Search for medium effects on light vector mesons

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Abstract. The photoproduction of vector mesons on various nuclei has been studied using the Cebaf Large Acceptance Spectrometer (CLAS) at Jefferson Laboratory. The ρ, ω, and Φ mesons are observed via their decay to e^+e^-. The ρ spectral function is extracted from the data on carbon, iron, and titanium. We observe no effects on the mass of the ρ meson, some widening in titanium and iron is observed consistent with standard collisional broadening.

INTRODUCTION

Hadron masses, for example the proton at ~1 GeV/c2, are much larger than the summed masses of their constituent quarks, which are a few MeV/c2, indicating that much of the hadron mass is generated dynamically. Hadron masses are somewhat effected by the spontaneous breaking of chiral symmetry. At high temperature or pressure, chiral symmetry may likely be restored. At normal nuclear densities, partial restoration of chiral symmetry may effect the properties of hadrons, in particular masses and widths. [1-6]

The first evidence of a medium-effected ρ mass came from CERN in 1995.[7,8] Theorists were able to account for the observations by assuming a decrease in the mass of the ρ meson.[9] Relativistic heavy-ion results are integrated over a wide range of densities and temperatures. Theoretical predictions of in-medium effects by the different models are so large that they should have observable consequences already at normal nuclear density in γ or π-induced reactions.

Hatsuda and Lee [4], based on QCD sum rule calculations, obtain spectral changes of the vector mesons in the nuclear medium. Their calculations result in a linear decrease of the masses as a function of density:

$$\frac{m_{VM}(\rho)}{m_{VM}(\rho=0)} = 1-\alpha\frac{\rho}{\rho_0}, \quad \alpha = 0.16 \pm 0.06 \qquad (1)$$

Models based on nuclear many-body effects predict a broadening in the width of the ρ meson with increasing density.[5,6] An observation of a medium-modified vector meson invariant mass decrease has been claimed by a KEK-PS collaboration.[10] Very recently, the Crystal Barrel/TAPS collaboration has reported a downward shift in the mass of the ω.[11] All these experiments are yielding results complementary to each other, but no clear consensus has yet emerged between the various analyzes.

EXPERIMENTAL SETUP

The data for this study were taken in 2002 using the CEBAF accelerator and the

CLAS detector located in the Hall-B of the Jefferson Laboratory.[12,13] CLAS is a nearly 4π-detector which was designed to track charged particles with momenta greater than 200 MeV/c. The detector is made of 3 regions of drift chambers, time-of-flight scintillators, Cerenkov counters (CC) and electromagnetic calorimeters (EC). The e+e- event selection and the rejection of the very large $\pi^+\pi^-$ background were done through cuts on the EC and the CC.

Lepton pair production has a background of random combinations of pairs due to the uncorrelated sources. We have treated this background using the combinatorial method that has successfully been used in the past for measurements involving opposite-sign pairs of pions or muons.[14,15]

RESULTS AND DISCUSSION

To simulate each physics process, the events were generated using a code based on a semi-classical Boltzmann-Uehling-Uhlenbeck (BUU) transport model developed by the group of U. Mosel at the University of Giessen.[16,17]

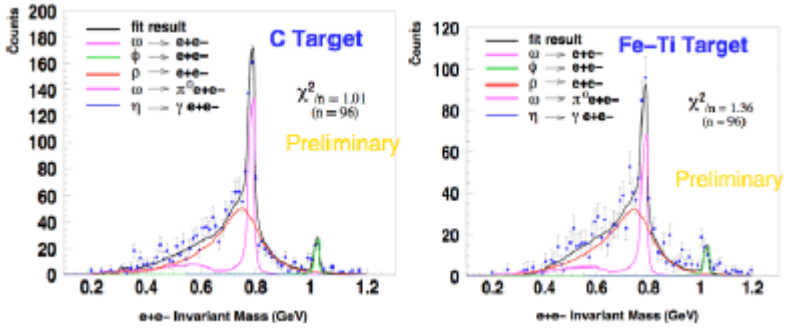

FIGURE 1. Results of the fit to the e+e- invariant mass obtained for C (left) and Fe-Ti (right) data. Curves are Monte-Carlo calculations by the BUU model [18,19] for various e+ e- channels.

The combinatorial background distributions are subtracted from the e+e- spectra. The shape of the narrow ω and Φ vector mesons, and the ω Dalitz channel are well described by BUU model. These fits for C and Fe/Ti are shown in Fig.1. The extracted ρ mass distributions and the ratio to the deuterium data are then simultaneously fit with the suggested functional form of 1/m3 times a Breit-Wigner function.[20-22] The result of the fits are tabulate in Table 1. The fits describe the data very well. The masses are consistent with the PDG values and the widths are consistent with the collisional broadening. We don't observe the doubling of the ρ width reported by NA60.[23,24] Our results do not favor the prediction of Brown and Rho for the mass shift (20%) or Hatsuda and Lee (α =0.16 ± 0.06).

TABLE 1. Mass and width of the □ meson obtained from fits to the mass spectra.(Preliminary results)

Target	Mass (MeV) g7 data	Width (MeV) g7 data	Mass (MeV) BUU	Width (MeV) BUU
D_2	770.3 ± 3.2	185.2 ± 8.6	No BUU	No BUU
C	762.5 ± 3.7	176.4 ± 9.5	769.2 ± 2.0	160.3 ± 3.0
Fe	779.0 ± 5.7	217.7 ± 14.5	764.0 ± 2.5	186.5 ± 5.0

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