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

LBNF update & progress for CD-1

Jim Strait/Elaine McCluskey

LBNC Meeting

19 April 2015

LBNF Scope Summary for CD-1 Refresh

1) Neutrino beamline and supporting facilities

- The beamline reference design largely follows LBNE design as it stands now.
- All systems are designed for initial 1.2 MW beam power
- All systems which cannot be replaced later are designed for 2.1 - 2.4 MW beam power in the proton energy range 60 - 120 GeV respectively, per the expected operating parameters of the Fermilab accelerator complex.
- NuMI-style horns and target, with R&D towards a more optimized configuration of target and focusing system; associated cost of R&D and possible better target and focusing system to be included in the cost range but not the base cost.
- LBNE-design target hall is the reference design. Scope increase options include changing the atmosphere of the target pile from air to a different gas (e.g helium or nitrogen). Increasing the size of the target chase and associated shielding to provide flexibility for more capable focusing systems in the future is highly desirable and will be studied and implemented if possible between CD-1 and CD-2. The associated cost increments are to be included in the cost range but not the base cost
- 4 m diameter, 204 m long helium-filled decay pipe; scope increase option to increase diameter up to 6 m with associated cost increment included in the cost range but not the base cost.
- Primary proton beamline tunable between 60 and 120 GeV

LBNF Scope Summary for CD-1 Refresh

2) Near Detector facilities

- The near detector facilities are sized for the reference design near neutrino detector (fine-grained tracker based on that in the Indian Detailed Project Report). The base cost and schedule estimate of the facility will be based this reference design.
- A scope increase option is to increase cavern length (excavation only) by ~x2, which would allow for future expansion either for a second near detector or for a yet-to-be proposed separate experiment. The additional excavation cost would be included in the cost range but not the base cost.

LBNF Scope Summary for CD-1 Refresh

3) Far site facilities

- The full scope of the far detector is a total 40 kt (fiducial) LAr-TPC, implemented as four separate 10 kt fiducial mass (~17.5 kt liquid mass) modules. *The CDR and RLS will be presented for the full scope. The part that will be presented for CD-2a/3a will be clearly specified.*
- The cavern layout consists of two detector caverns pairs, each with two independent 10 kt sized detector pits and a common laydown area between them, and a central utility cavern between the two detector cavern pairs.
- The detectors are housed in four nominally identical steel-frame membrane cryostats, with a volume of approximately 13×10^3 m^3 each.
- The refrigeration system consists of with four cold boxes (underground) and four compressors (on the surface).
- Purification systems and LN2 storage for backup cooling are provided for each detector module.
- Cryostat and cryogenic system for the singe-phase prototype test at CERN are included in the CDR and RLS.

Costs presented in the RLS

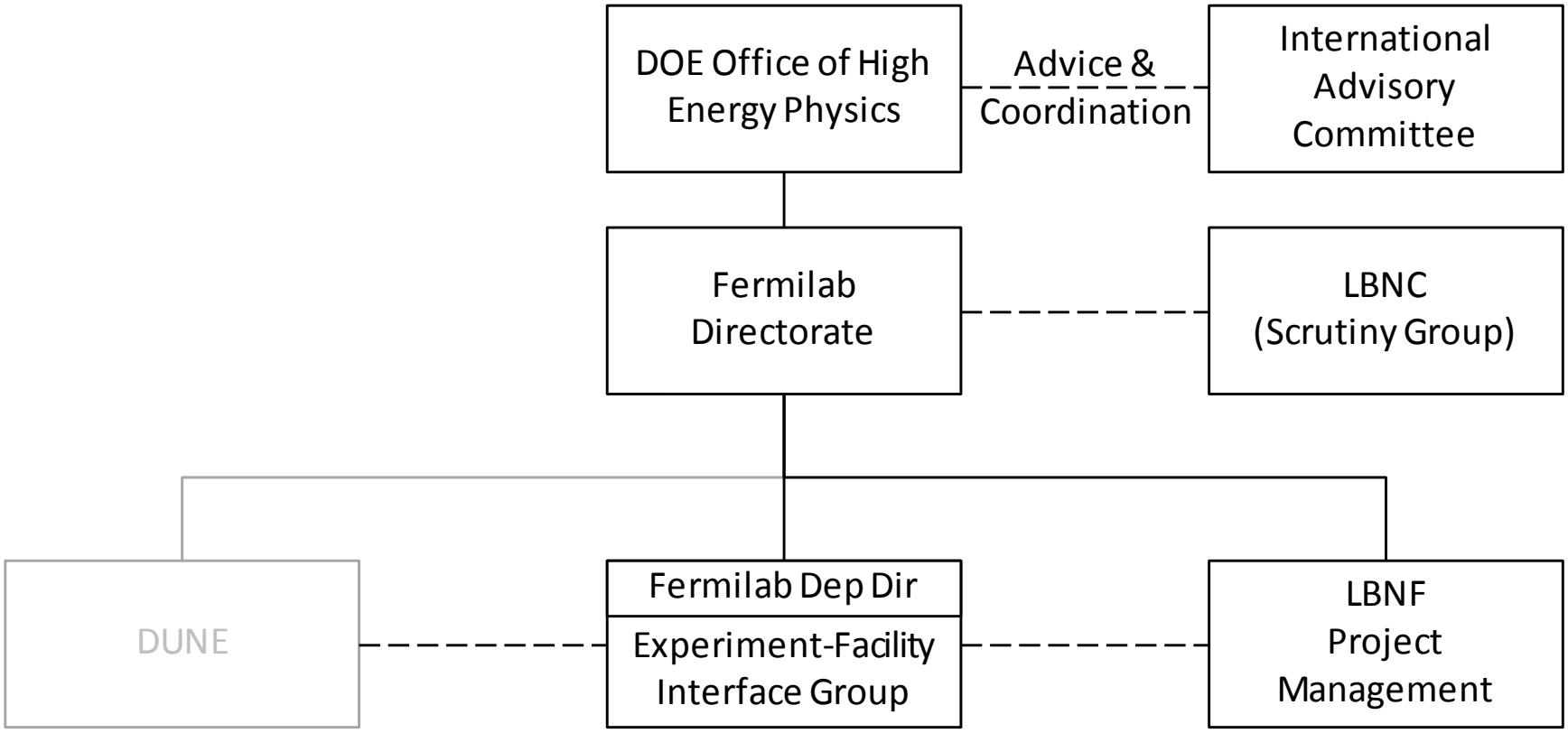
- Cost for the entire LBNF scope will be presented in CORE cost units
- Costs will be assigned to DOE or other funding sources at an appropriate level in the WBS and RLS
- Cost for the elements assigned to DOE will also be presented in standard DOE Total Project Cost accounting

LBNF Scope summary for CD-2a/3a

3) Far site facilities

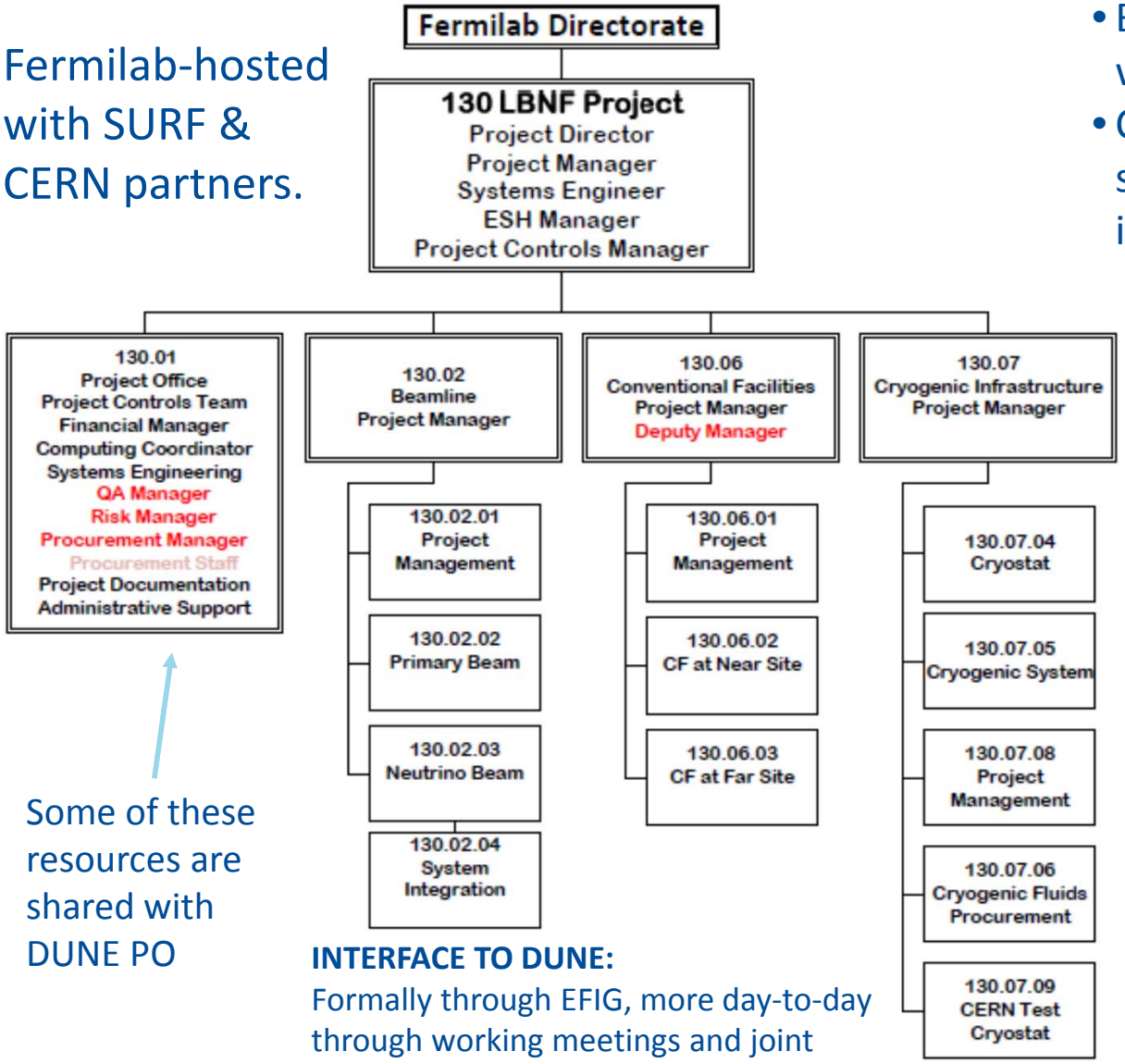
- Excavation of all caverns and drifts is included in the CD-2a/3a scope.
- Two cryostats are included in the CD-2a/3a scope.
- Three cold-box / compressor sets and all of the cryogenic piping between the surface and underground are included in the CD-2a/3a scope.
- Purification systems and LN_2 storage for backup cooling are provided for two detector modules in the CD-2a/3a scope.

International Governance Model (as we understand it)



LBNF WBS and Organization

Fermilab-hosted with SURF & CERN partners.



Some of these resources are shared with DUNE PO

INTERFACE TO DUNE:
Formally through EFIG, more day-to-day through working meetings and joint management team of both projects

- Project Office is largely Fermilab team that includes BNL.
- Beamline & CF team all Fermilab with SURF support.
- Cryo Infrastructure management still evolving with increasing CERN involvement.
  - Cryo Fluids may move to Common Fund, with responsibility for oversight and procurement TBD. Scope, cost, schedule, & management presently in LBNF.

FUNDING ASSUMPTIONS

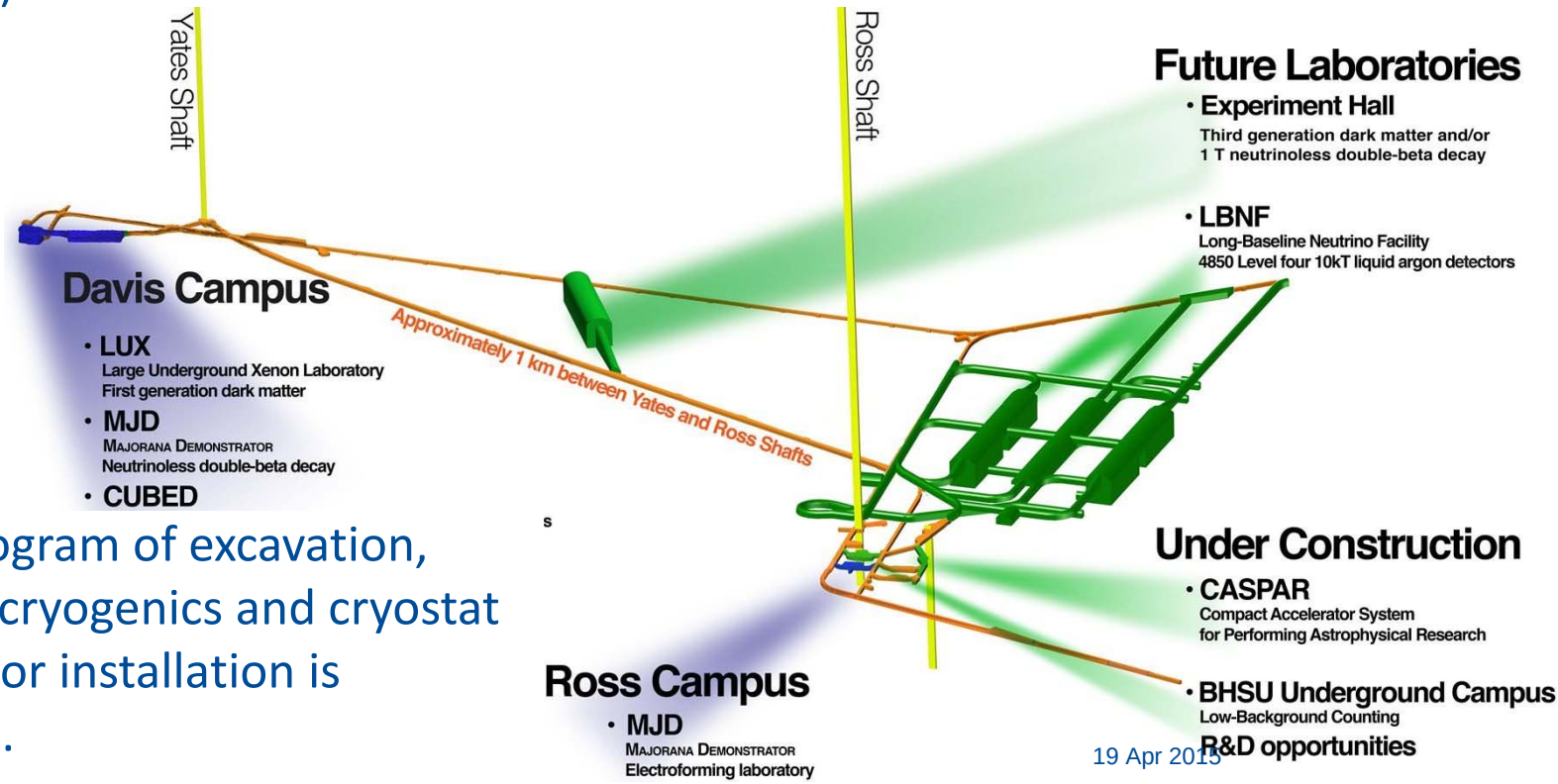
	DOE	NON-DOE
PO	ALL	NONE
BEAMLINE	~70%	~30%
CF	ALL	NONE
CRYO	LOWER	HIGHER

CF Far Site Scope: Underground excavation & utilities

Sanford Underground Research Facility

Reference design:

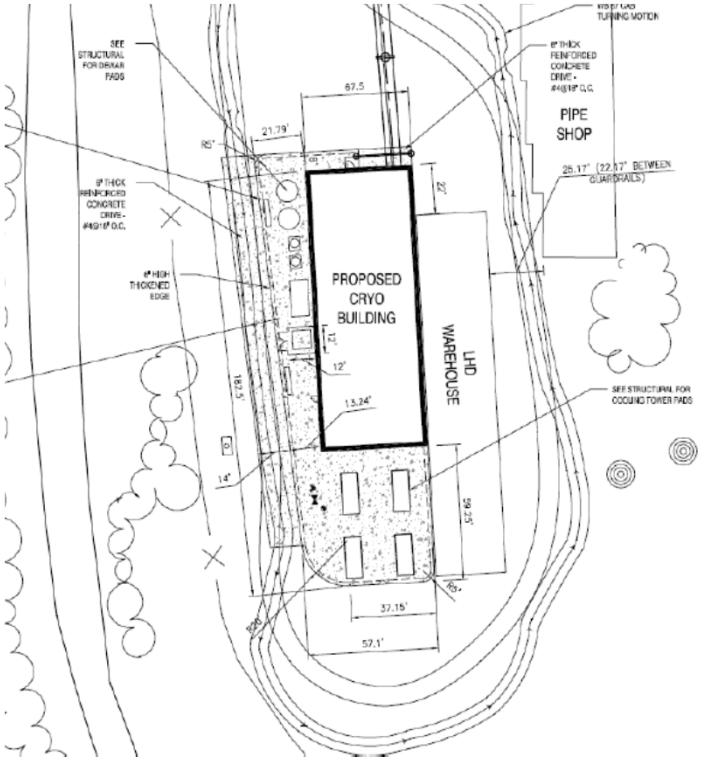
- Rectangular caverns
- 4 caverns, each to hold a 10 kt fiducial mass detector with laydown spaces
- Two 10 kt caverns fully outfitted and detector-ready
- Two additional 10 kt caverns excavated for future expansion
- Central utility cavern to house cryogenic equipment and common utilities
- Life safety and conventional utilities (water, power, fire protection, lighting, ventilation) in drifts & 2 initial caverns



- Phased program of excavation, outfitting, cryogenics and cryostat and detector installation is envisioned.

CF Far Site Scope:
Surface and shaft infrastructure

- Waste rock handling conveyance system from top of Ross shaft to truck-loadout station along Kirk Rd
- Surface cryo building at Ross Complex
- Minor building rehab of Ross Crusher Building for waste rock handling process
- Site work to enable truck deliveries to cryo building
- Power and cyberinfrastructure to underground & cryo building
- Water, gas, and sewer to cryo building



CFFS scope recent addition (not described as such in CDR): near-term SURF infrastructure projects

- SURF recognized in late 2014 that several maintenance/operations items would need to be addressed or there could be a risk to LBNF construction once started. ~$7M total in FY15$
  - Hoist motors
  - Water inflow control
  - 4850L refuge chamber enhancements
  - Oro Hondo fan replacement (main SURF exhaust)
  - Ross headframe building reinforcement to meet code
- Also, funding to complete the Ross shaft rehab is only identified to Jan 2016. To complete in 2017, need ~$9M over FY16 & 17.
- Other non-LBNF but important to SURF ops projects identified at ~$3M
- Outlined issues to DOE and thought originally this would be covered in operations funding to SURF; direction from Procario on 7 April to include all this work in LBNF except for possibly modest HEP operations funding in FY15, possibly FY16.
- Working to add this to RLS and CDR now. Immediate impact is funding available to excavation in early years.

Cryogenic Infrastructure Scope: Steel-Frame Cryostat

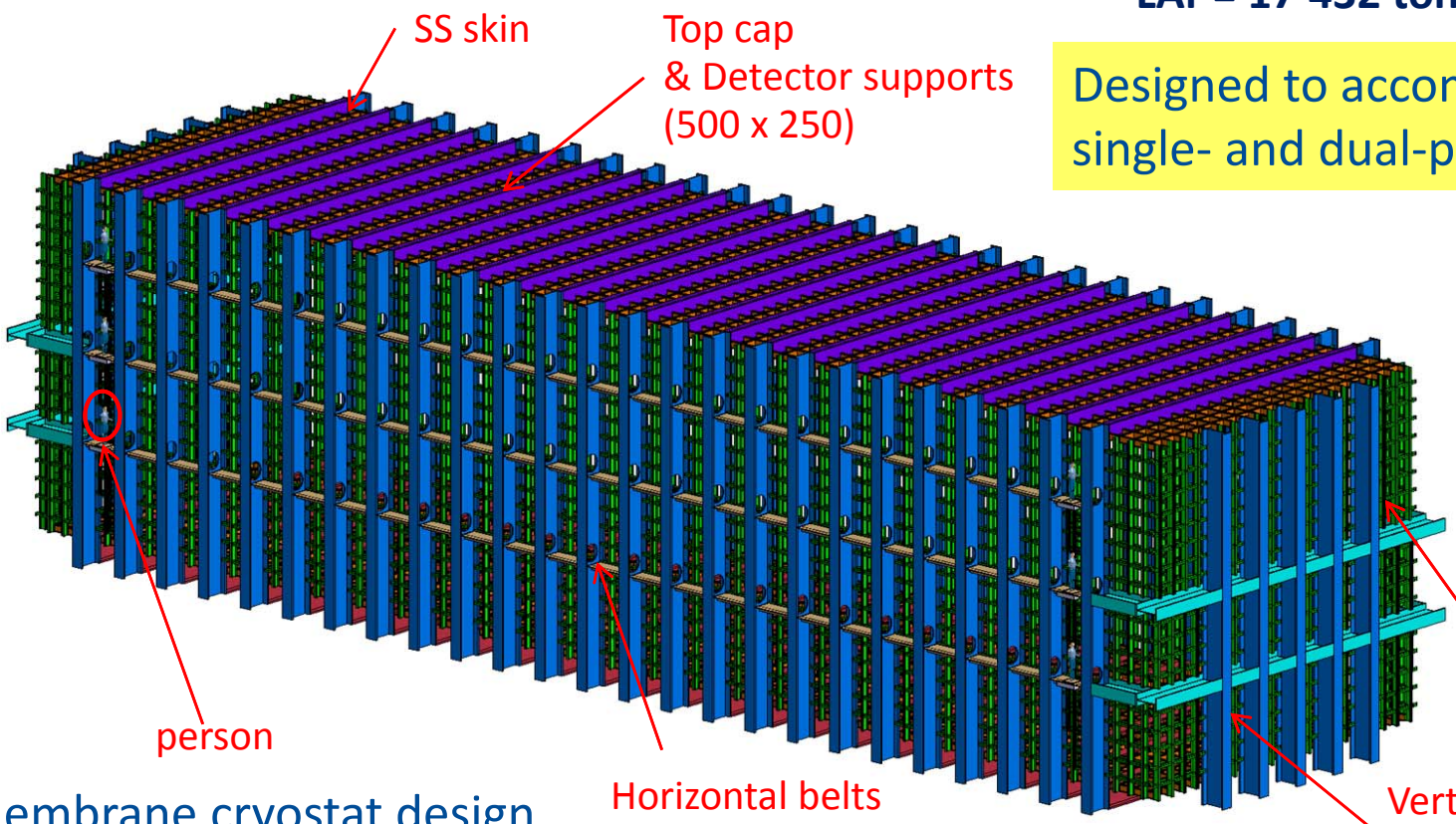
Design being developed by CERN

Inner dimension (liquid+gas):

- **L = 62.00 m**
- **W = 15.10 m**
- **H = 14.00 m**

LAr = 17'432 tons (95% liquid)

Designed to accommodate both single- and dual-phase detectors.



Membrane cryostat design based on LBNF work for LBNE and CERN work for LBNO/WA105.

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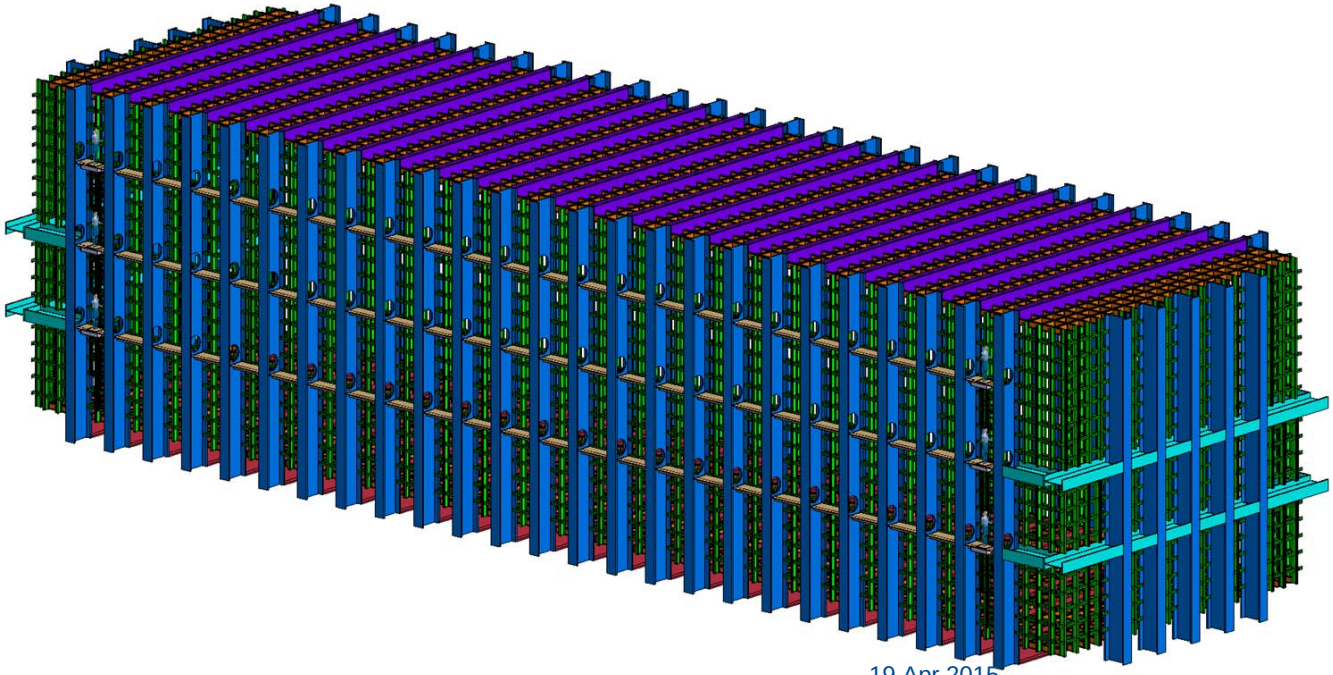
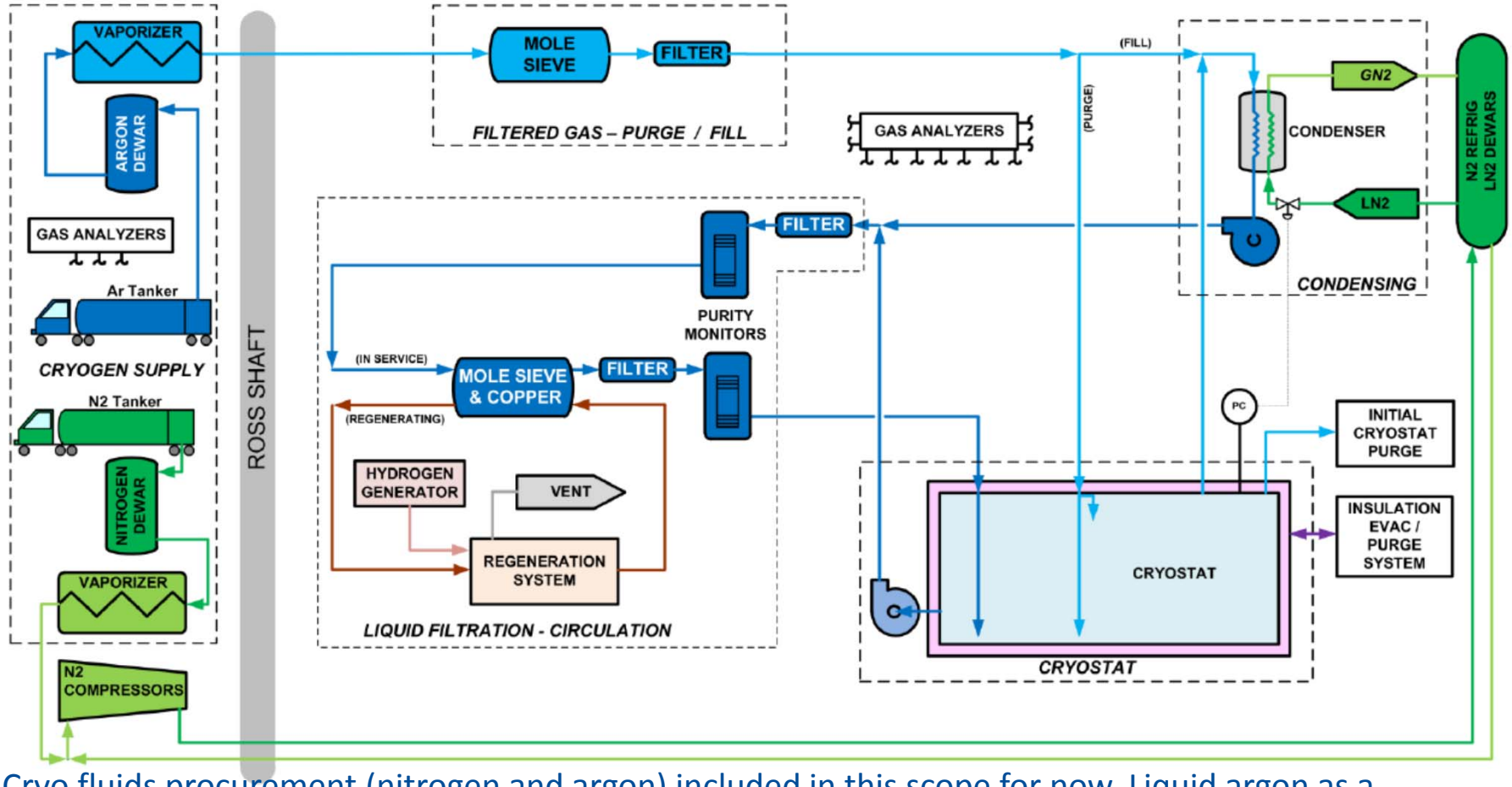
Key interfaces to DUNE far detector

- Signal and HV feedthroughs on the top plate
  - Very different systems for single- vs. dual-phase
- Access ports for detector assembly (and maintenance??)
  - Access through the top specified for single-phase detector
  - Access through the side at the bottom specified for dual-phase detector



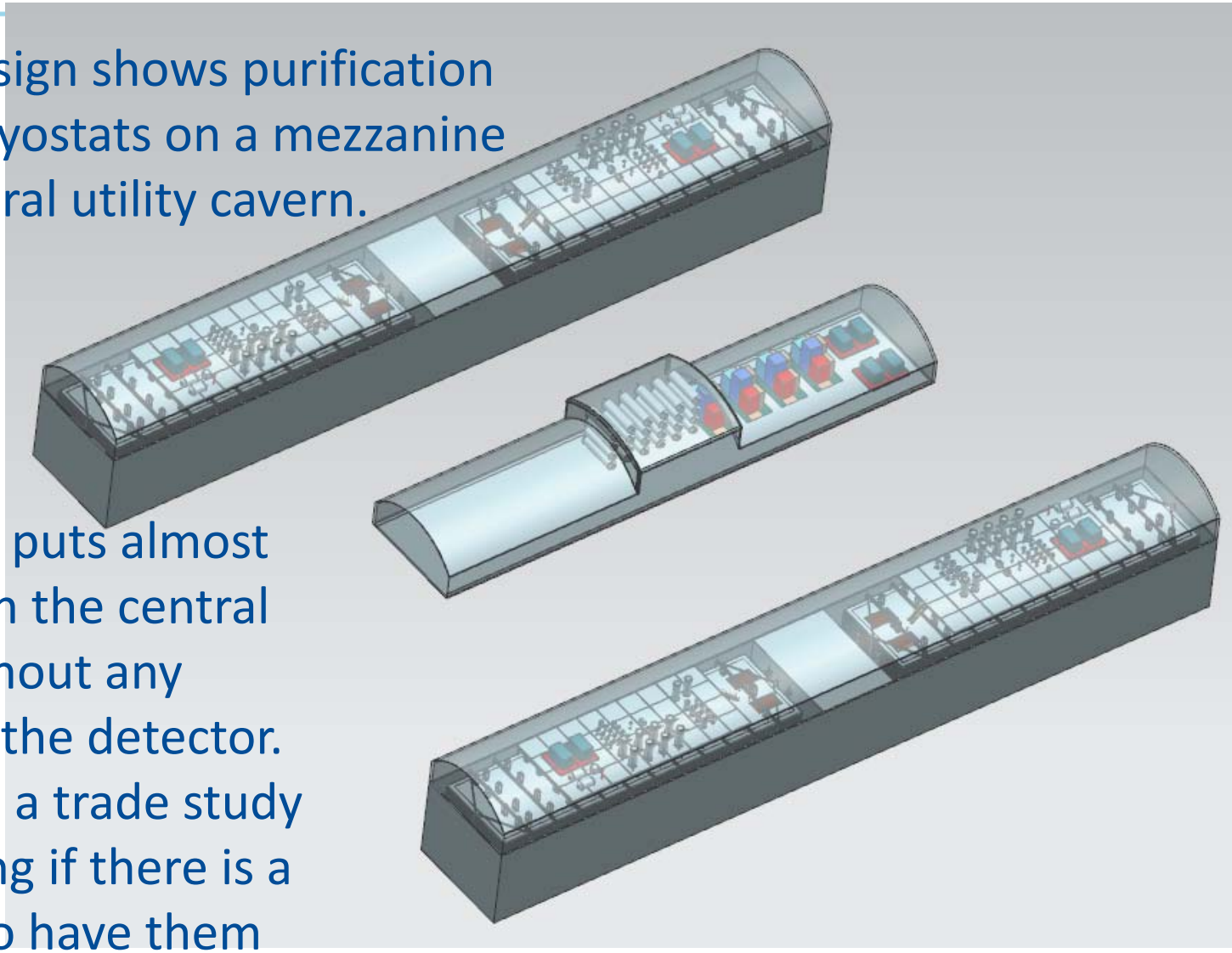
Cryogenic Infrastructure Scope: Cryogenic System & Fluids



Cryo fluids procurement (nitrogen and argon) included in this scope for now. Liquid argon as a commodity price is very volatile right now. Working with industry consultant to understand which vendors are most likely suppliers as well as the supply chain. Presently adding significant contingency to this.

CF and Cryogenic Infrastructure Scope includes 2 alternates: Cryogenic Systems in the Caverns

This alternate design shows purification systems above cryostats on a mezzanine with smaller central utility cavern.



Reference design puts almost all cryo systems in the central utility cavern without any mezzanines over the detector. Decision requires a trade study and understanding if there is a political reason to have them separate in each cavern.

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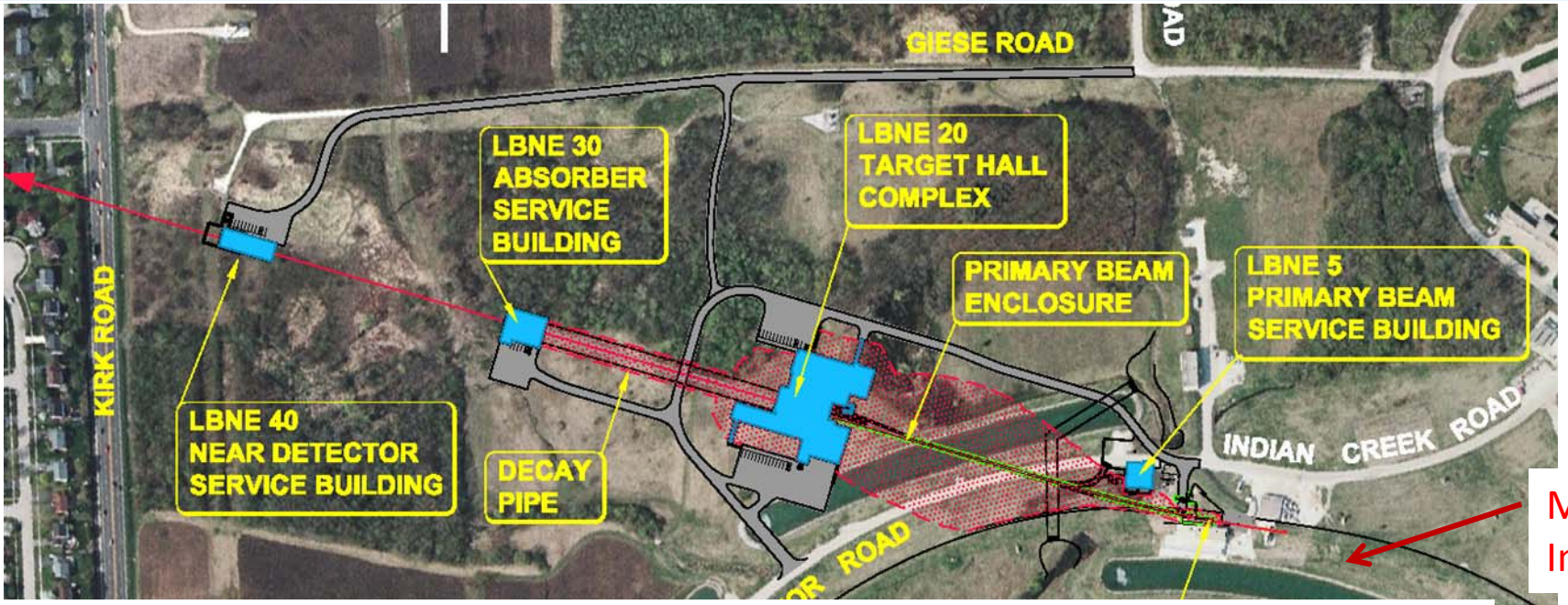
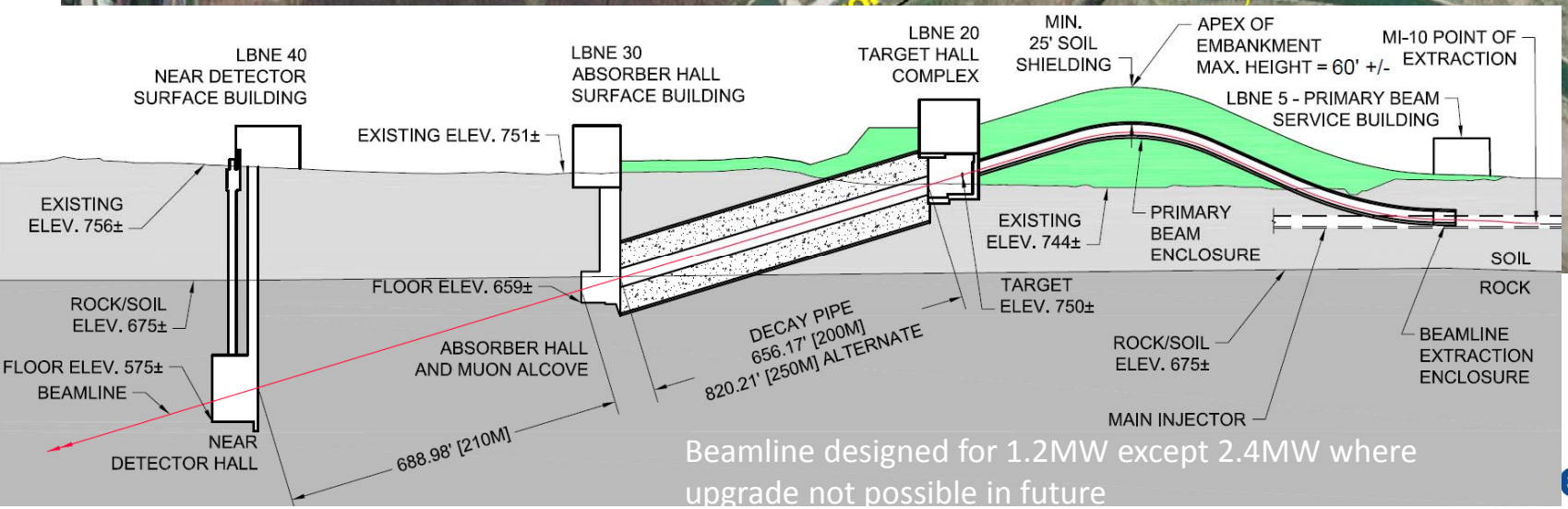
Beamline and CF Near Site Scope

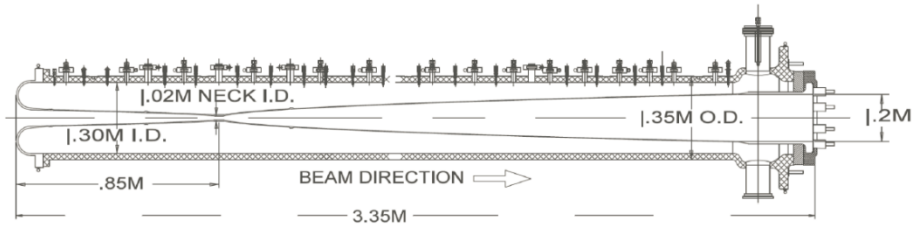




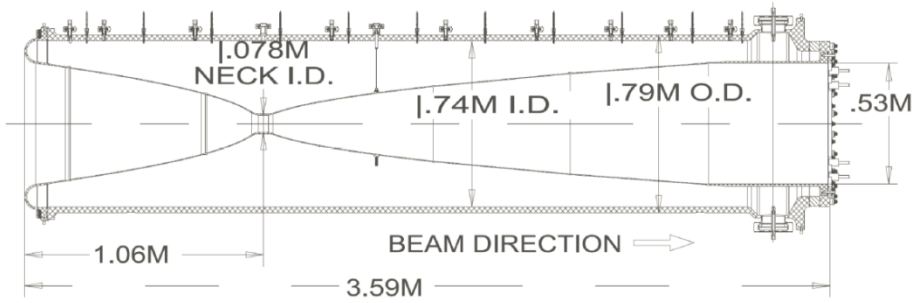
Beamline designed for 1.2MW except 2.4MW where upgrade not possible in future

Horn design comparison

NuMI Focusing Horns

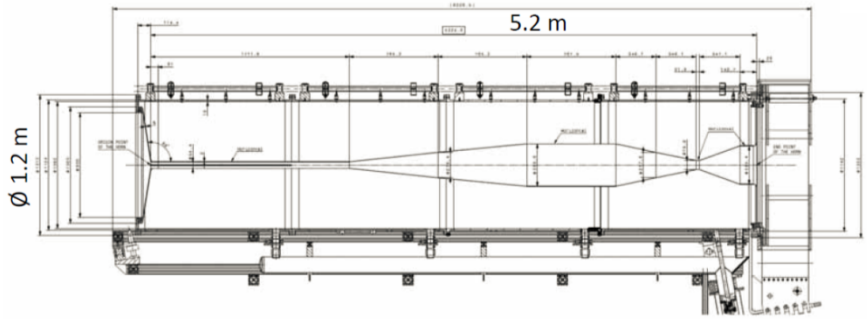


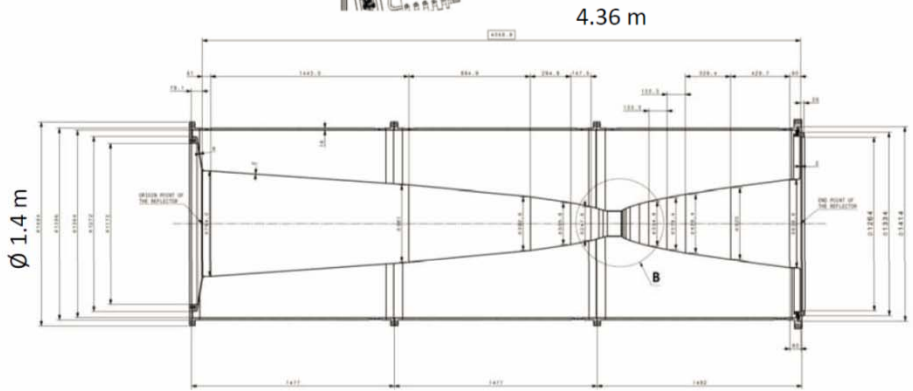
HORN #1



HORN #2

LBNO horns

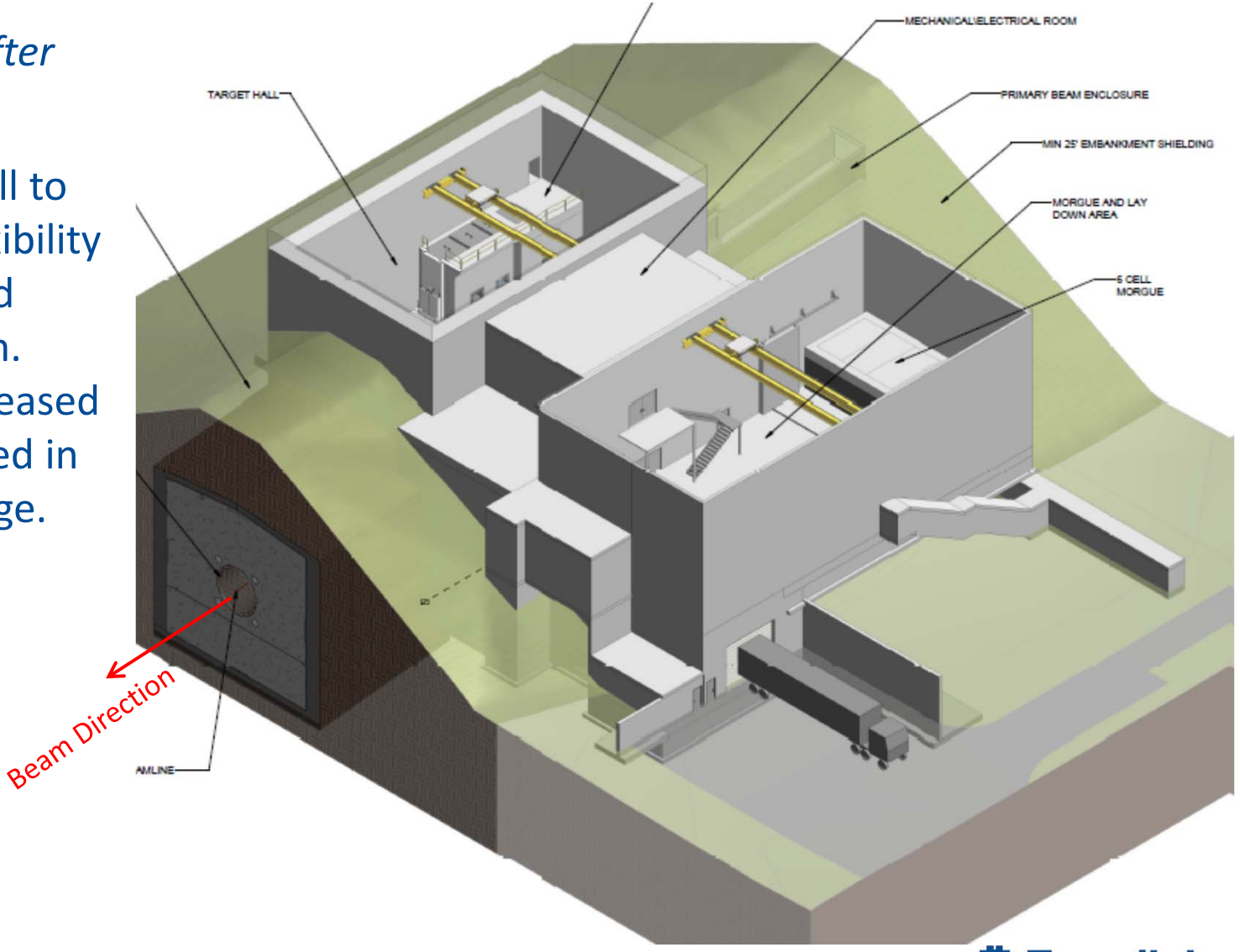




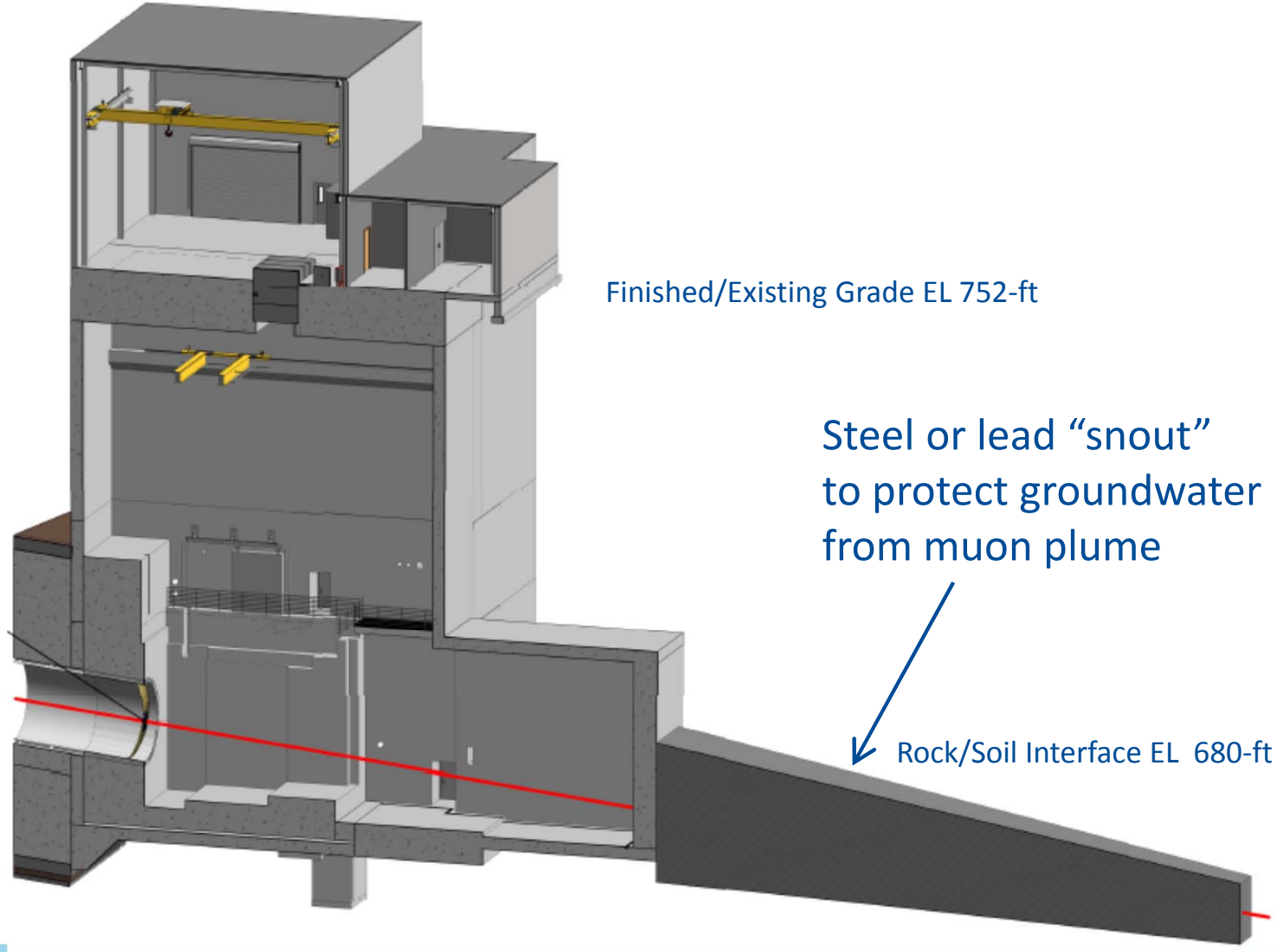
CFNS Scope:
Target Hall Complex

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.



CFNS Scope: Absorber Hall



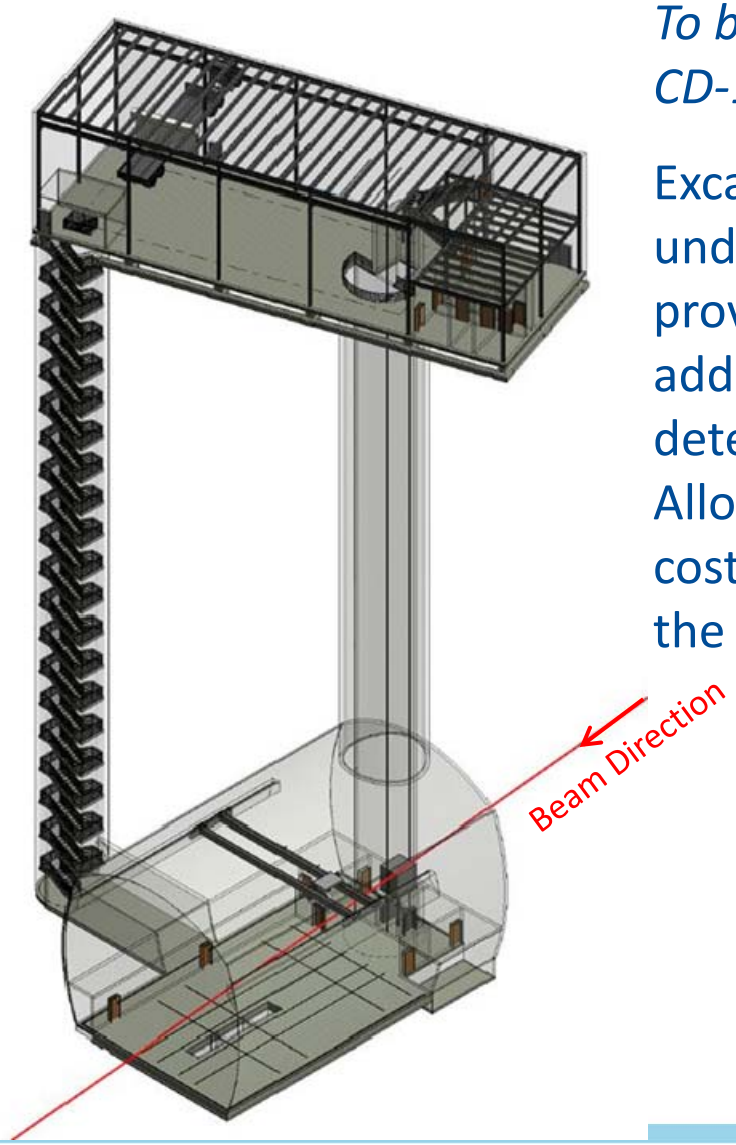
CFNS Scope:
Near Neutrino Detector Hall

Finished/Existing Grade EL 750-ft

Rock/Soil Interface EL 675-ft

Cavern Crown EL 625-ft

Cavern Invert EL 575-ft



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 Independent Design Reviews

- Independent Design Review is a prerequisite for CD-1
- We are planning reviews of individual subprojects, focusing on things that have changed since previous reviews
- Design reviews being planned:
  - Cryogenic system: week of May 11 at Fermilab
  - Cryostat: week of May 25 at CERN
  - Beamline: 27-28 May at Fermilab
  - Conventional Facilities: reviewed by independent A/E firms between now and the Director's Review
- This collection of reviews, in combination with design reviews conducted since prior CD-1 are anticipated to be meet the CD-1 requirement for independent design reviews.

LBNF Beamline Design Reviews

Reviews since prior CD-1 for updated designs:

Review	Date
Hadron Absorber Core Advanced Conceptual Design	20-22 Jan 2015
Beamline Corrector Magnet	29 Oct 2014
Shielding for LBNF Hill	27 Mar 2014
Hadron Absorber Core Design	21 Nov 2013
Beamline Decay Pipe Shielding	3-4 Apr 2013

- Air Releases Review scheduled by Beamline L2 Manager for 27 April, with website being set up.
- Review documentation available in our document database and we will provide username/password for you to access documentation.

LBNF Beamline Additional Design Review

- 27-28 May at Fermilab (seeing if this can move to following week just before Director's Review)
- 3-4 external to the project reviewers: KEK, CERN, Fermilab

Charge from the LBNF Project Director/Project Manager
Independent Conceptual Design Review of the LBNF Beamline Project
27-28 May 2015

The Committee is requested to conduct an independent conceptual design review for the Beamline of the Long-Baseline Neutrino Facility (LBNF) Project. This review is a prerequisite for a planned CD-1 Refresh DOE Independent Project Review/Independent Cost Review (IPR/ICR) scheduled for July 2015.

The Long-Baseline Neutrino Facility (LBNF) Project will enable a world-class program in neutrino physics for the Deep Underground Neutrino Experiment (DUNE) focused on precision measurements of the neutrino mixing matrix via ν_e appearance and ν_μ disappearance measurements, with goals of determining the sign of the mass hierarchy and searching for CP violation in the lepton sector. LBNF consists of a high-power, broad-band neutrino beam at Fermilab that will illuminate the DUNE far detector at the Sanford Underground Research Facility in Lead, South Dakota as well as the near detector on the Fermilab site, the cryogenic infrastructure to support the far detector, and all the necessary conventional facilities.

The predecessor LBNE Project achieved CD-1 in Dec 2012. The configuration and scope of DUNE-LBNF has evolved since then to enable a broader physics program with international partners. Significant changes in the Beamline configuration include introduction of helium in the decay pipe and an associated upstream beam window, designing the Beamline components to accept 1.2 MW beam power at the beginning of operations, revised shielding thicknesses based on updated and improved shielding calculations, reconfiguration of target chase shielding to utilize recovered steel, and significant progression of the hadron absorber design. Design reviews have been conducted for a few of these elements.

There are several options that may be pursued that could result in future modifications to the Project's scope. These are not currently part of the CD-1 scope; however they will be presented briefly and the committee will be asked to comment on them.

The committee is to review the entire Beamline Project's design, focusing on the changes that have not been previously reviewed, to verify that it is technically adequate, and should achieve the Project's scientific goals. To meet the requirements for CD-1 the design has to be at the conceptual level or greater. The committee will make their assessment based on outcomes of prior design reviews, LBNF's Conceptual Design Report, drawings, specifications, and discussions with the project team.

LBNF Neutrino Beamline Independent Design Review
27-28 May 2015
Fermilab

DRAFT Agenda

Wednesday 27 May 2015

8:00	(0:45)	Committee Executive Session
8:45	(0:40 +0:20)	Overview and Requirements
9:45	(0:30 +0:15)	Primary Beamline
10:30	(0:15)	Break
10:45	(0:20 +0:10)	Neutrino Beam Overview
11:15	(0:20 +0:10)	Targetry
11:45	(0:20 +0:10)	Horns
12:15	(1:00)	Lunch
13:15	(0:20 +0:10)	Horn Power Supply
13:45	(0:20 +0:10)	Target Shield Pile and RAW
14:15	(0:30 +0:15)	Decay Pipe Including Windows
15:00	(0:30 +0:15)	Scope Options for Target/Horn
15:45	(0:15)	Break
16:00	(0:20 +0:10)	Absorber and RAW
16:30	(0:20 +0:10)	Remote Handling
17:00	(1:00)	Committee Executive Session
18:00	(0:15)	Questions from the Committee
18:15		Adjourn for the Day

Thursday 28 May 2015

8:00	(0:30 +0:15)	System Integration
8:30	(0:40 +0:20)	Radiation Protection and Shielding
9:10	(0:15)	Break
9:25	(0:45)	Committee Executive Session
10:10	(0:45)	Answers to Committee Questions
10:55	(4:00)	Committee Executive Session / Report Writing /
14:55	(0:30)	Closeout
15:25		End

LBNF Cryostat and Cryogenic System Reviews

- Cryostat review planned to be at CERN week of May 26
- Two Fermilab cryogenic engineers external to LBNF but familiar with membrane cryostats
- Review of CERN-designed steel support structure with membrane cryostat

- Cryogenic systems review planned for week of 11 May at Fermilab
- Engineers from Jefferson Lab and from Fermilab external to LBNF.
- Review of cryo system at mid-preliminary design completion as designed by Fermilab to date.

LBNF CF Design Reviews

- Designs are prepared by A/E firms under contract for entire design
- Peer reviews being done by other A/E firms under contract to Fermilab with a report deliverable by mid-May.

CFFS charge

1. Reasonableness - Do the design concepts appear reasonable? For each component of the facility?
2. Do you see any opportunities for streamlining? Making the design more efficient?
    a. Not a VE exercise, but do not close the door
3. Construction phasing and sequencing - Please comment on concept of phased excavation/isolation of activities
4. Are there any interfaces that seem to be undefined and/or unclear (is anything missing)?
5. Are the requirements provided by the users appropriate and clear enough, and are these requirements satisfied by the design?"
6. Is the degree of progress consistent with 30% PD?

CFNS charge

1. Reasonableness - Do the design concepts appear reasonable? For each component of the facilit
    a. Embankment section
        1. Systems in place to protect Main Injector
        2. Soil Reinforcement/Side Slopes
    b. Please comment on concept of open cut construction - Laid-back slopes v. braced excavation
2. Do you see any opportunities for streamlining? Making the design more efficient? Not a VE exercise, but do not close the door
3. Construction phasing and sequencing - Please comment on concept of phased excavation/isolation of activities
4. Are there any interfaces that seem to be undefined and/or unclear (is anything missing)?
5. Are the requirements provided by the users appropriate and clear enough, and are these requirements satisfied by the design?
6. Is the degree of progress consistent with 100% Preliminary Design for ASP and 100% Conceptua Design for BCF?

Cost/Schedule Status

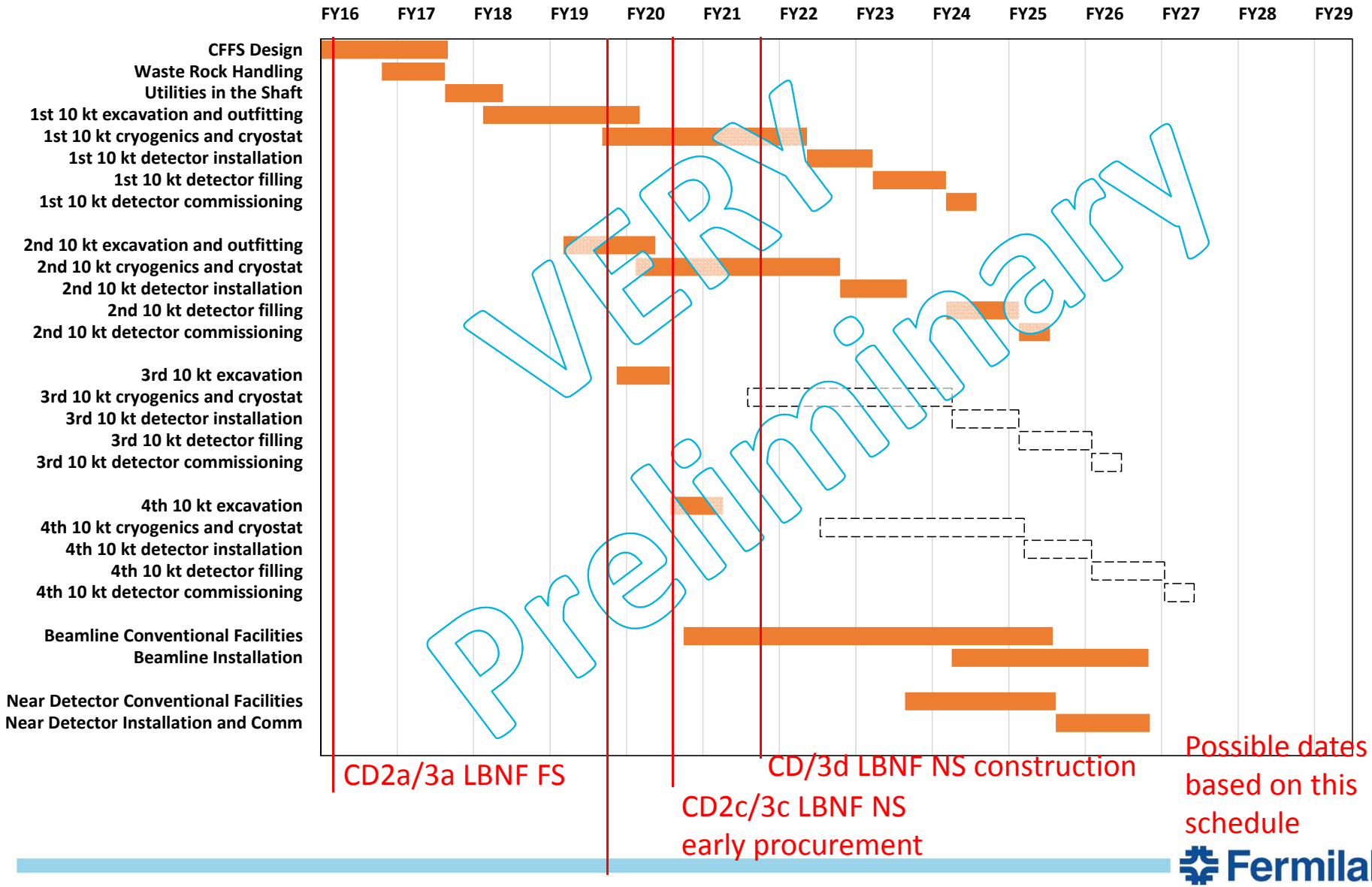
- LBNF cost/schedule developed in P6/Cobra from prior LBNE schedule.
  - PO, Beamline, Cryo, CF have separate WBS L2 schedules (DUNE PO, ND & FD also) linked by common high level interface milestones.
  - Entire project (both projects actually) are integrated and overall schedule and obligation/resource profiles generated.
- Costs are being loaded as FY15$US and labor hours with estimate uncertainty contingencies assigned at activity level
  - Basis of estimates being updated or created for all activities.
  - Based on using resources from institutions as known today, and if not known, as US lab resources.
  - Labor rates and escalation included to provide DOE-type cost for full project.
- CORE accounting for international purposes also being developed (see next slide)
- At reviews, expect to show CORE costs for entire project and DOE accounting for only DOE portion of project (but will have full DOE accounting available for DOE as outlined in CD-1-R criteria memo).

Costs in CORE Accounting

- CORE method focuses on and puts a value on direct production costs and excludes basic infrastructure and personnel costs. Thus, it includes things like components, production, outsourced assembly, installation, and commissioning, or what is known in the U.S. as M&S costs.
  - Does not include items such as infrastructure at institutions for production or technical support, the labor or materials for R&D, design, or small scale prototyping.
  - Does not include direct laboratory or university labor by scientists, engineers, or technical or administrative staff.
- Unit costs will be developed in FY15US$ and do not use escalation or contingency. Responsible funding agencies and institutions take care of this in accordance with each agency's own policies.
- CORE cost book will show M&S cost and direct labor hours, extracted from RLS.

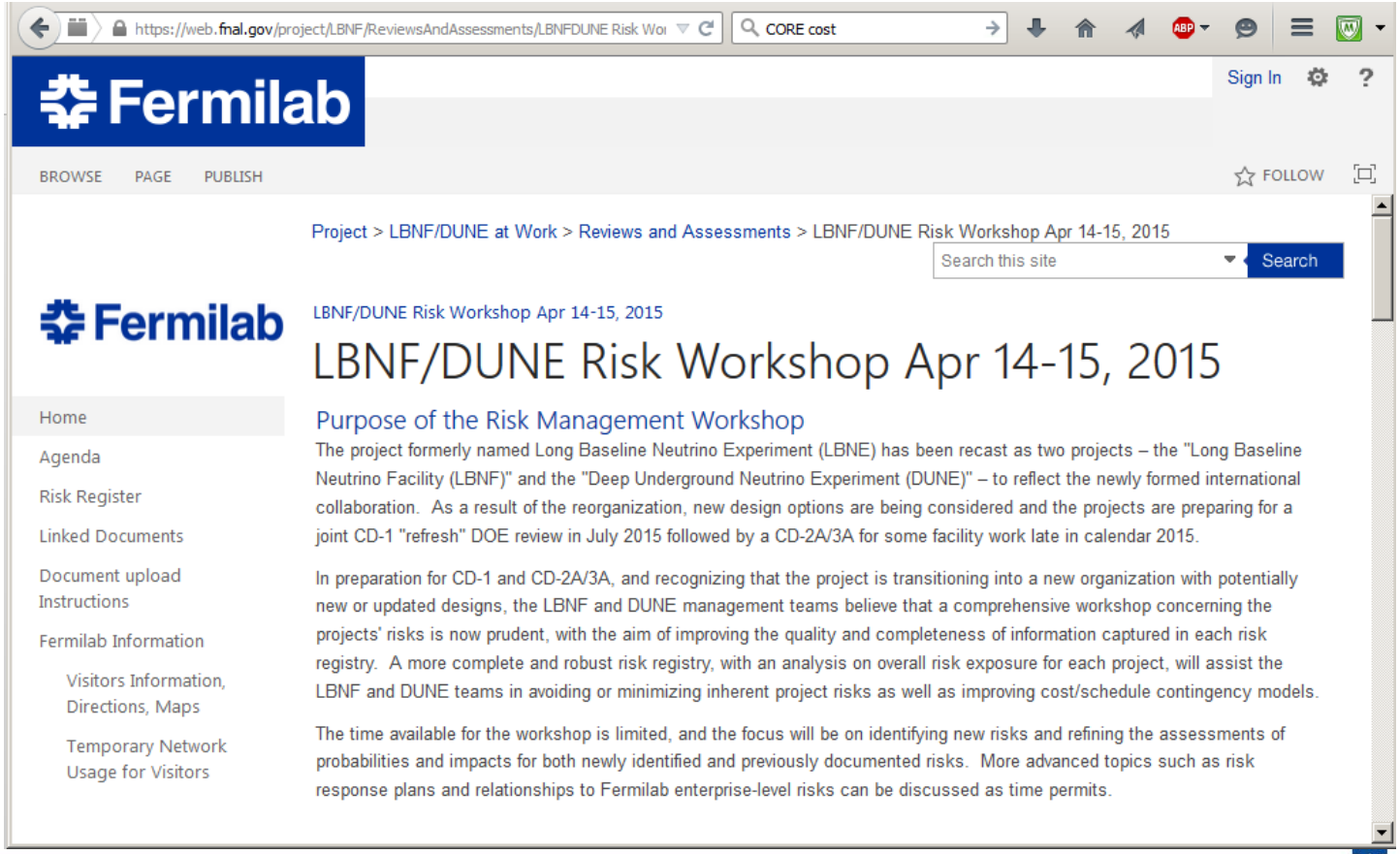
Possible Schedule

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.



Risk Assessment and Register

- Combined DUNE-LBNF Risk Workshop held earlier this week.
  https://web.fnal.gov/project/LBNF/ReviewsAndAssessments/LBNFDUNE%20Risk%20Workshop%20Apr%202015/SitePages/Home.aspx



Risk Workshop and Activities

- Several new risks identified in many areas and some prior risks reviewed & discussed (ran out of time to do all!).
- Expect to develop cost and schedule contingency due to identified risks for CD-1-R.
  - New risks need probabilities and impacts
  - Project leadership needs to decide what items will be included on project-managed risk register for this purpose and which risks will be monitored by L2 projects only.
  - Project-managed register provided to risk support manager for Monte Carlo with cost/schedule contingency as outcome.
  - Robust project schedule and logic required – will do this on a summary version of the schedule for CD-1-R.

DOE Required CD-1 Documentation Assessment for DUNE+LBNF

Documentation - DOE Required Documents

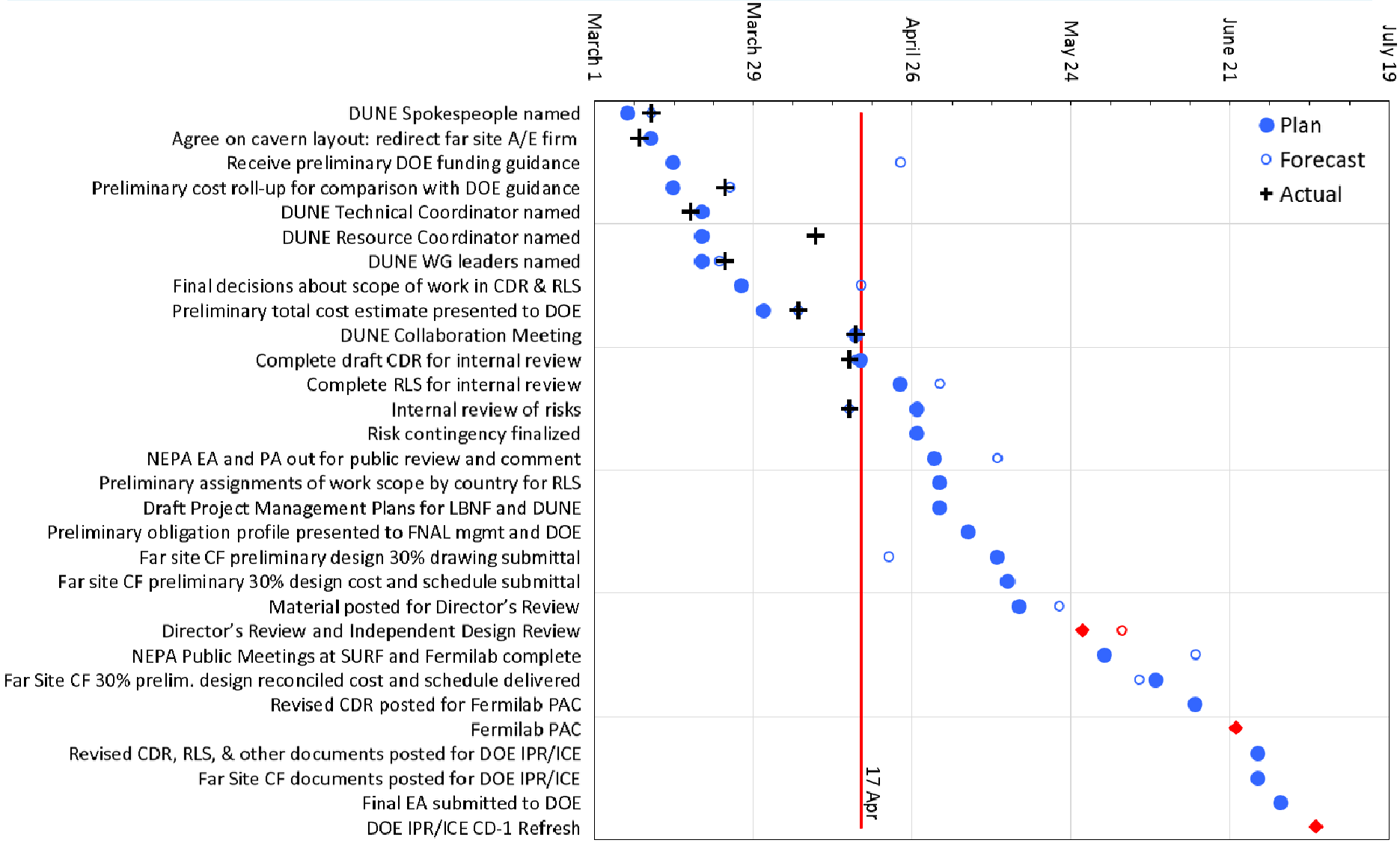
Status	Document	Comments/Issues	RESPONSIBLE	support/ edting/writing
	Acquisition Strategy	to be updated	Carolan	McCluskey
	Project Execution Plan (Preliminary for CD-1)	to be updated	Carolan	McCluskey
	Risk Management Plan	use Fermilab's with any tailoring in PMP	McCluskey	
	Comply with the One-for-One Building Space Replacement (only for projects with civil facility scope)	complete		
	Document High Performance & Sustainable Building and Sustainable Environmental Stewardship (only for projects with civil facility scope)	complete		
	Conceptual Design Report (CDR) for CD-1	in progress - 4 volumes with editors assigned complete draft to be ready by May 5th	LBNF-DUNE leadership team	Heavey/Nayar
	Preliminary Design Report (or TDR – Technical Design Report) for CD-2	N/A		
	Completion of Design Review conducted by team external to project was Conducted (Link to review final report; Also list and link to any project internal project reviews)	to be completed by 4th week of May	McCluskey/James	
	Hazard Analysis Report (Preliminary for CD-1)	to be updated	Andrews	McCluskey
	Integrated Safety Management Plan	to be updated (mostly name changes)	Andrews	McCluskey
	Quality Assurance Plan (QAP)	to be updated (mostly name changes)	Dolph	McCluskey
	Identify general Safeguards and Security requirements for the recommended alternative (May be included in PEP)	to be updated (mostly name changes)	Andrews	McCluskey
	Issue National Environmental Policy Act (NEPA) determination (for CD-1)	complete		
	Issue Final EIS or EA and Finding of No Significant Impact (for CD-2)	in progress - will describe status in some document	McCluskey	Walton
	Established Cost and Schedule Performance Management Baseline (PMB) - for CD-2	N/A		
	Lifecycle Costs with Alternative Assessment (may be included in design report or other document)	to be updated Also goes in PPEP	McCluskey/James	

Other CD-1 Documentation Assessment for DUNE+LBNF

Other Documentation

Status	Document	Comments/Issues	RESPONSIBLE	support/ edting/writing
	Project Management Plan	to be updated - one document	LBNF-DUNE leadership team	McCluskey
	Risk Register and Risk Assessment	to be updated - 1 register	Dolph	Taylor
	Project Organization Chart	to be updated - need several, all in development	LBNF-DUNE	
	BOEs w/reference documents	in progress	O'Sullivan	other PCS
	Schedule o Full project Gantt Chart o One Page high level Gantt Chart o Critical Path o Milestone Waterfall Chart (sorted by level and date)	in progress	O'Sullivan	other PCS
	Resource Profile Graphs o At Project Level o At each Level 2	will have	O'Sullivan	other PCS
	Assumptions Document	to be updated - 1	Dolph	McCluskey
	WBS Dictionary	to be updated - 1	LBNF-DUNE	McCluskey
	Milestone Dictionary	to be updated - 1	LBNF-DUNE	O'Sullivan
	Configuration Management Plan	to be updated - 1	Dolph	McCluskey
	Procurement Management Plan	to be updated - 1	Efstathiou	McCluskey
	Memos of Understanding (MOUs) / Statement of Work (SOWs)/CRADA/International Agreements	will have a list of some partner and university agreements plus SDSTA agreements	James/McCluskey/ Lockyer/Siegrist	Stewart/Mauger
	Science & Technical Requirements and Specifications	to be updated	Dolph	Heavey
	Status/Progress on prior review recommendations	being updated	McCluskey/James	
	Presentations (drafts post two weeks before review, final versions posted one week before review) o Plenary Talks o Breakout Talks	will have		
	Have dry runs of drill down exercises and presentations been planned or conducted? Note: CPO should be informed of dry runs.	not yet		
	Scope Contingency Plan (potential adds and removals)	will be updated - 1	LBNF-DUNE leadership team	McCluskey

Milestones Toward CD-1 Refresh
DUNE + LBNF



https://web.fnal.gov/project/LBNF/ReviewsAndAssessments/SitePages/Milestones%20to%20CD-1.aspx

Evolving CFFS design to CD2a/3a

- CFFS team:
  - L2 manager Tracy Lundin
  - L2 Deputy with construction management experience - hiring
  - L3 manager Josh Willhite (recently Fermilab transferred from SDSTA)
  - SDSTA engineering staff (underground/shaft infrastructure, geotechnical, electrical)
  - Dedicated CF project controls specialist
  - A/E selected for the duration of this design/construction
  - Also critical for this process is sufficient procurement leadership – hiring LBNF Procurement Manager to manage procurement team
- SDSTA has been managing design - submitted 30% preliminary design for surface and infrastructure; updated design for revised cavern scope due end of April. Cost/schedule expected later in May.
- Design will continue through summer with preliminary design (almost) and updated cost/schedule due for CD2a/3a review.
- Hiring contractor construction manager for CM/GC contract to be on board at start of final design to aid in pre-construction cost/schedule/constructability but then to manage construction.
- Decisions to be made prior to baselining on scope:
  - Location of cryo equipment – mezzanine or utility cavern
  - Confirmation of detector size and aspect ratio
  - Requirements for permanent cranes
  - Requirements on drifts for access/egress for excavation and detector installation
  - Requirements for 2-phase detector if different from 1-phase

Evolving Cryogenic Infrastructure design to CD2a/3a

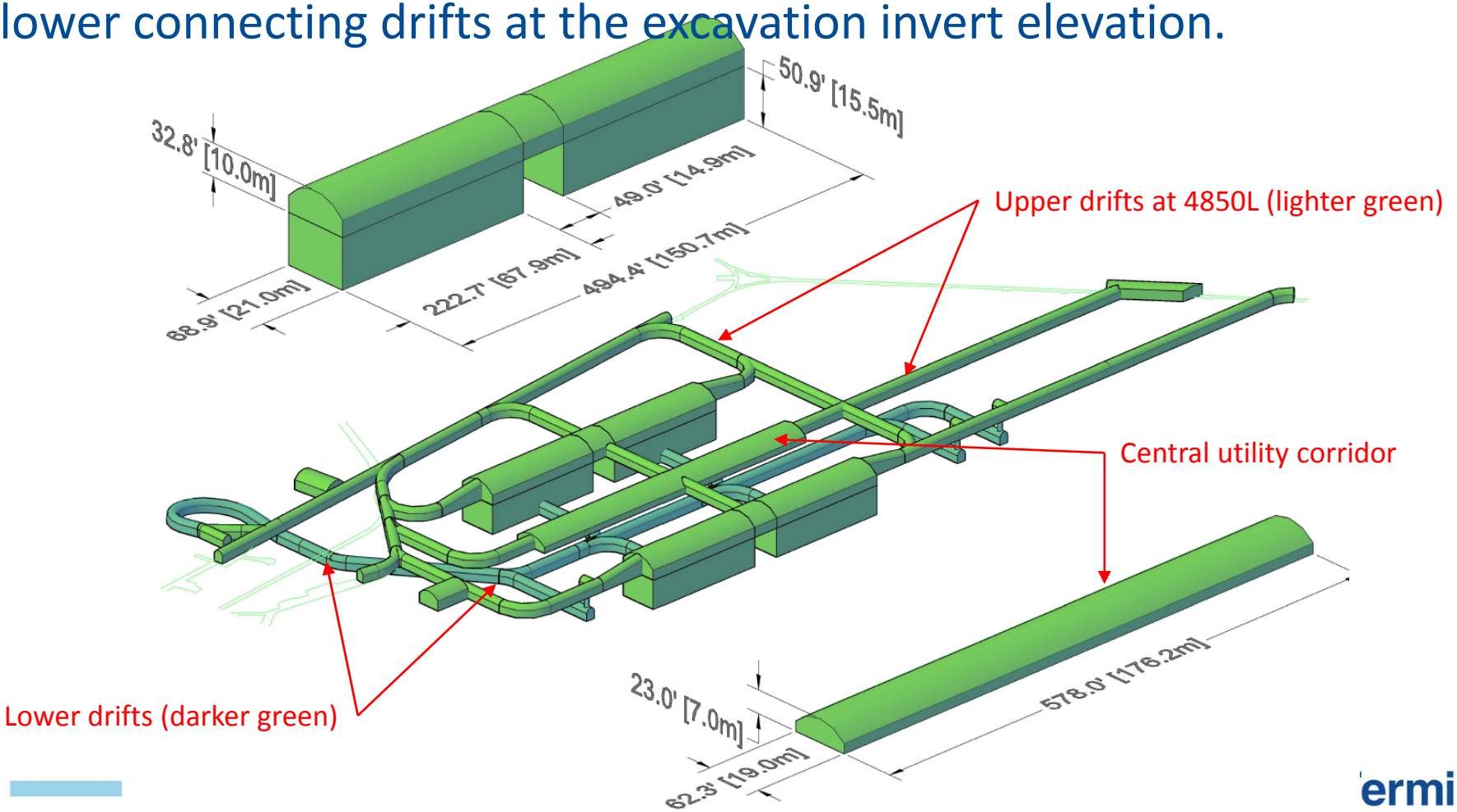
- Cryogenic Infrastructure team – evolving into joint team with CERN
- At Fermilab, several also working on SBN and CERN prototypes:
  - L2 manager presently Barry Norris, but may change
  - L2 Deputy presently David Montanari
  - L3 manager cryo systems presently Mark Adamowski
  - L3 manager cryostats presently David Montanari
  - Dedicated cryo project controls specialist
  - Other cryo and mechanical engineers and designers
- At CERN:
  - Cryo systems Johan Bremer
  - Steel cryostat structure presently 5 engineers in engineering study
  - Membrane cryostat Marzio Nessi working with GTT
- Cryostat design will evolve through CERN and anticipated agreements with GTT
- Cryo systems design will evolve through Fermilab and CERN engineering team
- Need to better understand
- Decisions to be made prior to baselining on scope:
  - Location of cryo equipment – mezzanine or utility cavern
  - Scope by CERN vs Fermilab and resources assigned by each to this project in light of SBN and CERN prototypes

For both CFFS and Cryo Infrastructure: for baselining & construction approval review

- Need to determine if CD3a covers all construction or only early procurement
- Finalize agreements with SURF including lease and written agreements for working together (thought to be a CRADA)
- NEPA determination – FONSI on track for late August – EA ready for public in May
- Better understand and plan cryo installation sequence in conjunction with ongoing CF
- independent cost/schedule estimates for all relevant work
- Set baseline early enough to allow for practicing EVMS and change control
- Show risks are being managed – also planning risk workshop for late August/early September
- Finalize contingency
- Develop final design plan and construction plan

CFFS Scope:
Far Detector Phasing

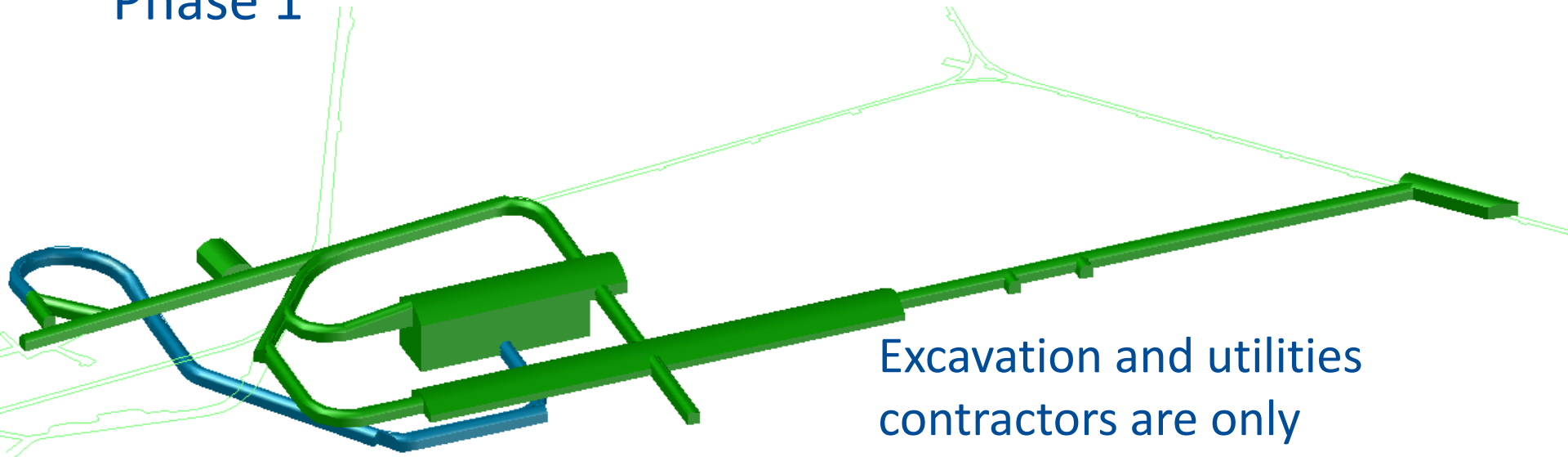
Four LAr detector caverns, one central utility corridor, a series of connecting drifts at the 4850L (upper elevation), another series of lower connecting drifts at the excavation invert elevation.



Far Detector Caverns: Phased excavation

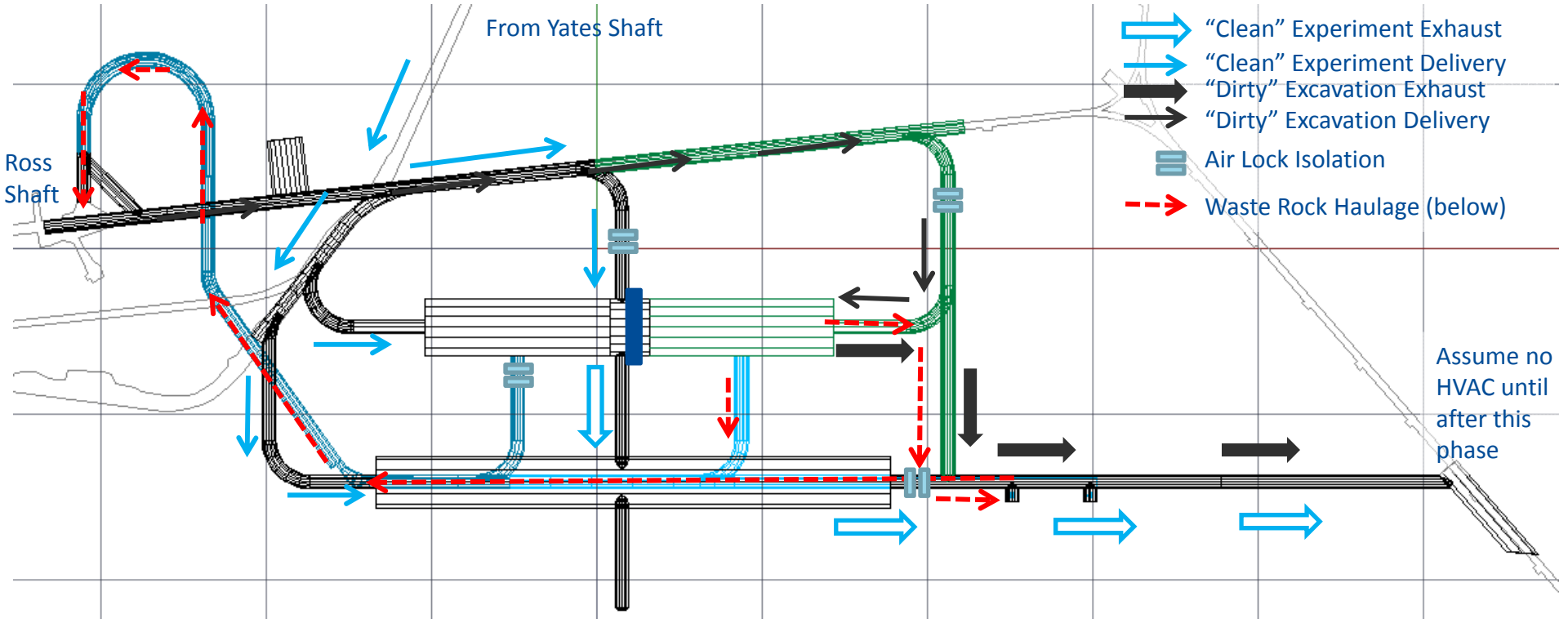
Phasing of the work will be critical to separate dirty activities (excavation) from clean activities (cryostat and detector installation)

Phase 1



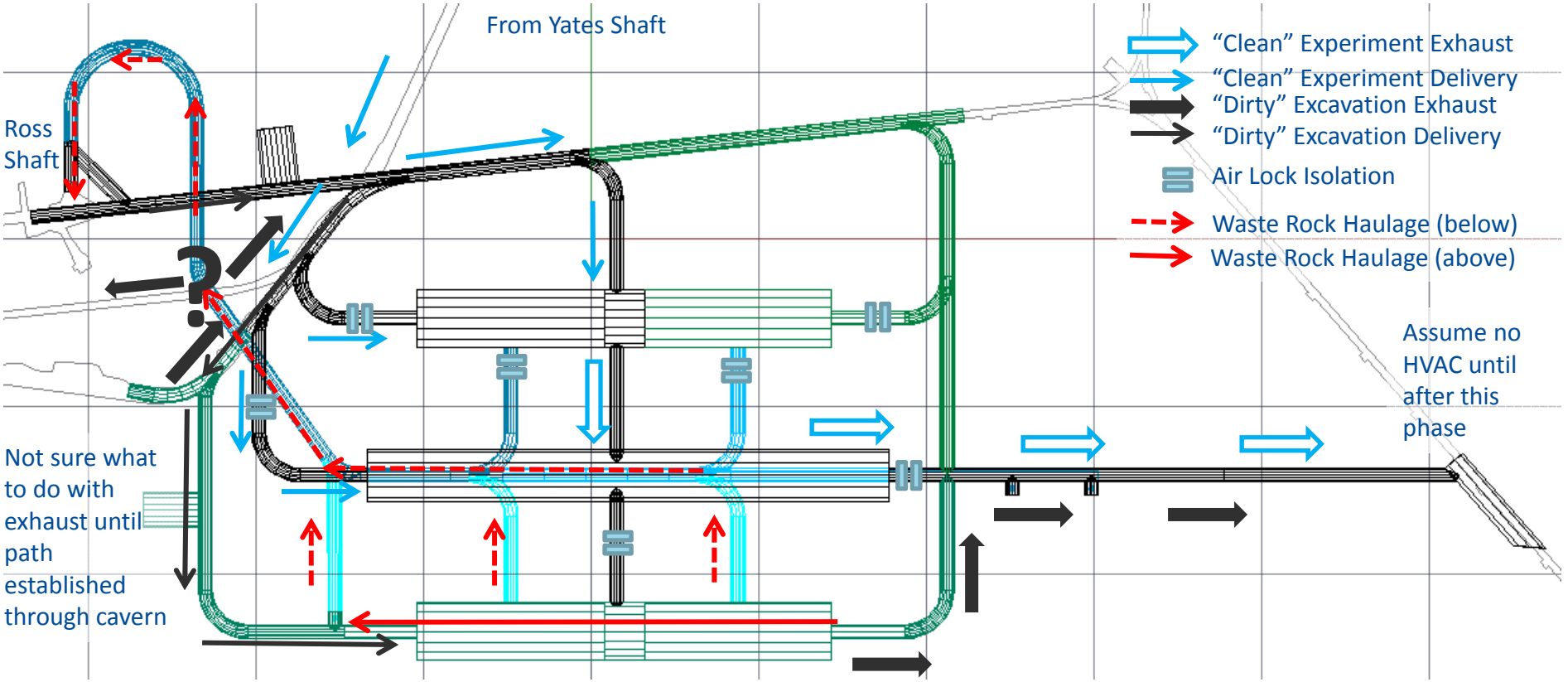
Excavation and utilities contractors are only occupants. Very long period due to need to establish ventilation & egress for next phase.

Phase 2 –
excavating cavern 2, cryostat/cryo systems installation



- Until a connection is made to the lower level, waste rock must be hauled through governor's corner, creating interference with cryostat component delivery
- Explosives use would become progressively slower and more expensive as the excavation approaches the existing cavern. A temporary wall (black box) would be installed within the laydown space to prevent fly rock entering the pit when breaking through. The final break through would be extremely slow to avoid air blast damage to the wall.
- The first chamber would be evacuated at every blast. This could be up to twice a shift for 30-45 minutes at a time.
- The permanent cooling system cannot be commissioned at this time, since there will be dust flowing through the spray chamber

Phase 2 –
excavating caverns 3/4, cryostat/cryo systems installation in 1/2



- The first and second chamber will be evacuated at every blast. This could be up to twice a shift for 30-45 minutes at a time.
- The permanent cooling system cannot be commissioned at this time, since there would be dust flowing through the spray chamber. If this is a problem, we would have to add a drift or duct. Cooling should not be needed until the first detector is filled.
- Until a connection to the lower mucking drift is established, rock would be hauled past the other caverns, and around Governor's Corner, interfering with cryostat/detector component delivery and creating dust.
- Until a ventilation connection is made, air may need to be ducted long distances to avoid contaminating the first cavern and/or other experiments. For reference, 100,000 cfm (approximate excavation equipment need) would require a 7' diameter duct.
- This cavern could be excavated as quickly or as slowly as desired, from one end or both (after the initial path is established).

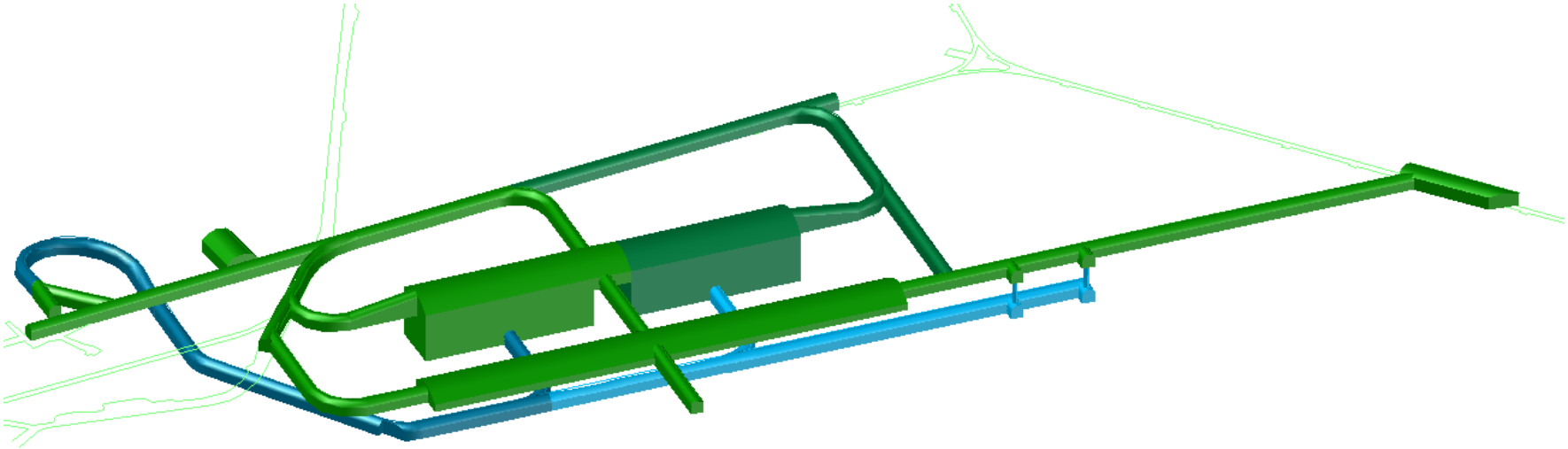
Impacts of phased installation

- Complicated access/egress for safety, ventilation, and cryo/exp installation – more drifts, more time to excavate, more cost
- Excavation is slower due to reductions in blasting energy and constraints on the excavation contractor – more cost
- Requires use of Yates shaft for cryo/exp delivery until excavation is complete – more traffic in west drift – possibly more cost for LBNF to improve this drift; delays Yates shaft renovation.
- Many interfaces from multiple parties being underground simultaneously. Had previously envisioned linear excavation-utilities-cryostat-cryo systems-experiment completion to lessen complications and possible contractor delay claims.
- Requires planning out steps for installation after number & timjing of trips for each element is understood – systems engineering issue.
- May require single construction manager to schedule and coordinate all LBNF and possibly DUNE work through shaft and underground.

Backup slides

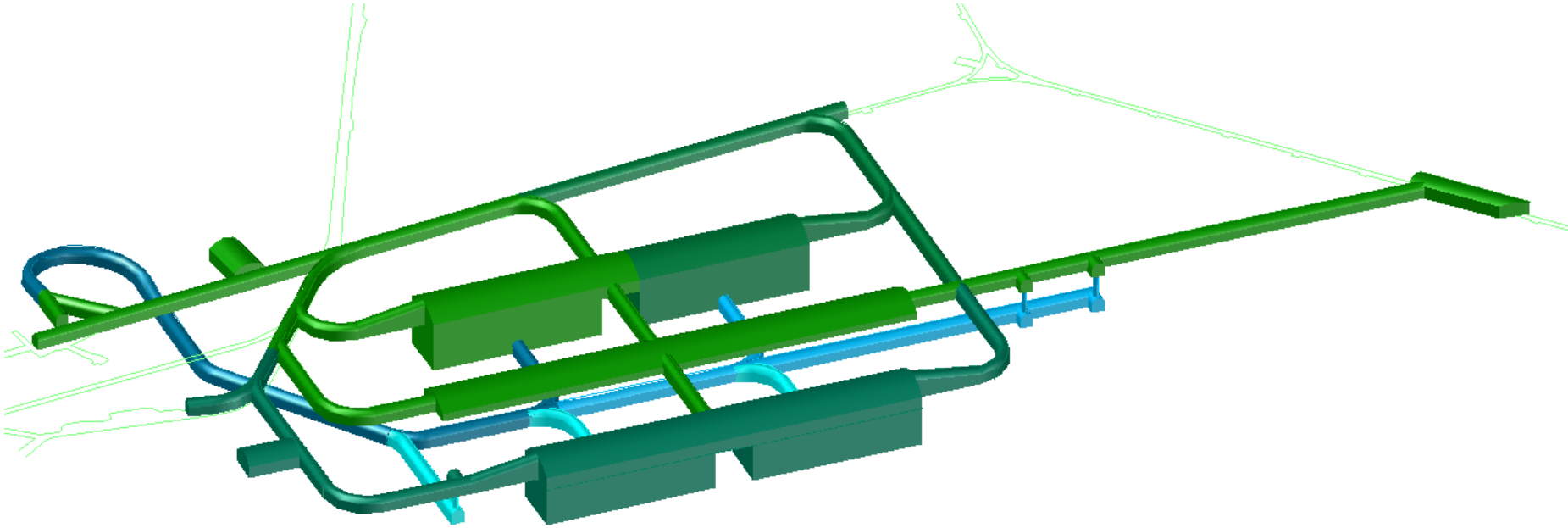
CFFS Scope:
Far Detector Caverns: Phased excavation

Phase 2

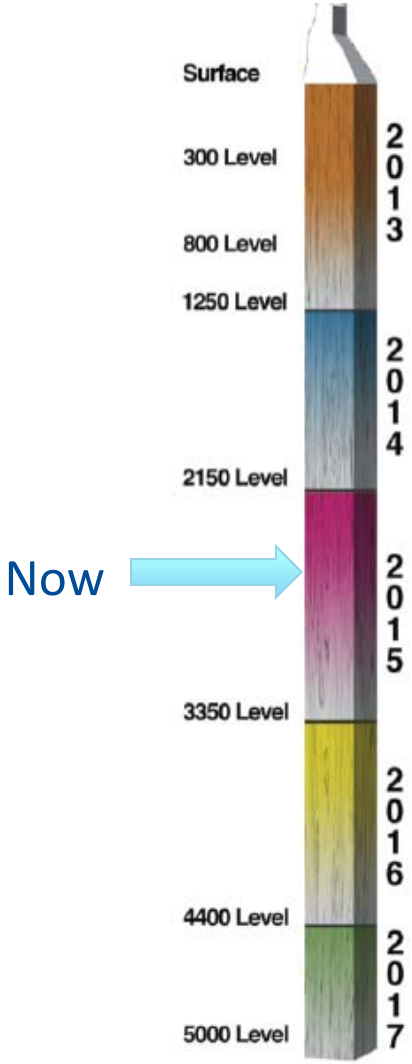


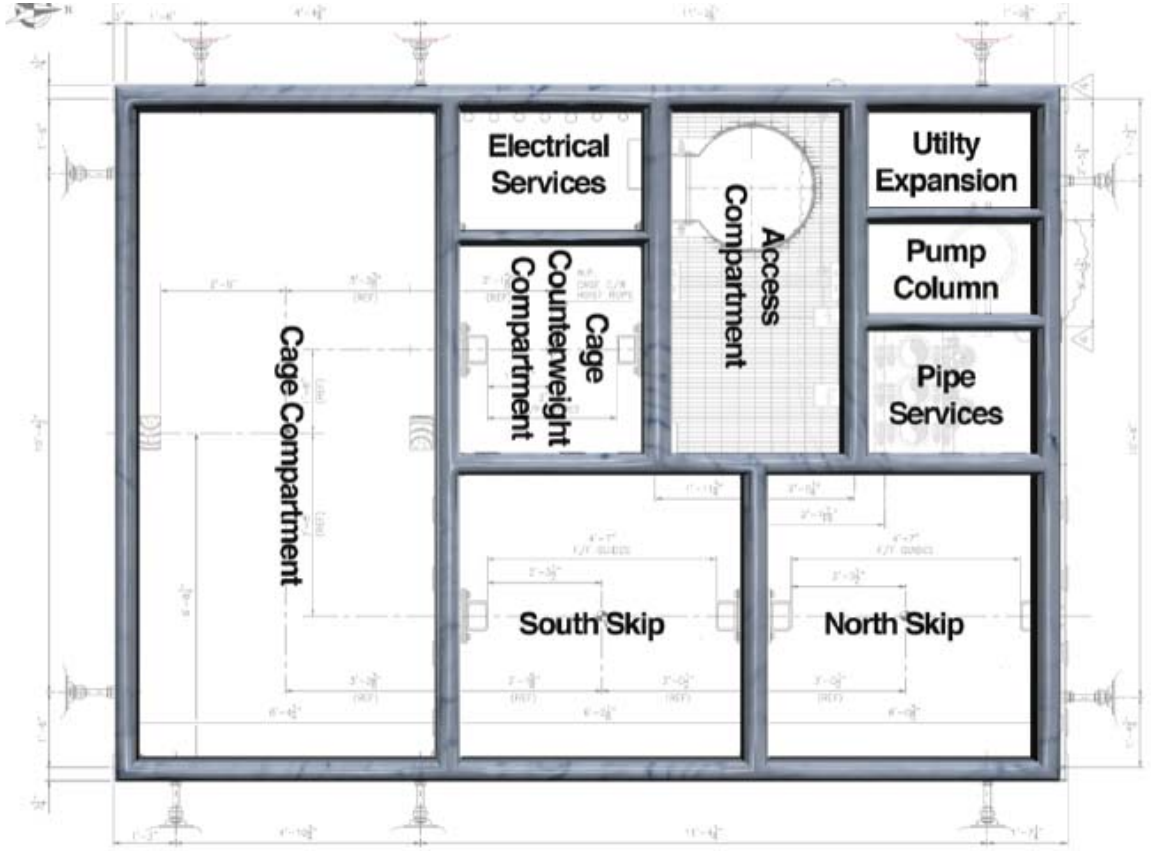
CFFS Scope:
Far Detector Caverns: Phased excavation

Phase 3



Ross Shaft Rehabilitation





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

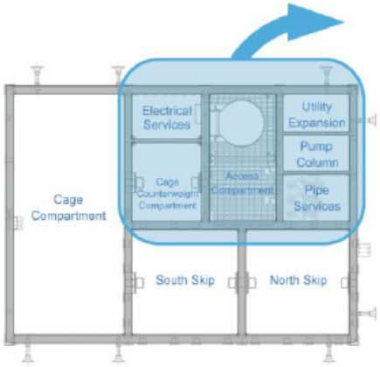
From M. Headley Presentation Oct 8-10, 2014

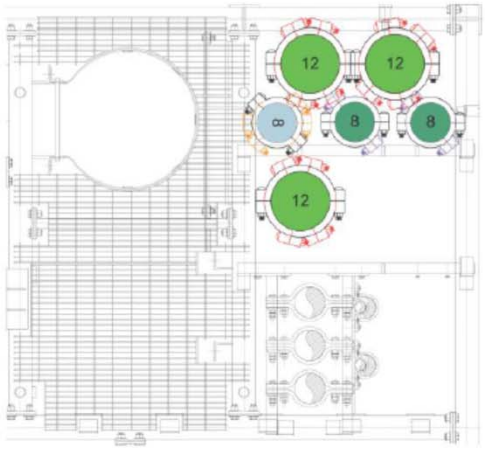
Scale of 1 cryostat … Building 156 at CERN

Potential GN2/LN2 Cycle with Ross Shaft Vertical Pipe Run

Surface compressors

ROSS SHAFT



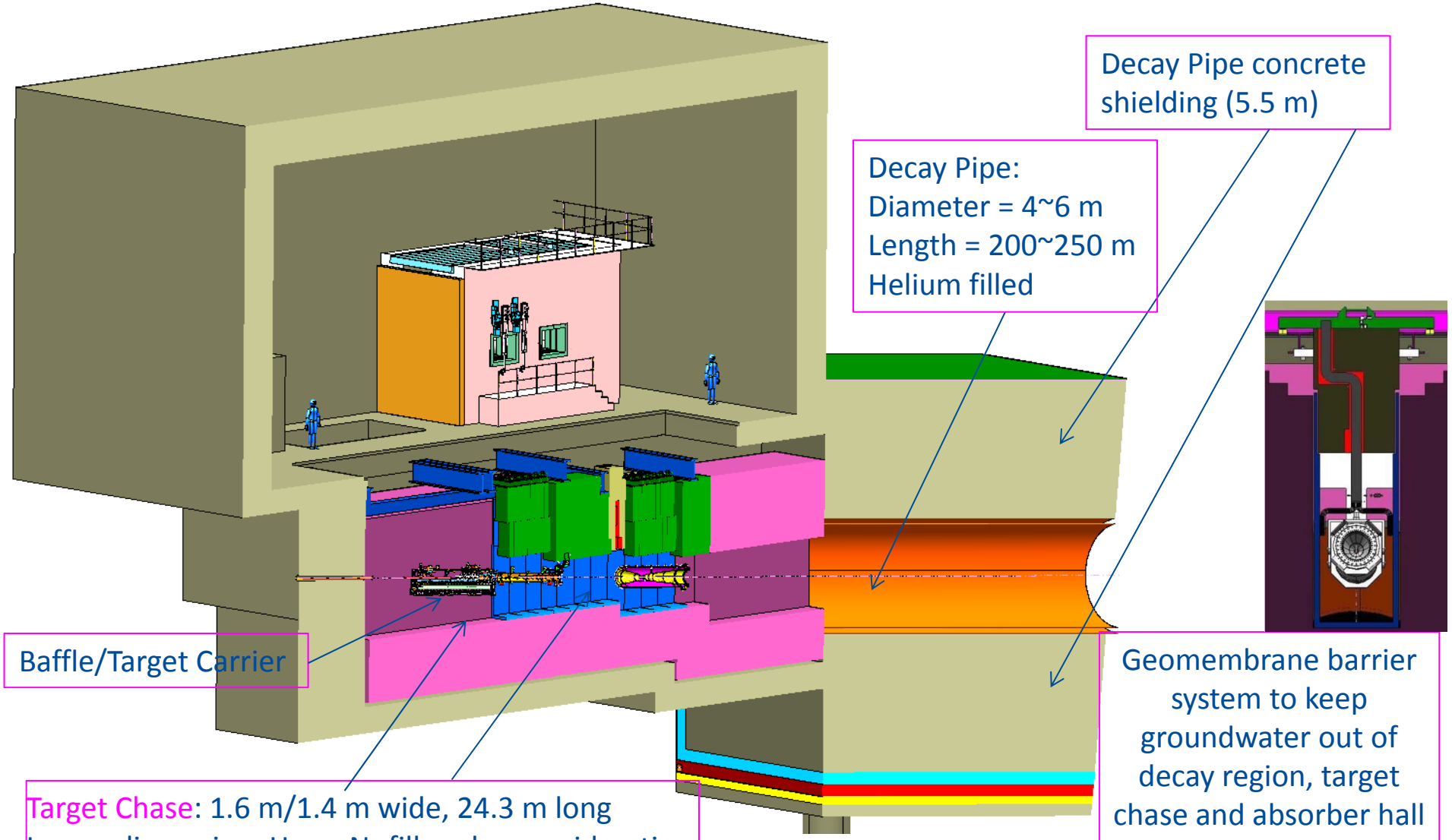


COSMODYNE
A Cryogenics Industries, Inc. subsidiary

One of four LN2 Cold Boxes

Fermilab

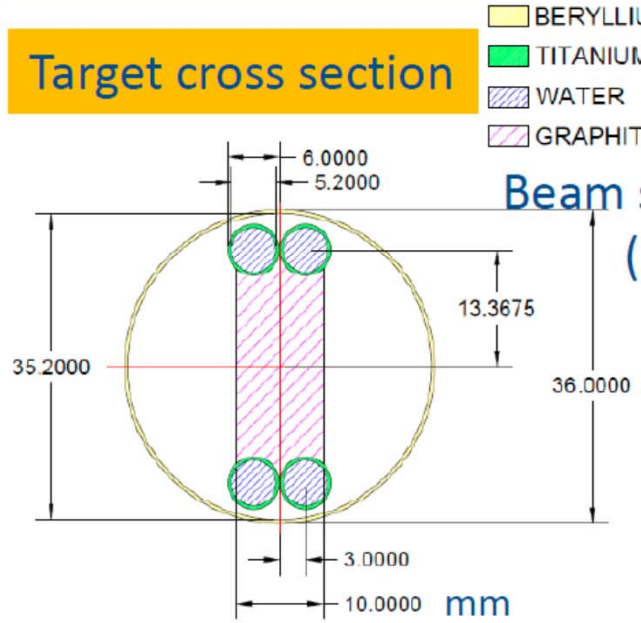
Beamline Scope:
Target Hall and Decay Pipe Layout



1.2 MW components inside the target chase

47 graphite target segments, each 2 cm long

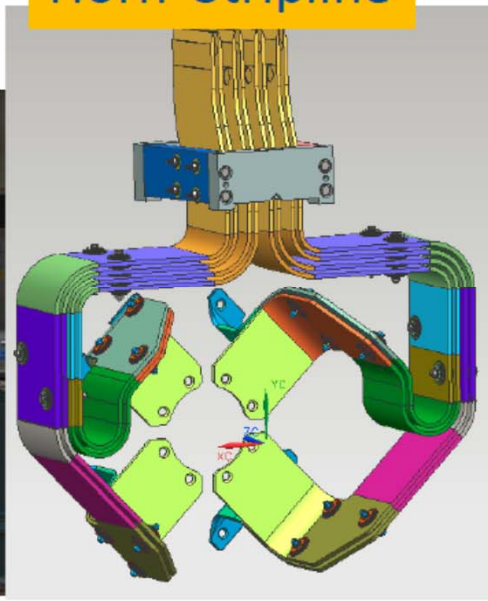
Target cross section



Beam size on target 1.7 mm
(reducing stress)

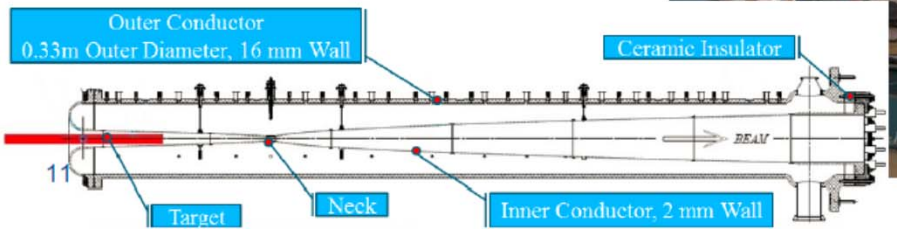
Baffle

Horn Stripline



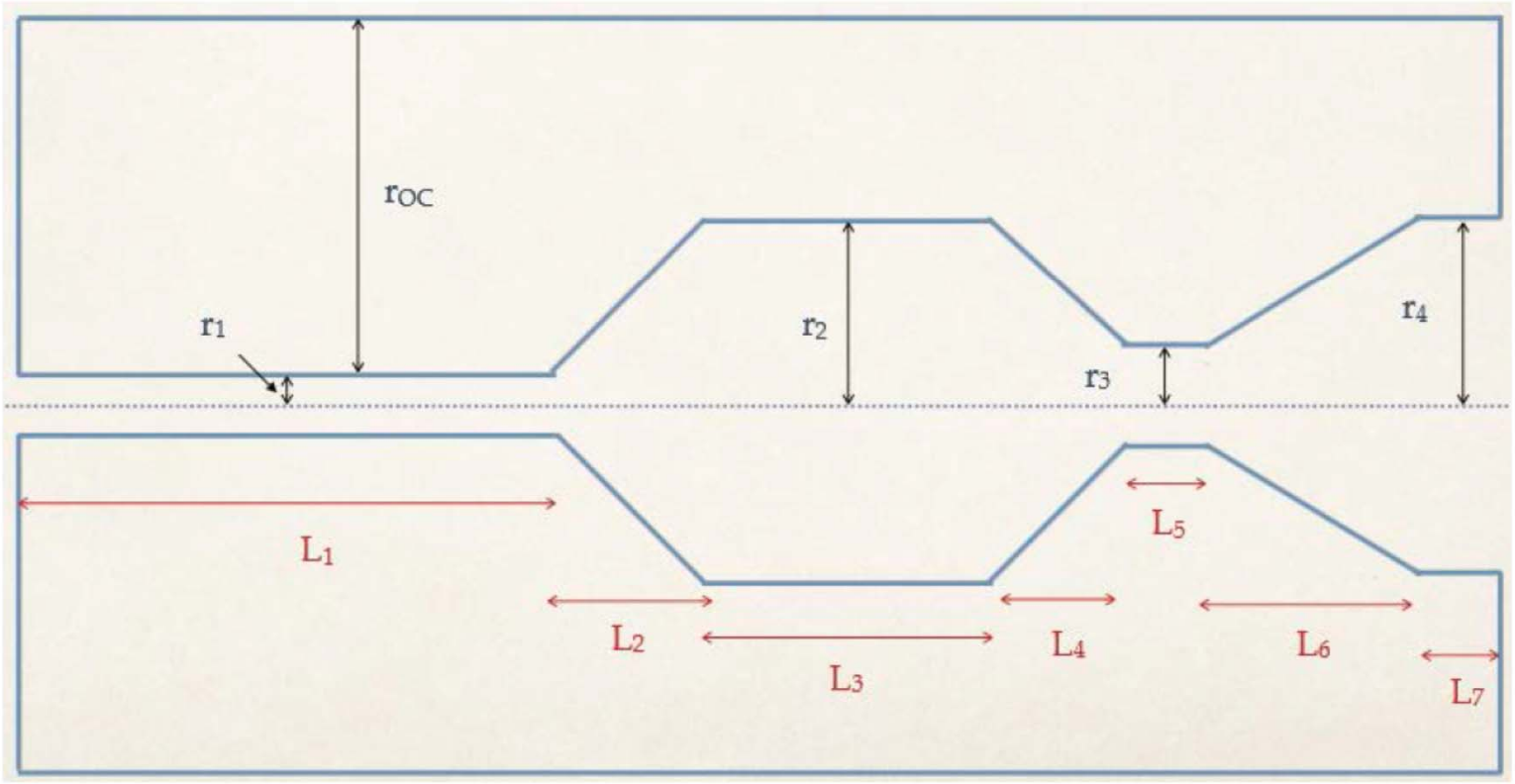
200-230 KA

Horn



Possible improvements in the focusing system

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

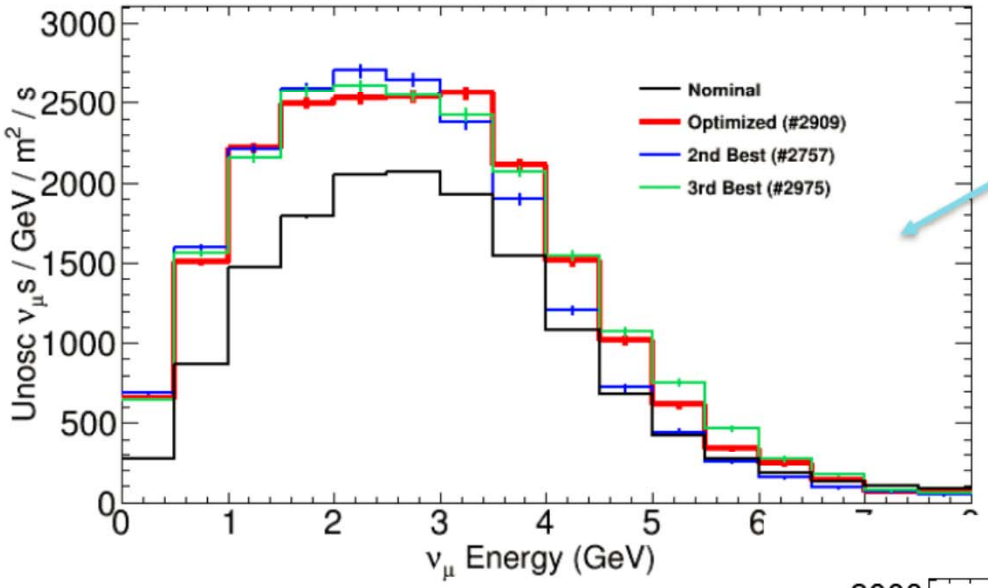


Optimized horn 1 is 5.1 m long

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

Muon neutrinos in neutrino running

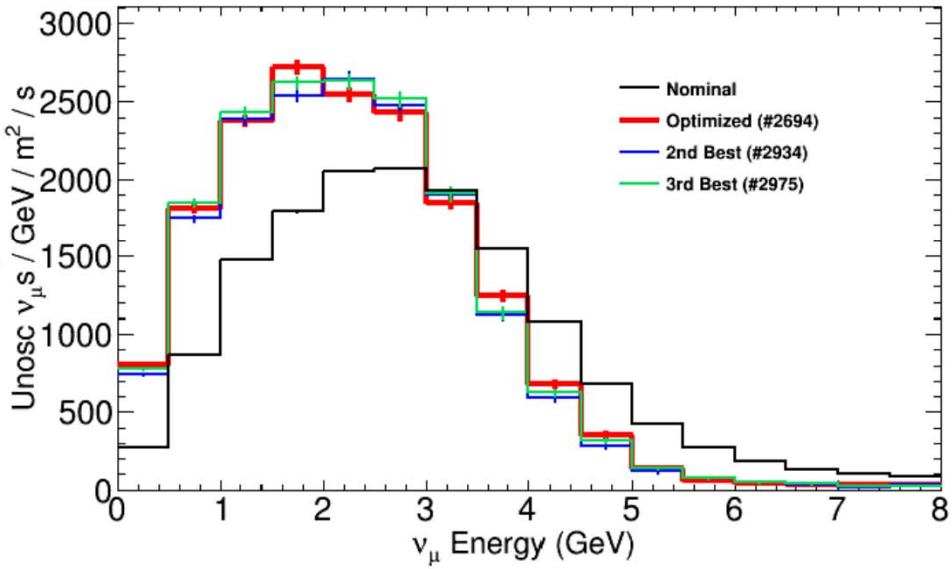
Laura Fields



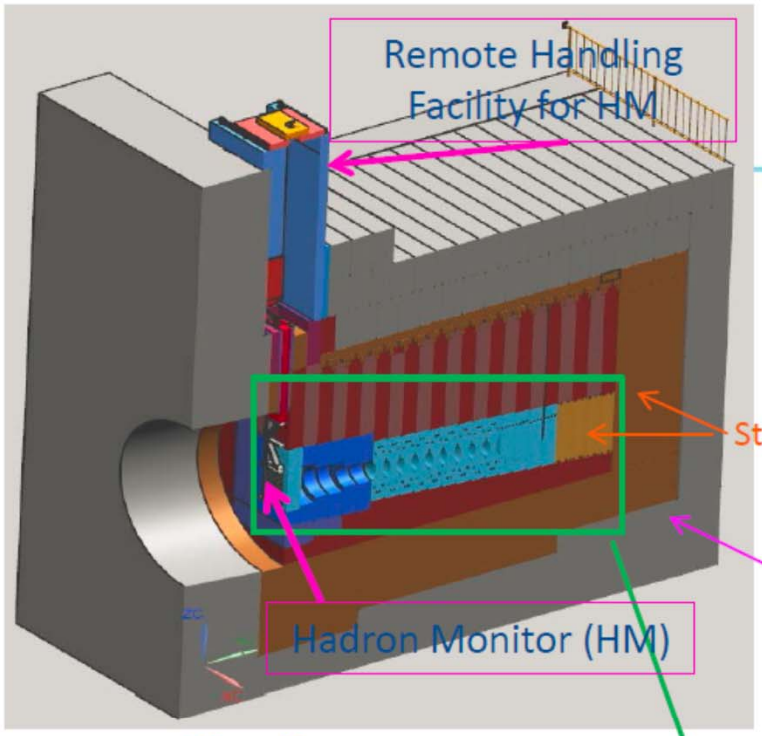
Optimizing Flux integrated between 1 and 4 GeV

3 years of neutrino running-34 kt

Optimizing CP Sensitivity

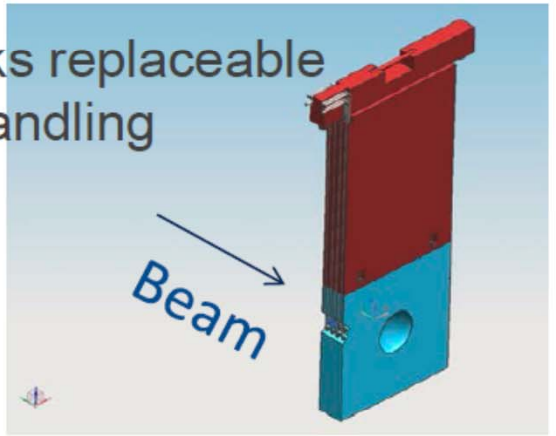


Current Configuration of Hadron Absorber

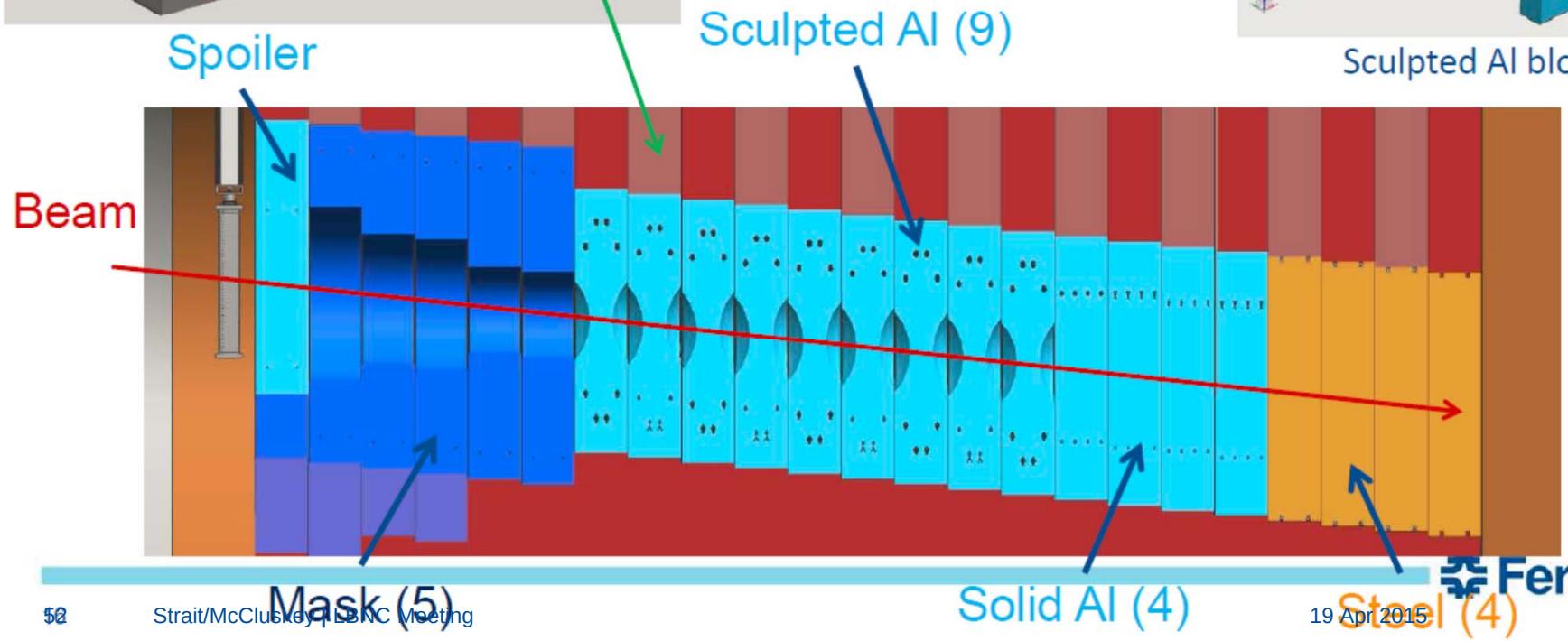


The Absorber is designed for 2.4 MW

- All core blocks replaceable via remote handling



Sculpted Al block



Near Detector Surface Building

Schedule

Schedule Goals set in the LOI

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