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Electromagnetic Probes and Heavy Flavor in PHENIX

Deepali Sharma (For the PHENIX Collaboration)

Department of Particle Physics, The Weizmann Institute of Science, Rehovot, 76100, Israel

Abstract

These proceedings summarize the di-electron spectrum measurements by PHENIX in $p+p$ and $Au+Au$ collisions at $\sqrt{s_{NN}} = 200$ GeV, along with a comparison to the expectations from hadronic sources and various model predictions. An overview of the latest PHENIX results on open heavy flavor and quarkonia production, measured through the electron and muon channels at mid-rapidity and forward/backward rapidity for $p + p$, $d + Au$ and $Au + Au$ collisions is also presented.

Keywords: Quark gluon plasma, heavy quarkonium, open heavy flavor, dileptons

Electromagnetic probes such as dileptons and photons are ideal for the investigation of the hot and dense matter created in high energy heavy ion collisions. Being colorless, they do not suffer any strong interaction, and so carry all the information about the conditions and properties at the time of their production. The dilepton pairs originate either from the pseudo-scalar or vector-meson decays, typically after the collision, or from hard scattering processes like open heavy flavor production, Drell-Yan pair production *etc*, all occurring early in the collision. The measurement of direct thermal radiation (photons or dileptons) can be used to derive a limit on the initial temperature of the hot and dense medium created in the heavy ion collisions

The PHENIX detector [1] at RHIC has measured dileptons in $p + p$ and $Au + Au$ collisions at mid-rapidity. The heavy flavor has been measured using non-photonic electrons at mid-rapidity ($|\eta| \leq 0.35$) and muons at forward rapidity ($1.2 \leq \eta \leq 2.4$). Charmonium has been measured in different states (J/ψ, ψ' and χ_c) by fully reconstructed leptonic decays (e^+e^-) at mid and forward/backward ($\mu^+\mu^-$) rapidity. The following sections report these measurements for $p + p$, $d + Au$ and $Au + Au$ collisions at $\sqrt{s_{NN}} = 200$ GeV and what is expected for the near future.

1. Low mass dileptons

PHENIX has measured the e^+e^- mass spectrum in $p + p$ [2] and $Au + Au$ [3] collisions at $\sqrt{s_{NN}} = 200$ GeV as a function of transverse momentum and mass. 1 shows the invariant mass distribution of electron pairs measured in $p + p$ (left) and minimum bias $Au + Au$ (right) collisions. The combinatorial background was subtracted statistically utilizing mixed events and the like-sign pairs. The data are compared to a cocktail of the expected hadronic sources calculated using a Monte Carlo and filtered by the PHENIX acceptance. For $p + p$ collisions, the agreement between data and simulation over the full mass range of $0 < m_{ee} < 8$ GeV/c^2 is excellent, as is evident from the ratio of data to cocktail shown in the lower left panel. A comparison of the integrated yield between data and PYTHIA in the intermediate mass region of $1.1 < m_{ee} < 2.5$ GeV/c^2, which is dominated by open charm, yielded a total charm cross-section of $\sigma_{c\bar{c}} = 544 \pm 39$(stat.)$\pm$142(syst.)$\pm$200(model) μb in the $p + p$ collisions. Using a simultaneous fit of the mass shapes from simulation to the data, the charm and bottom cross-sections were disentangled. The fit results

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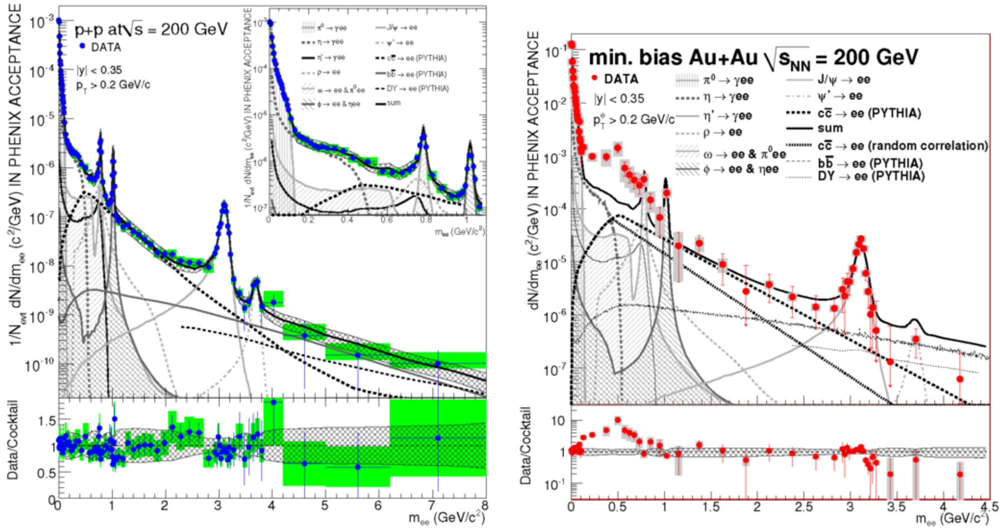

Figure 1: Electron-positron pair yield per inelastic collision as a function of pair mass in $p + p$ (left) and $Au + Au$ (right). The data are compared to a cocktail of known sources.

yielded $\sigma_{c\bar{c}} = 518 \pm 47$(stat.)$\pm 135$(syst.)$\pm 190$(model) μb and $\sigma_{b\bar{b}} = 3.9 \pm 2.4(stat.) \pm^{3}_{-2} (syst.)\mu b$ respectively, for the charm and bottom cross-sections.

The right panel in 1 shows the e^+e^- pairs measured in minimum bias $Au + Au$ collisions, after subtracting the combinatorial background. An excellent agreement to the cocktail is seen at very low masses, up to ~ 100 MeV/c^2. For the masses above the ϕ meson, the agreement is also good, in particular the continuum in the intermediate mass region is fully accounted by the contribution from charm decays. However, in the low mass region from $0.15 \leq m_{e^+e^-} \leq 0.75$ GeVc^2, there is a considerable excess of e^+e^- pairs of the order of $3.4 \pm 0.2(stat.) \pm 1.3(syst.) \pm 0.7(model)$ μb. The excess is present at all pair p_T, but is more pronounced at low pair p_T ($p_T < 0.7$ GeV/c) [3].

The enhancement was also studied as a function of centrality. The integrated yield, divided by the number of participating nucleons pairs ($N_{part}/2$) is shown in the left and middle panels of 2 for three different mass windows. Whereas the low mass yield for the region dominated by π^0 Dalitz decay ($0 < m_{ee} < 100$ MeV/c^2), is in good agreement with the cocktail (left panel (b)), reflecting the expected increase with the pion yield, a very strong enhancement is observed in the low mass continuum region ($150 < m_{ee} < 750$ MeV/c^2). The yield in the mass region, $1.2 < m_{ee} < 2.8$ GeV/c^2 normalized to the number of binary collisions (middle panel 2) shows no significant centrality dependence and is consistent with the expectations based on PYTHIA. However, this scaling with N_{coll} which is expected for charmed meson decays [4], may be a mere coincidence resulting from two balancing effects: the suppression of charm which increases with N_{part} and a thermal contribution that could increase faster than linearly with N_{part}. So far, the models that successfully described the low mass region results at SPS based on the broadening of the ρ meson spectral function, fail to reproduce PHENIX results [10, 11] as can be seen in the right panel of 2.

Utilizing the idea that every source of real photons should also emit virtual photons which convert to low mass e^+e^- pairs, PHENIX analyzed the dilepton yield observed in $Au + Au$ collisions with low masses ($m_{ee} < 300$ MeV/c^2) and high transverse momentum ($1 < p_T < 5$ GeV/c). In this restricted kinematic window, PHENIX observes a significant excess of e^+e^- pairs beyond the expected yield from the hadronic cocktail of light mesons and open charm decays as seen in 3. The e^+e^- invariant mass excess is transformed into a spectrum of real photons under the assumption that the excess is entirely due to internal conversion of photons. 3 (right panel) shows the resulting invariant cross-section for the direct photons. The figure also shows the direct photon data measured by PHENIX at high p_T in $Au + Au$ collisions [3, 5]. The two data sets are in good agreement over the p_T region of overlap. The $p + p$ data shown in the

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