Grounding

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TPC Electronics and WIB System Review

March 10, 2020

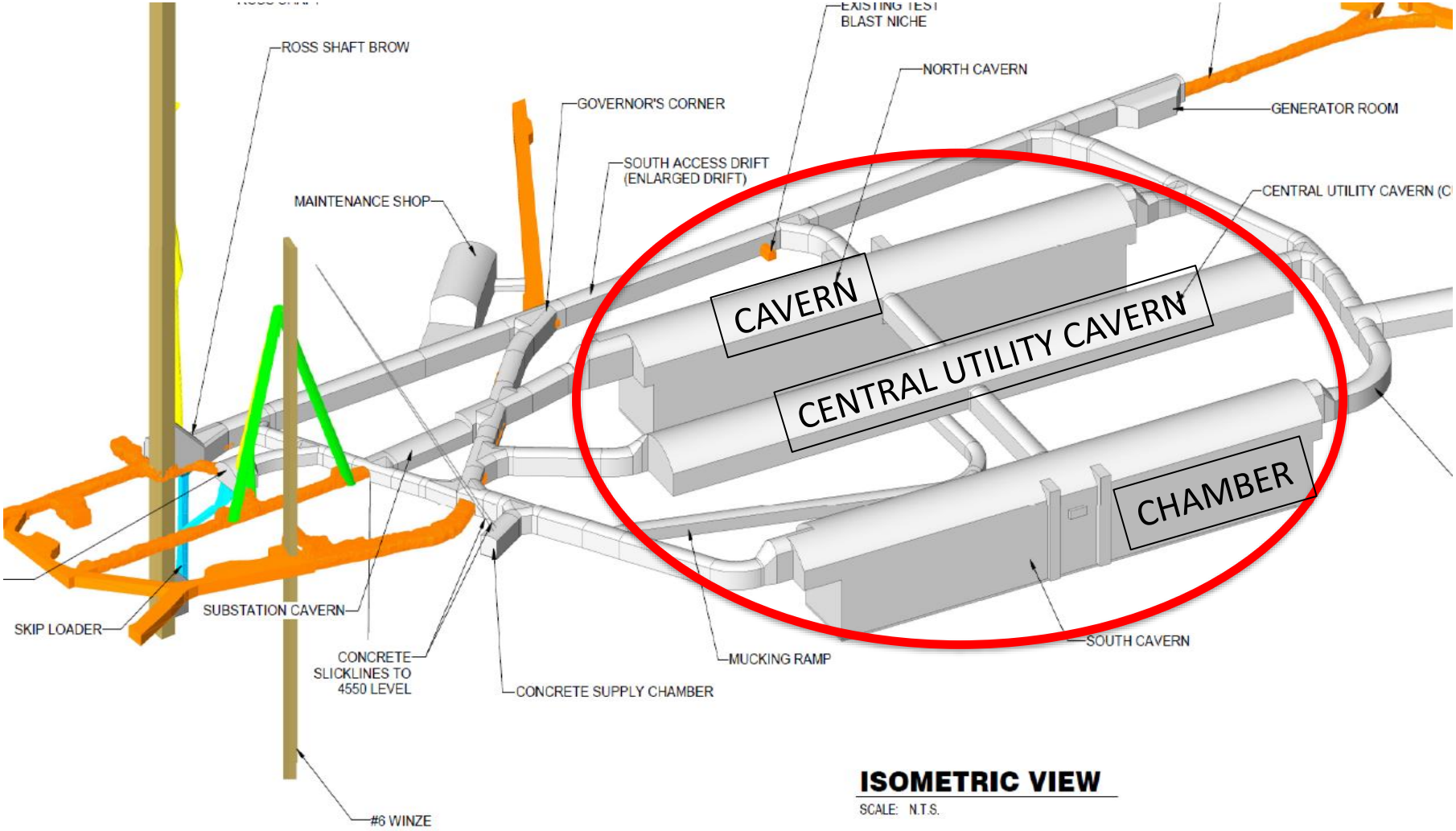
Outline

- Ground system motivation
- Ground definitions
- General grounding rules
- Detector grounding rules
- APA readout grounding rules
- Ground connection graphics
  - Overall CE crate electronics
  - Wire Bias, Field cage, ground monitor

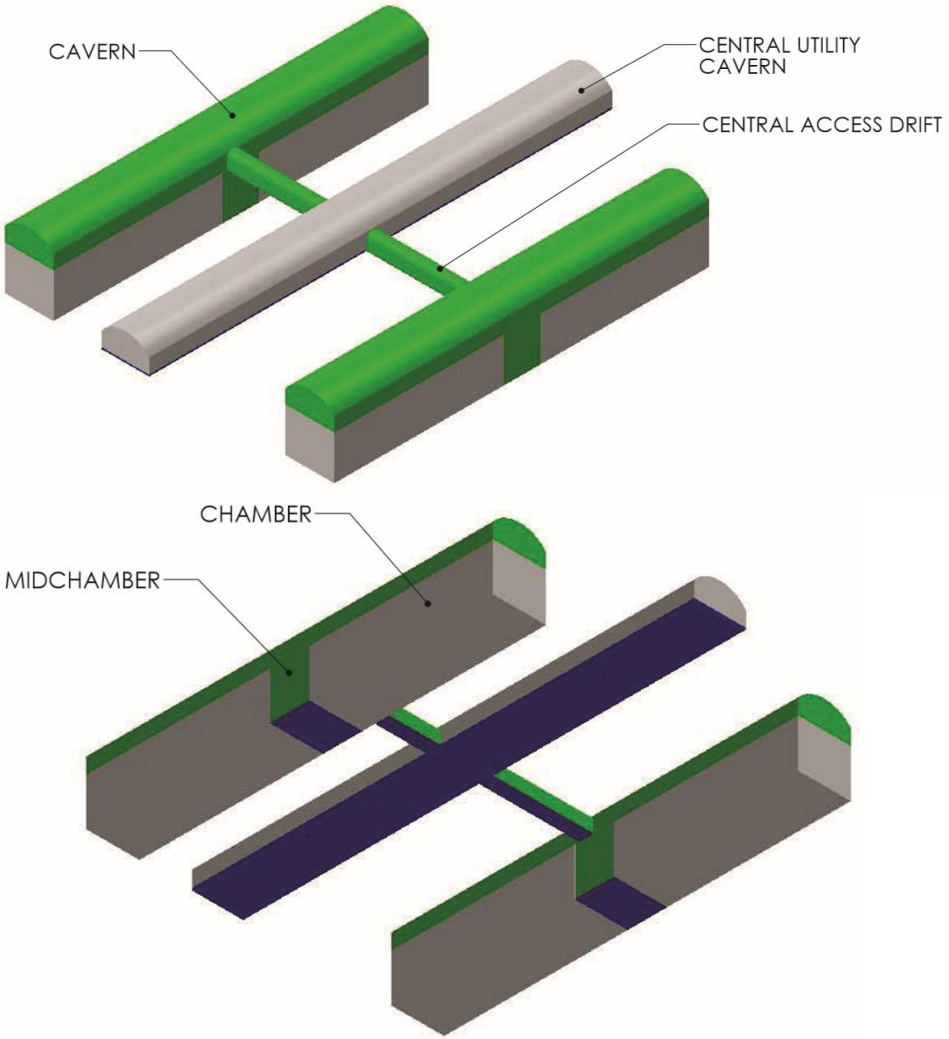
Ground System Motivation

- The DUNE LAr detectors require a low electrical noise environment. The rock masses, located at the SURF 4850 level, are expected to have extremely poor and inconsistent conductive properties. Therefore, a ‘low noise’ grounding scheme has been developed.
- The LBNF/DUNE Far Site Detector Grounding system Requirements were developed by the DUNE Grounding Committee
  - T. Shaw, L. Bagby, P. Bauer, S. Chappa, M. Johnson, V. Radeka
  - https://edms.cern.ch/document/2095975
- Detector electronics designs also follow a set of ‘grounding’ rules to mitigate unwanted noise.

LBNF/DUNE Far site



LBNF/DUNE ground structures

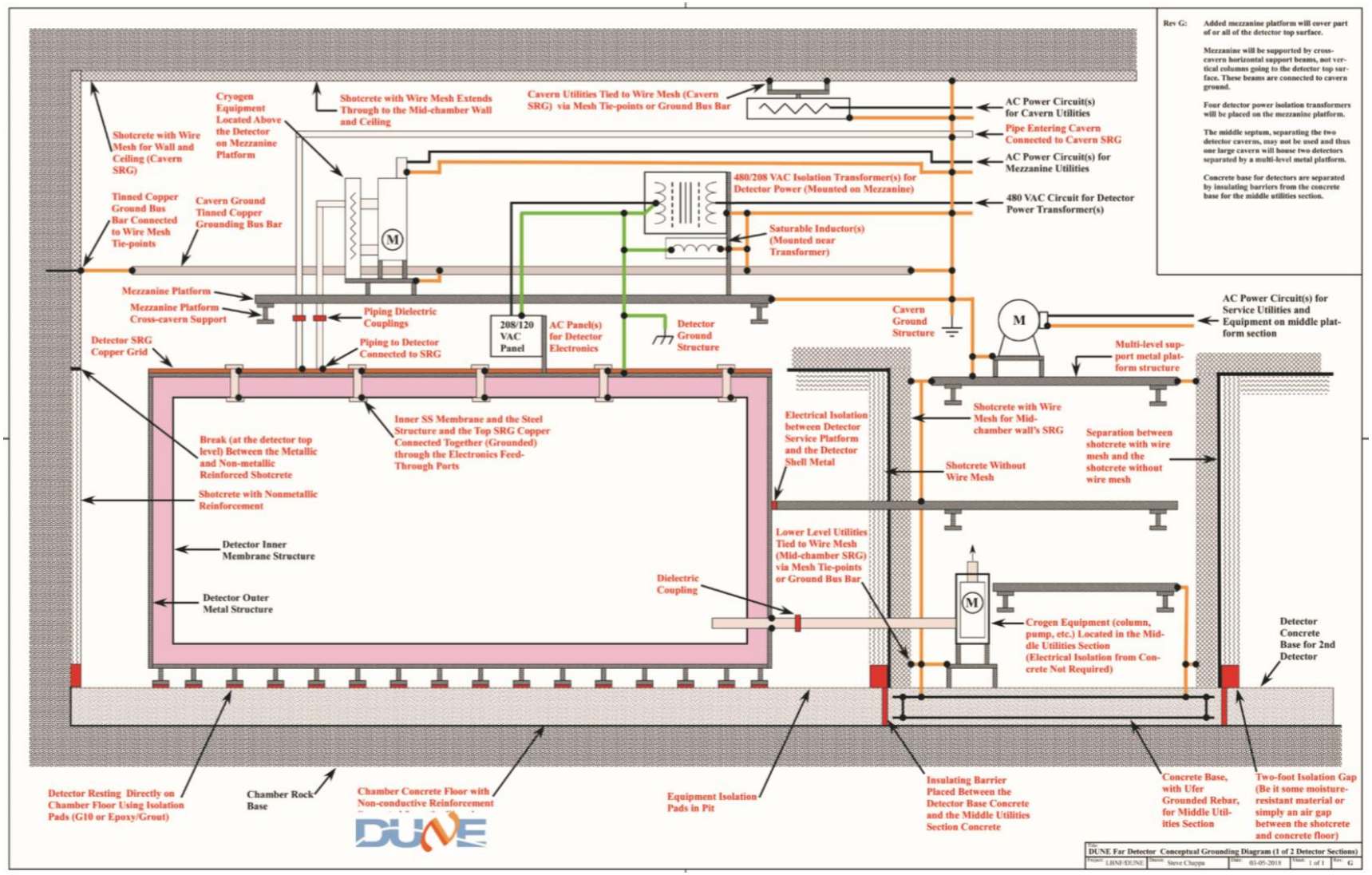


- CAVERN GROUND
  - Consists of all walls and crown areas above the 4850 sill level in the north and south detector caverns and associated central access drift areas.
  - Composed of overlapping wire mesh supported by rock bolts and covered with shotcrete.
- UFER GROUND
  - Consists of metal rebar embedded within the concrete floors of the cavern mid-chambers, central utility cavern, and central access drifts.

Detector Ground

Composed of the warm box enclosing the cryostat and all metal structures attached or supported by the detector vessel.

Separated from the LBNF ground structures via saturable inductors.



General Grounding Rules

- Detector cavern concrete floor contains non-conductive fiber reinforcement.
- No floating metal. All conductive objects are solidly bonded to either cavern ground or detector ground.
- No conductive connections (copper cables, cryogenic piping) from equipment powered from the cavern power system to equipment powered by the detector power system.
- VFDs (variable frequency drives) and motor controllers must be reviewed by grounding committee.

Detector Grounding Rules

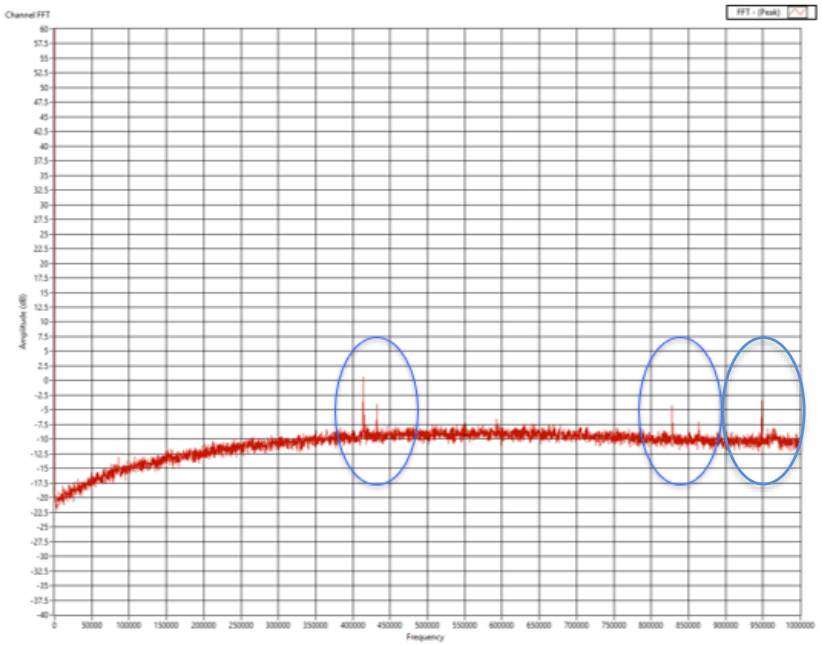
- Guidelines provided in https://edms.cern.ch/document/2095958
- The detector cryostat is treated as a Faraday cage.
- Any penetrations into the cryostat must include appropriate connectorization and filters to preserve the Faraday cage feature as much as possible.
- Power connections
  - All power connections into the cryostat must be referenced as close to the point of penetration into the cryostat as possible.
  - Power supply returns should ‘float’ at the supply and be referenced at the cryostat flange.
- Cable shields
  - Cables with overall shields are connected at both ends to maintain the Faraday cage integrity.
  - If needed, ‘soft’ grounds (low Z connection including a resistor, capacitor, inductor) may be implemented at the detector side.

Cable Shield Studies

- Several studies were conducted to understand the source of noise signatures at ProtoDUNE, both on the Cold Box and the cryostat.
- The Cold Box studies (BNL) minimized the number of subsystems as possible sources.
- The Cryostat studies (CERN) offered more possible noise sources; cameras, lights, heaters, temperature readout, purity monitor, etc.
- The initial cable shield configuration was to terminate at the source end, open at the destination, with the provisions to connect at the destination.

Cold Box Study (BNL)

Step7 FFT of U15 (chip1chn2)

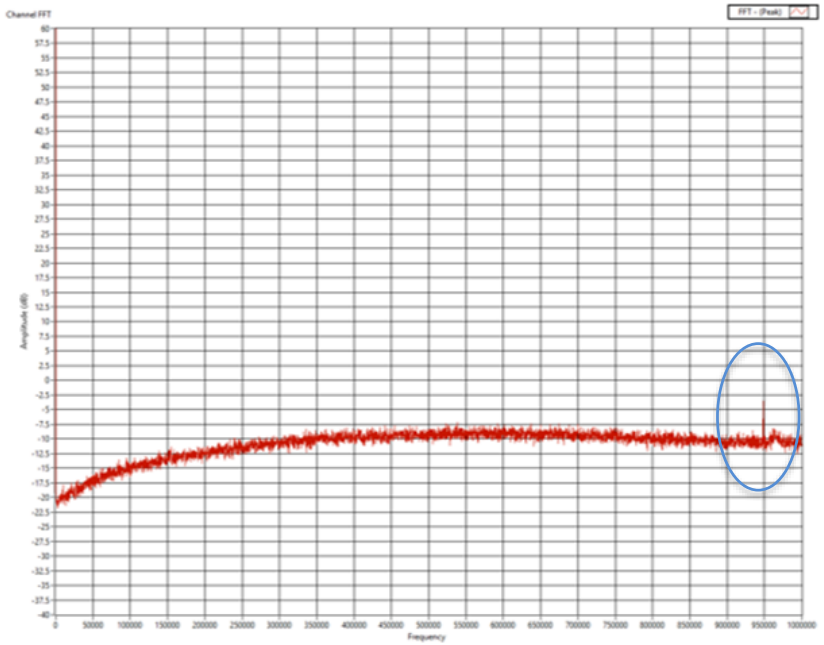


Power cable shield connected at power supply, open at PTC card (CE crate side)

Observed:

415/830 kHz, 430kHz/860kHz, 950kHz

Step8 FFT of U15 (chip1chn2)

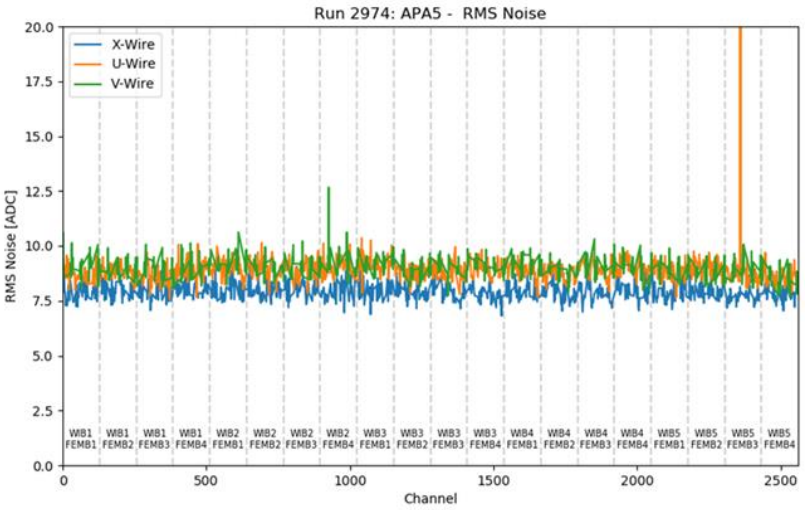


Power cable shield connected at power supply and PTC card (CE crate side)

Observed:

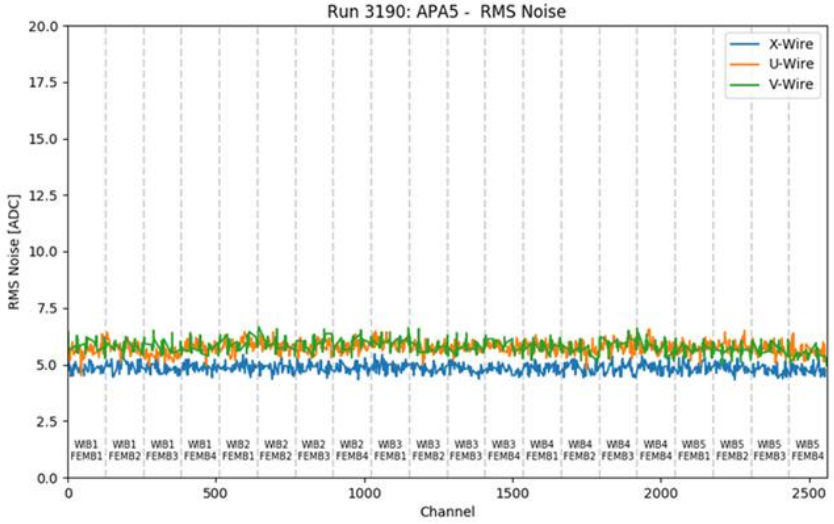
950kHz

Cryostat Study (CERN)



RTD sensors for the Hawaii and Valencia cable shields connected at power supply only.

Observed: 7.5-10 ADC pedestal



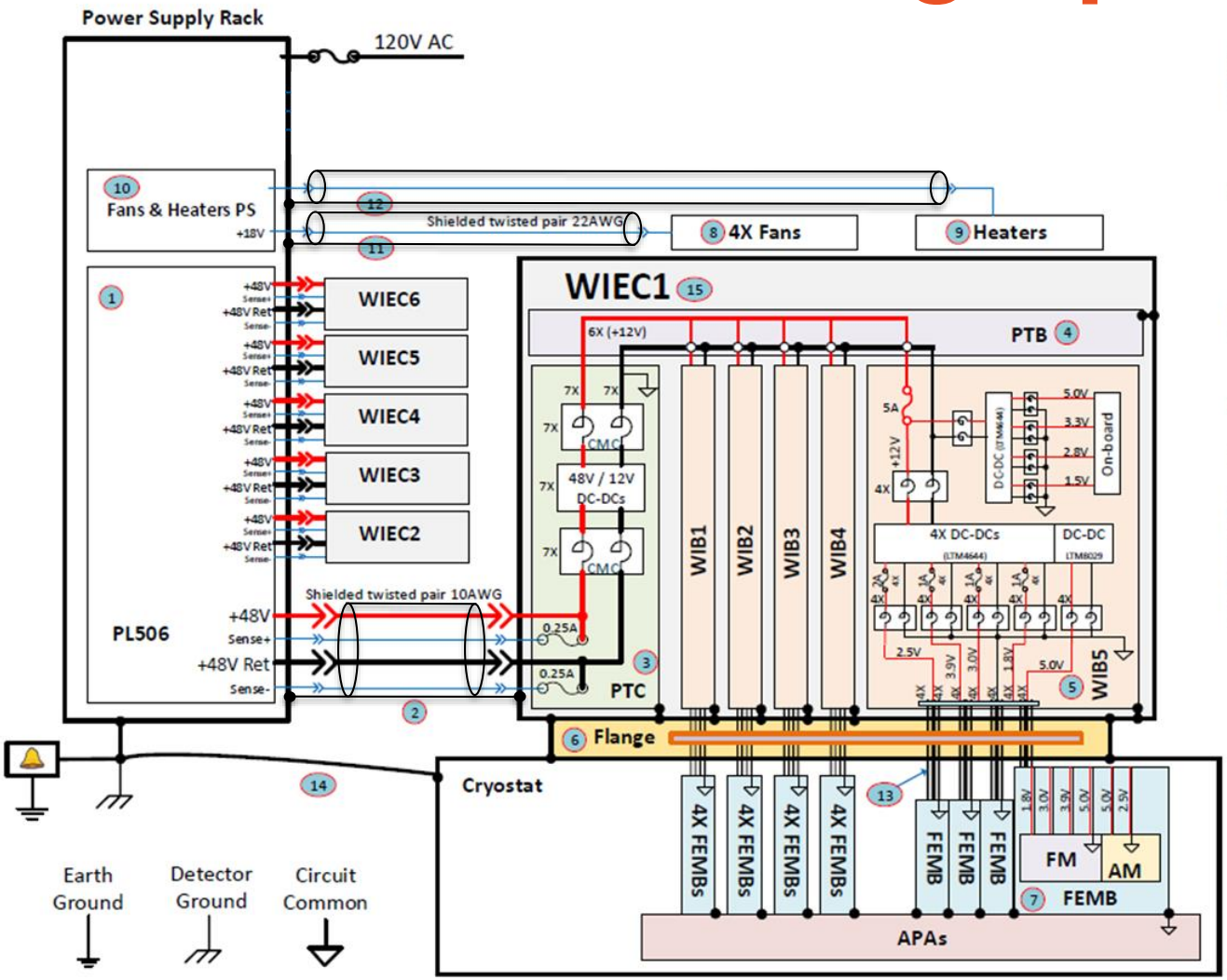
RTD sensors for the Hawaii and Valencia cable shields connected at power supply and cryostat.

Observed: 5-6 ADC pedestal

APA Readout Front-end Grounding Rules

- The warm electronics crate preserves the cryostat as a Faraday cage.
- APA frames are insulated from each other and the cryostat.
- Cables (power and signal) associated with each APA will be routed to a single associated feedthrough.
- The APA frame is connected to the circuit common of cold electronics cards.
- The circuit common of the cold electronics cards is connected to the enclosure of the cold FE module.
- Cold electronics card power line returns and cable shields are connected to the circuit common plane of the cold FE module and the flange of the feedthrough. This is the ONLY connection from the APA frame to the cryostat.
- The last stage of the Field Cage, and Ground plane monitor circuits are referenced to the cryostat.
- The cold Wire Bias CR boards are referenced to the APA frame.

Overall CE crate graphic



1: Weiner PL506 Power Supply
2: 48V power cable
3: PTC (Power and Timing Card)
0.25A Fuse P/N: 3404.0006.11
Choke P/N: PLT10HH501100PNL
4. PTB (Power and Timing Backplane)
5: WIB (Warm Interface Board)
5A Fuse P/N: 3404.0017.11
2A Fuse P/N: 0468002.NR
1A Fuse P/N: 0468001.NR
Choke P/N: PLT5BPH5013R1SNL
6: Flange Board
7: FEMB (Front End Motherboard)
FM: FPGA Mezzanine
AM: Analog Motherboard
8: Fans box
Fans are electrical isolated from WIEC
9: Heater
Heater is electrical isolated from WIEC
10: Fans & Heater power supply
11: Fans power cable (shielded)
12: Heater power cable
13: 7m cold power cable
14: Grounding cable
15: Warm Interface Electronics Crate (WIEC)

Notes
(1) Fans and heaters are isolated from WIEC
(2) PTB is mounted with the brass standoffs as a grounding connection
(3) The grounding connection between WIBs and WIEC is through front panels and side bars
(4) The grounding connection between PTB and WIEC is through front panels and side bars
(5) Flange (and flange board) is the place that the FEMB circuit common is referenced to the cryostat (detector ground)

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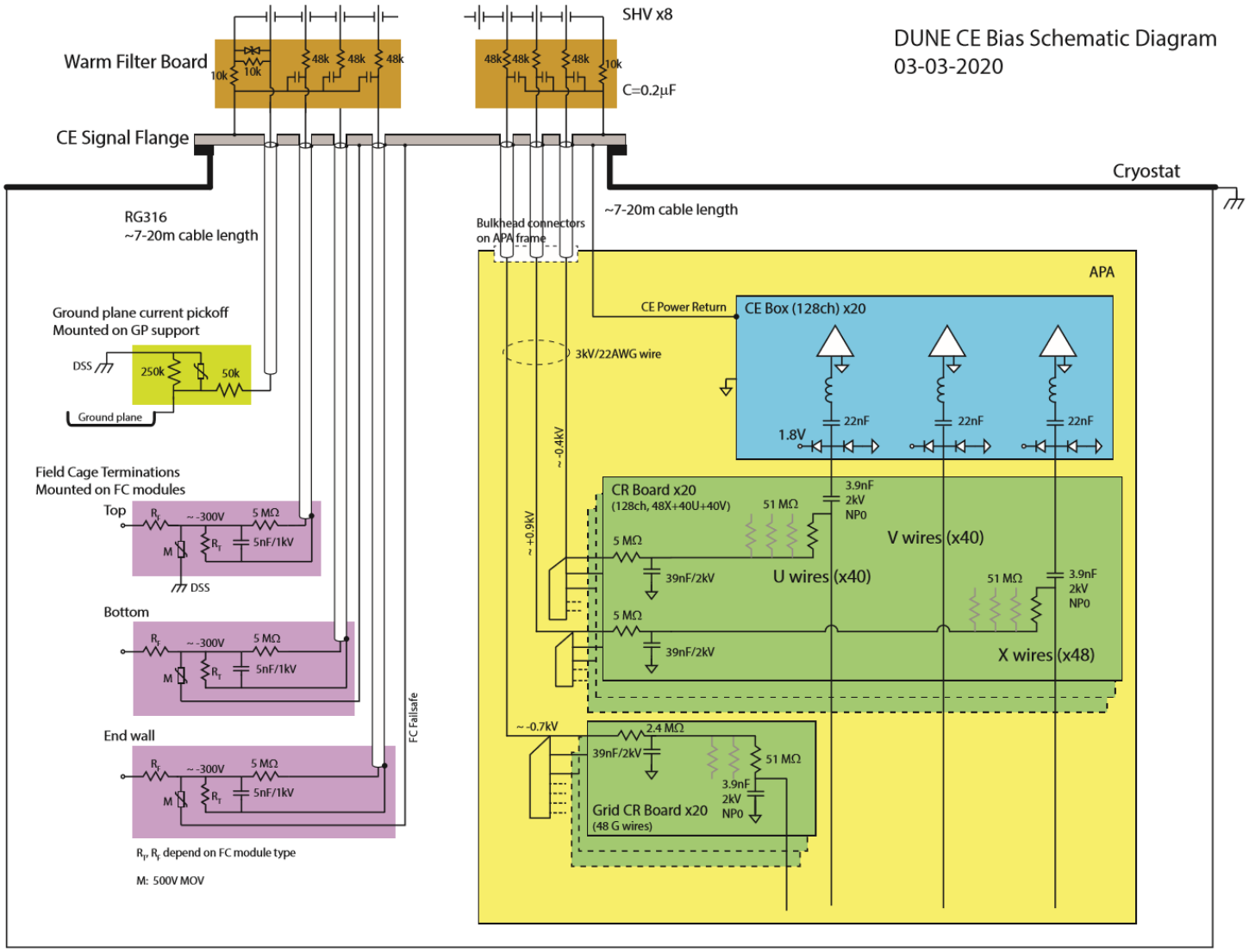
Overall Wire Bias, FC, Monitor graphic

Wire Bias from floating output power supply, RG58, SHV



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Summary

- There are two distinct ground structures within LBNF and the DUNE experiment; Cavern ground and Detector ground.
- Rules for grounding are defined, both for general equipment as well as detector electronics.
- All cold and warm APA readout electronics follow the grounding rules.

Back Up

Impedance Monitor

AC Schematic