Production, calibration and performance of the layer 1 replacement modules for the CMS pixel detector

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Current Phase-1 upgraded pixel detector installed during EYETS 2016/2017

Due to radiation damage, the innermost layer (L1) of the pixel barrel detector (BPix) would have to be replaced during Run 3

L1 replacement built now during LS2
  - Also features an improved readout chips

Joint project of PSI, ETH Zurich, Helsinki Institute of Physics, and RBI
  - RBI team’s main task to perform a complete qualification and calibration of 140 pixel modules

More details about other upgrades covered in Klaas Padeken’s talk
L1 module overview

• High-density interconnect (HDI10d)
  – Glued on top of the sensor and wire-bonded to readout chips (ROCs)
  – Routes control and data signals between ROCs and token bit manager chips (TBMs)
  – Routes high-voltage to the sensor

• Sensor
  – “Sandwiched” between HDI and ROCs
  – Connected with ROCs through bump-bonds (bottom image)

• Read-out chips (PROC600 v4)
  – 16 chips at the bottom of the module
  – “Reads” signals from sensor, processes them and sends to TBM
Test setup and procedure

**Goal:** production of 96 installable modules + 20% spares

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**Cold box setup at PSI**
- Up to 4 modules tested in parallel
- IV curve taken after each FQ&C
- FQ&C+IV@-20 °C, 5 T-cycles (from -20 to +10 °C), FQ&C+IV@-20 °C, FQ&C+IV@+10 °C
- Takes ~8 hours in total

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**X-ray setup at ETHZ**
- Pixel hit efficiency at high rates
- Calibration of Vcal DAC into electrons

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All test results published online at [http://cms.web.psi.ch/L1Replacement/](http://cms.web.psi.ch/L1Replacement/)

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- Chips bump bonded to sensor at Advacam
- TBMs glued to HDI
- Bare modules tested
- HDI tested
- HDI glued to bare module and wire-bonded to chips
- Reception test
- Cap gluing
- Full qualification and calibration
- X-ray test and calibration

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Module performance

**Threshold trimming**
- Trimming to about 2000 e⁻
- Thresholds uniform within about 40 e⁻

**Noise per pixel**
- Mean of about 200 e⁻ and small tail
- Under X-rays, higher noise with longer tail, rate of noisy pixels still low (~1-2%)
Production and testing campaign successfully completed

Final production yield of 78% (110 installable modules)

Modules ranked based on their quality and accordingly assigned to appropriate locations on L1

Module mounting on the L1 support structure successfully completed

Yield = (A + B) / Total = 110 / 141 = 78%

More details in the full poster