

SEARCH FOR SOMETHING

by

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SEARCH FOR SOMETHING

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University of Nebraska, 2020

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 boson. 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,

**CUANDO QUEDAS CON UN AMIGO EN IR
A HACER EJERCICIO A LAS 6:00am.
PERO AMBOS DUERMEN TRANQUILOS
PORQUE SABEN:
QUE ESO NUNCA SUCEDERÁ.**



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.

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.

Cuando eres el único que no se ha descargado [#TikTok](#) en esta [#cuarentena](#)



Figure 2.2: LHC luminosity.

2.2 CMS

Four experiments were designed and built to test different physics theories and search for undiscovered particles at the LHC. Two of them, A Toroidal Large Apparatus (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 designed to investigate heavy ion collisions. Four experiments were designed and built to test different physics theories and search for undiscovered particles at the LHC. Two of them, A Toroidal Large Apparatus (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 experi-



Figure 2.3: LHC dipoles.

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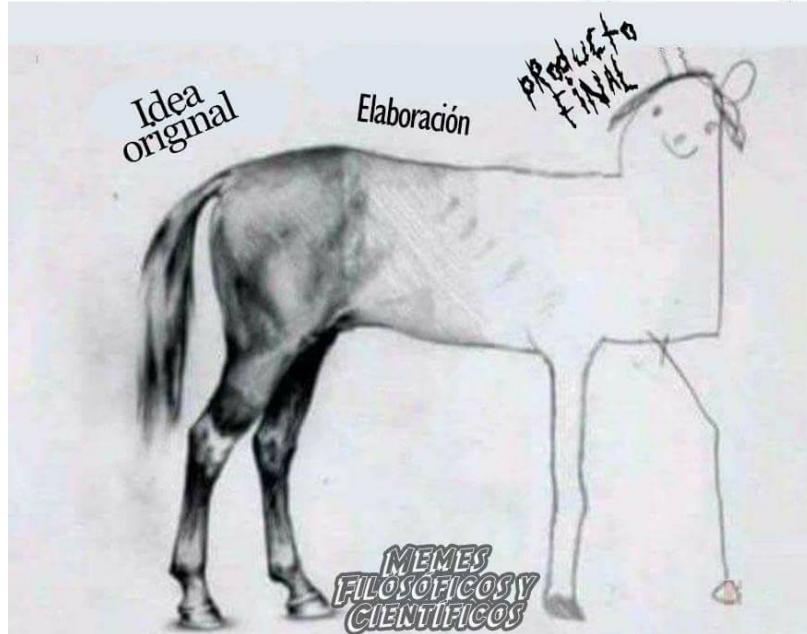


Figure 2.4: CMS cross sectional view.

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2.2.1 The Tracker Detector

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 exper-



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

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 Four experiments were designed and

**CUANDO LLEGAS A CASA
CON TU PRIMER TATUAJE**



Figure 2.8: phase o pixel detector.

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2.2.1.2 Silicon Strips

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 Four experiments were designed and

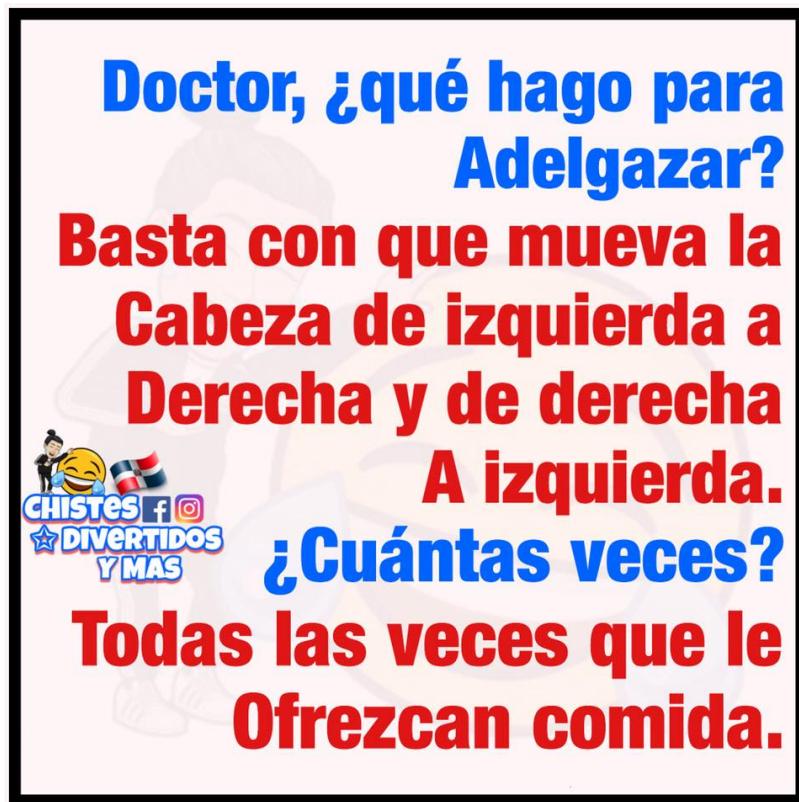


Figure 2.9: silicon strips detecto.

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 experi-

ment ALICE [4], A Large Ion Collider Experiment, was design to investigate heavy ion collisions

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

B-meson physics, the last experiment ALICE [4], A Large Ion Collider Experiment, was design to investigate heavy ion collisions



Figure 2.11: 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 B-meson physics, the last experiment ALICE [4], A Large Ion Collider Experiment, was design to investigate heavy ion collisions

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 $1 \times 10^{34} cm^{-2}s^{-1}$, which was then used in many analysis including the discovery of the Higgs boson 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 $2 \times 10^{35} cm^{-2}s^{-1}$. 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 H₁=2420 and 3 layers at each endcap as shown in Fig. 7.2. better

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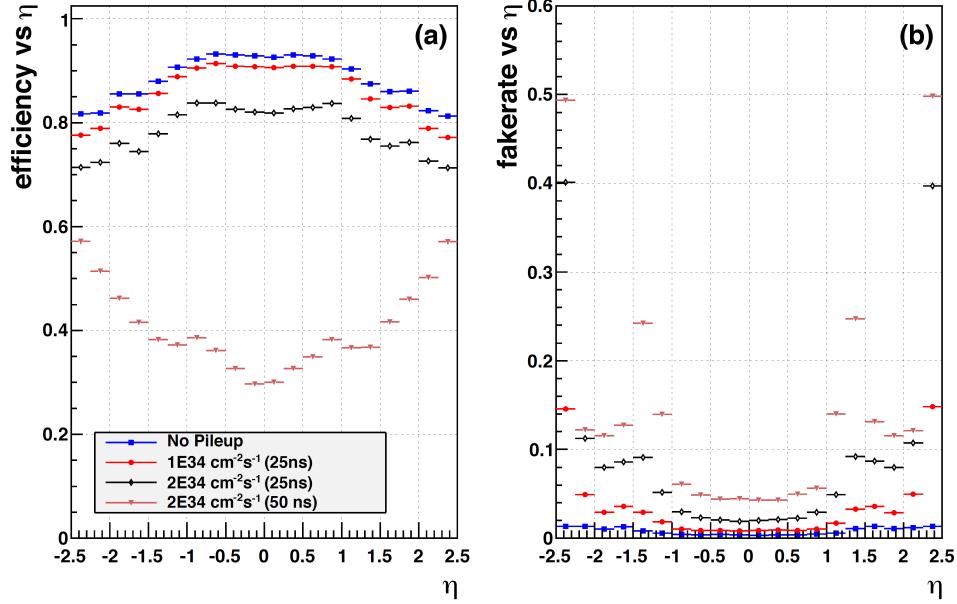


Figure 7.1: Expected performance of the original pixel detector under different luminosity conditions: a) track-finding efficiency; b) fake rate. Conventions are the same for both plots, considering zero pileup (blue squares), average pileup of 25 (red dots), average pileup of 50 (black diamonds), and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

slata la pagina

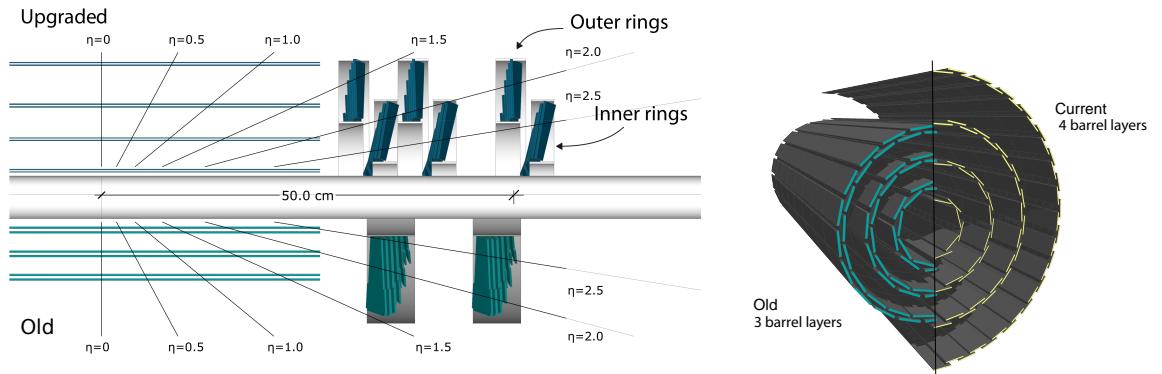


Figure 7.2: Layout and comparison of the layers and disks in the upgraded (Phase I) and old (Phase 0) pixel detectors [5].

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.

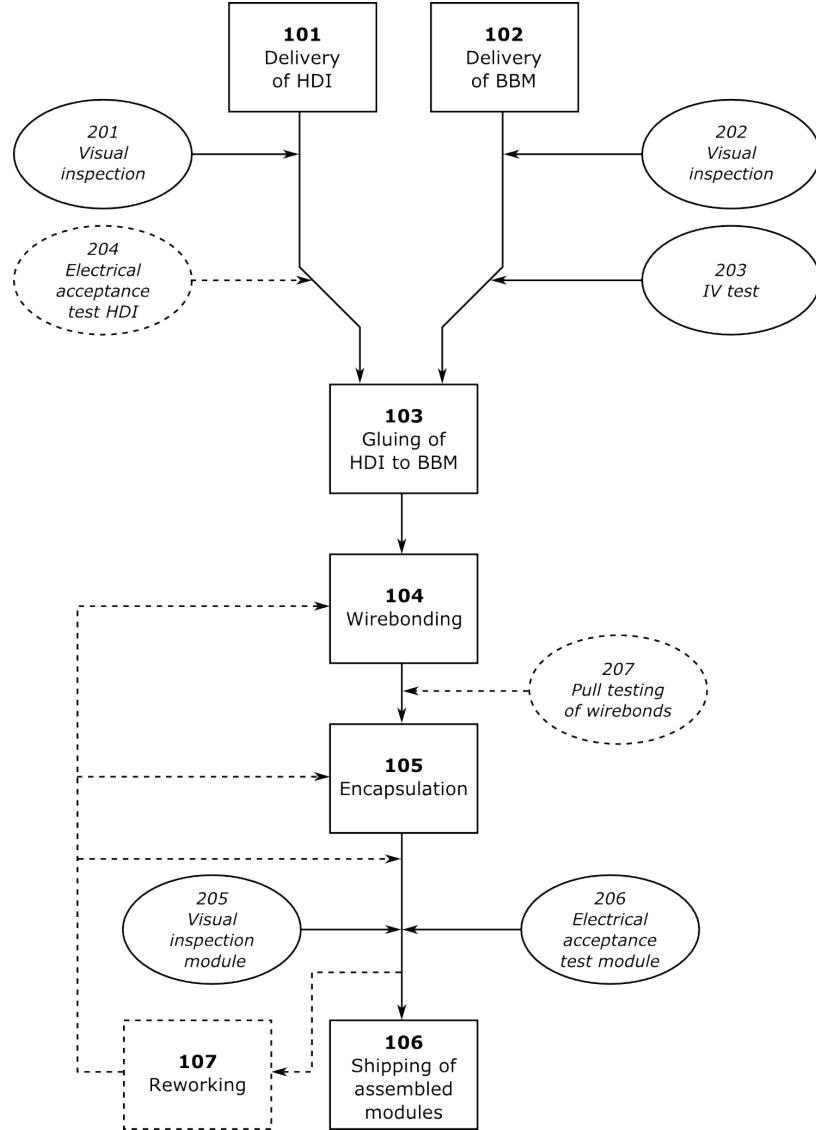


Figure 7.3: UNL module assembly workflow. Dashed lines represent occasional quality testing and reworking procedures [6].

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 work [improve](#).

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. 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.

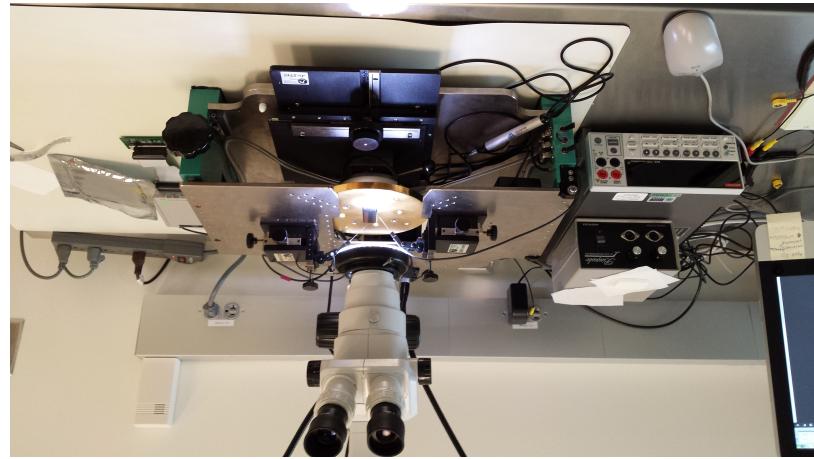


Figure 7.5: Photograph showing a BBM under the microscope during a visual inspection. This station also served as IV test stand.

During visual inspection BBM 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. Some of these defects (Fig 2(chipped)) will cause the module to be rejected immediately while others (Fig 3 and 4) 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.

why BBM has more scratches than the HDI?

7.2.2 IV Test

After both BBM and HDI were visually inspected

7.2.3 Gluing

The International Flat Earth Research Society (IFERS), better known as the Flat Earth Society, was set up by Samuel Shenton in 1956, in Dover, UK, as a direct descendant of the Universal Zetetic Society. This was just before the Soviet Union

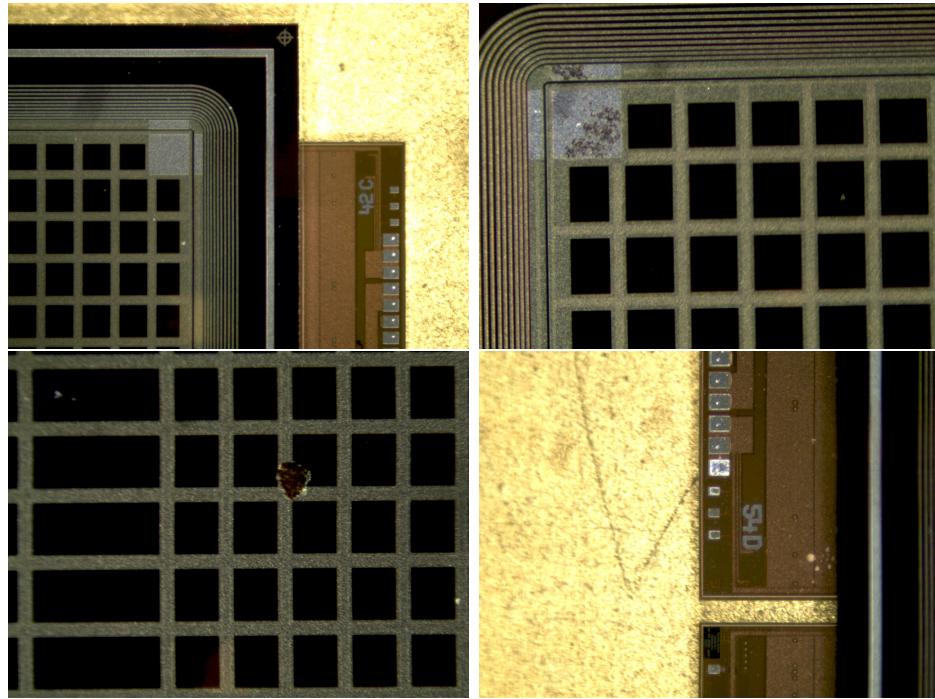


Figure 7.6: Photograph of the visual inspection of a BBM showing few of the things observed during a visual inspection: A good module (top left), scratches on the high voltage connection path (top right), scratch on the middle of the BBM (bottom left), and scratches on the wire bonds pad (bottom right)

launched the first artificial satellite, Sputnik; he responded: "Would sailing round the Isle of Wight prove that it were spherical? It is just the same for those satellites."

His primary aim was to reach children before they were convinced about a spherical Earth. Despite plenty of publicity, the space race eroded Shenton's support in Britain until 1967, when he started to become famous due to the Apollo program.

7.2.4 Wirebonding

Homer Wells es un huérfano al que no le falta familia. Ha crecido en el orfanato de St. Cloud's bajo la poco convencional pero tierna tutela del Dr. Wilbur que nunca ha dejado de dar afecto a sus chicos. Pero a medida que Homer se va haciendo un hombre y se da cuenta del gran abanico de posibilidades que le pero tierna tutela

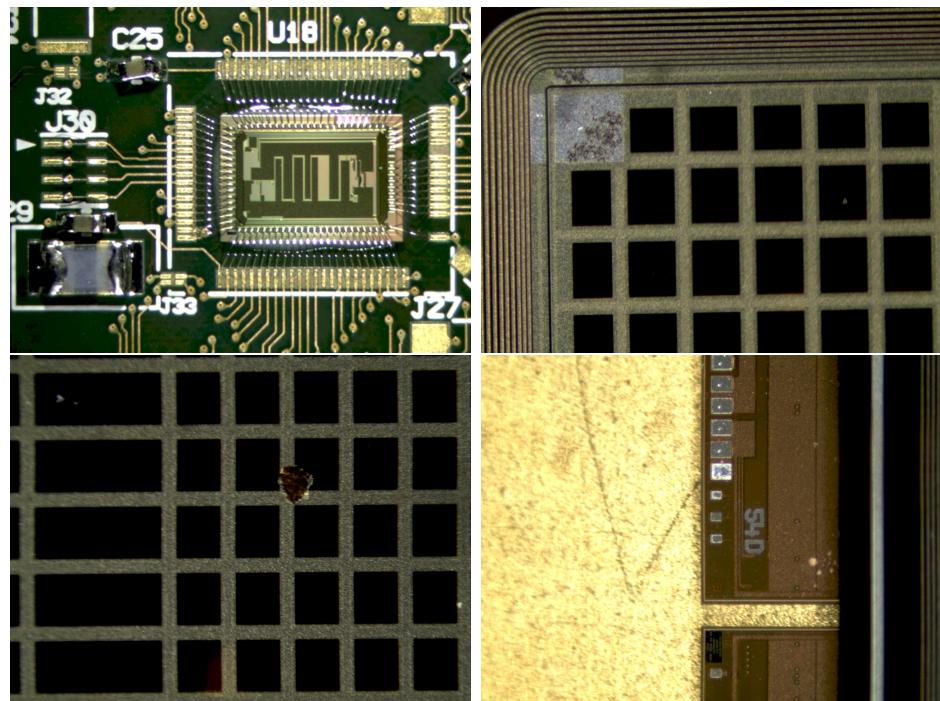


Figure 7.7: Photograph of the visual inspection of a BBM showing few of the things observed during a visual inspection: A good module (top left), scratches on the high voltage connection path (top right), scratch on the middle of the BBM (bottom left), and scratches on the wire bonds pad (bottom right)

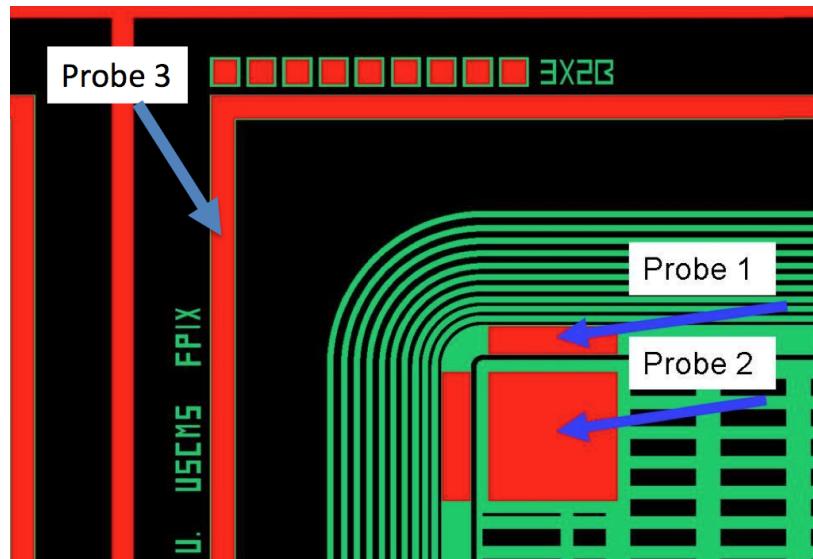


Figure 7.8: Probe position for an IV test on a BBM.

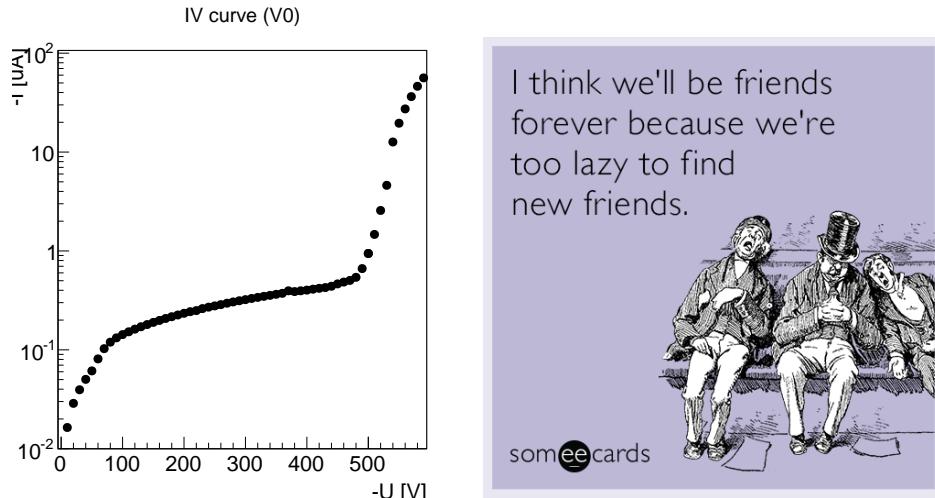


Figure 7.9: IV good and bad.



Figure 7.10: Gluing routine

del Dr. Wilbur que nunca ha dejado de dar afecto a sus chicos. Pero a medida que Homer se va haciendo un hombre y se da cuenta del gran abanico de posibilidades que le brinda la vida, empieza a dudar y a cuestionar los mÁltodos del Dr. Wilbur. brinda la vida, empieza a dudar y a cuestionar los mÁltodos del Dr. Wilbur. Homer Wells es un huÁlfano al que no le falta familia. Ha crecido en el orfanato de St. Cloud's bajo la poco convencional



Figure 7.11: bla bla.

7.2.5 Encapsulation

The International Flat Earth Research Society (IFERS), better known as the Flat Earth Society, was set up by Samuel Shenton in 1956, in Dover, UK, as a direct descendant of the Universal Zetetic Society. This was just before the Soviet Union launched the first artificial satellite, Sputnik; he responded: "Would sailing round the Isle of Wight prove that it were spherical? It is just the same for those satellites."

7.2.6 Electrical Test of a Fully assembly Module

The International Flat Earth Research Society (IFERS), better known as the Flat Earth Society, was set up by Samuel Shenton in 1956, in Dover, UK, as a direct descendant of the Universal Zetetic Society. This was just before the Soviet Union launched the first artificial satellite, Sputnik; he responded: "Would sailing round the Isle of Wight prove that it were spherical? It is just the same for those satellites."

His primary aim was to reach children before they were convinced about a spherical

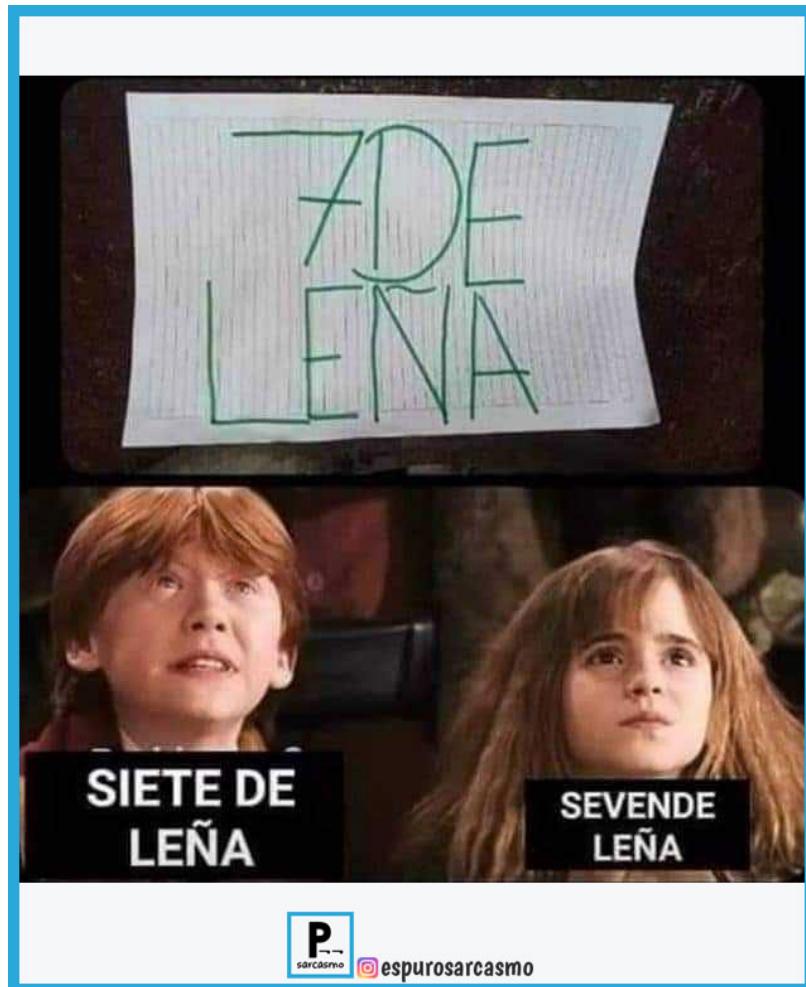


Figure 7.12: bla bla.

Earth. Despite plenty of publicity, the space race eroded Shenton's support in Britain until 1967, when he started to become famous due to the Apollo program.

7.2.6.1 Pretest

The International Flat Earth Research Society (IFERS), better known as the Flat Earth Society, was set up by Samuel Shenton in 1956, in Dover, UK, as a direct descendant of the Universal Zetetic Society. This was just before the Soviet Union launched the first artificial satellite, Sputnik; he responded: "Would sailing round the

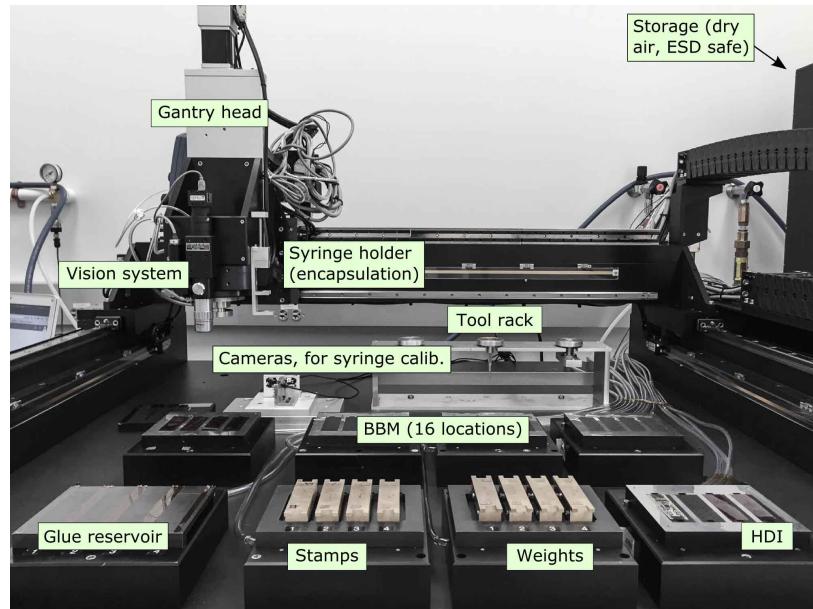


Figure 7.13: bla bla.

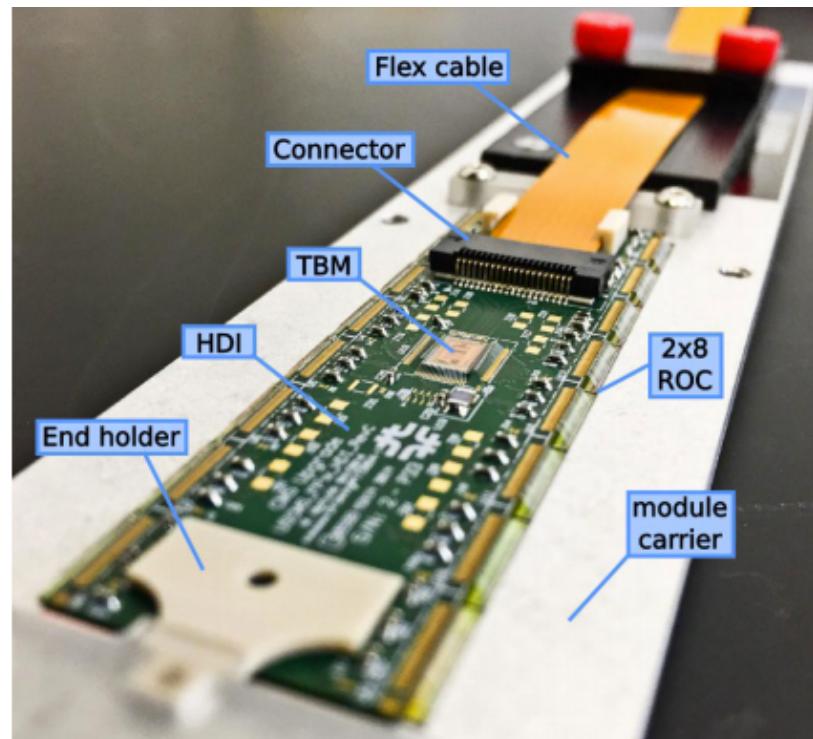


Figure 7.14: Fully assembly Module

Isle of Wight prove that it were spherical? It is just the same for those satellites."³⁰

His primary aim was to reach children before they were convinced about a spherical Earth. Despite plenty of publicity, the space race eroded Shenton's support in Britain until 1967, when he started to become famous due to the Apollo program.



Figure 7.15: Visual inspection of a bare module.

7.2.6.2 Pretest

The International Flat Earth Research Society (IFERS), better known as the Flat Earth Society, was set up by Samuel Shenton in 1956, in Dover, UK, as a direct descendant of the Universal Zetetic Society. This was just before the Soviet Union launched the first artificial satellite, Sputnik; he responded: "Would sailing round the Isle of Wight prove that it were spherical? It is just the same for those satellites."³⁰

-Amor, ¿estas brava?
 -Si.
 -¿hay algo que pueda darte para alegrarte?
 -si

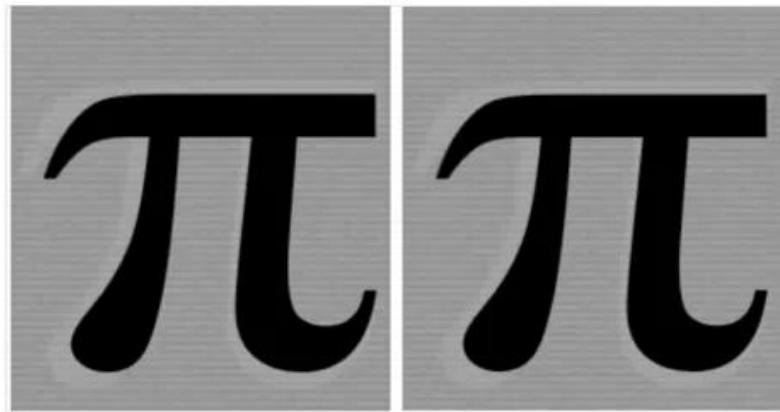


Figure 7.16: Electrical test station.

His primary aim was to reach children before they were convinced about a spherical Earth. Despite plenty of publicity, the space race eroded Shenton's support in Britain until 1967, when he started to become famous due to the Apollo program.

7.2.6.3 Pixel Alive

The International Flat Earth Research Society (IFERS), better known as the Flat Earth Society, was set up by Samuel Shenton in 1956, in Dover, UK, as a direct descendant of the Universal Zetetic Society. This was just before the Soviet Union launched the first artificial satellite, Sputnik; he responded: "Would sailing round the Isle of Wight prove that it were spherical? It is just the same for those satellites."

His primary aim was to reach children before they were convinced about a spherical Earth. Despite plenty of publicity, the space race eroded Shenton's support in Britain



Figure 7.17: Pretest.

until 1967, when he started to become famous due to the Apollo program.



Figure 7.18: Pixel alive good and bad.

7.2.6.4 Trim Test

The International Flat Earth Research Society (IFERS), better known as the Flat Earth Society, was set up by Samuel Shenton in 1956, in Dover, UK, as a direct descendant of the Universal Zetetic Society. This was just before the Soviet Union launched the first artificial satellite, Sputnik; he responded: "Would sailing round the Isle of Wight prove that it were spherical? It is just the same for those satellites."

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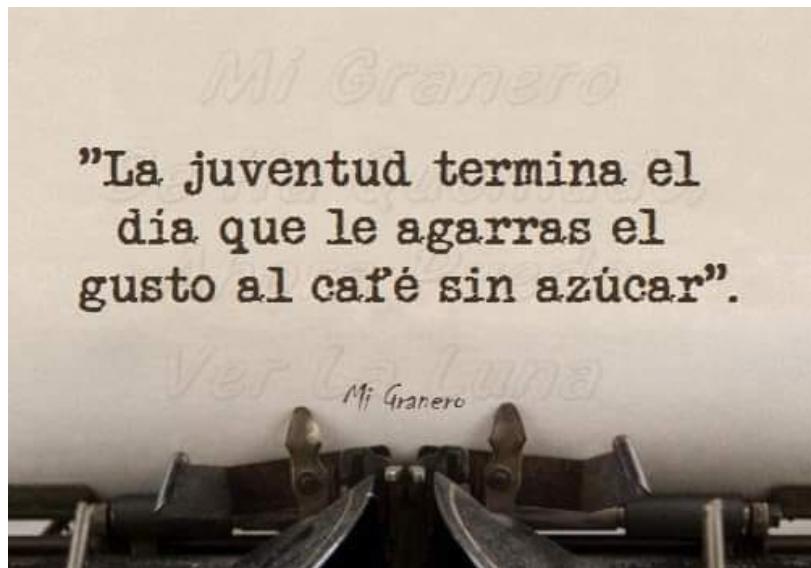


Figure 7.19: Trim test of a faulty and working module.

7.2.6.5 PH Optimization

The International Flat Earth Research Society (IFERS), better known as the Flat Earth Society, was set up by Samuel Shenton in 1956, in Dover, UK, as a direct descendant of the Universal Zetetic Society. This was just before the Soviet Union

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People I haven't seen in years:



Me:



Figure 7.20: PH optimization.

7.2.6.6 Gain Pedestal

The International Flat Earth Research Society (IFERS), better known as the Flat Earth Society, was set up by Samuel Shenton in 1956, in Dover, UK, as a direct descendant of the Universal Zetetic Society. This was just before the Soviet Union launched the first artificial satellite, Sputnik; he responded: "Would sailing round the Isle of Wight prove that it were spherical? It is just the same for those satellites."

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Figure 7.21: Gain pedestal.

7.2.6.7 Bond Bonding Test

The International Flat Earth Research Society (IFERS), better known as the Flat Earth Society, was set up by Samuel Shenton in 1956, in Dover, UK, as a direct descendant of the Universal Zetetic Society. This was just before the Soviet Union

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His primary aim was to reach children before they were convinced about a spherical Earth. Despite plenty of publicity, the space race eroded Shenton's support in Britain until 1967, when he started to become famous due to the Apollo program.

Yo todas las noches.



Figure 7.22: Bond bonding test.

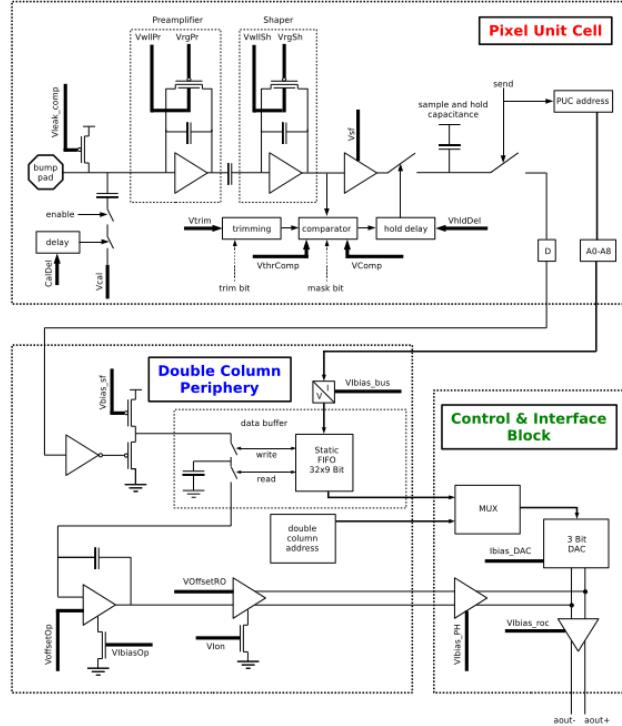


Figure 4. Schematic view of the readout chain

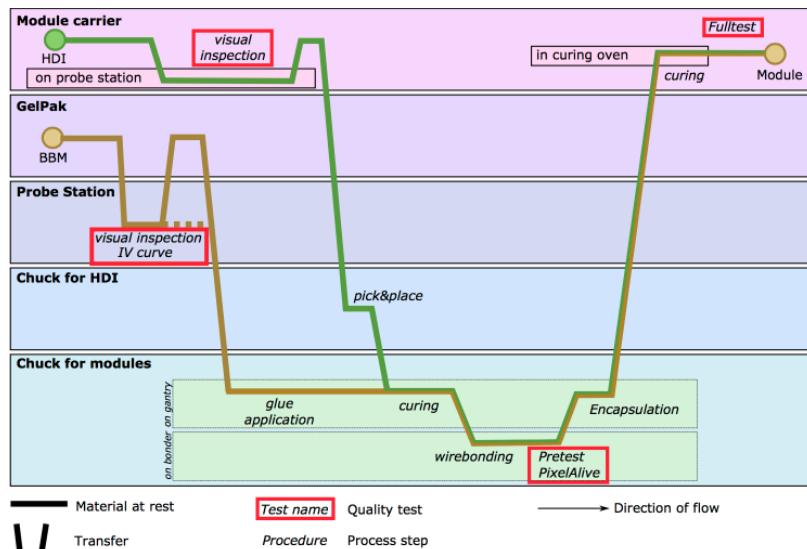
Figure 7.23: bla bla.

Figure 7.24: bla bla.

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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