The Neutrino Factory

K. Long on behalf of the IDS-NF collaboration

The phenomenon of neutrino oscillations constitutes the first evidence of physics beyond the Standard Model (SM). The tiny neutrino mass and large neutrino-mixing angles, so different from those of the quarks, may be related to physics at energy scales beyond the reach of colliding-beam facilities. Detailed, precise measurements of the properties of the neutrino provide a unique window through which it may be possible to elucidate the physics of flavour. The study of neutrino oscillations, therefore, is as fundamental as, and is complementary to, the high-energy collider programme.

The determination of θ_{13} [1–4] combined with the outcomes of various design studies [5–7] and the maturity of the R&D programmes (EMMA [8], MERIT [9] and MICE [10]) makes it possible to articulate a powerful, incremental programme. In the first stage, the combination of a long-baseline, wide-band-beam experiment such as LBNE [11] and an intermediate baseline, narrow-band-beam experiment such as T2HK [12] would allow the neutrino mass hierarchy to be determined and searches for leptonic CP-invariance violation of limited sensitivity to be carried out. To take the study of neutrino oscillations forward requires a novel facility capable of delivering intense beams of high-energy electron-neutrinos. The Neutrino Factory, in which intense, high-energy electron- and muon-neutrino beams are created from the decay of muons confined within a storage ring is the only proposed facility capable of delivering the requisite beams.

The International Design Study for the Neutrino Factory (the IDS-NF) baseline for the accelerator facility shown in the left panel of figure 1 provides 10^{21} decays per year from 10 GeV stored muons [7]. The baseline neutrino detector is the Magnetised Iron Neutrino Detector, a 100 kT sampling calorimeter optimised for the Neutrino Factory beam [13]. The precision which can be obtained on the CP phase (δ) is shown in the right panel of figure 1. With 10 years of running, the baseline facility is able to deliver a precision on δ approaching that with which the complex phase of the quark-mixing matrix is known [14]. The figure also indicates the precision that can be obtained if the product of neutrino flux and detector mass is reduced by factors of 10 and 40. The precision of LBNE, LBNO [15] and T2HK are also shown. The performance of the "de-rated" Neutrino Factory alternatives is comparable (or even superior) to the super-beam options and each has an incremental development path by which the full IDS-NF baseline performance can be recovered.

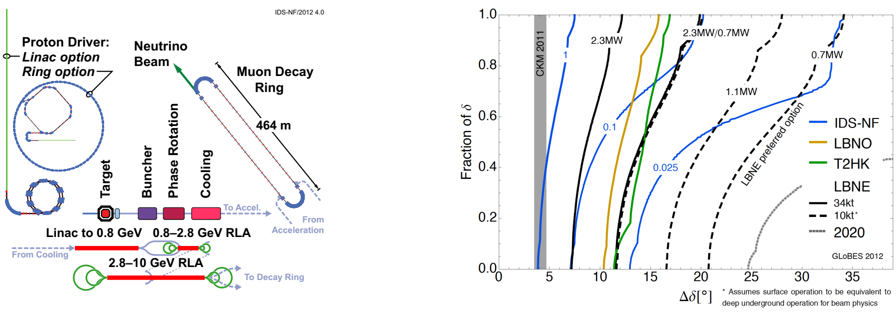

Figure 1: Left panel: schematic of the IDS-NF baseline accelerator facility. Right panel: precision on δ that can be achieved at the IDS-NF baseline Neutrino Factory (solid blue line labelled "1") [14]. The solid blue lines labelled 0.1 and 0.025 indicate the precision which can be reached at a Neutrino Factory in which the product of the neutrino flux with detector mass is reduced by a factor of 10 and 40 respectively. The precision of LBNE, LBNO and T2HK are also shown. The precision with which the phase in the quark mixing matrix is known (CKM 2011) is also indicated.

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