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The CMS Outer Tracker endcaps - All the tools needed

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For the high-luminosity LHC (HL-LHC), CMS will install a completely new silicon tracker. The future Outer Tracker will consist of two barrel parts and two endcaps (TEDD), one on each end. One TEDD is made of five double-disks (DD). One DD is assembled from four half disks (Dees) with a diameter of 2.2 m. This contribution will describe the entire process from integrating modules onto Dees, assembly of DDs, TEDD integration and the final insertion into the tracker support tube (TST). Many technical challenges had to be overcome to allow for an integration that maintains a totally stress-free handling of the detector parts and guarantee high precision positioning.

A key element of the integration tooling is the so-called Arc Frame, which holds one Dee during the entire integration procedure without exerting mechanical stress to the Dee. It interfaces to the different integration, assembly, storage and transport toolings. Four Arc Frames can be combined to a double-ring during the DD assembly, while maintaining high precision and minimal mechanical stress. The various challenges to achieve this, its final design and the verification of its suitability will be presented.

The Dee integration and DD assembly toolings have been finalized recently. Both have been verified with prototype or mechanical dummy Dees. The final design features will be presented. The integration testing of prototype detector modules to prototype Dees is ongoing. The requirements for appropriate grounding places additional requirements on the Dee mechanics. Electrical connections of Al inserts to carbon fiber face sheets and the surface preparation of the carbon fiber to allow an electrical spring finger to make contact have to be foreseen now. Key results from the integration and assembly testing will be presented.

For the TEDD integration, all five DDs have to be aligned to each other for which a tooling design has been made. It uses custom designed linear X/Y/Z stages, which recently have been delivered. After alignment the global mechanics components are attached to the DDs. In order to install the global services, the TEDD will be transferred to a rotation tool, allowing to rotate the TEDD around its central axis. An axle will be inserted into the inner bore of the detector, with pneumatic cylinders pressing on inserts located at the inner radii of the Dees. Each of the 46 cylinders will be equipped with load cells to configure the pressure and monitor the load transfer. This rotation tool has now been designed and a prototype including load testing systems is under construction. An in depth look at the tooling designs will be given.

The final challenge that needs to be addressed is the interplay of all the tooling. Considering the transport of detector parts from one integration step to the next, including storage, puts additional design constraints on each tooling. A review of the whole integration flow will be given to demonstrate that this interplay is properly taken into account.

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