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NESSiE: An experimental search for sterile neutrinos with the CERN-SPS beam

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Summary. — Anomalies observed in neutrino oscillation experiments show a tension with the standard three-flavor neutrino framework and seem to require at least an additional sterile neutrino with a mass at the eV scale. NESSiE (Neutrino Experiment with SpectrometerS in Europe) is an experiment at a new CERN Short-Baseline neutrino beam proposed to definitely address the sterile neutrino issue. The experiment is composed by two magnetic spectrometers at different distances from the proton target. Their design allows to measure the charge and momentum of the muons in a wide energy range, from few hundred MeV, using a magnetic field in air, up to several GeV measuring the bending and range of the muon in a large iron dipolar magnet. The spectrometers will complement large LAr detectors used as a target. The time scale foresees to start taking data by 2016.

PACS `14.60.St` – Non-standard-model neutrinos, right-handed neutrinos, etc..
PACS `29.40.-n` – Radiation detectors.

1. – Introduction

Recent results on neutrino oscillations have established a scenario consistent with the mixing of three physical neutrinos ν_e, ν_μ and ν_τ with mass eigenstates ν_1, ν_2 and ν_3. However, there are anomalies in the region of $\Delta m^2 \sim 1\,\text{eV}^2$ that may hint at unaccounted oscillations involving sterile neutrinos [1].

The direct, unambiguous measurement of an oscillation pattern requires necessarily the (simultaneous) observation at several different distances in order to separately identify the values of Δm^2 and of $\sin^2(2\theta)$. A new Short-Baseline neutrino beam facility has been proposed in the CERN North-Area (fig. 1) for this purpose [2]. The proton beam would be extracted from the CERN-SPS at an energy of 100 GeV to provide an L/E oscillation path length which ensures appropriate matching to the Δm^2 window for the expected anomalies.

The experimental program is based on two LAr-TPCs followed by magnetized spectrometers, observing the electron and muon neutrino events at the Far and Near positions

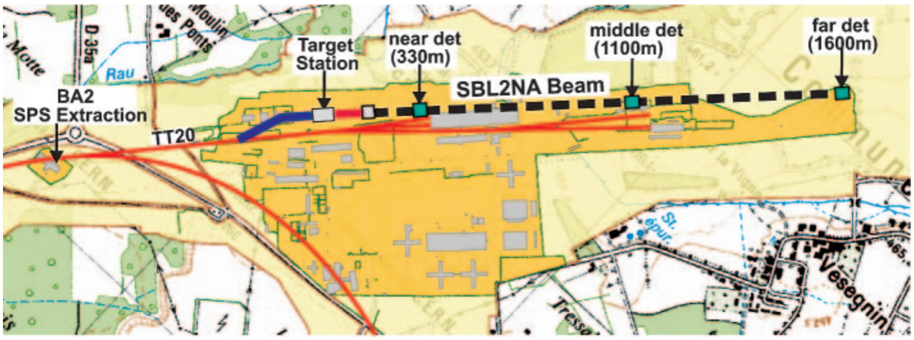

Fig. 1. – The proposed SPS North Area neutrino beam layout. From I. Efthymiopoulos/CERN.

1600 and 300 m from the proton target, respectively. Important new features, which would allow a definitive clarification of existing "anomalies" are: i) "imaging" detector capable to identify unambiguously all reaction channels with a LAr-TPC (ICARUS); ii) magnetic spectrometers to determine muon charge and momentum in a wide momentum range (NESSiE); iii) interchangeable ν and anti-ν focused beams; iv) very high rates ($> 10^6$ ν_μ, $\sim 10^4$ ν_e) in order to record relevant effects at the % level; v) both initial ν_e and ν_μ components clearly identified.

The ICARUS project will exploit the ICARUS T600, moved from Gran Sasso to the CERN Far position. An additional 1/4 of the T600 detector (T150) will be constructed and located at the Near position [3,4]. The NESSiE project is composed by two spectrometers placed downstream of the two LAr-TPC detectors [5].

2. – The NESSiE Detector

The NESSiE Near and Far Spectrometers will exploit a classical dipole magnetic field (1.5 T) with iron slabs (21 planes/arm) like the OPERA Magnet design [6], and a new concept Air-Core Magnet (0.15 T), to perform charge identification and muon momentum measurements from low energy (< 1 GeV) in a wide energy range over a large transverse area ($> 50\,\mathrm{m}^2$). A schematic of NESSiE far detector is shown in fig. 2 (left).

The spectrometers will be instrumented with large area detectors for precision tracking of muon paths.

A resolution of $\sim$ few millimiters is needed for the identification of low momentum muons crossing the magnetic field in air. Several detector options are under study.

Standard bakelite RPC are placed within the iron slabs of the spectrometers. Double coordinate read-out is obtained by copper strip panels. The strip pitch will be 2 cm. RPC's are used in streamer mode operation with a digital read-out for track reconstruction.

Low-momentum muons, which would not cross a sufficient number of iron-layers to determine their curvature, are measured by the Air-Core Magnet. Instead muons with higher momenta are well measured by crossing several iron-layers. Figure 2 (right) shows the performances in terms of charge identification with Iron and Air-Core magnets.

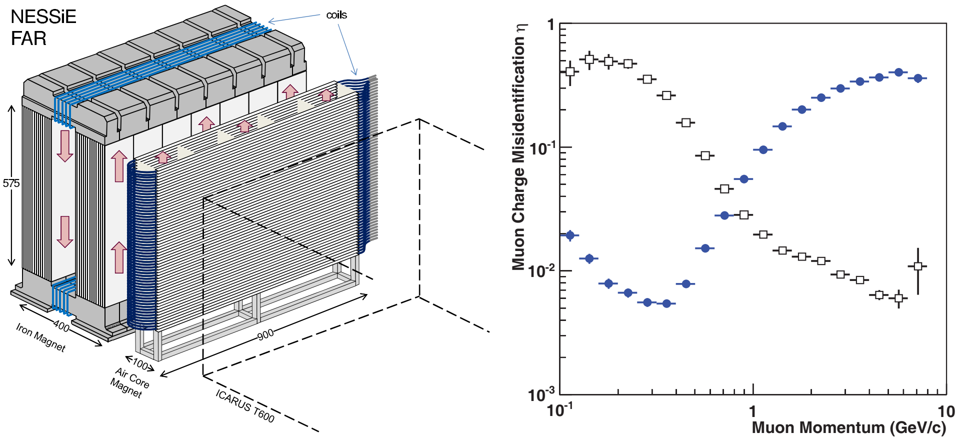

Fig. 2. – Left: Schematic view of NESSiE far detector. Right: The charge mis-identification percentage including all the selection, efficiency and reconstruction procedures by the NESSiE system. Circles (squares) correspond to the measure performed by the air-core (iron) magnet.

3. – Expected results

For 1 year of operation, either with negative or positive polarity beam, table I reports the expected interaction rates in the LAr-TPCs at the Near (effective 119 t) and Far locations (effective 476 t), and the expected rates of fully reconstructed events in the NESSiE spectrometers at the Near (effective 241 t) and Far (effective 661 t) locations, with and without LAr contribution.

The ν_μ disappearance signal is well studied by the NESSiE spectrometers, with large statistics and disentangling ν_μ from $\overline{\nu}_\mu$ interplay. As an example, fig. 3 shows the sensitivity plot (at 90% CL) for two years negative-focusing plus one year positive-focusing. A large extension of the present limits for ν_μ by CDHS [7] and the recent SciBooNE+MiniBooNE [8] will be achievable in $\sin^2(2\theta)$, Δm^2.

Table I. – *The expected rates of interaction (LAr) and reconstructed (NESSiE) events 1 year of operation* [1]. *Values for Δm^2 around $2\,\mathrm{eV}^2$ are reported as example (Test Point).*

	Near (Negative foc.)	Near (Positive foc.)	Far (Negative foc.)	Far (Positive foc.)
$\nu_e + \overline{\nu}_e$ (LAr)	35 K	54 K	4.2 K	6.4 K
$\nu_\mu + \overline{\nu}_\mu$ (LAr)	2000 K	5200 K	270 K	670 K
Appearance Test Point	590	1900	360	910
ν_μ CC (NESSiE+LAr)	230 K	1200 K	21 K	110 K
ν_μ CC (NESSiE alone)	1150 K	3600 K	94 K	280 K
$\overline{\nu}_\mu$ CC (NESSiE+LAr)	370 K	56 K	33 K	6.9 K
$\overline{\nu}_\mu$ CC (NESSiE alone)	1100 K	300 K	89 K	22 K
Disappearance Test Point	1800	4700	1700	5000

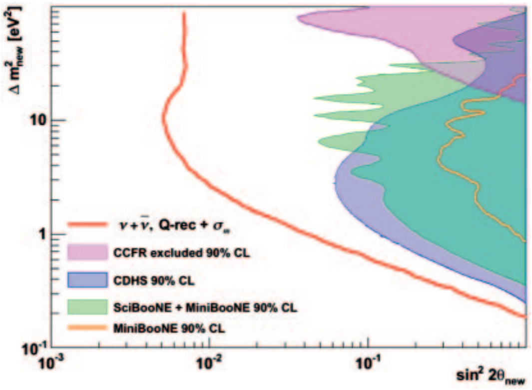

Fig. 3. – Sensitivity plot (at 90% CL) considering 3 years of the CERN-SPS beam (2 years in antineutrino and 1 year in neutrino mode) from CC events fully reconstructed in NESSiE+LAr. Red line: ν_μ exclusion limit. The three filled areas correspond to the present exclusion limits on the ν_μ from CCFR [9], CDHS [7] and SciBooNE+MiniBooNE [8] experiments (at 90% CL). Orange line: recent exclusion limits on ν_μ from MiniBooNE alone measurement [10].

4. – Conclusions

The NESSiE spectrometers are capable of precise momentum measurements and would complement LAr detectors by allowing the measurements of ν_μ disappearance in a wide energy range. This is a key information for rejecting/observing the existing anomalies over the whole parameter space considered for sterile neutrino oscillations. The measurements of the neutrino flux at the Near detector in the full muon momentum range is relevant to keep the systematic errors at the lowest possible values.

The measurement of the muon charge would enable to separate ν_μ from anti-ν_μ in the anti-neutrino beam (where the ν_μ contamination is large). This is a critical issue to fully exploit the experimental capability of observing any difference between $\nu_\mu \rightarrow \nu_e$ and anti-ν_μ $\rightarrow$ anti-ν_e (CP violation signature). Muon charge identification will also reduce the data taking period by collecting both ν_μ and anti-ν_μ.

REFERENCES

[1] Abazajian K. N. *et al.*, arXiv:1204.5379v1.
[2] Antonello M. *et al.*, SPSC-P-347 (2012), CERN-SPSC-2012-010, arXiv:1203.3432v1.
[3] Rubbia C. *et al.*, SPSC-P-345 (2011).
[4] Raselli G. L., *ICARUS T600: status and perspectives of liquid Argon technology for neutrino physics*, these Proceedings.
[5] Bernardini P. *et al.*, SPSC-P-343 (2011), arXiv:1111.2242v1.
[6] Acquafredda R. *et al.*, *JINST*, **4** (2009) P04018.
[7] Dydak F. *et al.*, *Phys. Lett. B*, **134** (1984) 281.
[8] Mahn K. B. M. *et al.*, *Phys. Rev. D*, **85** (2012) 032007; arXiv:1106.5685v2.
[9] Stockdale I. E. *et al.*, *Phys. Rev. Lett.*, **52** (1984) 1384.
[10] Mahn K. B. M. *et al.*, *Phys. Rev. Lett.*, **103** (2009) 061802; arXiv:1106.5685v2.