Study of Chiral Property of Dense Nuclear Matter through Measurements of Meson Mass-Modification in Medium (E325)

J. Chiba[a], H. En'yo[b], H. Funahashi[b], H. Hamagaki[c], , M. Ieiri[a], M. Ishino[b], M. Kitaguchi[b], S. Mihara[b* 1], T. Miyashita[b], T. Murakami[b] R. Muto[b], M. Naruki[b], M. Nomachi[d], K. Ozawa[b****], O. Sasaki[a], F. Sakuma[b], M. Sekimoto[a], H. D. Sato[b], T. Tabaru[b], K. H. Tanaka[a], S. Yamada[b], S. Yokkaichi[b**] and Y. Yoshimura[b***]
a) KEK, Particle and *b*) Department of Physics Kyoto University, Kitashirakawa-Oiwakecho, Kyoto 606 Japan. CNS University of Tokyo[c], Osaka University[d]

In quantum chromodynamics, hadrons are described as a bound state of confined valence quarks which obtained their effective mass due to the spontaneous breaking of chiral symmetry. This mechanism determines the properties of hadrons in free space, such as the mass and the decay width. In hot or dense matter those properties can possibly be modified. It is theoretically predicted that observation of in-medium mass modification on vector mesons (Spin=1, Parity=-1 mesons) can provide a direct measure of how much the chiral symmetry is broken in nuclear medium. Such studies thus provide crucial information of the nature of QCD in the non-perturbative region.

Several experimental efforts including this work are underway to investigate effects of the partially-restored chiral symmetry at normal nuclear-matter density, and experiments are about to start at RHIC in BNL focusing on hot nuclear matter.

The present experiment E325 was designed and built at the primary beam line EP1B in KEK 12–GeV Proton Synchrotron, to explore this new field of physics by measuring the invariant mass spectrum of those vector meson produced via 12GeV p+A interactions. The special emphases are put on the detection of slowly moving mesons which have a larger probability to decay inside nucleus, and on the simultaneous measurements of $\phi \to K^+K^-$ and $\phi \to e^+e^-$ decays in the same apparatus. Apparently the spectrometer can detect $\omega/\rho \to e^+e^-$ decays also. It should be noted that high quality primary beam on thin targets is needed to suppress the background from γ-conversion in the e^+e^- channel.

Figure 1 and 2 show a schematic layout of the experiment. Beam protons were delivered to three targets (typically carbon, copper and polyethylene) placed in-line at the center of the spectrometer magnet.

[1]Present Address: *)ICEPP, University of Tokyo. **)RIKEN. ***)Xaxon Cooperation. ****)CNS, University of Tokyo

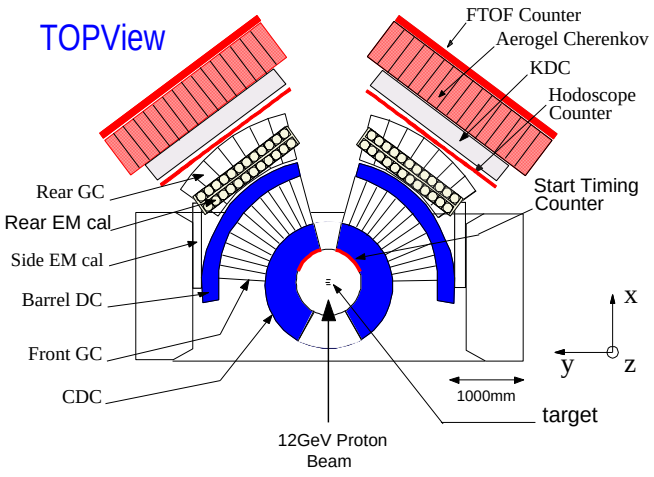

Figure 1: Top view of the E325 setup

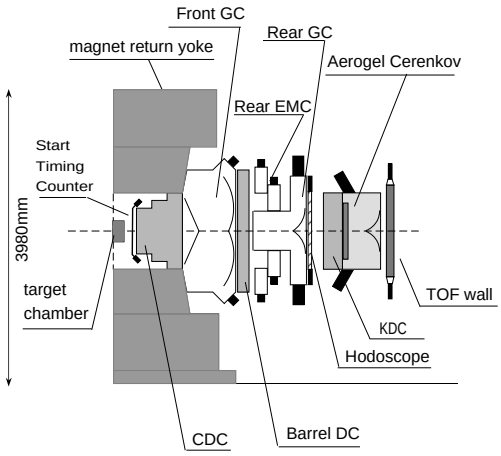

Figure 2: Side view of the E325 setup

The spectrometer has two arms for kaon and electron detection, sharing the magnet and the tracking devices as common. The kaon arms cover from $\pm 12^\circ$ to $\pm 54^\circ$ horizontally and $\pm 6^\circ$ vertically, where the horizontal angle was measured from the beam line and the vertical angle was measured from the horizontal plane. The electron arms have a much larger acceptance covering from $\pm 12^\circ$ to $\pm 90^\circ$ horizontally and $\pm 22^\circ$ vertically.

The spectrometer construction was completed in 1997, and the physics data taking is continuing since 1998. So far we have successfully observed invariant-mass peaks of ϕ, ω, Λ and K_s. Among them a striking feature was observed in the e^+e^--pair spectrum as shown in Figures 3 and 4 for carbon and copper targets. A clear peak of ω meson is observed in the carbon target data. A difference between the copper case from the carbon case is quite obvious, attributed to the difference of the nuclear radii. The broader peak (or can be double peaks) in the copper target data can be the signal of nuclear matter modification on ω. The width of the mass spread is consistent with the prediction by Hatsuda *et al.*.

This experiment is the first attempt to measure the production and the decay of vector mesons in the kinematical region where the effect of nuclear media should play an important role. The surprising feature observed in the e^+e^- spectrum is based on the data taken in 1998. The analysis of the data in 1999 is now going on, and further data accumulation is scheduled in 2000 and later, so that better statistics will soon be available. The final results will provide the dispersion relation of vector mesons in nuclear media for the first time.

References

[1] T. Hatsuda and S. H. Lee, Phys. Rev. C46 (1992) R24.

[2] E325 proposal, http://www.pn.scphys.kyoto-u.ac.jp/~enyo/e325/phi_root.ps.Z)
S. Yokkaichi, Memoir of The Faculty of Science, Kyoto University, (doctor thesis), in print.
G.J. Lolos et al. (TAGX Collaboration),Phys. Rev. Lett. 80 (1998) 241-244.
T. Kinashi *et al.*, Exciting physics with new accelerator facilities 55-62.
W. Schoen et al.(HADES Collaboration), Acta Phys. Polon. B27:2959-2963,1996.
GSI/SIS proposal S214, Search for bound η- and ω- nuclear states using the recoilless $(d,^3He)$ reaction.

Publication List of E325

- Study of nuclear matter effect on K^+K^- invariant mass measured in in 12-GeV p + A interaction
  M. Ishino (Doctor thesis), To appear in Memoirs of the Faculty of Science, Kyoto University.

- Study of Nuclear Dependence of Production and Decay of ϕ meson in 12-GeV p + A interaction
  S. Yokkaichi (Doctor thesis), Memoirs of the Faculty of Science, Kyoto University, Vol.XXXXI, No.1, Article 3, 2000.

- Mass production of hydrophobic aerogel and readout optics of Čerenkov light
  M.Ishino et al. (KEK-PS-E325 collaboration)
  To appear in Nucl. Inst. Meth.

- MEASUREMENTS OF NUCLEAR MEDIA MODIFICATION ON $\phi \to e^+e^-$ DECAYS AT KEK–PS
  K. Ozawa. et al. (KEK-PS E325 collaboration).
  Contribution paper at International Workshop e^+e^- Collisions From ϕ to J/ψ. March 1999, Novosibirsk, To appear in Nuclear Physics B.

- Nuclear production of ϕ meson at KEK
  H. En'yo et al. (KEK-PS E325 collaboration).
  Invited talk at the 2nd KEK-Tanashi International Symposium on "Hadron and Nuclear Physics with Electromagnetic Probes" (Oct.25 - 27, 1999), KEK-Tanashi, Tokyo, Japan. KUNS-1637, to appear in Nuclear Physics.

- Study of Chiral Property of Nuclear Matter through the Measurements of phi Meson Decays
  H. En'yo et al. (KEK-PS E325 collaboration).
  Invited talk at the KEK-Tanashi International Symposium on "Physics of Hadrons and Nuclei", 14-17 December 1998,Sanjo Conference Hall, University of Tokyo, Tokyo,Japan.
  Published in Nucl.Phys.A670:182c-185c,2000

- MEASUREMENTS OF PHI MESON DECAYS IN NUCLEAR MATTER AT KEK-PS.
  By KEK-PS-E325 Collaboration (S. Yokkaichi et al.). 1998. Given at 13th International Conference on Ultrarelativistic Nucleus-Nucleus Collisions (Quark Matter 97), Tsukuba, Japan, 1-5 Dec 1997.
  Nucl.Phys.A638:435-438,1998.

- LEPTON PAIR PRODUCTION AT JHF: MESON MODIFICATION IN NUCLEAR MEDIA AND QCD CHIRAL SYMMETRY RESTORATION.
  By H. Enyo (Kyoto U., FIHS). 1998.
  Given at International Workshop on JHF Science (JHF 98), Tsukuba, Japan, 4-7 Mar 1998.
  In *Tsukuba 1998, JHF science, vol. 2* 178-181.

- MEASUREMENTS OF PHI MESON DECAYS IN NUCLEAR MATTER AT KEK-PS.
  By KEK-PS-E325 Collaboration (S. Yokkaichi et al.). 1998.
  Published in Nucl.Phys.A638:435-438,1998

- ϕ Decay in Nuclear Matter
  Hideto En'yo

Proceedings fo the U.S.-Japan semnor, 'Properties & Interactions of Hypeons' 25-28 October, 1993, Maui,Hawaii, published from Worlid Scientific, Edited by B.F. Gibson, P.D. Barnes and K. Nakai

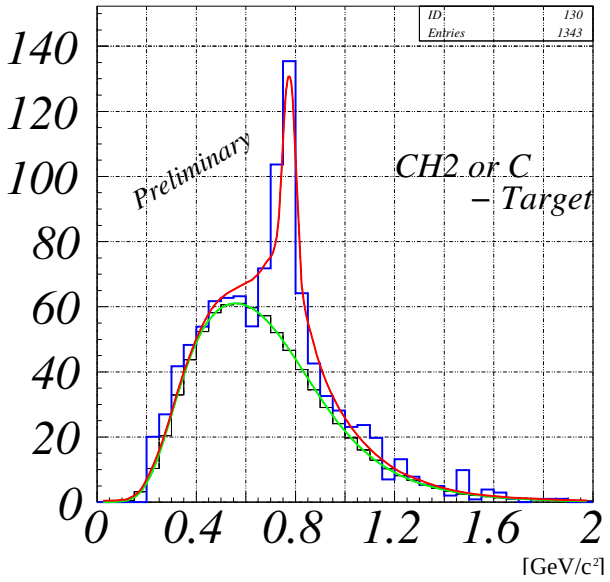

Figure 3: Preliminary e^+e^- invariant-mass spectrum for carbon target (blue). The curves are the fit of ρ/ω resonances (red) with a mixed-event background (green).

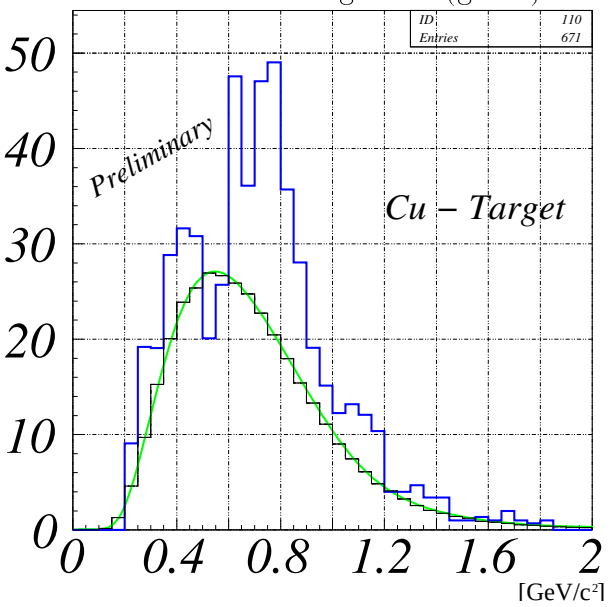

Figure 4: Preliminary e^+e^- invariant-mass spectrum for copper target (blue). The green line is the estimated background by event mixing.