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MAPS: from vertex detectors to space applications

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Over the past decade, Monolithic Active Pixel Sensors (MAPS) have well established their position in high-energy physics experiment vertex detectors. By integrating both the readout circuitry and the sensitive volume on a single chip manufactured via commercial processes, MAPS enable the development of ultra-thin, large-scale tracking detectors. The ALICE Inner Tracking System 2 (ITS2), currently the largest MAPS-based vertex detector, employs the state-of-the-art ALPIDE chip across seven cylindrical layers, covering a total area of approximately 10 m^2 around the interaction point. Fabricated using TowerJazz's 180 nm CMOS imaging sensor process, the ALPIDE chip has demonstrated an excellent detection efficiency ($\gg 99\%$) and spatial resolution ($< 5\ \mu\text{m}$) performance at low power dissipation ($< 40\ \text{mW}/\text{cm}^2$) and extremely low fake-hit rate ($< 10^{-7}$ hits/pixel/event).

To enable operation even closer to the interaction point, the ALICE Collaboration is planning an upgrade in 2028 (ITS3), which necessitates the development of wafer-scale sensors with dimensions on the order of $10 \times 30\ \text{cm}^2$. This upgrade requires the adoption of stitching techniques in sensor fabrication. The first prototype based on this approach, the Monolithic Stitched Sensor (MOSS), implemented in a TPSCo 65 nm CMOS imaging sensor process, has been extensively characterized and meets the stringent performance criteria. Furthermore, this new technology underpins plans for the subsequent ALICE upgrade in the 2030s (ALICE3), which will impose unprecedented demands on sensor radiation hardness (up to 10^{16} $1\ \text{MeV}\ n_{\text{eq}}/\text{cm}^2$ non-ionizing and 300 Mrad ionizing tolerance) while covering even larger surfaces (approximately $60\ \text{m}^2$).

Similar challenges arise in the development of next-generation particle detectors for space applications. Although the radiation tolerance requirements are comparatively relaxed, the power consumption constraints become significantly more stringent. For example, the ALADInO experiment proposal envisions a $68\ \text{m}^2$ silicon tracker achieving a spatial resolution below $5\ \mu\text{m}$ with a power consumption of less than $2\ \text{mW}/\text{cm}^2$.

This contribution will review the current state-of-the-art in MAPS technology developed within the ALICE and CERN EP R&D frameworks and will discuss the opportunities and challenges associated with implementing these sensors in space-based trackers, including their capabilities for energy and time measurements.

Eligibility for "Best presentation for young researcher" or "Best poster for young researcher" prize

No

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