The CMS Silicon Strip Tracker - System Aspects

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For the CMS Tracker Collaboration
Outline

- Description of the SST and its components
- Test Beam results May 2003
- System Tests in the Laboratory
- Conclusions
- Outlook
Scale of the CMS tracker

CMS tracker

210 m² Si

CMS

Compact Muon Solenoid

L3 HCAL

L3
Silicon Strip Tracker layout

Outer Barrel -- TOB -

Inner Barrel & Disks -- TIB & TID -

End Caps -- TEC 1&2 -

2.4 m

5.4 m
Silicon module components

(TEC ring 6 module)

- HV
- CLK / Data / LV
- FE Hybrid
- Pitch adapter
- Inter-wafer bonds
- CF frame

- Wafer 1
- Wafer 2
Tracker Endcap (TEC)

- TEC building block is the PETAL
- CF / honeycomb, integrated cooling
- Up to 21 Si modules – 16 SS, 6 DS
Tracker Outer Barrel (TOB)

The “rod” is the self-contained TOB building block

6 (SS) or 12 (DS) Si modules
Interconnection electronics
Control electronics
Optoelectronics
Cooling pipe + module cooling elements

integrated on
a CF frame
Tracker Inner Barrel (TIB)

- TIB “shell”
- CCU ring
- F.E. Hybrid
- Mother (interconnect) cable
- Cooling loop
Final system

~10 M Channels, 256:1 MUX => 40,000 optical data links (fibres)
May 2003 Test Beam

- CERN SPS X5 experimental hall
- 25 ns (LHC – like) bunch structure
- Choice of pions (10**5/cm²) or muons (1000/cm²) at 120 GeV
- All 3 sub-systems represented:
  - 6 TOB modules
  - 6 TIB modules mounted on almost final SHELL
  - 10 modules mounted on a PETAL close to final design
- All sub-systems used Digital Optical Link
- Emphasis on systems integration aspects rather than detector performance
- TIB: power supply study (comparison CAEN / LABEN)
- TEC: cooling study (petal cooled to –20 °C)
Test Beam Systems

10 front petal modules
All ICB
2 CCUs
10 Analog opto-hybrids

6 IB2 modules
4 mother cables
4 CCUs
6 Analog opto-hybrids
Layer3 mechanics

Beam direction

TEC petal

TEC position

TOB position

TIB

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DAQ – set-up

RU 0 - FED (TOB)

RU 1 - FED (TIB)

Analog opto receivers
DAQ - Commissioning

• Debugging phase:
  - Three systems running in parallel (TIB, TOB, TEC)
  - Easy integration from DAQ point of view: 2 hours to start data taking once HW is OK → smooth running
  - FED sampling tuning with ticks + Opto gain adjustment
  - Timing scan (Latency+PLL) → best working point
  - User friendly Run Control (direct XDaqWin as backup)

• TIB + TOB integration
  - Done in few hours → demonstrate commission capability of the system
  - Trigger latency +PLL scan for time alignment of the two detectors one respect to the other and with respect to the beam
  - Major milestone in DAQ development
  - TEC integration not possible due to the ring instabilities
Peak Muon run
Bias = 300V

S/N ~ 26

Cluster S/N (i)

Entries | 55191
\hline
\chi^2/\text{ndf} | 368.6 / 62
P1 | 2222
P2 | 25.85
P3 | 0.2985

Counting-room
TIB
Power supplies
Cluster S/N (ii)

Signal to noise distribution (deconvolution)

TIB2 (S/N = 18.0235)

Counting-room
TIB
Power supplies

TIB
320μm

TOB
500μm

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Cluster S/N (iii)

TEC
500µm

Ring 5 stereo detector

S/N Ring 5 stereo module

Entries 2755
Mean 30.81
RMS 15.87

normal side
deconvolution mode, HV = 250 V

Entries 2786
Mean 28.88
RMS 16.23

decorrelation mode, HV = 250 V
TIB Power Supply Set-up

Caen counting-room Prototype

+ 90 m of LIC17 cable
+ 35 m of LIC11 cable

Laben counting-room Prototype

An interlock system was implemented (220V mains, temperature and relative humidity are controlled)
Power supplies - performance

- From data taken in similar conditions with both 'counting-room type' prototypes...

- Preliminary data: no evident differences!
- Stable performances during ~18 days of data taking → not a single spurious Reset on TIB
TEC Petal Cooling (i)

- Si sensors and electronics cooled by cooling loop integrated into petal
- Used CMS cooling fluid (C6F14)
- Petal placed in insulated box
- Continuous dry N2 flow
- Temperature and humidity monitoring with probes mounted on petal (T:12, RH:4)
- LV/HV interlock
Conclude: problem with petal cooling at certain module locations!
Lab System Tests

- Cooling optimisation
- Noise studies
- Tests of control ring, timing, etc. (not covered)
Cooling System - Insert

Goal:

\[ T_{\text{wafer}} = -10^\circ C \]
&

\[ T_{\text{fluid}} = -20^\circ C \]

\[ \Rightarrow \Delta T_{\text{max}} = 10^\circ C \]

<table>
<thead>
<tr>
<th>Material</th>
<th>Thermal Conductance [W/mK]</th>
<th>Dimensions</th>
</tr>
</thead>
<tbody>
<tr>
<td>K800x/EP</td>
<td>384/97/0.7 (x/y/z)</td>
<td>t = 0.7 mm</td>
</tr>
<tr>
<td>Aluminum</td>
<td>154</td>
<td>D = 9mm / 7mm</td>
</tr>
<tr>
<td>Araldit/AIOx</td>
<td>0.5</td>
<td>t = 0.025mm</td>
</tr>
<tr>
<td>Titanium</td>
<td>16</td>
<td>D = 3.95mm t = 0.1mm</td>
</tr>
</tbody>
</table>
Crimp ‘C’

- enlarge area of heat transfer \( \sim 85 \text{mm}^2 \)
- connect upper and lower CFC surface

\[ \Delta T_{\text{upper-lower}} = 2K \]

\[ \text{CFC} \]

\[ \text{compensate for low thermal conductivity} \]
Ring 5 stereo modules:
* 4x1W on 3 inserts
* worst case middle insert
* 9mm impossible in middle!

\[ \Delta T_{\text{(bare CFC)}} \approx 27K \]
\[ \Delta T_{\text{('C')}} \approx 16K \]
\[ \Delta T_{\text{('C'\&DC340)}} \approx 10K \]

\[ \rightarrow \text{'C' & DC340 will do the Job!} \]
Experimental Verification

- C-crimp and DC340
- Tested with water at room temp.
- Fluid flow rate as in CMS

\[ \Delta T \] is within spec. at all positions
TOB Cooling Results

Design figure:
$\Delta T < 10 \, ^\circ C$
with irradiated sensors
and highest optohybrid settings

$\Delta T \, (\text{Si-pipe}) \approx 6 \, ^\circ C$

All tests performed at room temperature so far
Basic measurements to be repeated in the cold room in the coming weeks

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Noise - TEC Ring 4

Position 4.1

Position 4.2

Position 4.3

Position 4.4

⇒ non-flat noise on position 4.3
Noise - TEC Ring 6

Position 6.1

Position 6.2

Position 6.3

Position 6.4

⇒ non-flat noise on position 6.3
Shielding on ICB

Prototype shielding foils for main ICB produced in industry
Thickness of Shielding

⇒ Thickness of at least 10 µm is necessary.
   No significant difference between 15 and 20 µm.
   (Foils with a thickness of 17.5 microns are available at the company)
TOB Shielding

Same problem seen in TOB

Source of noise identified as *external* in both cases (power supplies)
TIB Lab Set-up

- Si Module
- AOH
- MCable
- Dummy MCables
- Tested
  - Control ring
  - Module readout through the AOH
  - Possible E.M. interference

- Prototype power supplies (CAEN / Laben)
- Long cables (100 m)
- No shields / Faraday cage
Raw data noise distr. per chan.

No noise problems encountered by TIB

Si @ 200 V

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Common mode noise

Si @ 200 V

CMN noise
1.15 ADC ch

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Conclusions

- All 3 SST sub-systems in test beam May 2003
- Readout and control functioning properly *with full optical link*
- DAQ verified with multiple sub-systems (TIB and TOB)
- Two CMS prototype power supplies successfully tested
- Cooling efficiency problem identified for some TEC module positions (now solved)
- Unacceptable noise distributions present for some module positions in TEC and TOB
- Noise problem solved using appropriate shielding
Outlook

• Mass production of most major SST components started or about to begin:
  – Modules
  – Support structures (Rods, Shells, Petals)
  – Super-structures (e.g. TEC CF disks)
  – Final back-end electronics (FED & FEC with integrated optical receivers / transmitters)
  – Power cables and optical fibres

• As these become available, will test progressively larger assemblies

• Ex. One full TEC cooling loop – 10 petals mounted on disks with -10 °C ambient temp.

• Testing of interlock / safety systems