In-medium hadron properties from a Holographic QCD model

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We discuss hadron properties and their interaction vertices in the framework of the Sakai-Sugimoto model \cite{1}, introducing the medium effects via the zeroth component of a $U(1)$ field in the fifth dimension. The spin components being removed by rescaling wavefunctions in conformally flat coordinates, the 5D action of the model is reduced to the following form:

\[ S_{5D} = \int d\mathbf{x} d^4w \{ i \gamma^M \partial_M - m_5(w) - N_c \mathcal{A} \gamma^0 \} \Psi(x, w) + \text{other terms}, \]

where $\mathcal{A}$ is the zeroth component $U(1)$ gauge field. The equation of motion can be derived by taking a variation of this action

\[ \{ i \gamma^\alpha \partial_\alpha - N_c \gamma^0 \mathcal{A} + \gamma^5 \partial_5 - m_5(w) \} \Psi(x, w) = 0. \]

Defining $\Psi(x, w) = \psi_L(x)f_L(w) + \psi_R(x)f_R(w)$, we obtain the equations for the profile functions $f_{L,R}(w)$ in nuclear medium

\[ \begin{align*}
-f_L'(w) + m_5(w)f_L(w) &= \{ m_4^* + h[\alpha, f_L(w), f_L'(w), f_R(w), f_R'(w)] \} f_R(w), \\
-f_R'(w) + m_5(w)f_R(w) &= \{ m_4^* - h[\alpha, f_L(w), f_L'(w), f_R(w), f_R'(w)] \} f_L(w).
\end{align*} \tag{3} \]

where $\alpha$ is a density-dependent parameter and $m_4^*$ the effective mass of the baryon in nuclear matter. When $\alpha$ is small, one can use it as a perturbation, i.e. $f_{L,R} = f_{L,R}^{(0)} + \alpha f_{L,R}^{(1)} + (1/2)\alpha^2 f_{L,R}^{(2)} + O(\alpha^3)$ and $m_4^* = m_4^{(0)} + \alpha m_4^{(1)} + (1/2)\alpha^2 m_4^{(2)} + O(\alpha^3)$.

![Figure 1: Relative mass $m_4^*/m_4^{(0)}$ as a function of $\alpha$. Dashed and solid curves represent the results including the first- and second-order corrections, respectively.](image)