IL NUOVO CIMENTO Vol. 37 C, N. 3 Maggio-Giugno 2014
DOI 10.1393/ncc/i2014-11779-1

Colloquia: Pontecorvo100

Measurements of neutrino velocity with LVD

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Summary. — The CERN-SPS accelerator has been operated from May 10th to May 24th 2012, with a special bunched-beam structure allowed to measure the neutrino velocity on an event-by-event basis. LVD has detected 48 neutrino events, associated to the beam, with a high absolute time accuracy. These events allow to establish the following limit on the difference between the neutrino speed and the light velocity: $-3.8 \times 10^{-6} < (v - c)/c < 3.1 \times 10^{-6}$ (at 99% C.L.). This value is an order of magnitude lower than previous direct measurements.

The best limit on electron anti-neutrino velocity was obtained in 1987 year by the SN1987a explosion results [1]. This is $|v - c|/c < 2 \times 10^{-9}$ for $E \approx 10$ MeV . For the energies $E < 30$ GeV ratio is estimated as $|v - c|/c < 4 \times 10^{-5}$ [2]. The MINOS collaboration [3] has performed a neutrino time-of-flight measurement on a ≈ 735 km baseline and with a beam with average energy $< E >= 3$ GeV. The MINOS result is $(v - c)/c = (5.1 \pm 2.9) \times 10^{-5}$ at 68% C.L.

In this paper was suggested to measure neutrino velocity on LVD detector in the frames of CNGS project throught direct measurement of muons from muon neutrinos from CERN-SPS accelerator [4]. Average energy of neutrino flux is $< E >= 17$ GeV . At the period from May, 10 up to May, 24 of 2012 year special for neutrino velocity measurements another CNGS beam proton waveform was made. There is 4 batch mode, time between modes is 300 ns, time inside one mode between signals is 100 ns, width of signal is ~ 3 ns (Fig.1, grey lines). Total it was 1.89×10^{17} protons on target (p.o.t.).

Main goal of detector LVD is the search for neutrino bursts from collapsing stars. LVD can measure all types of neutrinos which interact with liquid scintillator $(C_nH_{2n}, n = 9.6)$ of detector or the iron of the detector structure. LVD consists of 3 towers, each tower contains 7 levels and 5 columns of portatanks. Portatank has 8 tanks each 1.5 m^3 viewed by 3 photomultiplier tubes (PMT). LVD standart electronics is described in [5], [6].

Absolute time accuracy was about one microsecond. Therefore for such precision task as neutrino velocity measurement special Super-Set system was made. Fast LEDs were put in the 58 tanks and these tanks were calibrated by them. Central PMT's in each counter are equipped with longer cables to determine the 3-fold coincidence. A new trigger has been implemented in parallel with the standard one and a new time interval counter has been provided. Also new High Precision Time Facility has been installed in the external buildings of Laboratory (precision 50 ps) [7], LVD clock connect to trigger of this system.

Distance between LVD Super-Set system wall and Beam Current Transformer Detector in CERN is 731291.87 ± 0.04 m [8].

Total 190 events were detected. 79 of them were registered in the Super-Set counters. Finally only 48 events come all cuts and they have been used for determing muon neutrino time of flight (Fig.1, black lines).

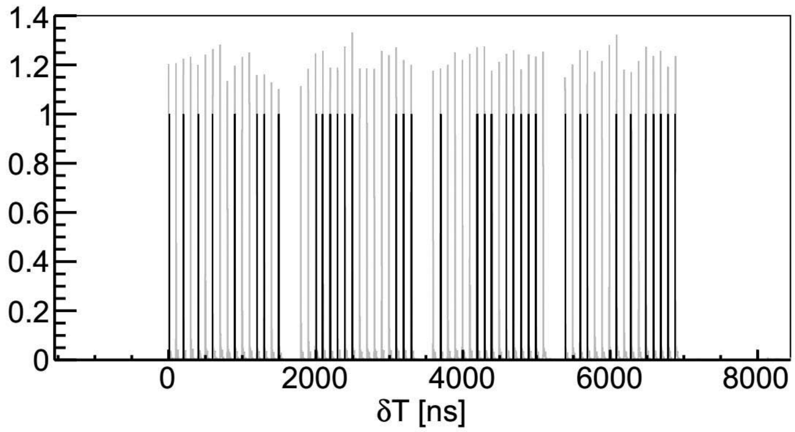

Fig. 1. – Comparison of the δT values of the 48 selected events (black lines) with the summed waveforms of proton extraction (grey lines). The origin of time for the waveforms is given by the maximum of the first bunch.

The deviation from the time expected from propagation at the speed of light has been found to be:

$$\delta t = 0.3 \pm 0.6_{stat.} \pm 3.2_{sys}$$

The corresponding limit on the speed of neutrino, at 99% C.L. is

$$-3.8 \times 10^{-6} < (v - c)/c < 3.1 \times 10^{-6} .$$

Limit on the neutrino mass is

$$m_{\nu_\mu} < 44 \text{ MeV}/c^2 \text{ (99\% C.L.)}.$$

Detailed information is presented in [9].

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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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