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Beam test measurements of hit efficiency and resolution of DEPFET pixel sensor modules for the Belle II experiment

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The Belle II experiment at the super-B-factory SuperKEKB in Tsukuba, Japan started data taking in 2019. Its purpose is the measurement of electroweak phenomena and rare decays with unprecedented high precision. A up to 40-fold increase in instantaneous luminosity compared to the predecessor experiment Belle is targeted and will allow for recording a large dataset at the $\Upsilon(4S)$ center-of-mass energy. Besides the e^+e^--collider itself, the individual detector components are upgraded to higher precision and to resist the higher radiation flux. One of the significant improvements in Belle II is the silicon pixel detector surrounding the beam pipe. Two layers of DEPFET pixel based sensor modules are arranged at radii of 14 mm and 22 mm around the interaction point. Utilizing the DEPFET technology, very thin sensors (75 μm thickness of the fiducial volume) with a high signal-to-noise ratio (about 40) were constructed, featuring pixel pitches of $50 \times 55\,\mu\mathrm{m}^2$ to $50 \times 85\,\mu\mathrm{m}^2$. The sensor modules are all-silicon, self-supporting structures with three types of application-specific integrated circuits (ASICs) steering the read-out.
Pixel sensor modules of the final design were characterized and their operation parameters optimized in laboratory measurements. Two measurement campaigns at the DESY electron beam test facility ($2 - 6$ GeV electrons) were conducted to measure the sensor modules' hit efficiencies and intrinsic hit resolutions at different incidence angles and operation parameters. The results confirm satisfactory hit efficiency numbers and hit resolutions that benefit from charge sharing among pixels. Furthermore, a sensor module has been irradiated with a continuous spectrum of up to 40 keV x-rays to a TID of about 260 kGy. The measurements show that, to this irradiation dose, the shift of the MOSFETs gate threshold can be compensated for and that the sensor module can still be operated at an unchanged hit efficiency.

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