Medium effects in rho-meson photo-production

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Medium modifications of hadron properties in hot and/or dense matter are of fundamental interest in connection with the chiral and deconfinement phase transition(s) in QCD. E.g., dilepton spectra measured in high-energy heavy-ion collisions are consistent with a strong broadening of the ρ-meson spectral function in hot and dense hadronic matter [1]. The prevalent medium effects on the ρ are attributed to the baryonic component of the medium, but the rapid expansion of the fireball formed in heavy-ion reactions implies a rather large range of temperatures and densities contributing to the total dilepton spectrum. It is therefore desirable to test medium effects in a static environment, such as provided by ground-state nuclei. Dileptons are of special interest due to their negligible final-state interactions. In the present work [2] we evaluate dilepton spectra resulting from photon-induced ρ-production off nuclei. Toward this goal we combine a previously constructed model for the elementary photo-production process on the nucleon [3] with an in-medium ρ spectral function [4] which has been successfully applied to dilepton spectra in heavy-ion collisions.

The ρ-meson spectral function of Ref. [4] has been calculated within hadronic many-body theory. It includes medium modifications of the pion cloud and direct couplings of the ρ-meson to resonances on pions, nucleons, etc. Constraints on the interaction vertices from hadronic and radiative decays (as well as from total photo-absorption cross sections) lead to rather soft hadronic formfactors which, in turn, induce a considerable 3-momentum dependence of the spectral function: The medium effects are significantly larger at low momentum than at high momentum.
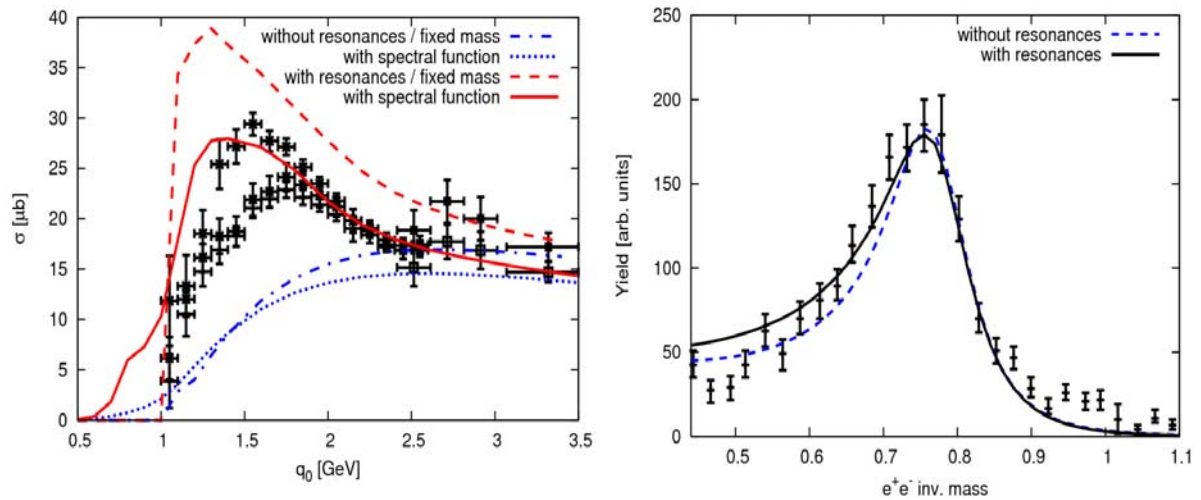

FIG. 1. Left panel: Total cross section for γ p →p ρ^0 as a function of incident photon energy in the laboratory frame. The calculations are based on either a fixed ρ-mass of 770 MeV (dash-dotted and dashed line) or a full vacuum spectral function (dotted and solid line). Right panel: Dilepton invariant-mass spectrum for ρ photo-production off deuterium compared to CLAS data after subtraction of ω- and φ-decay contributions [5].

The ρ photo-production model by Oh and Lee [3] is based on *t*-channel meson-exchange as well as *s*- and *u*-channel nucleon-exchange; it provides a good description of experimental data for photon energies above ~2 GeV. Here, we additionally include baryon-resonance contributions precisely corresponding to the resonance-hole excitations in the ρ spectral function, with identical formfactors but relativistic vertex functions (requiring a slight adjustment in the coupling constants to recover the same decay branching ratios). This establishes consistency between the elementary production amplitude and the in-medium spectral function. Without further readjustments, experimental data for total ρ photo-production cross sections on the nucleon and dilepton invariant-mass spectra on the deuteron are rather well reproduced, cf. Fig. 1. The baryon resonance contributions provide the required low-energy strength which is not accounted for by *t*-channel exchange processes.
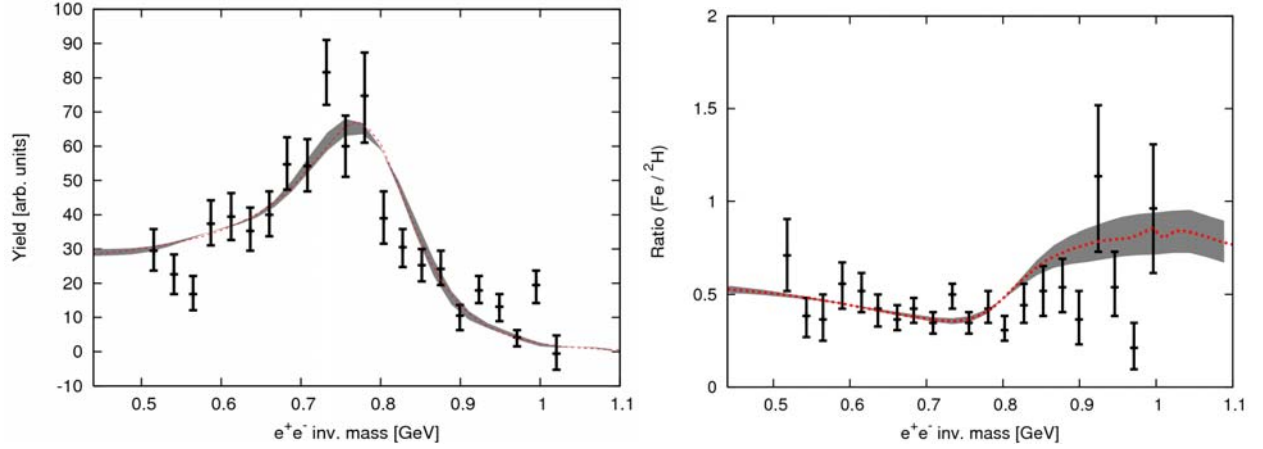

FIG. 2. Left panel: Calculated dilepton invariant-mass spectra resulting from ρ photo-production off iron for a nuclear density range $\rho_N=(0.4-0.6)\rho_0$, normalized and compared to CLAS data (where ω and φ decays have been subtracted) [5]. Right panel: iron-to-deuteron ratio of the dilepton spectra.

Turning to nuclear photo-production, it is important to note that the ρ is produced with appreciable 3-momentum relative to the nucleus, enhancing the probability for its decay outside the nucleus. It is thus mandatory to properly evaluate the effective densities probed. For incoming photon energies of ~1.5-2.5 GeV we estimate [2] the average density at the decay point to be $(0.5\pm0.1)\rho_0$ for an iron target.

Our results for dilepton invariant-mass spectra are compared to the corresponding ``excess'' spectra measured by the CLAS collaboration at Jefferson Lab [5] in Fig. 2. In the absence of an absolute normalization of the data, the calculations are normalized to the same integrated strength as the data. We find fair agreement for both iron and carbon targets (the latter are not shown), with a χ^2 per data point of $\chi^2/N=1.35$ (or 1.29 with a normalization which minimizes χ^2). The extracted ``average'' in-medium width of the ρ-meson amounts to ~200 MeV, moderately enhanced over its vacuum value. This is to be compared to ~(350-400) MeV as recently extracted [1] from NA60 data in In(158AGeV)-In collisions at the CERN-SPS [6], employing the same underlying model for the in-medium ρ spectral function [4]. Thus, the rather pronounced 3-momentum dependence of the latter turns out to be an important ingredient in the consistent understanding of dilepton spectra in photo-nuclear and heavy-ion reactions.

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