Revised Weinberg Operator

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The evaluation of the Weinberg operator in the matrix element for $DD \to \alpha\pi^0$ show a disturbingly significant dependence on the ^{4}He wave function employed [1]. We suggest that this is due to using a point-like strong pion-nucleon vertex function, and provide a revised operator.

The Weinberg pion production operator is taken (at threshold, and neglecting terms of order m_π/m_N) for the homework problem as due to the quark mass difference effects [2]

$$\mathcal{O} \equiv \sum_{i<j} \mathcal{O}_{i,j}, \tag{1}$$

$$\mathcal{O}_{i,j} = -\frac{f}{4\pi\mu F_\pi^2\sqrt{2\mu}}[\delta m_N(\boldsymbol{\tau}^{(i)}\cdot\boldsymbol{\tau}^{(j)} + \tau_3^{(i)}\tau_3^{(j)}) - \bar{\delta} m_N(\boldsymbol{\tau}^{(i)}\cdot\boldsymbol{\tau}^{(j)} - \tau_3^{(i)}\tau_3^{(j)})]$$
$$(\boldsymbol{\sigma}^{(i)} - \boldsymbol{\sigma}^{(j)})\cdot(-i\hat{\boldsymbol{r}})\frac{d}{dr}\left(\frac{e^{-\mu r}}{r}\right), \tag{2}$$

$$\mathbf{r} \equiv \mathbf{r}_i - \mathbf{r}_j \tag{3}$$

where $F_\pi = 186$ MeV is the pion decay constant, μ is the pion mass, and f is the pion-nucleon coupling constant ($f = g_A\mu/F_\pi$ in leading order; $f^2/4\pi = 0.075$ is used here). The parameters, δm_N and $\bar{\delta} m_N$, account for the effect of the current quark mass difference $m_d - m_u$ and the electromagnetic contribution. The sum of these is fixed by the nucleon mass difference $m_n - m_p = 1.3$ MeV. Note that for $np \to d\pi^0$, $\mu = \sqrt{3/4}$.

The factor $\frac{1}{\sqrt{2\mu}}$ is a phase space factor, valid only at threshold. Its appearance has a historical origin, rooted in models which treat the nucleon as static.

We take the pion-nucleon vertex to have a monopole form factor :$\frac{\Lambda^2}{\Lambda^2+\mathbf{k}^2}$. In this case, the Weinberg operator takes the form:

$$\mathcal{O}_\Lambda \equiv \sum_{i<j} \mathcal{O}_{i,j}(\Lambda), \tag{4}$$

$$\mathcal{O}_{i,j}(\Lambda) = -\frac{f}{4\pi\mu F_\pi^2\sqrt{2\mu}}[\delta m_N(\boldsymbol{\tau}^{(i)}\cdot\boldsymbol{\tau}^{(j)} + \tau_3^{(i)}\tau_3^{(j)}) - \bar{\delta} m_N(\boldsymbol{\tau}^{(i)}\cdot\boldsymbol{\tau}^{(j)} - \tau_3^{(i)}\tau_3^{(j)})]$$
$$(\boldsymbol{\sigma}^{(i)} - \boldsymbol{\sigma}^{(j)})\cdot(-i\hat{\boldsymbol{r}})\left(\frac{\Lambda^2}{\Lambda^2-\mu^2}\right)\frac{d}{dr}\left(\frac{e^{-\mu r}}{r} - \frac{e^{-\Lambda r}}{r}\right). \tag{5}$$

The idea is that with some value of Λ the sensitivity to wave functions would disappear. Using this operator would modify the analysis of the $np \to d\pi^0$ reaction. It is likely that the extracted value of δm_N would be increased.

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