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Compensated LGADs as a pathway to the extreme fluences

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The next generation of high-energy and high-intensity hadron colliders for particle physics will require tracking detectors able to efficiently record charged particles in harsh radiation environments, where expected fluences exceed 10^{17} particles/cm^2.

Recently, thin Low-Gain Avalanche Diodes (LGADs), with an active thickness of $\sim 50\ \mu m$, have proven their ability to combine precise timing with precise tracking measurements, making them suited candidates for 4D tracking in future experiments. At present, the gain mechanism of LGAD sensors under irradiation is maintained up to a fluence of $3{\cdot}10^{15}$ particles/cm^2.

To enable the usage of LGADs in the extreme fluence regime, an innovative design of the LGAD gain layer, the p^+ implant responsible for the local and controlled signal multiplication has been implemented to enhance their radiation tolerance by more than one order of magnitude: the compensated LGAD.

In the standard LGAD design, the gain layer is obtained by implanting a high dose of an acceptor dopant, referred to as p^+, in the region below the n^{++} electrode. In the compensated design, the gain layer results from the overlap of a p^+ and an n^+ implant: the difference between acceptor and donor doping will bring an effective concentration similar to standard LGADs. The new design will be more resilient to radiation, as both acceptor and donor atoms will undergo removal with irradiation, but if properly engineered, their difference will remain constant. Therefore, the compensated LGADs will empower the 4D tracking ability to a fluence of 10^{17} particles/cm^2 and above.

The first production of compensated LGAD sensors has been released by the FBK foundry at the end of 2022. Electrical characterisation and signal analysis from compensated LGAD sensors before and after irradiation with neutrons will be presented and discussed. Future evolution of the design of compensated LGADs will be envisaged.

Autori principali: SOLA, Valentina (Istituto Nazionale di Fisica Nucleare); PATERNOSTER, Giovanni (Fondazione Bruno Kessler); MOROZZI, Arianna (Istituto Nazionale di Fisica Nucleare); ARCIDIACONO, Roberta (Istituto Nazionale di Fisica Nucleare); BORGHI, Giacomo (Istituto Nazionale di Fisica Nucleare); BOSCARDIN, Maurizio (Istituto Nazionale di Fisica Nucleare); CARTIGLIA, Nicolo' (Istituto Nazionale di Fisica Nucleare); COSTA, Marco (Istituto Nazionale di Fisica Nucleare); CROCI, Tommaso (Istituto Nazionale di Fisica Nucleare); FERRERO, Marco (Istituto Nazionale di Fisica Nucleare); FONDACCI, Alessandro (Istituto Nazionale di Fisica Nucleare); GIORDANENGO, Simona (Istituto Nazionale di Fisica Nucleare); LANTERI, Leonardo (Istituto Nazionale di Fisica Nucleare); MENZIO, Luca (Istituto Nazionale di Fisica Nucleare); MOSCATELLI, Francesco (Istituto Nazionale di Fisica Nucleare); MULARGIA, Roberto (Istituto Nazionale di Fisica Nucleare); PASSERI, Daniele (University and INFN Perugia); PASTRONE, Nadia (Istituto Nazionale di Fisica Nucleare); SIVIERO, Federico (Istituto Nazionale di Fisica Nucleare); WHITE, Robert Stephen

Relatore: SOLA, Valentina (Istituto Nazionale di Fisica Nucleare)

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