

Beamline Status

Jonathan Lewis

LBNC Meeting

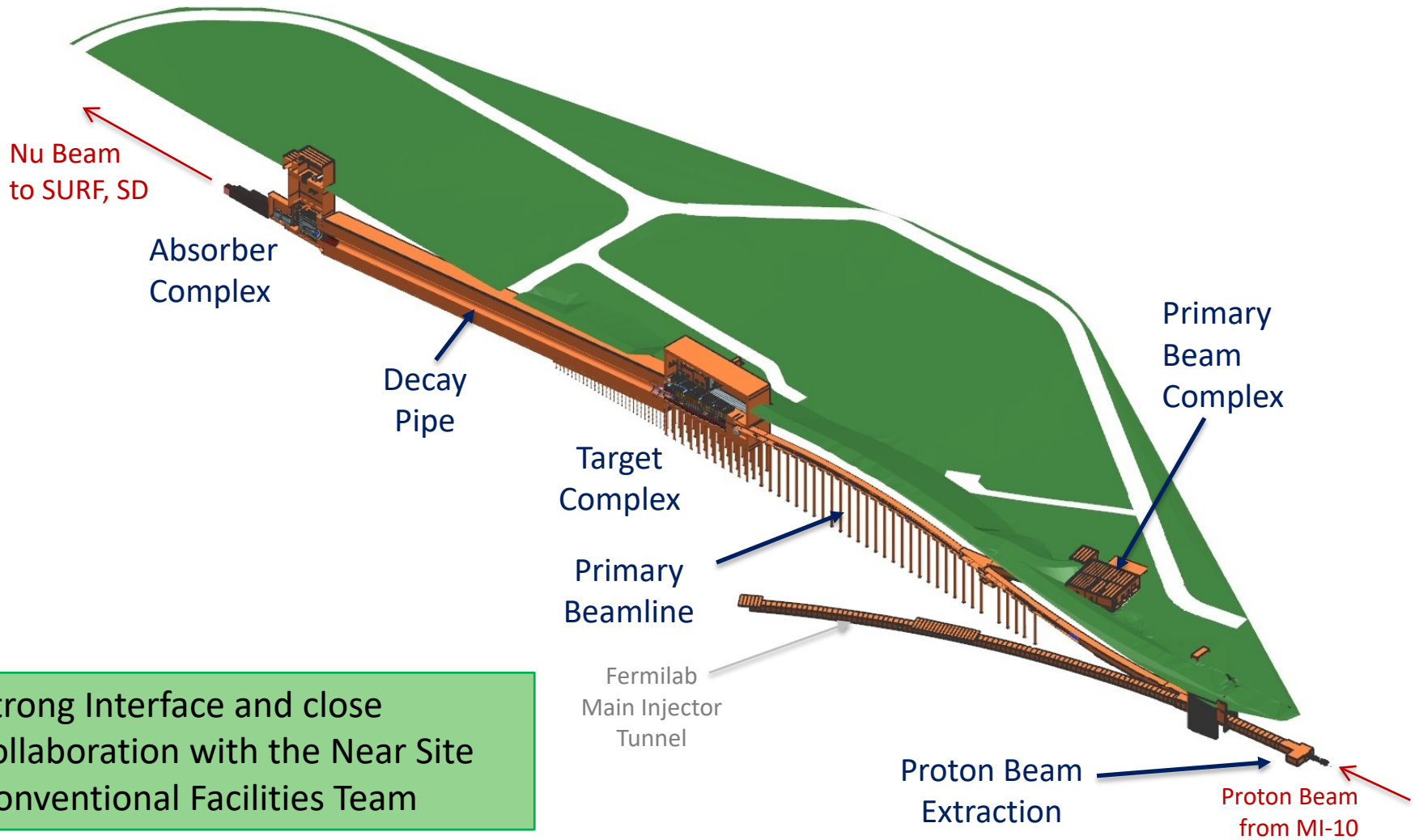
6 December 2019



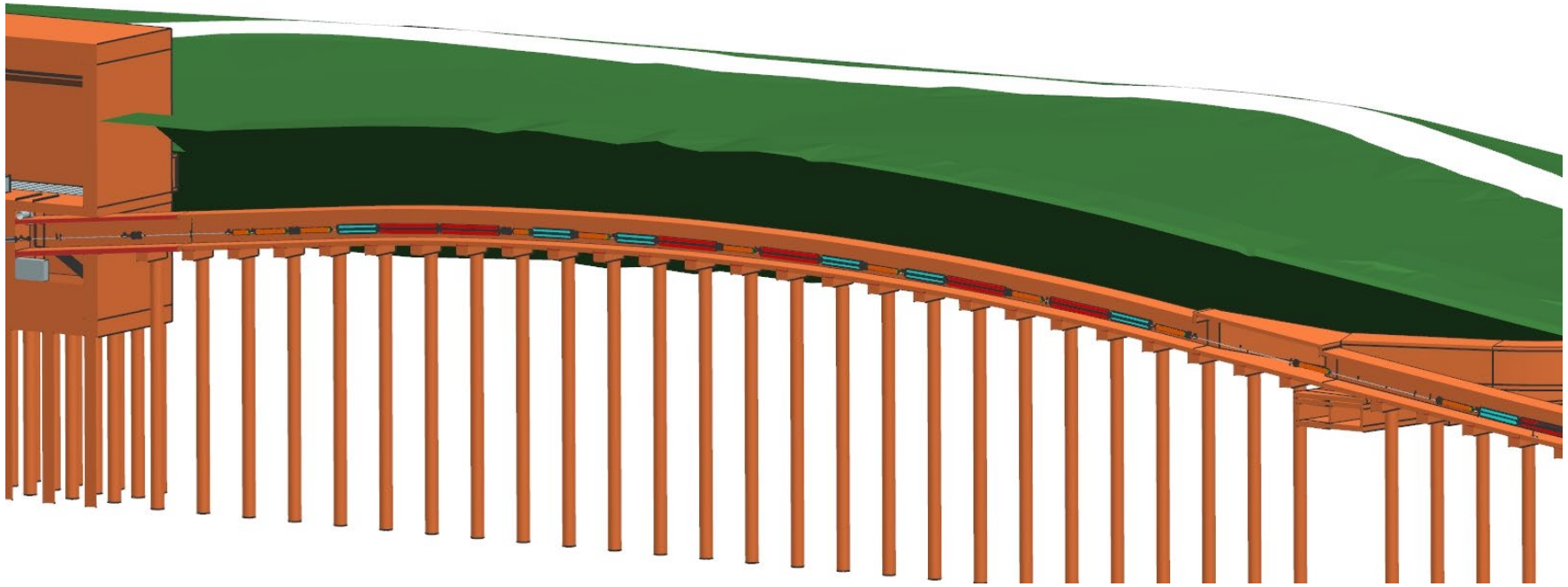
Outline

- Scope Overview
- Organization
- Design Status
- DOE project cost and overall schedule status
- ESH
- QA
- Risks
- Plan to CD2
- Summary

Scope: Beamline Technical Components

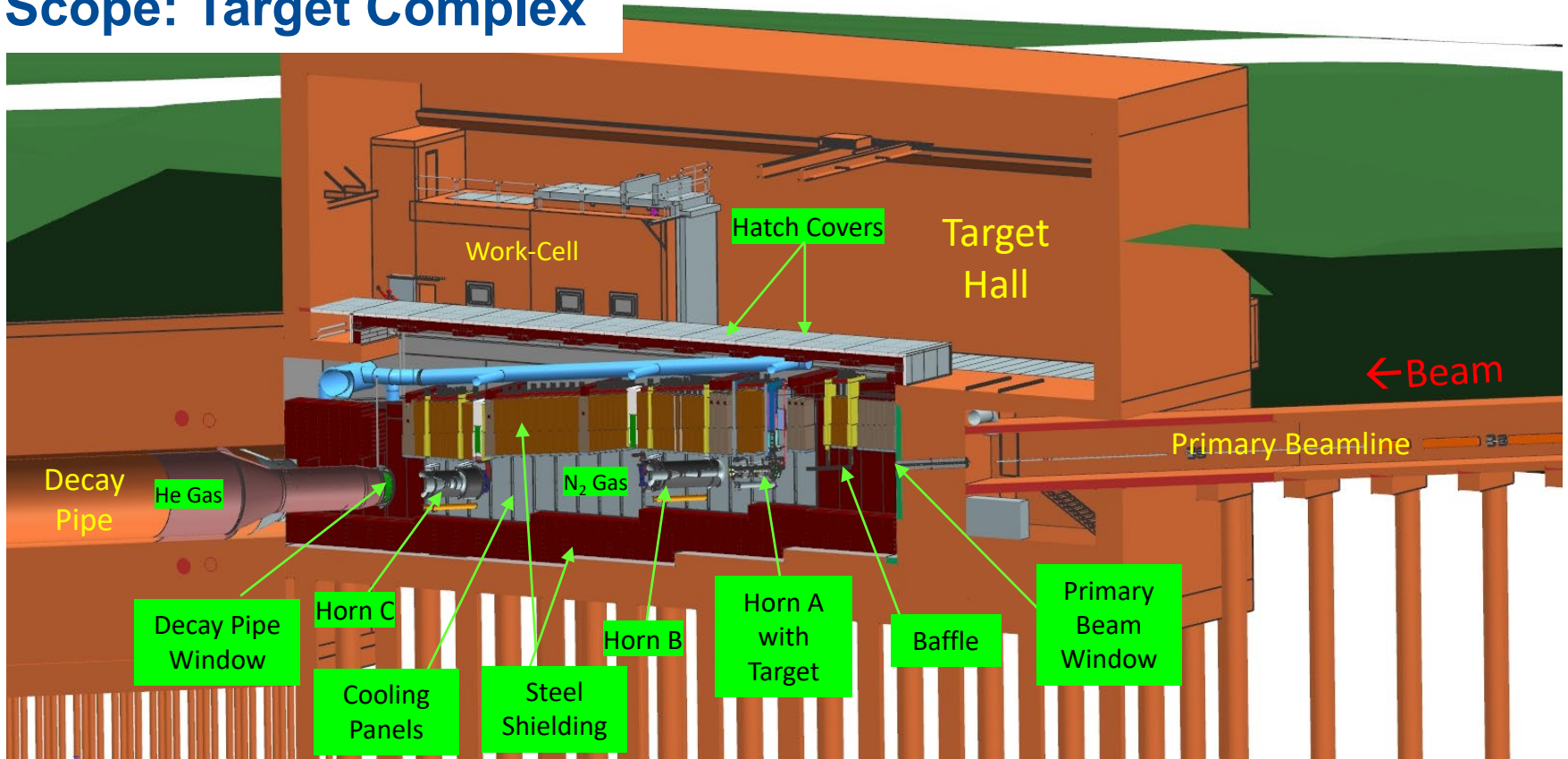


Scope: Primary Beam



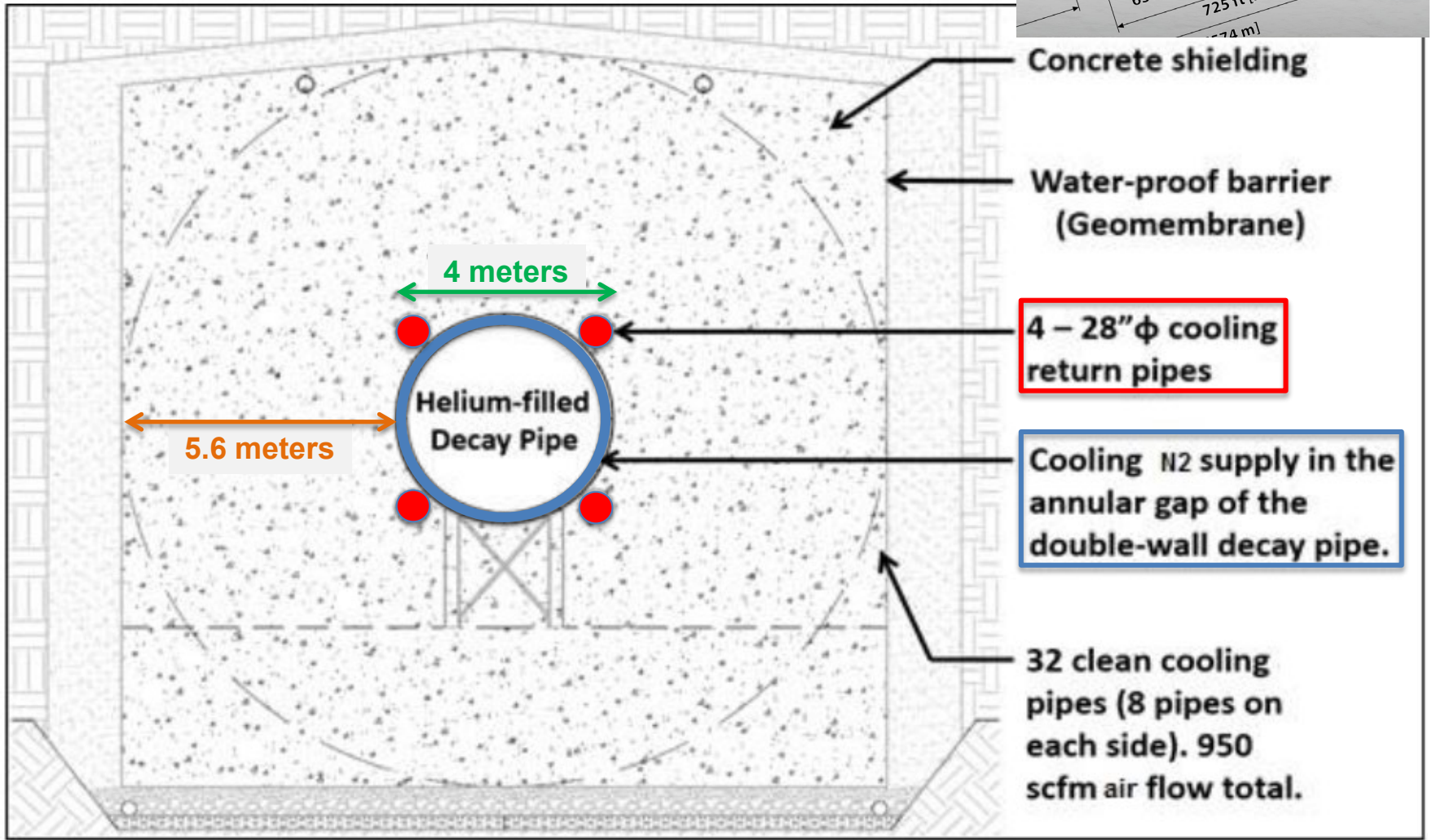
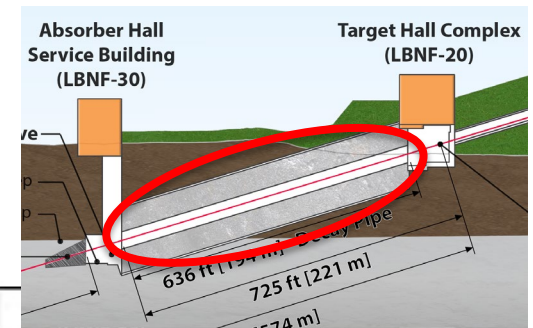
- Beam optics, magnets, magnet power supplies, water systems, vacuum, beam instrumentation, installation
 - International contributions
 - Corrector Magnets: IHEP
 - Main Dipole & Quadrupole Magnets: BARC

Scope: Target Complex

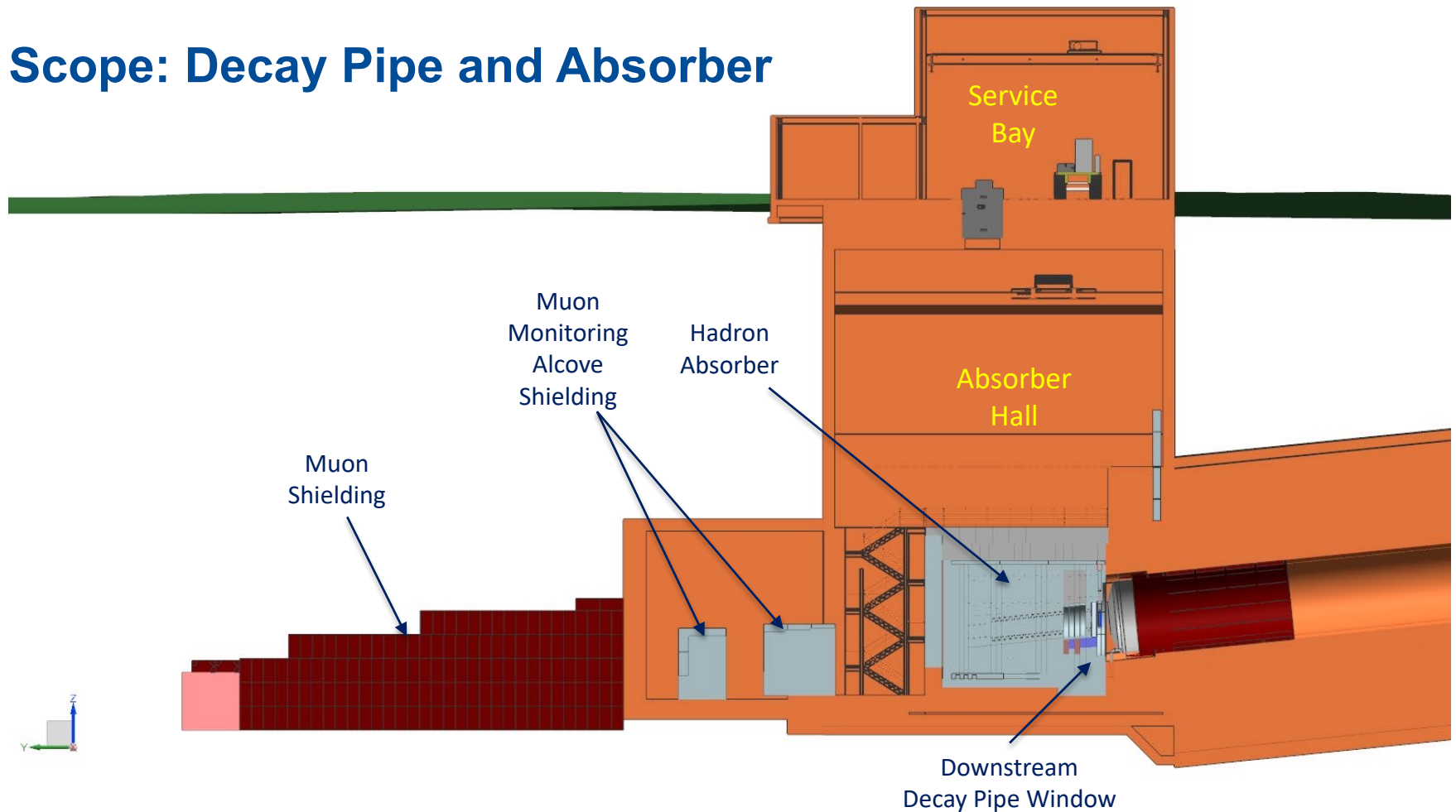


- Baffle, target, focusing horns, support modules, horn power supply, target shield pile, radioactive water systems, remote handling, storage of radioactive components
- International Contributions:
 - Target, Baffle and associated systems: RAL-UK
 - Stripline Feedthrough & Hatch Cover Prototypes: KEK-JPARC

Decay Pipe - Diagram



Scope: Decay Pipe and Absorber



- Primary beam window, decay pipe cooling and windows, hadron absorber, hadron monitor, muon systems

Additional Scope

- Beamline System Integration
 - Controls, Interlocks, Alignment, Installation Infrastructure and Coordination
- Project Management
 - Includes Beamline Modeling and Radiation Physics & Protection.

Beamline Requirements & Assumptions

- Driving physics considerations for the LBNF Beamline are the long baseline neutrino oscillation analyses.
- Beam directed towards SURF in Lead, South Dakota, 1300 km from Fermilab (5.8 degree overall vertical bend).
- Primary beam, single turn extracted from MI, is designed to transport high intensity protons in the energy range of 60-120 GeV to the LBNF target.
- Broad band, sign selected neutrino beam with its spectrum to cover the 1st (2.4 GeV) and 2nd (0.8 GeV) oscillation maxima => covering 0.5 ~ 5.0 GeV.
- Uptime (including the accelerator complex) of at least 55%

Beamline Requirements & Assumptions Contd.

- All systems are designed for 1.2 MW initial proton beam power and facility is upgradeable to 2.4 MW proton beam power.
- All systems that are prone to failure, such as water-cooled systems, are designed to be repairable and/or replaceable.
- Overall, LBNF can take up to 20% of lab's offsite radiation dose budget with stringent limits placed on radiological protection of environment, workers and the public. Self imposed 30% limit of lab's radioactive air emissions "cap". Entire facility encapsulated in water-proof barrier.
- Facility assumed to operate for 20 years within a 30 year span. Design life of Target & Absorber Hall Complexes and of Decay Pipe is 50 years, design life of water barrier system is 80 years.

Beamline Operating Parameters

$(1.1 - 1.9) \times 10^{21}$ POT/yr

Pulse duration: 10 μ s

Beam size at target:
tunable 1.0 - 4.0 mm
Present size \sim 2.7 mm

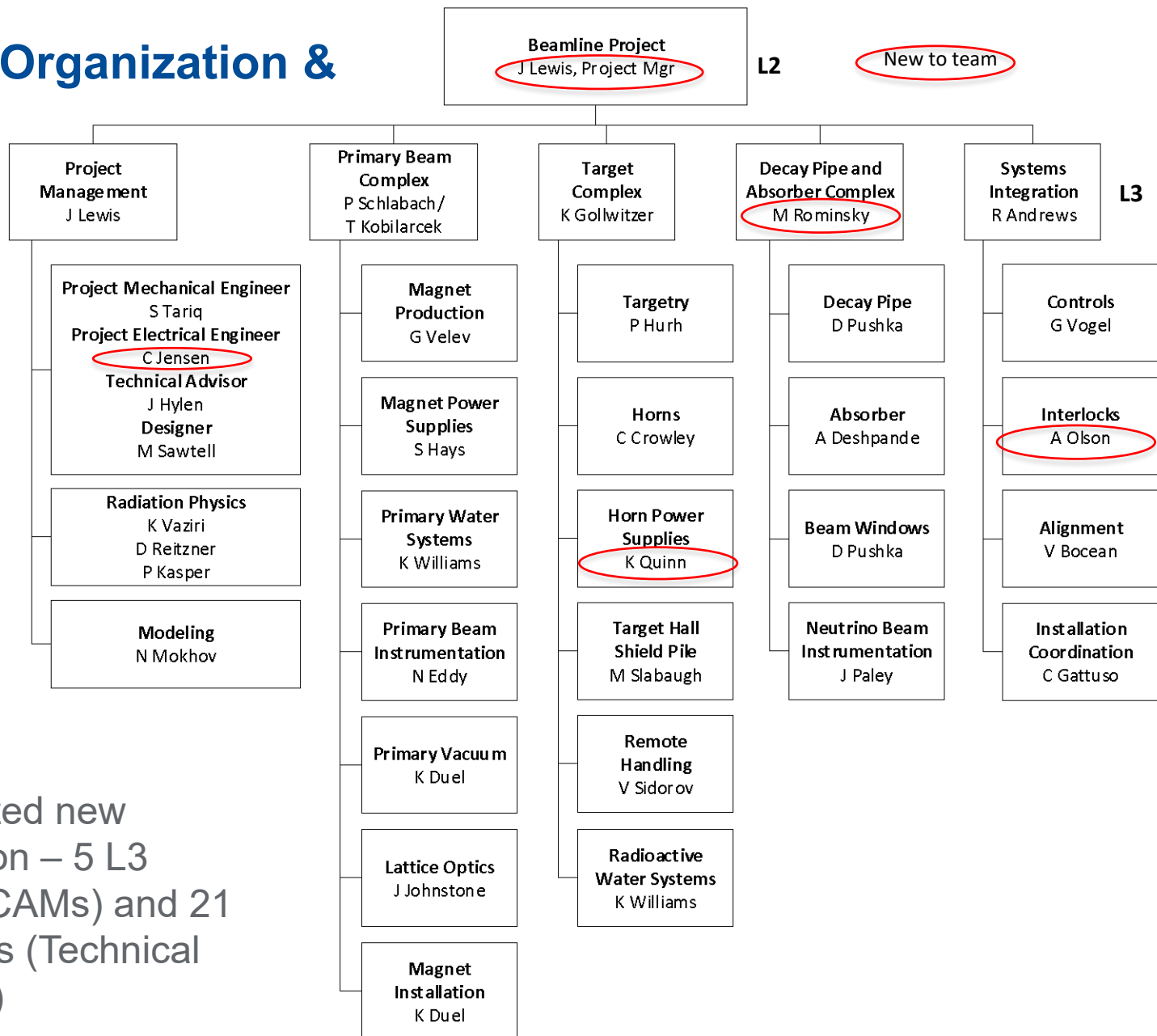
Parameter	Protons per cycle	Cycle Time (sec)	Beam Power (MW)
≤ 1.2 MW Operation - Current Maximum Value for LBNF			
Proton Beam Energy (GeV):			
60	7.5E+13	0.7	1.03
80	7.5E+13	0.9	1.07
120	7.5E+13	1.2	1.20
≤ 2.4 MW Operation - Planned Maximum Value for LBNF 2nd Phase			
Proton Beam Energy (GeV):			
60	1.5E+14	0.7	2.06
80	1.5E+14	0.9	2.14
120	1.5E+14	1.2	2.40

- Some Tevatron, NuMI components and some existing Fermilab steel available to LBNF
- Actively implementing lessons learned from MiniBooNE, NuMI/MINOS, NuMI/NOvA, JPARC and other Neutrino Facilities.

Systems being designed for 2.4 MW

- Upgrading these items later would be prohibitively expensive and inconsistent with ALARA:
 - Size of enclosures (primary proton beamline, target chase, target hall, decay pipe, absorber hall)
 - Radiological shielding of enclosures (except for the target hall roof that can be easily upgraded for 2.4 MW when needed)
 - Primary Beamline components
 - Target chase cooling panels
 - Decay pipe, its cooling and the decay pipe downstream window
 - Hadron Absorber
 - Remote handling equipment
 - Radioactive Water (RAW) system piping
 - Horn support structures are designed to last for the facility lifetime

Beamline Organization & Staffing



- Implemented new organization – 5 L3 systems (CAMs) and 21 L4 systems (Technical Managers)

Beamline Design – Recent Progress

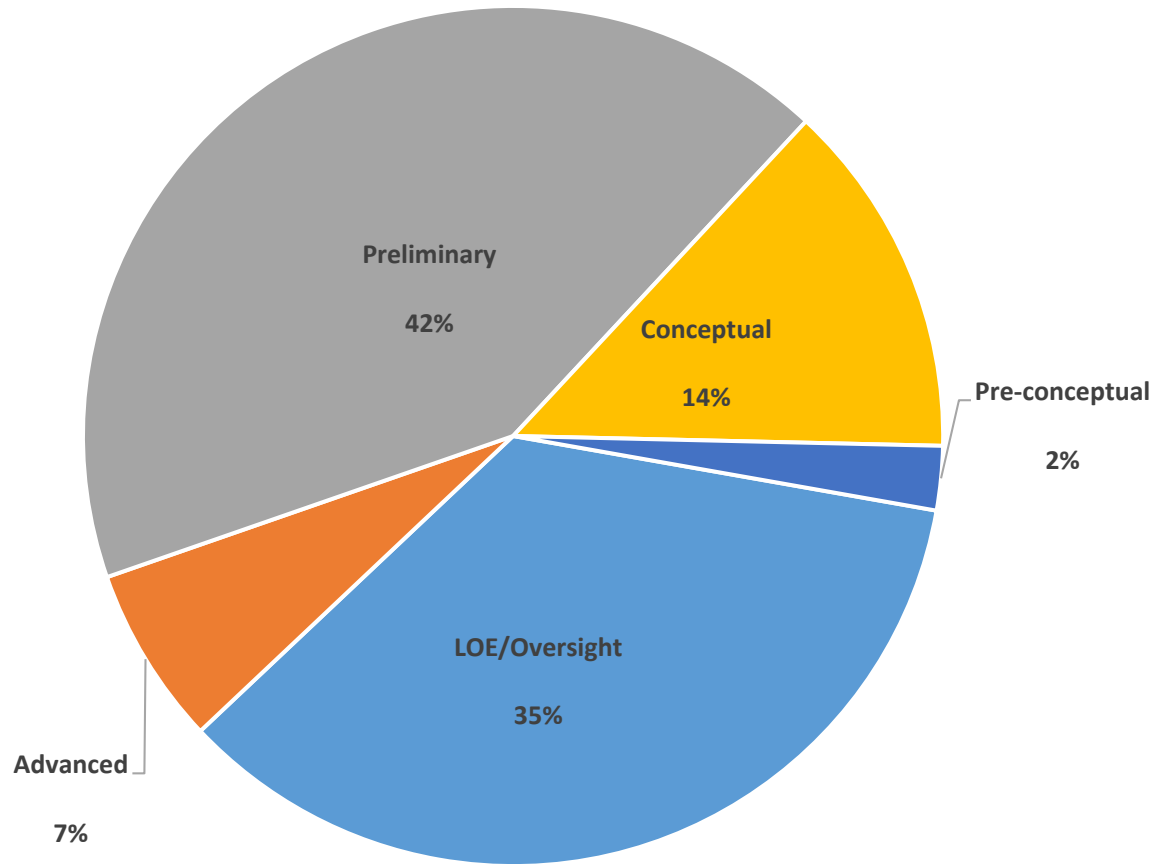
- Preliminary design progressing – continuing to push hard on design maturity (see next slide) and securing needed resources.
 - Continue to mature 3D CAD integration models
- Filled management and added mechanical engineering resources
- Working with professional estimator to update BOEs for all procurements
- Completed all high-level interface specifications and requirements between Beamline and NSCF
 - Working with CF to review preliminary design from A/E
- Working on Beam-Beam interface definitions – 75% interfaces completed, on plan to complete >90% interfaces by end of CY19.

Design Maturity

- Maturity as of 9/30/19
- Maturity of Primary Beam, Target Complex, Decay Pipe & Absorber Complex, and Systems Integration weighted by BCWS costs of each element.
 - Project Management excluded
- **Overall: 52%**

WBS Name	Design Maturity
Primary Beam	0.76
Magnet Production	0.90
Magnet Power Supplies	0.75
Primary Water System	0.50
Primary Beam Instrumentation	0.80
Primary Vacuum	0.64
Lattice Optics	0.92
Magnet Installation	0.53
Target Complex	0.45
Targetry	0.18
Horns	0.25
Horn Power Supplies	0.30
Target Hall Shield Pile	0.65
RAW Water Systems	0.40
Remote Handling Equipment	0.50
Decay Pipe and Absorber Complex	0.39
Decay Pipe	0.30
Absorber	0.65
Beam Windows	0.20
Neutrino Beam Instrumentation	0.25
System Integration	0.52
Controls	0.65
Interlocks	0.63
Alignment	0.38
Beamline Installation Coordination	0.50

Beamline Quality of Estimate – based on design maturity



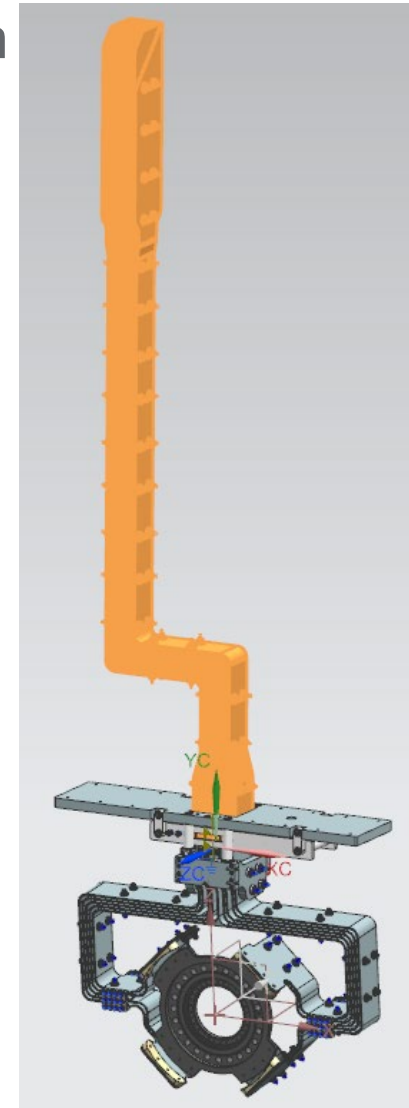
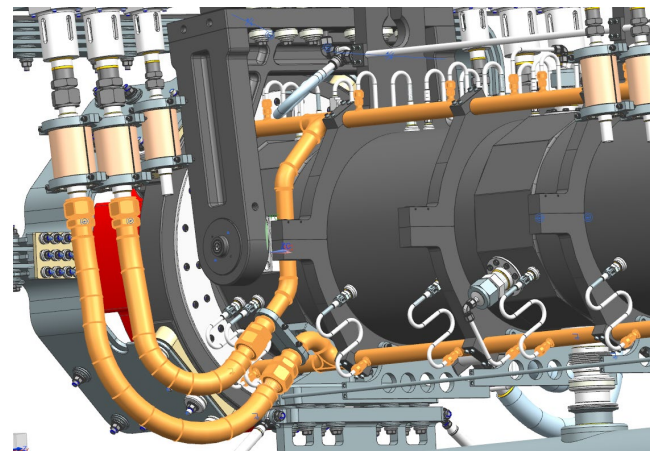
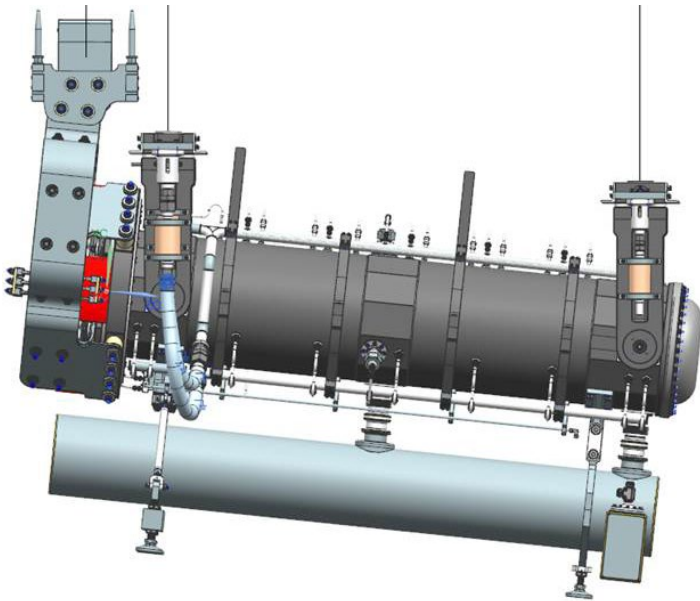
Primary Beam Design Progress highlights

- Optimized the layout of the Primary beam Service Building (LBNF 5) and MVA (Magnet Vehicle Access) tunnel for improved utility routing and operational efficiency.
- Completed requirements and specifications for the Magnet Vehicle (to transport and install magnets), identified capable vendors, working with procurement on a RFI.
- Completed dipole magnet stand design technical review.
- Low Conductivity Water system preliminary design nearly done. Review scheduled.
- Started on preliminary design for primary beam vacuum.



Target Complex Design Status Highlights

- Advanced Horn A and module design. Working with RAL on the target interface and exchange mechanism including layout of all the utilities.
- Completed thermal analysis for the target shield pile (TSP) – Preliminary results show acceptable temperature distribution.



Target Complex Design Status Highlights

- Completed horn stripline electrical design together with the ceramic insulator mechanical design. Also providing stripline electrical design input to J-PARC for the stripline feedthrough.
- Made several value engineering and operational improvements to the Target Complex such as relocating the truck bay.
- Several technical reviews completed: Horns and stripline FE analysis review, Cooling panel prototype design review.
- Advanced conceptual design for control of tritium and ^{41}Ar

Decay Pipe & Absorber Complex Design Status highlights

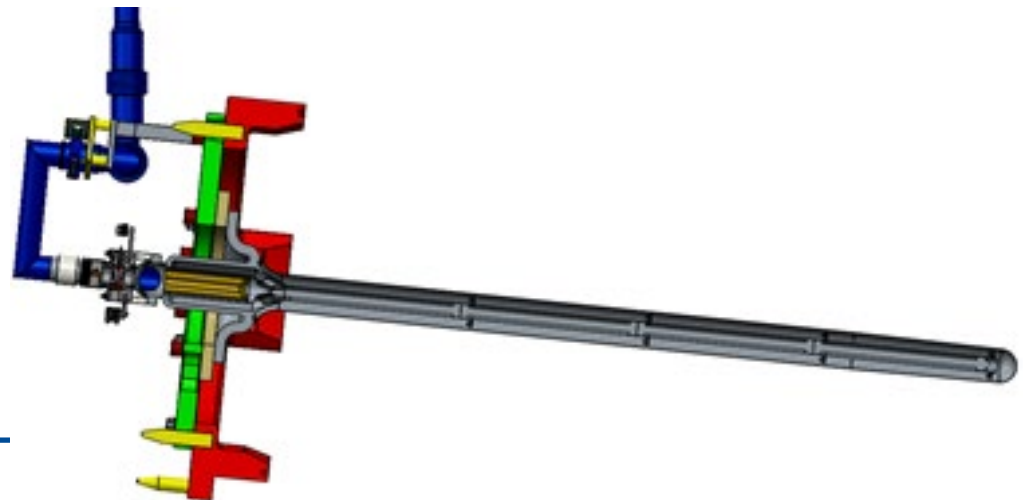
- Completed conceptual design for decay pipe upstream window exchange mechanism
- Advanced the design of the downstream decay pipe N₂ return system.
- Completed first pass at installation procedure for Absorber – showed that the existing layout of Absorber Service Building and hatch are adequate for Beamline needs.
- Revised accident condition to account for the baflette and reanalyzing decay pipe window
- Analyzing absorber to account for 1.5m target

System Integration Design Status highlights

- Working on interface control documents within Beamline scope
 - 147 interfaces identified. Conducting verification with stakeholders
- Controls: Preliminary design work was completed in January 2019 with an AD/Controls Preliminary Design review completed in February 2019. Further development contingent on planned accelerator controls upgrade.
- Interlocks: Awaiting design of enclosures for delineation of location of entrances.
- Alignment: Completed preliminary design, full prototype assembly, and testing of Remote Survey Equipment for Aligning Target and Horns.
- Installation Coordination: An internal review of the task estimates (costs and duration) is being conducted, in addition the scope of each task is being verified.

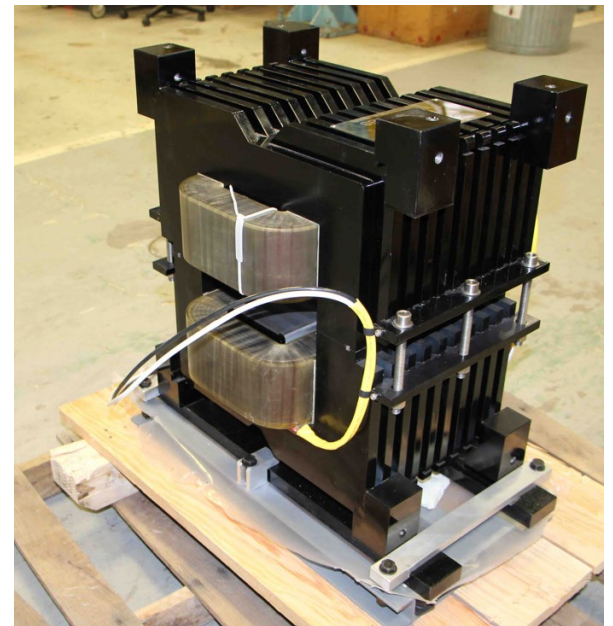
International Partner Status – Contributions

- RAL-UK collaboration on target progressing well.
 - Considered three target options
 - Conceptual design for a cantilevered, helium-cooled graphite cylinder was approved at Aug. 21 review
 - 1.5m target will be taken to preliminary design and prototyped
 - Goal is prototype can act a functional spare
 - Lessons to be learned from prototype may allow final design and production target to be longer
 - Goal is 4 interaction lengths = 1.8m of graphite



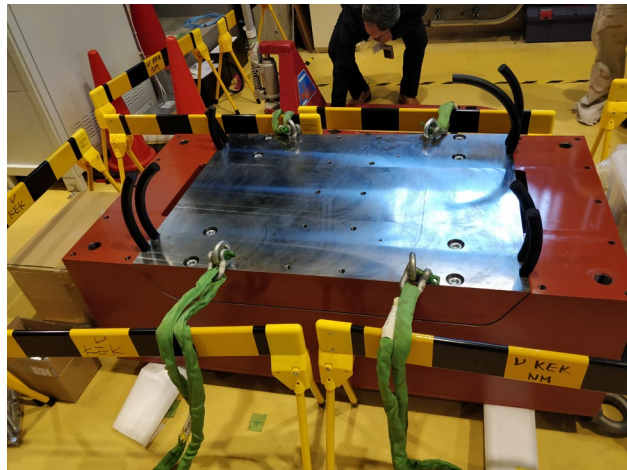
International Partner Status – Contributions

- IHEP-China production of corrector magnets completed
 - First five magnets have passed all tests at FNAL
- BARC-India collaboration solidified
 - India to build main dipole and quadrupole magnets
 - Using FNAL designs with minor modifications
 - Interoperable with existing magnets



International Partner Status – R&D and Prototyping

- KEK-Japan collaboration ongoing – Japan continuing to fund R&D for LBNF beamline in 2019/2020.
 - Prototype hatch cover tested at J-PARC and shipped to FNAL
 - Prototype fabrication and testing for horn stripline currently underway at J-PARC (Fermilab engineers visited J-PARC in April for the prototype testing).
 - Other projects were discussed in Feb 2019
 - Helium cooling for target and hydrogen recombination for RAW systems

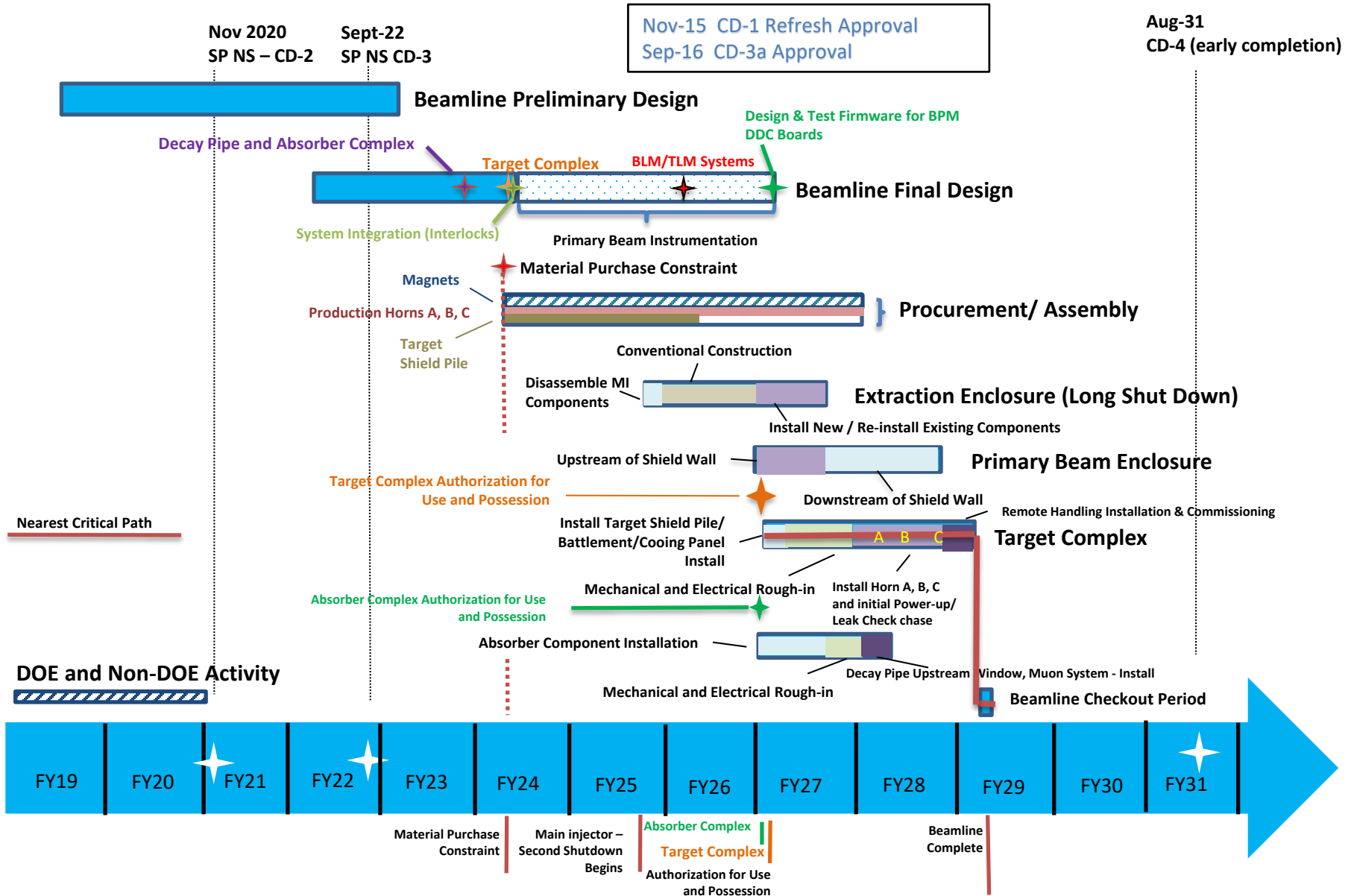


O-ring

Hatch Lid



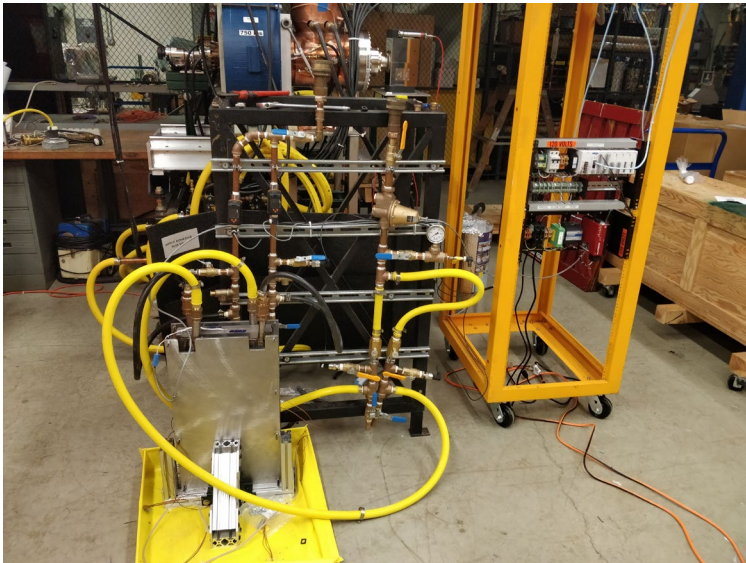
Beamline - Schedule Summary



Prototypes

- Prototype development and testing underway for several sub-systems:

Target Shield Pile Cooling Panel prototype being assembled at FNAL



Target Shield Pile Hatch Cover prototype being vacuum and pressure tested at J-PARC. Initial results look very good. (Joe Angelo, FNAL engineer, on left)

Horn Stripline Feedthrough prototype being pressure tested at J-PARC



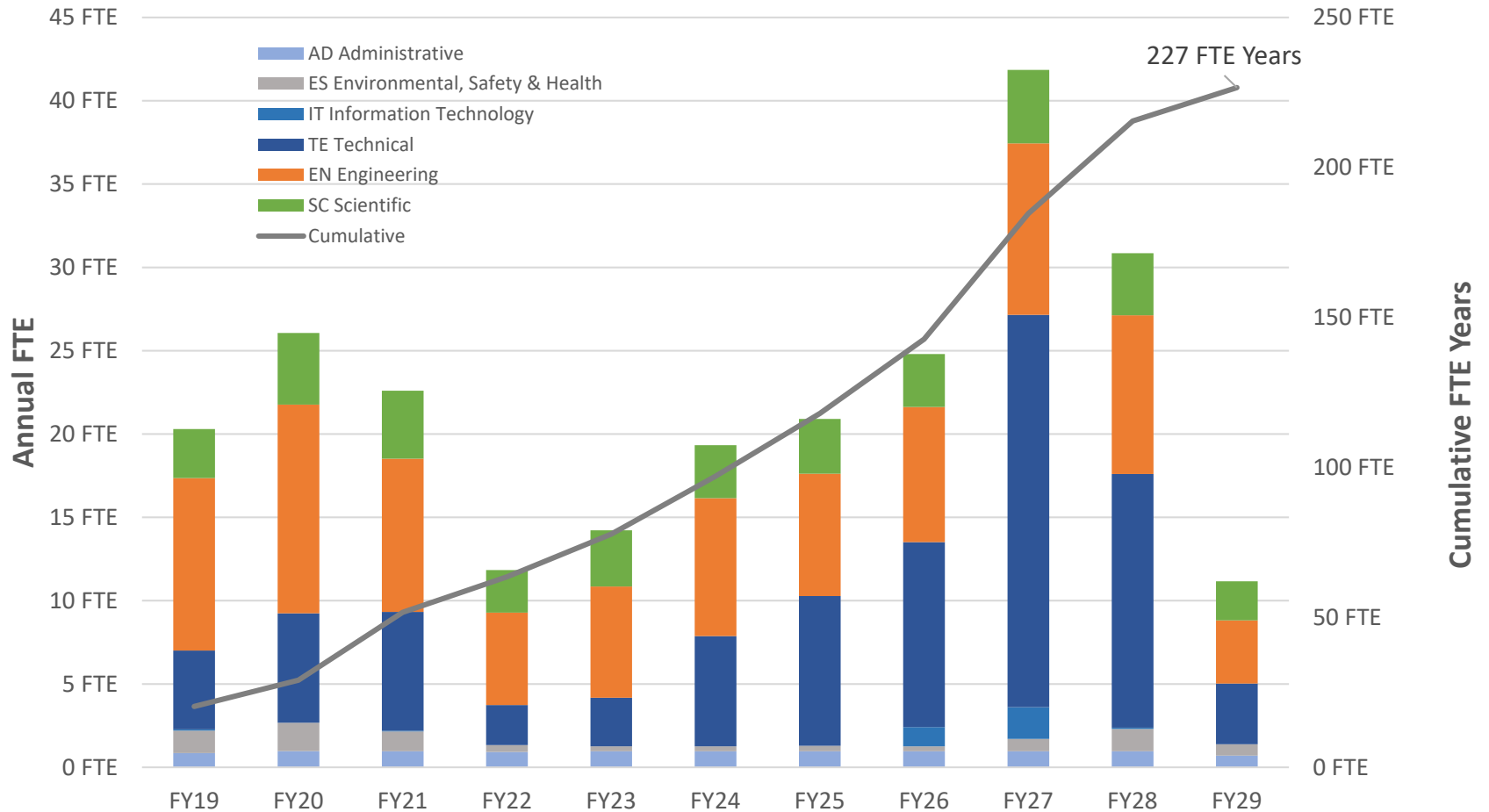
Prototyping Plans

Prototype	Institution	Timeframe to be built
Target	RAL/UK	2019-2021
Horn A	Fermilab	2021-2023
Stripline for Horn B/C	Fermilab	2023-2024
Target shield pile hatch cover nitrogen seal	KEK/Japan	In progress
Horn stripline feedthrough	KEK/Japan	In progress
Absorber core aluminum block and cooling lines	Fermilab	In progress

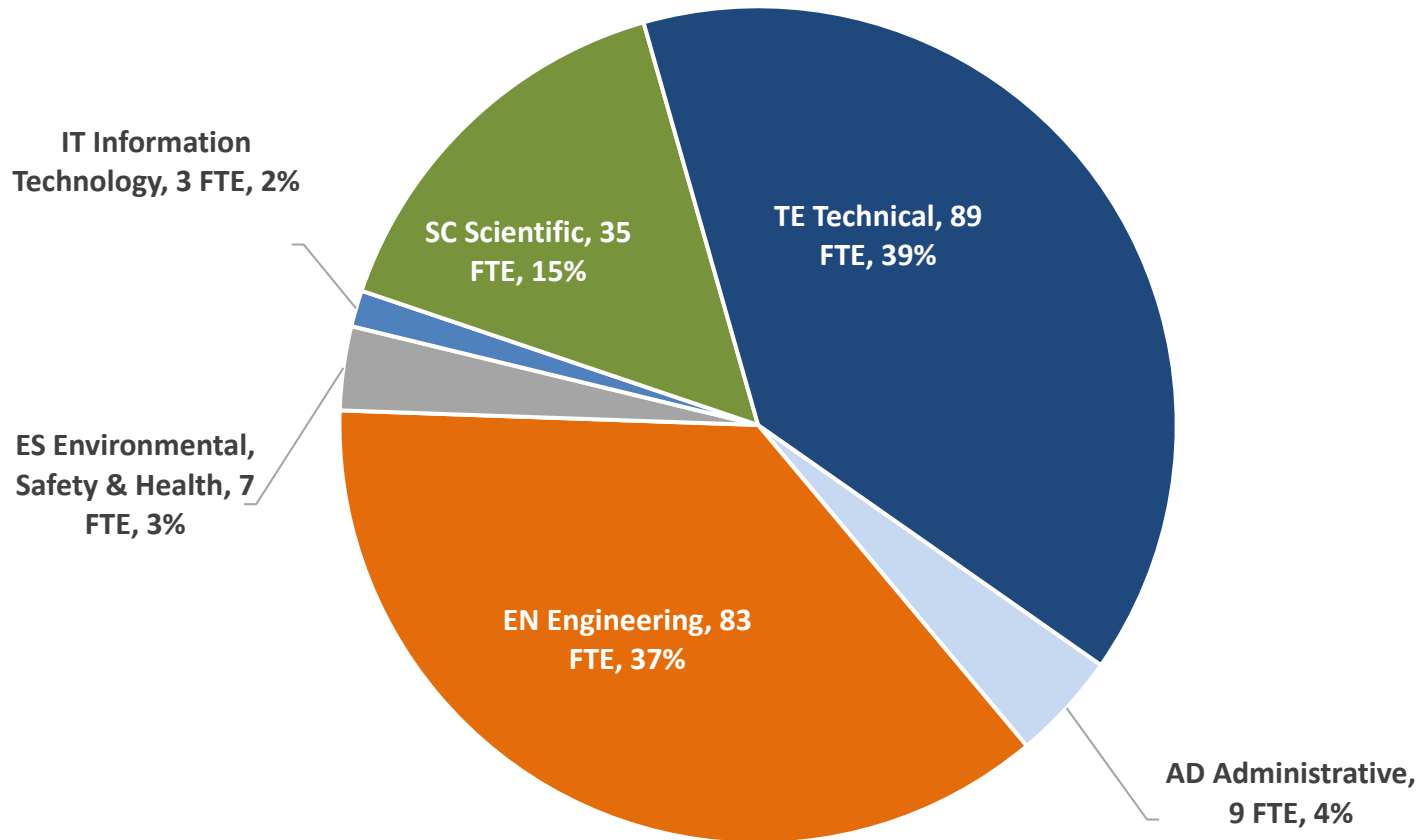
Plans for Reviews

Activity Name	Date	Activity Name	Date
Primary Beam		Target Complex	
Preliminary Design Review Primary LCW System	31-Oct-19	N2 Fill/Purge System Preliminary Design Review	22-Nov-19
Primary LCW System Electrical Bus Prelim. Design Review	31-Oct-19	Horn PS Unit Preliminary Design Review	20-Feb-20
Peer Review Preliminary Design of Vacuum System	6-Jan-20	Preliminary Design Review RAW Exchange System Skid TH	24-Mar-20
PBE Quad Stand Preliminary Design Review	13-Jan-20	Prelim. Design Review Shielding/Cooling Panels RAW	24-Mar-20
Magnet Install Plan Preliminary Design Review	16-Jan-20	Preliminary Design Review Target RAW Skid	24-Mar-20
Kicker Preliminary Design Review	10-May-21	Preliminary Design Review Horn A RAW Skid	24-Mar-20
Decay Pipe and Absorber		Preliminary Design Review Intermediate Cooling Skid TH	8-Apr-20
Absorber Components Preliminary Design Review	7-Jan-20	Battlement & Hatch Cover System Preliminary Design Review	30-Apr-20
Decay Pipe Air Cooling Routing Preliminary Design - review CF design	6-Mar-20	Preliminary Design Review Horn B RAW Skid	15-May-20
Decay Pipe Preliminary Design - review of CF design	12-Mar-20	TH Shielding Preliminary Design Review	27-May-20
Preliminary Design Review Intermediate Cooling Skid AH	24-Mar-20	Target Chase Cooling Preliminary Design Review	27-May-20
Preliminary Design Review Absorber RAW Skid	24-Mar-20	Preliminary Design Review Horn C RAW Skid	19-Jun-20
Preliminary Design Review RAW Exchange System Skid AH	31-Mar-20	Horn PS Preliminary Design Review	24-Jun-20
Decay Pipe Upstream Window Preliminary Design Review	22-May-20	Baffle Module/ Carrier Preliminary Design Review	22-Sep-20
Beam Windows Preliminary Design Review	26-May-20	He System Preliminary Design Review	20-Oct-20
Neutrino Beam Instrumentation Prelim. Design Review	9-Apr-21	Target Preliminary Design Review	24-Nov-20
Preliminary Design Hadron Monitor and Review - Labor	13-May-21	Baffle Carrier & Module Structural & Thermal Analysis Rev.	15-Jun-21
RH Absorber Complex Preliminary Design Review	17-Sep-21	Remote Handling TH Preliminary Design Review	27-Aug-21
		Horns Preliminary Design Review	6-Apr-23

Beamline Labor Resource Profile – (FY19+)



Beamline Labor Resources by Type (Est to Complete) – FTE-Years



Beamline Management and Resources

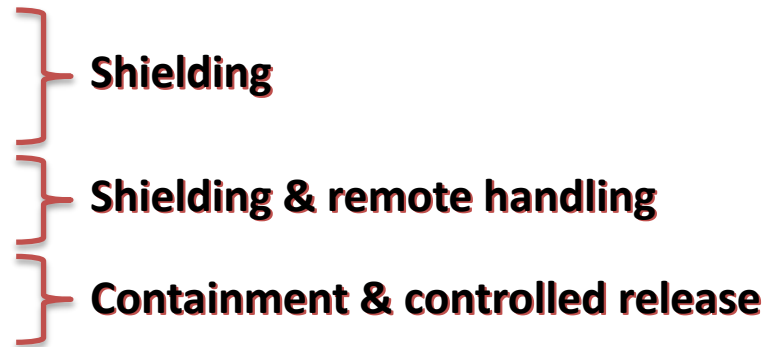
- We have individuals identified in the schedule through FY20. For Lab planning purposes we provide as well the disciplines needed by Fermilab Divisions/Sections beyond FY20.
- All of the Beamline labor is fully matrixed from AD, TD, and PPD.
 - PPD provides FEA expertise plus mechanical design engineers
 - TD provides most of primary beam technical expertise (magnets)
 - AD provides the lions share of effort on Beamline
- The Beamline Manager has bi-weekly meetings with Head and Deputy Head of Accelerator Division to discuss LBNF Beamline issues and resources
- Given that majority of Beamline resources are from Accelerator Division, an MOU is being developed between Beamline and AD.

Beamline Management and Resources (2)

- Proactive succession planning ongoing and critical given the duration of this project.
- AD has hired a number of junior engineers to help fully staff beamline design efforts – new engineers are working on magnet installation, primary vacuum, LCW, and stripline design.
- Competing programmatic priorities (PIP-II, Mu2e, Operations) continues to be a challenge for some of our key engineering resources.

ESH Radiological Issues

- Radiological safety issues cover both off-site and on-site
- Main Beamline Radiological Issues:
 - Ground water and surface water
 - Prompt radiation
 - Residual radiation
 - Activated air emissions
- Continue to incorporate design improvements from latest MARS simulations and calculations plus lessons learned from NuMI
- The LBNF radiological design goal is to contribute to less than 30% of the limits of the environmental radiological quantities specified by the Fermilab policies and implement ALARA in all aspects of the design.



Beamline Approach to ESH and QA

- ESH and QA incorporated into all activities with continual involvement of LBNF ESH and QA managers.
- Compliance with Fermilab's Engineering Manual, ES&H Manual (FESHM), Radiological Control Manual (FRCM), and QA Manual together with the LBNF/DUNE QA Plan, plus compliance with all national codes and standards (ASME, OSHA, etc.).
- Preliminary Design reviews, Final Design Reviews and Production/Operational Readiness Reviews included in the schedule for all activities, together with focused technical reviews as called by project management. Compliance with the LBNF Review Plan.
- All procurement activities include requirements and spec docs with vendor/fabrication oversight and inspection upon delivery.

Beamline Approach to ESH and QA (2)

- ESH Construction Safety Specialist under Beamline Project Management during the installation phase.
- Full-time construction oversight by lead engineers (plus other experts as needed) during installation to assure everything meets design specifications.
- Construction Coordinator/Task Managers will be performing the responsibilities of Quality Assurance Representatives to ensure requisite Quality Control is being adequately performed and documented during construction.
- LBNF QA Manager will perform assessments on the effectiveness of the Beamline team's compliance with the LBNF DUNE QA Plan

Beamline Risks Status

- **Beamline Risks: 39**

- **Threats: 39**

- **Risks Rank: 7 High, 13 Medium, 20 Low/Negligible**

- **Opportunities: 0**

- Since January 2019, we have closed/retired 4 risks and added 13 new risks.
 - Retired risk BEAM-107 (Unacceptable Magnetic Field Uniformity at Horn Drain Ports), significant schedule risk driver for DUNE/LBNF.
- We have a well-developed and mature process for managing risks – risks are actively evaluated and updated, plus the project holds annual/biannual risk workshops to assess all risks.
- Risks from in-kind partners are included with a schedule impact only – joint risk workshop held with RAL to align our risks, plan to do the same with other partners.

High and Medium Risks – Current

Risk Rank	Sub-Project	RI-ID	Title	
3 (High)	Beamline	RT-131-BEAM-008	Tritium mitigation design is found to be inadequate	
→ 3 (High)	Beamline	RT-131-BEAM-094	Single Domestic Ferrite Vendor	Updated - changed from Low to High
3 (High)	Beamline	RT-131-BEAM-106	Hadron Monitor preliminary design unsuccessful	
→ 3 (High)	Beamline	RT-131-BEAM-118	Power Supply to test spare horns	Redefined/changed from Med to High
3 (High)	Beamline	RT-131-BEAM-120	Commodity price fluctuations cause costs to increase or decrease.	
→ 3 (High)	Beamline	RT-131-BEAM-138	No thyratons available for Beamline extraction kicker	New Risk
3 (High)	Beamline	RT-131-BEAM-141	Manufacturing Difficulties - Target	New Risk
2 (Medium)	Beamline	RT-131-BEAM-046	Kicker ceramic beam tubes damaged before installation	
→ 2 (Medium)	Beamline	RT-131-BEAM-052	Beamline engineering labor resources are unavailable	
2 (Medium)	Beamline	RT-131-BEAM-099	Target - Horn Integration Issues (requires target redesign)	
2 (Medium)	Beamline	RT-131-BEAM-104	Beam-based alignment capability compromised by required target/baffle geometries	
2 (Medium)	Beamline	RT-131-BEAM-105	Target preliminary design inadequate and/or prototyping	Updated - changed from Low to Medium
2 (Medium)	Beamline	RT-131-BEAM-108	Horn fails or is damaged before Beam Delivery KPP	Redefined risk
2 (Medium)	Beamline	RT-131-BEAM-117	Target Horn Integration Issues (requires horn redesign)	
2 (Medium)	Beamline	RT-131-BEAM-139	Design Difficulties - Target Exchange System	New Risk
2 (Medium)	Beamline	RT-131-BEAM-140	Manufacturing Difficulties - Target Exchange System	New Risk
2 (Medium)	Beamline	RT-131-BEAM-143	Manufacturing Difficulties - Baffle	New Risk
2 (Medium)	Beamline	RT-131-BEAM-144	Design Difficulties - Target He gas system	New Risk
2 (Medium)	Beamline	RT-131-BEAM-145	Manufacturing Difficulties - Target He gas system	New Risk

→ Risks to be addressed before CD-2

Beamline Strategy to prepare for CD-2

- Focus on design maturation and completing interface definitions.
- Progress as necessary the design of non-DOE scope items (where partners have yet to engage), to inform the preliminary design of interfacing systems within the DOE scope.
- Although we do not anticipate any major unresolved technical issues post CD-2, we are capturing the design uncertainty by introducing cost and schedule risks.
- Mitigate identified risks associated with cost/schedule drivers.
- Complete Preliminary Design Report, followed by DOE Independent Technical Review, and Director's Review prior to CD-2.

Summary

- Beamline design continues to progress according to plan
- Significant work to enable CF preliminary design by A/E
- We are working to a plan that will get us to an appropriate design maturity for CD-2 where our cost is well understood.
- Beamline organization is fully staffed and focused on completing the design

Backup

Key Performance Parameters

Sub-Project	Description of Scope	Threshold KPP*	Objective KPP*
SP-NS	Beamline to produce neutrinos directed to the far detector site	<p>A fully commissioned and operational beamline as demonstrated by authorization for proton beam operations after Accelerator Readiness Review.</p> <p>(Note: this goal depends on delivery of hardware by non-DOE partners.)</p>	<p>A fully commissioned and operational beamline as demonstrated by</p> <ol style="list-style-type: none"> 1) authorization for proton beam operations after Accelerator Readiness Review 2) detecting muons downstream of the target complex 3) generating a neutrino beam using a 3-horn focusing system. <p>(Note: these goals depend on delivery of hardware by non-DOE partners.)</p>

- The plan is set up to achieve the Objective KPP

Advisory bodies and tools to guide us through CD-2

- Beamline Technical Board
- Focused Design Reviews
- Risk Workshops with outside consultant and SME's
- NSCF/Beamline weekly integration meetings
- We are currently exercising “EVMS-light” on a monthly basis within the Beamline Team. A plan exists to have EVMS fully implemented in March 2020, prior to CD-2
- We will document the design status in a Preliminary Design Report (PDR) by March 2020, in time for the CD-2 related Technical Reviews.

Beamline - Main Milestones Status

Control Account	Milestone Name	Start	Finish
Primary Beam	T6 MS - Lattice Optics Final Design Review Complete		21-Jan-21
Primary Beam	T6 MS - Final Design Reviews Complete		7-Jan-22
Primary Beam	T6 MS - MI Extraction Magnets Installed		2-Mar-27
Primary Beam	T6 MS - Kicker Magnet Assembly Complete		4-May-27
Primary Beam	T5 MS - Primary Beam Installation / Checkout Complete		20-Oct-28
Primary Beam	T6 MS - Horn PS Conceptual Design Review Complete		04-Feb-19 A
Target Complex	T5 MS - Prototype stripline feedthrough fabrication Complete		11-Feb-19 A
Target Complex	T5 MS - Prototype hatch cover fabrication Complete		01-May-19 A
Target Complex	T6 MS - Targetry Conceptual Design Review Complete		30-Aug-19 A
Target Complex	T6 MS - Target Chase, Shielding and Decay Pipe Cooling Preliminary Design Ready for Review		6-Feb-20
Target Complex	T6 MS - RAW Water Systems Preliminary Des Review Complete		21-Apr-20
Target Complex	T6 MS - Horn PS Preliminary Design Review Complete		24-Jun-20
Target Complex	T6 MS - Targetry -Preliminary Design Review Complete		24-Nov-20
Target Complex	T4 MS - Beamline - Horn Prototype Design Complete		22-Feb-21
Target Complex	T6 MS - Remote Handling Preliminary Design Review Complete		17-Sep-21
Target Complex	T6 MS - RAW Water Systems Final Design Review Complete		13-Jan-22
Target Complex	T6 MS - Target Shield Pile Final Des Review Complete		18-Jan-22
Target Complex	T6 MS - Horn PS Final Design Review Complete		7-Mar-22
Target Complex	T6 MS - Horns Preliminary Design Complete		8-Nov-22
Target Complex	T5 MS - Target Complex Preliminary Design Complete		8-Nov-22
Target Complex	T6 MS - Horns Preliminary Design Review Complete		6-Apr-23
Target Complex	T6 MS - Targetry - Final Design Review Complete		8-Sep-23
Target Complex	T6 MS - Horns Final Design Review Complete		22-Feb-24
Target Complex	T6 MS - Horn PS Assembly Complete - Ready for Horn Testing		20-Mar-24
Target Complex	T4 MS - Target Complex Final Design Complete		10-Apr-24
Target Complex	T4 MS - Beamline - Horn Prototype Assembly Complete		13-Nov-24
Target Complex	T4 MS - Beamline - Horn Prototype Testing Complete		7-Feb-25
Target Complex	T6 MS - Horns Fabrication Procurement Complete		23-Oct-26
Target Complex	T6 MS - Absorber Complex - Remote Handling Installation / Checkout Complete		30-Mar-28
Target Complex	T6 MS - Horn A Installation Complete		12-May-28
Target Complex	T6 MS - Horn PS Installation / Checkout Complete		12-Jun-28
Target Complex	T6 MS - Horn B Installation Complete		11-Jul-28
Target Complex	T6 MS - Horn C Installation Complete		6-Sep-28
Target Complex	T6 MS - Targetry Installation / Checkout Complete		17-Oct-28
Target Complex	T6 MS - Target Shield Pile Installation / Checkout Complete		15-Dec-28
Target Complex	T5 MS - Target Complex Installation / Checkout Complete		30-Mar-29

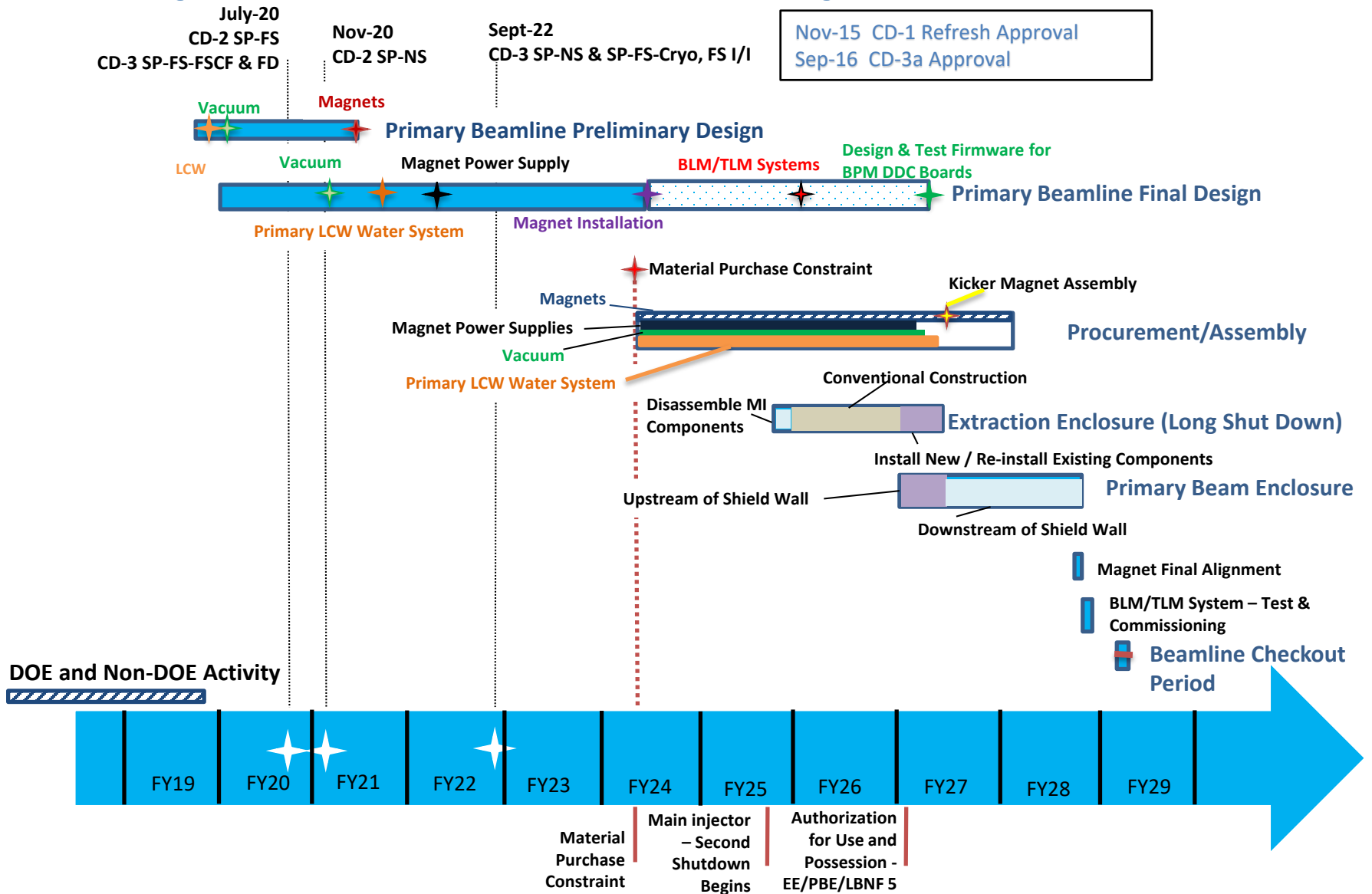
Beamline - Main Milestones Status

Control Account	Milestone Name	Start	Finish
Decay and Absorber Complex	T6 MS - Absorber Preliminary Design Review Complete		15-Nov-19
Decay and Absorber Complex	T6 MS - Primary Beam Window Energy Deposition and Thermal Modeling for 1.2 MW beam complete.		2-Mar-20
Decay and Absorber Complex	T5 MS - Decay Pipe and Absorber Complex Preliminary Design Complete		26-May-20
Decay and Absorber Complex	T6 MS - Absorber Final Design Review Complete		18-Feb-21
Decay and Absorber Complex	T5 MS - Neutrino Beam Instrumentation Preliminary Design Review Complete		9-Apr-21
Decay and Absorber Complex	T6 MS - Decay Pipe Final Design Review Complete		9-Sep-21
Decay and Absorber Complex	T6 MS - Beam Windows Final Design Review Complete		6-Apr-22
Decay and Absorber Complex	T4 MS - Decay Pipe and Absorber Complex Final Design Complete		8-Sep-23
Decay and Absorber Complex	T6 MS - Decay Pipe Upstream Window Assembly Complete		3-Jan-25
Decay and Absorber Complex	T6 MS - Primary Beam Window Assembly Complete		9-Jan-25
Decay and Absorber Complex	T6 MS - Absorber Fabrication Procurement Complete		30-Mar-26
Decay and Absorber Complex	T5 MS - Decay Pipe and Absorber Complex Fabrication Procurement Complete		15-Dec-26
Decay and Absorber Complex	T6 MS - Hadron Monitor Installation Complete		28-Jul-27
Decay and Absorber Complex	T6 MS - Absorber Installation / Checkout Complete		18-Aug-27
Decay and Absorber Complex	T6 MS - Primary Beam Window Installation Complete		22-Nov-27
Decay and Absorber Complex	T5 MS - Diamond Detector Installation Complete		6-Dec-27
Decay and Absorber Complex	T5 MS - Neutrino Beam Instrumentation Complete		1-May-28
System Integration	T6 MS - Controls Preliminary Design Review Complete		01-Mar-19 A
System Integration	T5 MS - Beamline Matrix Chart Interfaces Completed (30% progress).		28-Jun-19 A
System Integration	T6 MS - Finish Preliminary Review Installation Schedule		30-Sep-19
System Integration	T4 MS - Beamline Matrix Chart Interfaces Completed (90% progress)		20-Dec-19
System Integration	T6 MS - Controls Final Design Review Complete		7-Apr-21
System Integration	T5 MS - System Integration Final Design Complete		17-Apr-24
System Integration	T4 MS - NSCF - Authorization for Use and Possession - Absorber Complex / LBNF 30	7-Nov-26	
System Integration	T4 MS - NSCF - Authorization for Use and Possession - EE/PBE/LBNF 5	17-Nov-26	
System Integration	T4 MS - NSCF - Authorization for Use and Possession - Target Complex Complex / LBNF 20	23-Dec-26	
System Integration	T4 MS - Absorber Complex - Complete		8-May-28
System Integration	T4 MS - EE/PBE/LBNF 5 - Complete		20-Oct-28
System Integration	T4 MS - Target Complex Complex / LBNF 20 - Complete		30-Mar-29
System Integration	T5 MS - System Integration Installation / Checkout Complete		27-Apr-29

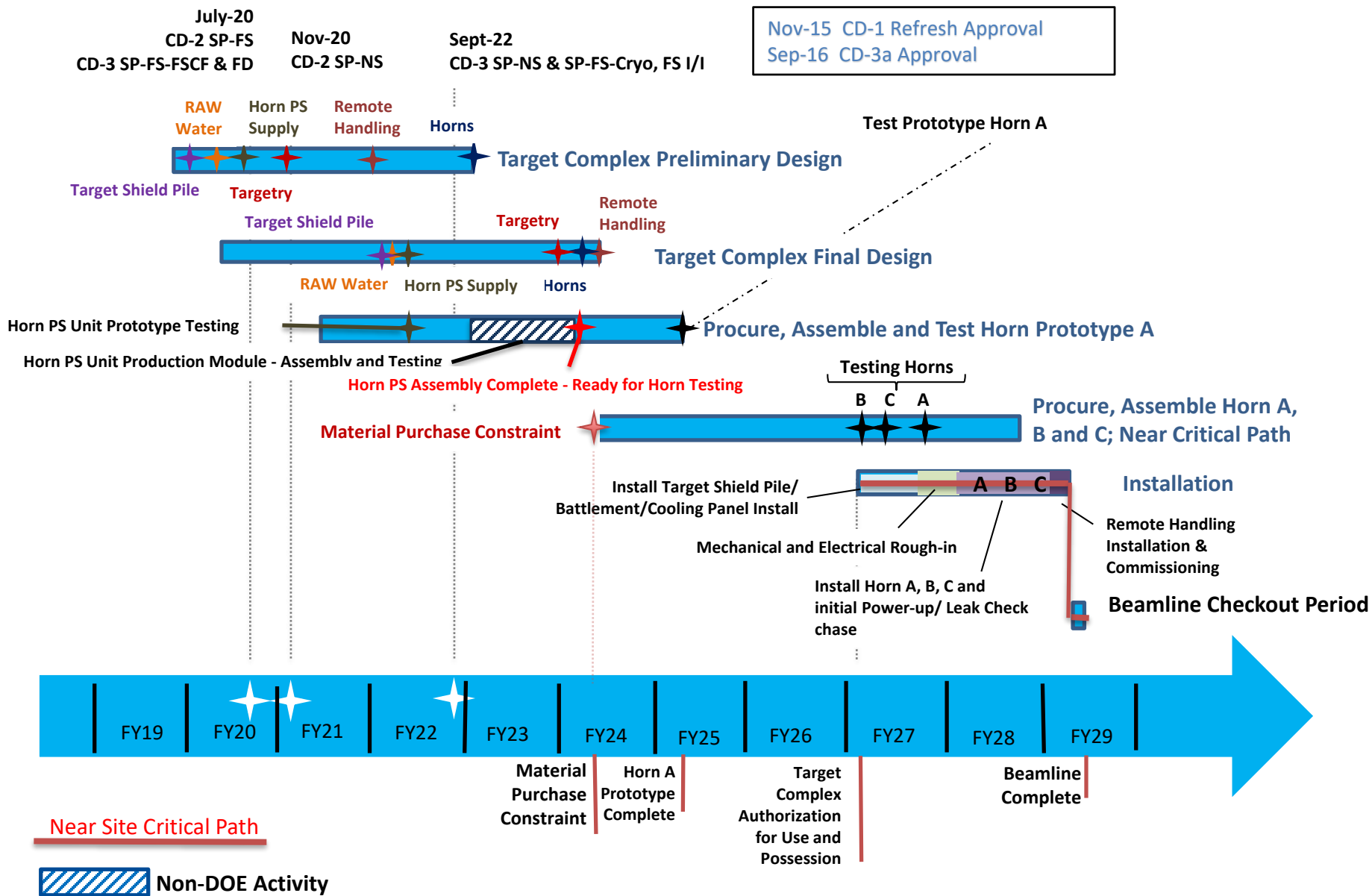
Beamline High Level Milestones/Important Dates

- DOE Review: **October 2020**
 - CD-2 Director's Review: **April 2020**
 - CD-2 Preliminary Design Complete for Baselineing → Independent Technical Review of Beamline: **April 2020**
 - Decision on DOE-non-DOE scope: **April/May 2020**
 - DOE Independent Cost Estimate/Review: **April-August 2020**
- CD-2 Approval: **October 2020**
- CD-3 Approval: **September 2022**
- AUP (Acceptance for Use and Possession) for Primary Beam Enclosure, Target Hall Complex and Absorber Hall Complex: **Nov-Dec 2026**
- Beamline Installation Complete: **April 2029**

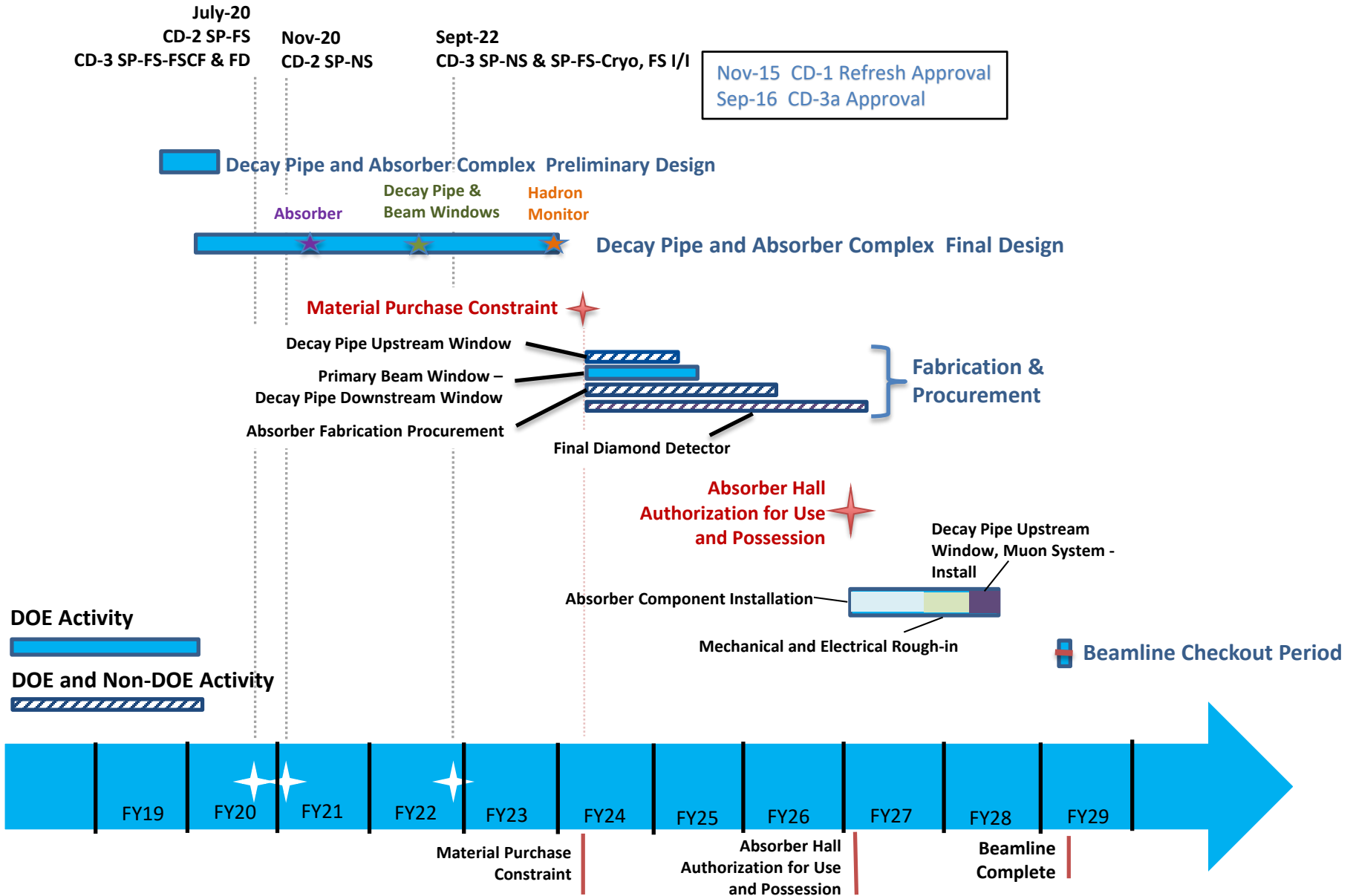
Primary Beam - Schedule Summary



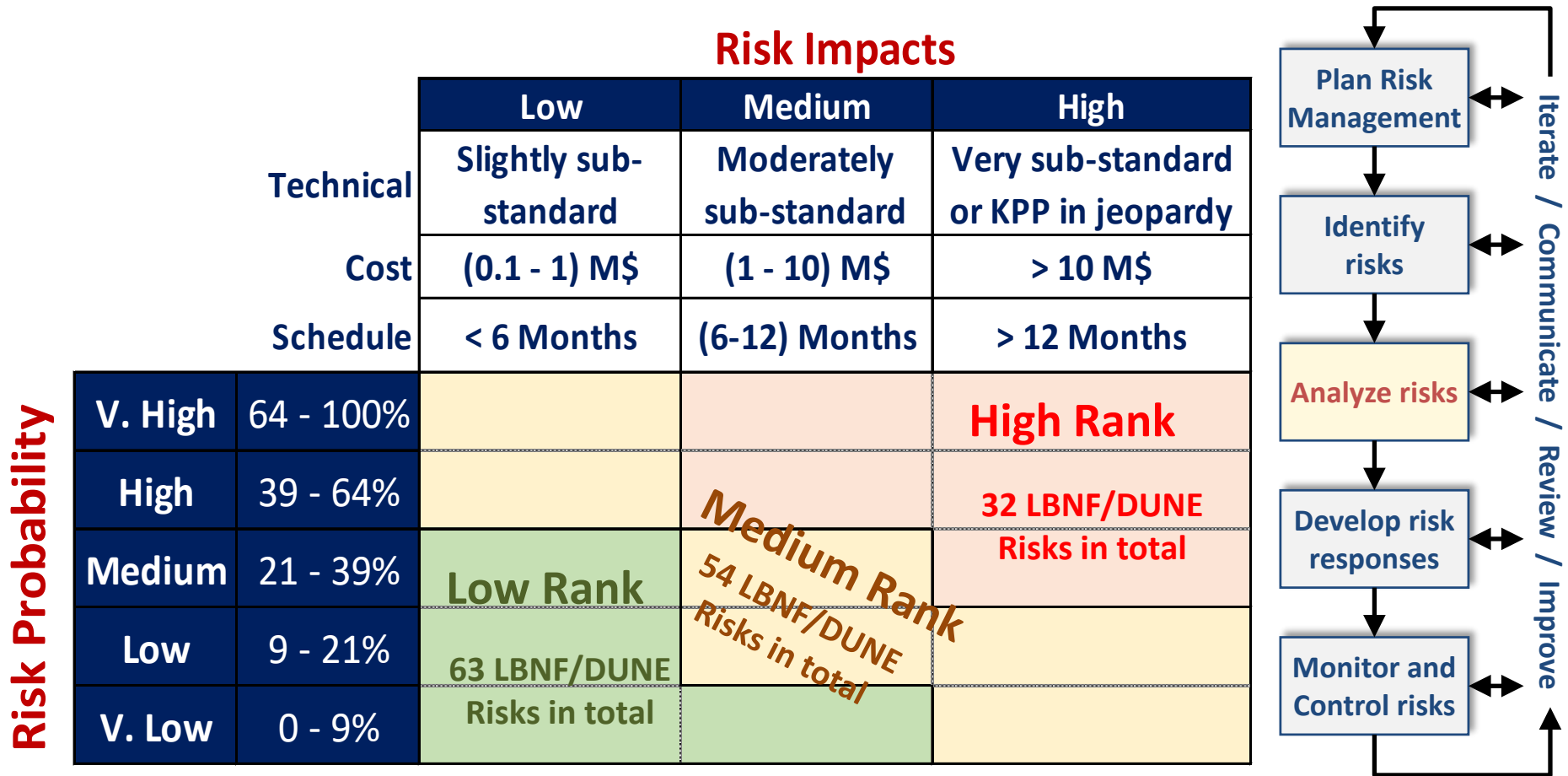
Target Complex - Schedule Summary



Decay Pipe and Absorber Complex - Schedule Summary



Risks are ranked by probability and impacts



- More details in M. Elrafih's **LBNF/DUNE Risk Management** breakout talk.

Beamline Labor Resource Profile FY19-22 – FTE-Years

