Near Detector Status

Dan Dwyer

ND Engineering Meeting

11 July 2019

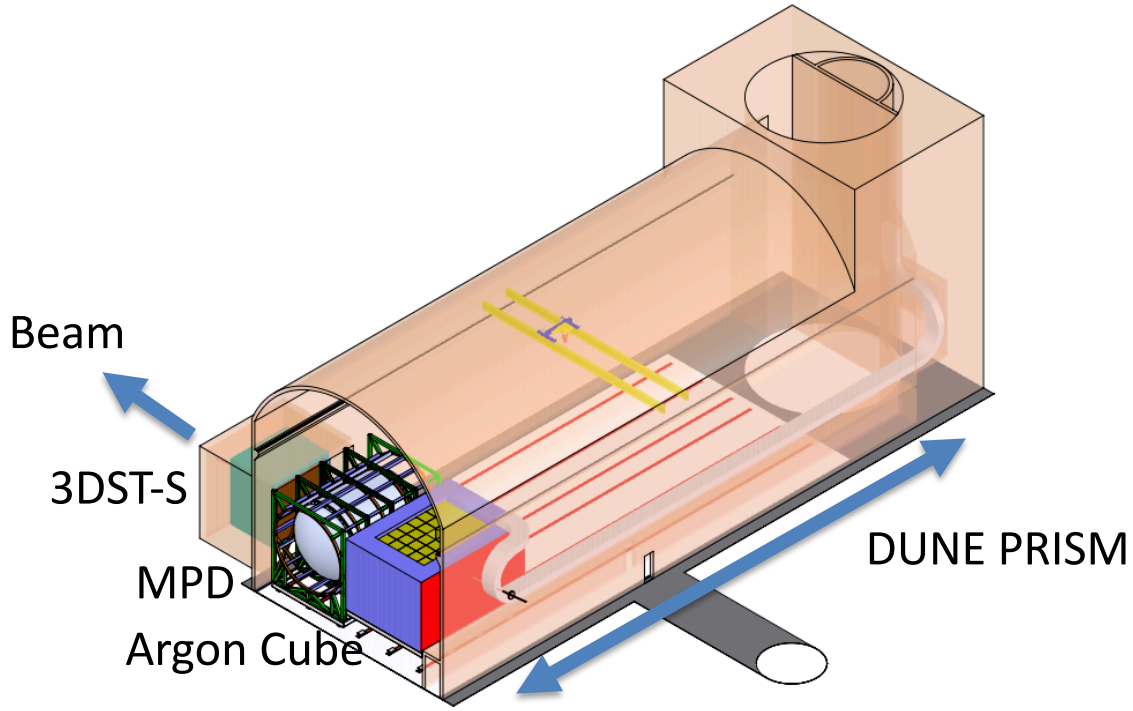
Scope Overview

- ND context through CD2/3a reviews:
  - DUNE will produce a CDR for the ND by December, 2019.
  - For the Far Site/Detector CD2/3a review in December 2019, US DUNE will establish a cost envelope for the ND as part of the TPC definition.
  - The ND will be baselined at the 2020 CD2/Near Site review. CD3/Near Site will follow in 2021.
- Path to final ND scope
  - The DUNE Near Detector Design Group has defined a reference design that consists of a liquid argon TPC (LArTPC), a multi-purpose spectrometer, and a beam monitor.
  - A clear decision has been taken on the ND hall size and configuration that allows for the eventual implementation of this reference design.
  - Sufficient functional elements of the reference design will be present on day 1; and the final reference design will be realized in stages.
  - The initial scope will include the LArTPC, an interim spectrometer solution, and a partially instrumented beam monitoring solution.

Near Detector Requirements

1. Overarching: predict the spectra of all four flavors of neutrino interactions at the far sit to enable tests for neutrino CP violation. Control flux⊗cross section⊗detector response.
2. Constrain neutrino cross sections for argon→liquid argon near detector.
3. Disentangle energy response from cross section models→off-axis running capability.
4. Measure energy spectra→liquid argon calorimetry plus downstream muon spectrometry.
5. Predict spectra for neutrinos and antineutrinos→magnetic spectrometry.
6. Maintain fidelity of predictions over multi-year runs→beam monitoring.

Reference design solution



- Modular liquid argon TPC with pixelated readout to handle pile-up: “Argon Cube”.
- Multiple purpose detector with superconducting magnet, high pressure argon gas TPC, and calorimeter: “MPD”
- Highly segmented beam monitor with fast timing and neutron detector: “3DST-S”.
- Movable Argon Cube+MPD. Wide detector hall plus transport system: “DUNE PRISM”.

Results from Independent Science Review

- LBNC-appointed Review of ND Reference Design (June 4, 2019)
  - "DUNE has convincingly demonstrated that a capable near detector is required in order to achieve its physics goals"
  - "In the judgment of the review committee, the proposed movable liquid argon TPCs and MPD, when combined with the DUNE-PRISM technique and a suitable on-axis beam monitor, will allow DUNE to reach its physics goals."
    - "The primary target mass for the ND should therefore consist of liquid argon TPCs."
    - "a magnetized detector capable of determining the sign and momentum of charged particles is required downstream of the liquid argon TPCs."
    - "the unique capacities of a high-pressure gaseous argon TPC provide an exceptional opportunity to achieve additional physics in a way that alternate magnetic spectrometers could not."
    - "The committee found the DUNE-PRISM concept compelling and strongly endorses the necessity for a movable near detector."
    - "An on-axis beam monitor is required that is capable of accurately measuring the beam center, lateral profile, and rates on a few days' timescale."
    - "We were therefore concerned that the proposed 3DST lacks a strong physics motivation"

June 4, 2019: LBNC Review Summary Statement

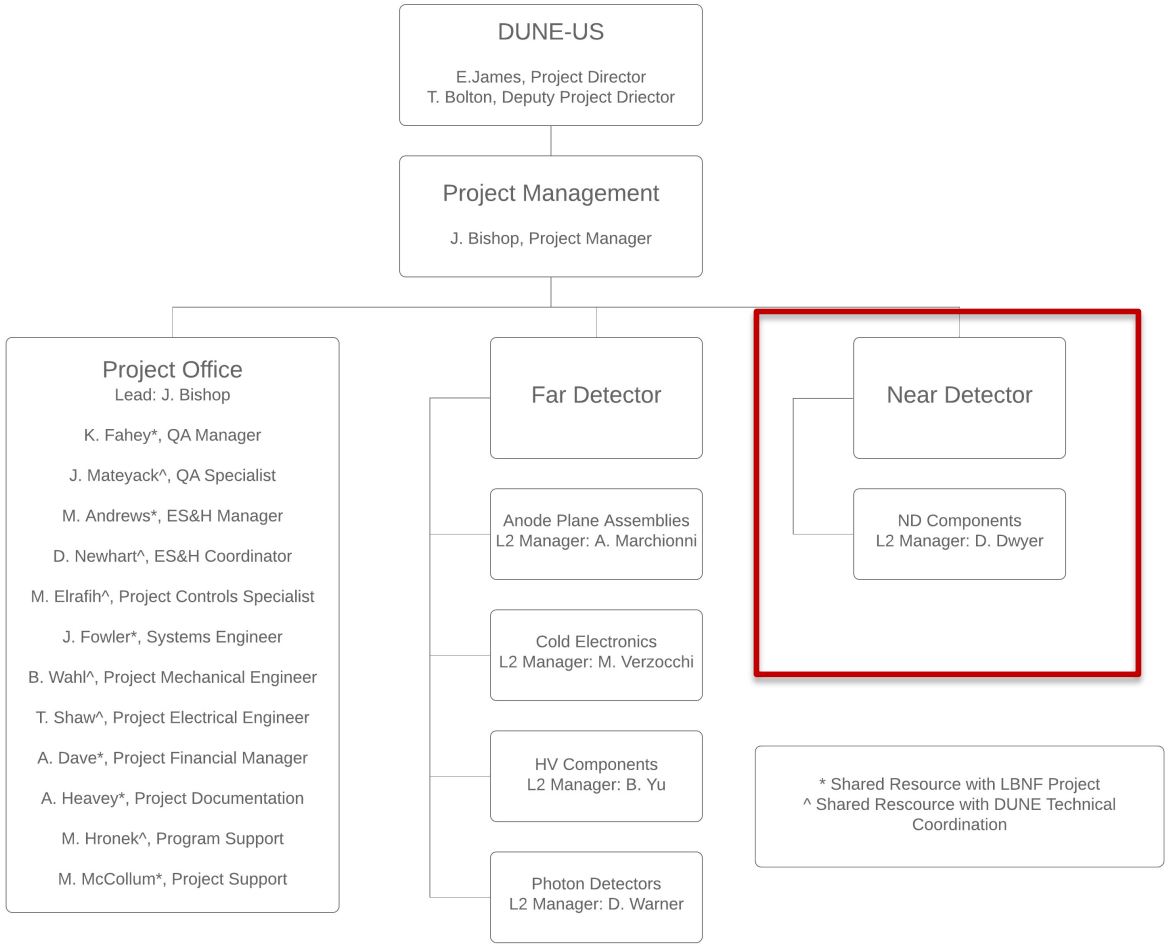
In considering possible optimization or descoping of the near detector, the review committee's judgment is that a minimally capable near detector must include:

1. Liquid argon TPCs
2. A magnetic spectrometer downstream of the liquid argon TPCs
3. The ability to move these detectors across a broad range of off-axis angle (out to ~30m off-axis)
4. An on-axis beam monitor capable of measuring the beam center, profile, and rates on a few day's timescale.
5. These minimal elements are deemed necessary from the start of data-taking, and should not be delayed until later in the DUNE program.

US Project Near Detector Strategy

- Develop Near Site Facilities (now at 50% design maturity) to support implementation of full reference design, most likely in a staged program.
  - Realization of “opportunity risks” in terms of international contributions could accelerate staging.
- Develop plan/cost/schedule based on a near detector that satisfies minimal requirements for Far Detector CP violation program at turn-on.
  - Modular, pixelated LArTPC based on the University of Bern (Switzerland) Argon Cube concept (https://cds.cern.ch/record/2268439) (now at 50% design maturity).
  - Magnetized segmented muon detector. (https://arxiv.org/abs/1704.08079). (conceptual design underway).
  - Beam monitor spectrometer built around the KLOE magnet + calorimeter (Italy), pending cost analysis (Adinolfi, M *et al.* Nucl.Instrum.Meth. A488 (2002) 51-73) (conceptual design underway).
    - Alternative: additional magnetized segmented muon detector modules.

US Near Detector Organization



DUNE Collaboration

E. Blucher, Spokesperson
S. Soldner-Rembold, Spokesperson
E. James, Technical Coordinator
R. Rameika, Resource Coordinator

DUNE Technical Coordination

E. James, Technical Coordinator
S. Kettell, Deputy Technical Coordinator
.
.
.
Near Detector Engineer: M. Leitner
Near Detector Integration: R. Flight
.

DUNE Near Detector Design Group

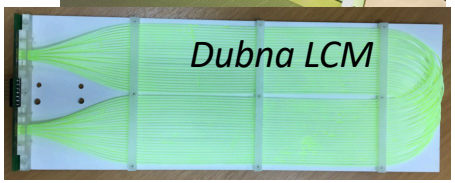
A. Bross, Convener
H. Tanaka, Convener
A. Weber, Convener

High Level Milestones

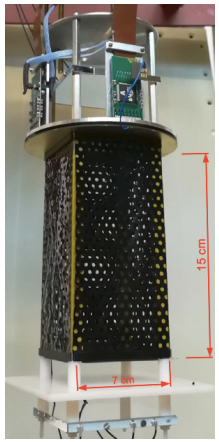
- Aug. 2019: Initial Near Detector Plan (sufficient to establish US ND estimate for DUNE TPC)
- Late 2019: NDDG/DUNE Collaboration finalizes ND conceptual design
- Early 2020: CD-2/3a Far Site Review: LBNF/DUNE
- Late 2020: CD-2/Near Site Review
- Late 2021: CD-3c/Near Site Review

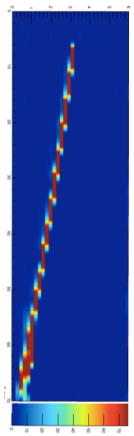
ArgonCube Collaboration: Staged Detector Development

Technology Prototypes (2016-2018) *off-project*



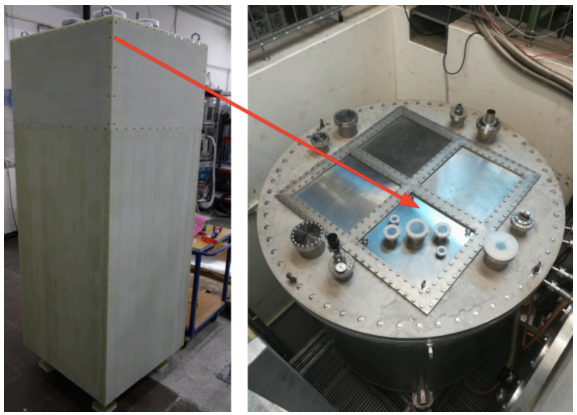
Enhanced Light Readout



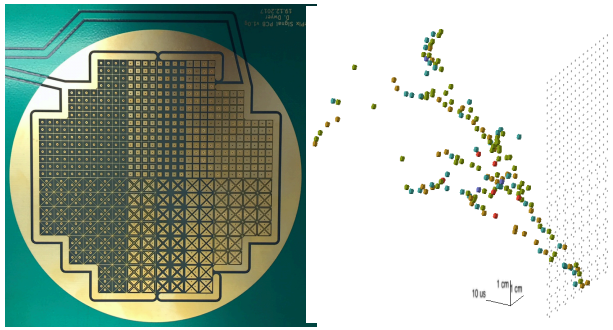


Resistive Field Cage and Cathode

Modular TPC Design



Pixel Charge Readout

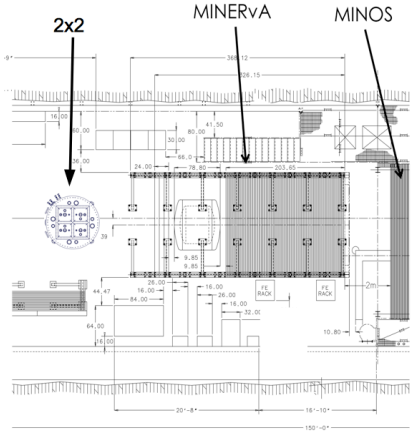


(add journal refs)

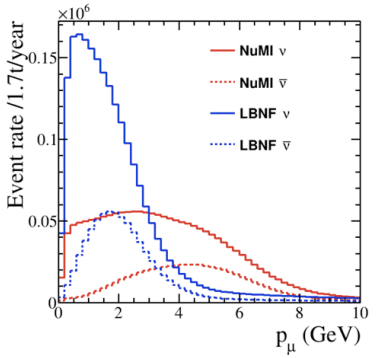
Integrated Demonstrator (2019-2020)

a.k.a. ArgonCube 2x2 Demonstrator off-project

a.k.a. ProtoDUNE-ND

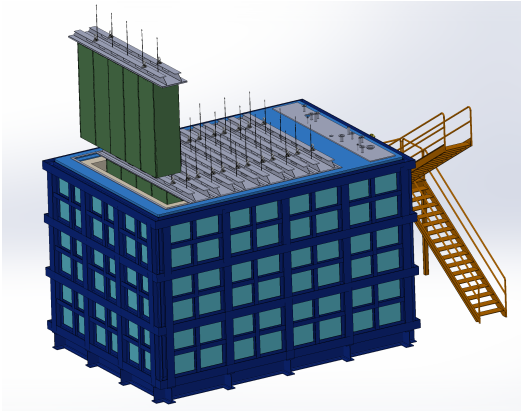


(Run 2: 2021-2022?)



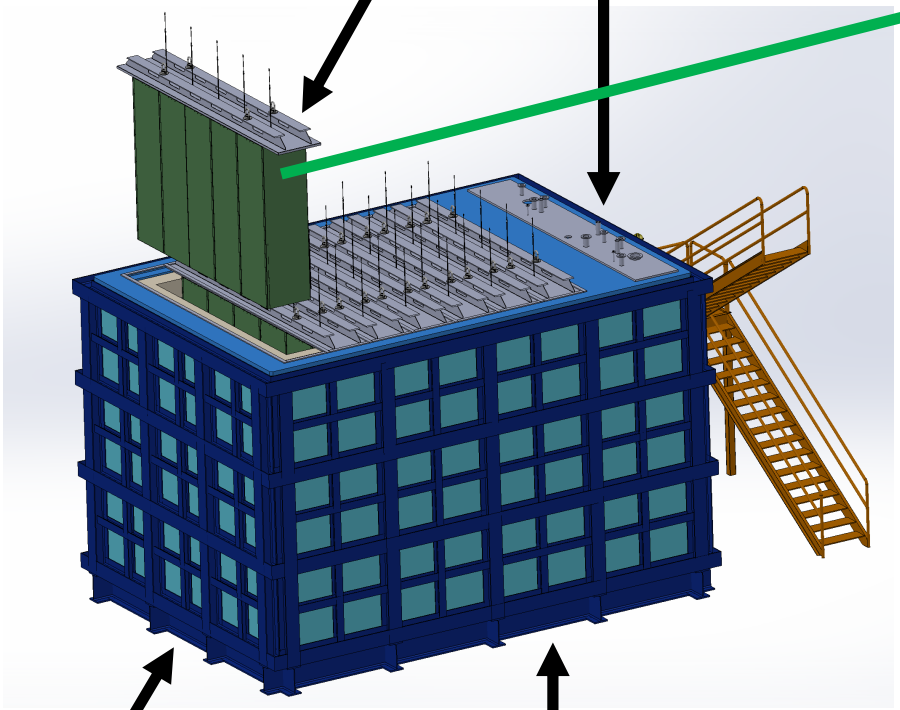
Pre-production Demonstrator (2023)

Near Detector (2025-2029)



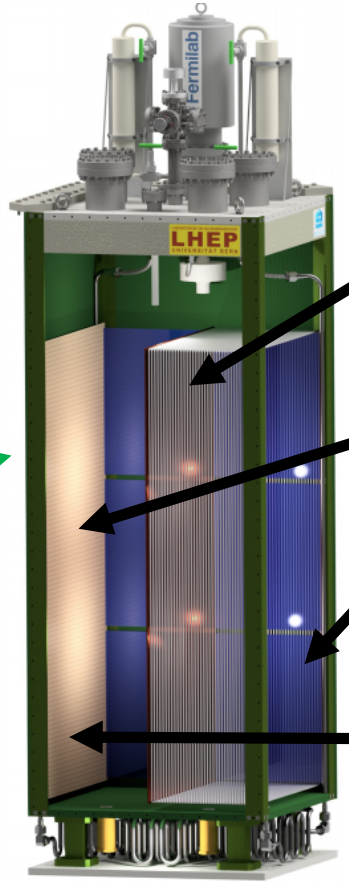
LArTPC Components

- **X.2:** ND LArTPC



X.2.3: Cryogenics and Purification

X.2.4: Module structures



X.2.5: High Voltage

X.2.6: Cathode and Field Cage

X.2.7: Charge Readout System

X.2.8: Light Readout System

X.2.9: Calibration

X.2.2: Cryostat

X.2.12: PRISM Movement system

Others:

X.2.1: ND LArTPC Management

X.2.10: DAQ → *Integrate across Near (+Far?) Site*

X.2.11: Controls and Monitoring → *Integrate?*

X.2.13: TPC Module Integration and Testing

Related:

X.X.X: Near Site Installation and Integration

LArTPC Responsibilities

WBS Element	Institutions - ArgonCube 2x2 Prototype
X. Near Detector	
X.1 ND Management	
X.2 ND LArTPC	
X.2.1 ND LArTPC Management	Bern
X.2.2 ND LArTPC - Cryostat	Bern
X.2.3 ND LArTPC - Cryogenics and Purification	**FNAL** ←
X.2.4 ND LArTPC - Modularization Structures	Bern
X.2.4 ND LArTPC - HV	Bern
X.2.6 ND LArTPC - Cathode and Field Cage	**SLAC** ←
X.2.7 ND LArTPC - Charge Readout	**LBNL/Caltech/CSU/UCSB/UPenn/UTA** ←
X.2.8 ND LArTPC - Light Readout	Dubna/Bern
X.2.9 ND LArTPC - Calibration	**-** ←
X.2.10 ND LArTPC - DAQ	LBNL/Bern/Roch./Rutgers? ← *Integrate across Near (+Far?) sites*
X.2.11 ND LArTPC - Controls and Monitoring	Bern/FNAL ← *Integrate across Near (+Far?) sites*
X.2.12 ND LArTPC - PRISM Movement System	**-** ←
X.2.13 TPC Module Integration and Testing	**Bern/UTA/CSU** ←
X.3 ND Multipurpose Detector	
X.4 ND 3DST-S	
X.5 ND Muon Spectrometer	

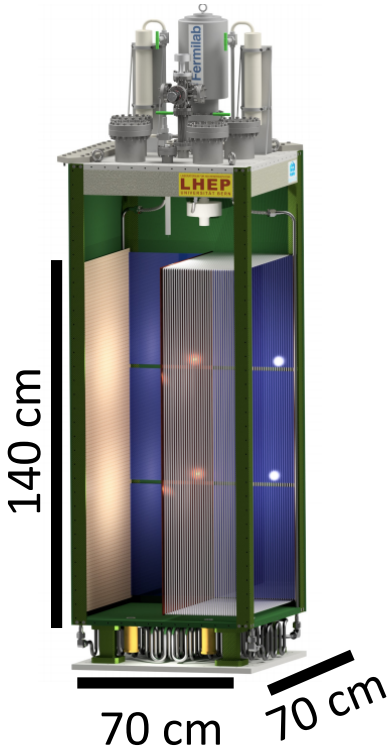
Planned US Project Roles in ND LArTPC

X.2 Deliverables: Subsystems tested, packaged, ready for installation in Near Hall.

→ Installation in Near Hall is covered by a separate Installation/Integration WBS

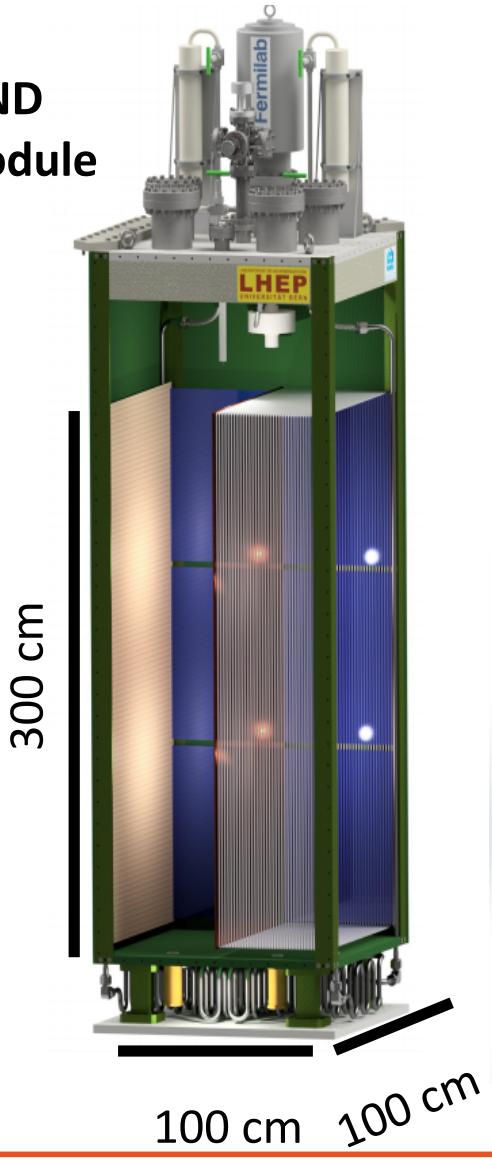
From ArgonCube 2x2 Demonstrator to ND LArTPC

2x2 Demonstrator Module



2x2 Cryostat

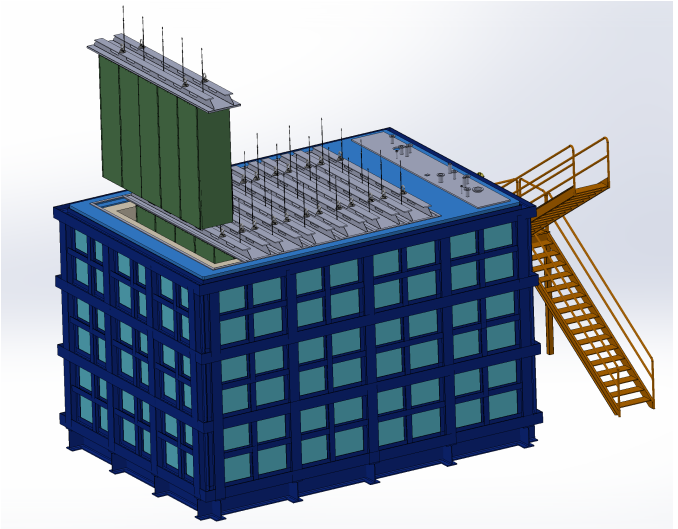
ND Module



Expect 2x2 Demonstrator to retire most risks:

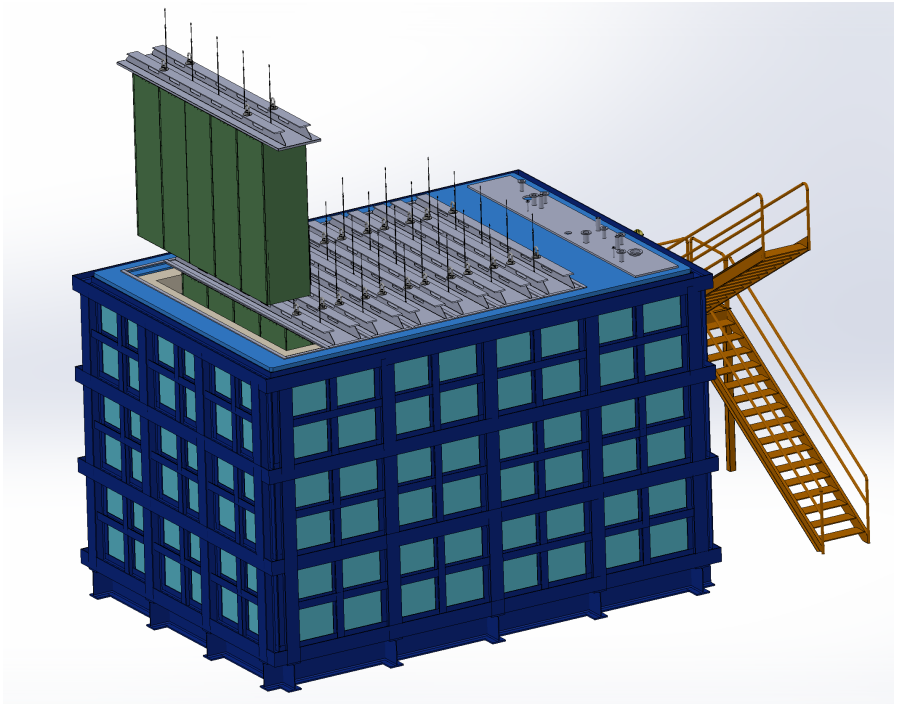
- technical design
- system integration
- cost

ND Cryostat



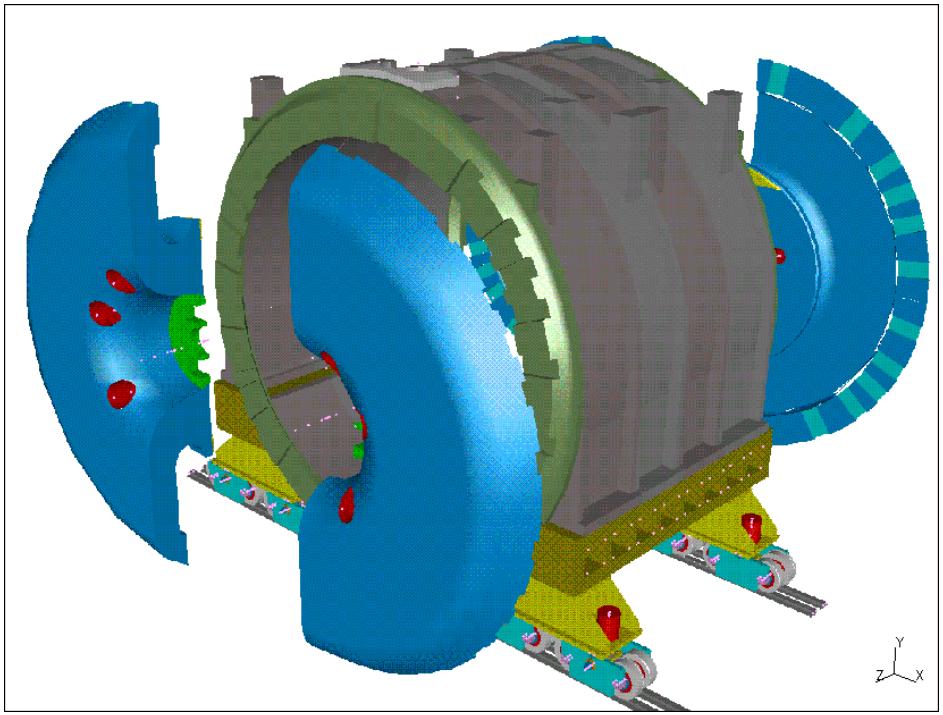
LArTPC Integrated Engineering Design

- Led by new Near Detector Lead Engineer: Matthaeus Leitner (LBNL)
- Current focus: fully capture Near Detector engineering scope, facilities interfaces
- Target: Complete conceptual-level ND engineering design by Sep. 2019
- Working with broader design team:
  - Cryostat shell scoping (T. Miao)
  - Top plate integration (J. Sinclair, M. Kim)
  - Mezzanine, support platform (M. Leitner)
  - PRISM moving mechanism (B. Flight)
  - Cryogenics Routing (M. Kim)



Early concepts for minimal muon spectrometer, beam monitor

Segmented magnetized muon detector



KLOE SC solenoid plus calorimeter. Possible beam monitor pending cost review. Fallback: additional segmented magnetized muon detector units.

Near Detector responsibilities

	US	Non-US
ND Management	✓	✓
LArTPC		
Modularization Structures		✓
HV		✓
Cathode and Field Cage	✓	
Charge Readout	✓	
Light Readout		✓
Calibration	✓	✓
TPC Module Integration and Testing	✓	✓
Muon Spectrometer		
Iron Plates and Magnetic Coils	✓	
Magnet Power and Cooling	✓	
Tracker Plates	✓	✓
DAQ		✓
Controls and Monitoring	✓	✓

High Level Risks (with mitigations)

- Technical risks (purity, HV, noise, pileup, etc.) for new pixelated modular LArTPC technology.
  - Retire with 2X2 demonstrator (“ProtoDUNE-ND”).
  - Possible follow-on for further risk reduction (“ProtoDUNE-ND-2”).
- LArTPC cryogenics, cryostat outside US project scope
  - Discussions with international partners.
  - Move to integration and installation.
- Minimal spectrometer/beam monitor does not support observation of maximal CP violation at Far Detector.
  - Optimize and validate design with simulation.
- Minimal spectrometer/beam monitor costs escalate.
  - Adopt conservative design choices.
  - Consolidate muon spectrometer and beam monitor into one device.

Personnel risks

- Insufficient scientific support for minimal ND concept.
  - Inform DOE/NSF research programs on scientific priorities for ND.
  - Work with DOE/NSF research programs to maintain R&D efforts towards full realization of ND reference design concept.
- A full risk resister will be developed for CD2/Near Site.

Summary

- Near Detector conceptual design advancing rapidly
- US scope focused on achieving ‘minimally capable’ Near Detector, complementing major contributions from international partners
- Detailed WBS, schedule, resource estimates in progress, aiming for robust versions later this year.
- Expect near-term technical demonstrator (ArgonCube 2x2 Demonstrator / ProtoDUNE-ND) to address most significant risks of ND LArTPC.
- Need to rapidly transition from conceptual to technical design phase, project planning to be ready for Near Detector CD-2 Review.