



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

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Introduction and motivation

- 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







Module performance









Threshold trimming

- Trimming to about 2000 e⁻
- Thresholds uniform within about 40 e⁻

Noise per pixel

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- Mean of about 200 e⁻ and small tail
- Under X-rays, higher noise with longer tail, rate of noisy pixels still low (~1-2%)

High rate efficiency



- 300 MHz/cm² X-ray rate corresponds the expected hit rate on L1 at the LHC
- Modules not installable if hit efficiency <95%
- Great majority of ROCs have hit efficiency above 98% (target for PROC600)

Summary

Cumulative production graph Grade A+B Grade C incomplete # modules 60 40 20 03-01 01-31 03-31 04-30 05-30 06-29 07-29 08-28 2020 2020 2020 2020 2020 2020 2020 2020

Mounted L1 modules



Grading overview

	Grade			
	Α	В	С	Total
Full qualification	13	110	3	126
High rate test	87	24	12	123
Failed at reception (incomplete)	1	1	1	5
Faulty after assembly	1	/	/	10
Final	8	102	14	141

A: <1% defective pixels per ROCB: 1%<4% defective pixels per ROC

Module grade based on the worst performing ROC. **A** and **B** both installable

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

- 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

More details in the full poster