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Characterization of a Prototype Batch of Long Polyimide Cables Designed for Fast Data Transmission on ATLAS ITk Strip Staves

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The silicon-strip system in the ATLAS ITk detector has individual sensor modules mounted on staves to provide integrated solution for mechanical support, power, cooling, and data transmission. The data and power are transmitted to individual modules on polyimide tapes placed on thermo-mechanical stave cores. The 1.4 m long tapes transmit module data at rates up to 640 Mbps, several multi-drop clock and command links, and power lines. The first batch of 25 tapes has been produced. We characterized the line impedance and its variation across the batch, examined the tape cross-section, and assessed the variation between design and fabrication.

Summary

Modern HEP experiments feature large-scale silicon-based tracking systems that require data and power delivery to individual modules cooled to required operational temperatures. Providing these services on the per-module basis would require too much material in the tracking volume causing deterioration of tracking performance. Therefore, higher level integrated solutions are necessary. The ATLAS ITk strips adopted the "stave"as a higher level object to accommodate an array of up to 14 modules on each side of cores providing mechanical support and thermal management. Data and power are supplied on tapes co-cured with carbon fibre skins, which are then glued to a carbon fibre honeycomb to form the stave cores. The modules are mounted on top of the tapes. To achieve a good thermal performance, the tapes need to be sufficiently thin, while tracking performance requires a minimal amount of metal inside. Due to large data volume coming from individual modules, a scheme of 640 Mbps point-to-point links is adopted for module data output. Due to the stave dimensions, these links are up to 1.4 m long. The design challenge is to achieve good signal integrity given the very tight space constraints. The clock and command lines are used in multi-drop configuration to save space and material. They are required to run at 160 Mbps.

We have designed a new prototype tape which takes into account several features that were found to be important in earlier tests. A bottom shield layer is placed underneath data lines to isolate the signals from dissipative effect of the carbon fibre layer under the tape. Individual receivers present impedance perturbation for the multi-drop lines. Since each stave side can have up to 14 modules, and each module has up to 2 data controllers, the line can have up to 28 receivers, which significantly affects the signal shape. In order to minimize such variation, we have split the multi-drop line into several lines connecting up to 5 modules each. Finally, we targeted 100 Ω impedance for individual data lines through the trace geometry and dielectric thickness.

The first batch of 25 prototype tapes has been produced and we started to characterize their performance. The Time Domain Reflectometry method is used to measure the line impedance. Measurements of the impedances of the lines within one tape show excellent uniformity with an RMS of about 1 Ω. Measurements for different tapes show a slightly larger but still acceptable variation. However the measured impedances are slightly different to the calculated ones and we are trying to understand the origins of this discrepancy. We are checking the dielectric properties and examining the fabricated line geometry with cross-sectional measurements of the tapes to identify variation with design parameters. We will incorporate the fabrication artefacts into future prototype tape designs to achieve the desired impedance. This work is relevant to experiments using fast data transmission on long polyimide tapes.

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