Hanohano: Hawaiian Antineutrino Observatory

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Abstract. Design studies are underway for the deep ocean antineutrino observatory Hanohano. The 10 kton monolithic underwater detector will be able to make precision measurement of neutrino mixing parameters (including $\theta_{13}$ and neutrino mass hierarchy) if stationed around 60 km offshore, from the nuclear reactor. Hanohano will be a mobile detector and placing it in a mid-Pacific location will provide the first ever flux measurement of geoneutrinos (antineutrinos emitted in the radioactive decay series of uranium and thorium), coming from the Earth’s mantle and perform a sensitivity search for a hypothetical natural fission reactor in the Earth’s core. Additional deployment at a different mid-ocean location will lead to tests of lateral heterogeneity of uranium and thorium in the Earth’s mantle. These measurements would provide an important insight into deep-Earth geophysics, mantle composition and understanding of the Earth’s heat flow and sources of energy inside the Earth.

1. Introduction
Hawaiian Antineutrino Observatory (Hanohano) is under development in Hawaii and elsewhere. Hanohano is envisioned as a 10 kton monolithic detector filled with ultra-pure scintillator fluid. Inverse beta decay reaction is used to detect electron anti-neutrinos with energy of 1.8 MeV or higher. The 10 kton target volume is surrounded with an array of 10-inch photomultiplier tubes, placed in 13-inch pressure housings (see Fig. 1 and [1][2]). PMTs will collect scintillating photons from interactions taking place inside the detector. The detector will have energy resolution of 3.5%/\sqrt{E_{vis}}$, where $E_{vis} = E_\nu - 0.8$ MeV is visible energy inside Hanohano. It will be deployed in the deep ocean at depth between 3 and 4 km to obtain sufficient overburden. Low muon incidence rate, combined with thick shielding of the target volume and ultra-pure scintillator will result in a very high detection efficiency. Hanohano will be deployed from the barge, with about 30 minutes needed for descent and ascent. Hanohano’s mobility significantly increases its science potential. While a location offshore from the nuclear reactor will allow precision measurement of neutrino mixing parameters including $\theta_{13}$ and neutrino mass hierarchy, additional deployment near Hawaii will provide excellent measurement of terrestrial anti-neutrinos.

2. Scientific potential
2.1. Neutrino Mixing Parameters
Understanding of the phenomenon of neutrino oscillations has improved dramatically over the last decade and precision measurements of the most of the neutrino oscillation parameters have been obtained. However, neutrino oscillation angle $\theta_{13}$ is still only confined by an upper limit and a question of the neutrino mass hierarchy is still open.
One year long deployment of Hanohano, 60 km offshore from San Onofre nuclear plant (7 GW power level) in California, or Maanshan reactors (6 GW power level) in Taiwan could resolve mass hierarchy problem for $\sin^2 2\theta_{13} \geq 0.05$ and measure $\theta_{13}$ without the need for the near detector [2].

2.2. Terrestrial Antineutrinos
Measurement of the terrestrial antineutrino flux is of great importance to geophysics. Recent results from KamLAND [3] provided the first ever experimental evidence of terrestrial antineutrino flux. The measurement was rather crude and could only confirm our current understanding of the Earth’s composition and energetics. More precise measurement and at different location would shed light and potentially differentiate among different Earth models.

One year long deployment of Hanohano near Hawaii would provide the first ever measurement of geoneutrino flux from the mantle with 25% uncertainty. In addition, remoteness of Hawaii location from man-made nuclear reactors, is ideal for testing the hypothesis for the existence of the natural nuclear fission reactor in the earth’s core. This reactor is predicted to be in the energy range from 1-10 TW. Hanohano would set a 99% C.L. limit to the geo-reactor power at 0.3 TW, or a 1 TW reactor (if proven to exist) would be detected at 5σ C.L.

2.3. Other physics opportunities
Ten kton scintillator detector will detect a strong galactic supernova signal and even search for relic supernovae neutrinos. The signal can be as large as 4 events per year [4]. If the radio purity level is high enough, the flux from sub-MeV solar neutrinos may be measured. Finally, Hanohano can detect proton decay in the following mode: $p \rightarrow \nu + K^+$ and may reach a sensitivity of almost $10^{34}$ years.

3. Conclusion
Hanohano is a deep ocean antineutrino observatory being developed in Hawaii and other places. One year long deployment, 60 km away from the nuclear reactor can resolve mass hierarchy for $\sin^2 2\theta_{13} \geq 0.05$ without the near detector. Additional one year long deployment in mid-pacific will measure the flux of geoneutrinos from U and Th decay series with 25% uncertainty and either measure or severely limit the power level of the hypothetical geo-reactor. Monte Carlo studies, accompanied by lab and field tests are underway.

References
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