Overview of the HL-LHC CMS outer tracker upgrade & lessons learned from 2S module production

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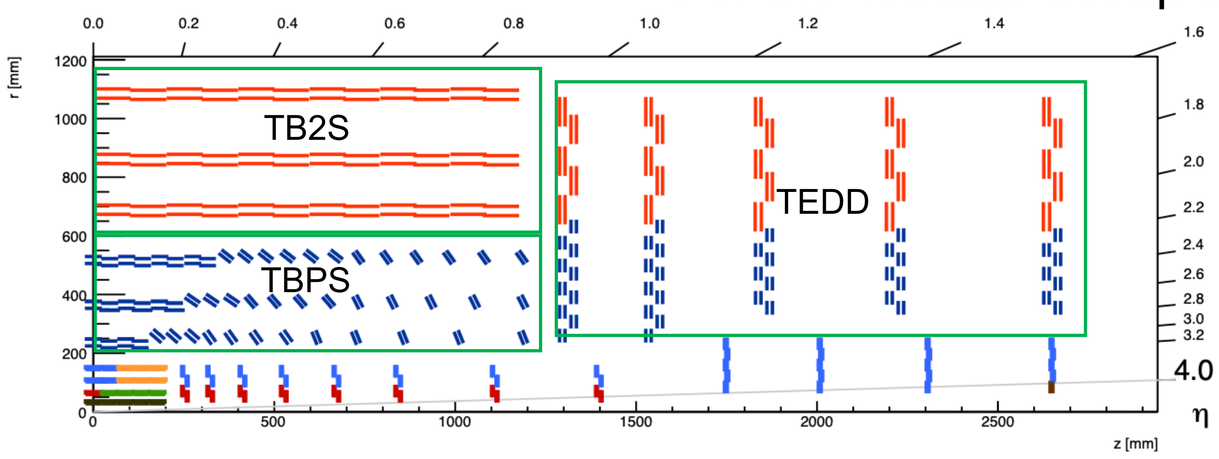
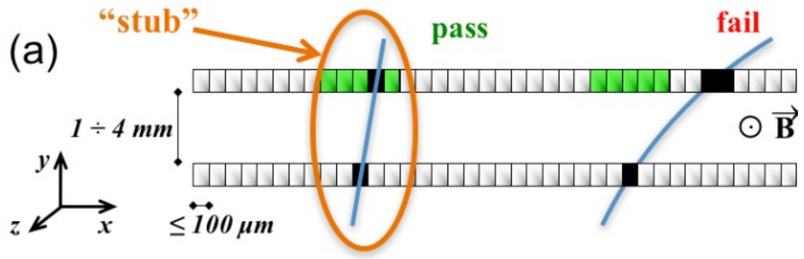
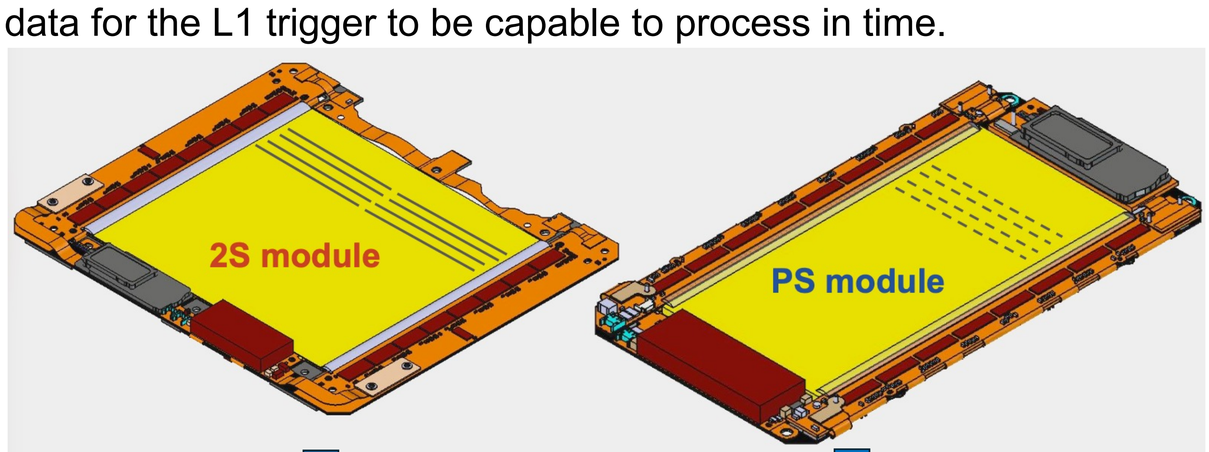
For the Tracker Group of the CMS Collaboration



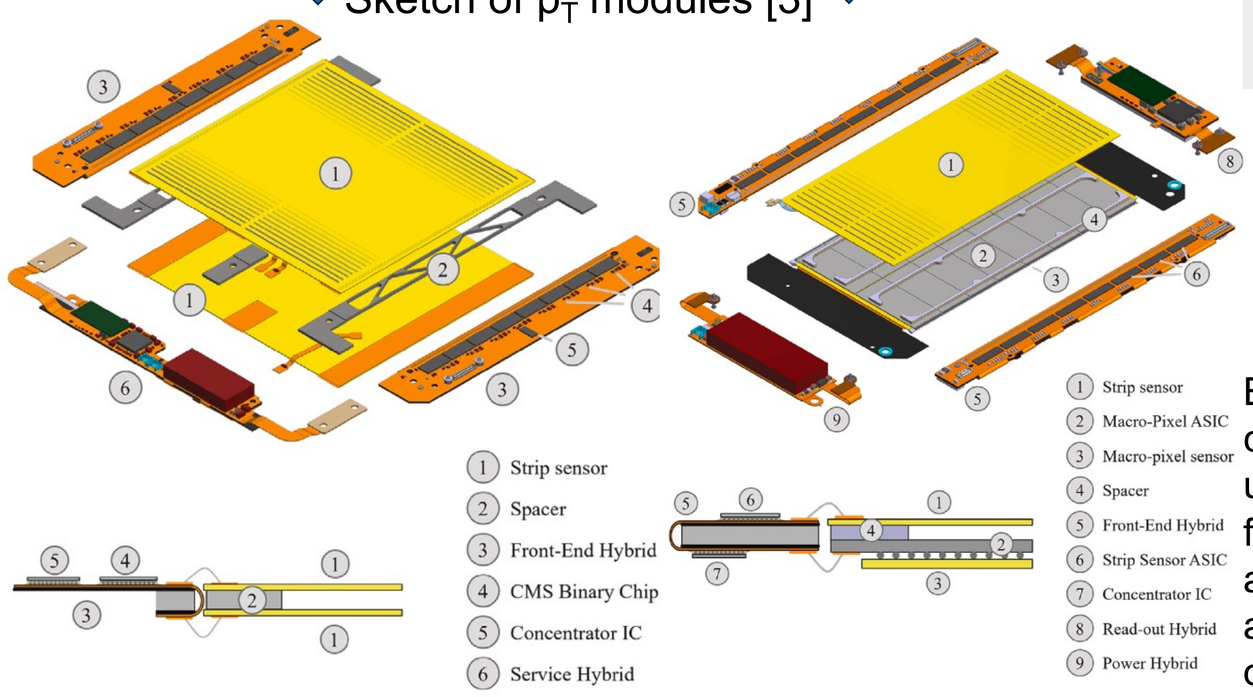
Compared with the current LHC CMS tracker, the new CMS tracker of the High-Luminosity LHC is undergoing significant enhancements with improved radiation hardness, higher granularity, and extended coverage up to a pseudo-rapidity of |η|~4. The outer tracker (OT) ranges up to |η|~2.4, including 3 partitions: TB2S, TBPS, TEDD [1].



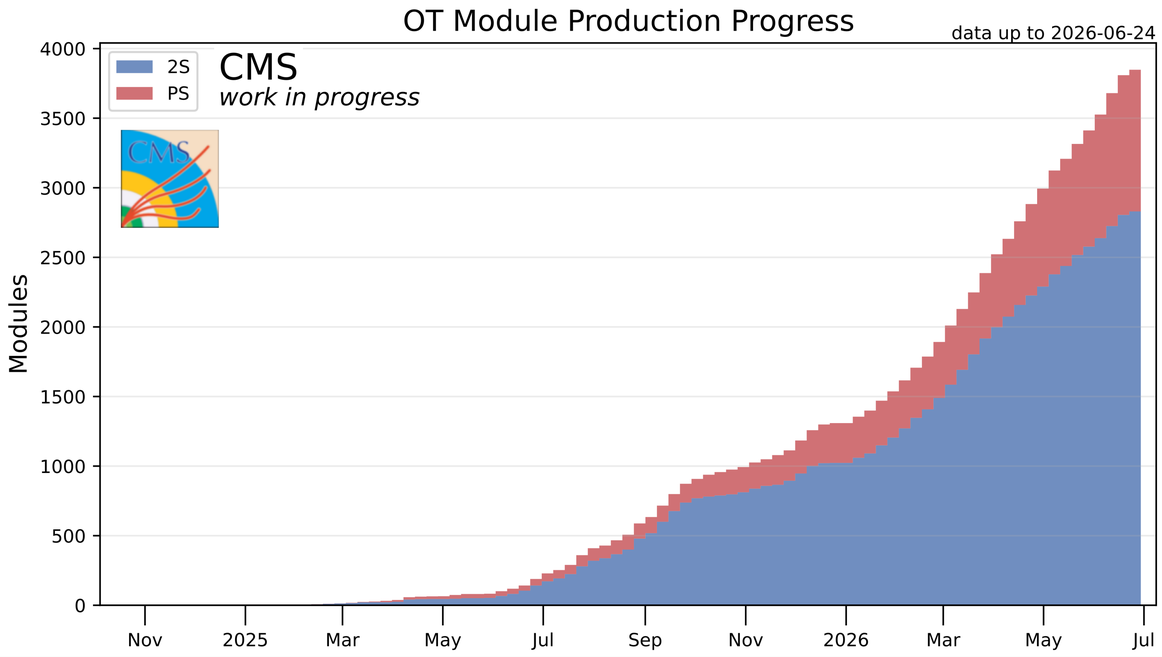
The outer tracker (OT) will be equipped with two types of p_T modules (2S & PS). By using these modules, the information from the tracker will be sent to the Level-1 (L1) trigger [2] for the first time. They will identify charged particles with p_T > 2 GeV, to reduce vast mount of data for the L1 trigger to be capable to process in time.



Sketch of p_T modules [3]

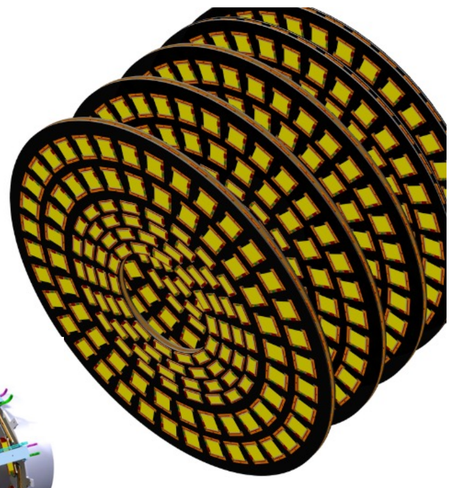


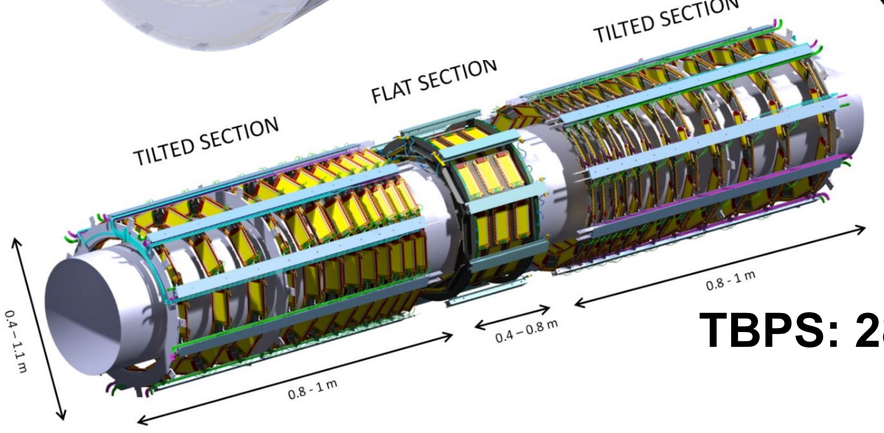
The CMS tracker international team (~10 centers across Asia, Europe, North America) are producing hundreds of modules per week.



TB2S: 4416 modules

TEDD: 5912 modules

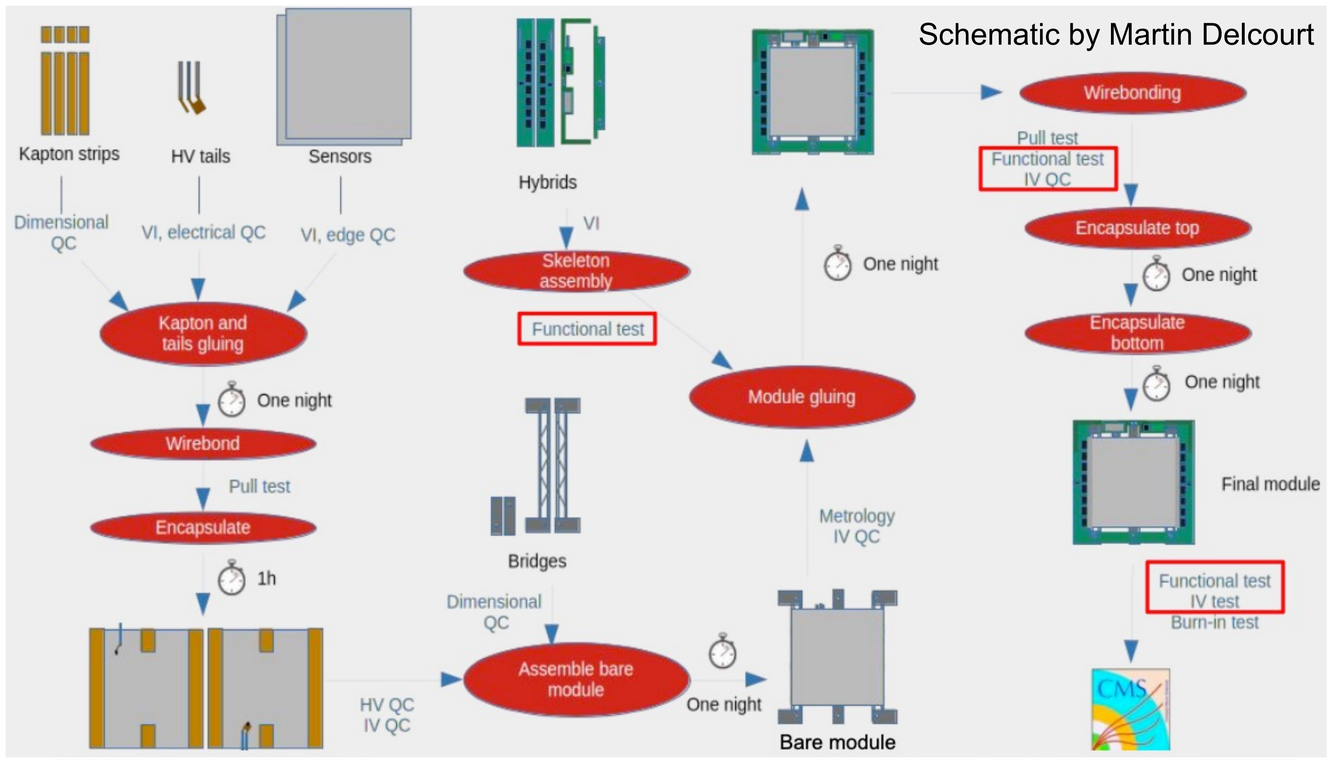


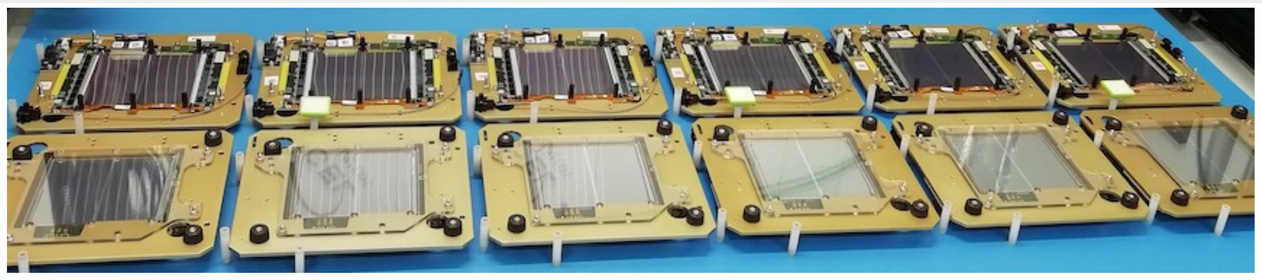


TBPS: 2872 modules

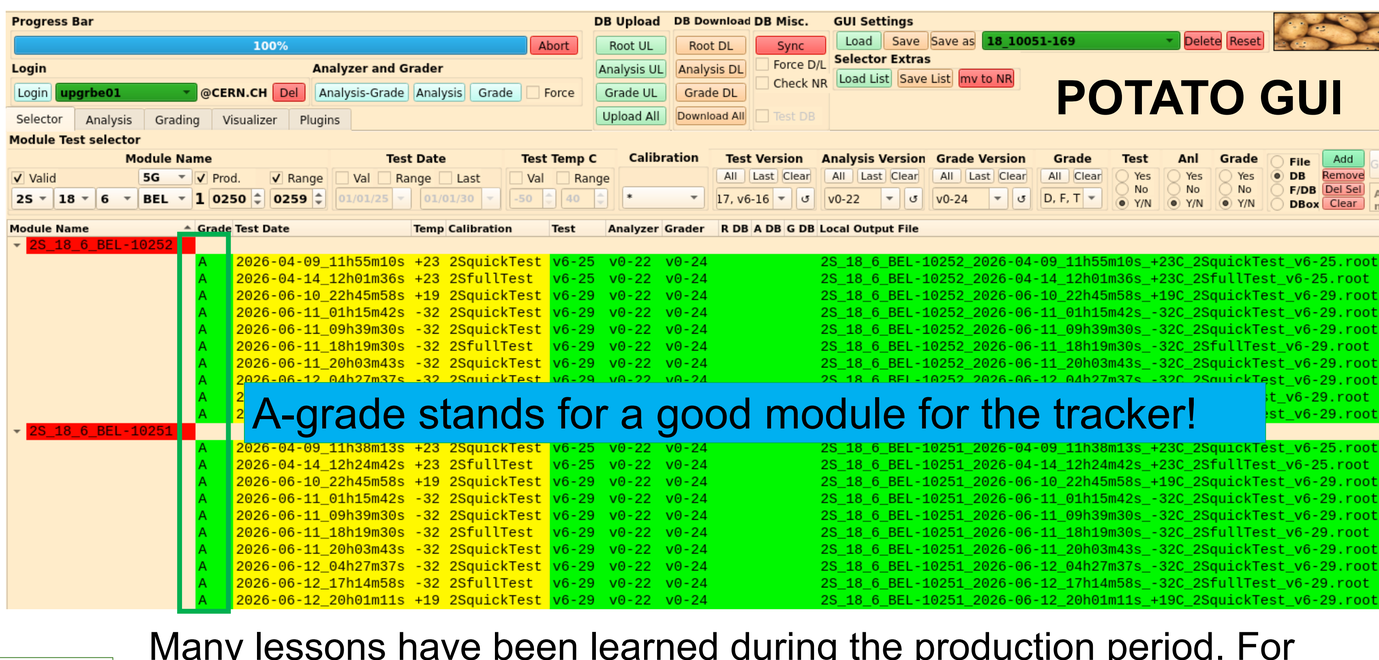
The mechanical structures are still in production. Some centers are already starting to test produced mechanical segments with multiple modules mounted using cosmic rays and measure their common mode.

2S Module assembly procedure





Brussels (ULB, VUB, Antwerp, Ghent) is one of the 2S module production centers, committed to produce 1500 modules. The Belgian team assemble up to 24 modules per week in a typical production rate. As shown in the figure above, each module is assembled in a strictly controlled streamline, and it must pass a sequence of tests. The testing results of each module are analyzed and assigned with a grade by the Phase-II Outer Tracker Analyzer of Test Outputs (POTATO). This C++ application is developed to qualify each module if it is good for the CMS tracker, and help centers to trace the hint of problematic modules, and to evaluate the possibility of recovering them.



Many lessons have been learned during the production period. For example, module IV-curve could become bad during the handling procedure. That can cause noisy strips during readout test. Many of them could be cured by wiping the sensor and/or long biasing at 800V.

References:
[1] The CMS Collaboration, "The Phase-2 Upgrade of the CMS Tracker", CMS-TDR-014
[2] The CMS Collaboration, "The Phase-2 Upgrade of the CMS Level-1 Trigger,", CMS-TDR-021
[3] The CMS Tracker Group, "Design and construction of the CMS Outer Tracker for the HL-LHC Upgrade"