Short Status Update on the WA105 experiment (2016) at the Neutrino Platform

The WA105 Collaboration

1 Introduction

The double (or dual) phase liquid Argon TPC represents a novel concept for liquid argon detectors. This concept, developed during several years within the EC FP7 LAGUNA-LBNO design study, has been shown to provide a cost-effective solution for implementing very large deep underground liquid argon detectors with very fine imaging performance and low detection thresholds, such as those needed in next-generation long-baseline experiments.

The Deep Underground Neutrino Experiment (DUNE) \footnote{http://www.dunescience.org} aims at constructing four large liquid argon detectors of 10-kt fiducial mass each, to be located underground at the 4850L level of the Sanford Underground Research Facility (SURF) in South Dakota. DUNE considers both single- and dual-phase designs for the far detectors. There is recognition that the staged approach with the deployment of consecutive modules will enable an initial science programme to begin early, while allowing implementation of improvements and developments of the far detector technology during the lifetime of the experiment. Compared to the single-phase, the dual-phase design will provide a fully active volume without dead material with a smaller number of readout channels, a finer readout pitch, a more robust signal-to-noise ratio with tunable gain, a lower detection energy threshold, and a better pattern reconstruction of the events. These will allow to best exploit the “bubble chamber”-like features of the liquid argon TPC at the 10-kt scale.

The aim of the WA105 experiment at the CERN Neutrino Platform is to fully demonstrate the concept developed in LAGUNA-LBNO for the DUNE Far Detector, by constructing and testing full-scale detector components, assessing their installation procedures in the $6\times6\times6m^3$ DLAr demonstrator.
and to measure the performance and to calibrate such a detector with a charged particles test beam. While waiting for the availability of the EHN1 extension, the Collaboration has decided to develop a $3 \times 1 \times 1 \text{m}^3$ LAr-Proto presently in advanced stage of construction to be operated in 2016 at CERN in Blg 182.

The WA105 Memorandum of Understanding (MoU) has collected all the signatures from the funding agencies and now defines in details the contributions of the various institutes involved in the construction of the WA105 $6 \times 6 \times 6 \text{m}^3$ DLAr. According to the MoU, CERN will provide the WA105 cryostat for the $6 \times 6 \times 6 \text{m}^3$ DLAr in the North Area by October 2016. Detector installation would proceed in 2017 with the aim to start commissioning with cosmic data in January 2018. This timescale is consistent with the recommendations of SPSC which “encourages CERN and the WA105 collaboration to converge as soon as possible on the Memorandum of Understanding with the focus on LAr TPCs and to undertake all efforts to be ready with DLAr in the EHN1 extension for first beam before the start of the Long Shutdown 2.”

An important recent development is the announcement of the incorporation of the CERN WA105 experiment (in the DUNE Collaboration referred to as dual-phase protoDUNE) within the organizational structure shown in Figure 1, allowing us to take maximum advantage of the synergies between the single (approved in December 2015) and dual-phase efforts in the CERN EHN1 area. Furthermore, the management teams for the single-phase and dual-phase protoDUNE activities at CERN are now in place and have started to take an active role in the organization of these efforts. D.Autiero and T.Hasegawa have been nominated coordinators for the double-phase ProtoDUNE activities.

## 2 Progress on the $6 \times 6 \times 6 \text{m}^3$ DLAr design and construction

Since the last SPSC meeting in 2015 we have continued to the work on the design and preparation of the $6 \times 6 \times 6 \text{m}^3$ DLAr detector.

In collaboration with the Neutrino Platform personnel we defined the cryostat requirements for the Technical Specifications Document needed for the GTT design study of the cryostat. We defined all the cryostat interfaces and penetrations including the signal chimneys, the other feedthroughs, the beam window and the Temporary Construction Opening (TCO) at the side of the cryostat. The integration of the fixation system of the photomultipliers on the membrane floor of the cryostat was worked out as well. A full integration scheme was defined for the detector inside the new cryostat inner volume shape, which is now common to the single and double phase cryostats.

The last months focused on finalizing the design of the $6 \times 6 \times 6 \text{m}^3$, taking into account what has been learnt from the prototyping activity for the $3 \times 1 \times 1 \text{m}^3$ and considering all the aspects related to the design of the 10 kton double-phase detector modules at SURF. The $6 \times 6 \times 6 \text{m}^3$ will allow performing
a final test of the detector elements foreseen in the 10 kton design, implementing a construction chain and procedures which could then be extended to the production needed for the 10 kton, including all the QA/QC procedures. This design activity was conducted in collaboration with the DUNE Far Detector working groups.

The Charge Readout Plane (CRP) is a fundamental basic element of the dual-phase design. It integrates the $50 \times 50 \text{cm}^2$ LEM-Anode sandwiches and the extraction grid on a support frame which is hung on a suspension system which allows to adjust its height and planarity with respect to the LAr surface. The CRP design for the $6 \times 6 \times 6 \text{m}^3$ was adapted in order to include the $3 \times 3 \text{m}^2$ CRP modules defined in the DUNE Conceptual Design Report for the 10kton dual-phase detector. The DUNE 10 kton module is foreseen to include 80 CRPs in order to instrument a detection surface of $12 \times 60 \text{m}^2$. Similarly the $6 \times 6 \times 6 \text{m}^3$ will use four (4) $3 \times 3 \text{m}^2$CRPs. The $6 \times 6 \times 6 \text{m}^3$ will therefore implement all the production procedures of the CRPs and validate their operation as a final engineering test for the 10 kton.

The procedures for the CRP installation and cable connections have been studied as well. The CRP design is currently being finalized on the basis of all these requirements. R&D activities are ongoing to study the implementation of the cathode under the form on an array of PMMA transparent panels with ITO coating. In order to minimize the underground work and simplify the installation the CRP planes will be completely preassembled and quality controlled at the production sites. They will be
then transported to SURF, down to the underground site in customized boxes of $3.1 \times 3.1 \times 0.5 m^3$. These boxes will be inserted in the cryostat via a vertical TCO thanks to a rail system fixed on the exoskeleton structure. The TCO is externally surrounded by a clean room buffer and a SAS for the introduction of the box. The rail manipulation system will include a rotation tool in order to rotate the box from the vertical to the horizontal position and proceed with the hanging and connections of the CRP. The TCO and clean room buffer scheme have been already integrated in the conventional facility definition of LBNF.

Following these developments, we have defined a construction procedure in the EHN1 area which mimics as much as possible the underground installation procedure at SURF. The CRPs will be preassembled in a clean room at CERN. A suitable candidate location has been identified in the clean room buffer of building 185, currently used for by WA104 for the T600 refurbishing and which should become available by the beginning of the year 2017. This is a clean room class 10k with inner dimensions of $20(l) \times 5(w) \times 4.8(h)m^3$. This installation provides all the necessary space for the CRPs assembly, metrology and quality controls and insertion in the transportation boxes. The cryostat of WA105 will be connected via its TCO to a clean room buffer of about $7(l) \times 3.5(w) \times 4(h)m^3$ set up inside the pit area. The CRPs will also be introduced vertically in the cryostat and then rotated, as foreseen for the final installation in the 10 kton.

We have defined a detailed procurement, production and installation schedule which has been integrated in the overall schedule of the EHN1 activities V1.5 released in December 2015. This schedule foresees as main milestones:

- September 2016: Start of cryostat construction
- April 2017: Start of detector installation inside the cryostat
- December 2017: Seal of TCO and cryostat
- January 2018: Start of cryogenic operations
- March 2018: Ready to collect beam

Some activities already entered in a procurement phase as the front end analog and digital electronics for which procurement and production activities were launched at the end of 2015 for what concerns the ASIC cryogenic amplifiers, the uTCA digitization system and the White Rabbit time and trigger distribution system. A first batch of the electronics will be employed in the tests of the $3 \times 1 \times 1 m^3$ foreseen since the beginning of this summer. There are plans also of starting tests on the $3 \times 1 \times 1 m^3$ of a reduced scale implementation of the DAQ online storage and data processing facility.
3 Update on the $3 \times 1 \times 1 \text{m}^3$ LAr-Proto construction

A significant amount of progress has been made since the last report of June 2015. The detector installation will take place this year following a detailed construction plan. Some of the major milestones are:

- February 2016: delivery of top-cap and fixation on the detector installation structure.
- March-April-May 2016: detector installation and cabling in assembly structure + testing.
- June 2016: move top-cap with detector to cryostat and install internal cryo-piping.
- August 2016: cryogenic installation complete
- September 2016: setup ready for liquid argon filling.

Below we briefly summarise some of the recent progress.

a) On site integration and safety.

The layout of the experiment in b. 182 is shown in Figure 2. It consists of a) the clean room for the CRP construction, b) the temporary assembly structure where the detector will be assembled hanging from the top-cap and c) the cryostat with the platform for cryogenic installation. The temporary assembly structure and the cryostat are both fully constructer. The cryogenic platform has been designed and the material is about to be ordered. The ODH study has been done and we are in close contact with HSE to ensure that all the appropriate safety equipment (containment pools, sensors, etc..) are installed in time.

b) Cryostat and top-cap.

The membrane tank was constructed and leak tested last summer. The top cap is currently in production and is scheduled to be delivered in February.

c) Charge Readout plane (CRP).

The mechanical frame is ready in the clean room and has been test-assembled with the extraction grid. The connectors are all soldered on the anodes. The LEMs were successfully tested in pure gas argon at 87K. The CRP will be fully assembled in the clean room around April and brought to the temporary assembly structure for suspension under the top-cap.
d) Cryogenic installation.

The design was finalised last year and an invitation to tender has been sent out to companies in December 2015. The tendering process closed on January 14th and a number of companies have replied. In the document it is specified that the installation should be ready for commissioning in September 2016.

e) Chimneys and feedthroughs

The card insertion and vacuum tests on the first signal feedthrough have been successful and the remaining five have been ordered and should arrive very soon. The slow control flanges have been delivered and the high voltage feedthrough should be delivered and tested in February. The three CRP suspension chimneys are ready for installation.

f) Detector slow control.

All the sensors, connections and cables are ready, the cable routing has been defined. The racks have been cabled and tested in b. 21. Part of them will be soon be shipped to b. 182. A portable rack containing the same hardware and software interfaces that will be used for the $3 \times 1 \times 1 \text{m}^3$ slow control
was produced last year and has been extensively used for the monitoring of other small scale setups (e.g. open bath tests, LEM testing, ...). It has proven to be a very valuable prototype to optimise and test the entire slow control chain (sensor, cable types, PVSS software, ...).

4 Progress on software and analysis

The WA105 Science Board is covering software developments, which includes simulation, reconstruction, and integrated data modelling for the real data and the simulation data in view of test beam data taking. Another important aspect is the analysis related to the validation of the physics sensitivity of future large underground liquid argon TPC detectors based on the dual-phase technology. Recent developments were listed as follows:

- Optimization of the raw data model for WA105, enabling an efficient treatment in the analysis of both real data and simulated data, is continuing. Validation of the code with single particle event, as well as, overlapping cosmic event foreseen with ground surface operation of the detector, is on-going. Procedure for benchmarking, associated with code development, is established.

- The charge signal reconstruction code, including, functionality of the identification of the signal in the space-time phase-space and the track reconstruction is developed, and being examined with overlapping cosmic event.

- Since the $6 \times 6 \times 6\text{m}^3$ will operate on surface, space charge effects can be induced by the cosmic rays flux. Detailed simulation of the electric field with COMSOL which includes back flow of the charge from gas multiplication process, electronegative impurity effect, and charge recombination effect, is completed. Obtained information is reflected as electric field map in QSCAN. Evaluation of the effect of convection motion has started.

- Effort to implement the light signal map, which is produced by the dedicated light signal simulation, is completed, and under validation. The code, representing realistic photomultiplier response, including, time structure of the signal, single photon response, quantum efficiency and, gain as a function of supply high voltage, is developed.

- The performance of Huffman lossless compression is examined. Data size compression factor for the raw data is evaluated with the realistic simulation data including noise. Good signal to noise ratio of above 100 foreseen with dual-phase technology enables more than factor of ten compression of the data size. The impact of the compression factor for online processes is under consideration.
• Systematic studies of the $dE/dx$ measurement and delta-ray production are continuing. Fundamental steps on the charge signal reconstruction, including, precise reconstruction of ionization charge deposition in the detector from digitized electronics output by deconvolution, effect of noise, effect of attenuation impurity loss, and delta-ray effect are checked one by one.

• As a world wide effort to facilitate common platform for the optimization of the liquid Argon TPC technology, effort to implement the codes which are specific to dual phase technology into the framework LArSoft, where broad effort to standardize platform by several experiments (ICARUS, ArgoNeuT, MicroBOONE, LArIAT, SBND, DUNE), is proceeding.

5 Conclusion

Since the last SPSC, WA105 has continued to make significant progress in all areas under the responsibility of the Technical Board and the Science Board which regularly follow the technical and software developments for the preparation of the WA105 $6 \times 6 \times 6$ m$^3$ DLAr detector in the North Area. In particular all the hardware activities benefited largely of the possibility of performing an immediate implementation of the components designed for the $6 \times 6 \times 6$ m$^3$ DLAr detector on a smaller $3 \times 1 \times 1$ m$^3$ LAr-Proto prototype being completed in the Building 182. Hardware activities are on track to start commissioning of the $3 \times 1 \times 1$ m$^3$ LAr-Proto in September 2016. Meetings between CERN and WA105 on the integration in the North Area have continued on a regular basis, to ensure that a smooth installation in the North Area will happen following our expected schedule. The present progress leads us to be confident that the $6 \times 6 \times 6$ m$^3$ DLAr detector should be ready for data-taking in 2018, in order to take beam data before the LHC LS2, as was recommended by SPSC in April 2015. The WA105 activities have now been embedded in the DUNE organisation, which considers single- and dual-phase tests with equal priority.