Design and Performance study of Sealed MRPC (SMRPC) with extremely low gas flow for muon tomography

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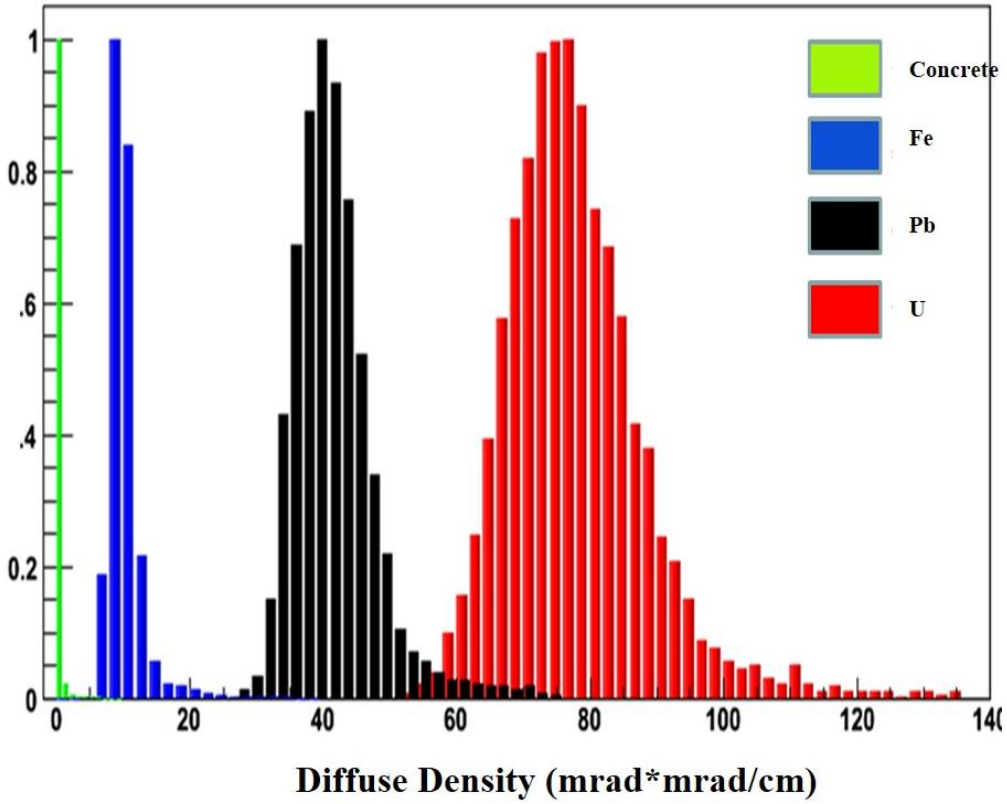
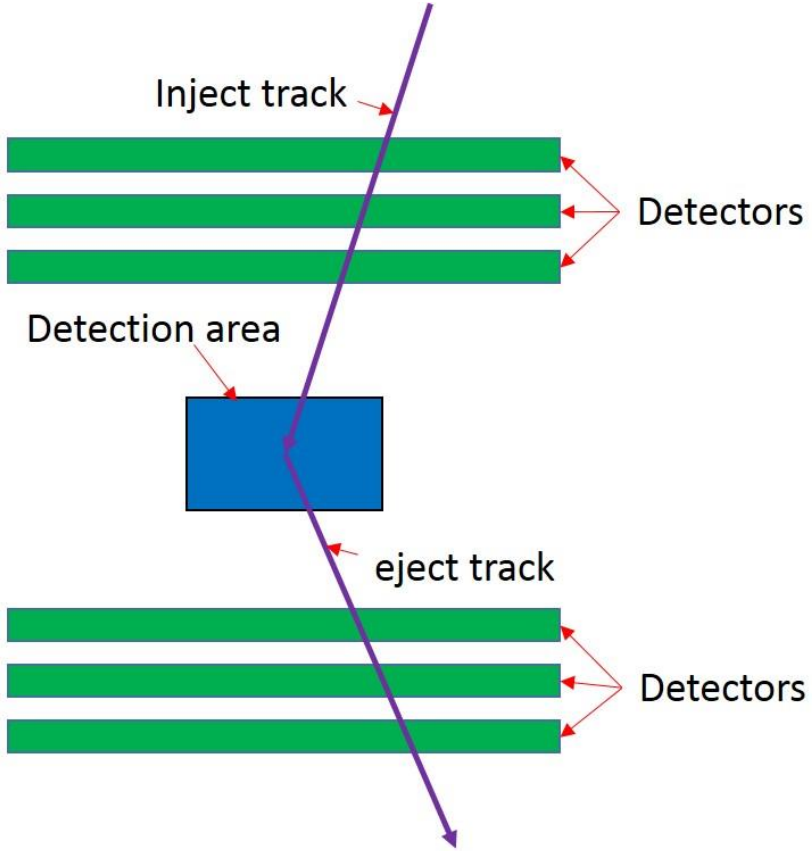
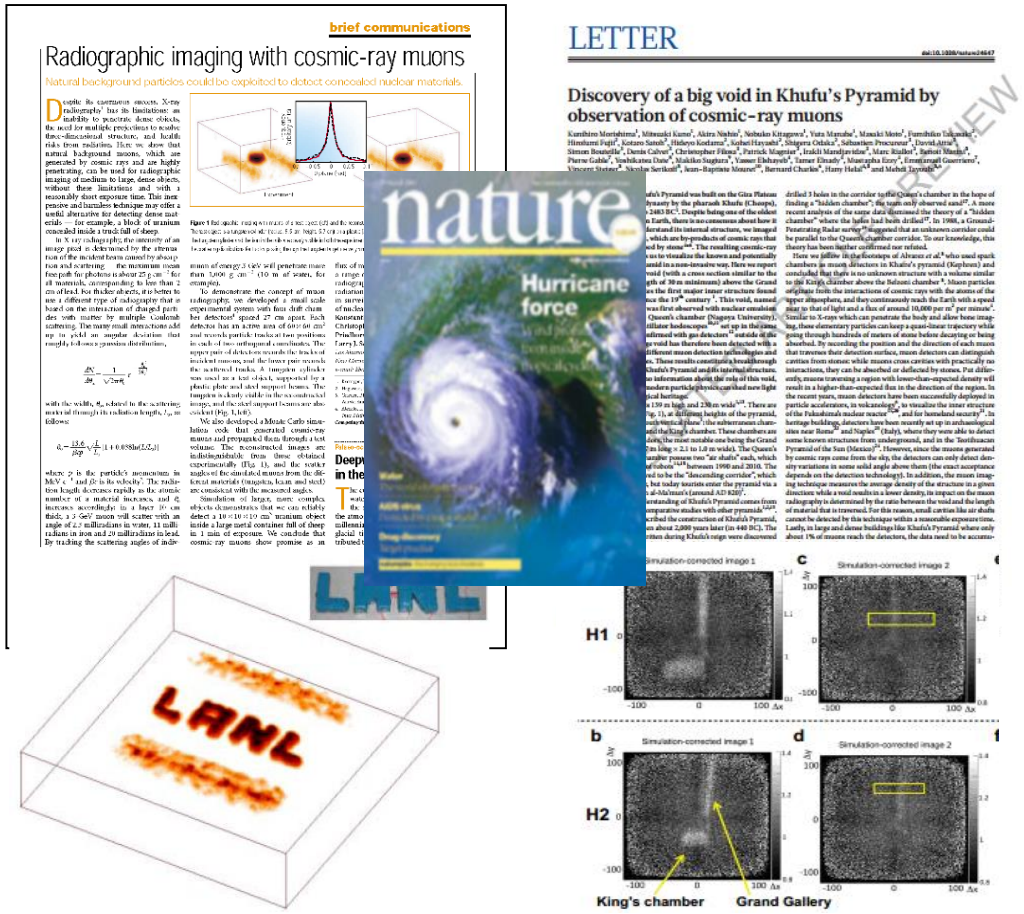
What's muon tomography





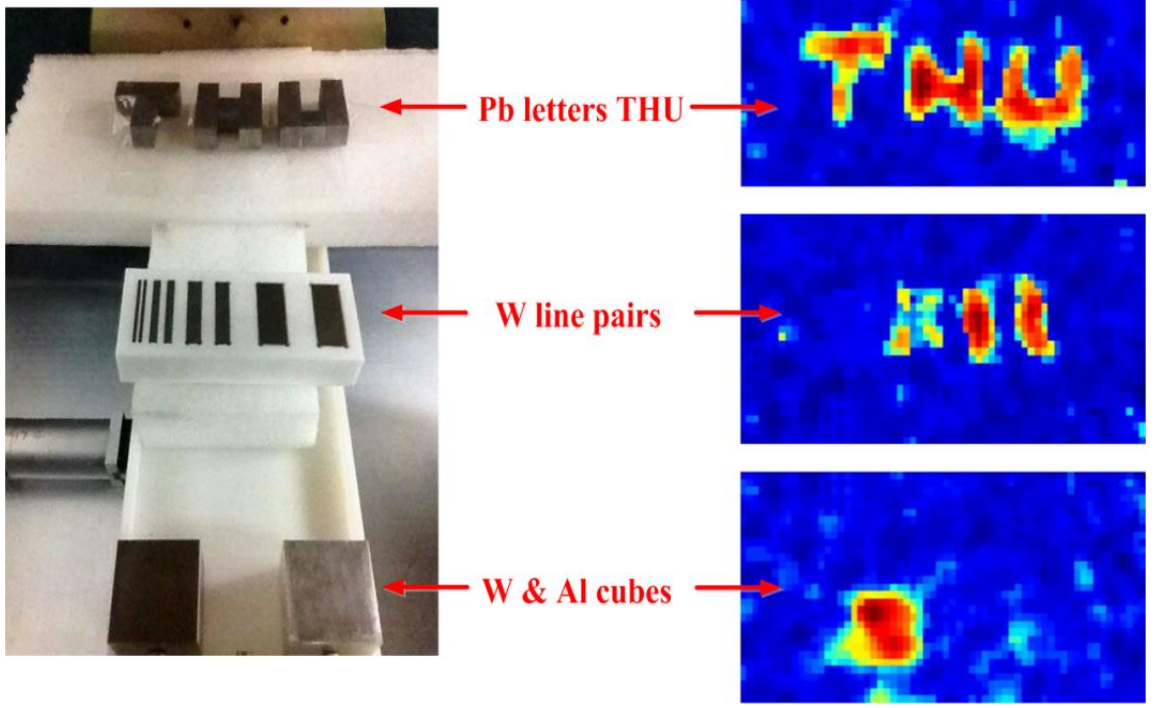
Background

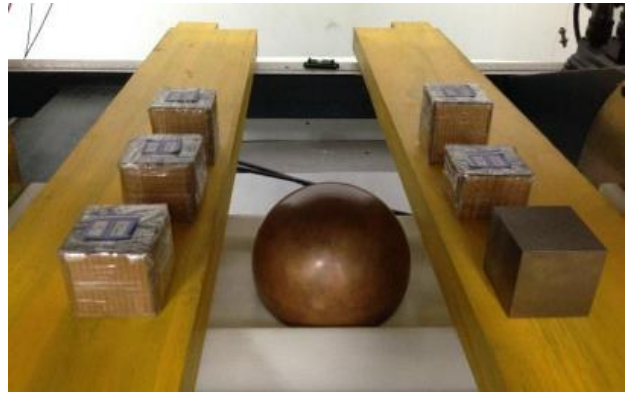


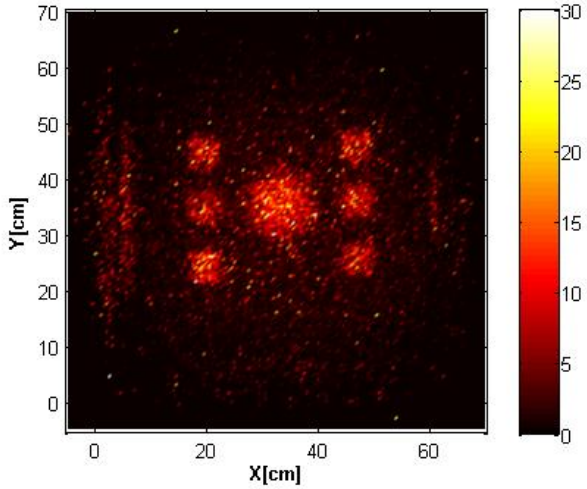
LANL and Khufu's Pyramid muon tomography system

	Institution	Detector
USA	LANL	multi-filament proportional chambers
	FIT	GEM
Russia	IHEP	Drift chamber
Italy	INFN	Scintillator and Drift chamber
Canada	AECL(CRIPT)	Scintillator and Drift chamber
UK	AWE	RPC

The “TUMUTY” (Tsinghua University Muon Tomography)



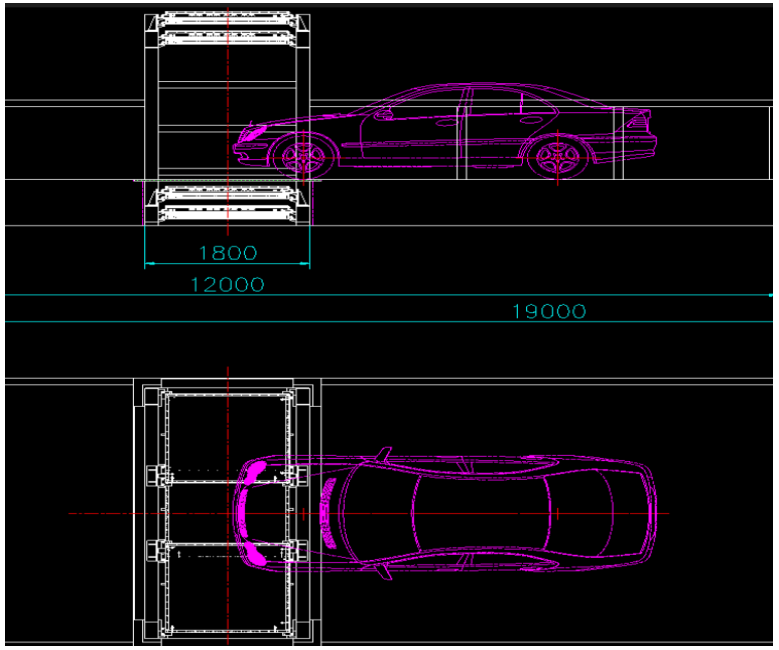




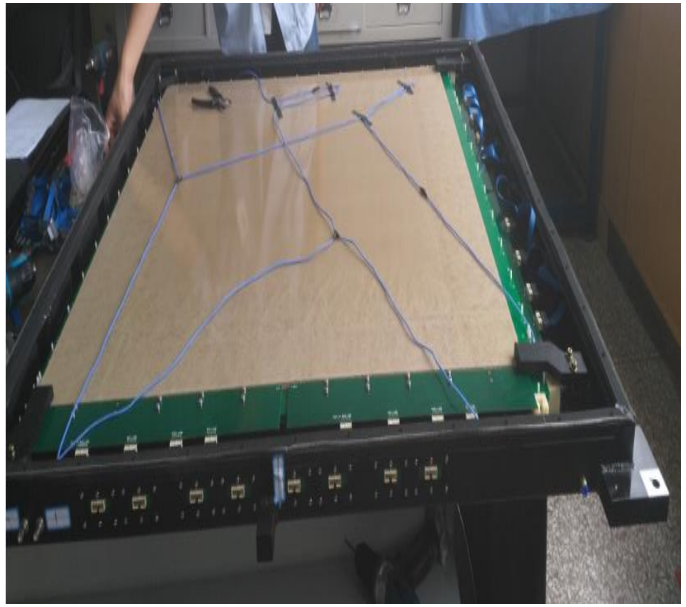
The “TUMUTY” system and imaging results

- Height: 3 m
- 6 groups of detectors
- Each group includes 2 MRPCs, can realize the 2D readout.
- Detector area: 736mm×736mm

Car detection and big sensitive area MRPC



Car detection project



Advantage of MRPC:

1.Easy to production

2.High efficiency

3.Low cost

4.Large area production

Limit of MRPC:

1.Need gas flow all the time

2.GWP gas pollution

More smarter structure：

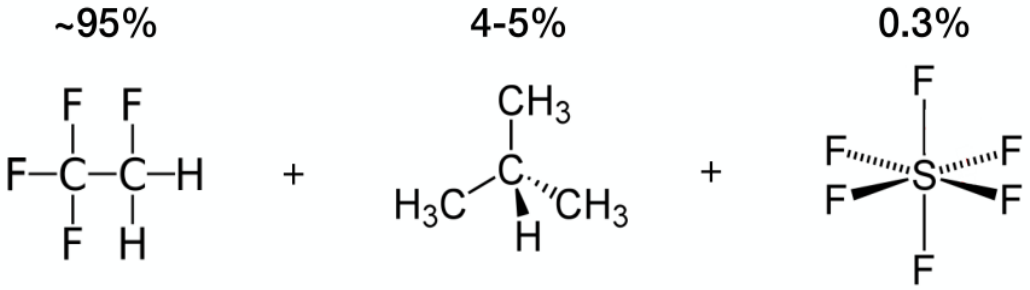
1.Sensitive area reach $1m^2$

2.Single MRPC can realize 2D readout

3.Put the fine-fine encoding readout device into the gas box.

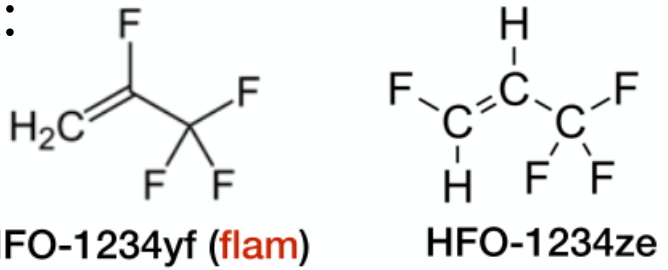
Motivation

Standard gas:



Eco-gas replacements:

-for Freon:



- 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.

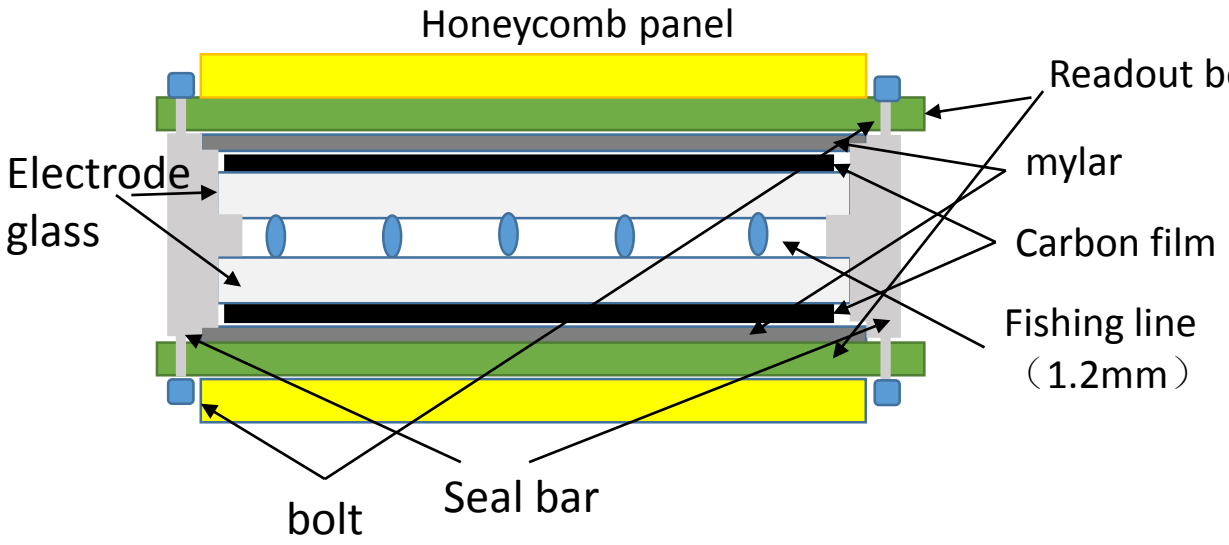
Cons, higher price

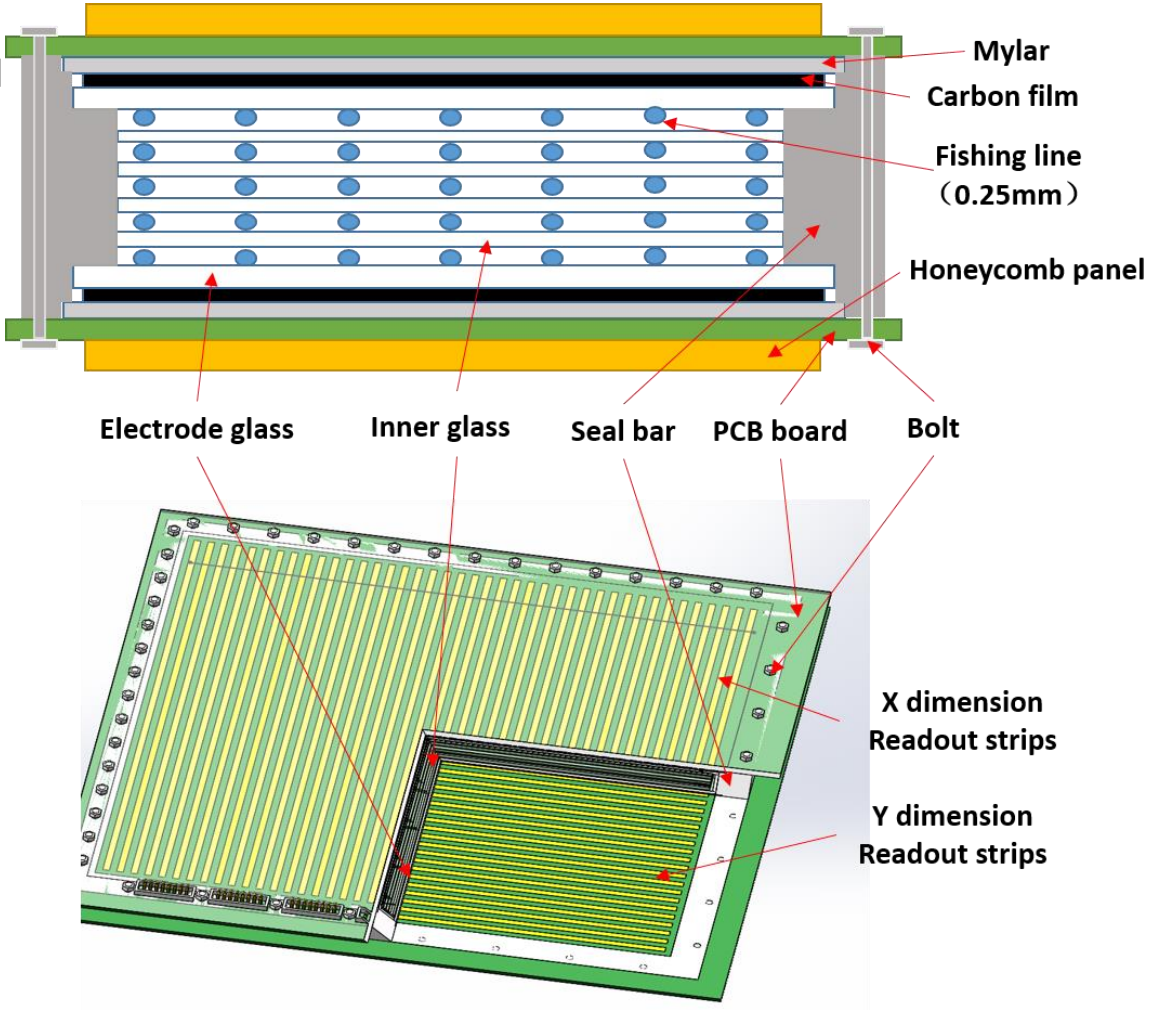
MRPCs and RPCs with HFO are still in study

SMRPC is so come into being. Improve the sealed characteristics of MRPC work with low gas flow or without gas flow, to reduce the cost and GWP effect.

Schemes

- SRPC or SMRPC





- SRPC, simple structure, cost-effective, less volume and weight
- SMRPC, high efficiency, good space resolution and time resolution

Technical difficulties

- **Technical difficulties**

1、The outgassing performance of the detector structure material.

2、 Search for small deflation glue；

Try to use the material, such as the glass, fishing line, glue and so on, with low air releasing property.

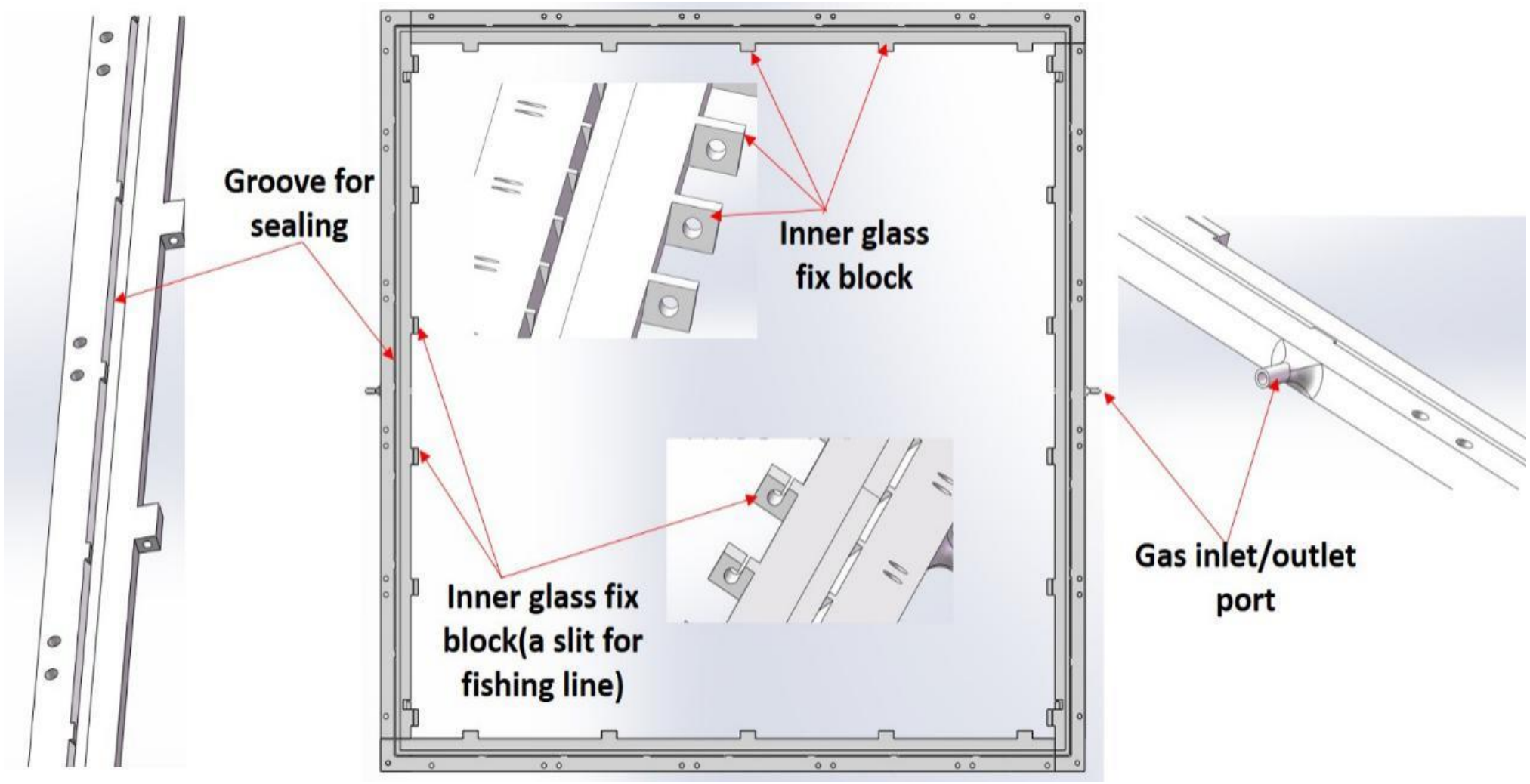
- To determine the monitoring performance

1、 Look for the most representative indicators to the performance changes of SMRPC

2、 Find the failure threshold of the index；

A lot of experiments are needed.

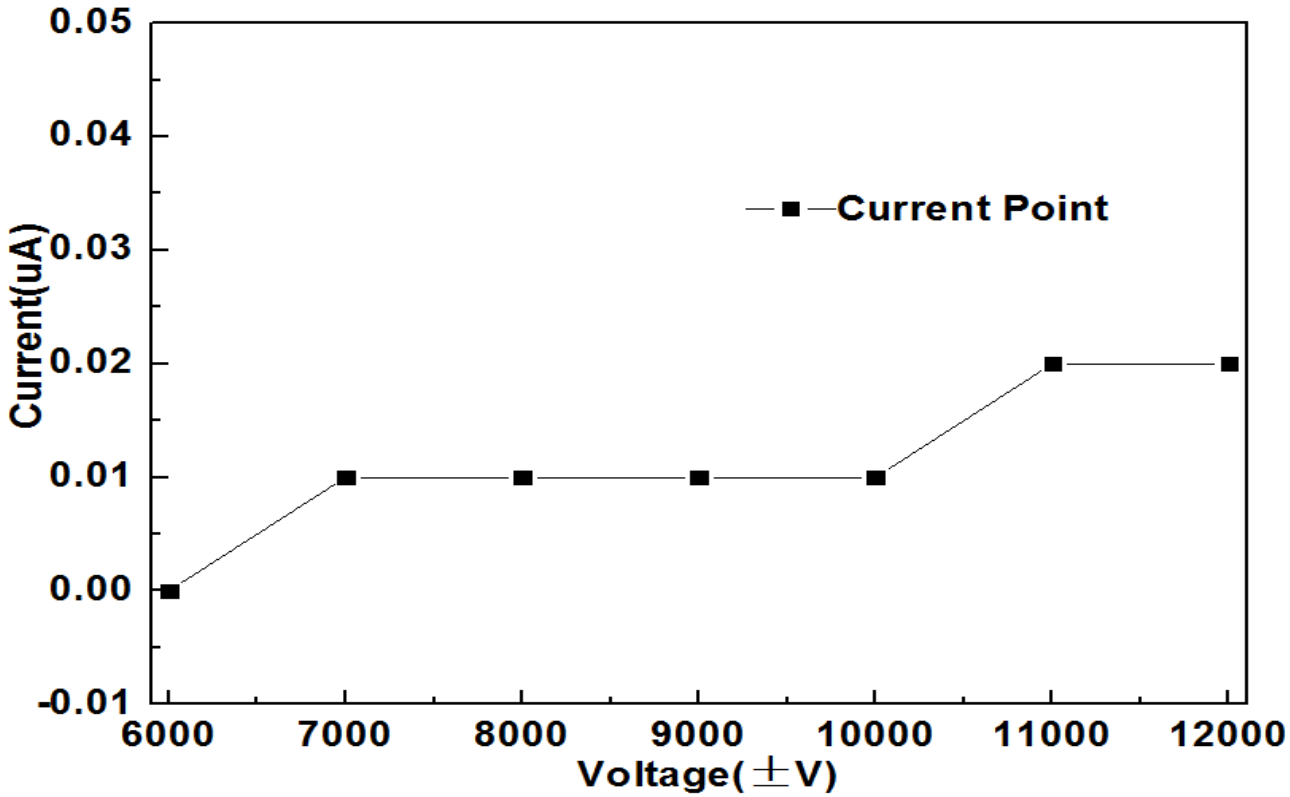
The sealing bar designed



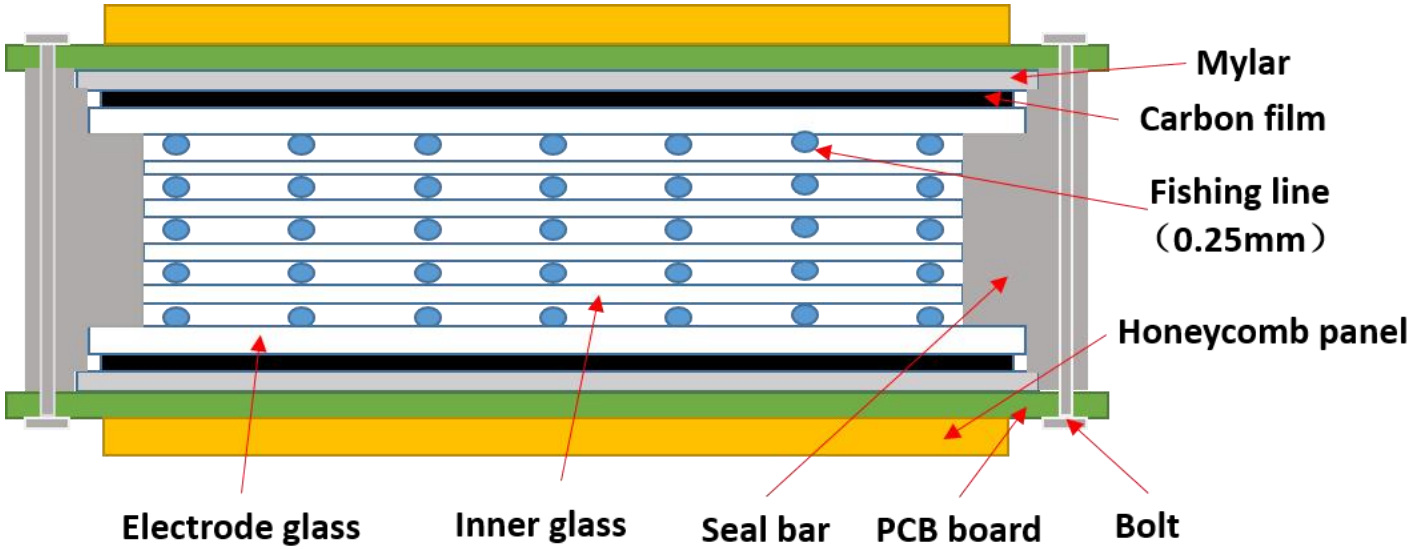
The sealing bar designed

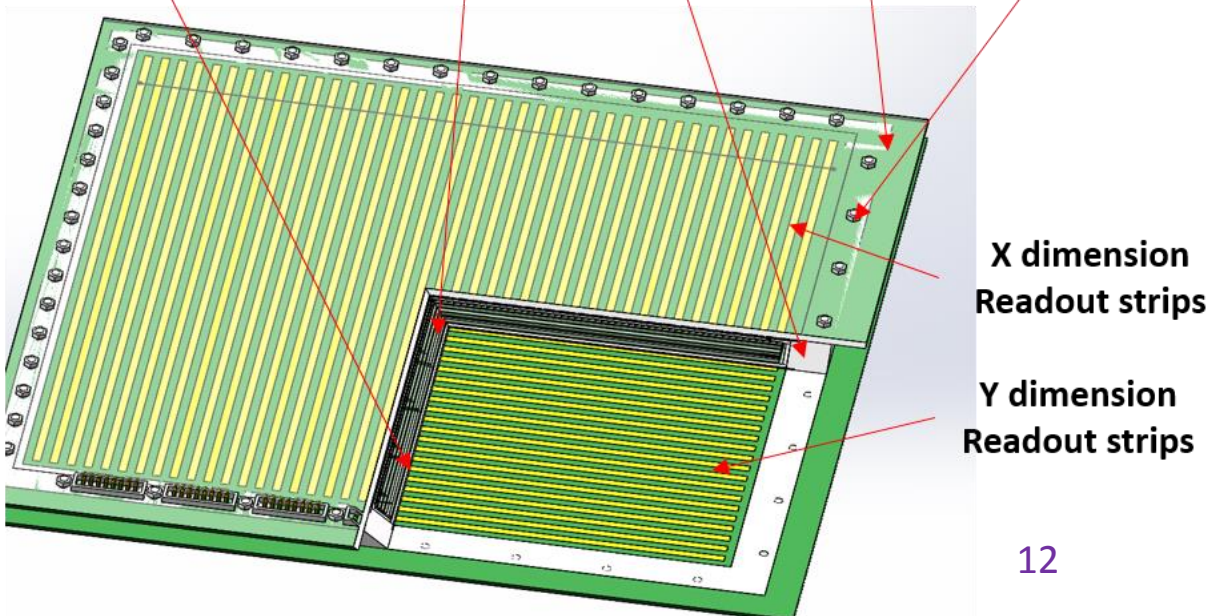
- Material---- Class ABS resin

High voltage resistance test



The final design

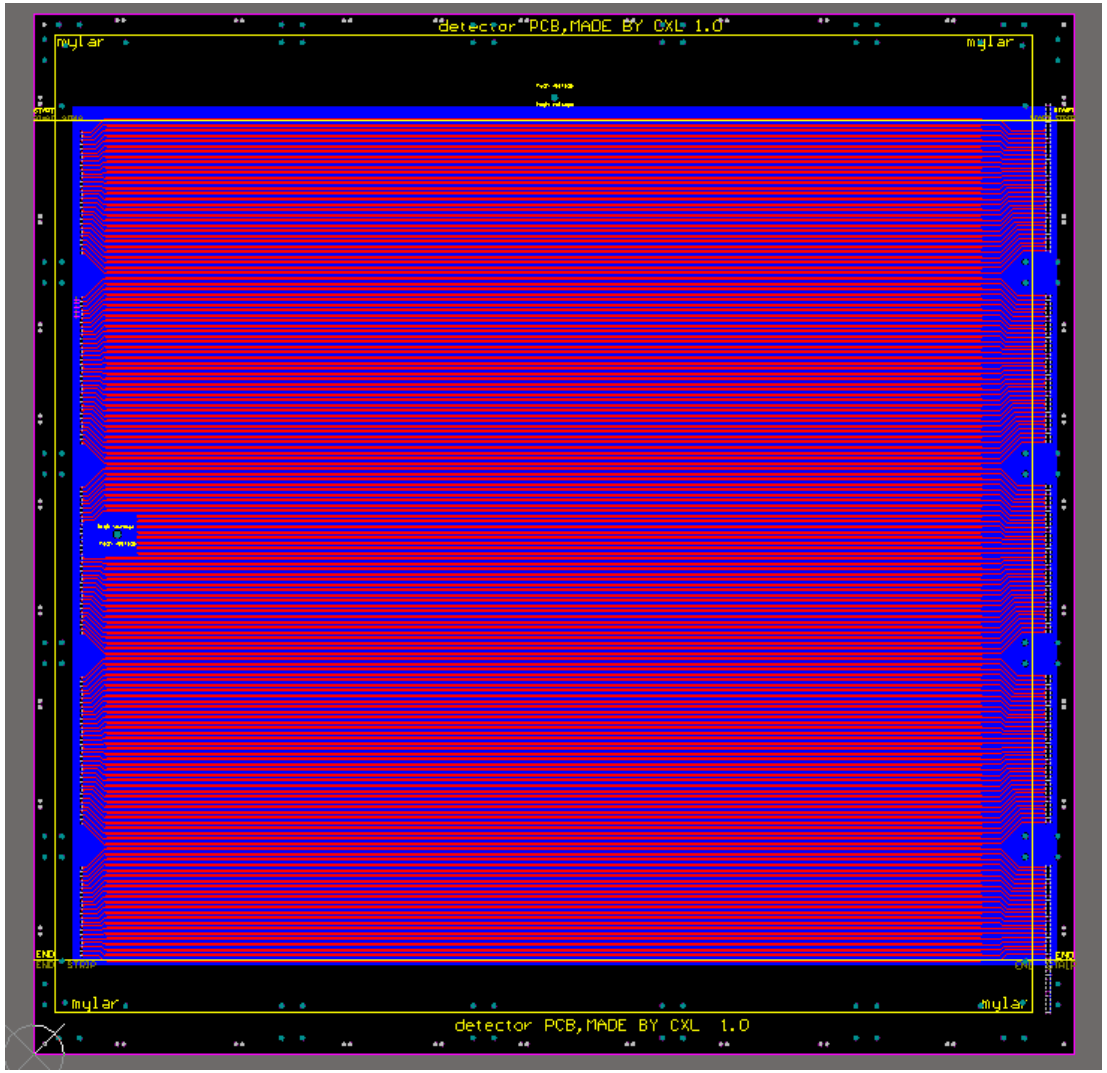


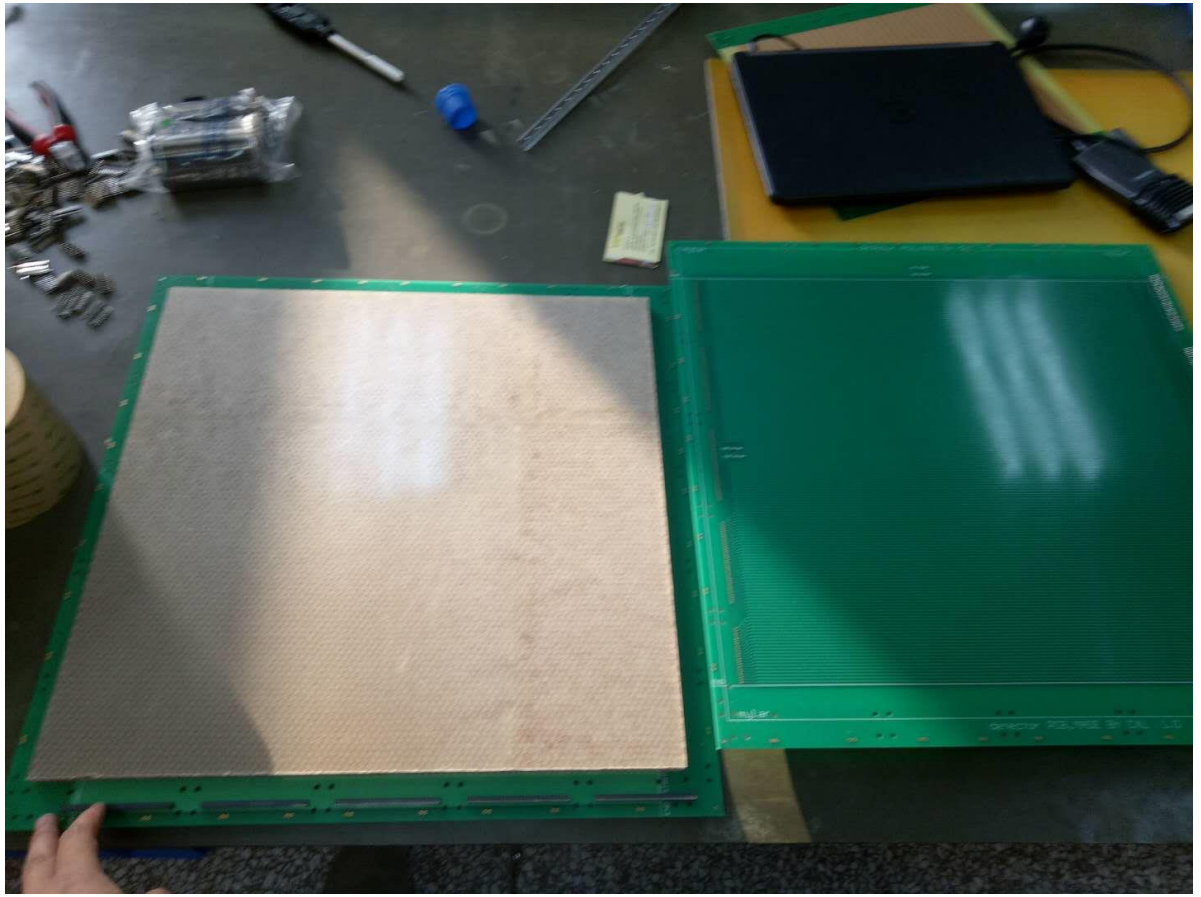


Parameters

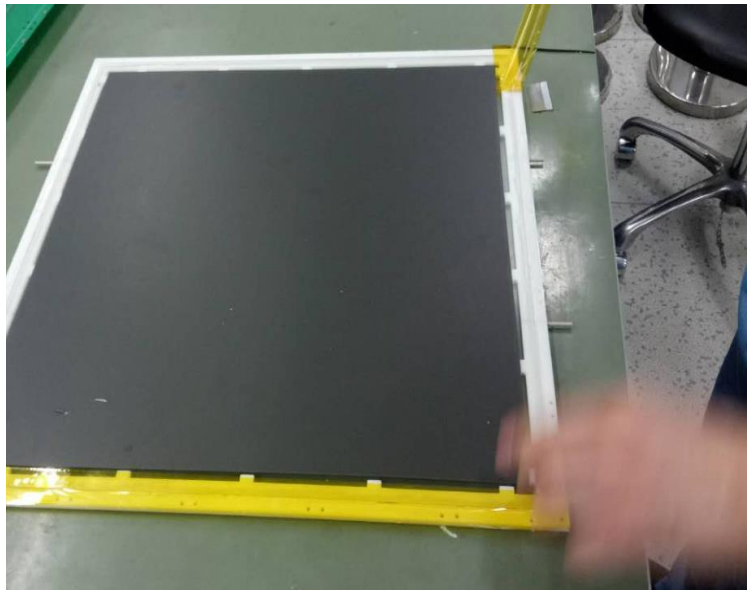
Dimensions	Value
Inner glass size	420*420mm^2
Outer glass size	470*470mm^2
Glass thickness	0.7mm
Gas gap thickness	0.25mm
Number of gas gaps	5
PCB size	500*500mm^2
Sensitive area	420*420mm^2

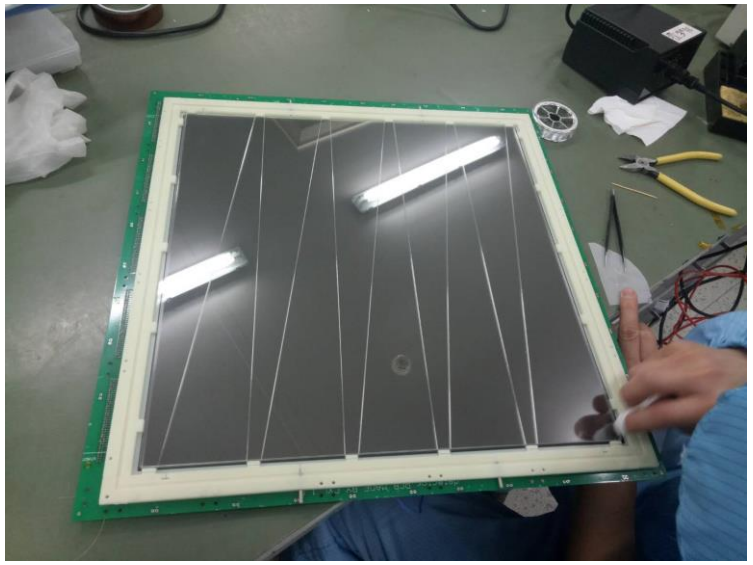
The readout board

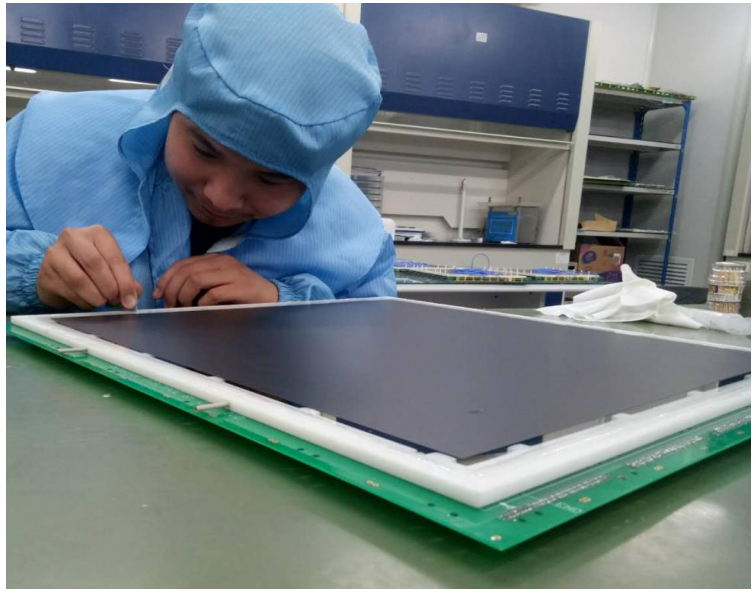


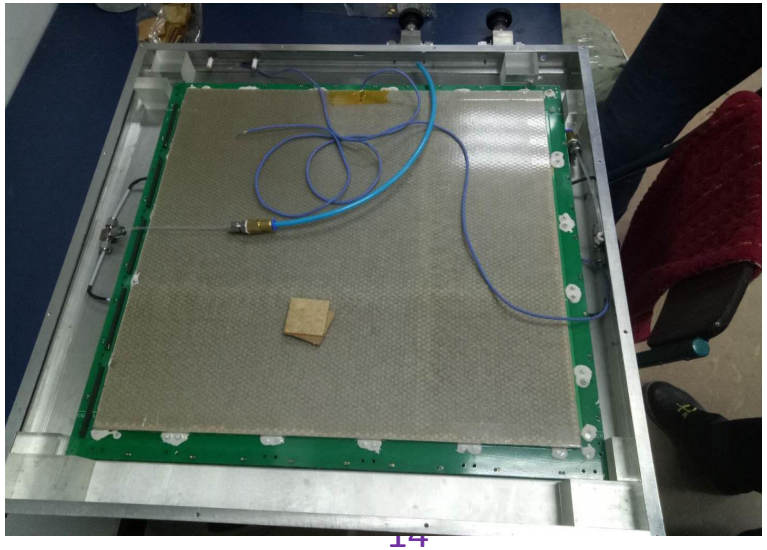


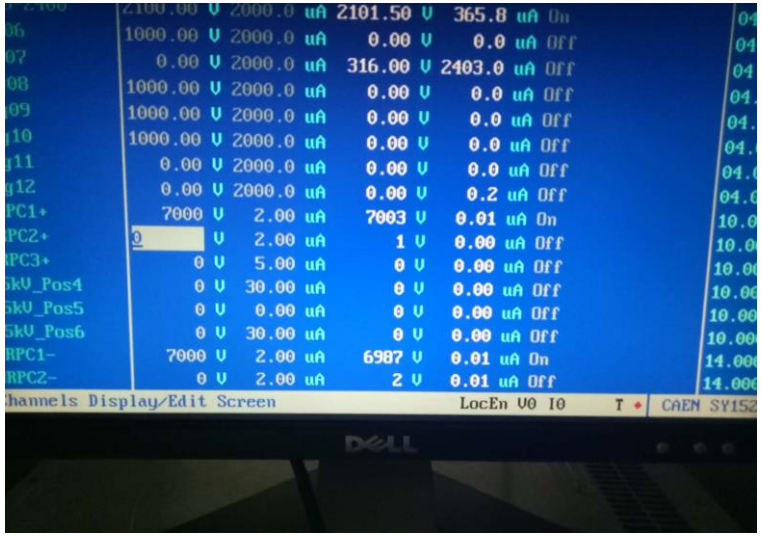
The process of assembly



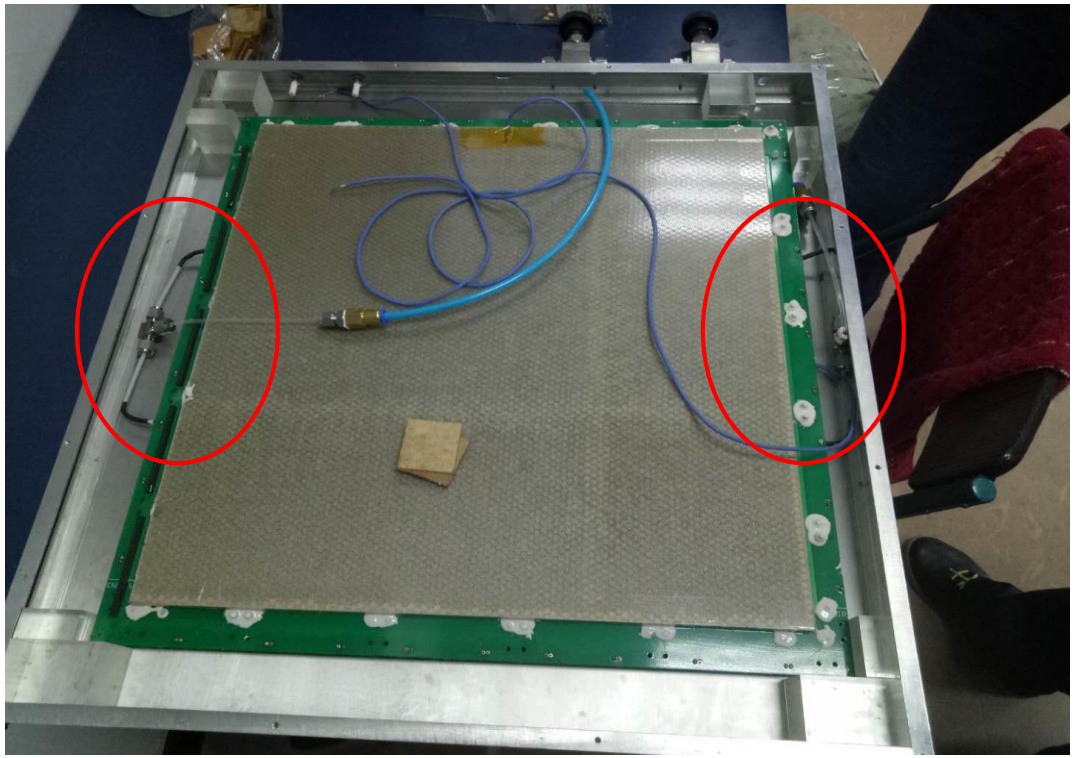




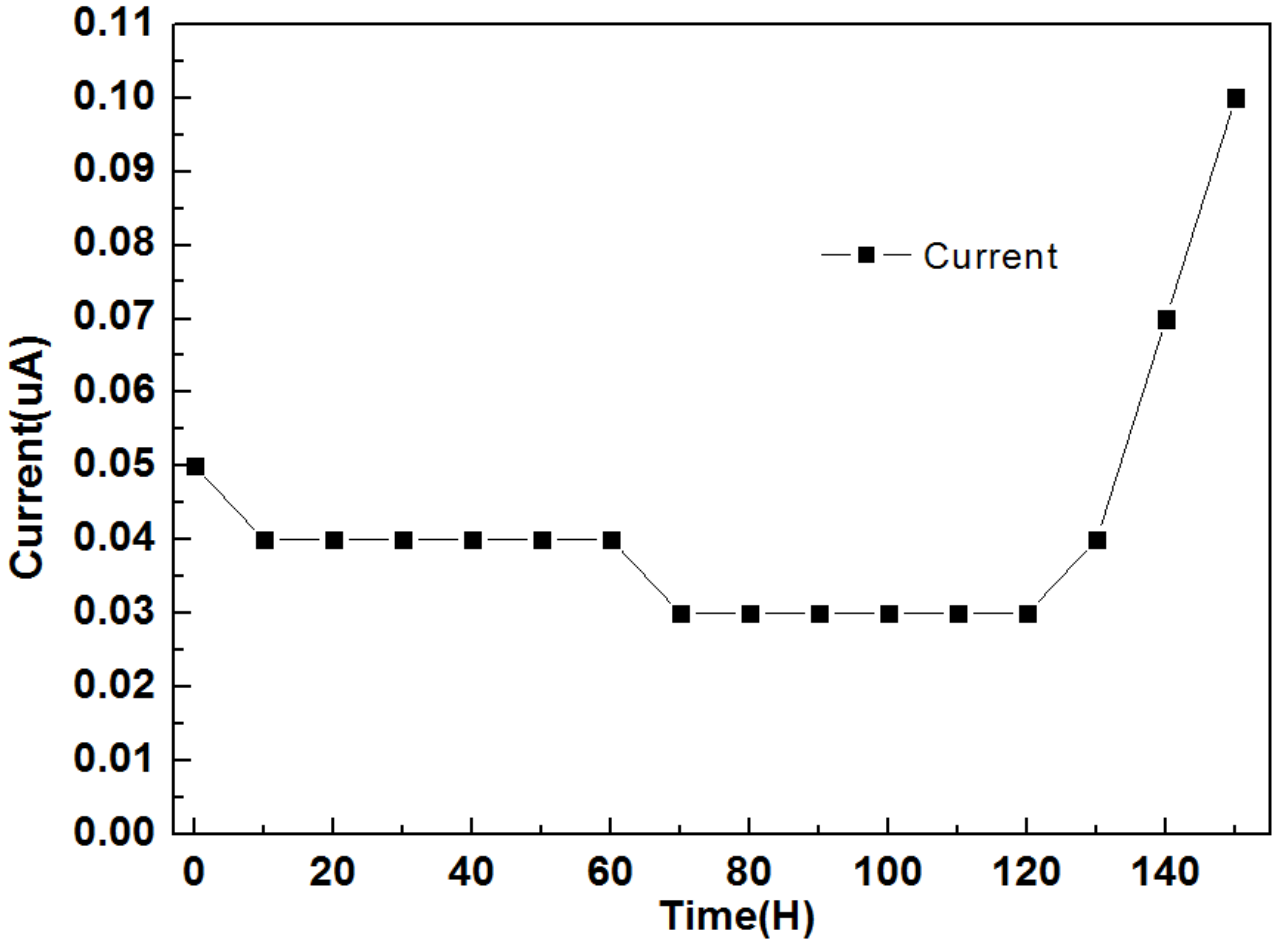




The first version and it's performance(3ml/min)



With two inlets and two outlets



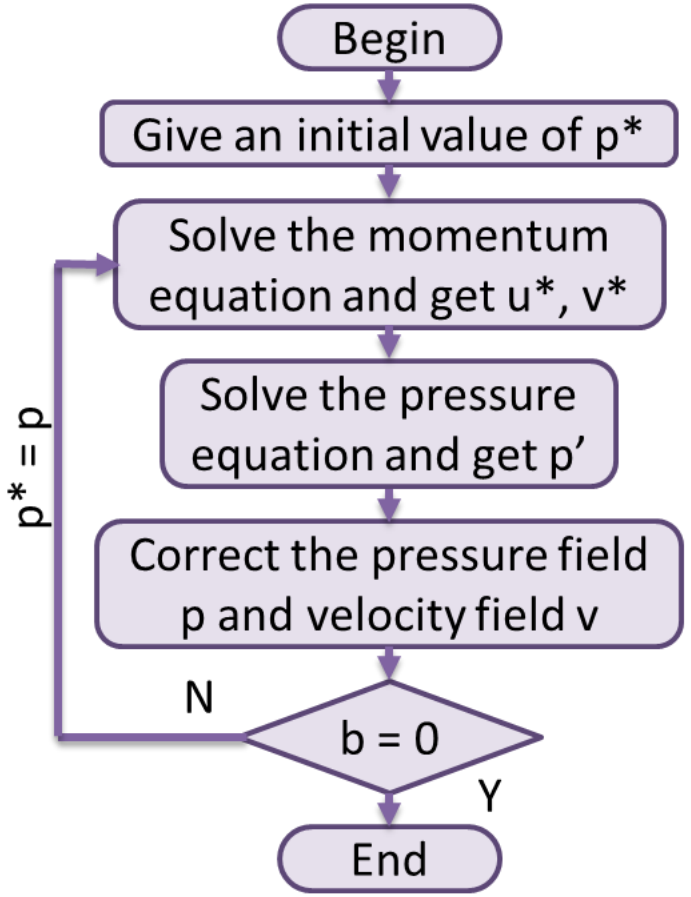
Study on Gas Flow in Detector with fluent

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

Control function

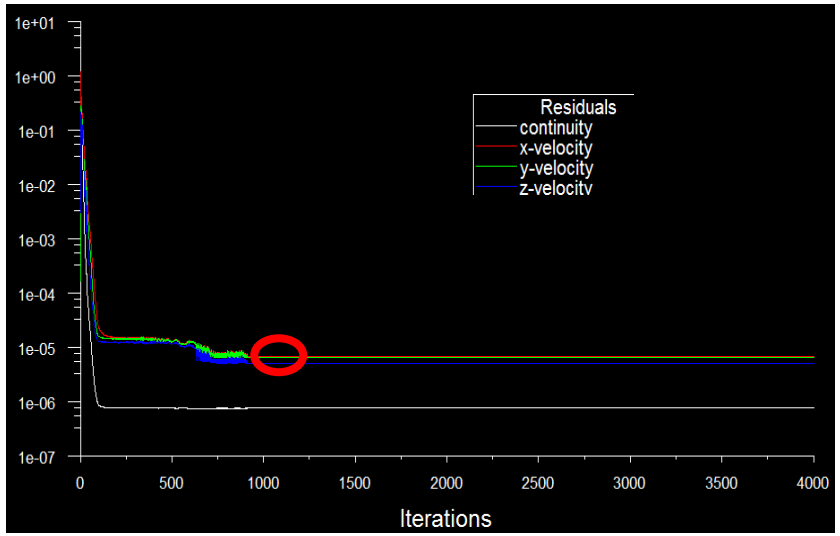
$$\underbrace{\frac{\partial(\rho\phi)}{\partial t}}_{\text{Unsteady}} + \underbrace{\nabla\cdot(\rho\vec{v}\phi)}_{\text{Advection}} = \underbrace{\nabla\cdot\left(\Gamma_\phi\nabla\phi\right)}_{\text{Diffusion}} + \underbrace{S_\phi}_{\text{Source}}$$

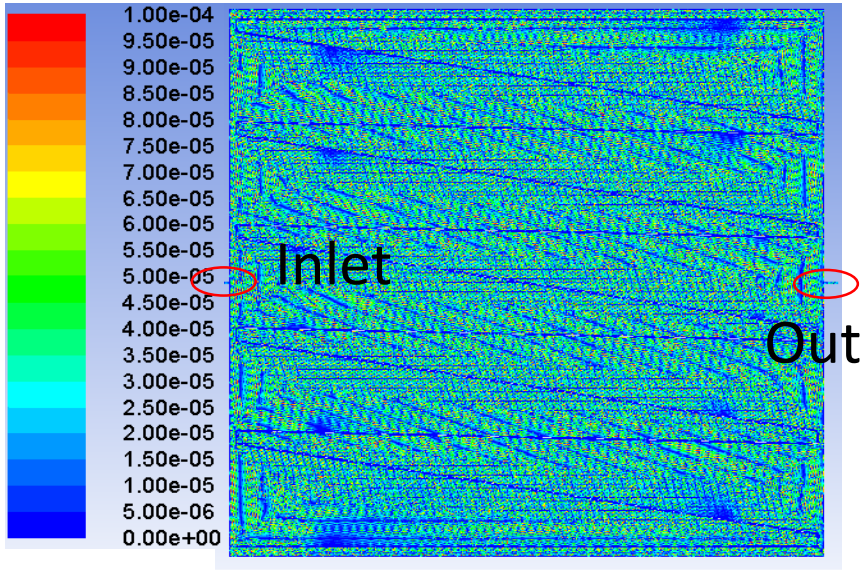
Finite Element Method (FEM) ; SIMPLE algorithm (Semi-Implicit Method for Pressure-Linked Equations)



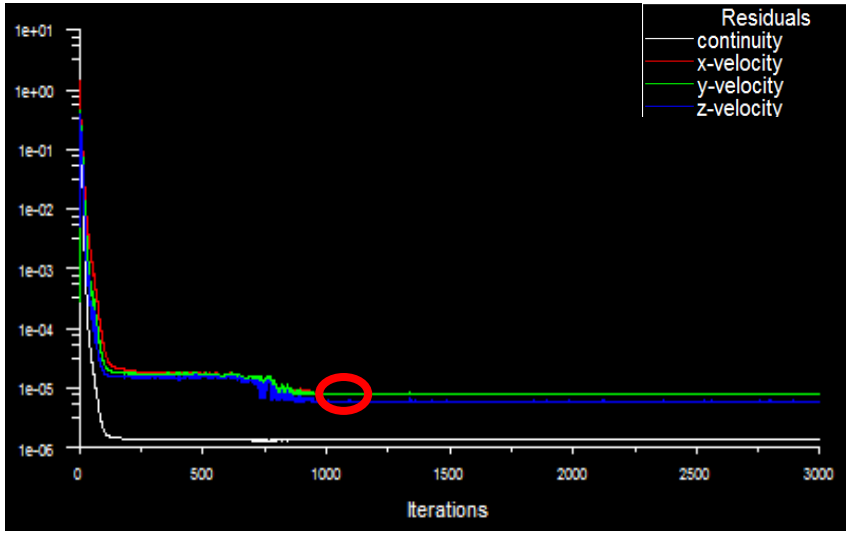
Simulation results (Velocity V at 30ml/min)

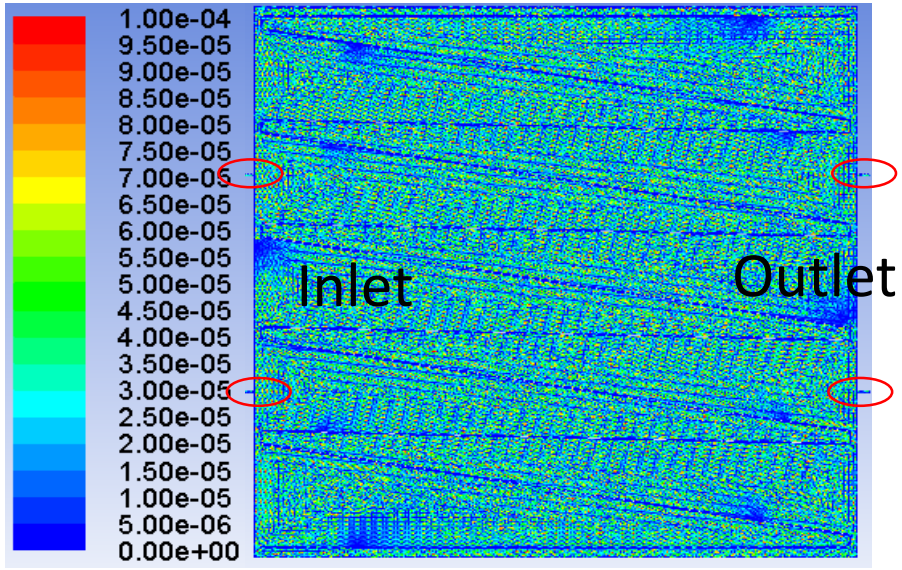
1hole 30ml/min





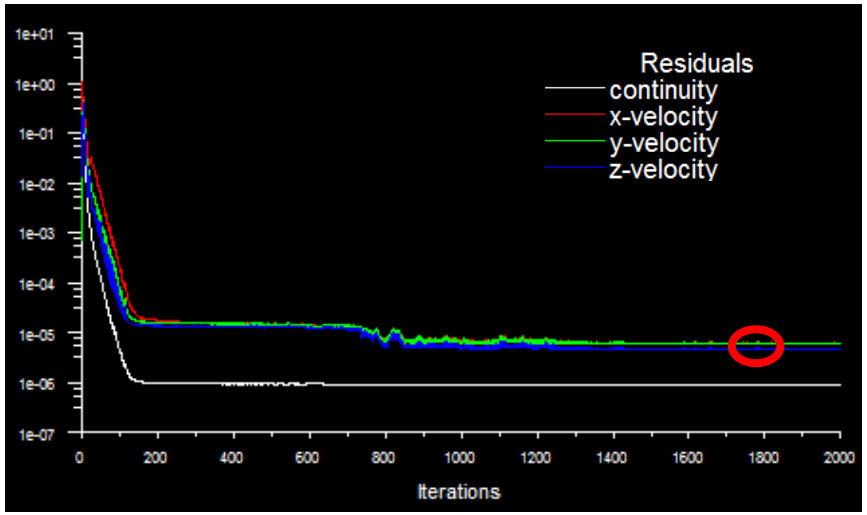
2hole 30ml/min

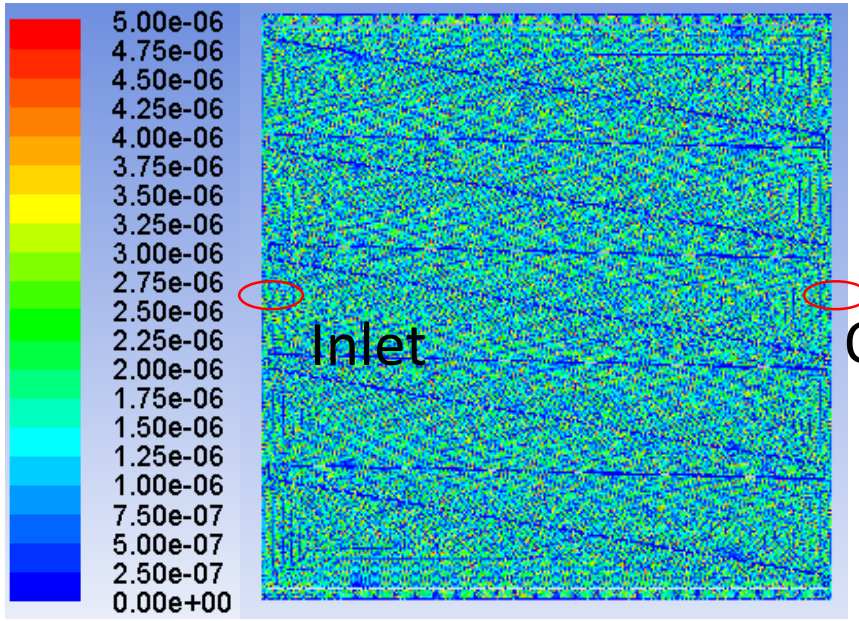




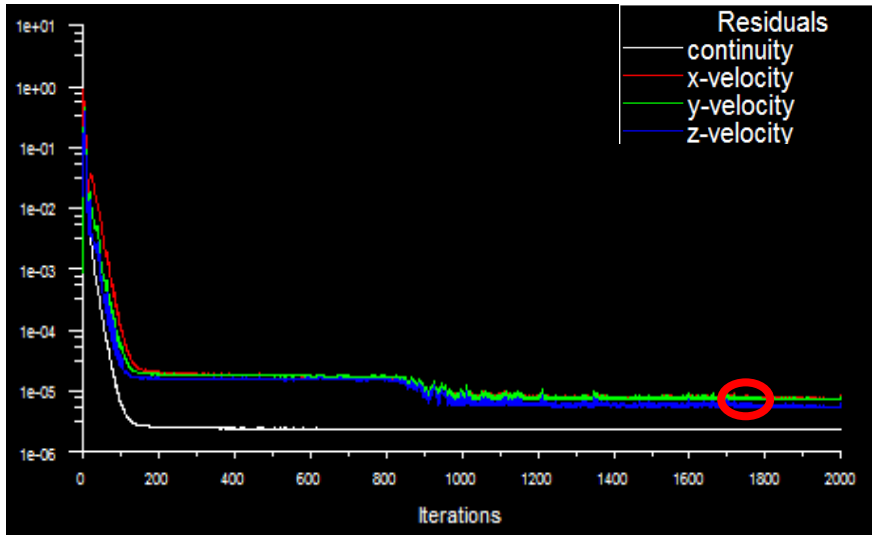
Simulation results (Velocity V at 3ml/min)

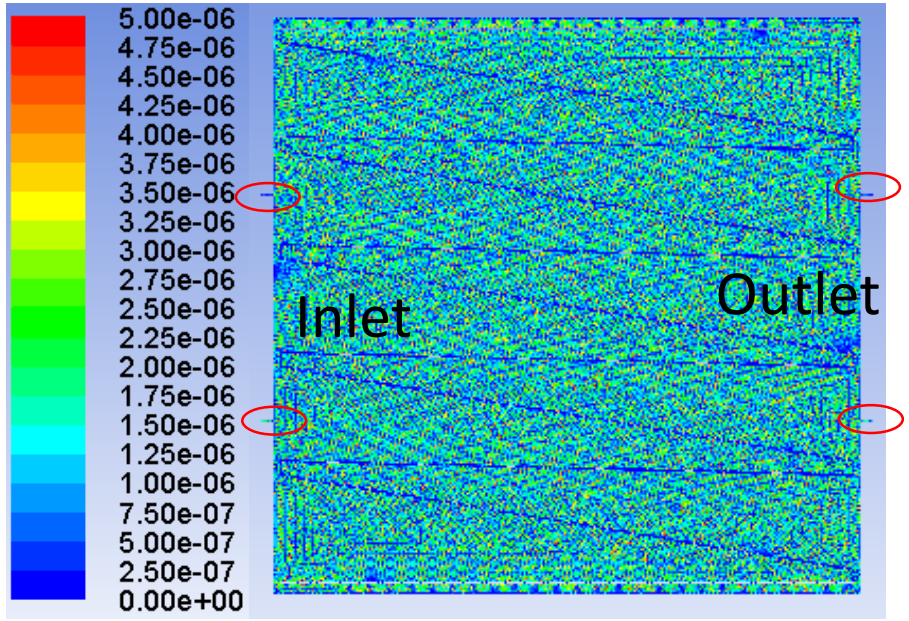
1hole
3ml/min





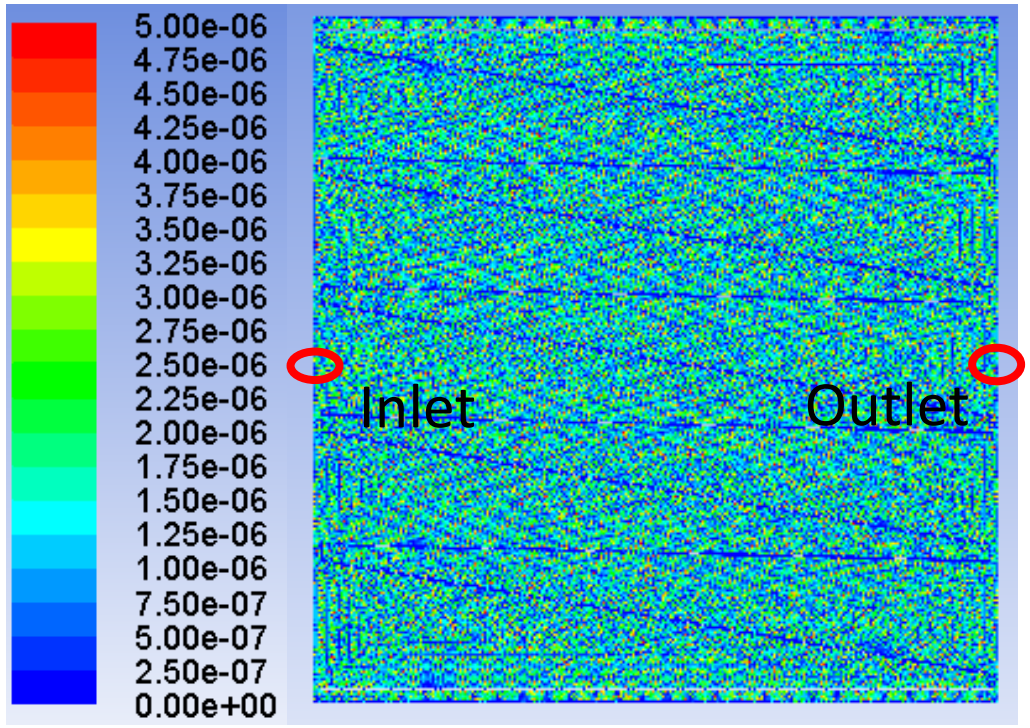
2hole
3ml/min

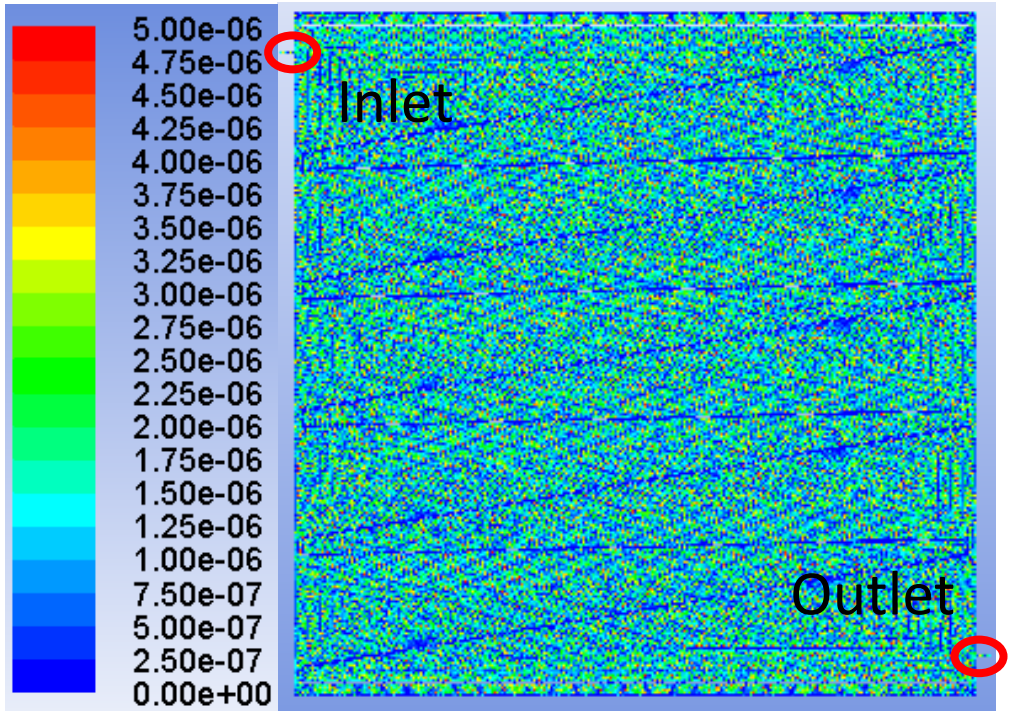




Simulation results

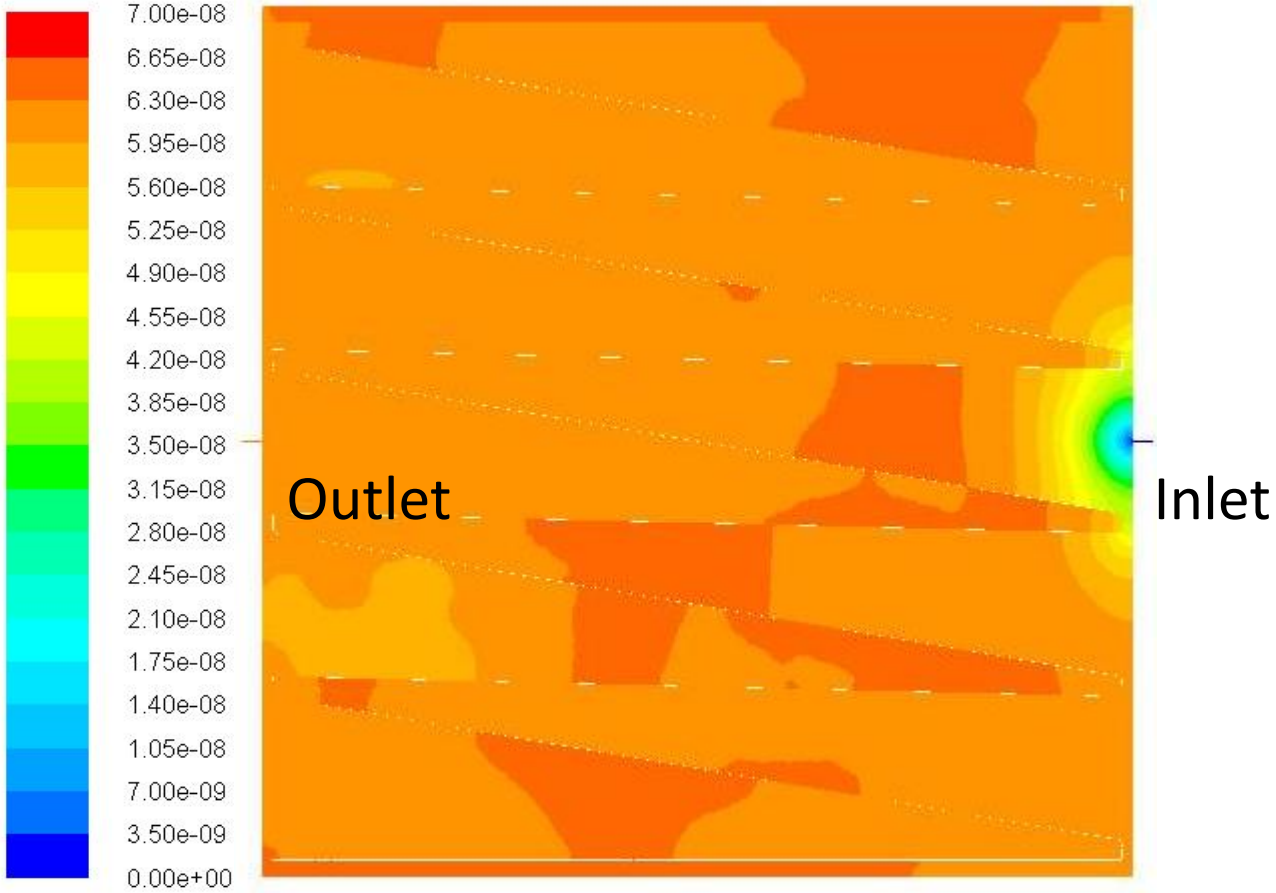
- The one inlet and outlet at different place



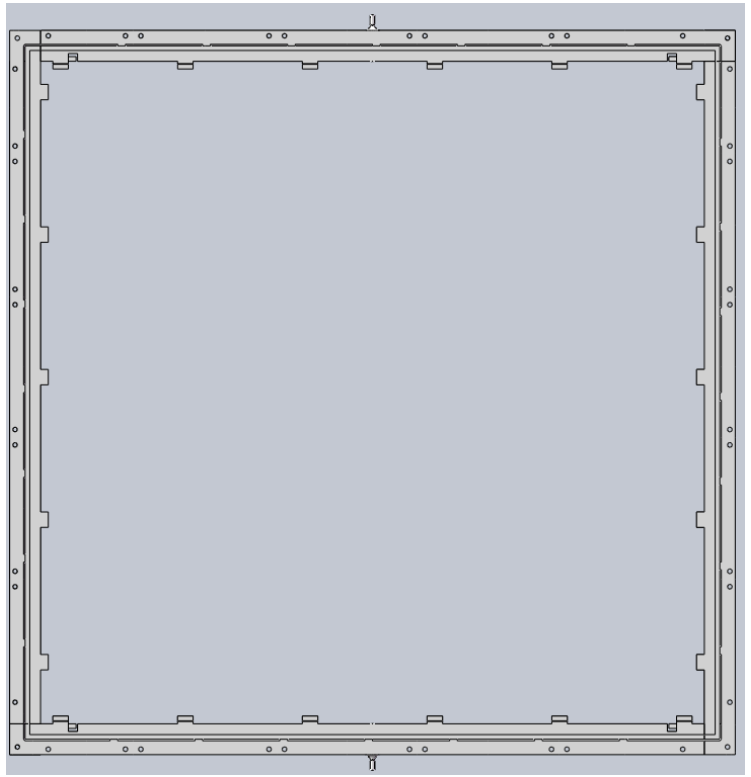


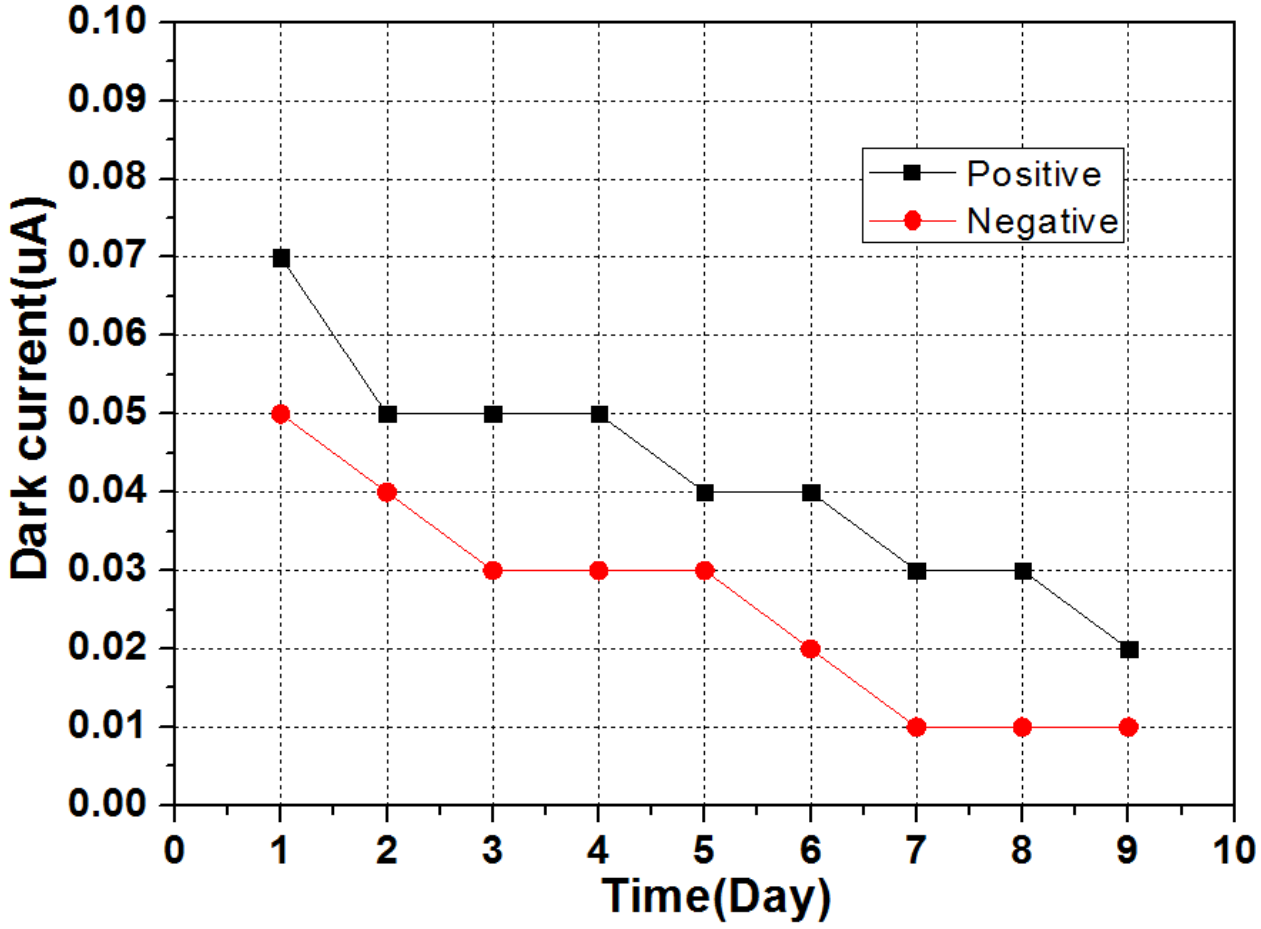
The distribution of pollutant concentration

1hole 3ml/min 0.5HZ/cm^2

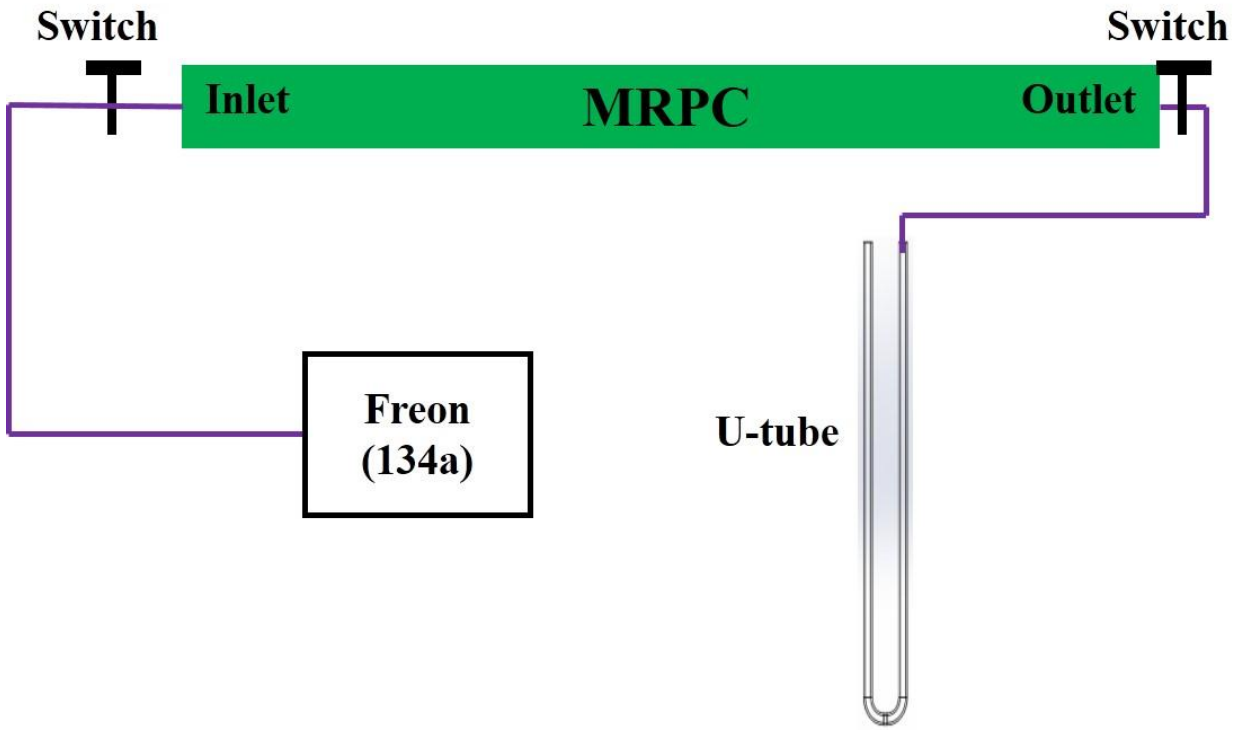


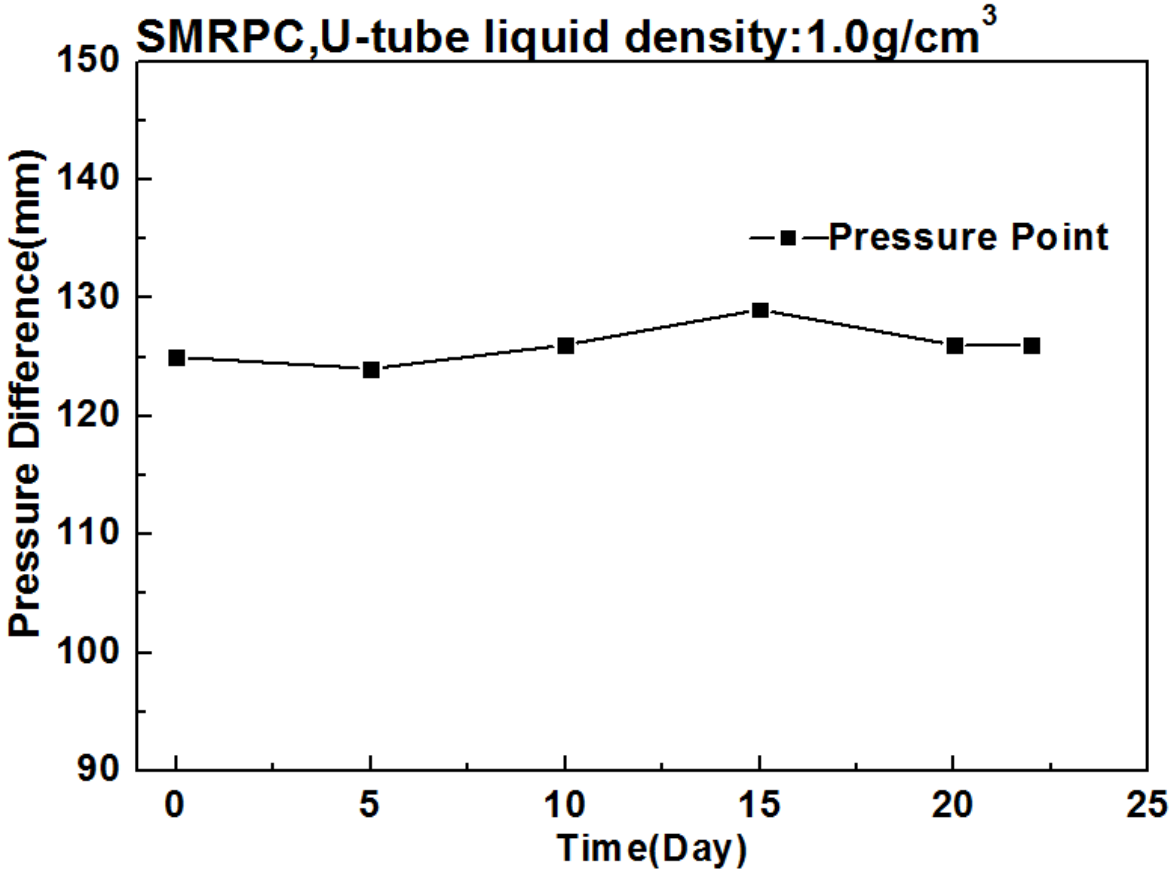
The improved version



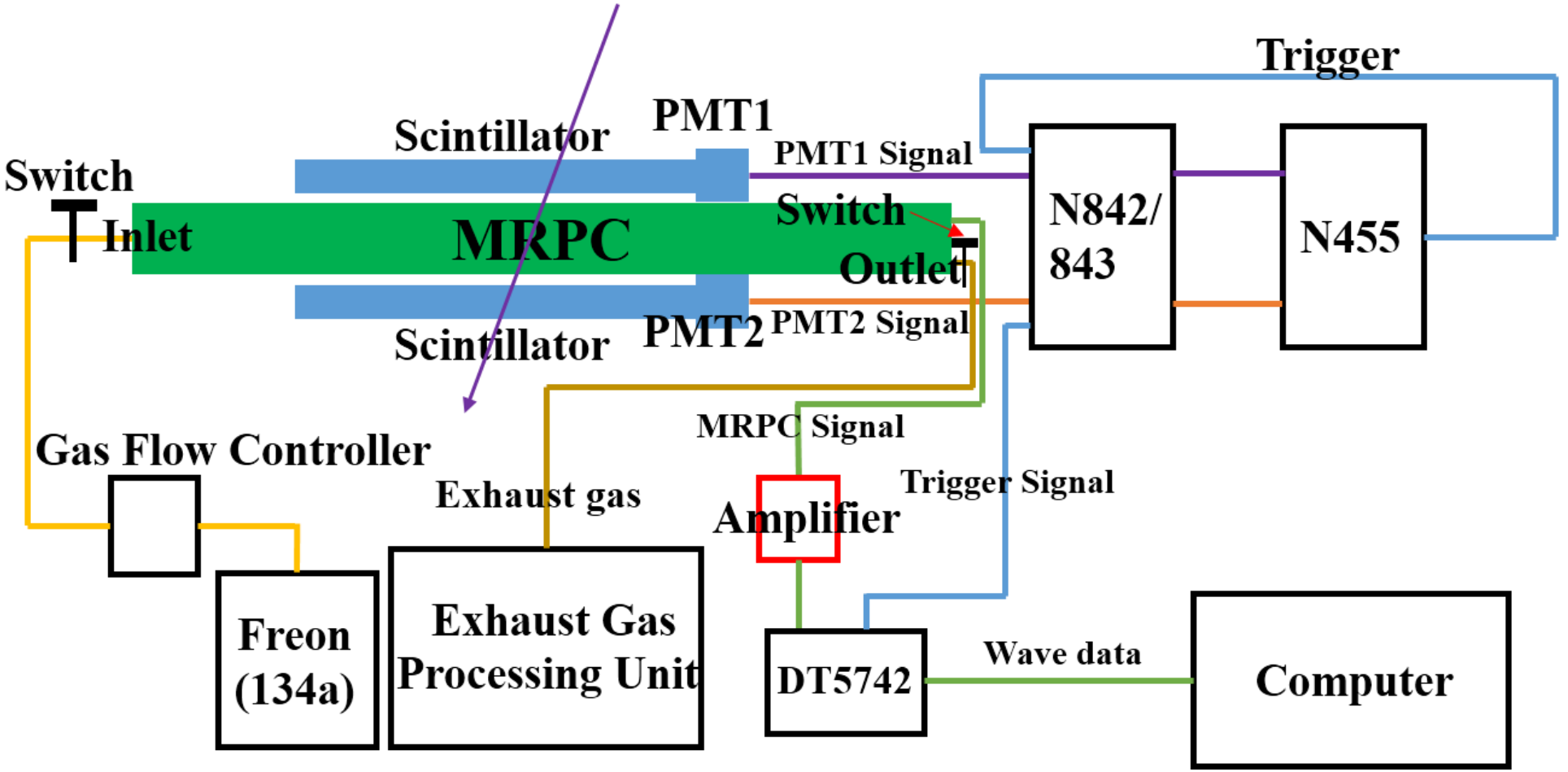


The schematic design of air tightness test





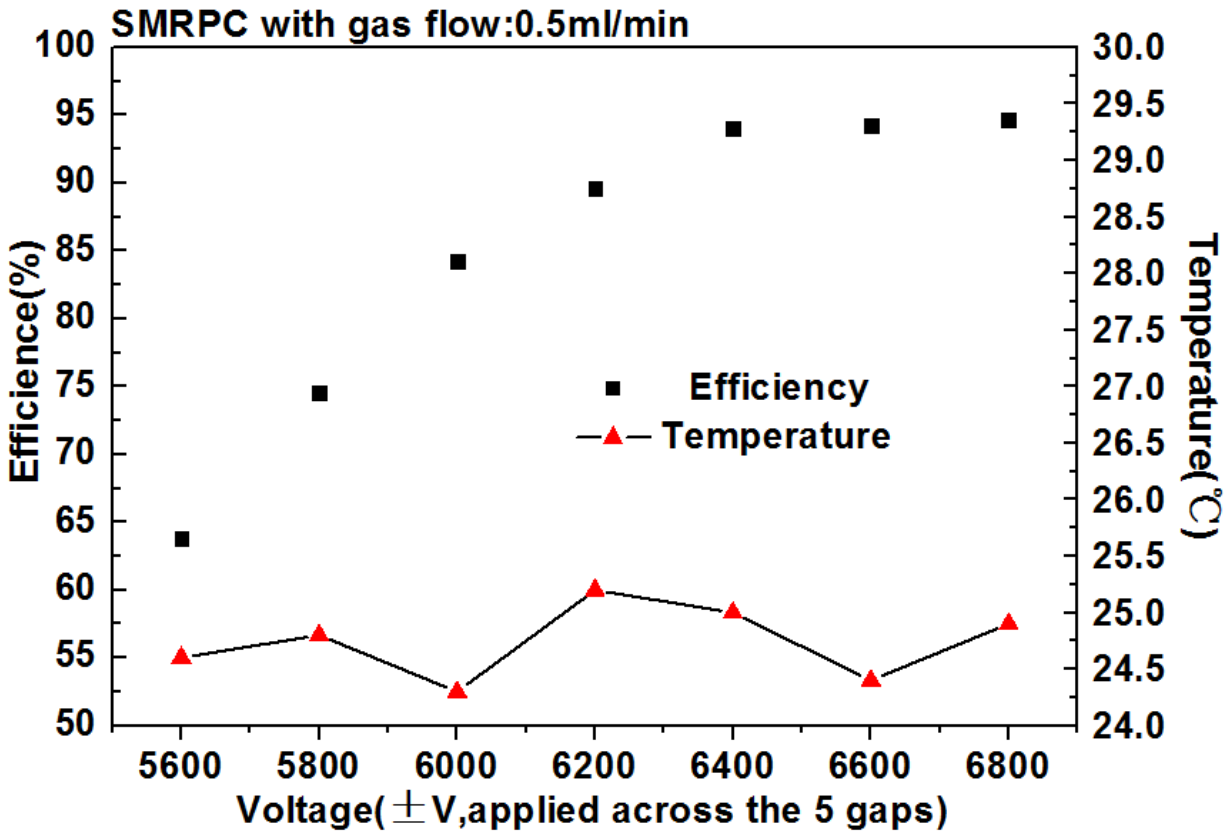
The schematic of Cosmic ray test system

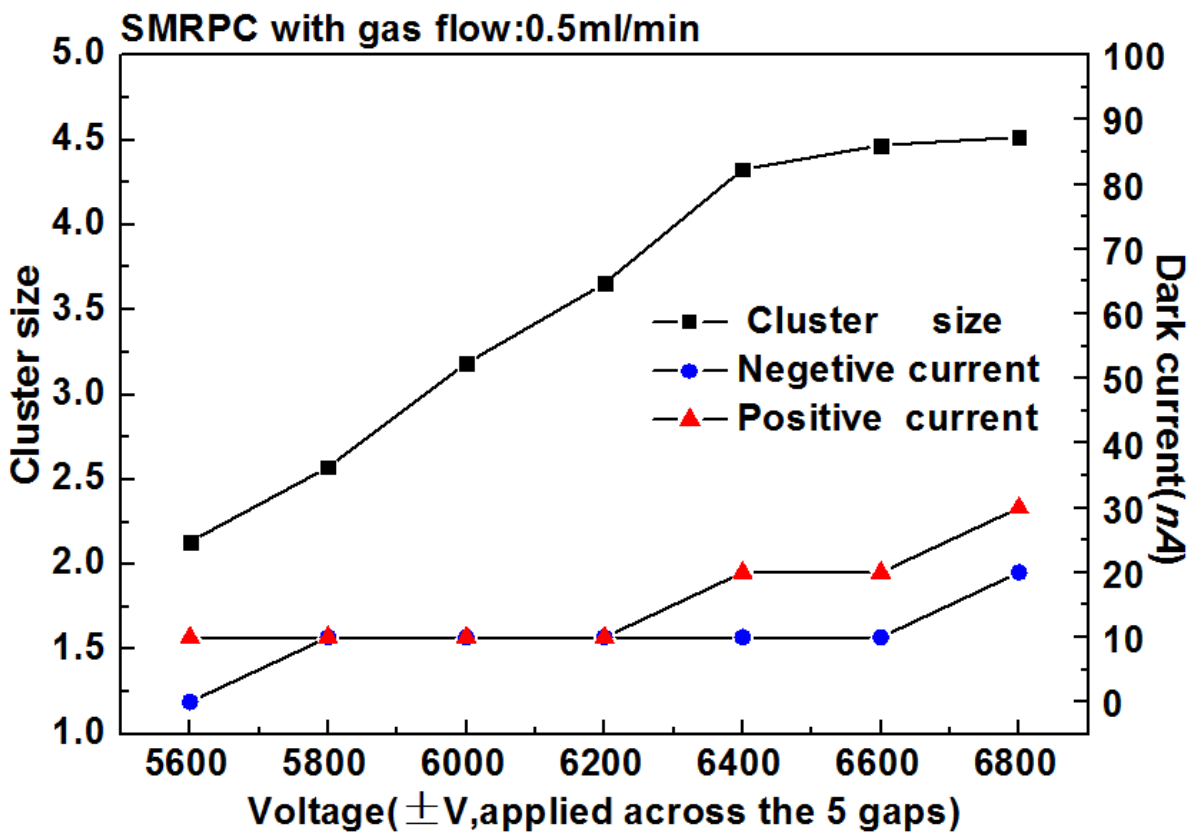


Amplifier: gain and bandwidth are 30 kΩ and 24 MHz

The performance of new SMRPC(Freon 100%)

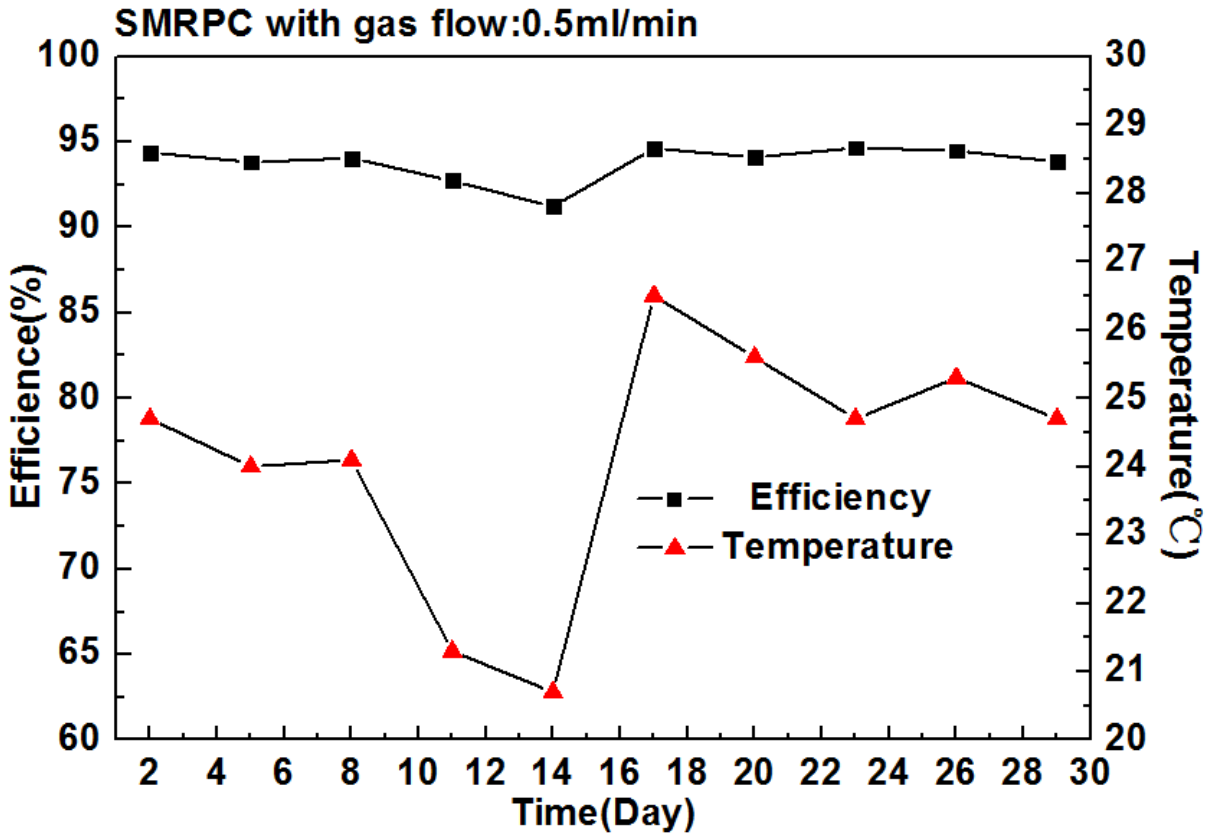
Gas flow speed is 0.5ml/min

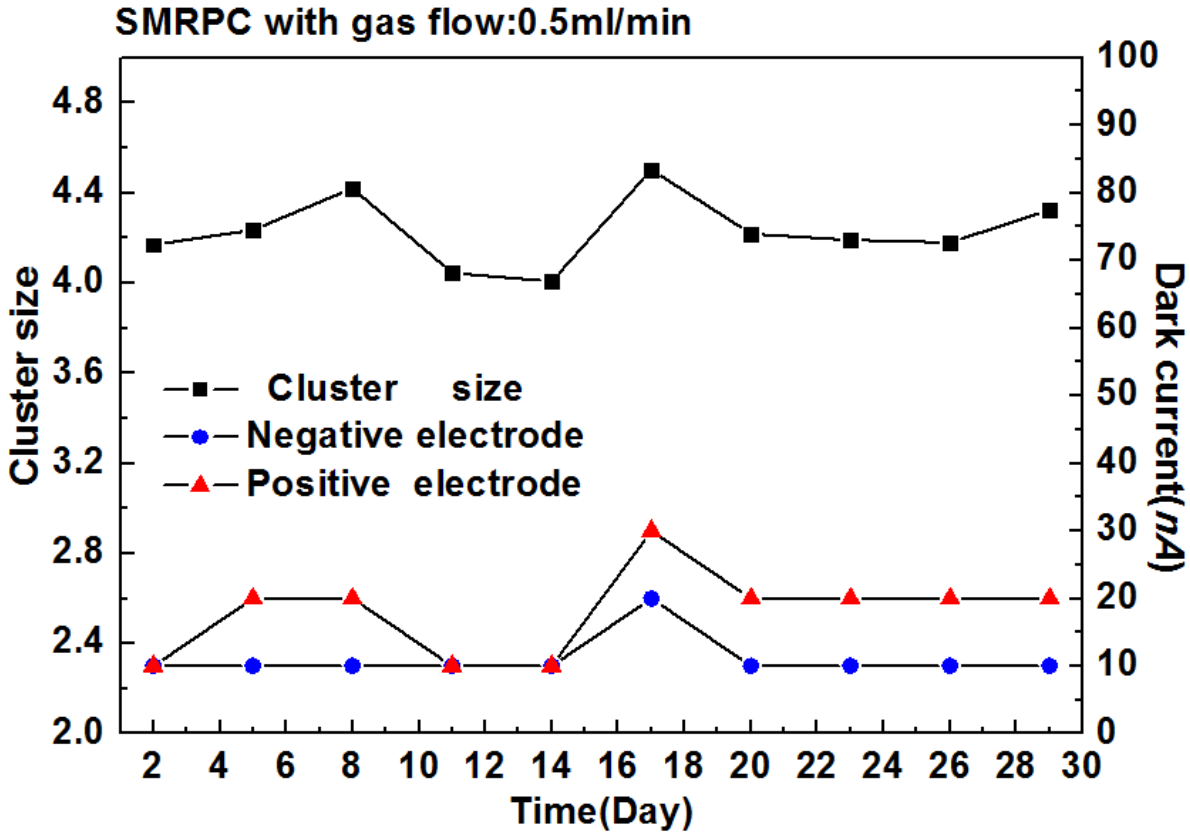




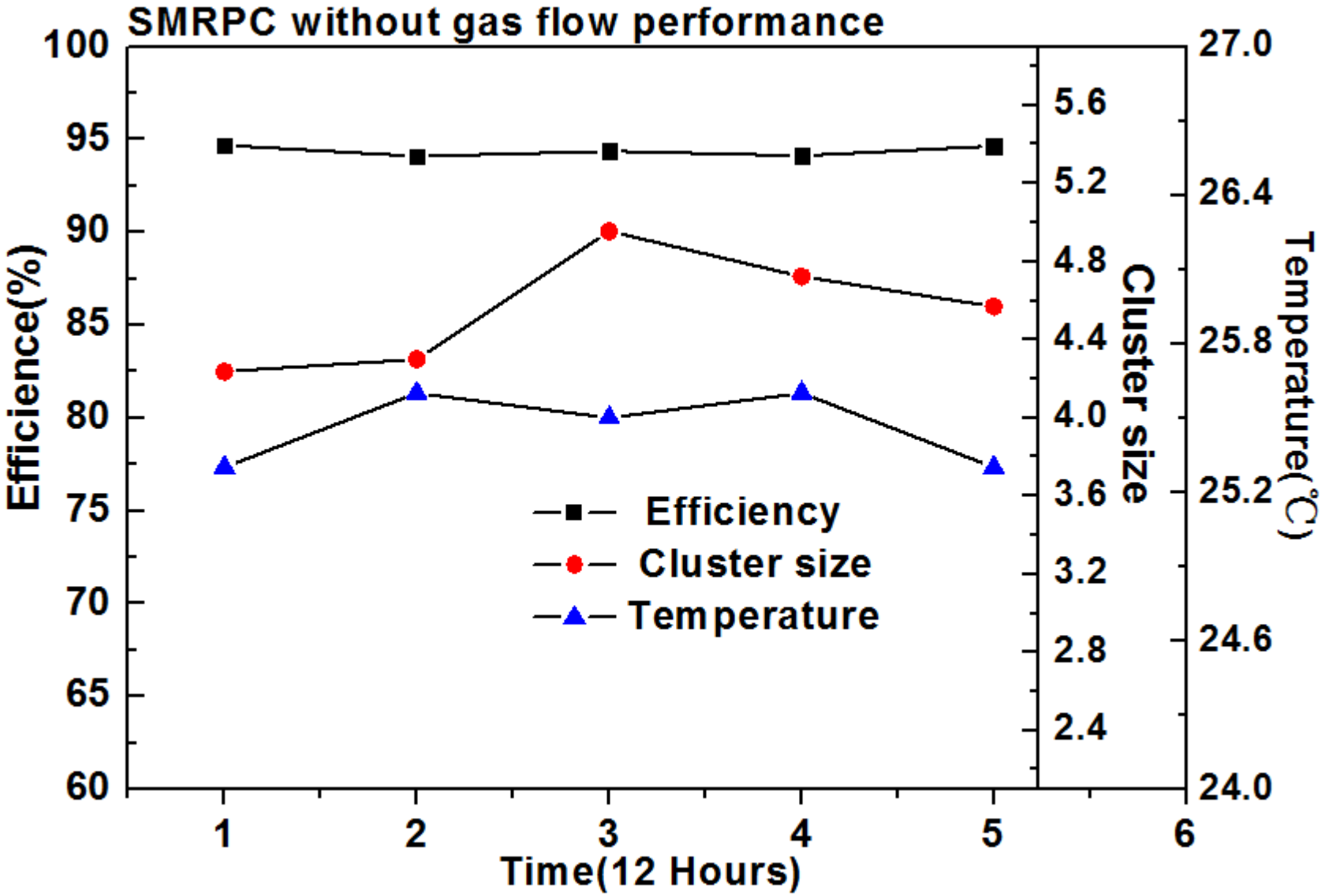
Stability test(Freon 100%)

Gas flow speed is 0.5ml/min

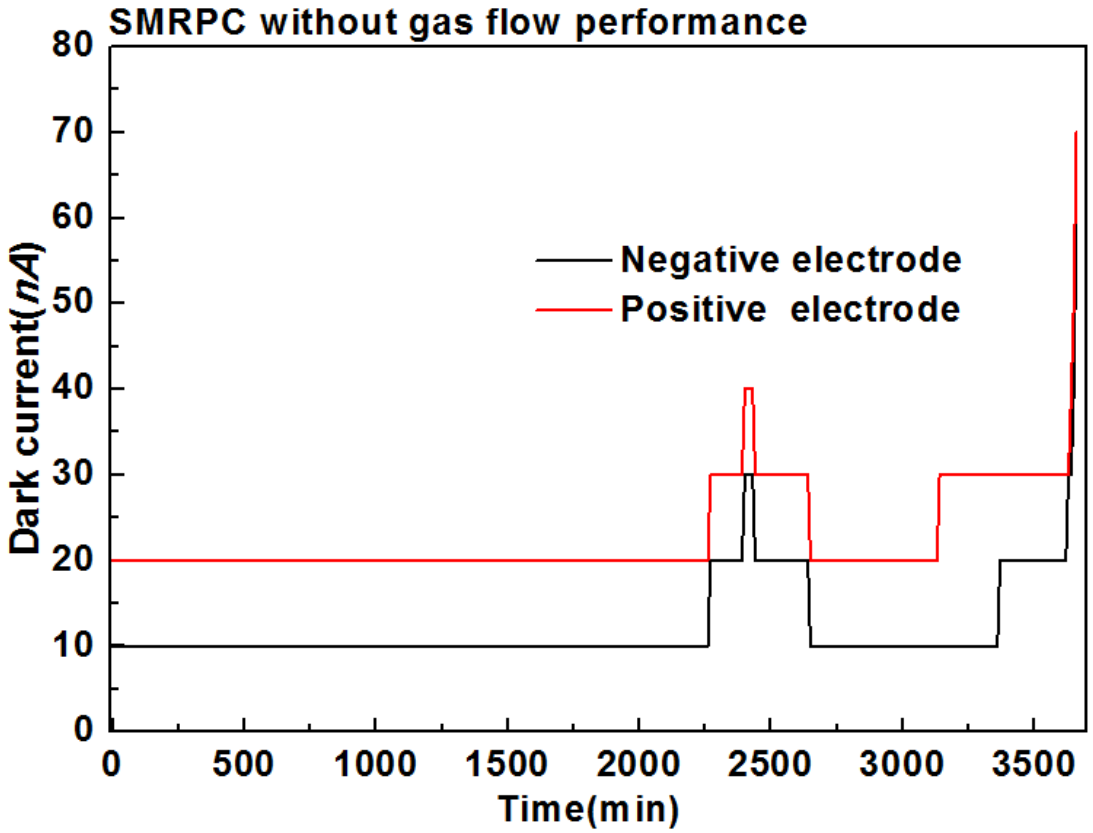


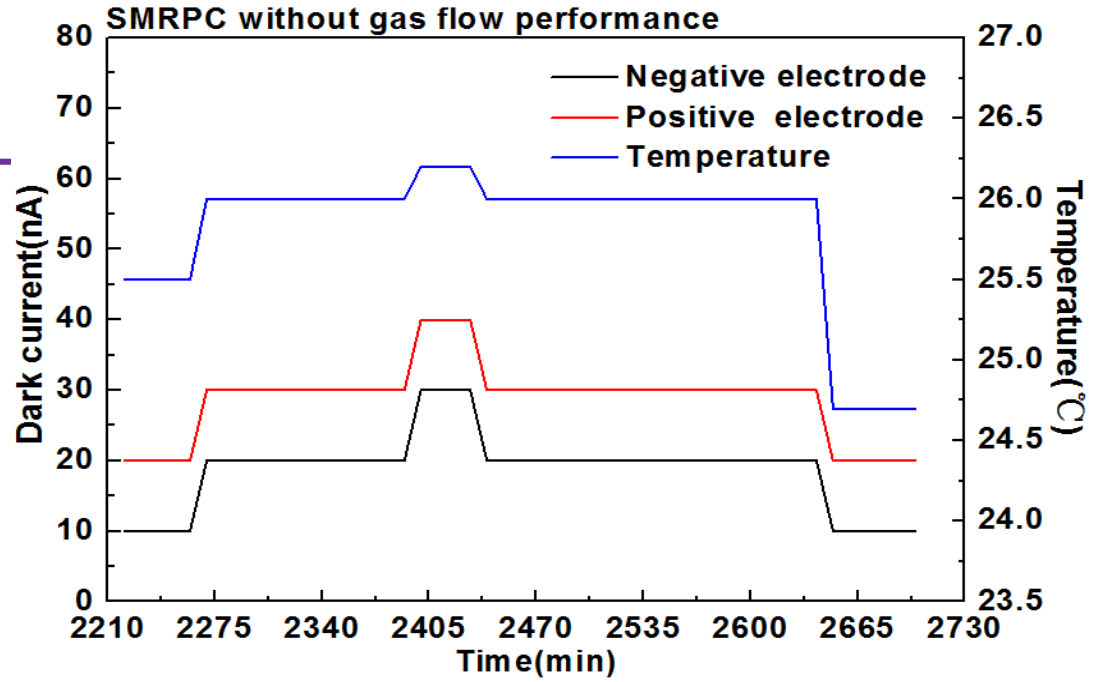


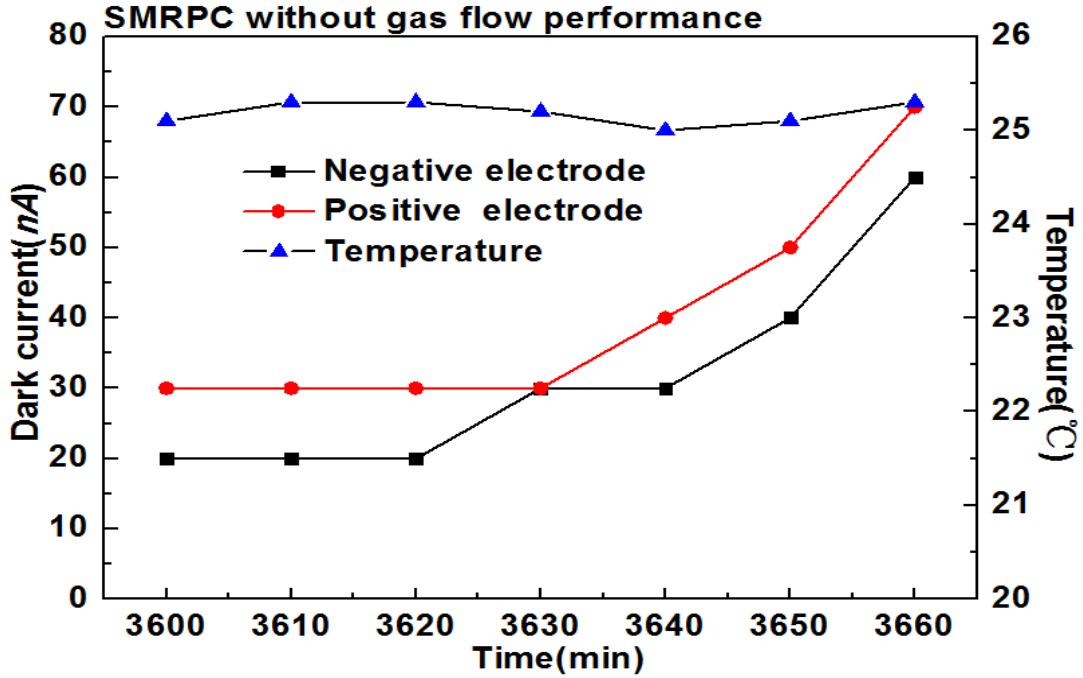
The performance with inlet and outlet shut off(Freon 100%)



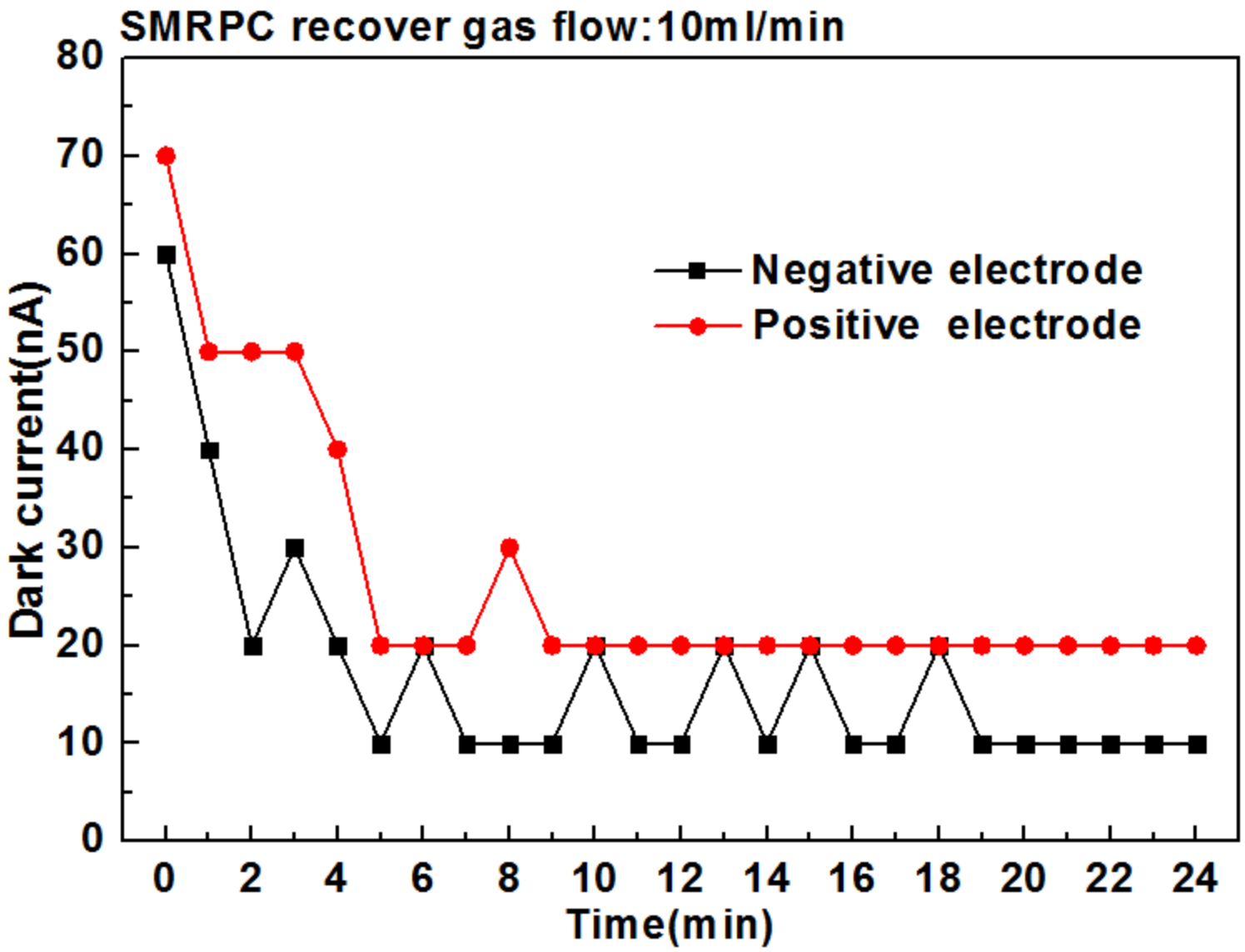
The performance with inlet and outlet shut off(Freon 100%)



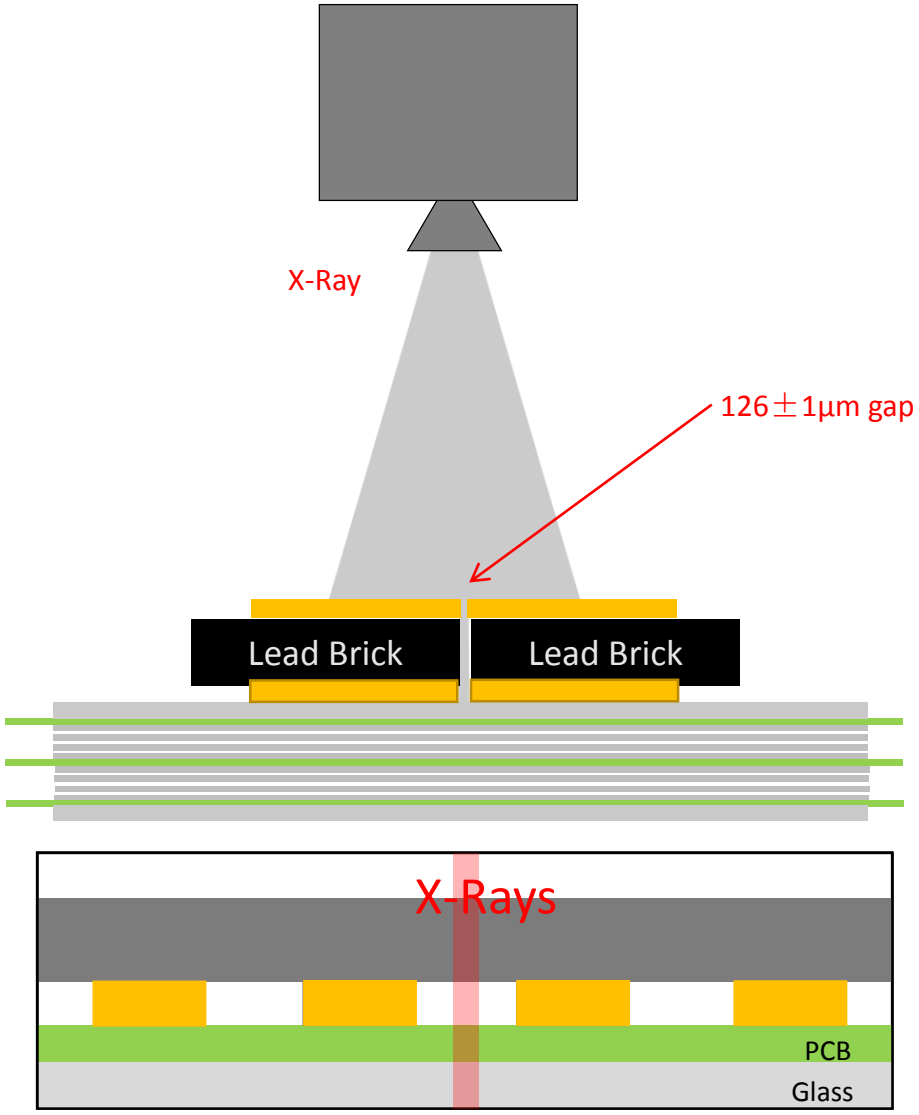


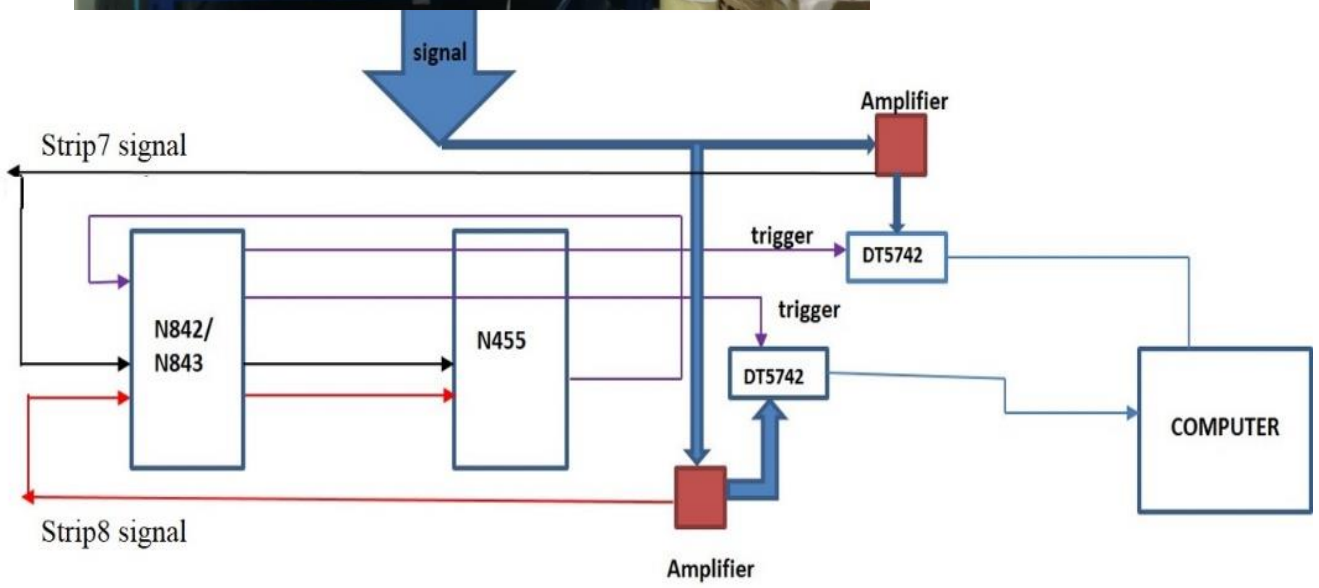


The performance of new SMRPC(Freon 100%)

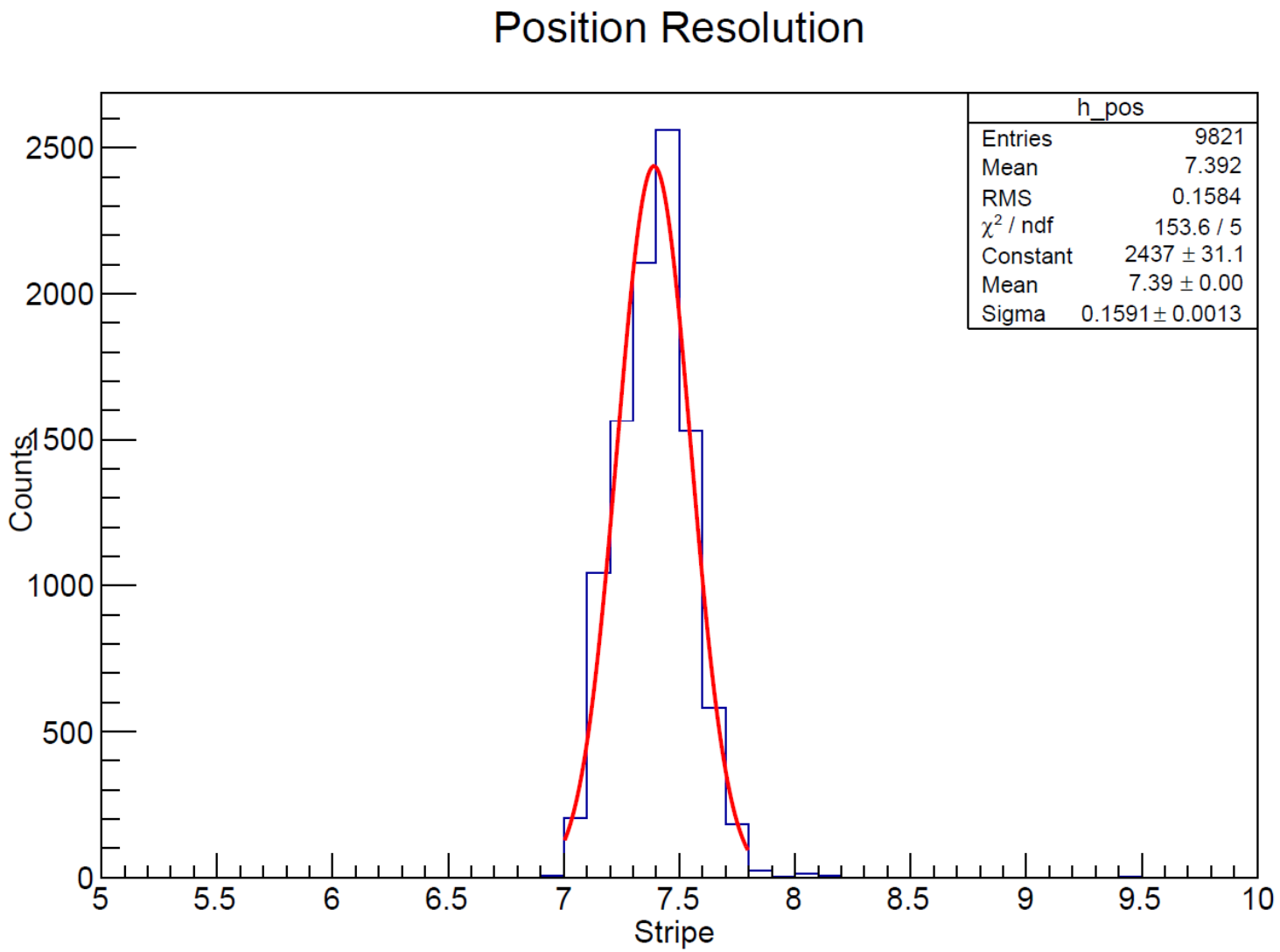


Position resolution test(Freon 100%)





The performance of SMRPC(Freon 100%)



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

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

δ_{MRPC}=0.404mm

Summary and outlook

Summary:

1. the SMRPC was designed and assembly with well tightness
2. the SMRPC can work with a gas flow 0.5ml/min stably with efficiency near 95%
3. the SMRPC can work without gas exchange more than 60 hours(Equivalent to gas flow 0.05ml/min)
4. the SMRPC position resolution is around 0.4mm

Outlook:

1. More detectors connect and learn their performance
2. Extremely low gas flow 0.5ml/min can works well, but why only 60 hours without gas flow， detail learning need to do.

THANKS FOR YOU LISTENING