Dune Grounding Issues
Impedance Concerns

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Grounding Plan

- Grounding Plan can be found in DUNE docdb 285

https://docs.dunescience.org:440/cgi-bin/ShowDocument?docid=285

- Need to consider the resistivity of concrete slab.

Electronics Low Noise Design

- What are we trying to address?
- The noise level at the front end electronics is measured in electrons. We expect on order of 500 electrons rms noise.

- $I = \Delta Q / \Delta t$
- $= (500\ e\text{-} \times\ 1\ \text{Coulomb} / 6.242 \times 10^{18}\ e\text{-}) / 500 \times 10^{-9}$ seconds

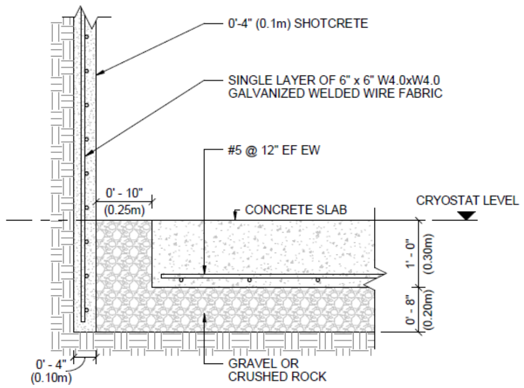
  = 160 picoamps

- We need to make sure the front end electronics see a contribution much less than 160 picoamps from any infrastructure ground noise.

Detector Ground Isolation

Cryostat Construction

- At ProtoDUNE, the cryostat sits on a thin G10 insulator to make a DC break with the building concrete with “building” rebar
- At DUNE, the cryostat sits on concrete pad which should not have conductive reinforcement, a gravel bed and then stone.
- NOTE: non-conductive reinforcement is required to lower capacitive coupling between “earth” and “detector” grounds.



CONCRETE SLAB DETAIL - INVERT CHAMBERS

SCALE: 1" = 1'-0"

B
C-201

Old picture; before our grounding rules

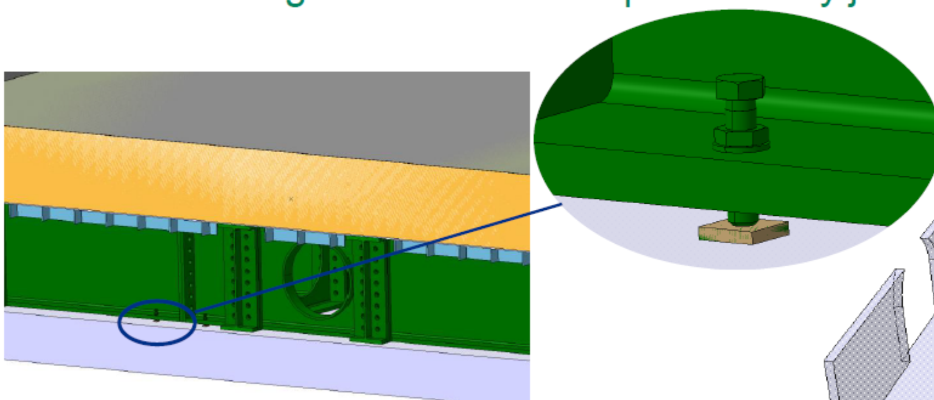
Cryostat Construction/Installation

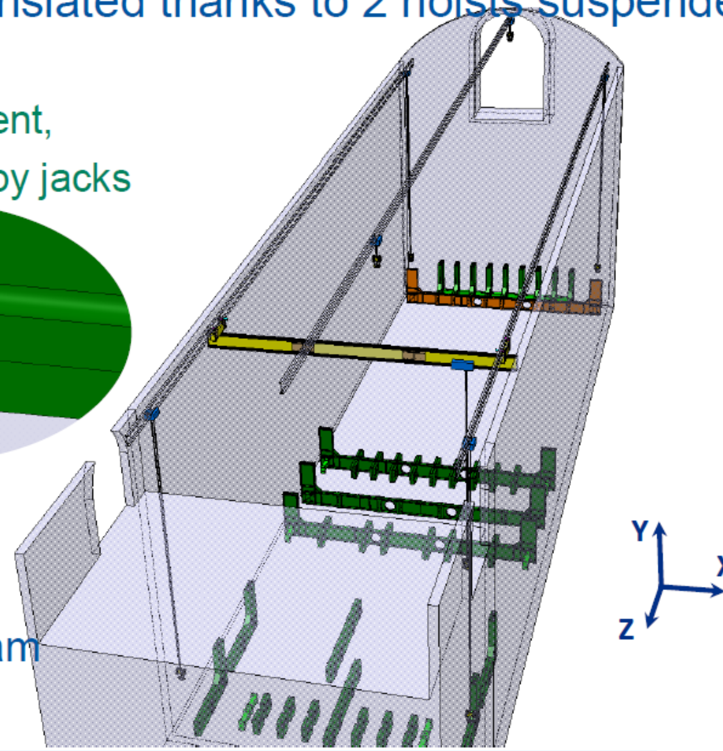
1- Floor beams installation

- 1st portal floor beam installation, translated thanks to 2 hoists suspended to side monorails

Positioning guaranteed by survey measurement,

Flatness of the ground/beams compensated by jacks





- Preparation of following portal floor beam

LBNF
19 8/21/2017

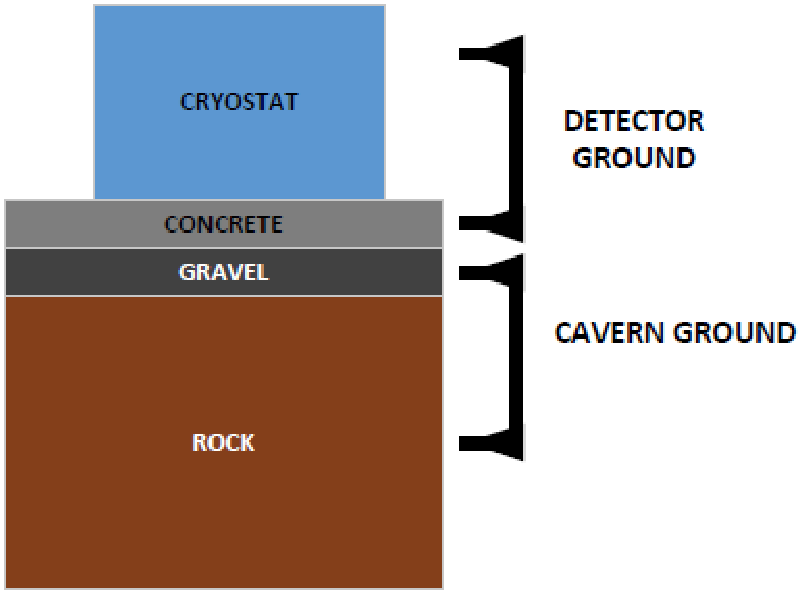
CERN NP
EP-DT
Detector Technologies

Grounding Concerns

- Ideally the resistance between “detector” ground and the “Cavern/building” ground should be >10 ohms. Resistance must be much greater than the resistance of our “safety ground” (saturable inductor).
- If we provide proper low impedance connections to the equipment located on each of the two ground structures, this will help reduce stray currents from flowing between the two “isolated” systems and reduce noise.
- NOTE: We must pay attention to and approve the building services and cryo connections as well as the detector connections. Of particular concerns are any pumps and VFD controllers that can radiate noise.

Getting to “10 ohms” btw grounds

- Problem – resistivity of concrete needs to be taken into account
- If we take the below slice as our model, we need the concrete slab to provide us with the 10 ohms resistance.



Resistivity of concrete

Resistivity and Resistance Models

A simple model of the resistance seen between "Detector Ground" and the "Cavern Ground and Ufer Ground" references would be viewing the cryostat as an electrode with contact to Cavern/Ufer Ground through the concrete pad the detector rests upon.

Email from Bo Yu (10/31/2017)

The beam structure on the bottom of the cryostat is 0.4m wide at 1.6m centers along the length of the cryostat. Transversely, there are 6 beams along the full length, 9 beams at the ends (on 1.6m pitch). See picture below.

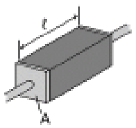
Here is a tally of the floor contact area:

beam type	area	number	total
long beam	26.4	6	158.4
short beam	2.2	6	13.2
transverse beam	7.6	39	296.4
overlap (double counted)	0.16	246	39.36
total contact surface			428.64

The total surface is about 430m^2.

From McMaster Carr, ½" FRP plate cost $230/m^2, FR4 is about $400/m^2. The total material cost is 100-200k$.

Resistivity of concrete



$$\rho = R\frac{A}{\ell},$$

where

R is the electrical resistance of a uniform specimen of the material
ℓ is the length of the piece of material
A is the cross-sectional area of the specimen

Conclusions:

- Concrete does not give us the resistance we seek
- A thin isolator between the cryostat and the concrete, such as G10 or some epoxy resin, does

Resistance of concrete pad under the metallic contact of the cryostat Frame:

Bottom of Cryostat is 430 m^2

Concrete Pad is 1 foot thick or 304.8 mm

Choose concrete resistivity of

a) **Conventional Concrete ~50 ohm-meter**
   R=ρl/A = 50 ohm-meter * 0.305 meter / (430 m^2) = **35 mOhms**

b) **High Performance Concrete ~500 ohm-meter**
   R=ρl/A = 500 ohm-meter * 0.305 meter / (430 m^2) = **355 mOhms**

For comparison, look at adding a thin layer of G10 insulator (like at ProtoDUNE):

Resistance of 0.1mm G10 insulator

http://advancedmaterialscience.com/assets/nema-g10.pdf

6×10^6 megohm-cm

R=ρl/A = 6×10^{10} ohm-meter * 10^{-4} meter / (430 m^2) = **13.95 Kohms**

Also, for comparison look at approximate resistance of 1 meter of rock which is under concrete pad:

Resistivity of rock ~50,000 ohm-cm (guess)

R=ρl/A = 500 ohm-meter * 1 meter / (65.896 meter * 18.996 meter) = **0.4 ohms**

Construction

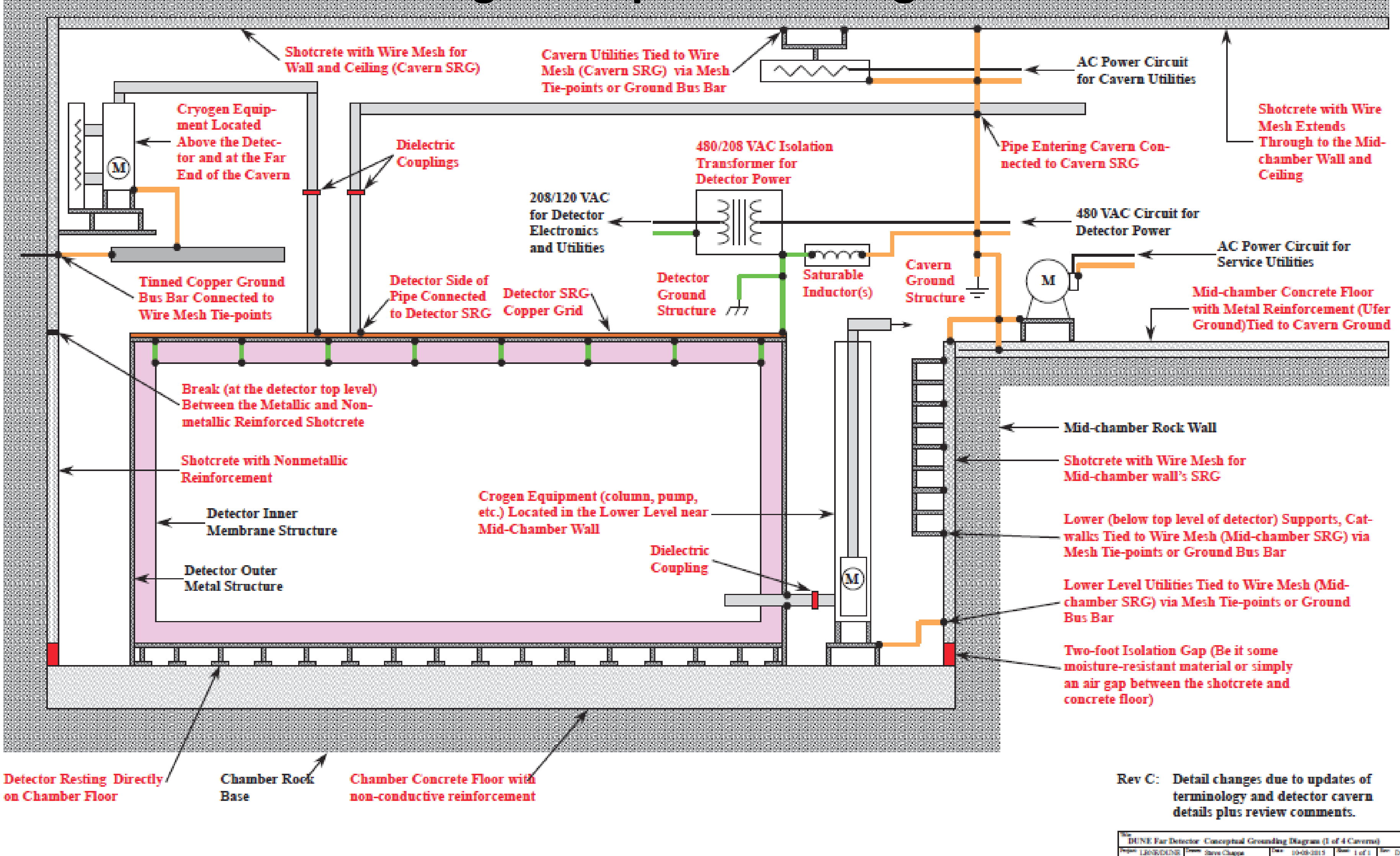
- We should plan to incorporate a thin piece of G10 on the beam bottoms.
- Could consider use an epoxy grout with high resistivity during construction

Email from Tom Hamernik – November 20, 2017

… Epoxy has excellent dielectric properties (including volume resistivity values of 10^12 ohm-cm and greater, a high dielectric strength) and high compressive strength, as well. It is commonly used in civil construction and available for a number of applications, including as a grout and as a floor coating. ….

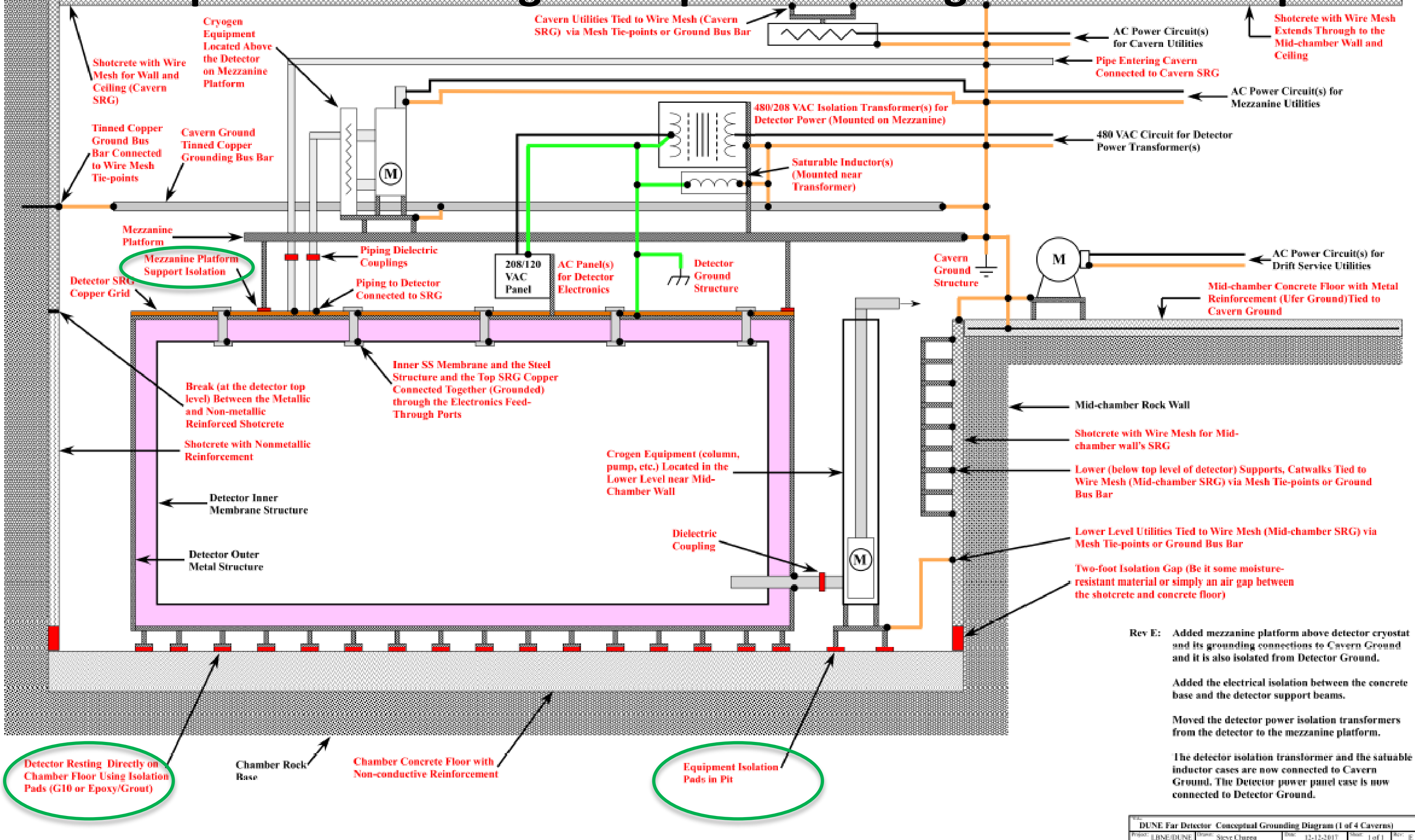
Idea is that we could use epoxy grout and maybe coat beam bottoms or concrete with epoxy.

Current Grounding Conceptual Drawing



DUNE

Proposed Grounding Conceptual Drawing – with Rock Septum



Backup

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Capacitance

Plate Capacitor Capacitance Calculator

C= K*Eo*A/D, where Eo= 8.854x10-12 F/m

where:

K is the dielectric constant of the material, 4.5 for concrete

A is the overlapping surface area of the plates,

d is the distance between the plates, and

C is capacitance

Capacitance for concrete under steel beams

K ~4.5 for concrete

C= 4.5 * 8.854x10-12 Farads/meter * (430 m^2) / 0.305 m = 0.056 µF

Capacitive Reactance is $|X_c| = 1/2\pi fC$; is 284 ohms @ 10KHz and 1.42 ohms at 2MHz

Capacitance for 0.1mm G10 under beams

K ~4.2 for G10

C= 4.2 * 8.854x10-12 Farads/meter * (430 m^2) / 0.0001 m = 159.9 µF

Capacitive Reactance is $|X_c| = 1/2\pi fC$; is 99.5 mOhms @ 10KHz and 0.5 mOhms at 2MHz

Total Capacitance

Treat concrete and G10 as series capacitors, total capacitance is 0.056 µF

Capacitive Reactance is $|X_c| = 1/2\pi fC$; is 284 ohms @ 10KHz and 1.42 ohms at 2MHz