Low-mass Dileptons and Dropping Rho Meson Mass

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The full dilepton data set from heavy ion collisions at the Bevalac has recently been analyzed by the DLS collaboration [1]. The measured cross section is found to be more than a factor of five above theoretical results from transport model calculations that include pn bremsstrahlung, π^0, η and Δ Dalitz decay and pion-pion annihilation, as well as contributions from the decay of ρ and ω that are produced directly from nucleon-nucleon and pion-nucleon scattering in the early stage of the collisions [2, 3]. Including medium effects on the rho spectral function [4], only a factor of two enhancement has been obtained [2]. Since a rho meson couples strongly to $N^*(1520)$ [5, 6], we have studied dilepton production [7] using the Hadron String Dynamics (HSD) model [8] to include this effect in rho meson production from πN scattering.

Using free hadron masses, the dilepton invariant mass spectrum from ^{40}Ca+^{40}Ca collisions at 1 GeV/nucleon and after correcting for the experimental acceptance filter (version 4.1) is shown in the upper part of Fig. 1. It is seen that with increasing dilepton invariant mass, the dominating contribution shifts from π^0 Dalitz decay to Δ Dalitz decay, to η Dalitz decay, and finally to direct ρ decay, as in Refs. [2, 3]. In particular, the contribution from the direct decay of rho mesons produced from πN scattering through the $N^*(1520)$ (dot-dashed curve) is most important in the mass region $0.35 < M < 0.75$ GeV/c^2 and exceeds that from other ρ production channels (dashed curve) – $\pi\pi$ annihilation, pion-baryon (without $N^*(1520)$) and baryon-baryon collisions. This is different from heavy-ion collisions at CERN SPS, where dilepton production from the $\pi\pi \to \rho$ channel is more important than that from the $\pi N \to \rho N$ channel as a result of the large pion to nucleon ratio in these collisions. Compared with the experimental data the theoretical results for the total dilepton spectrum are, however, about a factor of three lower in the invariant mass region $0.2 < M < 0.5$ GeV/c^2 and practically the same as in the spectral function approach of Ref. [2].

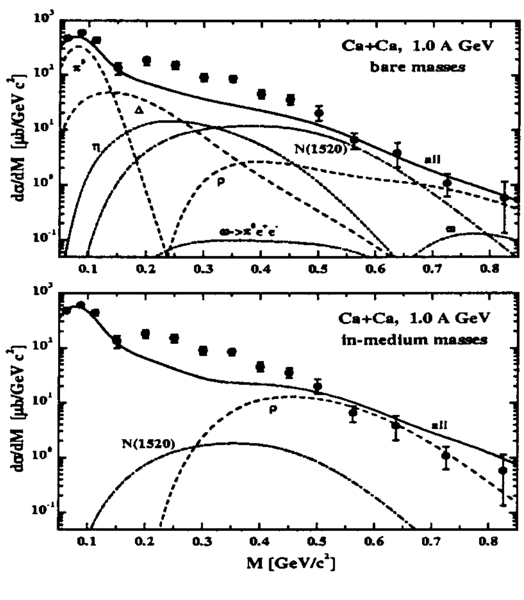

Figure 1: The dilepton invariant mass spectrum from ^{40}Ca+^{40}Ca collisions at 1 A·GeV with free (upper part) and in-medium (lower part) hadron masses in comparison to the DLS data [1].

To see how the results are modified by

medium effects, we introduce the rho/omega meson in-medium masses as in Ref. [9, 10] but keep the baryon masses unchanged, i.e., $m^*_{\rho/\omega} \sim m_{\rho/\omega}(1 - 0.18\rho_B/\rho_0)$. According to Ref. [6], part of the decrease of the ρ meson mass in nuclear medium can be accounted for by the attractive interaction due to $N^*(1520)$-particle-nucleon-hole polarization.

The dilepton invariant mass spectrum from the same reaction for the case of dropping rho meson mass is shown in the lower part of Fig. 1. We find that with dropping rho meson mass low-mass dilepton production from πN scattering through $N^*(1520)$ is substantially reduced due to a significant increase of its width. Although dileptons from other ρ production channels are enhanced, they are not sufficient to compensate for the reduction due to the broadening of N(1520). Including also the contributions from the Dalitz decays of π^0, Δ, η, and ω as well as the direct decay of ω, which are not much affected by the reduction of hadron masses, the total theoretical dilepton spectrum (solid curve) remains about a factor of three below the experimental data for $0.2 \leq M \leq 0.5$ GeV. Similar results are obtained if we also allow the nucleon and N(1520) masses to decrease according to the constituent quark model, i.e., a factor 3/2 reduction relative to that for the ρ meson.

Unlike the enhanced low mass dileptons observed in heavy ion collisions at SPS energies, which is dominated by pion-pion annihilation and can be explained by the decrease of hadron in-medium masses, the DLS result cannot be explained by dropping hadron masses and remains a puzzle.

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