Karlsruhe Institute of Technology

CMS Germany

BMBF FSP-CMS

Modulbauentwicklung für das Phase-II Upgrade des äußeren CMS-Spurdetektors

Module Prototyping for the Phase-II Upgrade of the CMS Outer Tracker

DPG Würzburg – 19.03.18 T 41.8

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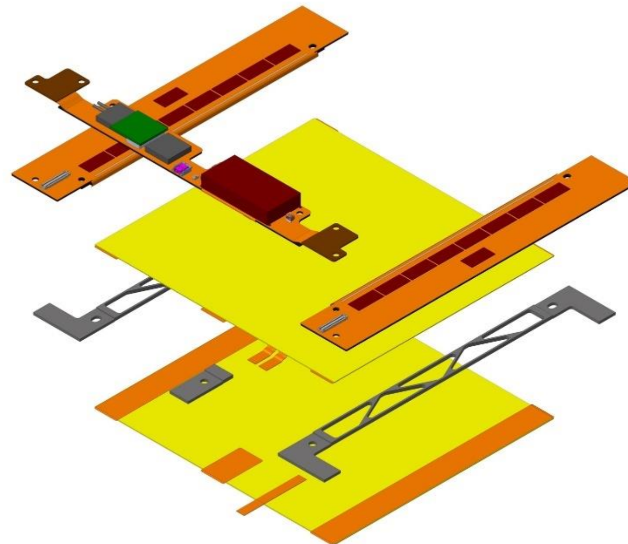
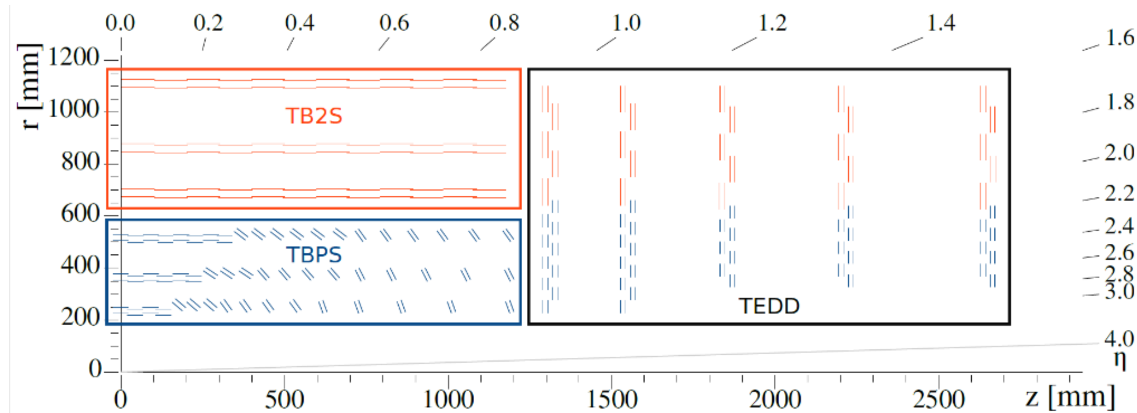


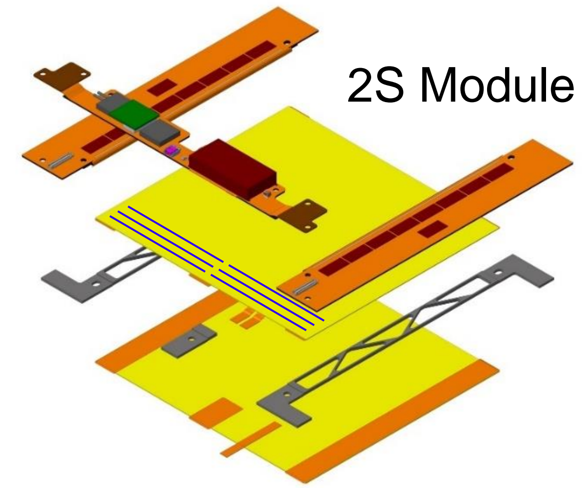
The Phase-II Upgrade of the CMS Outer Tracker

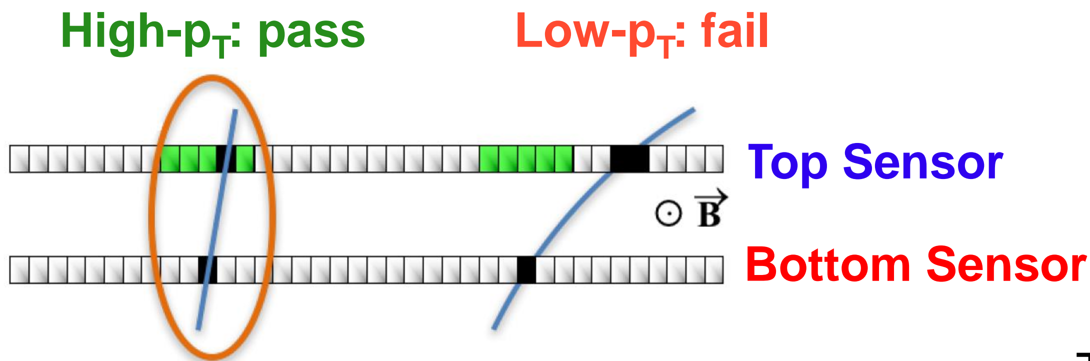


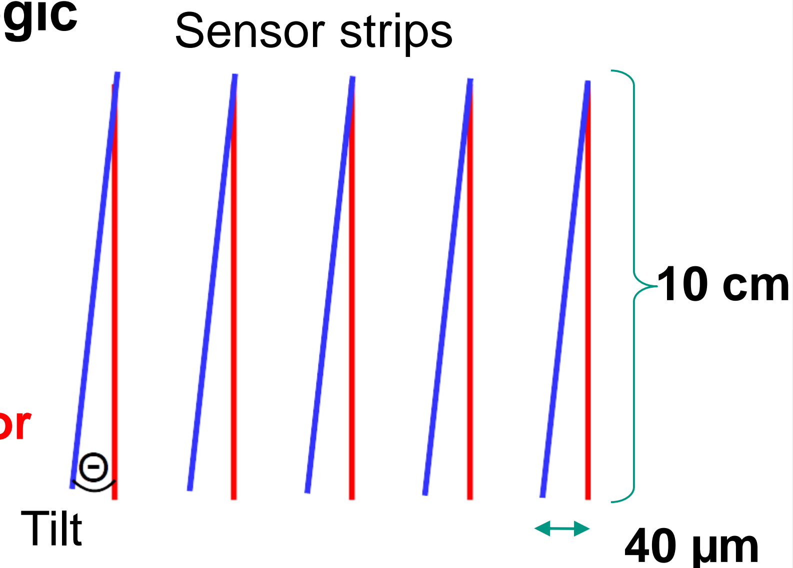
- New silicon tracker of the CMS-Experiment for HL-LHC by 2026
  - Increased granularity
  - Radiation tolerant to up to 10^{15} n_{eq}/cm^2
  - Reduced material budget
  - Sensors operated at –20°C
- Outer tracker will consist of ~13000 double-sided modules
  - 2S: strip/strip sensor
  - PS: pixel/strip sensor
- Contribution to Level 1 Trigger by p_T-module concept

p_T-Module Concept

- Bending of tracks identified on double-sided sensor module by a coincidence logic
- High-p_T particle information contributes to Level 1 trigger
- Cut on p_T keeps trigger rates under control → **Alignment of superimposed strips in 2S Modules needs to be Θ < 400 µrad to ensure functionality of coincidence logic**
  (offsets can be corrected by software)







2S Module for the CMS Outer Tracker

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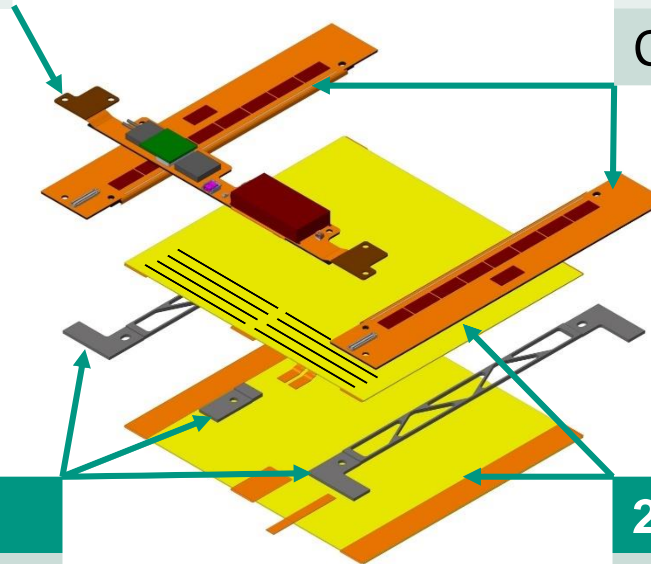
Service Hybrid
Powering
Data transmission

2 Front-end Flex Hybrids
8 CMS Binary Chips each
1 Concentrator Chip each
Connected to both sensors



Spacer
Carbon fiber reinforced aluminum
Mechanical fixation

2 Silicon Strip Sensors
2 x 1016 strips (5 cm) each
Bottom to top strip alignment of <400 μrad

Assembly and test procedure of 2S Modules

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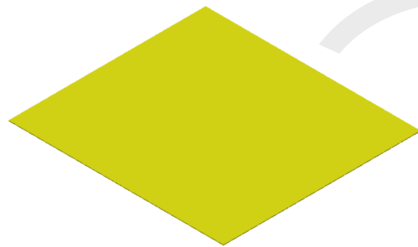
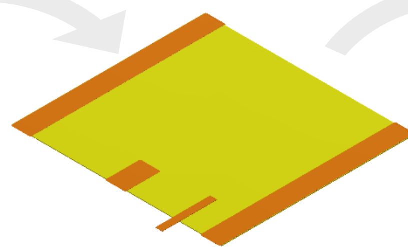
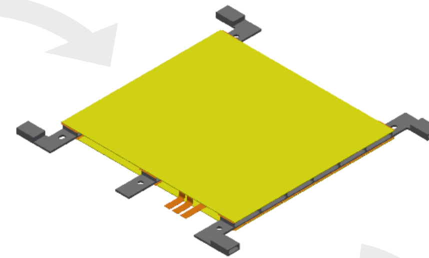
1. Glue polyimide HV isolation and attach HV tails on sensor backside

2. Glue sensors on bridge







- Dicing precision (metrology)

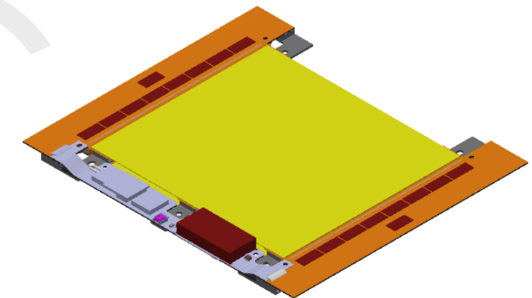
- Optical inspection
- Sensor I(V)

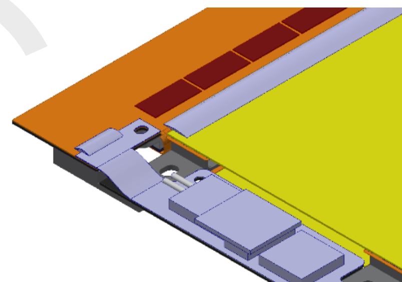
- Module metrology
- Sensor I(V)

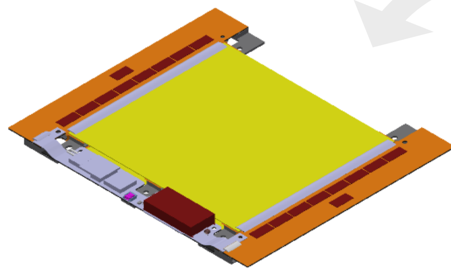
3. Glue readout and service hybrids on bare module

4. Place 4000 wire-bonds

5. Encapsulate wire-bonds







- Optical inspection
- HV/LV test

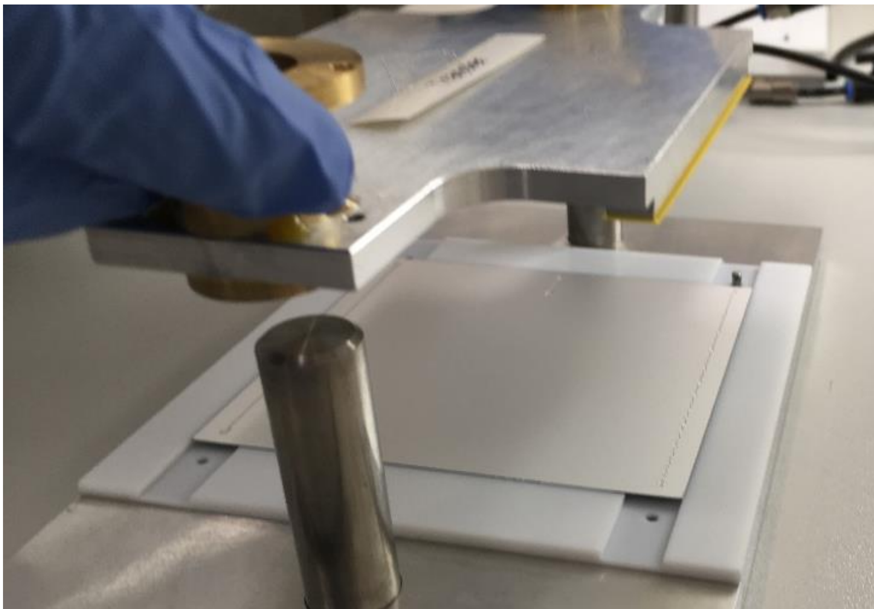
- Module test

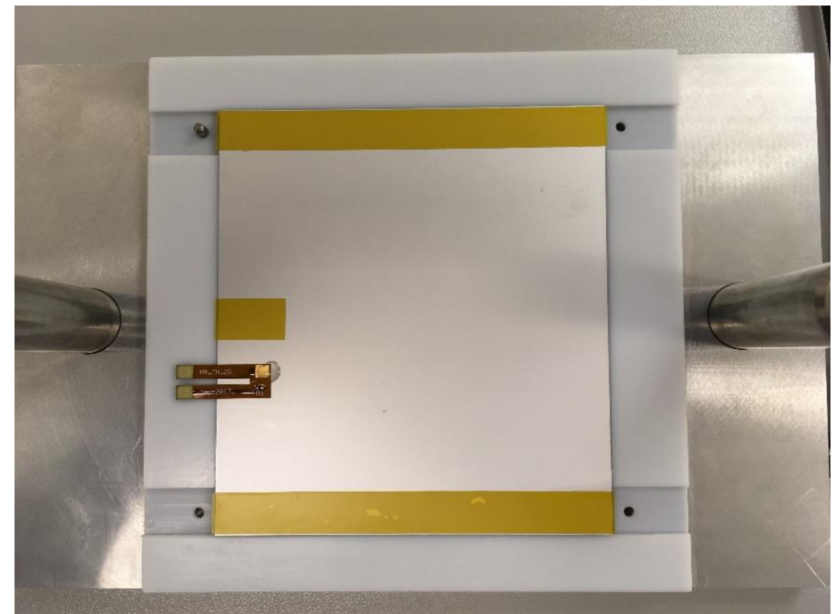
- Module test

For module test station, see Roland Koppenhöfer, T25.1

Backplane polyimide isolation and HV tails

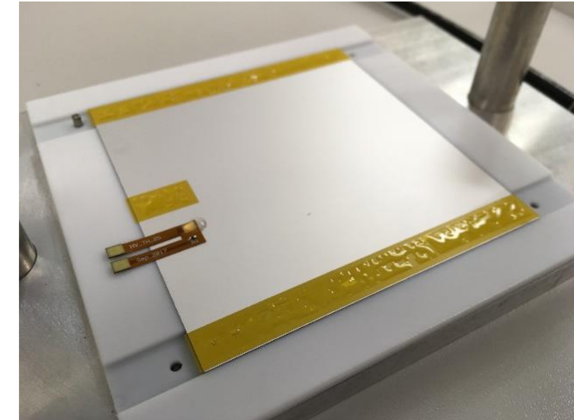
- Thin gluing layer for good cooling contact
- Apply thin glue line with 0.06 ml/mm on sensor backplane with a volumetric dispenser on gantry
- Place polyimide strips with precision jigs and attach HV tails

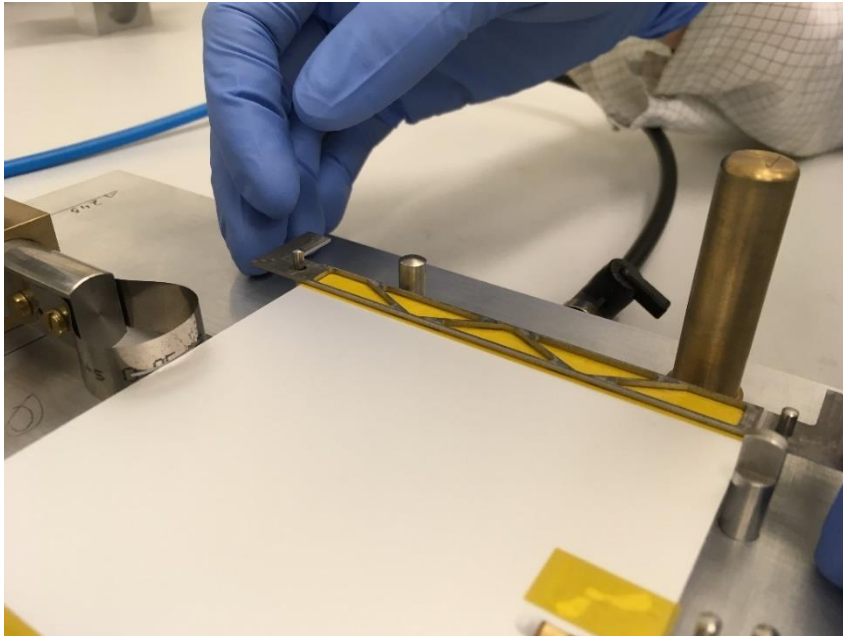


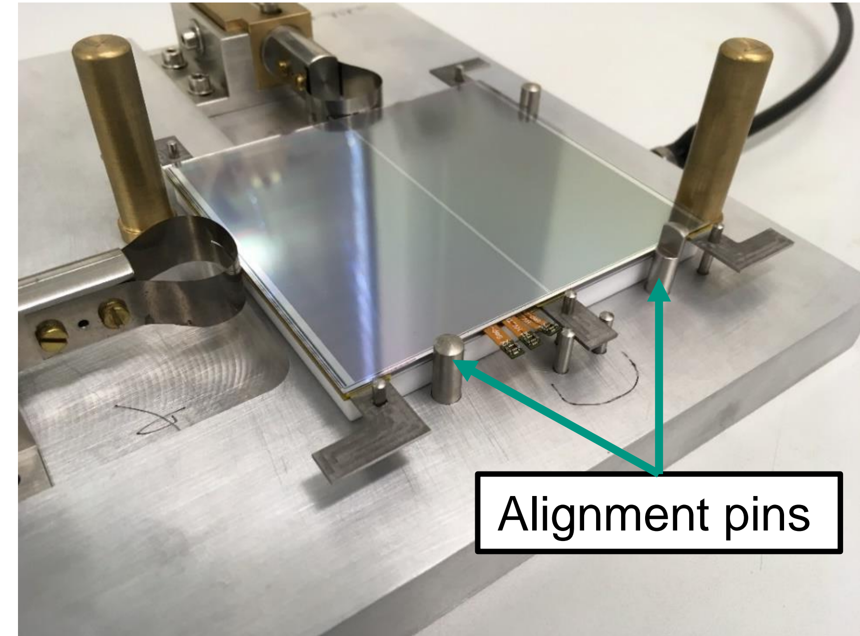


Bare module gluing

- Glue applied on polyimide with a stamp
- Sensors and bridges are precisely placed on top of each other in a jig
- Alignment pins allow high gluing precision
  → **High sensor dicing precision necessary for good top strip to bottom strip alignment**

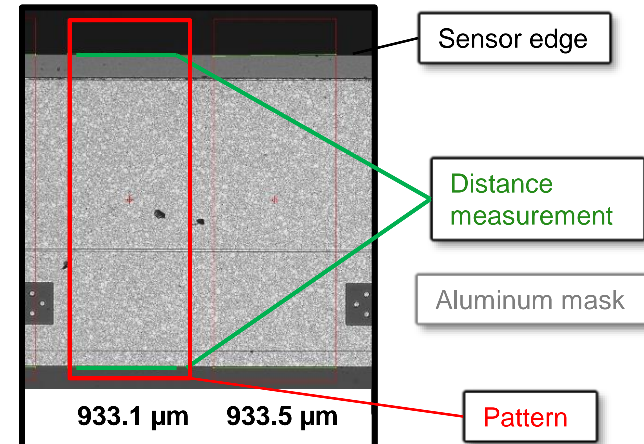


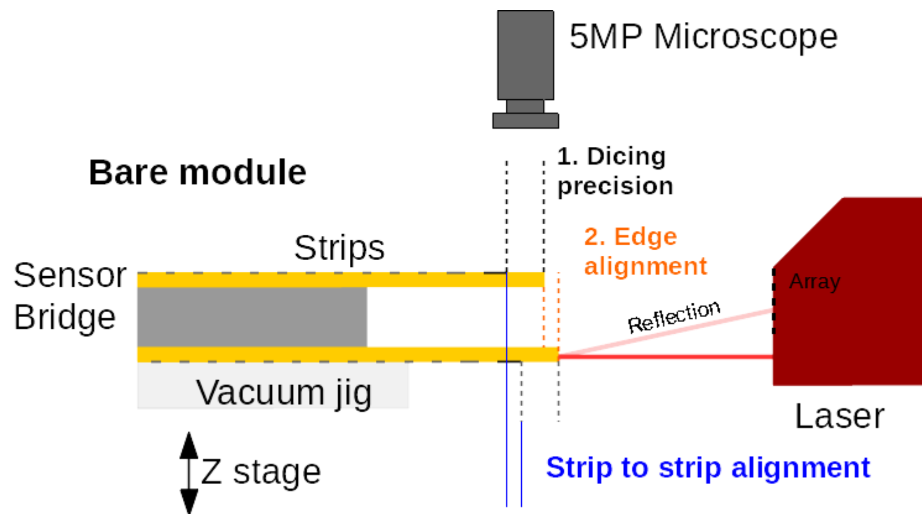


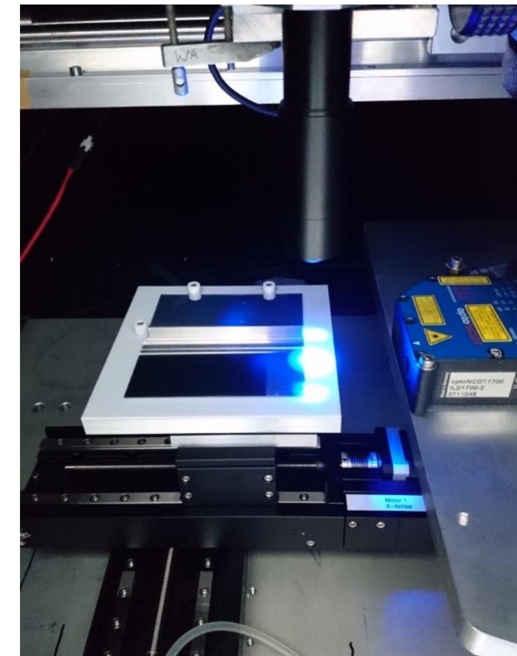


Bare module metrology – concept

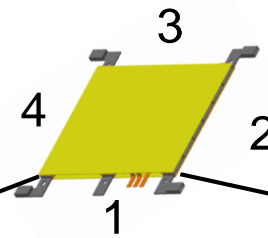
- Two-step measurement to measure bottom strip to top strip alignment
  - Sensor dicing angle
    - Optical, pattern recognition
    - Before assembly
  - Edge alignment
    - Laser measurement along edge
    - After assembly



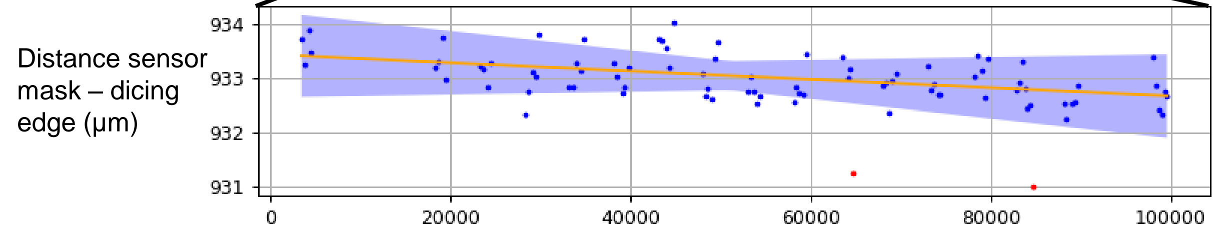




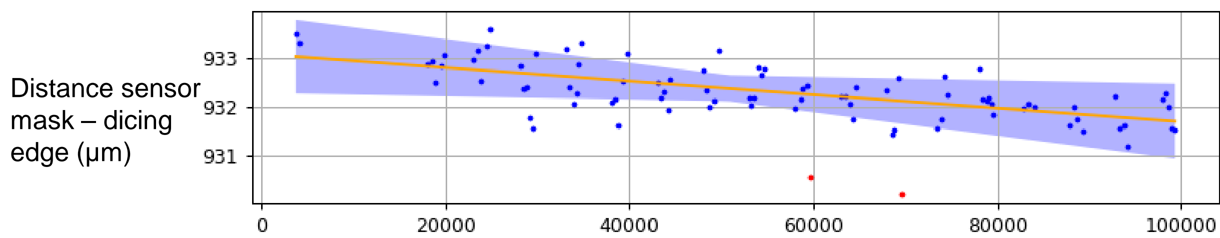
Metrology measurements



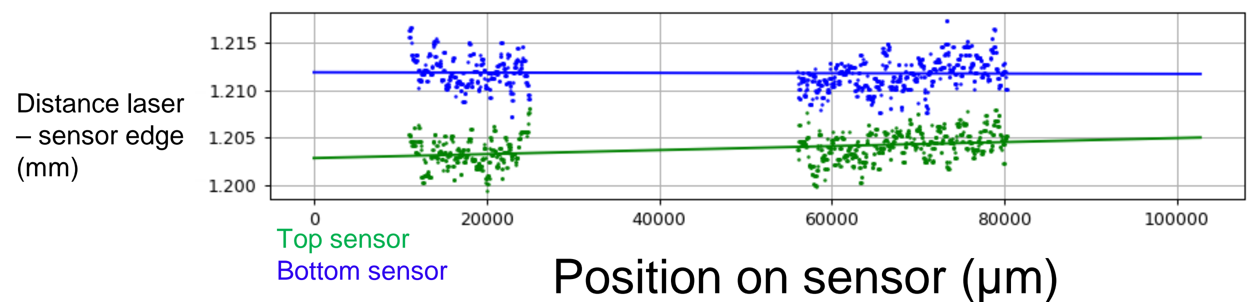
- Bottom sensor dicing angle: **– 9 ± 11 µrad**



- Top sensor dicing angle: **– 15 ± 11 µrad**



- Edge alignment: **23 ± 35 µrad**



- Top strip to bottom strip alignment: **– 1 ± 57 µrad**

Specs: < 400 µrad

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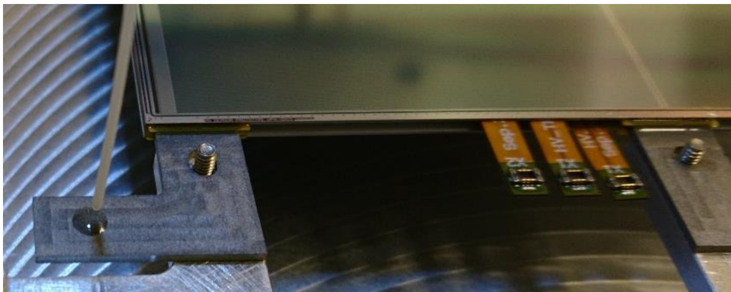
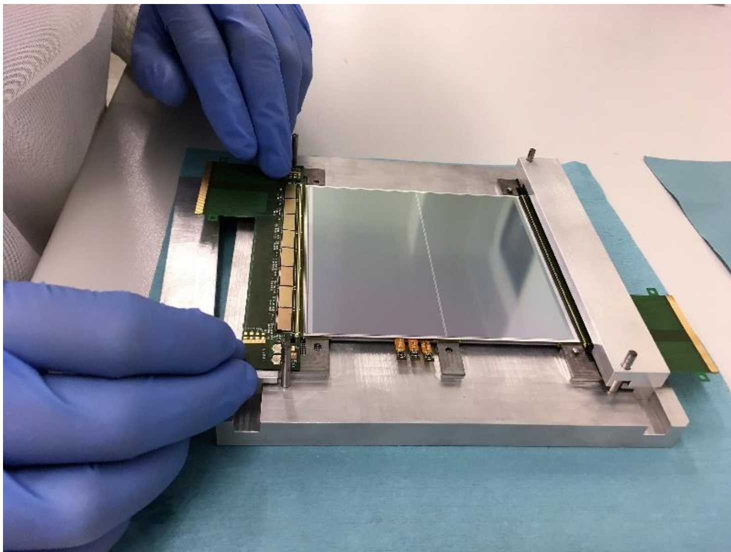
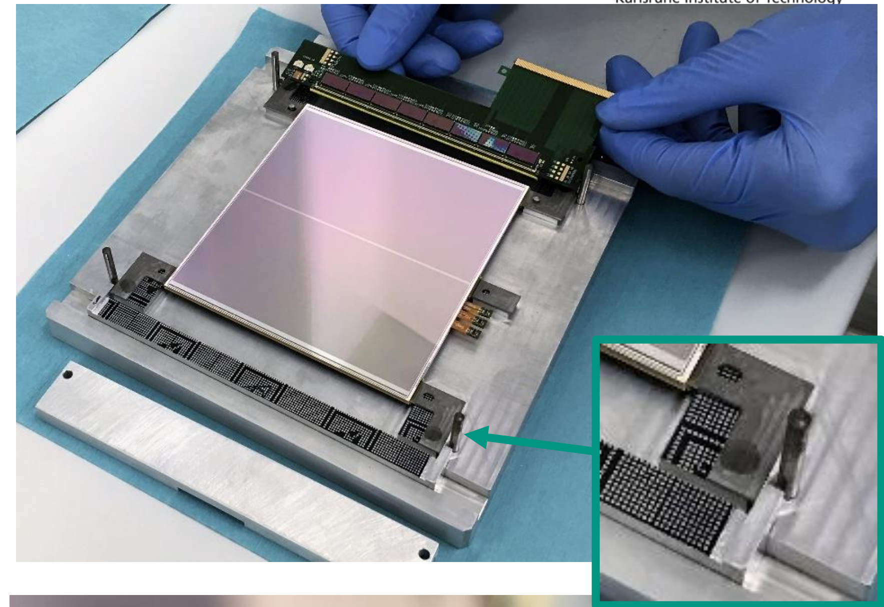
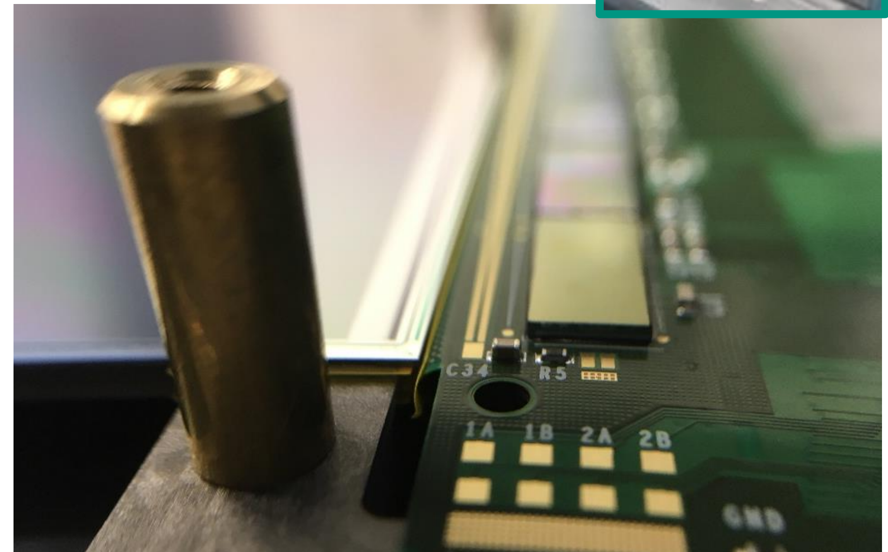
Hybrid gluing

- Hybrids aligned to sensors on jig
- Apply 1.5 mg of glue with dispensing gantry on each joint



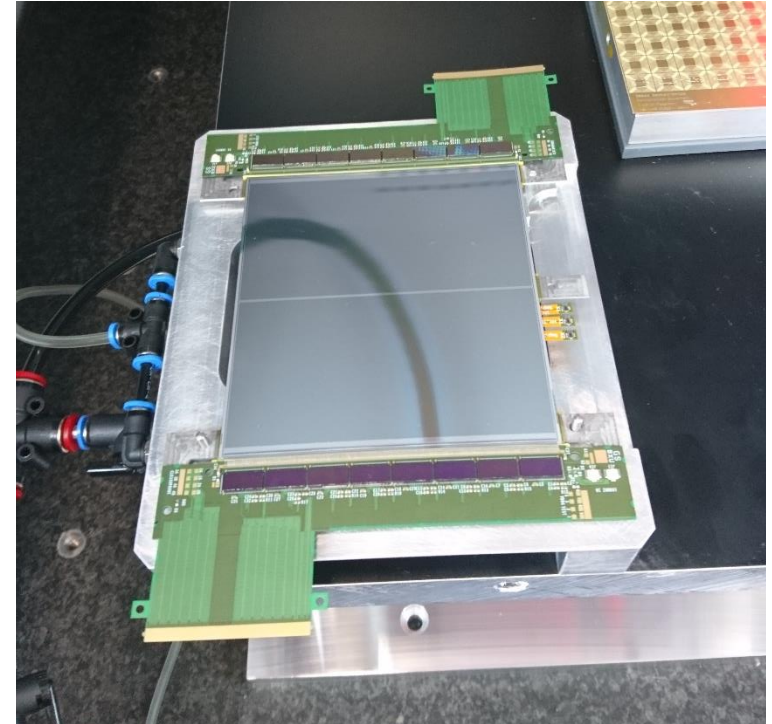




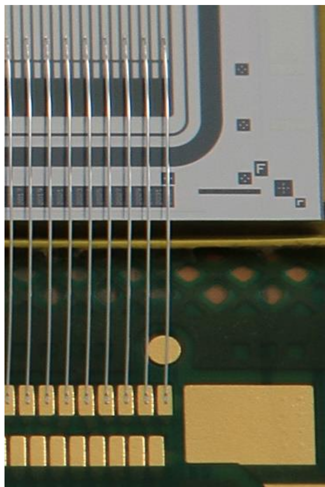


Wire-bonding

- Wire-bond jig locks module into position during bonding
- ~4000 wire-bonds per module
- Preliminary studies for bond parameters:
  - No lift-offs
  - ~10g pull force



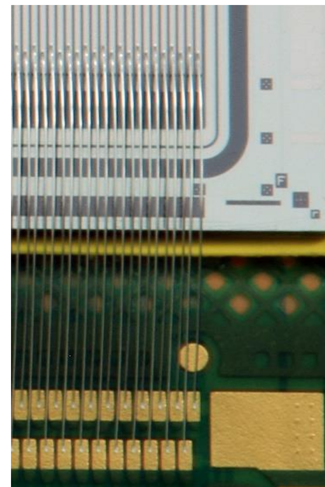
- Each readout channel successfully wire-bonded



Bottom row

Length: 3.4 mm

Height: 500 µm



Top row

Length: 4.2 mm

Height: 600 µm

Sr90 source measurement

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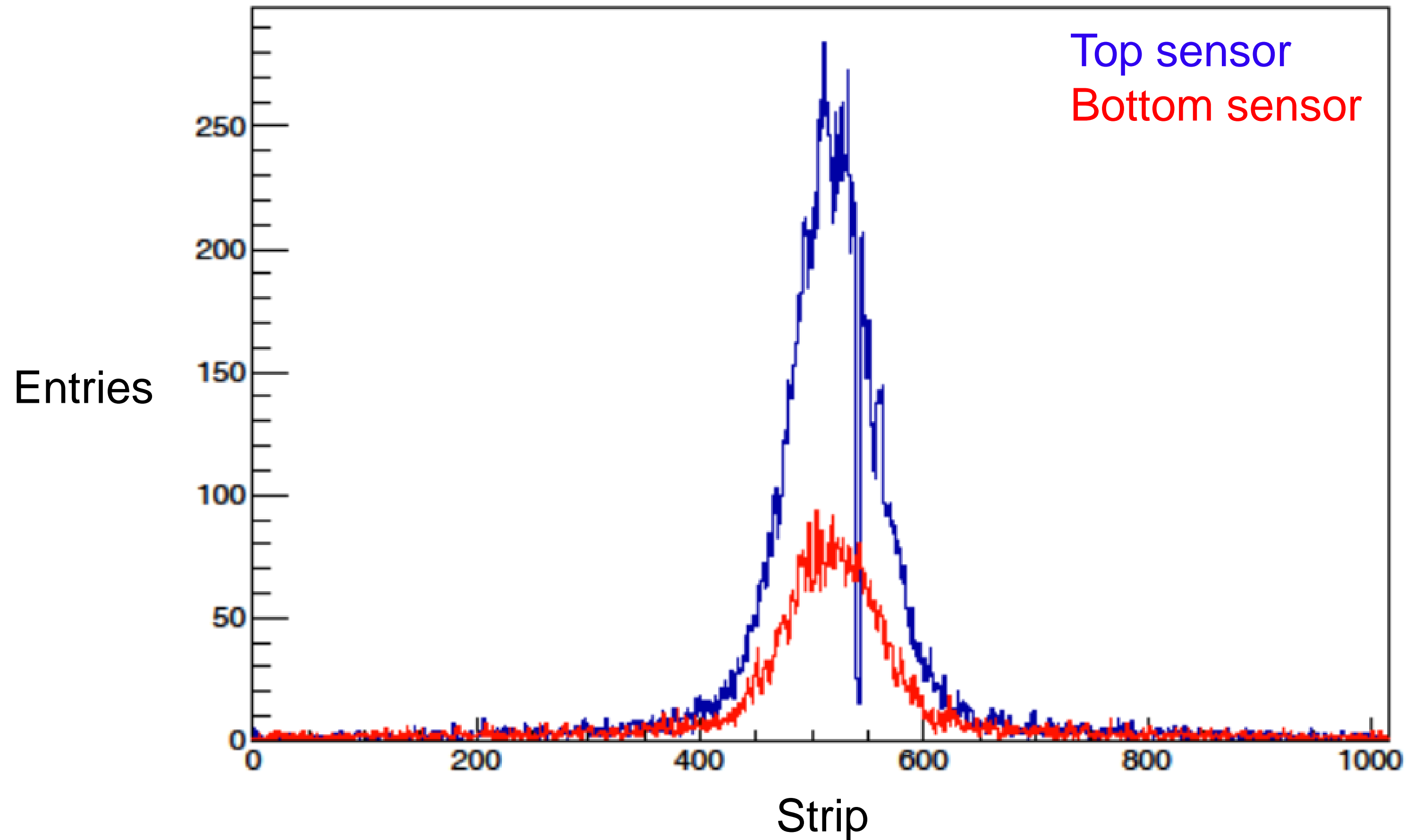
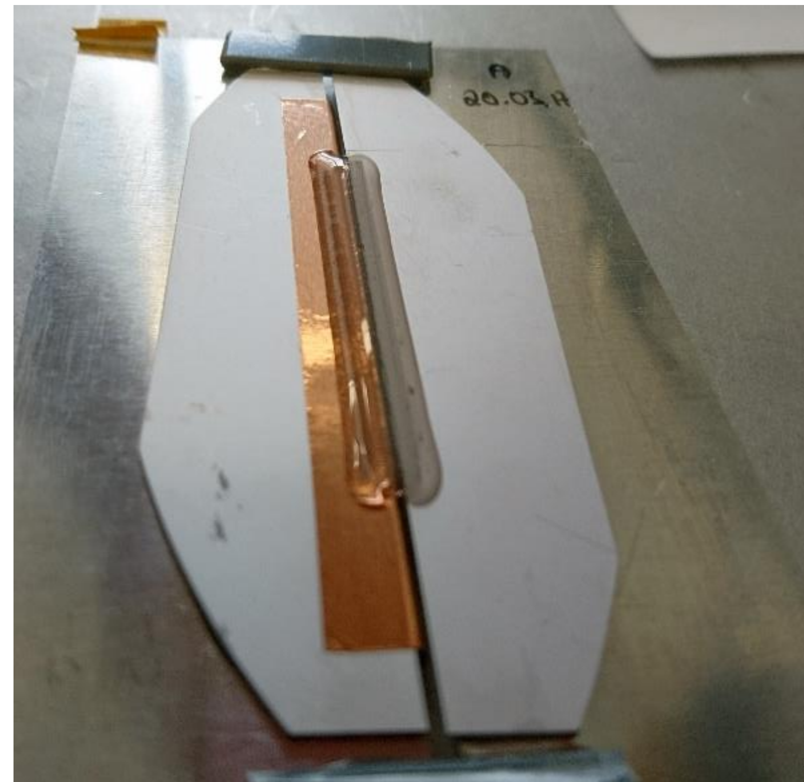


To come: Wire-bond encapsulation

- Protect bonds with silicone elastomer
  - Mechanical damage: touching
  - Chemical damage: (electrochemical) corrosion
  - Keep bond feet from lifting from the bond pad
- Earlier: Tested on dummy material
  - Application techniques
  - Irradiation studies
- Next: Further studies on dummy modules planned



Summary, Outlook

- p_T-Modules are a key element of the CMS Outer Tracker Upgrade
- The modules detect high-p_T particles with a coincidence logic connected to two precisely aligned silicon sensors
- During production various assembly and test stations are used
  - Precision jigs
  - Dispensing gantry
  - Metrology station
  - …
- **We built our first functional 2S module within specification**
  - Bottom to top strip alignment: **– 1 (± 57) µrad**
  - HV stable up to 1000 V
  - I(V) characteristics not impaired during assembly