Status of the Module-0 Paper

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ND-LAr Consortium Meeting

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Overview

- Paper Basics:
  - 35 pages, 41 figures
  - Authored by the full DUNE collaboration
  - Intended to be submitted to MDPI *Instruments*
- Review status:
  - Has already undergone consortium review
  - Is currently under review by the APB through specially-appointed Analysis Review Committee (ARC)

MDPI

Article

Performance of a modular ton-scale pixel-readout liquid argon Time Projection Chamber

DUNE Collaboration

† In memory of our colleague, Dr. Davide Salvatore Porzio, who is no longer with us.

Abstract: The Module-0 Demonstrator is a single-phase 600 kg liquid argon time projection chamber operated as a prototype for the DUNE liquid argon near detector. Based on the ArgonCube design concept, Module-0 features a novel 80k-channel pixelated charge readout and advanced high-coverage photon detection system. In this paper, we present an analysis of an eight-day data set consisting of 25 million cosmic ray events collected in spring 2021. We use this sample to demonstrate the imaging performance of the charge and light readout systems as well as the signal correlations between the two. We also report argon purity and detector uniformity measurements, and provide comparisons to detector simulations.

1. Overview

Charge readout in Liquid Argon Time Projection Chambers (LArTPCs) has traditionally been accomplished via a set of projective wire planes, as successfully demonstrated e.g. in the ICARUS [1], MicroBooNE [2] and ProtoDUNE-SP [3,4] experiments, and as planned for the first large detector module of the DUNE experiment in preparation at the SURF underground laboratory in South Dakota [5]. However, this approach leads to inherent ambiguities in the 3D reconstruction of charge information that present serious challenges for LArTPC-based near detectors, where a high rate of neutrino interactions and an associated high-intensity muon flux cannot be avoided. In particular, 3D reconstruction becomes limited by overlap of charge clusters in one or more projections, and the unique association of deposited charge to single interactions becomes intractable. To overcome event pile-up, a novel approach has been proposed and is being developed for the LArTPC of the near detector complex of the DUNE experiment, close to the neutrino source at Fermilab. This technology implements three main innovations compared to traditional wire-based LArTPCs: a pixelated charge readout enabling true 3D reconstruction, a high-performance light readout system providing fast and efficient detection of scintillation light, and segmentation into optically decoupled regions. By achieving a low signal occupancy in both readout systems, the segmentation enables efficient reconstruction and unambiguous matching of charge and light signals.

The Module-0 demonstrator is the first tonne-scale prototype of the DUNE Liquid Argon Near Detector (ND-LAr) design. That detector will consist of a 7×5 array of $1 \times 1 \times 3$ m^3 detector modules [6] based on the ArgonCube detector concept [7], each housing two 50 cm–drift TPC volumes with nearly 30% optical detector coverage. Module-0 has dimensions of $0.7 \times 0.7 \times 1.4$ m^3, and represents the first fully-integrated prototype of the ND-LAr module design, bringing together the innovative features of LArPix [8,9] pixelated 3D charge readout, advanced ArCLight [10] and Light Collection Module (LCM) [11] optical detectors, and field shaping provided by a low-profile resistive shell [12]. This integrated prototype also tests the charge and light system control interfaces, data acquisition, triggering, and timing. Module-0 is the first of four functionally-identical modules that together will comprise an upcoming 2×2 ND-LAr prototype, known as ProtoDUNE-ND. Following construction and initial tests with cosmic ray event samples, this larger detector will be deployed underground in the NuMI neutrino beam at Fermilab

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Published:

ARC Review

- ARC composition:
  - Mitch Soderberg (chair), Xiao Luo, José Maneira, Mike Kordosky, Michal Rigan

- Review status:
  - About 1 week ago received first round of comments from ARC
  - Andy and Pedro met with ARC on Tuesday October 11 to go through them

- General impression from the ARC:
  - This is a great paper! Worth investing time in it as it will likely be a reference for every graduate student working in the DUNE ND

Comments Received

- Most comments are related to style and/or language issues:
  - Cumbersome but not hard to implement (already in progress)
  - Issue also raised about uniformity of graphics (legend, labels, etc…)

- Most significant comments on the content:
  - Increase the amount of structure
  - Improve the flow by changing order of certain parts and/or more clearly stating goals or each section/subsection
  - Expand certain key parts (e.g. the introduction) to make the paper more accessible to people without LArTPC experience

Sample of comments received:

email	SECTION	NUMBER	STYLE/SUBSTANCE	COMMENT
makordosky@wr	assume text if empty	19	substance unless noted	Maybe need an introduction to LArTPCs and the particular features of this one and what challenges it faces/mitigates. Slowness of LArTPC , high occupancy (give #s). Why LAr in general? I'm thinking of the uninitiated reader.
		37		We dive right into the gory details. I think the overview is done at this point and we need a new section. A friendlier overview for the novice would be nice.
		39		unclear what 30% refers to. Surface area?
		111		is there a corresponding MIP value for these thresholds? It will help the reader to normalize. I know it is determined later in the paper but some foreshadowing is fine here.
		117		only a single ASIC? It can still work with multiple failures, right? I think a rephrase is needed here.
		131		The first light readout system paragraph could use a rewrite / reorganization. Perhaps needs to be split in two? I'd have to try my hand at it in order to come up with a better comment.
		132		technically scintillation light isn't emitted by charged particles. Perhaps say induced?
		132		awkward sentence. try "128 nm scintillation light emitted .. LAr" and drop "along with"
		133	style	optical detection. Is there some other kind of detection for photons? is optical needed?
		136		capable? It "is" placed inside of the field shaping structure.
		136		--> LRS uses a novel light detection...
		144	style	We write "First, ..." but there is no second or third.
		153		I think the general concept behind how these systems work should be presented earlier in this section and then delve down into the details of our particular implementation. You could split the previous paragraph around line 137 an then graft on this explanation of the general concept, then follow with details (power supply, slow controls, DAQ) later on.
		167		center module uses bis-MSB. Do we want to say why? Evaluating both coatings?
		246		instead of intrinsic fluctuations maybe say fluctuations in energy loss to be specific about what kind of fluctuations you are talking about.
		256		Here and elsewhere there are cases where a rate type of measurement is stated but the amount of exposure isn't specified. Number of triggers per what?
	figure	10		remove second "y is" in caption
	figure	12		just to make sure, this is a historgram of the FWHM of each channel?
		261		preceeding... what? The idea here is that the drifting charge creates a signal by induction before any drift electrons hit the anode? If so, could we make that clearer in the text?
	figure	13		is the exposure the same for the low and high threshold curves? I.e., is the normalization meaningful?
	figure	13		I may be slow but how do we derive hits/mm? Isn't the segmentation 4mm? We just divide by 4? Is this a histogram or a plot of an average quantity vs hit charge (profile histogram?)

Plan

- Andy and Pedro will continue going through all the comments
  - Directly incorporate some and delegate the rest to subsection / plot editors
  - Hope to communicate delegated comments in ~1 week, together with some guidelines on the plots

- Get back to ARC in 2-3 weeks