Long-baseline Neutrino Facility (LBNF) and Deep Underground Neutrino Experiment (DUNE) Update

Chris Mossey, LBNF/DUNE-US Project Director

Fermilab Community Advisory Board

26 Jan 2023

LBNF Project partners:

US/DOE

Brazil/FAPESP-UNICAMP

CERN

India/DAE

Poland/WUST

Switzerland/SERI, and

UK/UKRI-STFC

plus the DUNE international Collaboration and consortia

Fermilab

CERN

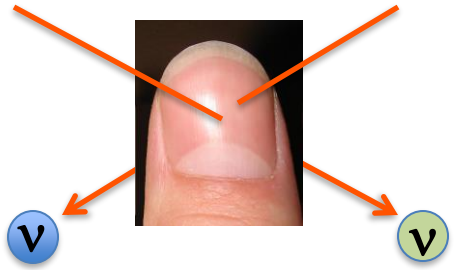
Sanford Underground Research Facility

U.S. DEPARTMENT OF ENERGY | Office of Science

v0

What are Neutrinos?

- **Ever present**
  - One of Mother Nature's handful of fundamental matter particles
  - More neutrinos in the Universe than any other matter particle
  - ~65 billion pass through every cm^2 every second
- **Mysterious and surprising**
  - Almost massless
  - Almost always pass straight through matter without interacting



- **Important**
  - Pivotal role in the evolution of the Universe
  - May hold the key to why there is so little anti-matter (i.e. why the matter that makes up stars, planets, and everything else in the universe, including us, exists)
- **Experimentally Challenging**
  - Need different approach than CERN's circular Large Hadron Collider
  - Observable interactions very rare
    - Need very powerful beams (many, many neutrinos)
    - Need very large detectors

Thanks to Steve Brice

LBNF will support DUNE Science Objectives:

Neutrinos – the most ubiquitous matter particle in the universe, yet the least understood → Opportunities for game changing physics discoveries:

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

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

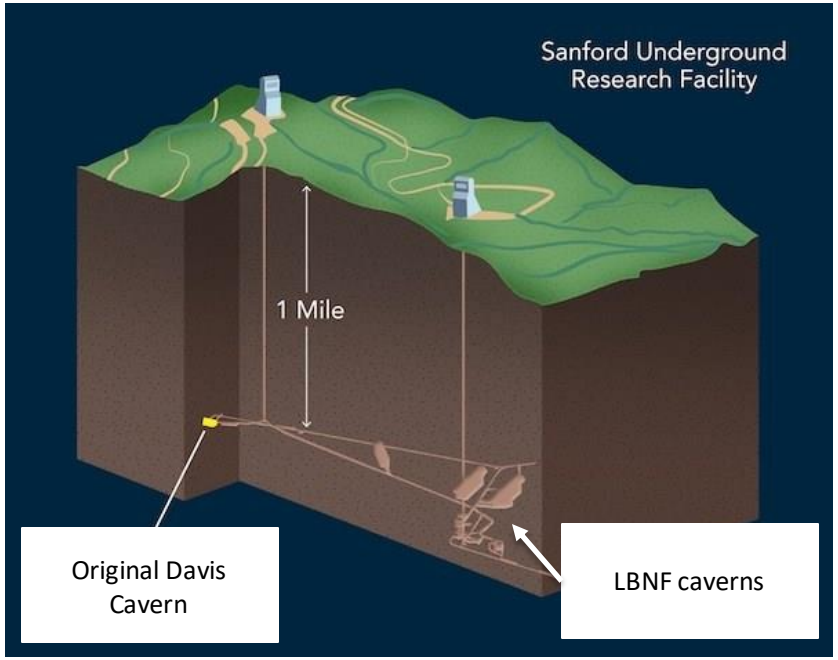
- **Unification of forces**
  Move closer to realizing Einstein's dream of a unified theory of matter and energy by looking for proton decay

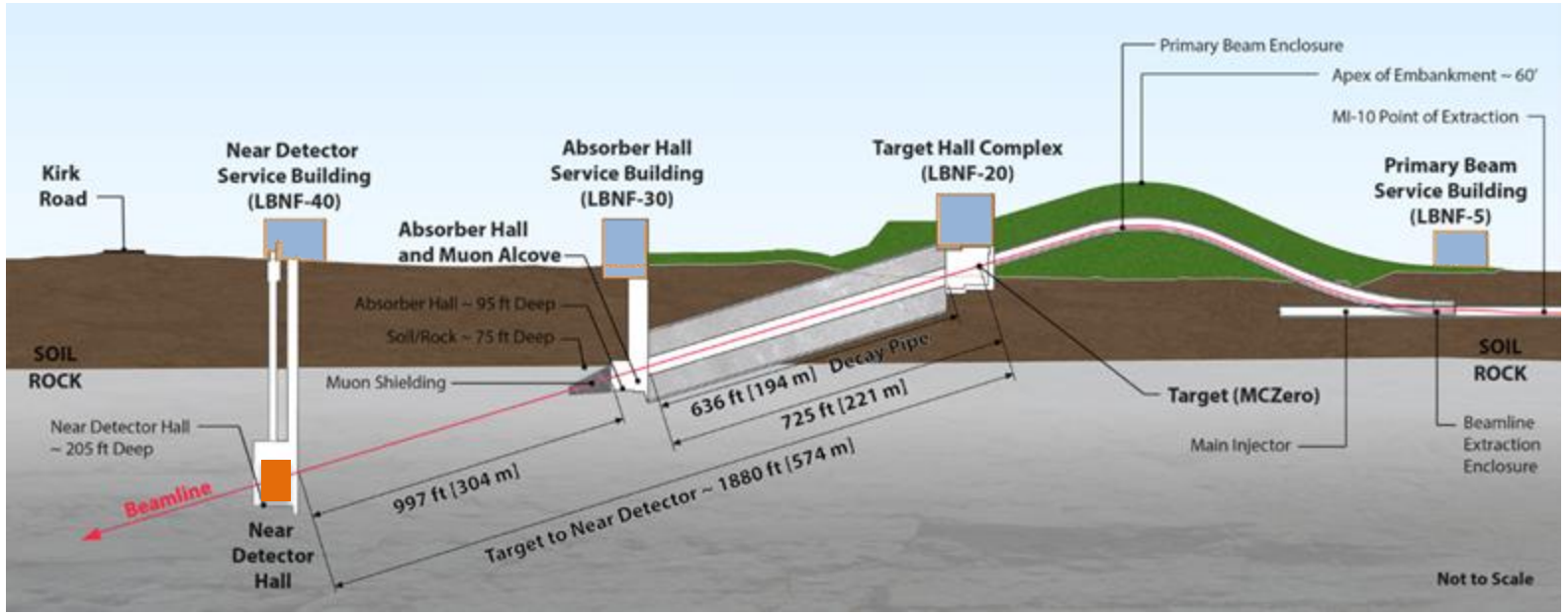
LBNF will drive neutrino discovery science forward the way CERN's Large Hadron Collider drove the Nobel Prize-winning Higgs discovery

LBNF: From Illinois to a mile underground in South Dakota

Illinois: ➔

- World's most powerful and advanced neutrino beamline
- DUNE "near" detector





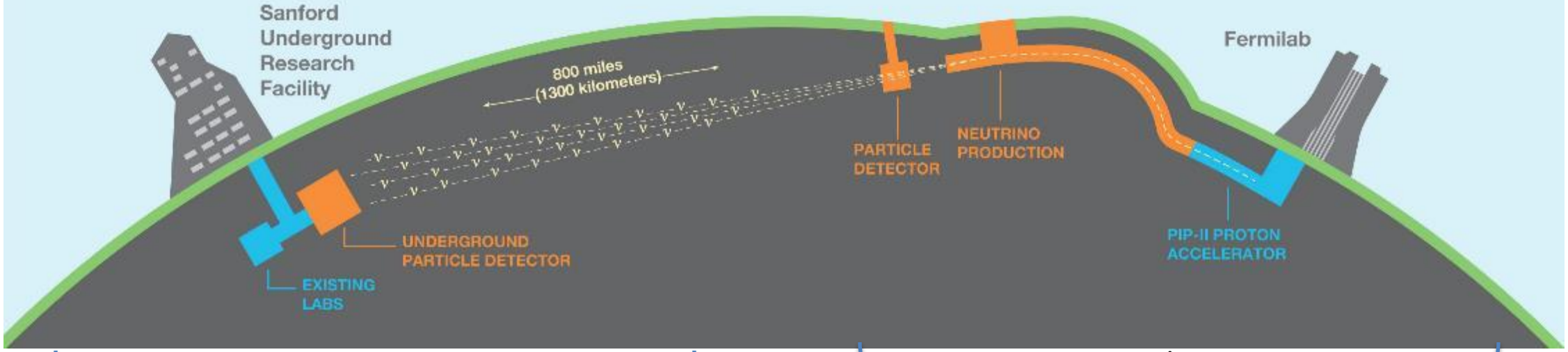
➔ **South Dakota:**

- Surface and underground facilities
- Cryostats - Massive membrane cryostats to hold liquid argon
- Cryogenic systems
- DUNE "far" detectors – up to four liquid argon detector modules

Project Scope - Delivered at Two Sites through Five Subprojects

Far Site – SURF in Lead, SD
Facility/Infrastructure and Far Detectors

Near Site – FNAL in Batavia, IL
Facility/Infrastructure, Neutrino Beamline, and Near Detectors



Three subprojects

- **FSCF-EXC** – Far Site Excavation
- **FSCF-BSI** – Far Site Building & Site Infrastructure
- **FDC** – Far Detectors and Cryogenic Infrastructure

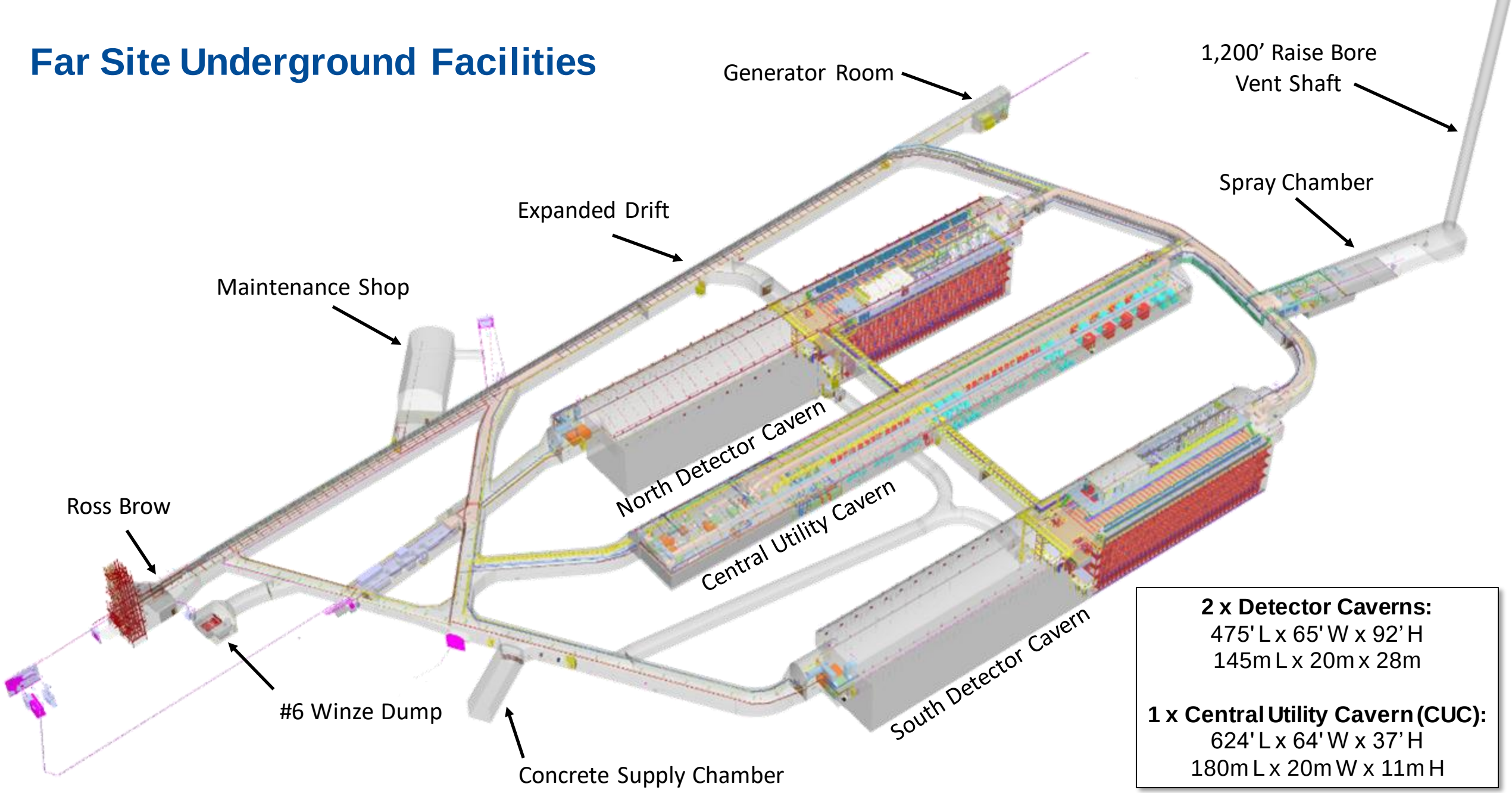
Two subprojects

- **NSCF+B** – Near Site Conventional Facilities + Beamline
- **ND** – Near Detectors

The “Far Site” in Lead, South Dakota – Former Homestake Gold Mine

The far site at Sanford Underground Research Facility (SURF) , Lead, SD

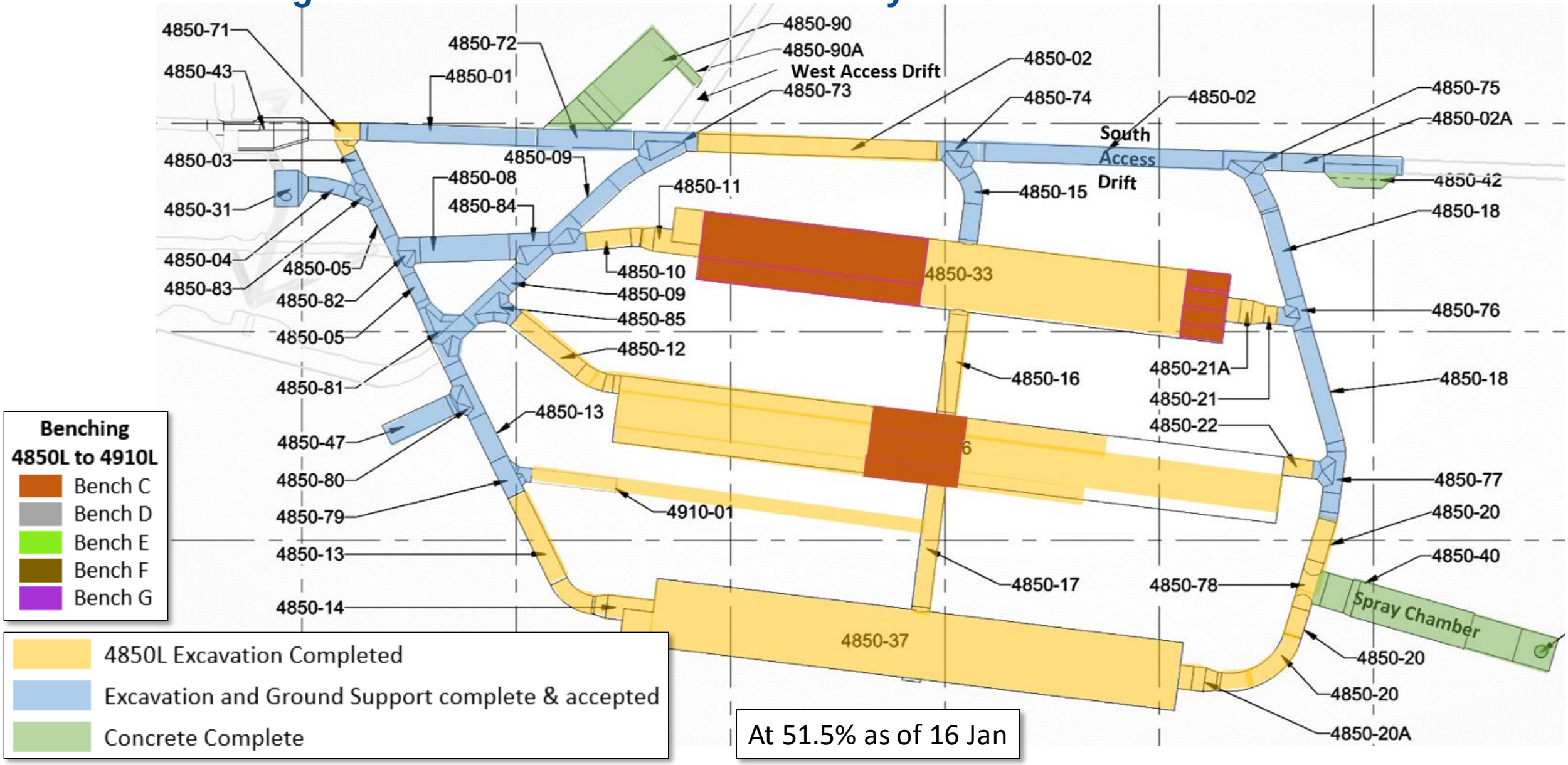
Far Site Underground Facilities



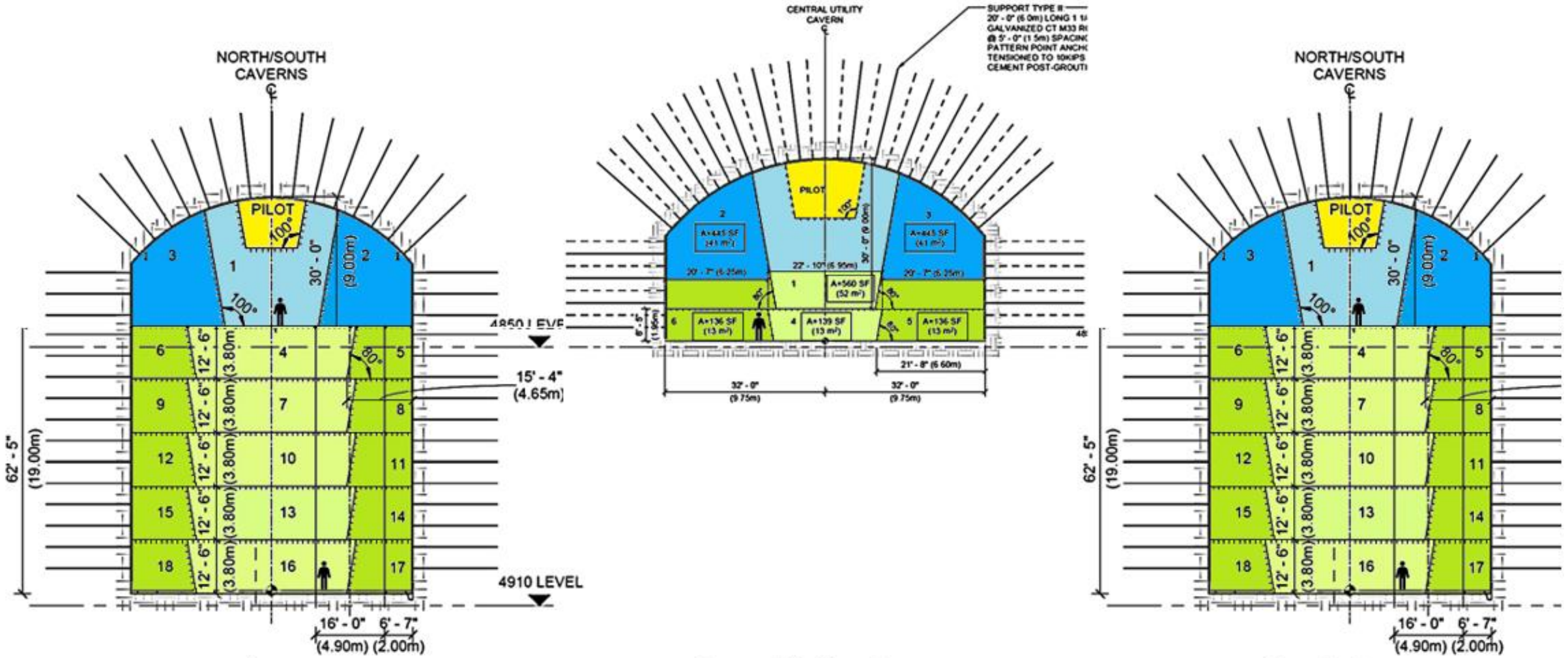
2 x Detector Caverns:
475' L x 65' W x 92’ H
145m L x 20m x 28m

1 x Central Utility Cavern (CUC):
624' L x 64' W x 37’ H
180m L x 20m W x 11m H

Excavation Progress – Reached 50% on 9 January 2023

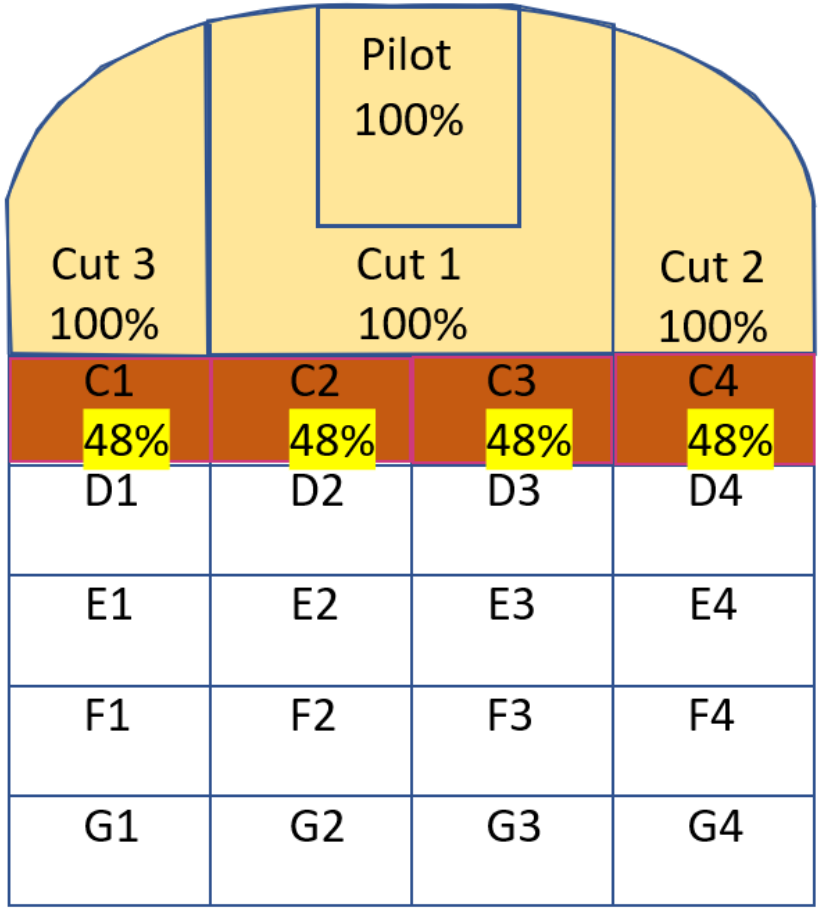


Excavation Sequence Cross Sections

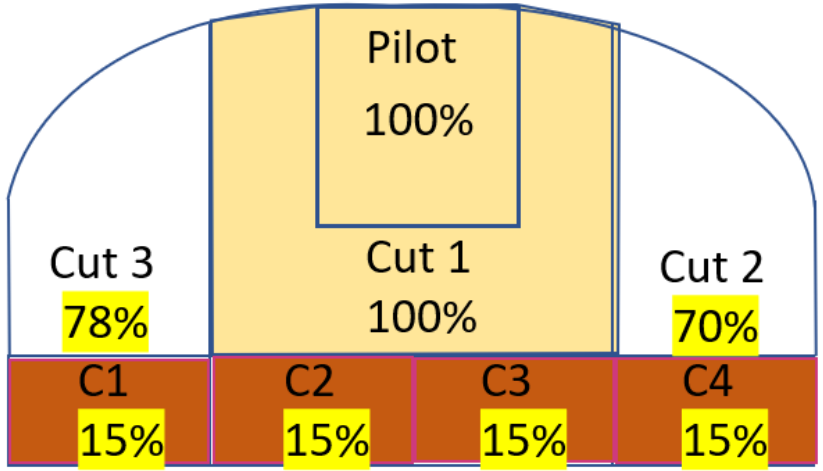


North Cavern | Central Utility Cavern | South Cavern

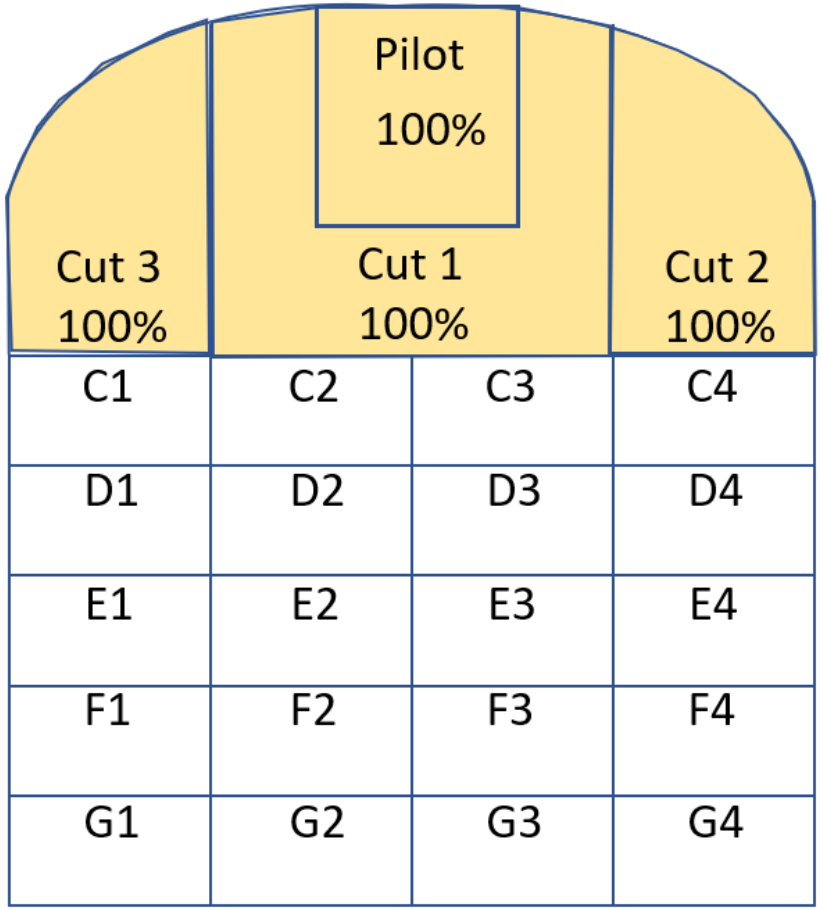
Main Excavation Focus now on “Benching” down in each cavern



North Cavern



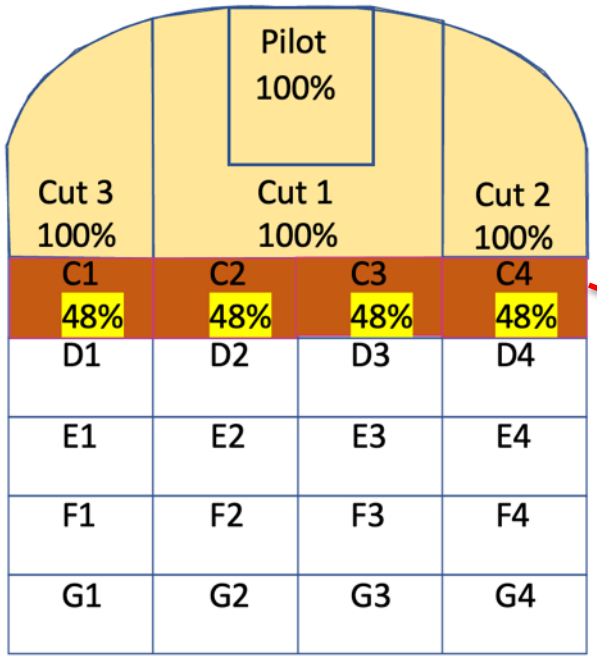
CUC Cavern



South Cavern

At 51.5% of in-situ rock volume removed as of 16 Jan 2023

Benching in North Cavern



North Cavern

North Detector Cavern – West End

Drilling holes for blast charges for bench C (left) and removing muck (right) in North Detector Cavern (4850-33)

Photo by Matt Kapust, SDSTA – 19 Jan 2023

Central Utility Cavern

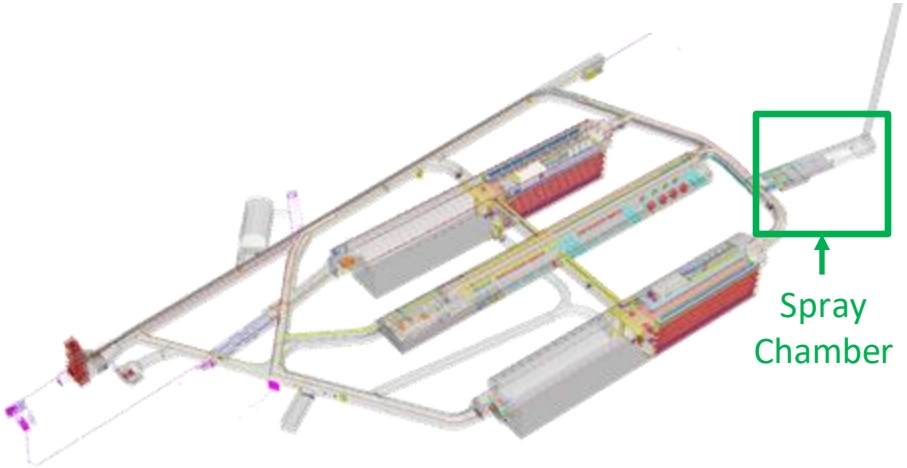
Drilling holes for blast charges in Central Utility Cavern (4850-36)

Installing CT Rock Bolts in Central Utility Cavern (4850-36)

South Detector Cavern

Extending monorails that will support material handling cranes in South Detector Cavern (4850-37)

Spray Chamber



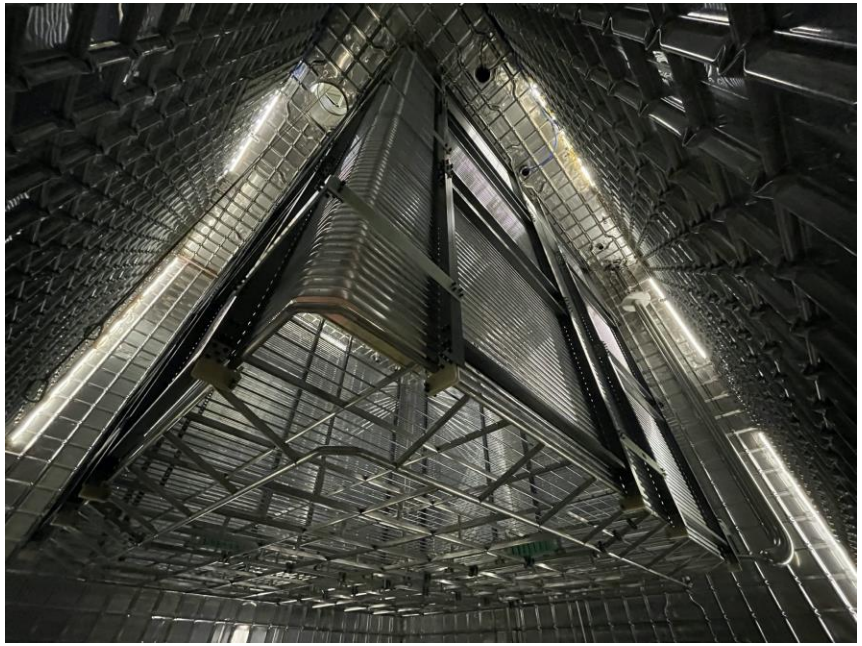
Photos taken in Spray Chamber (facility to reject heat from cryogenics systems and transfer up the raise bore)

DUNE Far Detectors Status

- 1st far detector module to be based on Anode Plane Assembly (APA) technology with horizontal drift
- 2nd far detector module to be based on Charge Readout Plane (CRP) technology with vertical drift
- CERN Neutrino Platform has operated two 8m x 8m x 8m prototypes to mature and prove technology
  - Both detectors have performed extremely well and in excess of specification/requirement
- Approximately 50% of each detector is being provided by DUNE international partners

APAs for Module 0 ProtoDUNE being tested at Daresbury Laboratory, UK. One 2.3m x 6.3m APA is shown; UK to provide 130 APAs.

NP-02 and NP-04 ProtoDUNE 8m x 8m x 8m detector prototypes at CERN.

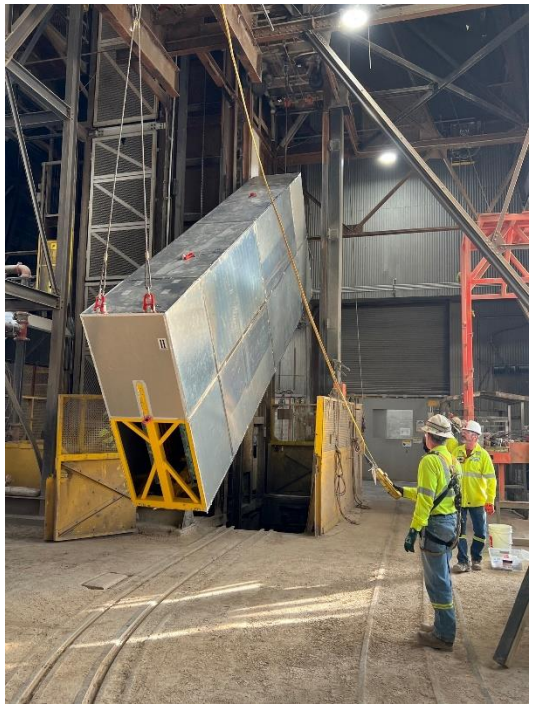


NP-02 ProtoDUNE 8m x 8m x 8m cryostat at CERN has demonstrated 300 kV across field cage for CRP detector technology

Far Site – Logistics Planning for Far Detectors

- Anode Plane Assembly (APA) test lift successfully completed at SURF between in early November – proves the largest detector components can be successfully moved to 4850L.
  - Test included handling and lowering of the APA shipping container (holding 2 APAs) to the 4850L.
  - "Slung load" movement in the shaft was smooth and stable. Traveled at 100 ft/min to the 4850 level, which takes ~45 minutes.
  - The APAs are now at Fermilab for wire fidelity and tension testing – critical validation test.
  - Lessons learned include some minor redesign to shipping frame and better sealing against moisture in the shaft.

One 2.3m x 6.3m APA is shown

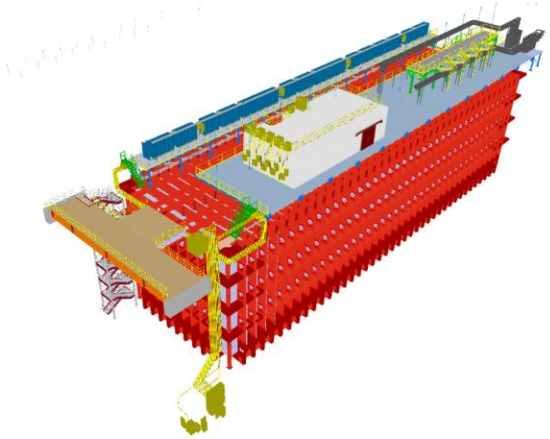


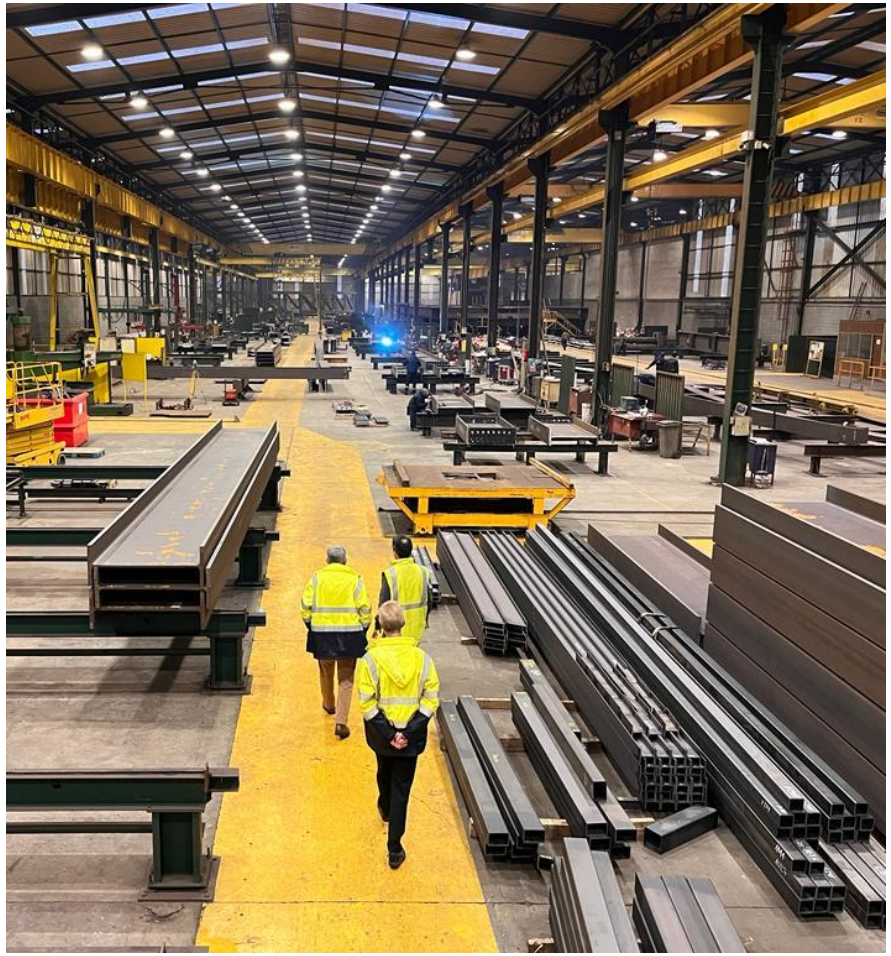
Signature Ceremony - Agreement for CERN to Provide Second Cryostat

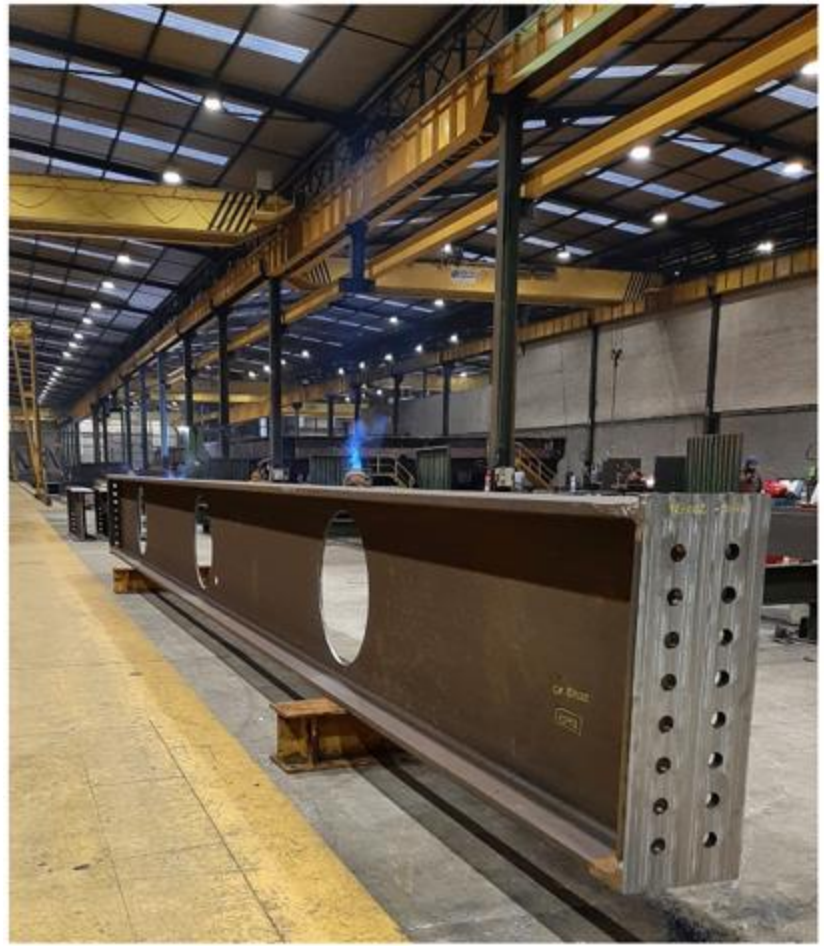
Ceremony at CERN on 16 September 2022; Agreement signed by Fabiola Gianotti (CERN DG) and Dr. Asmeret Berhe (DOE Director of Office of Science)
Photo by Jacques Fichet, CERN

FDC - Cryostat Fabrication Progress

Thank you to CERN Neutrino Platform!



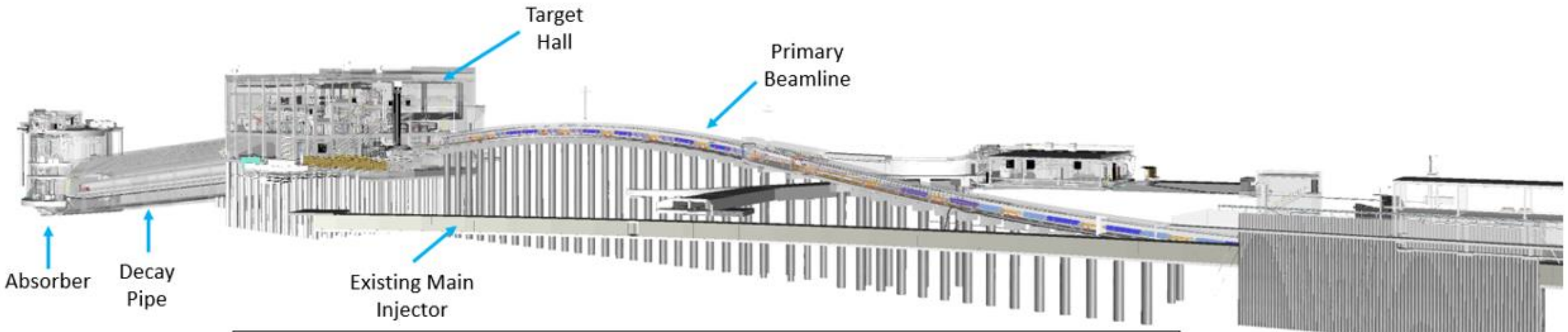




Photos by Dimitar Mladenov, CERN

Near Site Conventional Facilities + Beamline Subproject (NSCFB)

- Beamline design is at >69% final design status and on track
- Conventional facilities design remains at 100% final design status. Preparing construction documents.
- Schedule for this subproject is funding limited, plan contract awards in 2025.

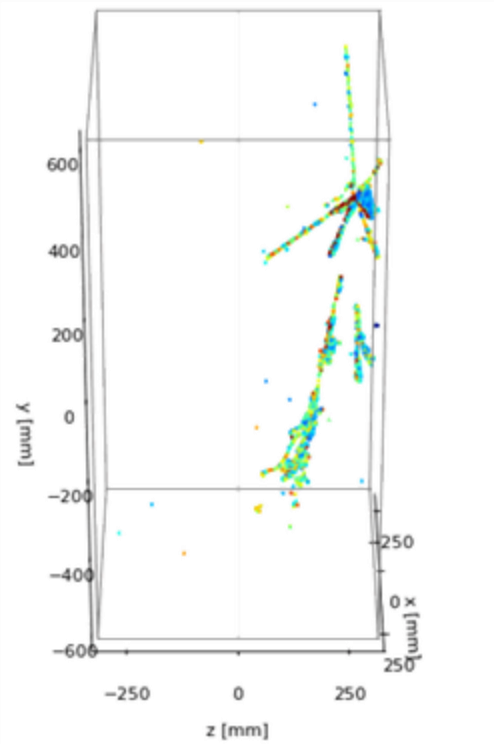


Beamline Complex: Upstream end view of Primary Beamline, Target Hall, Decay Pipe, and Absorber

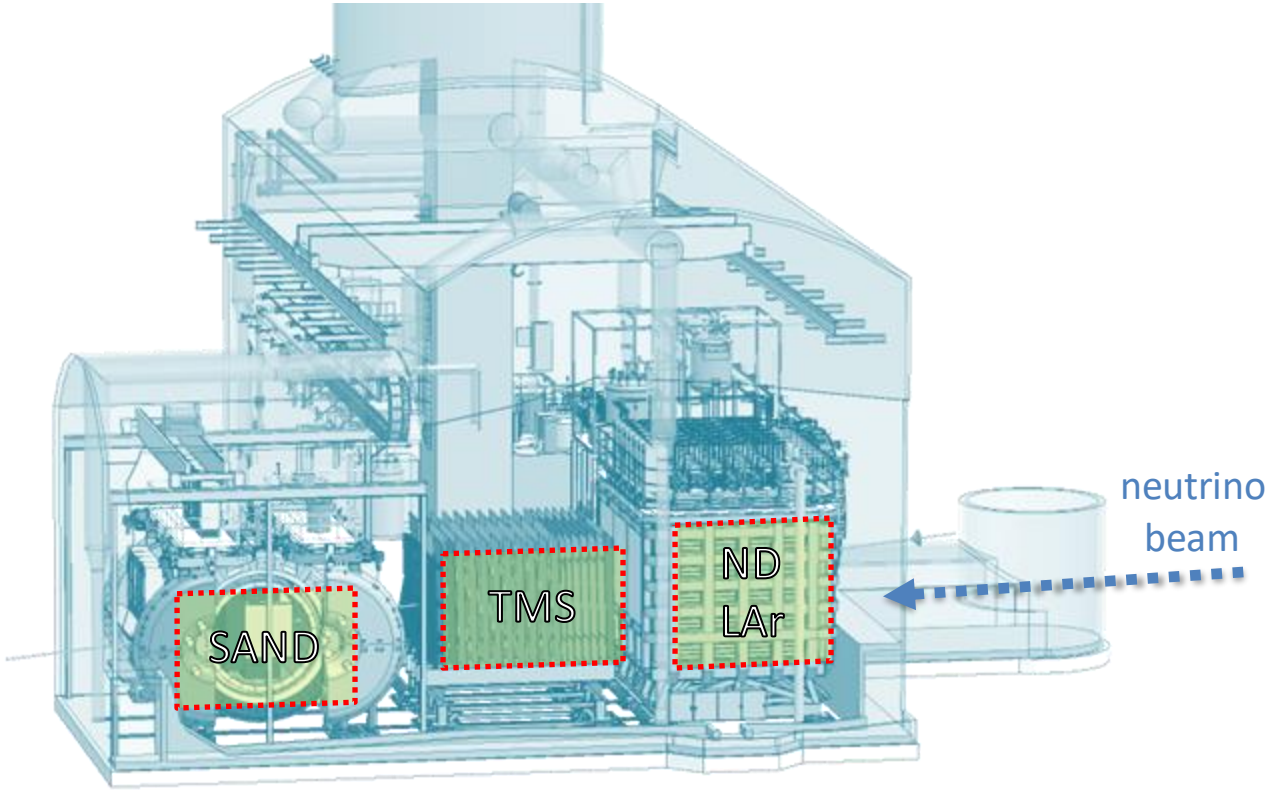
Note: ND Hall facilities is part of NSCF+B Subproject

DUNE Near Detector

- The Near Detector is a critical element to make neutrino measurements in DUNE



fully instrumented 20% scale ND-LAr prototype has been successfully operated at LHEP/University of Bern



Dr. Martina Hirayama (Swiss State Secretary for Education, Research, Innovation) visited FNAL with Swiss delegation on October 20. Photo credit: Ryan Postel.

LBNF/DUNE-US Safety Performance through December 2022

	Current Calenddar Year to Date*						Cumulate to Date*					
Organization	Labor hours	DART Cases	DART Rate	TRC Cases	TRC Rate	ORPS Cases+	Labor hours	DART Cases	DART Rate[1]	TRC Cases	TRC Rate[2]	ORPS Cases+
LBNF/DUNE-US	191,626	0	0	0	0	2	1,439,535	0	0	0	0	3
SDSTA	53,675	0	0	0	0	2	284,963	3	2.1	5	3.5	7
KAJV	68,083	0	0	0	0	0	552,176	0	0	1	0.4	3
TMI	337,799	0	0	1	0.6	4	578,147	0	0	1	0.3	6
Granite/JACOBS	0	0	0	0	0	0	45,542	0	0	0	0	0
Other Subcontractors	271	0	0	0	0	0	26,710	0	0	1	7.5	2
Project Total	651,454	0	0	1	0.3	8	2,927,073	3	0.2	8	0.5	21
Comparision with:												
Heavy and Civil Engrg Construction (237)									1.5		2.4	
Metal Ore Mining (2122)									1.4		1.9	

*Reflects labor hours & incidents through December 2022. Industry DART and TRC data from Bureau of Labor Statistics, U.S. Department of Labor.
+Does not include NO2 Abatement plan ORPS reports

[1]**DART** = Days Away, Restricted, or Transferred

[2]**TRC** = Total Case Rate

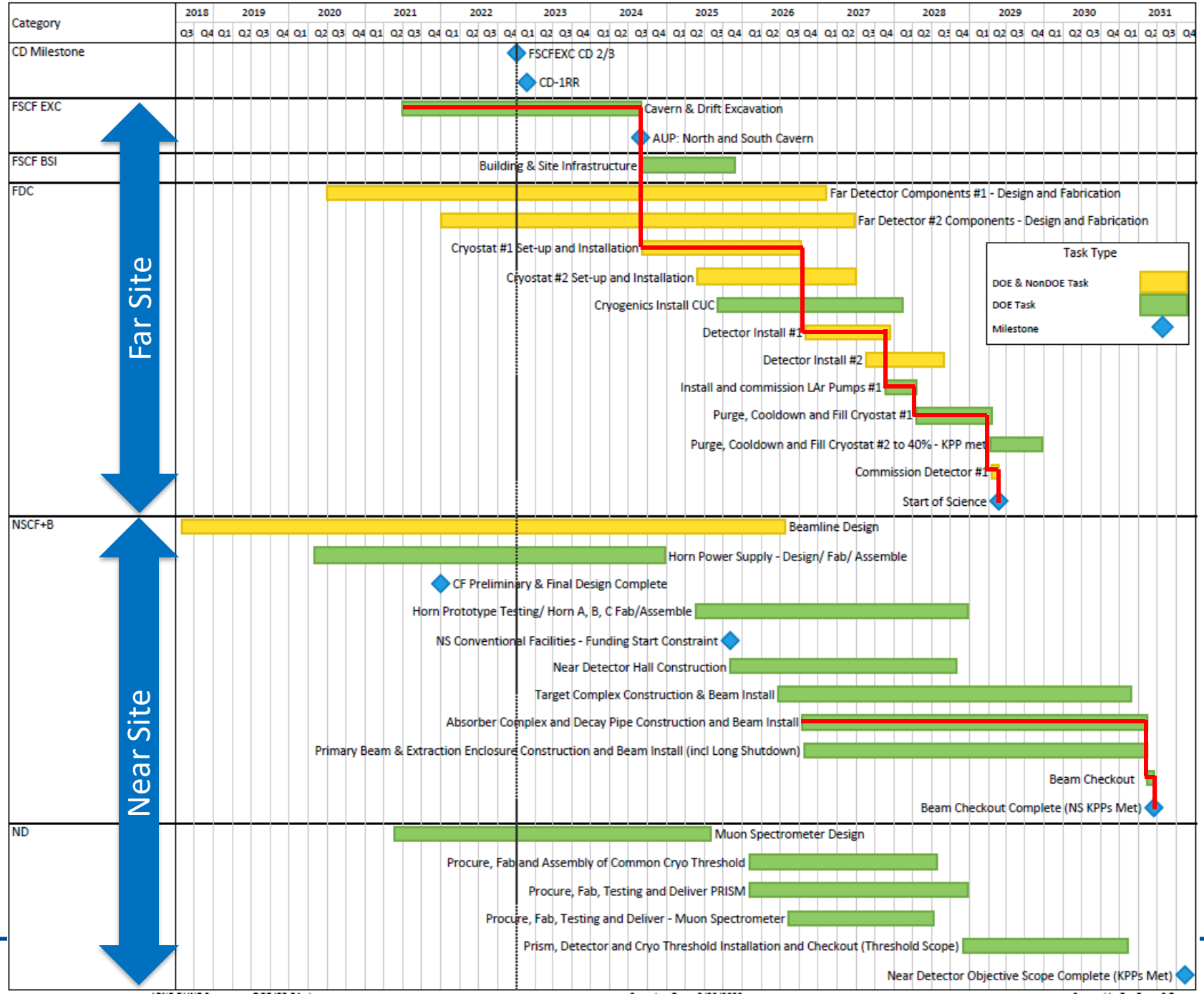
Numbers represent rates; lower rate of occurrence is better

- LBNF/DUNE subcontractors continuing strong overall safety performance

Thank you. Questions?

Videos:
PIP-II/LBNF/DUNE
Science of DUNE
Far Detectors

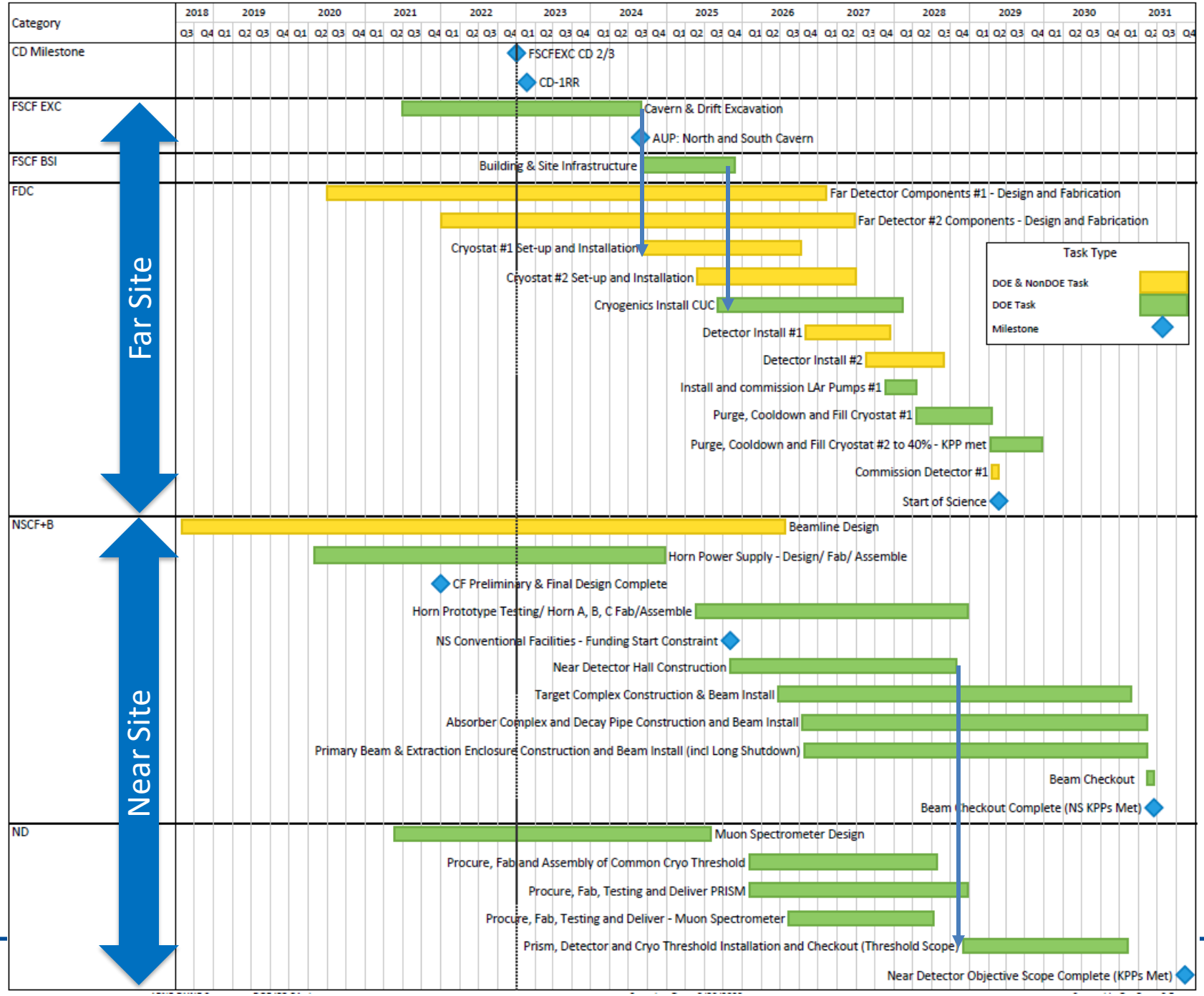
Summary Schedule with Critical Paths through Start of Science (FD1) and Beam-on



Notes:

- Fiscal Year display
- Sep 2022 reporting cycle
- Based on “CD-1RR ESAAB” funding profile

Summary Schedule with Subproject Links



Notes:

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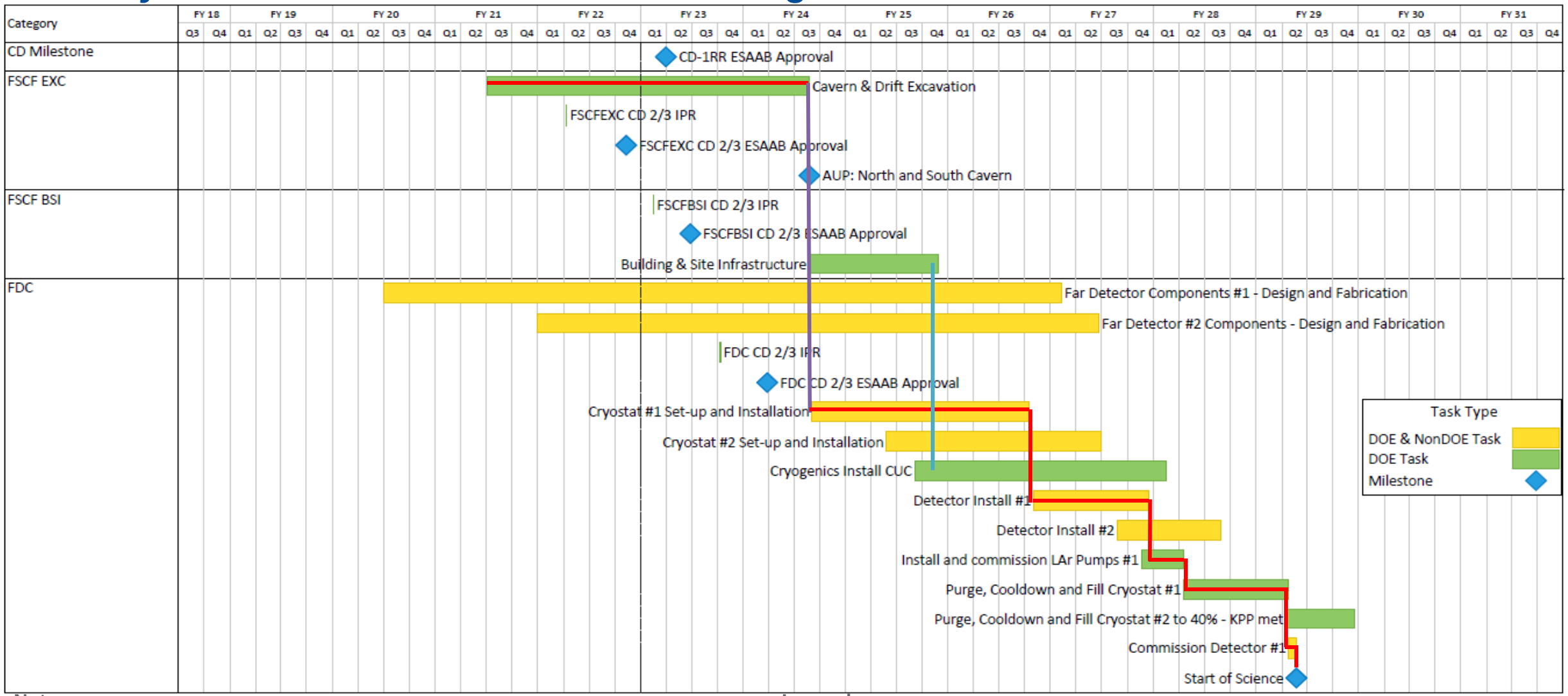
Summary Schedule with Critical Paths through the Far Site



Notes:
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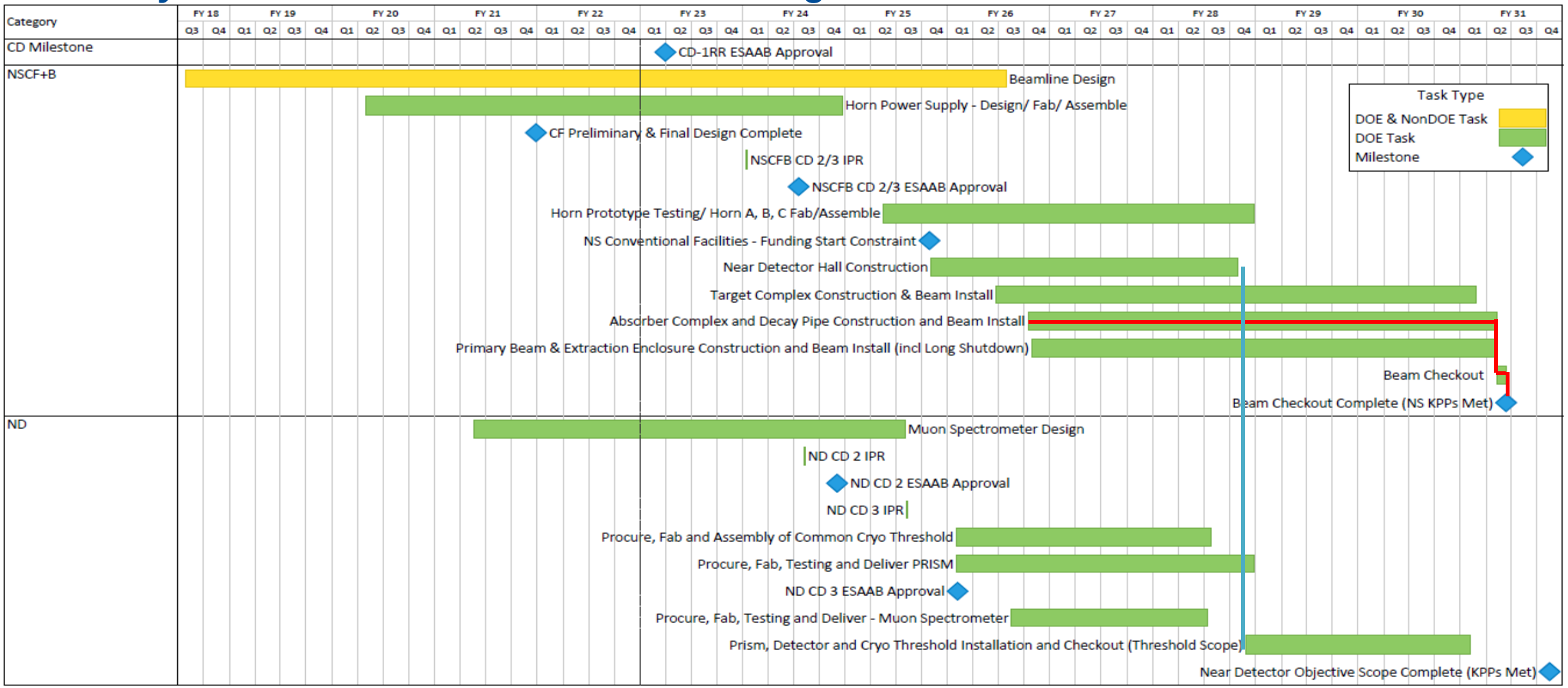
Legend:
Red: Critical Path
Blue: Subproject Links
Purple: Critical Path and Subproject Links

Summary Schedule with Critical Paths through the Near Site



Notes:
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Legend:
Red: Critical Path
Blue: Subproject Links

Capabilities Planned in Phases

- **Phase I:** (what the project will deliver)
  - Accomplished with PIP-II, LBNF/DUNE-US, and DUNE International Partners
  - Meets P5 minimum requirements to proceed by 2035 timeframe
  - Same project scope as proposed at CD-1R in July 2015

- **Phase II** (future, not part of project)
  - Increased mass at Far Detector
  - More Capable Near Detector (MCND)
  - Increased beam power by Booster replacement

Capability Description	LBNF/DUNE-US Project + DUNE Int'l Project: Phase I	Phase II
Beamline		
1.2MW (includes 2.4MW infrastructure)	X	
2.4MW		X[1]
Far Detectors		
FD1 – 17 kton	X	
FD2 – 17 kton	X	
FD3		X
FD4		X
Near Detectors[2]		
ND LAr	X	
TMS	X	
SAND	X	
MCND (ND GAr)		X

Note 1: requires upgrades to LBNF neutrino target and upgrades to Fermilab accelerator complex. The LBNF facility is built to support 2.4MW in Phase I.
Note 2: Near Detector Subproject threshold scope provides "day 1" requirements to start the DUNE experiment