Baryonic contributions to the dilepton spectra in relativistic heavy ion collisions

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One of the explanations for the enhanced production of low-mass dileptons observed in heavy ion experiments [1, 2] is the broadened in-medium ρ spectral function [3] owing mainly to the coupling of the ρ with baryonic resonances [4]. In particular, the N*(1520) plays a dominant role as first pointed out in [5]. This feature is at first view puzzling, since the baryons are a minor component of the hadron population at CERN energies [6]. We have thus set out to explicitly investigate the role of baryons in dilepton production in relativistic nuclear collisions without introducing any medium effects such as the broadening of the rho spectral function [3] or the decrease of the rho in-medium mass [7].

Since spin 3/2 baryon resonances give the most imperant contribution to dileptons, we consider their interaction Lagrangian for the Dalitz decay to dileptons $R \to Ne^+e^-$ [8],

$$\mathcal{L}_{RN\gamma} = \frac{ieg_1}{2M}\bar{\psi}^{\mu}_{R}\Theta(z_1)_{\mu\nu}\gamma_\lambda \Gamma T_3 \psi_N F^{\nu\lambda} - \frac{eg_2}{4M^2}\bar{\psi}^{\alpha}_{R}\Theta_{\alpha\mu}(z_2)\, T_3\, \Gamma\, \partial_\nu \psi_N\, F^{\nu\mu} + h.c., \quad (1)$$

where $\Theta_{\mu\nu}(z) = g_{\mu\nu} - 1/2(1+2z)\gamma_\mu\gamma_\nu$. Γ is either 1 or γ_5 depending upon the parity of the resonances and T is a $3/2 \to 1/2$ isospin transition operator or a 2×2 Pauli matrix, depending on the isospin of the resonance. Ψ^{μ}_{R} and ψ correspond to Rarita-Schwinger and nucleon spinors respectively, $F^{\mu\nu}$ is the electromagnetic field tensor, and M is the nucleon mass. The influence of the off-shell parameter z is seen in calculations of electromagnetic transitions of nucleon resonances into different multipolarities [8]. For the $N^*(1520)$ resonance, we take $g_1 = -1.839$, $g_2 = 0.018$, $z_1 = -0.092$ and $z_2 = -0.024$ to obtain the following widths: $\Gamma_{N^*(1520)\to N\gamma} = 0.78$ MeV and $\Gamma_{N^*(1520)\to N\rho} = 22.35$ MeV. The experimental values are 0.55±0.1 MeV and 24.0 ± 6.0 MeV, respectively.

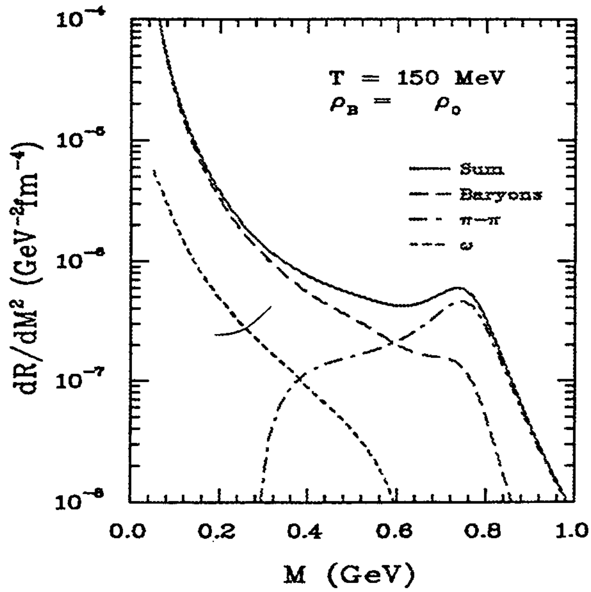

Figure 1: The relative importance of mesonic and baryonic contribution to the dilepton rate is shown. The solid line corresponds to the total yield while the dashed line represents the sum over baryonic contributions. Dashed and dotted curves refer to the π-π annihilation and ω Dalitz decay, respectively.

We first consider the relative importance of mesonic and baryonic rates in hadronic matter at temperature $T = 150$ MeV and baryon density $\rho_B = \rho_0$, where ρ_0 is the normal nuclear matter density. As shown in Fig. 1, the baryons dominate the low invariant mass region while the $\pi - \pi$ channel picks up near the ρ peak.

To include the nuclear collision dynamics, we have carried out a calculation by extending the transport model of Ref. [9] to include the $N^*(1520)$ resonance. The results for the dilepton invariant mass spectrum from the collision of Pb+Au at 160 GeV/nucleon are shown in Fig. 2 together with the experimental data from the CERES collaboration [2].

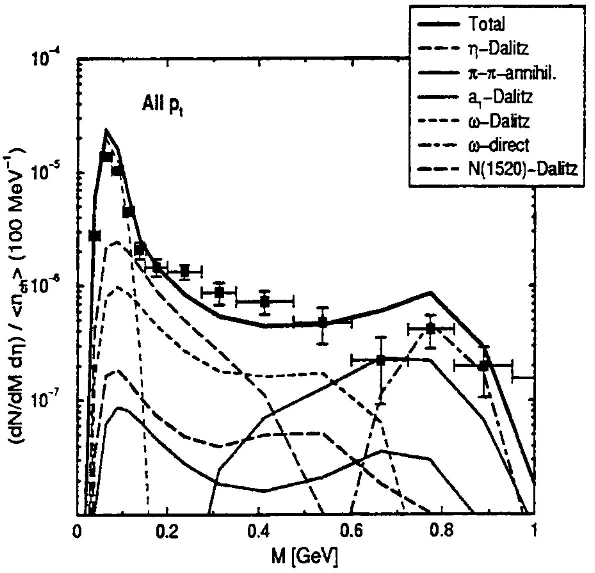

Figure 2: Invariant mass spectrum from Pb+Au collisions at 160 GeV/nucleon. Data are from [2].

We see that our transport results lead to a very small baryonic contribution to the net dilepton yield. This is to be contrasted with the baryon influence on the net rate, as shown in Fig. 1. The reason for this difference is two-fold. First, the baryonic contribution are severely cut down by the CERES acceptance which we apply to our transport results in Fig. 2. Second, the baryon content of the central rapidity region is smaller than its mesonic content, owing to the dynamics of the stopping power systematics and of the phase space for particle creation. As shown in Ref. [10], the $N^*(1520)$ becomes, however, important in the invariant mass region 0.35 $< M <$ 0.75 GeV/c^2 in heavy ion collisions at lower energies around 1 GeV/nucleon.

There remain small discrepancies between the theoretical results and the experimental data at invariant mass around the rho peak and 0.4 GeV/c^2. Whether this is due to medium effects from either a broadened rho spectral function [3] or a reduced rho meson mass [7] remains to be studied.

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