Medium modifications of the ρ meson in nuclear photoproduction

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The restoration of the spontaneously broken chiral symmetry in QCD implies that the spectral functions of hadrons are modified at high temperatures and density, especially when approaching the chiral phase transition [1]. Precursor effects are expected to occur already in more dilute hadronic matter. Dilepton decays of vector mesons are particularly suitable observables since the leptons do not suffer strong final-state interaction and thus carry the invariant-mass information of the parent particle at its moment of decay to the detector. The CLAS collaboration at Jefferson Lab has recently measured dilepton spectra in photoproduction off nuclear targets [2], reporting a moderate broadening of the ρ-meson spectral function for iron targets relative to deuterium. In Ref. [3] we conducted an initial analysis of these data by combining a model for the ρ production amplitude on the nucleon [4] with an in-medium ρ spectral function which has been successfully used in the interpretation of dilepton spectra in heavy-ion collisions [1]. With a simplified (average) treatment of the nuclear density profile, a reasonable agreement with the experimental dilepton invariant-mass spectra emerged. Here [5], we have improved and expanded on this work in several respects, by (a) folding the ρ-decay distribution over a realistic nuclear density profile (rather than using an average density), (b) accounting for the 3-momentum and density dependence of the decay rate, and (c) evaluating additional observables to better discriminate medium effects, including low-momentum cuts, the nuclear-mass (A) dependence and the so-called nuclear transparency ratio. It turns out that item (a) further improves the description of the measured mass spectra, reducing, e.g., the χ^2/N value for Fe targets from 1.29 in Ref. [3] to 1.05. The dependence of the mass spectra on the dilepton 3-momentum, q, is illustrated in Fig. 1 for uranium targets, indicating an appreciable increase in medium effects at low q: slow ρ mesons stay longer in the nuclear volume (enhancing the fraction of in-medium decays) and the medium effects in the ρ spectral function increase at small q. The width increase of the ρ in the medium implies stronger absorption on nuclear targets relative to a single free nucleon, which is quantified in terms of the nuclear transparency ratio, T_A, in Fig. 2. We predict a 40% reduction in the dilepton yield from ρ -mesons for heavy target nuclei.

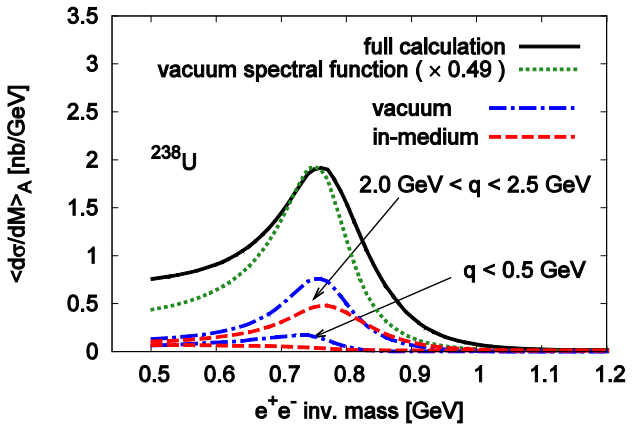

FIG. 1. 3-momentum dependence of dilepton invariant-mass spectra from decays of ρ mesons produced in photoproduction off uranium.

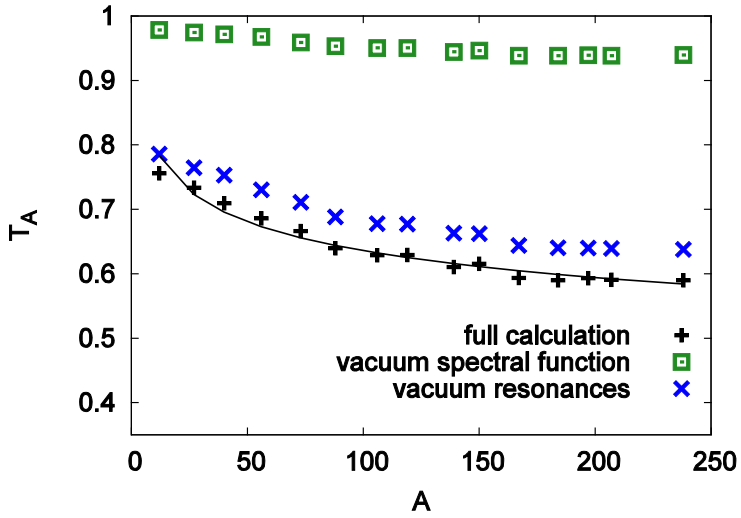

FIG. 2. Nuclear transparency ratio for $\rho \rightarrow e^- e^+$ decays, characterizing the survival probability relative to the production on a free nucleon.

[1] R. Rapp, J. Wambach and H. van Hees, Landolt Börnstein, New Series I/23-A (2010), in press.

[2] M.H. Wood *et al.* (CLAS Collaboration), Phys. Rev. C **78**, 015201 (2008).

[3] F. Riek, R. Rapp, T.-S.H. Lee, and Y. Oh, Phys. Lett. B **677**, 116 (2009).

[4] Y. Oh and T.-S.H. Lee, Phys. Rev. C **69**, 025201 (2004).

[5] F. Riek, R. Rapp, Y. Oh and T.-S.H. Lee, LANL arXiv:1003.0910 [nucl-th]; Phys. Rev. C (submitted).