SEARCH FOR SOMETHING

by

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SEARCH FOR SOMETHING

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Advisers: Dan Claes and Aaron Dominguez

my abstract

"... Josefa.

"...laca."

yo y tu.

"...come lady come."

pa darte.

to Nenas and nenita

ACKNOWLEDGMENTS

Many people has contributed to make this work possible that it is impossible to name them all.

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Chapter *1*

Introduction

Talk about particle physics in general and the organization of the documents

Chapter 2

The LHC Accelerator and the CMS Experiment

In the 1960s Peter Higgs and others *need ref* put up the finishing touches on a theory combining three of the four fundamental forces. This theory became to be known as the Standard Model (SM) of particles physics. It predicted the existence of several particles which were discovered in the following decades. However, one particle was proving to be elusive, the so-called Higgs bosson. With this in mind the European Organization for Nuclear Research (CERN) started plans to build an accelerator large enough to be able to find this elusive particle. Hence, the Large Hadron Collider (LHC) was born.

2.1 The LHC Accelerator

A circular ring of 27 Km in circumference, the LHC was built at the French-Swiss border outside Geneva, Switzerland, see figure 2.1.

Four experiments were designed and build to test different physics theories and search for undiscovered particles at the LHC. Two of them, A Toroidal Large Aparatus (ATLAS) [1] and the Compact Muon Solenoid (CMS) [2] are large multipurpose experiments. The third experiment is LHCb [3], which is specifically dedicated to study B-meson physics, the last experiment ALICE [4], A Large Ion Collider Experiment,

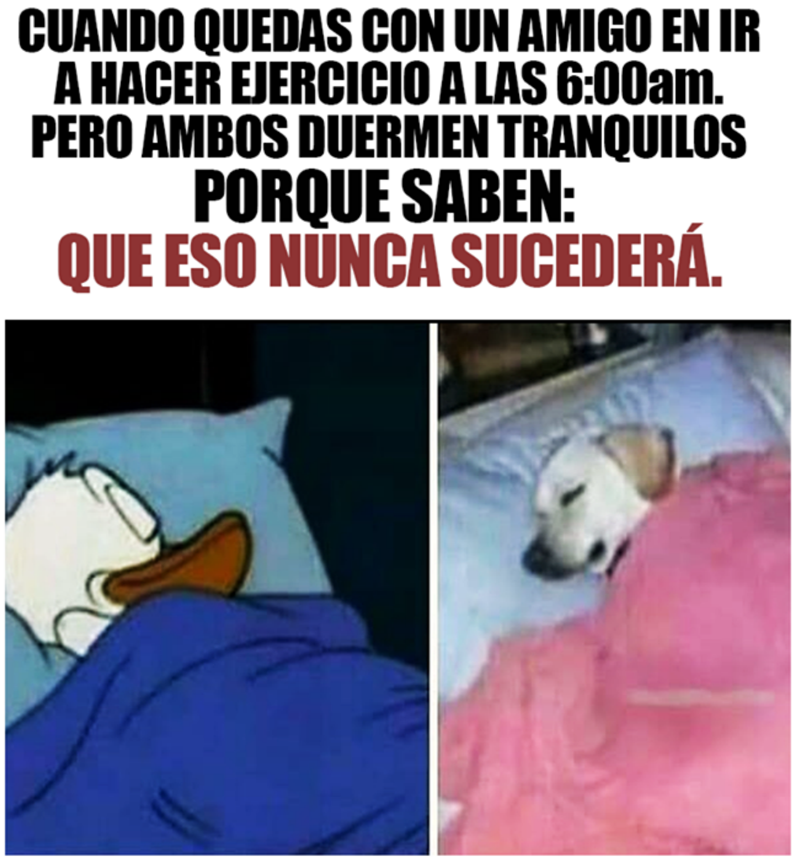

Figure 2.1: The CERN acceleration *facilities* showing the location of the four main experiment as well as the acceleration process[need ref].

was design to investigate heavy ion collisions.

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Figure 2.2: LHC luminosity.

2.2 CMS

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Figure 2.3: LHC dipoles.

Figure 2.4: CMS cross sectional view.

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2.2.1 The Tracker Detector

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Figure 2.5: CMS Tracking system.

Figure 2.6: CMS cross sectional view.

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Figure 2.7: CMS cross sectional view.

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2.2.1.1 Pixel Detector

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Figure 2.8: phase o pixel detector.

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2.2.1.2 Silicon Strips

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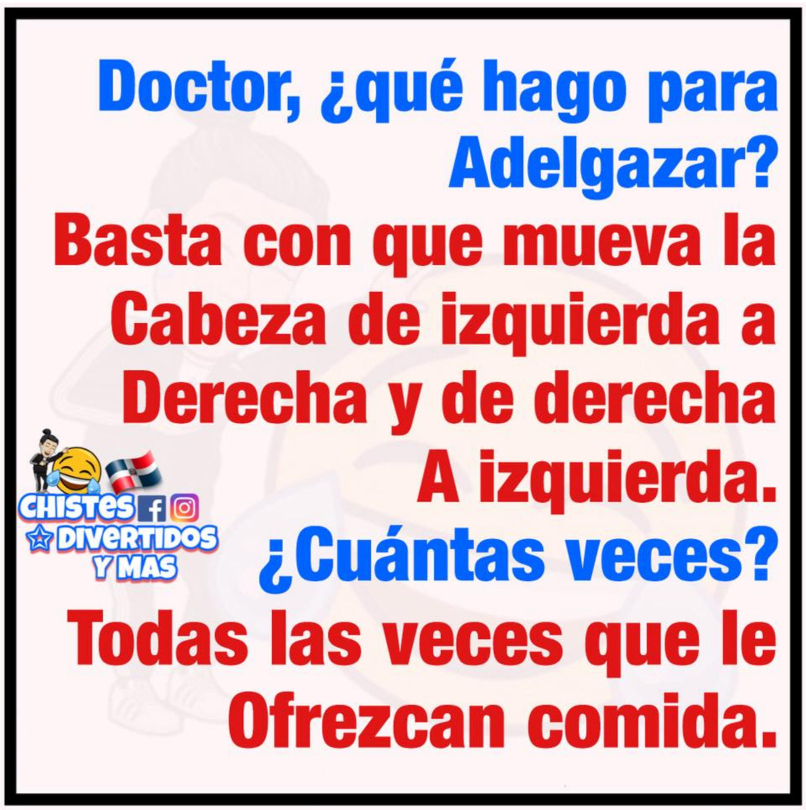

Figure 2.9: silicon strips detecto.

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2.2.2 The Electromagnetic Calorimeter

Figure 2.10: The Electromagnetic Calorimeter.

2.2.3 The Hadronic Calorimeter

Four experiments were designed and build to test different physics theories and search for undiscovered particles at the LHC. Two of them, A Toroidal Large Aparatus (ATLAS) [1] and the Compact Muon Solenoid (CMS) [2] are large multipurpose experiments. The third experiment is LHCb [3], which is specifically dedicated to study

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Figure 2.11: The Hadronic Calorimeter.

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2.2.4 The Muon Chambers

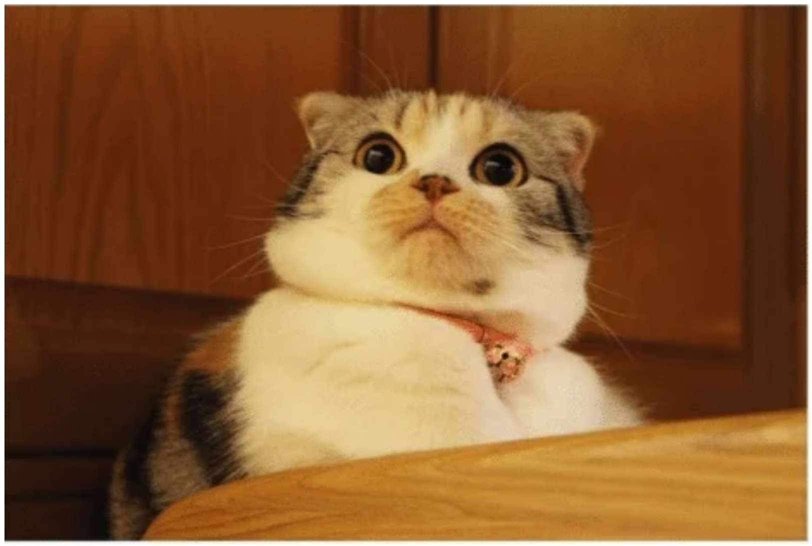

Figure 2.12: The Muon Chambers.

Four experiments were designed and build to test different physics theories and search for undiscovered particles at the LHC. Two of them, A Toroidal Large Aparatus (ATLAS) [1] and the Compact Muon Solenoid (CMS) [2] are large multipurpose experiments. The third experiment is LHCb [3], which is specifically dedicated to study B-meson physics, the last experiment ALICE [4], A Large Ion Collider Experiment, was design to investigate heavy ion collisions

Chapter *3*

The SM and BSM Theories

Proposed in the 1960s the standard model of particles physics has been successful in describing many phenomena of the particle world

Chapter 4

Event generation, simulation and reconstruction

Description of event generation and simulation

Chapter 5

Search for the particle

Data analysis details

Chapter *6*

More on the Analysis?

More?

Chapter 7

Module Production for the Phase I CMS Pixel Detector Upgrade

As discussed in chapter 2 the CMS pixel detector will *suffer* from radiation damage throughout its lifetime hence the need for periodical updates. The first version of the detector was known as phase 0, it became fully operational 2010 after solving a setback during the original starting period in 2008. In 2017 the pixel detector was replaced during the so-called phase 1 upgrade, the University of Nebraska, high energy group (UNL-HEP) played a major role in assembling and testing over 500 modules, from 2013 to 2016, which then became part of the forward region of the pixel detector (FPix). The next update of this detector (phase 2) is projected to take place in 2025 when the current detector will be reaching its limits. In this chapter we describe why the phase 0 pixel detector needed an upgrade making

the work done by the UNL-HEP group. Some of these steps will be highlighted and described in detail as they were my contributions to this production campaign. Specially the and highlighting

7.1 The CMS Pixel Detector Phase I Upgrade

The CMS pixel detector is composed of two sections, the barrel section (BPix) and the forward section (FPix). Each of these sections (for phase 0) was composed of three layers originally designed to record three 3D positions (tracks) of the particles emerging from the *pp* collisions. As well as to provide information to reconstruct primary and secondary vertices of decaying particles. This detector performed well during the LHC run I,incorporate the bunch crossing? taking data at the design luminosity of $1x10^{34}cm^{-2}s^{-1}$, which was then used in many analysis including the discovery of the Higgs bosson published in 2013. But after a few years of operation the pixel detector started to degrade due to radiation damage, causing an increase of fake rates as well as loose on resolution. Moreover, for run II the LHC planned to double the luminosity with successive increment until reach its peak of $2x10^{35}cm^{-2}s^{-1}$. A simulation of the performance of the pixel detector under different luminosity conditions can be seen in figure 7.1

This degradation prompted the need for an improved pixel detector. It was designed to have four layers in the barrel ubicated at distances of Hena2420 and 3 layers at each endcap as shown in 7.2. better

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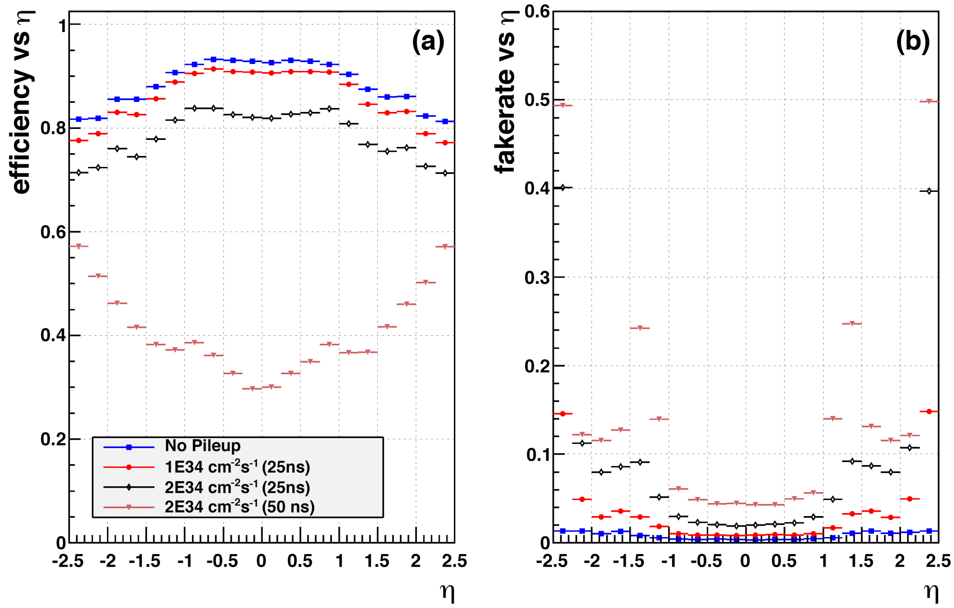

Figure 7.1: Expected performance of the original pixel detector under different luminosity conditions: a) track-finding efficiency; b) fake rate. Conventions are the same for both plots, considering zero pileup (blue squares), average pileup of 25 (red dots), average pileup of 50 (black diamonds), and average pileup of 100 (magenta triangles). [5]

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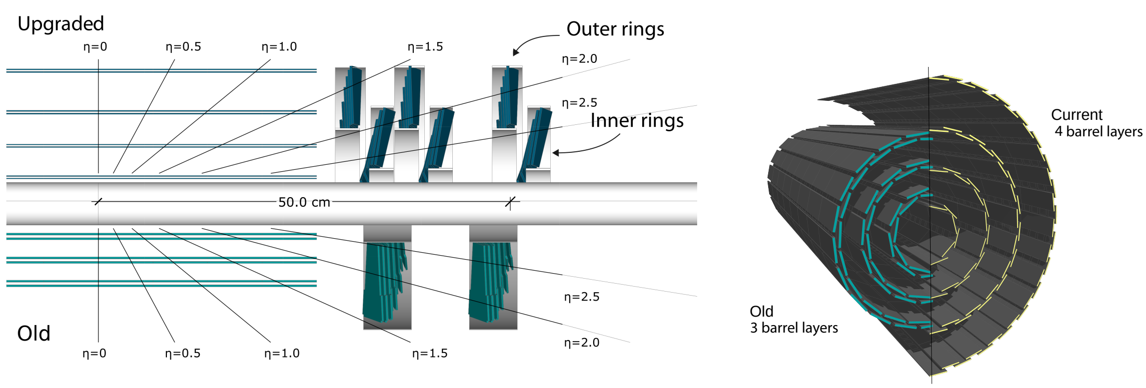


Figure 7.2: Layout and comparison of the layers and disks in the upgraded (Phase I) and old (Phase 0) pixel detectors [5].

7.2 Module Production at UNL

The UNL module production workflow was designed to follow a pipeline-like structure as shown in figure 7.3.

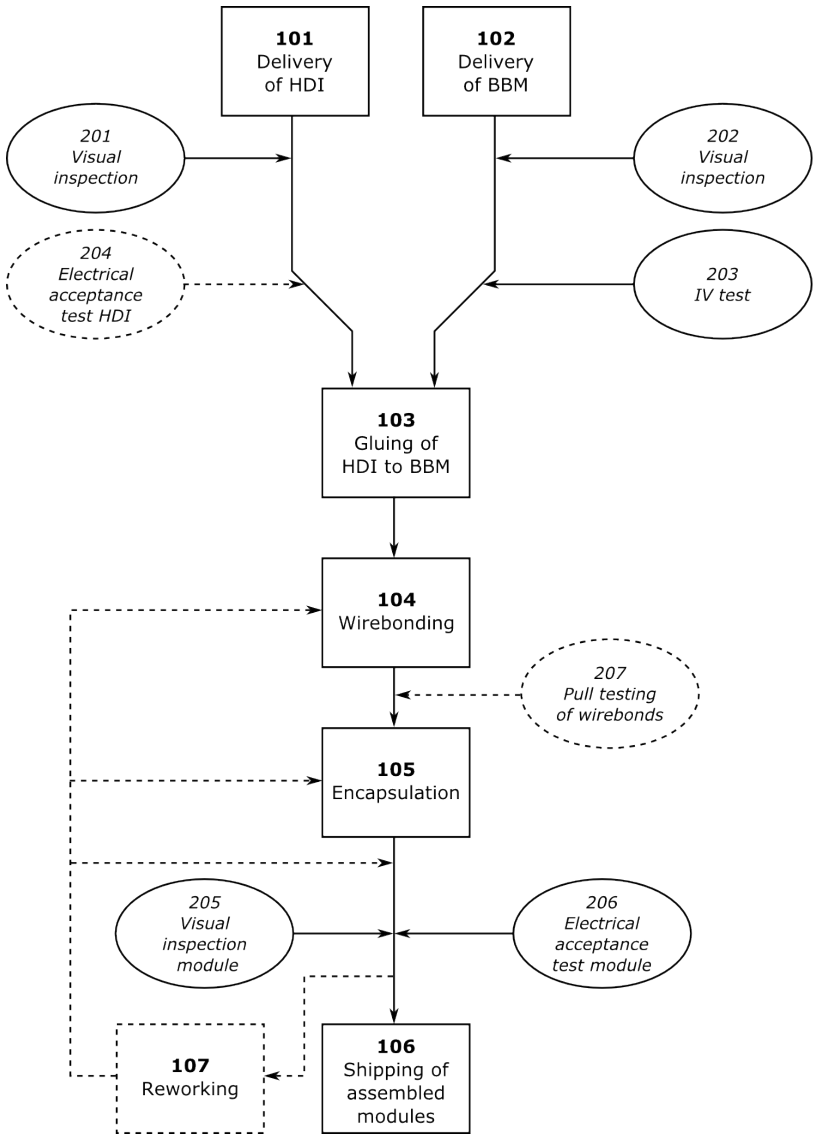
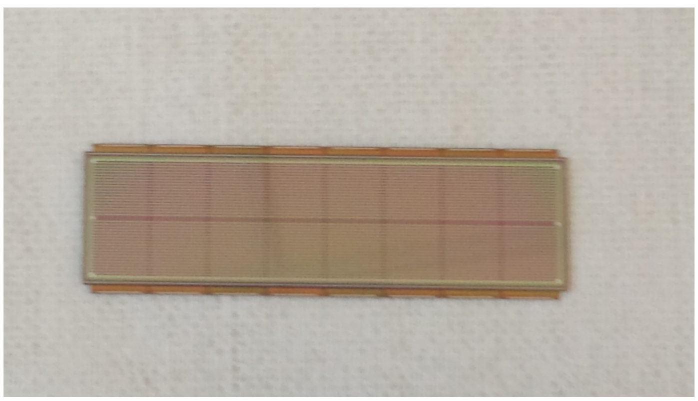


Figure 7.3: UNL module assembly workflow. Dashed lines represent occasional quality testing and reworking procedures [6].

This allows for different batches of modules to be going through it at different stages without stopping the workflow. Following is a short description of the tests and procedures performed during the production in the UNL silicon Lab. Special emphasis will be made in IV test, visual inspection and electrical test, the stages where the author of this work made most of the workimprove.

7.2.1 Visual Inspections

The UNL-HEP group assembly workflow started upon receiving two components: a Bare Bonded Module (BBM) and a High Density Interconnect (HDI), see figure 7.4.



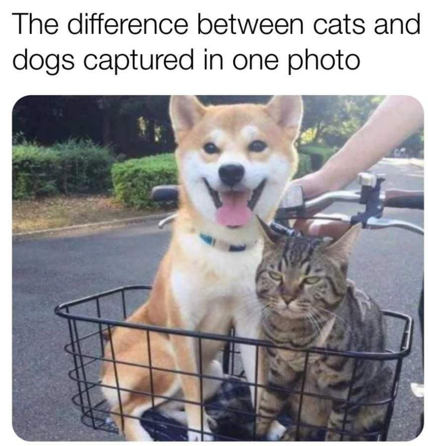


Figure 7.4: Photograph of a BBM (left) and HDI (right) as received by the UNL-HEP group.

The first stage of the module production was to do a visual inspection on these components to ensure they were in good conditions and able to continue into the production pipeline. punto aparte? To get a good view of such a small components a powerful microscope with magnification of confirm, an attached camera, and LED ring illumination was used. A photograph of the set up is shown in figure 7.5. BBM were received in a gel pack while the the HDI were usually received in their modules carriers. BBM and HDI were moved from the container into the probe station using a vacuum pen and taking the appropriate safety precaution: ESD wristband, gloves, face mask, etc.

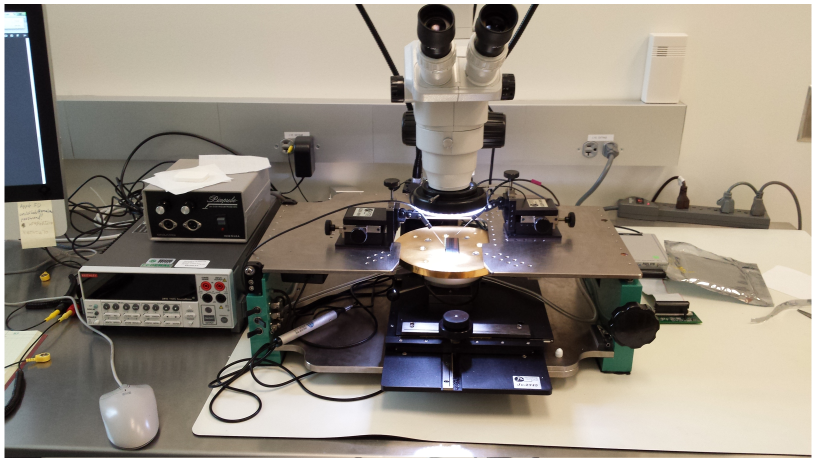


Figure 7.5: fix Photograph showing a BBM under the microscope during a visual inspection. This station also served as IV test stand.

During visual inspection BBMs were scanned for unusual features or sign of damage, special attention was given to the high voltage connection and bond pads. Figure 7.6 shows different parts of four different modules where defects are observed defects are on only 3. Some of these defects, bottom right figure, caused, the module to be rejected immediately while others, top right and bottom left plots, will still undergo an IV test. While for the HDI the bond pads of the 16 ROCs, the wirebonds of the tbm, and the address pads were carefully checked. Figure 7.7 shows the TBM wirebonds as well as the bondpads of a ROC in a HDI.

Figures 7.6 and Fig. 7.7 show a trend that was observed throughout the entire production. In general more unusual features and damage were observed in BBMs than on HDI. This was because BBM were derivered directly from the production company to our lab while the HDI were delivered to the Fermi National Laboratory (FermiLab) first where they were preliminary tested before the arrived at our testing facilities.

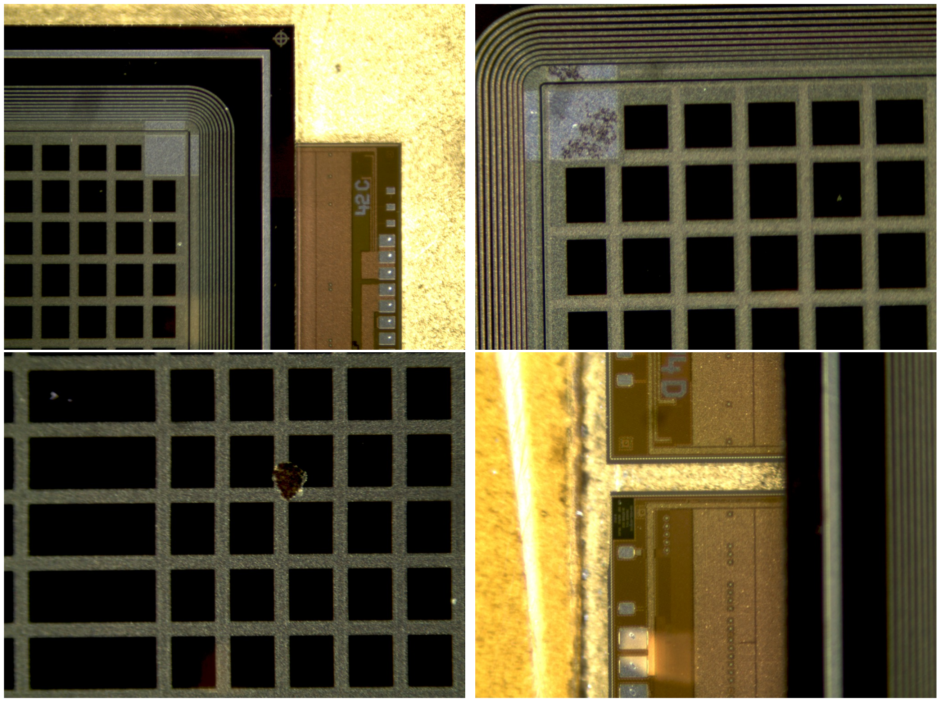


Figure 7.6: Photograph of the visual inspection of a BBM showing few of the things observed during a visual inspection: A good module (top left), scratches on the high voltage connection path (top right), scratch on the midle of the BBM (bottom left), and scratches on the wire bonds pad (bottom right)

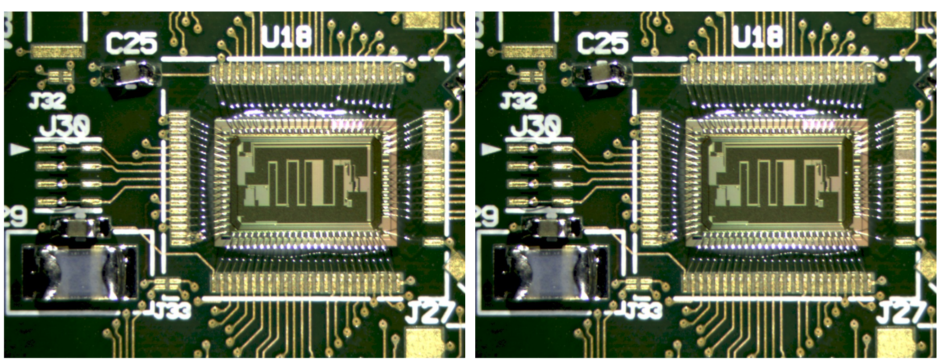


Figure 7.7: Photograph of the visual inspection of a HDI shwing the bondpads of the TBM (left) and of a ROC (right)

7.2.2 IV Test

After both BBM and HDI succesfully passed the visual inspection the BBM continues to the probe station for a current vs voltage (IV) test. The test

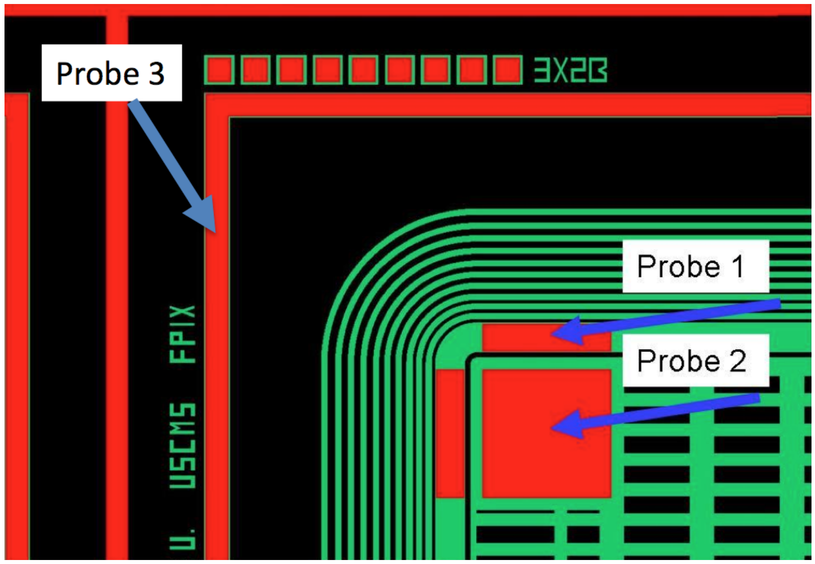


Figure 7.8: Probe position for an IV test on a BBM. Probe 2 is high voltage, probe 3 is ground, and probe 1 was not used

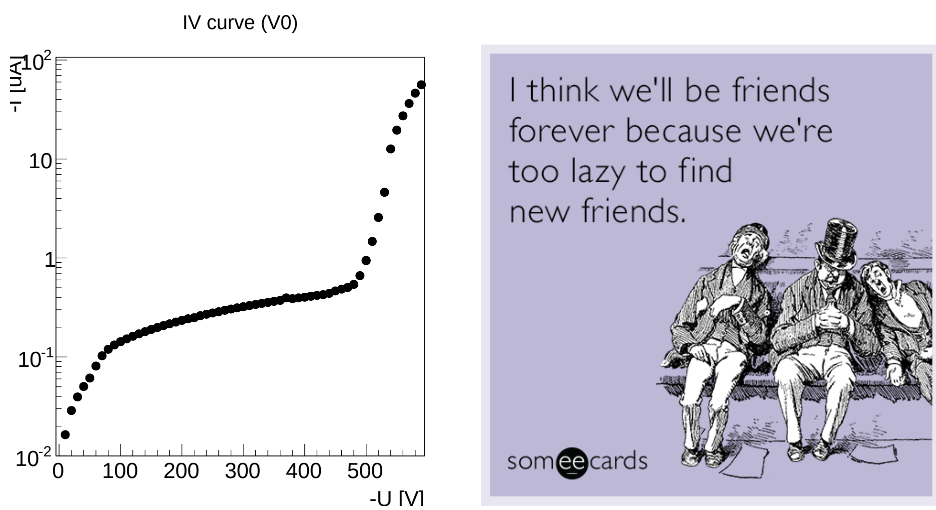


Figure 7.9: IV test for a good BBM (left) and for a BBM that reached compliance before the expected value.

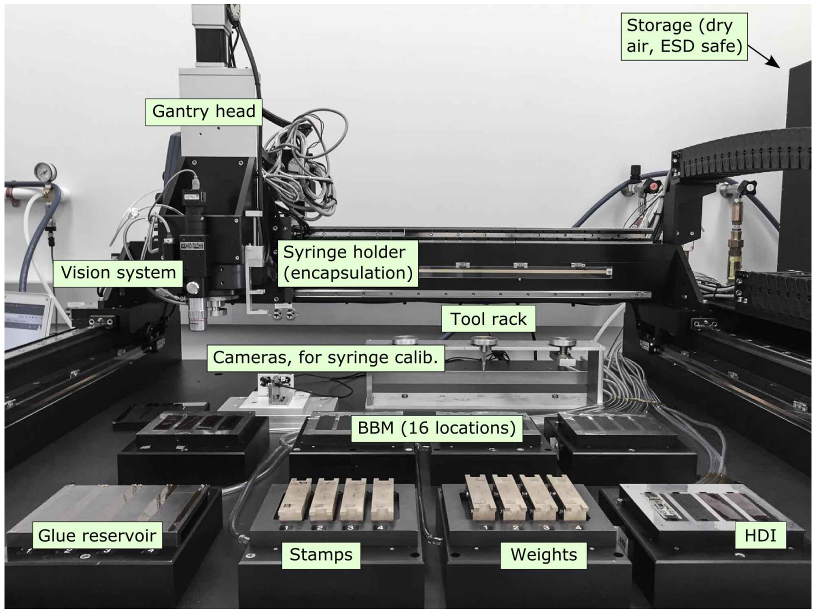


Figure 7.10: Gluing and encapsulation set up

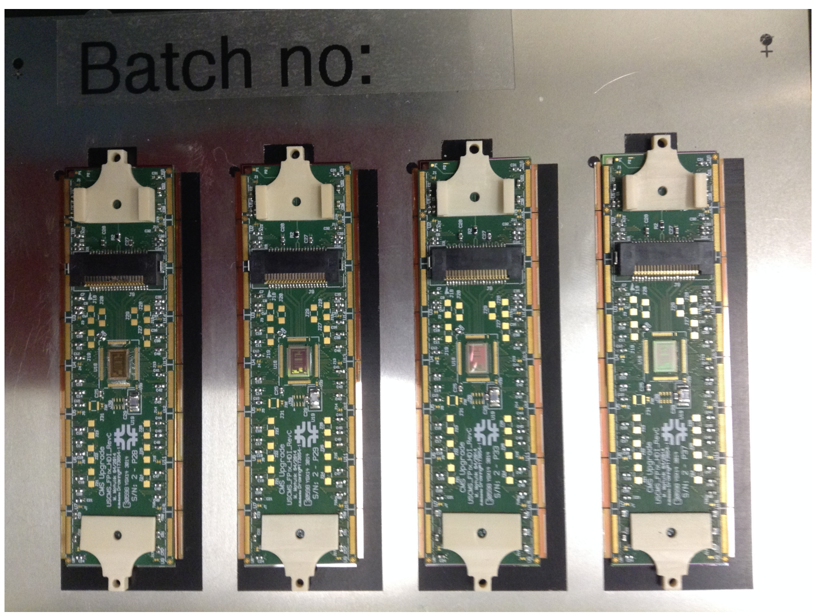


Figure 7.11: HDI glued on top of a BBM

7.2.3 Gluing

7.2.4 Wirebonding

7.2.5 Encapsulation

7.2.6 Electrical Test of a Fully assembly Module

7.2.6.1 Pretest

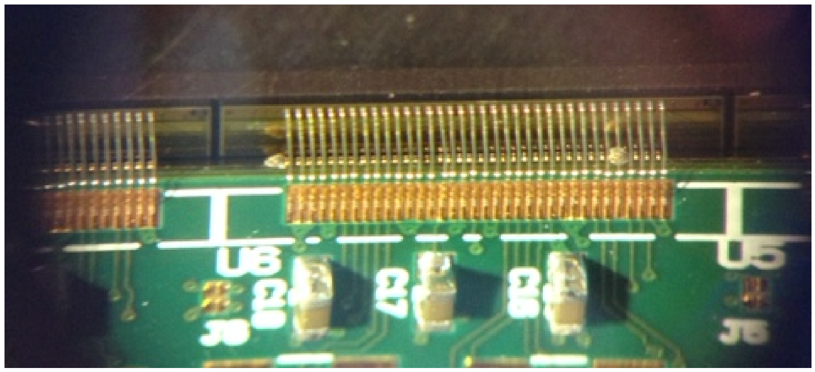


Figure 7.12: bla bla.

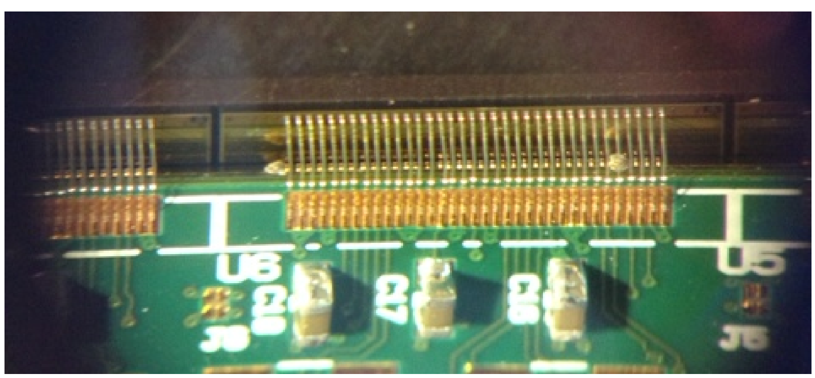
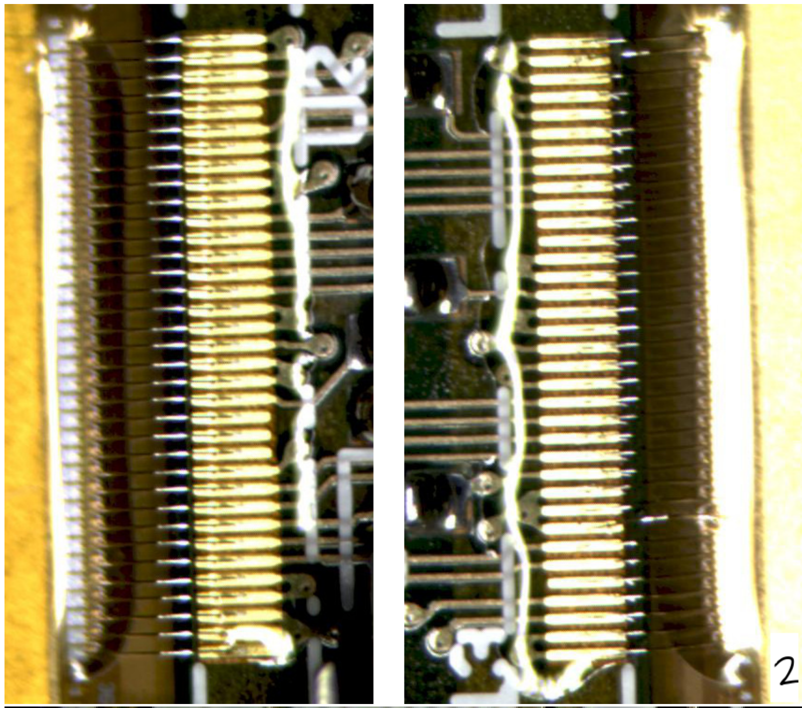


Figure 7.13: bla bla.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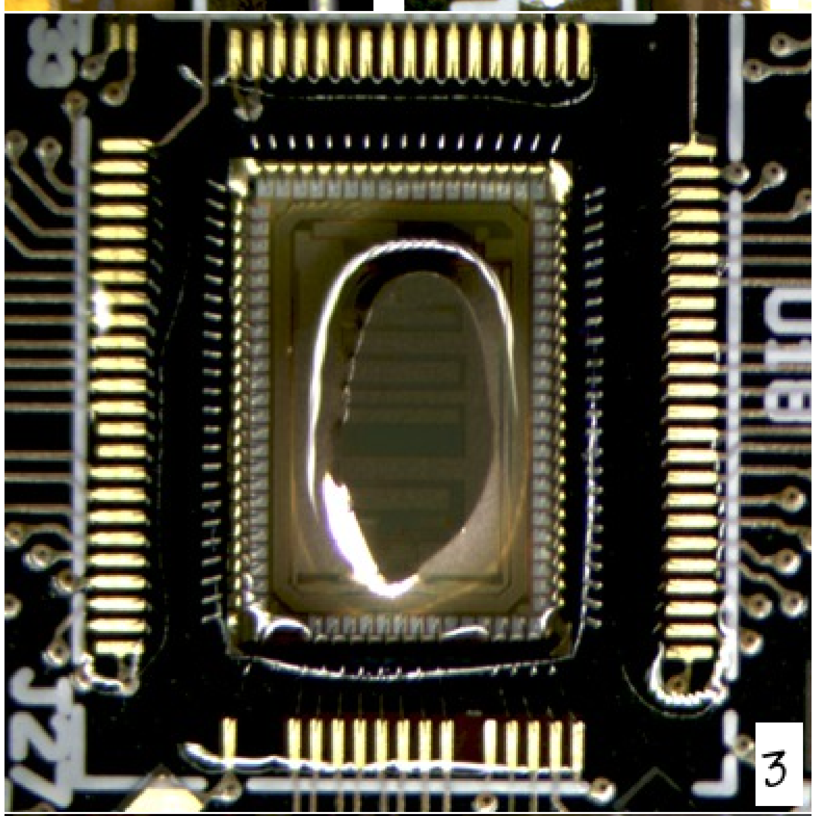
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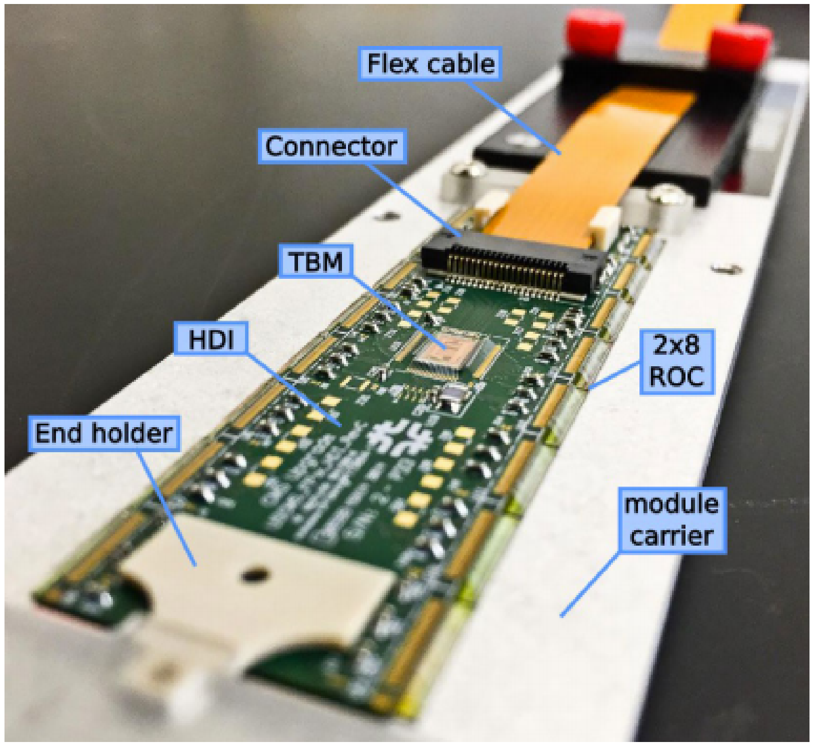

Figure 7.15: Fully assembly Module

Figure 7.16: Pretest.

Figure 7.17: Pixel alive good and bad.

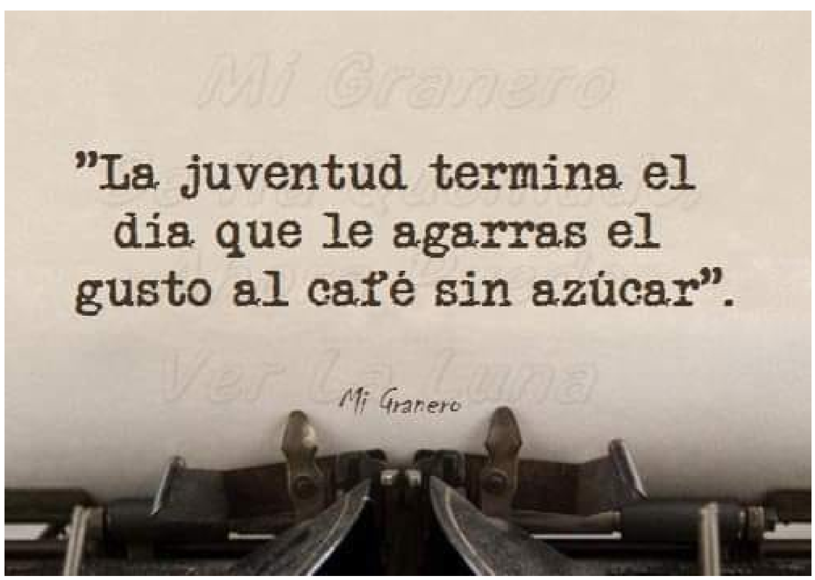

Figure 7.18: Trim test of a faulty and working module.

Figure 7.19: PH optimization.

Figure 7.20: Gain pedestal.

Figure 7.21: Bond bonding test.

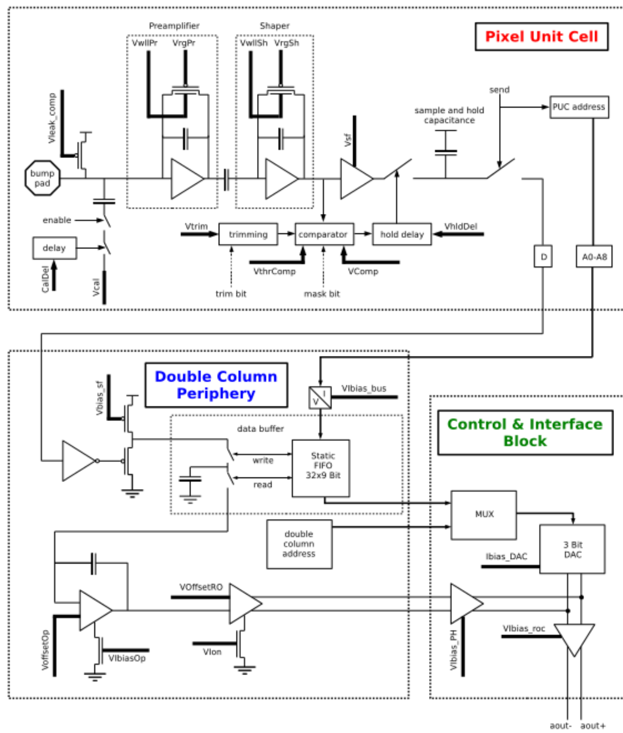

Figure 4. Schematic view of the readout chain

Figure 7.22: bla bla.

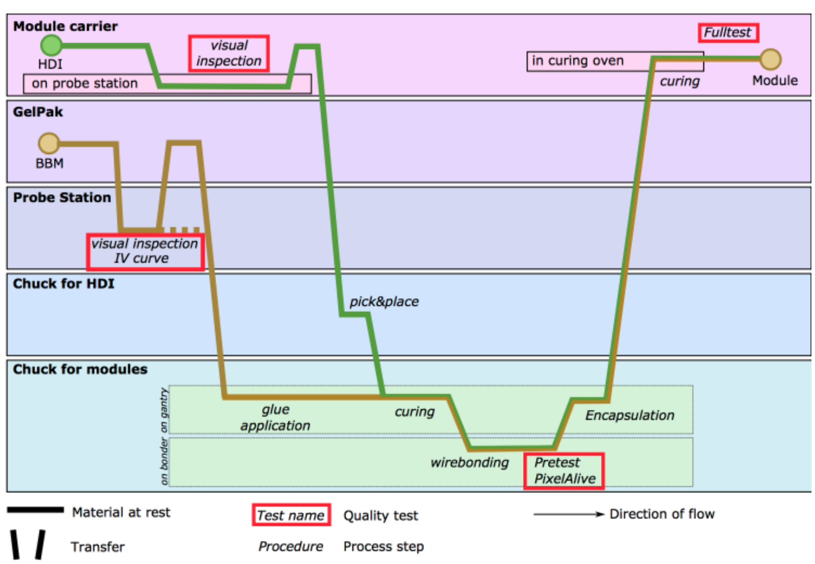

Figure 7.23: bla bla.

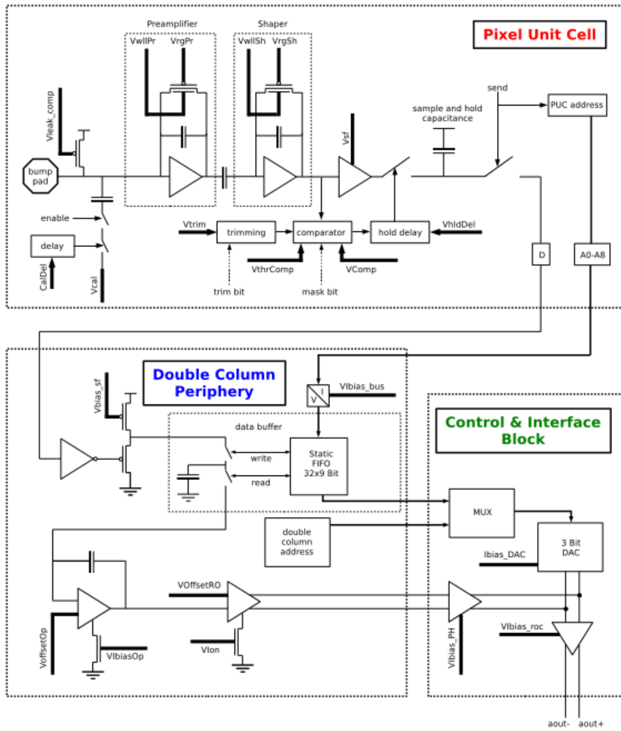

Figure 4. Schematic view of the readout chain

Figure 7.24: bla bla.

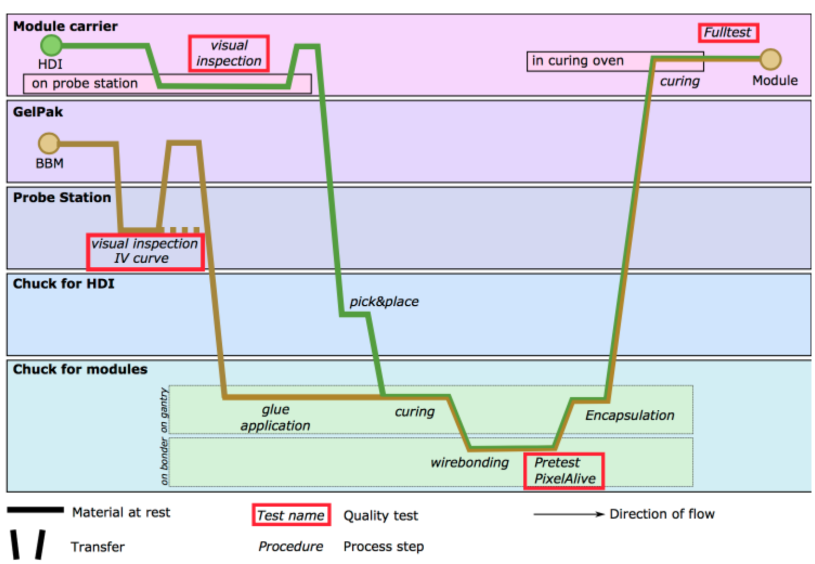

Figure 7.25: bla bla.

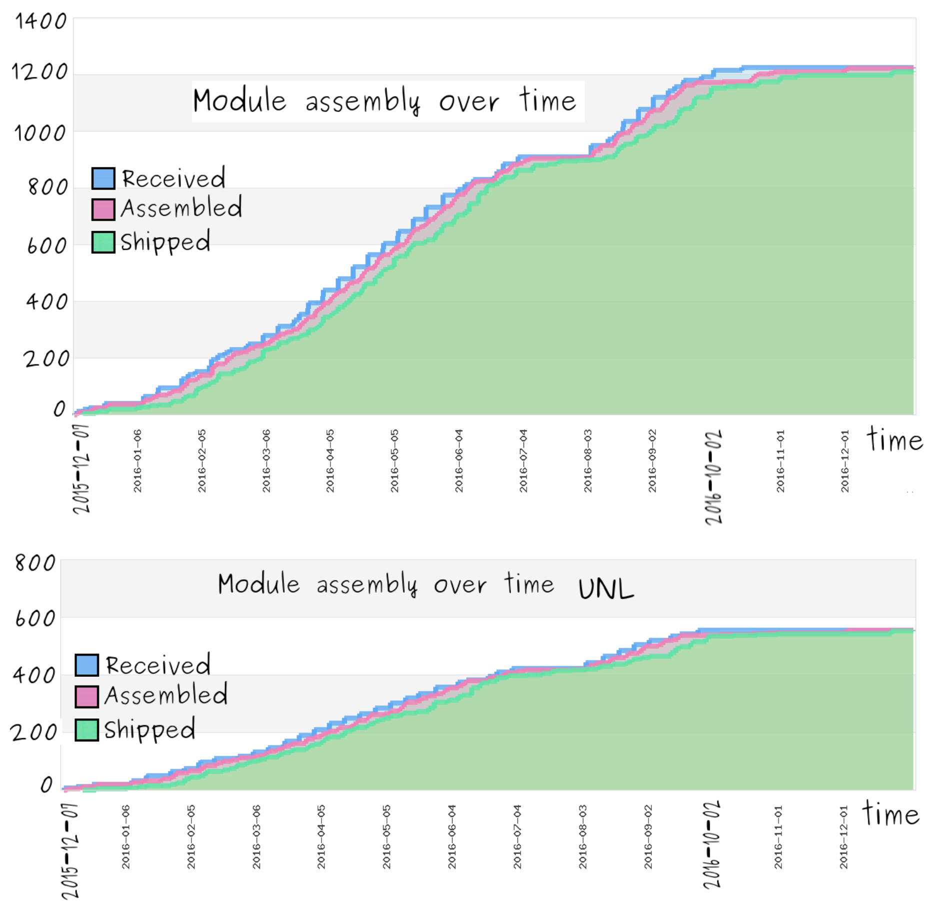

Figure 7.26: Module assembly over time for both assembly sites (top) and for UNL (bottom).

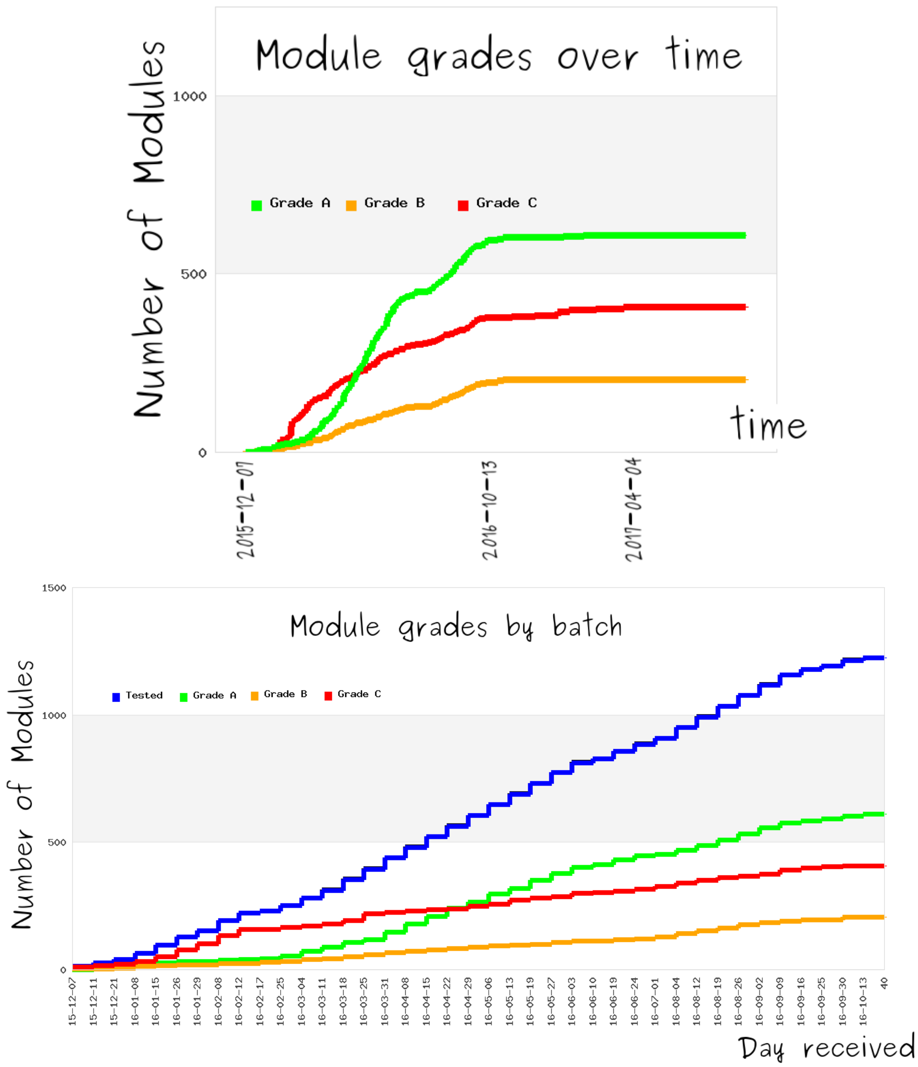

Figure 7.27: Module grade over time (top) and per received batch at the integration site(bottom).

Chapter *8*

Beam Test of the RD53 chip for CMS Pixel Detector Upgrade Phase 2

8.1 Introduction

8.2 The RD53 Chip

8.3 Purpose of Test Beam

8.4 Test Beam Set Up

8.5 Results

CHAPTER *9*

Conclusions

9.1 Analysis

9.2 Phase 1

9.3 Beam Test

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