RPC Gap-Production & Test for the CMS-RPC Upscope

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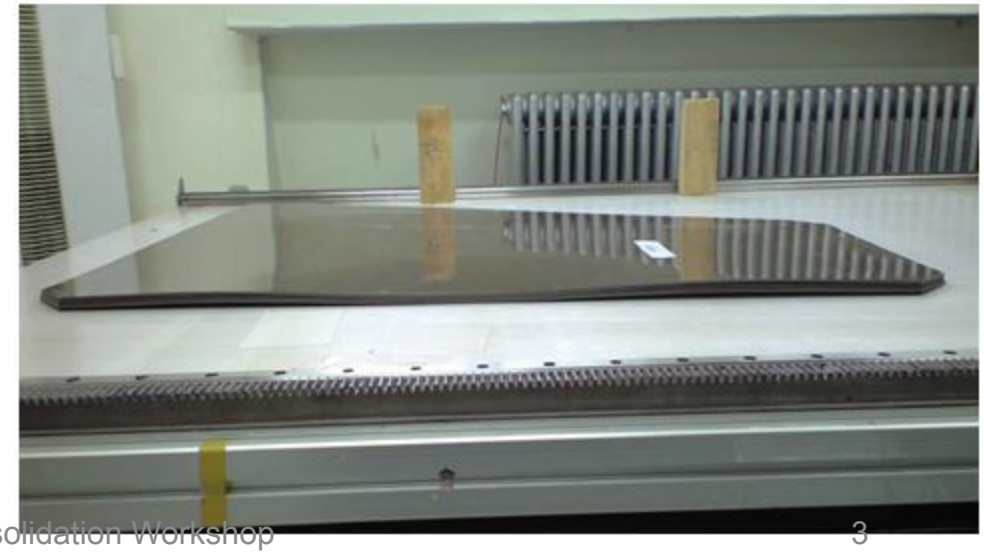
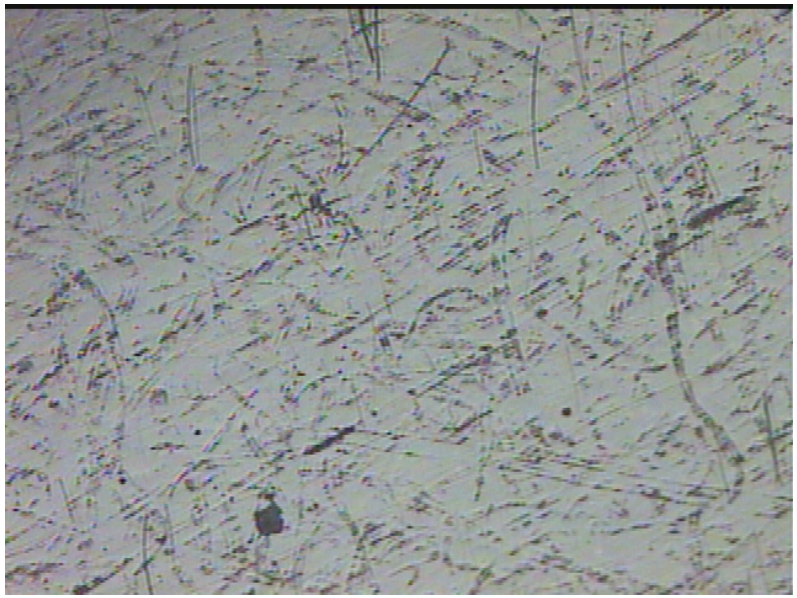
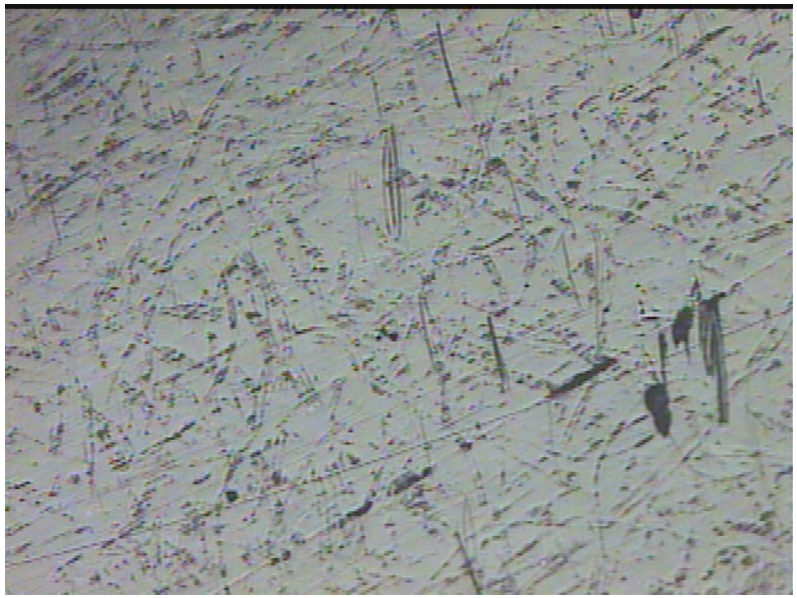
1. Production of RPC core detector : gaps
2. QA & handling
3. Performances
4. Conclusions for gap production
5. R&D of 4-gap RPCs

Pre-production Inspection

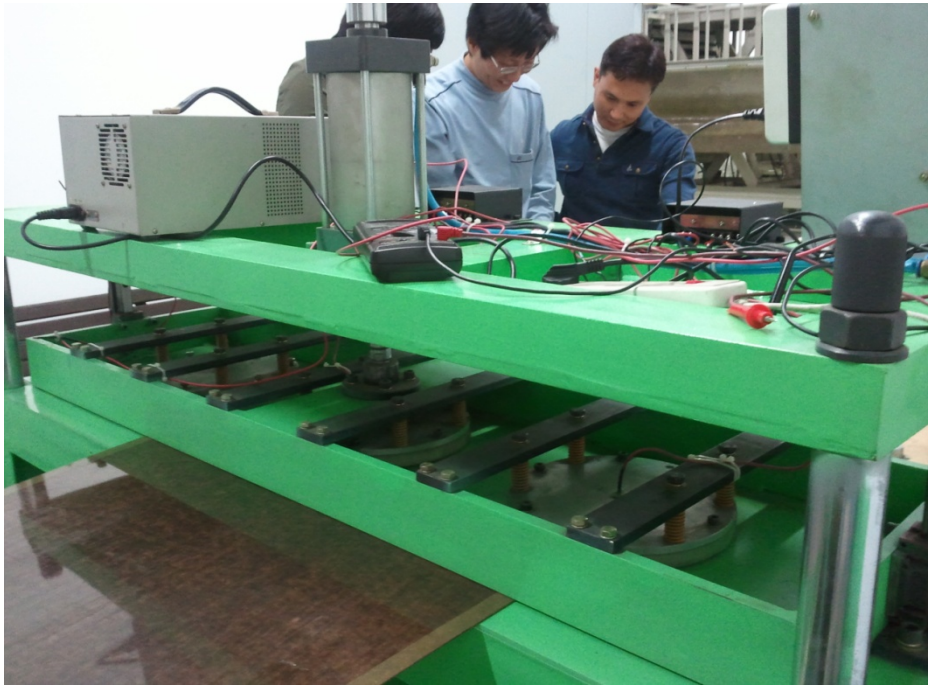
Inspection Cont'd







Resistivity-measurement tool for HPL



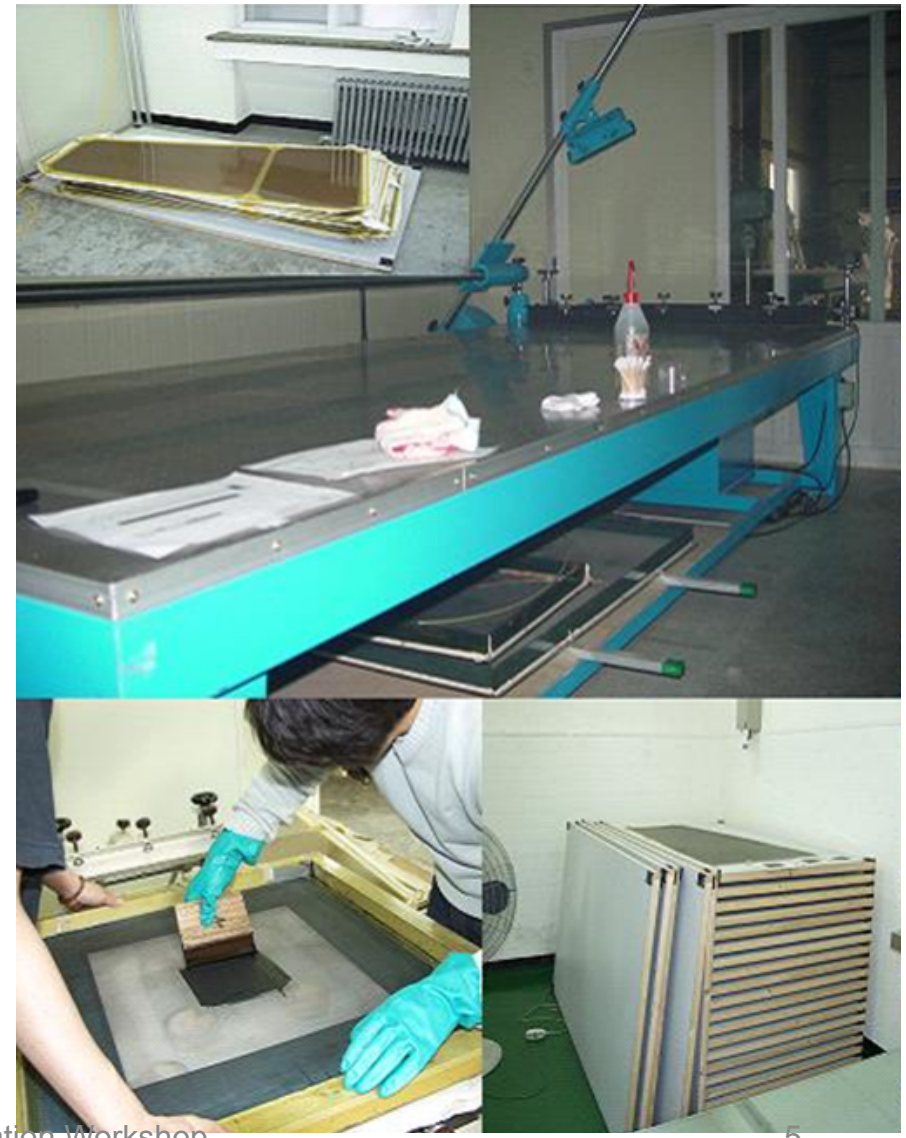
1. Production of RPC core detectors : gaps

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

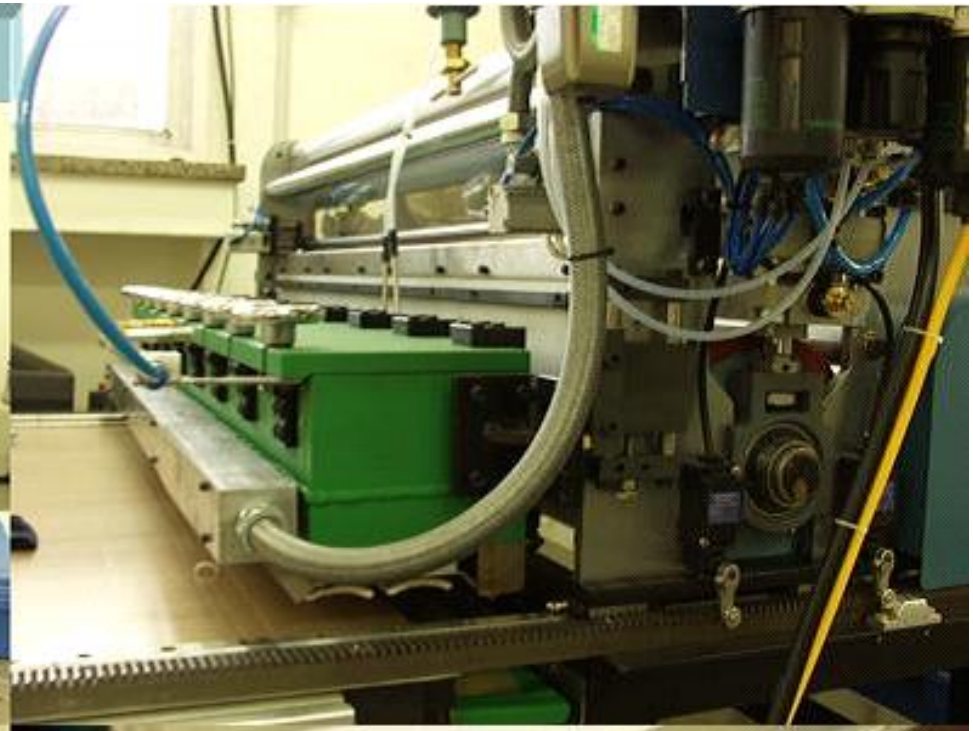
1. Graphite coating for RPC electrodes
   - Silkscreen method
   - Surface resistivity of electrode ranges fro m
     50 to 200 kΩ/square

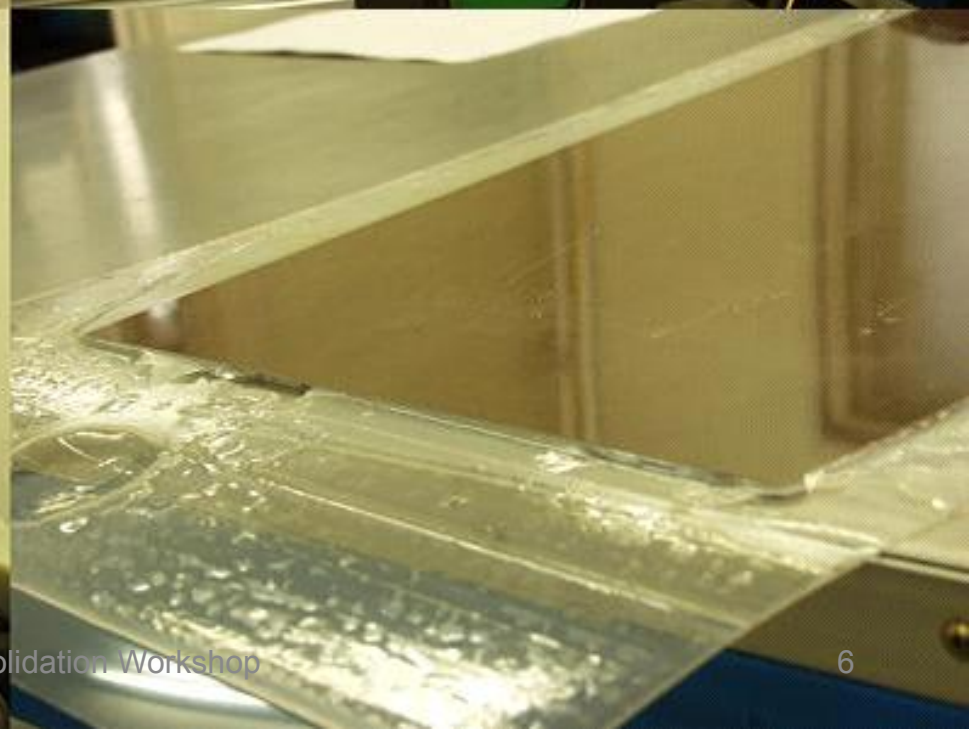
2. PET film coating for protection of gra phite electrodes
   - 1 layer of 200 micron PET film
   - Ethylene Vinyl Acetate base glue
   - 1 extra layer of PET to be attached during the RPC assembly

Silkscreen tool



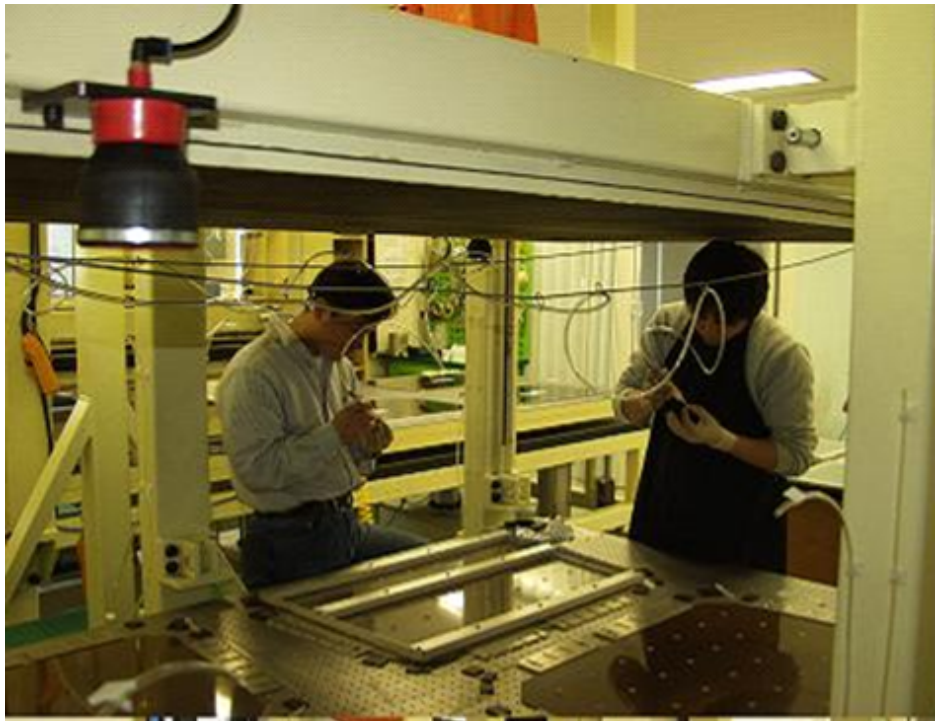
PET film insulations





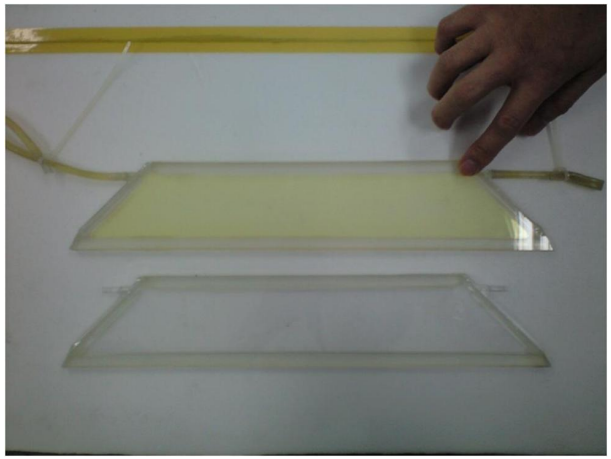
3. Gap assembly

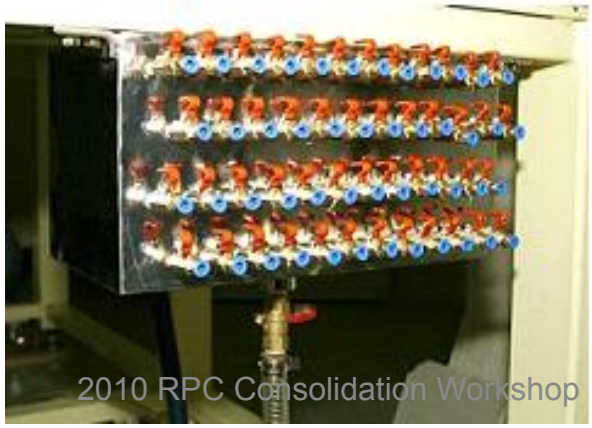
- multi-layered metric tables and shelves fo
  r the assembly and glue curing
- Glue curing time : 24 hours
- Glue : DP460, 3M production
- Selection of spacers : 2 mm +/- 20 µm
- Use spacer jigs for the location of spacers



4. 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%





2. QA & handling

1. Tests for pop spacers and leak (QA)
   - No pop spacer allowed at + 20 hPa
   - Gas leak : less than 0.2 hPa drop for 10 mins at +20 hPa

2. HV tests (QA)

- Total period of test : 6 days

  36 hours for gas circulation : 10 volume-circulation before applying HV to the gaps

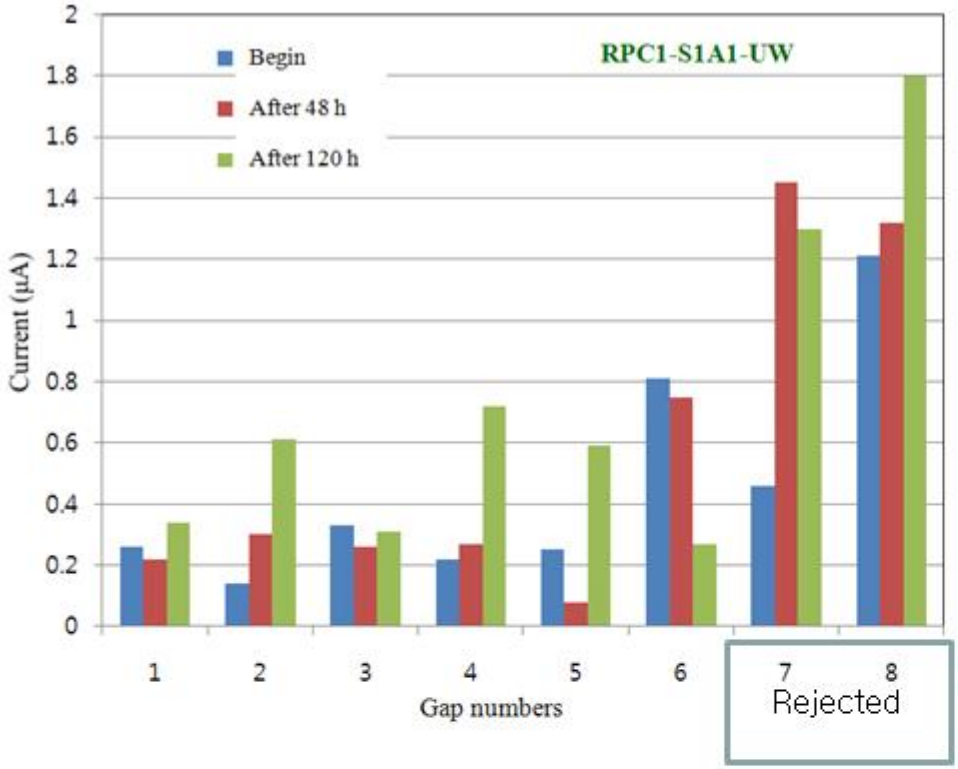
  12 hours at 8.5 kV to observe Ohmic currents

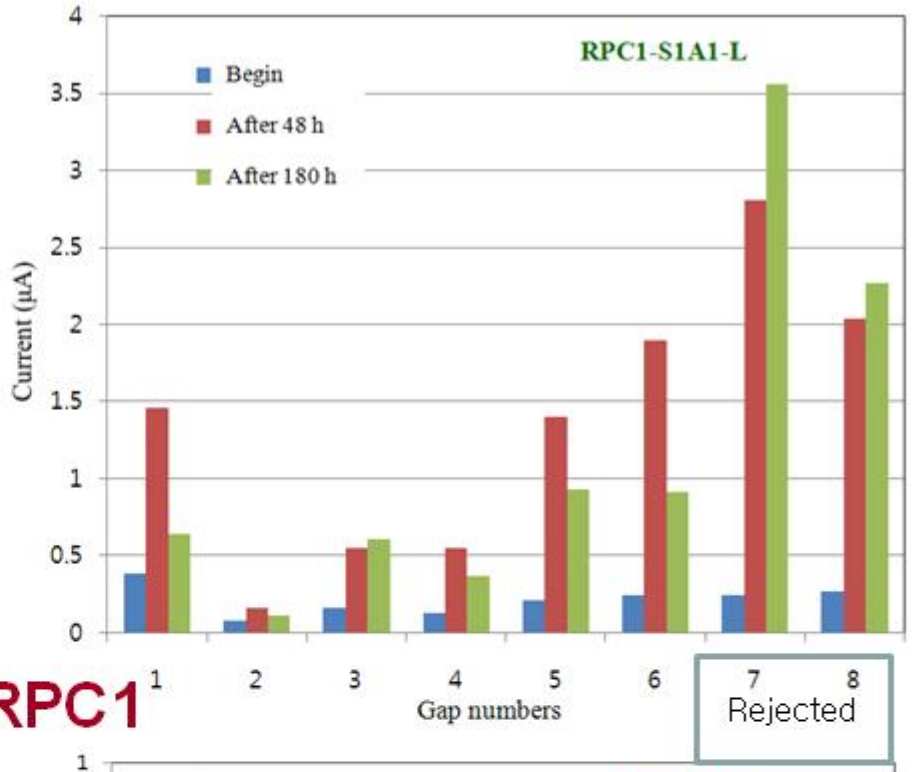
  120 hours at working voltage (9.4 kV) to observe the current behavior at the i nitial stage of gas operation

3. Performances

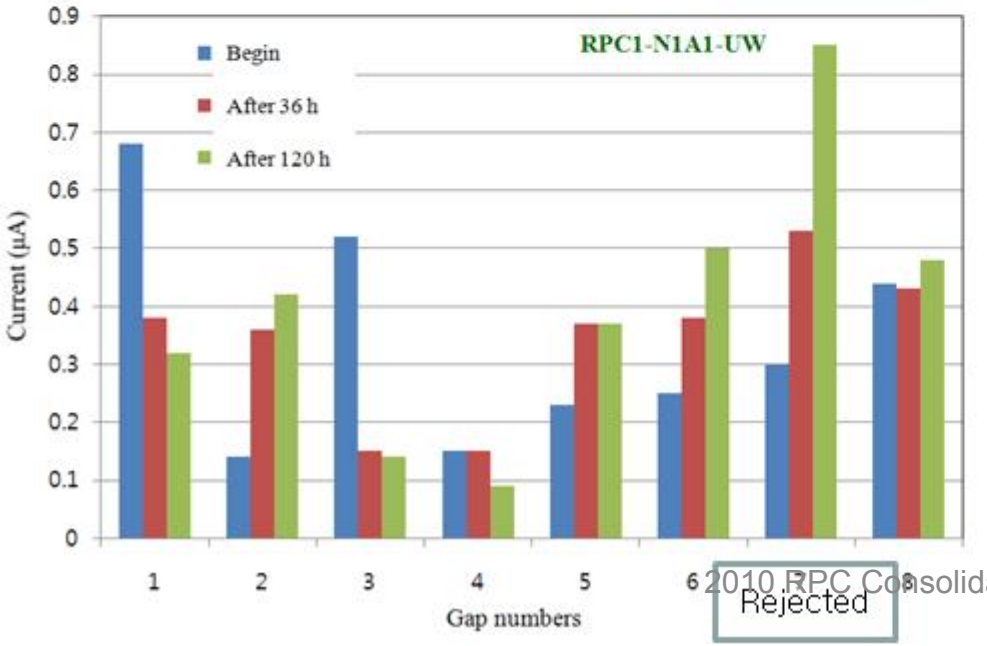
Excel data sheets

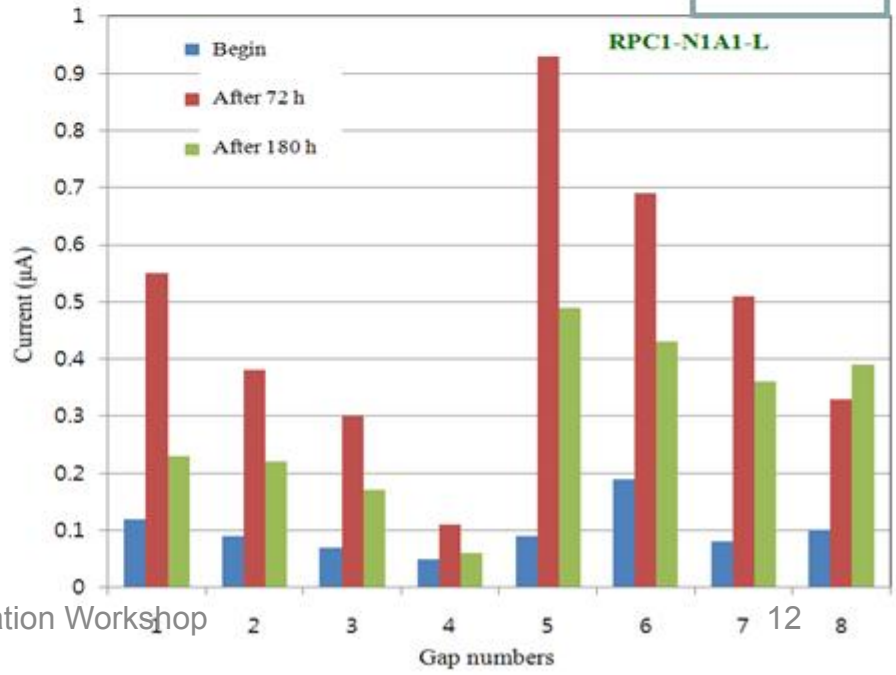
	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q
1	Bar Code	Bak codeGND	Sta	Silk	Bak code HV	Sta	silk	8.5kV/C	8.5KV/C	9.0KV/C	9.4KV/C	9.4KV	9.4 KV	9.4 KV	9.4 KV	9.4 KV	9.4 KV/
2								P/T(1018/18	T(1018/16	T(1018/16	T(1018/16	T(1022/16	T(1022/16	T(1020/16	T(1018/16	T(1016/17	T(1016/17
3								12h, begin	12h, final	30 min	120h, begin	0h, after 120	h, after 240	h, after 360	h, after 480	h, after 72	120h, FINAL
4	KODEL-PHE-RPC-3-A-U1	PHENIX-RPC-ST3-212-A	G	165kΩ	PHENIX-RPC-ST3-257-A	G	154kΩ	0.12	0.07	0.12	0.18	0.21	0.28	0.33	0.29	0.33	0.29
5	KODEL-PHE-RPC-3-A-U2	PHENIX-RPC-ST3-210-C	G	141kΩ	PHENIX-RPC-ST3-264-A	G	250kΩ	0.08	0.04	0.07	0.11	0.13	0.2	0.17	0.15	0.22	0.23
6	KODEL-PHE-RPC-3-A-U3	PHENIX-RPC-ST3-236-D	G	218kΩ	PHENIX-RPC-ST3-213-C	G	203kΩ	0.05	0.05	0.06	0.11	0.11	0.18	0.18	0.23	0.25	0.31
7	KODEL-PHE-RPC-3-A-U4	PHENIX-RPC-ST3-263-B	G	230kΩ	PHENIX-RPC-ST3-237-A	G	197kΩ	0.05	0.04	0.04	0.08	0.05	0.08	0.05	0.07	0.07	0.09
8	KODEL-PHE-RPC-3-A-U5	PHENIX-RPC-ST3-224-B	G	168kΩ	PHENIX-RPC-ST3-203-C	G	211kΩ	0.06	0.04	0.08	0.09	0.11	0.16	0.13	0.17	0.19	0.33
9	KODEL-PHE-RPC-3-A-U6	PHENIX-RPC-ST3-258-C	G	293kΩ	PHENIX-RPC-ST3-206-B	G	263kΩ	0.03	0.03	0.03	0.13	0.05	0.06	0.06	0.06	0.09	0.13
10	KODEL-PHE-RPC-3-A-U7	PHENIX-RPC-ST3-228-B	G	194kΩ	PHENIX-RPC-ST3-237-C	G	235kΩ	0.07	0.06	0.08	0.06	0.14	0.21	0.18	0.24	0.28	0.34
11	KODEL-PHE-RPC-3-A-U8	PHENIX-RPC-ST3-261-B	G	298kΩ	PHENIX-RPC-ST3-200-A	G	156kΩ	0.05	0.04	0.05	0.13	0.08	0.14	0.13	0.17	0.18	0.25
12	KODEL-PHE-RPC-3-A-U9	PHENIX-RPC-ST3-204-B	G	158kΩ	PHENIX-RPC-ST3-259-C	G	212kΩ	0.04	0.03	0.05	0.05	0.09	0.11	0.07	0.11	0.12	0.16
13	KODEL-PHE-RPC-3-A-U1(	PHENIX-RPC-ST3-265-C	G	198kΩ	PHENIX-RPC-ST3-200-C	G	267kΩ	0.07	0.07	0.07	0.11	0.23	0.31	0.23	0.35	0.39	0.47
14	KODEL-PHE-RPC-3-A-U1	PHENIX-RPC-ST3-236-A	G	186kΩ	PHENIX-RPC-ST3-260-C	G	230kΩ	0.03	0.03	0.06	0.06	0.05	0.08	0.04	0.05	0.06	0.06
15	KODEL-PHE-RPC-3-A-U1	PHENIX-RPC-ST3-255-D	G	147kΩ	PHENIX-RPC-ST3-203-A	G	221kΩ	0.03	0.02	0.03	0.05	0.04	0.05	0.2	0.03	0.04	0.04
16	KODEL-PHE-RPC-3-A-U1	PHENIX-RPC-ST3-207-C	G	183kΩ	PHENIX-RPC-ST3-211-A	G	156kΩ	0.05	0.04	0.08	0.11	0.17	0.31	0.34	0.32	0.47	0.45
17	KODEL-PHE-RPC-3-A-U1	PHENIX-RPC-ST3-255-B	G	182kΩ	PHENIX-RPC-ST3-261-A	G	195kΩ	0.06	0.05	0.08	0.11	0.18	0.32	0.21	0.26	0.29	0.39
18	KODEL-PHE-RPC-3-A-U1	PHENIX-RPC-ST3-226-C	G	196kΩ	PHENIX-RPC-ST3-201-B	G	188kΩ	0.03	0.03	0.05	0.07	0.08	0.13	0.05	0.07	0.08	0.07
19	KODEL-PHE-RPC-3-A-U1	PHENIX-RPC-ST3-222-A	G	292kΩ	PHENIX-RPC-ST3-231-B	G	172kΩ	0.04	0.04	0.05	0.08	0.1	0.15	0.09	0.13	0.18	0.29
20	KODEL-PHE-RPC-3-A-U1	PHENIX-RPC-ST3-230-B	G	139kΩ	PHENIX-RPC-ST3-254-A	G	129kΩ	0.06	0.13	0.14	0.17	0.14	0.18	0.09	0.12	0.11	0.11
21	KODEL-PHE-RPC-3-A-U1	PHENIX-RPC-ST3-220-D	G	183kΩ	PHENIX-RPC-ST3-209-A	G	102kΩ	0.03	0.02	0.03	0.06	0.08	0.16	0.08	0.15	0.15	0.19
22	KODEL-PHE-RPC-3-A-U1	PHENIX-RPC-ST3-234-A	G	212kΩ	PHENIX-RPC-ST3-240-C	G	192kΩ	0.03	0.03	0.05	0.08	0.07	0.14	0.07	0.1	0.11	0.14
23	KODEL-PHE-RPC-3-A-U2(	PHENIX-RPC-ST3-226-A	G	231kΩ	PHENIX-RPC-ST3-229-A	G	152kΩ	0.03	0.03	0.04	0.09	0.09	0.16	0.1	0.17	0.16	0.18
24	KODEL-PHE-RPC-3-A-U2	PHENIX-RPC-ST3-208-D	G	234kΩ	PHENIX-RPC-ST3-233-B	G	223kΩ	0.04	0.03	0.06	0.09	0.09	0.14	0.06	0.09	0.11	0.11
25	KODEL-PHE-RPC-3-A-U2	PHENIX-RPC-ST3-224-D	G	168kΩ	PHENIX-RPC-ST3-225-D	G	145kΩ	0.04	0.03	0.04	0.06	0.07	0.11	0.07	0.11	0.19	0.26
26																	
27	Bar Code	Bak codeGND	Sta	Silke	Bak code HV	Sta	silke	8.5kV/C	8.5KV/C	9.0KV/C	9.4KV/C	9.4KV	9.4 KV	9.4 KV	9.4 KV	9.4 KV	9.4 KV/
28								P/T(1010/17	T(1013/18	T(1013/18	T(1013/18	T(1013/18	T(1019/17	T(1017/17	T(1017/17	T(1018/17	T(/
29								12h, begin	12h, final	30 min	120h, begin	0h, after 240	h, after 480	h, after 560	h, after 96	120h, FINAL	
30	KODEL-PHE-RPC-3-A-U2	PHENIX-RPC-ST3-266-D	G	140kΩ	PHENIX-RPC-ST3-201-A	G	199kΩ	0.13	0.12	0.17	0.27	0.28	0.48	0.53	0.35	0.45	
31	KODEL-PHE-RPC-3-A-U2	PHENIX-RPC-ST3-257-D	G	115kΩ	PHENIX-RPC-ST3-205-A	G	227kΩ	0.1	0.15	0.22	0.34	0.43	0.72	0.91	0.68	0.87	
32	KODEL-PHE-RPC-3-A-U2	PHENIX-RPC-ST3-268-D	G	122kΩ	PHENIX-RPC-ST3-265-D	G	91kΩ	0.1	0.11	0.16	0.21	0.24	0.48	0.57	0.51	0.54	
33	KODEL-PHE-RPC-3-A-U2	PHENIX-RPC-ST3-262-D	G	177kΩ	PHENIX-RPC-ST3-221-A	G	156kΩ	0.05	0.04	0.06	0.09	0.13	0.21	0.22	0.21	0.22	
34	KODEL-PHE-RPC-3-A-U2	PHENIX-RPC-ST3-202-C	G	150kΩ	PHENIX-RPC-ST3-260-D	G	265kΩ	0.05	0.07	0.11	0.13	0.46	0.55	0.66	0.62	0.6	
35	KODEL-PHE-RPC-3-A-U2	PHENIX-RPC-ST3-230-D	G	163kΩ	PHENIX-RPC-ST3-231-D	G	272kΩ	0.06	0.06	0.1	0.13	0.15	0.34	0.39	0.52	0.75	
36	KODEL-PHE-RPC-3-A-U2	PHENIX-RPC-ST3-267-B	G	155kΩ	PHENIX-RPC-ST3-233-D	G	230kΩ	0.07	0.07	0.09	0.12	0.29	0.45	0.49	0.43	0.44	
37	KODEL-PHE-RPC-3-A-U3(	PHENIX-RPC-ST3-204-A	G	200kΩ	PHENIX-RPC-ST3-211-C	G	231kΩ	0.04	0.02	0.02	0.09	0.04	0.05	0.06	0.03	0.06	
38	KODEL-PHE-RPC-3-A-U3	PHENIX-RPC-ST3-264-C	G	164kΩ	PHENIX-RPC-ST3-229-C	G	215kΩ	0.04	0.04	0.06	0.07	0.09	0.21	0.24	0.2	0.18	
39	KODEL-PHE-RPC-3-A-U3	PHENIX-RPC-ST3-208-C	G	288kΩ	PHENIX-RPC-ST3-258-D	G	231kΩ	0.04	0.08	0.11	0.14	0.26	0.39	0.42	0.38	0.41	
40	KODEL-PHE-RPC-3-A-U3	PHENIX-RPC-ST3-207-B	G	250kΩ	PHENIX-RPC-ST3-253-D	G	237kΩ	0.02	0.04	0.05	0.07	0.1	0.14	0.16	0.14	0.14	
41	KODEL-PHE-RPC-3-A-U3	PHENIX-RPC-ST3-202-A	G	214kΩ	PHENIX-RPC-ST3-227-D	G	285kΩ	0.03	0.04	0.06	0.09	0.12	0.17	0.21	0.16	0.18	
42	KODEL-PHE-RPC-3-A-U3	PHENIX-RPC-ST3-206-A	G	133kΩ	PHENIX-RPC-ST3-240-A	G	292kΩ	0.02	0.06	0.07	0.11	0.14	0.19	0.22	0.17	0.2	
43	KODEL-PHE-RPC-3-A-U3	PHENIX-RPC-ST3-210-B	G	264kΩ	PHENIX-RPC-ST3-256-D	G	228kΩ	0.05	0.06	0.08	0.15	0.18	0.32	0.41	0.32	0.37	

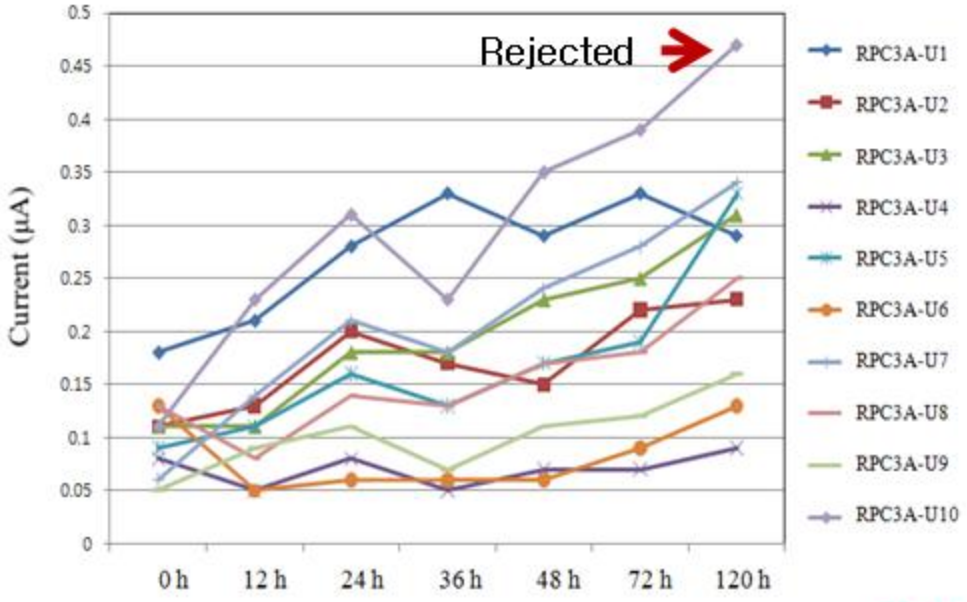

RPC1-S1A1-UW
Begin
After 48 h
After 120 h
Current (μA)
Gap numbers
Rejected

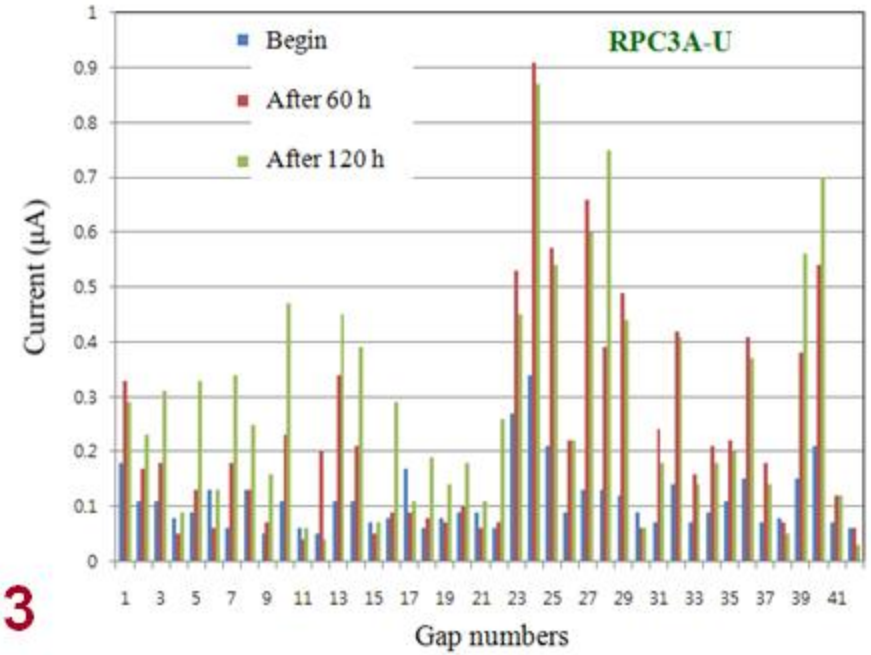

RPC1-S1A1-L
Begin
After 48 h
After 180 h
Current (μA)
Gap numbers
Rejected

RPC1

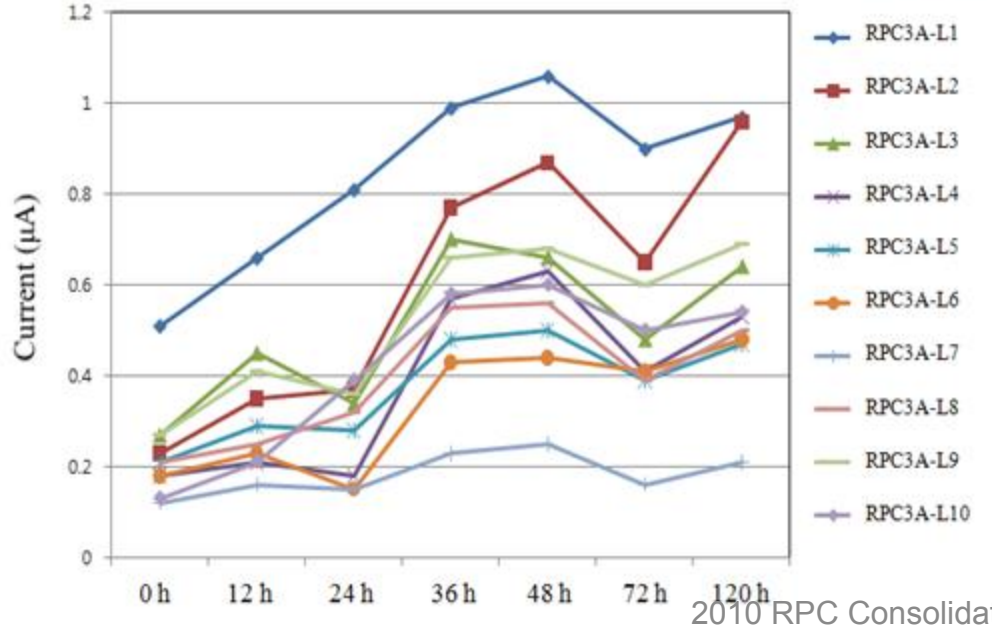

RPC1-N1A1-UW
Begin
After 36 h
After 120 h
Current (μA)
Gap numbers
Rejected

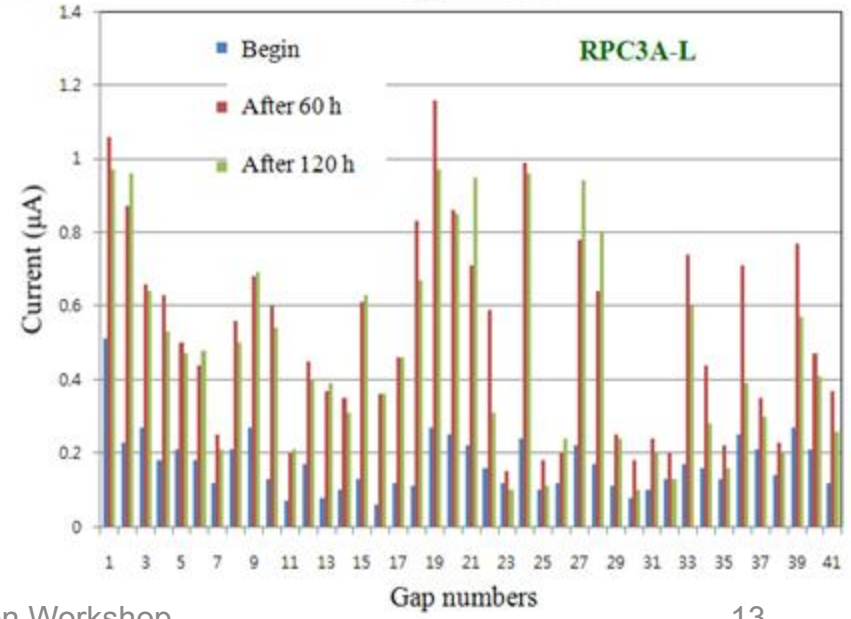

RPC1-N1A1-L
Begin
After 72 h
After 180 h
Current (μA)
Gap numbers


Rejected
Current (μA)
0.5
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
0 h
12 h
24 h
36 h
48 h
72 h
120 h
RPC3A-U1
RPC3A-U2
RPC3A-U3
RPC3A-U4
RPC3A-U5
RPC3A-U6
RPC3A-U7
RPC3A-U8
RPC3A-U9
RPC3A-U10


RPC3A-U
Begin
After 60 h
After 120 h
Current (μA)
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
1 3 5 7 9 11 13 15 17 19 21 23 25 27 29 31 33 35 37 39 41
Gap numbers

RPC3

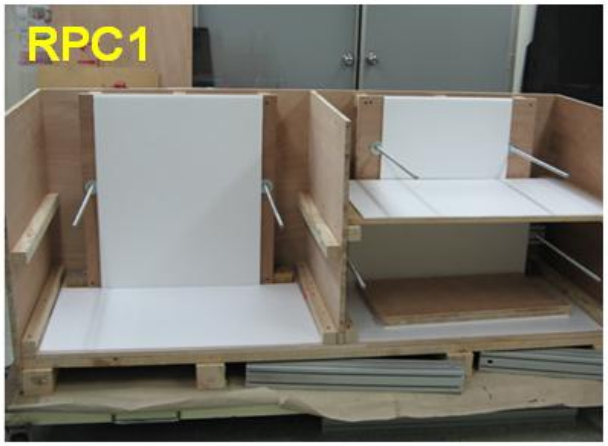

Current (μA)
1.2
1
0.8
0.6
0.4
0.2
0
0 h
12 h
24 h
36 h
48 h
72 h
120 h
RPC3A-L1
RPC3A-L2
RPC3A-L3
RPC3A-L4
RPC3A-L5
RPC3A-L6
RPC3A-L7
RPC3A-L8
RPC3A-L9
RPC3A-L10


RPC3A-L
Begin
After 60 h
After 120 h
Current (μA)
1.4
1.2
1
0.8
0.6
0.4
0.2
0
1 3 5 7 9 11 13 15 17 19 21 23 25 27 29 31 33 35 37 39 41
Gap numbers

3. Shipping boxes

- Loading gaps vertically inside the boxes.
- All the gas pipes should be fully open to adapt any sudden change of air pressure

Packing



4. Summaries and conclusions

1. Gaps for CMS RPC produced based on the previous RPC technology.

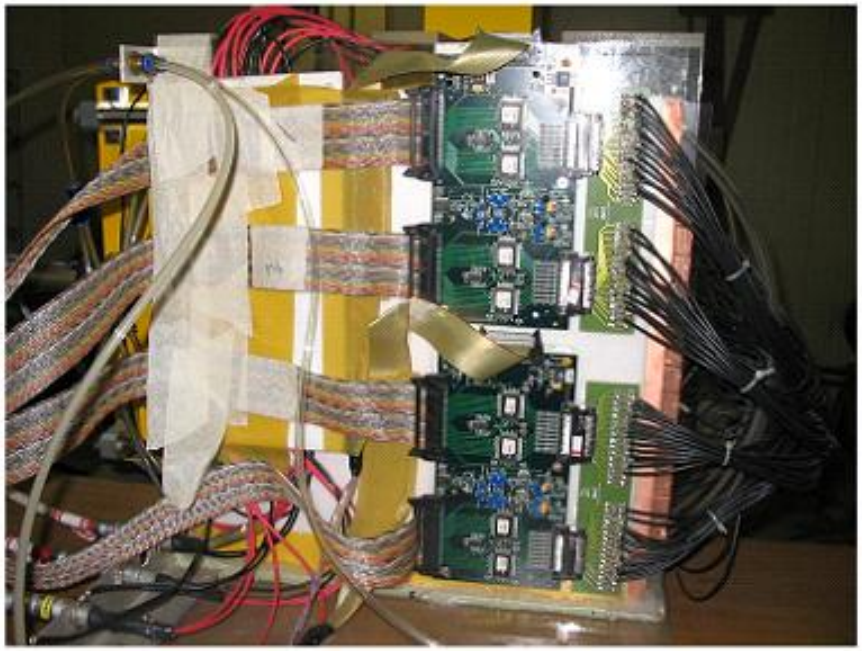
2. Test results after gap production should be as good as the gaps achieved in the previous production.

3. The maximum capacity of the gap production (100 ~ 200 gaps/month)

4. KODLE is ready for the upcoming mass production and quality assurance.

200 mCi ^{137}Cs gamma irradiation facility & DAQ + electronics

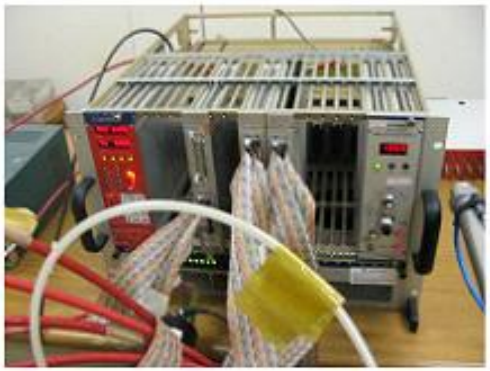
<High Voltage Connection>

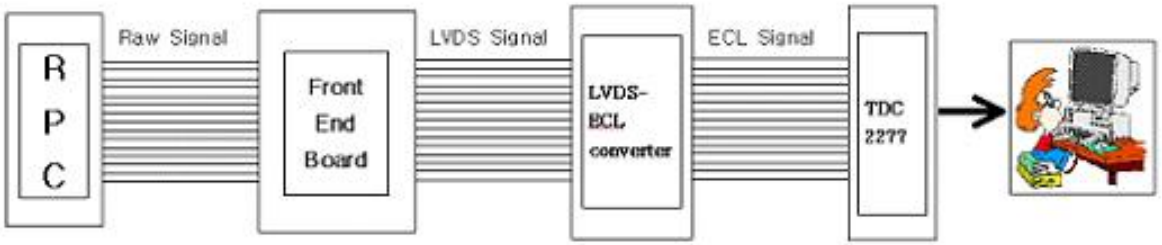


<Front End Board>

<HV Supply Crate>

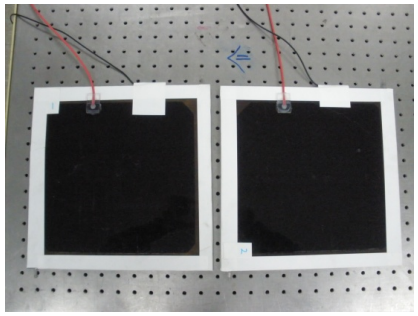
<LVDS-ECL Converter>

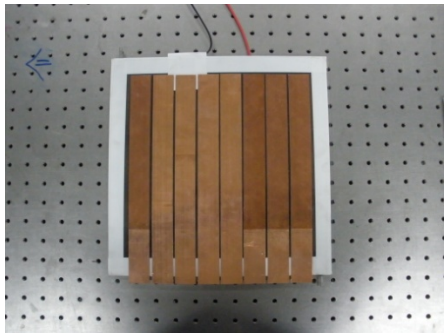


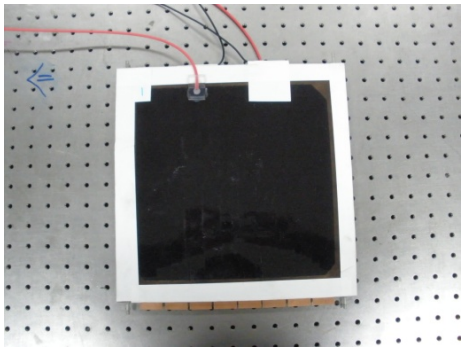


5. 4-gap RPCs for RE1/1 (Upscope)

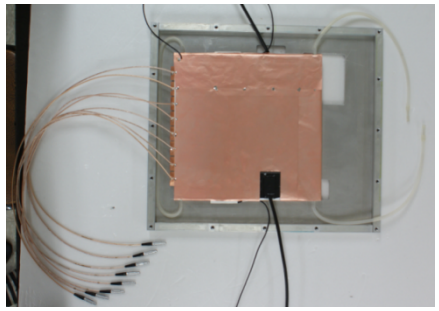
Assembly of multi-gap RPC

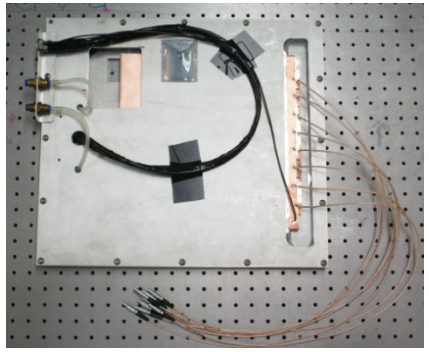


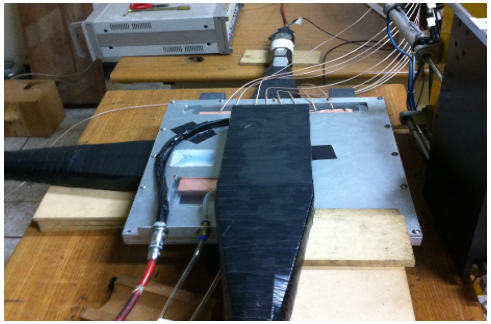




KODEL







Resistivity tests for High Pressure Laminated(HPL)

HPL A : 2mm sample by melamine + phenol

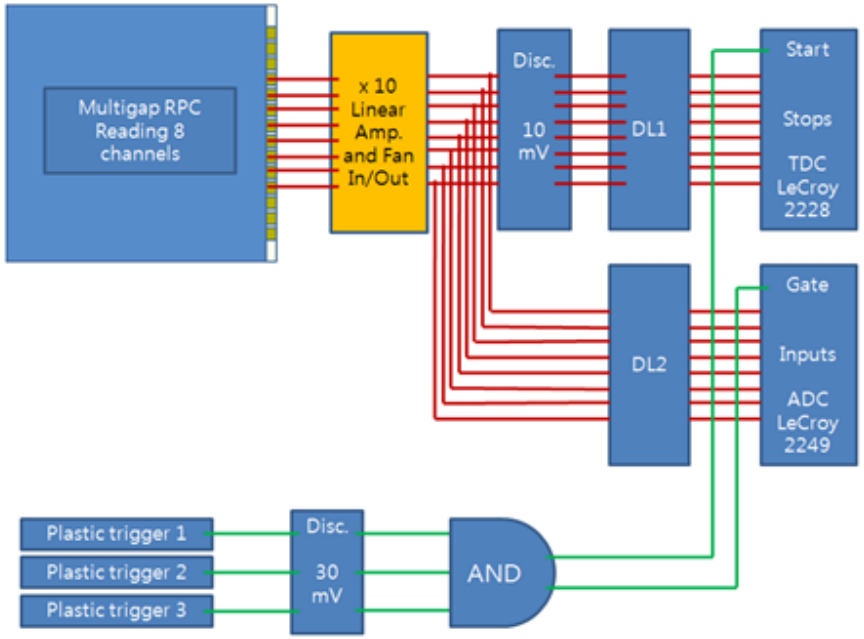
HPL B & C : 1mm sample by melamine + phenol

$$\rho_b^{20} = \rho_T e^{\alpha(T-T_0)}$$

α = 0.12/°C♪

	HPL A (2mm)	HPL B (1mm)	HPL C (1mm)
Average	$2.23 \times 10^{10}\ \Omega cm$	$3.29\times 10^{9}\ \Omega$cm	$5.37\times 10^{9}\Omega$cm
Max.	$2.40\times 10^{10}\ \Omega cm$	$3.98 \times 10^{9}\ \Omega$cm	$6.46 \times 10^{9}\ \Omega cm$
Min.	$1.99 \times 10^{10}\ \Omega cm$	$2.91\times 10^{9}\ \Omega cm$	$4.76\times 10^{9}\ \Omega$cm

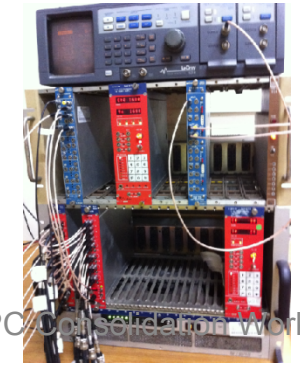
Set equipment



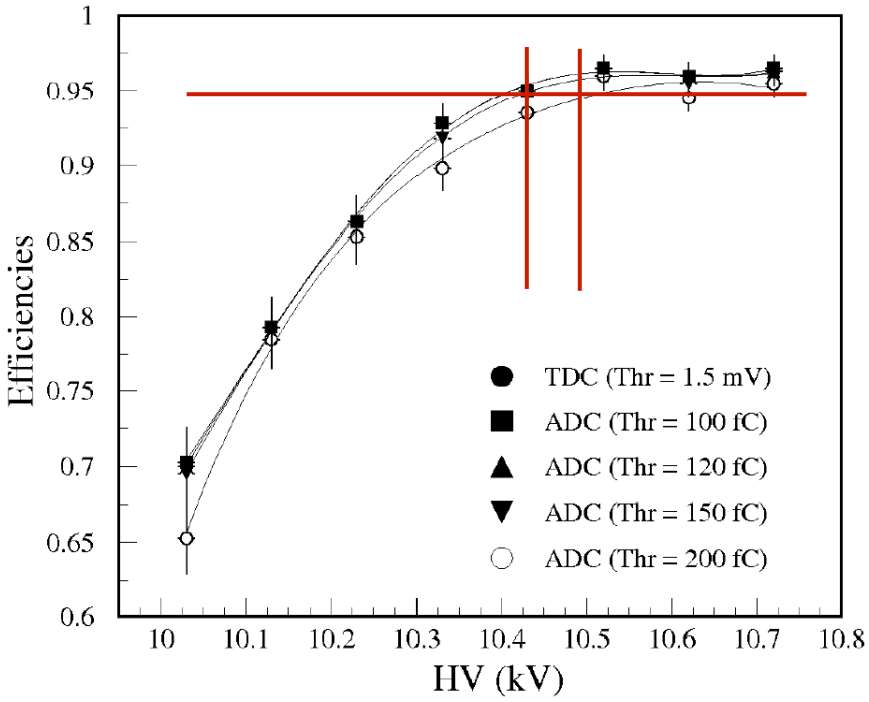
❖ Gas system

➢ Gas mixture :
Freon (93%)
iso-butane (6.6%)
sf6 (0.4%)

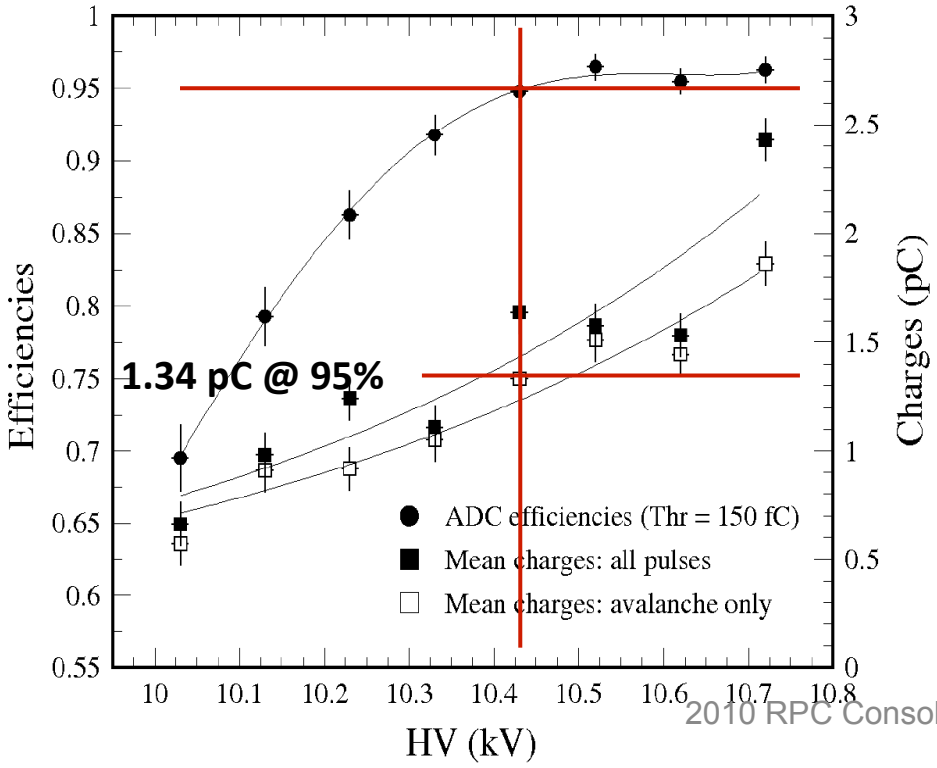
❖ electronics

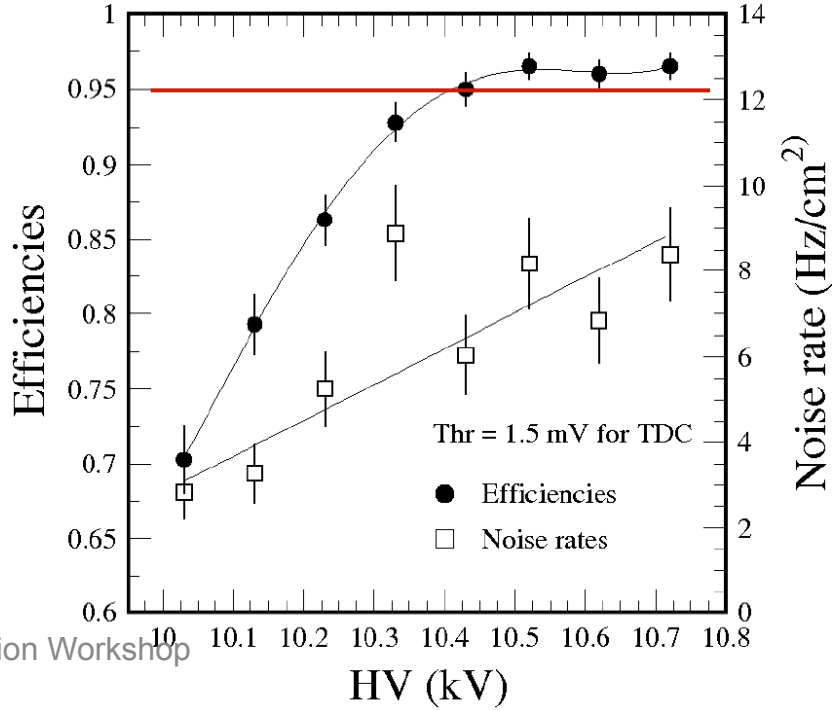


Efficiencies

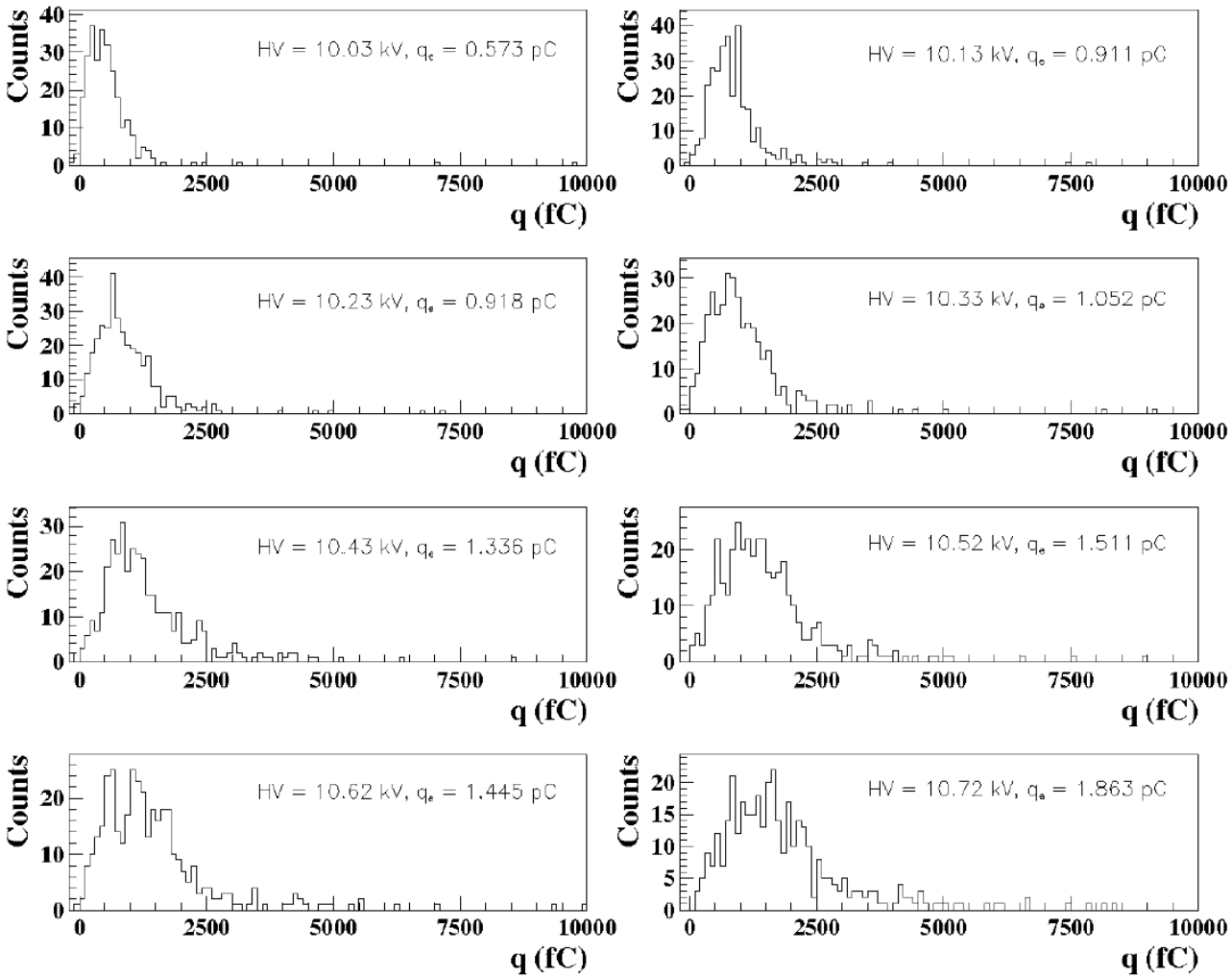


Fast charges

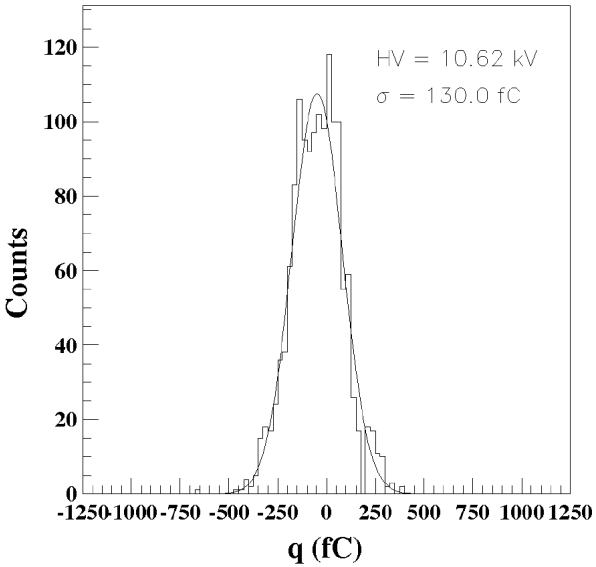




Charge distributions



Resolution measuring fast charges ~ 130 fC



Cluster sizes