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Response of 3D pixel sensors to grazing angle incident particles

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Finely segmented 3D pixel sensors are being considered for the innermost layer of the Phase-2 Tracker upgrade of CMS due to their intrinsic radiation tolerance and low demanding power consumption. No significant degradation of performance is observed up to fluences of 1e16 neq/cm2.

The innermost layer of the Phase-2 Tracker will be placed as close as 3 cm from the beam and will extend 20 cm in both directions from the center of the detector along the beam direction. Ionizing particles originating at vertices near the center of the detector will
therefore traverse the modules at the edges of the innermost barrel layer at essentially grazing angles of incidence which could be as large as 87 degrees. Pixel sensors in this region will have particles traversing a long distance inside the sensors and deposit charge in a large number of pixels, resulting in pixel "clusters" of extremely large size. Apart from the reduced resolution along the beam direction, these tracks create a potential "cluster breaking" problem: if the generated charge of any pixel along the particle trajectory fluctuates low and remains under the detection threshold of the front-end readout electronics, this pixel is lost, and the cluster breaks into several sub-clusters.

In this presentation, test beam data obtained with 3D sensors tilted almost horizontally with respect to the beam, are analyzed to quantify and study the potential cluster breaking in 3D sensors. The results show that fresh 3D sensors are not affected by cluster breaking. Even unbiased, the cluster breaking rate never exceeds 3%. This is a direct consequence of the homogeneity of charge collection independently of the depth of the track, as is also shown.

Author: Dr DUARTE CAMPDERROS, Jordi (Universidad de Cantabria and CSIC (ES))

Presenter: Dr DUARTE CAMPDERROS, Jordi (Universidad de Cantabria and CSIC (ES))

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