Simulation Updates for ProtoDUNE-I & ProtoDUNE-II

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Completed Work

- ProtoDUNE single-phase detectors have been modeled with computational fluid dynamics (CFD) simulations to predict flow characteristics, offer design insights, and validate the methods for simulating future studies.

- A series of parametric studies were conducted on the ProtoDUNE's liquid region by varying geometric features and heat sources.

- The results of the ProtoDUNE-I SP liquid region have been compared with temperature sensor data from the physical system.

Baseline Simulation Conditions

Initial Parameters	Value	Units
Inlet Temperature #1	88.519	[K]
Inlet Temperature #2	88.534	[K]
Inlet Temperature #3	88.503	[K]
Inlet Temperature #4	88.520	[K]
Electronic Heat Load	336	[W]
Liquid Argon Height	7.4	[m]
Room Temperature	26.1	[°C]
(in K)	299.25	[K]
LAr Mass Flow Rate	1.66801	[kg/s]
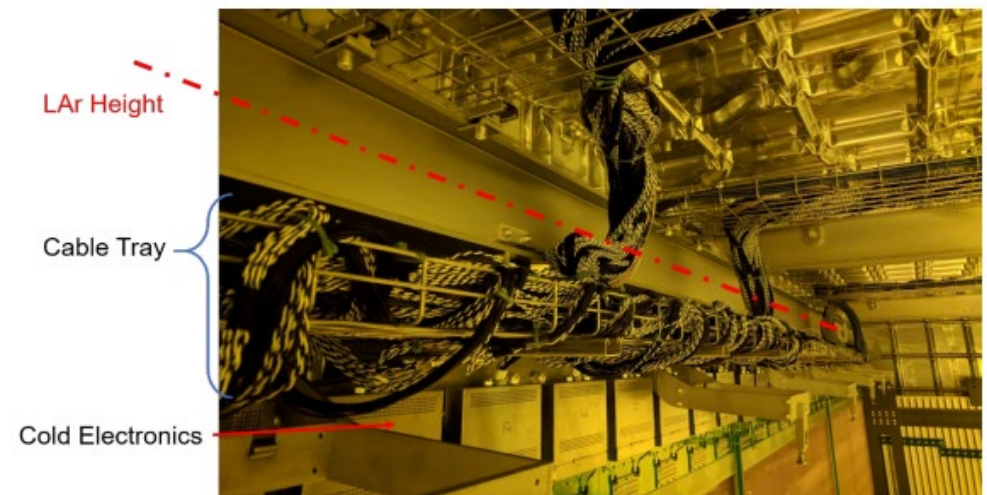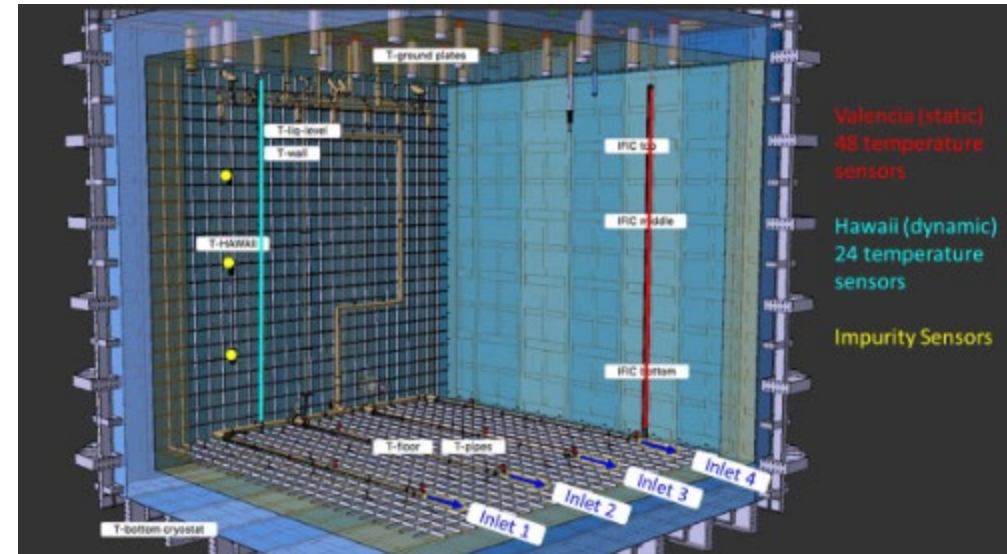
Parametric Study

Parameter	Variation(s)			Units
Inlet Temperature	±0.1	±0.2	±0.3	[K]
Electronic Heat	±10	±20	±30	[%]
LAr Height	±0.05		±0.1	[m]
Room Temperature	±5		±10	[°C]
LAr Mass Flow Rate	±5	±10	±15	[%]
Electronic Heat Load	1080			[W]

For Hawaii probe, we are looking at bottom 19 sensors

For Valencia probe, we are looking at bottom 46 sensors
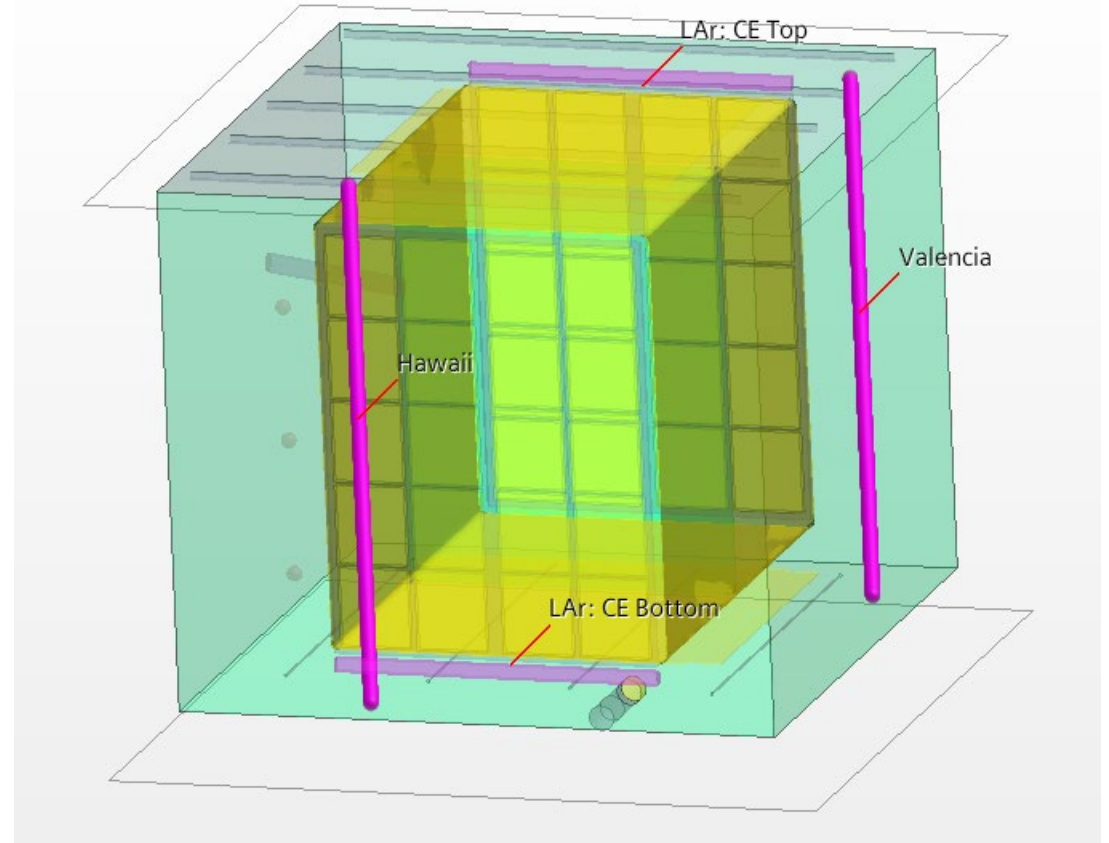
ProtoDUNE-II Complete 3D Model

Beam Plug

Lower APA (South)

CPA

Cold Electronics

Source: https://edms.cern.ch/project/CERN-0000209067
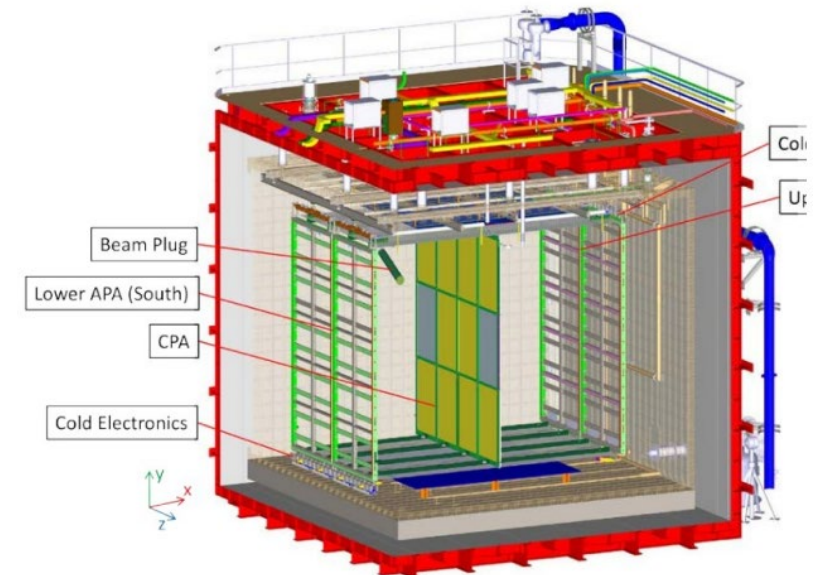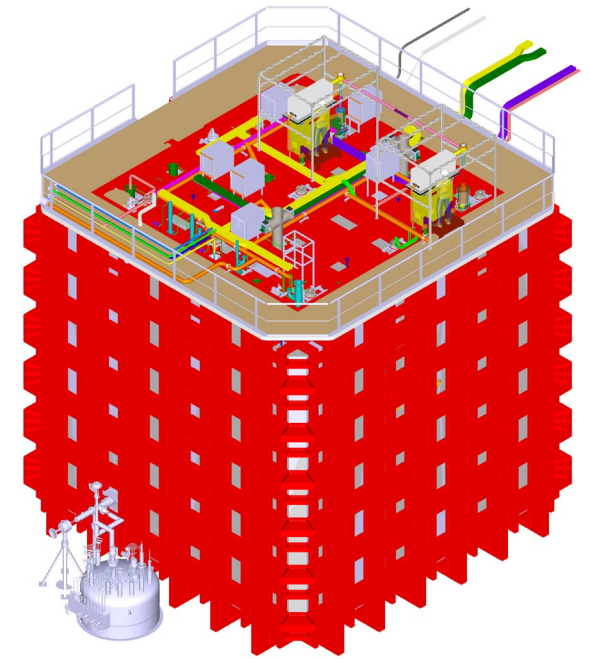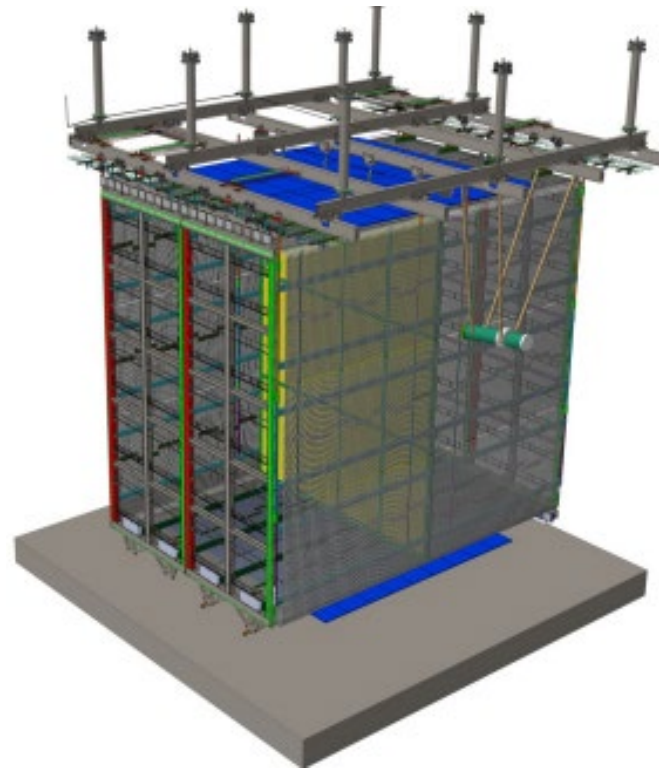
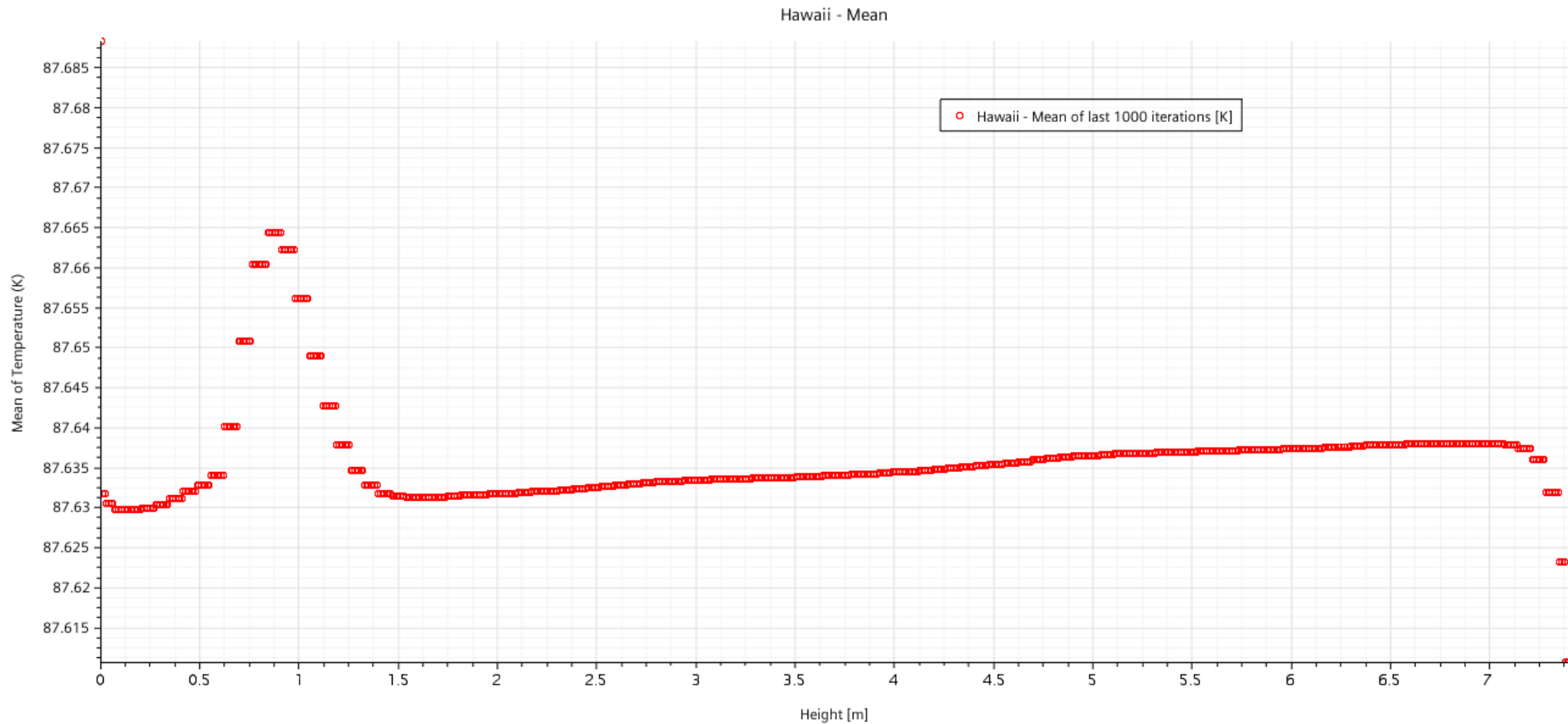# Position of Valencia & Hawaii probes
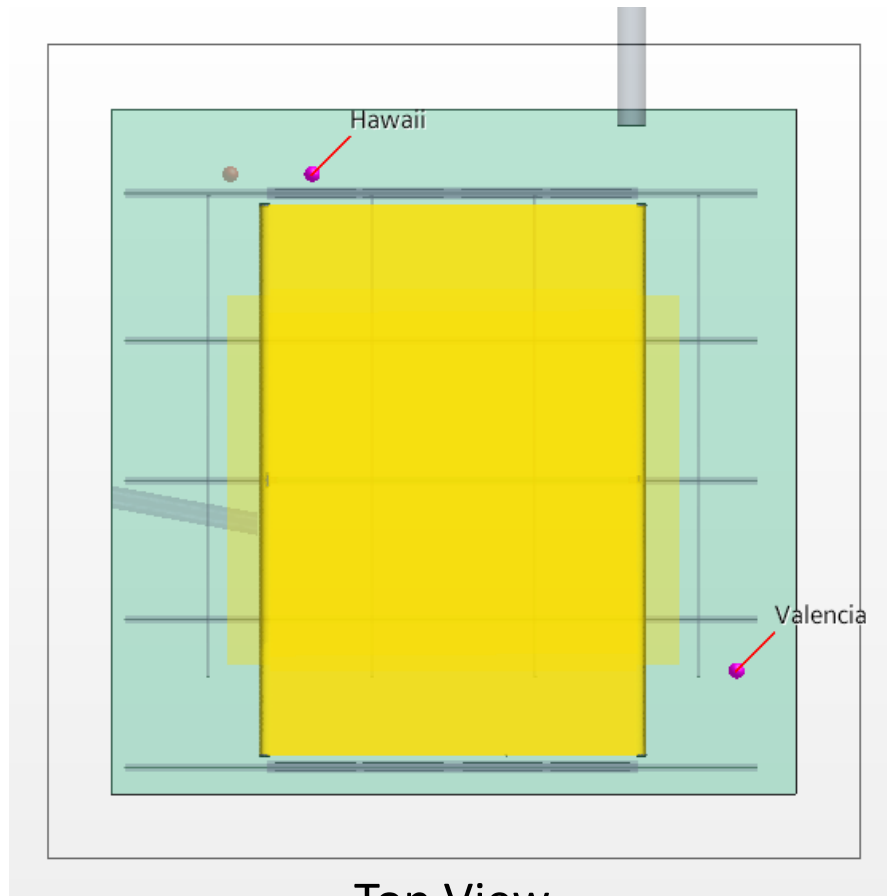
Top View
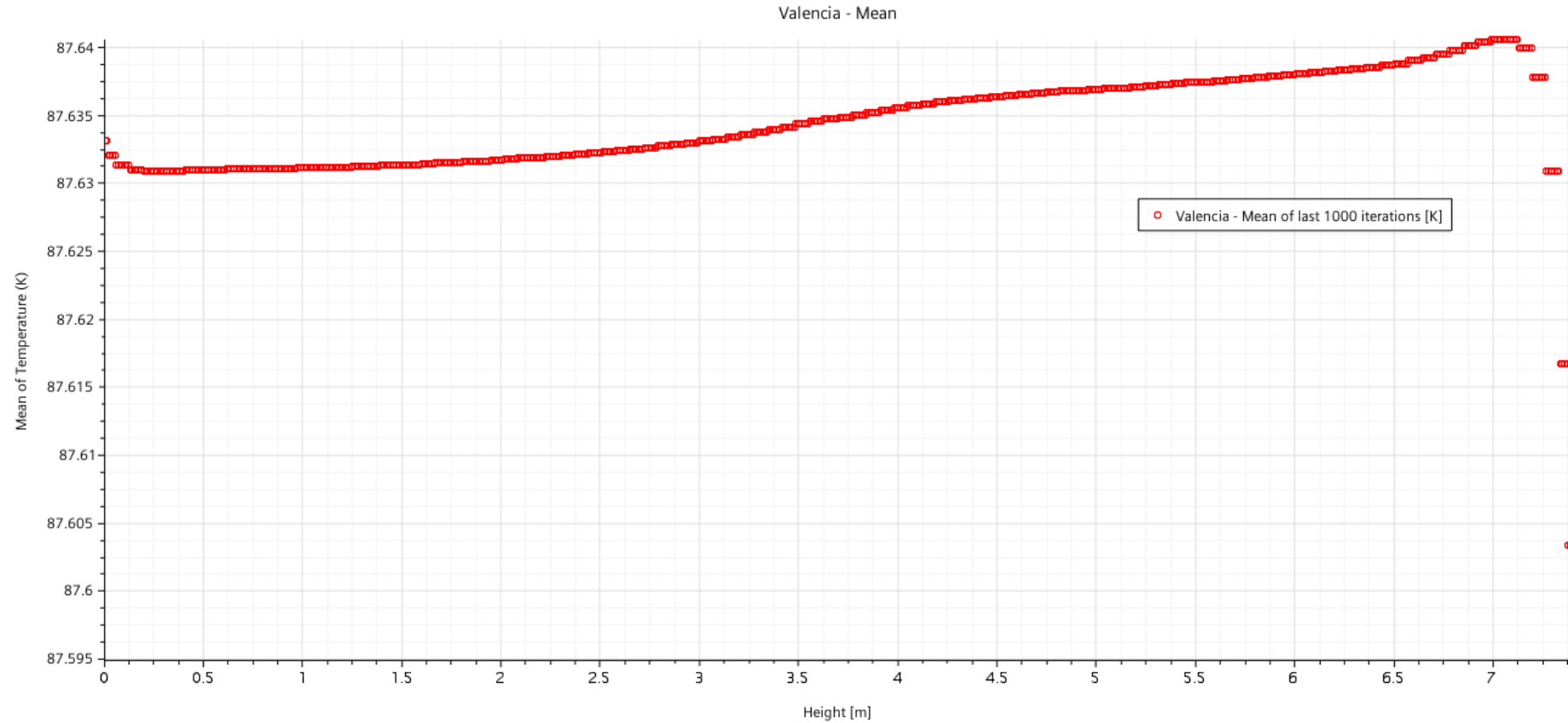
Isometric view

Preliminary Results for Hawaii Profile

Since CE are at bottom on the APA which is close to **Hawaii probe** a bump in temperature around 0.8 [m] is observed.

Preliminary Results for Valencia Profile

On the other APA which is close to **Valencia probe**, CE are at top, so we observe a linear increase in temperature with height with maximum temperature around 7.1 [m].

Updates to ProtoDUNE- II since last results:

- New geometries added (Cable trays, Valencia probe)

- Pressure coefficient study for porous regions (APA, FC & GP) with new thickness completed and implemented in the simulation model.

- Mesh refinement for porous planes and insulation.

- Cold electronics heat source value of 360W for each CE (total: 720W)

LAr: Cables

LAr: Rods & Fiberglass
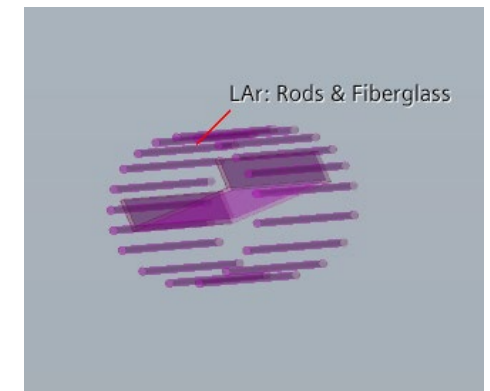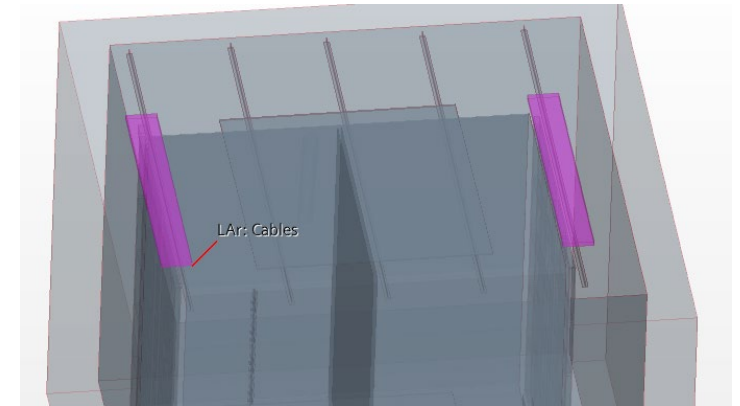
*Simulations under process

Far Detector Model simplification:
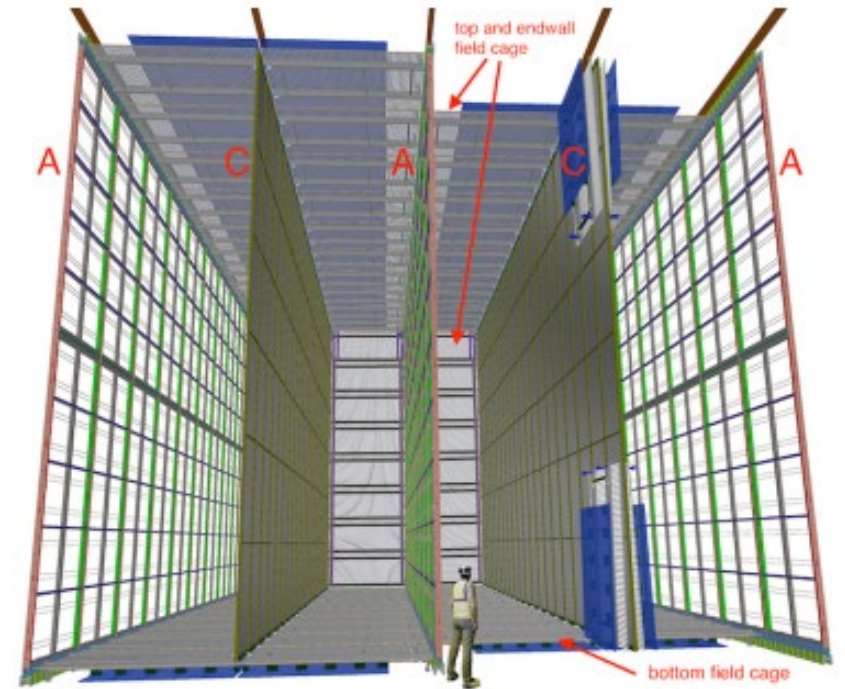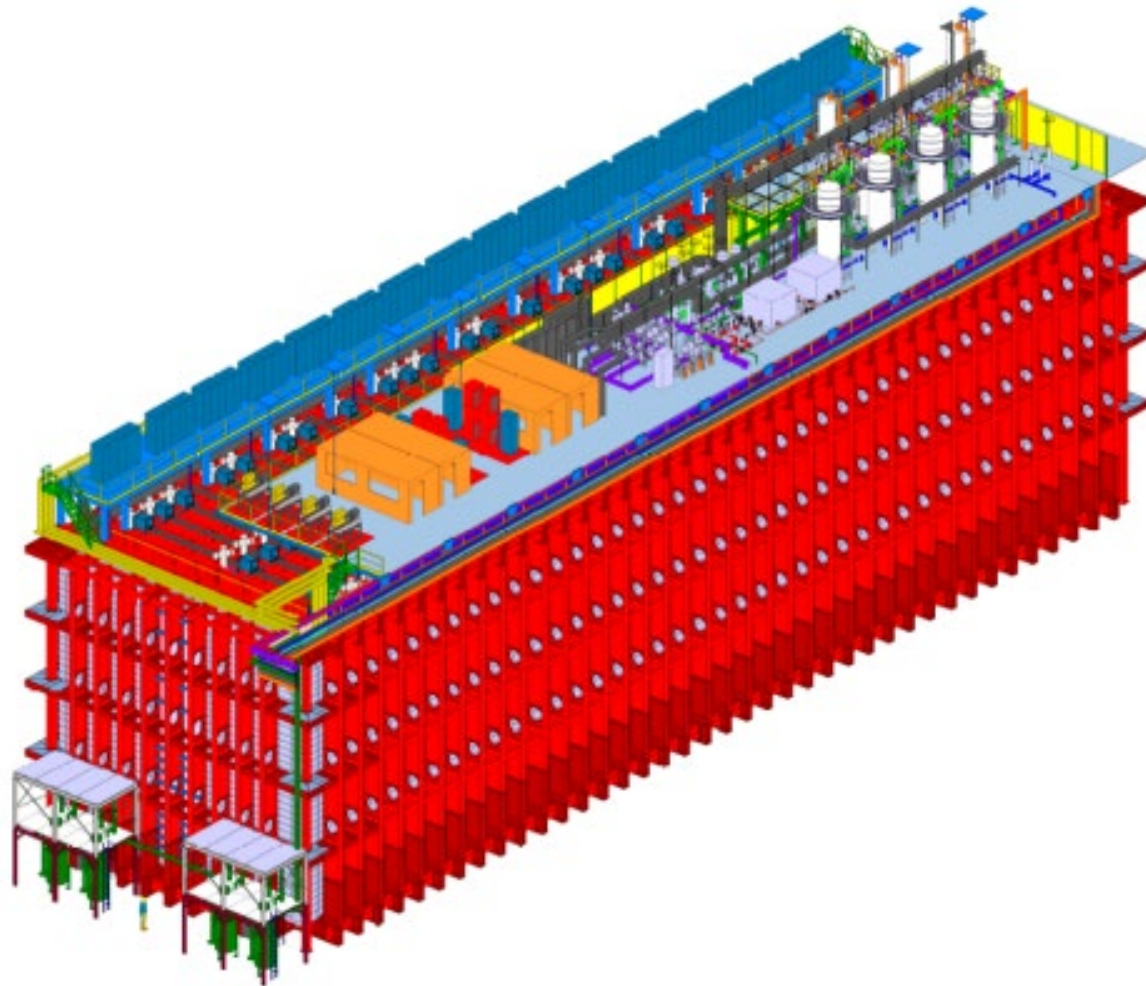
Far Detector (FD-HD) Model simplification.

- Referring to CAD files and Technical Design reports for dimensional analysis

- Referring to Previous study done on LBNF at SDSU (2017-18) for model simplification methodology and boundary conditions.

Objective for FD-HD study

- To use temperature measurements to constraint CFD and predict purity, and thus electron lifetime, everywhere in the cryostat

- Simulate TMS sensor distribution and mock data for a given TMS resolution

- Compare several CFD simulations with mock data and produce X^2 plots for different TMS resolutions
  - Vary several CFD parameters affecting temperature (as in ProtoDUNE-SP)
  - Find error on impurity prediction by looking at CFD impurity predictions associated to the constrained temperature maps

Far Detector (FD) cont.

Technical Design Report 1

Referenced dimensions:
Anode Plane Assembly
(APA)
Cathode Plane Assembly
(CPA)

Table 3.1. Key parameters for a 10 kt FD SP module.

Item	Quantity
TPC size	12.0 m × 14.0 m × 58.2 m
Nominal fiducial mass	10 kt
APA size	6 m × 2.3 m
CPA size	1.2 m × 4 m
Number of APAs	150
Number of CPAs	300
Number of X-ARAPUCA PD bars	1500
X-ARAPUCA PD bar size	209 cm × 12 cm × 2 cm
Design voltage	−180 kV
Design drift field	500 V/cm
Drift length	3.5 m
Drift speed	1.6 mm/μs

Far Detector (FD) cont.

Technical Design Report 4

Referenced dimensions:
Field Cage (FC)
Ground Plane (GP)

Table 3.3. HV field cage components.

Component	Count	Length (z)	Width (x)	Height (y)	Submodules	Grand Total
Top FC modules	100 (4 × 25)	2.3 m	3.5 m	-	-	100
Bottom FC modules	100 (4 × 25)	2.3 m	3.5 m	-	-	100
Profiles per module (all top and bottom module types)	57	2.3 m	-	-	-	11400
GP modules per top or bottom FC module	5	2.3 m	0.7 m	-	-	1000
Endwall FC plane	2	-	14.4 m	12 m	4	2
Endwall FC modules per endwall FC	32	-	3.5 m	1.5 m	-	64
Profiles per endwall FC module	57	-	-	1.5 m	-	3648