Physics Opportunities with DAEδALUS

G. Karagiorgi, for the DAEδALUS Collaboration

November 1, 2011

DAEδALUS combines multiple $\pi^+ \to \mu^+$ decay-at-rest $\bar{\nu}_\mu$ sources with the 300 kton water Cherenkov detector being considered for LBNE (4850 ft level), doped with gadolinium. This experimental setup allows for a powerful search for CP violation in three-neutrino mixing.

The experimental configuration assumes three cyclotron accelerator complexes [1], at 1.5 km, 8 km, and 20 km each from the presently proposed detector location at DUSEL. Each complex produces an isotropic, high-flux ($4\times10^{22}\nu$/flavor/yr) $\bar{\nu}_\mu$ beam. The carefully chosen baselines allow sensitivity to $\bar{\nu}_\mu \to \bar{\nu}_e$ oscillations at the atmospheric Δm^2, which are dependent on θ_{13} and δ_{CP}. Rather than following the conventional approach of comparing oscillation probabilities for neutrinos versus antineutrinos ($\delta_{CP} \to -\delta_{CP}$) at the same L/E, the DAEδALUS search uses only antineutrinos, but compares oscillation probabilities at different L/E, exploiting the L-dependence of the CP-violating interference terms in the three-neutrino oscillation probability.

The signal $\bar{\nu}_e$ events are identified by the double-coincidence signature of Cherenkov light from the e^+ produced in inverse beta decays ($\bar{\nu}_e p \to e^+ n$) followed by light emitted in neutron capture on gadolinium. The beams are staggered, allowing the baseline for each event to be determined by timing. Assuming a 67% neutron capture efficiency, one expects on the order of a few hundred or more signal events for each baseline during a five year run, regardless of δ_{CP} and mass hierarchy, assuming $\sin^2 2\theta_{13} = 0.05$. Predicted backgrounds, including intrinsic beam $\bar{\nu}_e$ and non-beam backgrounds, correspond to roughly 950, 400, and 350 events for each baseline.

Assuming a ten year run, DAEδALUS' sensitivity reach for δ_{CP} and θ_{13} is found comparable to that of LBNE [2]. However, combining DAEδALUS and LBNE searches proves significantly advantageous, resulting in a factor of five improvement over either search (LBNE or DAEδALUS). The large increase in phase space coverage comes from the level of complementarity that LBNE and DAEδALUS share, one offering a high-statistics neutrino sample of higher energy, the other being a lower-energy high-statistics antineutrino search, which is also insensitive to matter effect induced degeneracies. With an additional ten year of simultaneous running with Project-X, the combination of the two searches gains an additional factor of three over either single search, giving 3σ sensitivity to values of $\sin^2 2\theta_{13} < 0.001$, and a 50% chance for δ_{CP} discovery (3σ) potential for $\sin^2 2\theta_{13} \sim 0.001$.

Aside from a potential independent confirmation of a θ_{13} and δ_{CP} measurement, or the increased sensitivity to θ_{13} and δ_{CP} that DAEδALUS offers, the DAEδALUS proposal also fits nicely within a wider physics program at DUSEL. By construction, the detector requirements for DAEδALUS overlap with the <100 MeV physics searches for supernova, relic neutrinos, and proton decay. In addition, the new accelerator facility (near) and neutrino (multi-)source at DUSEL provides opportunity for new experiments and enhancement of the DUSEL neutrino program. To date, the consideration of such source has prompted proposals for several searches for new physics. Those include searches for coherent neutrino scattering, non-standard neutrino interactions, sterile neutrino oscillations, axion searches, and low-Q^2 measurements of $\sin^2\theta_W$.

The combination of LBNE with a large water Cherenkov detector at DUSEL and DAEδALUS is worth being further explored, as it allows for a stronger and more well-rounded physics program for the intensity frontier, covering high energy neutrino physics and decay-at-rest source antineutrino physics, but also lending itself to and strengthening other fields such as particle astrophysics.

References

[1] J. Alonso, "DAEδALUS Beam Source", FNAL Neutrino Working Group Meeting, Oct. 24, 2011.

[2] J. Alonso *et al.*, arXiv:1006.0260 [physics.ins-det].