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Test results of irradiated hybrid and monolithic CMOS pixel circuits in LFoundry 150 nm technology for the ATLAS Inner Tracker Upgrade

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A major upgrade for the ATLAS Inner Tracker at the Large Hadron Collider (LHC) is scheduled in 2026. The depleted CMOS pixel sensors on high resistivity substrates in LFoundry 150 nm technology have been proven to be promising for this upgrade. Recently two large demonstrators, one based on hybrid concept called LF-CPIX and the other based on monolithic concept called LF-MONOPIX have been produced. The chips were fully characterized in the lab and irradiated up to 150 Mrad under the 24 GeV Proton Synchrotron at CERN. In this work we will describe the behaviour under radiation of the two prototypes.

Summary

The ATLAS experiment will upgrade its inner tracker system for the 2026 HL-LHC run. After this upgrade, the LHC will reach an extremely high instantaneous luminosity of nearly 7.5×1034cm-2s-1. To cope with the harsh environment, depleted CMOS pixel sensors on high resistivity substrates have been developed. By applying a high voltage, the high resistivity bulk should lead to large depletion region, which enables the charge to be promptly collected by drift. In this work, a new large size (10mm×10mm) demonstrator chip named LF-CPIX using LF 150 nm technology has been produced. The LF-CPIX circuit is based on hybrid pixel concept. At the same time, the first fully monolithic prototype called LF-MONOPIX, which integrates the sensor, analog readout from the LF-CPIX pixel and the FE-I3 like readout logic into one single chip was designed.

Two versions, V1 and V2 were designed for the LF-CPIX circuit. They have the same electronics inside the pixels but different guard-ring strategies. The breakdown voltage of V2 chip was measured at 230 V, so that larger depleted region and better charge collection efficiency are expected. In each digital pixel, the charge signal is first amplified by a charge sensitive amplifier, then compared to an adjustable threshold through a discriminator. By using shift register, we can store the hit information from discriminator. The threshold dispersion of the pixels for different flavours is around 300 e- before tuning and 50 e- after tuning. The ENC value of the whole matrix is less than 200 e-, which is similar to simulation results. Moreover, LF-MONOPIX with the FEI-3 like readout logic, the chip is fully functional. There are total nine flavours in the chip which correspond to different designs. The dispersion of the threshold differs by flavours. However, all the flavours of pixels have fully integrated read-out logic and can be tuned with a dispersion less than 100 e-. The ENC value for different flavours falls between 180 e- and 280 e-. Furthermore, few samples for both the prototypes were irradiated up to 150 Mrad under the proton beam. Under the irradiation, both LF-CPIX and LF-MONOPIX showed very promising results as the electronics proved to be radiation hard up to 150 Mrad. The chips were again tested at -20 ℃ in which the ENC and dispersion values were almost similar to before irradiation.

I will present the characterization results in detail before radiation as well as measurement under radiation level up to 150 Mrad at the 24 GeV Proton Synchrotron (PS) at CERN.

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