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High Power, High Energy Cyclotrons for Decay-At-Rest Neutrino Sources: The DAEdALUS Project

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Neutrino physics from muon decay is very much at the forefront of today's physics research. Large detectors installed in deep underground locations perform neutrino mass, CP violation, and oscillation studies using long- and short-baseline beams of neutrinos from muons decaying in flight. DAEdALUS looks at neutrinos from stopped muons, "Decay At Rest (DAR)" neutrinos. The DAR neutrino spectrum has no electron antineutrinos (nu-e-bar) (pi-minus are absorbed to level of 10^-4), so a detector with much hydrogen (water-Cherenkov or liquid scintillator) is sensitive to appearance of nu-e-bar's oscillating from nu-mu-bar via inverse-beta-decay. Oscillations are studied using shorter baselines, less than 20 km reaching the same L/E range as the current and planned neutrino experiments originating at Fermilab. As the neutrino flux is not variable, nor is the energy, the baseline is varied: plans call for 3 accelerator-based neutrino sources at 1.5, 8 and 20 km with staggered beam-on cycles. Key is cost-effectively generating megawatt beams of 800 MeV protons. A superconducting ring cyclotron, accelerating H2+ ions is being designed by L. Calabretta and his group at INFN-LNS-Catania. Having a design peak power of 8 MW, the 5 emA circulating beam is extracted via a stripping foil, avoiding beam-loss problems that would be encountered in classical cyclotron extraction. The molecular hydrogen beam also reduces the severity of space charge effects at the low-energy central region for the injected beam. The system consists of two cascaded cyclotrons, and an axial injection line from an external microwave source. >20 emA of H2+ ions, CW, are seen with an available source. The injector cyclotron will bring beam to 50 MeV/a, and a short transfer line will take beam to the main ~15 meter diameter Ring cyclotron. This will consist of 8 sectors of superconducting magnets, with maximum field of 6 T. Isochronicity is maintained by field design and suitable trim coils. RF cavities between the magnet sectors accelerate the beam. An extraction channel of the lower-rigidity protons exiting the stripper foil is plotted through the highly-variable magnetic field, and exits cleanly from the machine. A large water-cooled graphite target provides the source of neutrinos from pi-mu decays. For DAEdALUS applications, each of the three machines will be run at ~20% duty factor, so events in the detector can be tagged unambiguously with a source. Timing is arbitrary, beam on time for each machine can range from seconds to days. Average power from each source still exceeds 1 MW, providing adequate neutrino flux at the detector for very fine sensitivity to the measurements desired. It should be noted that the original, and even revolutionary design of these accelerators can facilitate many other "ADS" (Accelerator-Driven Systems) applications, such as driving subcritical reactors, waste transmutation, etc.

Summary

The DAEdALUS experiment studies CP violation in the neutrino sector, and other neutrino properties using 800 MeV, megawatt beams of protons as sources of Decay-At-Rest neutrinos that are devoid of electron antineutrinos, and looking for appearance of these neutrinos in large detectors with high proton content (water Cherenkov or liquid scintillator). Basis for experiment is a new technology for superconducting cyclotrons accelerating H2+ ions. Using molecular hydrogen, and stripping extraction, avoids several of the problems of high-power beams in cyclotrons. The cyclotrons will be described.

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