DUNE Status

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Ed Blucher

LBNC Meeting

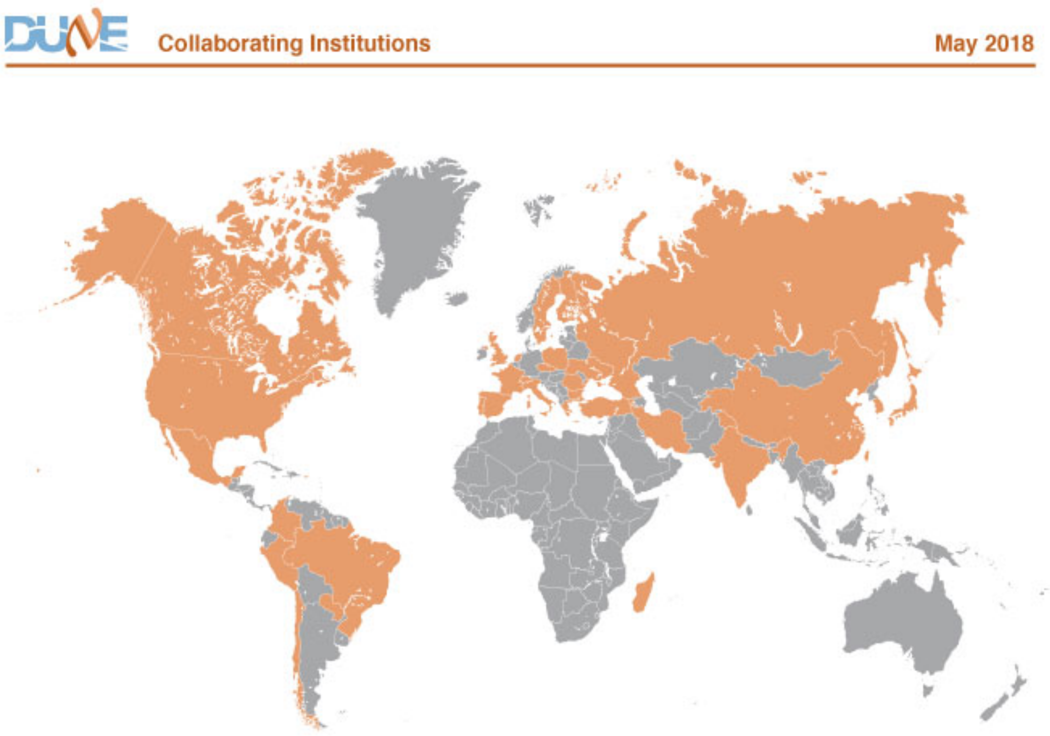
6 December 2018

Fermilab

MANCHESTER 1824

DUNE continues to grow

- 1179 collaborators from 178 institutions in 32 countries
- 624 faculty/scientists, 200 postdocs, 114 engineers, 232 PhD students



Armenia (3), Brazil (29), Bulgaria (1), Canada (1), CERN (32), Chile (3), China (5), Colombia (13), Czech Republic (11), Spain (34), Finland (4), France (23), Greece (4), India (45), Iran (2), Italy (63), Japan (7), Madagascar (8), Mexico (8), The Netherlands (4), Paraguay (4), Peru (8), Poland (6), Portugal (7), Romania (7), Russia (10), South Korea (4), Sweden (1), Switzerland (35), Turkey (2), UK (148), Ukraine (4), USA (637)

DUNE Collaboration Meeting (24-28 Sept)

Next Meeting: 28 Jan – 2 Feb 2018 at CERN

DUNE Collaboration Meeting (24-28 Sept)

Jace DeCory,
Black Hills State
University

http://vms.fnal.gov/asset/detail?recid=1957092

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

DUNE Far Detector Consortia

Single-Phase

- APA: Christos Touramanis (Liverpool)
- Photon Detection System: Ettore Segreto (Campinas)
- TPC Electronics: Dave Christian (FNAL)

Dual-Phase

- CRP: Dominique Duchesneau (LAPP)
- Photon Detection System: Ines Gil Botella (CIEMAT)
- TPC Electronics: Dario Autiero (IPNL)

Joint SP/DP

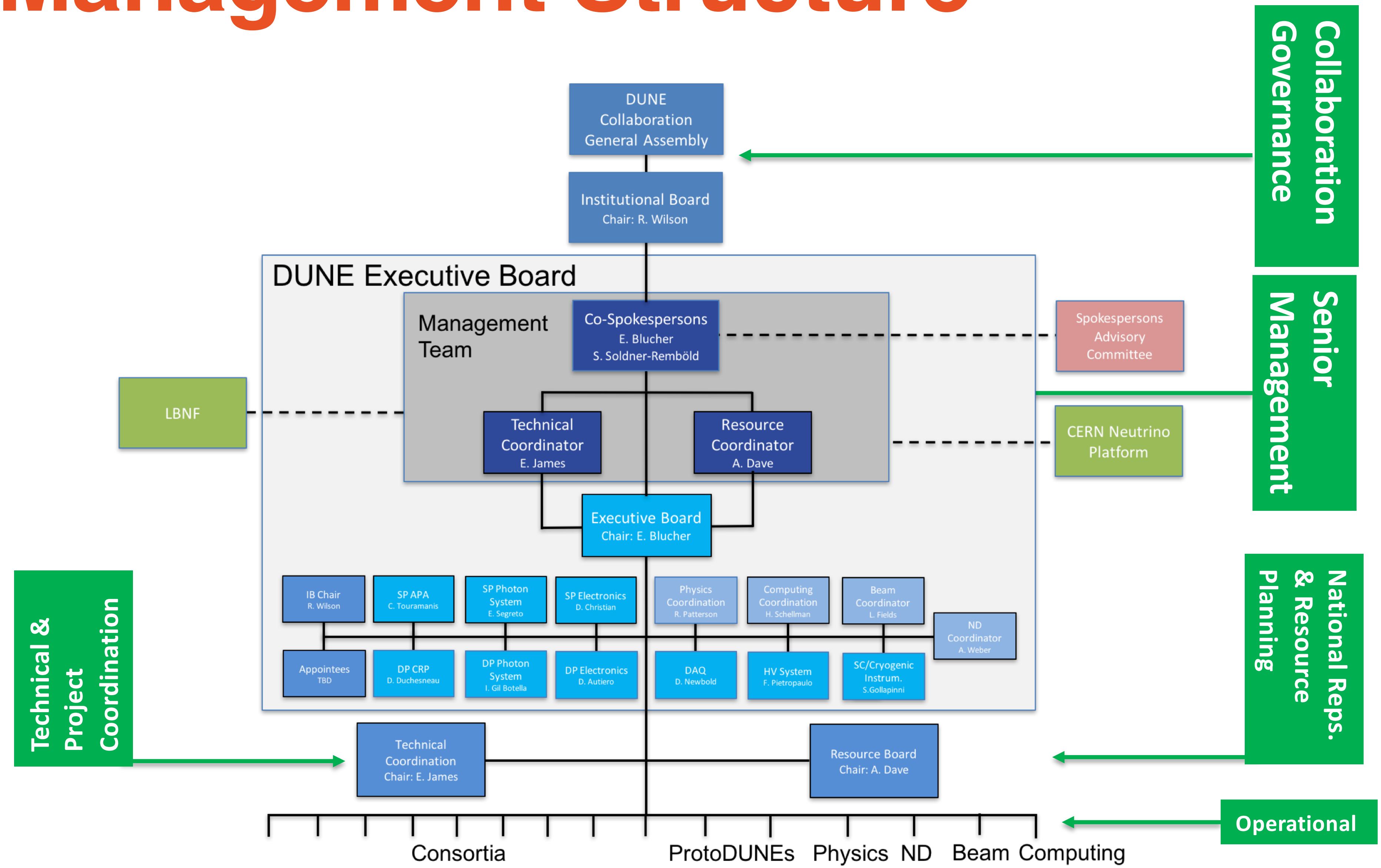
- HV System: Francesco Pietropaolo (CERN)
- DAQ: Dave Newbold (Bristol)
- Slow Controls/Instrumentation: Sowjanya Gollapinni (Tennessee)
- Computing: Heidi Schellman (Oregon State)
- Calibration: Jose Maneira (LIP)

New Consortia and Task Forces

We have formed two new Consortia and one new Task Force:

- Computing Consortium
  - CL: Heidi Schellman, Oregon State; FTL: Mike Kirby, ITL: tbc
  - Develop international computing model for DUNE
- Calibration Consortium
  - CL: Jose Maneira, LIP; TL: Kendall Mahn (MSU)
  - Laser system, neutron source, radioactive sources
  - Calibration Task Force will continue in parallel until TDR
- Background Task Force
  - Simon Peeters (Sussex) and Jürgen Reichenbacher (SDSMT)
  - Requirements and specifications for radiopurity, neutron background

Management Structure



Charge of this meeting

- In-depth presentations covering the development of the Dual Phase option, including a look forward to 2019 with ProtoDUNE DP, and preparations for a TDR.
- TDR and CDR preparations in a few key areas.

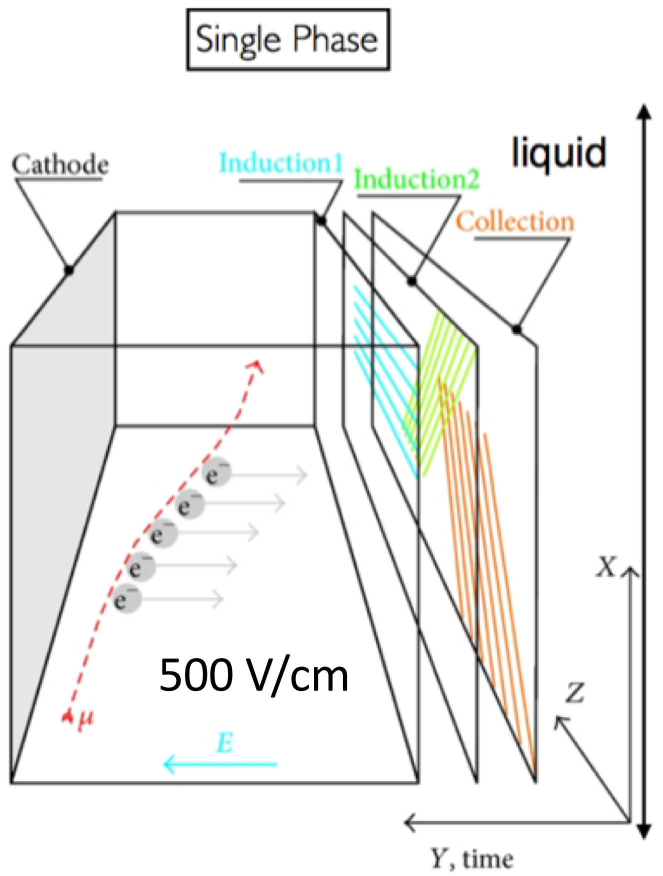
We hope that holding this meeting at CERN will provide an opportunity to familiarize the Committe with the excellent progress made on both ProtoDUNEs since the last LBNC Meeting.

Different format of this LBNC with only plenary presentations:

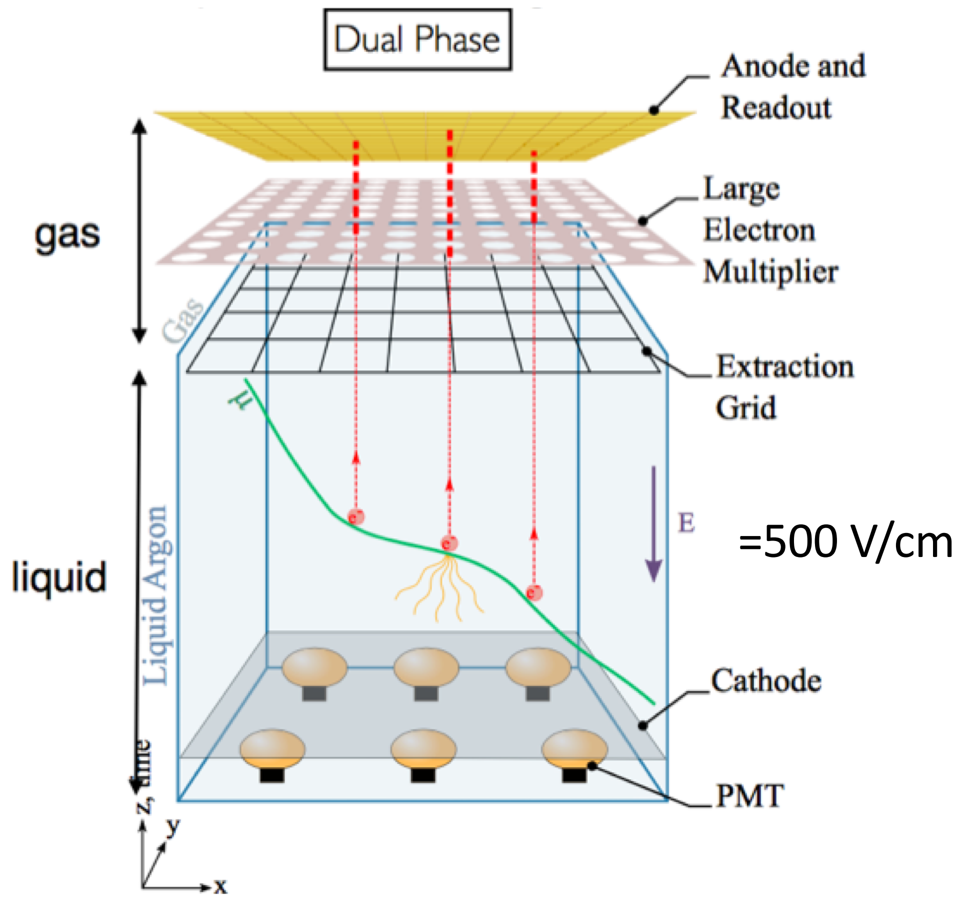
Plenary Talks - Today

Today's focus is on Dual-Phase Technology:

- Results from the 1x1x3 m^3 Demonstrator **S. Murphy**
- CRP Assembly & Cold-Box Testing **D. Duchesneau**
- LEM Production & Testing **E. Mazzucato**
- ProtoDUNE-DP Installation **F. Resnati**
- DUNE-DP IDR & TDR Status **D. Autiero**



- 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

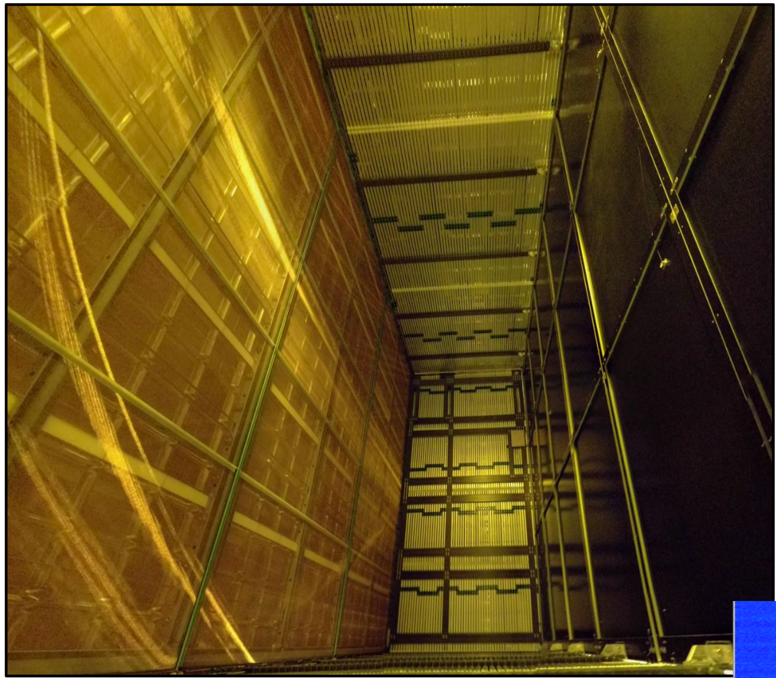
DUNE is committed to deploying both technologies – staging depends on funding and ProtoDUNE results

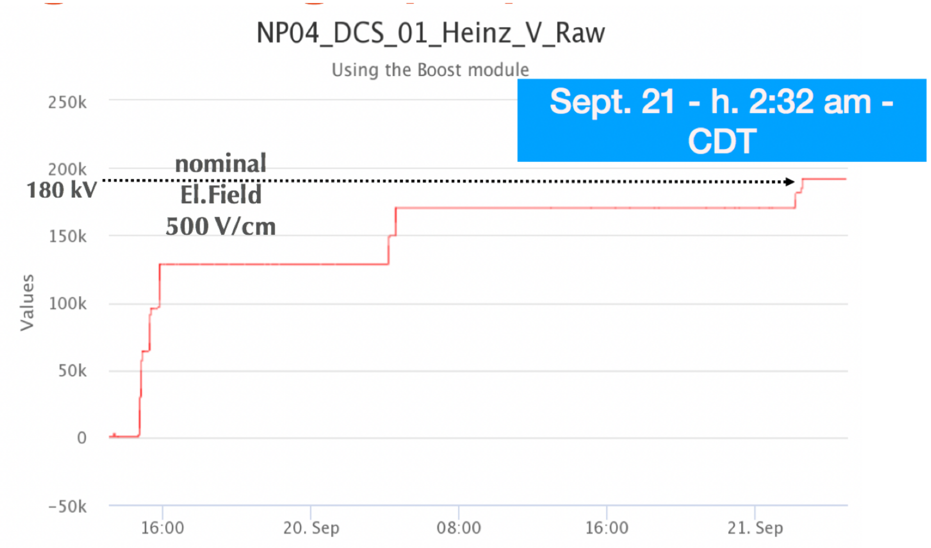
CERN Neutrino Platform

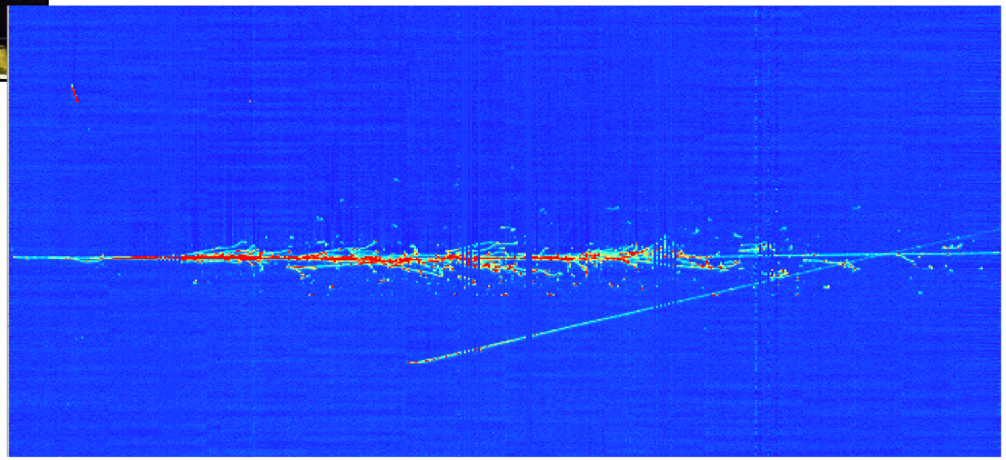
Dec 2015

Regina Rameika

ProtoDUNE Single-Phase

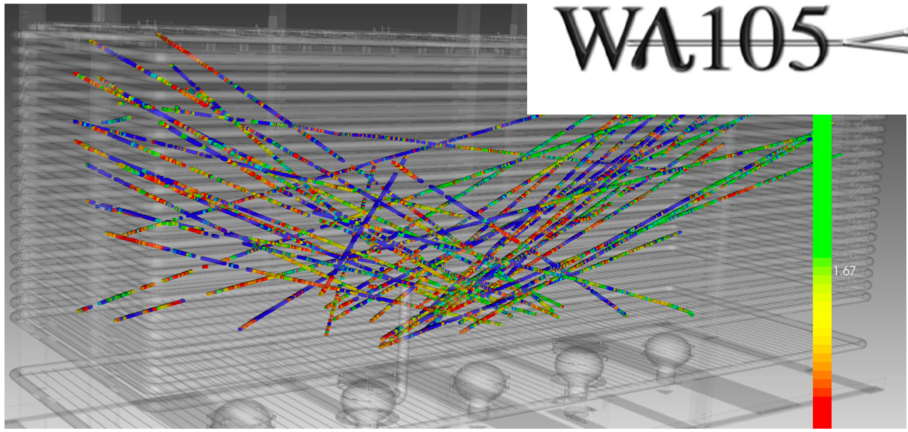


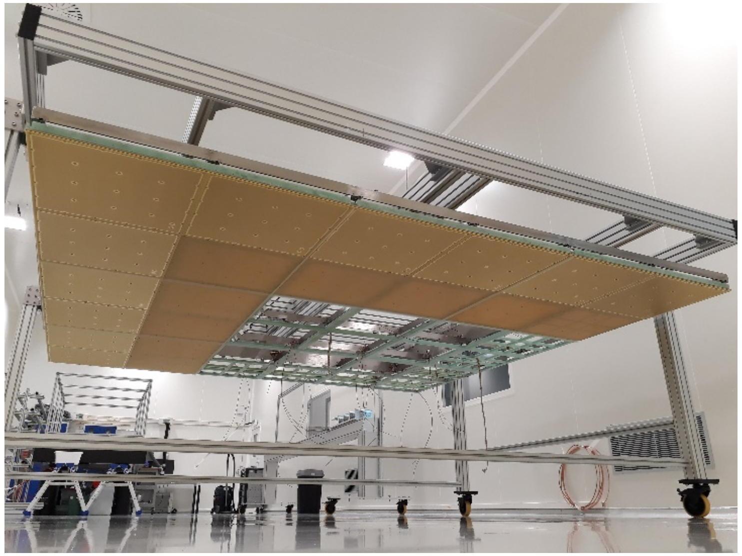




- Successful beam data taking has ended
- Continue to take cosmic-ray data to study detector parameters

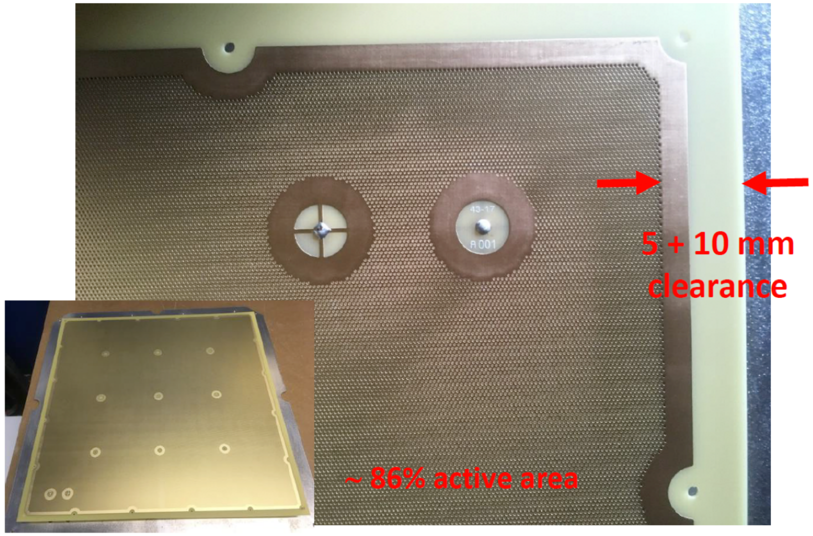
1x1x3 m^3 Demonstrator, data taking July-Nov 2017





Modified LEM Design for ProtoDUNE

CFR-35 – NP02



ProtoDUNE-DP CRP assembly and Cold Box testing, May 2018-today

ProtoDUNE-DP Assembly

- Successful Cold Box tests - next step to demonstrate technology in ProtoDUNE
- Requires all components to come together, purging and filling of cryostat.
- This will take approximately 6 months, see talk by F. Resnati.

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Summary ProtoDUNE Status

- ProtoDUNE-SP
  - Construction completed in July 2018
  - Data taking with hadron test beam ended on Nov. 12
  - Excellent performance
  - Will continue to take data with cosmics
- ProtoDUNE-DP
  - Plan to close cryostat with 4 CRPs (2 operational) in early 2019
  - Data taking with cosmics expected around June/July 2019
  - Collected data will allow us to validate TDR design decisions

Proposal submitted to SPSC for additional running of ProtoDUNEs after LS2 to test final DUNE detector components (DUNE DocDB 11206)

Running of ProtoDUNE-SP (NP04) and ProtoDUNE-DP (NP02) After Long Shutdown 2

The DUNE Collaboration[1]

I. Introduction

The two ProtoDUNE detectors (NP02 and NP04) serve a critical role in validating the designs of the DUNE far detectors. The DUNE Collaboration plans to use the single-phase (SP) technology for at least two of its four modules and the dual-phase (DP) technology for at least one module. A SP pixel-readout scheme has been proposed as a possible technology for the fourth module. An Interim Design Report (IDR) published in 2018 describes the DP and SP technologies and the physics reach of the DUNE experiment [1].

The construction of the ProtoDUNE-SP detector (NP04) was successfully completed, on schedule, in July 2018, and the detector is now collecting valuable hadron-beam and cosmic-ray data. One of the first events recorded in the ProtoDUNE-SP Time Projection Chamber (TPC) is shown in Figure 1. The ProtoDUNE-DP detector (NP02) is in the final stages of assembly (Fig. 2). We expect to close the ProtoDUNE-DP cryostat with two of four charge readout planes (CRPs) installed in early 2019, with cosmic-ray data collection beginning in March/April 2019. The two ProtoDUNE detectors are located in two similar cryostats. However, the single and dual-phase cryostats each have a unique arrangement of feedthroughs on the top face that are specific to the technologies being tested.

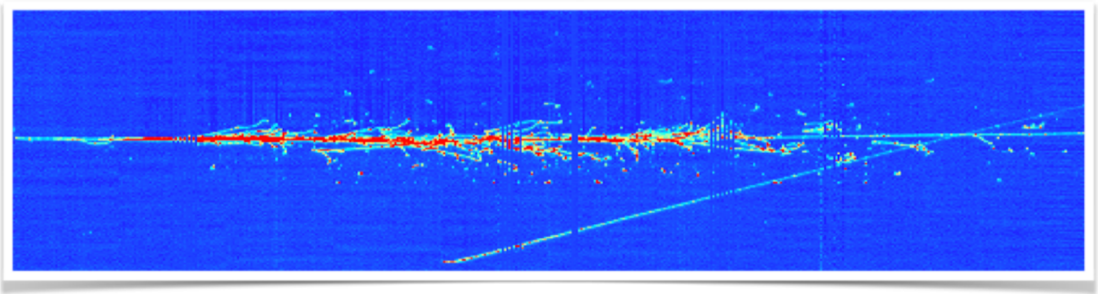


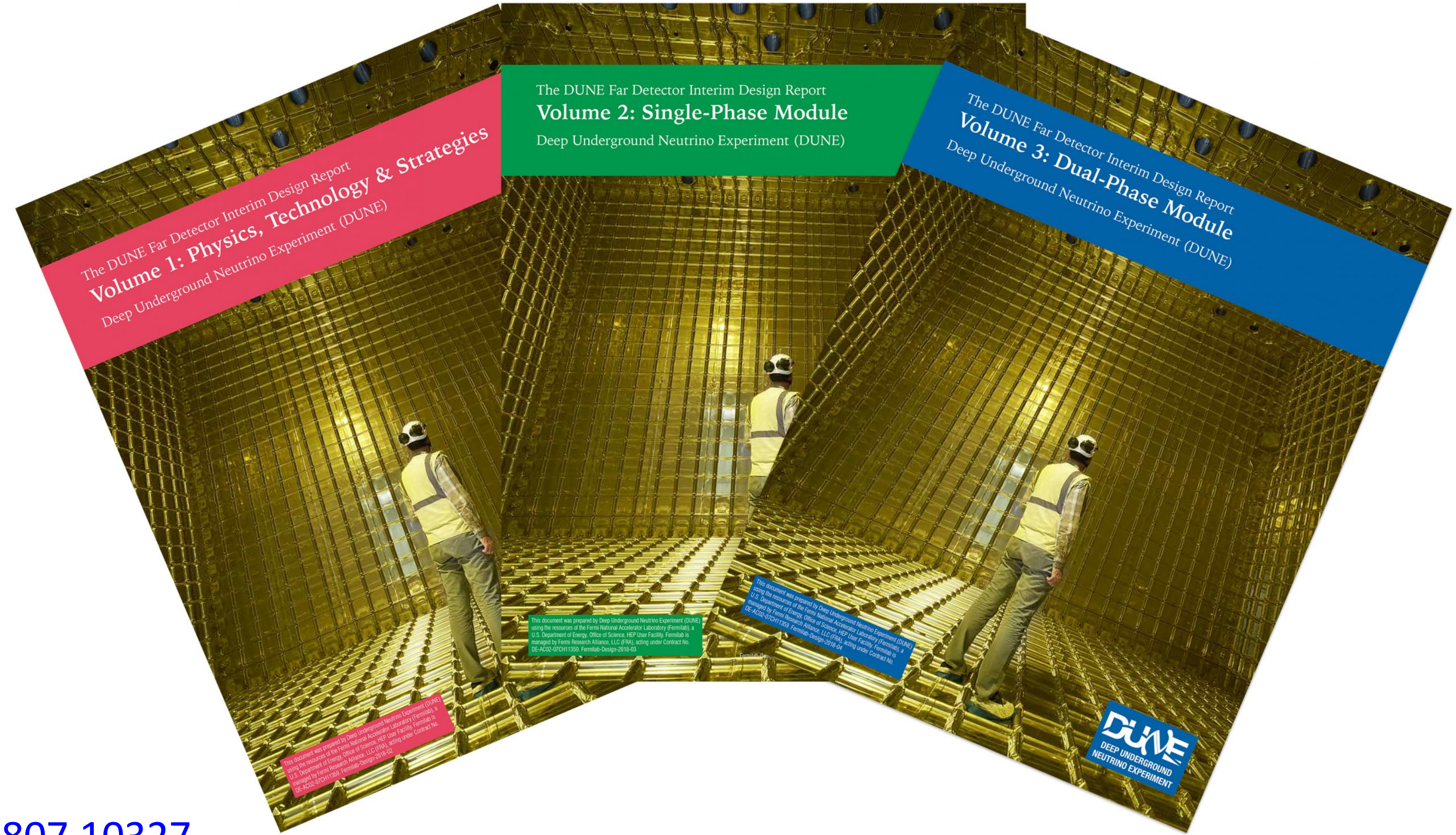
Figure 1: A beam halo muon initiating an electromagnetic shower in ProtoDUNE-SP.

Plenary Talks - Tomorrow

Tomorrow's focus is on TDR preparation:

• Overall View/Plan/Status	**T. Bolton**
• Physics TDR Status/Preview	**J. Urheim**
• Computing Organization Status	**H. Schellman**
• APA TDR Status/Preview	**C. Touramanis**
• Near Detector CDR Status/Preview	**A. Bross**

DUNE Interim Design Report



arXiv:1807.10327

TDR Schedule

- Tim Bolton and Sam Zeller as TDR editors have developed a detailed plan for providing the TDR drafts to allow for a meaningful LBNC review.
- Different sections of TDR to be submitted for review between December 2018 and July 2019 – depending on readiness.
- Important that we stick to this schedule (both sides).
- We hope that the LBNC appreciates that some of these documents are still drafts when given for first review (but we are still worried about it).

LBNC Recommendations

- We continue to track and act on all LBNC recommendations.
- In total, 188 recommendations so far.
- Status of recommendations maintained in a central document.
- Open recommendations (11) (DUNE DocDB 11629)
  - Physics and Reconstruction (2)
  - APA (1)
  - DUNE-SP PD (3)
  - DUNE-DP PD (2)
  - Software and Computing (1)
  - Calibration Plan (2)
- Most related to requirements.

Physics Requirements

- LBNC has emphasized the importance of requirements at several of the past meetings and its recommendations.
- The EB will play an active role and take ownership of the requirements.
- We are moving away from requirements to newly defined 'goals' and 'specifications', which better fit the problem.
- These are described in a single document (DUNE DocDB 11431) and a Requirements/Specifications Table (DUNE DocDB 11074)
- These documents will continue to evolve under EB ownership

DUNE Far Detector (Single Phase) Design Choices and Physics Connections

I. INTRODUCTION

A. Science program

As described most recently in the DUNE Interim Design Report [1], the science goals of DUNE are to:

- Carry out a comprehensive program of neutrino oscillation measurements using ν_μ and $\overline{\nu}_\mu$ beams from Fermilab. This program includes measurements of the charge parity (CP) phase, determination of the neutrino mass ordering, measurement of the mixing angle θ_{23} and the determination of the octant in which this angle lies, and sensitive tests of the three-neutrino paradigm. Paramount among these is the search for CP violation in neutrino oscillations, which may give insight into the origin of the matter-antimatter asymmetry, one of the fundamental questions in particle physics and cosmology.

- Detect and measure the ν_e flux from a core-collapse supernova within our galaxy, should one occur during the lifetime of the DUNE experiment. Such a measurement would provide a wealth of unique information about the early stages of core-collapse, and could even signal the birth of a black hole.

- Search for baryon number violation, including proton decay, in several decay channels. The observation of BNV would represent a ground-breaking discovery in physics, providing a key requirement for grand unification of the forces.

Requirements/Specifications Table

Name	Primary Text	Value	Value (LaTeX)	Goal	Rationale (brief)	Validation (brief)
Descriptive name of the specification (max 100 characters including spaces) (REQUIRED)	**Full text of the req/specification. Example: The DAQ shall provide (REQUIRED)**	**Specification value: number plus units (as needed) (REQUIRED)**	**Specification value: number plus units (as needed) (REQUIRED)**	**Number plus units (as needed)**	**Max 120 characters (REQUIRED)**	**Max 120 characters (REQUIRED)**
Minimum drift field	The drift field in the TPC shall be greater than 250 V/cm, with a goal of 500 V/cm.	>250 V/cm (goal 500 V/cm)	$>$\,\SI{250}{ V/cm}	$>$\,\SI{500}{ V/cm}	Lessens impacts of e-Ar recombination, e- lifetime, e- diffusion and space charge.	ProtoDUNE
Remainder of Level 1 key parameters block						
Level 2 selected central parameters block						
Level 3 consortium parameters block.						

Long version as DUNE DocDB 11074

High-Level Detector Specifications

Parameter	Specification	Goal
Drift field	>250 V/cm	500 V/cm
Electron lifetime	>3 ms	10 ms
System noise	<1000 enc	ALARA
Light yield	>0.5 p.e./MeV	5 p.e./MeV
Time resolution	<1 μs	100 ns

TABLE I: Summary of high-level design specifications.

- Specification: This is the intended value for the parameter or, more often, the upper or lower limit for the parameter.
- Goal: This is an improved value that offers some benefit, and the collaboration aims to achieve this value where it is cost effective to do so.

Other Science Design Specifications

Parameter	Specification	Goal
Gaps between APAs		
on same support beams	<15 mm	ALARA
on different support beams	<30 mm	ALARA
Field non-uniformity throughout volume		ALARA
due to component alignement	<1%	ALARA
due to HV system	<1%	ALARA
APA wire angles		
X and G	0°	
U and V	±35.7°	
APA wire spacing		
X and G	4.669 mm	
U and V	4.790 mm	
APA wire position tolerance	±0.5 mm	ALARA
HV PS ripple contribution to system noise	<100 enc	ALARA
Front-end peaking time	1 μs	adjustable
Signal saturation level	~500,000 electrons	
LAr nitrogen contamination	<25 ppm	ALARA
Detector down time	<0.5%	ALARA

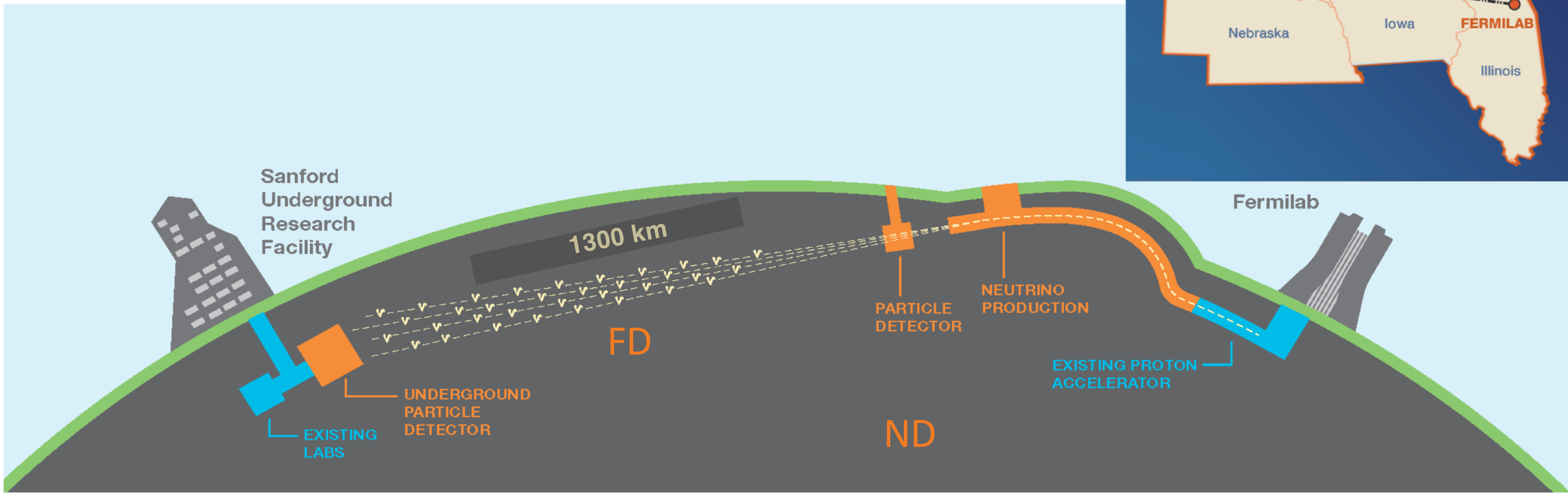
TABLE II: Summary of other scientific design specifications.

Engineering Design Specifications

Parameter	Specification	Goal
Cathode resistivity	$>1\ M\Omega/cm^2$	$1\ G\Omega/cm^2$
Cryogenic monitoring devices	see text	
ADC sampling frequency	$\sim$2 MHz	
Number of ADC bits	12	
Cold electronics power	$<$50 mW/channel	ALARA
Data rate to tape	$<$30 PB/year	
Supernova trigger efficiency	$>$90% for dist$<$100 kpc	
Local electric fields	$<$30 kV/cm	ALARA
Non-FE noise contributions	$\ll$1000 enc	ALARA
LAr impurities from components	$\ll$30 ppt	ALARA
Introduced radioactivity	below ^{39}Ar	ALARA
Dead channels	$<$1%	ALARA

TABLE III: Summary of engineering design specifications.

DUNE in a Nutshell



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.

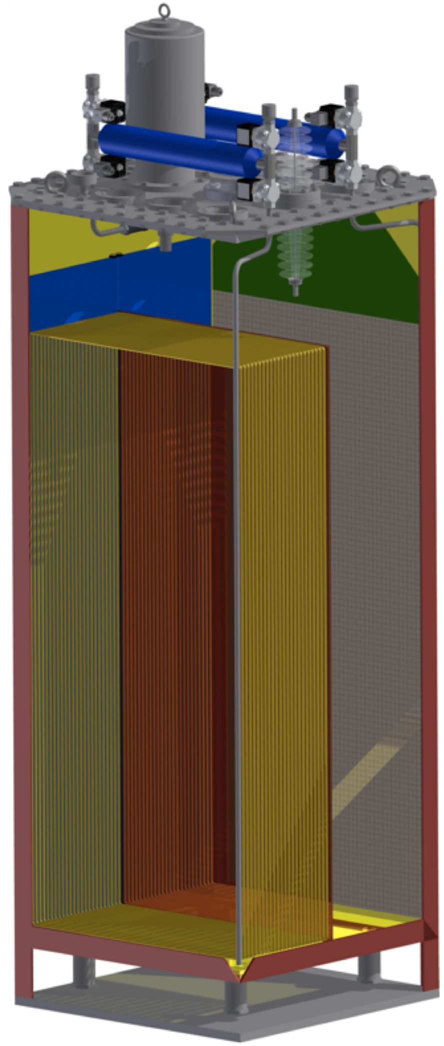
Near Detector

$$\frac{N^{\mathrm{FD}}_{\nu_i}}{N^{\mathrm{ND}}_{\nu_\mu}}(E_{\mathrm{rec}}) = \frac{\int \Phi^{\mathrm{FD}}_{\nu_\mu}(E_\nu) \cdot P_{\nu_\mu \to \nu_i}(E_\nu) \cdot \sigma^{\mathrm{Ar}}_{\nu_i} \cdot T^{\mathrm{FD}}_{\nu_i}(E_\nu, E_{\mathrm{rec}})\, \mathrm{d}E_\nu}{\int \Phi^{\mathrm{ND}}_{\nu_\mu}(E_\nu) \cdot \sigma^{\mathrm{X}}_{\nu_\mu} \cdot T^{\mathrm{ND}}_{\nu_\mu}(E_\nu, E_{\mathrm{rec}})\, \mathrm{d}E_\nu}$$

- Constrain systematic uncertainties for long-baseline oscillation analysis (large effect on exposure required!).
- Determine flux, cross sections, and detector systematics (transfer matrix)

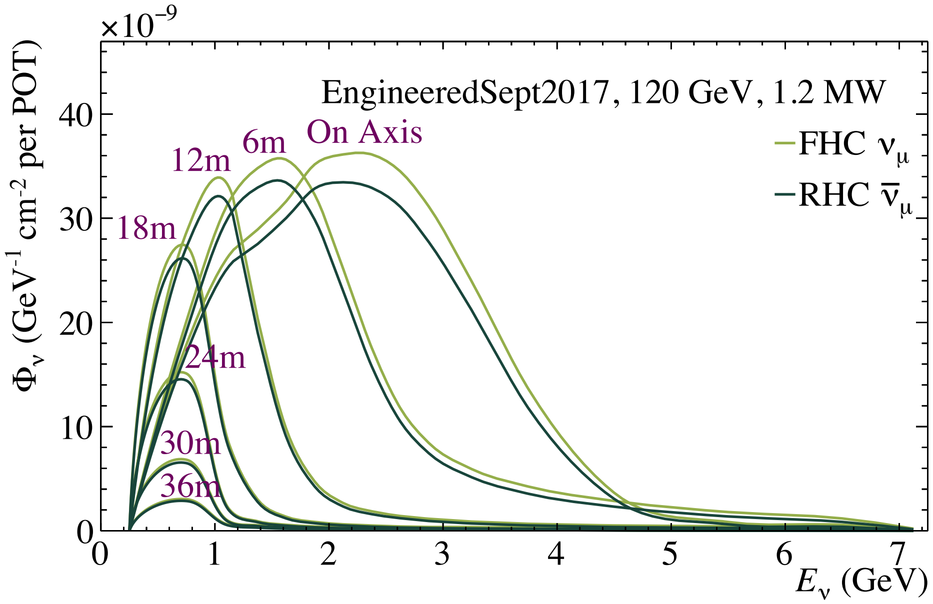
The DUNE Near Detector

- Constrain systematic uncertainties for long-baseline oscillation analysis
  - flux, cross-section, and detector
- In addition, >100 million interactions will also enable a rich non-oscillation physics programme
- DUNE ND design concept is an integrated system composed of multiple detectors:
  - Highly segmented Liquid-argon TPC (ArgonCube)
  - Magnetized multi-purpose tracker (High Pressure Gas TPC)
  - 3D Scintillator Technology (3DST)
  - Electromagnetic calorimeter/Muon Chambers
  - Newly built magnet



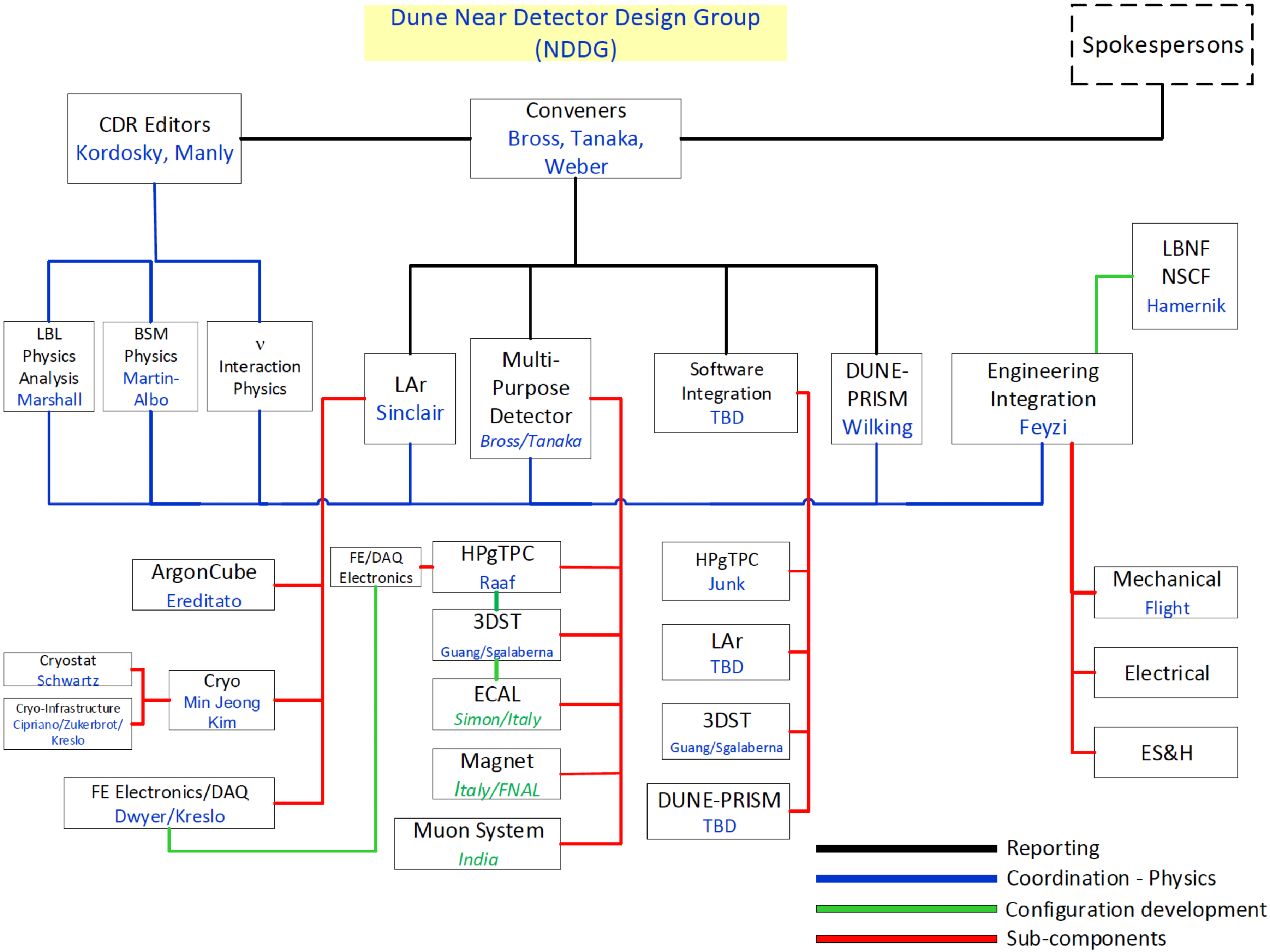
The DUNE Near Detector

- Capability to move ND for off-axis measurements (DUNE-Prism)



- New ND Design Group working toward conceptual design report in 2019
- Broad international involvement (Germany, Italy, Switzerland, India, CERN, US, and others)
- Meeting with Indian groups last month, Italy-ND meeting in planning

NDDG Organization



DUNE Strategic Goals 2017 - 2019

- **Preparation of DUNE TDRs for LBNC review**
  - A major scientific and technical goal for the collaboration
- **Construction and operation of large-scale prototypes at CERN**
  - Critical to demonstrate viability of technology, and that the DUNE collaboration can implement a major construction activity
- **Resource matrix for construction of DUNE**
  - Define responsibilities for DUNE construction
  - Funding for TDR scope needs to be understood in 2019
  - Resource matrix is an essential component of planned multi-institutional MOU for DUNE

Selected DUNE Milestones

- May 2018: Decision on conceptual design of ND
- May 2018: Far Detector Interim Design Report
- July 2018: Completion of DUNE prototypes at CERN
- Mar 2019: RRB to review status of funding matrix for first two FD modules
- July 2019: FD TDR submitted (including near detector CDR summary)
- July 2019: LBNC and Cost Group Review of DUNE TDR
- Sep 2019: RRB to approve funding matrix for first two FD modules
- Oct 2019: CD2/3b Review of LBNF, US DUNE scope
- Late 2020: Near Detector TDR

International Project Milestones	Date
Start Main Cavern Excavation	2019
Start Detector #1 Installation	2022
Beam on with two detectors	2026

Summary

- DUNE on track to meet strategic goals and milestones for the period 2018-2019.
- Management structure working well; evolving to adapt to changing requirements.
- ProtoDUNE-SP running is an extraordinary success.
- ProtoDUNE-DP is progressing well based on successful Cold Box tests - expect detector data in 2019.
- IDR published - TDR preparation progressing well