Soryushiron Kenkyu (Kyoto), Vol. **102** (2001), E191-E194

Measurements of Mass Modification of Vector Mesons in Nuclear Matter

Kyoichiro OZAWA[a* *)],
J. CHIBA[b], H. EN'YO[a], H. FUNAHASHI[a], H. HAMAGAKI[c], , M. IEIRI[b],
M. ISHINO[a**], M. KITAGUCHI[a], S. MIHARA[a**] T. MIYASHITA[a], T. MURAKAMI[a]
R. MUTO[a], M. NARUKI[a], M. NOMACHI[d], O. SASAKI[b], F. SAKUMA[a],
M. SEKIMOTO[b], H. D. SATO[a], T. TABARU[a], K. H. TANAKA[b], S. YAMADA[a],
S. YOKKAICHI[a***] and Y. YOSHIMURA[a****]

a) Department of Physics, Kyoto University, Kitashirakawa Sakyo-Ku, Kyoto, 606-01, Japan
b) KEK, 1-1 Oho, Tsukuba, Ibaraki 305-0801 Japan
c)CNS, Graduate School of Science, University of Tokyo, 7-3-1 Hongo, Tokyo 113-0033, Japan
d) Osaka University,10-1 Mihogaoka, Ibaraki, Osaka 567-0047, Japan

We have measured Invariant mass spectra of electron-positron and K^+ K^- pair produced in 12GeV p+A reactions. We have observed a significantthe line shapes of ρ and ω mesons p+C and p+Cu interactions, which is attributed to the in media mass modification of the ρ and ω meson.

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[1)] 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[2)] 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.

---

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

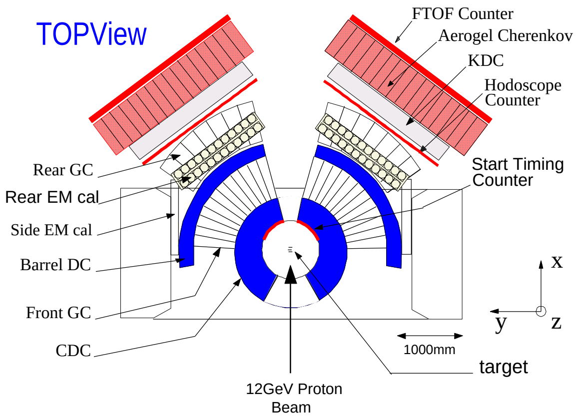

Fig. 1. Top view of the E325 setup

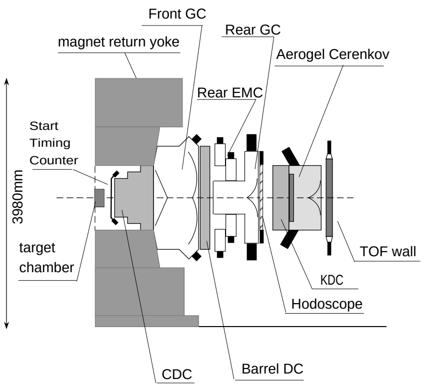

Fig. 2. Side view of the E325 setup

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. The spectrometer has two arms for kaon and electron detection, sharing the magnet and the tracking devices as being 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.

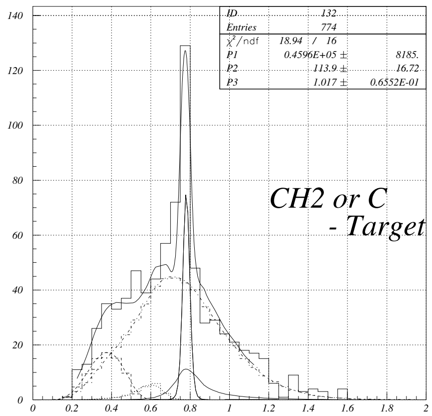

Fig. 3. Preliminary e^+e^- invariant-mass spectrum for carbon target. The curves are the fit of ρ/ω resonances and other meson-decay contributions with a mixed-event background.

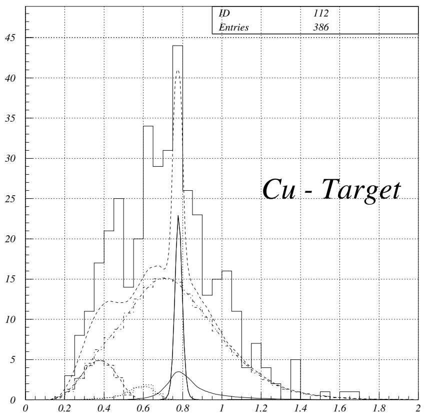

Fig. 4. Preliminary e^+e^- invariant-mass spectrum for copper target. The curves are the fit of ρ/ω resonances and other meson-decay contributions with a mixed-event background.

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.

On the other hand, in the $\phi \to K^+K^-$ channel we havn't observed any in-medium decay effect within the available statistics. The spectrum was consistently described by the nuclear cascade code JAM as shown in Fig.5. Nuclear mass-number dependence of production cross section is found to be close to unity both in the data ($\alpha = 1.01 \pm 0.09$) and in the JAM simulation ($\alpha = 1.08 \pm 0.01$).

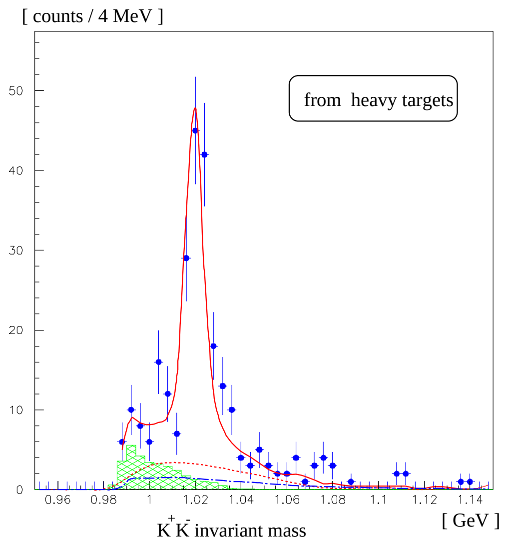

Fig. 5. K^+K^- invariant-mass spectrum for heavy nuclear targets (Cu and Gd are combined). The full line is the fit result. The hatched histogram represents the $a_0/f_0 \to K^+K^-$ decay which is rescaled to 27%. Other lines are the contamination from the particle miss identification and combinatorial background.

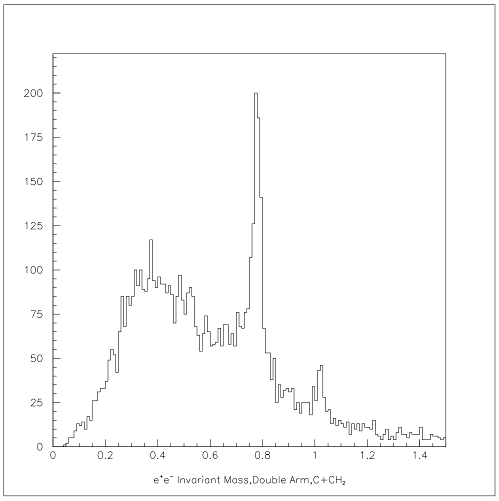

Fig. 6. Preliminary e^+e^- invariant-mass spectrum for the C and CH2$_2$ target. (1999-year data)

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 showing the clear indication of $\phi \to e^+e^-$ decay peak (see Fig.6). Further data accumulation is scheduled and partially executed 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) W. Schoen et al.(HADES Collaboration), Acta Phys. Polon. B27:2959-2963,1996
G.J. Lolos et al. (TAGX Collaboration),Phys. Rev. Lett. 80:241-244,1998
GSI/SIS proposal S214, Search for bound η- and ω- nuclear states using the recoilless $(d,^3He)$ reaction.
T. Kinashi, K. Takanashi, M. Fujiwara, T. Hotta, T. Nakano, In Hyogo 1997, Exciting physics with new accelerator facilities 55-62.