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Measurement of a large electron lifetime in a liquid argon TPC

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Summary. — An unprecedentedly high value of electron lifetime in a liquid argon TPC, about 21 ms, has been measured in a test facility at INFN-LNL. This results opens the way to the future development of TPCs with very long drift distances.

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1. – The LAr-TPC technology and the purity issue

Liquid argon TPCs are very promising detectors for neutrino and nucleon decay physics, due to their high granularity ($\approx$ mm^3), good-energy resolution and 3D imaging, allowing for full and precise event reconstruction and good e/π^0 separation.

After intense R&D, ICARUS T600 started data acquisition in LNGS in May 2010; it will perform a significant neutrino physics programme both with the CNGS (CERN Neutrinos to Gran Sasso) beam and with natural sources (atmospheric, solar, SN), and improve sensitivity on several nucleon decay channels. A new generation of LAr TPCs is being discussed for the future, with masses of some tens of kton and drift distances of ≈ 5 m.

The electron signal in a LAr TPC is attenuated by capture on electronegative impurities (O_2, H_2O) resulting in a finite lifetime τ ($Q = Q_0 e^{-t/\tau}$). A very good purity is essential to keep a large signal/noise ratio over long drift distances: current values, from ICARUS test runs in 2001, are $\tau \approx 1$ ms ($\lambda \approx 1$ m) with an electronegative impurity concentration of 10^{-10} (oxygen equivalent). An improvement in purification techniques is therefore needed for larger-size detectors (drift lengths of few meters).

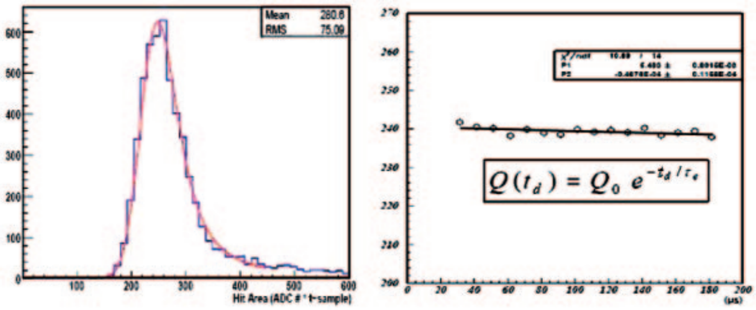

Fig. 1. – Landau-Gaussian distribution of a single time slice (left) and variation of Q as a function of drift time (right).

2. – Experimental setup

A small TPC (ICARINO) operating in INFN-LNL has been used to test filling and purification procedures and measure the obtained lifetime [1]. ICARINO has a sensitive volume of 27 l read by two orthogonal wire planes. The second plane (*Collection*) collects the drifting electrons, giving a signal proportional to the energy deposition. A set of 10 external PMTs are used for triggering the TPC with cosmic rays.

Special attention has been given to purification procedures: before filling, the dewar containing the TPC was evacuated to about 10^{-3} Pa. It was then rapidly cooled, while connected to an external cold dewar (*cryogenic trap*) in order to "suck up" the residual argon inside the TPC dewar, which has a high concentration of impurities due to degassing. During the run, argon was continuously purified: gaseous argon evaporating from the TPC dewar was passed through molecular sieves (*Oxysorb*), reliquefied in a thermal bath and reinserted in the dewar.

3. – Measurement of electron lifetime

For the purity measurement, ≈ 1200 cosmic-ray muons at $\approx 45°$ w.r.t. to Collection wires , selected by PMT trigger and suitable geometrical cuts, were used. Events with large delta rays were removed, in order to have events with almost constant $\mathrm{d}E/\mathrm{d}x$ on all wires. The integral Q of the signal recorded on wires is proportional to $\mathrm{d}E/\mathrm{d}x \cdot e^{-t/\tau}$. The lifetime was extracted by an analysis of $Q(t)$ behaviour: the hit integral distribution from all events was considered, subdivided into 16 time bins of 10 μs each. In each bin, hit integrals follow a Landau-Gaussian distribution; a fit provides an estimate of $Q(t)$ in each bin. $Q(t)$ is then fitted exponentially (fig. 1), obtaining $\tau = 21.4^{+7.3}_{-4.3}$. This corresponds to an impurity concentration of a few tens ppt ($\approx 10^{-11}$).

Another algorithm allows to estimate the lifetime based on a single event; this method has a lower precision, but gives compatible results, on average, with the global one.

This unprecedented value of liquid argon purity has been kept stable during a 2-week run; this result opens the way to realistic LAr TPCs with very long drift distances (the signal attenuation on 5 m would only be $\approx 15\%$), ideal for next-generation neutrino physics (θ_{13}, CP violation) and nucleon decay studies.

REFERENCES

[1] Baibussinov B. *et al.*, *JINST*, **5** (2010) P03005.