Status of DUNE

Ed Blucher

Fermilab Users Meeting

8 June 2017

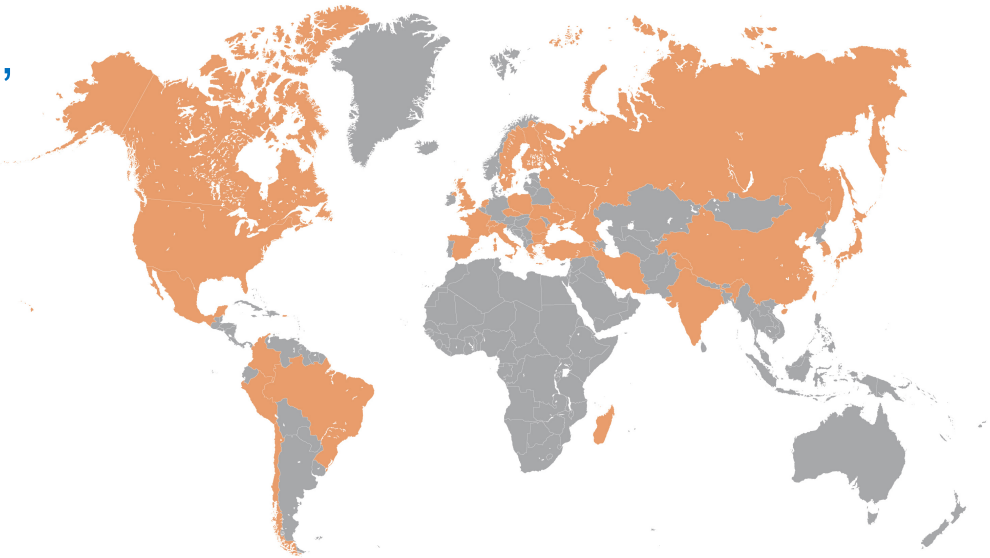
The DUNE Collaboration

As of today:

60 % non-US

970 collaborators from 162 institutions in 31 nations

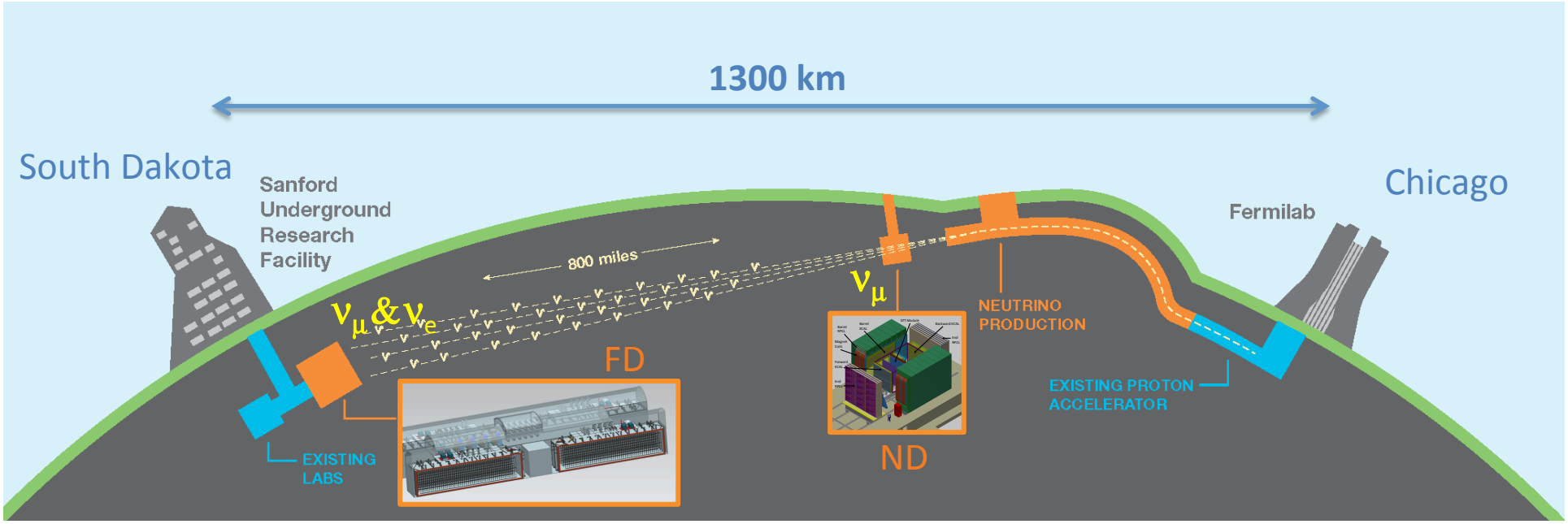
Armenia, Brazil, Bulgaria, Canada, CERN, Chile, China, Colombia, Czech Republic, Spain, Finland, France, Greece, India, Iran, Italy, Japan, Madagascar, Mexico, Netherlands, Peru, Poland, Romania, Russia, South Korea, Sweden, Switzerland, Turkey, UK, Ukraine, USA



DUNE: a fully international science collaboration
LBNF (Long Baseline Neutrino Facility): US(DOE)-hosted project with international contributions

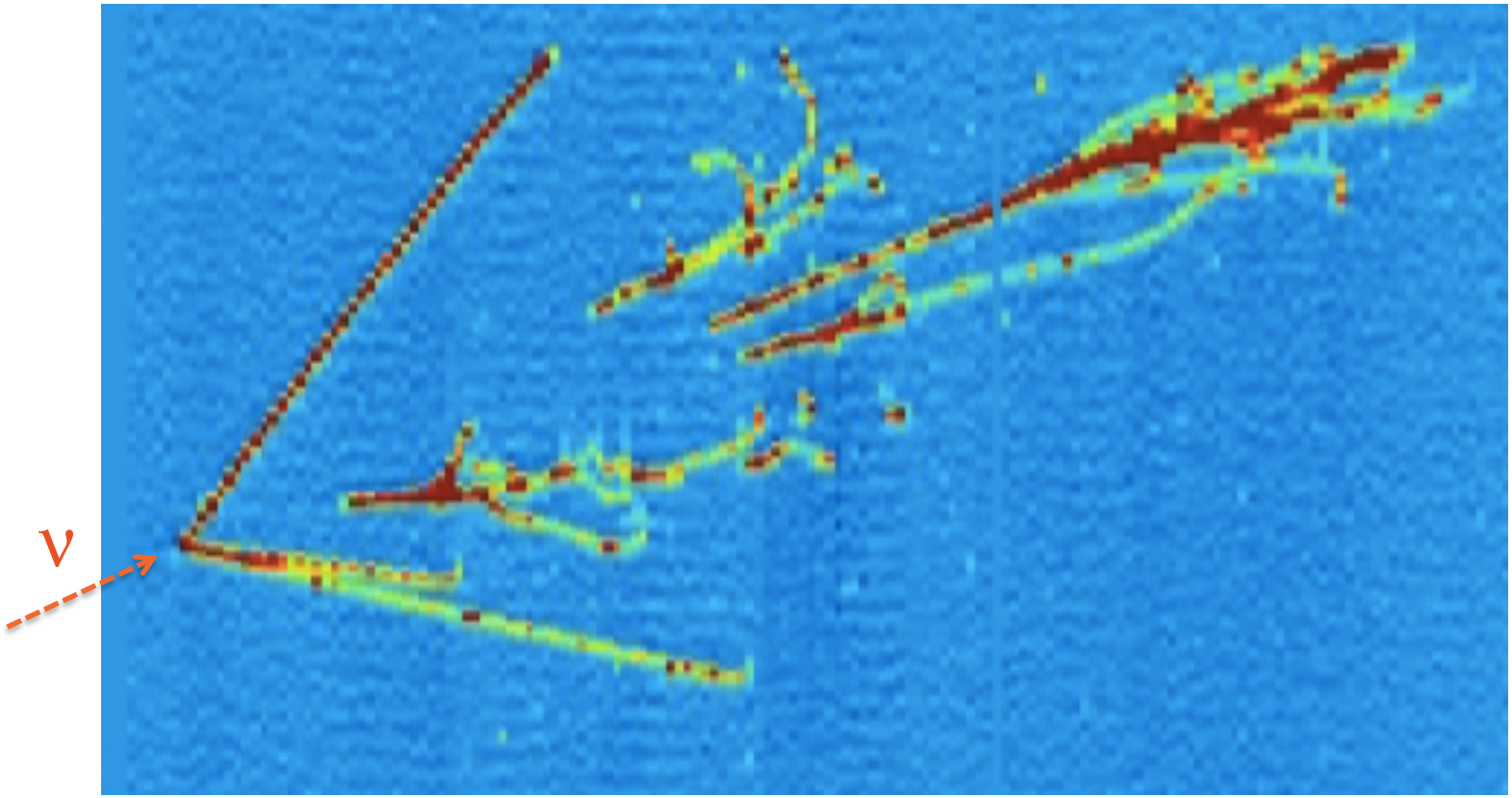
LBNF/DUNE Overview

- Muon neutrinos/antineutrinos from high-power proton beam
  - **1.2 MW** from day one; upgradeable to 2.4 MW
- Massive underground Liquid Argon Time Projection Chambers
  - **4 x 17 kton** fiducial mass of > 40 kton
- Near detector to characterize the beam (100s of millions of neutrino interactions)



DUNE Science

Combination of world's most intense neutrino beam, a deep underground site, and massive LAr detectors enables broad science program addressing some of the most fundamental questions in particle physics.

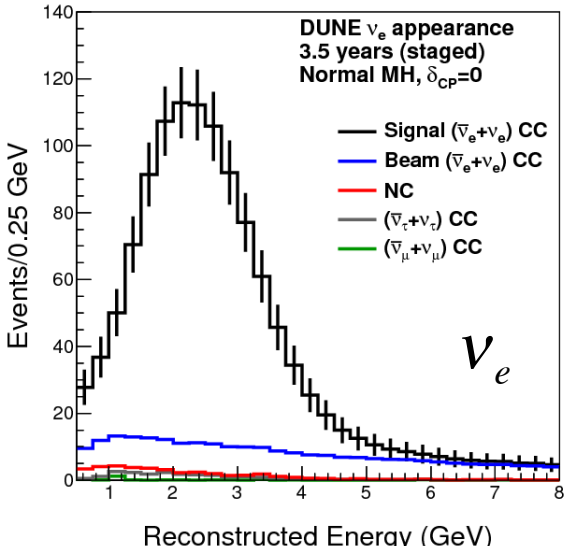


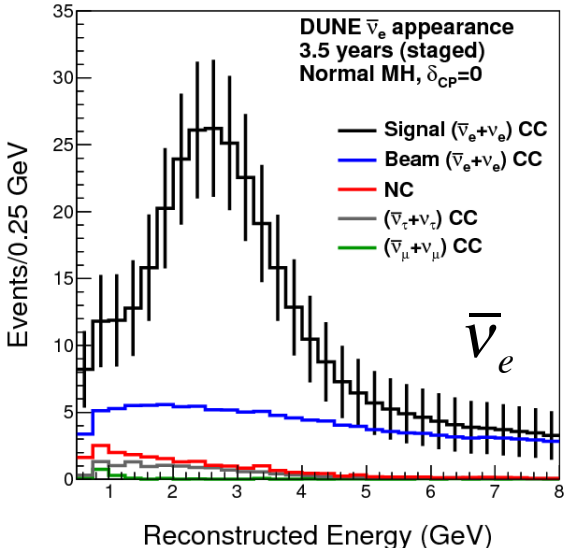
DUNE Science Program

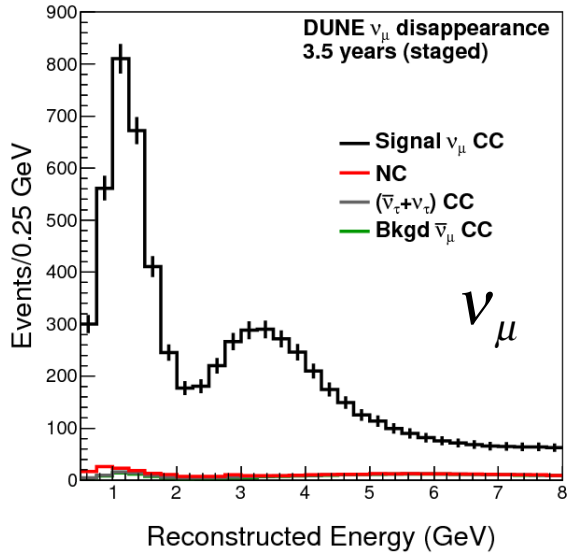
- Neutrino Oscillation Physics
  - **Search for leptonic (neutrino) CP Violation**
  - Resolve the mass hierarchy ($m_3 > m_{1,2}$ or $m_{1,2} > m_3$)
  - Precision oscillation physics
    - Parameter measurements, θ_{23} octant
    - **Testing the current 3-neutrino model, non-standard interactions,** …
- Nucleon Decay
  - Particularly sensitive to $p \rightarrow K^+ \bar{\nu}$
- Supernova burst physics and astrophysics
  - 3000 ν_e events in 10 sec from SN at 10 kpc

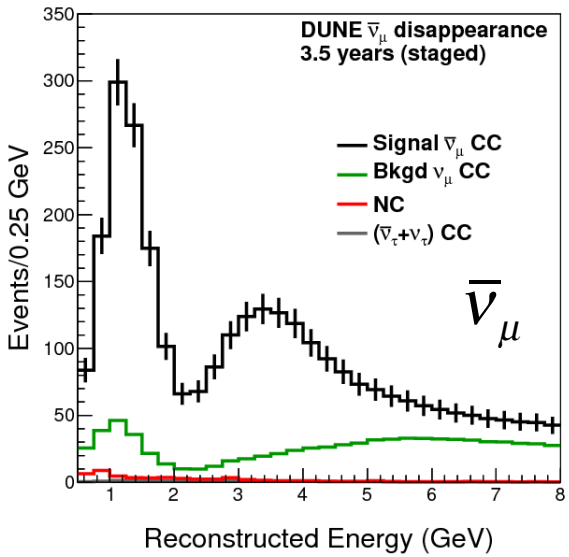
+ many other topics (ν interaction physics with near detector, atmospheric neutrinos, sterile neutrinos, WIMP searches, Lorentz invariance tests, etc.)

Appearance and disappearance spectra



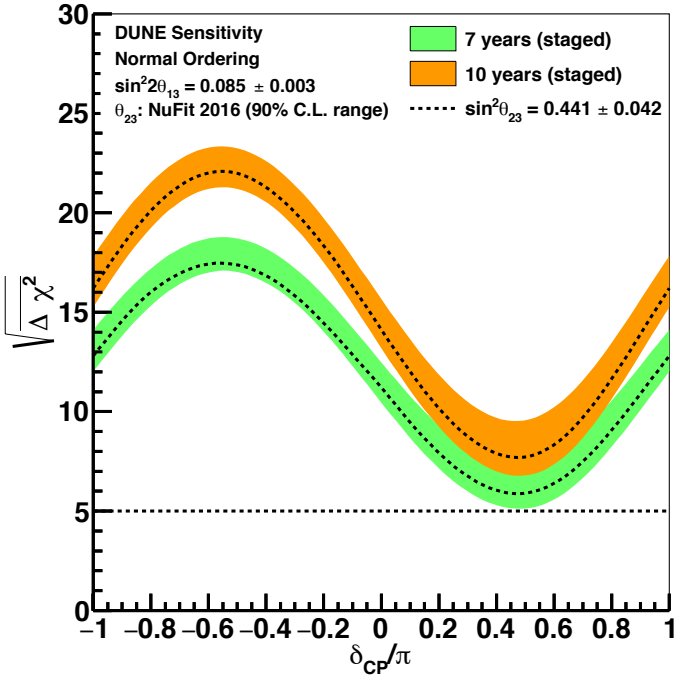




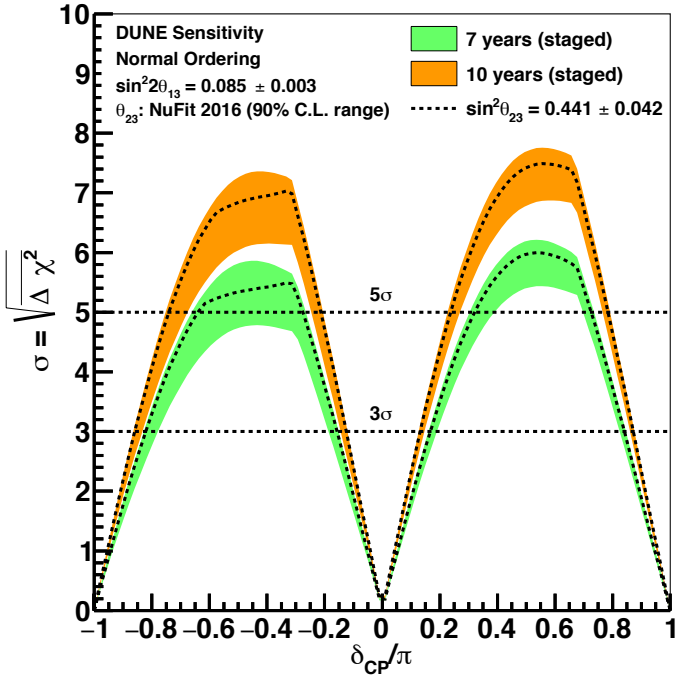


Mass Hierarchy and CP Violation

Mass Hierarchy Sensitivity



CP Violation Sensitivity

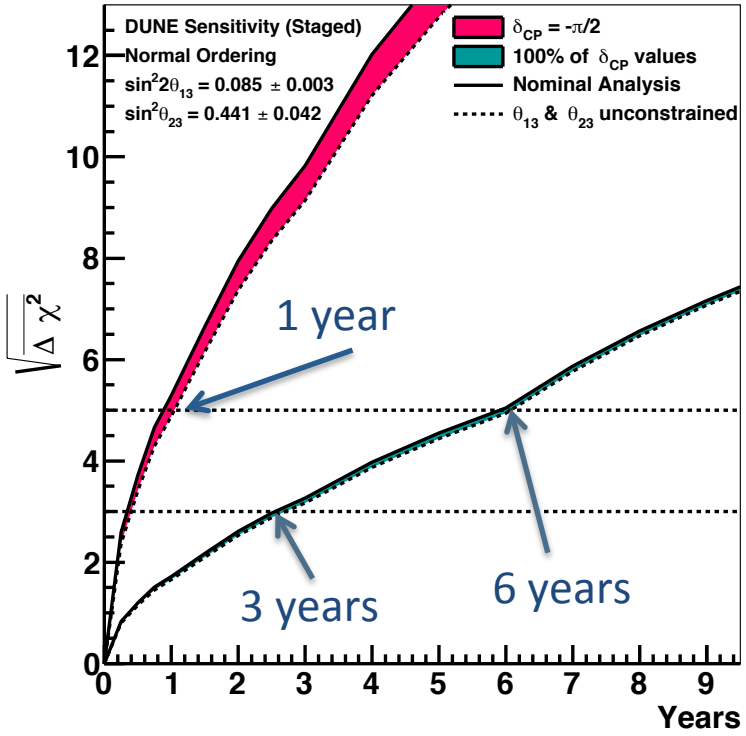


After 7 years (staged):

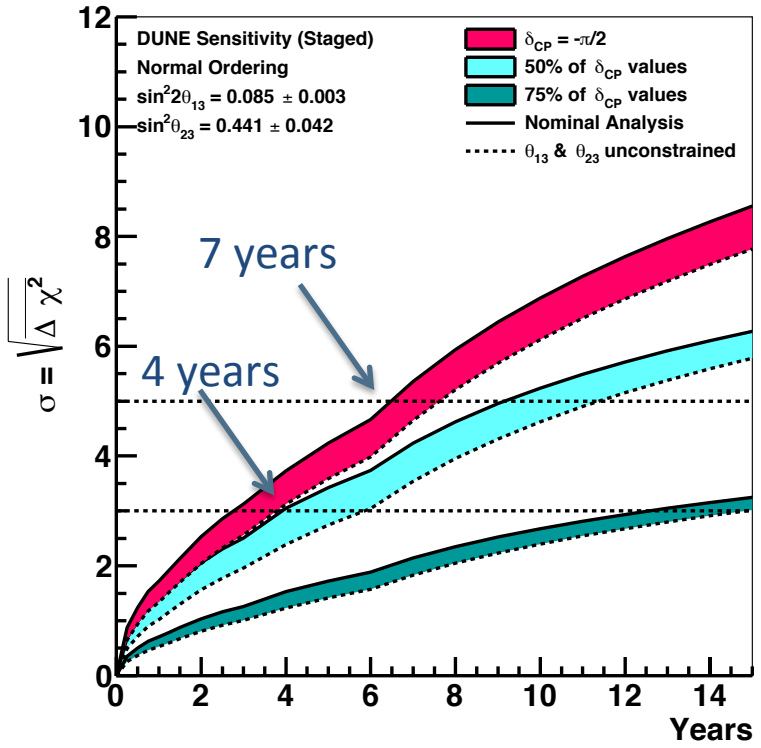
- CP Violation: 5σ if δ_{CP} near $-\pi/2$; 3σ over 65% of δ_{CP} range
- Mass hierarchy determination: > 5σ for all parameter values

Sensitivity vs. time

Mass Hierarchy Sensitivity

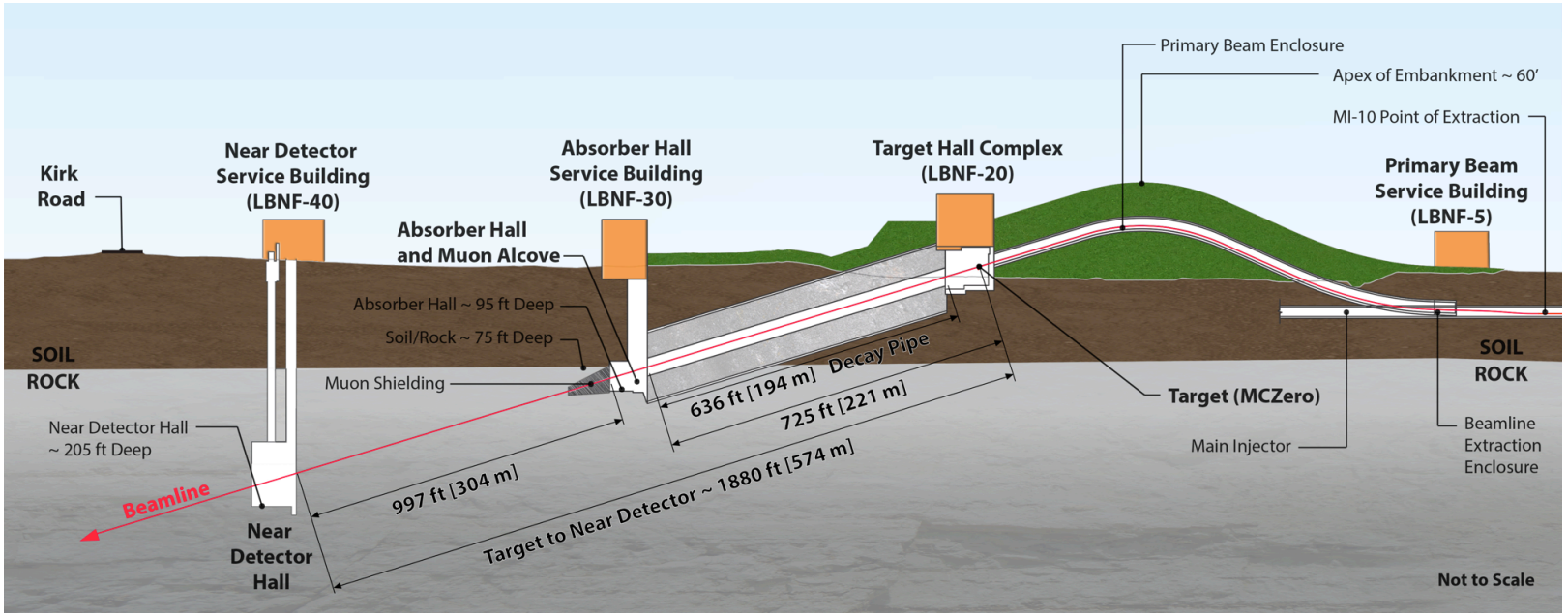


CP Violation Sensitivity



Important sensitivity milestones throughout beam physics program

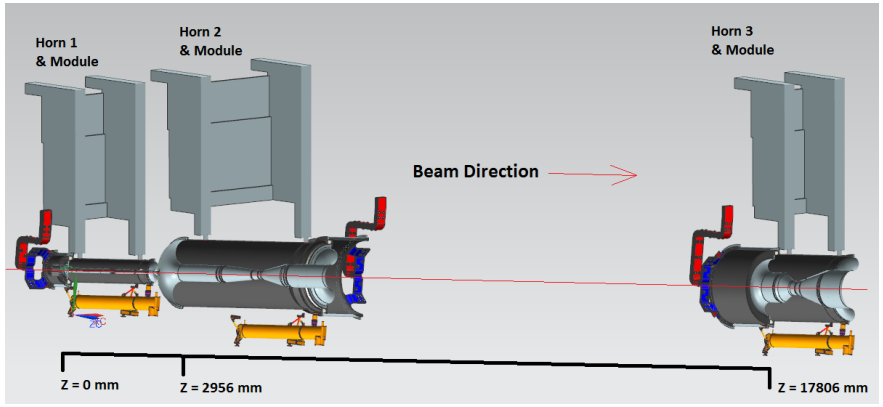
Beam and Near Detector

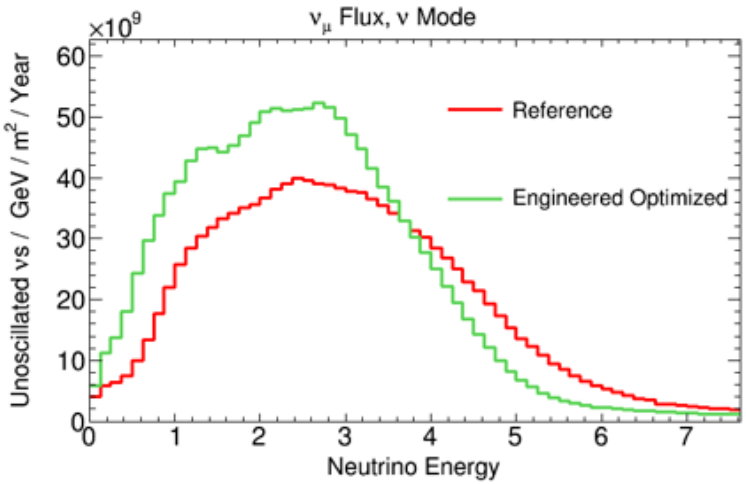


- Primary proton beam @ 60-120GeV extracted from Main Injector
- Initial 1.2 MW beam power, upgradable to 2.4 MW
- DUNE Near Detector
  - Precisely measure beam neutrino fluxes
  - Constrain systematic uncertainties for oscillation measurements
  - Multiple designs under consideration (2-day workshop starts tomorrow)

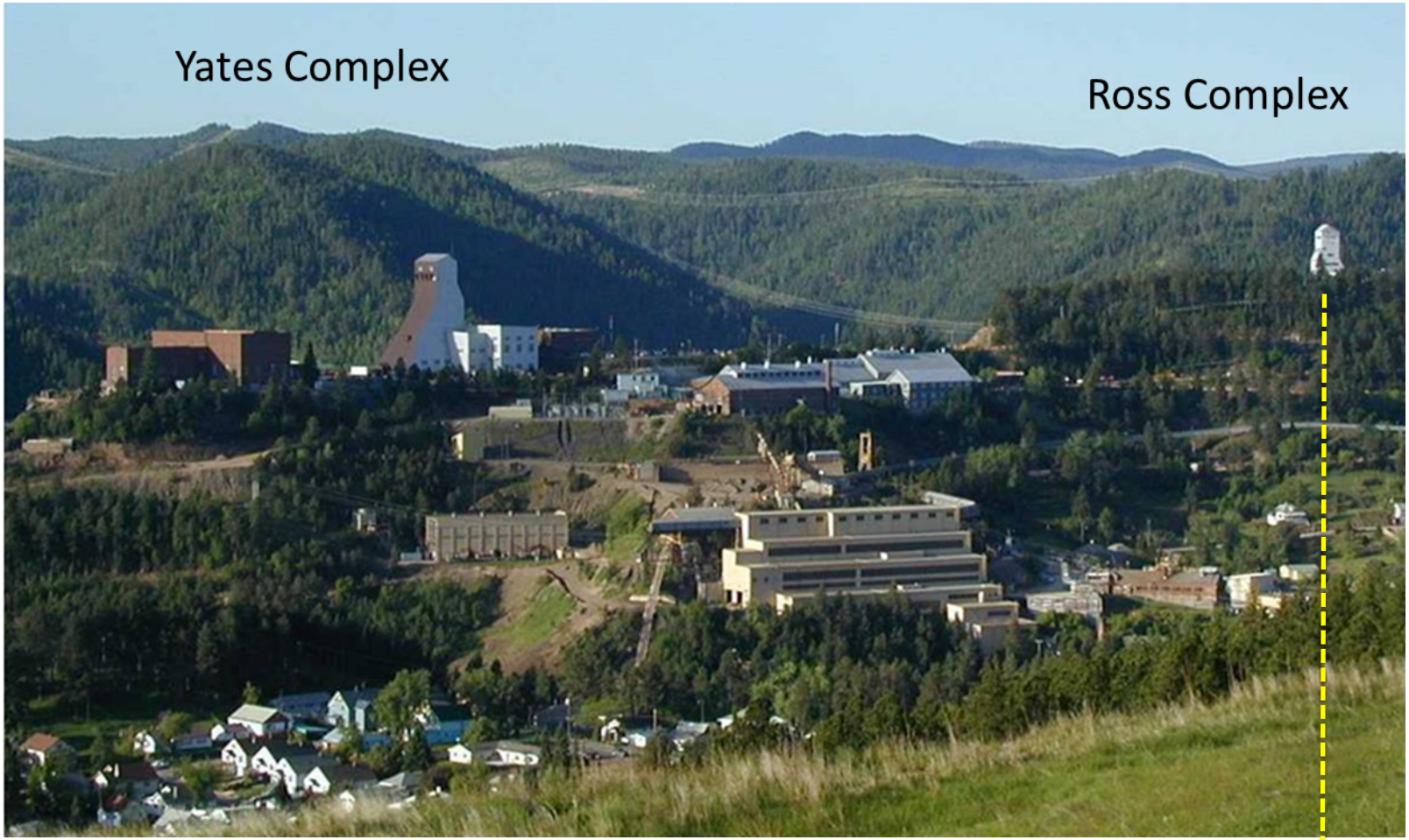
Optimization of neutrino beamline

- Significant effort to optimize target and horn system for better sensitivity to CP violation
- Currently, evaluating technical and cost impact of design with 4 interaction-length target and 3 horns.



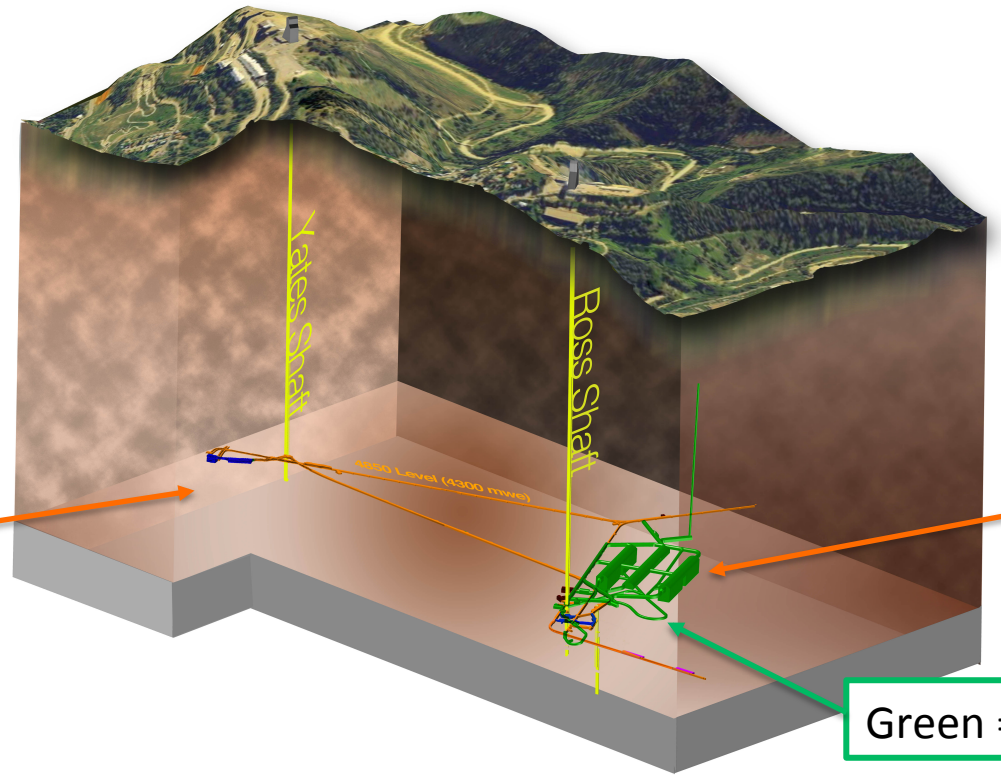


DUNE/LBNF Far Site



DUNE Far Site

Ross Campus of 4850 ft level of Sanford Underground Research Facility



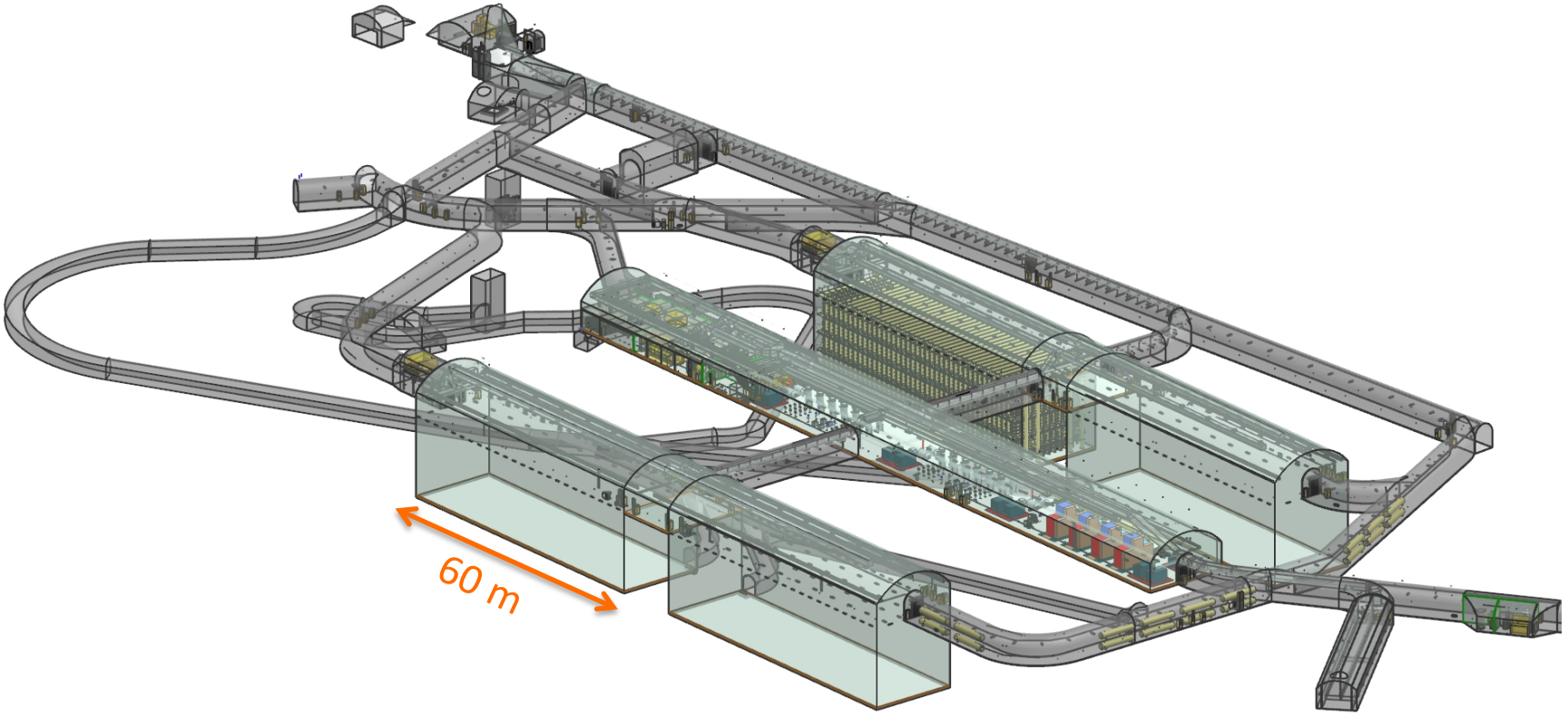
Davis Campus:
- LUX
- Majorana demo.
- …
- **LZ**

Ross Campus:
- CASPAR
- …
- **DUNE**

Green = new construction

DUNE Far Detector

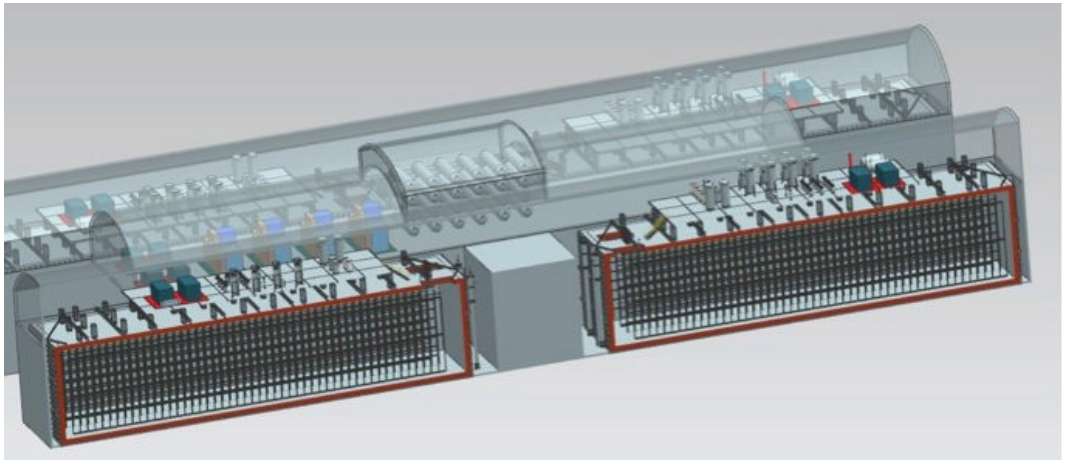
- **70-kt LAr-TPC = 4 x 17 kt (4 x 10 kt fiducial) detectors**

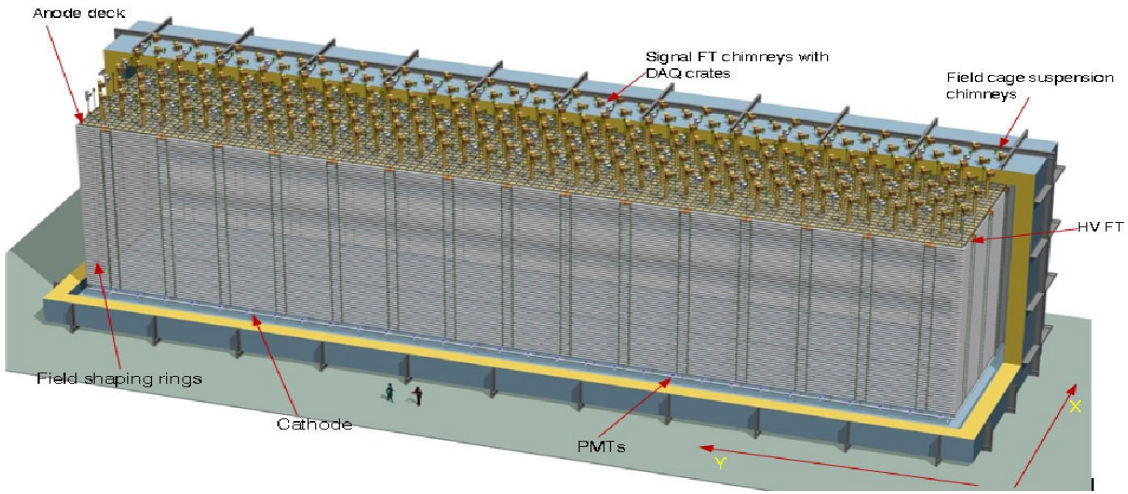


- **4 chambers, each hosting a 10 kt fiducial module**
- **Modules will be similar, but likely not identical**

DUNE Far Detector Technologies

Collaboration is considering (and prototyping) two liquid argon readout technologies:





Single Phase

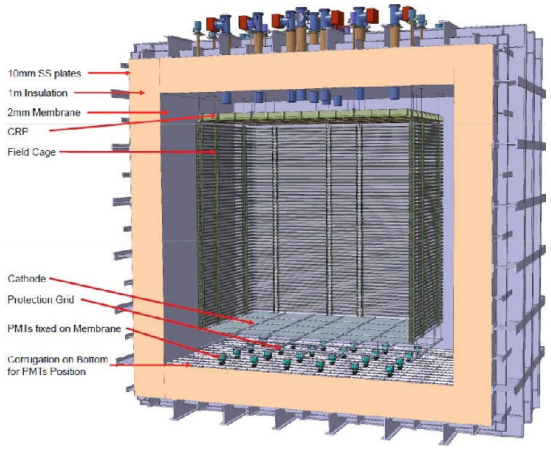
- drift electrons detected in the liquid
- Readout technology of ICARUS, ArgoNeuT, MicroBooNE, SBND
- 3.5 m max drift

Dual Phase

- amplification of electron signal in gas phase
- Pioneered at large scale by WA105.
- 12 m max drift

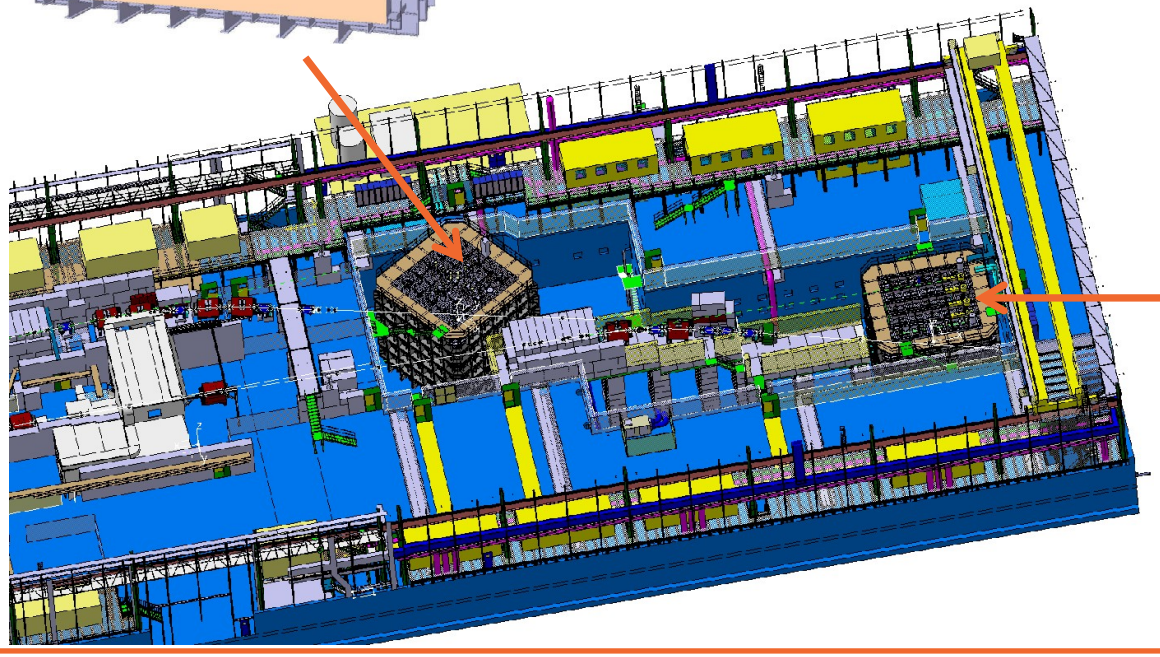
Prototypes at CERN Neutrino Platform

ProtoDUNE Dual Phase

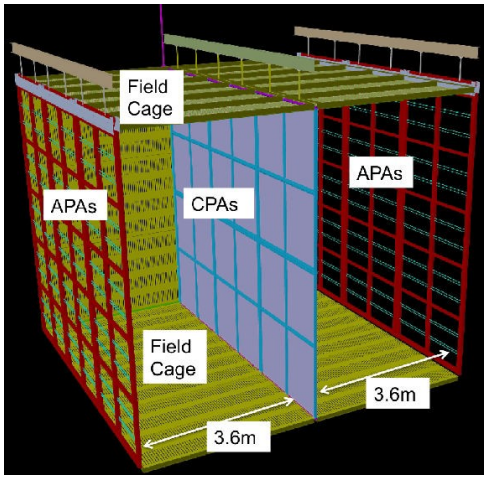


Major CERN investment to support DUNE

- EHN1 extension in the North area
- Two tertiary charged-particle beam lines
- Two 8m×8m×8m cryostats & cryogenic systems



ProtoDUNE Single Phase



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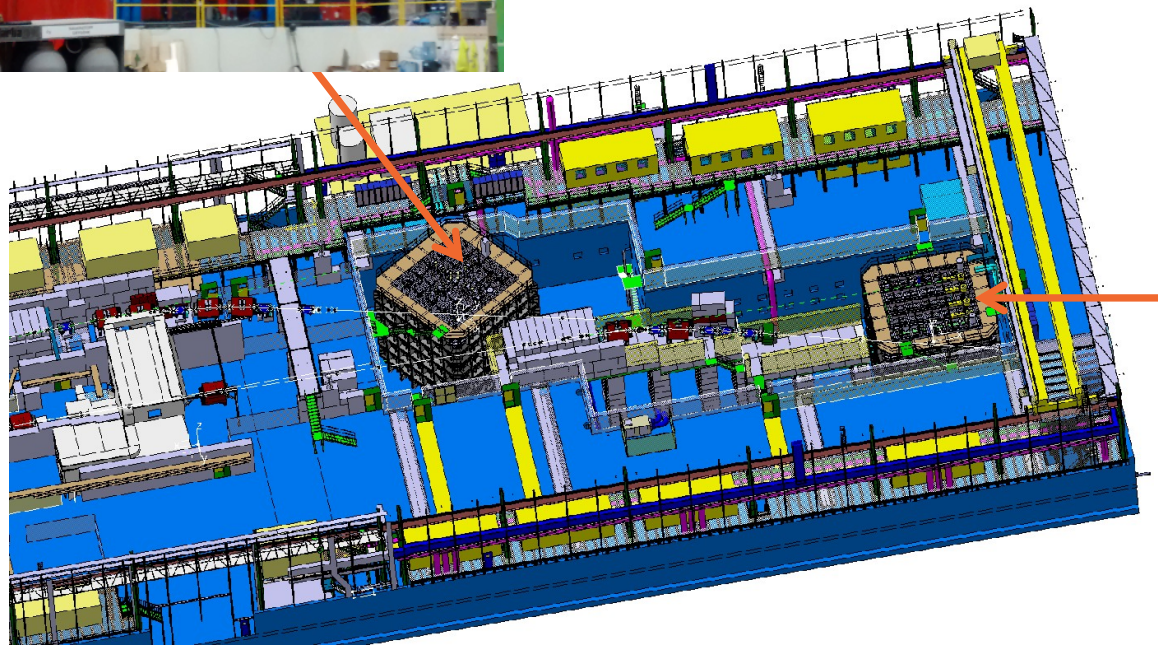
Prototypes at CERN Neutrino Platform

ProtoDUNE Dual Phase

Both ProtoDUNEs aim to begin data taking in mid 2018.

EHN1 Webcams:
http://cenf-ehn1-np.web.cern.ch/images/np04-webcam-neutrino-platform-hall-ehn1



ProtoDUNE Single Phase

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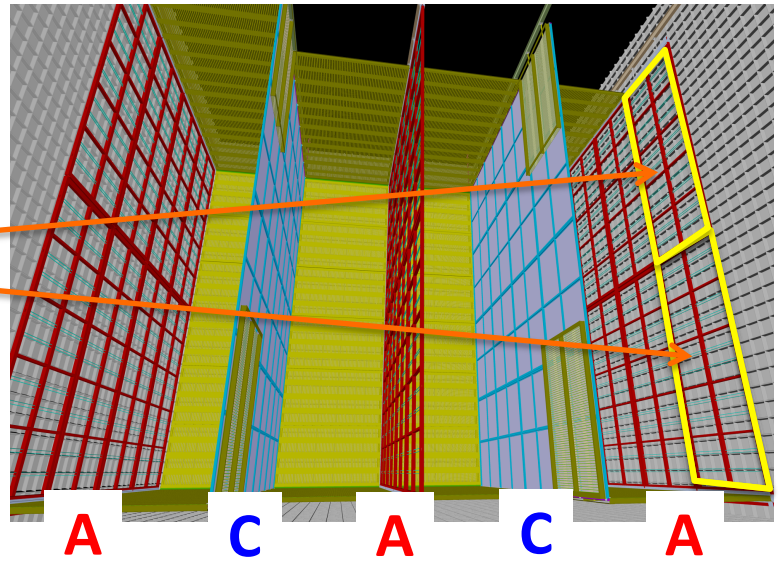
DUNE → ProtoDUNE-SP

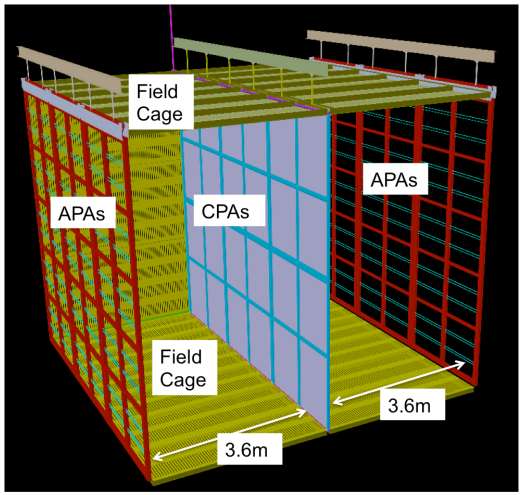
DUNE Far Detector

- Active volume: **12m x 14m x 58m**
- 150 Anode Plane Assemblies
  - 6m high x 2.3m wide
- 200 Cathode Plane Assemblies
  - Cathode @ -180 kV for 3.5m drift

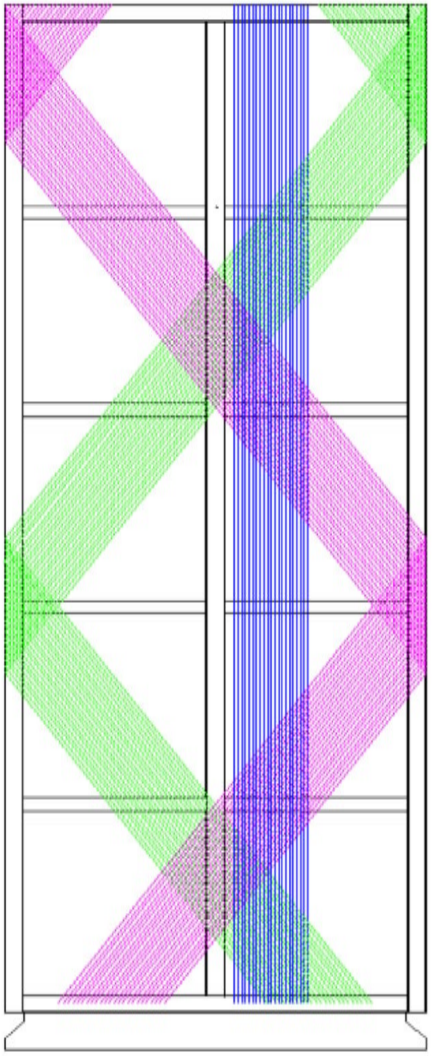


ProtoDUNE-SP

- 1/25 of full DUNE far detector
- 6 full-sized drift cells (150 in far detector)



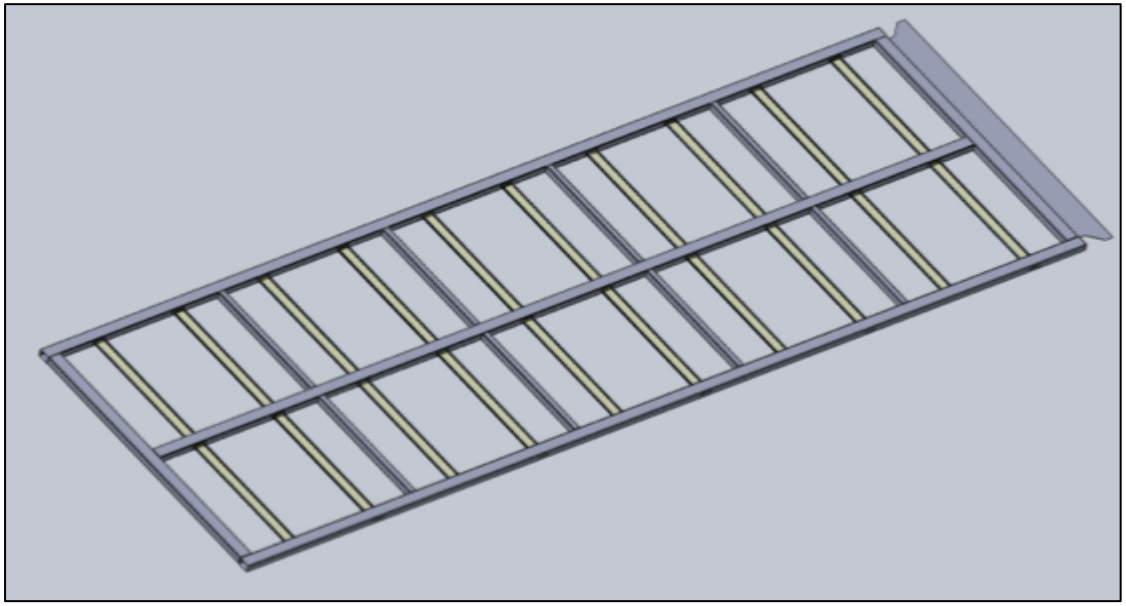
Anode Plane Assemblies for ProtoDUNE-SP



First APA ready for shipment from U of W PSL to CERN

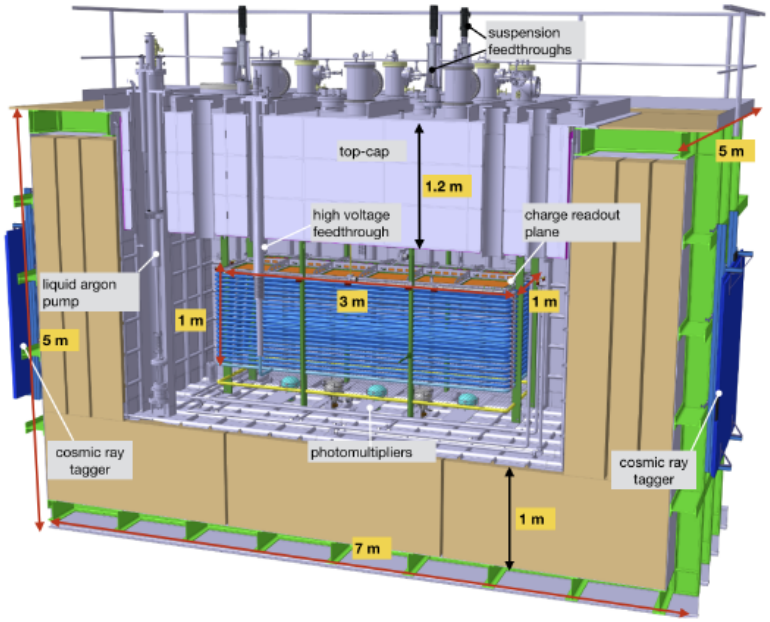
UK winder ready for operation

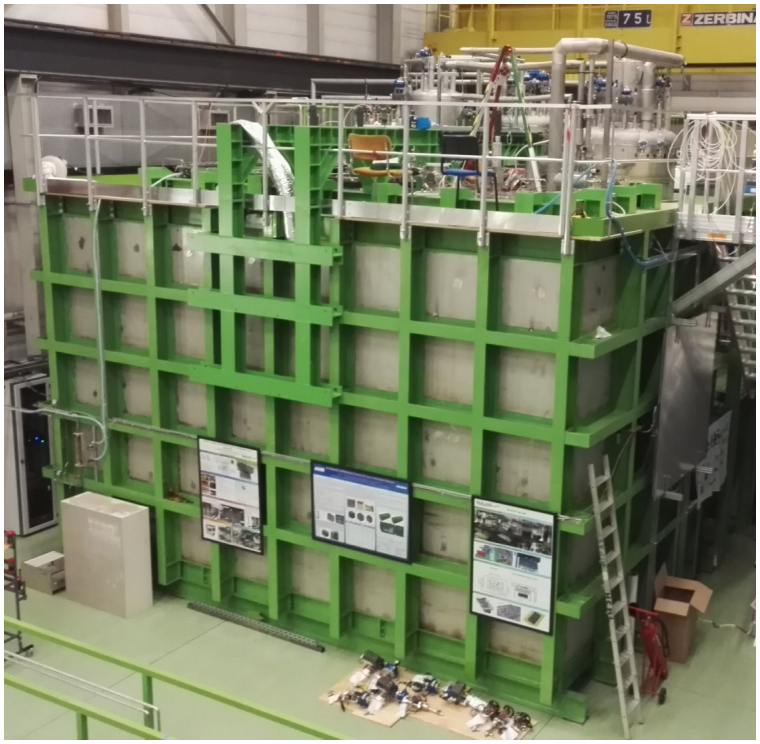
Photon detector system



- 10 photon detector system bars per anode plane assembly
- 3 designs being tested in ProtoDUNE-SP
  - Radiator/WLS Bar
  - Dip-coated bars
  - ARAPUCA Arrays

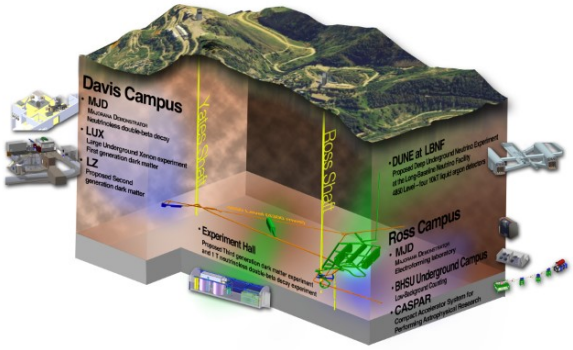
Pre ProtoDUNE-DP: 1m × 1m × 3m

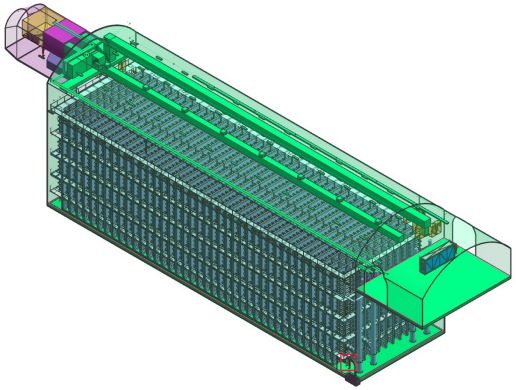


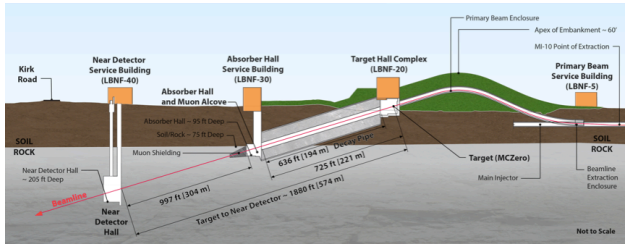


Installation completed in Fall 2016, but cryogenic problems delayed start of operation.

DUNE Timeline







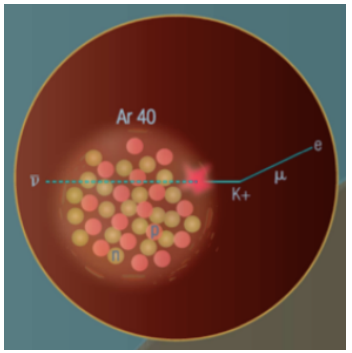
2017: Far Site Construction Begins

2018: protoDUNEs at CERN

2021: Far Detector Installation Begins

2024: Physics Data Begins

2026: Neutrino Beam Available



40 kton + 2 MW beam to follow in subsequent years

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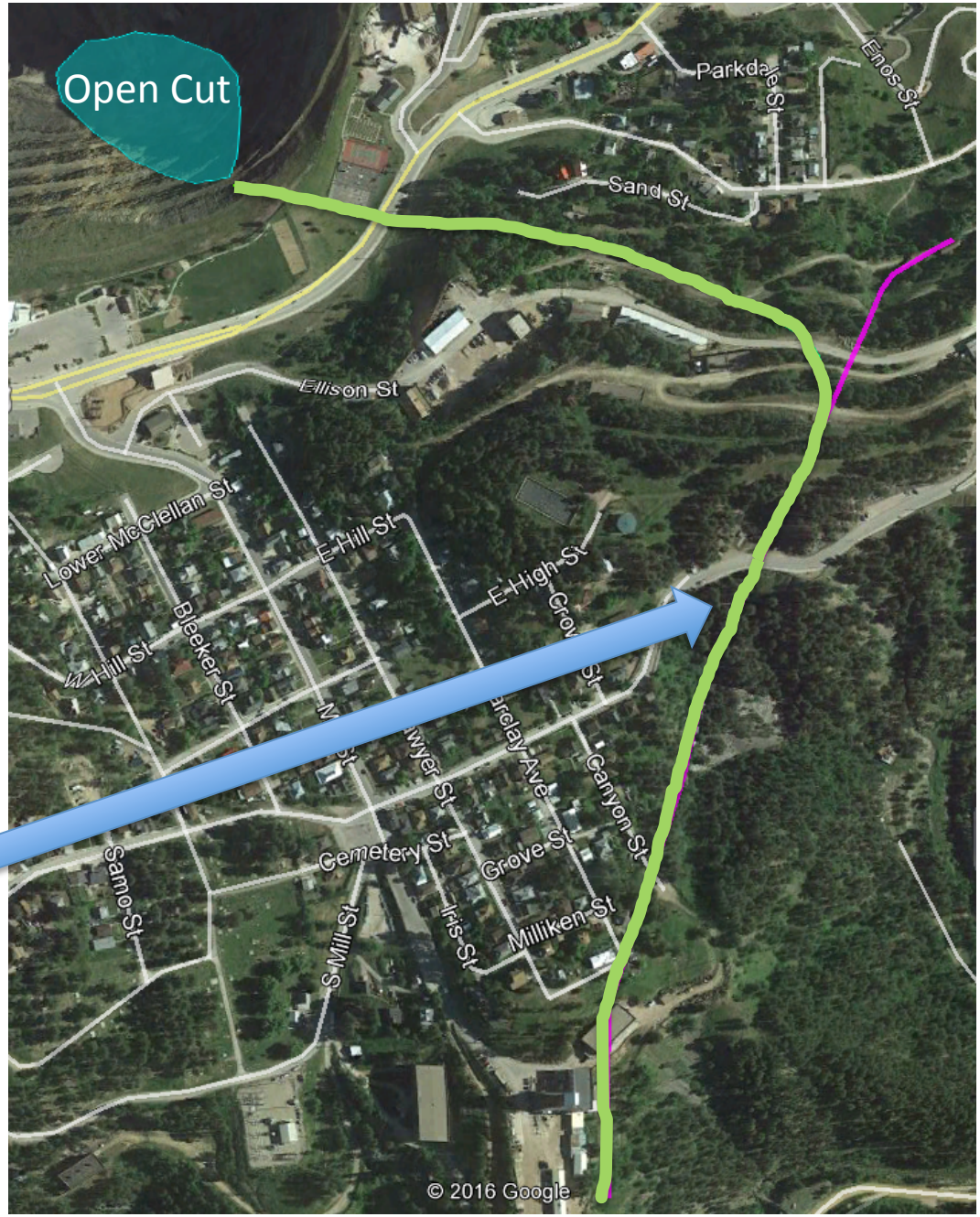
LBNF Update

With the FY17 appropriation, LBNF has moved into a new phase: **Start of Construction**

- **Contract to design (with option to fabricate) a rock conveyor, 3,700 feet long: plan award this week.**



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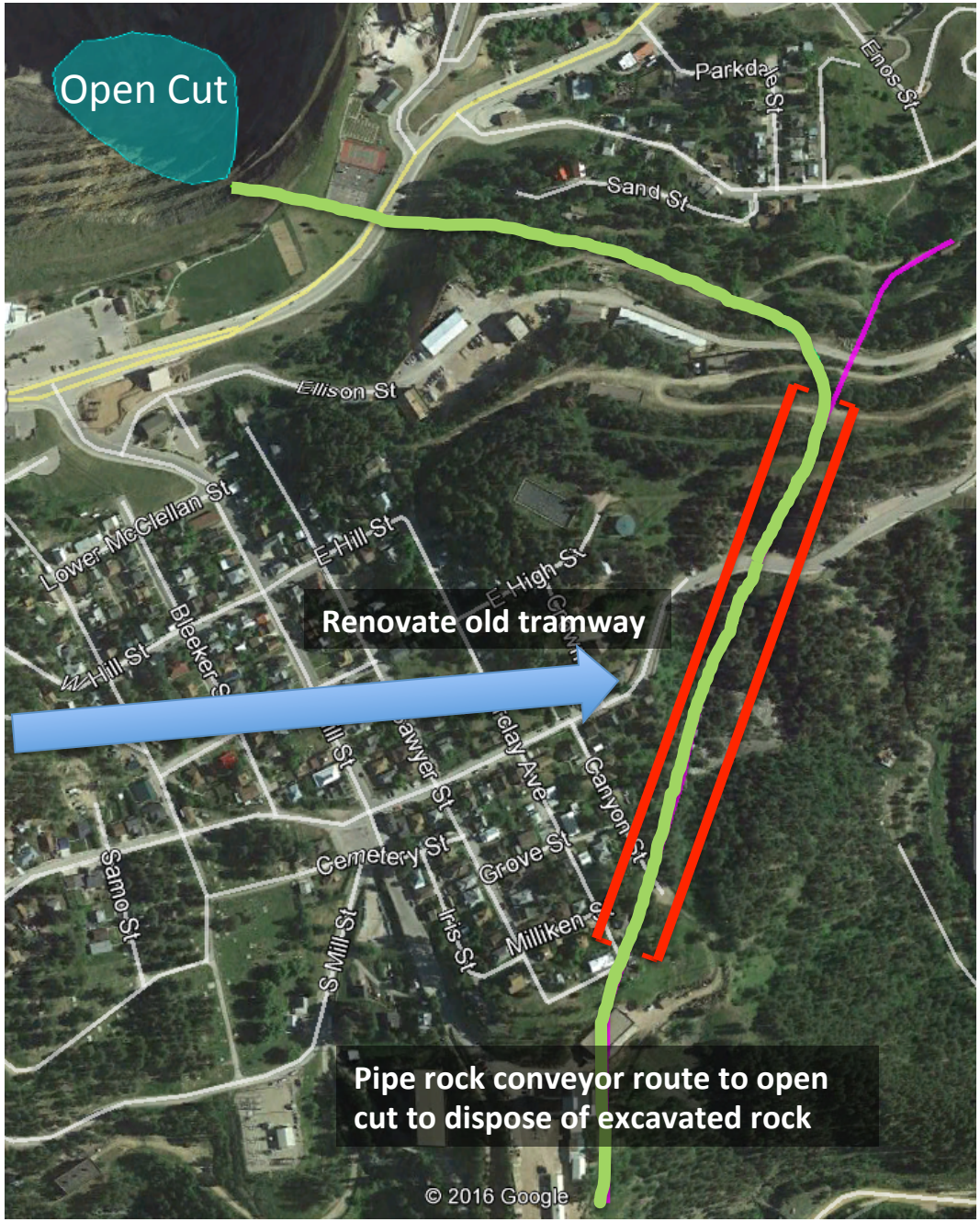

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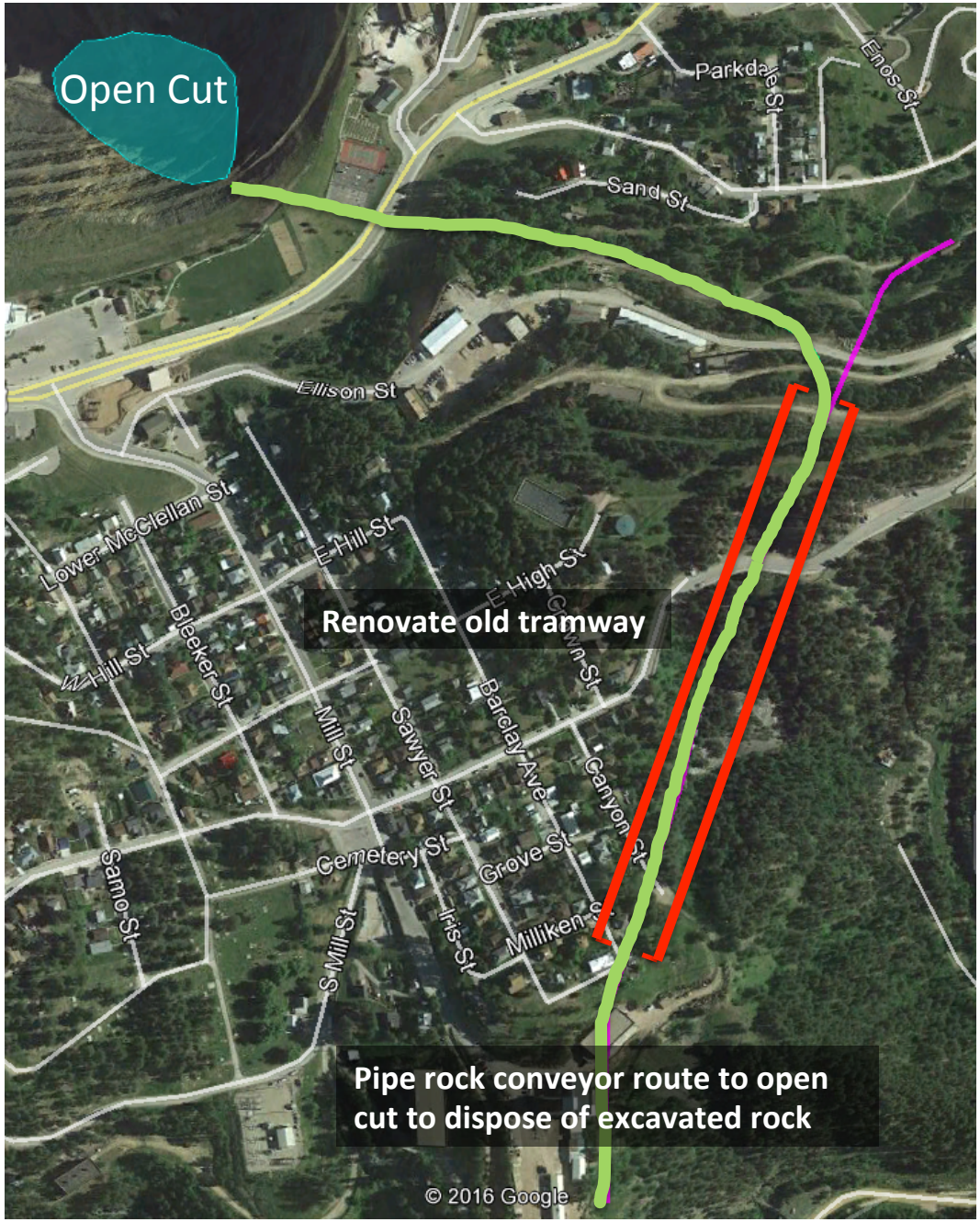

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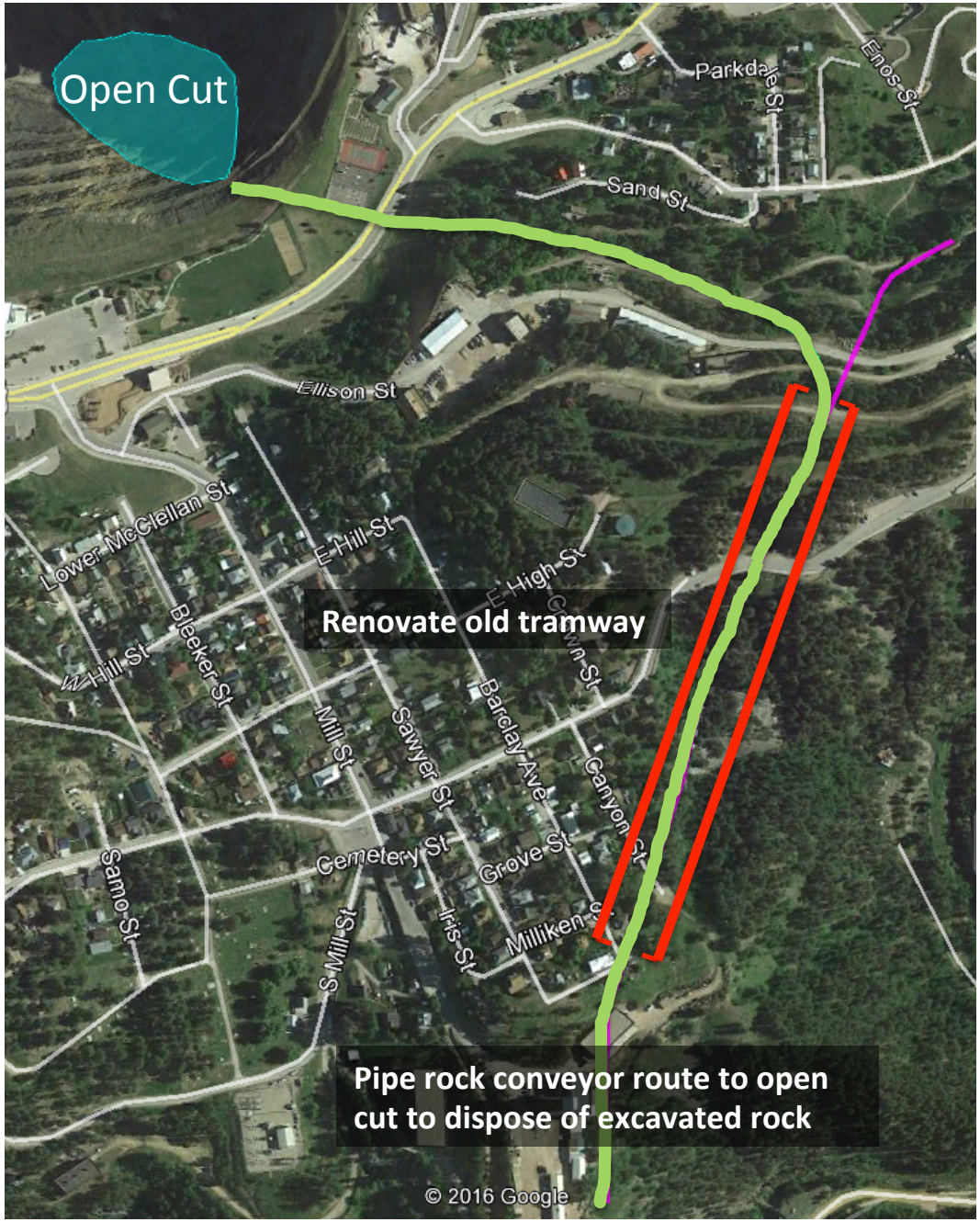
- The CM/GC contract to do all excavation work is under DOE review and also plan to award in June.
- **Working to set up Groundbreaking July/Aug**



Summary

- Very exciting and busy time for LBNF and DUNE!
- Groundbreaking at far site scheduled for this summer
- On track to operate ProtoDUNE-SP and ProtoDUNE-DP at CERN in summer 2018
- We look forward to start operation of first far detector module in 2024, and first data with beam, near detector, and first two far detector modules in 2026!

Staging assumptions

- Year 1 (2026): 20-kt FD with 1.07 MW (80-GeV) beam and initial ND constraints
- Year 2 (2027): 30-kt FD
- Year 4 (2029): 40-kt FD and improved ND constraints
- Year 7 (2032): upgrade to 2.14 MW (80-GeV) beam (technically limited schedule)

Exposure (kt-MW-years)	Exposure (Years)
171	5
300	7
556	10
984	15