Fermilab

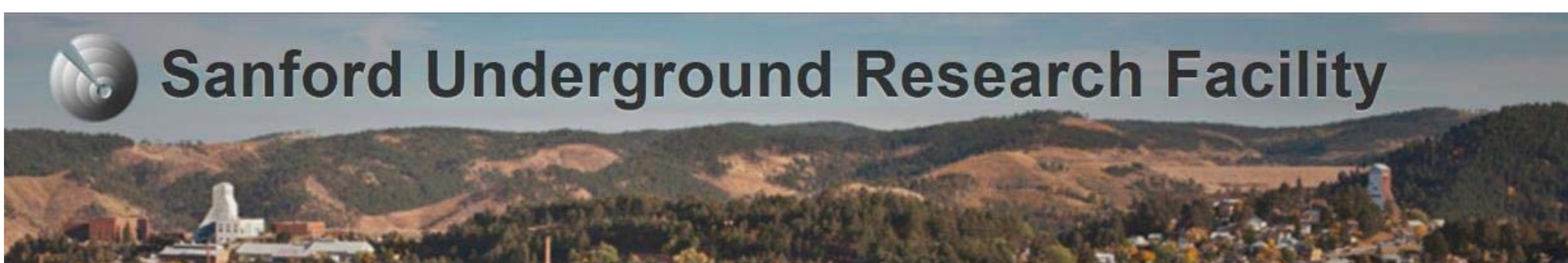
Managed by Fermi Research Alliance, LLC for the U.S. Department of Energy Office of Science

Long-Baseline Neutrino Facility

Jim Strait, Fermilab

2nd International Meeting for Large Neutrino Infrastructures

20 April 2015



Outline

- Beam power evolution of the Fermilab Main Injector Complex

  350 kW → 450 kW → 700 kW → 1.2 MW → 2.4 MW
- Long-Baseline Neutrino Facility
- LBNF Beamline and Conventional Facilities at Fermilab
- LBNF Conventional Facilities at SURF
- LBNF Cryogenic Systems at SURF
- DUNE-LBNF Schedule

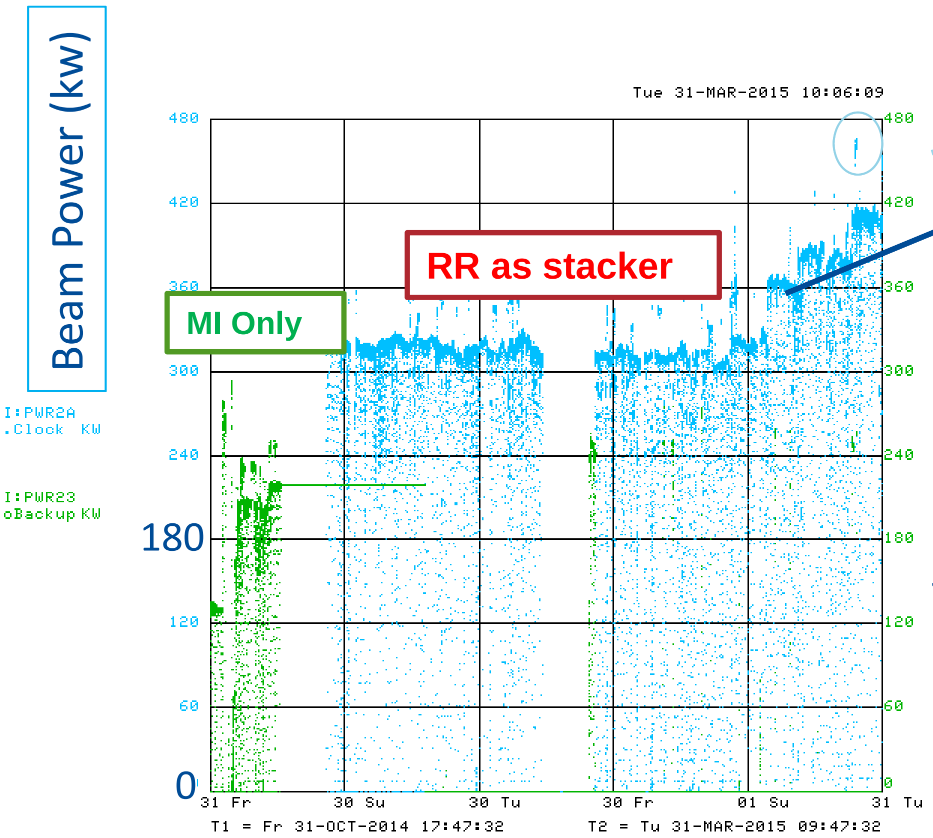
Beam power evolution of the Fermilab Main Injector Complex

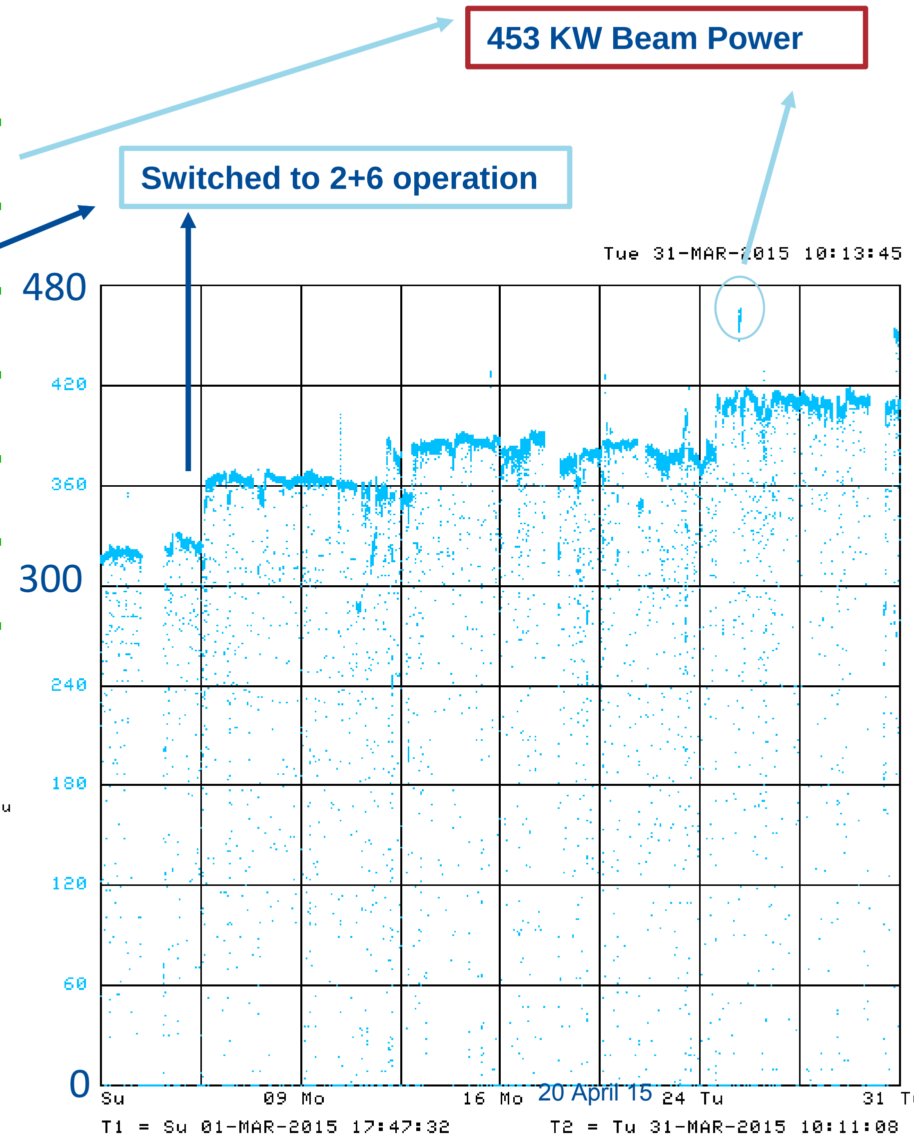
Fermilab Accelerator Complex

Current high power operation and plans for NuMI

- The MI has been delivering 2.4E13 ppp every 1.333sec by using the Recycler as a proton stacker (6 batches, no slip stacking).
  - 350 KW beam power (315 KW with SY120)
- On March 5th, 2015 it switched to 2+6 operation, currently delivering ~420 KW of beam power.
  - 453 KW new MI Beam Power record (running without SY120) achieved on March 25th, 2015.
- Plan to demonstrate 4+6 operation in May 2015, before the summer shutdown.
- Achieve 575 KW with 4+6 operation-November 2015 (19 re-furbished Booster RF stations, 7.5 Hz operation).
- Achieve 700 KW with 6+6 operation-Feb. 2016 (20 re-furbished Booster RF stations, 9 Hz operation).

MI Beam Power since long shutdown and during March 2015





PIP-II accelerator upgrade at Fermilab

P5 Recommendation 14:

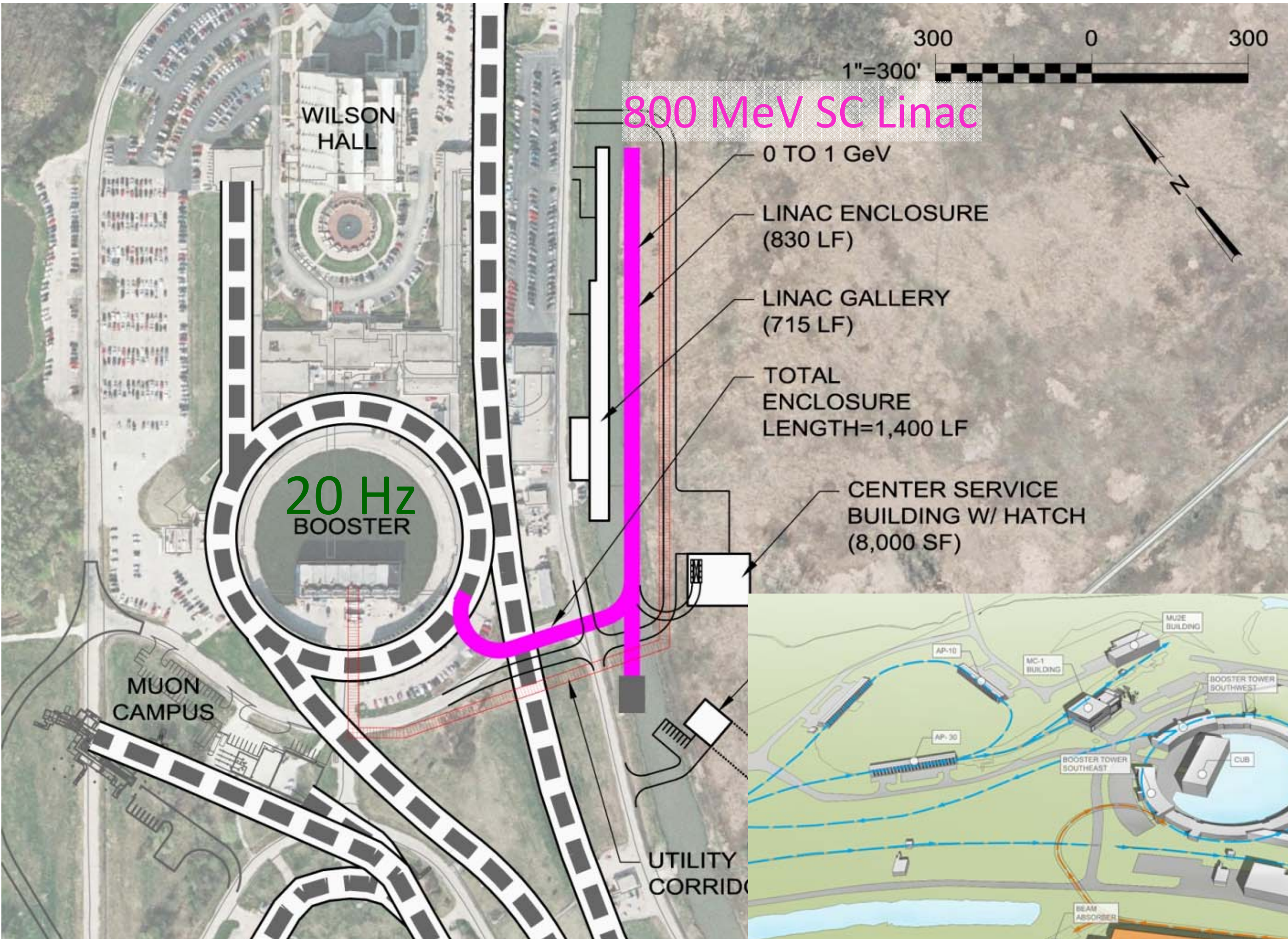
> "Upgrade the Fermilab proton accelerator complex to produce higher intensity beams. R&D for the Proton Improvement Plan II (PIP-II) should proceed immediately, followed by construction, to provide proton beams of > 1 MW by the time of first operation of LBNF"

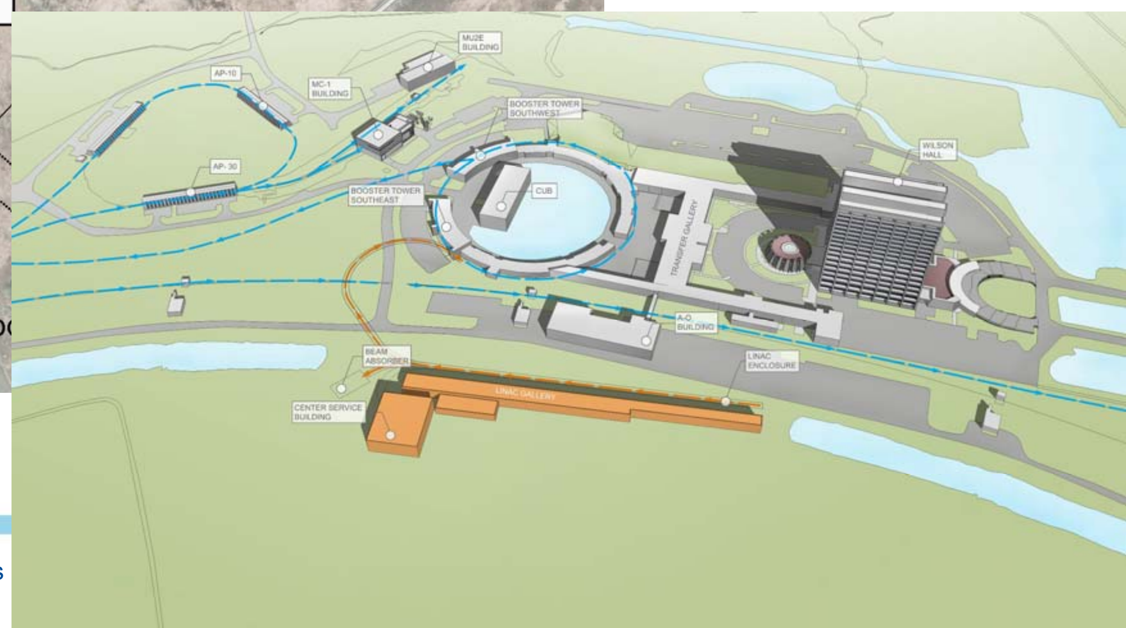
- PIP-II will allow Fermilab to maintain the lead with the most powerful neutrino beam in the world
- R&D for PIP-II is well along…India/DAE major partner
- CD-0 review scheduled in June

India Collaboration…is working extremely well

- Annex I signed ($200M)…..accelerator agreement
- Recent Siegrist/Lockyer trip to BARC
- We concluded India is in great shape with top engineers involved and world-class infrastructure installed & being used
- R&D deliverables being established with BARC director
  - Four India labs: VECC, IUAC, RRCAT, BARC
  - Two months we should be able to sign
- Strategy: build each type of dressed cavity (4) and one prototype of each cryomodule (2)…. and test
- Work well underway in India & Fermilab to reduce risk by end of FY18 for PIP-II

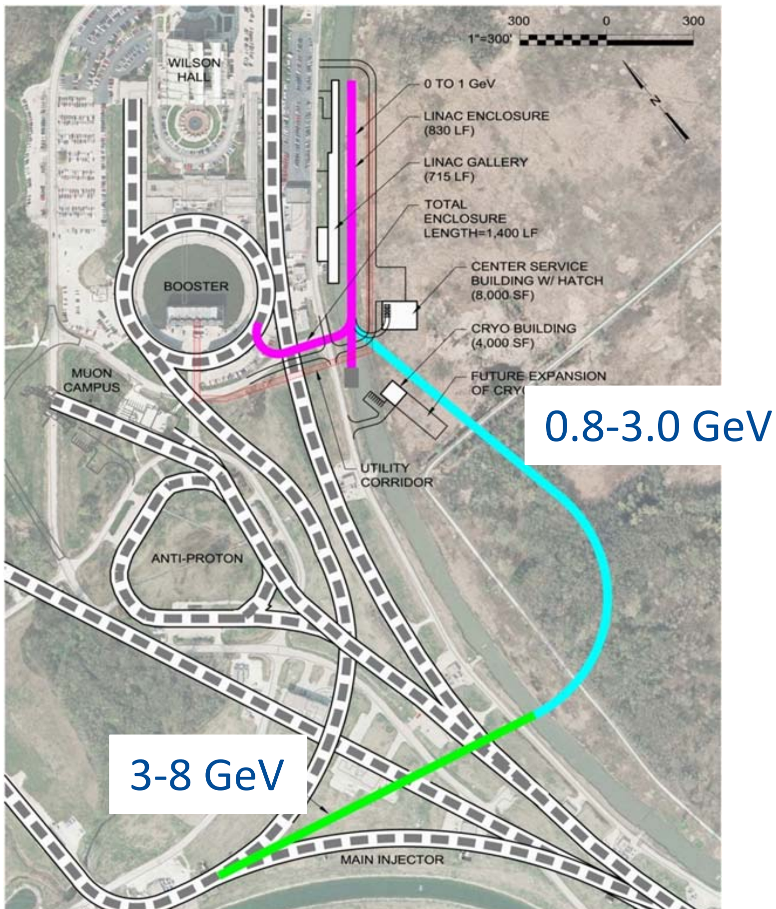
Proton Improvement Plan-II (PIP-II) Site Layout (provisional)

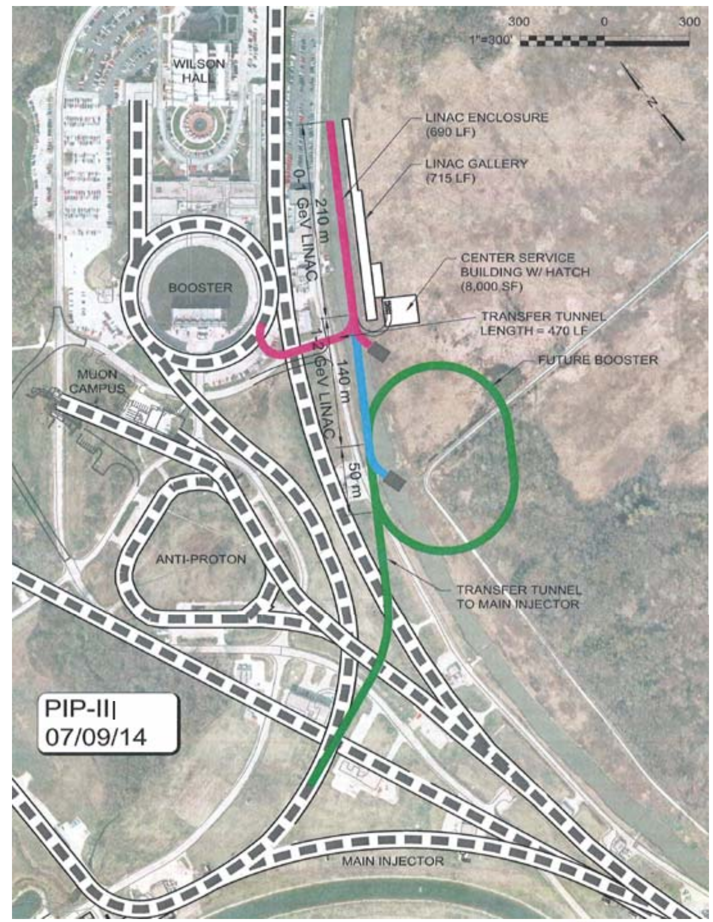




Flexible Platform for the Future (PIP-III)

- Opportunities for expansion include full energy (8 GeV) Linac or RCS





LBNF Beam Operating Parameters

Summary of key Beamline design parameters for ≤1.2 MW and ≤2.4 MW operation

Parameter	Protons per cycle	Cycle Time (sec)	Beam Power (MW)
≤ 1.2 MW Operation - Current Maximum Value for CD4			
Proton Beam Energy (GeV):			
60	7.5E+13	0.7	1.03
80	7.5E+13	0.9	1.07
120	7.5E+13	1.2	1.20

PIP-II

≤ 2.4 MW Operation - Ultimate Maximum Value LBNE Final Phase			
Proton Beam Energy (GeV):			
60	1.5E+14	0.7	2.06
80	1.5E+14	0.9	2.14
120	1.5E+14	1.2	2.40

PIP-III

Long-Baseline Neutrino Facility

Long-Baseline Neutrino Facility

A facility to enable a world-leading international program in neutrino physics, nucleon decay, and astroparticle physics.

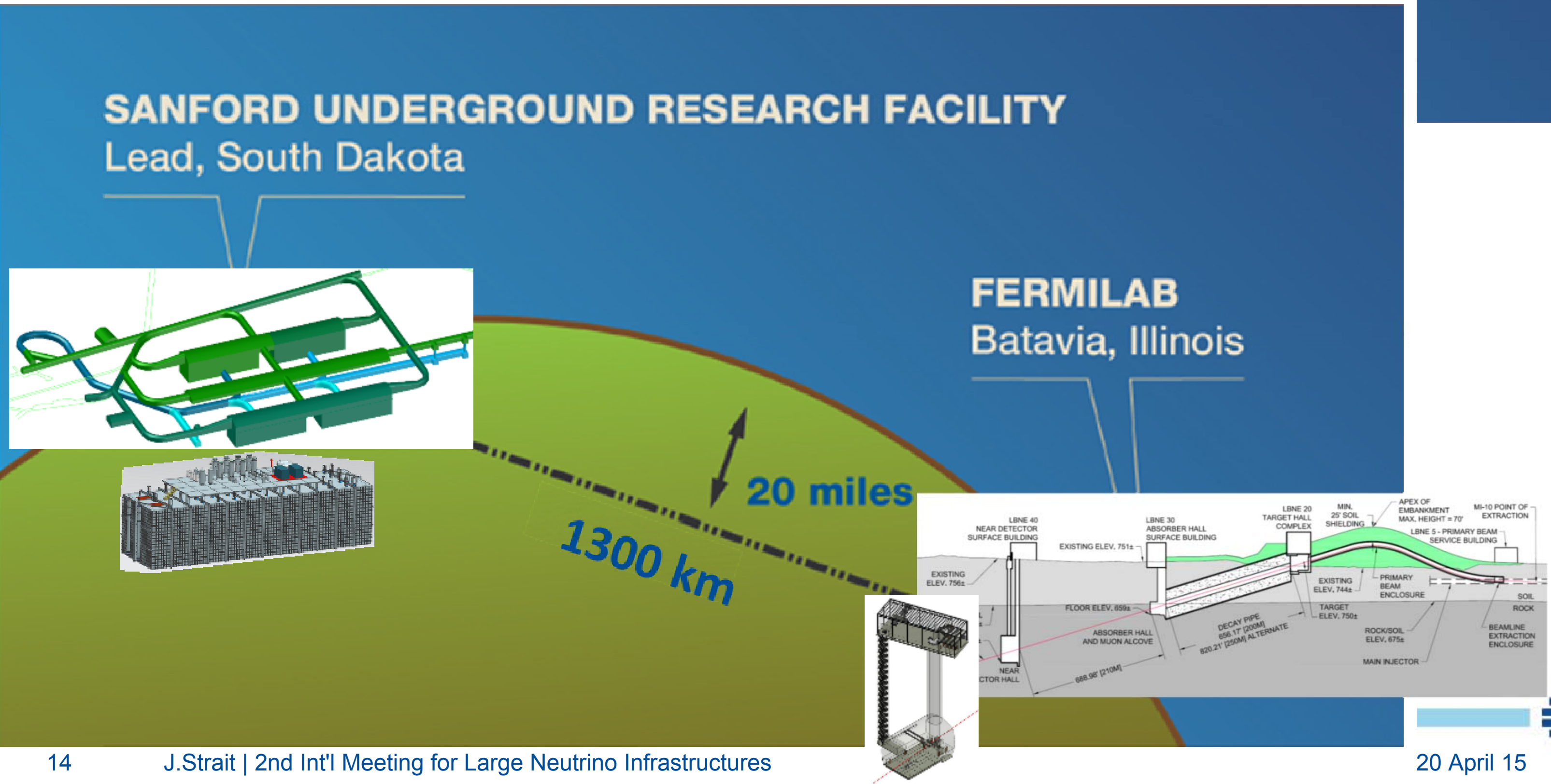
LBNF comprises:

- Underground and surface facilities at the Sanford Underground Research Facility capable of hosting a modular LAr TPC of 70 kt liquid mass (fiducial mass ≥ 40 kt)
- Cryostats, refrigeration and purification systems to operate the detectors
- A high-power, wide-band, tunable, ν beam at Fermilab
- Underground and surface facilities to host a highly-capable near detector at Fermilab … and potentially other non-oscillation neutrino experiments

All in the service of the detectors of the DUNE collaboration.

LBNF Overview

- LBNF is a DOE/Fermilab hosted project with international participation.
- Major partners include CERN and SURF.



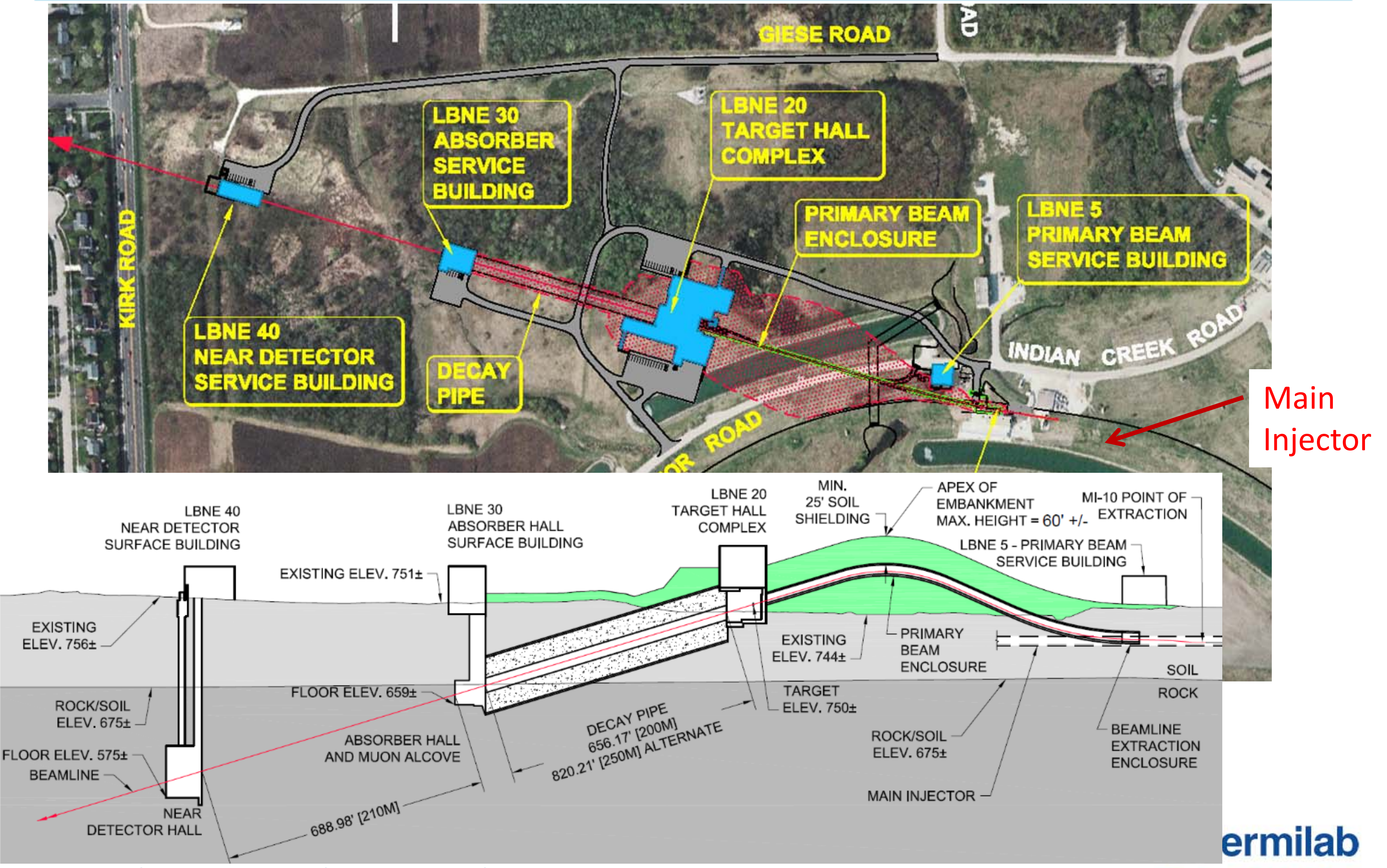
The LBNF Facilities Team

The designs shown here are being developed by the LBNF Project Team, working closely with the DUNE collaboration and other partners.

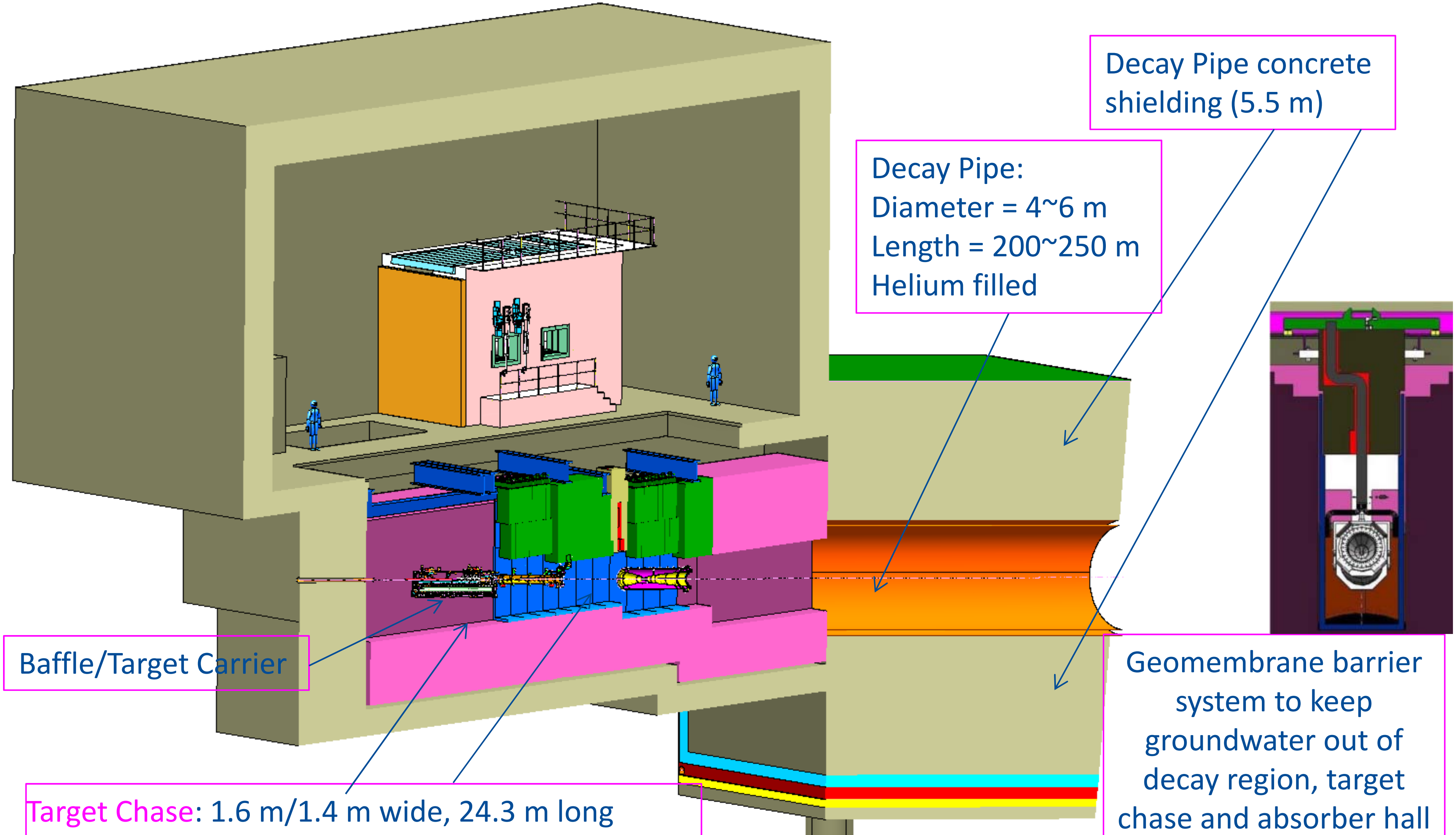
- Beamline: Fermilab with collaborations with UTA, RAL, RADIATE Collaboration, CERN, US-Japan Task Force, IHEP/Beijing, the former LBNO collaborators, and others.
- Conventional Facilities: Fermilab, SURF and contractors including those from the LAGUNA-LBNO design study
- Cryostat and cryogenic systems: Fermilab, CERN and LBNO-DEMO/WA105

LBNF Beamline and Conventional Facilities at Fermilab

Beamline for the Long-Baseline Neutrino Facility



Target Hall and Decay Pipe Layout



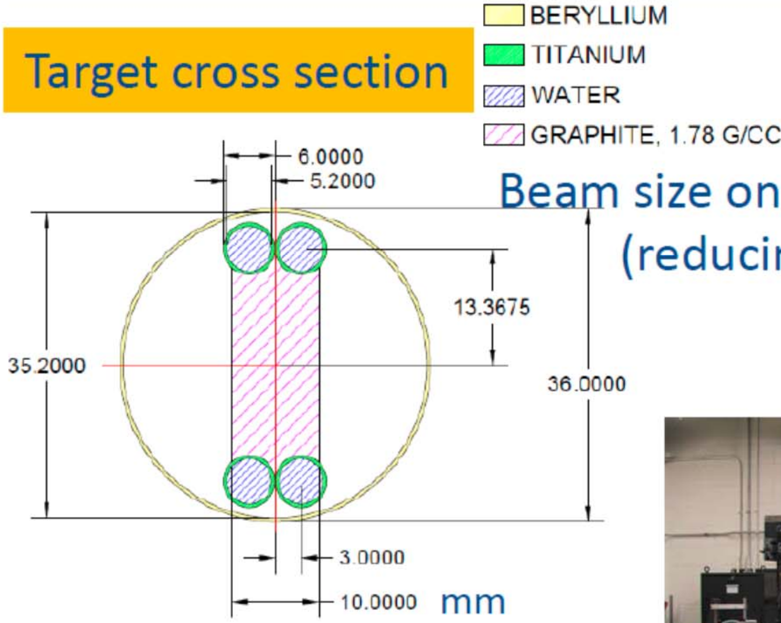
Target Chase: 1.6 m/1.4 m wide, 24.3 m long
Larger dimension, He or N_2 fill under consideration

Target/Horn System Development for 1.2 MW

47 graphite target segments, each 2 cm long

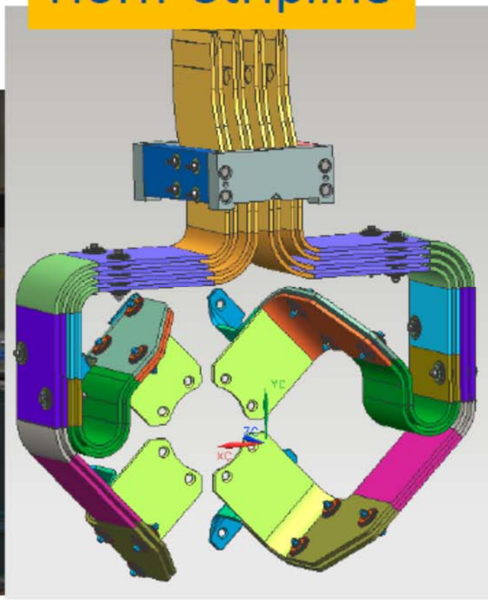
Baffle

Target cross section

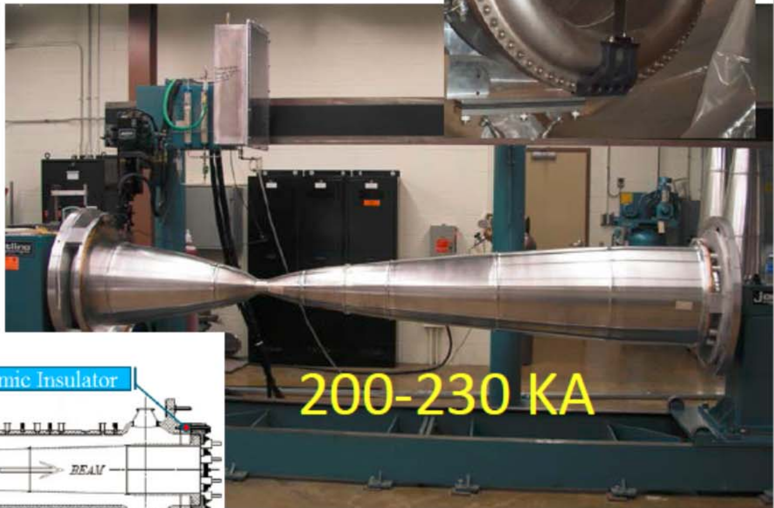


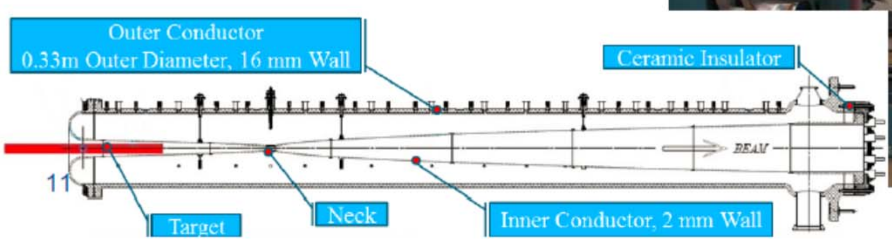
Beam size on target 1.7 mm
(reducing stress)

Horn Stripline



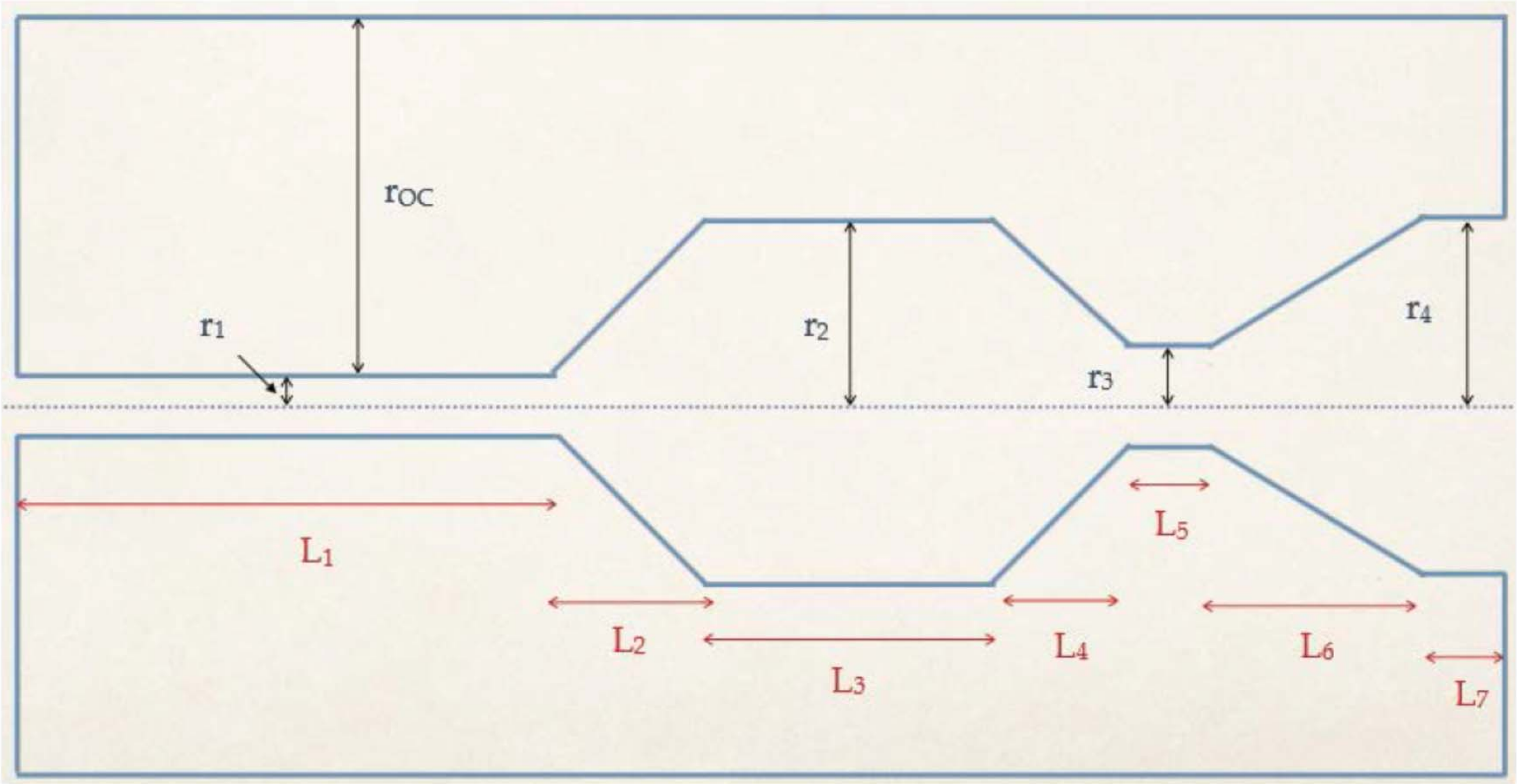
Horn





Improvements in the Focusing System

Horn 1 simulation using LBNO's opt. method
Horn 2 is NuMI shape

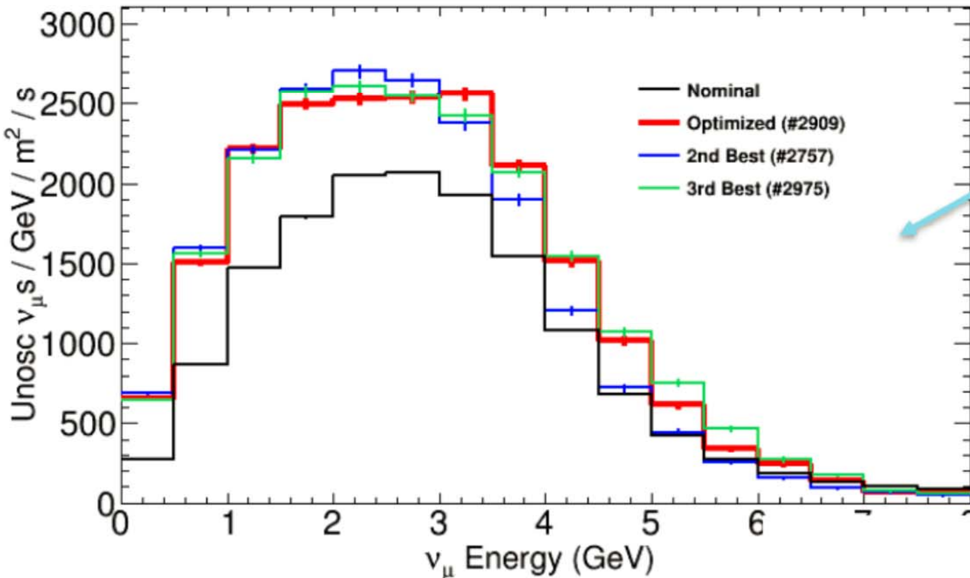


Optimized horn 1 is 5.1 m long

Neutrino Flux of best configurations compared with nominal (Optimized for 20 beam parameters)

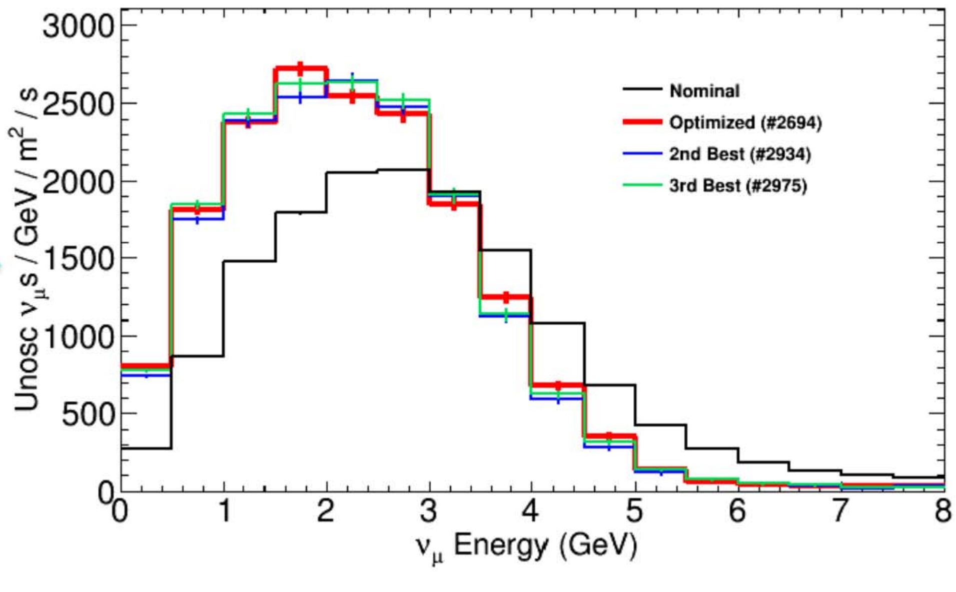
Muon neutrinos in neutrino running

Laura Fields

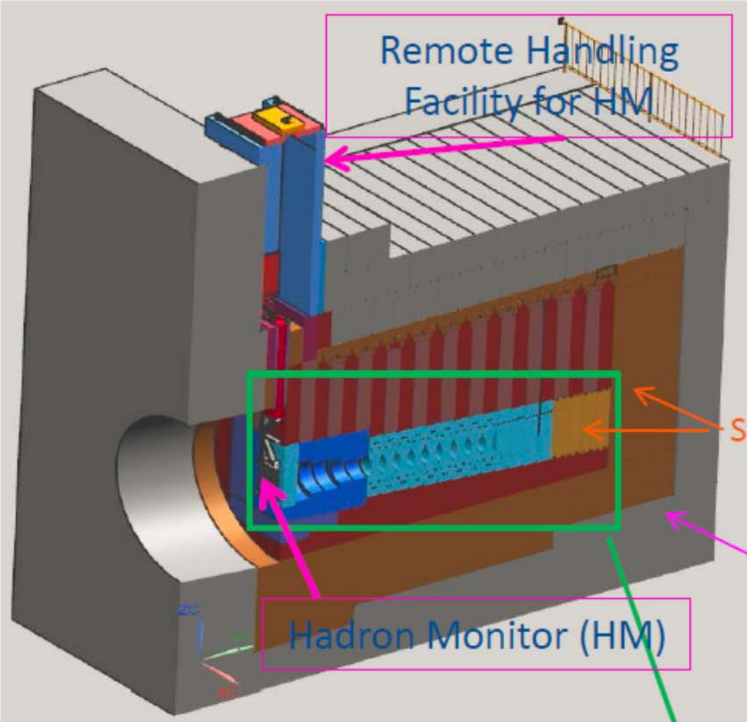


Optimizing Flux integrated between 1 and 4 GeV

Optimizing CP Sensitivity

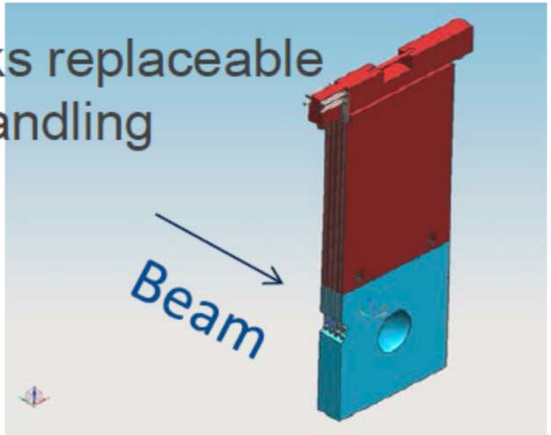


Current Configuration of Hadron Absorber

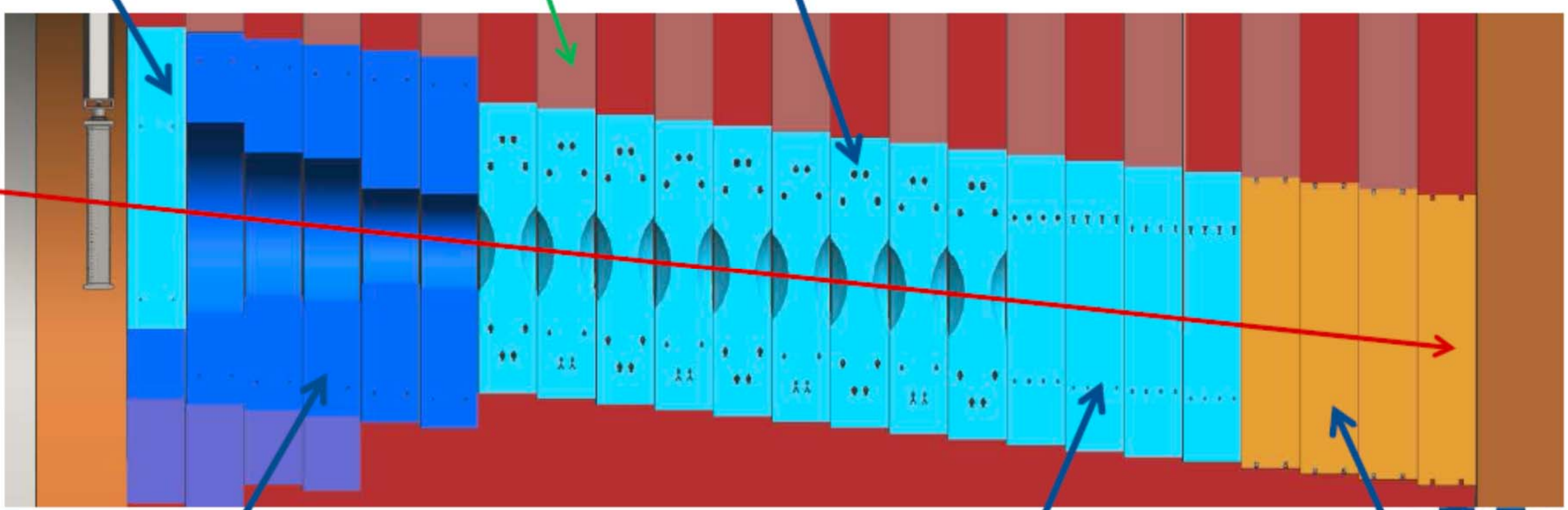


The Absorber is designed for 2.4 MW

- All core blocks replaceable via remote handling



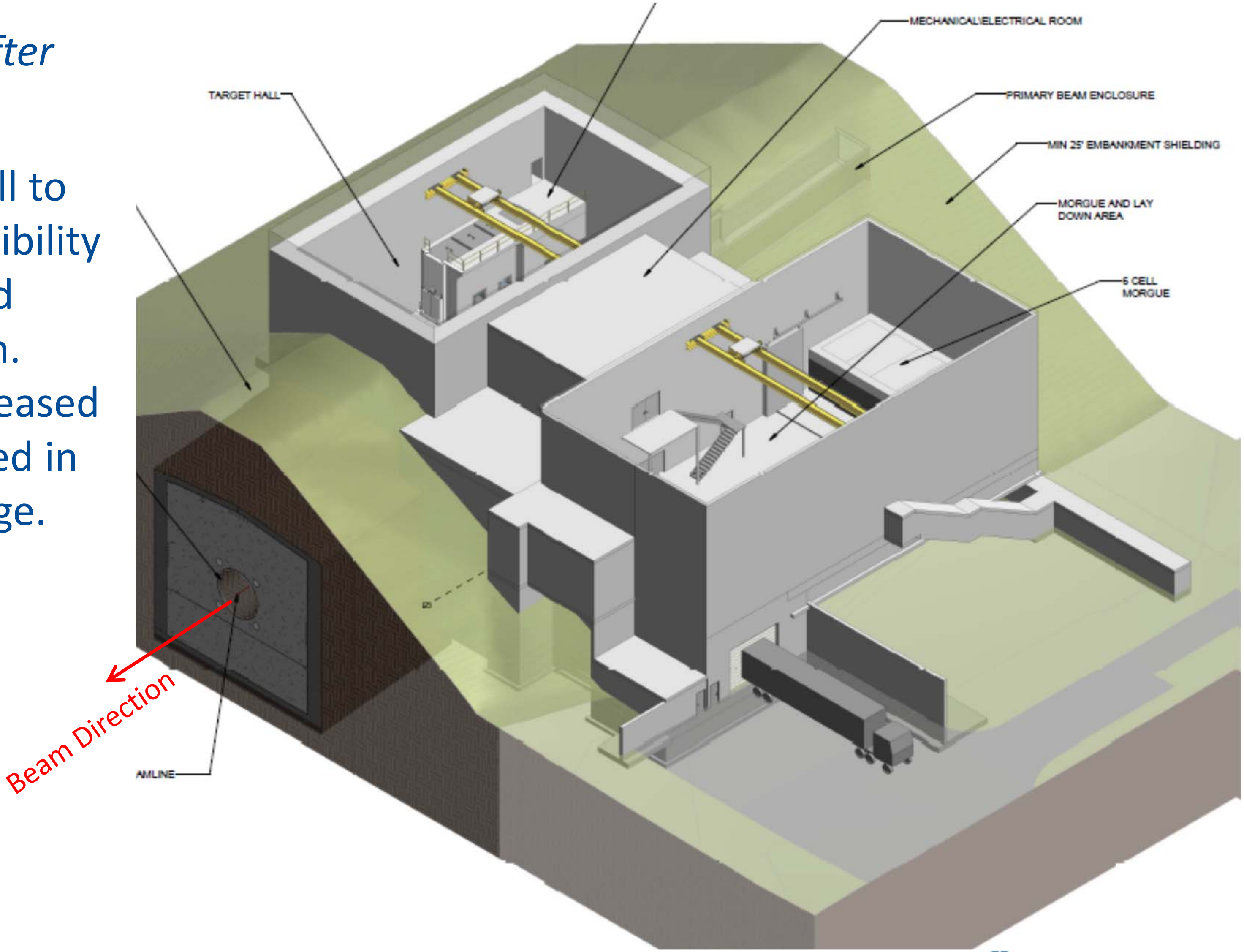
Sculpted Al block



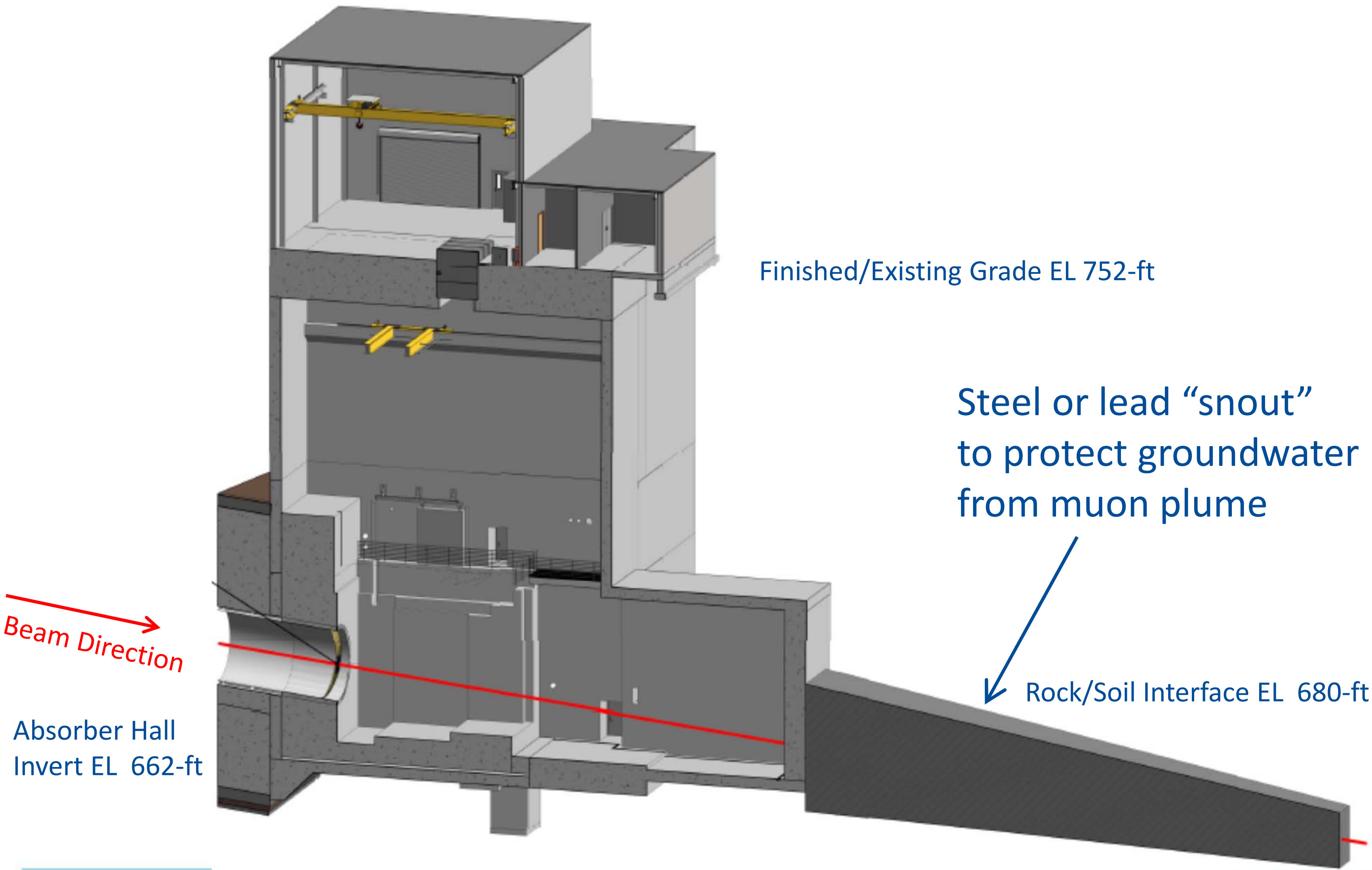
Target Hall Complex

To be developed after CD-1 Refresh:

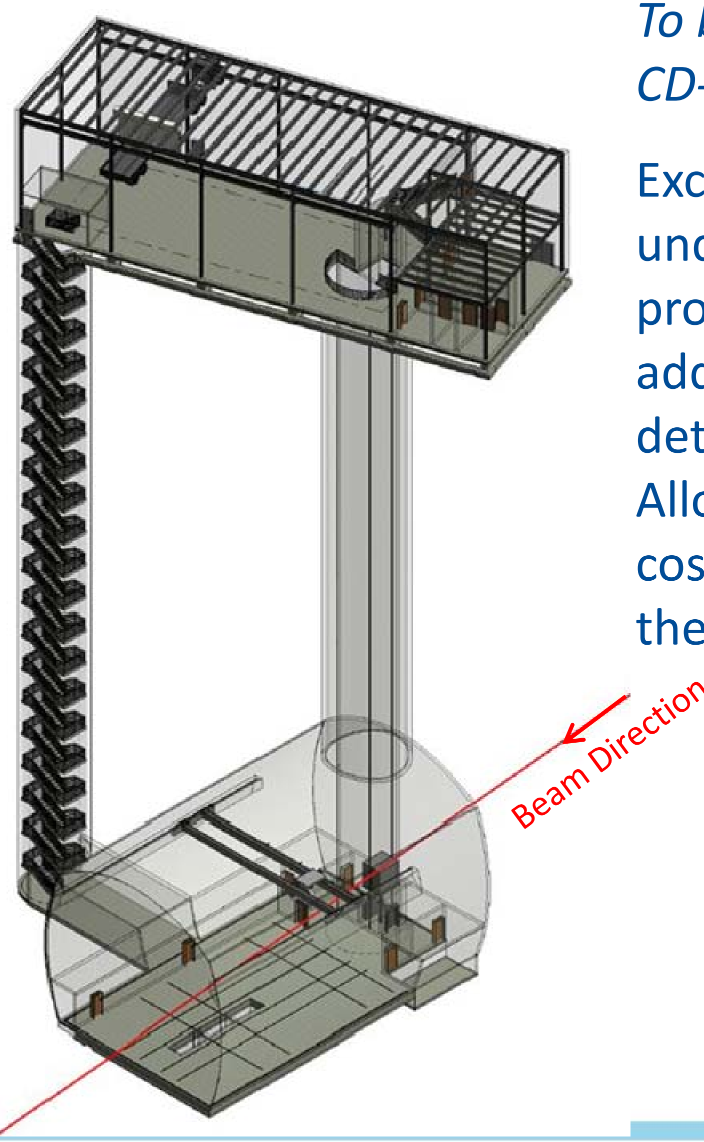
Enlarged target hall to provide future flexibility for more optimized target-horn system. Allowance for increased cost will be included in the CD-1 Cost Range.



Absorber Hall



Near Neutrino Detector Hall



To be developed after CD-1 Refresh:

Excavate ~x2 larger underground cavern to provide future facility for additional neutrino detector / experiment. Allowance for increased cost will be included in the CD-1 Cost Range.

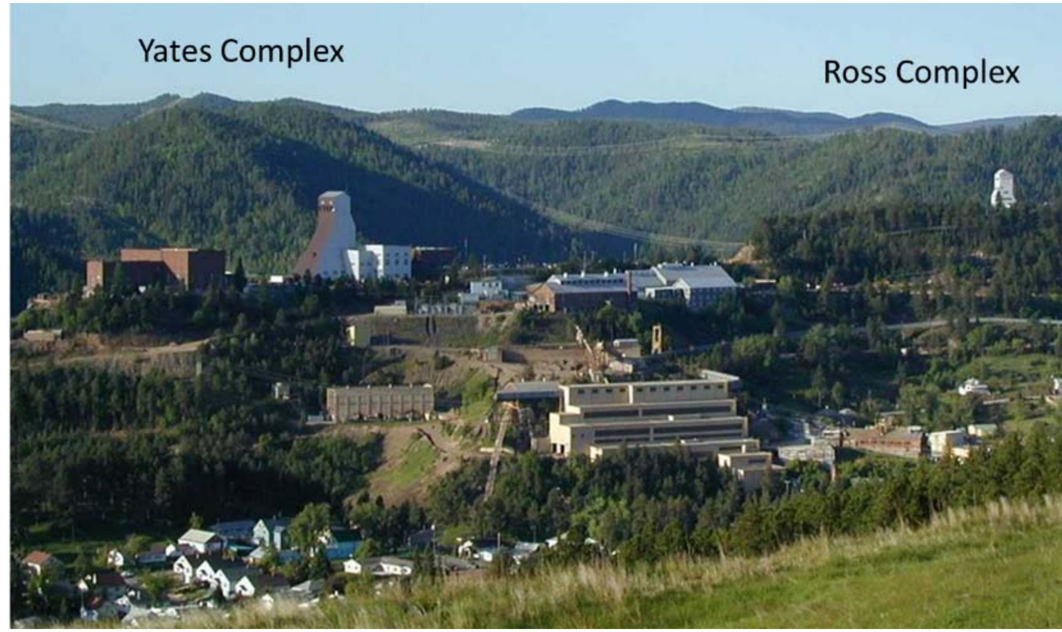
LBNF Conventional Facilities
at SURF

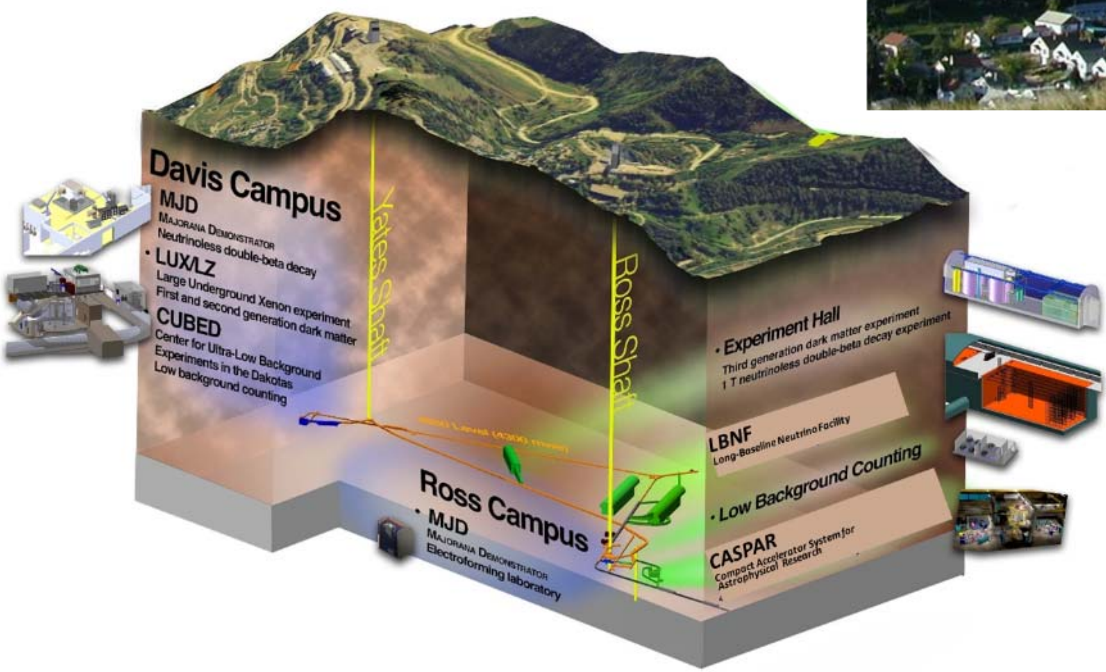
Sanford Underground Research Facility

Experimental facility operated by the State of South Dakota.

Current experiments:

- LUX (dark matter)
- Majorana ($0\nu\beta\beta$)
- Several smaller experiments





Future home of:

- LZ (G2 dark matter experiment)
- CASPAR (Compact Accelerator System for Astrophysical Research)
- DUNE-LBNF

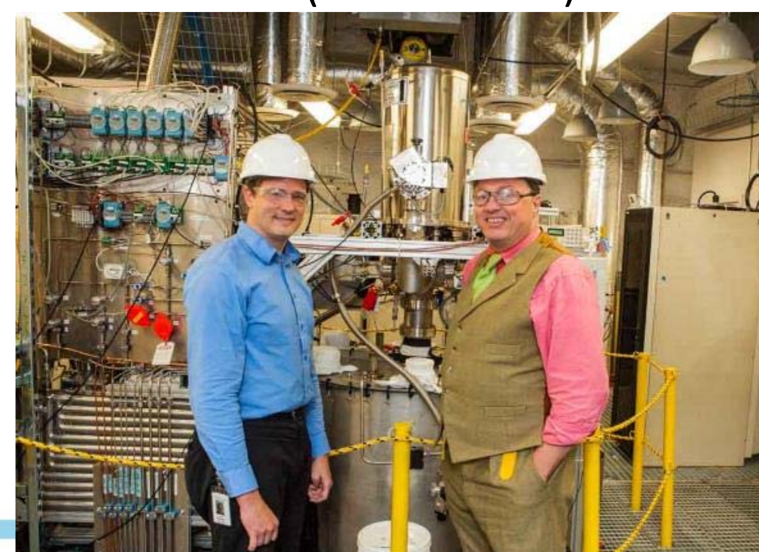
Sanford Underground Research Facility

Entrance to Davis Campus

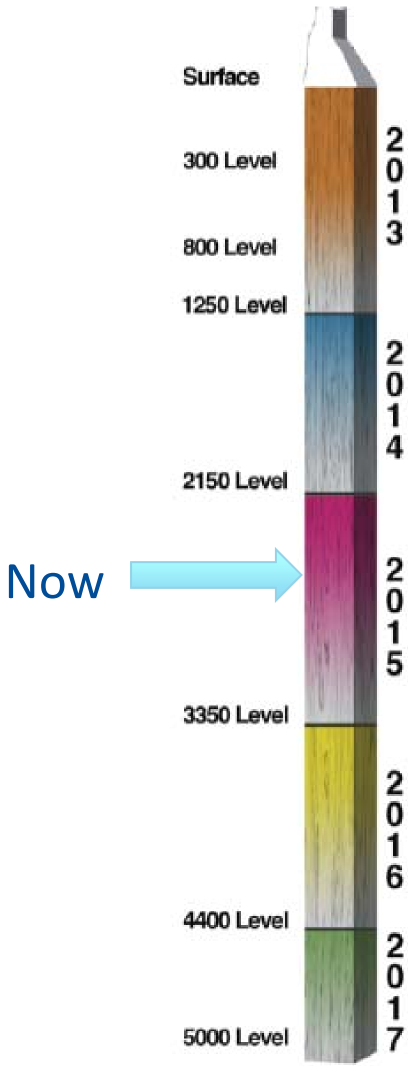
Majorana Demonstrator ($0\nu\beta\beta$)

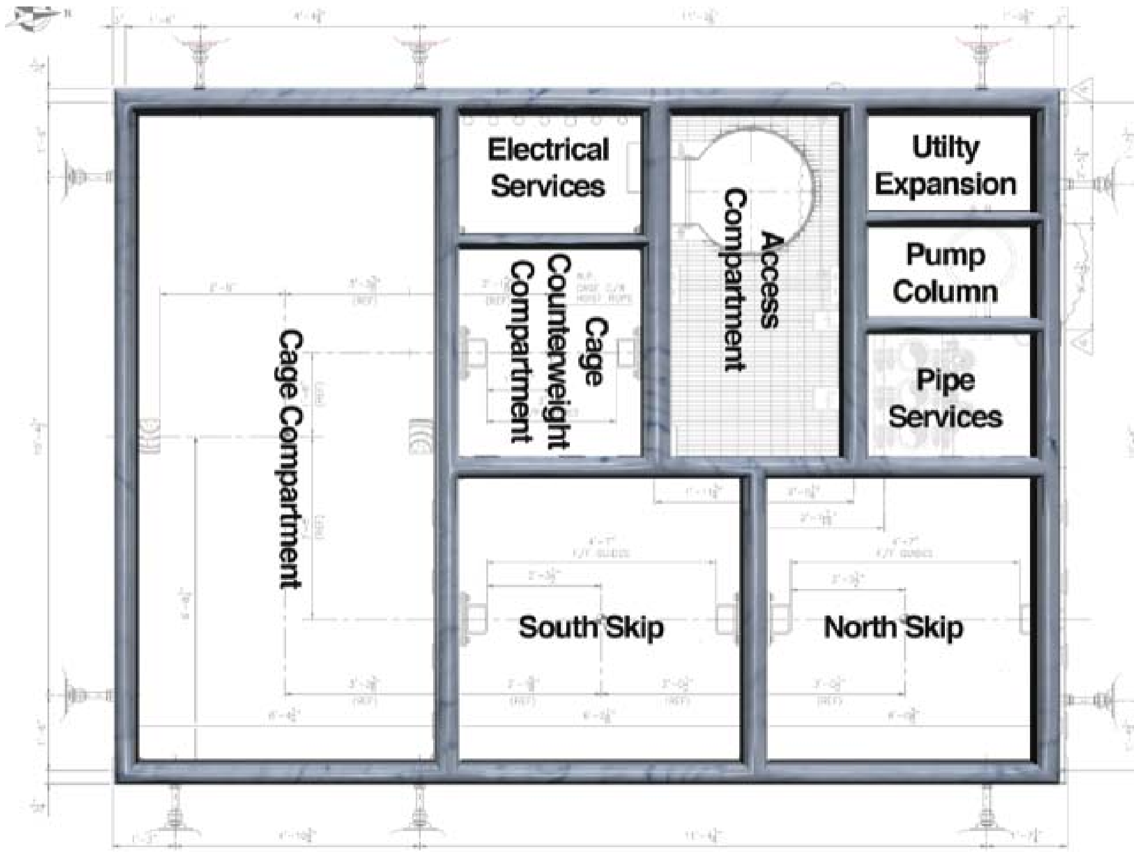
- Experimental Facilities at 4300 mwe
- Two vertical access shafts for safety
- Shaft refurbishment in process and is complete to the 2450 foot level
- Total investment in underground infrastructure is >$100M
- Facility donated to the State of South Dakota for science in perpetuity

LUX (dark matter)



Ross Shaft Rehabilitation

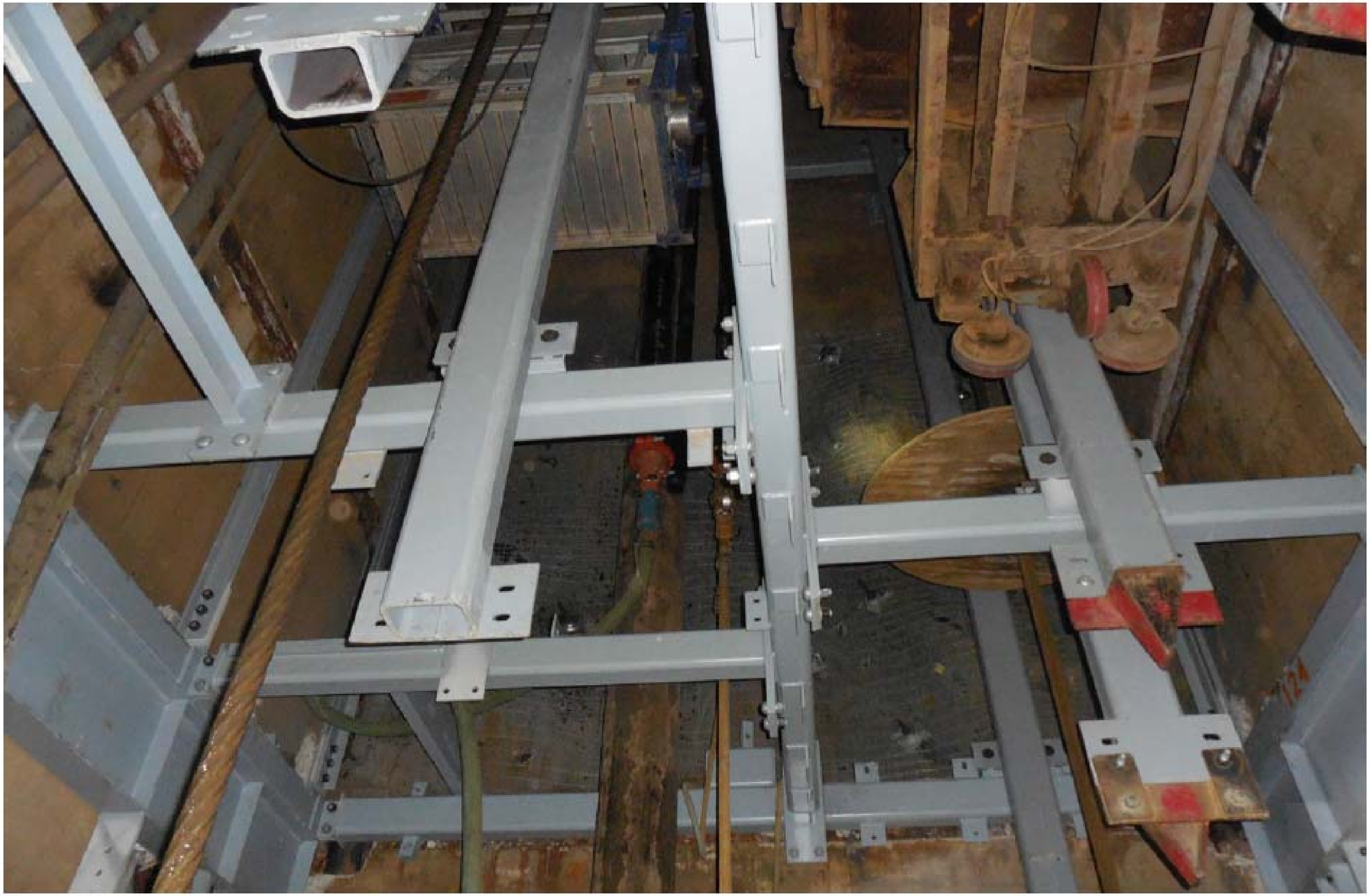




- Removing old steel (6' set spacing). Installing new ground support and ~6 million pounds of new shaft steel (18' set spacing)

From M. Headley Presentation Oct 8-10, 2014

Ross Shaft Refurbishment - Looking up at Set 124
(2,087 feet or 636 meters)

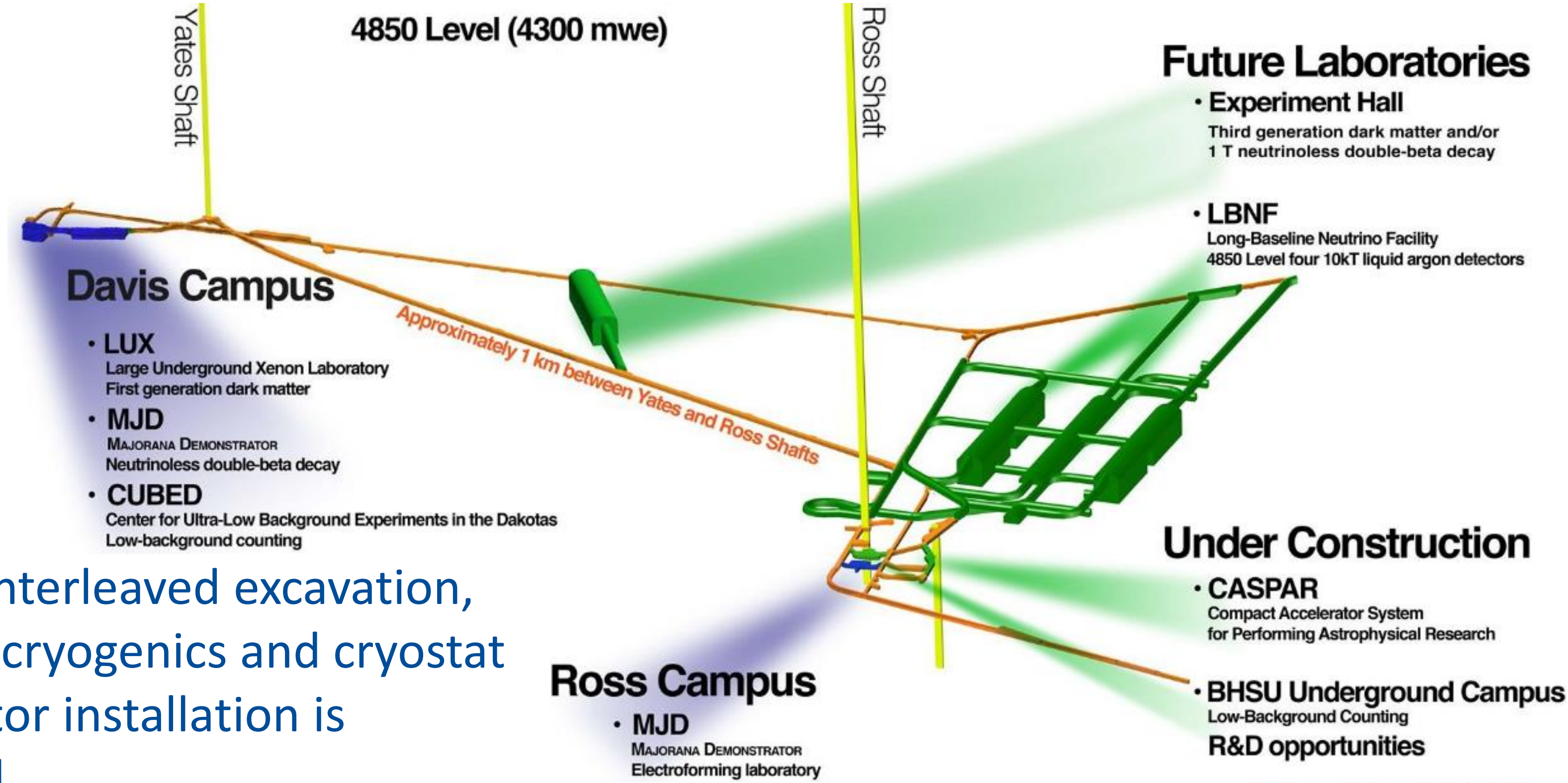


From M. Headley Presentation Oct 8-10, 2014

Planned Location of LBNF Caverns

Reference design:

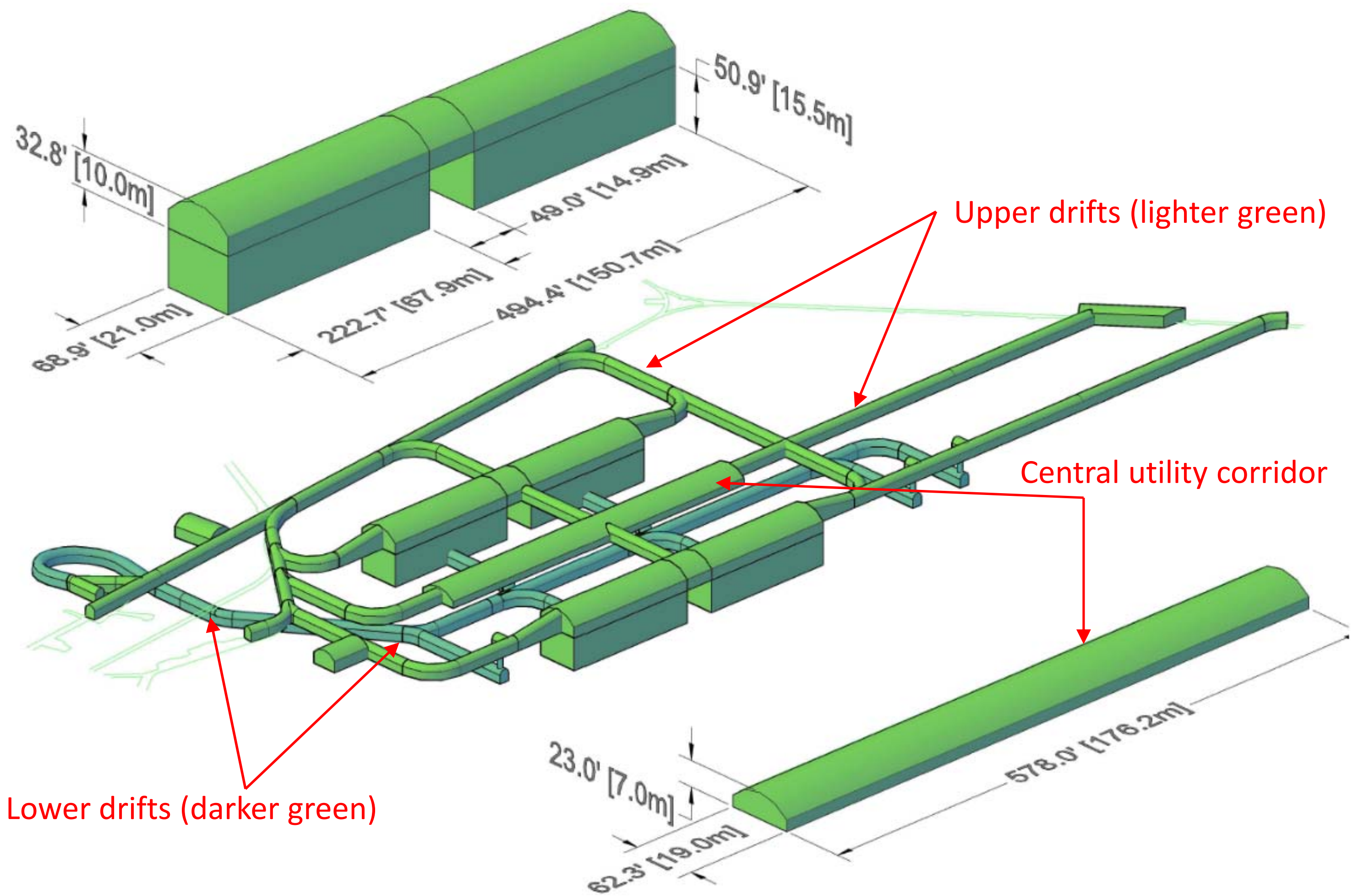
- Rectangular caverns
- 4 caverns, each to hold a 10 kt fiducial mass detector
- Central utility cavern to house cryogenic equipment and common utilities



- Potential interleaved excavation, outfitting, cryogenics and cryostat and detector installation is envisioned.

New Far Detector Cavern Layout developed by the DUNE-LBNF Team

Four LAr detector caverns, central utility corridor, connecting drifts for excavation, equipment access and ventilation.



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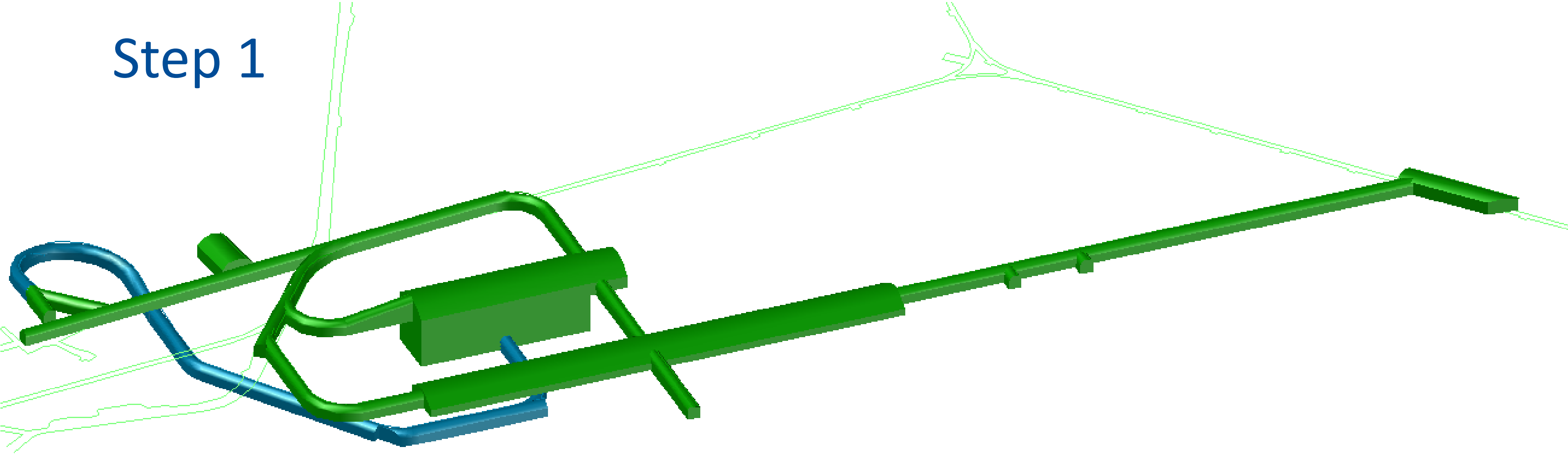
Far Detector Caverns: Excavation Steps

Breaking the work into carefully considered steps will be critical to separate dirty activities (excavation) from clean activities (cryostat and detector installation)

Step 1



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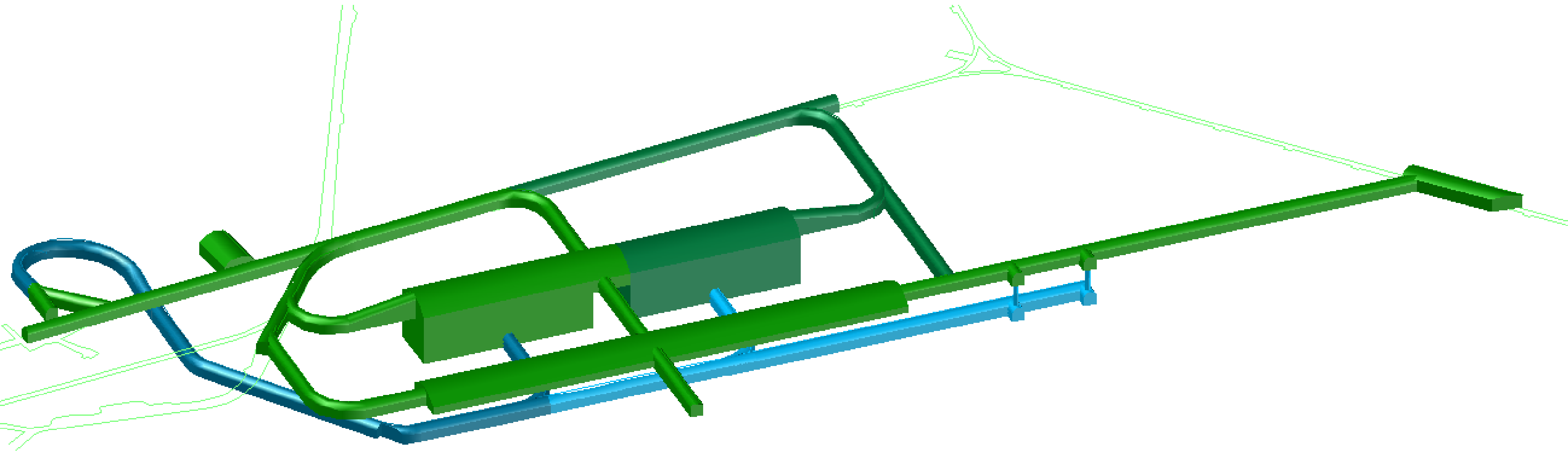
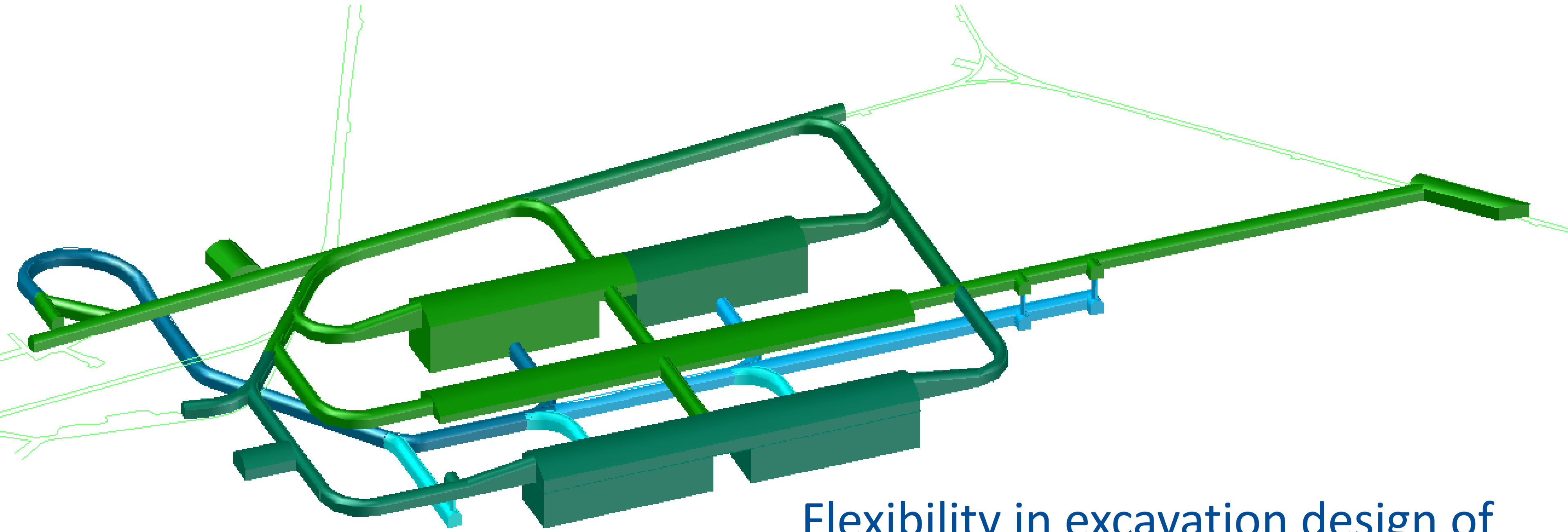
Far Detector Caverns: Excavation Steps

Step 2



Far Detector Caverns: Excavation Steps

Step 3



Flexibility in excavation design of caverns 3 and 4 to accommodate detector design evolution

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LBNF Cryogenic Systems at SURF

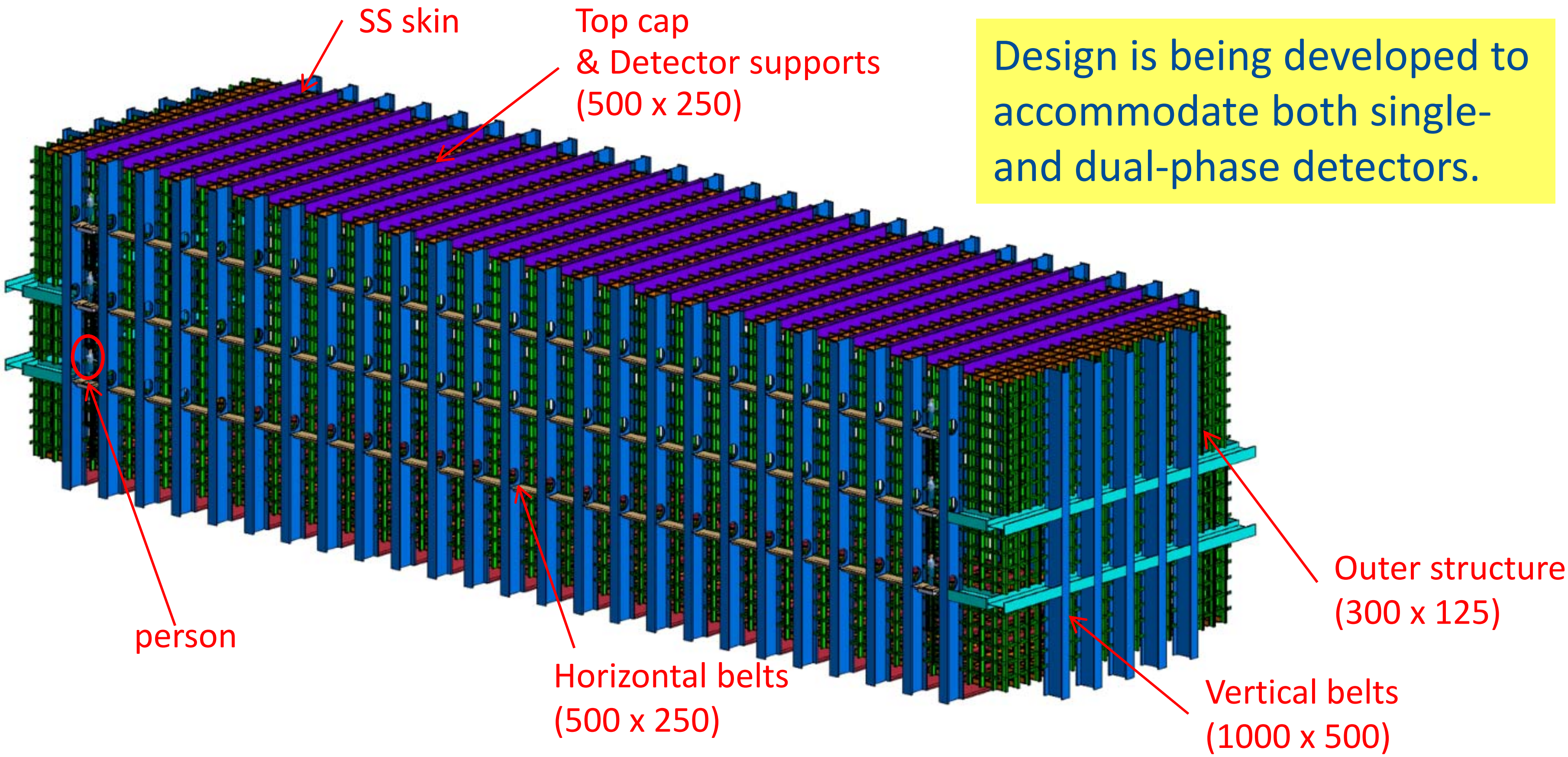
Steel-Frame Membrane Cryostat

Design being developed by CERN

Inner dimension (liquid+gas):
- **L = 62.00 m**
- **W = 15.10 m**
- **H = 14.00 m**

LAr = 17'432 tons (95% liquid)

Design is being developed to accommodate both single- and dual-phase detectors.



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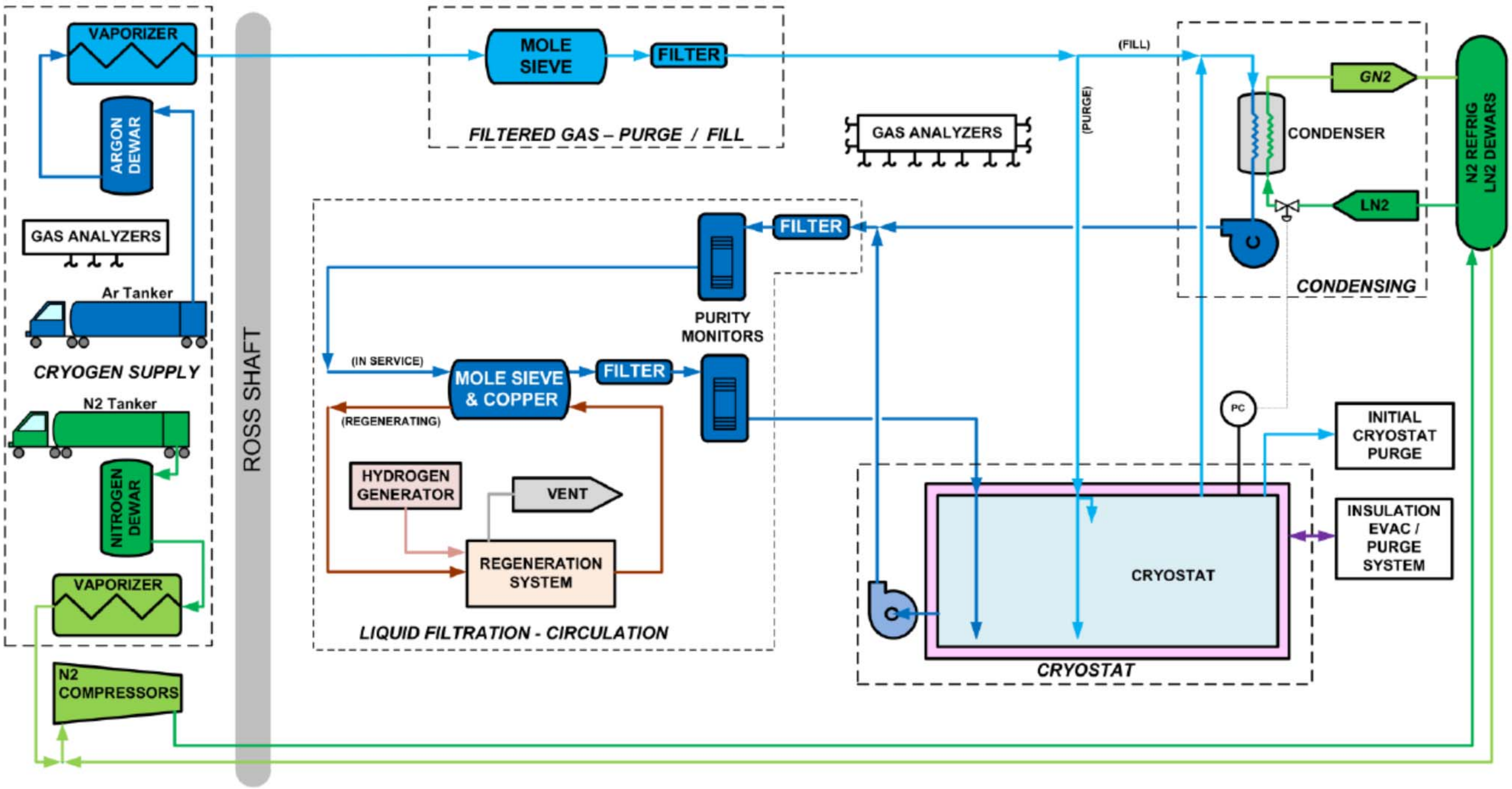
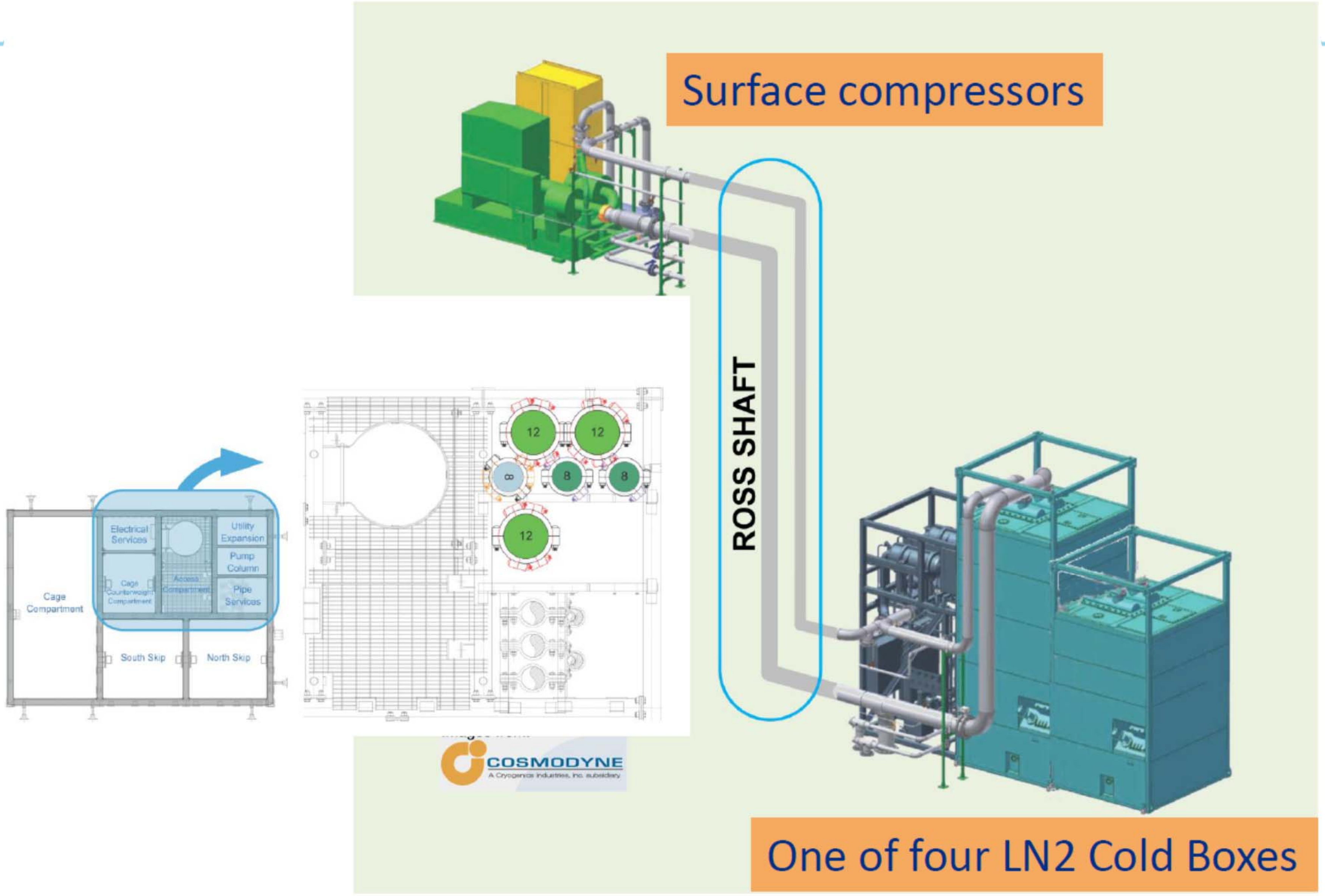
Scale of 1 cryostat … Building 156 at CERN

Cryogenic System

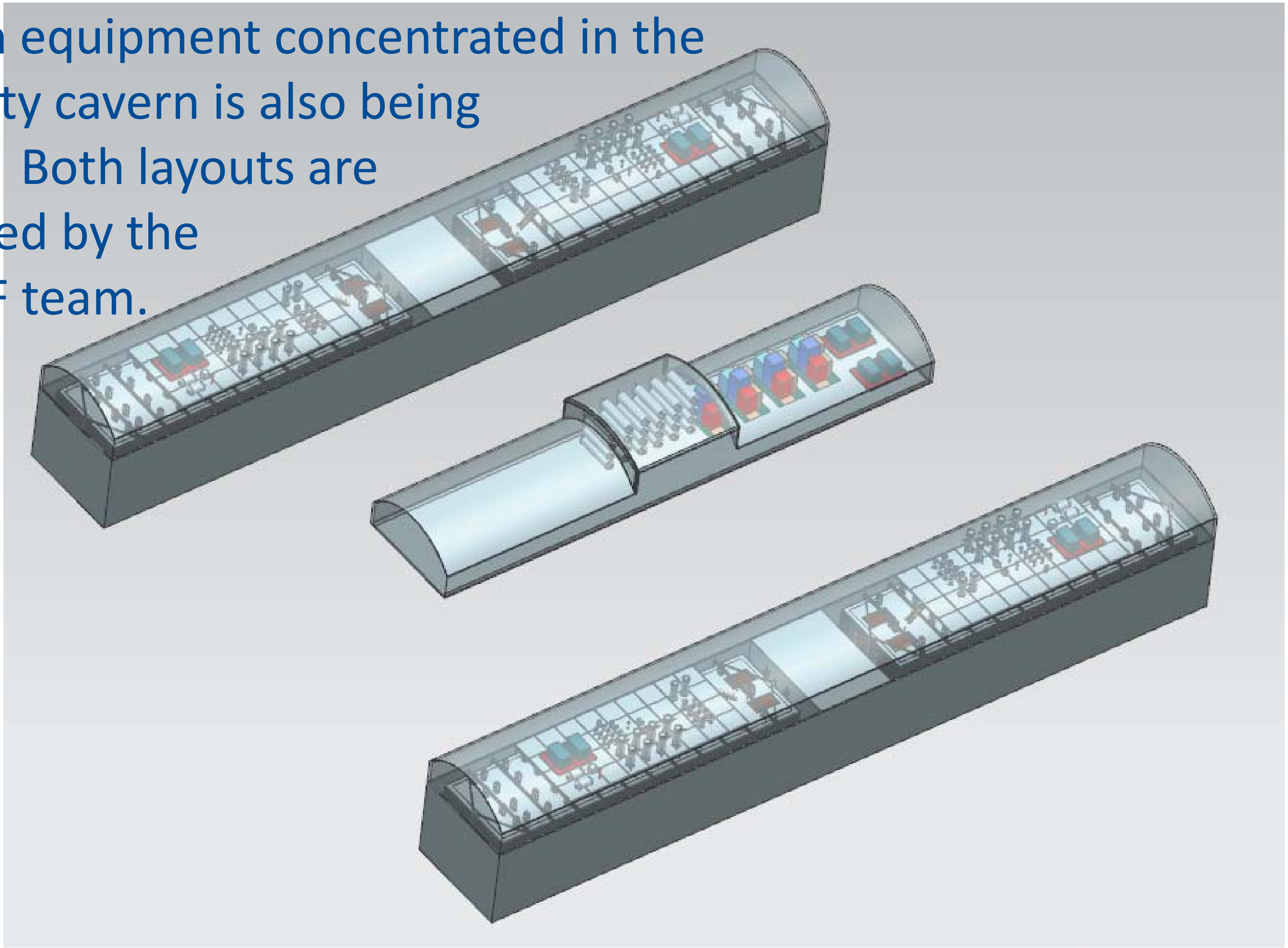


Potential GN2/LN2 Cycle with Ross Shaft Vertical Pipe Run



Possible Layout of Cryogenic Systems in the Caverns

Layout with equipment concentrated in the central utility cavern is also being developed. Both layouts are being studied by the DUNE-LBNF team.



DUNE - LBNF Schedule

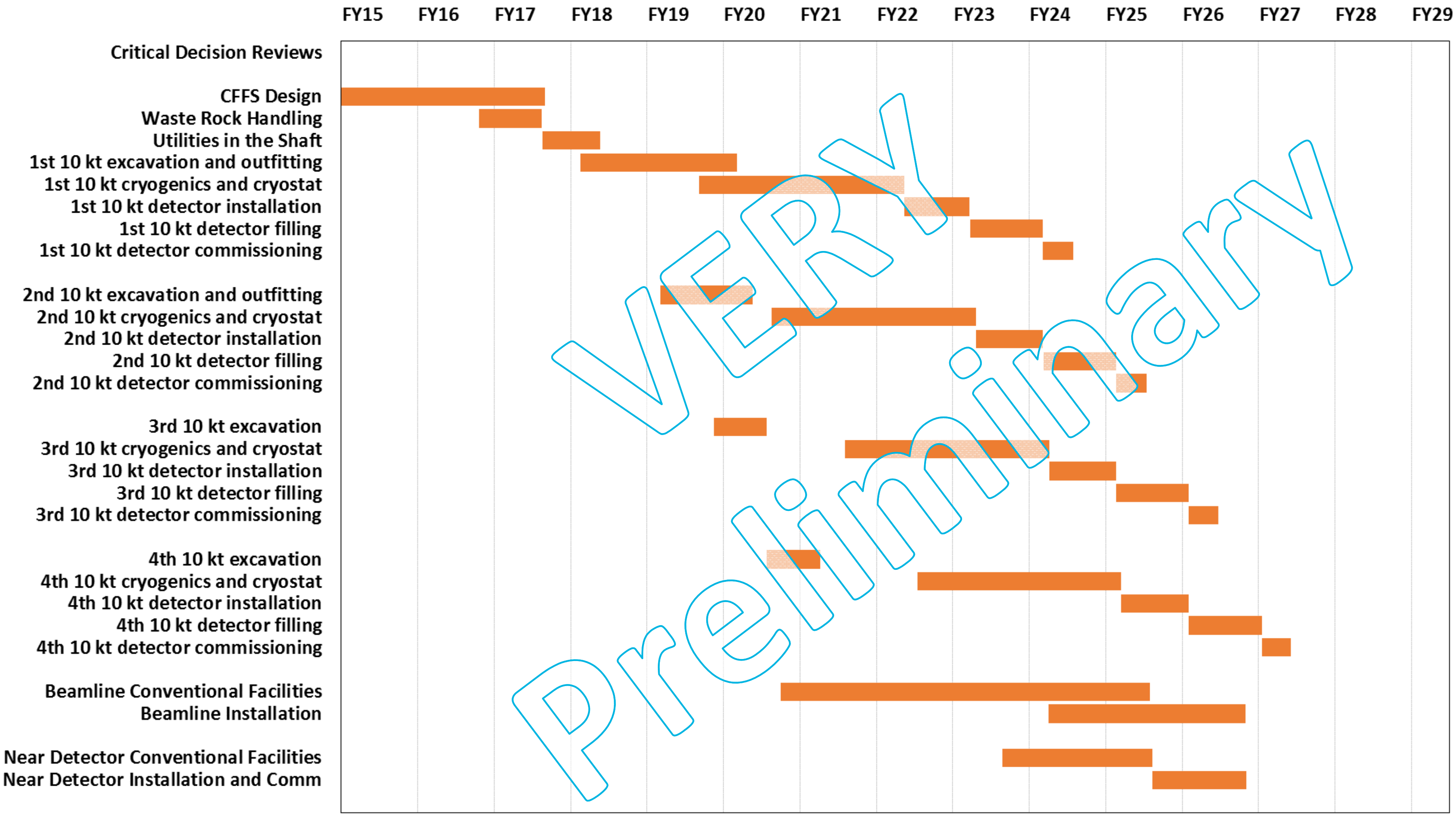
Schedule

Schedule Goals set in the LOI submitted to the Fermilab PAC

> The new international team has the necessary expertise, technical knowledge, and critical mass to design and implement this exciting discovery experiment in a relatively short timeframe. The goal is the deployment of the first 10-kt fiducial mass detector on the timescale of 2021, followed by future expansion to the full detector size as soon as possible. The PIP-II accelerator upgrade at Fermilab will provide 1.2 MW of power by 2024 to drive a new neutrino beam line at Fermilab. There also exists a plan that could further upgrade the Fermilab accelerator complex to enable it to provide up to 2.4 MW of beam power by 2030.

- A project plan is being developed to try to meet them as closely as possible, subject to both on technical limitations and funding.
- Break the project into pieces which can be implemented in a sequence determined by the scientific strategy:
  - Far detector in 10 kt fiducial mass modules
  - Neutrino Beam
  - Near Detector

Possible Schedule: DUNE + LBNF



Actual schedule will depend on funding profile not yet provided by DOE and on partner agreements and their schedules to deliver their parts of the two projects.

DOE Reviews

DOE is very supportive of the aggressive schedule goals

- Excavation of the caverns for the far detector starting in 2017
- Initial 10 kt detector operating as soon as possible.

To support the funding required, DOE has called for a “CD-1 Refresh” review in July for the whole LBNF + DUNE enterprise...

- New / updated CDR and other technical documents incorporating designs and alternatives from all DUNE/LBNF partners.
- New / updated cost and schedule estimates.
- New / updated management plans and related documents

... and a CD-2a/3a review in November for the far site facilities.

- CD-2a: Project baseline (TDR-level) for this part of the project.
- CD-3a: Authorization to begin construction at the far site when funds become available.

Summary

- The designs of all elements of LBNF are advancing rapidly
  - Far site conventional facilities, cryostats and cryogenic systems for a phased implementation of the DUNE far detector
  - Beamline and supporting facilities for a high-power, broad-band neutrino beam. Options to increase its capability and flexibility are under consideration.
  - Facilities for the DUNE near detector with the option to make a hall large enough to accommodate future expansion or another neutrino experiment
- Preparation for the CD-1 Refresh review and subsequent CD-2a/3a for the far site facilities are moving quickly, but there is much yet to do.