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Operational Experience and Performance with the ATLAS Pixel detector at the Large Hadron Collider at CERN

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ATLAS is one of the four major experiments at the Large Hadron Collider (LHC) at CERN. It is a general-purpose particle physics experiment run by an international collaboration and is designed to exploit the full discovery potential and the huge range of physics opportunities that the LHC provides.
The tracking performance of the ATLAS detector relies critically on its 4-layer Pixel Detector, located at the core the ATLAS tracker. The ATLAS pixel detector consists of four barrel layers and a total of six disk layers, three at each end of the barrel region. The four barrel layers are composed of n+-in-n planar oxygenated silicon sensors at 33, 50.5, 88.5, and 122.5 mm from the geometric center of the ATLAS detector. The sensors on the innermost barrel layer (the insertable B-layer or IBL) are 200 µm thick, while the sensors in the other layers are 250 µm thick. At both ends of the innermost barrel layer, there are n+-in-p 3D sensors that are 230 µm thick. The innermost barrel layer pixels pitch is 50 × 250 µm2; everywhere else the pixels pitch is 50 × 400 µm2.
It has undergone significant hardware and readout upgrades to meet the challenges imposed by the higher collision energy, pileup and luminosity that are delivered by the Large Hadron Collider (LHC), with record breaking instantaneous luminosities of 2 x 1034 cm-2 s-1 recently surpassed.
The key status and performance metrics of the ATLAS Pixel Detector are summarised, and the operational experience and requirements to ensure optimum data quality and data taking efficiency will be described, with special emphasis to radiation damage experience.
By the end of the proton-proton collision runs in 2018, the IBL had received an integrated fluence of approximately Φ = 9 × 1014 1 MeV neq/cm2. The innermost of the three outer layers (B-layer) has been exposed to about half the fluence of the IBL, and lower fluences for other layers.
The ATLAS collaboration is continually evaluating the impact of radiation on the Pixel Detector. In particular, signs of degradation are visible but are not impacting yet the tracking performance (but will): a trend of decreasing charge collection, dE/dX, occupancy reduction with integrated luminosity, under-depletion effects with IBL, effects of annealing that are significant for the inner-most layers.
A quantitative analysis of all these effects will be presented and discussed, as well as the operational issues and mitigation techniques adopted during the LHC run and the ones foreseen during the LHC Long Shutdown 2.
In addition, the strategy to contain the readout bandwidth limitation will be discussed, required by the LHC over-performing.

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