

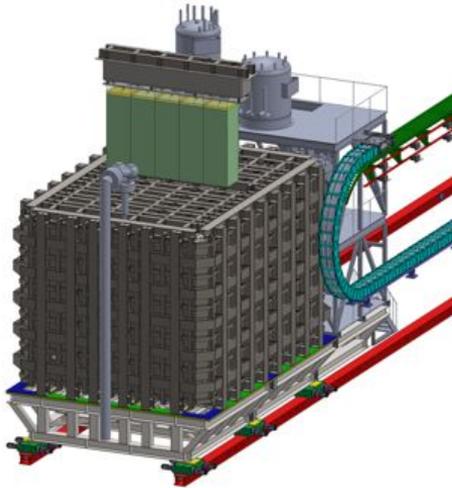
Status of ND-LAr

Weber / Dwyer
February 2021

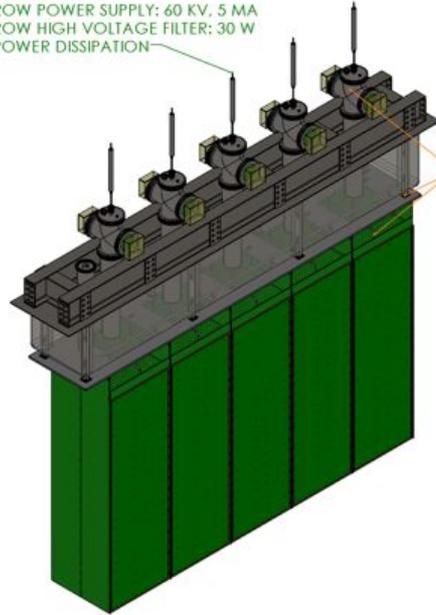
Overview

ND LArTPC Scope:

- Design, prototyping, production, and testing of 7 (+1) rows of 5 LArTPC modules
- External HV and detector electronics
- Support during installation in Near Hall



WBS 131.02.03.02.02
HIGH VOLTAGE - UNIVERSITY OF BERN
PER TPC ROW:
 ROW POWER SUPPLY: 60 KV, 5 MA
 ROW HIGH VOLTAGE FILTER: 30 W
 POWER DISSIPATION

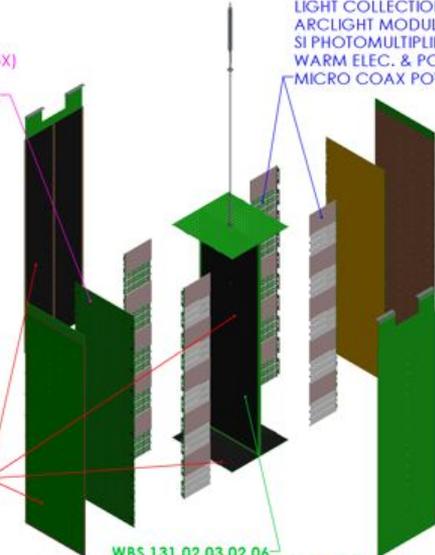


WBS 131.02.03.02.04
CHARGE READOUT - LAWRENCE BERKELEY LAB
PER TPC:
 LARPIX TILES (40X)
 - 6400 ASICS, 409600 PIXELS
 - PIXEL SIZE = 3.5 MM X 3.5 MM
 - PIXEL PITCH = 4.0 MM
 PCB FEEDTHROUGH & PACMAN (5X)
 RIBBON DATA CABLES
 TWINAX POWER/GROUND CABLES

WBS 131.02.03.02.01
MODULE STRUCTURES - UNIVERSITY OF BERN
PER TPC ROW:
 ND LArTPC ROW STRUCTURAL SUPPORT
 HV, DATA, AND POWER FEEDTHROUGH (5X)
 LIQUID ARGON DELIVERY (5X)
 - 25 G/S (125 G/S TOTAL)
 - 86 K - 90 K
 GAS ARGON RETURN (5X)
 - 50 MBARG
 - 90 K - 300 K
 PT100 STRING PER ANODE (10X)

WBS 131.02.03.02.03
FIELD STRUCTURES - SLAC NATIONAL ACCELERATOR LAB
PER TPC:
 HV DELIVERY CABLE
 - 25 KV
 - 50 KV
 FIELD SHAPING SIDE PANELS (2X)
 FIELD SHAPING TOP & BOTTOM PANELS (PERFORATED)
 CATHODE
 FIELD STRENGTH
 - 0.5 KV/CM (NOMINAL)
 - 1.0 KV/CM (MAXIMUM)

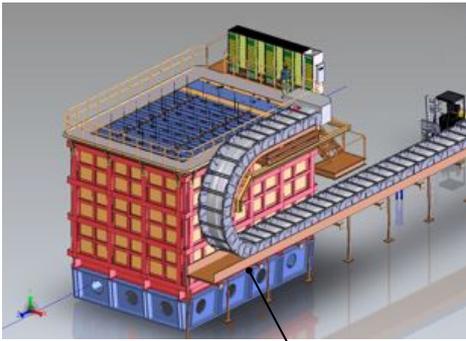
WBS 131.02.03.02.05
LIGHT READOUT - UNIVERSITY OF BERN/JOINT INSTITUTE OF NUCLEAR RESEARCH
PER TPC:
 LIGHT COLLECTION MODULES (60X)
 ARCLIGHT MODULES (20X)
 SI PHOTOMULTIPLIERS & E-BOARD (240X)
 WARM ELEC. & PCB FEEDTHROUGH
 MICRO COAX POWER/DATA CABLES



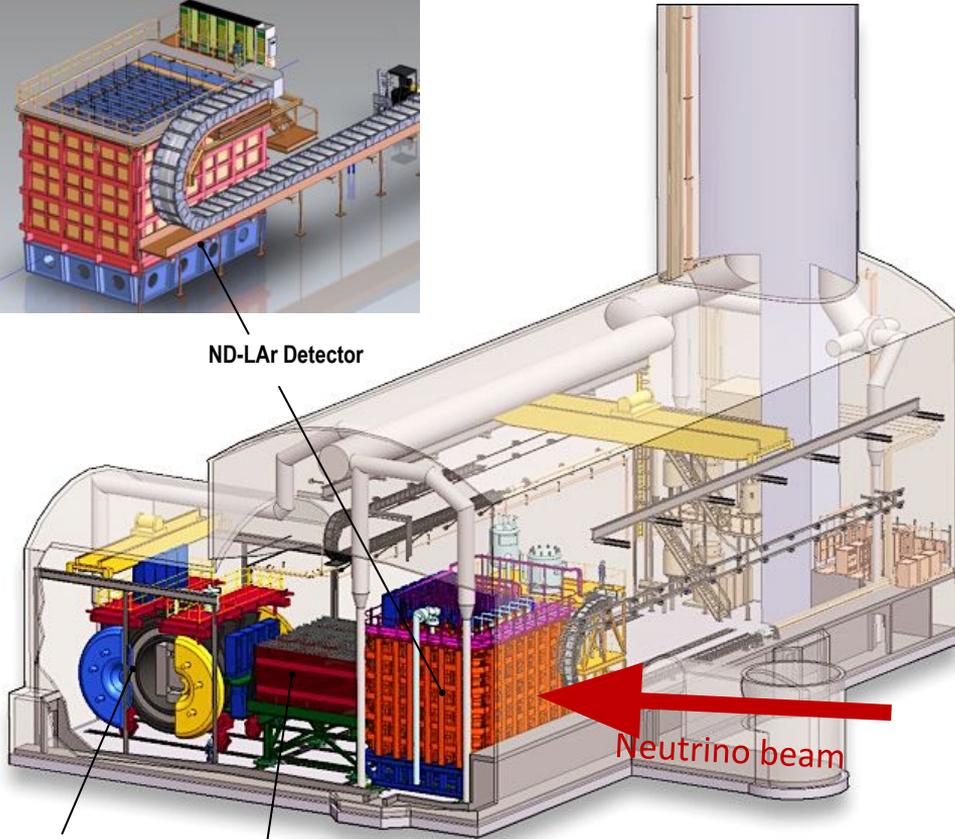
WBS 131.02.03.02.06
CALIBRATION - UNIVERSITY OF HAWAII
PER TPC:
 PHOTO-ELECTRIC DISKS/STRIPS IN CATHODE
 - 300 DISKS
 - 56 STRIPS
 UV LIGHT INJECTION VIA OPTICAL FIBER
 - 6 INJECTION FIBERS

Others:

- 131.02.03.03.07: TPC Module Integ. & Testing
- 131.02.03.03.08: TPC Module Installation
- 131.02.03.03.09: ND LArTPC Management



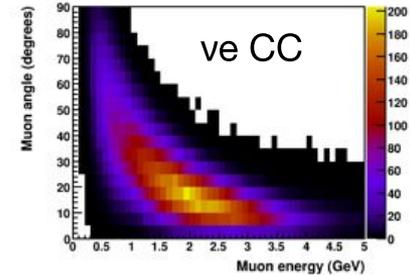
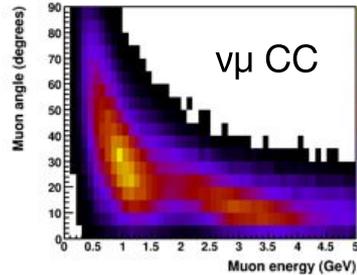
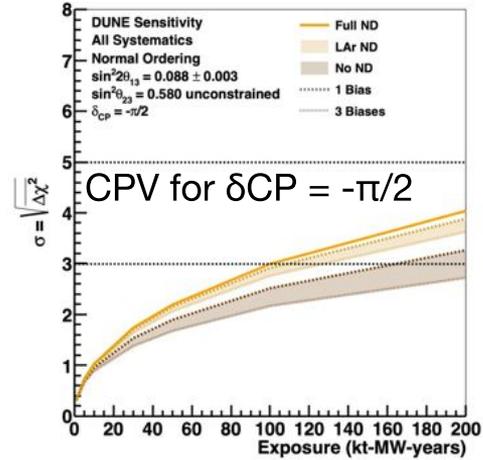
ND-LAr Detector



Neutrino beam

SAND beam monitor

Muon spectrometer (later a Gar TPC)



ND-LAr size is driven by containment, not rate
 Rate and pile-up motivate modular design

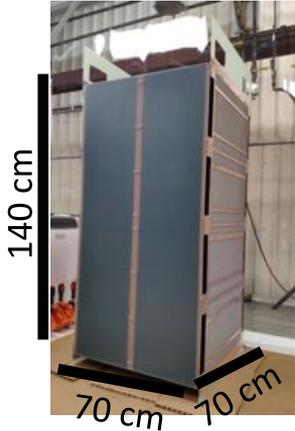
ND LArTPC: From Prototyping to Production to Installation

2019-2021

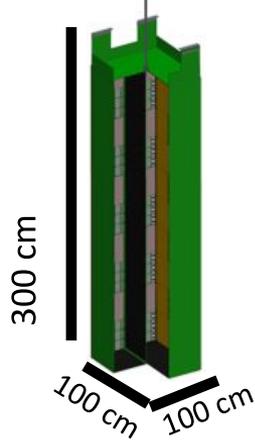
Module 0

SingleCube,
then 1 module (Module 0),
then 4 modules (2x2)

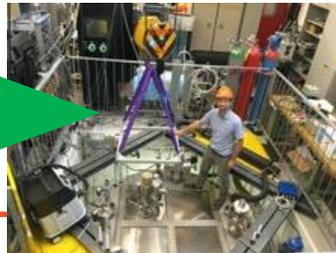
Operated in cryostat at Bern,
then FNAL in NuMI beam



2021-2023
Full-scale ND Demonstrator



ArgonCube 2x2



2022-2026

Production



1 production
'first article'

35 (+5) Production modules
Each fully tested in single-module cryostat



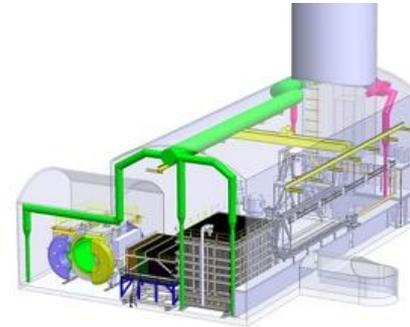
Deliverable: modules packed and ready for installation underground

2027-2029

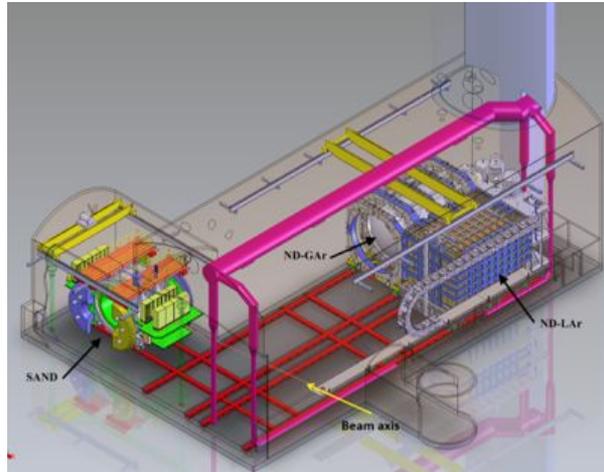
Installation

Support of TPC module installation in Near Site

Activity driven by Near Site Integration (NSI)



THE DUNE ND REFERENCE DESIGN AND REQUIREMENTS



- Components of the DUNE Near Detector (ND)
 - **ND-LAr:** modular LArTPC
 - **ND-GAr:** magnetized high pressure GAr TPC + ECAL/ μ -ID
 - **DUNE-PRISM:** Ability of ND-LAr+ND-GAr to move to measure in different neutrino fluxes
 - **SAND:** on-axis beam monitor using KLOE magnet + ECAL

Global Science Requirement

FD measurements
not limited by ND

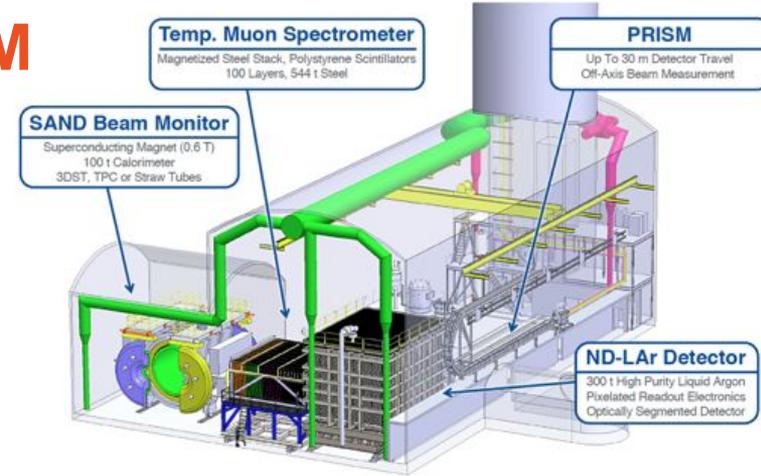
ND measurements shall be of sufficient precision to ensure that when extrapolated to FD to **predict the FD event spectra**, the associated systematic error must not dominate the measurement precision.

ND-O0 | Predict the observed neutrino spectrum at the FD

- ND-O1** Transfer measurements to the FD
- ND-O2** Constrain the cross section model
- ND-O3** Measure the neutrino flux
- ND-O4** Obtain measurements with different fluxes
- ND-O5** Monitor time variations of the neutrino beam
- ND-O6** Operate in high rate environment

“DAY 1” MEASUREMENT PROGRAM

	Parent requirement	Measurement Requirement	
ND-M1	ND-O1,2	Classify interactions and measure outgoing particles in a LArTPC with performance comparable to or exceeding the FD	
ND-M2	ND-O1,2	Measure outgoing particles in ν -Ar interactions with uniform acceptance, lower thresholds than a LArTPC, and with minimal secondary interactions	
ND-M3	ND-O3	Measure the neutrino flux using neutrino electron scattering	ND-LAr+TMS
ND-M4	ND-O3	Measure the neutrino flux spectrum using the "low- ν' " method	+GAR TPC
ND-M5	ND-O3	Measure the wrong-sign component	
ND-M6	ND-O3	Measure the intrinsic beam ν_e component	
ND-M7	ND-O4	Take measurements with off-axis flux with spectra spanning region of interest	DUNE-PRISM
ND-M8	ND-O5	Monitor the rate of neutrino interactions on-axis	SAND
ND-M9	ND-O5	Monitor the beam spectrum on-axis	
ND-M10	ND-O6	Assess External Backgrounds	



- **ND-LAr+TMS** must complement each other in fully reconstructing $\nu_\mu/\bar{\nu}_\mu$ CC interactions
- Continuous **on-axis (SAND)** measurements are necessary to ensure beam stability with “Day 1” 1.2 MW LBNC operations
- Off-axis (**PRISM for ND-LAr+TMS**) measurements are necessary to reduce impact of (very difficult) ν -Ar interaction modeling uncertainties

Documentation and Reviews

Key Documents:

Conceptual Design Report (CDR):

Focused on 'DUNE Reference Design' concept
Reviewed by the Long Baseline Neutrino Committee (LBNC)
Nearly complete; to be published soon

Preliminary Design Report (PDR):

Covers the 'Day-1 ND' technical design (must cover all US scope)
To be reviewed by the US DOE (July 2021 DOE IPR)
Finalized in advance of DOE CD-2/3b Review

Technical Design Report (TDR):

Covers the complete International ND Design, Day-1 and Reference.
Will be an expansion of the PDR
To be reviewed by the LBNC
Completed in advance of the Near Detector Final Design Reviews (2022)

Key Reviews:

Completed:

DUNE Review of the Day-1 ND Conceptual Design (July 2020)
US DOE Independent Project Review (IPR) of LBNF/DUNE (14-16 July 2020)
LBNC Review of LBNF/DUNE (14-16 Sep 2020)
LBNC Review of LBNF/DUNE (2-4 Dec 2020)
US DOE IPR of LBNF/DUNE (6-13 Jan 2021)
Swiss funding review (Jan 2021)

Upcoming:

LBNC Review of the Day-1 ND Physics Program (16-17 Feb 2021)
LBNC Review of LBNF/DUNE (3-5 Mar 2020)
[ND-LAr Subsystem Technical Design Reviews \(May 2021\)](#)
US DOE IPR of LBNF/DUNE (July 2021)
[ND-LAr Preliminary Design Review \(Sep 2021\)](#)
US DOE CD-2/3b Review of LBNF/DUNE (Dec 2021)

PDR

1 Deep Underground Neutrino Experiment (DUNE)

2 DUNE-US Near Detector 3 Preliminary Design Report

4 ND-LAr Chapter

5 January 29, 2021

6 The DUNE Collaboration

2	Contents	i
3	List of Figures	ii
4	List of Tables	1
5	1 The Near Detector Liquid Argon TPC	2
6	1.1 Overview of ND-LAr	2
7	1.1.1 Introduction and Scope	3
8	1.1.2 Principle of Operation	4
9	1.1.3 Design Parameters	6
10	1.1.4 Performance	6
11	1.2 System Design	18
12	1.2.1 Field Structures	18
13	1.2.2 Charge Readout	23
14	1.2.3 Light Readout	31
15	1.2.4 Calibration	37
16	1.2.5 Module Structures	42
17	1.2.6 High Voltage	48
18	1.3 Interfaces	53
19	1.4 Risks and Mitigations	54
20	1.5 Schedule	58
21	1.6 Prototyping Plans	59
22	1.6.1 SingleCube Demonstrators	59
23	1.6.2 ArgonCube 2x2 Demonstrator	59
24	1.6.3 Full-scale Demonstrator	62
25	1.7 Construction Plans	63
26	1.7.1 Module Integration Facility	63
27	1.7.2 TPC Module Assembly	65
28	1.7.3 TPC Module Testing	66
29	Glossary	69
30	References	72

Coming up: fully instrumented Module-0

- Integrated 70% size test
- Demonstrate fully-integrated TPC performance
- Achieve Technical Readiness for PDR

Fully-instrumented:

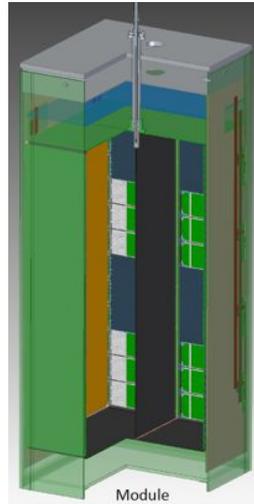
16 pixel tiles

8 LCM

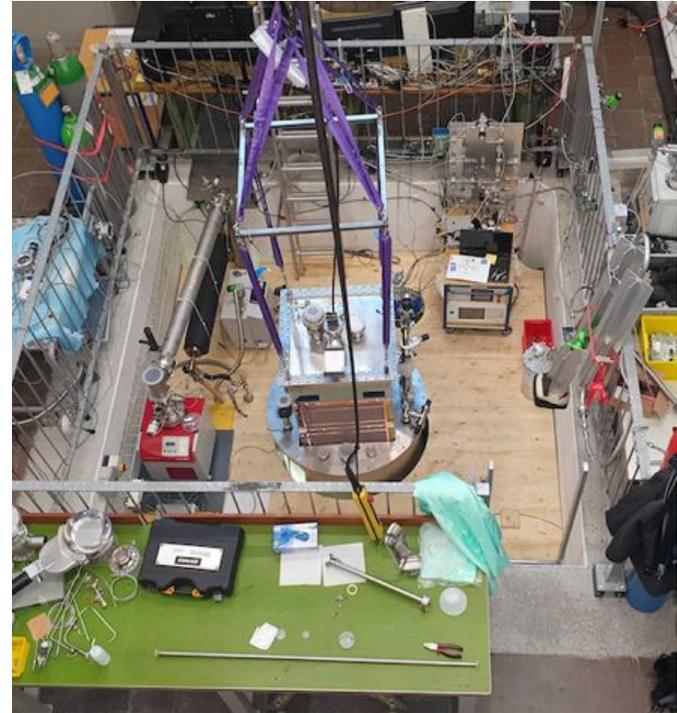
8 ArCLight

Planned operation:

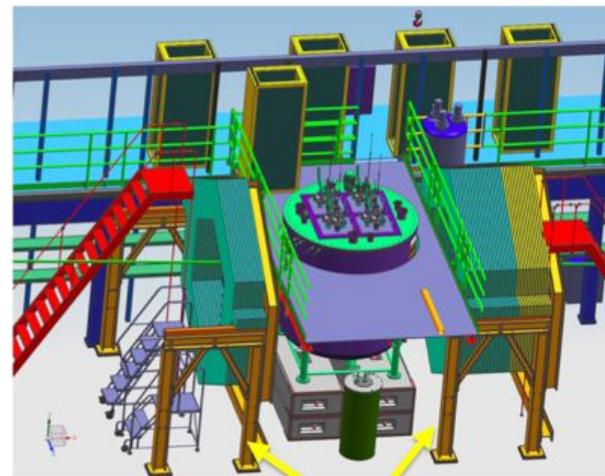
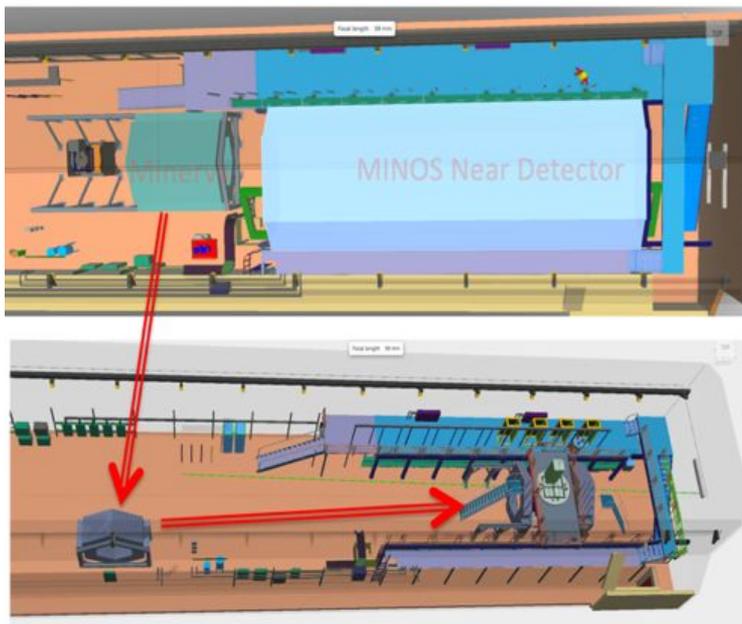
Mar 2021 @ Bern



Installation in Single Module Test System



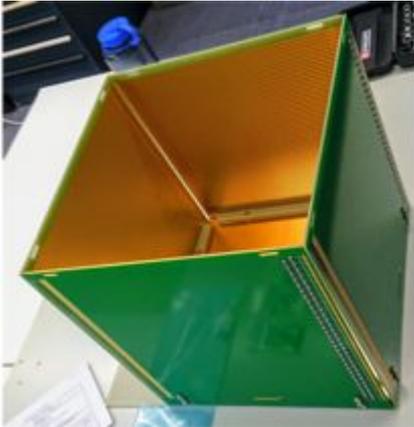
2x2 ProDUNE-ND @FNAL



Significant work ongoing to prepare for 2x2
 Electrical and cryo preparations advancing
MINOS hall is to be ready before summer
 – it is becoming an underground LAr lab (ProtDUNE-ND)

Test setups

Several online and coming online !



SingleCube



SingleModule



Mechanical setups

MoUs

Overall DUNE MoUs

Annexes -- e.g. Common funds, **but also LAr-ND**

We should agree on contents and details

- Scope
- Institutions and funding agencies
- Funding envelopes
- Institutional responsibilities, deliverables and involvements for design, construction, integration, procurement
- In-kind
- Software, reconstruction ?

Separately: overview of group/institute personnel
