Problems during the Production of the Silicon Strip Detector Modules for the CMS Tracker End Caps

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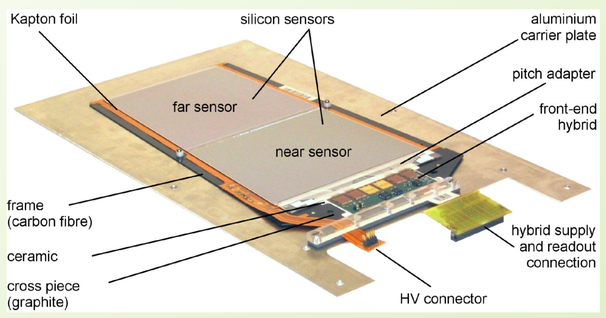
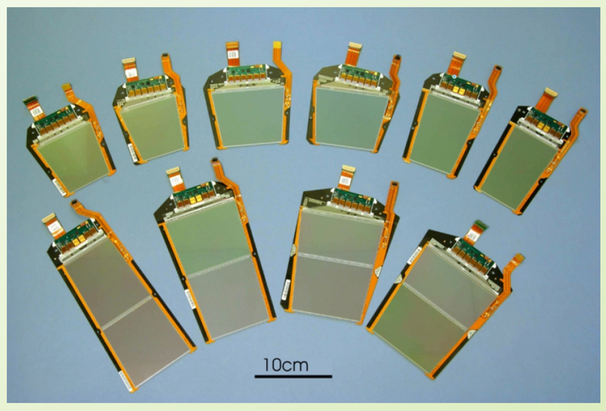
ABSTRACT

The CMS Silicon Strip Tracker was successfully completed and first operations started in March 2007 in the Tracker Integration Facility at CERN. In September 2007 the Silicon Strip Tracker will be lowered to the LHC to get integrated into the CMS experiment.
To finalise the two CMS Tracker End Caps 6400 silicon microstrip detector modules in 10 different geometries were needed. In total 7228 (+325 prototype) modules were produced. During the production some minor and major problems occurred.
This poster refers to the huge amount of time and effort which was invested to recover the repairable modules and gives an overview of the different reasons why modules got faulty. More than 800 problematic modules could be repaired and in addition 202 faulty modules got disassembled and their sensors could successfully be reintroduced into the module production.
A big fraction of the problems did not occur systematically but lie in small details like the via connection between different layers of the hybrid, problems with the conductive glue used for the backplane HV connection and handling problems resulting in touched bonds and scratches on the sensors.
In the end, all occurred problems could be solved and the quality of the CMS Silicon Strip Tracker is excellent. Only about 0,2% of the 9,6 million channels included in the CMS Silicon Strip Tracker are considered as bad channels.

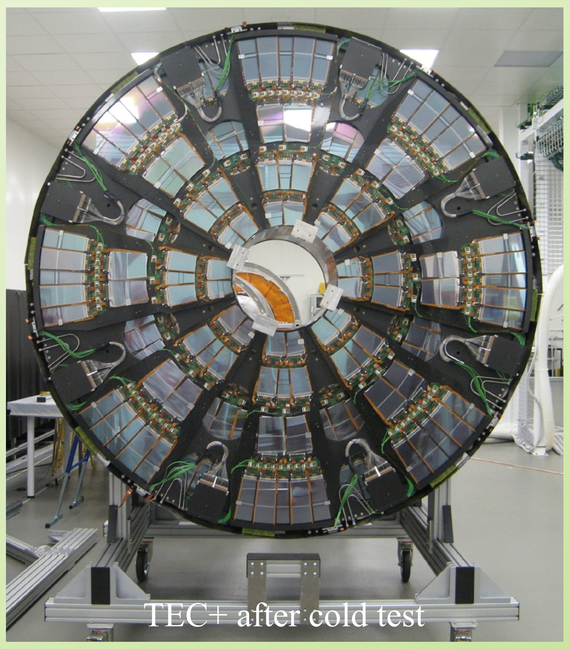
TEC MODULE PRODUCTION

Accomplished by a huge collaboration:
- 5 institutes: support frame and kapton foil
- 6 institutes: sensors quality assurance
- 6 institutes: hybrid and glass pitch adapter
- 14 institutes: module production
  - 6 gantry centers
  - 12 bonding centers
- 7 institutes: modules mounted on petals
- 2 institutes: assembly of TEC- and TEC+





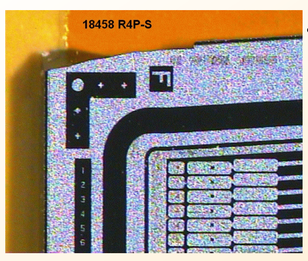
6400 modules required for TEC
- 10 mechanically different module types plus 2 types of alignment modules
- All module types had to be produced in parallel and in fixed ratios to enable a steady petal production



Summary of the final amount and quality of the produced TEC modules:
(after the module assembly on petals)

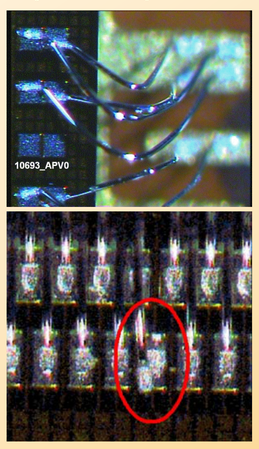
Ring	produced modules	good	faulty	yield
R1N	169	161	8	95,27
R1S	171	159	12	92,98
R2N	321	305	16	95,02
R2S	315	304	11	96,51
R3	711	667	44	93,81
R4	681	641	40	94,13
R4A	470	437	33	92,98
R5N	820	762	58	92,93
R5S	820	771	49	94,02
R6	946	903	43	95,45
R6A	167	160	7	95,81
R7	1.637	1.491	146	91,08
TEC	7.228	6.761	467	93,54

HANDLING PROBLEMS

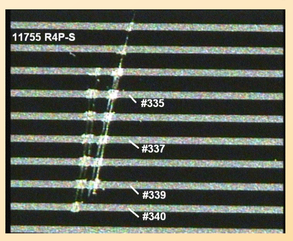


- **Mechanically Broken**
  - carbon / graphite frame
    → sensor recuperation
  - hybrid
    → sensor recuperation
  - sensor
    → frame + hybrid recuperation

- **Touched Bonds** between
  - sensor and sensor
    → repairable: remove and rebond
  - pitch adapter and sensor
    → repairable: remove and rebond
  - pitch adapter and APV or APV and hybrid
    → sensor recuperation
    (the APV bond pads are too small to proper bond a second time)



- **Scratches** on
  - pitch adapter
    → increased number of bad channels
    → sensor recuperation
  - sensor
    → increased number of bad channels or IV problem
    → frame + hybrid recuperation



IV & NOISE PROBLEMS

- **Humidity Problems**
  - Some sensors are more sensitive to humidity and had too high leakage currents due to humidity problems during the production or transport. This is caused by surface current effects. Modules where this fault was assumed were dryed and long term checked to verify their faultiness.
    → repairable: drying with dry air

- **Sensor Scratches** can lead to too high leakage currents or even complete breakthroughs
  →not repairable: hybrid + frame recuperation

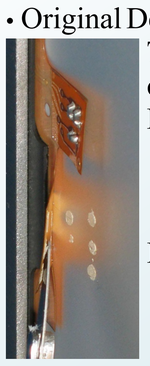
- **Broken Capacitors** on the Kapton foil lead to very early IV breakthroughs
  →repairable: replacement of the capacitor

- **Micro-Discharges**
  - A channel with micro-discharges creates a very large noise above a certain bias voltage applied to the sensor. This noise is attributed to localised peaks in the electric field which can cause avalanche effects.
  - The influence of such a noisy strip is not limited to its neighbours, even the noise of the whole APV can be effected. Because of the large number of bad channels such a module is indicated as faulty..
  - The task of identifying such a strip is quite difficult because all neighbouring strips show a similar noise, but after the appropriate bond is removed, the noise of the other channels normalise in most cases.
    →repairable: remove bond

CONDUCTIVE GLUE

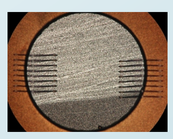
Conductive glue (EPO-TEK EE 129-4) was foreseen to connect the backplane of the sensors and the copper lines on the Kapton foil, carrying the bias voltage.

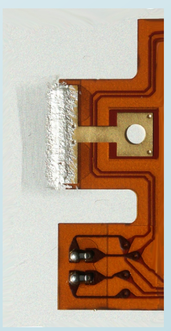
- Original Design:



The connection was realised by a few dots of conductive glue.
Problem:
The resistance of this connection increased during long time tests including thermal cycles and occasionally ended in a complete failure.
Explanation:
The isolating aluminum oxide layer on the sensor backplane was not efficiently broken during the automatic assembly procedure.

- Solution:
A so-called ”glue enhancement procedure” was introduced:
1) prior the application with glue the oxide layer was removed via brushing.
2) a much larger glue dot was applied.
→ no further failures were observed with this enhancement





- For safety reasons it was further decided to bond the backplane connection.

Only about 355 TEC modules remain glue enhanced without bonds.

ADDITIONAL PROBLEMS

- **Cracks in Positioning Holes**
During the startup of a few module assembly setups the pins used to fix the frame to the assembly table had a slightly too large diameter. Some frames broke and in some frames cracks in the positioning holes occured.
→The cracks could be repaired in most cases.

- **Too Much / Less Glue**
During the module assembly for some modules too much / too less glue was used - bonding pads got unusable and electronical shorts occured between strips / sensors or the Kapton foil got loose.
→In a few cases this faults could be repaired - rubbing off silicon glue / reglueing of the loose parts.

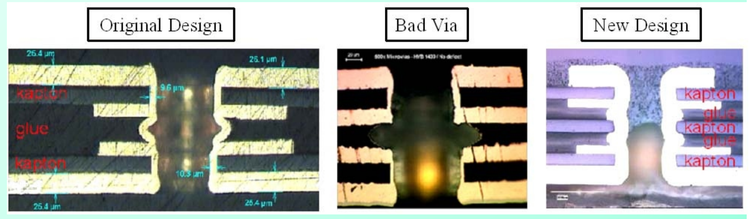
- **Touched Hybrid Test Bonds**
On every hybrid test bonds were made by default - some of them were located exactly at the position of the pic up tool of some gantries and had to be removed before assembly; later it was decided to remove all test bonds from hybrids to minimise the possibility of loose bonds inside the tracker.

- **I²C Communication Problems**
At some electrical test setups during the hybrid- and module-tests I²C communication problems occured - it was needed to retest these hybrids and modules to validate their functionality. In a few cases they had to be sent to another test center.

ELECTRONICALLY FAULTY HYBRIDS

- 72 modules were build with electronically faulty hybrids on these hybrids at least one component (APV, DCU, MUX, ...) did not work proper.
→ their sensors were recuperated

- Via Problem
167 modules were build with hybrids containing bad vias connections. Electronical failures of the hybrids occured during long term tests of the modules. The subsequent investigation showed that vias between different layers of the hybrids systematically broke. These failures forced a complete stop of the hybrid production and a redesign of the hybrids:



1) the hole diameter of the vias was increased from originally 100 m to 120 m
2) to reduce the thickness of the glue between the layers an additional central Kapton layer was introduced

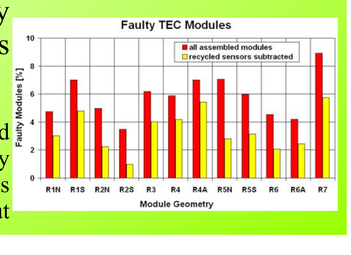
This change in the hybrid design lead to a huge delay in the module production and made the hybrid production rate its limiting factor.

SENSOR RECYCLING

- Sensors of 222 modules (and of 190 prototype modules) got disassembled and reintroduced into the module production

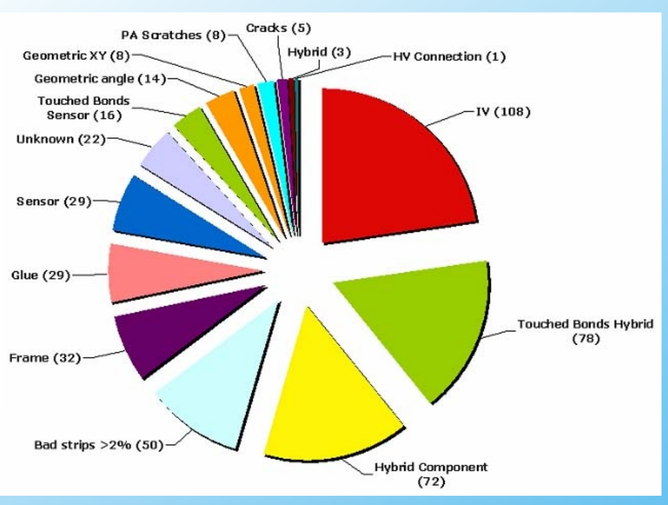
- Disassembly Procedure:
  - first, all sensor bonds were removed
  - the glue was softened with alcohol
  - the sensors were detached from the frame with a thin nylon string
  - the remaining glue on the sensor backplane was slowly rubbed off
  (This procedure took about half an hour per module.)

- Thanks to this huge effort only 3.4% of the assembled sensors are lost in faulty modules.



Plot on the right: percentage of assembled faulty modules per geometry
red: all assembled modules
yellow: disassembled modules taken out

FAULTS DISTRIBUTION



Final distribution of the faulty TEC modules divided by the different faults (number of modules). After all repairs 467 modules are left faulty, leaving 6761 (93,54%) good modules.

**Please keep in mind that this poster only displays problems. Thanks to our great collaboration the TEC module production was a huge success. The quality of TEC modules mounted in TEC is excellent:
the Tracker End-Cap modules contain about 4,1 million channels of which 99.8% are flagged ok!**