Characterisation of p-type detectors for the future Super-LHC

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Abstract

A technology for the fabrication of p–type microstrip silicon radiation detectors using moderate p–spray implant insulation has been developed at CNM-IMB. The p–spray insulation has been optimised in order to withstand the ionising irradiation dose expected in the middle region of the ATLAS tracking system for the future Super–LHC. The best technological options for the moderate p–spray implants were found by using a simulation software package and dedicated calibration runs. Detectors have been fabricated with Float Zone and Magnetic Czochralski p–type high resistivity silicon substrates in the Clean Room facility of CNM-IMB, and characterised at IFIC–Valencia.

Key words: silicon, p–type, microstrip, SLHC
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1 Introduction

The luminosity of the LHC will increase over the first several years of operation reaching $10^{34} cm^{-2}s^{-1}$ and, very likely, requiring detector upgrades in critical areas. Over the last years an upgrade of the LHC, the SuperLHC (SLHC) [1], towards higher luminosities ($10^{35} cm^{-2}s^{-1}$) has been discussed as an extension of the LHC physics program. Such an upgrade will extend the LHC mass reach and require challenging improvements in the detectors.

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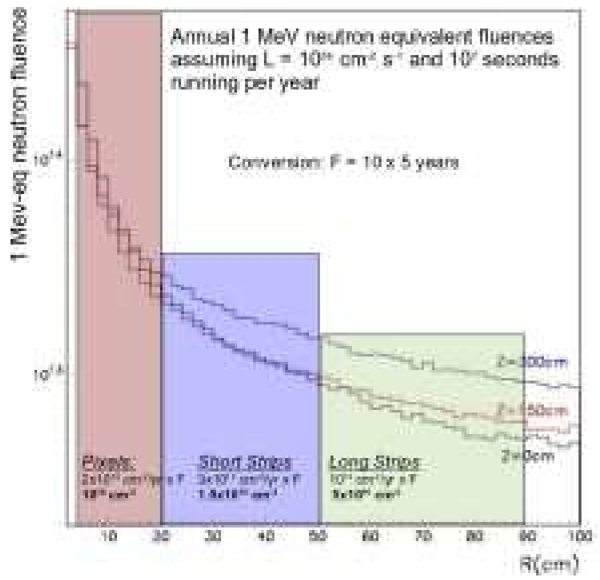

Fig. 1. Fluence as a function of radial distance to the beam for various Z planes [2]. Superimposed are the regions, in R, for pixel sensors at small radii, short strips at intermediate radii and long strips.

The SLHC will require the development of a tracking system capable of dealing with an instantaneous luminosity of $10^{35} cm^{-2} s^{-1}$ and between 5 and 10 years of further operation, having to withstand doses of up to 10^{16} 1 MeV neutrons/cm^2 in order to guarantee the operation. In the case of ATLAS, an all-silicon tracker would need to be implemented that would require completely new designs for the factor 10 higher radiation doses and would have much greater granularity to cope with the much higher occupancies that would rise from the 20 events per crossing at LHC becoming 200 at the SLHC.

Three regions can be defined, in the new ATLAS tracking system, according to the radiation level. Pixel sensors will be placed at radii below 20 cm, short strip silicon sensors at intermediate radii and long strip sensors at the outer layers of the inner detector as shown in Fig 1. Current technologies could well serve for the latter, while the pixels and the short strip sensors will certainly require new concepts.

2 Short strip silicon sensors

The factor 10 increase of luminosity translates into an increase of particle fluencies that will further augment the challenges on the detector performance and design. In particular, in order to maintain the same occupancy and track separation capabilities, the area of the sensing elements –pixels and strips– might need to be reduced by a factor 5 at the same radius with the subsequent increase of readout channels.

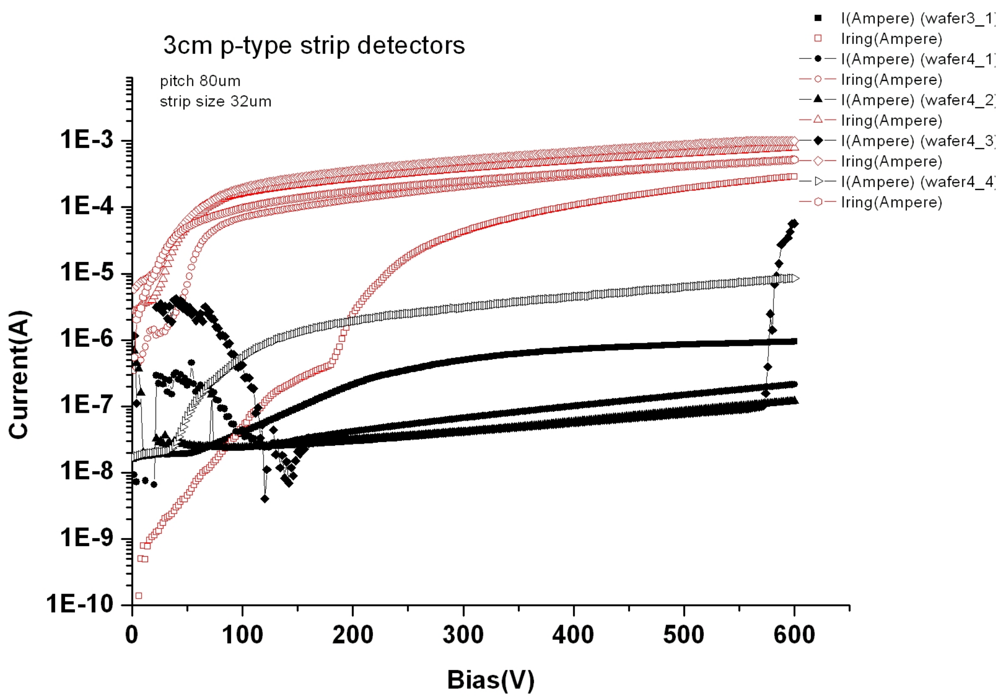

Fig. 2. Leakage current of not irradiated p–type sensors.

Short strip –3 cm long– silicon sensors are envisaged for the intermediate region of the ATLAS tracking system for the SLHC. Moreover, in order to provide sensible data until the end of the operation period, the possibility of fabricating those sensors with a p–substrate is being investigated.

Previous attempts on this technology by CNM-IMB, in collaboration with the University of Liverpool, have already manufactured this kind of sensors [4] showing very promising results for doses up to 7.5×10^{16} 1 MeV neutrons$/cm^2$.

A technology for the fabrication of p–type microstrip silicon radiation detectors using moderate p–spray implant insulation has been developed at CNM-IMB [3]. The p–spray insulation has been optimised in order to withstand the ionising irradiation dose expected in the middle region of the ATLAS tracking system for the future Super–LHC. The best technological options for the moderate p–spray implants were found by using a simulation software package and dedicated calibration runs. Detectors have been fabricated with Float Zone and Magnetic Czochralski p–type high resistivity silicon substrates in the Clean Room facility of CNM-IMB, and characterised at IFIC–Valencia.

Fig. 2 shows the current–voltage characteristics, measured at $20\,^oC$, of some of those sensors. The leakage current in the guard rings is much higher than in the central active area, meaning that the isolation between the surface and the back-plane is not adequate [3].

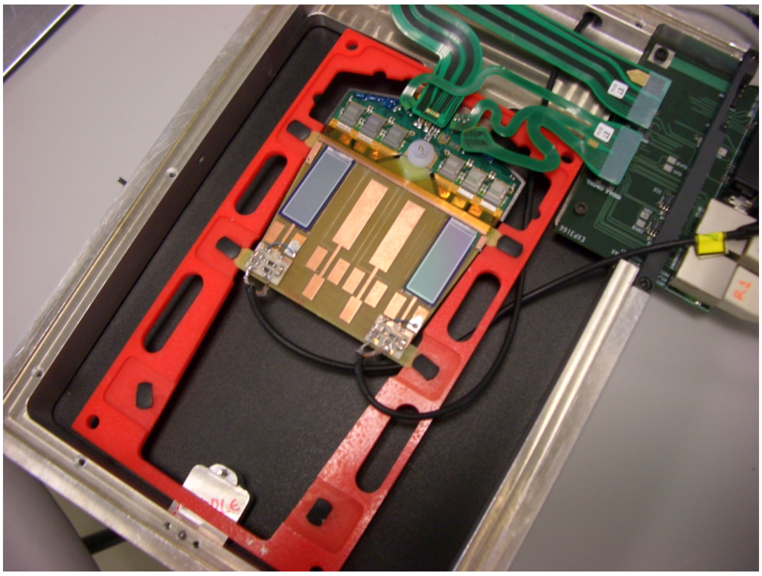

Fig. 3. CNM p–type sensors attached to an ATLAS–SCT Endcap module hybrid.

3 Measurements

A number of sensors have been irradiated with neutrons up to a dose of 10^{15} neutrons/cm^2. A pulsed infrared laser with a wave length of 1060 nm and an energy per photon of 1.170 eV will be used to measure charge collection efficiency and charge sharing between neighbour channels on a sample of those sensors. A pulse generator is used to trigger simultaneously the laser and the acquisition system, which consists, mainly, of a charge sensitive amplifier. In addition, similar tests will be made with a ^{90}Sr source.

Another sample of the sensors has been assembled together with an ATLAS-SCT Endcap module hybrid, as show in Fig.3, in order to read it out with a speed comparable to that of real operation. In this case, the acquisition system will be the one used to test the ATLAS-SCT Endcap modules during the production period which is described in [5] and references therein.

Fig. 4 shows the integrated charge as a function of the sensor bias voltage for a non irradiated sensor –sensor 4_1 in Fig. 2– exhibiting the typical behaviour: the signal increases as the depletion region grows with the bias voltage. Once the sensor is fully depleted the signal remains constant. The depletion voltage of this detector is, according to Fig. 4, 40 V.

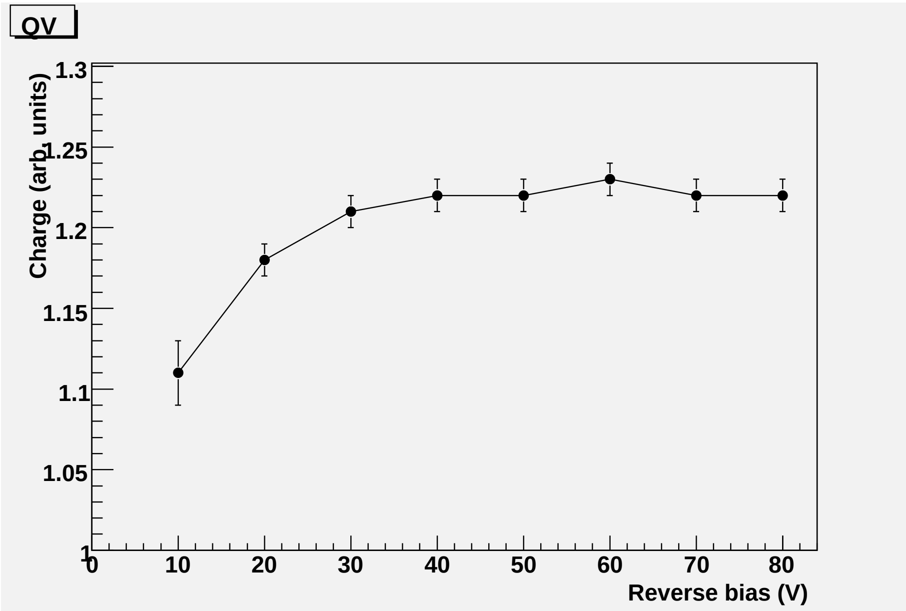

Fig. 4. Charged collected versus sensor bias voltage. According to this, the depletion voltage of this detector is about 40 V.

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