The CEE-eTOF wall constructed with new sealed MRPC

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Outline

• Background and motivation
• General design of CEE-eTOF wall
• Structural design of sealed MRPC
• Cosmic test results
• Summary and outlook
Background

The CSR (Cooler Storage Ring) External-target Experiment (CEE)

➢ @ Heavy Ion Research Facility in Lanzhou, China. (HIRFL)

➢ **Physics destinations**: Low temperature & high density in QCD phase diagram, EOS for nucleus matter, hyper-nucleus.

➢ **Beam from CSR**: Heavy ion (up to U+U) collision, 0.5-1.2GeV/u, $10^4$evts/s

➢ **Timing detectors** (MRPC): $T_0$, iTOF, eTOF

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## Background

### Timing detectors using MRPC technology

<table>
<thead>
<tr>
<th>index</th>
<th>T0</th>
<th>iT0F</th>
<th>eTOF</th>
</tr>
</thead>
<tbody>
<tr>
<td>Distance from collision</td>
<td>10~20cm (barrel inner diameter)</td>
<td>≥50cm</td>
<td>3m</td>
</tr>
<tr>
<td>Effective coverage</td>
<td>1m$^2$</td>
<td>3m$^2$</td>
<td>8m$^2$</td>
</tr>
<tr>
<td>channel</td>
<td>300</td>
<td>~1200</td>
<td>~1500</td>
</tr>
<tr>
<td>Timing requirement</td>
<td>50ps</td>
<td>50ps</td>
<td>80ps</td>
</tr>
<tr>
<td>Gas gaps</td>
<td>10~12</td>
<td>24~32</td>
<td>10</td>
</tr>
</tbody>
</table>
General design of CEE-eTOF wall

eTOF wall design

For each:

➢ 2m×2m coverage => acceptance much better than 50% (center of mass).
➢ Overlap: x – 3cm; y – 1.8cm (1 strip).
➢ 768 readout channels => occupancy < 10%.
➢ 3m from collision center
➢ 80 ps time resolution

Module design:

➢ 24 counters in 8 modules.
➢ 3 serial counters for gas supply
General design of CEE-eTOF wall

Future eTOF MRPC detector

Performance requirements:

➢ Efficiency: over 95%
  ➢ Double stacks, $2 \times 5$ gas gap, 0.25mm for each gap
➢ Time resolution: better than 80 ps
  ➢ Double-end readout
➢ Geometry:
  ➢ 16 strips
  ➢ Pitch 22mm, 18mm width + 4mm gap.
  ➢ Length 52cm
➢ Estimated strip impedance 30Ω *
➢ Sealed design

Conceptual layout

* Based on the empirical formula in:
Motivation

Sealed design —— Decreasing gas consuming for MRPC

➢ High GWP value

\[
\begin{align*}
F = C &= H \\
F = C &= H
\end{align*}
\]

\[
\begin{align*}
GWP &= 1430 \\
GWP &= 3.3 \\
GWP &= 22800
\end{align*}
\]

➢ Gas leak

- RPC takes up most of the GHG emission.
- e.g. CMS Phase-II RPC, gas leakage 900L/h in 2019

➢ High flow

- gas exchange for MRPC is mainly by diffusion.
- To keep the pure environment, gas flow can’t decline much.
- Shrink the gas box volume -> sealed design

RPC 2020, Rome, Italy.
Structural design of sealed MRPC

**New thought for sealing**

Using outermost glass plates and sealing frame

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**Different thoughts:**

PCB or glass plate as sealing panel.

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Structural design of sealed MRPC

Sealing frame by 3D printing
- Gas inlet/outlet
- Spacers
- Glass position holder
- Screwing hole

Material: photosensitive resin
- HV tolerance up to +/-10kV in test
- No aging damage observed under X-ray (45kV 0.3mA)
Structural design of sealed MRPC

Gas flow uniformity

- Inlet/outlet placement
- 3D Flow field simulation by ANSYS Fluent
- Low velocity zone indicates pollutant concentration.

2 pairs:

Gas flow: 3ml/min
Sealed MRPC prototype

Type similar as MRPC3a
- 2 stack * 4 gas gap * 0.25mm
- Float glass plates of 0.7mm width
- 30 channels, differential signal
- 2-end readout
- Strip length 27cm, 7mm width + 3mm gap
- Sealed design, total gas volume ~170ml
Cosmic test system

Originally developed for CBM-TOF MRPC3a mass production
Performances of 3 counters can be obtained in single run
Dut: Detector under test
Ref: provide time reference
Beamref: for hit selection

Trigger and readout board v3 (TRB3):
<20ps RMS between 2 channels
8*(64+1) channels
Web interface
Hit rate up to 66MHz

PreAmplifier-Discriminator ASIC chip (PADI)
50Ω impedance
Bandwidth ~400MHz, Gain 30mV/fC
Threshold set to 300mV during test.

2* scintillators
Triggering area: 5cm*20cm
Parallel to strip length
Cosmic test system

Cosmic test system
- 2*MRPC3a for CBM as references
- TRB3 chip as DAQ
- Strip->PADI10 FEE->TDC->TRB-> Computer

- Environment: ~25°C, 23%
- HV: CAEN SY4527

In test runs:
- Quick gas exchange at 20ml/min flow
- Apply the working HV within 1hr.
- For comparison, gas box needs 2 days before applying HV

Standard gas supply system
Cosmic test results

Standard gas flow 4 ml/min (minimum setting for mixer)
Freon/iC$_4$H$_{10}$/SF$_6$ 90/5/5; Temp: 25°C, dark current ~20nA
At working point 5600V(112kV/cm): Eff 97.5%, time resolution 85.5ps (time difference)

Reference MRPC3a, flow 50ml/min for gas box:
Working HV 5300V (106kV/cm), eff 97.9%, time resolution 83ps
Cosmic test results

Pure Freon flow 1ml/min
Temp: 25°C, dark current ~20nA
At working point 5300V (106kV/cm):
Eff: 96%, time resolution 102ps
Cosmic test results

Pure Freon flow 1ml/min, serial chambers, stability test

➢ No leak point/performance decline/gas chock
➢ Temp. dependency, humidity insensitive ~19-25%
➢ Event number >10k for each run
➢ Timing — events dependency may caused by temperature fluctuation.

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Summary and outlook

• The CEE-eTOF wall will be constructed with sealed MRPC.
• By gluing the electrode glasses with sealing frame, gas volume reaches as low as 170ml, in which case gas exchange becomes better.
• To optimize flow field uniformity, placements of space holder, in/outlets, etc. must be considered and verified by simulation.
• Sealed MRPC prototype has low gas consume and works stably under cosmic ray, at a flow 1ml/min for over 20 days. time resolution can reach ~60ps in standard gas.

Next step:
• Eco-gas test
• Real-size prototypes for CEE
• High-rate aging test

Thank you!