Integration and Installation of the ALICE Silicon Pixel Detector (SPD)

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Radial coverage defined by beampipe and requirements for track-matching with the TPC

Inner layers:
- high multiplicity environment (~80 tracks/cm²)
- unambiguous 2D-readout
- secondary vertexing capability

⇒ 2 layers of Silicon Pixel Detectors

SPD
Half-Barrel

Intralayer
Cooling tubes
Compact and lightweight!
Outline

- SPD parts
- Integration and pre-commissioning
- Installation in ALICE and first tests
- Summary
1. SPD Parts

- 2 barrel layers
- Radius inner layer: 3.9 cm
- Radius outer layer: 7.6 cm
- Beampipe - inner layer: ~5 mm
- Inner layer $|\eta| < 2$
- Outer layer $|\eta| < 1.4$
SPD Half-Barrels - Schematic

Inner layer

Cone

Power cables, optical fibres, cooling tubes
Sector

8 half-staves mounted on outer layer
4 half-staves mounted on inner layer

Optical connections
Power supply
100 m optical fibres connect each half stave with the off-detector electronics in CR4

ALICE pit

Control-Room 4

10 Pixel Chips/Half-stave

Analog pilot
Digital pilot
GOL
RX40

Optical package

Link receiver

Deserializer format and encoder
Serializer

Router

MCM
Material Thickness

- CF support: 200 µm
- Cooling tube (Co-Cr-Ni alloy): 40 µm wall thickness
- Grounding foil (Al-Kapton): 60 µm
- Pixel chip (Silicon): 150 µm
- Bump bonds (Pb-Sn): diameter ~15-20 µm
- Silicon sensor: 200 µm
- Bus (Al+Kapton): 240 µm
- SMD components
- Glue (Ecobond) and thermal grease

>> total material budget ~ 1%\(X_0\) (active region)
2. Integration Tests

System Integration

Mechanical Integration
Functionality of sectors and half-barrels
Qualification of final off-detector components
Integration Tests

- Test system installed which uses final components and simulates as close as possible the “real” conditions
  - $\text{C}_4\text{F}_{10}$ cooling plant
  - 30 m LV cables, 100 m HV cables
  - 35 m optical fibres
  - CAEN Easy Crates and HV and LV modules
  - Interlock
  - DAQ and Trigger system
  - SPD DCS and ECS

- Integration system planed to test 10 sectors in parallel

- Each sector is tested individually before mechanical integration into the half-barrel at which point the full test sequence is repeated
Test Bench

Half-barrel
Sector
HV/LV cables
Optical fibres
Cooling lines

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Test Setup Schematics

- Cooling
- FE-PVSS
- Conf. DB
- DAQ/DAT
- MOOD
- Online
- HV/LV-PVSS
- Analysis Tool (CDT)
- HV/LV PS
- Off-detector Electronics
- Router/LRx
- Trigger
- Sector or Half-barrel

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Test Sequence

Static tests
- Visual inspection
- Pixel chip and MCM current consumptions
- Sensor I-V characteristic
- Pixel chips and MCM temperature
- Thermal image
- Optical power

Data taking - Calibration runs
- Minimum Threshold Scan
- Mean Threshold Scan
- Generic DAC Scan
- Uniformity Matrix Scan
- Noise Scan
- Delay Scan
- Fast-OR Uniformity Scan
Sensor I-V Characteristics

- I-V recorded for each half-stave from 0 V to 50V on each sector
- On 10 HS reduced operating voltage necessary due to current $I_{HS} > 10\mu A$, but all voltages are above depletion ($V_{fd} \sim 12V$)

Current limit for ladder acceptance: $2 \times 2\mu A$
**HS Temperature**

- 1.5 kW dissipated heat, C$_4$F$_{10}$ evaporative cooling system
- Pixel chip temperatures measured by two independent Pt1000 chains

Thermal grease

Cooling tube
HS Temperature

- Two Pt 1000 measurements compared with temperature measured with thermal camera at three temperature settings (RT, cooled ~ 15°C, powered ~28°C)
Minimum Threshold

- Threshold is set via an internal DAC in each chip (pre_vth, 8-bit) >> scan each chip for the minimum threshold setting
- Minimum threshold of all HS ~ 2000 e⁻
The response of each sector is tested with a Sr90 source
Complementary test to the test-pulse scan in order to detect non-working pixels

Source moved across outer layer
Non-Working Pixels

- Results from ladders tests (repeated during HS and sector tests)
- Number of ladders qualified for mounting: 343 (74 reworked) - out of 445 => 77%

![Histogram of non-working pixels per chip](image)

Cut for class 1 ladders
Noisy Pixels

Tested in noise runs on each sector

Number of noisy pixels per sector (~1 mio cells)
Total: 35
Average: 3.5
Test with Cosmics - FO Trigger

- Data taken using self-triggering with FastOr (FO) trigger
- FO signal is generated in each pixel chip on arrival of a hit
- FO is sent off detector every 100 ns
- FO signal will contribute to L0 (min. bias in p-p, centrality trigger and selection of impact parameters in heavy ion collisions, ..)

Pixel Trigger system

- To DAQ in control room
- 120 G-Link
- 1200 bits @ 10 MHz
- Fast-OR extraction
- Optical splitters
- Processing
- CTP
Test with Cosmics

- Coincidence between inner and outer layer FO signal
- Reconstructed clusters
- \( z \) correlation between inner and outer layer

<table>
<thead>
<tr>
<th>Estimated ( \mu ) rate</th>
<th>Event rate (avg. 43 mins)</th>
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<tbody>
<tr>
<td>0.17 s(^{-1})</td>
<td>0.14 s(^{-1})</td>
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Cluster size (inner layer)

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3. Installation

- On June 15 and 16, 2007 both half-barrels were transported to the ALICE pit.
- Each box weighs ~ 200kg - most of it is not the half-barrel!

![Image with labeled components: Transport box, Half-barrel suspension system, Shock sensor]
Moving the Half-Barrels

Transport to the installation platform
Removing of the Beampipe Protection

TPC

ITS

Be beampipe

Absorber

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Installing the Upper Half-Barrel

Inner layer
Outer layer
SPD Installed - View onto the Cone
Moving of the ITS over the SPD
First Tests after Installation

- One side (side C/absorber side) has been fully connected electrically (power supply cables and optical fibres)

- The cooling is not yet operative as the final connections can only be done once the mini-frame support is positioned on side A. Only then the circuit can be closed and the pixel chips can be switched on (foreseen Nov. 12, 2007)

- All MCMs on side C have been powered from the final rack positions, using the final power supply modules. A complete readout test of the MCMs was carried out from CR4.

- Sensor currents have been verified on a subset of half-staves.
Tests after Installation

- Side A has been connected to the patch panels on the cones. All MCMs have been tested connecting locally a power supply at the cone patch panels and connecting to a fibre leading to CR4.

- All MCMs on side A and C have been found to be fully functional.

- The connection of side A from the cones to the service chariot is done. The test of these connections can only be done after the TPC has been moved to the IP (foreseen Sep. 24, 2007).

- Final tests from the racks and to CR4 on side A can be done after the mini-frame has been installed.
During the integration test all 120 half staves have been tested on sector and half-barrel level using final system components.

The SPD has been transported and installed in ALICE at the end of June. The ITS has been moved over the SPD.

First limited functional tests have been carried out and showed all 120 MCMs to function correctly.

Installation of the off-detector electronics in the pit is almost completed and first tests are being carried out.

We expect that the SPD can be switched on before the end of the year.
SPD inside the ITS

Absorber

ITS