Characterisation of a innovative RPC prototype with 1mm of gas gap thickness

XVI Workshop on Resistive Plate Chambers and Related Detectors

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Outline

Why 1mm gap thickness design?
Detector prototype layout and experimental setup description
Efficiency and muon cluster results
Time resolution measurement
Study with eco-friendly gas mixtures
Why 1mm gas gap thickness?

Avalanche charge ↔ Gas gap thickness

Reducing gap thickness
Smaller avalanche cloud
Lower WP
Smaller CLS ➔ better space resolution
Fast signal ➔ better time resolution and rate capability

FEB capable to operate at lower THR (≈ 50 fC)
Low noise operational conditions

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Detector prototype

Gaps manufactured at KODEL

- Gap area: 70x100 cm²
- Gap thickness: 1 mm
- HPL: 1.43 mm thick

Assembly in BARI University

- 1x0.5 m² strip PCB
- 48 strips
- 1 cm pitch
- 4752 cm² active area
- XY read-out

KOrea DEtector Laboratory, Korea University
Detector prototype

Front-end Electronics LYON v2.2

lower charge signal at the same time to keep efficiency high, the new front-end electronics are designed for the new iRPC

FEB is sensitive, has low-noise and high time resolution

The FEB composed of:
- 3 ERNI connectors with 32 channels each
- 6 ASICs PETIROC 2C (top & bottom)
- 3 FPGAs Cyclone V (non rad-hard)
- GBTx/GBT-SCA/VTRx.
Gamma Irradiation Facility (GIF++)

Located at the H4 beam line in EHN1, Prevessin North Area
High gamma radiation Cs-137 source up to 12 TBq
Muon beam 10-450 GeV/c
Gamma flux modulated independently using a system of six attenuation filters

RPC set-up at GIF++

RPC 1mm prototype at 3. m from the source in Trolley 3
2 PMTs as muon trigger
Detector commissioning

Current and noise scan

Source and beam OFF
Current density below 3e-04 $\mu$A/cm²
Mean noise $\approx$ 1 Hz/cm²

Detector-beam alignment
Results double gap mode

Muon efficiency, muon clus. size and clus. multiplicity measurements

\[ E = \frac{E_{\text{max}}}{1 + e^{-\frac{\lambda}{\nu}(H\nu_{\text{eff}}-H\nu_{50})}} \]

\[ WP = \frac{-\log(1/(0.95 - 1))}{\lambda} + H\nu_{50} + 120 \]

THR 7DAC (≈ 35 fC)

CLS ≈ 1.5

WP shift 150 V up to 2 kHz/cm² gamma clus. rate

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Time resolution measurements

Single gap prototype

Gas gap 1mm thickness
Gap area 70x100 cm²
32 strips, 1 Kodel FEB
THR: 750 uV (~90 fC)
Strip pitch: 1.27 cm
Time resolution measurements

Tracking system

2D readout detector
Each dimension has 32 strips, pitch x 1.0 and y 2.0 cm, double gap 1.4 mm thickness
Fixed at WP 7.4 kV with muon eff. of 98 and 95 % (Source OFF)
Time resolution measurements

Experimental schema and results

\[ \sigma_{1.4\text{mm}} = \frac{\sigma_{\text{RPC2D}_{1.4}} - \sigma_{\text{RPC}_{1.4}}}{\sqrt{2}} \]

\[ \sigma_{1.0\text{mm}} = \sqrt{\sigma_{\text{RPC2D}_{1.4}}^2 - \sigma_{\text{RPC}_{1.4}}^2 - \sigma_{1.4\text{mm}}^2} \]

Same FEB for all chamber

Analysis cuts

1D tracking using RPC2D chamber

Single strip triggering

Time resolution

1mm gap and std. gas mixture

331 ps

Peak mean: 47.44 ns

Peak width (\(\sigma\)): 0.68 (0.07) ns

Time res. (\(\sigma_{1.0\text{mm}}\)): 0.331 ns

Kodel2Dy 

\(\Delta(T_{\text{BAR}i} - T_{\text{Kode}d2y})\) 224

0 5 10 15 20 25 30 35

Hits / 100 ps

40 45 50 55 60 65 70

Time (ns)

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Fluorinated greenhouse gases (GHGs) with high Global Warming Potential (GWP) have been limited in EU [EU regulation 517/2014]. CERN is committed to reducing its direct greenhouse gas emissions.

Extensive RPC applications (CMS, ATLAS) ➤ higher contribution to GHG consumption.

<table>
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<th>eco-friendly mixtures</th>
<th>R134a</th>
<th>i-C6H10</th>
<th>SF6</th>
<th>HFO</th>
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<tr>
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<td>1</td>
<td>35</td>
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</tbody>
</table>
Eco-friendly gas mixture study

Results single gap

Max eff. $\approx 95\%$ with STD
ECO2 mix more promising with eff 90-79\% till 800 Hz/cm²
WP shift 6.65-6.9 kV for ECO2 and 6.3-6.45 kV for ECO3

Asymmetric sigmoidal $\Rightarrow$
no charge saturation with HFO-based mixtures
Eco-friendly gas mixture study

Results single gap muon clus. size analysis

smaller CLS with ECO2 mix ($\text{CLS}_{\text{ECO3}} / \text{CLS}_{\text{ECO2}} \approx 1.3$)

➤ better space resolution
Eco-friendly gas mixture study

Results single gap current plots

Similar currents with STD and ECO2
ECO2 and ECO3 at equivalent rate $I_{ECO3}/I_{ECO2} \approx 1.6$

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Conclusions and next steps

• Fully performant RPC using 1mm gas gap
• Muon efficiency of 92% at WP with high background radiation on 2.2 kHz/cm2 (ex: required for HL phase of CMS)
• Fast conventional RPC with a time resolution of 331 ps
• ECO2 mixture more suitable but still with low efficiency

Next:
• Aging irradiation campaign and new performance analysis
• Space resolution measurements
• New eco-mixture tests
Thanks!

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