Long-Baseline Neutrino Facility
and
Deep Underground Neutrino Experiment

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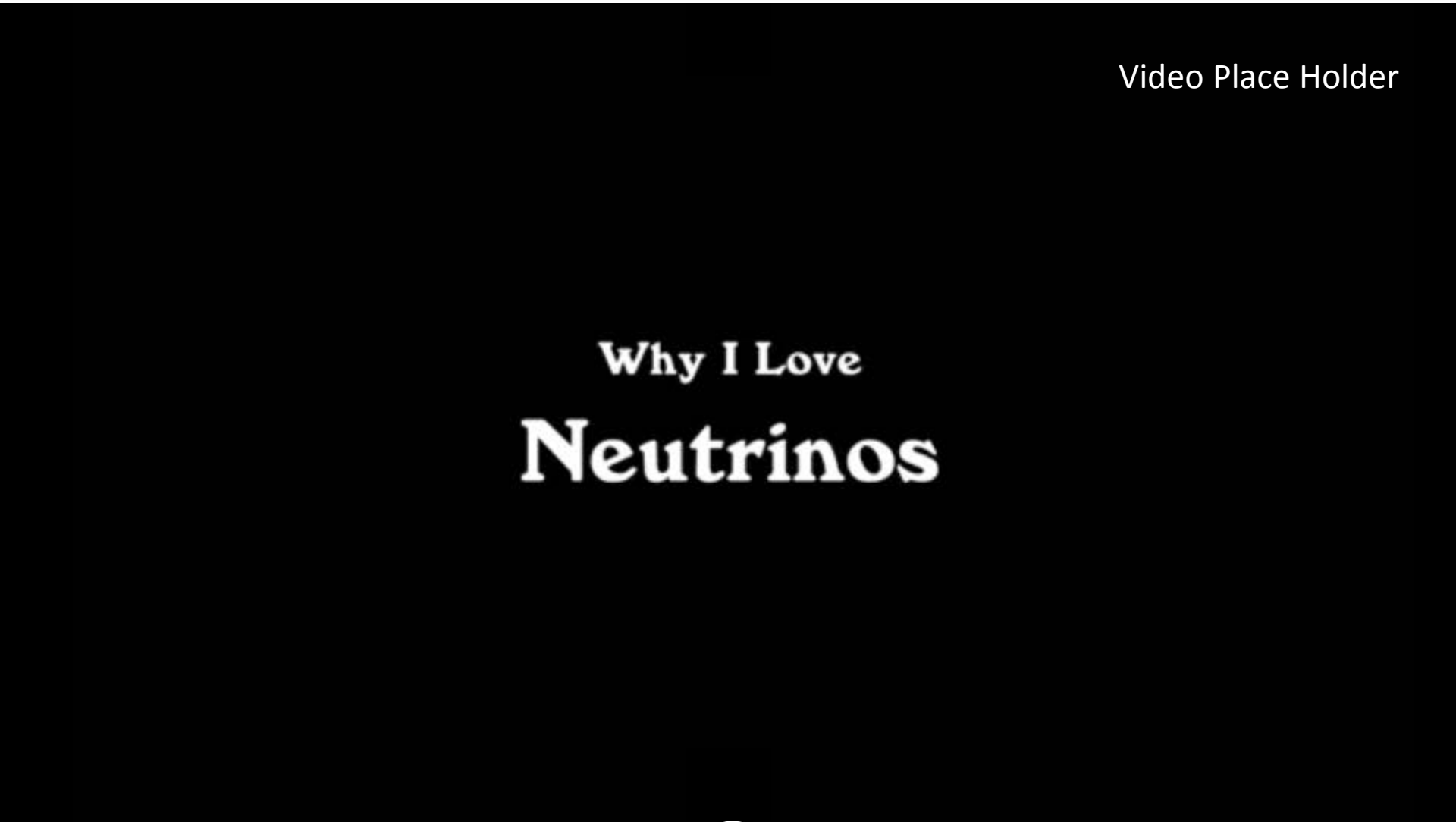
LBNF Project Director

23 March 2016

Outline

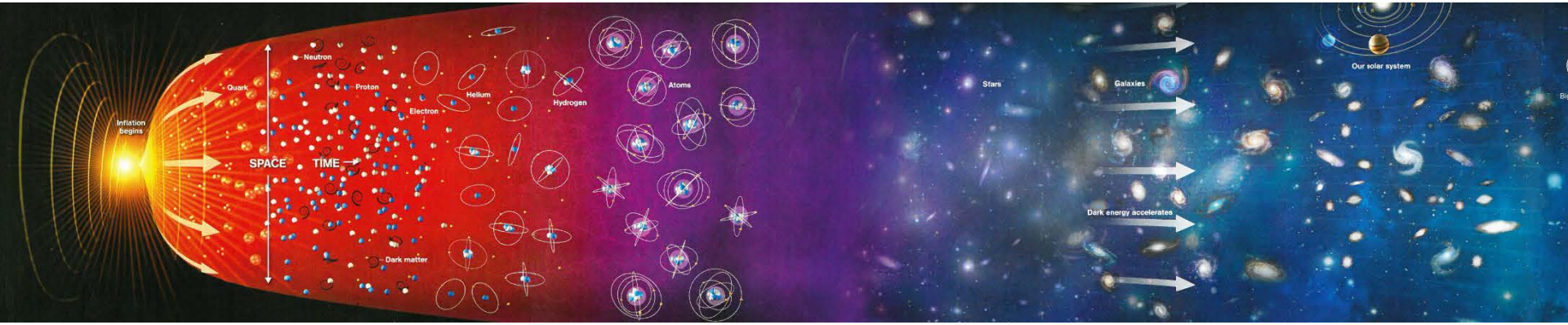
- Why I love Neutrinos!
- Neutrino Science and Experiment Goals
- What is DUNE? What is LBNF?
- Convergence of International Physics Community!
  - International partnership
  - “International from the start”
- Project Overview
  - Scope
  - Schedule
- Governance and oversight
- “Reliability” pre-construction phase work
- Miscellaneous Project Management items

Video Place Holder



Neutrino Science

– Neutrinos are the most numerous matter particles in the universe, but the least understood. The properties of neutrinos as seen in experiments so far are both **surprising** and confusing.



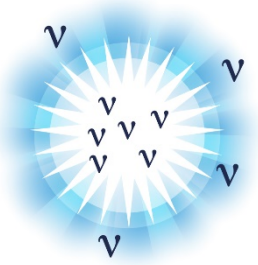
– A fundamental question in science is the matter - anti-matter asymmetry in the Universe "CPV in the leptonic sector"

– Big Bang: matter & anti-matter created in equal amounts

- As Universe cools down matter and anti-matter then annihilate
- All things being equal, no matter/anti-matter remains, just light
- This is not what happened – there is matter left in the Universe

Neutrinos: key to our current best bet to understand why matter exists

DUNE Science Goals



- **Origin of matter**
  Discover what happened after the big bang: Are neutrinos the reason the universe is made of matter?

- **Black hole formation**
  Use neutrinos to look into the cosmos and watch the formation of neutron stars and black holes in real time

- **Unification of forces**
  Move closer to realizing Einstein's dream of a unified theory of matter and energy

Neutrinos are Exciting Science!

The Nobel Prize in Physics 2002

Raymond Davis Jr.
Prize share: 1/4

Masatoshi Koshiba
Prize share: 1/4

Riccardo Giacconi
Prize share: 1/2

The Nobel Prize in Physics 2002 was divided, one half jointly to Raymond Davis Jr. and Masatoshi Koshiba *"for pioneering contributions to astrophysics, in particular for the detection of cosmic neutrinos"* and the other half to Riccardo Giacconi *"for pioneering contributions to astrophysics, which have led to the discovery of cosmic X-ray sources"*.

The Nobel Prize in Physics 2015

Photo: A. Mahmoud
Takaaki Kajita
Prize share: 1/2

Photo: A. Mahmoud
Arthur B. McDonald
Prize share: 1/2

The Nobel Prize in Physics 2015 was awarded jointly to Takaaki Kajita and Arthur B. McDonald *"for the discovery of neutrino oscillations, which shows that neutrinos have mass"*

What is DUNE? What is LBNF?

- The **D**eep **U**nderground **N**eutrino **E**xperiment will be a game-changing experiment for **neutrino science**, potentially transforming our understanding of why the universe exists as it does.
- The **L**ong-**B**aseline **N**eutrino **F**acility is the infrastructure necessary to send a powerful beam of neutrinos 800 miles through the earth, and measure them deep underground at South Dakota's Sanford Underground Research Facility.
- The DUNE/LBNF project will be the first internationally conceived, constructed, and operated mega-science project hosted by the Department of Energy in the United States.

LBNF will drive neutrino science forward the way CERN's Large Hadron Collider drove Nobel Prize-winning Higgs discovery

International Particle Physics Community Convergence

- **2013: European Strategy for Particle Physics updated**
  - Endorsed high priority of neutrino physics
  - Bottom line: CERN should help the European neutrino community participate in a long-baseline program ***outside of Europe***

European Strategy for Particle Physics

Building for Discovery

Strategic Plan for U.S. Particle Physics in the Global Context

Report of the Particle Physics Project Prioritization Panel (P5)

- **2014: "P5" Plan**
  - A strategic plan for U.S. particle physics maximizing opportunities for breakthrough science
  - Explicit prioritization, hard choices made within realistic budget scenarios
  - Particle physics community unified behind the plan: 2,331 signatures on letter sent to Secretary Moniz

International Particle Physics Community Convergence

- **2015: New DOE-CERN-NSF partnership agreement signed**
  - Allows CERN to support science initiatives **outside of Europe** for first time in 60 year history

"A model for the kinds of international scientific collaborations that can enable breakthrough insights and innovations." ***John Holdren, President's Science Advisor***

"This agreement is also historic since it formalizes CERN's participation in U.S.-based programs such as prospective future neutrino facilities for the first time." ***Rolf Heuer Director General, CERN***

LBNF/DUNE meets P5* Mandate

P5 recommendation 13: "Form a **new international collaboration** to design and execute **a highly capable Long-Baseline Neutrino Facility (LBNF)** hosted by the U.S. To proceed, a project plan and identified resources must exist to meet the minimum requirements [in the report]. LBNF is the highest-priority large project in its timeframe."

…with a facility scope based on science requirements:

- "The minimum requirements to proceed are the identified capability to reach an exposure of at least **120 kt*MW*yr** by the 2035 timeframe, the far detector situated underground with cavern space for expansion to at least 40 kt LAr fiducial volume, and 1.2 MW beam power upgradable to multi-megawatt power.

…to address fundamental questions in science, such as why there is more matter than anti-matter, i.e., the universe!

LBNF/DUNE Project will meet P5 requirements

* Particle Physics Project Prioritization Panel

International Partnership

- LBNF/DUNE leverages the **European Strategy for Particle Physics**, the **P5 report**, and the **DOE-CERN-NSF partnership agreement**.
- International partnership is critical to LBNF/DUNE success.
- CERN is a **major partner** in facility infrastructure at Sanford Lab and is also key to facilitate European engagement.
  - Signed four partnership protocols on 18 Dec 2015 including neutrinos
  - Have already committed to provide first cryostat (valued at $90M U.S. TPC)
  - Facilitating engagement with member countries and European high energy physics community
  - Supporting prototyping effort with short baseline and protoDUNEs with CERN "neutrino platform"
- Brazil, India, Italy, Switzerland, and the UK are showing **strong leadership and early support**… campaign to engage all 27 countries underway.
- And of course, **South Dakota**, where more than $146M has been invested in the Sanford Underground Research Laboratory to date.

"International from the start…"

"This project will be the first time the U.S. has hosted a truly international mega-science project on U.S. Soil"… SC-2

- Unique project characteristics - We must be a good host and a flexible and reliable partner to be successful… which means:
  - **Accounting**: We adopt "core" costing for international partners
  - **Contingency**: No DOE contingency on non-DOE contributions. We trust that our partners will deliver.
  - **Project management**: Earned value system for DOE scope; milestones for partners.
- Unique challenges and approaches:
  - Codes and standards
  - International agreements
  - Acquisition strategy and more…

Project Overview: LBNF/DUNE

LBNF and DUNE: two sub-projects with a single DOE Federal Project Director

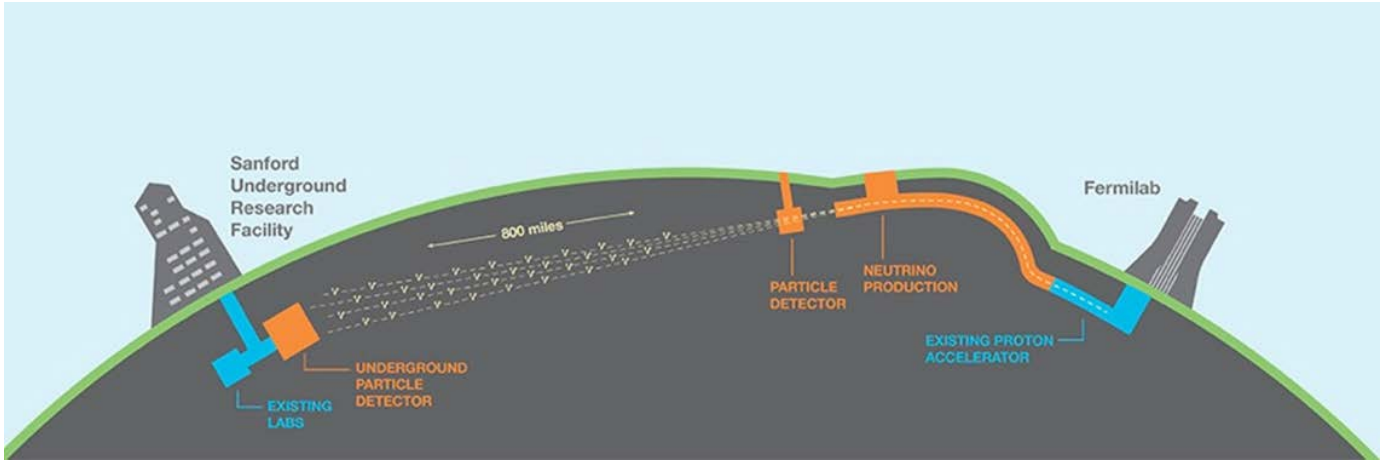
- This facilitates CERN as a facility partner
- Share common project office resources

LBNF: **DOE project with support from non-DOE partners**. Provides facility infrastructure at two locations to support the experiment:

- Near site: Fermilab, Batavia, IL – facilities to create neutrino beam
- Far site: Sanford Underground Research Facility, Lead, SD – facilities to support DUNE detectors

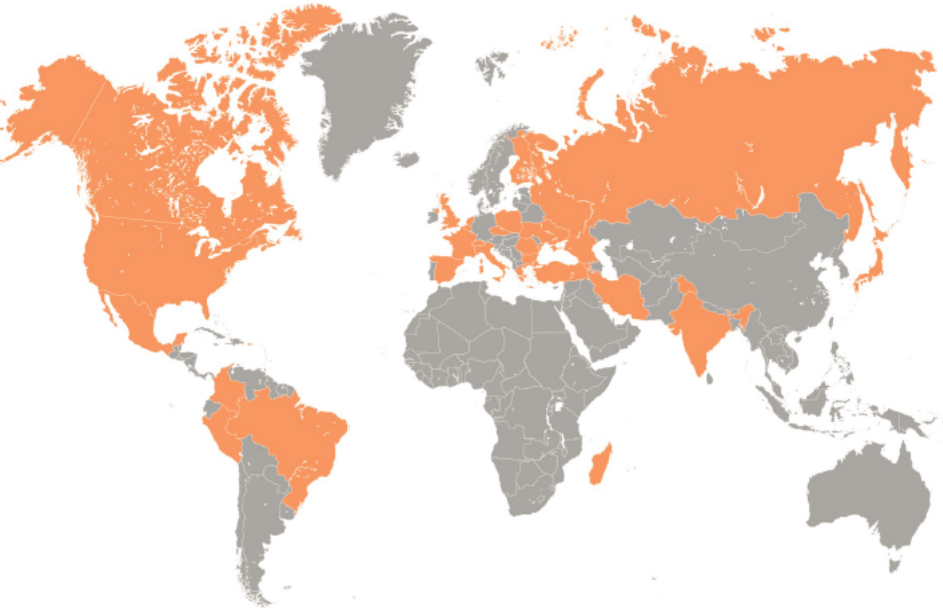
DUNE: Deep Underground Neutrino Experiment

- Near and far site detectors: **U.S. as partner in international project**



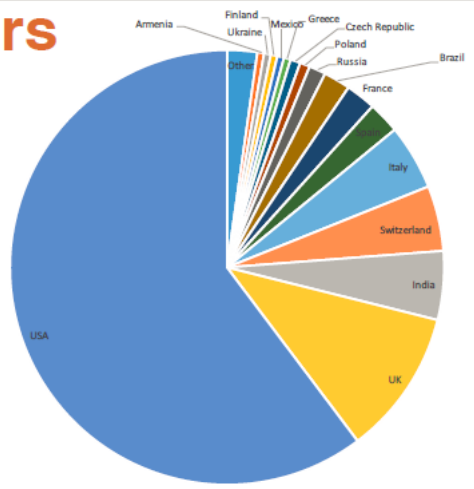
The DUNE Collaboration

DEEP UNDERGROUND NEUTRINO EXPERIMENT



Keeps growing:

805 Collaborators
27 Nations
146 institutions



Armenia Yerevan Inst. for Theoretical Physics and Modeling
Belgium Univ. de Liege
Brazil Univ. Federal do ABC; Univ. Federal de Alfenas em Poços de Caldas; Univ. de Campinas; Univ. Estadual de Feira de Santana; Univ. Federal de Goias; Observatorio Nacional
Bulgaria Univ. of Sofia
Canada York University
Colombia Univ. del Atlantico
Czech Republic Charles University, Prague; Czech Technical University, Prague; Institute of Physics ASCR, Prague
France Lab. d'Annecy-le-Vieux de Phys. des Particules; Inst. de Physique Nucleaire de Lvon: APC-Paris: CEA/Sacla
Finland Jyväskylä
Greece Athens
India Aligarh Muslim University; Banaras Hindu University; Bhabha Atomic Research Center; Univ. of Delhi; Indian Inst. of Technology, Guwahati; Harish-Chandra Research Institute; Indian Inst. of Technology, Hyderabad; Univ. of Hyderabad; Univ. of Jammu; Jawaharlal Nehru University; Koneru Lakshmaiah; Univ. of Lucknow; Panjab University; Punjab Agri. University; Variable Energy Cyclotron Centre
Iran Inst. for Research in Fundamental Sciences
Italy Lab. Nazionali del Gran Sasso, Assergi; Univ. di Catania; Gran Sasso Science Institute; Univ. di Milano; INFN Sezione di Milano Bicocca; INFN Sezione di Napoli; Univ. of Padova; Univ. of Pavia, INFN Sezione di Pavia; CNI Pisa; Univ. di Pisa
Japan KEK; Kavli IPMU, Univ. of Tokyo
Madagascar Univ. of Antananarivo
Mexico Univ. de Colima; CINVESTAV
Netherlands NIKHEF
Peru PUCP
Poland Inst. of Nuclear Physics, Krakow; National Centre for Nuclear Research, Warsaw; Univ. of Warsaw; Wroclaw University
Romania Horia Hulubei National Institute
Russia Inst. for Nuclear Research, Moscow
Spain Inst. de Fisica d'Altas Energias, Barcelona; CIEMAT; Inst. de Fisica Corpuscular, Madrid
Switzerland Univ. of Bern; CERN; ETH Zurich
Turkey TUBITAK Space Technologies Research Institute
Ukraine Kyiv National University
United Kingdom Univ. of Cambridge; Univ. of Durham; Univ. of Huddersfield; Imperial College of Science, Tech. & Medicine; Lancaster University; Univ. of Liverpool; University College London; Univ. of Manchester; Univ. of Oxford; STFC Rutherford Appleton Laboratory; Univ. of Sheffield; Univ. of Sussex; Univ. of Warwick
USA Univ. of Alabama; Argonne National Lab; Boston University; Brookhaven National Lab; Univ. of California, Berkeley; Univ. of California, Davis; Univ. of California, Irvine; Univ. of California, Los Angeles; California Inst. of Technology; Univ. of Chicago; Univ. of Cincinnati; Univ. of Colorado; Colorado State University; Columbia University; Cornell University; Dakota State University; Drexel University; Duke University; Fermi National Accelerator Lab; Univ. of Hawaii; Univ. of Houston; Idaho State University; Illinois Institute of Technology; Indiana University; Iowa State University; Kansas State University; Lawrence Berkeley National Lab; Los Alamos National Lab; Louisiana State University; Univ. of Maryland; Massachusetts Institute of Technology; Michigan State University; Univ. of Minnesota; Univ. of Minnesota (Duluth); Univ. of New Mexico; Northwestern University; Univ. of Notre Dame; Ohio State University; Oregon State University; Pacific Northwest National Lab; Univ. of Pennsylvania; Pennsylvania State University; Univ. of Pittsburgh; Princeton University; Univ. of Puerto Rico; Univ. of Rochester; SLAC National Accelerator Lab; Univ. of South Carolina; Univ. of South Dakota; South Dakota School of Mines and Technology; South Dakota Science And Technology Authority; South Dakota State University; Southern Methodist University; Stanford University; Stony Brook University; Syracuse University; Univ. of Tennessee; Univ. of Texas at Arlington; Univ. of Texas at Austin; Tufts University; Virginia Tech; Wichita State University; College of William and Mary; Univ. of Wisconsin; Yale University

The DUNE Collaboration

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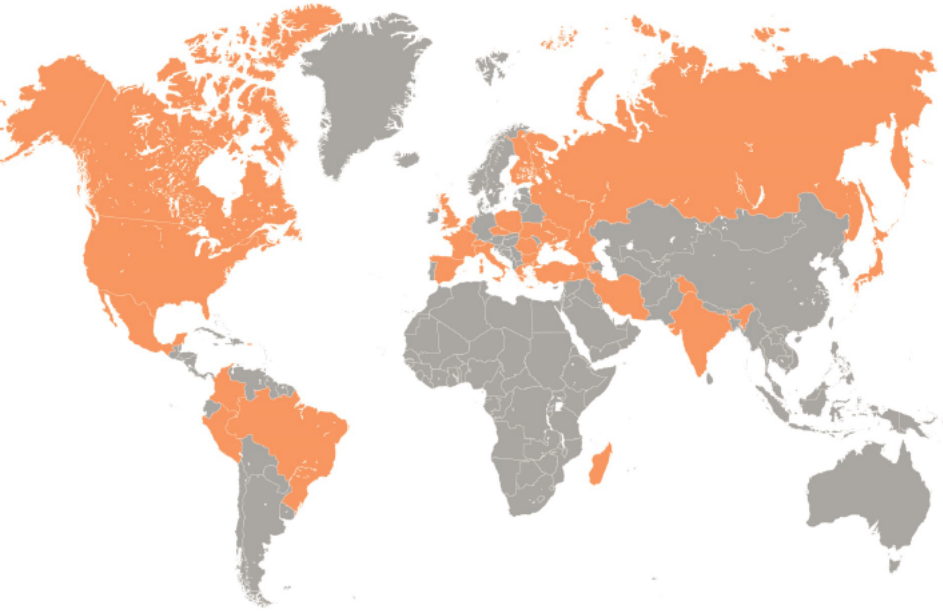

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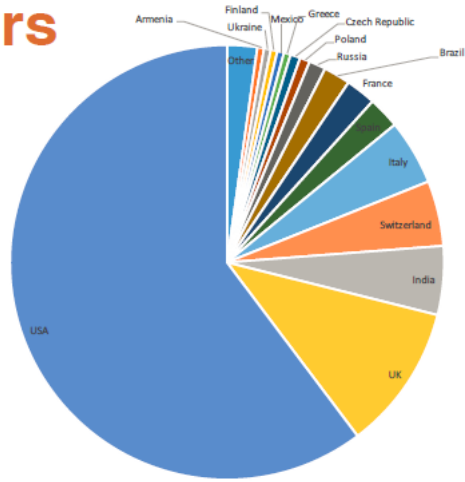
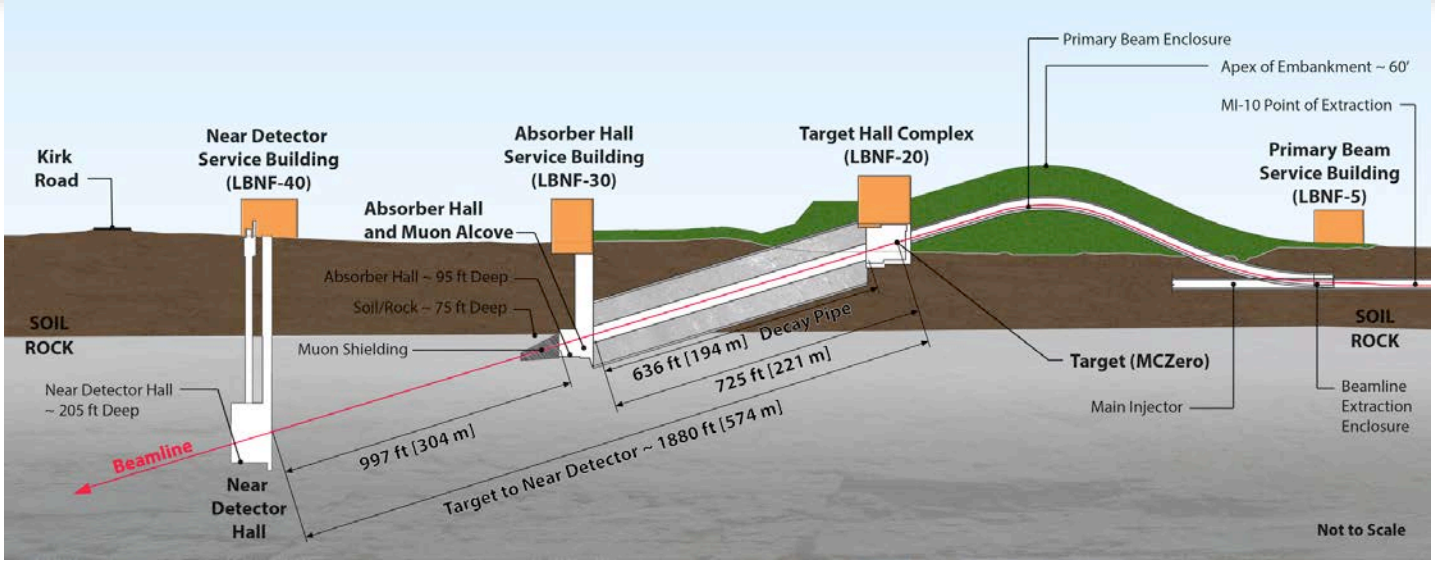


Collaboration has come together faster than even the optimistic schedule considered by P5… an indication of strong interest in this science and the perception that the U.S. is **prepared to host an ambitious world-class** neutrino facility.

Overview - “Near Site” – LBNF/DUNE at Fermilab, Batavia, IL



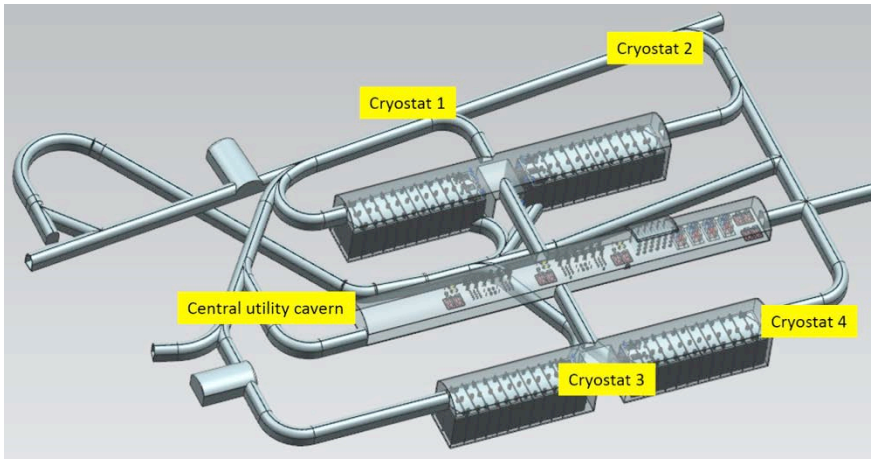
- Primary proton beam @ 60-120GeV extracted from Main Injector
- Initial 1.2 MW beam power, upgradable to 2.4 MW
- Embankment allows target complex to be at grade and neutrino beam to be aimed to Lead, SD
- Decay region followed by absorber
- Four surface support buildings
- Near Detector facility
- DUNE Near Detectors (fine grained straw tube with gas targets)

Beamline design based on Fermilab’s NOvA beam, currently the most powerful neutrino beam in the world

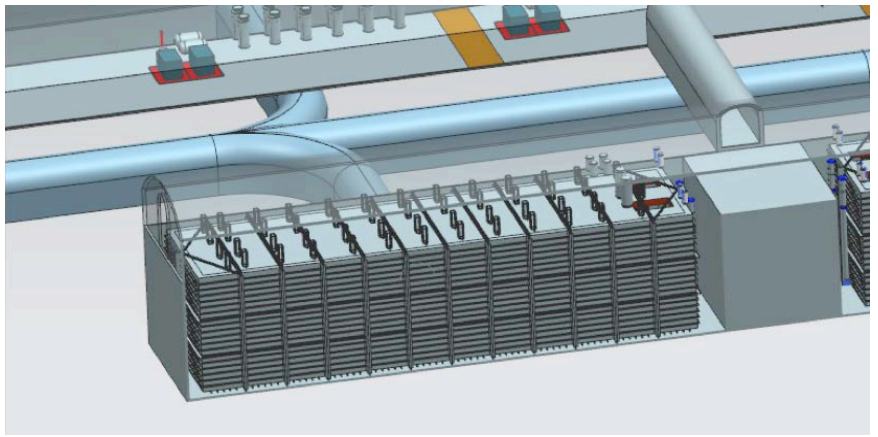
Overview – "Far Site" – LBNF/DUNE at Sanford Lab, Lead, SD

- **Conventional Facilities**:
  - Surface and shaft Infrastructure including utilities
  - Drifts and two caverns for detectors
  - Central utility cavern for conventional and cryogenic equipment
- **Cryostats**:
  - Four membrane cryostats supported by external steel frames
- **Cryogenic Systems**:
  - LN2 refrigeration system for cooling and re-condensing gaseous Argon
  - Systems for purification and recirculation of LAr
- **Argon: 70kt LAr (~40kt "fiducial" mass)**
- **DUNE LAr-TPC Detectors**

Extensive prototyping program in progress to scale LAr TPC detector technology to 10kt fiducial volume



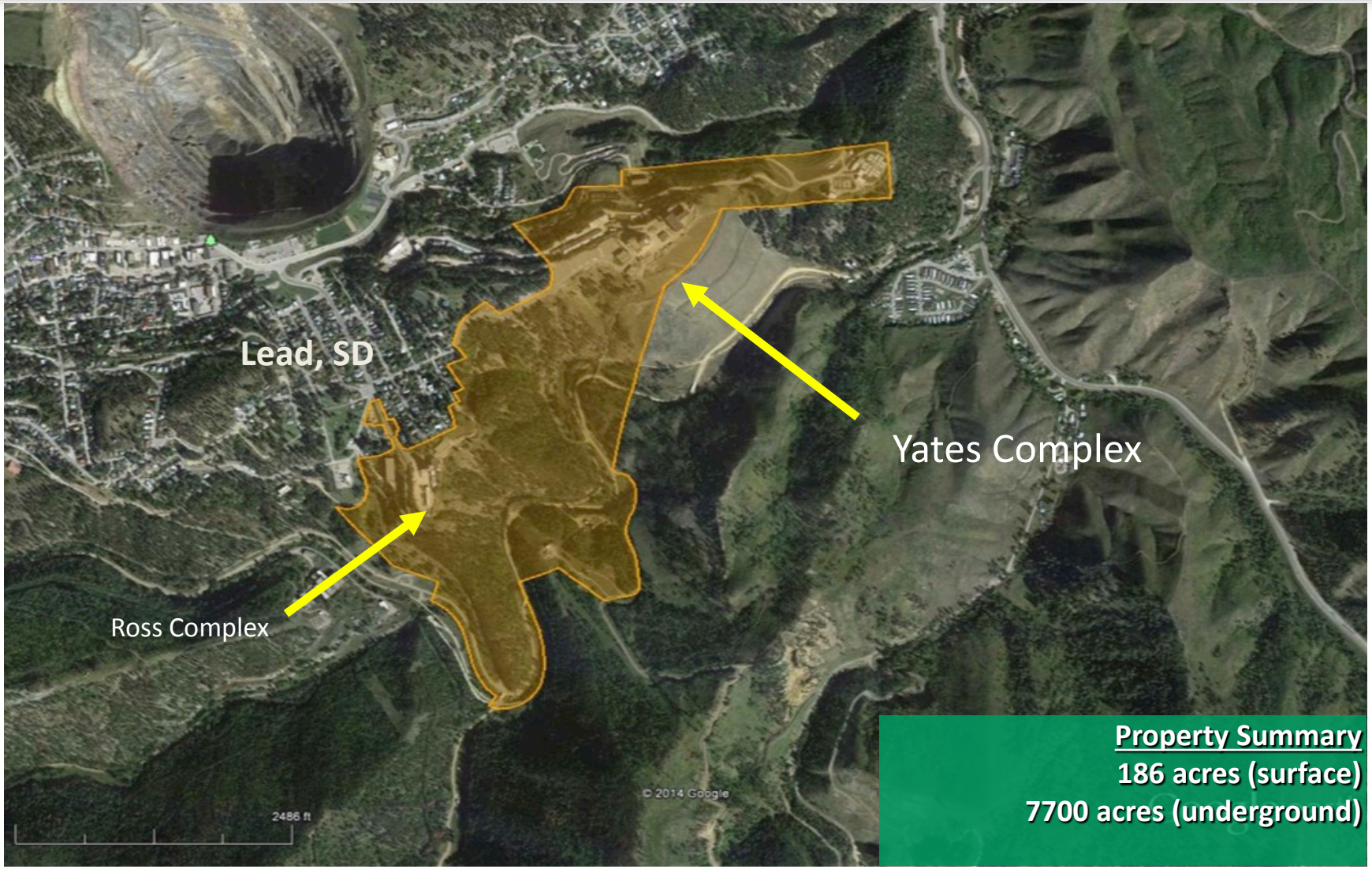
4850L cavern and drift layout



Single cryostat

Sanford Underground Research Laboratory

Far Site Overview – Sanford Lab in Lead, SD



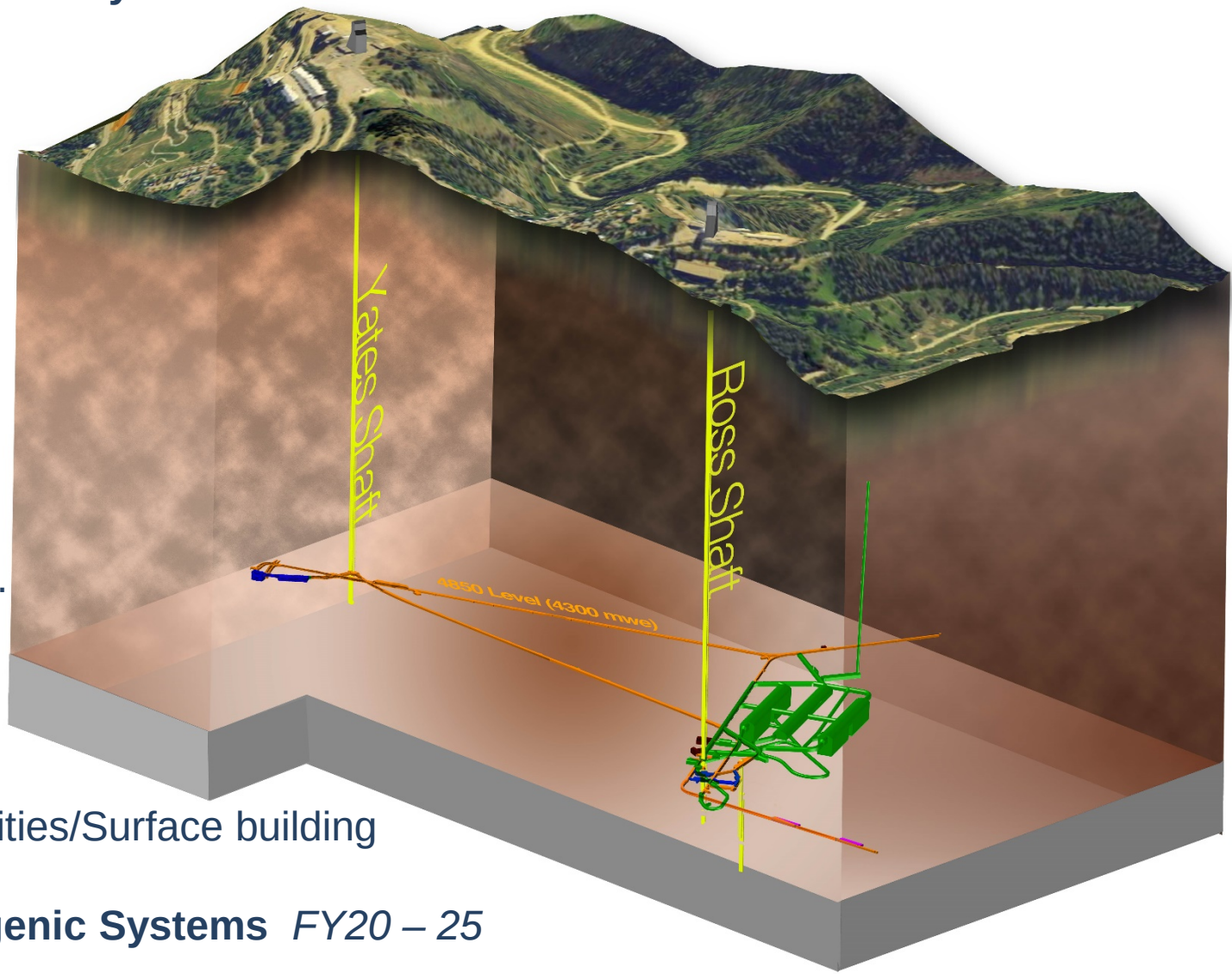
Far Site Scope – Overview of Phases of Work

1. **Sanford Lab Reliability Projects**
   FY16 – 18
   - Ross shaft rehab
   - Hoist motor rebuilds, more…

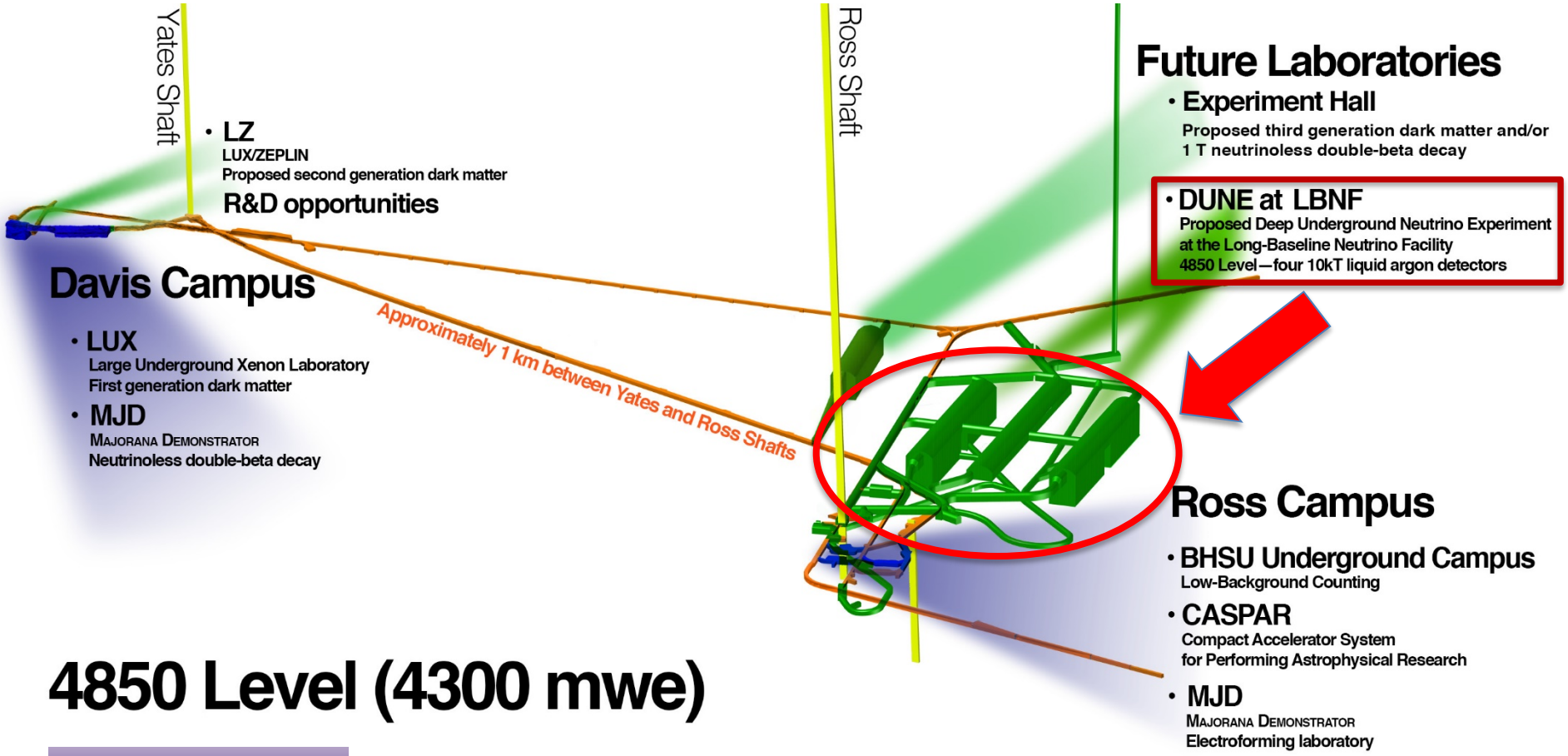
2. **Pre-Excavation**
   FY17 - 20
   - Rock disposal systems
   - Ross brow expansion, more…

3. **Excavation/ Construction**
   FY18 – 22
   - Caverns/Drifts/Utilities/Surface building

4. **Cryostats/Cryogenic Systems** *FY20 – 25*



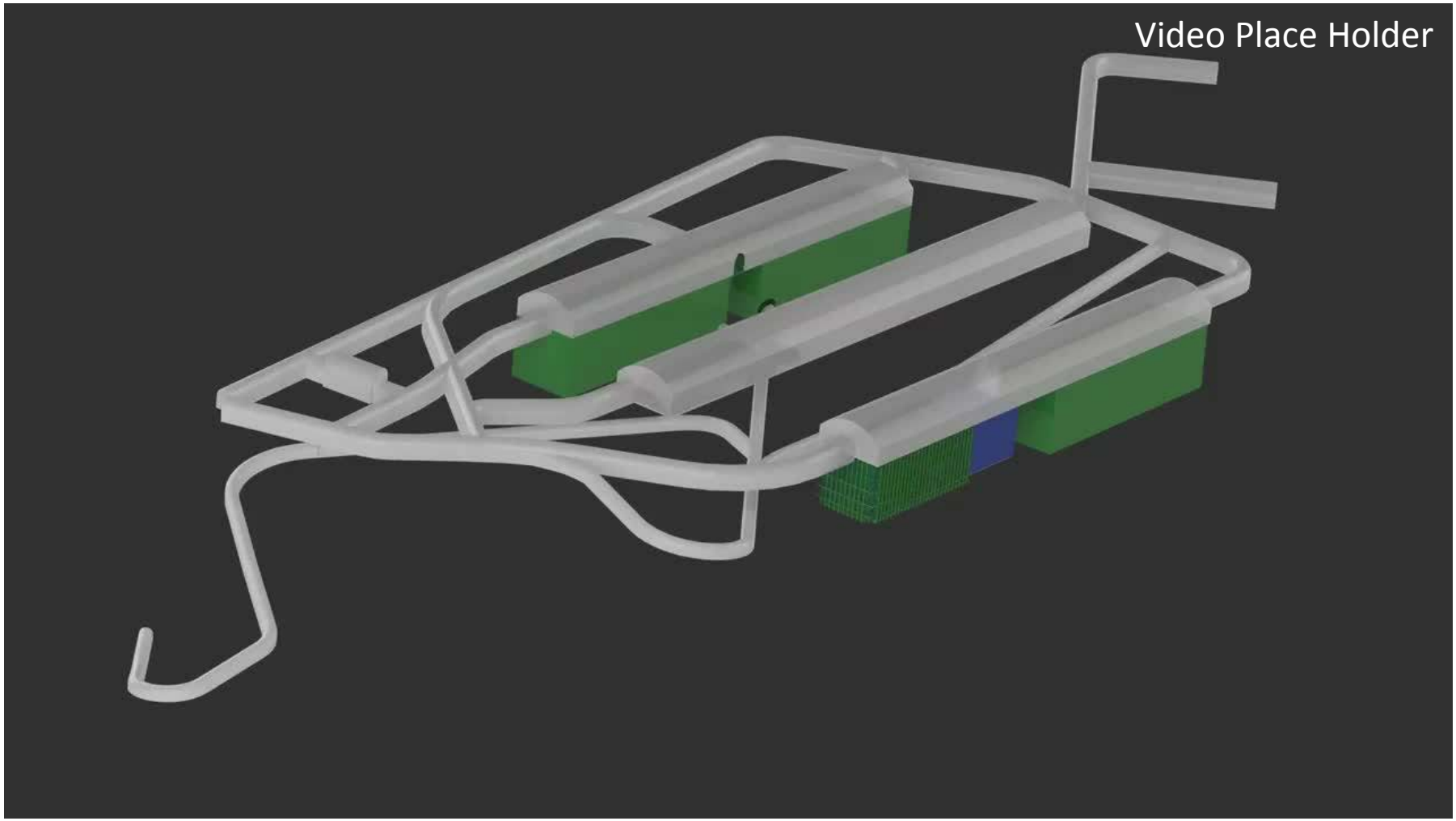
Far Site Context – part of an Underground Campus



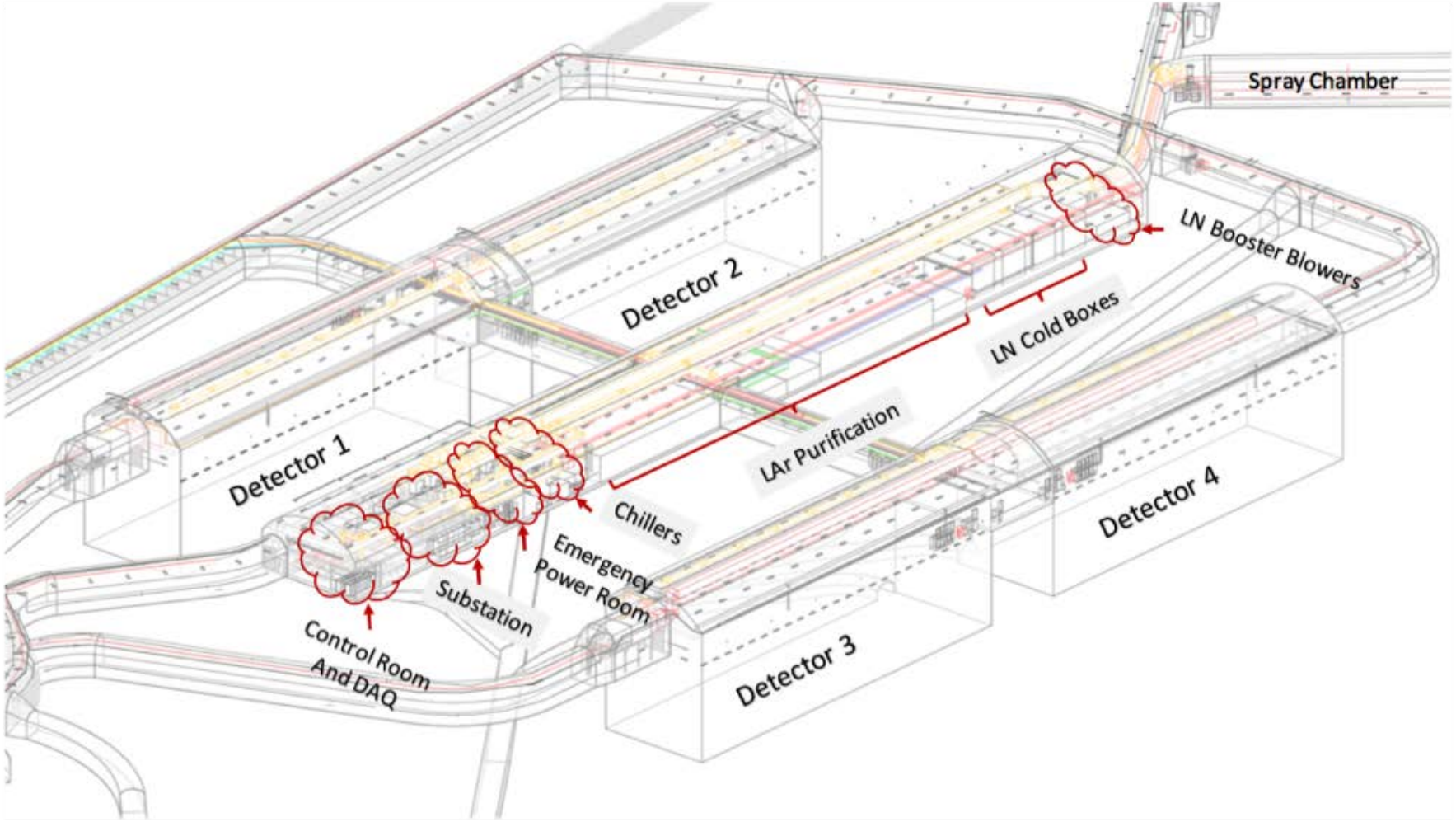
Existing facilities

Proposed facilities

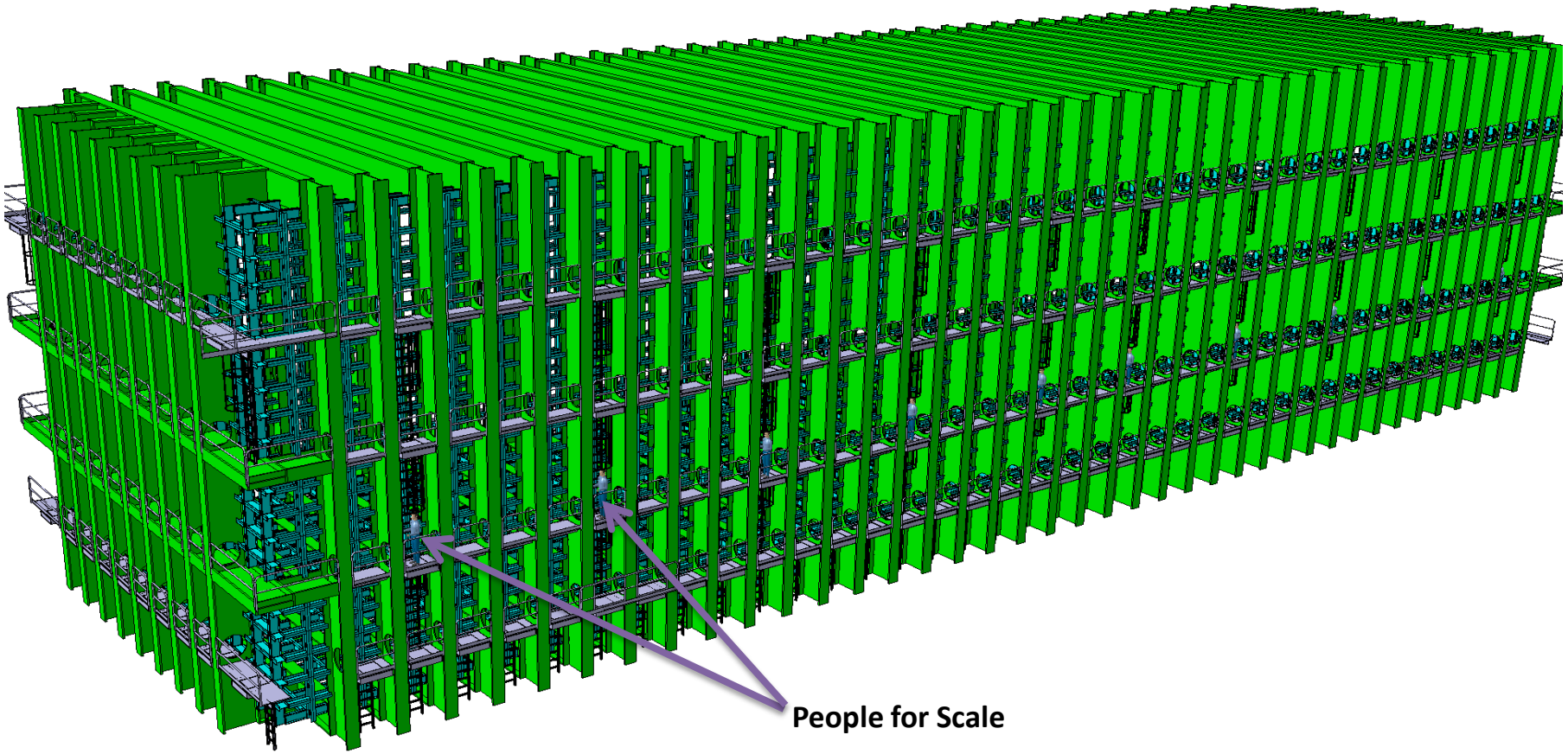
LBNF / DUNE Far Site



Design Scope – Central Utility Cavern



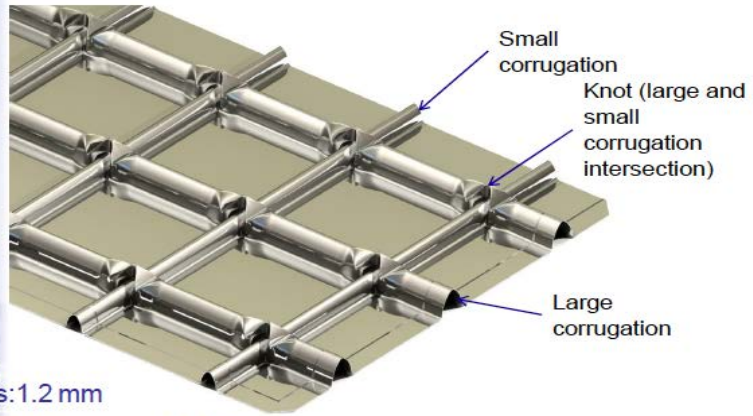
Free-Standing Steel Cryostat Design



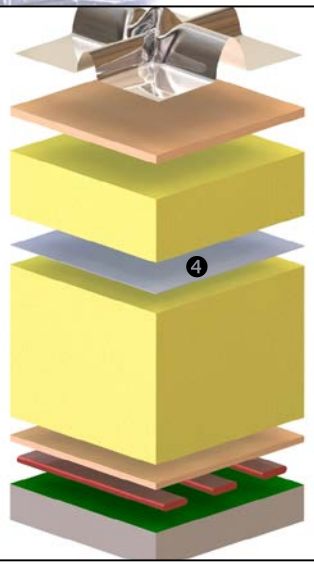
External (Internal) Dimensions
19.1m (15.1m) W x 18.0m (14.0m) H x 66.0m (62.0m) L

Membrane Cryostat Design

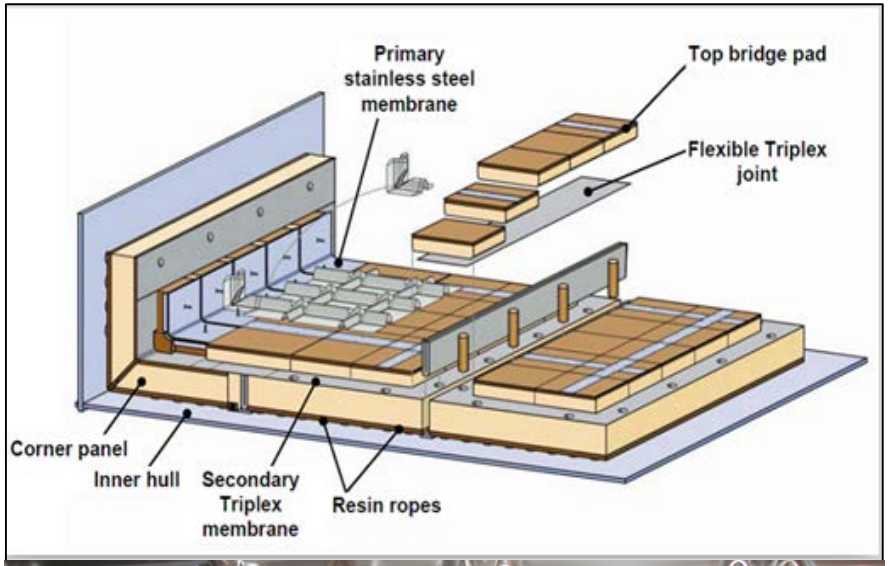
The corrugated stainless steel primary barrier:



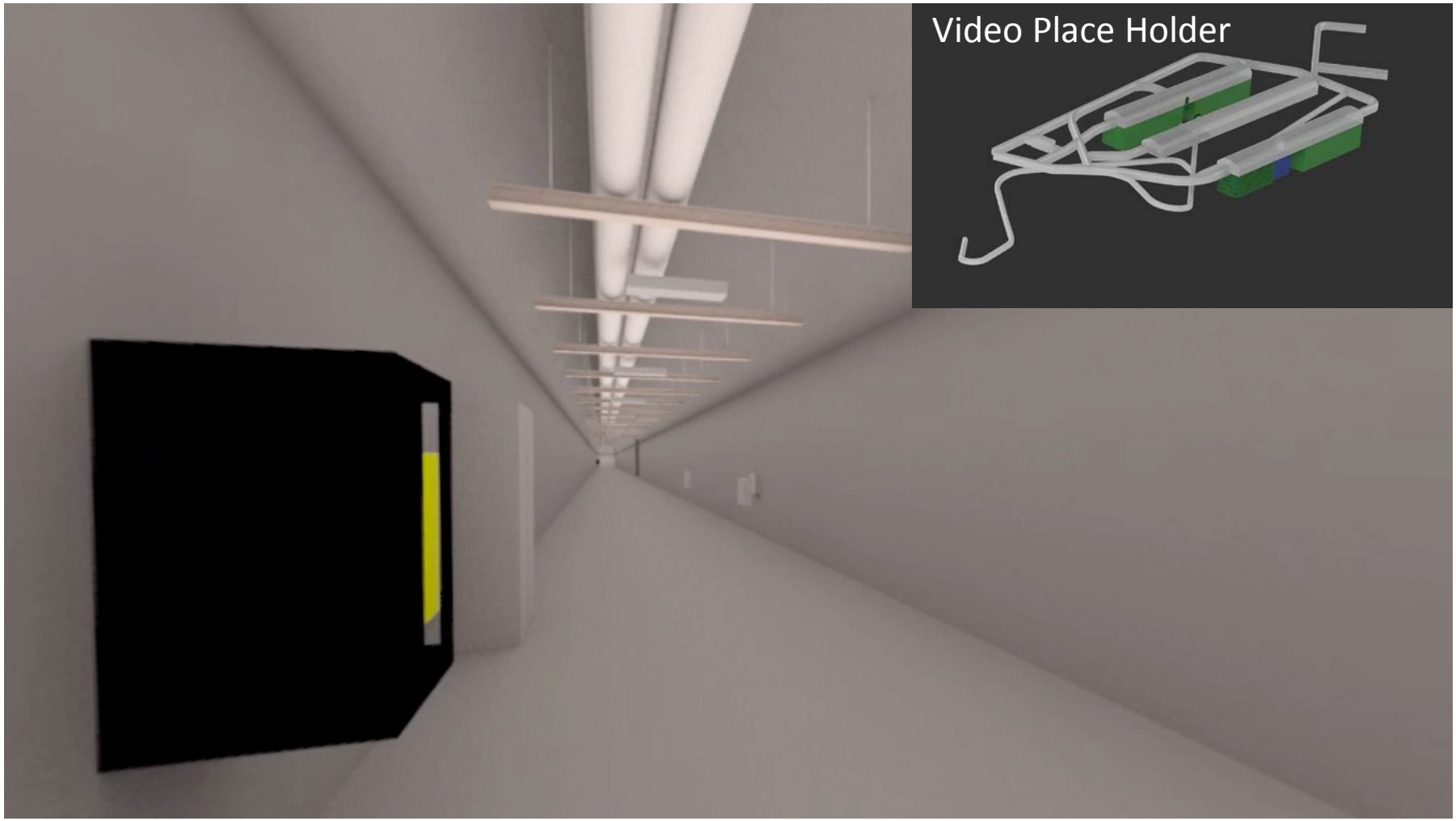
- Thickness:1.2 mm
- Material: Stainless steel 304L



barrier

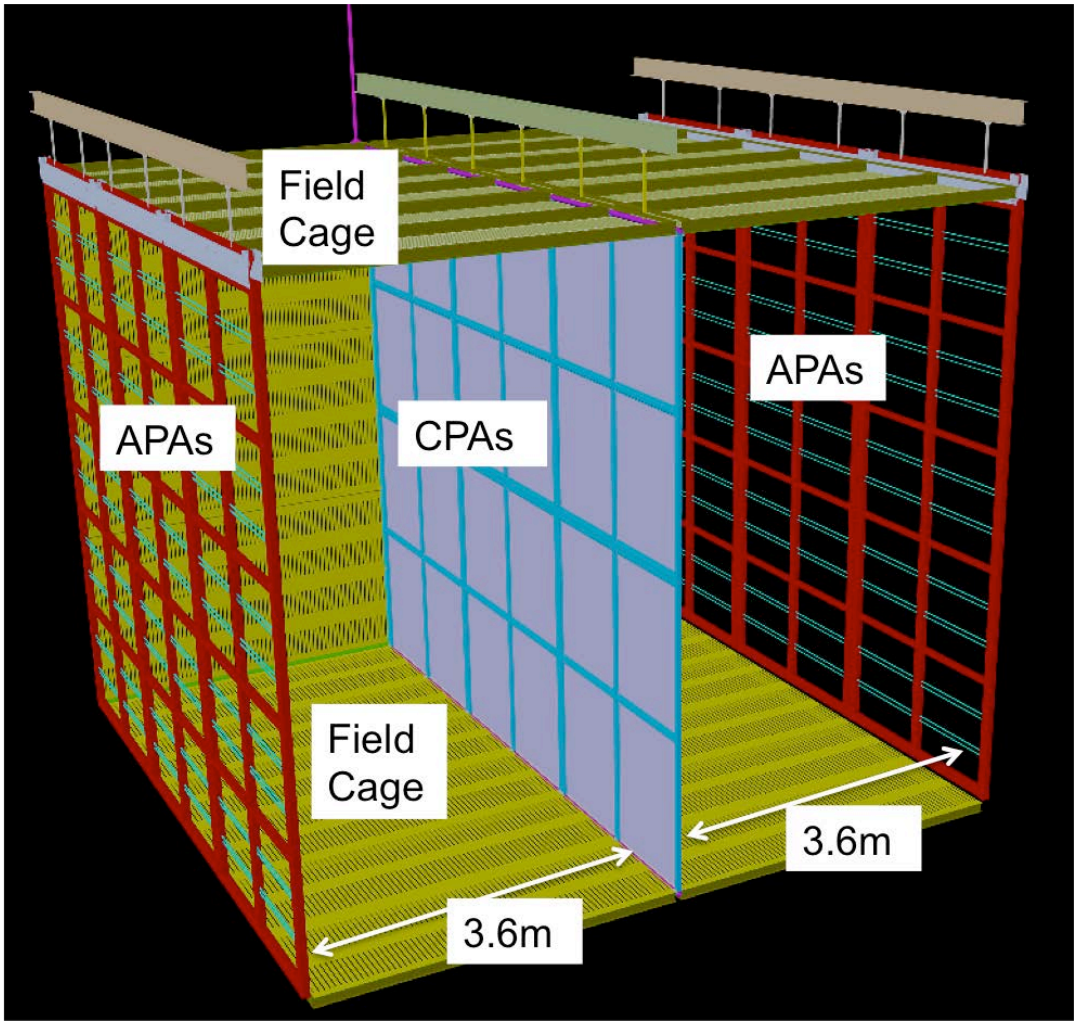


LBNF Virtual Walkthrough



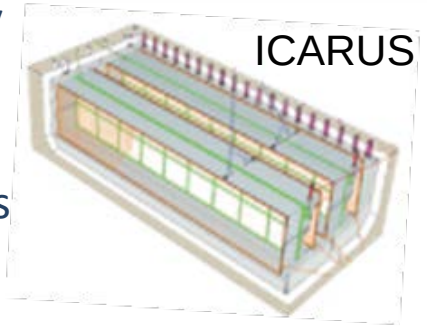
Single Phase Detectors inside the Cryostats

- Detectors consist of:
  - Anode Plane Arrays
  - Cathode Plane Arrays
  - Field Cage
  - Photon detectors
  - Readout electronics and DAQ
- How they work:
  - Neutrinos (occasionally) collide with Argon atom.
  - Resulting particles cause electrons to be knocked loose from liquid argon atoms, which “drift” to the APAs



DUNE Far Detector Prototyping

- Single-Phase design based on ICARUS detector LAr TPC technology initiated by Carlo Rubbia
- Fermilab and CERN neutrino platform are providing a strong development and prototyping program for the DUNE Far Detectors
- Also developing Dual-Phase LAr TPC technology

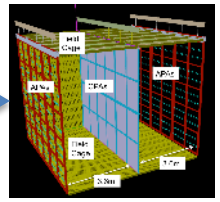


Single-Phase

2015

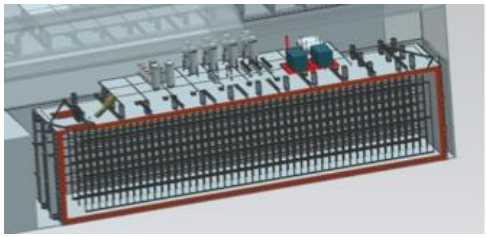
35-t prototype

2018



DUNE SP PT @ CERN

DUNE Reference Design



2021

Dual-Phase

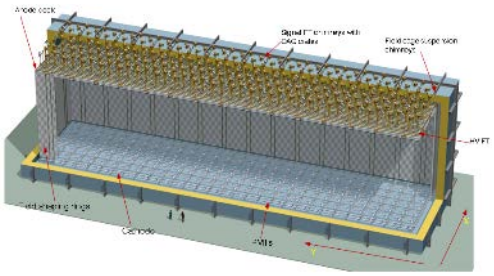
2016

WA105: 1x1x3 m^3

2018

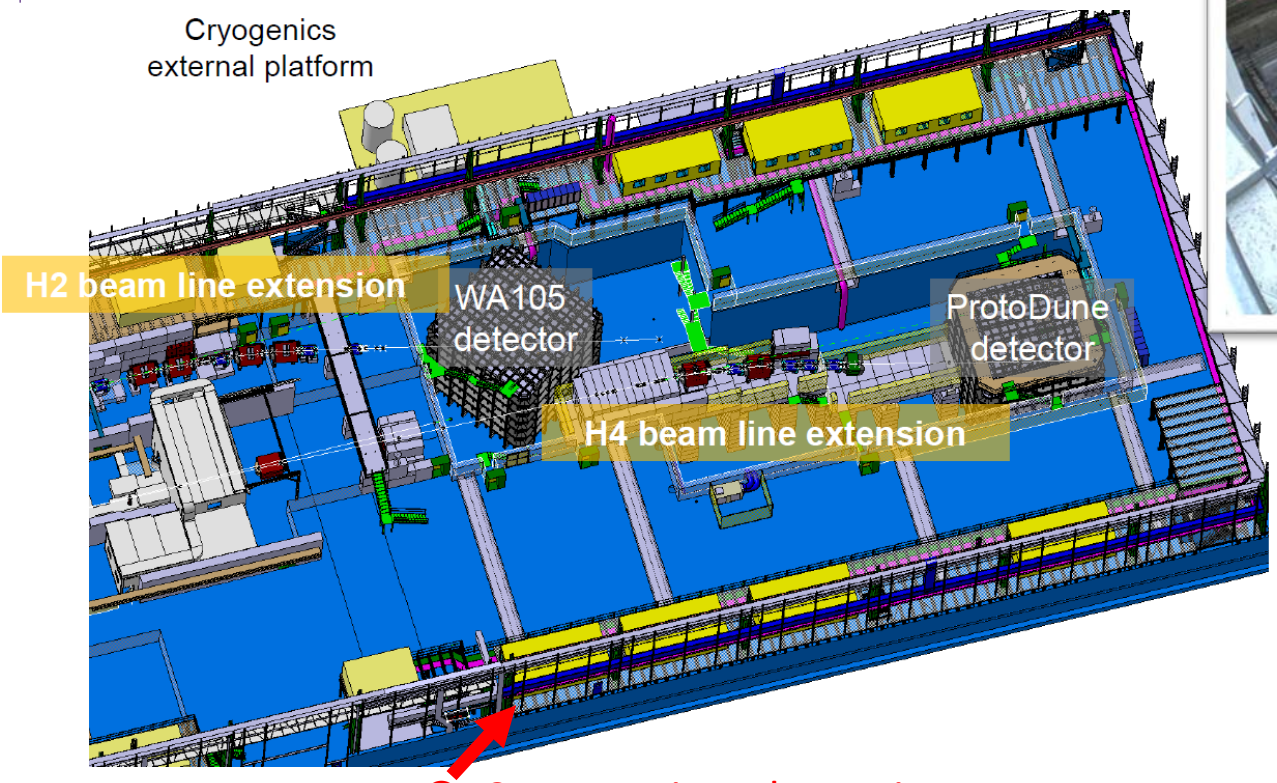
DUNE DP PT @ CERN

DUNE Alternative Design



CERN Test Beam Infrastructure

- protoDUNE facility at CERN will include 2 test beams, 2 cryostats
  - CERN invested ~$6 million CHF into each prototype
- Construction of detector hall well underway



Detector hall construction

LBNF/DUNE Governance Chart – "International from the start"

INC: International Neutrino Council

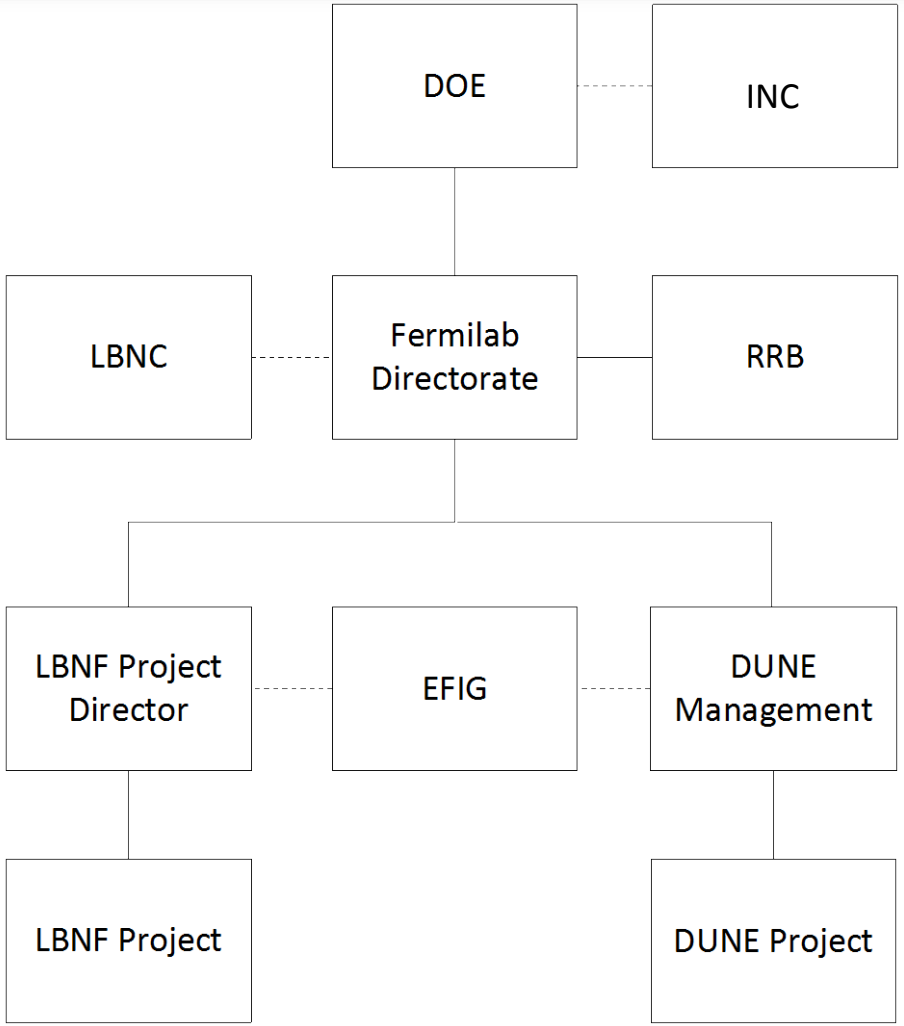
RRB: Resources Review Boards

LBNC: Long-Baseline Neutrino Committee

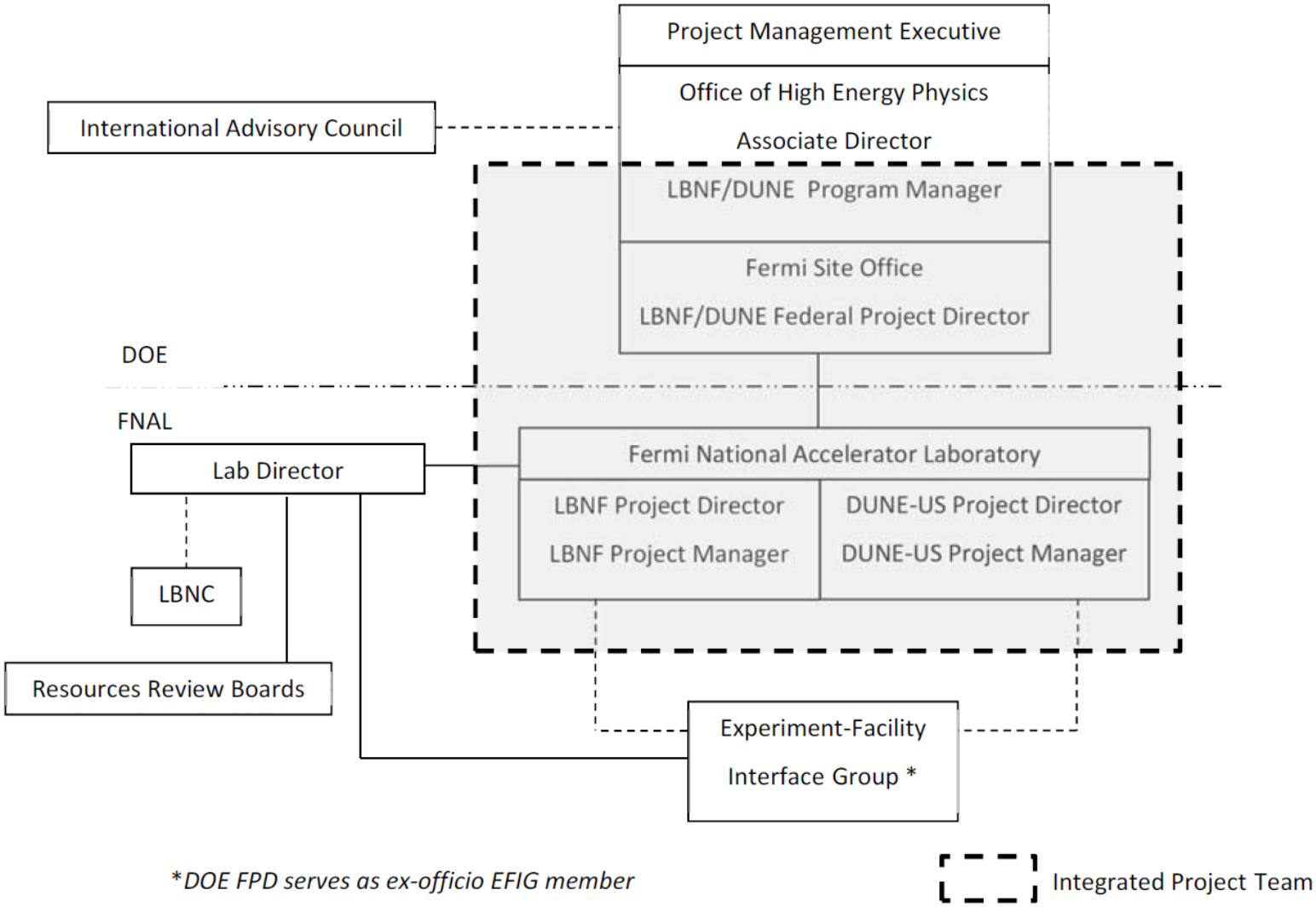
EFIG: Experiment-Facility Interface Group

Fermilab Directorate: The Fermilab Director and the two Deputy Directors

Governance patterned on successful CERN LHC model

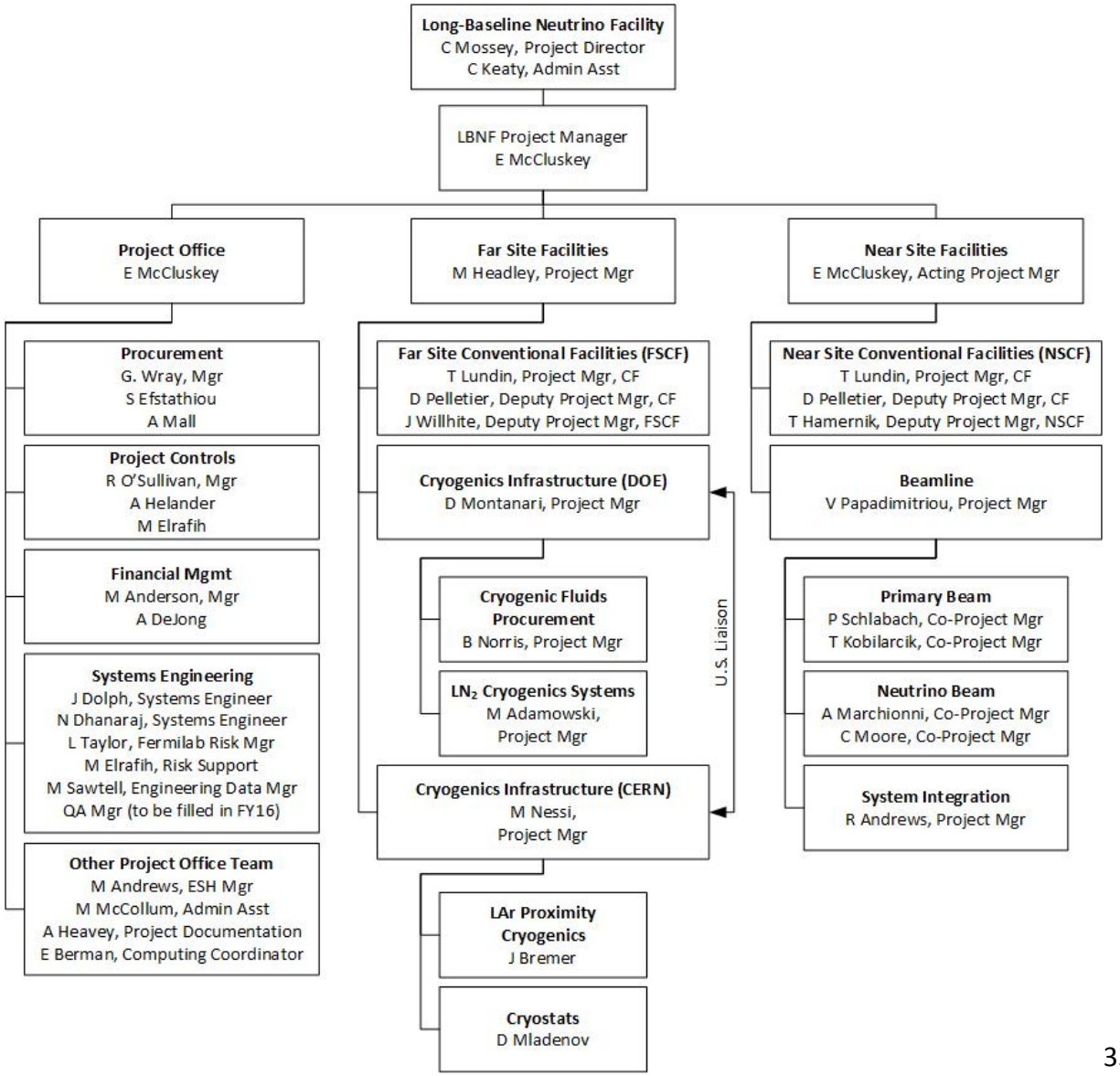


DOE Organization for U.S. LBNF/DUNE (PPEP)



Experienced LBNF Project Team

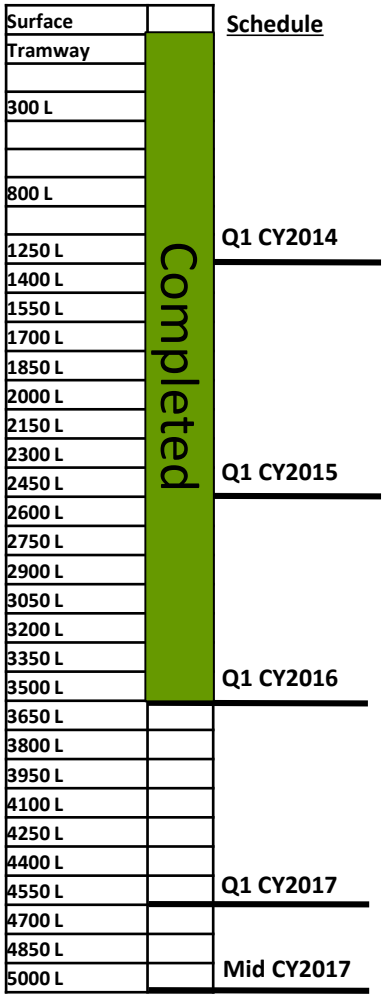
- LBNF Project team:
  - Organized around **three** L2 managers
  - Organization concept: **location** vs. function
  - CERN team is **tightly** integrated



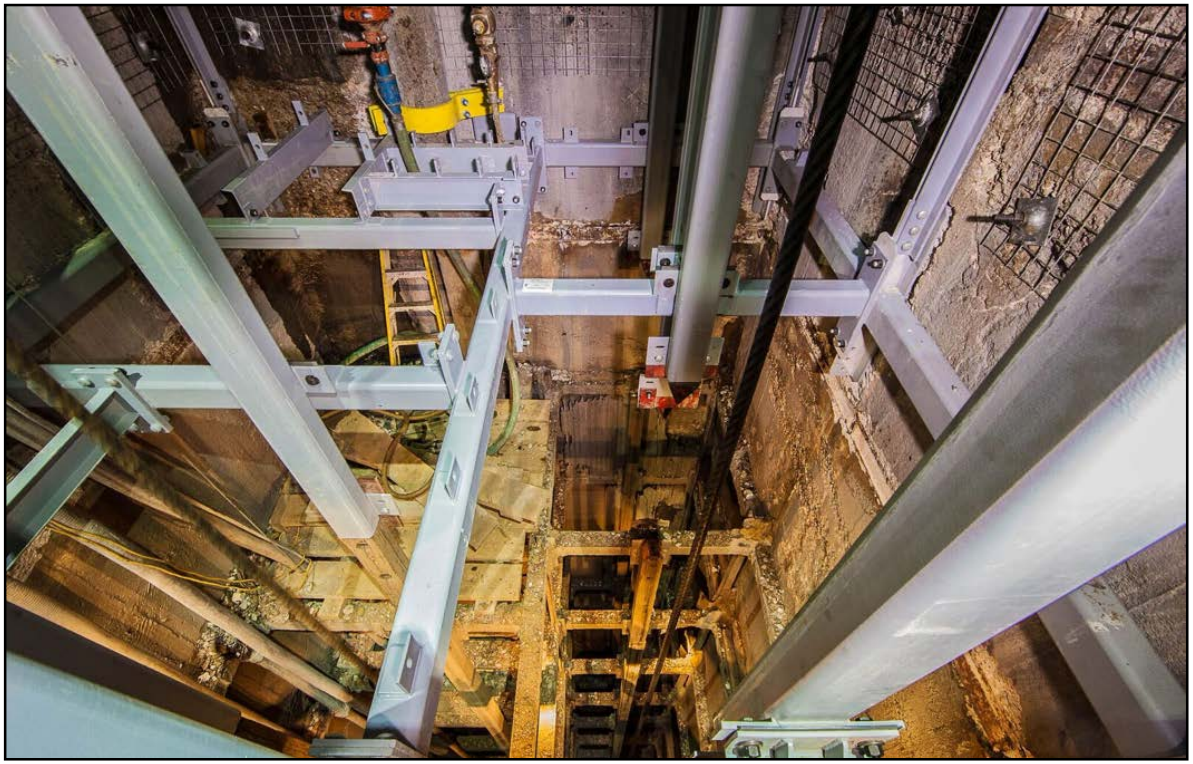
Coordinated Management at Far Site

- Far Site organizational structure lead by Mike Headley ensures coordination and single point of contact for LBNF work at Sanford Lab:
  - **Shaft usage**: manage and coordinate demand for shaft usage (which is controlled by Sanford Lab) to minimize impacts to existing and planned experiments.
  - **Logistics**: overlapping scopes of work to be executed simultaneously (e.g., excavation + cryostat construction) coordinated through one entity
  - **Interfaces**: FSCF and cryogenic infrastructure tied together with one manager to work with DUNE Far Detector management on interface issues.
  - **Environmental, Safety, Health (ESH)**: ESH responsibilities are coordinated through the FSF manager and Sanford Lab director.

Ross Shaft Refurbishment On Track

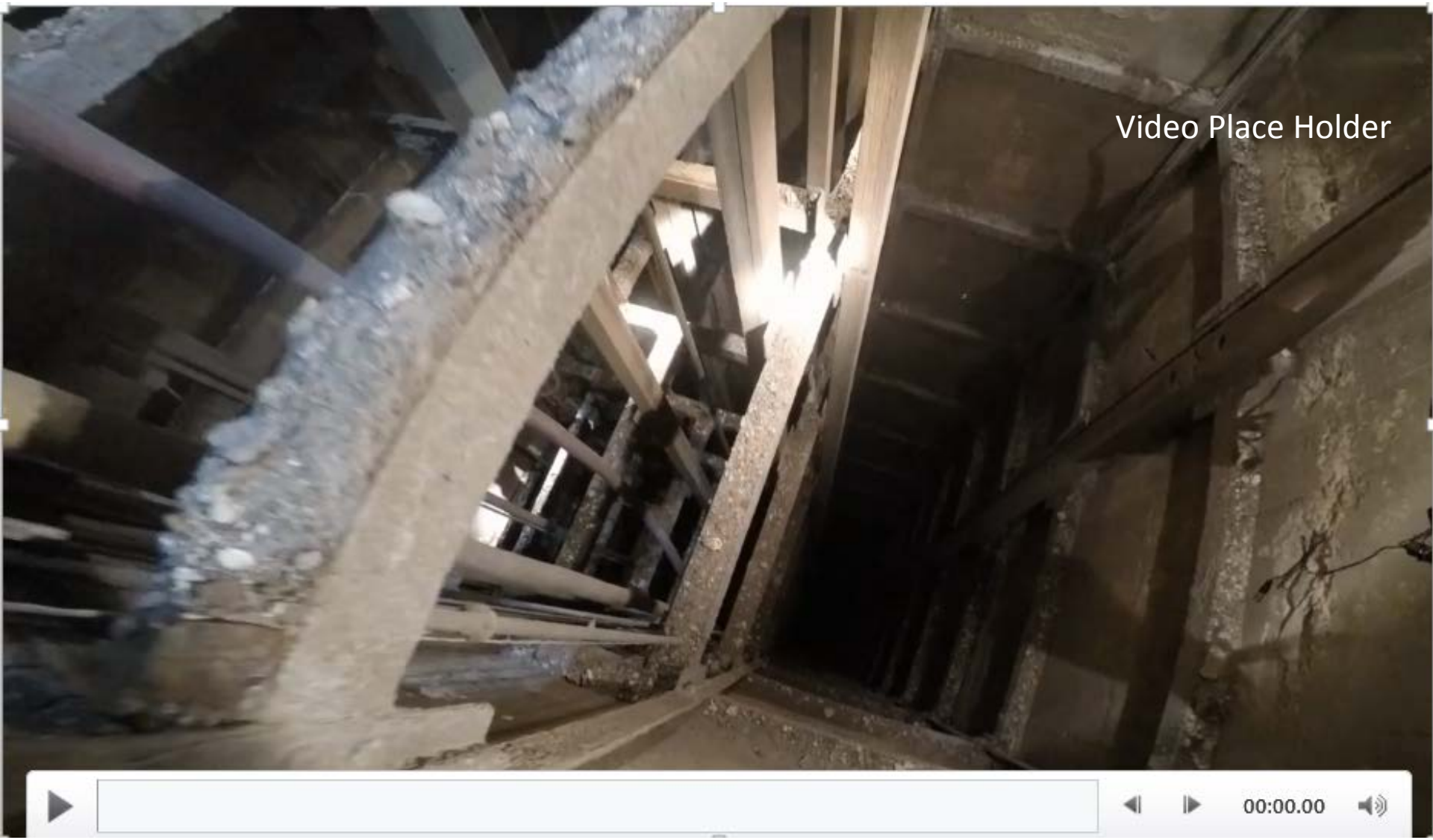


- Ross Shaft refurbishment required to support construction of the Long-Baseline Neutrino Facility (LBNF) Project. Shaft originally build in 1930's.
- The Ross Shaft has been refurbished to 3,615 feet from surface (70% completed). On track for a 2017 completion and a transition to LBNF construction.

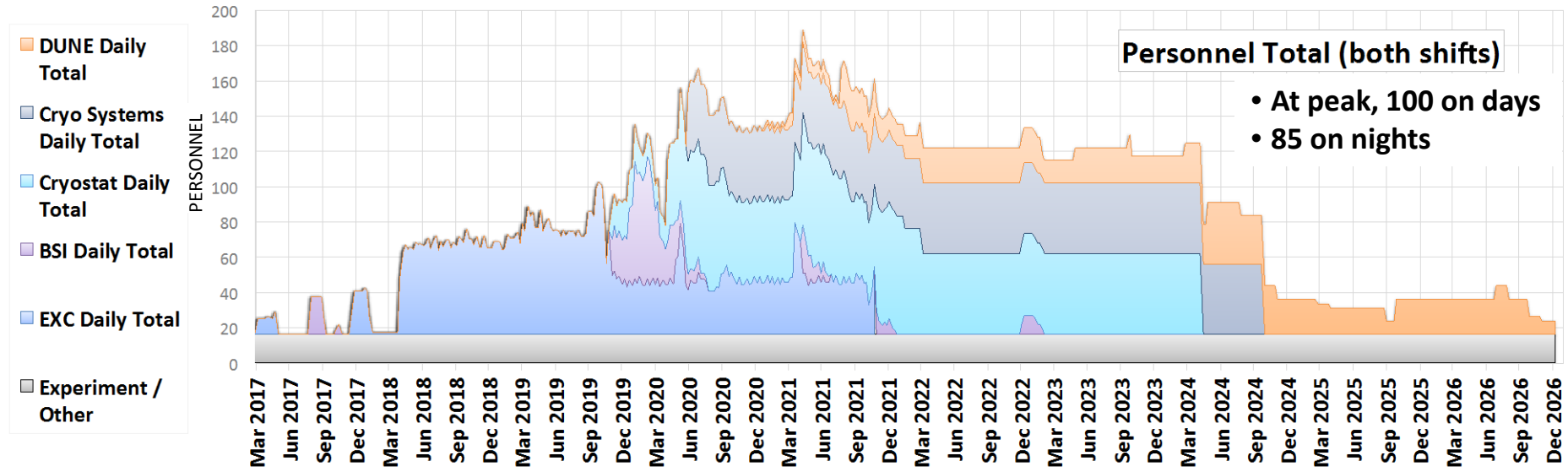


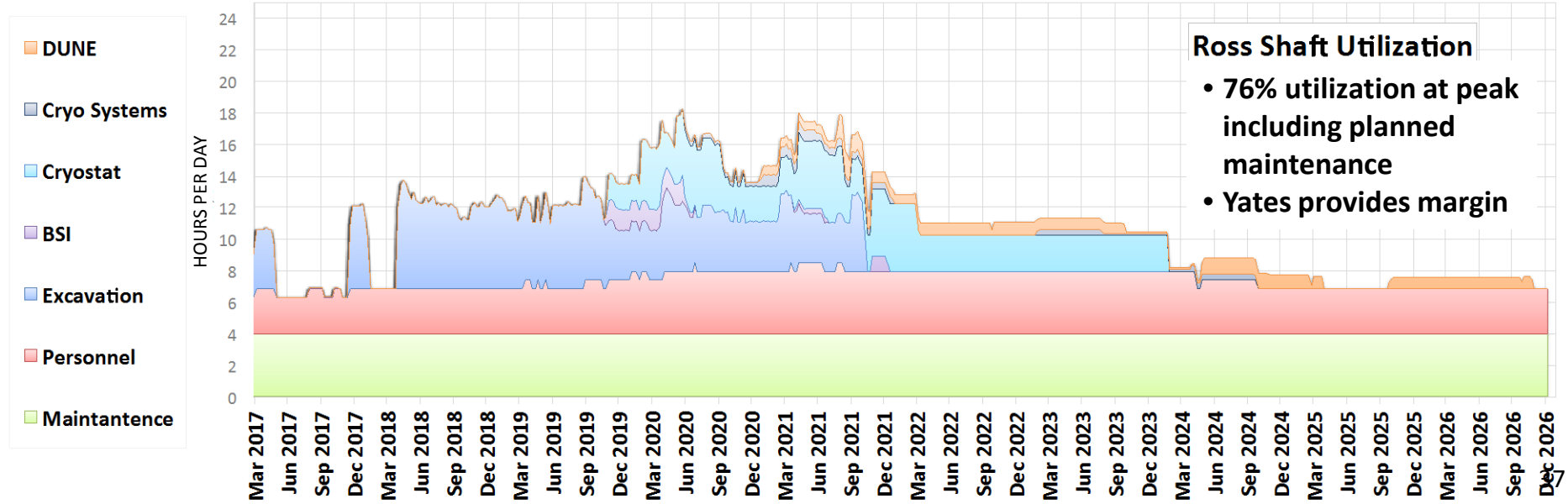
New Shaft Steel Recently Installed

Traversing Up the Ross Shaft Video - from old steel into new



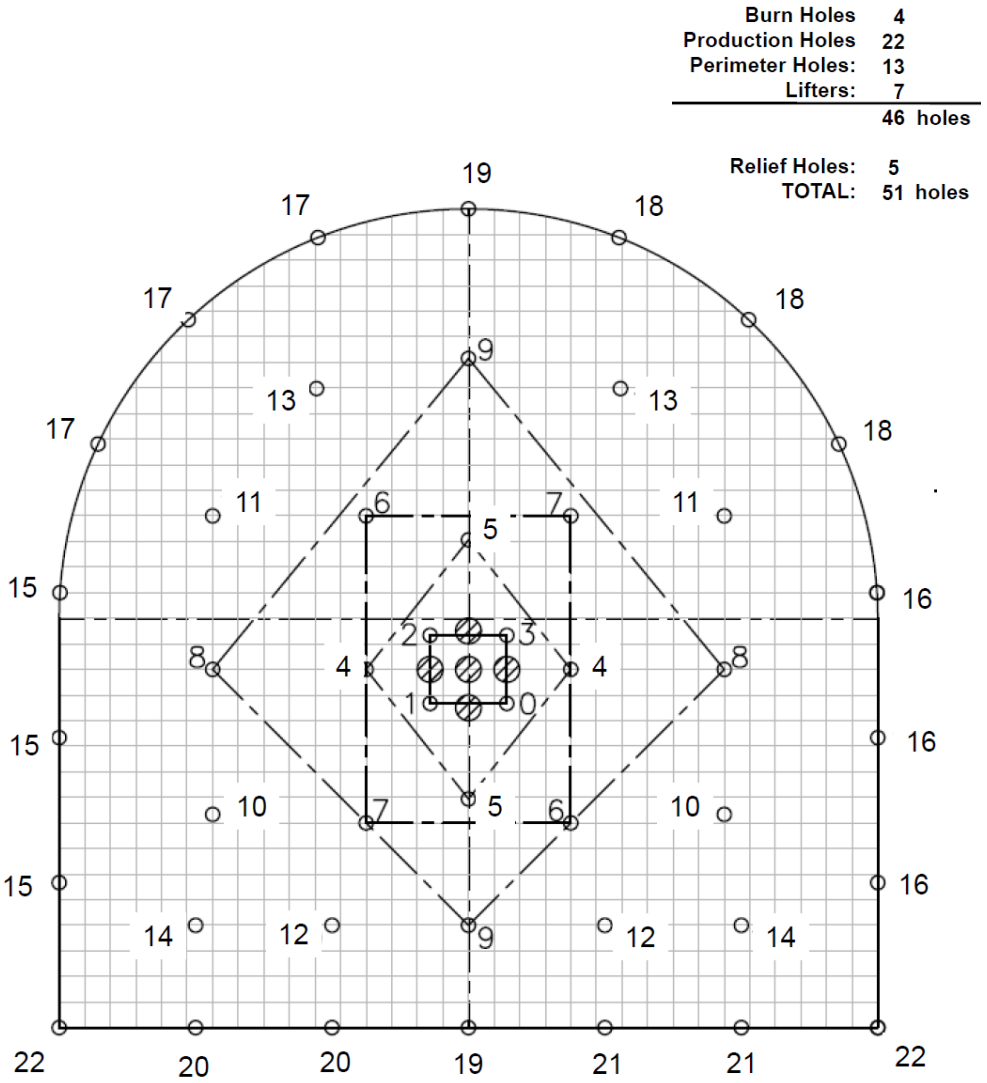
Personnel Underground & Ross Shaft Utilization





Construction Logistics Planning: Test Blast Program

- Excavation design includes a model for vibration & blast air overpressure
  - Based on industry experience and geotechnical site investigation
  - Potential risks to other 4850L experiments discussed during Logistics Workshop
- Completed test program in March to validate assumptions and provide input to final design



PM: ES&H: *Planned into Project*

- The projects are being planned to ensure the safety of everyone involved and to preserve the quality of the environment. This approach is integrated into:
  - The design process and studies
  - The CM/GC contract and sub-contract requirements
  - Reviews: regular technical reviews + special safety reviews
  - Management structure and organization
  - NEPA/NHPA process completed

PM: FNAL Management Oversight of Projects

- Lab has a critical role in project management and construction
- Oversight/engagement through:
  - Project Management Group (PMG) – LBNF/DUNE - monthly
  - Performance Oversight Group (POG) – all projects - monthly
  - Chief Project Officer - accountable for project portfolio in concert with successful operation of the scientific program.
  - CPO, Office of Project Support Services, Office of Integrated Planning and Performance Management are all collectively focused on project success
  - All work closely with DOE Program Managers and FSO PD's; DOE team attends lab oversight/management meetings

PM: LBNF/DUNE Project Major Reviews & Workshops 2015

DOE REVIEWS	
July 14-16, 2015	DOE/SC CD-1R Independent Project Review
July 7-8, 2015	DOE PMOA CD-1R Independent Cost Estimate
December 2-4, 2015	DOE/SC CD-3a Independent Project Review
December 1-4, 2015	DOE PMOA CD-3a Independent Cost Estimate
DIRECTOR'S REVIEWS	
June 2-4, 2015	LBNF/DUNE CD-1-Refresh Director's Review
Sep 3-6, 2015	Long-Baseline Neutrino Committee CD-3A Mini-Review
Oct 27-29, 2015	Director's CD-3a Readiness Review
PROJECT-WIDE WORKSHOPS	
August 11-13, 2015	LBNF/DUNE Logistics
December 16, 2015	Far Site
April 14-15, 2015	Risk Workshop
Aug 31 - Sep 1, 2015	LBNF/

Plus 15 other project directed internal and external reviews

PM: LBNF/DUNE Project Management Systems

- Using FNAL systems:
  - Laboratory P6 and Cobra for resource loaded schedule
  - Laboratory risk management tool to track and manage risks; Primavera risk analysis module for MC analysis
  - Laboratory EVMS system
    - Completing training; begin implementation in March 2016
  - Rely on lab's document tools for storage and version management:
    - Teamcenter
    - DocDB
    - SharePoint

PM: Risks Constantly Managed

- LBNF/DUNE-wide focus on risks:
  - Technical, management, external
  - Robust risk identification, assessment, and analysis
  - Multiple workshops with stakeholders and external experts to identify and assess risks:
    - Last one focused one Far Site risks and informed CD-3a
    - Incorporates risks identified by Far Site CF A/E and Sanford Lab
  - Compiled in online Fermilab Risk Registry
  - Managed through regular Risk Management Board meetings
  - Provides basis for risk-related cost and schedule contingency

Risk Rank	Risks affecting FS-CF	Risks not affecting FS-CF	Total risks
High	4	10	14
Medium	7	27	34
Low	15	64	79
Total	26	101	127

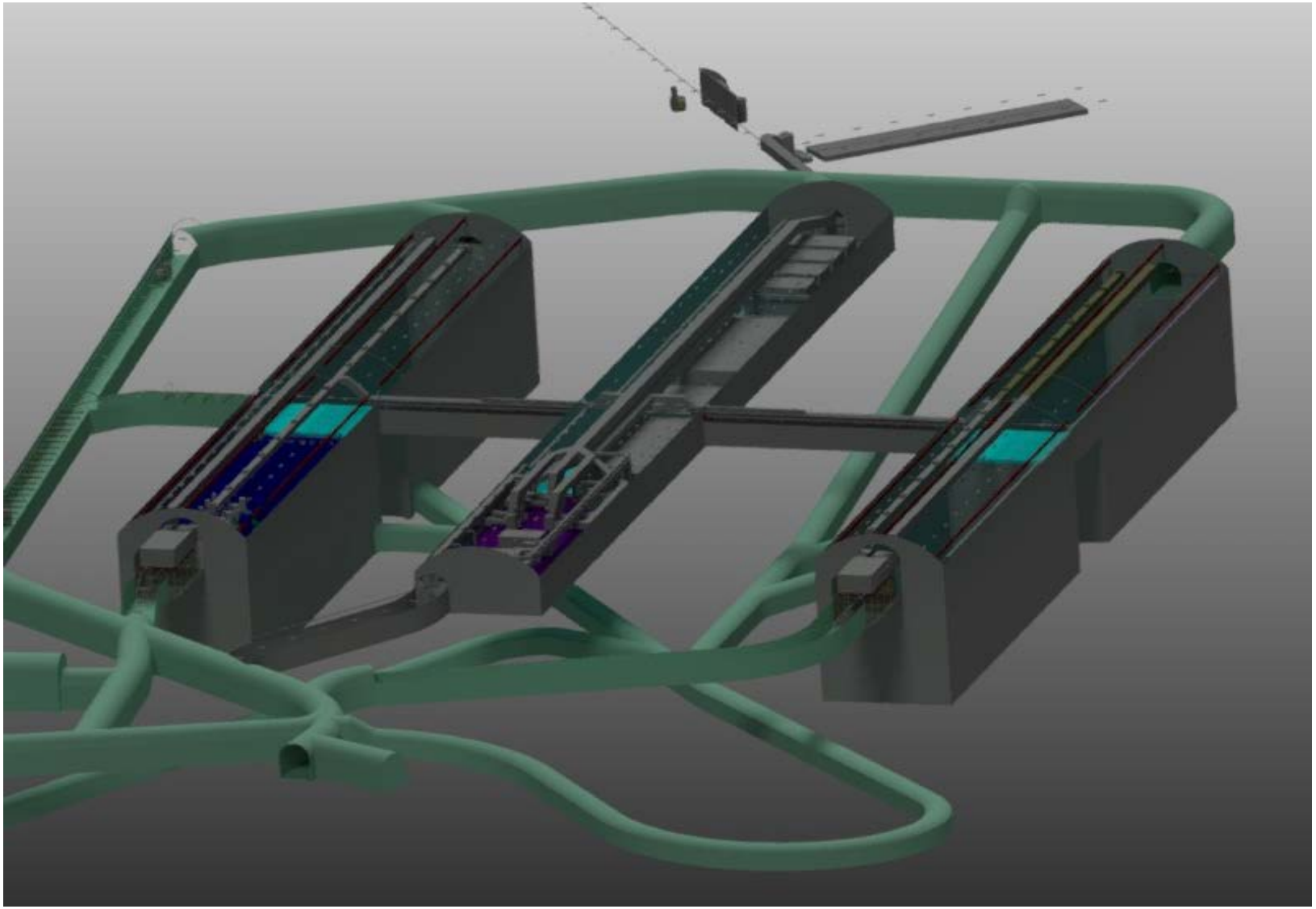
PM: Design Integration

- Project using TeamCenter engineering toolset to integrate CAD models across the project to verify interfaces and design

- Each discipline utilizes industry-standard or lab-specific software to produce 3D models of their designs, for example
  - Fermilab mechanical designs: NX
  - Conventional Facilities: Revit
  - Cryogenic Systems: AutoCAD Plant
  - CERN Cryostat: Catia

- Project implementing processes and protocols to manage integration activities

Design Integration Example: Integrated CAD model



PM: Interface Matrix Example– Far Site

LBNF-DUNE Far Site Interface Control Documents Matrix													
Far Site Entity	CF, Far Site - Surface	CF, Far Site - Shafts and Drifts	CF, Far Site - Caverns	Far Detector Design	Far Detector Construction	Cryostat Design	Cryostat Construction	Cryogenics Ar System - Design	Cryogenics Ar System - Construction	Cryogenics N2 System - Design	Cryogenics N2 System - Construction	Cryogenic Fluids	SURF
CF, Far Site - Surface													
CF, Far Site - Shafts & Drifts													
CF, Far Site - Caverns													
Far Detector Design	199	197	201										
Far Detector Construction	198	196	200										
Cryostat Design	433	483	492	102									
Cryostat Construction	230	491	499		103								
Cryogenics Ar System-Design	231	501	508	77		106							
Cryogenics Ar System-Construction	71	502	510		100		107						
Cryogenics N2 System-Design	69	504	512	75		105		74					
Cryogenics N2 System-Construction	70	506	513		101		108		73				
Cryogenic Fluids	216			104	217								
SURF				195	109	514	515	202	209	204	206	215	

Interfaces are in place and under configuration management

LBNF/DUNE Project Status

- CD-0 approved in January 2010
- CD-1R approved in November 2015
  - "R" = Revised
  - Project restructured and using combining work of:
    - "LBNE" (mostly U.S.)
    - "LBNO" (mostly Europe)
    - Other interested institutes
- Successful CD-3A review in December 2015 (anticipating PMRC and ESAAB in Spring 2016)
- Current schedule calls for:
  - CD-3B in Spring 2019
  - CD-2/CD-3C in Spring 2020
  - CD-4 in Spring 2027

International neutrino community expectation is to complete commissioning of first 10 kTon far detector module in 2024

2016 – Activities Underway and Planned

- Begun execution by DOE/FNAL of Sanford Lab "reliability projects," such as Ross Shaft renovation, to reduce risk during main excavation operations
- Execute Lease for LBNF exclusive use areas at Sanford Lab
- Achieve CD-3a milestone
- Leverage CD-3a milestone to advance international involvement and contributions to LBNF/DUNE
- Advance the construction of protoDUNE single phase and dual phase detectors
- Issue RFP and award CM/CG contract for Far Site Conventional Facilities work this summer
- Begin final design for far site conventional facilities
- Be ready to start construction activities in 2017

Project Goals – 2017 through 2026

- Initiate pre-excavation construction work in FY2017
- Complete Sanford Laboratory reliability projects in FY2018
- Progress protoDUNE detectors to enable testing in CERN beam in 2018
- Initiate major cavern excavation work in FY2018 and continue aggressively through FY2021
- Complete first cryostat and cryo systems construction to enable detector install to begin in 2021, with commissioning in 2024
- **Produce neutrino beam in 2026!**

Video Place Holder

Summary

- Fermilab has developed unprecedented strong partnership with CERN intertwining LHC & neutrinos. CERN is investing outside of Europe for the first time in 60 years.
- DUNE is an experienced, well-organized international team that has assembled quickly, motivated by the prospect of installing the first detector module beginning in 2021.
- President's Budget to Congress has requested construction authority for far site initial work starting in FY2017 (e.g., just ~7 months from now).
- Strong international interest to participate in design and construction of LAr TPC far detectors, fine-grained tracker near detector, and MW-class neutrino beam. Many international funding agencies informed and involved.
- Project enjoys DOE, administration, and congressional support. Look forward to signaling U.S. commitment with CD-3A milestone.
- **LBNF/DUNE will drive game changing science in neutrino and astro-particle physics.**