Plans for ProtoDUNE/SBND Integrated System Testing

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Cold Electronics Review

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Outline

- Motivation
- Planned Integration Test Systems
  - Cold Box at BNL
  - RF copper shielded room at Fermilab
  - Cold Vertical Slice test at CERN
- Conclusion

Motivation

- LArTPC detectors require low noise to achieve the physics goals
  - Supernova burst: ν-Ar40 CC absorption: low e^- energy
  - Distinguish multiple tracks in EM shower events

The detector shall distinguish a Minimum Ionizing Particle (MIP) track cleanly from electronic noise everywhere within the drift volume.

- Leads to a necessary ENC ~650 e- per channel
  - Lessons learned from MicroBooNE, LArIAT, and 35-ton

"To have a chance at achieving a good performance, (a) the integral design concept of APA+CE+Feedthrough with Warm Interface and (b) strict isolation and ground rules will have to be followed." (V. Radeka)

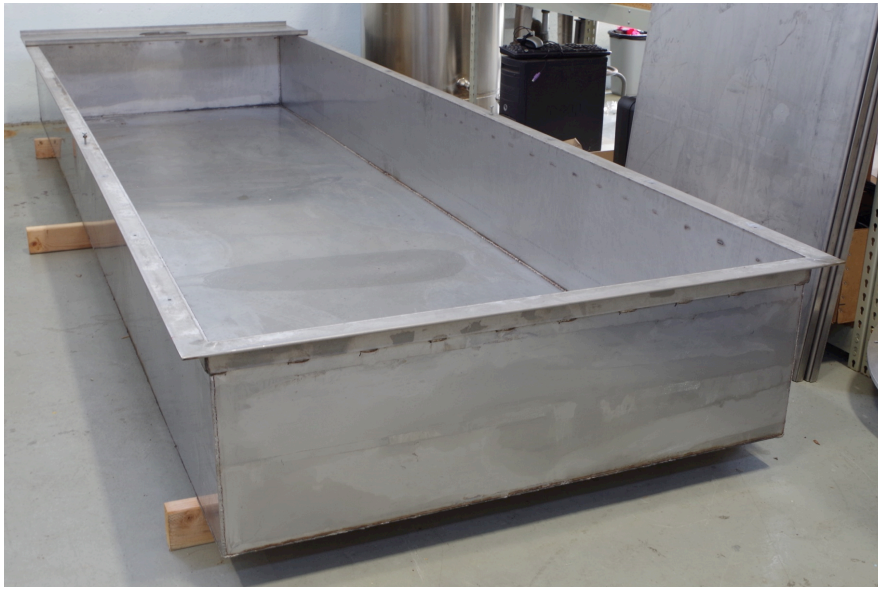
- Design teststands to carefully study integrated TPC readout design and isolation and ground rules proposed for SBND and ProtoDUNE-SP
  - RF Shielded Room at Fermilab to focus on grounding/shielding with integrated CE
  - Cold Box at BNL to focus on integrated CE performance with cryogenic electronics

BNL Cold Box with 40% APA

- 40% APA from PSL
  - 3m long (~1/2 the length of the DUNE APA)
  - 1 collection/2 induction wire planes/1 grid plane
  - Full APA wire board stack and capacitance-resistance (CR) board
  - Adapters to connect prototype FEMB to CR board, including RC filtering for wire bias
- Wires can be biased to nominal HV: -665V up to +820V
- Possible to add at least 1 Photon Detector module to APA in cold box

Cold Box

- Cold box will house APA+CE, plus cold LV and data cable
  - Can be tilted to submerge FEMB+cable in LN2
  - Read out up to 8 FEMB at full data rate to the warm interface electronics (~40 Gbps) at cryogenic temperatures (1/2 data volume of 35-ton)
- Signal feed-through assembly and warm interface electronics housed in the Faraday shielded crate will be installed on box



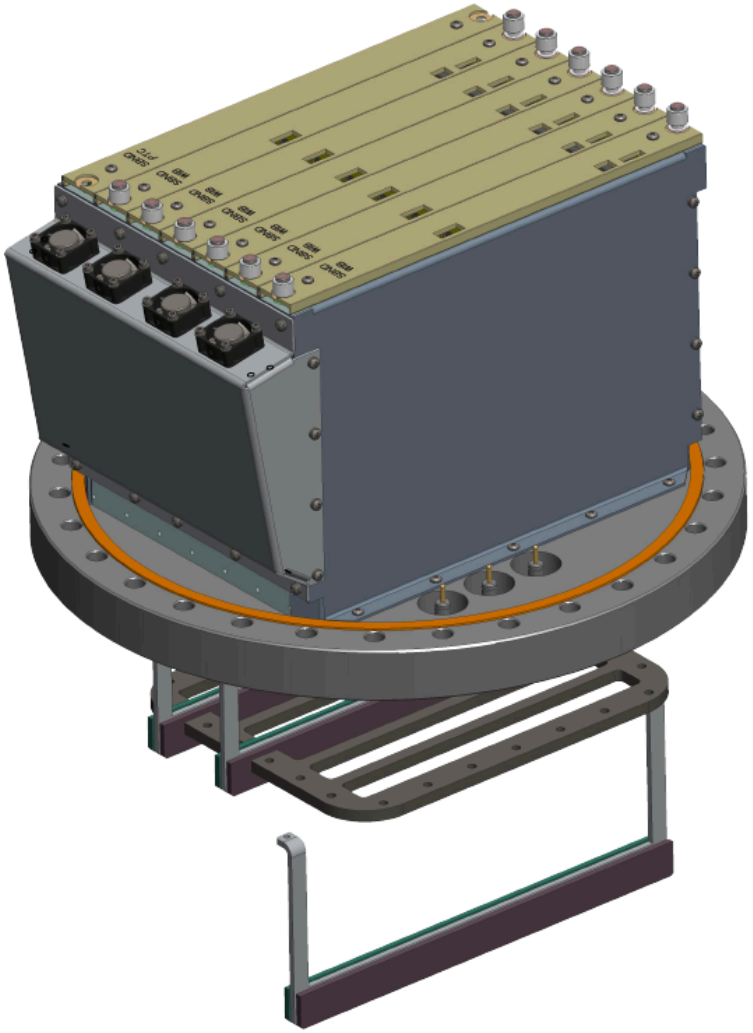
Full signal feed-through can be attached to port to carry both CE and PD signals

Warm Electronics

- Full flange and warm crate with WIB and PTC with local diagnostics
  - Onboard fan cooling and temperature sensors on WIB
  - DC-to-DC LV power supply to FEMB contained on WIB
  - SHV connectors to pass wire bias HV
  - Flange PCB connector to cold LV and data cable with built-in strain relief
- Transmit data to a Python based DAQ via FELIX PCIe card(s)

Will be a complete Vertical Slice of the APA+CE+Feedthrough with Warm Interface and real-time diagnostics at the flange.

- Fermilab screen room will use an identical flange and Warm Crate



Cold Box – what we will study

- Integrated TPC cold electronics readout open questions:
  - Cable noise: do we need shielding on the cold LV cables?
  - 35-ton "high-noise" state: not reproducible in the warm 35-ton cryostat, can it be reproduced with multiple CE at cryogenic temperature?
  - WIB noise: is noise injected into the cryostat by the Warm Electronics?
  - Grounding: is the CE and PD grounding plan adequate? (Later upgrade with PD system)

Test	Implementation	Goal
Readout functionality	Read out the full CE chain to a local DAQ for data analysis: measure baseline, RMS noise, and linearity on all channels.	Validate baseline operation of full CE chain.
Cable noise injection	Study RMS noise levels with multiple LV and data cable configurations and shielding schemes.	Validate cable selection, shielding, and design.
External noise injection	Study RMS noise levels under multiple external noise signals including shorted grounds, ground loops, and external sources near the warm electronics crate.	Study and analyse effects of ground scheme failures and validate warm electronics shielding.
High-noise state	Operate in similar configurations to the 35ton detector including multiple FEMB in cryogenic liquid but with well understood grounding and shielding.	Study high-noise (or lack) in a cryogenic, multiple FEMB teststand.
Warm interface noise	Operate a full warm electronics readout on a flange near cold FE electronics and wires with all functionality (*e.g.* DC-to-DC converters powering the FEMB).	Validate that low noise operation is achieved with the current WIB design.

Table 5: Overview of the testing in the BNL 40% APA teststand.

Cold Electronics QA/QC Plan: DUNE-doc-1809

Fermilab RF Copper Shielded Room

- Warm Vertical slice test of the APA wire readout is being instrumented at Fermilab
- An RF copper screen shielded room is being repurposed for this application
- RF room will serve to mock up the cryostat environment and is large enough to hold a 35T APA wire frame
- RF room has a door which allows easy access for personnel to enter and modify test environment
- A pass through plate on the side of the cryostat will be used to serve as the warm feedthrough

RF copper screen shielded room

Pass through plate

RF Room Power

- Proper AC distribution and grounding play a critical role in low noise electronics
- RF room will give us the ability to study the above
- Plan is to be able to supply power to the electronics via
  - A battery/UPS unit
  - Normal building power
  - Isolated power and ground
- The third option is what will be installed for ProtoDUNE and was described in Linda Bagby's earlier talk

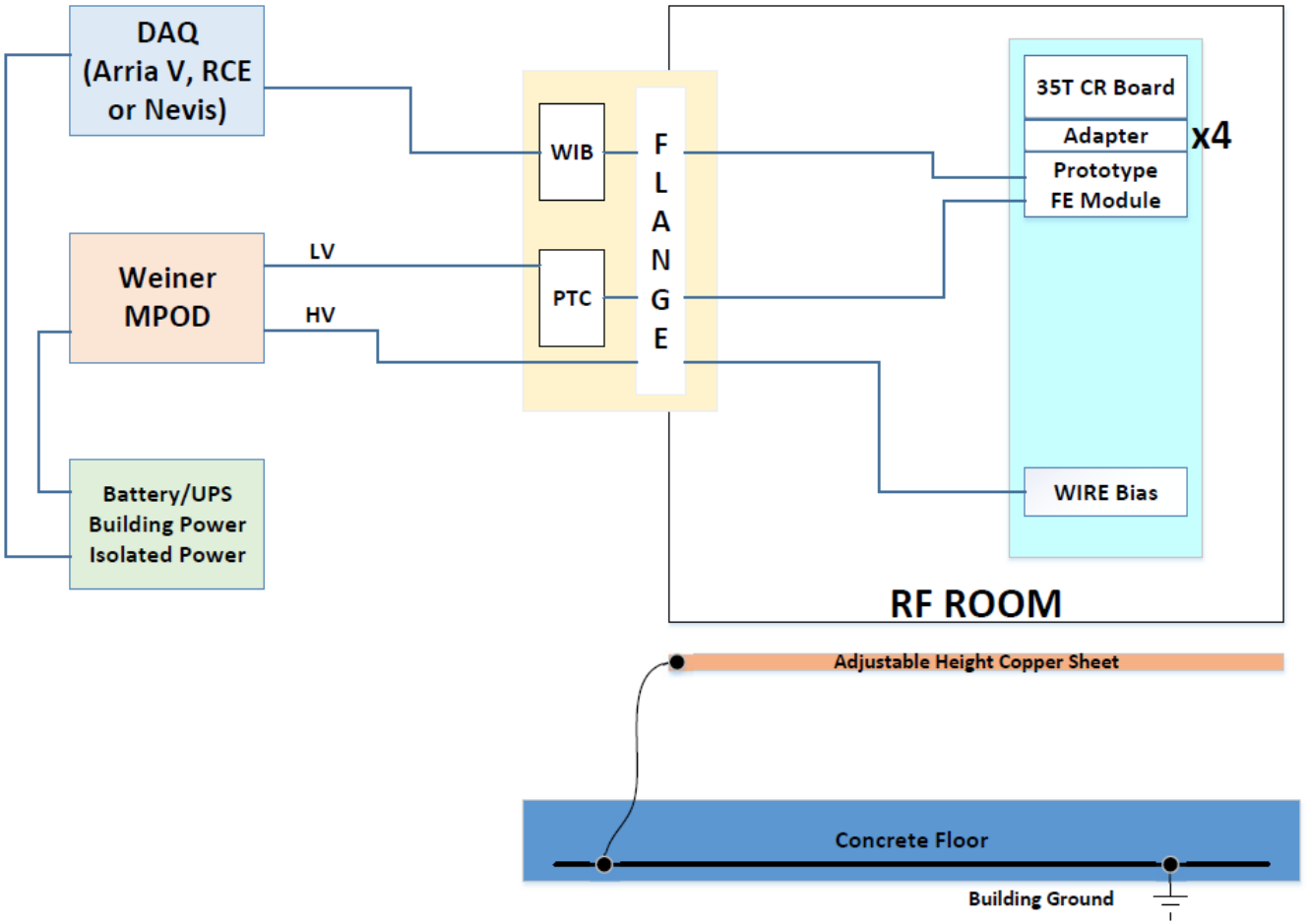
RF Room – Special features

- The RF room is currently in the process of being moved to D0, and its installation there gives us the ability to build in a special feature to study grounding – particularly the AC coupling of the "isolated" system to the building ground in the concrete floor underneath.
- The RF room will be lifted a couple feet into the air to reduce the capacitive coupling. Between the floor of the screen room (detector ground) and the concrete floor of the building (building ground) an adjustable height sheet of copper will be placed. This copper sheet will be connected to building ground.
- This will give us some ability to study the capacitive effect of building ground to detector ground.
- It also provides a unique opportunity to inject small currents onto the copper plate and study any possible effects of the FE electronics.

RF Room – what will we study

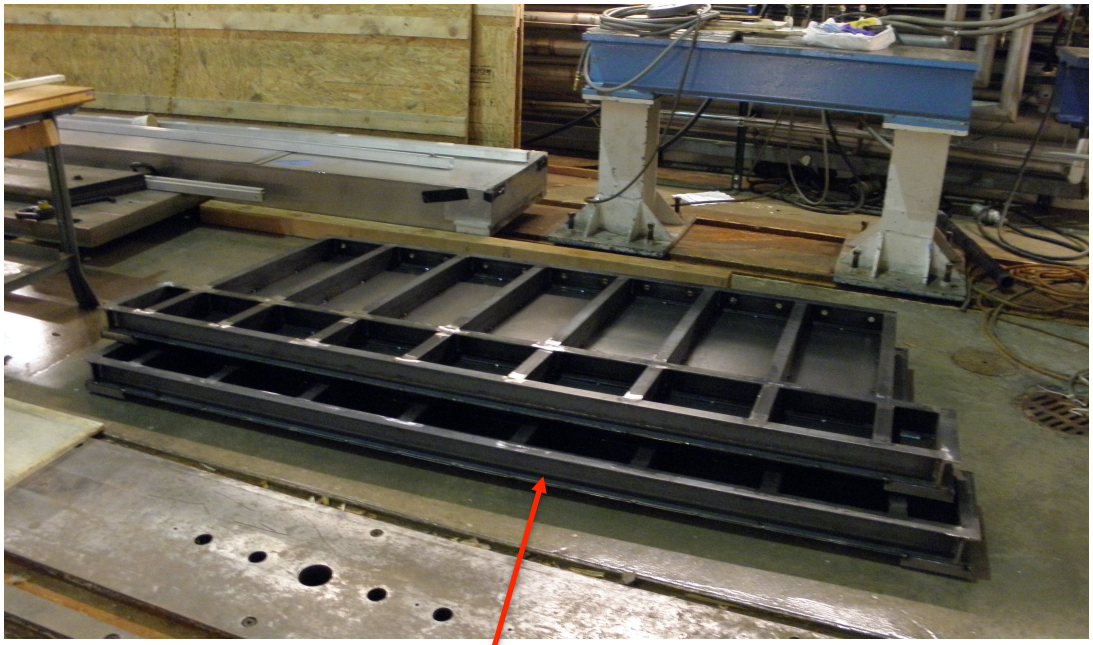
- Benchtop tests are currently ongoing in WH14. There we have a prototype FE card which is being readout via a standalone DAQ provided by BNL. As more prototype pieces become available we will build them into this system.
- The RF room is expected to be ready at the end on November
- At that time, or closely thereafter, we hope to have all the pieces in hand to build up a vertical slice to read out the wires of a 35T APA frame. Up to four FE cards can be installed on a 35T APA frame.
- Discussions are also underway to include Photon Detector readout.

Conceptual Drawing of RF Room and Test Setup



RF Room location – 2nd floor D0

RF Prep Work



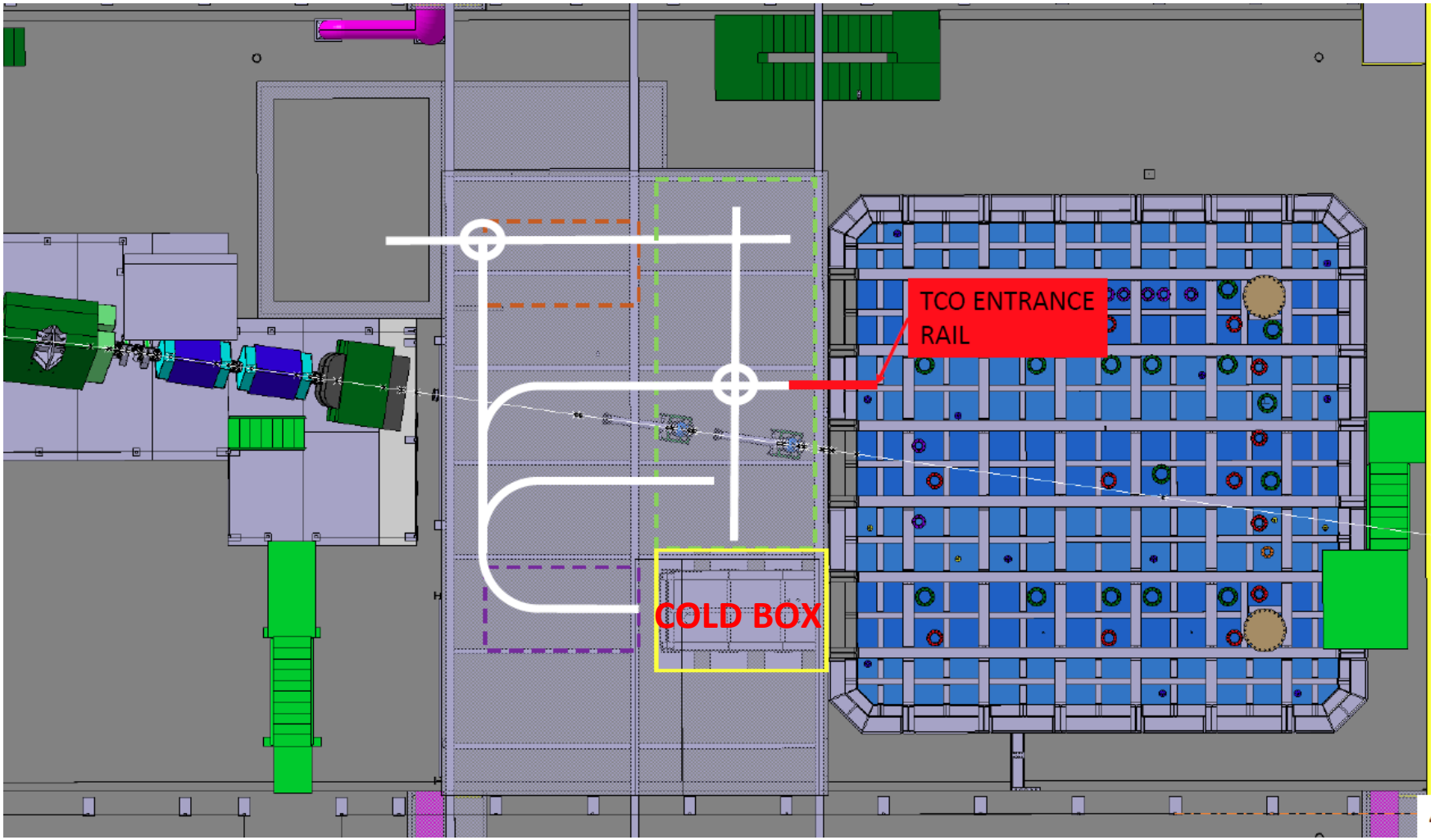
RF Room floor support

Copper Sheet Support Frame

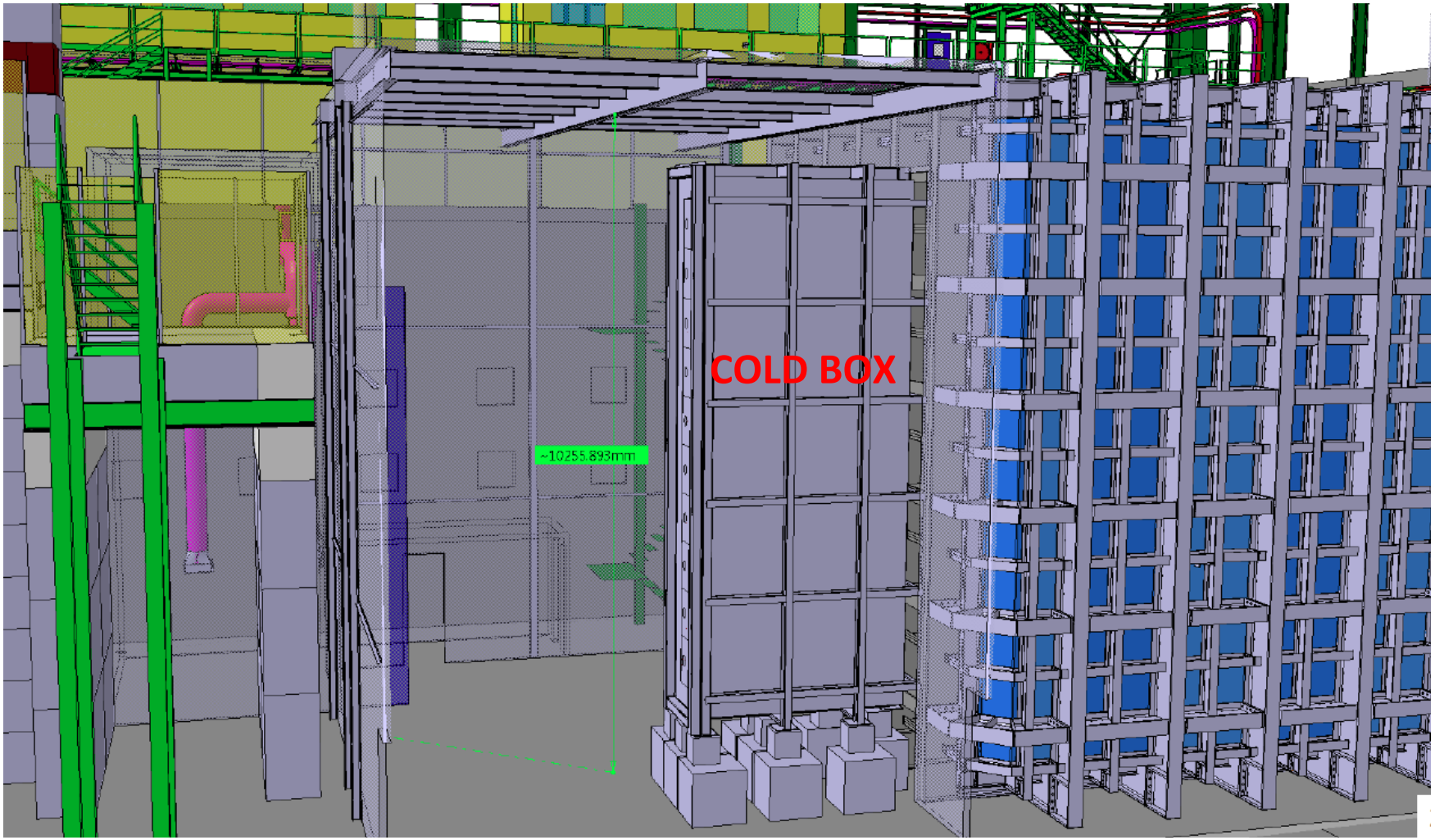
Vertical Slice at CERN ENH1

- Cold Box at CERN will allow vertical slice test of wire and photon detectors on production APA wire frames
- Cold Box will incorporate a full scale warm feedthrough and use cables and readout identical to the production system
- Power and Grounding will follow the same plan as for the detector electronics; the cold box will be isolated from building ground and will be powered with detector referenced power supplies

COLD BOX at CERN



COLD BOX at CERN



Conclusion

Are the proposed integrated system tests sufficient to assure that the systems will meet the performance requirements for ProtoDUNE-SP and SBND? Have applicable lessons-learned from previous LArTPC detectors been documented and implemented into the QA plan?

- LArTPC detectors require low noise to achieve the physics goals
- A program of integrated APA+CE+Feedthrough testing at Fermilab and BNL has been developed to address open issues of noise and grounding and are under construction
- A complete VST of full-size cold APAs in planned at CERN

- Experience from previous LArTPC has been documented: DUNE-doc-1704
  - Will be covered in more detail tomorrow in Dean's talk