CBM-XYTER Family Planning Workshop
GSI
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Frontend electronics specifications
for the silicon strip detectors of the
PANDA MVD
Introduction

- PANDA-Experiment
  - Fixed-Target-Experiment
    - Beam: Antiprotons (\(\bar{p}\))
    - Target: Helium or heavier nuclear targets

Luminosity: \(\leq 2 \cdot 10^{32} / \text{cm}^2 \text{s}\)
Event rate: \(\leq 10^7 / \text{s}\)
Momentum range: (2 ...15) GeV/c
Introduction

- Micro-Vertex-Detector (MVD)
  a. Tracking detector
  b. Innermost detector in PANDA
  c. High vertex resolution for primary interaction vertex as well as for secondary vertices of short living particles (e.g. mesons with charm and strange content) and delayed decay products
  d. Should provide additionally some dE/dx information for PID

\[ D^+ \rightarrow \bar{K}^0 x + K^0 y \]
\[ c\tau = 312 \mu m \]

\[ D^\pm \rightarrow \bar{K}^0 x + K^0 y \]
\[ c\tau = 147 \mu m \]
Vertex-Geometry

- Pellet-Target with envisaged primary vertex resolution of \((25 \ldots 50) \, \mu m\)
- MVD inside of outer tracker
- Target pipe crossing MVD volume

Consequences:
- Broken radial symmetry
- Sharp restrictions for MVD-volume
MVD Geometry

- 4 barrel layers along beam axis
  1. / 2. layer: Pixel detectors
  3. / 4. layer: Strip detectors
- Forward part: 6 disks
  1. – 4. disk: Pixel detectors
  5. – 6. disk: Pixel detectors (inner) Strip detectors (outer)
MVD-Geometry

- Restricted volumes: Red (beam-target + pixel part) / Green (strip part) / Yellow (regions of interference)
Strip part implementation

- Geometrical input
- Simulations of physics performance
- Feasibility for engineering process
Strip part implementation

- Sensor layout

FE pitch < minimum sensor pitch = 65 μm

Stereo angle: 90° 90° 15°

Pitch 0.130 (altern. 0.065) 0.130 (altern. 0.065) 0.070

No. of channels: 512 (1024) 256 (512) long side 512
256 (512) short side

No. of FE: 4 (8) 2 (4)

n \cdot \text{width}_{\text{FE}} = \text{width}_{\text{SENSOR}} + \text{safe}ty \ (\text{minimum distance between 2 FE})
Strip part implementation

- Module layout

  → FE connections

  >> Frontend
  >> Backend

  → Total module depth:
    sensor depth + d (FE-sensor) + FE depth + space for readout

FE keep out volume:
APV like (7.1 x 8.1 x 0.3) mm^3

width_{FE} = f(sensor pitch)

depth_{FE} = f(space requirement)
Strip part implementation

- Barrel layout

Impact of module sizes $= f($sensor size; FE size$)$

Module depth $\leftrightarrow$ space requirement: Inner + outer barrel radii / Minimum distances of super-modules / Keep out for target pipe
Count rate studies

- Maximum hit rates at highest beam momenta assuming an interaction rate of $10^7$/sec:
  → (1 ... 5) Mevts / sec / frontend
  → Several 10k evts / sec / single channel

→ Peaking in forward direction
→ Spatial non-uniformity
→ values differ by one order of magnitude
Cooling

- Water cooling
- Pipe diameter ~ 2 mm

- Cooling power very crucial design criterion!!!
- Critical: barrel part, readout of short strips, and for forward disks
Hardware development

- Test station: DTS1 (Lab setup)
  - Evaluation of silicon strip sensors
  - Modular setup allowing further prototype testing
Hardware development

• Main sensor boards for double-sided readout
Hardware development

- Data acquisition (Lab-setup)
  - Used FE: APV25
  - Scintillation trigger
  - Feature extraction in software
  - Numerous tools to characterize module performance
Hardware development

- Test-beam setup in Bonn
Measurements

Energy loss spectrum

Signal to noise analysis

Sensor / Frontend Noise

Cluster multiplicities

θ = 0

θ = 30°
Measurements

- Visualisation of 2D-imaging capability

>> Measurement with $^{90}\text{Sr}$ source at lab-setup

>> SMD device as absorber

>> 2 sensors with single-sided readout

- $90^\circ$ stereo angle
- distance: 3 mm
Database

Module Parameter Database (mysql)

- Test Station Framework
- Converter (Oracle, ASCI, Pandrao)

Query

Module: 16

- Location: Dresden
- I2C Addresses: FE1: 0110011
  FE2: 0110100
  FE3: 0110101

Calibration Module: 16

<table>
<thead>
<tr>
<th>Field</th>
<th>Channel</th>
<th>Parameter</th>
<th>Error (mm)</th>
<th>Chip</th>
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<tbody>
<tr>
<td>0</td>
<td>0</td>
<td>5.326376</td>
<td>0.04956</td>
<td>29.965182 Graph</td>
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<tr>
<td>0</td>
<td>1</td>
<td>6.113111</td>
<td>0.00866</td>
<td>1.090123 Graph</td>
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<td>0</td>
<td>2</td>
<td>6.176593</td>
<td>0.00594</td>
<td>0.418843 Graph</td>
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<tr>
<td>0</td>
<td>3</td>
<td>6.899384</td>
<td>0.00116</td>
<td>0.359524 Graph</td>
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<td>0</td>
<td>4</td>
<td>6.169224</td>
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<td>0.250523 Graph</td>
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<td>0</td>
<td>5</td>
<td>6.140880</td>
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<tr>
<td>0</td>
<td>6</td>
<td>6.128975</td>
<td>0.00177</td>
<td>0.370097 Graph</td>
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<td>7</td>
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<td>8</td>
<td>5.676704</td>
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<td>9</td>
<td>5.40176</td>
<td>0.00409</td>
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<td>10</td>
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<td>0.00163</td>
<td>0.27171 Graph</td>
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<td>0</td>
<td>11</td>
<td>5.475609</td>
<td>0.00549</td>
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<tr>
<td>0</td>
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<td>5.439588</td>
<td>0.00059</td>
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<td>13</td>
<td>5.40356</td>
<td>0.005206</td>
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<tr>
<td>0</td>
<td>14</td>
<td>5.40356</td>
<td>0.006049</td>
<td>0.376762 Graph</td>
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</tbody>
</table>

Leakage Current

Channel Distribution

CBM-XYTER Family Planning Workshop, GSI, 2008/12/05, Th. Würschig, H.-G. Zaunick
Frontend electronics specifications for the silicon strip detectors of the PANDA MVD
FE requirements

• Updated specifications based on:
  ♦ Experimental setup
  ♦ Physics requirements
  ♦ Input of detailed implementation
    ➢ Mechanics
    ➢ Cooling
    ➢ Support
    ➢ Design optimisation:
      technical feasibility <> detector simulations
  ♦ Input of measurements with test station
<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Geometry</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>width</td>
<td>≤ 8 mm</td>
<td></td>
</tr>
<tr>
<td>depth</td>
<td>≤ 8 mm</td>
<td></td>
</tr>
<tr>
<td>input pad pitch</td>
<td>≤ 50 µm</td>
<td></td>
</tr>
<tr>
<td><strong>pad configuration</strong></td>
<td></td>
<td>lateral pads occupied only for diagnostic functions, must be left unconnected for final setup</td>
</tr>
<tr>
<td><strong>FE channels</strong></td>
<td>2⁶ ... 2⁸</td>
<td>default: 128 channels</td>
</tr>
<tr>
<td><strong>Input Compliance</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>sensor capacitances, full depletion</td>
<td>&lt;10 pF</td>
<td>rect. short strips</td>
</tr>
<tr>
<td></td>
<td>&lt;50 pF</td>
<td>rect. long strips + ganging</td>
</tr>
<tr>
<td></td>
<td>&lt;20 pF</td>
<td>fw. disc strips</td>
</tr>
<tr>
<td>charge polarity</td>
<td>either</td>
<td>selectable via slow control</td>
</tr>
<tr>
<td>input ENC</td>
<td>&lt; 800 e⁻</td>
<td>C_{Sensor} = 10 pF</td>
</tr>
<tr>
<td></td>
<td>&lt; 1100 e⁻</td>
<td>C_{Sensor} = 25 pF</td>
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<tr>
<td><strong>Signal</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>dynamic range</td>
<td>160 ke⁻</td>
<td>24.000 e⁻ MIPs in 300 µm Silicon, guaranteed within lifetime</td>
</tr>
<tr>
<td>min. SNR for MIPs</td>
<td>12</td>
<td>typical Si drift times</td>
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<tr>
<td>peaking time</td>
<td>≈ 10...25 ns</td>
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<tr>
<td>digitization resolution</td>
<td>≥ 8 bit</td>
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</table>
## FE requirements

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
<th>Remarks</th>
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<tbody>
<tr>
<td><strong>Power</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>overall power dissipation</td>
<td>&lt;1W</td>
<td>assuming 128 channels/FE</td>
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<tr>
<td><strong>Dynamical</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>trigger</td>
<td>internally generated</td>
<td>when charge pulse exceeds adjustable threshold level</td>
</tr>
<tr>
<td>time stamp resolution</td>
<td>&lt;20 ns</td>
<td></td>
</tr>
<tr>
<td>dead time / ch</td>
<td>&lt;6 μs</td>
<td>baseline restored to within 1% of equilibrium</td>
</tr>
<tr>
<td>overshoot recovery time / ch</td>
<td>&lt;25 μs</td>
<td></td>
</tr>
<tr>
<td>average hit rates / ch</td>
<td></td>
<td>simulations @ 15 GeV beam mom.</td>
</tr>
<tr>
<td>(poissonian mean)</td>
<td></td>
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<tr>
<td>hot spots</td>
<td>9.000 s⁻¹</td>
<td>$\bar{p}p$</td>
</tr>
<tr>
<td></td>
<td>40.000 s⁻¹</td>
<td>$\bar{p}Au$</td>
</tr>
<tr>
<td></td>
<td>6.000 s⁻¹</td>
<td>$\bar{p}p$</td>
</tr>
<tr>
<td></td>
<td>30.000 s⁻¹</td>
<td>$\bar{p}Au$</td>
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<tr>
<td>average occupancy</td>
<td></td>
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<tr>
<td><strong>Interface</strong></td>
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<td></td>
</tr>
<tr>
<td>slow control</td>
<td>any</td>
<td></td>
</tr>
<tr>
<td>data</td>
<td>sparsified digital</td>
<td></td>
</tr>
</tbody>
</table>

Radiation Hardness: ~ 1Mrad (TID)

http://panda-wiki.gsi.de/cgi-bin/view/Mvd/FEspecs