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DUNE-PRISM
Study of Technical Approach/Feasibility & Cost for a Mobile LAr Detector (Conceptual)

LAr Detector Engineering Group
Technical Support Department, Neutrino Division

DUNE-PRISM Technical Discussion, July 30, 2018

Recommendations from DUNE Near Detector Concept Study Group [DUNE-doc-8184-v2]

- (R1) The LArTPC at the near site should be optically segmented, with a short drift space and 2-dimensional pixelated readout, similar to the concept being studied by the ArgonCube collaboration.

- (R2) The design of ***a mobile LAr detector*** (moving in a direction transverse to the beam) that can make measurements at one or more off-axis positions should go forward (DUNE-PRISM).
  - A proper arrangement of cryogenic system (optimized for motion together with detector; see Slide 9) is required. We assumed a platform in size of 2 m x 6.4 m in 2 levels, shared with detector electronics, etc., is available to house the cryogenic equipment.

- (R3) Additional study of the DUNE-PRISM for technical feasibility and cost should be made.

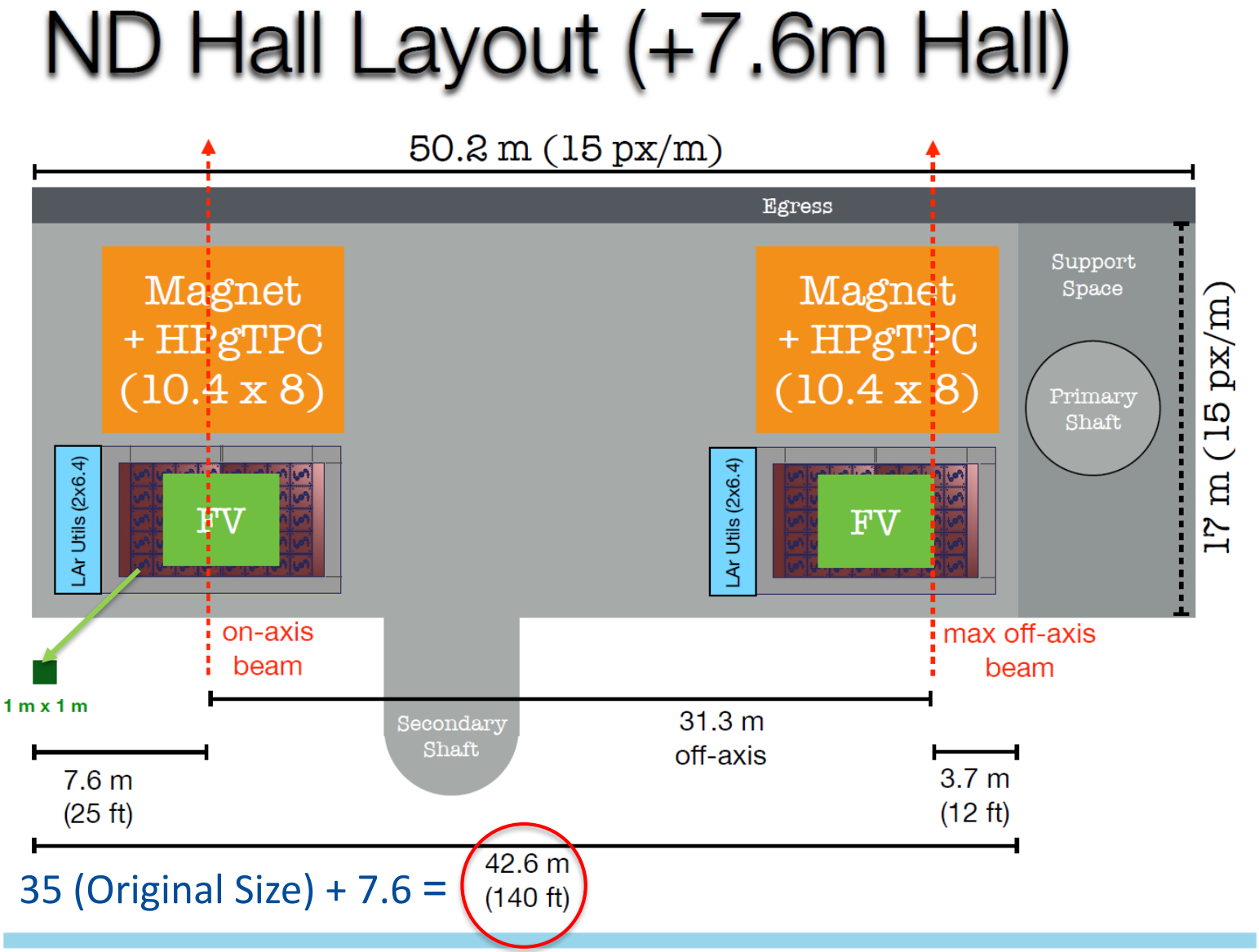
Technical Feasibility: Three Options Considered

- In option 1 (ideal),
  - The LAr detector can take data while moving for about 31.3 m distance back and forth (between on-axis and off-axis extreme).
  - Continuous motion at a slow rate (about 0.5-5 cm/min).

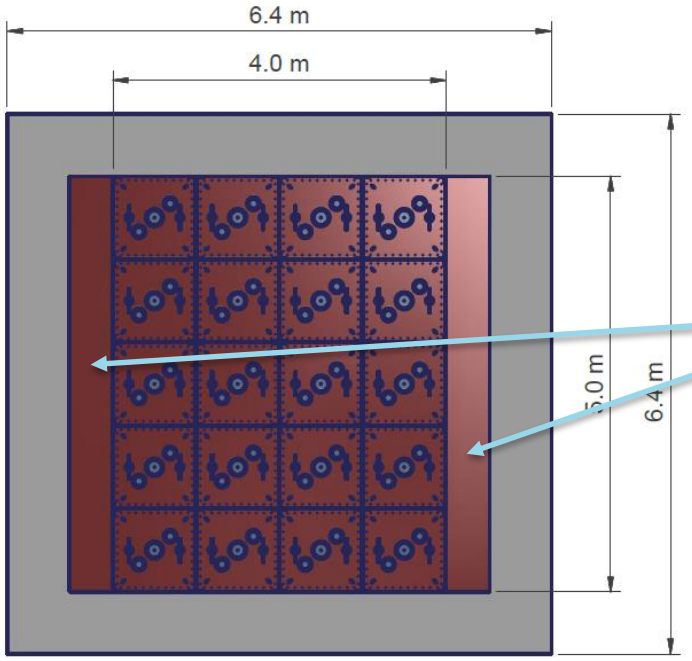
- In option 2 (baseline),
  - The LAr detector can be moved to several (about 10) pre-designated positions and readied for data taking in a few hours. It will take a day for transition to the next data taking including detector travel time.

- In option 3 (the least favored option due to cost?),
  - Design a larger (x3 wider) LAr detector
  - Install more (x3) ArgonCube modules

Near Detector Hall Layout

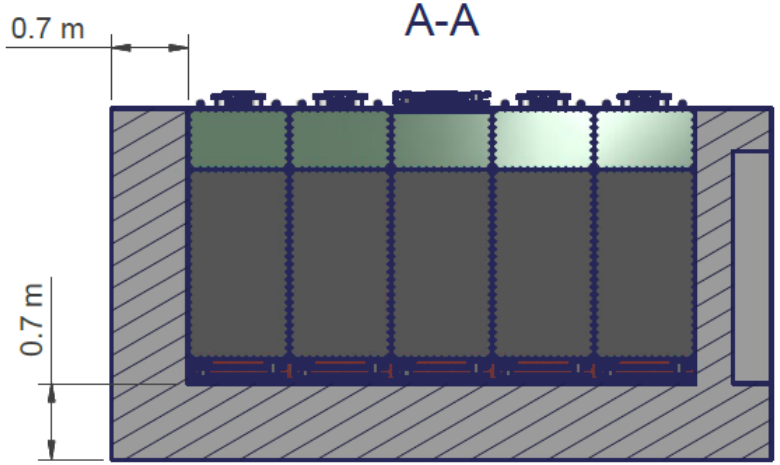


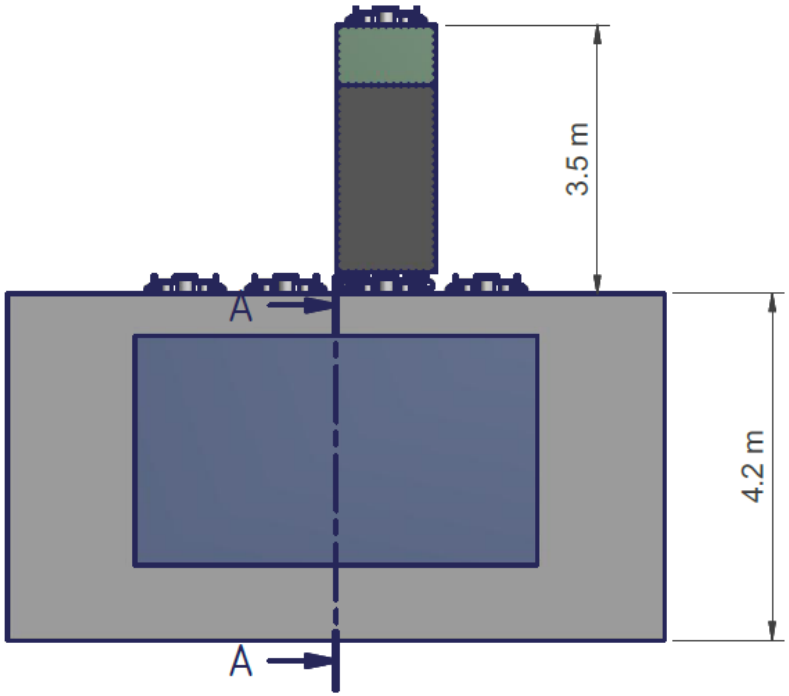
Rough Cryostat Dimensions (with ArgonCube Concept)



5 x 8 ArgonCube Module Layout (Slide 4):
10.4 m (W) x 6.4 m (L) x 4.2 m (H)

Space to house equipment associated with the cryo-coolers, pumps, and instrumentation. It may be useful to the physics reduce the size of volume, if possible.

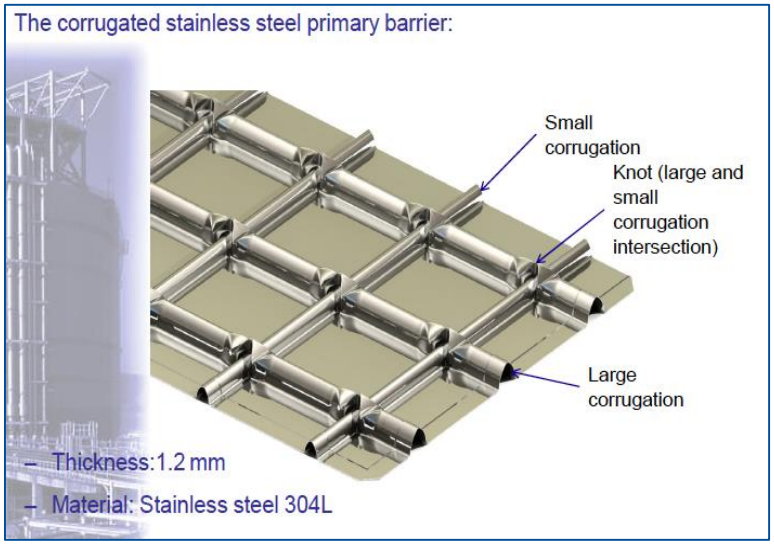




Membrane Cryostat

- What other options do we have for cryostat other than "Membrane Cryostat"? We believe its very unlikely
- We assume:
  - Requirement on maximum radiation length along beam direction (designing the cryostat downstream wall like basement window).
- Dimensions of cryostat may require small adjustment compared to the drawing on Slide 5.
  - The membrane corrugations have different knuckle heights depending on vendors:

    GTT (France): 69 mm; IHI (Japan): 138 mm
  - Reminder (for future design changes): The membrane corrugations can be considered as sharp edges (have potential of being a cause of high voltage breakdown or distortion in electron drift field).
  - The cryostat may need space for internal cryogenics: facility for service (cryostat piping for piston purge, etc.)



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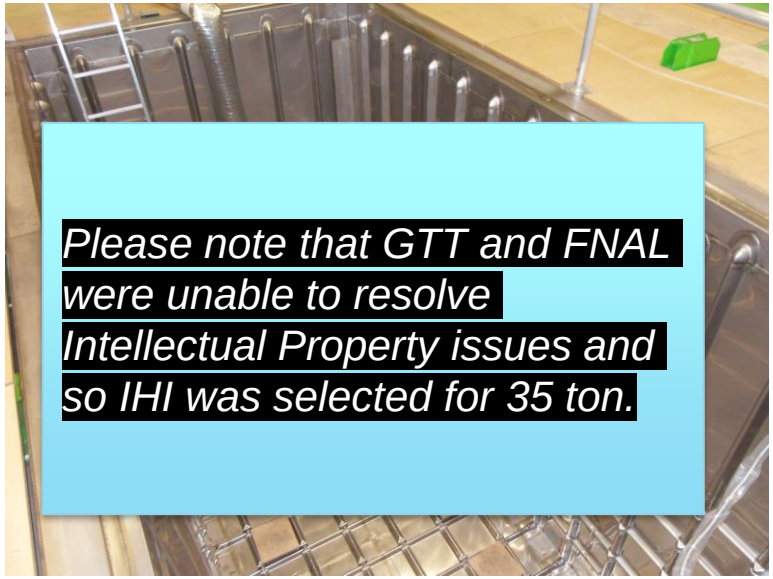
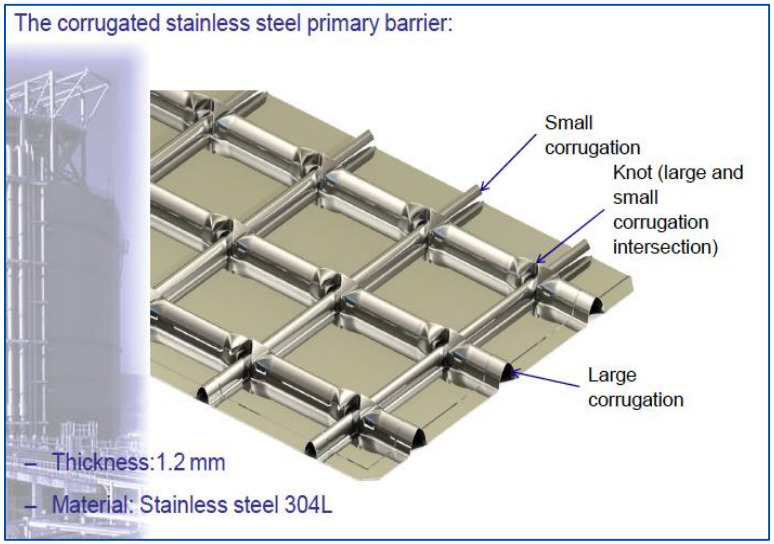
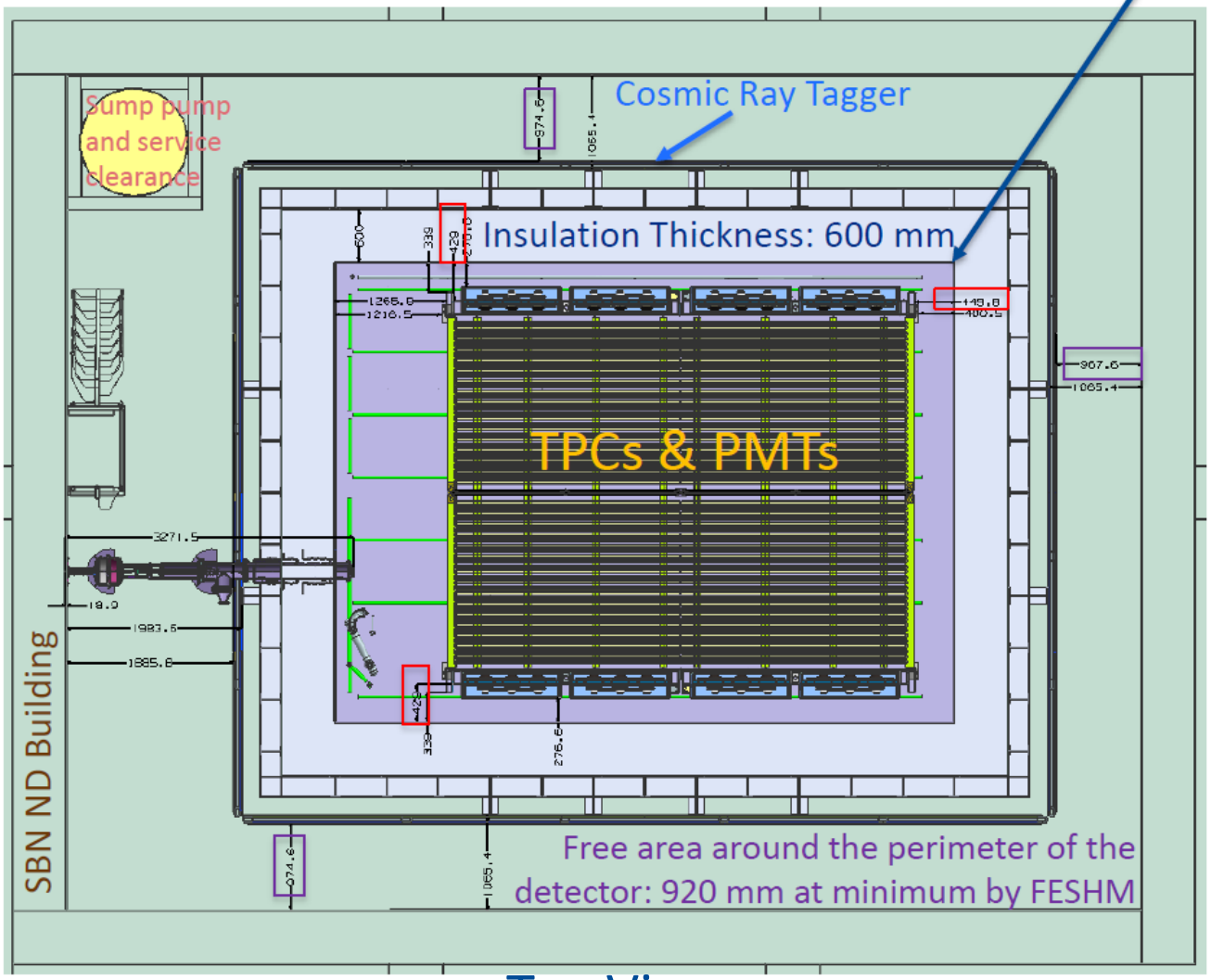




SBN-ND/SBND Cryostat

Example of Space Requirements

Cryostat Internal Dimension (Width [mm] x Length [mm] x Height [mm]): 5202 x 7027 x 5423



< Top View >

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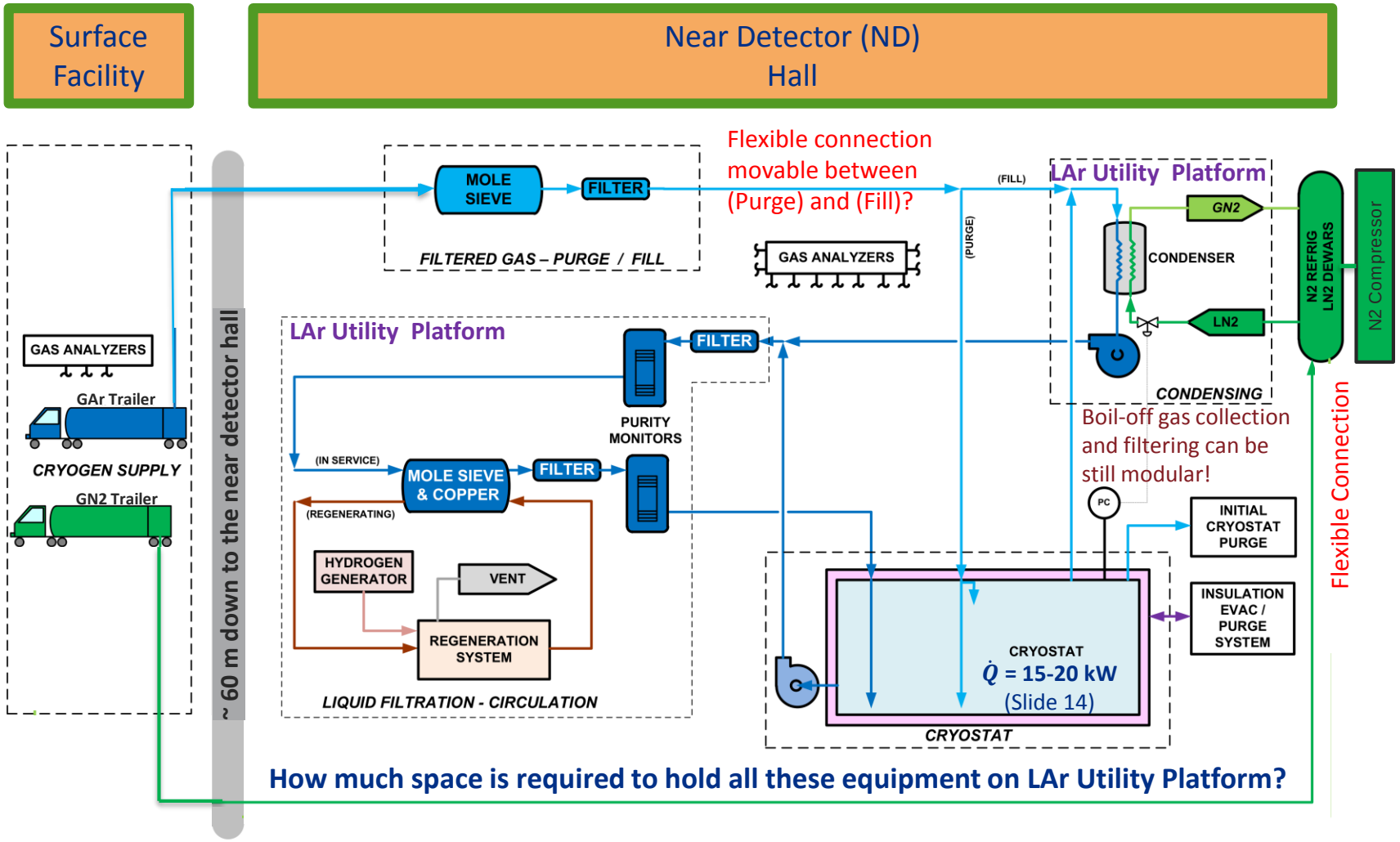
Proposal for Cryogenic System (with or without cryocoolers)



Proposal for DUNE-PRISM Cryogenic System Block Flow Diagram

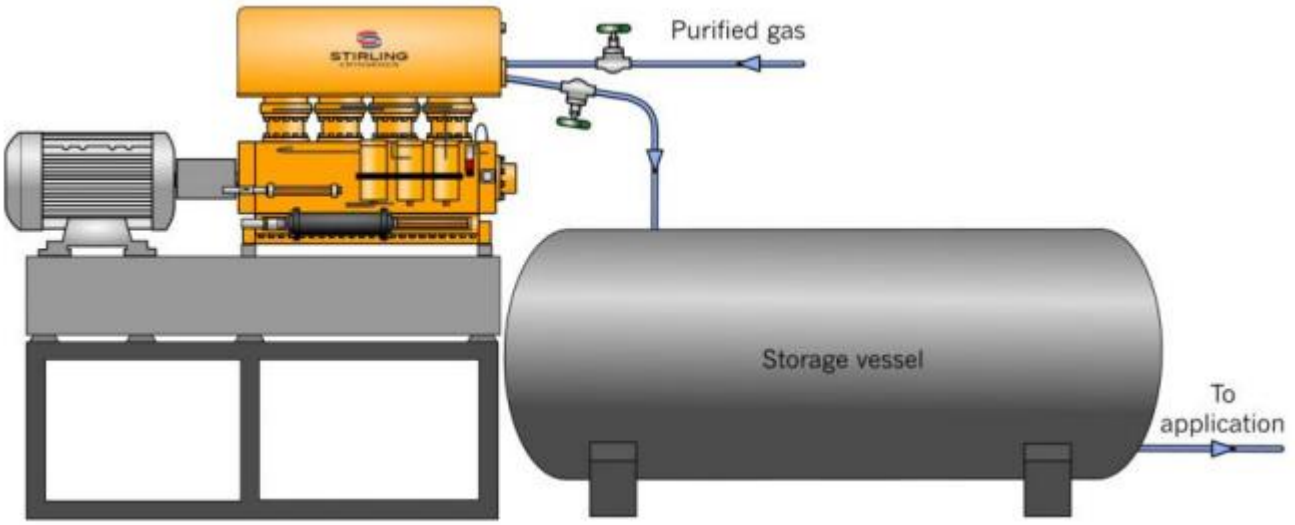
Video of Original ICARUS Cryo system from Stirling

- Example: ICARUS 30 kW Cooling System

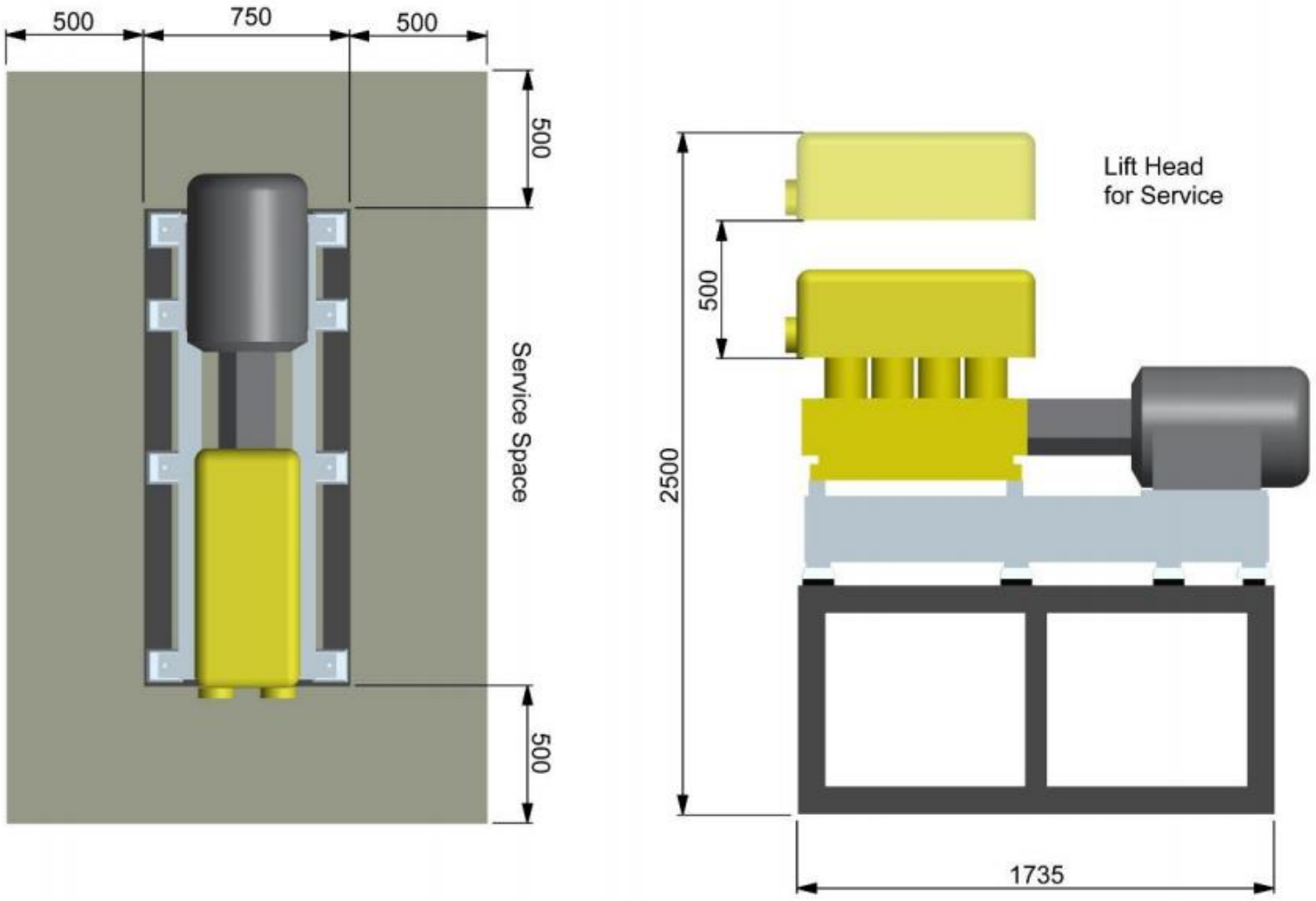
- Original ICARUS used 10 x 4 kW cryogenerators. Present calcs of heat leak for DUNE PRISM would require ~ five units with one unit being a spare.

- Other companies exist including Cosmodyne which sells closed loop liquefiers.
  - https://www.cosmodyne.com/nitrogen-oxygen-liquefiers/elm-series

Stirling Equipment – Closed Loop Cycle



Size of a Single



Comment on Refrigeration Needs for DUNE-PRISM

- In order to advance forward in the approach to cryogenic system design, we must have a Working Group which includes BERN and FNAL (minimum).
- WG must decide the method of cooling and purifying the modules because this will decide the size of the ‘external cryogenic cooling system’.
- For example the approach using cryo-coolers on each ArgonCube module sums to 8 kW cooling or 200 W by 40 modules. This is equal to the total heat load we calculate from the remainder of the systems: cryostat, pipe, pump power, etc.
- That is under present design approach that we understand the heat load can be 16 kW or more. As a note we expect SBND to be at ~10 kW.
- We would like to optimize module top plate heat leak. The ability to reduce heat leak will define the space required for cryogenic equipment as well as capital investment.

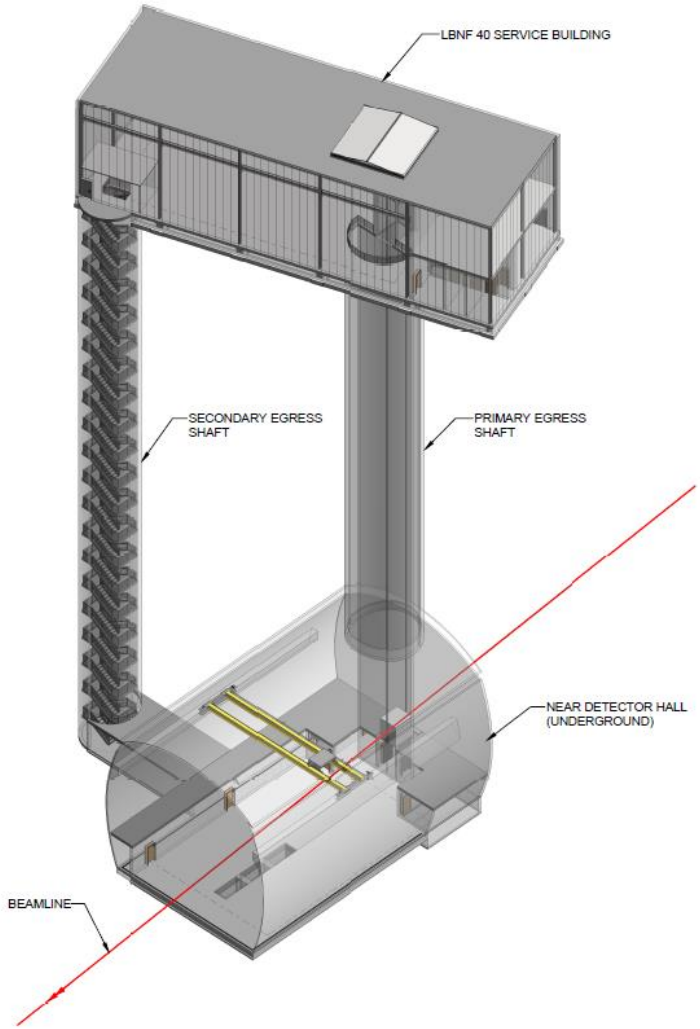
Requirements on Cryogenic System

- When we think about the cryogenic purity of ArgonCube modules “is too pure an issue or does the detector not care?”. I know because of drift length we need to get to ppb rather than ppt but if we attained ppt would the detector have issues? The potential for electrical discharges (i.e. "sparking") the best information we have on this issue is probably from MicroBooNE.

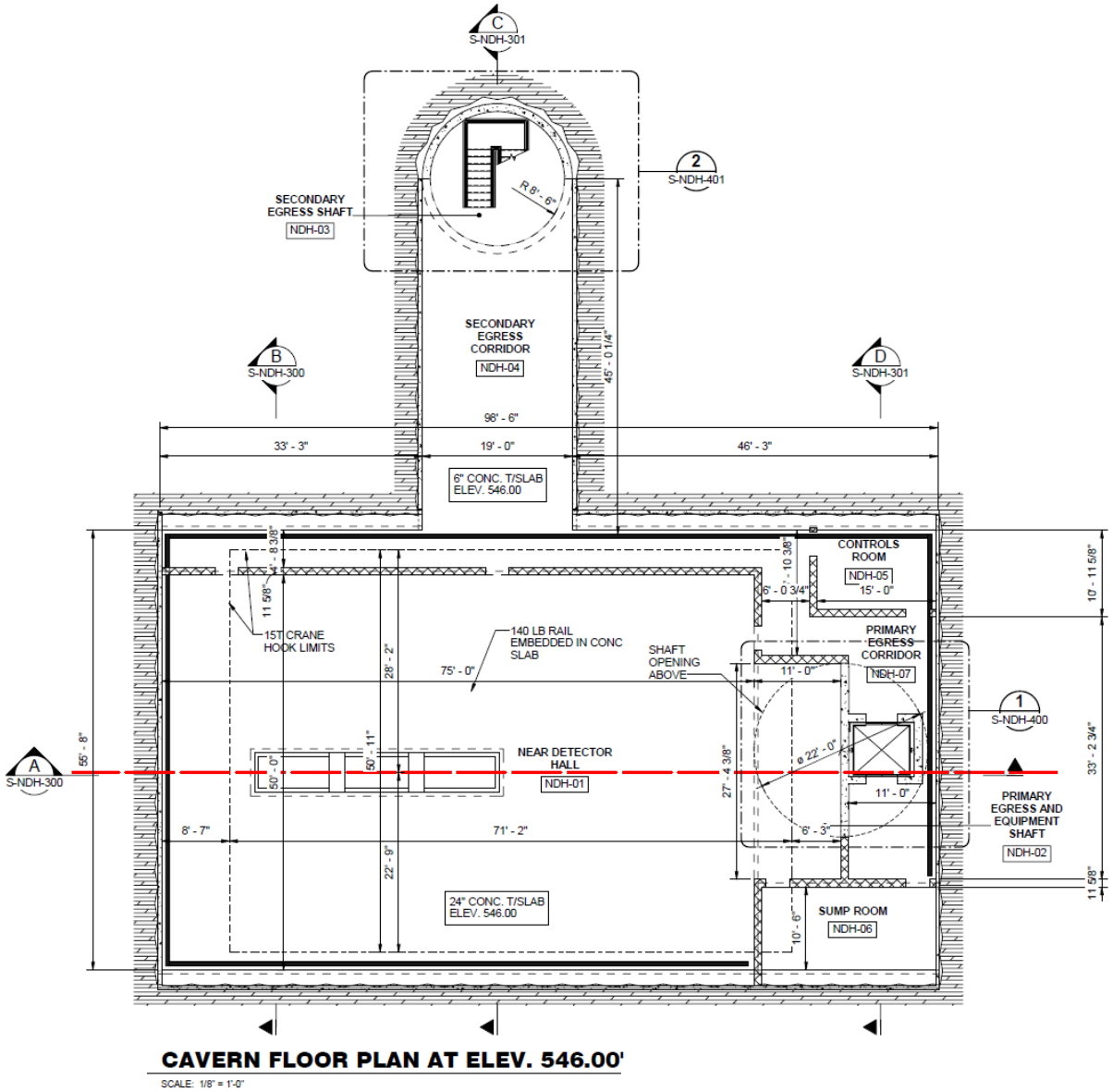
- Total heat leak used to determine the refrigerator capacity: 15-20 kW
  - Heat leak through cryostat sides and bottom: 1.3 kW
  - Heat leak through cryostat roof: 8 (= 0.2 x 40) kW
  - Miscellaneous (3 kW from detector electronics assumed plus heat leaks from piping, filters, etc.): 7.2 kW

- Question on ArgonCube module design
  - The existence of insulation on the top of module?
  - Temperature gradient required for detector cooldown if there is any restriction?

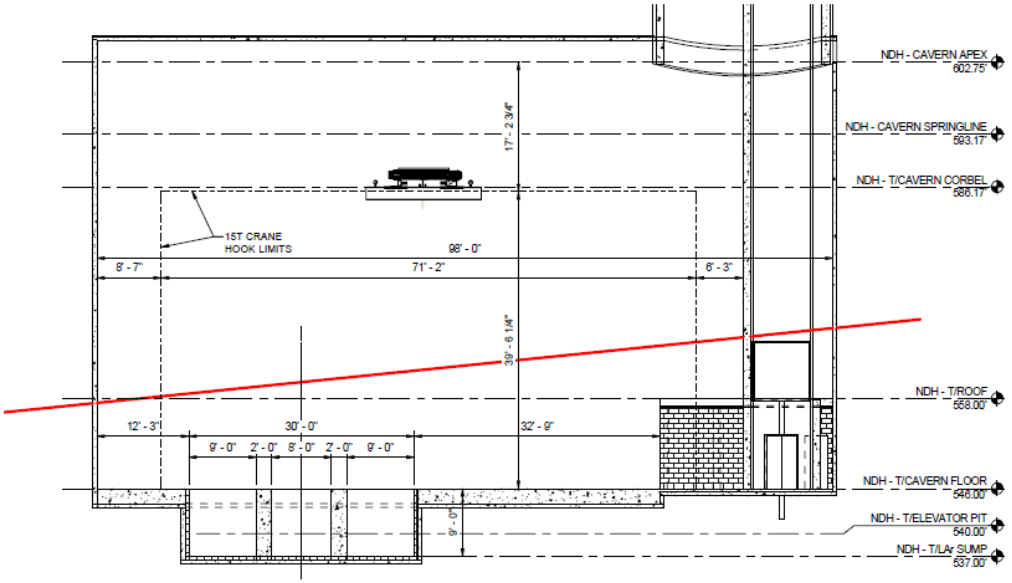
LBNF Near Site Conventional Facilities: Near Detectors



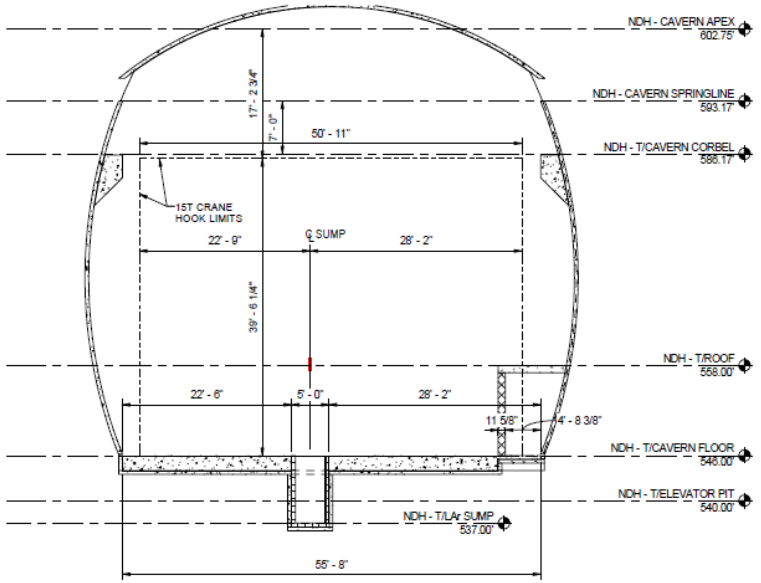
Near Detector Hall Cavern Floor Plan



Near Detector Hall Section Views

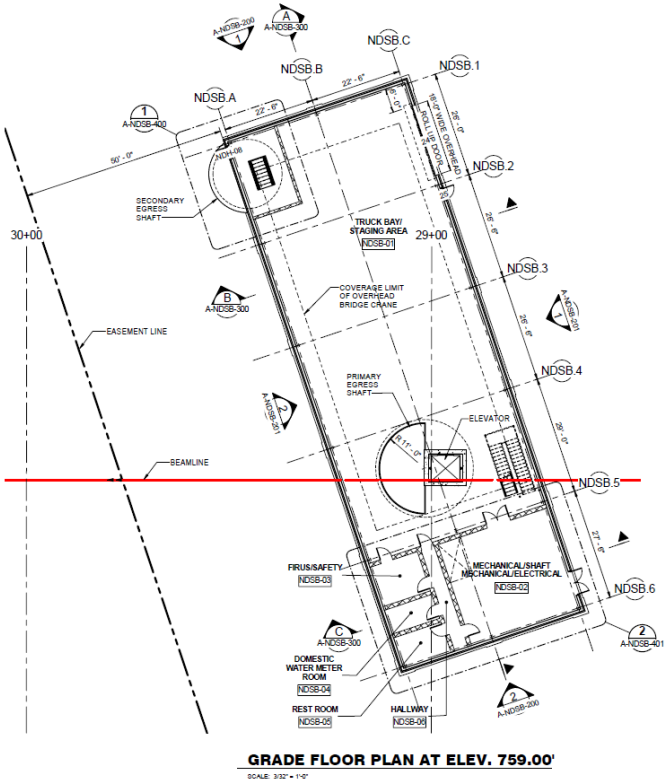


SECTION A S-NDH-300
SCALE: 1/8" = 1'-0"

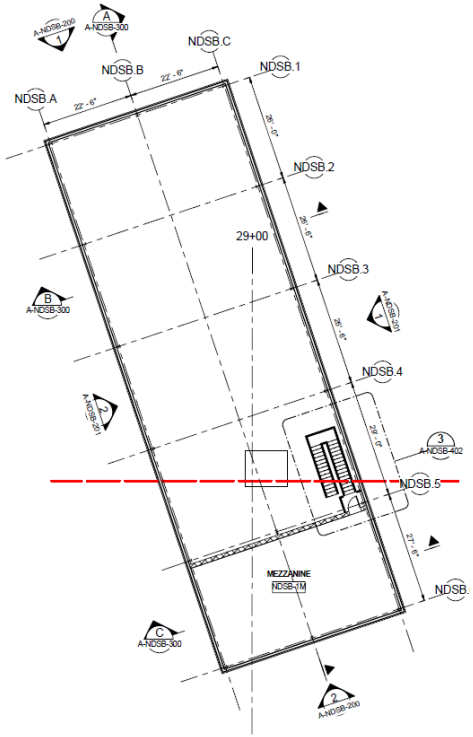


SECTION B S-NDH-300
SCALE: 1/8" = 1'-0"

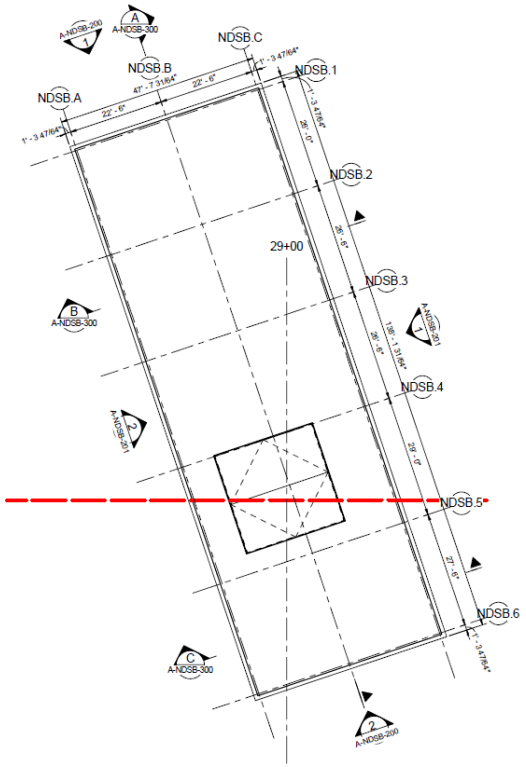
Near Detector Hall Service Building Floor Plans



GRADE FLOOR PLAN AT ELEV. 759.00'



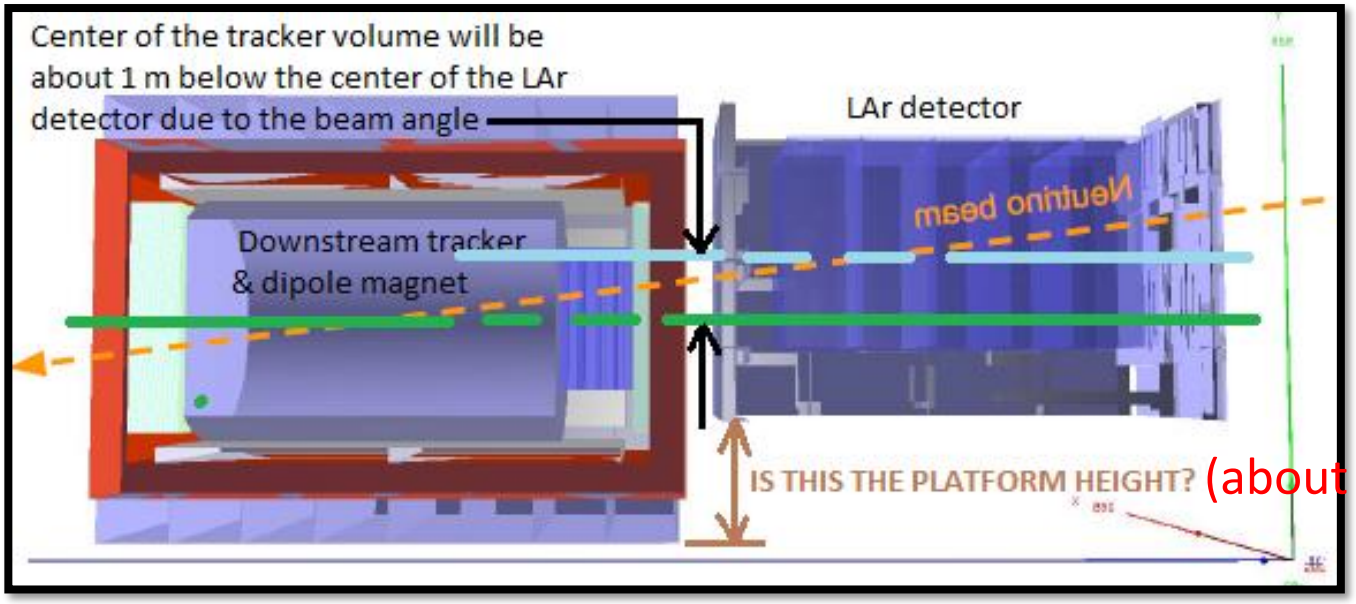
MEZZANINE FLOOR PLAN AT ELEV. 777.00'



ROOF PLAN AT ELEV. 797.00'

Determination of Drive System

- Factors to determine the (design of) drive system for a mobile LAr detector:
  - The platform height for LAr detector will depend on [1] the platform height for moving downstream tracker & dipole magnet, [2] the dimension of dipole magnet, [3] the cryostat design parameters, and so on.
  - Total load on the platform (including cryostat and cryogenic system, LAr, ArgonCube modules and detector electronics, etc.): **xxx,xxx kg**
  - Detector travel speed: **~0.5-5 cm/min**
  - Conditions (or Infrastructure) for the detector hall: shaft/elevator, utilities, etc.
  - Availability in the market: We want to use **standard commercial components**.



(about 1.75 m)

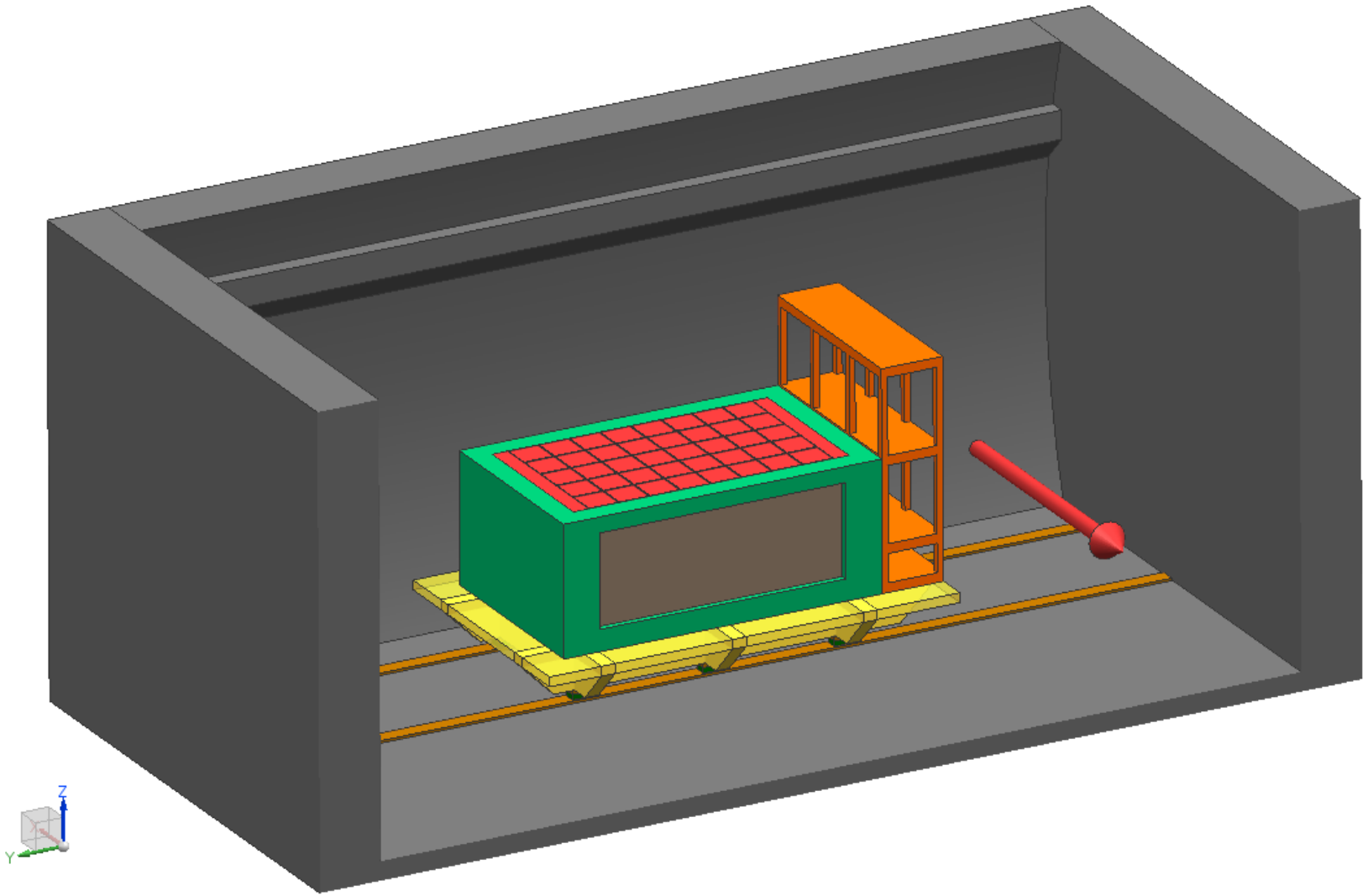
Drive System

- The LAr detector platform riding on Hilman rollers with cam followers on guide rails.
- A Rack-and-Pinion Type with Multiple Drives

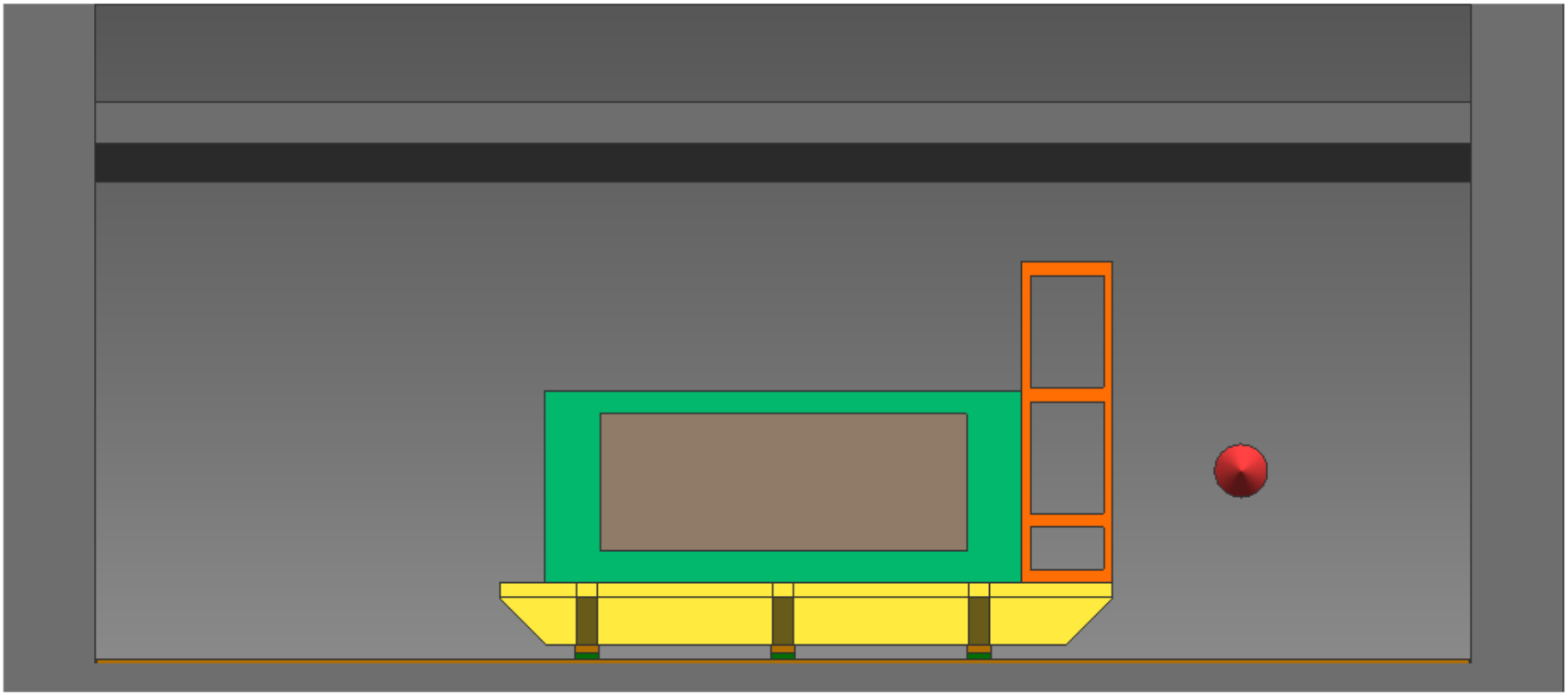
Drive System (continued)

- Possible types of Drive System to move the LAr detector in consideration of the conditions (or infrastructure) in the detector hall:
  - ***hydraulic drive system:***
    - **Requirements on providing containment for hydraulic systems**: We can have secondary containment for hydraulic fluid leaks, even big ones. Leaks can happen anywhere along the hoses and hydraulic motors.
    - Would hydraulic fluid leaks into the trench/sump system cause any problems?
    - We will protect other equipment (cryo, racks, etc.) from being sprayed with hydraulic fluid.
    - Remote control.
  - ***Electrical drive system:***
    - Need 480 VAC power distribution in the cryostat platform.
    - Variable speed drives.
    - Remote control.
- Drive system components are installed on the cryostat platform.
- Speed reducers.
- Elimination of stick-slip motions.

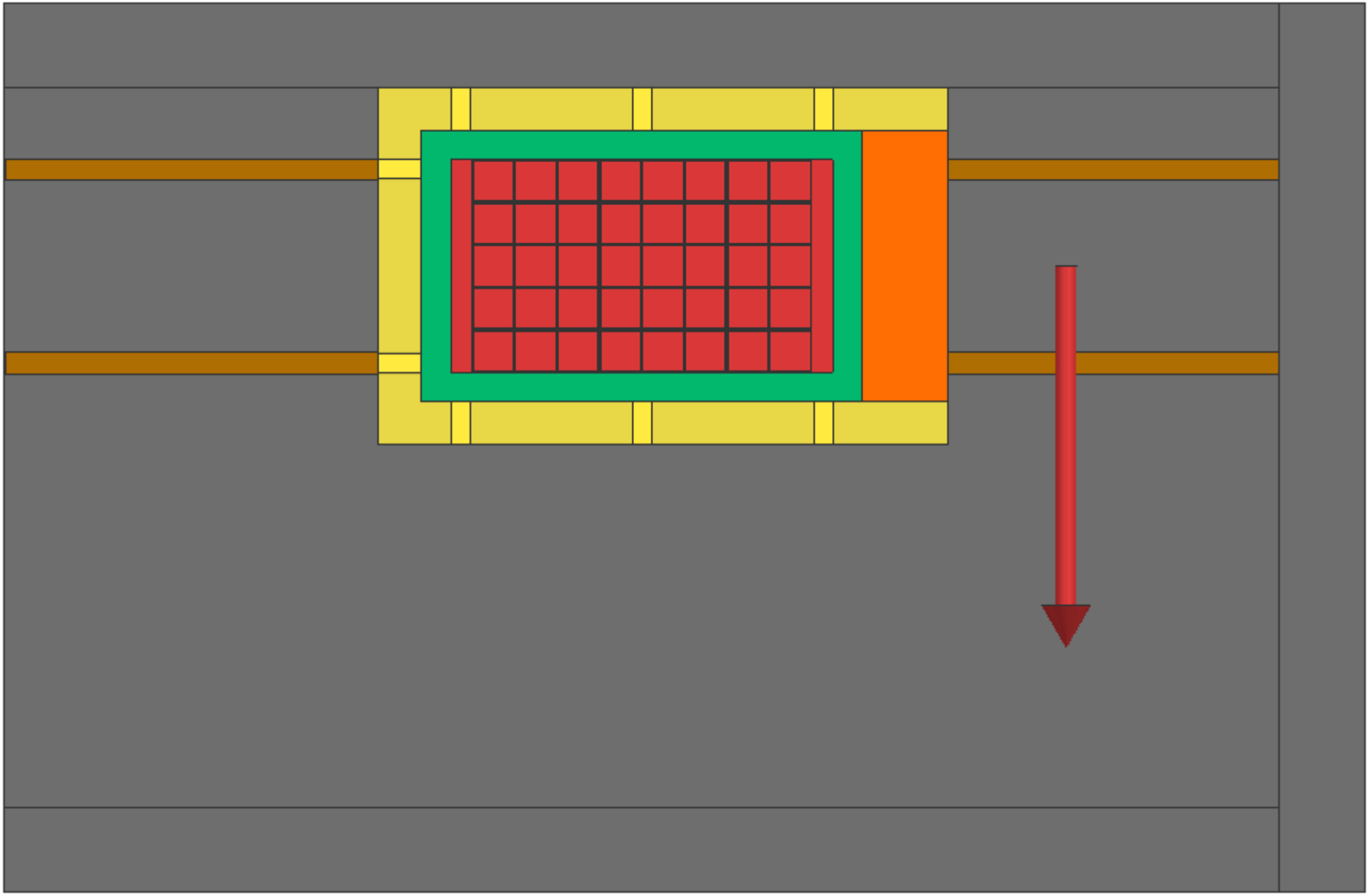
Isometric view



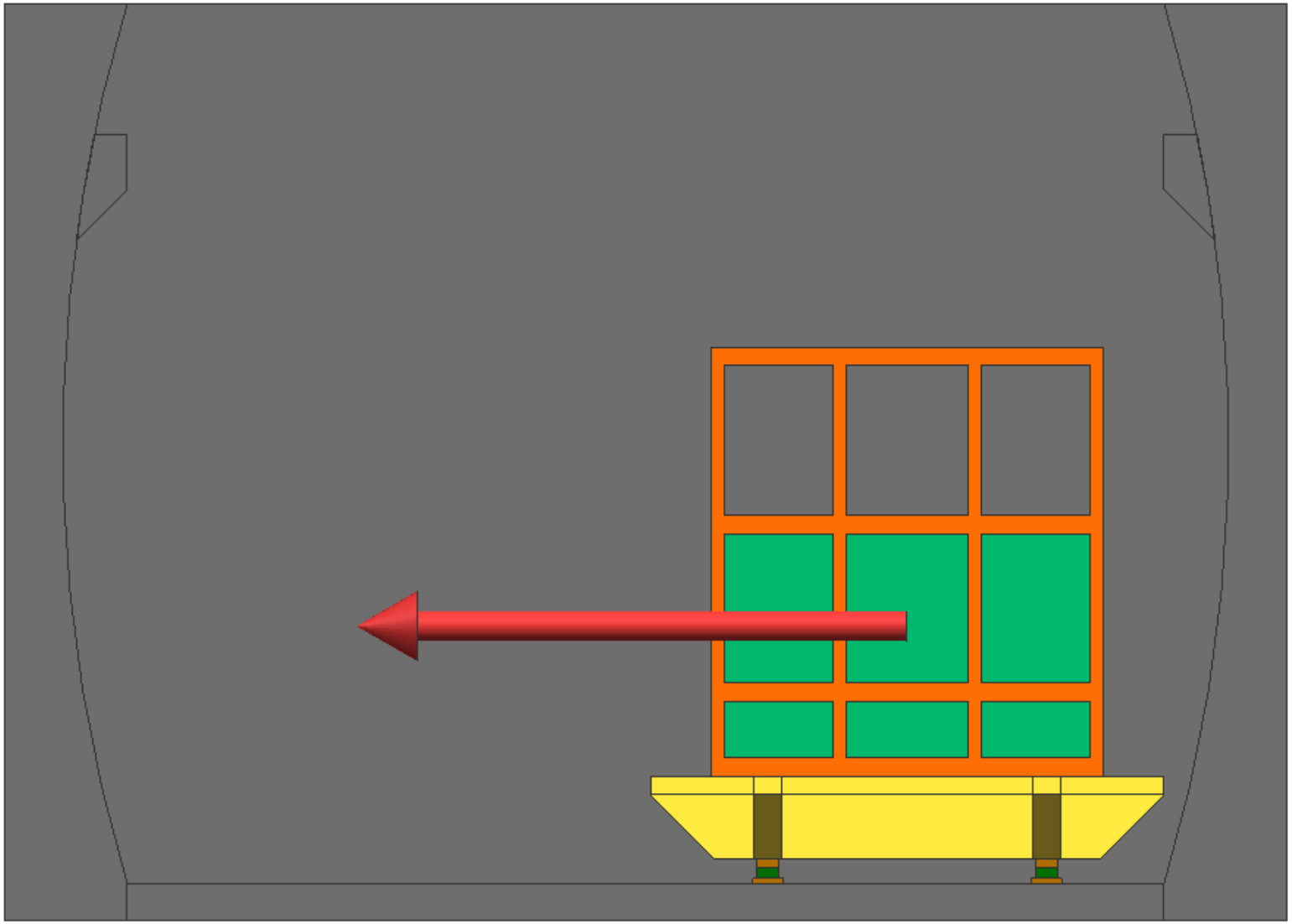
Side view



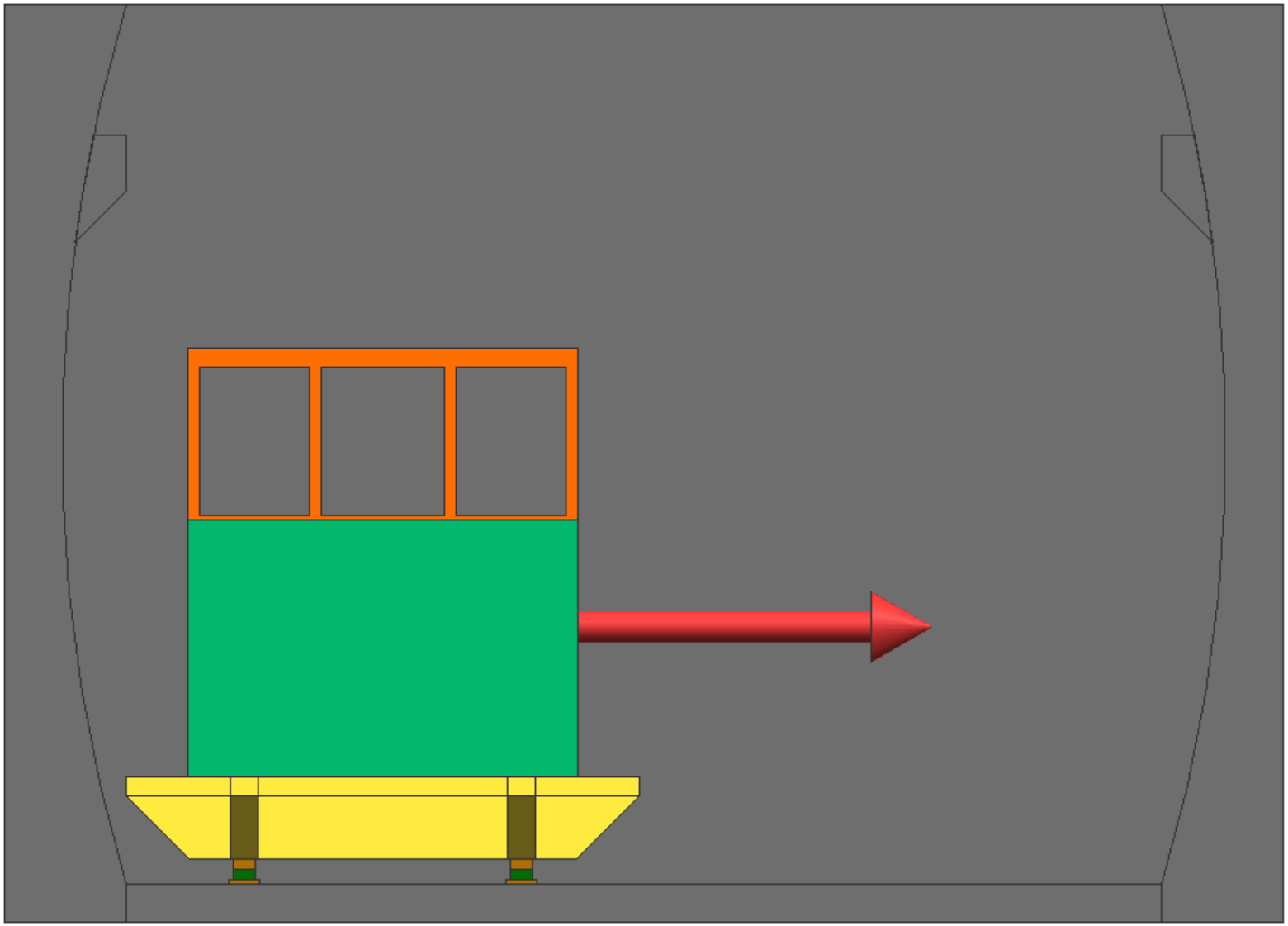
Plan view



Utility platform end view



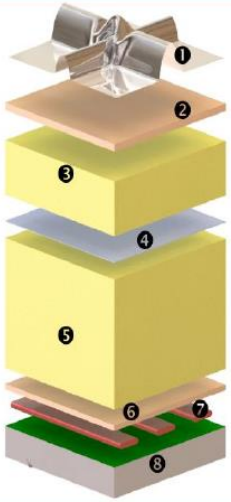
End view



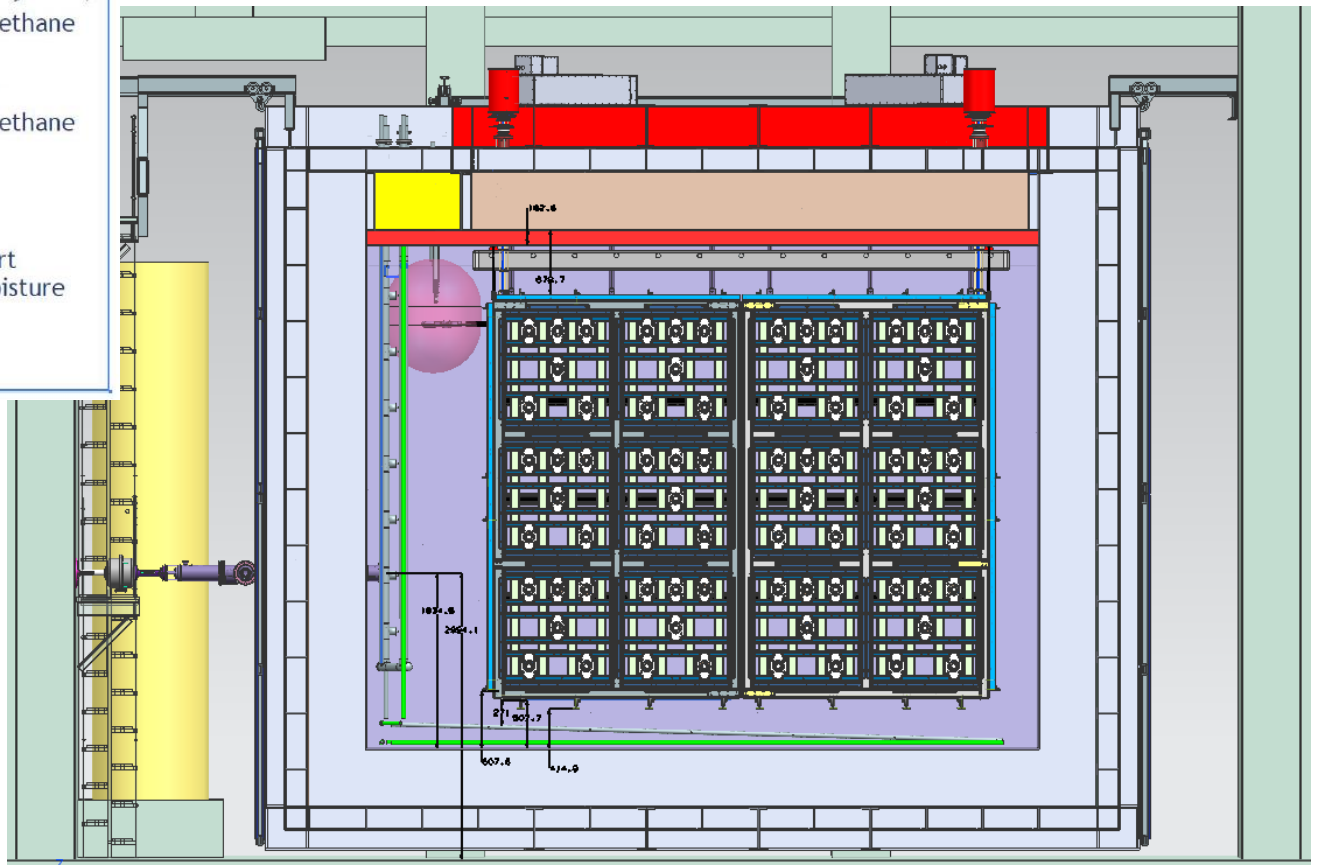
Backup Slides

SBN-ND/SBND Cryostat

"Cryostat in a kit" design by GTT



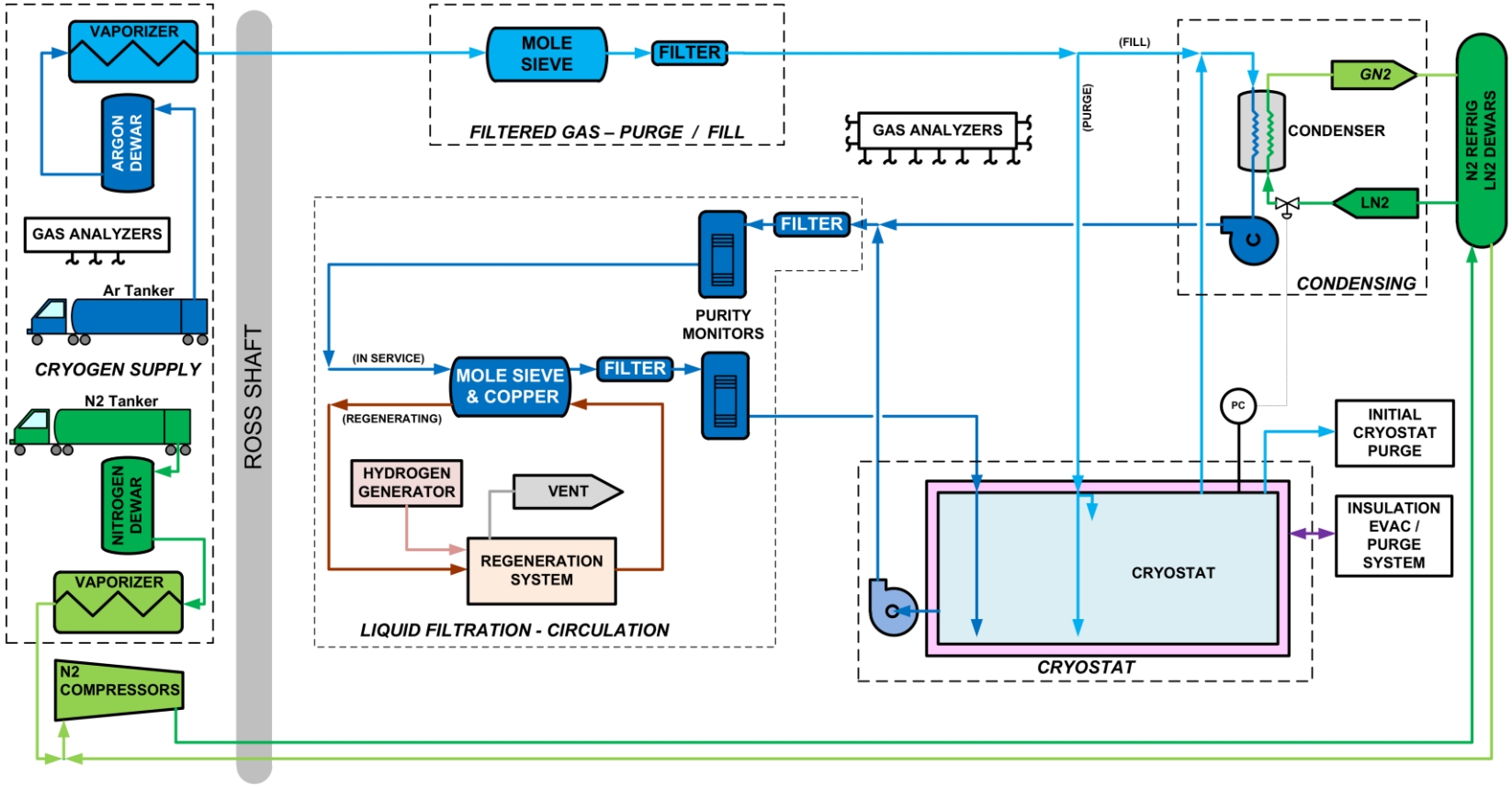
1) Stainless steel primary membrane
2) Fireproof board (Plywood)
3) Reinforced polyurethane foam
4) Secondary barrier
5) Reinforced polyurethane foam
6) Plywood board
7) Bearing mastic
8) Steel outer support structure with moisture barrier



< Side View >

DUNE Far Detector Cryogenic System

- Pump(s), filtration and cooling are outside of main cryostat (as we do in Fermi experiments, SBN's, and ProtoDUNEs)



DUNE FD Cryogenic System Block Flow Diagram