Comments and Addenda

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Revised value for the $\pi \rightarrow e\nu$ branching ratio*

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Using the current value for the pion lifetime, we have recomputed the branching ratio for $\pi \rightarrow e\nu$ decay obtained from the 1963 experiment of Di Capua *et al.* and find $\Gamma(\pi \rightarrow e\nu + \pi \rightarrow e\nu\gamma) / \Gamma(\pi \rightarrow \mu\nu) = (1.274 \pm 0.024) \times 10^{-4}$, a change of 2%. The theoretically predicted value lies within two standard deviations, compared to the $\frac{1}{2}$ standard deviation reported previously.

The branching ratio measurement for the electronic mode of pion decay is one of the most sensitive tests of the principle of electron-muon universality. The most accurate experiment, performed by Di Capua *et al.*,[1] used a NaI crystal to detect the electrons as well as the photons emitted in internal bremsstrahlung. The measured ratio is

$$\frac{\Gamma(\pi \rightarrow e\nu_e) + \Gamma(\pi \rightarrow e\nu_e\gamma)}{\Gamma(\pi \rightarrow \mu\nu_\mu)} .$$

The experimental setup made the measured ratio dependent on the pion decay rate λ_π, such that

$$R_{\rm exp} = \frac{\lambda_\mu}{\lambda_\pi - \lambda_\mu} \frac{N_{\pi e}}{De^{\lambda_\mu t_s} - N_{\mu e}} (1 - e^{-(\lambda_\pi - \lambda_\mu)t_s}) , \tag{1}$$

where λ_μ is the muon decay rate, D, $N_{\pi e}$, $N_{\mu e}$ are experimentally measured electron yields, and t_s is the separation between two experimental time bins. The measured ratio obtained with the known pion lifetime 25.5 ± 0.3 nsec in 1963 (see Ref. 2) was $R_{\rm exp} = (1.247 \pm 0.028) \times 10^{-4}$. The theoretically predicted ratio, taking into account radiative corrections,[3] was found to be 1.232×10^{-4}. This agreement is considered a great success of the $V-A$ theory and a confirmation of the hypothesis of electron-muon universality[4] to better than 1%.

We have recomputed the experimental branching ratio in Eq. (1), using the current value[5] of the pion lifetime, 26.030 ± 0.023 nsec, to obtain $R_{\rm exp} = (1.274 \pm 0.024) \times 10^{-4}$, and also the theoretical result, with radiative corrections, using the current value[5] of the pion mass, to obtain $R_{\rm theo} = 1.233 \times 10^{-4}$. The theoretical value is within 2 standard deviations of the experimental one, compared to the $\frac{1}{2}$ standard deviation reported previously.

The above theoretical result uses the same ultraviolet cutoff parameter Λ for both the $\pi \rightarrow e\nu$ and $\pi \rightarrow \mu\nu$ virtual-photon corrections. It is interesting to note that if we take the ratio of the values of Λ for the two processes to be in the ratio of the masses of the electron and muon, $\Lambda_e / \Lambda_\mu \simeq m_e / m_\mu$, then the theoretical result becomes $R_{\rm theo} = 1.258 \times 10^{-4}$, in better agreement with the experiment.

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[1] E. Di Capua *et al.*, Phys. Rev. 133, B1333 (1964).
[2] J. Ashkin *et al.*, Nuovo Cimento 16, 490 (1960).
[3] T. Kinoshita, Phys. Rev. Lett. 2, 477 (1959).
[4] See, for example, R. E. Marshak, Riazzudin, and C. P. Ryan, *Theory of Weak Interactions in Particle Physics* (Wiley-Interscience, New York, 1969).
[5] V. Chaloupka *et al.*, Phys. Lett. 50B, 1 (1974).