Long Baseline Neutrino Committee Report

LBNF/DUNE IPR

January, 2019

Fermilab

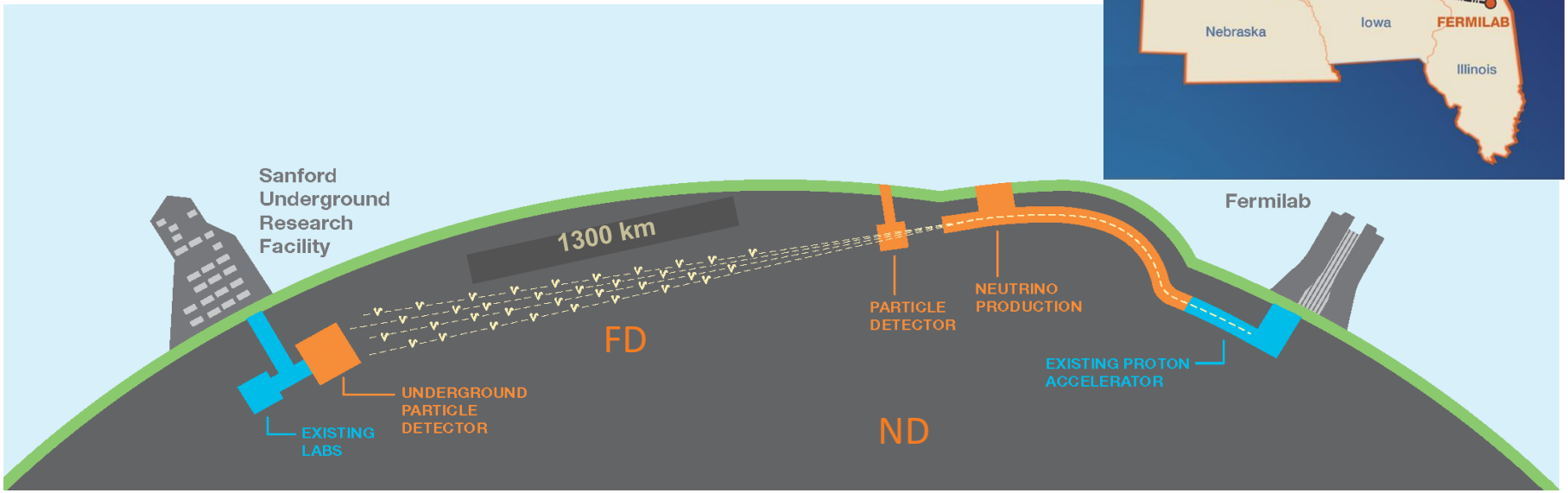
Montgomery

January 9, 2019

Outline

- DUNE The Experiment
- LBNC Scope and Process
- DUNE Intermediate Design Report
- ProtoDUNE status
  - ProtoDUNE DP
  - ProtoDUNE SP
- ProtoDUNE Plans
- Near Detector Status
- Planning and Status of TDR Reviews
  - Schedule
  - Issues
- Conclusions

DUNE Concept



1. A high-power, wide-band neutrino beam (~ GeV energy range).
2. A ≈ 40 kt liquid-argon Far Detector in South Dakota, located 1478 m underground in a former gold mine.
3. A Near Detector located approximately 575 m from the neutrino source at Fermilab close to Chicago.

DUNE Science Program

Neutrino Oscillation Physics

Search for leptonic (neutrino) CP Violation

Resolve the mass hierarchy ($m_3 > m_{1,2}$ or $m_{1,2} > m_3$)

Precision oscillation physics

Parameter measurements, θ_{23} octant

Testing the current three-neutrino model, non-standard interactions, …

Nucleon Decay

Particularly sensitive to channels with kaons

Supernova burst physics and astrophysics

3000 ν_e events in 10 sec from SN at 10 kpc

+ many other topics (ν interaction physics with near detector, atmospheric neutrinos, sterile neutrinos, WIMP searches, Lorentz invariance tests, etc.)

Scope of LBNC

- LBNC is used by the Director for oversight of the international experiment DUNE.

- Oversight of LBNF is limited to those aspects of DUNE which feed directly into DUNE activities. (Below was discussed between LBNC and LBNF leadership but not yet been ratified by Director.)
  - Cryostat and Cryogenic Systems
  - Beamline Implementation for DUNE and Facility for Near Detector
  - Management of LBNF-DUNE Interfaces
  - Monitoring of Risks to International Milestones
  - Regular Plenary Status Report, (subgroup as needed.)

(The initial scope of LBNC was extremely broad, and is posted on PAC/LBNC web page. In order to clarify, the Director communicated as below. The PAC/LBNC web page will be updated.)

LBNC Membership

- **LBNC Members**
  - **Sampa Bhadra, Amber Boehnlein, Dave Charlton, Angela Fava (Sci-Sec), Joel Fuerst, Bob Laxdal, Christiano Galbiati, Beate Heinemann, Patrick Huber, David MacFarlane (past-Chair), Naba Mondal, Jocelyn Monroe, Hugh Montgomery (Chair), Kevin Pitts, Marco Pallavicini, Tom Peterson, Jimmy Proudfoot, Bob Tschirhart**
- **LBNC Consultants**
  - **Alan Bross, Carl Dahl, Eliana Gianfelice-Wendt, Hugh Lipincott, Adam Para, Anna Pla-Dalmau, Kem Robinson, Tom Shutt, Craig Tull**
- **Member Rotation (partial) in Progress**

DUNE continues to grow

- 1180 collaborators from 178 institutions in 32 countries
- 628 faculty/scientists, 199 postdocs, 119 engineers, 234 PhD students

Armenia (3), Brazil (30), Bulgaria (1), Canada (1), CERN (34), Chile (3), China (5), Colombia (13), Czech Republic (11), Spain (32), Finland (4), France (24), Greece (5), India (45), Iran (2), Italy (65), Japan (7), Madagascar (8), Mexico (10), The Netherlands (4), Paraguay (4), Peru (8), Poland (6), Portugal (7), Romania (7), Russia (10), South Korea (4), Sweden (1), Switzerland (36), Turkey (2), UK (148), Ukraine (4), USA (637)

Status: 1/1/2019

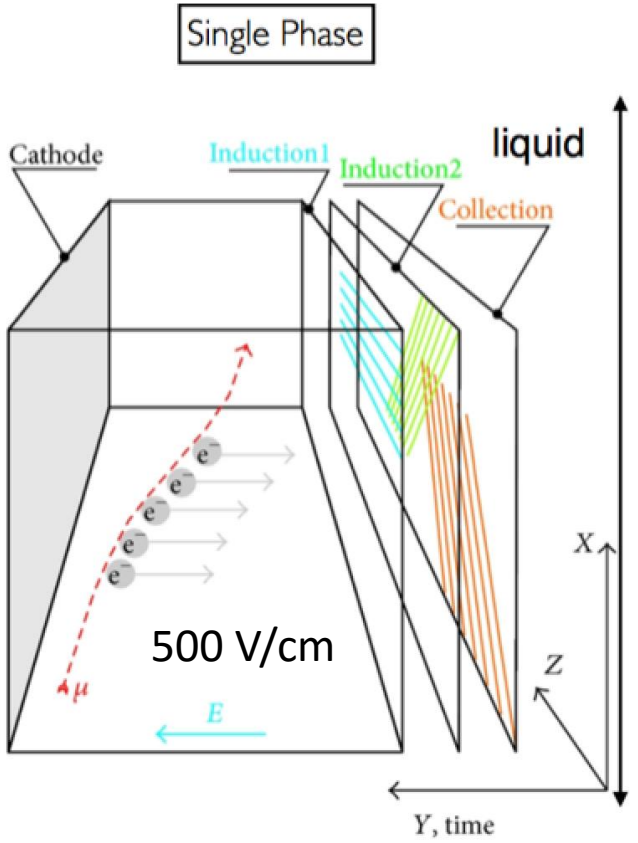
DUNE International Progress

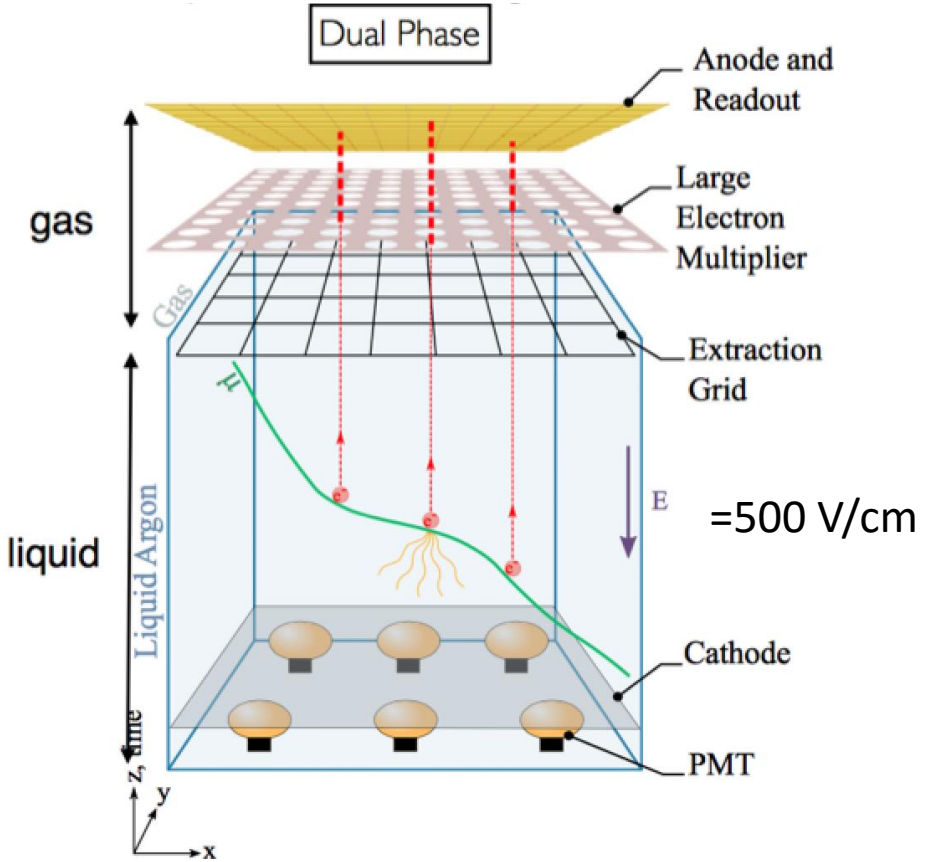
- **Europe:**
  - DUNE submission to the European Strategy for Particle Physics
  - UK: $88M commitment to LBNF/DUNE/PIP-II
  - France: DUNE on the research infrastructure road map
  - Portugal: joined DUNE at May 2018 meeting
  - Germany: growing interest within community (including DESY), first funding for a University through Excellence Initiative
  - Italy: engaged and interested in near detector, far detector
  - Spain: engaged and funding requests under discussion
  - Switzerland: DUNE on Swiss road map, funding request
- **Americas:**
  - Latin America: meetings with FA representatives: Brazil, Colombia, Mexico, Peru; discussions in Brazil last week
  - Canada: joint FNAL-York position on DUNE
  - US NSF: planning grant for APA construction; discussions ongoing
- **Asia:**
  - India: Annex 2 for cooperation on neutrinos was signed; India DUNE workshop recently held at TIFR, excellent attendance.
  - Korea: ICRADA with Chung Ang University
  - Japan: eager to have broader involvement of Japanese groups

Global DUNE Strategy (Current)

- **Module 1 Single Phase (SP)**
- **Module 2 Dual Phase (DP)**
- **Module 3 Single Phase (SP)**
- **Module 4 Future Tech Choice**

Subject to discussion for modules 2-4



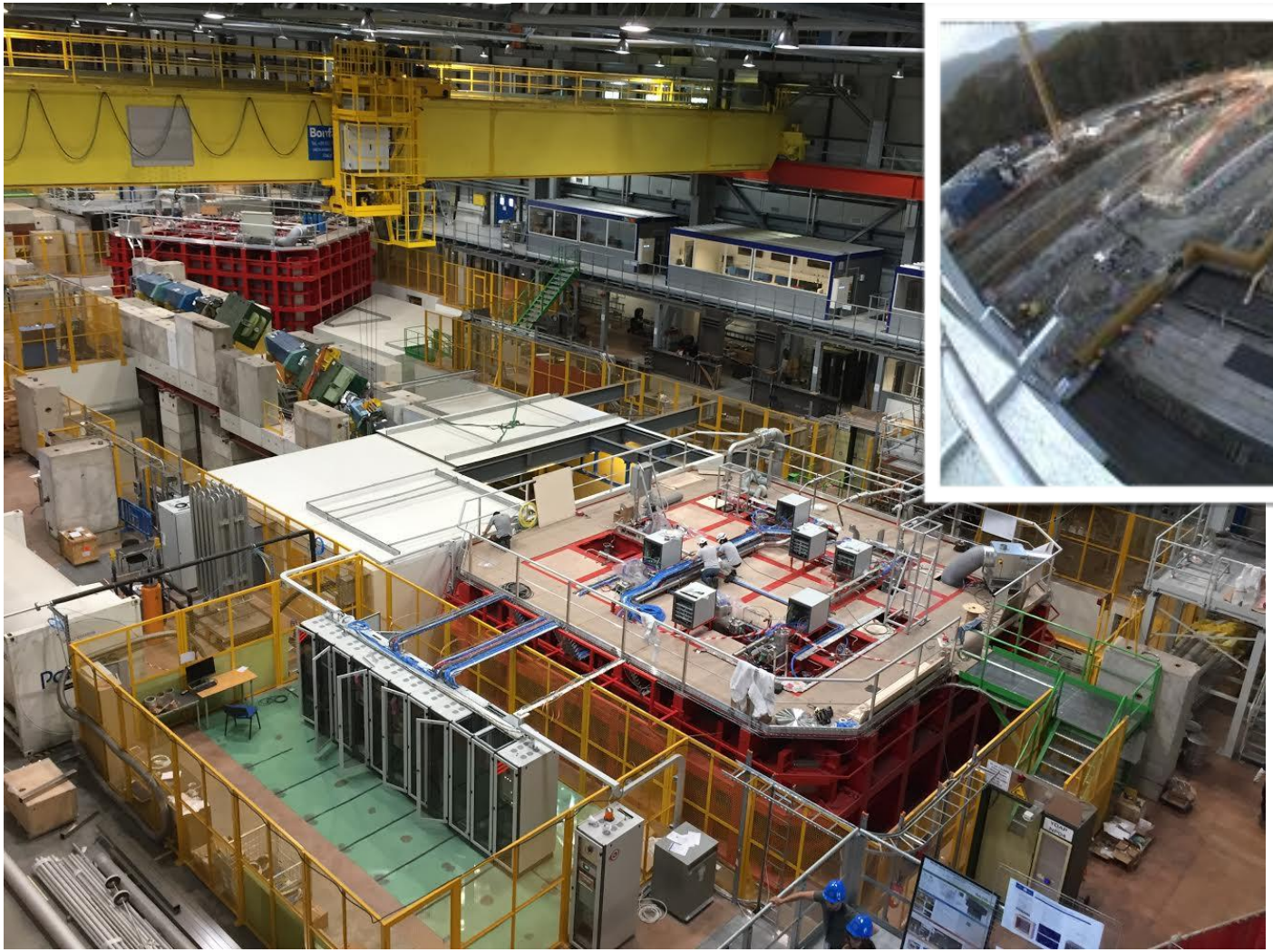


- Ionization charges drift horizontally and are read out with wires
- No signal amplification in liquid
- 3.6 m maximum drift
- Read out by APAs

- Ionization charges drift vertically and are read out on PCB anode
- Amplification of signal in gas phase by LEM
- 12 m maximum drift
- Access through chimneys on top

DUNE is committed to deploying both technologies – staging depends on funding and ProtoDUNE results

CERN Neutrino Platform

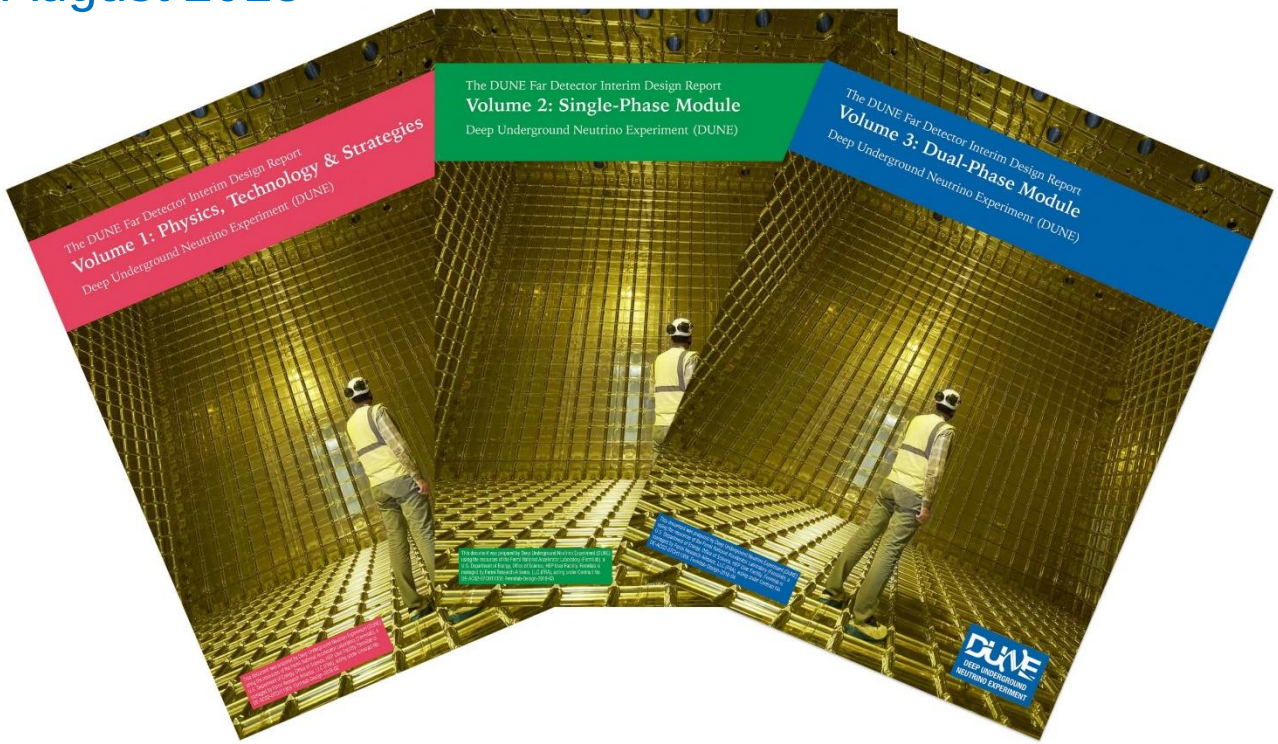


Dec 2015

DUNE Intermediate Design Report

- Mainly Reviewed in Summer 2018
- Reported in LBNC August 2018

arXiv:1807.10327



- Dual Phase Status Reviewed in December 2018
- Expect that Commentary and Recommendations will inform the TDRs

December 2018 LBNC: DUAL Phase Status: Results from the 1x1x3 m^3 Demonstrator

The 1x1x3 took 400K cosmics in the period July-November 2017 and demonstrated many key technical and performance measures for a Liquid Argon Dual Phase TPC, for example 500v/cm drift field, electron lifetime ~4msec, equal charge sharing between anode collection planes, stable liquid argon level during recirculation, correlation between scintillation light and collected charge.

Stable operating conditions required a compromise between the voltages across the induction plane, the Large Electron Multiplier (LEM) and the absolute grid HV; LEMs were operated with electric fields in the range from 23 and 31 kV/cm, most of the data were taken at 28kV/cm corresponding to an effective gain in the range of ~3. Global trips occurred after operating the LEMs for ~ 1hr and it was not possible to bring the LEMs to high fields – prompting a change in the LEM design to incorporate a larger guard ring.

A number of additional design changes were implemented based on the results of the demonstrator testing.

These results have recently been published in JINST.

December 2018 LBNC: DUAL Phase Status: LEM Production & Testing

Results were presented for the 74 LEMs produced and tested for Charge Readout Planes (CRP1 & CRP2)

LEMs were tested up to 3.5 kV (35kV/cm) in Ar at 3.3 bar and have <1 spark/20 minutes

For an optimum induction voltage of 1 kV, stable operation in the cold box was not achieved for HV configurations which give an effective gain ~20; the source of instability is not fully understood. Stable configurations can be achieved by decreasing the induction field between the anode and the top of the LEM and can achieve an effective gain from 24-31

Dark spots were seen in the corner of LEMs in CRP1 following removal from cold box; this was attributed to uncontrolled sparking due to a lack of protection in the power supply.

Following rework, two CRPs are operational though with the limitation above on the induction field and corresponding LEM HV (bottom HV on the LEM)

Further understanding/improvement of LEM design is being addressed; the committee is concerned at the impact of sparking on LEM performance and viability for DUNE-DP

Recommendations

- Develop an R&D plan to improve the LEM design to the specification needed for DUNE-DP (stability, gain, reliability, spark rate, operational lifetime)

December 2018 LBNC: DUAL Phase Status: CRP Assembly & Cold-Box Testing

The cold-box has proven to be an effective tool for CRP testing and substantially enhances the capabilities of the CERN NP infrastructure; the planarity of CRP distance to liquid level in the CB is stable to within 1.75mm and the relative distance between the liquid and the CRP is stable to 0.25mm.

4 CRPs are being prepared for installation in ProtoDUNE-DP, two of these will be dummies (i.e. with no LEMs or anodes); construction time was approximately 1 CRP/month; CRP4 will be delivered to CERN at the end of January

Following initial tests: modifications to grid tension, HV connection and HV distribution were implemented; for CRP1, 4 LEMs were removed cleaned and re-installed (see above); for CRP2, 1 LEM was replaced by a spare (insufficient time to clean)

Recommendations

- Feed back lessons learned from assembly defects requiring rework into CRP construction and QA/QC plan (e.g. residual flux on wires, grid wire tension at cold, HV shorts on grid)

December 2018 LBNC: DUAL Phase Status: ProtoDUNE-DP Installation

The external cryogenic system has been completed following the conclusion of PD-SP operation with beam.

Proximity cryogenic systems were installed in SEP2018.

Installation of 4 CRPS in the DP cryostat is in progress, two of these CRPS will be dummies

A problem appeared during the insertion of CRP3 in the cryostat where 3 wires broke in the process and 7 more in the following days

The installation schedule presently shows closing of the NP02 Cryostat by week 14 of 2019, with filling and purification completing by week 28, 2019 (22nd July)

No cosmic data-taking plan was presented

Lessons learned from ProtoDUNE-SP operations will be of use in ProtoDUNE-DP operations

Recommendations

- Develop a plan for incorporation of commissioning measurements, and if possible cosmic ray data, from ProtoDUNE-DP which will inform the DUNE-DP TDR on key performance metrics

December 2018 LBNC: ProtoDUNE SP Status

- The LBNC offers its warm congratulations to ProtoDUNE on the construction, filling, operation and successful data-taking of PD SP
- The rapid attainment of a 500 V/cm drift field, a 6(+) ms e- lifetime, and noise of 500-600 ENC are highly impressive and very promising for DUNE
- We look forward to seeing more results from analysis of beam and CR data from analyses underway or starting – crucial to support the TDRs
- We would like to see progress on photon detector data/performance
- Prompt documentation on lessons learnt is important throughout, including root cause analyses

DUNE is on a path to establish a baseline technology

ProtoDUNE SP/DP 2019

- **CERN has agreed to operate the Neutrino Platform through 2019**
- **ProtoDUNE SP**
  - Operation of PD SP during 2019 has the strong support of the LBNC
  - The push to make rapidly a detailed prioritization and scheduling of goals for 2019 operations is strongly supported, informed by needs for the DUNE TDR
  - The LBNC emphasizes the importance of establishing and studying the operational baseline and its long-term stability, for the TDR
  - We see the interest of addition of Xe at the end of the run, provided the photon detector performance is sufficient.
- **ProtoDUNE DP**
  - The installation schedule presently shows closing of the TCO by week 14 of 2019, with filling and purification completing by week 28, 2019 (22nd July)
  - A plan for data taking with Cosmic Rays is needed
- **The SPSC has requested and received proposals for future running**

Near Detector Motivation

- Neutrino Oscillations seek to measure changes in the neutrino content of the beam between source and Far Detector.

- A Near Detector aims to DEFINE the source, and to provide a knowledge base which mitigates uncertainties in:

The Flux

The Neutrino Cross-Section

The smearing of the Energy Measurement

- The understanding of these are recognized as critical to controlling the systematic uncertainties at the desired levels.

- The Near Detector may also enable other physics measurements

December 2018 LBNC: Near Detector Status

- Proposed Near Detector suite consists of a LArTPC , a Multi-Purpose Detector (MPD) consisting of a HPgTPC, an ECAL and 3D Scintillator Tracker (3DST) in a magnet.
- The DUNE –PRISM concept envisage LArTPC and probably MPD to be mobile and make measurements at several off-axis positions along with on-axis measurements. will help to simultaneously constrain neutrino flux, cross sections and energy smearing.
- Detailed simulation effort is ongoing to understand the systematics reach of this detector concept.
- The concept appears to be interesting and LBNC looks forward for a full review of the design and its capabilities and its cost in the summer of 2019.
- There are several milestones coming up that will need a clear and approved time line for Near Detector.

Recommendations – One Added after the fact

- The description for review should be explicit in giving the impact of each aspect of the design for the important physics goals.

TDR preparation schedule

Consortium	1st draft	2nd draft	To LBNC
SP-HV	2-Nov-18	7-Dec-18	21-Dec-18
SP-APA	2-Nov-18	14-Dec-18	21-Dec-18
SP-DAQ	12-Nov-18	14-Dec-18	21-Dec-18
SP-PDS	7-Dec-18	11-Jan-19	25-Jan-19
SP-CISC	30-Nov-18	11-Jan-19	25-Jan-19
TC	7-Dec-18	11-Jan-19	25-Jan-19
PHYSICS	30-Nov-18	11-Jan-19	25-Jan-19
SP-CE	14-Dec-18	8-Feb-19	22-Feb-19
DP-Electronics	14-Dec-18	8-Feb-19	22-Feb-19
Computing Exec Summary	14-Dec-18	8-Feb-19	22-Feb-19
DP-HV	1-Feb-19	1-Mar-19	29-Mar-19
SP-IIC	1-Feb-19	1-Mar-19	29-Mar-19

Consortium	1st draft	2nd draft	To LBNC
DP-PDS	1-Mar-19	5-Apr-19	26-Apr-19
SP-Calibration	1-Mar-19	5-Apr-19	26-Apr-19
SP-Exec Summary	1-Mar-19	5-Apr-19	26-Apr-19
ND-Exec Summary	1-Mar-19	5-Apr-19	26-Apr-19
DP-IIC	5-Apr-19	10-May-19	31-May-19
DP-DAQ	5-Apr-19	10-May-19	31-May-19
DP-CISC	5-Apr-19	10-May-19	31-May-19
DP-Calibration	10-May-19	7-Jun-19	28-Jun-19
DP-CRP	10-May-19	7-Jun-19	28-Jun-19
DP-Exec Summary	10-May-19	7-Jun-19	28-Jun-19
Overall Exec Summary	10-May-19	7-Jun-19	28-Jun-19
TDR Final			26-Jul-19

This schedule is ambitious both for DUNE and for the LBNC.
Goal is to report to Director and to September RRB

December 2018 LBNC: TDR Overall Status

- The general organisation and planning of the TDRs looks good, including the provision to the LBNC of “2nd drafts” early, mixed across TDR volumes
- The committee appreciates the willingness of the collaboration to share these drafts to facilitate timely review
- The LBNC expects to need multiple, detailed, iterations on the design and performance as outlined in the individual chapters
- It is important that an overview of each volume, including the big picture design and relation to physics requirements, is available at the start of the review process – this should contain the drivers of the design described in the rest of the volume, not simply summarise that design

Recommendations

The LBNC appreciates the production of the “DUNE Far Detector (Single Phase) Design Choices and Physics Connections” document, but asks to see the physics connections further developed in the TDR

December 2018 LBNC: Exec Summary:

- DUNE and LBNF have made good progress on a number of fronts.
- There are numerous technical issues that will need to be decided on a weekly basis. The EB needs to be aware and to weigh in on the important ones.
- The DUNE approach to detector requirements and their justification needs further refinement to tighten connections with the physics performance.
- DUNE should be complimented on the Computing Consortium developments.
- Congratulations to the Collaboration for the success of ProtoDUNE-SP. This leads to the need for a plan for 2019 operations.
- The progress with the DP has been slower than planned.
  - Several technical challenges have been encountered.
  - The operation of NP02 will occur in the second half of 2019; we encourage the continued strong support of CERN for the Dual Phase effort.
  - A program of R&D at the level of the LEM is needed and planned, in parallel with the performance assessment in ProtoDUNE-DP
- The Near Detector concept is being developed and should be reviewed in mid 2019.

We look forward to the TDR Review Phase over the next 6 months

- **Backups Follow**

Compilation of LBNC December 2018 Recommendations I

- **Exec Summary**
  - **Recommendations: None**
- **LBNF Status**
  - **Recommendations: None**
- **ProtoDUNE SP Status**
  - **Recommendations: None**

- **DUAL Phase Status**
  - **Results from the 1x1x3 m^3 Demonstrator**
  - **Recommendations: None**
  - **LEM Production & Testing**
  - **Recommendations:**
    - **The DUNE-DP consortium should develop an R&D plan to improve the LEM design to the specification needed for DUNE-DP. Performance characteristics to be studied should include LEM stability, gain, reliability, spark rate, and operational lifetime and should have a clear physics motivation.**

Compilation of LBNC December 2018 Recommendations II

- **CRP Assembly & Cold-Box**
- **Recommendations:**
  - **The DUNE-DP consortium should feed back the lessons learned from assembly defects observed in the tests of LEMs and CRPs which required rework into the plan for CRP construction and QA/QC plan for DUNE (e.g. residual flux on wires, grid wire tension at cold , HV shorts on grid).**
- **ProtoDUNE-DP**
- **Recommendations:**
  - **Develop a plan whereby performance data from operation of cold box and ProtoDUNE-DP/SP tests can be incorporated into the DUNE-DP TDR**
  - **Quantify the tradeoff between LEM gain and physics performance and scope**
  - **Develop a combined simulation and performance measurement plan to demonstrate the validity of the extrapolation of ProtoDUNE-DP performance to a 12m drift distance**
  - **A number of optimizations are planned to the design of the field cage, cathode and ground in extending the ProtoDUNE-DP designs to the full 12 m detector required for DUNE-DP. The DUNE-DP TDR should present the plan by which these changes to the design are qualified.**

Compilation of LBNC December 2018 Recommendations III

- DUNE-DP IDR & TDR
- Recommendations:
  - The DUNE-DP consortium should prepare a TDR which addresses the concerns articulated above.

- TDR/CDR Preparation Status
  - TDR Overall Status:
  - Recommendation:
    - The LBNC appreciates the production of the "DUNE Far Detector (Single Phase) Design Choices and Physics Connections" document, but asks to see the physics connections further developed in the TDRs.
  - Physics TDR Status
  - Recommendations: None
  - Computing Plans
  - Recommendations:
    - For the computing strategy summary in the TDR we recommend a tight focus, stressing the impact of the ProtoDune experience, a short description of the consortium model, and long lead-time items, such as SURF WAN.

Compilation of LBNC December 2018 Recommendations IV

- APA TDR Status
- Recommendations:
  - The TDR in preparation should be responsive to the commentary above, which reiterated the recommendations on the IDR.

- Near Detector Status:
  - Recommendations:
    - Include in the TDR and the 2019 review a clear linkage between the physics drivers and the technical requirements arising from those drivers for the detector performance. This should support scope decisions should resource limitations need to be applied.