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

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What’s muon tomography
LANL and Khufu's Pyramid muon tomography system

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<td></td>
<td>Scintillator and Drift chamber</td>
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<tr>
<td>UK</td>
<td>AWE</td>
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<td>RPC</td>
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The “TUMUTY” (Tsinghua University Muon Tomography)

- 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

More smarter structure:
1. Sensitive area reach 1m²
2. Single MRPC can realize 2D readout
3. Put the fine-fine encoding readout device into the gas box.

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
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

![Graph showing current vs voltage]

Current (µA) vs Voltage (±V) graph
The final design

Parameters

<table>
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<tr>
<th>Dimensions</th>
<th>Value</th>
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<tbody>
<tr>
<td>Inner glass size</td>
<td>420*420mm²</td>
</tr>
<tr>
<td>Outer glass size</td>
<td>470*470mm²</td>
</tr>
<tr>
<td>Glass thickness</td>
<td>0.7mm</td>
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<tr>
<td>Gas gap thickness</td>
<td>0.25mm</td>
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<tr>
<td>Number of gas gaps</td>
<td>5</td>
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<tr>
<td>PCB size</td>
<td>500*500mm²</td>
</tr>
<tr>
<td>Sensitive area</td>
<td>420*420mm²</td>
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</tbody>
</table>
The readout board
The process of assembly
The first version and its performance (3ml/min)

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

Control function

\[
\frac{\partial (\rho \phi)}{\partial t} + \nabla \cdot (\rho \vec{v} \phi) = \nabla \cdot (\Gamma \nabla \phi) + S_{\phi}
\]

Finite Element Method (FEM); SIMPLE algorithm (Semi-Implicit Method for Pressure-Linked Equations)
Simulation results (Velocity V at 30ml/min)

1 hole
30ml/min

2 hole
30ml/min
Simulation results (Velocity V at 3ml/min)

1 hole
3ml/min

2 hole
3ml/min

Inlet
Outlet

Residuals
- continuity
- x-velocity
- y-velocity
- z-velocity
Simulation results

- The one inlet and outlet at different place
The distribution of pollutant concentration

1 hole 3 ml/min 0.5 HZ/cm²
The improved version
The schematic design of air tightness test

[Diagram showing the schematic design with labels for Switch, Inlet, MRPC, Outlet, Freon (134a), U-tube, and pressure difference graph with SMRPC, U-tube liquid density: 1.0 g/cm³.]

- Switch
- Inlet
- MRPC
- Outlet
- Freon (134a)
- U-tube

Graph showing pressure difference over time (Day) with pressure point indicated.
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 0.5 ml/min
Stability test (Freon 100%)

Gas flow speed is 0.5 ml/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%)

126 ± 1μm gap

X-Rays

Lead Brick  Lead Brick

PCB  Glass
The performance of SMRPC (Freon 100%)

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

\[ \delta_{MRPC} = \sqrt{(0.1591 \times 2.54)^2 - \frac{0.126^2}{12}} \]

\[ \delta_{MRPC} = 0.404 \text{mm} \]
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