ICARUS-T600: results from CNGS and future perspectives

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Abstract. ICARUS-T600 is the first large mass Liquid Argon TPC ($\sim$ 600 t) exposed to CNGS ν beam and collecting cosmic rays since May 2010 at the INFN-LNGS underground laboratory. Results on 2010 and 2011 runs with CNGS neutrino beam are presented, together with the recent precision measurement of the neutrino velocity with the 2012 data. Perspectives on a sterile neutrino search at CERN with a double LAr-TPC detectors complemented by magnetic spectrometers are also presented in the framework of the recently comeback sterile neutrino puzzle.

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ICARUS-T600 DETECTOR: LAYOUT AND OPERATION

The ICARUS T600 detector [1] consists of a large cryostat split into two identical, adjacent and independet half-modules, with an overall mass of about 760 tons of ultra-pure liquid Argon. Each half-module houses two Time Projection Chambers (TPCs) separated by a common cathode. A uniform electric field E_D = 500 V/cm ensures the coverage of the 1.5 m maximum drift distance in 1 ms. The anode of each TPC is made of three parallel wire planes, 3 mm apart, oriented at 0° and $\pm 60^\circ$ w.r.t. the horizontal direction: in total 53248 wires are installed. By appropriate voltage biasing, the first two planes are transparent to drift electrons and measure the induced signal, whereas the ionization charge is collected by the last plane (Collection). Scintillation light detection provides trigger and the absolute time of the ionizing events. For this purpose arrays of Photo Multiplier Tubes (PMTs) are installed behind the wire planes [2].

Gas and liquid recirculation systems with Hydrosorb/Oxysorb filters allow to keep electro-negative impurities at 0.06 ppb O_2 equivalent concentration. The resulting free electron lifetime is constantly above 5 ms (only 17% charge attenuation at 1.5 m drift distance), opening the way to longer drift paths for larger mass LAr-TPCs.

The main ICARUS T600 trigger system relies on the analog sum of PMTs signal (Σ-PMT) with $\sim$ 100 photo-electron discrimination threshold for each TPC chamber.

- The CNGS trigger requires the presence of Σ-PMT in at least one TPC chamber within $\sim$ 60 μs beam gate ("early warning" signal sent from CERN to LNGS 80 ms before the extraction). About 80 events/day are recorded (1 mHz rate).
- For cosmic rays an efficient reduction of the spurious signals, still maximizing the detection of low energy events, is provided by the coincidence of Σ-PMT of the two adjacent chambers in the same module, relying on the 50% cathode transparency. A 125 events/hour trigger rate (35 mHz) has been achieved thanks to the recent improvement in the PMTs HV biasing scheme and signal treatment.

Performance of the trigger system can be pushed forward by using the charge information. A new dedicated DR-slw algorithm, able to online identify hits with 1 board (32 wires) modularity [3], has been software implemented during 2011 in an independent 2-levels trigger for CNGS events. The same algorithm is being hardware implemented on a FPGA chip installed on the digital boards: the Collection view has been fully equipped, and it's being used to trigger on cosmic low energy localized events.

CNGS NEUTRINO RUN: PHYSICS RESULTS & POTENTIAL

ICARUS CNGS 2010 run started in stable conditions on October 1^{st} 2010, collecting 5.8×10^{18} protons on target (pot) out of the 8×10^{18} delivered by CERN up to November 22^{nd}. During the 2011 run 4.44×10^{19} pot over the 4.78×10^{19} pot delivered by CERN has been collected, with detector live-time of 93%. Data taking with CNGS beam resumed on 2012, March 23^{rd}, and is smoothly proceeding, collecting 2.1×10^{19} pot up to now with almost 94% detector live-time. The first 3.3×10^{19} pot of the 2010-2011 data sample have been processed, resulting in 1091 neutrino interactions with vertex in 433t LAr fiducial volume, in good agreement with MC expectation.
The case of a superluminal propagation speed of neutrinos, depicted by the OPERA Collaboration announcement [4], has been deeply addressed by the ICARUS Collaboration. A first result was triggered by the Cohen and Glashow [5] argument that such superluminal neutrinos should lose energy by producing photons and e+e- pairs, through Z^0 mediated processes analogous to Cherenkov radiation. No candidate event was found, setting a tight negative limit on $(v_\nu - c)/c$ of 2.5×10^{-8} at 90% C.L. [6].
A direct measurement was performed with a 3 ns wide bunched beam shortly operated at the end of 2011 CNGS run, leading to a result $\delta t = tof_c - tof_\nu = -0.3 \pm 4.9_{stat.} \pm 9.0_{syst.}$ ns [7] compatible with the simultaneous arrival of all events with speed equal to that of light (Figure 1, left). This measurement has been recently perfected with a data sample collected during May 2012, when the CERN-CNGS neutrino beam was operated for two weeks for a total of 1.8×10^{17} pot in bunched mode, with a ~ 3 ns narrow width proton beam bunches, separated by 100 ns. Both the ICARUS-T600 PMT-DAQ and the CERN-LNGS timing synchronization have been substantially improved for this campaign, taking advantage of additional independent GPS receivers, both at CERN and LNGS as well as of the deployment of the "White Rabbit" protocol both at CERN and LNGS. The ICARUS-T600 detector has measured the neutrino time of flight with 25 beam-associated events, using all different time synchronization paths. The final result $\delta t = tof_c - tof_\nu = 0.18 \pm 0.69_{stat.} \pm 2.17_{syst.}$ ns [8] is in agreement with the value previously reported but with improved statistical and systematic errors (Figure 1, right).
The main goal of the ICARUS T600 programme [9] is the search for $\nu_\mu \rightarrow \nu_\tau$ oscillation in the CNGS beam, especially in the $\tau \rightarrow e\overline{\nu}_e\nu_\tau$ channel where kinematical selection criteria based on missing transverse momentum allow full rejection with 50% efficiency the associated background. On the same beam the search for sterile neutrinos in LNSD parameter space is also performed, looking for an excess of ν_e CC events. Finally, ICARUS-T600 is studying atmospheric neutrinos and, thanks to the powerful background rejection and its 3×10^{32} nucleons, it can play a role in proton decay search, in particular in interesting exotic channels not accessible to Čerenkov detectors.

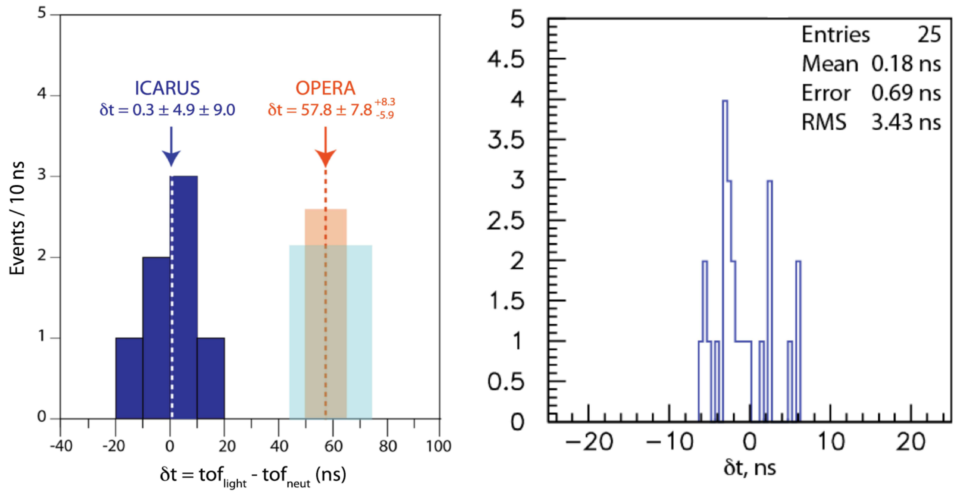

FIGURE 1. 2011 (left) and 2012 (right) event distribution in ICARUS-T600 for δt.

STERILE NEUTRINO SEARCH AT CERN/SPS WITH ICARUS

The observations of an electron excess in anti-ν_μ beams, made by the LSND and MiniBooNE experiments, and of a possible disappearance signal in the anti-ν_e events collected by the reactor neutrino experiments, seem to suggest the presence of a new invisible “sterile” neutrino type. The ideal device to try to solve at the same time all these anomalies is the LAr-TPC thanks to the detection capability to recognize the genuine electron neutrino events combined with the high level of rejection of the associated background events due for example to NC π^0 interactions. A new experimental search with an intense $\sim$2 GeV neutrino beam at CERN/SPS is proposed in order to definitely clarify the possible existence of additional neutrino state [10]. It is based on two strictly identical LAr-TPC detectors complemented by magnetized spectrometers detecting electron and muon neutrino events at Far (1600 m) and Near (300 m) positions w.r.t. the proton target: respectively ICARUS-T600 detector, to be moved to CERN after its exploitation at LNGS, and an additional 150 t detector to be built anew.

REFERENCES

1. S. Amerio, et al., *Nucl. Instr. and Methods A* **527**, 329 – 410 (2004), ISSN 0168-9002.
2. A. Ankowski, et al., *Nucl. Instr. and Methods A* **556**, 146 – 157 (2006), ISSN 0168-9002.
3. B. Baibussinov, et al., *Journal of Instrumentation* **5**, P12006 (2010).
4. The OPERA Collaboration, *ArXiv e-prints* (2011), `1109.4897`.
5. A. G. Cohen, and S. L. Glashow, *Phys. Rev. Lett.* **107**, 181803 (2011).
6. M. Antonello, et al., *Physics Letters B* **711**, 270 – 275 (2012), ISSN 0370-2693.
7. M. Antonello, et al., *Physics Letters B* **713**, 17 – 22 (2012), ISSN 0370-2693.
8. M. Antonello, et al. (2012), `arXiv/1208.2629`.
9. F. Arneodo, et al., The icarus experiment, a second-generation proton decay experiment and neutrino observatory at the gran sasso laboratory, LNGS-P 28/2001 (2001).
10. A. Antonello, et al. (2012), `arXiv/1208.0862`.