US CRP Assembly Site Cold Box: Operations

Yale DUNE CRP Team

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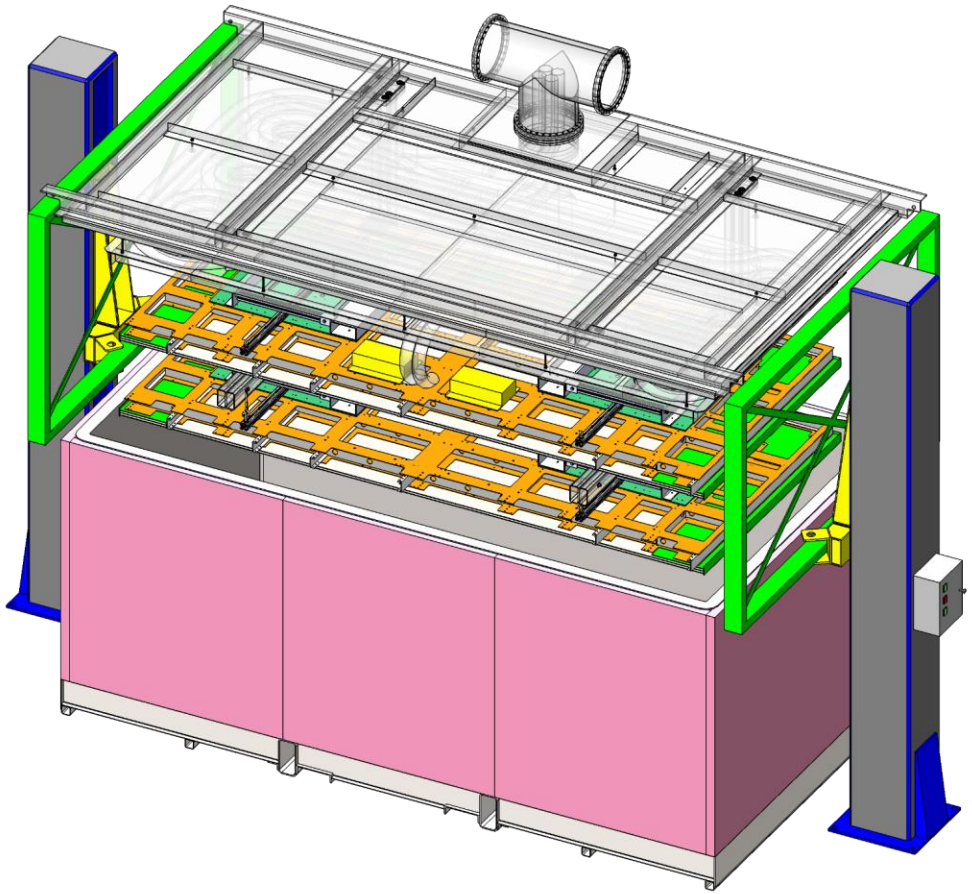
Overview

- **Operational Purposes**: Validate and test assembled CRUs
- **Pre-Operation Checks**: System readiness, environmental checks, personnel safety
- **Handling and Installation**: Transport and insertion procedures
- **Cooldown Protocols**: Steps for controlled cooldown
- **Operation Protocols**: Test procedures, monitoring, and duration
- **Data Logging**: HWDB entry and data collection practices
- **Warmup Protocols**: Controlled return to ambient temperature
- **CRU Removal and Storage**: Extraction and safe post-test handling
- **Roles and Responsibilities**: Defined duties for all personnel
- **Safety and Cleanliness Standards**: Standards for ESD, ODH, etc

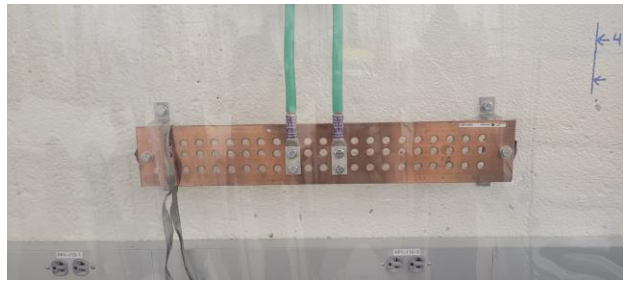
Operational Purposes and Requirements

- Production Requirements:
  - Must cryo-cycle 2 CRU per week
- CRP Requirements:
  - Anode, AB/EC/CE interconnection QC
  - Test at warm and cold
- BDE Requirements:
  - BDE WIB crate on top of cold box (handles 24 FEMBs)
  - 9m signal and power cables inside of cold box
  - Cold box must act as Faraday cage
  - QC test of CRU channels at warm
  - QC test of channels at cold
  - HV test to check for leakage currents at cold (SHV cables)
  - QC test of CRU channels at warm again



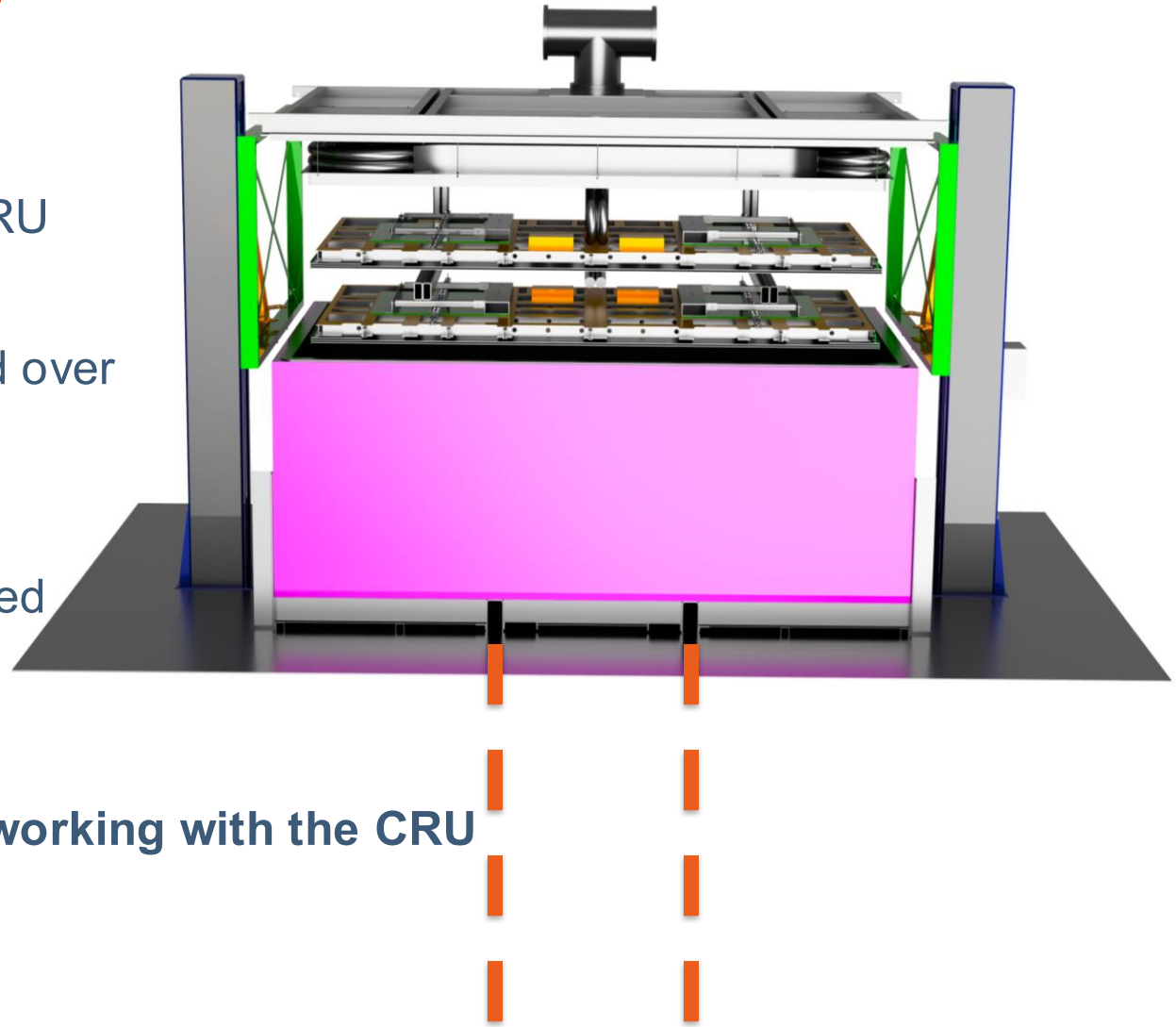
Pre-Operational Checks

- **System Readiness**
  - Confirm cold box is shorted with busbar to clean ground
  - Confirm cold box is clean and free of foreign objects
  - Confirm WIB Crate and CE power supply are connected but powered off
  - Confirm temperature, level, and ODH sensors (personal and fixed) are operational
- **Personnel Readiness**
  - PPE check:
    - Gloves, safety glasses, and ESD wrist straps
- **Cryogenic Readiness**
  - Verify no leaks in cryogenic lines and that cryogenic systems are sealed shut
- **Schedule and Environment Confirmation**
  - Confirm Wright Lab high bay door will **not** be opened during insertion of CRU into cold box
  - Confirm and ensure pathway for pallet stacker is clear



Handling and CRU Installation

- **Bottom CRU first**
- **Pallet Stacker Handling**
  - Align pallet stacker with pre-marked floor lines for CRU placement
  - Advance pallet stacker forward until CRU is centered over cantilever support
  - Attach hanging wires to CRU
  - Lower pallet stacker gently until CRU is fully supported by hanging wires
- **CRU Handling**
  - **All personnel must wear ESD wrist straps when working with the CRU**
  - Connect long BDE cables to patch panels
  - *Connect the HV via SHV through the flange*



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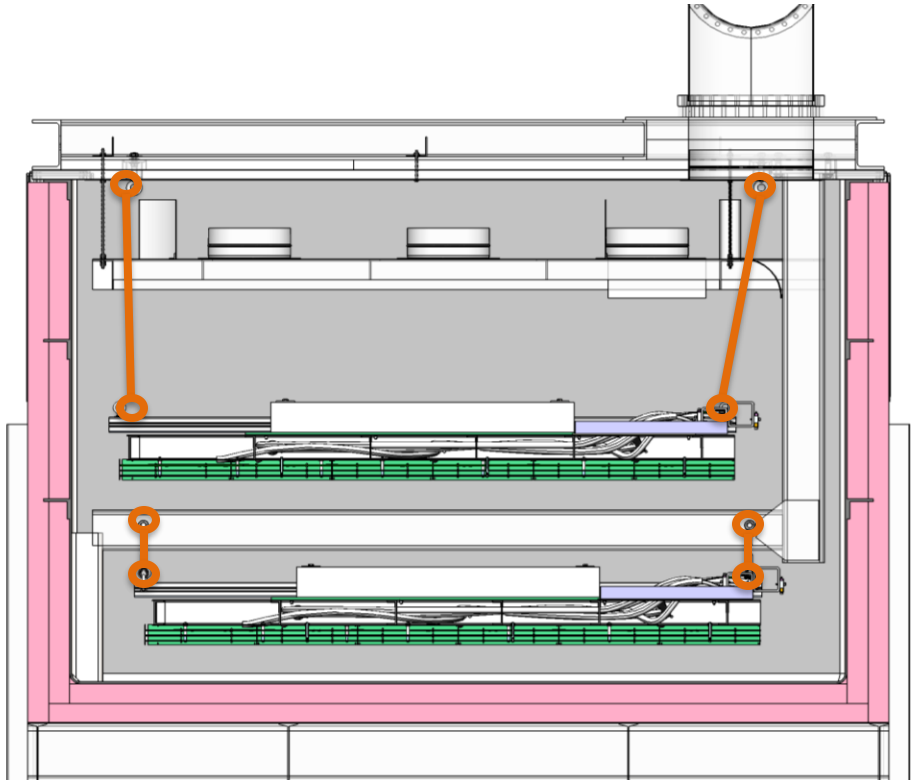
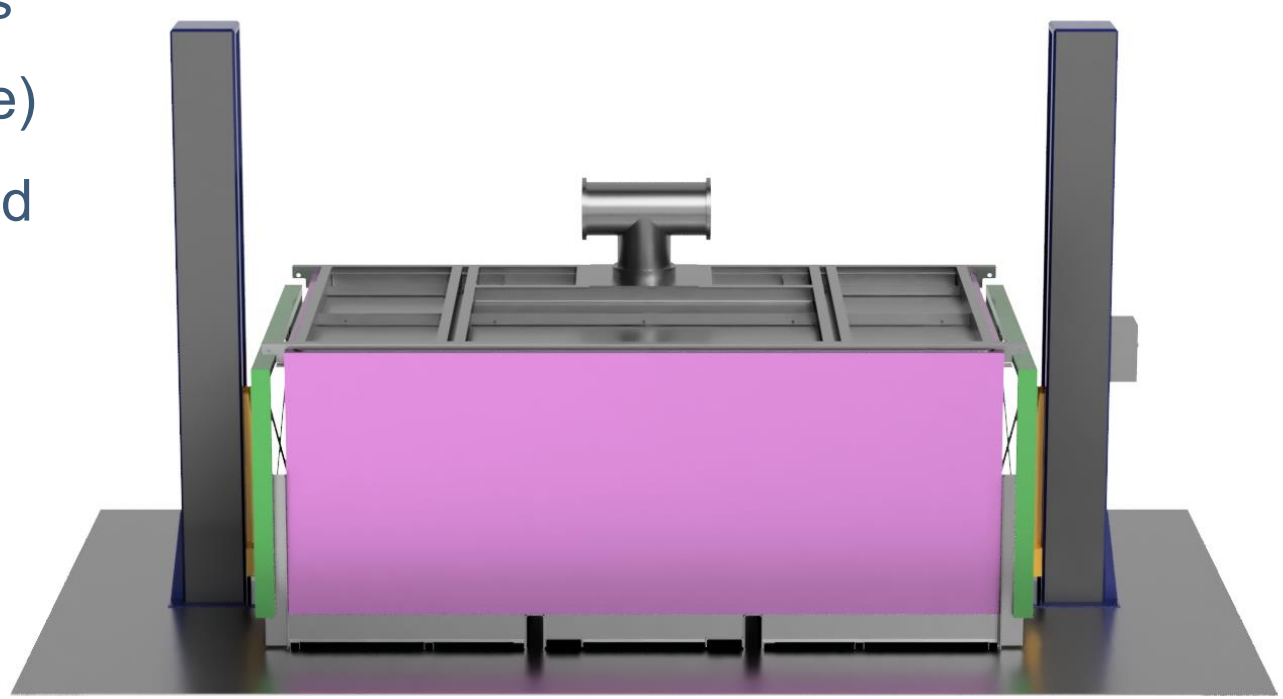


Operation Protocols

- Lower cold box lid until cold box is sealed
- Ensure BDE WIB test stand is connected and operational
- Begin purge by opening cryogenic gas lines
  - Ensure nitrogen gas entering the cold box is warm.
  - Monitor temperature via slow control sensors
- Purge for XX minutes (TBD based flow rate)
- Run BDE test script from the WIB test stand
  - Monitor and log test output

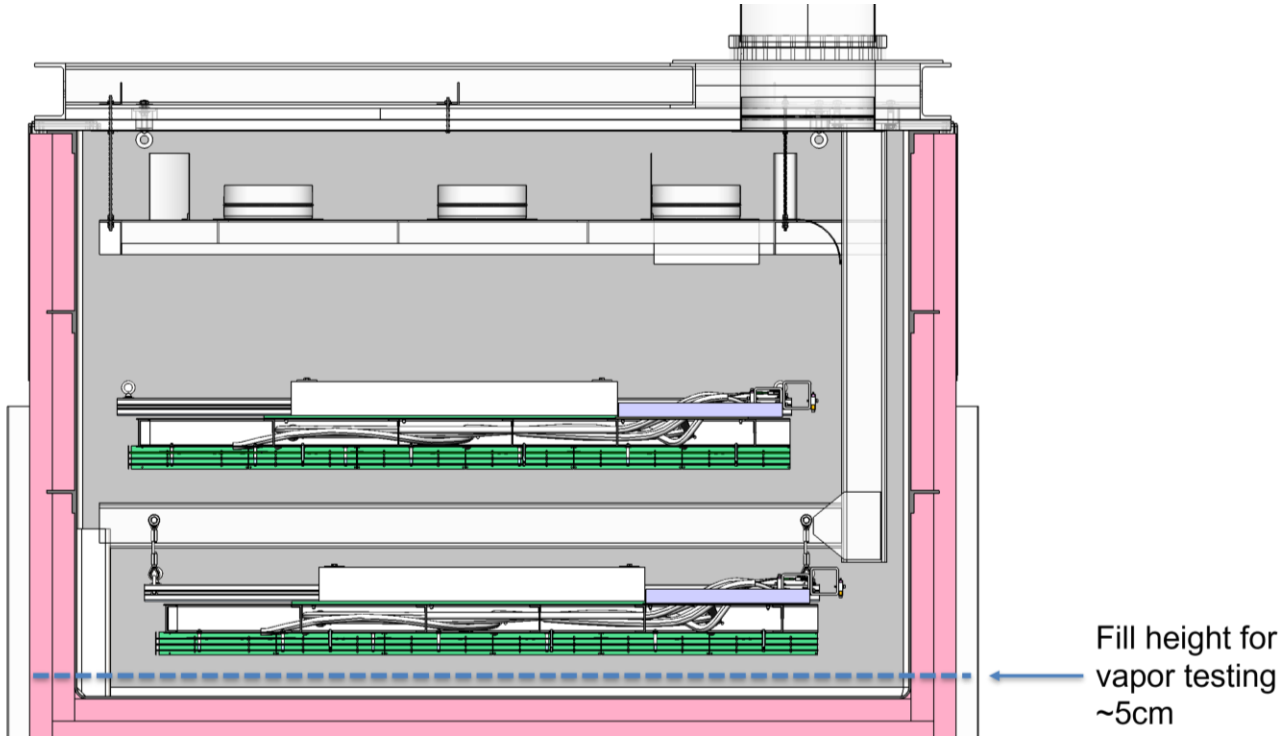


Cooldown Environmental Prep

- High bay door can open while cold box is filled with LN_2
- Post the area around the Cold Box and install a safety barrier (minimum 4ft); no through traffic during fill
- Restrict access around the LN_2 supply tank to trained personnel with PPE when cold
- Post ODH hazard signage on all high bay entrances
- Fixed Oxygen monitors will be monitored with slow controls
- Operators must wear portable Oxygen monitors during filing and cooldown
  - Relaxation permitted only in steady-state if monitoring allows
- Notify all personnel in the high bay before LN_2 filling
- Minimum crew size for fill: 2 operators
- Post signage for cold surface hazards on exposed metal components

Cooldown Protocols: Gas Tests

- Confirm that the cold box has been sufficiently purged
- Initiate LN_2 fill to establish liquid volume in base pan
- Track CRU temperatures via slow control and confirm uniform cooldown in the following steps
- Hold LN_2 level at **5 cm** until bottom and top CRU reaches -130C to -160C
- Run BDE test script from the WIB test stand
  - Monitor and log test output
- *TBD: HV biasing at cold?*

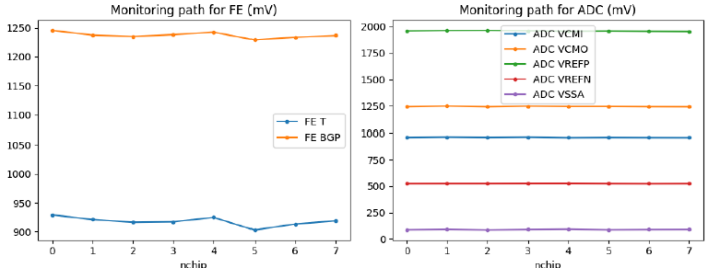


Data Logging

- A BDE Test Stand script is run: [Github Repository]
- Each FEMB tested during cold box operations generate a structured test report of metrics
  - Power, Baseline stability, Pulse response, ADC monitoring
- Results are automatically classified as pass/fail and flagged issues are traced to specific channels and chips
- Information is logged to the HWDB
  - Use Python-based HWDB interface app for direct data entry from BDE Test Stand

Power Consumption = 7.353 W

name	V_set/V	V_meas/V	I_meas/A	P_meas/W
BIAS	5.0	4.999	0.0	0.0
LArASIC	3.0	2.975	0.43	1.279
ColdDATA	3.0	2.995	0.229	0.686
ColdADC	3.5	3.463	1.556	5.388



FEMB#0001 Checkout Test Report

Tester: cmacias
Date: 06_04_2021_19_07_54
Temperature: RT
Input Capacitor(Cd): 0pF
Note: crp6_2 femb1 1st test
FEMB configuration: 200mVBL, 14_0mVfC, 2_0us, 500pA, DAC=0x20

Measurement	Result
Power Measurement	Pass
Temperature	Pass
BGP	Pass
RMS	Fail
200mV Baseline	Fail
Pulse_SE	Fail
Pulse_DIFF	Fail
ADC Monitoring	Fail

RMS issued channels: [16]
RMS issued chips: [1]
200mV BL issued channels: [72]
200mV BL issued chips: [4]
Pulse_SE positive peak issued channels: [16]
Pulse_SE positive peak issued chips: [1]
Pulse_DIFF negative peak issued channels: [16]
Pulse_DIFF negative peak issued chips: [1]
ADC MON VCMI issued chips: [0, 1, 2, 3, 4, 5, 6, 7]
ADC MON VREFP issued chips: [0, 1, 2, 3, 4, 5, 6, 7]
ADC MON VREFN issued chips: [0, 1, 2, 3, 4, 5, 6, 7]
ADC MON VSSA issued chips: [0, 1, 2, 3, 4, 5, 6, 7]

Warmup Protocols

- Once cold testing has concluded, initiate warmup by enabling heaters via slow control
- Monitor temperature rise using temperature sensors in slow control
  - Ensure uniform heating across cold box
- Monitor nitrogen environment using oxygen meters in slow control during LN_2 boil-off
- After reaching ambient temperature
  - Disable heaters
  - Run BDE test script from the WIB test stand for warm data collection

Example slow control system at Grenoble

CRU Removal and Storage

- **Schedule and Environment Confirmation**
  - Confirm Wright Lab high bay door will **not** be opened during removal of CRU from cold box
  - Confirm and ensure pathway for pallet stacker is clear
  - Ensure all workers are grounded with grounding wrist straps
- Raise the cold box lid using the control system
- Disconnect 9m BDE cables from patch panels
- Disconnect the HV connection
- Remove the top CRU using pallet stacker
  - Place CRU on a height adjustable table with a grounding mat
- Roll the table to the Cantilever Storage racks
  - Utilize the pallet stacker and lift the CRU from the table and attach it to the cantilever storage racks
- Repeat for bottom CRU

Schedule For Dual CRU Cold Box

- For detailed breakdown of Dual CRU cold box setup production:
  - (May CM: Slides 9 to 14)

	Wednesday *2-2.5 Workers*	Thursday *1-2 Workers*	Friday *1 Worker*	Weekend	Monday *1 Worker*	Tuesday *2-2.5 Workers*
Early AM	Load CRUs into cold box	Contingency for loading	Fill cold box	Boil Off	Contingency for warm up	Remove CRUs from cold box
Late AM						
Early PM		Warm Test CRUs	BDE Cold Test HV Cold Test		Warm Test CRUs	
Late PM		Purge cold box	Boil Off			
Overnight						

- Warm up can extend until end of day Monday (72 hours)
  - No cold box activities on Monday
  - Built in contingency time if needed

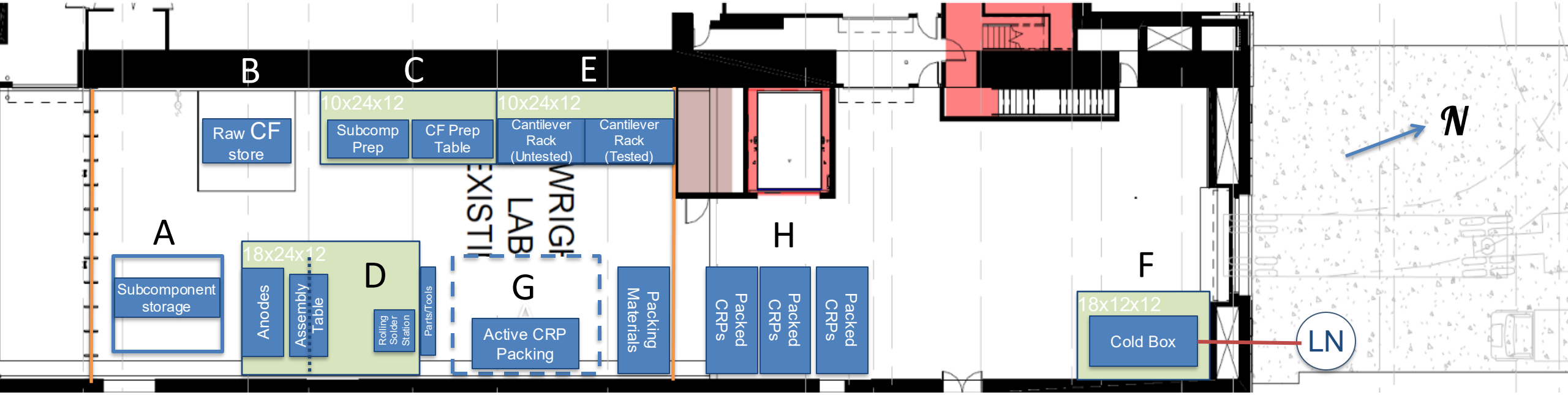
Additional schedules exist for short weeks, holiday weeks, etc

Safety and Cleanliness Standards

- **Assembly Site Specification: Positive Pressure Environment**
  - Maintains clean airflow during movement of CRUs between work stations
  - Controlled access with gowning protocols and routine cleaning procedures
- **Cleanroom Specifications**
  - Assembly site clean tents conform to ISO 8 standards
    - Verified by slow control particle count monitoring
- **Electrostatic Discharge (ESD) Specifications:**
  - All personnel must wear ESD wrist straps when working with CRU electronic subcomponents and within marked work stations
    - Connected to busbar and clean ground
  - CRU transport table includes ESD mat
- **ODH Monitoring:**
  - Fixed Oxygen monitors will be placed within at cold box workstation in accordance with lab safety coordinators
  - Oxygen levels will be monitored at the cold box workstation
    - Personal Oxygen monitoring systems will also be worn
- **Training Requirements:**
  - Personnel will be trained in proper cleanroom behavior, ESD protocols, and emergency procedures
  - All technical staff will report to the lead physicist and engineer

Yale Assembly Site Floor Layout

Scale: 1" = 16'



- 8 CRU assembly workstations
- Clean Ground busbars installed throughout for ESD protection
- **Cold box situated next to high bay door**

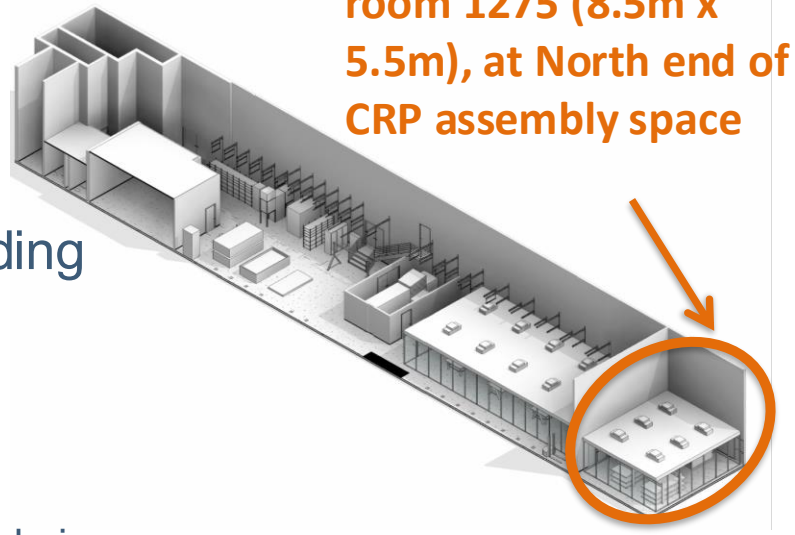
Indiana Site Specific Considerations

Fatma Boran, Mark Messier, Tanaz Mohayai, Jon Urheim

+ Center for Exploration of Energy and Matter Technical Support Team

- **IU Cold Testing Facility Configuration and Operations will follow closely the specifications for the Yale facility**
  - Departures are well understood, and largely due to differences in the physical layout of the laboratory space at IU
- **Key Distinction:**
  - IU facility located on the 2nd floor, at the north-most end of MESH building
    - No direct access to high-bay/loading dock door
      - All Yale protocols pertaining to high-bay door don't apply directly. Replaced with special attention to egress accessibility.
      - May also motivate installation of exhaust fan, similar to Grenoble factory, for rapid air exhaust in response to low O2 level detection. Can be undertaken as part of IU OVPR's facility preparation cost-sharing agreement with IU-DUNE.
    - Penetrations through exterior wall (variably concrete or sheet metal) either exist or can be provided.
    - Facility location enables proximal installation of external LN2 tank, hence short runs for cryogenic lines.

Cold Testing Facility in room 1275 (8.5m x 5.5m), at North end of CRP assembly space



LN2 Tank can go here

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Summary

- The operating procedures cover installation, warm testing, cooldown, cold testing, warm up, and removal with the Dual CRU Cold Box
  - Well defined roles within these procedures exist
- The Dual CRU Cold Box provides a well-monitored environment for CRU cryogenic testing
- The Dual CRU Cold Box allows for 2 CRU/week throughput with built in contingency time
- Data logging and HWDB integration ensure full traceability of test results
  - Can trace AB/EC/Anodes back to their HWDB QC test results for full CRU test history
- Safety protocols are up to cleanroom standards ensure quality CRU production

Extra Slides

Bottom CRP Weekly Production Schedule

- ~72 hours available for warmup in schedule for dual CRU cold box scenario!

		Assembly Table 1			Assembly Table 2		CF-Prep Table	Cold box	Crating	HWDB Entry
Monday	8:00-12:00	First		AB + Jumper prep				Warm-up		CRPa Entry
		Second + Third		CF prep						
		Fourth								
	13:00-17:00	Fifth	BDE Prep	Sixth			CF-Prep Table prep			
		CE Installation						Warm Testing		CRPa Entry
Tuesday	8:00-12:00	CE warm Test CRPa			Clean & Prep for next assembly			Remove CRPa' + CRPb'' to rack		
							CF-Prep#1			CRP Entry
	13:00-17:00						CF-Prep#2+#3			
		Prep CRPa for insertion			AB + Jumper prep + CF prep			Clean coldbox		CRP Entry
Wednesday	8:00-12:00				First	AB + Jumper prep		Insert CRPa		
					Second + Third	CF prep				
					Fourth	BDE prep				
	13:00-17:00				Fifth	Sixth		Insert CRPb'		
					CE Installation					
Thursday	8:00-12:00				CE warm Test CRPb			Close Cold box	Crate prep	CRP Entry
								Warm Testing	Crate CRPa	
					Prep CRPb for insertion					
	13:00-17:00							Purge (overnight)	Crate CRPb	
Friday	8:00-12:00	Clean & Prep for next assembly						Fill CRP		CRP Entry
							CF-Prep#1			
	13:00-17:00						CF-Prep#2+3	Cold testing		
								Warm-up		Extra/Make-up Entry

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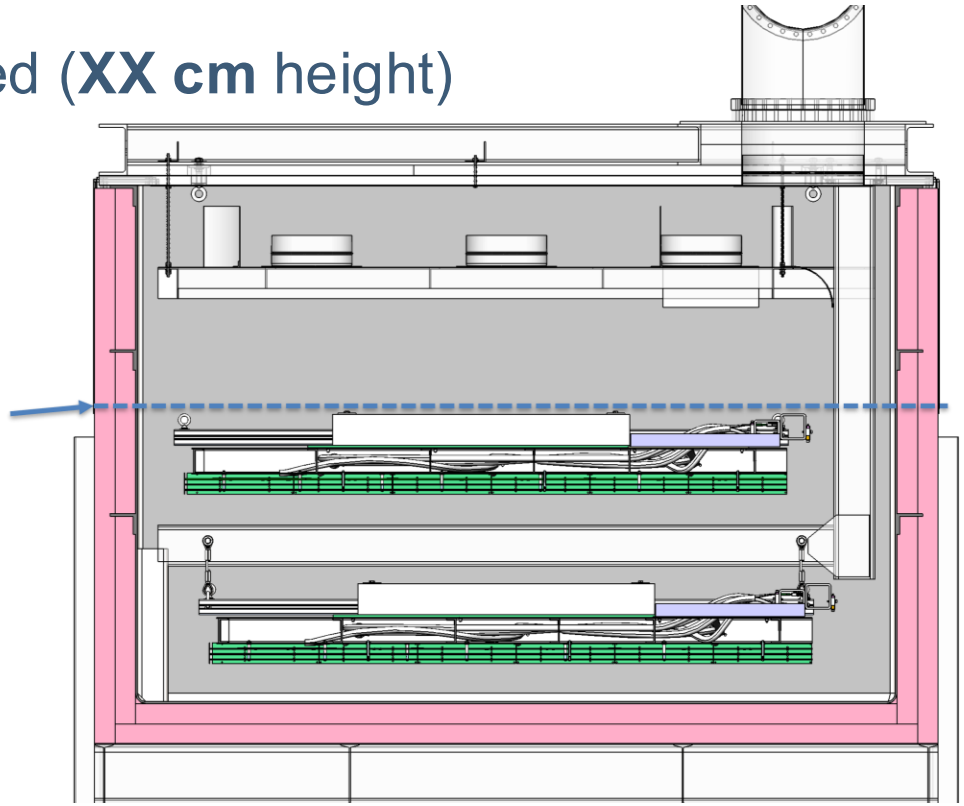
Roles and Responsibilities

- **Monday**
  - Key Tasks: Warm-up, monitor slow control, warm test
  - Number of workers: 1
- **Tuesday**
  - Key Tasks: Remove CRUs and clean cold box
  - Number of workers: 2 – 2.5
- **Wednesday**
  - Key Tasks: insert CRU
  - Number of workers: 2 – 2.5
- **Thursday**
  - Key Tasks: close cold box, Warm test, and LN_2 purge overnight
  - Number of workers: 1 – 2
- **Friday**
  - Key Tasks: Fill cold box, monitor slow controls, cold test, and warm-up
  - Number of workers: 1

Additional schedules exist for short weeks, holiday weeks, etc

Cooldown Protocols: Liquid Tests

- Confirm that the cold box has been sufficiently purged
- Initiate LN_2 fill to establish liquid volume in base pan
- Track CRU temperatures via slow control and confirm uniform cooldown in the following steps
- Hold LN_2 level at **X cm** until bottom CRU reaches -100C
- Resume fill at **Y L/min** until bottom CRU is fully submerged (**XX cm** height)
- Hold LN_2 at **XX cm** until top CRU reaches -100C
- Continue filling at **Y L/min** to final height of 75 cm
  - 5 cm above top CRU patch panel
- Run BDE test script from the WIB test stand
  - Monitor and log test output
- *TBD: HV biasing at cold?*