Production of Vector Mesons in Pion Nucleus Reactions ◊

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Model independent constraints from QCD sum rules connect the vector meson mass with the gap Δ between the nπ continuum and the $< q\bar{q} >$ vacuum state. At normal nuclear density, Δ is expected to be reduced by about 15% as a consequence of the restauration of chiral symmetry [1,2]. In this work, the spectral functions of the vector mesons calculated in infinite matter are combined with a Monte Carlo simulation of π^- induced production and propagation of vector mesons inside nuclei.

The self-energy of the vector mesons in matter Π_v is based on the low density approximation which connects the vacuum self-energy Π_0 with the meson nucleon scattering matrix T_{vN}: $\Pi_v(\omega,\vec{q},\rho) = \Pi_0(\omega,\vec{q}) - \rho T_{vN}(\omega,\vec{q})$. The potential (and therefore the mass shift) depends to leading order linearly on the baryon density ρ: $2\omega U = \Pi_v(\omega,\vec{q},\rho) - \Pi_0 = \rho T_{vN}(\omega,\vec{q})$. The resulting spectral functions for infinite matter at $\rho = \rho_0$ show a different behavior for the ω- and the ρ meson (Fig. 1). While the pole mass of the ρ meson is shifted only slightly, its width is heavily influenced by $\rho N \rightarrow \pi N$, $\rho N \rightarrow \pi\Delta \rightarrow \pi\pi N$ and $\rho N \rightarrow \omega N \rightarrow \pi\pi\pi N$ scattering. Effectively, the ρ-meson is dissolved in the nuclear medium. The ω-meson pole mass is shifted by about -80 MeV/c^2 and the width is broadened from 8 to 40 MeV/c^2. However at $\rho = \rho_0$ the ω-meson still keeps its quasi-particle character. The MC-simulation is based on measured cross sections for $\pi^- + p \rightarrow \rho, \omega + n$ reactions. The absorption channels are calculated via detailed balance. The baryon density distribution of the Pb nucleus is based on measured charge distributions. The fermi motion of the nucleons is taken into account. With an elementary ω-meson cross section of 2.5 mb (p_{π^-} = 1.3 GeV/c) one could expect Z_{Pb}*2.5≈200 mb for a Pb nucleus. However the calculated cross section is only 33 mb. Because of the strong interaction of π^- with nuclear matter, only the hemisphere of the nucleus facing the beam takes part in the reaction. The mesons are produced with vacuum pole mass. In case of decay the mass of the meson is sampled according to the local baryon density at this "freezeout" point based on the spectral functions for infinite matter. The sampling is done in accordance with energy conservation. The spectral functions in the finite system (Fig. 2) are obtained by integration over the probability distribution of the meson decays. The majority of the ω-mesons decay outside the Pb nucleus and produce a narrow structure. The contributions from the inner part of the nucleus (full shift of the ω-meson mass) and the surface (reduced shift) increase the broadening of ω-mesons from 40 to about 80 MeV/c^2. This additional broadening is a consequence of the finite size of the system. The reaction $\pi^- Pb$ seems to be a promising experiment to probe the in-medium spectral distribion of vector mesons. The predicted dilepton spectra could be measured with the HADES spectrometer [3]. In Fig. 2 the HADES resolution is taken into account. Below the η mass strong contributions from η Dalitz and other channels are expected. In the mass region of the (shifted) ω peak both πN Bremsstrahlung [4] and combinatorial background from π Dalitz decay [5] contribute still below the ρ-meson contribution.

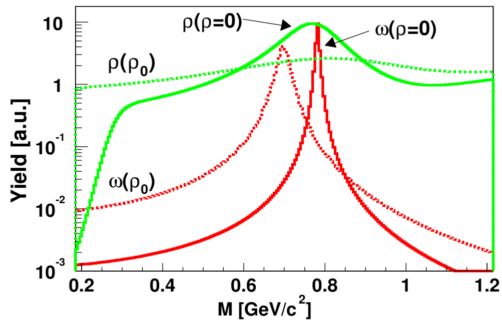

Fig. 1: Spectral functions in infinite matter for the ρ- and ω-meson at normal nuclear density (ρ_0)) and in vacuum ($\rho = 0$). The spectra are normalised to each other at the pole mass ($\rho = 0$).

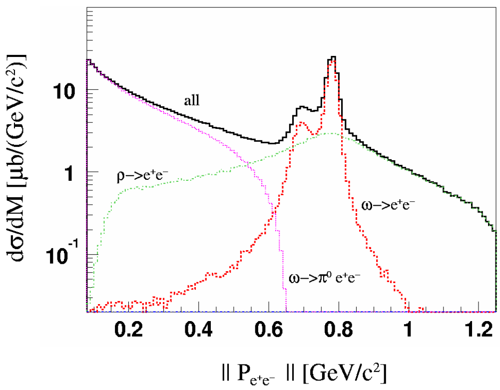

Fig. 2: ρ- and ω-meson contributions to the dilepton specta for $\pi^- Pb$ at p_π=1.3 [GeV/c].

References

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