TABLES OF EXPERIMENTAL DATA

539.12

EXPERIMENTAL DATA ON THE VERIFICATION OF THE RULE $\Delta S = \Delta Q$

M. V. TERENT'EV

Institute of Theoretical and Experimental Physics, Moscow

1. SEARCHES FOR THE $K^0 \to \pi^+ e^- \nu$ DECAYS

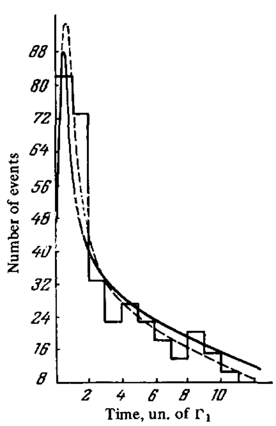
Definitions: $A(K^0 \to \pi^+ e^- \nu)/A(K^0 \to \pi^- e^+ \nu) = x \equiv |x| e^{i\Phi}$; $x = 0$ if $\Delta S = \Delta Q$; $\Phi = 0$ if CP = 1. One measures $N^{\pm}(t)$—the number of decays of $K^0(t)$ into $e^{\pm}$ as a function of the time

$$N^{\pm}(t) \sim |1+x|^2 e^{-\Gamma_1 t} + |1-x|^2 e^{-\Gamma_2 t} \pm 2(1-|x|^2)\cos \Delta t e^{-\Lambda t} + 4|x| \sin \Delta t \sin \Phi e^{-\Lambda t},$$

$$\Lambda = \frac{1}{2}(\Gamma_1 + \Gamma_2),\quad \Delta = m_1 - m_2.$$

Experimental data	Literature
335 lepton events $\lvert x \rvert = 0.26^{+0.08}_{-0.11}$, $\Phi = 50^{+25}_{-27}$	1
116 lepton events $\mathrm{Re}\, x = 0.17^{+0.16}_{-0.35}$, $\mathrm{Im}\, x = 0.0 \pm 0.25$	2

Notes: 1. The characteristic distributions of the events in time (according to [1]) is shown in the figure. We see that the case $x = \Phi = 0$ cannot be excluded.



Experimental data on the verification of the $\Delta S = \Delta Q$ rule (data of [1]: 355 events, $x = 0.26$, $\Phi = 50°$ (solid curve); $x = 0$, $\Phi = 0°$ (dashed).

2. Earlier data (see [3-5]) practically coincide within the limits of errors with those of [1] and [2], but are difficult to interpret, since different values of Δ were used in the data reduction.

[1] D. Hill et al., Phys. Rev. Lett. 19, 668 (1967). (Brookhaven, bubble chamber, $\Delta = -0.58\Gamma_1$).

[2] L. Feldman et al., Phys. Rev. 155, 1611 (1967). (Brookhaven, spark chamber, $\Delta = -0.55\Gamma_1$).

[3] P. Franzini et al., Phys. Rev. B140, 127 (1965). (Brookhaven, bubble chamber $\Delta = -0.79\Gamma_1$).

[4] M. Baldo-Geolin et al., Nuovo Cimento 38, 684 (1965). (CERN, bubble chamber, $\Delta = -0.15\Gamma_1$).

[5] B. Aubert et al., Phys. Lett. 17, 59 (1965). (CERN, bubble chamber, $\Delta = 0.47\Gamma_1$).

2. SEARCHES FOR THE DECAYS $\Sigma^+ \to n e^+ \nu$ AND $\Sigma^+ \to n \mu^+ \nu$ ($\Delta S = -\Delta Q$).

Number of cases of $\Sigma^+ \to$ lepton decays	Number of cases of $\Sigma^- \to$ lepton decays	$\frac{\Gamma(\Sigma^+ \to \text{leptons})}{\Gamma(\Sigma^- \to \text{leptons})}$	Literature
0	260 ($e^- + \mu^-$)	$\leqslant 3.7\%$	1
0	130 ($e^- + \mu^-$)	$< 12\%$	2
1 (μ^+)	?	$\frac{\Gamma(\Sigma^+ \to \mu^+)}{\Gamma(\Sigma^- \to \mu^-)} \sim 10\%$	3
1 (μ^+)	~ 100 (e^-)	?	4
1 (e^+)	~ 16 (e^-) ~ 4 (μ^-)	?	5

[1] G. Snow et al., cited in: W. Willis, Heidelberg Conf. on Elementary Particles, 1967 (Brookhaven, bubble chamber; Maryland University Group); see also Bull. Amer. Phys. Soc. 12, 568 (1967).

[2] W. Willis et al., Phys. Rev. B136, 1791 (1964). (CERN, bubble chamber. Total of 5×10^5 $\Sigma^{\pm}$ decays observed).

[3] E. Eiselle et al., cited in paper by W. Willis, Heidelberg Conf. on Elem. Particles, 1967. Heidelberg group; see also: Heidelberg Conference, September 1967, Abstracts of Contributions.

[4] A. Barbaro-Galtieri, Phys. Rev. Lett. 9, 26 (1962). (Berkeley, emulsion).

[5] U. Nauenberg et al., Phys. Rev. Lett. 12, 679 (1964). (Brookhaven, bubble chamber).

3. SEARCHES FOR $K^+ \to \pi^+ \pi^+ e^- \nu$ AND $K^+ \to \pi^+ \pi^+ \mu^- \nu$ DECAYS (K^+_{e4} AND $K^+_{\mu 4}$ DECAYS, $\Delta S = -\Delta Q$)

No decays with $\Delta S = -\Delta Q$ were observed. The total statistics of the K^+_{e4} and $K^+_{\mu 4}$ decays with $\Delta S = \Delta Q$ is given in the table.

Number of observed decays	Literature
310 (K^+_{e4})	1
208 (K^+_{e4})	
15 ($K^+_{\mu 4}$)	3

Notes: 1. See also [4,5].

2. The amplitudes of the K_{e4} decay are of the form

$$\langle \pi^+\pi^- | J^A_\lambda | K^+ \rangle = \frac{f}{m_K}(p_+ + p_-)_\lambda + \frac{g}{m_K}(p_+ - p_-)_\lambda,$$

$$\langle \pi^+\pi^- | J^V_\lambda | K^+ \rangle = \frac{ih}{m_K^3} \varepsilon_{\lambda\mu\nu\sigma}(p_K)_\mu (p_+ + p_-)_\nu (p_+ - p_-)_\sigma,$$

$f \sim e^{i\delta_0}$, g, $h \sim e^{i\delta_1}$, δ_0, δ_1—scattering phase shifts in s and p waves, respectively. The decay $K^+ \to \pi^+ \pi^+ e^- \nu$

($\Delta S = -\Delta Q$) contains only the J_λ^V contribution and the phase δ_1. The interpretation of the experimental data depends strongly on the $\pi\pi$-scattering phase shifts and on the J_λ^V contribution. For an analysis of the K_{e4} amplitudes see[6].

[1]M. Esten et al., Phys. Soc. Conf., London, 1967. (Berkeley, cited in[6]).

[2]B. Birge et al. (Berkeley, bubble chamber. Cited in[6]. See also Phys. Rev. **B139**, 1600 (1965); 69 K_{e4}^+ decays were observed in part of the accumulated statistics; a total of 3×10^6 K^+ decays were observed.

[3]V. Bisi et al., Phys. Lett. **B25**, 572, 1967 (CERN, bubble chamber; altogether, 61400 decays of K^+ into three particles were observed.

[4]D. Cline et al., Phys. Lett. 15, 293 (1965) (1 $K_{\mu 4}^+$ event).

[5]D. Greiner et al., Phys. Rev. Lett. 13, 284 (1964) (1 $K_{\mu 4}^+$ event).

[6]F. Behrends et al., Preprint, 1967. See also Heidelberg, Conf. on Elem. Part. Physics, September, 1967, Abstract of contributions.

539.12

III

CONSERVATION OF LEPTONS AND BARYONS AND THE NEUTRINO MASS

B. PONTECORVO

Joint Institute for Nuclear Research

Idea of experiment	Experimental procedure	Results (confidence level of limits about 70% unless otherwise stipulated	Remarks
		1. Lepton conservation	
$\nu_e \neq \bar{\nu}_e$; searches for neutrinoless double Beta decay	Magnetic spark chambers	$T_{ee\nu\nu}^{Ca^{48}} > 3 \cdot 10^{19}$ yrs [4]	Theoretical half-lives (years) for double β-decay processes[1-3]
		$T_{ee}^{Ca^{48}} > 1.6 \cdot 10^{21}$ yrs [4]	$T_{ee\nu\nu}^{Ca^{48}} = 10^{21 \pm 2,5}$
	Semiconductor Ge counter as source and detector	$T_{ee}^{Ge^{76}} > 3 \cdot 10^{20}$ yrs [5]	$T_{ee}^{Ca^{48}} = 5 \cdot 10^{15 \pm 2}$ $T_{ee\nu\nu}^{Ge^{76}} = 10^{23 \pm 2,5}$ $T_{ee}^{Ge^{76}} = 8 \cdot 10^{16 \pm 2}$ $T_{ee\nu\nu}^{Te^{128}} = 10^{27 \pm 2,5}$
	Mass spectrometric analysis of Xe and Kr in the minerals Te and Se of known age. T^A determined from the relation	$T^{Te^{128}} \geq 3 \cdot 10^{22}$ yrs [6]	$T_{ee}^{Te^{128}} = 2 \cdot 10^{19 \pm 2}$ $T_{ee\nu\nu}^{Te^{130}} = 10^{22 \pm 2.5}$
	$\frac{1}{T^A} = \frac{1}{T_{ee\nu\nu}^A} + \frac{1}{T_{ee}^A}$	$T^{Tc^{130}} =$ $= (8 \pm 0,6) \cdot 10^{20}$ yrs [6] $T^{Te^{130}} =$ $= (3 \pm 0.4) \cdot 10^{20}$ yrs [7] $T^{Te^{130}} =$ $= 6 \cdot 10^{20 \pm 0,3}$ yrs [3]	$T_{ee}^{Te^{130}} = 2 \cdot 10^{16 \pm 2}$ $T_{ee\nu\nu}^{Se^{82}} = 10^{22 \pm 2,5}$ $T_{ee}^{Se^{82}} = 1 \cdot 10^{16 \pm 2}$
		$T^{Se^{82}} =$ $= 6 \cdot 10^{19 \pm 0,3}$ yrs [3]	"Neutrinoless" half-lives calculated in the case of maximum violation of the lepton conservation law for unpolarized neutrinos
$\nu_\mu \neq \bar{\nu}_\mu$; investigation of sign of charged muons produced in collision with nuclei of high energy ν_μ: $\nu_\mu + \left\{ \begin{array}{l} n \to \mu^- + \ldots \\ p \to \mu^+ + \ldots \end{array} \right.$	Spark chambers [8]	$\sigma_{\mu^+} < 0,02\sigma_{\mu^-}$ ($\sim$ 1000 neutrino events)	Accuracy limited by the fact that the ν_μ beam contains a ν_μ admixture