University of Groningen

Remark on the status of non-conservation of parity in nuclear beta-decay

van Klinken, J; Koks, FWJ; Behrens, H

Published in:
Physics Letters B

DOI:
[10.1016/0370-2693\(78\)90221-6](https://doi.org/10.1016/0370-2693(78)90221-6)

IMPORTANT NOTE: You are advised to consult the publisher's version (publisher's PDF) if you wish to cite from it. Please check the document version below.

Document Version
Publisher's PDF, also known as Version of record

Publication date:
1978

[Link to publication in University of Groningen/UMCG research database](#)

Citation for published version (APA):

van Klinken, J., Koks, FWJ., & Behrens, H. (1978). Remark on the status of non-conservation of parity in nuclear beta-decay. *Physics Letters B*, 79(3), 199-201. [https://doi.org/10.1016/0370-2693\(78\)90221-6](https://doi.org/10.1016/0370-2693(78)90221-6)

Copyright

Other than for strictly personal use, it is not permitted to download or to forward/distribute the text or part of it without the consent of the author(s) and/or copyright holder(s), unless the work is under an open content license (like Creative Commons).

The publication may also be distributed here under the terms of Article 25fa of the Dutch Copyright Act, indicated by the "Taverne" license. More information can be found on the University of Groningen website: <https://www.rug.nl/library/open-access/self-archiving-pure/taverne-amendment>.

Take-down policy

If you believe that this document breaches copyright please contact us providing details, and we will remove access to the work immediately and investigate your claim.

Downloaded from the University of Groningen/UMCG research database (Pure): <http://www.rug.nl/research/portal>. For technical reasons the number of authors shown on this cover page is limited to 10 maximum.

REMARK ON THE STATUS OF NON-CONSERVATION OF PARITY IN NUCLEAR BETA-DECAY

J. van KLINKEN and F.W.J. KOKS¹*Laboratorium voor Algemene Natuurkunde, University of Groningen, The Netherlands*

and

H. BEHRENS

Zentralstelle für Atomkernenergie-Dokumentation, Kernforschungszentrum, Karlsruhe, Germany

Received 4 September 1978

Equality of β -decay coupling constants $C'_A/C_A = C'_V/C_V = 1$, implying $V - A$ interaction, is less verified than commonly assumed. Deducing limits $0.52 < C'_V/C_V < 1.93$ and $0.82 < C'_A/C_A < 1.22$ we discuss a possible $V + A$ admixture with a mass ratio $m(W^{V-A})/m(W^{V+A}) < 0.56$ for intermediate bosons $W^{V\pm A}$.

Unification of weak and electromagnetic interaction draws the attention of many investigators both in theoretical and in experimental physics. One of the profound differences between these two types of interaction is the fact that parity violation is manifest with overwhelming evidence in, e.g., nuclear β -decay, but not in electromagnetic transitions. As brought forward by Beg et al. [1], and several years ago in a somewhat different context by Lipmanov [2], it is relevant to investigate to which extent the experiments indicate a *maximum* non-conservation of parity in β -decay with pure $V - A$ currents or, in other words, to which extent a $V + A$ admixture can be present.

The experimental results so far obtained are consistent with an exclusive $V - A$ interaction and a hamiltonian with equal coupling constants for the parity conserving and the parity violating part of the interaction: $C_i = C'_i$ with $i = V$ (vector) or A (axial-vector). Unfortunately, the ratio C'_i/C_i is observed in parity experiments via a form $x_i = 2C'_i C_i / (C_i'^2 + C_i^2)$ which is insensitive to small deviations of C'_i/C_i from unity. The determination of C'_A/C_A is largely confined to work in the years immediately after the discovery of parity violation in weak interactions, pos-

sibly because a realization of drastic improvements seemed to be difficult.

In a survey of 1965 Steffen and Frauenfelder [3] proposed

$$0.4 < C'_V/C_V < 2.5, \quad 0.85 < C'_A/C_A < 1.15. \quad (1)$$

In 1970 Paul [4] deduced from a least-squares adjustment to data from the literature $0.69 < C'_V/C_V < 1.22$ and $1.04 < C'_A/C_A < 1.16$, using the smallest of external and internal error margins. Later Kropf and Paul [5] felt it safer (as we do) to use the larger of the two error assignments. Enlarging the margins by a factor $1/0.41$ from ref. [4] the ranges become

$$0.50 < C'_V/C_V < 1.80, \quad 0.95 < C'_A/C_A < 1.25. \quad (2)$$

The limits (1) and (2) have not been derived in such a way that quantitative confidence levels could be specified. In the following a confidence level is obtained by taking into account the a priori knowledge $|x_i| \leq 1$.

This letter is restricted to processes giving straightforward and unambiguous information. No observables are used which depend on $C'_V C_A + C_V C'_A$ as the β -symmetry with oriented neutrons. We consider only allowed transitions (unlike in ref. [1]) and we assume CP conservation and absence of scalar and tensor interactions [4].

¹ Present address: Rijnlands Lyceum, Sassenheim, The Netherlands.

Table 1

Average β -polarization and $\beta\gamma$ circular polarization correlation results. Systematic errors were added quadratically when original papers give only statistical errors. Older data are in refs. [4,6].

Vector interaction via P_β :

	source	x_V
Hopkins et al. [8]	^{14}O	0.97 ± 0.19
Koks and van Klinken [6]	^3H	1.03 ± 0.14
		adopt: 1.01 ± 0.11

Axial-vector interaction

	source	x_A
via P_β [6, 11]:		
Lazarus and Greenberg	^{60}Co	1.02 ± 0.03
van Klinken	^{60}Co	1.002 ± 0.016
Brosi et al.	^{32}P	0.99 ± 0.02
van Klinken	^{32}P	0.98 ± 0.02
Wenninger et al.	^{32}P	1.01 ± 0.03
Koks and van Klinken	^3H	1.01 ± 0.03
via $A_{\beta\gamma}$ [12]:		
Appel	^{60}Co	1.01 ± 0.08
Steffen	^{60}Co	1.03 ± 0.08
Schopper et al.	^{60}Co	0.97 ± 0.04
Schopper et al.	^{22}Na	1.00 ± 0.05
		adopt: 1.001 ± 0.012

Both for pure Fermi and for pure Gamow–Teller decays x_i can be measured via the longitudinal polarization of β rays: $P_\beta/(v/c) = \pm x_i$; + for β^+ and – for β^- decays. Further information is obtained from the mixed decay of tritium [6] for which

$$-P_\beta/(v/c) = x_m = \rho x_V + (1 - \rho)x_A, \quad (3)$$

with a mixing parameter $\rho = 0.187$. For Gamow–Teller decays x_A can also be measured via the $\beta\gamma$ circular polarization correlation ($A_{\beta\gamma} = \pm \frac{1}{2} x_A \cdot v/c$, higher-order terms can be neglected [7]) or via the β -asymmetry of oriented nuclei. The latter way has, to our knowledge, not yet been used for *absolute* measurements of significant accuracy, but may offer good future possibilities.

Most parity experiments gave no *absolute* results in the strict sense that uncertainties in instrumental asymmetries and in sensitivity of utilized polarimeters have

been taken into account fully. For instance P_β can be measured with a Mott polarimeter by observing $\delta - \delta^0 = P_\beta S$. Here δ is the observed asymmetry from which a possible instrumental asymmetry δ^0 must be subtracted in order to obtain the true polarization asymmetry; δ^0 must be small with respect to δ . In Groningen the polarization sensitivity S has been measured via double scattering of unpolarized electrons [6]. Other investigators used calculated S -values with an estimated computational accuracy of 1.0 to 1.5% for infinitely thin scatterers. Adaptation of theoretical S -values for realistic scatterers and solid angles leads, however, in our experience to at least 2% uncertainty in P_β measurements. We judge that the analysing efficiency can be uncertain to 3% or more for $A_{\beta\gamma}$ measurements.

In table 1, a compilation of average P_β and $A_{\beta\gamma}$ results, the only pure Fermi decay concerns the P_{β^+} measurement by Hopkins et al. with ^{14}O . Unfortunately, the conditions imposed by this isotope caused relatively large uncertainties. In order to obtain narrower constraints on C'_V/C_V we reanalysed the beta-polarization for the mixed decay of tritium with respect to its separate Fermi and Gamow–Teller parts. Fig. 1 shows isopolarization contours according to eq. (3) and an area for $0.960 < x_m \leq 1$, the range to which x_m is confined with 90% confidence by the measured [6] value $x_m = 1.005 \pm 0.026$. The outer tritium contour gives

$$0.48 < C'_V/C_V < 2.06, \quad 0.73 < C'_A/C_A < 1.38. \quad (4)$$

The separate x_V and x_A values for ^3H in table 1 correspond to these ranges.

The uncertainties assigned to the finally adopted values for x_V and x_A are intended to be standard deviations. The error in x_V stems from the combined statistical evidence for ^{14}O and ^3H data, the error in x_A from combining the accuracies of uncorrelated absolute measurements. We searched a posteriori for values x'_i such that we are willing to accept with 90% confidence that the true but unknown value of x_i is within the interval $x'_i < x_i \leq 1$. With an objectivistic treatment [9] and with a subjectivistic bayesian^{†1} approach [10] we obtained essentially the same limits:

^{†1} Using the Bayes rule, we assumed that within the confinement $|x_i| \leq 1$ each value of x_i is equally probable. Assuming equal probability for the corresponding C'_i/C_i values would slightly narrow the ranges (5): e.g. $0.57 < C'_V/C_V < 1.91$.

Fig. 1. Iso-polarization contours for various $P_\beta(^3\text{H})$ values. The outer contour corresponds to the result of ref. [6] with a 90% confidence level, and confines C'_V/C_V and C'_A/C_A to the shaded area.

$$x'_V = 0.817, x'_A = 0.98, \text{ giving}$$

$$0.52 < C'_V/C_V < 1.93, \quad 0.82 < C'_A/C_A < 1.22. \quad (5)$$

These limits do not impeach a pure $V - A$ interaction with $C'_i = C_i$, but they offer a surprising leeway for alternative possibilities; e.g. admixtures of a $V + A$ interaction mediated by a W^{V+A} boson. Lipmanov [2] gave the relation

$$-P_\beta/(v/c) = 1 - 2G_+^2/(G_-^2 + G_+^2), \quad (6)$$

where $G_\pm$ are coupling constants related to $V \pm A$ interactions: $G_\pm/G_- = (C_i - C'_i)/(C_i + C'_i)$ with $i = V$ or A . For instance, if a $V + A$ admixture would proceed with $C'_V \neq C_V$ and with $x_V > 0.817$ (the 90% confidence limit), we find $m(W^{V-A})/m(W^{V+A}) = (G_+/G_-)^{1/2} < 0.56$ for the ratio of corresponding boson masses.

The limits (5) are based on allowed nuclear β -decay. The bounds can be narrowed, though not rigorously, by using a broader range of input data from less straightforward processes. Recently, we learned that this complementary approach has been made by Holstein and Treiman [13], taking results from first-forbidden β -decay, muon decay and decay of polarized ^{19}Ne with 2σ deviations without truncations. They did not take into account the P_β data for V -interaction via decay of ^{14}O and ^3H , but their constraint on C'_A/C_A (via their parameter y) is somewhat narrower than (5) due to additional input of data from first-forbidden β -decay.

Considering future experiments, it is evident that

improved β -polarization measurements are desirable, especially measurements on Fermi transitions. With proper investment of time and facilities it must be possible to improve polarimeters based on Mott scattering, on Bhabha scattering or on polarization effects of bremsstrahlung and annihilation radiation. For absolute $A_{\beta\gamma}$ measurements essential improvements seem not to be achievable for the moment. The reason is that the analysing efficiency for the γ -ray circular polarization can not be measured with an accuracy of a few percent.

This investigation was supported by the Netherlands Organisation for Pure Research (Z.W.O.) through the Stichting voor Fundamenteel Onderzoek der Materie (F.O.M.).

References

- [1] M.A.B. Bég, R.V. Budny, R. Mohapatra and S. Sirlin, Phys. Rev. Lett. 38 (1977) 1252.
- [2] E.M. Lipmanov, Soc. J. Nucl. Phys. 6 (1968) 395.
- [3] K. Siegbahn, Alpha-, beta- and gamma-ray spectroscopy (North-Holland, Amsterdam, 1966) Vol. 2, Ch. XXIV.
- [4] H. Paul, Nucl. Phys. A154 (1970) 160.
- [5] A. Kropf and H. Paul, Z. Phys. 267 (1974) 129.
- [6] F.W.J. Koks and J. van Klinken, Nucl. Phys. A272 (1976) 61; J. van Klinken, Nucl. Phys. 75 (1966) 145; F.W.J. Koks, thesis, Groningen (1977).
- [7] H. Behrens et al., Ann. Phys., to be published.
- [8] J.C. Hopkins, J.B. Gerhart, F.H. Schmidt and J.E. Stroth, Phys. Rev. 121 (1961) 1185.
- [9] T.A.B. Snijders, private communication and to be published; R.V. Hogg and A.T. Craig, Introd. mathem. statistics (MacMillan, New York, 1965).
- [10] D.J. Husdon, CERN 64-18 (Geneva, 1964); M. Annis, W. Cheston and H. Primakoff, Rev. Mod. Phys. 25 (1953) 818.
- [11] D.M. Lazarus and J.S. Greenberg, Phys. Rev. D2 (1970) 45; A.R. Brosi, A.I. Galonsky, B.H. Ketelle and H.B. Willard, Nucl. Phys. 33 (1962) 353; H. Wenninger, J. Stiewe, H. Muusz and H. Leutz, Nucl. Phys. A96 (1967) 177.
- [12] H. Appel, Z. Phys. 155 (1959) 580; R.M. Steffen, Phys. Rev. 115 (1959) 980; H. Schopper et al., Nucl. Instr. Meth. 49 (1967) 277.
- [13] B.R. Holstein and S.B. Treiman, Phys. Rev. D16 (1977) 2369; C16 (1977) 753.