

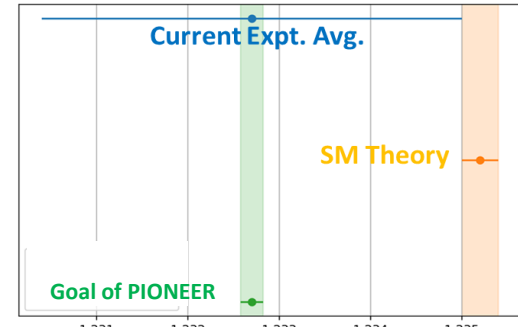
Advancing PIONEER test of lepton universality through enhanced detector simulation/design and seeding improved BNL capability for fast frontend amplifiers

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PIONEER will explore existing hints of lepton non-universality and CKM non-unitarity through precision measurements of the charged pion branching ratio to electrons vs. muons $R_{e/\mu}$, and of the branching ratio of the pion beta decay (BRPB), $\pi^+ \rightarrow \pi^0 e^+ \nu(\gamma)$. The 15 times improvement in precision of $R_{e/\mu}$ over the current experimental value will probe new physics up to PeV mass scale. The one order magnitude in precision of BRPB will allow for tests of CKM unitarity considering the Cabibbo Angle Anomaly and the theoretically cleanest extraction of $|V_{ud}|$ at the 0.02% level. **This proposal will develop and validate with simulations the conceptual design of PIONEER consisting of active stopping target and calorimeter detector, including i) physics studies to demonstrate the capability of conceptual design to reach the precision goal of the experiment with a full simulation and reconstruction chain, and ii) seeding the development of a frontend ASIC chip utilizing the BNL cold electronics technology for the active stopping target as evolutionary development of LArASIC chip that is being widely used in LArTPC experiments.** Such a new ASIC chip can also be used to readout SiPM light detectors. Considering the expected DOE project prioritization process post P5 report, **this LDRD support is critical to the development of US DOE PIONEER project through providing continuous support. This LDRD will transform R&D activities to US DOE PIONEER Project, which will secure funding for further R&D and realization of PIONEER experiment.**

The physics program of PIONEER is a prominent constituent of DOE Intensity Frontier. It was endorsed by Snowmass Community Planning Exercise and was presented as a small-scale experiment to and well accepted by P5, pending final P5 report in December 2023. BNL should take the leading role in realizing the PIONEER experiment, which includes collaborators from Canada, Europe, Japan, China, and U.S.A., from both nuclear physics and particle physics communities. This effort is well aligned with BNL's mission to advance fundamental research in nuclear and particle physics to gain a deeper understanding of matter. BNL is in a uniquely favorable position to become the US leading lab for PIONEER, given our long history in physics of rare processes and precision measurements, as well as unequalled technological expertise in two major detector components in the conceptual design of PIONEER experiment: the silicon detector technology and noble liquid calorimetry.



$$\Delta_{\text{CKM}} = |V_{ud}|^2 + |V_{us}|^2 - 1 = (-19.5 \pm 5.3) \times 10^{-4}$$

