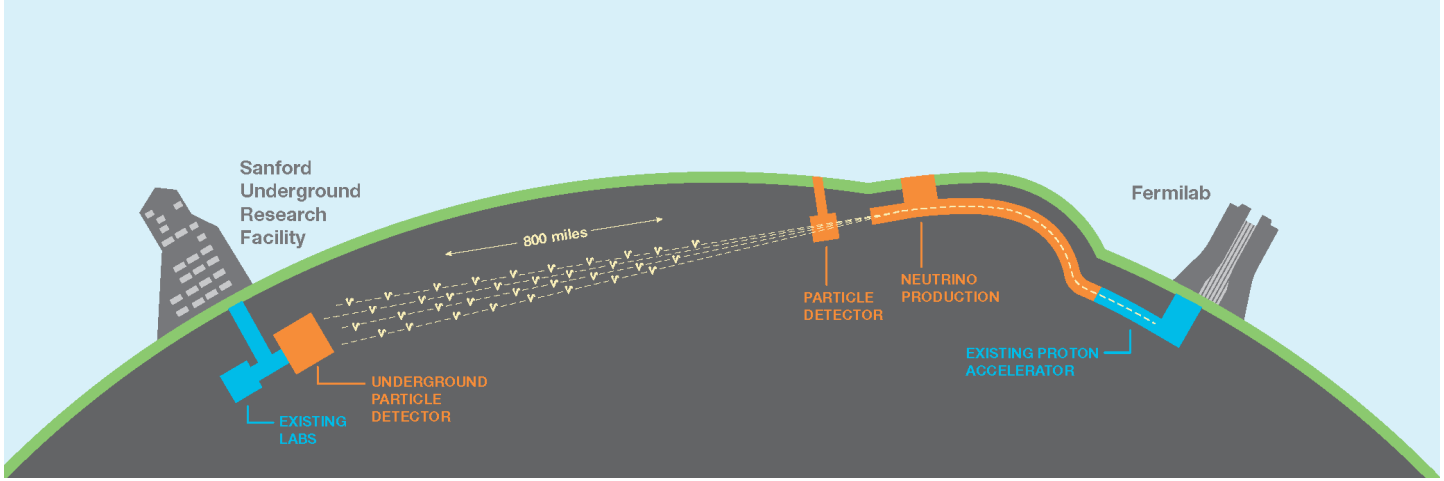


DUNE Detector Development

Mark Thomson

on behalf of DUNE

Neutrino Detector R&D Facilities Workshop

21st January 2016

UNIVERSITY OF CAMBRIDGE

1. Introduction

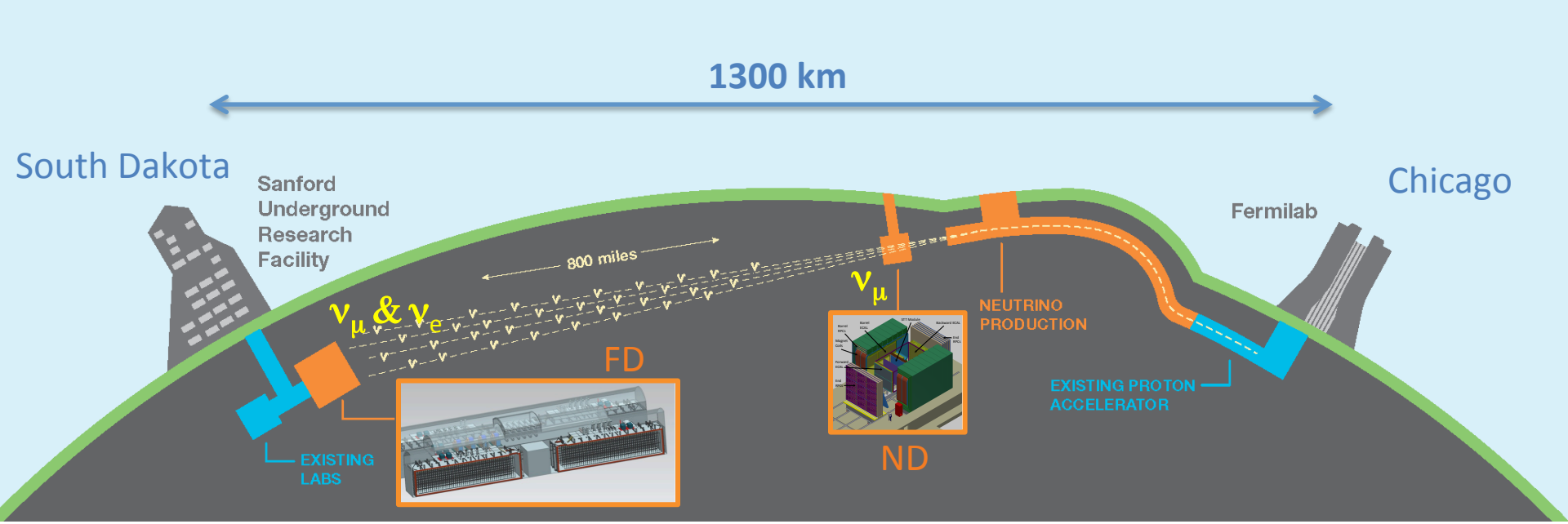
- **This talk will cover**
  - Overview of roadmap for DUNE detectors
  - Prototyping plans at FNAL and CERN
  - Options for detector development

- **Aim**
  - Give a high-level overview
  - Promote discussion

2. DUNE in a Nutshell

★LBNF/DUNE

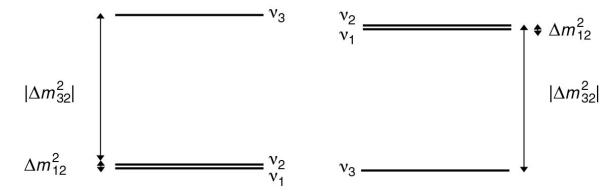
- Muon neutrinos/antineutrinos from high-power proton beam
  - **1.2 MW** from day one (upgradeable)
- Large underground **Liquid Argon Time Projection Chamber**
  - **4 x 17 kton ⇨ fiducial mass of >40 kton**
- Near detector to characterize the beam



DUNE Primary Science Goals

Focus on fundamental open questions in particle physics and astro-particle physics:

- **1) Neutrino Oscillation Physics**
  - **Discover CP Violation** in the leptonic sector
  - Determination of the Mass Hierarchy
  - Precision oscillation physics (θ_{23} octant, …)
  - Testing the 3-flavour paradigm (the Neutrino Standard Model)



- **2) Nucleon Decay**
  - Targeting SUSY-favored modes, e.g. $p \rightarrow K^+\bar{\nu}$
- **3) Supernova burst physics & astrophysics**
  - Galactic core collapse supernova, sensitivity to ν_e

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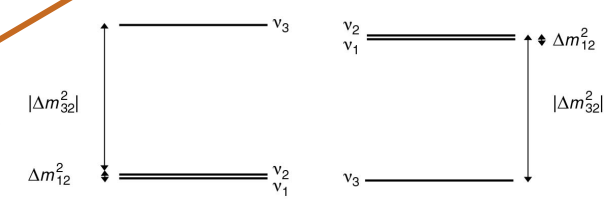
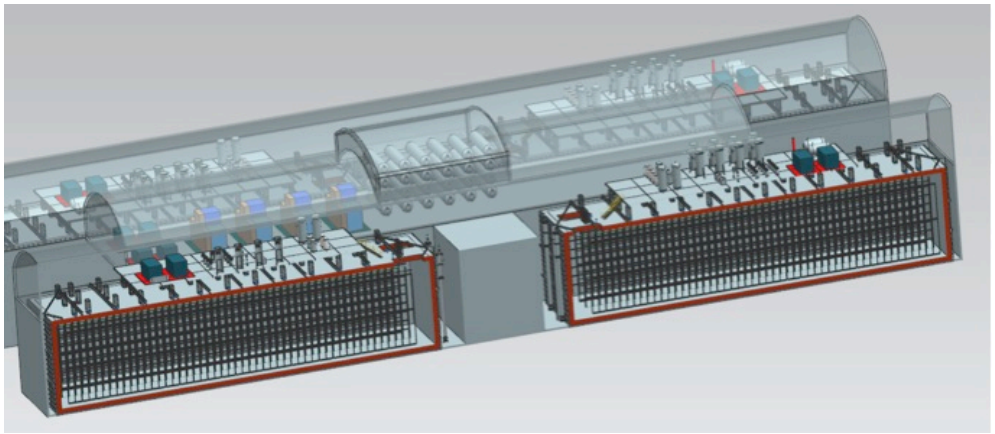


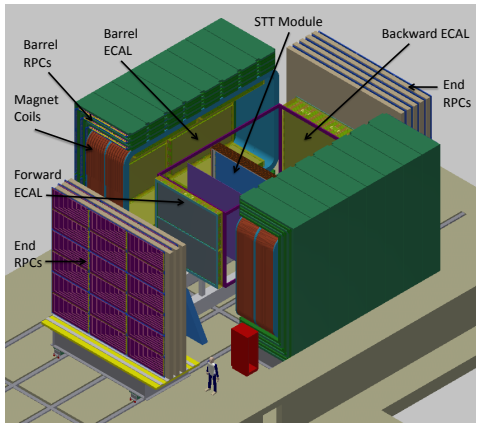
All areas drive detector requirements

3. DUNE Detectors

Far detector: 40-kt LArTPC



Near detector: Multi-purpose high-resolution detector



LAr-TPC Technologies

LAr-TPC technology has been demonstrated by ICARUS

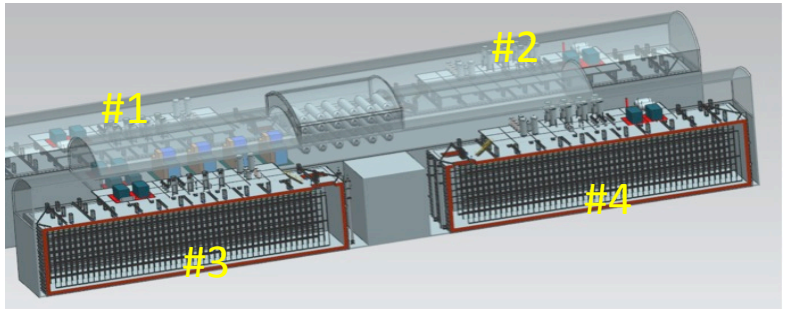
DUNE is considering two options for readout of ionization signals:

- **Single-phase wire-plane readout**
  - Ionization signals (collection + induction) read out in liquid volume
  - As used in ICARUS, ArgoNEUT/LArIAT, MicroBooNE
  - Long-term operation already demonstrated by ICARUS T600
- **Dual-phase readout**
  - Ionization signals amplified and detected in gaseous argon above the liquid surface
  - Being pioneered by the WA105 collaboration
  - If demonstrated, potential advantages over single-phase approach

Staging the Far Detector

The Far Detector at the SURF:

- Four identical chambers/cryostats hosting four independent 10-kt FD modules
- First 10-kt module: "ICARUS-style" single-phase TPC
- Flexibility to adopt different designs for subsequent modules
  - dual-phase [see André's talk today]
  - refinements to single-phase design
- Choice will be informed by
  - Prototyping activities at FNAL and CERN
  - Developments in detector technologies



Far Detector Challenges

Perhaps the largest challenge is the scale

- Cryostat for 10-kt fiducial: 15.1 (W) x 14.0 (H) x 62 (L) m^3
- A big step up from ICARUS & MicroBooNE

Technical challenges

- Mechanical engineering
- Light readout (Photon Detection System)
- Cold electronics
- …

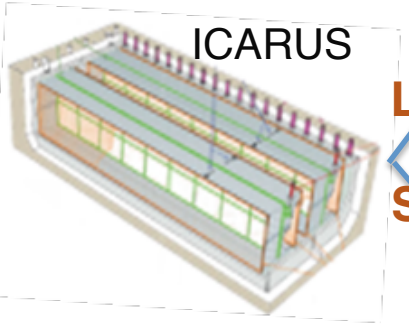
Solutions exist

- But large-scale prototyping is essential
- + open to new ideas/approaches:
  - staged approach to the FD leaves open this opportunity
- For now, the priority is the large-scale prototypes

Prototyping DUNE

Fermilab SBN and CERN neutrino platform provide a strong **LArTPC** development and prototyping path

Single-Phase



LBL

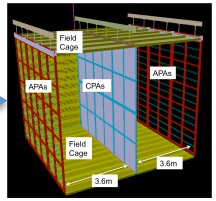
SBL

35-t prototype

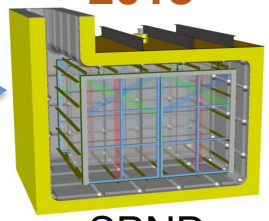
2015/16

MicroBooNE

ProtoDUNE-SP @ CERN

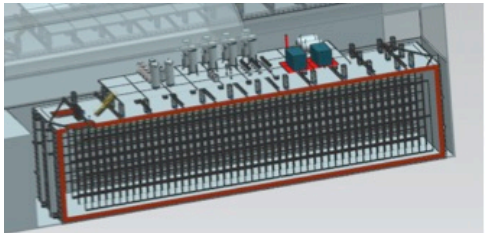


2018



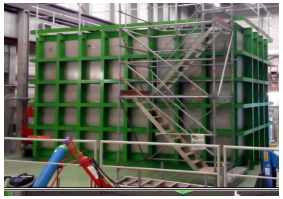
SBND

DUNE SP Design



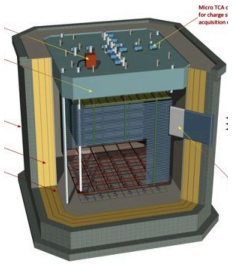
Dual-Phase

2016



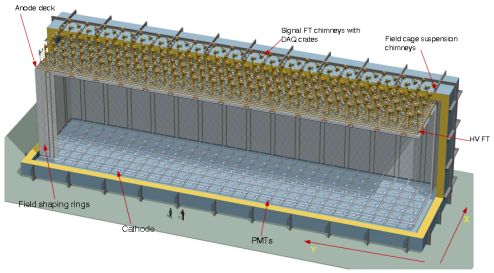
WA105: 1x1x3 m^3

2018

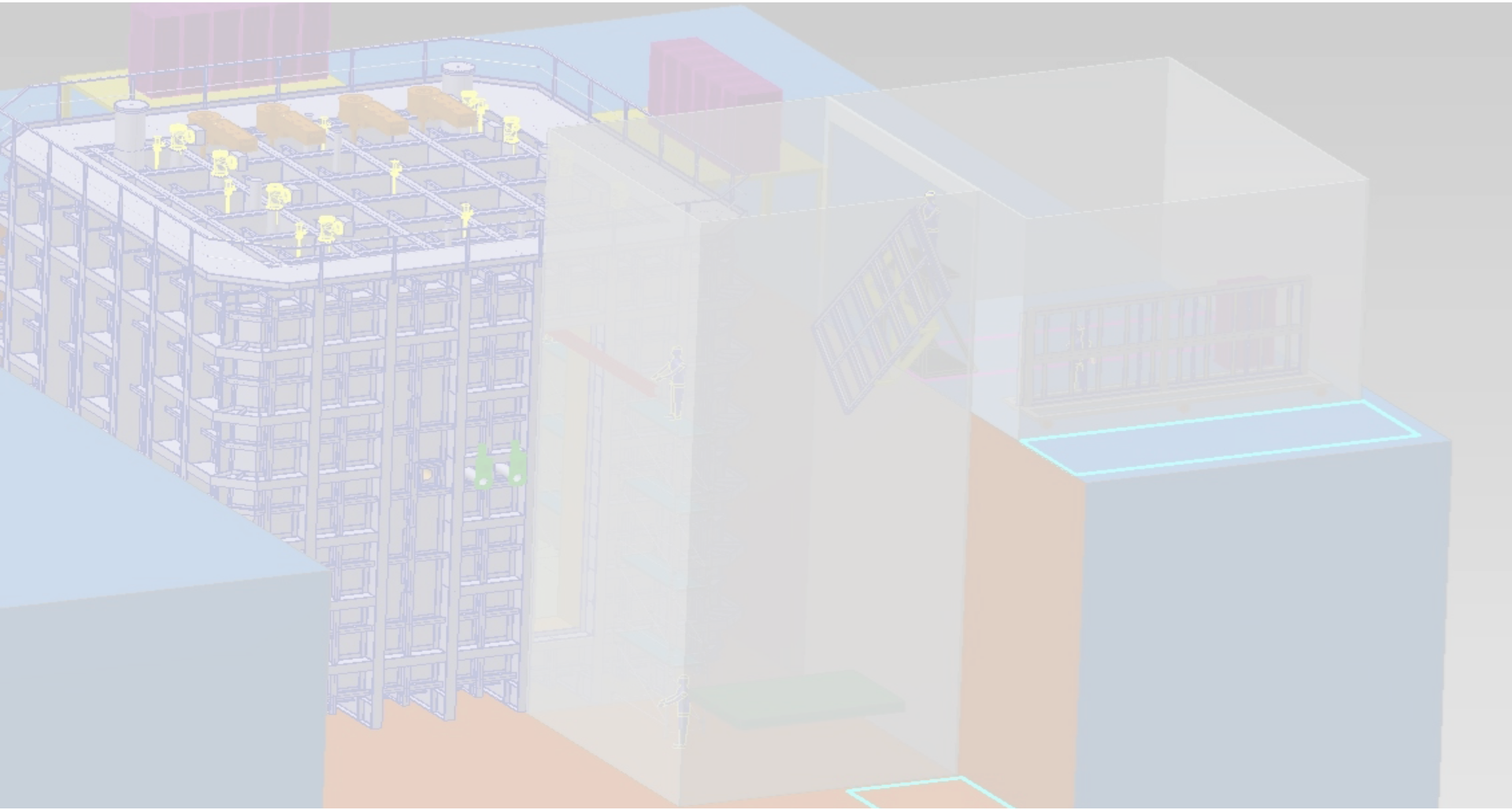


ProtoDUNE-DP @ CERN

DUNE DP Design



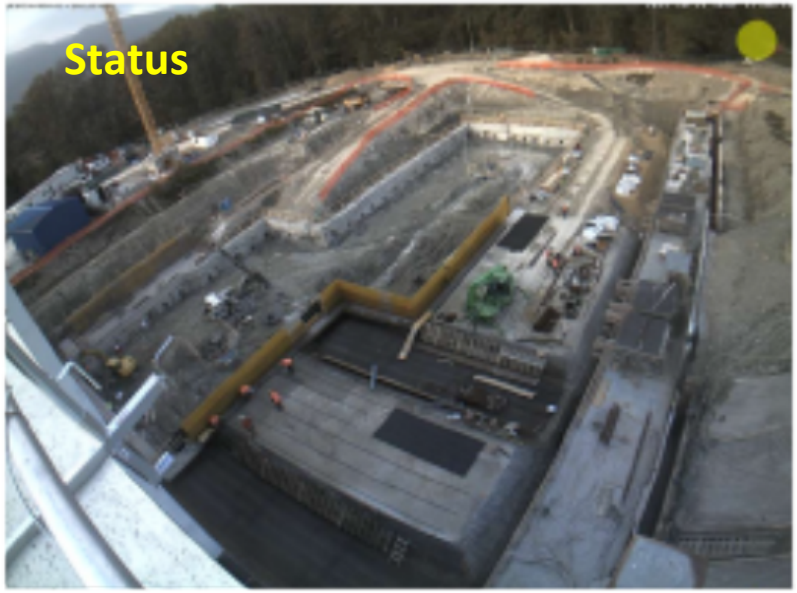
4. ProtoDUNEs



CERN Neutrino Platform

CERN support of international neutrino programme

- Major investment for DUNE:
  - **New building: EHN1-extension**
  - Two tertiary charged-particle beam lines
  - Two large cryostats & cryogenic systems



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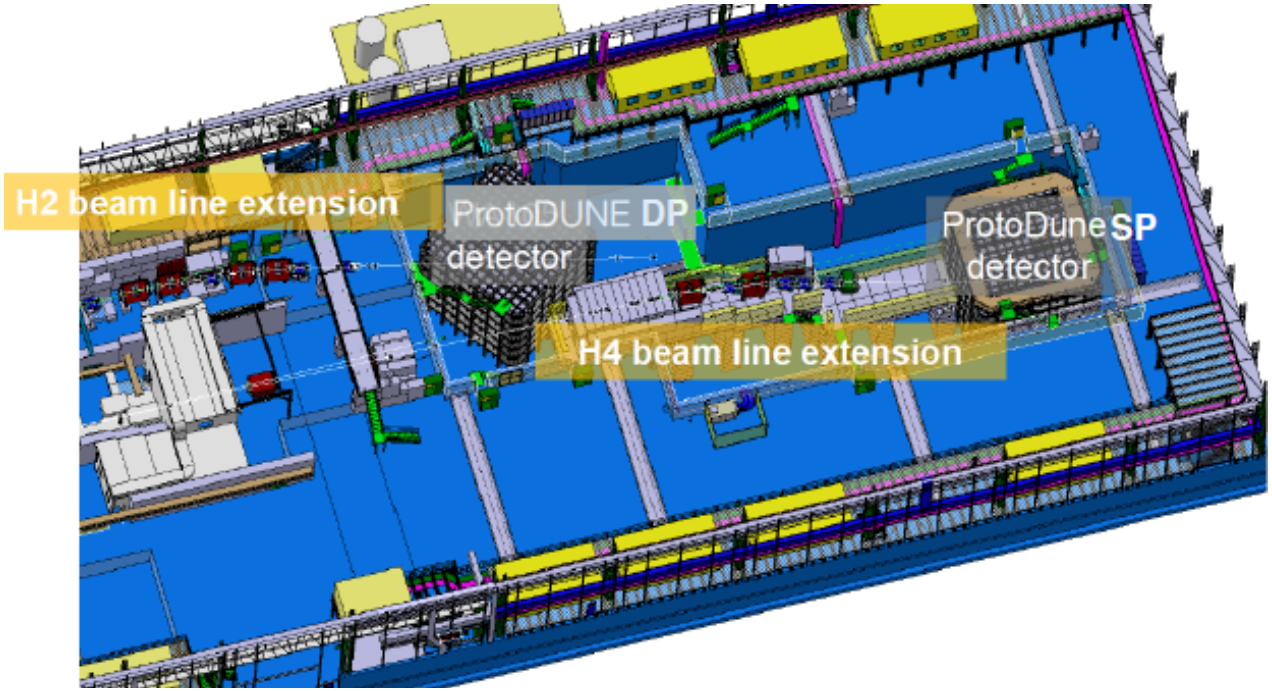

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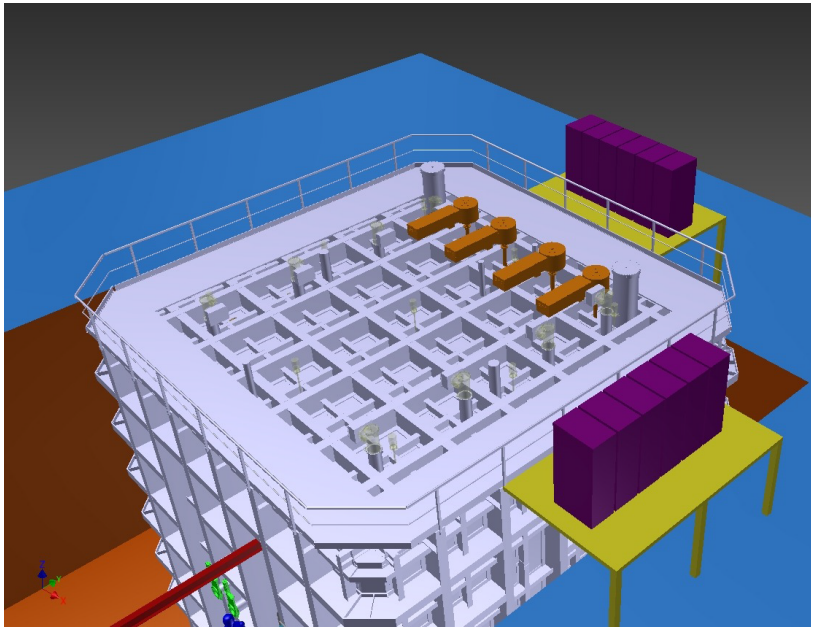
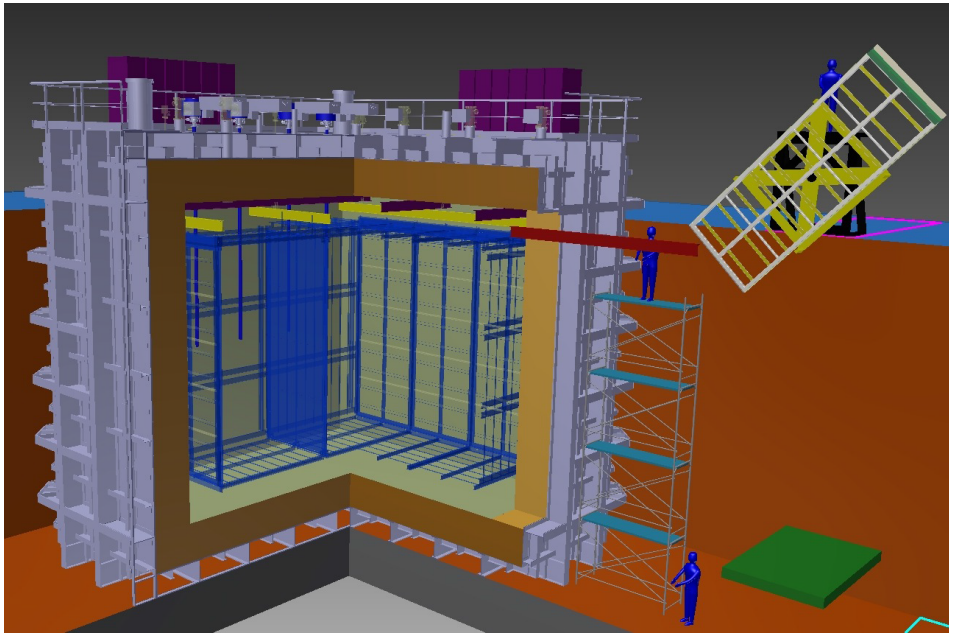




The ProtoDUNE Programme

DUNE is committed to the construction/operation of

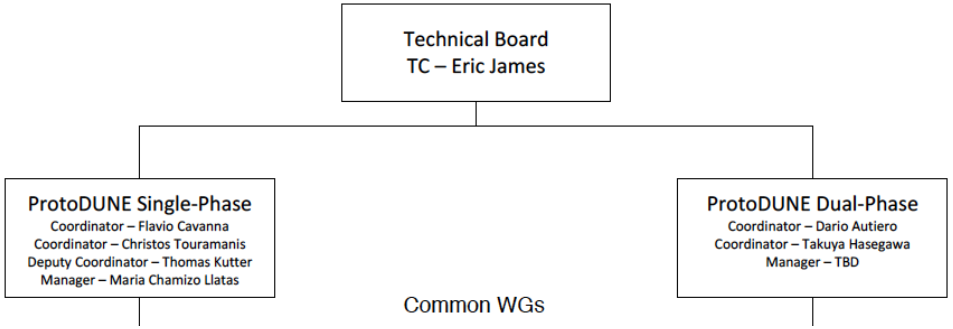
- **ProtoDUNE (single-phase)**
  - Test of design for first 10-kt module
- **ProtoDUNE (dual-phase)**
  - Offers potential advantages for one or more subsequent modules

F.Cavanna/ FNAL

C.Touramanis /Liverpool

T.Kutter/ LSU

M.Chamizo/ Stony Brook



D.Autiero/ IPNL

T.Hasegawa/ KEK

tbd

ProtoDUNE within DUNE

ProtoDUNE is a central part of the DUNE strategy for construction of the Far Detector

- *Production*: stress testing of the production and quality assurance processes of the detector components will mitigate the associated risks for the far detector.
- *Installation*: test of the interfaces between the different elements and will mitigate the associated risks for the far detector.
- *Operation* (cosmic-ray data): provide validation of the design and performance.
- *Test beam* (data analysis): essential detector and physics calibration benchmarks.

Prototyping, Risk Mitigation & Essential Calibration Data

5. Detector Development Priorities

LBNF/DUNE will be the flagship of the Fermilab program

- Ambitious physics goals
- Collaboration committed to getting physics as early as possible

⇒ **Ambitious timeline**

⇒ **Very focused approach**

Approximate timeline

- Today + 3 months: completion of 35-t program?
- Today + 6 months: design of ProtoDUNE fixed
- Today + 9 months: 1x1x3 m^3 WA105 dual-phase demonstrator running
- Today + 1 year: elements of ProtoDUNE being constructed
- Today + 2 years: ProtoDUNE detectors being installed at CERN
- Today + 3 years: TDR (for CD2) being written
- Today + 4 years: far detector construction underway

DUNE Far Detector Priorities

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1) Success of ProtoDUNE program

- crucial to success of DUNE

DUNE Far Detector Priorities

1) Success of ProtoDUNE program

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"How best to participate in DUNE detector development?"

- at this moment in time, the answer is simple:

ProtoDUNE

Many opportunities…

- need a strong team of detector experts
- these are large, challenging and exciting experiments

ProtoDUNE in the US

Although ProtoDUNE detectors will operate at CERN the construction is distributed

- Construction of ProtoDUNE-SP TPC components will take place in US and elsewhere
  - Multiple opportunities to contribute to the construction
  - Careful testing of the detector elements is essential
    - FNAL has the necessary cryogenic facilities (see SP's talk on PAB)
    - Need to build these facilities into the DUNE QC/QA plans
  - Many opportunities for "@FNAL hands-on" contributions to the ProtoDUNE program
- Currently in process of putting together the ProtoDUNE detector teams
  - If interested please get in touch

Role of Fermilab Facilities

Test facilities at FNAL have been/are essential

- PC4
  - Purification and cryoplant for LAPD
  - DUNE 35-t prototype
  - No concrete plan for use beyond 35-t
- MTS (Materials Test System)
  - Test out-gassing of materials for detector construction (μB & 35-t)
  - Essential facility but has some limitations
  - Clearly will be needed in the future
- Tall Bo
  - Valuable test stand, e.g. relative performance of photon detectors
  - Will be valuable in future

6. Beyond ProtoDUNE

Development activities broadly fall into four categories

- Detector system development
  - e.g. improved photon detection system
  - Four 10-kt modules ⇨ there is time for R&D
- Understanding issues with prototypes
  - Need to retain ability/facilities to address issues that arise
  - e.g. if HV breakdown is a problem…
- Physics measurements from other experiments
  - e.g. CAPTAIN-Minerva
  - Essential to establish connection to DUNE physics
- Prototyping
  - e.g. High-Pressure Gaseous Argon TPC
  - Need to establish/understand physics case

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+ target, horn, beam developments

Detector development ideas

Dedicated session at Jan 2016 DUNE collaboration mtg.

- CAPTAIN-Minerva – what can it do for DUNE
  - Neutrino interactions in LAr, complementary to BNB
- Decay at Rest neutrinos from NuMI
  - Response to very low energy electron neutrinos, relevant to SNνs
- LArIAT
  - e.g. test electron/photon separation as function of wire spacing
- Prototyping a High-Pressure GArTPC
  - If this is a good option for the ND tracker, it will need prototyping
- Future opportunities at LAPD
  - Unique facility, but does it have a role in the future [see Alan's talk today]
- HV Tests
  - Improve our understanding of HV breakdown in LAr

Detector development ideas

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- Decay at Rest neutrinos from NuMI
  - Response to very low ene
- LArIAT
  -
-
  - , it will need prototyping
-
  - APD
  - but does it have a role in the future [see Alan's talk today]
- HV tests
  - Improve our understanding of HV breakdown in LAr

All would/could be of value:

But relative importance depends on:

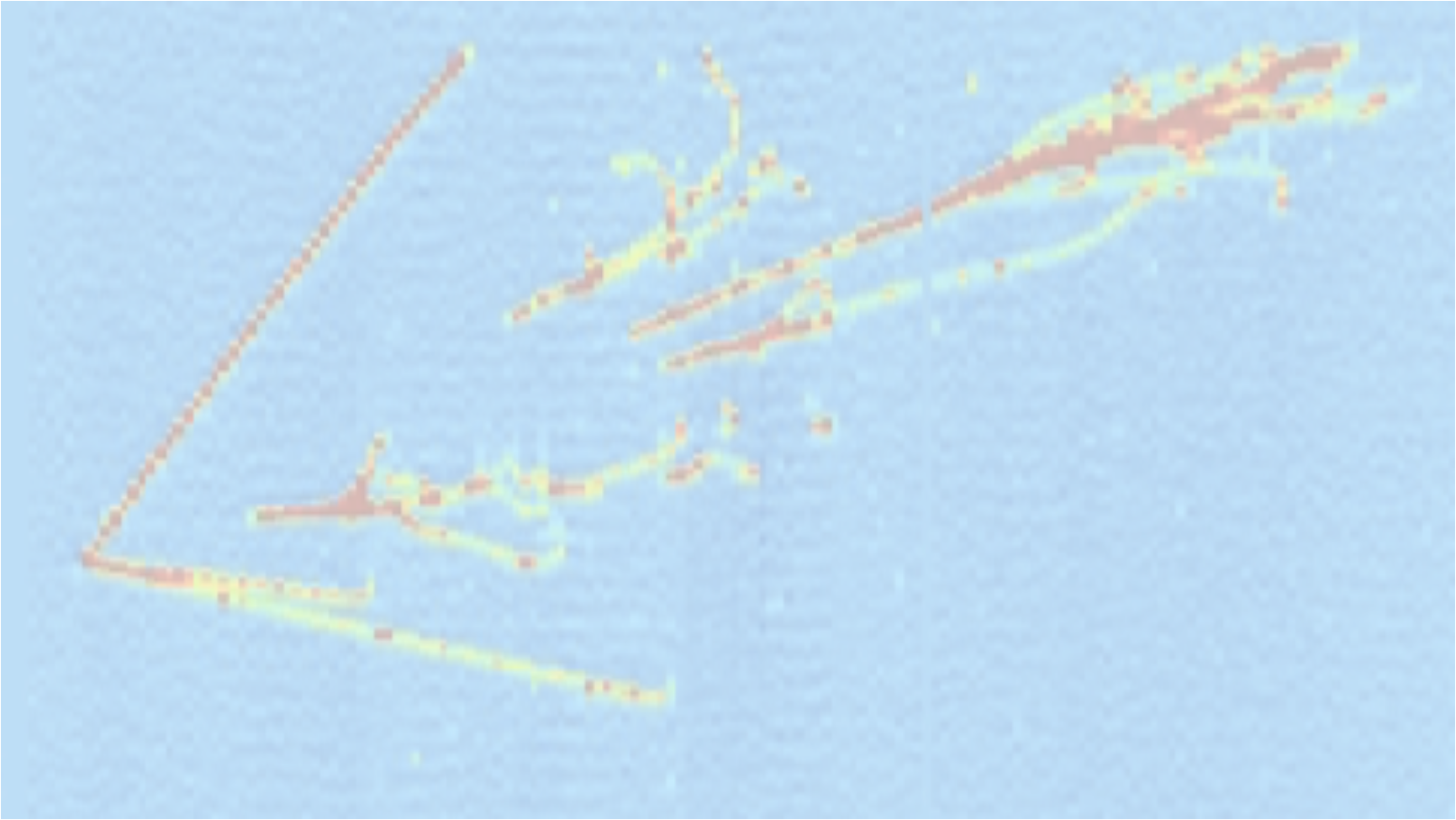
- Establishing the impact on the DUNE physics case
- Need to resolve issues observed in prototypes (if any)

7. Personal viewpoint

The opinions expressed on this slide are...

- DUNE must remain highly focused on success of ProtoDUNEs
  - Many challenges including scale and schedule
  - Need strong involvement of neutrino detector community
  - Major and exciting opportunity
- FNAL facilities will provide essential support to this program
  - QA/QC is a important
  - MTS & Tall Bo will be invaluable
- Must retain flexibility in the FNAL facilities to respond to issues
  - e.g. what if HV breakdown is an issue in the 35-t
- Physics measurements to support DUNE could be important
  - but (from the DUNE perspective) the direct connection to the DUNE physics should be established

8. Summary



8. Summary

- **DUNE is moving into the construction phase**
  - We have a clear plan
- **ProtoDUNE-SP and ProtoDUNE-DP**
  - The CERN prototypes are a major part of this plan
  - Provide the road to CD2
  - A major opportunity to be involved in an exciting LArTPC project
- **Fermilab facilities**
  - Will be needed & it is essential not to lose important capabilities
- **R&D**
  - We have a long-term construction program for the four FD modules
  - Opportunities for adopting technological advances

Thank you.

Questions?
Comments?
Suggestions?