MEASUREMENTS OF ϕ MESON DECAYS IN NUCLEAR MATTER AT KEK–PS

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The experiment KEK-PS E325 measures decays of the ϕ meson in 12GeV p+A reactions both in the $\phi \to K^+K^-$ and the $\phi \to e^+e^-$ channels to investigate experimental signatures of mass shift in nuclear matter at normal density. Status of the experiment is presented and the preliminary data are shown.

1. INTRODUCTION

In recent years, studies of chiral properties of QCD in hot(T$\neq 0$) or dense($\rho \neq 0$) matter attract wide interests in relation to quark-gluon plasma(QGP) formation. Although an order parameter of chiral symmetry, $\langle \bar{q}q \rangle$, is not an observable, the vector-meson masses can provide a good estimate of $\langle \bar{q}q \rangle$. Experimental observation of in-medium modifications of the vector mesons is thus desirable to explore natures of quark matter.

In hot matter $\langle \bar{q}q \rangle$ is expected to decrease rapidly to zero around T_c where QCD phase transition will occur and chiral symmetry is restored. The observed excess in lepton pairs in the CERN heavy-ion experiments may already hint a precursor of the symmetry restoration[1].

On the other hand, in dense matter, linear decrease of $\langle \bar{q}q \rangle$ is also expected theoretically[2]. Several experimental efforts, including this work, have been started to investigate effects of partially restored chiral symmetry at normal nuclear-matter density [3], taking advantage of *constant* density of nucleus.

The present experiment focuses on measurements of the ϕ meson, for the sake of experimental sensitivities as explained below. Based on QCD sum rule, Hatsuda and Lee [2] predicted that the ϕ meson mass decreases as shown in Figure 1. According to this model, mass decrease of the ϕ at normal nuclear density ρ_0 is 20 $\sim$ 40 MeV. Although the model predicts larger mass shift for the ρ or the ω meson, there are two advantageous aspects in the ϕ decay, namely the width and the decay modes.

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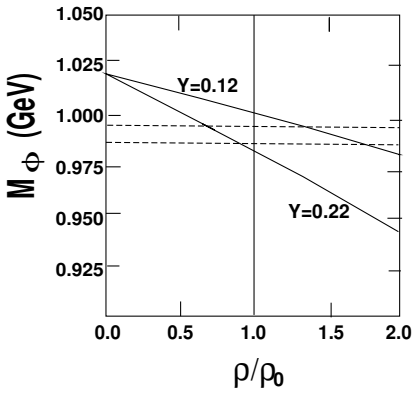

Figure 1. Expected mass shift of the ϕ meson as a function of density[2]. Two lines represent an ambiguity of $\langle \bar{s}s \rangle$ in nucleus.

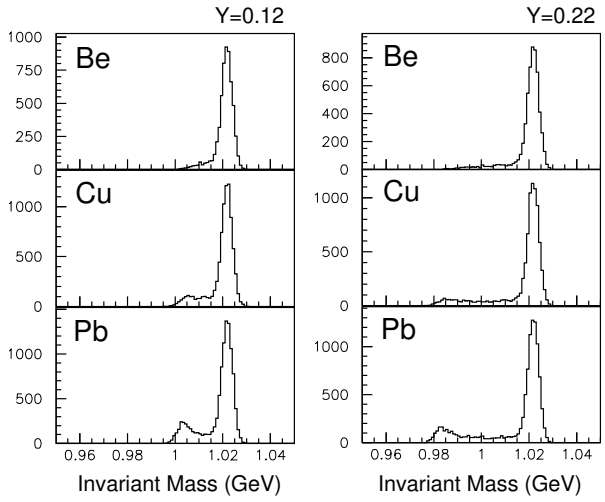

Figure 2. Expected mass spectrum of the ϕ meson for Be, Cu and Pb targets. The left and right columns correspond to the two lines in Figure 1.

Figure 2 shows the expected invariant-mass spectra[1] of the ϕ for Be, Cu and Pb nuclei. In Cu case, about 10% of ϕ's decay inside the nucleus, and make the second peak on left side of the main peak which consists of ϕ's decayed outside the nucleus. It should be noted that in the K^+K^- channel, the invariant mass spectra could be deformed due to kaon rescatterings in nucleus. Measurements in the e^+e^- channel is thus more attractive.

The decay branching ratios are sensitive to the mass shift of the ϕ and kaon because of the small Q-value, 32MeV, in the K^+K^- channel. Even if the kaon mass shifts and the ϕ mass is unchanged, the effect results in a change of the branching ratios.

The combined observation of the mass distributions and the branching ratios is important to conclude the meaning of the signatures.

2. EXPERIMENTAL PROCEDURE

The spectrometer has been built at the primary beam line EP1B in the 12GeV-PS at KEK. The layout is shown in Figure 3. We measure the invariant mass spectra both in the e^+e^- channel and in the K^+K^- channel, and measure the ratio, the number of the ϕ decays into K^+K^- over e^+e^-. The target mass-number dependences of those observables are examined to distinguish the in-medium effect from artificial experimental effects.

There are two key points in this experiment. First is to detect slowly moving ϕ's ($\beta\gamma \leq 2$) which has a larger probability to decay inside nucleus. Second is to use high quality primary beam on thin targets to suppress the γ-conversion background in the

[1]The Woods-Saxon type nuclear density distribution is employed in the Monte Carlo calculation which treats the ϕ with $\beta\gamma_{lab} \sim 1$. The dispersion of mass in media which is experimentally measurable is neglected in the calculation.

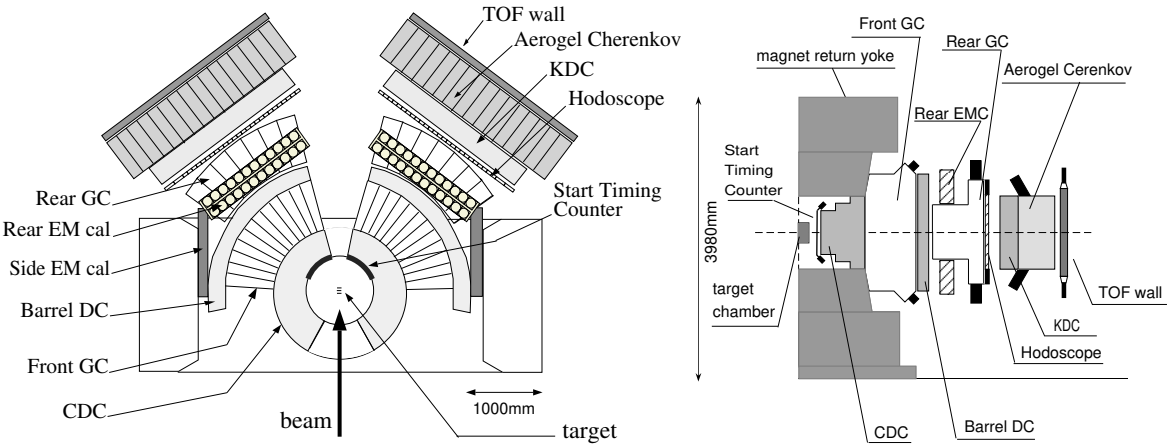

Figure 3. Schematic view of the E325 spectrometer, the top view and the side view.

e^+e^- channel.

The spectrometer has two arms for electrons and kaons, sharing the magnet and the tracking devices as common. The electron arms cover from $\pm 12°$ to $\pm 90°$ horizontally and $\pm 22°$ vertically. The kaon arms cover from $\pm 12°$ to $\pm 54°$ and $\pm 6°$. Primary protons with intensity of 1×10^9 Hz are delivered to the targets at the center of the magnet. Three targets (C,CH_2, Cu/Pb) with thickness of 0.1$\sim$0.2% in radiation length are placed in-line. Tracking is performed with the Cylindrical Drift Chamber (CDC) and the Barrel Drift Chambers (BDC). The design value of mass resolution is 5MeV/c^2 for e^+e^- and 1.1MeV/c^2 for K^+K^- through the magnetic field of 0.78 Tm. The Kaon Drift Chambers(KDC) are used to discard decayed kaons.

For the kaon identification, segmented silica aerogel Čerenkov counters (AC) and the Time-Of-Flight counters (TOF) are used. The AC uses 500 litters of aerogel[2] of which the transmittance is high enough to adopt the optical system with collection mirrors for Čerenkov photons. Veto efficiency of 98% for π above 0.5GeV/c is achieved in the test.

Since we do not count the beam, the start timing is given by the Start Timing Counters(STC) placed at the entrance of each kaon arm. They are operated with 2-inch fine-mesh PMT's in the magnet with the field strength of 0.7 T. The Forward TOF counters in combination with the Hodoscope counters(HOD) determine the charge and the momentum of particles, and make the kaon selection possible with the β measurements in the second level trigger.

For electron identification, the segmented Gas Čerenkov counters(FrontGC/RearGC) and the lead glass EM calorimeters (SideEMC/RearEMC) are used. The FGC and the RGC use isobutane as radiator. Aluminum evaporated mirrors and Winston cones are used to collect Čerenkov photons. These counters reject 99.7% of π's below 2GeV/c.

The EMCs use lead glass (SF6W) recycled from TRISTAN. Inside the return yoke they have a hodoscope-like structure (SideEMC). In one segment, 5 glass blocks are stacked

[2]By introducing new technology to produce hydrophobic and highly transparent aerogel[4] the production is made by ourselves in Mori-Seiyu Co. Ltd.

vertically and glued by epoxy resin. Čerenkov photons from EM shower are transported by total reflection along the surface to the PMTs. The pion rejection is better than 90% in the energy region of interest (0.4GeV∼2GeV).

3. PRESENT STATUS OF THE EXPERIMENT AND OUTLOOK

The first physics run has been performed in June 1997. Major production runs will start in March 1998 toward the collection of more than 10^4 $\phi \rightarrow e^+e^-$ decays for each target nucleus. In the end the branching ratios can be compared with 4% accuracy between the heavy target case and the hydrogen case (obtained via CH_2-C subtraction).

Figure 4 shows the preliminary data of the invariant mass distribution of the K^+K^- decay channel. Although the track fitting is very premature in this stage of analysis (hence the mass resolution is not optimized), $\phi \rightarrow K^+K^-$ decays are clearly identified. Further data accumulation and analyses will give an answer to the possible matter modification of the ϕ meson mass.

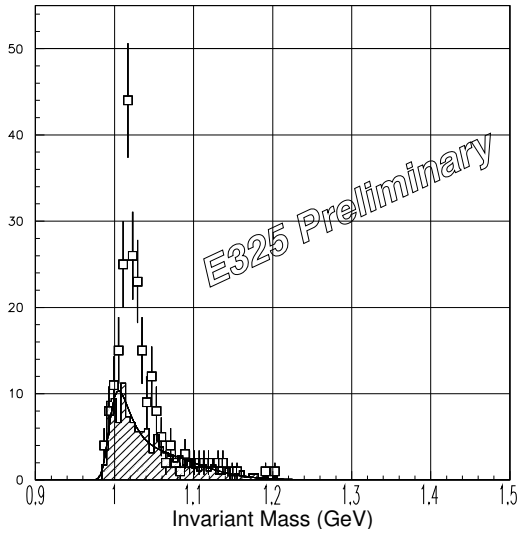

Figure 4. Invariant mass distribution of the K^+K^- channel. The hatched area represents the background estimated with mixed events.

REFERENCES

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3. HADES at GSI is preparing for the stopped ω production via the $\pi + A \rightarrow \omega + A^*$ interaction (http://piggy.physik.uni-giessen.de/hades/). A new proposal is accepted at GSI/SIS to search for bound η- and ω- nuclear states using the recoilless $(d,^3He)$ reaction. The TAGX collaboration in CNS-ES at University of Tokyo published the data showing ρ^0 mass modification in the $^3He(\gamma,\rho^0)ppn$ reaction (Phys. Rev. Lett. 80 (1998) 241). On the ϕ meson our experiment is presently the only one (http://www.pn.scphys.kyoto-u.ac.jp/~yokkaich/phi/pub/E325_project.html). There is a planned experiment for $\gamma + A \rightarrow \phi + A^*(\phi \rightarrow K^+K^-)$ at SPring-8 in Japan.
4. I.Adachi et al., Nucl. Instr. and Meth. A 335 (1995) 390.