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Overview of Recent Results from the STAR experiment

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Abstract

Hard and electromagnetic (EM) probes are excellent tools for studying the quark-gluon plasma (QGP). These probes include jet production and modification, productions of heavy flavor hadrons and quarkonia, and productions of photon and dileptons. They provide essential information to characterize the properties of the QGP such as the parton energy loss mechanism and the temperature, lifetime, and viscosity of the QGP. The Solenoidal Tracker at RHIC (STAR) experiment utilizes t excellent detectors to measure these probes, and provides numerous results via hard and EM probes. This overview reports some of the selected results from e^+e^- and direct virtual photon productions, heavy flavor hadrons and quarkonia, and jets.

Keywords: Quark-gluon plasma, e^+e^- production, direct virtual photon, heavy flavor production, quarkonia, jet

1. Introduction

Quark gluon plasma (QGP), a hot and dense matter with partonic degrees of freedom, is produced in the relativisitic heavy-ion collisions and is similar to the state of the early universe. To study the properties of QGP, some products at the early stage of collisions have been proposed as probes. Direct photons and e^+e^- pairs are interesting EM probes, as they are produced through almost all the stages of the collisions. After subtracting yields from the freeze-out stage, the contributions are mostly from in-medium, short-lived mesons and thermal radiations. These can serve as thermometer for the fireball created in heavy-ion collisions [1, 2]. Furthermore, the integrated yield of these probes is related to the duration time of the fireball [1, 2]. Heavy quarks are predominantly produced in the hard scatterings at RHIC, therefore, their relative productions in heavy-ion collisions comparing with that in binary collisions can provide insights on the interactions between the heavy quarks and the QGP. Jets are also produced in the hard scatterings, their productions and modifications carry essential information of the parton energy loss mechanism.

STAR is presenting results from two recently installed detectors. The Heavy Flavor Tracker(HFT), which enables the topological reconstruction of heavy flavor hadrons [3], and the Muon Telescope Detector (MTD) [4], which provide muon identification capability. STAR's main detector is the time-projection chamber (TPC), which has good performance in the tracking and particle identification at mid-rapidity. In addition, the time-of-flight (TOF) and barrel electro-magnetic calorimeter (BEMC) enable clean electron identification at low and high transverse momentum (p_T), respectively. The results of e^+e^- production, direct virtual photon, quarkonia and open heavy flavor hadron, and shared momentum fraction (z_g) in jet are presented in this paper.

2. Electro-magnetic probes

e^+e^- pairs are produced during whole evolution of collision system. In low mass region (LMR) $M < 1\mathrm{GeV}/c^2$, the e^+e^- pairs are from Dalitz decay of light mesons, two-body decay of vector mesons, semi-leptonic decay of correlated charm and anti-charm hadrons, and thermal radiations. The physics interest in the LMR focuses on the modification of in-medium

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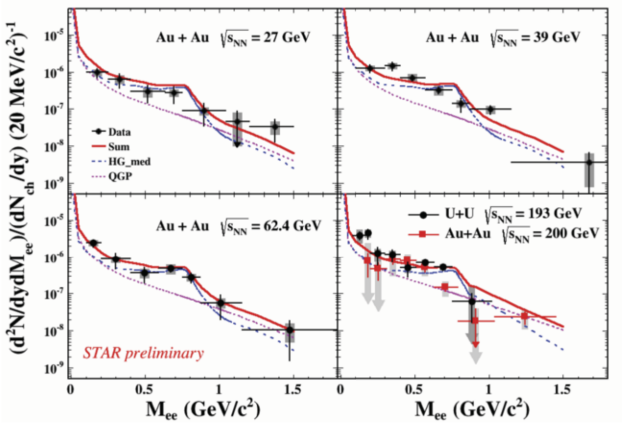

Figure 1: Efficiency and acceptance corrected e^+e^- invariant mass distribution in Au+Au at $\sqrt{s_{NN}}$ = 27, 39, 62.4 GeV and in U+U at $\sqrt{s_{NN}}$ = 193 GeV. Model calculations [5, 6, 7] are compared with the data.

vector mesons, which can be translated to the change of in-medium ρ meson yield with respect to the vacuum ρ yield because of its short lifetime and high interacting cross-section with medium.

Figure 1 shows the efficiency and acceptance corrected e^+e^- invariant mass distribution in Au+Au at $\sqrt{s_{NN}}$ = 27, 39, 62.4 GeV and in U+U at $\sqrt{s_{NN}}$ = 193 GeV, after subtracting hadronic cocktail contributions, which are $\pi^0, \eta, \omega, \phi, \eta'$, and $c\bar{c} \to e^+e^-$. It is also called excess yield. The excess yield is normalized by the number of charged particles per rapidity unit (dN_{ch}/dy) for each energy. The results from different energies and collision systems are consistent with Rapp's model calculations [5, 6, 7]. The model is based on the effective many-body theory incorporating a broadened ρ spectral function. The model includes in-medium ρ meson broadening and the potential thermal radiation from both the hadron gas and the QGP phase. From this model [2], the integral yield of excess e^+e^- in the LMR is proportional to the fireball lifetime. The excess yields are integrated in $0.4 < M_{ee} < 0.75$ for Au+Au at $\sqrt{s_{NN}}$ = 19.6, 27, 39, 62.4 and 200 GeV [1] and U+U at $\sqrt{s_{NN}}$ = 193 GeV, the integrals are shown in Fig. 2 and compared with the corresponding lifetimes used in the model calculations, which are presented with the bars and dashed line [2]. The integrated yield increases as dN_{ch}/dy increases. A similar trend is seen for fireball lifetime in the model. Noticing that the QGP contribution is still significant in the LMR at the lowest energy, the integrated yield can also be considered as a probe to search for the turn-off of the QGP in the future Beam Energy Scan program at RHIC.

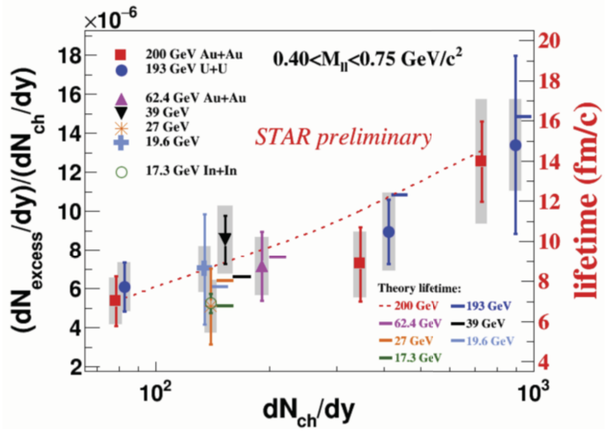

Figure 2: (Color online) (Left y-axis) The integrated acceptance-corrected excess yield normalized by dN_{ch}/dy as a function of dN_{ch}/dy. Statistical uncertainties are represented by the error bars and the systematic uncertainties are represented by the boxes. (Right y-axis) The lifetimes of the fireball as calculated by Rapp et al. [2] are represented by the solid bars that have been offset in the x-direction. The red dashed curve the lifetime in Au+Au at $\sqrt{s_{NN}}$ = 200 GeV.

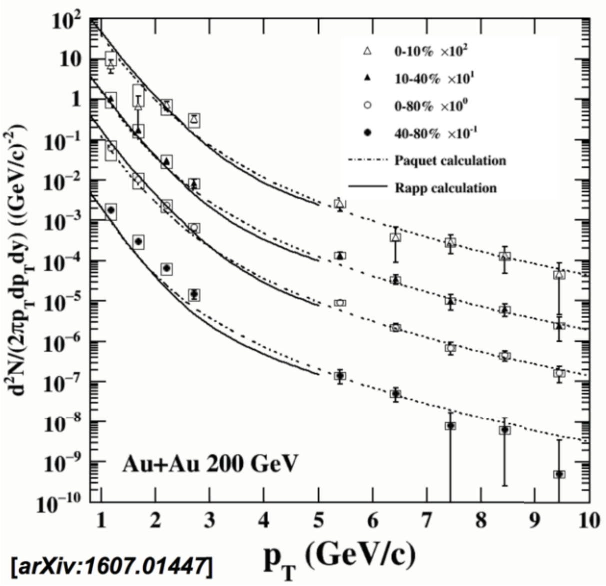

Figure 3: The direct photon invariant yields as a function of p_T in Au+Au collisions at $\sqrt{s_{NN}}$ = 200 GeV [8] compared with model predictions from Rapp et al. [10, 11] and Paquet et al. [12]. The statistical and systematic uncertainties are shown by the bars and boxes, respectively.