Grounding
35T, DUNE & ProtoDUNE

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Outline

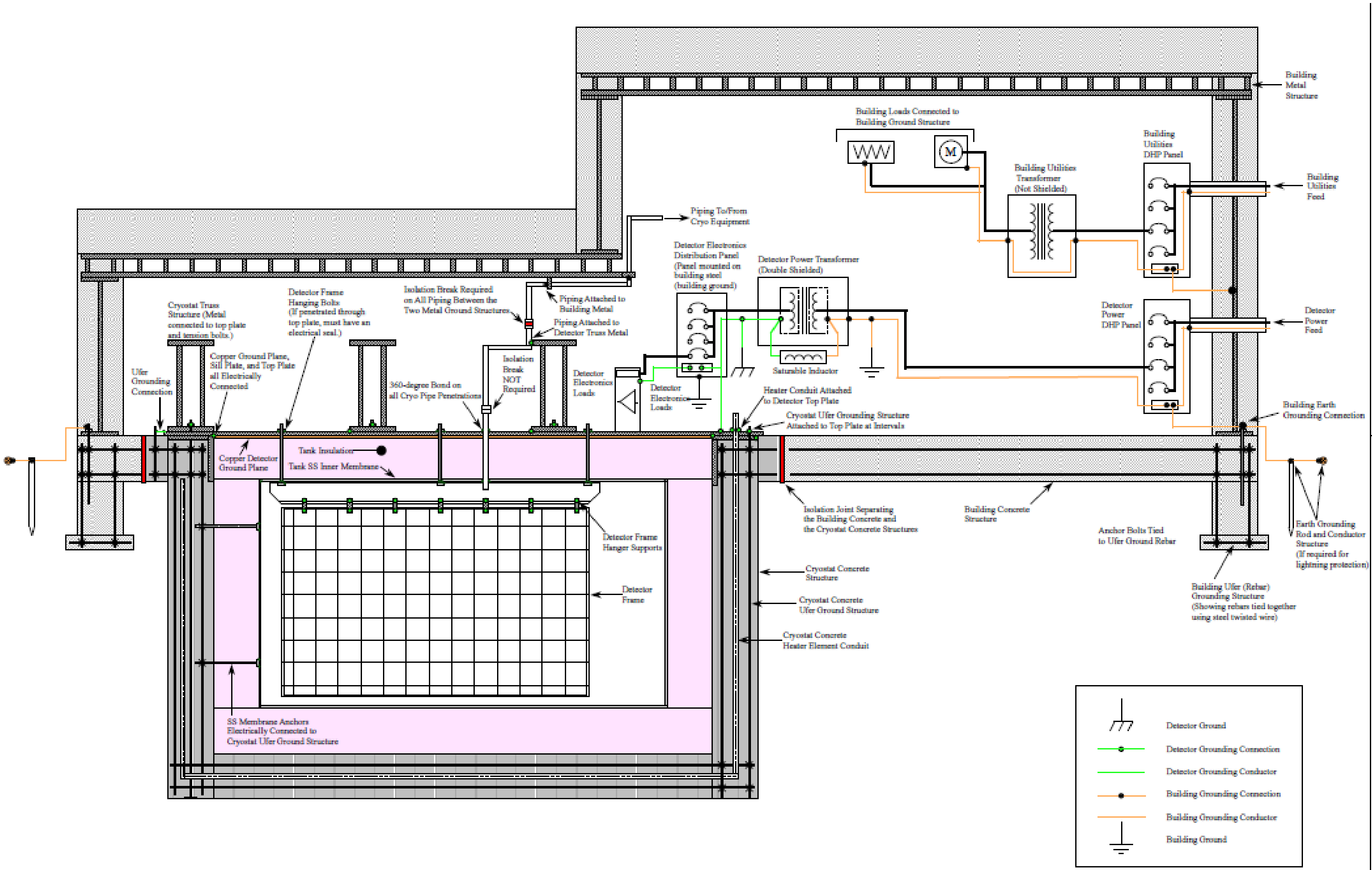
- Ground implementation at 35T
- Ground Plans at DUNE Far Detector
- Plans at protoDUNE
  - What we can learn/apply to DUNE Far Detctor

35T Grounding Plan

35T Grounding Plan

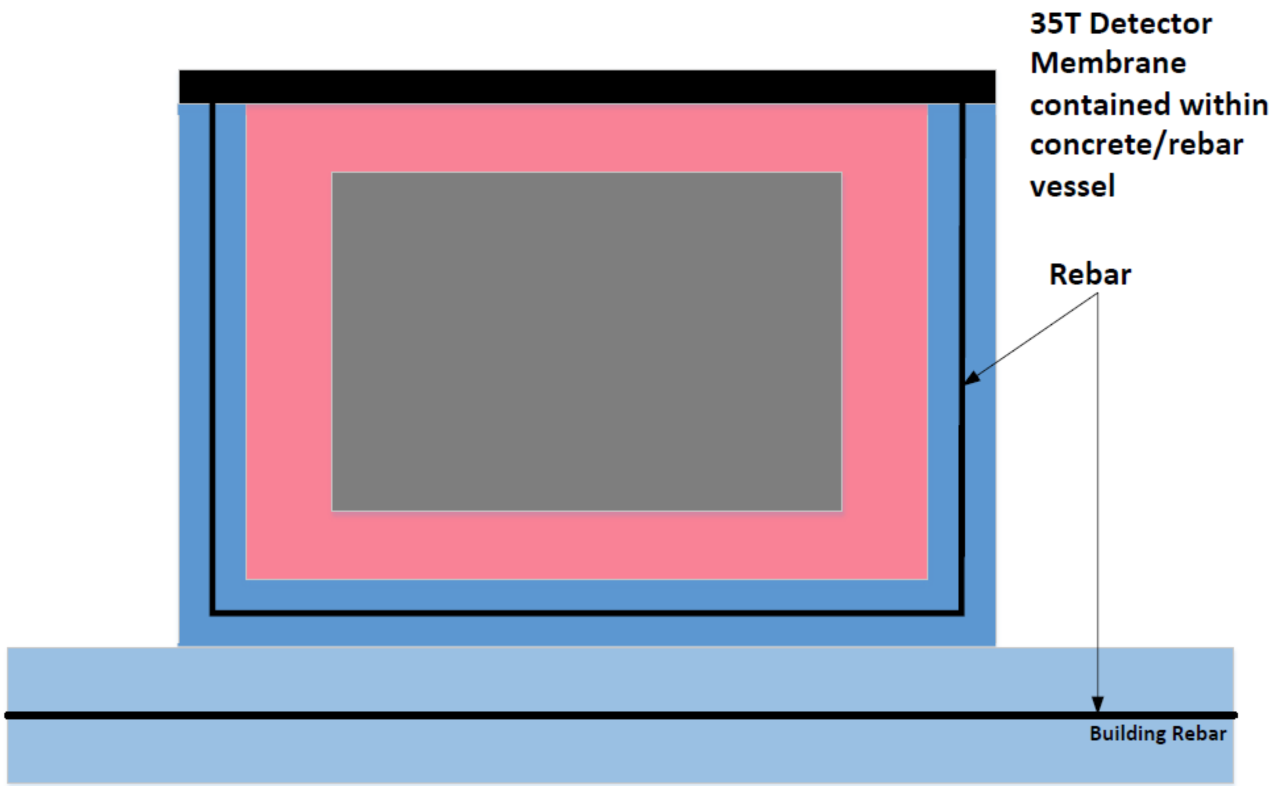
- Tried to match it to the plan we had for the FD at the time
  - FD was a surface detector
  - Concrete/rebar container supported by rock
- Attempted to isolate Detector Ground and Building Ground
- Saturable inductor used to provide a safety ground

Obsolete Above Ground FD Plan



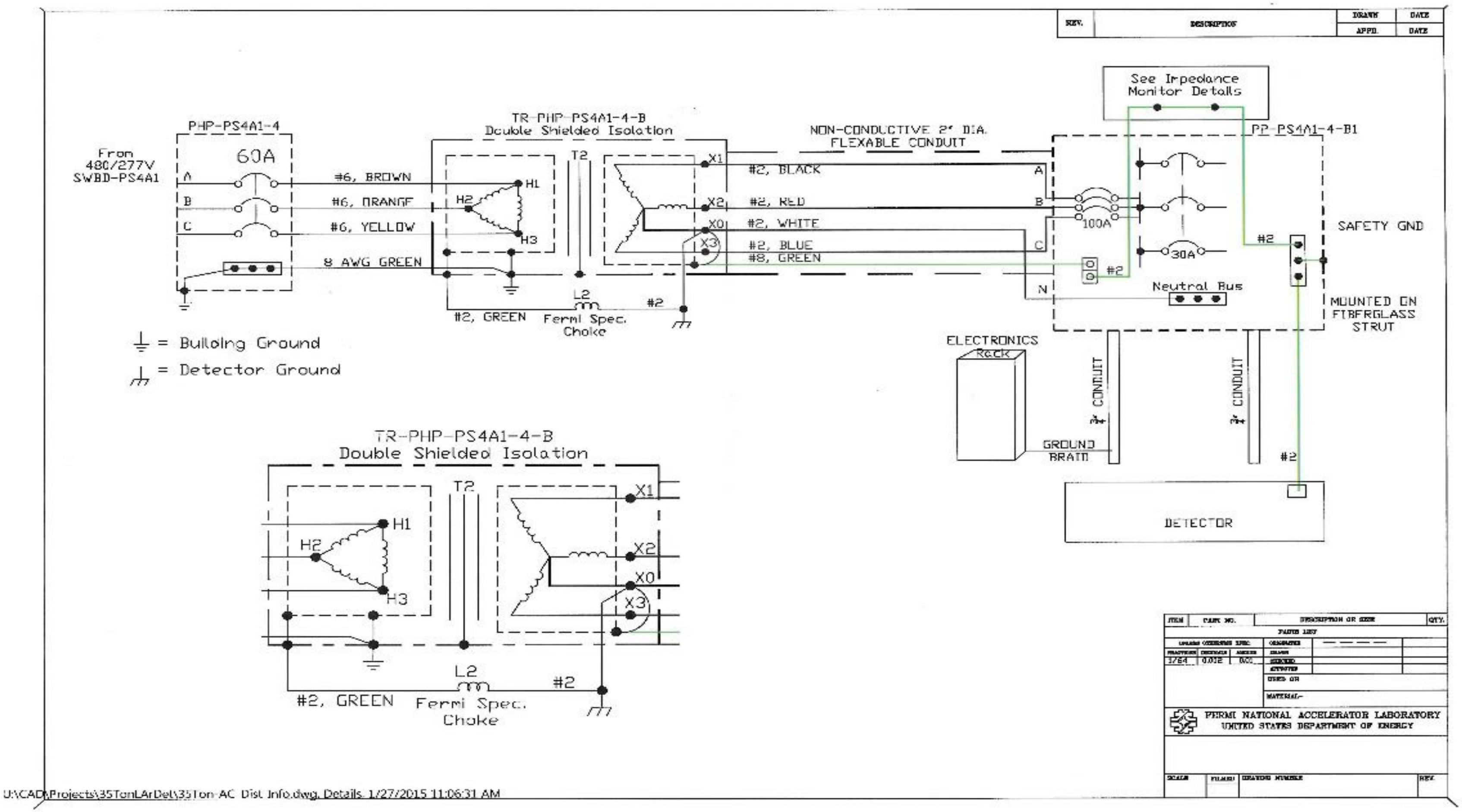
35T Grounding

At the Fermilab PC4 installation, the 35T cryostat membrane is contained within a concrete/rebar vessel.



- Maintained separate Building and Detector Grounds
- Saturable Inductor as safety ground between the two ground systems
- Isolated double shielded transformer used for detector power

35T AC distribution



35T Grounding

How well was isolation maintained?

- Measured isolation was less than what was expected
  - Initial readings were made to determine the isolation between the detector and building ground. Using a Fluke meter, it provided a reading in the 1-2 Mega ohm range. *Meters were later found to read incorrectly when voltage is present.*
  - Then, to measure resistance, applied current of ~7 Amps at just under 50VAC.
  - The value measured was 40.6V @ 7.14A or 5.6Ω; lower than what we hoped for!
  - Also, we now expect the AC impedance to be <5 ohms, when we model the rebar in the concrete floor and the rebar at the bottom of the containment vessel as a parallel plate capacitor.
  - We will get more information on how well this grounding approach worked when we begin taking data in a couple months.

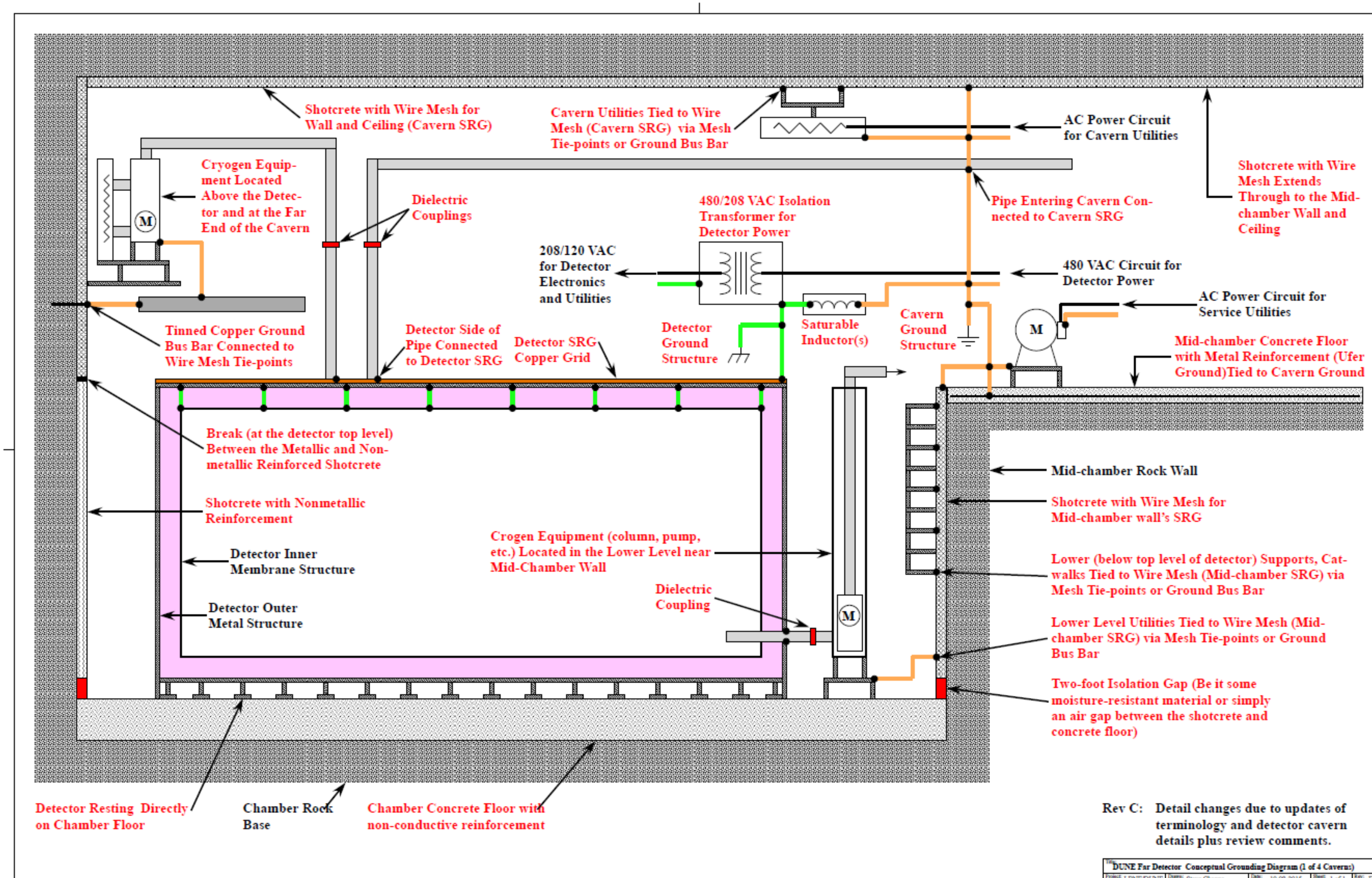
DUNE FD Grounding and Conventional Facilities

- To insure adequate sensitivity of the detectors, ground systems must be put in place that will isolate the detectors from all other electrical systems and equipment, and minimize the influence of inductive and capacitive coupling and ground loops.
- DUNE defines two distinct ground systems: **Detector Ground** and **Cavern Ground** (cryo and building services).
- A safety ground, consisting of two or more saturable inductors, will connect the two ground systems and maintain a low impedance current path for equipment short circuit and ground fault currents, and insure personnel safety by limiting equipment/equipment and equipment/ground touch potentials.
- DUNE ground plan requirements for Conventional Facilities are specified in DUNE Document 285; approved by Dune Technical Board on October 14, 2015.

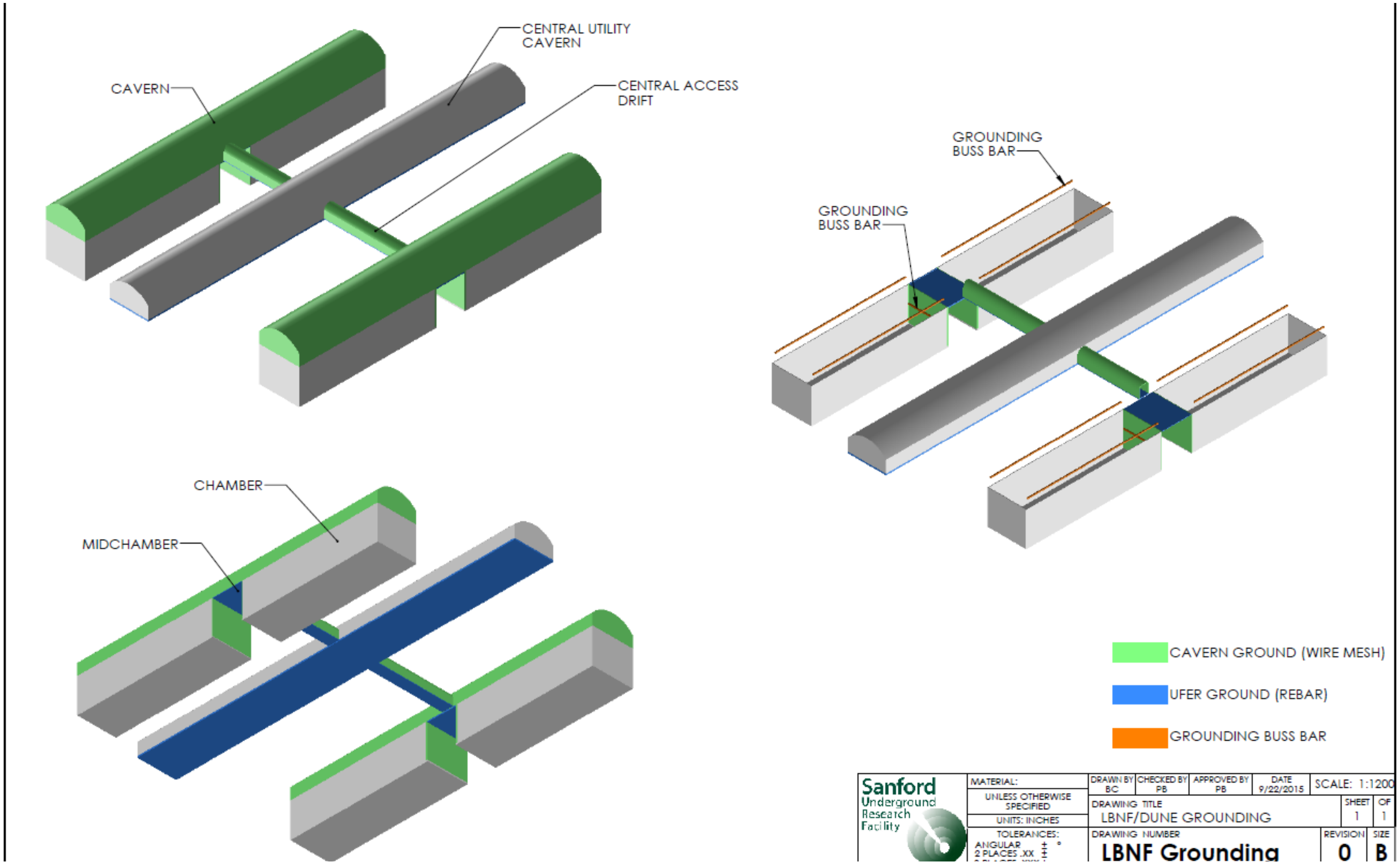
DUNE FD Main Grounding Points with respect to CF

- **Detector Ground** consists of the steel containment vessel enclosing the cryostat, the cryostat, and all metal structures attached to or supported by the detector vessel. Dielectric breaks will be required on all cryo piping and any other metal structures referenced to **Cavern Ground**.
- To further isolate the **Detector Ground** from any stray **Cavern Ground** currents, the concrete pad the detector rests upon, should contain no conductive rebar.
- **Cavern Ground** is a combination of the UFER ground formed by the rebar in the concrete floor of the Central Utility Cavern, Central Access Drifts and Detector Cavern mid chamber, as well as the wire mesh enhanced shotcrete to be located in the Central Access Drifts and the crown areas above the detector.
- An easy access to the **Cavern Ground** will be provided by buss bars which run the length of each side of the detector chambers. Any "non-detector" equipment can be referenced to this low impedance path to **Cavern Ground**.

Far Detector Ground



Far Detector Ground



protoDUNE Grounding

Ideally, we would make the protoDUNE grounding as similar to the planned FD grounding scheme as possible.

- Reality is we are dealing with very different environments

At protoDUNE, we do not believe it is possible to achieve isolation between the “building” and “detector” grounds. The impedance between the building structure and the steel structure will be low due to the large plate capacitance effect.

-> no double shielded transformer or saturable inductor safety ground is needed for protoDUNE. Everything referenced to building ground.

protoDUNE Grounding

- Need to pick an analog reference plane for the APA and photon systems. The best choice is the top of the cryostat! **This is same as FD plan**
  – All readout electronics, associated power supplies and drift field power supply need to be referenced to this plane
  – All connections to this plane need to avoid any ground loops

- Need to minimize AC potential between the cryostat and the ground reference. This requires us to reduce the inductance of the connections. System should work to about 30 MHz for the photon system.

Implies-> internal “ground” metal structures tied together; multiple ties between cryostat and top plate. 30MHz means we conservatively have less than ~10 meter divided by 4 spacing between ties. I think we have on the order of 3m from penetrations.

- Treat the cryostat as a faraday shield so all penetrations break the grounds at the cryostat
- Isolate all cryogenic connections

protoDUNE Grounding

- All internal monitors need to have a low noise design
- All VFDs near the cryostat need careful design to prevent ground currents from flowing on the cryostat. This is different from DUNE because the cryostat is not ground isolated

protoDUNE Grounding and Cabling

- All external cable lengths need to be a short as possible and installed in shielded trays.
- All cable shields need to be connected at one point at the feed through ports to avoid shield currents. Noise currents flowing on a shield can inductively couple into the center conductors
- It is very preferable to have the readout racks on top of the cryostat so that all the readout can be on a common ground system. Note that inductance is a logarithmic function of conductor size so long connections are difficult to make with low impedance.

Potential Issues

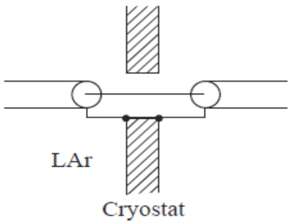
Want good low impedance path between APAs and top plate.

- Are APAs on rolling mounts? YES! Will need additional ground straps to tie APAs to cryostat.

- Where are racks located?
  - Strong preference for racks to be on top of detector.

Shielding Cable Penetrations

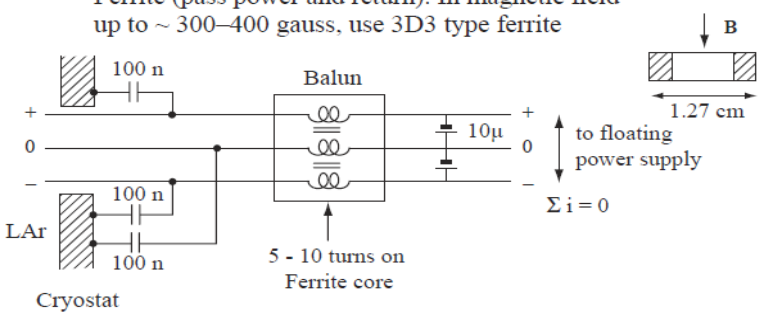
1. Coaxial Cables



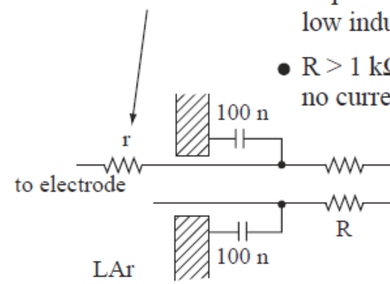
- Shield connected to cryostat before penetrating Faraday cage
- Short connection, low inductance
- Performed on standard feedthroughs

2. Power Supplies

- Capacitors with short leads, close to cryostat low inductance connection
- No net DC Current in Balun to avoid saturating Ferrite (pass power and return). In magnetic field up to ~ 300–400 gauss, use 3D3 type ferrite



3. Probes, HV



- Capacitors with short leads, close to cryostat, low inductance connection
- R > 1 kΩ can be replaced by L > 1mH when no current flows

Figure 5. Rules for Entering a Shielded Detector Enclosure (e.g., cryostat).

SHIELDING AND GROUNDING IN LARGE DETECTORS*

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