Silicon Sensor and Detector Developments for the CMS Tracker Upgrade

- sLHC requirements for the tracker
- Tracker Sensor RD program
- Tracker Trigger RD

R. D'Alessandro* on behalf of the CMS Tracker Collaboration

* Università di Firenze & INFN- Firenze (Italy)
Requirements

- The CMS tracker for sLHC needs to have:
  - higher radiation resistance, with respect to both instantaneous and integrated levels
  - higher readout granularity, to keep the channel occupancy at an adequate level
  - develop sensors able to give information about track $p_T$ and direction for the trigger

- The Challenge: Build a replacement Tk for $L > 10^{34}$ cm$^{-2}$s$^{-1}$ with L1 trigger capabilities
Requirements (2)

- Silicon sensors must survive accumulated dose levels 10 times higher than the current Tracker.
- Higher granularity and (perhaps) thinner sensors will be required made with different technologies.
Substrate types:
- FloatZone (FZ), Magnetic - Czochralski (MCZ), Epitaxial (Epi).

Implants:
- p-in-n (N-type), n-in-p (p-stop) (P-type), n-in-p (p-spray) (Y-type)
- p-in-n (double metal), n-in-p (p-stop; double metal), n-in-p (p-spray; double metal)
RD objectives

- Conduct tests, before and after irradiation, to determine the characteristics of single-sided silicon sensorsof various thicknesses and materials acquired from HPK in order to establish optimal material and strip/pixel features for the upgrade of the CMS Tracker.

- Collaboration wide effort. For example (this talk):
  - Efforts on Multi-Strip-Siliconstrip Detector (MSSD) sensors at:
    - Cern, Fermilab, Florence, KIT, Others
Many complicated and variegated scenarios

• Examples (just for beam tests) ..... 
  – Sensors for beam test in November?
    • MSSD (mostly irradiated, MCz non-irradiated, FZ320 as reference)
    • MPIX (MCz non-irradiated)
    • Baby_Strixel (maybe, if possible)
  – Sensors for beam test in October (HEPHY)
    • Baby_PA
    • Baby_Std_2nd_metal_layer
    • Baby_Add_2nd_metal_layer
  – Next year test beam with Baby_Std
MSSD sensor under study

- 65744.25um x 32792um
- 12 regions – Different: pitch, width, ratios

<table>
<thead>
<tr>
<th>region</th>
<th>pitch</th>
<th>implant width</th>
<th>alu width</th>
<th>w/p</th>
<th>DC Padsize</th>
<th>AC Padsize</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-120</td>
<td>120</td>
<td>16</td>
<td>29</td>
<td>0.133</td>
<td>85x38</td>
<td>150x50</td>
</tr>
<tr>
<td>2-240</td>
<td>240</td>
<td>34</td>
<td>47</td>
<td>0.142</td>
<td>85x38</td>
<td>150x50</td>
</tr>
<tr>
<td>3-80</td>
<td>80</td>
<td>10</td>
<td>23</td>
<td>0.125</td>
<td>85x38</td>
<td>150x50</td>
</tr>
<tr>
<td>4-70</td>
<td>70</td>
<td>8,5</td>
<td>21,5</td>
<td>0.121</td>
<td>85x38</td>
<td>150x50</td>
</tr>
<tr>
<td>5-120</td>
<td>120</td>
<td>28</td>
<td>41</td>
<td>0.233</td>
<td>85x38</td>
<td>150x50</td>
</tr>
<tr>
<td>6-240</td>
<td>240</td>
<td>58</td>
<td>71</td>
<td>0.242</td>
<td>85x38</td>
<td>150x50</td>
</tr>
<tr>
<td>7-80</td>
<td>80</td>
<td>18</td>
<td>31</td>
<td>0.225</td>
<td>85x38</td>
<td>150x50</td>
</tr>
<tr>
<td>8-70</td>
<td>70</td>
<td>15,5</td>
<td>28,5</td>
<td>0.221</td>
<td>85x38</td>
<td>150x50</td>
</tr>
<tr>
<td>9-120</td>
<td>120</td>
<td>40</td>
<td>53</td>
<td>0.333</td>
<td>85x38</td>
<td>150x50</td>
</tr>
<tr>
<td>10-240</td>
<td>240</td>
<td>82</td>
<td>95</td>
<td>0.342</td>
<td>85x82</td>
<td>150x82</td>
</tr>
<tr>
<td>11-80</td>
<td>80</td>
<td>26</td>
<td>39</td>
<td>0.325</td>
<td>85x38</td>
<td>150x50</td>
</tr>
<tr>
<td>12-70</td>
<td>70</td>
<td>22,5</td>
<td>35,5</td>
<td>0.321</td>
<td>85x38</td>
<td>150x50</td>
</tr>
</tbody>
</table>
MSSD examples

- Multi-SSD, P-type:
  - Individual p-stops
  - 120um Pitch
  - 16um Implant
  - 29um Al

- Multi-SSD, N-type
  - 240um Pitch
  - 34um Implant
  - 47um Al
Reuse existing hardware

- We used TEC und TOBhybrids with 4 APV’s
- Also produced many new pieces

Pitch adapters for example:

- TOB_hybrid_PA (44µm - 110µm)
- TEC_hybrid_PA (44µm - 139µm)
- 100 pieces TOB_hybrid_PA
- TOB_Extension_PA (110µm)
- TEC_Extension_PA (139µm)
- MPIX_PA (multi-pixels - 110µm)
- MSSD_PA (multi-strips - 139µm)
MSSD Test setup

- Firenze setup for static measurements

22 July 2011 - EPS Grenoble
R. D'Alessandro on behalf of CMS Tracker
MSSD sensor mounting

- The sensor and the pitch adapter are glued to a thin ceramic frame.
- Sensor and PA are then bonded.
- This is the basic assembly that is then shipped around the participating institutes.
- When measurements need to be done:
  - the assembly is placed on an aluminium support structure
  - bonds connect the sensor to two PCBs that route guard rings and strips to a connector
Float Zone sensors

- Three thicknesses: 320um, 200um, 120um.

C_back capacitance on all 12 regions on FZ thicknesses 120, 200 and 320um compared for N, P and Y
Float Zone sensors

Interstrip capacitance on all 12 regions on FZ thicknesses 120, 200 and 320µm compared for N, P and Y.
Measurements

- Campaign just started. First irradiated sensors not measured yet.
- Intercalibration between centres is still ongoing.
- Setups are now stable and we have converged to a common procedure and data format for the results.
- Results are stored as xml files on an SQL database.
Trigger information

- Derive $p_T$ information LOCALLY
- In a B field, ideal case of cylindrical layers with non-flat modules:

$$p_T^{\text{meas}} [\text{GeV}/c] = 0.15 B [T] \cdot R [m] \cdot \frac{\Delta R [\mu m]}{TW [\mu m]}$$

$TW$ is the cluster size in terms of pitch
Studies from data

Performance of “trigger” modules evaluated with CMS data (7 TeV p-p collisions)

- Mainly MinBias/QCD events, $\pi$ & $\mu$ tracks inside hadronic jets
- Good quality tracks selected: $\chi^2 < 2$, #hits > 11, etc.

Double Sided (DS) modules considered to mimic the 2-in-1 stacked modules

- TOB Layer 2
  - $R = 70$ cm
  - $\Phi = 21.9$

Single Sided (SS) modules considered to study

- TOB Layer 6
  - $R = 108$ cm
  - $\Phi = 4.2$

$\eta$ Coverage of (1/4) present CMS Tk

2.8 m

1.2 m
Studies from data

- **SS:** Sensitivity to CW
  Tracks selected with CW < 3
  Selection efficiency as a function of $p_T$
  - Efficiency > 90% from 2 GeV/c onward.

- **DS:**
  Tracks selected with TW("d") < 1.5 mm
  Efficiency ~100% for high (> 5 GeV/c) $p_T$ tracks

22 July 2011 - EPS Grenoble
R. D'Alessandro on behalf of CMS Tracker
Stacked modules

- Pair of corresponding strips wire-bonded to a pair of neighboring readout channels
- Wire-bonding performed at ~40 µm effective pitch
- NO pitch adapter

- Pair of corresponding strips wire-bonded to the same readout channel
- Wire-bonding performed at ~80 µm and ~120 µm effective pitch (2 prototypes)
- through pitch adapter

22 July 2011 - EPS Grenoble

R. D'Alessandro on behalf of CMS Tracker
Stacked modules

- Detectors assembled with spare modules from the current CMS tracker
Conclusions

- A systematic RD campaign for a new tracking system has begun.
- Many items (electronics, data links, sensors, triggering, cooling, mechanics, etc.)
- Sensor campaign well underway with the objective of having all relevant information in by the end of 2012.
- Trigger studies have already led to the production of stacked modules which could be the basis for a future trigger layer.
Strixels tests

Baby_Striixel Example

One Baby_Striixel is divided in 2 x 256 strips