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Standard Model tests with T2K and other neutrino superbeams and by means of liquid-argon detectors

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Summary. — Present and future accelerator neutrino beams, designed to study mixing and leptonic CP-violation, will also offer the opportunity to test Standard Model. We investigated the potentialities of superbeams, in particular T2K. The ideal detector would be a liquid-argon one and our analysis can be applied to future experiments, like the proposal for neutrino experiments with the CERN-PS beam.

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The low-energy and high-intensity accelerator neutrino beams that are becoming available can be used to extract Standard Model parameters in a region far from the one of high-energy colliders, offering also a stringent test of theory consistency. In the last years we investigated this possibility for experiments which are designed to solve some of neutrino physics problems but use, at the same time, ideal beams for our purposes. We focused our attention on superbeams and in particular on T2K [1]. In this long baseline experiment a beam produced by the JPARC protosynchrotron is sent to SuperKamiokande detector. After a 1st run (about 3.23×10^{19} p.o.t.), a 2nd run started in November 2010 with about 10 times more statistics. The plan was to reach the designed luminosity by 2014/15, but the recent earthquake made the near-term data taking uncertain. Nevertheless T2K is committed to bring the experiment back as soon as possible.

At the relatively low energies of superbeams (and partially of β beams), the quasi-elastic neutrino-nucleon interaction is the ideal channel to investigate. For $E \simeq 1\,\text{GeV}$ it is still sizeable (about 50% of the total cross section) and it does not suffer from parton distributions uncertainty. The main problem is to disentangle the dependence on Weinberg angle from the one on hadronic form factors. Having in principle 6 cross sections at disposal and fixing the electric form factors, one has to fit six parameters: the

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TABLE I. – *Example of simultaneous fit of Weinberg angle and* 2 *form factors, obtained using as input value* $\sin^2\theta_W = 0.23120$ *and for a* 10 kton LAr *detector* [3].

Fitted parameters	Results of the fit
$\sin^2\theta_W, G_M^P, G_M^S$	$\sin^2\theta_W = 0.23116 \pm 0.00040$
$\sin^2\theta_W, G_M^N, G_M^S$	$\sin^2\theta_W = 0.23085 \pm 0.00040$
$\sin^2\theta_W, G_M^P, G_M^N$	$\sin^2\theta_W = 0.23145 \pm 0.00178$

electroweak mixing angle and 5 form factors, that is the proton and neutron magnetic (G_M^P and G_M^N), strange magnetic (G_M^S), axial and strange axial (G_A and G_A^S) form factors. Our analytical and numerical studies with simulated data [2], proved the possibility to extract from real future data a fit of Weinberg angle and a suitable subset of form factors.

The good performance of neutral current events detection and reconstruction in a narrow energy region around 1 GeV required by the analysis imposes a low-momentum threshold and, therefore, the kinematic cuts are too severe for Cherenkov detectors. A Liquid-Argon Time Projection Chamber (LAr TPC), like ICARUS, would be instead the ideal detector and we showed that, for instance, in the T2K case one can perform competitive low-energy measurements of the Weinberg angle already with a near detector mass around or below the kton. The detection of neutral currents on neutrons is under further investigation [3], but to be conservative we assumed to detect only the neutral current events on protons, reducing the experimental observables from 6 to 4. To estimate the accuracy in Weinberg angle determinations, we generated a fictitious set of data with spectrum distributions corresponding to the experiments under investigation and used them to perform a fit of the angle and the form factors. In T2K anaysis we considered a LAr TPC as near detector 2° off axis on the beam line, to get a narrow spectrum around a value between 800 and 900 MeV. The results of the satisfactory fit of the angle and 2 between the nucleon and the strange magnetic form factors (f.f.) are reported in table I.

The global fit of $\sin^2\theta_W$ and the 3 magnetic f.f. is still well compatible with the input value and with an uncertainty below 1%. For a report of the results for T2K and also for a generic neutrino beam we refer the reader to [3]. The indetermination on the functional forms adopted for the f.f. is also under control and our conservative estimate of the total uncertainty for a simultaneous variation of all the f.f. is of the order of 0.6%.

We also perfomed a "blind analysis", reproducing the form factors by means of a neural network, with no *a priori* assumption on their functional form. The results are encouraging for a single magnetic f.f. and even partially when 2 f.f. are reproduced by the neural network. The extention to 3 f.f. would require the adoption of more complicated algorithms, that is postponed to the analysis of future real experimental data.

Our approach can be extended also to the beams used for other experiments. For instance, the proposal for an experiment using the CERN-PS beam in association with two LAr-TPC detectors [4] in the near and far positions would probably offer interesting possibilities, that are under our investigation.

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