CBM Micro Vertex Detector
mechanical integration and cooling

Tobias Tischler for the CBM-MVD Collaboration
• MVD for CBM
  – Basic requirements
    • detector position
    • "ultra" low material budget
    • vacuum operation
    • operation in magnetic field

• Projects
  – Demonstrator ✔
  – Prototype Version 1 (MIMOSA-26)
  – Prototype Version 2 (MISTRAL)
  – SIS-100 MVD

• Open questions
MVD for CBM - basic requirements

• Detector position
  – inside vacuum chamber
    • compact arrangement
    • hard to access (e.g. for remote positioning)
    • cooling
  – close to the fixed target (5, 10, 15 cm downstream)
    • radiation hardness
      – sensors and materials of the MVD are exposed up to \(3 \cdot 10^{13} n_{eq/cm^2}\) and \(3 Mrad\) per CBM year
  – moveable
    • possibility of moving the MVD stations in and out of the beam area during beam tuning and beam focusing (restoration of precise alignment)
  – detector acceptance
    • active detector area ± 2.5° to ± 25°

• Vacuum operation
  – efficient cooling of MAPS (max. 2 W/cm²) to create an uniform temperature distribution over the sensor surface to set the optimum operation parameters
    • concept of conductive cooling
      – use of low mass but high heat conductive materials (active area)
      – use of Cu/Al for heat sinks and support structures (passive area)
    – low out-gassing materials required, e.g. glue EP21TCHT-1 (NASA approved)
• “Ultra”-low material budget
  – minimum multiple scattering to allow for precise determination of the secondary decay vertex (open charm reconstruction)
  – material budget within active detector area is limited to a few % $X_0$
    • use of thinned sensors (50 µm)
    • thin but mechanical stable support structure, which accommodates effective cooling

• Magnetic field
  – impact of Lorentz angle on data quality not studied yet
• Materials
  – combination of low mass but high heat conductive materials calls for the use of high performance materials

  • TPG (Thermal Pyrolytic Graphite)
  • CVD (Chemical Vapor Deposit) diamond

<table>
<thead>
<tr>
<th></th>
<th>TPG</th>
<th>CVD diamond</th>
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</thead>
<tbody>
<tr>
<td>Heat conductivity [W/mK]</td>
<td>1500</td>
<td>2000</td>
</tr>
<tr>
<td>Radiation length $X_0$ (cm)</td>
<td>19.03</td>
<td>12.22</td>
</tr>
<tr>
<td>Material surface</td>
<td>graphite</td>
<td>polished</td>
</tr>
<tr>
<td>Price [€/mm³]</td>
<td>0.03</td>
<td>up to 15</td>
</tr>
<tr>
<td>Thickness [µm]</td>
<td>below 300 difficult</td>
<td>120 – 300 ok</td>
</tr>
<tr>
<td>Project</td>
<td>Demonstrator / back-up</td>
<td>Prototype / SIS-100</td>
</tr>
</tbody>
</table>
CBM Micro Vertex Detector Prototype
Sensor of choice for the MVD Prototype

MIMOSA-26

Dimensions
13.7 x 21.5 mm²

Active area
10.6 x 21.2 mm²

Acceptance coverage for the first MVD station
4 quadrants with 4 sensors each mounted on CVD diamond

Heat sink (copper) for sensor cooling positioned outside of the acceptance
One heat sink is dedicated to cool 2 quadrants

Software used: Autodesk Inventor

MVD for CBM - Prototype
Optimize heat sink geometry in order to minimize

\[ T_{\text{abs}} \quad \text{the absolute operation temperature of the sensors (} T_{\text{abs}} \text{ in the order of } -20 \, ^{\circ}\text{C)} \]

\[ \Delta T \quad \text{the temperature gradient over the sensor surface (} \Delta T \text{ in the order of 10 K)} \]

Include safety margin for the power dissipation of the sensors (max. 2 W/cm²)

due to sensor's design and geometry,
assumption: maximal power dissipation of 100 W for the first station.

Temperature gradient: difficult, depending on support thickness

Absolute temperature: value reached (-20 °C with -70°C cooling fluid)

Four resistors used to simulate an expected power dissipation (25 W) of one quadrant (300 µm TPG)
First MVD Prototype station components

- 16 MIMOSA-26
- 8 Front-End boards
- 8 Converter boards
- 2 Driver boards
- Several Flex-Print Cables
MVD for CBM - Prototype
A 1:1 Mock-up of the MVD Prototype has been built in order to

• test the positioning and arrangement of all parts needed

• test the positioning of the Front-End read-out boards with respect to the sensors

• replace dummy parts with the real detector parts successively
Based on the FairRadLenManager the material budget for the Prototype including

- 50 µm silicon
- 150 µm CVD diamond
- FPC (0.0861 % $X_0$)

in a $\varphi$ slice 0 – 2.5° has been simulated (glue and heat sink were not taken into account).
CBM Micro Vertex Detector
SIS-100 MVD
MVD for CBM - SIS-100 MVD

Sensor of choice for the SIS-100 MVD

MISTRAL A

preliminary dimensions
full sensor
15 x 30 mm²
active area
10 x 30 mm²

MISTRAL B

preliminary dimensions
half sensor
7.5 x 30 mm²
active area
5 x 30 mm²

Sensor arrangement for the SIS-100 MVD

- 3 stations planned
- half sensor needed to keep integrated sensor read-out electronics away from the beam
- sensors are placed on both sides of the CVD diamond to cover the full acceptance with active sensor material

<table>
<thead>
<tr>
<th>Station</th>
<th>Position [cm]</th>
<th>inner radius [mm]</th>
<th>outer radius [mm]</th>
<th>active area [mm²]</th>
<th># of MISTRAL A</th>
<th># of MISTRAL B</th>
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<tbody>
<tr>
<td>0</td>
<td>5</td>
<td>5.5</td>
<td>25</td>
<td>1868</td>
<td>8</td>
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<td>1</td>
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<td>2</td>
<td>15</td>
<td>10.5</td>
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<td>17325</td>
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<td>Sum</td>
<td></td>
<td></td>
<td></td>
<td>26952</td>
<td>112</td>
<td>24</td>
</tr>
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</table>

assuming a 50% yield (cutting, thinning,...) this asks for minimum 300 sensors
MVD for CBM - SIS-100 MVD

Station 0 @ 5 cm

MISTRAL B
MISTRAL A

Station 1 @ 10 cm

Station 2 @ 15 cm

- active sensor area, front side
- active sensor area, back side
- passive sensor area
- detector acceptance

08.09.2011, T. Tischler, Workshop on system integration of highly granular and thin vertex detectors, Mont Saint Odile
Conversion of the actual SIS-100 MVD geometry to CBMRoot was also done.

All active sensor areas are named individually in the way:

MVD-SX-QX-LX-CX-PX

with SX for station [0,1,2]
with QX for quadrant [0,1,2,3]
with LX for layer [0,1]
with CX for chip [00,01]
with PX for active area [0,1]

Based on the FairRadLenManager the material budget for the first Station of the SIS-100 MVD including

- 50 µm silicon
- 150 µm CVD diamond
- aluminum frame
- copper heat sinks

in a φ slice 0 – 2.5° has been simulated.
Ongoing studies

for the Prototype:

- Cooling system
  - dimensions of the heat sink
  - configuration of the cooling pumps
    - number of cooling circuits

- Modular design
  - interface between Cu (heat sink) and CVD
  - dimensioning of services (besides cooling: bias, remote positioning,...)

for the SIS-100 MVD:

- Innovative solution
  - thinned sensors packed in polyimide
    (under study @ IMEC, Belgium and @ CERN)

- MISTRAL A/B properties
  - final form factor(s),...
MVD for CBM -
Open questions

• Materials
  – interplay between materials within the temperature range
given (-20 °C ↔ +20 °C)
  – glue(s)

• “Mass” production
  – alignment
    • precision of a (pre-)alignment of the
      – half stations
      – sensors
      – methods and techniques to simplify

  • tools and methods
    – “Fineplacer”, placing and positioning the sensors individually
    – masks for positioning and gluing more than one sensor at once

• Vacuum vessel
  – how to provide the services
  – influence of the magnetic field
**MVD for CBM - Laboratory**

- **equipment**
  - probe station PA 200 Süss MircoTec
  - manual bonding machine MEI1204W Wagner
  - 3D microscope VHX-600 KEYENCE
  - infra red camera VarioCam HR InfraTec
  - cooling systems cc405/cc815 huber

- **in preparation**
  - clean room (equipment (??))
    - class 10000 (ISO 7)
  - further equipment for producing 3 MVD stations & spares