Conf-750222--3

Weak Interaction Theories and Parity Mixing in ^{18}F and ^{19}F

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In many respects nuclear physics can serve as a useful tool in testing weak interaction models. For example, parity admixing induced by the weak interaction leads to parity forbidden γ-decay. The γ-asymmetry reaches an order of magnitude which can be seen by experiment if the level spacing of the admixed states is small and the induced transitions are not hindered. One would like to minimize the uncertainties in the nuclear structure aspects in the calculation. This is most likely to be the case for low-lying levels in light nuclei, which apparently are well described by conventional shell model

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+) Supported by Deutsche Forschungsgemeinschaft and Minister für Wissenschaft und Forschung des Landes Nordrhein-Westfalen

++) Research sponsored by the U.S. Energy Research & Development Administration under contract with Union Carbide Corporation

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calculations. Two good candidates for such calculations are ^{19}F and ^{18}F. The levels in question are shown in fig. 1.

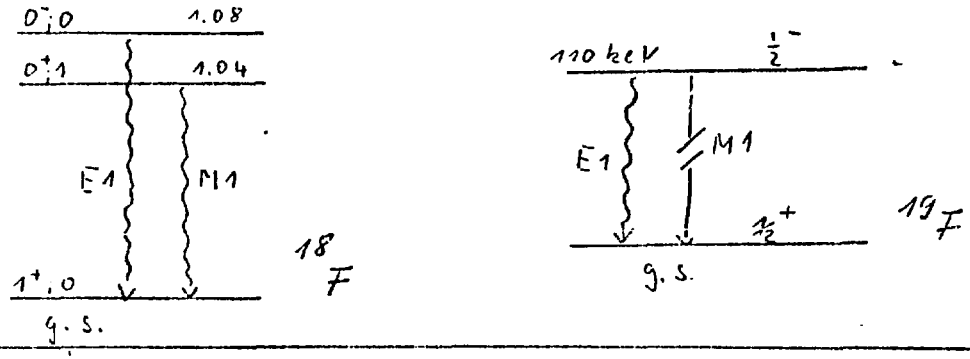

fig. 1

Let us first discuss those uncertainties in the case of ^{19}F which are not due to the unknown weak potential. Here we find an expression for the recently measured /1/ asymmetry

$$\delta = 2\,\frac{\langle \tfrac{1}{2}^+ \| M1 \| \tfrac{1}{2}^- \rangle - \langle \tfrac{1}{2}^- \| M1 \| \tfrac{1}{2}^- \rangle}{\langle \tfrac{1}{2}^+ \| E1 \| \tfrac{1}{2}^- \rangle\ \Delta E}\ \langle \tfrac{1}{2}^+ \| V_{weak} \| \tfrac{1}{2}^- \rangle$$

The level spacing ΔE and the E1-transition matrix-element can be directly taken from experiment. The M1-transition elements are proportional to the magnetic moments, which are well known for ground states. To get the magnetic moment μ $(1/2^-)$ we used a cluster model $|1/2^-\rangle = |^4He\rangle \otimes |^{15}N\rangle_{g.s.}$ and a shell model calculation. We found /8/

μ $(1/2^-)$ = -0.283 n.m. (cluster)

μ $(1/2^-)$ = -0.3 n.m. (shell model)

The calculated magnetic moments for ground states give the experimental data up to 10 %. For instance, we have /8/

$\mu(1/2^+) = 2{,}6287$ n.m. (exp.)

$\mu(1/2^+) = 2.530$ n.m. (calc.) .

In order to calculate the admixture

$$F = \langle 1/2^+ | V_{weak} | 1/2^- \rangle$$

for a given weak potential, we use the wave functions from McGrory and Wildenthal /2/. Since both states are low lying, they can be expected to be fairly well described by the shell model calculations. Because of the short range character of V_{weak}, one has to include short range correlations. There are still significant uncertainties as to how to include such correlations in a many-body system /3/. We took into account only the short range deformation of two particles in states ν_1, ν_2 in the Bethe-Goldstone approximation

$$\langle x_1 x_2 | \Psi_2 | \nu_1 \nu_2 \rangle_a = \langle x_1 x_2 | \nu_1 \nu_2 \rangle_a + \langle x_1 x_2 | S_2 | \nu_1 \nu_2 \rangle_a$$

with a correlation function S_2 which shows rapid healing for $|x_1 - x_2| \to \infty$. Using this form we find the effective weak potential to be

$$\mathcal{V}^{eff}_{weak} = \Psi_2^+ V_{weak} \Psi_2$$

As in earlier calculations we included the tensor force in our calculations /4/. We neglect intermediate range correlations. These should be due to the short range character of V_{weak}. We also did not include in the S_2 functions effects due to the renormalization of occupation probabilities. From nuclear matter calculations we estimate that corrections due to these effects are on the order of 30 %. Thus, we feel that these calculations can distinguish between various weak interaction

models if the models predict asymmetries which differ by a factor of 5-10. The results of our calculations are shown in table 1 and table 2. Within the limits discussed above, all the models predict asymmetries which are consistent with experiment for ^{19}F, so one cannot conclude anything about weak interaction theories from the ^{19}F case. As has been recently shown by Gari and Reid /7/, the deviations from Cabibbo model due to neutral currents as predicted by the Weinberg-Salam model are small for $\Delta T = 0,(2)$ admixtures but give a factor 10-20 in the case of $\Delta T = 1$ transitions. This is seen in table 2. Thus, a measurement of γ-asymmetry in ^{18}F would be a sensitive test of the Weinberg-Salam model.

Table 1 Asymmetry δ for $\frac{1}{2}^- \to \frac{1}{2}^+$ transition of ^{19}F /5/

strong interact. correlat.	conventional model		Quark model		Weinberg-Salam T-exch.
	ρ-exch.	π-exch.	$\rho+\omega$ exch.	$\rho+\omega+2\pi$	
uncorrel.	$2.25\cdot10^{-4}$	$0.2\cdot10^{-4}$	$3.5\cdot10^{-4}$	$4.5\cdot10^{-4}$	$3.2\cdot10^{-4}$
Reid-Soft (without tensor)	$1.1\cdot10^{-4}$		$1.4\cdot10^{-4}$		
(with tensor)	$0.65\cdot10^{-4}$	$0.14\cdot10^{-4}$	$0.86\cdot10^{-4}$	$1.3\cdot10^{-4}$	$2.2\cdot10^{-4}$
Hamada-Johnston	$0.42\cdot10^{-4}$	$0.14\cdot10^{-4}$	$0.65\cdot10^{-4}$	$0.8\cdot10^{-4}$	$2.2\cdot10^{-4}$

$\delta_{EXP} = (1.8 \pm 0.9)\cdot 10^{-4}$

Table 2 Asymmetry δ for $(0^-,0^+) \to 1^+$ transition in ^{18}F /6/

	convential model	Weinberg-Salam
uncorrelated	$3.8\cdot10^{-4}$	$6.1\cdot10^{-3}$
Reid-Soft (with tensor)	$3.6\cdot10^{-4}$	$5.7\cdot10^{-3}$

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