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The Engineering, Production and Quality Assurance of the Inner Barrel Staves for the Upgrade of the ALICE Inner Tracking System

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A major upgrade of the ALICE Detector is underway during LHC LS2 (2019-2020). This includes a new Inner Tracking System (ITS) consisting of seven cylindrical layers of CMOS Monolithic Active Pixel Sensors. The building blocks of each layer are azimuthal elements called Staves.

The Inner Layer Staves are made of a carbon fiber support structure (spaceframe), a carbon fiber cold plate and a Hybrid Integrated Circuit (HIC) consisting of Pixel Chips and passive components bonded onto an aluminum polyimide Flexible Printed Circuit (FPC).

This contribution will describe the Inner Layers Staves, the manufacturing processes and the quality assurance methodologies.

Summary

A major upgrade of the ALICE Detector is underway during LHC LS2 (2019-2020) to enhance its measurement and data recording capabilities. This includes a new Inner Tracking System (ITS) which consists of seven concentric cylindrical layers of CMOS Monolithic Active Pixel Sensors. The basic building blocks of the detector are azimuthal segments called Staves, extending over the whole length of each layer.
The staves of the three inner layers are 30 cm long. Those of the middle and outer layers are 92 cm and 154 cm long.
The radial distances from the beam line of the three innermost layers are 23, 31 and 39 mm. The radial distance of the outermost layer is 39 cm.

The staves constituting the three innermost layers (Inner Barrel) are identical. They feature an unprecedented low material budget of 0.357% X0.

They are made of a carbon fiber support structure (spaceframe), a cold plate, and a Hybrid Integrated Circuit (HIC). The cold plate is a sheet of high thermal-conductivity carbon fiber with embedded polyimide cooling pipes.

The HIC of the Inner Layers consists of the assembly of a Flexible Printed Circuit (FPC), nine Pixel Sensors and passive components. The FPC has two Aluminum layers (25 μm thick) on a 75 μm thick polyimide substrate. Its design has to satisfy stringent constraints. The FPC distributes the analog and digital supplies and the reverse-bias voltage for the sensors. The traces for the readout of data at 1.2 Gb/s and for the slow control of the chips are routed without through-vias. The FPC and the chip floorplan were co-designed to make a stack-up of the FPC with only two layers possible and to spread the connections of the supplies over the entire surface of the chips.
The manufacturing of the FPC is very demanding. The thickness of the conductive layers, the cleanliness and roughness of bonding surfaces, and the resistance of metals are verified after production to ensure the required quality.

The assembly of the Inner Barrel HICs employs innovative techniques and demands constant monitoring, particularly against contaminations by small foreign bodies, that can damage the 50 μm thick chips.
Custom developed machines are used to test and align the pixel sensors on assembly jigs. Next, glue is carefully

spread onto the FPC before it is flipped and placed on top of the pre-aligned chips. After curing and inspections, this assembly is then wire bonded with an innovative technique of bonding through holes in the FPC itself. Finally, the assembled HIC is glued onto the cold plate and support structures to form an Inner Barrel Stave. Electrical tests are carried out at several steps during the assembly process.

This contribution will describe the engineering and manufacturing of the Inner Barrel Staves, and the quality assurance methods. It will discuss challenges, findings and lessons learnt.

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