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Mapping the effects of ionising and non-ionising radiation on the measurement of inter-strip isolation with ATLAS ITk strip sensors

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In order to meet the physics goals of the forthcoming high luminosity (HL) era of the CERN Large Hadron Collider (LHC), the inner detector of the ATLAS experiment will be replaced by a new all-silicon tracking system, known as the inner tracker (ITk). The outer region of the ITk is instrumented with 22,000 nˆ+-in-p type silicon strip sensors manufactured by Hamamatsu Photonics (K.K.).

During HL-LHC operation, ITk strip sensors will be subjected to formidable doses of both ionising and non-ionising radiation. During the ongoing sensor production period, a comprehensive programme of Quality Assurance (QA) is taking place to ensure sensor batches delivered by the vendor operate as required after receiving the radiation doses expected after a lifetime of operation at the HL-LHC. The QA programme utilises a range of facilities to study the effects of proton, neutron and gamma-ray irradiation on the performance of sensor batches.

One parameter of critical importance to sensor performance is the inter-strip isolation, which can degrade substantially after significant radiation exposure, particularly due to the ionising radiation dose. Dedicated interdigitated test structures have been incorporated into the design of the ATLAS ITk strip QA test chip to facilitate the measurement of the inter-strip isolation after irradiation. The inter-strip resistance measured with the interdigitated test structures is expected to be affected by both ionising and non-ionising radiation damage effects, including the build-up of interface charge and changes in bulk resistance, respectively.

A dedicated investigation has been performed in which test chips are proton irradiated to several different fluence points, spanning the region from 1e14 n_eq cmˆ-2 to 2e15 n_eq cmˆ-2, at several distinct proton beam energies. The MC40 cyclotron at the University of Birmingham, CYRIC cyclotron at Tohoku University and the CERN IRRAD facility were utilised to irradiate samples with 23 MeV, 70 MeV and 24 GeV protons, respectively. The total ionising dose (TID) delivered per unit proton fluence at each facility differs due to the proton beam energies employed, leading to samples irradiated at each facility experiencing a different relative amount of ionisation and displacement (non-ionising) damage.

Studies of these irradiated samples allow the interplay between ionising and non-ionising radiation damage effects on the measurement of the interdigitated test structures to be mapped. These data are used to develop of a more complete understanding of the features observed in the inter-strip isolation measurements obtained after proton, neutron and gamma-ray irradiation at the facilities utilised by the ATLAS ITk strip QA programme.

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