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Application of material budget imaging for the design of the ATLAS ITk strip detector

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The technique of material budget imaging (MBI) allows to experimentally assess the material budget $\epsilon = x/X_0$ of a material with thickness x and its radiation length X_0. Here, multi-GeV electrons from a test beam facility such as the DESY-II test beam are used. This novel technique exploits the fact that the beam particles are deflected by multiple Coulomb scattering following a distribution of the deflection angle with a center at zero and a width depending on the traversed material. By reconstructing the individual kink angles from the measured particle trajectories in a high resolution beam telescope, the material budget can be extracted by applying appropriate models of multiple scattering theory, such as the Highland formula.
On the one hand, various materials with known material budgets were measured to calibrate the MBI technique and study also different systematic effects such as the beam telescope's acceptance and the variation of the beam energy. On the other hand, a number of material samples planned in the design of the local support structures of the new ATLAS Inner Tracker (ITk) strip detector were investigated to extract the according radiation length values not known beforehand. Here, also the possibility of two-dimensional imaging of complex structures was successfully demonstrated for carbon-fiber based sandwich structure (the "petal core") allowing an even deeper analysis of the detector design.
Overall, the potential of the MBI technique covers a wide range of applications: from the design of high-energy particle detectors over industrial investigations of high-Z materials up to applications in medical imaging ("electron CT").

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