

Cold Readout Electronics Production for DUNE Far Detector

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Introduction

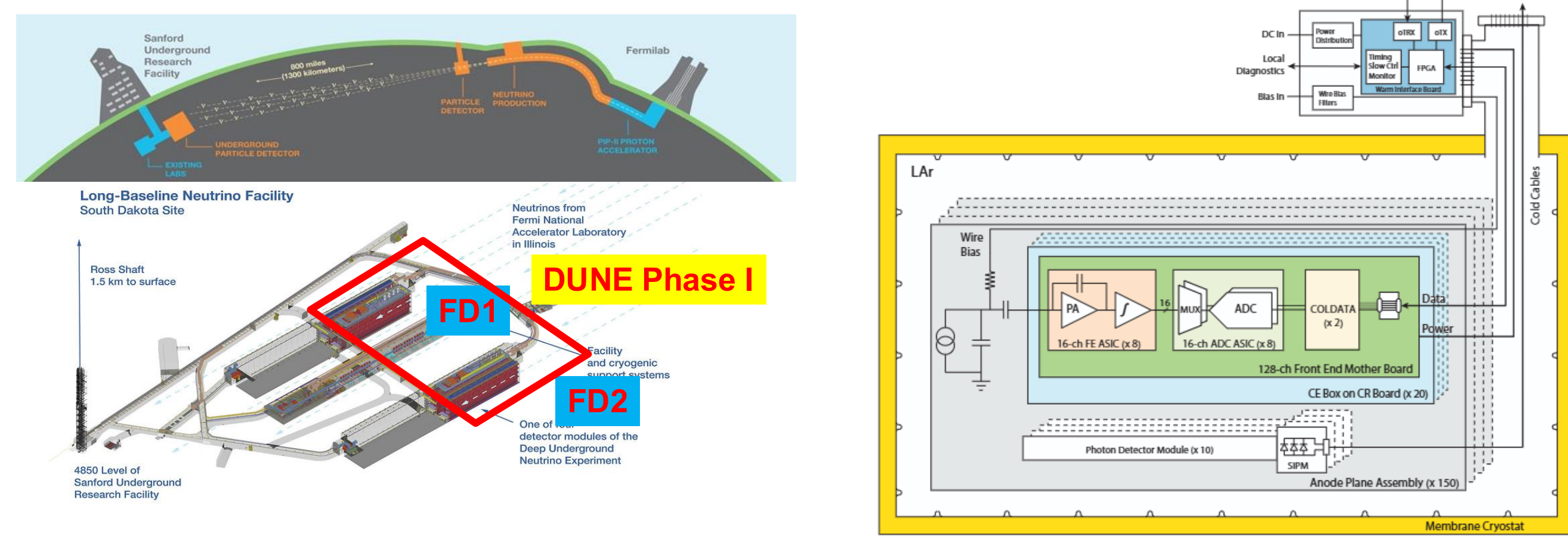
The **DUNE far detector phase I** consists of two 10-kt fiducial mass Liquid Argon Time Projection Chambers (**LArTPCs**)

- **FD-HD** (Horizontal Design) and **FD-VD** (Vertical Design)
- High-precision neutrino detection

Large number of cold readout channels:

- 384,000 channels, 150 Anode Plane Arrays (APAs) in FD-HD
- 245,760 channels, 80 Charge Readout Planes (CRPs) in bottom-drift of FD-VD
- Total over 600,000 readout channels by cold electronics directly in liquid argon.

Aim for 30 years of operation without replacement and maintenance



DUNE Phase I Far Detectors and Cold electronics

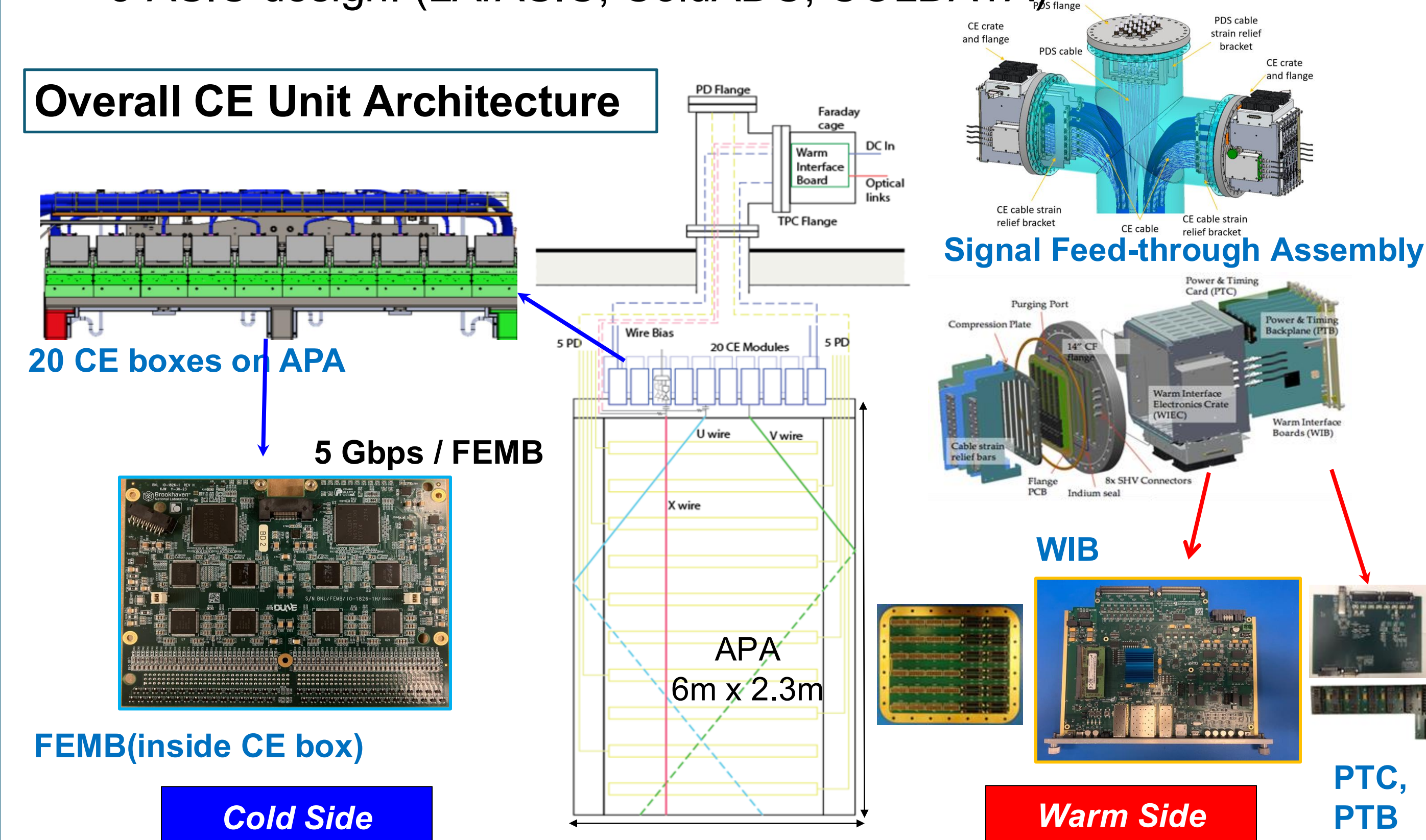
Cryogenic Readout Electronics Architecture

Warm Side

- **Warm Interface Board** for data aggregation and power distribution
- Interface to DAQ and timing system

Cold Side

- **Front-End Mother Board (FEMB, 128 channels / board)** with 3-ASIC design. (LArASIC, ColdADC, COLDATA)



FEMB: Perform digitized readout of 128 TPC electrodes in Liquid Argon

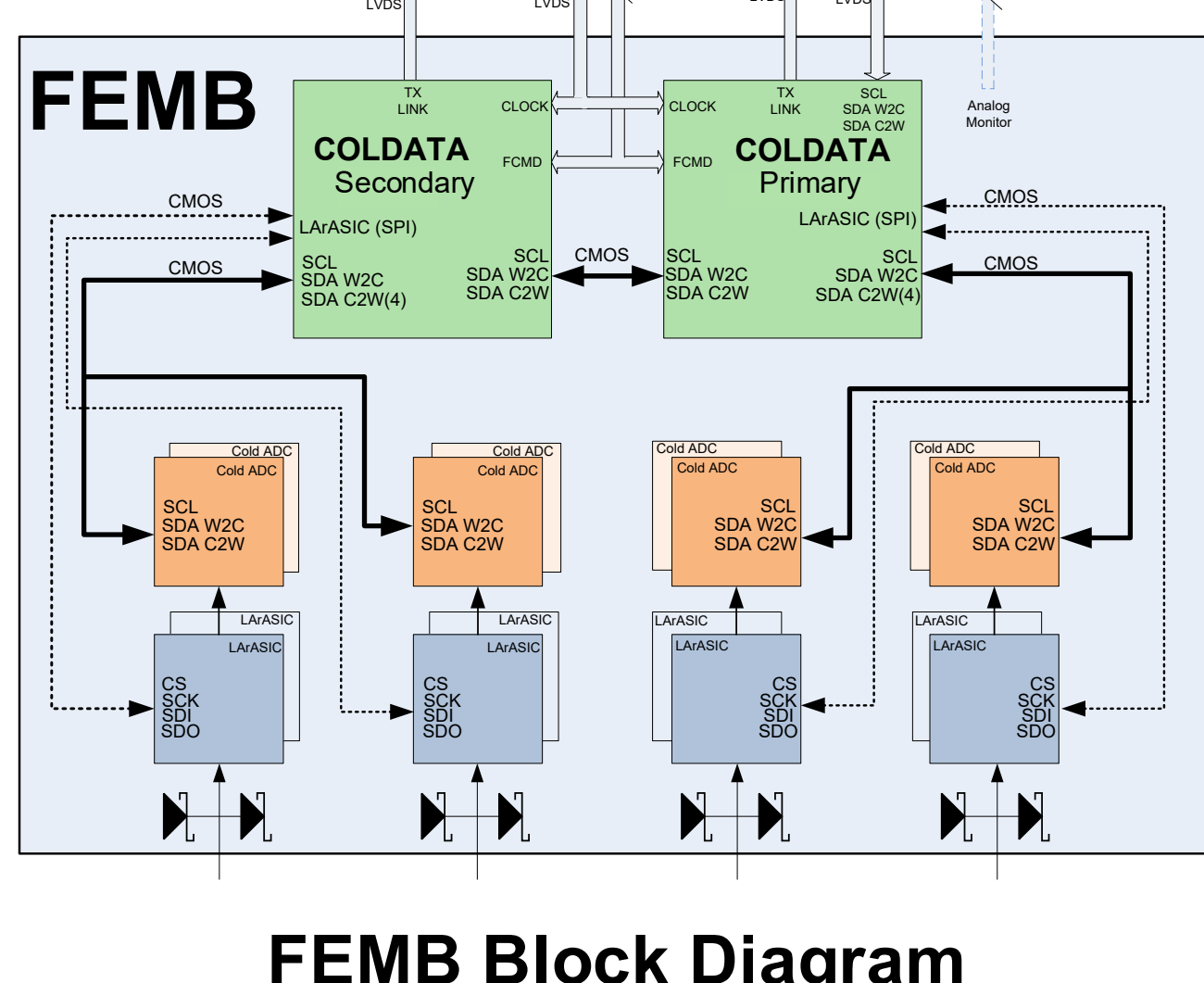
- Integrated 8 LArASICs, 8 ColdADCs, and 2 COLDATA ASICs to process charge signals from 128 sense electrodes originating from the APA/CRP

Functionality of 3 ASICs:

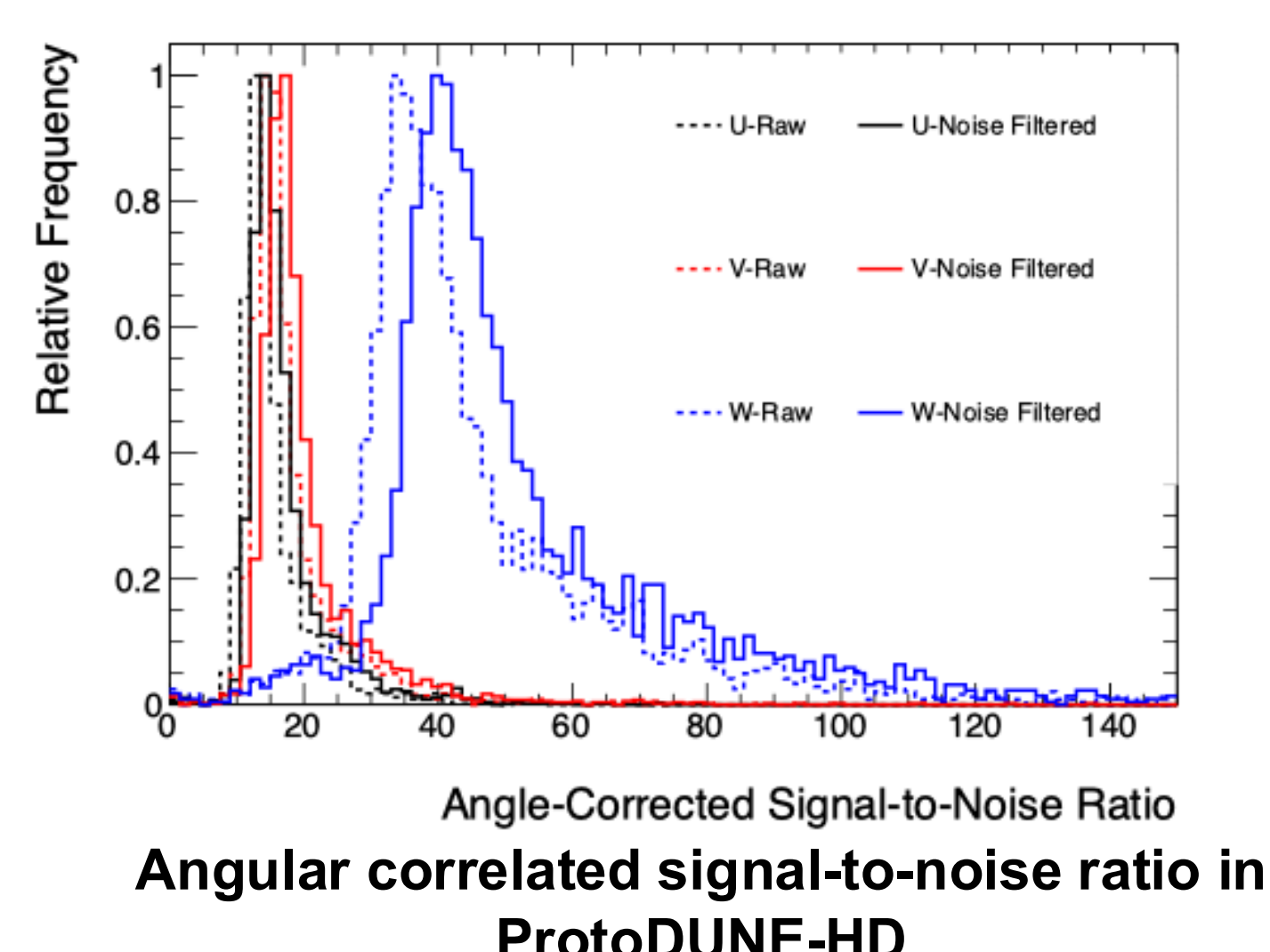
- **LArASIC:** analog front-end amplifier, amplifying and shaping the raw charge signals coming from the TPC electrodes.
- **ColdADC:** digitize the amplified signals
- **COLDATA:** collect ADC data, manage slow control & fast commands.

CE performance verification:

- **ProtoDUNE-SP, ProtoDUNE-HD** and **ProtoDUNE-VD** located in CERN neutrino platform has demonstrated excellent physics performance.
- Achieve high yield, low noise, and good stability of cold electronics.



FEMB Block Diagram



Angular correlated signal-to-noise ratio in ProtoDUNE-HD

Quality Control for Large Scale Production

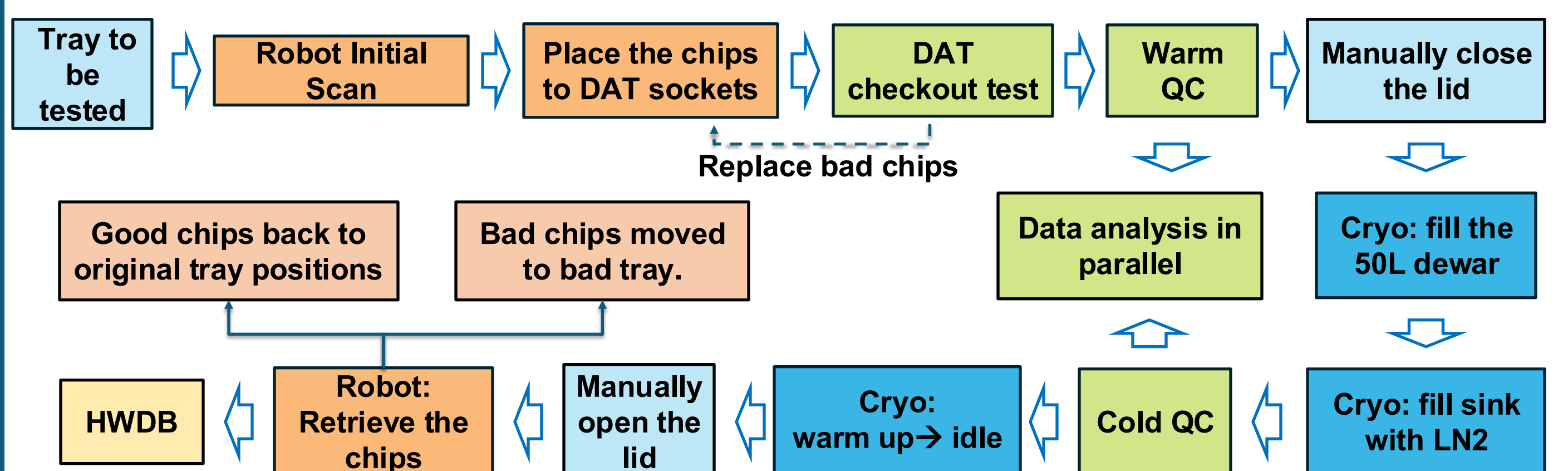
A production Quality Control (QC) strategy is developed to:

- **Maximize functional readout channels** that meet performance specifications, to **Minimize noise levels in the detector**.
- **Ensure long-term reliability**, since many CE components inside the cryostat cannot be accessed or repaired during detector operation.

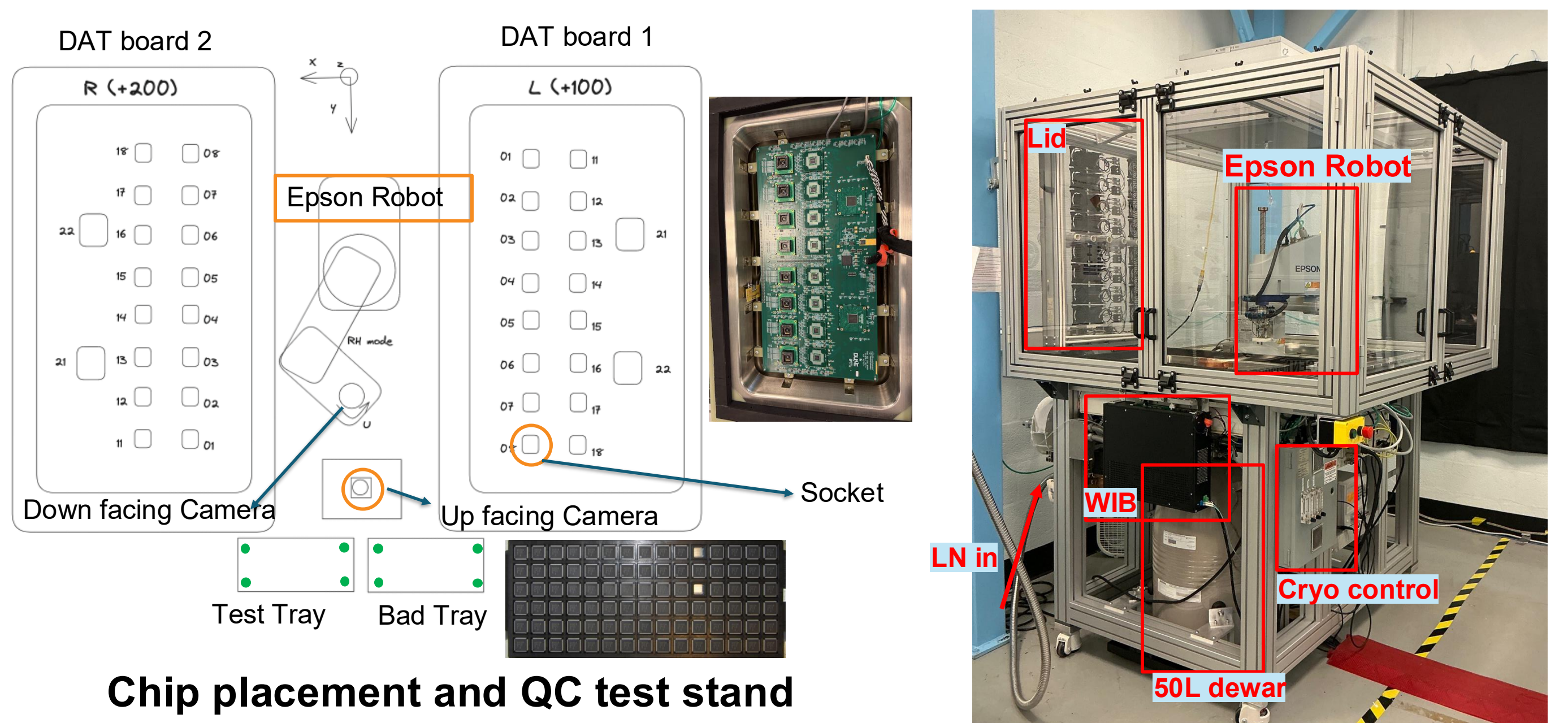
ASICs QC with Robotic Test Setup (RTS)

Identify defective ASICs early, improve FEMB yield rate

- **RTS:** A stable, automated, and highly integrated test infrastructure
- Chip movement with **Epson robot**
- **Warm** and **cold** test with **automatic cryogenic setup**
- Enable large-scale testing across multiple sites

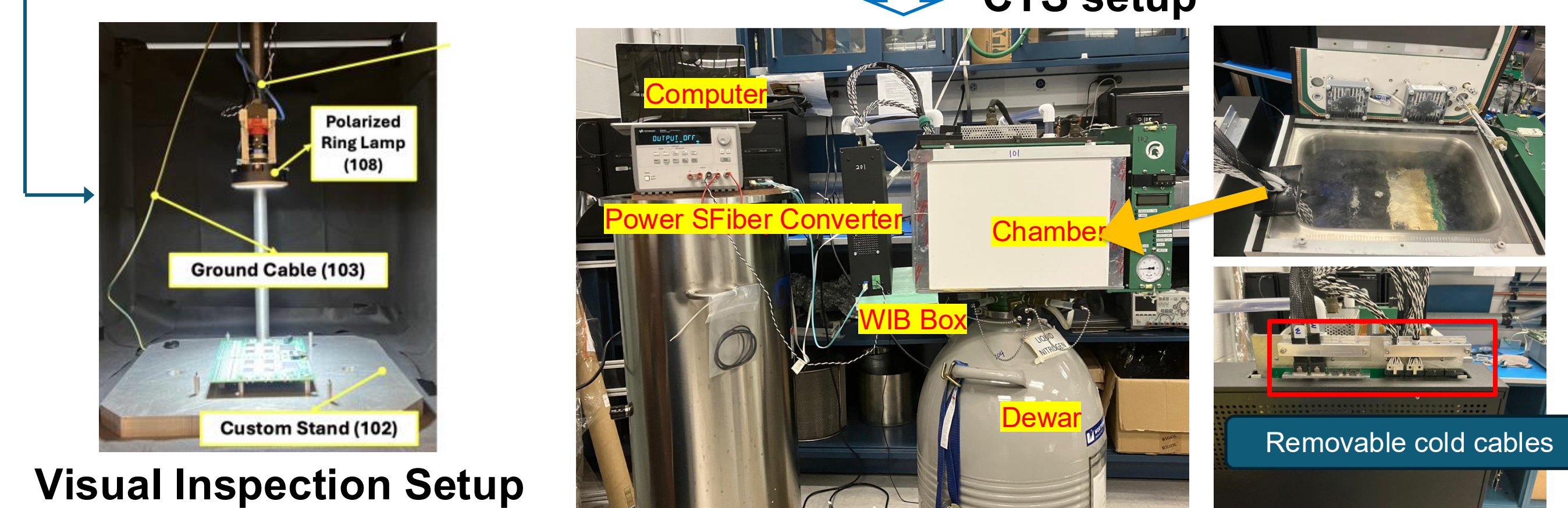
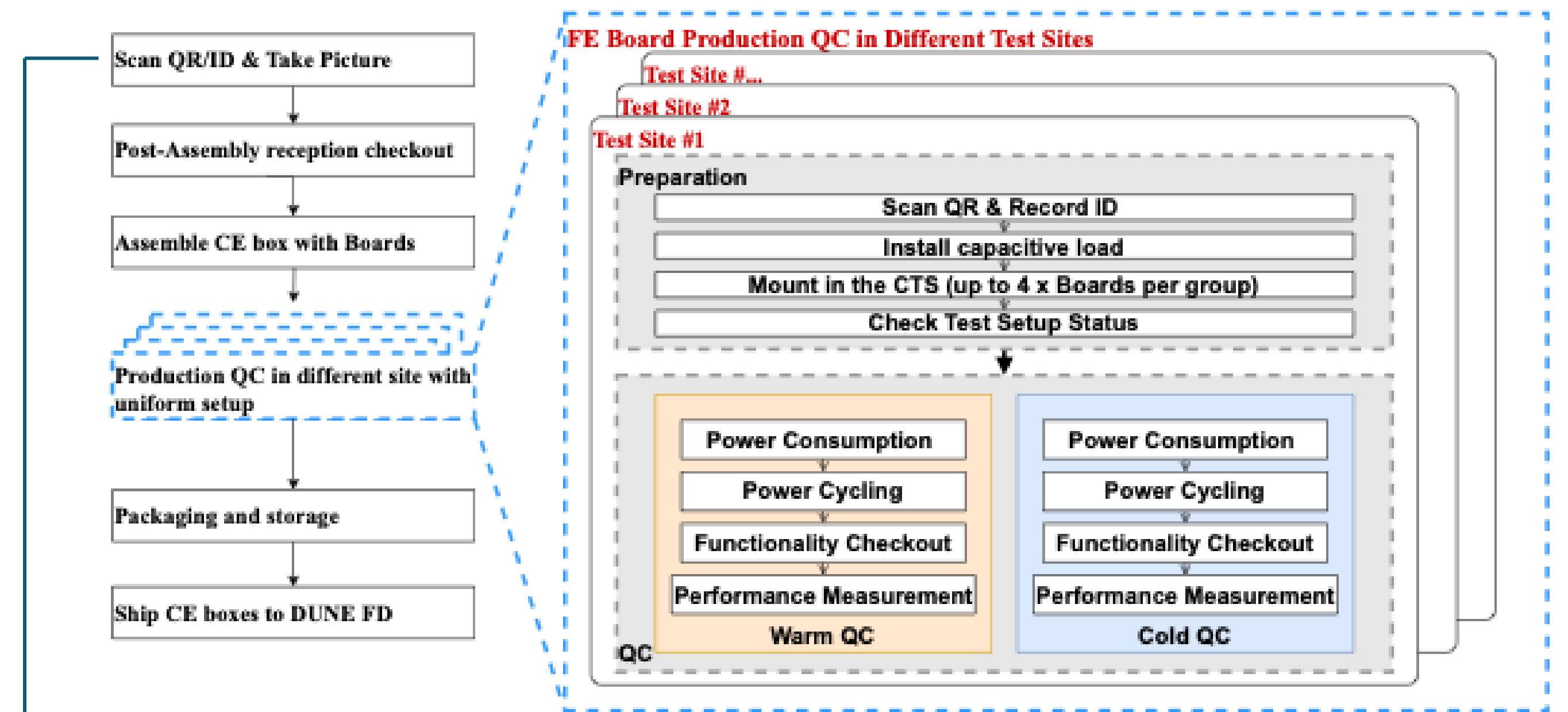


RTS Integration



FEMB QC with Cold Test Setup (CTS)

- Conducted on the final integrated unit (**CE box**)
- QC verification at **Warm** and **Cold** in CTS
- Implement functionality and performance evaluation of FEMBs
- Provide reliable standardized testing and procedures across sites



Conclusion

- Cold readout electronics design is completed and validated in ProtoDUNE-SP, ProtoDUNE-HD and ProtoDUNE-VD.
- Large-scale production preparation for DUNE, transitioning from prototypes to full detector construction.
- QC procedures: ASICs, FEMB production QC procedure has been developed and implemented.
- Future: Improve the whole QC procedure to provide high performance and consistent production for DUNE Far Detectors.

Coordinating Panel for Advanced Detectors (CPAD) Workshop Oct. 2025