

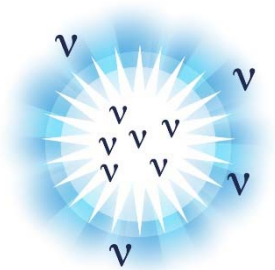
Overview of the Long-Baseline Neutrino Facility

C. J. Mossey
Deputy Director for LBNF
26 October 2016



Why I Love
Neutrinos

Ambitious, Far-Reaching Science Goals



- **Origin of matter**
Discover what happened after the big bang:
Are neutrinos the reason the universe is made of matter?



- **Black hole formation**
Use neutrinos to look into the cosmos and watch the formation of neutron stars and black holes in real time



- **Unification of forces**
Move closer to realizing Einstein's dream of a unified theory of matter and energy

Neutrinos are Exciting Science!

The Nobel Prize in Physics 2002



Raymond Davis Jr.
Prize share: 1/4



Masatoshi Koshihira
Prize share: 1/4



Riccardo Giacconi
Prize share: 1/2

The Nobel Prize in Physics 2002 was divided, one half jointly to Raymond Davis Jr. and Masatoshi Koshihira *"for pioneering contributions to astrophysics, in particular for the detection of cosmic neutrinos"* and the other half to Riccardo Giacconi *"for pioneering contributions to astrophysics, which have led to the discovery of cosmic X-ray sources"*.



The Nobel Prize in Physics 2015



Photo: A. Mahmoud
Takaaki Kajita
Prize share: 1/2

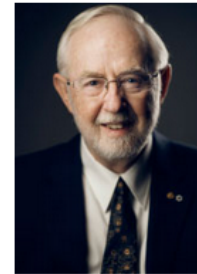


Photo: A. Mahmoud
Arthur B. McDonald
Prize share: 1/2

The Nobel Prize in Physics 2015 was awarded jointly to Takaaki Kajita and Arthur B. McDonald *"for the discovery of neutrino oscillations, which shows that neutrinos have mass"*



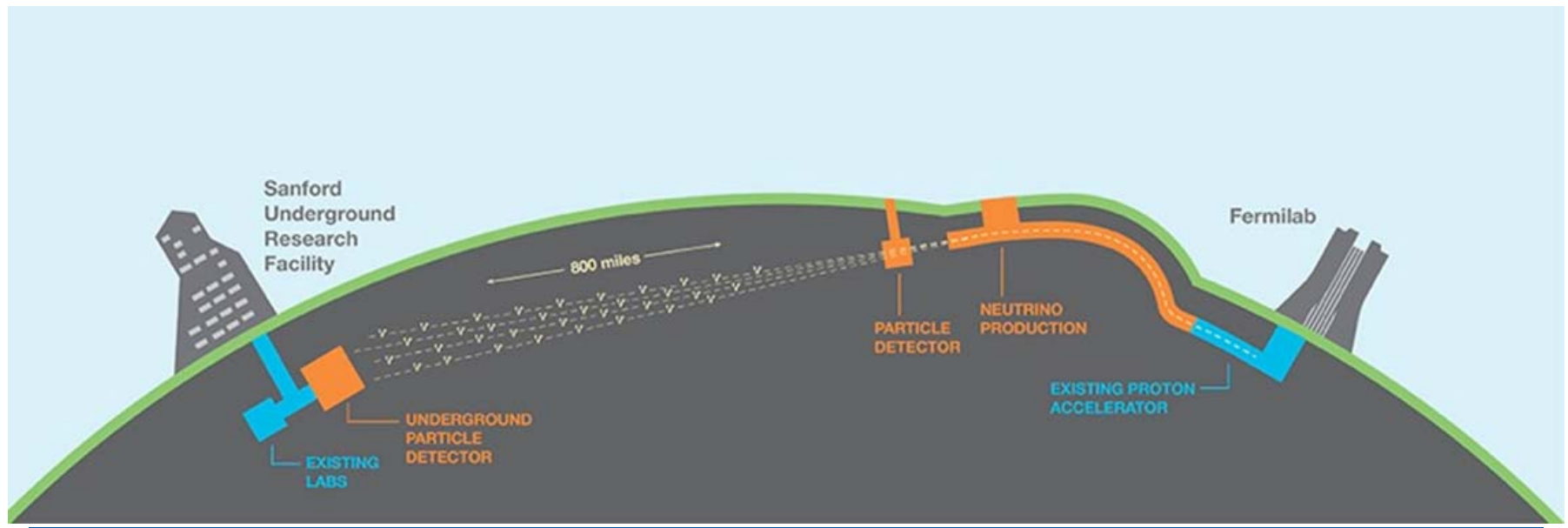
What's a DUNE? What's an LBNF?

- The **Long-Baseline Neutrino Facility** is the **infrastructure** necessary to send a powerful beam of neutrinos 800 miles through the earth, and measure them deep underground at South Dakota's Sanford Underground Research Facility. LBNF supports DUNE.
- The **Deep Underground Neutrino Experiment** will be a **game-changing experiment for neutrino science**, potentially transforming our understanding of why the universe exists as it does.
- The DUNE/LBNF project will be the **first internationally conceived, constructed, and operated mega-science project** hosted by the Department of Energy in the United States.

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

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- The **D**ep **U**nderground **N**eutrino **E**xperiment will be a **game-changing experiment for neutrino science**, potentially transforming our understanding of why the universe exists as it does.



The DUNE Collaboration

As of today:

60 % non-US

946 collaborators from 161 institutions in 30 nations

Armenia, Brazil, Bulgaria,
Canada, CERN, Chile, China,
Colombia, Czech Republic,
Finland, France, Greece, India,
Iran, Italy, Japan, Madagascar,
Mexico, Netherlands, Peru,
Poland, Romania, Russia,
South Korea, Spain, Sweden,
Switzerland, Turkey, **UK**,
Ukraine, USA

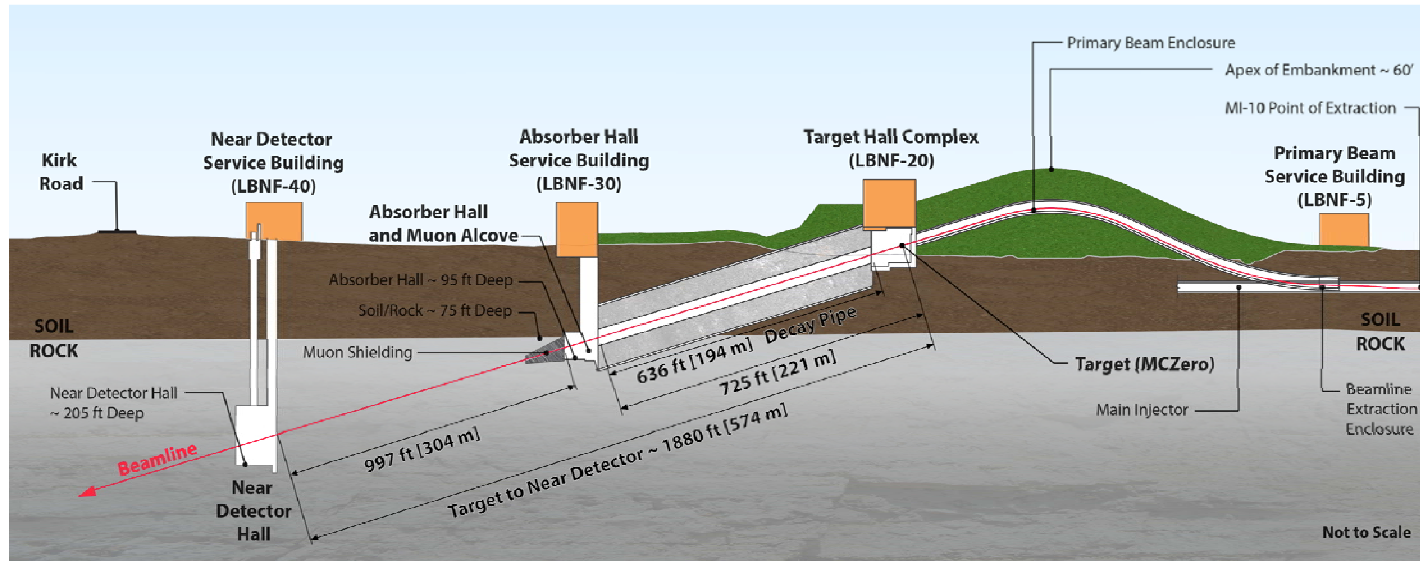


LBNF is an International Partnership/DUNE is an International Experiment

- International partnership is critical to LBNF/DUNE success!
- **LBNF**: CERN is a **major partner** in facility infrastructure at Sanford Lab and is also key to facilitate European engagement.
 - Signed four partnership protocols in Dec 2015 including neutrinos
 - Have already committed to provide first cryostat
 - Facilitating engagement with member countries and European high energy physics community
 - Supporting prototyping effort with short baseline and protoDUNEs with CERN's **neutrino platform**
- **DUNE**: The UK, Brazil, India, Italy, and Switzerland are showing **strong leadership and early support of the experiment...** campaign to engage all 30 countries underway.

LBNF welcomes international cryo system partners!

Overview - “Near Site” – LBNF/DUNE at Fermilab, Batavia, IL



- Primary proton beam @ 60-120GeV extracted from Main Injector
- Initial 1.2 MW beam power, upgradable to 2.4 MW
- Embankment allows target complex to be at grade and neutrino beam to be aimed to Lead, SD
- Decay region followed by absorber
- Four surface support buildings
- Near Detector facility
- **DUNE Near Detectors**

Beamline design based on Fermilab's NOvA beam, currently the most powerful neutrino beam in the world

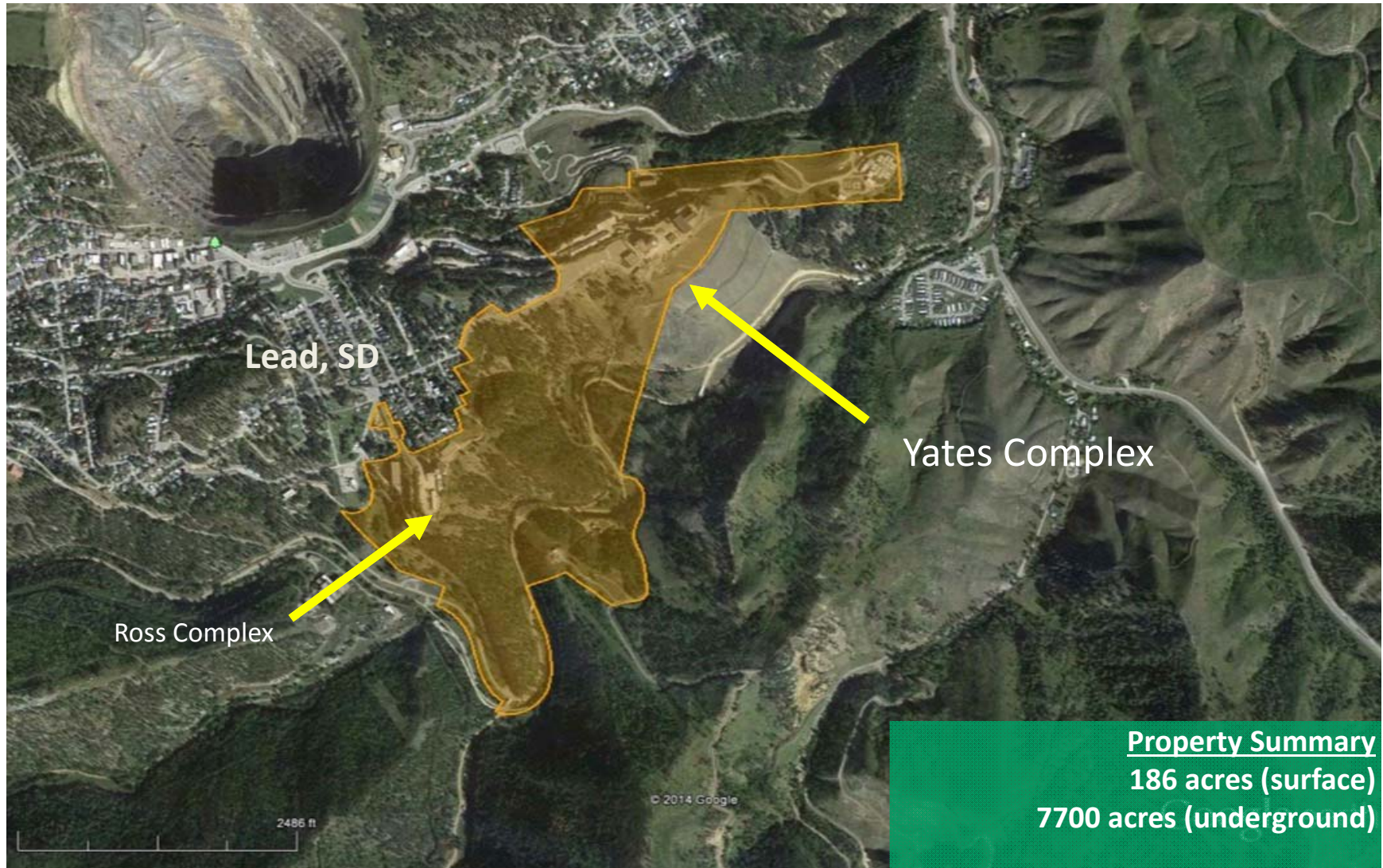
Sanford Underground Research Laboratory



10.26.2016 C. J. Missey | LBNL Project



Far Site – Sanford Lab in Lead, SD



Overview – “Far Site” – LBNF at Sanford Lab, Lead, SD

- **Conventional Facilities:**

- Surface and shaft Infrastructure including utilities
- Drifts and two caverns for detectors
- Central utility cavern for conventional and cryogenic equipment

- **Cryostats:**

- Four membrane cryostats supported by external steel frames

- **Cryogenic Systems:**

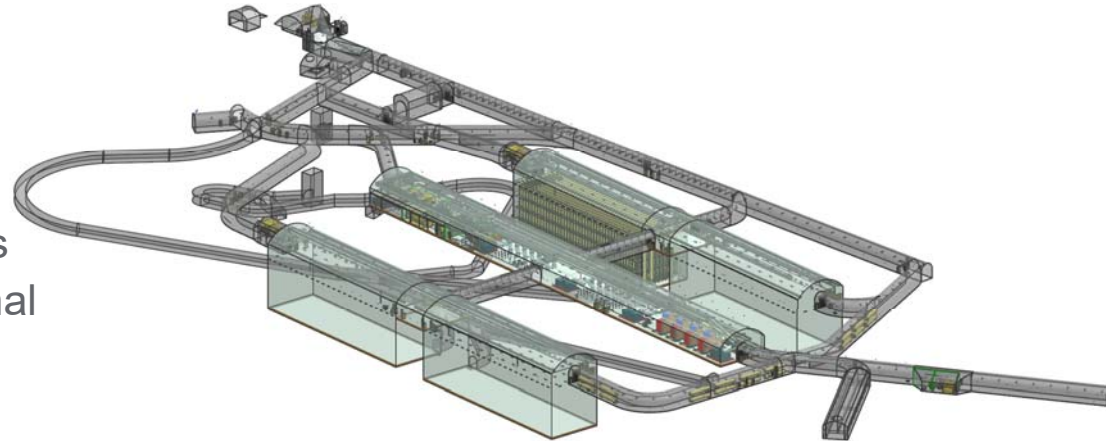
- LN2 refrigeration system for cooling and re-condensing gaseous Argon
- Systems for purification and recirculation of LAr

- **Argon:**

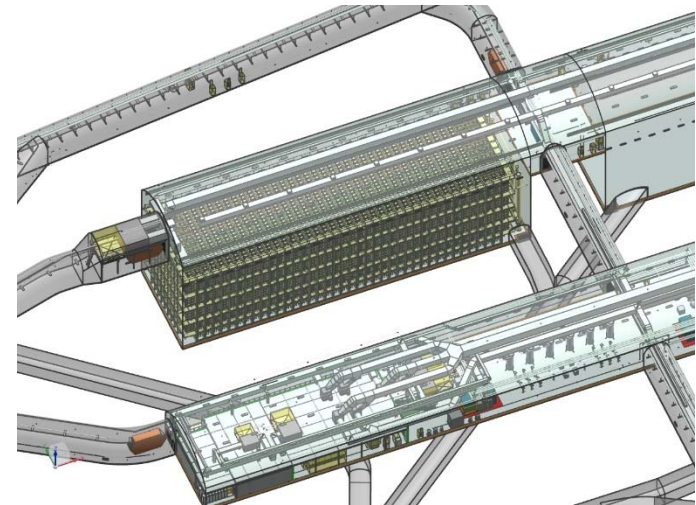
- 70kt LAr (~40kt “fiducial” mass)

- **DUNE LAr-TPC Detectors**

Extensive prototyping program in progress to scale LAr TPC detector technology to 10kt fiducial volume

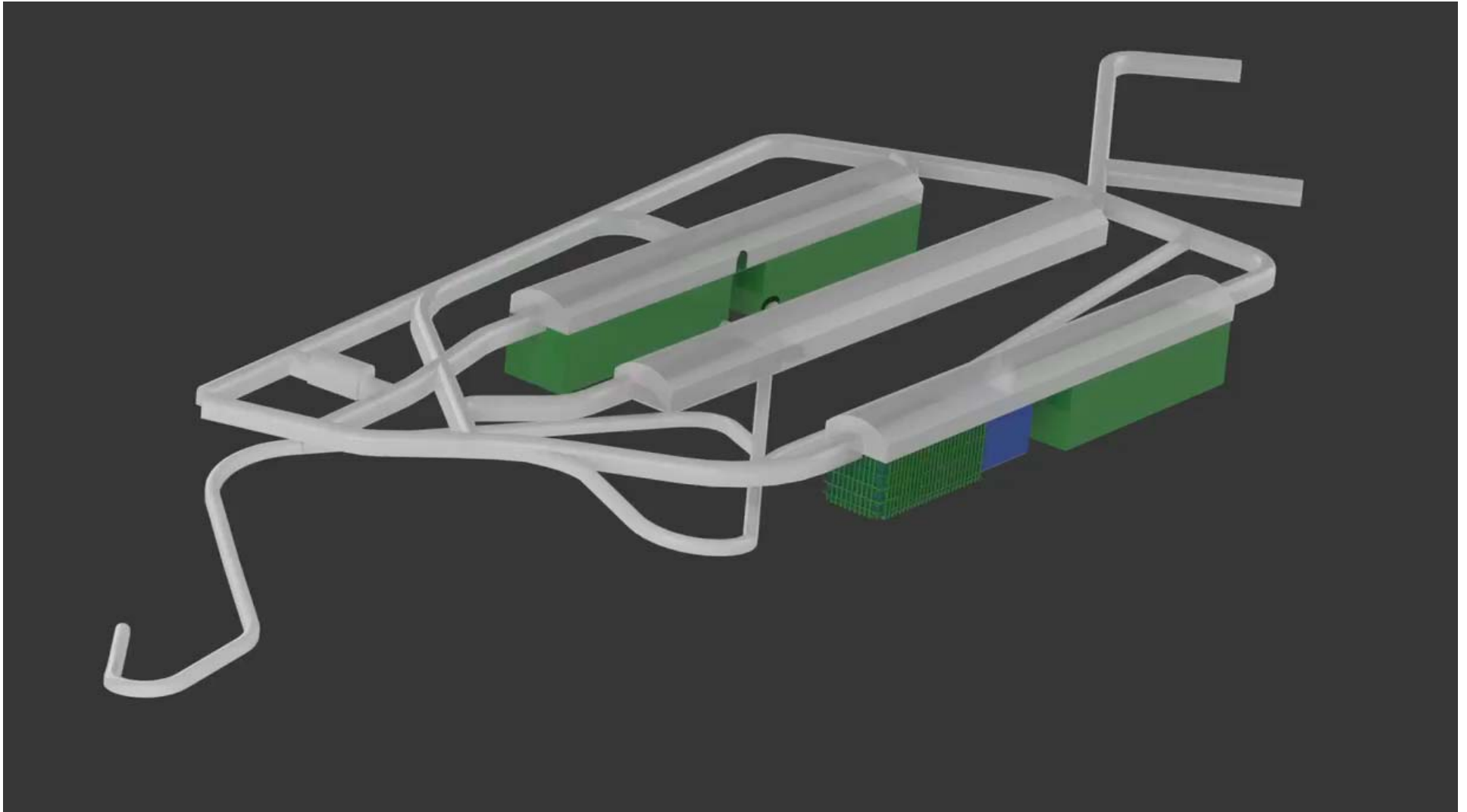


4850L caverns and drift layout

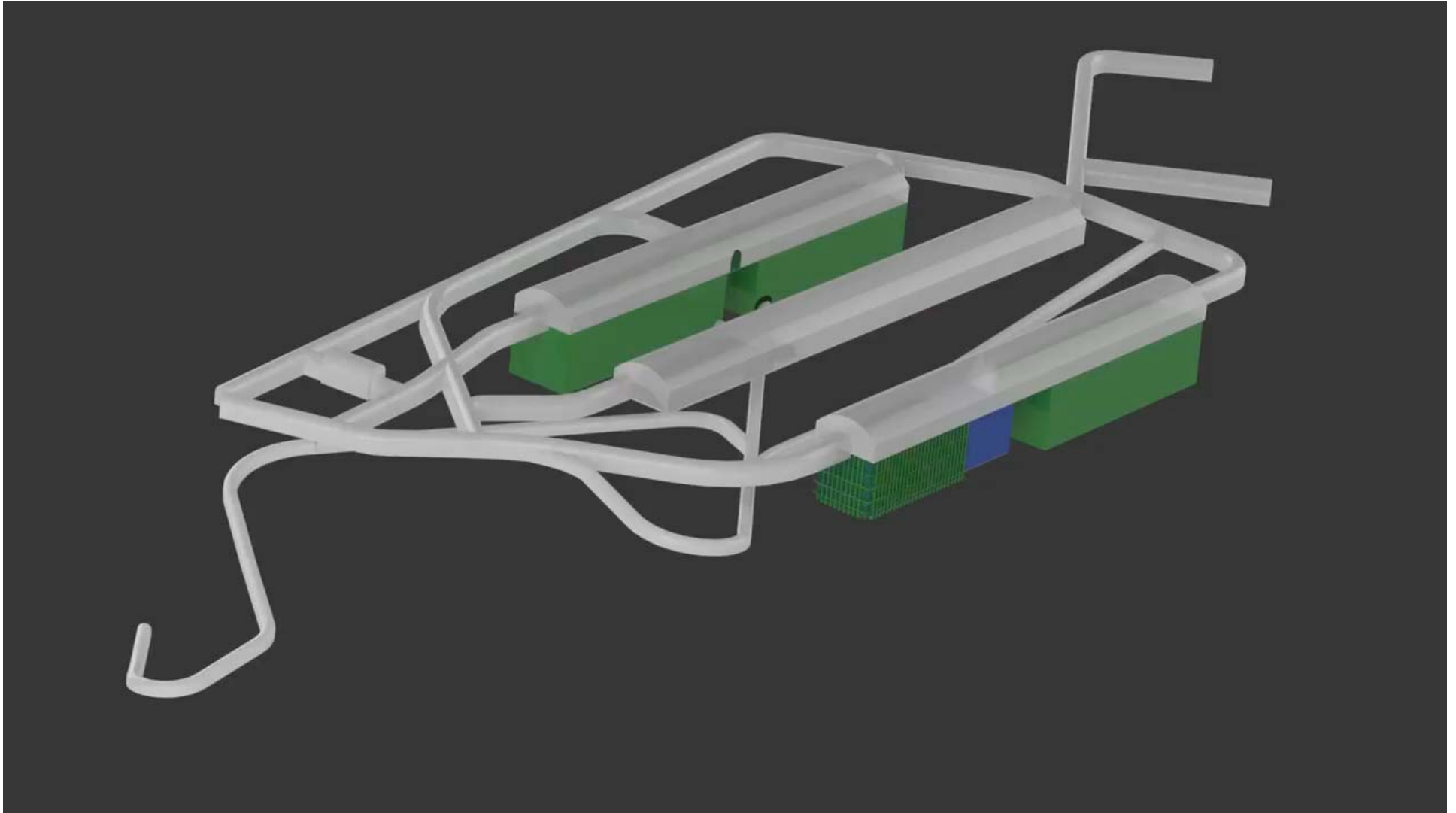


Single cryostat and portion of central utility cavern

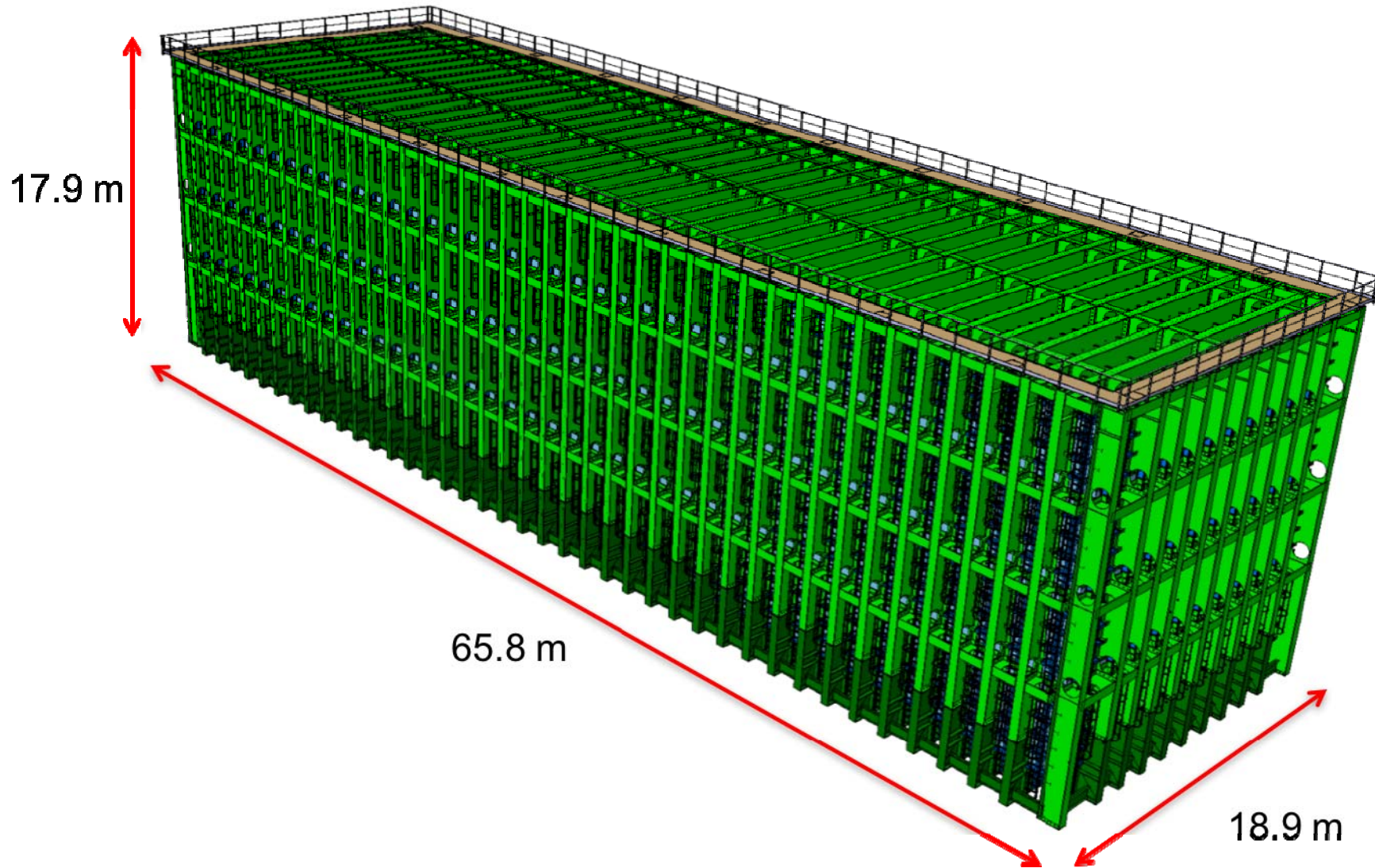
LBNF / DUNE Far Site



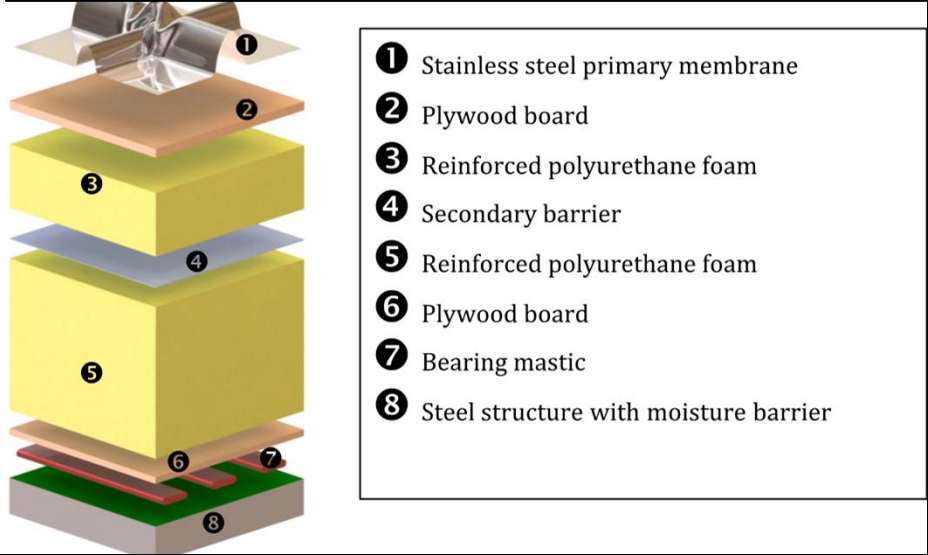
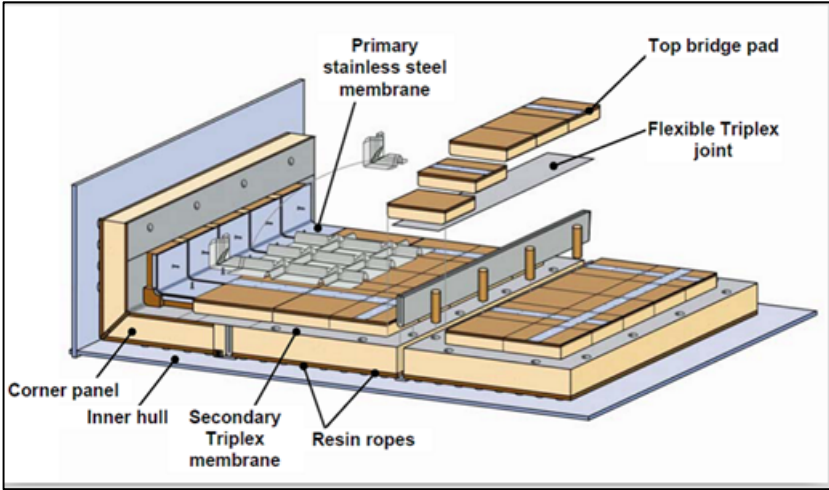
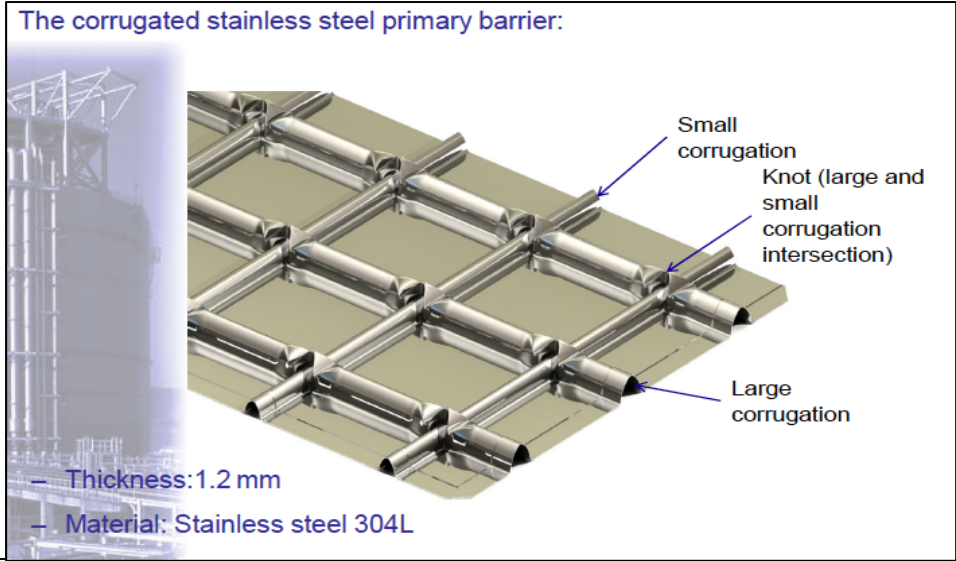
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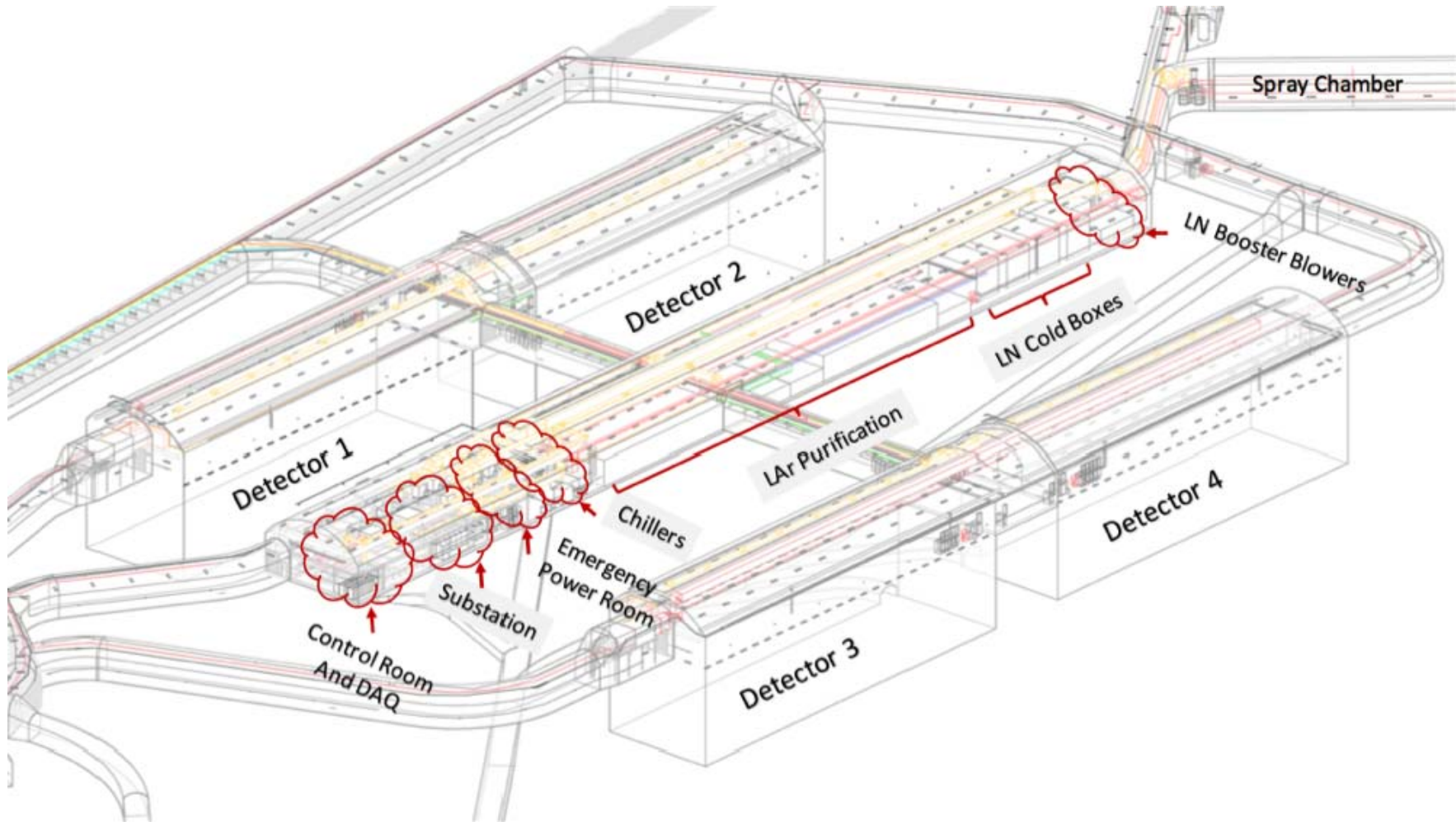
Free-Standing Steel Cryostat Design



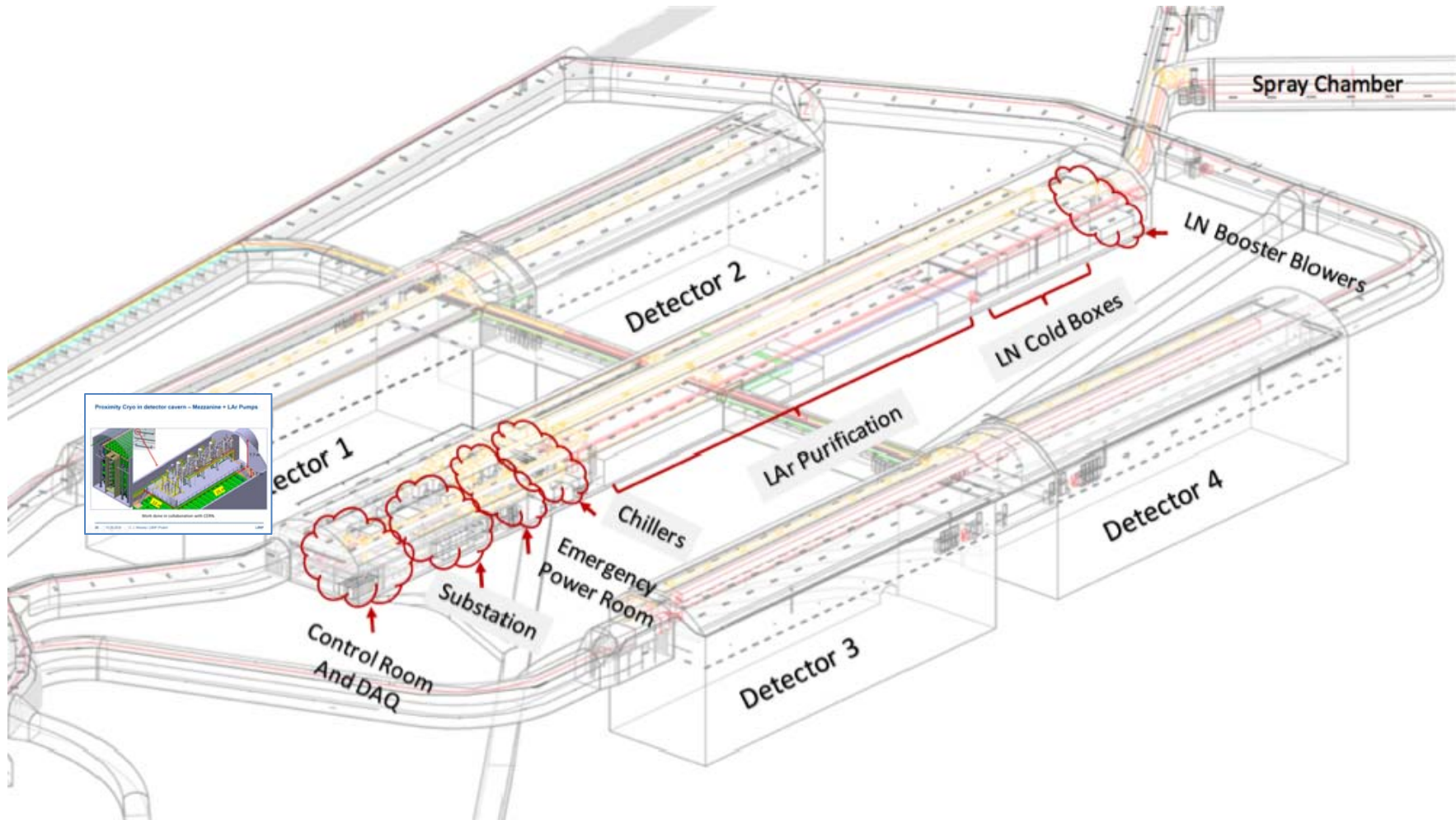
GTT Membrane Cryostat Design



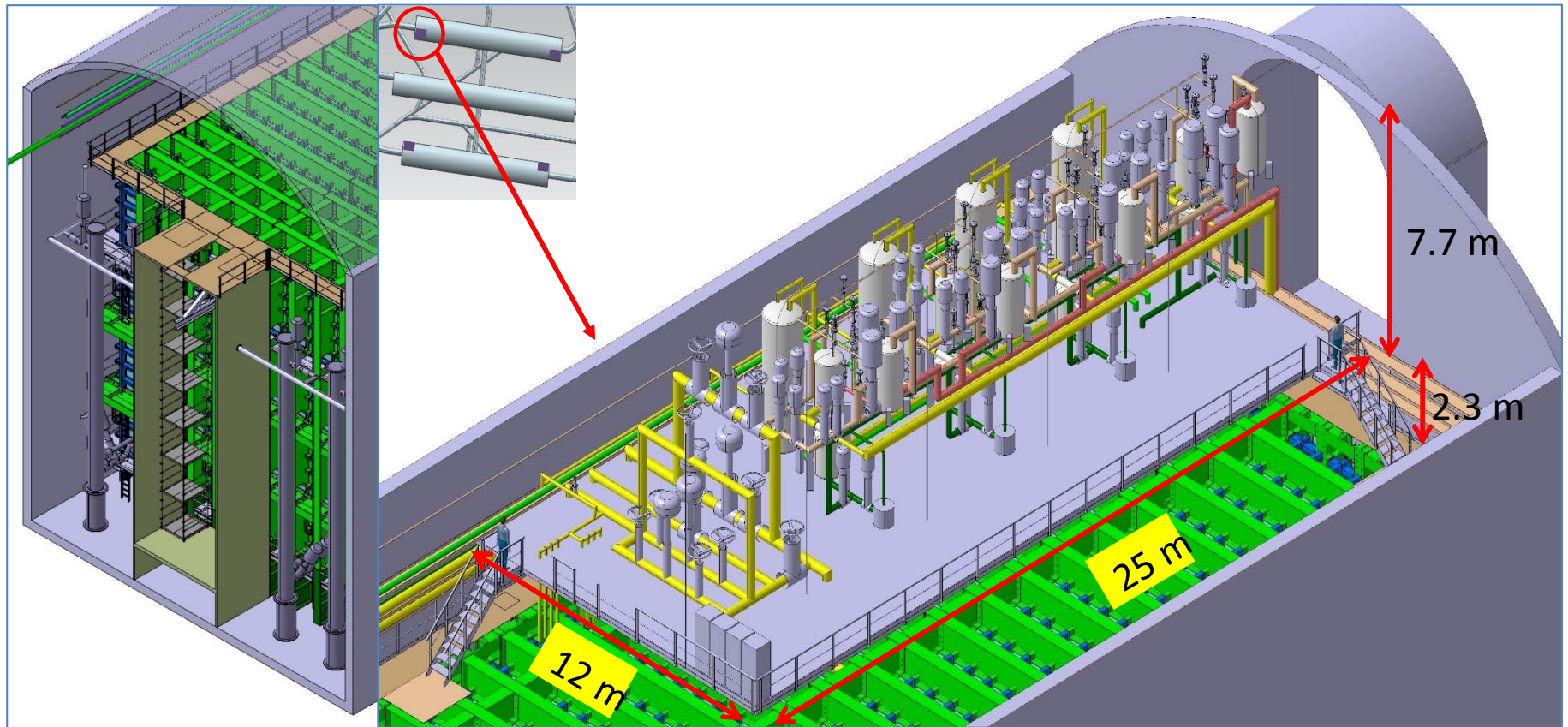
Cryogenic Systems



Cryogenic Systems

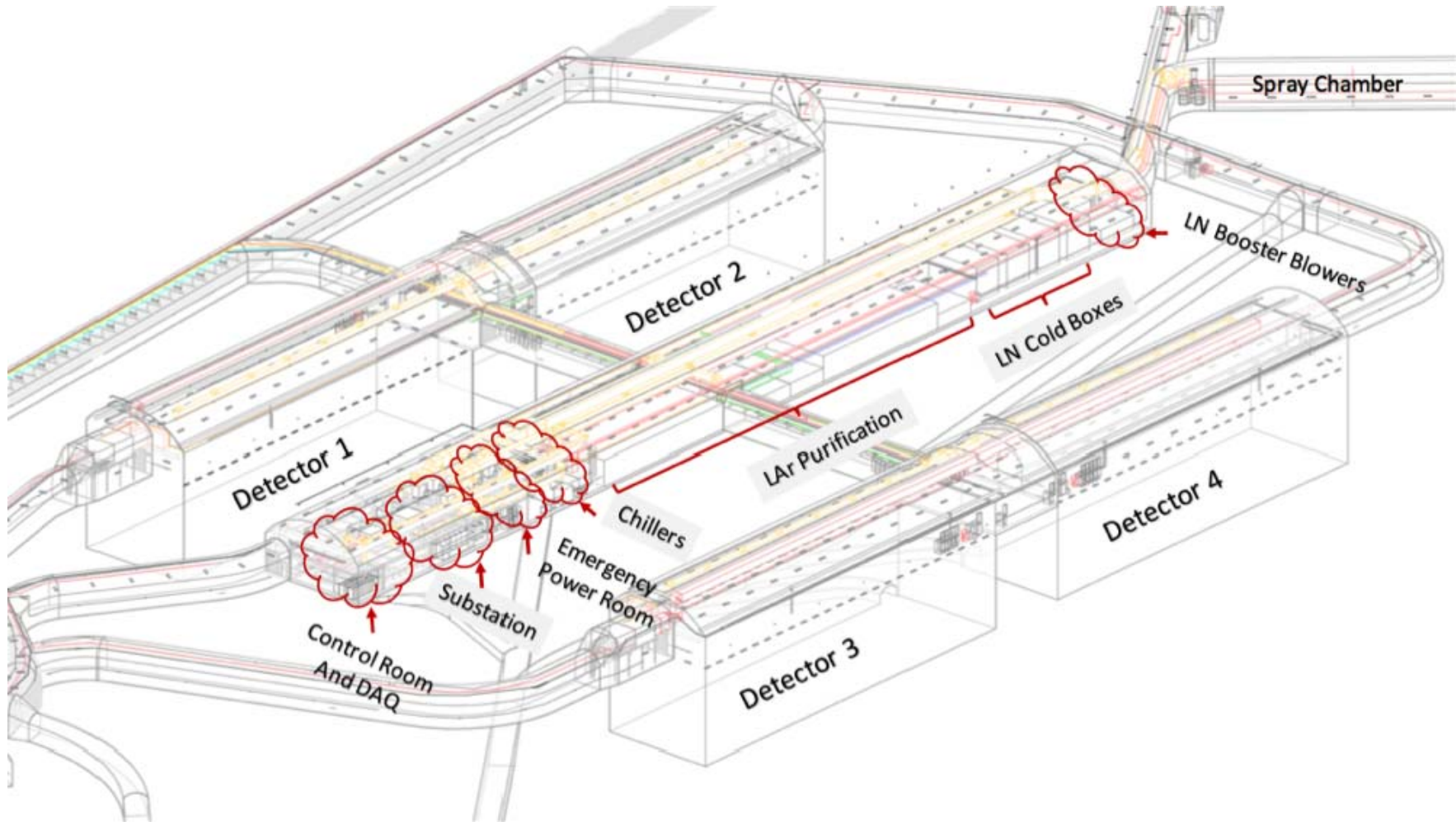


Proximity Cryo in detector cavern – Mezzanine + LAr Pumps

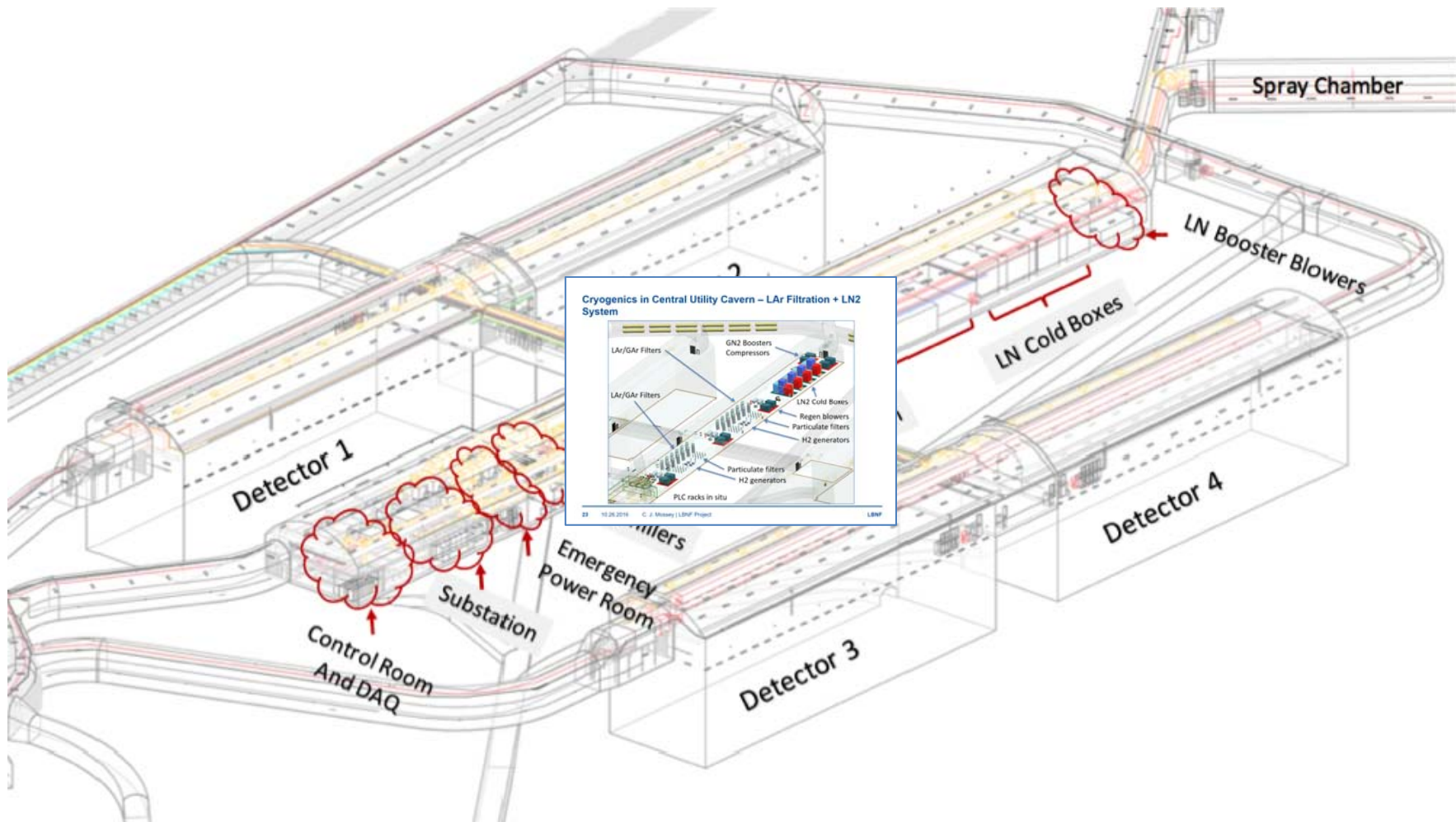


Work done in collaboration with CERN.

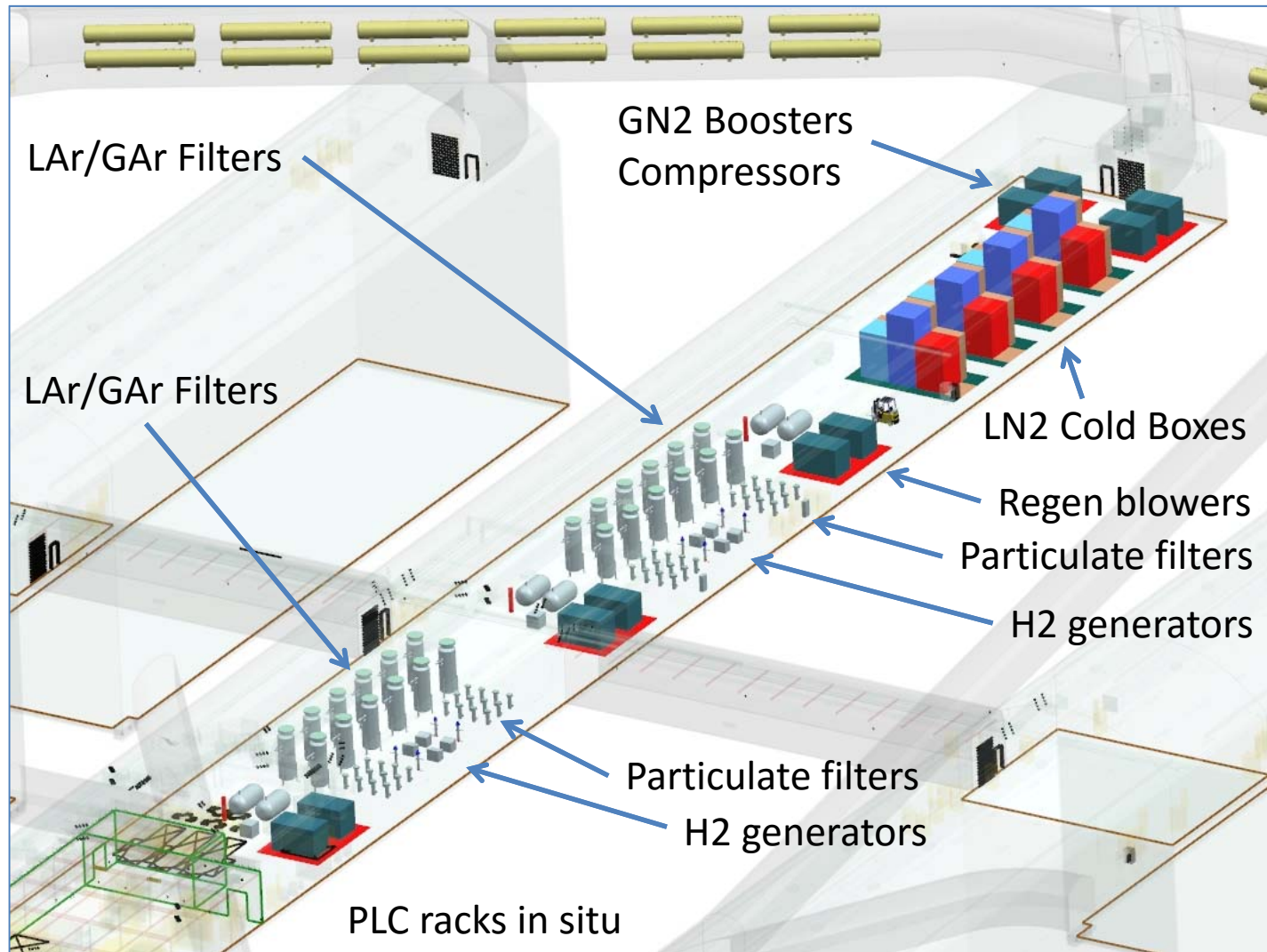
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Cryogenic Systems

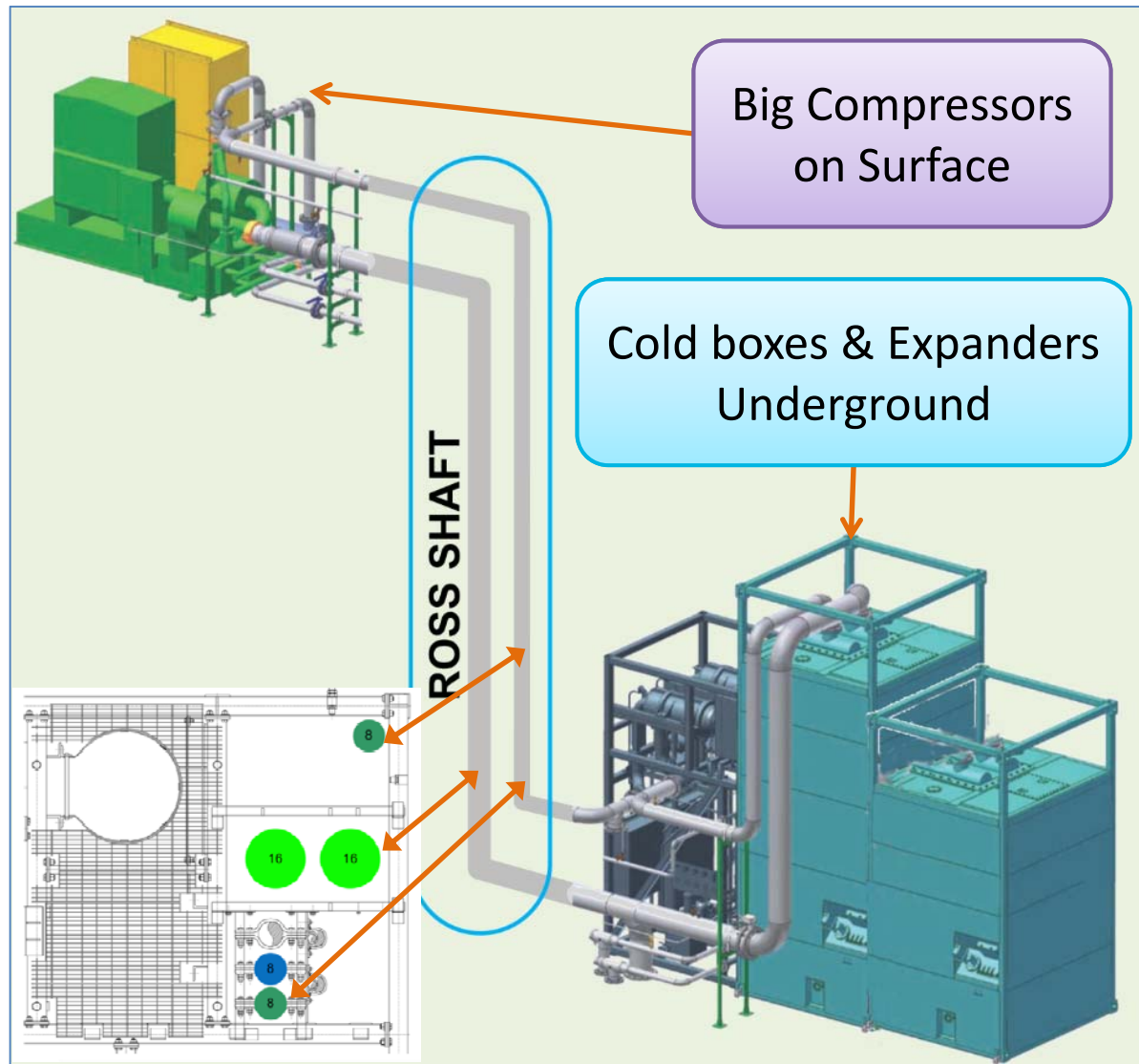


Cryogenics in Central Utility Cavern – LAr Filtration + LN2 System



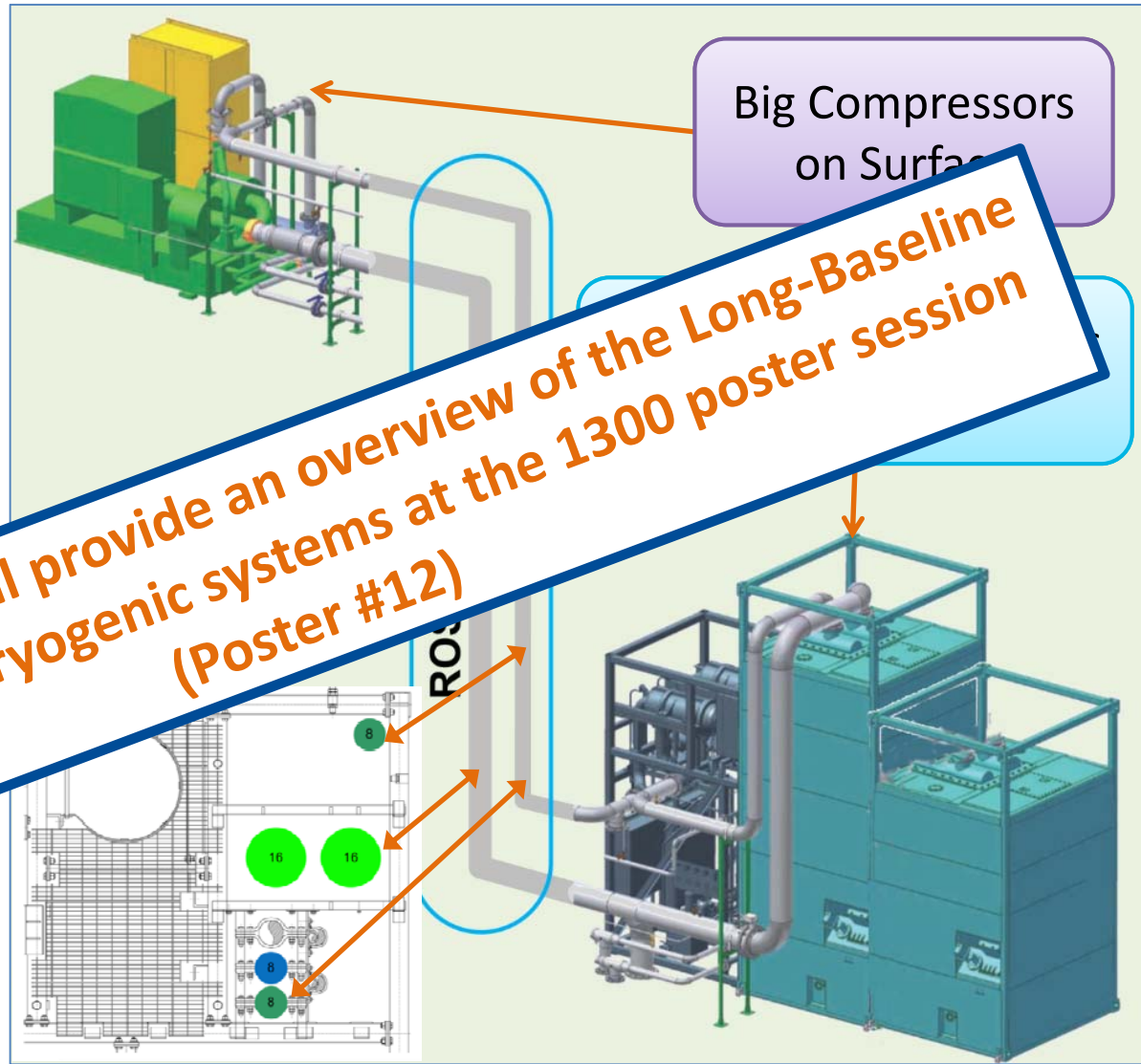
External Cryogenics – LN2 Refrigeration

- 4 Commercial units:
 - Cold boxes and gas boosters in the cavern.
 - GN2 compressors above ground.
- Units assembled in cavern, based on transport limits.
- 3 units for cryostats 1, 2 and 4th unit added for cryostats 3, 4.
 - 4x97 kW units.
- Piping in shaft is CF responsibility.

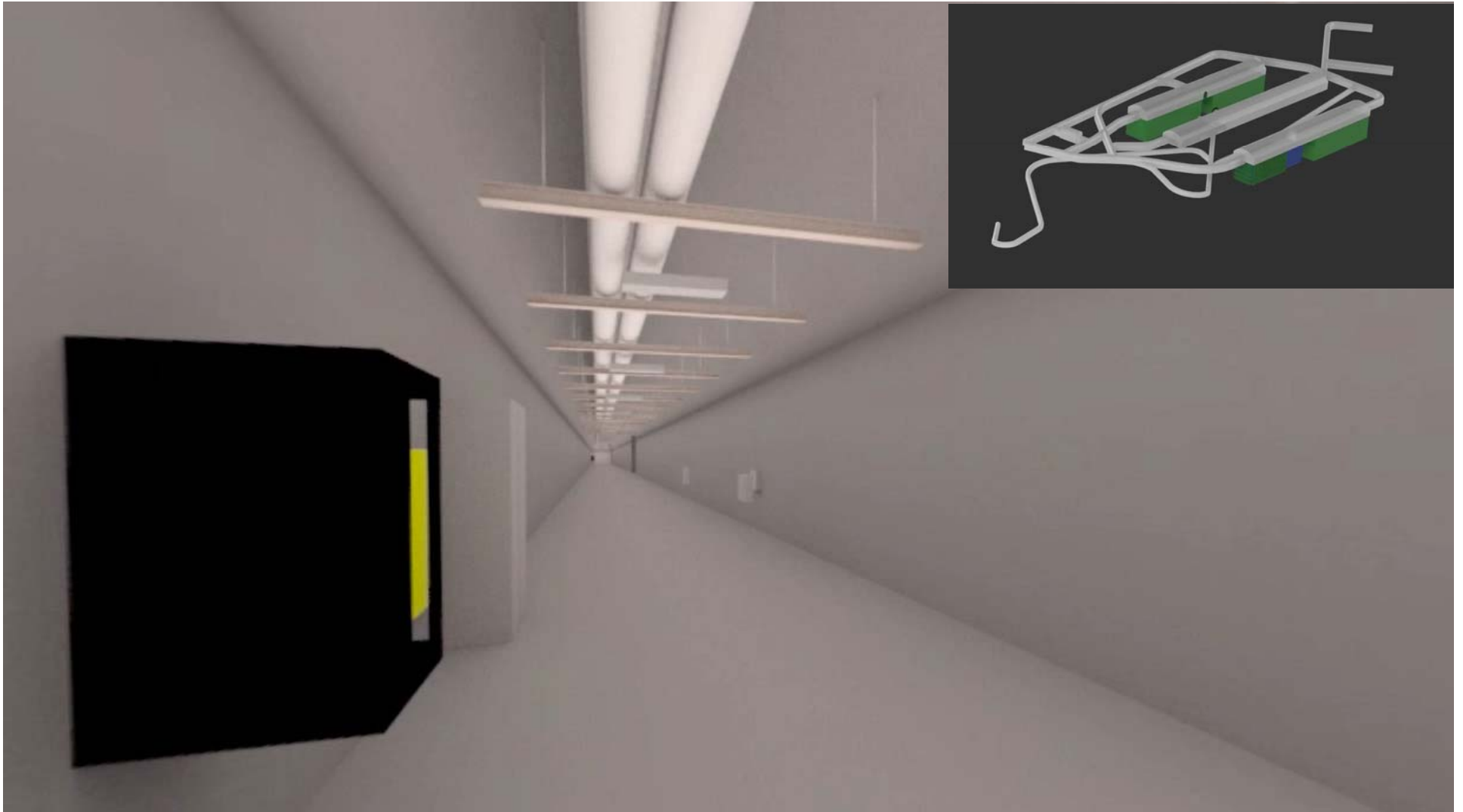


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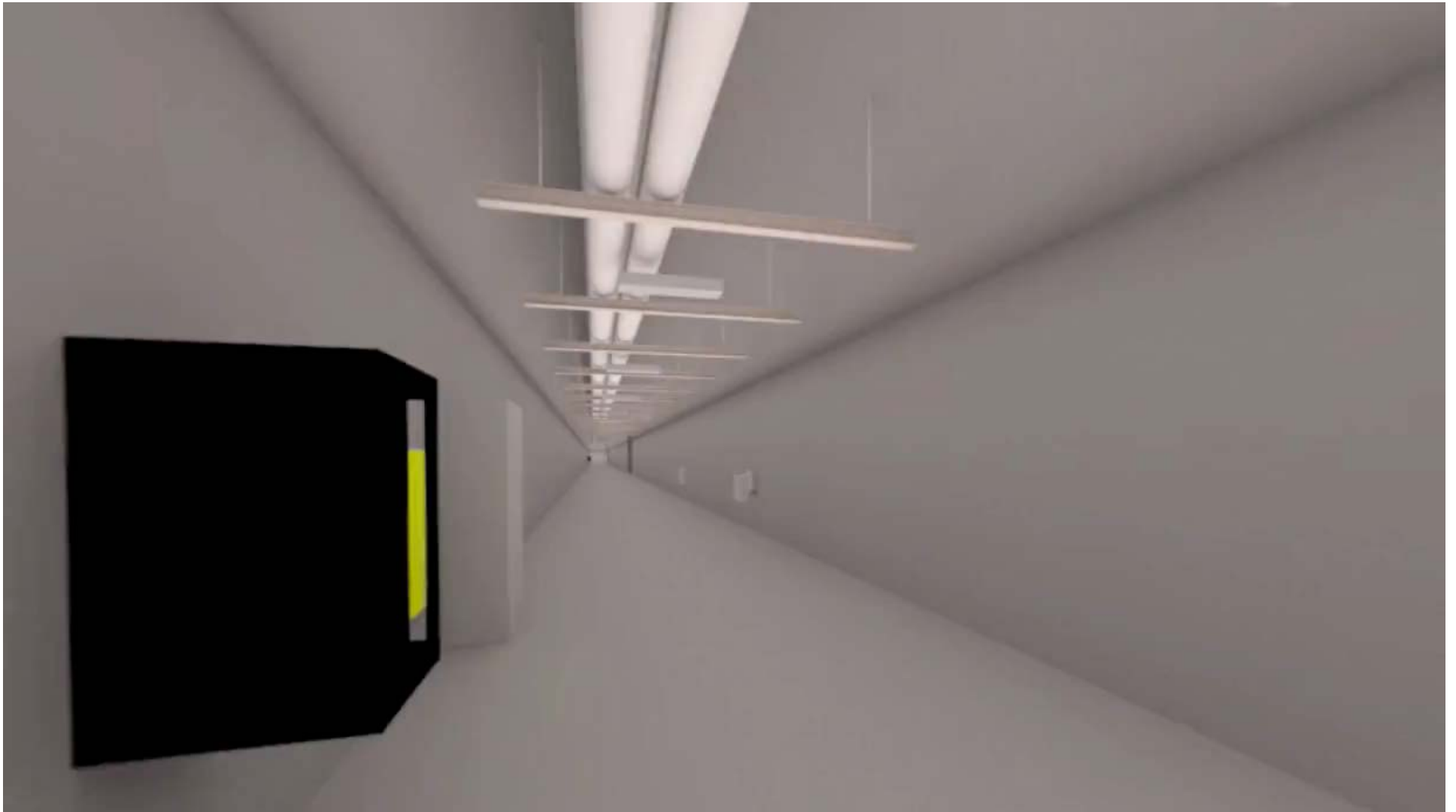
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LBNF Virtual Walkthrough

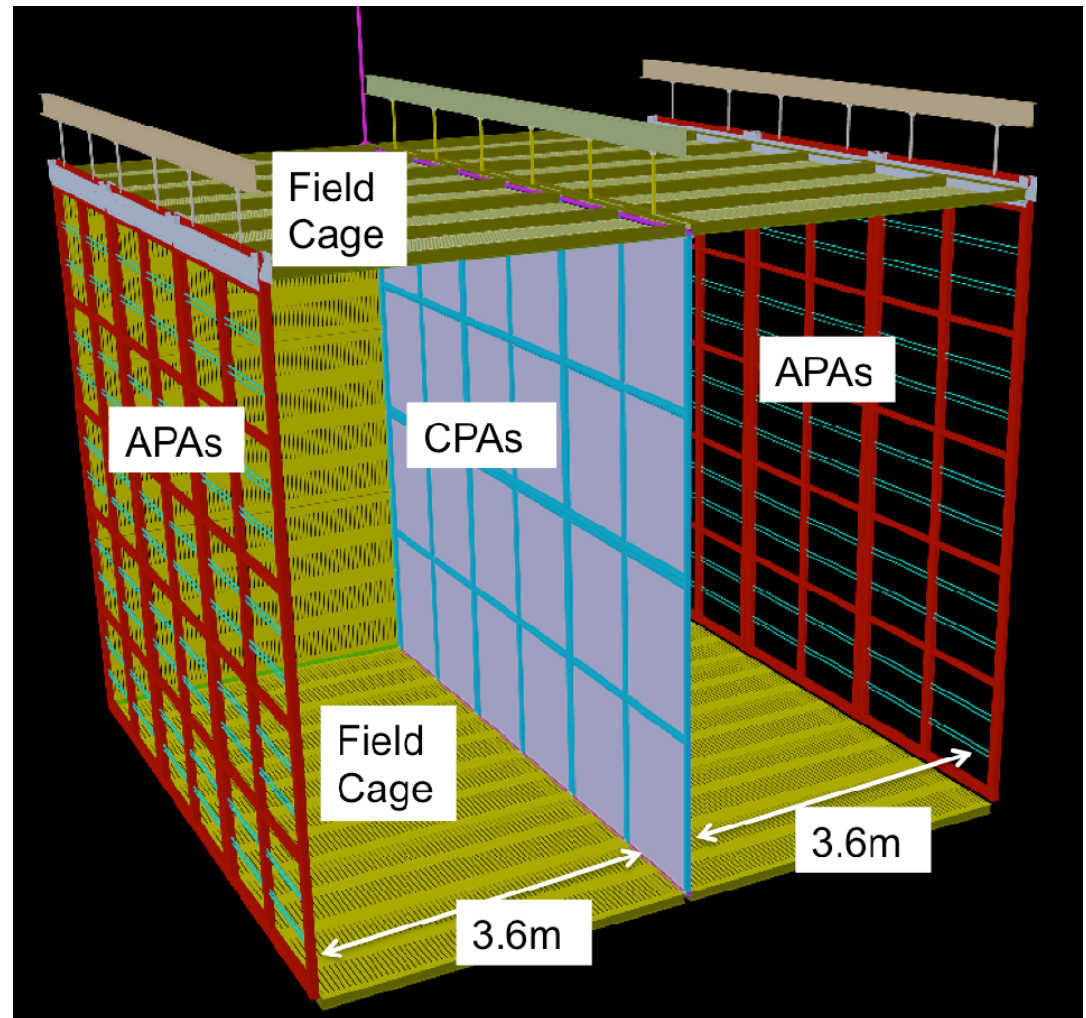


LBNF Virtual Walkthrough



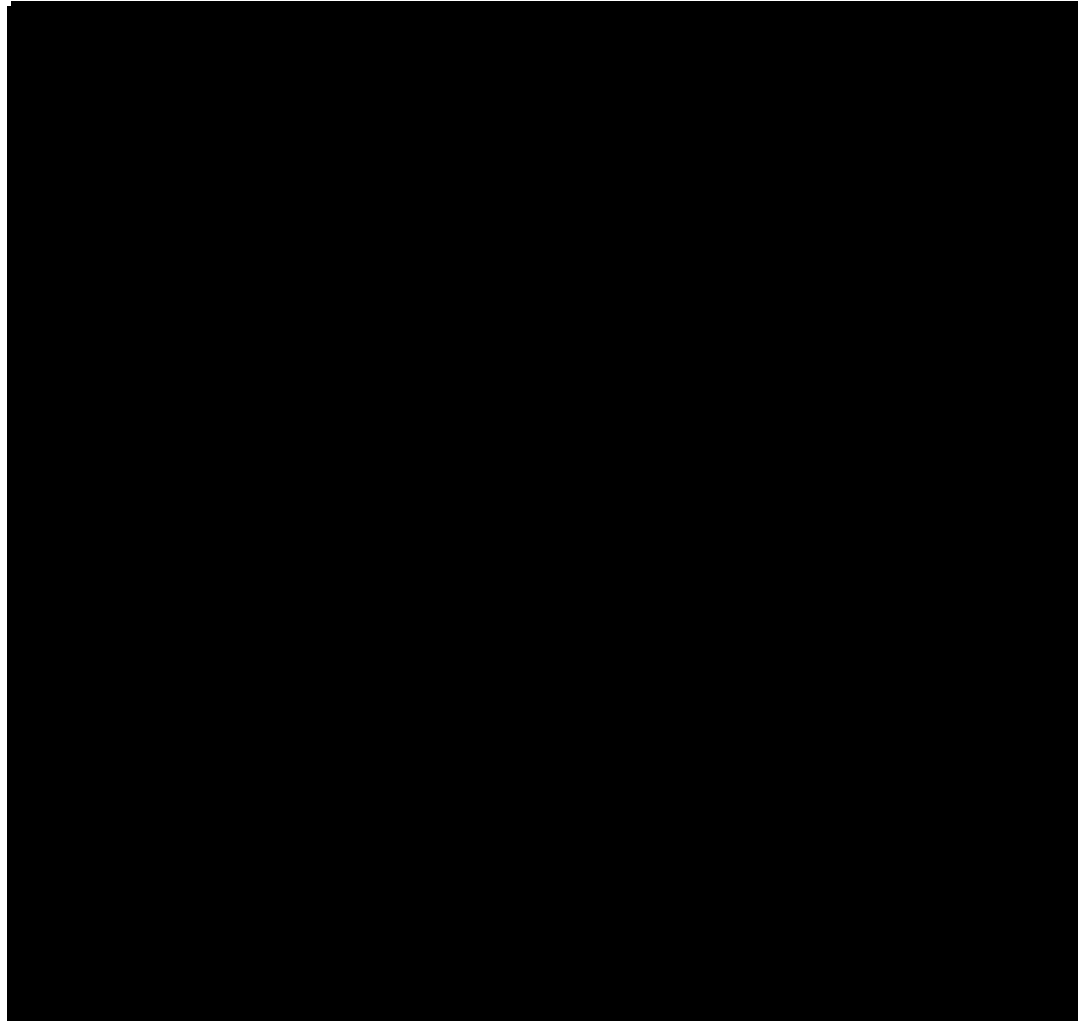
Single Phase Detectors inside the Cryostats

- Detectors consist of:
 - Anode Plane Arrays
 - Cathode Plane Arrays
 - Field Cage
 - Photon detectors
 - Readout electronics and DAQ
- How they work:
 - Neutrinos (occasionally) collide with Argon nucleus.
 - Resulting particles cause electrons to be knocked loose from liquid argon atoms, which “drift” to the APAs



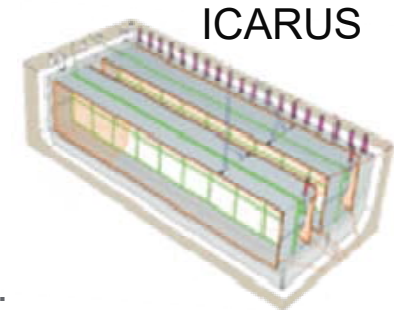
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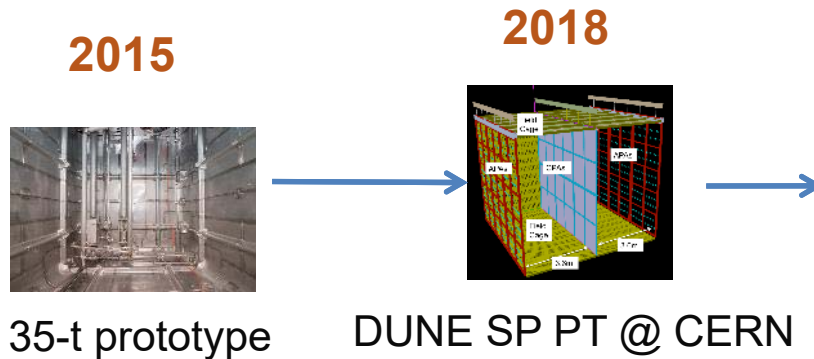


DUNE Far Detector Prototyping and Scaling

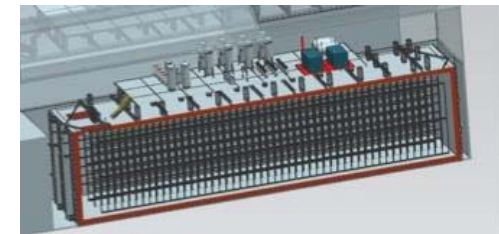
- Single-Phase design based on ICARUS detector LAr TPC technology
- Also developing Dual-Phase LAr TPC technology
- CERN neutrino platform and Fermilab are providing a strong development and prototyping program for the DUNE Far Detectors.



Single-Phase



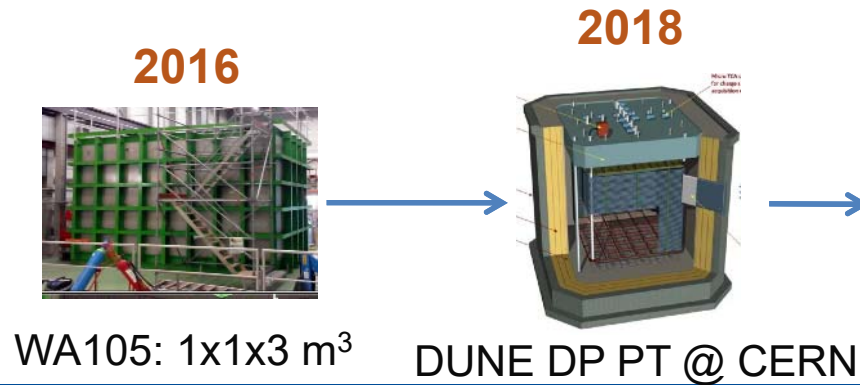
DUNE Reference Design



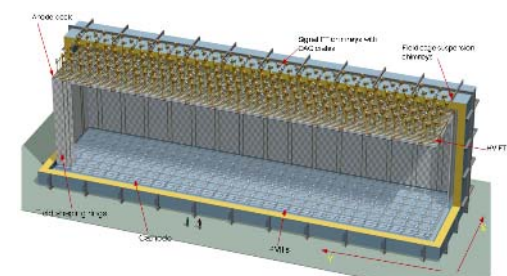
2021

↑ ↓

Dual-Phase



DUNE Alternative Design



Far Site Scope – Overview of Phases of Work

1. Sanford Lab Reliability Projects

FY16 – 18

- Ross shaft rehab
- Hoist motor rebuilds, more...

2. Pre-Excavation

FY17 - 20

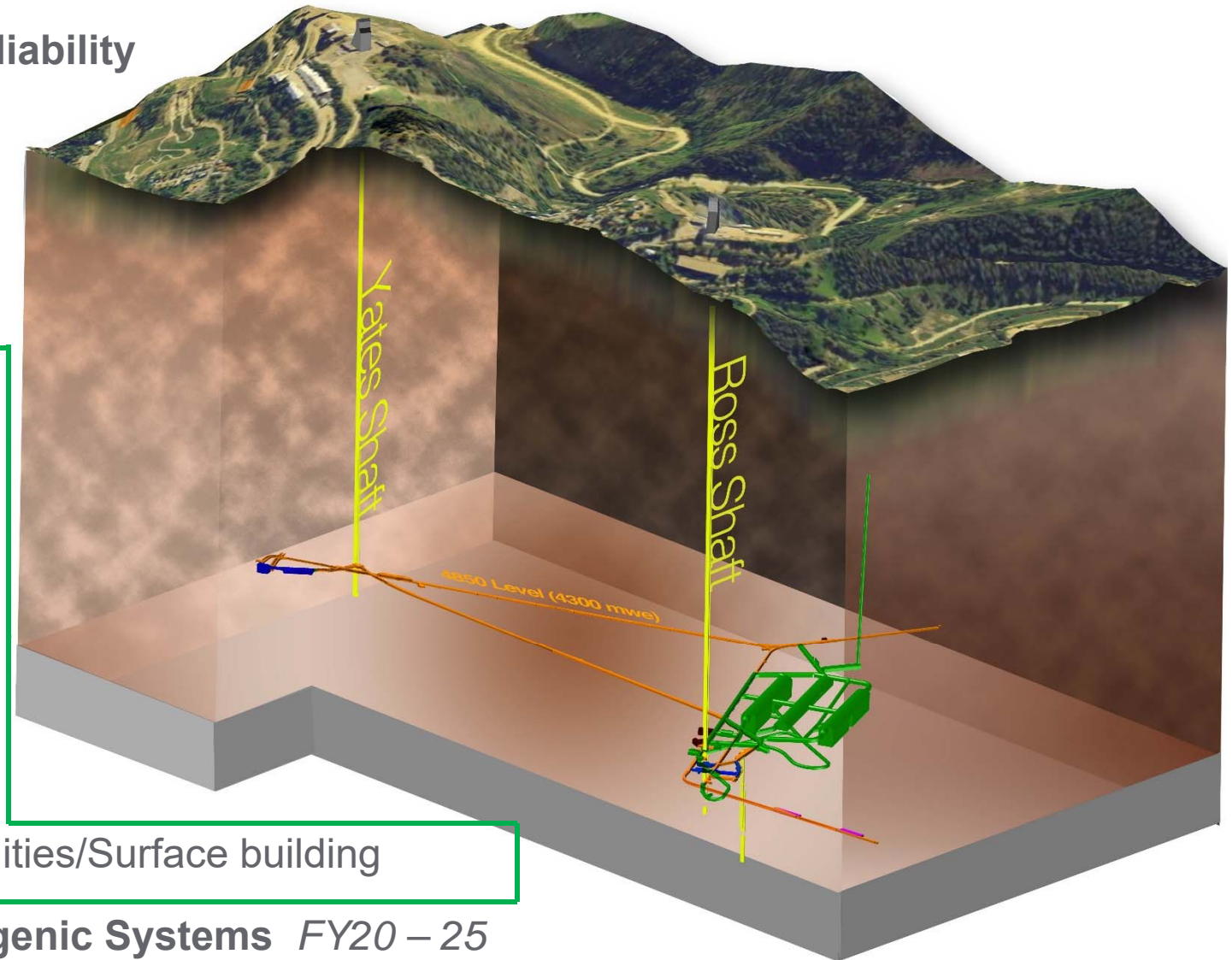
- Rock disposal systems
- Ross brow expansion, more...

3. Excavation/Construction

FY18 – 22

- Caverns/Drifts/Utilities/Surface building

4. Cryostats/Cryogenic Systems *FY20 – 25*







Questions?

