculated in two p_T bins in 10-40% central Au+Au collisions. The results are depicted in Fig. 2, where the invariant yield of D^0 from the same centrality bin [4] is also shown. The D_s/D^0 ratio as a function of p_T is shown in Fig. 3 for 10-40% central Au+Au collisions at $\sqrt{s_{\rm NN}} = 200$ GeV, along with a similar ALICE measurement for 0-10% central Pb+Pb collisions at $\sqrt{s_{\rm NN}} = 2.76$ TeV [6]. The two measurements follow the same trend within the large uncertainties. On the other hand, the Au+Au measurement is systematically higher than the ratio in p+p collisions predicted by PYTHIA [5].

Medium effects on D_s meson production are quantified as the nuclear modification factor, i.e. $R_{AA}(p_T) = (dN_{AA}/dp_T)/(N_{coll} dN_{pp}/dp_T)$, where dN_{AA}/dp_T is the differential yield in Au+Au collisions and dN_{pp}/dp_T is the corresponding yield in p+p collisions. N_{coll} is the number of binary collisions, derived from the Glauber model [15]. Since there is no measurement of D_s spectrum in p+p collisions at $\sqrt{s} = 200$ GeV, the charm quark cross-section measured by the STAR experiment in p+p collisions at the same collision energy [7] was used to derive the p_T spectrum for D_s meson. The fragmentation factor ($c \to D_s$) used to convert the charm cross-section to D_s cross-section is 0.09 ± 0.01 [8, 9, 10]. The R_{AA} of D_s at mid-rapidity ($|{\rm y}| < 1.0$) in Au+Au collisions at $\sqrt{s_{\rm NN}} = 200$ GeV for 10-40% centrality bin is presented in Fig. 5. Model calculations of R_{AA} for D_s(red band) and D^0(purple dashed-dotted lines) [1] are also shown in Fig. 5. STAR measurements are consistent with model calculations within uncertainties. The R_{AA} of D_s is systematically higher than that of D^0 [4] but the enhancement is not statistically significant.

The elliptic flow can be used to probe the dynamics of early stages of heavy-ion collisions [11]. In Fig. 6 , the measurement of D_s v_2 for 0-80% centrality bin in Au+Au collisions at $\sqrt{s_{\rm NN}} = 200$ GeV is shown. Within large uncertainties, the D_s meson v_2 is consistent with v_2 of D^0 [13] and ϕ [14].

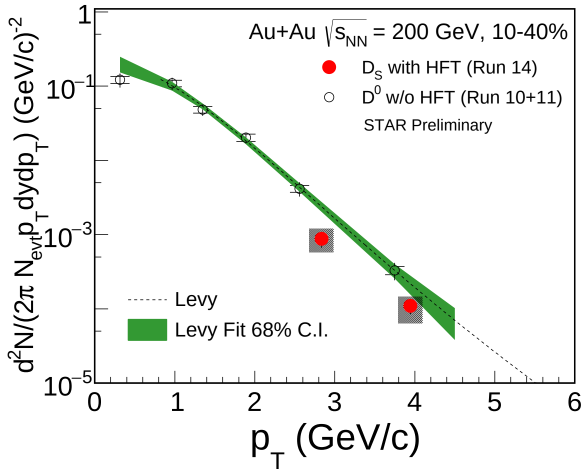

Figure 2. (Color online) The invariant yields of D_s in 10-40% central Au+Au collisions. The solid boxes represent the systematic uncertainties, while the vertical bars depict the statistical errors.

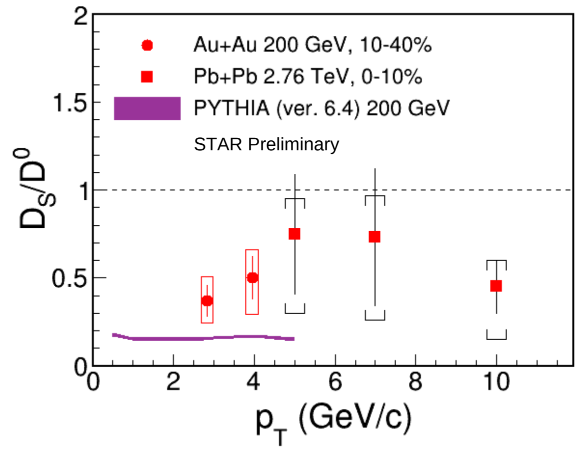

Figure 3. (Color online) The D_s/D^0 ratio in 10-40% Au+Au collisions at $\sqrt{s_{\rm NN}} = 200$ GeV(circle) in the range of $1.5 < p_T < 5.0$ GeV/c. A similar measurement in 0-10% central Pb+Pb collisions at $\sqrt{s_{\rm NN}} = 2.76$ TeV (squares) from the ALICE collaboration is shown for comparison.

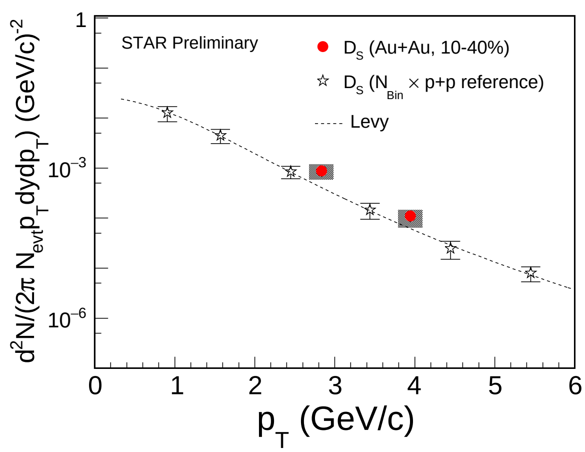

Figure 4. (Color online) The invariant yields of D_s in 10-40% central Au+Au collisions, compared to the scaled p+p reference

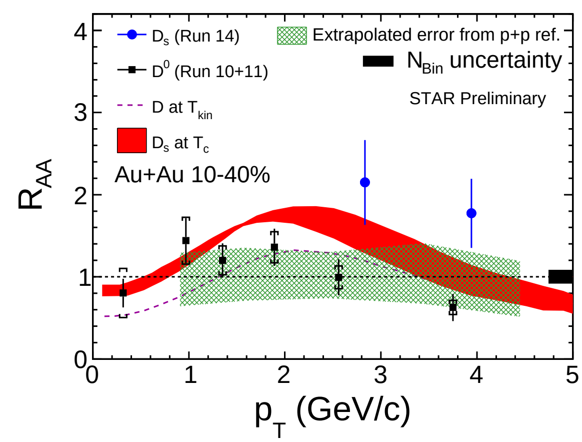

Figure 5. (Color online) The R_{AA} of D_s as a function of p_T in 10-40% central Au+Au collisions. Green band represents the extrapolated error from reference D_s spectra in p + p collisions.

4. Summary

We present the first measurement of D_s production in Au+Au collisions at $\sqrt{s_{\rm NN}} = 200$ GeV using the newly installed HFT at the STAR experiment. The D_s/D^0 ratio seems to be higher than that in p+p collisions predicted by PYTHIA at the intermediate p_T range. The nuclear modification factor of D_s are consistent with model calculations, and systematically higher than D^0 R_{AA}, indicating an enhancement of D_s production in Au+Au collisions. The R_{AA} of D_s is equal to 2.1 ± 0.5 (stat.) $\pm^{0.7}_{0.7}$ (sys.) and 1.7 ± 0.4 (stat.) $\pm^{0.5}_{0.7}$ (sys.) at $p_T = 2.8$ and 3.9

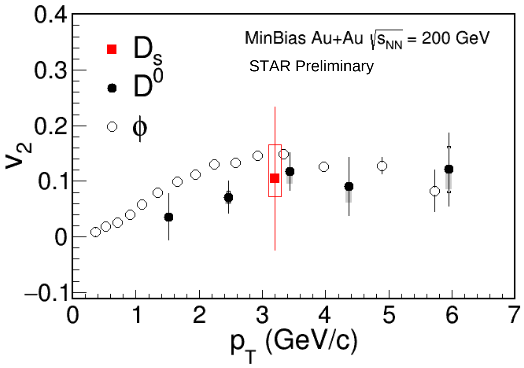

Figure 6. (Color online) Elliptic flow for D_s, D^0 [13] and ϕ [14] for 0-80% centrality bin in Au + Au collisions at $\sqrt{s_{\rm NN}} = 200$ GeV. Open boxes and cap symbols are the systematic uncertainties on corresponding data points. Shaded grey band on D^0 v_2 is for non-flow estimation. Vertical lines are statistical errors.

GeV/c respectively. We have also presented the first measurement of D_s meson v_2 in heavy-ion collisions.

References

[1] He M, Fries R J, and Rapp R 2013 *Phys. Rev. Lett.* **110**, 112301
[2] Cacciari M, Nason P and Vogt R 2005 *Phys. Rev. Lett.* **95**, 122001
[3] Contin G(for the STAR Collaboration) QM2015 proceedings
[4] Adamczyk L et al. (STAR Collaboration) 2014 *Phys. Rev. Lett.* **113**, 142301
[5] Sjostrand T, Mrenna S and Skands P 2006 *JHEP* **0605**, 026
[6] Adam J et al. (ALICE Collaboration) 2016 *JHEP* **03**, 082
[7] Adamczyk L et al. (STAR Collaboration) 2012 *Phys. Rev. D* **86**, 072013
[8] Chekano S et al. (ZEUS Collaboration) 2005 *Eur. Phys. J. C* **44**, 351
[9] Aktas A et al. (H1 Collaboration) 2005 *Eur. Phys. J. C* **38**, 447
[10] Abramowicz H, Abt I, Adamczyk L et al. 2013 *JHEP* **09**, 058
[11] Kolb P F et al. 2003 *Nucl. Phys. A* **715**, 653
[12] Poskanzer A M and Voloshin S. A. 1998 *Phys. Rev. C* **58**, 1671
[13] Lomnitz M (for the STAR Collaboration) 2016 **arXiv 1601.00743**
[14] Adamczyk L et al. (STAR Collaboration) 2015 **arXiv 1507.05247**
[15] Adler C et al. 2002 *Phys. Rev. Lett.* **89** 202301