NESSiE

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1 Introduction

Several experimental results provide indications for the existence of additional neutrinos beyond the three known states which couple via the electro-weak force (sterile neutrinos): a deficit of $\bar{\nu}_e$ from nuclear reactors measured at distances of $\mathcal{O}$(10-100 m) from the core [2], a deficit of ν_e from MCi ^{51}Cr and ^{37}Ar calibration sources at $\mathcal{O}$(m) distances (SAGE, GALLEX [3]), an excess of ν_e and $\bar{\nu}_e$ in artificial ν_μ and $\bar{\nu}_\mu$ at distances of $\mathcal{O}$(km) (LSND [4], MiniBooNE [5]). Furthermore, current cosmological fits based on CMB data show a moderate preference for extra neutrino states [6]. All these inputs triggered the community towards an experimental effort with the goal of, either disproving with large significance the existing indications, or leading to a ground-breaking discovery.

The ICARUS-NESSiE experiment (SPSC–P–347 [1]) is a joint proposal for the search for sterile neutrinos with a short-baseline neutrino beam based at CERN. The experiment concepts consists in exposing two almost identical detectors at two distances (640 and 1600 m) from a $\nu_\mu/\bar{\nu}_\mu$ neutrino source with a peak energy of about 2 GeV. The existence of extra neutrinos with a squared mass difference with respect to the three known states of $\mathcal{O}(\mathrm{eV}^2)$ is expected to manifest itself both with an energy-dependent disappearance of the ν_μ and/or appearance of ν_e above the instrinsic beam contamination. Each setup is composed of a liquid-Argon Time Projection Chamber (LAr-TPC) which is optimal for the reconstruction of the electronic component followed by a magnetic spectrometer for a complete reconstruction of muonic final states (Fig.1). A substantial part of the far-site LAr-TPC will consist of the ICARUS detector which will be transported from the LNGS underground laboratories. The muon spectrometers at the far and near sites will be build by the NESSiE (Neutrino Experiment with SpectrometerS in Europe) Collaboration which is currently composed by groups from Bari, Bologna, Lecce, LNF, Roma-1 and Padova. The final decision on the construction of the beamline in the North-Area (CENF, CErn Neutrino Facility) which would give the green-light for the startup of the program is expected by CERN before Summer 2013.

In order to measure with high precision the charge and the momentum of muons produced by neutrino interactions in the LAr target and those interacting in the spectrometer itself, two complementary spectrometers will be installed (Fig.1): an air-core magnet (ACM), followed by an iron-core magnet (ICM). The ICM is dedicated to the precise reconstruction of high-energy muons (up to 30 GeV) and to reach few % precision, through range measurement, on the momentum of muons with energy lower than 3 GeV while the ACM covers the low momentum region where it ensures high momentum resolution and charge discrimination (allowing to separetely study the ν

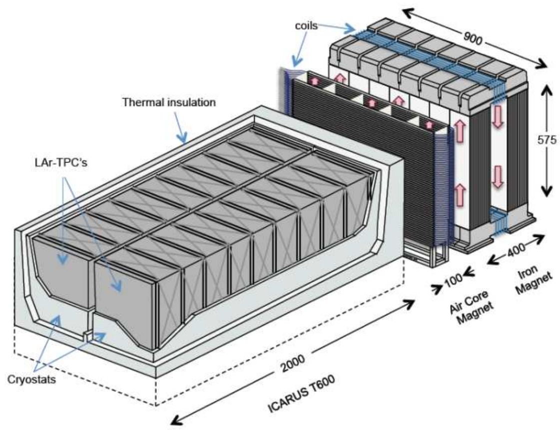

Figure 1: Sketch of the ICARUS-NESSiE experiment far location at 1600 m from the proton target.

and $\bar{\nu}$ components).

2 Activities of the LNF group

2.1 Iron-core magnets

The NESSiE collaboration can profit of the experience acquired with the OPERA experiment for the design and realization of the ICM. The two OPERA spectrometers are made of two arms, each composed by 12, 5 cm thick, iron slab layers alternated to 11 layers instrumented with Resistive Plate Chambers; two iron yokes, on top and on bottom, close the magnetic flux, providing a constant magnetic field of 1.5 T with opposite directions inside the two arms. The deflection of muons crossing the spectrometers is measured by means of drift tubes stations (two before, two in the middle and two after each magnet), reaching precisions of about 20% on momenta lower than 30 GeV and a charge confusion of 0.3% in the same energy range.

About 40 iron slabs of 5 cm thickness are needed to stop muons up to 3 GeV energy, but given the height of the ICARUS experiment, almost all of the iron needed for the far and the near site can be recovered from OPERA, cutting the present slabs and installing two iron core magnets, each with 24 magnetized slab layers, in order to recover also the yokes. The about 1000 resistive plate chambers installed in the OPERA spectrometers, for the same reasons, are sufficient to instrument both the near and far site spectrometers. The RPC gas system, two power supplies and the refrigerating system for the magnet coils of the OPERA spectrometers can also be recovered.

The LNF OPERA group, in sinergy with the SPAS service, is actively involved in the proposal since the beginning of the project and is playing a crucial role thanks to the recognised expertise gained during the design and construction of the OPERA ICM spectrometers. The schedule of the project in its present form is naturally connected with the dismantling of the OPERA detector, activity in which the group is naturally committed (definition of the schedule, costing, optimization).

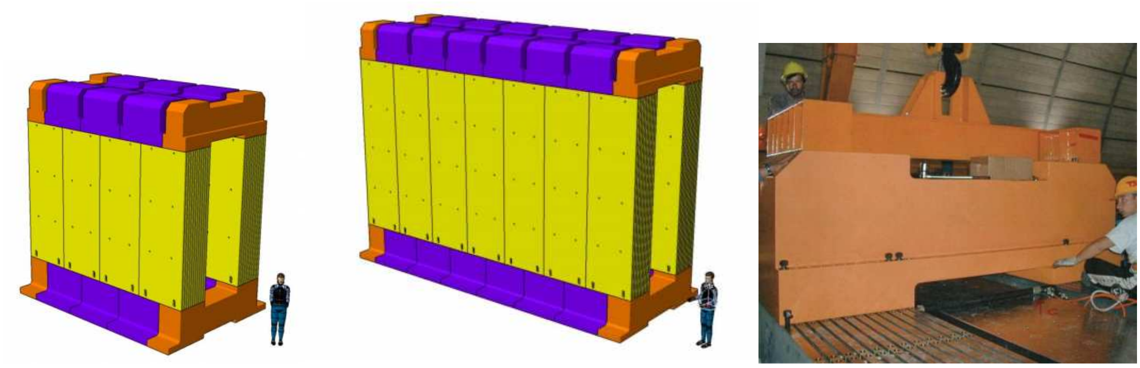

Figure 2: Mechanical model of the near ICM (left), far ICM (center) from the SPAS and a phase of the installation of the OPERA top yokes for the OPERA spectrometers in 2004 (right).

2.2 Simulation and optimization of the neutrino flux

Furthermore the Frascati group, in cooperation with CERN, is active in the optimization of the horn optics to maximize the neutrino flux produced by the 100-GeV SPS protons. The goal is to produce a high-intensity ν_μ flux with a low ν_e contamination and with a spectrum well matched to the region of interest in terms of the sterile oscillation phenomenology (and suppressed high-energy tails). In particular a systematic search based on a fine sampling of the space of possible configurations of a horn-reflector system has been conducted with a GEANT4-based simulation. Promising results in terms of enhancement of flux with a reduced horn current have been obtained recently. An example of a candidate configuration is shown in Fig. 3.

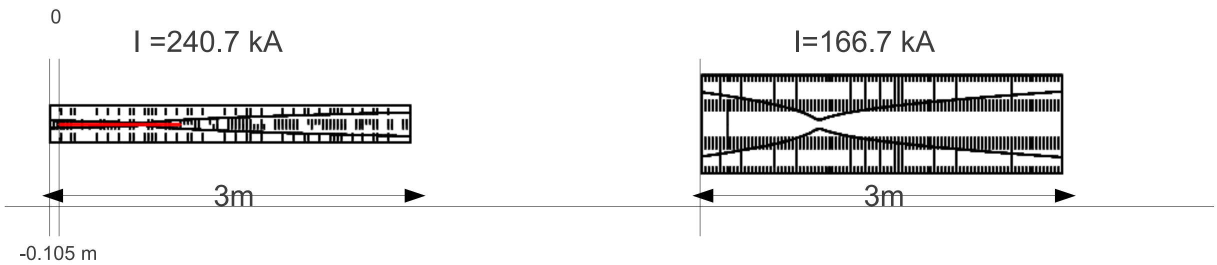

Figure 3: Sketch of an optimized bi-parabolic horn-reflector system for the neutrino flux for the ICARUS-NESSiE experiment.

3 Public presentations by group members

We have presented the status and perspectives of the ICARUS-NESSiE experiment at the following workshops/conferences:

- A. Longhin: "Search for sterile neutrinos at a new SBL neutrino beam at CERN: the ICARUS-NESSiE experiment", at the "GDR neutrino" meeting [7] in Caen (FR), 31 October 2012.

- N. Mauri: "Search for sterile neutrinos at a new SBL CERN beam" at the "24^{th} Rencontres de Blois (Particle Physics and Cosmology)" [8] (FR), in May 27-June 1, 2012.

3.1 More studies on future scenarios: leptonic CP violation

Following the confirmation of a large θ_{13} angle by the Daya-Bay and RENO experiments in March 2012 we have also engaged in a phenomenological study involving the possibility to measure the δ_{CP} phase with a future long-baseline neutrino beam based in Europe with a particular focus on possible opportunities for the CERN-to-Gran Sasso baseline. The results have been presented at the:

- "nuTURN" workshop, LNGS (IT), 20/09/2012, "Study of possible opportunities for leptonic CP violation and neutrino mass hierarchy at LNGS" (A. Longhin).
- SIF Congress, Napoli (IT), 20/09/2012, "Opportunitá per la violazione di CP leptonica e la gerarchia di massa ai laboratori del Gran Sasso nell'era di θ_{13} $\mathcal{O}(10^{-1}$" (A. Longhin).

A corresponding paper (whose content is also available on the arXiv [9] is in the process of publication in the EPJ-C journal.

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