LBNF Beamline

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NBI2019 - Fermilab

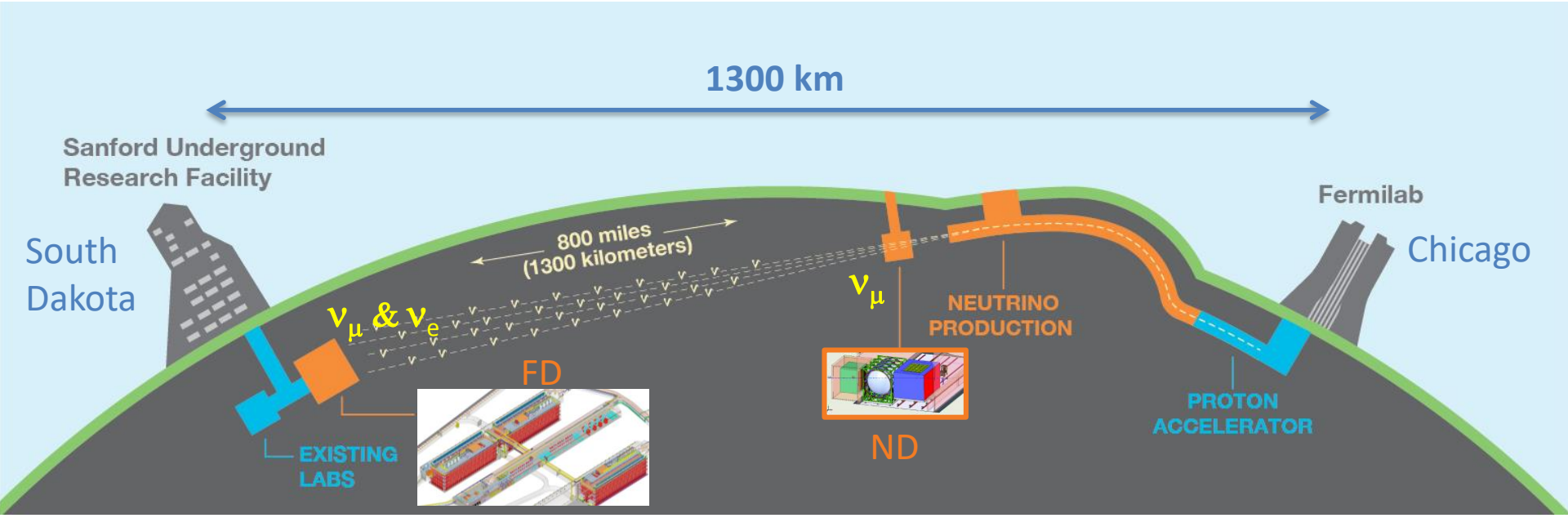
October 22, 2019

Outline

- LBNF/DUNE Overview & Key Milestones
- Beamline Scope
  - Primary Beam
  - Neutrino Beam
- Design Challenges
  - ESH Radiological Issues
- Design Status
- Summary

Several focused NBI talks on LBNF Beamline Subsystems:
Target Design, Horn Design, Primary & Upstream Decay Pipe Beam Windows, Hadron Monitor, Hadron Absorber, Remote Handling, Target Exchange System Design, Tritium Production

The Long-Baseline Neutrino Facility (LBNF) supporting the international Deep Underground Neutrino Experiment (DUNE)



"The LBNF/DUNE project will be the first internationally conceived, constructed, and operated mega-science project hosted by the Department of Energy in the United States" - DOE SC-2

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

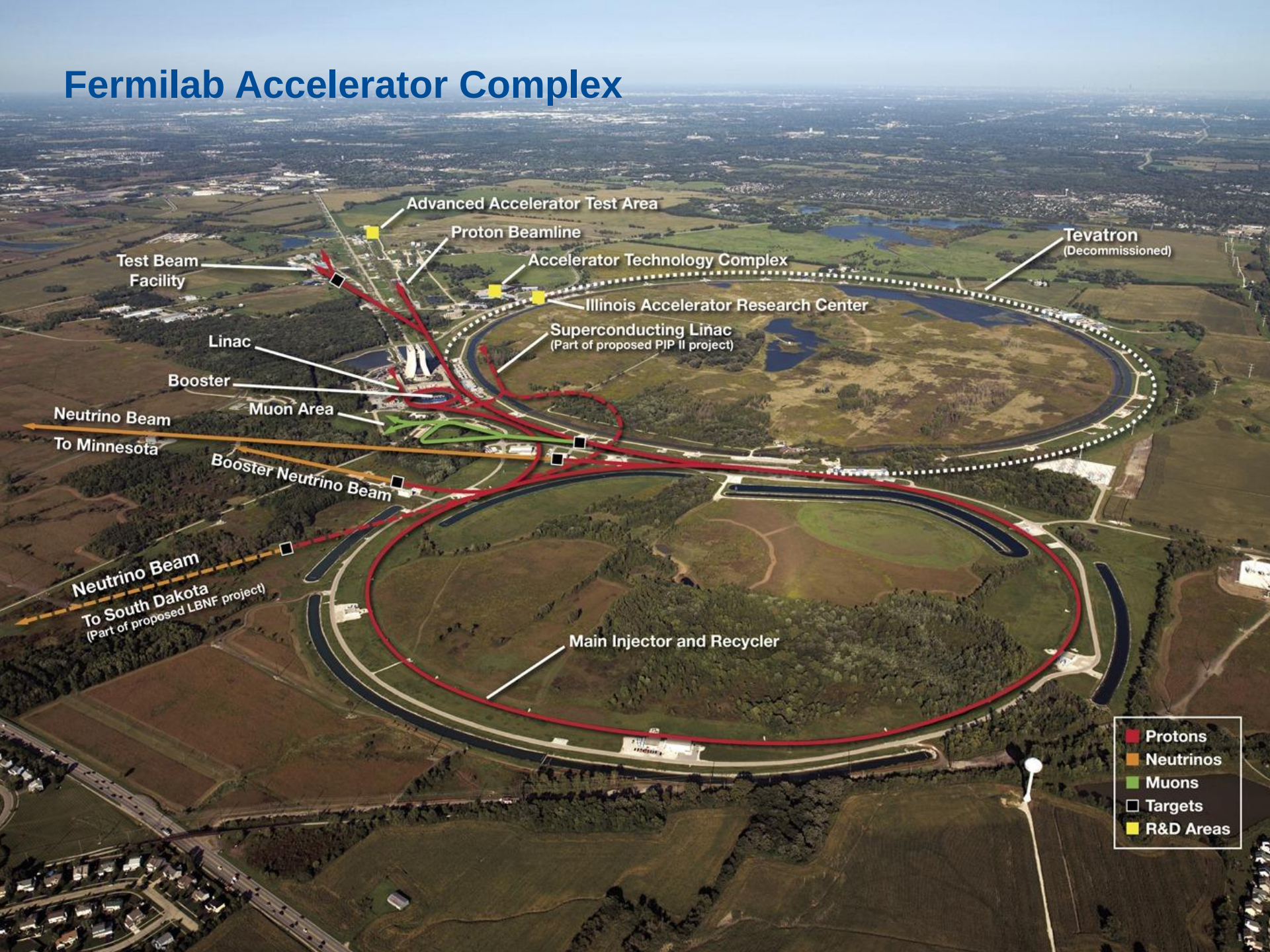
LBNF/DUNE Overview

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

DUNE Science

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

Fermilab Accelerator Complex



Overview of LBNF / DUNE Projects

LBNF: DOE project with **support from non-DOE partners**. Provides facility infrastructure at two locations:

- **Near site**: Fermilab, Batavia, IL – facilities to create neutrino beam (Beamline)
- **Far site**: Sanford Underground Research Facility, Lead, SD – facilities to support DUNE detectors

DUNE: U.S. as **partner** (DUNE-US) in international experiment

- Neutrino detectors at near and far sites

DUNE – a global Collaboration

1093 collaborators from
188 institutions in
31 countries + CERN

Continued growth, based on exceptional science program

Key Milestones – DOE Baseline and Construction Approvals

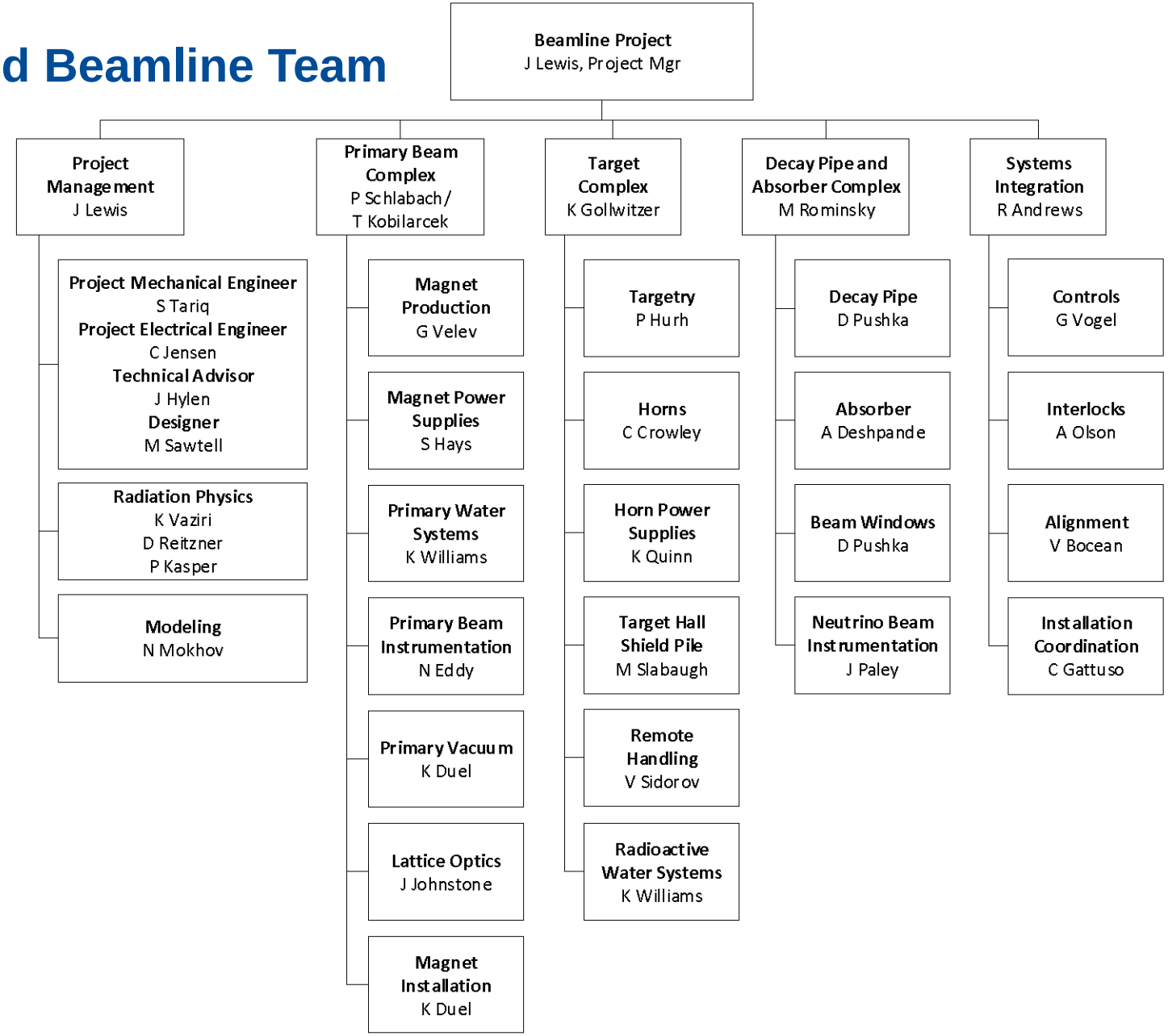
- Project plans to baseline (CD-2) DOE project scope in two steps, starting this fiscal year:
  - **Far Site "Sub-Project" (SP-FS)** - Baseline all Far Site work (FS conventional facilities, cryogenics, DUNE-US contribution to far detector, & US support of integration) with DOE review in winter 2020.
  - **Near Site "Sub-Project" (SP-NS)** – Baseline all Near Site work (NS conventional facilities, Beamline, DUNE-US contribution to near detector, & US support of integration) with DOE review ~ August 2020.
- Approach will allow 65% of U.S. project to baseline as soon as possible, while proceeding with understanding of near site detector requirements and maturing conventional facilities design into 2020.
- CD-3 authorization for DOE construction start necessary to maintain schedule:
  - For FSCF and Far Detector - in tandem with SP-FS CD-2
  - For Cryo, NSCF, Beamline, & Near Detector - up to 2 years after SP-NS CD-2 (presently planned for 2022)

Key Performance Parameters – LBNF Beamline

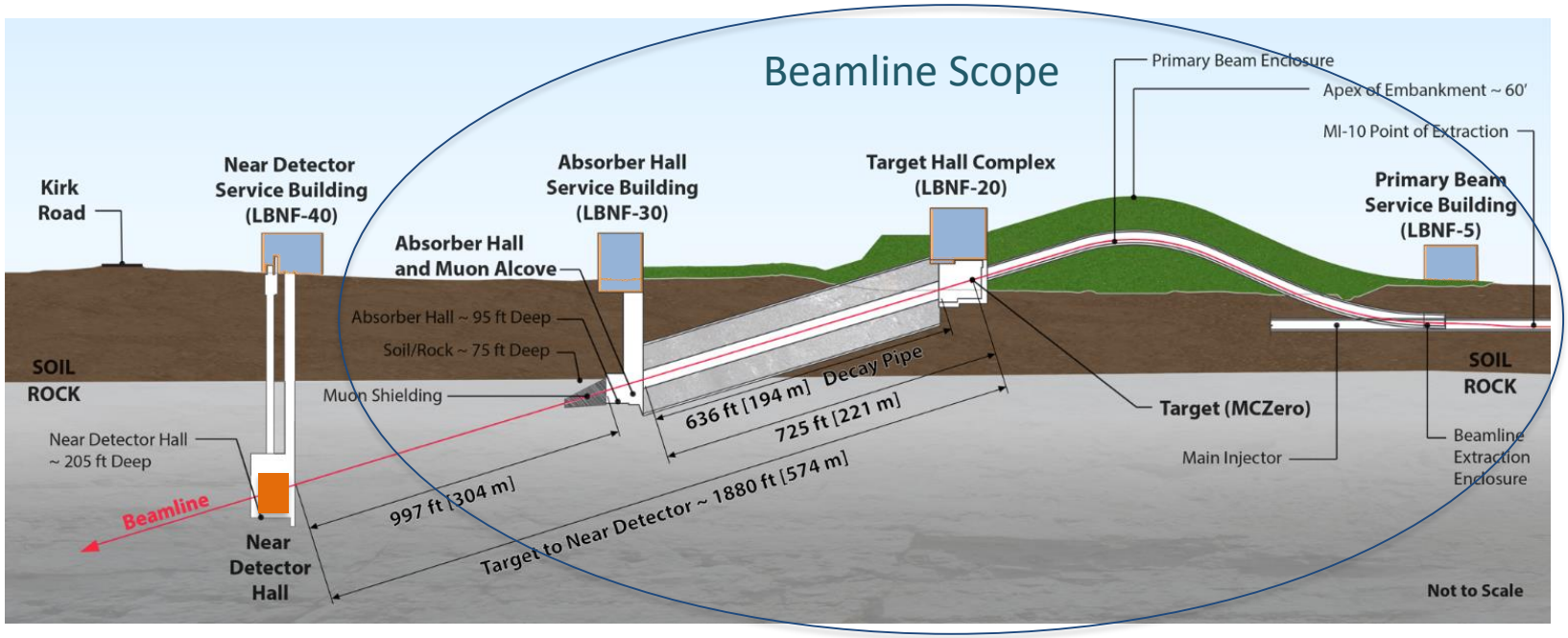
Sub-Project	Description of Scope	Threshold KPP*	Objective KPP*
SP-NS	Beamline to produce neutrinos directed to the far detector site	A fully commissioned and operational beamline as demonstrated by authorization for proton beam operations after Accelerator Readiness Review. (Note: this goal depends on delivery of hardware by non-DOE partners.)	A fully commissioned and operational beamline as demonstrated by 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. (Note: these goals depend on delivery of hardware by non-DOE partners.)

- Plan to achieve Objective KPP.

Fully Staffed Beamline Team

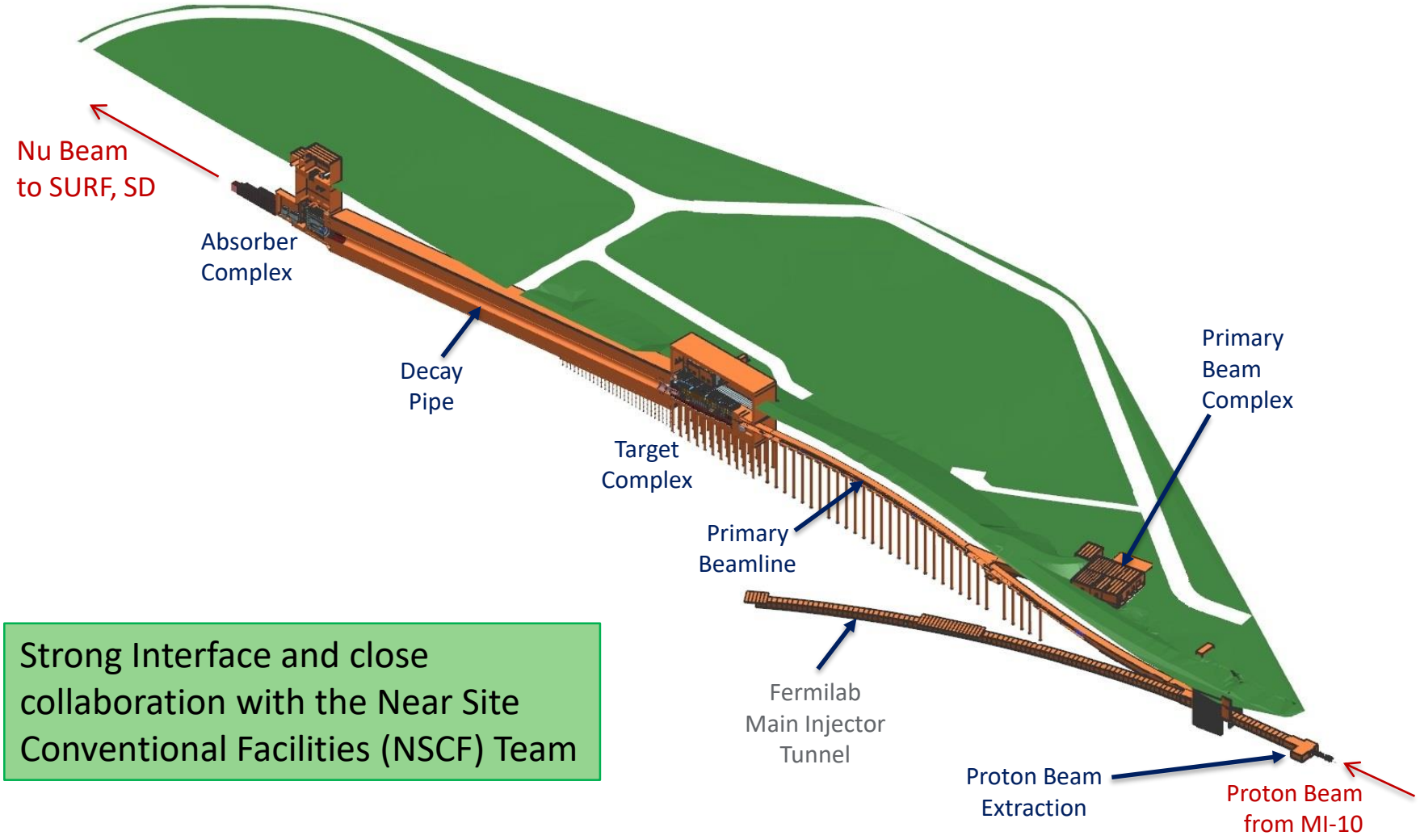


Overview – “Near Site” – LBNF Beamline at Fermilab



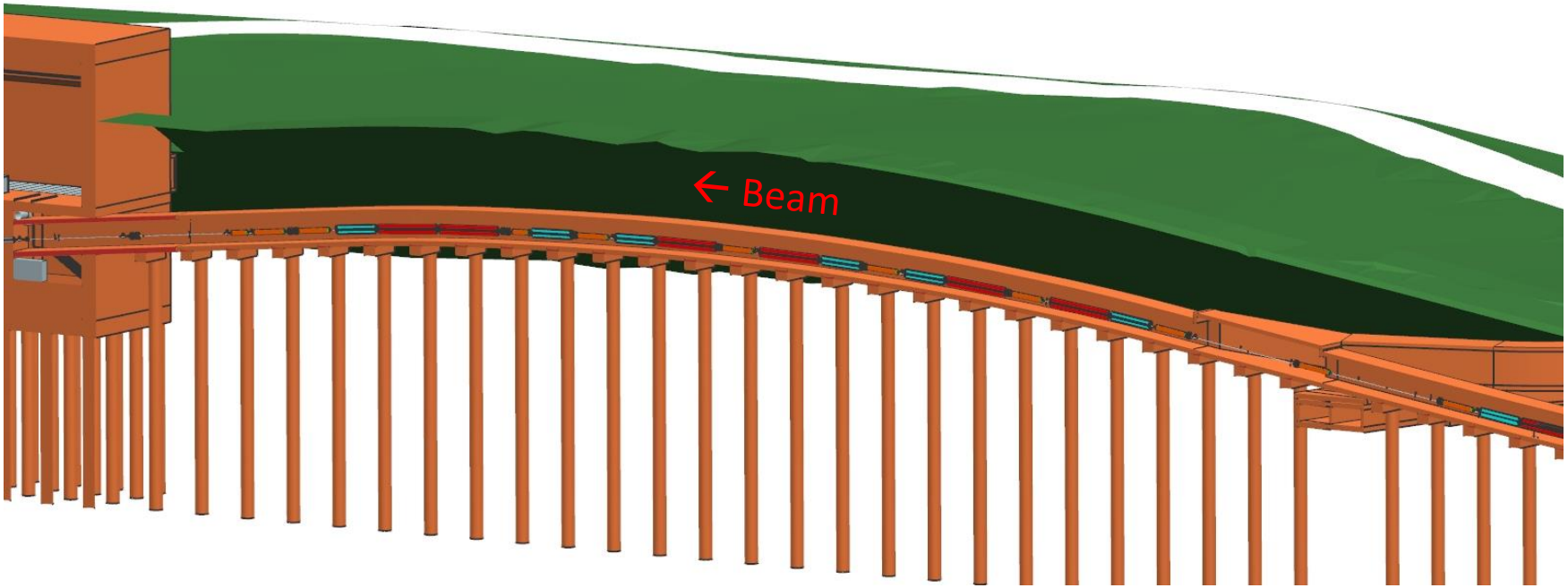
- Primary proton beam @ 60-120GeV extracted from Fermilab Main Injector
- Initial 1.2 MW beam power (PIP-II), upgradable to 2.4 MW (PIP-III)
- Embankment allows target complex to be at grade and neutrino beam to be aimed to SURF
- Decay region followed by absorber
- Three surface support buildings
- [Near Detector facility & DUNE near Detector NOT part of Beamline Scope]

Beamline Scope: Technical Components



Strong Interface and close collaboration with the Near Site Conventional Facilities (NSCF) Team

Beamline Scope: Primary Beam

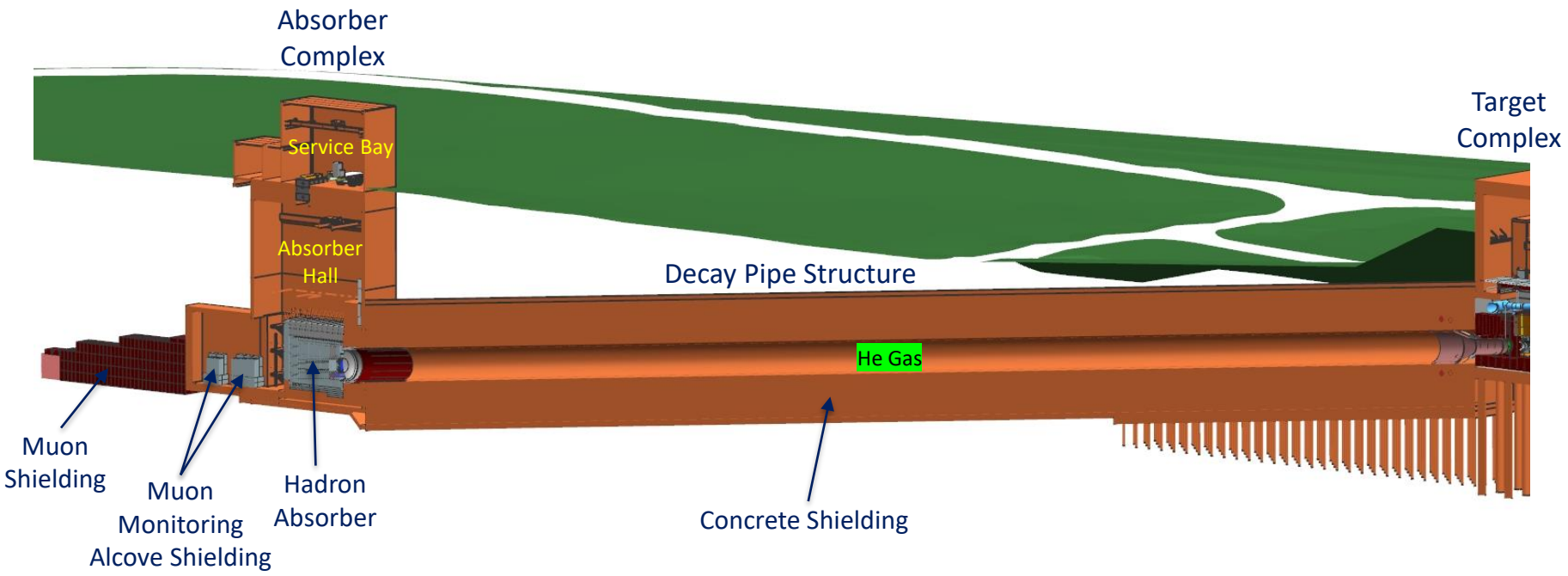


- Beam optics, magnets, magnet power supplies, water cooling systems, vacuum system, beam instrumentation, installation
  - International contributions:
    - Corrector Magnets: IHEP-China
    - Main Dipole & Quadrupole Magnets: BARC-India

Beamline Scope: Target Complex

- Baffle, target, 3 focusing horns, support modules, horn PS, target shield pile, radioactive water systems, remote handling, storage of radioactive components
  - International contributions:
    - Target, Baffle and associated systems: RAL
    - Stripline Feedthrough & Hatch Cover Prototypes: KEK-JPARC

Beamline Scope: Decay Pipe & Absorber Complex



- Primary beam window, decay pipe cooling and windows, hadron absorber, hadron monitor, muon systems
  - International contributions:
    - Discussions underway on muon monitors/EMT with KEK-JPARC

Beamline design challenges

- Intense Radiation
  - Protect people and the environment (more on ESH next slide)
    - Shielding - prevent direct exposure or activation of soil or ground water
    - Sealed air volumes - manage release of ^{3}H and ^{41}Ar
  - Dissipate heat
    - 2.4 MW of beam power yields ~50kW of neutrinos (pW at the detector)
    - The rest of the energy ends up as heat after particles are absorbed
      - Water in cooling systems becomes activated, H_2 production also an issue
- Strong focusing system - 300kA delivered to horns in a ms pulse
    - Work with large currents
    - Forces and stresses in structures
- Complicated interface between Target Complex and Decay Pipe
  - Need to maintain integrity of the N_2 vessel for experiment lifetime

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

Shielding

Shielding & remote handling

Containment & controlled release

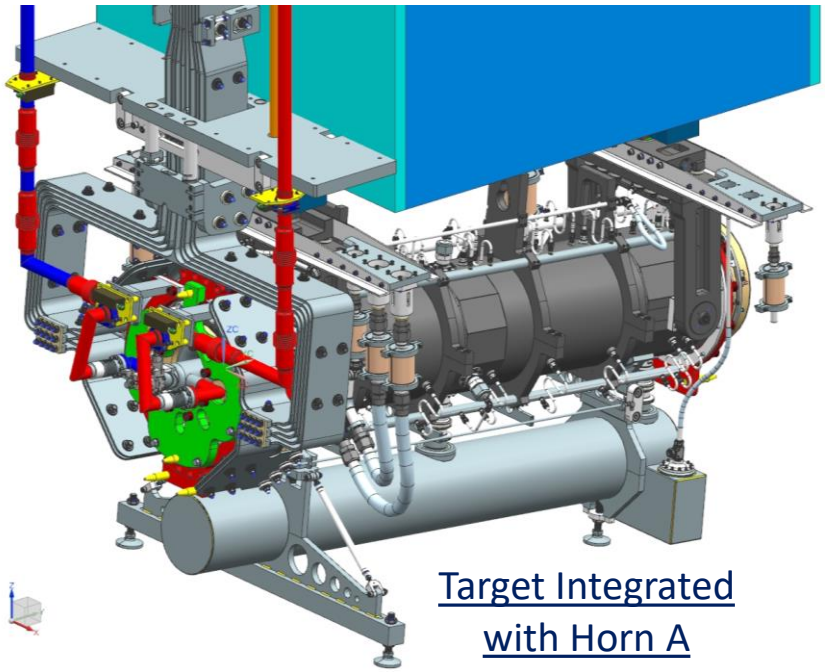
- Continue to incorporate design improvements from latest MARS simulations and calculations plus lessons learned from NuMI.
- The LBNF radiological design goal is to contribute to less than 30% of the limits of the environmental radiological quantities specified by the Fermilab policies and implement ALARA in all aspects of the design.

Beamline Design Status

- Preliminary design progressing
  - Design maturity advancing according to plan
  - Working to secure necessary engineering resources
  - Continue to mature 3D CAD integration models
- Completed all high-level interface specifications and requirements between Beamline and NSCF – contract awarded for A/E which has started working on the preliminary design.
- Working to complete all beam-beam interface control documents (interface points) by end of the calendar year.
- Evaluating alternative to H_2-O_2 recombination – studying using Argon and giving it a long enough decay path for ^{41}Ar while removing the hydrogen – more discussions on this topic planned for this Friday.

Horn & Target Designs

- Optimized beam design with 3 horns is now the reference design (genetic algorithm used to optimize horn & target geometry)
- Cantilevered He-cooled graphite target inserted inside Horn A – chosen after studying 3 different target design concepts.
  - Target length 1.5 – 1.8 m, expected to deliver better integrated performance with the ultimate objective of making the target length as long as possible without degrading overall operational performance.
- More details in LBNF Horn talk (C. Crowley) and LBNF Target talk (D. Wilcox)

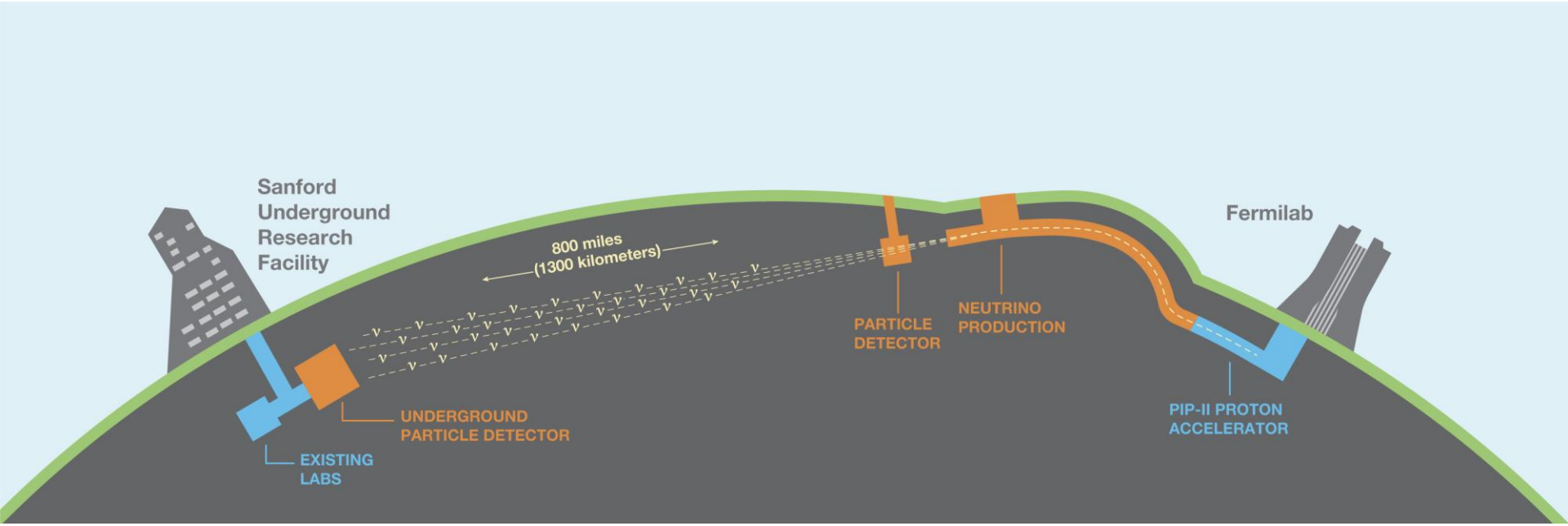


Target Integrated with Horn A

Summary

- Beamline design progressing according to plan with CD-2 planned for ~August 2020
- LBNF continues to receive extraordinary support from DOE leadership, administration, Congress, and international partners
- Completion of requirements and interfaces has enabled Conventional Facilities to start preliminary design by A/E
- Several design and operational challenges exist, such as tritium production & its management – special LBNF tritium meeting planned for Thursday evening after the tritium talks.
- Several opportunities exist to get involved in the Beamline, especially for non-DOE partners – please get in touch with Beamline team if interested.

Questions?



Animation Links:

- LBNF/DUNE animation (YouTube)
- Video page (FNAL website)

Webpage Links:

- Long Baseline Neutrino Facility (LBNF)
- Deep Underground Neutrino Experiment (DUNE)

Social Media Links:

- LBNF Facebook
- DUNE Facebook
- LBNF Twitter
- DUNE Twitter