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NEW DETERMINATION OF $|V_{us}|$ FROM K^+_{e3} DECAY

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On the assumption that only the vector current contributes to K_{e3}^{+} decay its matrix element can be written as [1, 2]

$$M = (G_F/\sqrt{2})V_{us}(f_+ p_\alpha + f_- q_\alpha)\bar{\psi}_\nu \gamma^\alpha (1+\gamma_5)\psi_{e^+} \ , \qquad (1)$$

where $\bar{\psi}_\nu$ and ψ_{e^+} are the leptonic spinors, $p = p_{K^+} + p_{\pi^0}$, and $q = p_{K^+} + p_{\pi^0}$ is the four-momentum transfer to the dilepton system. The vector form factors are functions of only the square of the invariant mass of two leptons and usually parametrized in q^2 as follows:

$$f_\pm(q^2) = f_\pm(0)(1 + \lambda_\pm q^2/m_{\pi^0}^2). \qquad (2)$$

Since the contribution from f_- in the square of K_{e3}^{+} matrix element is proportional to the lepton mass, therefore the value of λ_- does not significantly affect the electronic decay rate.

The K_{e3}^{+} decay has been investigated at the HYPERON spectrometer [3, 4]. The experimental facility is located at the Serpukhov accelerator in a $5 \div 15$ Gev/c positively charged secondary beam.

After data processing, the number of good K_{e3}^{+} events which we found is 3.2×10^4.

The q^2 dependence of the vector form factor f_+ can be extracted in a model-independent way by comparing the observed distribution of events to the distribution which is predicted from Monte Carlo simulation with using K_{e3}^{+} matrix element at $q^2 = 0$.

A sample of 1.5×10^7 K^+ decays was generated by the Monte Carlo technique. The experimental and simulated events were reconstructed with the same analysis program. The simulation took into account all cuts which are applied to the experimental data, the trigger requirements, the acceptance of the set-up, and uncertainties in determination of the particle kinematics parameters.

After comparing the experimental and simulated distributions we obtained q^2 dependence (fig.1) of the f_+ vector form factor and approximated it with linear function (2). The best fit gives the following value of the slope in the $f_+(q^2)$ linear expansion [5]

$$\lambda_+ = 0.0284 \pm 0.0027 \pm 0.0020. \qquad (3)$$

This result ($\chi^2 = 27$ for 22 degrees of freedom) is in good agreement with the ones of previous experiments [2, 6, 7, 8]. The systematic errors (the second error in (3)) were estimated by dependence of λ_+ on the selection criteria. The effect of the radiative correction according to [9] increases the value up to

$$\lambda_+ = 0.0296 \pm 0.0035. \qquad (4)$$

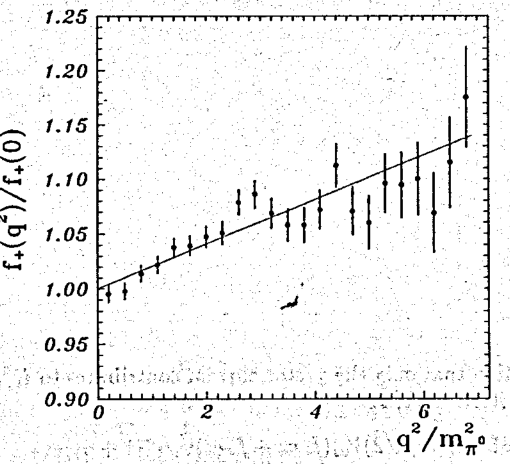

Fig.1. The ratio $f_+(q^2)/f_+(0)$ for the K^+_{e3} decay. The full line is a result of the fit with expansion (2)

Evaluating the phase space integral with the square of expression (1), the rate of the $K^+ \to \pi^0 e^+ \nu$ decay may be found

$$\Gamma = \frac{G_F^2}{768\pi^3} M_K^5 |V_{us}|^2 |f_+(0)|^2 (0.579 + 2.140\lambda_+ + 3.166\lambda_+^2), \qquad (5)$$

where $G_F^2 = G_\mu^2(1+\Delta)$. The factor Δ corresponds to the radiative corrections according to the formula [10]

$$\Delta = \frac{2\alpha}{\pi} \ln \frac{M_Z}{M_p}, \qquad (6)$$

where M_p and M_Z are the masses of the proton and Z respectively. The numerical calculation of the expression (6) yielded $\Delta = 0.02126$. Using the muon lifetime from [11] for determination G_μ one finds

$$G_F = (1.17870 \pm 0.00003) \times 10^{-5}\ GeV^{-2}. \qquad (7)$$

The rate which follows from the $K^+ \to \pi^0 e^+ \nu$ branching ratio given by the Review of Particle Properties [11] is

$$\Gamma = 0.2565(1 \pm 0.013) \times 10^{-17}\ GeV. \qquad (8)$$

Substituting in expression (5) the most accurate in the world value (4) of the slope in the $f_+(q^2)$ linear expansion, the value (7) of Fermi constant and the rate value quoted above we obtain

$$|f_+(0)||V_{us}| = 0.1524 \pm 0.0014 \qquad (9)$$

where the error includes the uncertainty in Δ and the accuracy in λ_+ and Γ determination. Using the theoretical number of $|f_+(0)|$ according to ref. [10]

$$|f_+(0)| = \frac{0.982 \pm 0.008}{\sqrt{2}} \qquad (10)$$

and value (9) we finally arrive at

$$|V_{us}| = 0.2195 \pm 0.0027. \qquad (11)$$

This result for the element $|V_{us}|$ of Kobayashi-Maskawa matrix is in good agreement with the value $|V_{us}| = 0.2196 \pm 0.0023$ from ref. [10]. It can be seen that the error in (11) is bigger than the one quoted above. This effect arises from the fact that the authors of the paper [10] used a value for the $K^+ \to \pi^0 e^+ \nu$ branching ratio $Br = (4.82 \pm 0.05)\%$ from ref. [12] and in our calculations the value $Br = (4.82 \pm 0.06)\%$ from [11] is applied.

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