US CRP Assembly Site Cold Box: Technical Overview

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Overview

- **Cold Box Requirements:** Assembly Site Needs
- **Cold Box Design Motivation:** Why we need a Dual CRU Cold Box?
  - Lessons learned from pre-production (ProtoDUNE-VD)
  - Required design changes for full production
- **Dual CRU Cold Box Design**
  - Current design
  - Design items in progress

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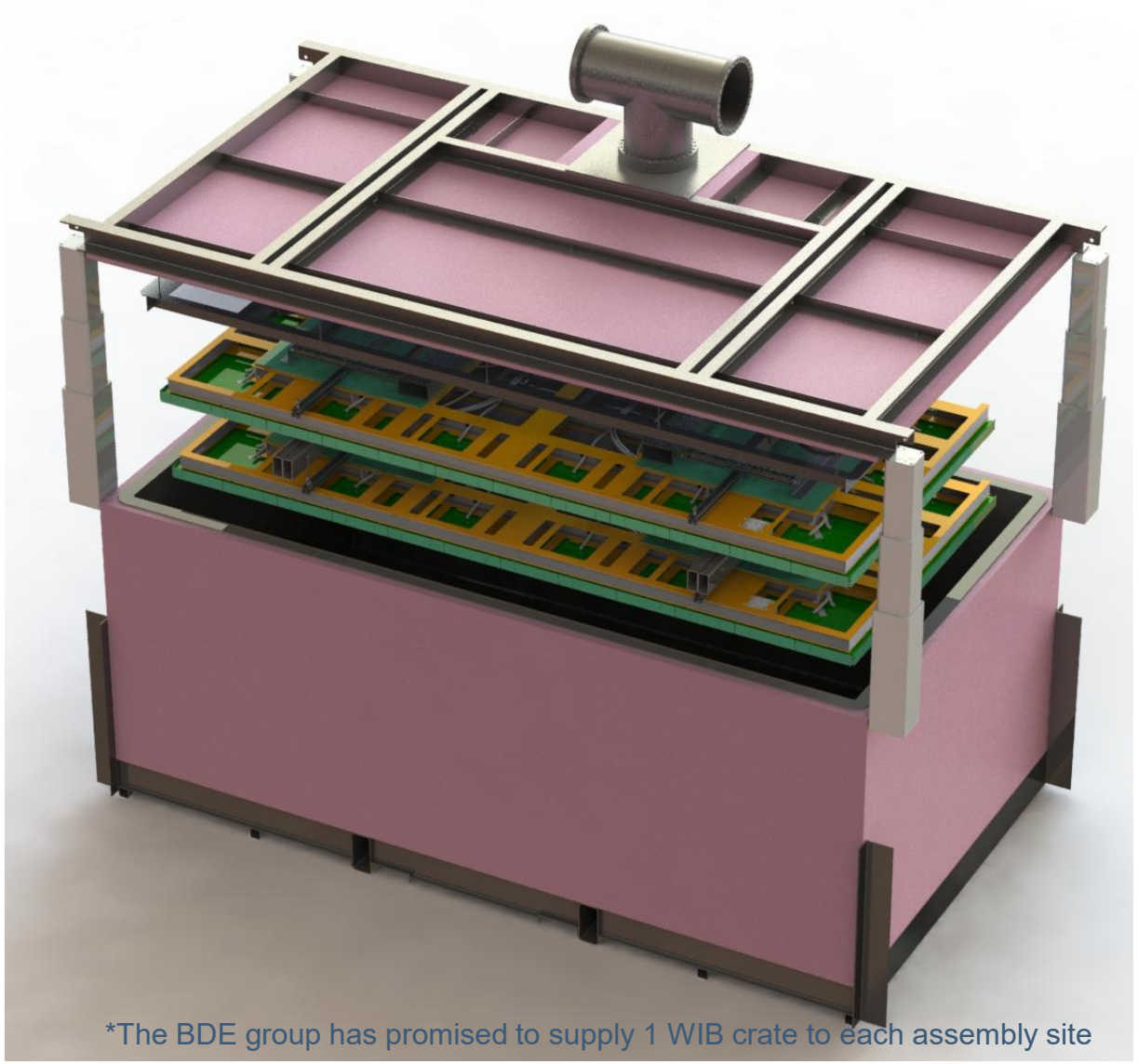
Operational Requirements

- Production:
  - Must cryo-cycle 2 CRU per week
- Electrical/QC:
  - Cold box must act as Faraday cage
  - Capable of testing:
    - Anode, AB/EC/CE interconnections
    - CRU channels at warm (ambient)
    - CRU channels at cold (<140K)
    - For HV leakage currents at cold

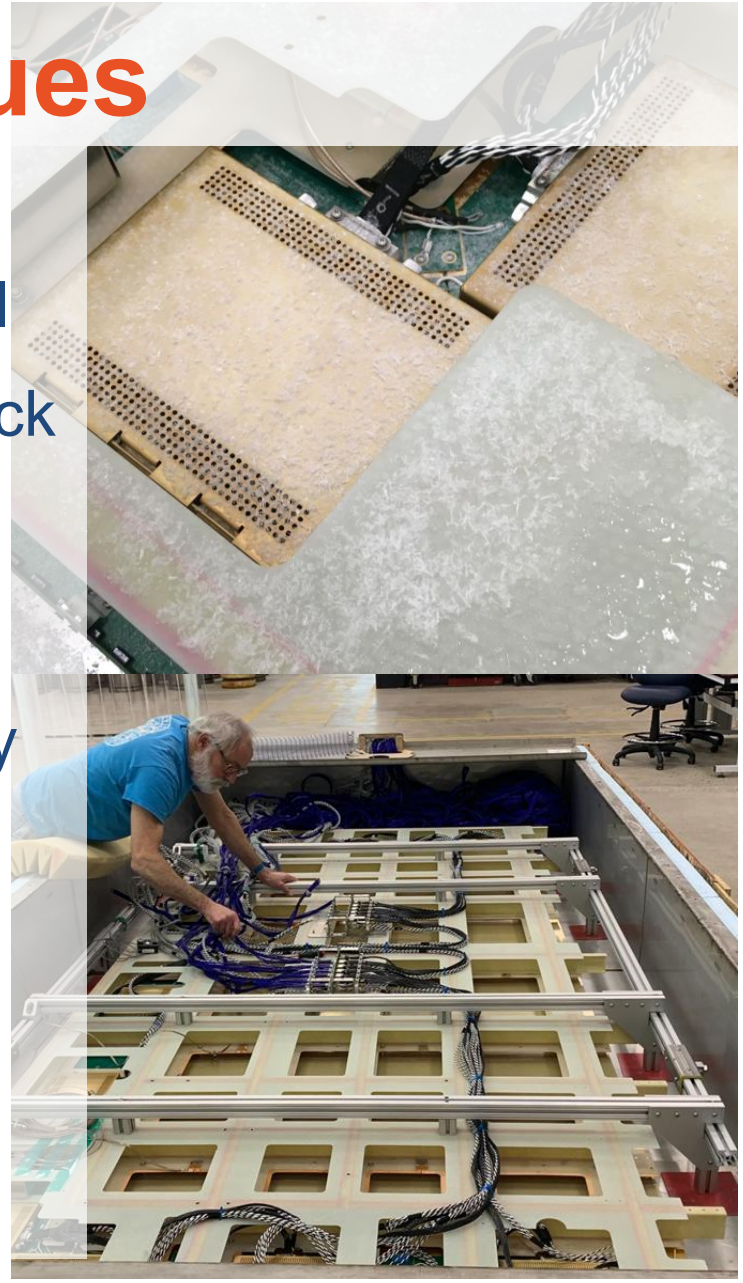


*The BDE group has promised to supply 1 WIB crate to each assembly site

Pre-production Cold Bath: Issues

- Shallow depth & top loading → only 1 CRU per test
- Lack of seal (by design) → exhaust difficult to control
- Passive boil off and warm up → operational bottleneck
- Ergonomics: patch panel access
- Required ~4 times the footprint to operate
- Lifting frame for testing not compatible with assembly
- Filling via dewars was labor intensive
  - Method has little contingency capacity

Not viable for sustained production



Design Goals: Full Production

- **Enable 2 CRU throughput per week**
- **Reduce assembly site footprint:** Side loading, external LN dewar
- **Minimize operational bottlenecks:** Filling time, boil off time, simultaneous testing
- **Improve ergonomics:** Patch panel access, cable management
- **Ensure cold box safety:** Stable exhaust, thicker & reinforced SS pan
- **Contingency:** Include weekly buffer to absorb unexpected delays and maintain throughput. Turn around in order of a few days, not a week

Dual CRU Cold Box: Concept

- Enables simultaneous testing of two CRUs
- Side Loading Design:
  - Enables ergonomic access for installation
  - Eliminates overhead crane
  - Reduces footprint
- Functions as Faraday cage for HV testing
- Exhaust improvements: sealing lid
- Design compatible with liquid nitrogen or cold nitrogen gas testing

Cold Gas v Liquid Testing: Differences

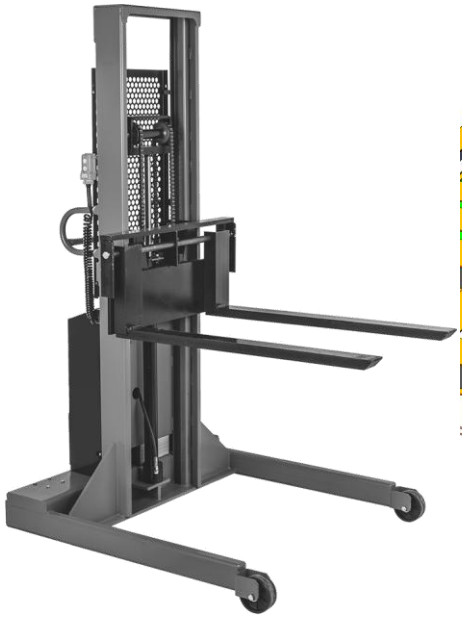
- Heaters required
  - Lower power → Less expensive
  - External to the cold box
  - Less complex control system
- Level sensors – Full height needed for liquid testing scenario
  - In a gas testing scenario, only the portion of the box filled with LN is instrumented
- Temperature sensors – Only necessary in gas testing scenario
- Length of cooldown

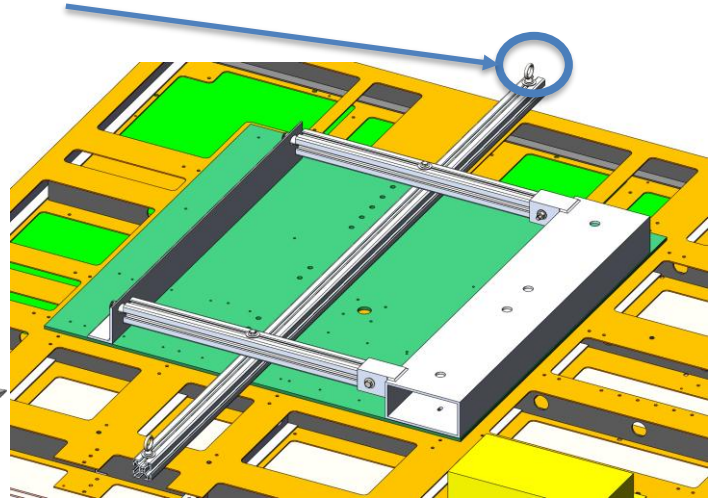
Dual CRU Cold Box: Construction

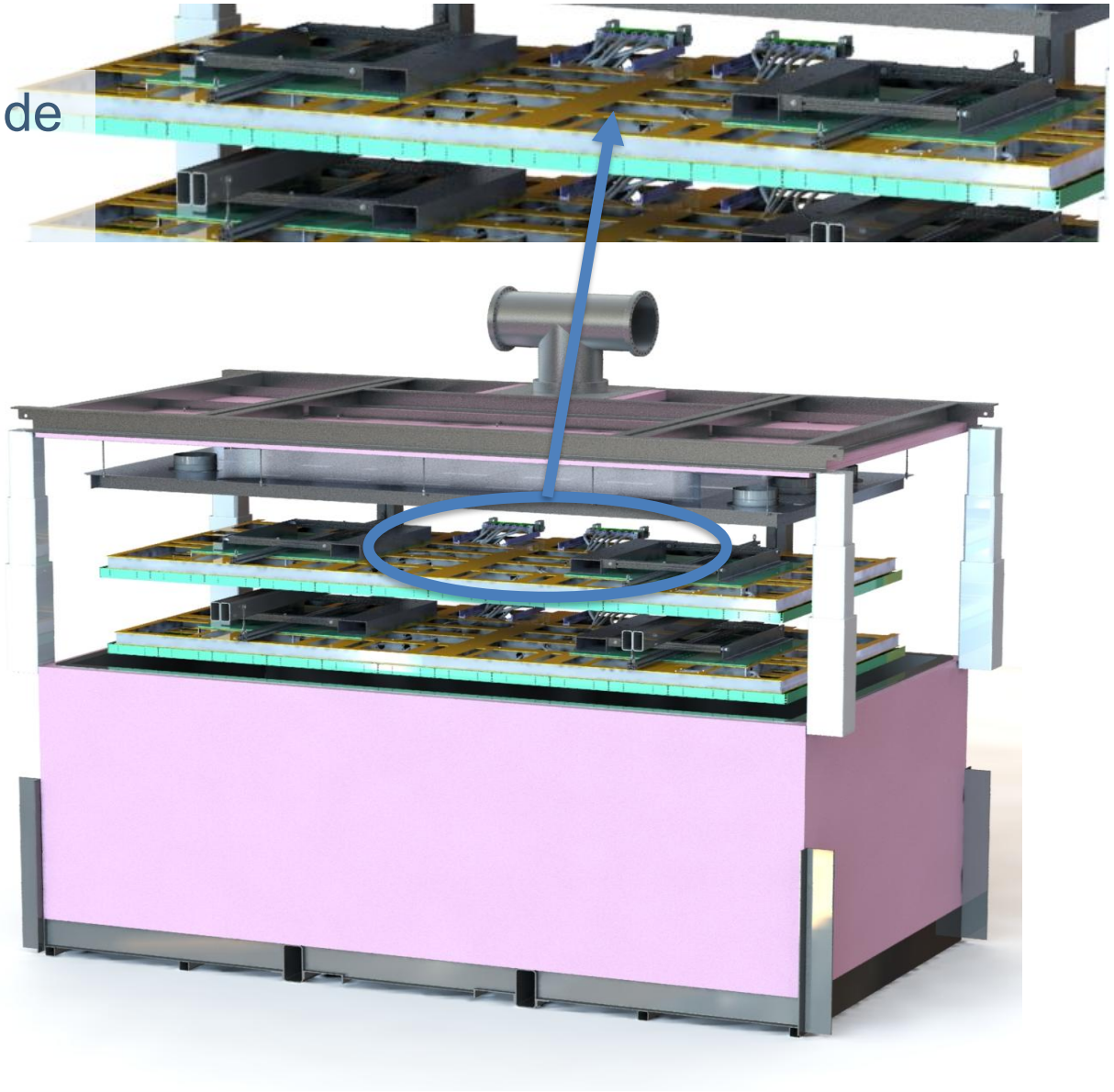
- Containment volume:
  - Welded 3/16” SS pan with 2.5” flange & reinforcing ribs
  - Dimensions: 140” x 74” x 50” [3.56m x 1.88m x 1.27m]
- Cover:
  - Aluminum framing with SS sheet skin
  - Lift mechanism: Linear stages
  - Includes chimney penetration and mounting
- Chimney:
  - SS pipe w/ 14” CF flanges.
- Base:
  - 6” steel beams
  - Structural steel base with welded framing

Sideloading Design

- Pallet stacker loads both CRUs from one side
- Fork receiving frames allow CRU to be transported by pallet stacker
- These frames also have suspension attachments for CRU in cold box





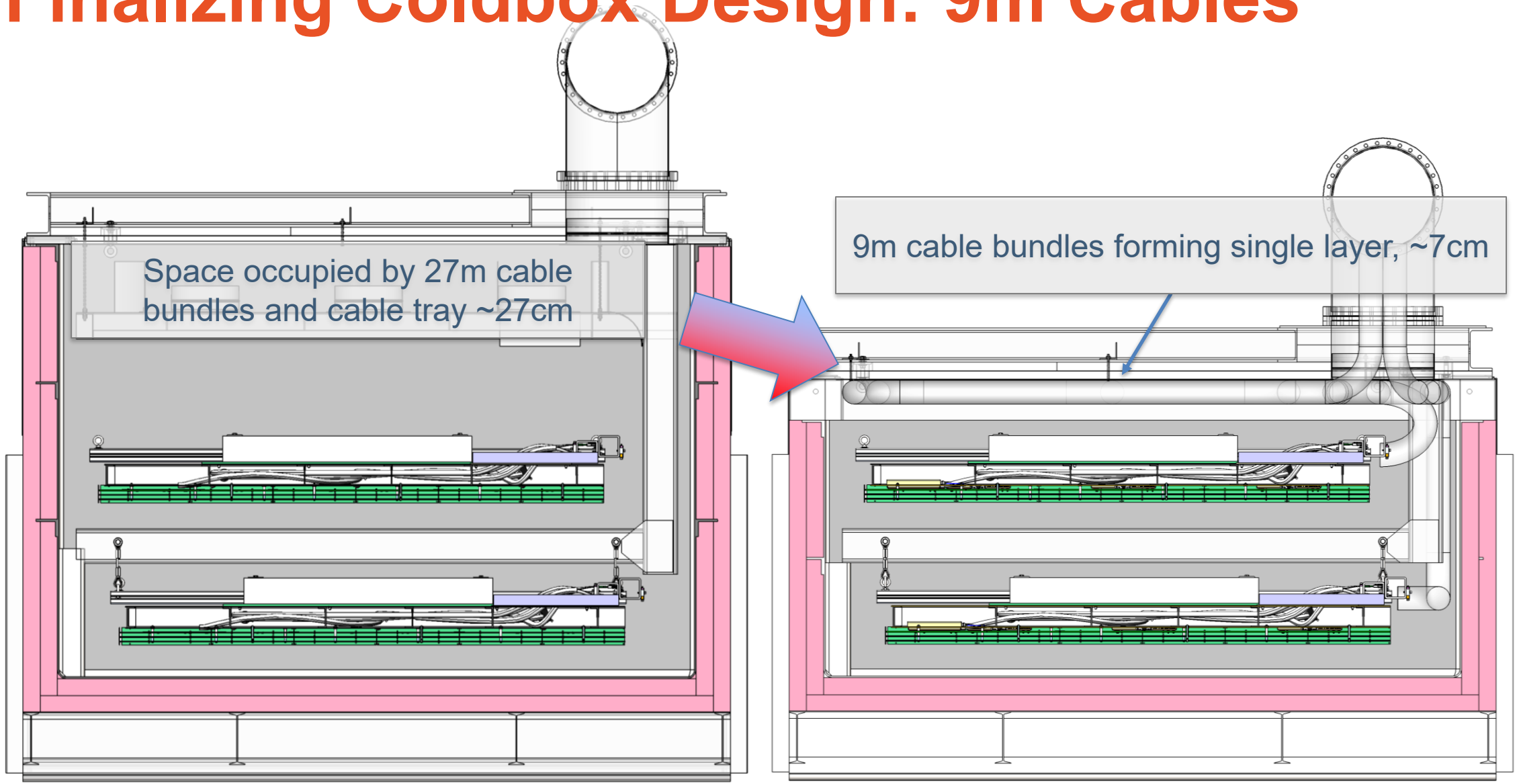


Design use mostly stock Al extrusion
Provisions for thermal contraction included to eliminate strain on CRU

Finalizing Coldbox Design

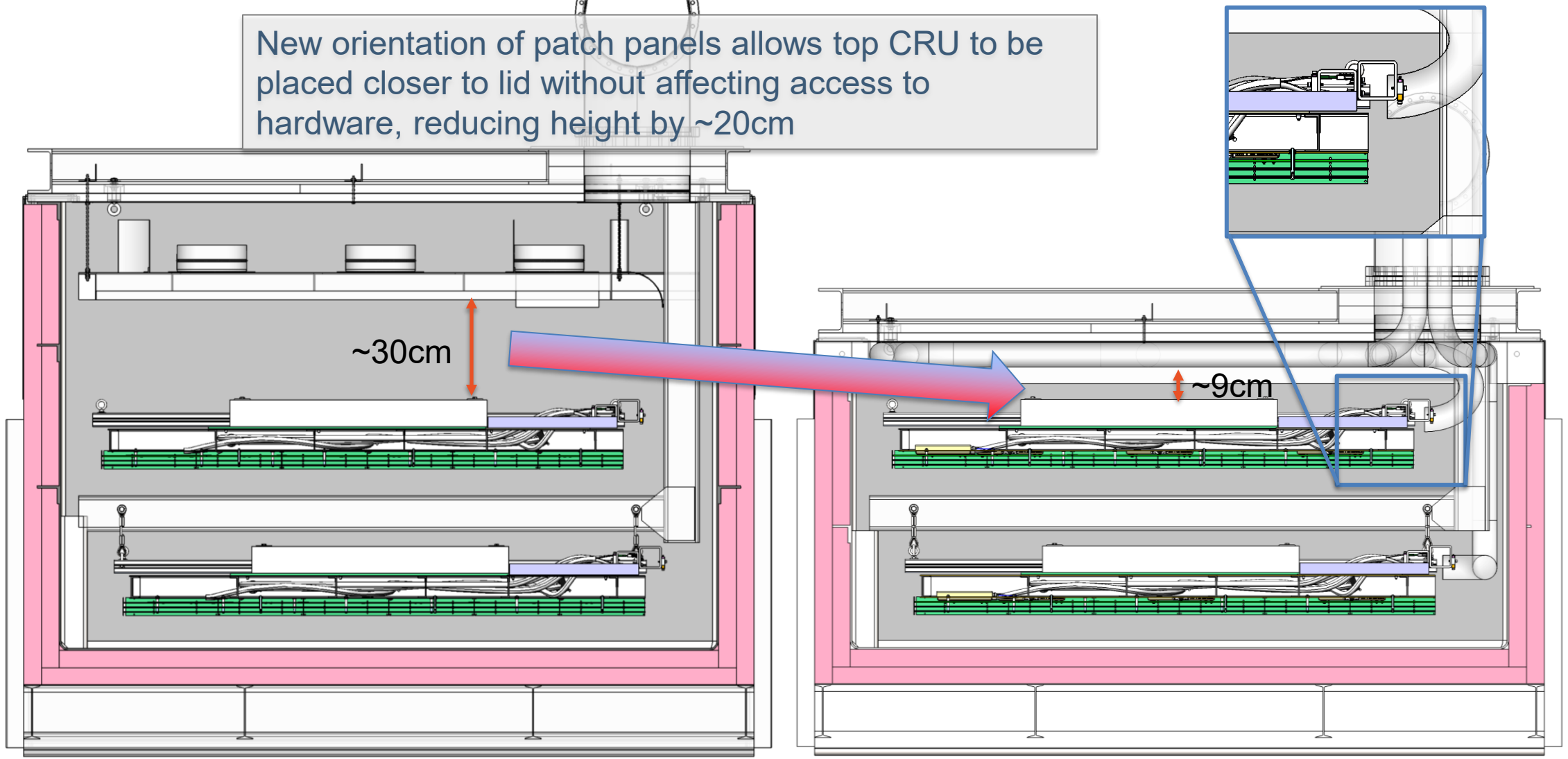
- ~~Rework cable routing for 9m BDE cables~~
- ~~Reassess vertical spacing between CRUs and Lid~~
  - ~~Can this be reduced while preserving accessibility for installation?~~
- Finalize lifting columns for cold box lid
  - ~~Identifying columns that can reach necessary height~~
- Incorporate liquid nitrogen and nitrogen gas delivery lines
- Finalize cold box pan dimensions based on necessary clearances
  - Between liquid nitrogen and nitrogen gas delivery lines and CRUs
  - Adjust base, lid dimensions accordingly

Finalizing Coldbox Design: 9m Cables



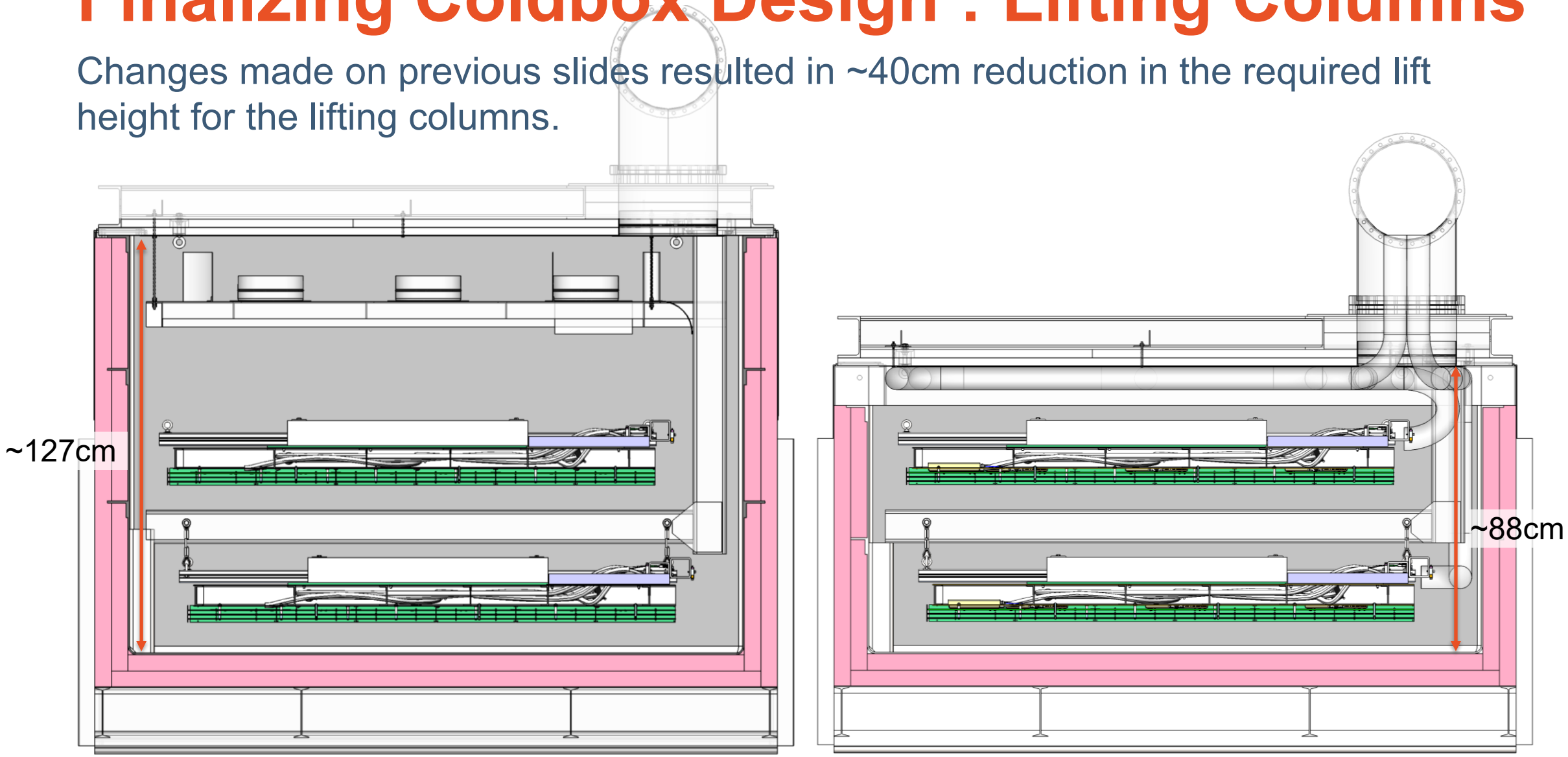
Finalizing Coldbox Design : Vertical Spacing

New orientation of patch panels allows top CRU to be placed closer to lid without affecting access to hardware, reducing height by ~20cm



Finalizing Coldbox Design : Lifting Columns

Changes made on previous slides resulted in ~40cm reduction in the required lift height for the lifting columns.



Finalizing Coldbox Design : Lifting Columns

LINAK
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Introduction

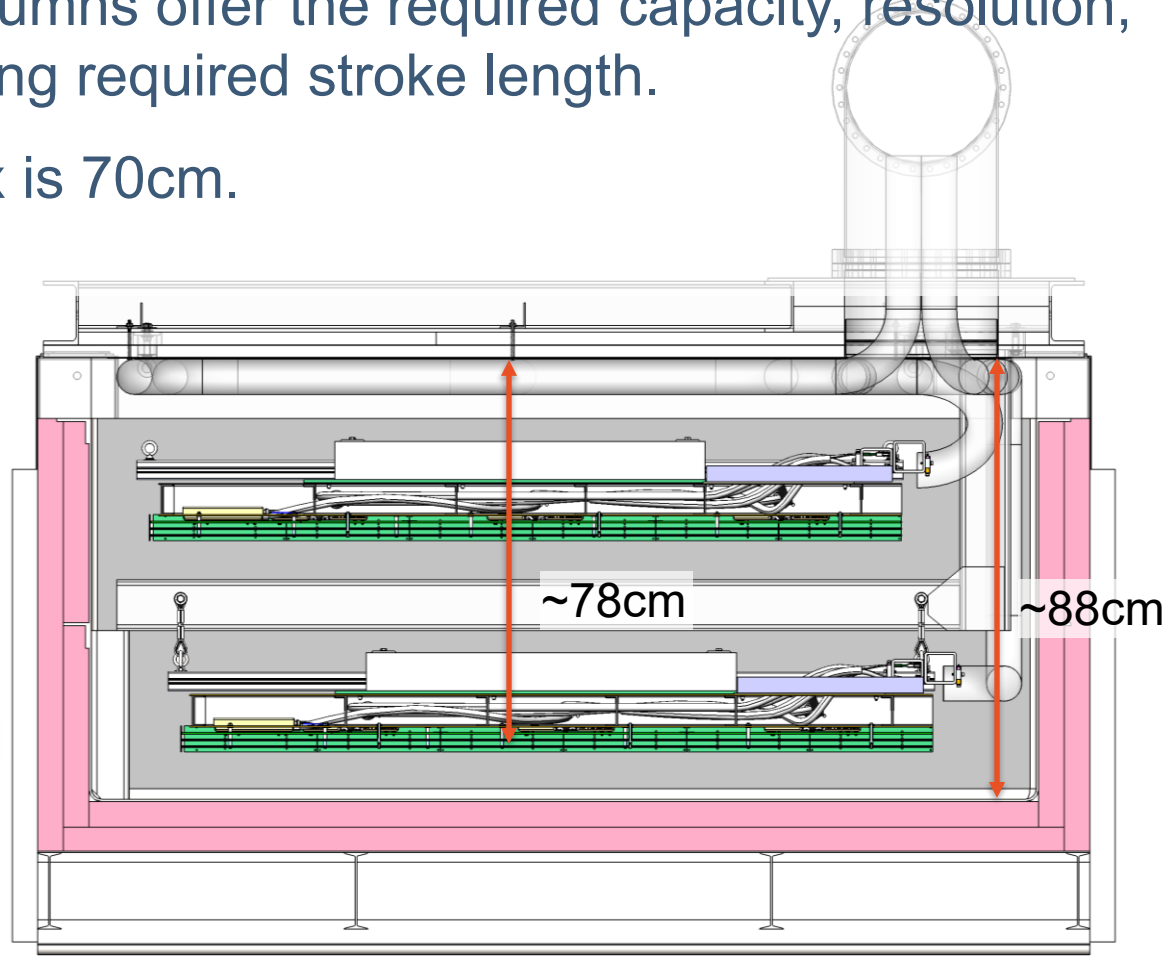
Aiming to use off the shelf, plug and play system.

LINAK's LC3 lifting columns offer the required capacity, resolution, and are close to meeting required stroke length.

Need ~80cm, unit max is 70cm.

Features and options

Load in push	4,000 N, 5,000 N, 6,000 N x 4 = 24kN
Load in pull	4,000 N
Profile colour	Anodised aluminium
Top and bottom plate colour	Zink grey
Protection class	IPX4 standard, IPX6 optional
Motor	24 V DC Type G to be used with LINAK control box Type B to be used with customer supplied control box
Stroke length	3-stage: 400-700 mm in steps of 50 mm, 200-700 mm in steps of 1 mm on request. 2-stage: 200-700 mm in steps of 50 mm, 200-700 mm in steps of 1 mm on request.



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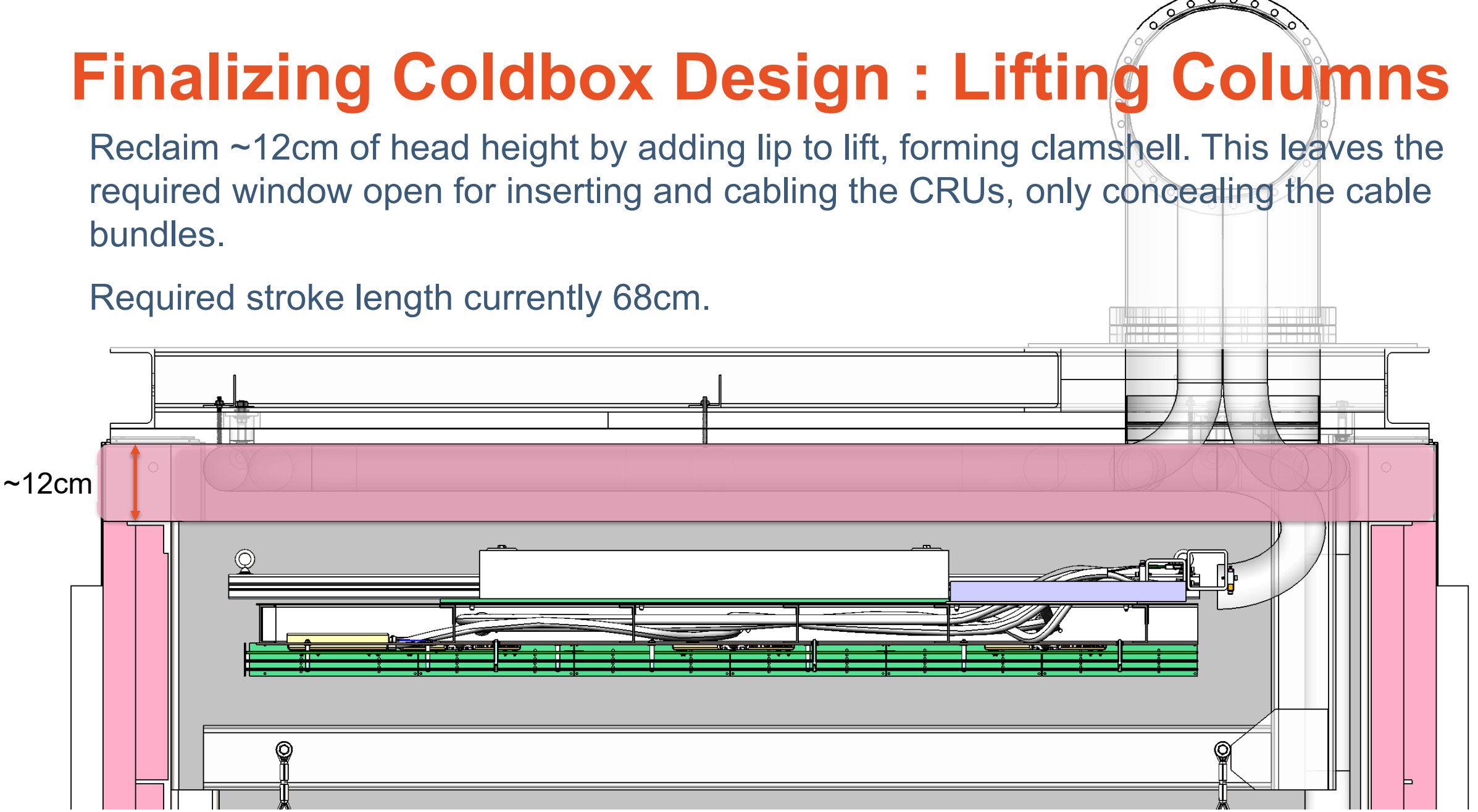
Finalizing Coldbox Design : Lifting Columns

Reclaim ~12cm of head height by adding lip to lift, forming clamshell. This leaves the required window open for inserting and cabling the CRUs, only concealing the cable bundles.

Required stroke length currently 68cm.



Summary

- Dual CRU Cold Box meets production requirements
  - 2 CRU throughput per week
- Design improvements informed from pre-production:
  - Reduced assembly site footprint
  - Operation bottlenecks mitigated
- Mechanical and structural design in place
  - Present concept works with both liquid nitrogen and cold gas testing
  - Welded SS pan, foam insulation, steel base, and lid supported by lifting columns
- Open questions:
  - Placement of nitrogen (liquid and gas) delivery lines
  - Finalizing cold box dimensions and necessary clearances

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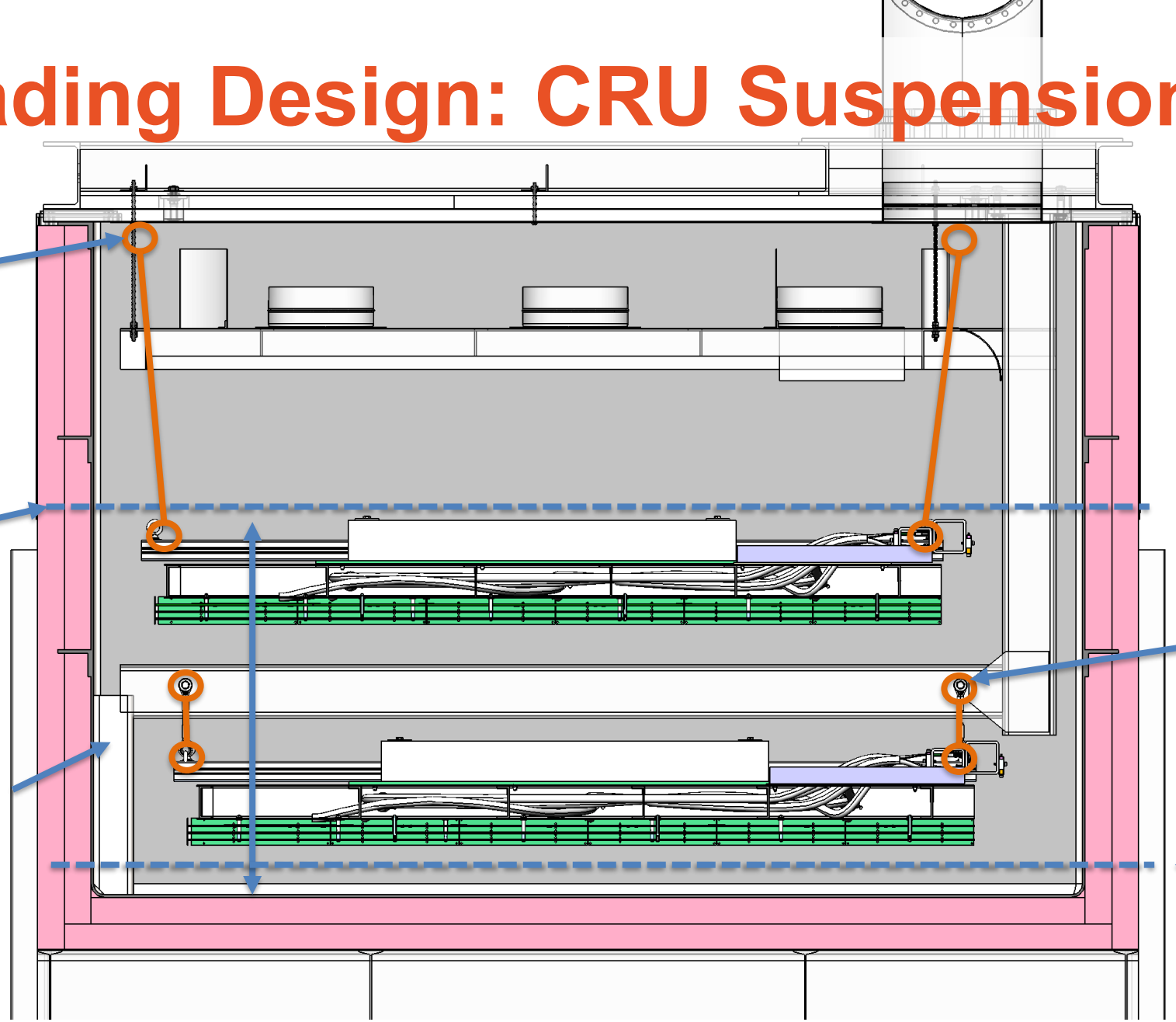
Extra Slides

Sideloading Design: CRU Suspension



CRU suspended from cantilever support via wire

Fill height for full liquid testing, ~70cm

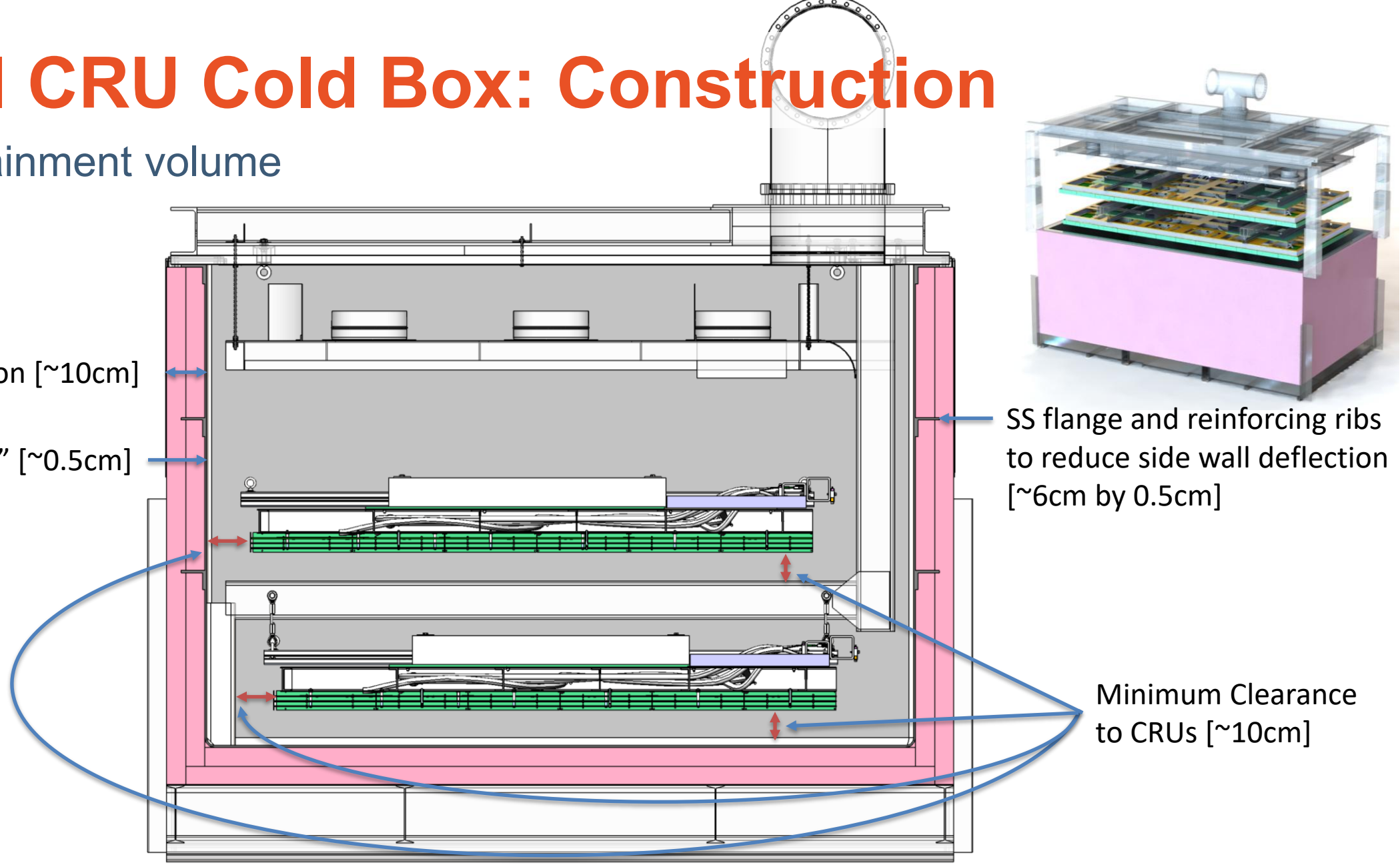
In lowered position, cantilever support arm rests on prop

CRU suspended from cantilever support via wire

Fill height for vapor testing, ~5cm

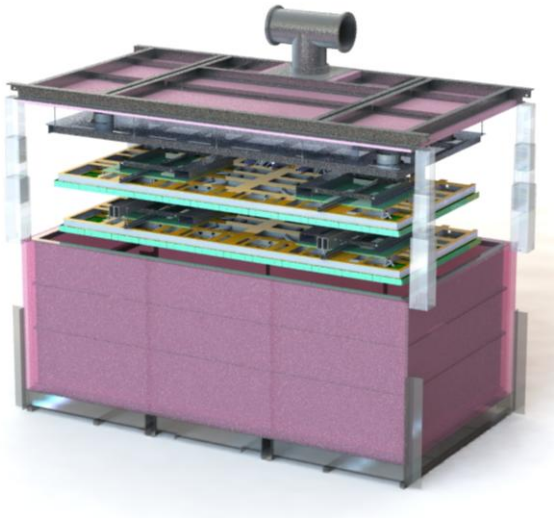
Dual CRU Cold Box: Construction

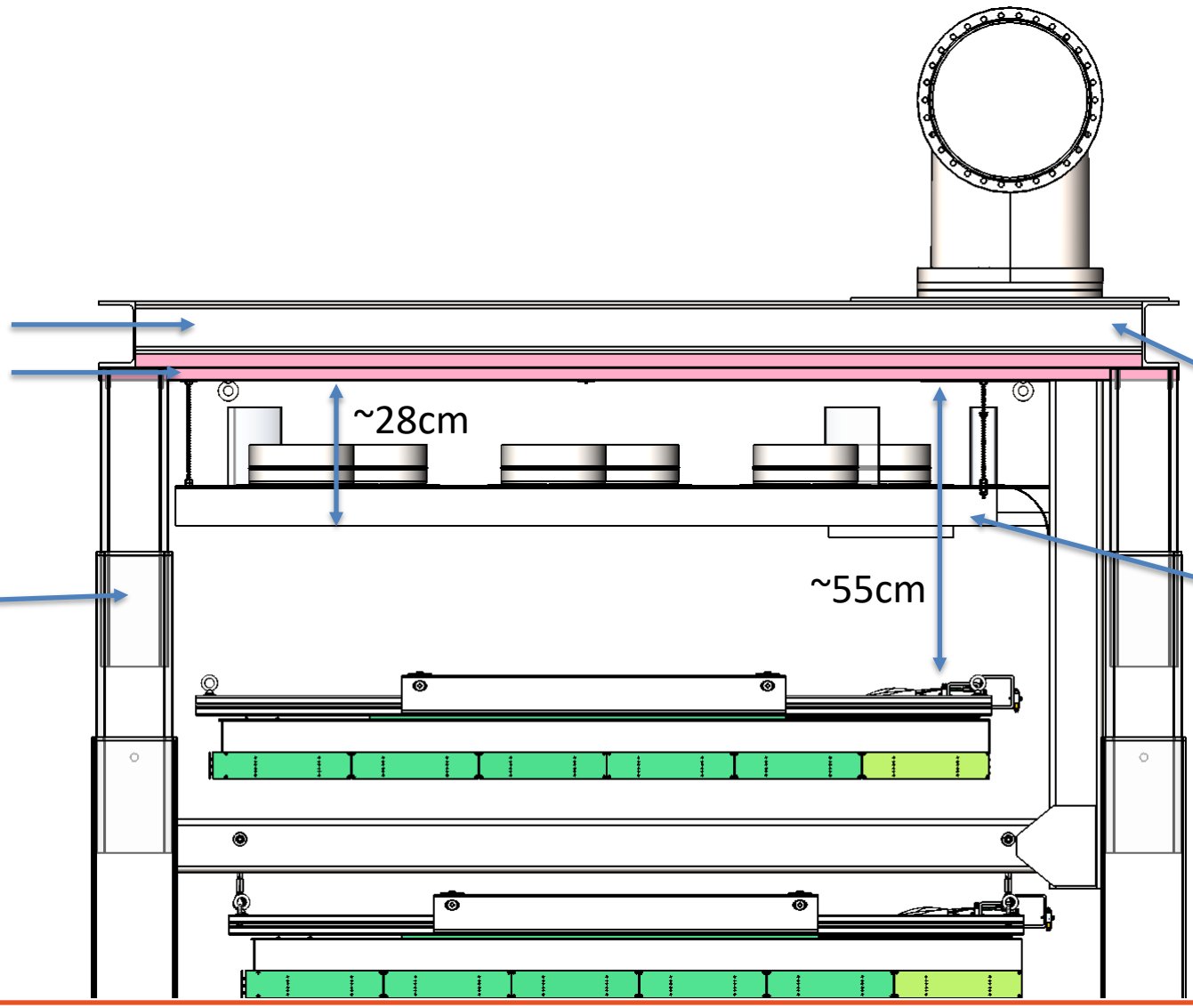
- Containment volume



Dual CRU Cold Box: Construction

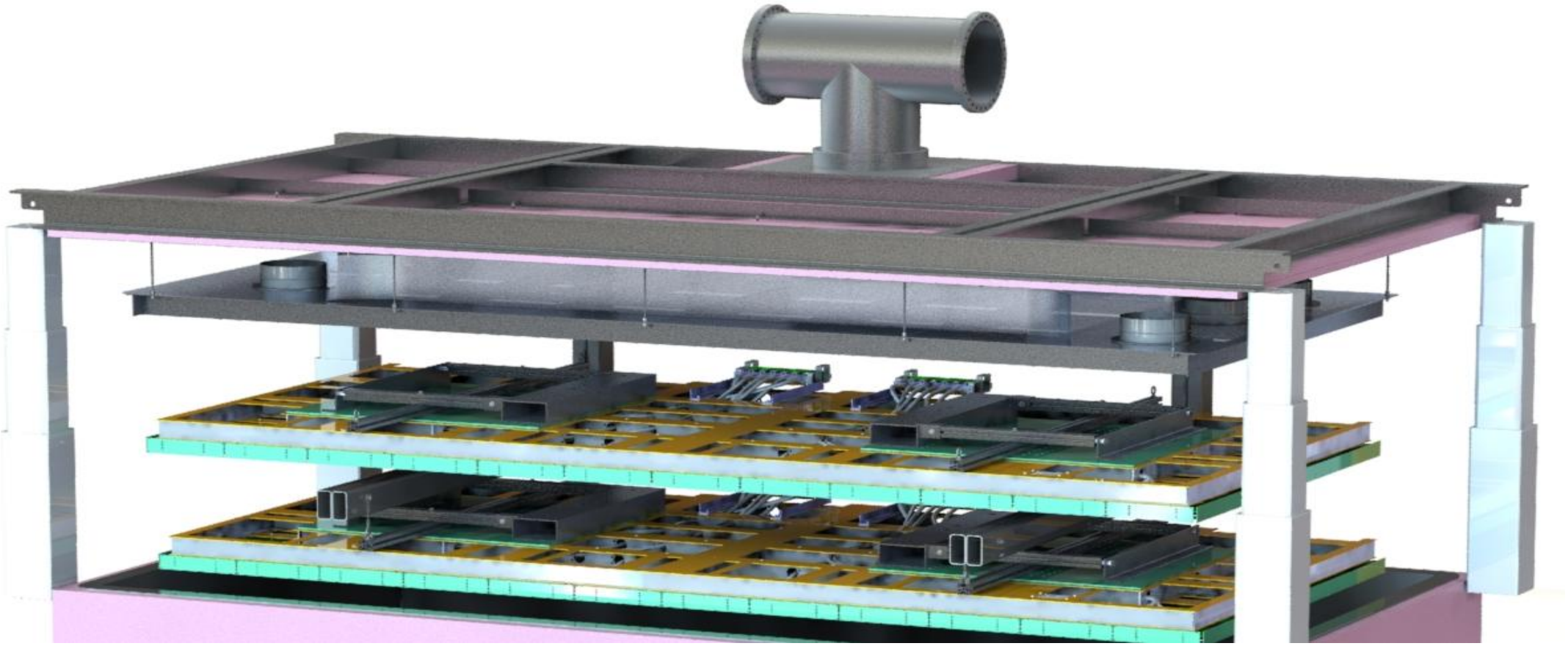
- Cover





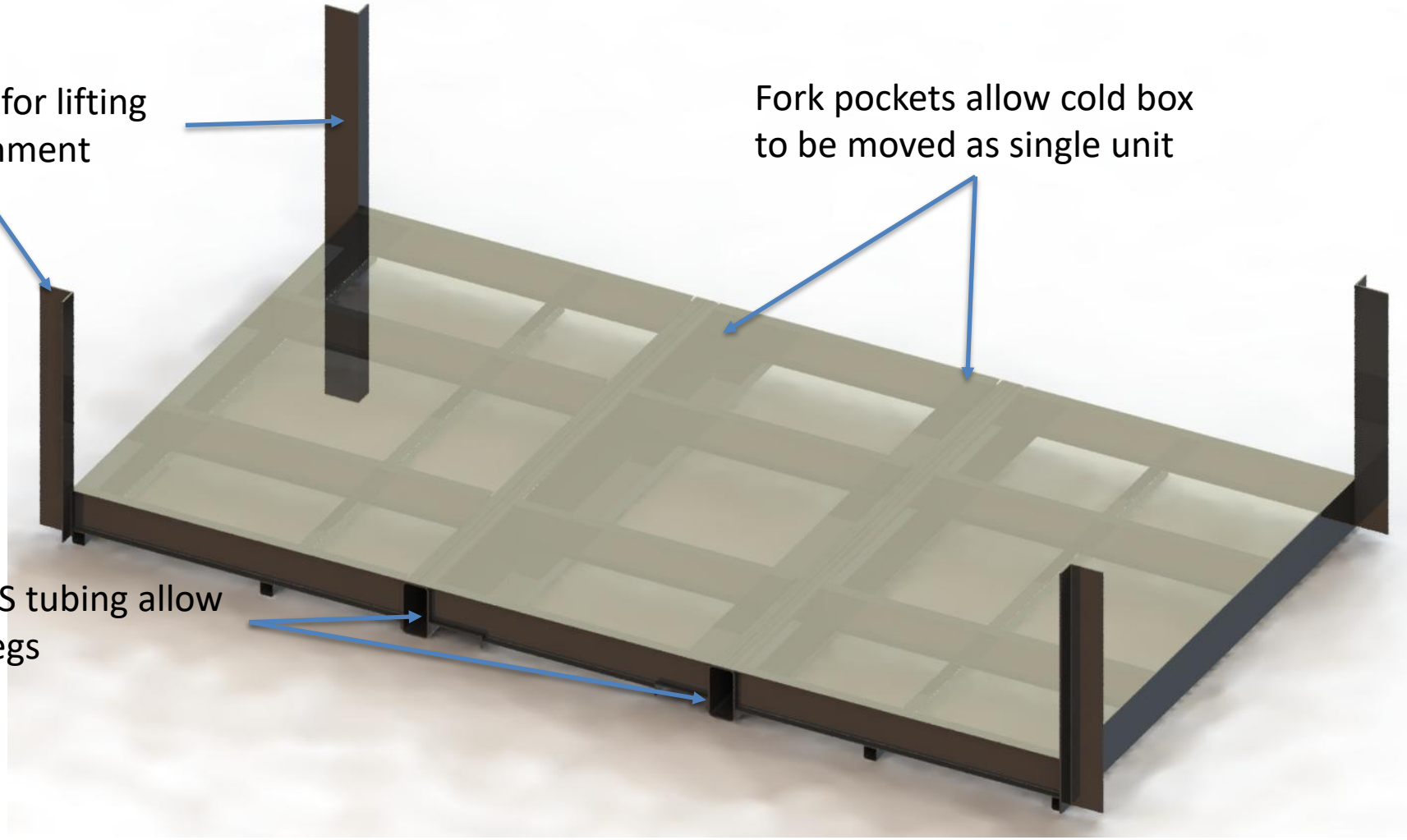
Dual CRU Cold Box: Construction

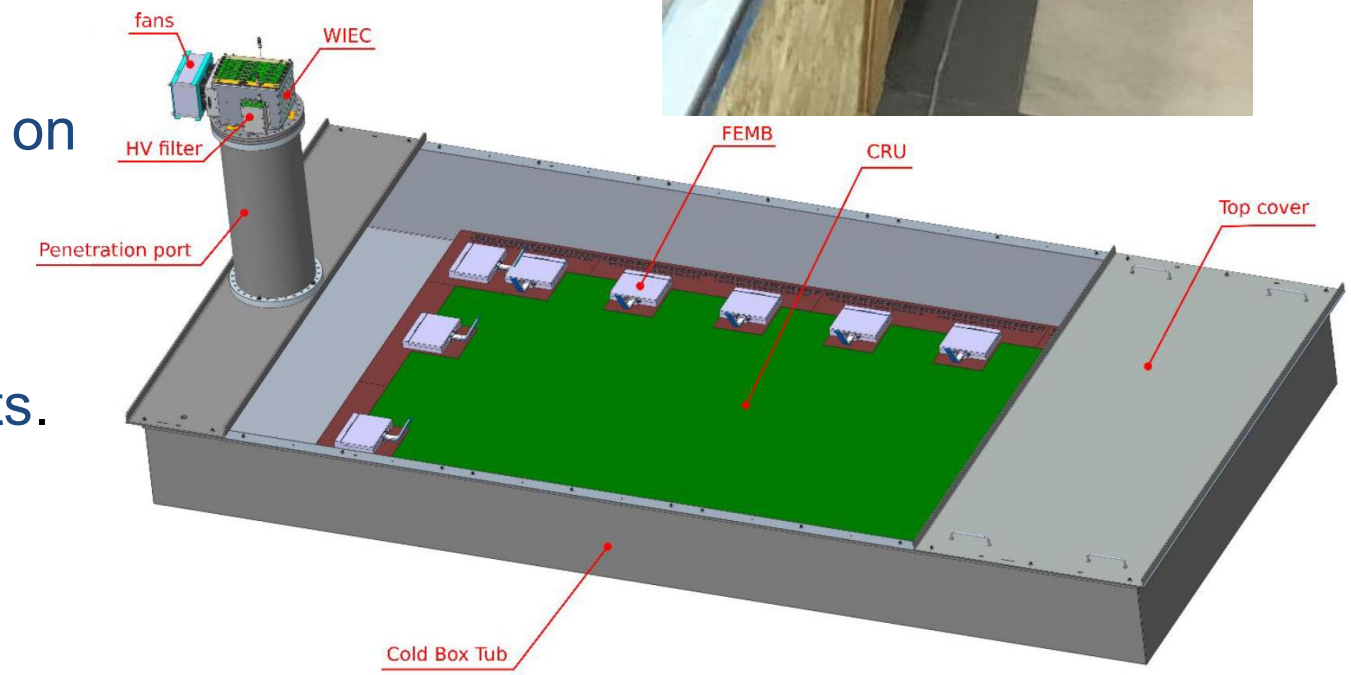
- Chimney: SS Tee w/ 14” CF flanges.
  - Supports WIB crate and slow control feedthroughs



Dual CRU Cold Box: Construction

- Base: Welded structural steel



Pre-production Cold Bath: Construction

- Containment volume:
  - Tub: Welded ⅛” SS pan with 2” flange
    160” x 74” x 16” [4.1m x 1.9m x 0.4m]
  - Cover: Five pieces (four ⅛” Al, one ¼” SS with chimney penetration and mounting)
- Chimney: SS pipe w/ 14” CF flanges
- Insulation: Residential foam board, 4” on sides and bottom. 2” on top
- Crating: ½” Plywood.
- Skid: 2x6’s w 2” steel pipe for lift points.