

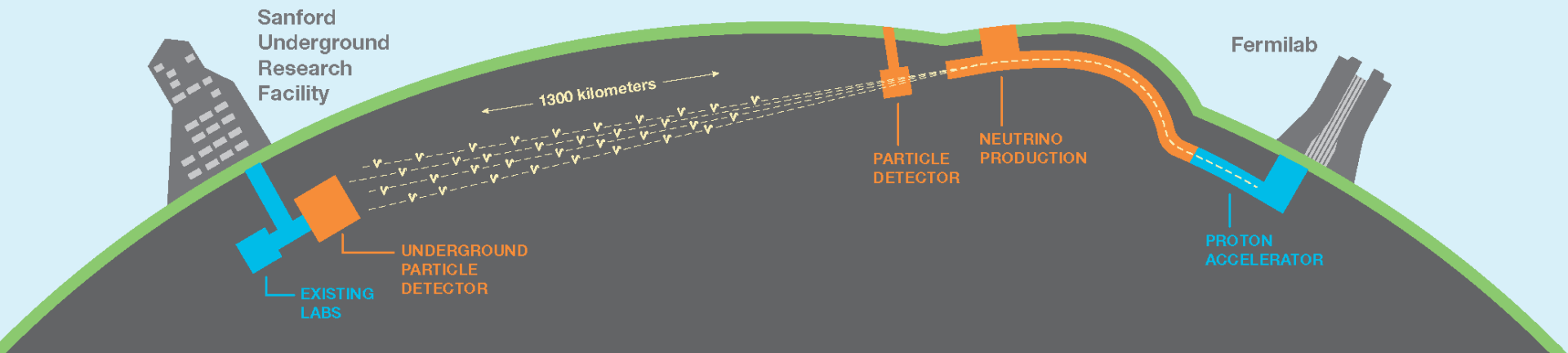
The DUNE Far Detector and ProtoDUNEs

Alex Himmel, Fermilab

38th International Conference on High Energy Physics
Chicago, IL

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What is DUNE?



- The **Deep Underground Neutrino Experiment** will be:
 - a 40 kTon liquid argon neutrino detector...
 - located 1.5 km underground...
 - 1300 km from Fermilab, which will host a 1.2 MW neutrino beam...
 - and a highly-capable near detector.

The DUNE Collaboration

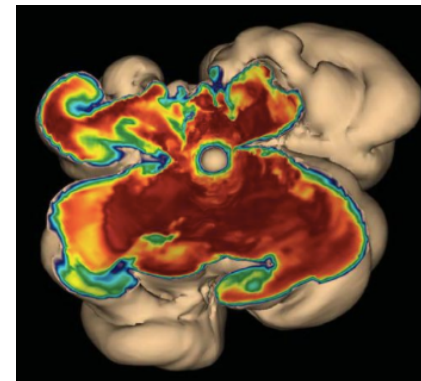
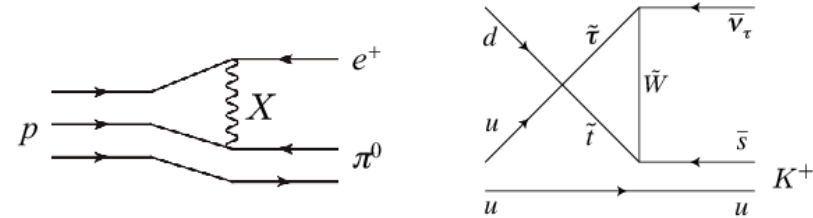
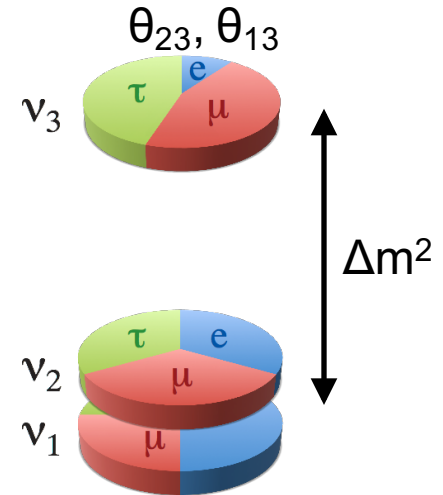


More than 800 scientists from 150 institutions in 27 countries.

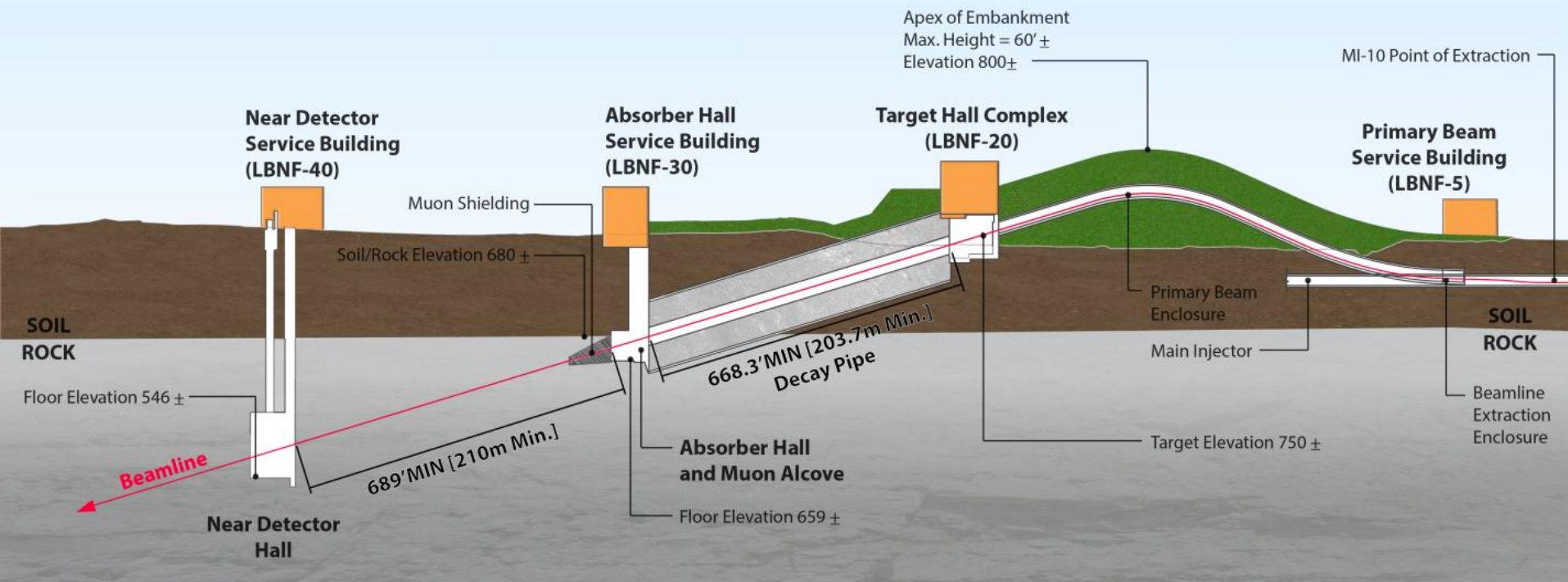
DUNE Physics Goals

- Make precise measurements of neutrino oscillations, including determining the **mass hierarchy** and the potential discovery of leptonic ***CP* violation**.
 - Using both neutrinos produced in the beam and in the atmosphere.
- Search for **nucleon decay**.
- Measure the spectrum and flavor composition of a **supernova burst** in our galaxy.

Lots more in Elizabeth's talk later this session.

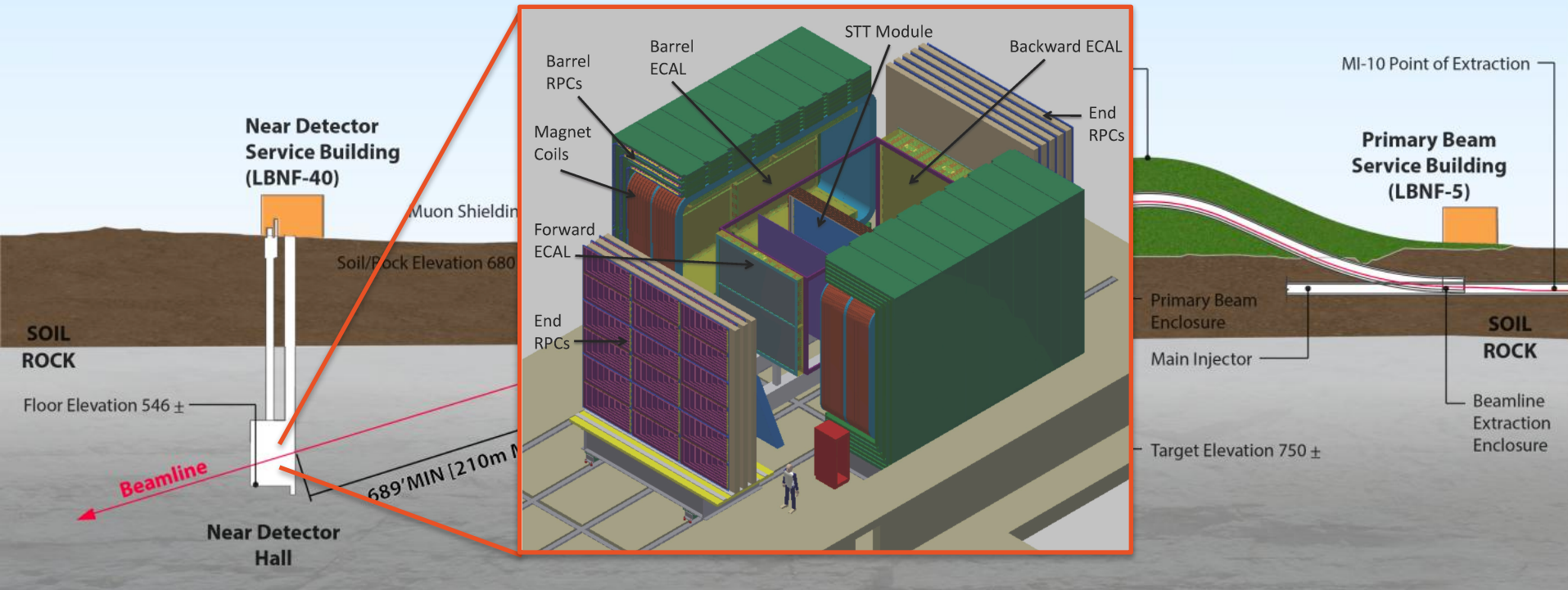


Long Baseline Neutrino Facility



- Conventional **horn-focused neutrino beam** using protons from the Main Injector.
- Horn and target design being optimized with a genetic algorithm developed LBNO.
 - Shows better sensitivity with a **longer target and larger horns**.
- Initially **1.2 MW**, upgradeable to **2.4 MW**

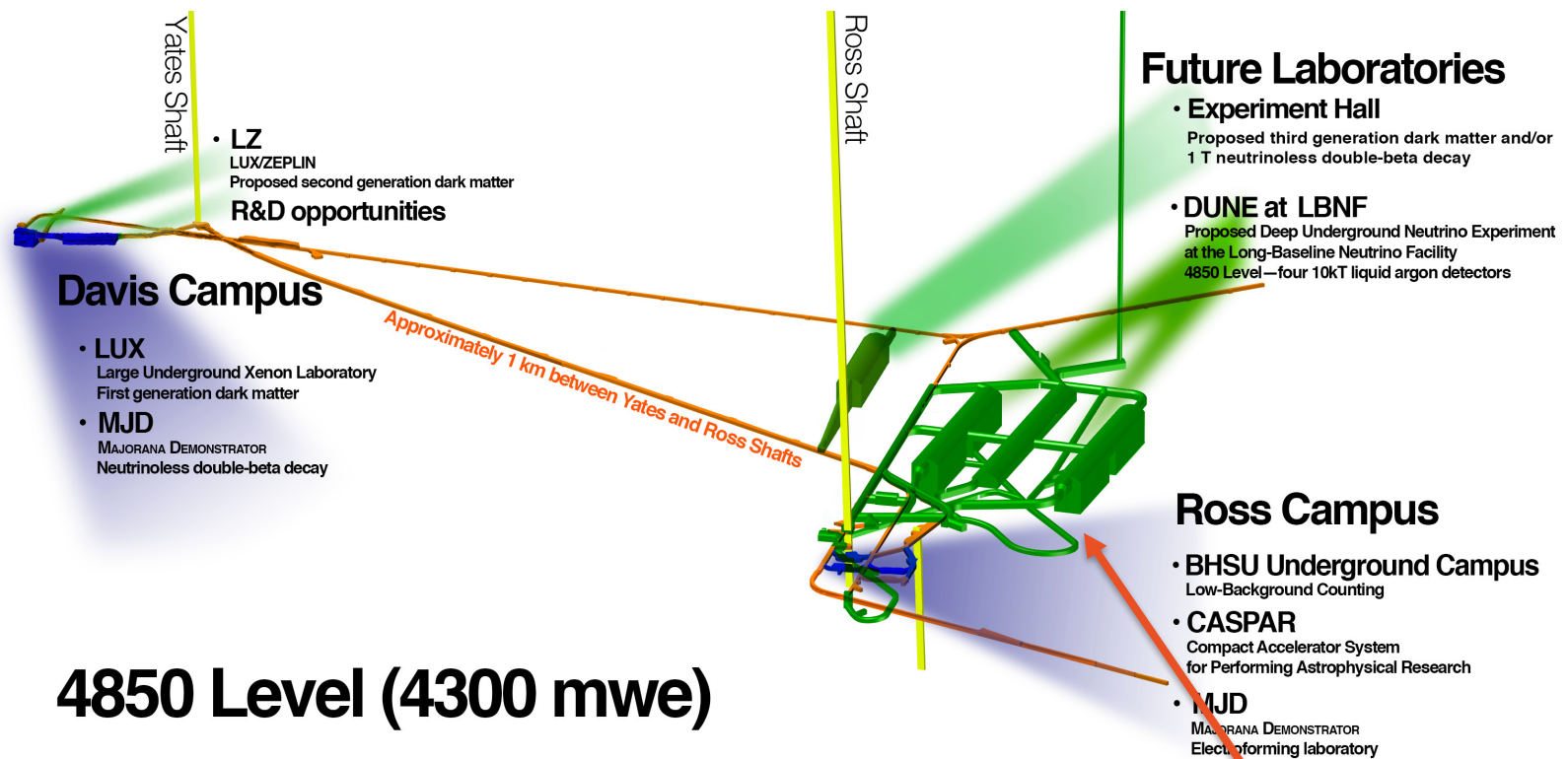
The DUNE Near Detector



- Reference design: **straw tube tracker** inspired by NOMAD.
- Liquid or high-pressure gaseous argon TPCs being considered.

Lots more in Sanjib's talk later this session.

Sanford Underground Research Facility

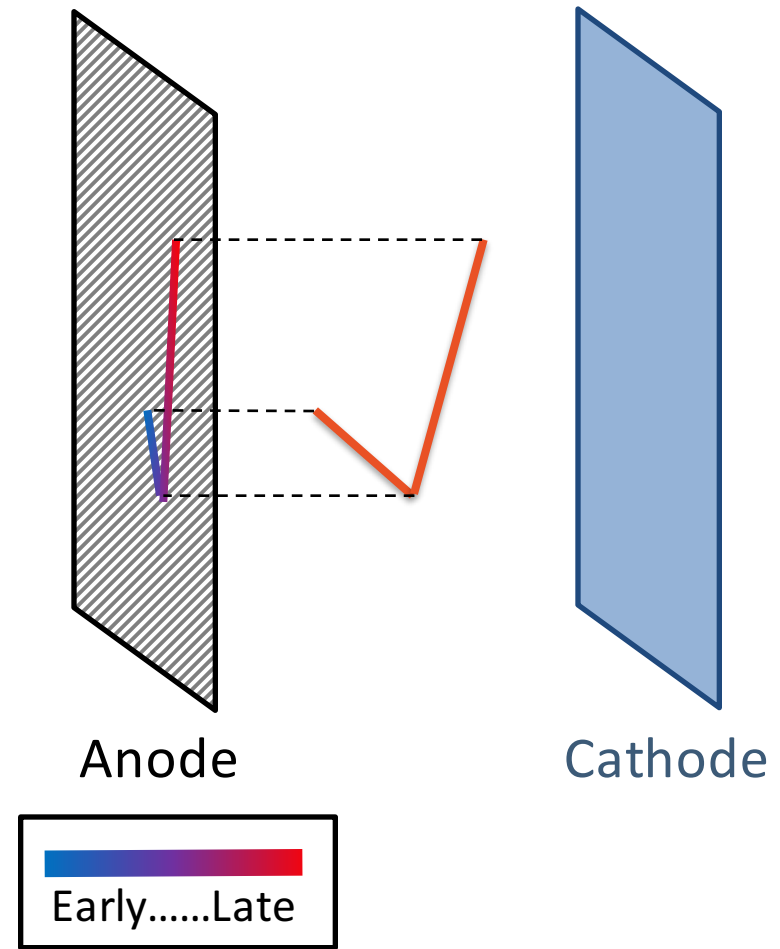


4850 Level (4300 mwe)

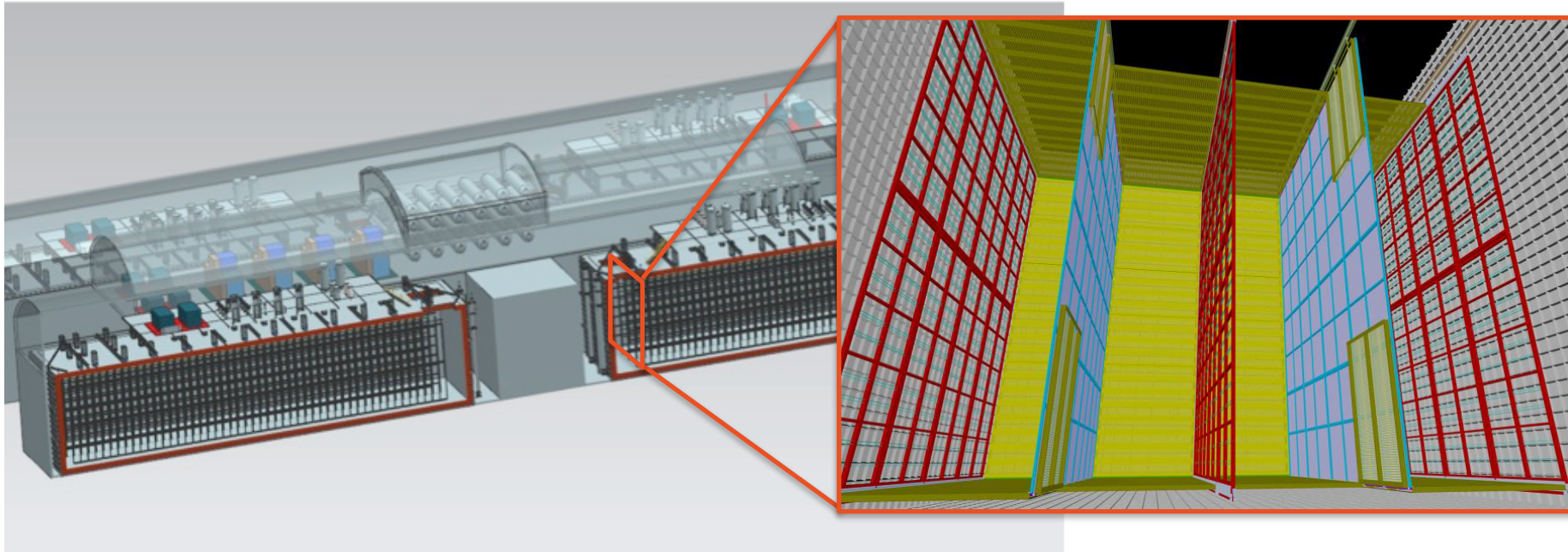
- Located in the Homestake gold mine in Lead, SD.
 - Former home of Ray Davis's solar neutrino experiment.
- New infrastructure for DUNE: 4 detector chambers and a utility hall.
- DOE approval pending to begin excavation.
 - Test blasts have already been conducted to measure vibrations.

A Time Projection Chamber

- Charged particles ionize the argon atoms.
- High electric field causes some of the **charge to drift**.
- The **2-dimensional projection** of the event can be read out.
- The **arrival time** of the charge gives the third dimension.
 - Requires beam timing or observing prompt scintillation light to set t_0 .
- Produces **high-resolution, 3-dimensional** images of events.

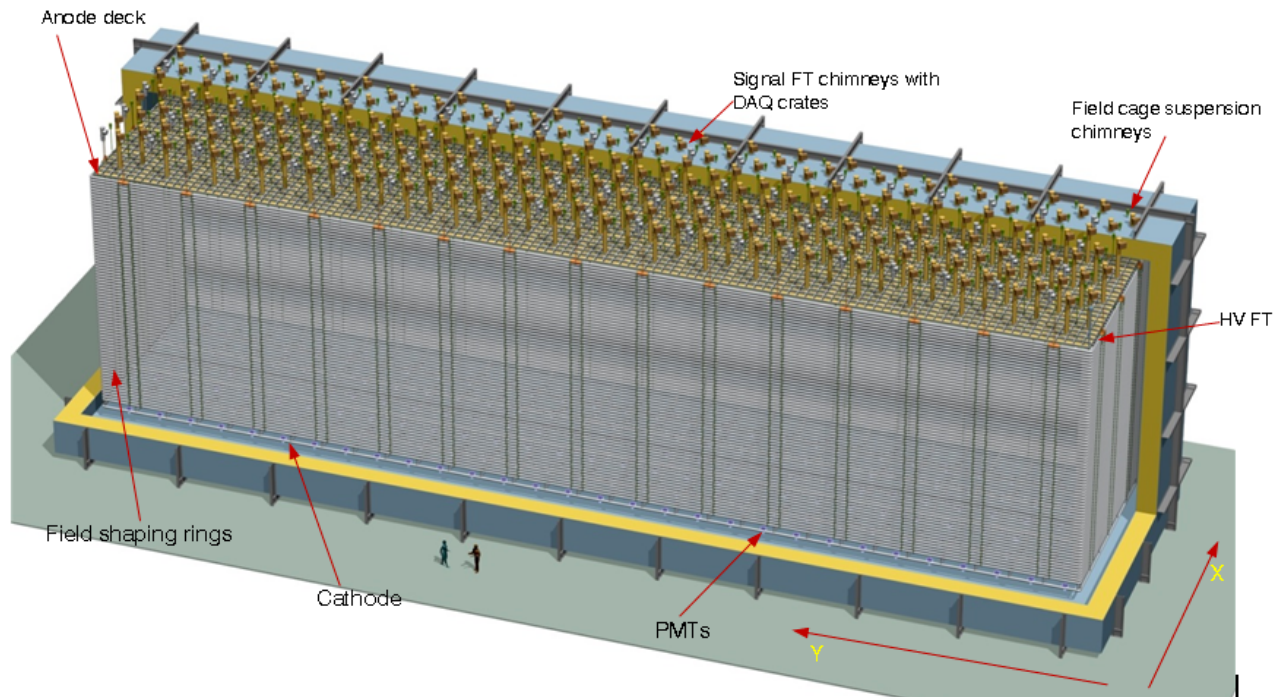


The DUNE Far Detector: Single Phase



- **Single-phase TPC** design based on LBNE modular drift cells.
 - Suspended Anode and Cathode Plane Assemblies (APAs & CPAs).
 - Induction wires at 37.7° angle wrapped around APA.
 - Photon detectors using light guides and SiPMs inside the APAs.

The DUNE Far Detector: Dual Phase



- **Dual-phase TPC** inspired by LBNO design.
 - 12 m vertical drift, LEM readout after gas amplification.
 - Excellent signal/noise: $\sim 100/1$
 - PMTs below the cathode (floor) for photon detection.

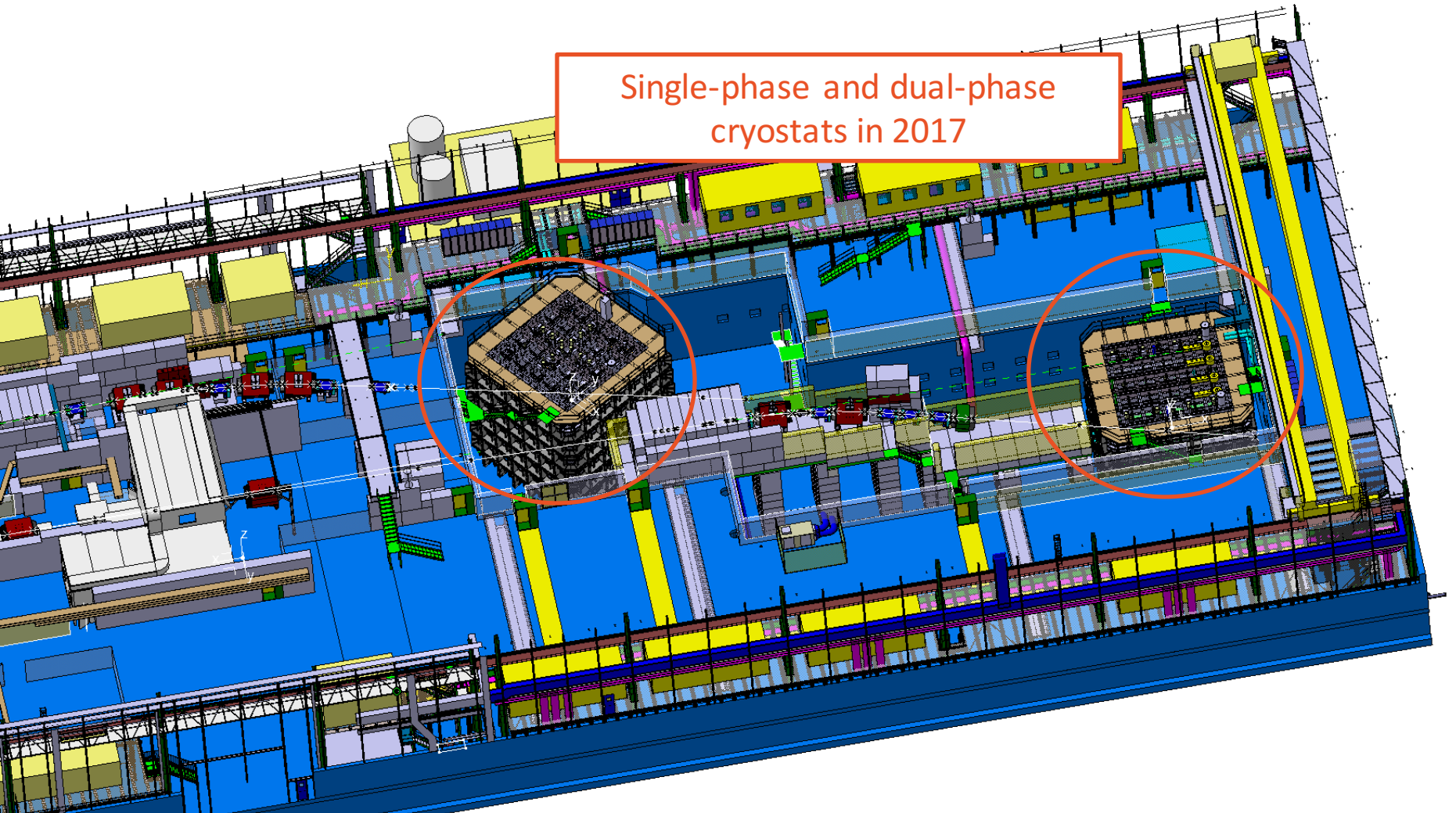
The Path to DUNE

- 2018 • Two ProtoDUNE Detectors (SP & DP) operational at CERN
- 2019 • DUNE Technical Design Report for US DOE and international organizations
- 2020 • Set up of Far Detector fabrication facilities
- 2021 • Start of FD installation: 1st module.
- 2022
- 2023 • Start FD installation: 2nd module. (Not necessarily the same design.)
- 2024 • 20 kt operational
- 2025
- 2026 • Beam operations at 1.2 MW

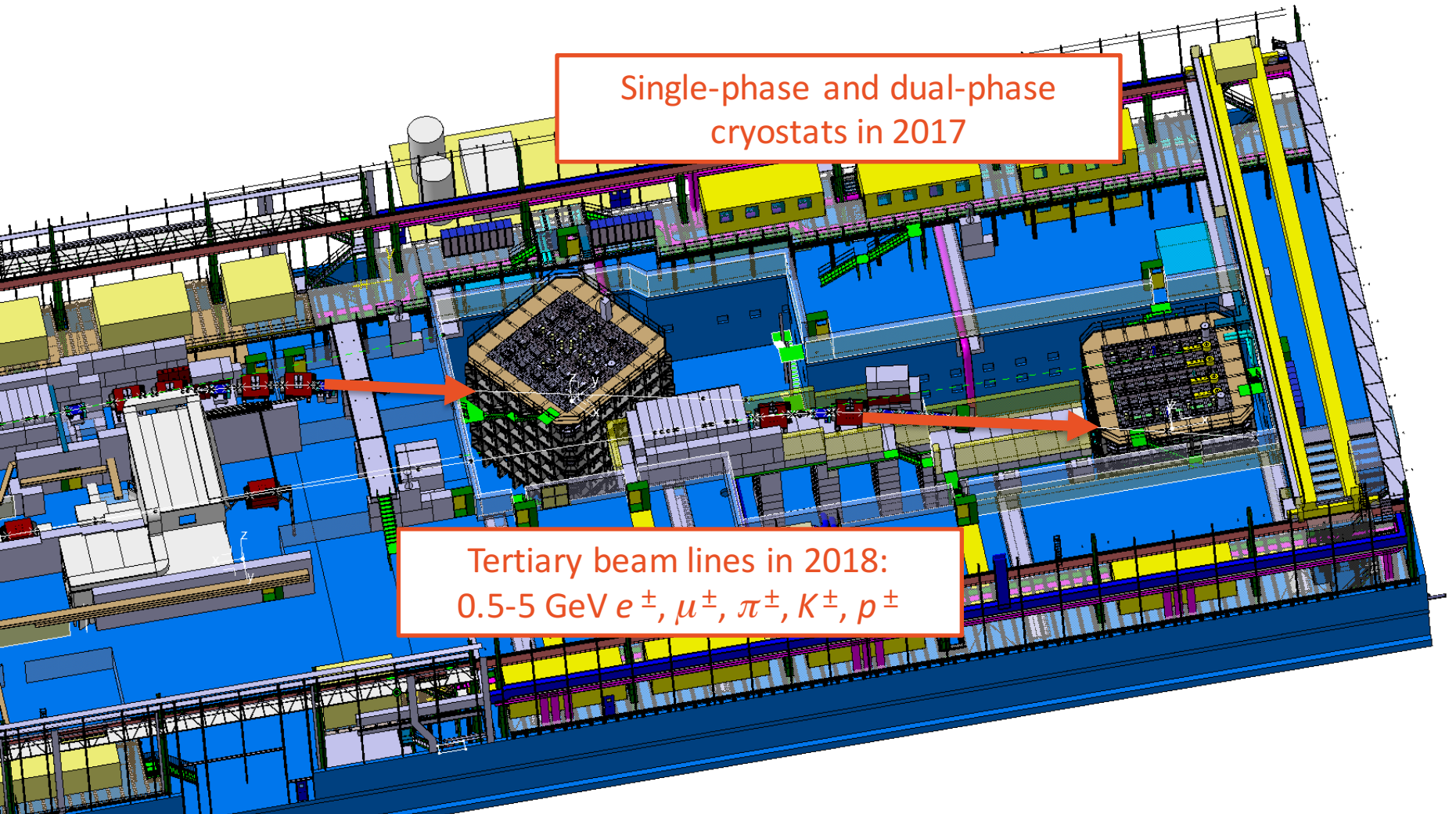
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The CERN Neutrino Platform



The CERN Neutrino Platform



Single-phase and dual-phase cryostats in 2017

Tertiary beam lines in 2018:
 $0.5-5 \text{ GeV } e^{\pm}, \mu^{\pm}, \pi^{\pm}, K^{\pm}, p^{\pm}$

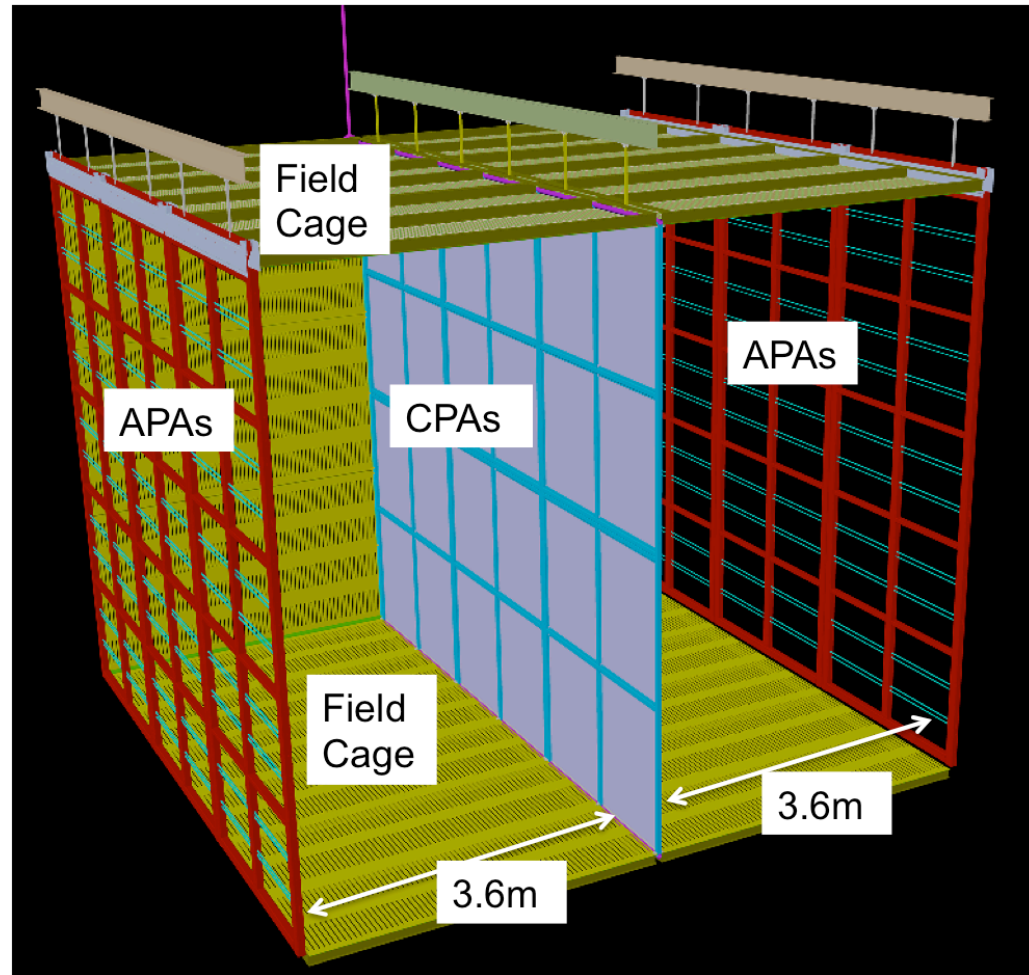
The CERN Neutrino Platform



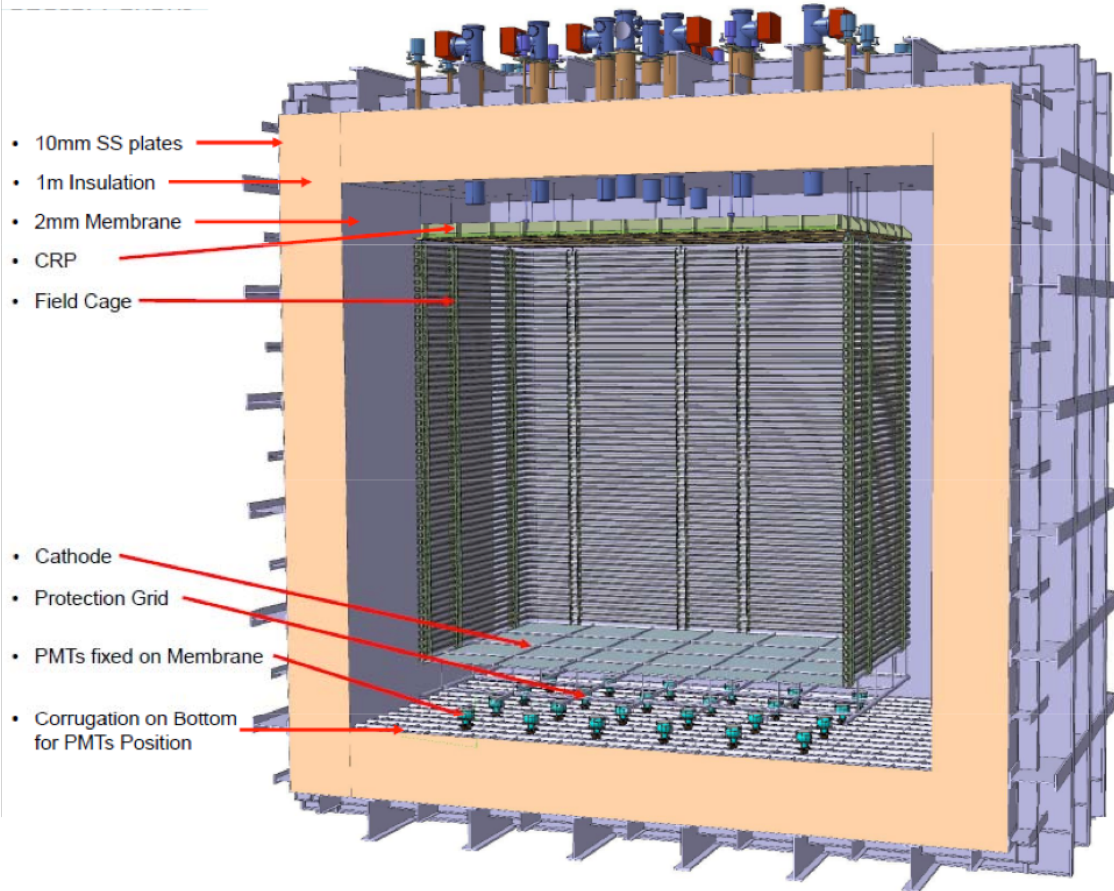
Under construction now, beneficial occupancy this Fall.

ProtoDUNE-Single Phase

- A full-scale engineering prototype.
 - Full-sized APAs and CPAs.
 - Full drift distance and field.
 - Comparing 2 photon detector designs.
 - Test of component construction, installation, commissioning, and performance.
- A test beam experiment.
 - Measure LAr response to charged particles.



ProtoDUNE-Dual Phase



- A full-scale engineering prototype.
 - Full-sized readout planes, cathodes, and light collection.
 - Half of final drift distance, but will operate some time at double field.
- A test beam experiment.
 - Measure LAr response to charged particles.

Conclusions

- We are on the path to building 40 kTons of liquid argon detector and a 1.2 MW neutrino beam.
 - Next step: 2 large-scale protoDUNEs at CERN.
- DUNE has been established as an international priority:
 - Fermilab support
 - Key role of the directorate
 - Synergy with the short baseline program
 - US Government support
 - Authorization for LBNF construction in 2017 budget (\$45M-\$55M)
 - International support
 - Key role of CERN, making rapid progress on the protoDUNEs
 - Discussions at advanced stages with governments & funding agencies