Characterization of a depleted monolithic pixel sensor in 150 nm CMOS technology for the ATLAS Inner Tracker upgrade

F.J. Igauz (IRFU/CEA-Saclay), on behalf of LF-CPIX collaboration

1.- LF-MONOPIX chip: design & pixel configuration

- Depleted Monolithic Active Pixel Sensor (DMAPS)
  - Large collecting well containing all the electronics:
    - High field -> Less trapping -> Radiation hard
    - Large (∼400 ff) sensor capacitance -> Noise & speed/power penalty & cross-talk

- LF foundry 150 nm HV-CMOS
  - Wafers can be thinned & backside processed
  - Chip size: 10 mm x 10 mm
  - Pixel size: 50 µm x 250 µm
  - Pixels distributed in 36 columns x 129 rows
  - 9 flavors (4 cols each) with different configurations

3.- Gain & input capacitance

A $^{55}$Fe source (5.9 keV x-rays) is used to measure:

\[ G = \frac{\Delta V_{out}}{160 \ e^-} \quad C_{inj}(F) = \frac{1620 \ e^-}{V_{inj}(F)} \ q_{th}(C) \]

<table>
<thead>
<tr>
<th></th>
<th>CMOS</th>
<th>NMOS</th>
<th>CMOS</th>
<th>NMOS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gain (µV/e-)</td>
<td>15.9 ± 0.1</td>
<td>12.0 ± 0.1</td>
<td>2.40 ± 0.05</td>
<td>2.82 ± 0.05</td>
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<tr>
<td>20.0 ± 0.1</td>
<td>13.0 ± 0.1</td>
<td>2.25 ± 0.06</td>
<td>2.47 ± 0.08</td>
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</tr>
</tbody>
</table>

4.- Threshold & electronic noise

Methodology:
- External injection signal scan, recording the probability of pixel firing at $V_{th} = 0.795$ V.
- Error function fitted to S-curves -> Threshold & noise parameters.

<table>
<thead>
<tr>
<th>Feature</th>
<th>Type</th>
<th>Untuned</th>
<th>Tuned</th>
</tr>
</thead>
<tbody>
<tr>
<td>Threshold</td>
<td>V1 disci</td>
<td>2960 ± 150</td>
<td>2990 ± 230</td>
</tr>
<tr>
<td></td>
<td>V2 disci</td>
<td>1926 ± 118</td>
<td>2430 ± 92</td>
</tr>
<tr>
<td>Thr. Disp.</td>
<td>V1 disci</td>
<td>533 ± 45</td>
<td>104 ± 14</td>
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<tr>
<td></td>
<td>V2 disci</td>
<td>926 ± 89</td>
<td>153 ± 21</td>
</tr>
<tr>
<td>Noise</td>
<td>CMOS</td>
<td>230 ± 17</td>
<td>238 ± 17</td>
</tr>
<tr>
<td></td>
<td>NMOS</td>
<td>193 ± 10</td>
<td>195 ± 13</td>
</tr>
</tbody>
</table>

5.- Chip threshold tuning

1. Each chip has been scanned for TRIM values between 0 & 11.
2. For each pixel:
   a) Linear function fitted to the dependence of threshold with TRIM.
   b) Linear fit used to get the TRIM value for a common threshold.
3. Chip scan repeated for the tunned TRIM values.

6.- LF-CPIX collaboration


7.- References

- T. Hirono et al., CMOS pixel sensors on high resistive substrate for high-rate, high-radiation environments, NIM A831 (2016) 94-98.