Performance of a large-area Mosaic MRPC

Yancheng Yu
Department of Engineering Physics,
Tsinghua University, Beijing, China
Feb 23\textsuperscript{th}, 2018
• Introduction of real-size mosaic MRPC
• 904 cosmic test
• HZDR beamtest
  – Beamtest preparation and setup
  – Preliminary result
• GIF++ beamtest
• Summary
The planned HL operation during the LHC phase-II:
- Larger instantaneous luminosity up to $5 \times 10^{34} \text{cm}^{-2}\text{s}^{-1}$
- Integrated luminosity up to $3000 \text{fb}^{-1}$
- Rate requirement: $2 \text{kHz/cm}^2$

High rate MRPC based on low resistive glass is best candidate for the upgrade of endcap muon system.
- High rate capability $>70\text{kHz/cm}^2$
- Time resolution $<100\text{ps}$, eliminate most of background
- Limitation: glass size $33 \text{cm} \times 28 \text{cm}$
- Solution: glass mosaic
Introduction of the mosaic MRPC

Mosaic design 1: glue glass

Mosaic design 2: block by fishing line
Gas gap number: 5
Gas gap width: 250 μm
Glass thickness: 0.7 mm
Glass bulk resistivity: ~ $10^{10}$ Ωcm
Mosaic interface: glass directly mosaic together

Strip number: 44
Strip shape: trapezoidal (6 mm/8 mm)
Strip interval: 3 mm
Strip length: 1 m
Cosmic test at CERN in Feb, 2017:
Gas component: \(90\% \ C_2H_2F_4 + 5\% \ i-C_4H_{10} + 5\% \ SF_6\).

Mosaic MRPC in gas box.  
Test module in cosmic setup.
Cosmic ray test at CERN in Feb, 2017: Scan000086: 5000 trigger events.

- NINOs signal
- Dark current
- Cluster size
- Efficiency
Maxime and xiaolong brought the **Mosaic MRPC to HZDR** by car on March 24\textsuperscript{th}.

Gas box was again opened to switch the Jupiter HV connector to SHV connector. Gas was flushed with a component: 90\% $\text{C}_2\text{H}_2\text{F}_4$ + 5\% i-$\text{C}_4\text{H}_{10}$ + 5\% $\text{SF}_6$. 
HZDR beamtest: Setup

Setup.

Coincidence triggering

Rate measurement

e- beam

Position selection

Coincidence triggering

S24
S25
S1
S2
MRPC
S13
S14
S6
S3
S4
**HZDR HV Scan: Setup**

**Run005 ~ Run021**: HV: \( \pm 5400 \text{ V} \sim \pm 6700 \text{ V} \); Rate: 11 kHz/cm\(^2\).

Beam spot position: Horizontal – center; Vertical: between 3\(^{rd}\) and 4\(^{th}\) strip.

Define the horizontal center on the mosaic interface as zero point, beam spot at (-8, -30).

PMT Trigger (S1&S2&S3&S4) dimension: 20 \( \times \) 20 mm\(^2\).

Beam spot dimension: 100 mm in diameter.
HZDR HV Scan: Current and Cluster Size

Rate: 11 kHz/cm²
HZDR HV Scan: Efficiency

Rate: 11 kHz/cm².

Efficiency

Cut on S6: $T_{ref} \& S_6 \& MRPC$ $T_{ref} \& S_6$

<table>
<thead>
<tr>
<th>HV/V</th>
<th>Efficiency</th>
</tr>
</thead>
<tbody>
<tr>
<td>±5400</td>
<td>6.7%</td>
</tr>
<tr>
<td>±5600</td>
<td>26.0%</td>
</tr>
<tr>
<td>±5800</td>
<td>49.8%</td>
</tr>
<tr>
<td>±6000</td>
<td>69.9%</td>
</tr>
<tr>
<td>±6200</td>
<td>83.1%</td>
</tr>
<tr>
<td>±6400</td>
<td>86.6%</td>
</tr>
<tr>
<td>±6500</td>
<td>89.0%</td>
</tr>
<tr>
<td>±6600</td>
<td>91.1%</td>
</tr>
<tr>
<td>±6700</td>
<td>92.6%</td>
</tr>
<tr>
<td>±6800</td>
<td>93.9%</td>
</tr>
</tbody>
</table>
HZDR HV Scan: Time Resolution

\[
\begin{align*}
TOF &= \left(\frac{\text{LeftLead} + \text{RightLead}}{2} - \text{LeadRef}\right) - (\text{RF} - \text{TRef}) \\
TOT &= \left(\frac{\text{LeftTrail} + \text{RightTrail}}{2} - \text{TrailRef}\right) - \left(\frac{\text{LeftLead} + \text{RightLead}}{2} - \text{LeadRef}\right)
\end{align*}
\]

Run005 ~ Run009

Run017 ~ Run021
Rate scan plan:
- at ±7000V

<table>
<thead>
<tr>
<th>Rate/kHz/cm²</th>
<th>Eff_t2</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.35</td>
<td>96%</td>
</tr>
<tr>
<td>2.3</td>
<td>96%</td>
</tr>
<tr>
<td>5</td>
<td>×</td>
</tr>
<tr>
<td>10</td>
<td>×</td>
</tr>
<tr>
<td>20</td>
<td>×</td>
</tr>
<tr>
<td>30</td>
<td>×</td>
</tr>
<tr>
<td>40</td>
<td>×</td>
</tr>
<tr>
<td>50</td>
<td>×</td>
</tr>
<tr>
<td>60</td>
<td>×</td>
</tr>
</tbody>
</table>

Actual rate scan:
- at ±6000V

<table>
<thead>
<tr>
<th>Rate/kHz/cm²</th>
<th>Eff_t2</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.35</td>
<td>68%</td>
</tr>
<tr>
<td>2.3</td>
<td>69%</td>
</tr>
<tr>
<td>4.9</td>
<td>59%</td>
</tr>
<tr>
<td>11.3</td>
<td>57%</td>
</tr>
<tr>
<td>21.3</td>
<td>54%</td>
</tr>
<tr>
<td>29.5</td>
<td>55%</td>
</tr>
<tr>
<td>42</td>
<td>52%</td>
</tr>
<tr>
<td>49.8</td>
<td>51%</td>
</tr>
<tr>
<td>60.5</td>
<td>49%</td>
</tr>
</tbody>
</table>

Current and efficiency in the rate scan:

- Before:
  - Rate scan from 2 kHz/cm² to 5 kHz/cm²
  - Current went up to 8 μA.
  - Rate went directly to 120 kHz/cm².

- After the MRPC was damaged:
  - Rate dropped back to 5 kHz/cm².
  - MRPC can’t work anymore.

When increasing from 2 kHz/cm² to 5 kHz/cm², rate went directly to 120 kHz/cm². Current went up to 8 μA. After 10 s, rate dropped back to 5 kHz/cm², but MRPC can’t work anymore.
HZDR Rate Scan: Efficiency

HV scan at different rate of 0.35 kHz/cm², 2.3 kHz/cm² and 11 kHz/cm² before the MRPC was damaged.

No efficiency loss at 2.3 kHz/cm².
HV scan at different rate of 0.35 kHz/cm$^2$, 2.3 kHz/cm$^2$ and 11 kHz/cm$^2$ before the MRPC was damaged.
GIF++ beamtest: Preparation

- Chamber has been repaired at CERN in Sep, 2017
- It was flushed with CMS gas: 95.2% $\text{C}_2\text{H}_2\text{F}_4 + 4.5\% \text{i-C}_4\text{H}_{10}$ + 0.3% $\text{SF}_6$
- Dark current was 0.02 $\mu\text{A}$ at $\pm$5000 V
GIF++ beamtest: Setup

Source

MRPC Chamber

External + Internal trigger

Internal trigger

External trigger

GT1 and GT2

External trigger

beam

External + Internal trigger
Get the strip projection of GT chambers and MRPC chamber
There is a big working point shift at different gas mixture!
Dark Current vs High Voltage

Source off
There is no efficiency loss along with high rate. Efficiency always reaches about 94% at ± 6000V.
Cosmic ray test at CERN
- Efficiency above 95% is reached at ±6800V.

30 MeV electron beam at HZDR at rate of 10kHz/cm²
- Efficiency reaches 95% at ±6800V
- Time resolution around 55ps.
- Efficiency loss at mosaic interface is about 2%.

The real size mosaic MRPC can keep good performance with CMS dry gas.
- Efficiency can reaches about 94% at ±6000V at rate of 10kHz/cm².
- Working voltage shift.
Thank You!

- Yu Yancheng
- Department of Engineering Physics,
- Tsinghua University, Beijing, China
- Feb 23th, 2018
Backup
Structure and performance of small mosaic MRPC

Table 1 Component of mosaic MRPC

<table>
<thead>
<tr>
<th>MRPC Component</th>
<th>Size (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Honey Comb</td>
<td>255 × 472 × 6</td>
</tr>
<tr>
<td>PCB</td>
<td>320 × 540 × 0.7</td>
</tr>
<tr>
<td>Mylar</td>
<td>260 × 480 × 0.18</td>
</tr>
<tr>
<td>Mosaic Glass</td>
<td>250 × 470 × 0.7 &amp;</td>
</tr>
<tr>
<td>Glass</td>
<td>250 × 200 × 0.7</td>
</tr>
<tr>
<td>Spacer</td>
<td>0.5</td>
</tr>
<tr>
<td>Gap</td>
<td>0.25 × 5</td>
</tr>
</tbody>
</table>

Fig.1  structure of mosaic MRPC

Fig.2  Noise rate

Fig.3  Efficiency, time resolution and cluster size

Fig.4  Efficiency, time resolution Vs. rate
Introduction of the mosaic MRPC

Gap number: 5  
Gap width: 250 μm  
Glass thickness: 0.7 mm  
Bulk resistivity: \( \sim 10^{10} \, \Omega \text{cm} \)

- 0.5 mm-wide fishing line block
- Strip number: 44  
- Strip shape: trapezoidal  
  (Narrow side 6 mm, Wide side 8 mm)  
- Internal width between strips: 3 mm  
- Strip length: 1 m
Cosmic Test: Noise Rate

![Graph showing the relationship between HV (V) and Noise Rate (Hz/cm²).](image)

- Noise Rate (Hz/cm²) vs. HV (V)
The geometry of the setup is as follows:

<table>
<thead>
<tr>
<th>element</th>
<th>material</th>
<th>thickness</th>
<th>width</th>
<th>height</th>
<th>diameter</th>
</tr>
</thead>
<tbody>
<tr>
<td>window</td>
<td>Be</td>
<td>0.2</td>
<td></td>
<td></td>
<td>40</td>
</tr>
<tr>
<td>drift</td>
<td>air</td>
<td>140</td>
<td></td>
<td></td>
<td>40</td>
</tr>
<tr>
<td>S24</td>
<td>BC408</td>
<td>2</td>
<td></td>
<td></td>
<td>40</td>
</tr>
<tr>
<td>drift</td>
<td>air</td>
<td>133</td>
<td></td>
<td></td>
<td>40</td>
</tr>
<tr>
<td>S25</td>
<td>BC408</td>
<td>2</td>
<td></td>
<td></td>
<td>40</td>
</tr>
<tr>
<td>drift</td>
<td>air</td>
<td>225</td>
<td></td>
<td></td>
<td>40</td>
</tr>
<tr>
<td>S1S2</td>
<td>BC418</td>
<td>5</td>
<td>20</td>
<td>20</td>
<td></td>
</tr>
<tr>
<td>drift</td>
<td>air</td>
<td>115</td>
<td></td>
<td></td>
<td>40</td>
</tr>
<tr>
<td>S14</td>
<td>BC408</td>
<td>2.5</td>
<td>5</td>
<td>15</td>
<td></td>
</tr>
<tr>
<td>drift</td>
<td>air</td>
<td>105</td>
<td></td>
<td></td>
<td>40</td>
</tr>
<tr>
<td>S13</td>
<td>BC408</td>
<td>2.5</td>
<td>15</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>drift</td>
<td>air</td>
<td>25.00</td>
<td></td>
<td></td>
<td>40</td>
</tr>
<tr>
<td>box</td>
<td>aluminum</td>
<td>3</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>MRPC</td>
<td>glass</td>
<td>215</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>S6</td>
<td>BC408</td>
<td>5</td>
<td>35</td>
<td>35</td>
<td></td>
</tr>
<tr>
<td>drift</td>
<td>air</td>
<td>155</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>S3S4</td>
<td>BC418</td>
<td>5</td>
<td>20</td>
<td>20</td>
<td></td>
</tr>
</tbody>
</table>
Timing of trigger.

Coincidence of scintillators: S1&S2&S3&S4.

R_F: Accelerator clock.

TDC trigger: S1&S2&S3&S4 & R_F.
Run005: Efficiency

Efficiency

No cut: \[ \frac{Tref \&\& MRPC}{Tref} = 93.62\% \]

Cut on S6: \[ \frac{Tref \&\& S6 \&\& MRPC}{Tref \&\& S6} = 93.93\% \]
Run005: Time Resolution

\[ \text{TOF} = \left( \frac{\text{LeftLead} + \text{RightLead}}{2} - \text{LeadRef} \right) - (\text{RF} - \text{TRef}) \]

\[ \text{TOT} = \left( \frac{\text{LeftTrail} + \text{RightTrail}}{2} - \text{TrailRef} \right) - \left( \frac{\text{LeftLead} + \text{RightLead}}{2} - \text{LeadRef} \right) \]
Run005: Time Resolution

\[ \sigma(\text{TOF}_{\text{MRPC}}) = \sqrt{(3.331 \times 24.4)^2 - 35^2} \approx 73.4 \text{ ps} \]
HZDR Rate Scan: Efficiency

HV: ±6000 V

Counter damaged