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Precision measurements of charged pion decays with the PIONEER Experiment

PIONEER is a next-generation precision experiment proposed at Paul Scherrer Institute, Switzerland, to perform high precision measurements of rare pion decays. The measurement of the charged pion branching ratio $R_{e/}$ = Γ(π+⟶e+ν(γ) / Γ(π+⟶ μ+ν(γ) for pion decays to positrons relative to muons is extremely sensitive to a wide variety of new physics effects. At present, the Standard Model prediction for $R_{e/}$ is known to the order of 10^{-4}, which is 15 times more precise than the current experimental result. An experiment reaching the theoretical accuracy will test lepton flavor universality at an unprecedented level, probing mass scales up to the PeV range. The measurement of the rare process of pion beta decay, π+⟶ π^0e+ν(γ) with an improvement in sensitivity by a factor of 3-10, will determine $|V_{ud}|$ in a theoretically pristine manner and test CKM unitarity, which is very important in light of the recently emerged tensions. In addition, various exotic rare decays involving sterile neutrinos and axions will be searched for with unprecedented sensitivity.

The experiment design benefits from experience with the PIENU and PEN experiments at TRIUMF and at PSI. Excellent energy and time resolutions, greatly increased calorimeter depth, high-speed detector and electronics response, large solid angle coverage, and complete event reconstruction are all critical aspects of the approach. In the PIONEER experiment design, an intense pion beam is stopped in a segmented, instrumented (active) target (ATAR). The proposed technology for the ATAR is based on low-gain avalanche detectors (LGADs), which can provide precise spatial and temporal resolution for particle tracks and thus separate even very closely spaced decays and decay products. The proposed detector will also include a ~2π sr, 25 radiation length (X_0) electromagnetic calorimeter. An additional, cylindrical tracker surrounding the ATAR may be used to link the locations of pions stopping in the target to showers in the calorimeter.

This presentation will cover the theoretical motivations for PIONEER, as well as the ongoing simulations efforts to precisely determine the detector performance and inform decisions on the experiment design. Results from recent beam test campaigns on the pion beamline itself, and silicon sensor and LYSO calorimeter crystal prototypes will be shown.

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