IL NUOVO CIMENTO Vol. 37 C, N. 3 Maggio-Giugno 2014
DOI 10.1393/ncc/i2014-11780-8

Colloquia: Pontecorvo100

Search for $\nu_\mu \to \nu_e$ oscillations with the OPERA experiment in the CNGS beam

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Summary. — A first result of the search for $\nu_\mu \to \nu_e$ oscillations in the OPERA experiment, located at the Gran Sasso Underground Laboratory, is presented. The experiment looked for the appearance of ν_e in the CNGS neutrino beam using the data collected in 2008 and 2009. Data are compatible with the non-oscillation hypothesis in the three-flavour mixing model. A further analysis of the same data constrains the non-standard oscillation parameters θ_{new} and Δm^2_{new}. For large Δm^2_{new} values ($> 0.1 eV^2$) , the OPERA 90% C.L. upper limit on $\sin^2(2\theta_{new})$ based on a Bayesian statistical method reaches the value $7.2 \cdot 10^{-3}$.

The OPERA experiment [1] is designed to perform an appearance search for the $\nu_\mu \to \nu_\tau$ oscillations [2] in the CNGS ν_μ beam. A charged-current (CC) ν_τ interaction in the lead-emulsion target can be identified by detecting the decay of the short-lived τ lepton through particle tracking in the high-resolution nuclear emulsions. The tracking capabilities of emulsions also allow to identify electrons produced in CC interactions of ν_e and therefore to search for ν_e appearance from $\nu_\mu \to \nu_e$ oscillations. OPERA has a good sensitivity $\Delta m^2 > 0.01 eV^2$ for long baseline experiment with energy range of ν_μ beam $< Ei >= 17$ GeV.

OPERA detector contains veto plane followed by two identical Super Modules (SM), each consisting of a target section and a magnetic muon spectrometer. The target sections are made of, in total, 150,000 emulsion/lead ECC modules (or "bricks") arranged in planes, interleaved by the scintillator "Target Tracker" (TT) planes. A target brick consists of 56 1-mm thick lead plates interleaved with 57 emulsion films. Detector OPERA capable measure tracks of particles with micrometric resolution.

The CNGS ν_μ beam contains a small contamination of $\bar{\nu}_\mu, \nu_e$ and $\bar{\nu}_e$. The energy spectra at the detector are obtained from a Monte Carlo simulation [3]. The analysis reported in this paper uses the data collected in 2008 and 2009, corresponding to 5.25×10^{19} pot. The identification of an electron is essentially based on the detection of the associated electromagnetic shower. 5255 candidate neutrino interactions were collected during the 2008 and 2009 runs, 2853 vertices were localized in the bricks, out of which 505 did not have a muon identified by the electronic detectors, i.e. were not classified as ν_μ CC interactions. Among those 505 events 19 ν_e candidates were found.

Two main sources of background are considered for the ν_e search: (a) $\pi 0$ misidentified as electron in neutrino interactions without a reconstructed muon (0.2 ± 0.2 events); (b) ν_τ CC interactions with the decay of the τ into an electron (0.3 ± 0.1). The total amount of the considered background for the ν_e CC interaction search is 0.4 ± 0.2 events.

We expect to observe $19.4 \pm 2.8(syst)\nu_e$ events from the beam contamination in the full energy range. Together with the backgrounds (a) and (b) we expect $19.8 \pm 2.8(syst)$ background ν_e events. This number is in agreement with the 19 observed candidate ν_e events and therefore the room for oscillations is reduced.

Using the following oscillation parameters [4] : $sin^2(2\theta_{13}) = 0.098, sin^2(2\theta_{23}) = 1, \Delta m^2_{32} = \Delta m^2_{31} = 2.32 \times 10^3 eV^2$, also assuming $\delta_{CP} = 0$ and neglecting matter effects, 1.4 oscillated ν_e CC events are expected to be detected in the whole energy range.

Energy cut at $E < 20$ GeV provides the best sensitivity to θ_{13}. Within this cut, 4.2 events from ν_e beam contamination and 0.4 events from the backgrounds (a) and (b) are expected. 4 events are observed. The number of observed events is compatible with the non-oscillation hypothesis and an upper limit $sin^2(2\theta_{13}) < 0.44$ is obtained at the 90% C.L.

Beyond the three-neutrino flavour oscillation model OPERA data also were used for setting an upper limit on non-standard $\nu_\mu \to \nu_e$ oscillations. The optimal cut on the reconstructed energy in terms of sensitivity is 30 GeV. 6 events below 30 GeV were observed (69% of the oscillation signal at large Δm^2_{new} remains in this region). Expected number of events from background is 9.4 ± 1.3 (syst). Three-flavour oscillation induced events have already included in this calculations. In this case, the oscillation probability does not contain the θ_{13} driven term. For large Δm^2_{new} values the OPERA 90% upper limit on $sin^2(2\theta_{13})$ reaches the value 7.2×10^{-3}, sensitivity corresponding to the pot used for this analysis is 10.4×10^{-3}. More full information is presented in [5].

First results of a search for $\nu_\mu \to \nu_e$ oscillations with the OPERA experiment at the Gran Sasso Underground Laboratory have been presented. The observation of 19 ν_e candidate events is compatible with the non-oscillation expectation of 19.8 ± 2.8 events. The current result on the search for the three-flavour neutrino oscillation yields an upper limit $sin^2(2\theta_{13}) < 0.44$ (90% C.L.). For non-standart oscillation for large Δm^2_{new} values, the 90% C.L. upper limit on $sin^2(2\theta_{new})$ reaches 7.2×10^3.

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We thank the Russian Foundation for Basic Research (grant no. 12-02-00213-a, no.12-02-31173 mol a), the Programs of Support of Leading Schools (grant no. 871.2012.2).

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