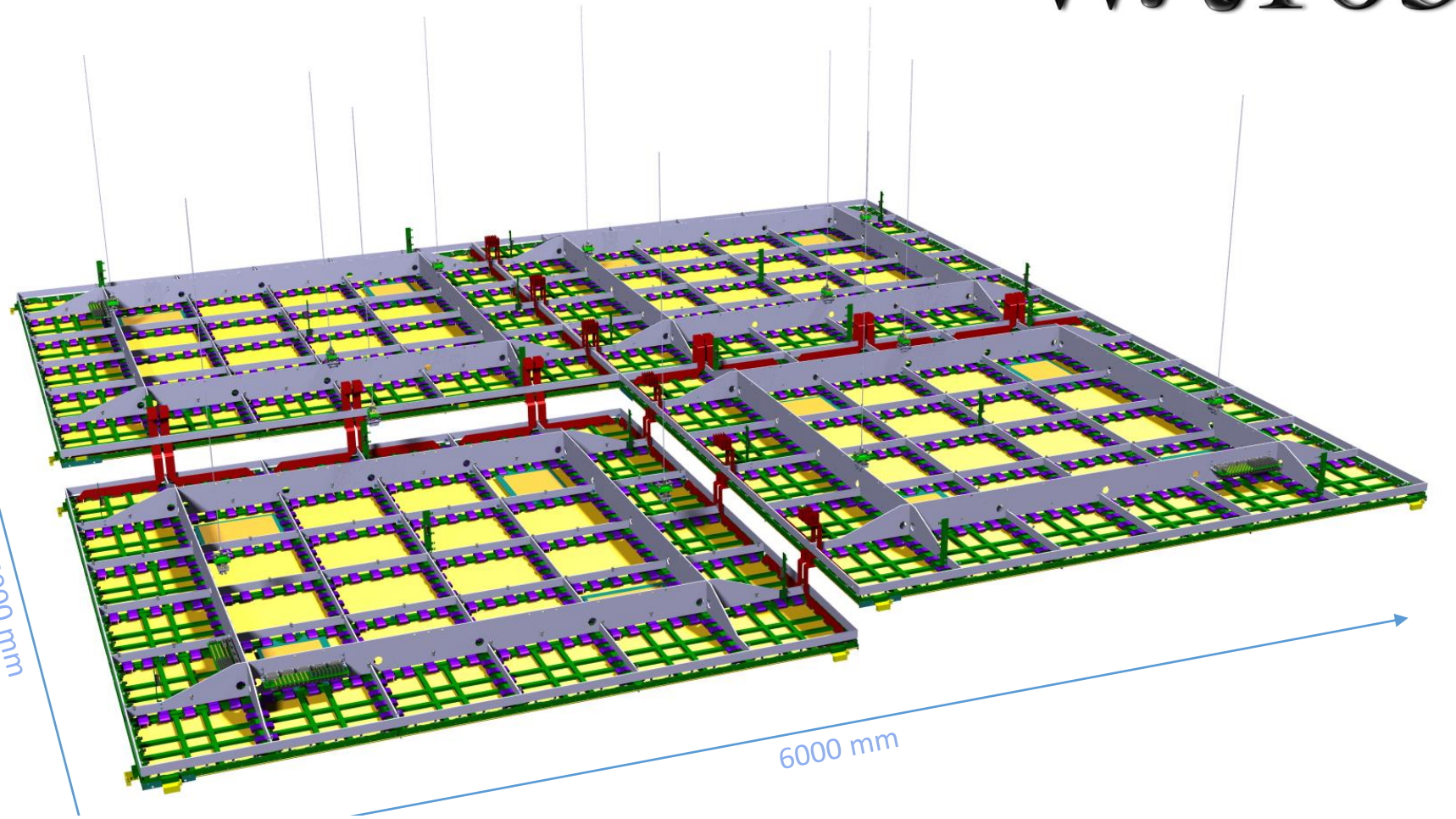


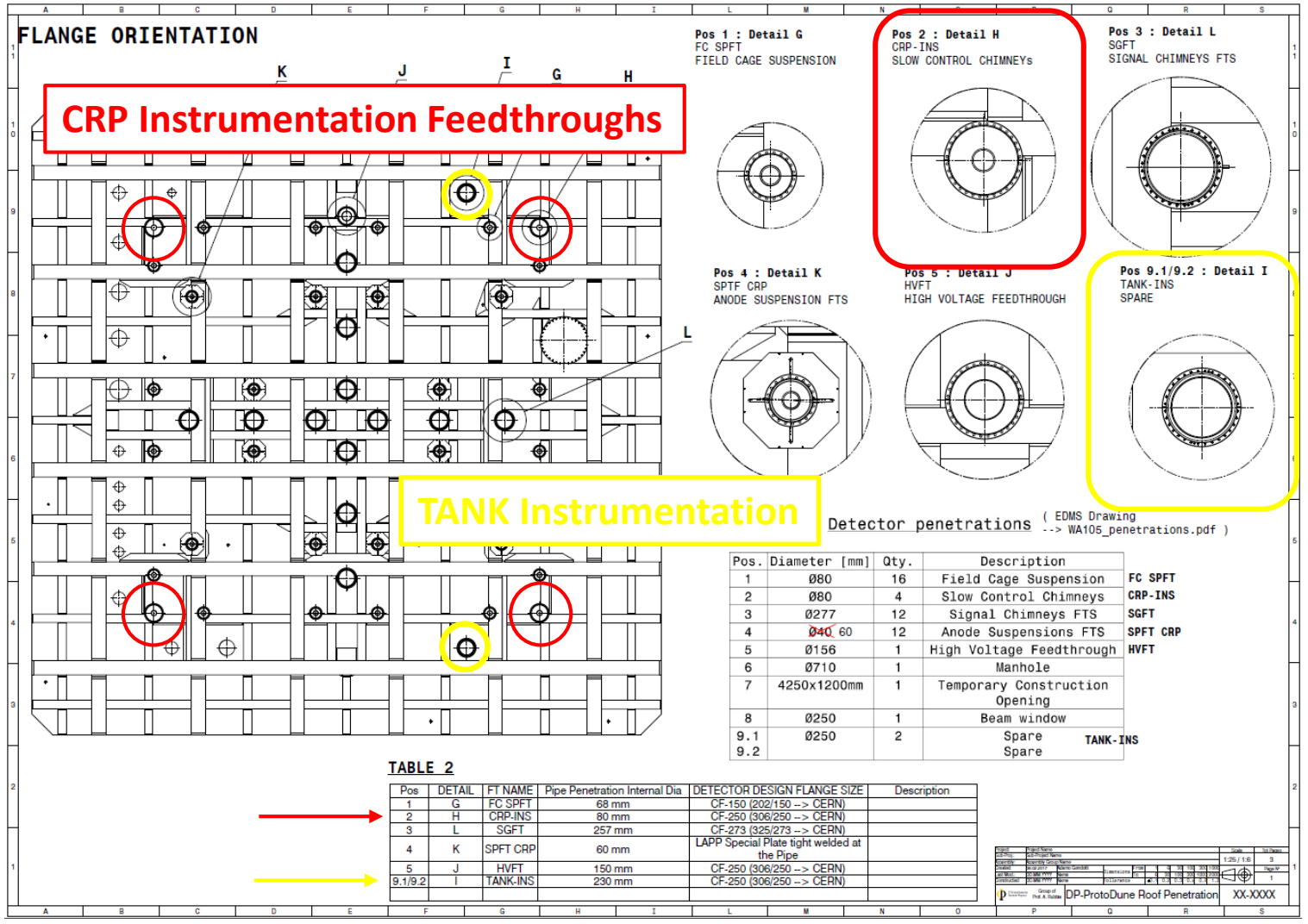
DP ProtoDUNE Technical Design Review 24th April 17

C.Cantini on behalf of ETHZ Group

Design of instrumentation for the 6x6x6 m3 Detector DP ProtoDune

- 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
- Purity Monitor

CRP Instrumentation Feedthroughs



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 Charge Readout Plane
- 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 6x6x6 m3 Detector – INSTRUMENTATION FLANGE WA105

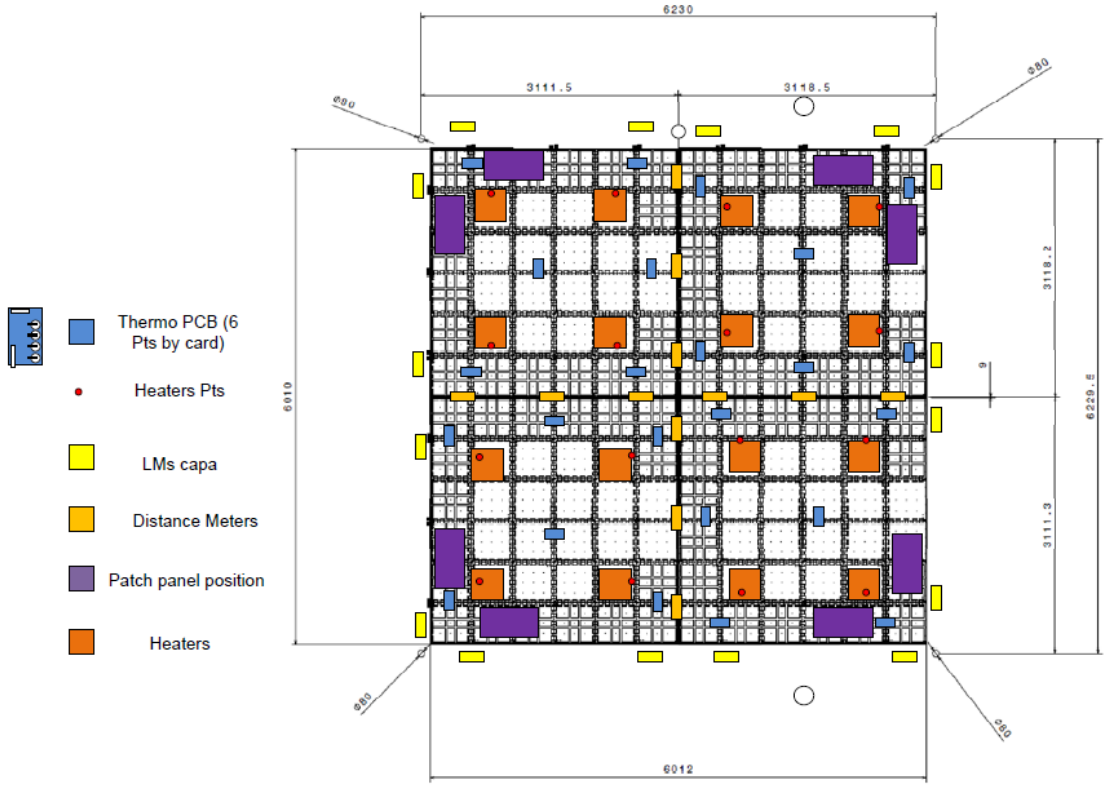
			SENSOR -> PATCH PANEL						PATCH PANEL -> FLANGE			
	Sensors/Items	**No. Items per CRP module**	**Cables**	**CODE**	**No. of cables**	**Diameter**	**Connector on patch panel IN**	**Patch Panel**	**Connector on patch panel OUT**	**Cables**	**CODE**	**Flanges**
x4	Thermometers (6 Pts)	6	3M 50 way Twisted Ribbon Cable, 1.27 mm pitch, AWG 28	RS 111-8900	3	63.5mm	SUBD 50 pins		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	Patch Panel 1	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		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	Patch Panel 2	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

List of sensors for 6x6x6 m3 Detector – TANK INST FLANGE

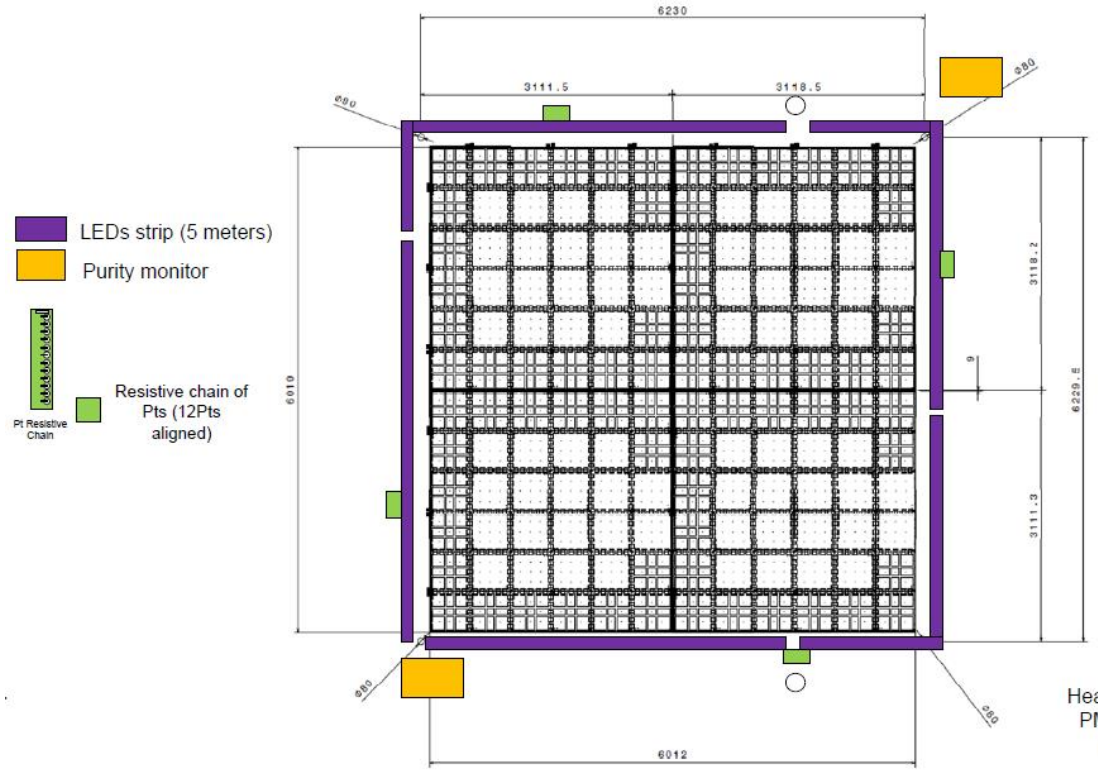
	Sensor/Item	No. Items per Flange	Cables	CODE	No. of cables	Diameter	Connector on Flange
x2	Chain of Pts (2 composed by 12 Pts)	24	3M 50 way Twisted Ribbon Cable, 1.27 mm pitch, AWG 28	RS 111-8900	2	63.5mm	2x SUBD 50 pins
TANK_INS_1, TANK_INS_2	Purity Monitor	2	KAPW50ohm	KAPW50	3	3x2.27 mm	6x SHV
	PMTs	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			

Distribution of instrumentation inside vessel

CRP INS flange

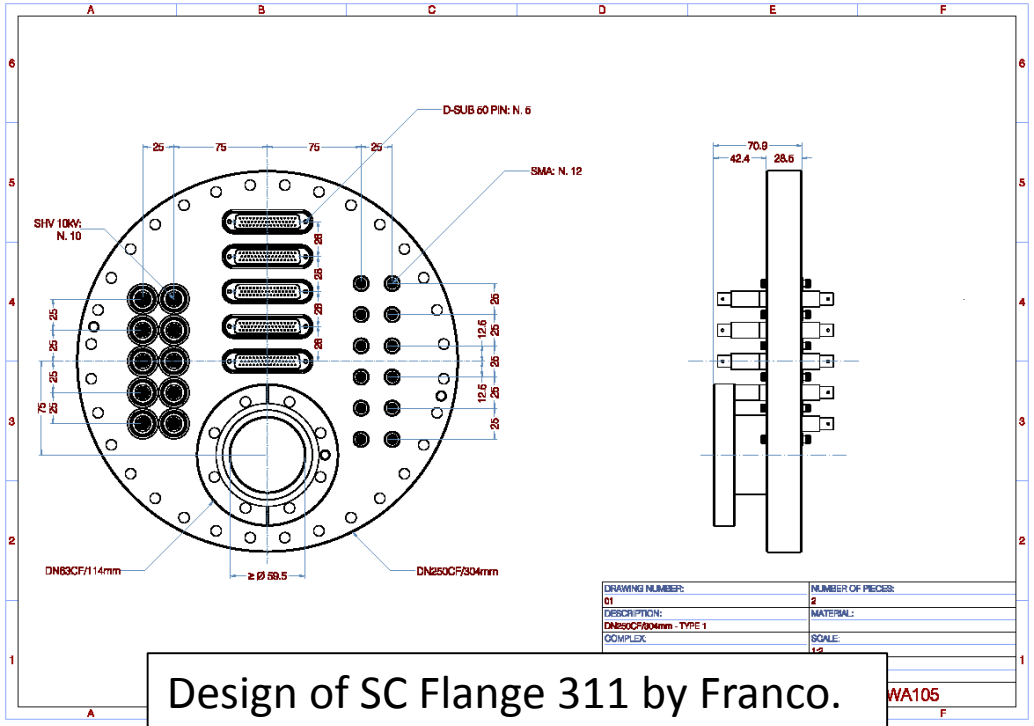


TANK INS flange



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

CRP INS Flange



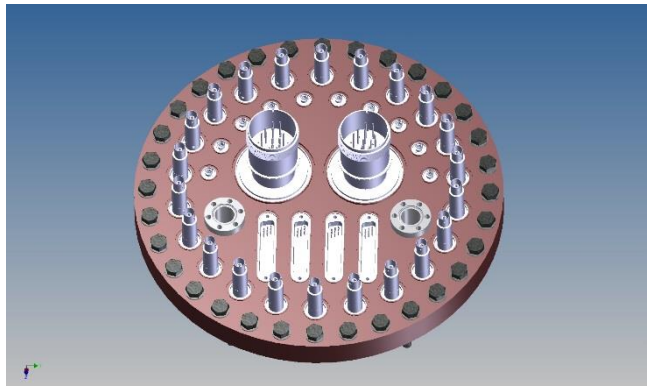
Design of SC Flange 311 by Franco. Number of connectors on CRP INS will be similar to the ones for 311 Detector.

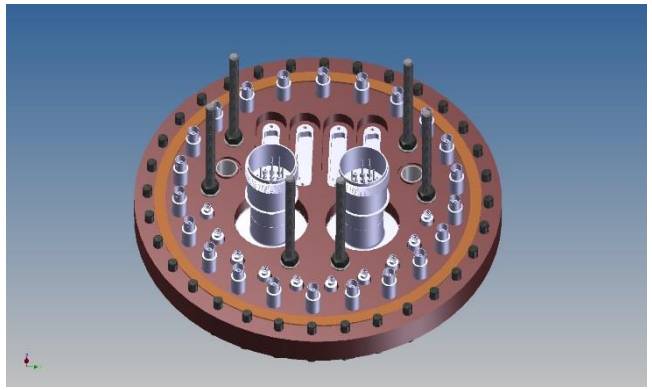
CRP INS flange dedicated to:

- 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.

TANK INS Flange

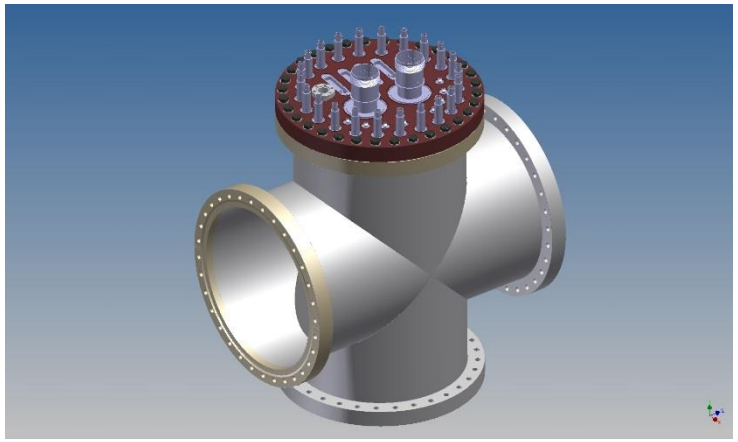




Design by Roger Haenni, Bern Group

TANK INS dedicated to:

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

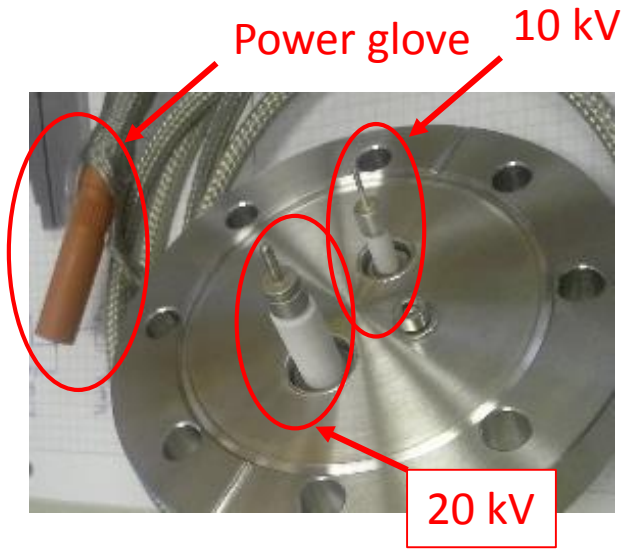


Design foresees a cross CF250 on top cap also there.
Plenty of room for all the connectors required for our sensors in the vessel.
We know already all the weldable connectors needed and thanks to previous experience we can now implement improvements at the level of stress release system or automated system to check remotely insertion of cables.
Preliminary design is now under internal review.

Middle high voltage for LEM biasing

- 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

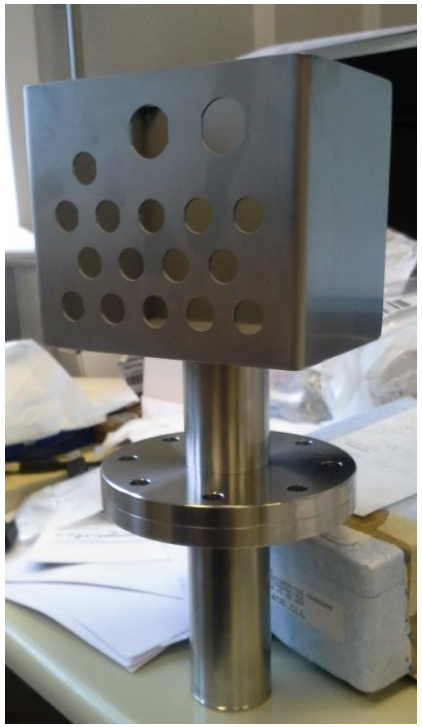


Test flange, prototype with 2 custom made single sided connectors:

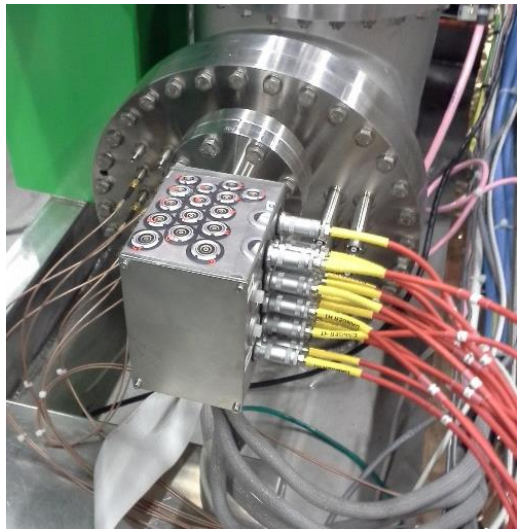
- Special silicon cable (”power glove”).
- Only available for 20 kV version.
- Tested successfully up to 20 kV in Air, GAr and Vacuum.
- A first batch of custom made coaxial thinner cables ordered, delivery time is 10 weeks from now.
- As soon as tested the design of the flange can be finalized.
- After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

Middle high voltage for LEM biasing

- 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*cm3/s)
  - Perfect dielectric performances, no leak current (less than 1 nA) above 10 kV
  - Reproducible results
  - Still a possibility for 6x6x6 Detector



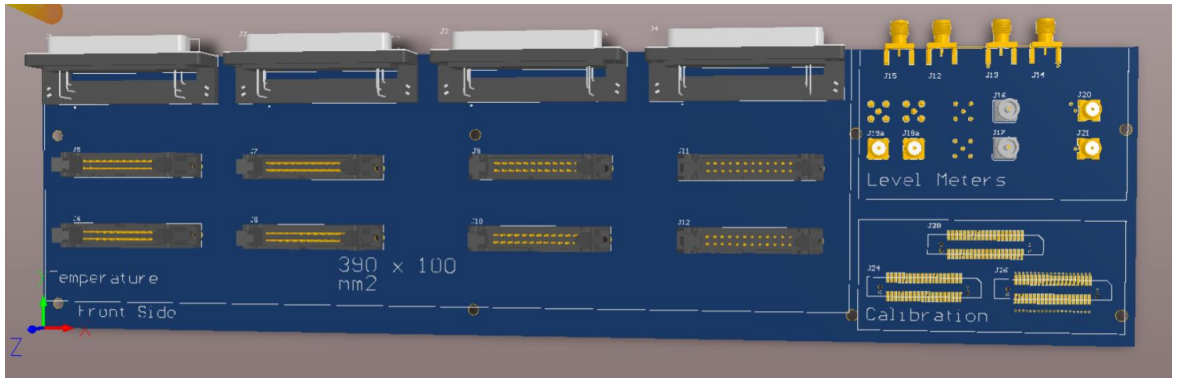
- We will start the production of a unit with 80 channels in May to cover the need of one CRP module – 2 months of production time.
- If meanwhile commercial solution outlined in previous slide will be proven then we can switch to it



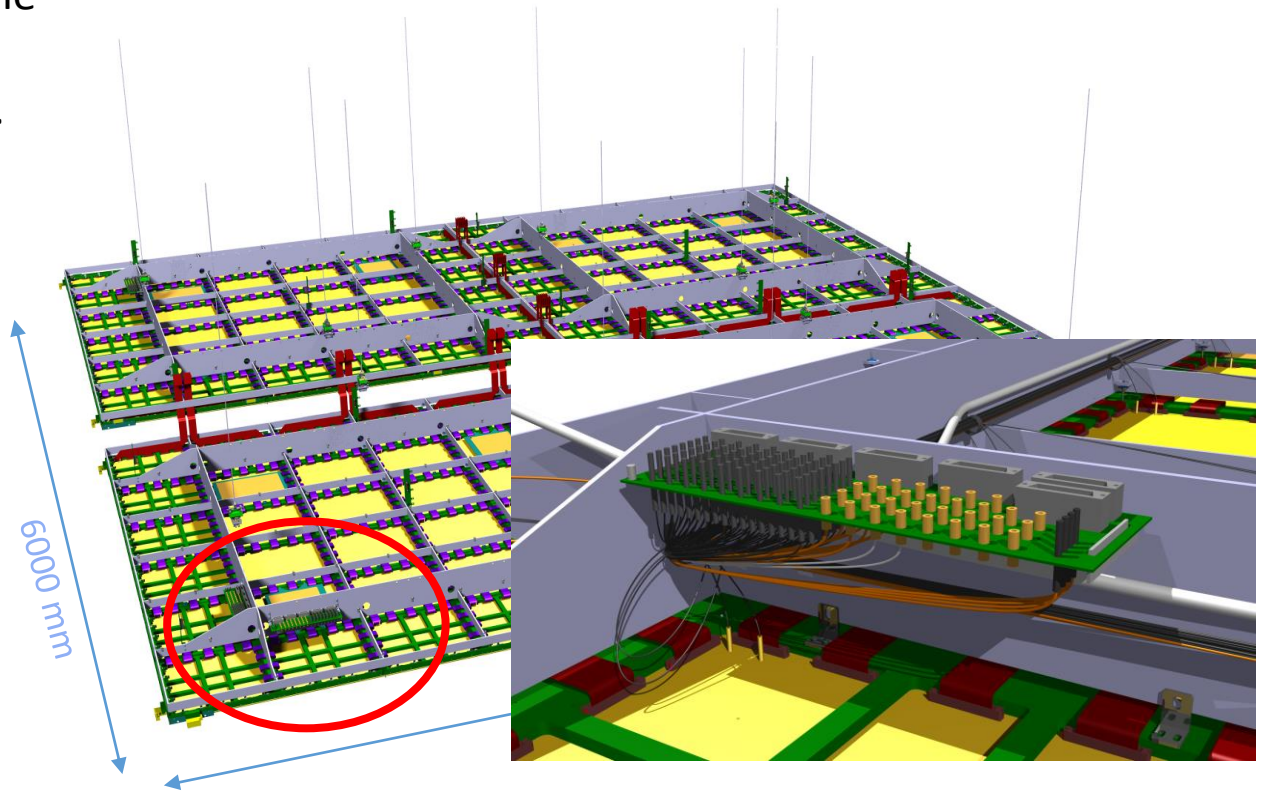
- LEMO HV panel mounted connector
- Kapton isolated coax KAPW50OHM
- Bi-component epoxy glue

A patch panel as interface in the vessel for sensors

- 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



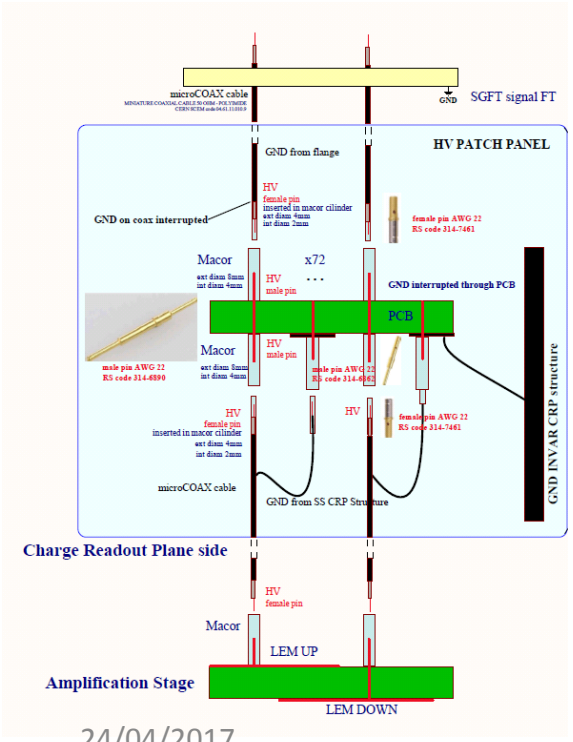
- Cabling in collaboration with Confectronic, Allectra and other workshops at CERN for custom made assemblies.

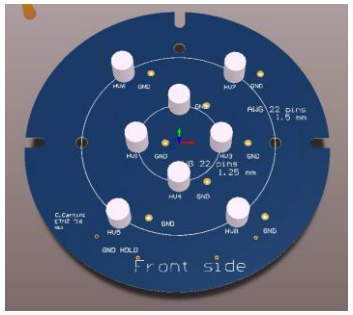


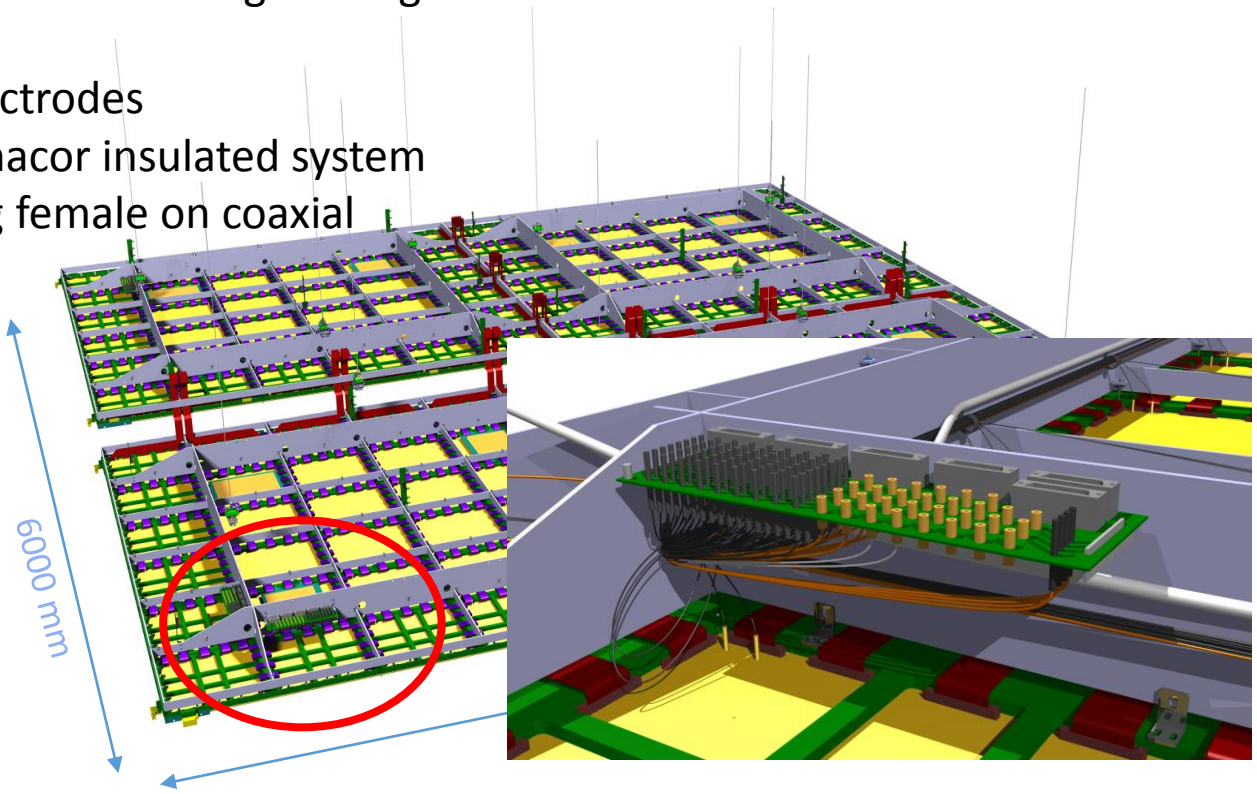
- Ready to be produced
- 3 weeks time from order to assembly
- 1 prototype ready mid May

A patch panel as interface in the vessel for HV

- 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



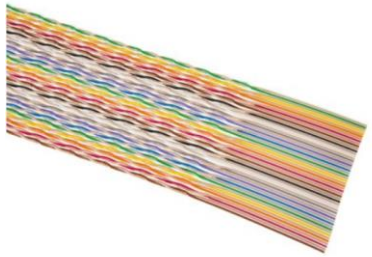




- Tested in argon gas
- Same idea used to connect to high voltage the LEM electrodes
- Tested in 311 Detector and previous ETHZ experiences

- 6 weeks time from order to assembly
  - Custom made macor cylinders
  - Standard PCB
- 1 prototype ready mid June

Temperature probes



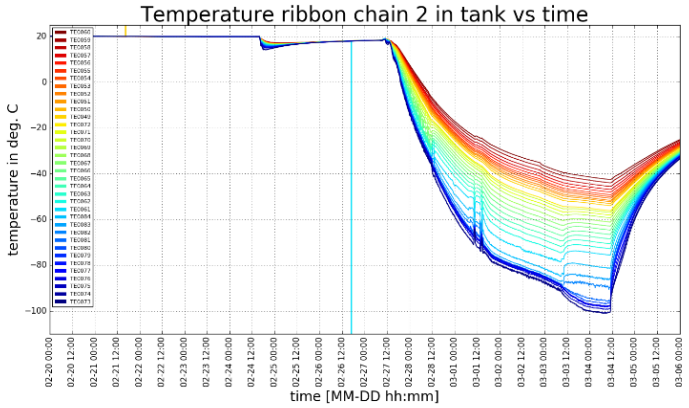
- 311 Detector has o(90) temperature probes distributed in main vessel, soldered on ribbon cable, spaced by 4 cm or arranged on “thermometers”
- 311 Detector has 45 temperature probes in the insulation space
- 4 wires method everywhere
- Pt interfaced to NI9219 modules outsides in racks

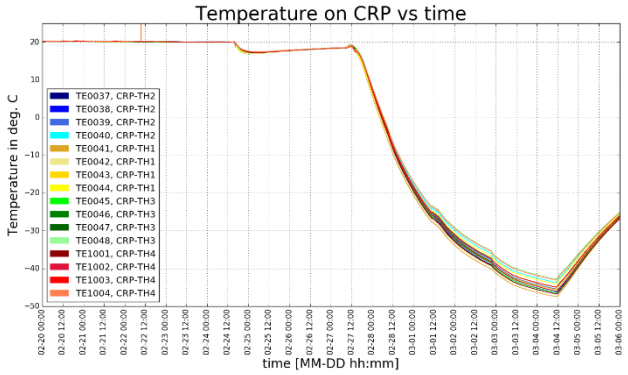
- 666 Detector o(150) temperature sensors, distributed between CRP INS flange and TANK INS flange
- Proposing same platinum sensors, same company (IST) - demonstrated <0.1 K error at TLAr, CLASS Y resistors

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

Temperature probes



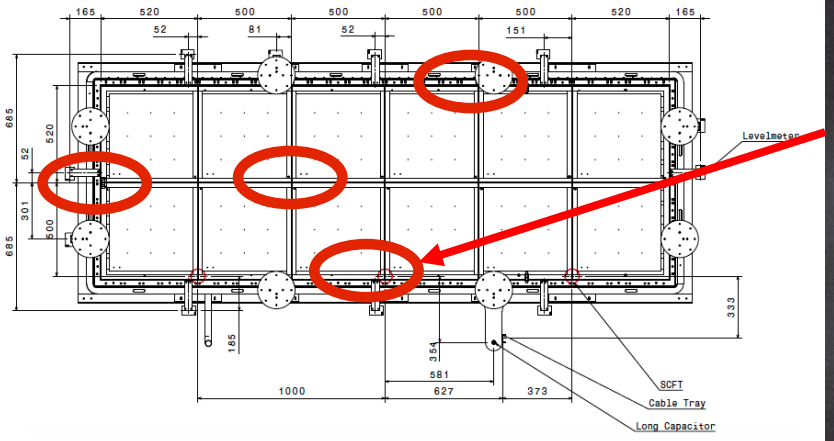


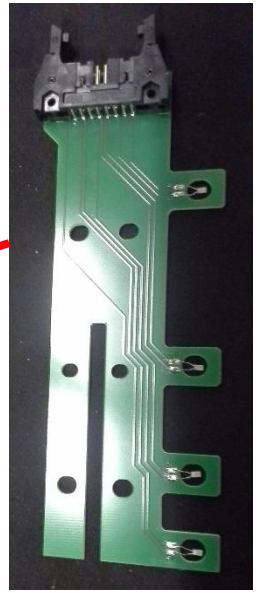
Thermometers 311 Det: 4 Pts
4 installed on CRP in gas phase

In 311 detector we monitor the temperature:

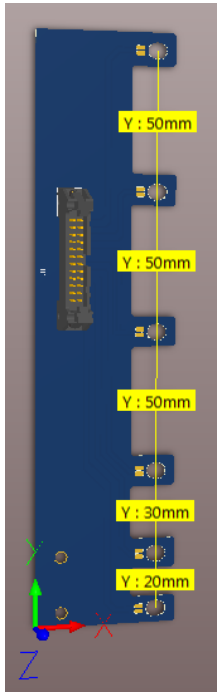
- Along the entire drift length (resistive level meter)
- On top of anode at different heights thanks to several PCBs where 4 Pt sensors are soldered (thermometers).

For 6x6x6 m3 a new version with 6 Pts was designed.
It has also 4 resistive chains (12 Pt each) connected to TANK INS along the 6 metres drift. They are hosted into cable trays





Thermometers 311

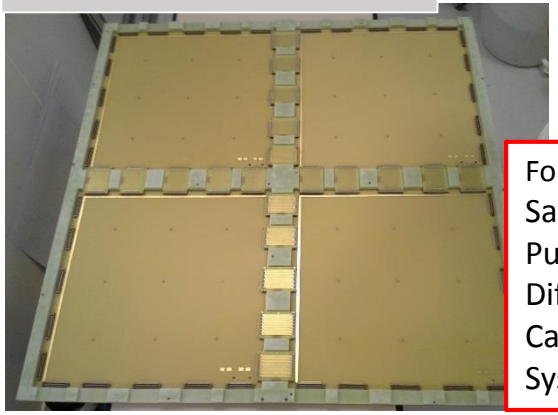


Thermometers new version: 6 Pts

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

Pulsing system for electronics

CRP 1m2 assembled



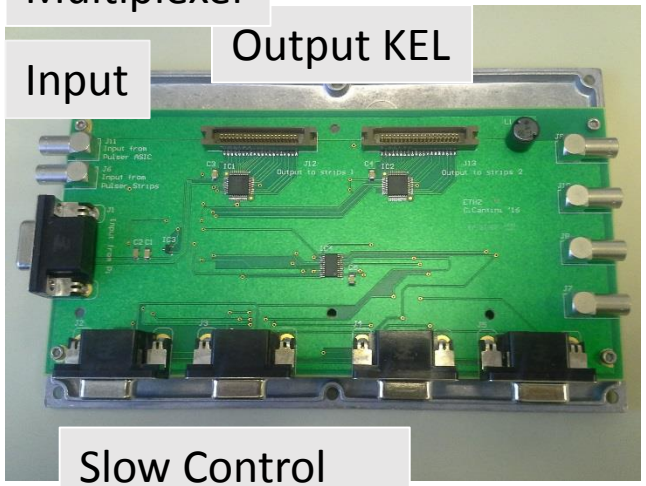
For 311 Detector:
Controlled distribution of pulses throughout the entire CRP thanks to a I2C controllable multiplexer.
Good way of testing continuity also.
It connects to a flange on slow control chimney 2, then each twisted pair connects to a set of serial 32 SMD Capacitors plugged on a connector on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

For DP ProtoDune:
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.

Multiplexer

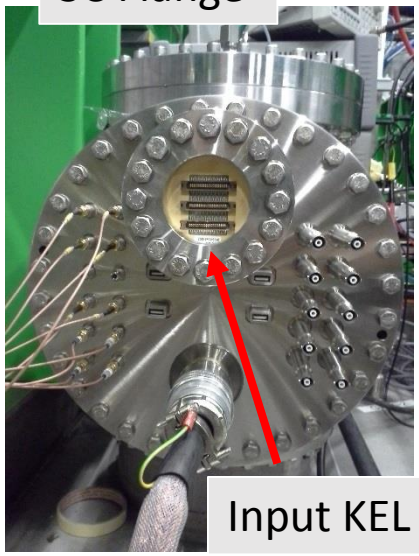
Output KEL

Input



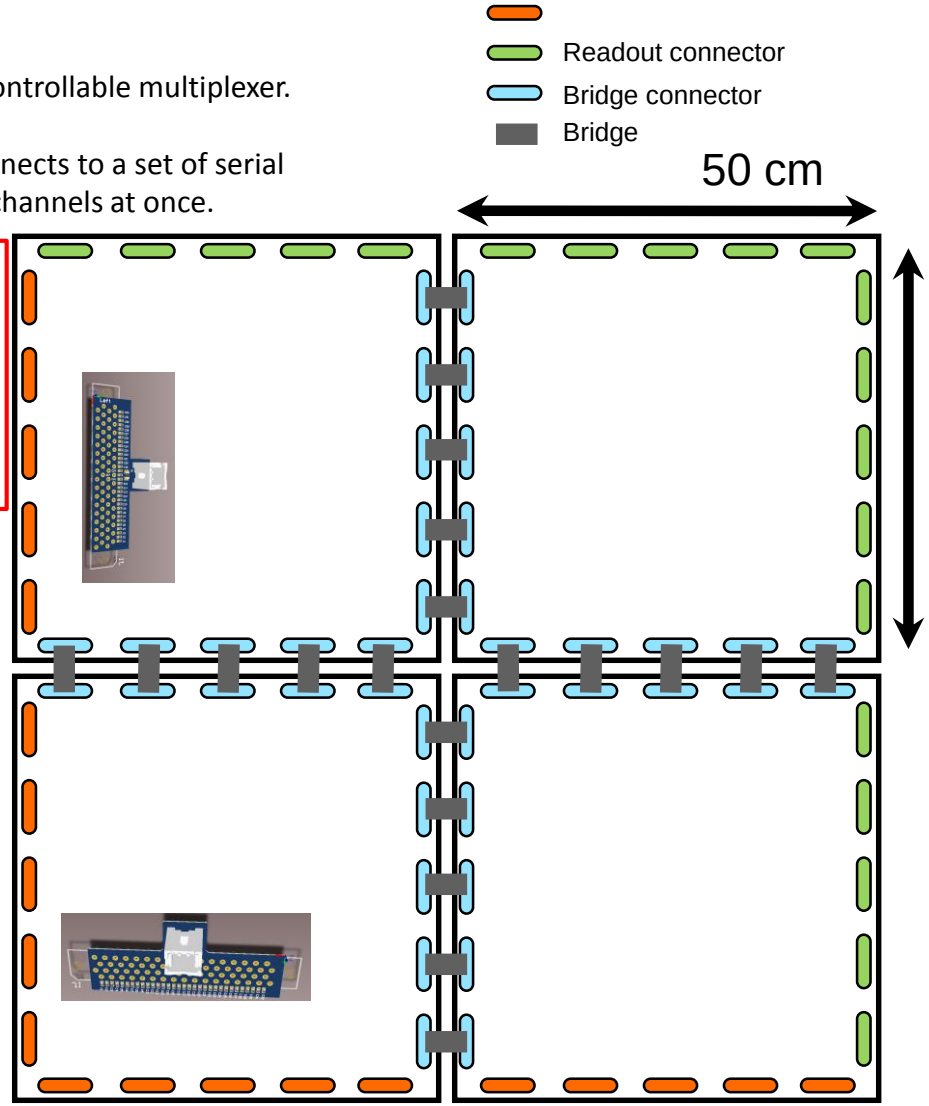
Slow Control for electronics

SC Flange



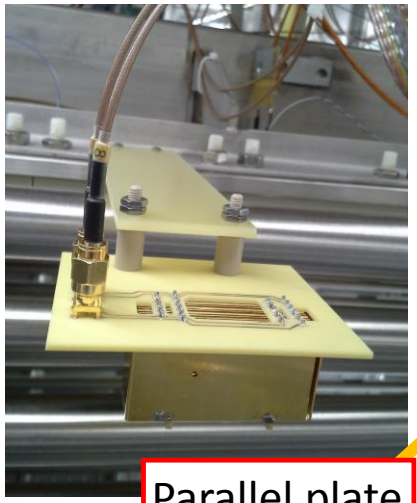
Input KEL

PCBs

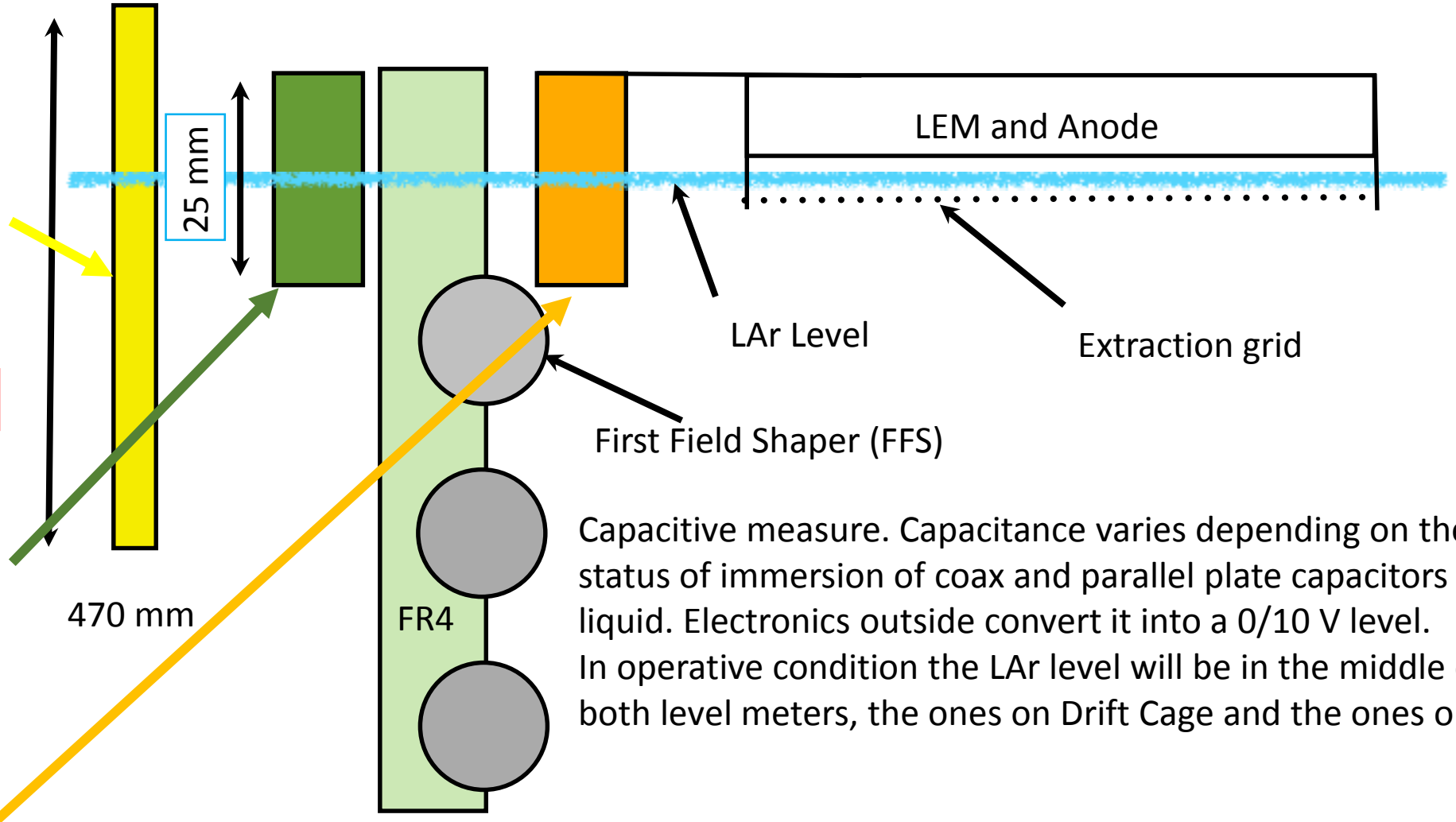


Liquid argon level meter in 311 Detector

Coax

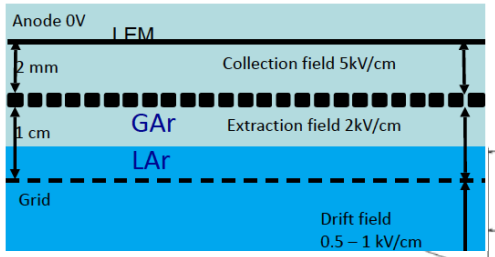


Parallel plate

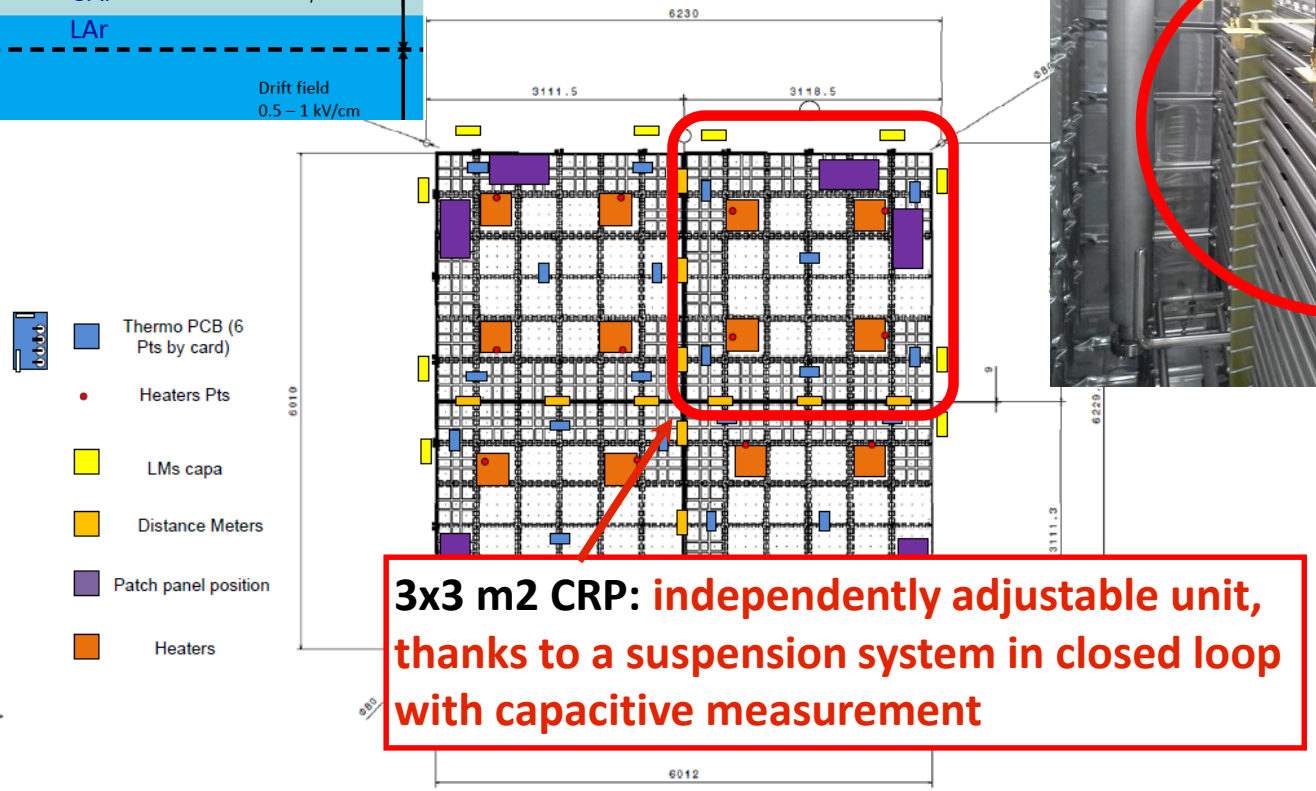


Capacitive measure. Capacitance varies depending on the status of immersion of coax and parallel plate capacitors into liquid. Electronics outside convert it into a 0/10 V level.
In operative condition the LAr level will be in the middle of both level meters, the ones on Drift Cage and the ones on CRP.

Position of level meter in 666 Detector

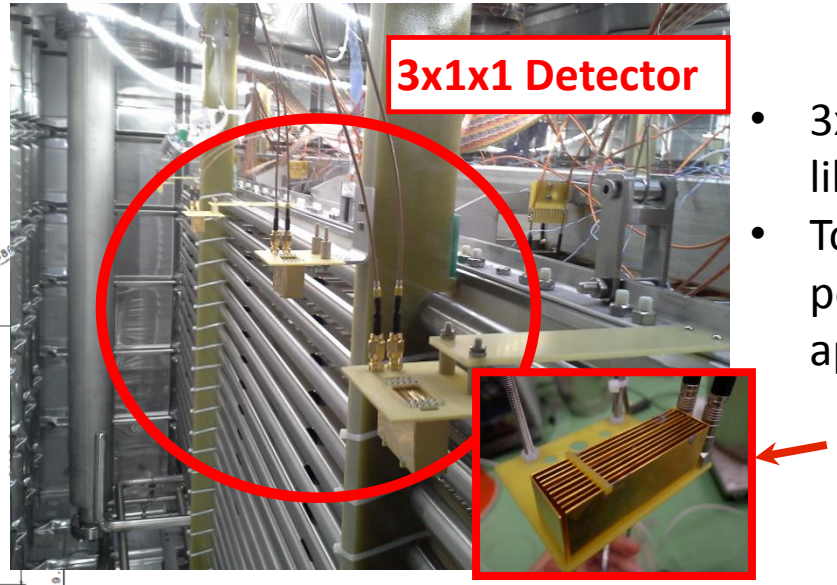


LEM



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

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



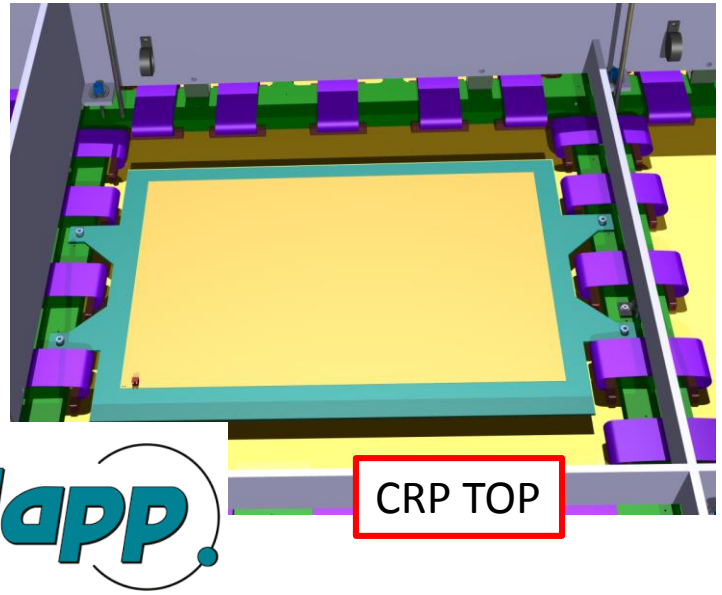
- 3x3 modules will have 4 LM like those on edges
- To have finer resolution on CRP position a complementary approach is proposed

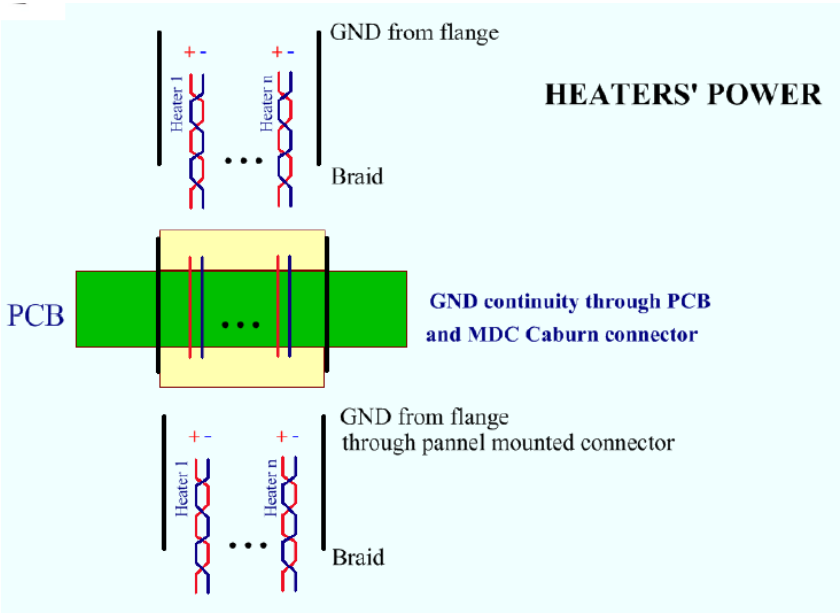
We can measure **capacitance between Grid and LEM's bottom electrode**, varying with the position of CRP across LAr level.

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

Heaters

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

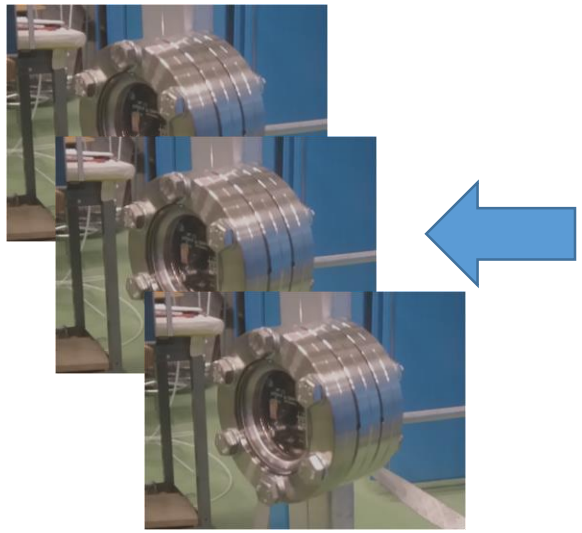
- Caburn multi pin panel mounted connector
- Shielded cable
- Connected internally to CRP INS flanges
- Same connectors for LEDs power on TANK INS flanges

Cryo - Cameras - hardware

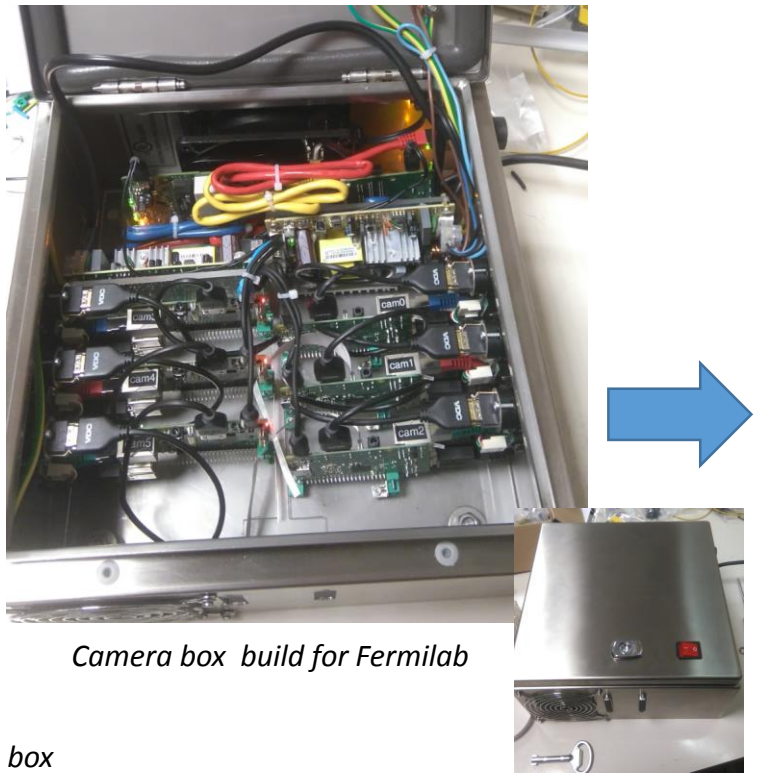
Box with :
- Fan
- Ground electrical link
- 5V power supply
- Ethernet switch
- 6 x RaspBerry module V3
- Max length tested in between camera and RaspBerry : 8 m

Each RaspBerry module :
- HDMI output
- 2x USB output
- Ethernet output
- 16 Gb SD Card with Raspian Linux OS

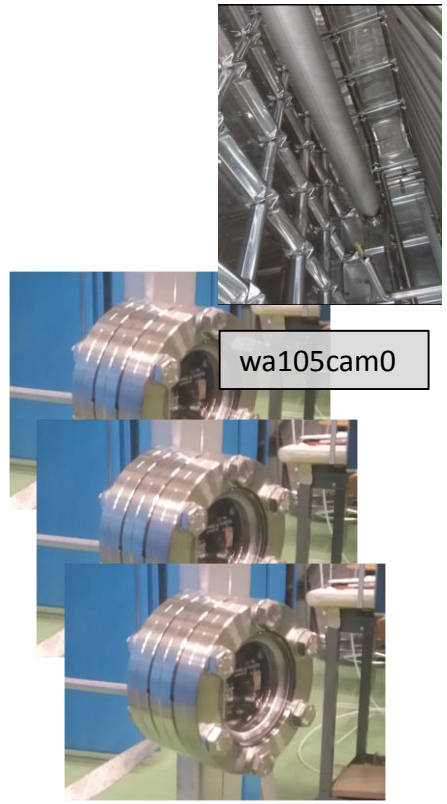
RaspBerry Pi and camera module - 15 pins cable connection



2 x 3 camera modules connected to the camera box



Camera box build for Fermilab



wa105cam0

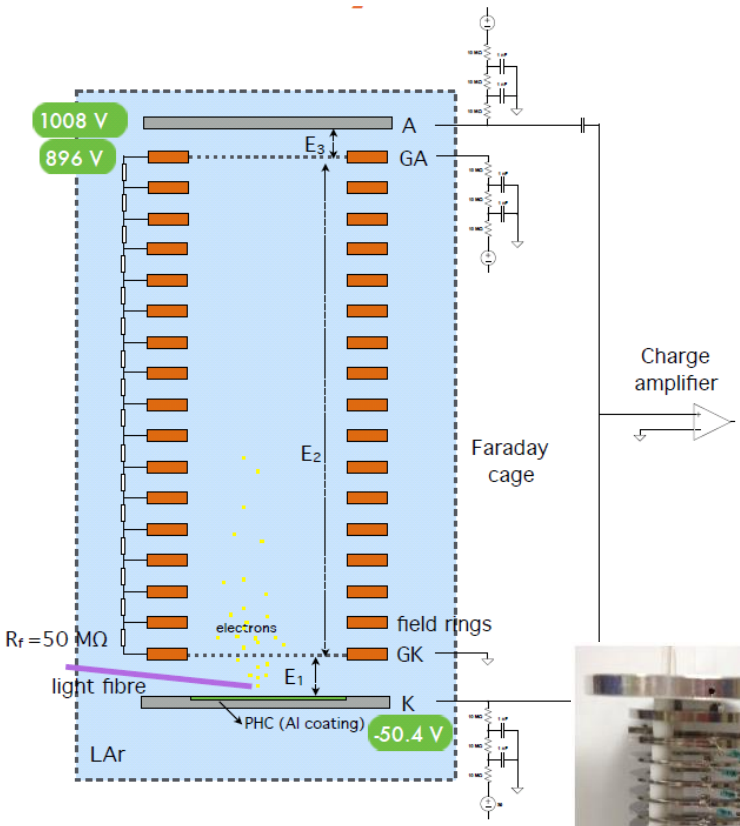
wa105cam1

wa105cam2

wa105cam3

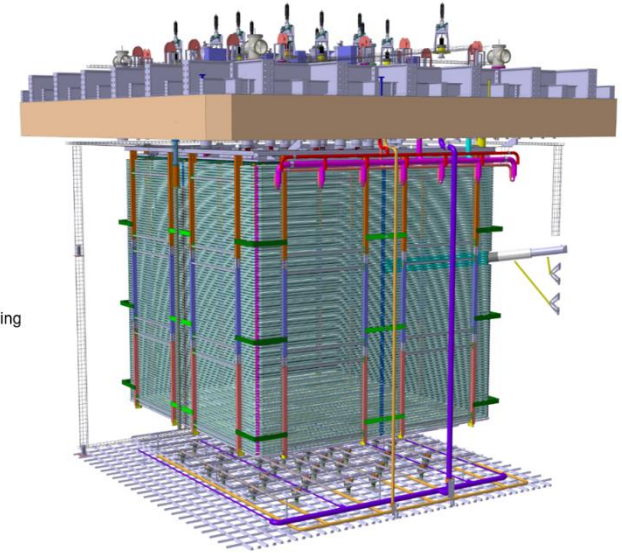
wa105cam4

Purity Monitors



- Positioned at various heights to monitor stratification of impurities
- 4 Purity monitors in the 6x6x6 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
- They will be refurbished version of ICARUS purity monitor
- 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

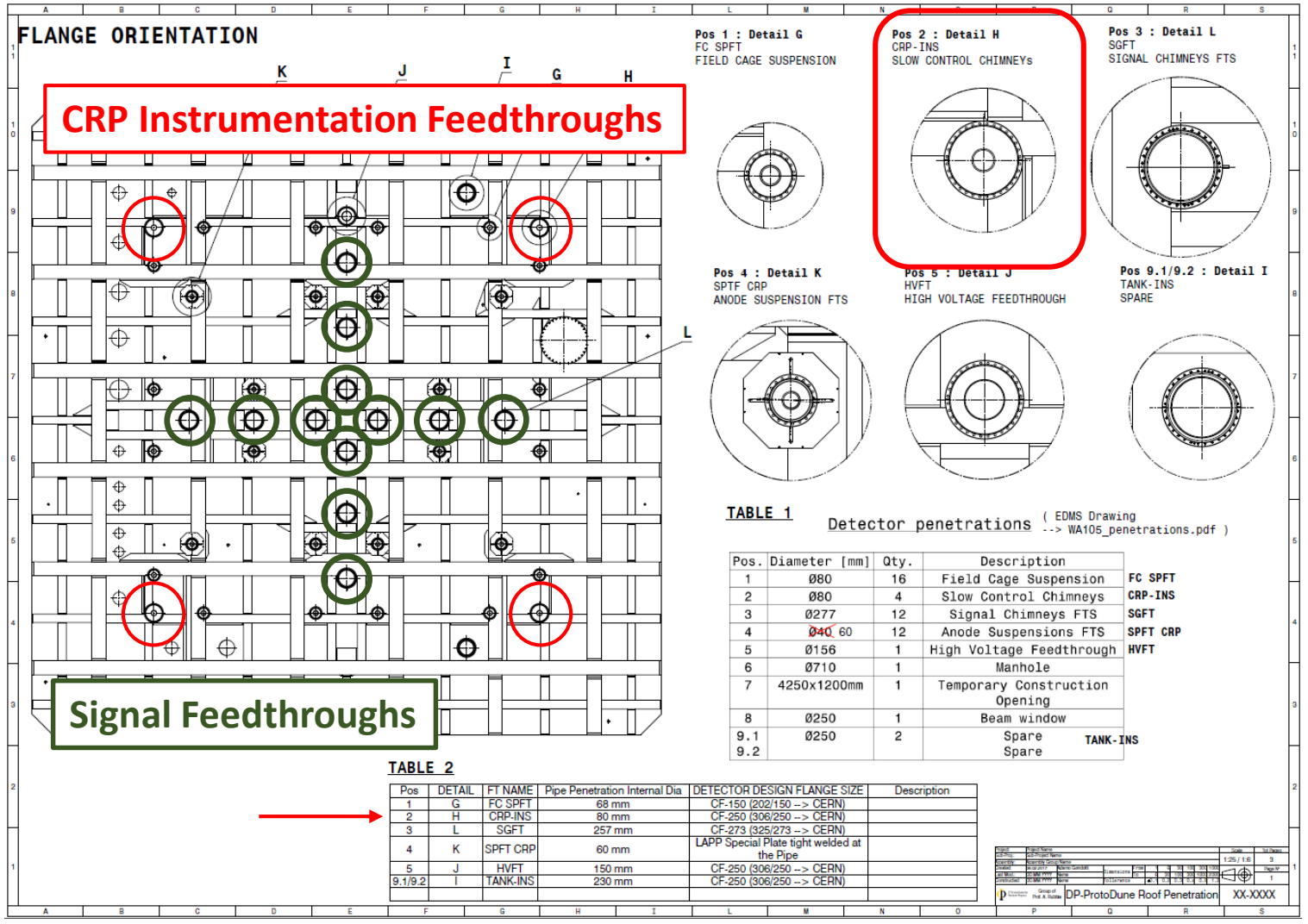


Conclusions and outlook

- We have a complete and integrated design for Slow Control of 6x6x6 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
- 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 tight schedule for the installation of the CRP this summer 2018
- 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

CRP Instrumentation Feedthroughs



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

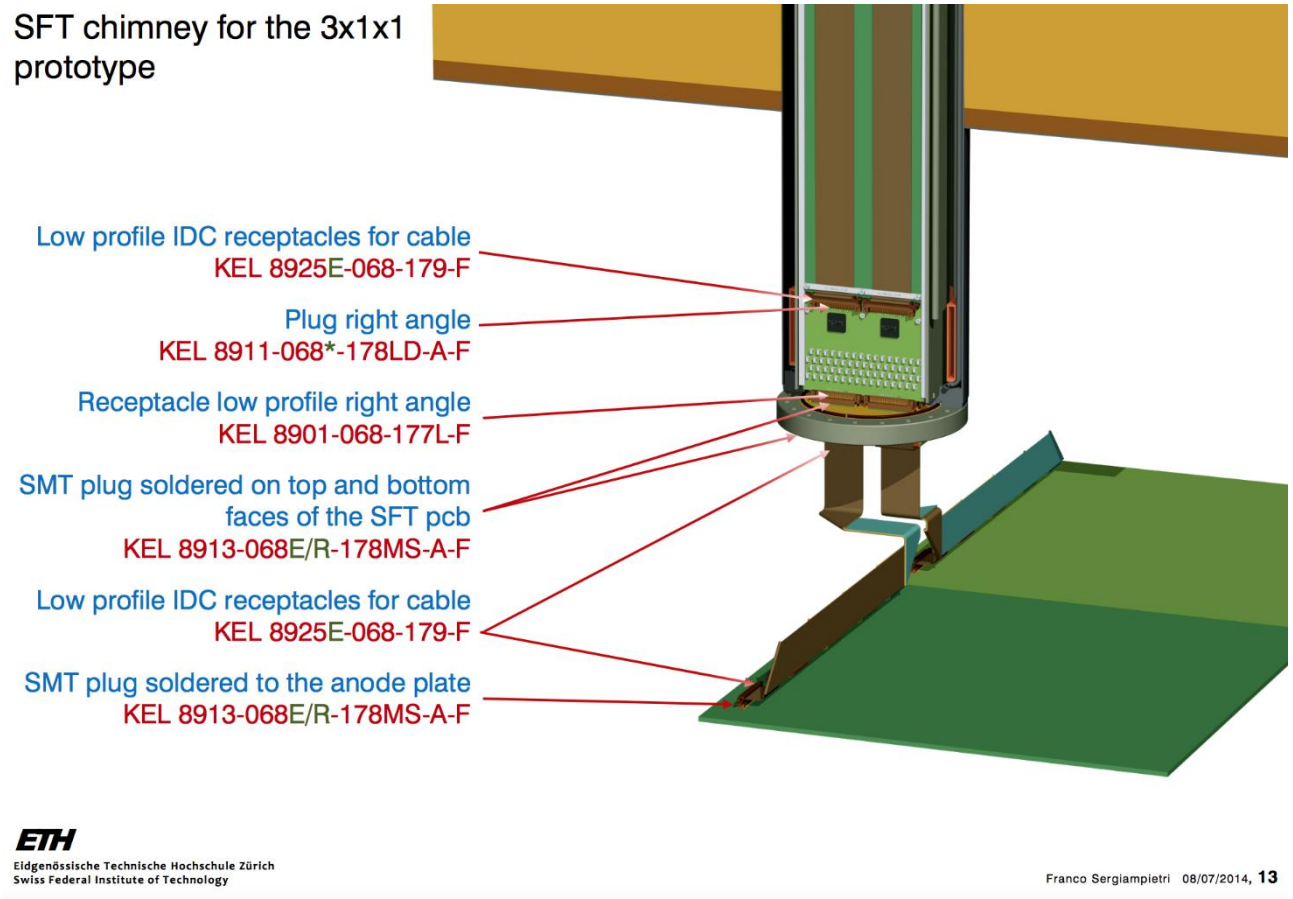
4 x CRP INS flange dedicated to:

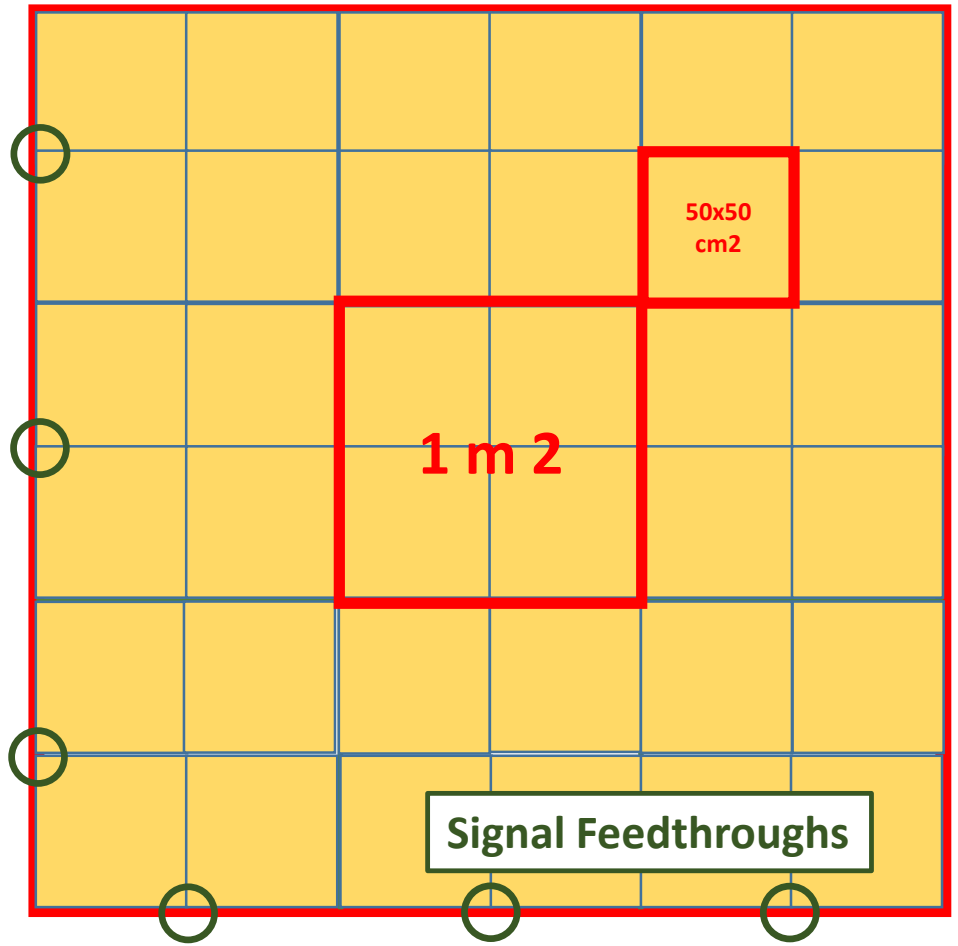
- Slow control signals (temperatures, LAr level meters, pressure…)
  - Connectors as 311 Detector
  - Improving internal cabling
- Middle High Voltage (10 kV rated channels)
- Pulsing system: under consideration

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

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

Connectors and cable for electronics

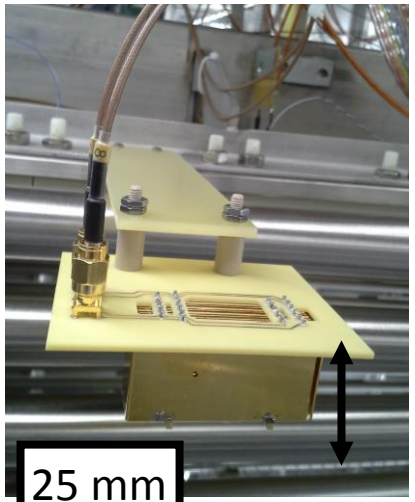


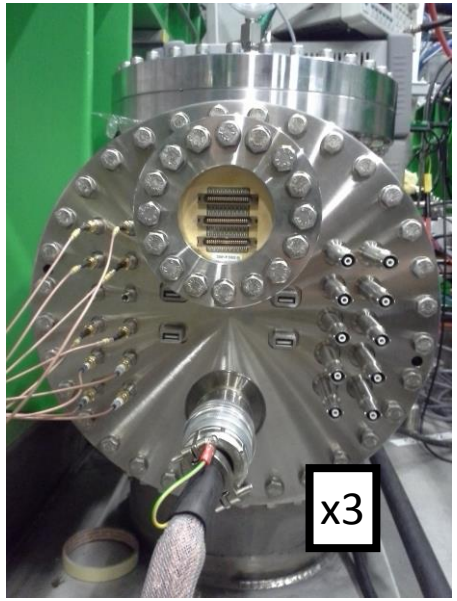


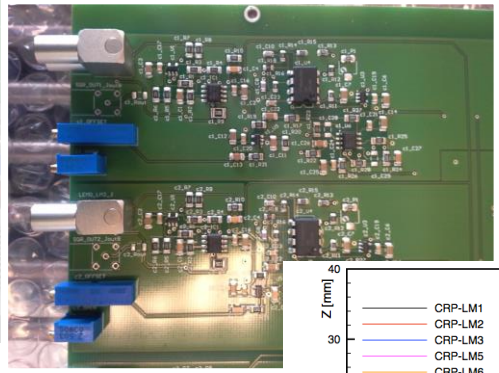
Electronics: each 9 m2 CRP module
Hitachi 68 c twisted pairs 0.635 mm pitch
Automated continuity test procedure during installation will be implemented

3x3 m2 = 9 m2 unit
36 anode 50x50 cm2

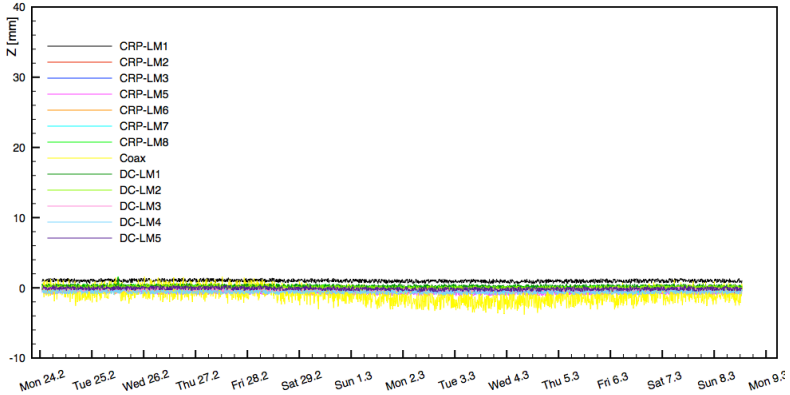
LAr level meter system in 311 Detector

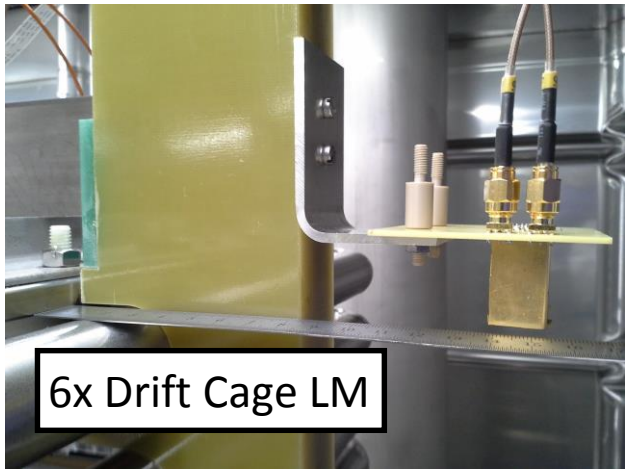


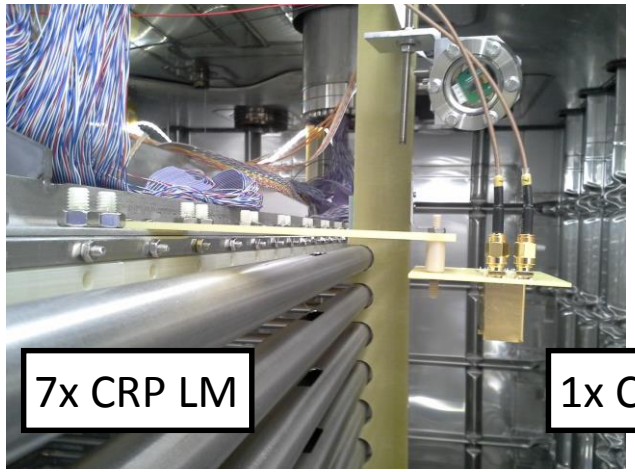




Custom sensing elements
Custom electronics

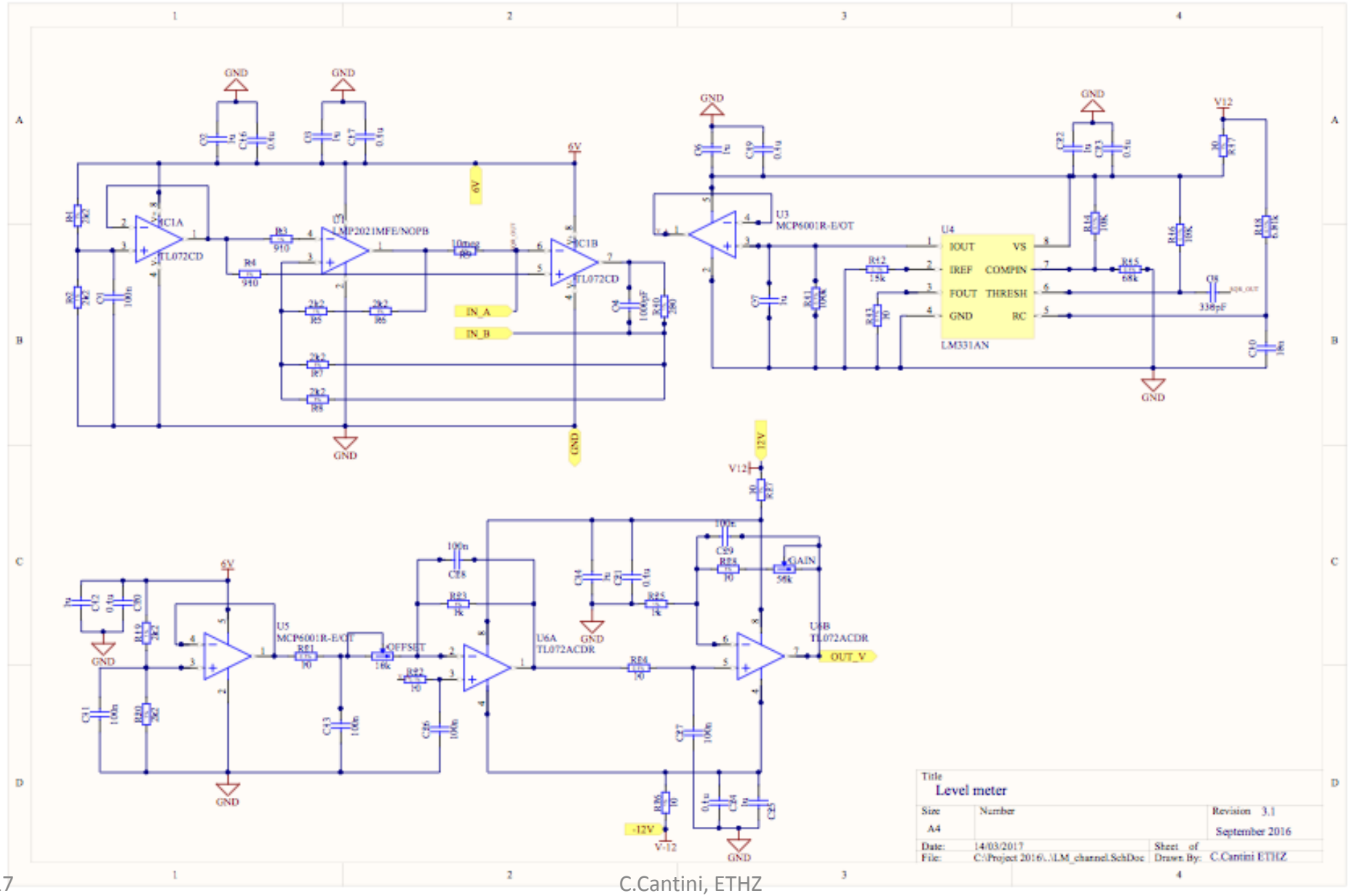






Currently all sensors in GAr atmosphere

Electronics for LAr level meter



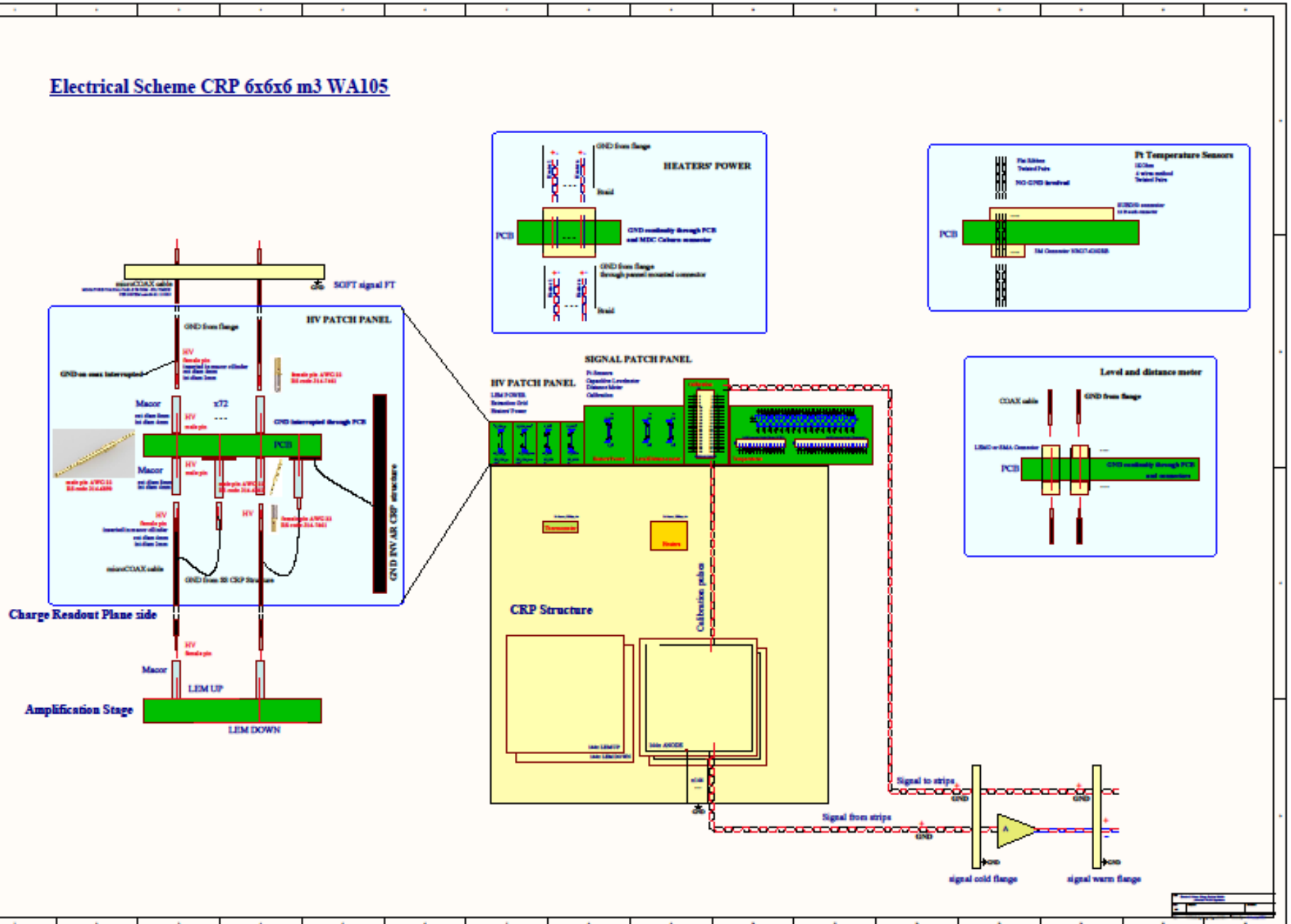
Cable for LAr level meter

Coaxial Cable, FEP Sheath RG316/U

Bedea - RG316/U

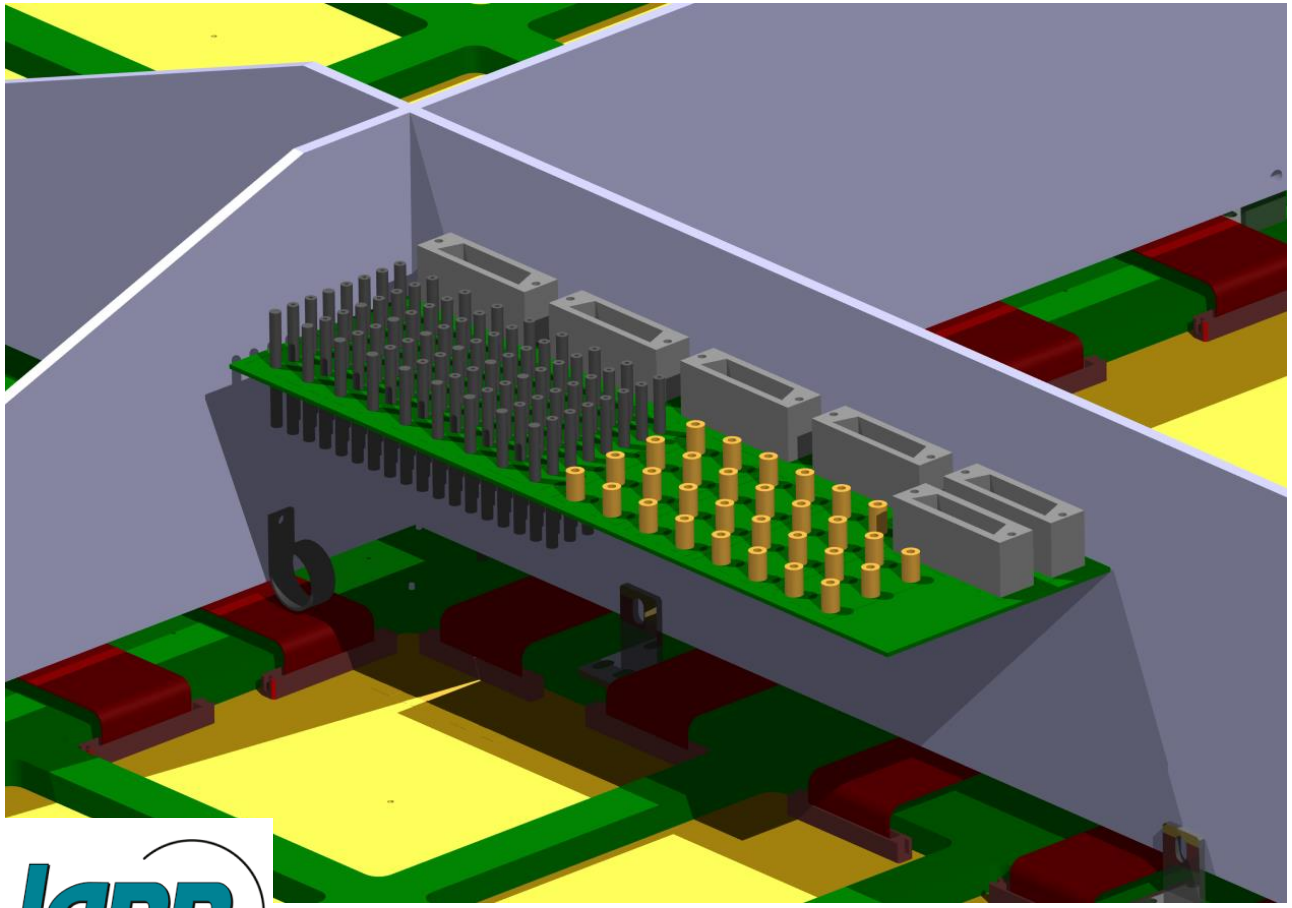
Characteristic resistance	50 Ω
Attenuation per 100 m	
100 MHz:	37 dB
200 MHz:	47 dB
1000 MHz:	102 dB
Internal conductor:	Silver-plated steel strand 7 x 0.17 mm
Dielectric:	PTFE Ø 1.52 mm
Shield braiding:	Silver-plated copper
Sheath:	FEP, brown
Outer diameter:	Ø 2.5 ±0.1 mm
Temperature range:	-70 °C → +200 °C
Weight approx.:	0.5 kg / 25 m coil
	2.1 kg / 100 m coil

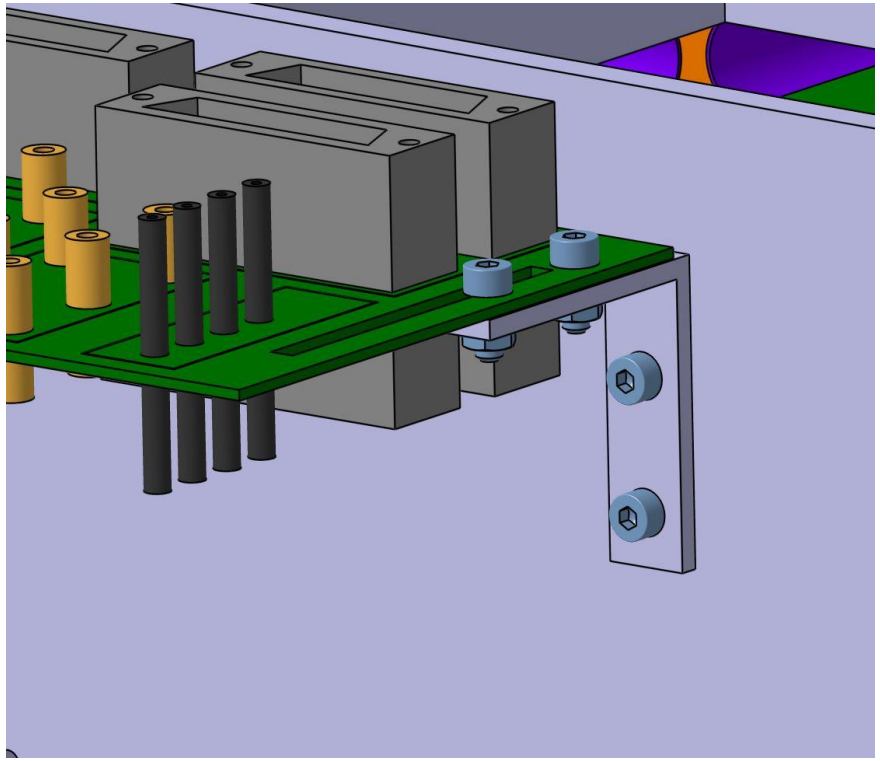
Used inside and outside the detector to connect sensors to flanges and then to electronics



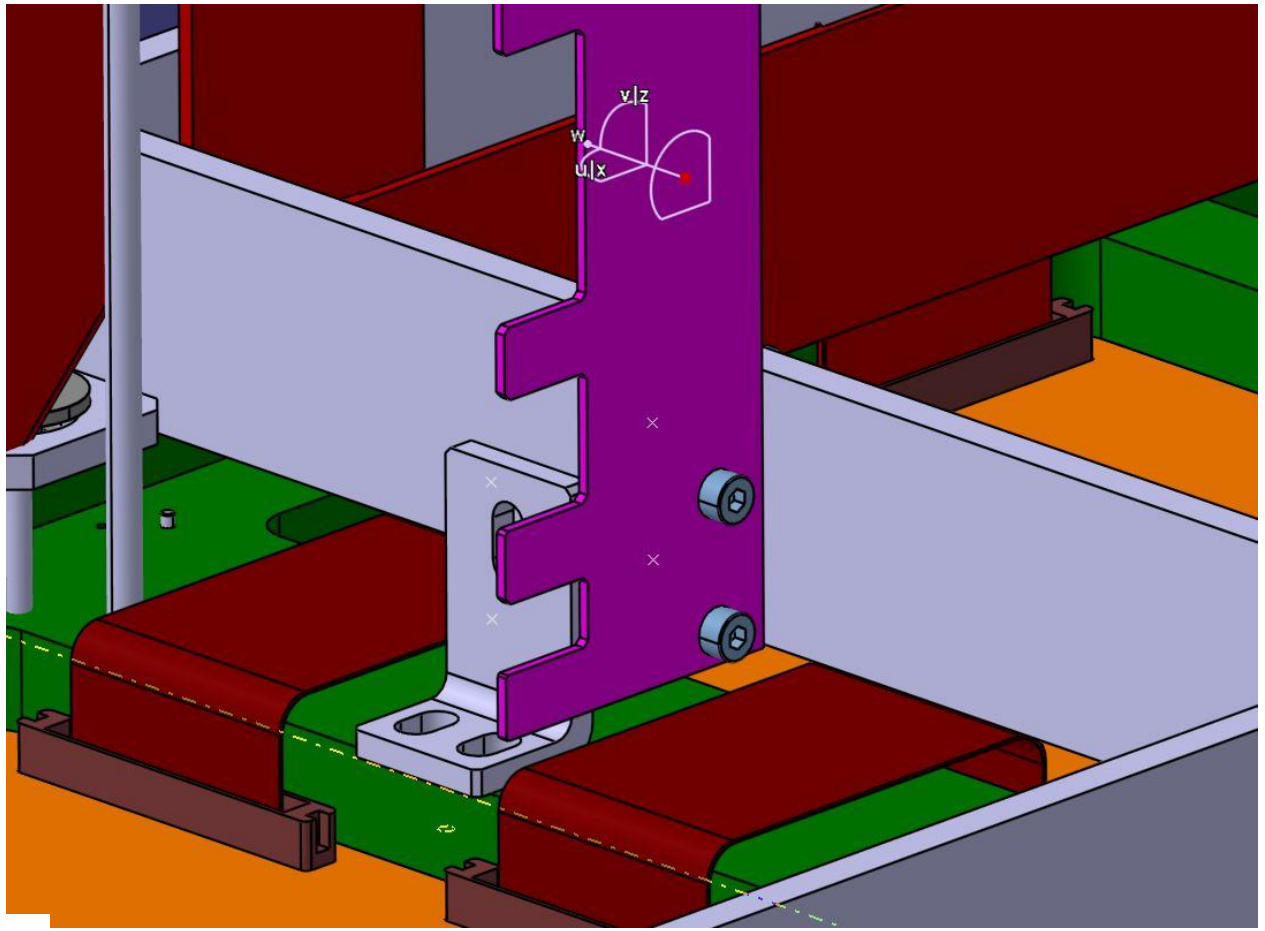
Elementary but comprehensive view of all the electrical parts on the CRP.
Important also to keep track of internal reference to GND.

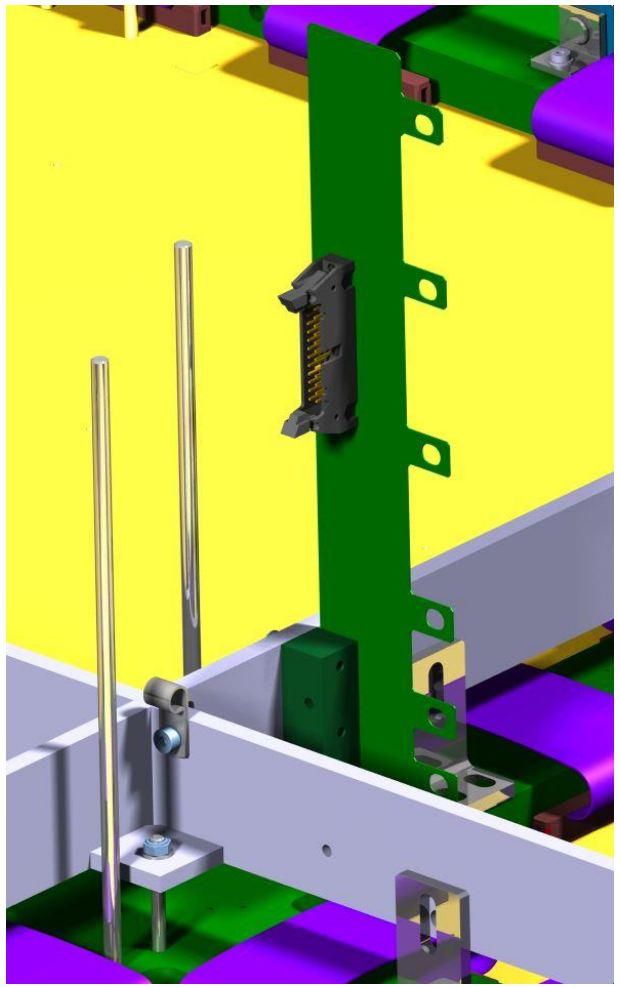
Fixation patch panels



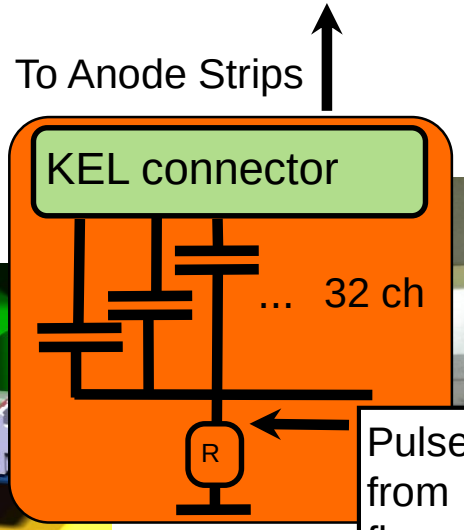


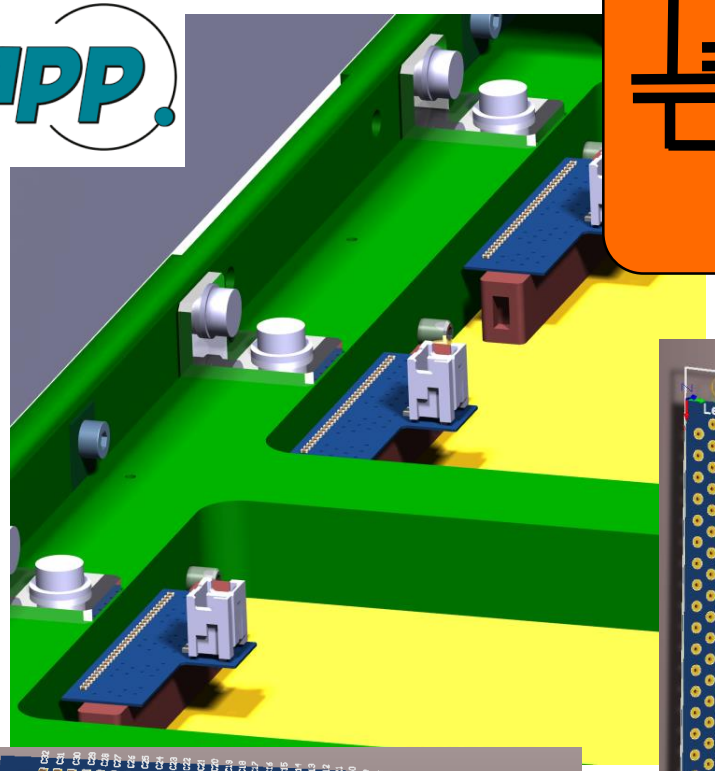
Fixation Thermometers

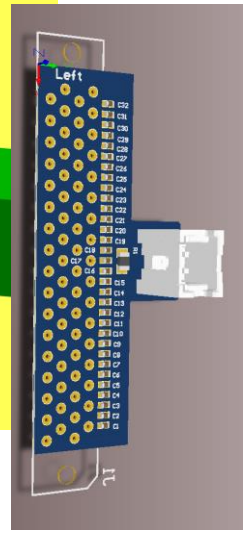


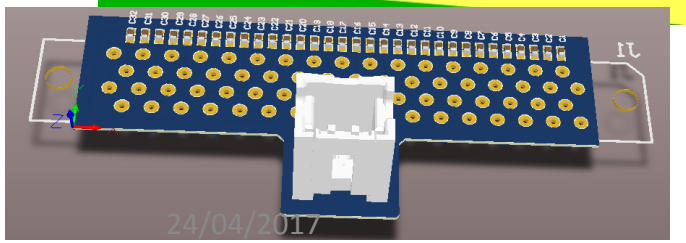


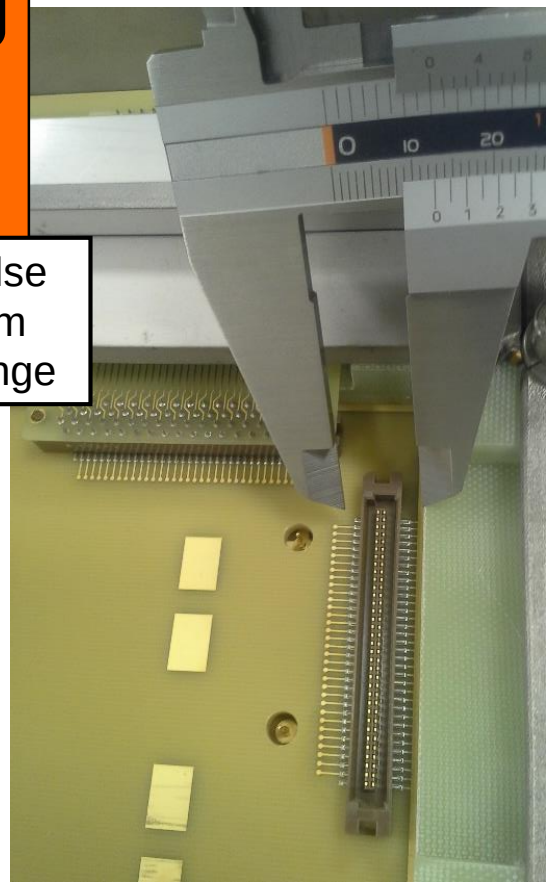
Details PCB for pulsing

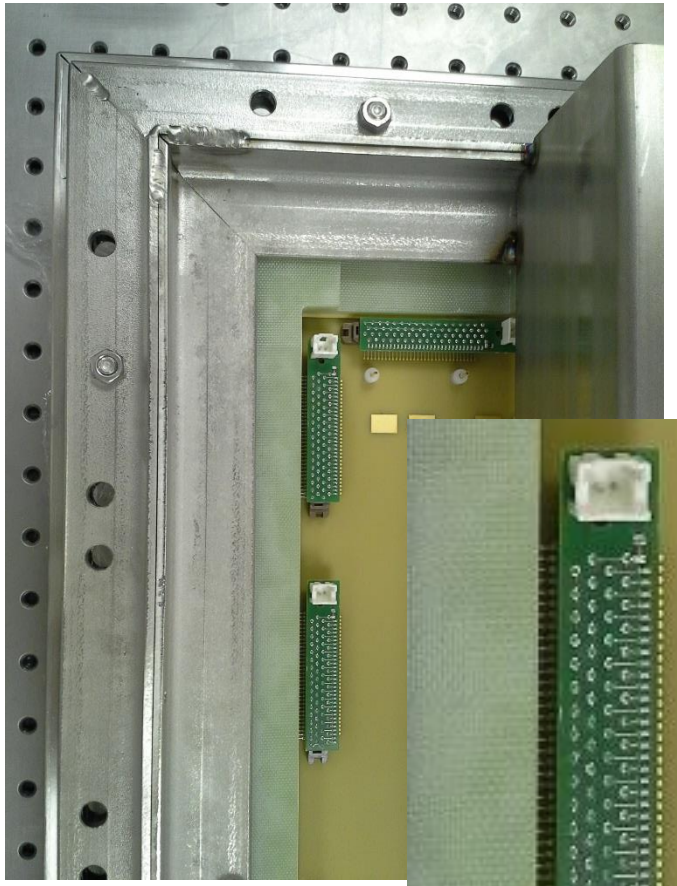






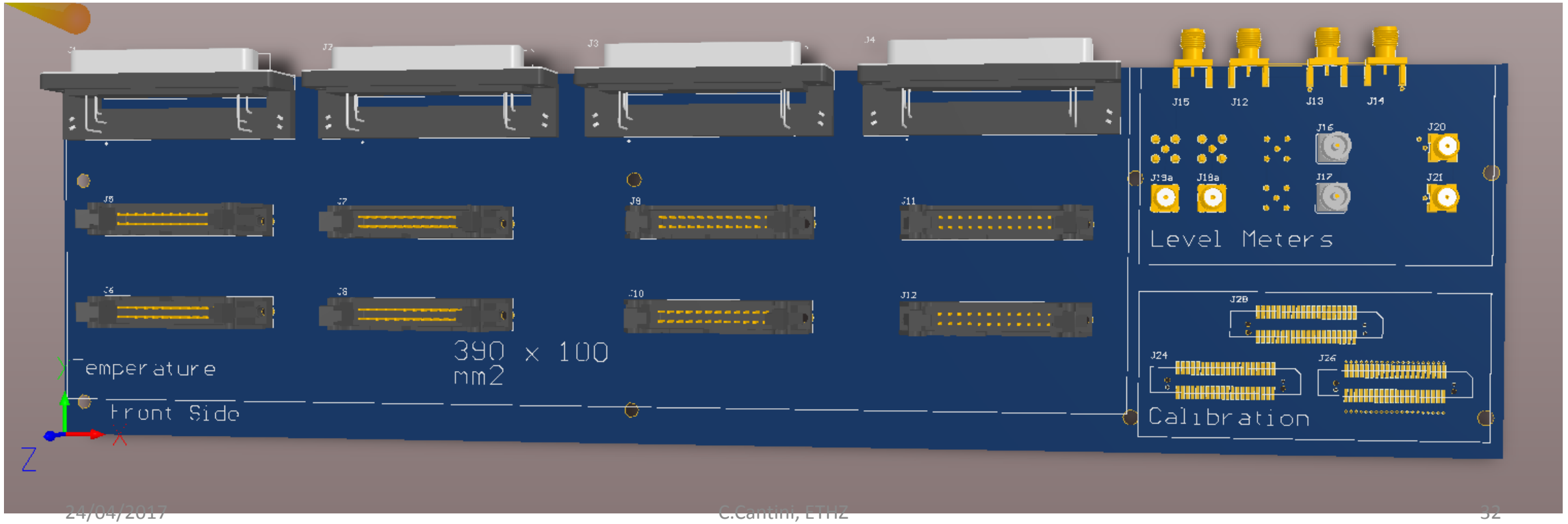






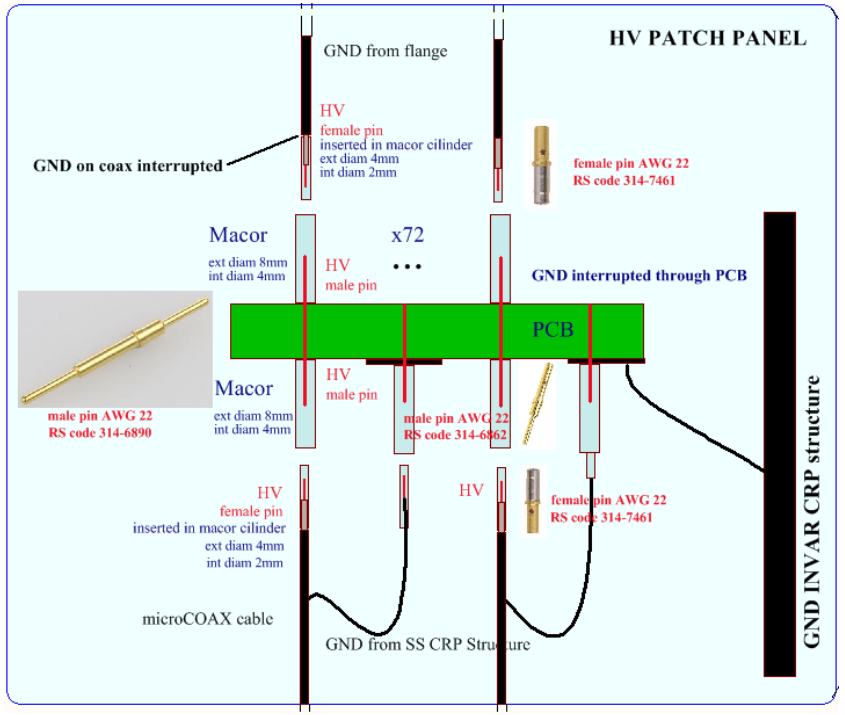
Details patch panel

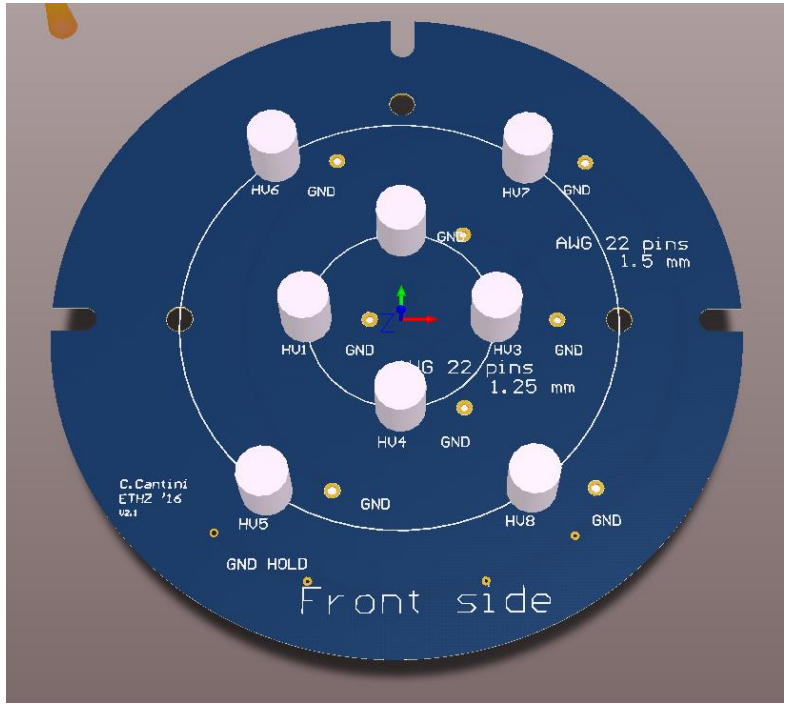
Prototype hereafter. Based on sensor_list_666, numbers of connectors may slightly vary.
3M connectors matching Thermometers connectors, SUBD50 towards flanges
Dimension 390x100 mm2 – can be adapted as needed
Fixation holes to match SS CRP structure

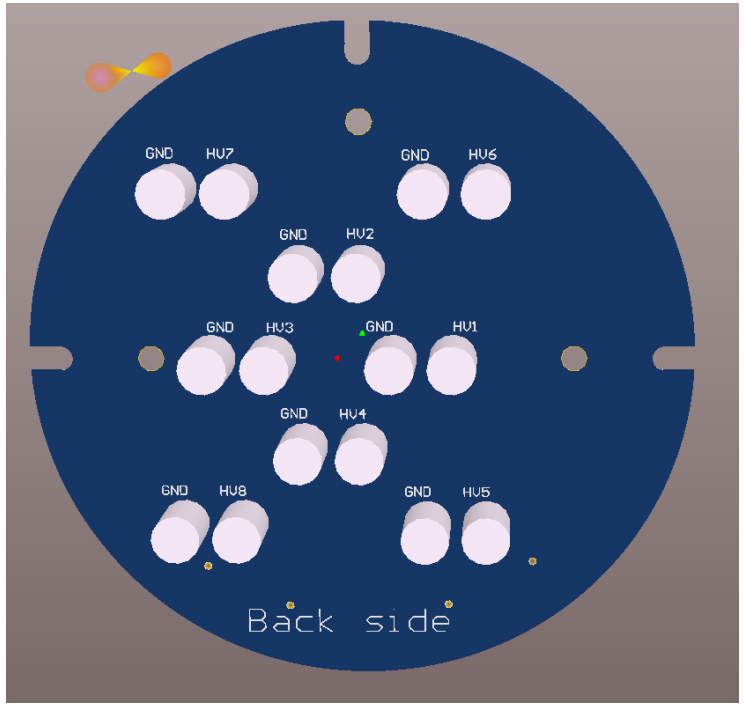


Details patch panel for high voltage

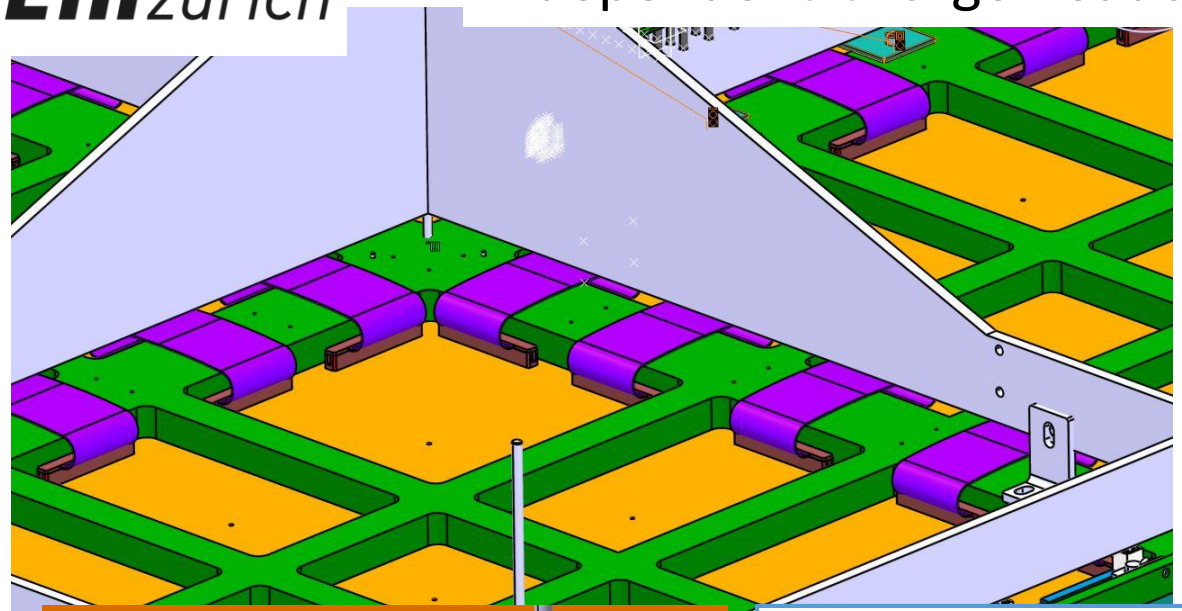
Prototype to test spark free connections in argon gas arranged in multipin
Makor cylinder technique – two macor cylinders inserted one into the other to provide isolation
Dimension here is 10 cm OD

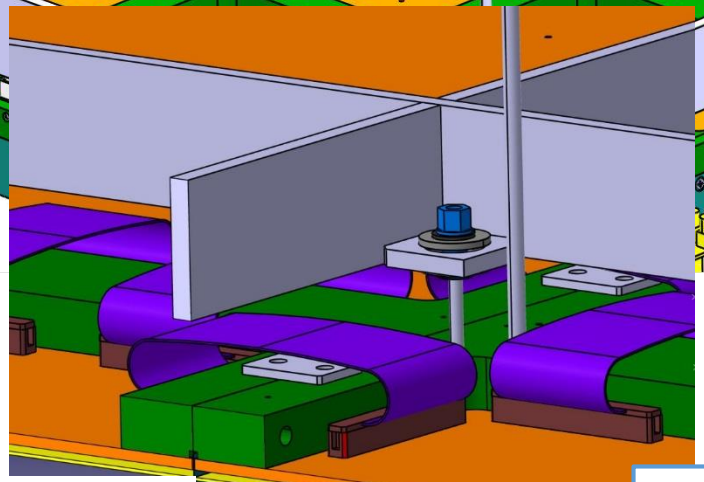


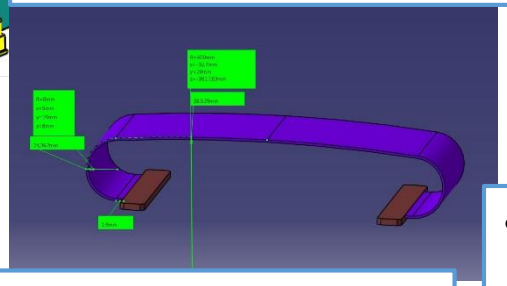




Independent Charge Readout Plane 3x3 m2 module

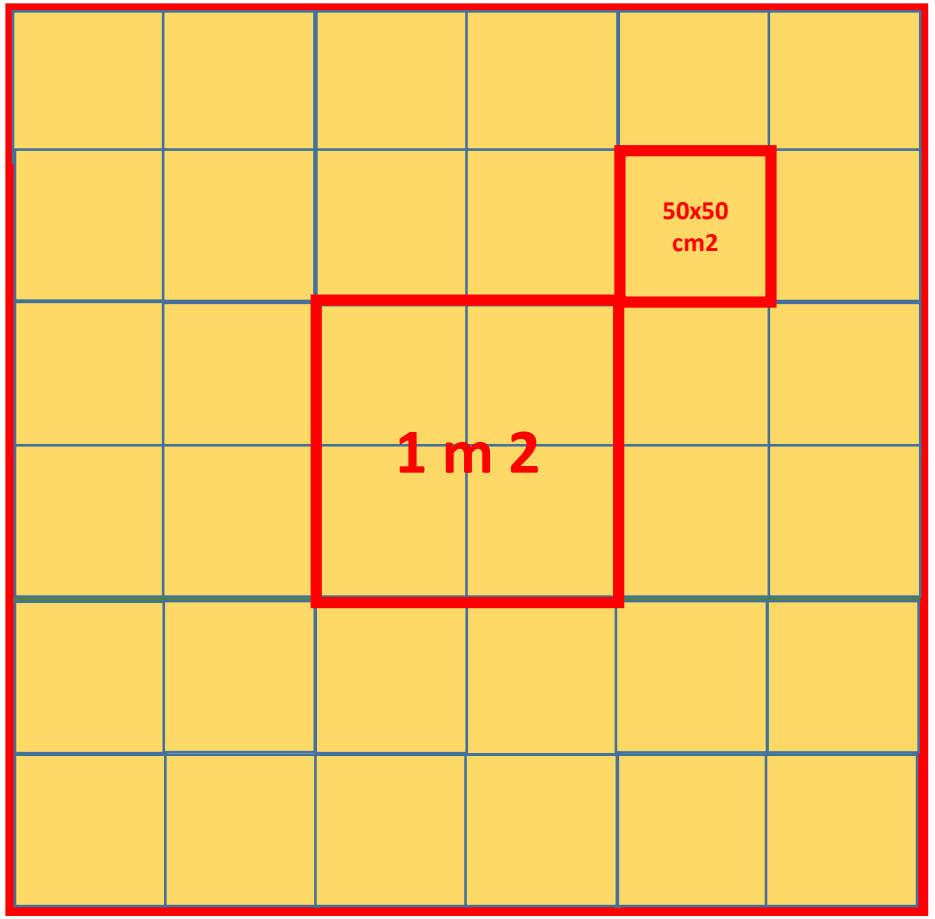






Bridge needed to electrically connect adjacent 50x50 cm2 anodes

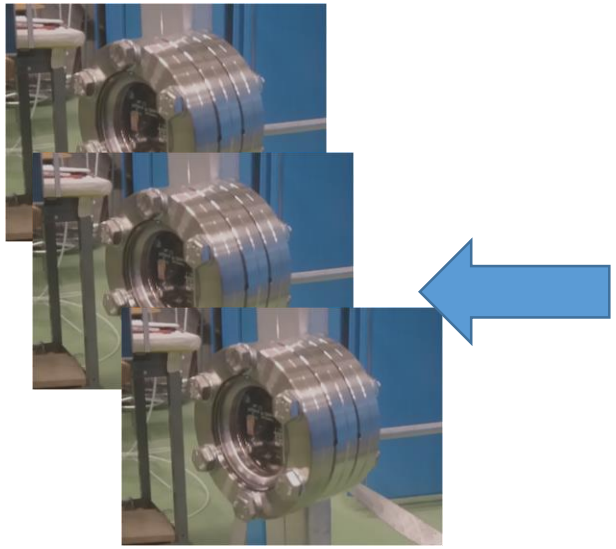
20 cm long flat cable 68c, 0.635 mm pitch, 30 AWG



- 300 bridge per 9m2 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)

Cryo - Cameras - hardware

RaspBerry Pi and camera module
- 15 pins cable connection

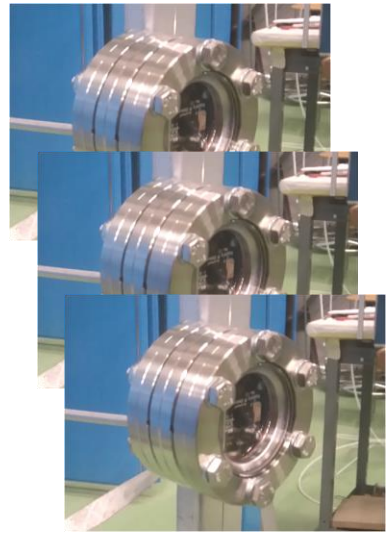


2 x 3 camera modules connected to the camera box

Camera box build for the Fermilab

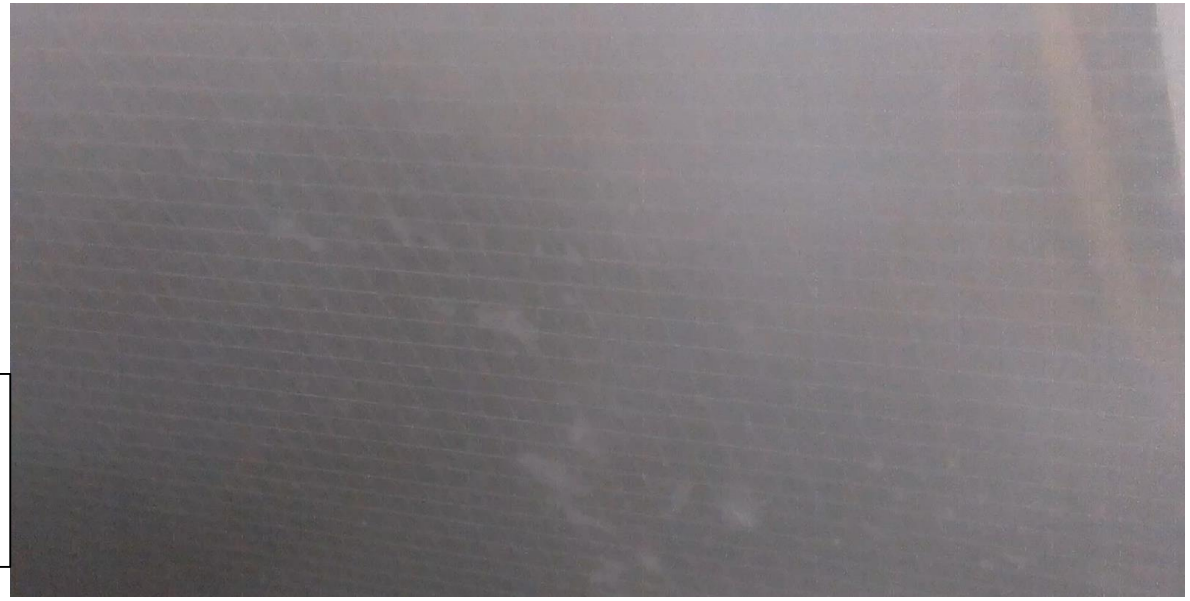
Box with :
- Fan
- Ground electrical link
- 5V power supply
- Ethernet switch
- 6 x RaspBerry module V3
- Max length tested in between camera and RaspBerry : 8 m

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

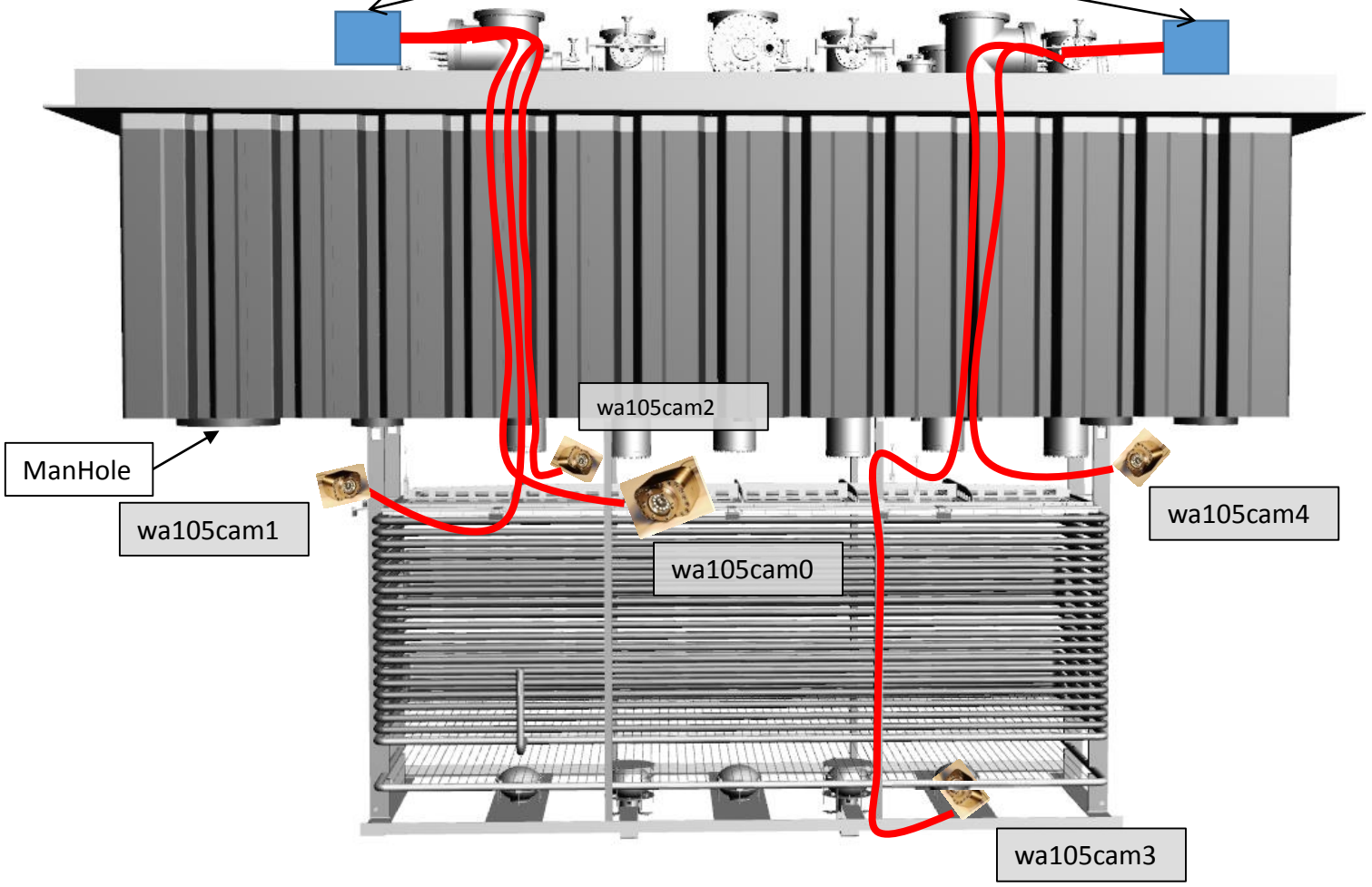
Condition of the test :
- RaspBerry Pi close to screen
- Camera module immerged in the liquid Argon
- Camera checking below the CRP



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

3 x 1 x 1 : WA105 cameras positioning

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



wa105cam0

wa105cam1

wa105cam2

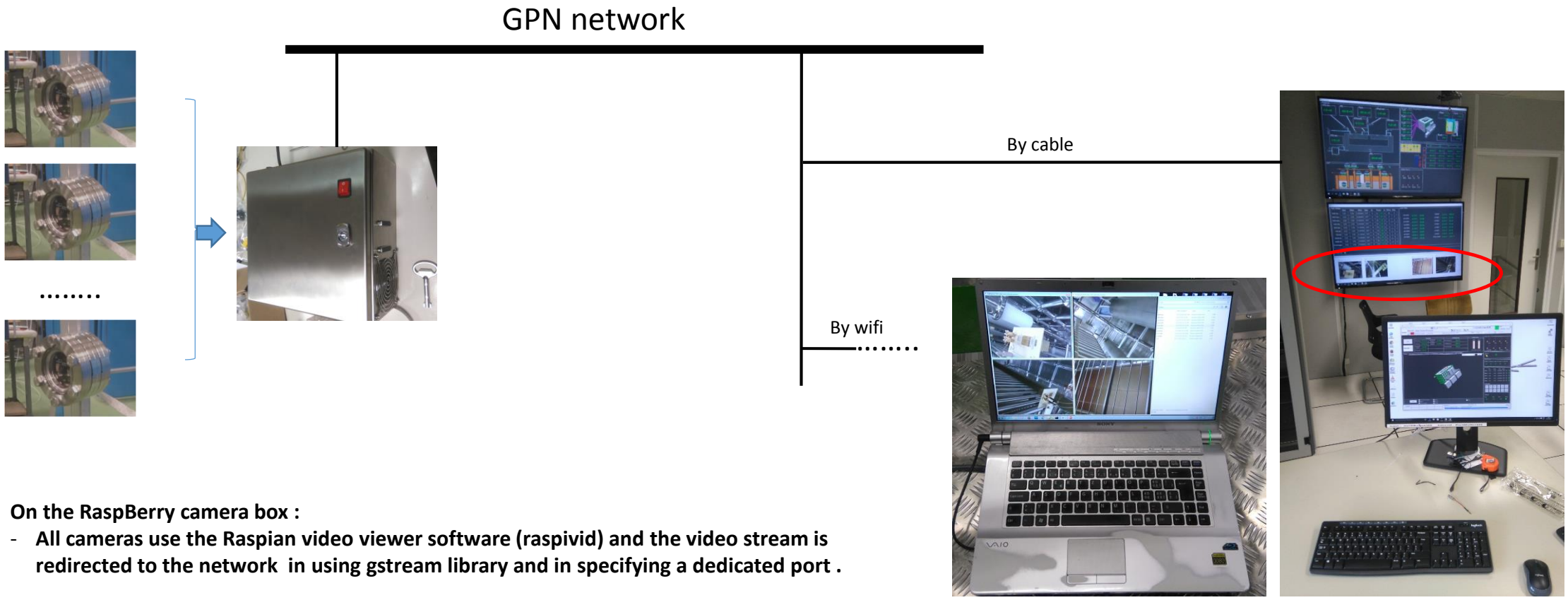
wa105cam3

wa105cam4

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

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

Cryo - Cameras software streaming video



3x1x1 Control room

On the RaspBerry camera box :

- **All cameras use the Raspian 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/