APA Installation Procedures
September 1, 2021

Tom Wieber
University of Minnesota

APA assembly tower and phase 2 DSS support structure @ Ash River

Outline

- ProtoDUNE II Installation plan
  - Upper APA extraction → Cleanroom
  - Lower APA extraction → Cleanroom
  - Cleanroom → Cryostat
  - Changes from ProtoDUNE
- APAs at SURF
  - Getting underground
  - Assembling the doublet
  - Transfer to the cryostat

- Focus of this presentation pertains to charge #4:
  - If the ~~design of the APA shipping frame~~ and plans for installation of the APAs in both ProtoDUNE-II and the DUNE Far Detector are mature enough to provide assurance that APAs, as currently designed, can be ~~safely transported and~~ installed within the detectors.

ProtoDUNE II Upper APA

- Ships in the ProtoDUNE style shipping box
- Involves several people and groups
  - Team to open up box
  - Overhead lifting crew for heavy items
  - Special truck crane for crate extraction
- ~1 day to open box and attach lifting gear
- ~1/2 day to hang on cleanroom rails
  - NB – Assumes all HSE documents are complete and signed off on
- This process has been done 7 times

Upper APA → Cleanroom 1

APA lifting fixture – tool manual link

Tool for lifting a horizonal APA out of a shipping crate and rotating vertical

EDMS PPSPS APA Insertion into clean room

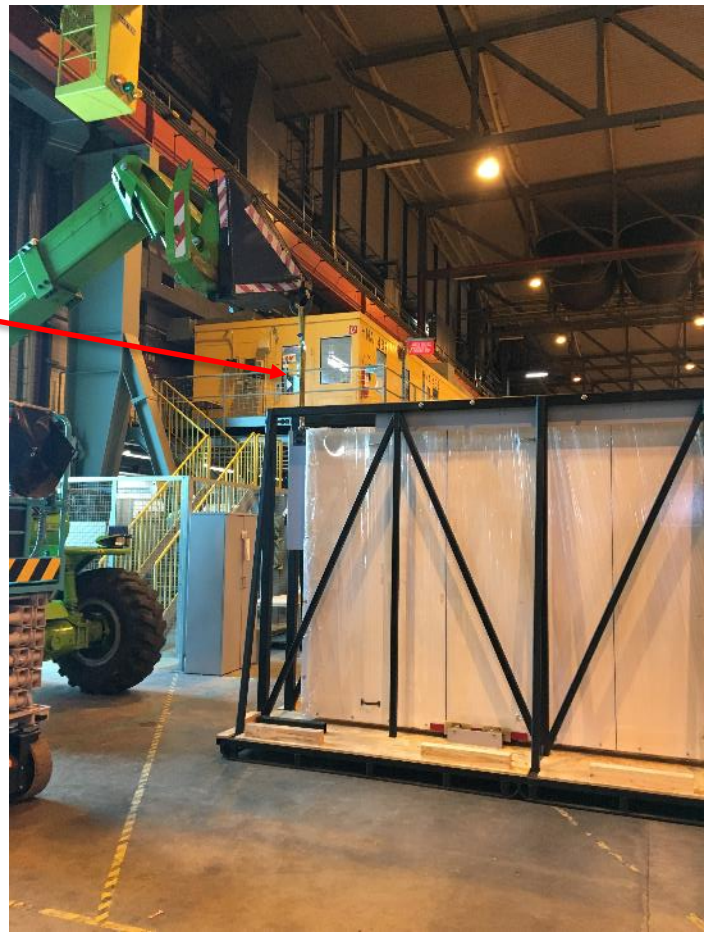
- Use crane to connect lifting fixture to APA

Remote controlled hoist

Solid connections

- The trolley should also be installed on the APA at this point

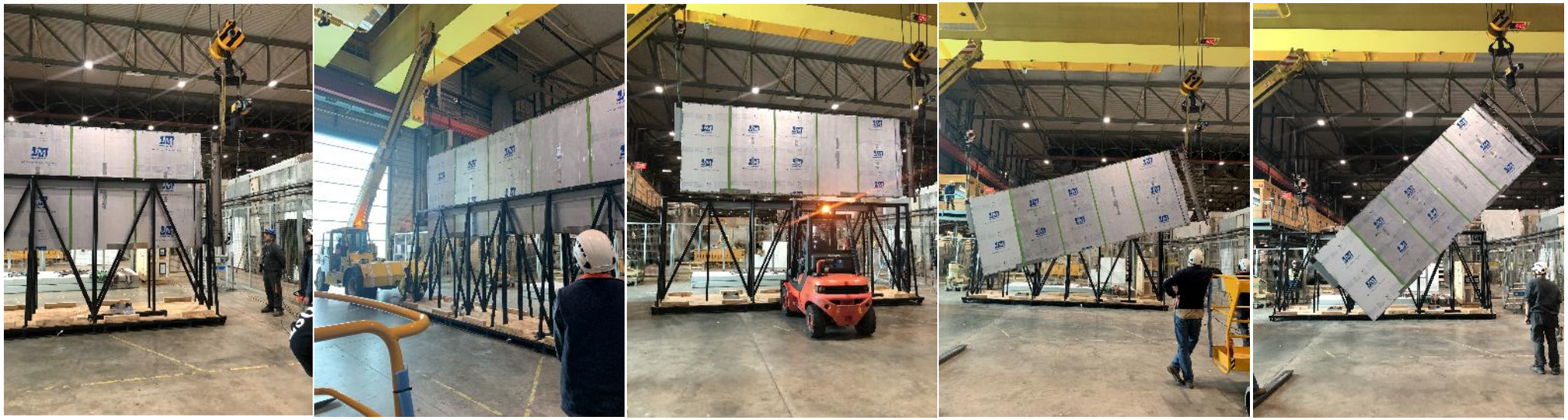
- Mobile crane connects to foot tube lifting fixture



Slight modifications for pDUNEII
- Longer bars
- Additional mass added to APA test load

In progress and well understood

Upper APA → Cleanroom 2

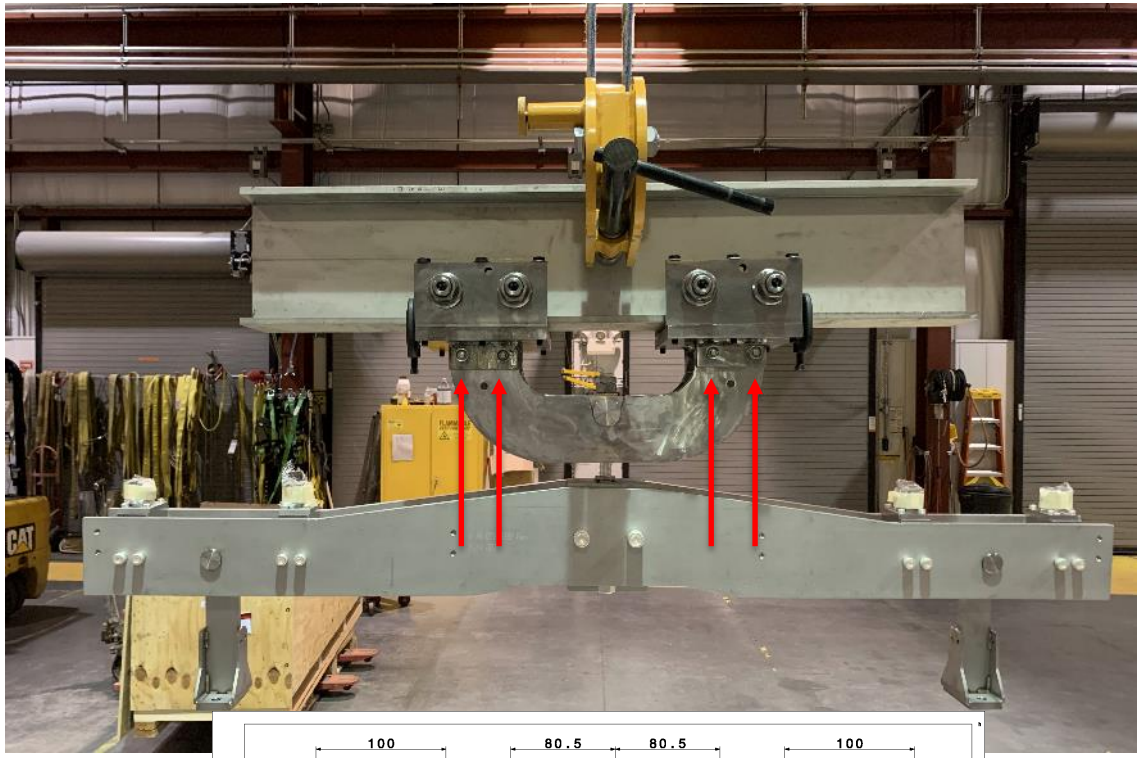


Bottom lifting fixture is removed once the APA is vertical

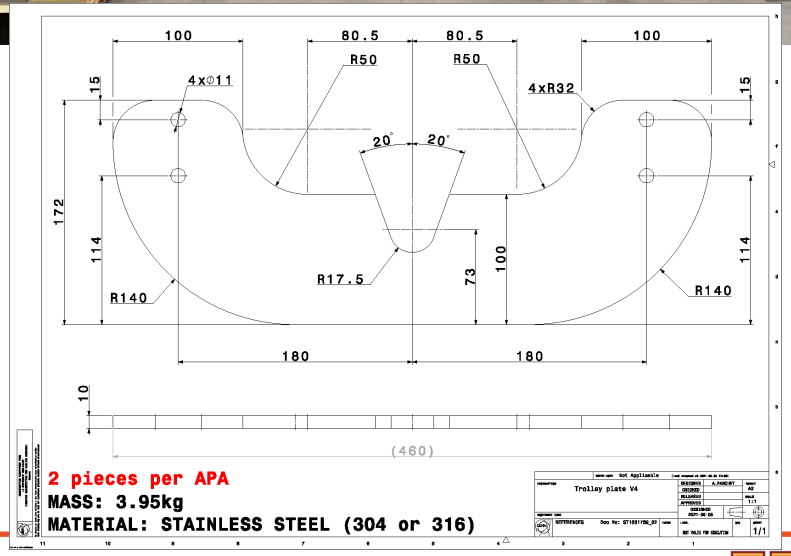
Upper APA Trolley Difference

- ProtoDUNE trolley

- ProtoDUNE II trolley

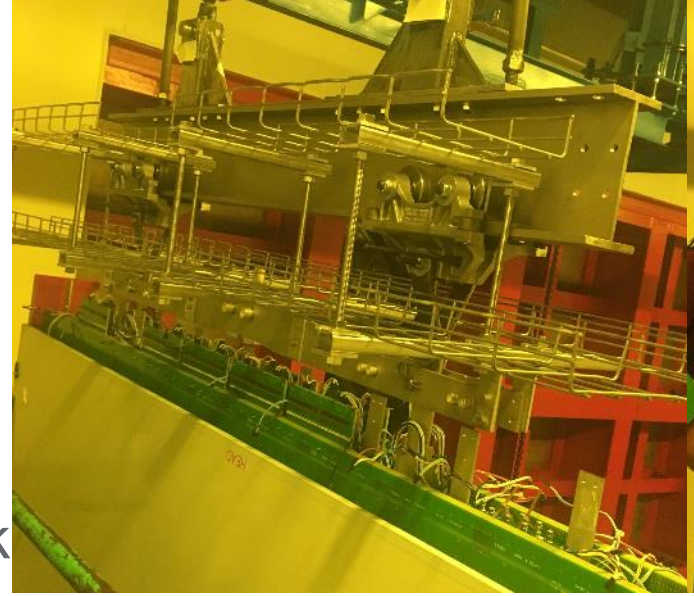


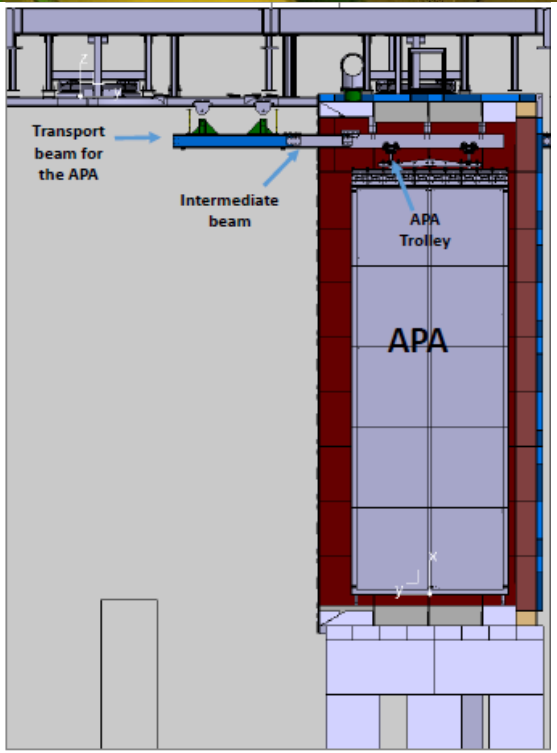
Lesson learned: All pins were not loaded, redesigned



Cleanroom activities

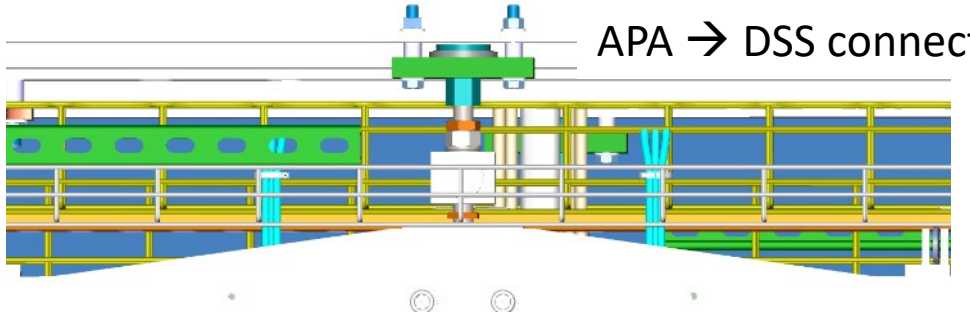
- Survey – 1-2 days
  - Includes protection removal and installation
- Install cable tray – 1 day (if not assembled)
- Install/test CE boxes and cabling – 1 week
- Photon detectors – 3 days
- Coldbox testing – varies
- Replace any CE – varies
- Roll into cryostat
  - Cryostat beams on trolleys
  - Align DSS beam with TCO opening
  - Travel to DSS via intermediate beam connection
- Total cleanroom time ~11 days



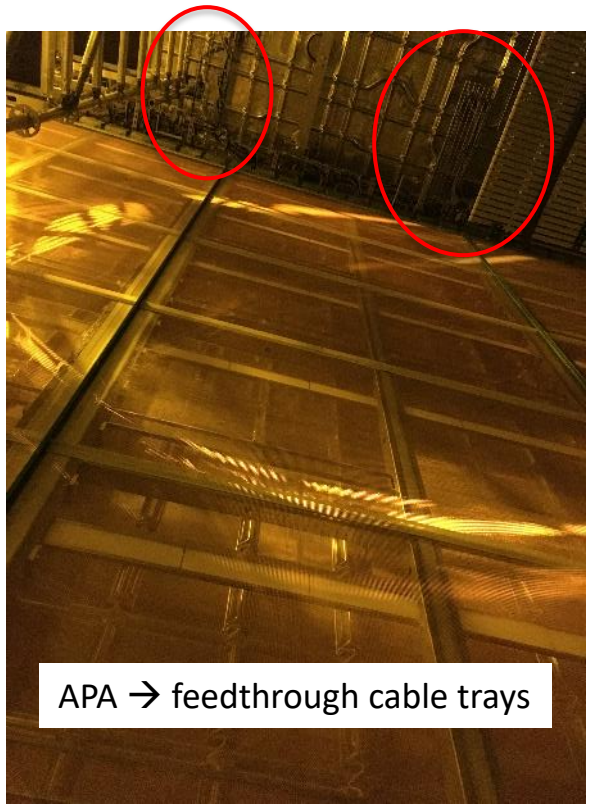


ProtoDUNE II Cryostat Activities

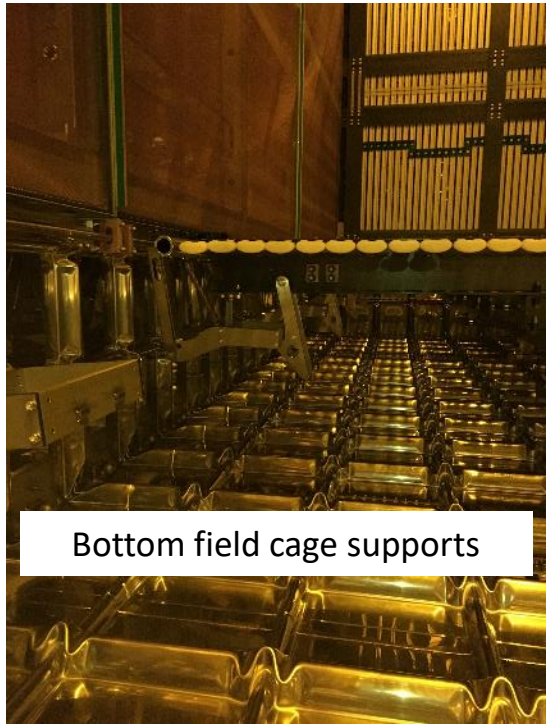
- First APA idles on the DSS until second APA rolls onto DSS beam
- DSS beam is rolled into position
- DSS beam is bolted into position
  - Remove DSS beam trolleys
- APA is positioned and bolted to DSS
  - Remove APA trolley
- Install APA → penetration cable trays
- Route APA cables to feedthrough
  - Connect and test connections
- Install top/bottom field cage latches
- Deploy field cages
- Make final connections endwall/APA & field cage/APA



APA → DSS connection



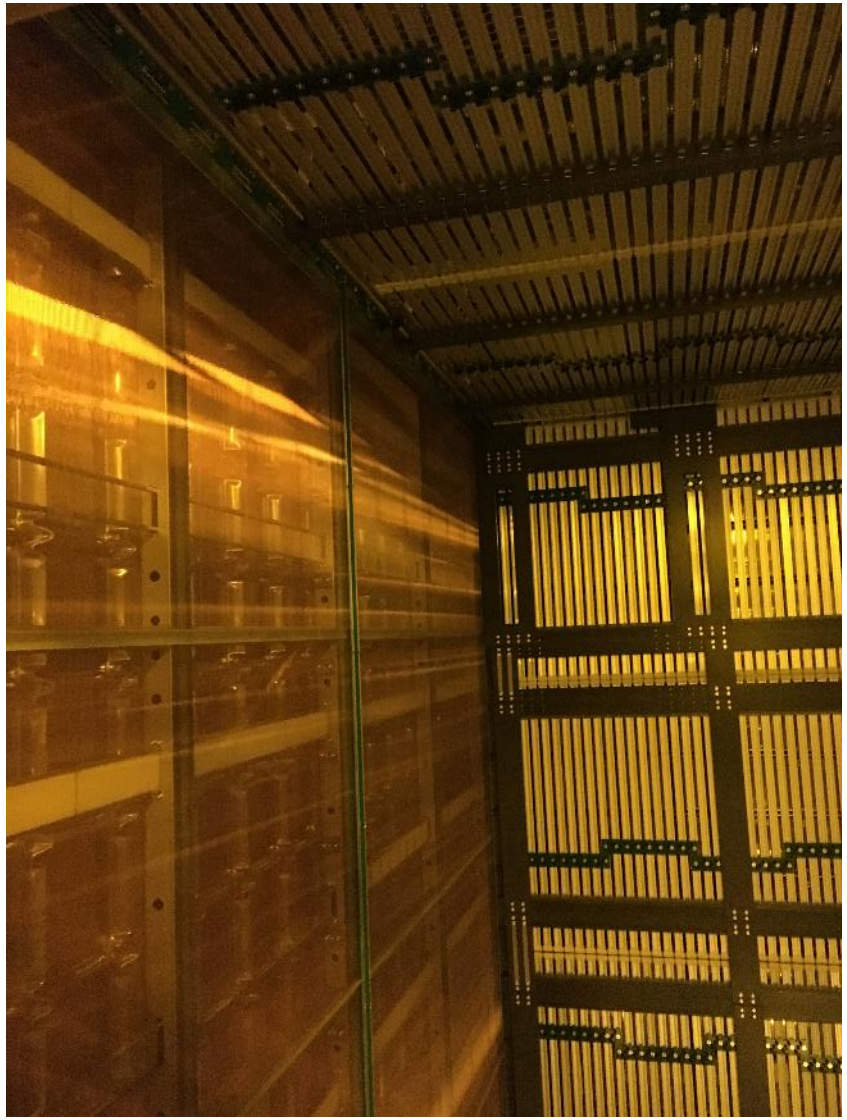
APA → feedthrough cable trays

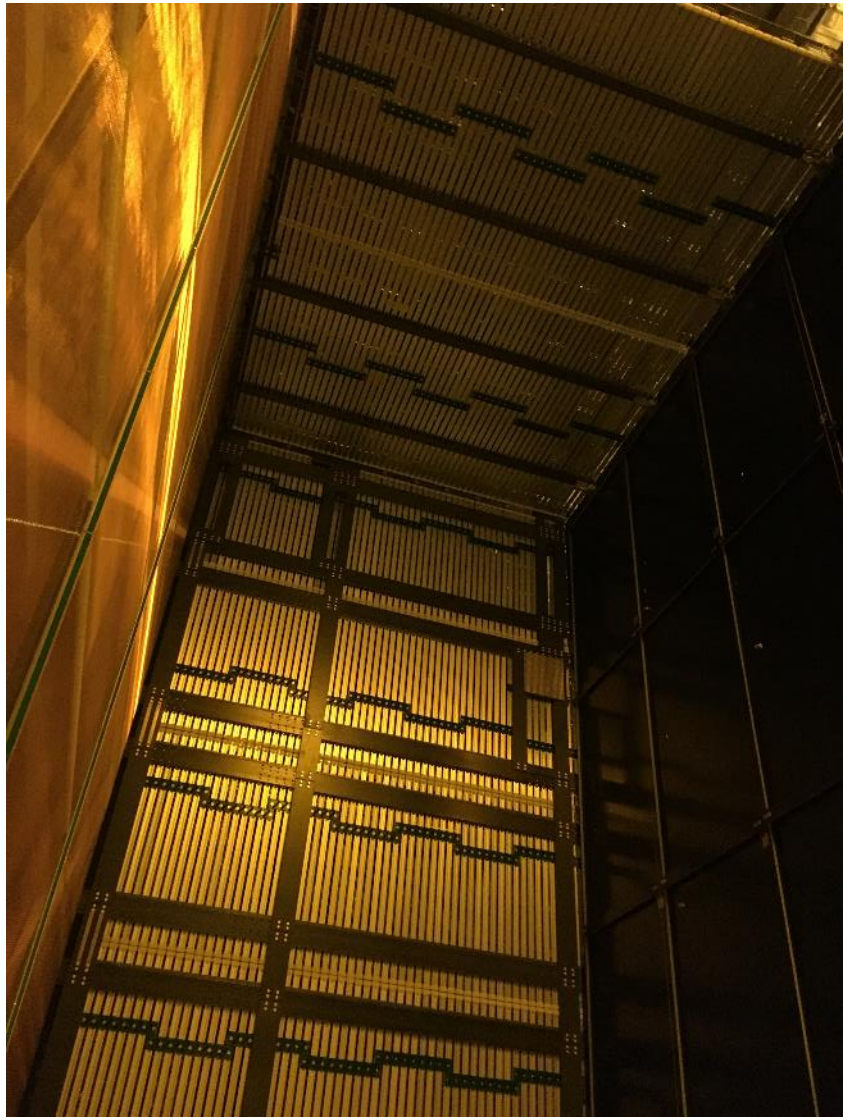


Bottom field cage supports

- Significant activities

Upper APA complete



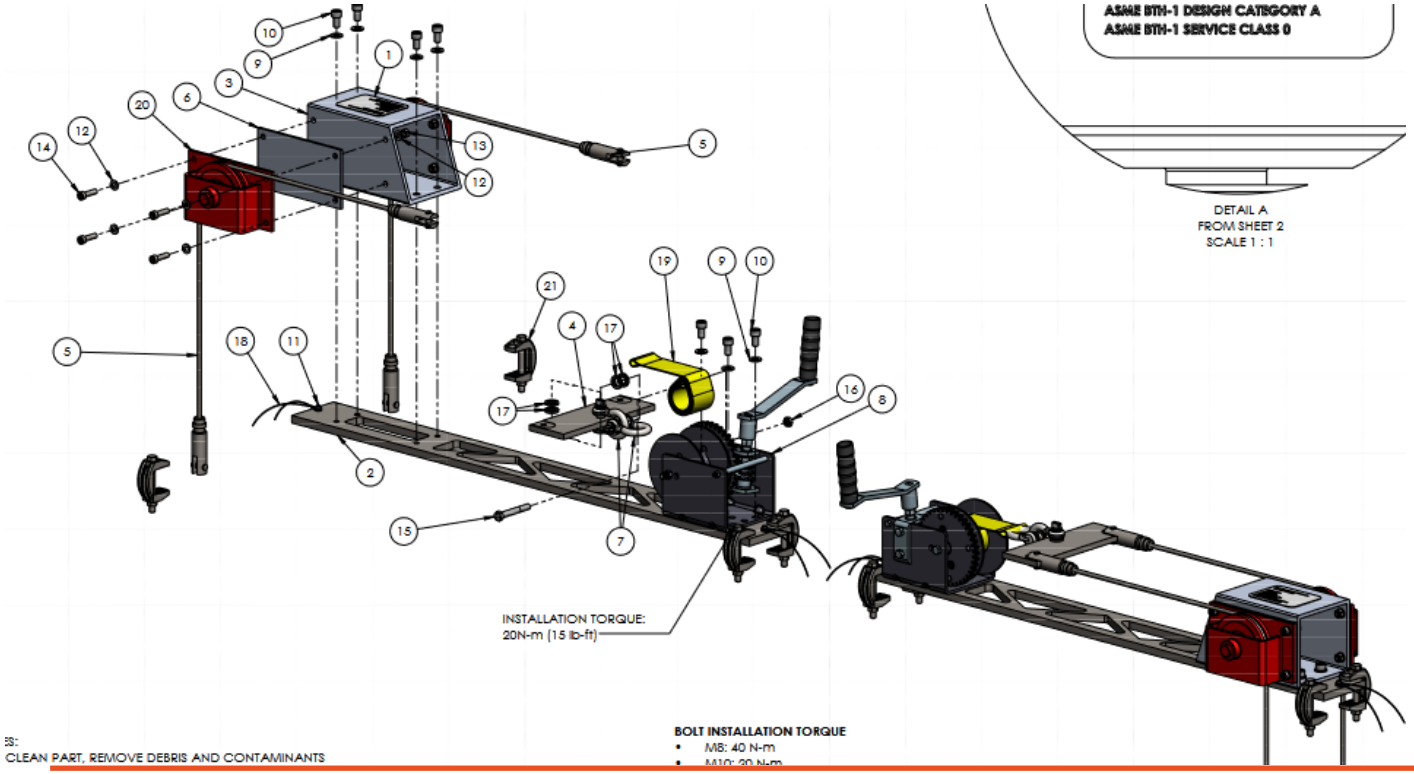


ProtoDUNE II Lower APA

- Yoke differs from upper
  - Carries APA via “wishbone link” (top left) vs structural tees
  - Yoke has multiple elevation configurations by using the APA lowering system
- Yoke connected to APA
  - “Highest” position for cold box clearance
- Crane raises to neutralize the load
- Disconnect from box
- Roll box away
- Deliver to cleanroom

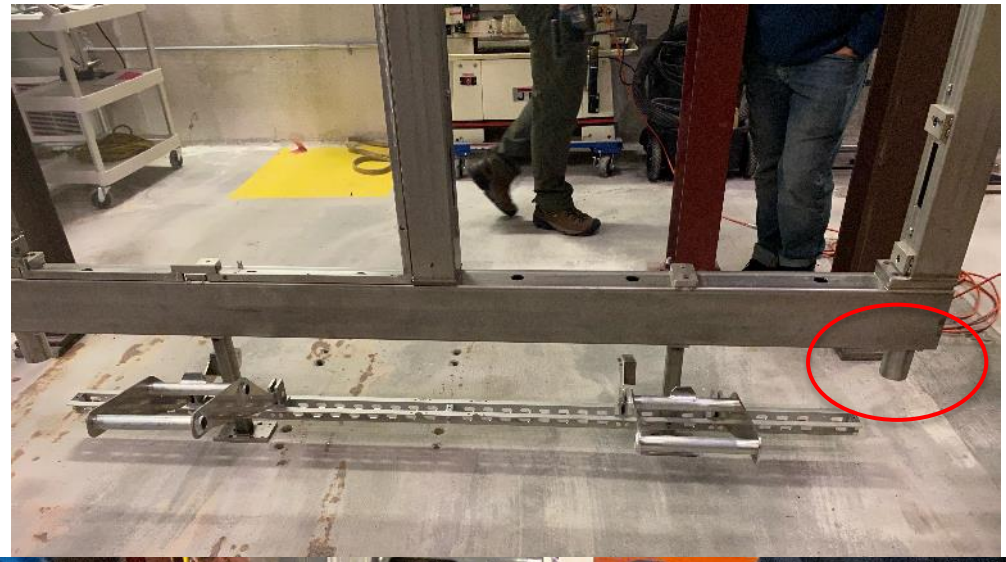
ProtoDUNE II Lower APA Lowering System

- Fabrication in progress at Ash River
- Testing soon
- APA stays in highest position until inside cryostat and floor is removed



ProtoDUNE II Lower APA Cleanroom

- Survey – 1-2 days
  - Includes protection removal and installation
- Install cable tray – 1 day (if not assembled)
- Install/test CE boxes and cabling – 7 days
  - Cables fed through conduit tube to foot end
- Photon detectors – 3 days
- Coldbox testing – varies
- Replace any CE – varies
- Roll into cryostat
  - Cryostat beams on trolleys
  - Align DSS beam with TCO opening
  - Travel to DSS via intermediate beam connection
- Total cleanroom time ~13 days (vs 11)



ProtoDUNE II Lower APA Cryostat Activities

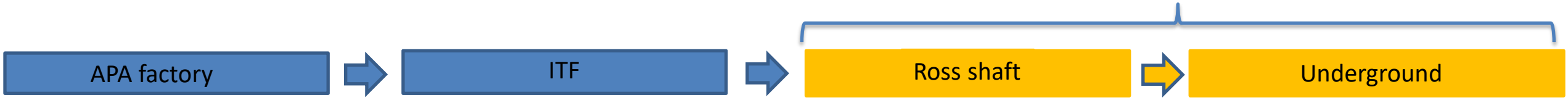
- First APA idles on the DSS until second APA rolls onto DSS beam
- DSS beam is rolled towards its position
  - Stop one floor width away from cryostat wall
- Remove floor underneath APAs, preserving floor near cryostat wall
- Lower APA is lowered using the lowering system
- APA is positioned and bolted to DSS
  - Remove APA trolley
- Remove floor along cryostat wall
- Roll DSS beam to final position
- Replace floor section away from cryostat wall
- DSS beam is bolted into position
  - Remove DSS beam trolleys
- Install APA → penetration cable trays
- Route APA cables to feedthrough
  - Connect and test connections
- Install top/bottom field cage latches
- Deploy field cages
- Make final connections endwall/APA & field cage/APA

Differences vs upper APA well understood

DUNE APAs @ SURF

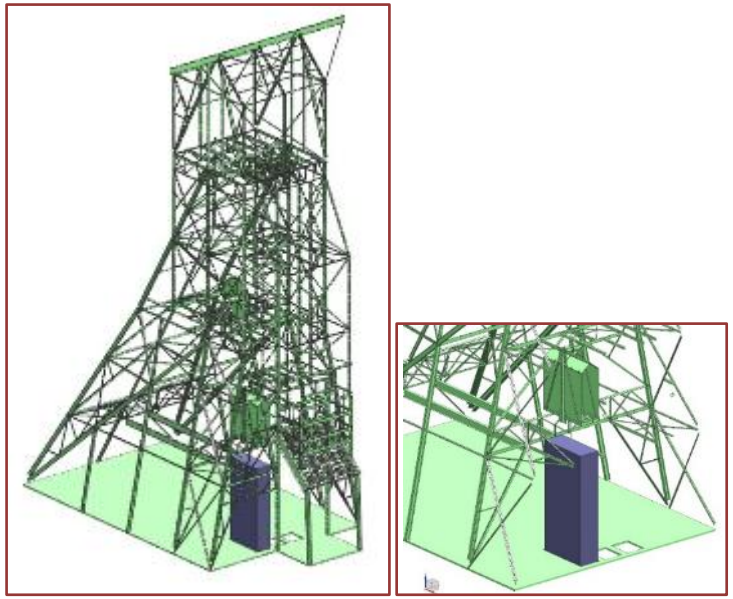
- Installation-Integration path from the factory to its final position inside the cryostat

- Relevant APA life cycle steps



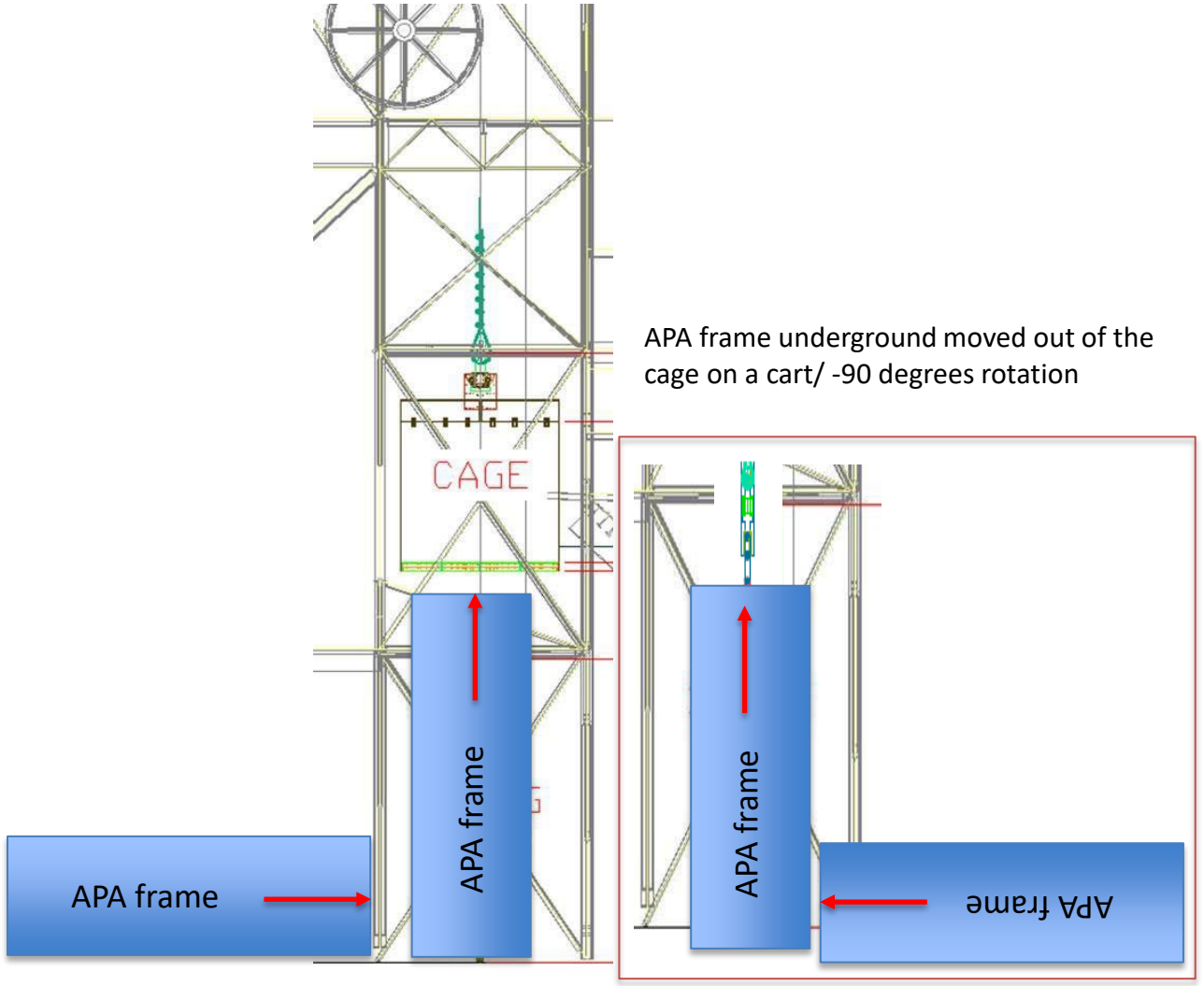
Ross Shaft

- Transport box arrives at the surface
- Slung load under the cage
- Arrives down below and is placed on horizontal cart for travel to the cavern
- Makes 180-degree rotation in this process



APA frame hung below the cage/ 90 degrees rotation

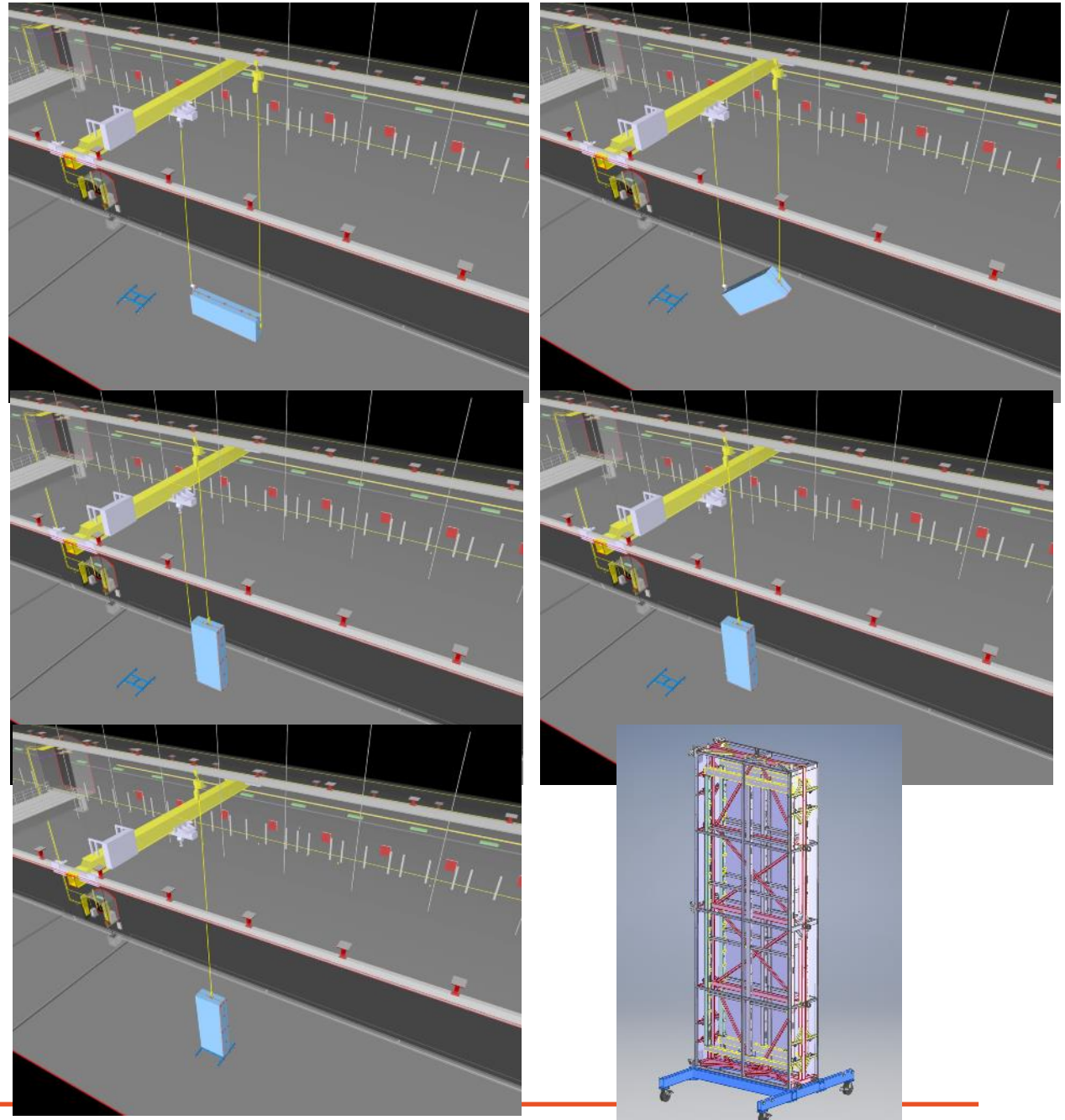
APA frame underground moved out of the cage on a cart/ -90 degrees rotation



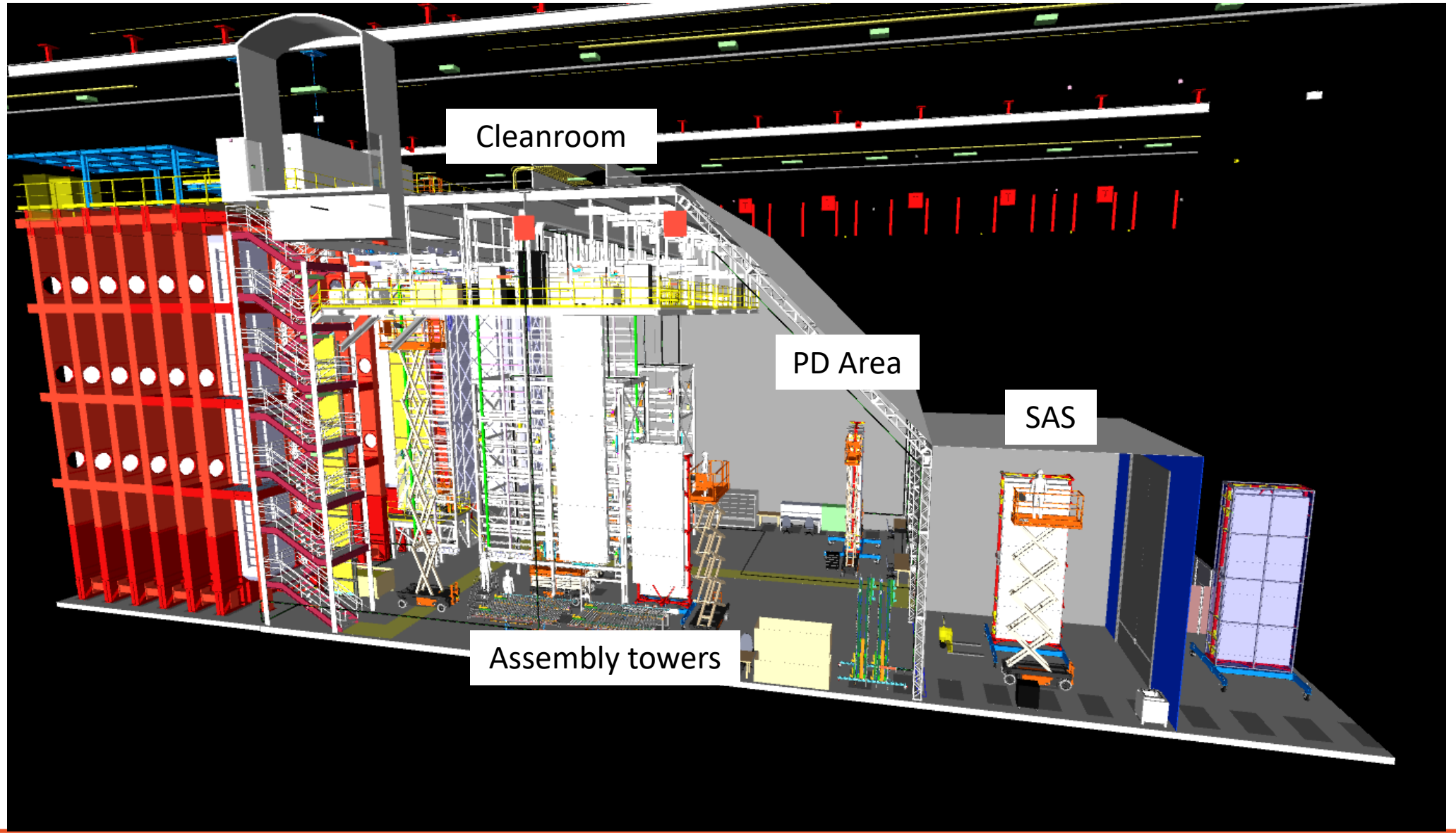
DUNE APAs → Cavern

- Process from this point well understood
  - Details in SP Detector #1 Installation Plan

- Box arrives at the West entrance of the north cavern at the 4850 level
- Using the crane and monorail, the box is rotated and lowered to the 4910 level
- Placed on vertical transport cart

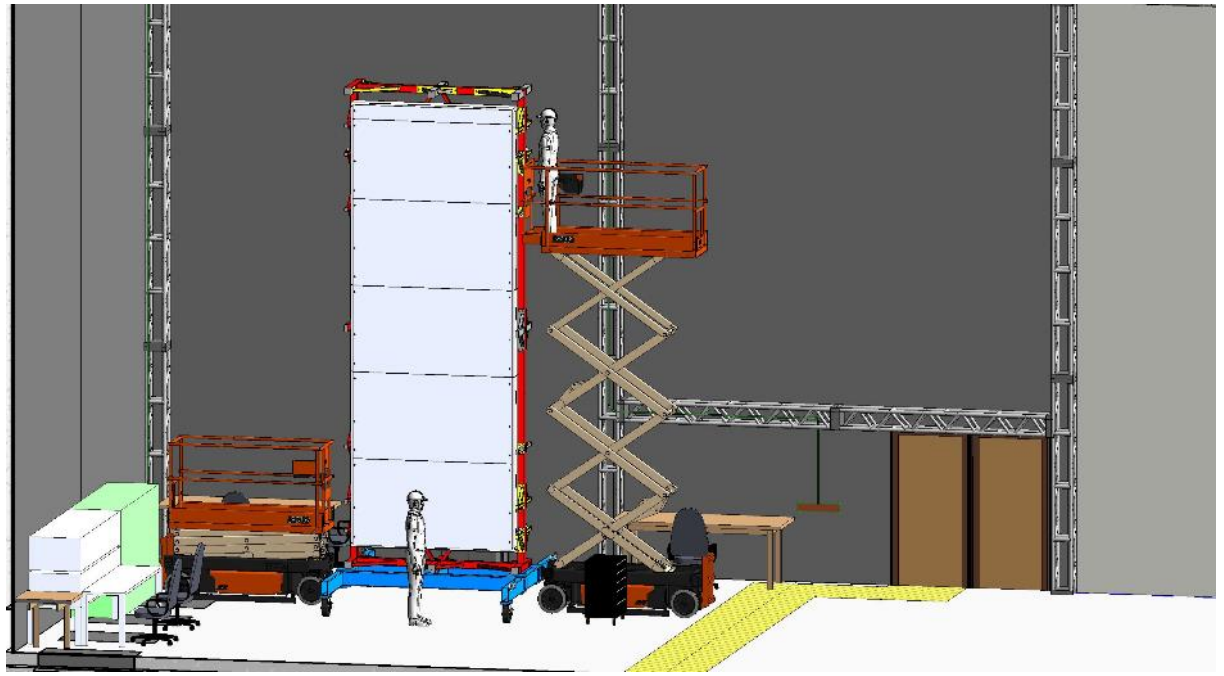


DUNE Cleanroom



DUNE APA PD

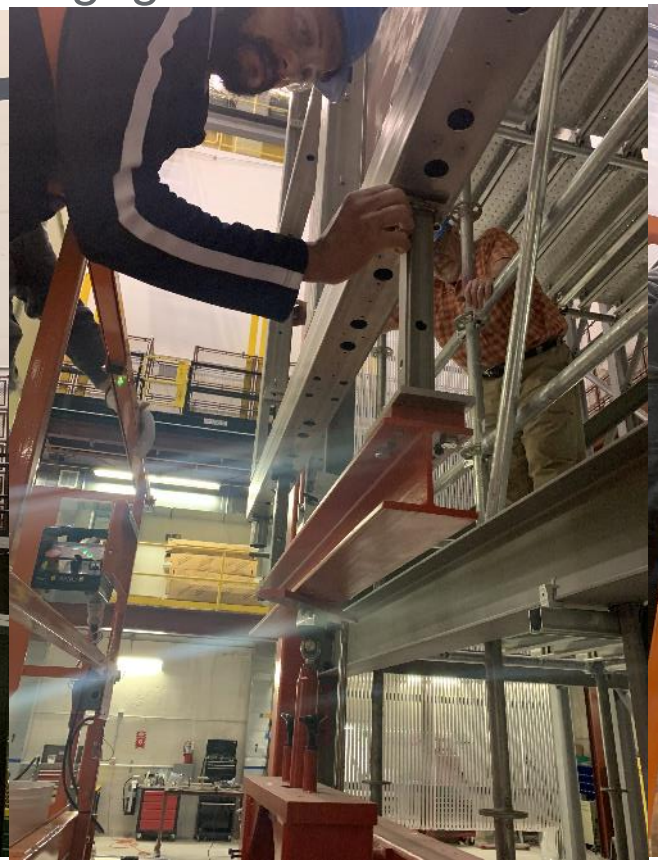
- Use the tugger to position in the PD installation area
- Scissor lifts on either side are used to access the PD slots
- Top access to the PD connectors for testing
- Also installed:
  - T-brackets
  - C-brackets
  - cable harness for wire bias on the APA



DUNE APA Assembly Area 1

- Vertical cart positioned near assembly tower
- Picked up by crane and cart moved out of the way
- The lower APA is translated over to the assembly frame
- Bottom standoffs are installed and actuator raised and takes the APA load
- Stabilizer pins are engaged

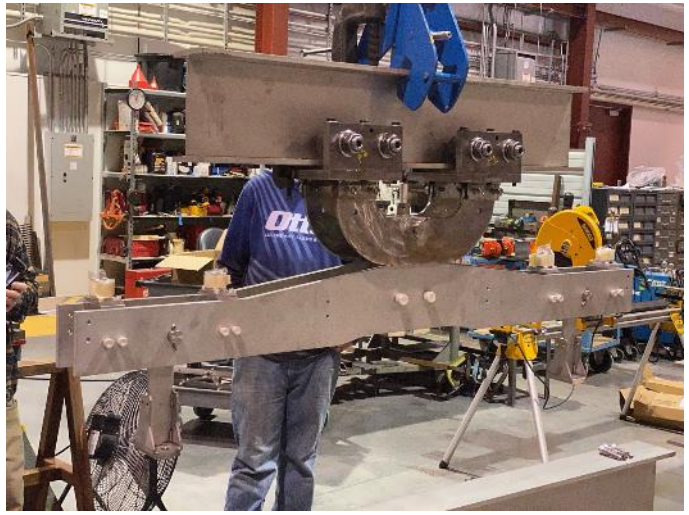
The APA connecting links should be installed after the APA is pinned to frame

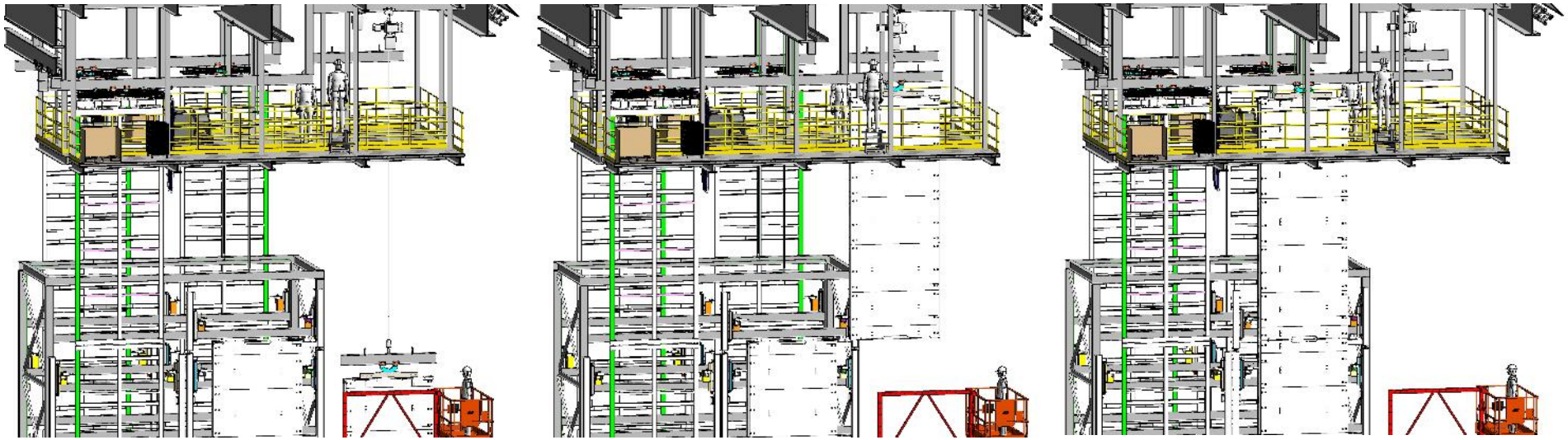


Concept is well understood at Ash River

DUNE APA Assembly Area 2

- Upper APA yoke is centered over vertical cart on the lifting beam
- Yoke and trolley are connected to APA
- Beam is lifted up and connected (bolts removed similar to lower APA when load cell indicates)
- APA is translated and pinned to assembly frame





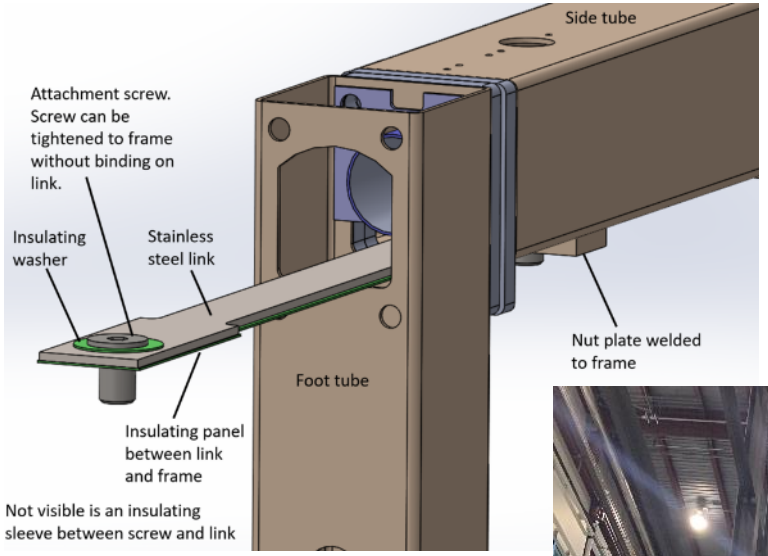
Procedure is well understood at Ash River

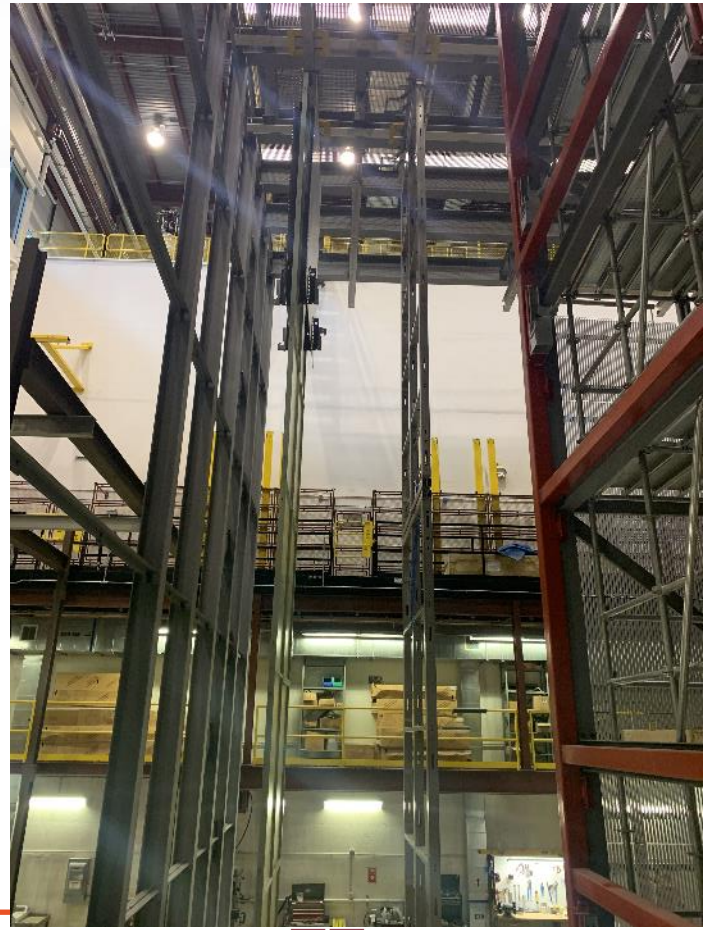
DUNE APA Assembly Area 3

- Making a doublet
  - EDMS link to procedure @ Ash River

- Actuator raises lower APA
- Partial lift → Hold to connect and test PD cables
- Continue raising until bolts can be connected
- Actuator beam is disconnected (stand offs remain on APA)
- Several brief electrical checks
- Reinstall stabilizer pins or translate to next station

Procedure is well understood at Ash River



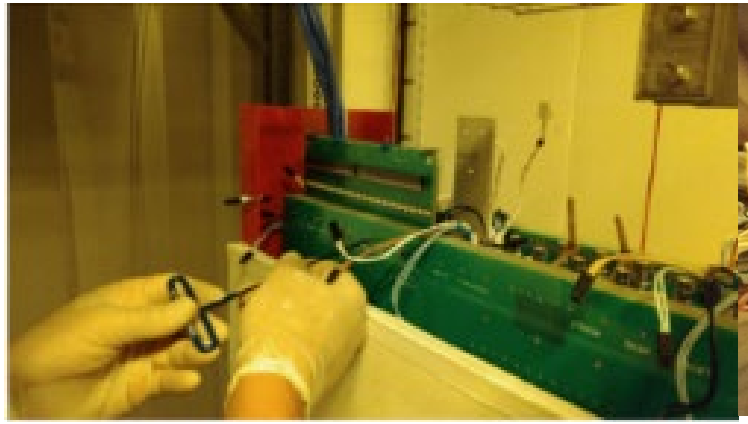


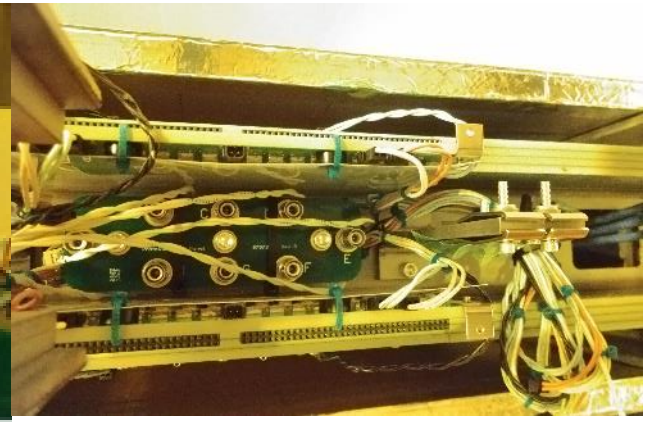
DUNE APA Assembly Outfitting 1

- Wire tensions are tested at this point
- CR boards installed
- SHV board
- FC termination board
- APA cable harness are mounted

- FEMBs can be installed

- Cable trays installed
- Cable spools are raised and fed into the conduit tube

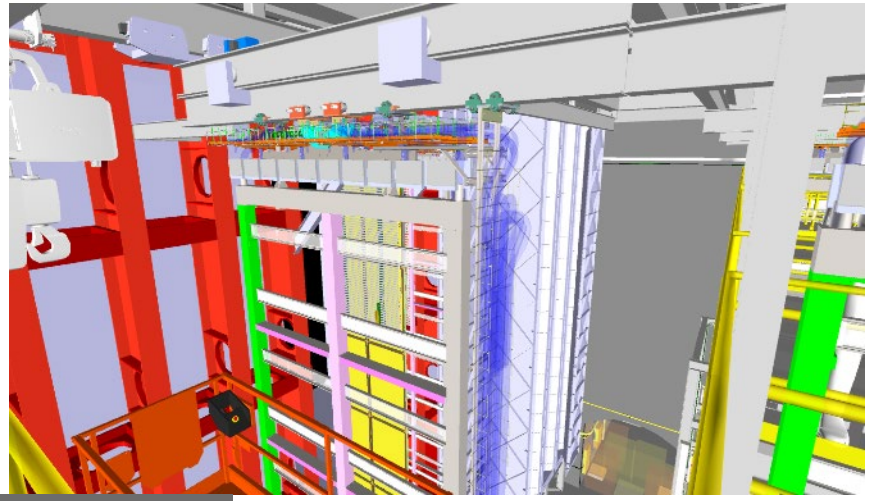


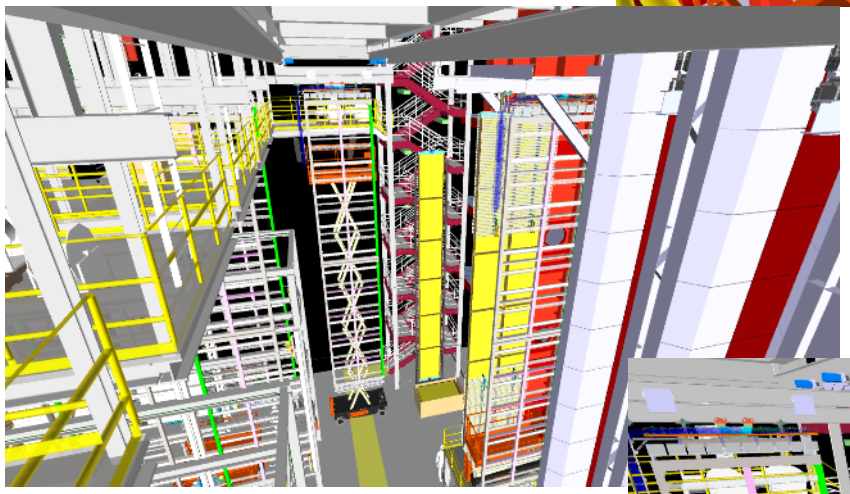


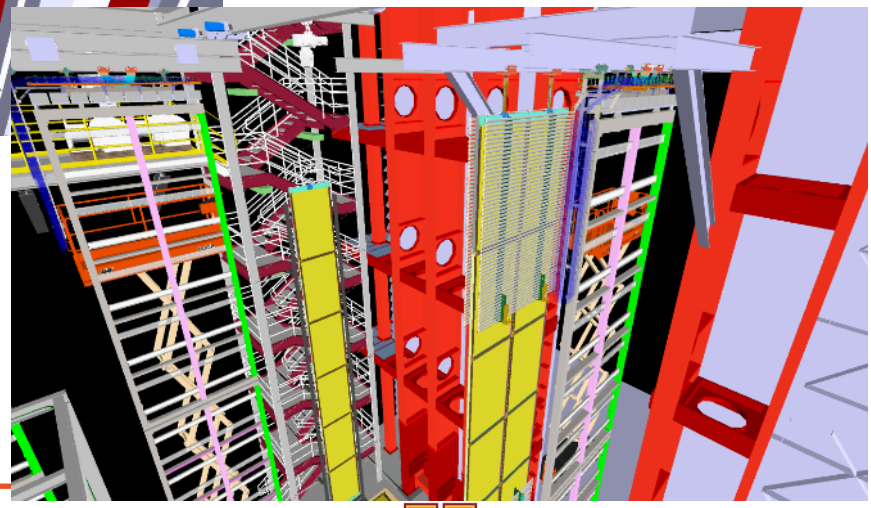
Cable spooling has been tested at at Ash River

DUNE APA Coldbox

- Protective panels removed
- Survey is completed
- APA is transferred to the telescoping beam
- Translated over to a cold box
- Inserted into coldbox
- Wires routed
- After testing
  - Back to assembly tower for repairs
  - Enters cryostat via TCO beam

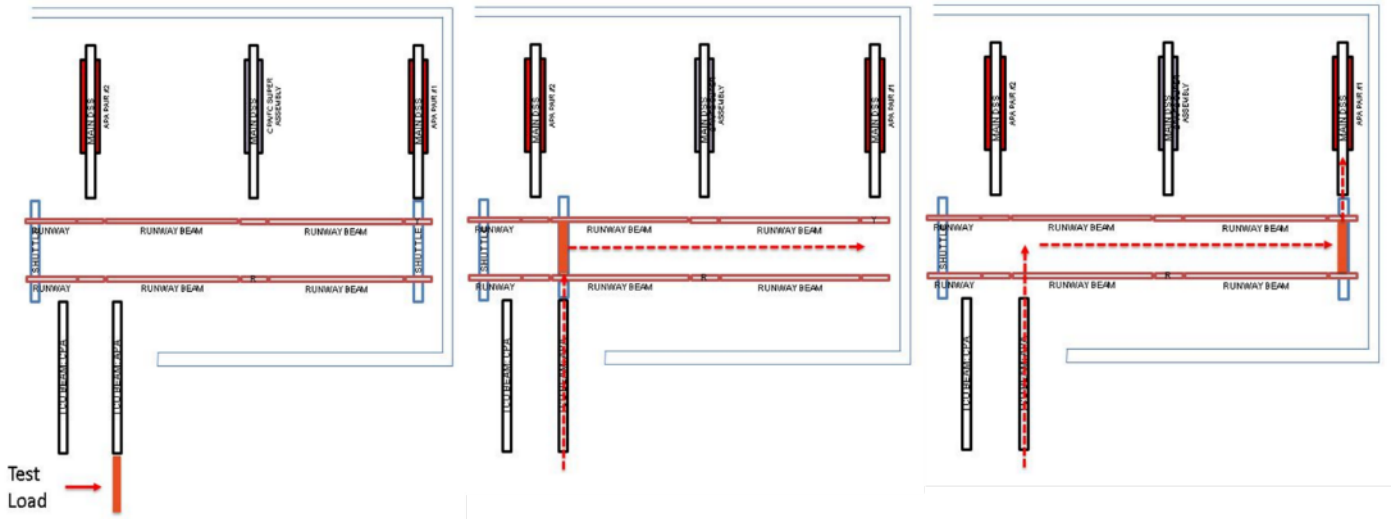






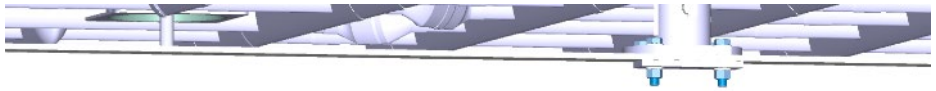
DUNE APA Inside Cryostat

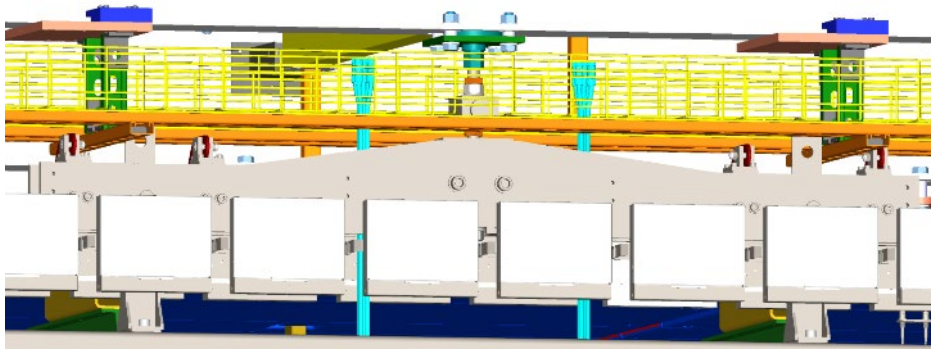
- Procedure for motions starting on the TCO beam and delivery to final DSS position detailed in [DSS Load Test Procedure at Ash River]

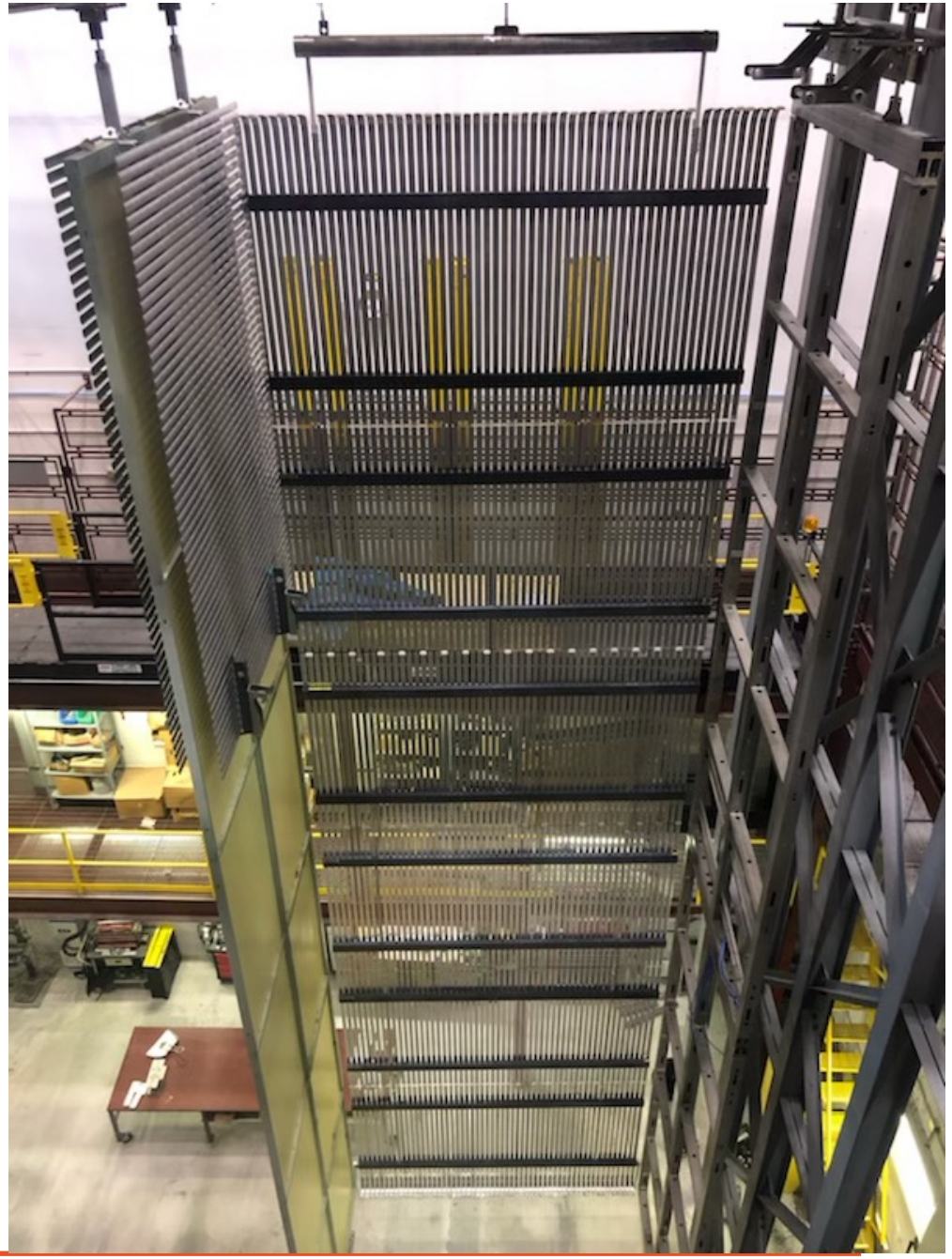


DUNE APA Cryostat Position

- APA is bolted to DSS at final position
- Trolley is carefully dismantled and removed
- Final cabling to the CE crosses
- Remove vertical cable tray (only needed during transport)
- Ground planes installed
- Field cages deployed
- APA installation is completed



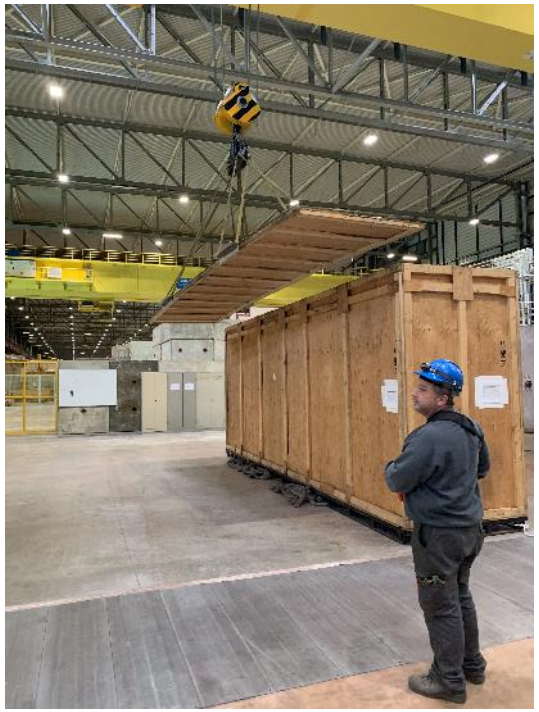


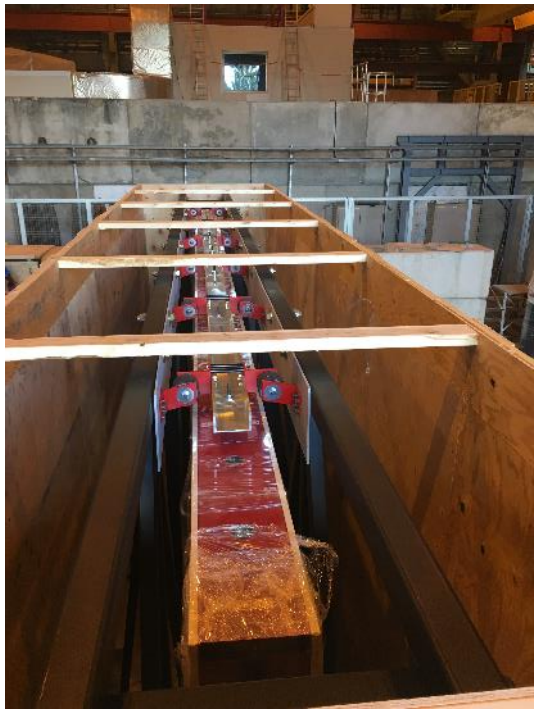


Backup

ProtoDUNE II Upper APA

- Begin removing bolts to free the top
  - Various techniques used
- Use crane or forklift to remove the top
- Remove the top bracing
- Remove wall pieces
  - Various methods used

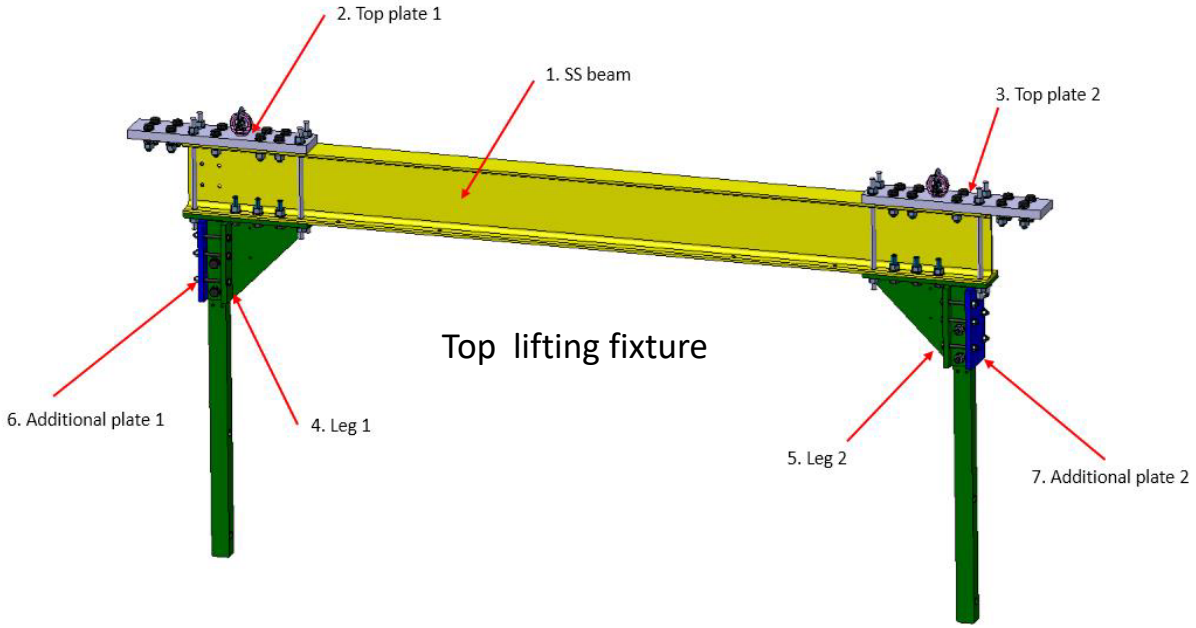


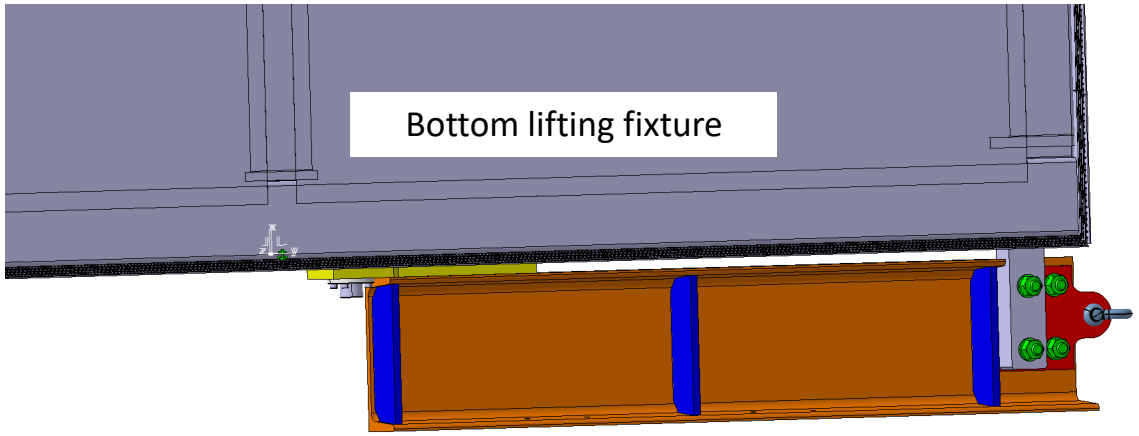


ProtoDUNE II Upper APA Lifting Fixture

- APA lifting fixture – tool manual link
  - Tool for lifting a horizonal APA out of a shipping crate and rotating vertical
  - EDMS PPSPS APA Insertion into clean room

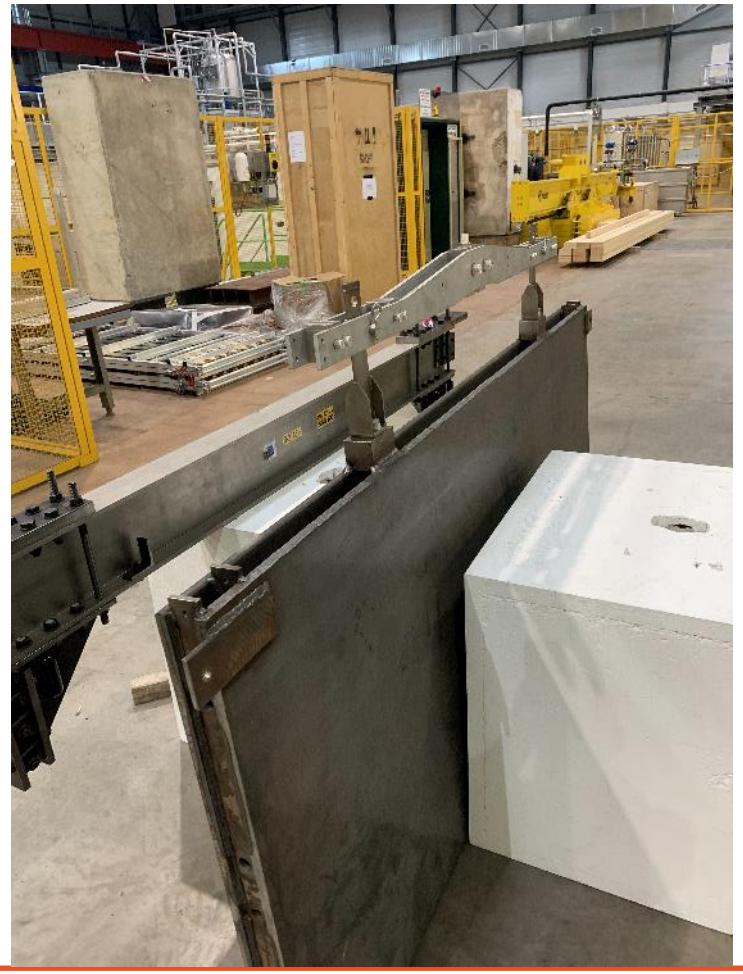
- Lifting fixture attaches directly to cleanroom rails where the APA is transferred to the transport beam inside the cleanroom





ProtoDUNE II APA Lifting Fixture

- All yokes were load tested prior to use with the APA dummy test load



- Slight modifications for pDUNEII
  - Longer bars
  - Additional mass added to APA dummy

- In progress and well understood

Upper APA → Cleanroom 1

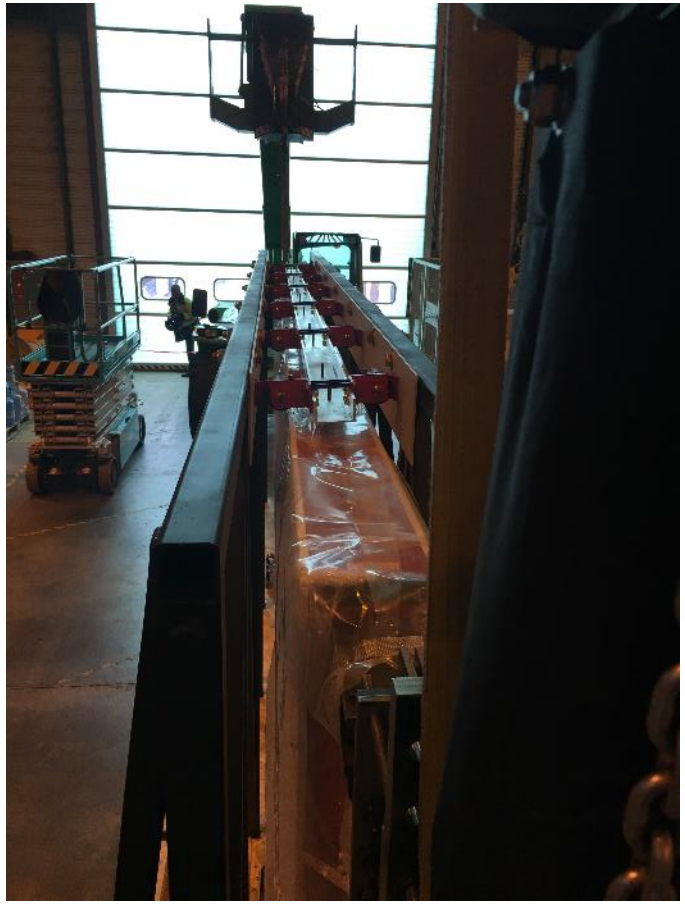
- Long bars are slid into the APA
  - Bars are connected to APA with 20mm bolt
  - Top bar is levelled and held with a bolt
  - Gravity pulls the bottom bar down until the lifting fixture sets the proper distance

- Yoke is installed on the APA
- Bottom fixture attaches to third long bar

Upper APA → Cleanroom 3

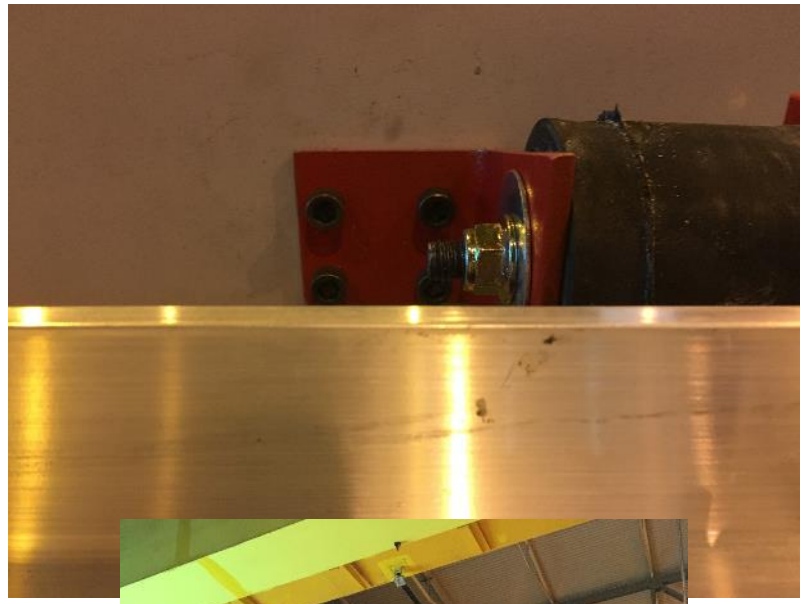
- Suspension system holds APA during transit

- Both cranes begin lifting slowly to neutralize suspension



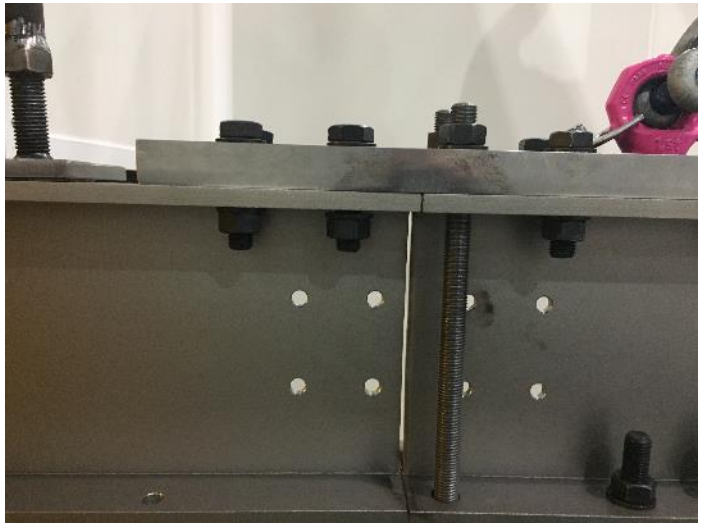
- Unbolt the suspension system when cranes take the load
  - Several minor adjustments needed to remove bolts

- Forklift carries suspension out

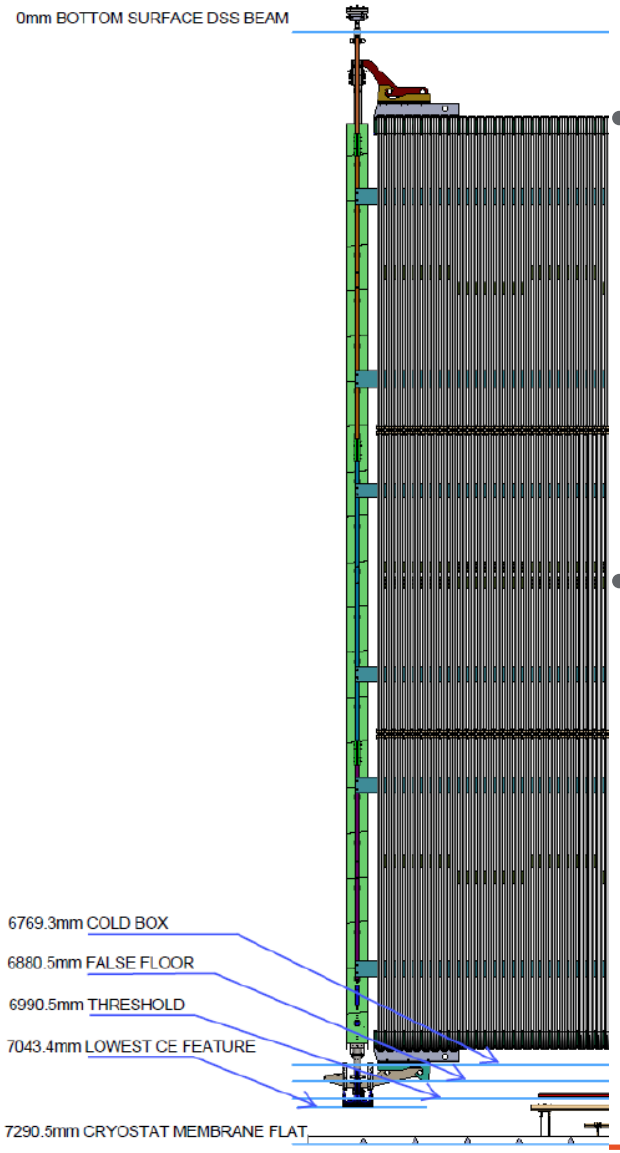


Upper APA → Cleanroom 5

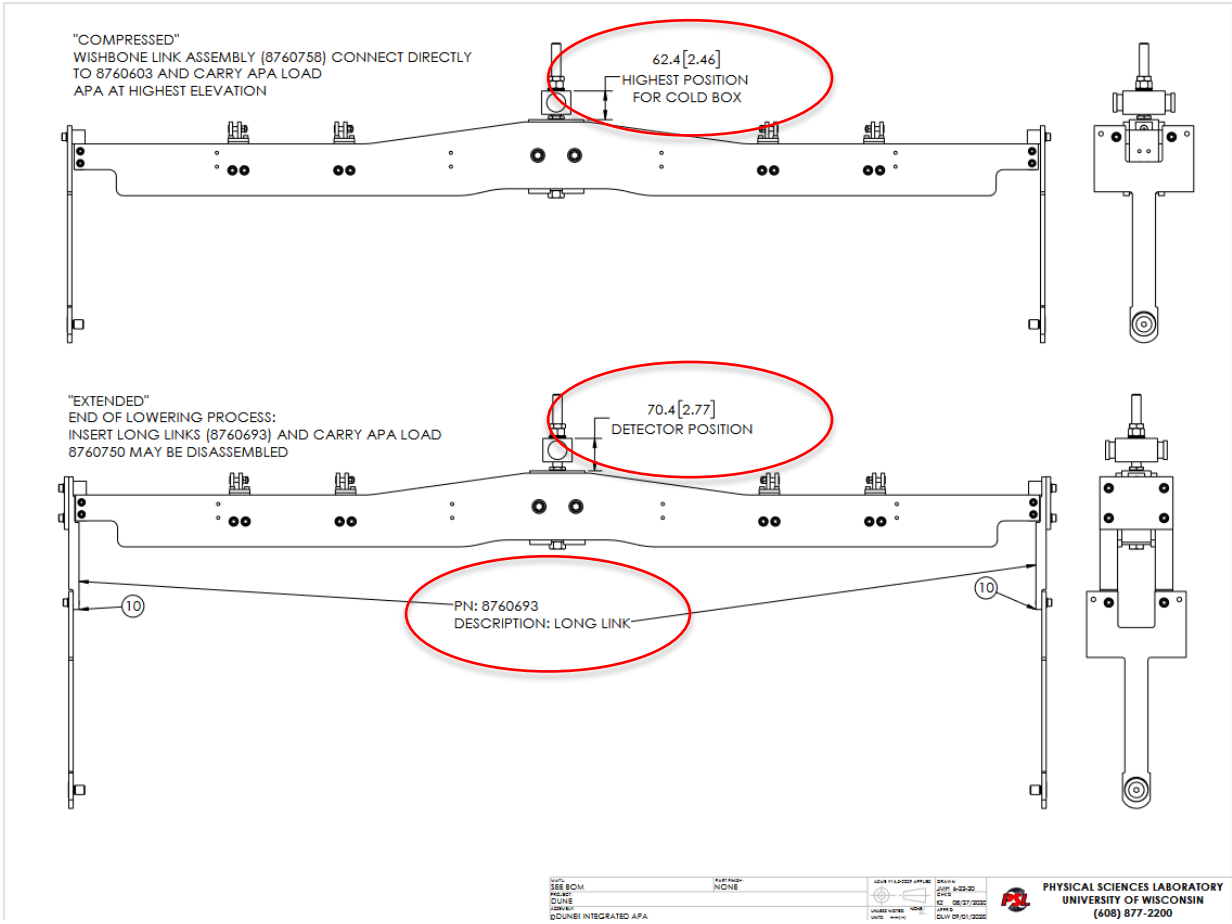
- Transport beam is moved to the SAS opening
- Lifting fixture connected to transport beam with bolts
- Use the crane to ensure level
- Begin slowly lowering the APA from the lifting fixture to the trolley by loosening the bolts evenly on each end
- Once trolley has the complete APA load, remove the lifting fixture legs and plates
- Remove the mechanical stops on fixture, roll onto transport beam, replace mechanical stops



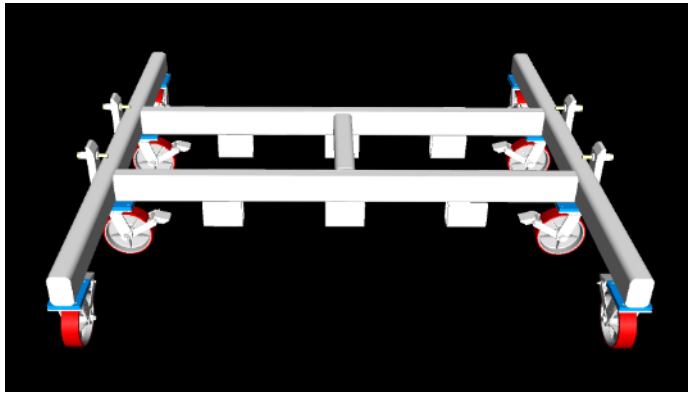
ProtoDUNE II Lower APA



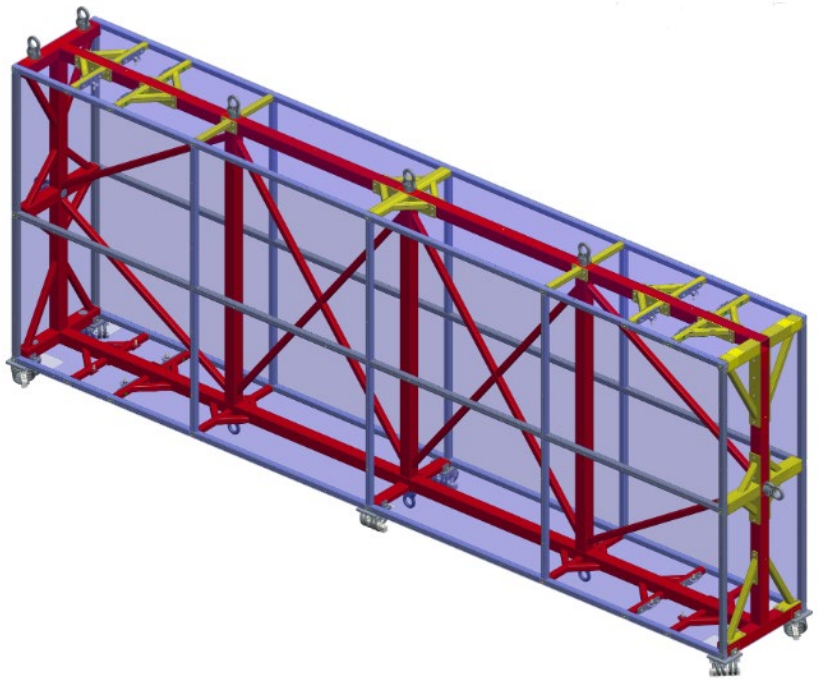
- Lower APA must hang at two different elevations:
  - Cold box position
  - Final detector position
- Adjustment made with the APA lowering system
  - [EDMS link]



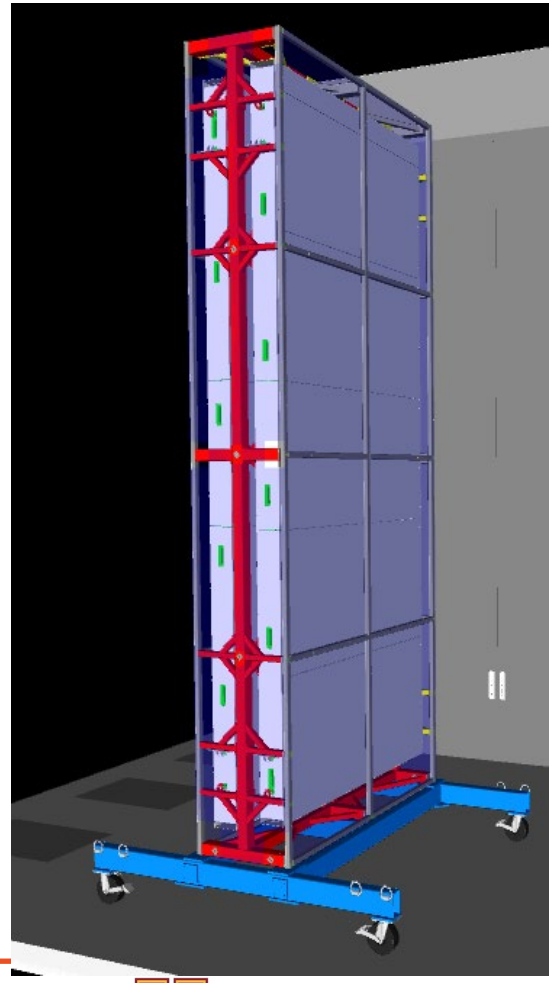
ProtoDUNE II Lower APA



- Lower APA will arrive in DUNE style transport box
- Transport box (left) is rotated vertical and placed on the cart (center)

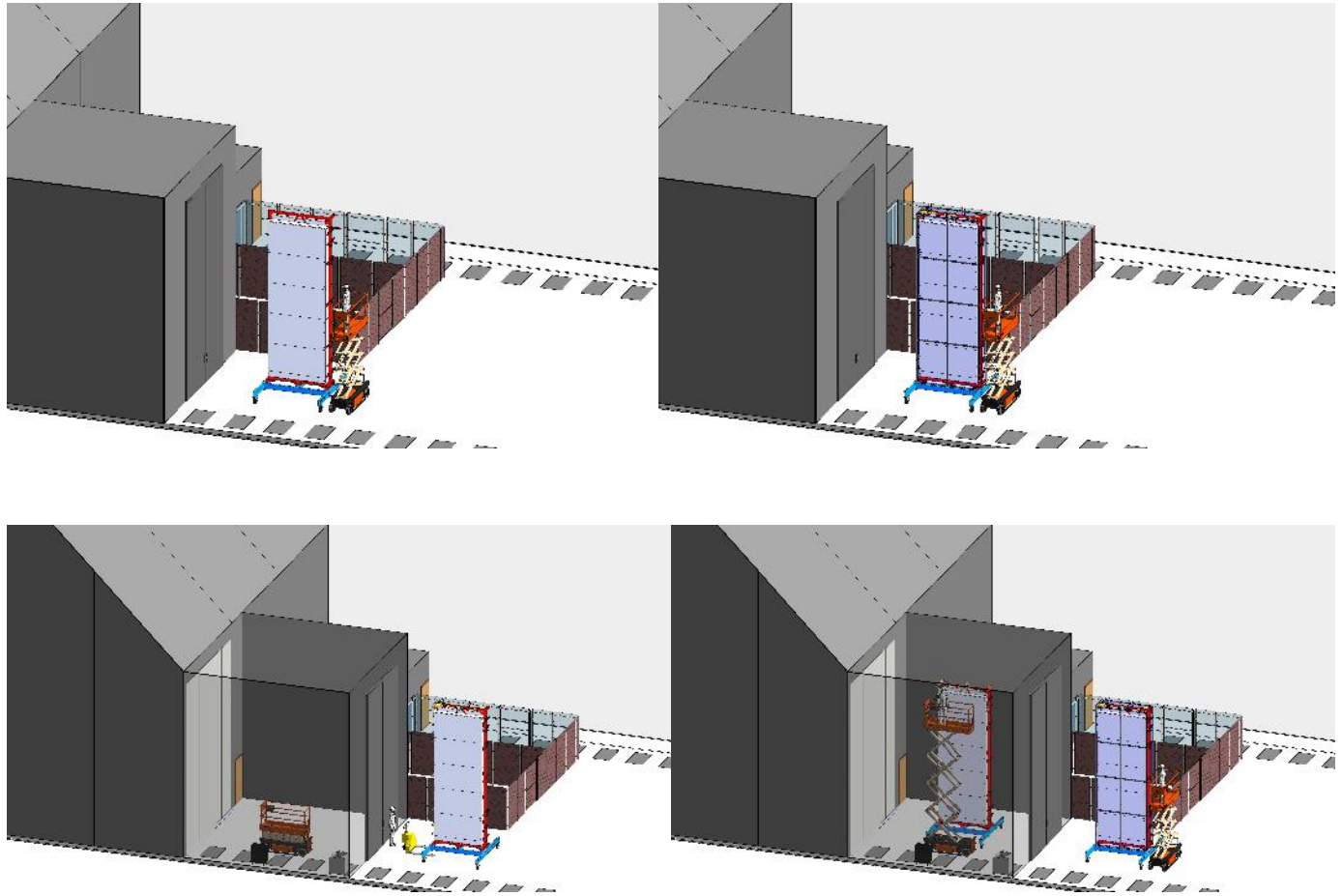


- Yoke is connected to lower APA
- Lifting fixture positioned above APA
- Trolley is installed
- Crane takes the APA load
- Box disconnected from APA
- Box rolls out of the way
- Carried to the cleanroom with lifting fixture and delivered like upper APA



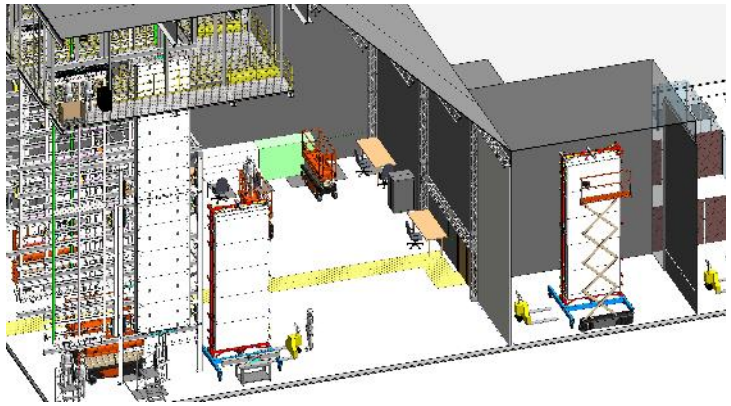
DUNE APA → Cleanroom

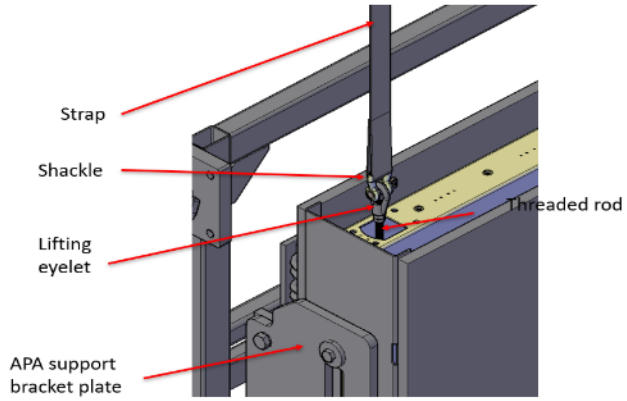
- The transport box covers are removed
- Using a tugger, the cart is pulled into the SAS
- The air in the SAS is purified every 15 minutes



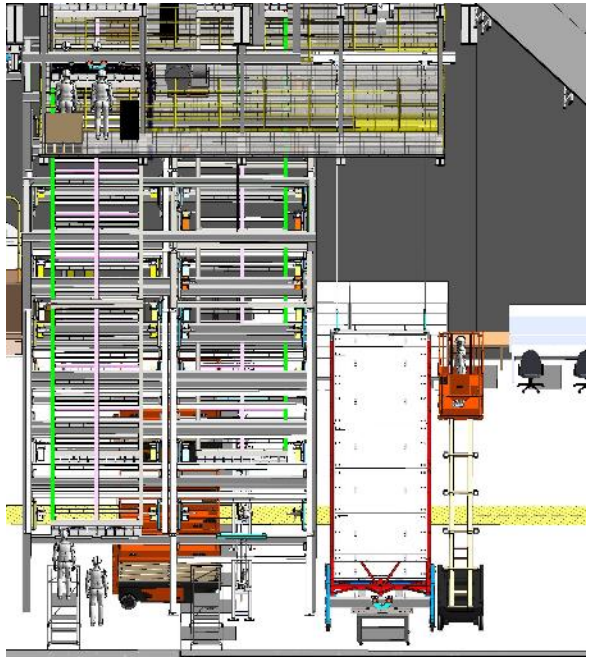
DUNE APA Assembly Area 1

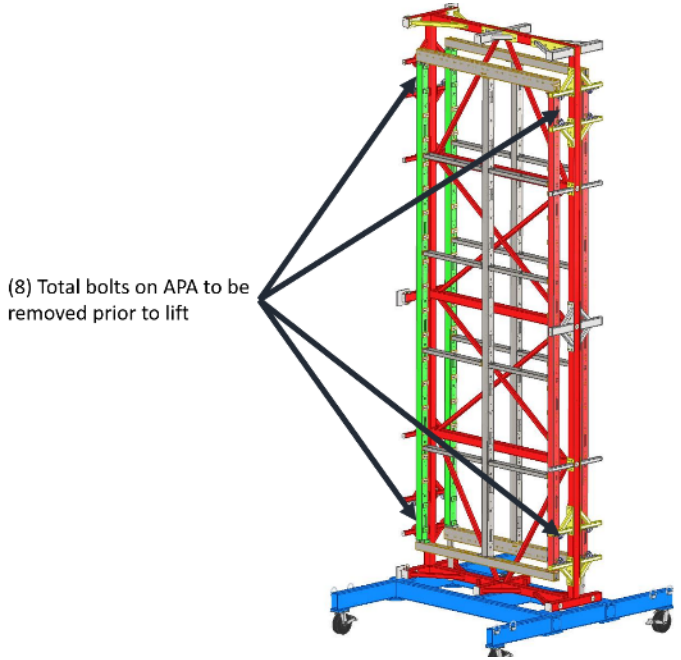
- The cart is moved over to the assembly line using the tugger
- The lower APA is delivered to the tower first
- Lifting beam has two trolleys with long lifting straps connected to clevis on the APA side tubes
- Load is transferred to the lifting beam
  - Load cell indicates when bolts can be removed
- Transport cart is tugged out of the way
- Lifting beam raised and connected to rail





Lifting gear connected to the APA





DUNE APA Assembly Outfitting 2

- Some additional testing at Ash River needed to determine optimum timing
- Cable tray can be installed before cables are routed through the tubes
  - May have to attach vertical cable tray after cable is routed
- Cable spools are craned up to top level
- Transferred to deployment spools
- Deployed
- Routed to FEMBs
- Cables dressed
  - Affix the vertical cable tray at this point