Whitepaper on the DAEδALUS Experiment
The DAEδALUS Collaboration, January 26, 2013

DAEδALUS (Decay-At-rest Experiment for δ_{CP} studies At the Laboratory for Underground Science) is a phased program leading to a high-sensitivity search for CP-violation [1, 2]. The system is formed of sets of "modules" consisting of an ion source, an injector cyclotron, a superconducting ring cyclotron (SRC), and a target/dump. Modules are arranged at three sites near an underground, ultra-large detector with free protons.

The experiment uses π/μ decay at rest to search for $\bar{\nu}_\mu \to \bar{\nu}_e$ with the atmospheric Δm^2. The $\bar{\nu}_e$ will be detected, via the inverse beta decay interaction, in an ultra-large neutrino detector. The CP-violation signal is extracted by measuring the oscillation wave as a function of distance L that the neutrinos have travelled, with positions at $L = 1.5$ km, 8 km, and 20 km. The final phase of the program leads to a unique CP-violation experiment, which is not subject to matter effects, and which has a sensitivity substantially beyond LBNE as it is presently reconfigured [3].

The program proceeds in four phases. Phase I, which is well underway, involves development and testing of an ion source and low-energy beam transport system. Phase II establishes the injector cyclotron, which is the same system used for the IsoDAR physics program [4], now in the proposal stage. Phase III will result in an SRC and target/dump, leading to the first full accelerator module. The module runs with a 13% duty factor, producing 0.8 MW average power on the dump/target. The SRC, which has many similarities to the existing RIKEN SRC [5], is the cost driver for the accelerator modules. The magnet [6] is estmated at $60M, fully loaded. The physics case for the single "near accelerator" module is based on short-baseline searches for Beyond Standard Model physics [7, 8]. Phase IV introduces the modifications for high-power running needed at the mid and far sites for CP-violation studies.

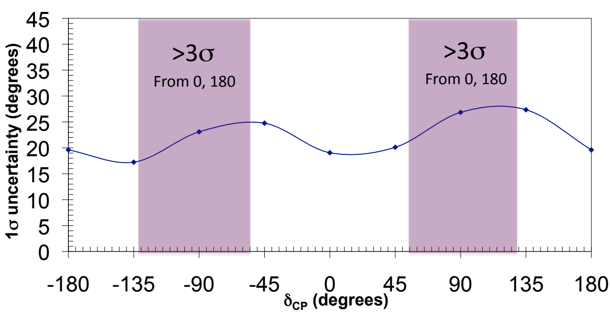

Figure 1: *The sensitivity of the CP-violation search when DAEδALUS is paired with LENA*

The program requires free proton targets, hence either oil or scintillator detectors. The original case was developed for a 300 kt Gd doped water detector at Homestake, in coordination with LBNE [9]. Subsequently, DAEδALUS was incorporated into LENA [10], and the sensivity is shown in Fig. 1. However, a phased program in Japan, beginning with the existing Super-K detector (with Gd-doping) and followed by running with Hyper-K [11] is attractive, since it could come on line quickly. This program combines DAEδALUS with the JPARC beam (including its planned upgrades) [12]. The intial Super-K-based program would be the only experiment to cover 50% of the allowed δ_{CP} space at $> 3\sigma$ for $\sin^2 2\theta \sim 0.1$ before 2030. Ten years of Hyper-K running provides 80% coverage of δ_{CP} at $> 5\sigma$. Lastly, the pairing of a Gd-doped MEMPHYS, based in Sweden, with a short-baseline beam from the ESS [13] is appealing, as neither the DAEδALUS nor ESS baselines will suffer matter effects.

This program has been well received by the wider community. The NRC Committee to Assess the Science Proposed for a Deep Underground Science and Engineering Laboratory wrote: "Proposals for new second generation experiments with water Cherenkov detectors include very imaginative possibilities, such as the DAEδALUS proposal to create neutrinos using a series of small nearby cyclotrons" [14].

References

[1] J. Alonso, *et al.*, [DAEδALUS Collaboration] ,"Expression of Interest for a Novel Search for CP Violation in the Neutrino Sector: DAEδALUS," arXiv:1006.0260 [physics.ins-det], 2010.

[2] J.M. Conrad and M.H. Shaevitz, Phys.Rev.Lett. **104**, 141802 (2010).

[3] http://www.fnal.gov/directorate/lbne_reconfiguration/files/LBNE-Reconfiguration-PhysicsWG-Report-August2012.pdf

[4] A. Bungau, A. Adelmann, J. R. Alonso, W. Barletta, R. Barlow, L. Bartoszek, L. Calabretta and A. Calanna *et al.*, arXiv:1205.4419 [hep-ex] Phys. Rev. Lett. **109**, 141802, 2012.

[5] H. Okuno, J. Ohnishi, K. Yamada, N. Fukunishi, K. Ikegami, T. Maie, H. Hasebe, M. Hamanaka, M. Kase, A. Goto, Y. Yano, IEEE Trans. on App. Supercon., **17**:2, 1063 (2007).

[6] J. Minervini, M. Cheadle, V. Fishman, C. Miller, A. Radovinsky and B. Smith, "Engineering Study of Sector Magnet for the Daedalus Experiment," arXiv:1209.4886 [physics.acc-ph].

[7] S. K. Agarwalla and P. Huber, "Potential measurement of the weak mixing angle with neutrino-electron scattering at low energy," JHEP **1108**, 059 (2011) [arXiv:1005.1254 [hep-ph]].

[8] S. K. Agarwalla, J. M. Conrad and M. H. Shaevitz, JHEP **1112**, 085 (2011)

[9] J. Alonso, *et al.*, [The DAEδALUS Collaboration], "A Study of Detector Configurations for the DUSEL CP Violation Searches Combining LBNE and DAEδALUS," arXiv:1008.4967 [hep-ex].

[10] M. Wurm *et al.* [LENA Collaboration], "The next-generation liquid-scintillator neutrino observatory LENA," arXiv:1104.5620 [astro-ph.IM] (2011).

[11] K. Abe *et al.* [The Hyper-K Collaboration] "Letter of Intent: The Hyper-Kamiokande Experiment — Detector Design and Physics Potential," arXiv:1109.3262 [hep-ex].

[12] This assumes upgrades that appear in the JPARC longterm plan, presented to the PAC, 21 January 2012. See: http://j-parc.jp/researcher/Hadron/en/pac_1201/minutes-j-parc-pac-20120115-final.pdf

[13] E. Baussan, M. Dracos, T. Ekelof, E. F. Martinez, H. Ohman and N. Vassilopoulos, arXiv:1212.5048 [hep-ex].

[14] An Assessment of the Deep Underground Science and Engineering Laboratory (DUSEL), by the Ad Hoc Committee to Assess the Science Proposed for a Deep Underground Science and Engineering Laboratory, A. Lankford, chair, available from the National Research Council, http://www.nap.edu/catalog.php?record_id=13204 (2011).