



# Exploration of wire capacitance measurement

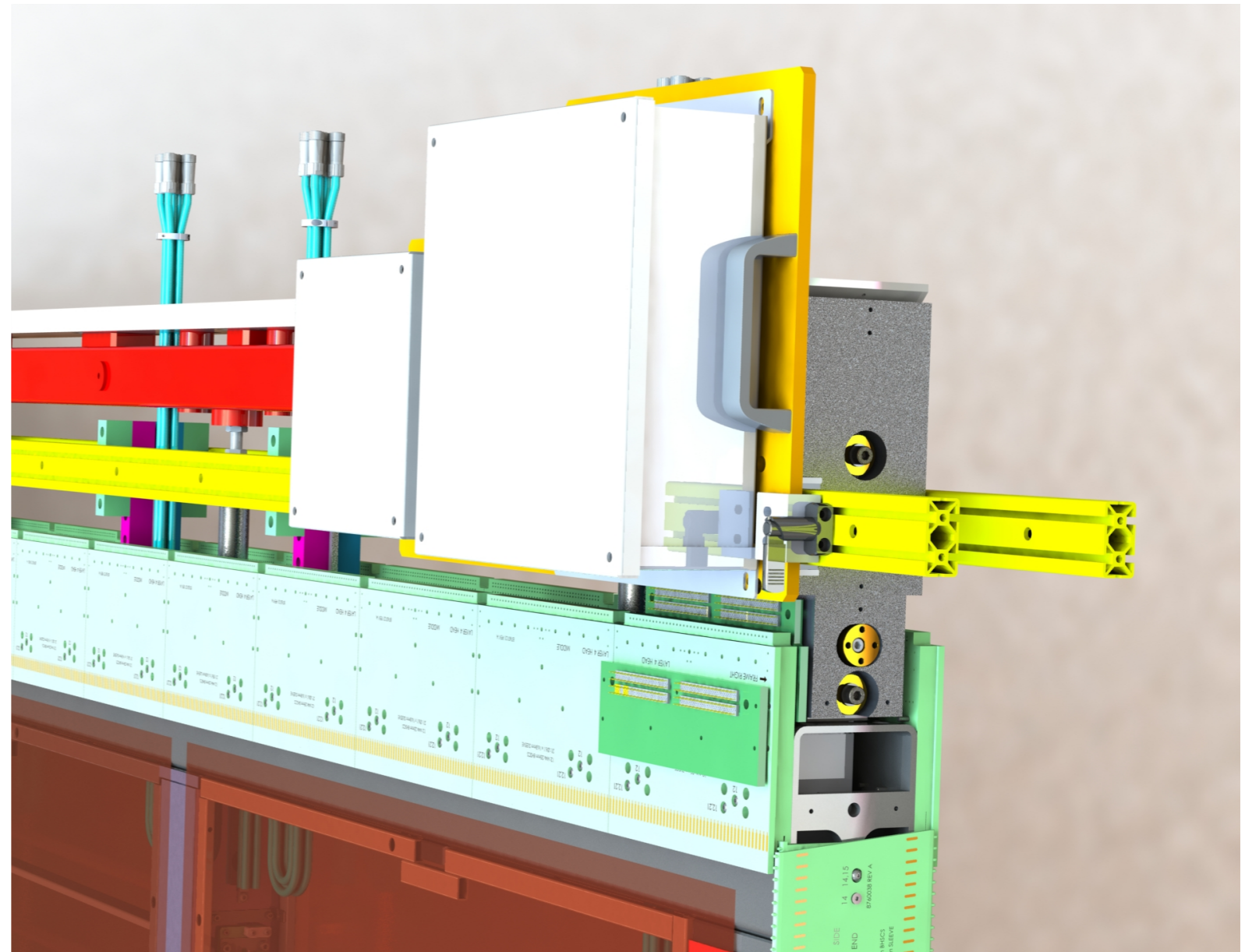
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APA Technical Meeting

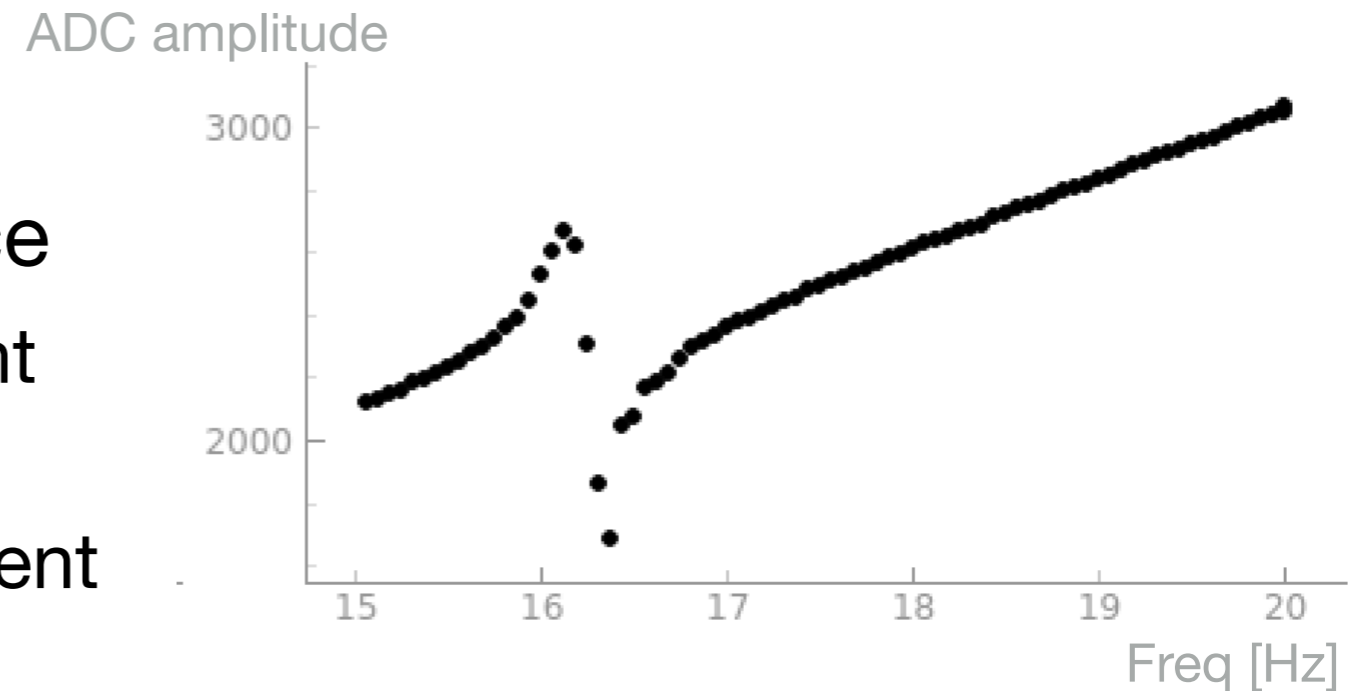
2021-03-23

- ▶ DUNE/Digital Wire Analyzer
  - DWA injects AC signal on some wire and reads signal on its neighbour
  - Measures wire tension via measuring a capacitance change when a wire oscillate
    - Relative capacitance measurement

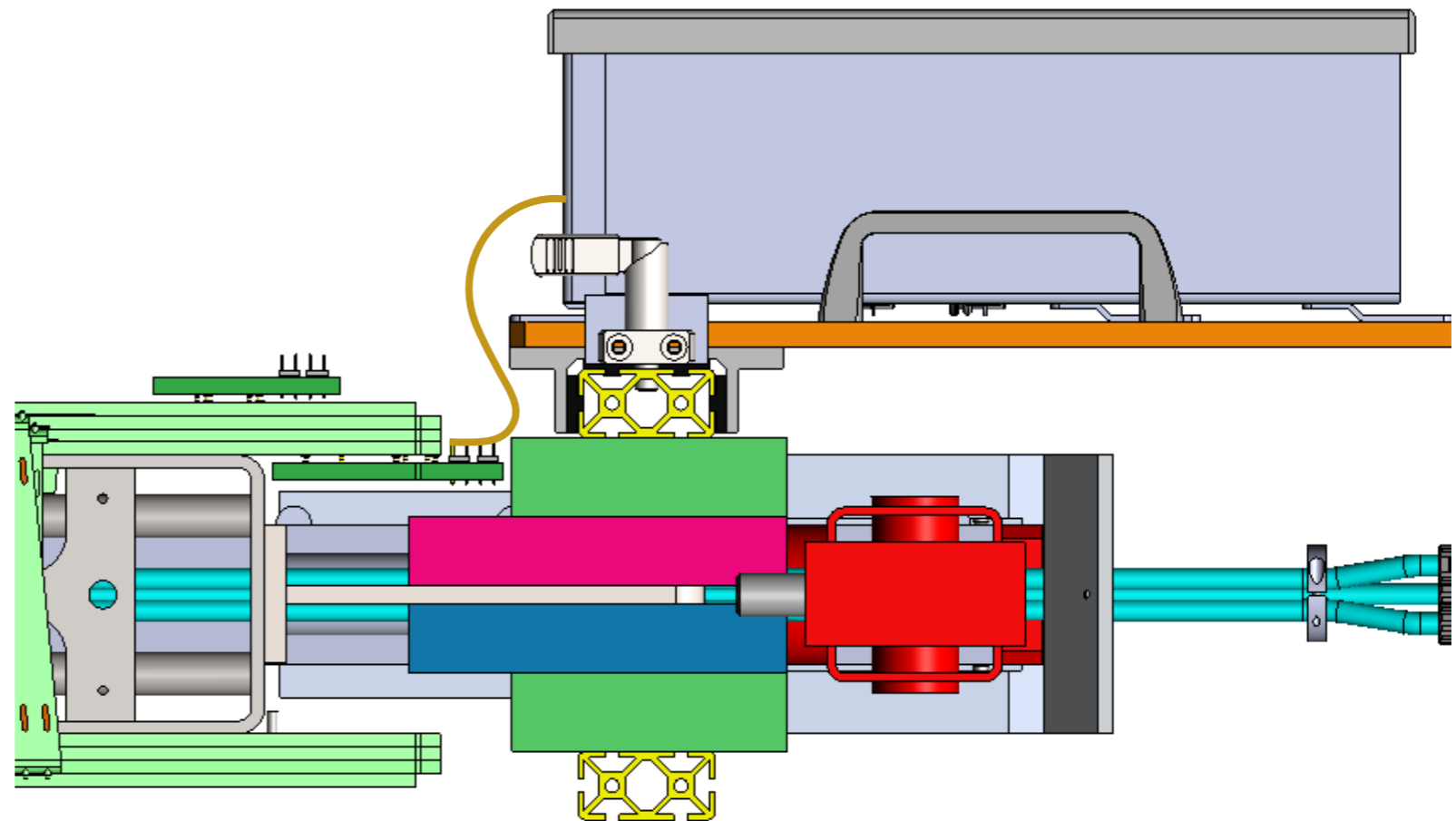
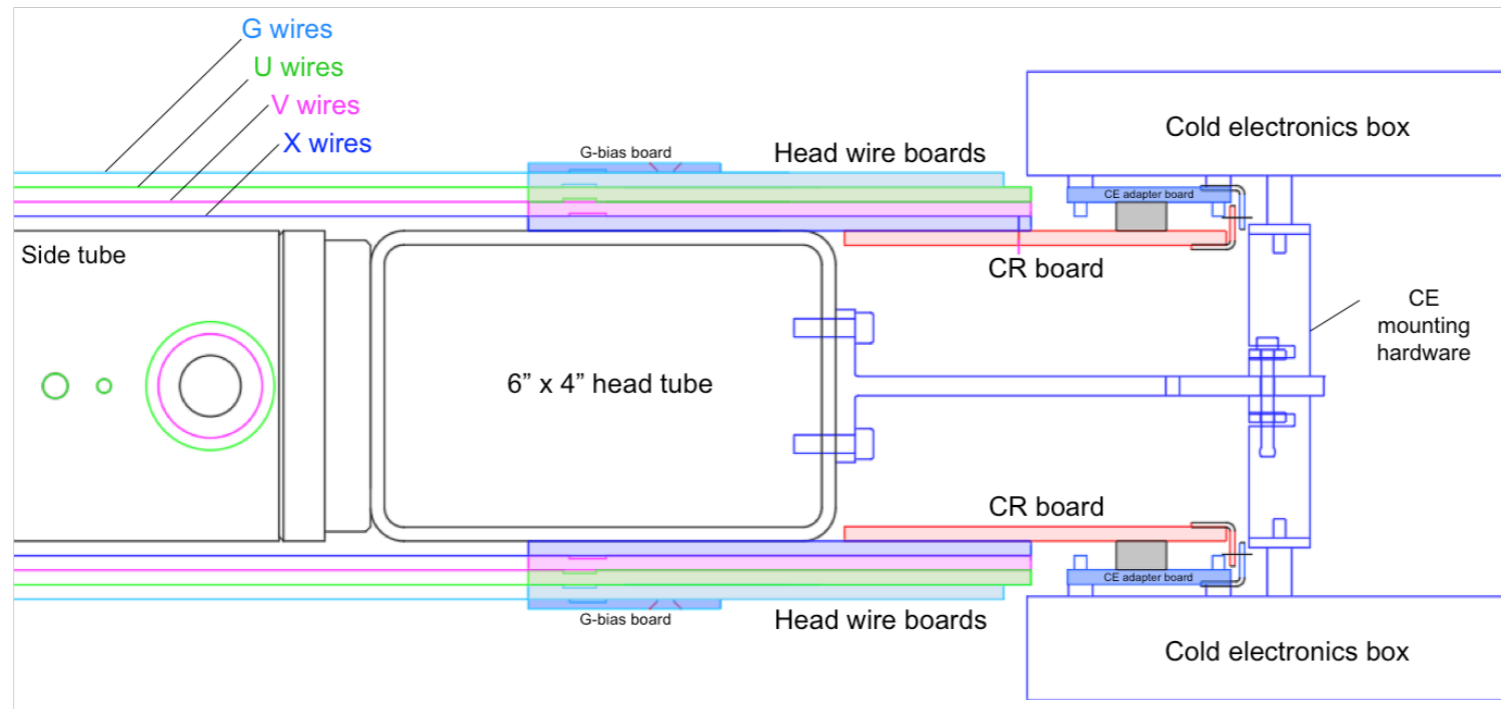


# DWA motivation

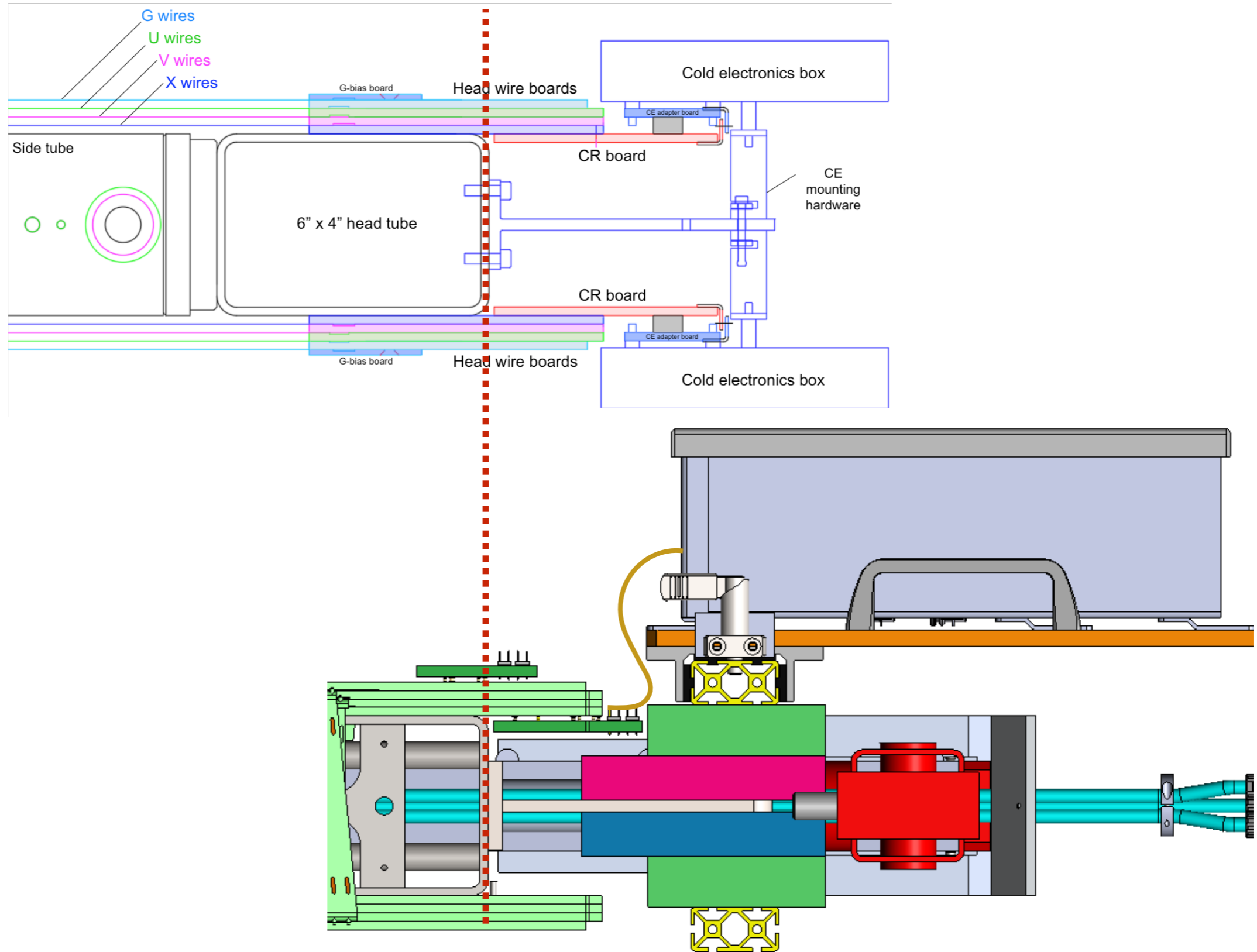
- ▶ Could possibly use DWA to measure absolute capacitance
  - Automatization of measurement and logging
  - Requires calibration of instrument
- ▶ DWA not tested on APA yet
  - Not reviewed/approved by APA consortium yet
- ▶ Still, work is ongoing in parallel to prepare for DWA production & testing assuming
  - Part of that production & testing includes calibration
- ▶ Want to better understand capacitance measurement goal



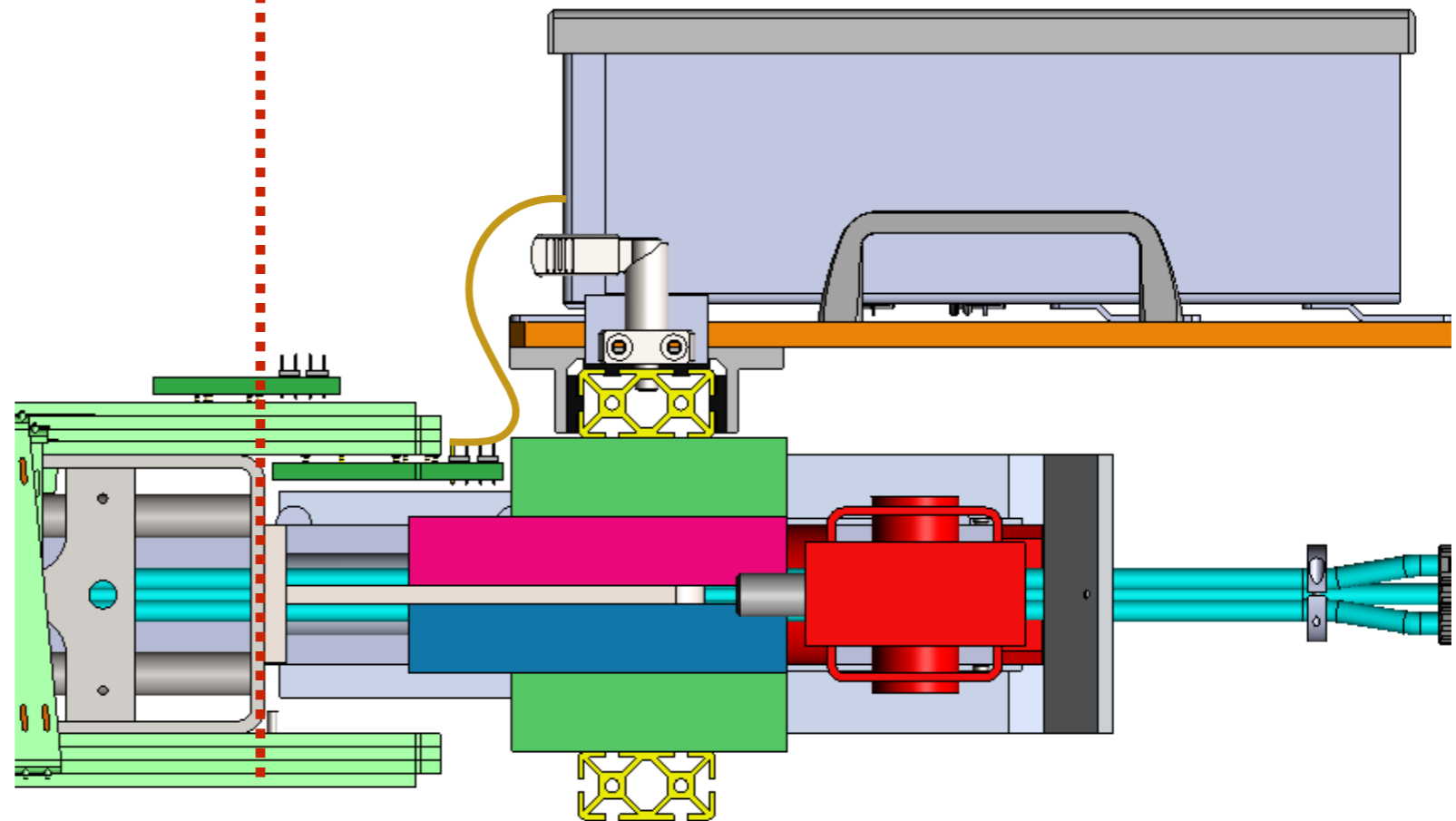
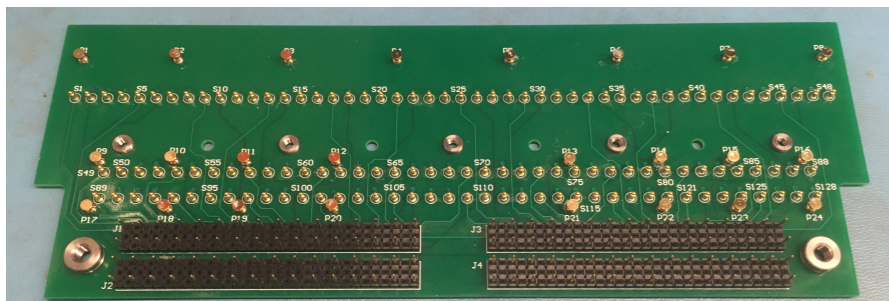
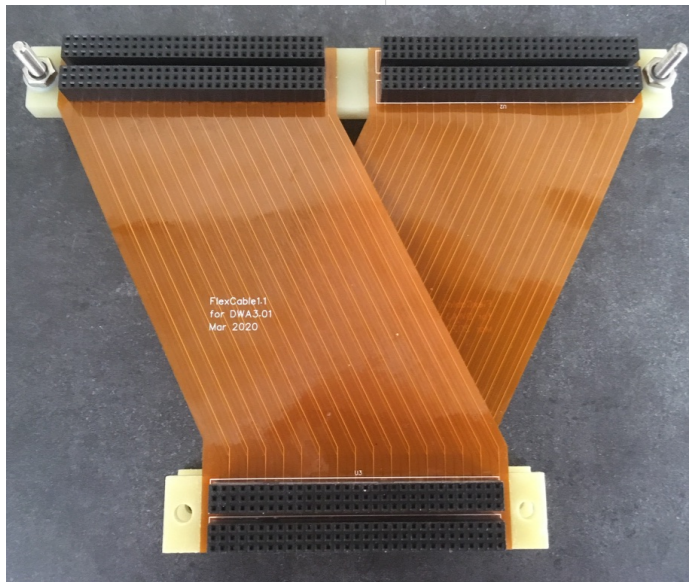
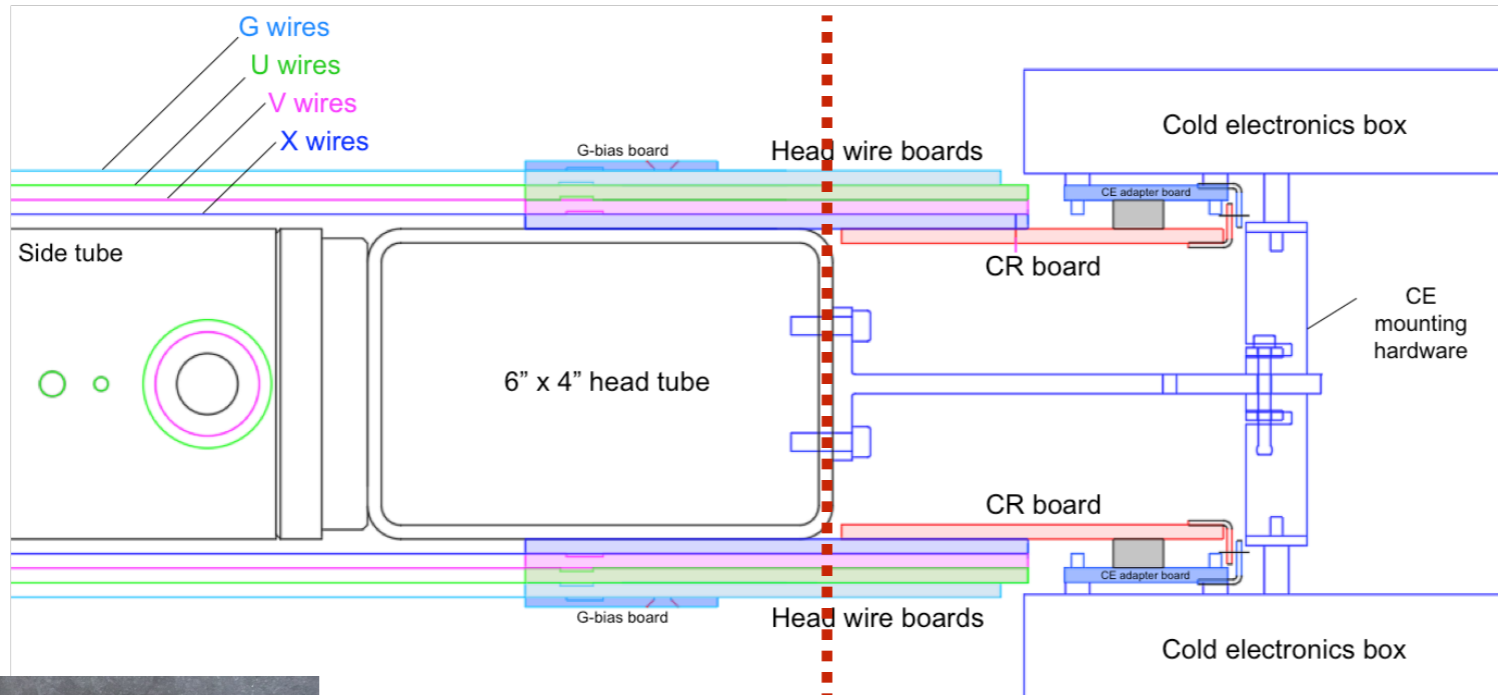
# Connection overview



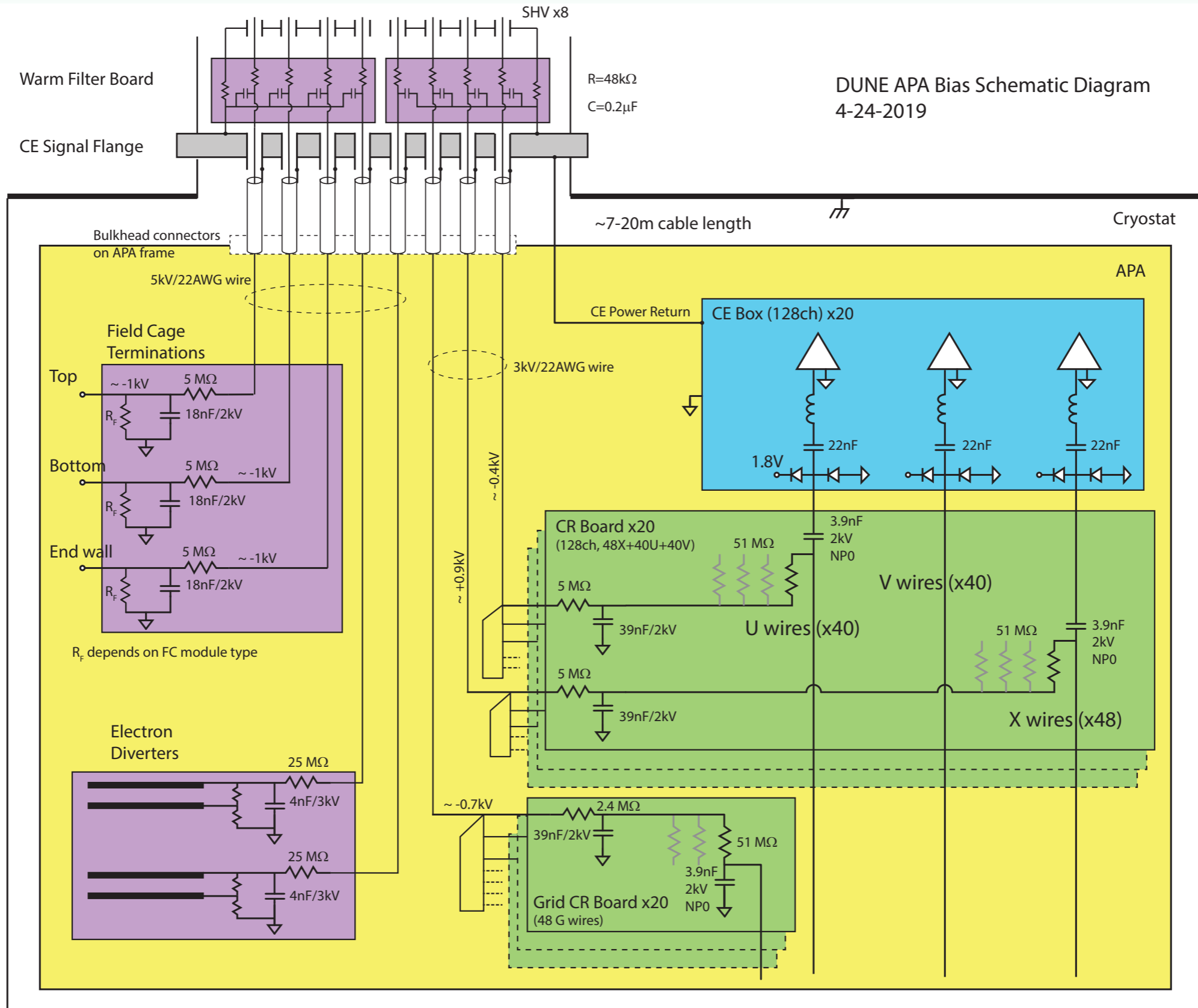
# Connection overview



# Connection overview



# Electrical overview



# Theoretical capacitance

- ▶ Capacitance of two wires (wikipedia):

$$C = \frac{\pi \epsilon \ell}{\operatorname{acosh} \left( \frac{d}{2a} \right)}$$

- ▶ Capacitance of middle X wire with other X wires:

$$C_X = \sum_{n=1}^{240} \frac{12\pi\epsilon_0}{\operatorname{acosh} \frac{4.8n}{0.15}} \approx 10^4 \text{ pF}$$

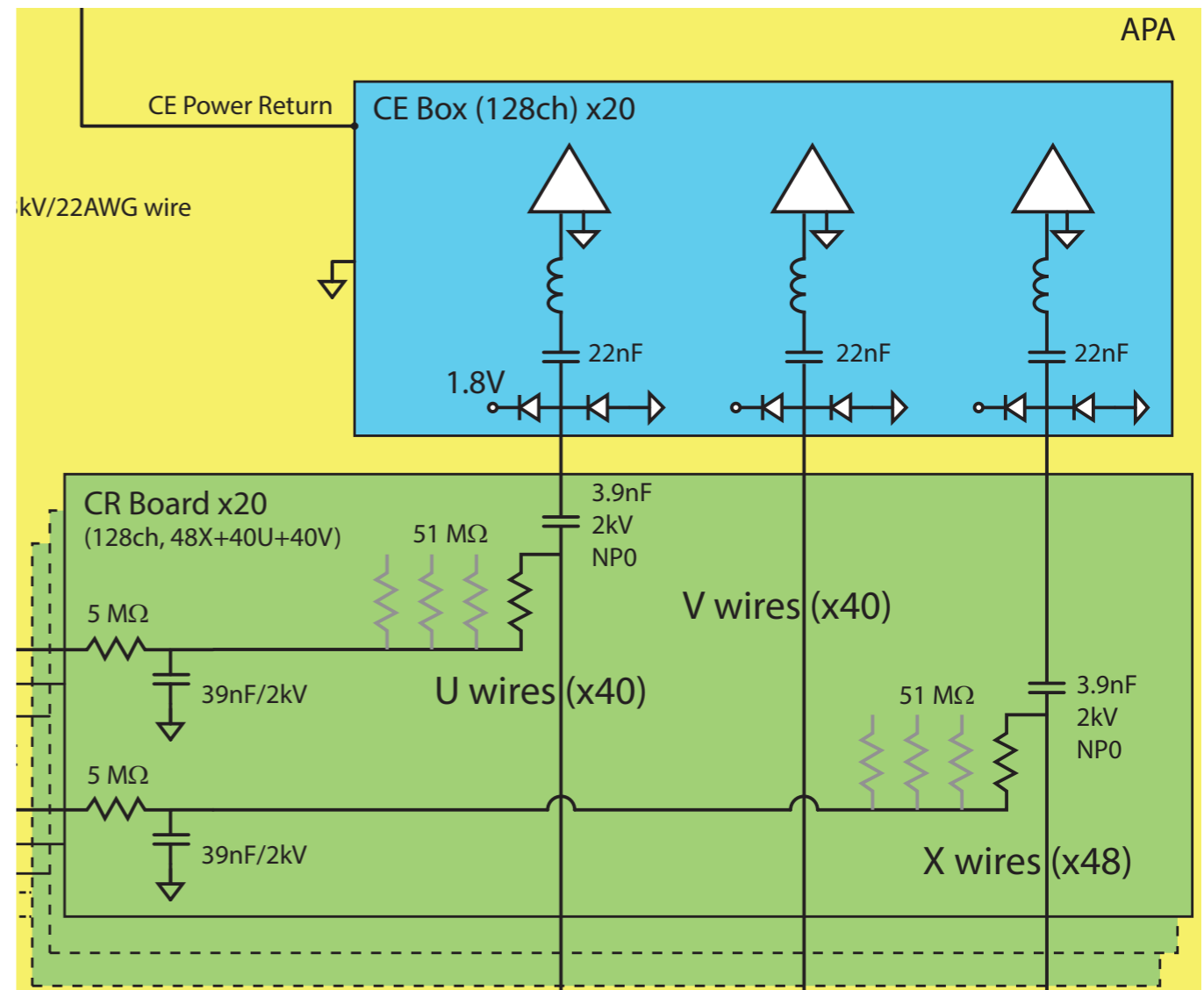
- Orders of magnitude off compared to estimate from COMSOL
  - U, V: 200 pF and X: 150 pF
  - Would like to understand this simulation model
    - ♦ Capacitance of what exactly?



# Charge calibration

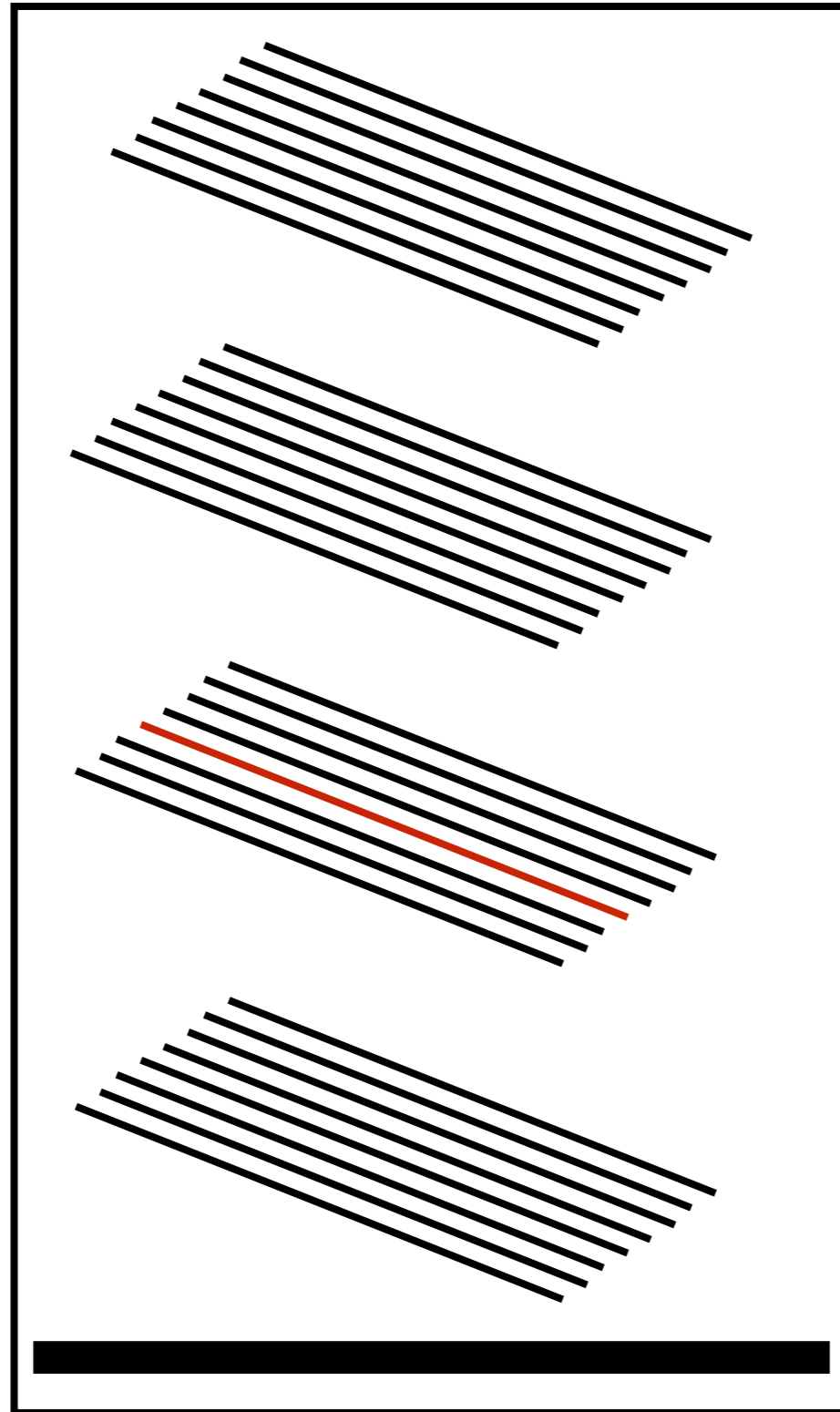


- ▶  $Q_{\text{tot}} = Q_C + Q_W$ 
  - $Q_C = C_C V_C$
  - $Q_W = C_W V_W$
- ▶  $V_W = 0$ 
  - On same plane, or otherwise  $V_{\text{bias}}$
- ▶  $V_C = V_{\text{bias}}$ 
  - Really grounded? Resistor missing?
- ▶ If  $V_C = V_W$ , then
 
$$\frac{Q_{\text{tot}}}{Q_C} = 1 + \frac{Q_W}{Q_C} = 1 + \frac{C_W}{C_C}$$
- ▶ If  $V_C \neq V_W$ , then
 
$$\frac{Q_{\text{tot}}}{Q_C} = 1 + \frac{C_W}{C_C} \frac{V_W}{V_C}$$
- ▶ Considerations
  - $C_W/C_C$  is percent-level
  - $C_C$  has 5% tolerance
  - $C_W$  depends on dielectric (air vs liquid argon)



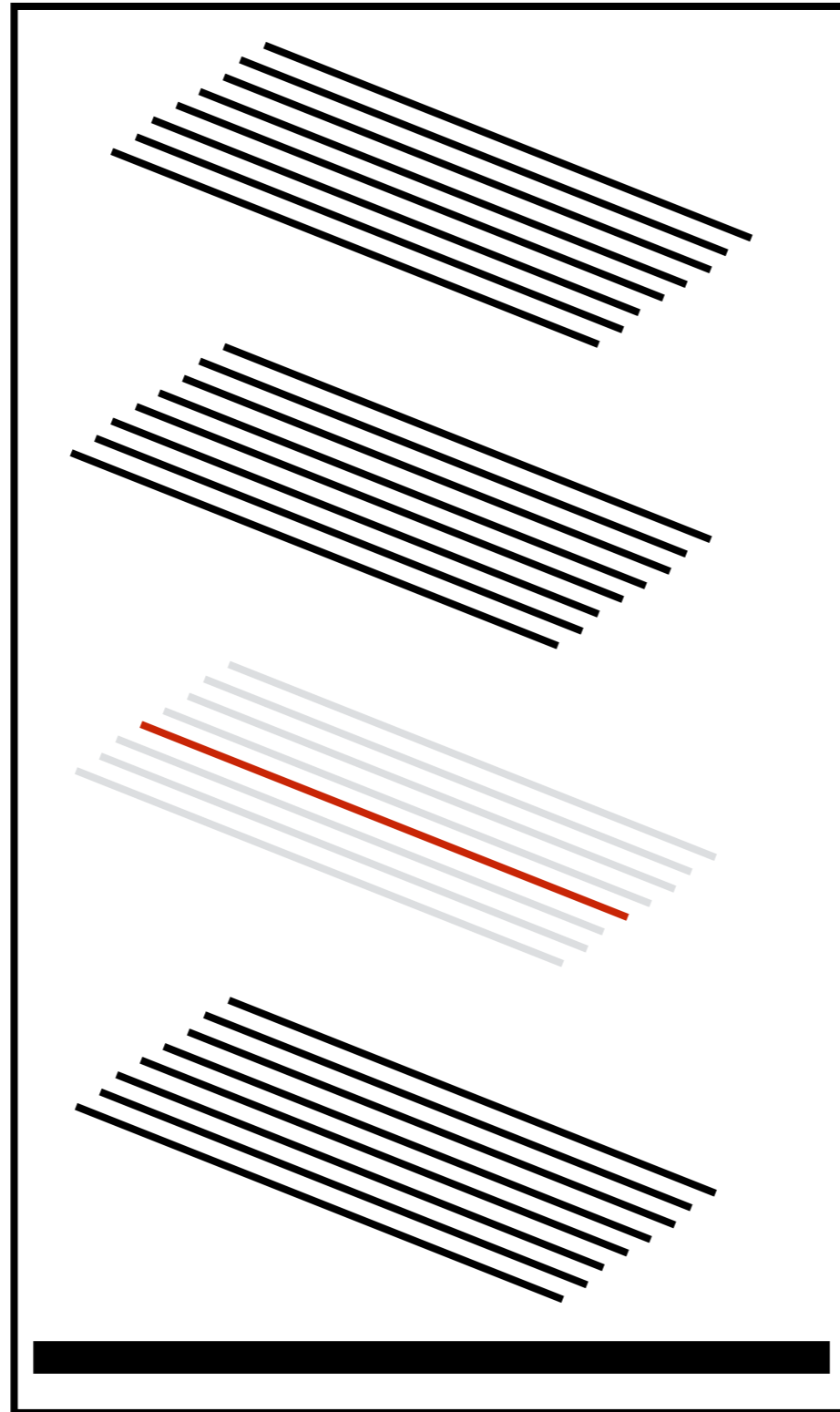
# Measurements wanted

Black: AC driven  
Red: read out  
Grey: other



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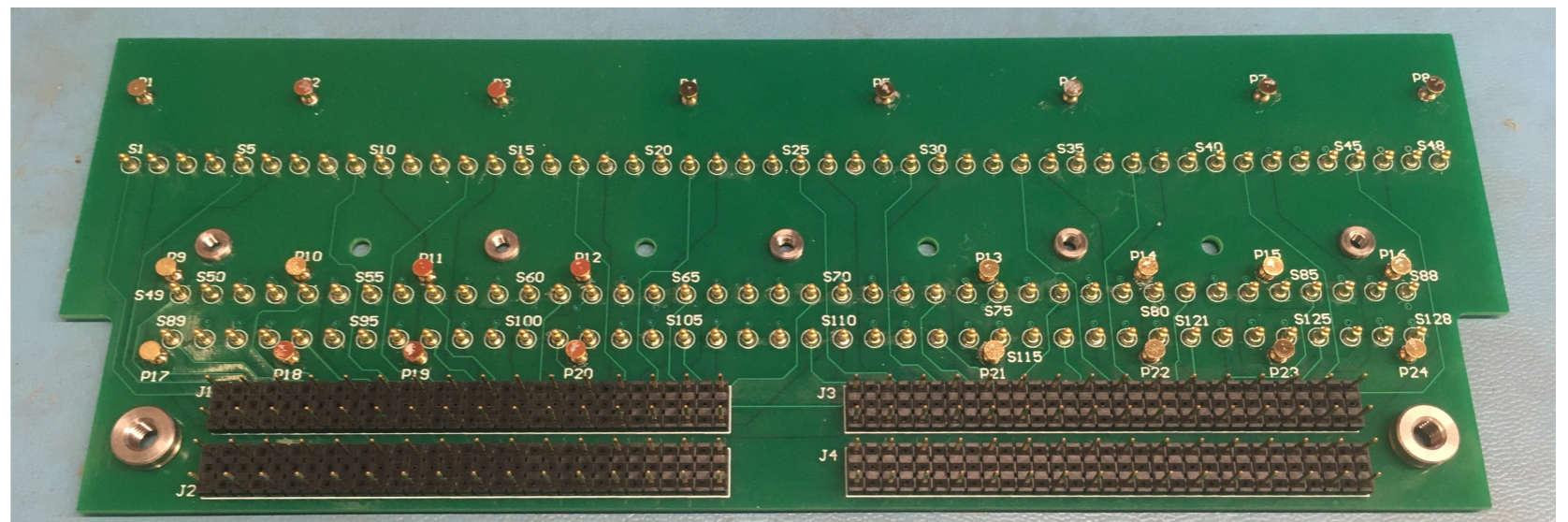
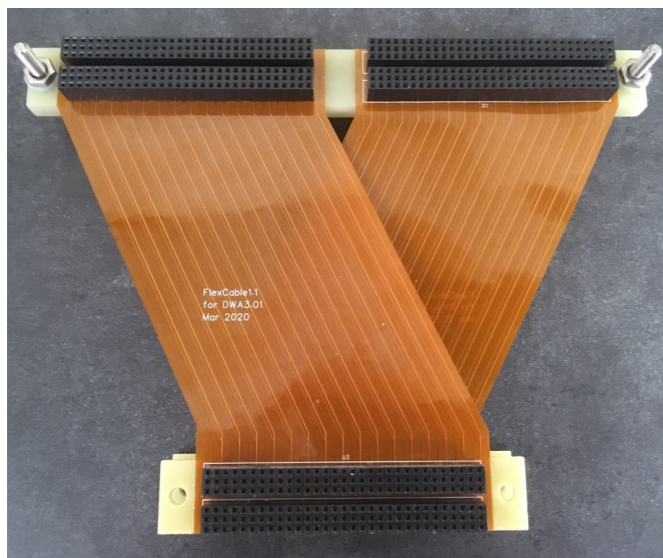




# Grounding

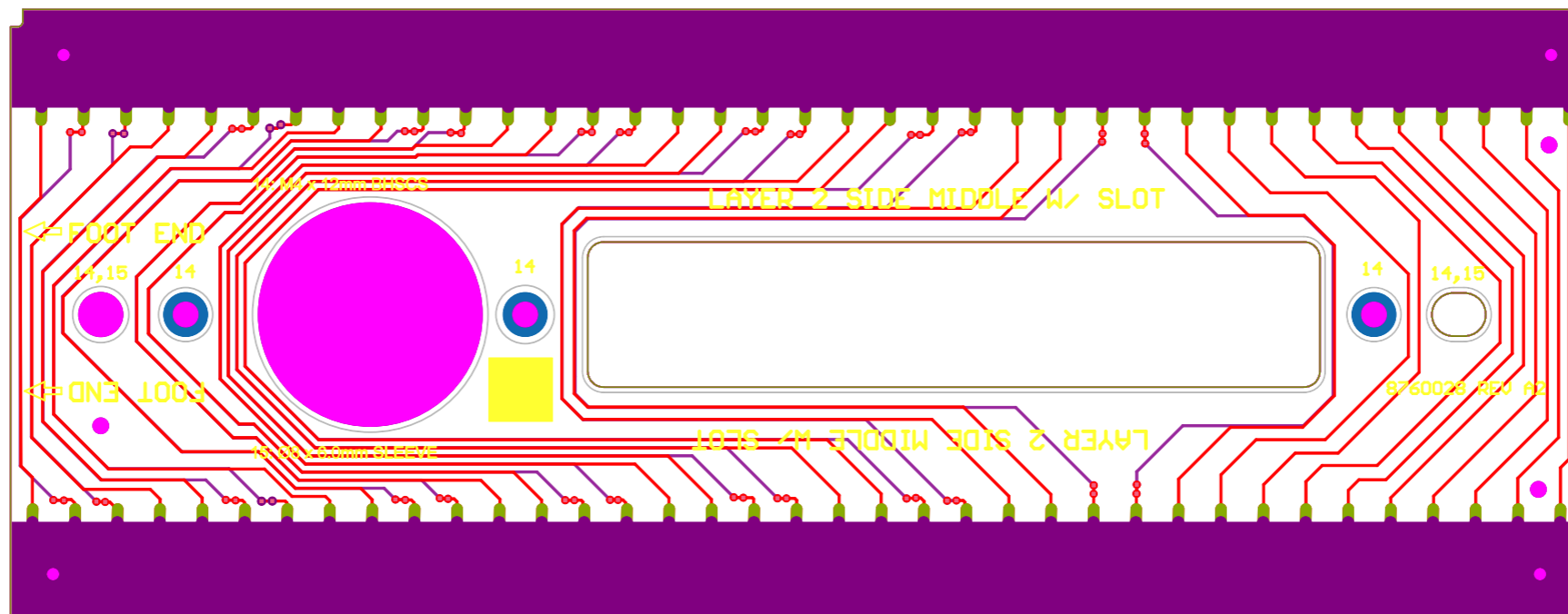


- ▶ Is it even possible to measure capacitance with floating conductors
  - Distorts electric field
    - Drive 80 Vpp so presence of other metal might be negligible?
  - Better to be grounded than floating?
  - Could check effect in simulation?
- ▶ Probe boards provide easy access to all U, V, X, G wires
  - Most likely cannot use flex cable
- ▶ Grounding bar used for electrical isolation
  - Similar idea could be used here



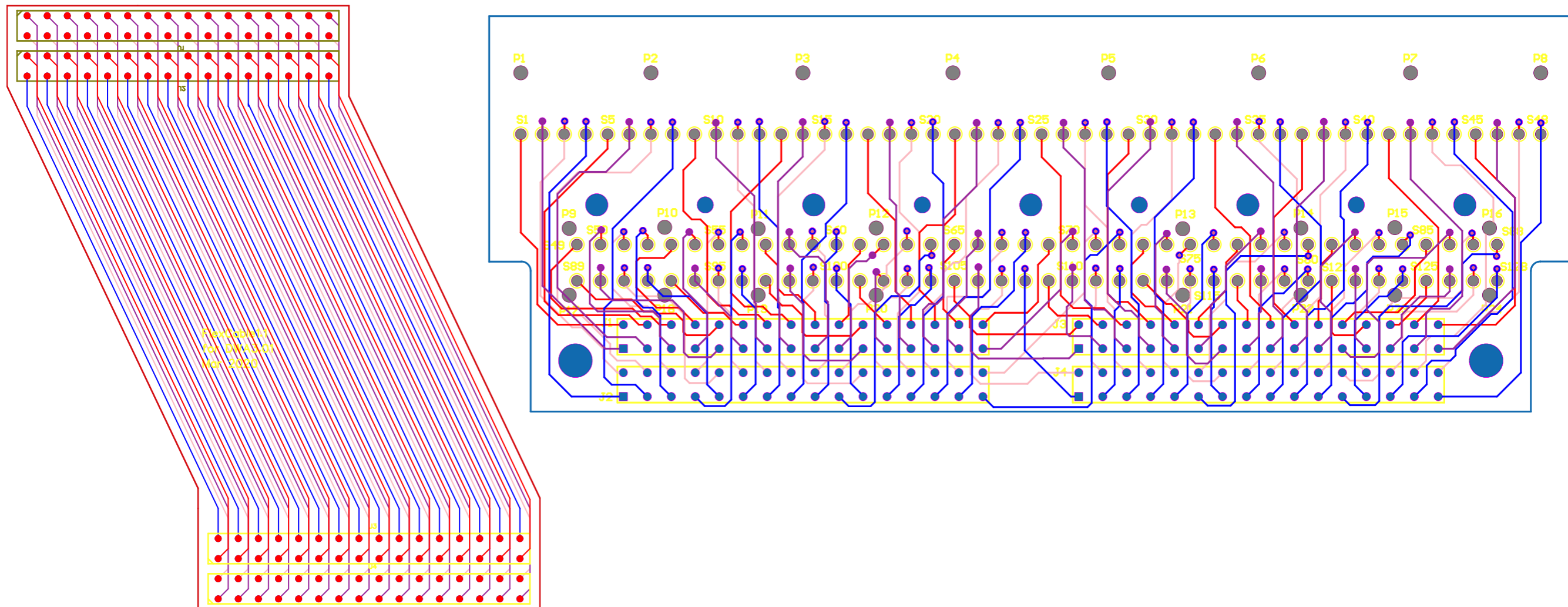
# Source of capacitance

- ▶ Measured capacitance has contributions from
  - Wires
  - Boards
    - Desired: head, side and foot boards
    - Undesired: flex cable and probe boards
    - Missing: CR, CE-CR adapter and FEMB boards
- ▶ Measuring every wire individually possibly necessary



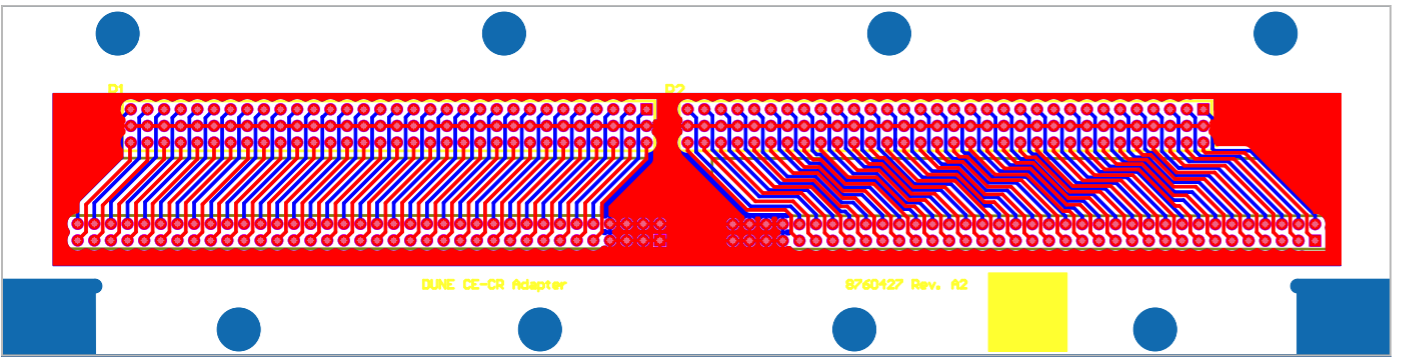
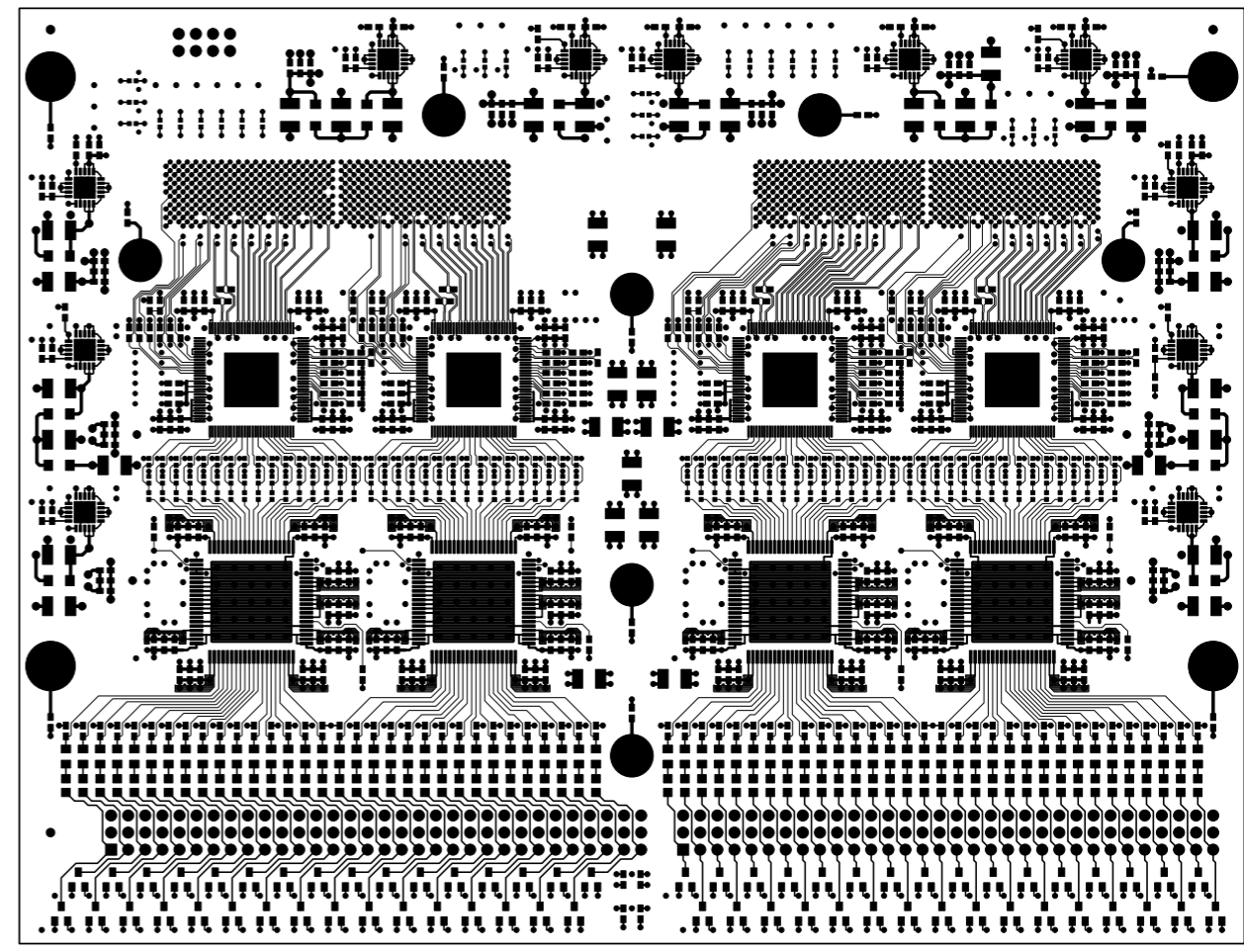
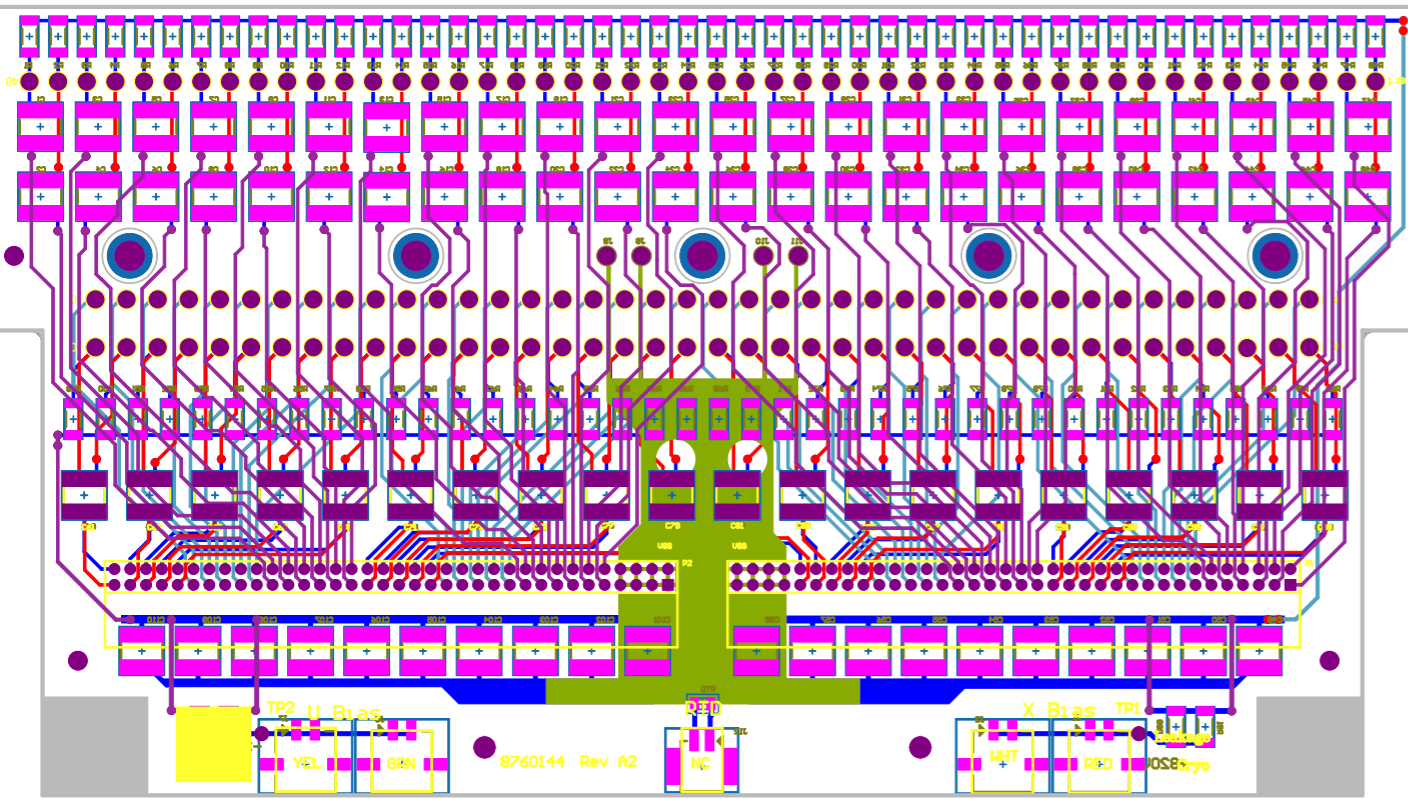
# Undesired capacitance

- ▶ Flex cable and probe boards
  - Not part of CE path but affects measured capacitance
    - Possibly flex cable wouldn't be used
  - No components
    - Capacitance could be stable and small enough to only be measured once



# Missing capacitance

- ▶ CR, CE-CR adapter and FEMB boards
  - Can't measure their trace capacitance at same time as wires
    - Would have to be measured separately, possibly once
  - Capacitors could also be measured



# Questions



- ▶ Specification questions
  - Capacitance measurement types?
  - Relative priority of measurements?
  - Capacitance runs up to what point (capacitor or ASIC)?
  - Every single wire need to be measured? For every APA?
  - Precision level?
    - 1% on  $Q_{\text{tot}}/Q_C$  means 15% on  $C_W/C_C$ , which means 15% on  $C_W$
- ▶ Technical questions
  - Expected capacitance value from COMSOL?
    - Would help with incoming DWA calibration
  - $V_C = V_W$ ?
  - Effect of floating conductors?
  - Grounding mechanism?
- ▶ Organization questions
  - Perform measurement at APA factory or underground?
  - Split some measurement work between APA and CE consortia?
  - Is wire capacitance worth effort and time to measure?