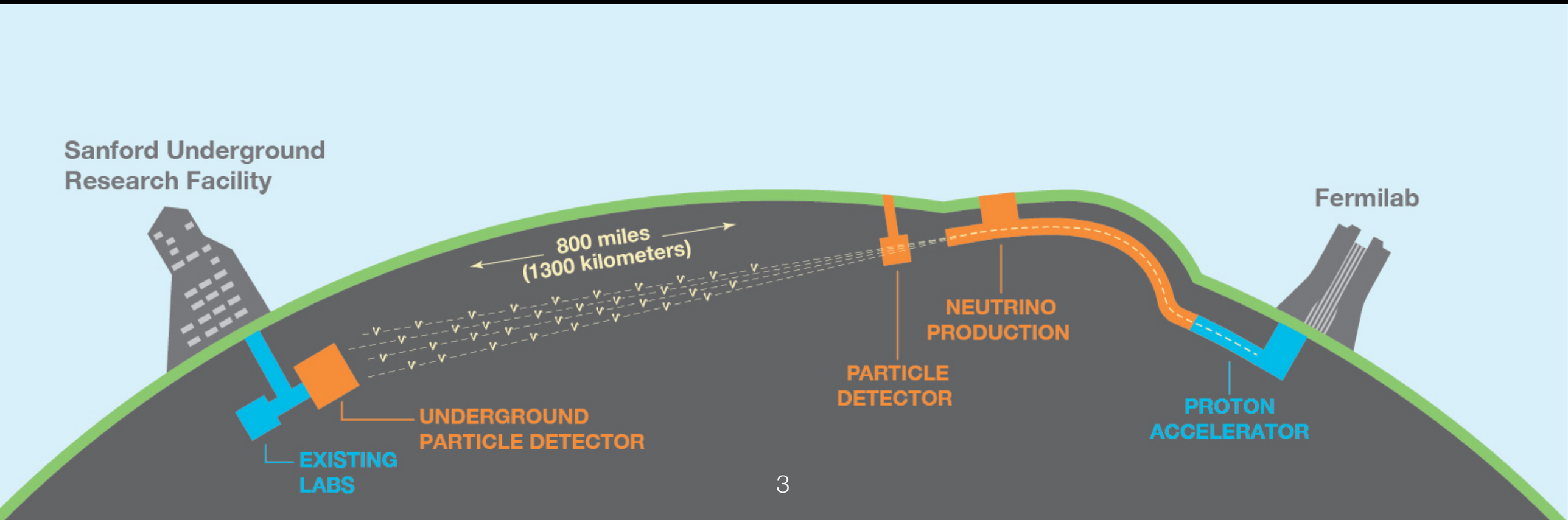
ProtoDUNE SP

Testing a Swimming Pool for Neutrinos

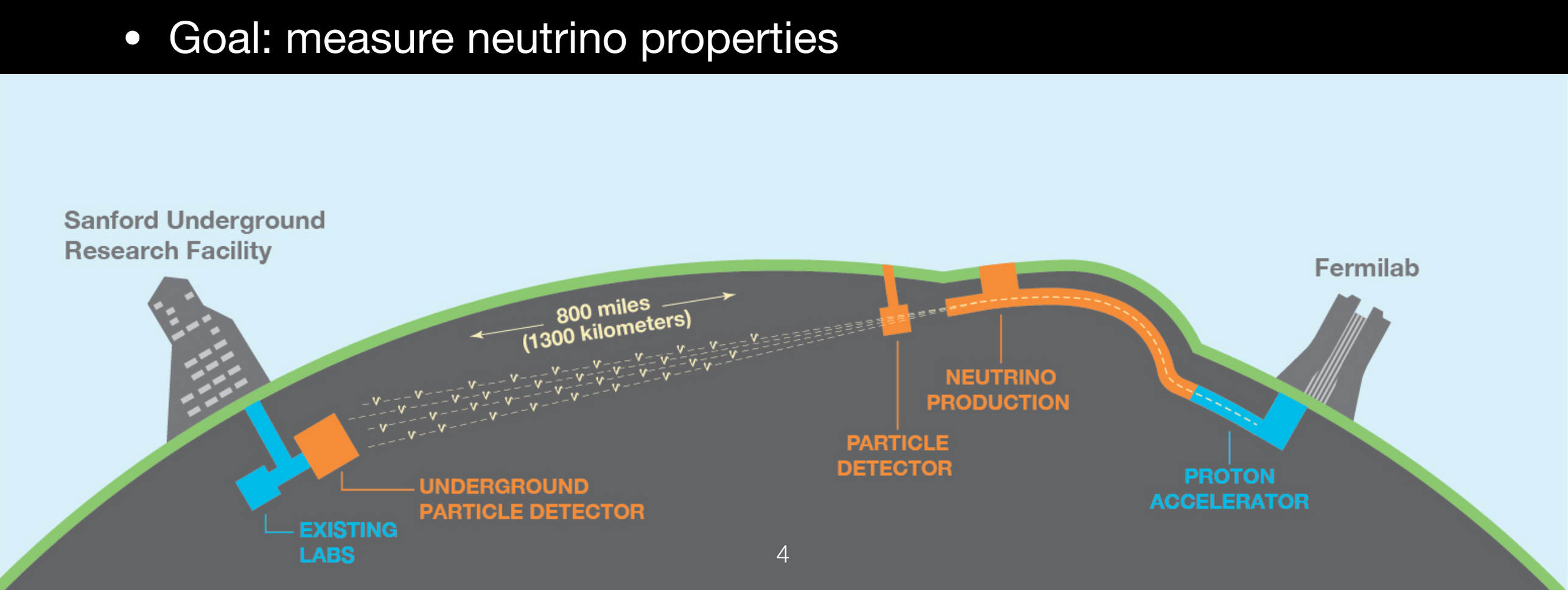
Milo Vermeulen — 2-11-2018

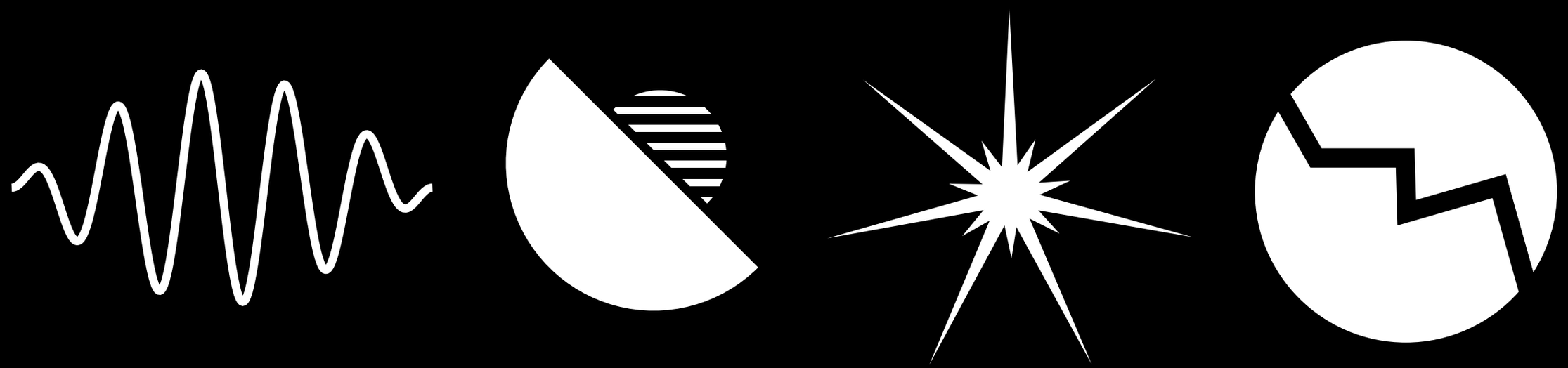
DEEP UNDERGROUND NEUTRINO EXPERIMENT

- Long-baseline neutrino experiment
- From FNAL to SURF
- Most intense neutrino beam in the world
- Biggest liquid argon time projection chamber (LAr TPC) in the world



- 1100+ collaborators
- 170+ institutions
- 32+ countries
- Goal: measure neutrino properties





DUNE Physics

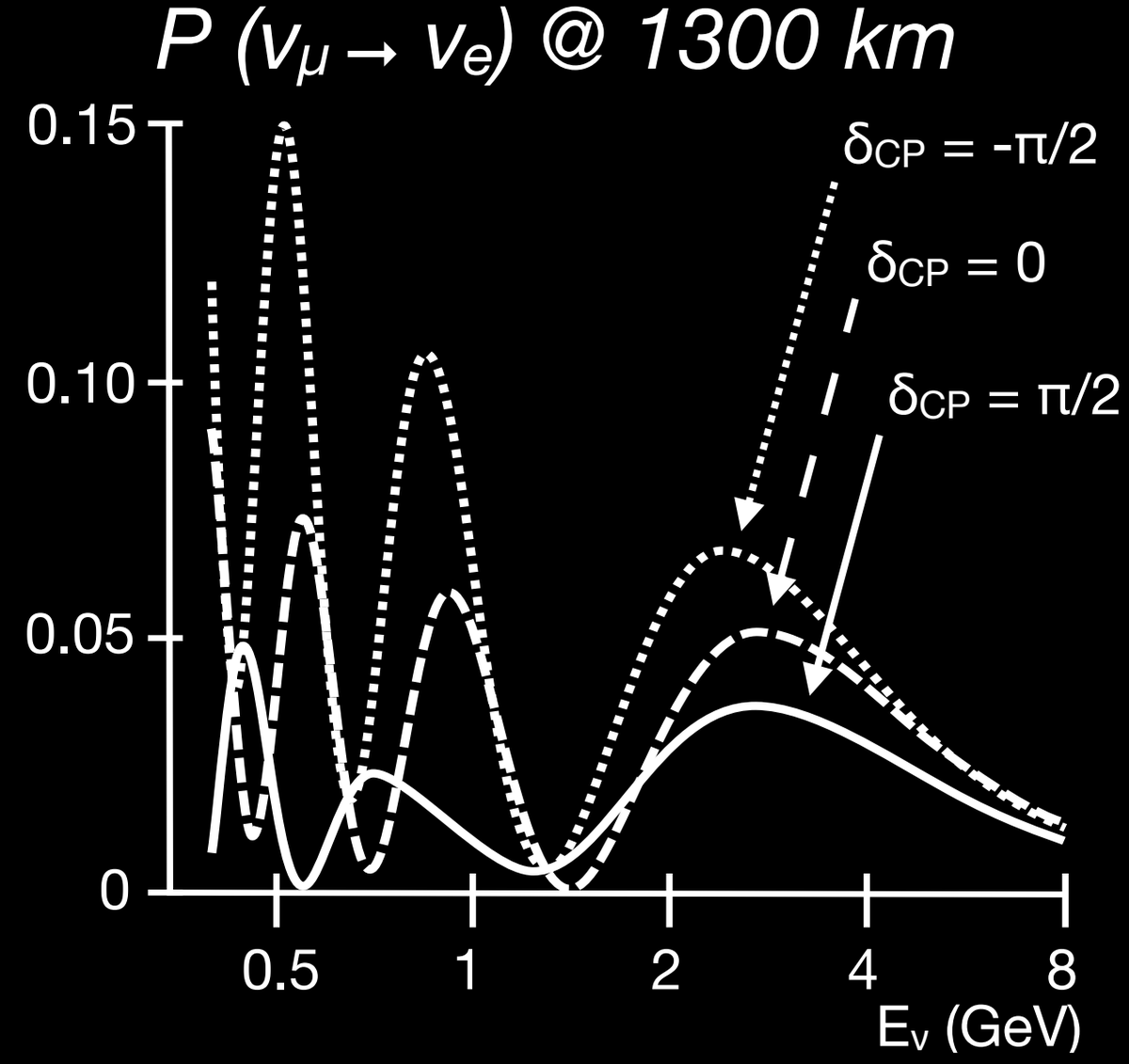
Neutrino Oscillation Parameters

And Other Properties

- Measurement of $P(\nu_\mu \rightarrow \nu_e)$ and $P(\bar{\nu}_\mu \rightarrow \bar{\nu}_e)$ puts limits on:
  - Oscillation parameters
  - CP-violating phase δ_{CP}
  - Mass hierarchy

Matter-Antimatter Asymmetry

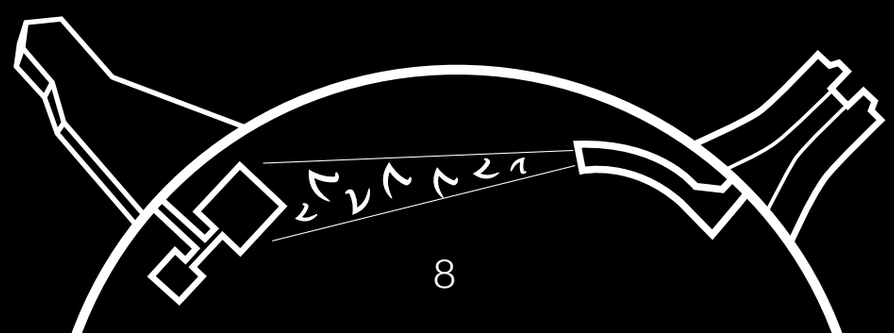
- Measuring energy spectrum of incoming neutrinos determines δ_{CP}
- Important peaks around 3 and 0.7 GeV



Mass Hierarchy

- Neutrinos in beam encounter electrons in the earth
- Causes asymmetry between neutrino and antineutrino oscillations
- Sign of asymmetry depends on sign of Δm^2_{31}

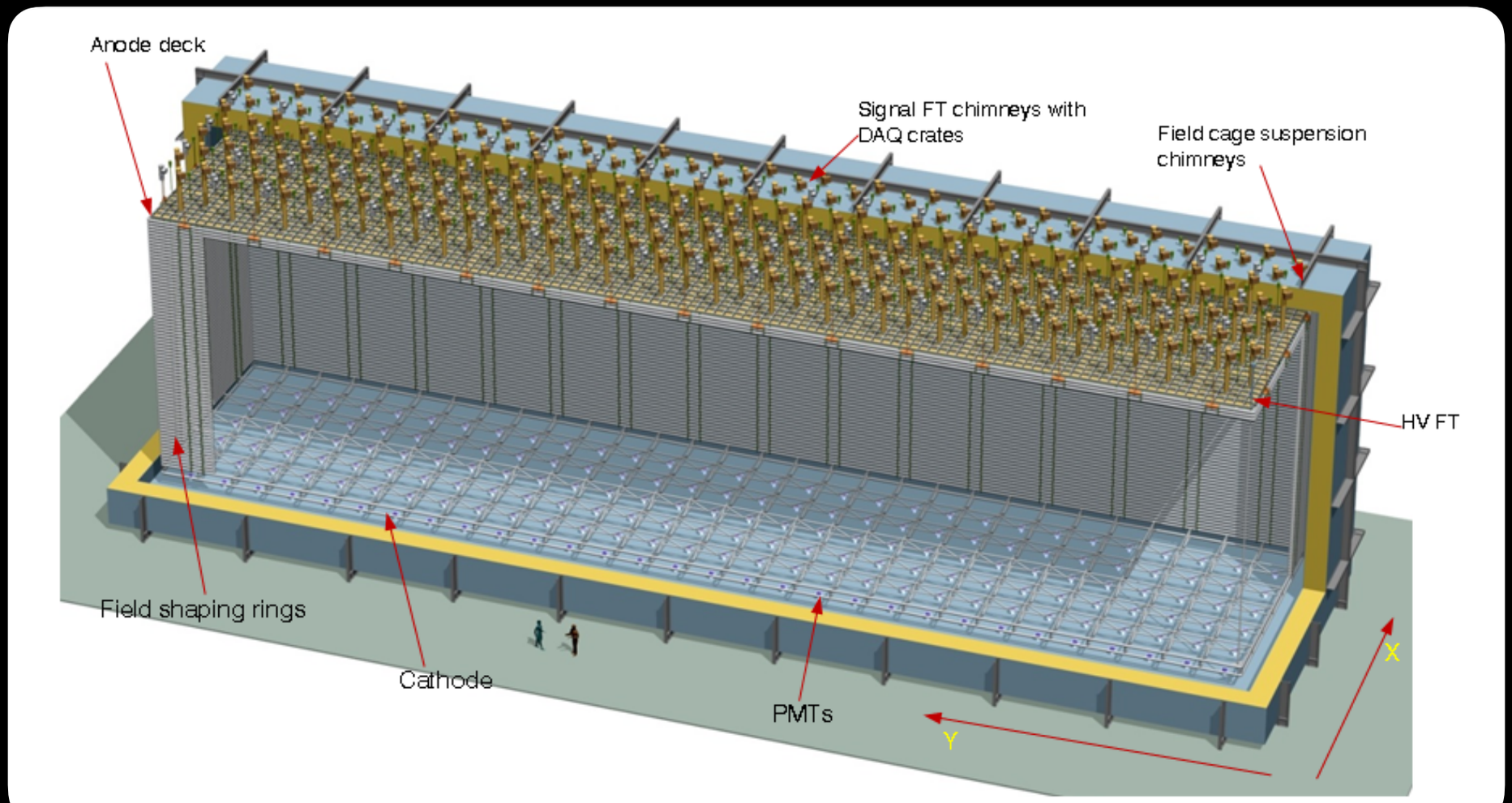
$$\mathcal{A} = \frac{P(\nu_\mu \to \nu_e) - P(\bar{\nu}_\mu \to \bar{\nu}_e)}{P(\nu_\mu \to \nu_e) + P(\bar{\nu}_\mu \to \bar{\nu}_e)}$$

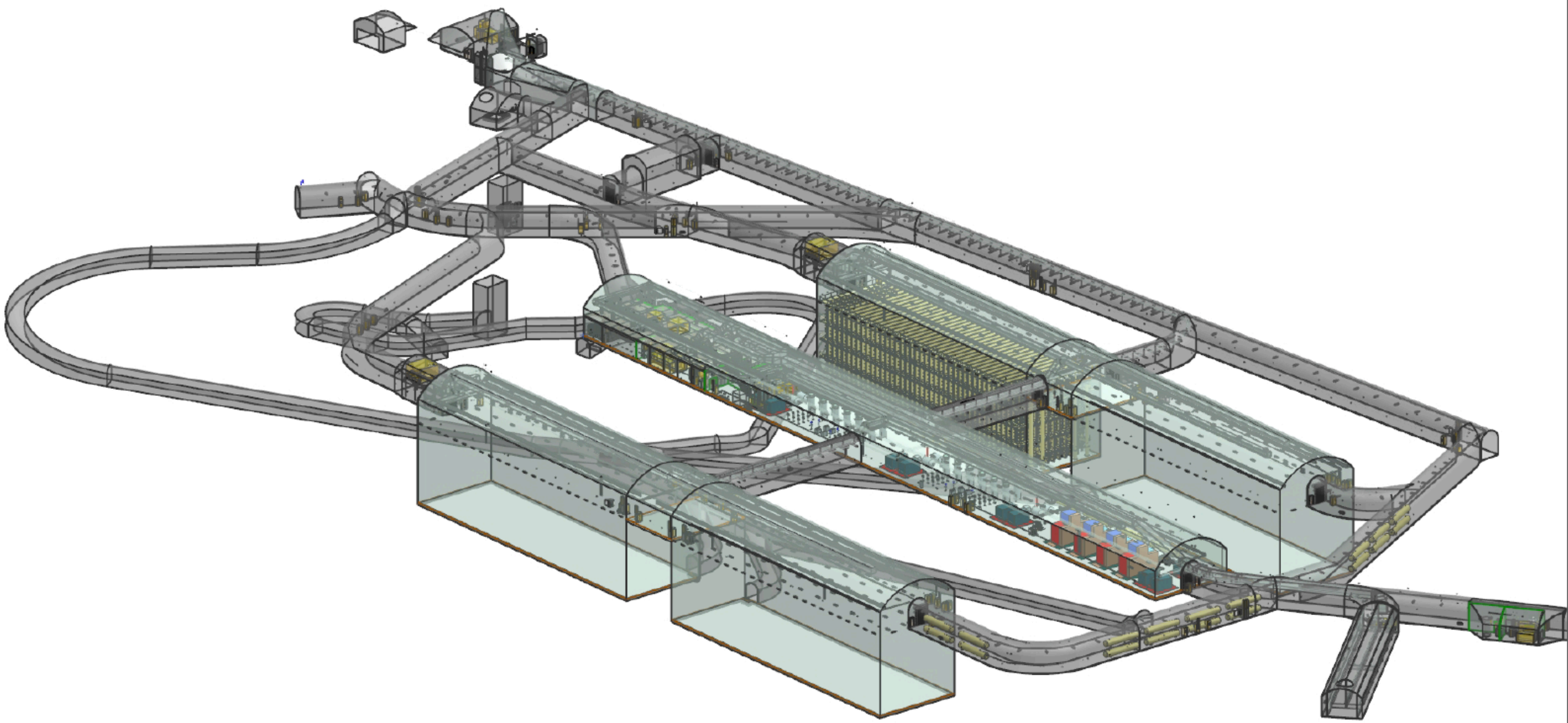


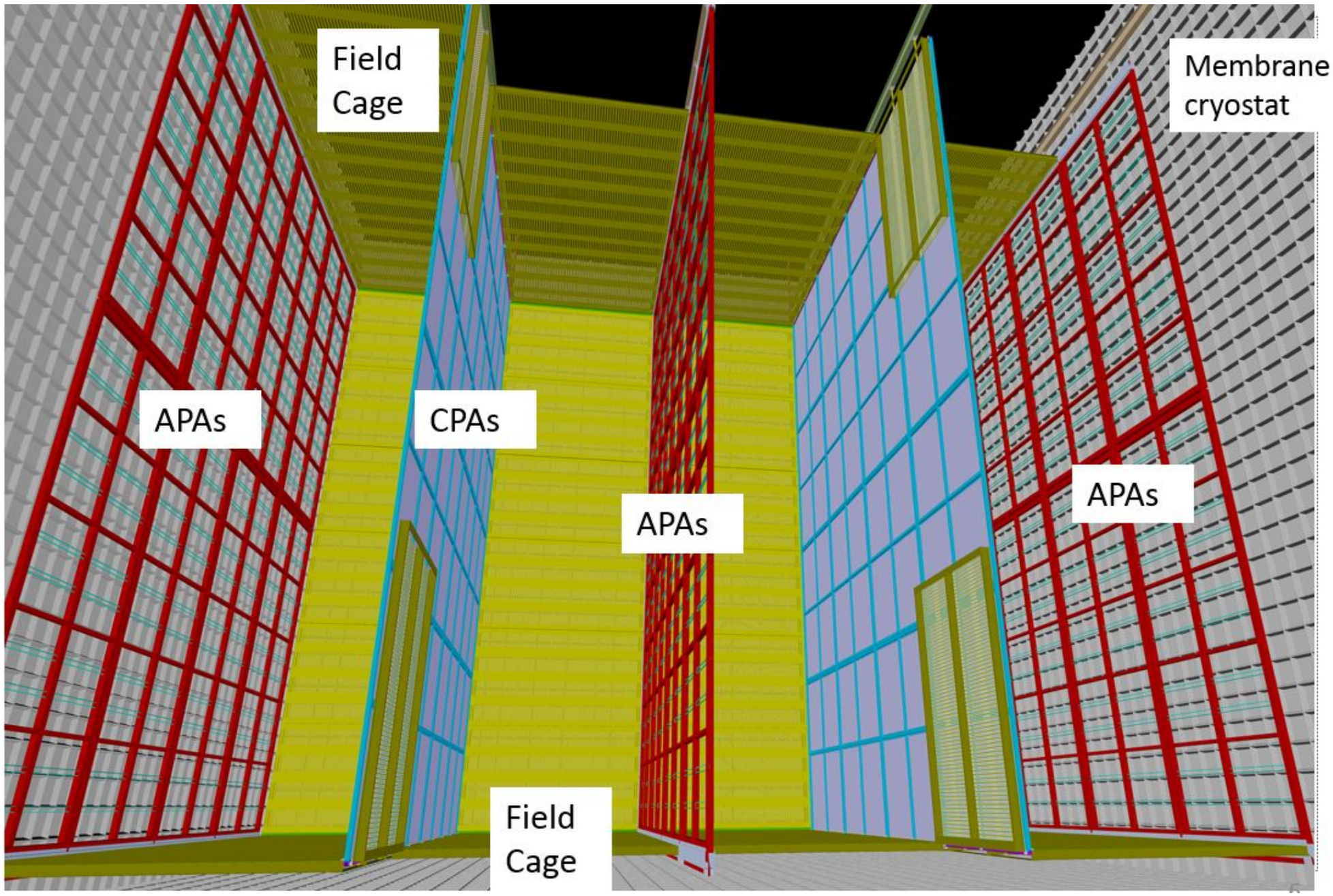
Supernova Neutrinos
Nucleon Decay

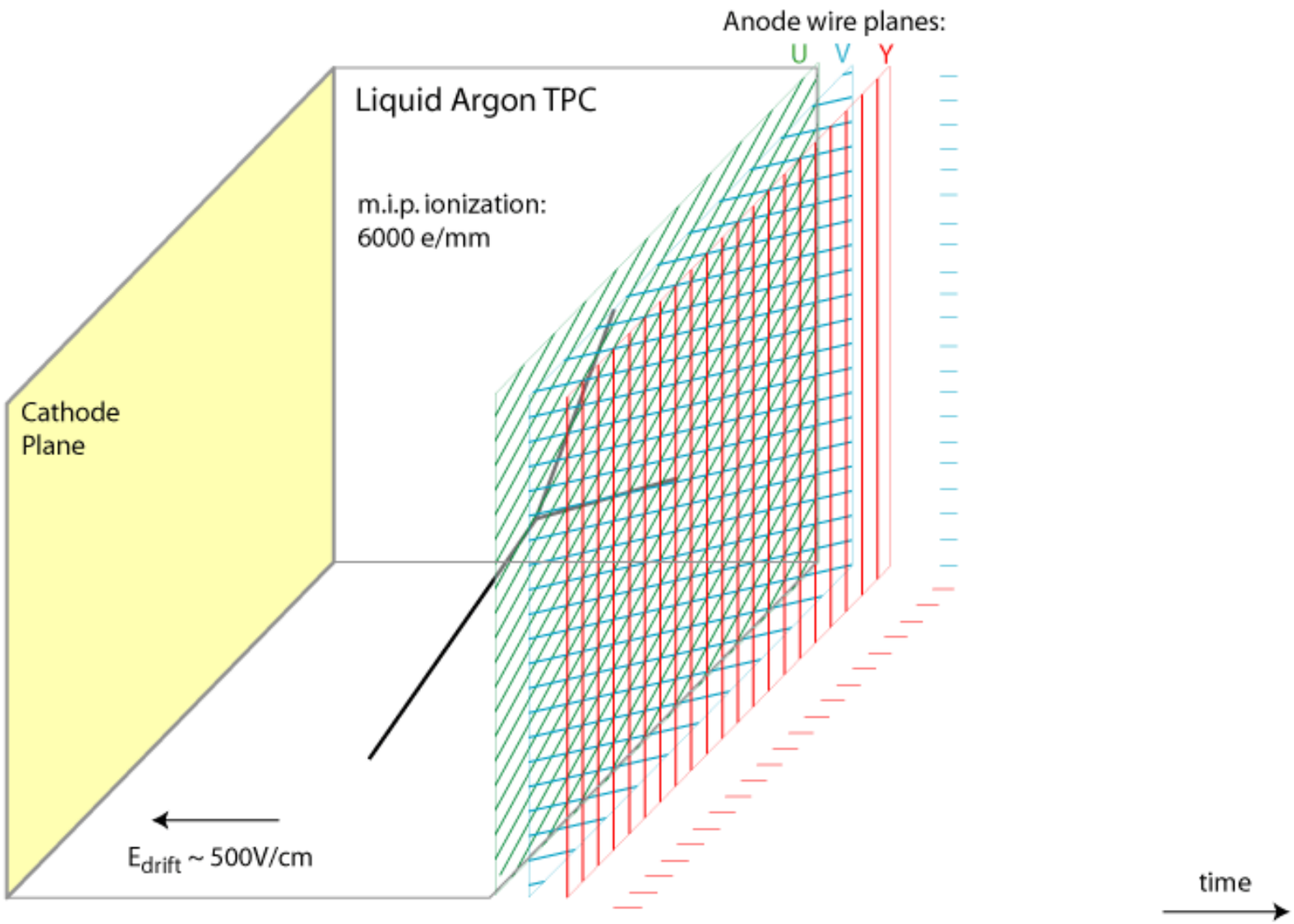
- DUNE is particularly sensitive to ν_e coming from supernovae
  - Relatively low-energy neutrinos of O(10 MeV)
- DUNE's low background environment and high mass makes it suitable for nucleon decay studies

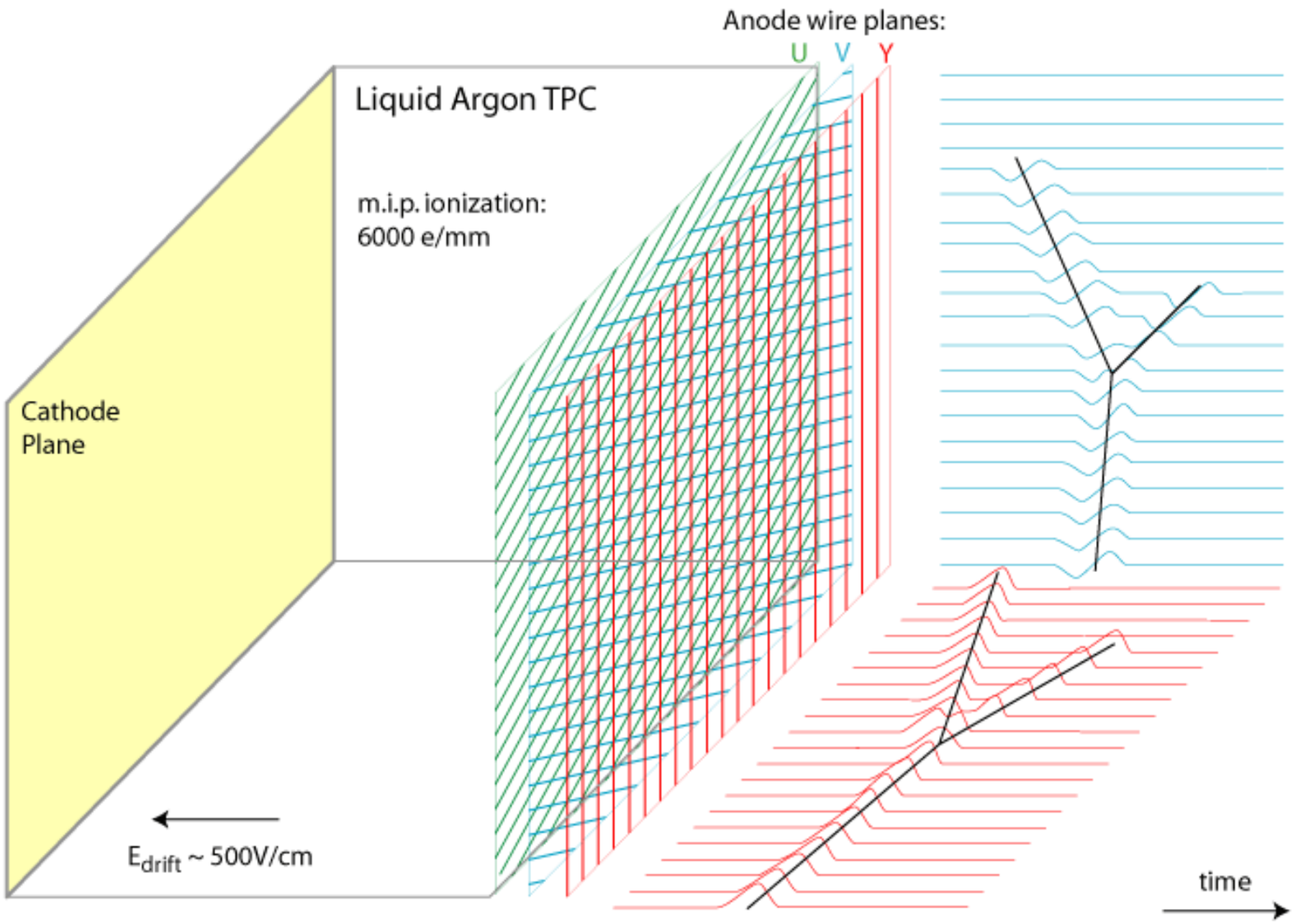
- 10 kt fiducial liquid argon per module (~17 kt total)
- Neutrino counter (both CC and NC)






Field
Cage
Membrane
cryostat
APAs
CPAs
APAs
APAs
Field
Cage


Anode wire planes:
U
V
Y
Liquid Argon TPC
m.i.p. ionization:
6000 e/mm
Cathode
Plane
E_{drift} ~ 500V/cm
time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- Going from ICARUS’ 0.6 kt to DUNE’s 4x17 kt is a big leap

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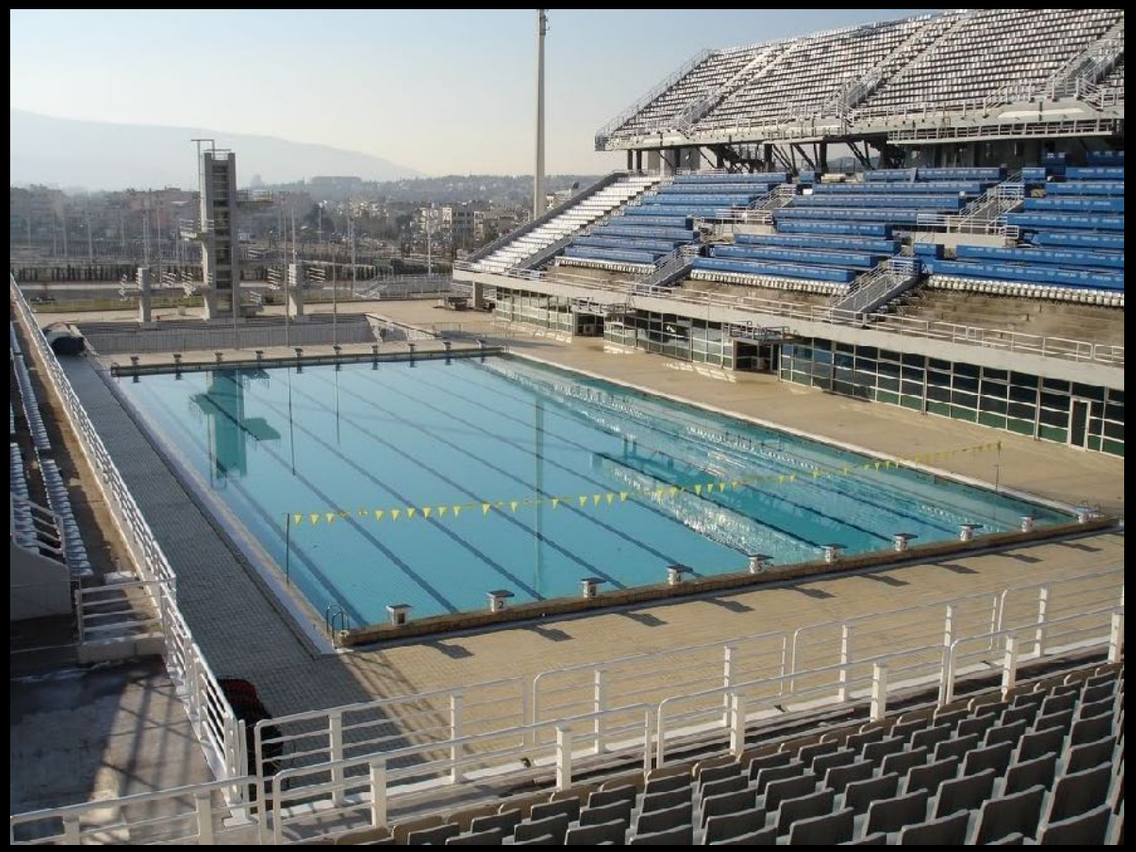
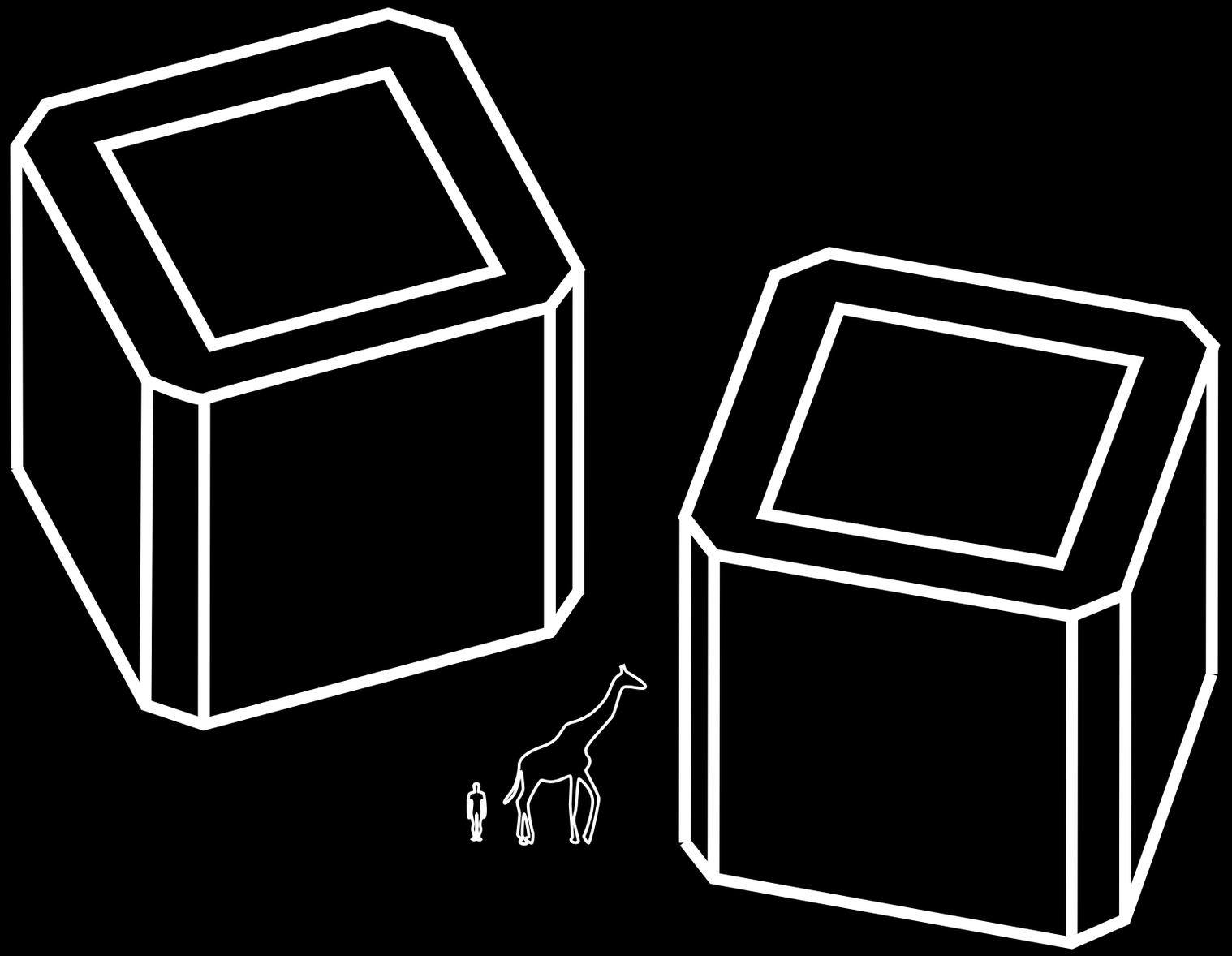


- Prototyping is needed!
  - Validation of technology at full scale
    - Test detector response of various beam particles
      - 1, 3 and 7 GeV protons, pions, electrons and some kaons
    - Develop reconstruction algorithms

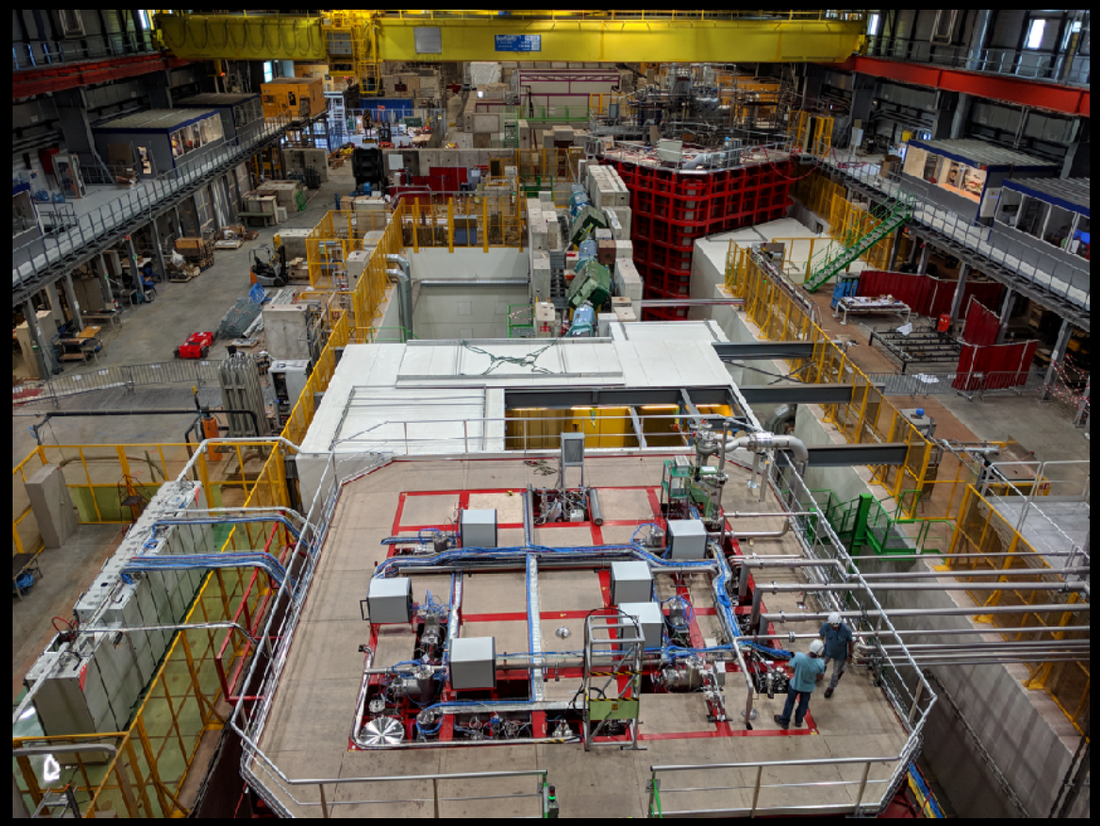


Proto DUNE SP

Proto DUNE SP

- Prototype for DUNE
- Built in two years
- 1% of final detector size
- Uses same components

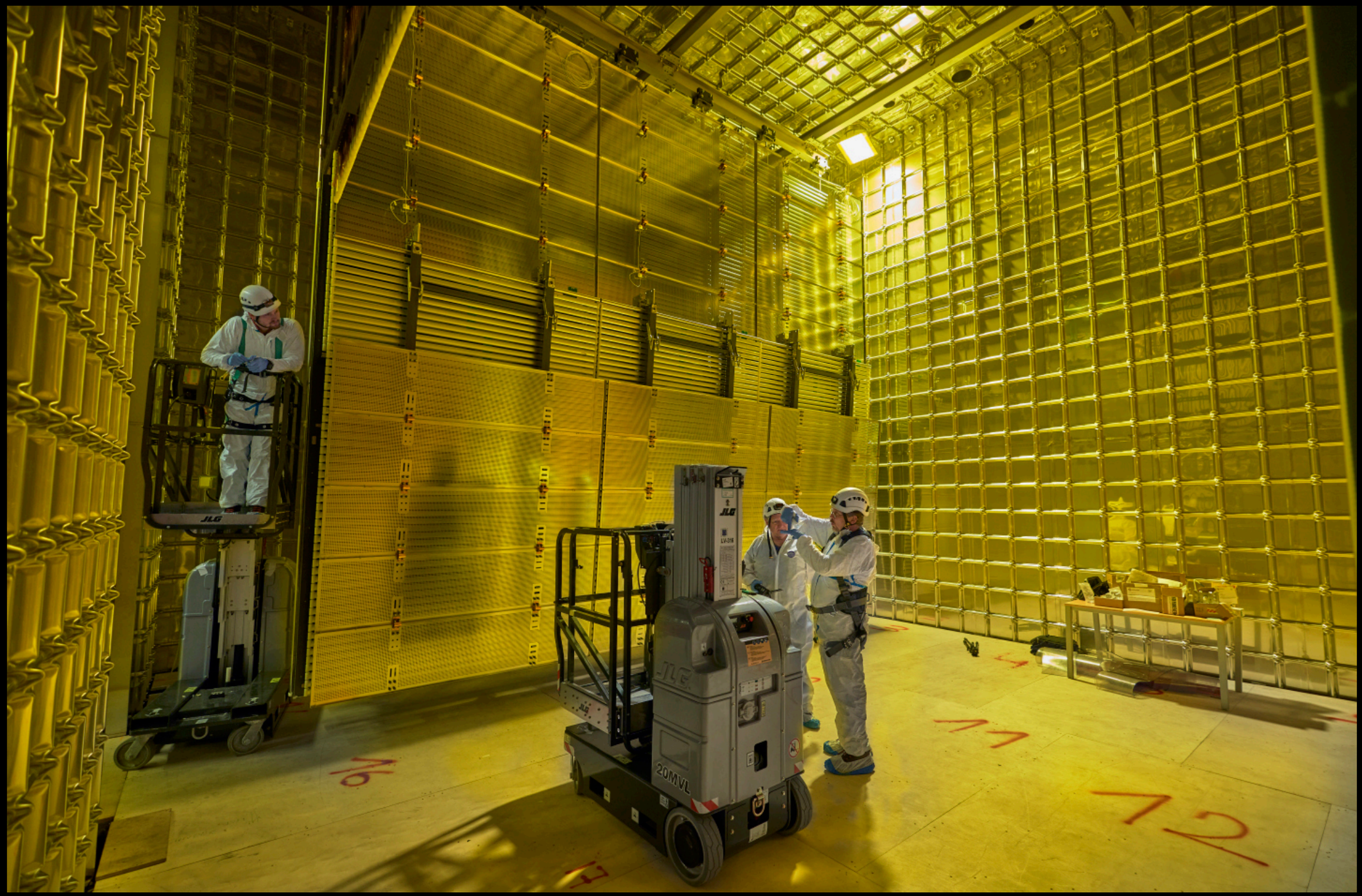
18th of October 2016



2nd of October 2018

Images from R. Acciarri, NuInt18

Proto DUNE SP



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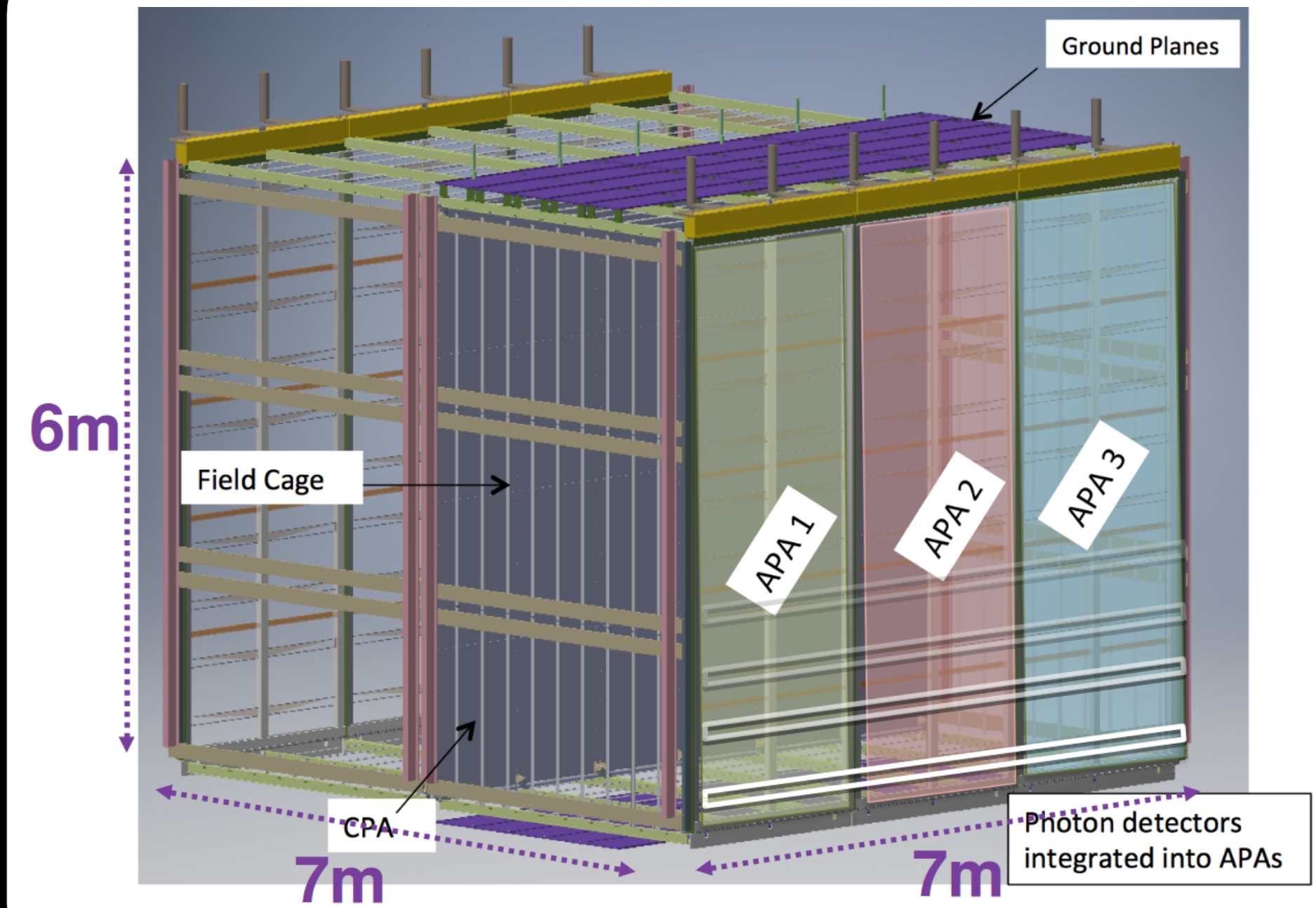
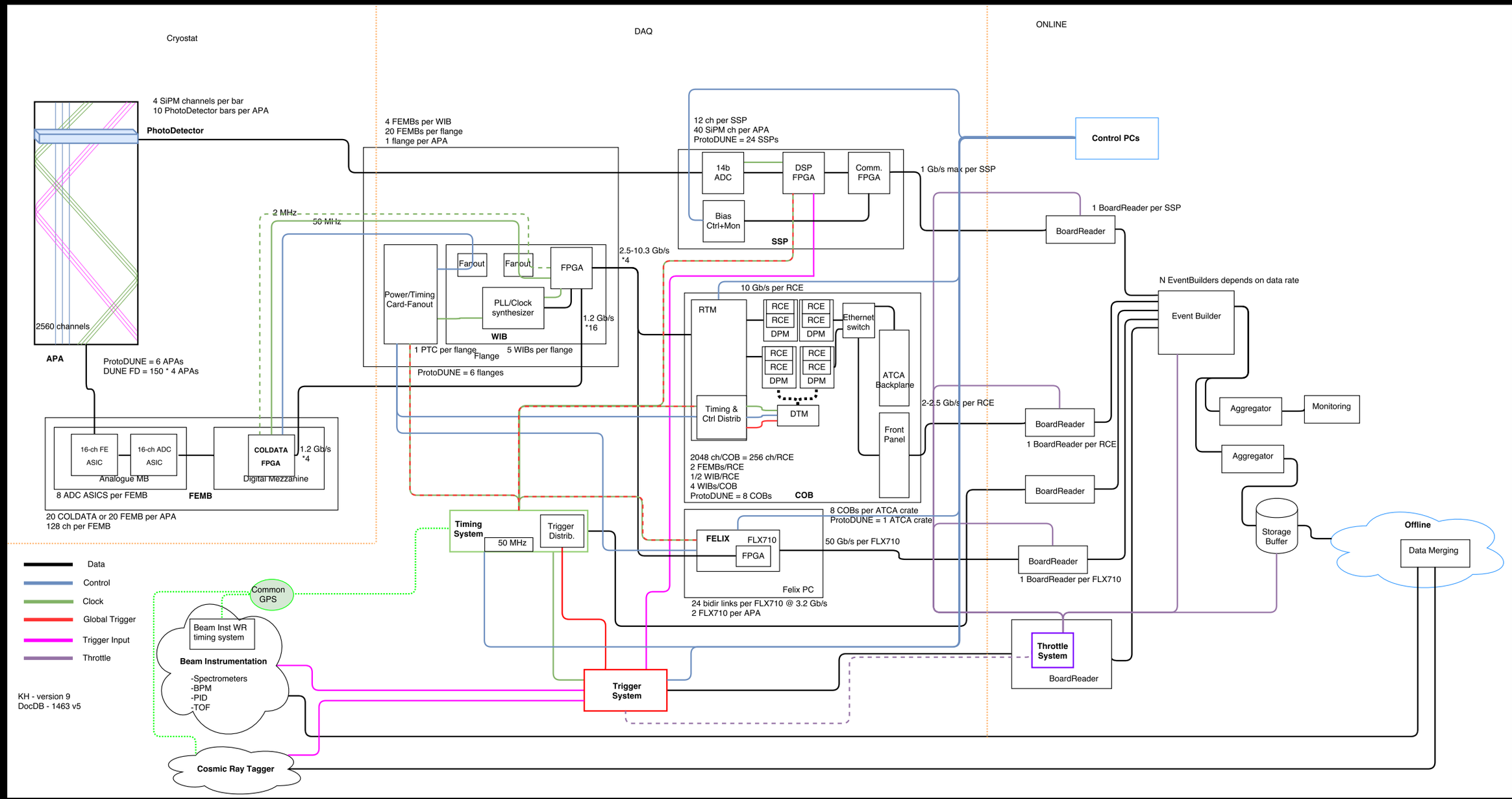
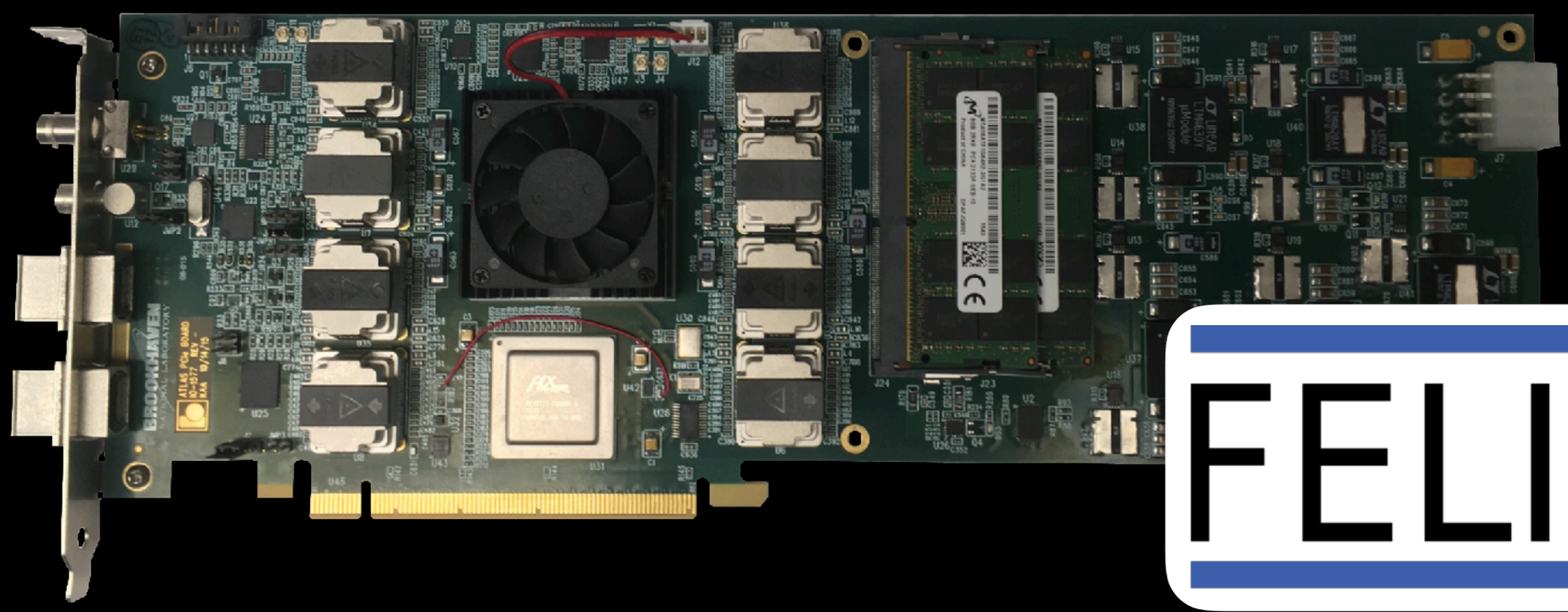


ProtoDUNE SP



Proto DUNE SP

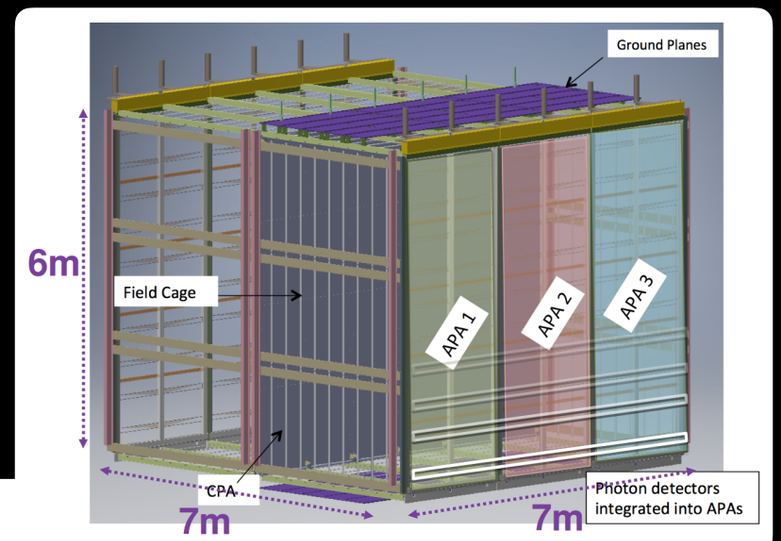
- FELIX is an ATLAS DAQ system
- Front-End LInk eXchange
- ProtoDUNE-SP: 96 Gb/s of data from one entire APA

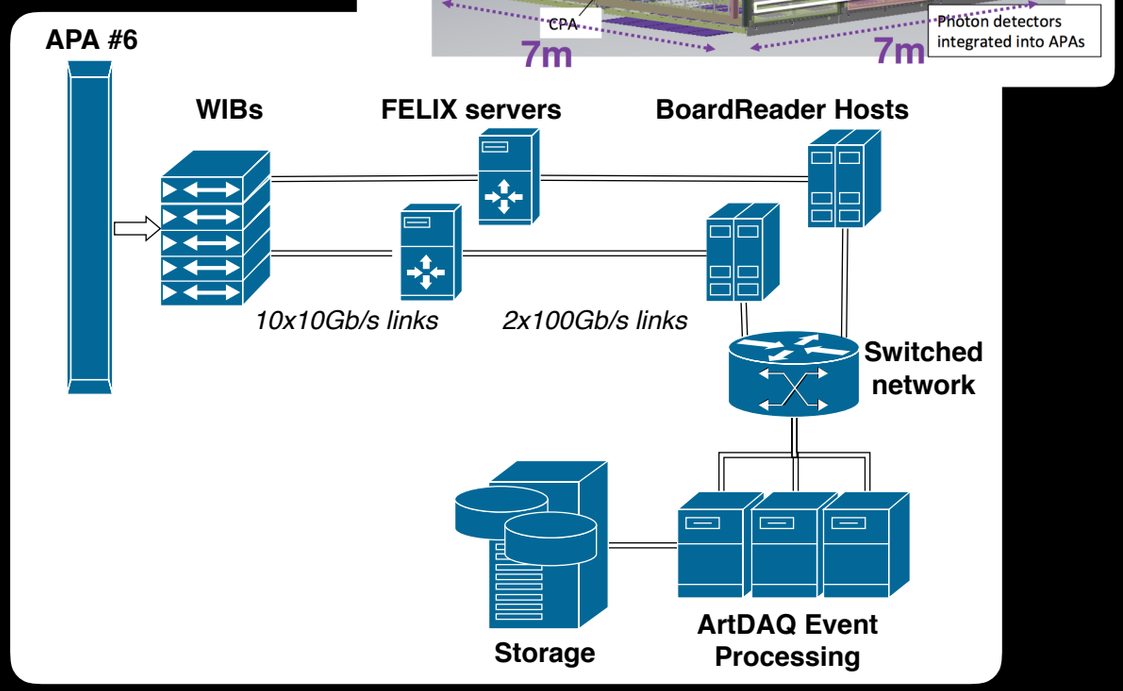


FELIX

Proto DUNE SP

- Principle: use commodity hardware as much as possible
  - Make use of industry advances
- Two cards in use in ProtoDUNE-SP
- Nikhef contributes soft-, firm- and hardware





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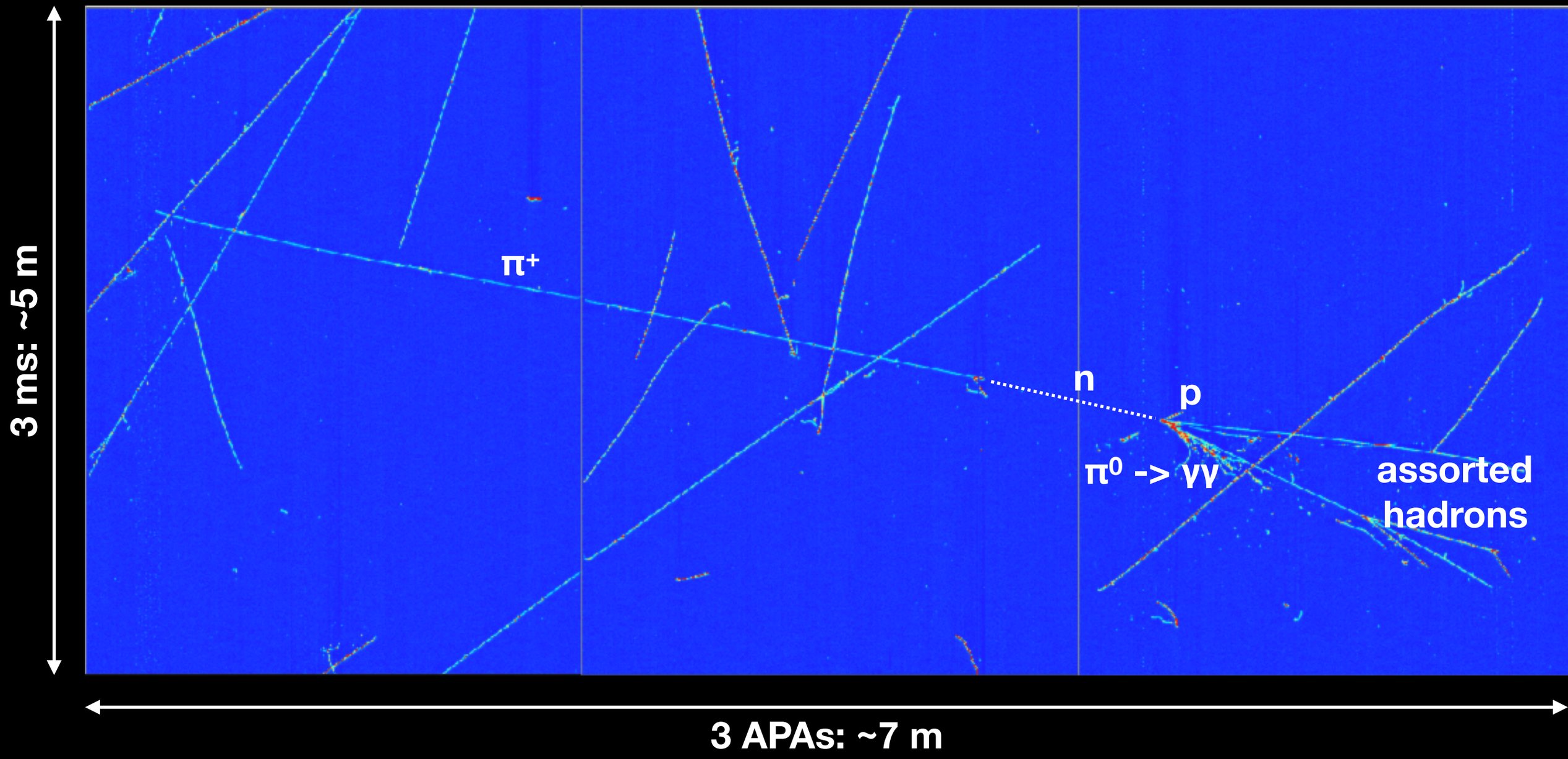


Proto DUNE SP

π^+

n

p

π^0 -> $\gamma\gamma$

assorted hadrons

Proto DUNE SP

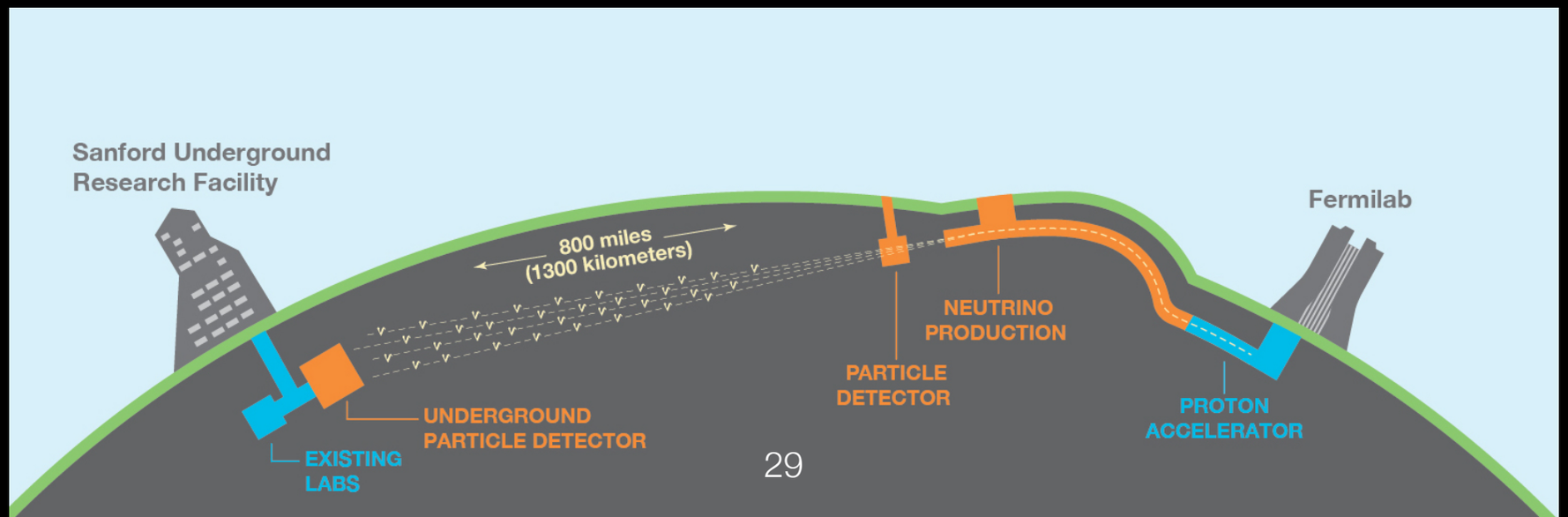
- DUNE: 70 kt LAr TPC neutrino detector
  - To resolve multiple outstanding questions in neutrino physics
- ProtoDUNE: 800 t “small” prototype for DUNE
  - Successfully taking data
  - First tracks look great!
  - Looking forward to understanding the detector and reconstruction performance

ProtoDUNE SP

Backup

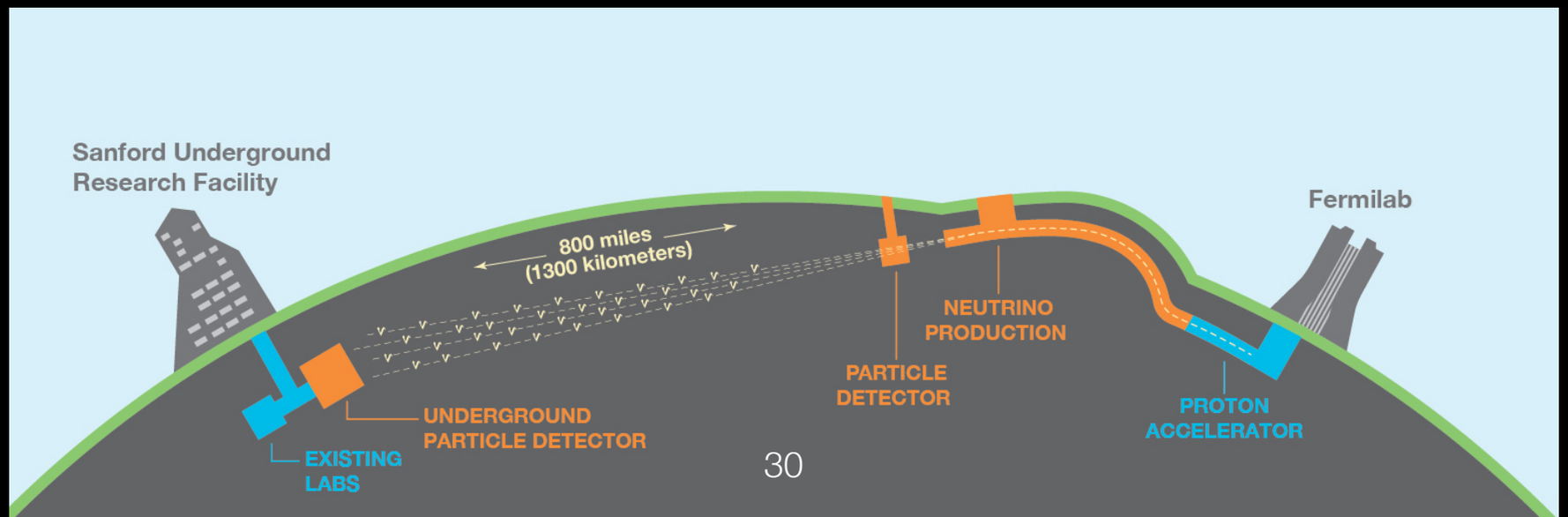
DUNE Timeline

- 2017: Far detector construction begins
- 2018: ProtoDUNEs at CERN
- 2021: Far detector installation begins
- 2024: First physics data
- 2026: Neutrino beam available



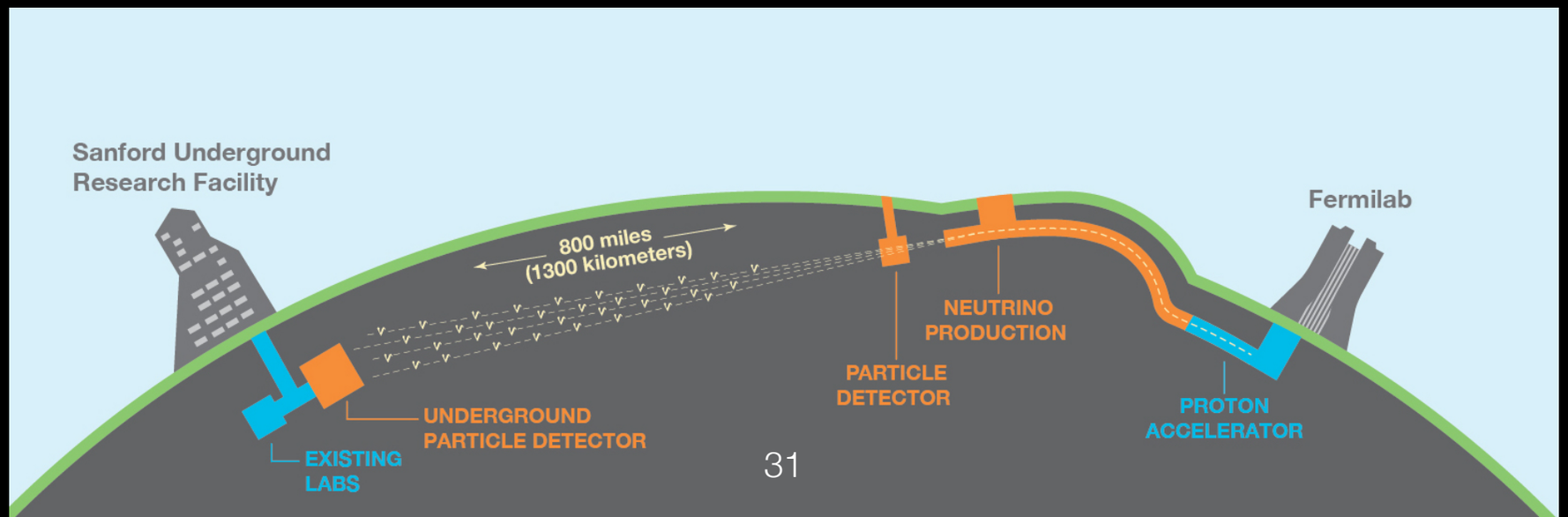
DUNE Cost

- Total: ~ $2 billion
- DUNE far detector: ~ $480 million
- US DoE: ~ $1.5 billion envisioned
- UK: ~ $88 million pledged



DUNE Measurement Projections

- Mass hierarchy determined at 5σ in 2—5 years
- δ_{CP} determined to within 7°—13° in 10 years
- Could catch Milky Way supernova neutrinos: 10,000 events over 10 seconds
- Put limits on proton decay ($\tau > 10^{33}$ years)



DUNE MSW effect