MIMOSIS,
the CMOS Pixel Sensor for the CBM Micro-Vertex Detector

Frédéric Morel on behalf of the mIcPHC team of IPHC and IKF team
Outline

- CBM
  - Introduction
- MVD
  - Requirements
- MIMOSIS
  - Global architecture
- MIMOSIS0
  - Preliminary results
- Conclusion
Detector installation and commissioning: 2021–2024
First beam: 2025
CBM: detector

Fixed Target experiment

Joachim Stroth | 56th Winter Meeting on Nuclear Physics | Bormio (Italy)
Micro Vertex Detector (MVD) for the CBM experiment at GSI/FAIR:

- Secondary vertex determination (~50 µm), background rejection in di-electron spectroscopy, reconstruction of weak decays
- Vacuum/magnetic field operation
- 4 stations
- ~300 CMOS sensors
- Power dissipation: 150 W
- Radiation tolerance: >3 \(10^{13}\) n_{eq}/cm\(^2\) & >3 Mrad

Quadrant (smallest functional unit):

- CVD Diamond / TPG carrier for heat evacuation
- CMOS pixel sensors: 50 µm thin, 150 mW/cm\(^2\), ~10 µs read-out
- Aluminum heat-sink (actively cooled)
**MVD: radiation**

**FLUKA: Maximum Radiation Load**

(Thanks to A. Senger)

- AuAu 12AGeV 100kHz non-ion
- AuAu 12AGeV 100kHz ion
- pAu 30GeV 10MHz non-ion
- pAu 30GeV 10MHz ion

**Stations at 5, 10, 15 and 20 cm**

<table>
<thead>
<tr>
<th>Reaction</th>
<th>Target</th>
<th>Reaction rate</th>
<th>Beam intensity [1/s]</th>
<th>Duty cycle</th>
<th># of projectiles / CBM year</th>
</tr>
</thead>
<tbody>
<tr>
<td>Au + Au, 12 AGeV</td>
<td>1 %</td>
<td>100 kHz</td>
<td>$10^7$</td>
<td>50%</td>
<td>$2.5 \times 10^{13}$</td>
</tr>
<tr>
<td>p + Au, 30 GeV</td>
<td></td>
<td>10 MHz</td>
<td>$10^9$</td>
<td></td>
<td>$2.5 \times 10^{15}$</td>
</tr>
</tbody>
</table>
MVD: hit density

Non uniform hit density in time and space
MVD: sensor requirement

<table>
<thead>
<tr>
<th></th>
<th>ALPIDE (demonstrated)</th>
<th>MIMOSIS (MVD design goal)</th>
<th>Factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ion. Rad. Tolerance</td>
<td>2.7 Mrad</td>
<td>&gt; 3 Mrad</td>
<td>1</td>
</tr>
<tr>
<td>Non. Io. Tolerance</td>
<td>1.7 $10^{13}$ neq/cm²</td>
<td>&gt; $3x10^{13}$ neq/cm²</td>
<td>2</td>
</tr>
<tr>
<td>Heavy ion tolerance</td>
<td>N/A</td>
<td>1 kHz / cm²</td>
<td>--</td>
</tr>
<tr>
<td>Time resolution</td>
<td>5-10 µs</td>
<td>5 µs</td>
<td>2</td>
</tr>
<tr>
<td>Hit rate</td>
<td>&gt; 12 kHz/mm²</td>
<td>700 kHz/mm² (peak)</td>
<td>56</td>
</tr>
<tr>
<td>Data rate</td>
<td>1 Gbps</td>
<td>2.5 Gbps</td>
<td>2.5</td>
</tr>
<tr>
<td>Data reduction</td>
<td>Trigger</td>
<td>Elastic buffer</td>
<td>--</td>
</tr>
<tr>
<td>Power consumption</td>
<td>20-35 mW/cm²</td>
<td>50-75 mW/cm²</td>
<td>0.4</td>
</tr>
<tr>
<td>GBTx compatible</td>
<td>No</td>
<td>Yes</td>
<td>--</td>
</tr>
</tbody>
</table>

- ALPIDE is not sufficient to fulfil all the requirements of the MVD
- Need a new architecture based on ALPIDE

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MIMOSIS

- Matrix dimension: 1024 (col.) x 504 (row)
- Pixel dimension: 26.88 µm (height) x 30.24 µm (width)
- SEU hardened by design with TMR/Hamming (except for data)
- Integration time: 5 µs
- TowerJazz 180 nm
Dual Port Memories for each block are (except elastic buffer):
- filled in series with data from bin time N
- emptied in parallel, the data from bin time N-1

8064 Pixels $\rightarrow$ 1 Region through 2 Priority Encoder
4 Regions $\rightarrow$ 1 Super Region through a common bus
16 Super Regions $\rightarrow$ 1 Elastic buffer through a multiplexer
MIMOSIS: Elastic buffer

• Write speed is 4 times higher than read speed
• Use time structure of beam fluctuations to average data frames
• The buffer can store up to 9 maximal frames
# MIMOSIS: bandwidth

<table>
<thead>
<tr>
<th>Component</th>
<th>Average</th>
<th>Maximum 3x average +2 sigma</th>
<th>Available</th>
</tr>
</thead>
<tbody>
<tr>
<td>Region</td>
<td>10/14</td>
<td>55/70</td>
<td>100</td>
</tr>
<tr>
<td>Super region</td>
<td>37/55</td>
<td>135/230</td>
<td>400</td>
</tr>
<tr>
<td>Elastic-Buffer input</td>
<td>345/600</td>
<td>1120/1790</td>
<td>3200</td>
</tr>
<tr>
<td>Elastic Buffer output</td>
<td></td>
<td></td>
<td>800</td>
</tr>
</tbody>
</table>

- **Au/Au 10 AGeV 100kHz**
- **16 bits words during 5 µs**
- **Beam fluctuations:**
  - Field: 100%/30%

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**Simulation**

**Words send to a region**

**Mvd Data load in worst Sensor**

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Philipp Sitzmann | deutsche physikalische gesellschaft 2017 | Münster (Germany)
MIMOSIS: Pixel

- 2 versions of sensing part:
  - DC coupled (similar than Alpide)
  - AC with medium voltage bias
- Small Area and Low power shaper amplifier:
  - Different versions (1 closed to Alpide)
- In-pixel Memory:
  - New version with double counting removal

Different pixel architecture tested with CE18 chips family
(see A. Dorokhov in Front End Electronics 2018)
MIMOSIS: development plan

- MIMOSIS0: portion of pixel array ➔ May 2017
  - 2 regions wide prototype with AC and DC coupled pixels

- MIMOSIS1: 1st full size sensor prototype ➔ Q1 2019

- MIMOSIS2: 2nd full size sensor prototype ➔ End 2019

- MIMOSIS3: final sensor pre-production ➔ 2020
MIMOSIS0: test setup

Test setup developed by IKF with support of IPHC test team
MIMOSISO: preliminary results

- S-curves density plot from all DC coupled pixels

![Charge injection density plot](image)
MIMOSIS0: preliminary results

- Fe55 response for DC and AC coupled Pixel

- Cluster size in function of threshold
MIMOSIS0: preliminary results

- Temporal Noise and Fixed Pattern Noise after Irradiation
Conclusion

• Close collaboration between IPHC and IKF for tests and design

• Tests:
  • Preliminary results of MIMOSIS0 are encouraging
    • AC coupled pixels are promising
  • Good accordance between tests from MIMOSIS0 and CE18 chips family

• Design:
  • MIMOSIS0 has validated a part of digital readout of MIMOSIS1
  • Digital periphery is under development ➔ no showstopper seen

• Next steps:
  • Continuing heavy testing (radiations) of MIMOSIS0 and CE18 chips family
  • Finalize design of MIMOSIS1 which will be very closed to the final sensors