

Design of the Field Cage and Electrical components for Proto-DUNE Dual Phase

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WA105 Collaboration meeting

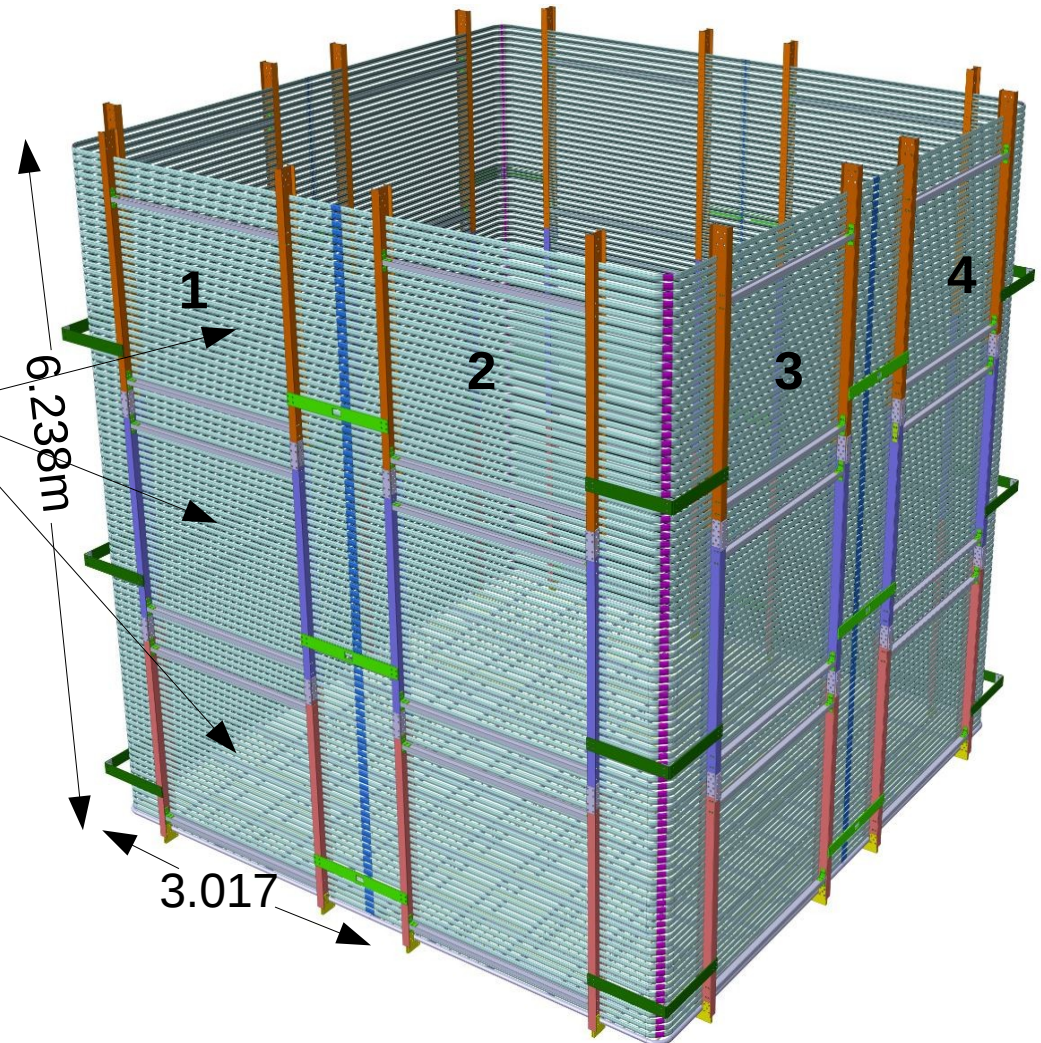
March 22, 2017

Outline

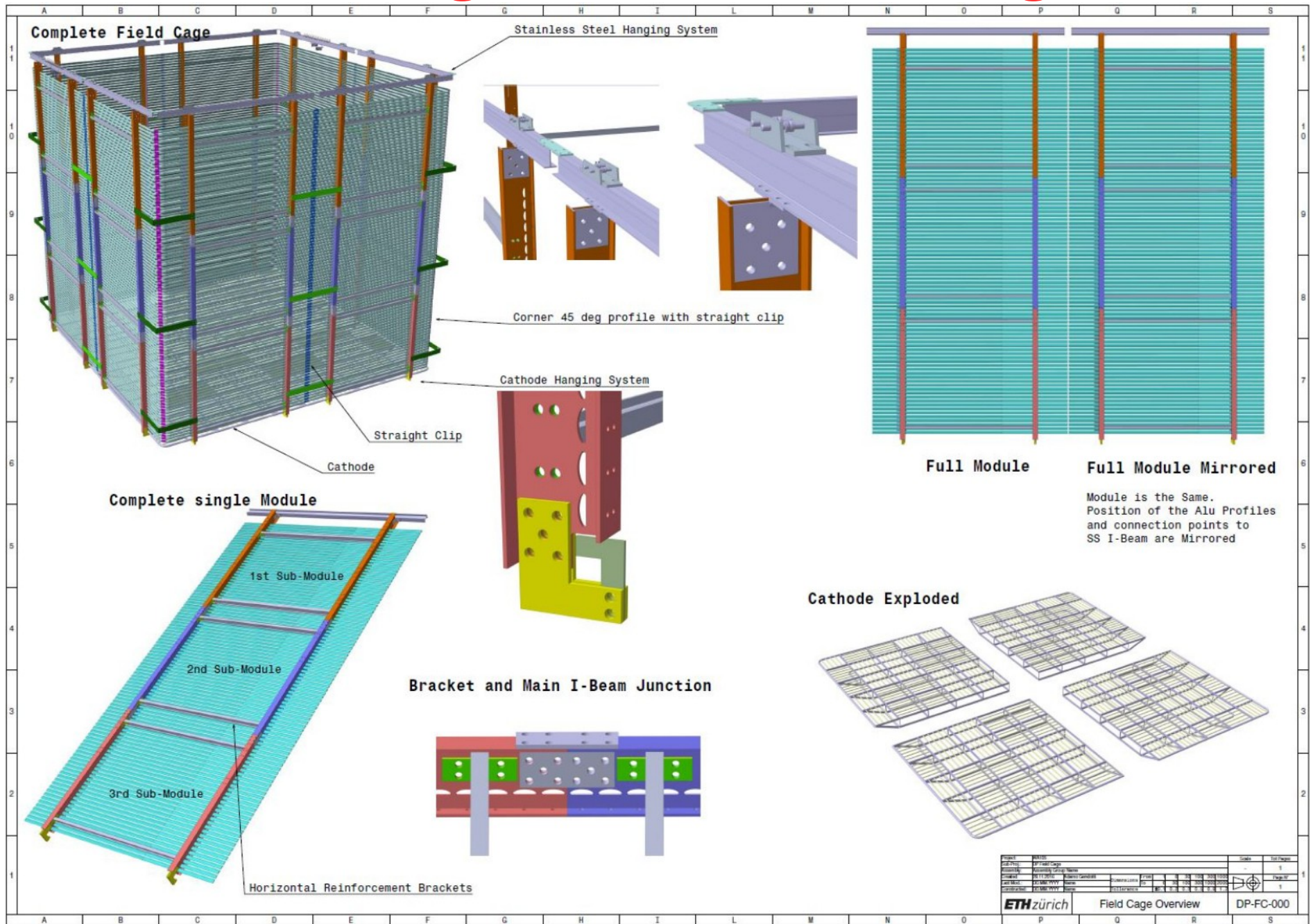
- Overview of Proto-DUNE Dual-Phase (DP)-Field Cage (FC).
- High voltage divider board and the components
- Status of Field Cage production at UTA .
- Time-line and milestone
- Conclusion

Overview of DP-FC

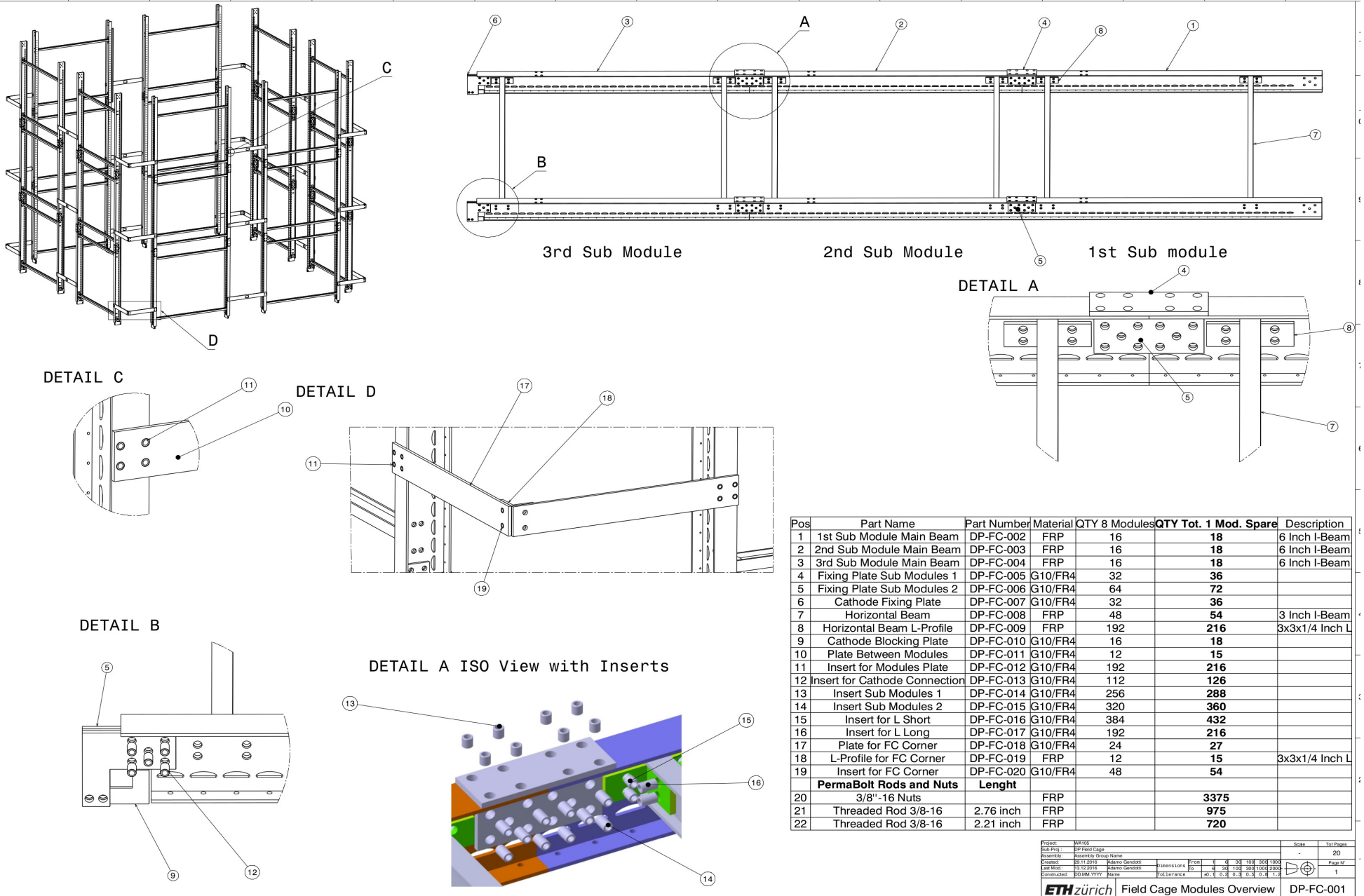
- Total 8 modules.
- 2 modules in each detector side.
- Size of each module is 6.2m x 3.0 m.
- Each module is composed of 3 sub-modules.
- Each module has 98 profiles.
- Center to center distance between two profiles is 60mm.
- Profiles between two modules are connected with clip.



Field cage technical drawings



Field Cage technical drawing



High Voltage system

- How the high voltage system will look like to have 500 v/cm E field?

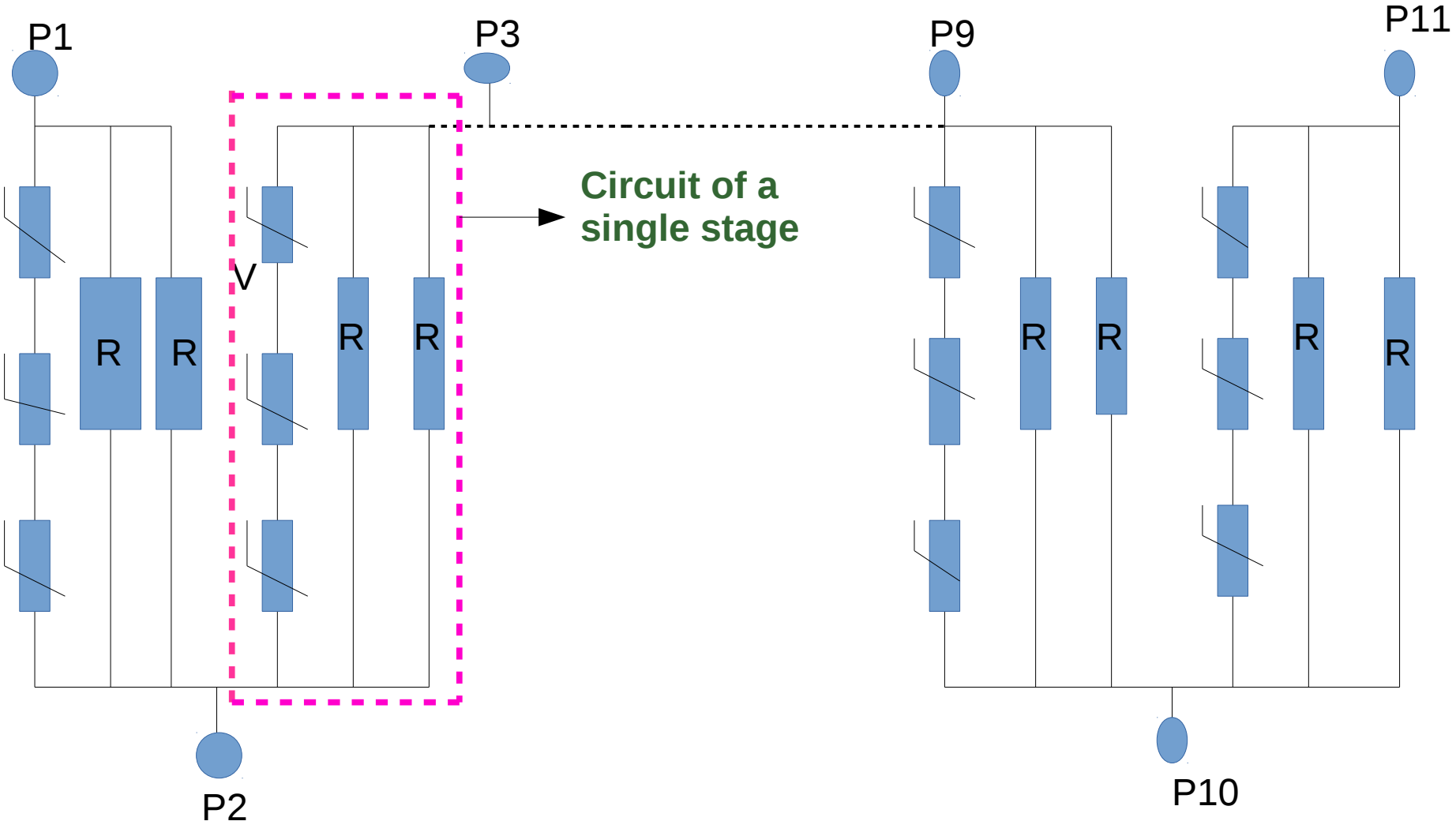
Insulation space	Voltage (kV)	Drift field (kV/cm)
	0	0
Anode	-1(LU)	5
LEM	-4(LL)	30
Extraction Grid	-6.5	2.5
First field shaper	-9.5	0.5
	-300.5	0.5
Last Field Shaper	-303.5	0.5
Cathode		
Ground		

Power supply

Voltage divider board: Outlook

- Goal to generate uniform electric field of 500V/cm across the drift volume.
- Design a printed circuit board
 - Easy installation, robust mechanical and electrical connection.
 - perform and survive in LAr for long time.
 - Use two columns of PCB board for redundancy.
- Divider board components :
 - **Resistors** : 2 resistors are in parallel in each stage to provide redundancy.
 - **Varistors** : Protect the circuit
 - High voltage discharge
 - In case both the resistor die.

Schematic diagram of a divider board





R= 2 Gohm, V= varistors, P1, P2, .. P11 connections with each profile

Divider board for 6x6 (in one column)

Parameter	Values	Note
Total number of profiles	98	
Number of profiles in each sub module	33, 33, 32	
Number of profiles connected with each PCB Board	11	
Number of stages	10	
Distance between two profiles	60 mm	
Total number of PCB board for entire volume	10	
Length of each PCB board	(10x60 mm) + 15 mm+ 15 mm = 630 mm	
Width and thickness	61 mm wide, 2mm thick	
Current flowing	3 uA	
Resistance in each stage	1 Gohm	2 resistors in parallel (each of 2 Gohm)
Varistors in each stage	3 varistors in series.	
Voltage drop between two profiles	3 kV	

Components of the divider board (one column)

Elements	Values (unit)	Part#	Requirement for each board	#Total (with spare)	
Resistors	2 GOhm		20	200 (260)	
Varistors	3 varistors in series	ERZV14D182	30	300 (400)	
Connections with profiles	M4 size brass screw		11	110 (150)	
Nuts and washers			11	110 (150)	

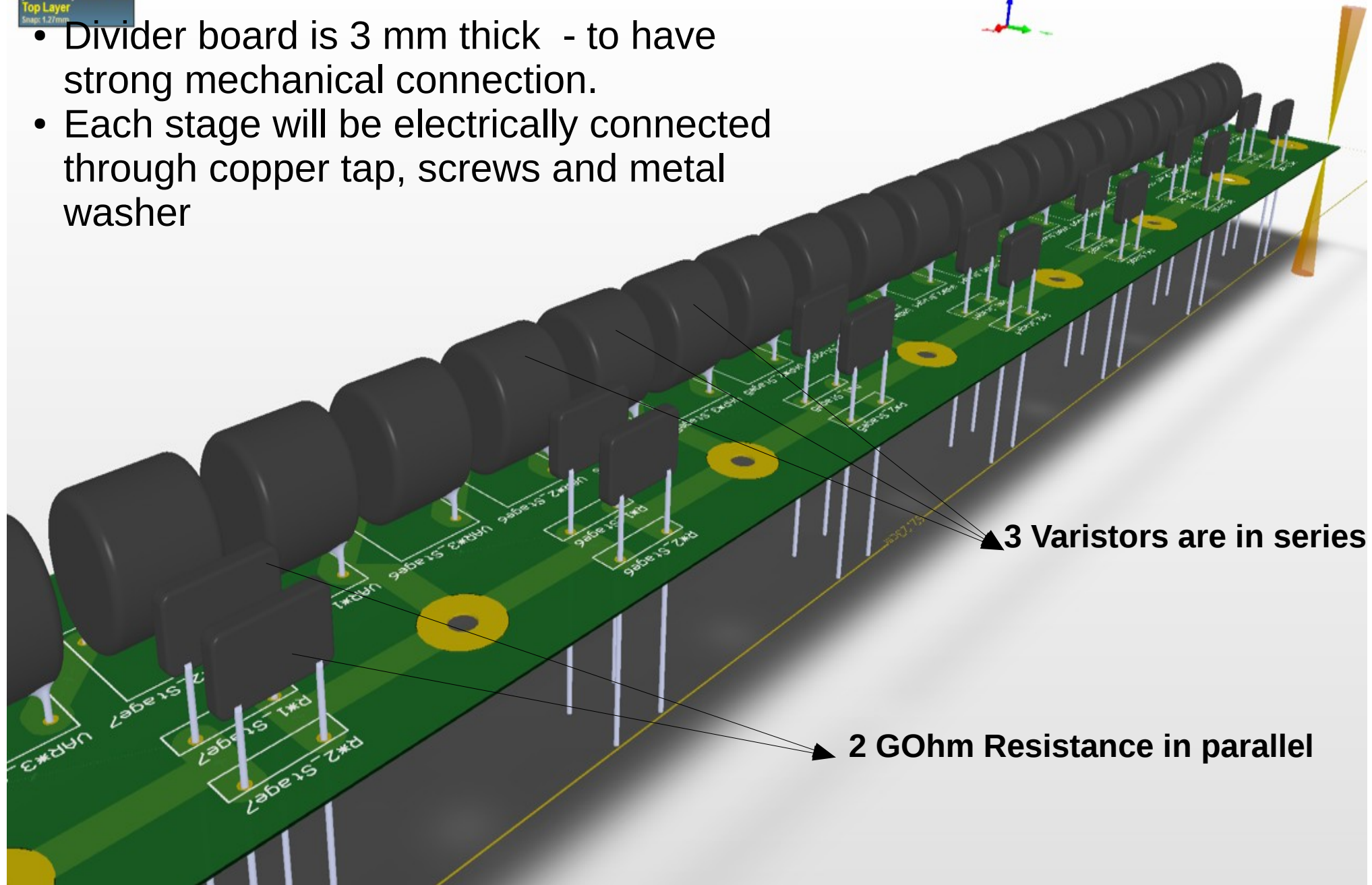
Requirements of the divider board

Parameter	Values	units	notes
FC-resistance tolerance	+ - 1	%	
FC- total resistance tolerance	+ - 1	%	
FC max voltage	150	%	
Maximum heat generated	0.1	Watt	0.9 mW in case of 500 V/cm

3D design of the divider board: Top layer

x:107.950 dx: 526.110 mm
y:173.990 dy: 33.020 mm
Top Layer
Snap: 1.27mm

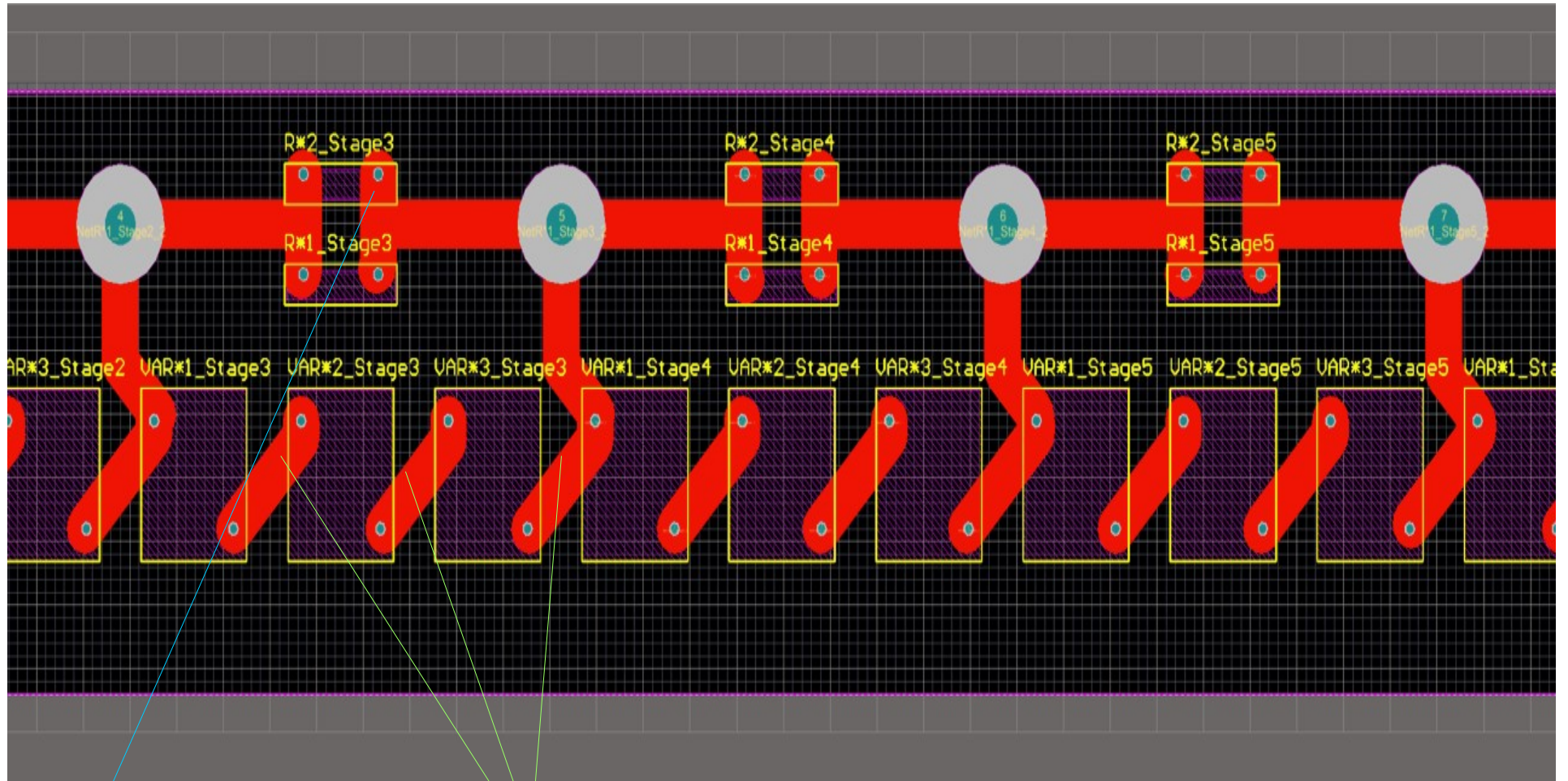
- Divider board is 3 mm thick - to have strong mechanical connection.
- Each stage will be electrically connected through copper tap, screws and metal washer



▲ 3 Varistors are in series

▲ 2 GOhm Resistance in parallel

Bottom layer: Close view



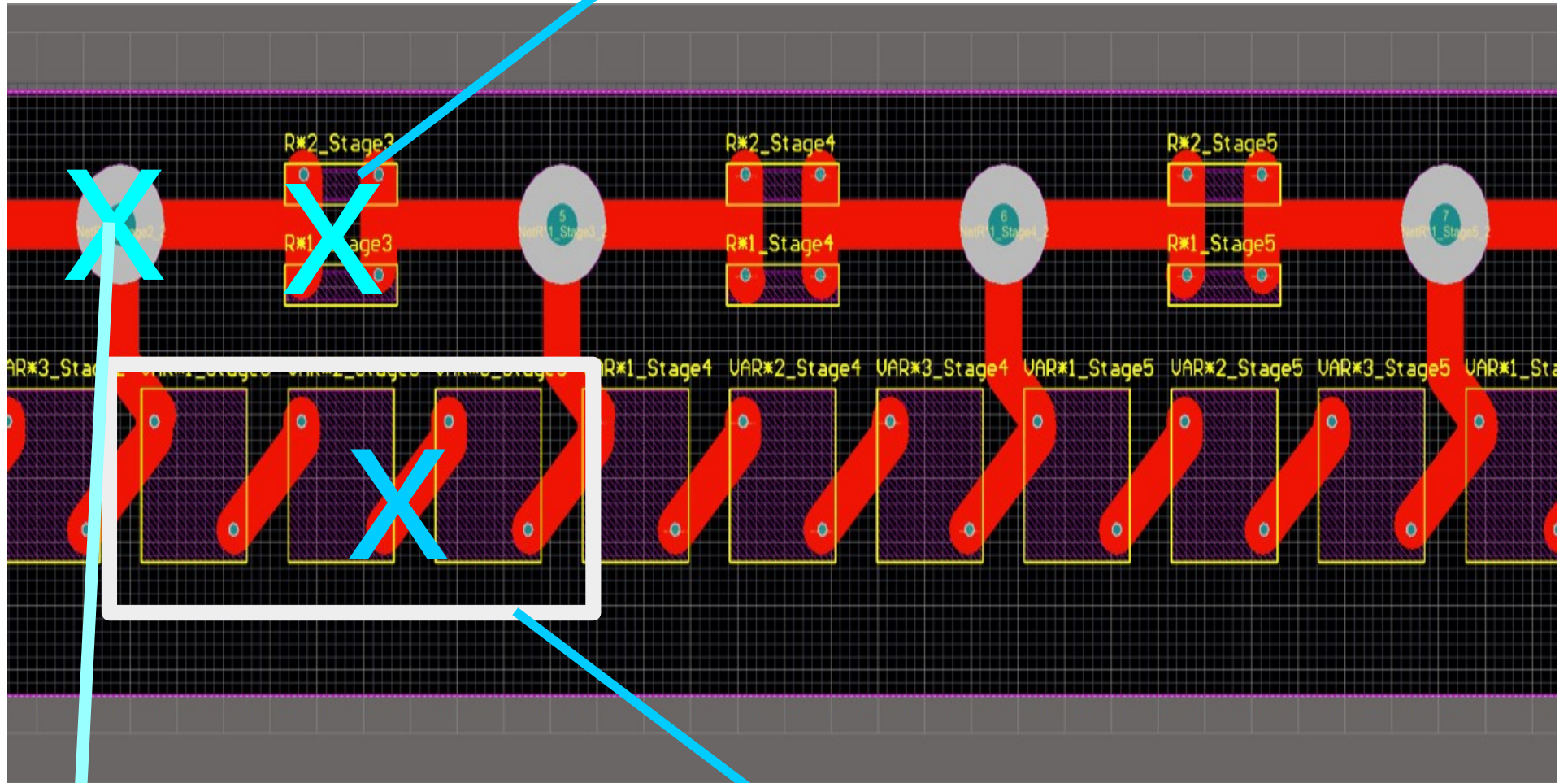
Resistors connections

3 varistors connected in series (in parallel with resistors)



Cases of divider board Failure

Resistors may die

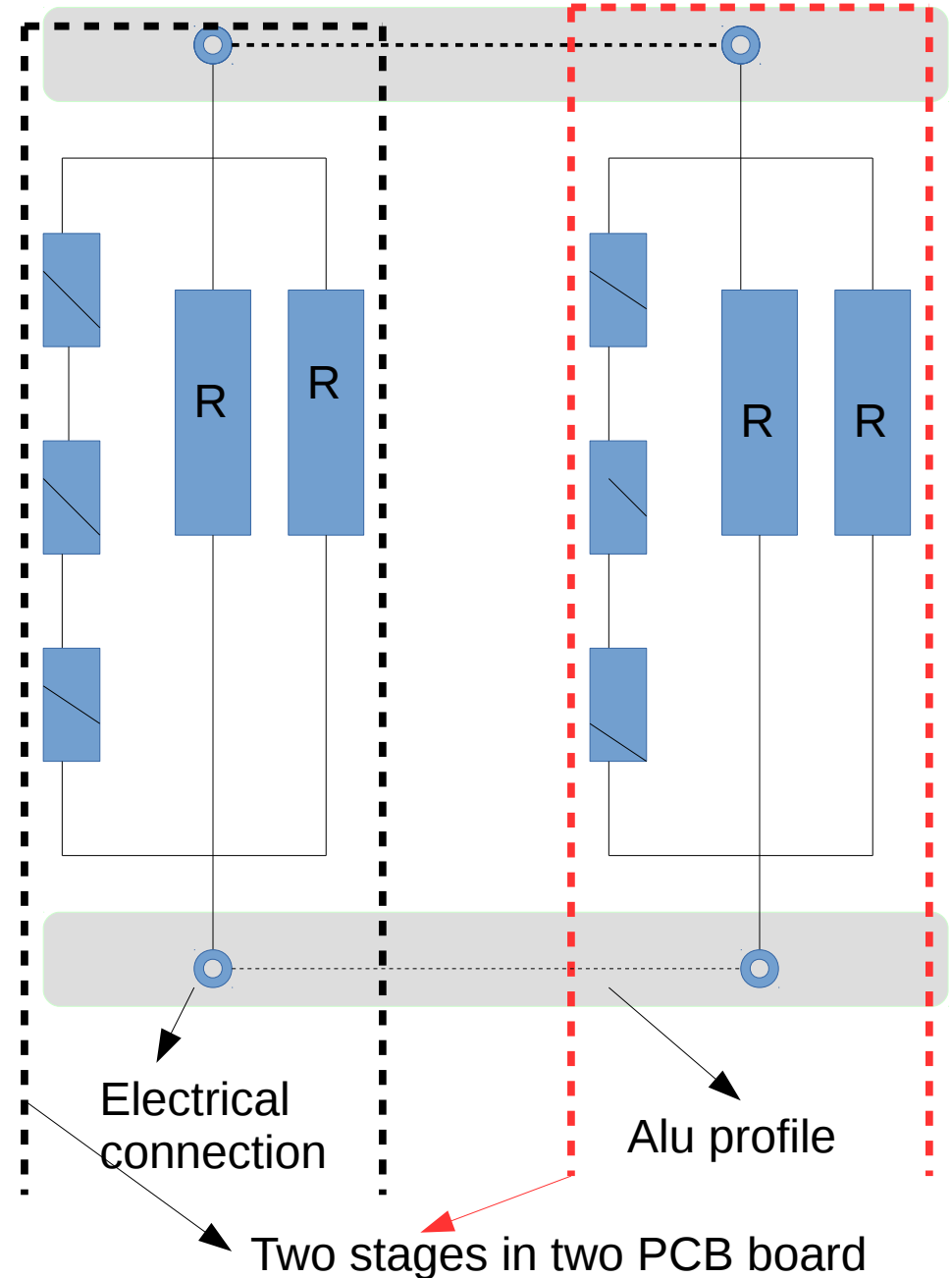


Electrical connection with the profile may broke

Varistors may not work

Redundancy : Two divider board in parallel

- Redundancy
 - Two divider board in parallel
- 4 resistors in parallel of value 2 GOHm each.
- Total resistance in each stage = 0.5 GOHm.
- Current = $294 \text{ kV} / 0.5 \text{ Gohm} = 6 \text{ uA}$.
- Current flow in case of one column of PCB board is 3 uA.
- Number of components will be double.



Advantage and disadvantage of having two boards in parallel

- **Advantage** : More effective in term of sustainability of electrical connection.
- Chances of failure will be much less.
- **Disadvantage** : More current flow, but within the limit of the current drawn by the supply.
- Double number of components, more costly.

It will better to have two board in parallel in-order to avoid of failure

Field Cage production at UTA

- Our goal is to construct ~ 27 field cage sub-modules of size 2m x 3m.
- Pass the production readiness review scheduled on May 15, 2017.
- Construct all 27 sub-modules by Sep 15, 2017.
- Complete the design, production and testing of all electrical components of divider board.

Field Cage Project status at UTA

- FC mechanical design completed (Thanks to Adamo)
 - The drawing sent to the vendor
- Profiles have been shipped to UTA.
- First draft of QC and production readiness review is in place.

FC electrical component status

- Divider board design is completed.
 - Two column of PCB board.
 - The design has to be signed off
- Placed an order for Resistors (2 Gohm), Varistors.
- In the stage to place an order once board design signed off.
- Test all the components both in warm and cold
 - Test the resistors select them according to the tolerance.
 - Test the varistors .
 - Test each stages of the divider board

Time-line and milestone

- April 15, 2017
 - Complete production facility setup
 - Complete draft quality control and production procedure document for production readiness review.
 - Sign off the design of the resistive divider board.
- May 15, 2017
 - Procure the divider board.
 - Test the resistors and varistors both in warm and in cold.
 - Complete sub-module zero production.

Time-line and milestone

- July 15 , 2017
 - Complete sub-module 1-10 production
 - Complete resistive divider board testing in room temperature.
 - ship the sub-modules at CERN
- August 15, 2017
 - Complete resistive divider board cold testing and final certification
 - Complete sub-module 10-20 production.
 - ship to CERN
- Sep 15, 2017
 - Complete sub-module 20-24 production.
 - ship to CERN

Conclusion

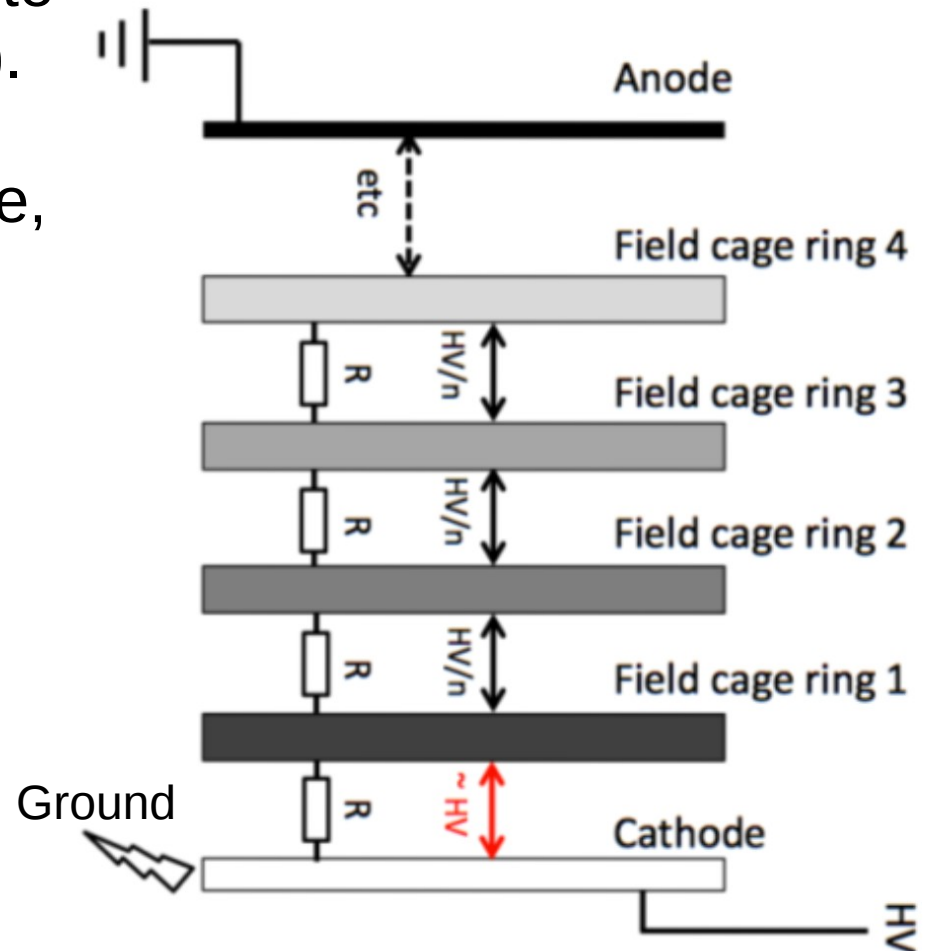
- Dual-Phase Field Cage design is finalized.
- Need to signed off the divider board design.
- Two divider board in two column will be appropriate to minimize failure.
- First goal is to pass the production readiness review and production of module zero.
- Production of sub modules at UTA and shipping within mid September.

Comparison between PCB board in one and two column

Components	Value (unit)	PCB board in one column	PCB board in two column	# of components required for one column	# required for two column
PCB board				10	20
Resistors	GOhm	1 Gohm in each stage	0.5 Gohm in each stage	200	400
Varistors		3 varistors in series	3 varistors in each board	300	600
Current flow		3 μ A	6 μ A		

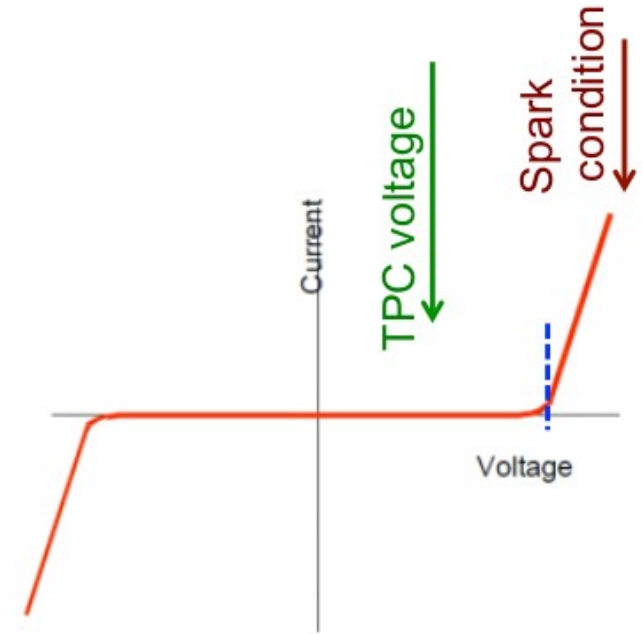
What will happen to the discharge (breakdown)

- Lets consider cathode discharge to ground (due to some breakdown).
- Field cage profile has capacitance, so remain charged.
- Large resistance prevent charge redistribution in the field cage.
- The relaxation time of a single stage is $= 1 \text{ Gohm} * 1 \text{ nF} = 1 \text{ s}$.
- In this time the large voltage difference (much higher than resistors rating) will damage the resistors.
- Same thing will happen if any profile discharges.

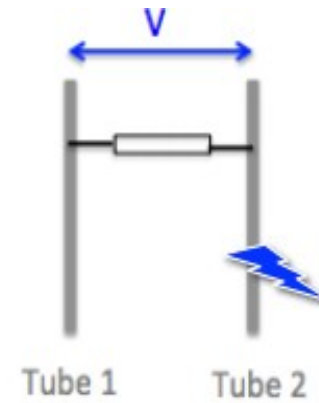
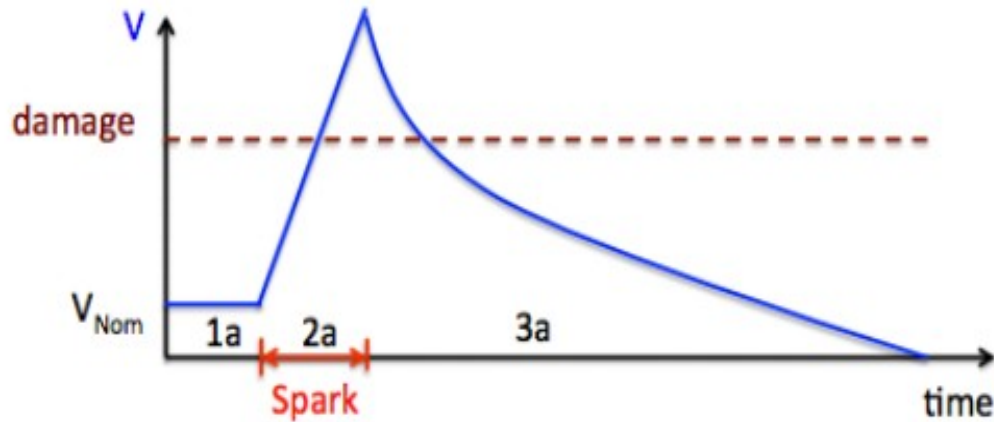


With Varistors

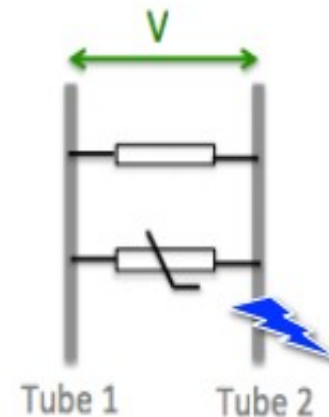
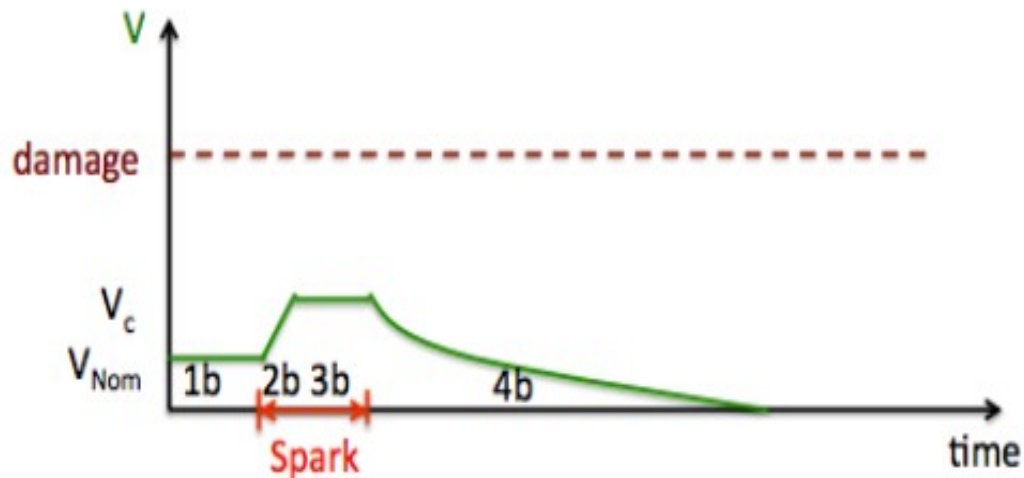
- Varistors have non-linear I-V characteristics.
- During the discharge, the voltage difference will be much higher than the clamping voltage of the varistors
- The resistance will go to be very low and voltage will be fixed at the clamping voltage.
- The relaxation will become very less and will be redistributed quickly.
- The voltage rating of the resistor should be higher than the clamping voltage of the varistors.



Without varistors



With Varistors



- With the varistors, the voltage never increases than the clamping voltage.
- It also helps G10 and argon breakdown.