Measurement of leptonic and hadronic decays of ω- and ϕ-mesons at RHIC by PHENIX

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Abstract. The PHENIX experiment at RHIC has measured production of ω- and ϕ-mesons in p+p, d+Au and Au+Au collisions at $\sqrt{s_{NN}} = 62.4$ and 200 GeV. Transverse momentum (mass) spectra measured in hadronic and di-electron decay channels are found to be in agreement with each other within the errors. Nuclear modification factors R_{AA} measured for both mesons are consistent with results obtained for other neutral mesons. The position of the meson mass peaks and their widths reconstructed in hadronic decay channels are in agreement with their properties measured in vacuum.

1. Introduction

Light vector mesons are among the most interesting probes of the matter created in relativistic heavy ion collisions. Measurements of meson properties in p+p, d+Au and Au+Au collisions provide a basis for observation of anomalous features specific to heavy ion collisions and allow separation of various effects on particle production.

One of the most exciting RHIC measurements is the observation of different suppression tendencies for baryons (protons) and mesons (π^0) in central Au+Au collisions [1]. Measurements of nuclear modification factors for vector mesons provide detailed information on the dependence of particle suppression on particle mass and composition. The short lifetimes of ω- and ϕ-mesons ($\Gamma_\omega = 8.5$ MeV, $\Gamma_\phi = 4.3$ MeV) mean that significant fraction of them decay inside the hot and dense nuclear matter produced in heavy ion collisions. Theoretical models [2] predict that basic properties of the light vector mesons such as mass, width and branching ratios can be modified in presence of the medium. Such modifications can be studied by comparison of meson properties measured in leptonic and hadronic decay modes in different collision systems.

2. Experimental setup and data analysis

The two central spectrometers of the PHENIX experiment [3] have the capability to measure both neutral and charged particles produced in RHIC collisions. Beam-Beam

‡ For the full list of PHENIX authors and acknowledgments, see appendix 'Collaborations' of this volume.

Counters provide the trigger and are used to determine z-coordinate of the collision vertex and the event centrality. The momenta of charged particles are measured with the Drift Chamber and the first layer of the Pad Chamber. Charged kaons are identified within $0.3 < p(\text{GeV}/c) < 2.0$ with high resolution TOF subsystem and within $0.3 < p(\text{GeV}/c) < 1.0$ with time-of-flight measurements in the Electromagnetic Calorimeter (EMCal). The electrons are identified with the Ring Imaging Cherenkov Detector and by matching of energy and momentum measured for the charged tracks. The EMCal is also used as a primary detector for reconstruction of γ and π^0-mesons [4].

For reconstruction of $\phi(\omega) \rightarrow e^+e^-$ and $\phi \rightarrow K^+K^-$ decays we combine oppositely charged identified particles to form invariant mass spectra containing both the signal and combinatorial background of uncorrelated pairs. The shape of the combinatorial background is estimated by a mixed event technique where particles are taken from different events in the same centrality and collision vertex class. The mixed event invariant mass distribution is normalized to $\sqrt{N_{++}N_{--}}$ where N_{++} and N_{--} are the measured integrals of like sign yields [5]. Raw yields are integrated around known particle masses after subtraction of mixed event distributions from invariant mass spectra.

Reconstruction of ω-mesons begins with the reconstruction of π^0- candidate in $\pi^0 \rightarrow \gamma\gamma$ channel. For $\omega \rightarrow \pi^0\gamma$ and $\omega \rightarrow \pi^0\pi^+\pi^-$ decays we combine selected π^0-candidates either with all other photons from the same event or with any pair of oppositely charged unidentified tracks. Integrals of peaks reconstructed in invariant mass distributions are extracted by fitting since mixed event approach does not reproduce background due to residual correlations [6]. In Au+Au collisions we analyzed ω-meson production only in $\omega \rightarrow \pi^0\gamma$ channel.

Extracted raw yields are corrected for reconstruction efficiencies evaluated with a full simulation of the PHENIX layout, detector responses, kinematics of particular decays and online trigger settings. For three body decay of ω-meson we also take into account the nonuniform population phase space. Total systematic error of the ω and ϕ-meson measurements is dominated by raw yield extraction, online trigger efficiency and total cross section uncertainties [6, 7].

3. Results

Left panel of Figure 1 shows ϕ-meson m_T spectra in p+p, d+Au and Au+Au collisions at $\sqrt{s_{NN}} = 62.4$ and $200\,\text{GeV}$. PHENIX has an extensive set of $\phi \rightarrow K^+K^-$ measurements in time-of-flight region for different collision systems and event centrality bins. Preliminary measurement in $\phi \rightarrow e^+e^-$ channel is limited by statistics because of small signal to background ratio and is consistent with the hadronic channel within the errors. Exponential fits shown in the same figure are used to extract integrated yields (dN/dy) and temperatures (T). The invariant p_T spectra measured for ω-mesons in p+p, d+Au and Au+Au collisions at $\sqrt{s_{NN}} = 200\,\text{GeV}$ are shown in the right panel of Figure 1. For two hadronic decays $\omega \rightarrow \pi^0\gamma$ and $\omega \rightarrow \pi^0\pi^+\pi^-$ having different

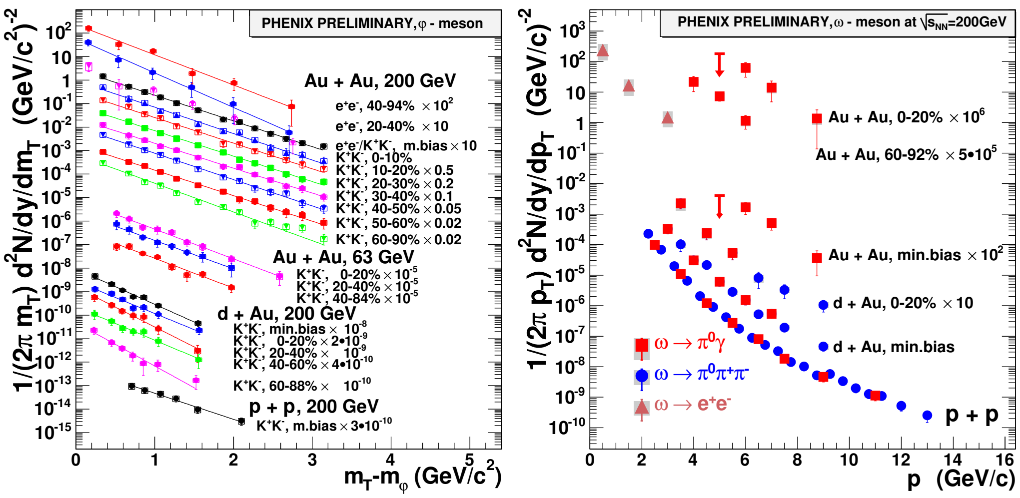

Figure 1. ϕ-meson m_T spectra (left) and ω-meson p_T spectra (right) in $p+p$, d+Au and Au+Au collisions at $\sqrt{s_{NN}} = 62.4$ and 200 GeV. Statistical errors are shown with error bars and systematic errors are shown with open and shaded boxes.

kinematics and reconstruction efficiencies we have a very good agreement in $p+p$ and d+Au. In Au+Au collisions we measured three p_T points in each most central, minimum bias and peripheral collisions in $\omega \to \pi^0\gamma$ channel. In minimum bias Au+Au collisions PHENIX also has preliminary measurement of $\omega \to e^+e^-$ production at low p_T.

Dependence of ϕ-meson temperature and integrated yield per participant on the system size is shown in the left panel of Figure 2. The extracted temperatures do not

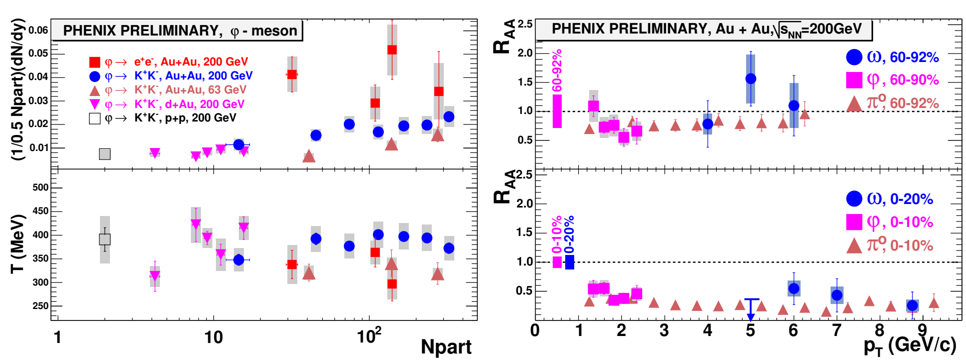

Figure 2. Left: ϕ-meson inverse slope and integrated yield per pair of participants as a function of centrality. Right: Nuclear modification factors for ω- and ϕ-mesons measured in Au+Au collisions at $\sqrt{s_{NN}} = 200$ GeV. Error bars and shaded boxes represent statistical and systematic errors respectively. Vertical bars on the far left side of the R_{AA} plots represent systematic errors from uncertainty of number of binary collisions for different centrality bins.

change among different collision systems at the same energy and only slightly grow between 62.4 GeV and 200 GeV. The integrated ϕ-meson yield per participant increases by a factor of two from peripheral to central collisions for two RHIC energies. The highest centrality bin for the $\phi \to e^+e^-$ channel has limited statistics and is derived from an independent analysis where the invariant yield is obtained using the integral yield and the correction factor integrated over m_T assuming $T = 366$ MeV. Preliminary measurement of the yields in leptonic channel looks higher then in $\phi \to K^+K^-$ channel. However, the size of the statistical and systematical errors prevent us from making any definite statements. The right panel of Figure 2 shows nuclear modification factors (R_{AA}), defined as the ratio of particle yields in Au+Au and p+p collisions scaled by the number of binary collisions, measured for ω- and ϕ-mesons in hadronic decays. In peripheral Au+Au collisions meson yields scale from p+p by number of binary collisions. But in most central collisions we observe a suppression on the level of 0.3-0.4 that is consistent, within errors, with results for other neutral mesons [8].

Short lived light mesons are considered a good probe of chiral symmetry restoration, which can be seen as modification of meson properties in leptonic channels in heavy ion collisions. Some recent publications suggest that modification of meson masses can also

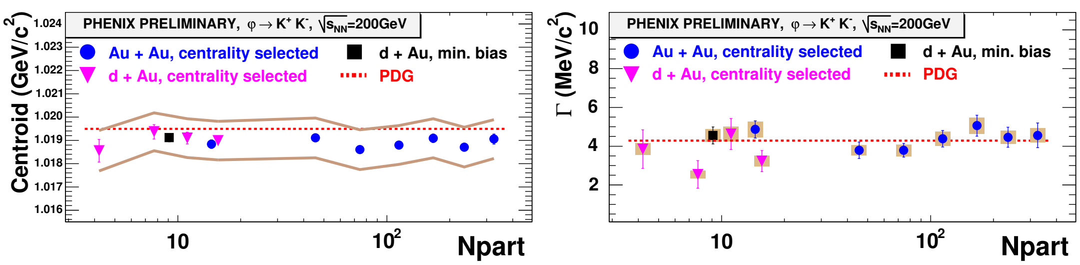

Figure 3. Centrality dependence of the width and mass of ϕ-meson in $\phi \to K^+K^-$ channel in d+Au and Au+Au collisions at $\sqrt{s_{NN}} = 200$ GeV. Statistical errors are shown with error bars. Shaded boxes and bands represent systematic errors.

be observed in hadronic decays and not only in heavy ion collisions [9, 10]. The centrality dependence of the mass and width of ϕ-mesons reconstructed in $\phi \to K^+K^-$ decay channel in d+Au and Au+Au collisions at $\sqrt{s_{NN}} = 200$ GeV is shown in Figure 3. No modification of the ϕ-meson mass or width measured in hadronic channels is observed. In p+p and d+Au collisions, within the errors of the measurement, we find reconstructed ω-meson mass in agreement with PDG value at p_T >2.5 GeV/c [6].

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