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MISTRAL & ASTRAL: Two CMOS Pixel Sensor Architectures dedicated to the Inner Tracking System of the ALICE Experiment

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A detector, equipped with 50 um thin CMOS Pixel Sensors (CPS), is being designed for the upgrade of the Inner Tracking System (ITS) of the ALICE experiment at LHC. Two CPS flavours, MISTRAL and ASTRAL, are being developed at IPHC aiming to meet the requirements of the ITS upgrade. The first is derived from the MIMOSA28 sensor designed for the STAR-PXL detector. The second integrates a discriminator in each pixel to improve the readout speed and power consumption. This paper will describe in details the sensor development and show the preliminary test results.

Summary

A major motivation for the upgrade of the Inner Tracking System (ITS) of the ALICE experiment is to extend the physics reach for charmed and beauty particles down to low transverse momenta. This requires a substantial improvement of the spatial resolution, material budget and the data rate capability of the ALICE-ITS. To achieve this goal, the new ITS is going to be equipped with 50 um thin CMOS Pixel Sensors (CPS) covering either the 3 innermost or all the 7 layers of the detector.

In order to improve the sensor performances in terms of radiation hardness and readout speed, the sensor design at IPHC has migrated from a 0.35 to a 0.18 µm CMOS Imaging Sensor process. At the end of 2011, a first prototype, called MIMOSA32, was designed to validate the process. After the return from the foundry, the chip was extensively tested in the laboratory and at the CERN-SPS with O(10^2)GeV hadron beams, before and after irradiation with a combined dose of 1MRad and 1013neq/cm^2. A MIP detection efficiency of ˜100% was measured at an operating temperature of 30℃.

In parallel with the process validation, two different sensor architectures, called MISTRAL and ASTRAL, are developed at IPHC. MISTRAL is derived from the ULTIMATE (MIMOSA28) sensor designed for the STAR-PXL detector. It is based on a column parallel read-out with amplification and correlated double sampling (CDS) inside each pixel of 22x33μm^2. Each column is terminated with two high precision discriminators in order to read out 2 rows simultaneously. The matrix is read out in a rolling shutter mode (200ns/2-rows). The discriminator outputs are processed through an integrated zero suppression logic (SUZE02). The first level of the SUZE02 searches windows of 4x5 pixels which contain hit cluster information. The sparsified results are stored in 4 SRAM blocks allowing either continuous or triggered readout. The data are serialised onto a ˜Gbit/s serial link. The MISTRAL sensor will have an active area of ˜1x3cm^2 with a power consumption of <350 mW/cm^2 and a readout speed of ˜30 k frames/s. With its mature architecture, MISTRAL is presently the baseline sensor for the ALICE-ITS upgrade.

ASTRAL provides a further improvement of the MIMOSA28 architecture. The emerging architecture is called AROM (Accelerated Read-Out of Mimosa). Its read-out is based on a column parallel, rolling shutter mode, with an architecture similar to that of MIMOSA28. Thanks to the 0.18µm CIS quadruple-well process, signal discrimination is embedded in each pixel. As a consequence, the analogue signals driving over centimetre long traces are replaced by the digital signals. This architecture has at least 2 advantages. The first one is a doubling of the pixel read-out frequency. The second is the power consumption reduction. With the same active area as MISTRAL, the expected power consumption of ASTRAL is <200 mW/cm^2 with a read-out speed of ˜60 k frames/s.

This contribution will discuss in details the design progress of the MISTRAL & ASTRAL sensors and provide first test results of some of their prototyping chips.

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