LBNF Project

C. J. Mossey, LBNF Project Director

49th Annual Fermilab Users Meeting

16 June 2016

Background

- **Science Opportunity:**
  - Neutrinos – **most ubiquitous** matter particle in the universe, yet the **least understood**.
  - **2015 Nobel Prize in Physics** awarded for neutrino oscillation discovery
  - Opportunity for **game changing** physics discoveries:
    - **Origin of matter**: Leptonic CP violation, mass hierarchy, and precision oscillation physics
    - **Neutron Star/Black hole formation**: ability to observe supernovae events in real time
    - **Nucleon Decay**: advance unified theory of energy and matter

- **Convergence of global HEP science community**:
  - 2013: European Strategy for Particle Physics
  - 2014: “P5” Plan – Strategic Plan for U.S. Particle Physics in global context
  - 2015: New DOE-CERN-NSF partnership agreement

- **Long Baseline Neutrino Facility & Deep Underground Neutrino Experiment:**
  - The first internationally conceived, constructed, and operated mega-science project hosted by DOE in the United States
  - Based on the CERN LHC model; will drive neutrino science forward the way the LHC drove Nobel prize-winning Higgs discovery.

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

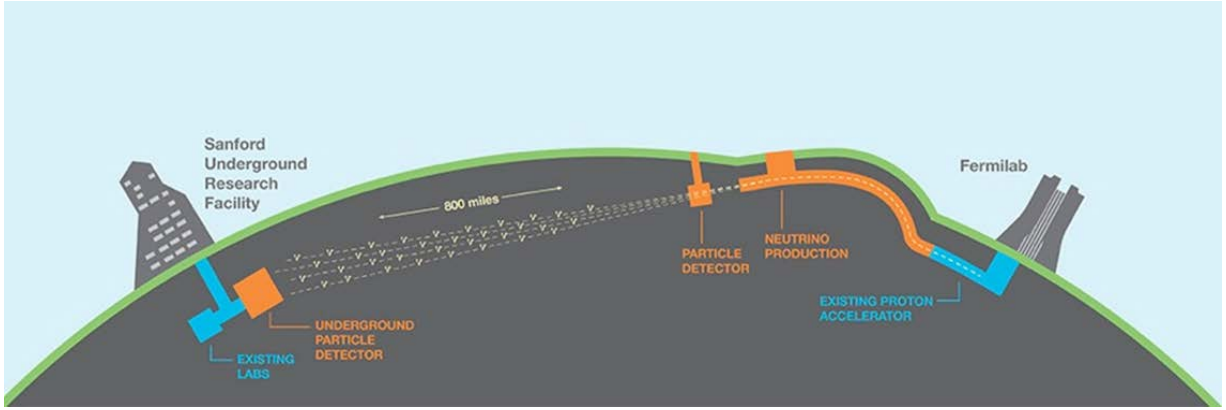
* Particle Physics Project Prioritization Panel

Quick Project Overview: LBNF/DUNE

LBNF and DUNE: two sub-projects
- 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 experiment**



Quick Project Overview: LBNF/DUNE

LBNF and DUNE: two sub-projects

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

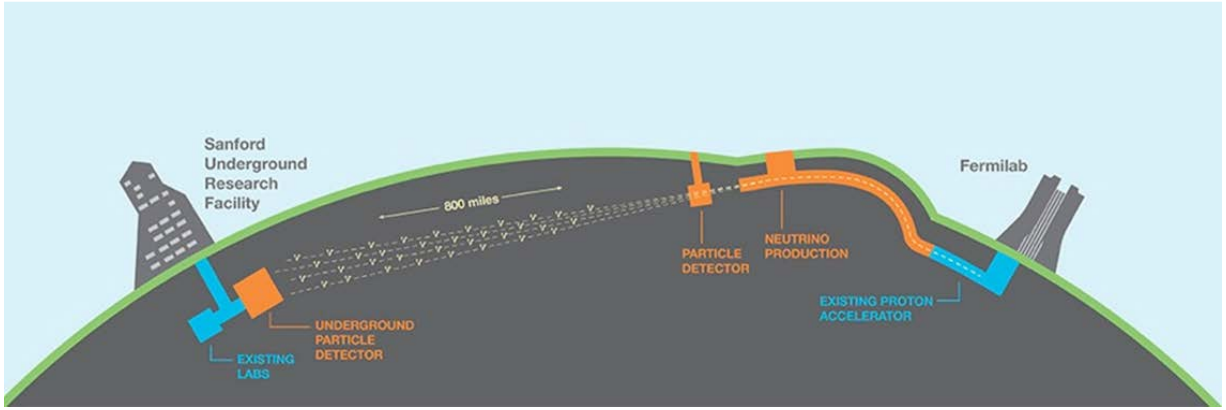
Present focus

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

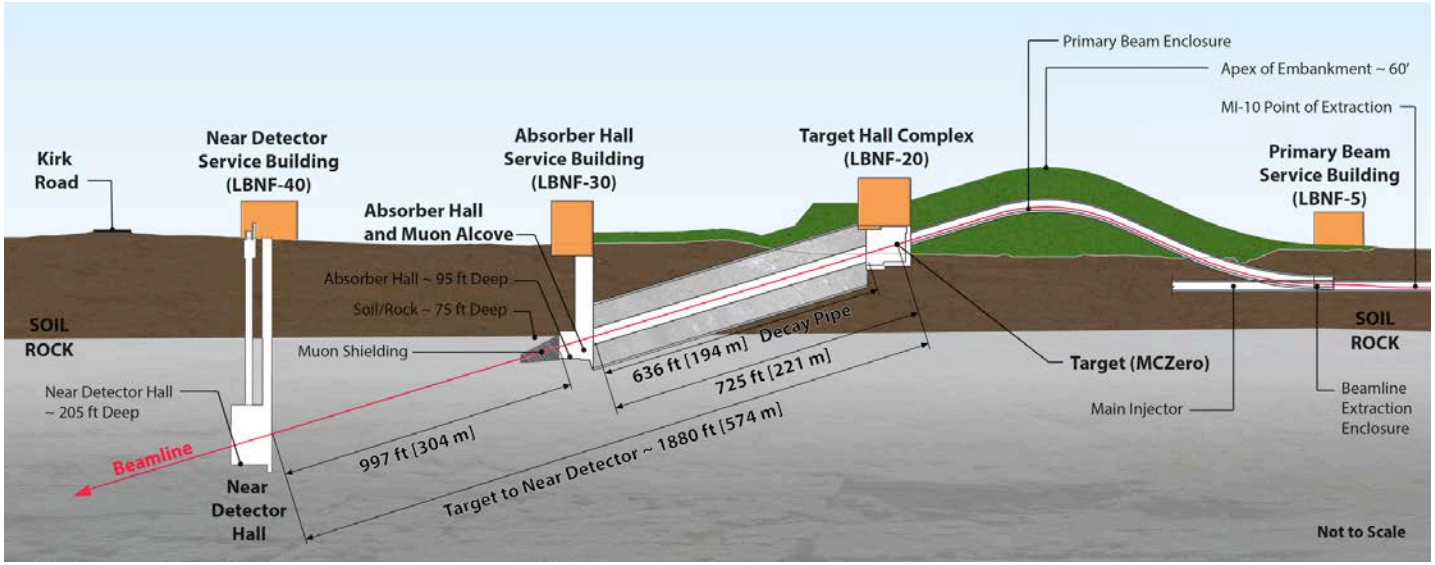
- Near site: Fermilab, Batavia, IL – facilities to create neutrino beam
- Far site: Sanford Underground Research Facility, Lead, SD – facilities to support DUNE detectors

DUNE: Deep Underground Neutrino Experiment

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



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



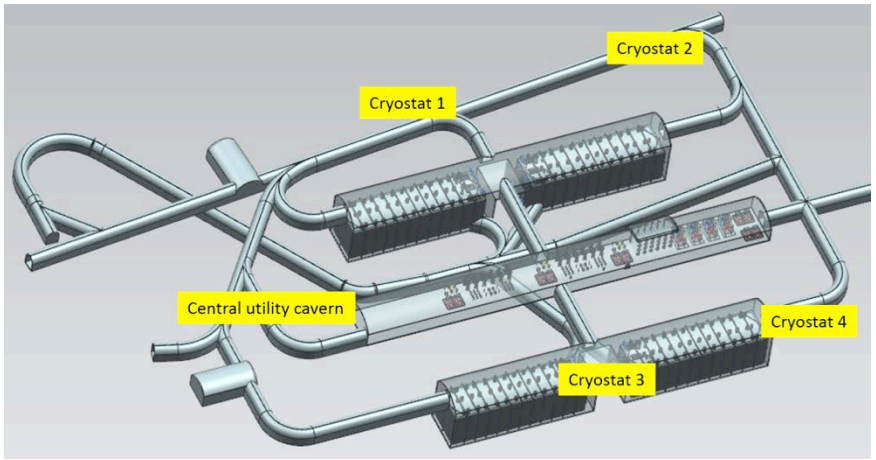
- Primary proton beam @ 60-120GeV extracted from Main Injector
- Initial 1.2 MW beam power, upgradable to 2.4 MW
- Embankment allows target complex to be at grade and neutrino beam to be aimed to Lead, SD
- Decay region followed by absorber
- Four surface support buildings
- Near Detector facility
-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

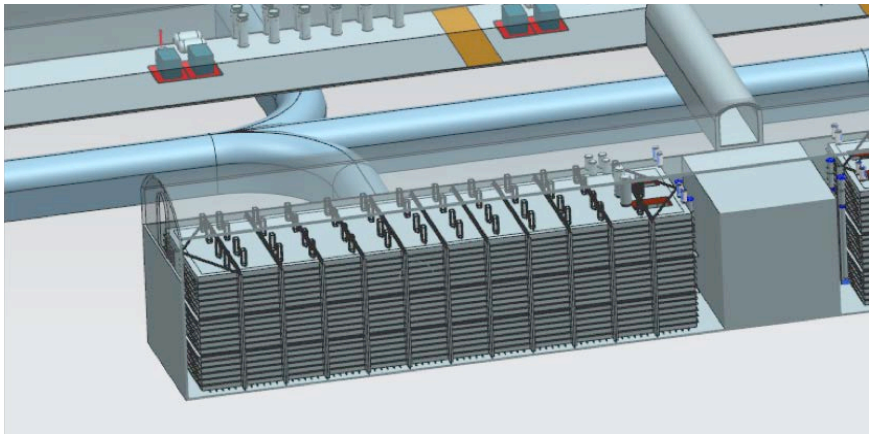
Quick Overview – "Far Site" – LBNF/DUNE at Sanford Lab

- **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

“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.
- Many unique challenges; new approaches necessary!:
  - Codes and standards, ESH&Q policies, reviews
  - International agreements
  - Acquisition strategy and more…

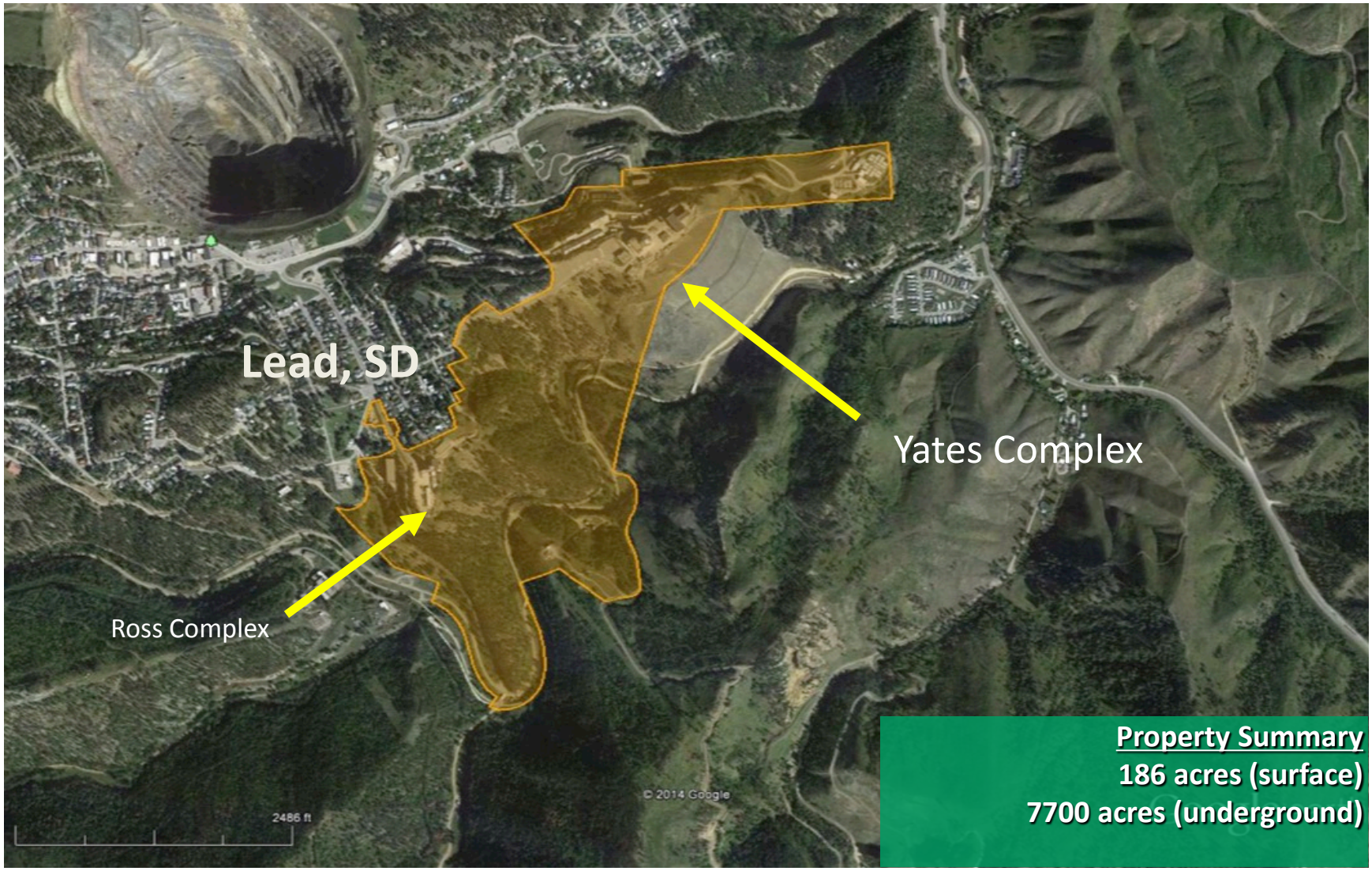
International Partnership

- 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 HEP community – may facilitate other LBNF partners
  - Supporting prototyping effort with short baseline and protoDUNEs with CERN “neutrino platform”
- IHEP-China providing prototyping of corrector magnets
- UK proposing to do essential Target R&D
- India providing major contribution to PIP-II which supports LBNF
- Campaign underway to engage all 30 countries in the DUNE collaboration
- And of course, South Dakota, where more than $146M has been invested in the Sanford Underground Research Laboratory to date.

Sanford Underground Research Laboratory

One mile!

Far Site Aerial View – Sanford Lab in Lead, SD



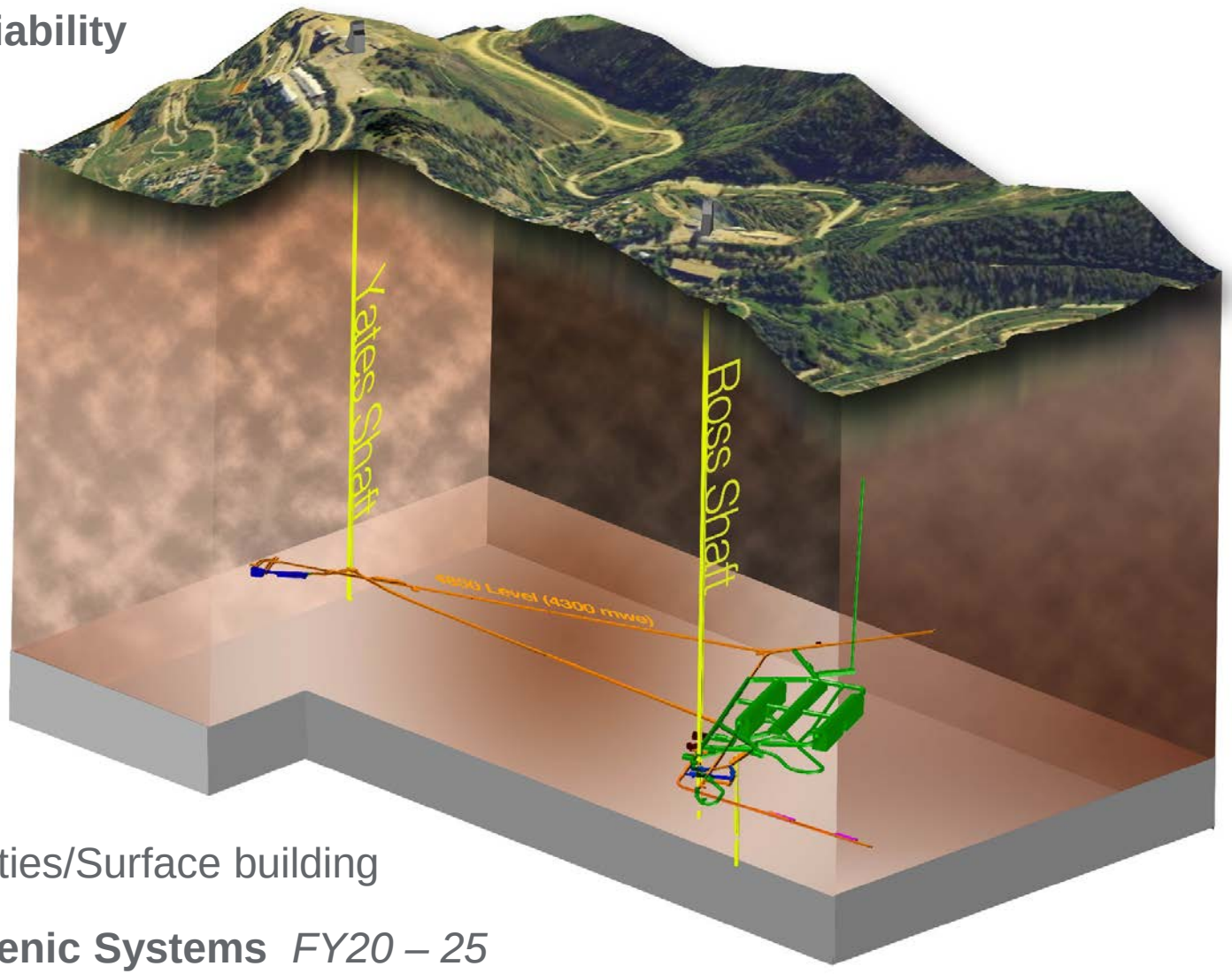
Far Site Scope – Overview of Phases of Work

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

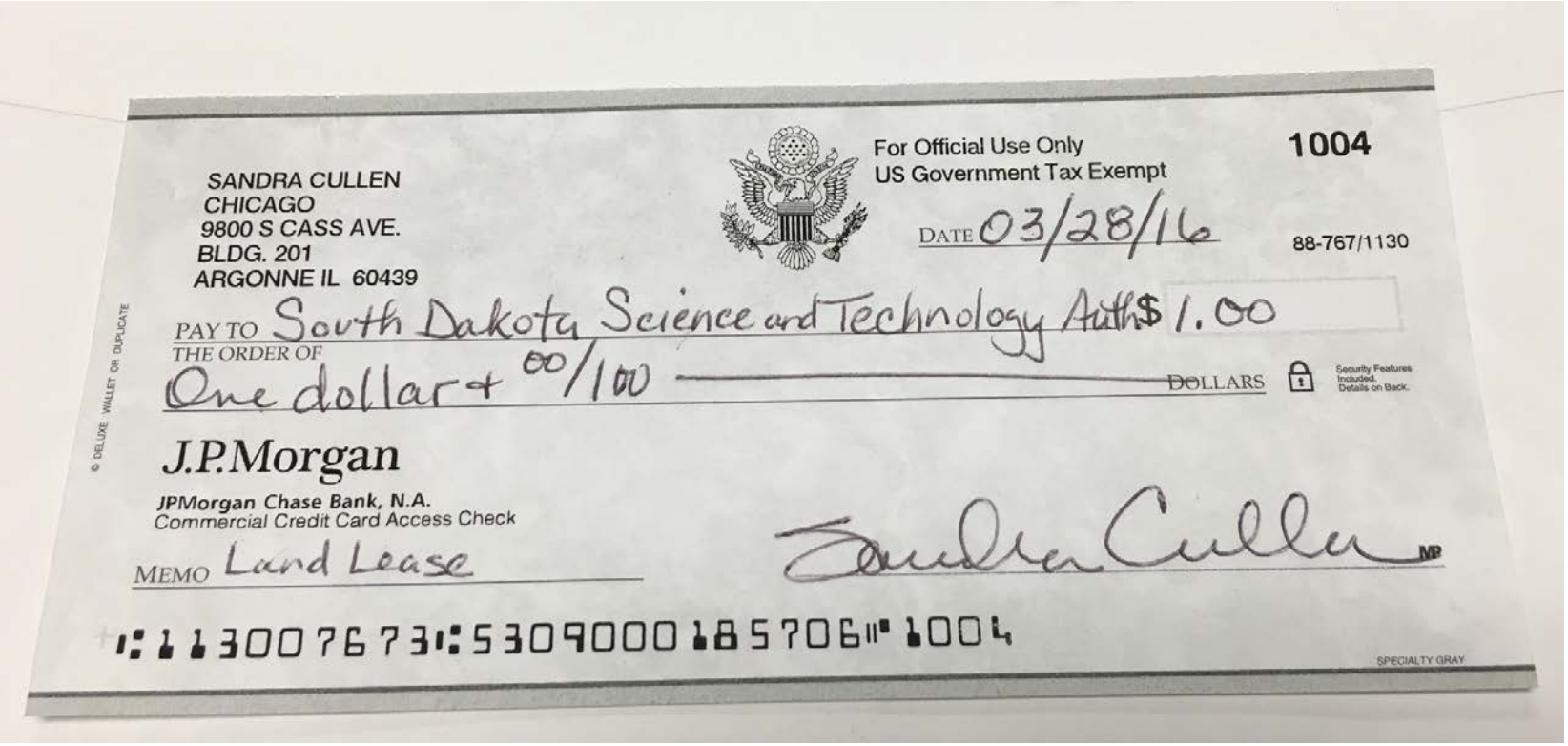
2. **Pre-Excavation**
   FY17 - 20
   - Rock disposal systems
   - Utilities support, more…

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

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



Lease for LBNF footprint in place!



Check for 1st year's lease

Funding Status

- **FY17 Funding Status:**
  - President's budget submit requested $45M for LBNF/DUNE
  - House and Senate both propose to increase LBNF funding in FY2017 above the President's budget request:
    - House: +$5M
    - Senate: +$10M
  - Both House and Senate versions of appropriations bill authorize start of construction at Sanford Lab in FY2017

- **FY18 Funding Status:**
  - Strong support from DOE Office of Science to develop an overall funding profile concurrent with CD-3a approval
  - Plan to request CD-3a milestone in Sep timeframe, in alignment with DOE's FY18 budget development process

The Road to CD-3a Milestone

Status of actions required to achieve "early construction start" milestone:

✓ Recommendations from December DOE IPR necessary for CD-3a milestone have been addressed

✓ Independent Cost Estimate (ICE) completed

- DOE PM office conducted review of LBNF cost estimate for CD-3a scope from Dec 2015 to Jan 2016
- Conclusions of review include:
  - ICE base estimate $12M less then project estimate
  - ICE estimated contingency $20M less then project estimate
  - ICE estimate for Total CD-3a Request **10% below** project estimate

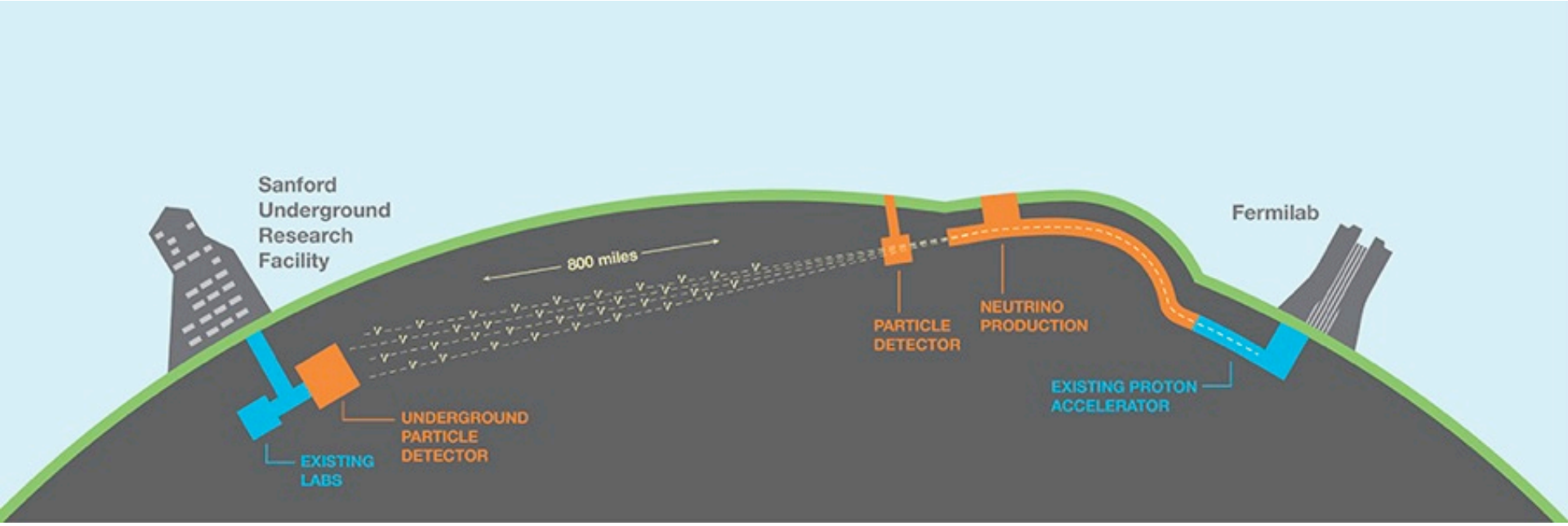
❑ PMRC and ESAAB review/approval September timeframe

Summary

LBNF Activities Recently Completed, Underway, and Planned

- ✓ Began execution by DOE/FNAL of Sanford Lab “Reliability Projects” such as Ross Shaft refurbishment, to reduce risk during main excavation operations
- ✓ Began final design for Far Site conventional facilities
- ✓ Executed Lease for LBNF exclusive use areas at Sanford Lab
- Achieve DOE CD-3a milestone
- Award CM/GC contract
- Start construction activities at Sanford Lab in 2017
- Initiate major cavern excavation construction work in 2018
- Complete first cryostat and cryo systems construction to enable **detector install to begin in 2021**, with **commissioning in 2024**
- Produce **neutrino beam in 2026**!

Questions?



Animation Links:

- LBNF/DUNE animation (YouTube)
- Video page (FNAL website)

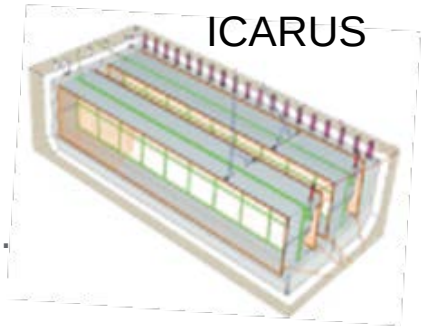
Social Media Links:

- LBNF Facebook
- DUNE Facebook
- LBNF Twitter
- DUNE Twitter

Backup

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

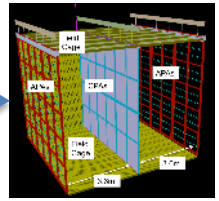


Single-Phase

2015

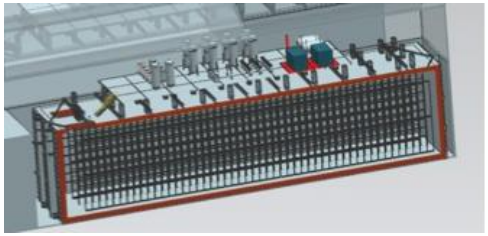
35-t prototype

2018



DUNE SP PT @ CERN

DUNE Reference Design



2021

DUNE Alternative Design

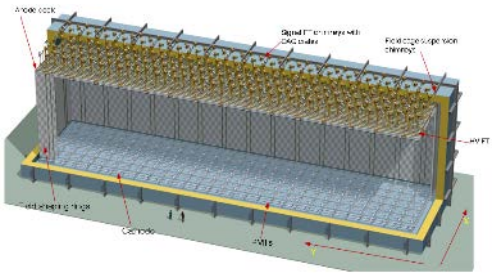
Dual-Phase

2016

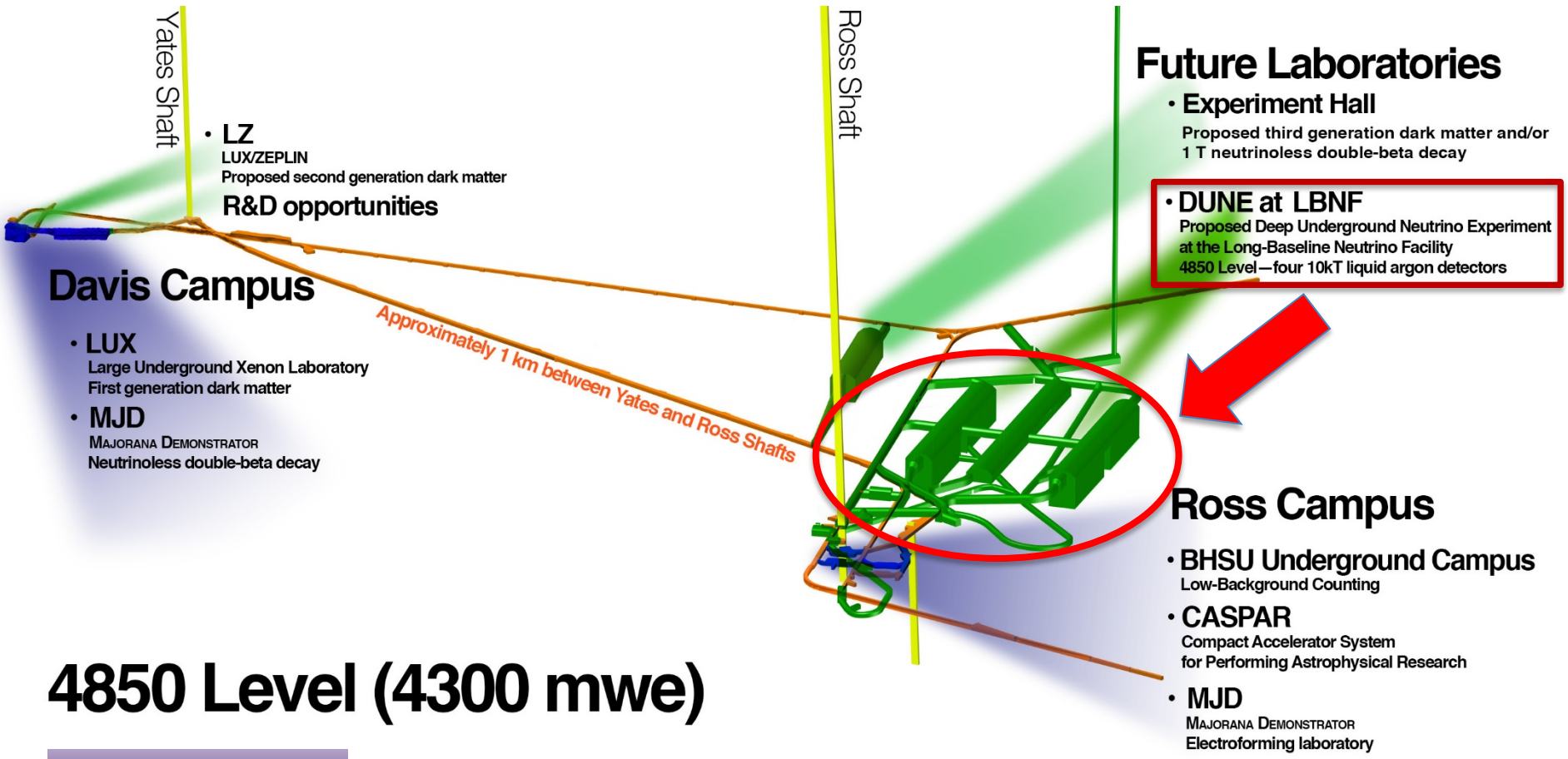
WA105: 1x1x3 m^3

2018

DUNE DP PT @ CERN



Far Site Context – part of an Underground Campus



4850 Level (4300 mwe)

Existing facilit

Proposed facili