Design and Performance study of Sealing MRPC (SMRPC) with extremely low gas flow

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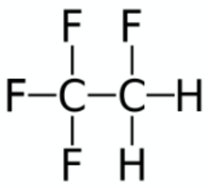
Motivation

Standard gas:

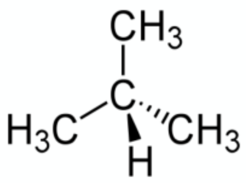
~95%



GWP 1430

+

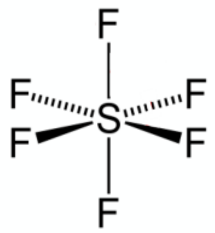
4-5%



GWP 3.3

+

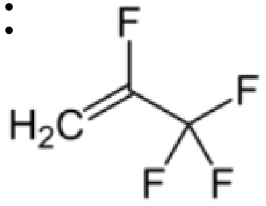
0.3%



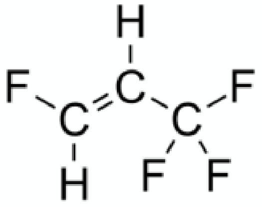
GWP 22800

Eco-gas replacements:

-for Freon:



HFO-1234yf (flam)



HFO-1234ze

GWP	4	6

- In 2000, European Union **"F-gas regulation"**:
- **-Limiting the total amount** of F-gases that can be sold in the EU
- **-Banning the use of F-gases** in many new types of equipment.
- **-Preventing emissions** of F-gases from existing equipment.

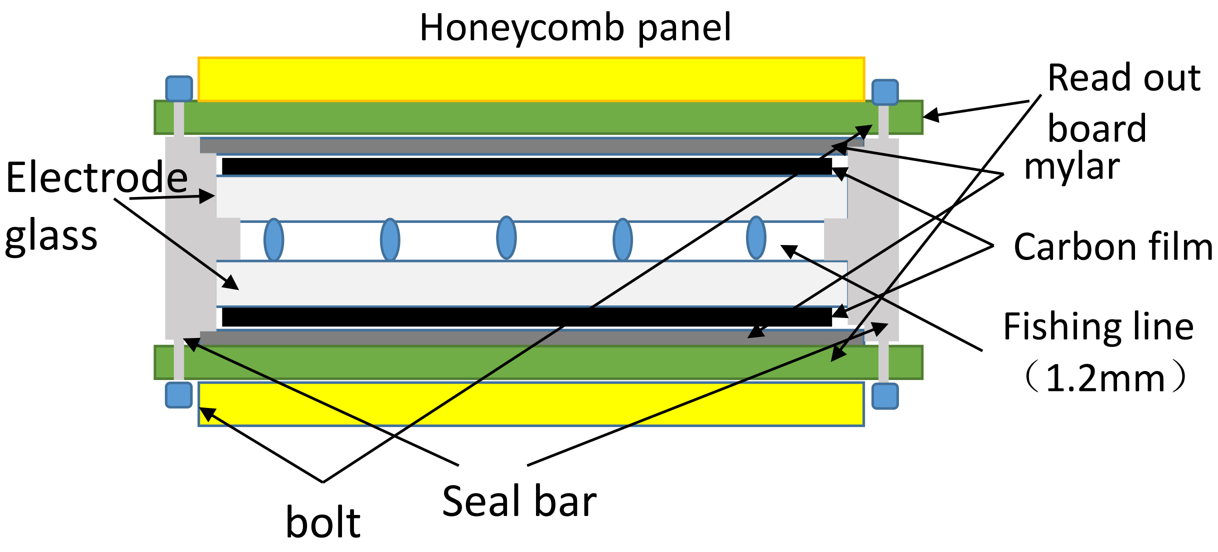
Cons, higher price

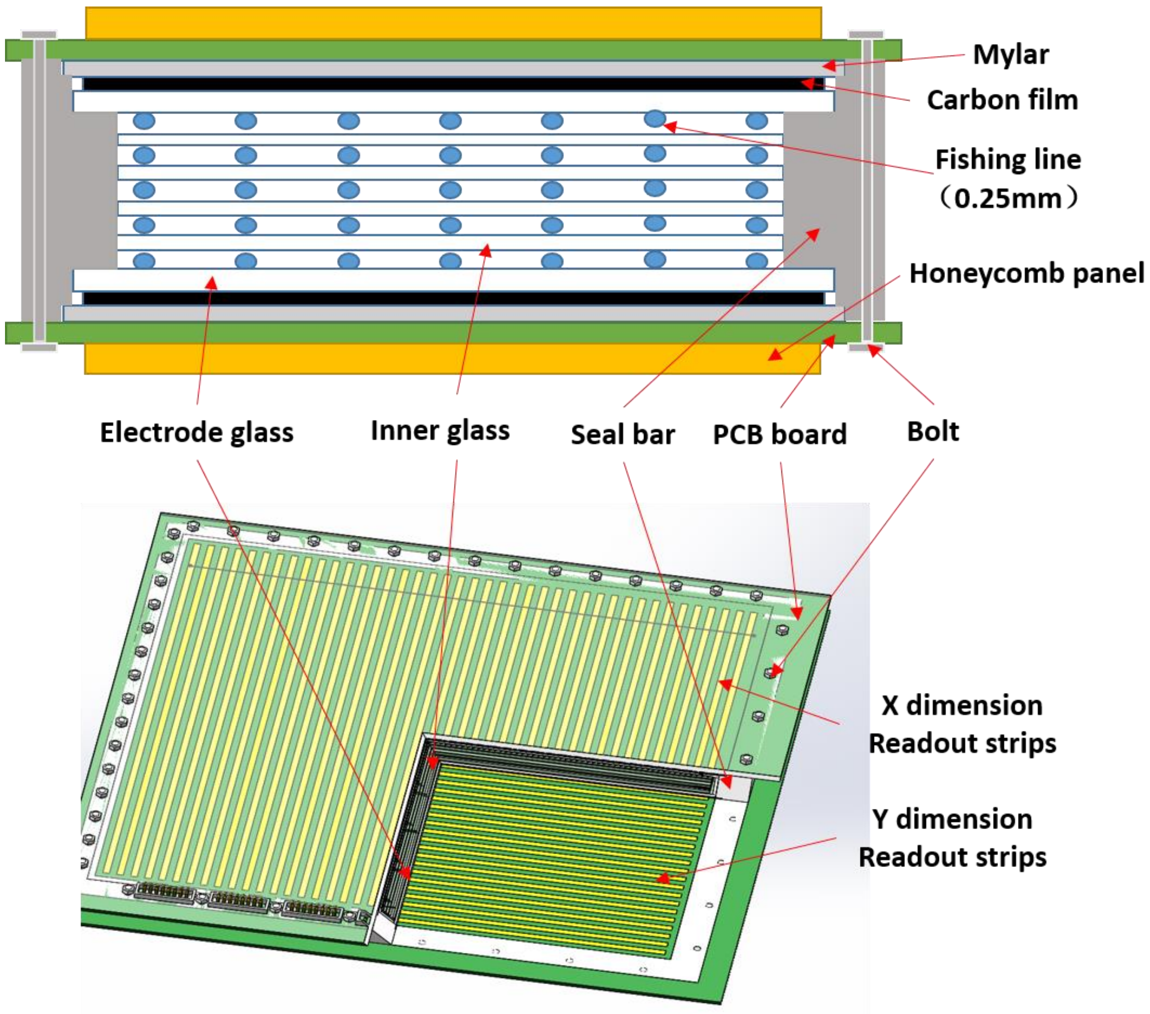
MRPCs and RPCs with HFO are still in study

So try to seal MRPC as tight as possible to reduce the gasflow, as well as gas cost, through the technological design.

Schemes

➢ SRPC or SMRPC

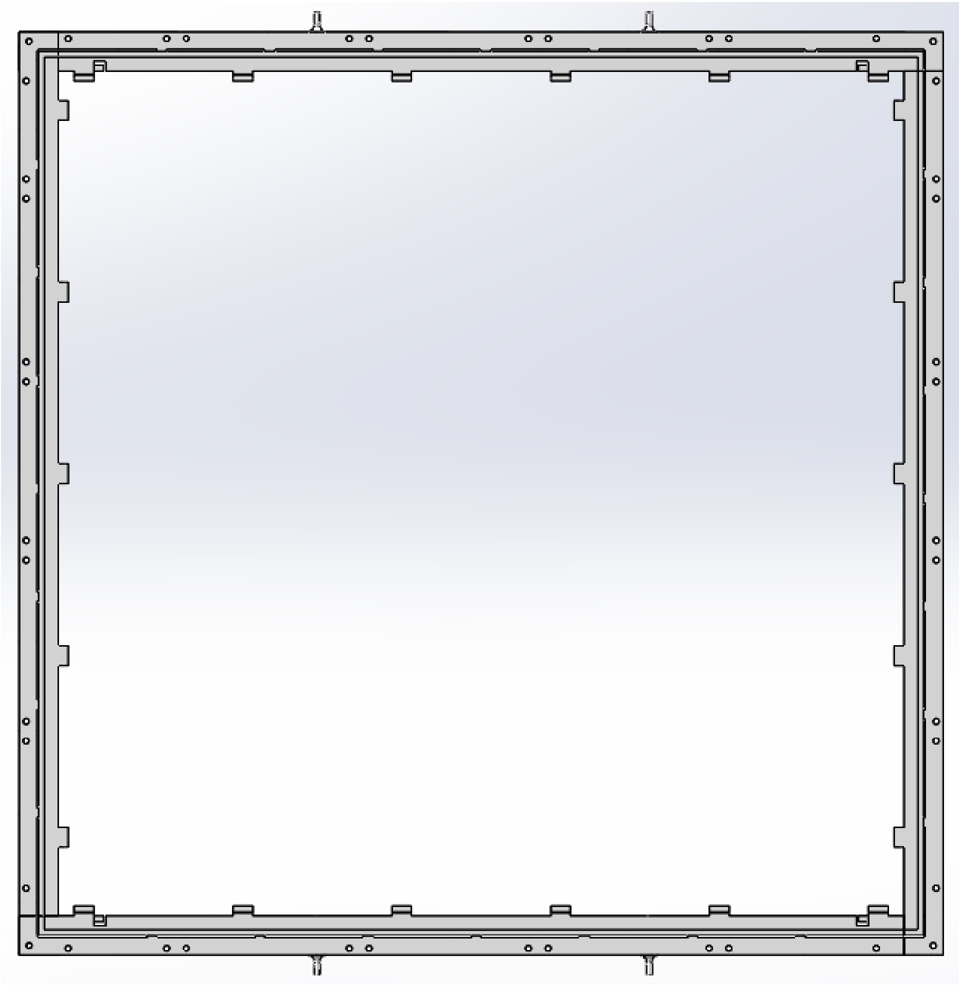


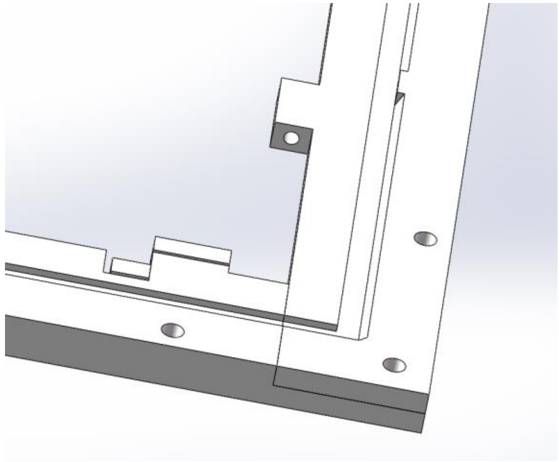


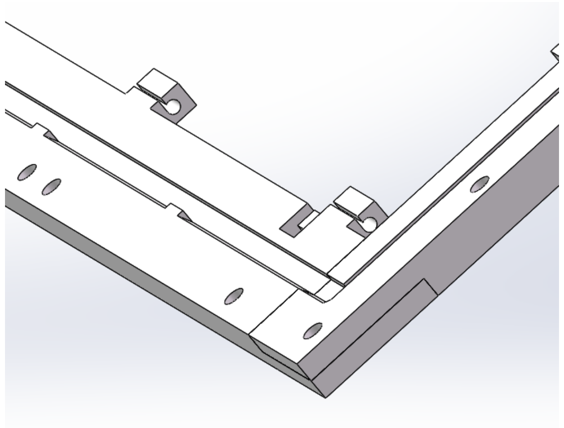
➢SRPC, simple structure, cost-effective, less volume and weight

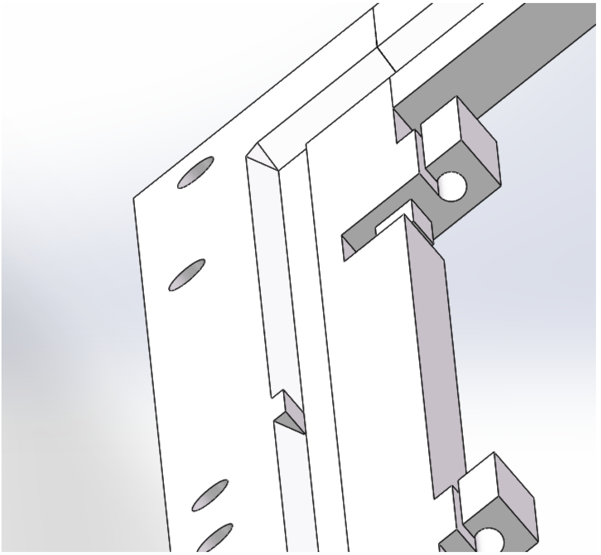
➢SMRPC, high efficiensy, good space resolution and time resolution

The sealing bar designed



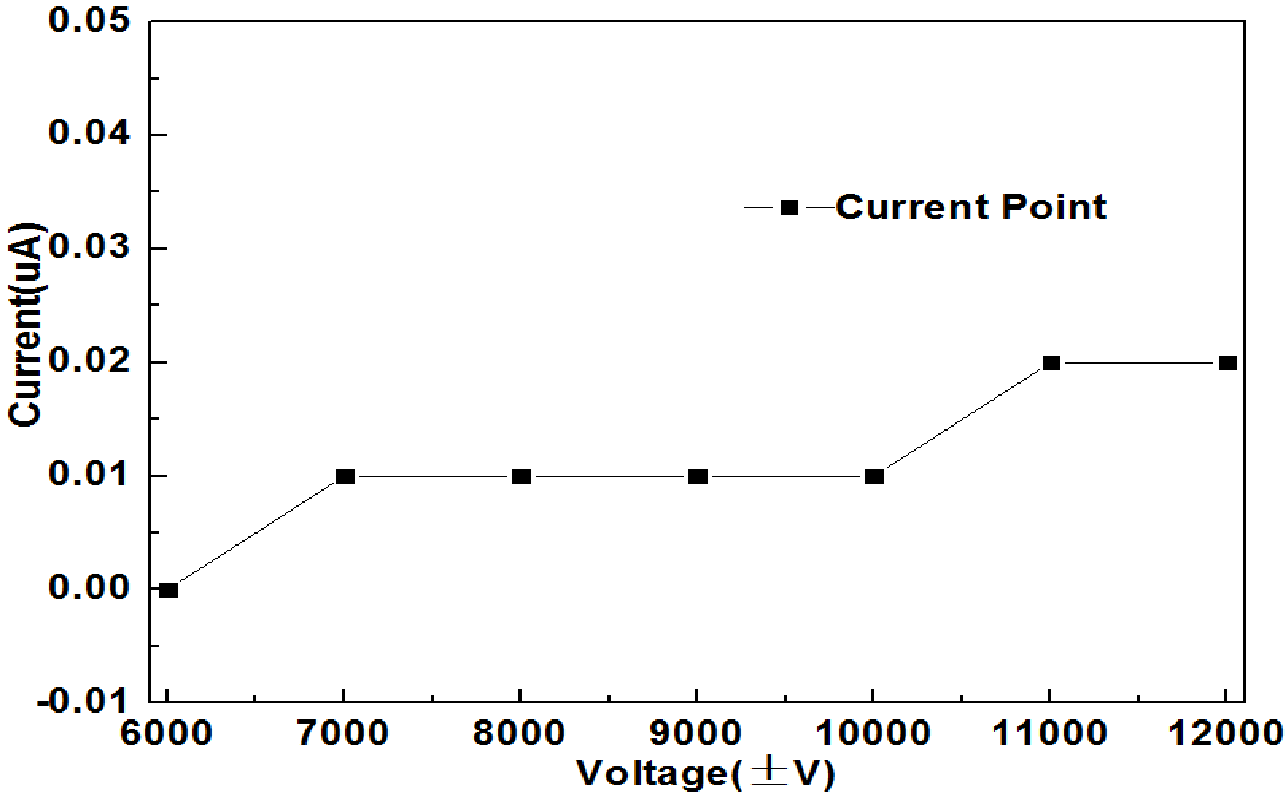






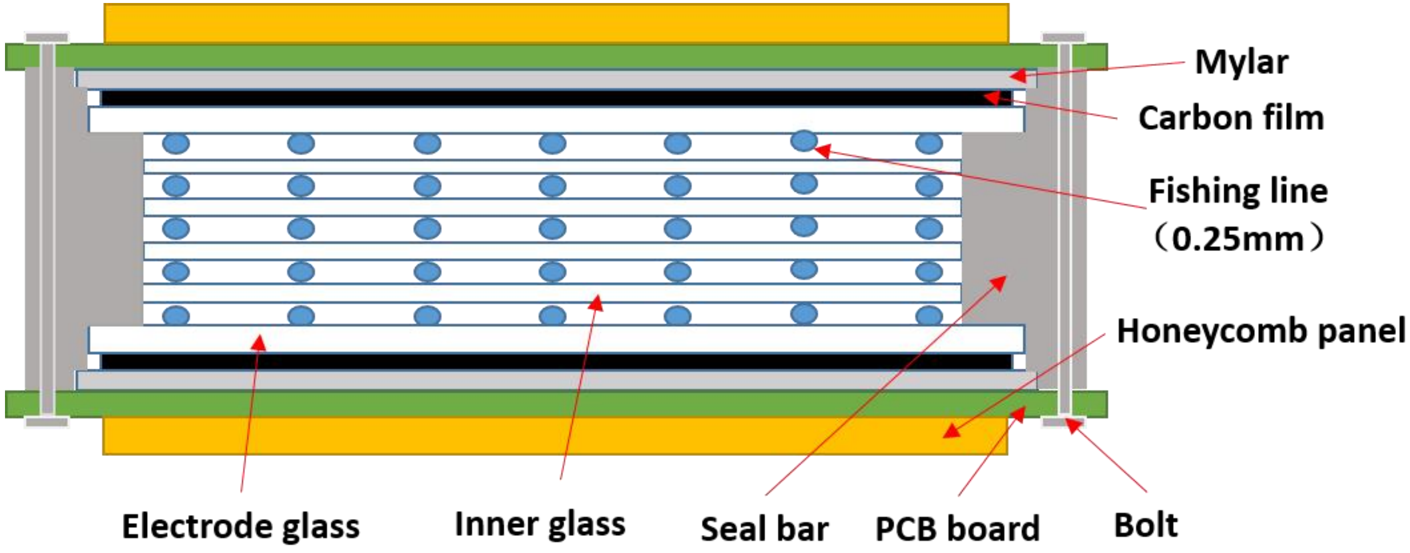
The sealing bar designed

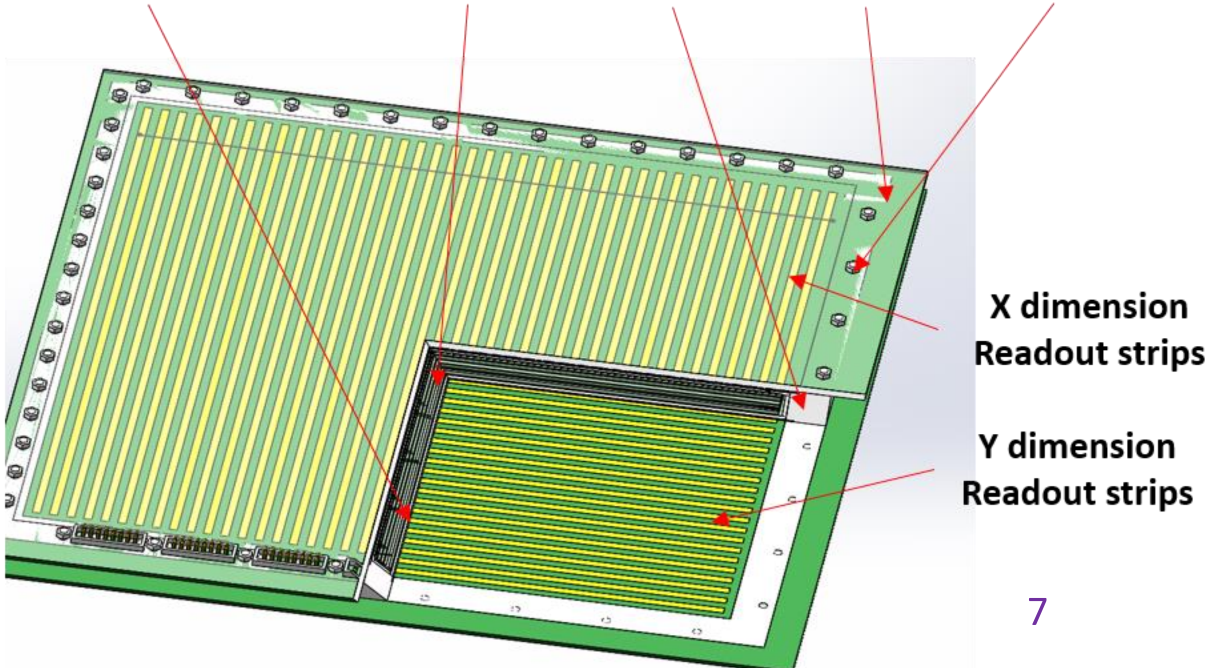
Try to use the material, such as the glass, fishing line, glue and so on, with low air releasing property. Sealing bar---- Class ABS resin



High voltage resistance test

The final design

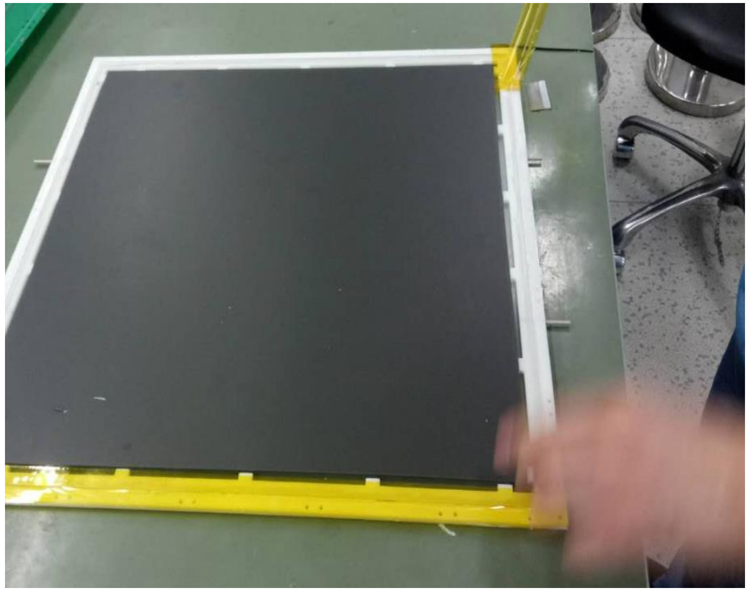


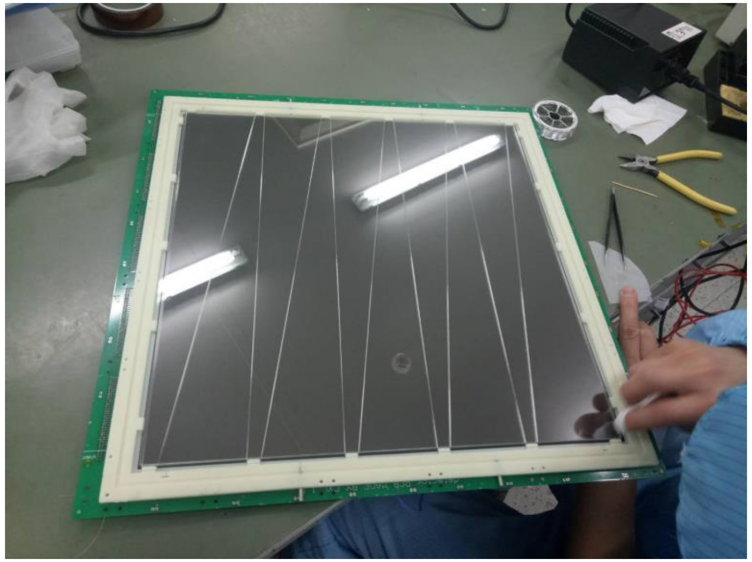


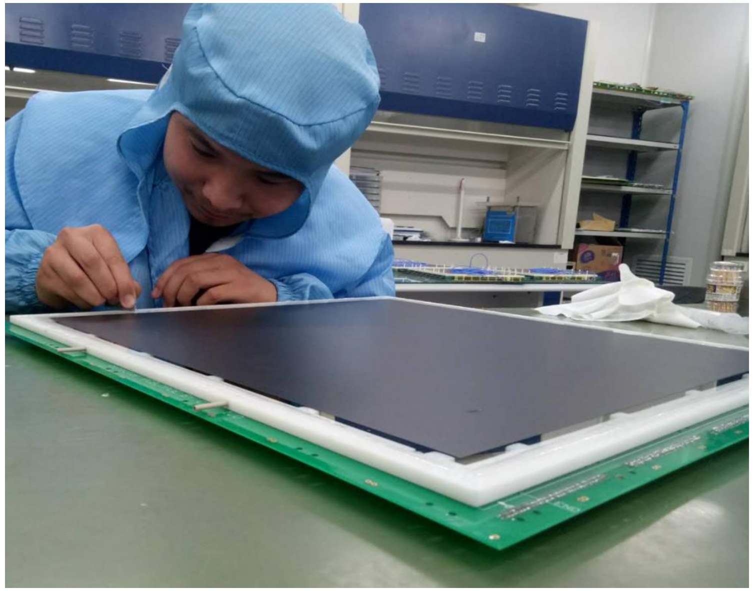
Parameters

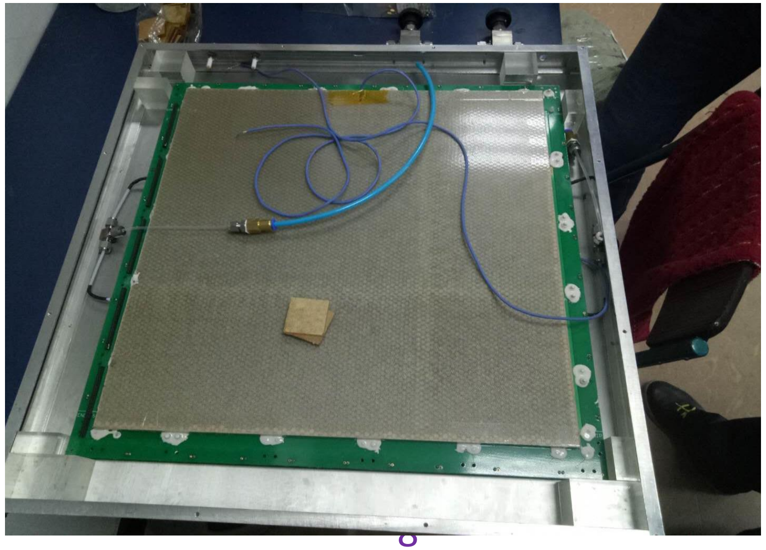
Dimensions	
Electrode glass size	450*450mm
Electrode glass thickness	1.1mm
Inner glass size	420*420mm
Inner glass thickness	0.7mm
Gas gap	0.25 mm
Number of gas gaps	5
Strip gap	1.1mm
Strip width	1.44mm
Readout board	500*500mm

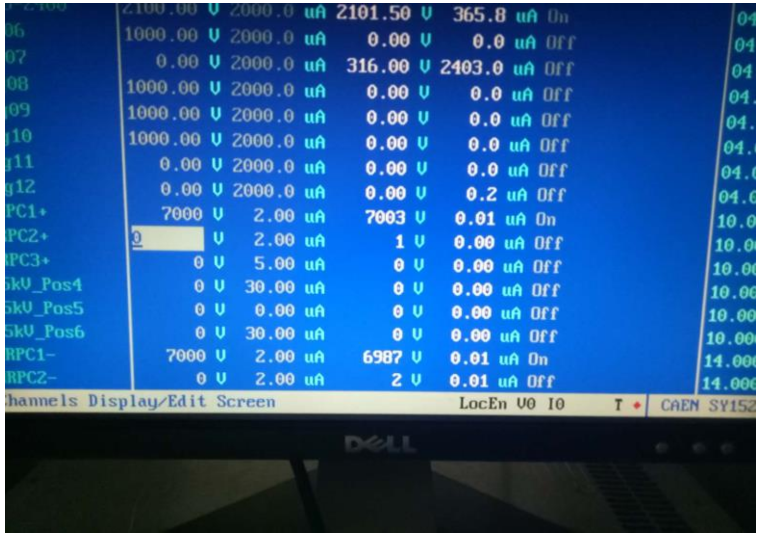
The assembly process



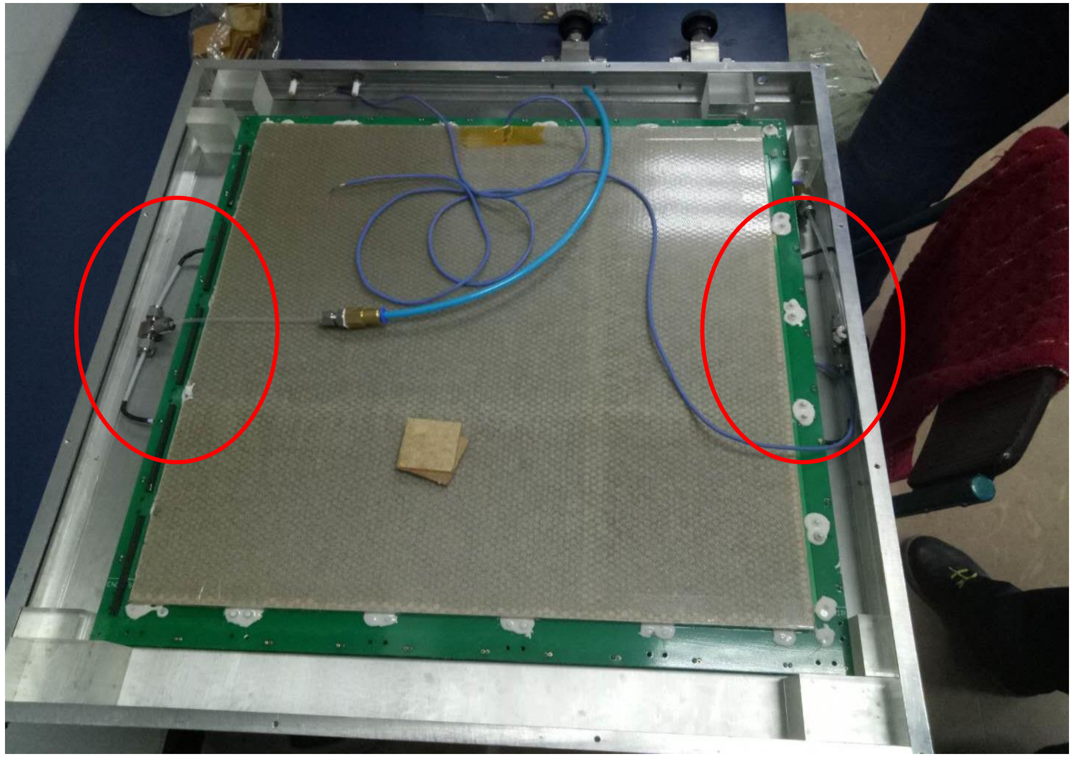




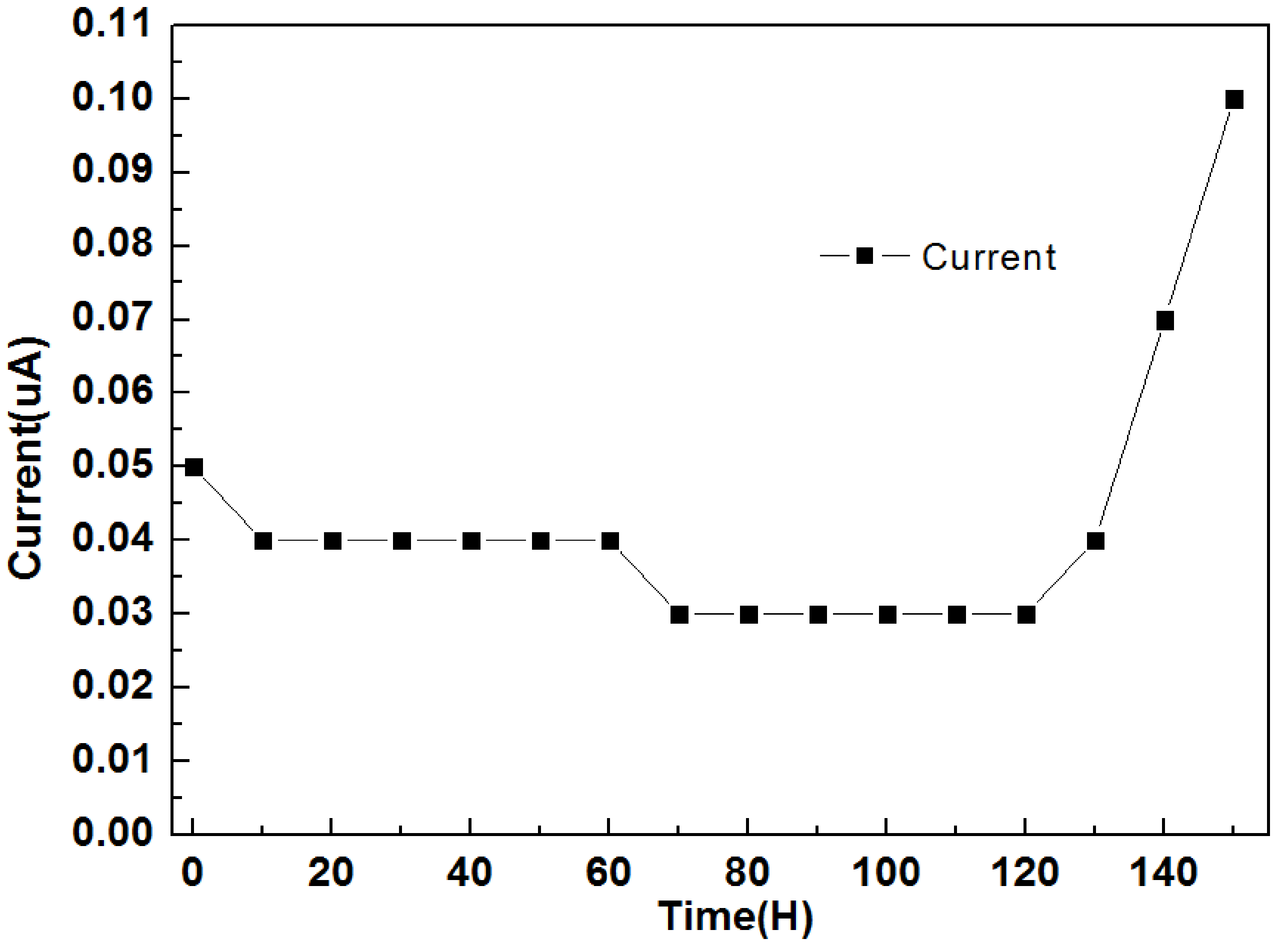




The first version and it’s performance



With two inlets and two outlets



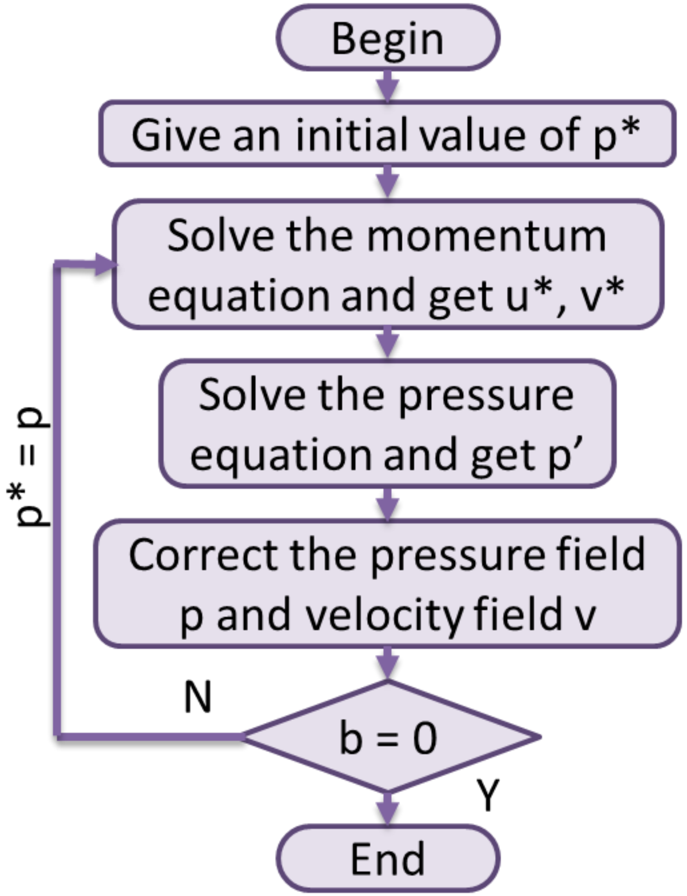
Study on Gas Flow in Detector with fluent

Fluent is used to simulate the internal gas flow including the flow volume, intake velocity, distribution of pollutant concentration, etc.

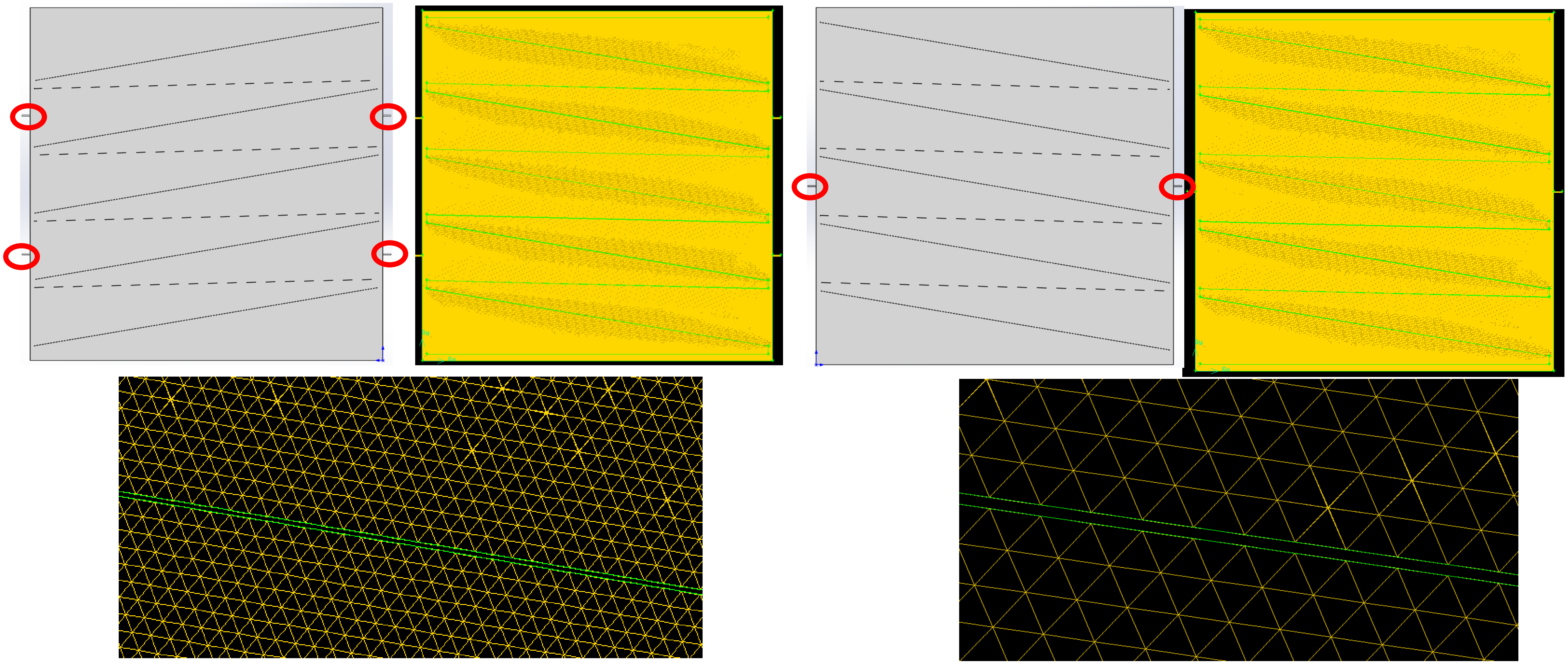
Control function

$$\underbrace{\frac{\partial(\rho\phi)}{\partial t}}_{\text{Unsteady}} + \underbrace{\nabla\cdot(\rho\vec{v}\phi)}_{\text{Advection}} = \underbrace{\nabla\cdot(\Gamma_\phi\nabla\phi)}_{\text{Diffusion}} + \underbrace{S_\phi}_{\text{Source}}$$

Finite Element Method (FEM) ;
SIMPLE algorithm (Semi-Implicit Method for Pressure-Linked Equations)

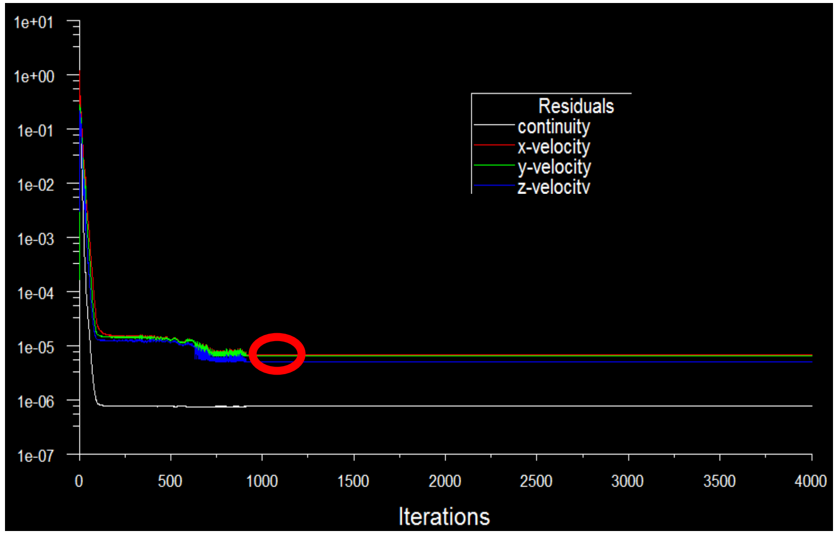


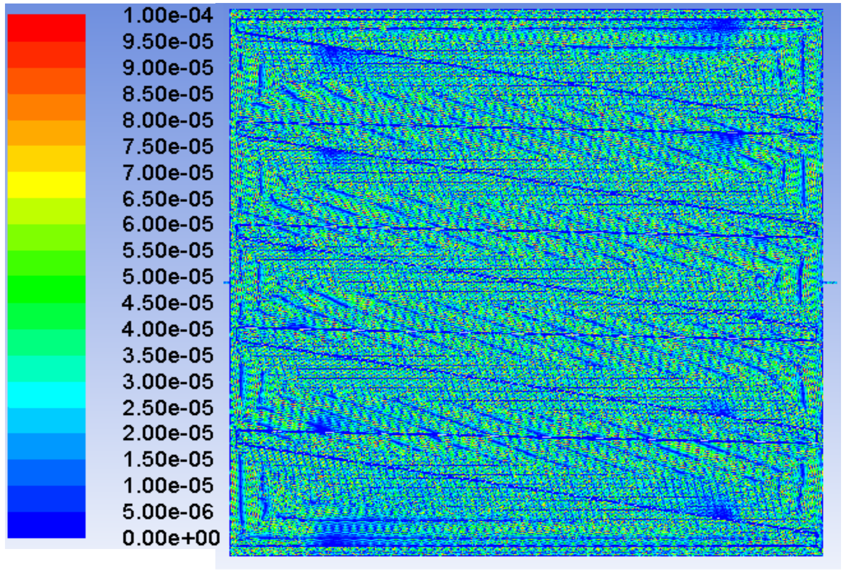
Detector Modeling and Gridding



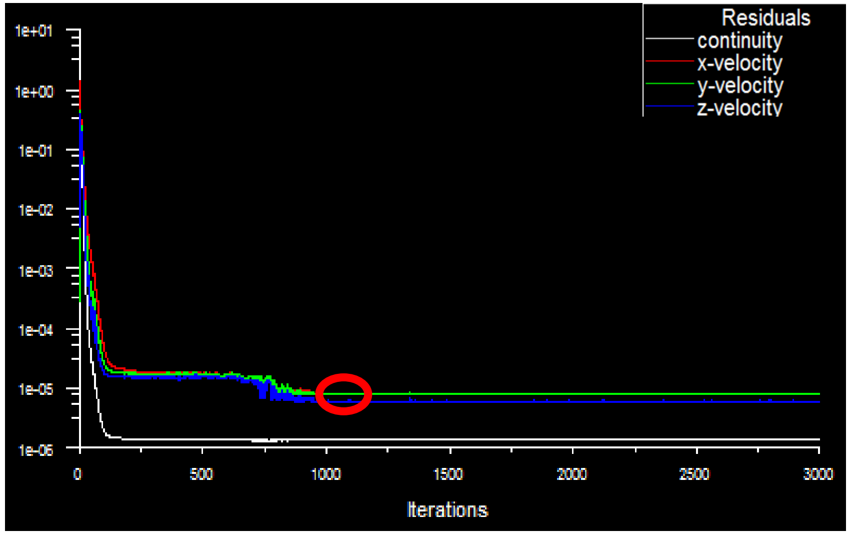
Simulation results (Velocity V at 30ml/min)

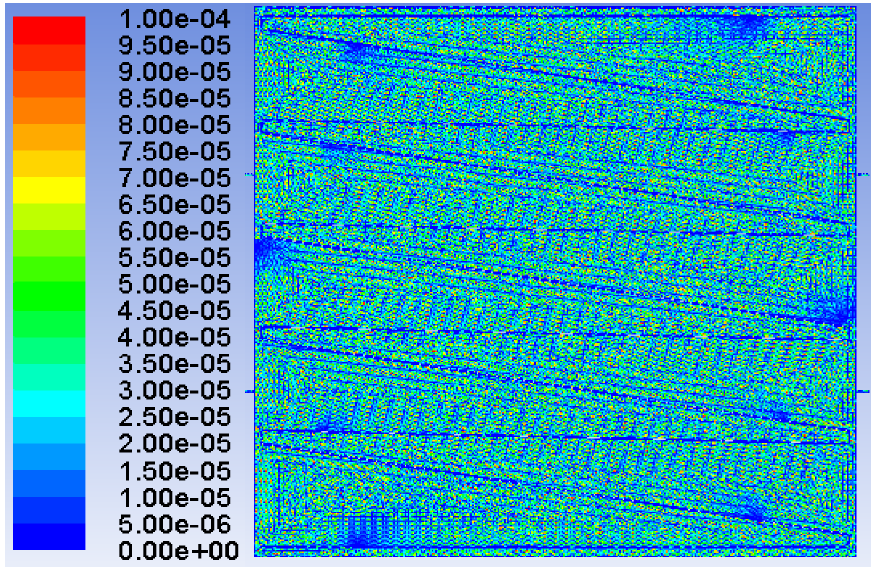
1hole
30ml/min





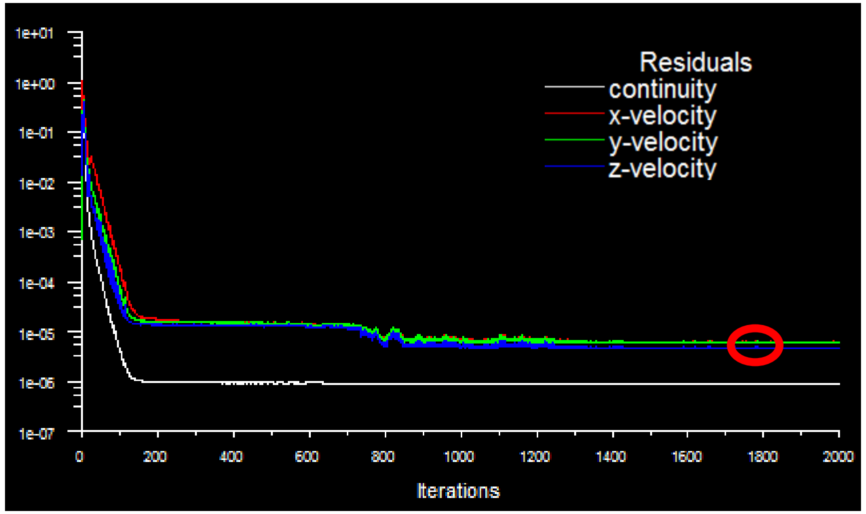
2hole
30ml/min

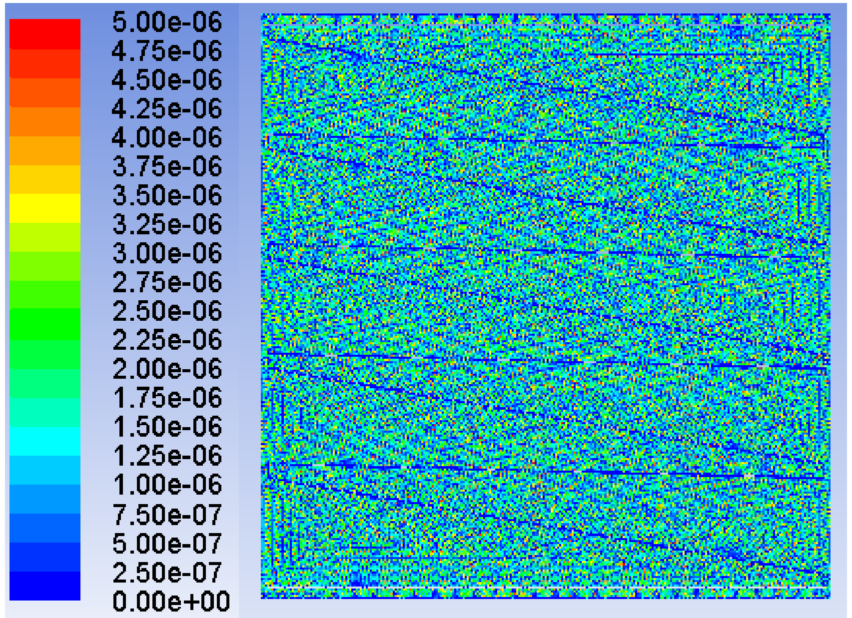




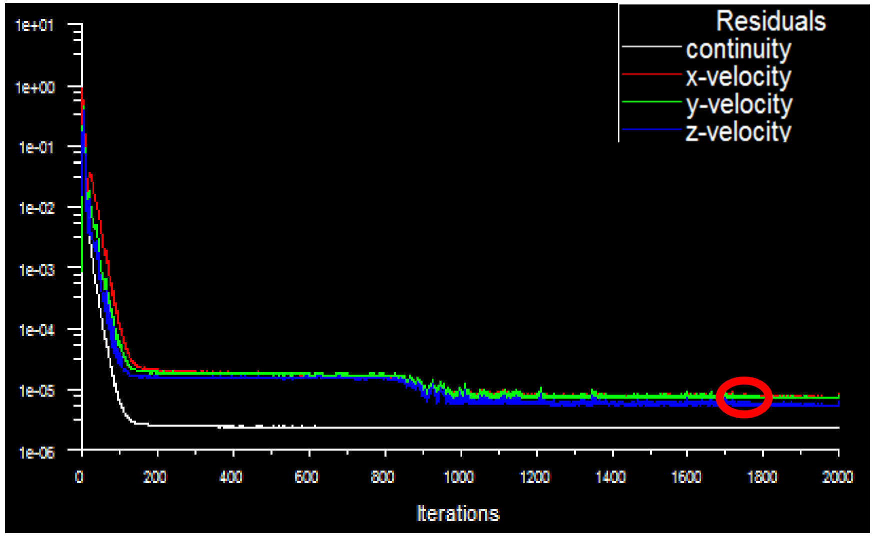
Simulation results (Velocity V at 3ml/min)

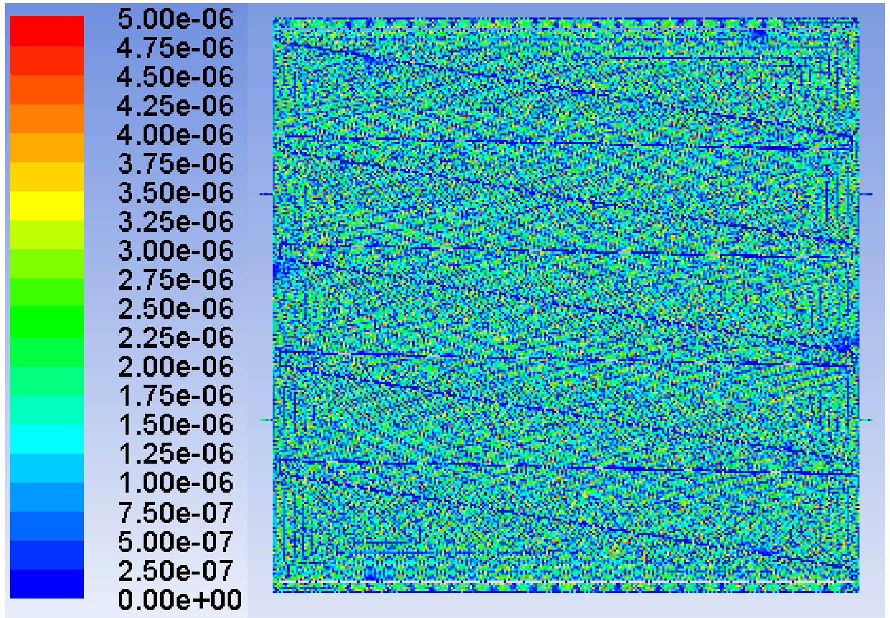
1hole
3ml/min





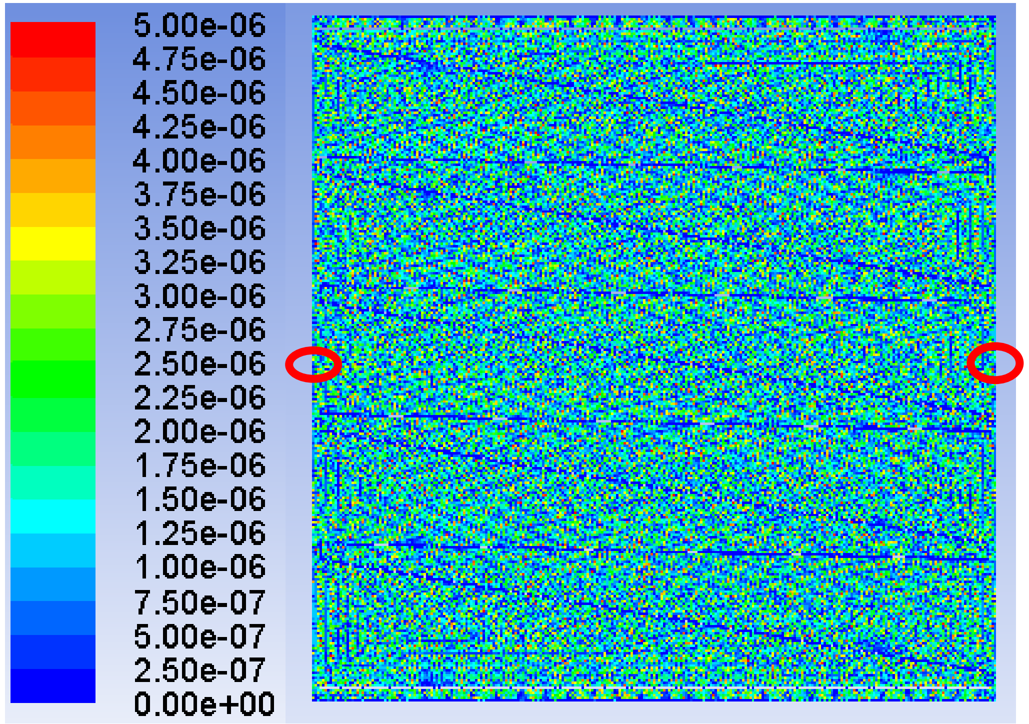
2hole
3ml/min

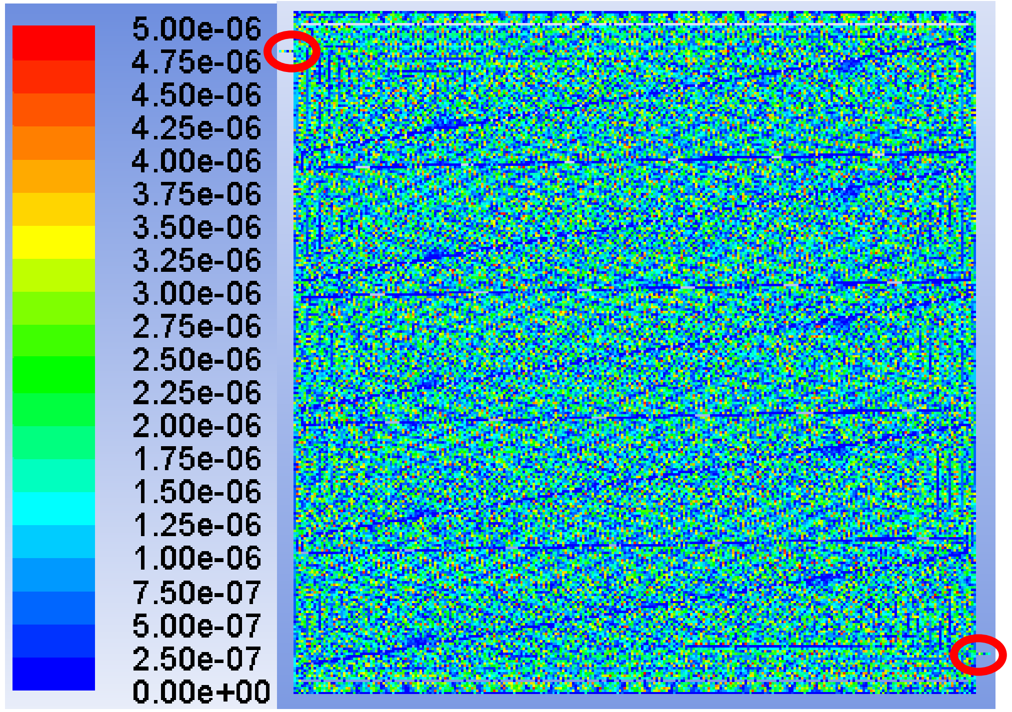




Simulation results

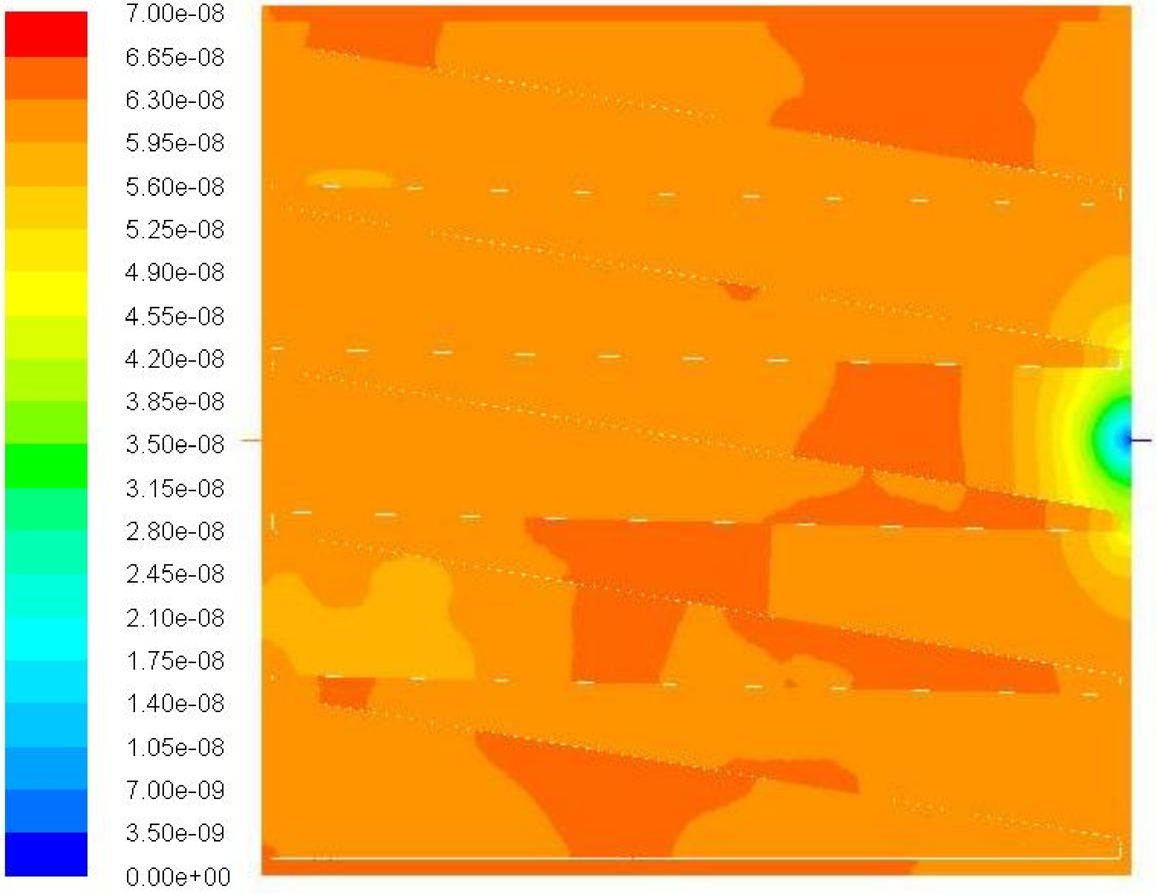
➢ The one inlet and outlet at different place



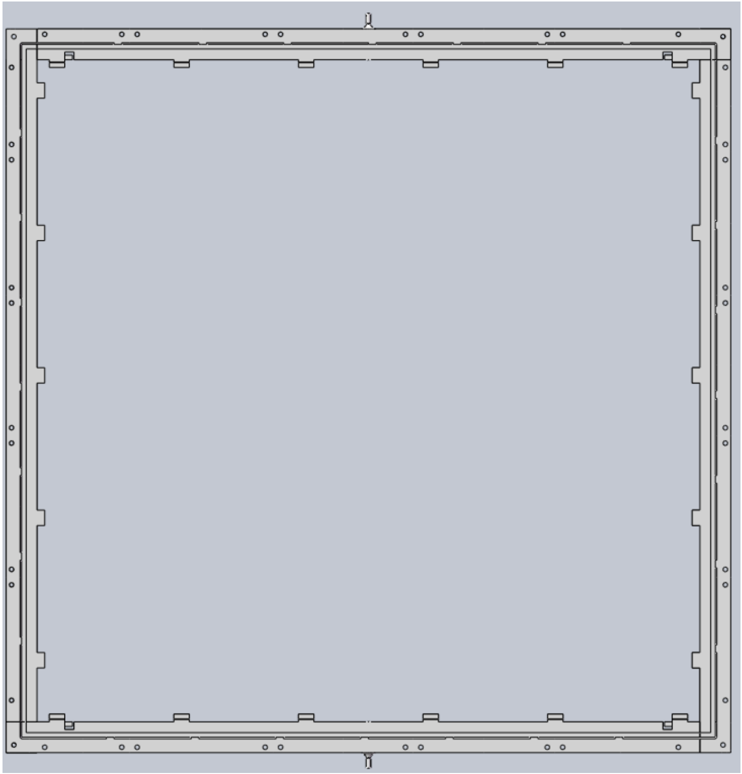


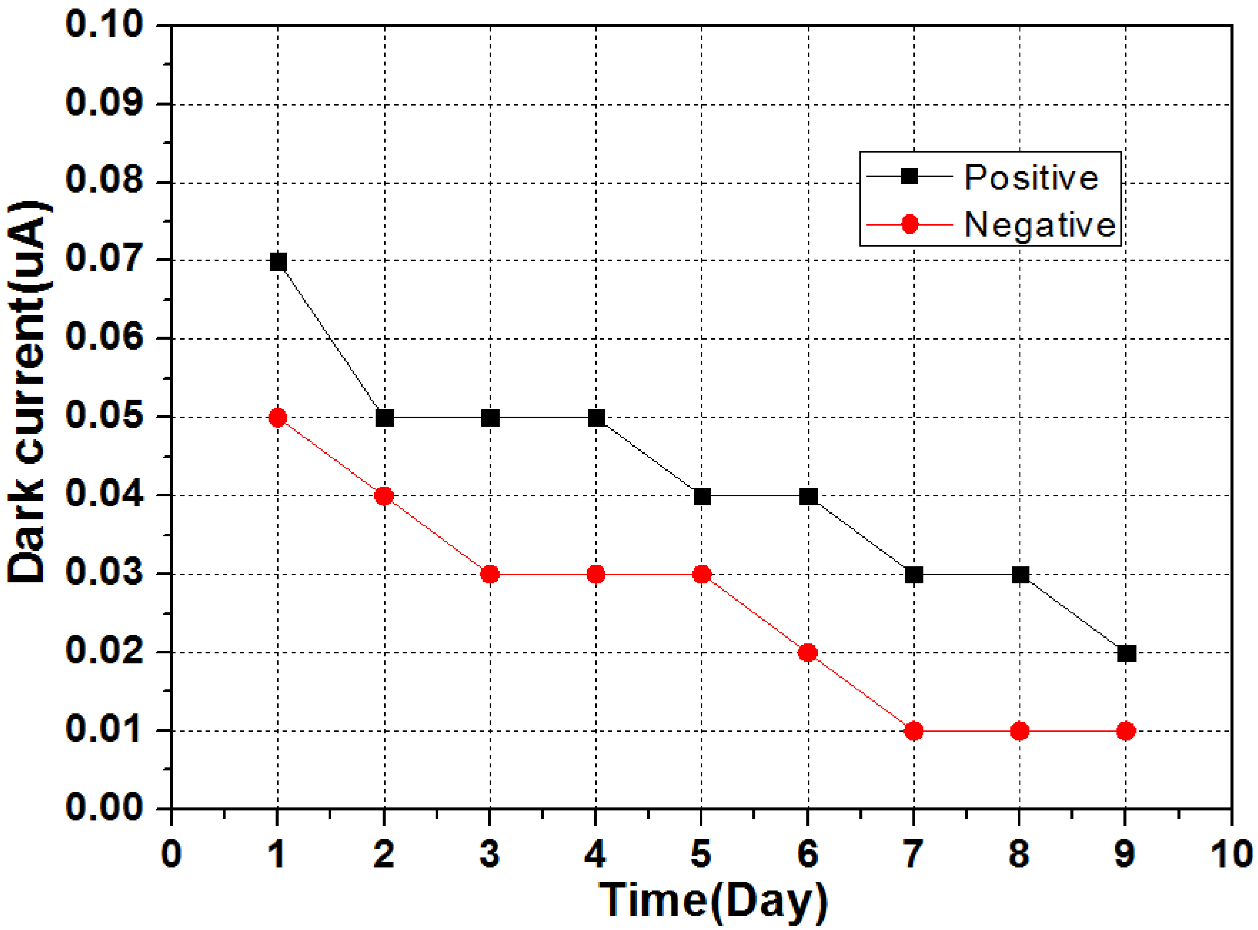
The distribution of pollutant concentration

1hole 3ml/min 0.5HZ/cm²

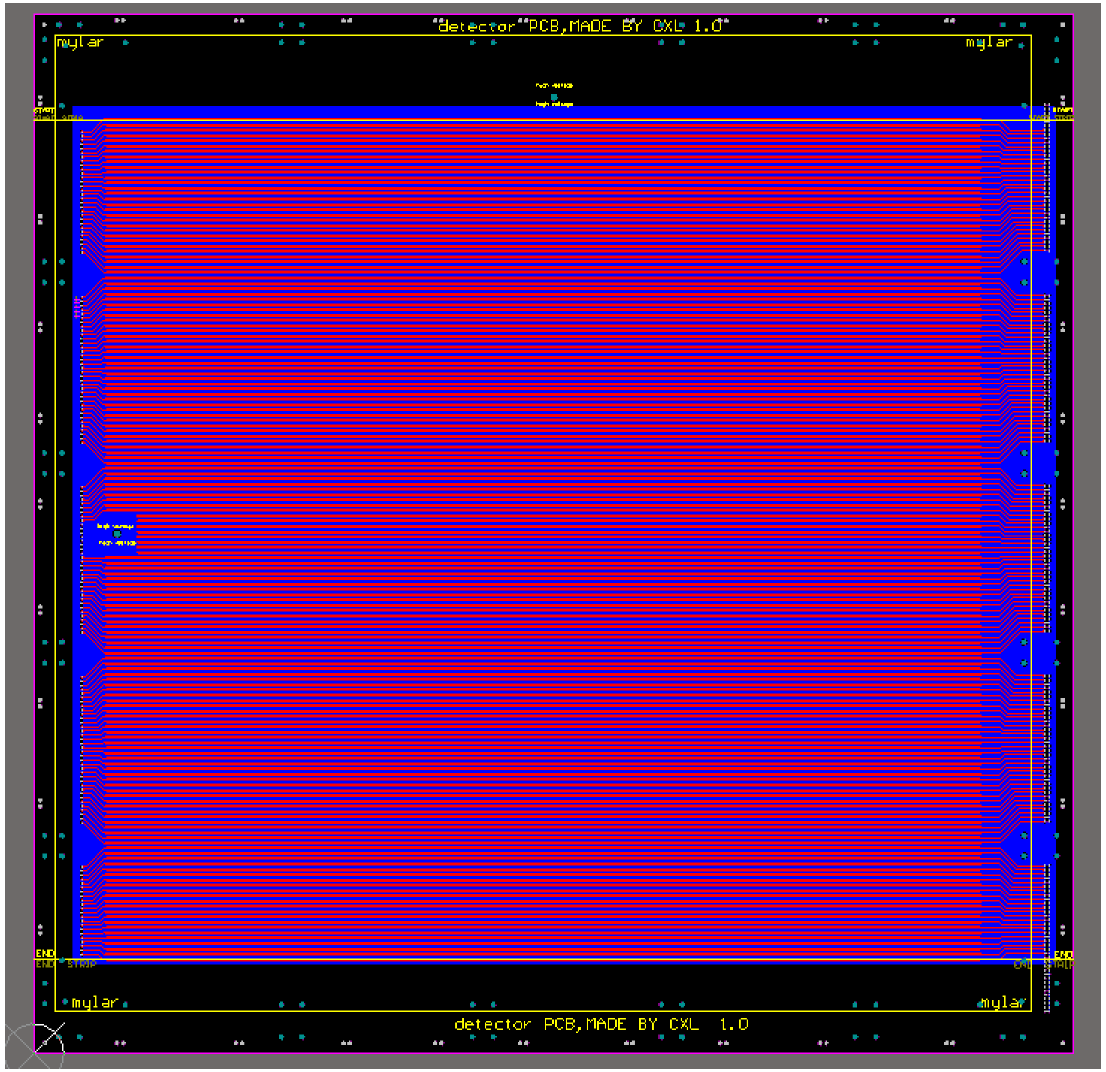


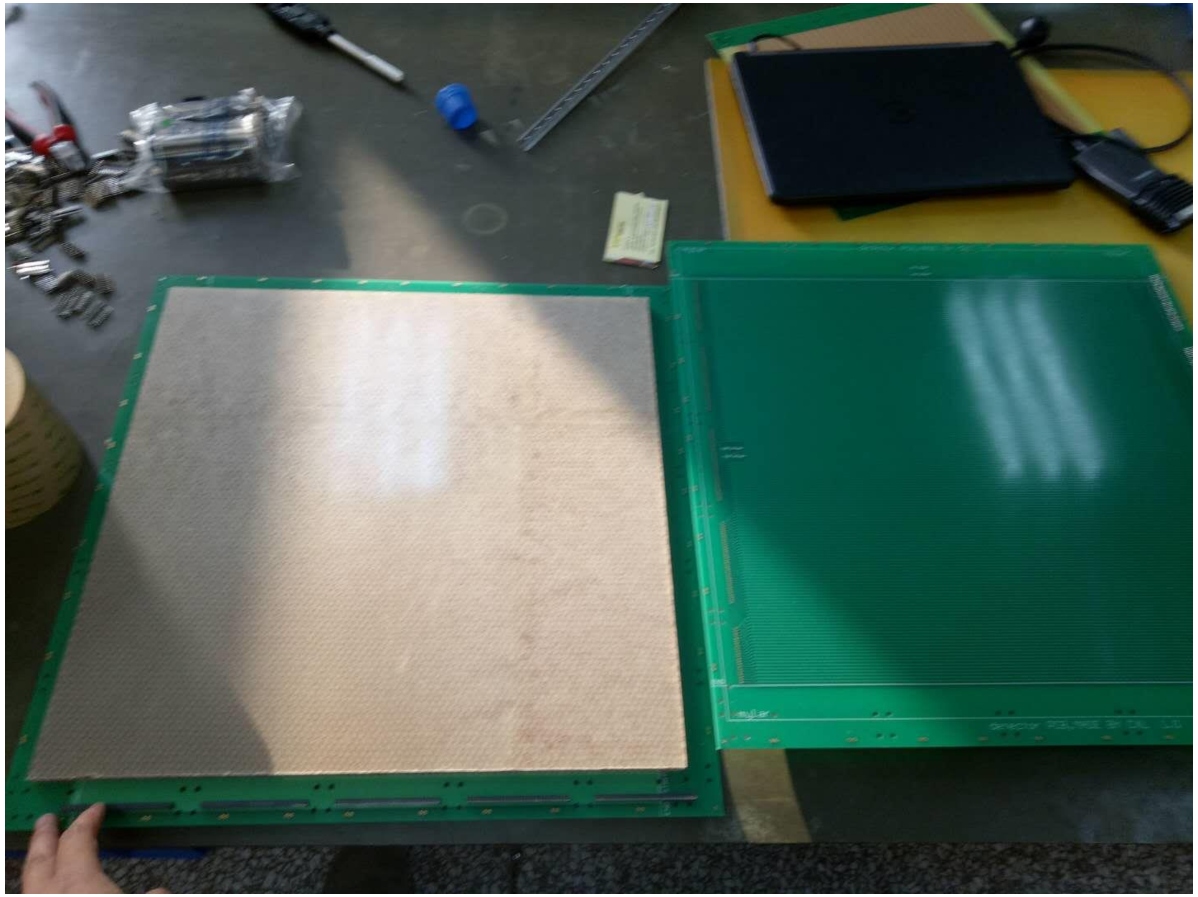
The new version





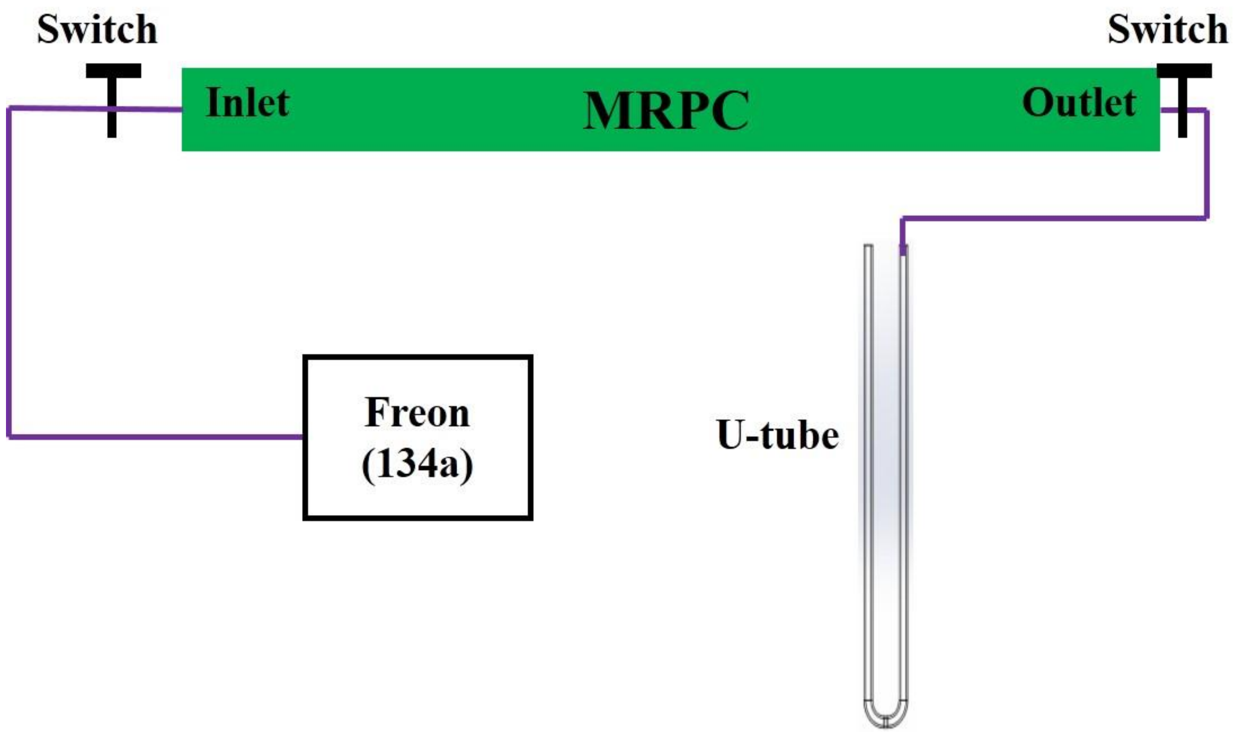
The readout board

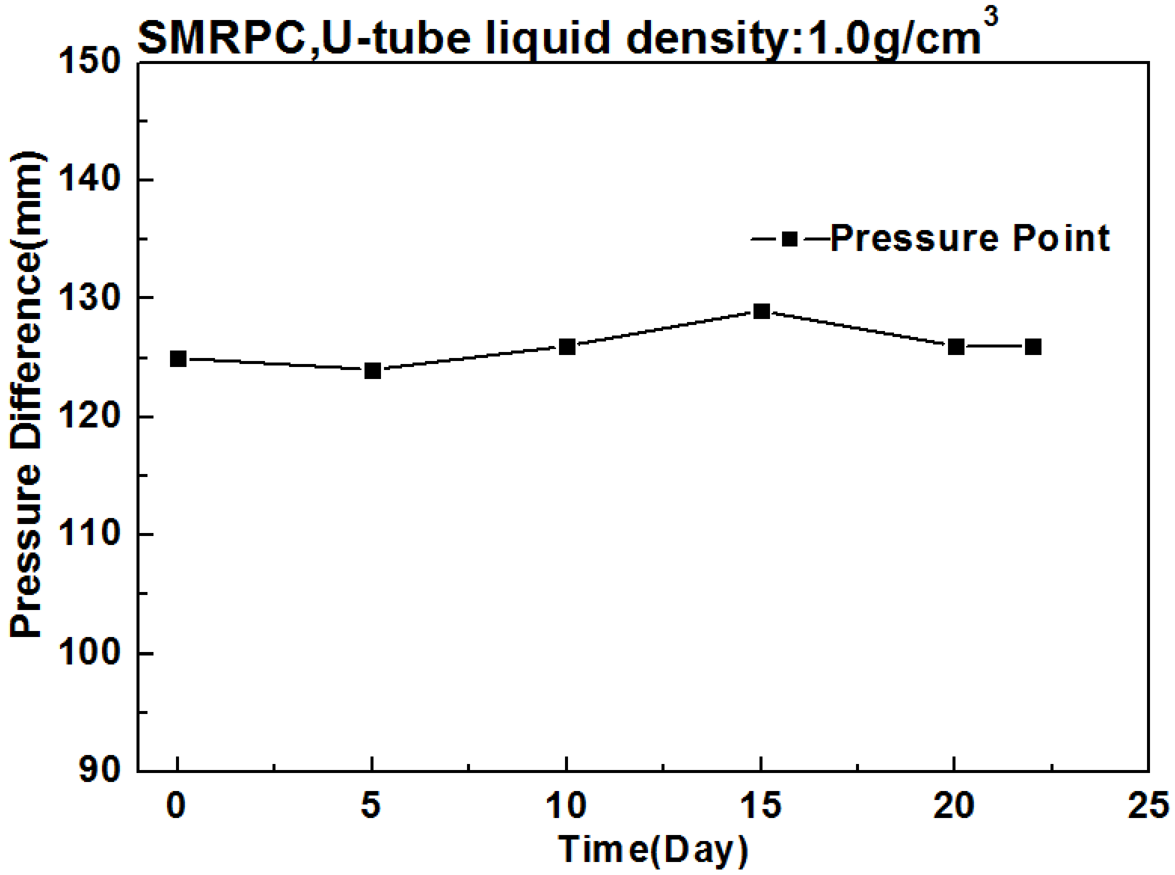




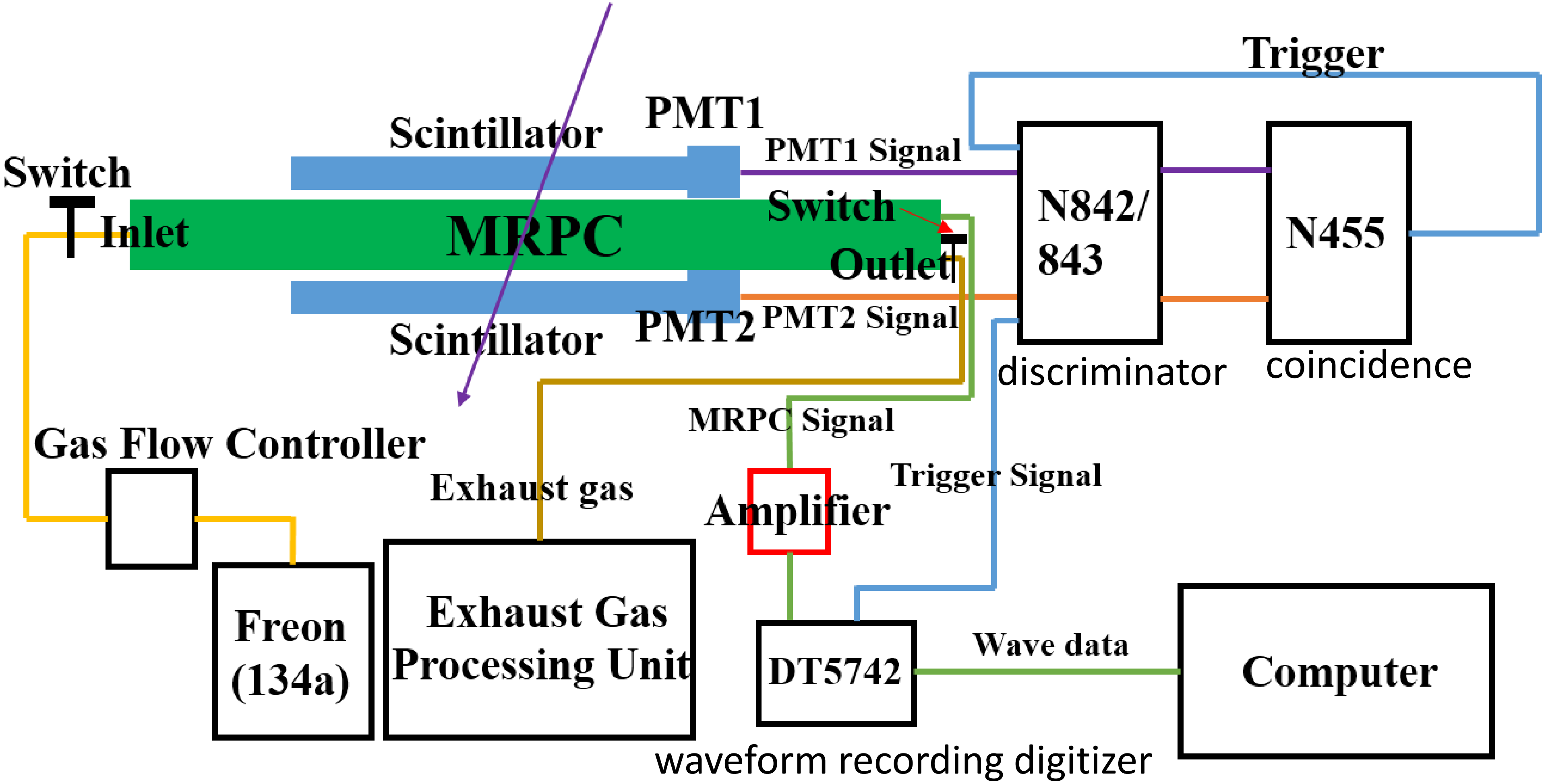
strip=1.44mm, strip gap=1.1 mm

Air tightness test





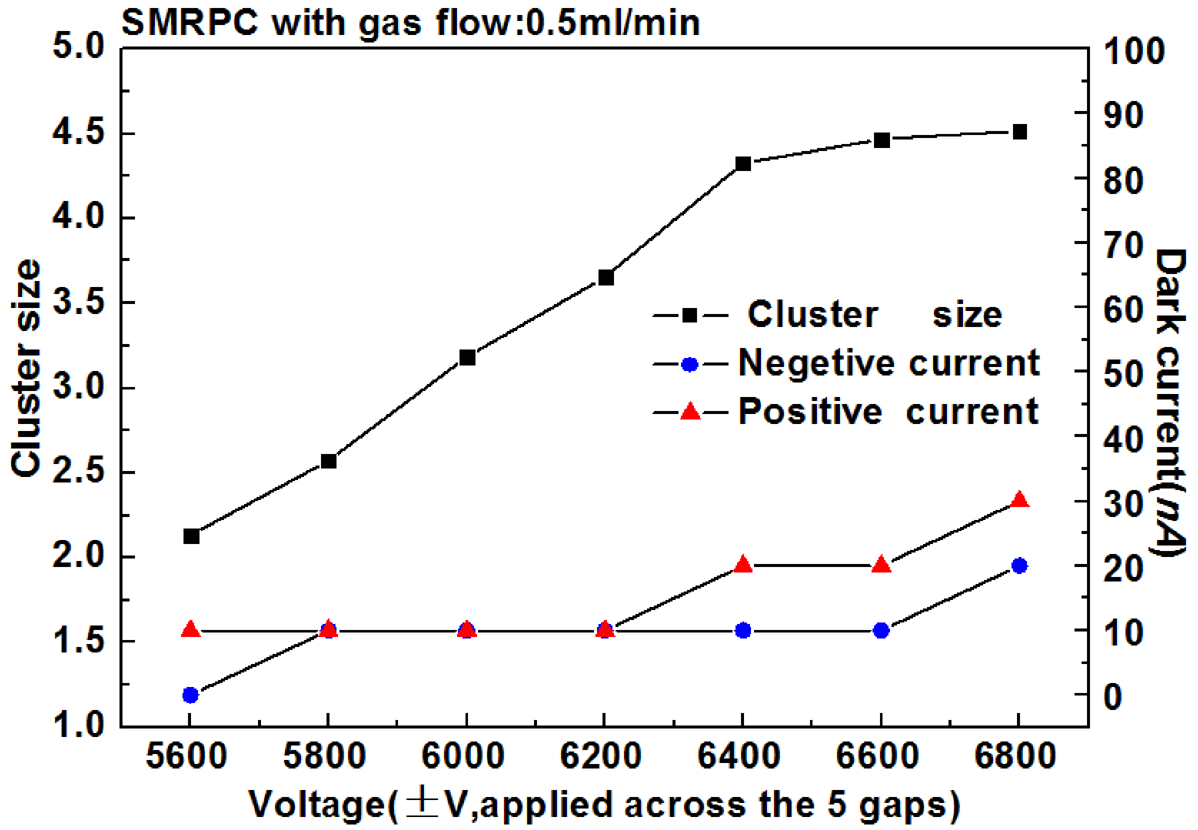
Experimental set-up of Cosmic ray test system

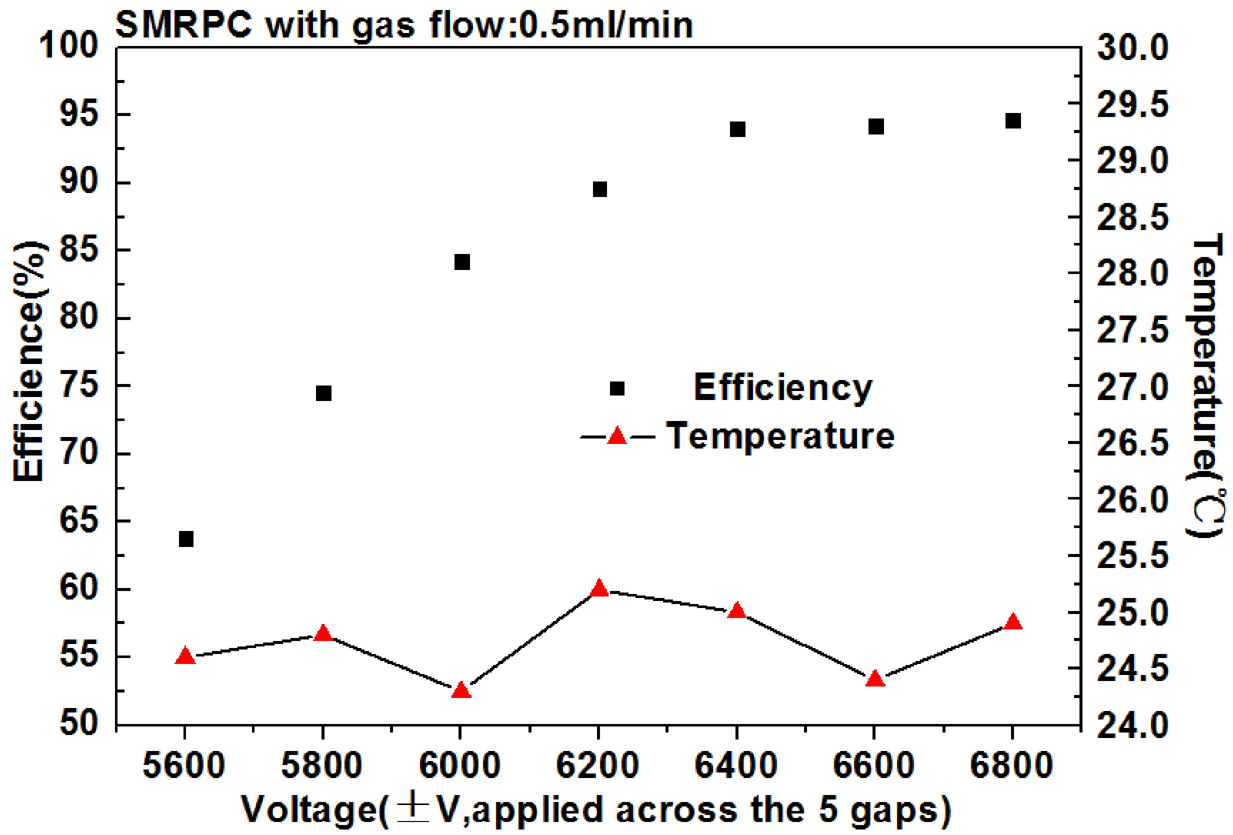


The amplifier is made by Tsinghua, whose gain and bandwidth are 30 kΩ and 24 MHz

The performance of new SMRPC

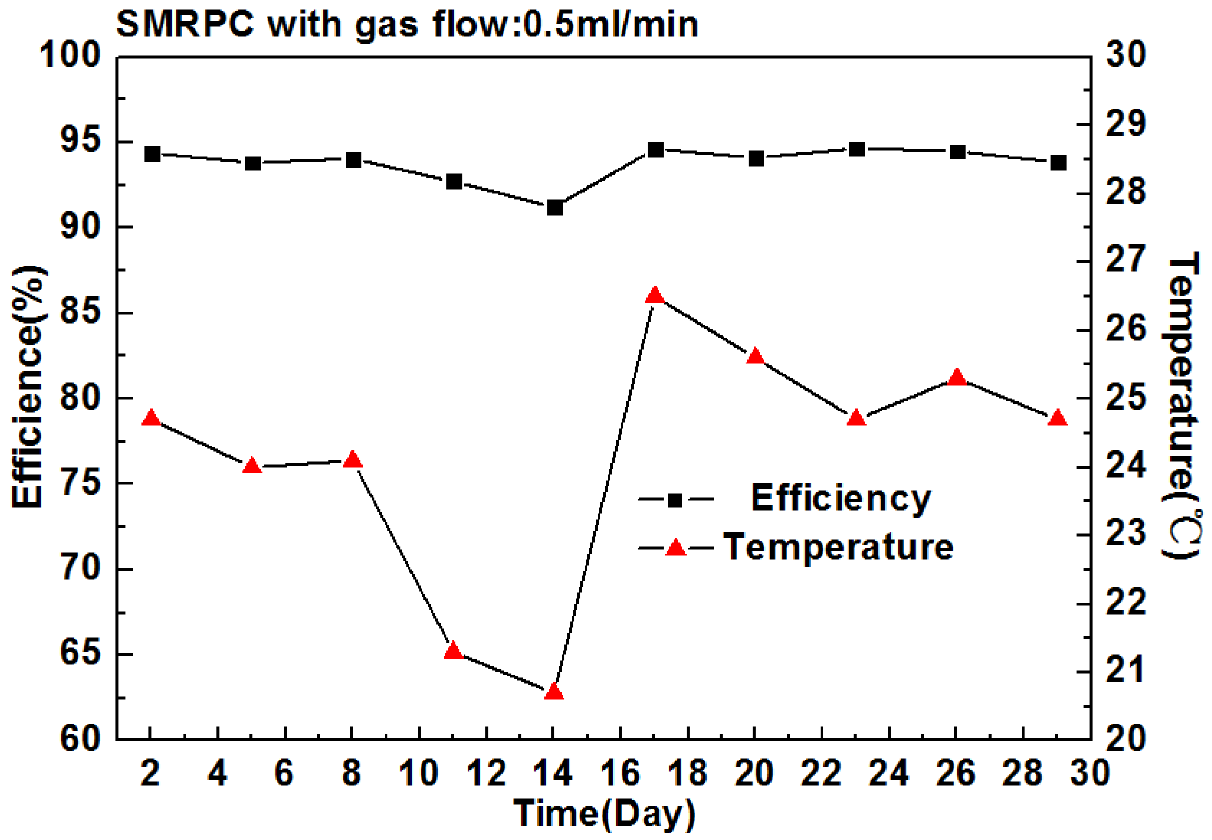
Gas, Freon(134a)
Flow speed is 0.5 ml/min

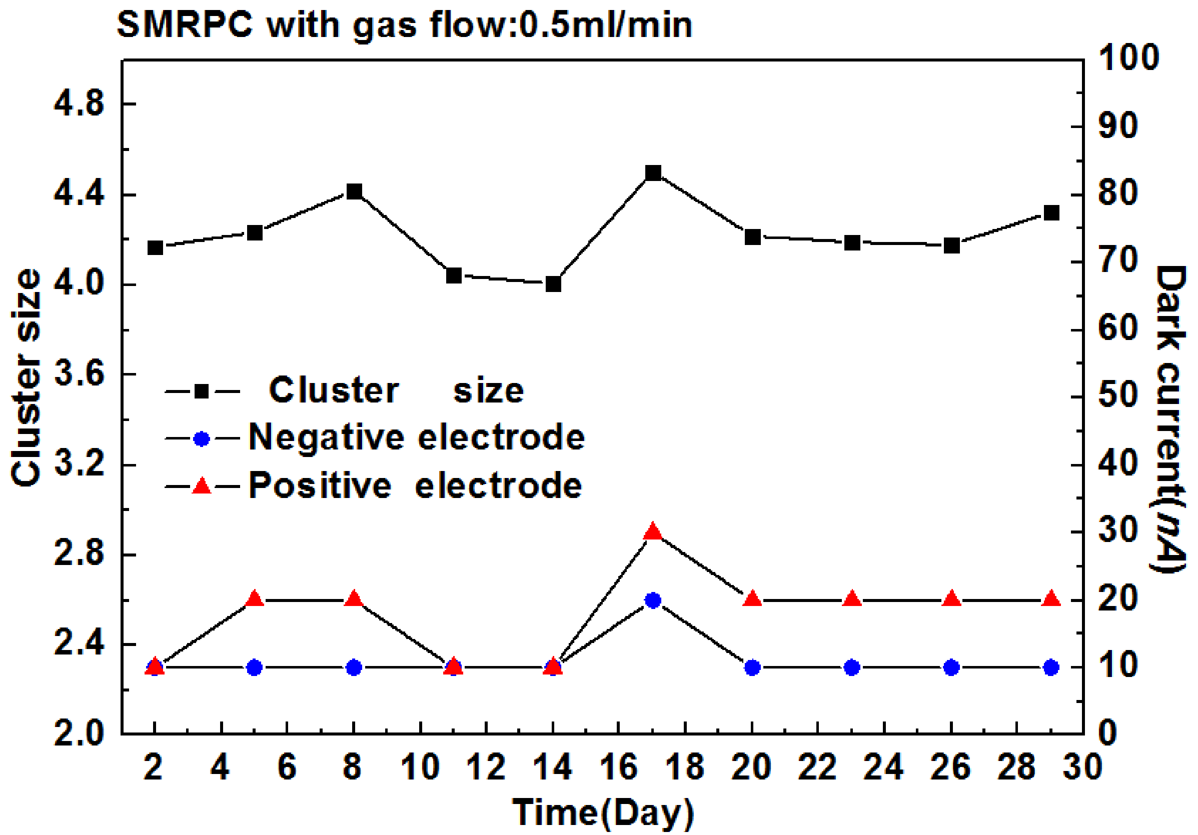




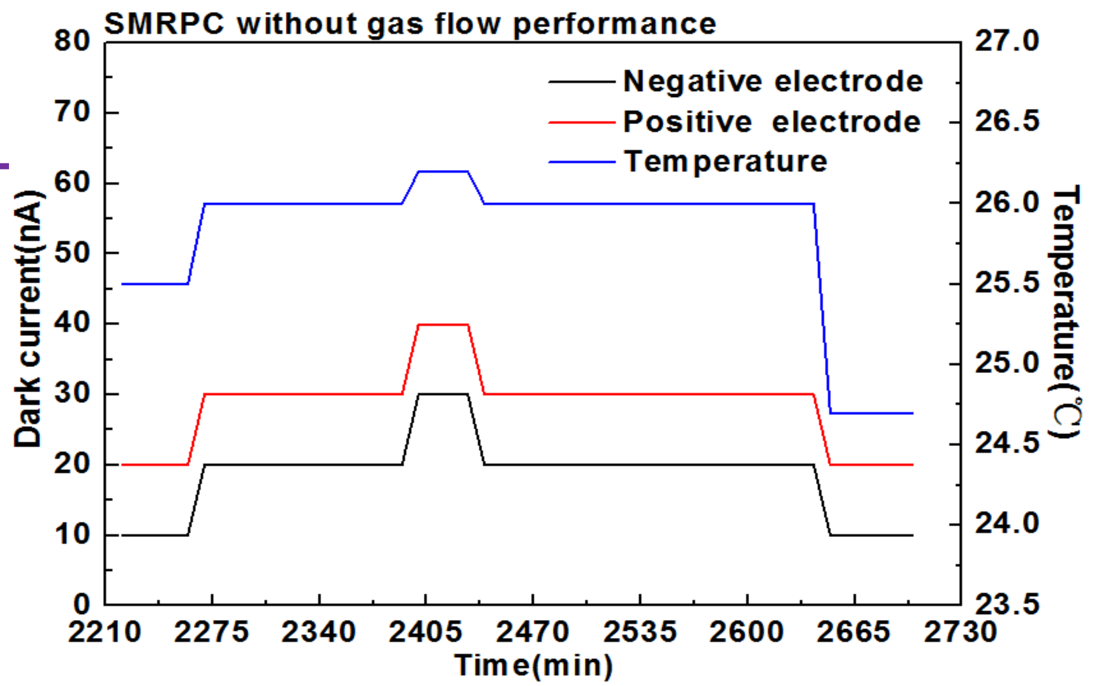
Stability test

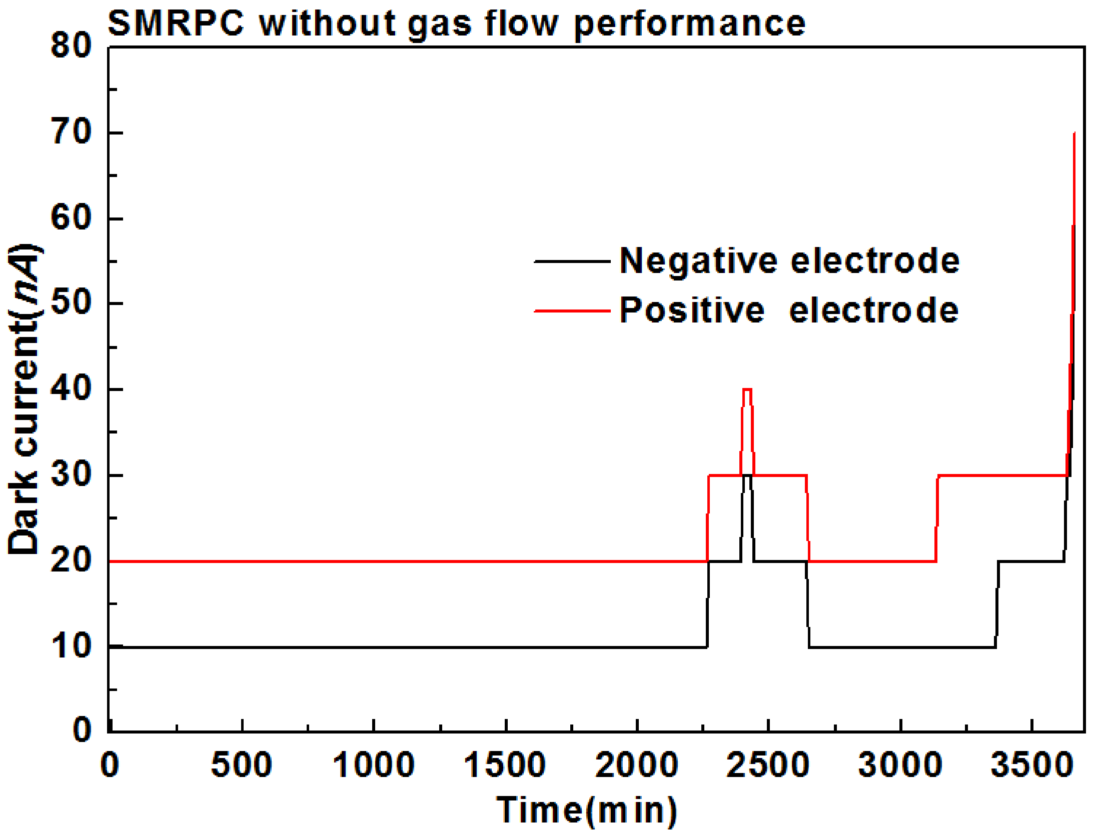
Gas, Freon(134a)
Flow speed is 0.5 ml/min

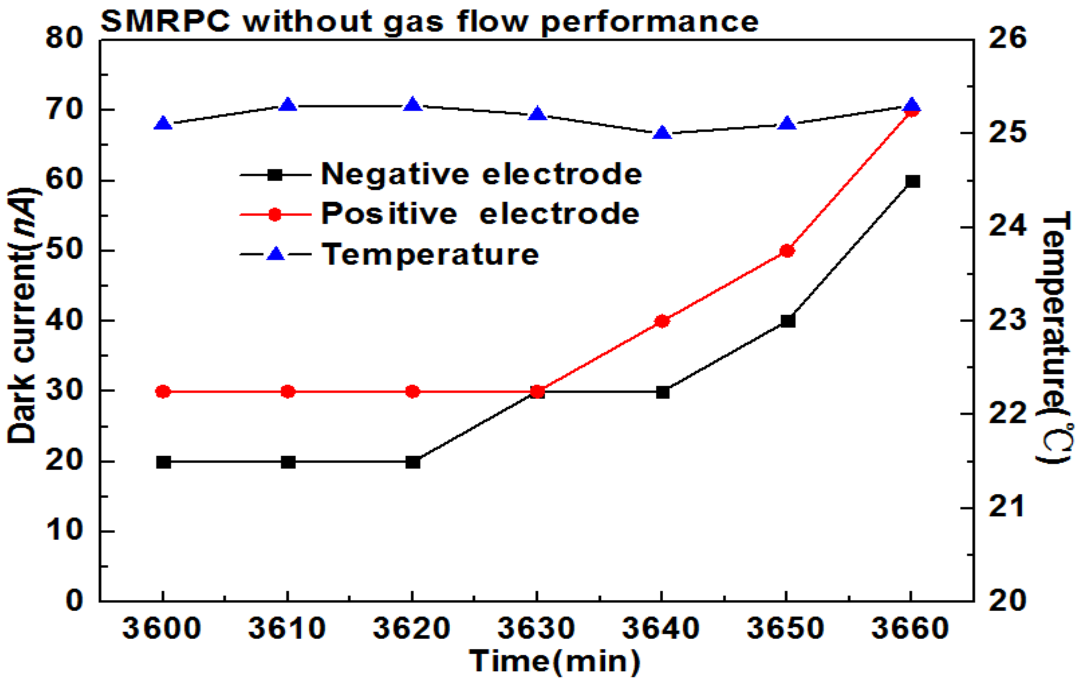




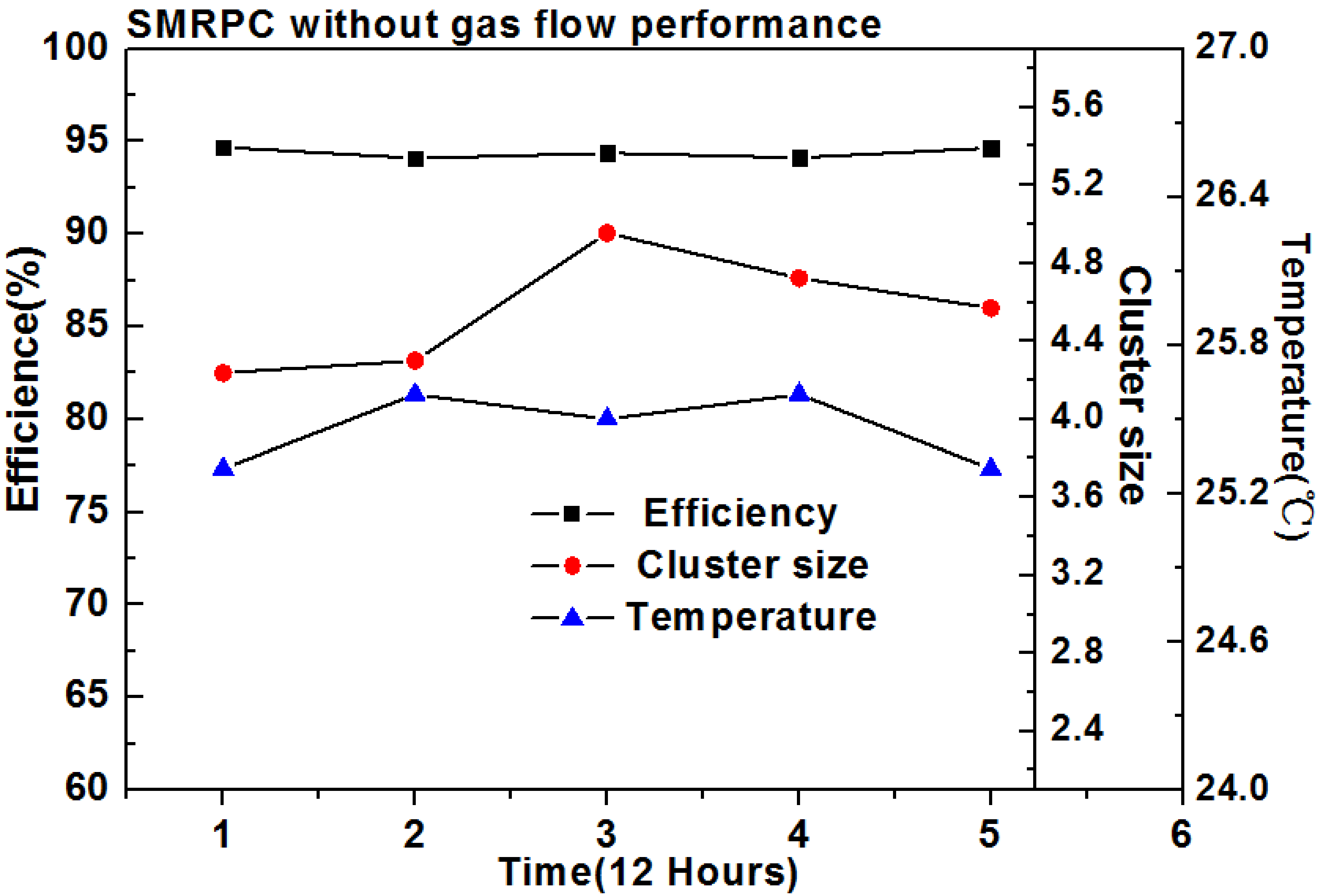
The performance with inlet and outlet shut off



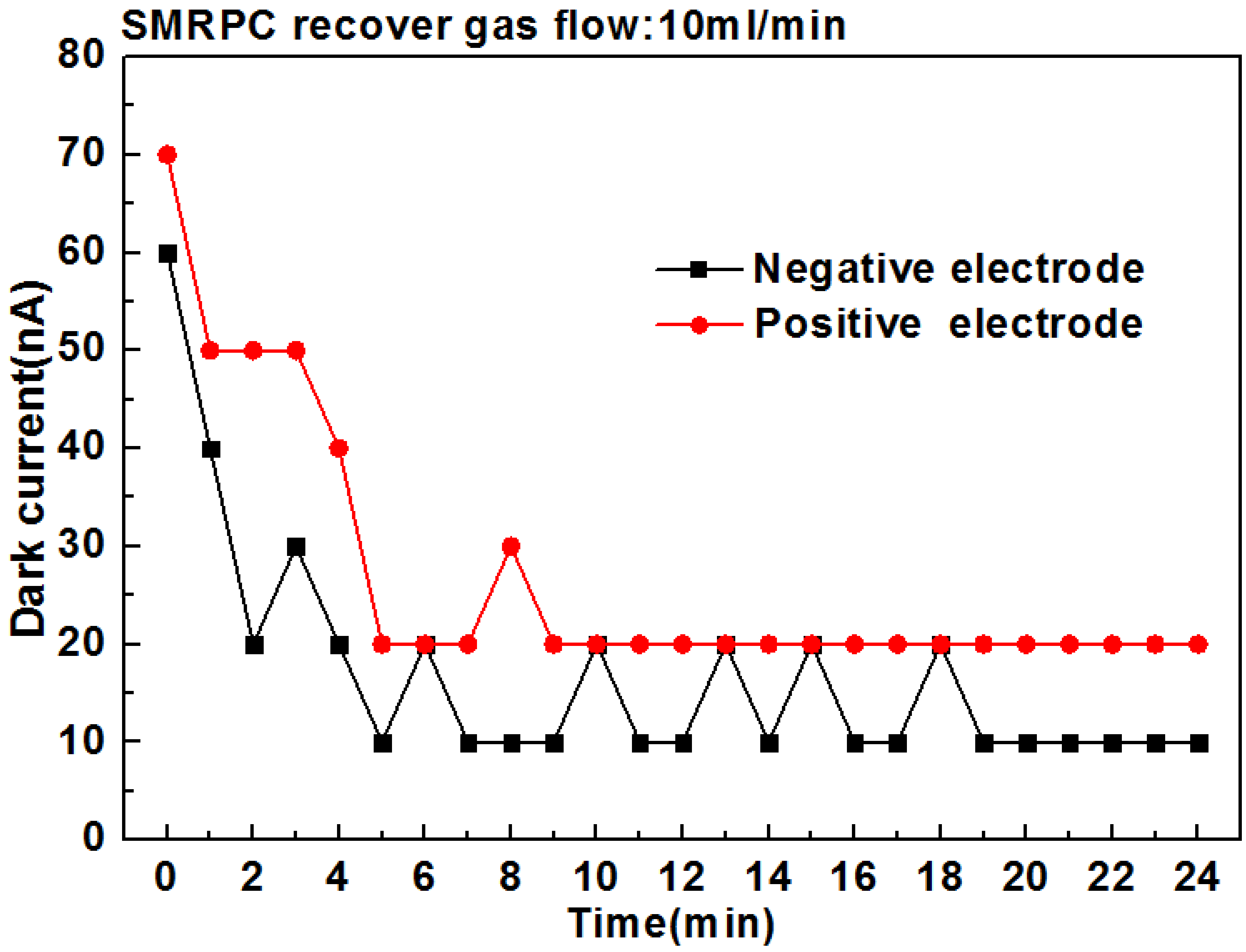




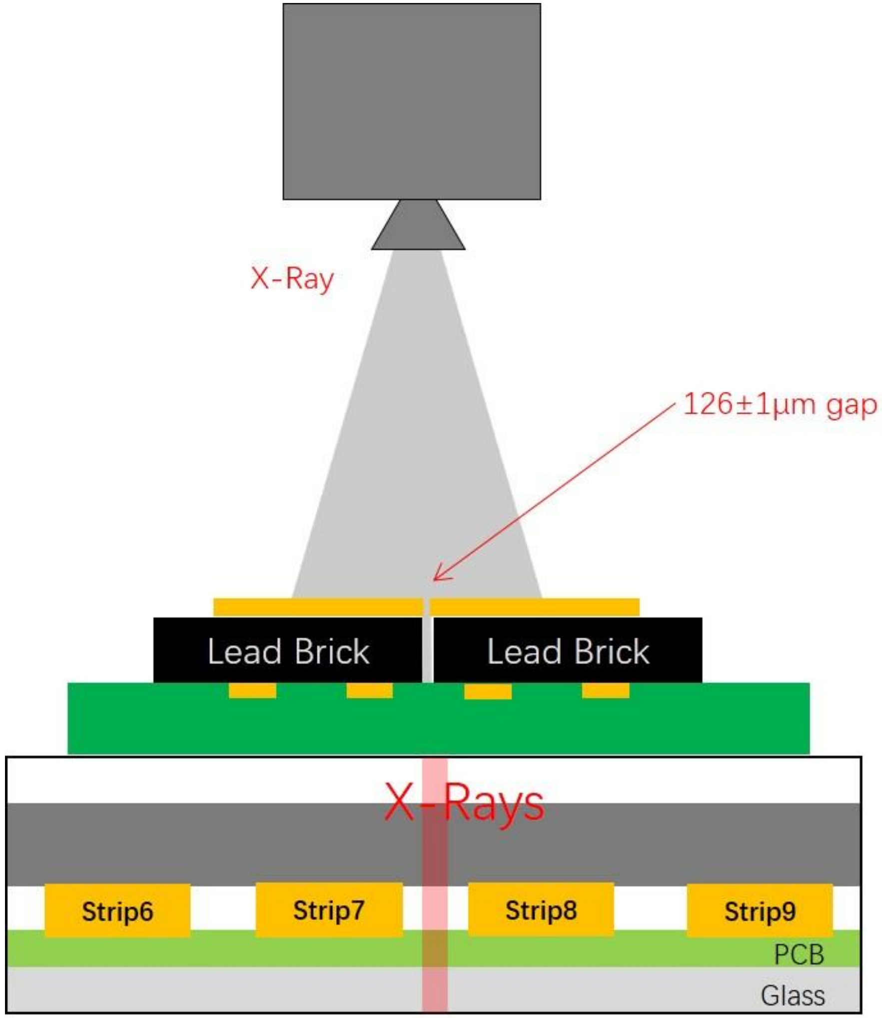
The performance with inlet and outlet shut off

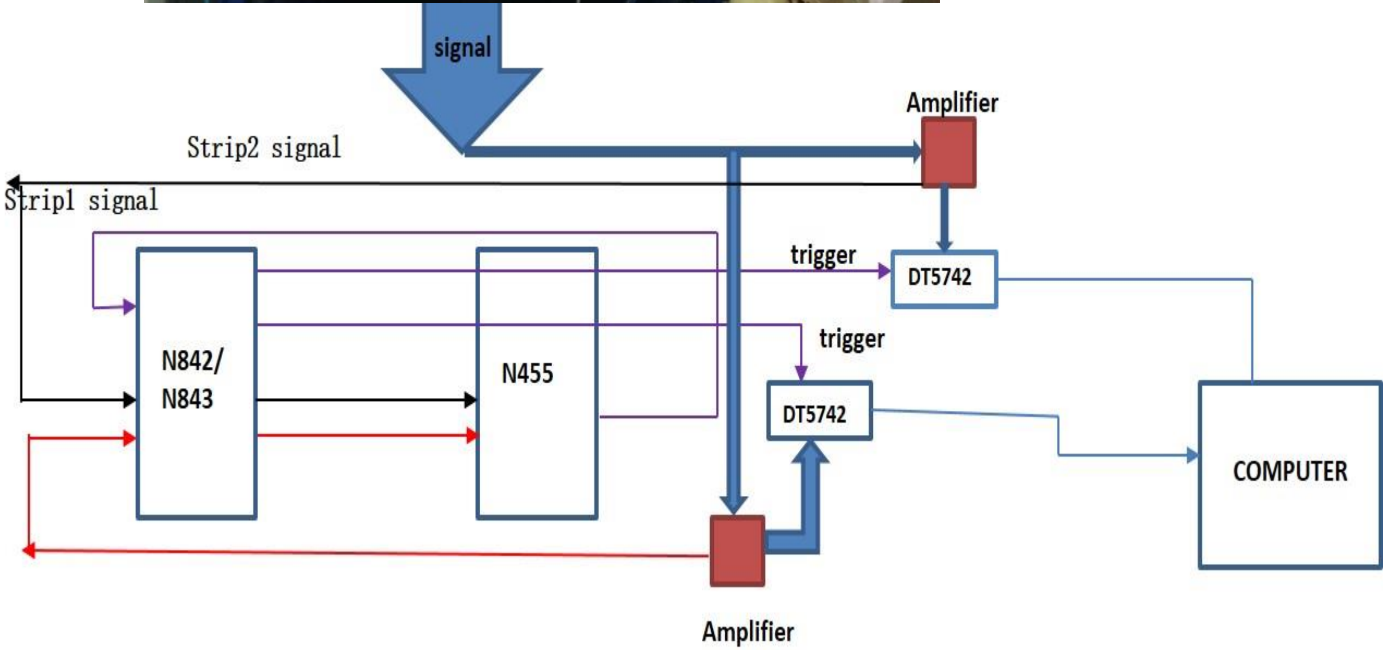


The performance of new SMRPC

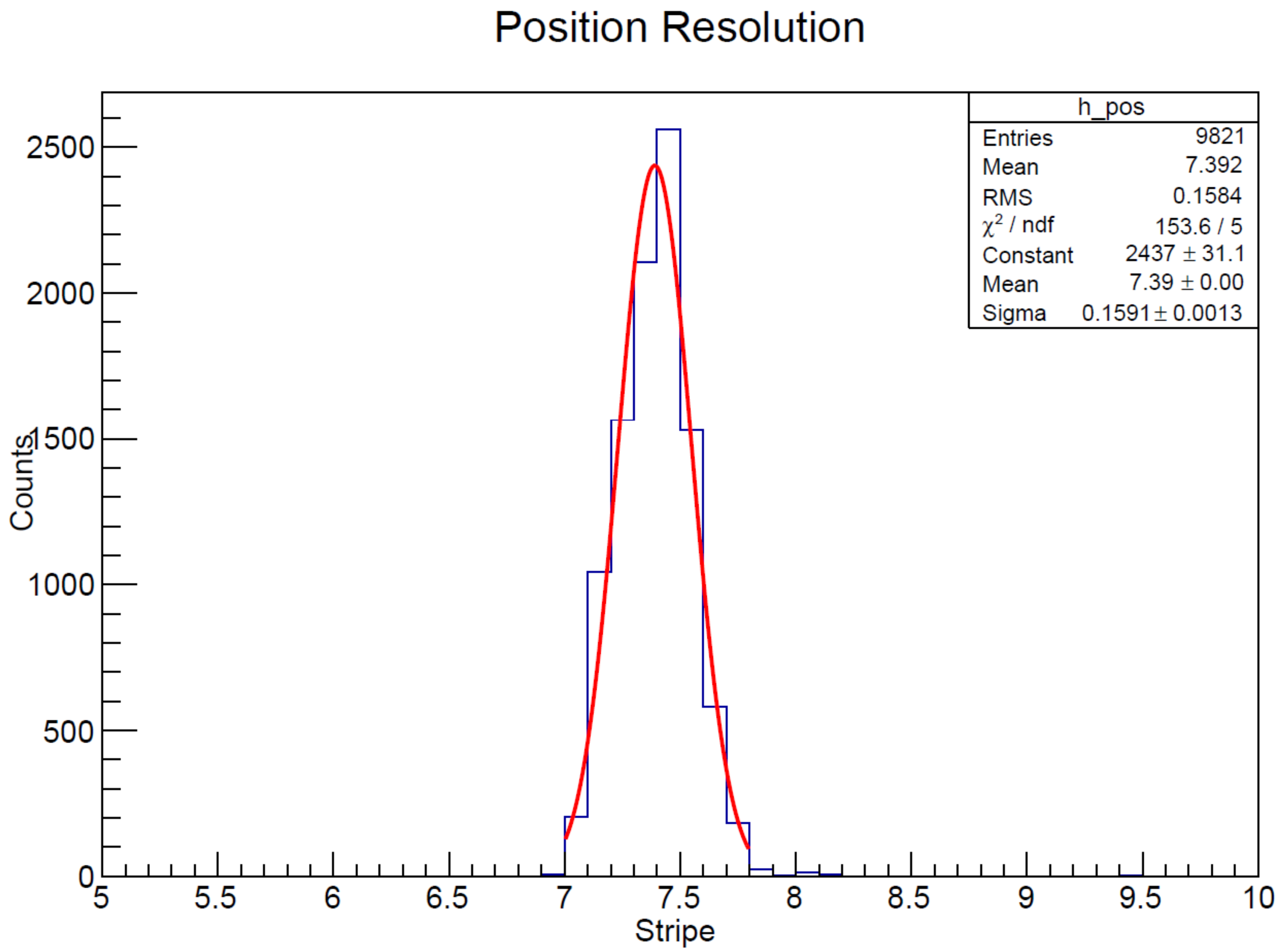


Position resolution test





The performance of SMRPC

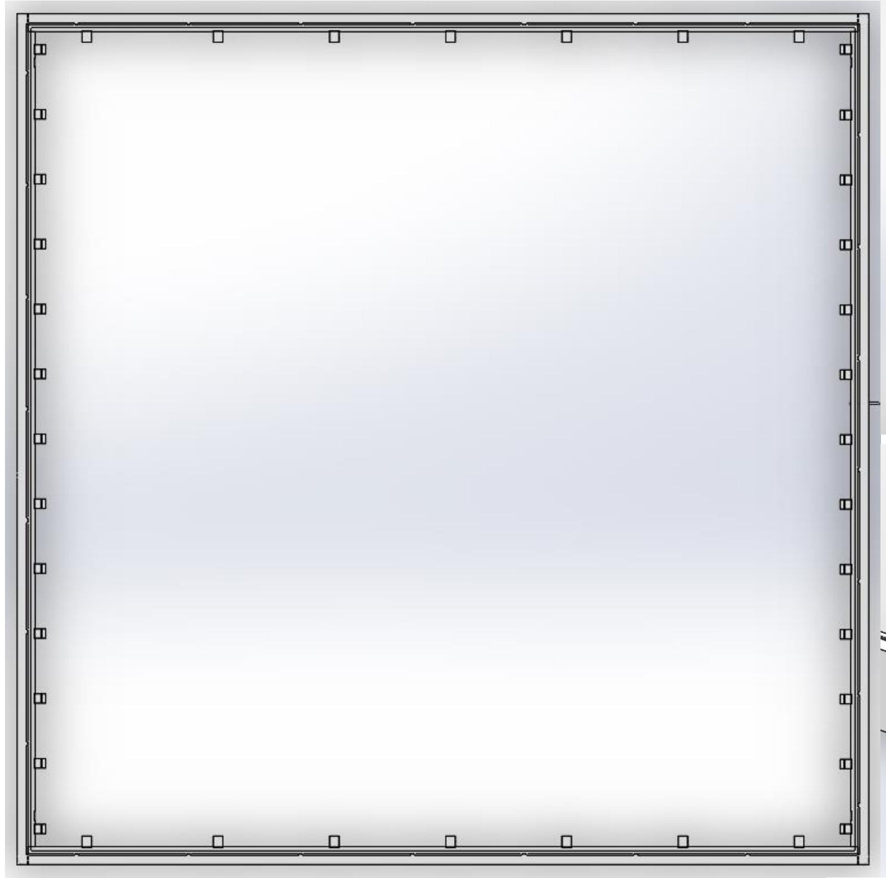


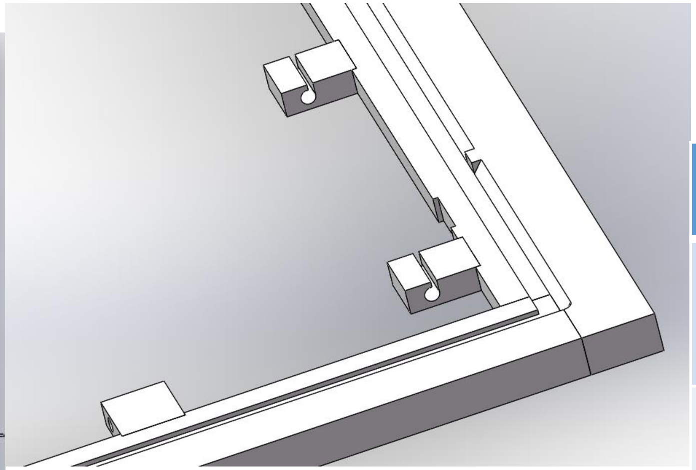
$$\sigma_{MRPC} = \sqrt{\sigma_{all}{}^2 - \sigma_{slit}{}^2}$$

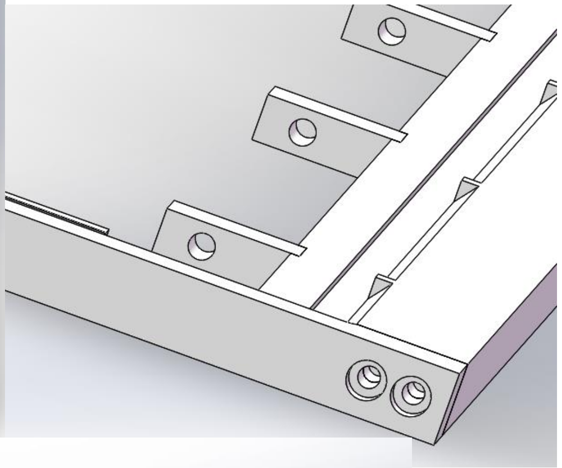
$$\delta_{MRPC} = \sqrt{(0.1591 * 2.54)^2 - \frac{0.126^2}{12}}$$

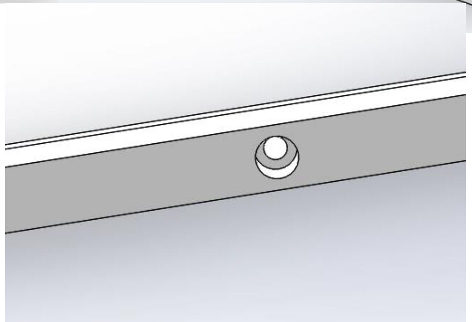
δ_{MRPC}=0.404mm

Large area SMRPC with 2 gas gaps





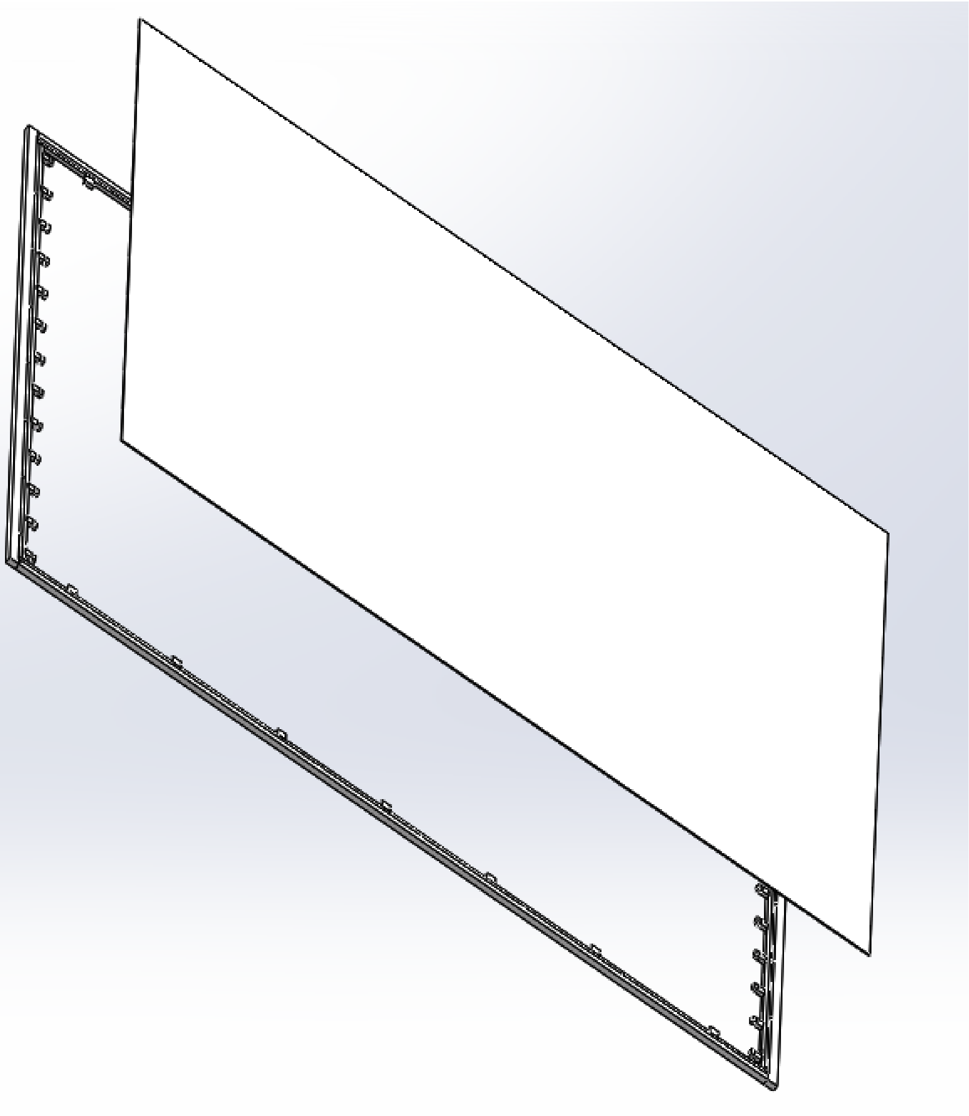


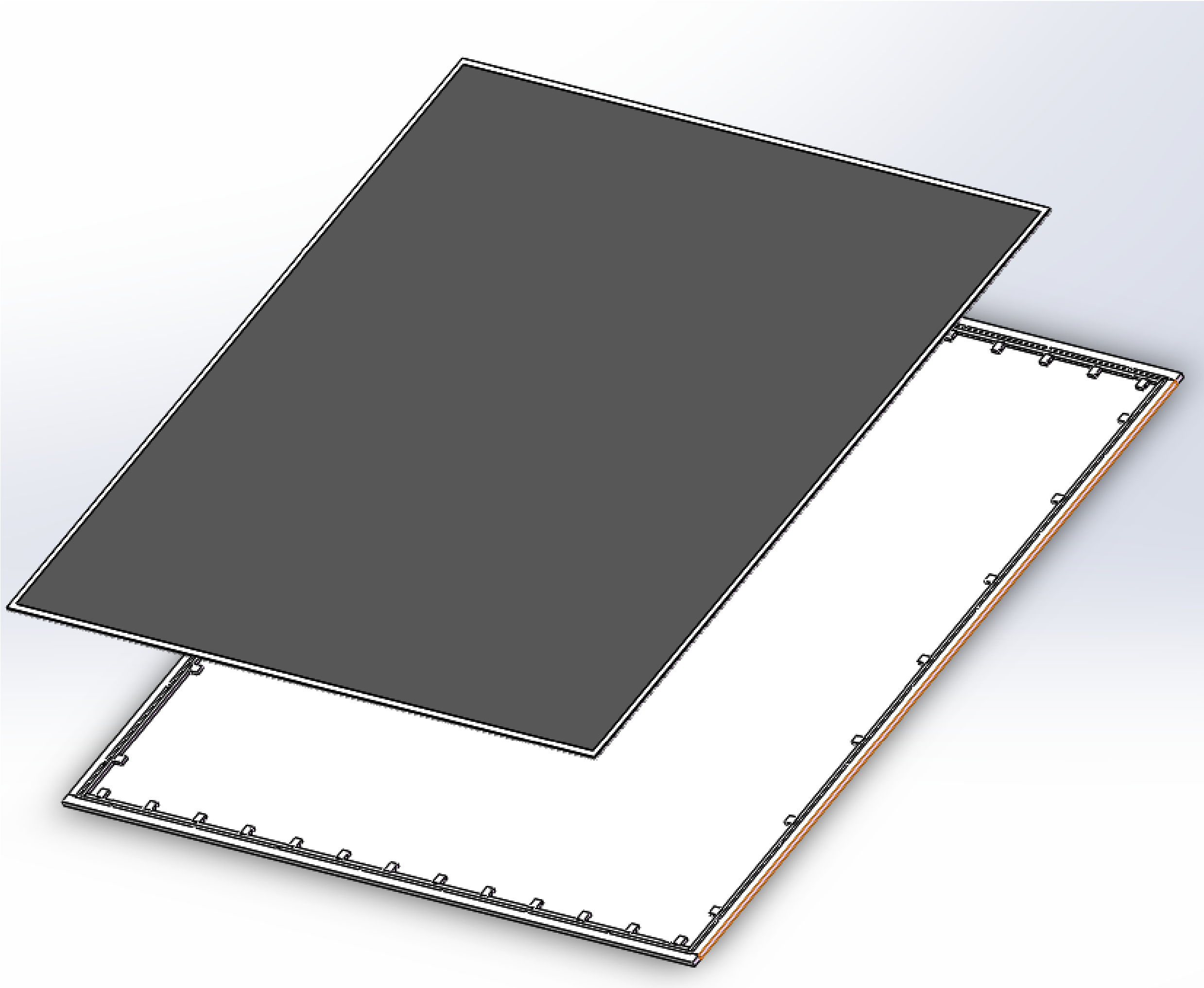


Parameters

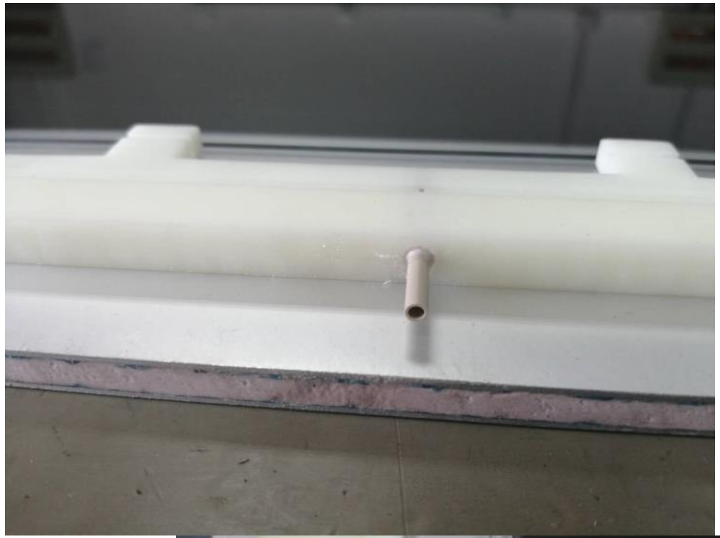
Dimensions	
Sealing bar	1180*1180 mm
PMMA plate	1150*1150 mm
Electrode glass size	1100*1100 mm
Electrode glass thickness	1.1 mm
Inner glass size	1100*1100 mm
Inner glass thickness	1.1 mm
Gas gap	1 mm
Number of gas gaps	2

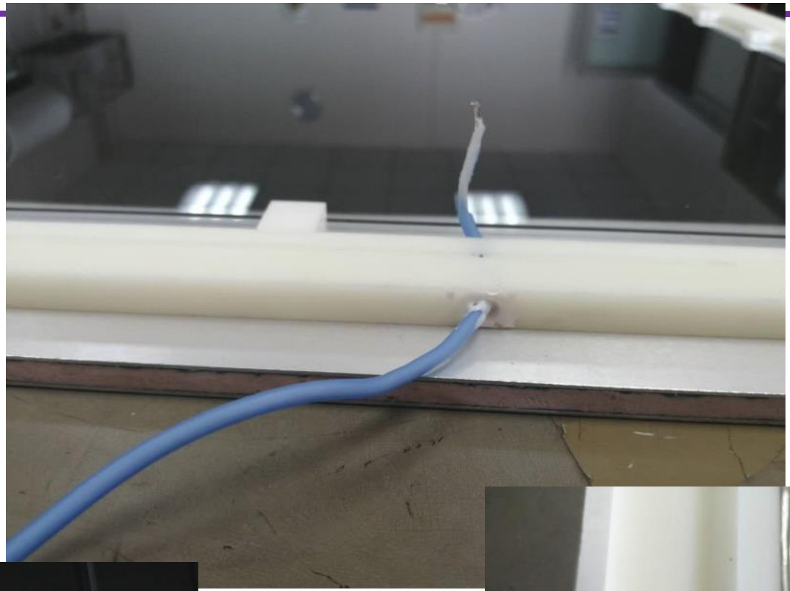
Assembly Overall View

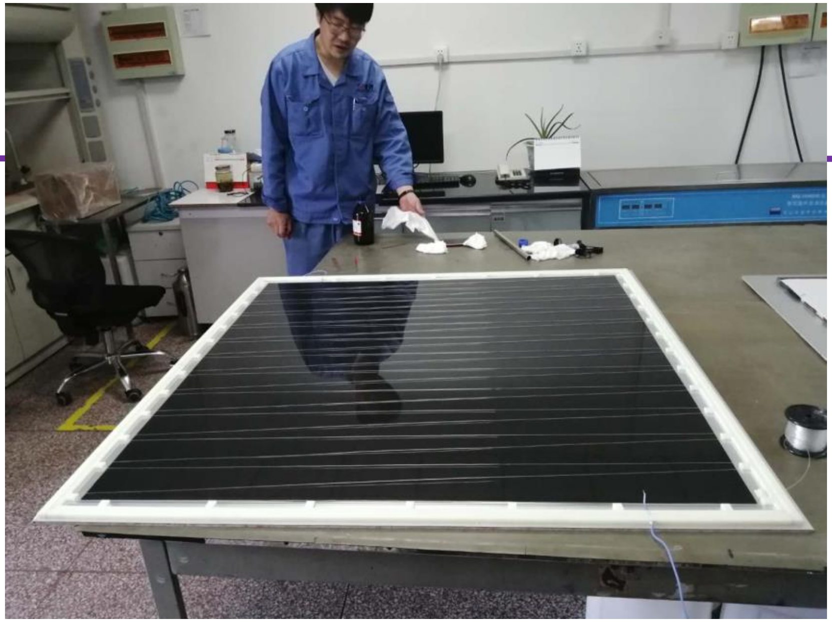


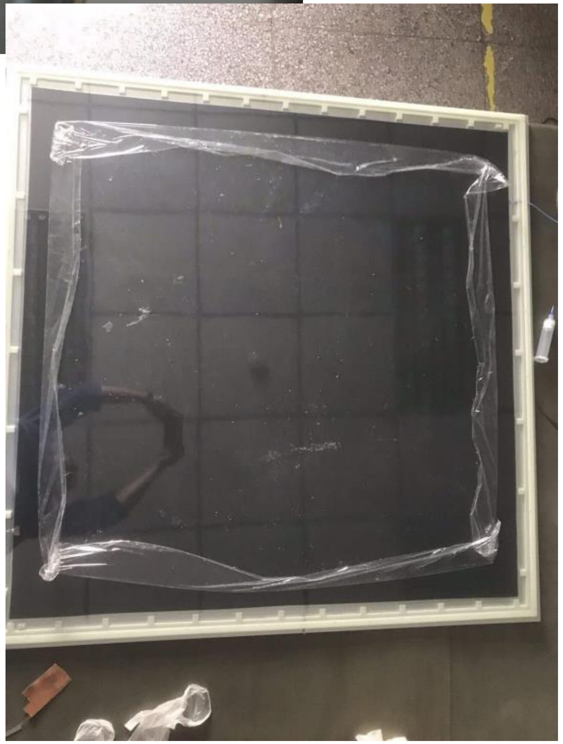


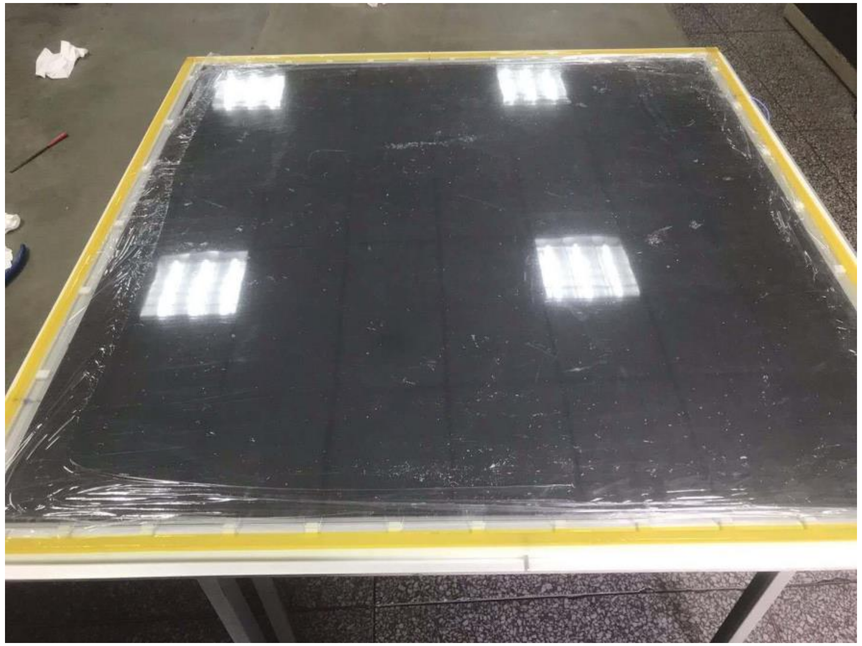
Detector asembly

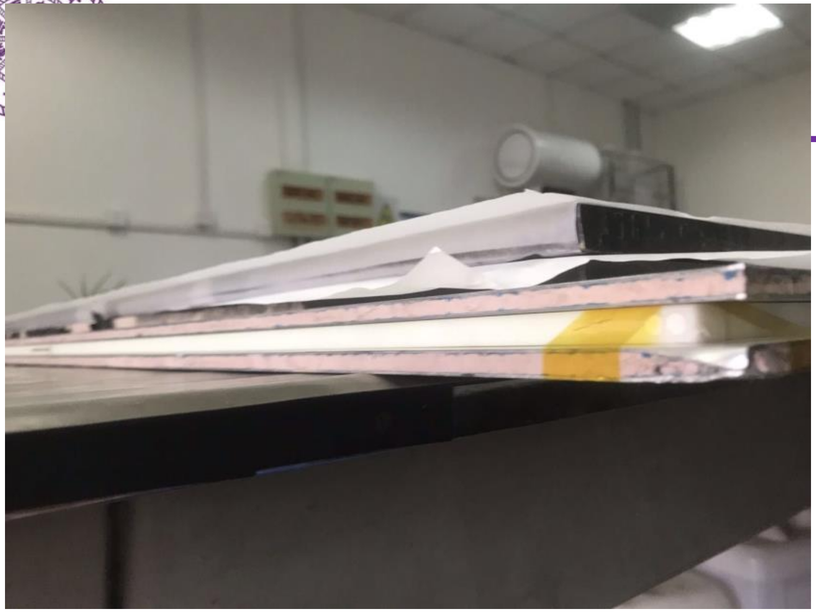


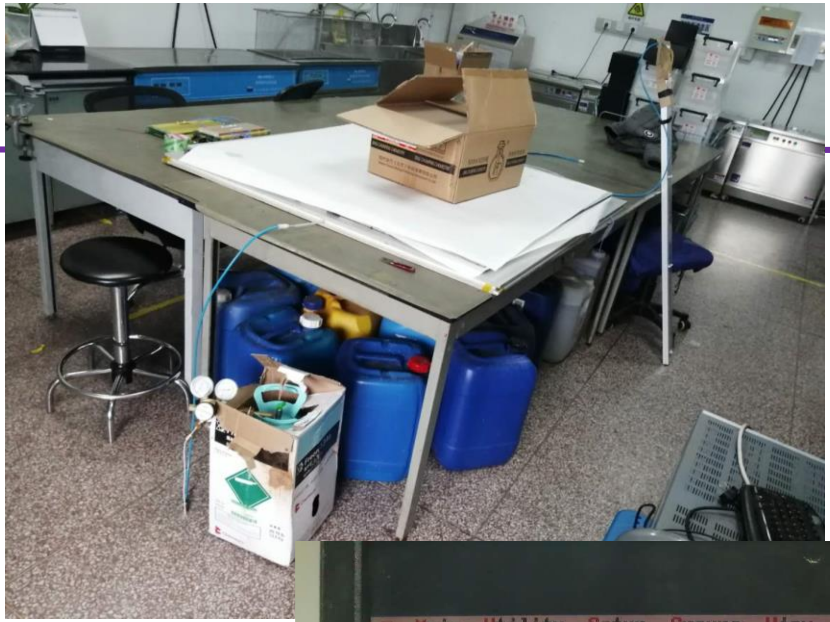


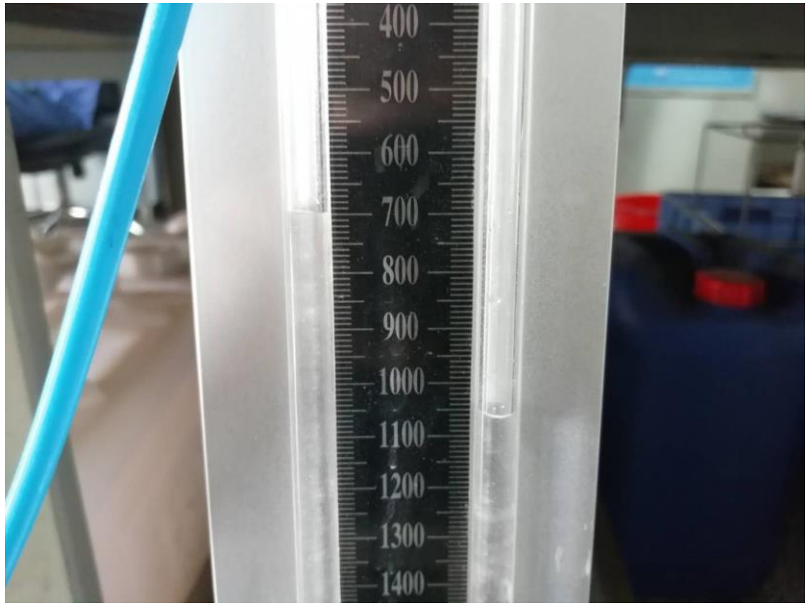


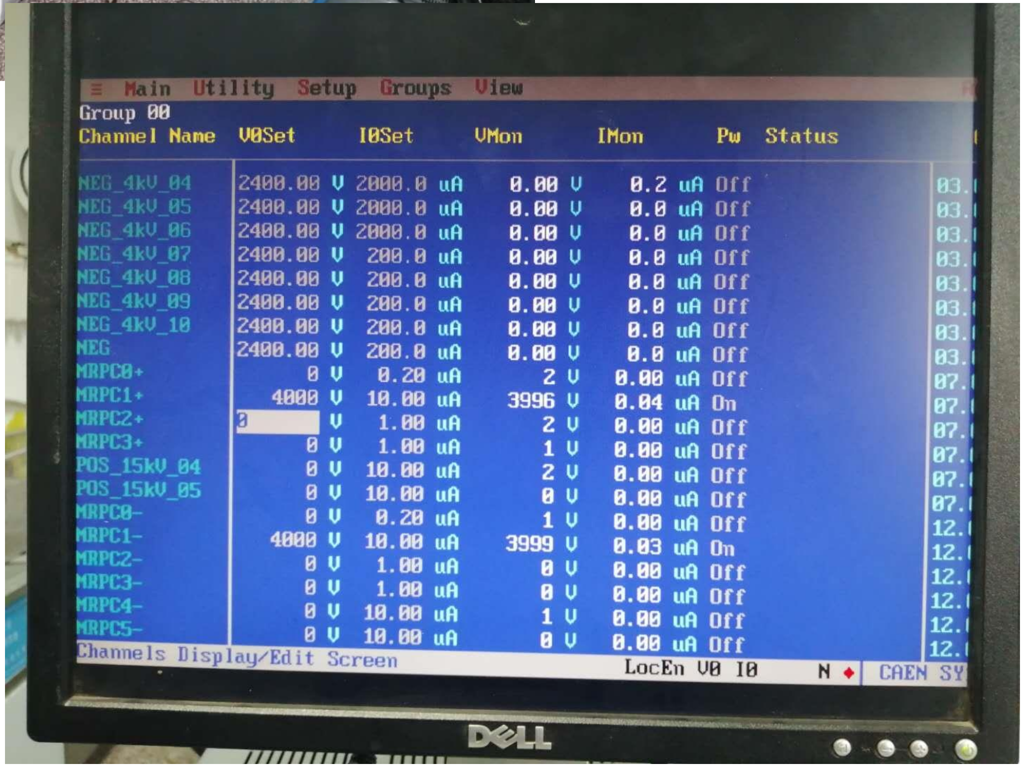









400
500
600
700
800
900
1000
1100
1200
1300
1400


Main Utility Setup Groups View
Group 00
Channel Name V0Set I0Set VMon IMon Pw Status
NEG_4kV_04 2400.00 V 2000.0 uA 0.00 V 0.2 uA Off
NEG_4kV_05 2400.00 V 2000.0 uA 0.00 V 0.0 uA Off
NEG_4kV_06 2400.00 V 2000.0 uA 0.00 V 0.0 uA Off
NEG_4kV_07 2400.00 V 200.0 uA 0.00 V 0.0 uA Off
NEG_4kV_08 2400.00 V 200.0 uA 0.00 V 0.0 uA Off
NEG_4kV_09 2400.00 V 200.0 uA 0.00 V 0.0 uA Off
NEG_4kV_10 2400.00 V 200.0 uA 0.00 V 0.0 uA Off
NEG 2400.00 V 200.0 uA 0.00 V 0.0 uA Off
MRPC0+ 0 V 0.20 uA 2 V 0.00 uA Off
MRPC1+ 4000 V 10.00 uA 3996 V 0.04 uA On
MRPC2+ 0 V 1.00 uA 2 V 0.00 uA Off
MRPC3+ 0 V 1.00 uA 1 V 0.00 uA Off
POS_15kV_04 0 V 10.00 uA 2 V 0.00 uA Off
POS_15kV_05 0 V 10.00 uA 0 V 0.00 uA Off
MRPC0- 0 V 0.20 uA 1 V 0.00 uA Off
MRPC1- 4000 V 10.00 uA 3999 V 0.03 uA On
MRPC2- 0 V 1.00 uA 0 V 0.00 uA Off
MRPC3- 0 V 1.00 uA 0 V 0.00 uA Off
MRPC4- 0 V 10.00 uA 1 V 0.00 uA Off
MRPC5- 0 V 10.00 uA 0 V 0.00 uA Off
Channels Display/Edit Screen
LocEn V0 I0 N
CAEN SY
DELL

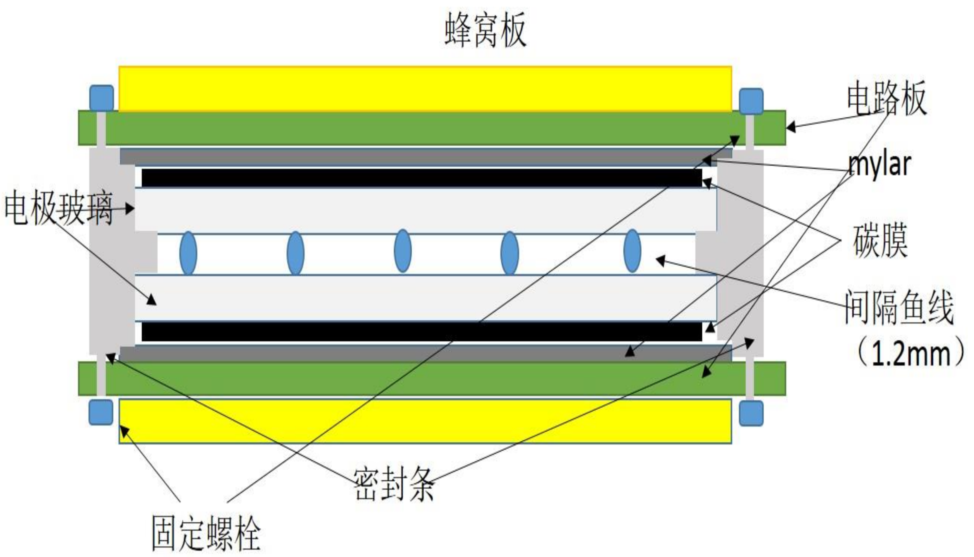
Summary

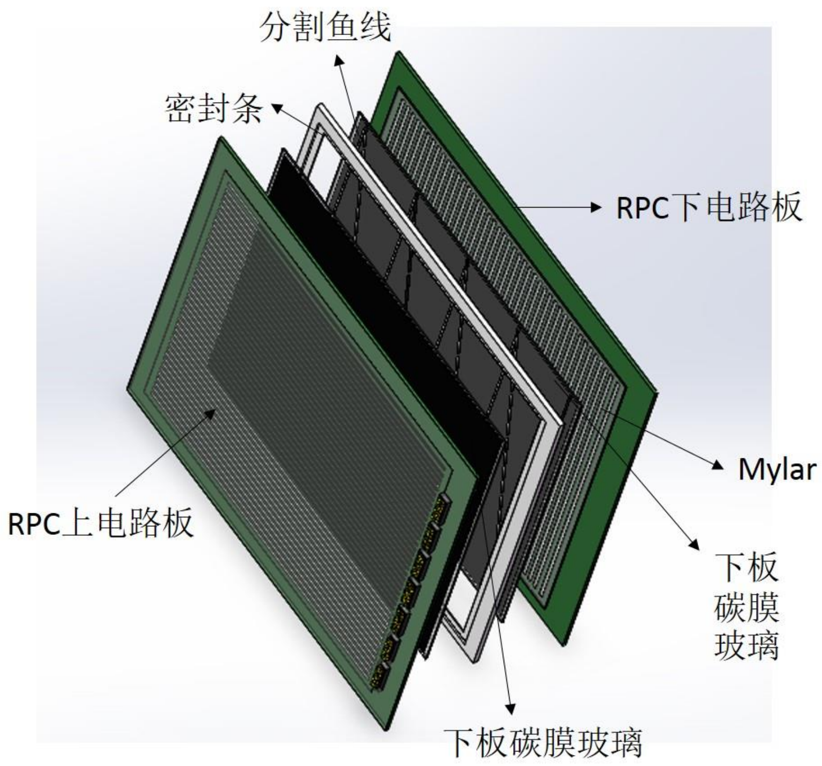
- Design a Sealing MRPC which can operate at low gas rate about 0.5 ml/min with efficiency above 90% and clustersize around 4.4.
- Simulate the gas flow and the distribution of pollutant concentration inside SMRPC.
- To do
  - Test the performance of large area SMRPC with pure Freon.
  - Try to find the Eco-friendly gas suitable for SMRPC operation.

Thank you for your attention

SRPC

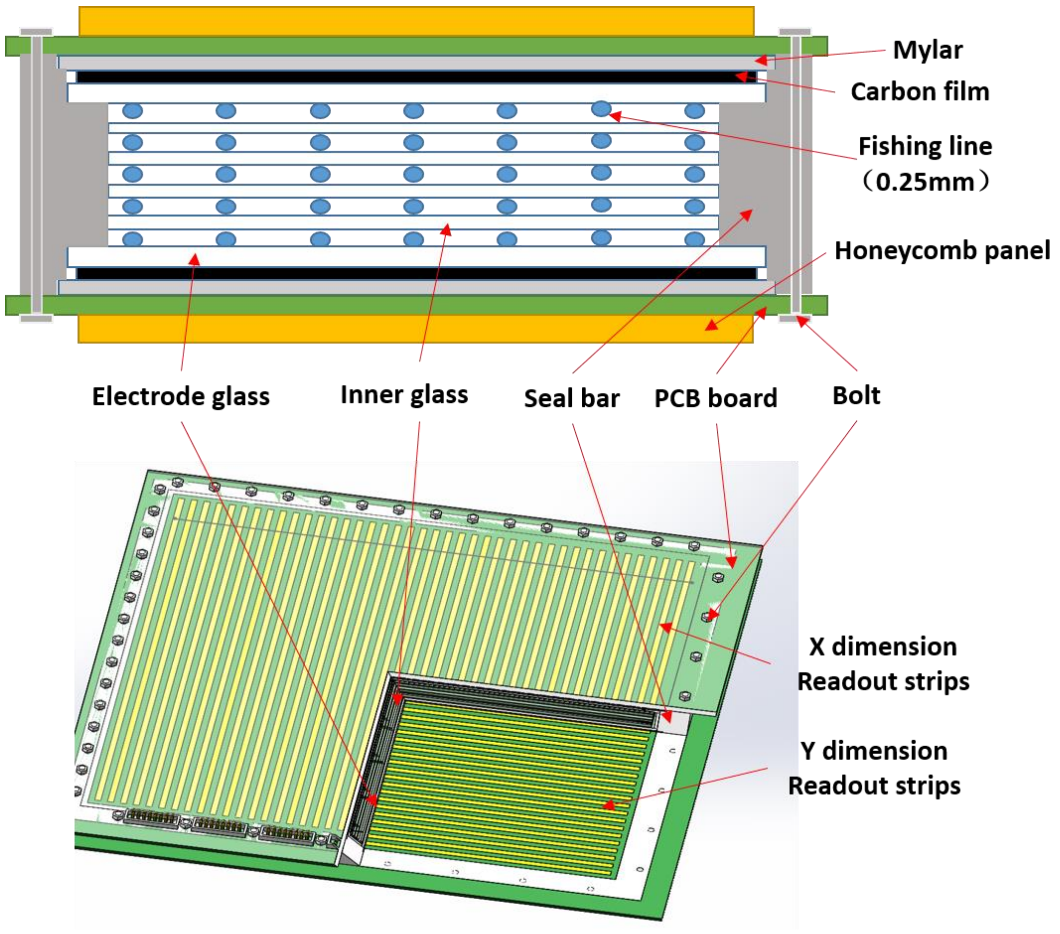
- SRPC





- Gas gap： 1.2mm
- Readout strip： 2.54 (1.44+1.1)mm
- Working gas： 90% Freon+5% Iso-butane+5%SF6
- Working voltage： ±5.7kV

SMRPC



- Gas gap： 0.25mm
- Number of gas gap： 5
- Readout strip： 2.54 (1.44+1.1)mm
- Working gas： 90% Freon+5% Iso-butane+5%SF6
- Working voltage： ±7kV

课题研究进展

➢ 其他几种情况的模拟（3ml/min）