Proposal for a neutrino Super Beam using the ESS 5 MW, 2.5 GeV linac as proton driver

We propose to make a feasibility study of a Super Beam (SB) neutrino oscillation experiment to measure primarily neutrino CP violation. Our study succeeds the FP7 Design Study EUROnu [1,2] of, in particular, the CERN based Super Proton Linac (SPL, 4.5 GeV protons, 4 MW) [3] SB. We propose to study a SB based on the linac of the European Spallation Source (ESS, 2.5 GeV protons, 5 MW) [6] at Lund with a megaton Water Cherenkov MEMPHYS [4,5] detector located in a ca 1100 m deep mine at a distance of somewhere between 200 to 550 km near the second neutrino oscillation maximum. The choice of the second maximum, rather than the first, is motivated by the recent measurements by reactor experiments of a θ_{13} value that is large, implying that a higher precision can be obtained at the second maximum. The proposal is to use the ESS proton driver for neutrino SB production [7] simultaneously with spallation neutron production. In a second stage, the Neutrino Factory (NF) [8], considered as the ultimate neutrino facility, could make use of the same proton driver. In order to reduce the length of the ESS linac pulses, an H^- injector and an accumulator ring are needed. We propose to study in detail the modifications of the ESS linac required to allow simultaneous acceleration of H^+ and H^- ions at an average power of 5+5 MW. The accumulator ring will be studied to design a device satisfying the requirements for both neutron and neutrino measurements. We propose to perform R&D also on the proton target, the hadron collector and the collector pulse generator for the ESS SB. Using simulations the optimal distance of the detector from the neutrino source will be evaluated. A few deep mines located within the range 200-550 km from Lund km have been identified and the geology of the mine among these that is at a distance closest to the optimum will then be investigated in detail to find the most favorable underground location and hall design for the MEMPHYS detector.
In the EUROnu project the price of a CERN-SPL based SB was estimated to be of the order of 1 BEUR (not including the detector). Using the ESS linac to produce a SB will imply that about 550 MEUR can be saved, compared to the cost of the SPL-SB project. Furthermore, if the accumulator is built in common with the ESS neutron community, a sharing of the cost could further reduce the price for the SB. The total cost of the ESS SB project will thus only be of the order of 1/3 of the investment cost for a SB project for which all components have to be built from scratch. Moreover, in case a NF is built subsequently to measure the neutrino oscillation parameters with yet higher accuracy and to investigate other neutrino physics subjects that may appear as a result of the SB project, both the modified linac and the accumulator can be used for the NF, provided that the design of the accumulator will be made such that is compatible with the NF beam chain.
ESS is an approved project and the construction of the facility is starting in 2013. First beam is expected before the end of this decade and the facility will be fully operational by 2023. Under the assumption that the ESS SB is approved towards the end of our study, which is foreseen to take 3.5 years, it is expected that neutrino physics results will start being produced before 2030.

Laboratories participating in the ESS Super Beam study: Strasbourg, Uppsala and Madrid Universities, STFC-RAL, ESS and CERN.

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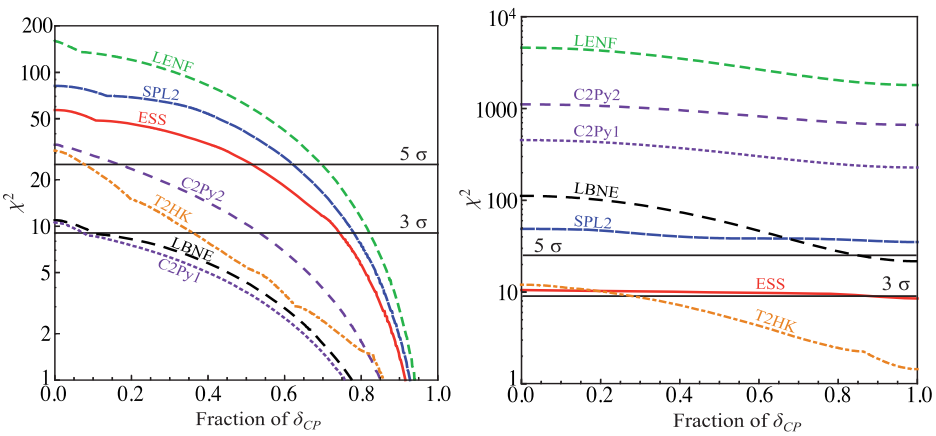

Left: CP violation performance vs the fraction of δ_{CP} parameter. Right: Mass hierarchy performance vs the fraction of δ_{CP} parameter.
LENF, C2Py1, C2Py2, SPL2, ESS, T2HK and LBNE stand for Low Energy Neutrino Factory (2000 km, 100 kt MIND), CERN to Pyhasalmi (SPS, 2300 km, 20 kt LAr), CERN to Pyhasalmi (SPS, 2300 km, 100 kt LAr), SPL to Canfranc (650 km, 500 kt WC), ESS Super Beam (400 km, 500 kt WC), T2HK Japan project and LBNE USA long baseline, respectively.

References

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