

Commissioning of the Phase-1 Upgrade of the CMS Pixel Detector

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CMS Phase-I Pixel Detector

Scope of this talk

- this talk: review of **component testing** and **system commissioning** of the CMS phase-1 pixel detector
- for details on detector construction
 - → see talk by S. Hasegawa



FPix (3 disks on each side)

BPix (4 layers)

Outline



Module Testing





FPIX bad bumps [O(1/1000)] (sum of all modules)

standardized test and qualification procedure following the module production chain:

- → bare modules: bump-bonds, IV curves
- full modules: ROC/TBM/pixel functionality, thermal cycling, IV curves
- X-ray tests: high rate, pulse-hight calibration







Benedikt Vormwald (UHH)

Commissioning of the Phase-1 CMS Pixel Detector

Testing of On-Detector Electronics

DCDC converters

- 1.9 times more channels
- same power cables
- DC-DC conversion near the detector 11V to 2.4V/3.0V
- 1184 converters needed
- intense testing:
 - thermal cycling (10 times from +20°C to -28°C)
 - monitoring of status&enable bits
 - output stability
- classification according to the output voltage







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Testing of On-Detector Electronics



Commissioning of CO₂ Cooling System

2-phase CO₂ cooling

- → very lightweight
- → very efficient
- stainless steel cooling loops: diameter 1.6mm, wall thickness 50µm





Installation & checkout

- cooling plant already installed and commissioned during LHC long-shutdown 1
- → routing of signal fibers, power cables, cooling pipes subject of very detailed planning
- no surprises when detector was finally connected
- → high pressure test at 100bar for leak detection \rightarrow no leak found with CO₂



Commissioning of CO₂ Cooling System

After first successful commissioning: adjustments of CO₂ flows between FPix and BPix:



- reduced flow: even better cooling performance due to improved vapor quality
- pixel detector modules now operated at about -10°C

Stability of cooling represented by CO₂ temperature and pressure in accumulator:

date	CO ₂ temper	rature [°C]	CO ₂ pressure [bar]			
2017/04/03	-19.98	-19.92	19.74	19.63		
2017/04/10	-20.10	-19.92	19.93	19.74		
2017/04/17	-20.10	-19.92	19.85	19.63		
2017/04/24	-19.98	-20.16	19.85	19.71		

Installation of Backend DAQ



- replacement of VME front-end boards
 - 108 FrontEndDrivers (FED) → detector readout
 - 16+3 FrontEndController (FEC) → detector control
- new CMS-wide crate standard: µTCA
 - all based on generic AMC card (FC7) built around Xilinx Kintex 7 FPGA and 4GB DDR3 RAM
 - different flavors realized with FPGA mezzanine cards/ firmware
- capable to drive/receive links of **up to 10Gb/s**



Commissioning of Backend DAQ





- FED tester: full emulator of pixel module optical output
- GLIB based µTCA board connected to CMS trigger system
- essential tool to test and validate the FED firmware using specific data pattern
- used to exercise and validate the throughput of FED to CMS central DAQ

Test of FED Data Throughput

- send 100kHz random triggers (L1A rate at CMS)
- load FED with emulated hits
- read out through 10G link of FEROL (FED Readout Link → CMS central DAQ)
- trigger rate gets throttled according to the FED status





Sufficient headroom for 2017 Work continues on parallel architecture

High Rate Test of Full Pixel System

workbench setup







- FED itself can emulate hits
- full pixel system (108 FEDs) in global run with 3 emulated hits per ROC (~PU=105)
- no problems

full pixel system





Detector Commissioning – Calibration



10 20 30

40 50 60

70 80 90 100 threshold [Vcal]

0 10 20 30 40 50 60 70 80 90 100

1Vcal=50e

threshold [Vcal

3

slope [ADC/VcalHR]

Commissioning of the Phase-1 CMS Pixel Detector

1VcalHR=350e

slope [ADC/VcalHR]

Detector Status – BPix Occupancy Map



Detector Status – FPix Occupancy Map



BPix&FPix 95.1% active channels

most problems affect groups of modules:

- power groups
- readout groups

Cosmic Runs – Alignment

Cosmic runs provided valuable input for spatial and timing alignment:

- **low occupancy** helps to prevent ambiguities
- determine correct bunch crossing to read out wrt L1 trigger from hit-on-track efficiency
- determine **position** of BPix and FPix from track fit





very good starting conditions for final alignment with collisions

- many tests during the production and system integration ensured a smooth commissioning within CMS
- CMS went through a challenging, but successful commissioning of the new pixel detector
- 95% of the channels are active and in a good condition



ready for collisions!

Detector Installation



28/02/2017 02/03/2017 04/03/2017





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