A review of rare pion and auon decays

Dinko Počanić

Department of Physics, University of Virginia
Charlottesville, VA 22904-4714, USA

More than a decade following the most recent published experimental work in the field, a new program of precise studies of rare pion and muon decays is under way and is producing results. The PIBETA collaboration at PSI uses a detector system [1] consisting of a large segmented spherical electromagnetic calorimeter with central tracking, surrounding an active target for stopped π^+ beam.

In the project's first phase, 1999–2001, the collaboration completed a set of measurements of the $\pi^+ \to \pi^0 e^+\nu$ (pion beta decay, $\pi\beta$), $\pi^+ \to e^+\nu$ (π_{e2}), $\pi^+ \to e^+\nu\gamma$ ($\pi_{e2\gamma}$), and $\mu^+ \to e^+\nu\bar{\nu}\gamma$ decays. Data for all of the decays except $\pi \to e\nu\gamma$ have been found to be in excellent agreement with predictions of the Standard Model, with $\sim$1 % accuracy, or better.

In particular, the current result for the pion beta decay branching ratio [2]:

$$R_{\pi\beta}^{\rm exp} = [1.034 \pm 0.004\,({\rm stat}) \pm 0.007\,({\rm syst})] \times 10^{-8}\,,$$

represents a five-fold improvement in precision over the most recent previous measurement [3], and is in excellent agreement with the Standard Model prediction using the currently accepted Particle Data Group (PDG) recommended value for V_{ud} [4]. Further improvement of the above result is under way.

The bulk of the measured $\pi_{e2\gamma}$ data are compatible with the standard (V$-$A) form of the weak interaction and have enabled a four-fold improvement in the pion form factor ratio [5]:

$$F_A/F_V = 0.443 \pm 0.015\,.$$

However, significant ($\sim$20 %) deviations appear in the kinematic region corresponding to high E_γ/low E_{e+}, not explained by instrumental or analysis inefficiencies. In 1990 a similar anomaly was observed in the ISTRA experiment [6] using a radically different technique, though with far lower event statistics; it was tentatively attributed to a small tensor term in the electroweak interaction. A new measurement [7], currently under way, has been designed to provide a definitive resolution of the issue.

[1] E. Frlež et al. (the PIBETA Collaboration), e-print hep-ex/0312017, to appear in NIM A.

[2] D. Počanić et al. (the PIBETA Collaboration), e-print hep-ex/0312030.

[3] W. K. McFarlane, et al., Phys. Rev. D **32**, 547 (1985).

[4] K. Hagiwara et al. (the Particle Data Group), Phys. Rev. D **66**, 010001 (2002).

[5] E. Frlež et al. (the PIBETA Collaboration), e-print hep-ex/0312029.

[6] V.N. Bolotov et al., Phys. Lett. B **243**, 308 (1990); Yad. Fiz. **51**, 717 (1990).

[7] PSI proposal R-04-01.1, available at `http://pibeta.phys.virginia.edu/docs/`

E-mail: pocanic@virginia.edu