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PROJECT FINAL REPORT

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4.1 Final publishable summary report

Executive Summary

One of the most important discoveries in Particle Physics in recent years is the observation that the neutrino changes type (or flavour) as it travels through space, a phenomenon referred to as neutrino oscillations. This means that neutrinos have a tiny, but non-zero mass and is the first indication that the so-called Standard Model of particle physics is incomplete. The implications are far reaching, e.g neutrino interactions may be responsible for the removal of all the anti-matter created in the Big Bang from the early Universe and the neutrino may have played a crucial role in the birth of the Universe itself.

Knowledge of the contribution of neutrinos in these areas needs precise measurements of the parameters governing neutrino oscillations. This will require a new high intensity beam-based neutrino oscillation facility in which neutrino beams are generated using new and highly challenging concepts. This Design Study has reviewed all three currently accepted methods of realizing this facility:

1) A neutrino Super-Beam, in which the neutrinos are made by firing a high power proton beam into a target to make pions, focusing the pions in the direction of a far detector and measuring the neutrinos from the pion decay. EUROnu has studied a CERN to Fréjus Laboratory Super-Beam, with a baseline of 130 km. The protons would be accelerated by the Superconducting Proton Linac (SPL) at CERN and the neutrinos observed in the 500 kt MEMPHYS water Cherenkov detector at Fréjus.
2) A Neutrino Factory, in which pions are created as for the Super-Beam, but then captured and allowed to decay to muons. The muons are accelerated and injected into a storage ring and the neutrino beams are produced from the muon decay. Both signs of muons are used to produce pure beams of neutrinos. The far detector in this case would be a 100 kt Magnetised Iron Neutrino Detector (MIND) at a baseline of about 2000 km.
3) A Beta Beam, which is similar to a Neutrino Factory, except that the stored beams are beta-emitting irons. These produce pure beams of electron neutrinos and anti-neutrinos. The far detector would again be MEMPHYS in the Fréjus Laboratory.

EUROnu has undertaken detailed studies of the three facilities, resulting in conceptual designs for each. The performance of the facilities, in terms of the properties of the beam produced, has then been determined. In addition, the performance of the near and far neutrino beam detectors been assessed. This information has then been combined to determine the overall physics reach in terms of the expected measurement errors for the unknown neutrino oscillation parameters, in particular the CP-phase. This has clearly demonstrated that the Neutrino Factory has the best physics reach and is still better when compared with the combination of the Super-Beam and Beta Beam.

EUROnu has also done a cost estimate for each facility, with a particular focus on the accuracy of the relative costs. This has shown that although the Neutrino Factory would be more expensive than building both the Super-Beam and the Beta Beam, the improvement in physics reach more than compensates for this. As a result, EUROnu strongly recommends the construction of the Neutrino Factory and has proposed a roadmap for doing this, using a number of steps. This recommendation has been passed on to the appropriate body for Particle Physics in Europe, the CERN Council, via an input to the CERN Strategy Update.

Further, EUROnu hopes to continue, in order to bring this recommendation about, via an appropriate programme in Horizon 2020.