Hall Reference Design
Near Detector Integration & Installation

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6th DUNE Near Detector Workshop at DESY

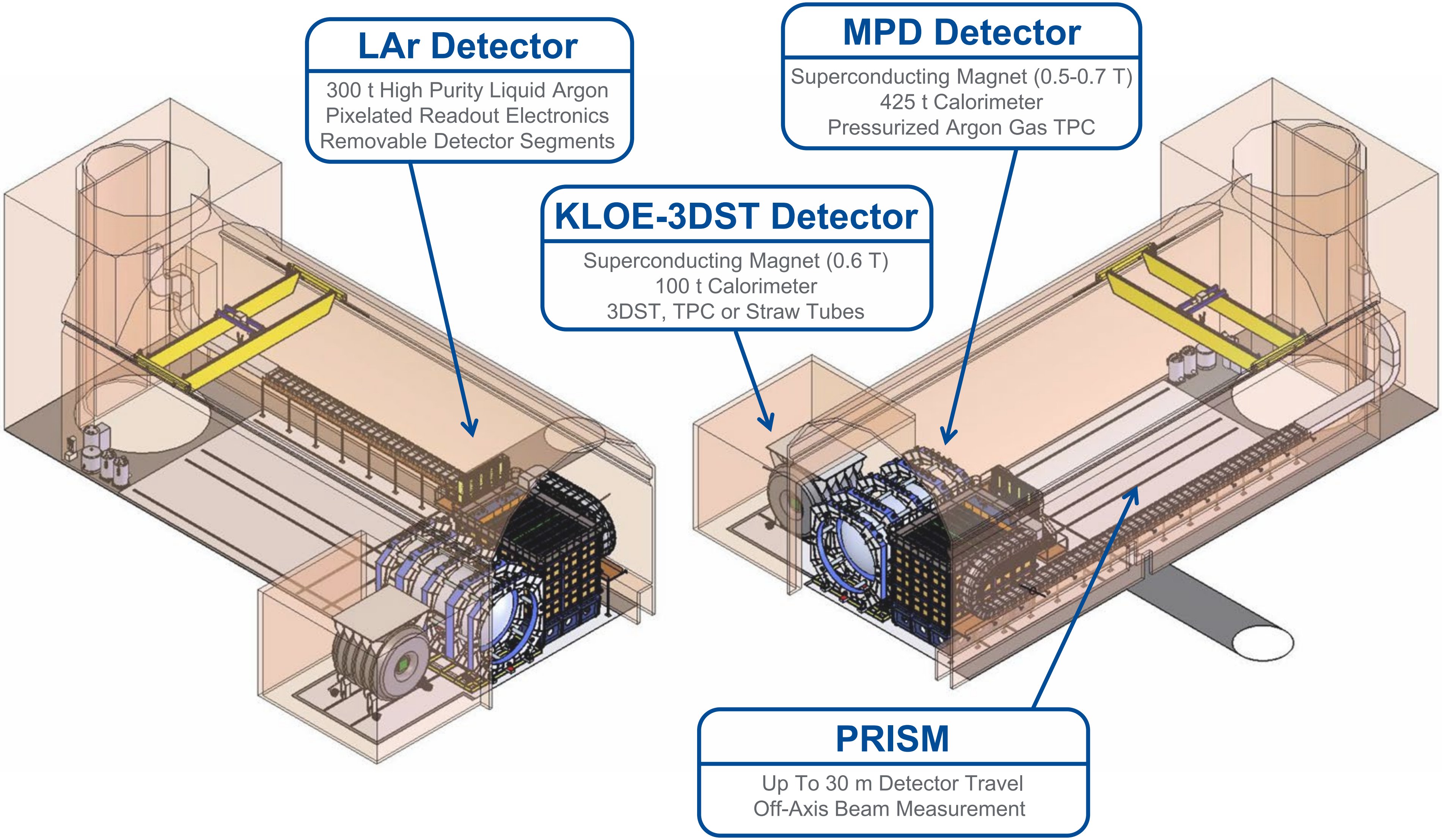
Oct. 20-23, 2019

Outline

- Near Detector Integration and Installation Scope (*)
- Detector Details
- Cavern Requirements
- Cavern Size Discussion
- Schedule
- Next Steps
- Summary

(*) LAr US-scope as well as Near Site LBNF scope details are not discussed

DUNE Near Detector (ND) Scope And Reference Design



US Is Strongly Committed To DUNE Near Detector: Budgeted Cost ~$150M Plus Contingency

- **LBNF**
  - Cavern large enough to accommodate full ND reference design
  - Surface building
  - Main power distribution infrastructure
  - LHe cryoplant procurement
- **LAr US Scope**
  - Cathode and Field Cage, Charge Readout, Module Integration
- **DUNE Near Site Integration & Installation**
  - LAr cryostat procurement cost
  - LAr cryogenics procurement cost
  - PRISM movement system and cable chain (incl. prototypes)
  - KLOE cryogenic distribution system procurement cost
  - Support for detector installations
  - Surface cryogenics (LAr and LHe)
  - Cavern preparation plus installation tooling and equipment
  - Cavern infrastructure (local power distribution, cable ways, cabling)

WBS 131.4.2 Technical Coordination Office

Near Detector Engineering Base Team In Place – Integration Matures Rapidly

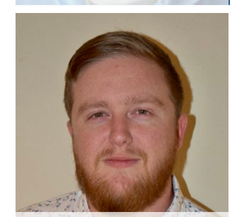
- **ND Integration Office:** FY 2020 to FY 2025
  - ✓ Lead Engineer
  - ✓ Detector Integration Engineer
  - ✓ Installation Engineer
  - ✓ Designer
  - ✓ Cryo Engineer and Electrical Engineer (shared with Far Site)
  - Travel and M&S

- **ND Installation Office:** beyond FY 2025
  - Lead Engineer
  - Detector Integration Engineer
  - Installation Engineer
  - Junior Planning Engineer
  - Cryo Engineer and Electrical Engineer (shared with Far Site)
  - Technician Lead
  - Four Core Technicians (Consortia must provide additional installation technicians)
  - Travel and M&S


M. Leitner

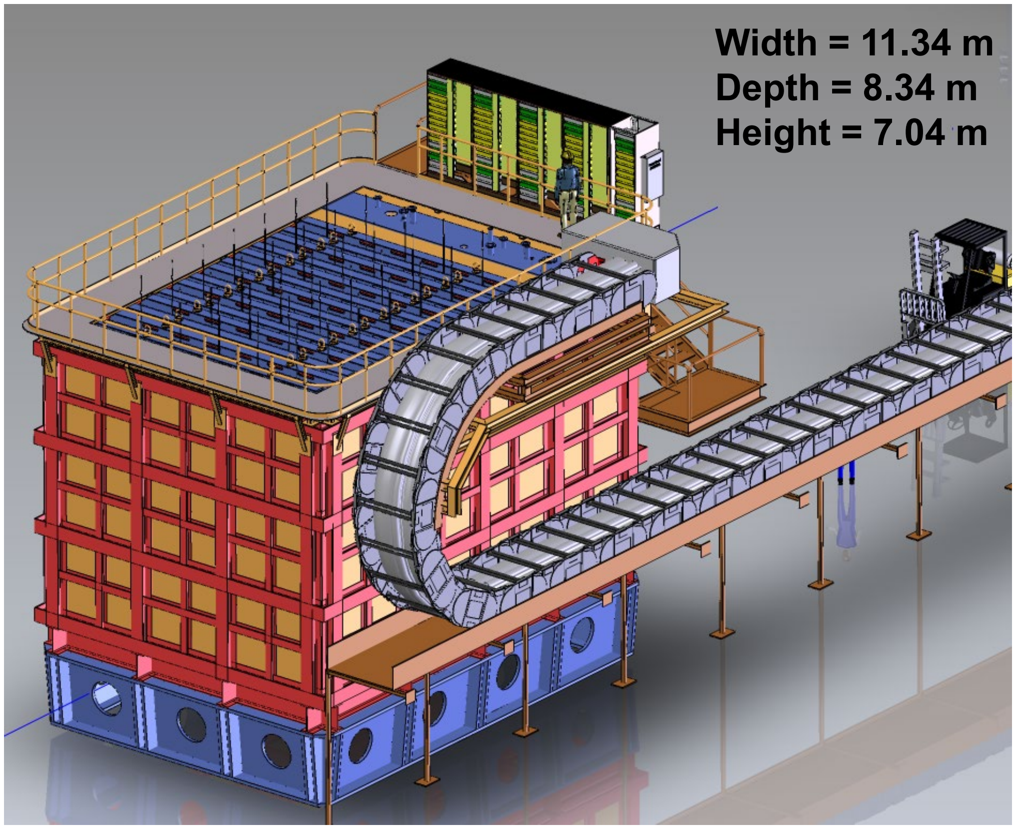

R. Flight


A. Lambert


A. Lawrence

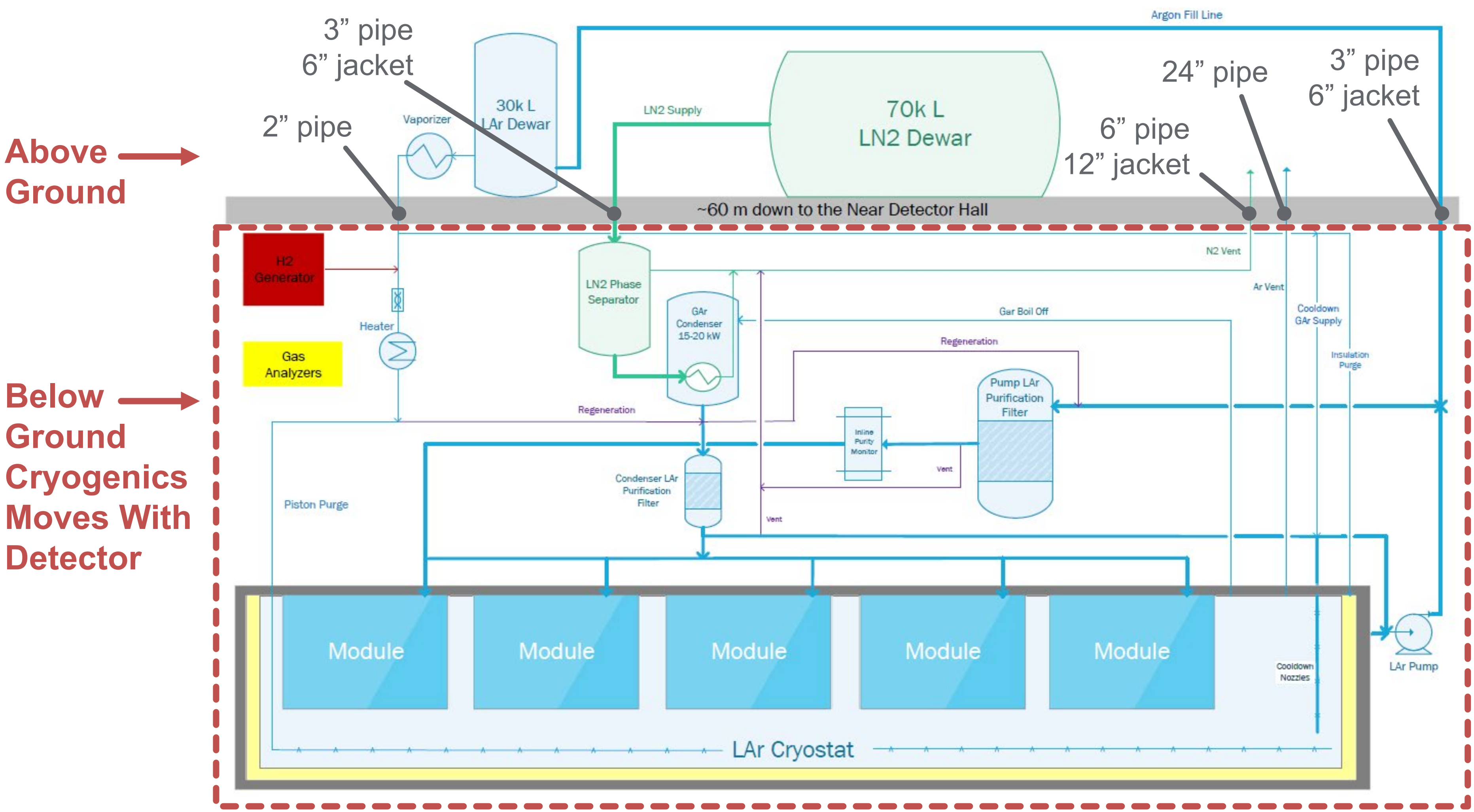
supported primarily through off-project DUNE Support Funds (DOE)

LAr Detector Main Structure Parameters:
Movable Membrane Cryostat With Segmented Detector Modules



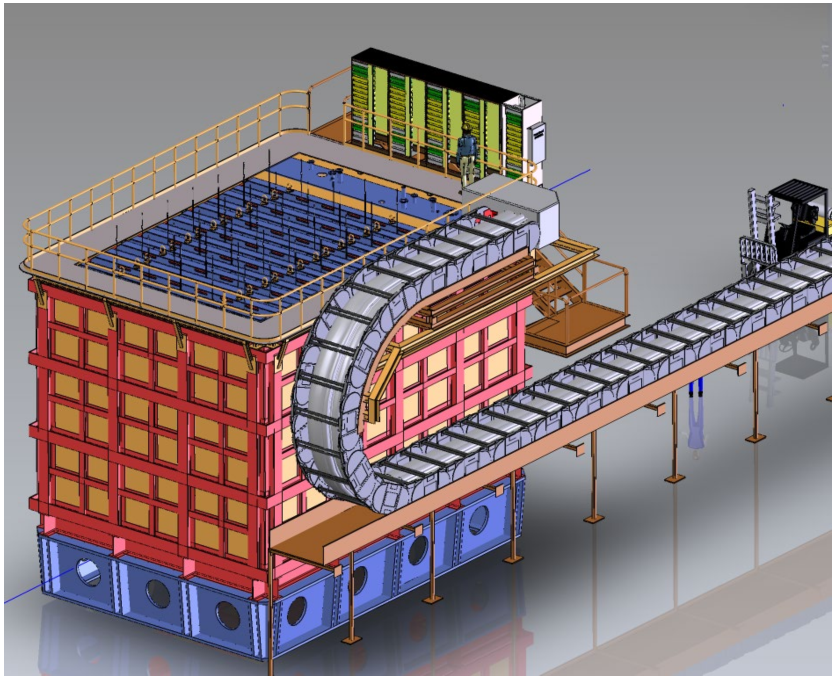
	Volume [m³]	Weight [tonne]	Reference
LAr Volume	232	325	CAD model, 1400 kg/m^3
Active Detector Units	-	53	Based on surface area[1]
SS Inner Membrane	0.44	3.5	CAD model
Membrane Cryostat	207	20.7	100 kg/m^3 avg. density
Top Membrane Cryostat	15.2	1.5	CAD model allowance
Top Inner SS Skin	0.18	1.5	CAD model allowance
Steel RT Membrane	3	24	CAD model
Top Steel RT Membrane	0.45	3.6	CAD model allowance
RT Beam Structure	10.8	86.3	CAD model
RT Beam Connections		25	30% of beam structure weight
Outer Wall Stiffeners		30	CAD model allowance
Base		200	Estimate based on CAD model
Inside Cryogenics		17	Piping
Outside Cryogenics		30	top of cryostat plus pumps
Cable Chain Segment		15	Weight of cable chain connection
Mezzanine and Stairs		20	CAD model
Racks		10	20 racks @ 0.5 tonne each
Prism Rollers		10	
LAr TOTAL WEIGHT		**~880**	

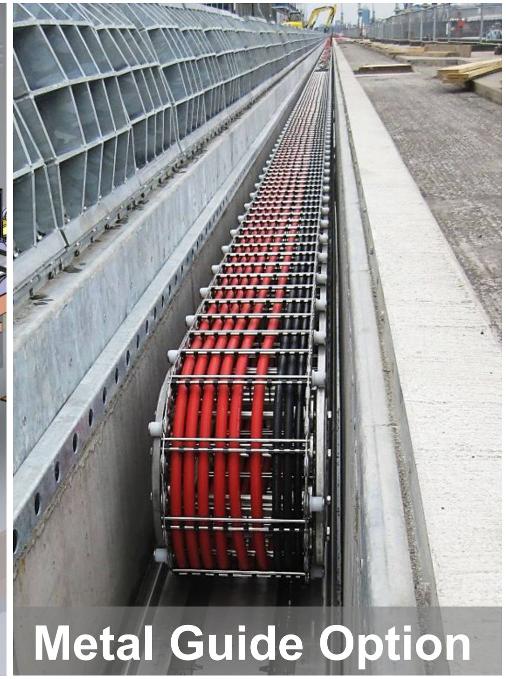
LAr Detector Simplified Flow Diagram:
Large Diameter Cryogenic Piping Needs To Move With Detector

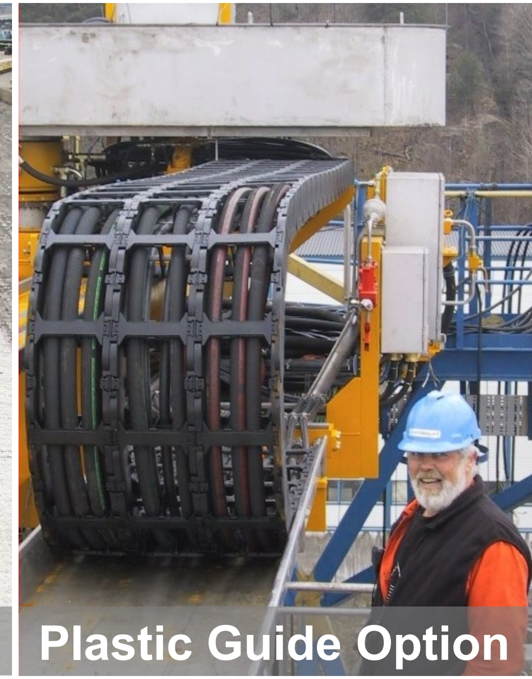


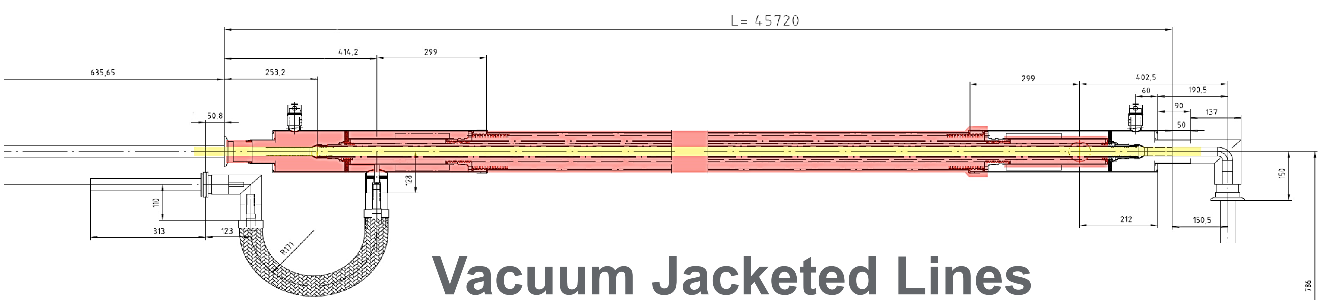
Graphic: Min Jeong Kim

Cryogenic Line Guides Require Novel Design Solution







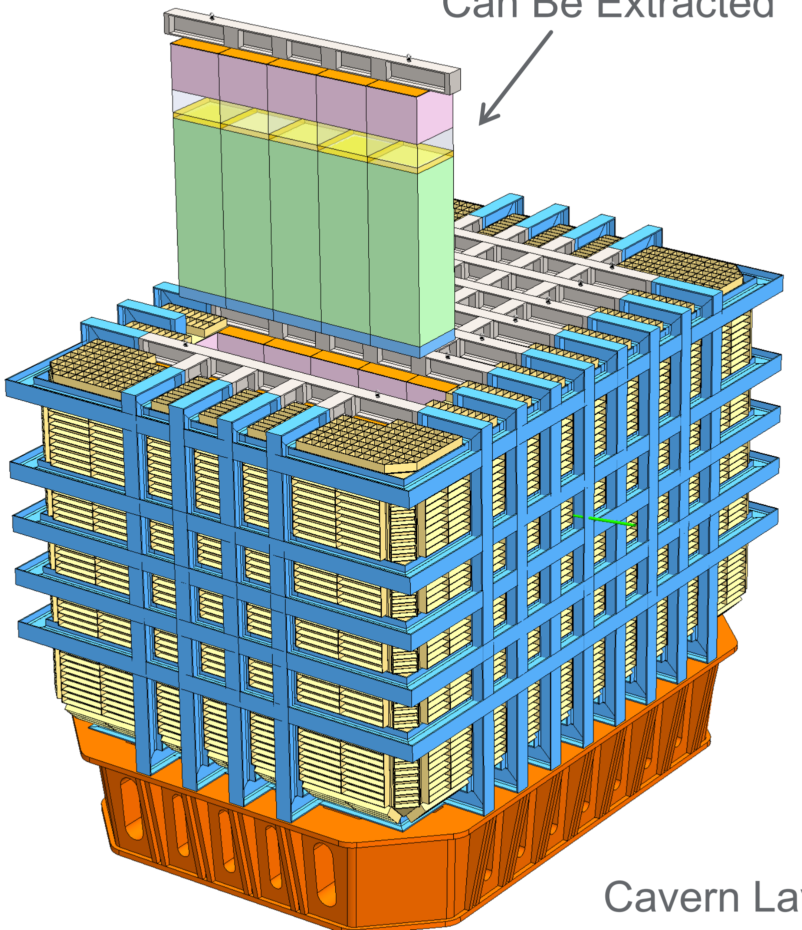


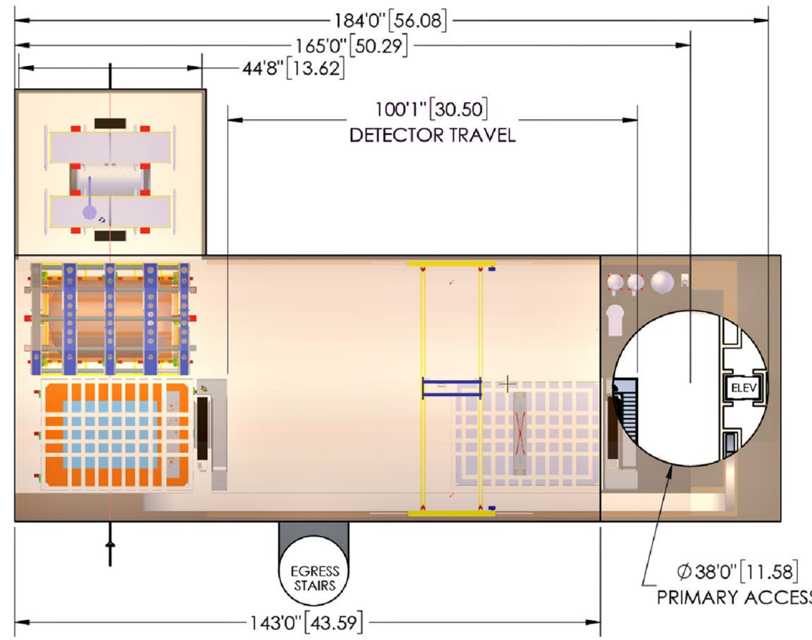
Vacuum Jacketed Lines

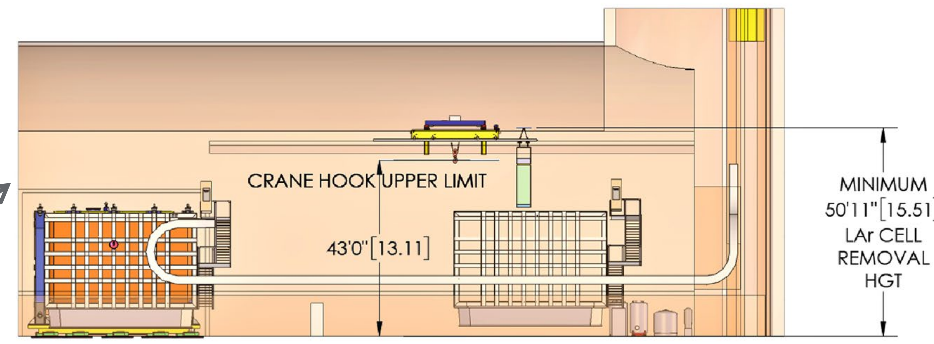
- Commercially Available
- Guide Designs Needs To Resist "Coil-Up" Under Vacuum Load

1. Corrugated inner pipe
2. Spacer
3. Super insulation
4. Vacuum space
5. Corrugated outer pipe
6. Jacket

LAr Cryostat Concept Based on SBND Design:
Framing Aligns With Detector Modules And Permits Extraction







Cavern Layout
Permits Servicing

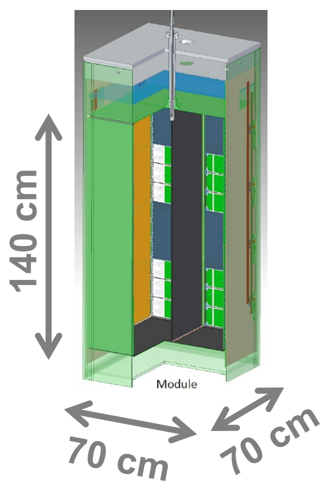
LAr detector cryostat conceptual design

D. Dwyer

LAr Module Design Will Be Validated In Phases: Captured In Detector And Installation Project Schedules

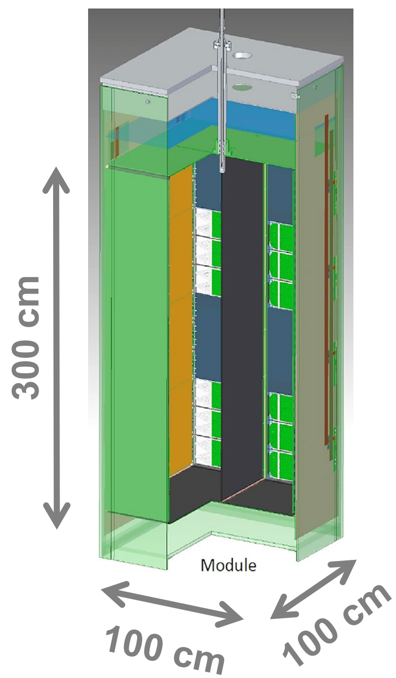
2019-2021 ArgonCube 2x2 Demonstrator

- 4 (+1) modules
- Operated in existing cryostat at Bern, then FNAL (NuMI)
- Technical demonstrator



2022-2023 Pre-production Demonstrator

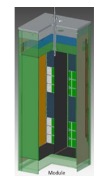
- 1 (+1) Full-scale ND module
- Operated in single-module cryostat



2024-2026 DUNE Production

Institutions:

Bern, LBNL, SLAC, CSU, UTA, +others

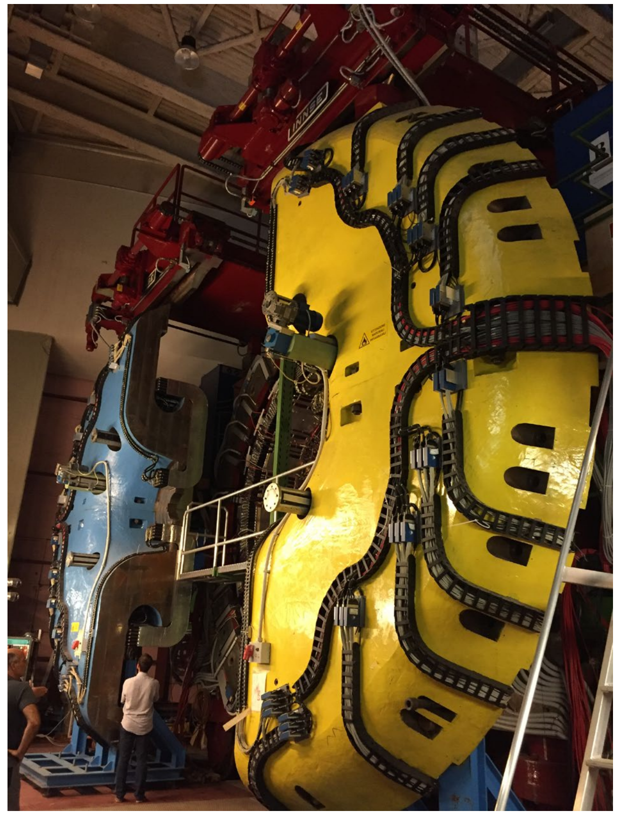


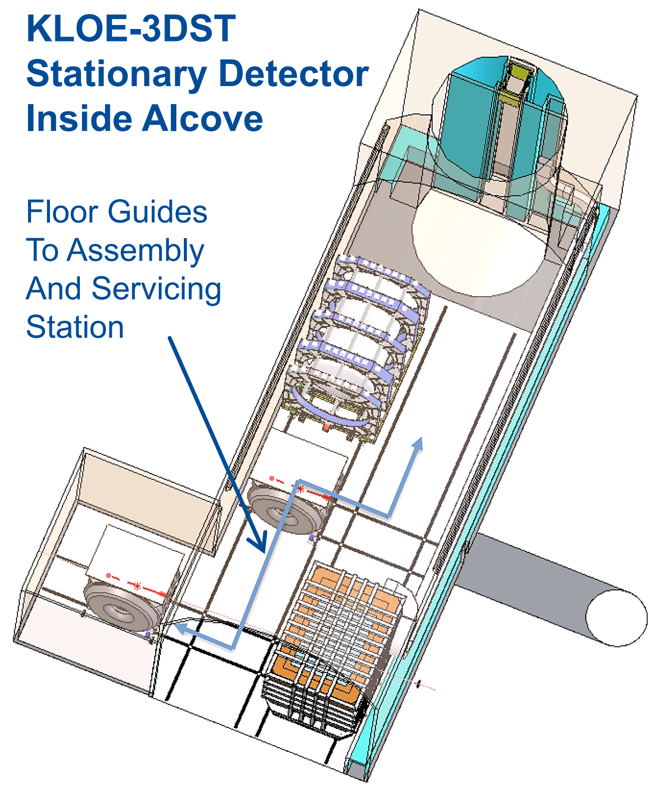
- One Production ‘First Article’

35 (+5) Production Modules

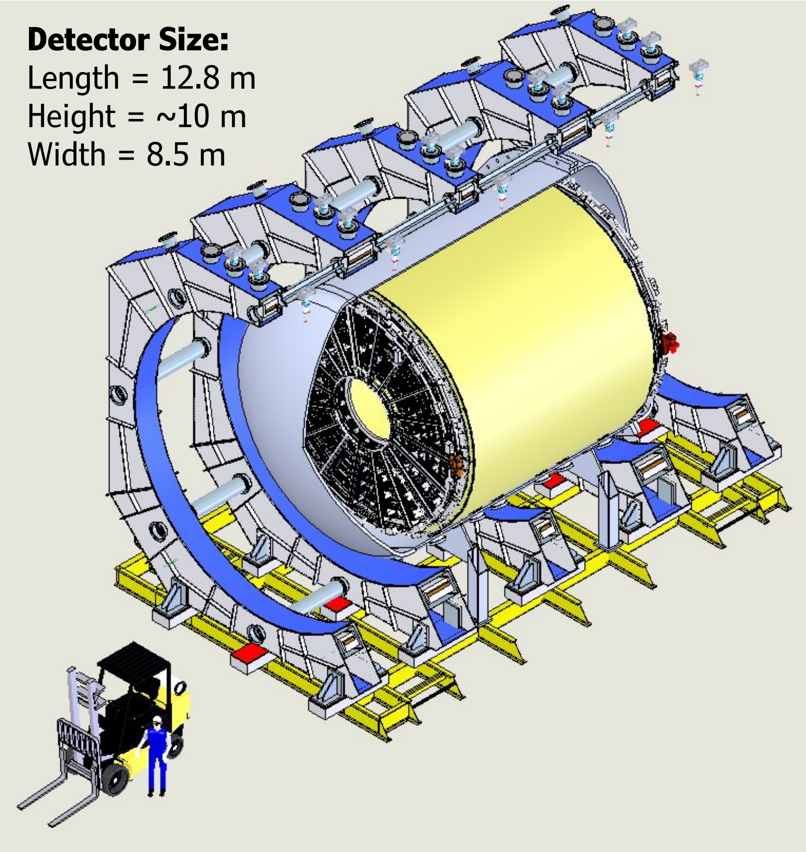
each fully tested in single-module cryostat

KLOE-3DST Detector Main Structure Parameters
Stationary Detector Will Primarily Serve As Beam Monitor



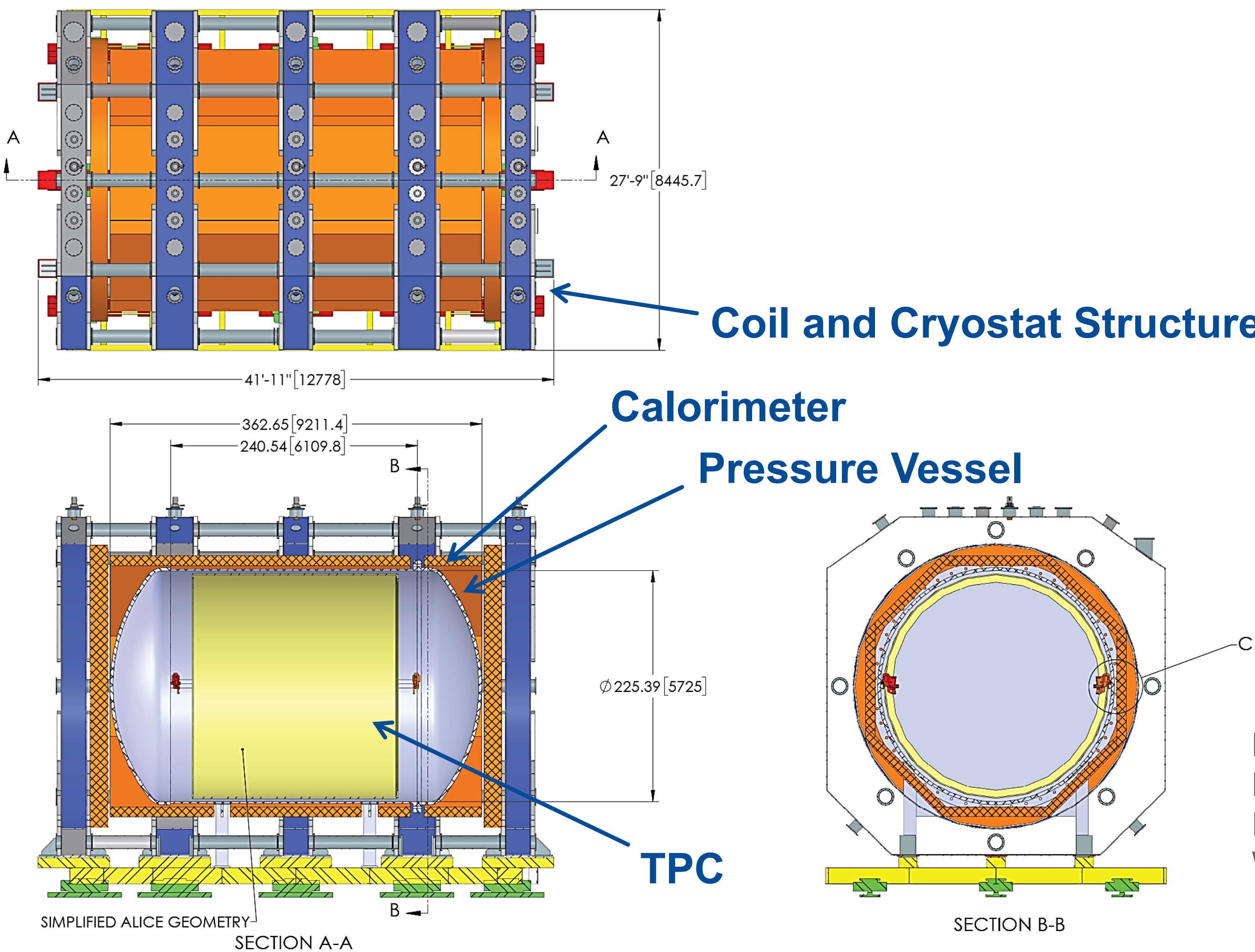


MPD Main Structure Parameters
MPD Design Matured: Achieved Fully Integrated Design



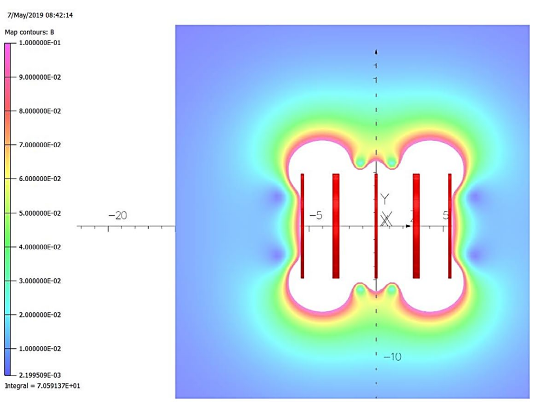
	Volume [m^3]	Weight [tonne]	Reference
Pressure Tank	13.5	40	40 tonne Al, 110 tonne SS
Alice TPC	5.51	15	NIM paper, CAD model
Magnet Outer Cryostat	5	50	40 tonne SS + 10 tonne flanges
Magnet Heat Shield	0.3	1	1 tonne Al, 3 tonne Cu
Coil + Bobbin		50	Assumes aluminum
Hardware, Components		10	Compared to other detectors
Support Frame	3	25	Steel, 3x larger then current CAD
Calorimeter	105	425	2mm Cu and 5 mm plastic
Calorimeter Frame		50	Compared to other detectors
Magnet Top Mezzanine		11	Compared to other detectors
Magnet Top Cryogenics		10	Compared to other detectors
LHe	30	4	estimate
Racks		10	10 racks @ 1 tonne each
MPD TOTAL WEIGHT		**~710**	

MPD Design Matured: Achieved Fully Integrated Design

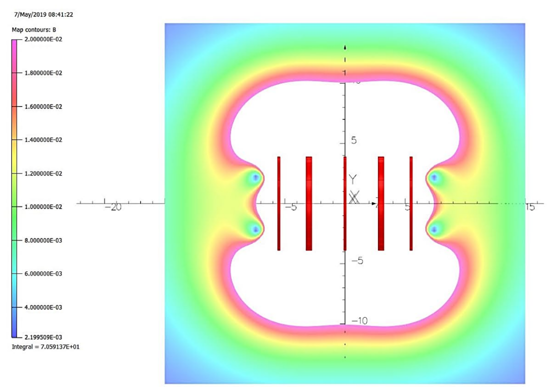


Detector Size:
Length = 12.8 m
Height = ~10 m
Width = 8.5 m

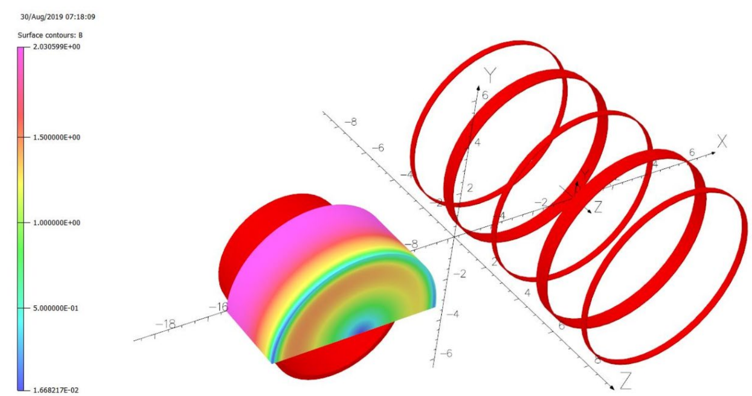
MPD Superconducting Coils Could Expose Adjacent Structures To Significant Magnetic Stray Fields



1000 G Contour



200 G Contour

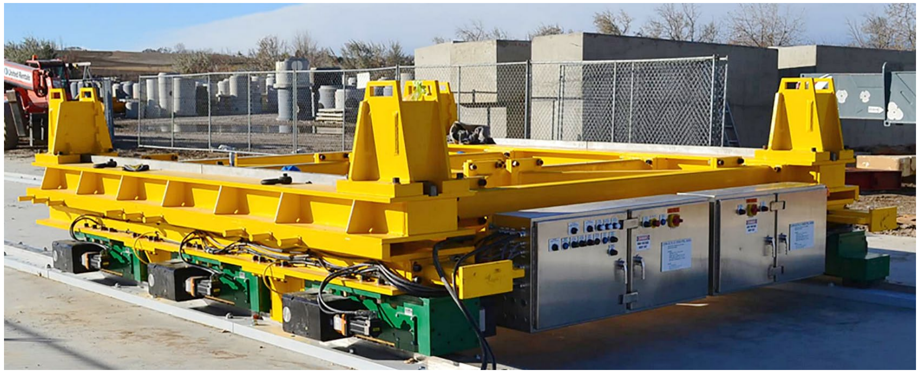


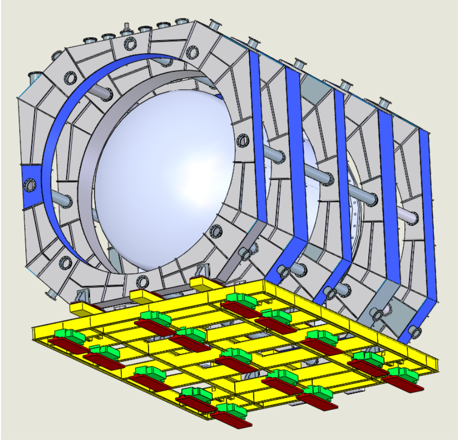
20 tonne-force between MPD and KLOE Plus Added Interaction Between Both Detector Coils

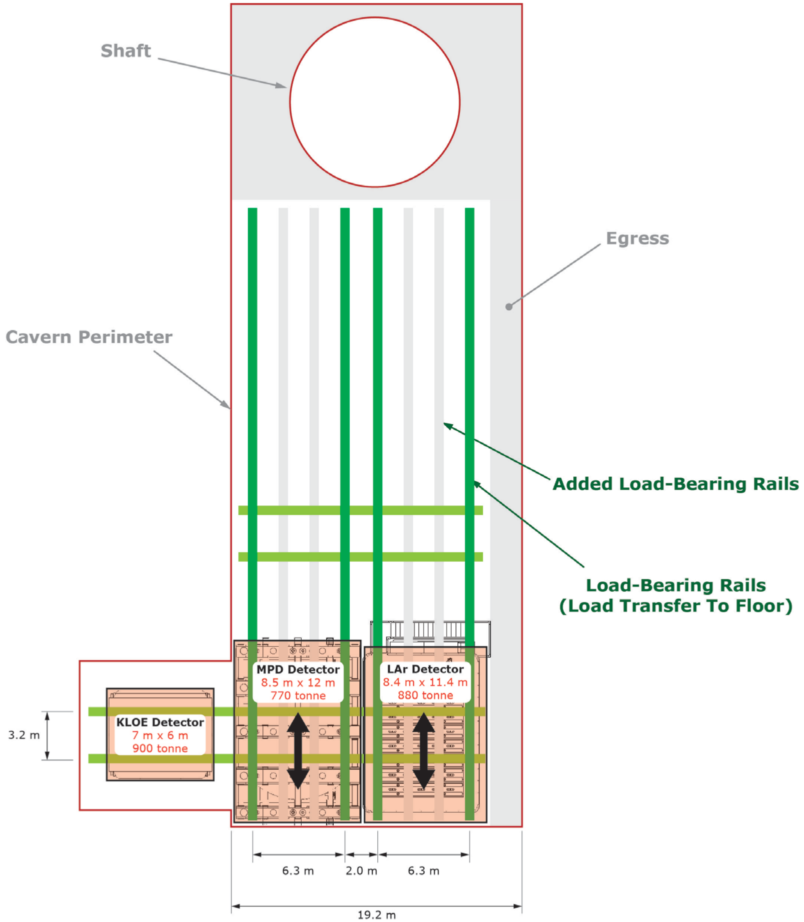
- MPD field may require LAr cryostat room-temperature structure to be fabricated out of stainless steel or aluminum
- More effort will be required to ensure magnetic interactions are fully understood

Simulations by Vladimir Kashikhin

DUNE ND Prism Design Utilizes Commercially Proven Roller Drives Which Distribute Significant Detector Weights







	Approx. Weight [tonne]
LAr Detector	880
MPD Detector	710
KLOE-3DST Detector	900
PRISM	added to detectors

- Control system can synchronize several rows of rollers to distribute weight
- **Guide rail design optimized together with cavern structural design**
- System Permits Smooth Movement

Crane Load Requirements

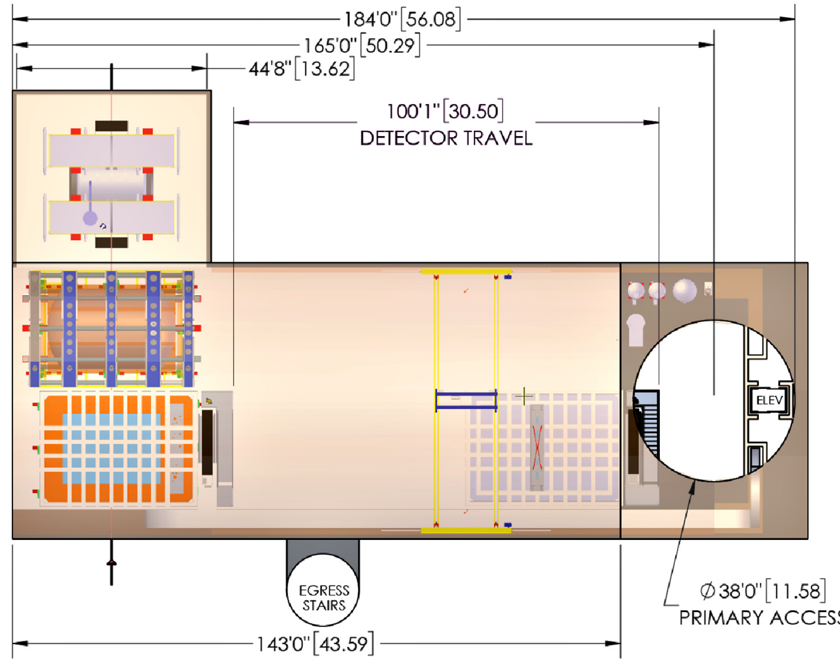
	Quantity
Crane Capacity	50 tonne
Hook Height	≥43 ft

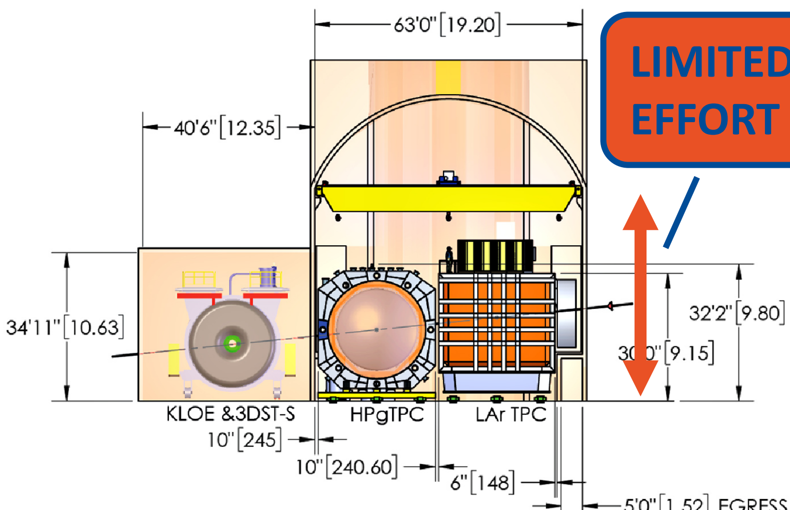
Largest Weights:

- KLOE Magnet (~42 tonne)
- MPD Pressure Vessel (~40 tonne)

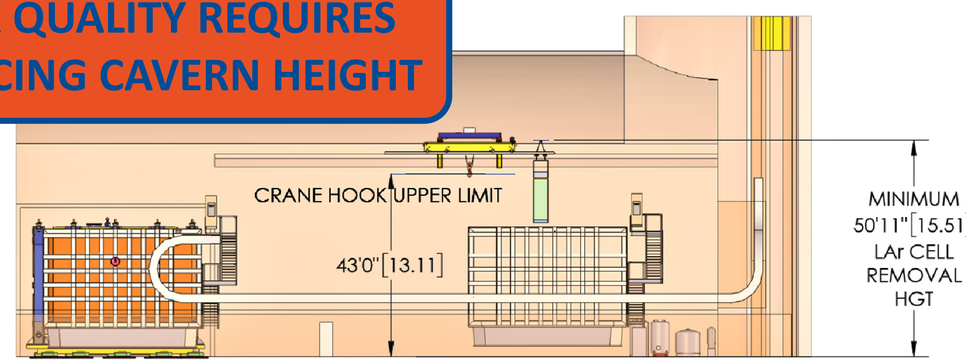
Largest Hook Height Needs:

- LAr Detector Module Removal
- Bridge crane will not permit full module extraction. A special lifting setup in the maintenance position will be implemented

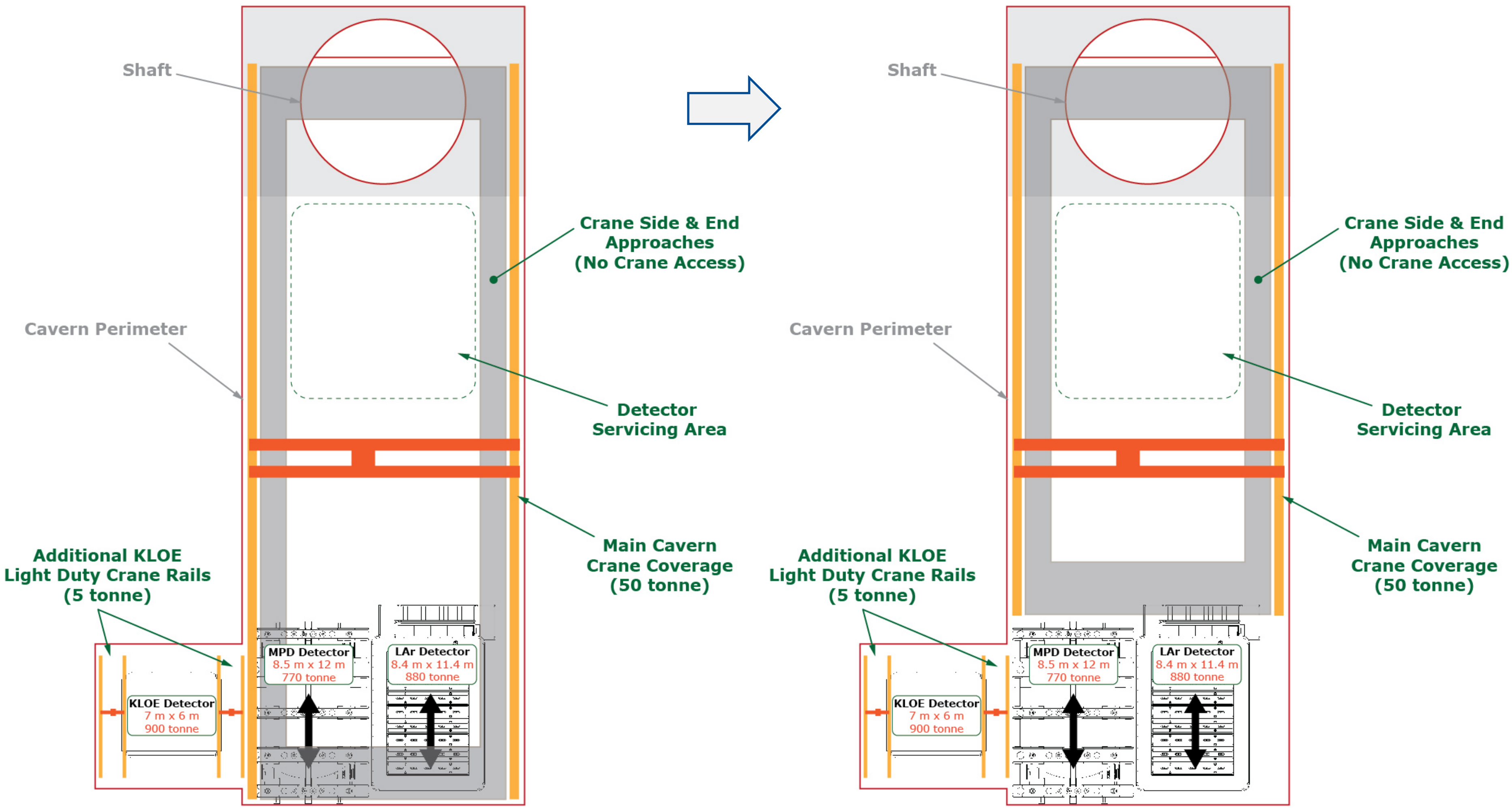




LIMITED ROCK QUALITY REQUIRES EFFORT REDUCING CAVERN HEIGHT



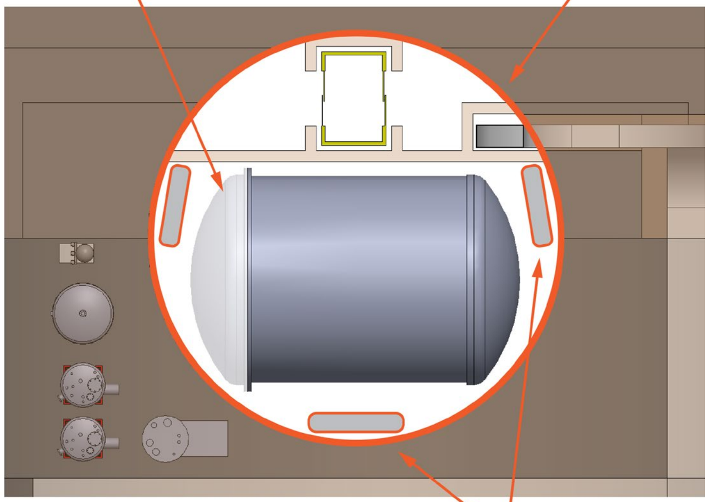
Crane Coverage Area May Be Limited Due To KLOE Alcove Impacting Cavern Structure Design



Shaft Size And Cavern Climate Control

Shaft:

- The cavern shaft must be of large enough diameter to permit lowering the largest detector components
- Largest component is MPD gas tank, a welded pressure vessel which must be lowered into the cavern as a complete unit
- The large shaft diameter will also allow inserting pre-welded LAr warm cryostat support panels
- Shaft will also provide space for utilities routing



	Quantity
Shaft Diameter	≥38 ft (≥11.6 m) diam.

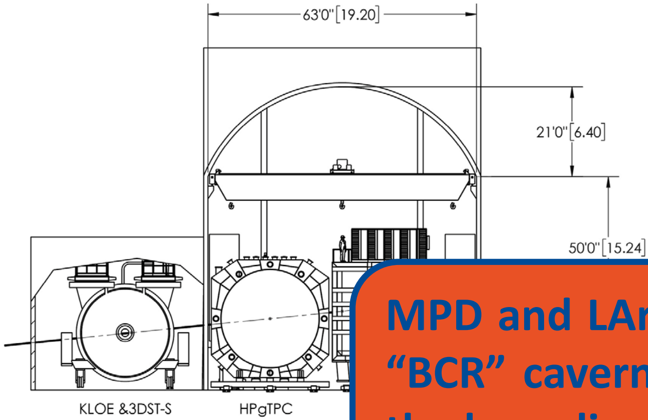
Cavern Climate:

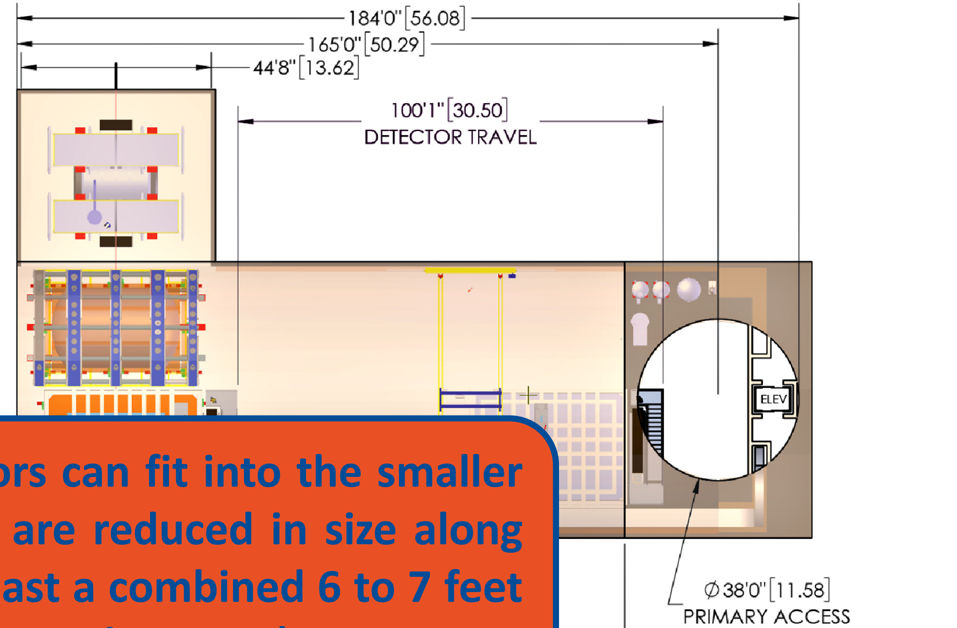
- Conditioned (dried) air will be generated at the surface building and blown into the cavern.
- This approach can control temperature and would significantly reduce cavern humidity. However, such approach cannot actively control or guarantee cavern humidity which will depend on water presence in the cavern or weather conditions on the surface.

Cavern Air Conditioning Requirements

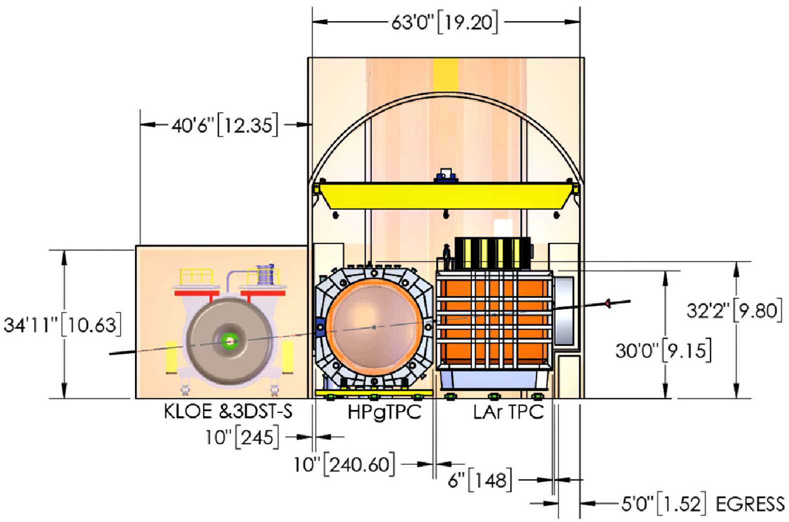
	Range
Temperature	21° ± 5° Celsius
Humidity	self-regulated based on influx of conditioned air from the surface building

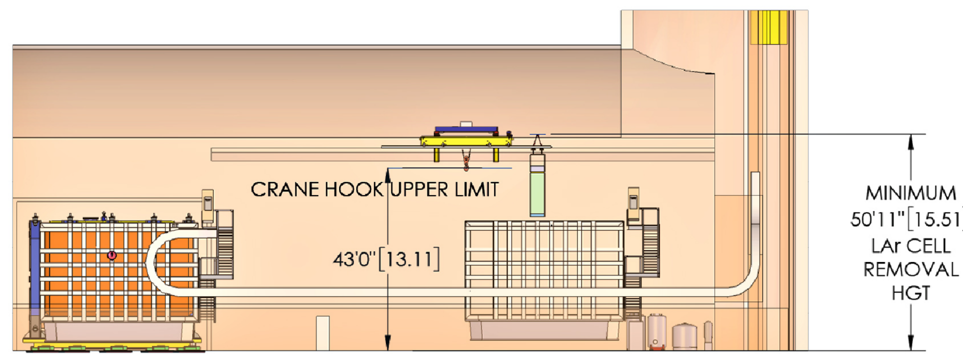
Overall Cavern Size





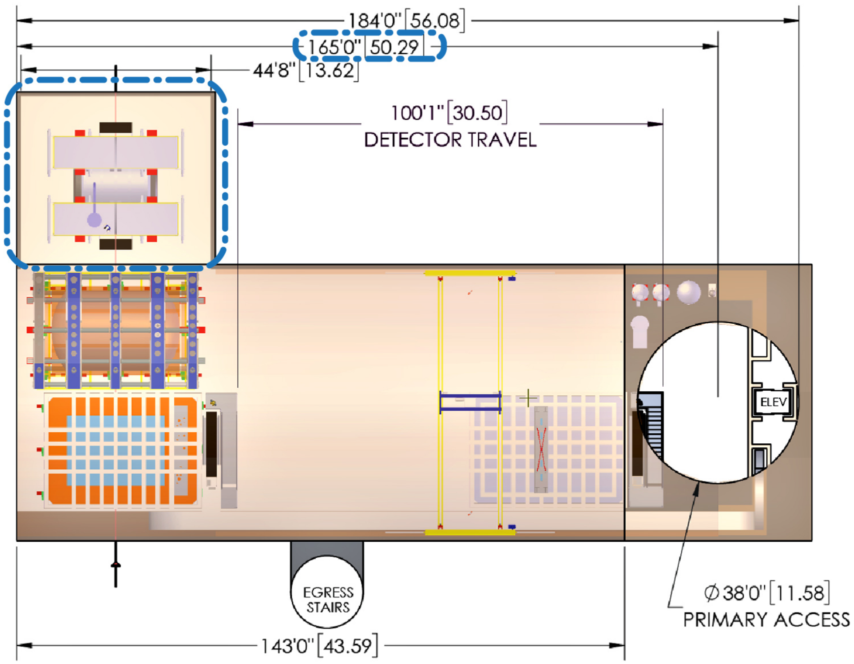
MPD and LAr detectors can fit into the smaller "BCR" cavern if they are reduced in size along the beamline by at least a combined 6 to 7 feet (shared between the two detectors).

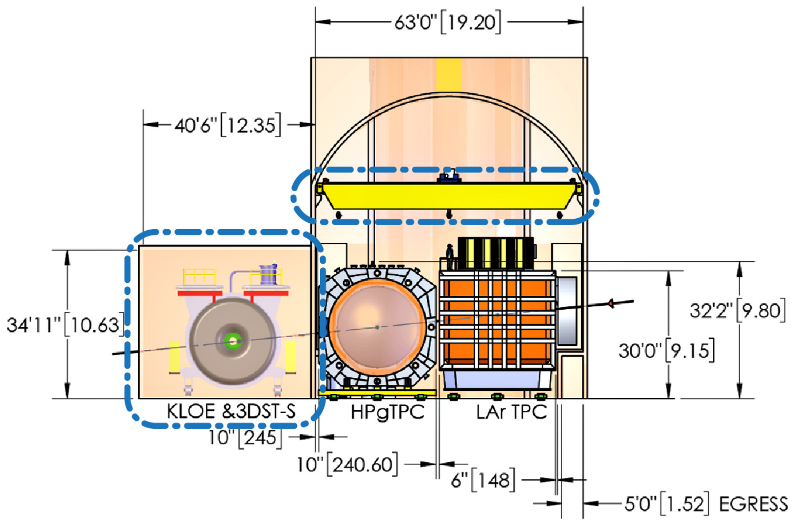


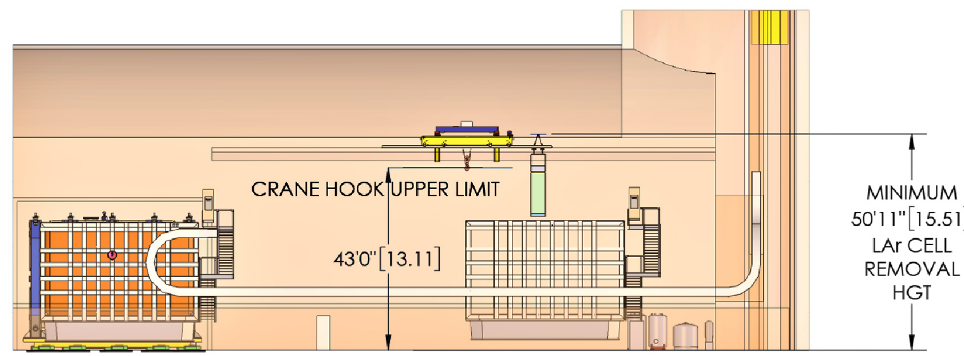


KLOE Alcove
Current Size Request

indicates features not included in LBNF BCR 0332:
(-) larger KLOE alcove
(-) 3 ft longer main cavern
(-) 50 ton crane

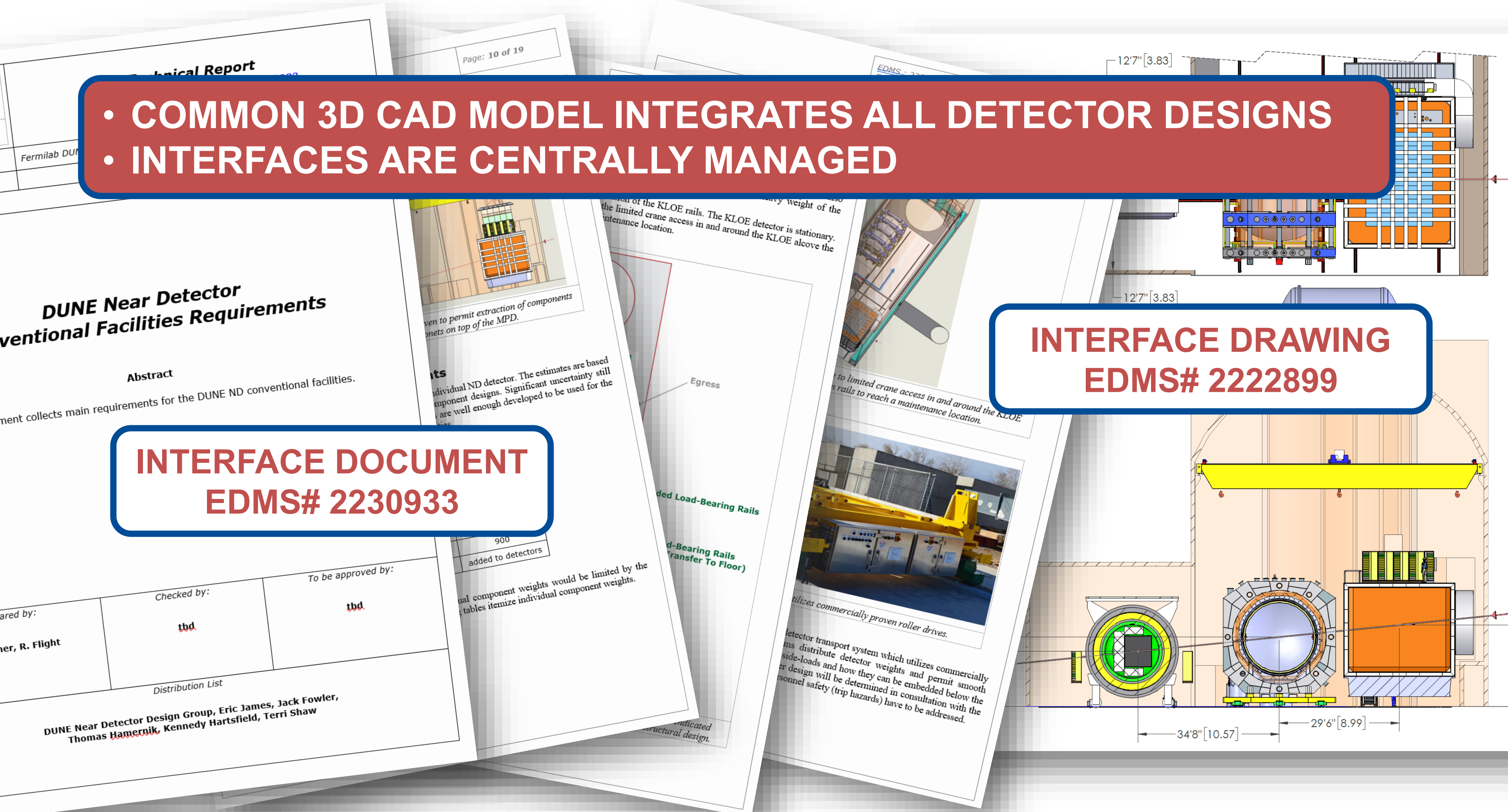






Detector Designs Matured:
ND Requirements Document Defines Facility Interfaces

- COMMON 3D CAD MODEL INTEGRATES ALL DETECTOR DESIGNS
- INTERFACES ARE CENTRALLY MANAGED

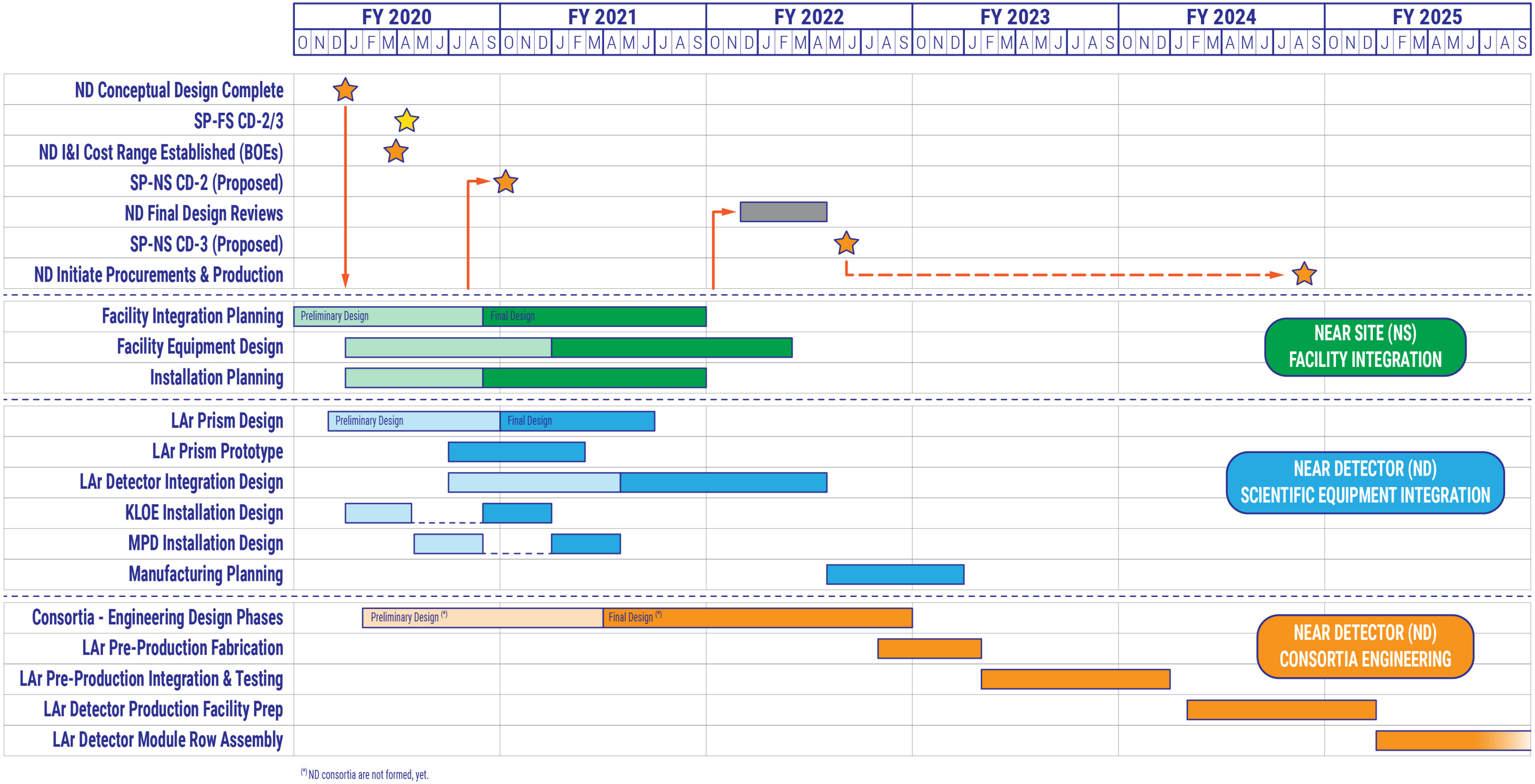


INTERFACE DOCUMENT
EDMS# 2230933

INTERFACE DRAWING
EDMS# 2222899

A frozen document is provided for the Oct DOE IPR on Doc-DB #16604

WBS 131.4.2 Integration & Installation
Design, Prototyping, and Pre-Production Schedule



DUNE-ND installation schedule matches US-project P6 schedule

DUNE-ND Integration Design Scope Definition Matures: Top-Level Schedule Built From Bottom-Up Activities

Facility Integration Planning
(WBS 131.04.02.01)

- **Systems Engineering**
- **Engineering Analysis**
- **Safety Engineering**
- **Procurement Planning**
- **Final Checkout and Energization Plan**
  - Facility Checkout and Energization Plan
  - Prism Checkout and Energization Plan
  - LAr Detector Checkout and Energization Plan
  - MPD Checkout and Energization Plan
  - KLOE Checkout and Energization Plan
- **LOE Activities**
- **M&S**
- **Travel**

Example Activity Breakdowns

- ~300 schedule activities
- Matches US detector scope schedule
- Matches US LBNF/DUNE project schedule
- Will be incorporated in P6 in November
- Labor and procurement cost envelope already captured in P6

Facility Equipment Design
(WBS 131.04.02.01)

- **Integrated Facility Layout**
- **Facility Interface Drawings and Document**
- **Shaft Utilities**
- **Cavern Power Routing**
- **Cavern Water Routing**
- **Cavern Additional Utilities Routing**
- **Top Building Power Routing**
- **Top Building Water Routing**
- **Top Building Additional Utilities Routing**
- **Top Building Cryogenic Storage**
- **Top Building Piping Drawings**
- **Control Room**
- **Interfaces with Conventional Facility Rooms**
- **Mezzanine and Support Structures**
- **Crane and Maintenance Structures**
- **Structural Engineering: Attachments to Cavern and Top Building**
- **Electrical Engineering**
  - Power Spreadsheet
  - Grounding
  - Power Distribution
  - Controls Layout
- **Electrical Routing Design - Cable Trays**
- **Electrical Routing Design – Racks and Servers**
- **Electrical Routing Design - Safety Systems**

Path To SP-FS CD-2/3: April 2020

- Detailed near detector schedule in P6
- Near detector initial BOEs
- Near detector initial risk analysis
- Installation plans
- Cavern and detector value engineering
- Implement formal configuration control

Path To SP-NS CD-2: October 2020

- Near detector BOEs
- Near detector risk analysis
- Start PRISM detail design
- Surface and cavern utilities/cryogenics routing design
- Continue detector detail design integration
  - Detector interface documents
  - Design reviews
- Enhance engineering support in remaining disciplines
  - Electrical engineering
  - Cryogenic engineering

Summary

- DUNE near detectors have significantly matured in design.
- US-scope near detector baseline design needs to be developed within a year. However, cavern size and major interfaces must mature within months.
- US-scope (LBNF, LAr US Scope, I&I) represents a substantial project commitment to the near detector reference design and will benefit the international near detector community.
- Staff is now in place to oversee ND systems engineering and to organize design integration and interface definitions.
- Integration & Installation (I&I) engineering staff also supports detector design activities related to integration and installation. I&I continues to develop a close working relationship with near detector physics and engineering personnel.