KERNFORSCHUNGSZENTRUM

KARLSRUHE

März 1965 KFK 313

Institut für Experimentelle Kernphysik

The charge dependent nuclear interaction and Fermi matrix elements of ß decay

H. Schopper

GESELLSCHAFT FUR KERNFORSCHUNG M.B.H.
KARLSRUHE

KERNFORSCHUNGSZENTRUM KARLSRUHE

März 1965 KFK 313

Institut für Experimentelle Kernphysik

The charge dependent nuclear interaction and Fermi matrix elements of β decay

H. Schopper

Gesellschaft für Kernforschung m.b.H. Karlsruhe

The charge dependent nuclear interaction and Fermi matrix elements of ß decay

If charge independence of nuclear forces were valid the Fermi matrix elements M_F of $\Delta T = \pm 1$ ß transitions would vanish. Therefore deviations from charge independence can be found by determining M_F from ß-γ circular polarization correlation or ß asymmetries from polarized nuclei.

Blin Stoyle and Le Tourneux [1] have introduced the charge dependent nuclear potential

$$\mathcal{H}_n = \sum_{i<j=1}^{A} \left\{ p(\tau_3^{(i)}+\tau_3^{(j)}) + q\tau_3^{(i)}\tau_3^{(j)} + \left[r(\tau_3^{(i)}+\tau_3^{(j)}) + s\tau_3^{(i)}\tau_3^{(j)} \right] \vec{\sigma}^{(i)}\vec{\sigma}^{(j)} \right\} V_o e^{-\beta r_{ij}^2} \qquad (1)$$

Charge independence implies $p = q = r = s = 0$ and for charge symmetry $p = r = 0$. If the potential is spin independent one has $r = s = 0$.

With this potential Blin-Stoyle and Novakovic [2], [3] derived the following expressions for Fermi matrix elements

$$Na^{24}: \quad M_F = 0{,}012 - 1{,}57\,p + 3{,}57\,r \qquad (2)$$

$$A^{41}: \quad M_F = 0{,}49\,(p-q) + 0{,}93\,(r-s) \qquad (3)$$

$$Sc^{44}: \quad M_F = 0{,}25\,(p-q) - 0{,}40\,(r-s) \qquad (4)$$

$$Mn^{52}: \quad M_F = 0{,}015 - 0{,}62\,(p+q) + 1{,}17\,(r+s) \qquad (5)$$

In addition Novakovic [3] has related p and r to the mass difference between Al^{24} and Na^{24} and obtains

$$-\,222{,}1\,p + 17{,}9\,r = 1{,}370$$

New precise measurements of the ß-γ circular polarization correlation of Na^{24} and A^{41} by Behrens and Schopper [4] together with older data for Sc^{44} and Mn^{52} (see the Table) make a determination of p, q, r and s possible. This can be achieved in the following way. Combining eq. (1) and (6) one obtains

$$10^3 p = -6.7 \pm 0,02 , \quad 10^3 r = \begin{cases} -5,9 \pm 0,3 , & M_F(Na^{24}) > 0 \\ -6,7 \pm 0,3 & < 0 \end{cases} \tag{7}$$

The ambiguity originates from the fact that experimentally only the sign of M_F/M_{GT} can be determined. Since the sign of M_{GT} is not known also the sign of M_F remains undetermined. Theoretical calculations [5] indicate that the signs of M_F for Sc^{44} and Mn^{52} are both negativ. This will be taken for granted for the subsequent analysis.

Adding and subtracting eq. (3) and (5) yields

$$p - 1.9r = \begin{Bmatrix} 7 \pm 6 \\ 25 \pm 6 \end{Bmatrix} \times 10^{-3} , \quad \begin{matrix} M_F(A^{41}) > 0 \\ < 0 \end{matrix} \tag{8}$$

$$q - 1.9s = \begin{Bmatrix} 25 \pm 6 \\ 7 \pm 6 \end{Bmatrix} \times 10^{-3} , \quad \begin{matrix} M_F(A^{41}) > 0 \\ < 0 \end{matrix} \tag{9}$$

If $p = -6.7 \times 10^{-3}$ is inserted into the first relation one finds

$$10^3 r = \begin{cases} -7 \pm 3 & M_F(A) > 0 \\ -17 \pm 3 & < 0 \end{cases} \tag{10}$$

The value $10^3 r \approx -7$ is in very good agreement with r as deduced from the Na^{24} data whereas $10^3 r = -17$ is too small. This implies that $M_F(A^{41}) > 0$. It would be very interesting to explain this emprical result by nuclear model calculations.

In order to determine q and s separately the data for Sc^{44} must be included. Combining eq. (4) and (5) gives

$$q = 0{,}056 \pm 0{,}007$$
$$s = 0{,}015 \pm 0{,}004$$

As a check the value of s may be put into eq. (9) and one obtains

$$q = \begin{cases} 0{,}054 \pm 0{,}009 & M_F(A) > 0 \\ 0{,}036 \pm 0{,}009 & < 0 \end{cases}$$

The upper value agrees with that deduced from Sc^{44} and corroborates that $M_F(A^{41})$ is positiv.

Summarizing one can state that all data are consistent and a reasonable set of parameters would be

$$10^3 p = -6{,}7 \pm 0{,}02 \qquad 10^3 r = \cdot 6{,}7 \pm 0{,}3$$
$$10^3 q = 55 \pm 6 \qquad 10^3 s = 15 \pm 4$$

These numbers show that there is a definite deviation from charge independence. Also charge symmetry is violated although to a lesser degree (since $|p|<|q|$, $|r|<|s|$).

In addition an appreciable spin dependence is found, since r and s are of the same order of magnitude than p and q.

Altman and MacDonald [6] have derived p, r, q, and s from the energy level shifts and the ft values of the O^{14}, N^{14}, C^{14} system. Data of the p-p and n-p scattering are also used. Our values of p and r agree nicely with their case II. These authors, however, find negative values for q and s. It is not quite clear if this discrepancy can be ascribed to a sign ambiguity.

Of course, the quantitative results for the parameters p, q,r and s should not be taken too serious since eq. (2) to (6) have been derived on the basis of a particular nuclear model. However, it seems that the Fermi matrix elements cannot be explained entirely by ordinary Coulomb effects.

Table Experimental data used in the analysis

Nucleus	ß-γ circ. pol asymmetry A	$M_F \times 10^3$	Reference
Na^{24}	0,100 ± 0,004	1,7 ± 0,4	Behrens and Schopper[4]
A^{41}	0,06[illegible] ± 0,02	9 ± 6	Behrens and Schopper[4]
Sc^{44}	-0,131 ± 0 013	(-)[illegible] ± 3	Bloom et al. [7] Mann et al. [8]
Mn^{52}	-0,029 ± 0,003	(-)5,1 ± 0,6	Postma et al.[9] Ambler et al [10] Daniel et al.[11] Mann et al.[12]

Literature

[1] R.J.Blin-Stoyle, J.Le Tourneux, Phys.Rev.123, 627 (1961)

[2] R.J.Blin-Stoyle, L.Novaković, Nucl.Phys. 51, 133 (1964)

[3] L.Novaković, Nucl.Phys. 60, 161 (1964)

[4] H.Behrens, H.Schopper, to be published

[5] P S Kelly and S.H. Moszkowski, Z.Phys.158 [illegible] (1960)

[6] A.Altman and W.M.MacDonald, Nucl.Phys.35, 593 (1962)

[7] S.D.Bloom et al., Phys.Rev.Lett. 5, 326 (1960)

[8] L.G.Mann et al., Bull.Am.Phys.Soc. II 9, 395 (1964)

[9] H.Postma et al., Physica 23, 259 (1957)

[10] E.Ambler et al.,Phys. Rev. 110, [illegible] (195[illegible])

[11] H Daniel et al., Phys Rev. 12[illegible], 261 (1962)

[12] L.G.Mann et al , Phys.Soc. II 9, 395 (1964)