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AIDAinnova

Advancement and Innovation for Detectors at Accelerators

Horizon 2020 Research Infrastructures project AIDAINNOVA

MILESTONE REPORT

PIXEL OPTIMISATION

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Abstract:

This task focuses on the development of novel pixel readout technologies to be integrated into next generation large liquid argon detectors. The goals of this task are the design and optimisation of an integrated light & charge readout tile for a kt-scale liquid argon module. This document reports on simulations developed at INFN-MiB, CIEMAT and UNIMAN, as well as tests made at LHEP.

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Delivery Slip

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1. INTRODUCTION

The LArTPC technology, in the last decade has witnessed several novelties, preparing the stage for the next generation of large-scale long baseline neutrino experiments such as DUNE. The design of new charge/light readout tiles with novel pixel geometry and configuration is done in the framework of a new detector concept, SoLAr. It aims to extend the sensitivities of such detectors to the MeV energy range, and expands their physics reach to observe solar neutrinos and potentially supernovae neutrinos. Even though this work package is primarily focussed on the charge readout, the core concept is centred around an integrated charge-light readout plane, consisting of pixel pads for charge collection and VUV SiPMs for direct detection of LAr scintillation light. The main challenges are to achieve low energy thresholds with an excellent energy resolution and successfully perform background rejection using pulse shape discrimination. The SoLAr concept is a possible technology choice for the DUNE 4th far-detector module which could serve as a next-generation multi-purpose observatory for neutrinos from the MeV to the GeV range. A staged prototyping program is planned to demonstrate the technology viability of the detector concept step by step. In October 2022, a small-scale SoLAr prototype was constructed and tested in LAr at Bern University.

2. E-FIELD SIMULATION FOR PIXEL OPTIMIZATION

One important aspect of the new charge tile geometries is to understand the electric drift field. A particular issue is the addition of SiPMs alongside the charge collecting pads on the same anode plane, which can introduce disturbances in the E-field lines at their endpoints near the anode. In order to understand the behaviour of E-field, simulation studies were carried out using the COMSOL package with different charge collection pad designs (Figure 1). The uniformity of the E-field and overall charge collection efficiency of different options were compared. A raised charge pad at the level of the SiPM provides the best electric field uniformity. Because this is technically and financially challenging, prototypes are now under study for assessing the charge collection performance with different designs.

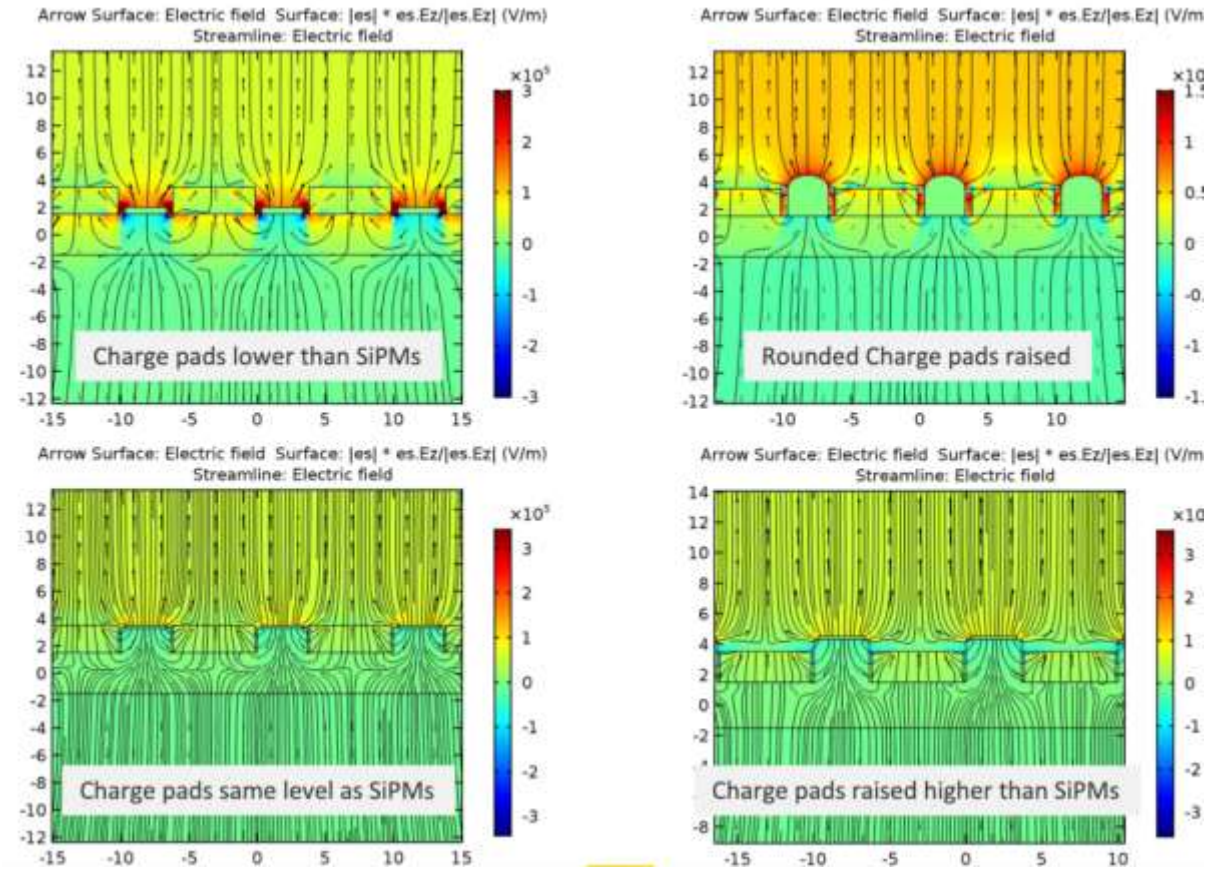

Figure 1: E-field simulations of the anode plane with SiPMs an charge collection pads

3. PROTOTYPES

3.1. SIPM TEST BENCH

In July 2022, after the delivery of the first batch of Hamamatsu VUV SiPMs (S13370-6050CN), a dedicated test setup was prepared at University of Bern to test and characterise the SiPM response to a UV LED inside a dark box at both room temperature and LAr temperature. In this test, three different designs of Flex cables, and a pre-amplification stage with possibility to float the SiPMs up to +- 300 V were tested.

Figure 2: SiPM test board, Flex cable and the Pre-amplification board

3.2. SOLAR PROTOTYPE-V1 (FIRST NOVEL CHARGE-LIGHT ANODE PLANE)

The SoLAr prototype-v1 was intended to demonstrate the feasibility of placing the charge and light readout on the same anode plane in an interleaved pattern, and verify the operation in LAr environment without inducing significant crosstalk and noise between the two readout systems. For this purpose, a small TPC with dimensions of 12 cm x 11 cm x 5 cm was designed. The dimensions were primarily restricted by the inner dimensions of a small cryostat which was intended to host the SoLAr prototype-v1 for the first test in LAr. The readout plane consists of three stacked PCBs. The outer layer hosting the LArPix ASICs, the middle layer hosting the SiPMs and the innermost layer hosting the charge collection pads. The sensitive region of the anode plane covers an area of 7 cm x 7c m and consists of 16 Hamamatsu VUV SiPMs, and a total of 256 charge pads a shown in figure 3.

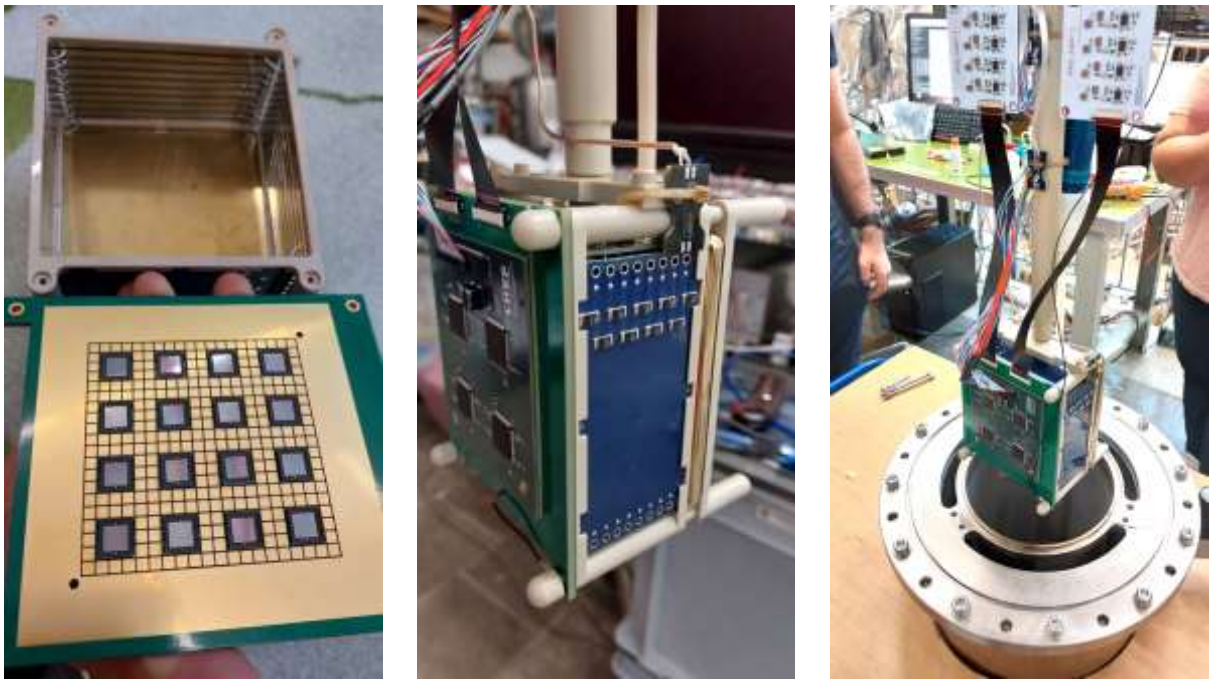

Figure 3: SoLAr Prototype-v1

The cosmics test run took place in October 2022, during which a sample of cosmic-muon data was collected. The TPC was operating with a nominal E-field of 0.5 kV/cm and a triggering line from the fast light signals were fed into the charge readout data stream as event start markers. The SiPMs were operating nominally with no floating potential. Special runs were acquired where the SiPMs were floating with a potential of -25V, -50V, -75V and -100V.

An event display from a cosmic muon track with both the light and the charged signals matched is shown in figure 4. In this display the SiPMs are displayed as larger square pads in a 4x4 array and the charge pads are displayed as smaller square pads surrounding the SiPMs and covering the entire active area.

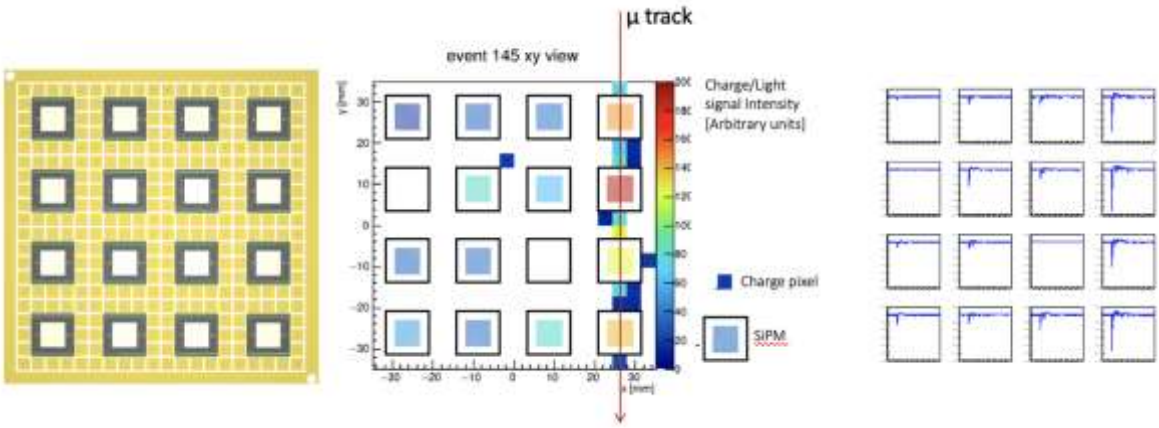

Figure 4: Event display of a muon track recorded SoLAr light and charge readouts

3.3. SOLAR PROTOTYPE-V2

The SoLAr prototype-v2, is a larger prototype, currently in the production stage. The anode tile is an 8 layer PCB and has dimensions of 30 cm x 30 cm. The sensitive area consists of an array of 8x8 identical regions with one SMD type Hamamatsu VUV SiPM in the centre surrounded by 60 charge pads of 3 mm x 3mm as shown in figure 5. The anode tile will be mounted in the Single Cube TPC setup and will be tested in LAr at Bern University in June 2023. The newly developed electronics components for this setup consist of the SoLAr Anode tile, pre-amplification board, light feedthrough, charge feedthrough and three types of flex cables.

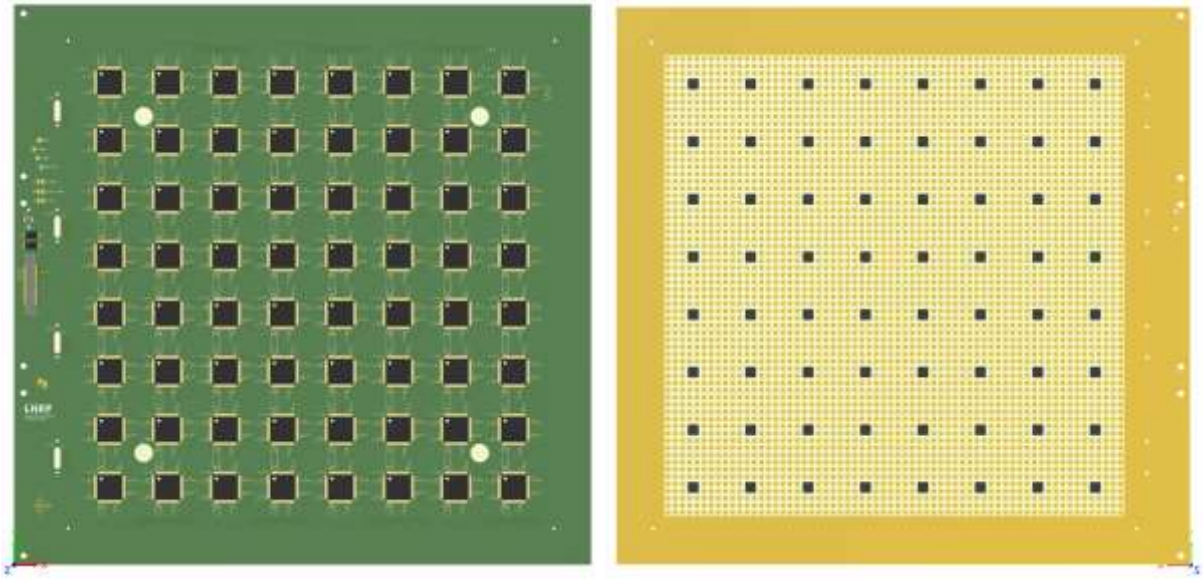

Figure 5: Anode tile for SoLAr prototype-v2. Backside (left) with LArPix readout chips. Front side (right) with square charge pads (light) and SiPMs (dark).

4. ACHIEVEMENTS:

- SoLAr Snowmass Whitepaper: arXiv:2203.07501

- Software:
  - E-Field simulations for pixel optimization (**Milestone 36**)

- Hardware:
  - VUV SiPM test (July 2022)
  - SoLAr prototype-v1 (October 2022)
  - SoLAr prototype-v2 (June 2023)

5. OUTPUT:

- CosSURF, May 2022, Nikola Mcconkey, Title: *SoLAr, Solar neutrinos in Liquid Argon*
- NNN workshop, Sep 2022, Daniele Guffanti, Title: *SoLAr, LArTPC in the next decade of Solar neutrino physics*
- MoO, Nov 2022, Anyssa Navrer-Agasson, Title: *SoLAr Concept*
- MoO, Nov 2022, Saba Parsa, Title: *4D LArTPCs, combined charge and light readout*
- DUNE CM, Jan 2023, Daniele Guffanti, Title: *SoLAr Concept*
- Boulby Workshop, Feb 2023, Stefan Soldner-Rembold, Title: *SoLAr demonstrator in Boulby*
- IOP, Apr 2023, Anyssa Navrer-Agasson: Title: *The SoLAr Concept, LArTPCs for solar neutrino physics*