Status of the radiation hardness of CMOS Monolithic Active Pixels Sensors for the CBM experiment

Benjamin Linnik
on behalf of the CBM-MVD-Collaboration
The CBM-MVD
**Micro Vertex Detector: Reconstruction of mesons**

1) Short decay range:
- High granularity
- Close to target
- Low material budget

![Diagram of the Micro Vertex Detector](image)

- Target
- Detector 1
- Detector 2
- Beam
- Primary vertex
- Secondary vertex
- Short living particle
  \[D^0 \ (c\tau \approx 120 \ \mu m)\]

**Z = 5 cm**
**Vertexdetektor: Rekonstruktion von D-Mesonen**

Central Au+Au collision at 25 AGeV
160 p  400 π  400 π+  44 K+  13 K

UrQMD + GEANT

1) Short decay range:
- High granularity
- Close to target
- Low material budget

2) RareProbe, therefore high rates
- fast readout
- radiation hard

Wanted: Technology to accomplish this
Sensor R&D: The operation principle

![Diagram of the sensor R&D operation principle](image)

- **SiO$_2$** layers are shown with **N++** and **N+** regions.
- **50µm** and **15µm** distances are indicated.
- **Reset** and **Output** terminals are connected with **+3.3V**.
- The diagram illustrates the basic components and connections of the sensor R&D system.
Effects of non-ionizing radiation

Trapping of signal electrons

Leakage current → higher noise

Cooling decreases this effect

S/N (Sr-90) >15 ⇔ typically > 99% MIP - efficiency

Pixel pitch

Defects due to radiation
Established knowledge on radiation tolerance

Radiation hardness $[n_{eq}/cm^2]$ vs. $Pitch_{eff}$ [µm] for different MIMOSA models:
- MIMOSA-9
- MIMOSA-18

AMS-0.35µm (10Ωcm) meets CBM Requirements.

Readout speed $T_{\ll 0°C}$
Established knowledge on radiation tolerance

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DPG 2016, Darmstadt
Test with Sr-90 $\beta$-source

Pitch: 33x33 $\mu$m², $T = -60^\circ$ C

- Not irradiated
- Irradiated with $5 \cdot 10^{13}$ $n_{eq}$/cm²

Sr90 $\beta$-source detection eff.: 104 %

S/N (Sr-90) $> 15 \iff$ typically $> 99\%$ MIP - efficiency

<table>
<thead>
<tr>
<th>$T = -60^\circ$ C</th>
<th>Signal MPV (e)</th>
<th>Avg. noise (e)</th>
<th>S/N</th>
</tr>
</thead>
<tbody>
<tr>
<td>Not Irradiated</td>
<td>747</td>
<td>11.1</td>
<td>67</td>
</tr>
<tr>
<td>$5 \cdot 10^{13} n_{eq}$/cm²</td>
<td>426</td>
<td>12.8</td>
<td>33</td>
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Signal response, 33x66 µm pitch pixel

Test with Sr-90 β-source  
Pitch: 33x66 µm², T = -10° C

- Not irradiated
- Irradiated with $10^{13}$ n$_{eq}$/cm²

Sr90 β-source detection eff.: 94%

S/N (Sr-90) >15 ⇔ typically > 99% MIP - efficiency

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<tr>
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<th>Signal MPV (e)</th>
<th>Avg. noise (e)</th>
<th>S/N</th>
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<tbody>
<tr>
<td>Not Irradiated</td>
<td>539</td>
<td>12.0</td>
<td>45</td>
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<tr>
<td>$10^{13}$ neq/cm²</td>
<td>354</td>
<td>12.2</td>
<td>29</td>
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</table>
Performances of MAPS

Material budget: 0.05% $X_0$
Spatial resolution: ~ 3-5 µm

- Rad. tol. non-ionizing
- Rad. tol. ionizing
- Readout speed

CBM/ALICE design goal

Radiation hardness
Non-ionizing [10^{13} n_{eq}/cm²]
Ionizing [1 MRad]

Frame rate [kfps]

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Larger pixel size means faster readout. Big radiation hard pixels are available. => Pixel fulfil the CBM requirements.

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Conclusion and outlook

Thank You for your attention!

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<tbody>
<tr>
<td></td>
<td>5 - 10</td>
<td>&lt; 0.05%</td>
<td>&gt; 30</td>
<td>&gt;10¹³</td>
<td>&gt; 1 000</td>
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</tr>
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AMS-0.35µm (10Ωcm)
AMS-0.35µm (~1kΩcm)
AMS-0.35µm (~1kΩcm)

AMS-0.35µm (>1kΩcm)
TOWER-0.18µm (>1kΩcm)