



Layout and Installation Support

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Cost & Schedule Review for ND-LAr 2x2 Demonstrator

August 2 – 4, 2021



Overview

- Introduction to subsystem and deliverables
 - Sub-systems: mechanical structure and support
 - Deliverables: layout and installation
- Scope of work
 - For 2x2 @ LArTF
 - For 2x2 @ MINOS
 - Interface to other systems
- Resource plan and schedule
 - High level design schedule & milestones
 - M&S
 - Labor
 - Resource plan and schedule: LArTF
 - Resource plan and schedule: MINOS
- List of risks
- Summary

Introduction to deliverables

- Layout and installation support at two test facilities:
 - LArTF @ BNB
 - MINOS @ NuMI
- 2x2 @ LArTF
 - Ground floor, garage area
- 2x2 @ MINOS
 - North end of the MINOS cavern
- Responsible institution: Fermilab (ND/PPD)

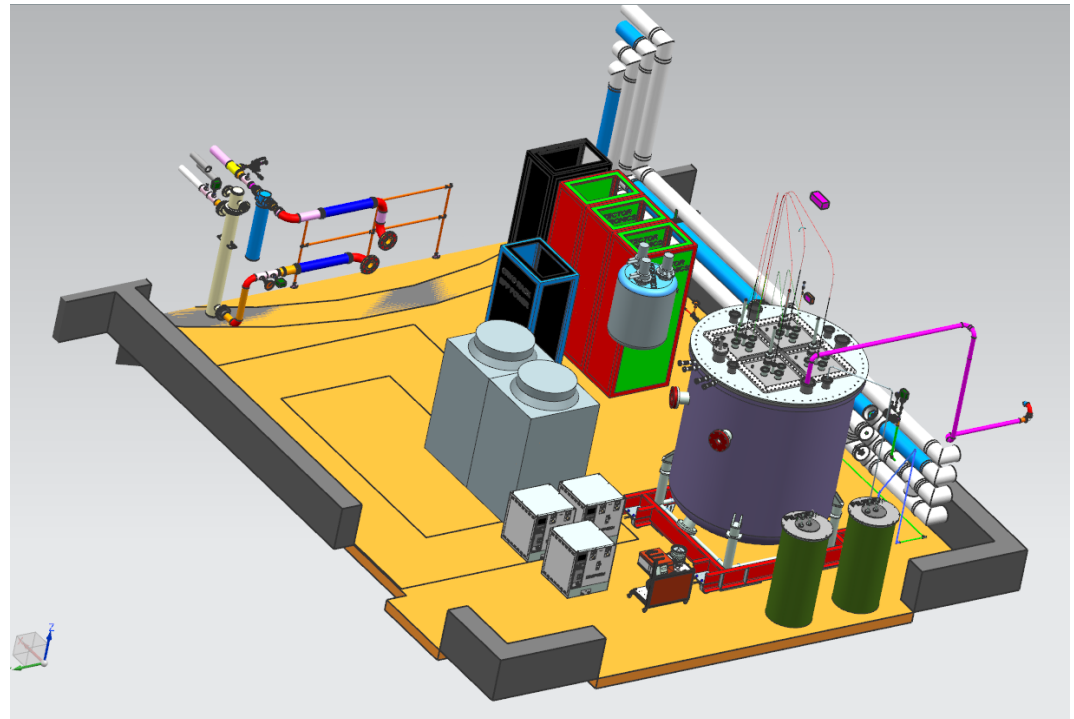


Yellow dashed line: Axis of the BNB (Booster Neutrino Beam)
Pink line: Axis of the NuMI (Neutrino Beam from Main Injector)

Introduction to Deliverables (continued)



- Goals for 2x2 @ LArTF
 - Test the cryogenic system and other subcomponents before moving to the MINOS underground area where the full prototyping will take place.
 - Perform cosmic ray and BNB runs
- Special features:
 - LAr fill from MicroBooNE
 - No use of LN₂:
Recondensing boil-off gas using water cooled cryo-compressors and a condenser; vacuum insulated filter vessels
 - Module insertion and extraction outside the building using mobile crane*

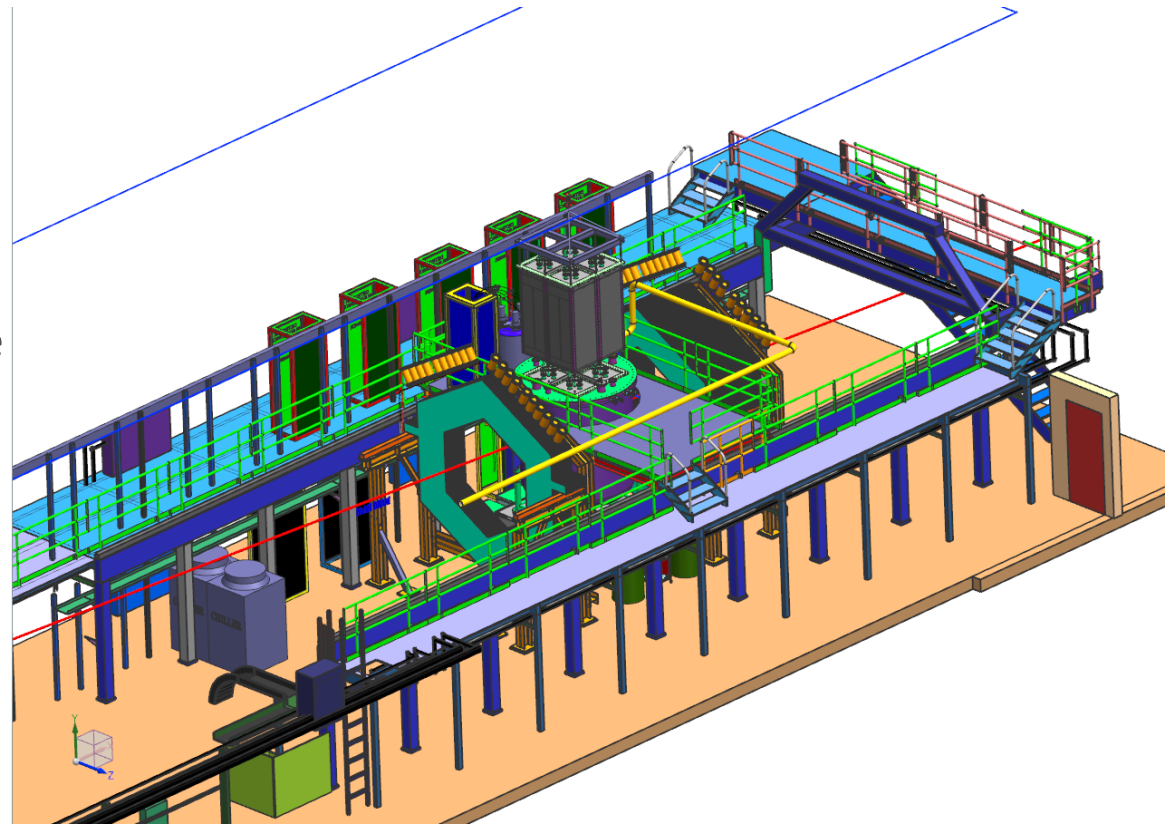


* 70-ton load capacity with alarming feature for overload and momentum

Introduction to Deliverables (continued)

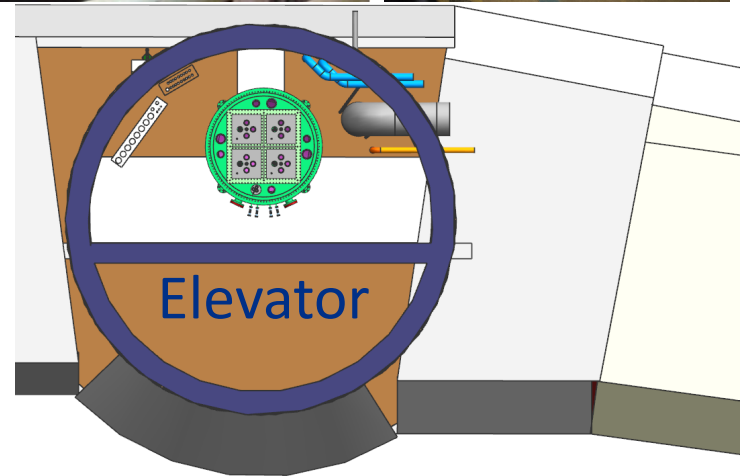
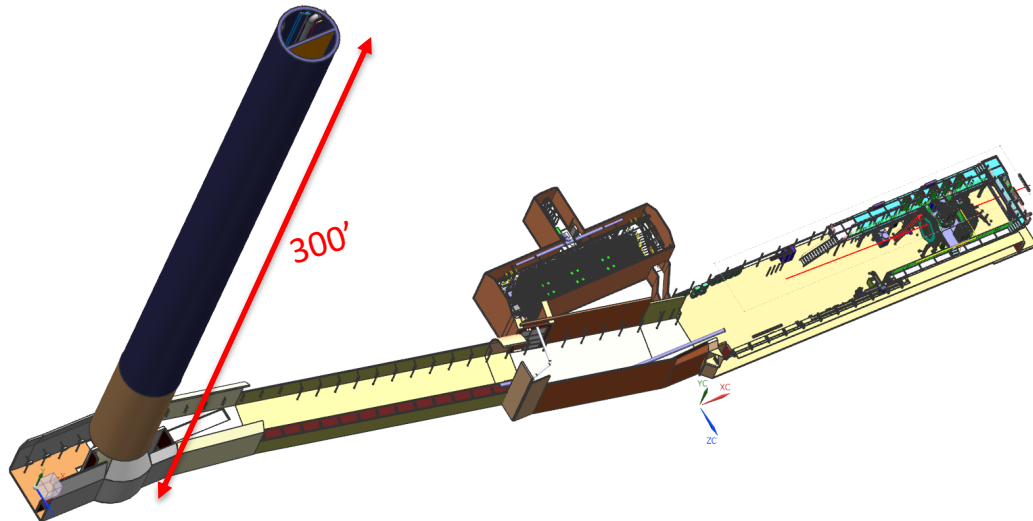


- Goals for 2x2 @ MINOS: Neutrino beam test for detector characterization
 - Collect neutrino data in NuMI beam
 - Develop neutrino reconstruction and analysis techniques
- Special features:
 - Challenge in ~300' underground installation
 - Initial fill with portable 160 liter LAr dewars: delivery of more than 60 dewars in elevator from the surface to the underground.
 - No use of LN₂



Introduction to Deliverables (continued)

- Surface building, access shaft, tunnel and MINOS hall



Scope of Work for 2x2 @ LArTF



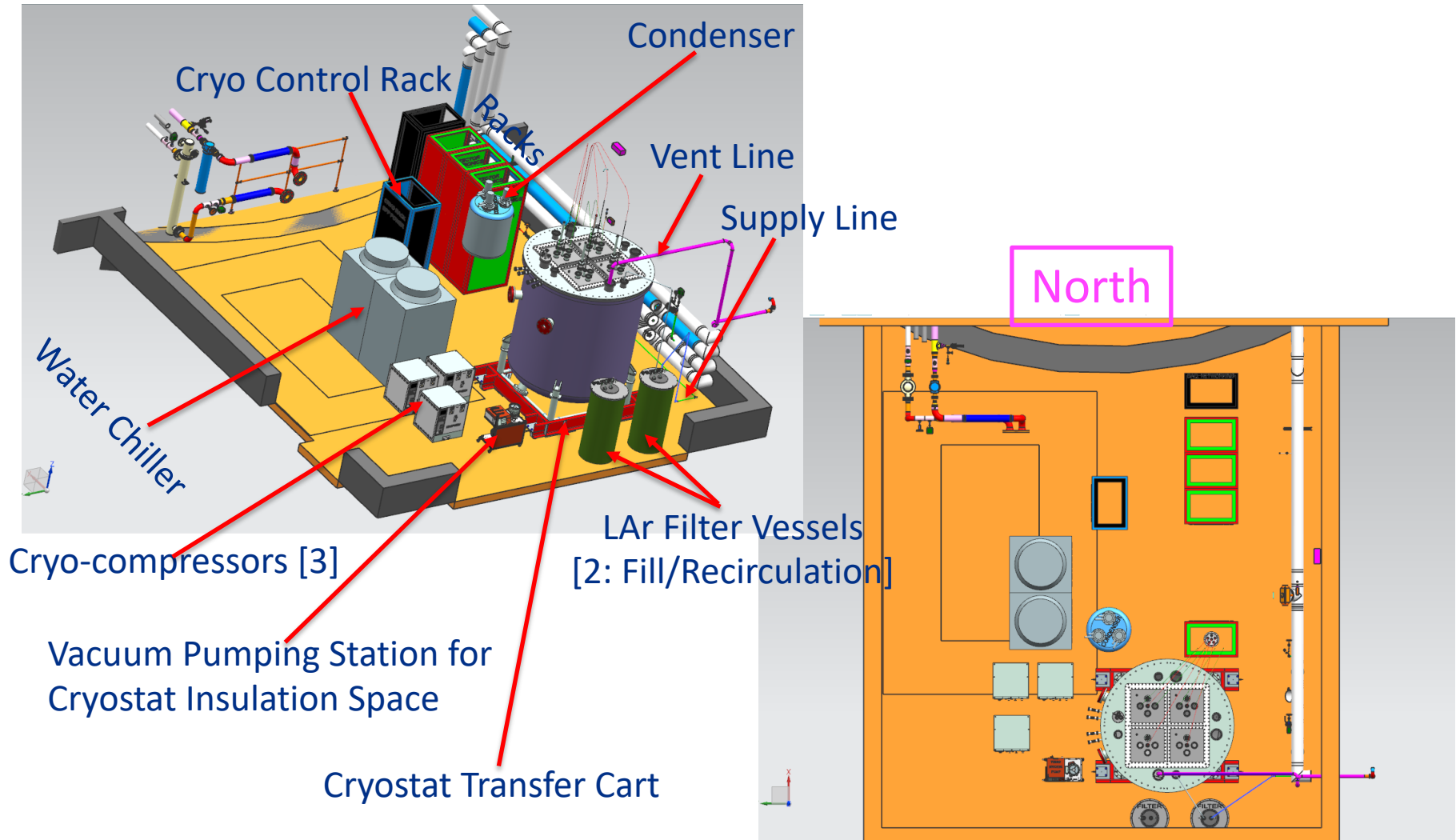
- Cryostat (low pressure vessel) qualification for the operations at Fermilab
- ODH analysis and mitigation
- QA/QC inspection for modules
- Inspection and certification of module service feedthroughs
- Installation of feedthroughs on module top flanges
- Module insertion to cryostat
- Installation of cryostat and cryogenic equipment
- Piping (vent and supply lines, connection between equipment) layout and installation
- Installation of cryogenics instrumentation and controls
- Installation of readout electronics, DAQ and networking system
- Safety reviews of sub-systems
- Safety reviews of work plan
- Operational Readiness Clearance (ORC) reviews and safety walk-throughs

Scope of Work for 2x2 @ LArTF (continued)



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- Layout



Scope of Work for 2x2 @ LArTF (continued)



- **Provision of mechanical structure** (Design, fabrication, and installation)
 - Cryostat transfer cart [shown on p. 8]
 - Module lifting fixture [shown on p. 11]
 - Cart for LAr filter vessel (easy handling for maintenance service)
 - Support for condenser and cryogenic piping
 - Support for cable trays, readout electronics and racks

Scope of Work for 2x2 @ MINOS



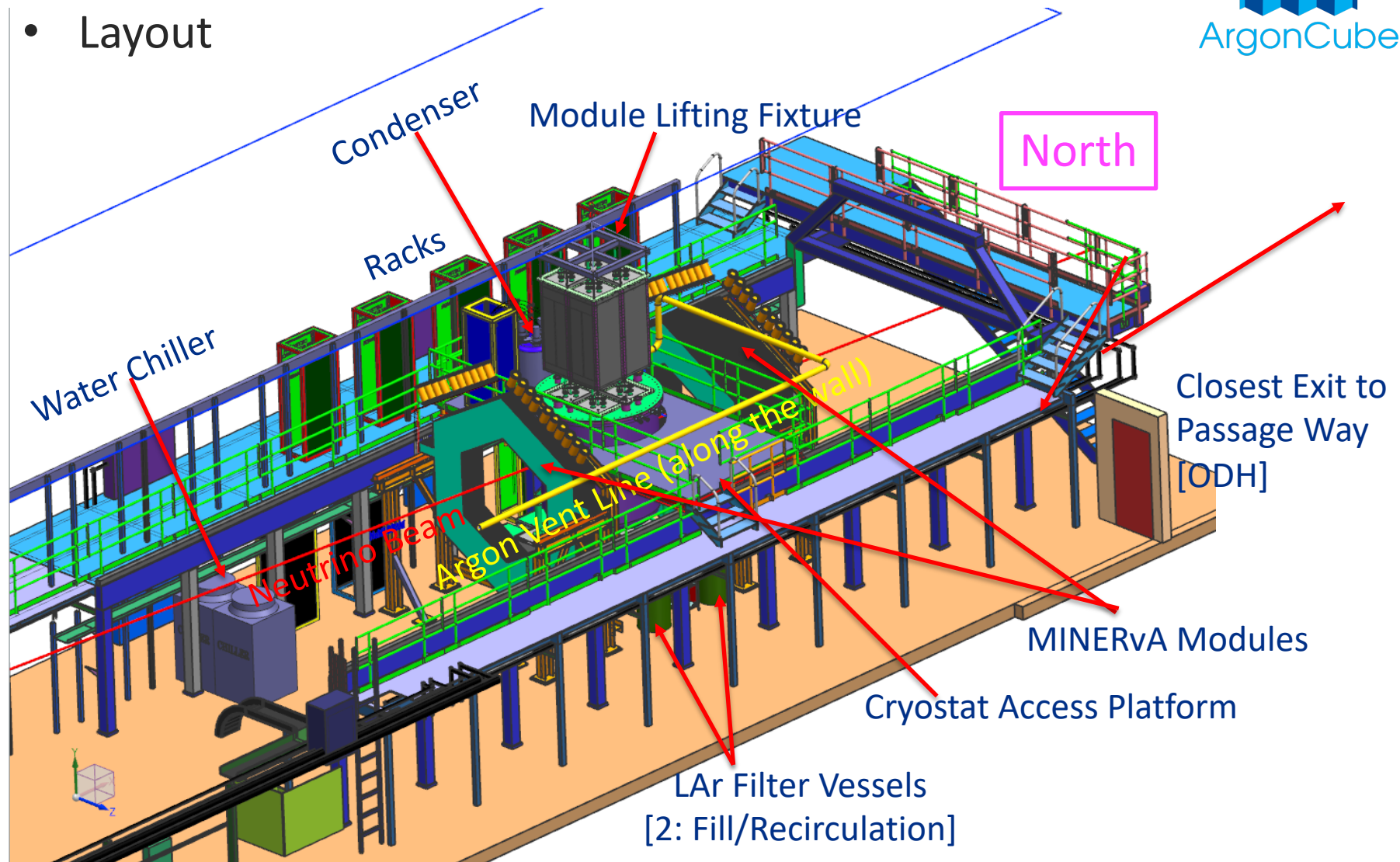
- Re-installation of MINERvA modules
- Installation of cryostat access platform
- Installation of ODH monitoring and mitigation system
- Decommissioning of 2x2 @ LArTF; transfer of cryostat, cryogenic system and modules to MINOS cavern
- QA/QC inspection for modules
- Installation of cryostat and modules
- Installation of cryogenic equipment
- Piping (vent and supply lines, connection between equipment) layout and installation
- Installation of readout electronics, DAQ and networking system
- Safety reviews of sub-systems
- Safety reviews of work plan
- Operational Readiness Clearance (ORC) reviews and safety walk-throughs

Scope of Work for 2x2 @ MINOS (continued)



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- Layout



Scope of Work for 2x2 @ MINOS (continued)



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- **Provision of mechanical structure** (Design, fabrication, and installation)
 - Cryostat transfer cart (used in locations where we don't have crane coverage for move: outside the LArTF and tunnel) [shown on p. 8]
 - Cryostat support (concrete blocks for elevation adjustment, electrical isolation) [shown on p. 31]
 - Module lifting fixture [shown on p. 11]
 - Cryostat access platform [shown on p. 11]
 - Cart for LAr filter vessel (easy handling for maintenance service)
 - Support for cryogenic equipment and piping
 - Support for cable trays, readout electronics and racks

Scope of Work – Interface to Other Systems



- **System [A]: *Integration & Installation (I&I)***
- **Interface with System [B]: *Cryogenics System (Fermilab)***
 - Equipment layout and support
 - System [B] provides the dimensions of cryogenic equipment and piping connection scheme.
 - System [A] provides a CAD layout design and installation support.
 - Piping layout and routing
 - System [B] provides the piping scheme of cryogenics, venting and ODH mitigation plan.
 - System [A] provides a CAD layout design and installation support.
 - Cryostat and cryogenic equipment access
 - System [B] defines a set of access requirements for cryostat and cryogenics operation.
 - System [A] provides an appropriate method (access platform, support stand, transfer cart, etc.)

Scope of Work – Interface to Other Systems



- **System [A]: Integration & Installation (I&I)**
- **Interface with System [B]: Electronics Integration**
 - Rack layout, support and installation
 - System [B] provides a list of racks, dimensions of racks and access and space clearance requirements.
 - System [A] provides a CAD layout and installation support.
 - Cable layout and routing
 - System [B] provides cable routing scheme from the module to electronics on (or near) the cryostat top or to the electronics racks.
 - System [A] provides a CAD layout, cable length estimate and installation support.
 - Cable tray support
 - System [B] provides a list of cable trays and their locations.
 - System [A] provides a CAD layout with design and installation support.

Scope of Work – Interface to Other Systems



- **System [A]: *Integration & Installation (I&I)***
- **Interface with System [B]: *Module Structure (Bern)***
 - Cryostat and module installation
 - System [B] provides a list of equipment on the cryostat and modules with CAD files.
 - System [A] integrates the equipment in the master CAD model, develop appropriate methods to handle them safely (e.g. cryostat transfer cart, module lifting fixture, etc.) and perform engineering studies and safety reviews required for their operations at Fermilab.
 - Module assembly QA/QC
 - System [B] provides module QA/QC procedure and instructions based on experience from Module-0 test.
 - System [A] provides mechanical support for QA/QC inspection.

Resource Plan and Schedule



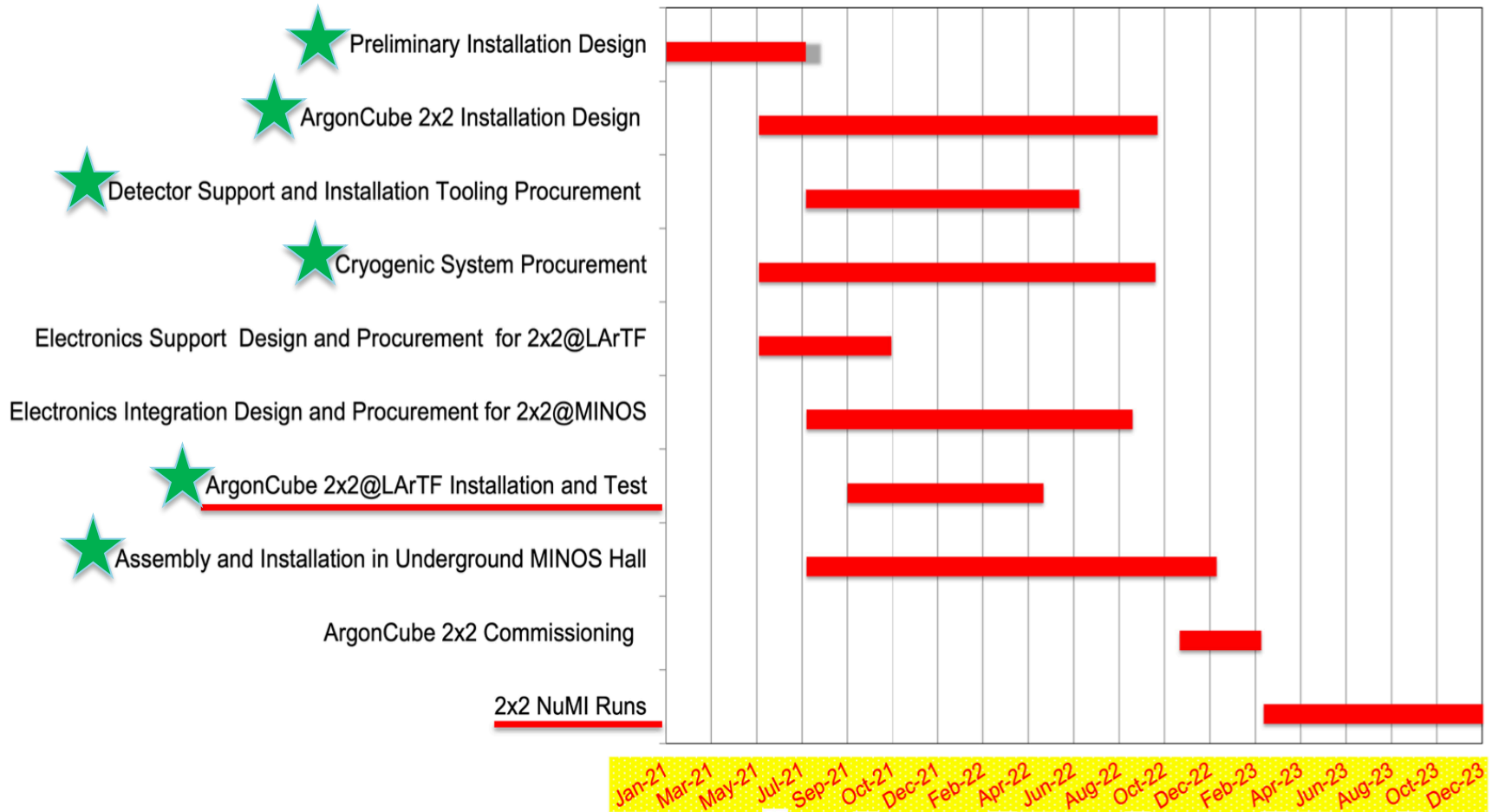
- High level design schedule and milestones

#	Milestone Tasks	Completion
✓ 1	2x2 cryostat arrives Fermilab from BERN	July 30, 2021
2	First TPC module and major cryogenics equipment received by FNAL	August 31, 2021
3	Last TPC module received for LArTF test (2nd TPC)	October 29, 2021
4	All drift HV component received for 2x2@LArTF	November 1, 2021
5	All light readout electronics received for 2x2@LArTF	November 1, 2021
6	All charge readout electronics received for 2x2@LArTF	November 1, 2021
★ 7	Completion of preliminary installation design	July 8, 2021
8	Completion of 2x2@LArTF cryogenics design	December 15, 2021
9	Electronics and DAQ are ready for 2x2@LArTF test	February 15, 2022
★ 10	Cryogenics system is ready for 2x2@LArTF test	February 22, 2022
11	Completion of LArTF test and 2x2 is ready to move to MINOS hall	May 19, 2022
12	Final TPC modules received for MINOS test (3rd and 4th TPCs)	July 6, 2022
13	Completion of 2x2@MINOS cryogenics design	October 17, 2022
★ 14	Cryogenics system is ready for 2x2 commissioning	December 16, 2022
15	Electronics and DAQ are ready for 2x2 commissioning	November 14, 2022
16	2x2 is ready to start commissioning	January 3, 2023
17	2x2 is ready for physics data running	March 3, 2023

Resource Plan and Schedule (continued)



- ArgonCube 2x2 Schedule



Resource Plan and Schedule: M&S



- Procurement status for big purchasing items

Equipment/Service	Status	Cost/Estimate [\$]	Contingency [%]	FY
1.8 kW cryocoolers (Cryomech AL600)	PO #679663 (Estimated Delivery: 02/08/22)	51K 154K	0	21 22
Water chiller (Haskris R1600)	PO # (Estimated Delivery: Oct/21)	38K	0	21
Condenser and other ancillary components (custom design by Cryomech)	Waiting for a quote	50K	20	21
Vacuum pumping station (Pfeiffer Vacuum, P/N: PM S48 811 00)	PO #679749 (Estimated Delivery: Dec/21)	30K	0	21
Cryostat safety relief valve (Anderson Greenwood 9300H low pressure pilot operated relief valve, P/N: 9390HP03RSTTHM)	Req # (Estimated Delivery: Mar/22)	Bern Deliverable		21
LAr filter vessels (custom design by a qualified vendor)	Technical specification document ready for RFQ	Bern Deliverable		21

Resource Plan and Schedule: M&S



- Procurement status for big purchasing items (continued)

Equipment/Service	Status	Cost/Estimate [\$]	Contingency [%]	FY
Cryogenic equipment on main cryostat and LAr filter vessels	Waiting for requirements to be finalized	30K	30	21
Heater and Vaporizer	Recycle from PC4	1K 1K	20	21 22
Gas analyzers	Recycle from MicroBooNE and PAB	1K 4K	20	21 22
Implementation of ODH measures @ MINOS (including exhaust fan replacement)	Conceptual Design	120K	40	22
Venting Lines (@LArTF, @ MINOS)	Waiting for requirements to be finalized	10K 10K	20	21 22
Supply line @ LArTF	Waiting for requirements to be finalized	5K	20	21
Purity monitor feedthrough and its readout electronics	Waiting for plan to be finalized	5K	20	21

Resource Plan and Schedule: M&S



- Procurement status for big purchasing items (continued)

Equipment/Service	Status	Cost/Estimate [\$]	Contingency [%]	FY
Cryostat inspection per API 510	Waiting for requirements to be finalized	10K	30	21
Cryostat transfer cart (In-house design)	Fabrication to be started when material arrives	5K	0	21
Module lifting fixture (In-house design)	Conceptual Design (shown on p. 41)	5K	40	21
LAr filter vessel cart (In-house design)	Waiting for requirements To be finalized	5K	30	21
Cryogenic equipment support	Waiting for requirements to be finalized	5K	30	21
Cryostat access platform and cryostat support for 2x2 @ MINOS (In-house design)	Conceptual Design	80K	40	22

Resource Plan and Schedule: Labor



- Labor

	Cryogenic Engineer [FTE Days]	Mechanical Engineer [FTE Days]	Mechanical Designer [FTE Days]	Process Control Engineer [FTE Days]	Mechanical Technician [FTE Days]	Electrical Engineer [FTE Days]	Electrical Technician [FTE Days]	Computing Specialist [FTE Days]
FY19 - 20	105	105	50	10	0	50	0	0
FY21	190	125	70	10	104	125	25	95
FY22 - 23	367	205	117	189	225	213	155	327
Total	662	435	237	209	329	388	180	422

Resource Plan and Schedule: 2x2 @ LArTF

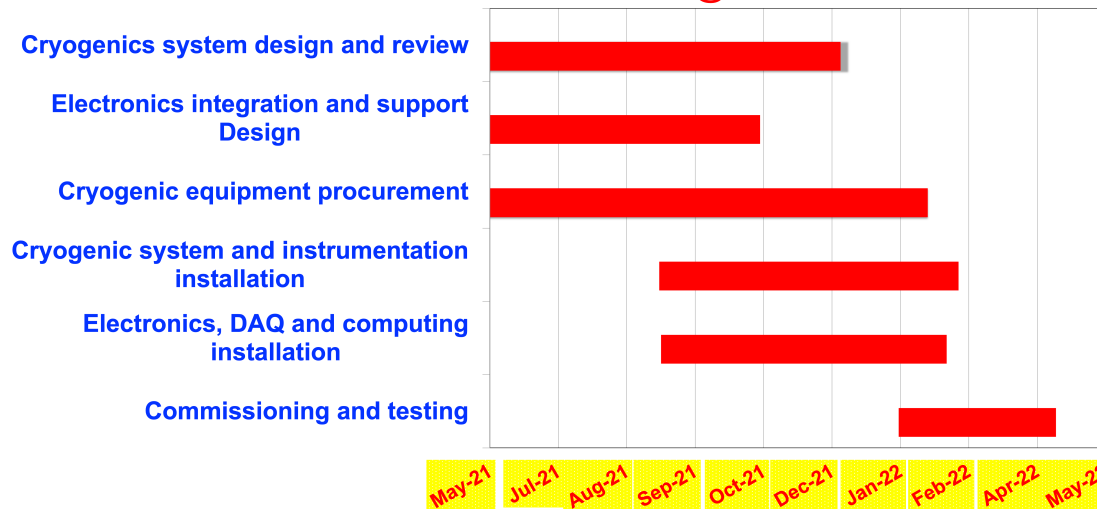


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- FTEs for design, installation and commissioning

Task	Start	Finish	ME [FTE-D]	ME-PC [FTE-D]	CE [FTE-D]	EE [FTE-D]	MD [FTE-D]	MT [FTE-D]	ET [FTE-D]	Com-Sp [FTE-D]	M&S [\$]
Cryogenics system design and review	05/07/21	12/15/21	40	20	120		30				
Electronics integration and support design	05/07/21	10/29/21		10		60				45	
Cryogenic equipment procurement	05/07/21	02/04/22			45						330K
Cryogenic system and instrumentation installation	08/31/21	02/22/22	40	10	60	12		120	20		
Electronics, DAQ and computing installation	09/01/21	02/15/22		12		36			60	7	
Commissioning and testing	01/18/22	04/20/22		20	30	20				20	

2x2@LArTF Installation



Resource Plan and Schedule: 2x2 @ MINOS

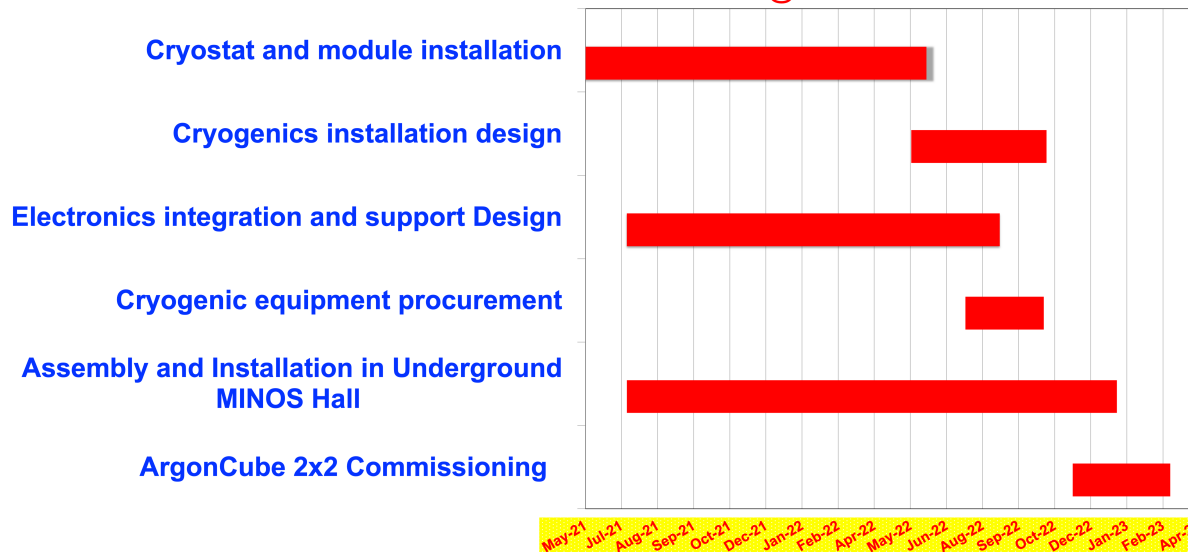


ArgonCube

- FTEs for design, installation and commissioning

Task	Start	Finish	ME [FTE-D]	ME-P [FTE-D]	CE [FTE-D]	EE [FTE-D]	MD [FTE-D]	MT [FTE-D]	ET [FTE-D]	Com-Sp [FTE-D]	M&S [\$]
Cryostat and module installation design	05/10/21	06/06/22	105		5		70				
Cryogenics installation design	05/20/22	10/17/22	40	25	110		40				
Electronics integration and support design	07/09/21	08/26/22		40		40			10	95	
Cryogenic equipment procurement	07/19/22	10/14/22	5		10						70K
Assembly and installation	07/09/21	01/03/23	55	15	55	70	10	194	70	65	
Commissioning and testing	11/15/22	03/03/23		25	30	25				90	

2x2@MINOS Installation



List of Risks



Ranking	Critical Tasks	Risk Impact	Task Completion Dates	WBS Element #
1	Cryostat vessel certification	Schedule	9/29/2021	1.2.5a.7 & 1.6a.2.0
2	Cryocooler system specification and delivery	Schedule & Cost	1/21/2022	1.4.1.1 to 1.4.1.6
3	Cryogenics P&ID and equipment specification	Schedule	9/29/21	1.2.5a.1
4	Cryocooler system installation	Schedule	2/22/2022	1.6a.2.8
5	Final ORC of readout electronics and DAQ for 2x2@LARvTF	Schedule	2/15/2022	1.6a.3.8
6	TPC module inspection QA/QC	Schedule & Cost	10/29/21, 8/3/22	1.6a.2.1, 1.6.5
7	Additional cryogenic equipment procurement for MINOS	Cost, Schedule & Technical	10/14/2022	1.4.4 & 1.2.5.1 & 1.6.7
8	ODH mitigation and monitoring system installation for 2x2@MINOS	Cost & Schedule	10/14/2022	1.6.3
9	Cryogenics and operation safety review for 2x2@MINOS	Schedule	12/16/2022	1.6.8
10	Cryostat access platform support installation	Cost & Schedule	6/6/2022	1.6.2
11	Low-noise transformer and AC distribution in MINOS	Cost	11/2/21	1.5.1 & 1.6.9
12	Networking upgrade in MINOS hall	Cost	9/14/2022	1.5.5 & 1.6.9
13	Timing and trigger interfaces with ACNET system	Schedule	9/14/22	1.5.3

List of Risks (continued)



- [Ranking #4] Cryogenic equipment layout, installation and support for 2x2 @ LArTF
 - Impact on *schedule* (to be completed: 02/22/2022)
 - Reason(s): (1) a few cryogenic equipment will show up very close to the completion date due to their long lead time, (2) COVID-19 may have impact on the delivery date of equipment.
 - Mitigation: (1) follow up with vendors to have the equipment delivered on time as promised, (2) advance planning for layout and installation, and (3) [partial] completion of review before the equipment arrives if a review is required.
- [Ranking #10] Cryostat access platform design and installation for 2x2 @ MINOS
 - Impact on *cost & schedule* (to be completed: 06/06/2022)
 - Reason(s): (1) contingency for cost estimate at the conceptual design level is high (~40% in p. 20), (2) identification of technician labor for fabrication.
 - Mitigation: (1) making an adequate planning for design, material procurement, fabrication and installation of the access platform, (2) follow up frequently with the potential technician workforce to have a good understanding on their workload.

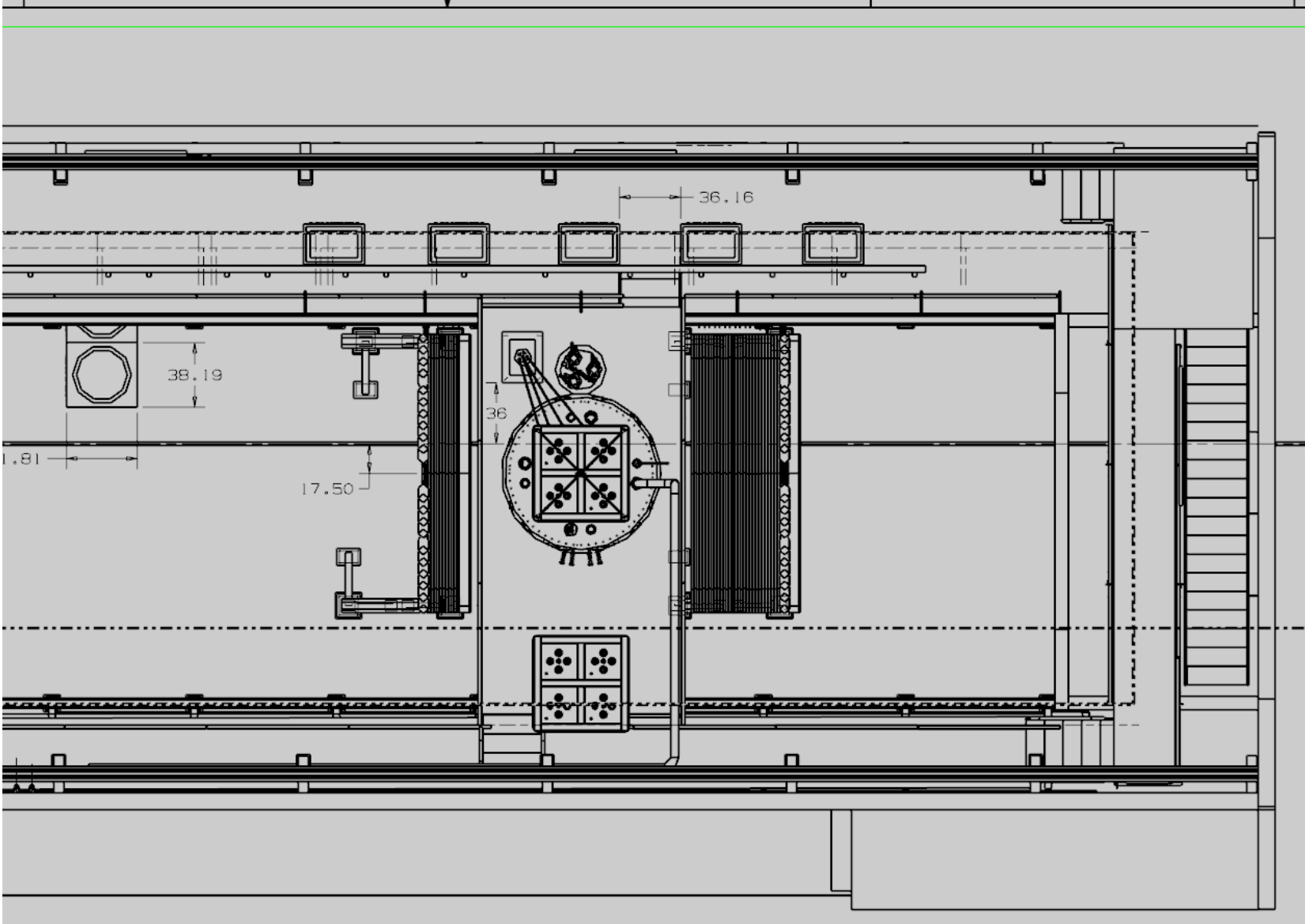
Summary

- Overall status: Completion of preliminary installation design
 - Major requirements are understood and specified.
 - There are baseline detector transportation and installation concepts.
 - There are baseline experimental layouts at two test facilities.
 - The orders for major cryogenic equipment have been placed except for couple remaining.
 - The conceptual designs of mechanical structure exist.
- Outlook
 - Continue to clarify the details of interface between systems for integration.
 - Finish up the procurement of major cryogenic equipment.
 - Continue to develop the design of mechanical structure and fabricate.
 - Continue to develop and refine installation plans (to ensure efficiency and safety).
- Concerns
 - Impact on schedule due to a few cryogenic equipment with long lead time
 - Availability of technician/welder workforce for the fabrication and installation of mechanical structure and other installation activities.

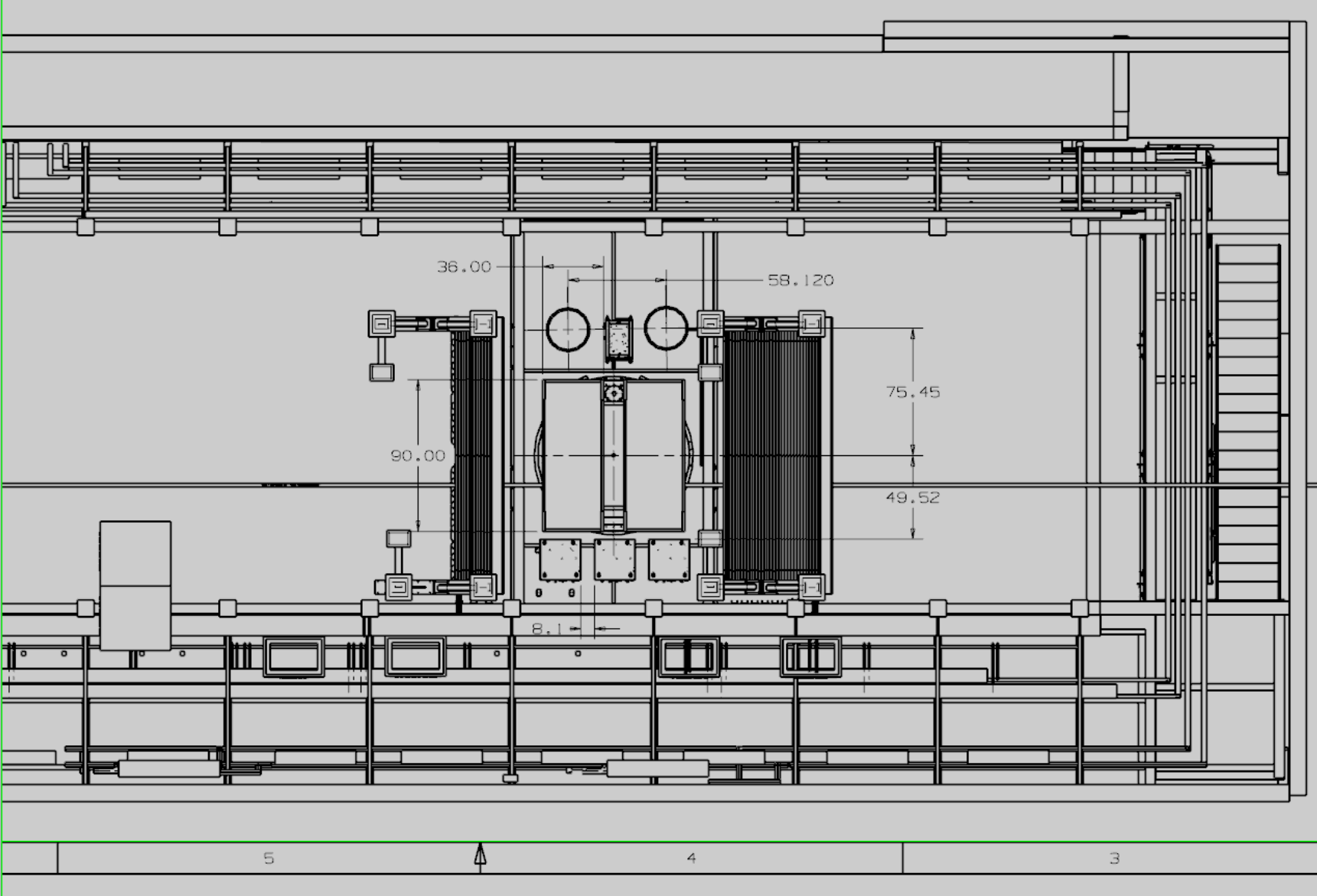
Backup Slides

Layout for 2x2 @ MINOS (Different views)
Module insertion and extraction for 2x2 @ MINOS
Design of cryostat transfer cart
Design of module lifting fixture

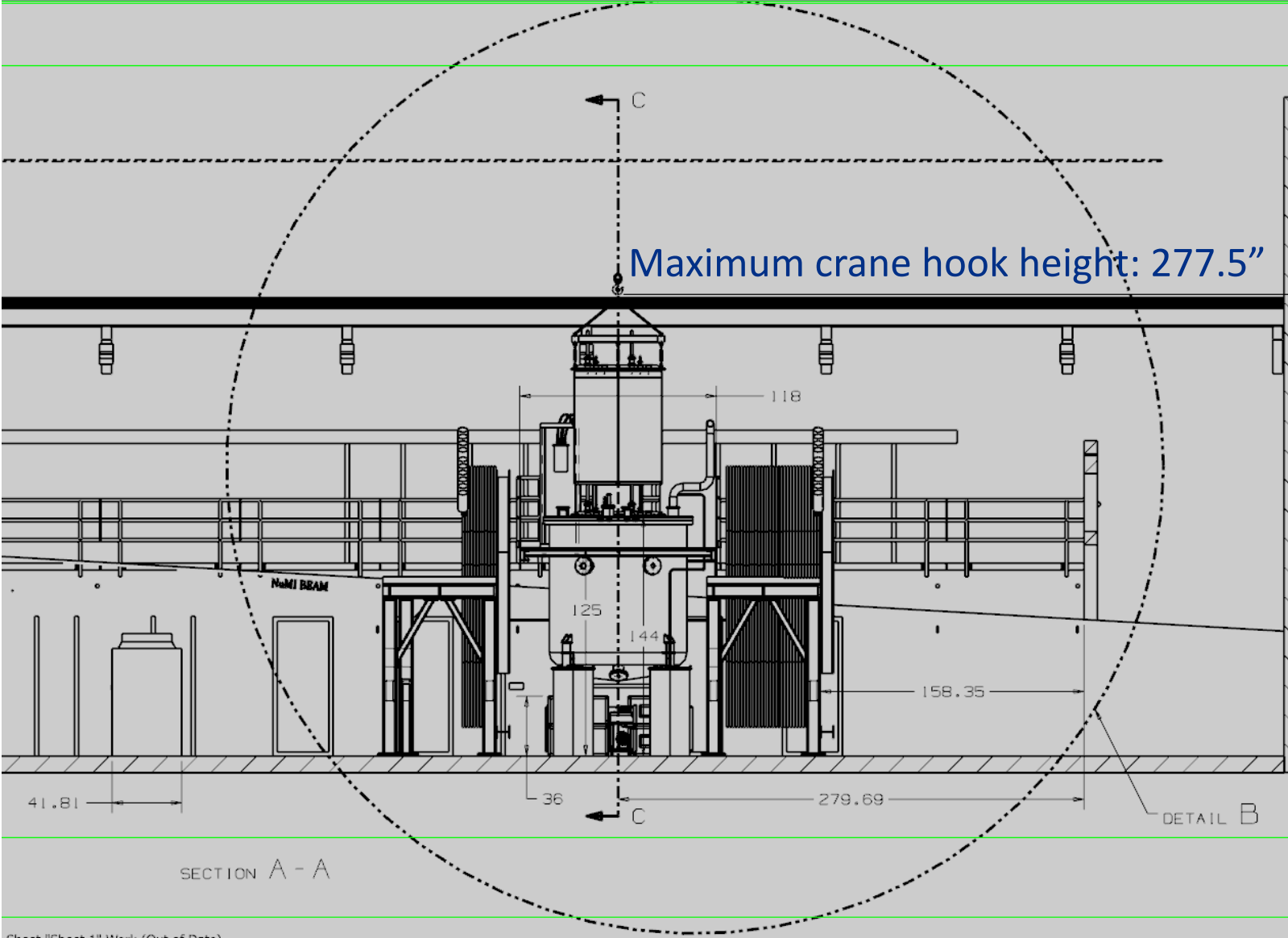
2x2 @ MINOS: Top View



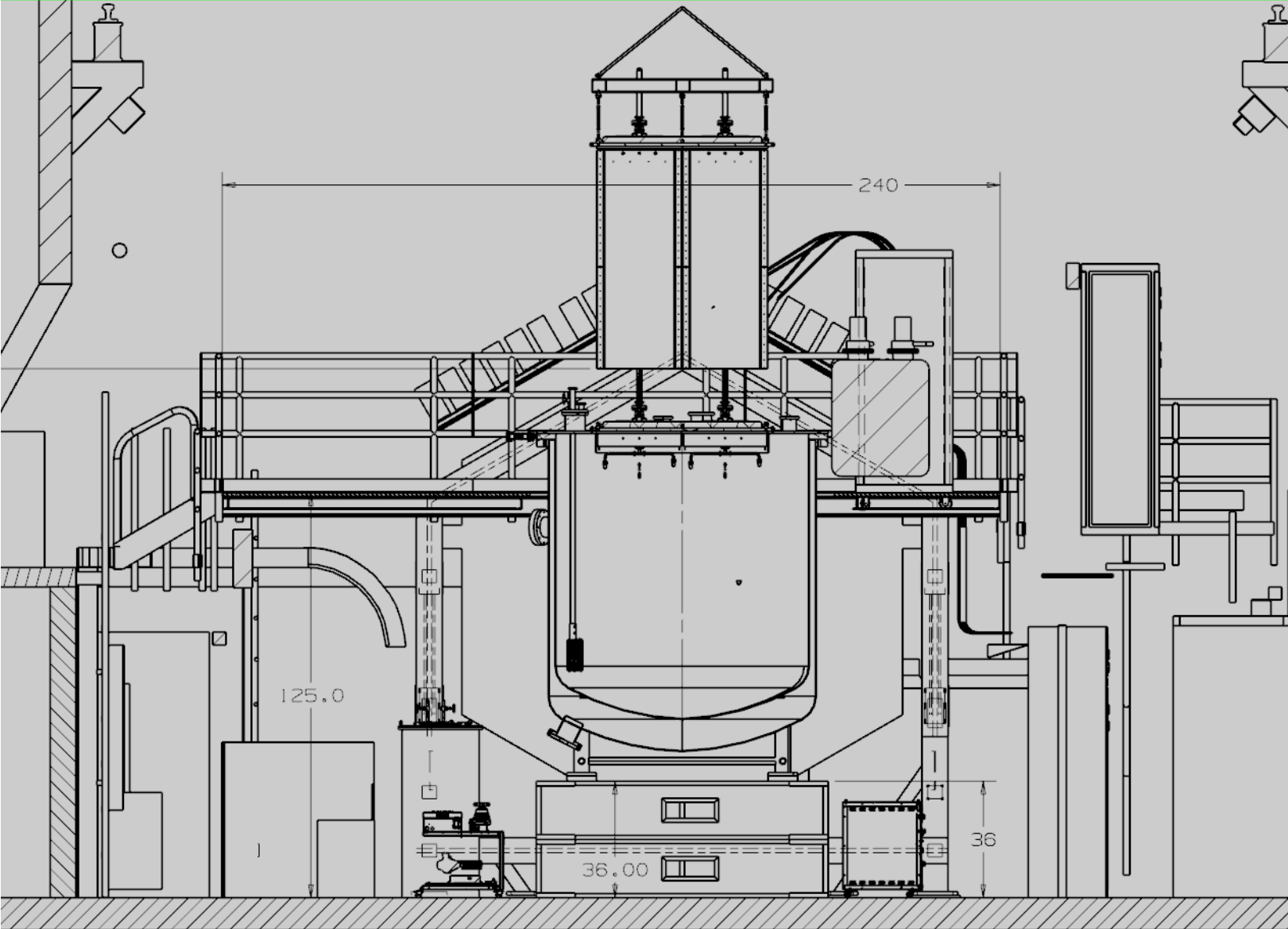
2x2 @ MINOS: Bottom View



2x2 @ MINOS: Side View from East



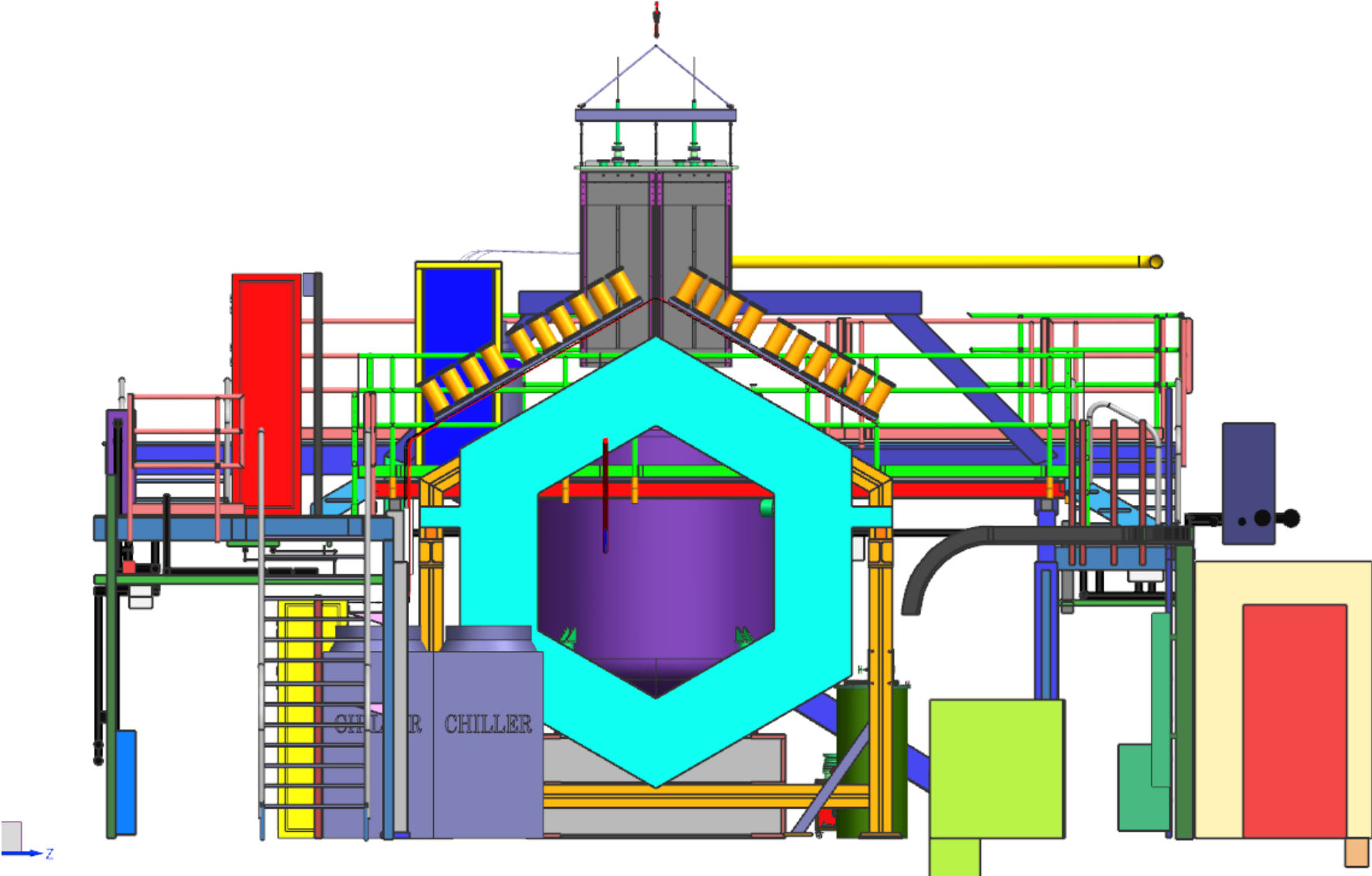
2x2 @ MINOS: Side View from North



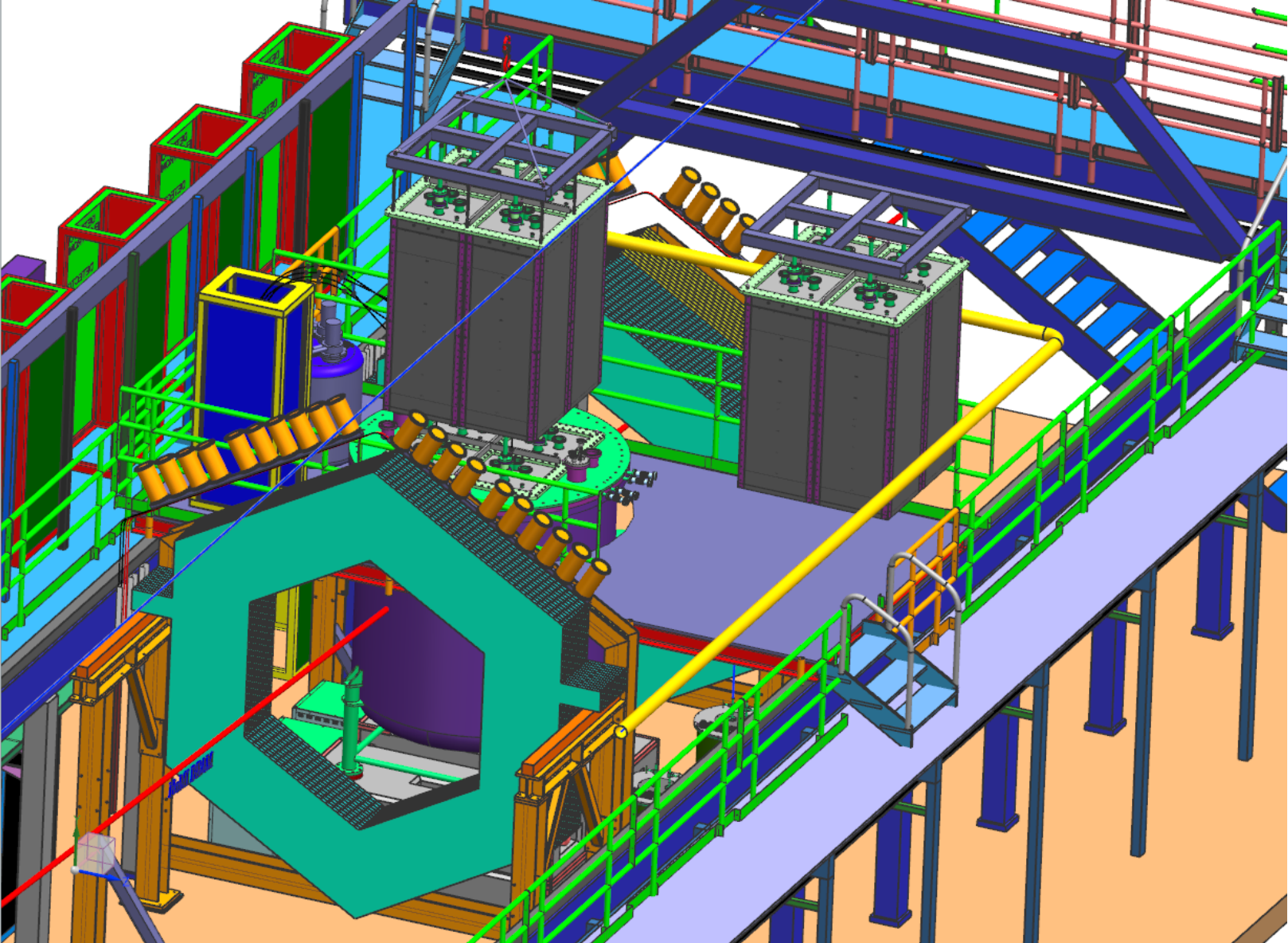
2x2 @ MINOS: Side View from West



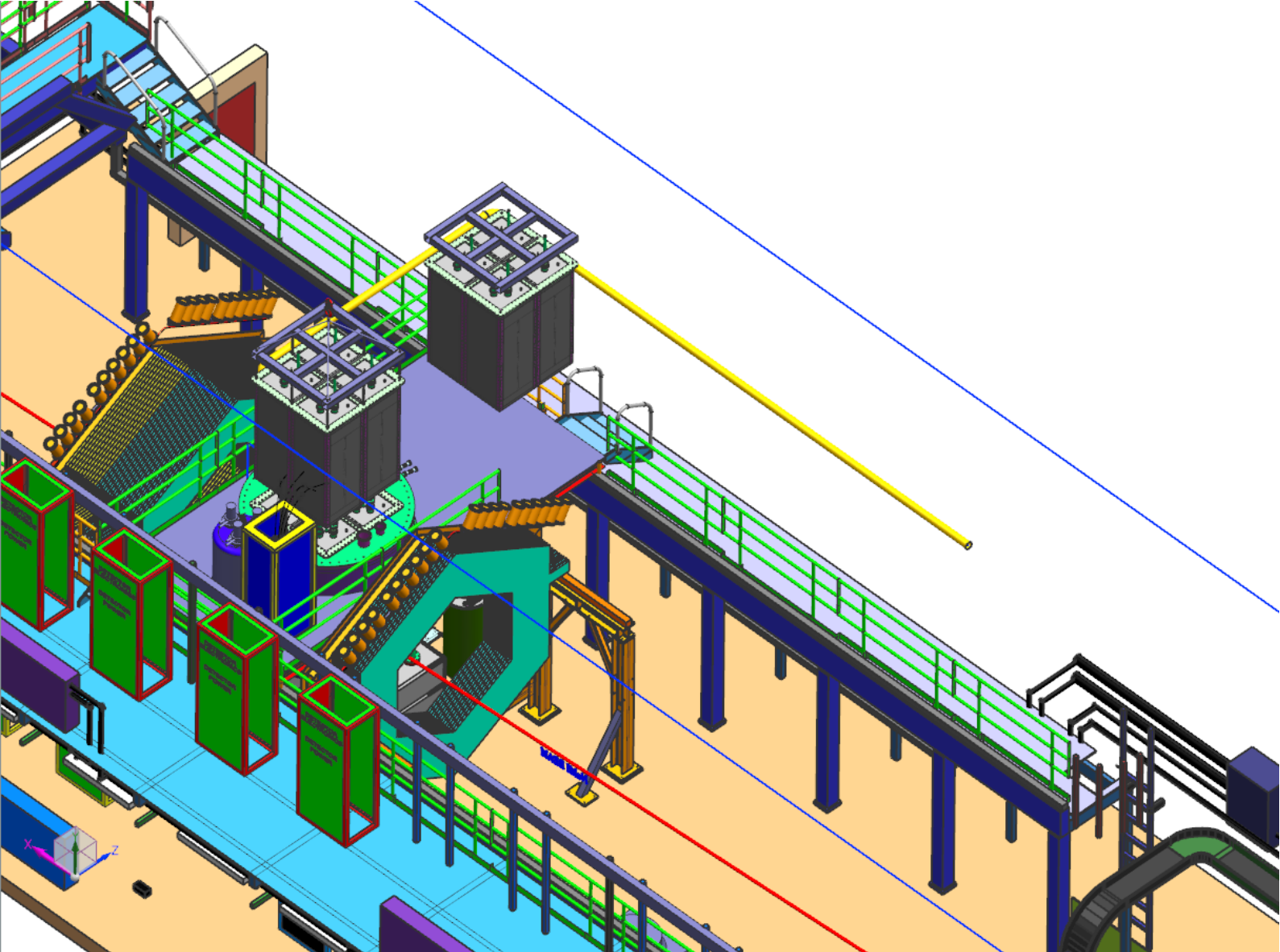
2x2 @ MINOS: Side View from South



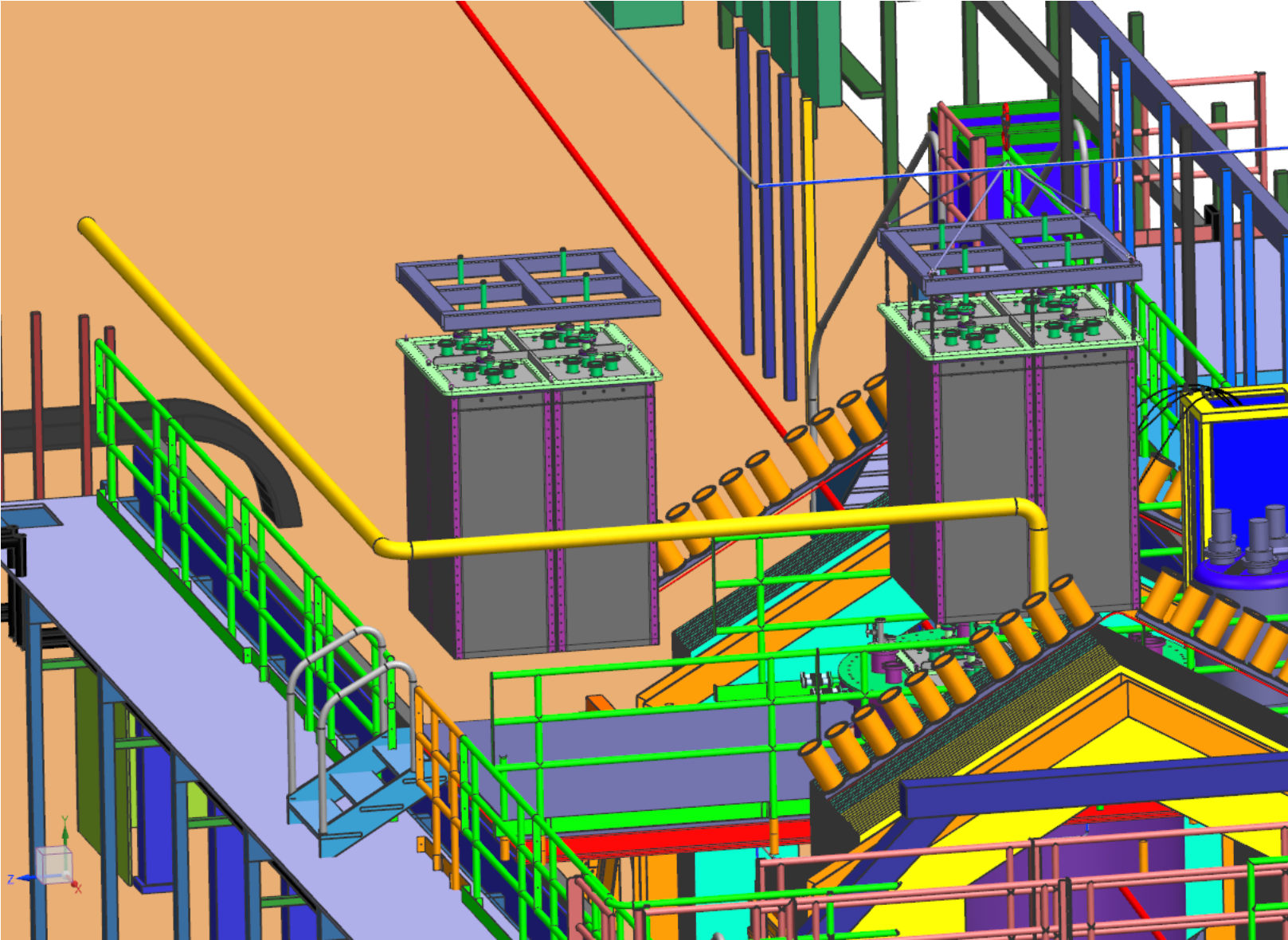
2x2 @ MINOS: Module Insertion and Extraction



2x2 @ MINOS: Module Insertion and Extraction

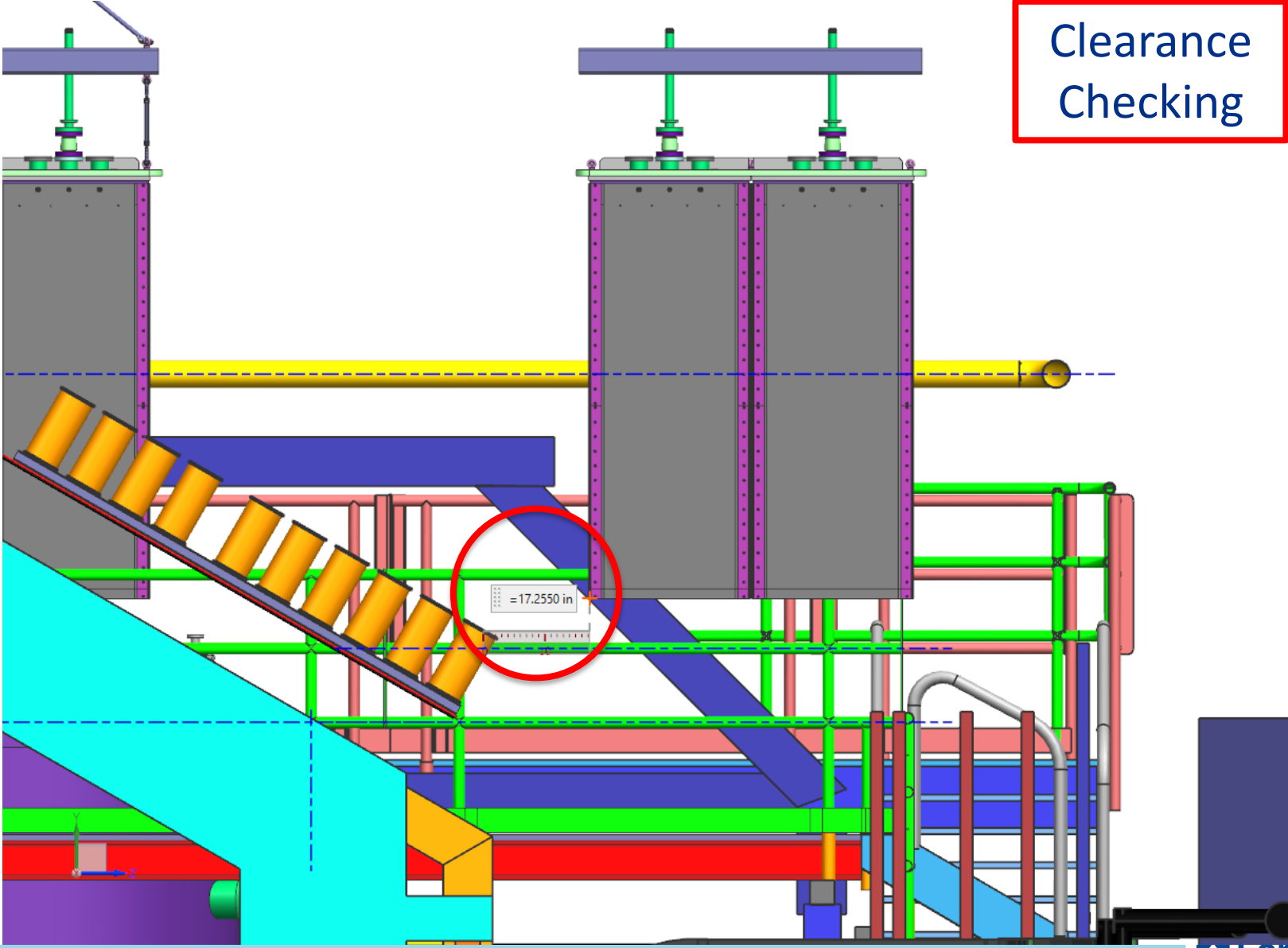


2x2 @ MINOS: Module Insertion and Extraction



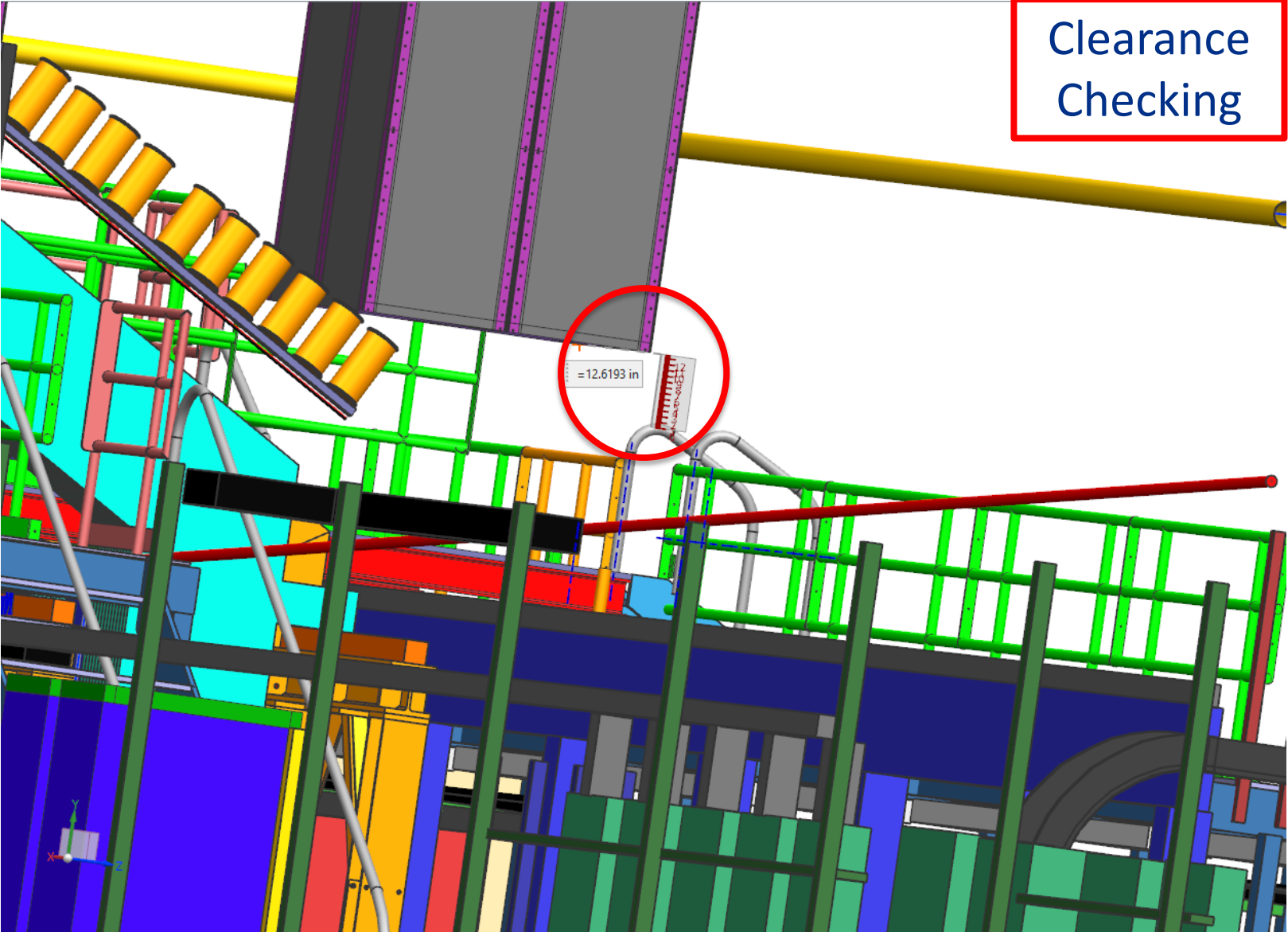
2x2 @ MINOS: Module Insertion and Extraction

Clearance
Checking

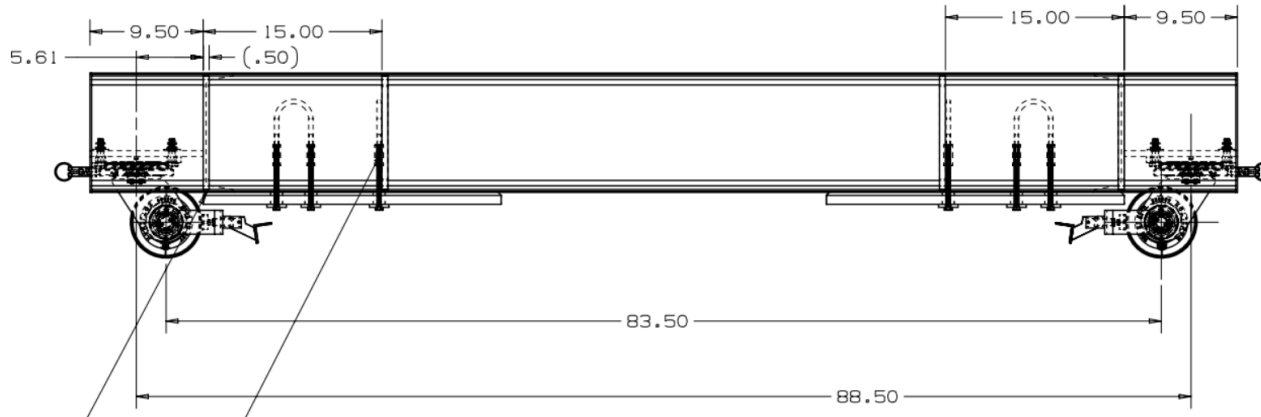
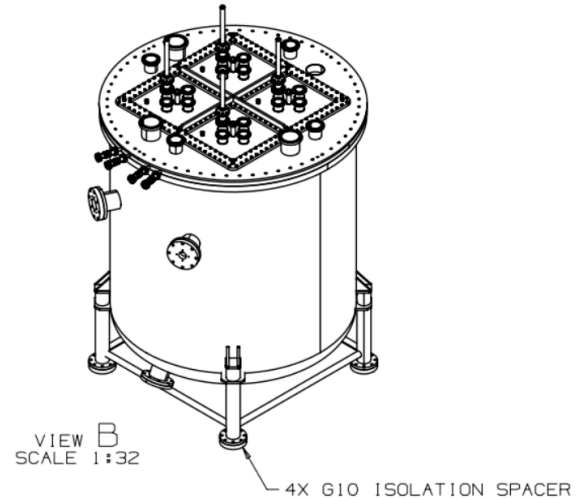
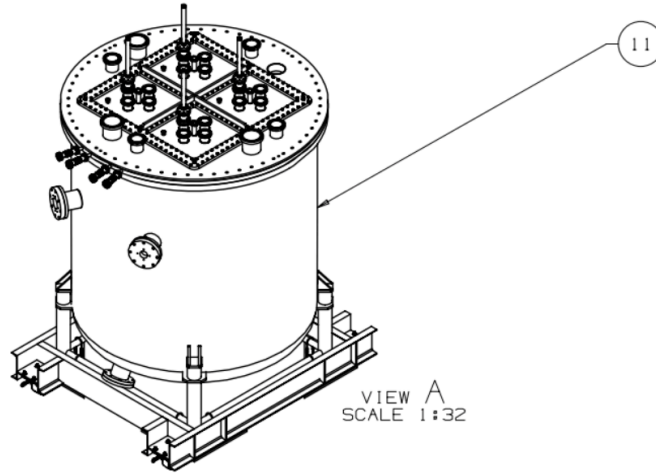


2x2 @ MINOS: Module Insertion and Extraction

Clearance
Checking



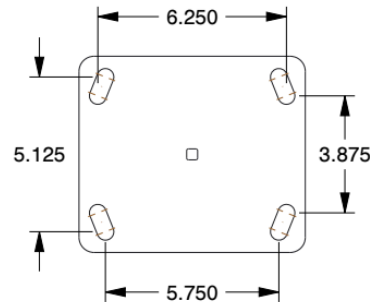
Design of Cryostat Transfer Cart



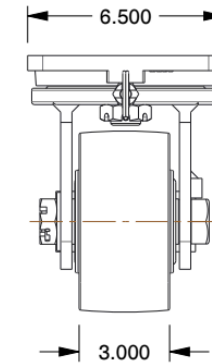
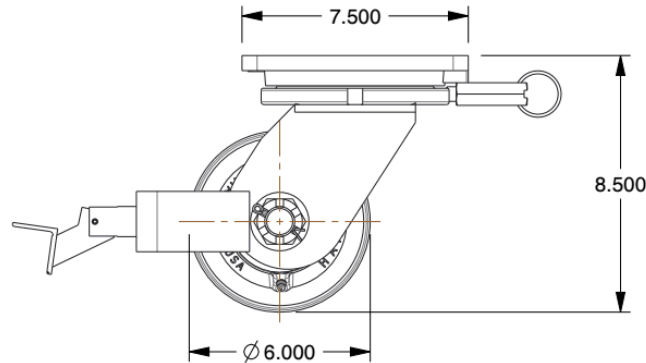
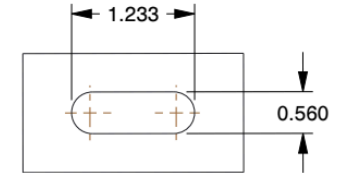
Design of Cryostat Transfer Cart (continued)



PLATE DETAILS



MOUNTING HOLE DETAILS



NOTES:

1. LOAD RATING : 10,000 lb.
2. WHEEL COLOR : Silver
3. FRAME FINISH : Zinc Plated Enamel
4. CASTER WHEEL BEARINGS : Roller
5. CASTER FRAME MATERIAL : Steel
6. CASTER WHEEL SHAPE : Standard
7. CASTER CORE MATERIAL : Forged Steel
8. CASTER WHEEL/TREAD MATERIAL : Forged Steel
9. CASTER LOAD RATING RANGE : Extra Super Duty
10. CASTER PRODUCT GROUP : Swivel Caster with 4-Position Directional Lock and Brake



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SCALE 0.19

COMPONENT	Plate Caster	
6AZN5	UNIT	INCH
	SHEET	1 of 1
	Pite Castr, Swvl, Frgd Stel, 6 in, 10, 000 lb	



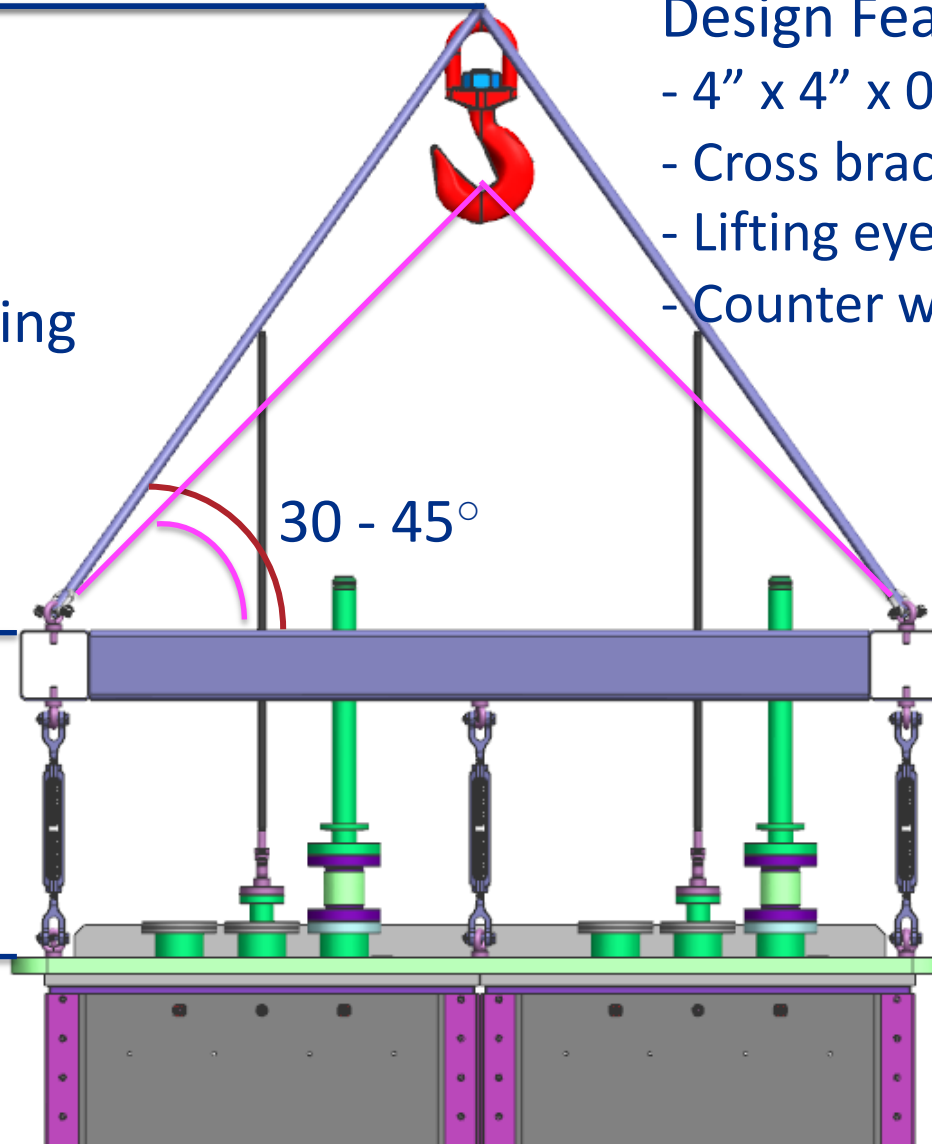
Design of Module Lifting Fixture

Design Features:

- 4" x 4" x 0.25" Box Beams
- Cross bracing
- Lifting eyes
- Counter weight mounting

4-point pick-up using shackles/slides

8-point pick-up using turnbuckles (~20" in height)



8 lifting eyes are provided on the module lifting frame by Bern.