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## Large area pixel modules for HL-LHC Tracker Upgrades

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To meet the challenges of tracking at the luminosities delivered by the HL-LHC requires replacing and upgrading the tracking systems. To be able to perform pattern recognition and vertexing in events with pile-up of up to 200 requires a larger area pixel system within the tracker. The increase in area requires the development of large area planar detectors for pixel layers at large radii and the pixel endcaps. The paper reports on the development of large area sensors of area  $2 \times 2 \text{ cm}^2$  have been fabricated and mounted onto 4 FE-14 readout ASICs, so called quad-modules, and their performance evaluated in the laboratory and testbeam. The current-voltage characteristics of the sensors have been studied and this has been used to improve the design of the biasing, guard rings and doping of the dicing streets. The assembled modules have been characterised in the laboratory to evaluate noise, threshold and bump-bond yield. A particular challenge in producing thinned large area modules is the bump-bonding, where low yield can be observed due to bowing of the sensor and readout chip during the bonding process. A new bump-bonding process using backside compensation to address the issue of low yield will be discussed. The performance of the modules in testbeams will also be presented.

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