

DP ProtoDUNE Technical Design Review 24<sup>th</sup> April 17

C.Cantini on behalf of ETHZ Group

## Slow control design for the ProtoDUNE-DP Detector

- List of sensors, items, instrumentation
- Distribution of sensors on Charge Readout Plane and in Tank
- Instrumentation flange (INS), Tank Instrumentation flange (TANK INS)
- Connectors, internal cabling
- Middle HV system
- Patch panel
- Pulsing system
- Level meter system
- Heaters
- Camera
- Purity Monitor

Based on sensors list and previous experience with 311 Detector, design for Flanges hosting CRP INS and TANK INS.

4 x CRP INS flange dedicated to:

- Slow control signals (temperatures, LAr level meters, distance meters)
  - Connectors as 311 Detector
  - Improving internal cabling
- Heaters Charge Readout Plane
- Middle High Voltage for LEM biasing
- Pulsing system

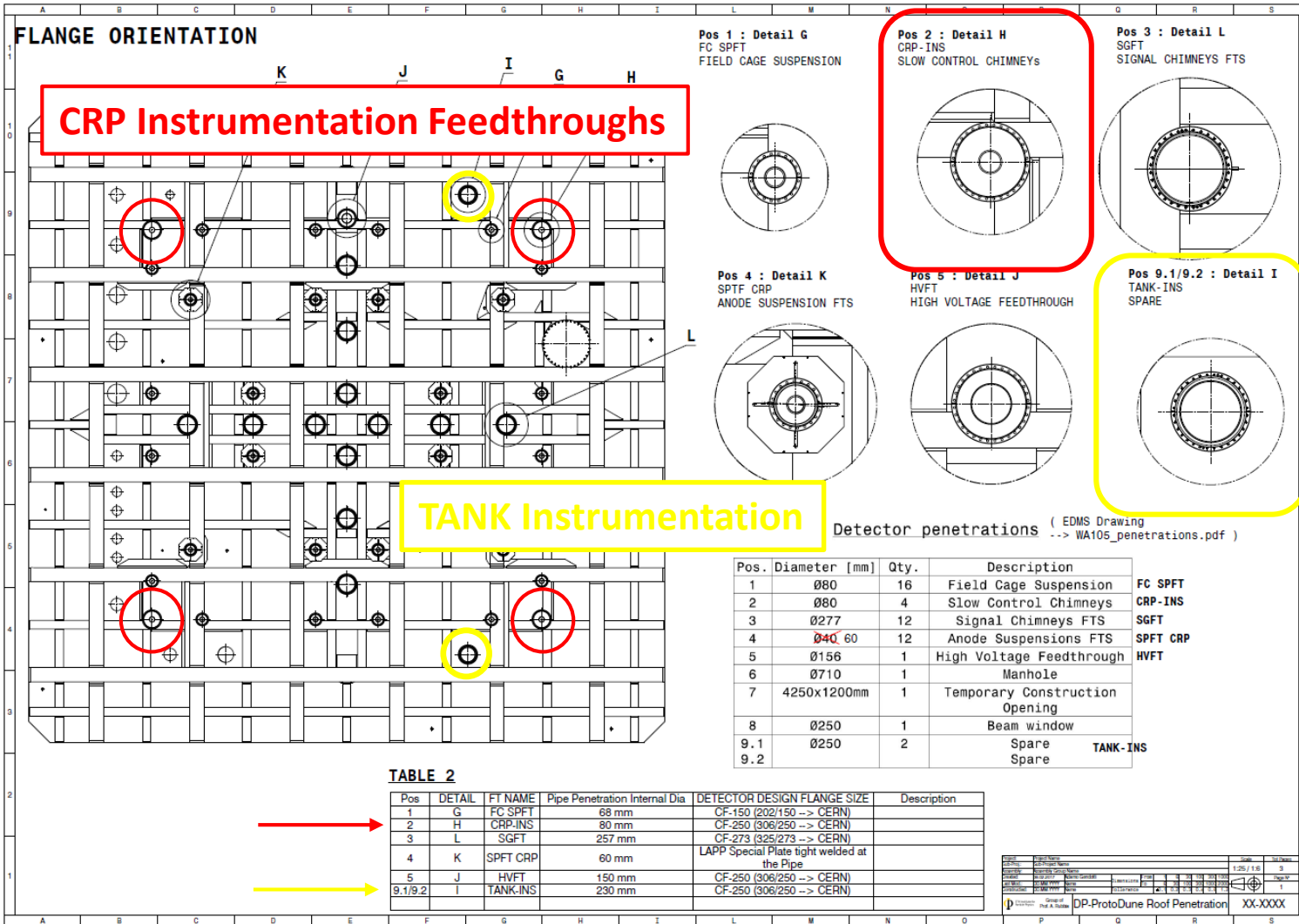
2 x TANK INS dedicated to:

- Heaters Bottom, on the membrane
- Purity monitors
- Power for PMTs
- Power for LEDs
- Cameras

Penetrations defined:

- 80 mm dia, CF250 flange for CRP INS
- 230 mm dia for TANK INS

A tee or cross will be needed, both for CRP INS and TANK INS.



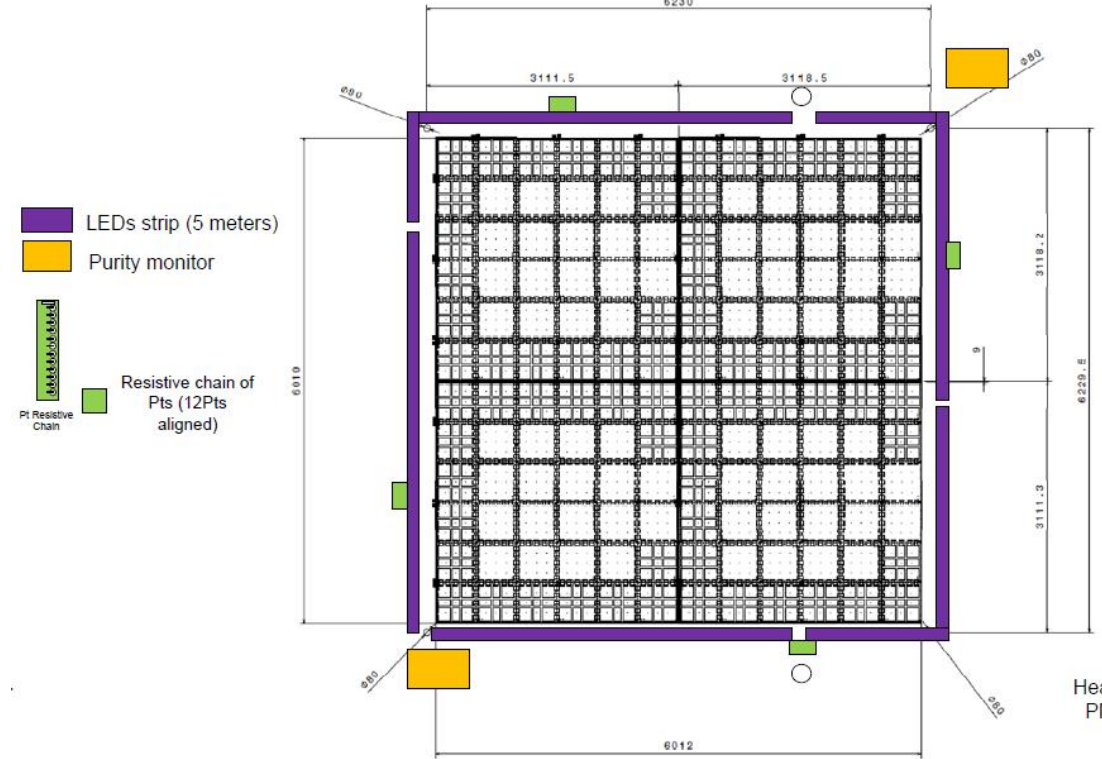
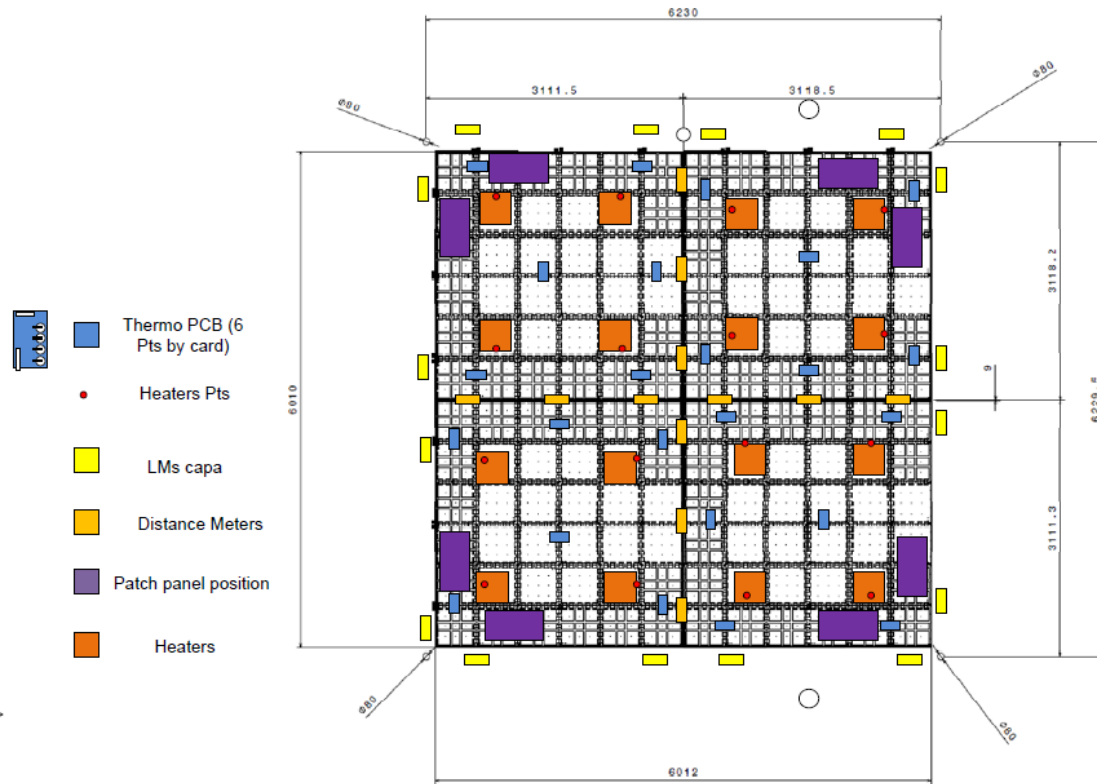
# ETH zürich List of sensors for ProtoDUNE-DP Detector – INSTRUMENTATION FLANGE WA105

		SENSOR -> PATCH PANEL						PATCH PANEL -> FLANGE				
	Sensors/Items	No. Items per CRP module	Cables	CODE	No. of cables	Diameter	Connector on patch panel IN	Patch Panel	Connector on patch panel OUT	Cables	CODE	Flanges
x4	Thermometers (6 Pts)	6	3M 50 way Twisted Ribbon Cable, 1.27 mm pitch, AWG 28	RS 111-8900	3	63.5mm	SUBD 50 pins	Patch Panel 1	SUBD 50 pins	3M 50 way Twisted Ribbon Cable, 1.27 mm pitch, AWG 28	RS 111-8900	SUBD 50 pins
	Temperature for heaters	4	3M 50 way Twisted Ribbon Cable, 1.27 mm pitch, AWG 28	RS 111-8900	1	21mm	SUBD 50 pins		SUBD 50 pins	3M 50 way Twisted Ribbon Cable, 1.27 mm pitch, AWG 28	RS 111-8900	SUBD 50 pins
Capacitive level meters	4	CABLE COAXIAL 50 OHM - RG316U	RS 260-5607	8	4.2mm	SMA	SMA		CABLE COAXIAL 50 OHM - RG316U	RS 260-5607	8x SMA	
Distance meters	3	CABLE COAXIAL 50 OHM - RG316U	RS 260-5607	6	4.2mm	SMA	SMA		CABLE COAXIAL 50 OHM - RG316U	RS 260-5607	6x SMA	
Heaters	4	KAPTON INSULATED WIRE	311-KAP Allectra	8	2.4mm	AMPHENOL MDC 20 pins	Patch Panel 2	AMPHENOL MDC 20 pins	KAPTON INSULATED WIRE	311-KAP Allectra	AMPHENOL MDC 20 pins	
HV LEM	72	kapton insulated KAPW50ohm or micro coax	LewWac KAPW50	72	2.1mm	MACOR own Design		MACOR own Design	kapton insulated KAPW50ohm or micro coax	LewWac KAPW50	LEMO HV	
Extraction Grid/FFS	4	kapton insulated ZKAPW 50ohm	Lewvac ZKAPWC	4	3.2mm	MACOR own Design		MACOR own Design	kapton insulated ZKAPW 50ohm	Lewvac ZKAPWC	LEMO HV	

	Sensor/Item	No. Items per Flange	Cables	CODE	No. of cables	Diameter	Connector on Flange
x2	Chain of Pts (2 composed by 12 Pts)	24	3M 50 way Twisted Ribbon Cable, 1.27 mm pitch, AWG 28	RS 111-8900	2	63.5mm	2x SUBD 50 pins
TANK_INS_1, TANK_INS_2	Purity Monitor	2	KAPW50ohm	KAPW50	3	3x2.27 mm	6x SHV
	PMTs	18	RG303	—	18	3x4.32 mm	18x SHV
	Heaters on the bottom	4	KAPTON INSULATED WIRE	311-KAP Allectra	8	8x 0.6 mm	AMPHENOL MDC 20 pins
	Temperature for heaters	4	3M 50 way Twisted Ribbon Cable, 1.27 mm pitch, AWG 28	RS 111-8900	1	63.5mm	1x SUBD 50 pins
	LEDs	5	KAPTON INSULATED WIRE	311-KAP Allectra	10	10x 0.6 mm	AMPHENOL MDC 20 pins
	Cameras	3	Raspberry CSI cable camera	—	3	(CSI flat)	1x SUBD 50 pins
	Coaxial Level meters	1	CABLE COAXIAL 50 OHM - RG316U	RS 260-5607	2	—	2x SMA
	Pressure	1	1/4" Gas, Keller sensors	PAA21Y			

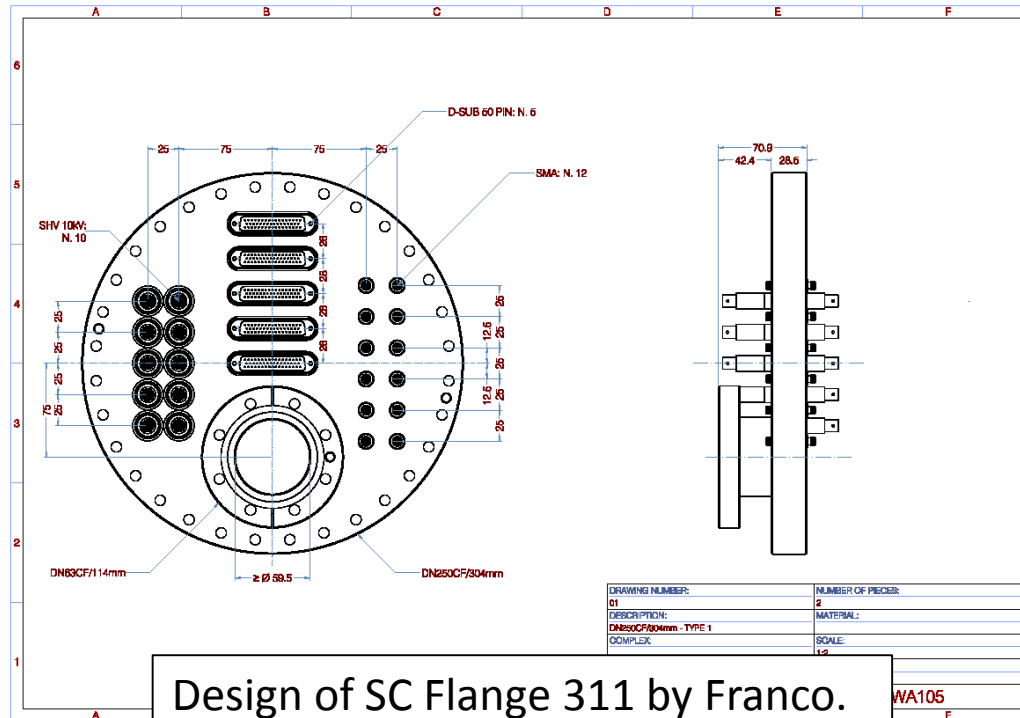
# CRP INS flange

# TANK INS flange



Heaters with Pts, Camera, PMts and coax LMs are not represented

Given modularity and symmetry of the CRP, the 4 CRP INS flange will be identical and also TANK INS will be identical



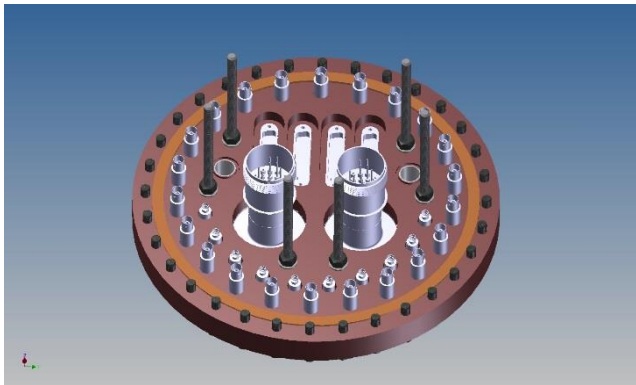
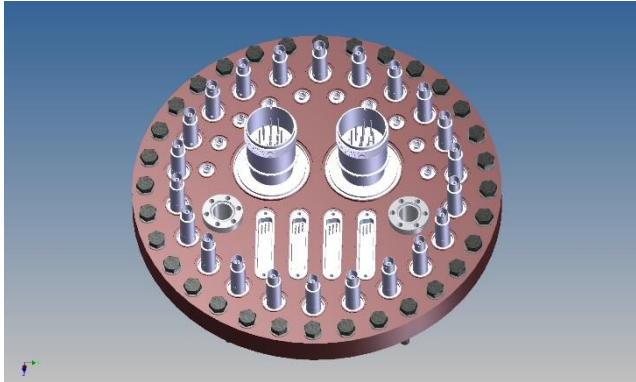
Design of SC Flange 311 by Franco.  
Number of connectors on CRP INS  
will be similar to the ones for 311  
Detector.

CRP INS flange dedicated to:

- Slow control signals (temperatures, LAr level meters, distance meters)
- Heaters Charge Readout Plane
- Middle High Voltage for LEM biasing
- Pulsing system, PCB board with KEL connectors on CF63
- See table in slide 3
- We have identified all the connectors

Design foresees a cross CF250 on top cap.

Plenty of room for all the connectors required for our sensors in the vessel  
Design and integration of the flange not yet there, but it is not critical in  
terms of timescale. It can proceed while finishing the design of the middle  
HV flange.



Design by Roger Haenni, Bern Group

TANK INS dedicated to:

- Heaters bottom of membrane
- Purity monitors
- Power for PMTs
- Power for LEDs
- Cameras

Design foresees a cross CF250 on top cap also there.

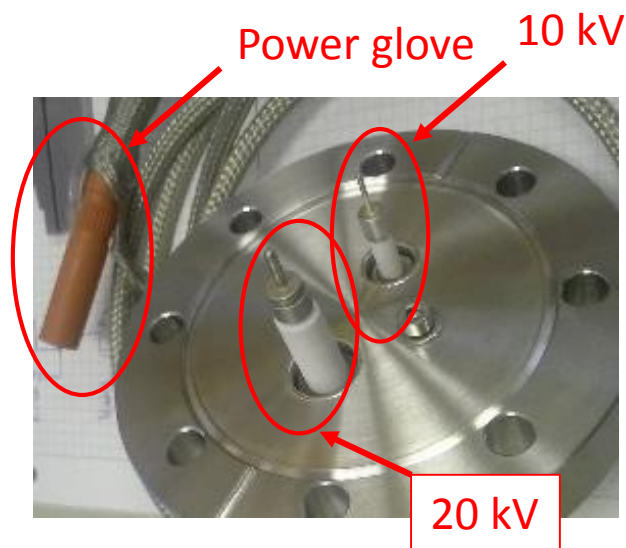
Plenty of room for all the connectors required for our sensors in the vessel.

We know already all the weldable connectors needed and thanks to previous experience we can now implement improvements at the level of stress release system or automated system to check remotely insertion of cables.

Preliminary design is now under internal review.



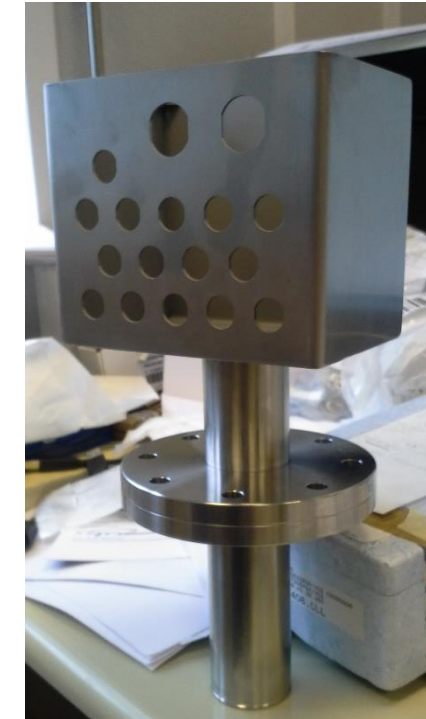
- High Voltage 10 kV rated channels
  - TOT 288 channels, split on 4 Flanges
  - O(80) per CRP INS FT
  - NO commercial available solutions
  - Experimented several
- Collaboration with Allectra to develop a weldable connector, single sided, working (no discharge, no leak current) in GAr up to 10 kV



Test flange, prototype with 2 custom made single sided connectors:

- Special silicon cable ("power glove").
- Only available for 20 kV version.
- Tested successfully up to 20 kV in Air, GAr and Vacuum.
- A first batch of custom made coaxial thinner cables ordered, delivery time is 10 weeks from now.
- As soon as tested the design of the flange can be finalized.
- After that we have to consider other 10 weeks for production of flanges and purchasing of material (cables mainly).

- Solution implemented for 311 Detector is custom made, to full fill the lack of a COTS solution to deliver 10 kV in argon gas
  - Isolation is guaranteed by epoxy glue (27 kV/mm dielectric strength)
  - Each channel tested in Gar, Air, vacuum before installation
  - Perfect isolation (E-12 Atm\*cm<sup>3</sup>/s)
  - Perfect dielectric performances, no leak current (less than 1 nA) above 10 kV
  - Reproducible results
  - Still a possibility for ProtoDUNE-DP Detector

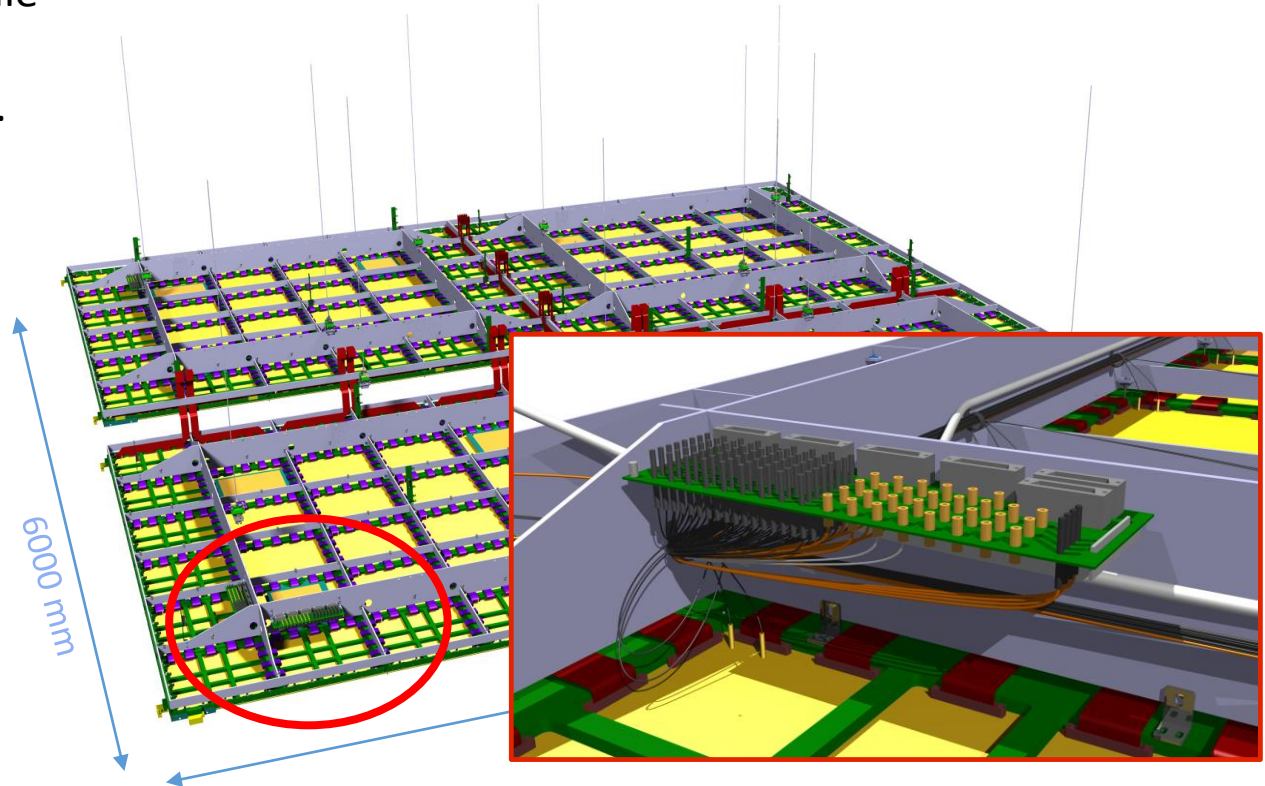
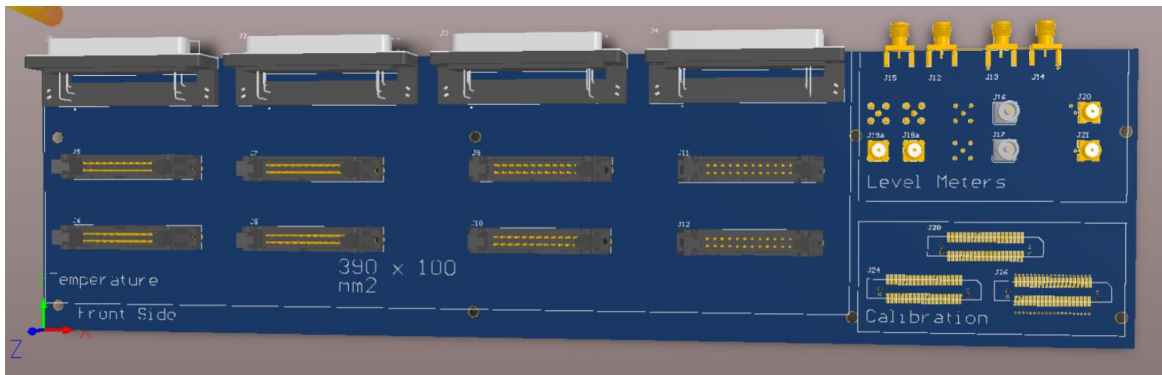


- **We will start the production of a unit with 80 channels in May** to cover the need of one CRP module – 2 months of production time.
- If meanwhile commercial solution outlined in previous slide will be proven then we can switch to it



- LEMO HV panel mounted connector
- Kapton isolated coax KAPW500HM
- Bi-component epoxy glue

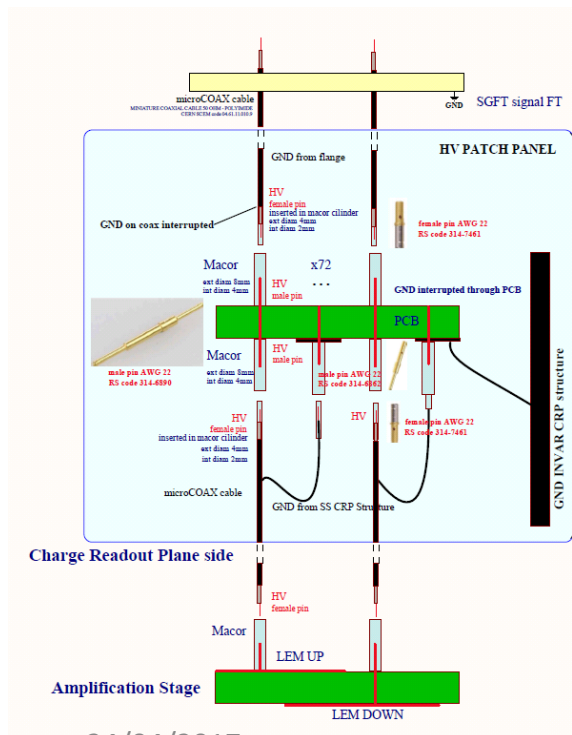
- PCB panel fixed on Charge Readout Plane – each module has one for sensors
- Purpose of the panel is to ease installation and cabling.
- It collects cables from:
  - Temperature sensors distributed on CRP
  - Liquid argon level meter for CRP positioning
  - Distance meter for relative alignment of modules
  - Pulsing system
- A second patch panel for LEM biasing – next slide



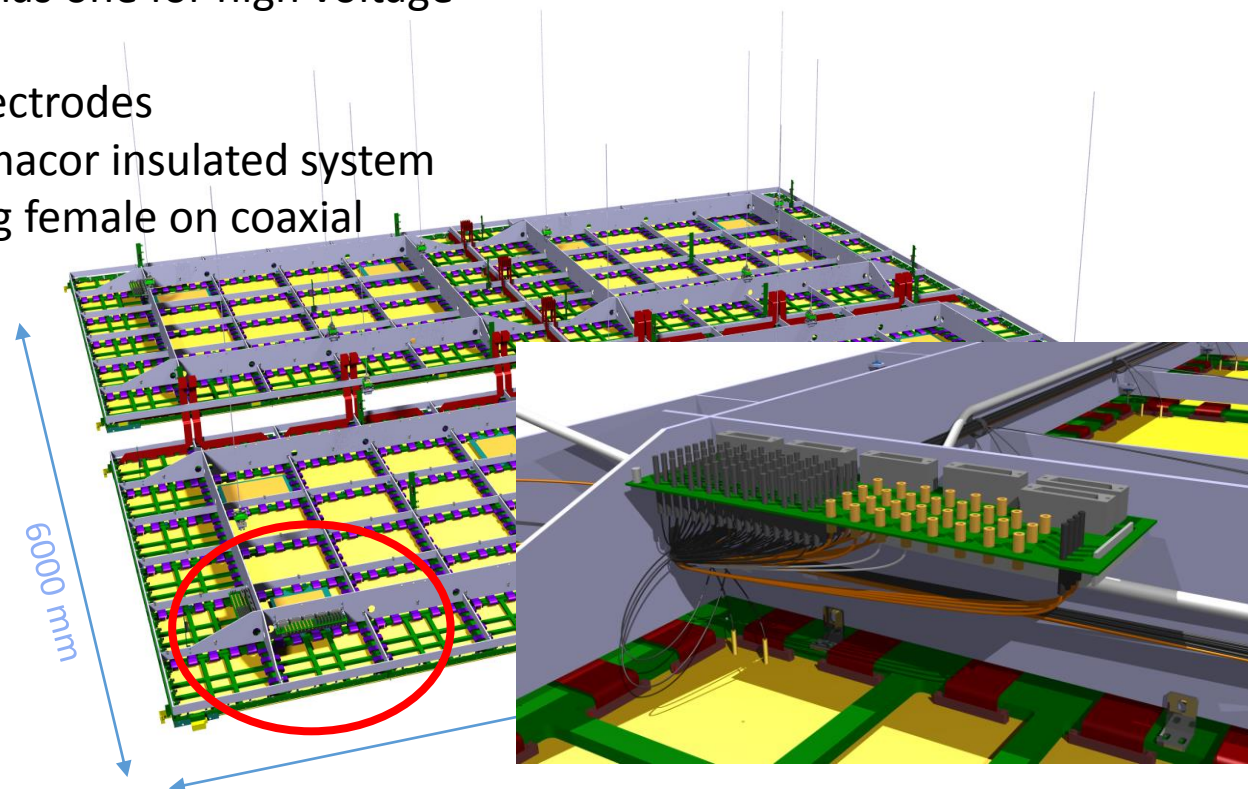
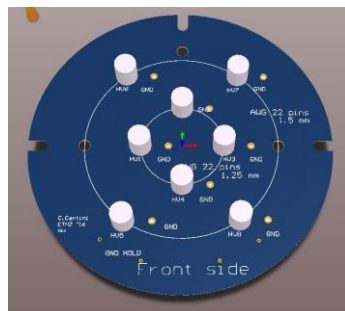
- Cabling in collaboration with Conflectronic, Allectra and other workshops at CERN for custom made assemblies.

- Ready to be produced
- 3 weeks time from order to assembly
- 1 prototype ready mid May

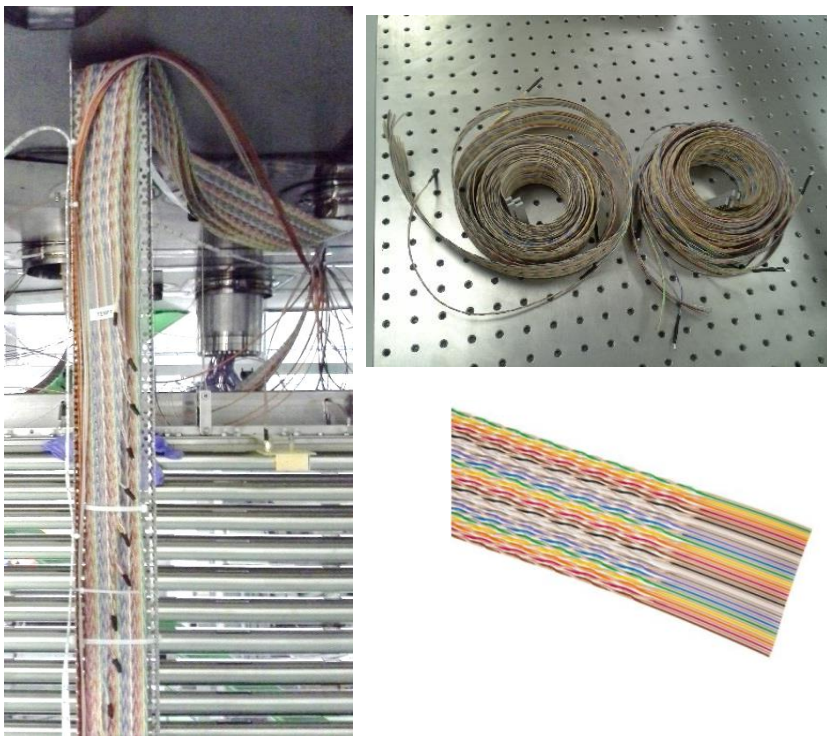
- PCB panel fixed on Charge Readout Plane – each module has one for high voltage
- Purpose of the panel is to ease installation and cabling.
- It delivers the biasing voltage for LEMs bottom and top electrodes
- To guarantee spark free contact, we developed a double macor insulated system which is isolating male pin (soldered on PCB) and receiving female on coaxial cable



24/04/2017



- Tested in argon gas
- Same idea used to connect to high voltage the LEM electrodes
- Tested in 311 Detector and previous ETHZ experiences
- 6 weeks time from order to assembly
  - Custom made macor cylinders
  - Standard PCB
- 1 prototype ready mid June



- 311 Detector has  $\approx 90$  temperature probes distributed in main vessel, soldered on ribbon cable, spaced by 4 cm or arranged on “thermometers”
- 311 Detector has 45 temperature probes in the insulation space
- 4 wires method everywhere
- Pt interfaced to NI9219 modules outside in racks
  
- ProtoDUNE-DP Detector has  $\approx 200$  temperature sensors, distributed between CRP INS flange and TANK INS flange
- Proposing same platinum sensors, same company (IST) - demonstrated  $< 0.1$  K resolution at TLA, CLASS Y resistors

#### Baseline choice for cable >

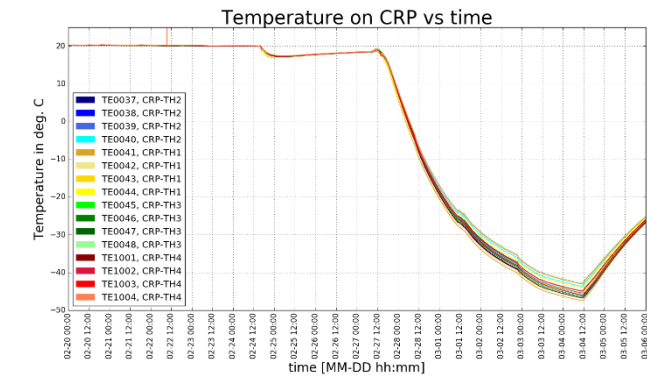
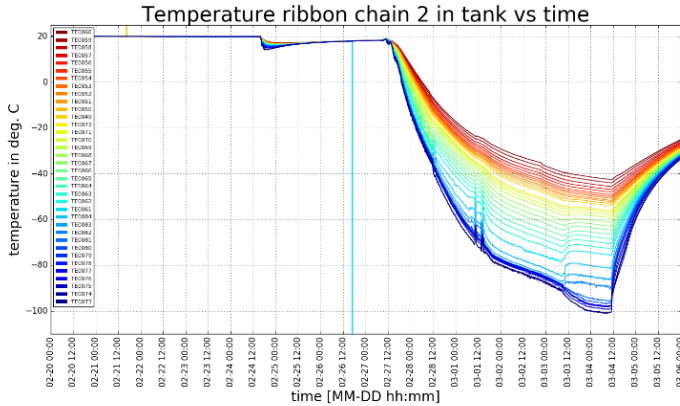
- 3M 50 way Twisted Ribbon Cable, 1.27 mm pitch, AWG 28, available through RS
- Used for resistive level meter and thermometers
- Intermediate interface at the patch panel
- Interfaced through SUBD50 weldable connectors on CRP INS and TANK INS flange to acquisition system

In 311 detector we monitor the temperature:

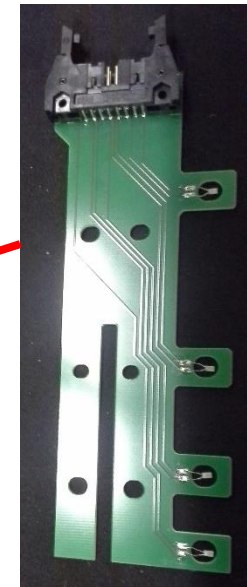
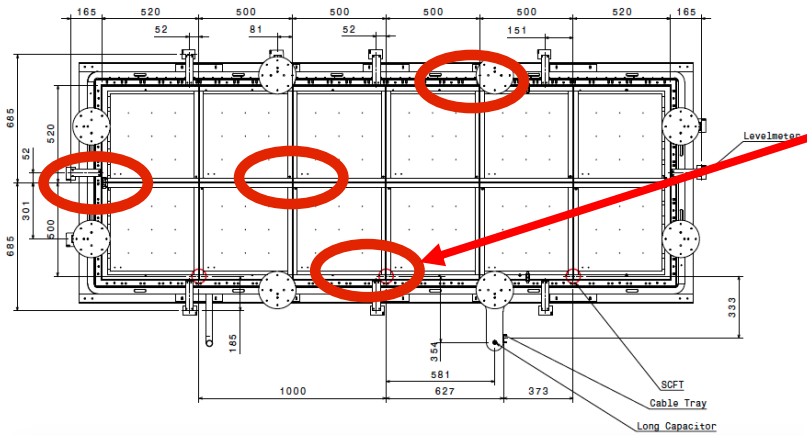
- Along the entire drift length (resistive level meter)
- On top of anode at different heights thanks to several PCBs where 4 Pt sensors are soldered (thermometers).

For ProtoDUNE-DP a new version with 6 Pts was designed.

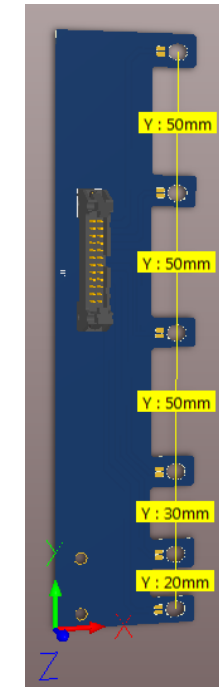
There are also 4 resistive chains (12 Pt each) connected to TANK INS along the 6 metres drift. They will be hosted into cable trays



Thermometers 311 Det: 4 Pts  
4 installed on CRP in gas phase



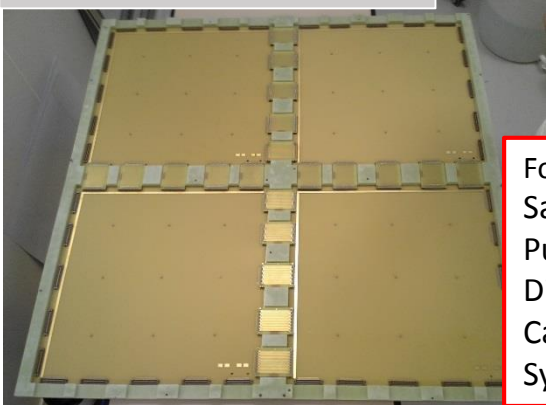
Thermometers 311



Thermometers new version: 6 Pts





Better fixation  
Integrated already in CRP design, time to produce them 2 weeks.

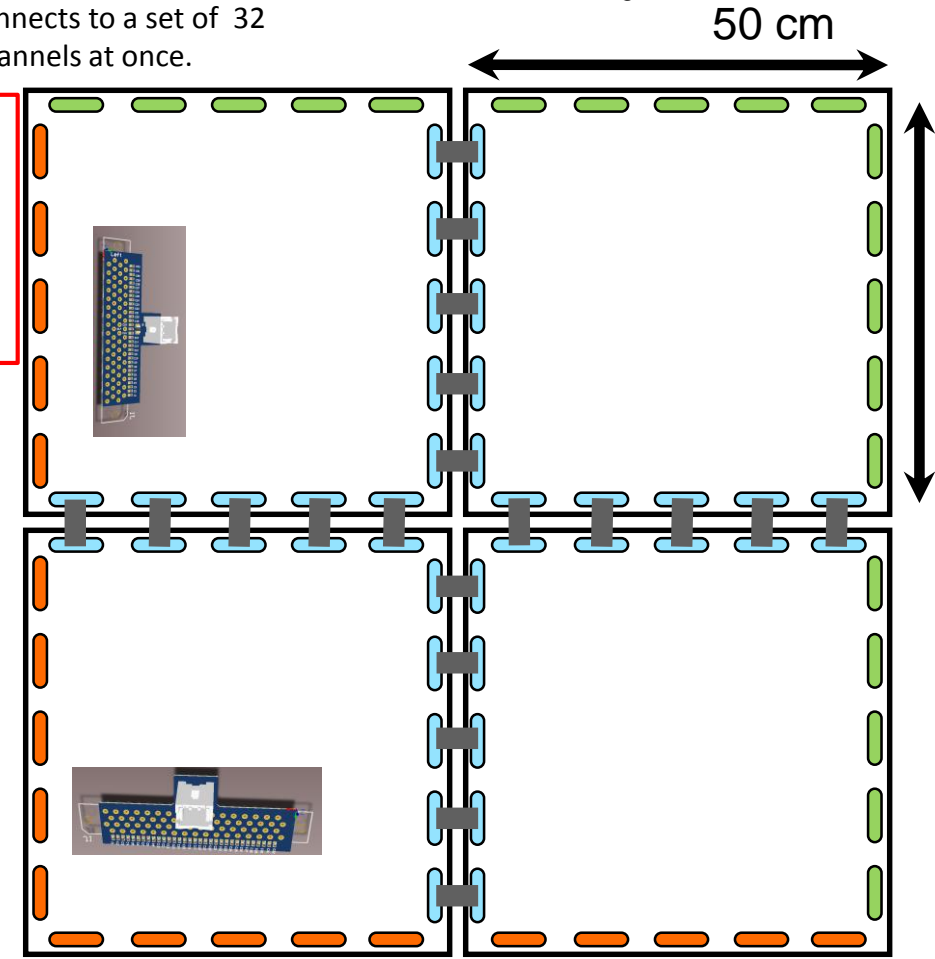
CRP 1m2 assembled



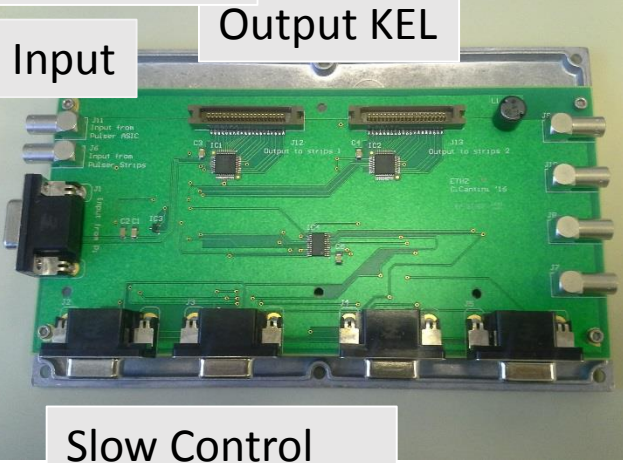
For 311 Detector:  
 Controlled distribution of pulses throughout the entire CRP thanks to a I2C controllable multiplexer.  
 Good way of testing continuity also.  
 It connects to a flange on slow control chimney 2, then each twisted pair connects to a set of 32 SMD Capacitors plugged on a connector on one end of Anode. Pulses 32 channels at once.

For ProtoDUNE-DP:  
 Same concept.  
 Pulsing will be done through CRP INS Feedtru.  
 Differentiating boards to plug on anode: design completed (see backups).  
 Cabling scheme defined, material identified.  
 Systematic QC system on capacitors is foreseen.

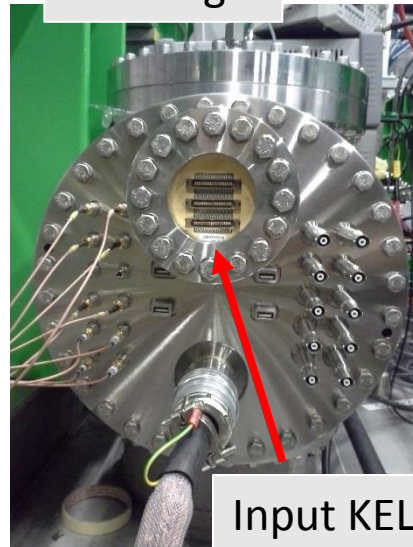
-  Pulsing connector
-  Readout connector
-  Bridge connector
-  Bridge



Multiplexer



SC Flange



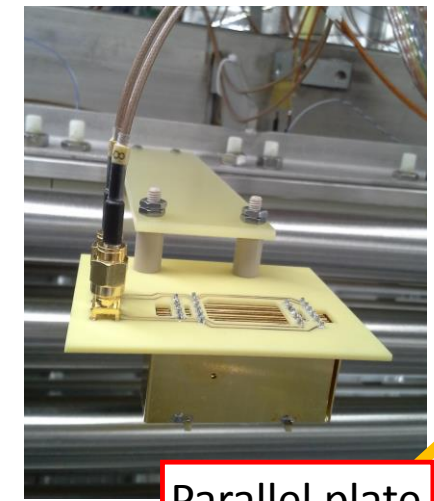
PCBs



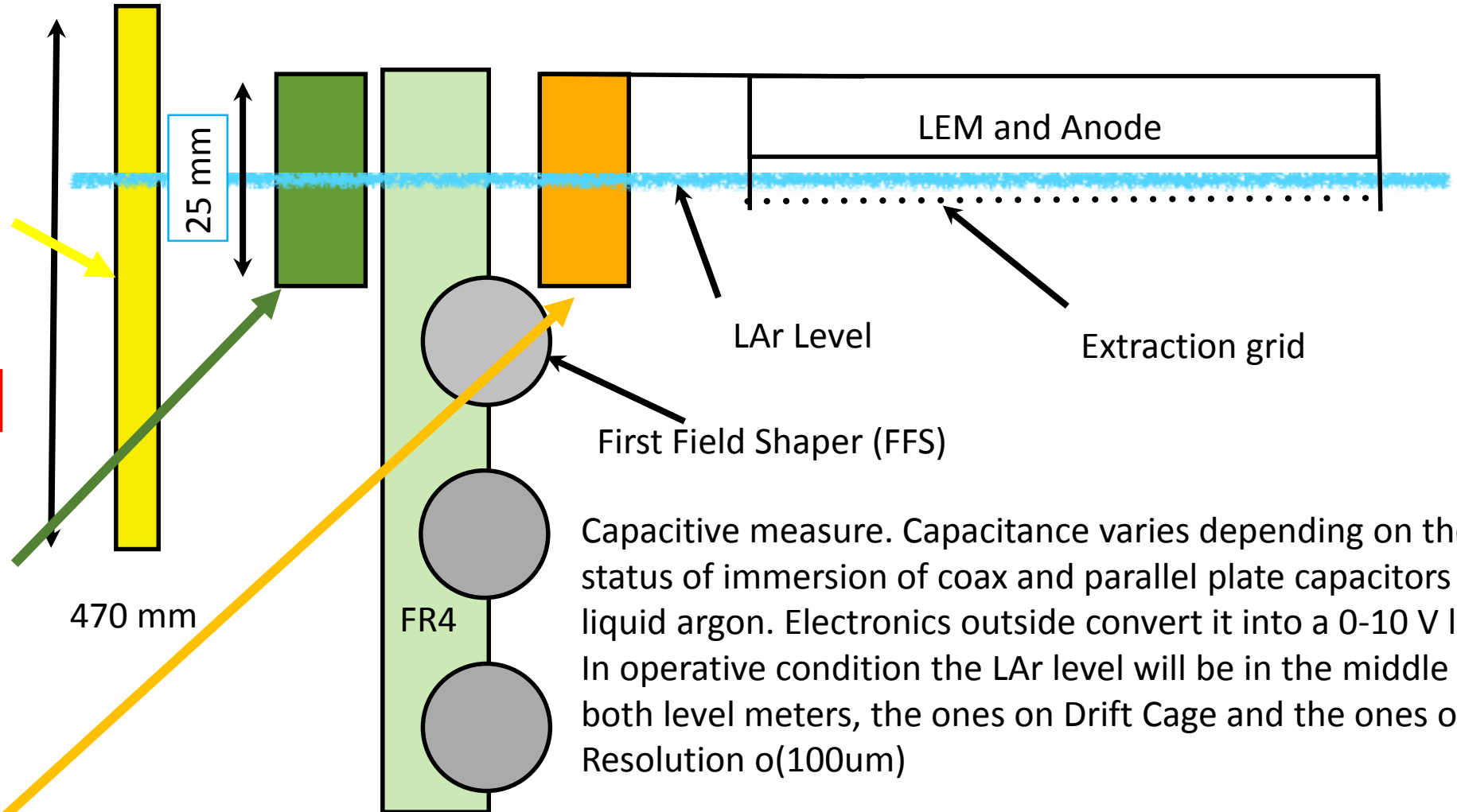
Slow Control for electronics



Coax

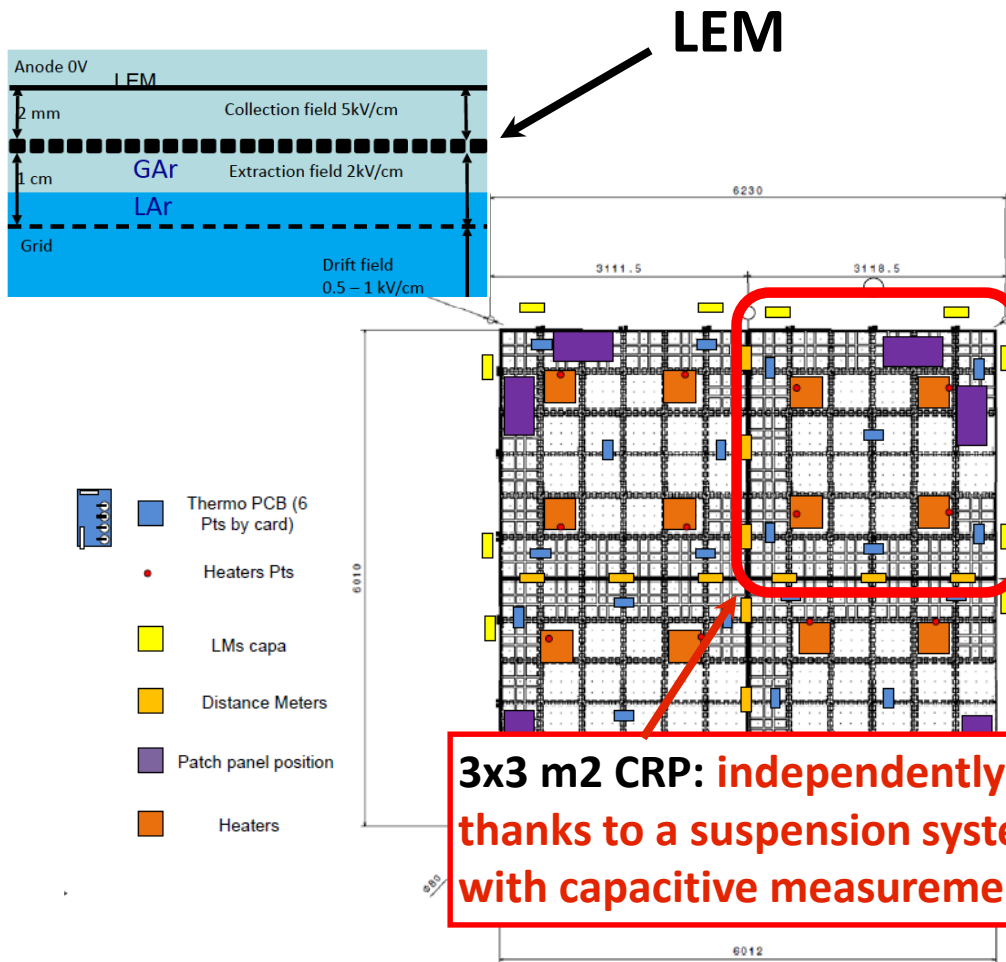


Parallel plate

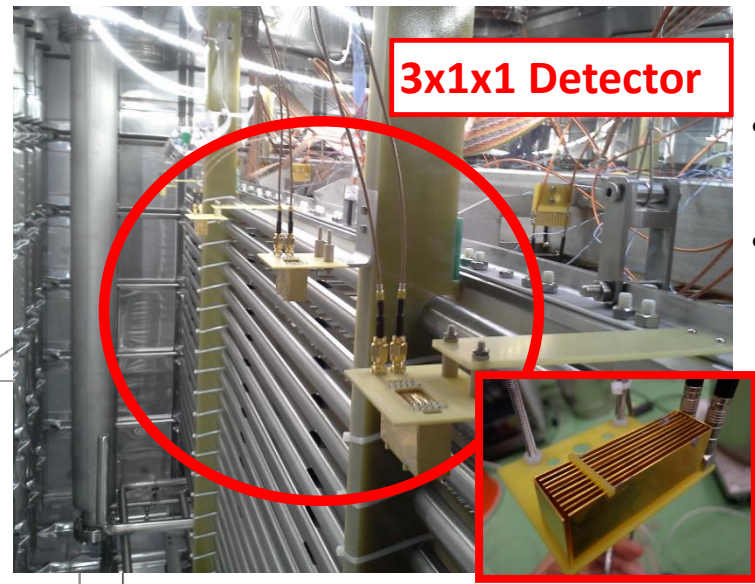


Capacitive measure. Capacitance varies depending on the status of immersion of coax and parallel plate capacitors into liquid argon. Electronics outside convert it into a 0-10 V level. In operative condition the LAr level will be in the middle of both level meters, the ones on Drift Cage and the ones on CRP. Resolution  $\sigma(100\mu\text{m})$





**3x3 m2 CRP: independently adjustable unit, thanks to a suspension system in closed loop with capacitive measurement**



- ProtoDUNE-DP: 3x3 modules will have 4 LM like those on edges
- To have finer resolution on CRP position a complementary approach is proposed

We can measure **capacitance between Grid and LEM's bottom electrode**, varying with the position of CRP across LAR level.

- distributed measure
- It has to be **tested** in 3x1x1 Detector when liquid will be there
- Same electronics as for the parallel plate capacitor measure

Relative distance between CRPs is monitored thanks to distance meters - LAPP

Favour the outgassing

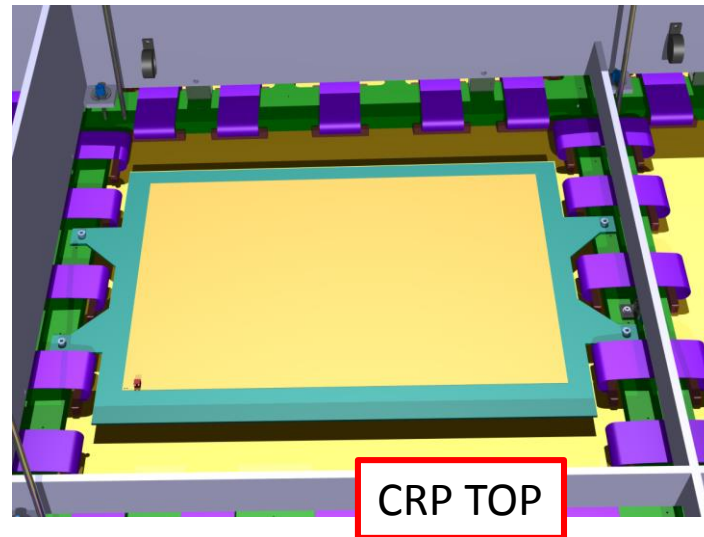
Avoid GAr stratification during cool down

Kapton Insulated Flexible Heaters by Omega or Alectra

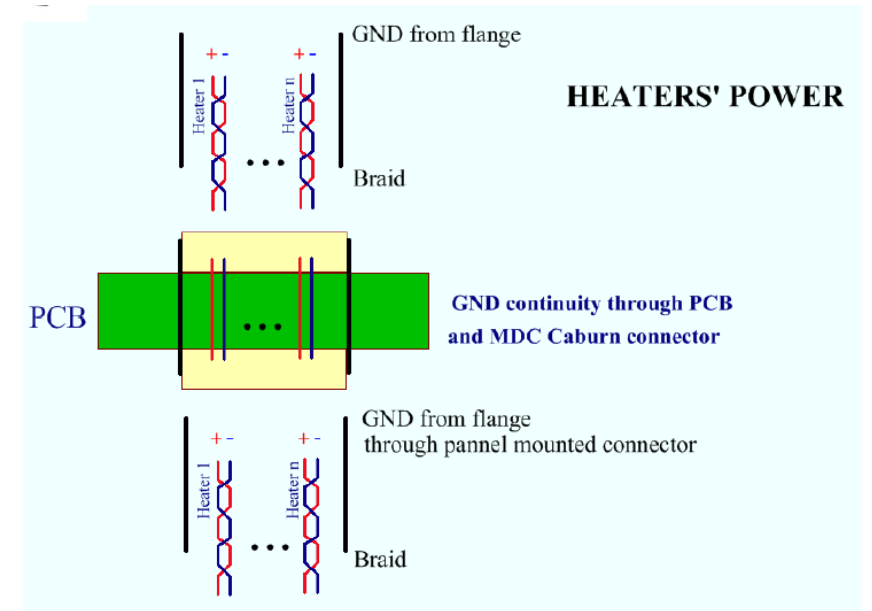
Custom made heaters foils, from few W up to hundreds each, customizable

Foreseen on top of CRP and on membrane floor

Up to 6 weeks delivery time



Mounted on FR4 plate on top of CRP and glued on membrane



- Caburn multi pin panel mounted connector
- Shielded cable
- Connected internally to CRP INS flanges
- Same connectors for LEDs power on TANK INS flanges

Box with :

- Fan
- Ground electrical link
- 5V power supply
- Ethernet switch
- 6 x RaspBerry module V3
- Max length tested in between camera and RaspBerry : 8 m

Each RaspBerry module :

- HDMI output
- 2x USB output
- Ethernet output
- 16 Gb SD Card with Raspian Linux OS

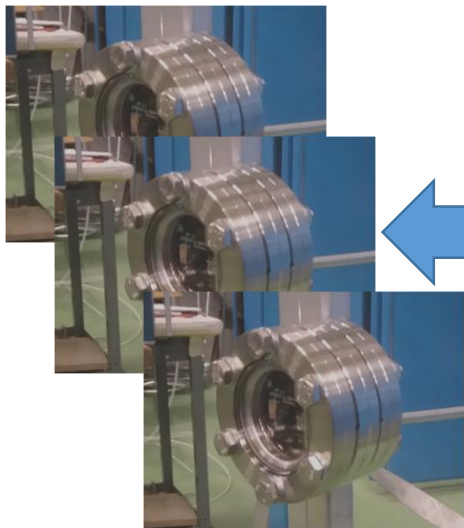
ProtoDUNE DP: 4 cameras connected to TANK INS flange through SUBD50 connectors



RaspBerry Pi and camera module  
- 15 pins cable connection

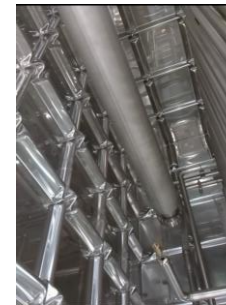


Camera box build for Fermilab

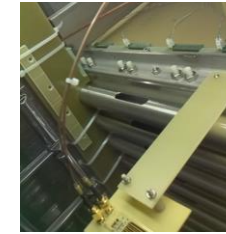


2 x 3 camera modules connected to the camera box

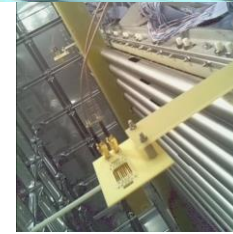
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wa105cam0



wa105cam1



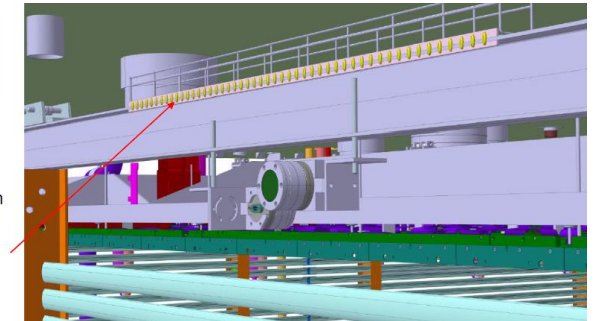
wa105cam2



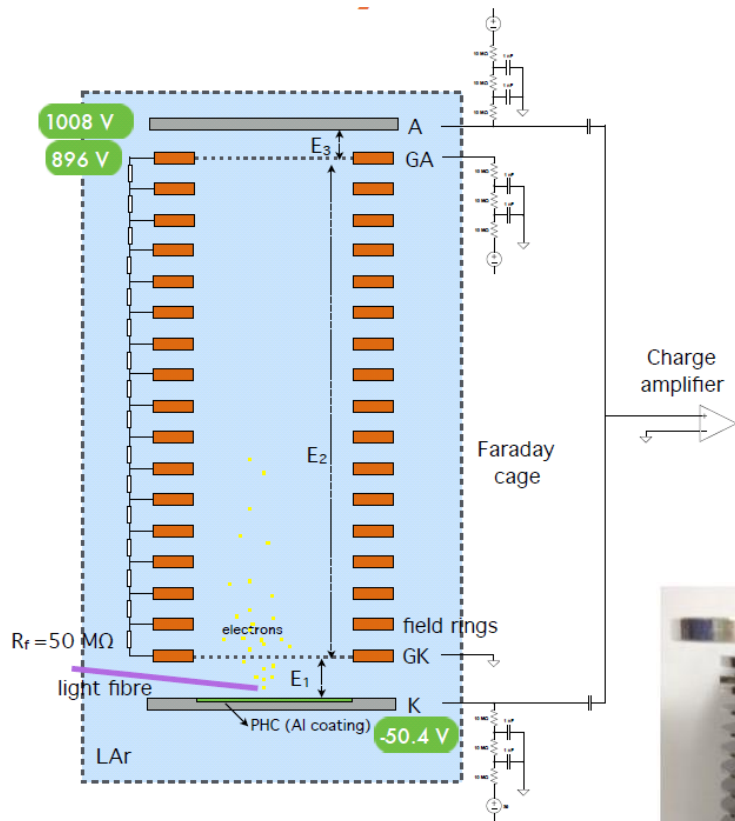
wa105cam3



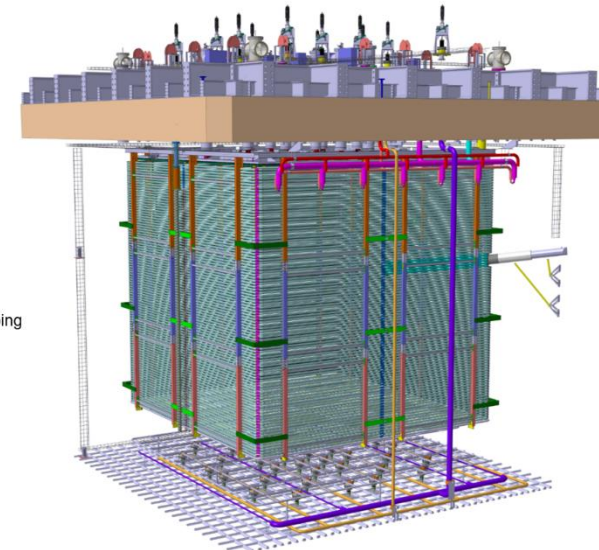
wa105cam4



- 4 x Cryocameras
- Same design of the 3x1x1
- Fixed at the Top SS I-Beam of the Field Cage modules
- LEDs



- Positioned at various heights to monitor stratification of impurities
- 4 Purity monitors in the ProtoDUNE-DP Vessel
  - 2 sitting on the membrane in 2 corners
  - 2 above the middle of the drift length
- They will be fed through TANK INS flanges
- Fixation: welding anchoring plates at the corner of the Cryostat.
- For the purity monitor on the bottom there will be a support plate.



- Top FTs
- Internal Cable Trays
- 4 x Purity Monitor
- Internal Cryogenic piping
- Beam Plug
- HVFT degrader

- We have a complete and integrated design for Slow Control of ProtoDUNE-DP Detector, consistent with what has been commissioned for 3x1x1 Detector – and already largely tested and validated at that scale.
- We have a complete list of material needed to implement the Slow Control for ProtoDUNE-DP Detector
- The design include sensors, instrumentation, cabling, high vacuum flange and interface to the acquisition system.
- We can benefit a lot from the experience developed with past smaller scale activities and with 3x1x1 Detector
- We can meet the schedule for the installation of the 1st CRP module within September 2017
- We are aware that some items (specifically the middle HV system) are crucial but we think we have contingency and the alternative design already deployed for 311 Detector makes us confident we have a safety margin on that item.

# Back up slides

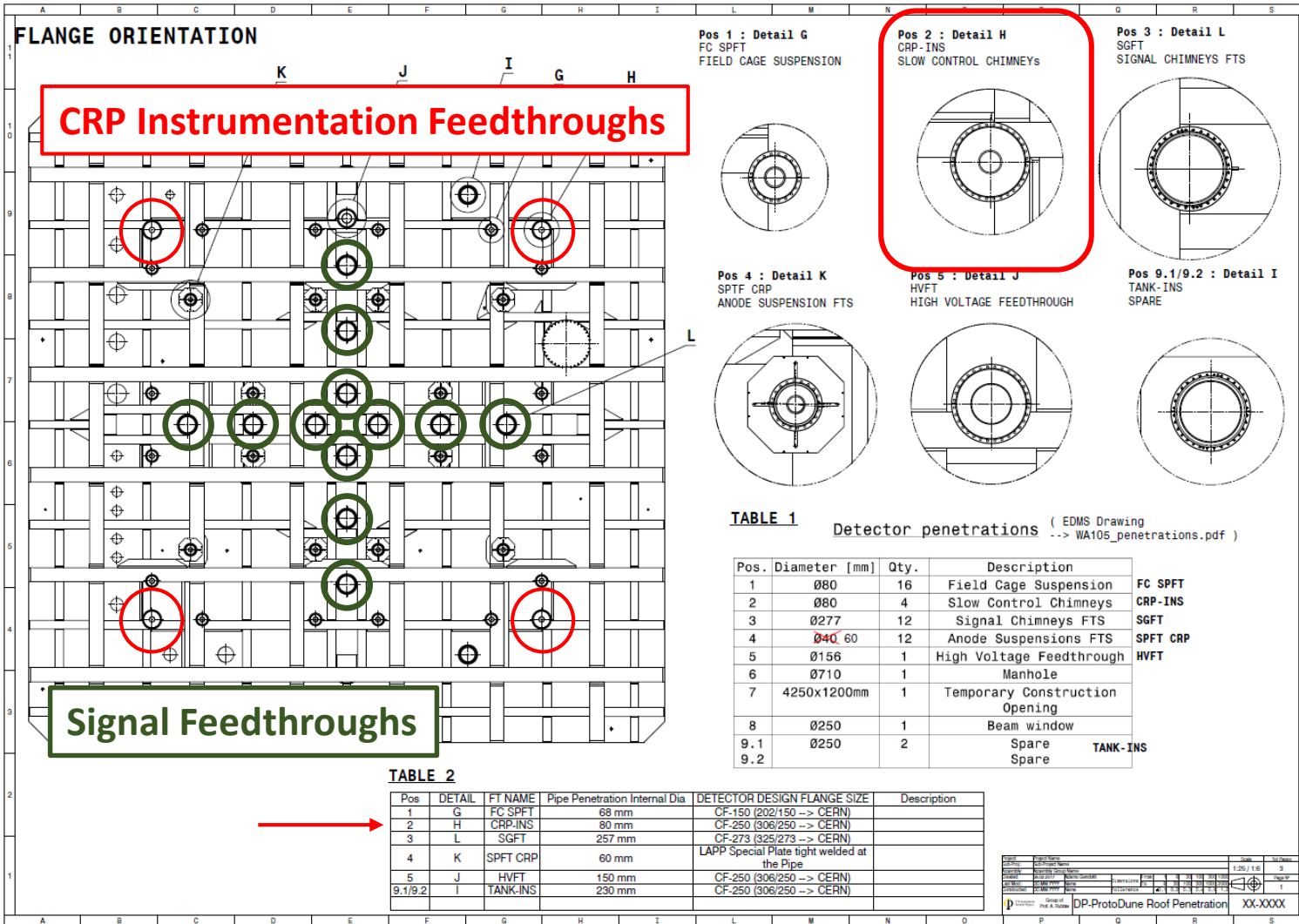
Based on new sensors list and previous experience with 311 Detector, preliminary design for Flanges hosting CRP INS.

4 x CRP INS flange dedicated to:

- Slow control signals (temperatures, LAr level meters, pressure...)
  - Connectors as 311 Detector
  - Improving internal cabling
- Middle High Voltage (10 kV rated channels)
- Pulsing system: under consideration

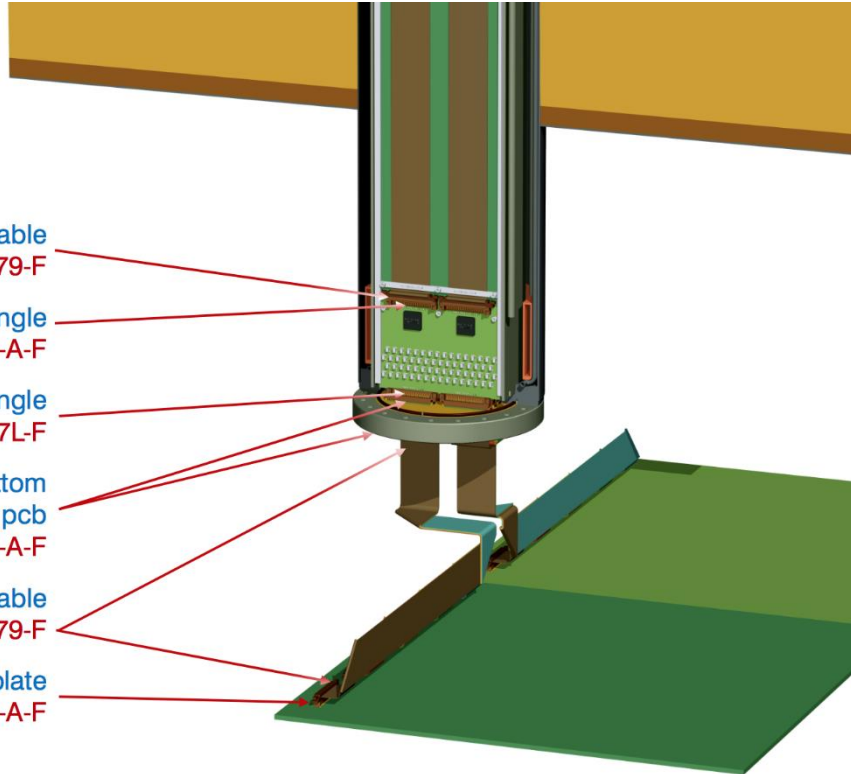
Penetrations already defined: 80 mm dia, CF250 flange for CRP INS.

A tee or cross will be needed, similarly to TANK INS Flanges

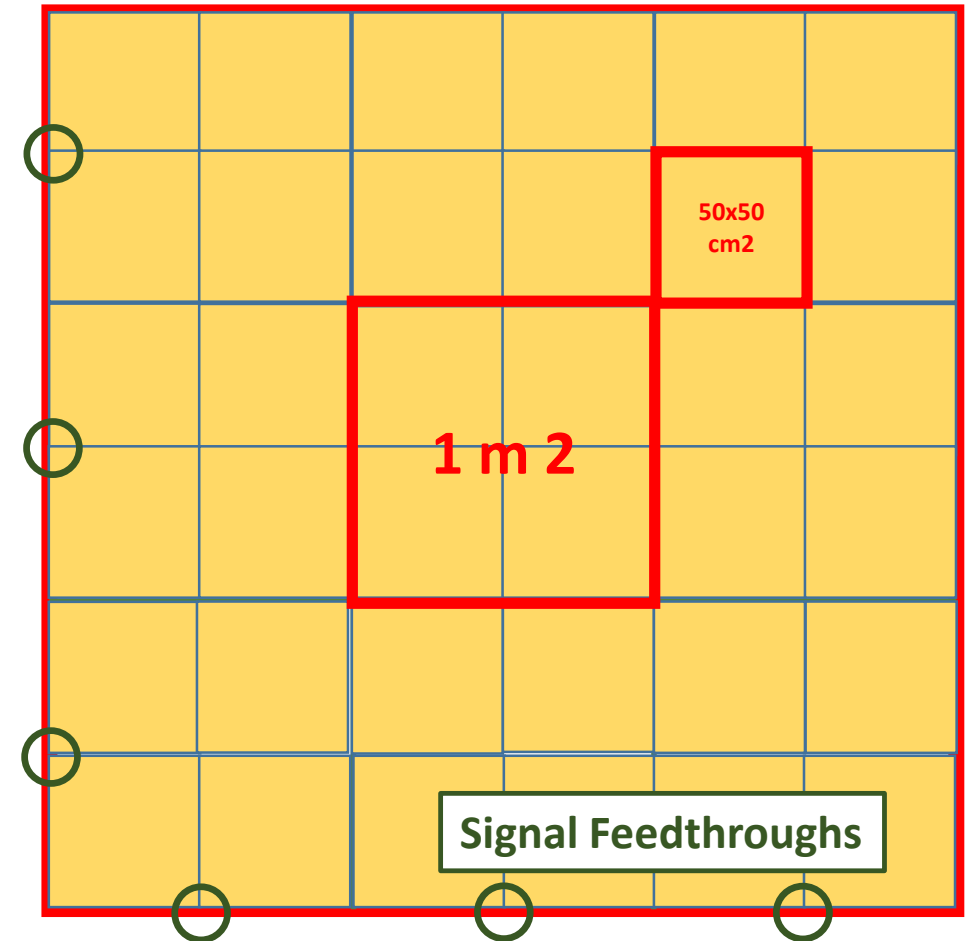


SFT chimney for the 3x1x1 prototype

- Low profile IDC receptacles for cable  
KEL 8925E-068-179-F
- Plug right angle  
KEL 8911-068\*-178LD-A-F
- Receptacle low profile right angle  
KEL 8901-068-177L-F
- SMT plug soldered on top and bottom faces of the SFT pcb  
KEL 8913-068E/R-178MS-A-F
- Low profile IDC receptacles for cable  
KEL 8925E-068-179-F
- SMT plug soldered to the anode plate  
KEL 8913-068E/R-178MS-A-F

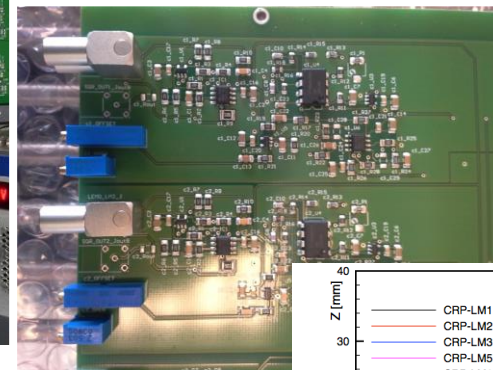
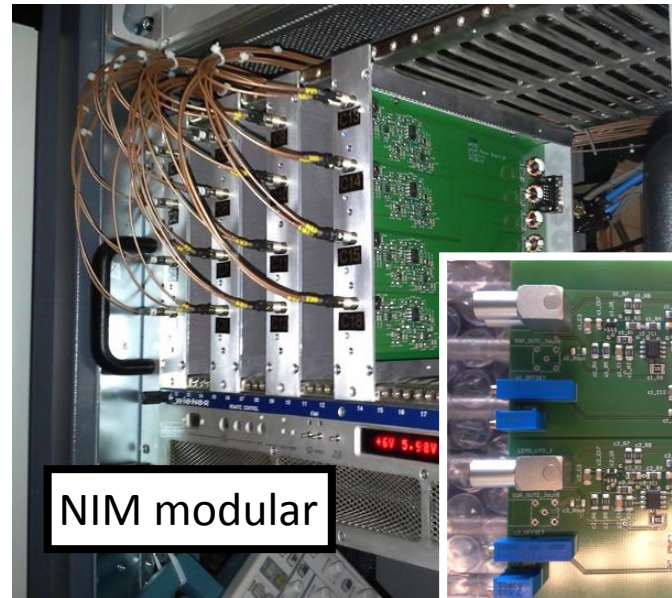
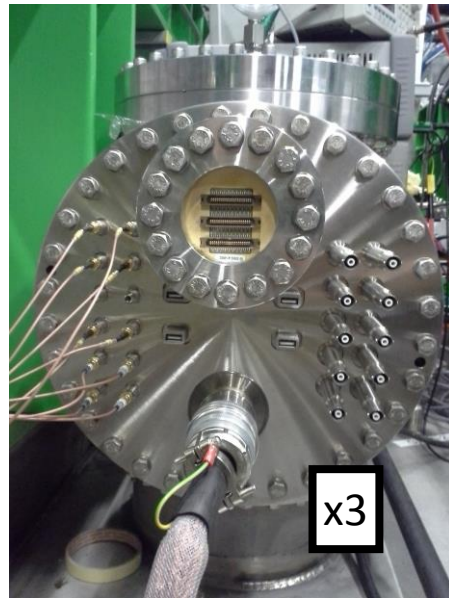
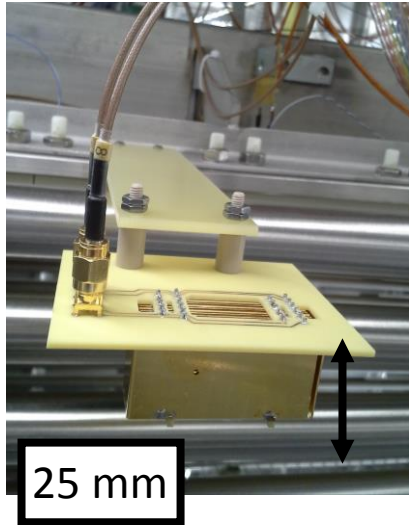


Electronics: each 9 m<sup>2</sup> CRP module  
Hitachi 68 c twisted pairs 0.635 mm pitch  
Automated continuity test procedure during installation will be implemented

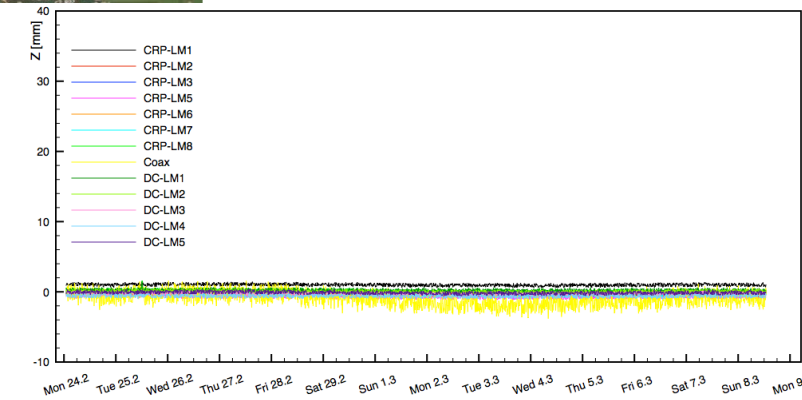
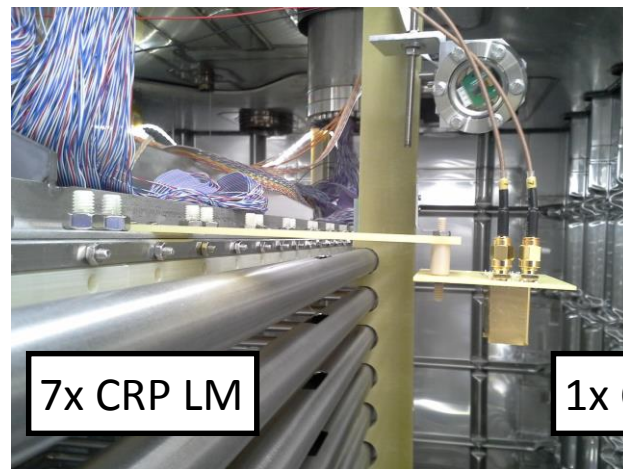
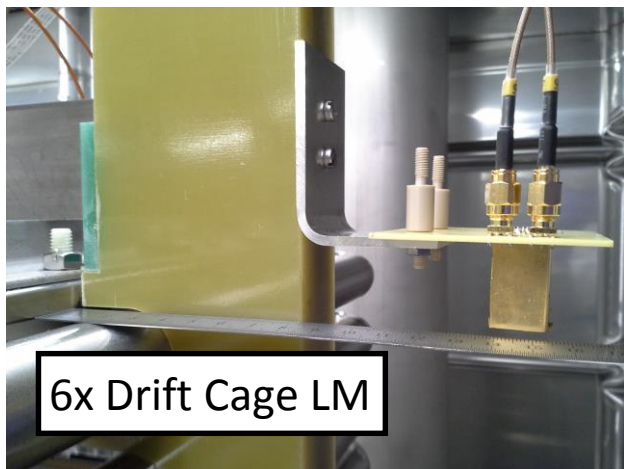


3x3 m<sup>2</sup> = 9 m<sup>2</sup> unit  
36 anode 50x50 cm<sup>2</sup>

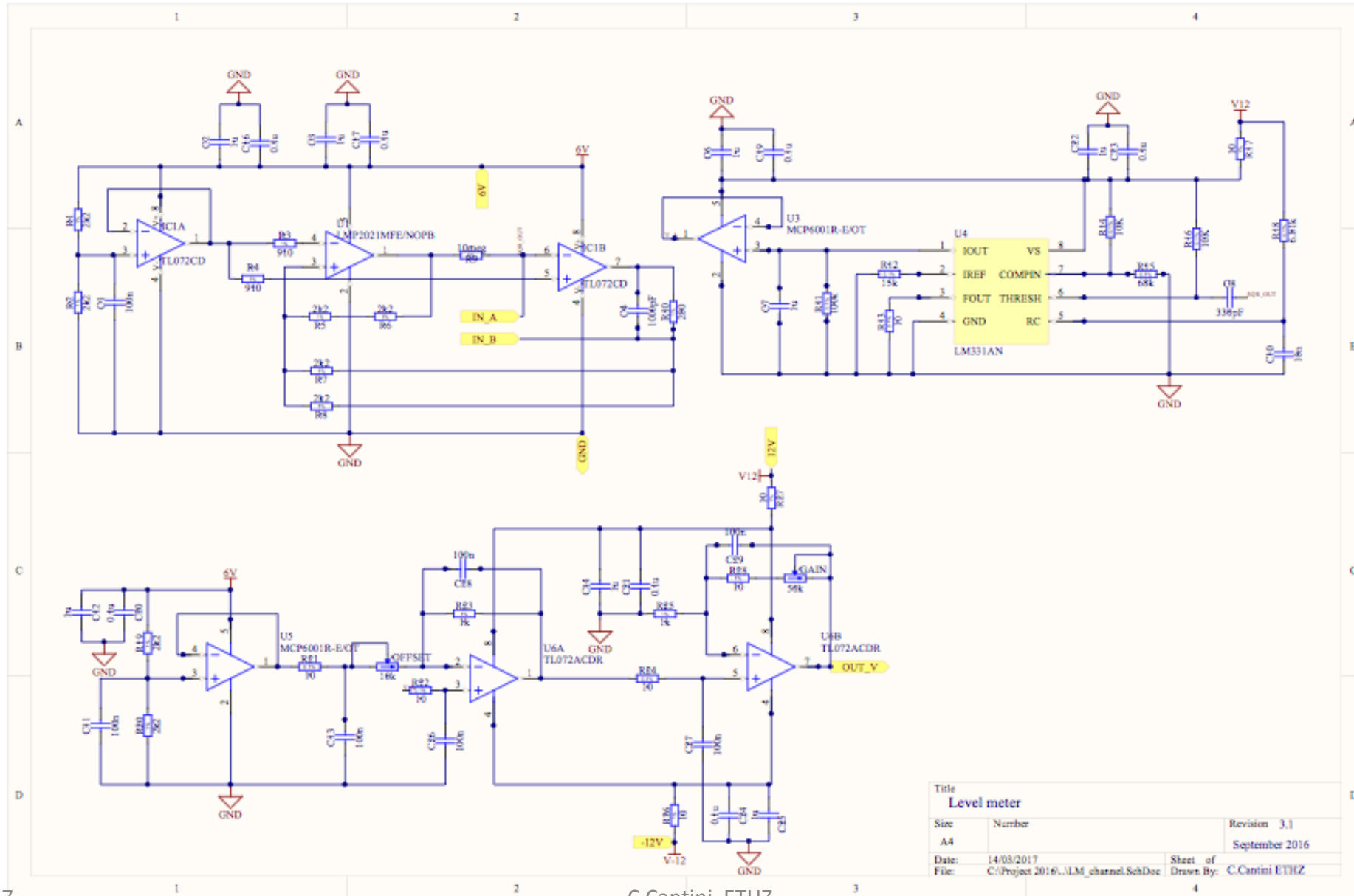




Custom sensing elements  
Custom electronics



Currently all sensors in GAR atmosphere



## Coaxial Cable, FEP Sheath RG316/U

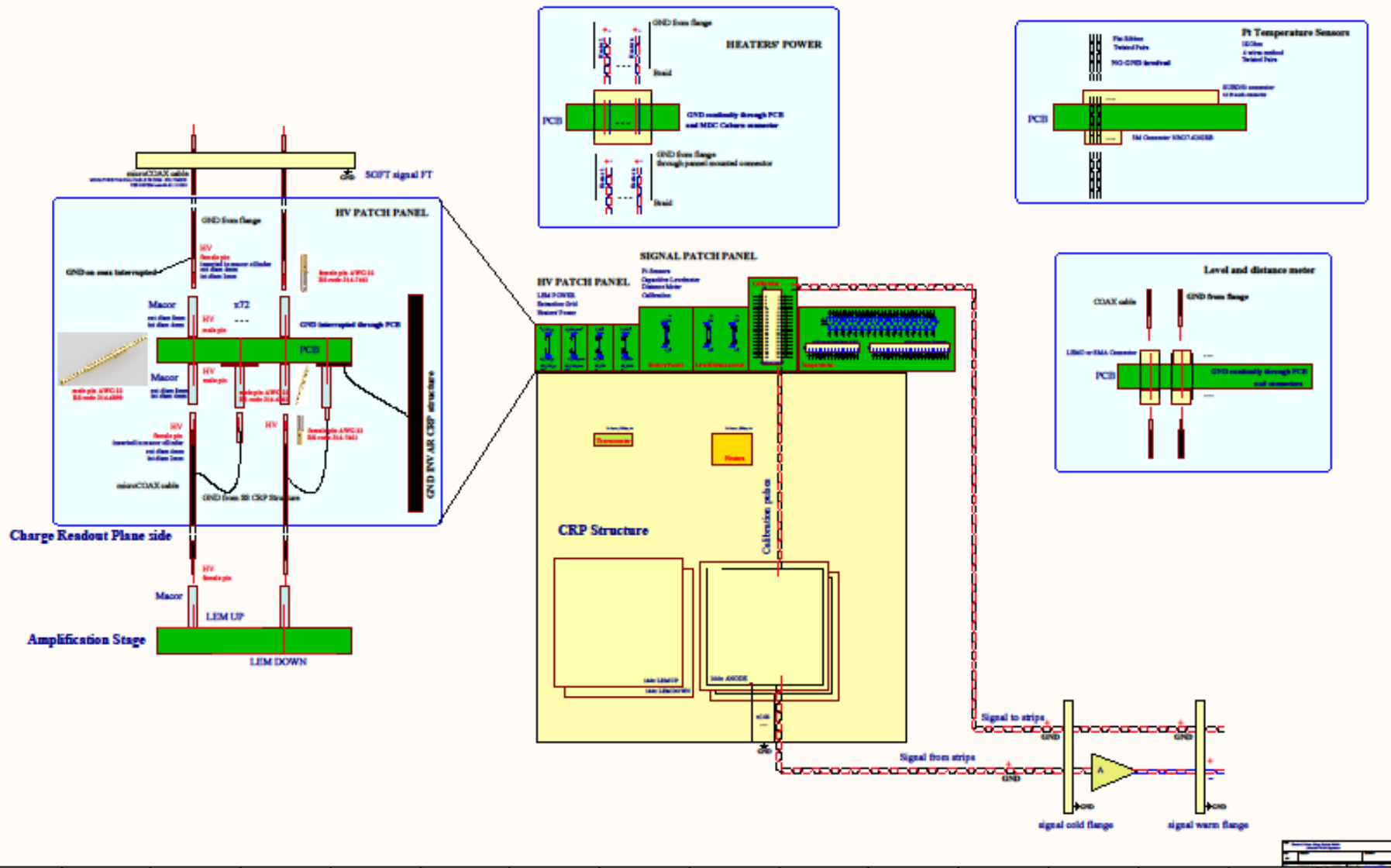
### Bedeac - RG316/U

Characteristic resistance	50 $\Omega$
Attenuation per 100 m	
100 MHz:	37 dB
200 MHz:	47 dB
1000 MHz:	102 dB
Internal conductor:	Silver-plated steel strand 7 x 0.17 mm
Dielectric:	PTFE $\varnothing$ 1.52 mm
Shield braiding:	Silver-plated copper
Sheath:	FEP, brown
Outer diameter:	$\varnothing$ 2.5 $\pm$ 0.1 mm
Temperature range:	-70 $^{\circ}$ C $\rightarrow$ +200 $^{\circ}$ C
Weight approx.:	0.5 kg / 25 m coil
	2.1 kg / 100 m coil



Used inside and outside the detector to connect sensors to flanges and then to electronics

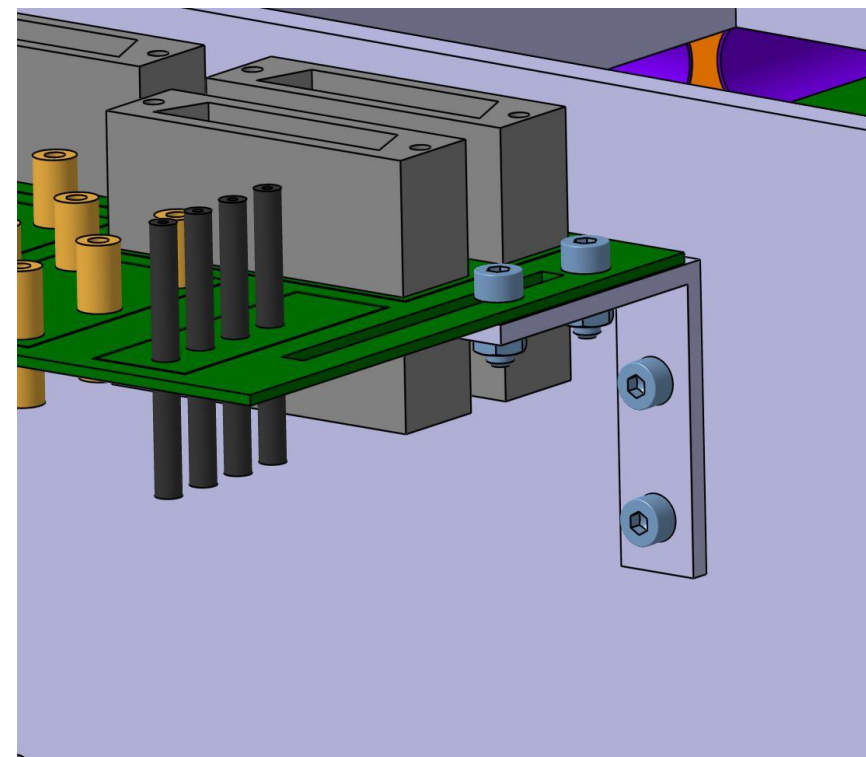
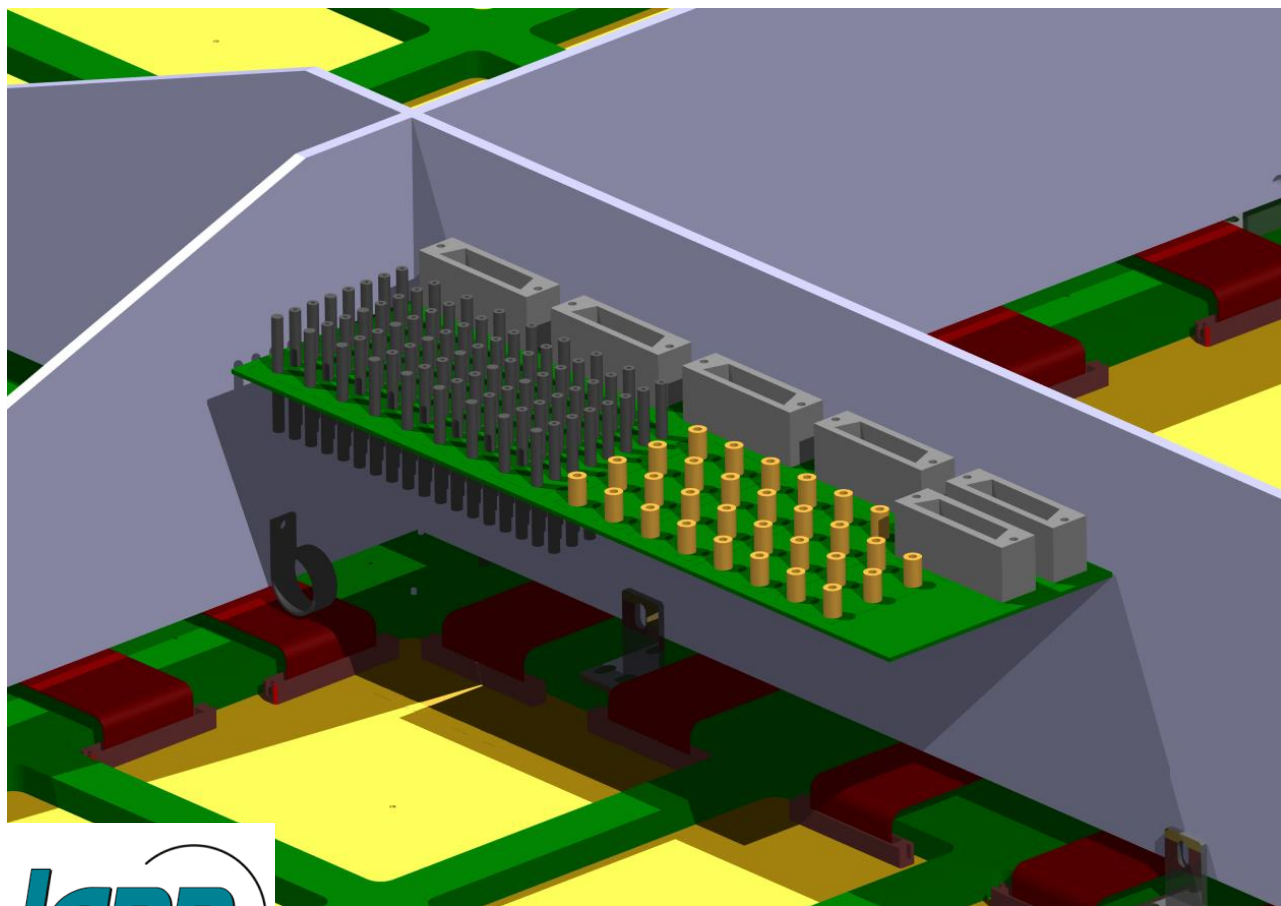
## Electrical Scheme CRP 6x6x6 m3 WA105

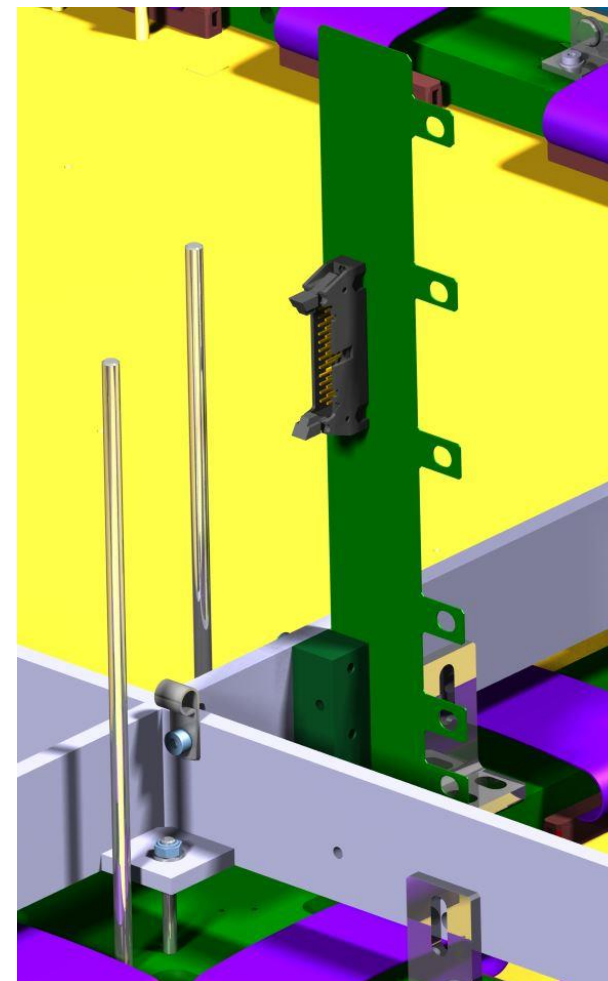
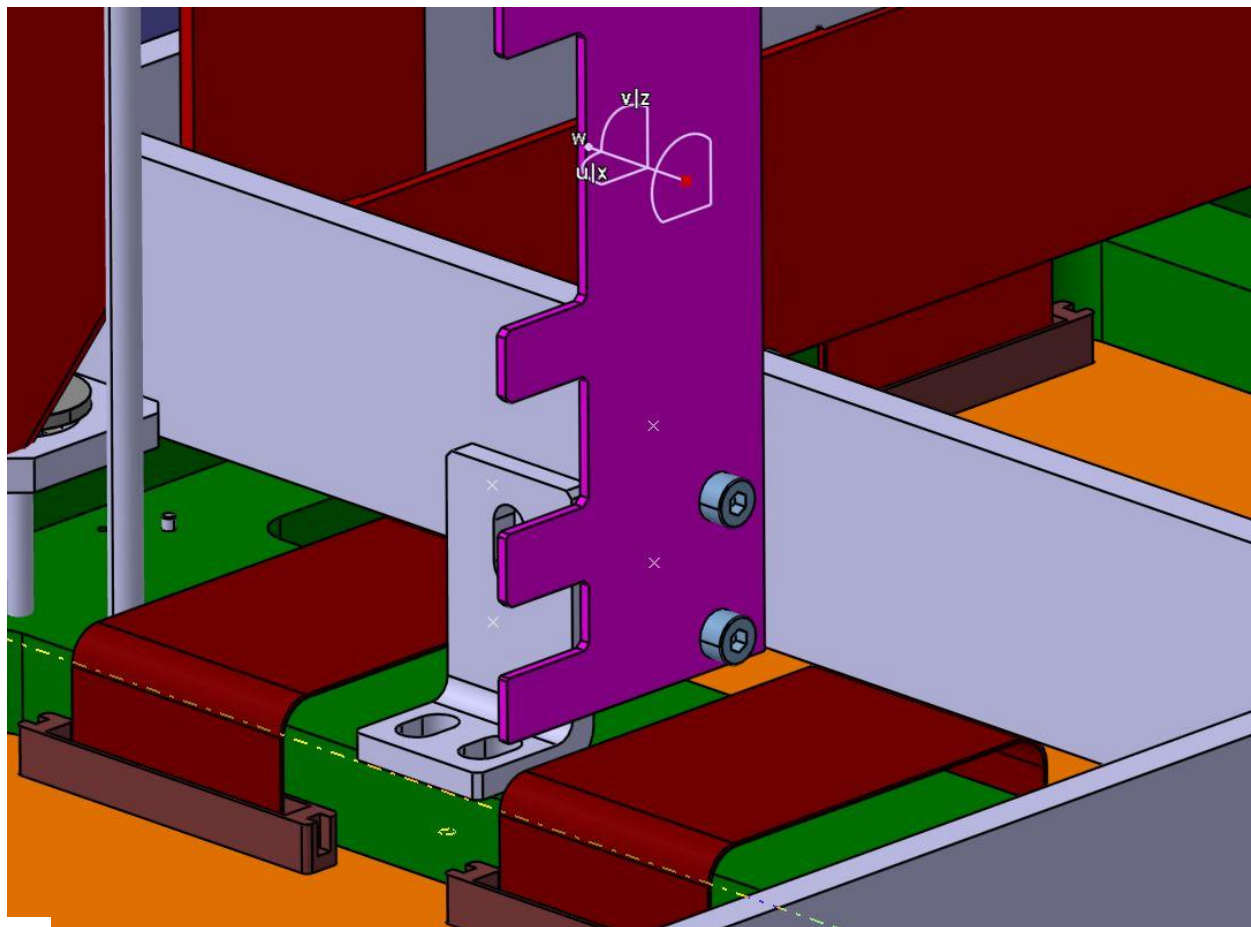


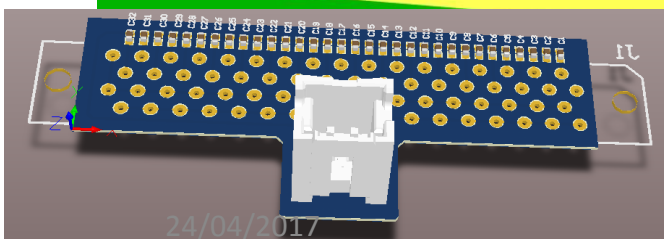
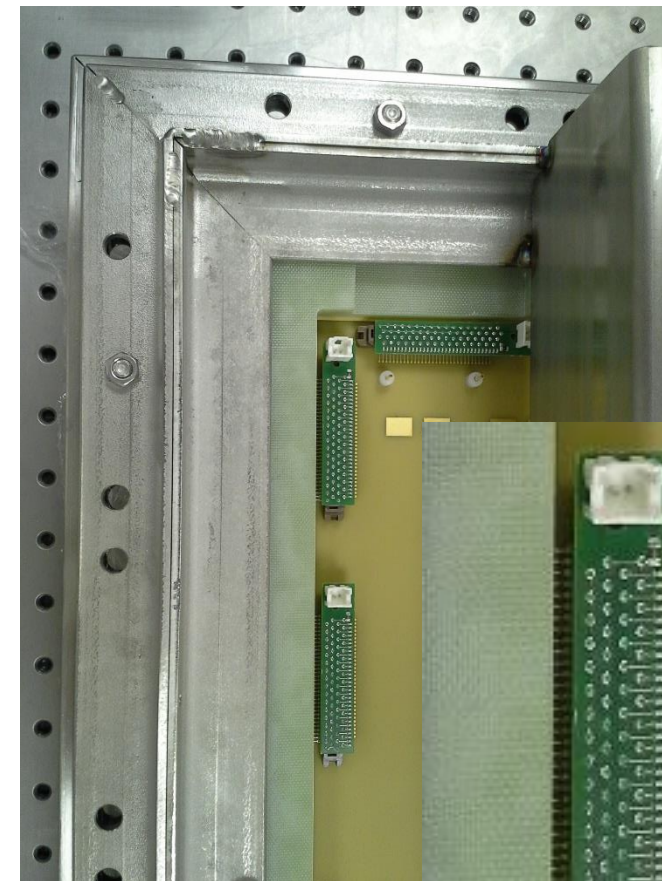
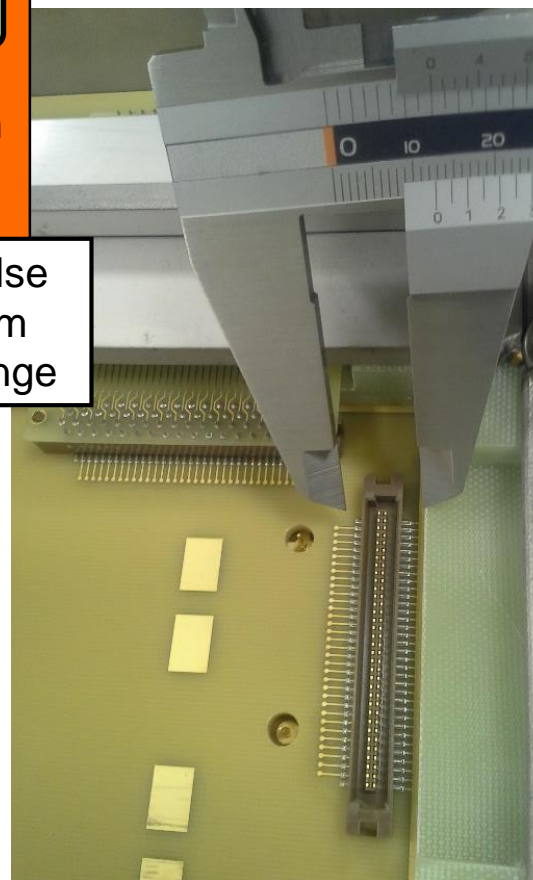
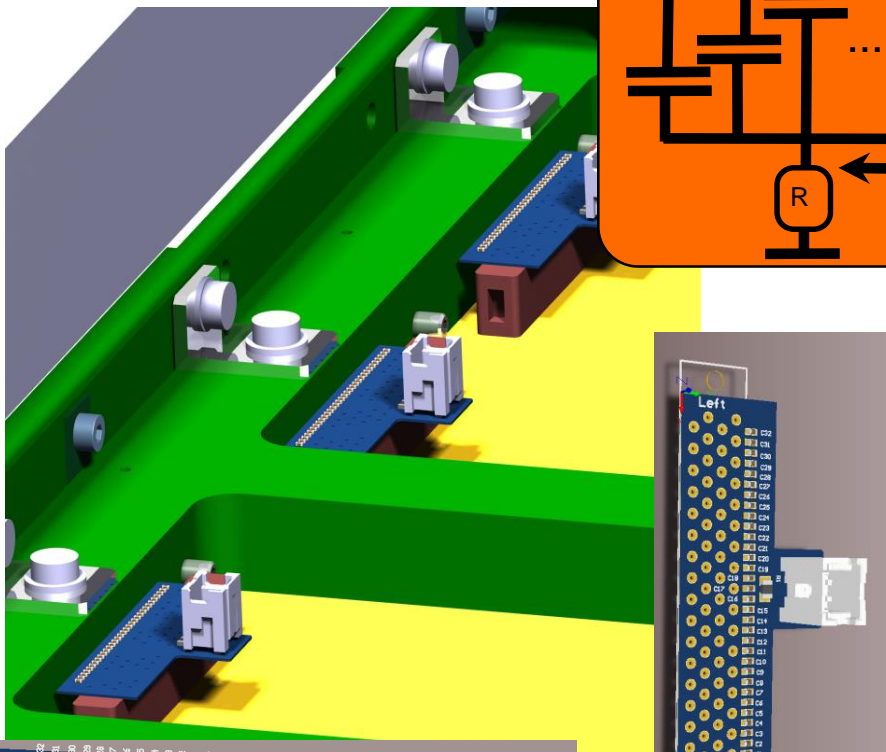
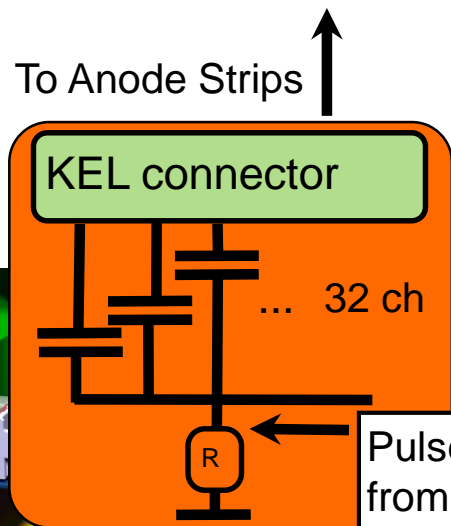
Elementary but comprehensive view of all the electrical parts on the CRP.

Important also to keep track of internal reference to GND.

WA105

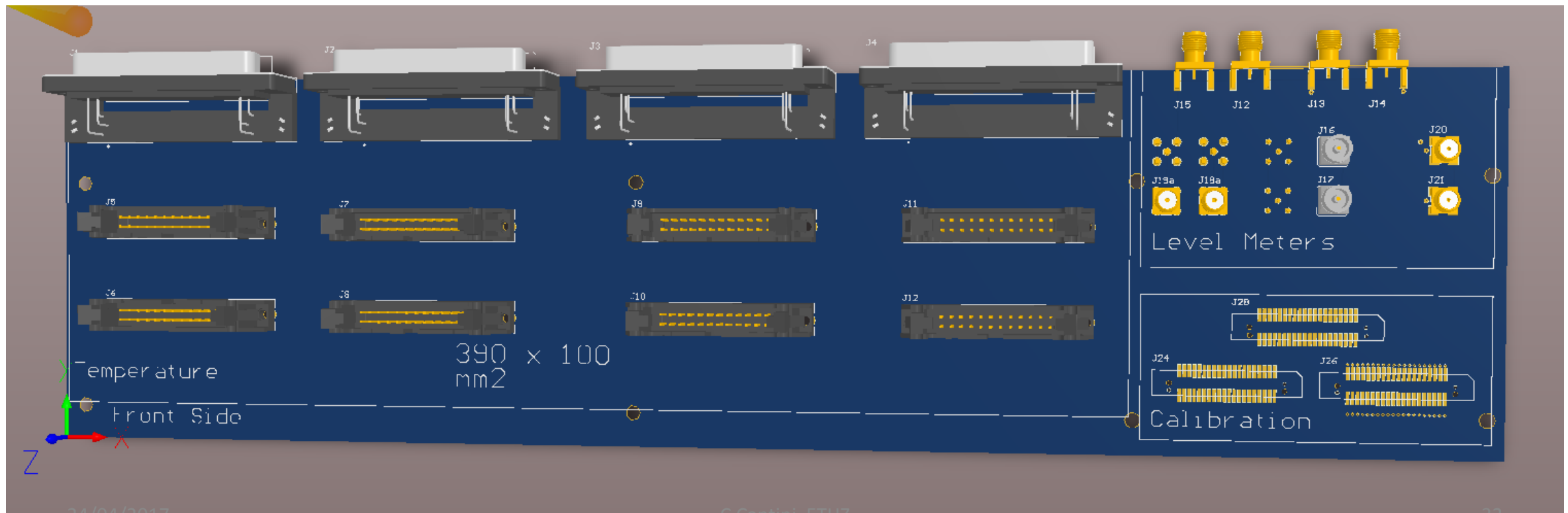






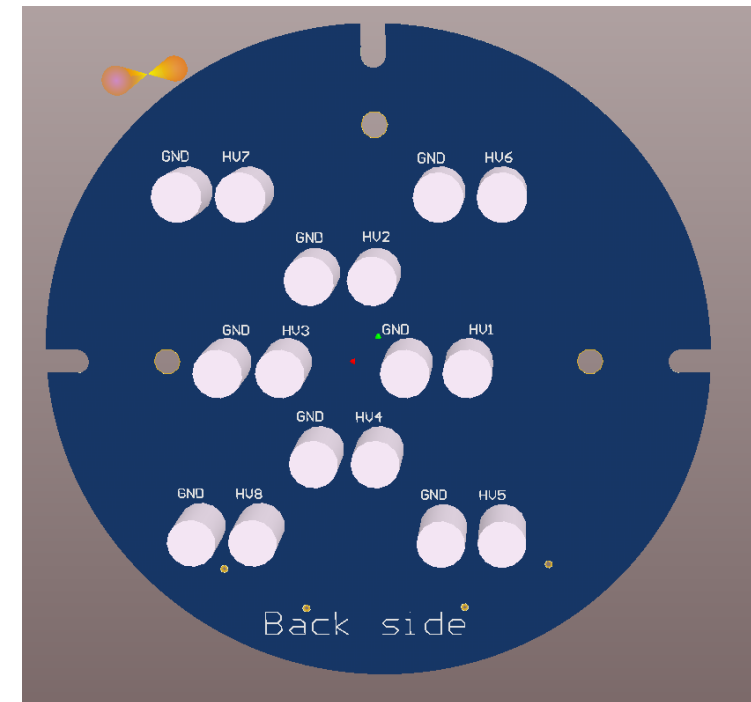
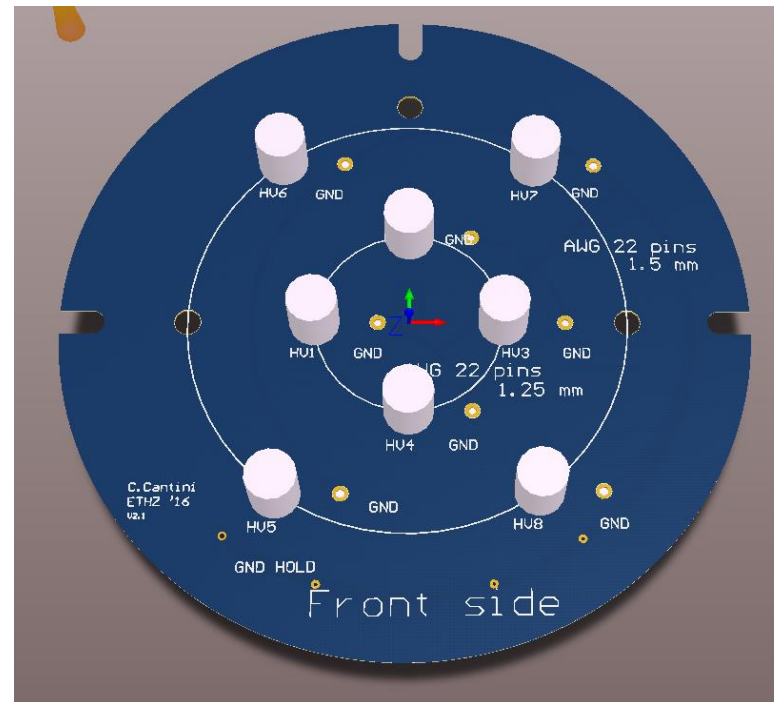
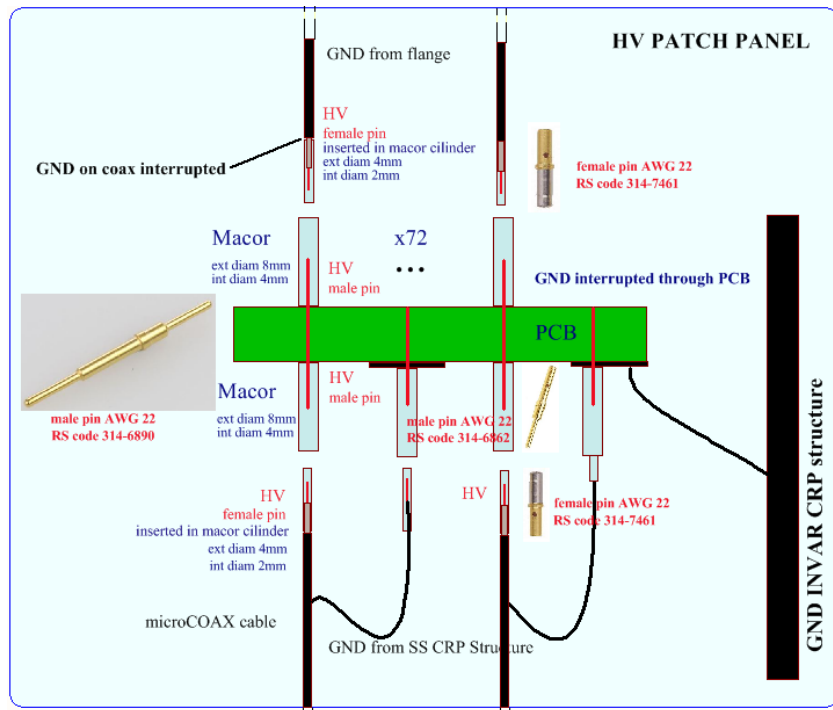
24/04/2017

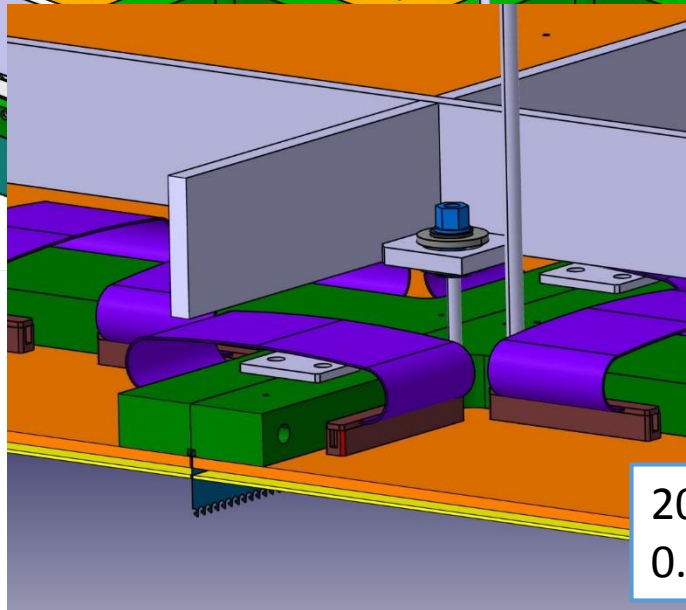
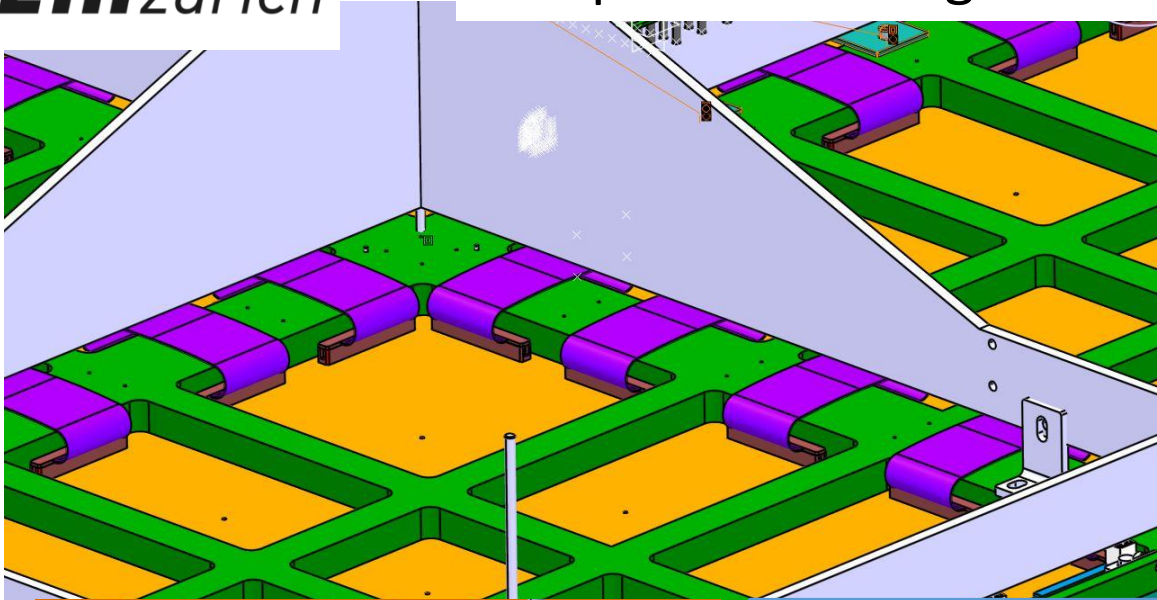
Prototype hereafter. Based on sensor\_list\_666, numbers of connectors may slightly vary.  
3M connectors matching Thermometers connectors, SUBD50 towards flanges  
Dimension 390x100 mm<sup>2</sup> – can be adapted as needed  
Fixation holes to match SS CRP structure



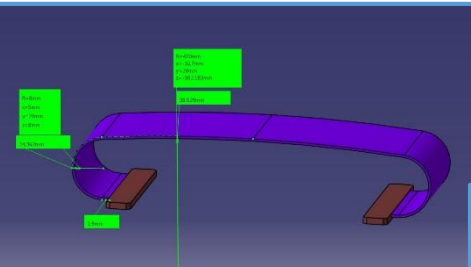


Prototype to test spark free connections in argon gas arranged in multipin  
 Makor cylinder technique – two macor cylinders inserted one into the other to provide isolation  
 Dimension here is 10 cm OD

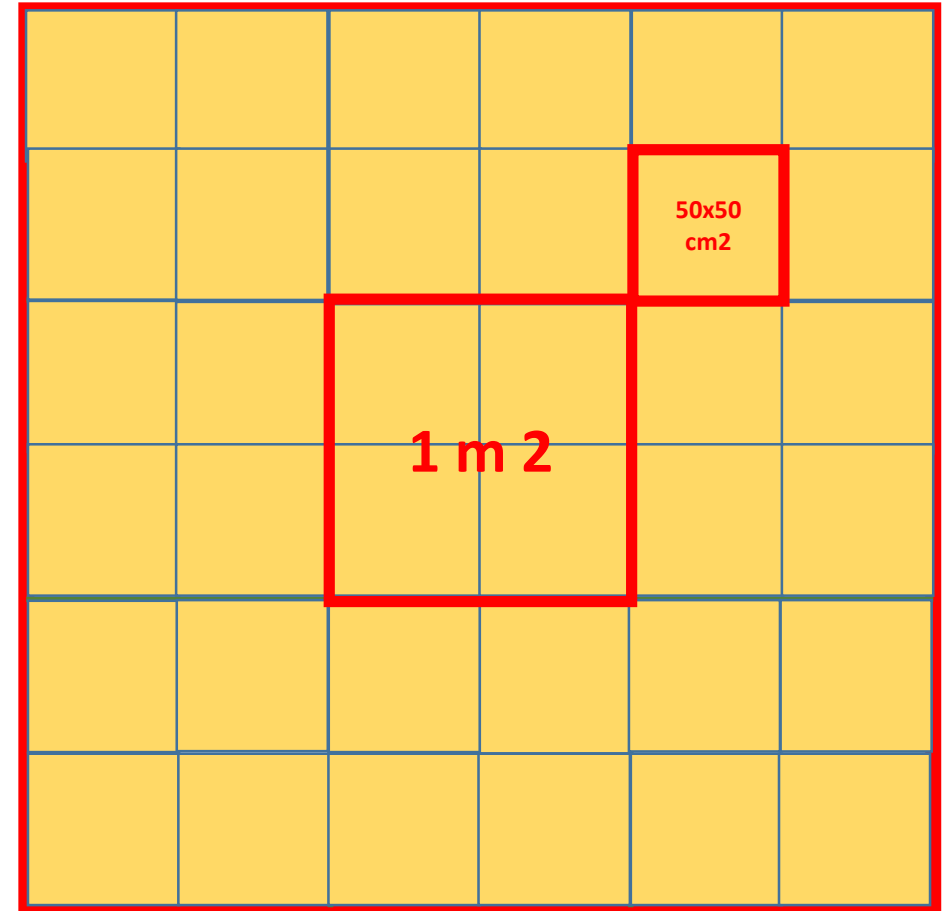




Bridge needed to electrically connect adjacent 50x50 cm<sup>2</sup> anodes



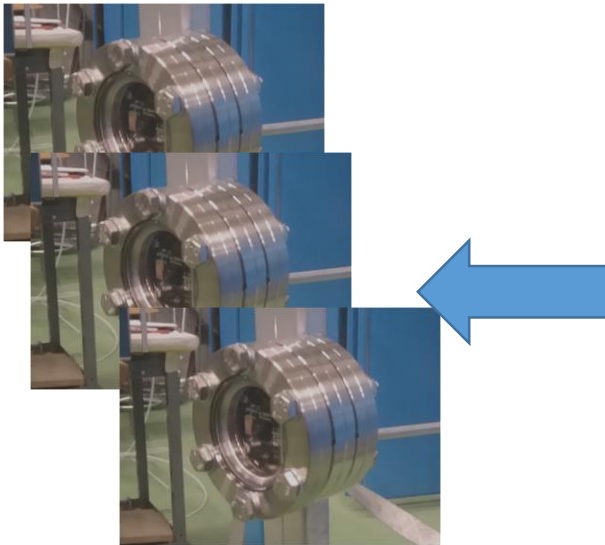
20 cm long flat cable 68c,  
0.635 mm pitch, 30 AWG



- 300 bridge per 9m<sup>2</sup> module needed
  - Several options under consideration – see backup
- 600 KEL 8925E-068-179-F (receptacles to be crimped on cable)
- 720 KEL 8913-068E/R-178MS-A-F (smd connectors for anode)



RaspBerry Pi and camera module  
- 15 pins cable connection



2 x 3 camera modules connected to the camera box



Camera box build for the Fermilab

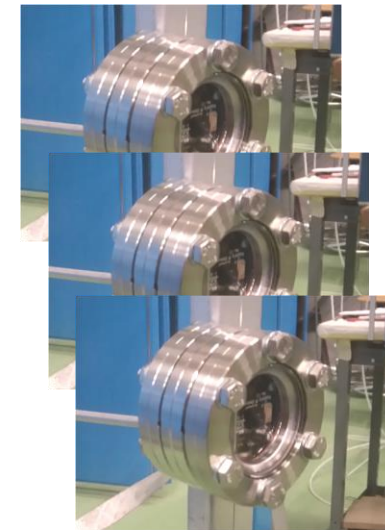


Box with :

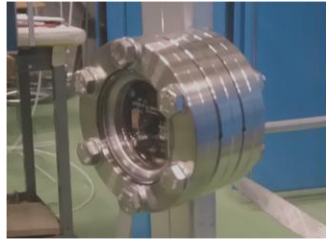
- Fan
- Ground electrical link
- 5V power supply
- Ethernet switch
- 6 x RaspBerry module V3
- Max length tested in between camera and RaspBerry : 8 m

Each RaspBerry module :

- HDMI output
- 2x USB output
- Ethernet output
- 16 Gb SD Card with Raspian Linux OS



# RaspBerry Camera in Liquid Argon during the CRP test

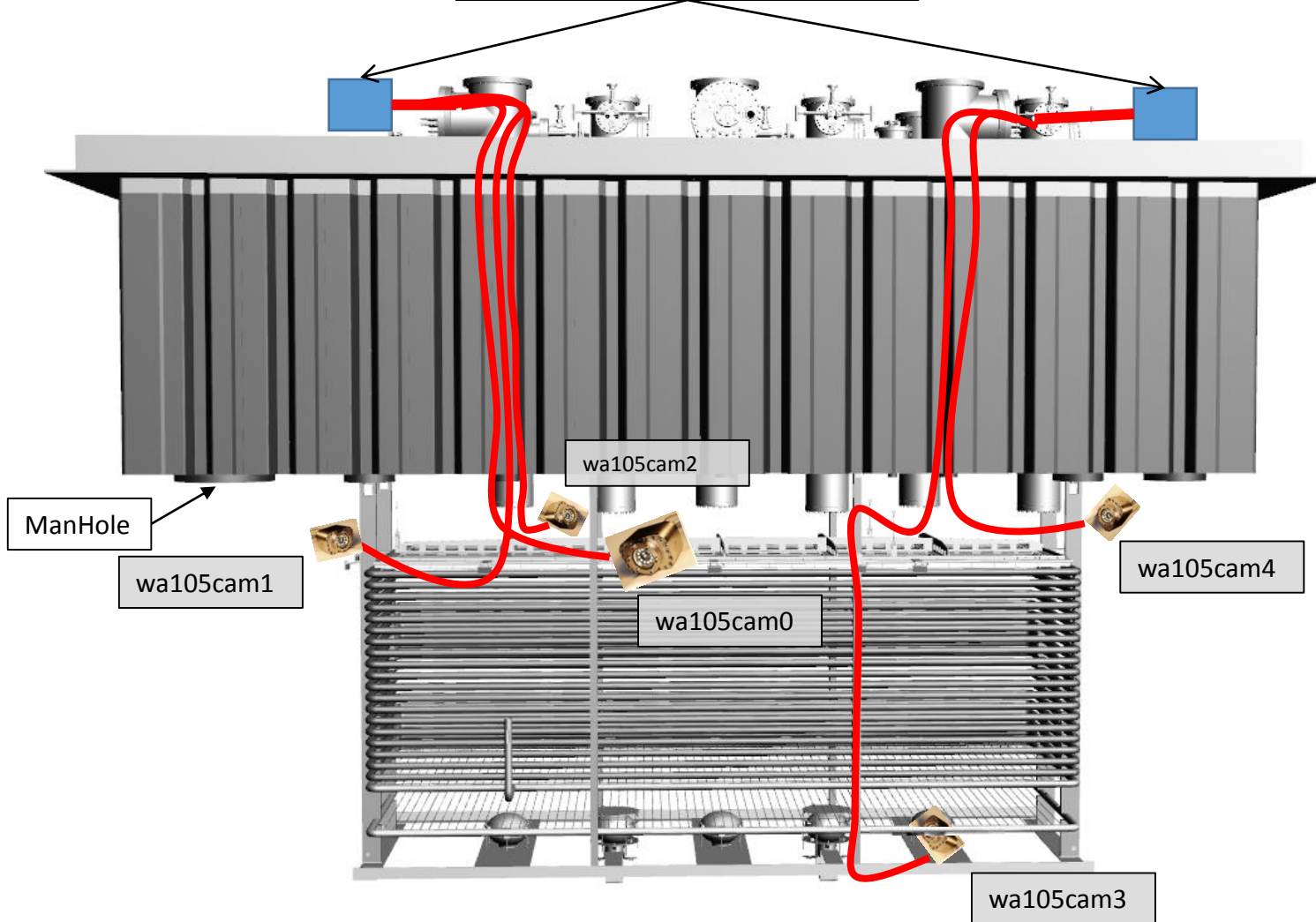


- Condition of the test :
- RaspBerry Pi close to screen
  - Camera module immersed in the liquid Argon
  - Camera checking below the CRP



- View from camera :
- Few ice block swimming in the Ar
  - Distance in between 10cm to 2 m

2 x RaspBerrys box connected with :  
 - ethernet cable  
 - 220V cable



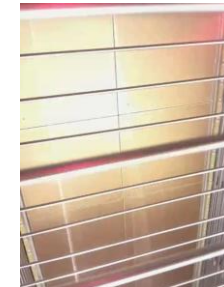
wa105cam0



wa105cam1



wa105cam2



wa105cam3

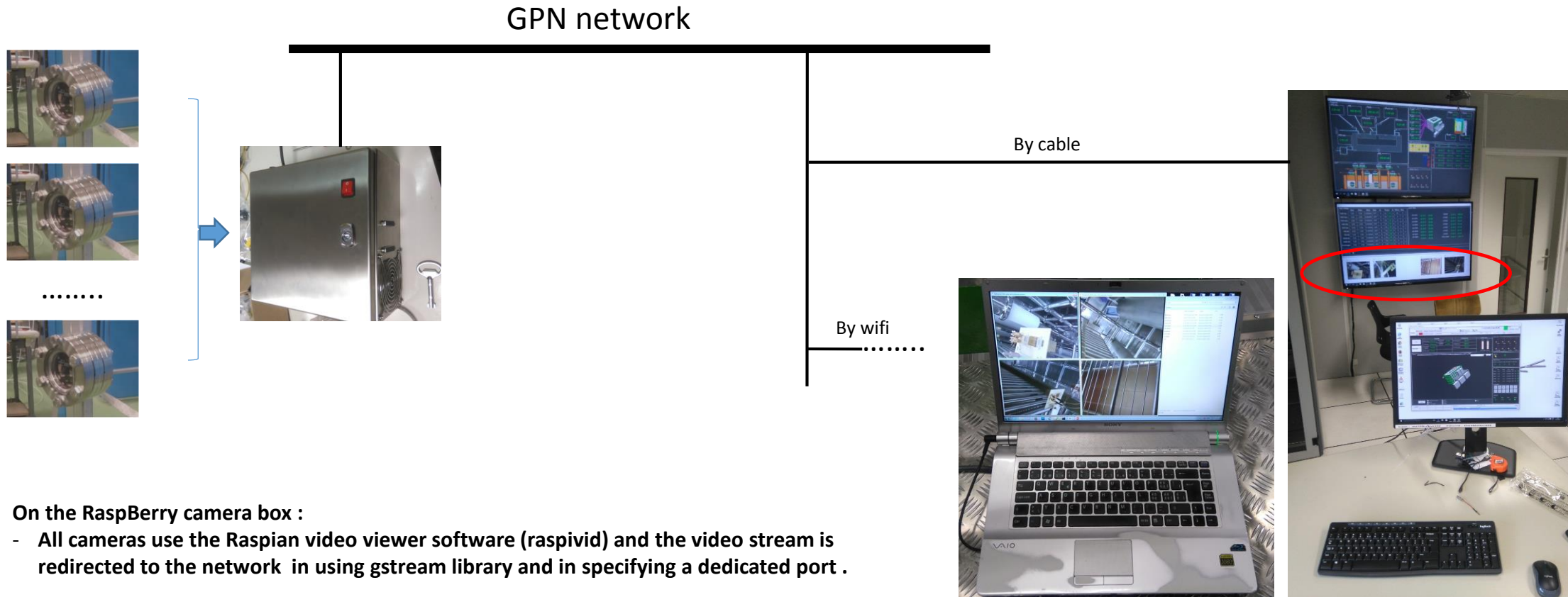


wa105cam4

4 cameras for the top in gaz Argon:  
 - one for each side  
 - one watching also the HV feedthrough  
 - ( 4 meters length cable )

1 camera for the bottom in liqAr:  
 - watching LEMs ( 6 meters length cable )

# Cryo - Cameras software streaming video



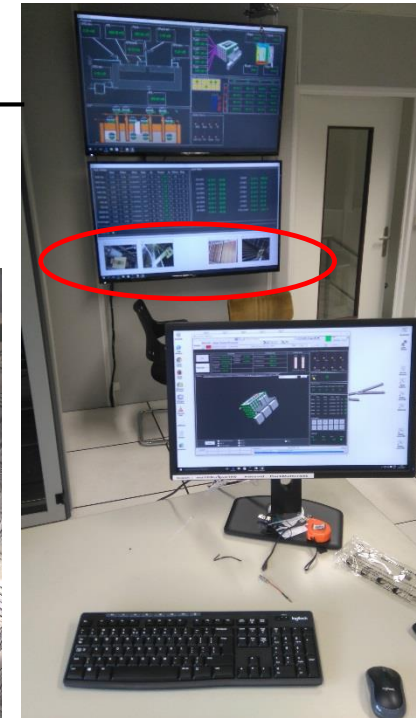
**On the RaspBerry camera box :**

- All cameras use the Raspbian video viewer software (raspivid) and the video stream is redirected to the network in using gstream library and in specifying a dedicated port .

**On computers :**

- In installing gstream library , any computers (windows or linux ) can be able to show all cameras with a correct fluidity . ( 10 to 25 frames/sec )

<https://gstreamer.freedesktop.org/>



3x1x1 Control room