Karlsruhe Institute of Technology

Institut für Experimentelle Kernphysik

VERTEX 2016 — The 25th International Workshop on Vertex Detectors — La Biodola (Isola d'Elba, Italy)

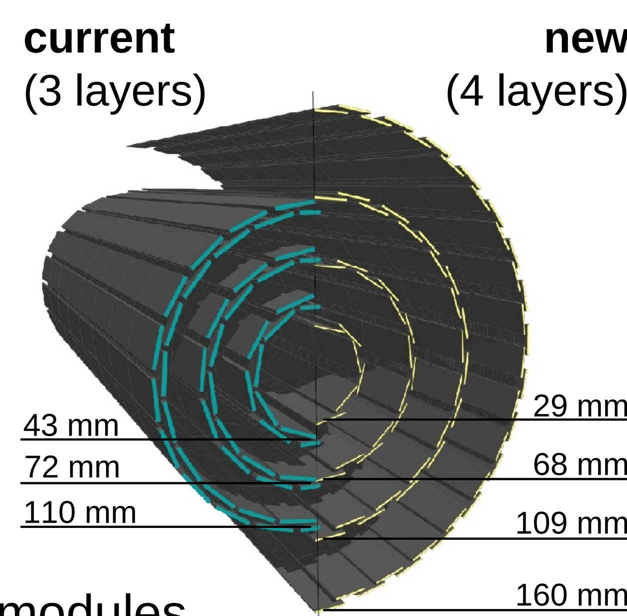
CMS

Qualification of Barrel Pixel Detector Modules for the Phase I Upgrade of the CMS Vertex Detector

Simon Kudella on behalf of the CMS Collaboration

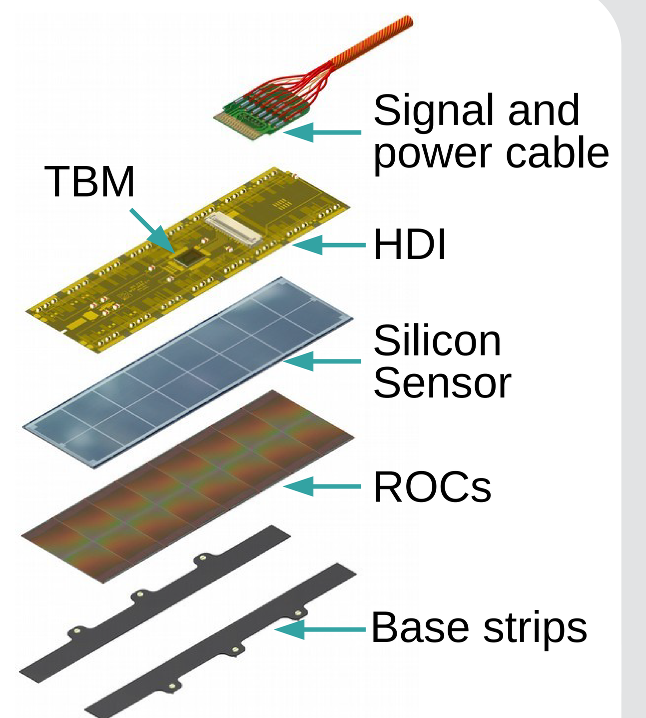
CMS Pixel Phase I Upgrade

- Increase of LHC luminosity by factor of two for runs 2 & 3 (up to $2 \times 10^{34}\,\mathrm{cm}^{-2}\mathrm{s}^{-1}$)
- Phase I Upgrade to deal with new challenges:
  - Additional fourth pixel layer in barrel region and third disk in endcap regions
  - Innermost layer closer to interaction point
  - Lower material budget in sensitive area
  - Data loss reduction by new digital readout chip
- Five barrel pixel production centers for >1400 modules



Barrel Pixel Detector Module

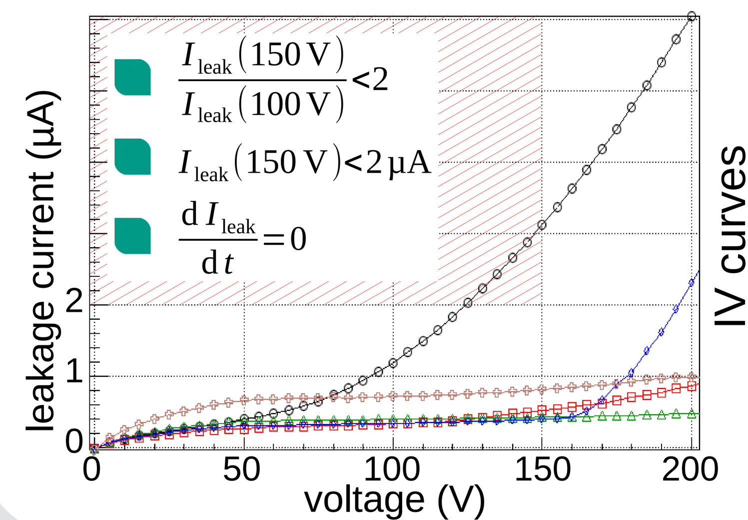
- Smallest subunit of the pixel detector:
  - Silicon sensor with 66560 pixel cells (pixel size: 100 x 150 µm²)
  - 16 Readout Chips (ROC) housing frontend electronics
  - Token Bit Manager (TBM) chip to control all 16 ROCs and send out data
  - High Density Interconnect (HDI): flexible PCB to connect TBM and ROCs
  - Base strips for fixation to mechanics



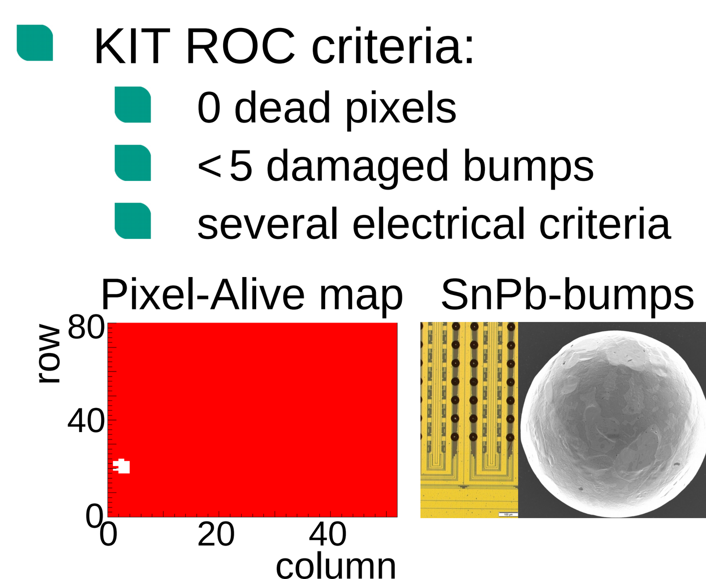
KIT/Aachen production line as example

Silicon Sensor & Readout Chip

- Components produced and preprocessed by external companies (thinning, dicing, bump deposition, under bump metallization)
- Several electrical tests, cleanings and optical screenings
- Sensor criteria:



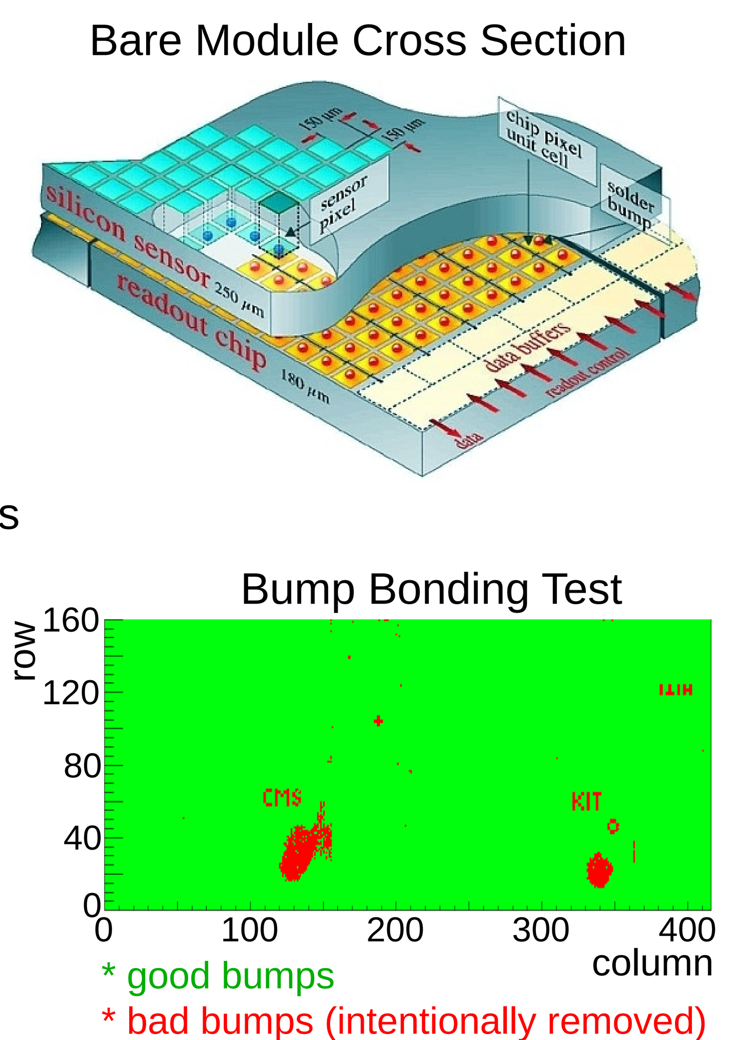
- KIT ROC criteria:
  - 0 dead pixels
  - < 5 damaged bumps
  - several electrical criteria



Bare Module

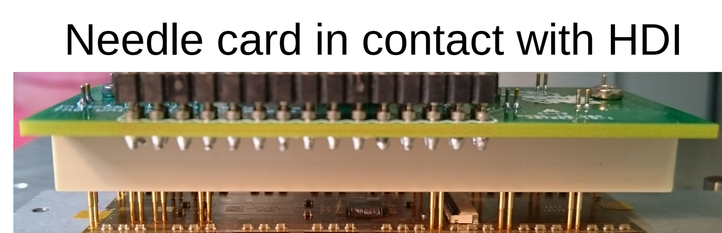
92 %

- Flip-chip bump bonding of 16 ROCs to silicon sensor
- Fully automated serial bonding process using thermocompression
- Bare Module Test in dedicated probe station:
  - Electrical tests of sensor and ROCs
  - Test of bump bond connections by capacitive injection of signals into sensor
    → Readout of injected signal not possible if bump bond connection broken
- Reworking possible if necessary
- Final vacuum reflow to improve connection and alignment



HDI & TBM

- Optical inspection of HDI
- TBM glued and wire bonded to HDI
- HDI & TBM tested together with needle card
  - Signals (height and pattern) checked with oscilloscope

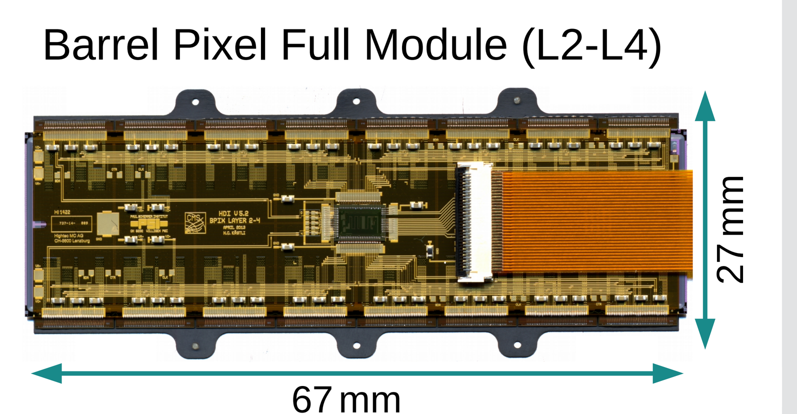

Needle card in contact with HDI

Full Module Assembly & Wire Bonding

36 %

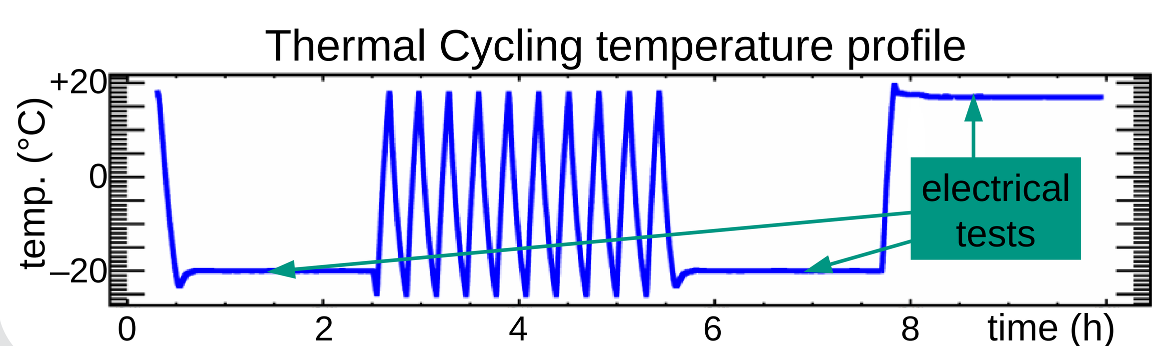
58 %

- Base strips, Bare Module and HDI glued together
- Wire bonding of Bare Module to HDI
- Internal electrical and X-ray tests for fast quality feedback

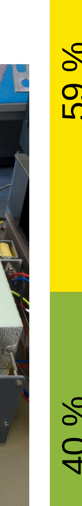


Thermal Cycling & Electrical Test

- 10 thermal cycles (–25 °C to +17 °C) in coldbox
- Electrical tests before and after thermal cycling
- Trimming of ROC Pixel Unit Cells (PUCs) to equate thresholds (@ –20 °C)



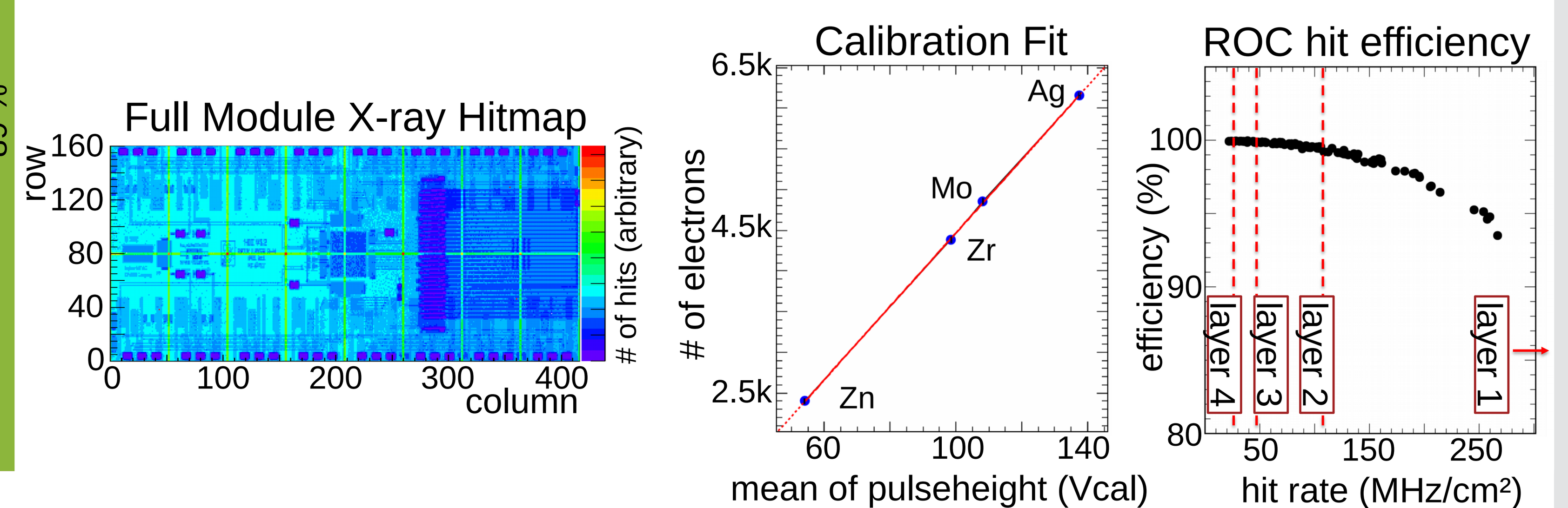
Aachen coldbox



X-ray Calibration & High-Rate Test

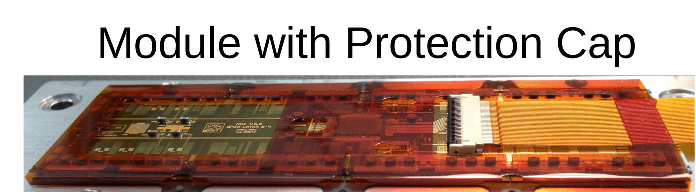
89 %

- Find defective pixels by their response to X-ray illumination
- Fluorescence spectra of several targets to calibrate ROCs
- Measure ROC hit efficiency at high illumination rates



Protection Cap & Reception Test

- Gluing of module protection cap to protect wire bonds during installation
- Final electrical test to reject modules damaged during handling and transportation


Module with Protection Cap

Final detector grading based on many different module parameters

Grade A – very good modules for detector installation (34.2 %)	Grade B – good modules with minor defects, good for detector installation (49.6 %)	Grade C – bad modules (16.1 %)

So far >1200 good (A+B) barrel pixel modules built for detector integration

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