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A process modification for CMOS monolithic active pixel sensors for enhanced depletion, timing performance and radiation tolerance

W. Snoeys, G. Aglieri Rinella, H. Hillemanns, T. Kugathasan, M. Mager, L. Musa, P. Riedler, F. Reidt, J. Van Hoorne, A. Fenigstein, T. Leitner



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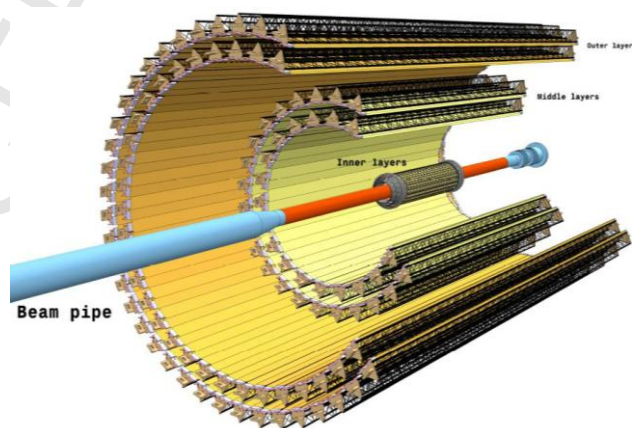
3 *W. Snoeys, G. Aglieri Rinella, H. Hillemanns, T. Kugathasan, M. Mager, L. Musa, P. Riedler, F. Reidt,*
4 *J. Van Hoorne, CERN, CH-1211 Geneva 23, Switzerland*

5 *A. Fenigstein, T. Leitner, TowerJazz Semiconductor, Migdal Haemek, Israel 23105*

6 **Abstract**

7 For the upgrade of its Inner Tracking System, the ALICE experiment plans to install a new tracker
8 fully constructed with monolithic active pixel sensors implemented in a standard 180 nm CMOS
9 imaging sensor process, with a deep pwell allowing full CMOS within the pixel. Reverse substrate
10 bias increases the tolerance to non-ionizing energy loss (NIEL) well beyond 10^{13} 1MeV n_{eq}/cm^2 , but
11 does not allow full depletion of the sensitive layer and hence full charge collection by drift,
12 mandatory for more extreme radiation tolerance. This paper describes a process modification to
13 fully deplete the epitaxial layer even with a small charge collection electrode. It uses a low dose
14 blanket deep high energy n-type implant in the pixel array and does not require significant circuit or
15 layout changes so that the same design can be fabricated both in the standard and modified process.
16 When exposed to a ^{55}Fe source at a reverse substrate bias of -6 V, pixels implemented in the
17 standard and the modified process in a low and high dose variant for the deep n-type implant
18 respectively yield a signal of about 115 mV, 110 mV and 90 mV at the output of a follower circuit.
19 Signal rise times heavily affected by the speed of this circuit are 27.8 +/- 5 ns, 23.2 +/- 4.2 ns, and
20 22.2 +/- 3.7 ns rms, respectively. In a different setup, the single pixel signal from a ^{90}Sr source only
21 degrades by less than 20 % for the modified process after a 10^{15} 1MeV n_{eq}/cm^2 irradiation, while the
22 signal rise time only degrades by about 16 +/- 2 ns to 19 +/- 2.8 ns rms. From sensors implemented
23 in the standard process no useful signal could be extracted after the same exposure. These first
24 results indicate the process modification maintains low sensor capacitance, improves timing
25 performance and increases NIEL tolerance by at least an order of magnitude.

26 **1 The standard process for the ALPIDE sensor in the ITS upgrade**



27

28 **Figure 1** Layout of the new ALICE ITS with 3 inner, 2 middle and 2 outer layers spanning a range in radius of 22 to
29 400 mm[1].

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