WORKSHOP ON PICO-SECOND TIMING DETECTORS FOR PHYSICS

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An LGAD-based full active target for the PiENuX experiment

PIENUX is a next-generation experiment to measure the charged-pion branching ratios to electrons vs muons, Re/μ and pion beta decay (Pib) $\pi+\longrightarrow\pi 0 e\nu$. Re/$\mu$ provides the best test of e-μ universality and is extremely sensitive to new physics at high mass scales; Pib could provide a clean high precision value for Vud. Order of magnitude improvements in precision to these reactions will probe lepton universality at an unprecedented level, determine ⊠⊠⊠ in a theoretically pristine manner and test CKM unitarity at the quantum loop level. The pion to muon decay ($\pi\longrightarrow\mu\longrightarrow e$) has four orders of magnitude higher probability than the pion to electron decay ($\pi\longrightarrow e\nu$). To achieve the necessary branching-ratio precision it is crucial to suppress the $\pi\longrightarrow\mu\longrightarrow e$ energy spectrum that overlaps with the low energy tail of $\pi\longrightarrow e\nu$. The high-acceptance and high-resolution design of the PIENUX calorimeter allows to reduce the tail correction to be < 0.01%.

A high granularity active target (ATAR) is being designed to suppress the muon decay background sufficiently so that this tail can be directly measured. In addition, ATAR will provide detailed 4D tracking information to suppress other significant systematic uncertainties (pulse pile-up, decay in flight of slow pions) to < 0.01%, allowing the overall uncertainty in Re/μ to be reduced to O(0.01%). The high precision 4D tracking would allow to separate the energy deposits of the pion decay products in both position and time. The chosen technology for the ATAR is Low Gain Avalanche Detector (LGAD). These are thin silicon detectors (down to 50 µm in thickness or less) with moderate internal signal amplification (up to a gain of ~50). LGADs are capable of providing measurements of minimum-ionizing particles (MiP) with time resolution as good as 17 ps. In addition, LGADs have fast rise time and short full charge collection time. The ATAR would be made of 48 planes of 2×2 cm strip LGADs with 120 µm of active thickness. To achieve a ~100% active region several technologies still under research are being evaluated, such as AC-LGADs and TI-LGADs. A dynamic range from MiP (positron) to several MeV (pion/muon) of deposited charge is expected, the detection and separation of close-by hits in such a wide dynamic range will be a main challenge. Furthermore the compactness and the requirement of low inactive material of the ATAR present challenges for the readout system, forcing the amplification chip and digitization to be positioned away from active region.

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