AIDA-2020-MS73

AIDA-2020

Advanced European Infrastructures for Detectors at Accelerators

Milestone Report

Bi-annual progress reports and meetings on ionisation charge readout

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Advanced European Infrastructures for Detectors at Accelerators

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MILESTONE REPORT

BI-ANNUAL PROGRESS REPORTS AND MEETINGS ON IONISATION CHARGE READOUT

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Abstract:

This task is intended to develop the aspects related to the study of ionization charge readout techniques in liquefied noble gases in view of building very large cryogenic detectors. The developed topics cover the dual-phase techniques for charge amplification with electrons extraction from the liquid phase and amplification with micro-pattern gas detectors in absence of quenching as well as the charge readout front-end cryogenic electronics and large scale digitization systems. The 3x1x1 m^3 WA105 prototype at CERN and related infrastructure have been exploited as a test bench for many of these techniques, going from the production and QA chain for micro-pattern detectors, their integration and operation over large surfaces and the development and tests of the analog cryogenic electronics and the digitization system.

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Delivery Slip

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Executive summary

Task 8.3 has been dealing with the aspects related to the implementation of the ionization charge readout techniques in liquefied noble gases in view of building massive detectors. The activities have been covering the assessment of the dual-phase techniques for charge amplification with electrons extraction from the liquid phase and amplification with micro-pattern gas detectors in absence of quenching, as well as the development of charge readout front-end cryogenic electronics and large scale digitization systems. This networking activity, involving several institutions, under the coordination of IPNL and main contributions by ETHZ, has been regularly carried on by exploiting the infrastructure provided by the CERN neutrino platform, exploiting in 2016-2017 as a test bench application for these techniques the 3x1x1 m^3 WA105 prototype. For the following topics, results were extracted from the 3x1x1 construction, integration, commissioning and operation:

- LEM production/cleaning/tests procedures (also in collaboration with WP13)
- LEM integration on large DP readout surfaces
- Cryogenic DP accessible electronics
- High bandwidth DAQ system for giant LAr detectors
- Synchronization system for giant LAr detector

Specific results extracted from the 3x1x1 activity, together with a general review on single and dual phase charge readout methods, are in the process of being fully documented on wiki pages structure. This structure will allow providing the final AIDA2020 deliverables for WP8 while at the same time contributing to the general dissemination of these techniques and global networking in the community.

1. INTRODUCTION

WP8 fosters knowledge sharing and common tools in the neutrino community as regards state-of-the-art in very large cryogenic liquid detectors. The construction of liquid argon detectors at the 10 kton scale is an essential ingredient of the future international long-baseline neutrino program unifying the European and USA efforts. WP8 activities focus on the most challenging aspects related to this detector development. One of these aspects, studied the networking activity of Task 8.3 concerns the design of the charge readout systems for massive LAr detectors, focused on the development of the dual-phase charge readout technique; the production, QA and integration of micro-pattern gas detectors on large surfaces, the design and development of the associated cryogenic electronics and large scale digitization systems. The 3x1x1 prototype built in the context of the neutrino platform activity at CERN allowed for a first operation experience, over several months, of dual phase detector over a surface of $3m^2$ and of the associated readout electronics and digitization system. This prototype provided in 2016 and 2017 to WP8 the opportunity for benchmarking the technologies to be scaled at the level of a larger prototype (the 6x6x6) under construction at CERN and then to the 10kton detector scale foreseen for DUNE. Aspects related to the production and QA chain for the micro-pattern gas detector (LEM or Thick-GEM) are synergic to the activity of WP13. Other aspects related to the PANDORA software for the events reconstruction are related to WP3. The groups involved in Task 8.3 could perform regular work by exploiting this test infrastructure. Overall, this networking activity was very effective in testing innovative aspects in the field and forming the community.

2. ACTIVITIES AND RESULTS

2.1. LEM PRODUCTION/CLEANING/TESTS PROCEDURES

A complete chain for the production/cleaning QA assessment and characterization of the LEM micro-pattern gas detectors and their charge collection anodes was set up in the framework of the neutrino platform infrastructure at CERN. The first detectors were then used in order to instrument the 3x1x1 prototype. This production chain has been then further developed in collaboration with Irfu/CEA Saclay in view of the larger production needed for the construction of the 6x6x6 prototype. Many production aspects are in common with the studies performed on micro-pattern gas detectors in WP13.

2.2. LEM INTEGRATION ON LARGE DP READOUT SURFACES

A dual-phase readout surface of 3x1 m^2 including the extraction grid, 12 LEM gas detectors of 50x50 cm^2 and the corresponding anodes for the charge collection in two orthogonal views were assembled for the 3x1x1 prototype at CERN. This allowed studying the LEM integration issues in this overall charge readout plane (CRP) which can be adjusted with respect to the LAr level. The 3x1x1 detector collected data for several months acquiring a detailed operational experience of such a large surface, which had not yet been attempted before. In parallel, characterization studies and stand-alone tests at cold were conducted in order to design larger supporting structures for CRP elements of 3x3m^3 to be used to equip the 6x6x6 prototype and eventually the 10kton dual-phase modules.

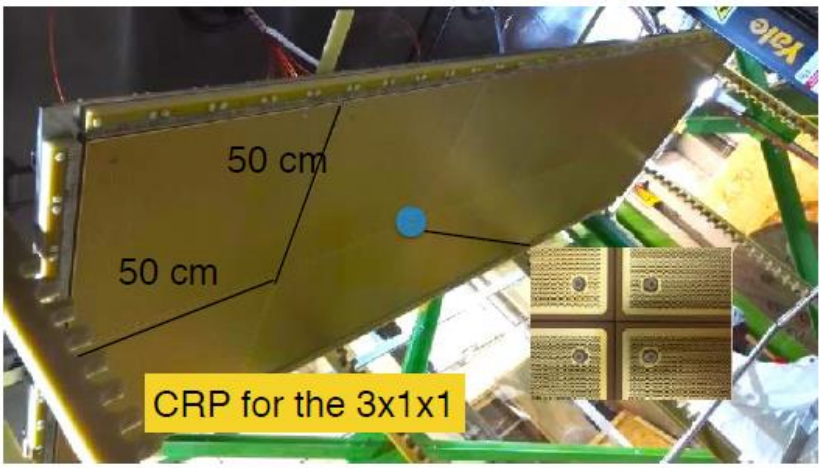

Fig. 1: Bottom view of the charge readout plane for the 3x1x1 prototype, integrating 50x50 LEM detectors.

2.3. CRYOGENIC DP ACCESSIBLE ELECTRONICS

Efforts focused on the design and on producing accessible cryogenic dual-phase electronics for the 3x1x1 and the 6x6x6 detectors. The accessibility to the electronics is provided by the “chimneys” which are long pipes closed at the bottom by a cold flange, which ensures tightness of the chimney inner volume with respect to the cryostat volume containing pure argon. Front-end cards with cryogenic ASIC amplifiers can then be plugged on the top side of these flanges by using insertion blades. The front-end cards are then operated at about 100 K, at a short distance from the CRP, but they can be removed at any moment without contaminating the LAr contained in the cryostat. 4 chimneys and 20 front end-cards, for 1280 readout channels, were installed on the 3x1x1 detector at the end of 2016. The system has been operating for slightly more than one year. This experience

allowed studying the noise at warm and at cold and validating the concept of extracting/inserting the cards via the chimney when the detector was operating.

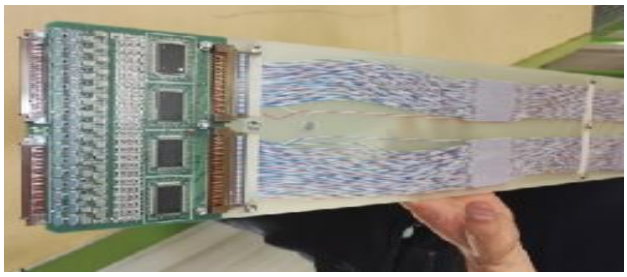

Fig. 2: A front-end card with 4 cryogenic ASIC amplifiers mounted on a supporting blade for insertion in a chimney

2.4. HIGH BANDWIDTH DAQ SYSTEM FOR GIANT LIQUID AR DETECTORS

Another effort of 8.3 is the development of high-bandwidth, low-cost digitization systems for giant LAr detectors. This activity was focused on the design and production of uTCA AMC digitization cards with 64 channels granularity and 10 Gbit/s bandwidth (see Fig.3) . The large bandwidth allows for operation without zero suppression at a sampling frequency of 2.5 MHz and 12 bits dynamics. 20 cards for 1280 channels were installed at the end of 2016 on the 3x1x1 detector and have been operating for slightly more than one year. A larger production has been performed in order to equip the 6x6x6 detector for 7680 channels. The 3x1x1 detector collected a large data set of cosmic ray events (see Fig.4). Event reconstruction studies using also the PANDORA software are ongoing in synergy with WP3.

Fig. 3: Picture of a 64 channels uTCA digitization card for the ionization charge readout

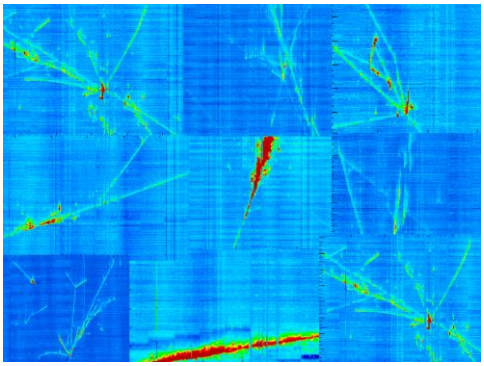

Fig. 4: A collection of event display of cosmic ray tracks acquired with the 3x1x1 prototype

2.5. SYNCHRONIZATION SYSTEM FOR GIANT LIQUID AR DETECTOR

An innovative aspect developed concerns the timing and synchronization systems for large detector. The sampling of the different digitization cards has to be aligned; absolute time, clocks and triggers have to be distributed to these units. The developments focused on the use of White-Rabbit in order to design a timing-trigger network to be distributed to the digitization cards in the uTCA crates. White –Rabbit allows for sub-ns synchronization with automatic calibration of the distributions of the transmission delays and very cheap implementation schemes. This activity implied also the design of a White-Rabbit uTCA slave node and a modification of the protocols and firmware in order to distribute signals time-tags via the same network in order to deal with the handling of triggers. This development is fully integrated in the High Bandwidth DAQ development.

3. REFERENCES

L. Zambelli and S. Murphy. WA105: A large demonstrator of a liquid argon dual-phase TPC. Journal of Physics: Conference Series888, 012202 (2017). http://stacks.iop.org/1742-6596/888/i=1/a=012202

Murphy, S. The WA105-3x1x1 m3dual phase LAr-TPC demonstrator. PoSICHEP2016(2016). arXiv:1611.05846.

Symmetry Magazine, 23/6/2017, World's biggest neutrino experiment moves one step closerS https://www.symmetrymagazine.org/article/worlds-biggest-neutrino-experiment-moves-one-step-closer

ANNEX: GLOSSARY

Acronym	Definition
LNG	Definition of Liquid Natural Gas
LAr	Liquid Argon
LEM	Large Electron Multipliers (micro-pattern gas detectors, also called "thick GEM")
DP	Dual-Phase: ionization charge readout technique which implies the extraction of the ionization charge from liquid argon to the gas argon phase and its amplification in avalanche process occurring in high field regions of micro-pattern gas detectors.
CRP	Charge Readout Plane: the readout plane which in dual-phase detectors incorporates micro-pattern gas detectors and can be individually adjusted at a precise distance parallel to the liquid argon surface
uTCA	MicroTCA is an open standard embedded computing specification
White-Rabbit	Timing synchronization protocol based on synchronous Ethernet combined with the exchange of PTP packets