Status of the construction of the ALICE Silicon Pixel Detector

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Abstract. The ALICE Silicon Pixel Detector (SPD) is constituted by two barrel layers with $\approx 10^7$ hybrid pixel cells. The basic detector element is the Half-Stave (HS), an array of two ladders, each composed of 5 pixel chips bump bonded to a Si sensor matrix. The ladders are mounted on a low-mass aluminum/polyimide multilayer bus for power distribution and signal routing. The assembly procedures of the half-staves and their mounting on the carbon fiber support sectors, implemented on high precision measuring tables, with computerized controllers for positioning and gluing, are described, and the present status of construction is overviewed .

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THE ALICE SILICON PIXEL DETECTOR

ALICE is the LHC experiment devoted to study the physics of hadronic matter under extreme conditions of heating and compression, in ultrarelativistic heavy-ions collisions. The Silicon Pixel Detector (SPD) constitutes the two innermost layers of the ALICE Inner Tracking System (ITS) [1]. The two layers in barrel configuration are located at average radii of 3.9 and 7.6 cm with a corresponding pseudorapidity coverage of $|\eta| < 2.0$ and $|\eta| < 1.4$, respectively. The main goal of the SPD is to improve the accuracy in the primary interaction vertex determination, as well as to give precise measurements of the impact parameters of secondary tracks from weak decays of particles with open heavy-flavour [1]. High granularity and spatial precision are required to obtain accurate tracking information in a region where track density, in the most central heavy-ion collisions, could reach 80 tracks/cm^2. The expected total ionizing dose and fluence, integrated over 10 years, are 2.5 kGy and $3\text{x}10^{12}$ n/cm^2 (1 MeV neutron equivalent) respectively [2]. The total material budget is less than 1% X_0 in each layer.

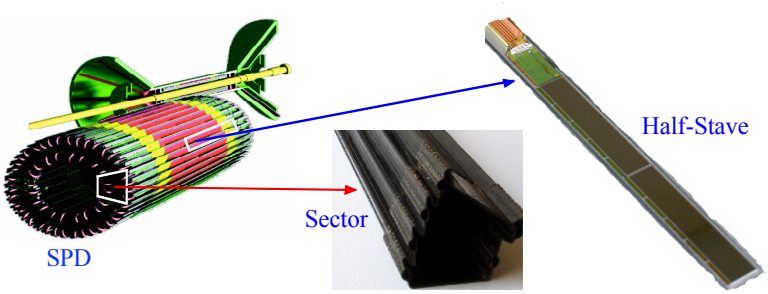

FIGURE 1. The ALICE SPD with its main components: the HS and the Sector.

The SPD is based on hybrid silicon pixels; the sensors are 2-D arrays of reverse-biased silicon diodes, bump bonded to readout chips. The pixel cell dimensions are 50μm (rφ) and 425μm (z). The pixel ASIC, in commercial 0.25 μm CMOS with radiation tolerant design [3], is a mixed-signal chip with 8192 readout cells arranged in 32 columns and 256 rows. Each cell contains a preamplifier-shaper with leakage current compensation, followed by a discriminator [4]. Five readout chips are flip-chip bonded, using Pb-Sn solder bumps, to a single silicon sensor matrix of 256x160 cells, 200 μm thick; this assembly constitutes a "ladder". The basic detector module is the HS, where 2 ladders are glued to an aluminum-polyimide multi-layer flex bus which carries signal and power lines. Each half stave is controlled and read out via a multi-chip module (MCM) with several ASICs, also in 0.25 μm CMOS with radiation tolerant design [5]. The MCM includes a custom design optical transceiver for data communication with the back-end electronics via optical fibers. A 5-layer low-mass Al-Kapton flex bus, 240 μm thick, ensures the distribution of power and signals on each HS. This bus is wire bonded to the readout chips and to the MCM. The two SPD layers contain 120 HS's mounted on 10 low-mass carbon fiber support sectors, in which very thin tubes are embedded for the cooling with C_4F_{10} in an evaporative system.

The assembly of the half staves and the mounting on the carbon fiber sectors are carried out on precision coordinate measuring machines, in INFN Laboratories, in Bari and Padova/LNL respectively [6].

Half Stave assembly in Bari

The H.S. assembly procedure has been developed and implemented in Bari. The HS components are aligned and glued with micrometric precision by means of a coordinate measuring machine (Mitutoyo), equipped with tools and jigs developed for that purpose. The assembly consists in a sequence of automatic and manual procedures. Automatic positioning of the assembled components is accomplished with a precision better then 50μm. The main steps of the H.S. assembly are the following:

- Positioning of the grounding foil,
- Dimensional check and alignment of the adhesive mask,
- Glue dispensing and gluing of ladders and MCM,
- Gluing of multi layer bus and of the extender,
- Wire bonding between MCM and bus and between bus and pixel chips electronics pads (each HS requires nearly 1,000 high precision wire bonds).

A special two-component Eccobond 45 glue, radiation resistant and with adequate elasticity requirements is used. The HS functionality is fully tested using a semi-automated data acquisition system. Calibration parameters are determined and stored in a database. The HS assembled in Bari are then sent to Padova/LNL using a special protective box, designed and built in Bari.

Carbon Fiber Support Sector (CFSS) assembly in Padova/LNL

The CFSS assembly procedure has been defined and qualified in Padova/LNL using a Johansson coordinate measuring machine, with custom designed jigs. The main operations of this assembly are:

- Alignment of the CFSS and of the two HS's,
- Thermal grease (to improve thermal contact between HS and cooling ducts) and UV glue dispensing,

- Moving of the HS onto the CFSS.

The assembly of the first SPD sector has been accomplished (Fig. 2) and a complete test with cooling system, readout electronics and power supply is currently under way.

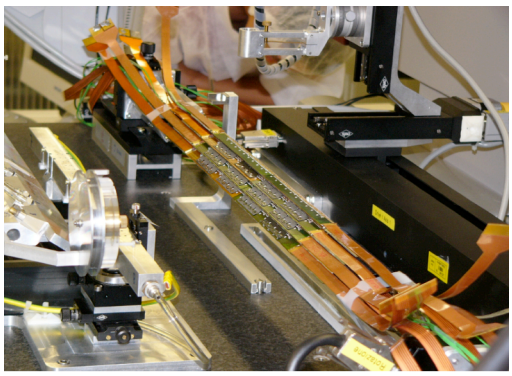

FIGURE 2. The first SPD Sector assembled in Padova/LNL.

SPD Construction Status

Specific and demanding technological developments and extensive tests of the SPD components have been finalized: in particular those ones concerning the FE r/o chip, the multi-layer bus, the MCM and the evaporative cooling. The production of ladders (200 μm thick sensor + 150 μm pixel chips), of the MCMs and of the all-Aluminium buses is under way.

HS and Sector assembly procedures have been developed and implemented in Bari and Padova/LNL with a production throughput of about 4 HS/week and the first SPD Sector has been assembled.

Conclusions

The SPD constitutes the two innermost layers of the ALICE inner tracker, with a total of about 10^7 hybrid pixel cells of 50 μm (rφ) x 425 μm (z). Its high granularity will provide high precision tracking information which will give ALICE the capability to measure heavy flavour production in ultra-relativistic nucleus-nucleus collisions.

The very strict constraints on the material budget and on the detector module dimensions constituted relevant challenges for the integration of the on-detector electronics. The SPD is now in construction phase and is scheduled to be ready to install at the end of 2006.

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