Mechanical Interfaces with the TPC Electronics Consortium

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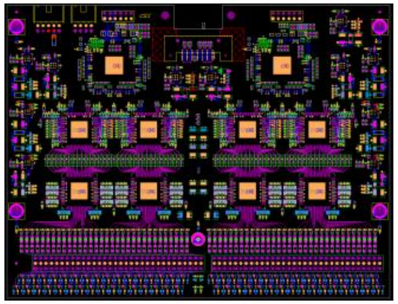
TPC Electronics Consortium (i)

- David Christian (Fermilab) – consortium leader
- Marco Verzocchi (Fermilab) – technical lead
- Manhong Zhao (BNL) – mechanical engineer
- Kyle Zeug (Wisconsin) – technical coordination, interface drawings

- For the horizontal drift detector we design, prototype, fabricate, test, integrate, install, and commission the electronics for the readout of the APA wires
  - 20 front-end motherboards (FEMBs) per APA, each with chain of three ASICs (LArASIC, ColdADC,COLDATA)

COLDATA FEMB

In the next months →



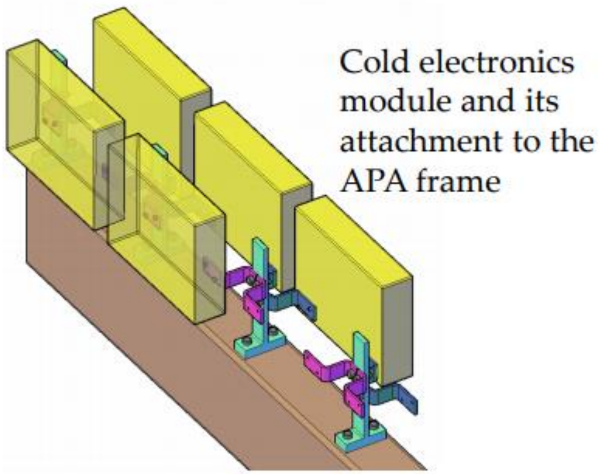
Monolithic FEMB

TPC Electronics Consortium (ii)

- Not just the FEMBs:
  - Cryostat penetrations with warm interface electronics crates (WIECs) mounted on the flanges of the spool pieces
    - Each WIEC contains 5 warm interface board (WIBs) and 1 power and timing control card (PTC)
  - Cold cables (signal, power, bias voltage for APA) between the flanges and the APAs / FEMBs
  - Services on top of the cryostat including
    - Bias and low voltage power supplies
    - Warm cables between supplies and WIECs
    - Optical fibers (CCM, SC connections to DAQ, FELIX readout)
    - Interface with DUNE detector safety system

TPC Electronics Consortium (iii)

- Horizontal Drift detector design
  - FEMBs are installed inside CE boxes that are supported by a system of brackets mounted on the head tube of the APA
  - Cables for the lower APA are routed through the side tubes of the APA frames
  - Cable trays are supported by the DSS and are used to handle excess length of cables in addition to housing the cables while the APA pairs is moved from the assembly tower into the cold box for testing and then into the cryostat



TPC Electronics Consortium (v)

- Horizontal Drift detector integration and installation
  - The FEMBs are installed on the APAs at SURF, cold cables are then connected to the FEMBs and an initial connectivity test is performed on the assembly tower (APA+TPC electronics+PD consortia)
    - All the FEMBs are tested in LN_2 prior to delivery to SURF
  - The APAs are then moved into the cold box where a test is performed at room temperature and at cold (~120 K) (TPC electronics consortium)
  - Then the APAs are moved into the cryostat and the cables are routed through the cryostat penetrations and connected to the CE flange (TPC electronics consortium)
    - Final readout test
    - Install more APAs in the same row, limiting access to the APAs and FEMBs
    - Continue readout test until the cryostat is sealed and later after filling

Vertical Drift Detector (i)

- The installation of the FEMBs on the CRUs takes place at the CRP factories
  - Deliver FEMBs that have been tested in LN_2
  - Pairs of CRUs are assembled on CRP
  - Fraction of (all ?) the CRPs are tested in a cold box prior to being shipped to SURF
  - Requires TPC electronics readout system (including cables) at the CRP factories
  - Requires that issues related to FEMB mounting on the CRUs are understood and proper mechanical / electrical design is done
  - Tested CRPs are then shipped to SURF
  - CRP consortium designs cable routing from the FEMBs to the wall of the cryostat

Vertical Drift Detector (ii)

- At SURF
  - TPC electronics consortium installs all the electronics on top of the flange, including the WIECs
  - TPC electronics consortium / I&I consortium design and install system of cable trays going from the cryostat penetration to the floor of the cryostat
  - Cold cables are routed from the CE flange to the bottom of the cryostat and secured to cable trays
    - Responsibility of the TPC electronics consortium
  - Bottom CRPs are moved into the cryostat and lifted in such a way that access is provided allowing the connection of the cold cables to the FEMBs
  - Once cables are connected readout tests are performed and finally the CRPs are lowered to their final position close to the floor of the cryostat
    - Joint responsibility of the CRP and TPC electronics consortia

Mechanical Interfaces

- Support of the FEMBs or of the CE boxes
  - Discuss today (rest of the slides to be covered today, until page 17)
- Cable routing on the CRPs (or on the floor of the cryostat)
  - Discuss in the next meeting (slides start at page 19)

CE Boxes

- Serve multiple purposes
  - If the heat dissipated on the FEMBs causes the LAr to boil, collect the bubbles and prevent them from reaching the sensitive volume
    - Not an issues, not enough heat dissipation and bubbles would collapse very quickly under hydrostatic pressure
  - Additional Faraday cage shield around the FE amplifier
  - Provide mechanical protection on FEMBs during transport / installation
  - Provide additional anchoring point for cold cables

CE Boxes/FEMBs on the CRUs

- Mounting scheme for FEMBs or CE boxes on the CRUs needs to address 2 different orientations

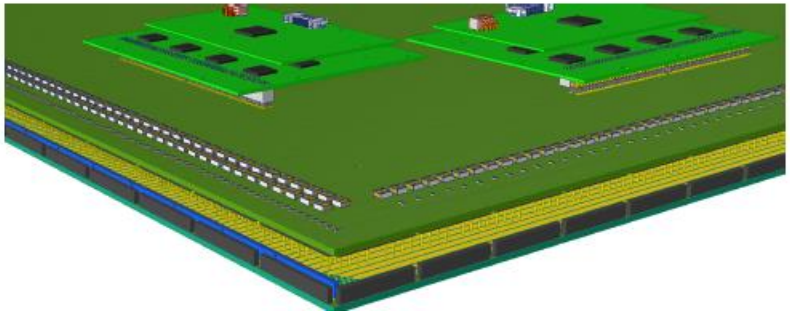
  a) FEMBs above the CRU

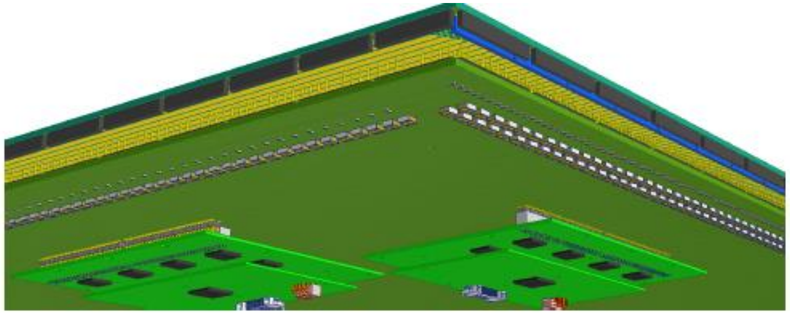
  - NP02 cold box test, ProtoDUNE-VD in NP02, cold box testing of Horizontal Drift detector CRUs
    - Easy access to the cables, easy cable routing to the cryostat penetrations

  b) FEMBs below the CRU

  - Final orientation of the CRU in the DUNE detector

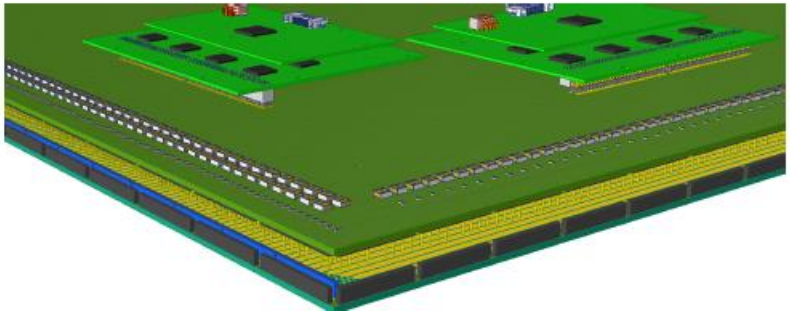
- Critical issues
  - Electrical contact between FEMB and connector in adapter PCB
  - Strain on the cables





Cold Box Orientation

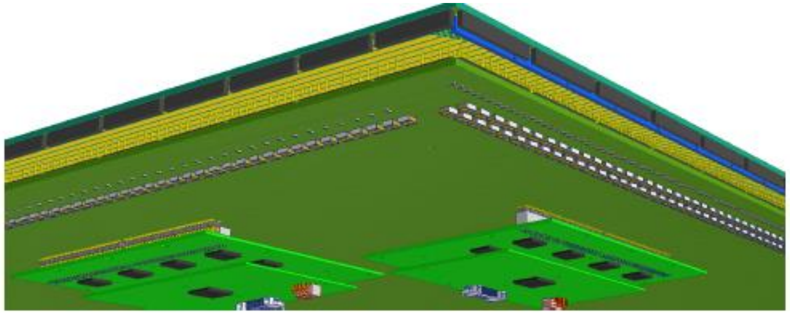
- In this configuration gravity helps avoiding problems with the electrical contact (weight of FEMB/CE boxes pushes the connector into the socket provided the entire FEMB is kept parallel to the adapter PCB)

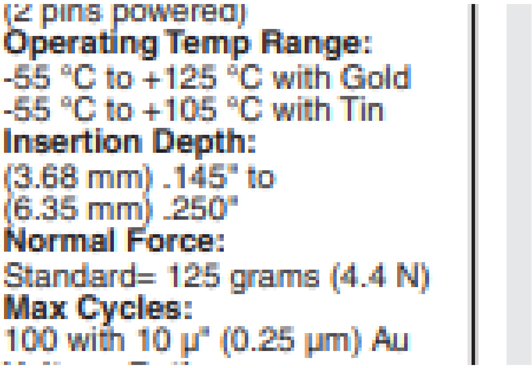


- Main mechanical issue to be addressed is avoiding strains on the cold cables
- Note: in ProtoDUNE-VD the TPC electronics is close to the surface of the liquid, bubbles will form and they will flow to the surface of the liquid

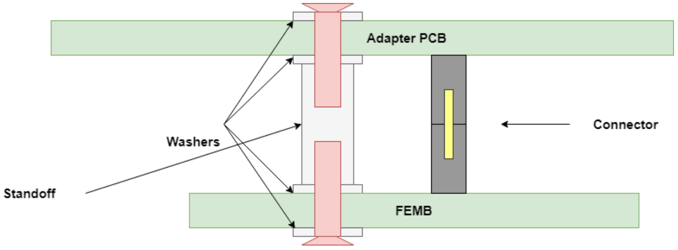
DUNE Orientation

- In this configuration gravity pulls the FEMB away from the adapter PCB
  - The FEMB (or the CE box) need to be connected to the adapter PCB that needs to support the weight
  - The relative height of the FEMB (or of the CE box) to the adapter PCB needs to be controlled to better than 1.5 mm (in principle the connector has a tolerance of 2.7 mm, but prefer to err on the safe side)
  - FEMB or CE box to be supported by standoffs with the appropriate height that are pre-mounted in the adapter PCB. FEMBs are screwed into the standoffs (which ensures that the FEMB is parallel to the adapter PCB)



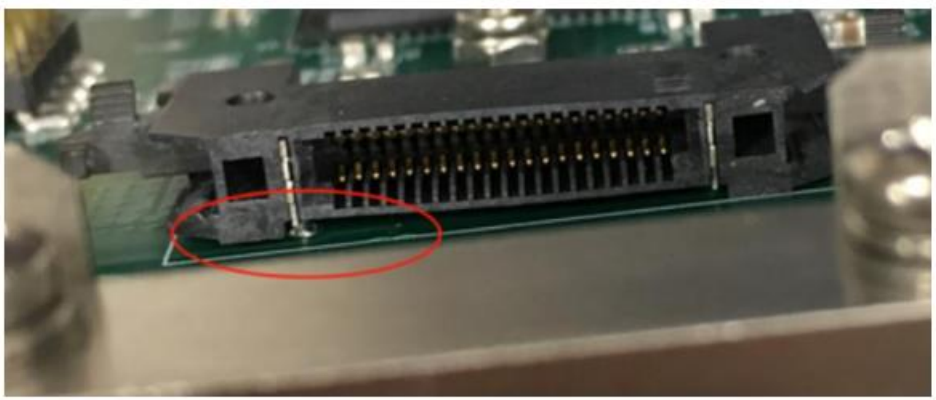


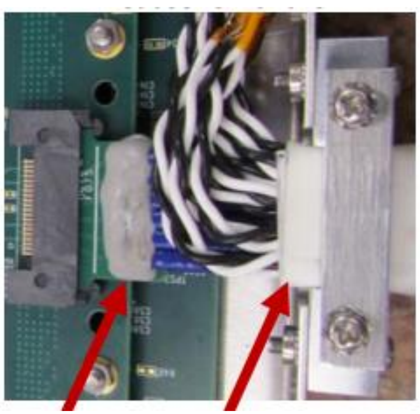
(2 pins powered)
Operating Temp Range:
-55 °C to +125 °C with Gold
-55 °C to +105 °C with Tin
Insertion Depth:
(3.68 mm) .145" to
(6.35 mm) .250"
Normal Force:
Standard= 125 grams (4.4 N)
Max Cycles:
100 with 10 μ" (0.25 μm) Au



Strains on Cables

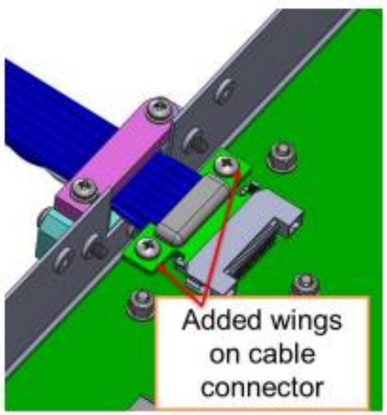
- One of the biggest issues in ProtoDUNE-SP with the TPC electronics was related to the signal connector on the FEMB
- Strain from the cable would cause the connector to lift off relative to the FEMB resulting in signal losses
  - Several FEMBs replaced because of this problem
  - Despite having a cable strain relief on the CE box



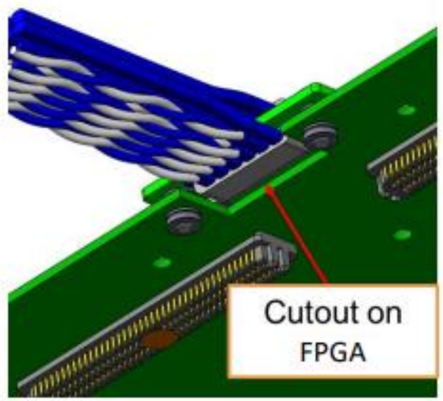


Improved Connector Design

New Connector Design

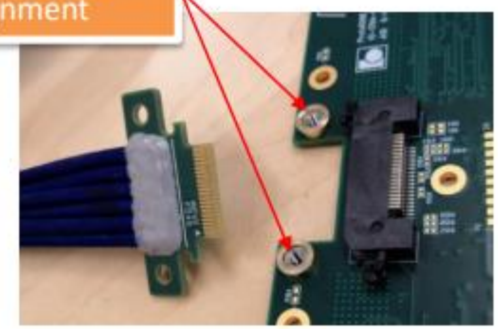


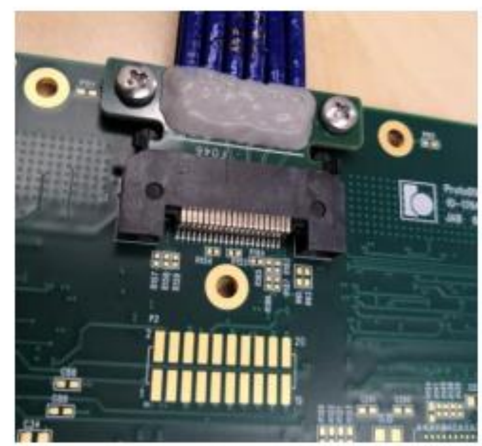
The printed circuit board on the cable connector is extended with two wings to secure the connector to the FPGA mezzanine board.



A small cutout added on the FPGA mezzanine board to accommodate the uneven application of epoxy on the cable connector.

Standoff to maintain perfect alignment





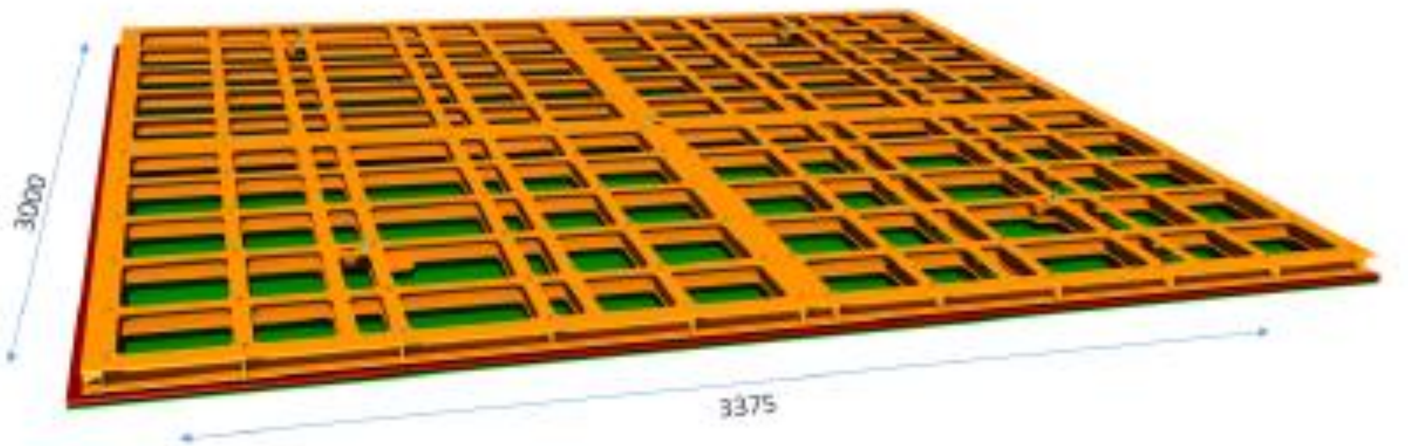
Strain Relief on the Cables

- If we have a CE box, the strain relief on the CE box prevents the cable from applying forces on the FEMB
- If we do not have a CE box, we will need an additional strain relief for the cables close to the FEMB
  - Clamp at the appropriate height relative to the FEMB that can be closed after installing the cables
- This is important both for the normal orientation in DUNE and for tests in the cold box
  - The cables are relatively rigid and can apply forces on the FEMBs when they are being routed

Plan for NP02 Cold Box Test

- We would like to evaluate both solution (with / without CE box)
- But first test in NP02 is done with one CRU read out with top electronics, one CRU read out with bottom electronics
- It does not make sense to split 6-7 FEMBs in “with/without CE box”
  - It may be simpler to make the first test without CE boxes
  - It would be good to design the CRP / adapter cards with the possibility of adding CE boxes to the design (i.e. don’t make the space around a FEMB too small)
  - Need to have cable restraint at the same height as the FEMB

The CRP Frame



- This is a picture of the CRP frame from the TDR
  - There seems to be a lot of material, do the CE boxes / FEMBs go in the gap between the orange beams (long pins for the connectors, not sure there is enough space for the cable restraints) or do they go on top of the orange structure
- May need to design CRP frame and adapter PCB taking into account the constraints from the FEMBs and from cabling

Discussion

- End of Part 1
- Slides that follows are for cable routing issues

Cable Routing for VD Detector

- Two different problems
- Cold box tests of the CRPs
  - Always the same set of cables that are fixed on the CE flange and that are connected to the FEMBs of the new CRP under test
  - Need anchoring point for cable ties on the CRP mechanical structure
  - If the cold box is filled with liquid would prefer to have the cables immersed in liquid (require cable ties)
  - If the cold box is filled with gas no need for cable ties (but they do help when moving the CRP in the cold box, if the CRP needs to be tilted)

Cable Routing for VD Detector

- Inside the cryostat

D. Bottom CRP Support System

The bottom CRP structure is composed of the PCB sandwich identical to the top ones supporting the four CRUs. Each of them is laying on five feet at about 100mm from the membrane surface as shown on Figure 27. Each foot is positioned inside a flat membrane part and has a vertical adjustment in order to adjust the horizontality and planarity of each CRP at the installation time. The top part of each foot connecting to the PCB frame includes a decoupling system to allow lateral sliding, except for the central one which is locked in order to have the CRP contracting around this point. Additional guiding system is added in order to forbid any rotation during the thermal contraction process.

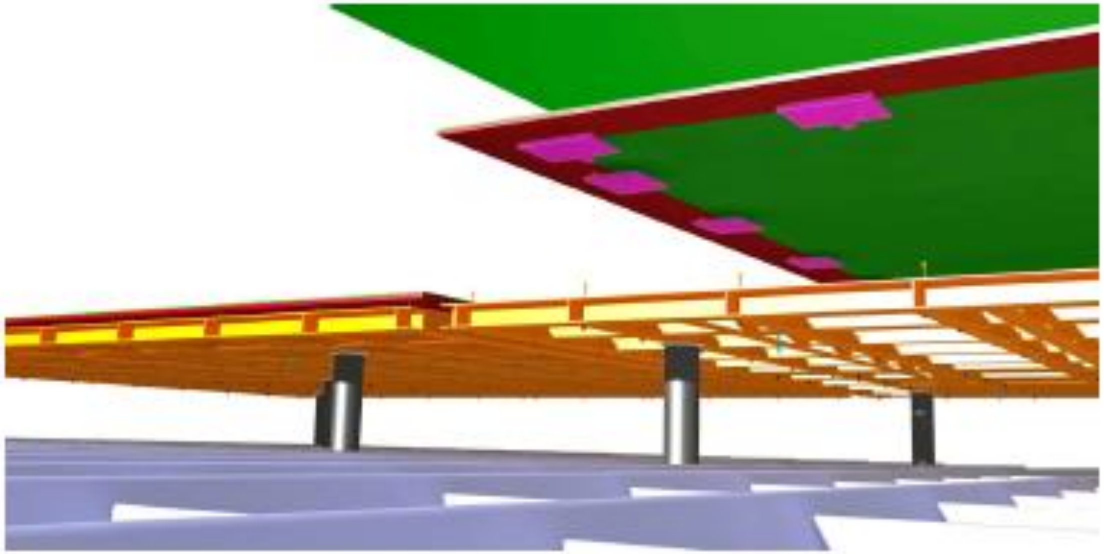


FIG. 27. Illustration of a bottom CRP laying on its supporting feet positioned in the membrane flat parts between corrugation

Cable Routing for VD Detector

- Installation

- Step 5 : Bottom CRP installation

  Starting from the region opposite of the TCO, the floor protections are removed, and the floor is cleaned. Lastly, the bottom anode modules are installed individually on special floor mounts, connected to their data and power cables, and adjusted to be at the same level. Row by row the bottom CRPs are readout and checked with the DAQ system.

  - This is a little bit naïve
  - 26 power cables (1 per FEMB)
  - 26 signal cables (1 per FEMB)
  - 3 or 6 bias voltage cables (1 or 2 for each plane)
  - The cables need to be connected with the CRP close to its final position (easiest solution is to lift the CRP, install the cables, lower the CRP, but how do you lift a CRP ?)

Maybe not too complicated ?

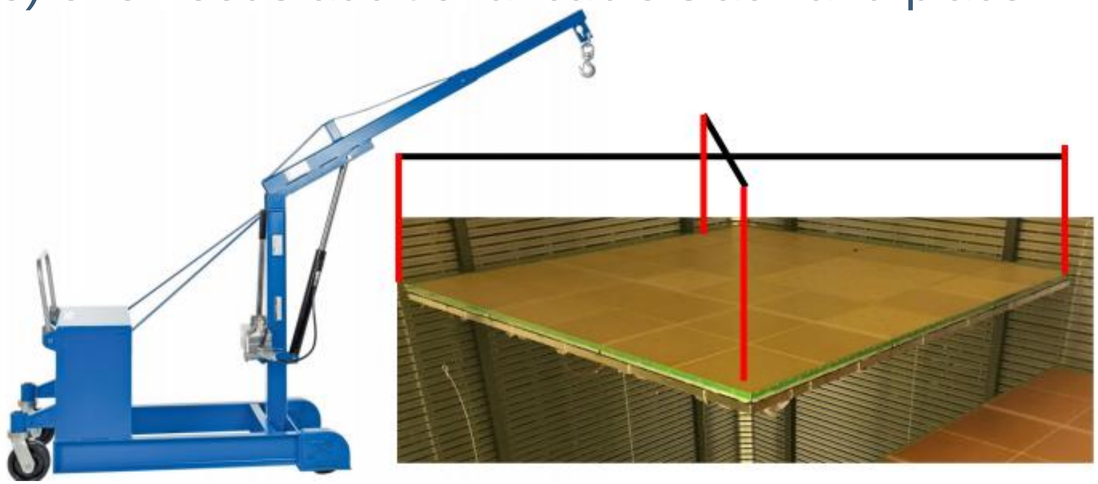
- Can we use a forklift to raise the CRP to a comfortable height, in such a way that we can
  - Install temporary supports below the CRP to be used during cable installation
  - Install and connect cables, test readout
  - Remove temporary supports, remove false floor
  - Install final leveling supports for CRP
  - Lower CRP, pull forklift back
- CRP is relatively light, forks for forklift come standard in lengths of up to 96” (2.4 m), well beyond the center of gravity of the CRP
  - There may be other ways to lift the CRP, need to understand how this is done before deciding on how to route cables

Forklift too heavy ?

- Jim Stewart says that forklifts may be too heavy for use inside the cryostat, even with floor reinforcement
- Can we use a counterbalance lift truck (other alternative in next slide)
- No work should be done under slung loads (need to install temporary structure supporting the CRP while cabling, then remove it)
- CRP structure needs to include channels for lifting in its design (if not using a lifting truck or a forklift, include mounting points for supports, take into account their interference with cabling)

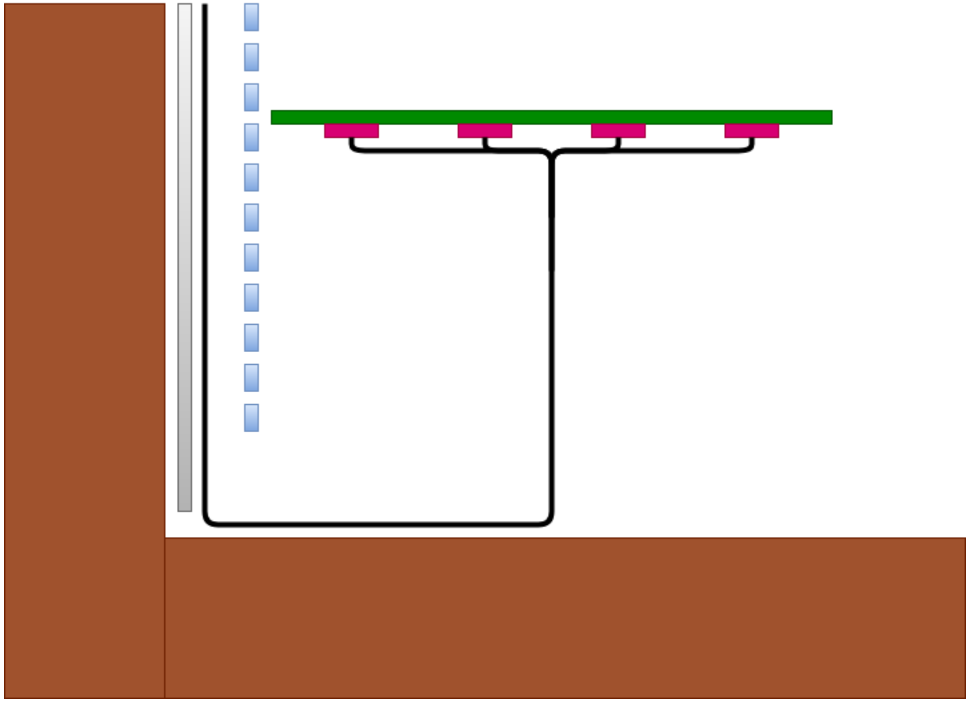
Floor Cranes

- How is the bottom CRP removed from its transport box ?
- Is the CRP stable in the box when it is facing down ? What is the weight ?
- The CRP needs to be held at least 1m (would prefer 2m) above the floor for cable attachment
  - The CRP design needs to have mounting point for temporary legs
- Counterbalanced floor crane requires rigging that then needs to be removed
- If cabling is not done in the final position (example put the CRP on a U-channel and push it in place) one needs additional cable slack and place for the cable slack



Field Cage

- The field cage is already in place and therefore the cables have to go all the way to the bottom of the cryostat
  - If you want to raise the CRP by 2 m (to allow people to work below), you need to have that amount of cable slack available somewhere



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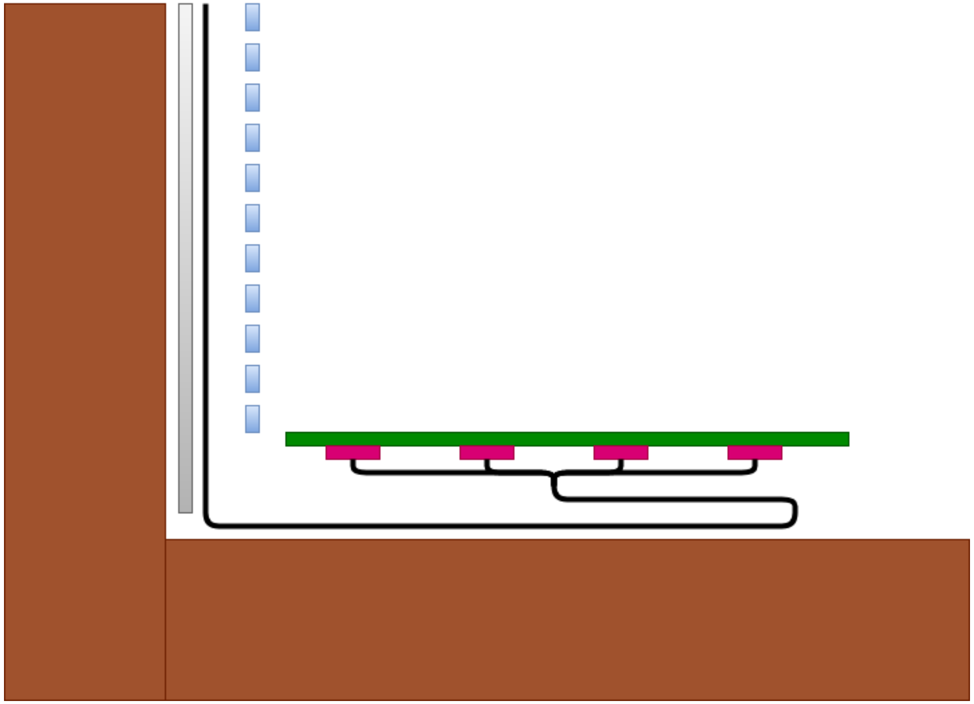
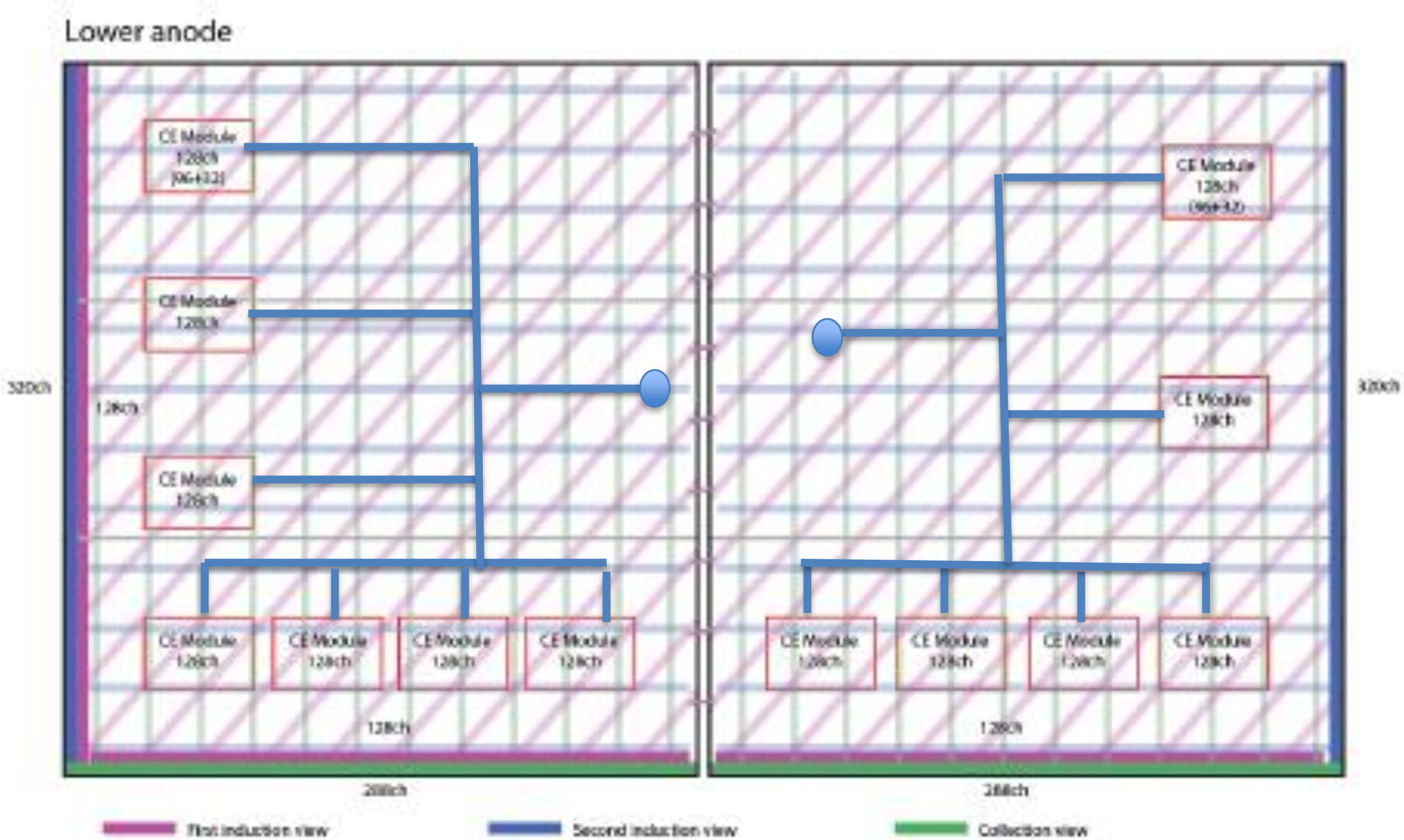


Cables

- For each CRP we have a total of 26 signal cables, 26 power cables, 3 or 6 bias voltage cables
- For the horizontal drift detector we make bundles of 10 signal plus 10 power cables and use stretchable mesh to keep the cables bundled up together
  - Bending radius (for the bundle) in the 5-10 cm range is feasible
- For the vertical drift detector we will have half of the cryostat penetrations with cables for 40 FEMBs and half of the cryostat penetrations with cables for 64 FEMBs (2 cryostat penetrations have all the cables for 4 CRPs)
  - 4 bundles of cables for 10 FEMBs from one cryostat penetration
  - 4 bundles of cables for 10 FEMBs plus 2 bundles of cables for 12 FEMBs from another cryostat penetration
  - Need to split bundles close to the wall and make bundles of cables for 7+6 FEMBs

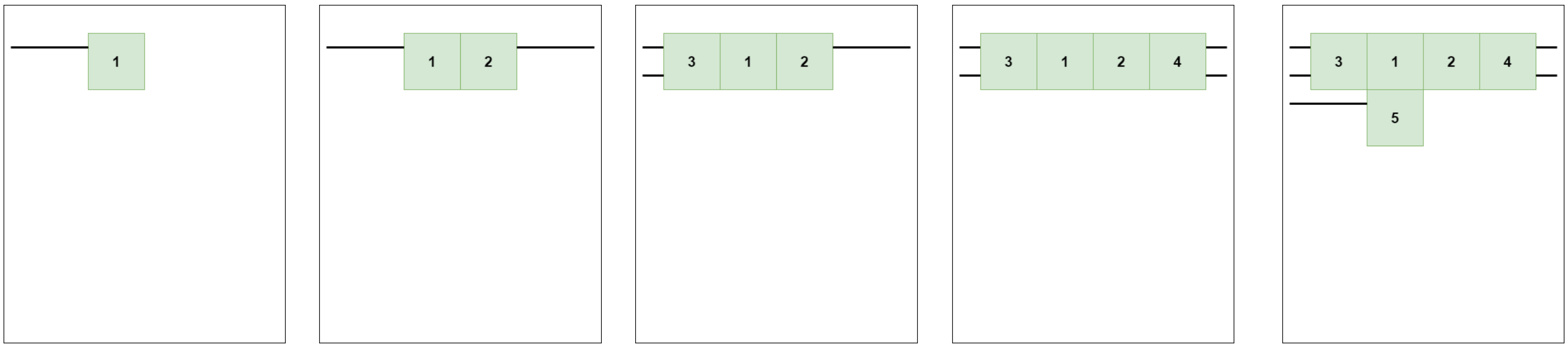
Cables



Lower anode
CE Module
128ch
(96+32)
CE Module
128ch
CE Module
128ch
320ch
128ch
CE Module
128ch
128ch
288ch
First induction view
Second induction view
Collection view

Installation Sequence

- Need to take into account cables from central CRPs during installation of the side CRPs



- Do we need cable trays (or mounting point for cable ties) on the floor of the cryostat ?

Alternatives ?

- Why not have a patch panel on the CRP and have cables between the FEMBs and the patch panel installed at the CRP factories ? Place the patch panel in a convenient position (accessible side of the CRP ?)
  - Yes, we should do this for the bias voltage connections, that don't take much space (i.e. bring the bias voltage connector to a corner of the CPR which is accessible after the CRP has been lowered in its final position). No need to make a bias voltage connectivity test (i.e. 50-100V) when the CRP is lifted from the ground
  - For the signal cables (which include 4 lines at 1 Gbit/s used to transmit data from the FEMBs to the WIBs) this is not really desirable (one more connector, additional signal distortions). Requires testing before we can commit to use this as an option.

Conclusions (i)

- I suspect that the design of the adapter PCBs, of the supports for the FEMBs (or CE boxes) need to be done taking into account
  - The needs of cabling
  - The installation plan
- Need supports for FEMBs (or CE box) that keep the FEMB parallel to the adapter PCB and can carry the weight of the FEMB/CE box
- If we are not using the CE boxes, need cable restraint that ensures that the signal cable enters the FEMB at the right height from the adapter card
- Need cable restraint for the big bundles (10 signal + 10 power cables)
- Need anchoring point for cable ties over the entire structure of the CRP

Conclusions (ii)

- Once an initial design is done, we should foresee building a mockup (plywood) of the CRP and test cabling before
  - We have learned a lot from doing this for the horizontal drift detector
  - Should foresee testing the installation / cabling procedure with a more realistic mockup of a CRP before finalizing the design (do this at CERN using a CRP for ProtoDUNE-VD or build an extra CRP for this purpose, possibly without the anodes, just CRP and adapter PCBs)
- Need to finalize the design to understand the length of the cold cables (plan on two lengths: arrays of CRPs close to the vertical wall of the cryostat, other CRPs)
- Initial operation in NP02 cold box and in ProtoDUNE-VD may not require this redesign, as gravity helps in that case