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Evolution of the electrical characteristics of the ATLAS ITk strip sensors with HL-LHC radiation exposure range

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In 2021, the ATLAS collaboration started the production phase of the new Inner-Tracker (ITk) strip sensors, so-called ATLAS18, that should be able to withstand the extreme radiation conditions expected for the forthcoming High-Luminosity Large Hadron Collider (HL-LHC) upgrade. The new all-silicon ITk detector will reach unprecedented accumulated fluences and ionizing doses, caused by the increase of the total integrated luminosity. Previous studies with prototypes showed that these severe radiation conditions can modify some of the electrical characteristics of the strip sensors in working conditions.
The objective of the study is to evaluate the evolution of the performance of the new ITk strip sensors as a function of radiation exposure, to ensure the proper operation of the upgraded detector during the lifetime of the experiment. For this purpose, ATLAS18 Barrel Short-Strip sensors with final layout design have been irradiated with neutrons at the TRIGA reactor in Ljubljana (Slovenia), and with gammas at UJP Praha (Czech Republic). The irradiations cover a wide range of fluences and doses that ITk will experience, going from 1e13 neq·cm-2 and 0.49 Mrad, to 1.6e15 neq·cm-2 and 80 Mrad. The split irradiation enables a proper combination of fluence and dose values of the HL-LHC condition which is not possible with a proton irradiation in 10 to 100 MeV kinetic range. The irradiation exposures used are equivalent to operational intervals between the first few days and the end of the HL-LHC data collection, including a 1.5 safety factor.
A complete electrical characterization of the key sensor parameters before and after irradiation is presented, including the study of the leakage current, bulk capacitance, and single-strip and inter-strip characteristics. The results confirm that the performance of the new ITk strip sensors fulfills the specifications established by the ATLAS collaboration. Additionally, the study of a wide range of fluences and doses allows to obtain detailed results about the frequency dependence of the bulk capacitance measurements, or the evolution of the Punch-Through Protection (PTP) for the radiation exposure range expected for the lifetime of the HL-LHC.

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