π^+ Decay and Lepton Universality

PIENU Collaboration
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In the Standard Model (SM), the coupling constants for the three Lepton families g_e, g_μ, g_τ are all set to be equal to a universal value g and the families differ only in their masses and couplings to the neutral physical Higgs scalar. Although the experimental evidence for the hypothesis of lepton universality is excellent [Lo04], new physics beyond the SM may affect apparent tests of lepton universality. For example, the reported 3σ discrepancy in the value of $\sin^2\theta_W$ from the SM model prediction in the NuTeV experiment [Ze02] could require new physics which would contradict universality.

Currently, the most sensitive method for testing lepton universality comes from measurements of the $\pi \to e\nu$ branching ratio $R_{\pi\to e}$ or the ratio of decay rates for $\pi^+ \to e^+\nu_e(\gamma)$ and $\pi^+ \to \mu^+\nu_\mu(\gamma)$. Since the $\pi \to e\nu$ decay has strong helicity suppression ($< 10^{-4}$) compared to the muon decay mode, it is extremely sensitive to effects of helicity-unsuppressed pseudoscalar or scalar couplings which can be enhanced by physics beyond the SM. Deviations of the branching ratio from that of the SM at the level of 0.1% are sensitive to pseudoscalar interactions at the mass scale of 1000 TeV.

Previous experimental values for $R_{\pi\to e}$ are $(1.2265\pm0.0034(\text{stat})\ \pm0.0044(\text{syst}))\times10^{-4}$ (TRIUMF [Br92]) and $(1.2346\pm0.0035(\text{stat})\ \pm0.0036(\text{syst}))\times10^{-4}$ (PSI [Cz93]), with an average of $1.231\pm0.004\times10^{-4}$. The highly precise theoretical value, including radiative corrections, is $(1.2353\pm0.0004)\times10^{-4}$ [MS93] leading to $g_e/g_\mu = 0.9985\pm0.0016$. Thus, lepton universality in the first two generations has been confirmed at the 0.16% level.

A new experimental measurement of $R_{\pi\to e}$ known as PIENU has been initiated at TRIUMF aiming for a precision of $< 0.05\%$, an order of magnitude improvement over earlier measurements. PIENU, patterned on the earlier experiment [Br92], employs a non-magnetic crystal spectrometer to detect electrons from the $\pi \to e\nu$ decay ($T_{e^+} = 69.3$ MeV) and also from the π-μ-e decay chain which has a maximum positron energy of 52.3 MeV. The detectors include a large NaI crystal surrounded by a ring of pure CsI crystals. Important improvements from the earlier experiments will result in substantial reduction of statistical and systematic uncertainties though the use of Si strip and gaseous drift tracking detectors, high speed digitizing of all pulses, an eight times increase in the detector solid angle, and longer running times. Data collection runs are expected to occur in 2007-09.

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