Production of RPC Gaps for CMS upgrade

Sung Park

Korea Detector Laboratory

On behalf of CMS Collaboration

KODEL

CMS Muon system

- Tracking : Drift Tubes + Cathode Strip Chambers
- Trigger : Resistive Plate Chambers

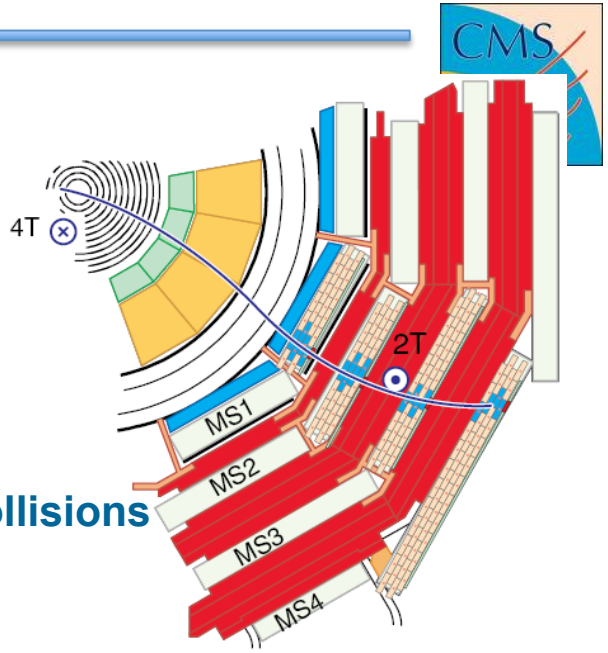
CMS RPCs, gas detectors in avalanche mode:

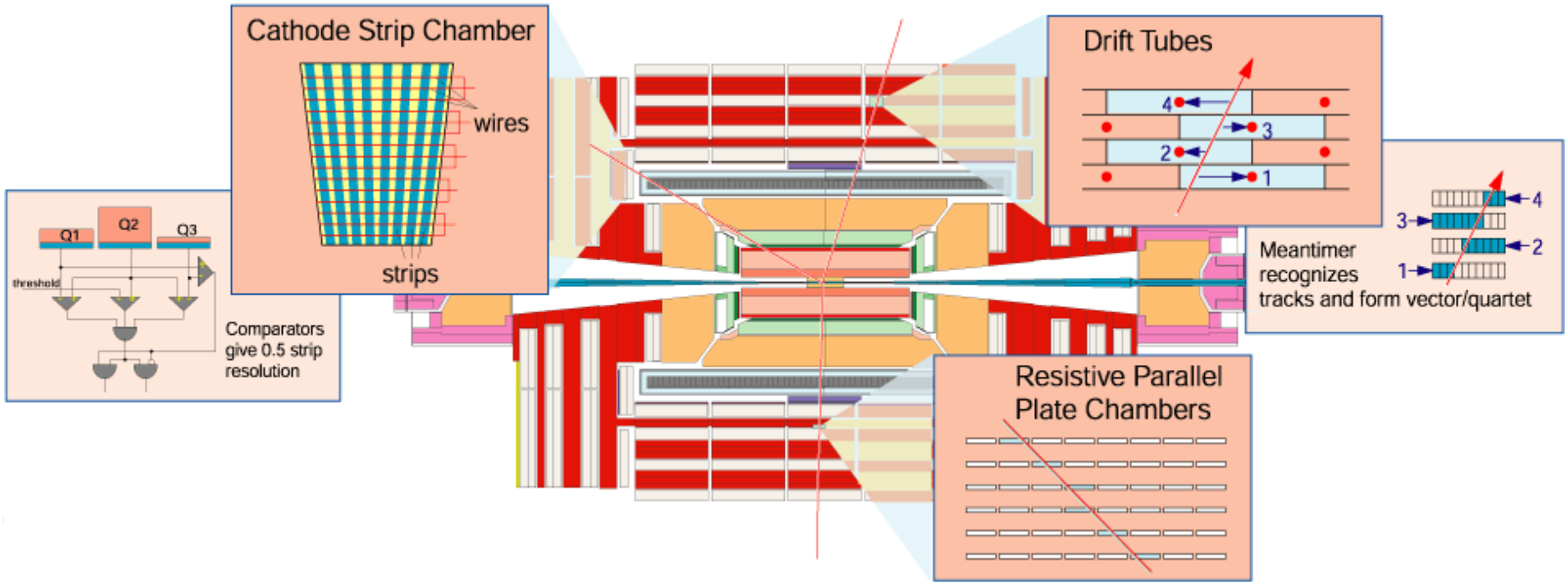
Fast time response (~ 10 ns) and resolution (~ 1 ns)

⇒ Suitable for tagging particles every 25 ns for LHC collisions

Thin panel detector structure of RPCs

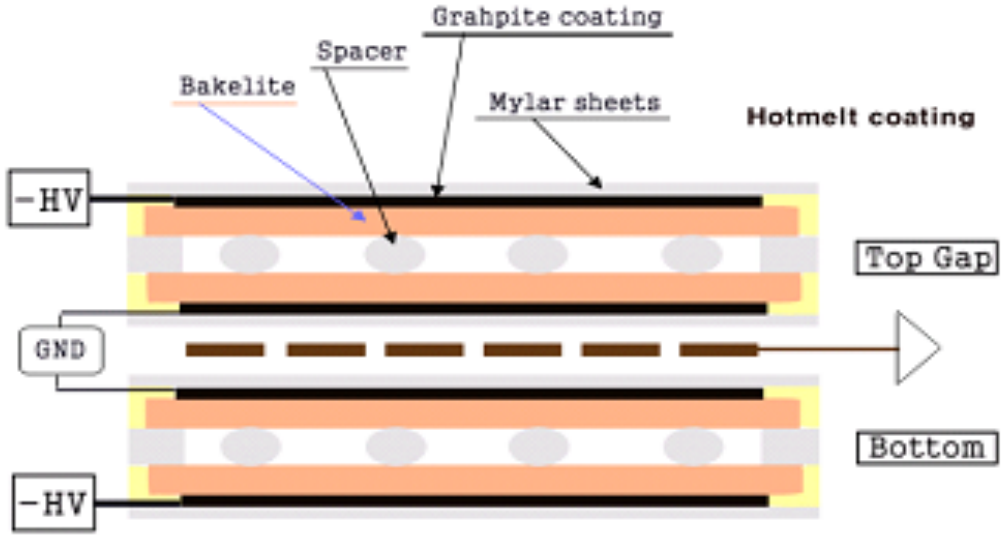
⇒ Designed to provide L1 trigger information to trackers via PACT





A standard double-layer RPCs consists of

- Two core detectors called ‘gas gaps’
  Each gas gap : made of two resistive plates
- A pickup strip plane for the signal readout
- Originally RPCs were designed for spark-mode operations, but now applied to avalanche mode operations to adopt for high rates.

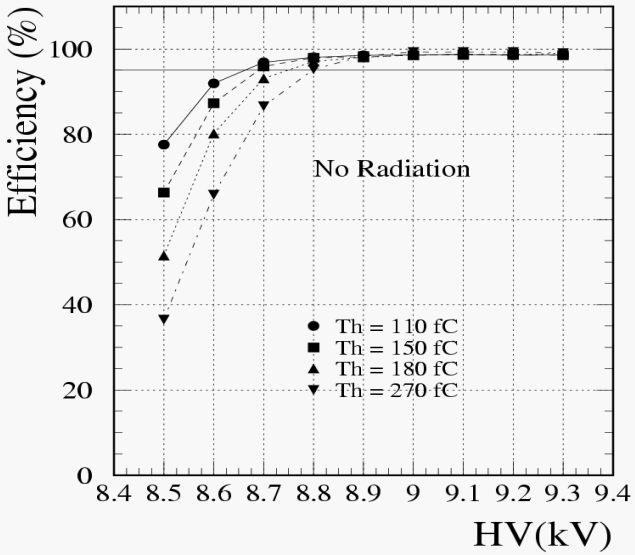


Typical Characteristics of CMS RPCs

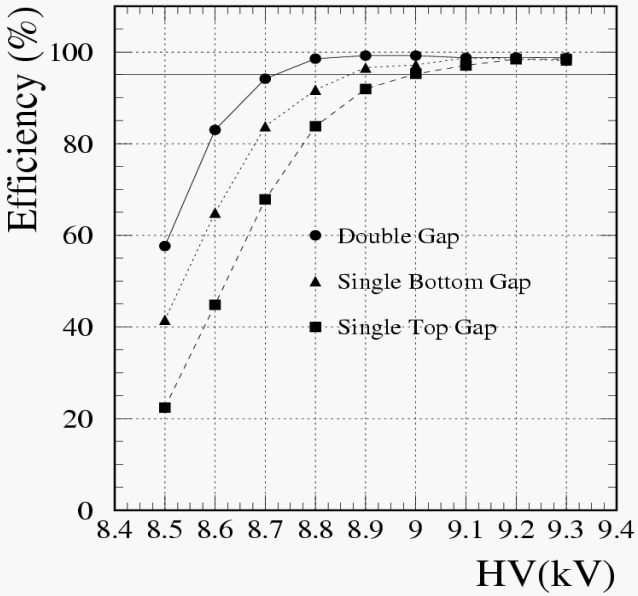
Double-gap RPCs for CMS

Characteristics	
Time Resolution	~ 1 ns
Efficiency	> 95 %
Rate Capability	~ 2 kHz/cm^2
Noise Rate	0.5 ~ 5 Hz/cm^2
Strip Multiplicity	1.5 – 3.0
Mean avalanche charge	2.5 ~ 5 pC
Charge threshold	200 fC

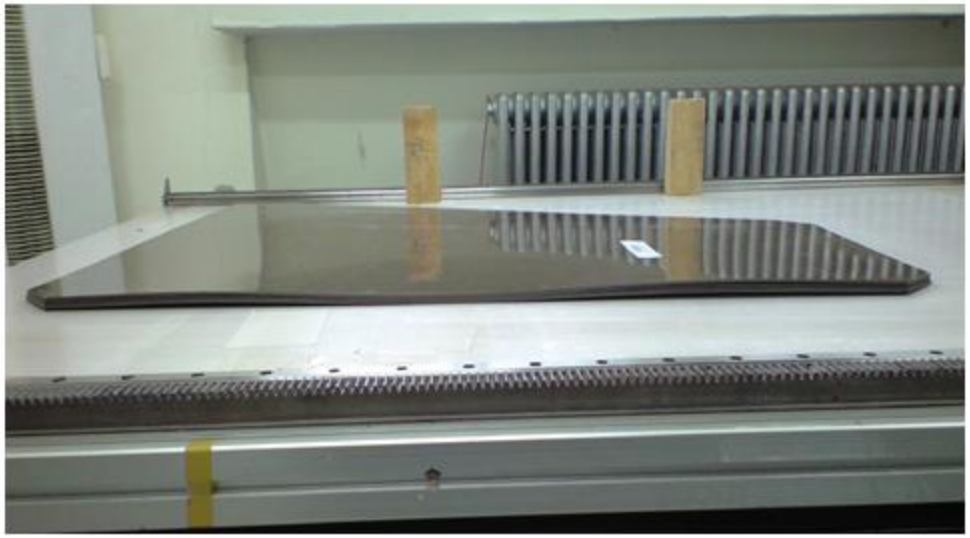
Typical efficiencies for various thresholds



Efficiencies for double- and single gap

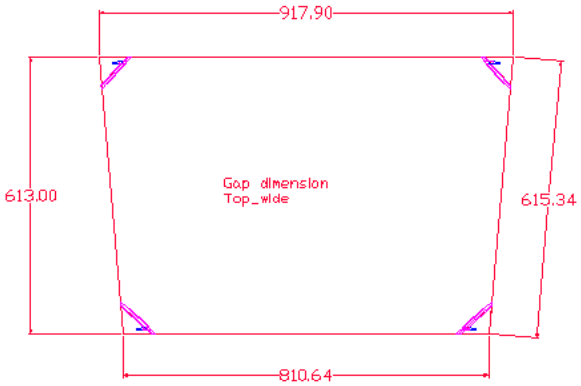


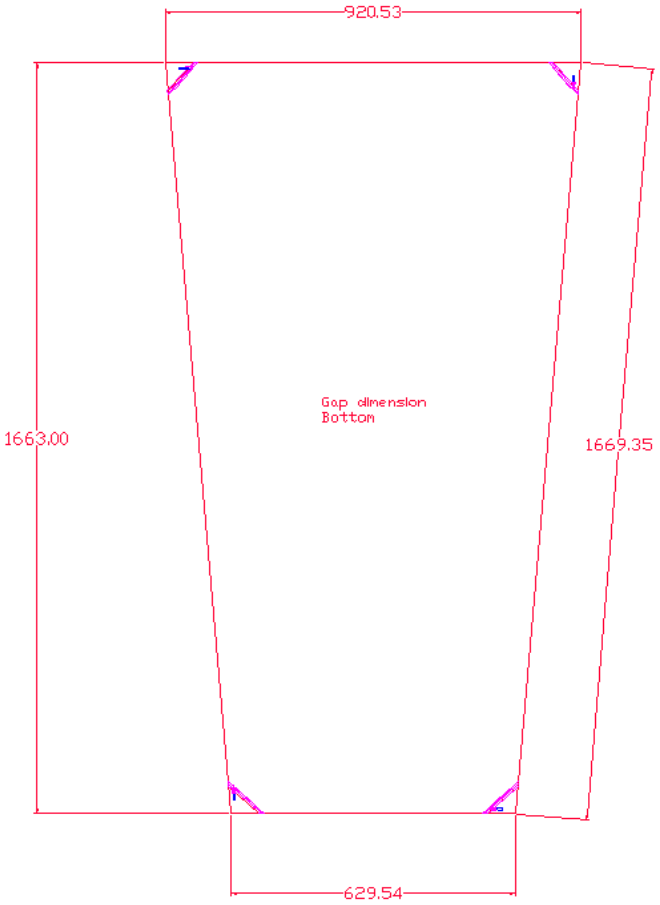
HPLs when arrived at KODEL

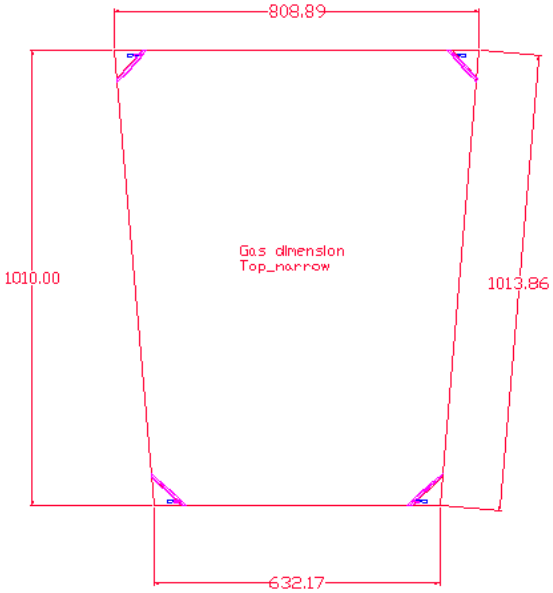


Visual inspection of the HPL just arrived

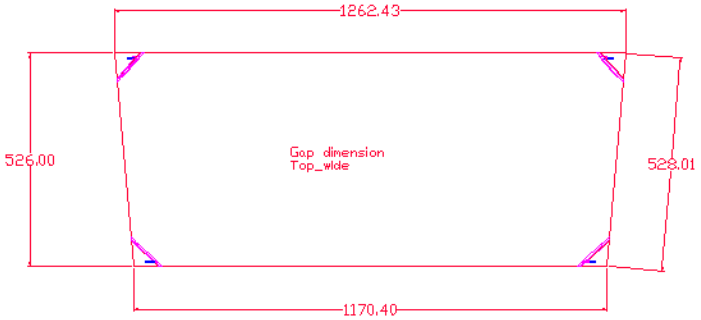
Gaps for RE4/2 Chambers

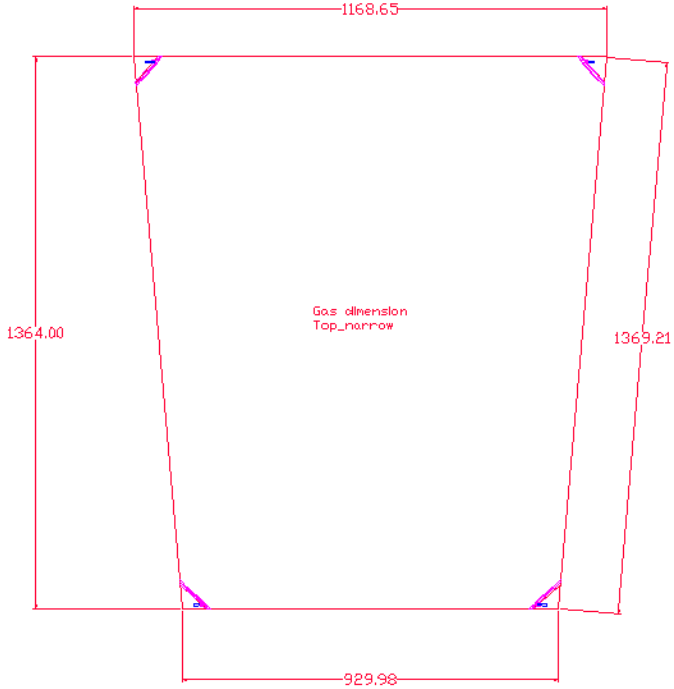


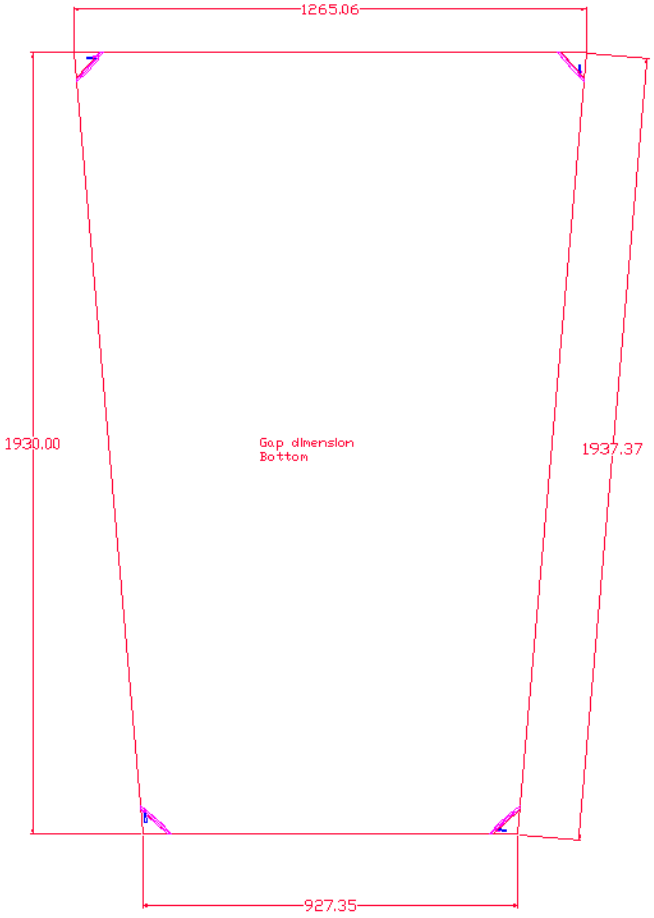




Gaps for RE4/3 Chambers



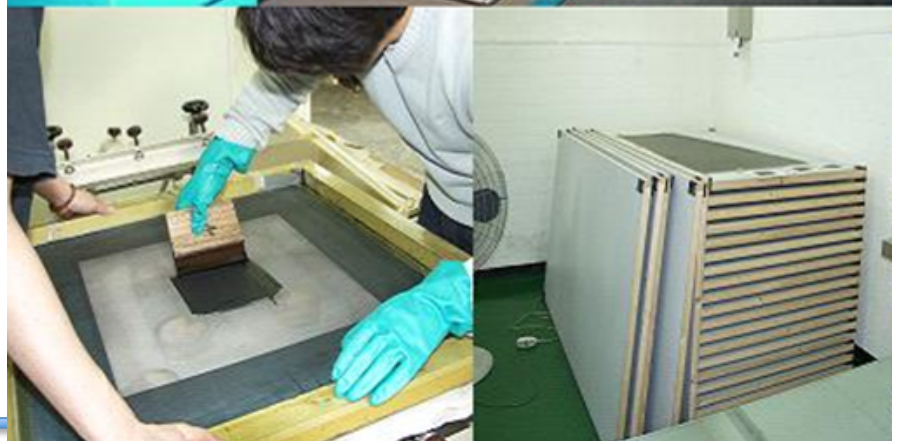


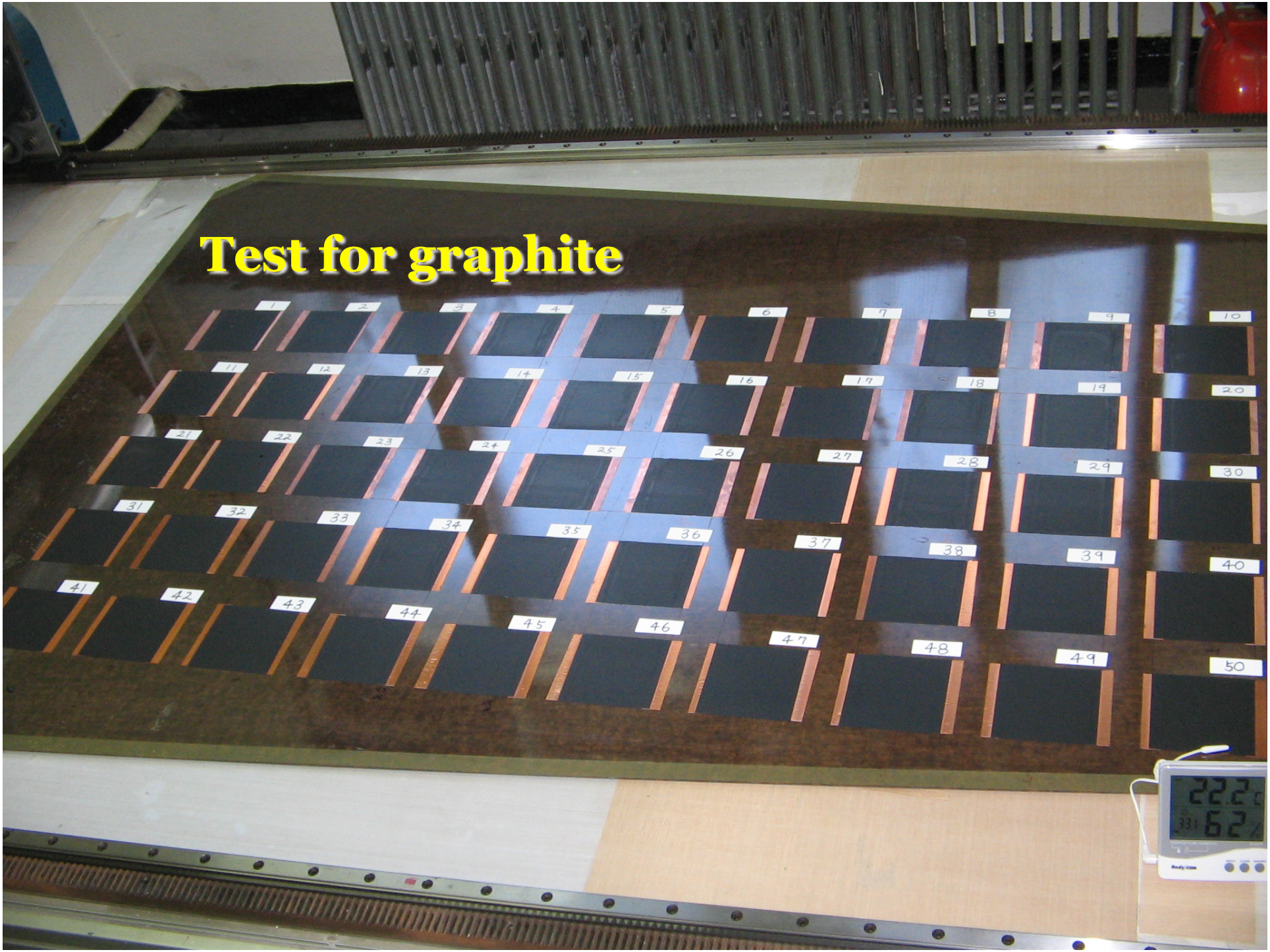


Silkscreen Procedure

Applying the same procedures and tools used for the CMS Forward RPCs

1. Graphite coating for RPC electrodes
   - Silkscreen method
   - Surface resistivity of electrode ranges from
     50 to 200 kΩ/square




Test for graphite
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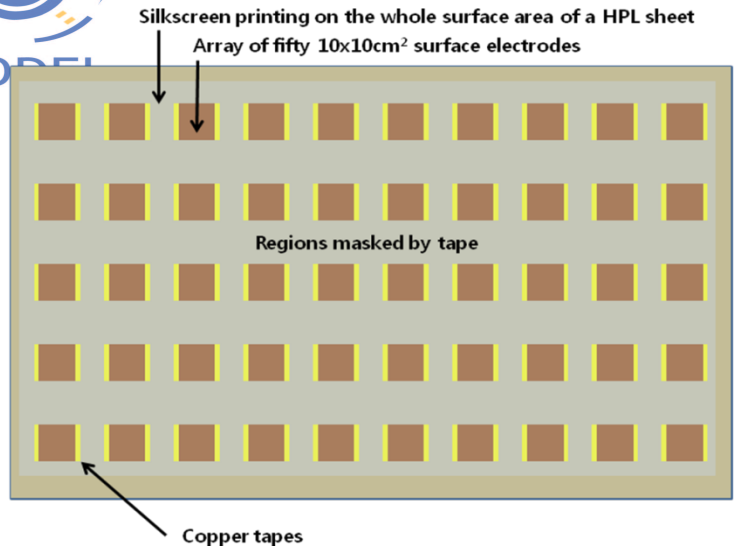
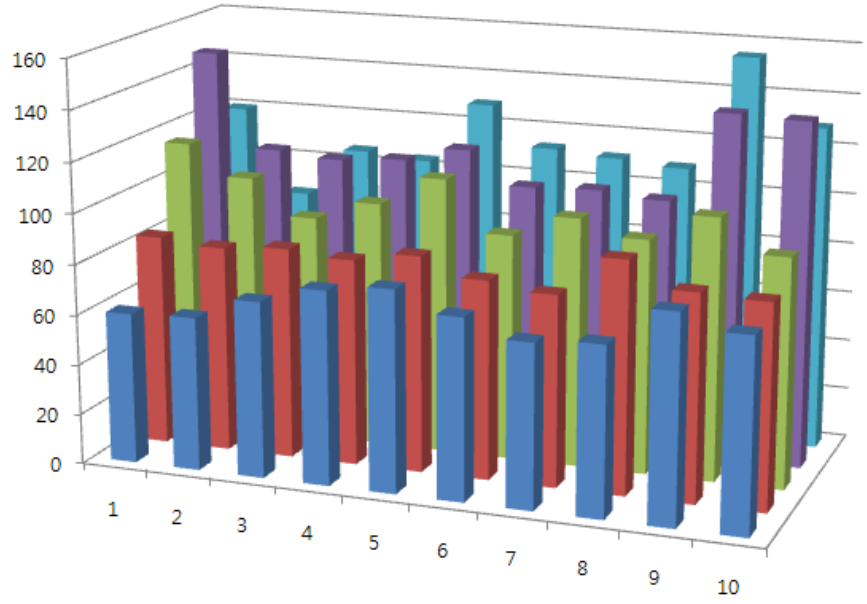
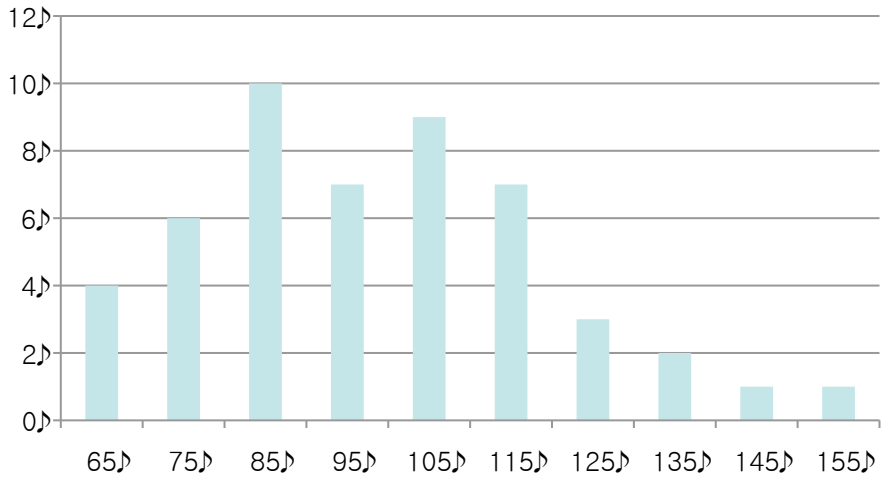


120	86	106	104	129	113	111	109	155	129	116.2
148	110	108	110	116	103	104	102	138	137	117.6
116	104	90	98	110	90	99	93	104	91	99.5
84	82	84	82	86	79	76	92	82	81	82.8
60	61	70	77	80	72	65	67	82	76	71
105.6	88.6	91.6	94.2	104.2	91.4	91	92.6	112.2	102.8	97.42
									σ =	21.84

Ave. = 97.42 kOhm♪
Sigma = 21.84 kOhm♪

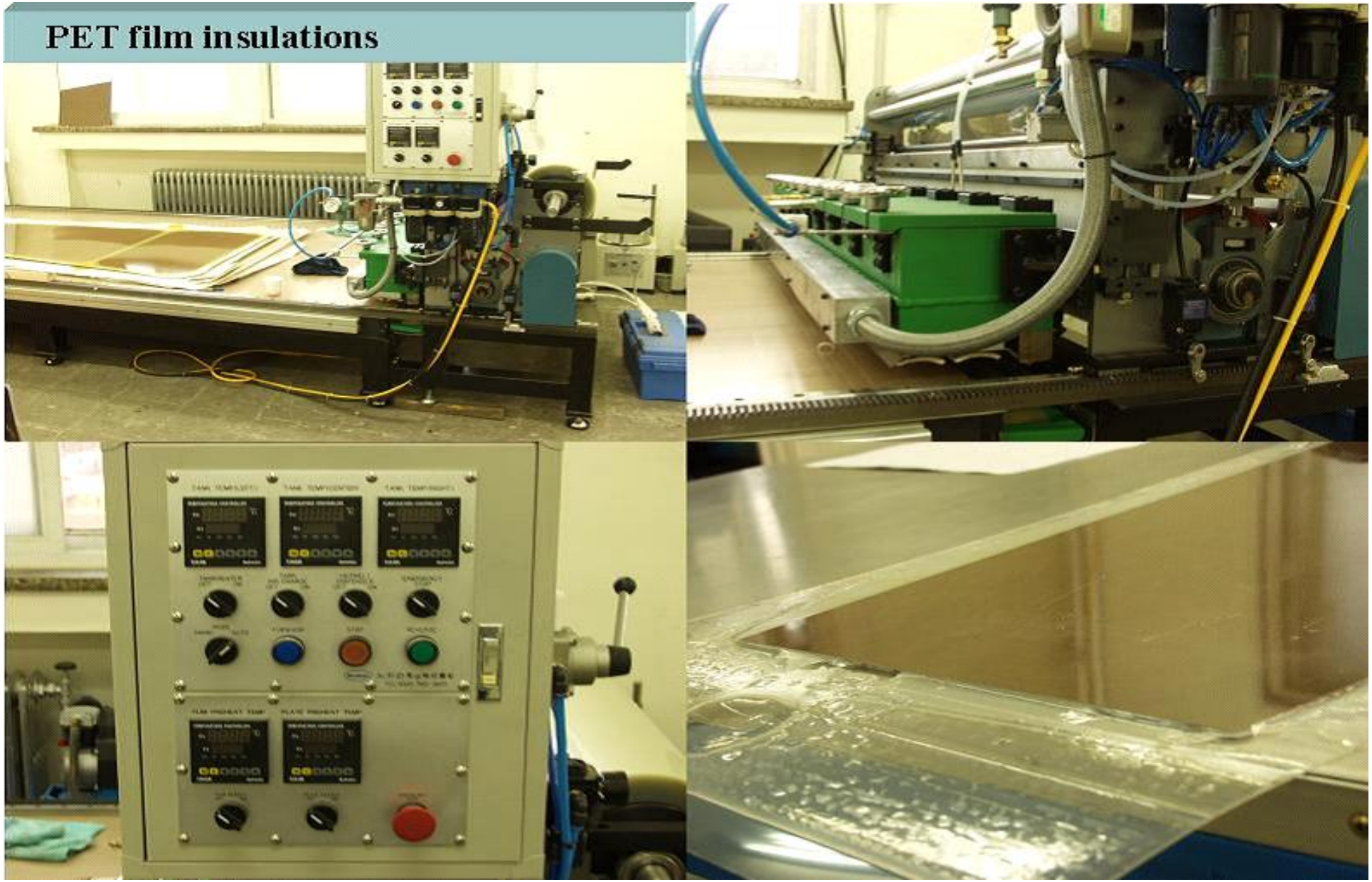




Electrodes Coated with Graphite

PET film coating for protection of graphite electrodes

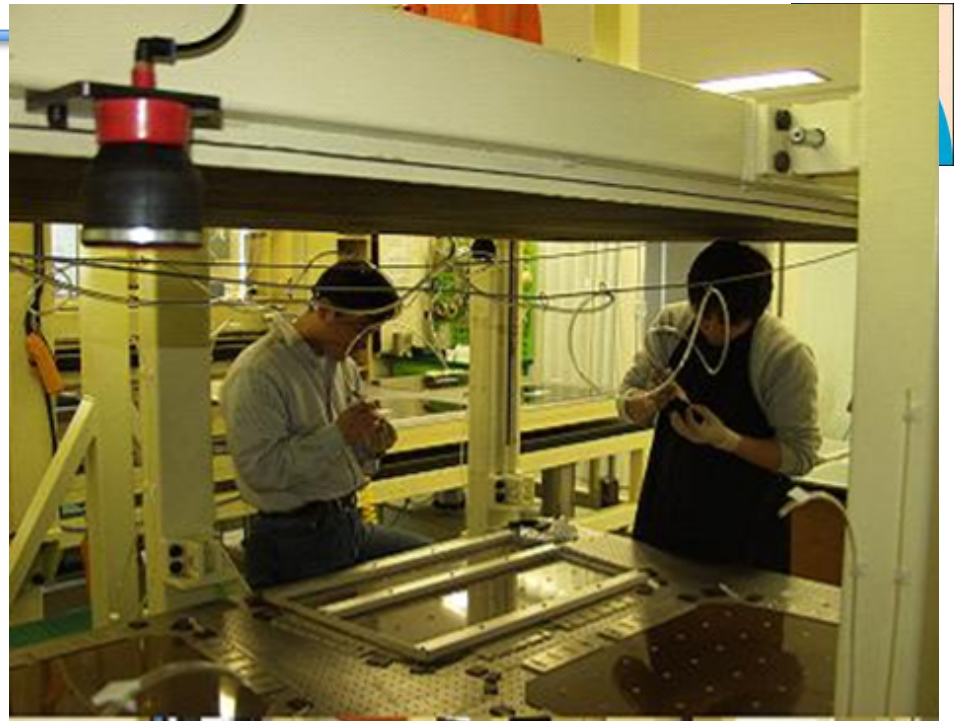
- 1 layer of 200 micron PET film, Ethylene Vinyl Acetate base glue



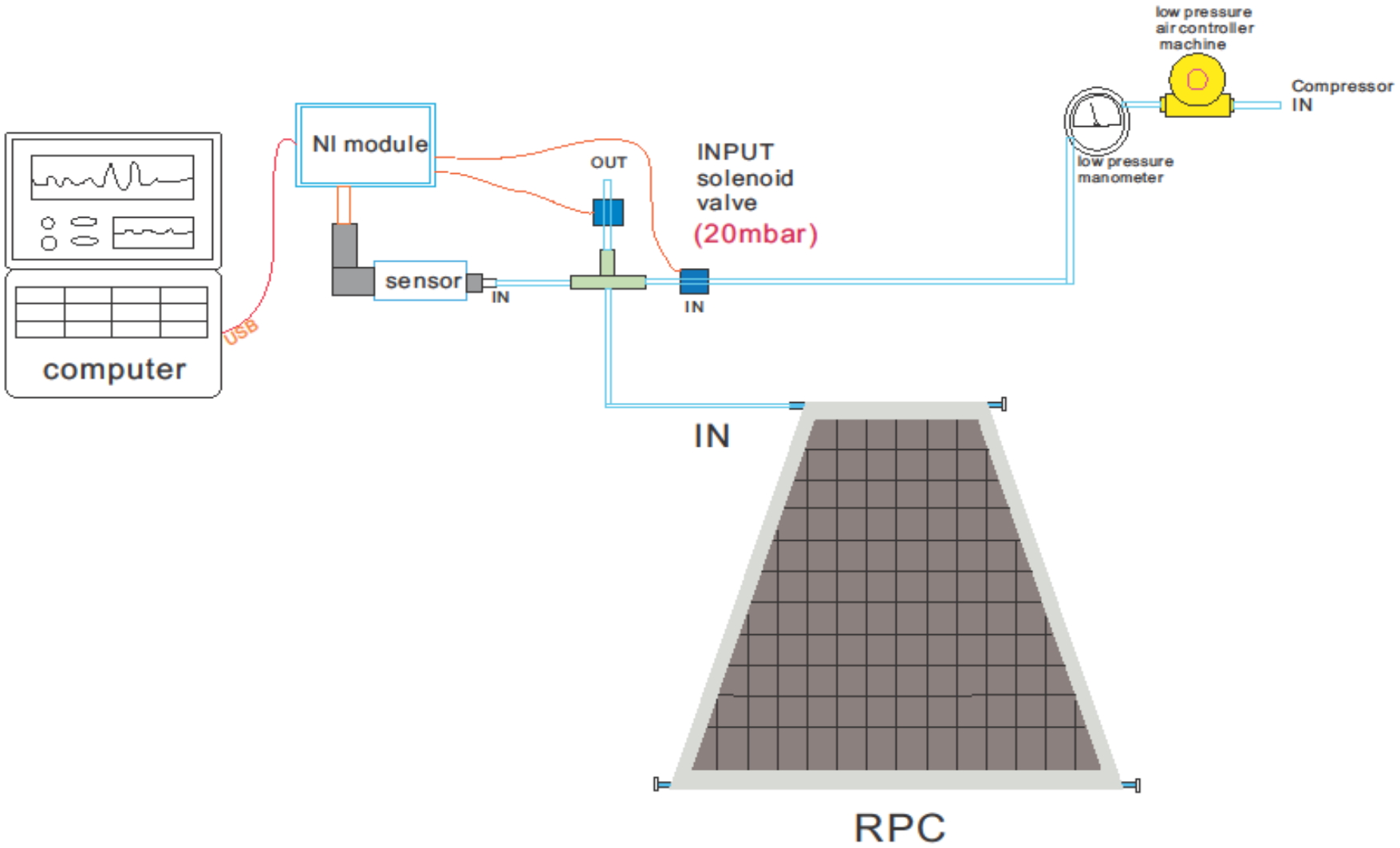
3. Gap assembly

- multi-layered metric tables and shelves for the assembly and glue curing
- Glue curing time : 24 hours
- Glue : DP460, 3M production
- Selection of spacers : 2 mm +/- 20 µm
- Use spacer jigs for the location of spacers

Accuracy of positions < 1 mm

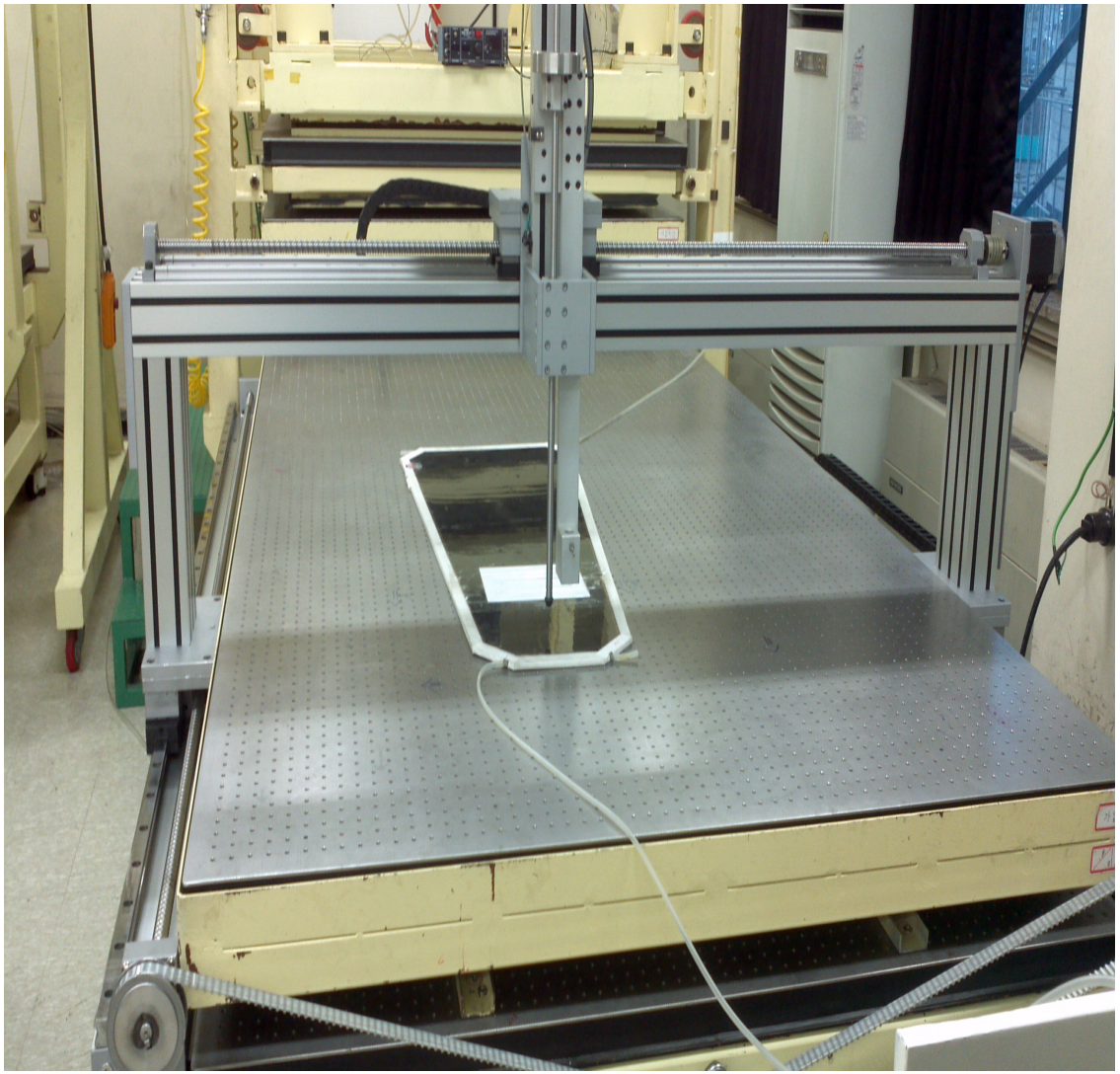


QA: Leakage and Pressure Test Procedure

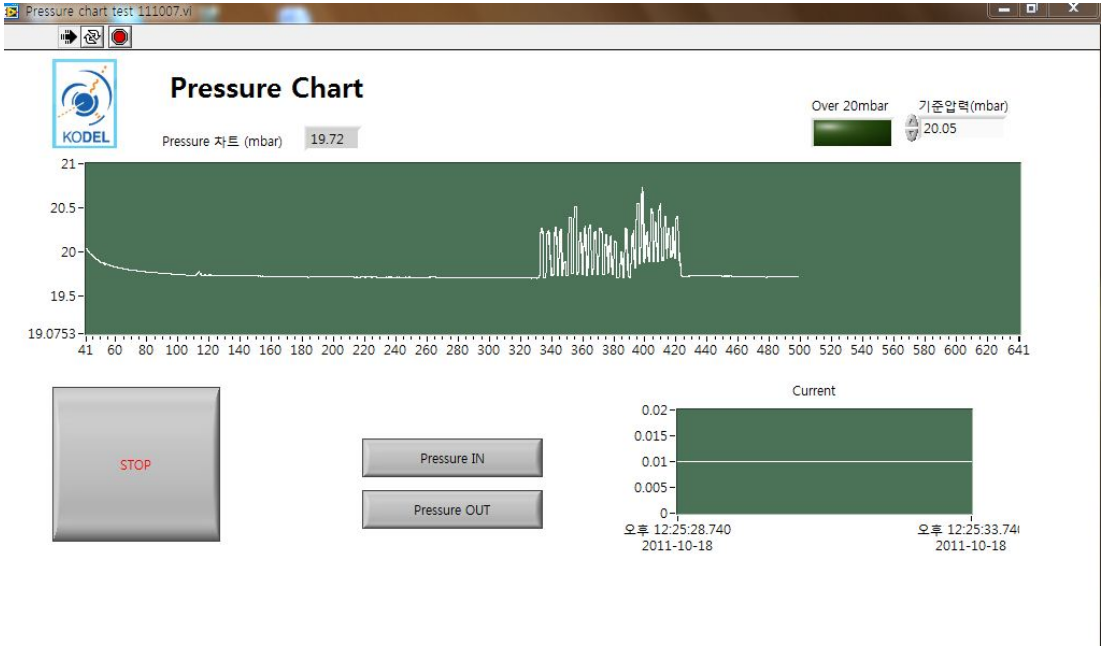


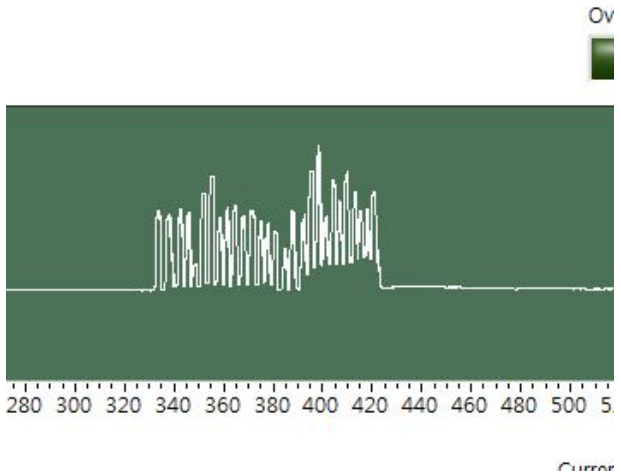
Testing the device

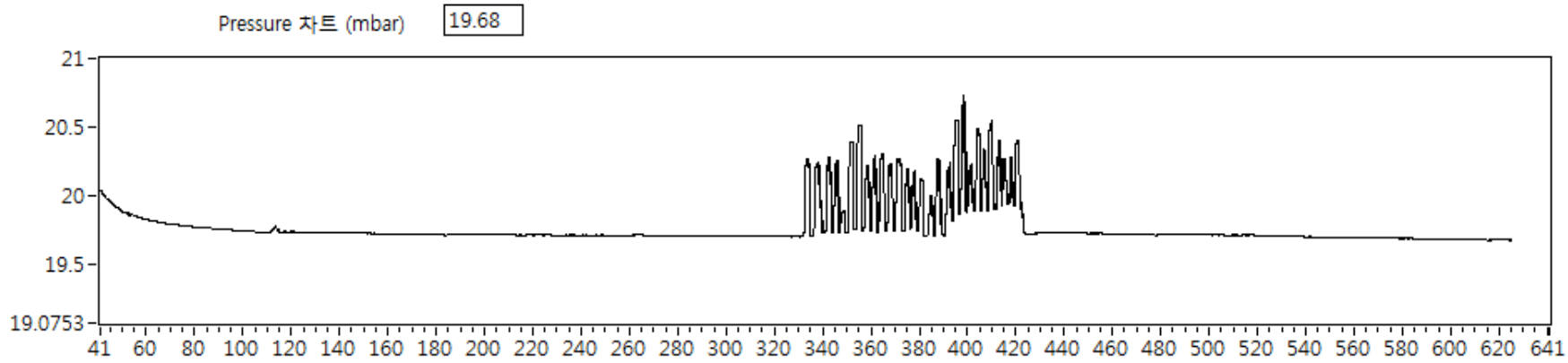
KODEL robot checking gas leak and pop-spacers



GUI: Test for gas leak and pop-spacers



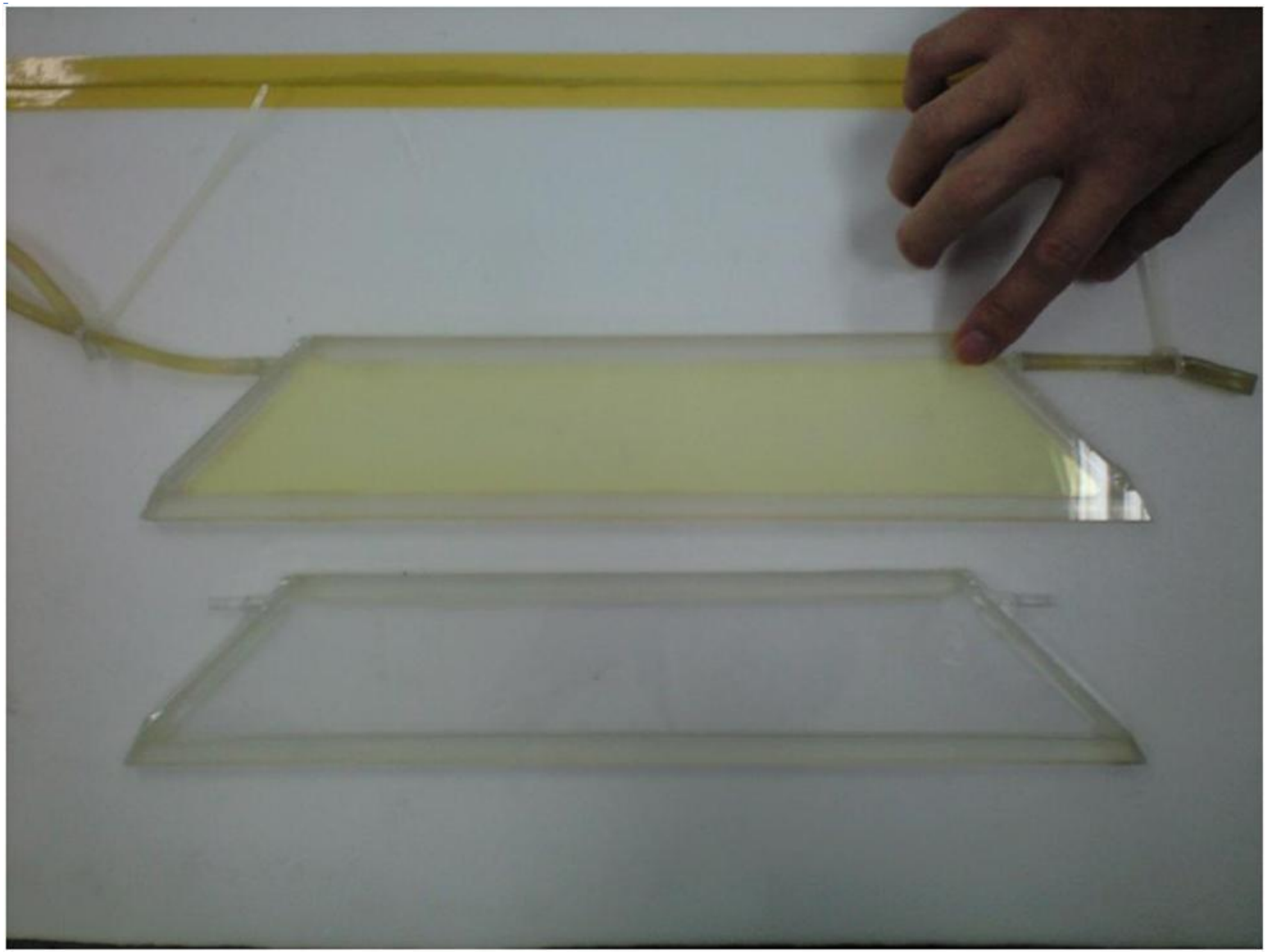




KODEL

Oiling for curing noises

- Linseed oil + heptane
  (Ratio : 40 % + 60 %)
- Polymerization with air
  Rate : 60 – 100 liter/h/gap
  Period : 72 – 96 hours
  Humidity : 40%



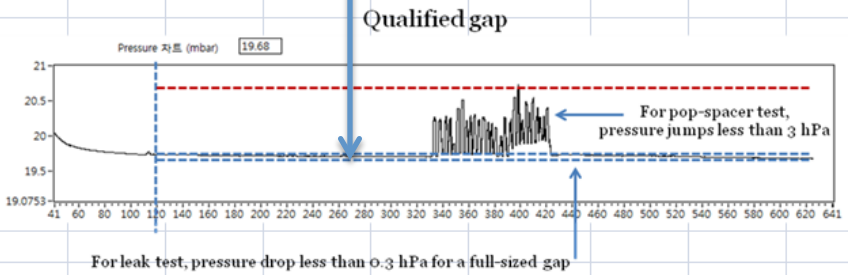
Preparation for gas test

QC steps
Leak
Pop spacers

1. Leak test (maxi. *p* drops allowed:
   0.2 ~ 0.4 hPa with +20 hPa
2. Pop spacer test (no pop spacer allowed)

Gap code	HPL code (GND)	HPL code (HV)
Kodel-CMS-RE4-2-B123		

1. Visual Inspections		Good	Not good	Description of the problem
	Bar code label	O		N/A
	Gas inlet and outlet-pipes	O		N/A
	Edges and gas corner piece	O		N/A
	HPL (HV)	O		Minor scratches
	HPL (GND)	O		N/A
	HV cable	O		N/A
	GND cable	O		N/A
	Graphite (HV) quality & surf. value (kΩ)	O		N/A
	Graphite (GND) quality & surf. value (kΩ)	O		N/A
	PET coating (HV)	O		Some bubbles bubbles on edges
	PET coating (GND)	O		N/A



Cen1	Cen2	Edge1	Edge2	Mean	Allowed range	
85	67	123	132	101	Minimum	50
Cen1	Cen2	Edge1	Edge2	Mean	Maximum	200
64	102	147	126	111		

2. Leak Test	require 2 mins to reach	an equilibrium		
Time (mins)	Pressure drop (hPa)	0.11	Certified	O
10			Not certified	

Leak Limits Allowed					
RE4/2 TW	RE4/2 TN	RE4/2 BT	RE4/3 TW	RE4/3 TN	RE4/3 BT
0.2 hPa	0.2 hPa	0.3 hPa	0.2 hPa	0.3 hPa	0.4 hPa

3. Pop spacers	Number of spacers	Number of popped spacers	Largest shift (hPa)	# of pop-spacers allowed	0	Certified	O
	120	0	1.1	Shift allowed	3 hPa	Not certified	

QC steps: HV test

7-day test including gas circulation.

4. HV tests

$$HV_0(293\,K, 1013\,hPa) = HV_{applied}\frac{1013\,hPa}{P}\frac{T}{293\,K}$$

Starting date of test		Dec. 23, 2011		Total gas rate = 20 l/h			Gas	Mixture
				Circulation bfr HV = 36 h			0.95 Freon	0.05 i-Bu
Time from test start	Date/ Time	*P* (hPa)	*T* (°C)	$HV_{applied}$ (kV)	HV_0 (kV)	I_ini (µA)	I_final (µA)	
0.0 h	06.12.2011/14.23	1023	20.4	1				
0.5 h				2				
1.0 h				3				
1.5 h				4				
2.0 h				5				
2.5 h				6.0 12 h test				
14.5 h				7				
15.0 h				7.5				
15.5 h				8				
16.0 h				8.4				
16.5 h				8.6				
17.0 h				8.8				
17.5 h				9				
18.0 h				9.2				
18.5 h				9.4				
19.0 h				9.6				
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72.0 h				test			x	
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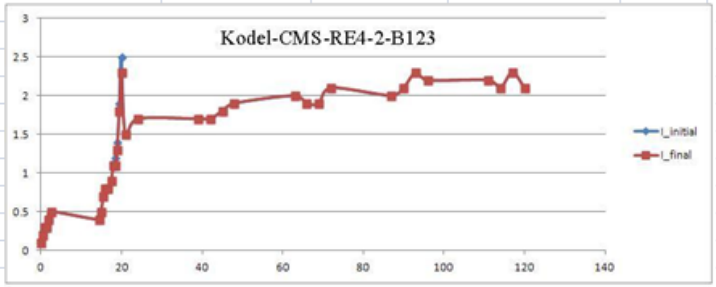
90.0 h								
93.0 h								
96.0 h								
108.0 h								
111.0 h								
114.0 h								
117.0 h								
120.0 h								

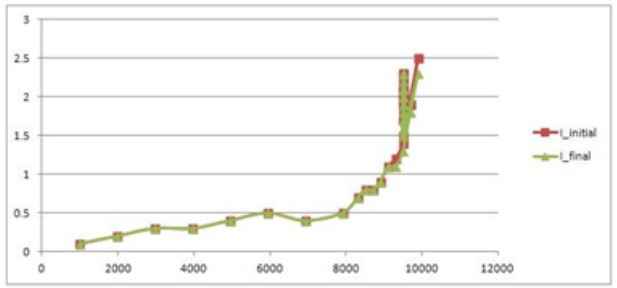
QC steps: HV test

Selection criteria for qualified gaps at three levels

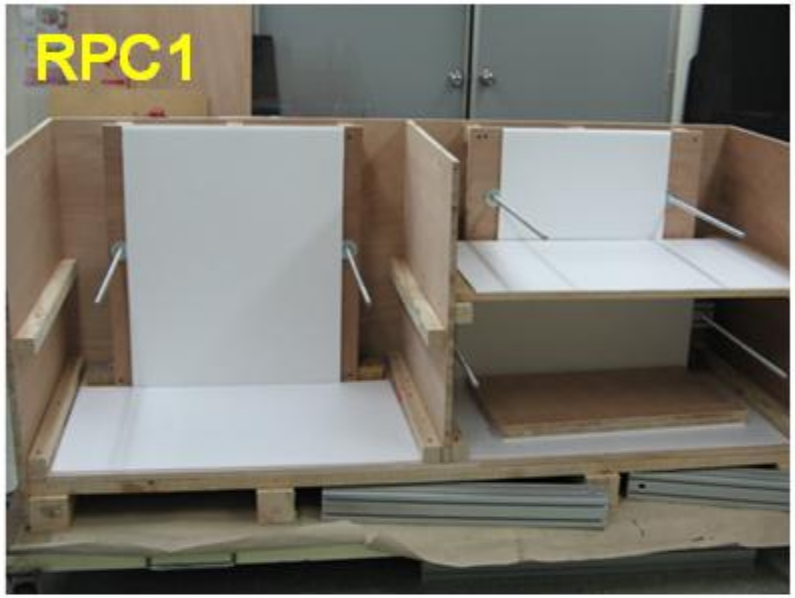
1. At 6.0 i < 1.5 µA for all type gaps
2. At 10.0 kV
   i < 5.0 µA for cut gaps
   i < 10.0 µA for full gaps
3. At 9.6 kV after 120 h

QC decision	Current Limits at 6.0 kV	RE4/2 TW	RE4/2 TN	RE4/2 BT	*i*(5h) at 6.0 kV		Final Decision	Certified	O
		1.5 µA	1.5 µA	1.5 µA	0.35				
		RE4/3 TW	RE4/3 TN	RE4/3 B					
		1.5 µA	1.5 µA	1.5 µA					
	Current Limits at 10.0 kV	RE4/2 TW	RE4/2 TN	RE4/2 B	*i*(24h) at 10.0 kV				
		5.0 µA	5.0 µA	10.0 µA	2.95				
		RE4/3 TW	RE4/3 TN	RE4/3 B					
		5.0 µA	5.0 µA	10.0 µA					
	Current Limits at 9.6 kV at t = 120 h	RE4/2 TW	RE4/2 TN	RE4/2 B	*i*(60h)	1.83		Not certified	
		2.0 µA	2.0 µA	3.5 µA	*i*(120h)	2.42			
		RE4/3 TW	RE4/3 TN	RE4/3 B	Criterion *i*(120h)/*i*(63h) < 1.5				
		2.0 µA	3.5 µA	5.0 µA	1.32				
5. Overal qualification	Certified	O							
	Not certified								





Packing



Summary and Conclusions

1. RE4/2 and RE4/3 of 660 Gaps for CMS upgrade are being produced at KODEL.

2. Productivity improvement is expected by the use of the KODEL Robot.

3. Quality assurance for gaps is effective.

4. Procedure of mass production for gaps is proven to be mature.