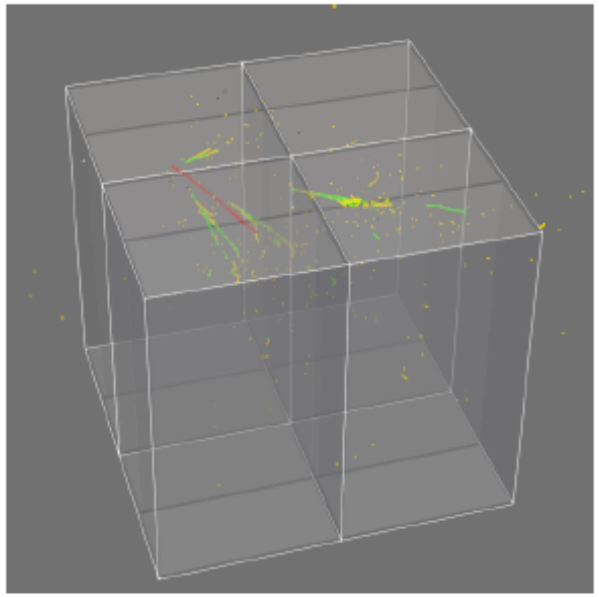
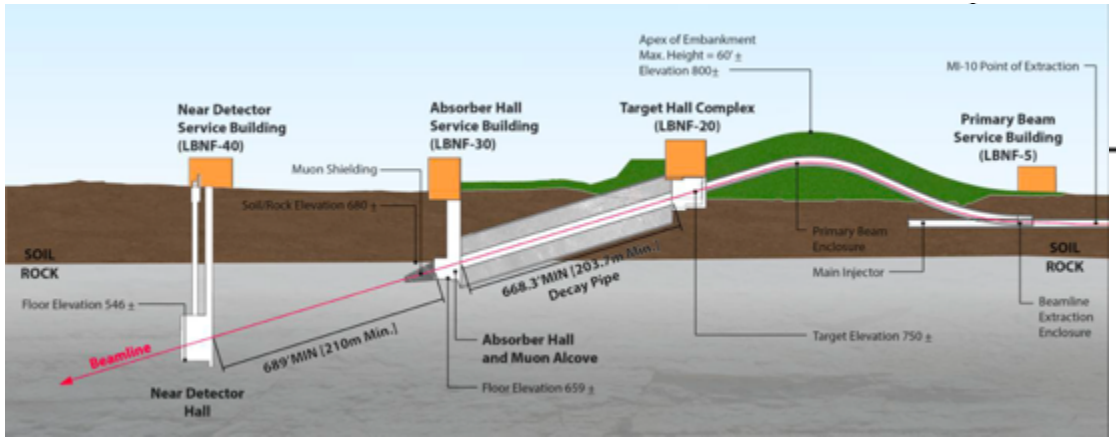
2x2 in the ND-LAr consortium



(b) $E_\nu = 3.36$ GeV

M. Weber
LHEP/AEC, University of Bern

DUNE/LBNF near detector

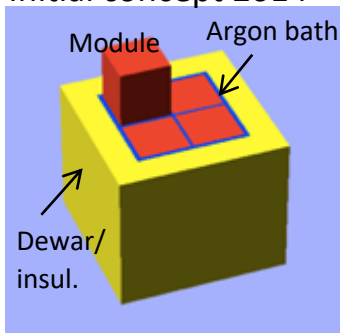


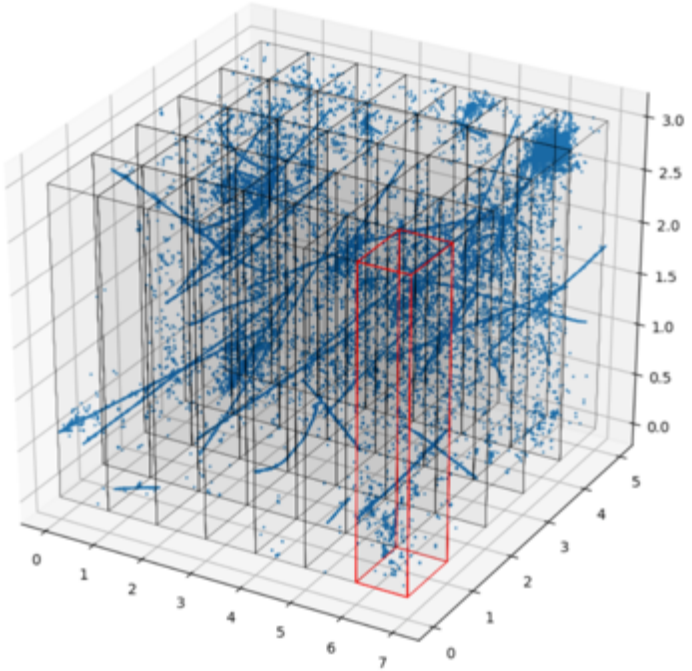
- Neutrino oscillations are measured from the distribution of νμ,e CC events at the far detector (FD) and the near detector (ND)
  - ND predicts distributions at the FD from production, oscillation, interaction, and detector response

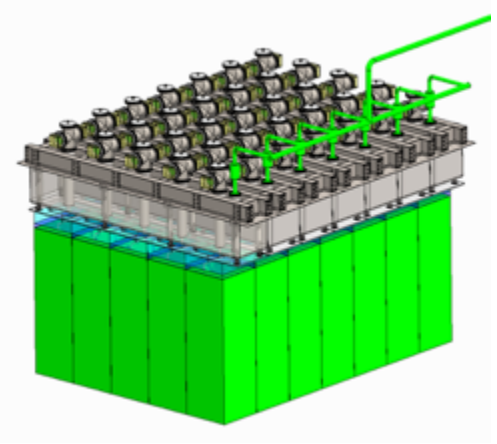
- Challenge
  - High event density
  - High event rate (pile-up)

- Modular approach
  - Reduced risks
  - Contained light
  - Distributed production
  - LArTPC V2.0

Initial concept 2014







"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

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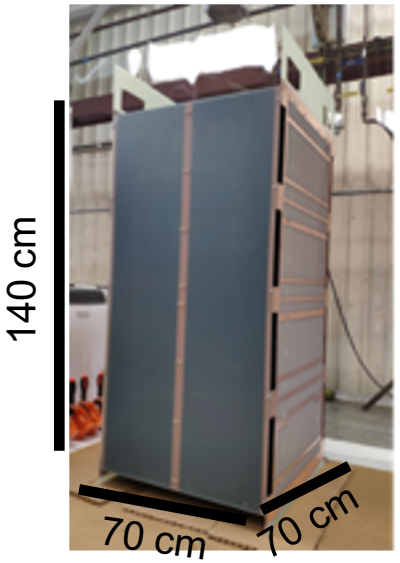
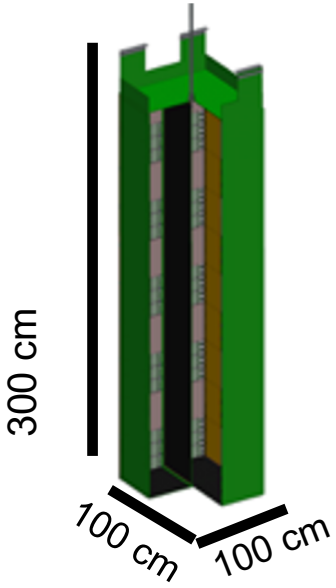
2019-2021

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--)

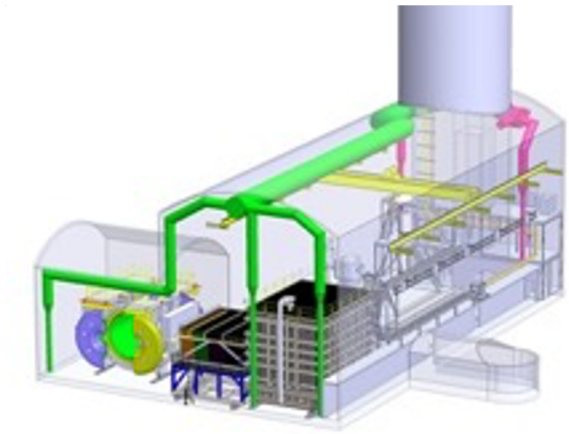
2024-2027
Production and testing

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

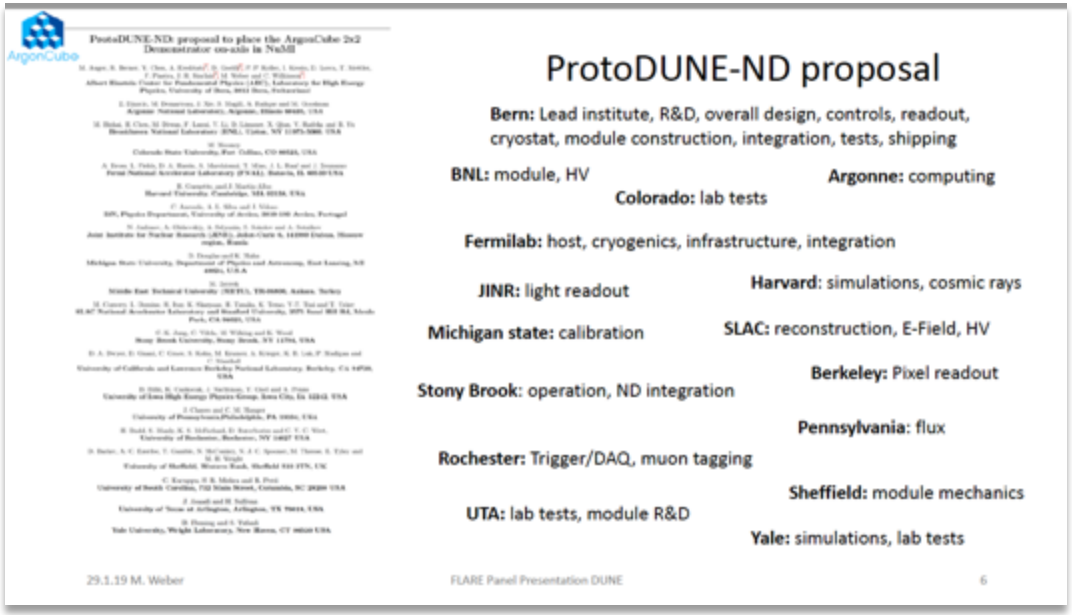
Activity driven by Near Site Integration (NSI)



Neutrino event Reconstruction

Timeline and high-level dependencies

- Module-0 test are completed
  They informs 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: proposed to place the ArgonCube 2x2 Demonstrator on-axis in NuMI

ProtoDUNE-ND proposal

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

Berkeley: Pixel readout

Stony Brook: operation, ND integration

Pennsylvania: flux

Rochester: Trigger/DAQ, muon tagging

Sheffield: module mechanics

UTA: lab tests, module R&D

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"

SNF Swiss National Science Foundation

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

Application form mySNF

Instrument **FLARE**

Part 1: General Information

Basic data

Project Title	FLARE: The DUNE/LBNF neutrino experiment
Project title in English	FLARE: The DUNE/LBNF neutrino experiment
Research Field	Mathematics, natural sciences
Main Discipline	20403 Particle Physics
University	Universität Bern - BE

Applicant(s)

Main Applicant	**Michael Weber**
Other applicant(s)	Antonio Ereditato
	Igor Kreslo

Grant Application

Amount requested (CHF)	Total	1'120'000
Related to project no.	173599	
Requested starting date	**01.04.2019**	
Duration (months)	**24**	

2x2 funded by Swiss Grant
(2019–2021)

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.

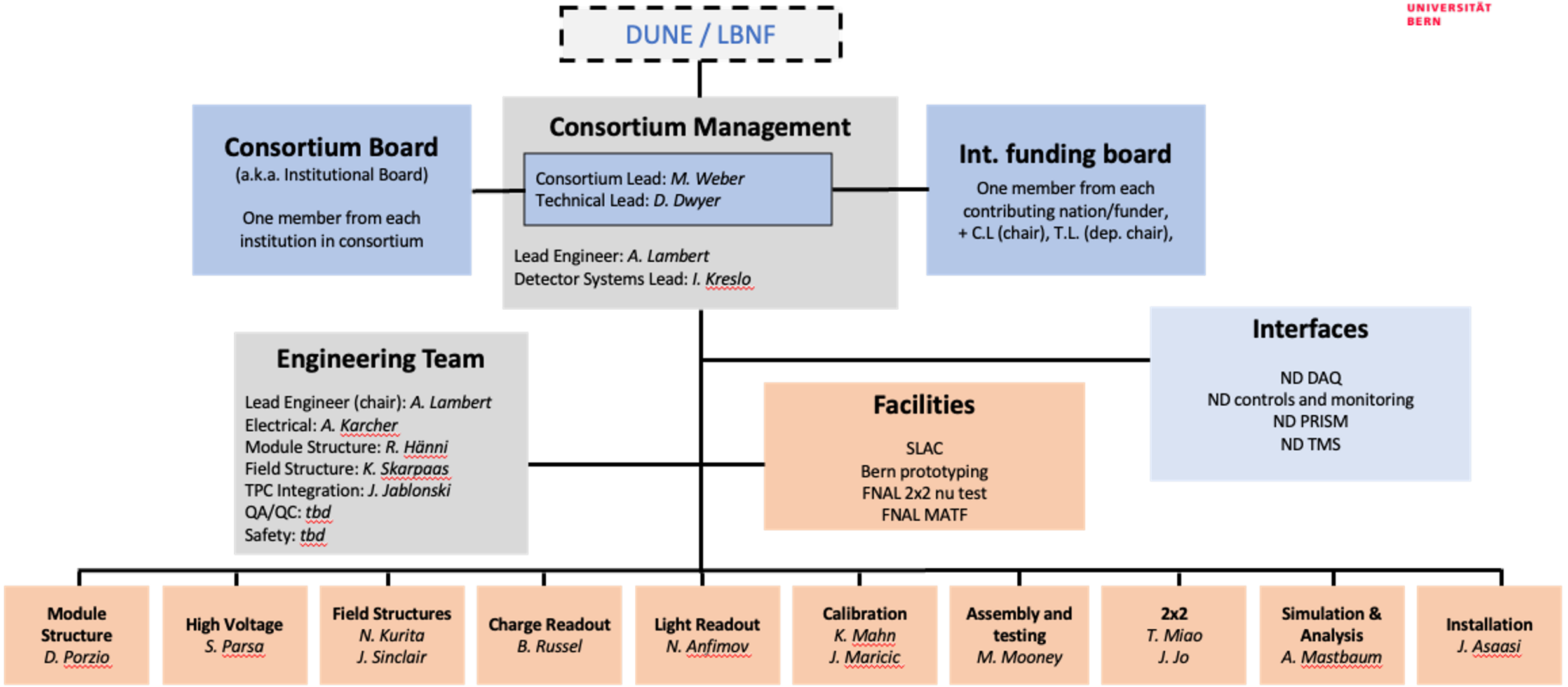
Deep Underground Neutrino Experiment (DUNE)

Near Detector Conceptual Design Report

DUNE ND CDR arxiv:2103:13910

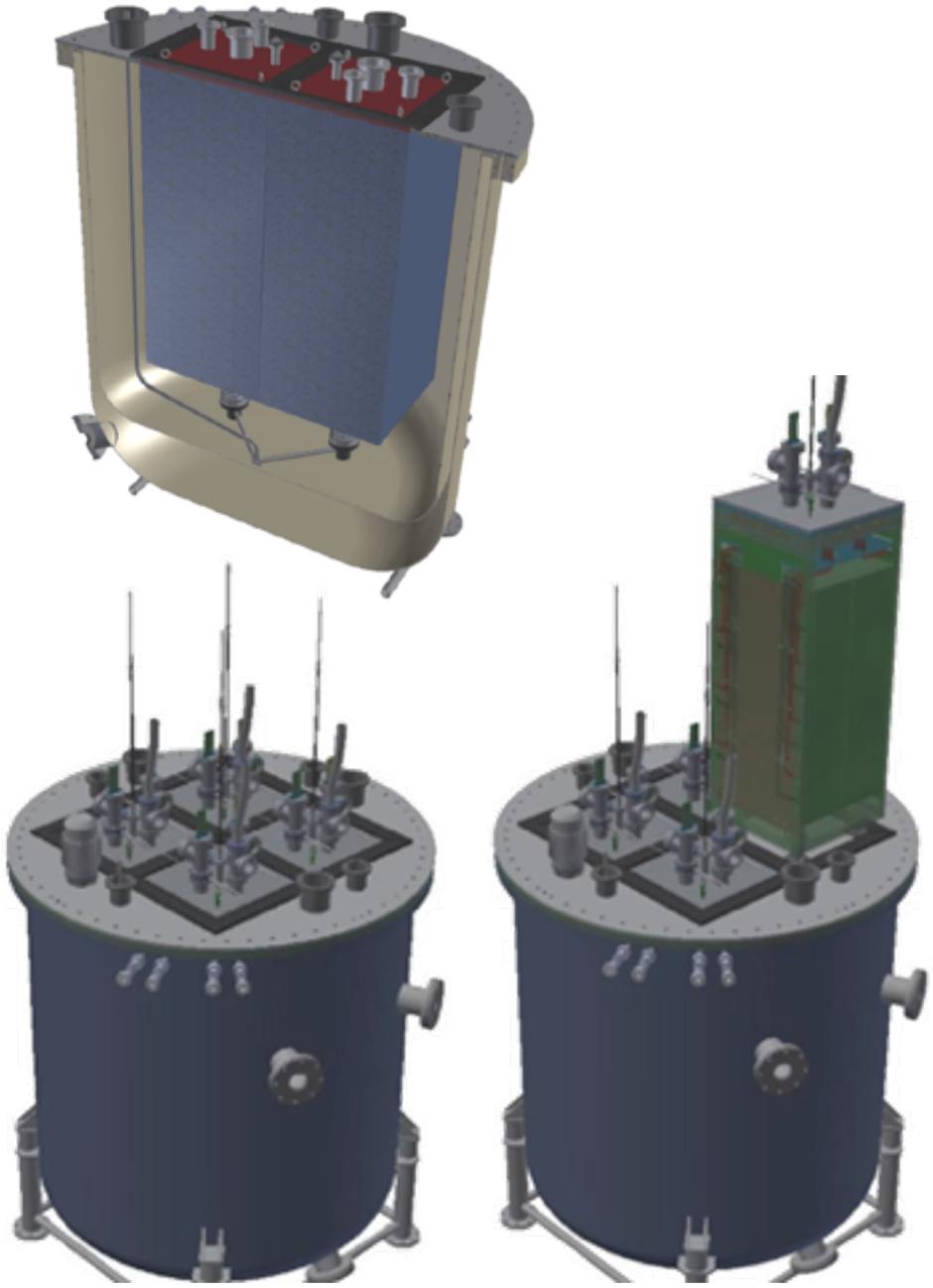
March 26, 2021

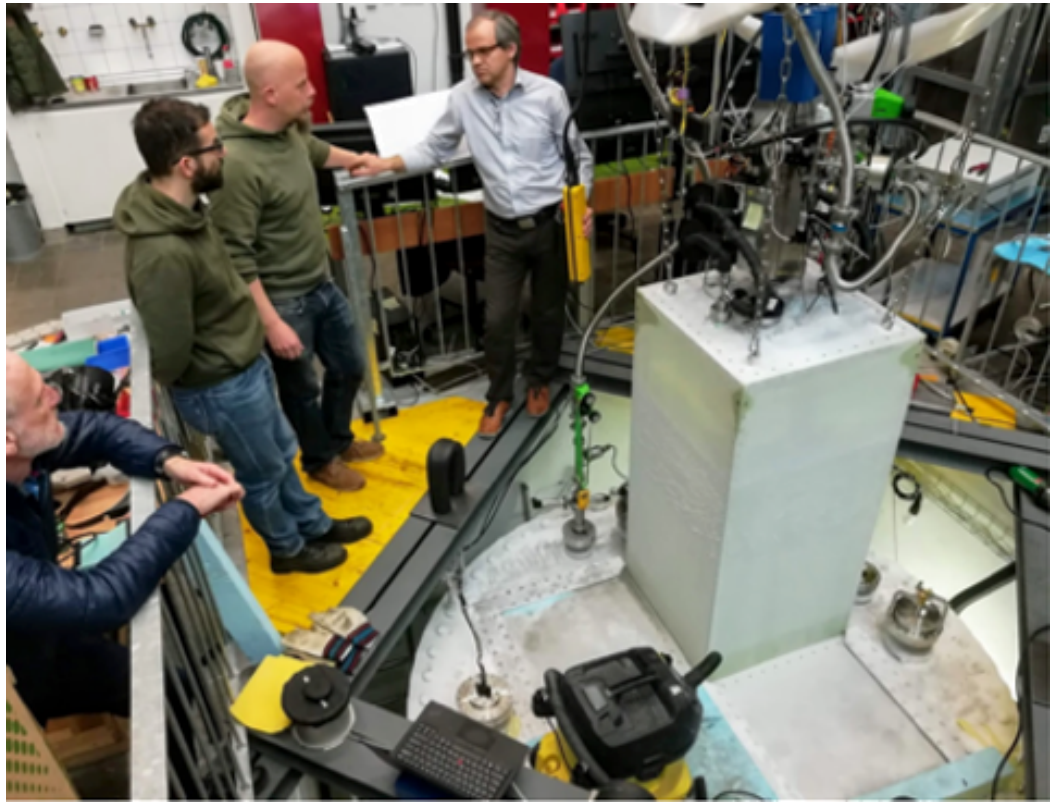
Organization: DUNE International – ND-LAr Consortium



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**

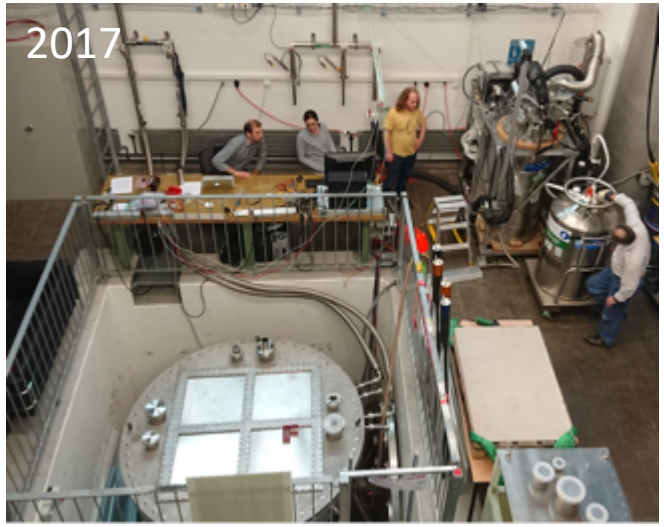


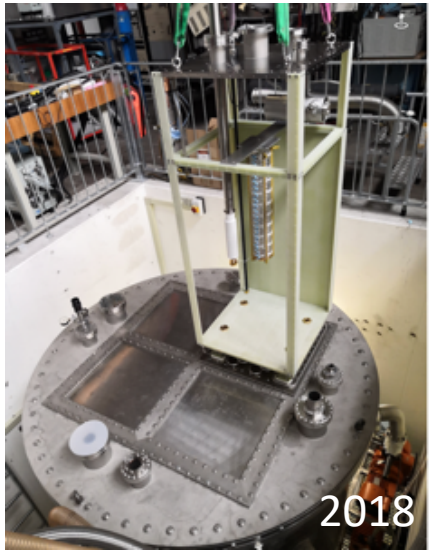


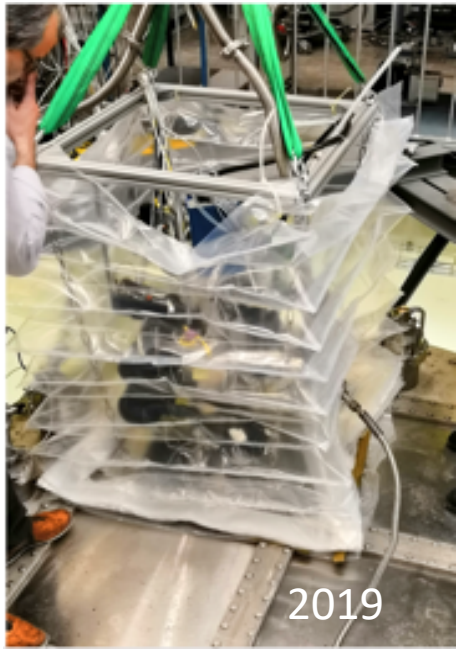
Operation in Bern 2019

Cryostat (2x2)

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

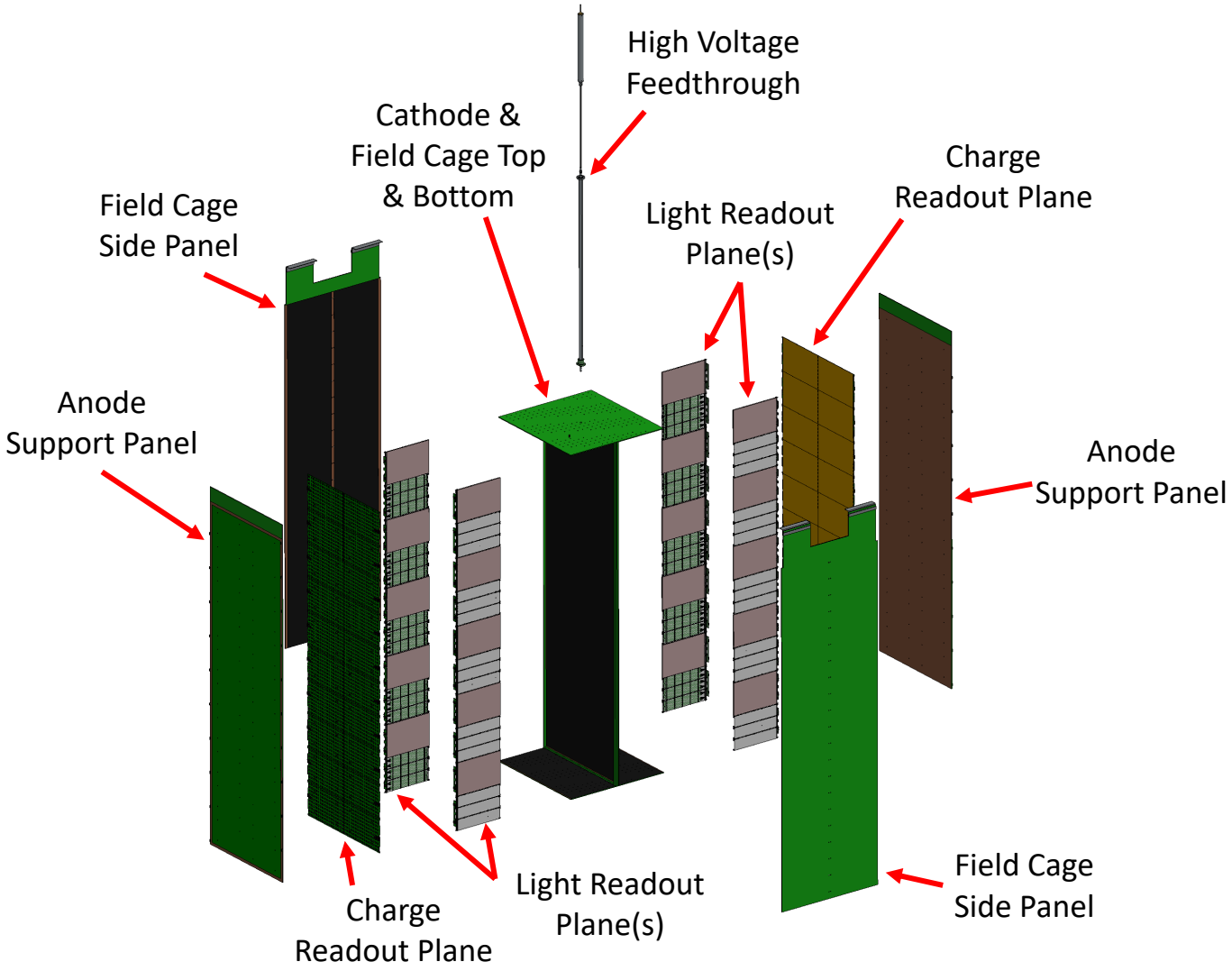


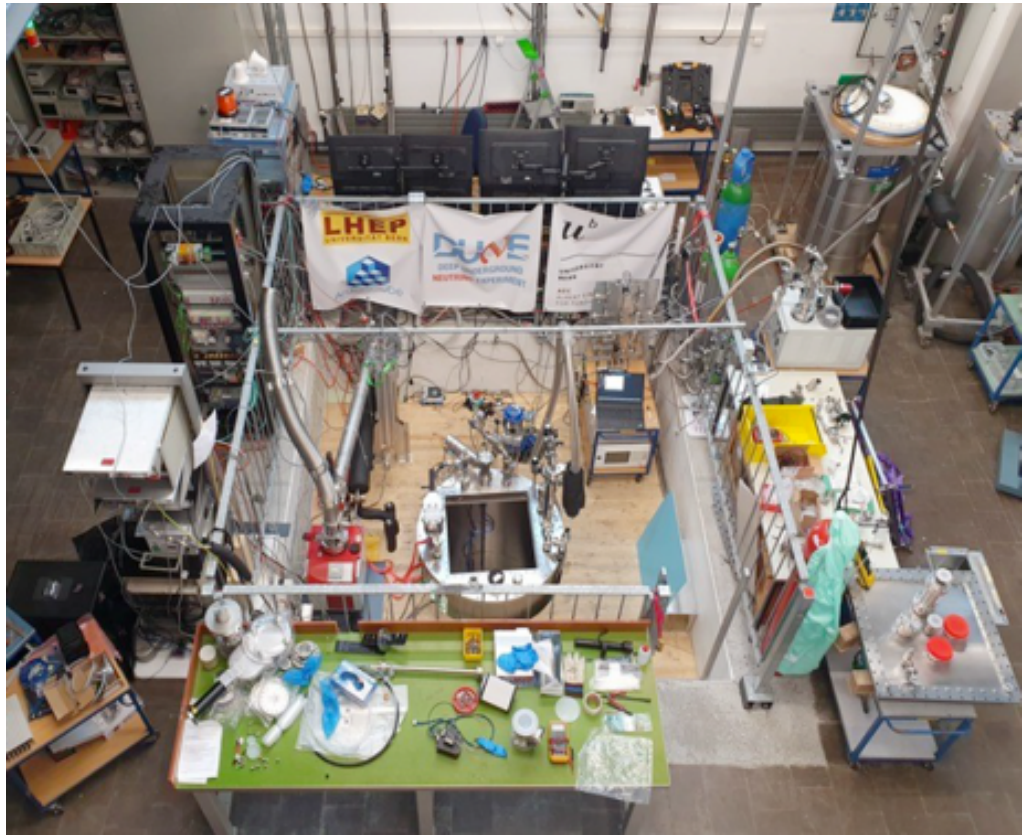




Pressure/vacuum test successful 6/8/2021

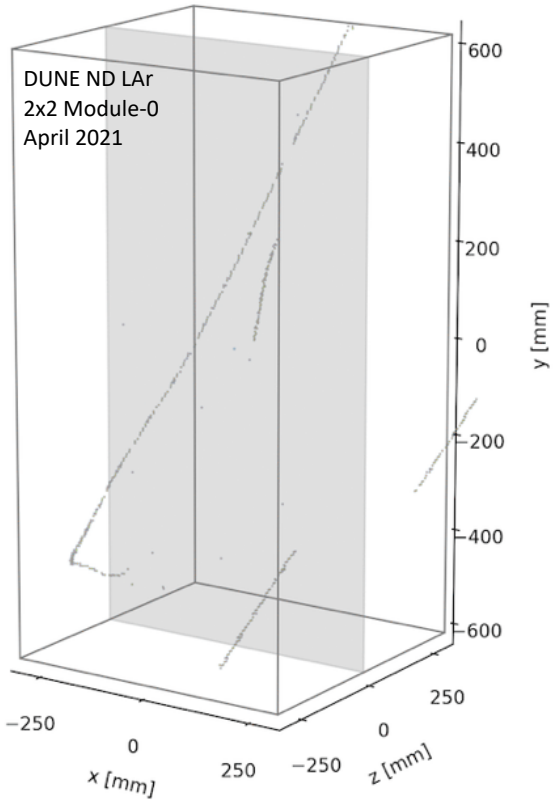
Arrival at FNAL in July 2021

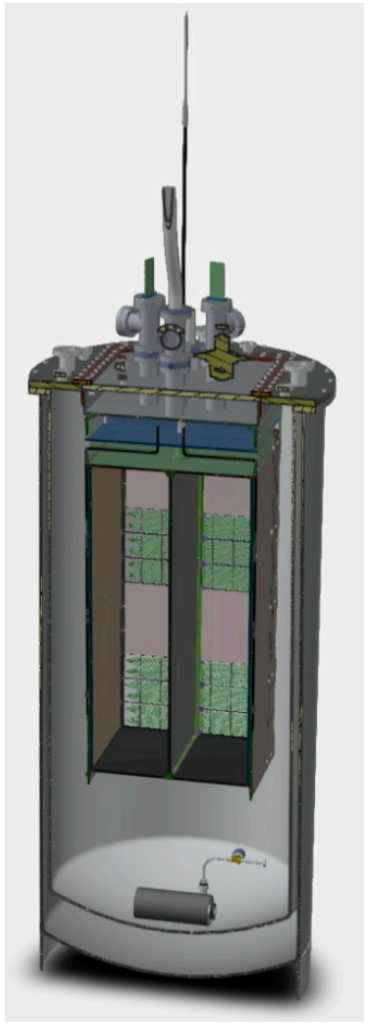

High Voltage
Feedthrough
Cathode &
Field Cage Top
& Bottom
Field Cage
Side Panel
Light Readout
Plane(s)
Charge
Readout Plane
Anode
Support Panel
Anode
Support Panel
Charge
Readout Plane
Light Readout
Plane(s)
Field Cage
Side Panel

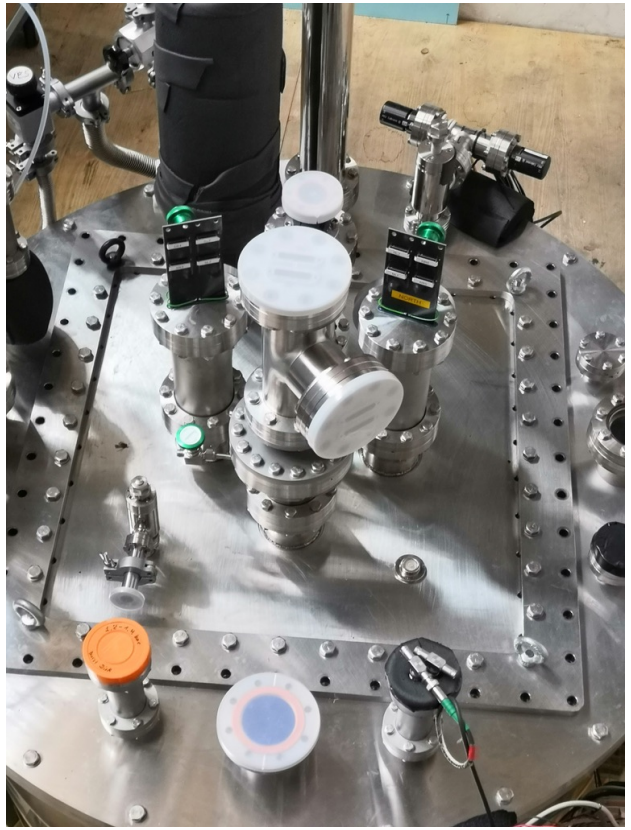

LHEP
DUNE

Successful Module-0 runs (first of 4 modules)

April and June 2021

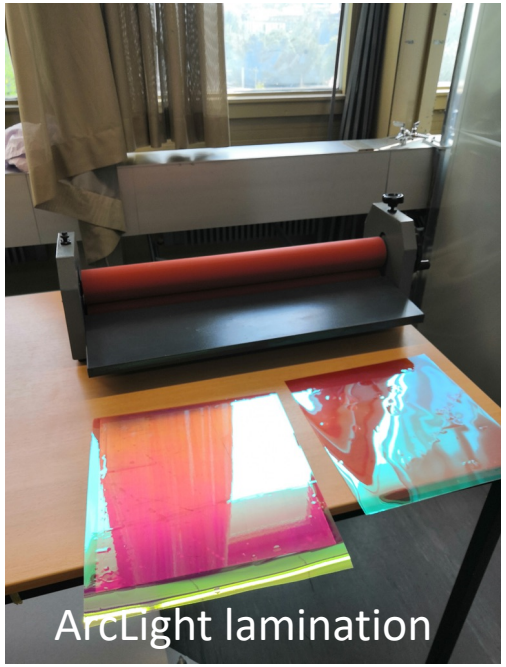






July 2021, module inserted in the single-module cryostat
Waiting-position for shipping

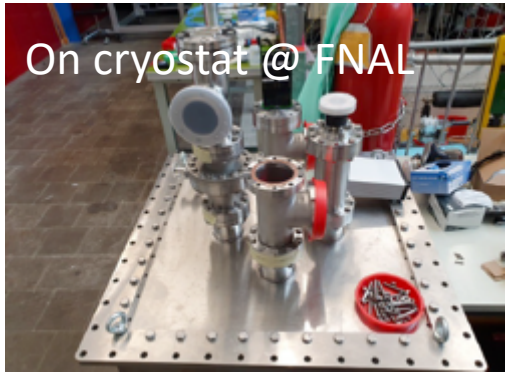
Building more modules (light and charge collection)



ETA
September 2021

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

Modules structure
material on-hand



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

Field shell
material in hand /
ordered (SLAC)

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

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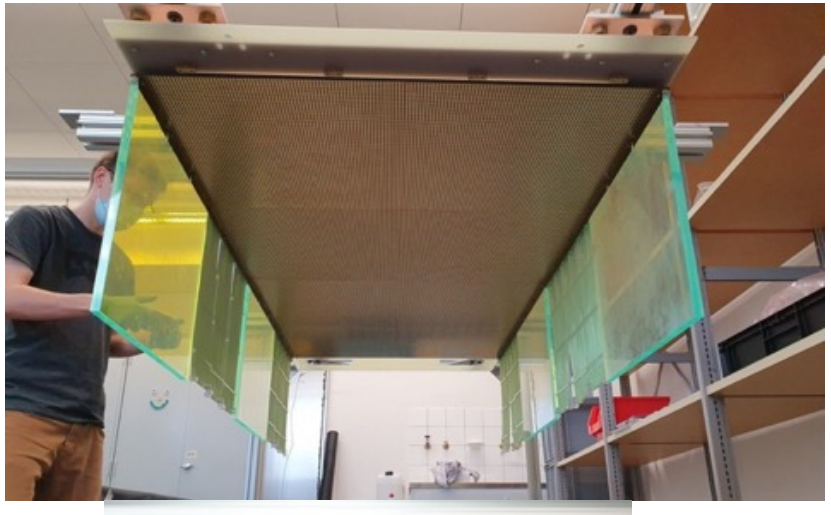
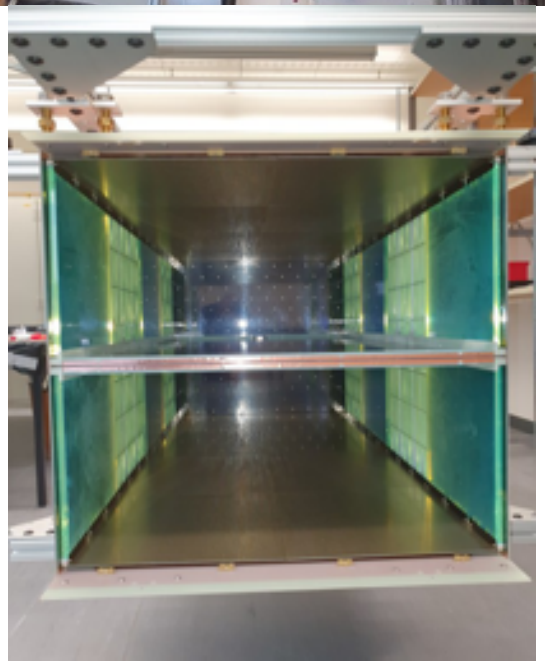
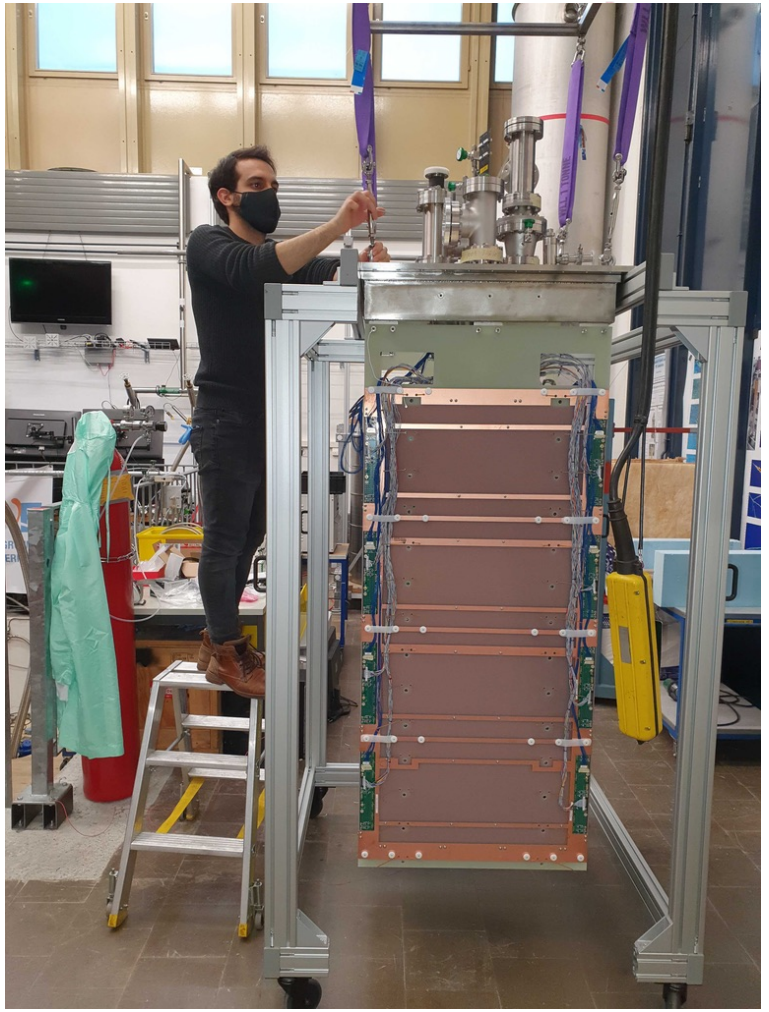
Module assembly and testing





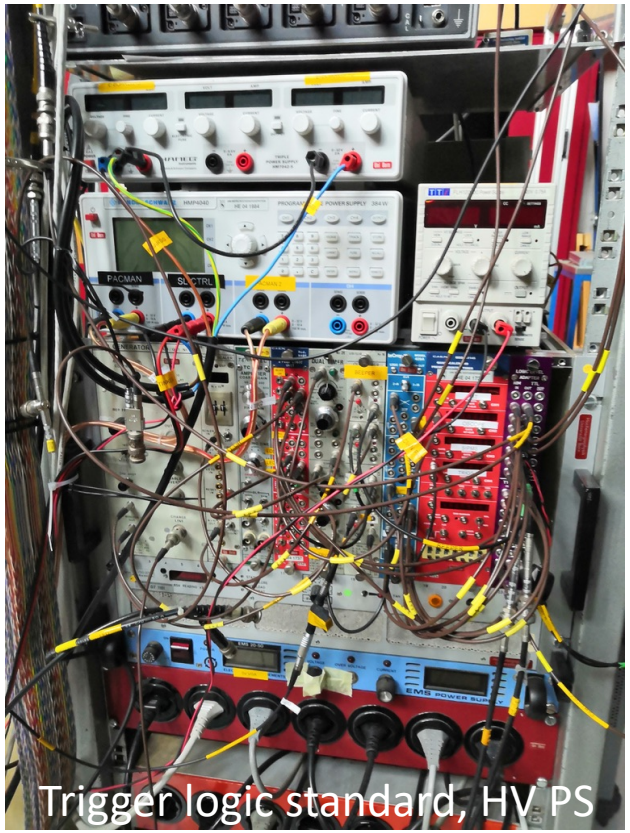


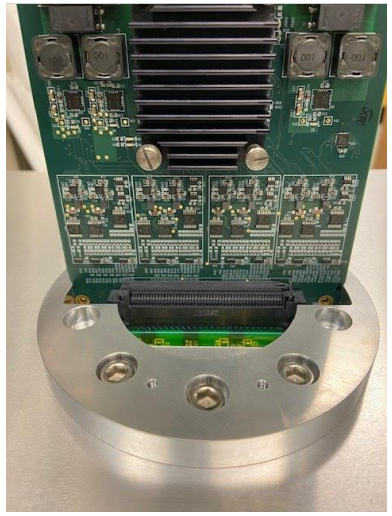
ETA 1 week per module + 1 week checkout

Timeline defined by cooldown-warmup of testing setup

Readout & powering

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





Charge r/o

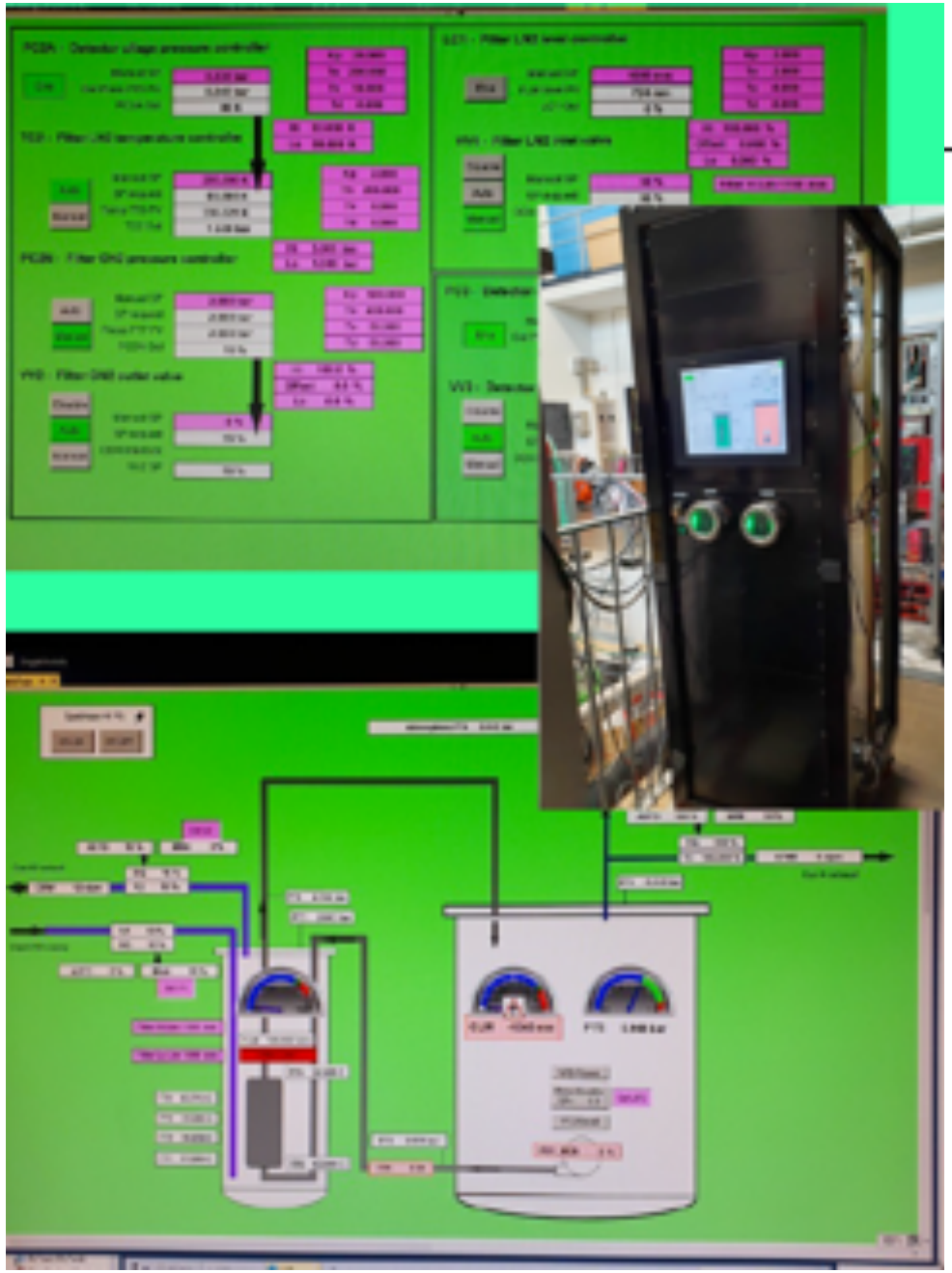
Light r/o

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

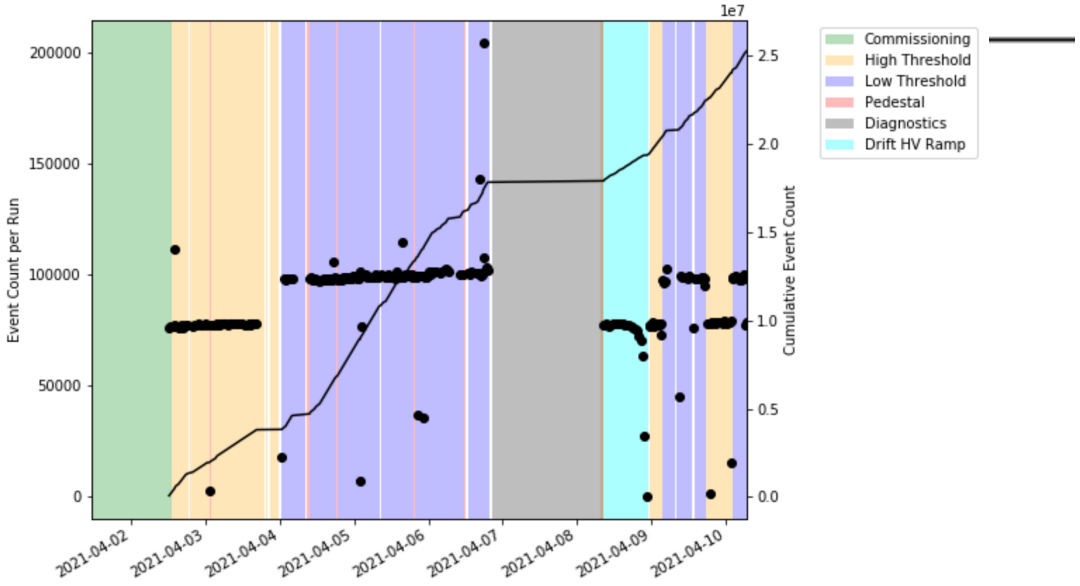


ArgonCube reconstrcution and analysis

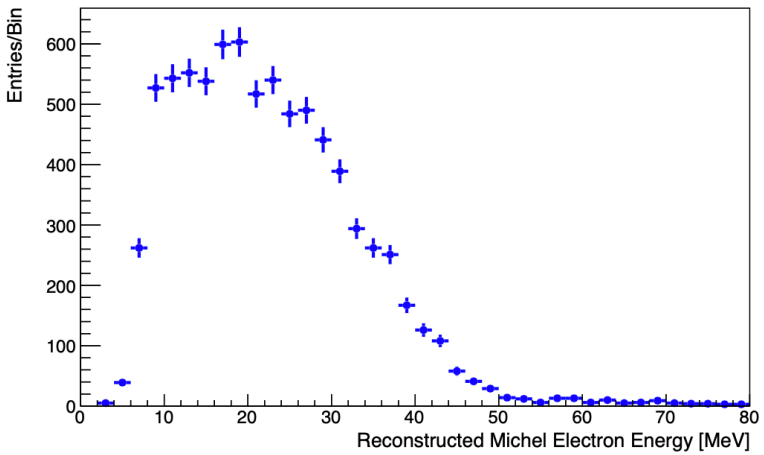
- Paper on analysis of Module-0 data
- Initial reconstruction of charge/light track/shower

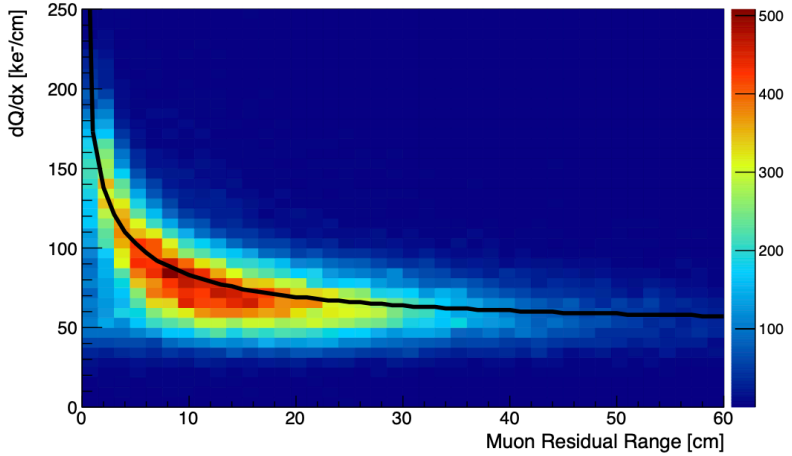
Contents

~25 million events collected over ~1 week of operation



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		Revisit numu CAF analysis	Truth matching	Basic light simulation integration	Revisit G4
	Read detector simulation		ND-LAr sample production		Adapt MicroBooNE algorithms
Interaction level reco		Revisit nu+e CAF analysis		Truth matching	
	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		Optimization
	Michel reco			M0 Data/MC	
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