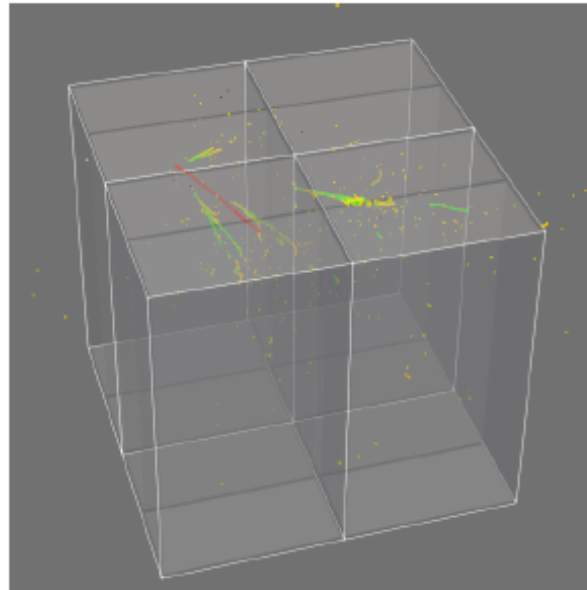


# 2x2 in the ND-LAr consortium

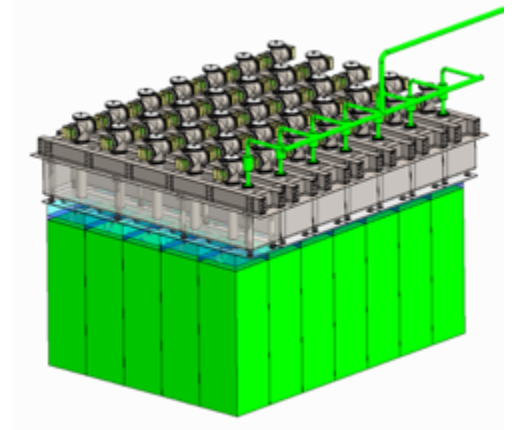
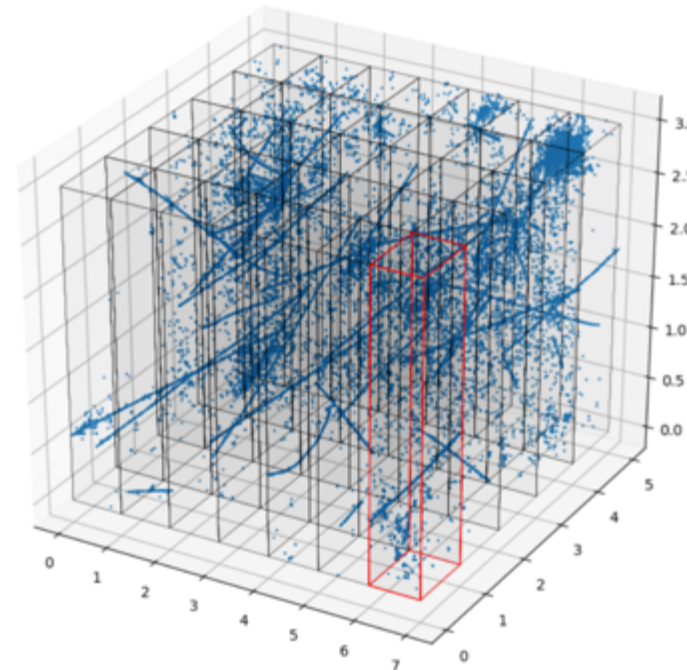
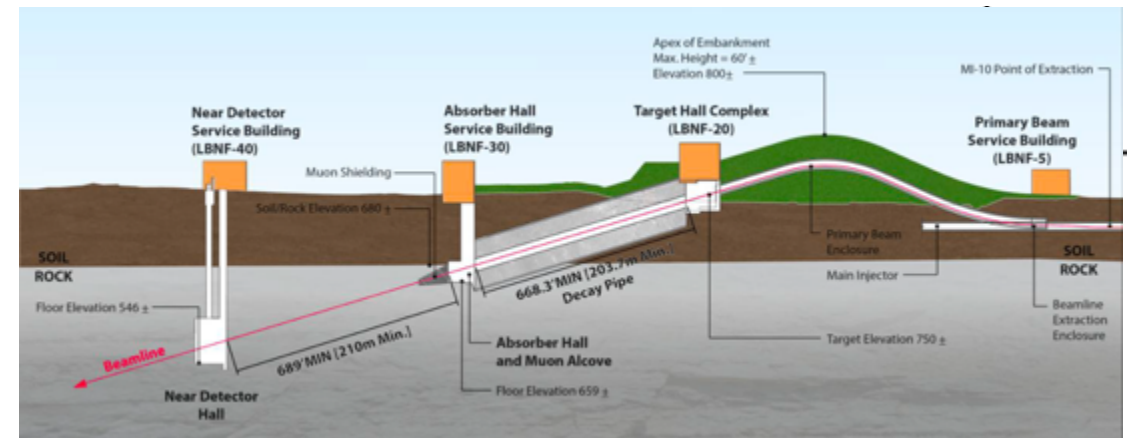
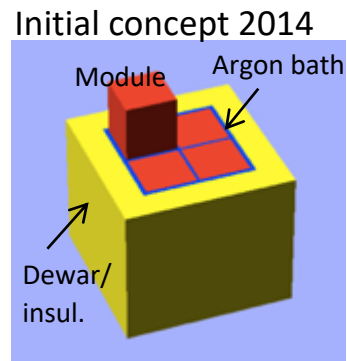


(b)  $E_\nu = 3.36$  GeV

M. Weber  
LHEP/AEC, University of Bern

# DUNE/LBNF near detector

- Neutrino oscillations are measured from the distribution of  $\nu_{\mu,e}$  CC events at the far detector (FD) and the near detector (ND)
  - ND predicts distributions at the FD from production, oscillation, interaction, and detector response
- Challenge
  - High event density
  - High event rate (pile-up)
- Modular approach
  - Reduced risks
  - Contained light
  - Distributed production
  - LArTPC V2.0

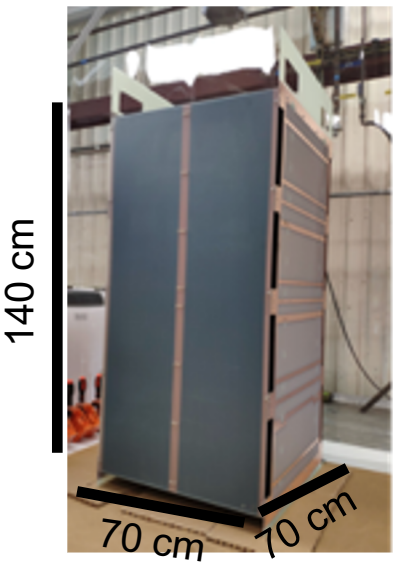


“The core of the near detector is a liquid argon TPC based on the ArgonCUBE design [developed and originally proposed by the Bern group]”

# ND LArTPC: From Prototyping to Production to Installation

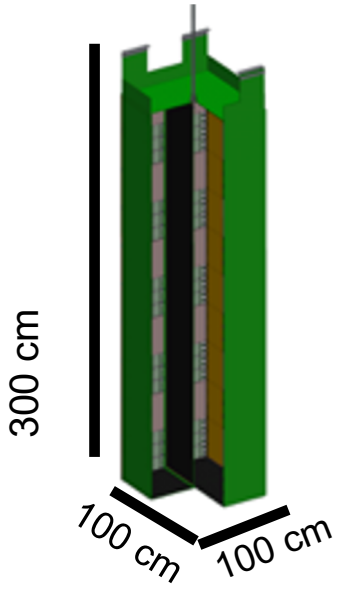
**2019-2021**

**Module 0**  
SingleCube,  
then 1 module (Module 0),  
then 4 modules (2x2)  
Operated in cryostat at Bern,  
then FNAL in NuMI beam



**2022-2023**

**Full-scale ND Demonstrator**



**ArgonCube 2x2 (2021--)**



**2024-2027**  
**Production and testing**

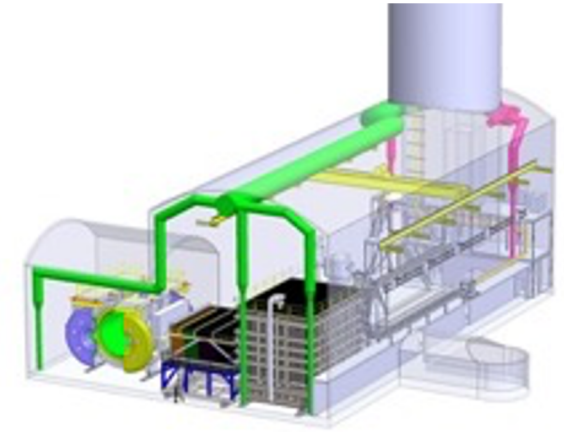
35 (+5) Production modules  
Each fully tested in single-module cryostat  
LAr Test at MATF @ FNAL



**2028-2029**  
**Installation**

Assemble rows of 5 modules  
Support of TPC module  
installation in Near Site

Activity driven by Near  
Site Integration (NSI)




**Neutrino event Reconstruction**

# Timeline and high-level dependencies

- Module-0 test are completed  
They inform the Preliminary Design Review PDR, calendar Q4 2021
- **2x2 analysis from NuMI events will inform the Final Design Review (FDR) → Q3 CY 2023**
  - **Goal:** satisfy the reconstruction and physics requirements
- **Will need to iterate over reconstruction and simulation**
- **Will need initial data from the neutrino beam in CY 2022**  
**High level milestone**
- **Start of neutrino beam operation underground at NuMI in October/November 2022 is critical**







**ProtoDUNE-ND proposal to place the ArgonCube 2x2 Demonstrator on-axis in NuMI**

Bern: Lead institute, R&D, overall design, controls, readout, cryostat, module construction, integration, tests, shipping

BNL: module, HV      Argonne: computing

Colorado: lab tests

Fermilab: host, cryogenics, infrastructure, integration

JINR: light readout      Harvard: simulations, cosmic rays

Michigan state: calibration      SLAC: reconstruction, E-Field, HV

Stony Brook: operation, ND integration      Berkeley: Pixel readout

Rochester: Trigger/DAQ, muon tagging      Pennsylvania: flux

UTA: lab tests, module R&D      Sheffield: module mechanics

Yale: simulations, lab tests

29.1.19 M. Weber      FLARE Panel Presentation DUNE      6

Proposal document to Fermilab ND  
(Jan 2019, DUNE-DocDB-12571)

iCRADA 2019 for DUNE and 2x2

INTERNATIONAL  
COOPERATIVE RESEARCH AND DEVELOPMENT AGREEMENT  
FOR  
BASIC SCIENCE COOPERATION  
(HEREINAFTER "CRADA") NO. FRA-2018-0032

BY AND AMONG  
FERMI RESEARCH ALLIANCE, LLC  
UNDER ITS U.S. DEPARTMENT OF ENERGY CONTRACT  
NO. DE-AC02-07CH11359  
TO MANAGE AND OPERATE  
FERMI NATIONAL ACCELERATOR LABORATORY  
(HEREINAFTER "LABORATORY")  
AND  
UNIVERSITY OF BERN  
(HEREINAFTER "PARTICIPANT")  
LABORATORY AND PARTICIPANT COLLECTIVELY REFERRED TO  
AS THE "PARTIES" AND SEPARATELY AS A "PARTY"



www.snf.ch  
Waldhainweg 3, Postfach 8232, CH-3001 Bern

Application form mySNF

2x2 funded by Swiss Grant  
(2019–2021)

Instrument FLARE

Part 1: General Information

Basic data

<b>Project Title</b>	FLARE: The DUNE/LBNF neutrino experiment	
<b>Project title in English</b>	FLARE: The DUNE/LBNF neutrino experiment	
<b>Research Field</b>	Mathematics, natural sciences	
<b>Main Discipline</b>	20403 Particle Physics	
<b>University</b>	Universität Bern - BE	
<b>Applicant(s)</b>		
<b>Main Applicant</b>	Michael Weber	
<b>Other applicant(s)</b>	Antonio Ereditato Igor Kreslo	
<b>Grant Application</b>		
<b>Amount requested (CHF)</b>	Total	1'120'000
<b>Related to project no.</b>	173599	
<b>Requested starting date</b>	01.04.2019	
<b>Duration (months)</b>	24	

2021: 2x2 as FNAL/PAC approved test experiment

# Prototyping plan and DUNE-ND CDR

## ND-LAr Consortium Prototyping Plan

Last Updated: 10 Sep. 2020 by D. Dwyer

### Overview

The prototyping plan for the Near Detector LArTPC detector will address a specific set of technical targets between now and the initiation of detector production. Prototyping activities fall into two categories: component-level and integration-level prototyping. Component prototyping is generally addressed via stand-alone small-scale tests, and the majority of these tests have been completed over the recent years of the ArgonCube R&D program. Integration prototyping addresses how these components come together and function coherently within the ND LArTPC design, as well as demonstrating the large-scale production and assembly processes necessary to construct the Near Detector.

### Integration Prototyping Plan

There are two stages to the integration prototyping plan: the ArgonCube 2x2 Demonstrator stage and the subsequent Full-scale Demonstrator stage. The 2x2 Demonstrator is a complete, but sub-scale, LArTPC detector system focused on verifying technical readiness of the ND LArTPC design before the completion of the Near Detector design phase. The Full-scale Demonstrator is a single production-scale LArTPC module that will validate the full-scale component production, assembly, and testing processes before the Consortium proceeds to Near Detector production.

## Deep Underground Neutrino Experiment (DUNE)

### Near Detector Conceptual Design Report

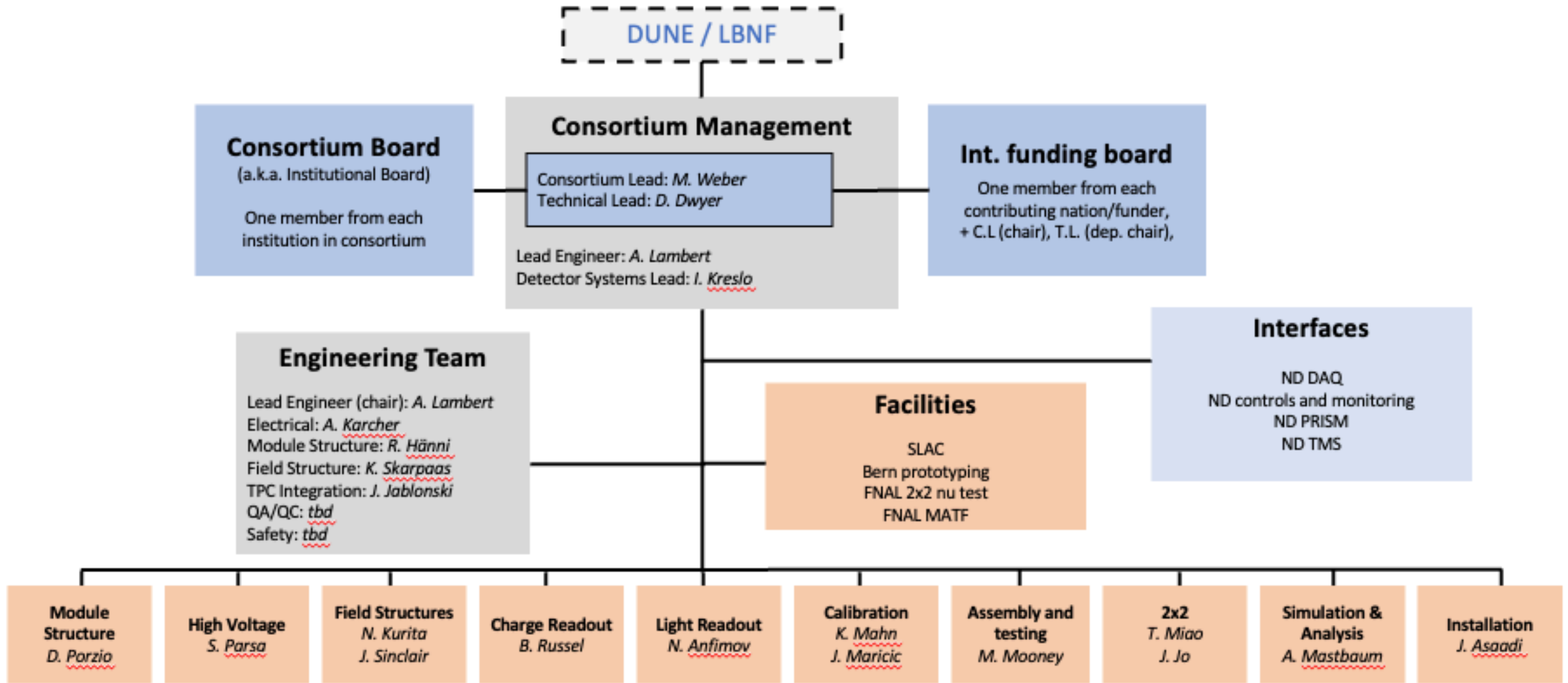
DUNE ND CDR arxiv:2103:13910

Mar 2021

March 26, 2021

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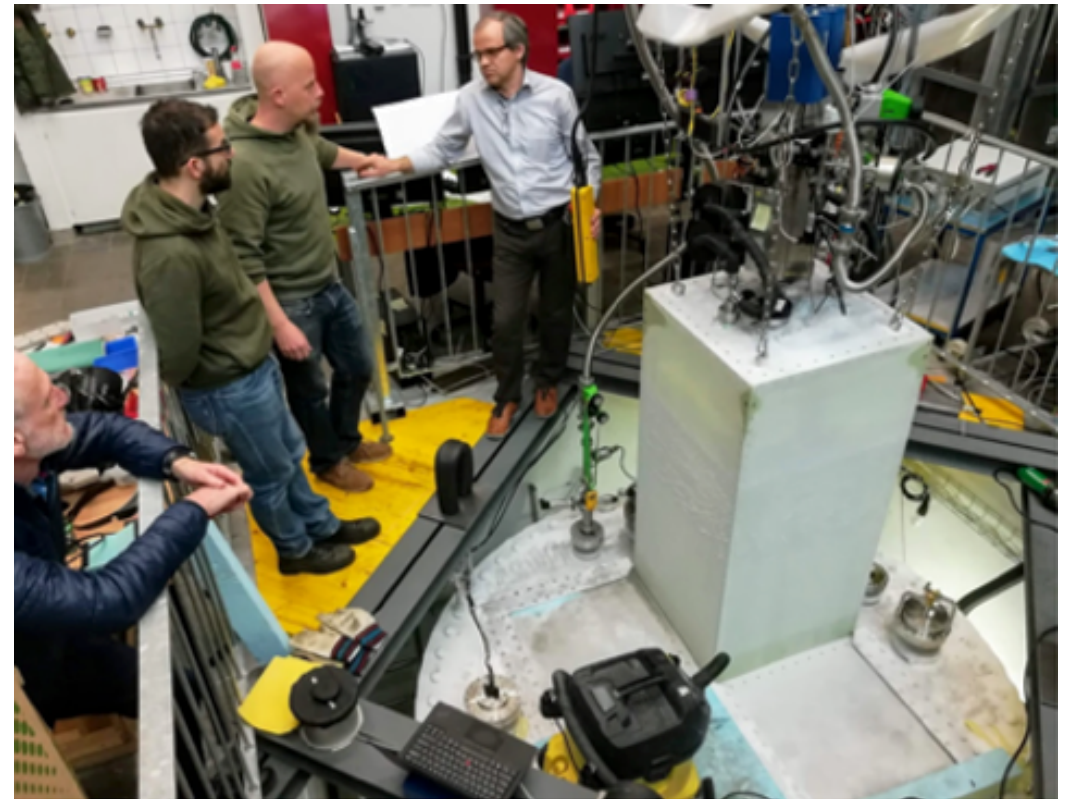
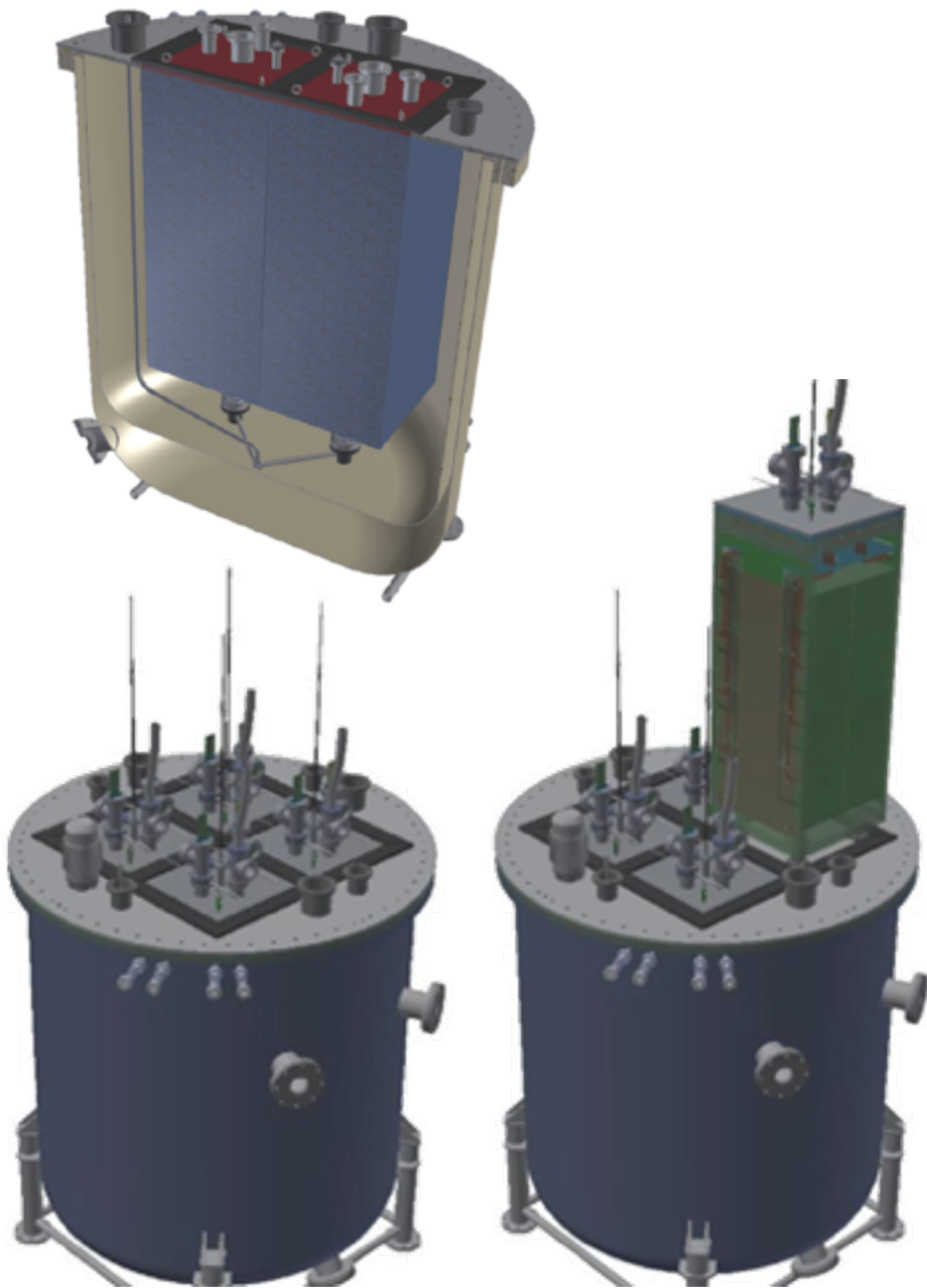
# Organization: DUNE International – ND-LAr Consortium



# ND LAr Consortium (red = 2x2 involvement)

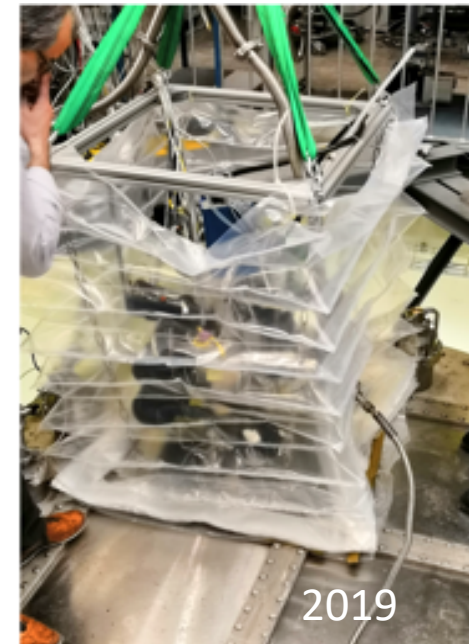
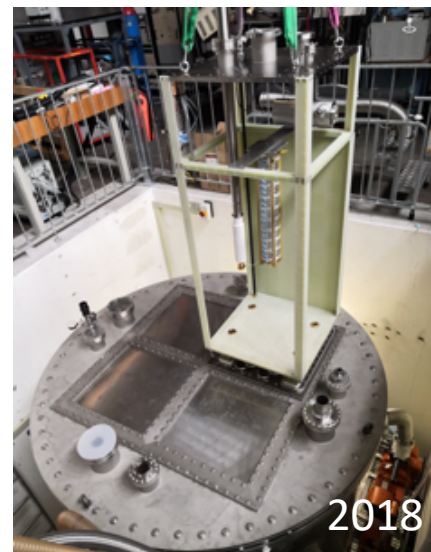
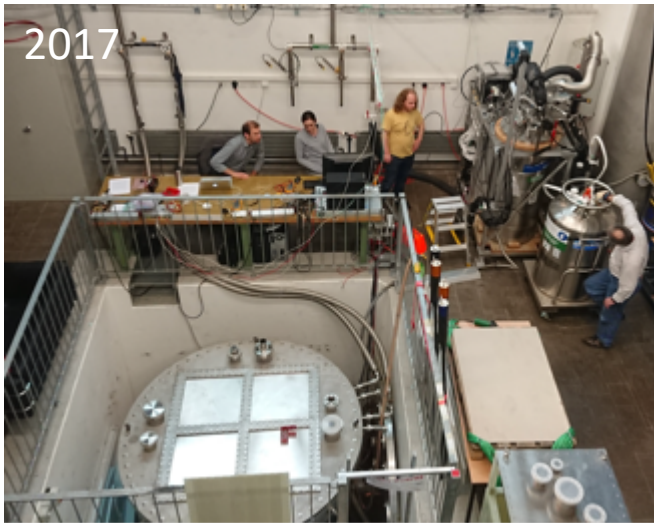
- **ANL**
- **U Bern**
- BNL
- **Caltech**
- U Cambridge
- **CSU**
- **UColorado**
- **Fermilab**
- **Houston**
- **Iowa**
- **JINR**
- **Lancaster**
- **LBNL**
- Manchester
- **Minnesota Duluth**
- MSU
- Penn
- **Rochester**
- **Rutgers**
- Sheffield
- **SLAC**
- **Tufts**
- **UC Berkeley**
- UC Davis
- UC Irvine
- **UC Santa Barbara**
- **UTA**
- Warwick
- Wichita State
- **William&Mary**
- **Yale**
- **York**





# Cryostat (2x2)

- Cryostat arrived in Bern in 2015
- Initial tests and rebuild 2016
- Cryogenics setup 2017
- Initial run 2018
- Runs for module extraction 2019

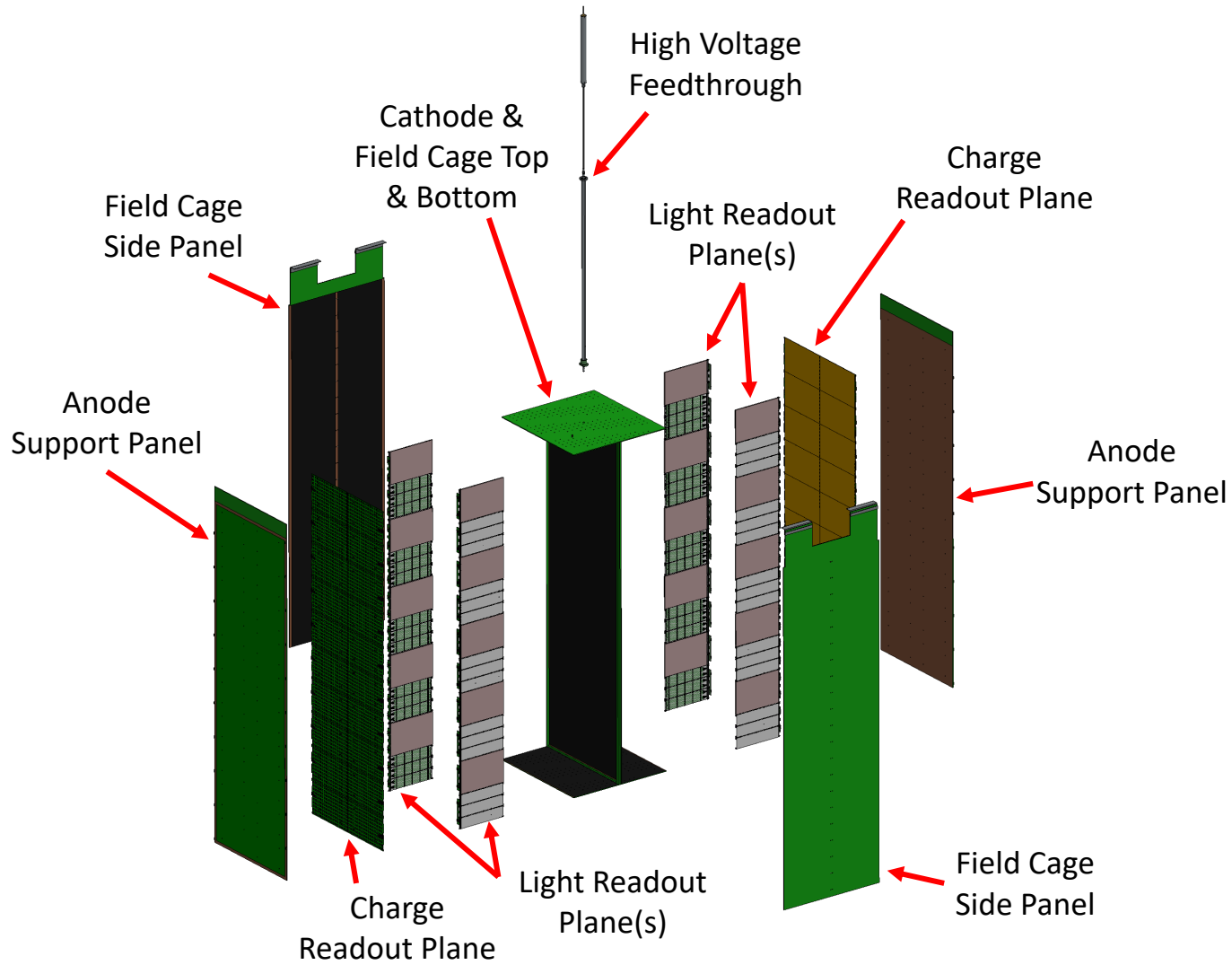






**Pressure/vacuum test successful 6/8/2021**

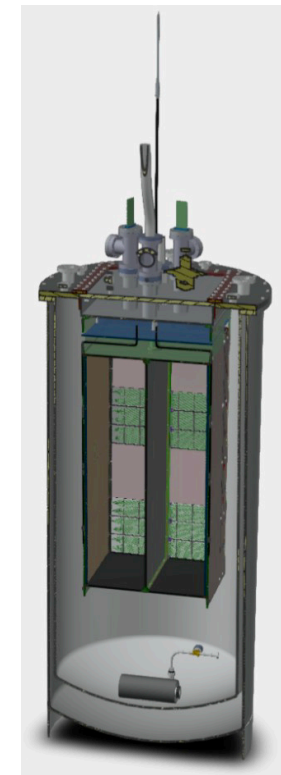
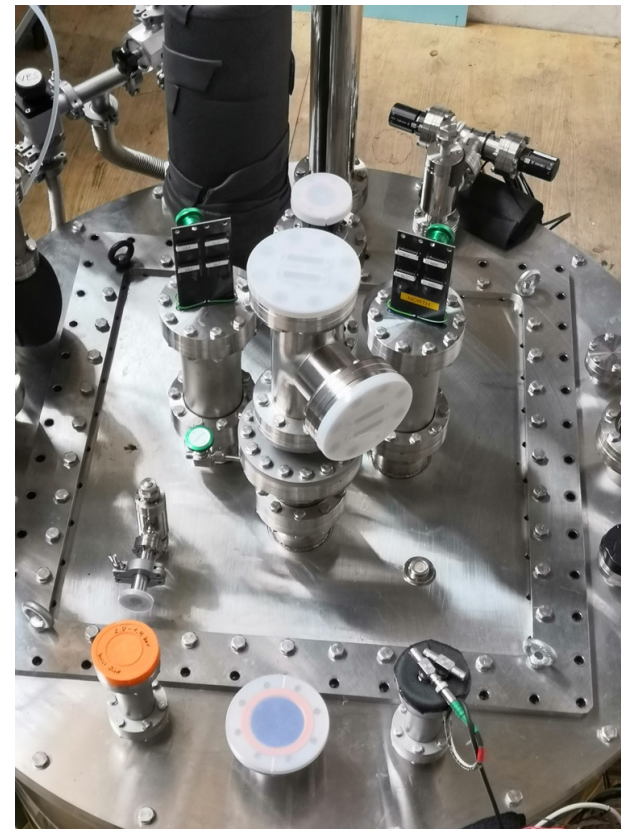
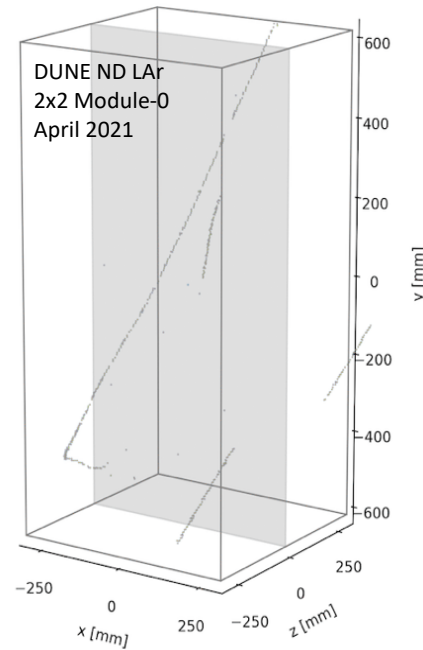
Arrival at FNAL in July 2021





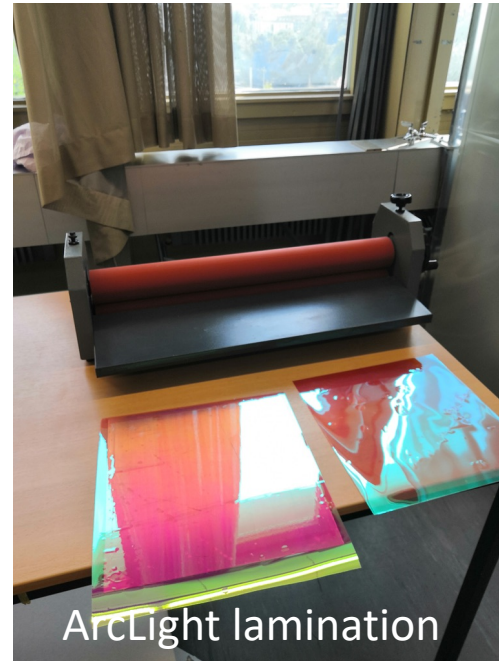
# Successful Module-0 runs (first of 4 modules)

April and June 2021



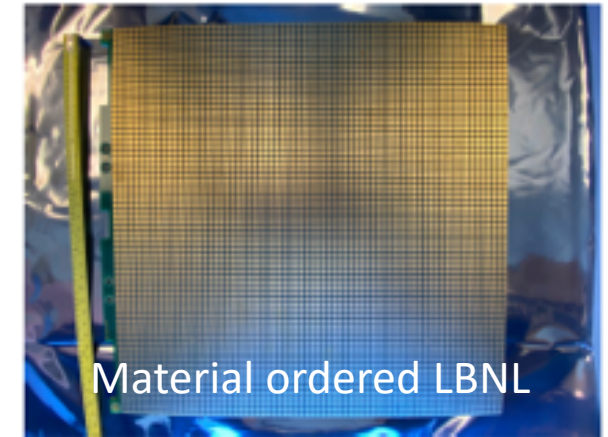
- Inserted in the single-module cryostat (waiting-position for shipping)
- Shipping crate design ongoing (engineering meeting scheduled this week)
- Shipment hopefully in August

# Building more modules (light and charge collection)



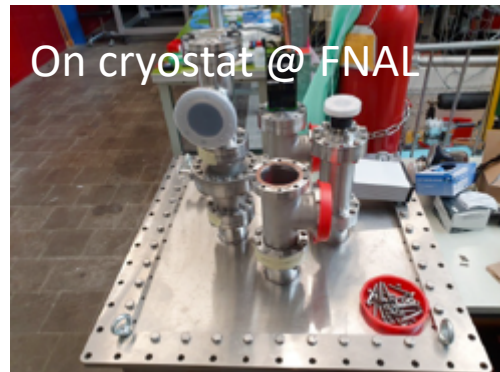
ETA  
September 2021

LArPix-v2 Pixel Anode  
4.9k pixels



ETA  
2021 for one additional module  
Early CY 2022 for all modules

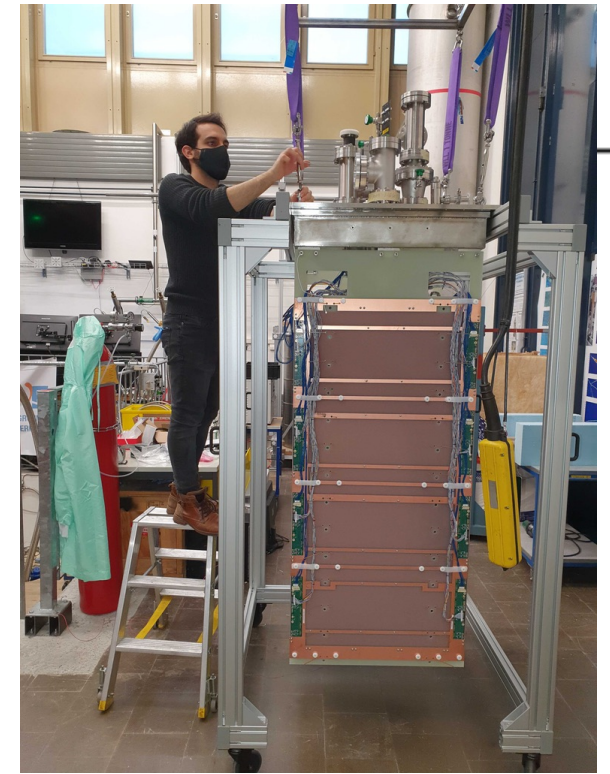
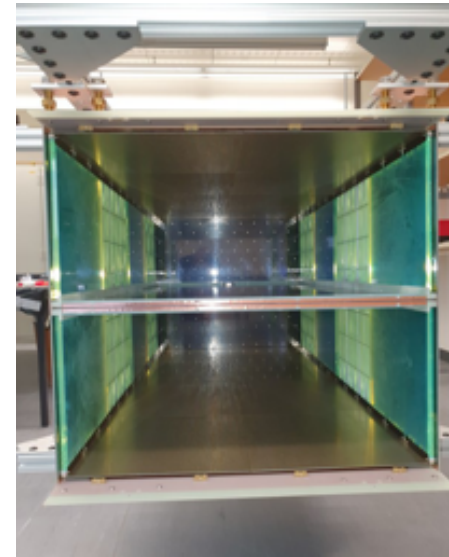
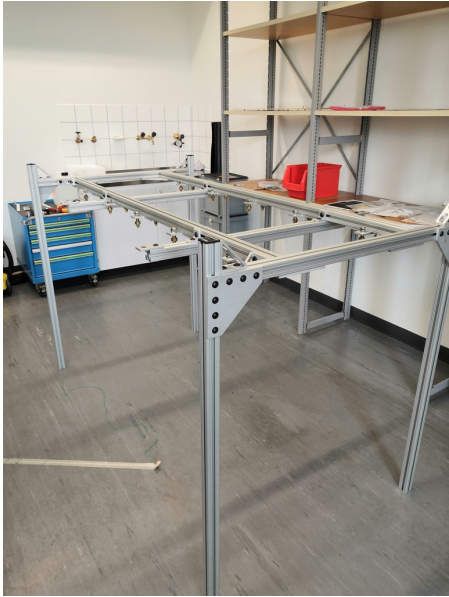




ETA field shell  
G10 support ordered  
DR8 resistive foil 50% delivered  
End 2021/early 2022 with same technology

Top flange also serves as cryostat seal  
Will ship back to Bern as new modules arrive at FNAL

# Module assembly and testing



ETA couple weeks per module assembly + 1 week checkout

Plus LAr-testing: **timeline defined by cooldown-warmup of testing setup (weeks)**

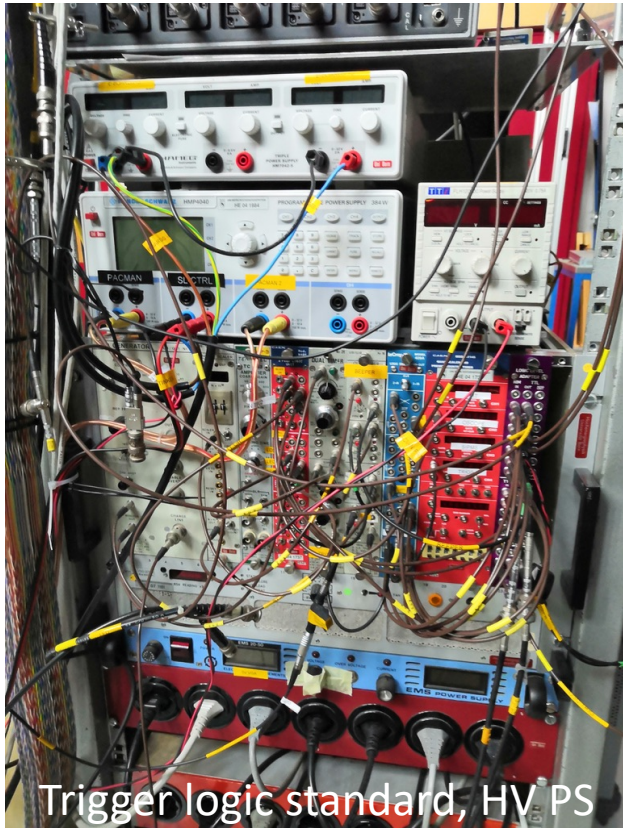
Expecting parts in Bern in late CY 2021 for one more module, assembly and testing in CY 2021  
3<sup>rd</sup> and 4<sup>th</sup> modules in early 2022.

Parallelize assembly and testing of modules in Bern to speed-up if needed.



# Readout & powering

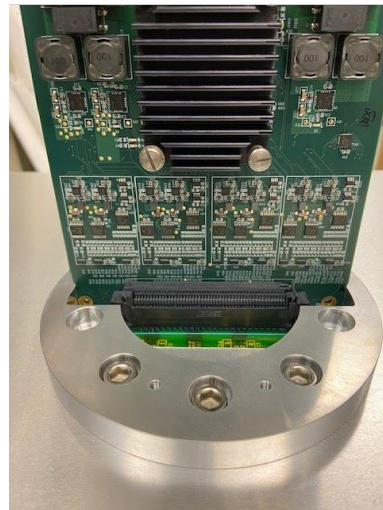
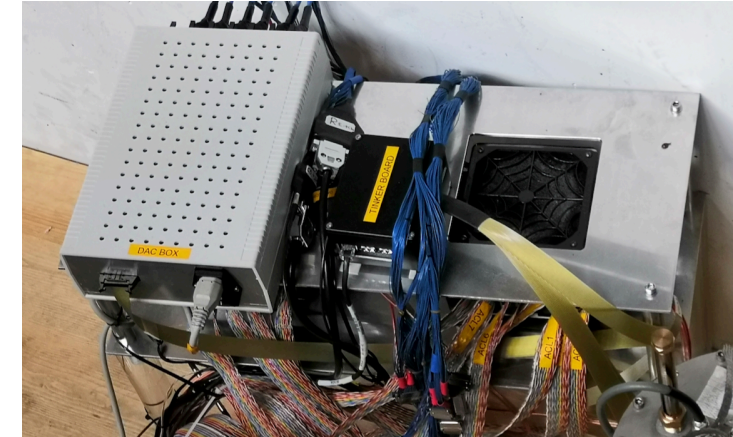
Several components:  
either ship what we have in Bern  
and duplicate for Bern;  
or wait for new copy and deliver to FNAL



Trigger logic standard, HV PS



HV filter available,  
can be duplicated



Charge r/o



Light r/o



# Readout and controls

Readout server (standard with ethernet)

Slow-control & PLC systems ready and used in Bern

Will be shipped to FNAL

A replica for Bern being built



# ArgonCube reconstrcuton and analysis

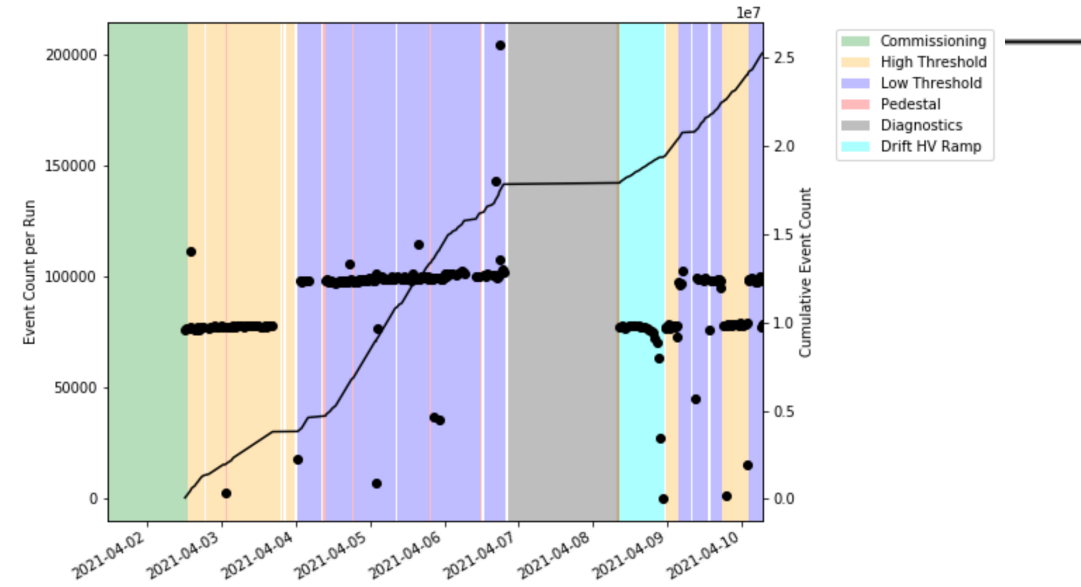
- Paper on analysis of Module-0 data
- Initial reconstruction of charge/light track/shower

## 11 Contents

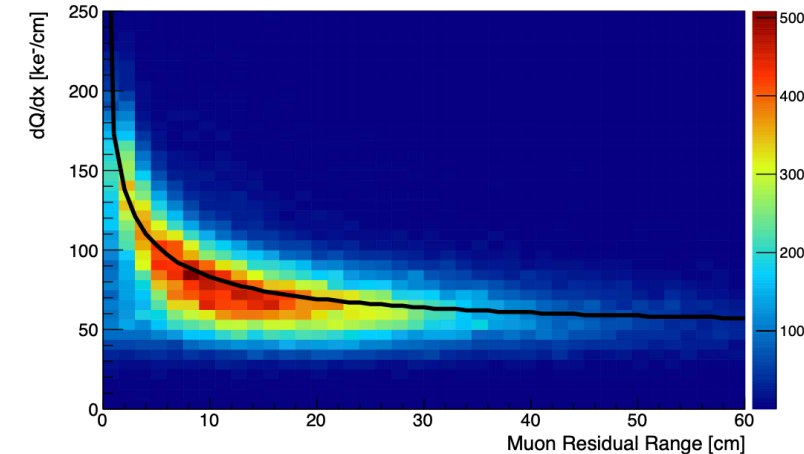
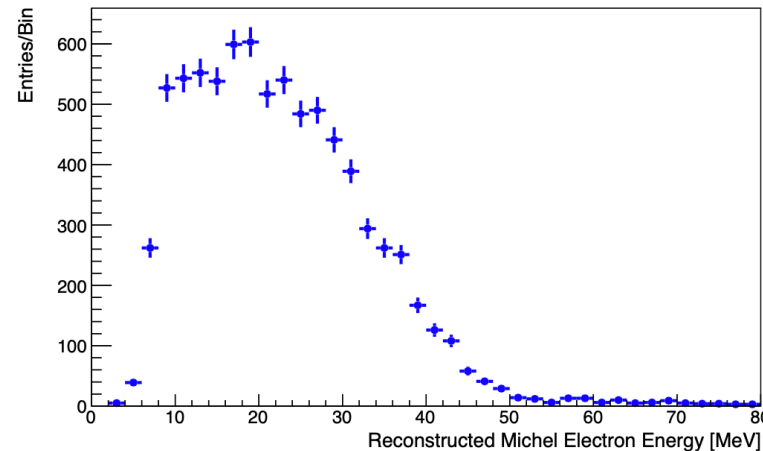
12	<b>1 Overview</b>	<b>1</b>
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~25 million events collected over  
~1 week of operation

$u^b$



## High-stats stopping muon sample: Michel e- spectrum and muon energy loss.



# End-to-end analysis by end CY 2021

- Integrate light+charge in simulation
- Complete reco chain: from basic (energy, light deposition) to high level (neutrino vertex/event) reco
- ML + conventional
- Neutrino + rock

(Mini-)Workshop

[ML] Reco (2)		CAFs (1)	Interfaces (1)	Light (1)	Pileup (1)
Improve track/shower	Read detector simulation	Revisit numu CAF analysis	Truth matching	Basic light simulation integration	Revisit G4
Interaction level reco		Revisit nu+e CAF analysis	ND-LAr sample production	Truth matching	Adapt MicroBooNE algorithms
	M0 Data/MC		GAr/MPD matching	M0 Data/MC	Smeared Q + L analysis
Full-chain on det. sim.		Revisit low-nu		Model tuning	
Model training		Revisit det. opt.	Model dist'n/VCS	Electronics sim	Integrate reco Q
numu reco	nue reco	Implement numu	Q/L data model	Model tuning	Reco Q + smeared L analysis
		Implement nue	Metadata & DBs	Light system Q/position reco	
Hadron reco	nu+e reco	Implement hadron & mis-IDs	Long-term production strategy	M0 Data/MC	Optimization
	Michel reco				
Documentation		Documentation	Documentation	Documentation	Documentation



# Summary

- 2x2 a main activity of the ND-LAr consortium
- **Critical to record good quality NuMI neutrino data starting in Nov 2022**, mission critical for DUNE
- Effort ongoing for 4+ years, internationally funded, getting to the final phase (neutrino beam)
- Most detector components in hand or can be assembled as needed
  - charge readout and field shell on critical path
- Analysis / reconstruction / simulation effort to ramp up for being ready on day-1



2x2 cryostat at FNAL, 28 July 2021  
Yes, it is the 2x2 cryostat.