TIPP 2023
4 - 8 SEPTEMBER 2023
CTICC CAPE TOWN SOUTH AFRICA

Contribution ID: **87** Type: **Oral Presentations**

The ALICE Inner Tracking System Upgrade

Wednesday, 6 September 2023 11:20 (20 minutes)

The ALICE experiment at CERN is developing an upgrade of the three innermost layers of the Inner Tracking System (ITS3) vertexing detector, to be installed during the Long Shutdown 3 of the LHC (2026-28)[1]. It will consist of three truly cylindrical sensors wrapped around the beam pipe, a concept that is enabled by the flexible nature of silicon when thinned down to less than 50 µm[2]. The three layers will be installed at a distance of 30, 24, and 18 mm from the interaction point, respectively — so close that a thinner beam pipe will also be installed. Full tracker half-layers will be covered by single wafer-scale CMOS monolithic active pixel bent detectors measuring up to 10×26 cm^2 in size, manufactured in a commercial 65 nm technology developed by Tower Partners Semiconductor Co. (TPSCo). In order to build detector elements larger than the reticle size, a process called stitching is used to join detector elements to build sensors up to 300 mm in length in a single wafer. Mechanical support is provided by carbon foam spacers, dramatically reducing the material budget in the region close to the interaction point from the current $0.35\%\ X/X_0$ down to $0.05\%\ X/X_0$ per layer. The new technology also provides improved power efficiency below 20 mW/cm², only requiring the use of forced air for cooling.

At the core of the development, the R&D process of the sensor ASIC poses an entire new set of challenges mainly revolving around designing and validating the first wafer-scale silicon detector for high-energy physics. To this purpose, a submission named Engineering Run 1 has been delivered in April 2023 that includes a large stitched detector prototype named Monolithic Stitched Sensor (MOSS). MOSS is the first full-size stitched sensor demonstrator designed to validate manufacturing yield and feasibility of power and signal transmission. A custom readout system has been developed to test the MOSS in all of its features and evaluate its functional yield at a high level of granularity down to each single one of its 7 million pixels. This was a challenge in itself, given the nearly 3000 connections needed to operate it and the expertise required to handle, bond, and mechanically support such a huge and delicate sensor in a variety of use cases such as lab testing or test beams. This contribution will provide an overview of the detector, the MOSS prototype, and its test system, including the early results of its characterization.

[1]
Musa, L. et al.,
Letter of Intent for an ALICE ITS Upgrade in LS3,
CERN-LHCC-2019-018; LHCC-I-034

[2]
Aglieri Rinella, G. et al.,
First demonstration of in-beam performance of bent Monolithic Active Pixel Sensors,
Nuclear Inst. and Methods in Physics Research A **1028** 166280

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Session Classification: D1