



Progress of the RPC development towards the production for ATLAS Phase-II upgrade

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Outline

- Introduction
- Readout panel production
- RPC gas gap production
- BIS singlet assembly training
- Summary

Introduction

➤ Motivation:

- The muon spectrometer must operate at high-luminosity environment without significant performance losses.
- The muon trigger need to be significantly upgraded to maintain low trigger momentum thresholds while keeping the trigger rates at a manageable level.

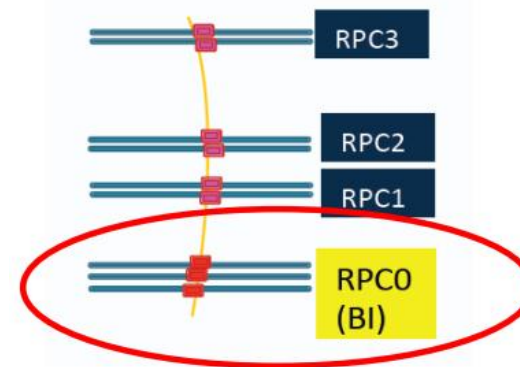
➤ The main limitation of the RPC when operate @HL-LHC

- The redundancy of the present RPC system is insufficient
- The present geometrical acceptance of the trigger in the barrel is only approximately 80%
- The rate and latency of trigger and readout electronics are incompatible with the Phase II requirements
- Long-term operation at high rates is not affordable for current RPC
- The greenhouse impact of the RPC gas mixture

Introduction

➤ Solution

- The installation of triplets of new-generation RPCs in the BI-RPC
- The replacement of the trigger and readout electronics
- Retrofitting with new front-end electronics in the BO chamber

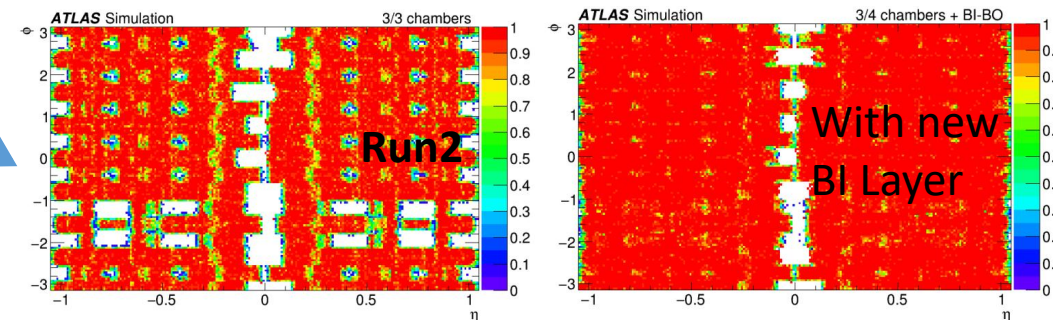


- 9 layers instead of 6

➤ Installation of triplets of new-generation RPCs in the BI-RPC

• Pros:

- ✓ Recover most of the current geometrical acceptance holes
- ✓ The redundancy of the system will be greatly enhanced
- ✓ Full trigger efficiency can be maintained even if the old RPCs have to be operated at reduced efficiency (mix gas or reduced HV)
 - Worse case: A reduction of the high voltage of the BM and BO RPCs to ensure their longevity



BM and BO efficiency (%)	Trigger efficiency × acceptance (%)		
	3/3 chambers	3/4 chambers	3/4 chambers + BI-BO
100	78	91	96
90	73	90	95
80	62	87	93
Worst case	63	85	92

- Components: 315 BIL + 359 BIS + 54 BIS78 chambers

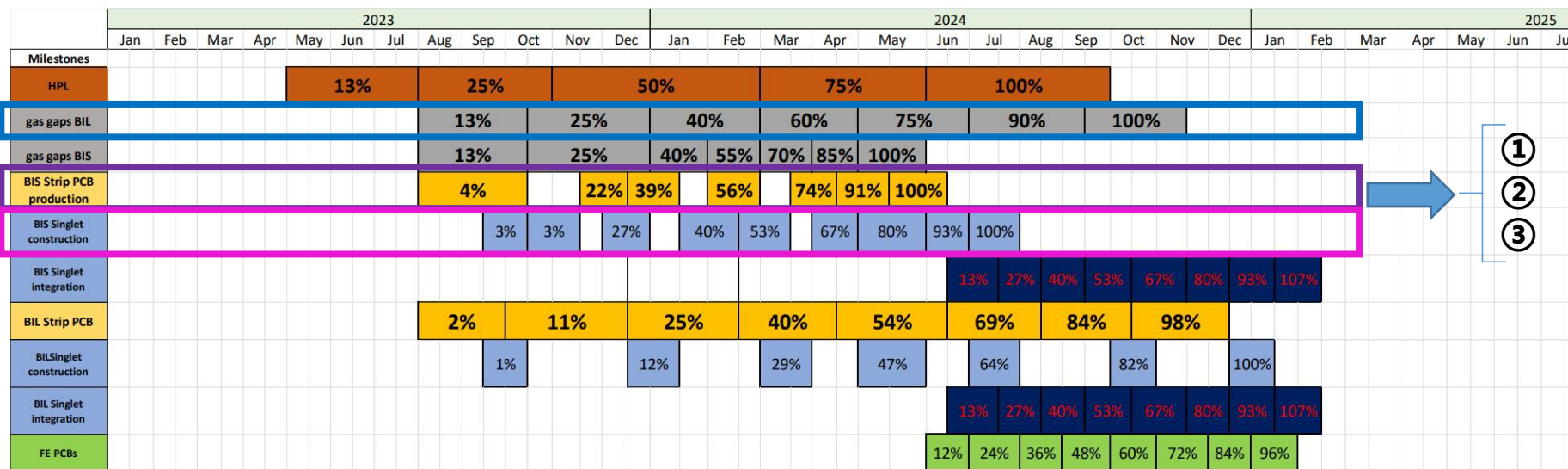
Tasks undertaken and production plan

➤ Tasks undertaken by ATLAS Chinese cluster (USTC-SDU-SJTU)

- ~ 900 BIS/BIL/BOM/BOR strip panels will be produced and qualified
- ~70 gas gap will be produced and qualified
- ~360 singlets assembly carried out in China

➤ The production plan

- BIS (576) strip pannel need to be produced and qualified around middle of June 2024
- BIL gas gap need to be finalized and qualified around middle of November 2024
 - ✓ 6 RPC gas gap prototypes need to be produced before Feb 2024 and sent to CERN to do the GIF++ qualification test
- BIS singlet assembly without FEE plan to be done around middle of July 2024



The schedule is quite tight

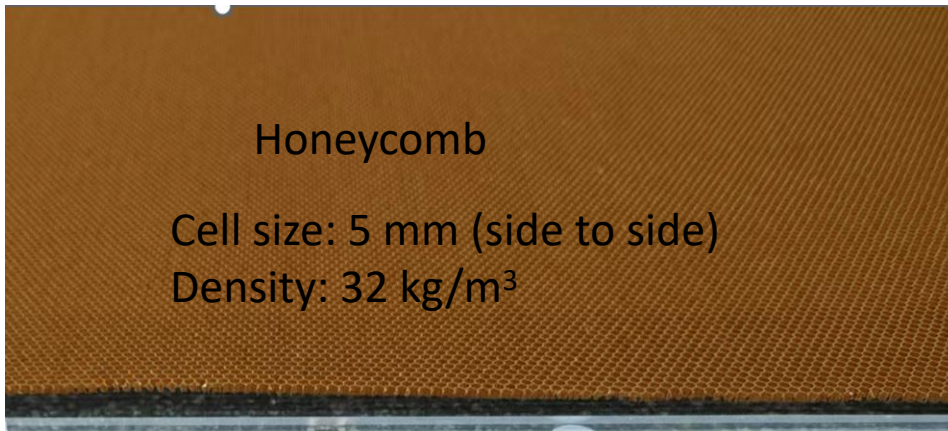
- ① Honeycomb readout panel production
- ② RPC gas gap production
- ③ Singlet assembly training in BB5

Today's topics

Honeycomb readout panel production

➤ Materials for production:

- PCBs: 8 set of PCBs (8 strip PCB + 8 GND panel (0.4mm thick, size: 1706x1070 mm))
- Honeycomb core: 3mm thick
- Glue: Araldite 2011 (~180g /side)



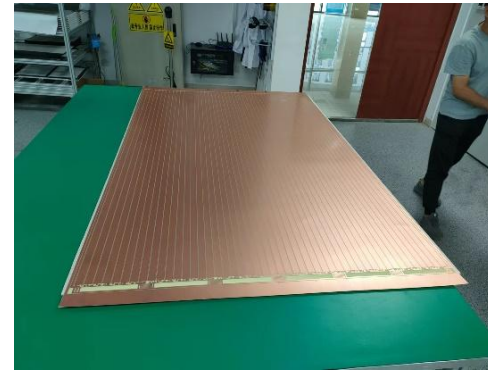
Specification:

The flatness of readout pannel < 0.1 mm

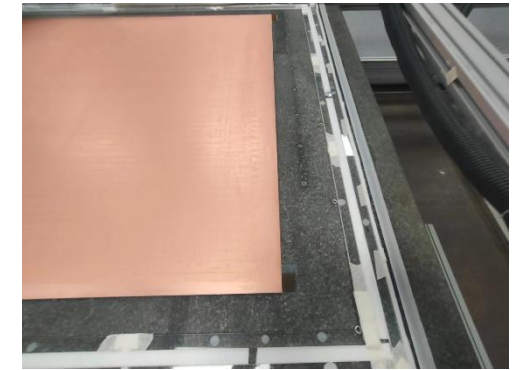
The length and width:

1705 +/- 1 mm

1072 +/- 1 mm



BIS-1 prototype

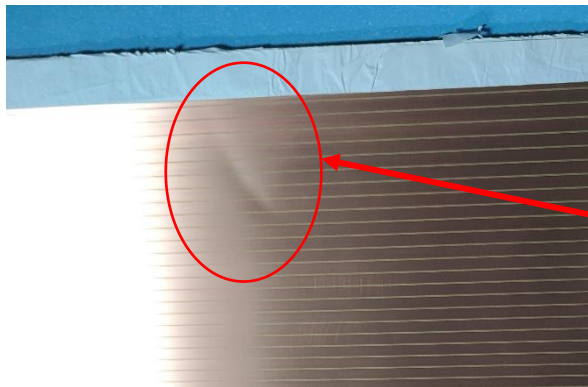
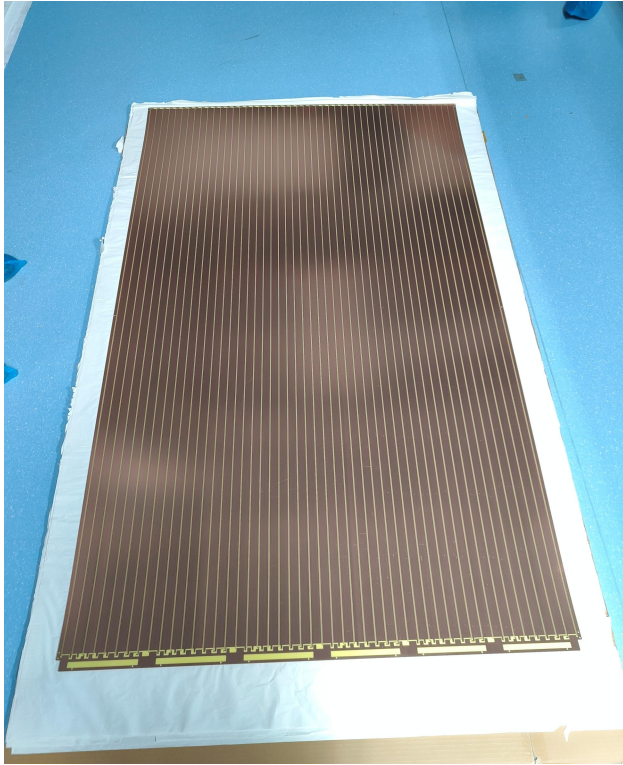


Araldite 2011



THINKY MIXER ARE-310

General checks on the PCBs



Visual check: Some slight fold marks observed on the surface of the PCB.

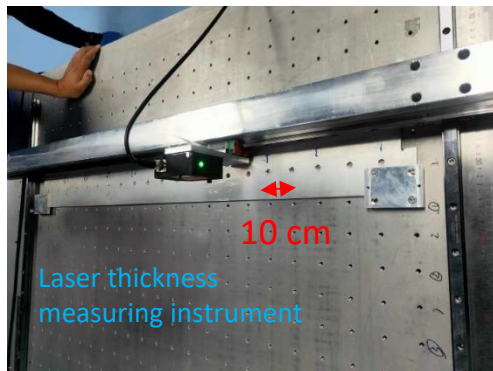


Electrical continuity checks

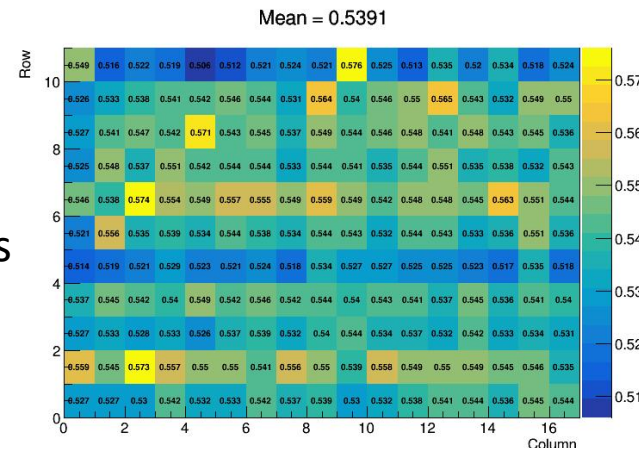
- All of 8 strip PCBs are checked
- No short or broken connections observed

The method to check the flatness of PCB/RO panel

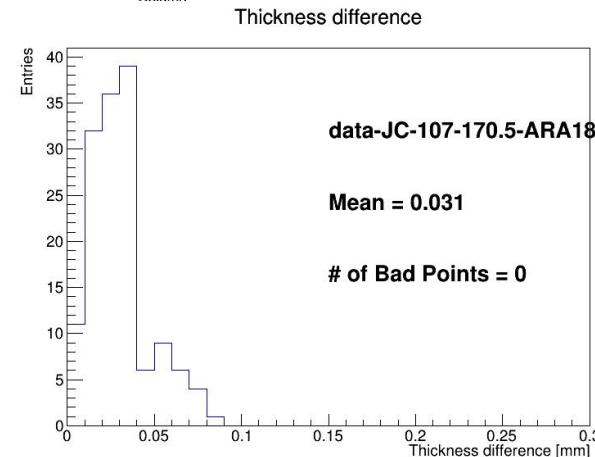
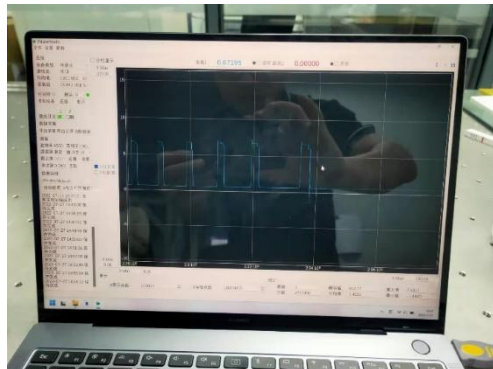
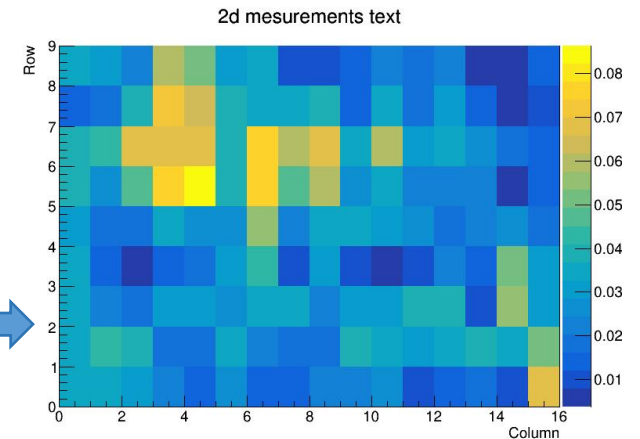
- The thickness is measured in a 10 x 10 cm matrix with a laser sensor.
- Flatness: Maximum variation of 4 points in a 10 x 10 cm range based on thickness.



Thickness

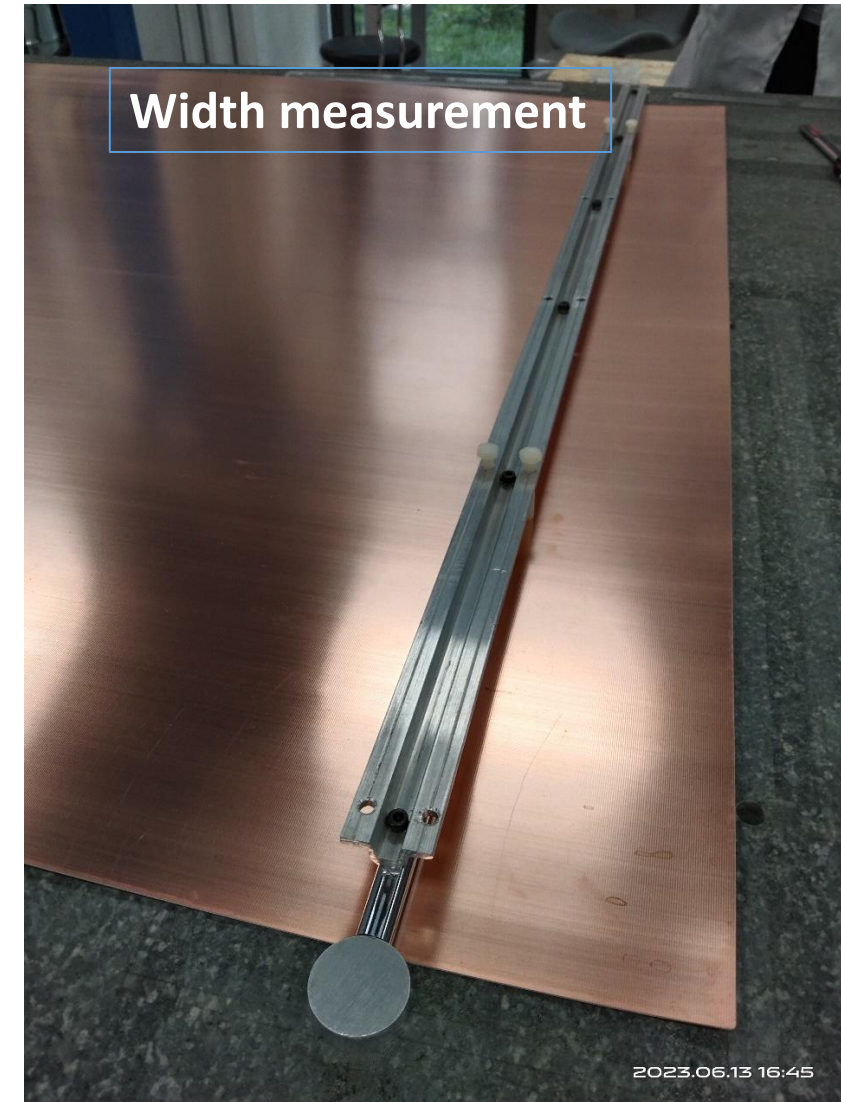


2D Flatness



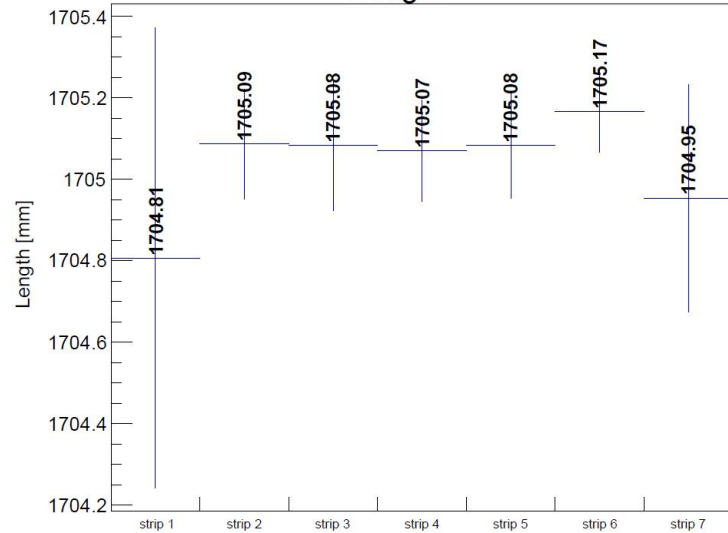
1D Flatness

The dimentional measurement

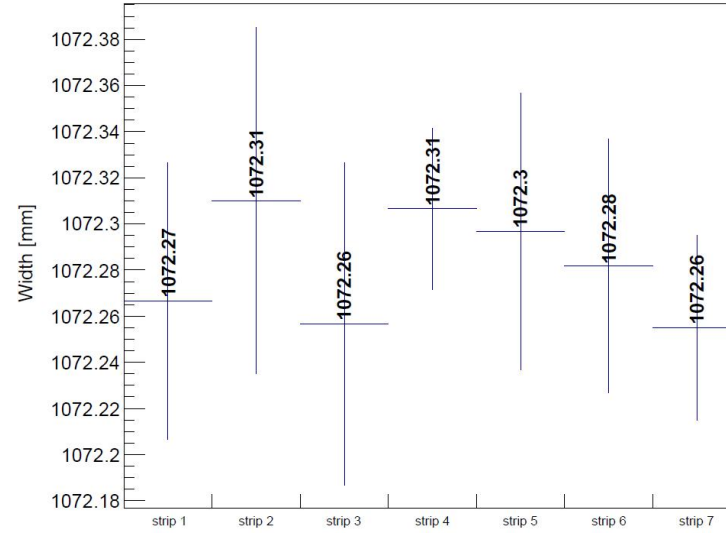


The dimentional results

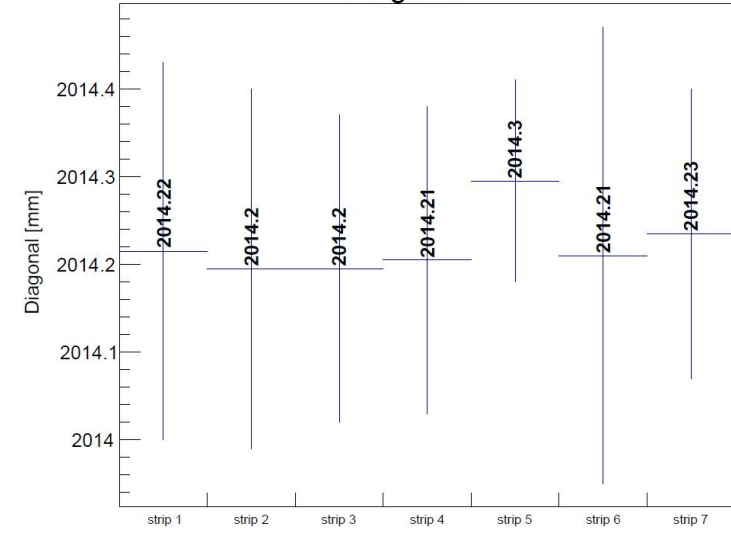
Length



Width



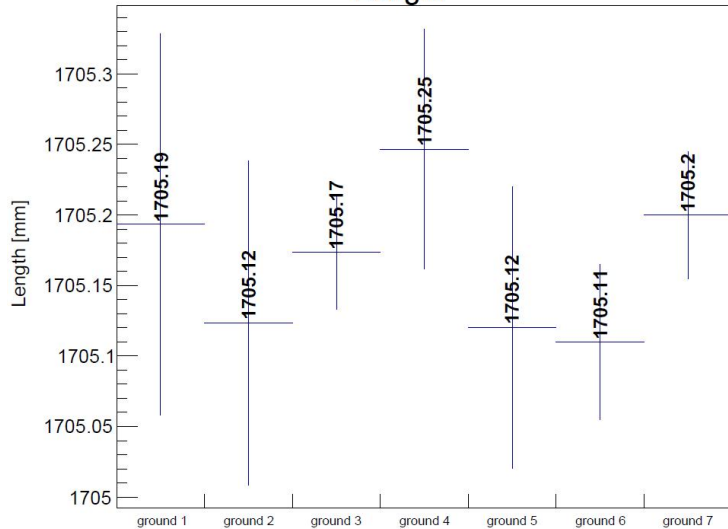
Diagonal



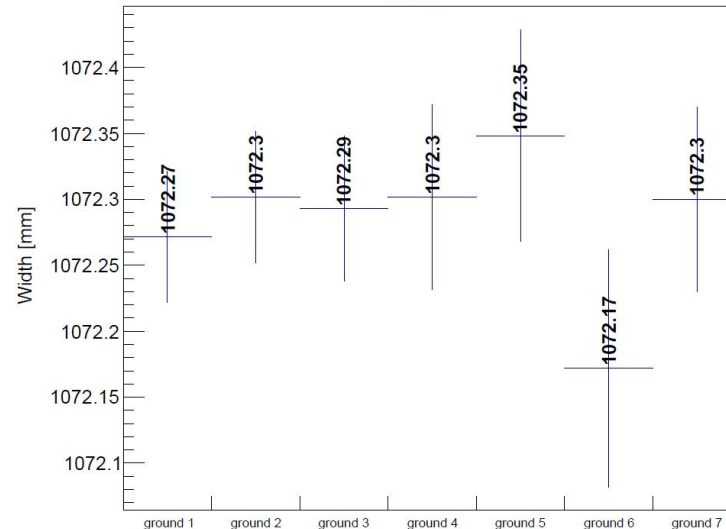
Nominal value:
Length: 1705mm
Width: 1072 mm
Diagonal: 2014 mm
Error: +/- 1 mm

Strip PCB

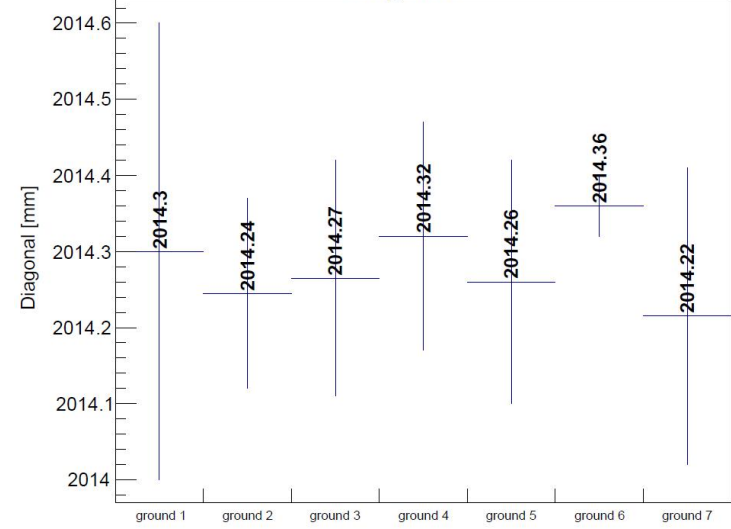
Length



Width



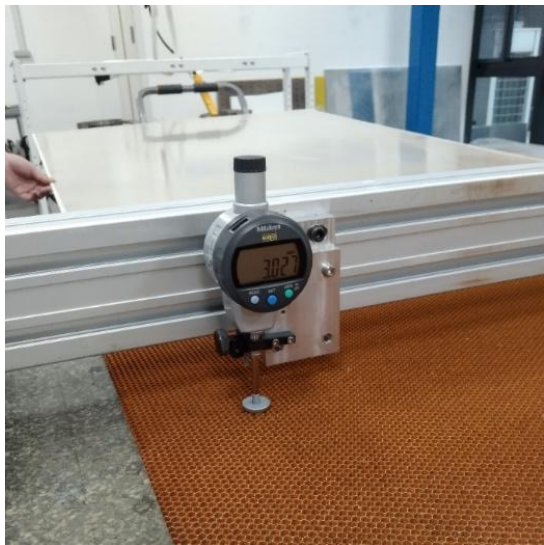
Diagonal



GND PCB

The quality of paper honeycomb

- 50 pieces of paper honeycomb (1220 x 2440 x 3 mm) received.
- Measure the thickness with micrometer gauge fixed on top of the marble table.

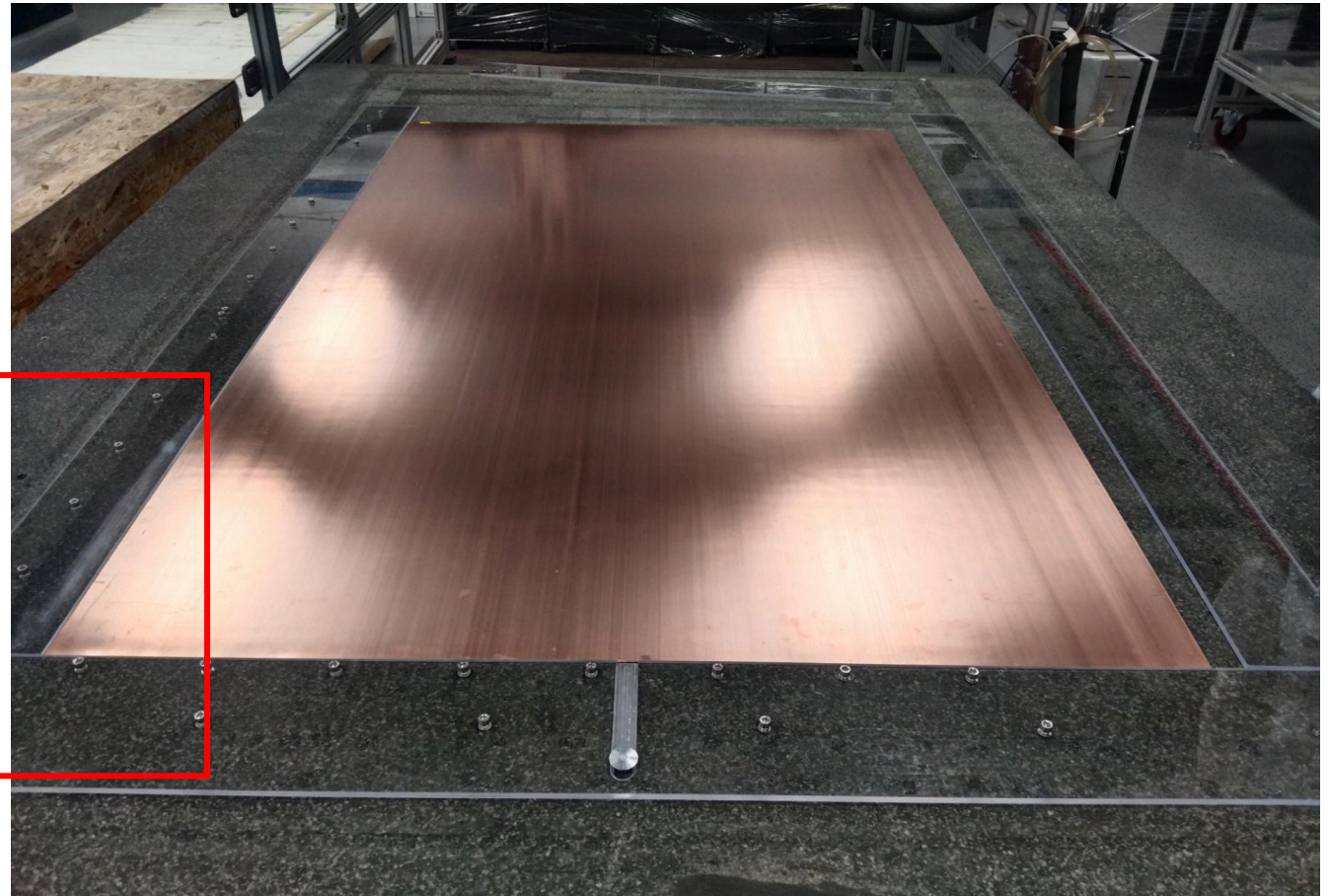


Sample #1			Sample #2			Sample #3		
	1	2		1	2		1	2
1	3.03	3.067	1	3.102	3.091	1	3.062	3.043
2	3.05	3.07	2	3.087	3.076	2	3.066	3.065
3	3.036	3.067	3	3.072	3.049	3	3.057	3.049
4	3.022	3.074	4	3.078	3.067	4	3.064	3.044
5	3.05	3.067	5	3.07	3.041	5	3.06	3.057
6	3.038	3.055	6	3.071	3.043	6	3.068	3.059
mean	3.038	3.067		3.08	3.061		3.063	3.053
Sample #4			Sample #5					
	1	2		1	2			
1	3.039	3.076	1	3.107	3.103			
2	3.063	3.074	2	3.096	3.099			
3	3.054	3.082	3	3.074	3.097			
4	3.061	3.092	4	3.079	3.097			
5	3.075	3.088	5	3.106	3.107			
6	3.078	3.079	6	3.106	3.119			
mean	3.062	3.082		3.095	3.104			

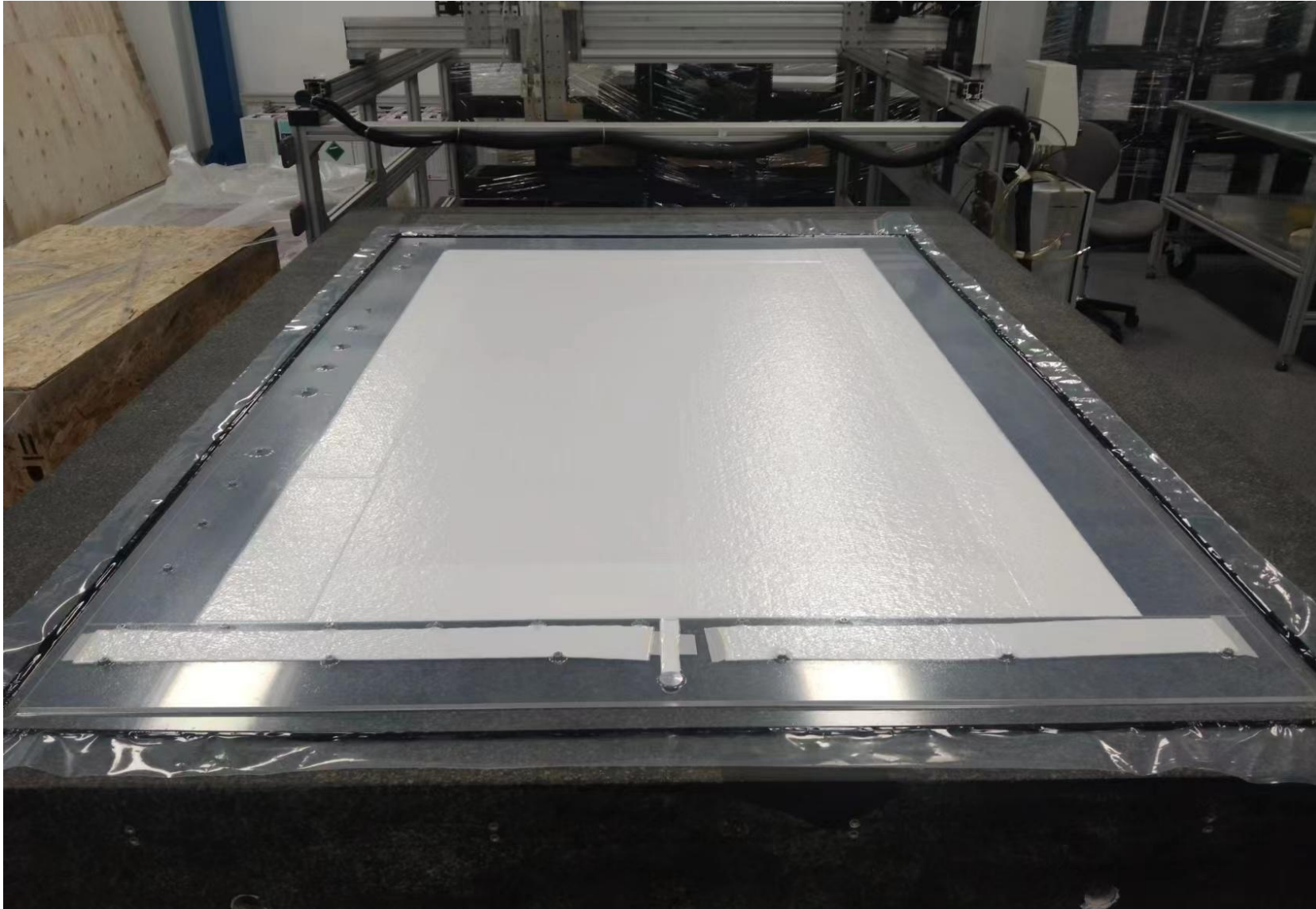
- 5 samples are selected randomly.
- All samples are checked with good quality.

The optimized method to construct readout panel

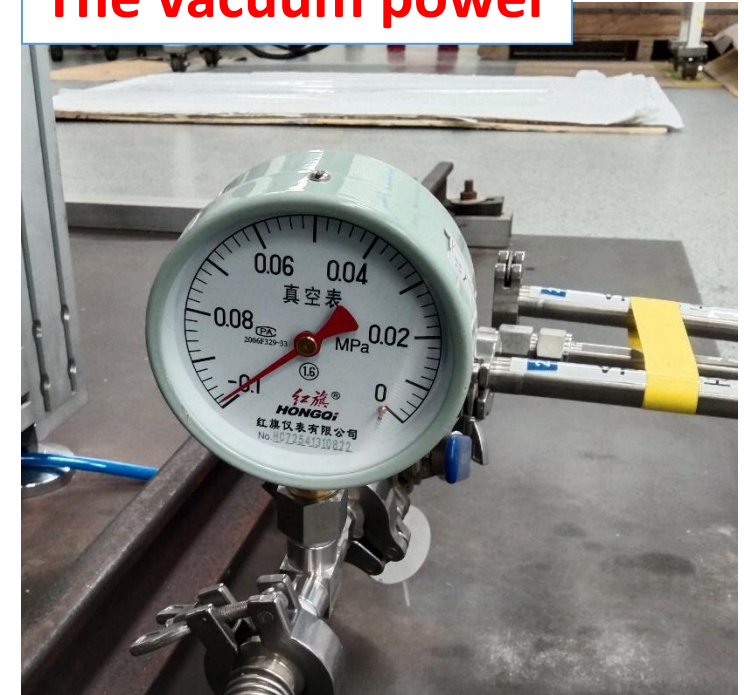
- All layers align to two reference bars fixed on the marble table.
- The panel can be glued at one time.



The panel under vacuuming

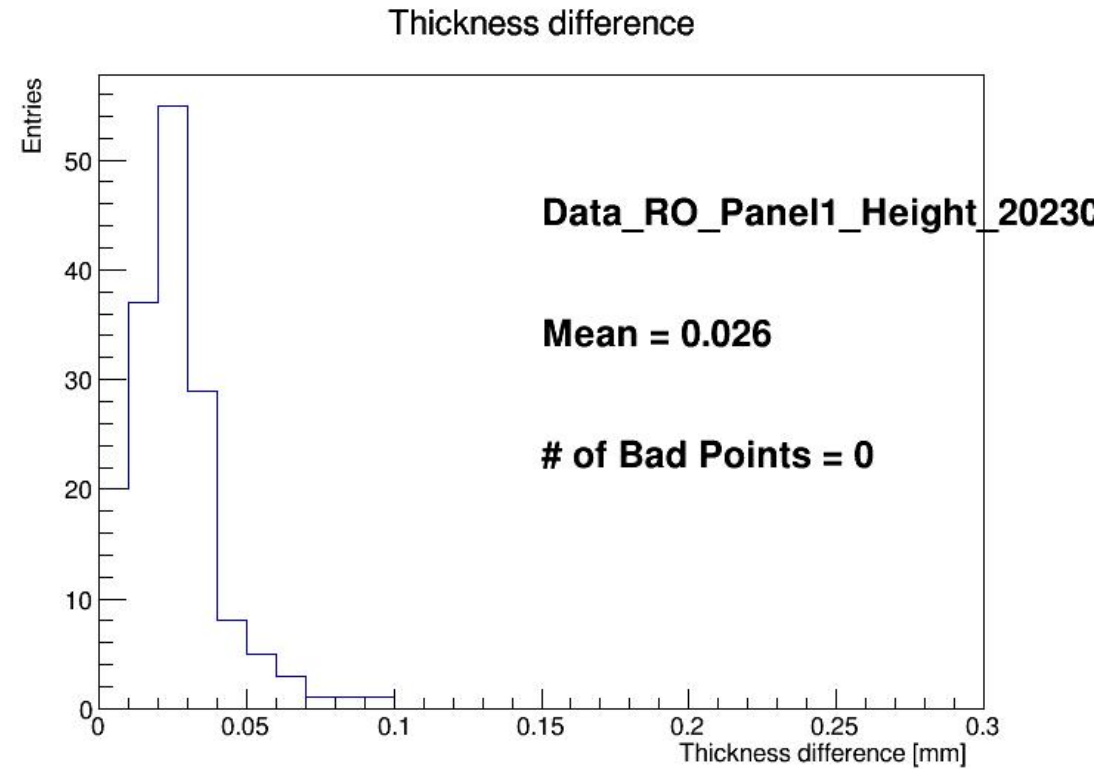
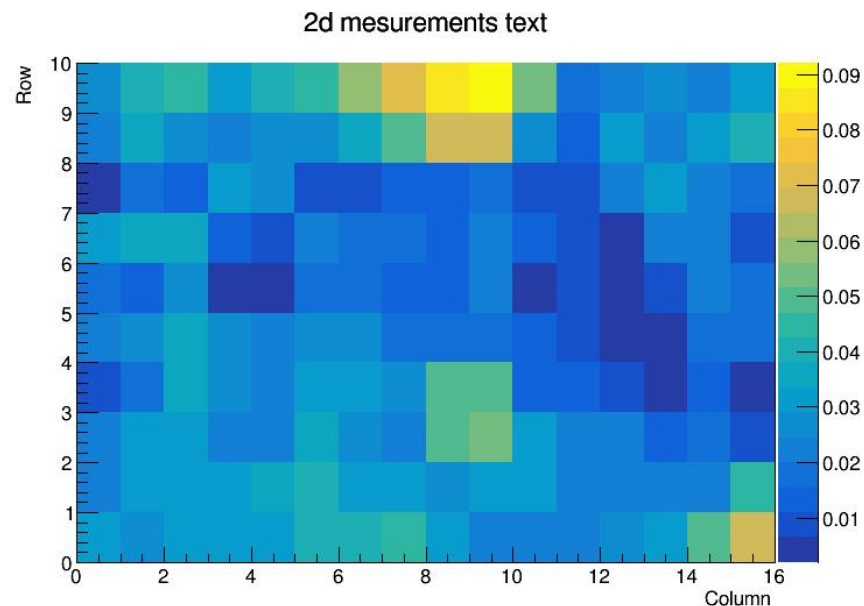
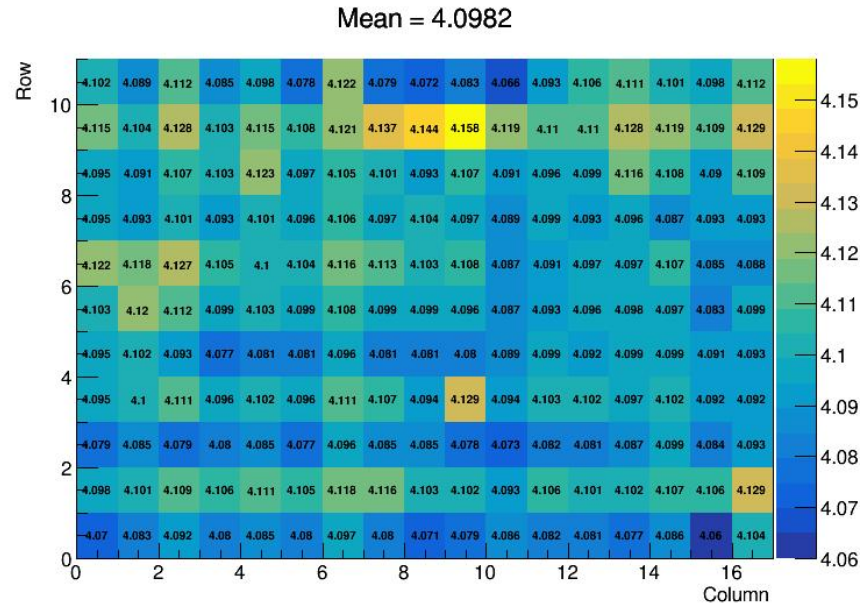


The vacuum power



keep at least 6 hours for the epoxy curing within the vacuum bag.

Thickness measurement of the readout panel

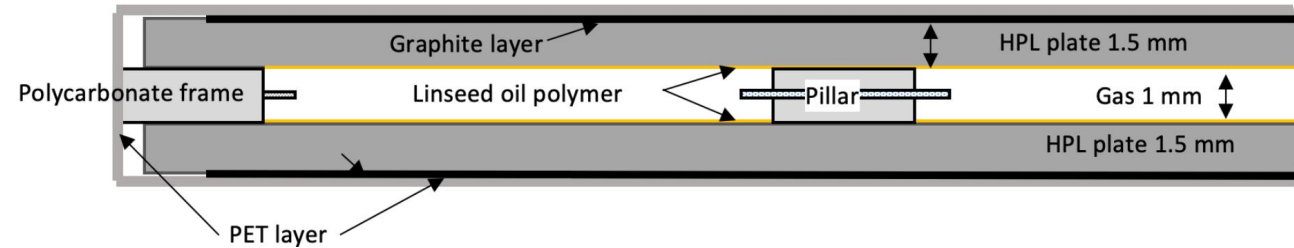


Thickness mean value = 4.098 mm
Flatness: good

RPC gas gap

➤ General description

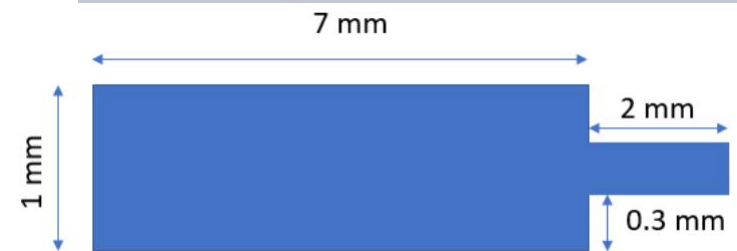
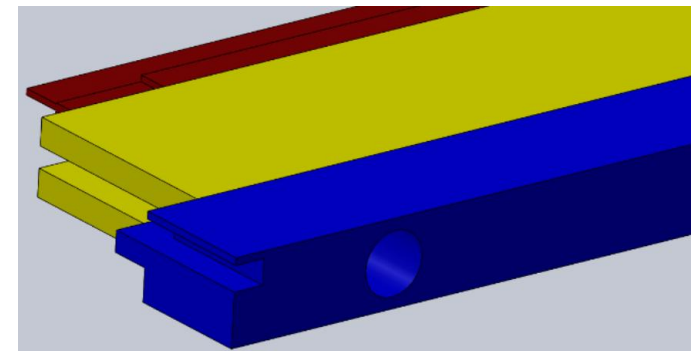
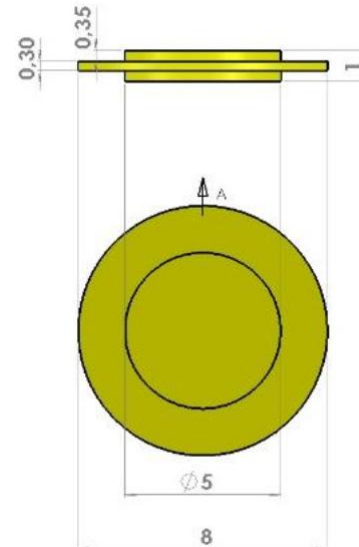
- It has large area parallel plate structure
- it works on the avalanche mode



Sketch of a Gas Volume

➤ Components:

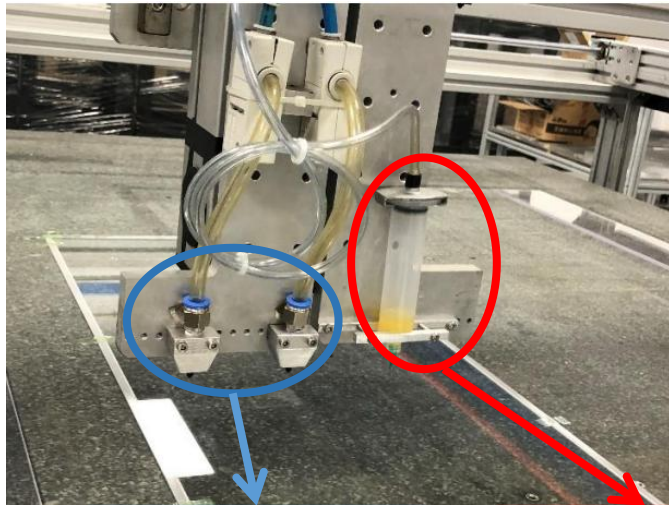
- Electrode plate: High-Pressure Laminate (HPL), 1.5mm thickness
- Spacer: 1.00 ± 0.01 mm
- Polycarbonate frame
- Graphite layer
- Graphite connected high voltage link
- PET layer
- Gas distributor



For test purpose, use glass to replace HPL in the following slides.

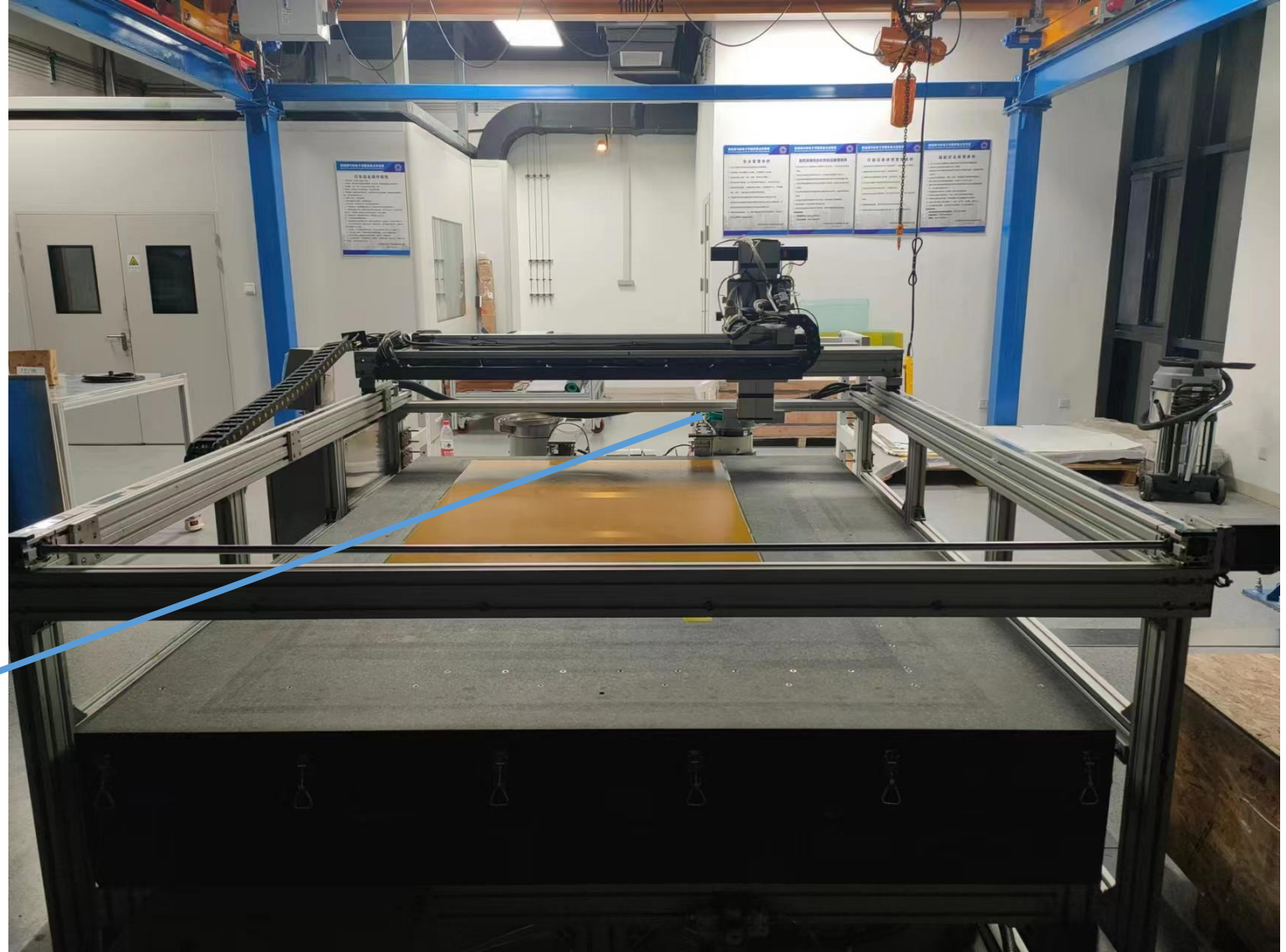
The platform of gas gap production

- A marble table as base:
2.5m×1.8m
- A head stock supported by a gantry moving in 2-dimentional
- 9 holes among the table are connected to the vacuum system.



Spacer pickers

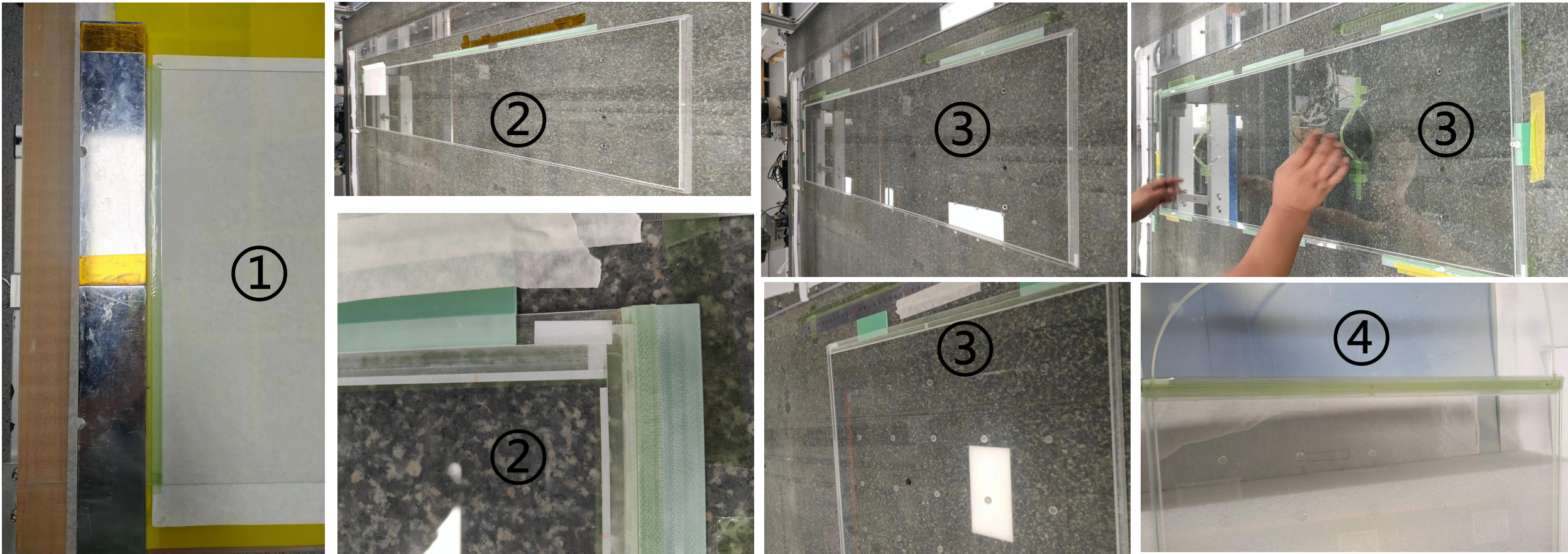
Glue syringe



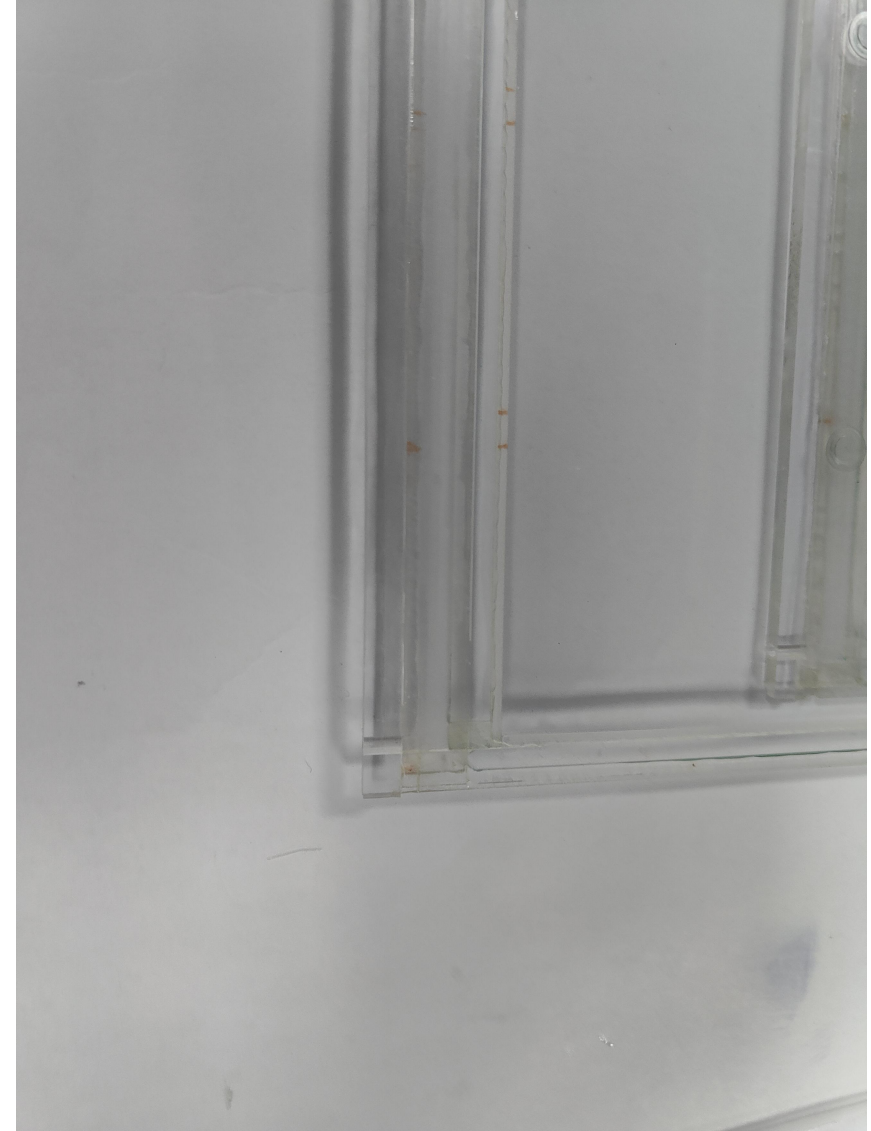
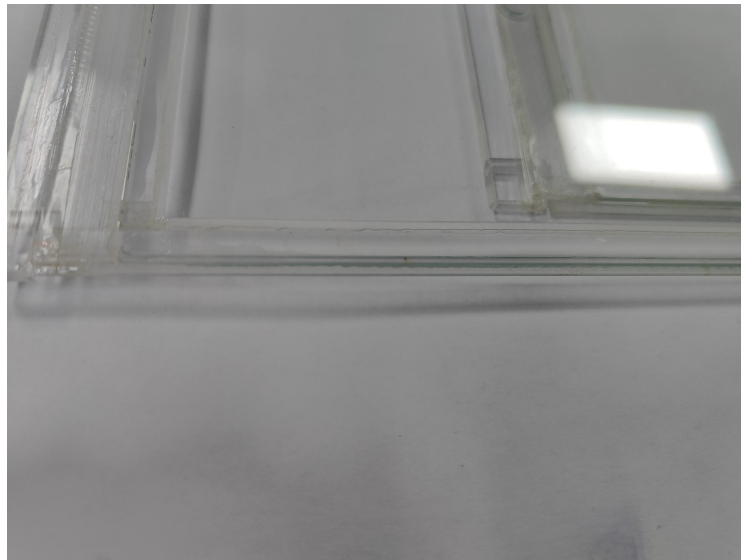
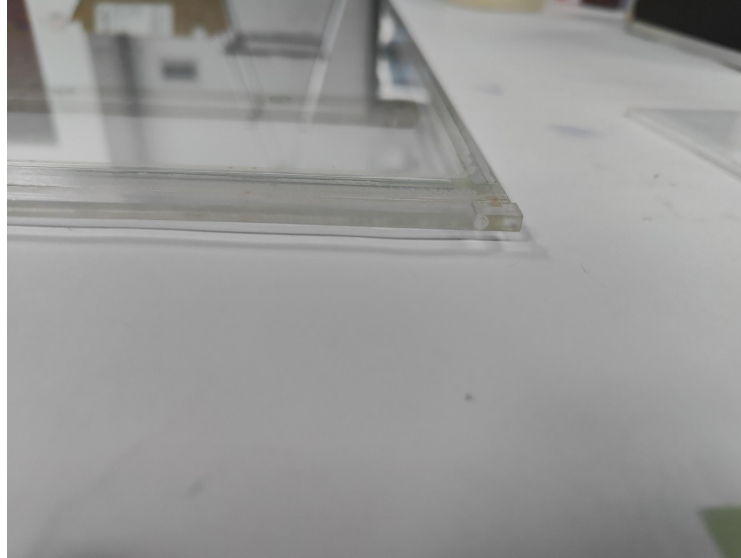
Gas gap production procedures

- The first step: Attach the floor plates on the glass
- The second step: Attach the long and short side frame on the glass and vacuuming
- The third step: Put the spacers and close the gas gap
- The last step: Put the perimetric polycarbonate frame into gas gap

**Full procedures will takes ~2 days
to produce one gas gap**



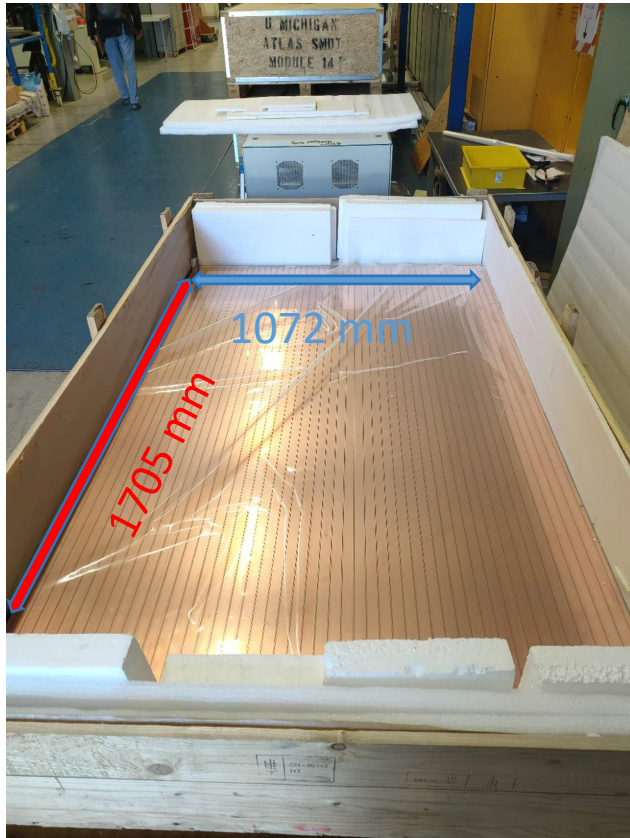
The final product



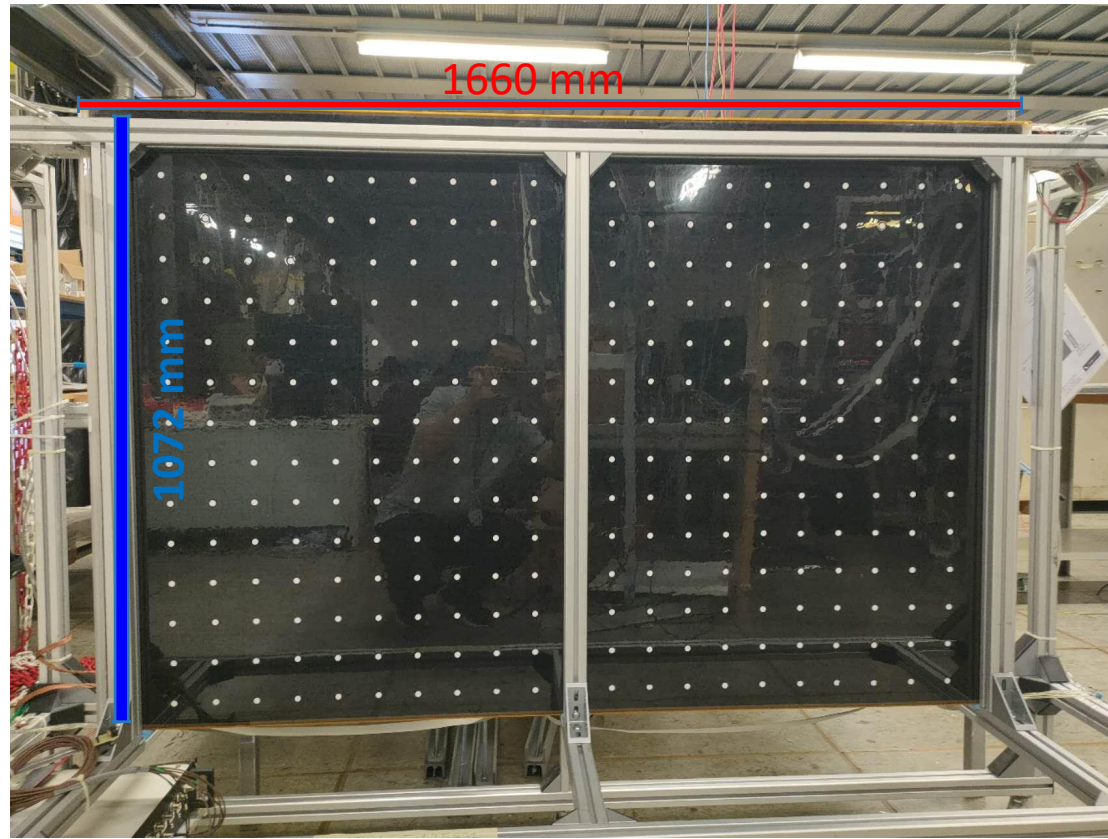
BIS assembly training at CERN

Materials for the BIS assembly

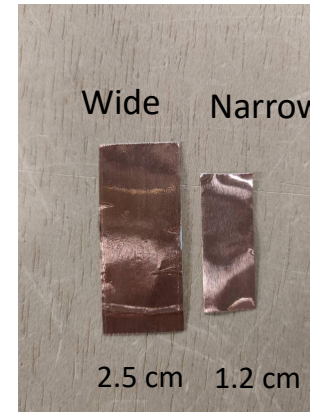
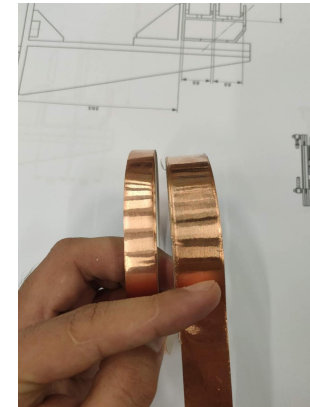
- 8 readout panels produced by USTC (Label: PCB1-PCB8)
- 4 gas-gaps produced by GTE (Label: BIS2A 2/23, BIS2A 3/23, BIS2A 4/23, BIS2A 6/23)



Readout panels



Gas gaps



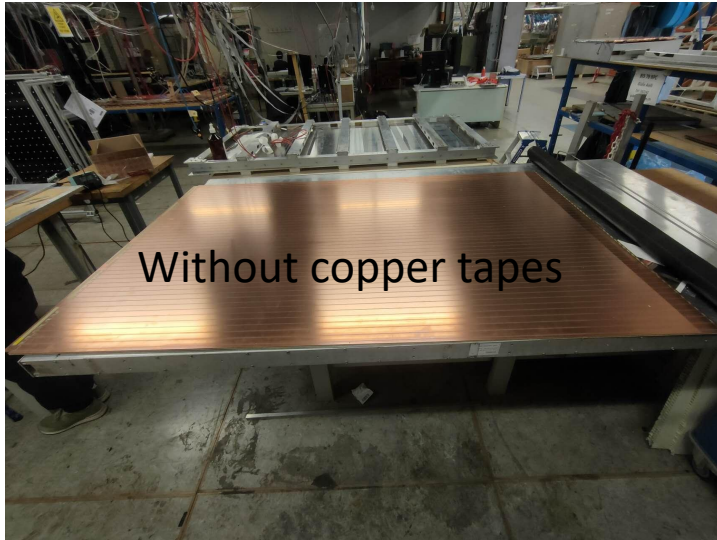
Copper tapes



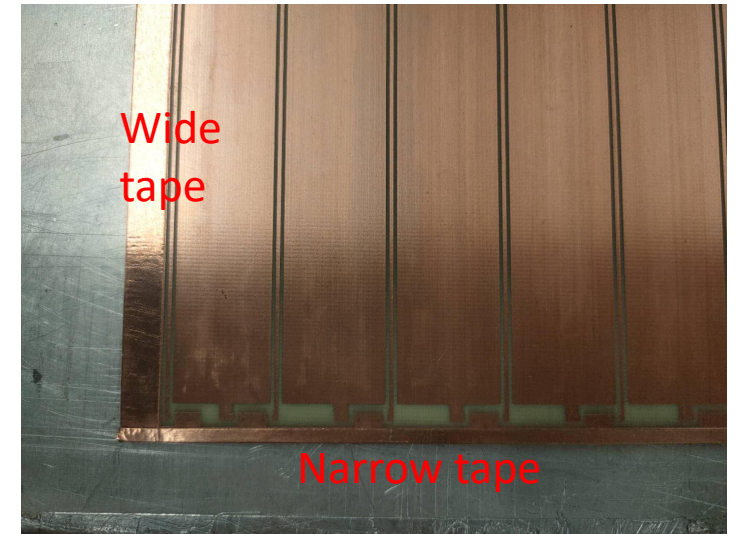
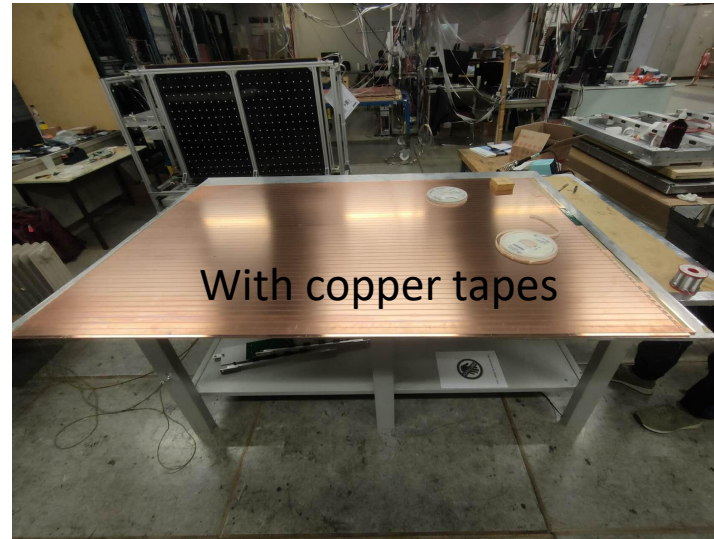
Resistors

Preparatory works

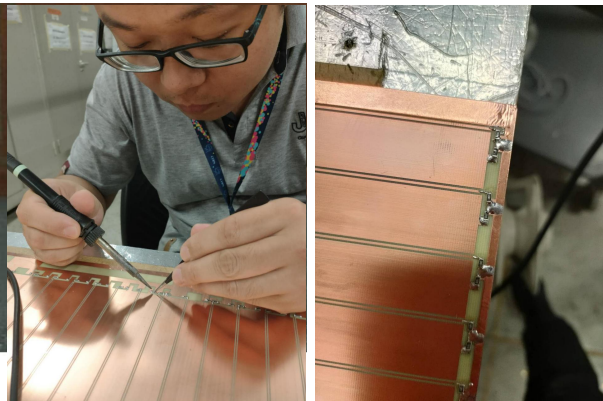
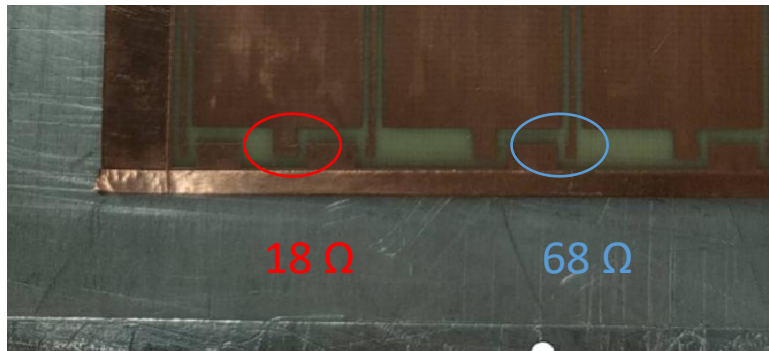
➤ Step 1: Attach tapes around the readout panels



20-30
minutes



➤ Step 2: solder the matching resistors: 18 Ω and 68 Ω



1 readout panel need $(48 * 2 + 1) * 2 = 194$ resistors,

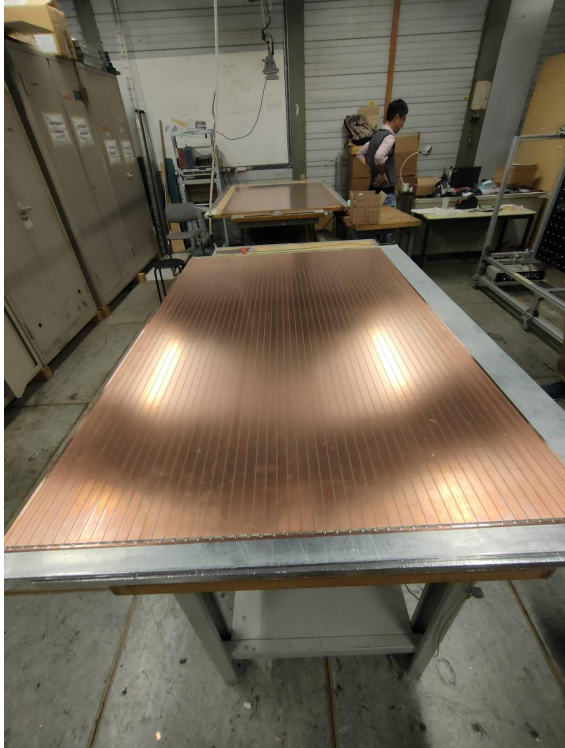
take 2.0 hours for each readout panel

1 singlet: $194 * 2 = 388$ resistors

1 chamber: $3 * 388 = 1164$ resistors

Very time consuming

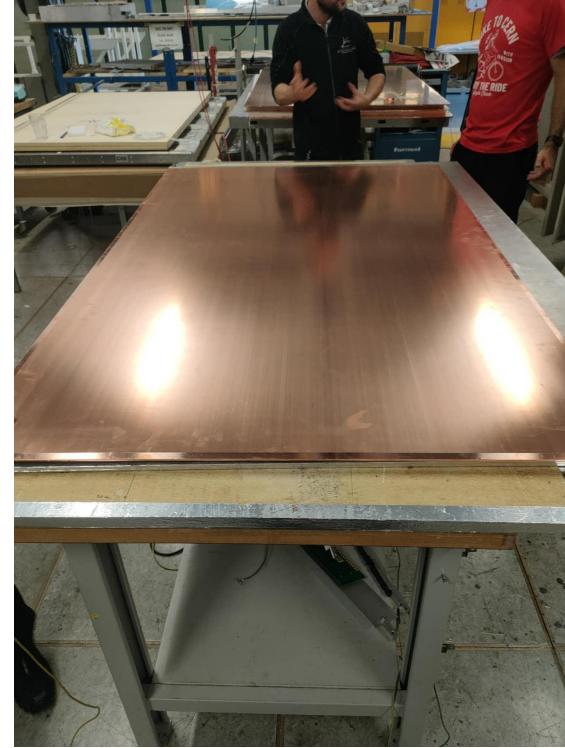
Assembly works



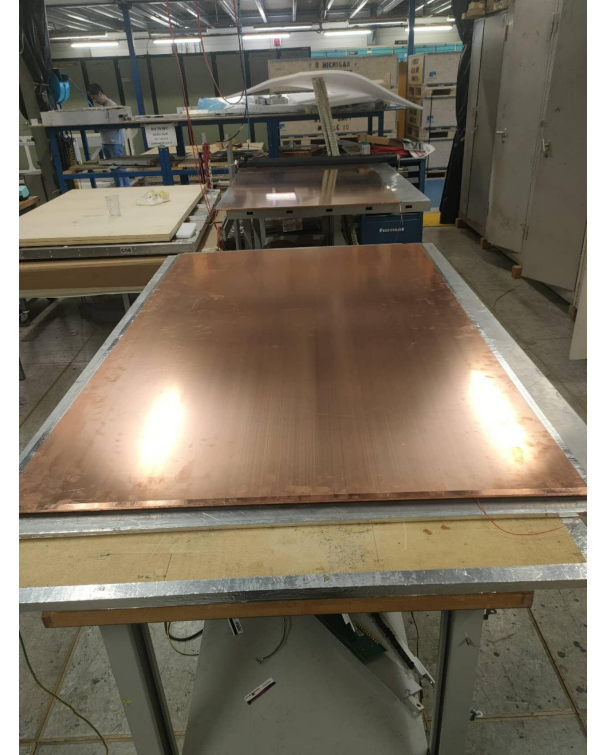
Step1:
Put the readout pannel in
the table with strip pannel
on the top



Step2:
Put the gas gap on the top
of the readout pannel



Step3:
Put another readout pannel
on the top of the gas gap



Step4:
Use the Aluminium tape
to fix those three layers
to form the singlet

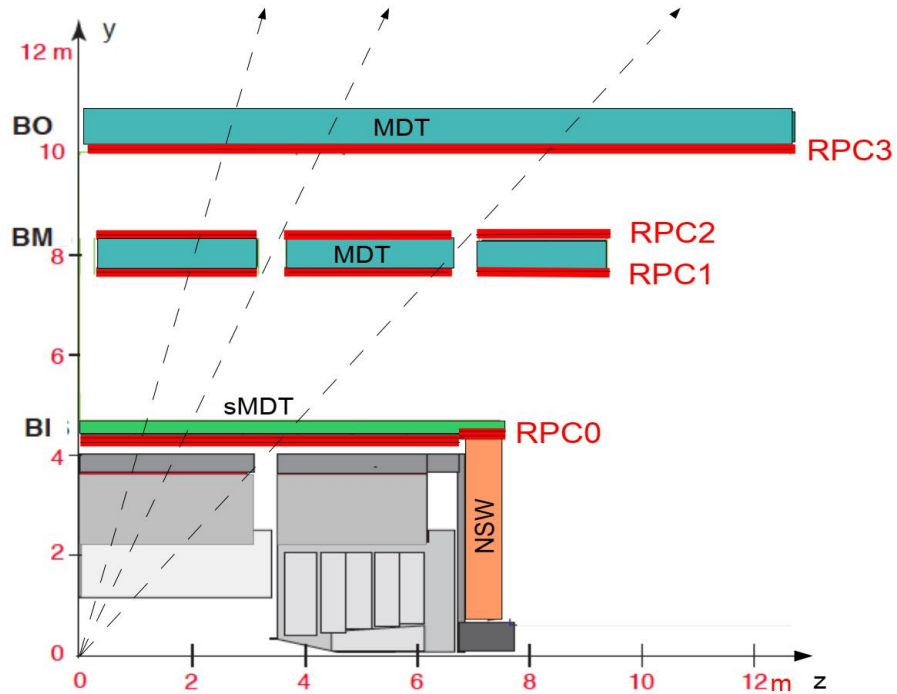
Summary

- The vacuum-bag-based honeycomb readout panel production method has been established and optimized at USTC.
- The full BIS size (1706x1070 mm) panels can be built, the flatness of the Readout panel $< 100\mu\text{m}$, satisfy the specification.
- The production procedures of gas gap are still working in progress.
- We are ready to assemble the BIS singlet in USTC.

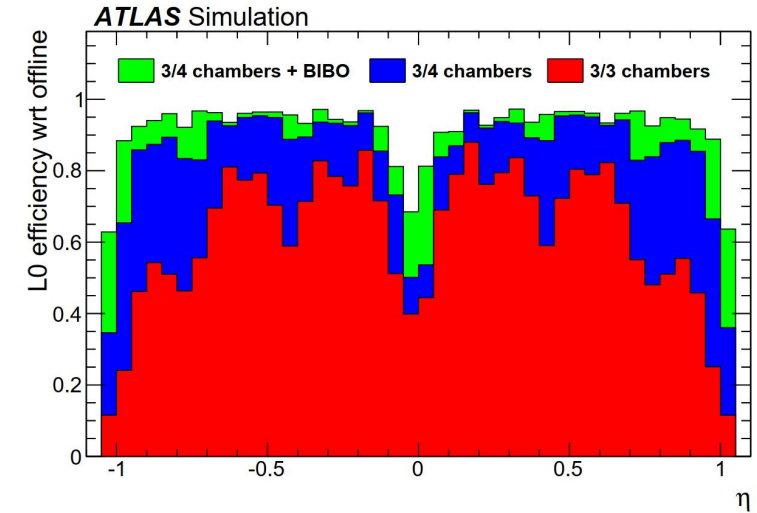
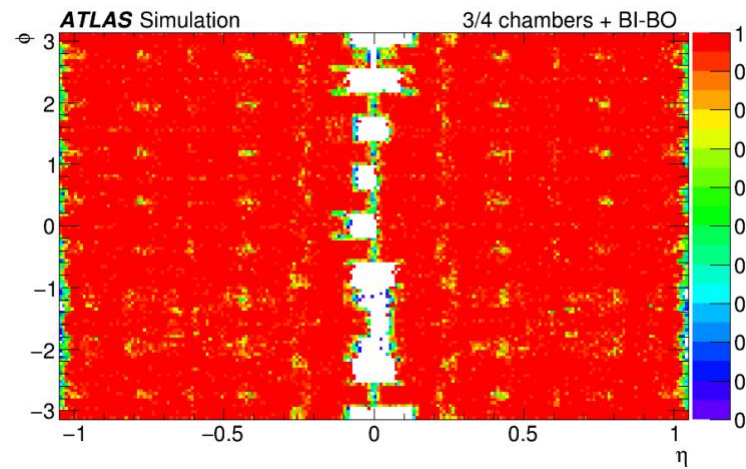
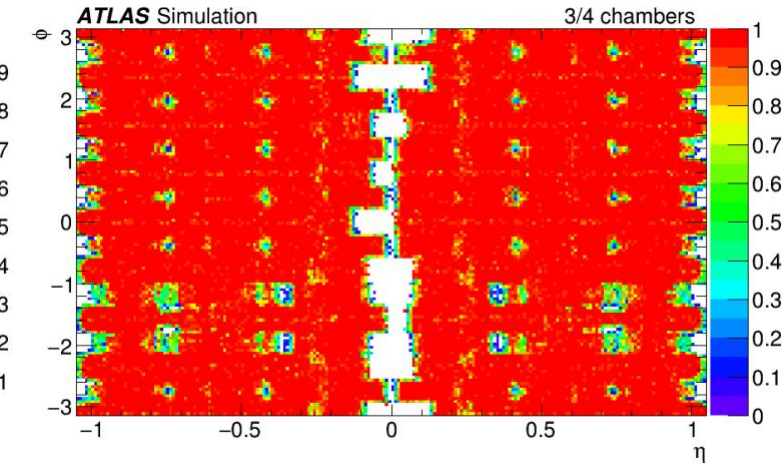
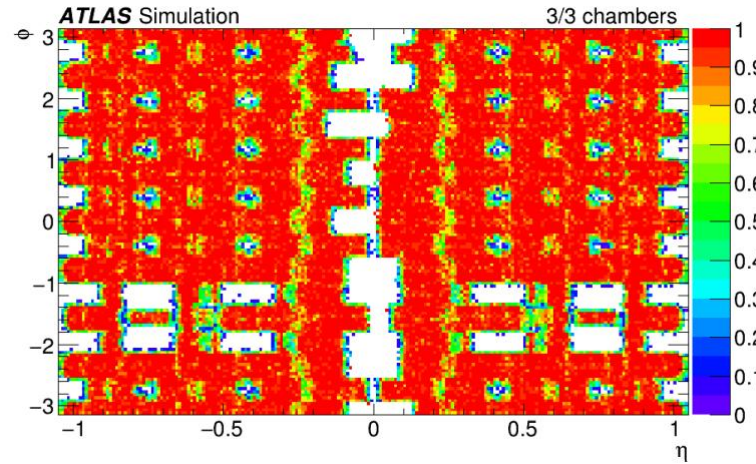
Thank you for your attention

Back up

Geometrical acceptance and trigger eff.



Trigger	Requirement
3/3 chambers	$3[\text{RPC1}+\text{RPC2}] \text{ AND } 1[\text{RPC3}]$
3/4 chambers	$(3[\text{RPC1}+\text{RPC2}] \text{ AND } 1[\text{RPC3}]) \text{ OR } (2[\text{RPC0}] \text{ AND } 3[\text{RPC1}+\text{RPC2}+\text{RPC3}])$
3/4 ch. + BI-BO	$(3[\text{RPC1}+\text{RPC2}] \text{ AND } 1[\text{RPC3}]) \text{ OR } (2[\text{RPC0}] \text{ AND } 3[\text{RPC1}+\text{RPC2}+\text{RPC3}])$ OR $(2[\text{RPC0}] \text{ AND } 1[\text{RPC3}])$



WORK
sharing

WORK IN PROGRESS									
PRIORITY			Number	GTE	INFN	MPI	USTC	HK	TK
1	BIL (excluding s7)	gas gap	312	100%					
		strip panel	624		100%				
		singlet	312		100%				
		triplet	104		100%				
1	BIL s7	gas gap 5-9 S7	30	backup			100%		
		gas gap(1-4+10)S7	30	100%					
		strip panel	120		50%		50%		
		singlet	60		50%		50%		
		triplet	20		50%		50%		
2	S9 @ Eta=0	gas gap S9@E=0	18	backup			100%		
		strip panel	36				100%		
		singlet	18				100%		
		triplet	6				100%		
1	BIS1-6	gas gap	288	100%					
		strip panel	576				100%		
		singlet	288				100%		
		triplet	96			100%			
2	BOR/BOM	gas gap	240	backup		100%			
		strip panel	480		50%		50%		
		singlet	240		25%	25%		25%	
		triplet	80		25%	25%		25%	
3	BIS7	gas gap	24	100%					
		strip panel	48						
		singlet	24		100%			100%	
		triplet	8		100%			100%	
3	BIS8C	gas gap	24	backup			100%		
		strip panel	48						
		singlet	24				100%		
		triplet	8				100%		
3	BIS78A	electronics replacement	48		50%			50%	
		triplet	16		50%			50%	
			Number	GTE	INFN	MPI	USTC	HK	TK
Total Singlets assigned to be built			942	624	402	60	360	60	60
Total Chambers assigned to be built			314		134	116	24	20	20
Total Singlets unassigned			24		24			24	
Total Chambers unassigned			8		8			8	
Total refurbishing unassigned			16		16			16	

Last refined balance the between p to optimize

Gas lines Germany qualified and expected

Close to final but waiting for formal approval

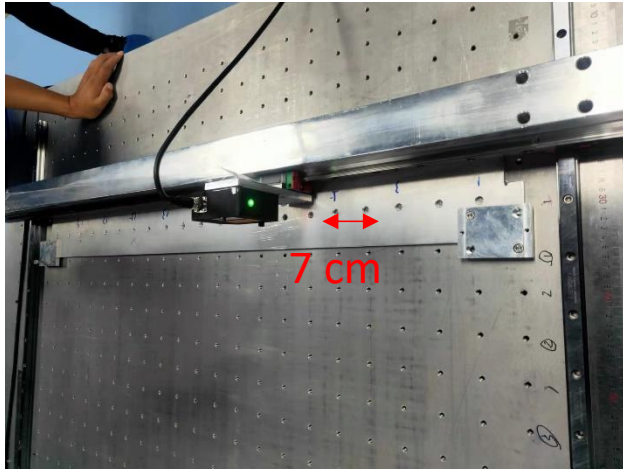
Giulio Aielli - PC BI Singlets PRR

Last refinements needed to balance the workload in between partner Institutes so to optimize the schedule slack

Close to final but waiting for formal approval

Gas gap production lines in USTC and Germany need to be qualified specifically and will undergo a dedicated PRR, expected in 10/24

The method to get the thickness of PCB/panel

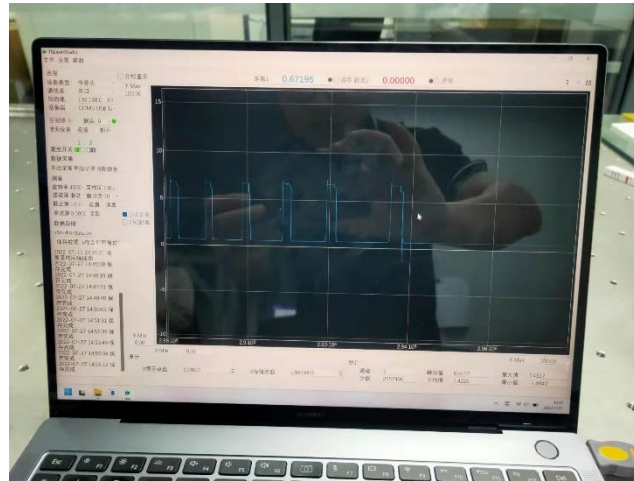


Measure the baseline

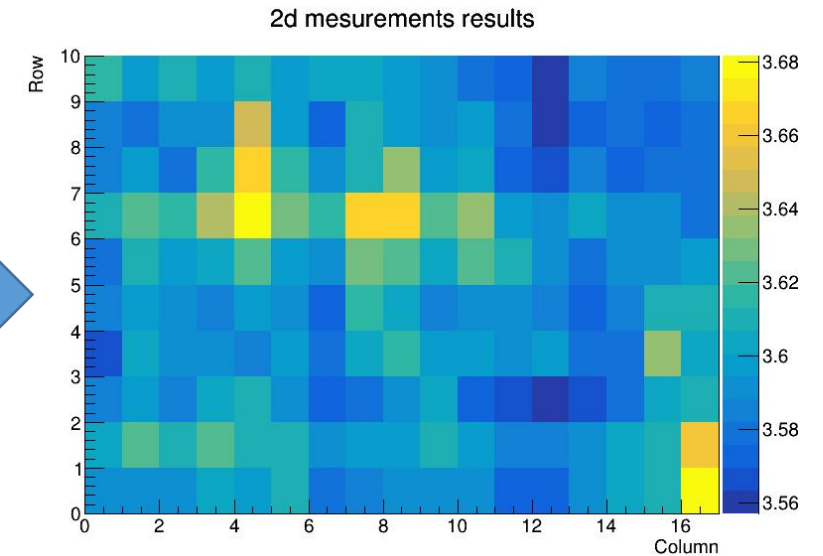


Baseline + PCB/panel

- A laser sensor sliding along a rail taking data continuously.
- The thickness at the sampling point (7 cm interval) achieved by a mask with holes.



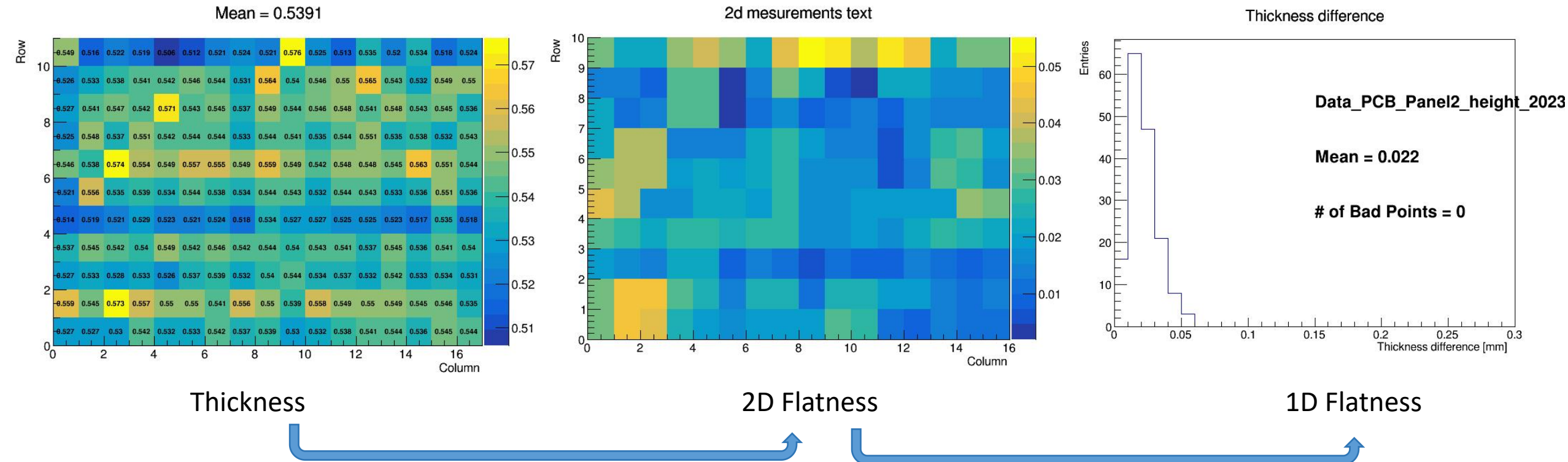
The dips along the measurement show the thickness of the panel.



The real height of the panel after baseline correction.

Flatness check on the PCB

- The thickness is measured in a 7 x 7 cm matrix.
- Flatness: The maximum variation of 4 points in a 7 x 7 cm range.
- The requirement of flatness < 100 μm can be achieved.



Y

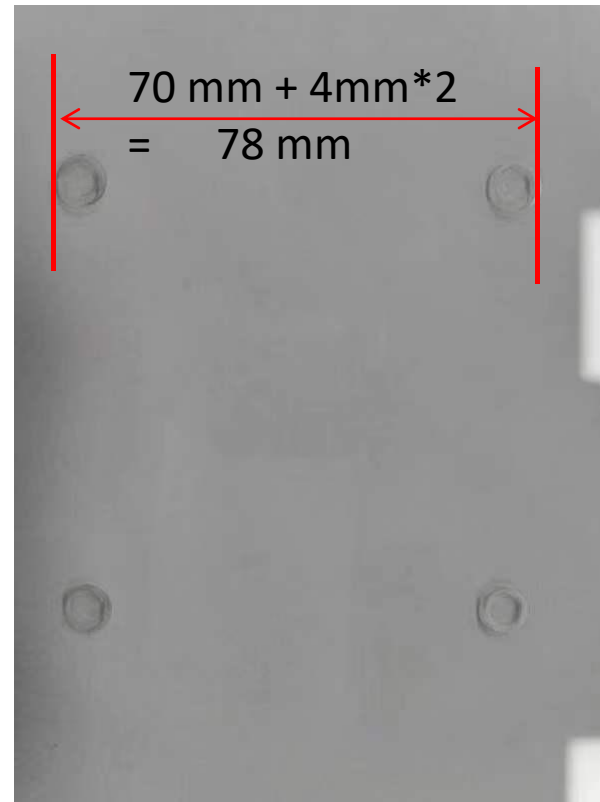


Nominal value:

radius of spacer: 4mm

height of spacer: 1mm

distance: 70mm*70mm



X

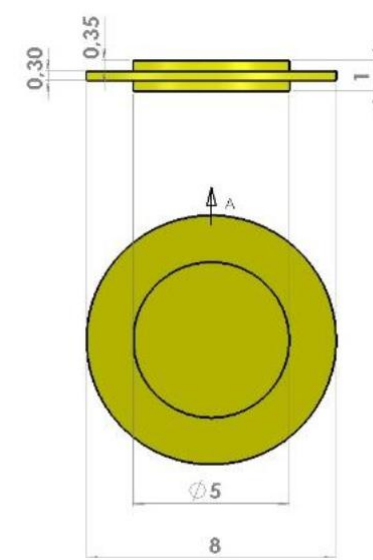
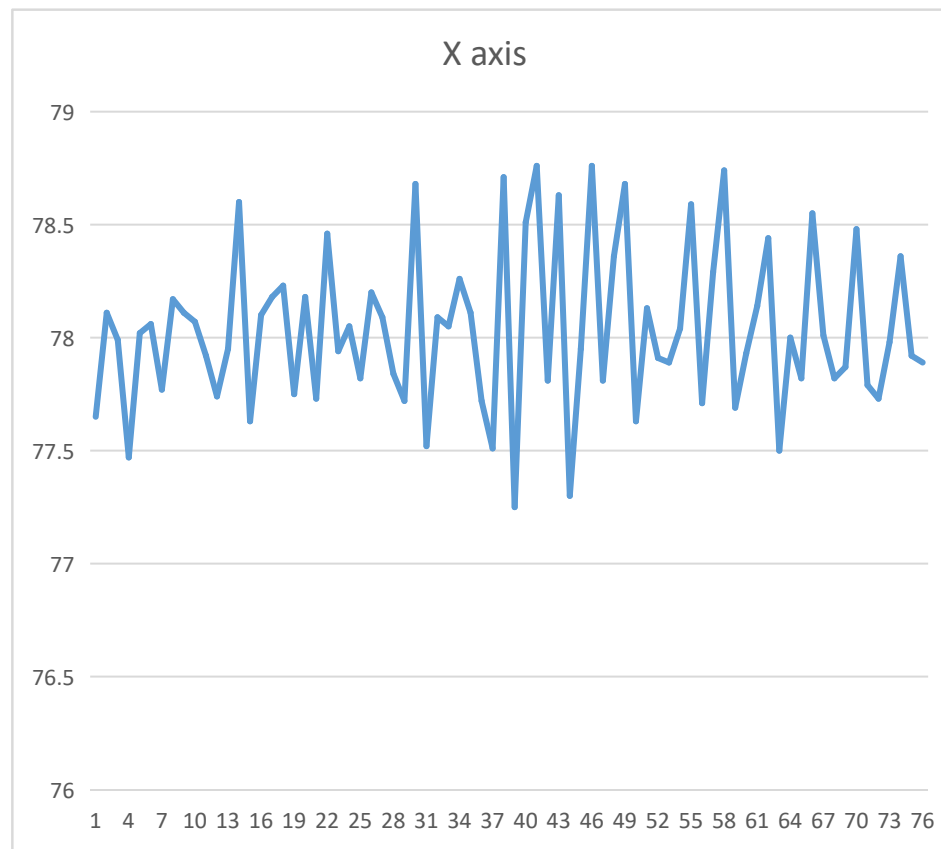


Figure 5: design of the cylindrical pillar with the guard ring.

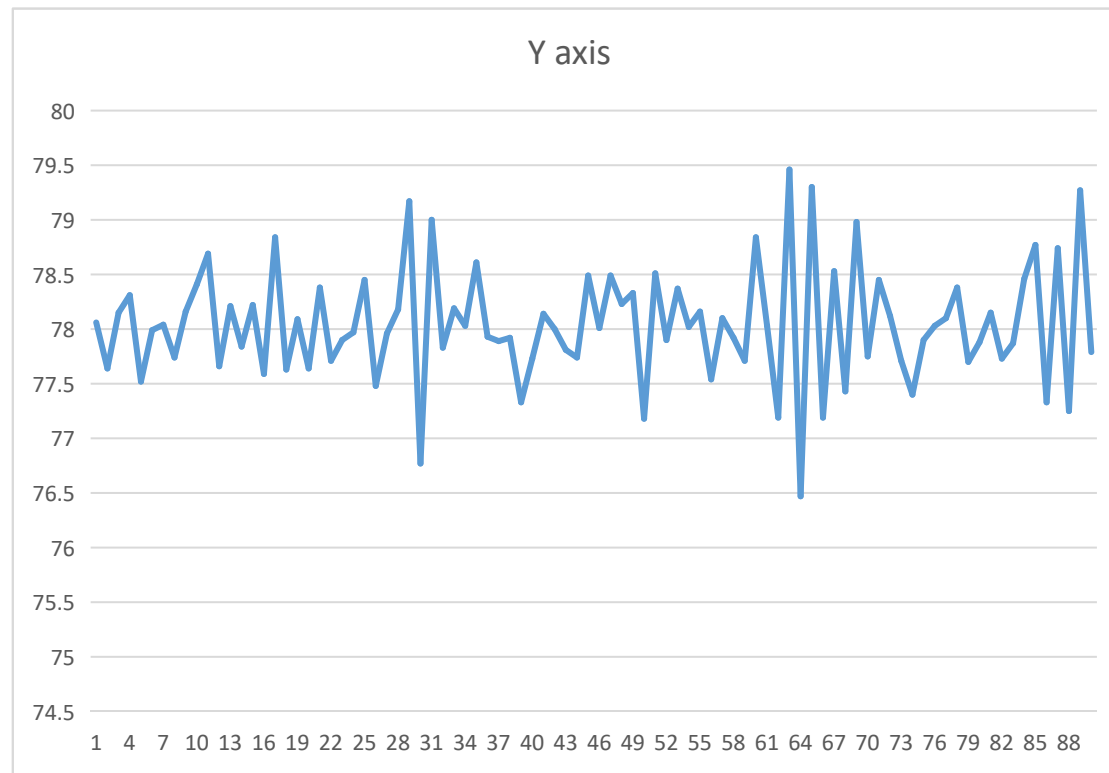
X axis

X mean=78.0429333



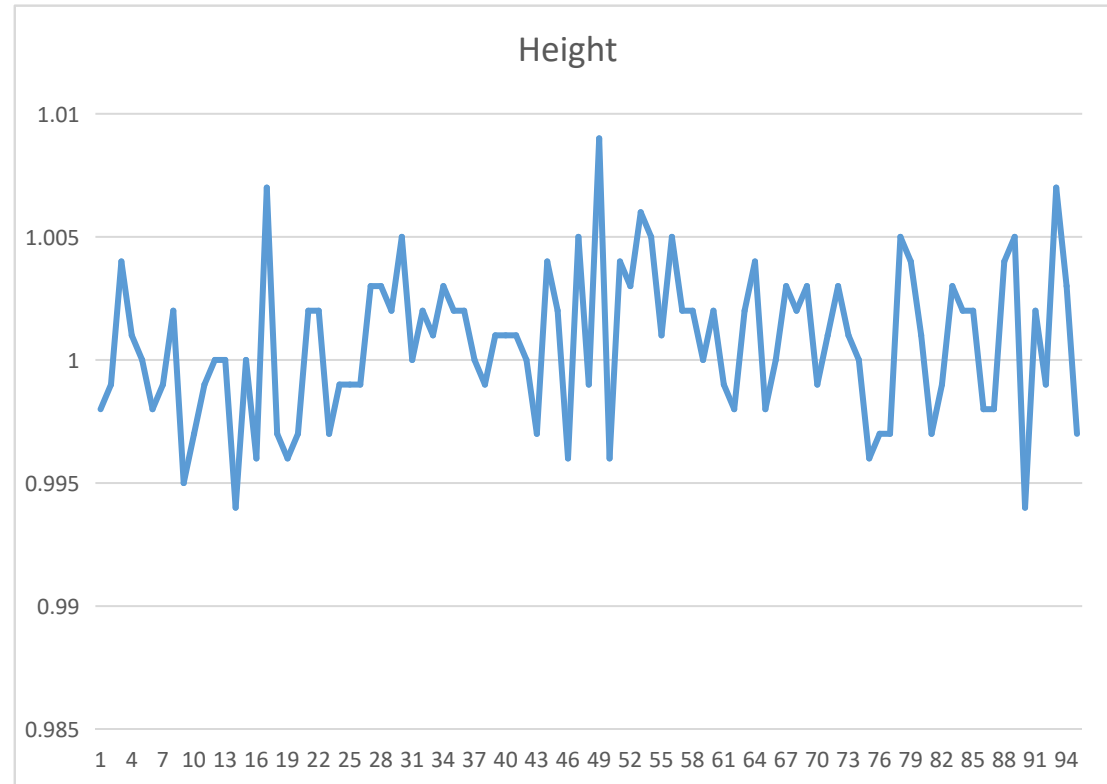
Y axis

Y mean=78.041222



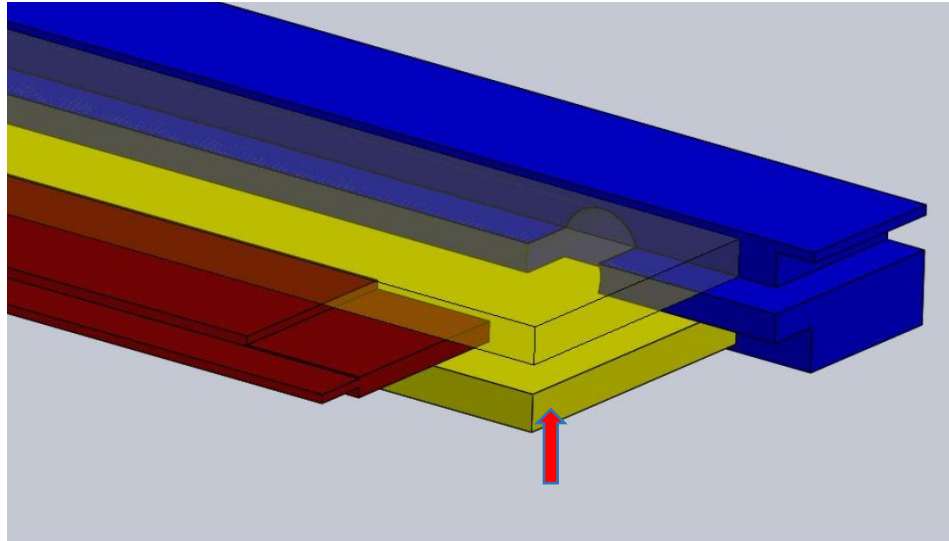
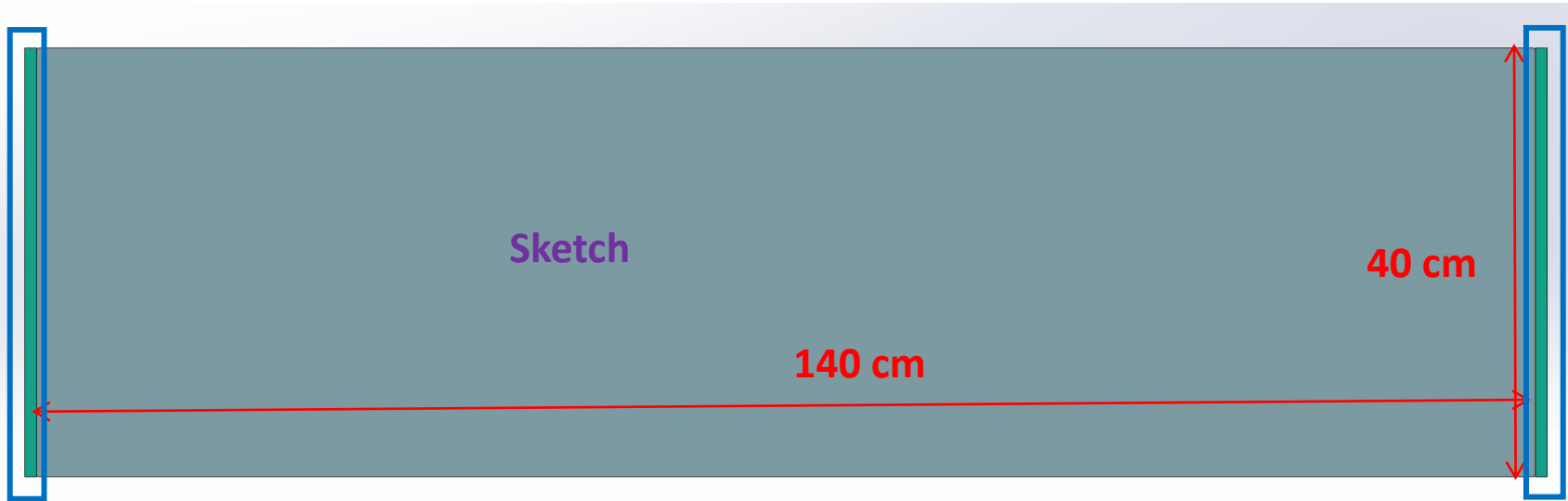
Height

H mean=1.000663158

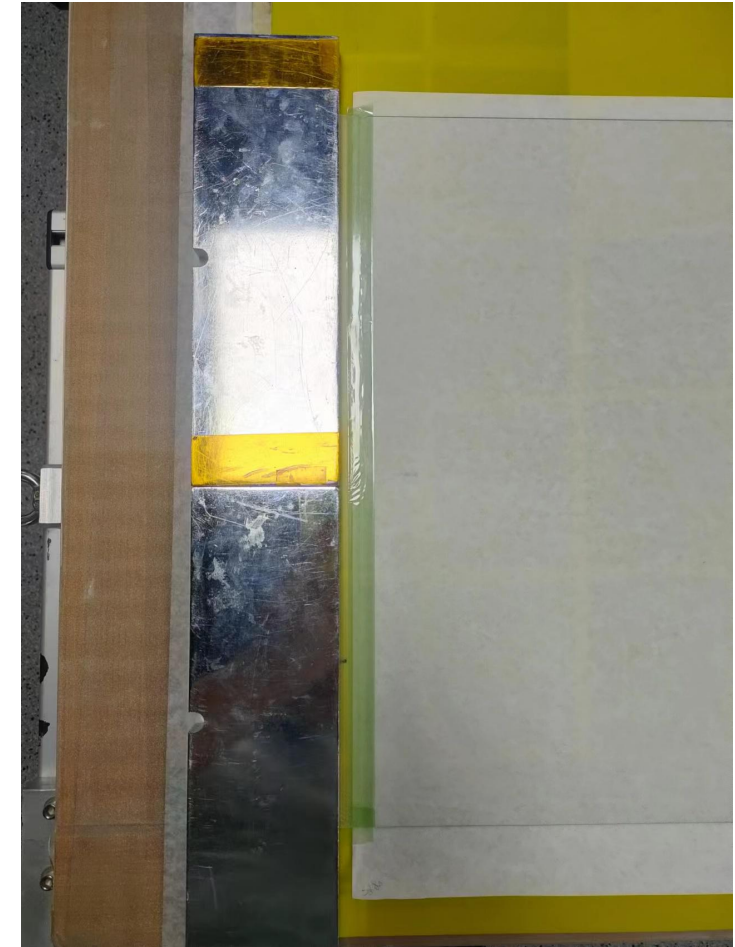


The first step

- Attach **2 floor polycarbonate plates** to the bottom glass with Araldite adhesive glue



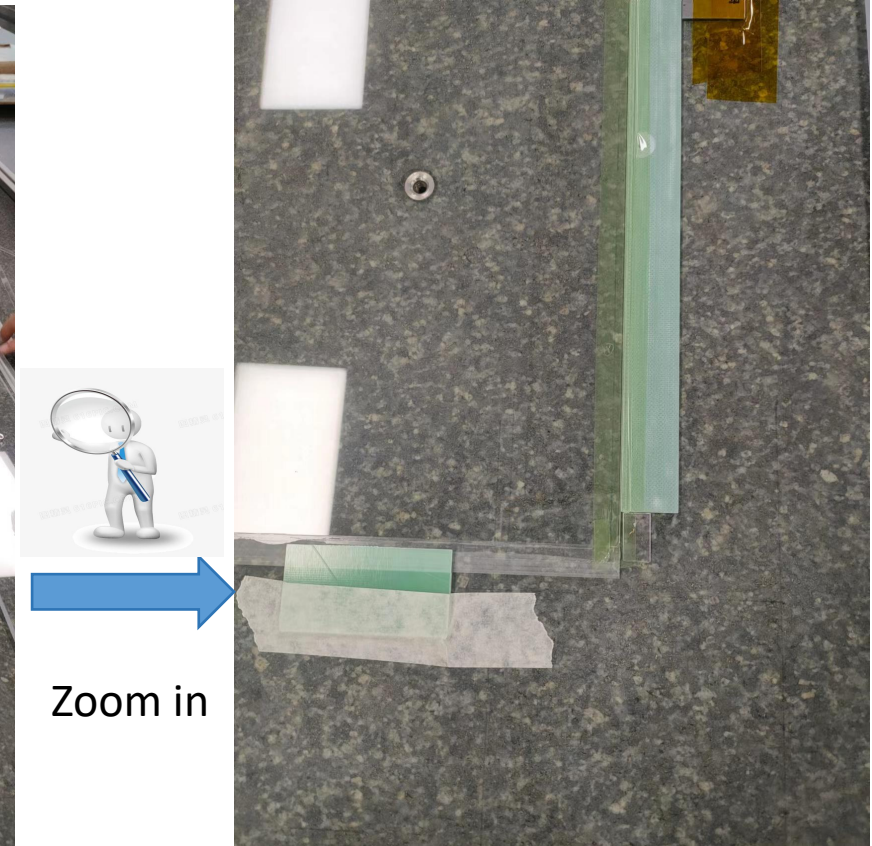
The glass and 2 floor plates will on the same plane



The second step (preparatory work)



1. Use the tooling to find the correct position of the long side frame
2. Use tape to fix the tooling and protect the marble platform (avoid glue seeping on it)



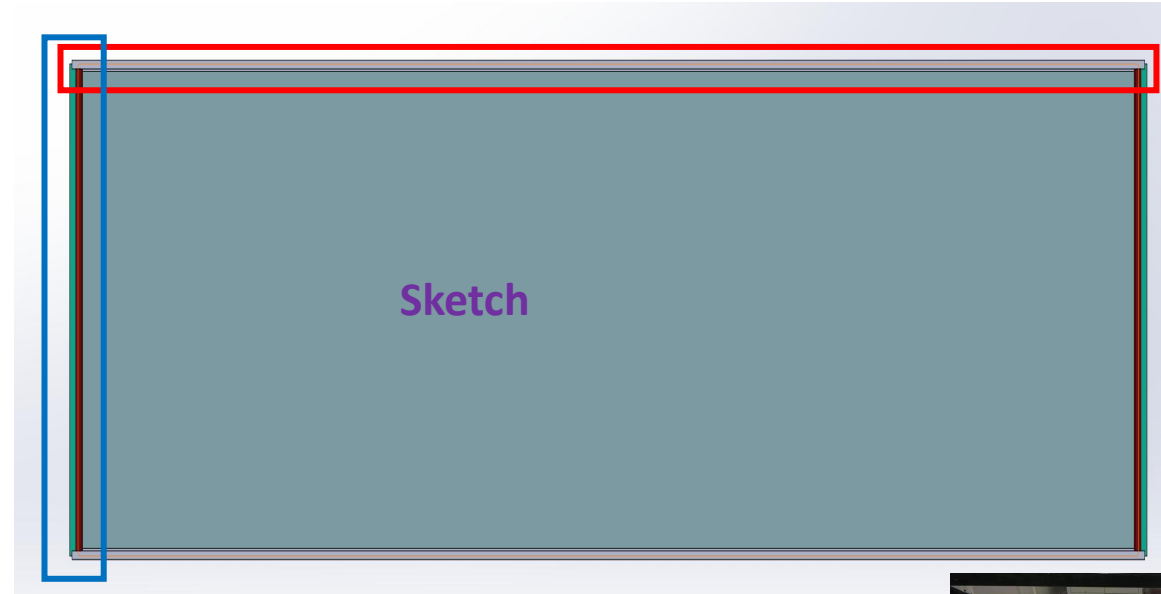
1. Move the glass on the marble platform carefully
2. Use the tooling to find the correct position of long and short side of frames

The second step

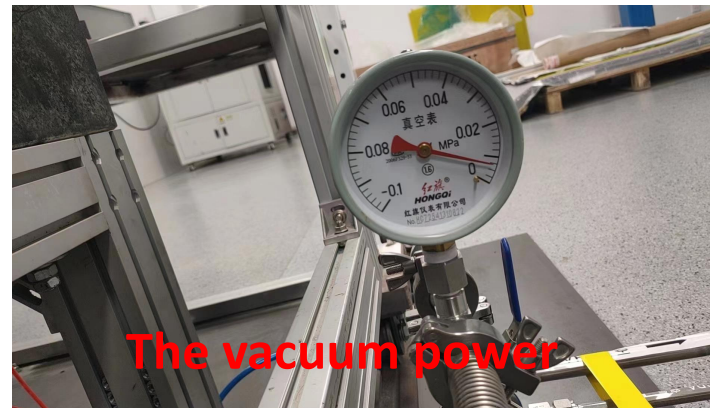
- Add the glue on the glass and attach the **long** and **short side** of polycarbonate frames with Araldite adhesive glue
- Vacuuming for 6 hours



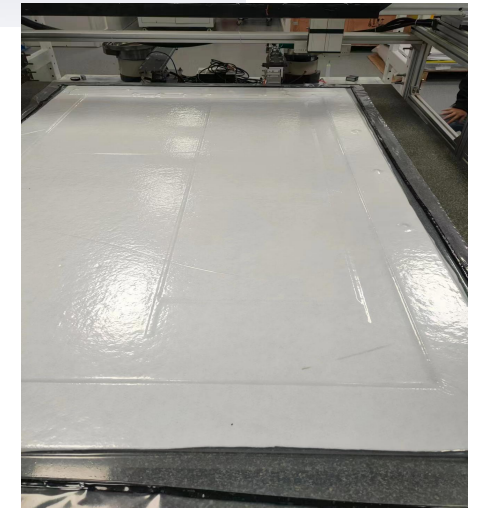
Zoom in



Vacuuming



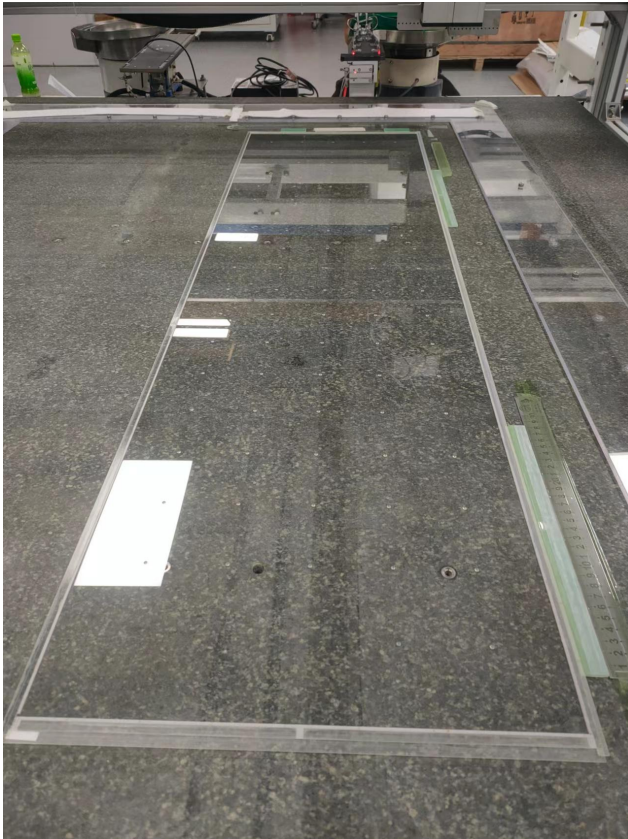
Slight less than 0.01Mpa



The third step (1)

➤ Attach the spacers on the glass

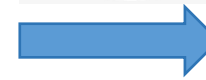
- dispensing work (Add glue on the glass)
- Put the spacers on the glue and the distance between 2 spacers is 70 mm.



~15 minutes



~36 minutes

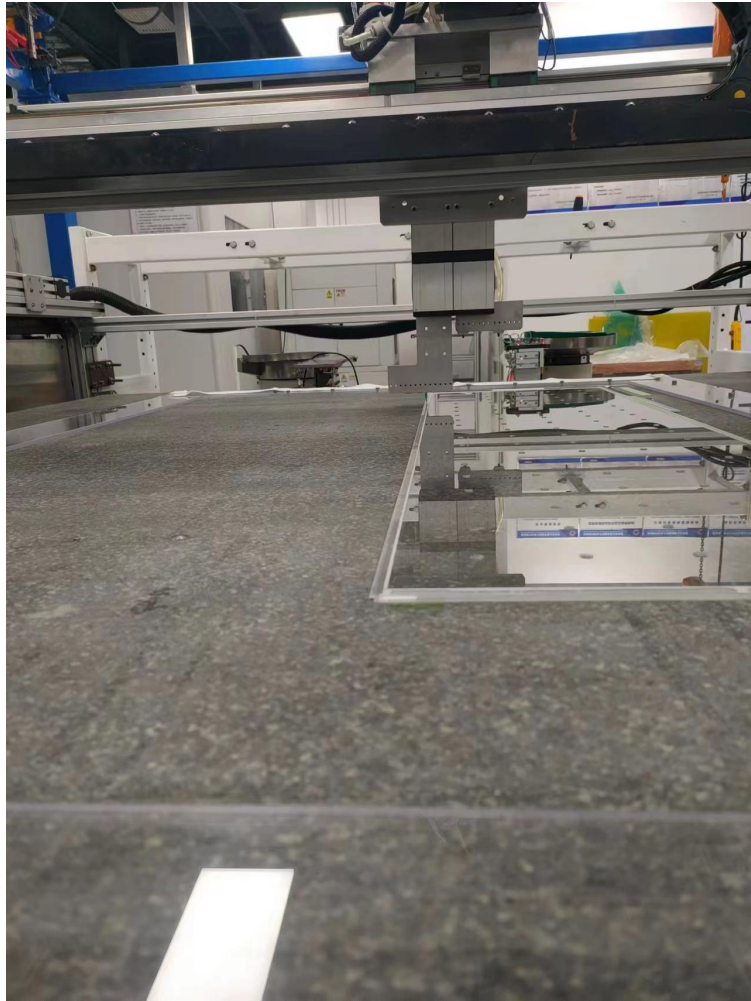


Zoom in

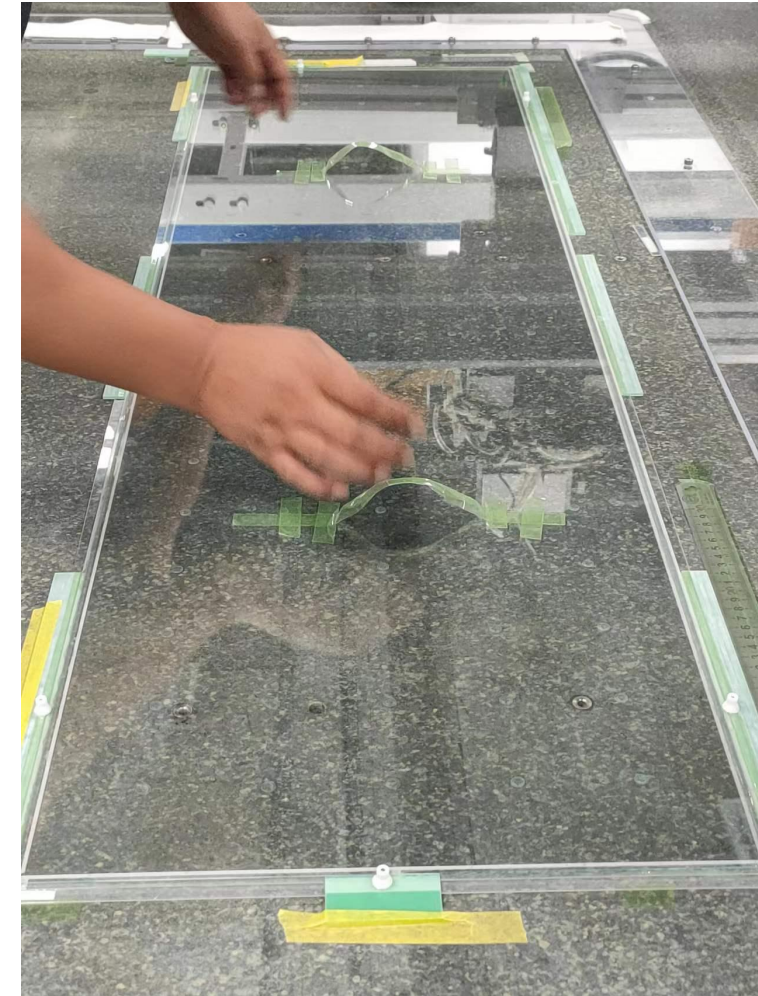


The third step (2)

- Apply glue on the frame and close the gas gap



Zoom in

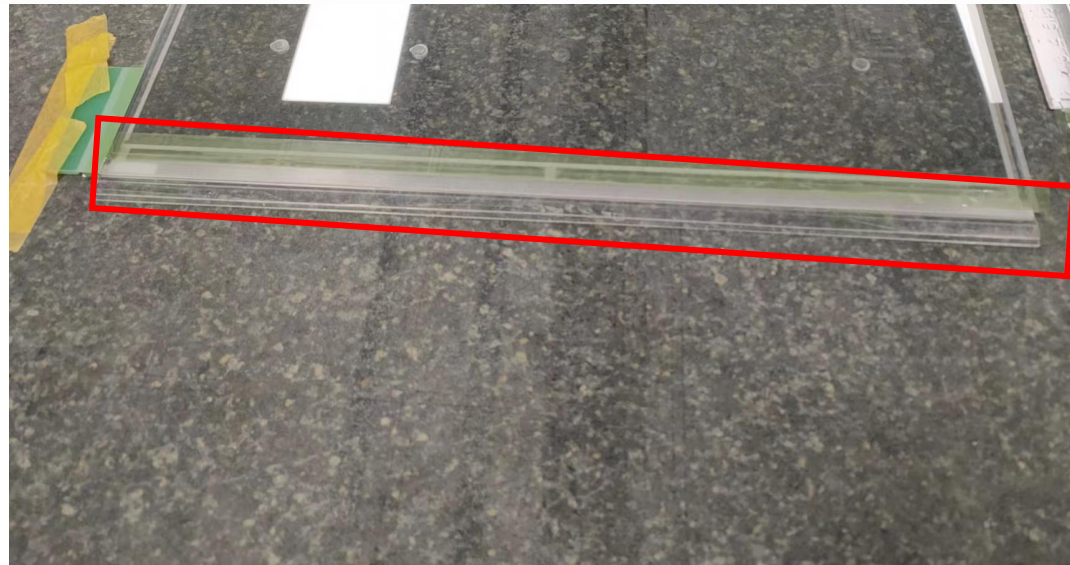


The third step (3)

- Attach 2 roof polycarbonate plates on it



Zoom in



The third step (4)

➤ Vacuuming



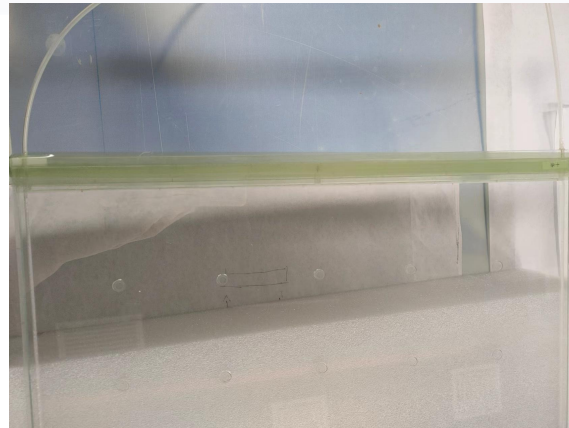
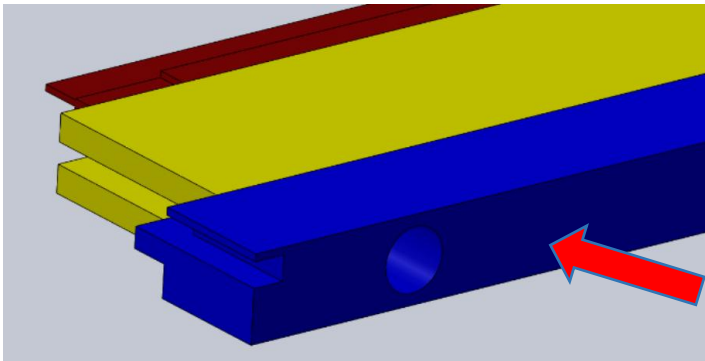
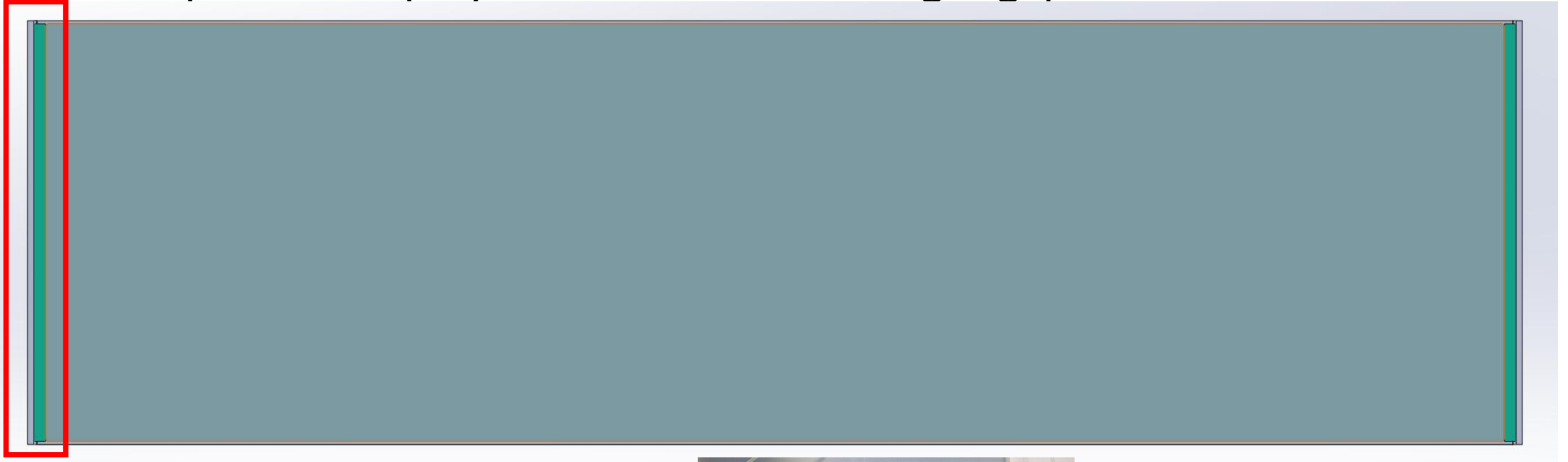
Use oiled paper to protect the ventilated felt



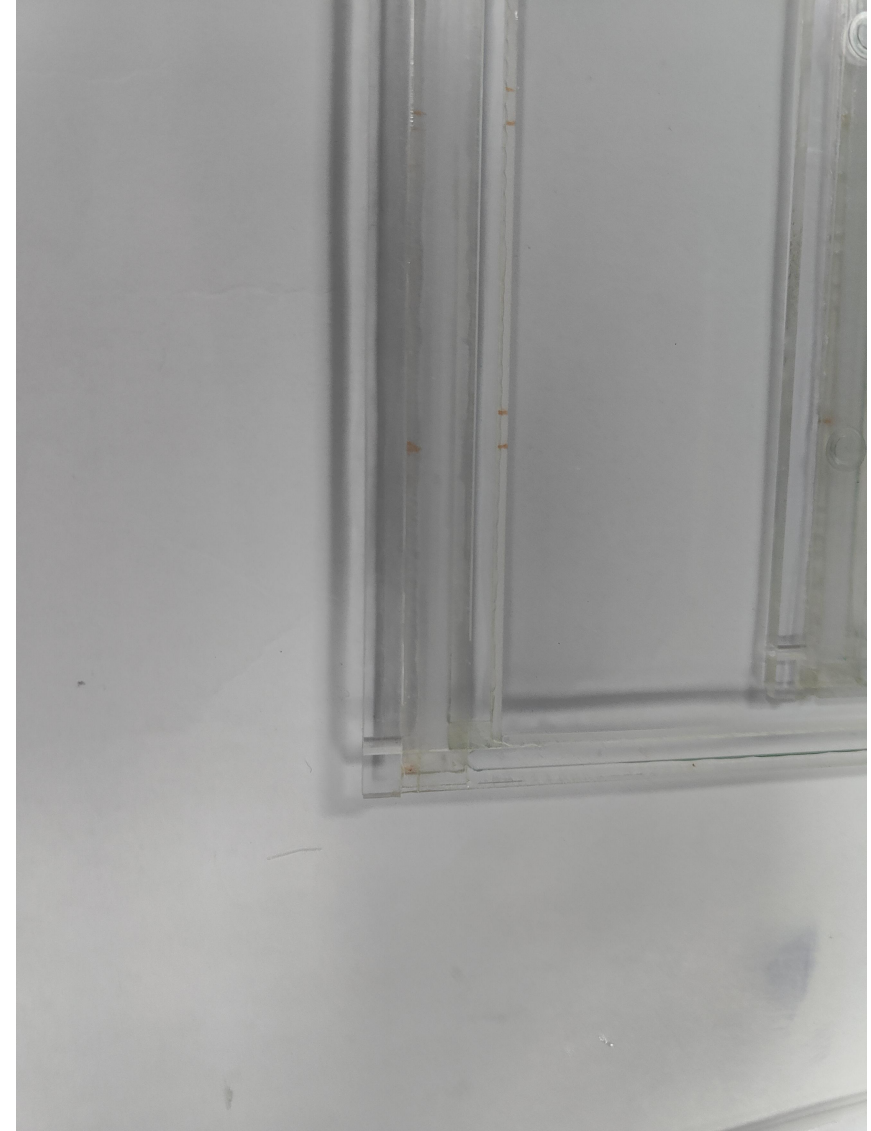
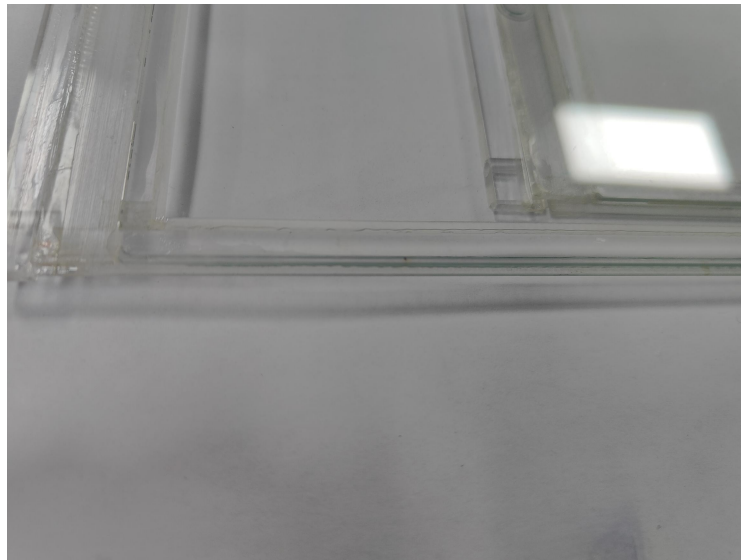
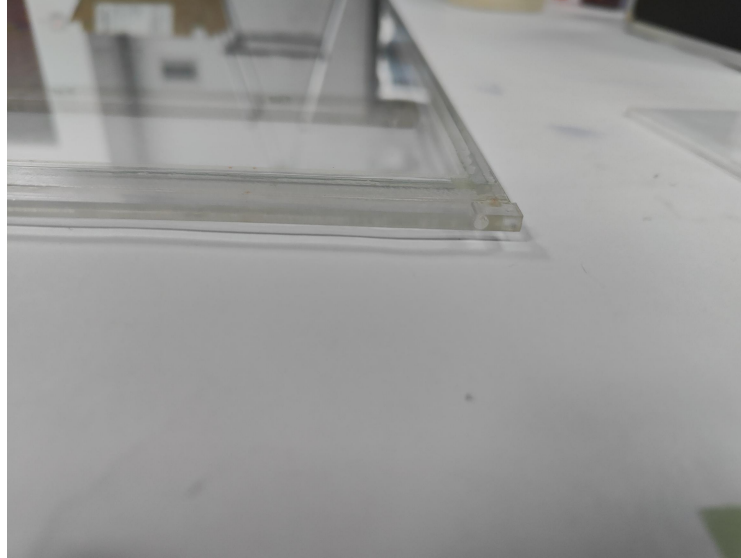
Hold for at least 6 hours

The final step

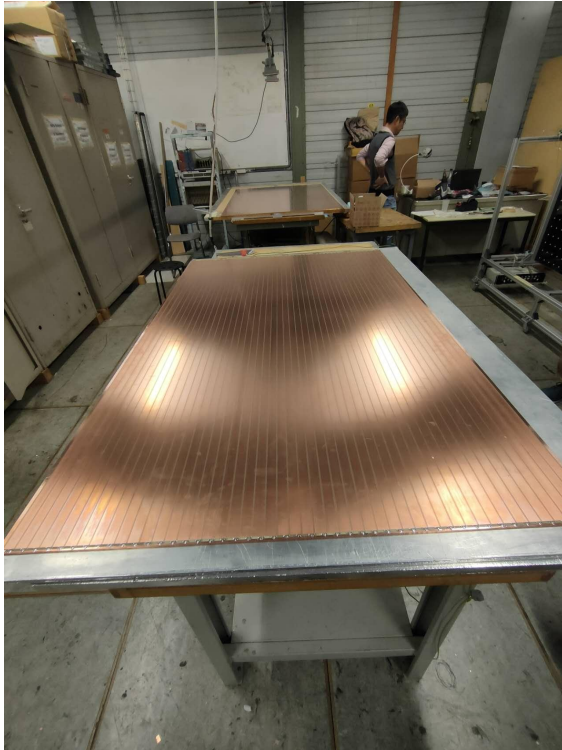
- Put the perimetric polycarbonate frame into gas gap



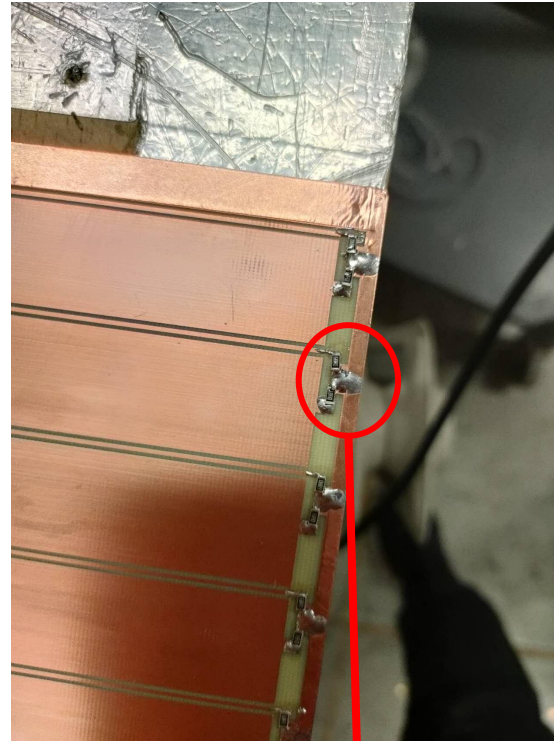
The final product



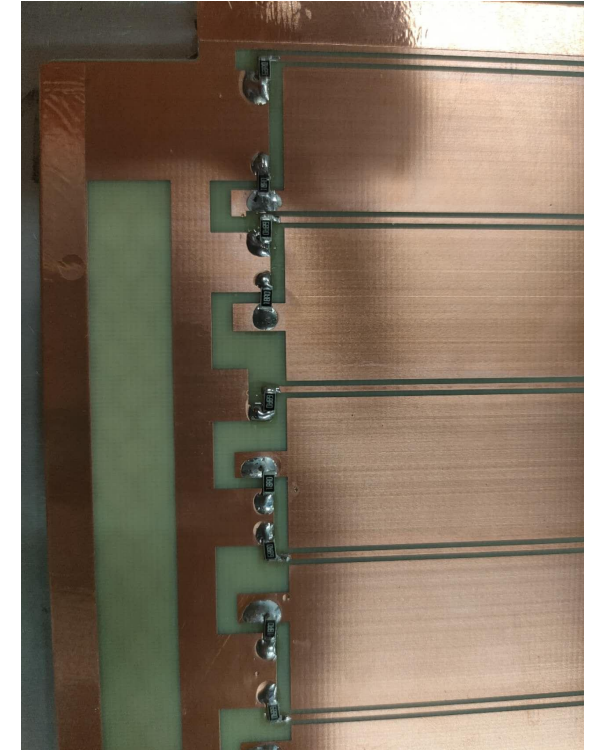
More detail information for each step (Step 1)



Step1:
Put the readout pannel in the table
with strip pannel on the top

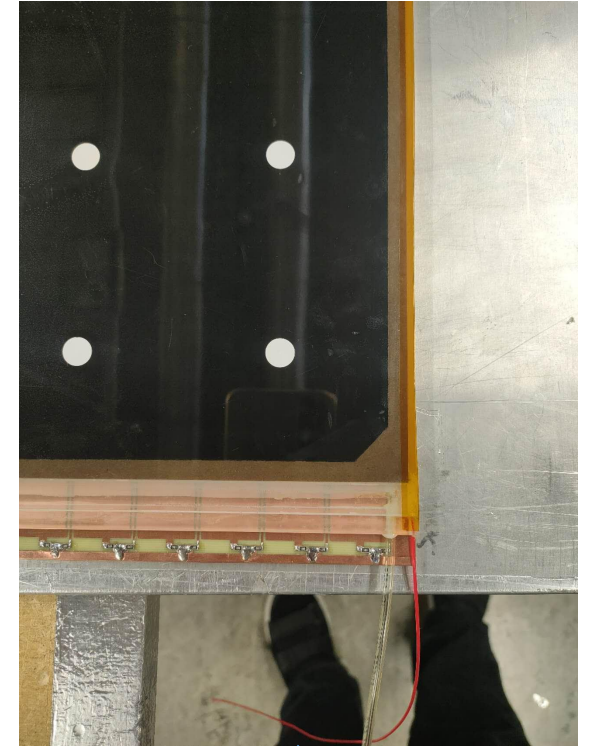
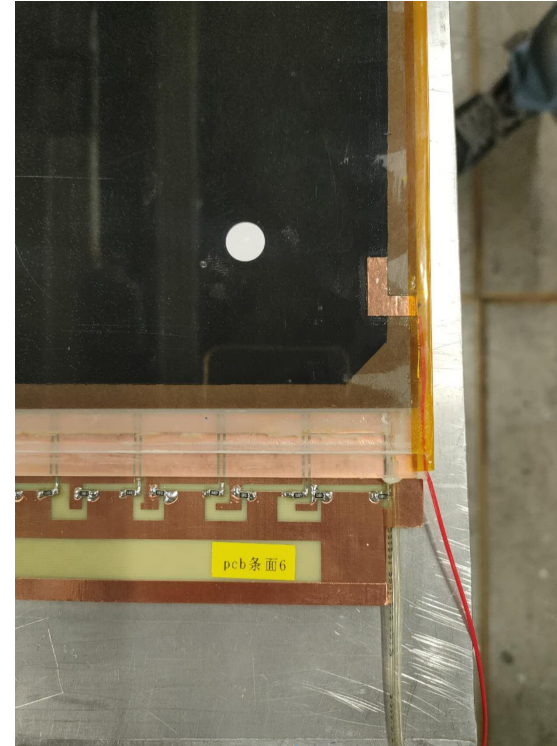
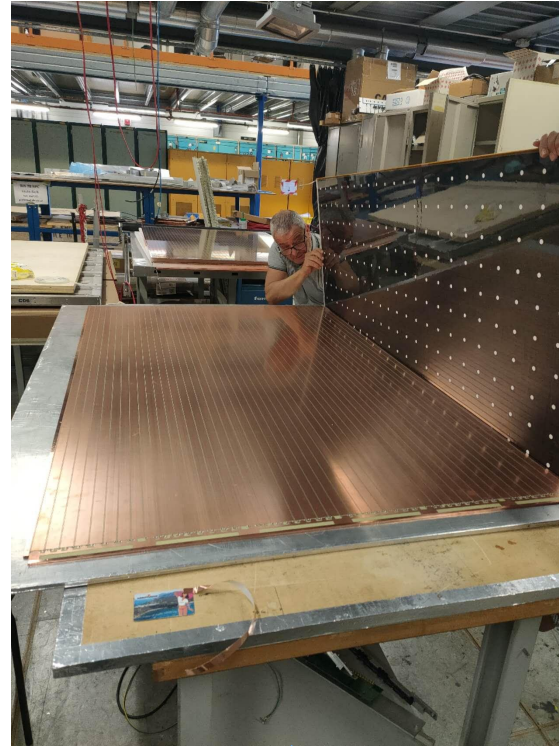


The resistors are mounted on the readout pannel and also
solder the copper sheet to the ground



Suggested by Alessia

More detail information for each step (Step 2)

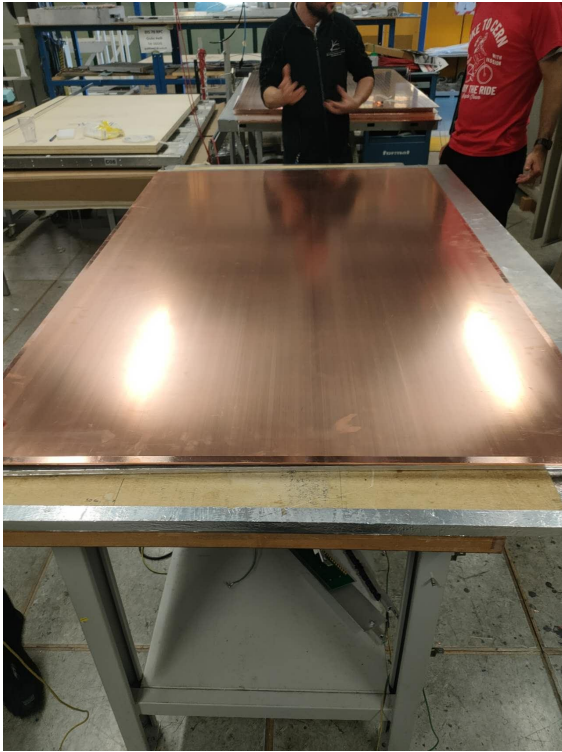


Step2:
Put the gas gap on the top
of the readout pannel

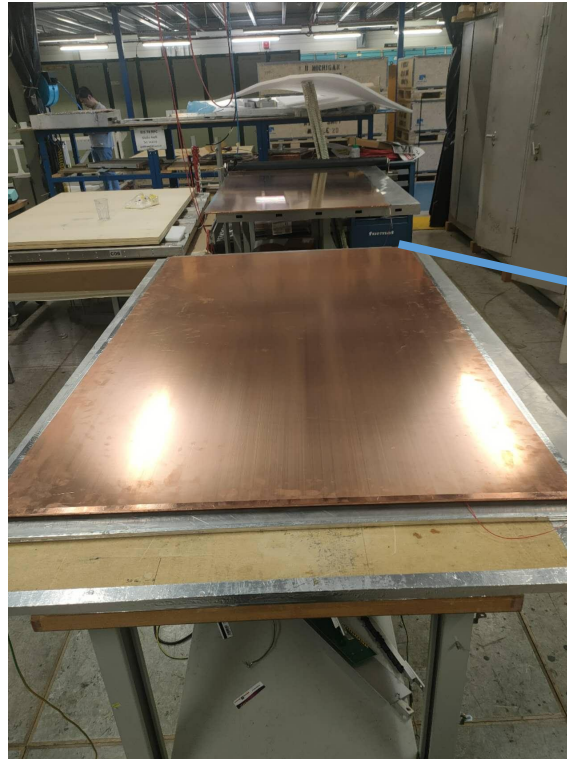
How to put the gas gap on the readout pannel ?

HV far away from the FEE and the HV
wire is on the right side

More detail information for each step (Step 3 + Step4)

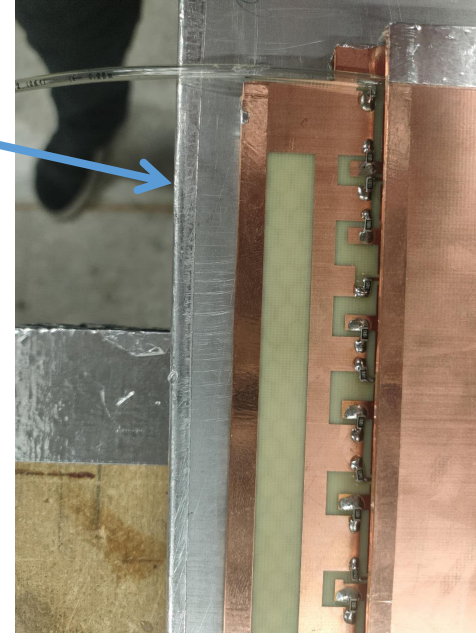


Step3:
Put another readout pannel
on the top of the gas gap

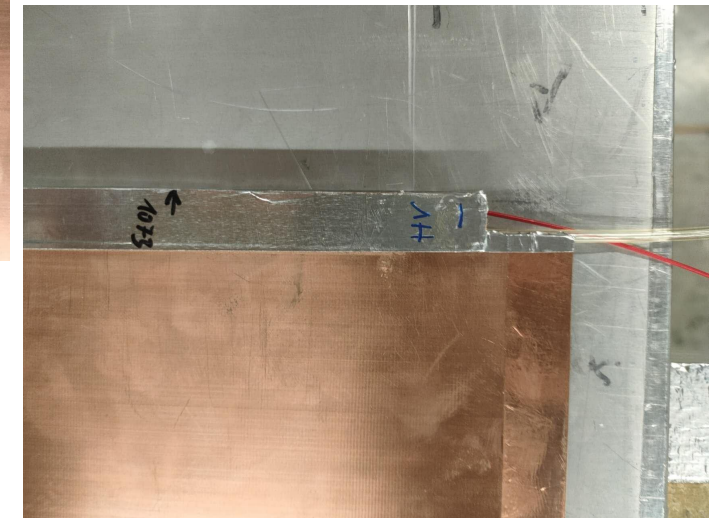
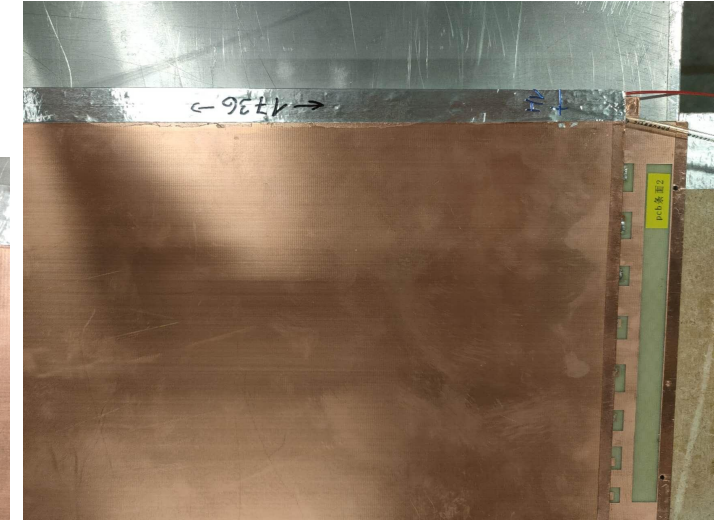


Step4:
Use the Aluminium tape
to fix those three layers
to form the singlet

Zoom in



The length of singlet is **1736 mm**



The width of singlet is **1073 mm**

The dimentional quality of this BIS singlet is very good