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The Low-Energy Neutrino Factory

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Abstract

The low-energy neutrino factory uses muons with energies of around 5 GeV and a corresponding single baseline of the order of 1000 km. It has been found that when combined with a magnetised 20 kton totally active scintillating detector or a magnetised 100 kton liquid argon detector, this setup has sensitivity to the oscillation parameters θ_{13}, δ and the mass hierarchy comparable to that of the high-energy neutrino factory if $\sin^2 2\theta_{13} \gtrsim 10^{-3}$. Additionally, the low-energy neutrino factory has sensitivity to the non-standard interaction parameters $\varepsilon_{e\mu}$ and $\varepsilon_{e\tau}$ down to $\sim 10^{-2}$.

The low-energy neutrino factory was first proposed in Refs. [1, 2] where it was realised that for an intermediate baseline of around 1000 km, the oscillation spectrum at energies below $\sim$ 5 GeV may be rich enough to enable precise measurements of the unknown oscillation parameters to be measured if θ_{13} is large. Since then, developments to the accelerator and detector designs have enabled the experimental simulations to be refined and detailed optimisation studies to be performed [3]. The key finding was that given sufficiently high statistics, an optimised low-energy neutrino factory can have excellent sensitivity to the standard oscillation parameters, competitive with the high-energy neutrino factory [4] for $\sin^2 2\theta_{13} \gtrsim 10^{-3}$. In particular, the sensitivity to CP violation is better than that of the high-energy neutrino factory.

The possibility of observing the platinum channels ($\nu_\mu \to \nu_e$ and $\bar{\nu}_\mu \to \bar{\nu}_e$) in addition to the golden channels ($\nu_e \to \nu_\mu$ and $\bar{\nu}_e \to \bar{\nu}_\mu$) was considered, as there are indications that the detector technologies considered may be able to detect and distinguish between e^- and e^+. The complementarity between the platinum and golden channels can be of great benefit if statistics are limited, improving the sensitivity to the oscillation parameters. However, for the anticipated flux of 1.4×10^{21} muon decays per year polarity, running for 5 years per polarity, there is little to be gained by including the platinum channel once realistic efficiencies and backgrounds levels are included. It is far more beneficial to concentrate on increasing the statistics of the golden channel instead.

However, for non-standard interaction parameters, the sensitivity is limited by the degeneracies between the oscillation parameters and non-standard parameters [5]. In this case, the addition of the platinum channels is vital in order to maximise the sensitivity of the setup which then has sensitivity to the parameters $\varepsilon_{e\mu}$ and $\varepsilon_{e\tau}$ down to $\sim 10^{-2}$, roughly an order of magnitude better than current bounds [6].

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