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ALICE ITS3: a bent stitched MAPS-based vertex detector

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ALICE ITS3 is a novel vertex detector replacing the innermost layers of ITS2 during LS3. Composed of three truly cylindrical layers of wafer-sized 65 nm stitched Monolithic Active Pixel Sensors, ITS3 provides high-resolution tracking of charged particles generated in heavy-ion collisions. This contribution presents an overview of the ITS3 detector, highlighting its design features, integration and cooling, and the latest results from the ongoing development towards the final sensor. Furthermore, the presentation introduces the off-detector service electronics, which play an essential role in the readout, control, and power supply of the detector.

Summary (500 words)

The ALICE Inner Tracking System (ITS) is a key component of the ALICE experiment, providing precise tracking of charged particles produced in heavy-ion collisions. ITS3, the third version of ITS, will replace the Inner Barrel of ITS2 during the LHC Long Shutdown 3 (2026-28). The novel detector consists of three truly cylindrical layers of wafer-scale stitched Monolithic Active Pixel Sensors in 65 nm technology. The sensors are thinned down to below 50 μm and bent at specific radii for each layer to create the cylindrical shape. The innermost layer of ITS3 is positioned just 18 mm from the interaction point and the detector has an unprecedentedly low material budget of 0.05%X0.

The reduced material budget of ITS3 is made possible by eliminating water cooling and instead relying on low-speed airflow at < 2ms-1, which is feasible due to a low power density of < 20 mW cm−2. At the periphery of the sensor, where the power density is higher, carbon foam rings act as radiators to improve heat exchange with airflow. Power and signal are routed on the detector silicon to avoid an FPC in the active area, further decreasing the material budget. Ultimately, the detector material comprises primarily of the Si of the sensor chip and the carbon of localized foam spacers.

Two prototypes of stitched sensor chips developed with CERN EP R&D, the MOnolithic Stitched Sensor (MOSS) and MOnolithic Stitched Timing (MOST), were submitted with Engineering Run 1 (ER1) in Q4 of 2022, and the wafer arrived for testing at CERN in Q2 2023. MOSS, which measures 14 mm × 259 mm, composes 10 stitched repeatable sensor units that can be powered and interfaced individually or collectively via the chip backbone addition using an endcap unit. An extensive testing campaign aims to verify that inter-stitch power and data routing is feasible with reasonable yield.

A MOSS successor, the ITS3 sensor prototype, will be submitted with Engineering Run 2 (ER2) in Q2 of 2024. The ER2 chip has been optimized in terms of power, using on-chip regulation to maintain voltage level and introduces high-granularity power domain segmentation to accurately handle on-chip shorts. Multiple high-speed data links per chip segment of 10.24 Gbps transmit data upstream. The data is encoded using the lpGBT-scheme in order to transmit data with negligible bit- and frame-error rates.

The ITS3 off-detector service electronics are using an alternative approach to the ITS2 service electronics. Its components will be located at a distance of 0.2 m to 0.4 m from the edge of the sensors, in the service barrel of the detector, still within the acceptance of the forward detectors of the experiment. The high-speed data links are connected directly to optical transceivers (VTRx+) within 0.5m and fibers of up to 135m are drawn directly to the backend electronics avoiding data processing in the radiation environment. The detector powering is based upon radiation-hard DC/DC converters.

This contribution provides an overview of the various aspects of the ITS3 detector, including integration, cooling, chip development, and readout architecture.

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