Ageing studies of resistive Micromegas detectors for the HL-LHC

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for the MAMMA collaboration
The New Small Wheel upgrade for the HL-LHC

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Performance requirements

- Rate capability: $10 \text{ kHz/cm}^2$
- Spatial resolution: $60 \mu\text{m/track segment}$
- Angular resolution: $0.3 \text{ mrad/segment}$
- Good double track resolution
- Trigger capability: BCID (angle $\approx 1 \text{ mrad}$)
- Efficiency: ‘at least as good as now’

- Radiation resistance: tbd
- Good ageing properties: tbd

NSW

Total area of micromegas detectors required

1200m$^2$

Large area due to multilayer micromegas will be implemented in each sector.
Micromegas detectors for the new small wheel

Micromegas concept

Multilayer description

• Each detector comprises eight active layers, arranged in two multilayers.

• The basic detector unit is an assembly of four layers that form a stiff multilayer.

• The individual layers should be arranged in two doublets in which the Micromegas are mounted back-to-back.

• The flat surfaces of all layers should be parallel to within 40–60 µm and the strips in all layers must be parallel with the same precision.
Resistive Micromegas technology development for high intensity environment

J. Galan

Micromegas technology

Resistive Micromegas technology

A spark-resistant bulk-micromegas chamber for high-rate applications
T. Alexopoulos a, J. Burnens b, R. de Oliveira b, G. Glonti b, O. Pizzirusso b, V. Polychronakos c, G. Sekhniaidze d, G. Tsipolitis a, J. Wotschack b,*

Spark mitigation is achieved by local field loss.
Detector is affected only locally.
No mesh discharge evolves!!

Non-resistive MM (Ar:CO₂ 85:15) Neutron flux = 10⁶ Hz/cm²

R11 (Ar:CO₂ 85:15) Neutron flux = 10⁶ Hz/cm²
Resistive prototypes dedicated to fast ageing

Geometrical properties

- Strip pitch/width for all: 250 \( \mu \text{m} / 150 \mu \text{m} 
- Top layer (Resistive strips): 35 \mu \text{m} thick
- Insulation (coverlay): 60 \mu \text{m}
- Y strips (90 degrees to R strips): 9 \mu \text{m} Cu
- Insulation (FR-4): 75 \mu \text{m}
- X strips (same direction as R strips): 9 \mu \text{m} Cu

Two resistive prototypes (R17) were sent to Saclay for performing aging tests

17A
- Resistance to GND: 80-140 MOhm
- Resistance along strips: 45-50 MOhm/cm

17B
- Resistance to GND: 60-100 MOhm
- Resistance along strips: 35-40 MOhm/cm

Both detectors show similar gain properties
Re-characterized at CEA for different gas mixtures

[Graph showing absolute gain vs. mesh voltage for different gas mixtures]
X-ray beam

Cold neutron beam

Alpha source

Gamma source

R17a detector is exposed to different radiation natures.

R17b detector is kept unexposed.

Gain control measurements are performed before and after each exposure.

After the ageing both detectors are taken to the H6 CERN-SPS pion beam line.

The goal to accumulate an integrated operation charge equivalent to the one would be obtained at the HL-LHC for 10 years for each type of radiation.
**Detector operated in nominal data taking conditions**

Gas mixture: Argon + 10% CO2  
Gas Flow = 0.5 l/h  
Gain 3000  
HVm = 540V  
HVd = 790 V

**Equivalent charge generated during 5 years HL-LHC**

Wi (Argon + 10% CO₂) = 26.7 eV  
Gain = 5000  
MIP deposit in 0.5 cm drift = 1248.5 eV  
Charge per iteration = 37.4 fC  

Expected rate at the HL-LHC: **10kHz/cm²**

5 years of HL-LHC operation (200 days X year)

Total detector charge generated during HL-LHC operation is estimated to be **32.5 mC/cm²**
X-ray gain evolution history

Acumulated charge: 918 mC in 21.3 effective days.

Mesh current [nA]

Gain [ADC units]

225 mC/cm²

versus

32 mC/cm²

Estimated per HL-LHC year

X-ray gain profile compatibility

R17a irradiated detector

R17b non-irradiated detector

9-holes mask
High intensity thermal neutron irradiation had place at C.E.A. Orphee reactor.

Several neutron research lines available.

Neutron flux: $\sim 8 \times 10^8$ n/cm²/sec

Neutron energy: 5 to 10 meV

After a short irradiation period the detector is quickly activated and takes long time to deactivate.

The activation rate measured saturates and reaches a limit of about 250kHz which does not increase with exposures longer than 2 hours.

<table>
<thead>
<tr>
<th>Time</th>
<th>Rate</th>
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<tbody>
<tr>
<td>11h08</td>
<td>206 kHz</td>
</tr>
<tr>
<td>14h04</td>
<td>35 kHz</td>
</tr>
<tr>
<td>16h03</td>
<td>26 kHz</td>
</tr>
<tr>
<td>18h16</td>
<td>21 kHz</td>
</tr>
<tr>
<td>8h52*</td>
<td>881 Hz</td>
</tr>
</tbody>
</table>
Neutron flux at the level of CSC in ATLAS $\sim 3.10^4$ neutrons/cm$^2$/s

10 years at HL-LHC ($\Rightarrow x10.10^7$ sec) with a security factor : $x3$

At the HL-LHC, we will accumulate $1.5.10^{13}$ n/cm$^2$

At Orphee we have $\sim 8.10^8$ n/cm$^2$/sec so in 1 hour we have : $8.10^8$ x 3600 $\sim 3.10^{12}$ n/cm$^2$/hour which is about 2 HL-LHC years (200 days year).
COCASE facility and equivalent gamma charge.

For 10 years of HL-LHC (assuming 1 y = 10^7 s):
  x5 luminosity increase
  x3 security factor
  x10 year
⇒ Total of time equivalent: 1.5 \times 10^9 sec
⇒ during 10 years of HL-LHC exposure

In hottest region we accumulate 2.7 \times 10^{13} gamma / cm^2

For LHC (L = 10^{34} cm^2 s^{-1}):
Hottest region for gamma (E> 30 keV) in muon spectrometer is in forward CSC region:
18 kHz/cm^2
Gamma irradiation - Mesh current history and control measurements

Gamma exposure between 22\textsuperscript{nd} of March and 11\textsuperscript{th} of April (2012).

Total exposure time : 480 hours
Total integrated charge : 1484 mC
Mean mesh current : 858.4 nA
Alpha irradiation. $^{241}$Am source.

About 30000 primaries are produced by an alpha in 0.5cm conversion region

In standard conditions, gains higher than 100 produce a spark on every alpha (Raether’s)

Time = 66 hours
G = 7000

Source production rate = 3 kHz
Gain = 100

Poster session B
Characterization and simulation of resistive-MPGDs with resistive strip and layer topologies
The two R17 prototypes were taken to the H6 SPS CERN pion beam to perform a **comparative study between both prototypes, irradiated and non-irradiated one.**

The performance was evaluated in terms of spatial resolution (SR) and efficiency.

**Simplified beam set-up with R17 detectors**

Detectors long offset produces systematics due to pion scattering. Resistive detectors were considered for track reconstruction. Non final set-up for intrinsic SR determination.

**Residual distribution and alignment of resistive R17 prototypes to reference chambers**
Beam tests took place at the end of October 2012. During two weeks R17 detectors took data. Three different zones were irradiated. And different settings were taken at each of these beam exposed regions.

**Spatial resolution history for the different runs taken during this period.**
The different scans are combined as a function of the Vmesh and equivalent absolute gain.

The efficiency of both detectors behaves good. In fact R17a detector efficiency grows faster. The gain curve of this detector was also growing faster and somehow is coherent with previous results.

Two different zones of R17a and R17b detector show same performance in terms of SR and efficiency!!
Mechanical design concept is ready and PCB strips within required precision.

Resistive technology shows robustness and it is a mature technology now.

Different nature irradiation processes (X-ray, neutron, gamma and alpha) took place in one of these resistive prototypes.

During the different ageing periods the irradiated detector response does not show performance decrease and its performance is comparable to that performance achieved with a similar non-irradiated detector.

Several additional tests have proven the capability of Micromegas chambers to reconstruct the track and determine the spatial resolution of this track within the required precision.
Additional micromegas studies which had place in parallel to these tests.

- 4 Doubles of X-precision chambers (0.4mm strip pitch – 5mm drift gap)
- 2 Doubles of XY reference chambers (0.25mm strip pitch – 5mm drift gap)
- Gas mixture: Ar + 7% CO2
- APV25 electronics – read-out with the SRS

SRS + APV daq

Detectors under test

Reference detectors mentioned previously
STRAIGHT TRACKS
Particle position via Centroid calculation

\[ x_c = \frac{\sum_i q_i x_i}{\sum_i q_i} \]

\[ w_c = \left( \frac{N_{cut}}{N_{strip}} \right)^2 \]

\[ w_\mu = \left( \frac{N_{strip}}{N_{cut}} \right)^2 \]

INCLINED TRACKS
Measuring the arrival times of charges on single strips it is possible to determine the particle trajectory with a linear fit

Optimum spatial resolution is achieved by combining both methods

\[ x_{comb} = \frac{w_\mu x_\mu + w_c x_c}{w_\mu + w_c} \]
It uses pillars to keep the mesh at a defined distance from the board.

The mesh is not fixed but integrated with the drift-electrode panel.

Placed on the pillars when the chamber is closed.

**Backup. Micromegas detectors assembly. Non-bulked Micromegas.**

- Precision of readout strips $\leq 10 \, \mu m$ (rms), measurements of made in CERN boards, within specs.

- Flatness of r/o panels almost, OK, glueing of panels needs to be improved.

- Alignment of boards with respect to each other seems to be easy, final method to be decided.

**Measurement of strips with traveling microscope**

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![Stiffening panel diagram](image)

- **Stiffening panel**

- **Drift electrode**

- **Pillars (128 µm)**

- **Aluminium support plate**

- **Rohacell**

- **PCB1**

- **PCB2**