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Photoproduction of mesons off nuclei and in-medium modifications of hadrons

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During the last few years, the TAPS, Crystal Barrel, and Crystal Ball collaborations have investigated in-medium effects on hadrons at the MAMI accelerator in Mainz and the ELSA accelerator in Bonn in photon induced meson production reactions. There are many predictions that vector mesons change mass and width in dense and hot nuclear matter, due to partial chiral symmetry restoration. The predicted size of the effects is related to nuclear density and temperature, so that many efforts have been directed towards heavy ion collisions. However, the baryon density varies dramatically with time due to the formation and expansion of the 'fireball', which complicates the interpretation. Furthermore, FSI effects are large, so that only meson decays into leptons (Dalitz-decays of ρ and ω mesons) could be used. In an alternative approach, photo-production of ω mesons from stable nuclei has been investigated at ELSA with the Crystal Barrel/TAPS setup. The ω mesons were identified via their $\pi^o\gamma$ decay. The advantages of this experiment are the much larger decay branching ratio (8.5% for $\omega \to \gamma\pi^o$ compared to 7×10^{-7} for $\omega \to e^+e^-$), the almost complete suppression of background from the ρ meson ($\rho \to \gamma\pi^o$ decay branching ratio: 8×10^{-4}) and the better control over experimental parameters like nuclear density. The experiment has for the first time directly established a downward shift of the ω-mass in nuclear matter via a comparison of the line shape of the ω invariant mass peak observed in photo-production off the free nucleon to the nuclear data. A detailed analysis of the scaling of the observed cross sections with nuclear mass number in the framework of different models has found an inelastic in-medium width of the ω meson in the range 130 - 150 MeV/c^2 at normal nuclear matter density for an average three-momentum of 1.1 GeV/c. Furthermore, a momentum dependent ωN cross section in the range of 70 mb has been extracted. In the sector of scalar mesons, in a series of experiments, double pion photo-production off heavy nuclei has been studied in view of possible in-medium effects on the much discussed σ-meson. Results from a measurement of double π^0 and $\pi^0\pi^\pm$ photo-production off carbon and lead have shown for the heavier nucleus a shift of the strength to lower invariant masses for the $\pi^0\pi^0$ channel; but not for the mixed charge channel. This is a possible argument, that the effect does not arise from FSI, which is assumed to be similar for neutral and charged pions. However, more detailed comparisons to model calculations have shown, that at least part of the effect can be explained by FSI.