LOW ENERGY POSITRONS FROM THE μ^+-e^+ DECAY

A. O. VAĬSENBERG

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The value $\rho = 0.72 \pm 0.10$ was obtained for the Michel parameter by analyzing available data on the spectrum of low-energy positrons emitted in μ^+-e^+ decays in photographic emulsions.

IN the study of the anisotropy in the directions of emission of positrons from the π^+-μ^+-e^+ decay[1,2] some indications appeared for low-energy positrons ($\lesssim$ 20 Mev) of a μ-e correlation which was larger than predicted by the two-component neutrino theory.[3] Because of this the study of the positron distribution in the low-energy region of the spectrum became of interest. It should be noted that in this region those radiative corrections to the spectrum are of greatest importance which depend on the covariant involved in the decay interaction and they affect the spectrum shape as well as the μ-e correlation. Consequantly this low energy region of the spectrum may be a source of information on the type of covariant involved in the μ-e decay interaction. However this region of the spectrum is poorly known. If measurements are carried out by electronic methods and the mesons are stopped in a layer of dense matter, the spectrum of slow electrons will be strongly distorted by initial energy losses and by scattering. In photoemulsions or in chambers, where the entire electron track from the decay point is available for study, the above mentioned difficulty does not occur; however the statistical accuracy of such measurements is usually low.

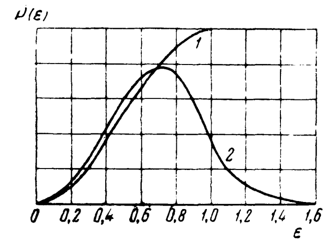
Vaĭsenberg et al.[1] measured the spectrum of 1100 positrons by their multiple scattering in emulsion. Analogous spectra,[4-9] published in recent years, contain a total of 1850 particles. Thus data is available on 2950 positrons where the energy of all the positrons was measured by the same method under approximately the same conditions, and therefore this composite spectrum may be studied in the low energy region. Such a study permits a relatively accurate determination of the Michel parameter ρ. This is possible because the low-energy region is most sensitive to the value of this parameter. From the expression for the positron spectrum as given by the four-fermion interaction

$$P(\varepsilon)\,d\varepsilon \sim 4\varepsilon^2\,[3(1-\varepsilon) + 2\rho\,(4/3\,\varepsilon - 1)]\,d\varepsilon \qquad (1)$$

(here ϵ is the positron energy in units of maximum energy) it is easy to show that as ρ varies from 0 to 0.75 the relative number of low energy particles

$$\eta_{<\varepsilon} = \int_0^{\varepsilon} P(\varepsilon)\,d\varepsilon \quad (\varepsilon \leqslant 0.3-0.4)$$

changes by approximately a factor of two. On the other hand those characteristics of the spectrum that are determined by high energy particles depend on ρ only slightly. Thus, for example, the above-mentioned change in ρ changes the average energy of the decay electrons merely from 0.6 to 0.7. Another circumstance favorable to the determination of ρ is the fact that the low-energy region is least affected by the spread in the scattering measurements and by bremsstrahlung in the emulsion. This can be seen from the figure, where we show the positron spectrum for $\rho = 0.75$, and the same spectrum washed out by the spread in the measurements and by bremsstrahlung in the emulsion under our experimental conditions. For ϵ less than 0.3 — 0.4 the two spectra differ by very little.



Positron spectrum from the $\mu^+ \to e^+$ decay for $\rho = 3/4$ (ε – positron energy, $p(\varepsilon)$ – decay probability): 1 – theoretical spectrum, 2 – same spectrum washed out by instrumental errors.

The experimental data are shown in the table. The second column gives the total number of particles in the spectrum and the fourth column gives the number of particles in energy intervals near the beginning of the spectrum. These data are subject to two corrections. In the first place, low-energy electrons are strongly scattered and leave the emulsion, so that the number of tracks of a given length depends upon the energy. This effect was estimated by Davies et al.[8] and by

Reference	Number of particles in spectrum	Energy interval	Number of low energy particles	Number of particles after corrections	ρ
		0—0.1	2		
		0.1—0.2	16	51	0.69±0.15
[1]	1100	0.2—0.3	46		
		0.3—0.4	96	71	0.48±0.14
[4]	405	0—0.26	22	18	0.41±0.30
		0—0.1	2		
		0.1—0.2	14	42	0.95±0.12
		0.2—0.3	36		
[5,6,7,8]	1161	0.3—0.4	88	71	0.60±0.13
		0—0.14	3		
		0.14—0.24	8	15	0.83±0.23
[9]	286	0.24—0.33	8		
		0.33—0.43	18	15	0.94±0.24

Bramson et al.,[9] and using their results we deduced the relevant corrections; they are not greater than a few percent in magnitude for the very lowest energies. Secondly, there are corrections due to the "washing out" of the spectrum (see figure). For our measurements in the energy interval from 0 to 0.4 this correction amounts to nearly 20%. The same correction was applied to the measurements of the other authors. This is justified by the smallness of the correction as well as by the fact that for low energies this correction should be approximately the same in all measurements, performed by the same method, of tracks of approximately the same distribution in length.

After integration we obtain from Eq. (1) the following expression for ρ:

$$\rho = 3(4-3\varepsilon)/8(1-\varepsilon) - 3\eta_{<\varepsilon}/8(\varepsilon^3-\varepsilon^4). \qquad (2)$$

In the sixth column of the table we give ρ, calculated in this manner, for the indicated energy intervals. The values of ρ lie in the interval from 0.41 to 0.95. However, as can be shown by applying the χ^2 test, they are in sufficiently good agreement with each other. Indeed, the extreme values of ρ are accompanied by large statistical errors. The average value, weighted according to the error, is $\rho = 0.72 \pm 0.06$.

Beside the statistical error one must consider the uncertainty in the determination of the scattering constant for electrons is emulsion. The existing data permit us to conclude that this constant is known accurate to 2 or 3%. A three-percent change in this constant corresponds to a ten-percent change in the value of ρ. Another source of error is to be found in the corrections that were applied. This error, however, is not too important since it amounts to only half the statistical error. Consequently the indicated statistical error should be multiplied by about 1.5 to take into account the uncertainty in the scattering constant. In conclusion we obtain

$$\rho = 0.72 \pm 0.10.$$

This value of ρ agrees well with the most precise determination known[10] in which, however, the main contribution comes from particles at the high energy end of the spectrum. Therefore it may be said that in the low energy region which we studied the spectrum shape is in agreement with that predicted by the two-component neutrino theory, which in the absence of radiative corrections gives the value 0.75 for ρ.

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