



上海交通大学
SHANGHAI JIAO TONG UNIVERSITY



Progress of Making RPCs

Qiu-Ping Shen

On behalf of RPC Lab, 6#113

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Outline

- RPC package
- Printing graphite layers
- Testing the graphite ratio
- Signal analysis
- Summary & Next plans



Resistive plate chamber



RPC size: $350*500*1.2\text{mm}^3$

Anode: 0.7mm glass for ground

Cathode: 1.1mm glass for negative high voltage

Nozzles: one pipe with 1.2mm as a inlet
three pipes as a outlet

Graphite layer: providing the uniform electric field for parallel glass (details as following slides)

Mylar film thickness: 197um for mainly protecting electronics and for safety



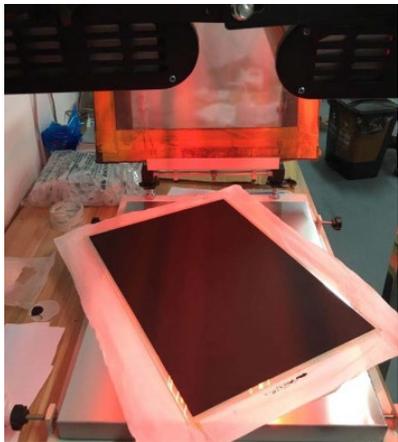
Printing graphite



Graphite coating with silk screen printing:

PM404 **84% (16.8g)** S6017 **16%(3.2g)** for
350*500mm RPC Stirring for **10mins** to
assure that mixture is enough uniform

Silk screen parameters: **300目 (grid density)**
350*500 effective area



Cooking condition: **one lamp,**
80-90°C, 2hours, diagonally cooking,
more uniform and stable temperature for
this size RPC

Better quality of layers(details as following
slides)



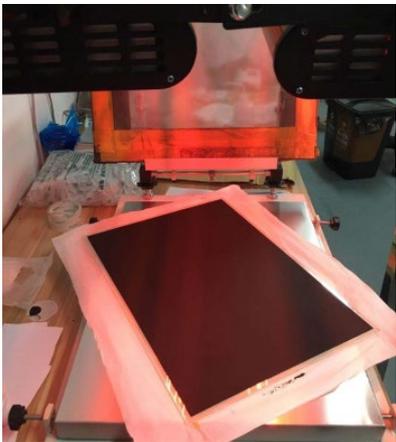
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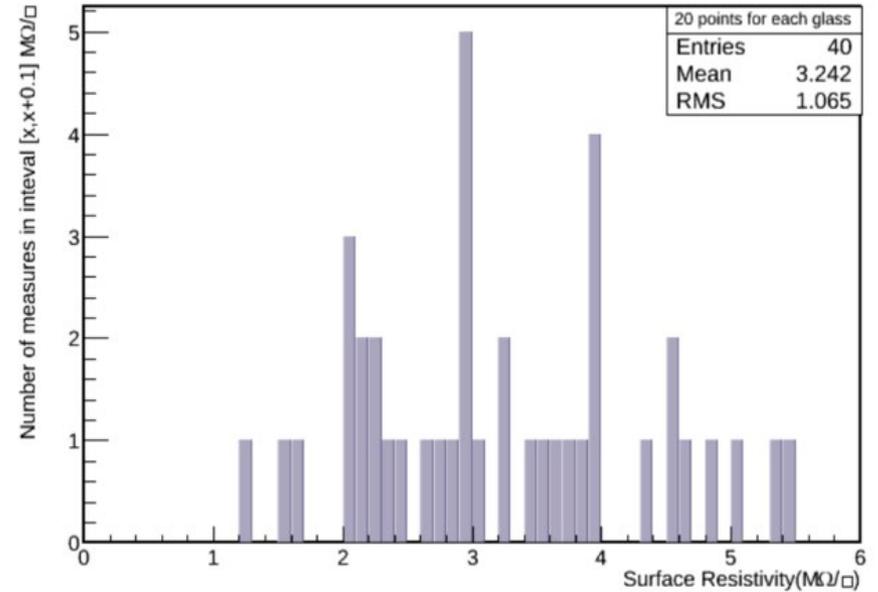
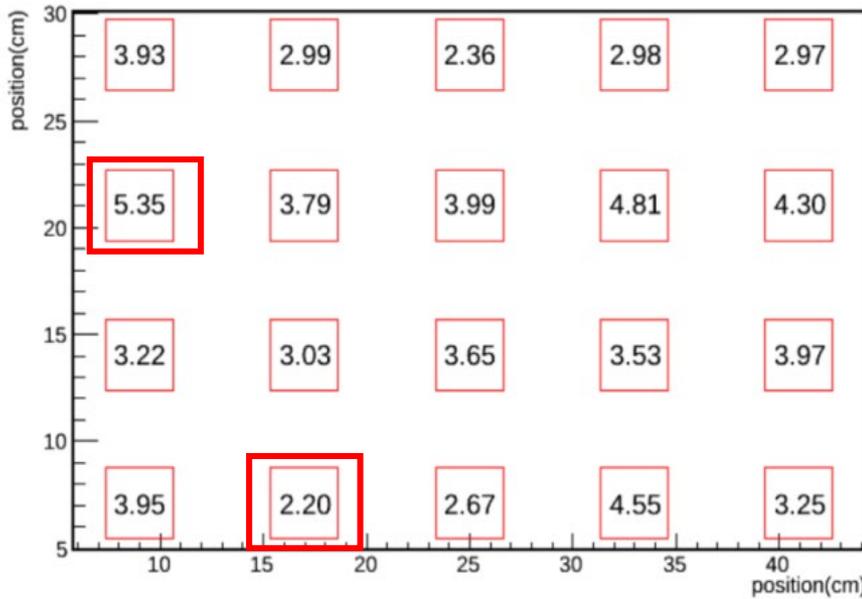


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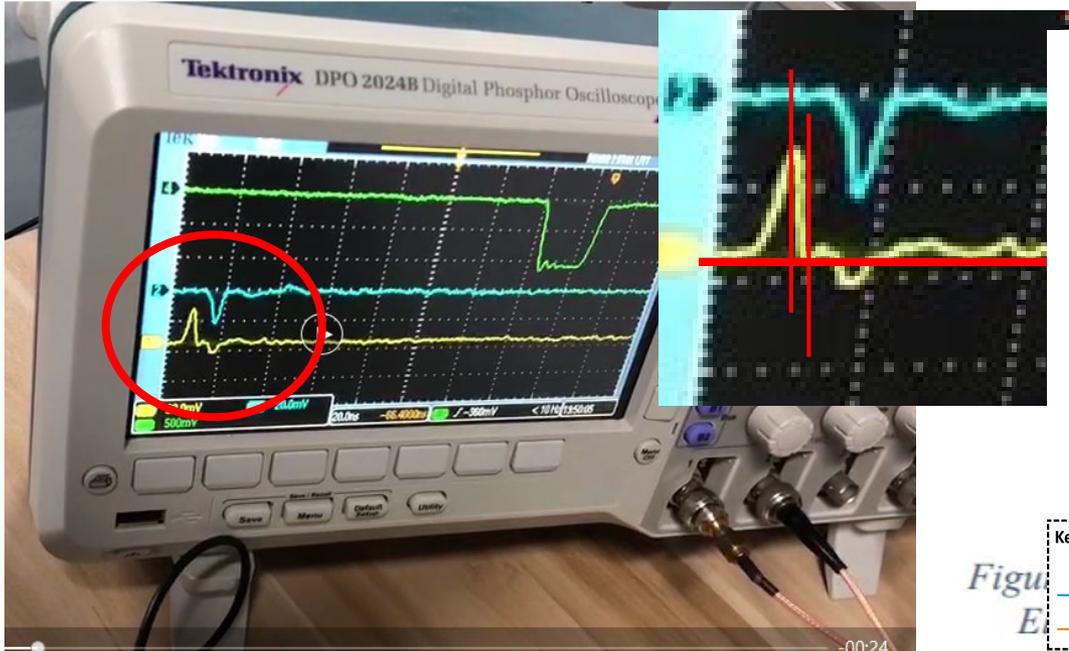
Surf resistivity testing



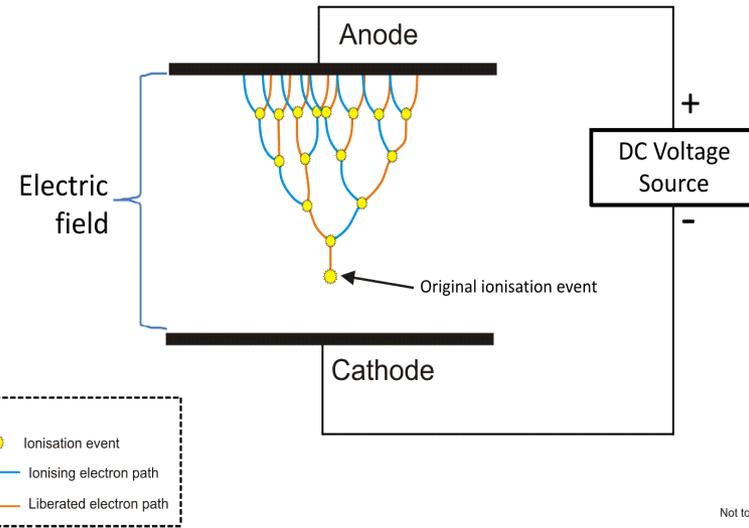
- Surf resistivity for one side testing by four probes, uniform
- Distribution of surface resistivity for two sides, mean value 3.242M Ω / \square factor between maximum and minimum is less than 3, which is enough good!



Signal analysis



Visualisation of a Townsend Avalanche



- Electron drift velocity : $0.06\text{cm}/4\text{ns} = 1.5 \cdot 10^7 \text{ cm/s}$
Upper time: 4ns
- Gas gap 1.2mm, electron drifted from half gas gap(0.06cm)

Normalized electric field: 450Td
 $1\text{Td} = 10^{-17}\text{V} \cdot \text{cm}^2$

Results roughly consistent with papers
<https://fenix.tecnico.ulisboa.pt/downloadFile/563345090413582/resumo.pdf>



Signal analysis

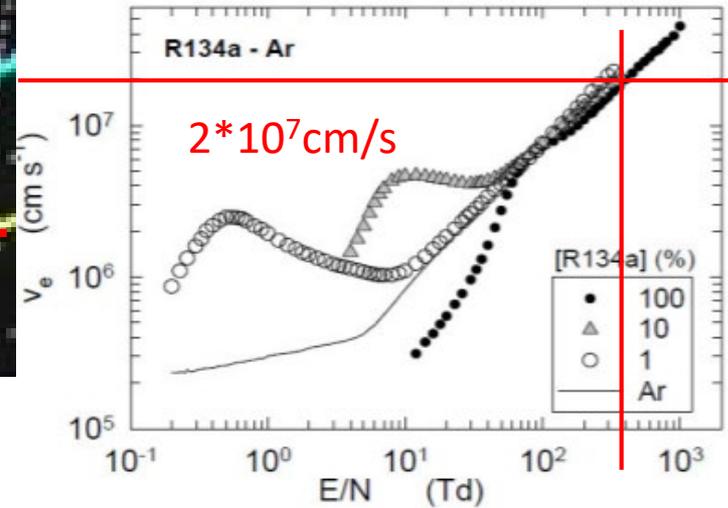
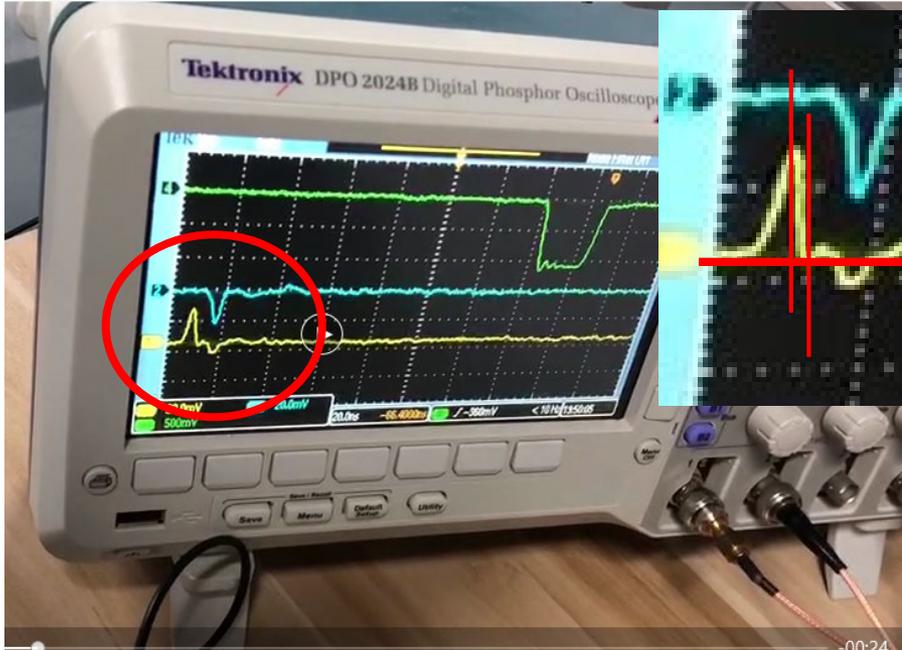


Figure 3 - Drift velocity as a function of the normalized Electric Fields for various R134-a mixtures [22].

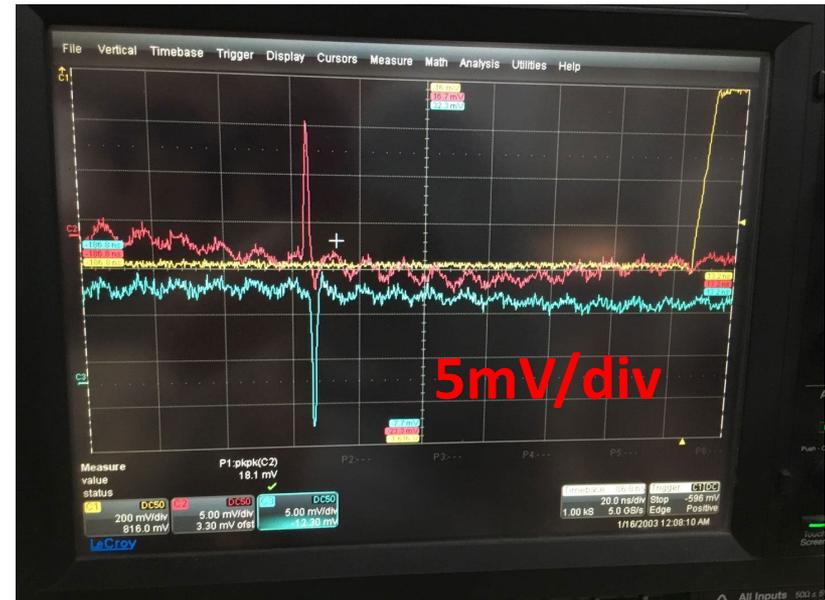
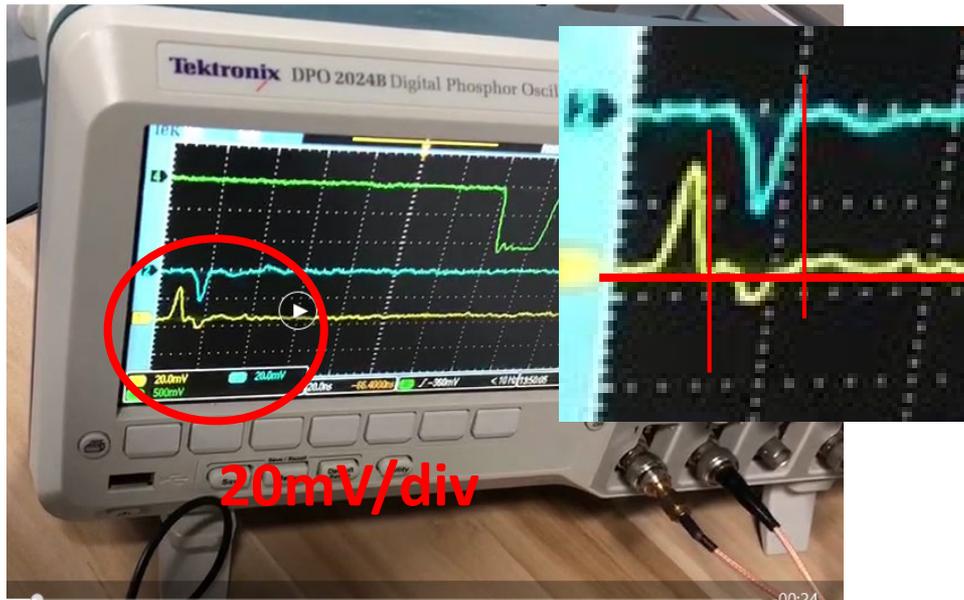
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Signal analysis



USTC signal picture

- Upper time difference between blue signal and yellow signal **8ns**
 - For two channels, signal cable with different length, length difference is 1.7m, electric field velocity in copper is $2c/3$ Time delay is around 8ns, which is roughly consistent with theory value time difference is caused by different length cable
- Peak amplitude are both 20mV



Signal analysis

Muon rate estimation:

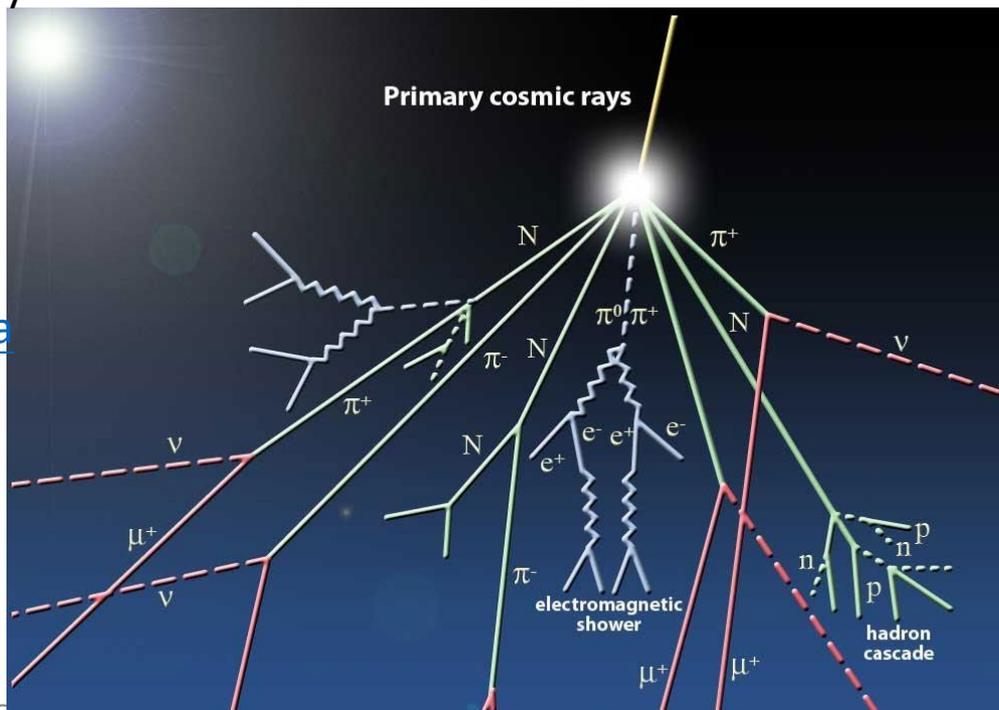
- Effective area: 350cm^2 (red square area)
- Event muon: 200 /min (counter module) considering the scintillator efficiency $0.95^4=0.814$

Fact muon rate: $200/0.814=250/\text{min}$

Muon Flux: $250/350=0.715/\text{min}/\text{cm}^2$

Reference: $1/\text{min}/\text{cm}^2$

https://cosmic.lbl.gov/SKliewer/Cosmic_Rays/Muons.htm

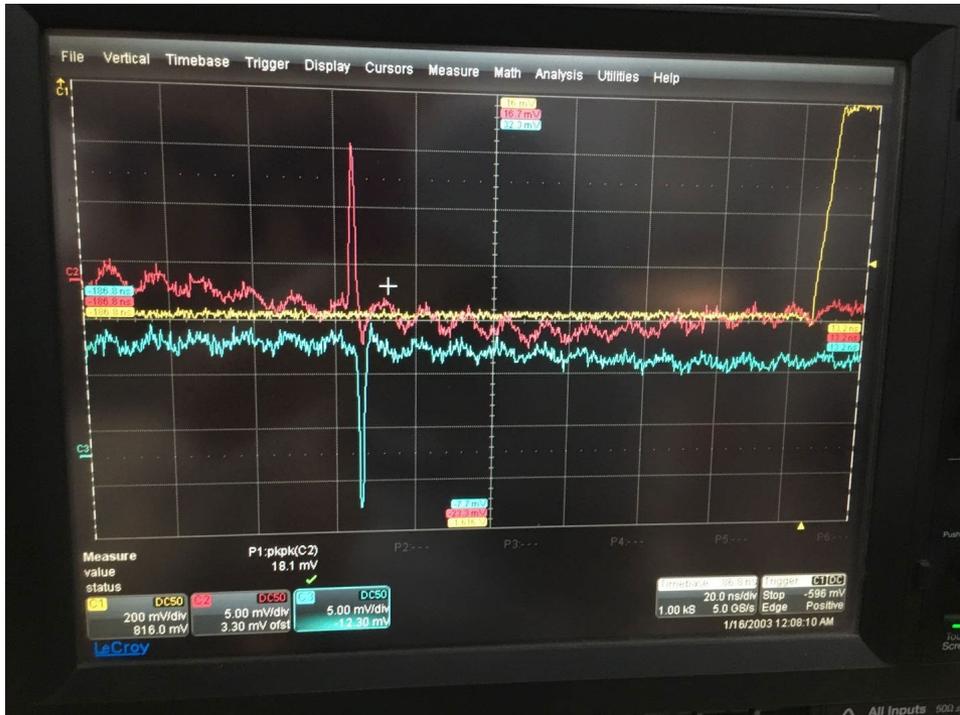


Summary & Plans

- Graphite coating can be stably controlled, including surface resistivity and peeling problem(on the progress)
- Complete RPC can observe the signal, which made great progress
- Some problems for high voltage electrode, maybe unsuccessfully apply high voltage???
- Gas system need to check if gas ratio is reasonable???

Backup Slides

- $(30000\text{V/cm}/6.67 \times 10^{18}\text{cm}^{-3}) * 10^{-17} \approx 450\text{Td}$





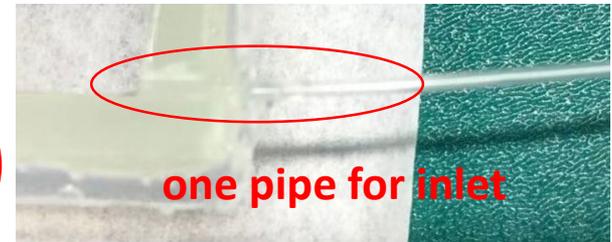
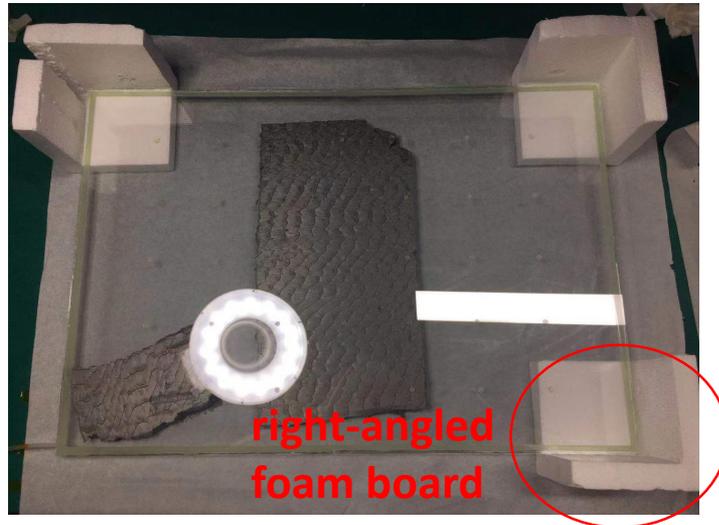
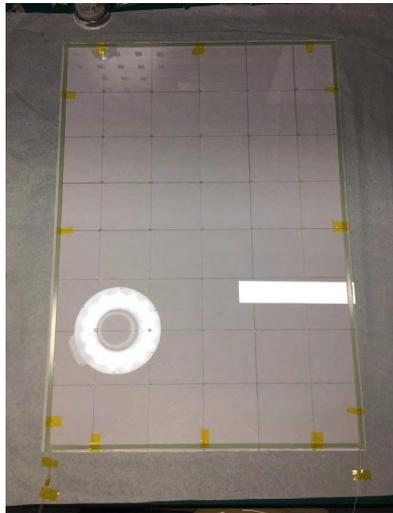
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Signal analysis



Optimizations of processes



Simple tricks:

- Made 35cm*50cm gas gap. After fixing the edge strip with tape(yellow part), then apply the glue.
 - Use four right-angled foam boards to secure the upper and lower glass sheets.
 - HOW to flip the gas chamber more conveniently for the glue???——Problem
- Set three pipes as the outlet from Lyon's group, five pipes of the outlet for bigger RPC 1m*2m.
(**Decrease the inner pressure**)
 - Put one pipe to the inlet



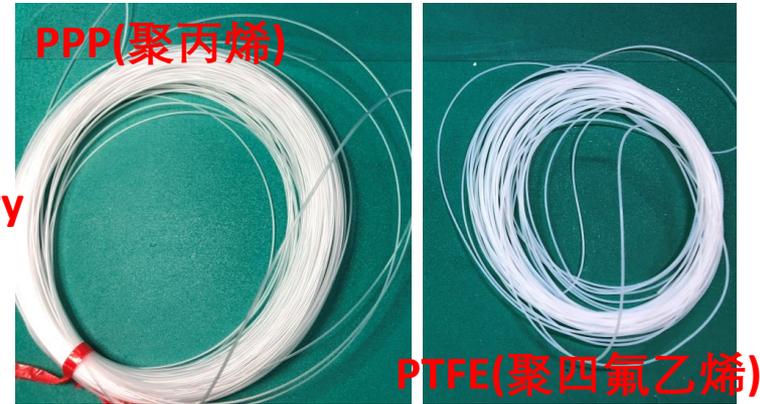
Optimizations of processes



- Use these spacers with thickness more precise
 - Size: 4mm*8mm*1.2mm with **$\pm 0.02\text{mm}$** , the tolerance always **less than 0.05mm**
 - Wall: FR4 material's thickness **1.2mm with positive tolerance**, a little thicker than spacers and different thickness everywhere! (Previous company is not serious, then NEED to find one better factory making FR4, 1000*40*1.2mm³)

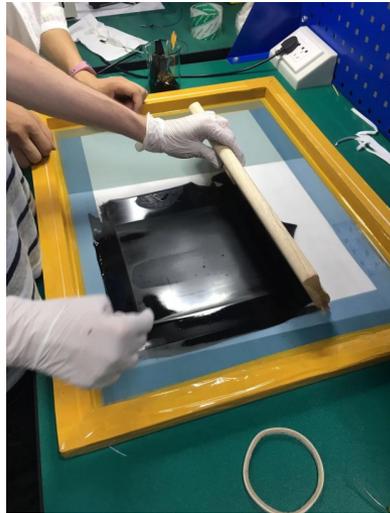
Use these pipes with outer diameter more precise

- Size: 0.8mm*1.2mm with diameter **$\pm 0.02\text{mm}$**
- **Old:** PTFE material(**soft, mainly for hospital, very weak and easy to break!!!**)
- **New:** PPP material(**hard, suitable for nozzles!**)





Silk screen printing



Test the graphite on 20cm*20cm glass



Use silk screen printing method for coating which is similar to printing a pattern onto clothes.

Frame size: 68cm*53cm **Effective area:** 50cm*35cm (RPC size)

Firstly testing the method with 20cm*20cm glass,

- **Easy way for graphite coating, very convenient and efficient!!!**
- **Better than spraying with air-compressed method in terms of process (very promising way)**

- Hair dryer moving by hand to bake the coating (**bad!!!**)
(**10 mins, not uniform**)
- Find one lamp for baking the coating
(**170°C, uniform**)



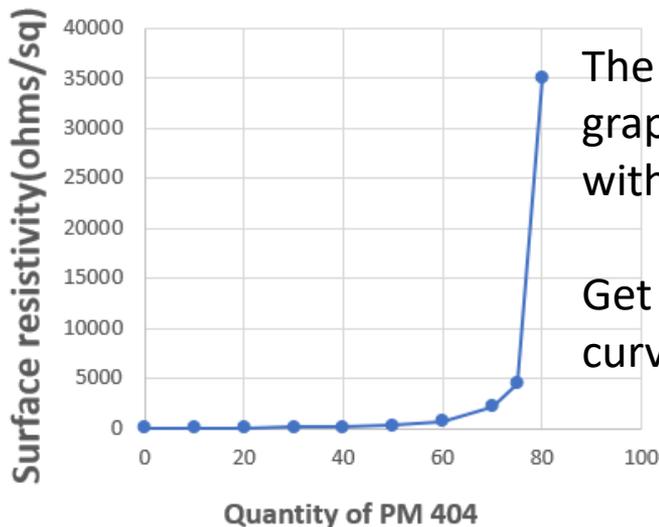
Test graphite mixture ratio



Electrical Properties **From PM-404-EN.pdf**
Sheet Resistivity
Blending ratios of Electrodag™ PM-404™ and Electrodag® 6017SS™, Dried 5 minutes @ 120°C, ohms/sq

Electrodag™ 6017SS™ (% by weight)	Electrodag™ PM-404 (% by weight)	@ 25µm dry coating thickness
100	0	35
90	10	50
80	20	70
70	30	105
60	40	170
50	50	290
40	60	675
30	70	2160
25	75	4500
20	80	35,000
10	90	> 1e9

PM 404 vs Surf R



The surface resistivity of graphite layer increases with PM 404 increasing

Get the ratio through fitting curve and test in the next.

Use silk screen printing method for coating and test with 20cm*20cm glass,
Test configuration: (from Bin)

17g(85%) PM404 & 3g(15%) EDAG 6017SS

Surface resistivity is mainly concentrated in around **50-70MΩ** (much larger!!! than Lyon's group 1-2MΩ/□) **NEED more trials!!!**



Graphite layer analysis

Graphite ratio depends **on humidity, temperature** etc. (From Imad)

Lyon also has lots of experiments for best ratio.

Layer thickness is less than 10microns, **very thin**. ——300目 silk screen

Next test the graphite ratio from different conditions in order to get the best ratio, taking influence factors into consideration



The reasons of the graphite splitting(**bad adhesion**):

- **Bake fast(10mins) and nonuniformly, just surface drying , not inside. Left the layer all night, then split in the second day.**
- **temperature for hair dryer is not far from enough, (products require baking at around 170°C to attain a stable surface resistivity. From Lyon's group)**

Summary & Next plans

- ✓ Bigger RPC construction(DONE three RPCs)
- ✓ Screen printing method was used to make graphite layer for the first time,
17g(85%) PM404 & 3g(15%) EDAG 6017SS and tested the coating
- ✓ Optimize the RPC production process

Next plans

- ❑ Test different graphite ratio for the optimal proportion with best surface resistivity and consider the influence of other factors such as temperature, humidity etc.
- ❑ Optimize the silk screen printing method for safety.(including mask and protection suit)
- ❑ Attempt to find better way to wash the Silk Screen Board.

Thanks!



Test graphite mixture ratio



Use the DIY simple electrode to roughly test graphite layer surface resistivity through multimeter