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Low mass carbon based support structures for the ATLAS pixel forward disks for the HL-LHC

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For the proposed upgraded pixel and strip detector systems of the ATLAS experiment on the HL-LHC near all carbon support structures are a candidate. These consist of two low-density carbon fibre reinforced polymer (CFRP) sheets (low areal weight), consisting of ultra-high modulus fibres, with metallic cooling tubes filled with refrigerant sandwiched between them. Low-density carbon foam is glued around the cooling tubes to connect them thermally and physically to the CFRP skins. The pixel modules are mounted onto the skins which provide the modules with both a thermal and a mechanical support.

Measurements of the thermal and mechanical properties of prospective low density foams and CFRP sheets are presented. Foams from two suppliers are investigated. Their different physical properties are discussed and the impact on their thermal and mechanical properties shown. The interfaces between the foam and the CFRP skin and the foam and cooling pipe are crucial for the performance of the structure. The thermal resistance of these interfaces are measured. Due to the difference in the coefficient of thermal expansion of the metallic cooling pipe and the CFRP skins the foam and interfaces will undergo a shear force. The effects of the shear force on the thermal conductivity of the interfaces and the foam are presented.

To minimize the material used in the supporting structure the design must be optimized based on the modulli of the material under the relevant low forces experienced by the structure. To this end the modulii under tension, compression and shear are measured for the foam and under tension for the CFRP skins. A custom made jig was used to remove twist in the sample to allow the modulus under tension at the very low stresses of interest to be measured.

The material characteristics extracted are used as input values to finite element analysis (FEA) models of proposed designs of the forward disks of the ATLAS HL-LHC upgrade. FEA simulation results are compared to measurements made on mechanical test structures. From these results extrapolation to a proposed design for the disks are presented. The disks thermal performance is shown from the perspective of maintaining the pixel sensor temperature from thermal run away and as robustness against variation in coolant temperature.

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