



X-ray testing of CMS BPIX Phase I modules

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26.08.2015



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TABLE OF CONTENTS

- Introduction
- 2 Module Testing
- 3 Bump-Bond testing
 - Vcal calibration
- 5 High-rate Efficiency
- 6 Read-out stability tests
 - Summary

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THE CMS BARREL PIXEL DETECTOR



MODULE TESTING

- each component is tested before assembly at manufacturer or PSI
- assembled module is tested at ETH

ELECTRICAL TESTS

SENSOR TEST

X-RAY TEST

- test of electrical properties of read-out chip
- \Rightarrow see Vittorios talk
- properties of sensor
- connection between sensor and read-out
- high-rate efficiency
- calibration
- readout stability

BUMP-BONDS

BUMP BONDS

- **bump-bonds** connect pixel cell on sensor and **pixel unit cell** on read-out chip
- can be missing or damaged
- use x-rays to test modules (easier to handle than particles like protons, electrons etc.)



X-ray - Hitmap



- x-ray hit-map shows large differences in number of hits per pixel
- HDI (high density interconnect), cable and other electrical components on top of the module absorb X-rays

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August 26, 2015 6 / 13

BUMP-BOND TESTING - HITMAP



- x-ray hit rate $\approx 100 \text{ MHz/cm}^2$ for few minutes
- pixels with no hits have missing/broken bump bonds (if they are electrically good)
- few missing bumps like shown here are still tolerable

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BUMP-BOND AND TEST-PULSES

- read-out can also be tested with **test pulses** instead of real particles
- voltage of test-pulses can be controlled with VCal DAC setting
- want to calibrate:
 VCal ⇔ electrons



how? via pulse height information

• calibration of **VCal** is important for electrical tests to convert results or set parameters (eg. threshold) to physical units!

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VCAL CALIBRATION

X-ray Calibration - Target Zn Method Spectrum Chip C7

1600F

1400

§1200

툴000

600 E

600

400

200

X-ray Calibration - Target Mo Method Spectrum Chip C7

X-ray Calibration - Target Ag Method Spectrum Chip C7

X-ray Calibration - Target Sn Method Spectrum Chip C7





- need to know number of electrons \Rightarrow flourescence spectra
- 4 different metal targets with different fluorescence lines
- fit number of electrons vs pulse height

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VCAL CALIBRATION



result \approx 47 e⁻/VCal

- we now can use test-pulses to simulate particle hits!
- eg. particle that creates 10,000 $e^- \Rightarrow$ VCal 213

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HR EFFICIENCY ANALYSIS



fiducial efficiency M2020 ROC 0



- illuminate modules with X-rays
- send **test-pulses**, check how many are read out
- $N_{\text{readout}} / N_{\text{sent}} \Rightarrow \text{efficiency}!$

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• target rate layer 2: 120 MHz/cm² $\Rightarrow \approx 99.3\%$

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Read-out stability tests

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- several more tests to detect problems with readout
- eg. ≈ 30 minutes readout stability test (number of hits per time unit) at hit rates comparable to Layer 2 expected rate

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SUMMARY

Reasons why X-ray tests are done:

- connection of sensor to read-out chip can be verified (bump bonds)
- efficiency can be measured
- test-pulses can be calibrated (Vcal calibration)
- various read-out problems can be detected