What does DUNE want from MicroBooNE + SBN Program?

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THE UNIVERSITY OF CHICAGO

DUNE and the SBN Program

- DUNE does not rely directly on any future “deliverables” from SBN program.
- DUNE, however, builds on and continues to take advantage of enormous investment in SBN program, particularly MicroBooNE:
  - Hardware development and testing
  - Operational experience
  - Understanding of calibration needs
  - Reconstruction and analysis techniques
  - Physics measurements
  - Development of community of physicists with LAr experience

Are DUNE and SBN experiments working effectively to ensure that DUNE takes full advantage of SBN experience?

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Yes.

- Overlap of people (165 of 987 DUNE collaborators work on SBN)
- Joint “lessons learned” workshops (Josh’s talk)
- Technical notes (MicroBooNE Public Notes)

Reconstruction and analysis techniques

- SBN program (particularly MicroBooNE) has been at the center of long-term investment in event reconstruction in LAr TPCs
  - There is no substitute for real data
- Multiple reconstruction techniques being developed in parallel
- LARSOFT, coordinated by FNAL scientific computing division, has helped to ensure that that all experiments invest in common software and techniques.
- To date, 90% of LARSOFT commits are from MicroBooNE.

- Note that cosmic rays make reconstruction in surface detectors more challenging than in DUNE

Important developments from other experiments

We also take advantage of software developments in other neutrino experiments. For example,

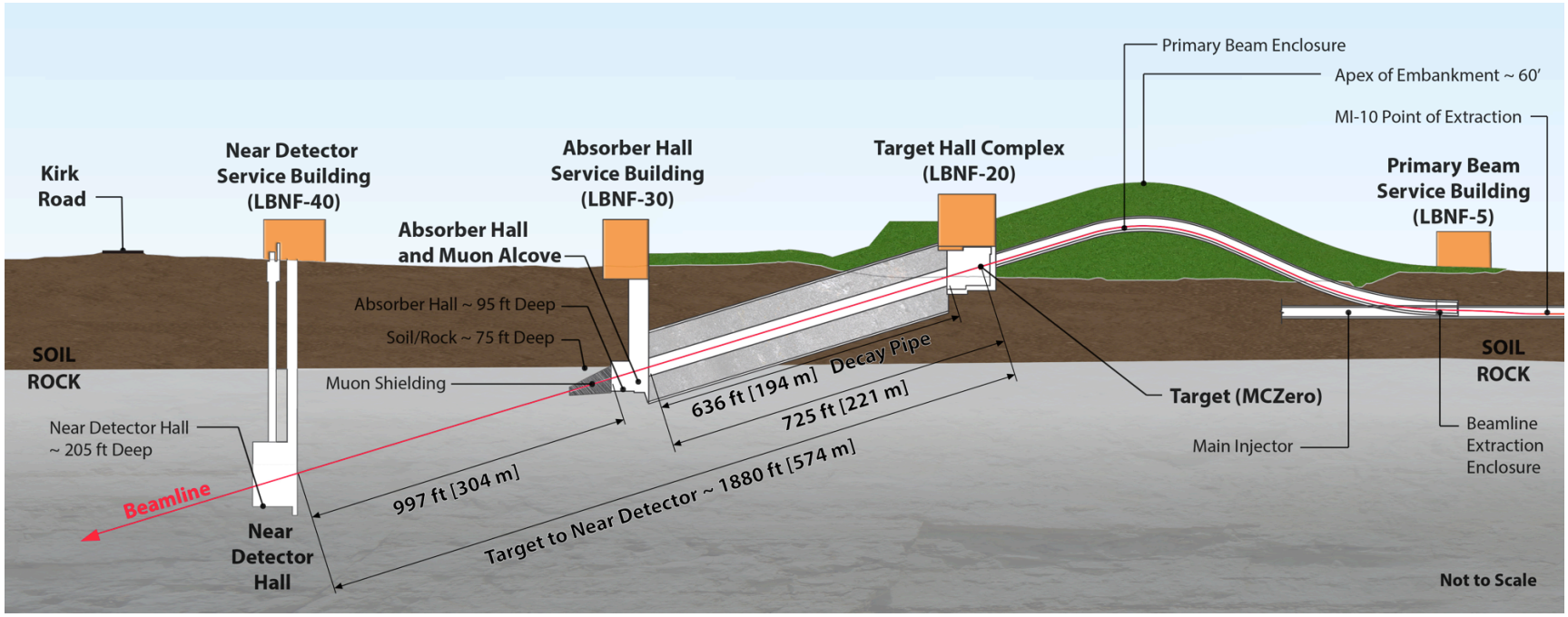
- VALOR (T2K)
- CAFAna (NOvA)
- Recent port of NOvA's convolutional visual network
  - Inputs are the (nearly) raw images from the three 2D detector views
  - Almost direct copy of NOvA network with no DUNE-specific optimizations
  - Already has best performance for classifying neutrino events.

Physics measurements

- SBND (1.5M ν_μ CC/year, 12k ν_e CC/year) will enable a broad program of ν-argon cross-section measurements that could have direct impact in controlling systematic uncertainties in oscillation measurements at DUNE
- Similarly, measurements from other experiments (Minerva, NA61, CLAS12, …) could help to constrain uncertainties in neutrino interaction models.

- In developing a near detector design, however, DUNE plans to minimize impact of external measurements.

Beam and Near Detector



- DUNE Near Detector
  - Precisely measure beam neutrino fluxes
  - Constrain systematic uncertainties for oscillation measurements
  - Multiple designs under consideration

Near Detector Concept Study

- Concept study coordinated by Kam-Biu Luk and Alfons Weber
- Charge: Develop a proposal for a DUNE collaboration near detector concept by the end of 2017.
- Study should:
  - ensure that the proposed near detector concept meets the requirements of the primary scientific goals of DUNE.
  - assume a single near detector hall of a similar to the CD-1-R design, located at a distance of between 360 m and 575 m from the target.
  - present a plausible funding model for the proposed concept, based on the interests and likely contributions to the detector construction from the international collaboration

Near Detector Status

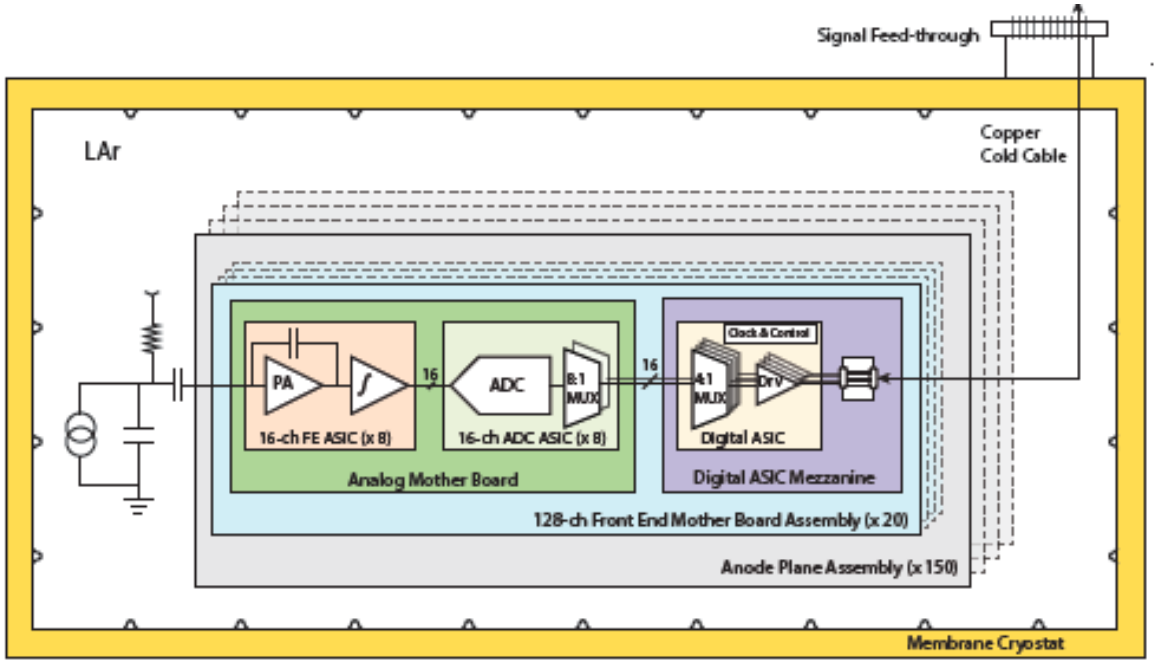
- We held two well-attended workshops at Fermilab (27-29 March, 9-10 June)
- Next workshop will be held on 6-7 November at CERN
- Agreed direction:
  - Near detector will have a non-magnetized LAr-TPC & magnetized (dipole or solenoid?) “multi-purpose tracker”
  - Near detector will remain at 575m, unless LBNF believes there are cost benefits in moving closer

SBND

- Near detector for SBN program, but also conceived as ”prototype” for DUNE single phase far detector
- ProtoDUNE now fills prototype role, but similarity of DUNE and SBND designs resulted in many common investments, including
  - Electronics
  - Cryostats and cryogenics

Electronics

- Initially, there was almost complete alignment between development of electronics for SBND and DUNE/ProtoDUNE
- 128 channel front-end mother boards including 3 types of ASICs:
  - 16 channel amplifier/shaper (8 chips)
  - 16 channel ADC (8 chips)
  - 64 channel communications ASIC (2 chips)



Electronics

- Initially, there was almost complete alignment between development of electronics for SBND and DUNE/ProtoDUNE
  - Both invested in development of P1/P2 versions of FE ASIC
  - Both invested in P1 version of ADC ASIC
  - Front-end motherboard and warm interface board designs for ProtoDUNE started with SBND designs, reducing development time and cost for DUNE.

- Performance issues with ADC resulted in divergence of systems:
  - SBND exploring commercial ADC, warm ADC (à la MicroBooNE), or multiple P1 ASIC / channel system
  - ProtoDUNE using P1 ASIC
  - DUNE developing new ASIC

DUNE electronics strategy

- At start of 2017, the DUNE technical coordinator assembled a task force to make recommendation on TPC electronics.
- Task force chaired by Dave Christian included representatives from FNAL, BNL, LBNL, SLAC, and Mike Shaevitz, who chaired similar task force for SBND.
- Task force presented conclusions at May 2017 collaboration meeting:
  - Current FE ASIC is likely to satisfy DUNE requirements after minor changes.
  - The current “domino” ADC is unlikely to meet DUNE requirements.
  - The communications/data concentrator ASIC (COLDATA) has not yet been tested, but is likely to work.
  - We recommend that a new ADC ASIC be developed using a more conventional architecture.
  - The SLAC group recommends to minimize risk by developing in parallel a fully integrated ASIC (FE+ADC+communications/control).

DUNE-EC endorsed Electronics Plan

1. The existing cold ADC ASIC design will no longer be pursued and a new cold ADC solution would be developed;
2. The development of the new ADC should be a collaborative effort between more than one institution, to avoid a possible single point of failure;
3. As part of a risk mitigation strategy, assuming resources are available, an alternative solution should be investigated. This could be a single-chip solution (combining the functionality of the front-end ASIC, the ADC and the COLDATA chip) or an alternative to the new baseline cold ADC (once chosen).

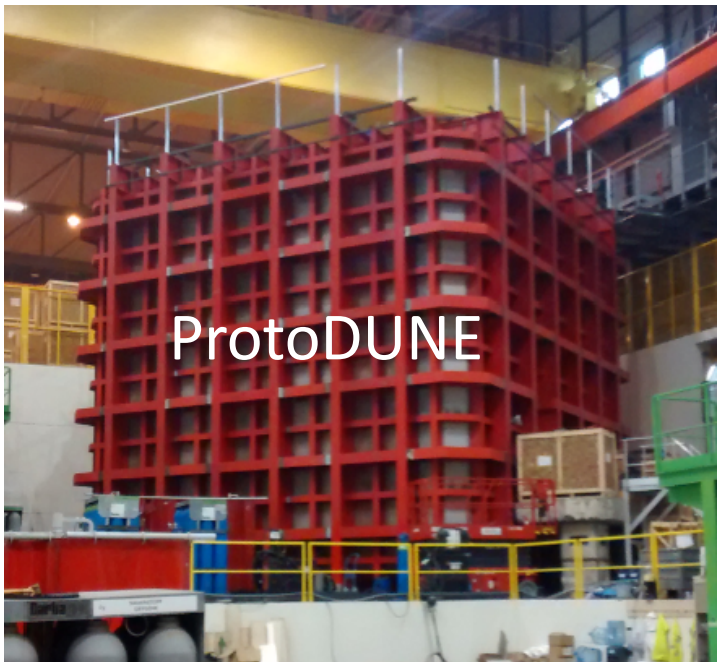
Future Electronics Synergies

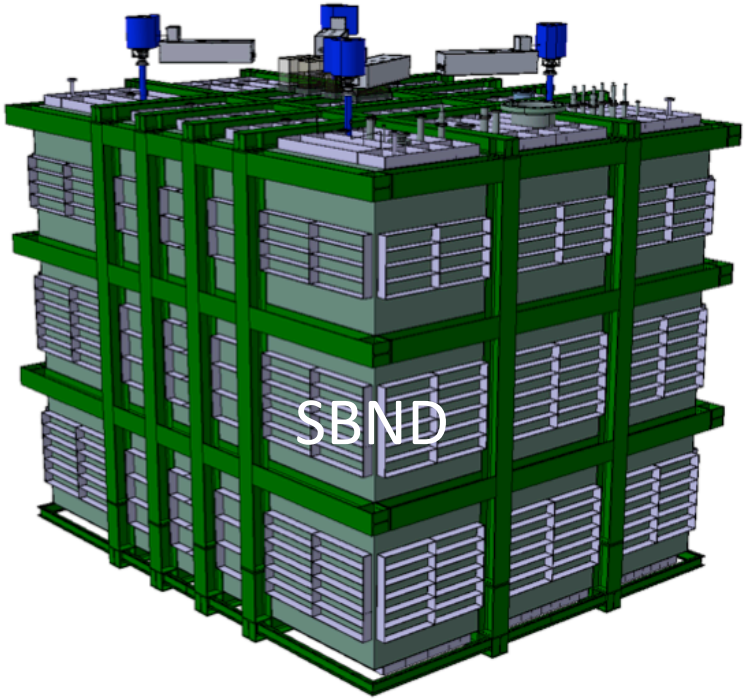
- Could DUNE cold electronics be tested in SBND?
  - It would require early success on DUNE ADC development and delay in SBND schedule.
  - Potential DUNE ADC development schedule:

    Sept '17: Conclude design study; decide on ADC architecture & technology node.
    Dec '17: Finish schematic level design.
    Mar '18: Finish layout.
    April-May '18: Finish layout verification; submit prototype.
    July-Sep '18: Receive prototype ADC, begin testing.
    Nov '18 - Jan '19: Finish prototype ADC tests.
- SBND lifetime qualification for commercial ADC could mitigate risk in DUNE ADC development.

Cryostats and cryogenics

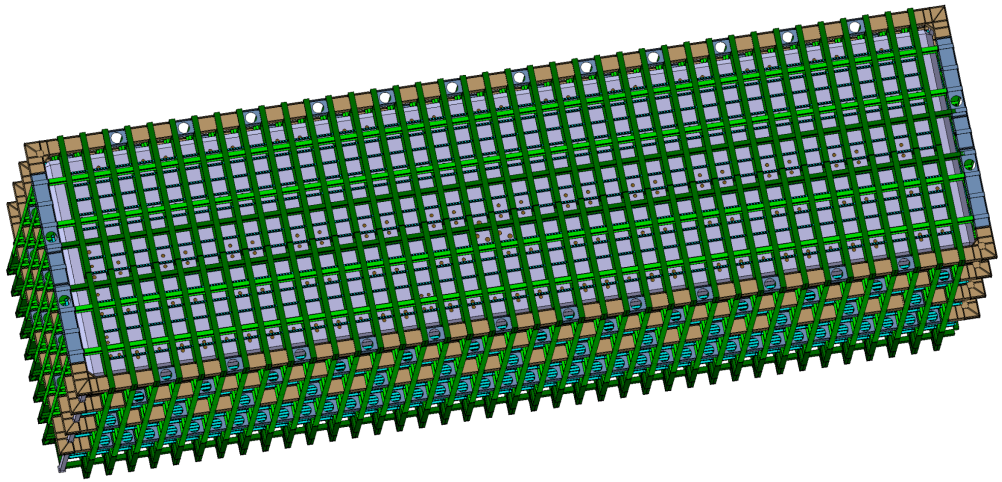
- SBN and LBNF together have developed working relationships between Fermilab and CERN engineering on cryogenics systems
- SBND cryostat is 3rd generation and final prototype before going to LBNF, at least for warm structure.

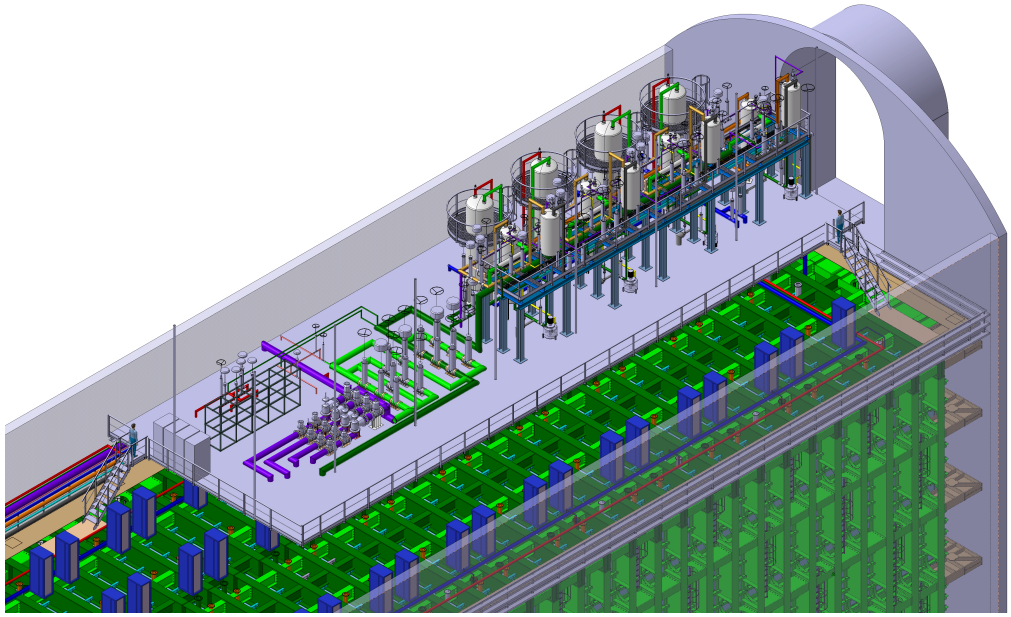




DUNE cryostat

- Cryostat final design review: 21-22 August 2017 at SURF
  - Detector layout proposal ready for DUNE internal discussion.
  - Includes all penetrations and envelopes for the first detector, mezzanine layout, and proximity cryogenics





Far Detector Consortia

- To complete TDR (2019) and construct detector, DUNE has decided to follow an LHC-like model and develop “consortia of institutions” responsible for detector sub-systems.
- Each consortium will have elected leader, technical leader, and consortium board.
- In August 2017, these consortia will replace much of our current working group structure.
- Initial list of consortia (SP=Single phase, DP = Dual phase)

APA (SP)

CRP (DP)

Photon System (SP)

Photon System (DP)

TPC Electronics (SP)

TPC electronics (DP)

DAQ

HV (field cage, cathode plane, feed-through)

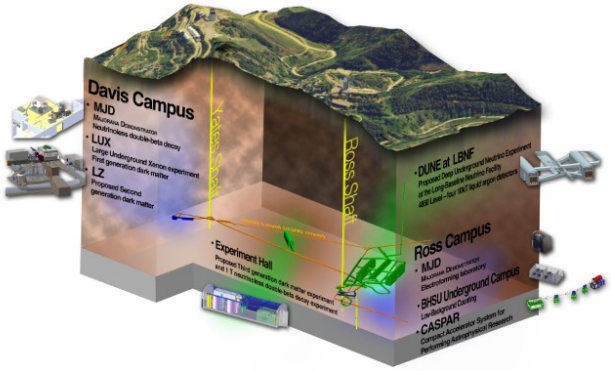
Slow controls and cryogenic monitoring

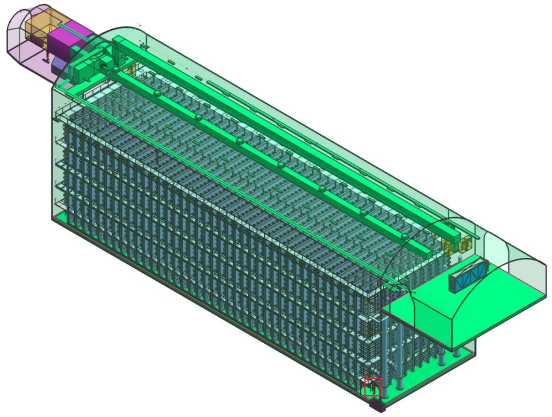
Far Detector Consortia Status

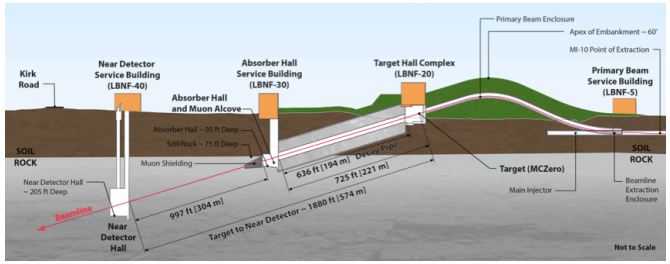
- During recent weeks, Eric James (tech. coor.) has worked with interested groups to develop lists of deliverables for each consortium.
- In about 1 week, we will issue a call for groups to join consortia.
- Co-spokespersons will steer election process for consortium leaders (managed democracy)
- We hope to have consortium leaders in place by August collaboration meeting.

This process has allowed us to bring the single and dual phase detectors into the same collaboration structure

DUNE Timeline







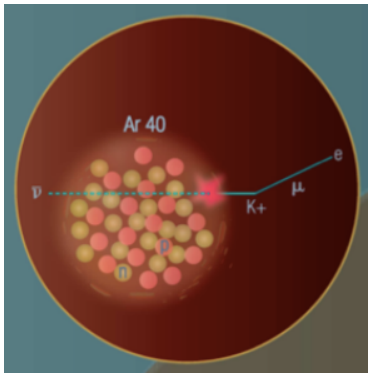
2017: Far Site Construction Begins

2018: protoDUNEs at CERN

2021: Far Detector Installation Begins

2024: Physics Data Begins

2026: Neutrino Beam Available



40 kton + 2 MW beam to follow in subsequent years

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Summary

- From P5 Report: Some of short-baseline experiments "should use liquid argon to advance the technology and build the international community for LBNF at Fermilab." → The SBN program is meeting this goal
- SBN program (MicroBooNE) has been critical to establishing viability of LAr technology for DUNE.
- Collaboration with SBN experiments will continue to be an important part of preparing to do the best possible physics with DUNE.
- Delays in SBN schedule may result in competition for resources as DUNE begins far detector construction.

- Very exciting and busy time for LBNF and DUNE!
- Groundbreaking at SURF on July 21.
- On track to operate ProtoDUNE-SP and ProtoDUNE-DP at CERN in summer 2018

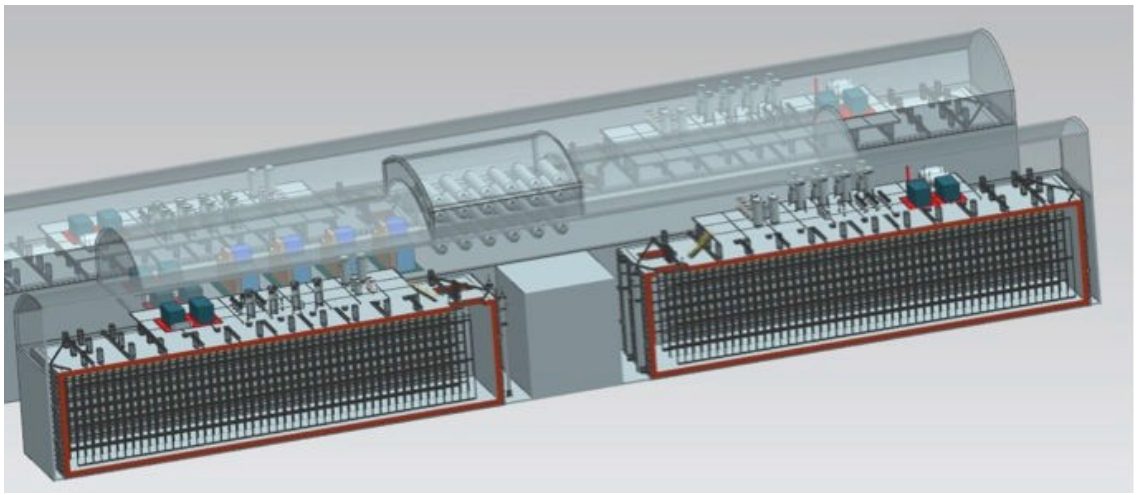
backup

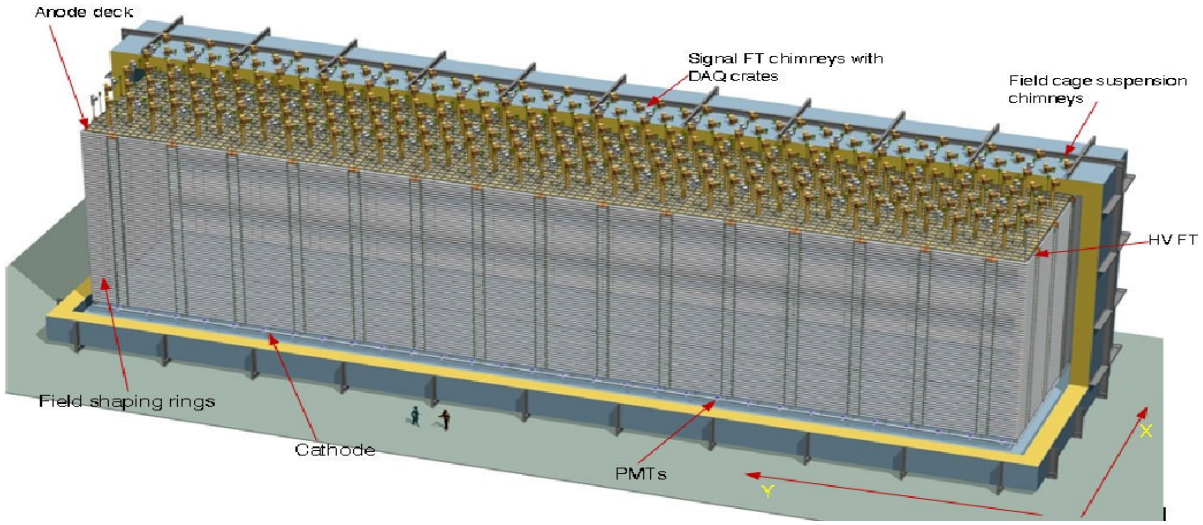
Timeline

- November 2017: First discussion of aspirations for consortia responsibilities to RRB
- Summer 2018: Begin data taking with ProtoDUNEs
- Summer 2018: Far detector (FD) technical proposal
- End of 2018: Decision on design of first two FD modules
- Summer 2019: LBNC review of TDR
- Fall 2019: Funding agency sign-off on responsibilities and funding
- Later fall 2019: DOE CD2 review of LBNF-far and DUNE US (far) – far site and first two far detector modules
- 2021: Far detector construction start
- 2024: First FD module complete
- 2026: First two FD modules, near detector, and beam ready

DUNE Far Detector Technologies

Collaboration is developing and prototyping two liquid argon readout technologies:





Single Phase

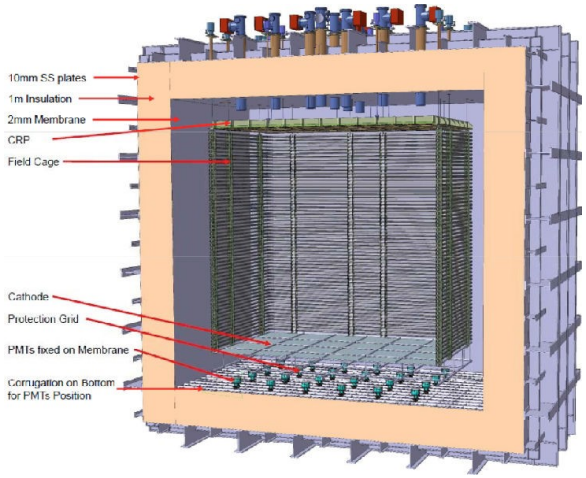
- drift electrons detected in the liquid
- Readout technology of ICARUS, ArgoNeuT, MicroBooNE, SBND
- 3.5 m max drift

Dual Phase

- amplification of electron signal in gas phase
- Pioneered at large scale by WA105.
- 12 m max drift

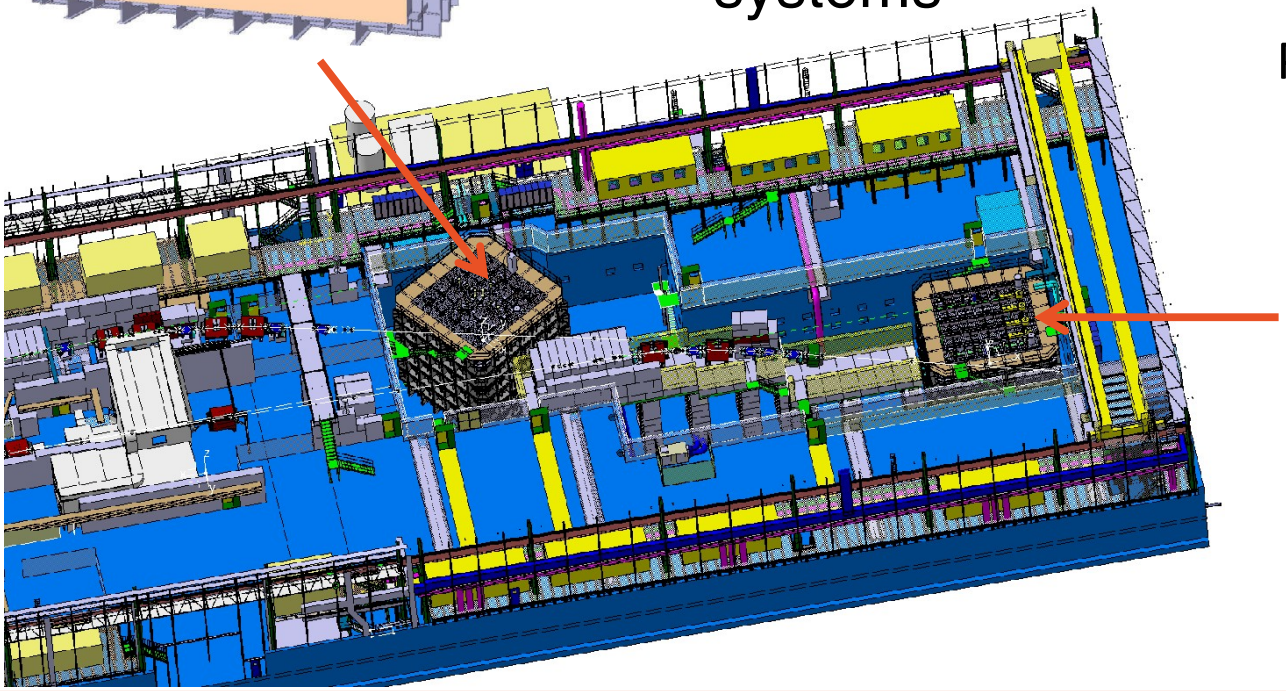
Prototypes at CERN Neutrino Platform

ProtoDUNE Dual Phase

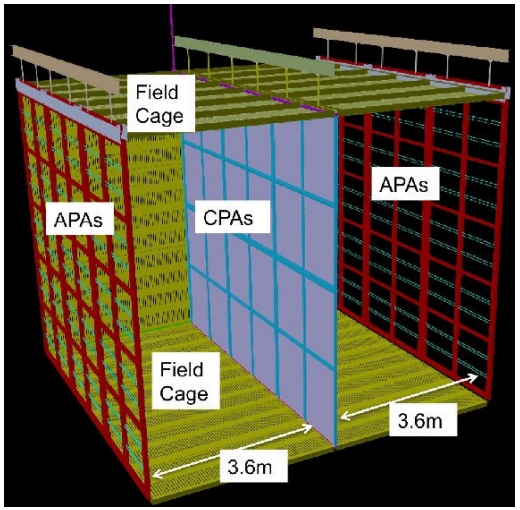


Major CERN investment to support DUNE

- EHN1 extension in the North area
- Two tertiary charged-particle beam lines
- Two 8m×8m×8m cryostats & cryogenic systems



ProtoDUNE Single Phase



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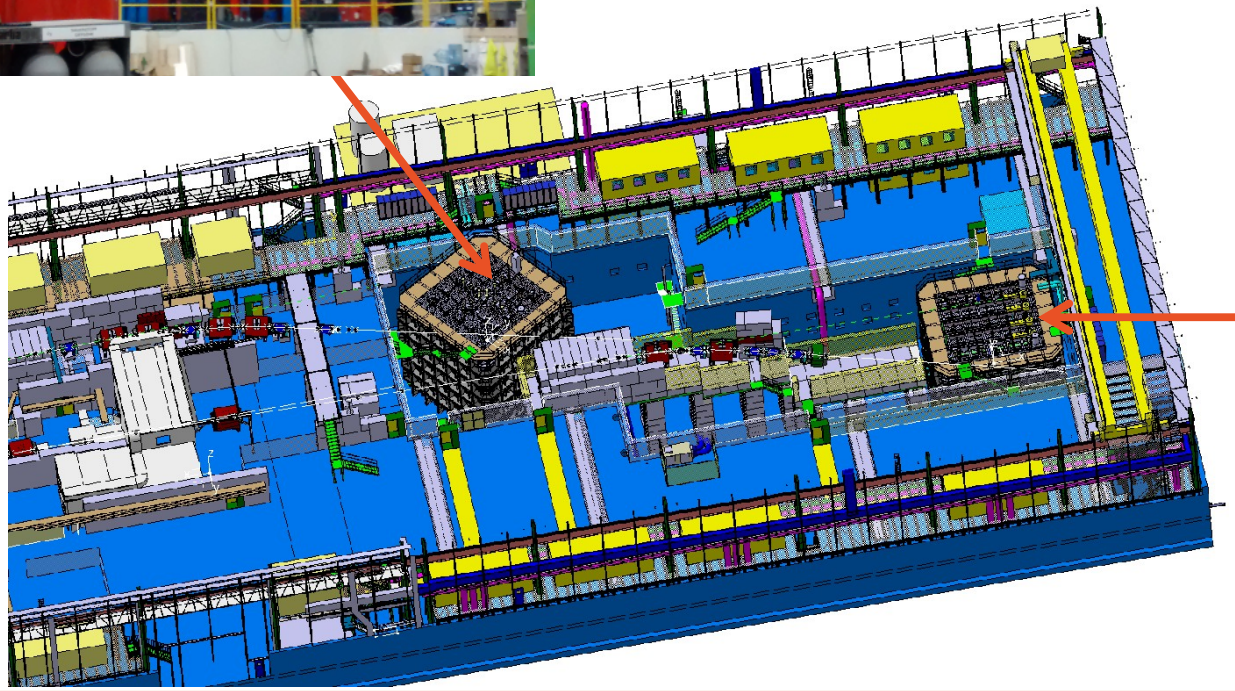
Prototypes at CERN Neutrino Platform

ProtoDUNE Dual Phase

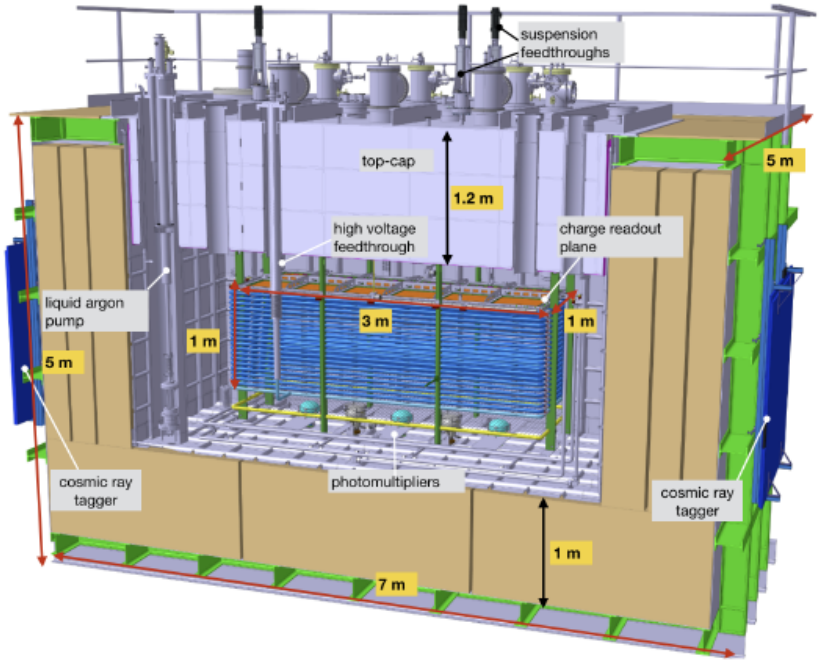
Both ProtoDUNEs aim to begin data taking in mid 2018.

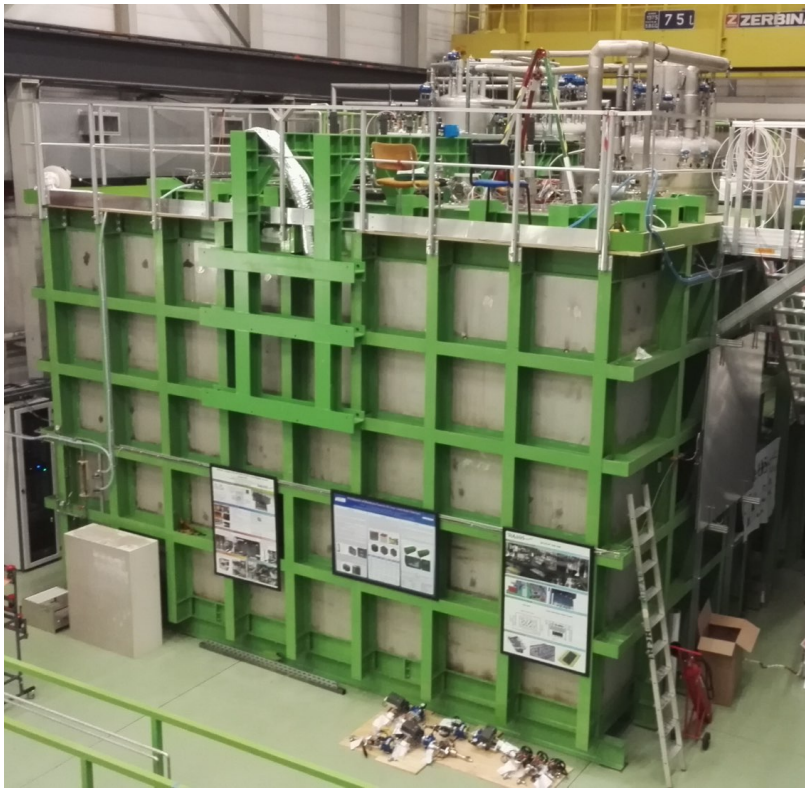
EHN1 Webcams: http://cenf-ehn1-np.web.cern.ch/images/np04-webcam-neutrino-platform-hall-ehn1



ProtoDUNE Single Phase

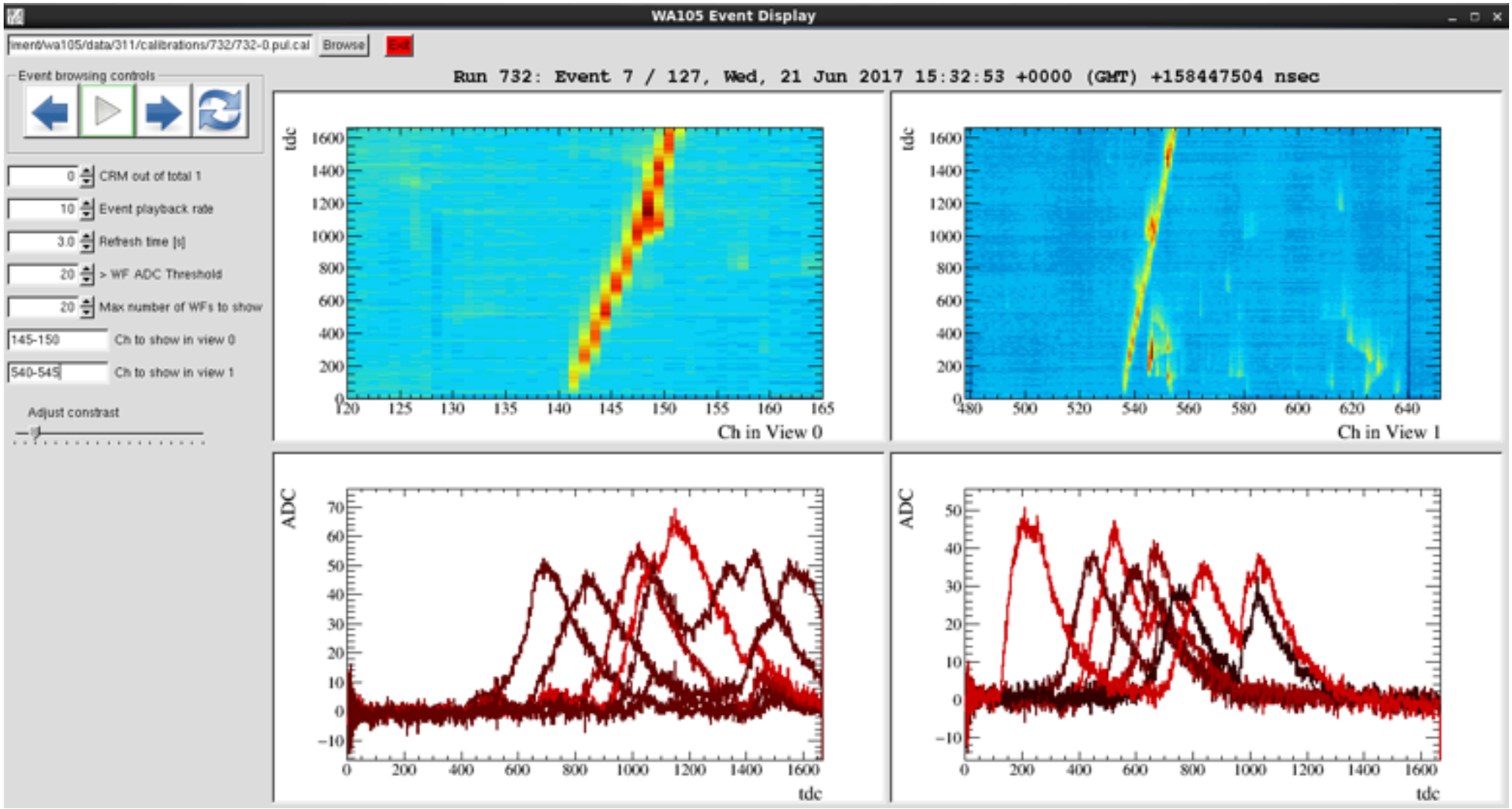
Pre ProtoDUNE-DP: 1m × 1m × 3m





First operation in late June 2017

First cosmic ray in dual phase



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