ϕ meson production in Au - Au collisions at $\sqrt{s_{NN}} = 200$ GeV

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A simultaneous measurement of the ϕ meson via its K^+K^- and e^+e^- decay channels was performed in Au + Au collisions at $\sqrt{s_{NN}} = 200$ GeV at mid-rapidity by the PHENIX experiment. The preliminary minimum bias yields dN_ϕ/dy in the kaon and electron channels are $2.01 \pm 0.22(stat.)^{+1.01}_{-0.52}(syst.)$ and $5.4 \pm 2.5(stat)^{+3.4}_{-2.8}(syst.)$, respectively. The centrality dependence of the yield in the K^+K^- channel is presented.

1. Introduction

The ϕ meson is an important probe for studying relativistic heavy ion collisions. Since the mass of the ϕ meson is close to twice the kaon mass, any medium modification of its spectral shape (mass and/or width) [1] as chiral symmetry restoration is approached may induce a change in its branching ratio in the kaon channel. The simultaneous measurement of ϕ decay into K^+K^- and e^+e^- is a very powerful tool in the search for such in-medium modifications. Consisting of $s\bar{s}$, the ϕ meson is also a sensitive probe of strangeness production [2]. The PHENIX experiment at RHIC, with its excellent mass resolution and particle identification capability, (comparable to or better than the natural width of the ϕ meson) has the unique capability to measure the ϕ meson through both K^+K^- and e^+e^- decay channels at mid-rapidity. We present the preliminary results of the ϕ meson measurement made during the 2001 RHIC run.

2. Experimental setup and data analysis

The results presented here were obtained using the two central arms of the PHENIX spectrometer [3]. The $\phi \rightarrow K^+K^-$ analysis used the drift chamber (DC), two sets of multiwire proportional chambers with pixel-pad readout (PC1 and PC3), and the time of flight (TOF) module of the east arm. The acceptance is defined by the TOF module which covers the pseudorapidity range $|\eta| < 0.35$ and an azimuthal range of $\Delta\phi \approx 30°$. The kaons were identified via reconstructed momentum combined with a TOF measurement with a time resolution ~ 120 ps. With a 2σ momentum dependent cut in the mass squared distributions, π/K were well separated up to $p \sim 2.0$ GeV/c.

The $\phi \rightarrow e^+e^-$ measurements were performed with the DC, PC1, PC3, the Ring Imaging Cerenkov Detector (RICH) and the electromagnetic calorimeter (EMCAL) of both the east and west arm, each one covering $\Delta\phi = 90°$ and $|\eta| < 0.35$. Electrons were identified

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primarily by the RICH. Further identification was provided by requiring the energy in the EMCAL to match the measured momentum of the tracks.

Charged particle tracks and their momenta were reconstructed using the DC and PC1. Tracks were confirmed by a matching hit in PC3 and TOF in the case of kaons, and in the EMCAL for electrons.

The beam-beam counters (BBC) and the zero-degree calorimeters (ZDC) provided the trigger and were used to determine the event centrality. The BBC were also used to determine the z-coordinate of the collision vertex (z_{vertex}). The analysis used 27.4×10^6 (for kaons) and 25.8×10^6 (for electrons) minimum bias events with a vertex position within $|z_{vertex}| < 30$ cm.

3. Analysis procedure

3.1. Data

All identified kaon tracks in a given event were combined to form the invariant mass distributions of the like sign (N_{++}, N_{--}) and unlike sign pairs. The large combinatorial background inherent to this procedure was estimated by an event mixing method in which all K^+ tracks from one event were combined with K^- tracks of ten other events of the same centrality and vertex class. The mixed event invariant mass distribution was then normalized to the measured $2\sqrt{N_{++}N_{--}}$. The validity of the method was tested by constructing, in a similar way, a combinatorial like-sign spectrum and comparing it to the measured like-sign pair distribution. Finally, the signal was obtained by subtracting the mixed event spectrum from the measured one. This gives the uncorrected ϕ-yield (N_ϕ^{Signal}) of the K^+K^- decay channel. An identical procedure was used for the measurement of the e^+e^- decay channel.

3.2. Corrections

In order to obtain the yield dN_ϕ/dy from the uncorrected signal, we correct our invariant mass distributions for detector acceptance and reconstruction efficiency. The correction was determined using Monte Carlo simulations in two steps. In the first step, we generated single ϕ mesons with an exponential transverse momentum distribution ($dN/dp_T \sim p_T \,.\, exp(-m_T/T)$), assuming a temperature of $T = 380$ MeV which is consistent with the measurement by the STAR experiment at $\sqrt{s_{NN}} = 130$ GeV [4]. The generated ϕ's were then propagated through the PHENIX detector simulation and the pair acceptance and reconstruction efficiency was calculated by:

$$\epsilon = \frac{N_\phi^{generated}}{N_\phi^{reconstructed}} \qquad (1)$$

In the second step, the multiplicity dependent efficiencies (ϵ_{mult}) were estimated by embedding single tracks into the real data events.

The final corrected yield is given by

$$\frac{dN_\phi}{dy} = \frac{N_\phi^{Signal} \times \epsilon \times \epsilon_{mult}^2}{N_{event} \times BR}, \qquad (2)$$

where BR represents the branching ratio for the specific decay channel ($e^\pm$ or $K^\pm$).

4. Results

4.1. Invariant mass distributions

Fig. 1 shows the minimum bias invariant mass distributions for $\phi \to K^+K^-$ (panel (a)) and $\phi \to e^+e^-$ (panel (c)). The kaon channel results for the 40%-80% centrality range are shown in Fig. 1(b), where we see a considerable improvement in the signal to background ratio compared with minimum bias spectrum. Since the combinatorial background increases quadratically with centrality, this means that the signal increases at a much lower rate with centrality.

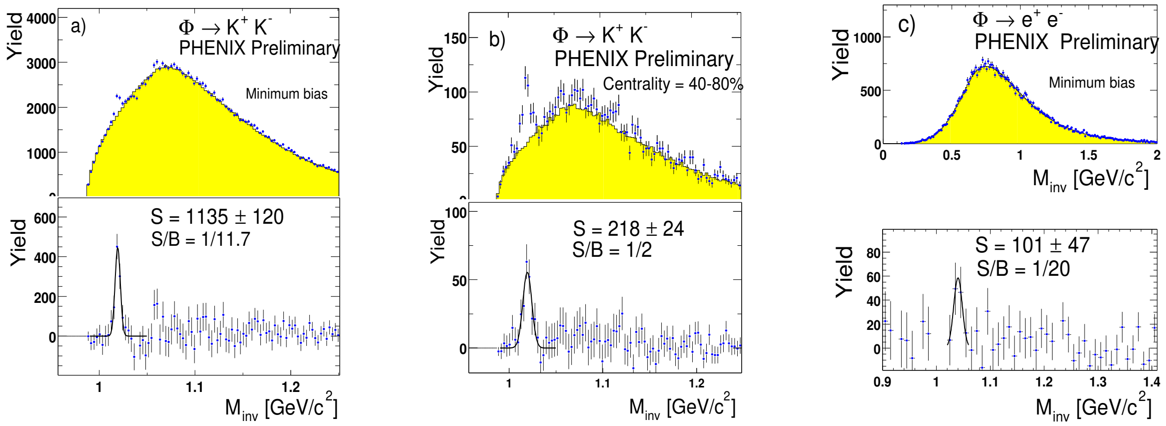

Figure 1: Invariant mass distributions of $\phi \to K^+K^-$ for (a) minimum bias events and b) 40-80% central events. The mass spectrum of $\phi \to e^+e^-$ for minimum bias is shown in (c). The points in the upper panels represent the data and the filled histograms show the combinatorial background whereas the lower panels exhibit the subtracted mass spectra.

4.2. dN_ϕ/dy

The rapidity density (dN_ϕ/dy) values calculated using Eq. (2) for the kaon and electron channels are shown in Table 1. The systematic errors in both cases originate from the correction factors in the Monte Carlo simulation and the analysis method. In the $\phi \to K^+K^-$ analysis, the main systematic uncertainty originates from the uncertainty (assumed to be $\pm 20\%$) in the temperature used in the Monte Carlo calculations. Since the TOF array has no acceptance for low pair p_T, the correction factor ϵ is very sensitive to the slope of the parent p_T distribution. For $\phi \to e^+e^-$, the analysis procedure is the major source of the systematic error. Within the present large statistical and systematic errors, the values of dN_ϕ/dy for both cases are consistent with each other. ϕ mesons from dimuon and kaon channels were also observed by the fixed target NA50 and NA49 experiments respectively at a beam energy of 158 AGeV at CERN. These two independent experimental results showed a factor of 5 difference in the dN_ϕ/dy values for the muon channel ($dN_\phi/dy \sim 13$) as compared to the kaon channel ($dN_\phi/dy \sim 2.35$) [5]. Higher statistics together with a better understanding of the systematics will enable us to see whether or not such a large difference persists at RHIC energies.

4.3. Centrality dependence

In Fig. 2(a), we plot dN_ϕ/dy as a function of centrality (expressed in percentiles) for the kaon channel. The variation of the rapidity density per participant with the

Table 1: ϕ - meson rapidity density in Au - Au at $\sqrt{s_{NN}}$ = 200 GeV

Decay channel	dN_ϕ/dy	Statistical error	Systematic error
$\phi \rightarrow K^+K^-$	2.01	± 0.22	$^{+1.01}_{-0.52}$
$\phi \rightarrow e^+e^-$	5.4	± 2.5	$^{+3.4}_{-2.8}$

number of participants is shown in Fig. 2(b). The shape of this curve differs from the $(1/N_{part}) \times (dN_{ch}/d\eta)$ vs. N_{part} distribution, which shows a steady increase of $\sim$ 20% from peripheral to central collisions [6].

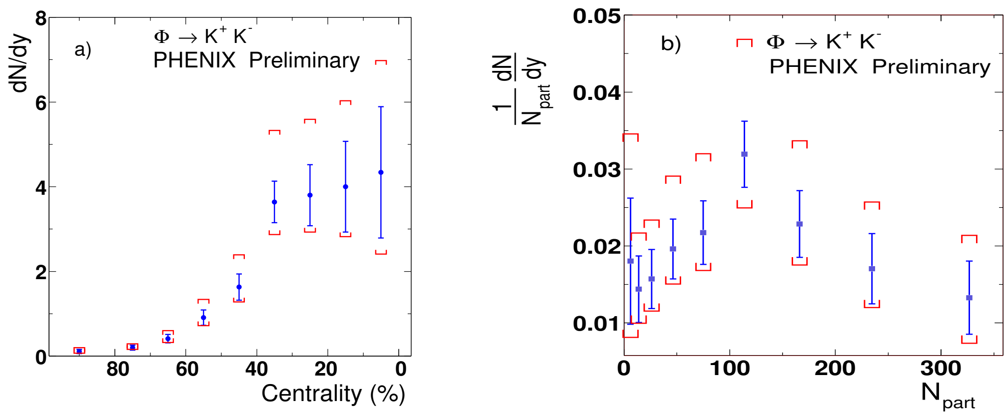

Figure 2: Centrality dependence of ϕ yields (solid lines are statistical and brackets represent systematic errors).

5. Summary

PHENIX has measured the yield of ϕ mesons via the K^+K^- and e^+e^- channels. The values of dN_ϕ/dy for $\phi \rightarrow K^+K^-$ and $\phi \rightarrow e^+e^-$ are consistent within the large statistical and systematic errors of the present preliminary analysis. The centrality dependence of the ϕ yields in the kaon decay channel is also presented.

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