2S-module prototyping and qualification for the CMS Outer Tracker upgrade at the HL-LHC

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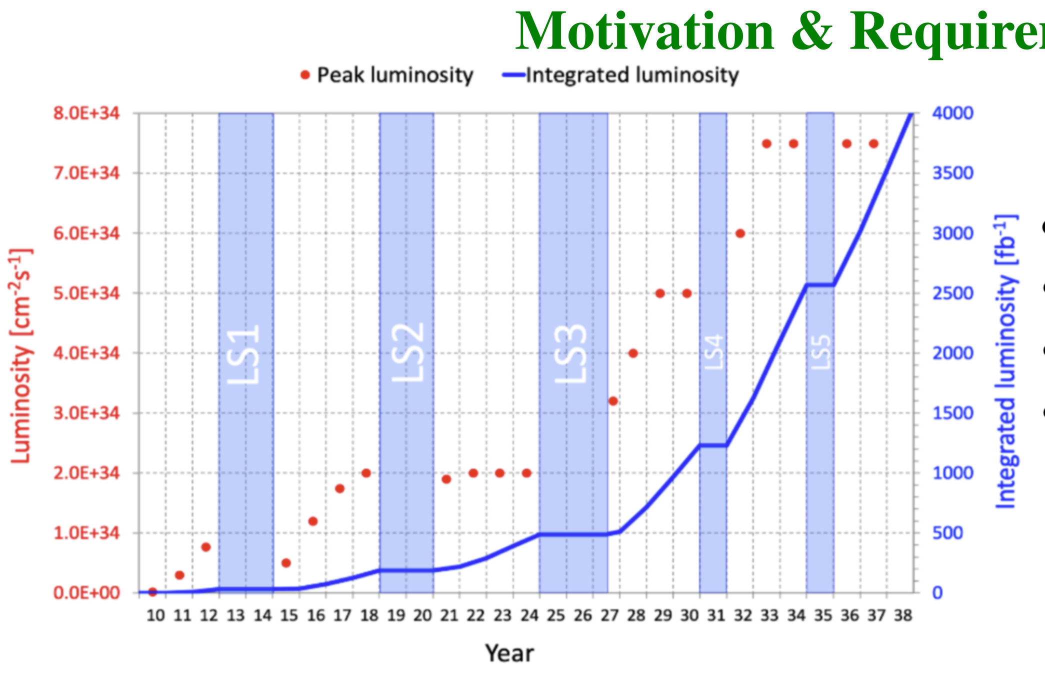
Abstract

In preparation for the High Luminosity LHC, the whole tracker detector of the CMS experiment will be exchanged within the Phase-2 Upgrade. The new outer tracker will be made of approximately 13000 silicon sensor modules called 2S modules (consisting of two parallel mounted silicon strip sensors) and PS modules (one pixel and a strip sensor combined in a module). These modules provide tracking information to the Level 1 trigger by correlating the hit information of both sensor layers and, thus, allowing to discriminate particle tracks by their transverse momentum. To guarantee successful operation during data-taking, the production of the outer tracker modules has to fulfill strict requirements. This poster will discuss the assembly procedures as well as some key results of the electronic, thermal and vibration tests performed at CERN for qualifying the 2S module design and for preparing the module assembly procedures.

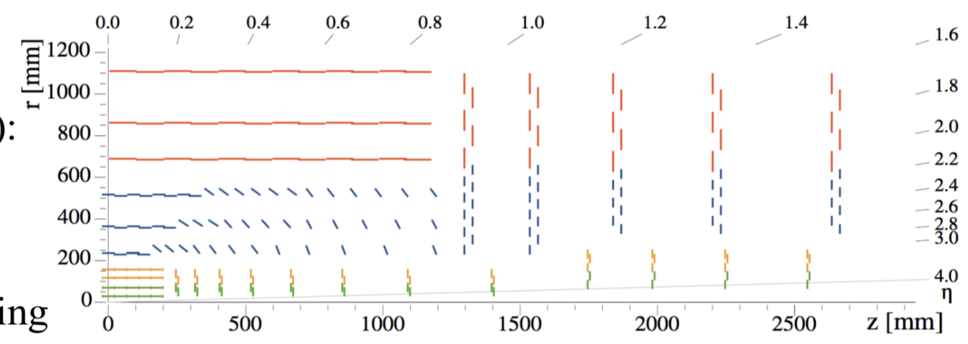
Motivation & Requirements



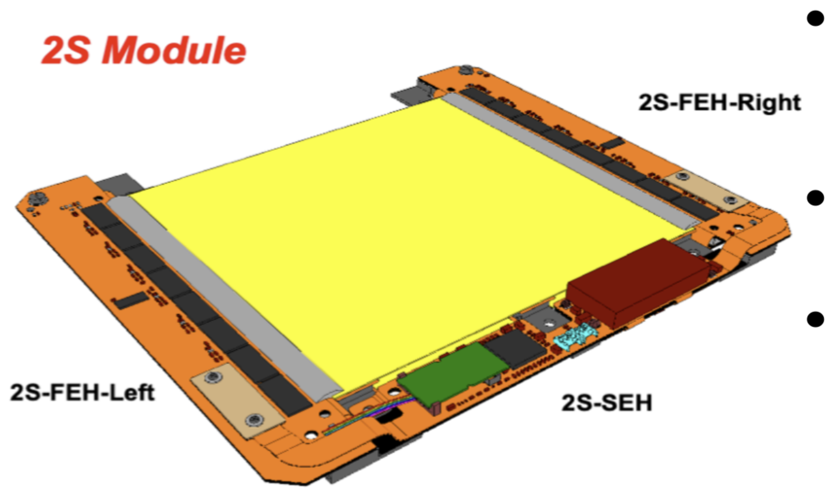
- **High Luminosity LHC upgrade:**
- Increased of pileup to ~200
- Peak Luminosity ~7.5×10^{34}cm^{-2}s^{-1}
- Integrated luminosity of ~4000fb^{-1}

- **CMS Tracker upgrade (key features):**
- High granularity
- Radiation hardness (total ionization dose):
  - Innermost layer: 1.2 Grad
  - Outer layers: 100 Mrad
- Low material budget for improving tracking performance in high pileup condition

CMS Tracker upgrade layout

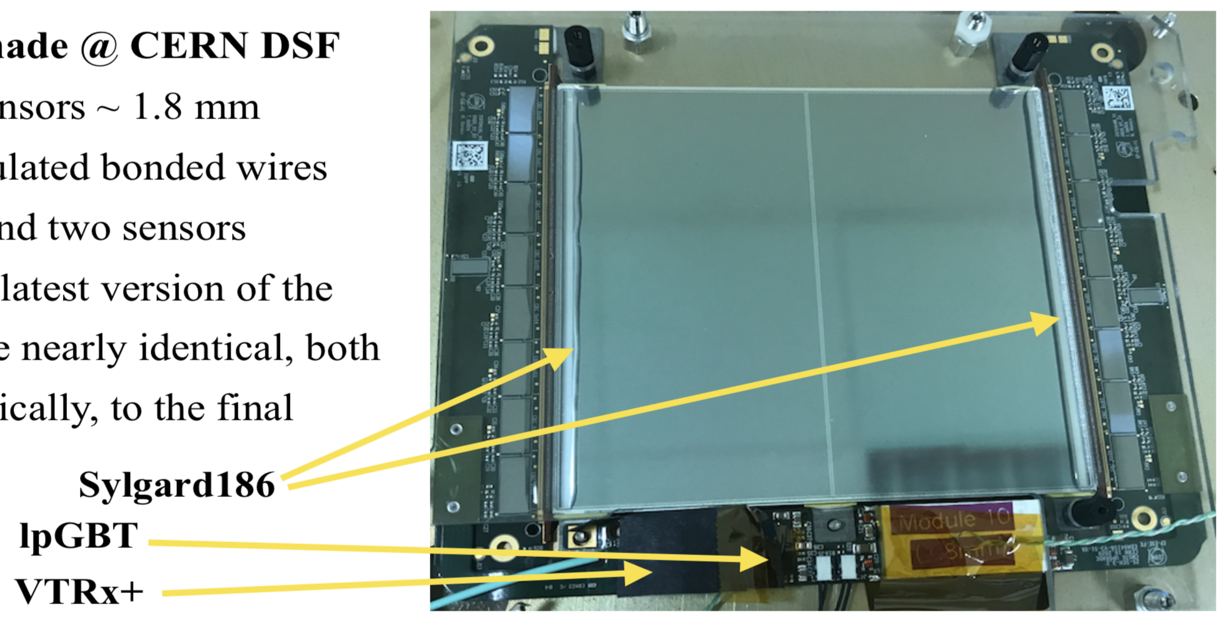


Schematic & Prototype



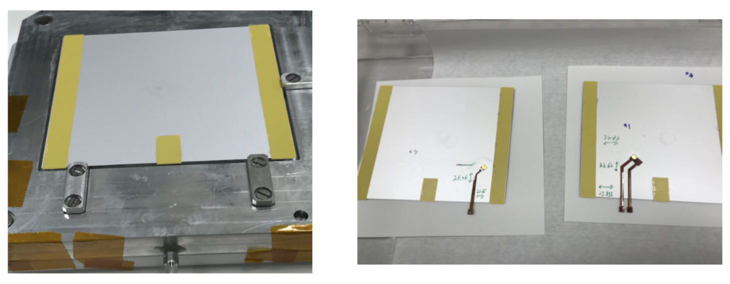
- **Two parallel silicon strip sensors**
  - 2×1016 strips, 90µm pitch
  - 90cm² active area
- **Left and Right side frond-end-hybrids (FEH)**
  - Bonded CBC3.1* chips and CIC* chip
- **One service hybrid (SEH)**
  - DCDC* converters based on BPOL* chips
  - Optical readout based on lpGBT* & VTRx+*

- **The latest prototype made @ CERN DSF**
  - Gap between two sensors ~ 1.8 mm
  - Sylgard 186 encapsulated bonded wires between the FEHs and two sensors
- This prototype uses the latest version of the hybrids which should be nearly identical, both mechanically and electrically, to the final version modules

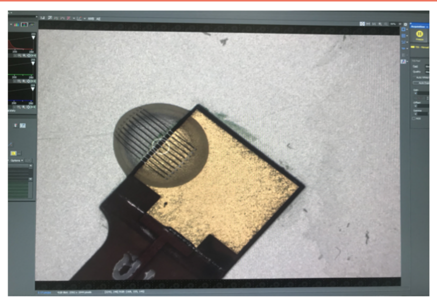


* The Phase-2 Upgrade of the CMS Tracker — Technical Design Report (CMS-TDR-014)

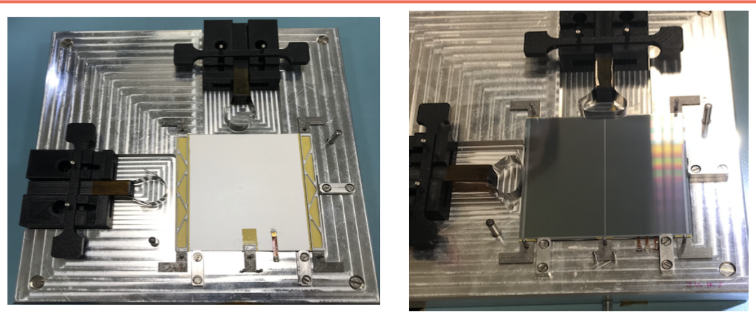
Module assembly procedure



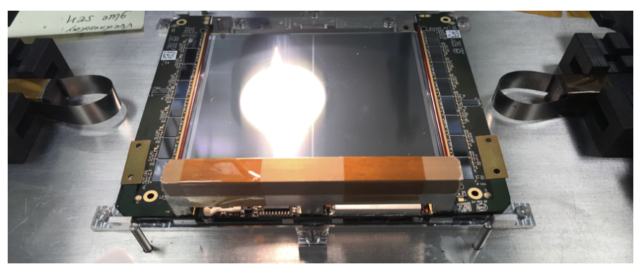
1. Glue Kapton isolators and HV tails on sensor backside



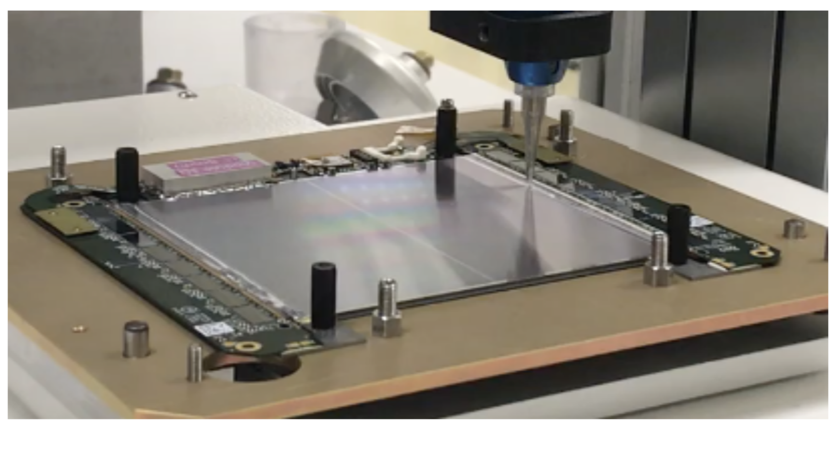
2. Wire bond and encapsulate HV tails



3. Glue Al-CF bridges & make sandwich

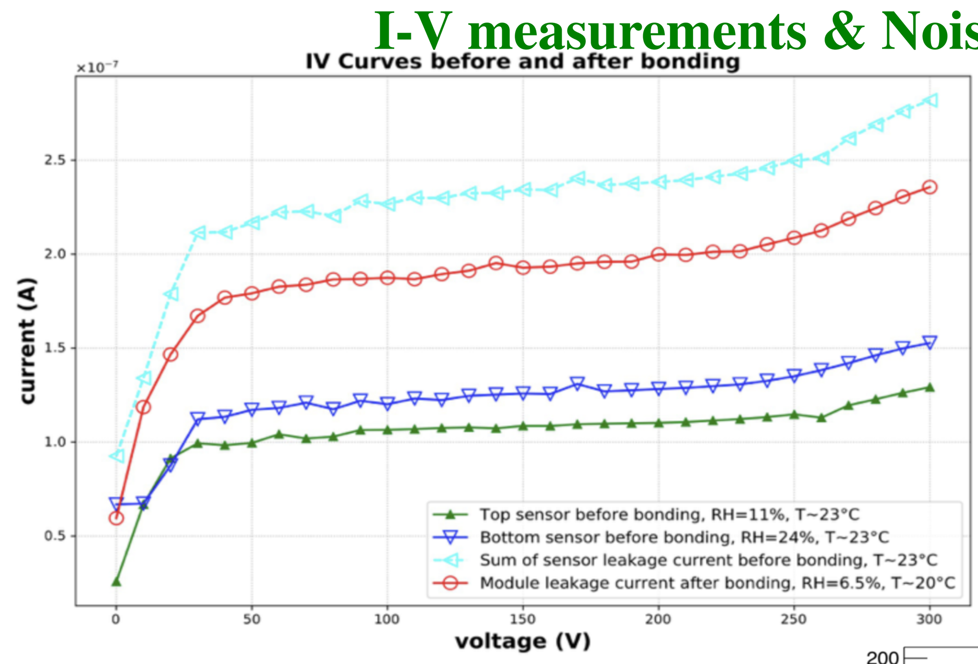


4. Glue hybrids to the sandwich



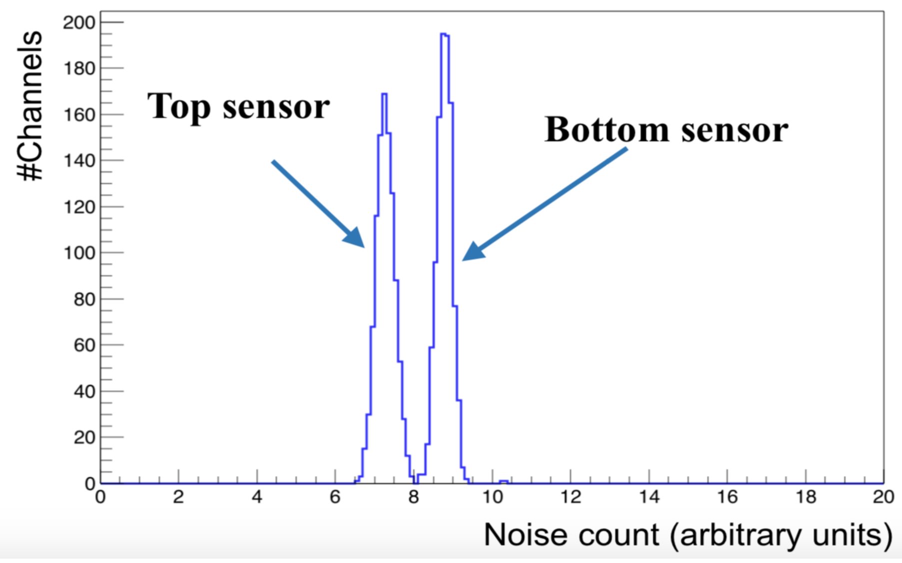
5. Wire bond FEHs to the sensors & encapsulation

I-V measurements & Noise measurement

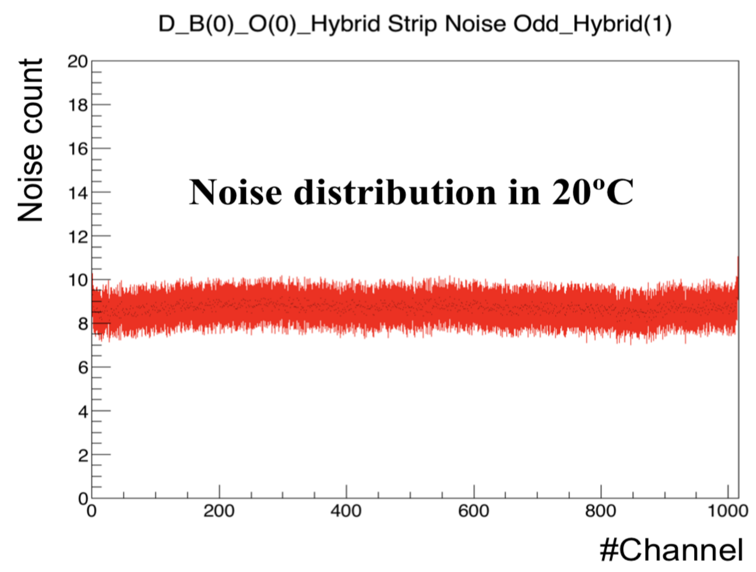


- **An example of I-V curve during an electrical test on a module prototype**
  - Leakage current before and after bonding should be nearly same if one takes into account different temperature of measurements
  - Many thanks to the KIT team for bonding the prototype and doing the IV measurement

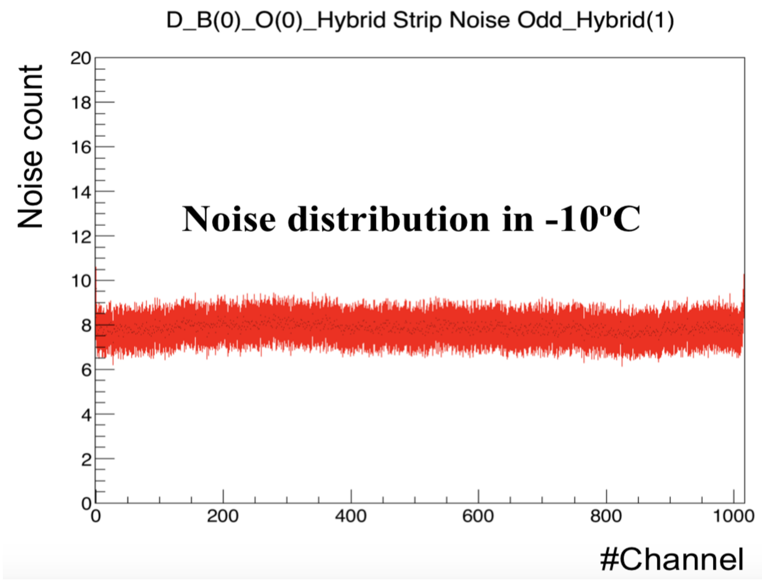
- **An example of noise profile during an electronic readout on a prototype (one side)**
  - Measured noise (in electrons) is close to expectation
  - The bottom sensor has higher noise than the top one:
    - the length of the lines on the hybrid connecting the bottom sensor with the CBC3 chips are much longer
    - additional pick-up effects and input capacitance

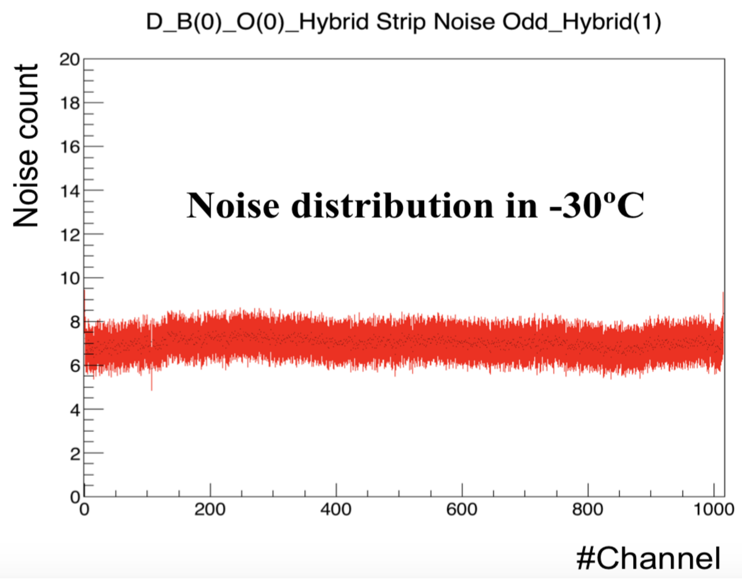


Thermal cycling tests

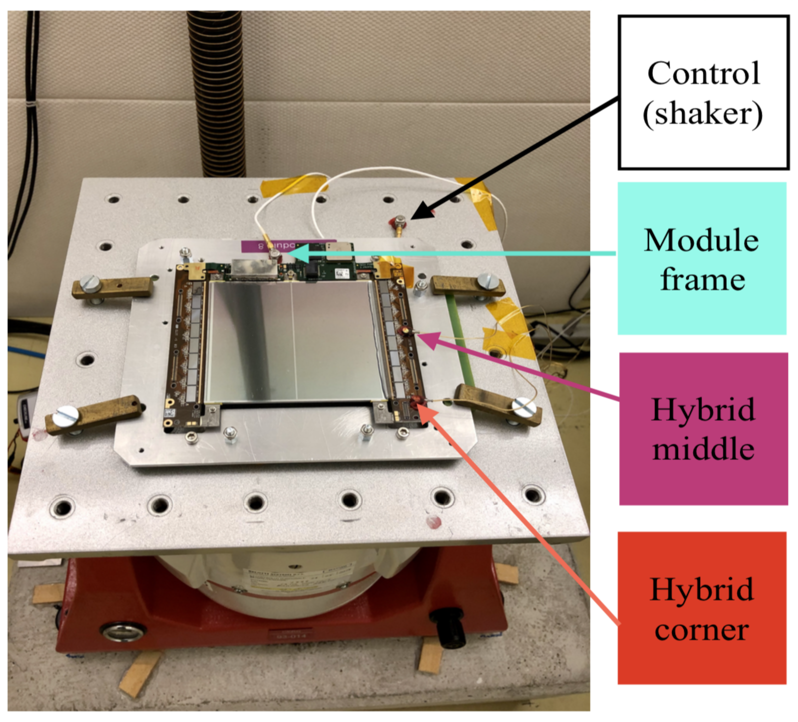


- The 2S modules are expected to be operated in ~ -30°C during HL-LHC run period
- Check if mechanics and electronics behave in varied temperatures: ranging from 20°C to -30°C
- At least 3 times of cycles have been tested
- Readout module noise in different temperatures:
  - Channel noise decreases when the temperature goes down
  - Any channel with much lower noise than the trend could indicate a broken channel





Vibration tests of module robustness



- Could transport vibration damage modules?
- Conducted resonant frequency tests of the module as it would be secured to its transport plate
- Focus on the movement of hybrids
  - 5 - 1000 Hz sine wave sweep (typical transport vibration frequencies)
- Peaks in the below plots show frequencies of resonances
  - Resonant peaks at lower frequencies observed for encapsulated module: ~250Hz

- One should always encapsulated the wire bonds, for their protection and it makes the modules more robust (especially the hybrids)
- The hybrids should not be free to "flap" during transport, they should be secured on their outside edges (this has been done in the latest module carrier)

Conclusion

Many (10) 2S module prototypes have been built at CERN in order to test and improve the module design and assembly procedures. Mechanical aspects of the designs have been studied, leading to modification of the design and development and modification of the assembly tooling. The prototypes have been subject to many electronic, electrical, thermal cycling and vibration tests in order to check that they meet the mechanical and electronic requirements and have the necessary robustness to survive the long working life under harsh environmental conditions expected in the HL-LHC. Final tests on the two prototypes with the latest version hybrids are on-going. The improvements made should allow for a much smoother pre-production and production of the module assembly.