COMMENTS

Implications of Recent Data on $\Sigma^- \to ne^- \nu$ for the Cabibbo Model

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A recent measurement of the electron-neutrino angular correlation in $\Sigma^- \to ne\nu$, taken by itself, is shown to be in remarkable agreement with the Cabibbo model. In contrast, the electron-spin asymmetry combines with it to distinctly favor the *wrong sign* for the axial-vector–to–vector form-factor ratio.

A precise measurement of the electron-neutrino angular distribution in the decay $\Sigma^- \to ne\nu$ has recently been reported.[1] The magnitude of the axial-vector–to–vector form-factor ratio was determined to be

$$|g_1/f_1| = 0.435 \pm 0.035 \tag{1}$$

under the assumptions of a V-A interaction, an octet extension of conserved vector current (CVC) for the weak-magnetism form factor f_2, absence of the induced pseudotensor form factor g_2, and vanishing momentum transfer (q^2) dependence for all the form factors.[2] This corresponds to a measured electron-neutrino correlation coefficient of

$$\alpha_{e\nu} = 0.284 \pm 0.048. \tag{2}$$

The prediction[3] of the Cabibbo model[4] for this ratio is

$$g_1/f_1 = -0.343 \pm 0.014. \tag{3}$$

Clearly, agreement on the magnitude appears to be poor; while, as is well known, the sign cannot be obtained from this measurement. It has long been recognized[5] that this sign—which is opposite to that expected in the old universal V-A scheme of Feynman and Gell-Mann[6]—is a characteristic feature of the Cabibbo model. Thus its determination constitutes a pivotal test of the model. In the present note we show that the results of Ref. 1 can be brought into good agreement with the predicted *magnitude* for g_1/f_1. However, when they are combined with the available phase-sensitive measurements, the wrong sign is favored.

First, it is important to recognize that the level of precision attained in Ref. 1 requires the inclusion of the q^2 dependence of $f_1(q^2)$ and $g_1(q^2)$ because it gives rise to effects comparable in size to the stated experimental error. We do this by introducing a linear slope as follows:

$$f_1(q^2) = f_1(0)(1 + \lambda_f q^2/M_\Sigma^2) \tag{4}$$

and similarly for $g_1(q^2)$.[2] In the spirit of the quark model, we assume the same q^2 dependence throughout the baryon octet. Then λ_f can be obtained by CVC from electron-nucleon scattering data, and λ_g from ν scattering data.[7] Our best estimates are $\lambda_f = 4.06$ and $\lambda_g = 3.61$. Using these slopes (really, only λ_g is relevant at this point[2]) in conjunction with the other assumptions listed earlier ($f_2/f_1 = -1.14$; $g_2 = 0$), the measured value of $\alpha_{e\nu}$ given in Eq. (2) implies

$$|g_1/f_1| \equiv |g_1(0)/f_1(0)| = 0.350 \pm 0.032, \tag{5}$$

in excellent agreement with the Cabibbo model prediction.

The electron-spin correlation coefficient α_e for polarized Σ^- β decay is the most accessible phase-sensitive parameter. Three experiments have sought to measure this quantity yielding results as shown in Table I. Despite the fact that their precision leaves something to be desired, the

TABLE I. Summary of experimental results for the electron-spin asymmetry parameter α_e for $\Sigma^- \to ne^-\nu$. The consistency $\chi^2 = 1.4$ for two degrees of freedom.

Experiment	Events	α_e
Gershwin[a]	61	-0.26 ± 0.37
Bogert *et al.*[b]	63	$+0.36 \pm 0.39$
Ellis *et al.*[c]	43	$+0.39^{+0.53}_{-1.9}$
Weighted mean		$+0.04 \pm 0.27$

[a]See Ref. 8.
[b]See Ref. 9.
[c]See Ref. 10.

three experiments are statistically consistent: $\chi^2 = 1.4$ for two degrees of freedom (d.f.).

We have performed a simple χ^2 fit to the weighted mean for α_e in Table I and $\alpha_{e\nu}$ as given in Eq. (2) above. The χ^2 minima correspond to

$$g_1/f_1 = +0.351 \pm 0.031 \tag{6}$$

with $\chi^2 = 1.3$ for one d.f., and

$$g_1/f_1 = -0.335 \pm 0.032 \tag{7}$$

with $\chi^2 = 6.2$ for one d.f. (1.2% χ^2 probability). The non-Cabibbo sign of Eq. (6) is clearly favored. The two solutions arise because $\alpha_{e\nu}$, which is better determined than α_e, carries no information about the sign of g_1/f_1. Within the context of our assumptions, the value of $\alpha_{e\nu}$ from Ref. 1 opens, so to speak, *two* rather narrow windows available to g_1/f_1. The more roughly measured parameter α_e then imposes a sign preference, shifting the magnitudes only slightly. Figure 1 is a graphical presentation of the situation. Note also that the non-Cabibbo sign would be even more strongly favored if we neglected the q^2 dependence of f_1 and g_1.

We wish to conclude by pointing out that the above discussion emphasizes the need for an accurate measurement of the electron-spin asymmetry parameter α_e in $\Sigma^- \to ne^-\nu$. The present situation is at best unsatisfactory, with the crucial information on α_e coming from an average of several imprecise experiments. The dramatic variation of α_e with g_1/f_1 (Fig. 1) gives rise to a very narrow region ($\alpha_e \simeq -0.55$ to -0.75) of consistency with the Cabibbo model. Were α_e proven to lie outside this region, then a drastic alteration of our present ideas about the weak interactions of the hadrons would almost certainly be required.

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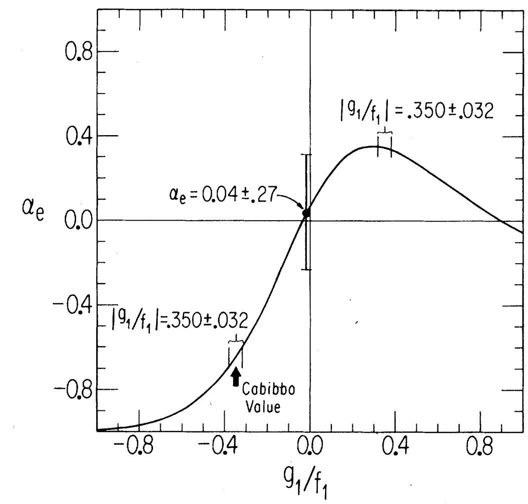

FIG. 1. The electron-spin asymmetry parameter α_e as a function of g_1/f_1 for $\Sigma^- \to ne^-\nu$. The data point is the weighted mean $\alpha_e = +0.04 \pm 0.27$ from Table I. The "windows" allowed by the results of Ref. 1 are indicated by vertical lines.

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$E2$-$E4$ Interference for (α, α') Reactions

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Although Coulomb-nuclear interference is certainly not a misnomer for the description of recently observed interference structure for α-particle excitation of 4^+ states in permanently deformed nuclei, the details of the interference are shown to be more easily understood as interference between $L=2$ and $L=4$ amplitudes.

Recent data and coupled-channel calculations for inelastic scattering of α particles[1-6] have shown striking interference phenomena for excitation of 4^+ members of rotational bands in permanently deformed nuclei. If one assumes that the Coulomb-nuclear interference of the first 2^+ state is an approximate measure of the impact parameter of a "grazing collision" (d_g), then these phenomena may be summarized as follows: (i) For nuclei with large-negative-β_4 deformations an extremely deep destructive interference minimum for excitation of the 4^+ state is observed but at an impact parameter smaller than d_g (e.g., approximately 0.8 fm smaller for ^{186}W); (ii) for nuclei with near-zero-β_4 deformations the interference minimum is shallow and occurs very close to d_g; (iii) for nuclei with positive-β_4 deformations the destructive interference is very weak and occurs at an impact parameter larger than d_g (e.g., approximately 1.2 fm larger for ^{154}Sm). These phenomena have been referred to as Coulomb-nuclear interference; although this is not incorrect, the purpose of this Comment is to point out that an easier understanding of these phenomena is achieved by thinking of the scattering as resulting from interference between $L=2$ and $L=4$ amplitudes.

The available data[1-6] examine the impact-parameter dependence of the cross sections by measuring excitation functions at large angles. Here, to reduce computing time, calculations were done for angular distributions at $E_{1\text{ab}}=20$ MeV; this is merely a simpler method, computationally, to examine the impact-parameter dependence of the cross sections. Calculations were performed with use of the coupled-channel code ECIS [7] Integrations were performed to 40 fm with forty partial waves; although larger $R_{\max}$ and $l_{\max}$ are preferable these are certainly adequate to obtain a physical understanding of the interference. All calculations done here are for ^{184}W with the use of the optical potential and deformation parameters of Ref. 3 (although the signs of the deformations were changed for some calculations); the deformations are listed in Table I. The complete coupled channel calculation using these parameters is shown as curve *a* in Fig. 1. The deep minimum near 120° corresponds to the minimum of the excitation function of Ref. 3 which occurs at $\theta_{1\text{ab}}=140°$ near $E_{1\text{ab}}=19$ MeV.

The first possible explanation examined was the possibility that the effects observed are due to the $L=2$ and/or $L=4$ reorientation matrix elements. Broglia[8] has recently predicted shifts of the interference minima for excitation of the first 2^+ states by heavy ions, oblate ($\beta_2<0$) nuclei shifting to smaller impact parameters and prolate ($\beta_2>0$) to larger impact parameters. This prediction is due solely to the presence of the matrix element $\langle 2^+||M(E2)||2^+\rangle$ and its qualitative similarity to the effects being examined here make it a promising possibility. To investigate this two calculations for ^{184}W were performed, one with all possible rotational-model matrix elements between the 0^+, 2^+, and 4^+ states and one which included only the matrix elements

TABLE I. Deformation parameters for ^{184}W.

$\beta_2{}^C$	$\beta_2{}^n$	$\beta_4{}^C$	$\beta_4{}^n$
0.254	0.192	-0.089	-0.076