WA105: A large demonstrator of a liquid argon dual phase TPC

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WA105: A large demonstrator of a liquid argon dual phase TPC

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Abstract. The Liquid argon technology has been chosen for the DUNE underground experiment for the study of neutrino oscillations, neutrino astrophysics and proton decay. This detector has excellent tracking and calorimetric capabilities much superior to currently operating neutrino detectors. WA105 is a large demonstrator of the dual-phase liquid argon TPC based on the GLACIER design, with a 6×6×6 m³ (appr. 300t) active volume. Its construction and operation test scalable solutions for the crucial aspects of this detector: ultra-high argon purity in non-evacuable tanks, long drifts, very high drift voltages, large area MPGD, cold preamplifiers. The TPC will be built inside a tank based on industrial LNG technology. Electrons produced in the liquid argon are extracted in the gas phase. Here, a readout plane based on Large Electron Multipliers (LEM’s) provides amplification before the charge collection onto an anode plane with strip readout. This highly cost effective solution provides excellent imaging capabilities with equal charge sharing on both views. PMTs located at the bottom of the tank containing the liquid argon provide the readout of the scintillation light. This demonstrator is an industrial prototype of the design proposed for a large underground detector. WA105 is under construction at CERN and will be exposed to a charged particle beam (0.5-20 GeV/c) in the North Area in 2018. The data will provide necessary calibration of the detector performances and benchmark sophisticated reconstruction algorithms. This project is a crucial milestone for the long baseline neutrino program DUNE.

1. Liquid argon TPC technology

In the quest of discovering neutrino mass ordering and the leptonic CP violation phase, as well as precisely measuring the neutrino mixing parameters, future long baseline neutrino projects are currently being designed. The DUNE underground experiment [1], using a neutrino beam from Fermilab to the Sanford Underground Research Facility (United States), has chosen liquid argon time projection chamber technology (LArTPC) for the 4×10 kt far detectors. The liquid argon is a dense, inert and relatively cheap material which allows large fully active drifting volumes with an excellent granularity. As for any TPC, the 3D imaging is performed by collecting electrons produced during ionization and transported to the anode by a high electric field (ranging from 0.5 to 1 kV/cm) applied across the drifting volume. As liquid argon is fully transparent to its scintillation light produced by a fast de-excitation of argon excimers, light collection can be used as an event trigger. Among LArTPC developments, two technologies are under discussion: single and dual phase. The latter features a layer (~1 cm) of gaseous argon before the charge collection readout. This allows charge amplification through a large electron multiplier (LEM) inserted before the anode. In order to have a full liquid-to-gas charge...
Figure 1. Left: Schematic view of a dual phase liquid argon TPC detector. Right: Close-up view of the charge amplification region [3].

extraction efficiency, a grid enabling a higher electric field is placed in the liquid just before the interface. In figure 1, a schematic drawing of dual phase LArTPC technology is presented. The charge amplification system allows a larger signal-to-noise ratio, longer drifting distance and a lower energy threshold as compared to the single phase technology. The WA105 collaboration will construct and operate at CERN medium to large size dual phase LArTPC in the near future. A $3 \times 1 \times 1$ m$^3$ demonstrator will be exposed to cosmic rays in spring 2017 and a $6 \times 6 \times 6$ m$^3$ prototype [2] will be exposed to a charged particle beam in 2018.

2. R&D on the charge amplification and readout system
The design of the large electron multipliers and the anodes results from extensive developments tested in a 3 l [3, 4] and 200 l [5] LArTPC at CERN. The final anode is manufactured in a single multilayer printed circuit board (PCB). The readout layout is designed for a perfectly symmetric charge sharing between both views, and is presented in figure 2 (top right). The anodes have a low capacitance in order to sustain long readout strips while keeping the noise to a minimum. The LEMs are made from standard 1 mm thick PCB with roughly 150 holes per cm$^2$. Holes, with a diameter of 500 µm, are surrounded by a 40 µm rim, a close up view is shown in figure 2. The effective gain of the LEMs has been monitored during 20 days with cosmic ray events in the 3 l LArTPC setup. As seen in figure 2, a stable effective gain of $\approx 15$ is achieved after a decrease with a characteristic time of $\tau \approx 1.6$ days. Final anode and LEM panels are $50 \times 50$ cm$^2$, and both are easy to be manufactured on a large scale. As shown in figure 2, the thickness uniformity has been controlled on a sample of 14 manufactured LEMs with good results.

3. Construction of $3 \times 1 \times 1$ m$^3$ prototype
The construction of the $3 \times 1 \times 1$ m$^3$ demonstrator started in January 2016. The charge readout plane (CRP) consists of a $3 \times 1$ m$^2$ fully active area. The extraction grid, the $50 \times 50$ cm$^2$ anode and LEMs are supported by one mechanical frame, independent from the drift cage and adjustable to the liquid argon level. The cold front-end electronics are plugged-in close to the anode inside feedthroughs in an independent volume. Two types of electronics will be tested during the cosmic ray run, and can be accessed anytime without spoiling the argon purity inside
Figure 2. Top left: Anode readout layout. Top right: close up view of the LEM holes. Bottom left: Time evolution of a $10 \times 10 \, \text{cm}^2$ LEM effective gain during 20 days of data taking. Blue lines indicates discharges [3]. Bottom right: Mean thicknesses of 14 $50 \times 50 \, \text{cm}^2$ LEMs manufactured for the $3 \times 1 \times 1 \, \text{m}^3$ demonstrator.

Figure 3. Pictures of the $3 \times 1 \times 1 \, \text{m}^3$ construction

the cryostat. Pictures of the construction are presented in figure 3.

References