

PAPER • OPEN ACCESS

Performance study of the new light collection system for the ICARUS T600 detector

To cite this article: A. Falcone and ICARUS Collaboration 2017 *J. Phys.: Conf. Ser.* **888** 012093

View the [article online](#) for updates and enhancements.

Related content

- [Electron diffusion measurements in the ICARUS T600 detector](#)
Marta Torti and ICARUS Collaboration
- [Operation and performance of the ICARUS T600 cryogenic plant at Gran Sasso underground Laboratory](#)
M. Antonello, P. Aprili, B. Baibussinov et al.
- [Upgrade of the ICARUS T600 Time Projection Chamber](#)
F Tortorici, V Bellini, C M Sutera et al.



IOP | ebooks™

Bringing you innovative digital publishing with leading voices to create your essential collection of books in STEM research.

Start exploring the collection - download the first chapter of every title for free.

Performance study of the new light collection system for the ICARUS T600 detector

A. Falcone *on behalf of ICARUS Collaboration*

Departments of Physics, University of Texas at Arlington, 502 Yates St., Arlington (TX), USA

E-mail: andrea.falcone@uta.edu

Abstract. The ICARUS T600 detector is the largest liquid argon time projection chamber (LArTPC) to be built and operated [1]. This detector was in operation in the INFN Gran Sasso underground laboratory until 2012, exposed to the CERN Neutrino to Gran Sasso (CNGS) ν_μ beam, performing neutrino oscillation studies. The ICARUS T600 is presently under refurbishment in order to make it suitable for surface level operation, as it will serve as the far detector for the Short-Baseline Neutrino (SBN) Program at Fermilab [2]. A major upgrade of the ICARUS detector in order to allow it to cope with a high cosmic background is the upgrade of the light collection system. The study presented here shows a simulation to optimize the PMT layout to allow for the localization and identification of interaction within the T600. An excellent performance can be obtained, with an error on the localization smaller than 20 cm and of the order of a few percent in the identification of cosmic rays.

1. Light collection system aims and simulation

The new ICARUS T600 light collection system aims are the generation of a light based trigger signal, the identification of the t_0 of each interaction with high time precision and the identification of event topology for fast selection purposes. To achieve these objectives the system has to fulfill various characteristics:

- high detection coverage, in order to be sensitive to the lowest expected neutrino energy deposition in the TPC (100 MeV), also using the light fast component only;
- high detection granularity in order to localize the events with sufficient precision to associate unambiguously the collected light to the deposited charge;
- fast time response and high time resolution, to be sensitive to the time of occurrence and to the evolution of each event in the T600 acquisition window.

A configuration with 90 8 in. diameter PMTs behind each wire plane (see Fig. 1), with a photo cathode covered area corresponding to 5 % of the wire plane area, is suitable for the experimental purpose.

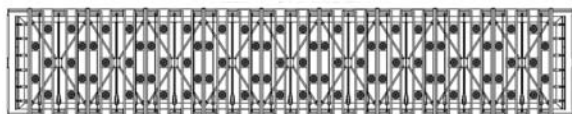


Figure 1. Layout of the new light collection system for the T600 detector.



A dedicated Monte Carlo simulation was realized to evaluate its performance. The simulation is geometrical, very fast and performed with a series of C++ routines. Three different event topologies are considered:

- electromagnetic (e.m.) showers, that simulate NC and ν_e CC interactions;
- muons generated from ν_μ CC interactions;
- crossing cosmic muons, that represent the most important source of noise.

Fine details of physical events, such as e.m. shower shape or particle multiple scattering, are not taken into account, because they are on a smaller scale with respect to the spatial resolution achievable with 20 cm diameter devices, spaced at ~ 0.5 -1.0 m. Muons are schematized as straight line, while e.m events as clusters of points (1 MeV each). Muons generated from ν_μ CC interactions are a superposition of the other two event topologies. From each simulated event, the photons originate isotropically; due to the short wavelength, LAr scintillation light is absorbed by all the detector material, so no reflection is assumed. A Rayleigh scattering length of 90 cm is considered. A 5% overall Quantum Efficiency (Q.E.) is assumed for the PMTs. An error of ± 1 ns on the arrival time and a $\pm 10\%$ uncertainty on the number of collected photons are set to take into account the foreseen instrumental error. An estimation of the number of photo-electrons collected per MeV of deposited energy in a single TPC, gives an average value of about 15 phe/MeV, 9 phe/MeV for events close to the cathode.

2. Trigger generation

In the future phase of the ICARUS experiment, the trigger will be given by a signal from the PMT system in coincidence with the beam gate: trigger will start only if a certain number of PMTs give a signal above a certain threshold, the value of which should be sufficiently high in order not to collect low energy signals coming from ^{39}Ar , i.e. the main source of physical noise in a LArTPC. ^{39}Ar induced events are simulated as point-like events, uniformly distributed in the active LAr volume, with an energy ranging from 100 keV to the β^- end-point energy (565 KeV). For the 81 m^3 ($1.5 \times 3 \times 18 \text{ m}^3$) of simulated LAr, a total activity of $\simeq 116$ kHz is calculated. As shown in Fig. 2, noise events giving a signal above 2-3 phe in more than 2-3 PMTs have a very low rate. On the contrary, the events with lower collected light intensity, i.e. 100 MeV events in proximity of the cathode, induces more than 10 PMT signals above 20 phe (see Fig. 3); the detection efficiency remains 100% for many combinations between signal threshold and PMT majority.

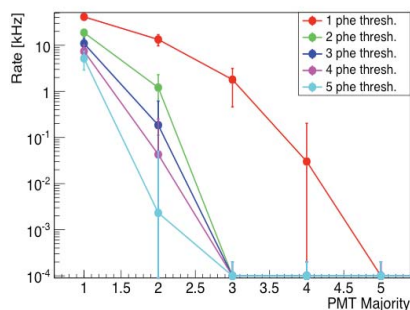


Figure 2. Residual ^{39}Ar rate (fast signal) as a function of the adopted phe threshold and PMT majority.

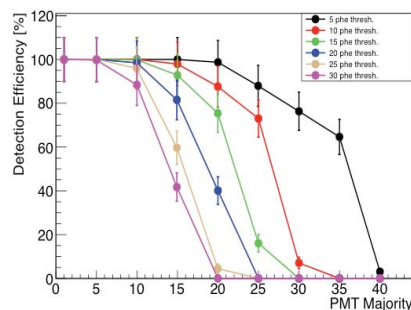


Figure 3. Detection efficiency (fast signal) for 100 MeV showers near cathode as a function of the phe threshold and PMT majority.

3. Localization of events

The PMT configuration permits a very good localization, with an error of $\simeq 20$ cm along the beam direction, just averaging on PMTs signals (see Fig. 4); with more sophisticated algorithms even better results can be obtained.

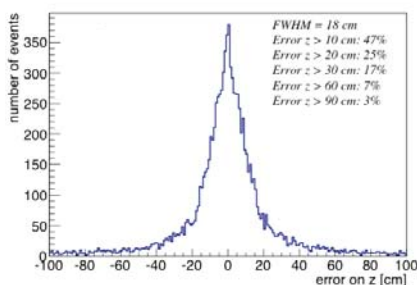


Figure 4. Evaluation of the precision on the localization of the correct position, along the beam direction, with a simple weighted average on PMT signals. The FWHM of the distribution and the percentage of events localized with an error greater than 10, 20, 30 60 and 90 cm are indicated.

4. Event identification

Each PMT provides, for each detected event, information about the arrival time of the prompt photons and the light intensity, from the fast component peak detection. The performance of the light detection system to discriminate between the topology of an incoming cosmic ray and events generated from an internal interaction (such as a neutrino event) is evaluated using a ROOT TmultiLayerPerception class Neural Network. The network has 2 inputs for each PMT and 1 output which discriminates between signal (output=1) and background (output=0). Three networks have been created, one for each kind of event: each network was trained with 10k signal events and 10k background ones (see Fig. 5 for the results of the network trained with muons as signal). For all the networks, misidentified events are mainly on detector boundaries, so they should be not considered due to the fiducial volume cut. The combined use of the different networks permits a good identification of cosmic muons. Defining a cosmic muon as an event with result bigger then 0.5 in the network for cosmic muons, less then 0.4 in the network for e.m. showers and less then 0.25 in the network for CC from ν_μ , a misidentification of cosmic of $\simeq 2\%$ can be obtained

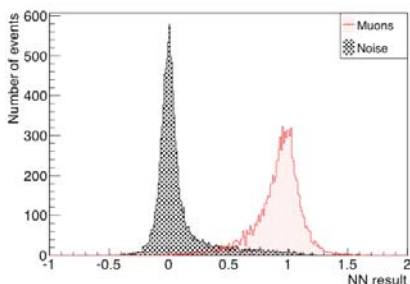


Figure 5. Result of the neural network trained with muons as signal. Setting 0.5 as threshold value, bad identified muons are $\sim 4\%$, while misidentified background is $\sim 7\%$.

[1] Amerio S et al. (ICARUS Collaboration), *Nucl. Instr. and Meth. A*, **527** (2004) 329.

[2] Acciari R et al., *A Proposal for a Three Detector Short-Baseline Neutrino Oscillation Program in the Fermilab Booster Neutrino Beam* arXiv:1503.01520.