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Radiation hardness studies of a 130 nm Silicon Germanium BiCMOS technology with a dedicated ASIC

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We present in this paper radiation hardness studies on devices of the 130 nm 8WL Silicon Germanium (SiGe) BiCMOS technology from IBM. This technology has been proposed as one of the candidates for the Front-End (FE) readout chip of the upgraded Inner Detector (ID) and the Liquid Argon Calorimeter (LAr) of the ATLAS Upgrade experiment. Gamma, neutron and proton radiation experiments have been scheduled using a purposely designed ASIC in order to take into account all radiation damage mechanisms of the devices. A study of the influence of thermal neutrons on the radiation hardness of devices of this technology has also been scheduled.

Summary

Large Hadron Collider (LHC) upgrade, the Super-LHC, will imply a luminosity increase in the experiment of an order of magnitude. This will mean a significant increase in the radiation levels inside the ATLAS detector. The current Semiconductor Tracker (SCT) and the readout electronics for the Liquid Argon Calorimeter (LAr) will have to be replaced completely in order to deal with the increased luminosity and the enhanced degradation created by the radiation environment. The 8WL SiGe BiCMOS technology from IBM has been selected by the SiGe group as one of the candidate technologies for these new readout chips. For this application, one of the main features of this technology to be validated is its radiation hardness to the high radiation levels expected in the experiment. In this work we present the experiments scheduled for the full study of the radiation resistance of the IBM 8WL technology.

A purposely designed test chip has been fabricated on the IBM 8WL process for these experiments. The SiGBiT ASIC includes 36 bipolar transistors, in the form of 18 bipolar differential pairs, of different performances and emitter geometries, along with a CMOS test structure, similar to the 8RF IBM test structure previously used by the CERN microelectronics group. A low mass Printed Circuit (PCB) test board has also been fabricated to facilitate irradiation and testing with low activation of the test chip. ASICs will be mounted on these test boards and devices will be wire-bonded to external pads on the test boards.

We have scheduled gamma, neutron and proton irradiations in order to take into account all radiation damage mechanisms on the devices under study, i.e., ionization, atomic displacement damage, and the combination of both, respectively.

Gamma irradiations will be performed at Brookhaven National Laboratory (BNL) facilities, in USA, and at CIEMAT facilities, in Spain. Devices will be exposed to a total dose of 0.65, 5, 10, 30 ad 50 Mrad(Si). A detailed irradiation program for the study of Enhanced Low Dose Rate Sensitivity (ELDRS) effects on the technology has also been developed.

Devices will be exposed to 800 MeV protons during fall of 2009 at the Los Alamos LANSCE facility. We expect to reach fluences up to 1e15 p/cm2.

Neutron irradiations will be performed at the TRIGA Nuclear Research Reactor of Josef Stefan Institute (JSI) in Ljubljana, Slovenia. Samples will be exposed to 1e14, 2e14, 6e14 and 1e15 neq /cm2 fluences. Devices will remain with all their terminals shorted together during irradiation. Samples will be irradiated inside a cadmium (Cd) shielding box, so as to limit radiation damage created by thermal neutrons. In order to observe the effect of slow neutrons on the radiation damage of devices, some devices will be irradiated without Cd shielding. Activation of three board materials (standard FR-4, halogen-free and alternate halogen-free) were measured after exposure to 1e14 neq /cm2 inside the Cd shielding to determine which would result in reasonable deactivation times –the time required before post-radiation tests can be performed. Samples from standard FR-4 material showed no measurable activity four weeks after irradiation. Test boards were fabricated with this material.

At the time of TWEPP conference, we expect to have finished the gamma and neutron irradiation program. These tests will give us reliable results about the radiation hardness of the IBM 8WL technology and a final result about the suitability of this technology for its application on the S-LHC experiment.

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