Lessons learnt from the Calorimeter Upgrade I

ECAL U-II Workshop

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Many thanks to those whose contributed to this talk

Monday 12th December 2022

INTRODUCTION

- **This presentation is very subjective**
  - I tried to get the input of other people contributing to the upgrade – I
    - Thanks to them !
  - What I found posi/nega-tive may have been nega/posi-tive for others

- **I will try to give my feeling**
  - What was good ? What was bad ?
  - What should have we done differently ?
  - What could have been improved ? What was well done ?
  - What have been the obstacles ?

OVERVIEW OF THE CALORIMETER UPGRADE

- **New design of the Front-end electronics, the acquisition and the slow control**
  - The calorimeter data sent @ 40 MHz to the upgrade-HLT / PC-farm
  - The gain of the cells was changed (HV + analog electronics gain) to improve the physics case
  - All the communications are based on the GBTx system
- **The SPD/PS system is removed**
  - Not so important after L0 disappears
  - Particle identification is affected
  - But easier calibration of the ECAL/better resolution

THE CALORIMETER SYSTEM – RUNS I & II

Acquisition

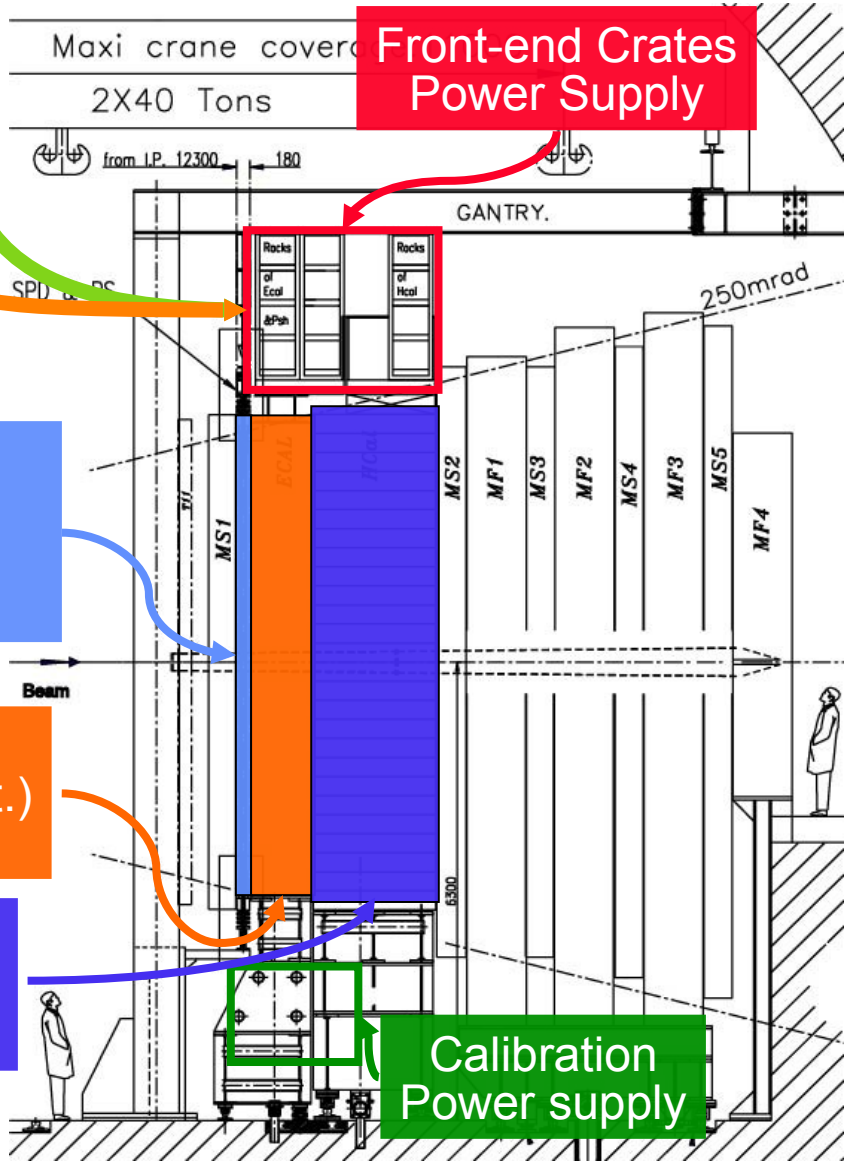
Slow Control / Monitoring

Front-end partly common

Scintillating Pad Det (SPD)
Preshower (PS)
Scint. Pad + Fibres+ MAPMT
6016 cells each

ECAL
Shashlik (Pb-scint.)
6016 cells

HCAL
Tiles (Iron-scint.)
1488 cells



Front-end Crates Power Supply

Calibration Power supply

WHAT WAS CHANGED FOR THE UPGRADE

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Slow Control / Monitoring

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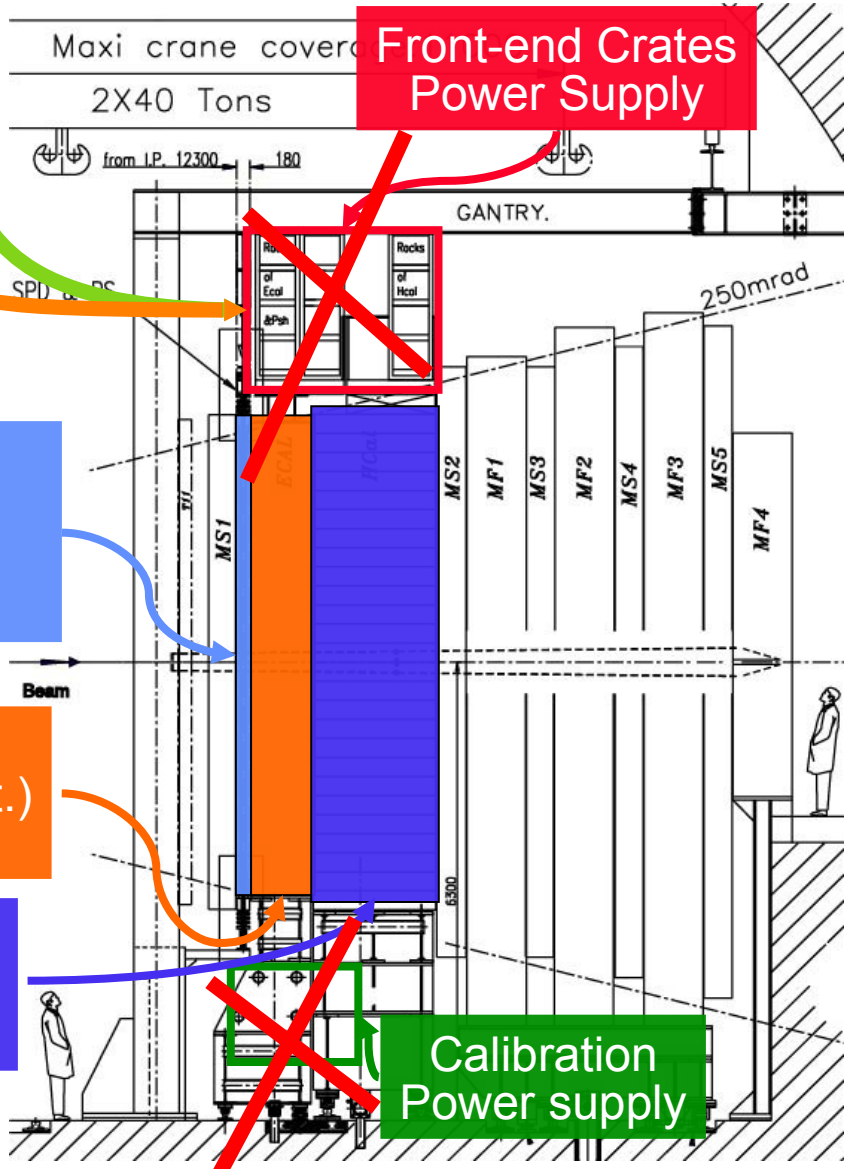


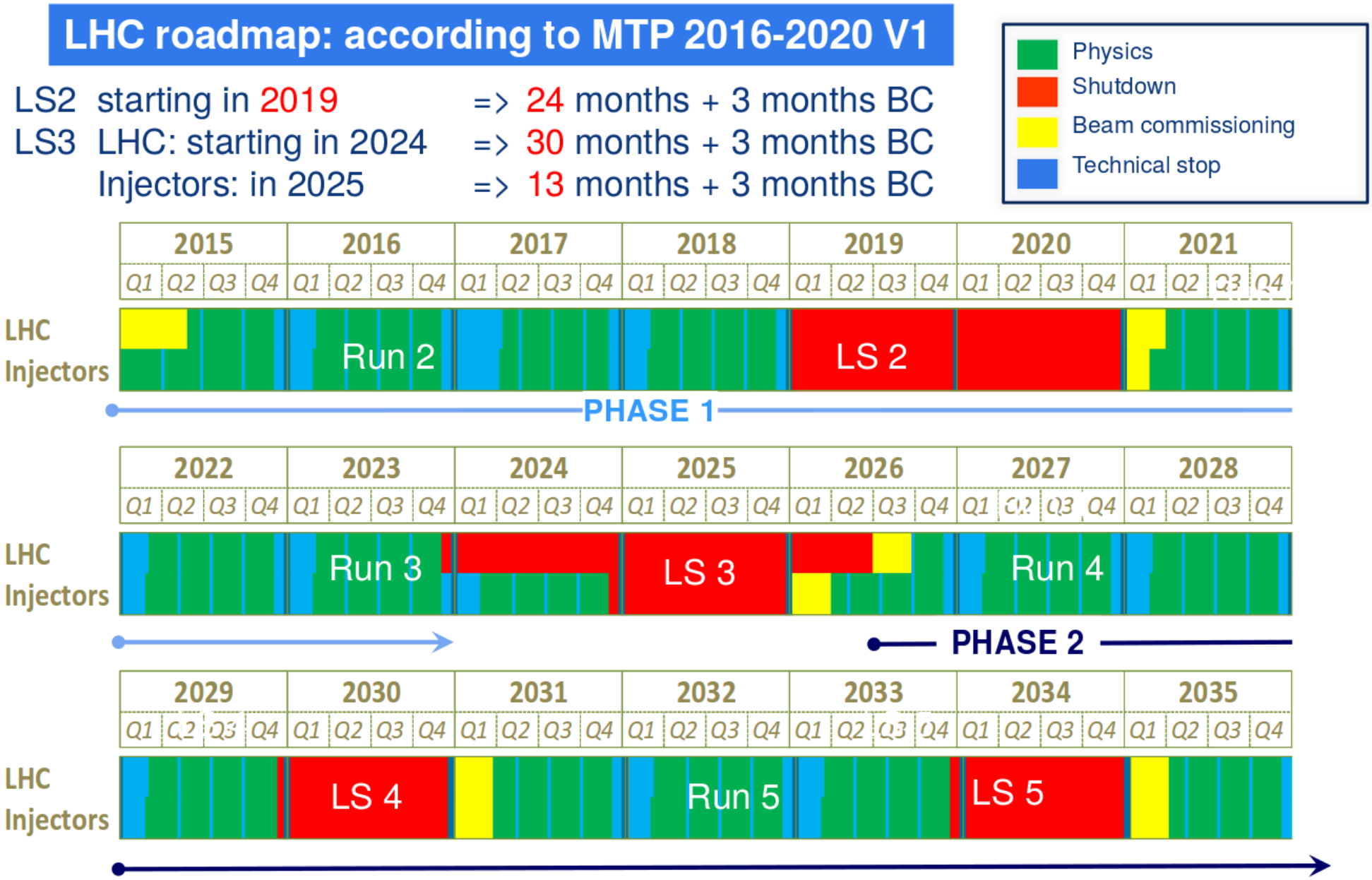
Front-end Crates Power Supply

Calibration Power supply

ORIGIN OF THE PROJECT

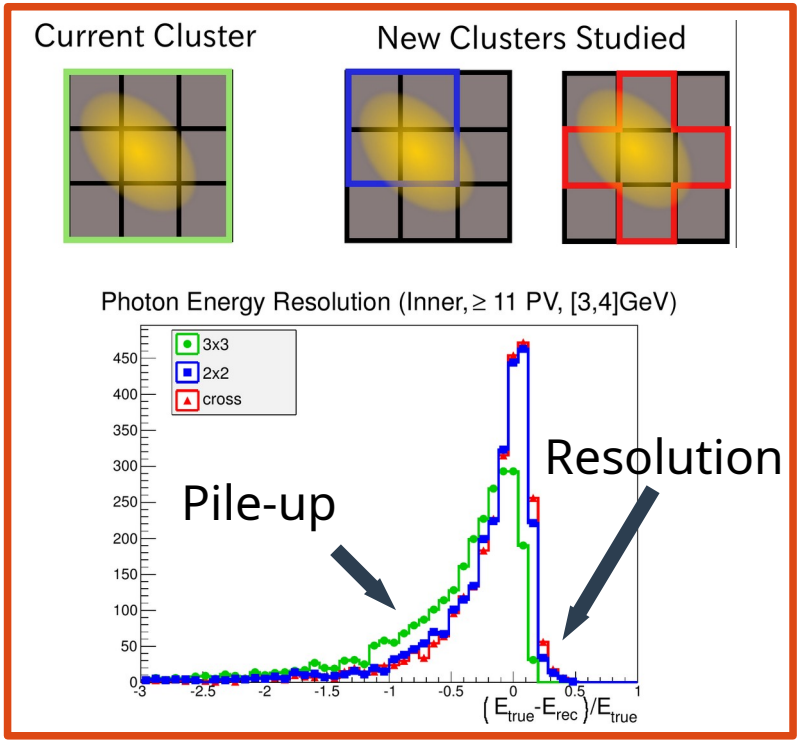
- It was important to well define the scope of the project
  - **Jacques Lefrançois** contributed a lot to the preparation of the project
  - Thanks also to **Marie-Noëlle Minard** for her strong support from the beginning
- We tried to think early of the details keeping in mind the time allowed
  - Mostly fixed by the schedule of the LHC (which drifted afterwards !)
  - Early, we had a clear idea of the possible financial resources we could get
    - We could not imagine having the budget to replace the modules
    - This clarified early the scope of the project
    - And clarified the human resources needed
  - We looked for external contributors straight away
    - 2 reasons :
      - IN2P3 / IJCLab(LAL) would not have been able to make it alone
      - We benefited a lot from the experience of the other groups
    - We wanted to share the work early and started to discuss with the people we knew to be capable of having a strong impact
      - Not always the people who speak loud but those that are competent
      - Among the contributors to the Runs I & II Calo → the **Barcelona group** (electronics of the SPD)
      - **Clermont** could not work on the project (SciFi)
        - But we benefited a lot from their knowledge of the SPD/PS for the dismantling → their responsibility and they did it perfectly !
      - **Annecy** was involved In the mechanics from the beginning → essential contribution (movement of the detector)
    - The **russian groups** had contributed to the HV / Calibration / Monitoring systems
      - Had to be adapted to the new slow control → important contribution from them (ITEP, INR, IHEP) → huge work from **Yuri Guz**

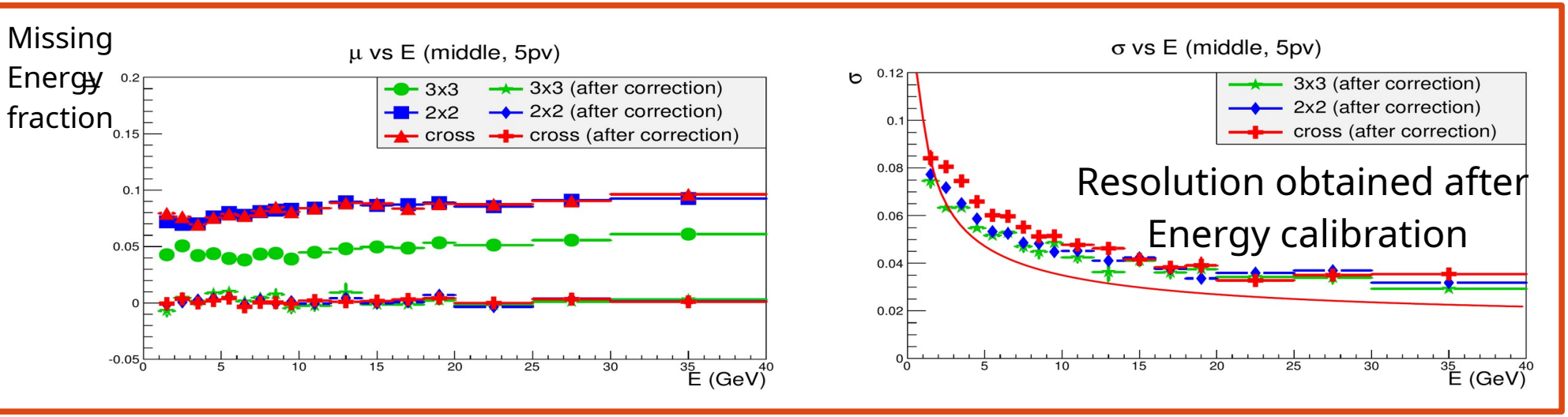
THE LHC SCHEDULE IN 2015...



EARLY PERFORMANCE STUDIES

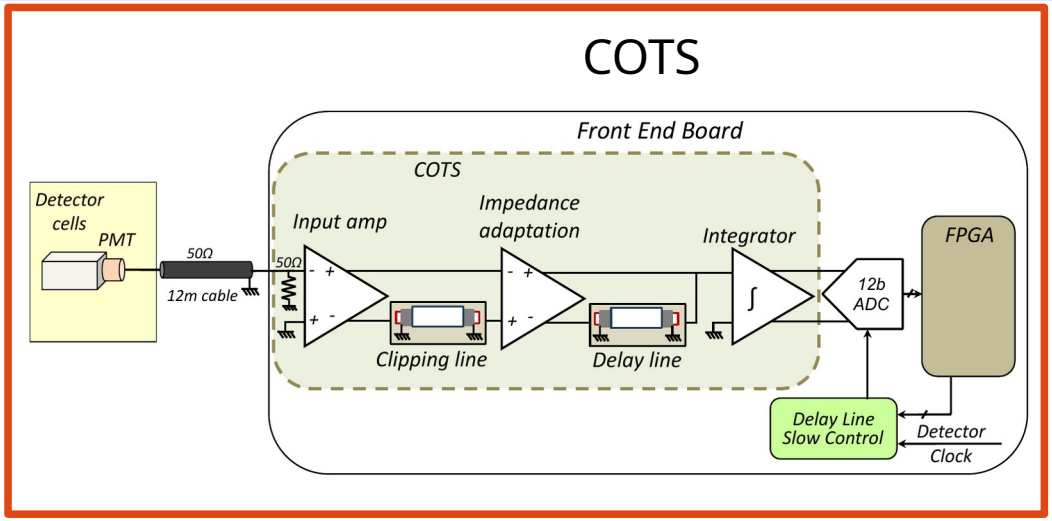
- **We studied the performances of the upgrade I detector (A. Vallier's thesis)**
  - It was not clear how to cope with the larger occupancy
  - We knew that we would not improve the overall performances
  - We tried to identify the possibilities to get similar performances as for the "original" calo

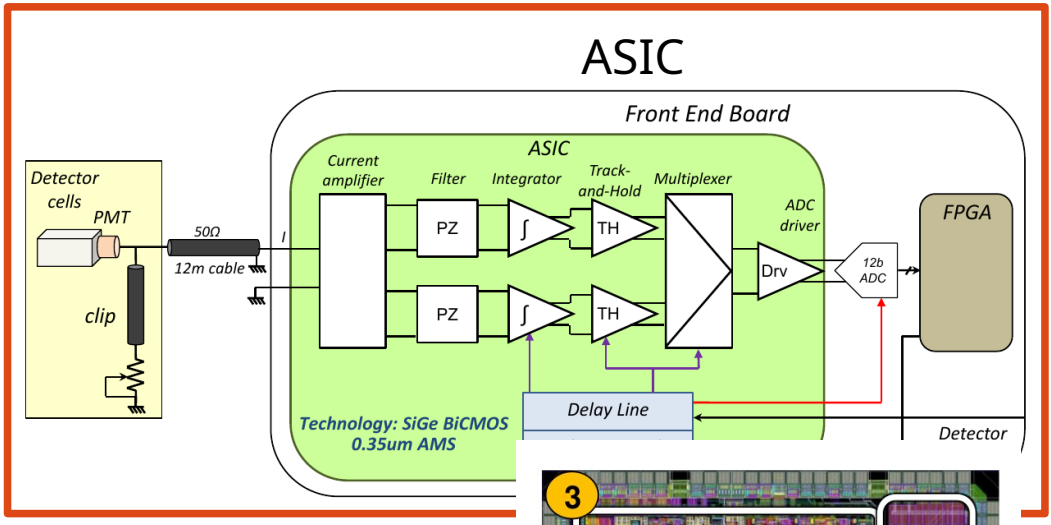


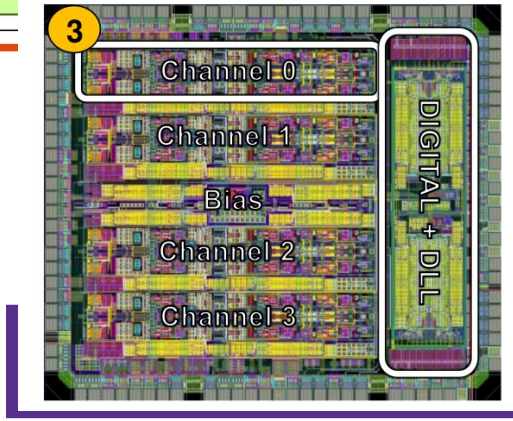


THE FE ELECTRONICS

- **We benefited from two parallel designs of the analog electronics by Barcelona**
  - The two groups worked together and most people contributed to the two developments
  - We benefited from the collaborations of the two "teams" and the sharing of knowledge
- **The final choice was based on the performances first, the cost was NOT the priority**
  - The criteria have been clearly defined early in the development of two designs
  - We could decide in 2015 without too much frustration to go for the ASIC
  - ICECAL production on a shared waffer
    - Important reduction of the cost







FE ELECTRONICS

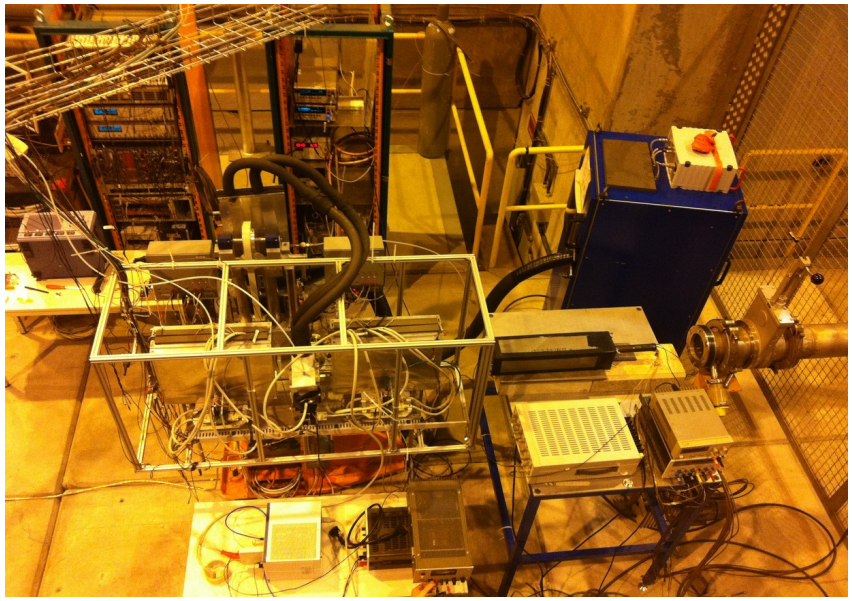
- The first prototype for a FEB was a board that we used essentially to test the analog part, new ideas and components (performances and radiation tolerance) :
  - Could host a mezzanine with any type of analog design
  - Two FPGAs
    - A Socket to host antifuse FPGA
    - A flash based FPGA was soldered

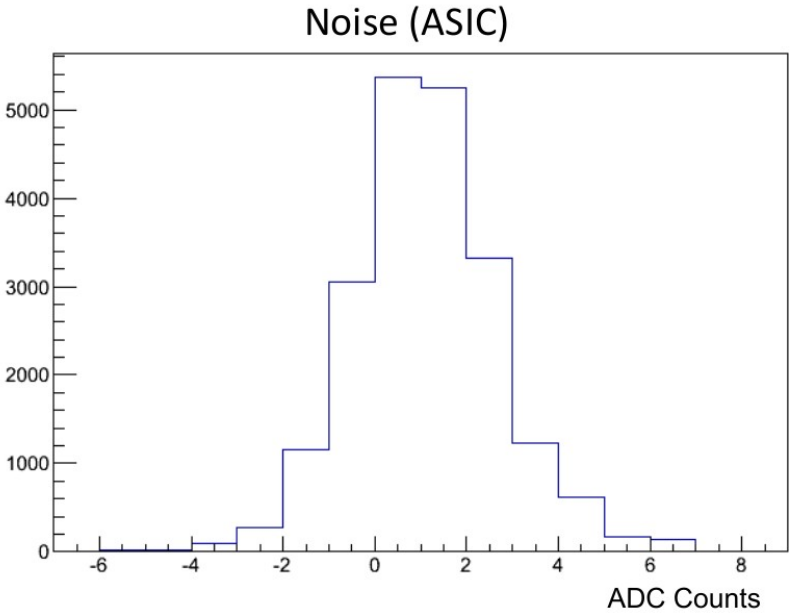
    used for the data acquisition
  - 12 clocks with adjustable phases feeding the Analog/FPGA
  - The board could produce its own clock or use an external one
    - Synchronisation during test beams
  - 10 input/output connectors (LEMO)
    - Used as tools to feed or extract user signals
  - Communications based on
    - A USB port associated to an acquisition / configuration / monitoring software
    - A SPECS mezzanine (to be used for irradiation tests)

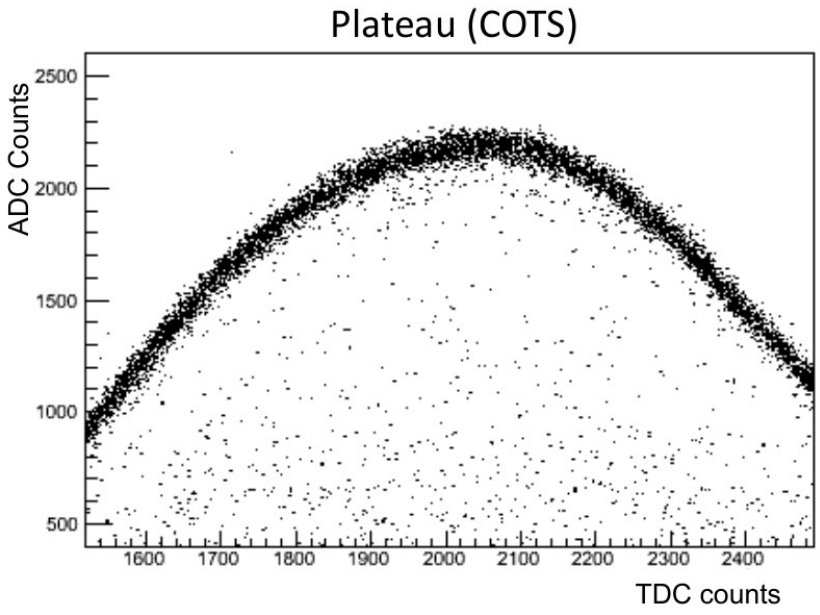
- Two copies of the same test bench in the two labs involved

TEST BEAMS

- **We did several test beams where we tried to reproduce the most realistic conditions**
  - We used from the beginning the same cables/modules/PMT/CW bases/… as those used in the cavern
  - The pulse shapes were digitised and stored to be generated in the labs in the future

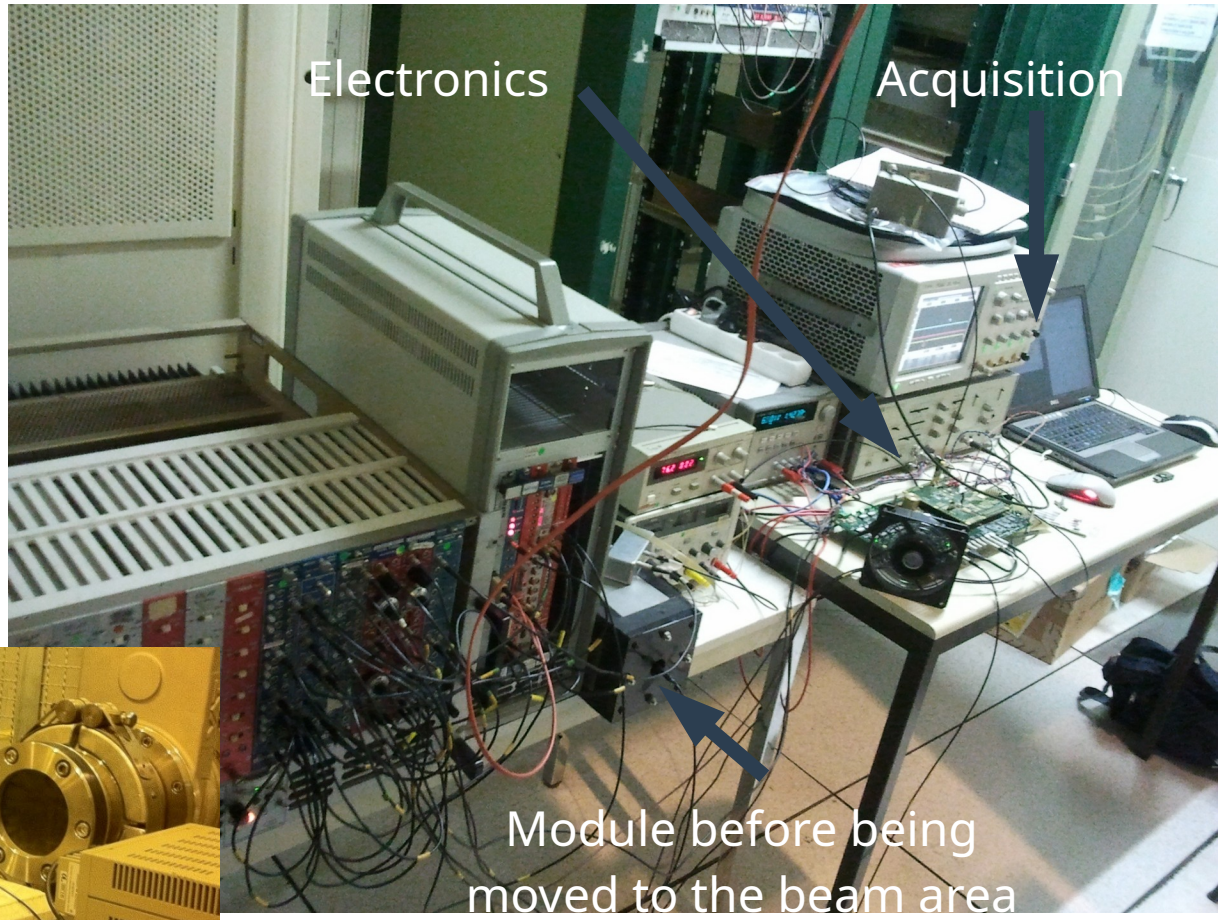


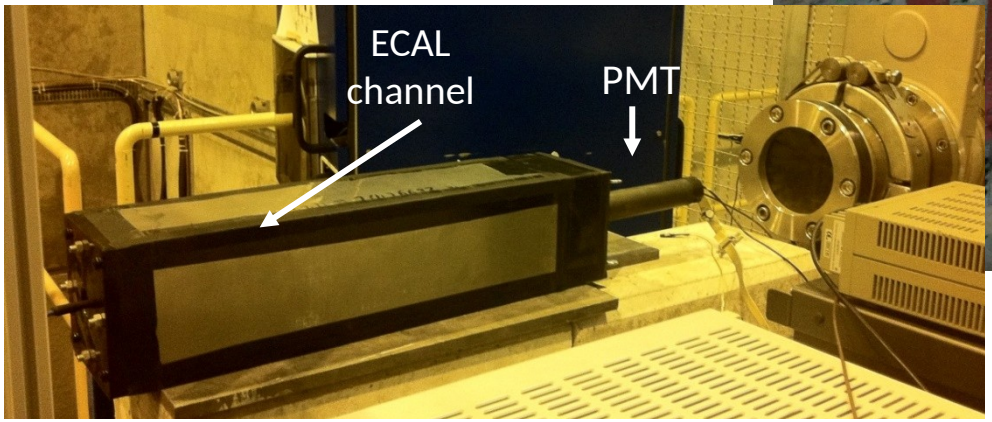




TEST BEAMS

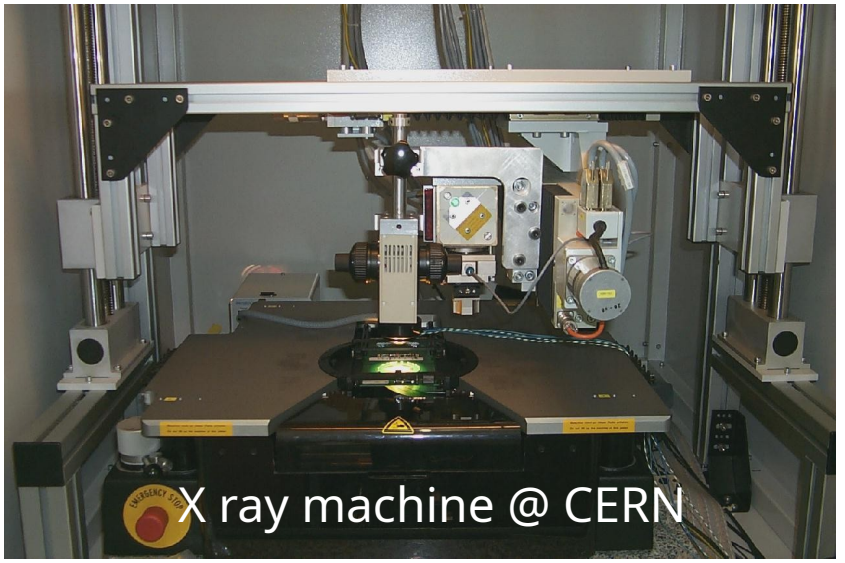
- We had a "home made" acquisition based on a USB interface and a software designed in our lab
  - The test beams have always been the place for discoveries of "features" of our systems
  - Having our own acquisition permitted to adapt it "on the fly" sometimes

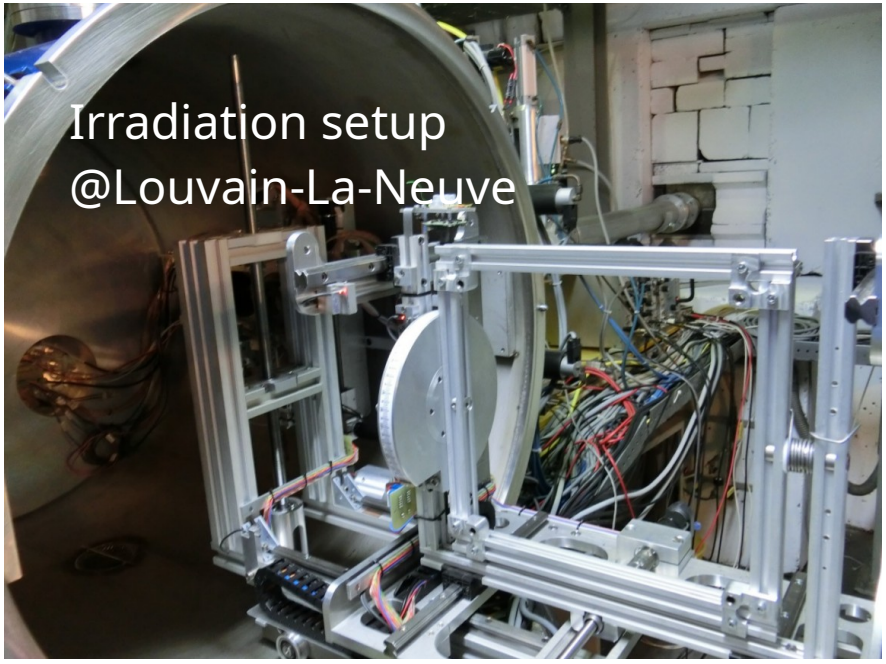




IRRADIATION TESTS

- We had done many tests before the Run I
  - GANIL, CERN, Louvain-La-Neuve, PSI, CPO
  - We re-used components tested for the Run I design
  - But we could not do that for the most critical ones (FPGA, analog chip, …)
- We organized tests at CERN and Louvain-la-Neuve
  - We benefited a lot from the possibility of “last minute” designs of tools by the technicians of the labs
  - Being able to adapt quickly was a quality



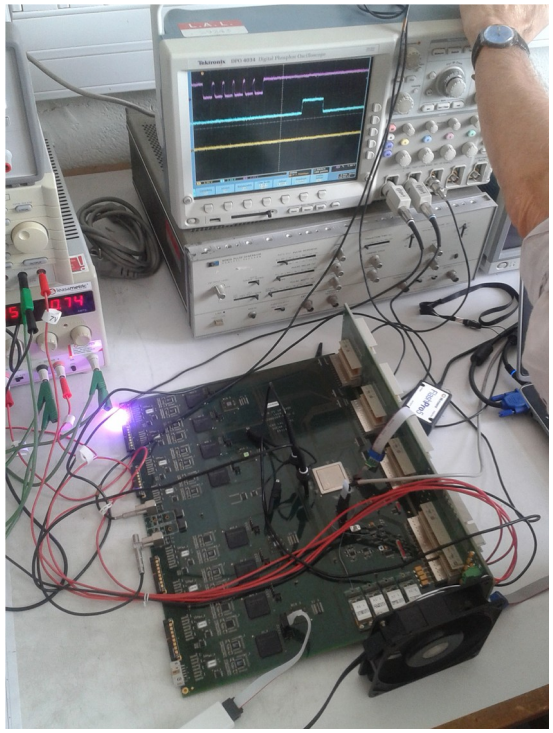


EDU AND JOAN IN THE PROTON IRRADIATION BUNKER

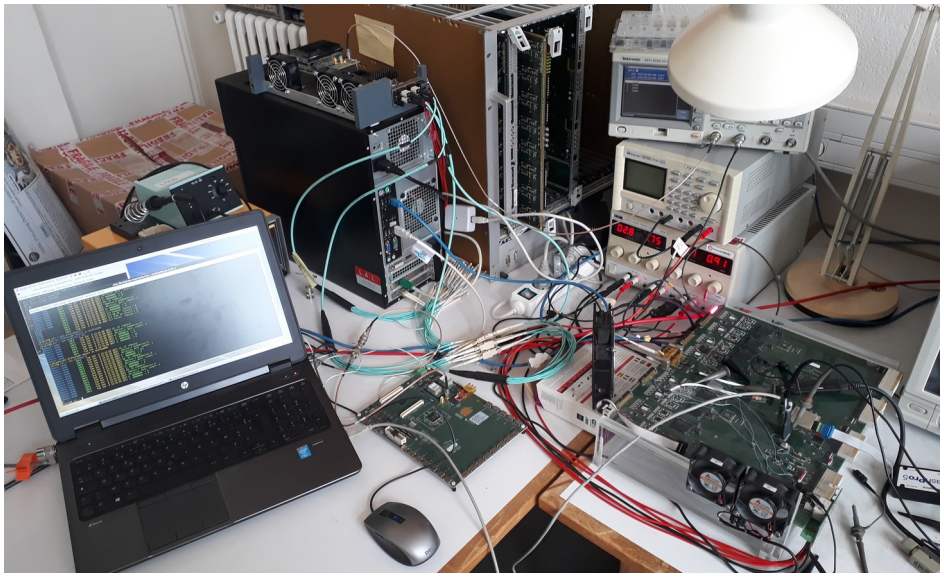
- A key ingredient consisted in having a nice and friendly atmosphere in the group
  - This depends on the people you work with !
  - I don't think that putting pressure on people is the way to go
  - But we could afford it as we had quite a lot of margin in the preparation of the Run III

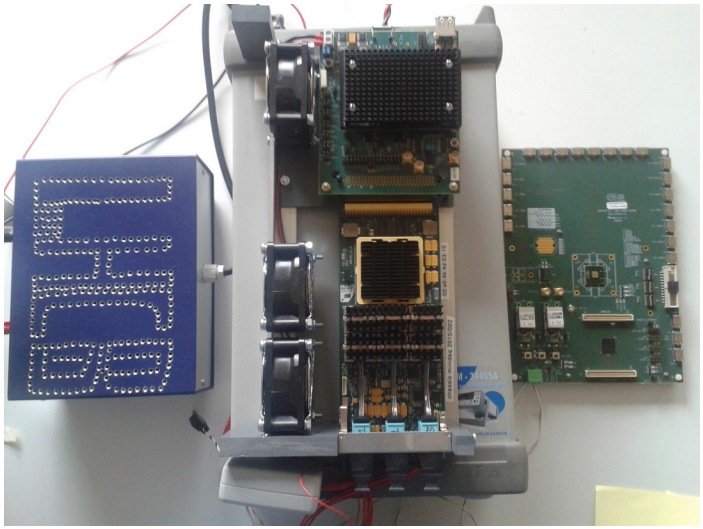
FIRST FEB PROTOTYPES

- It was important to have nice and efficient tools (not necessarily expensive !) to debug and study the systems under development
  - We benefited from old tools designed for the Run I
    - Handy backplanes, frames to hold the prototypes
    - Don't necessarily dump old things

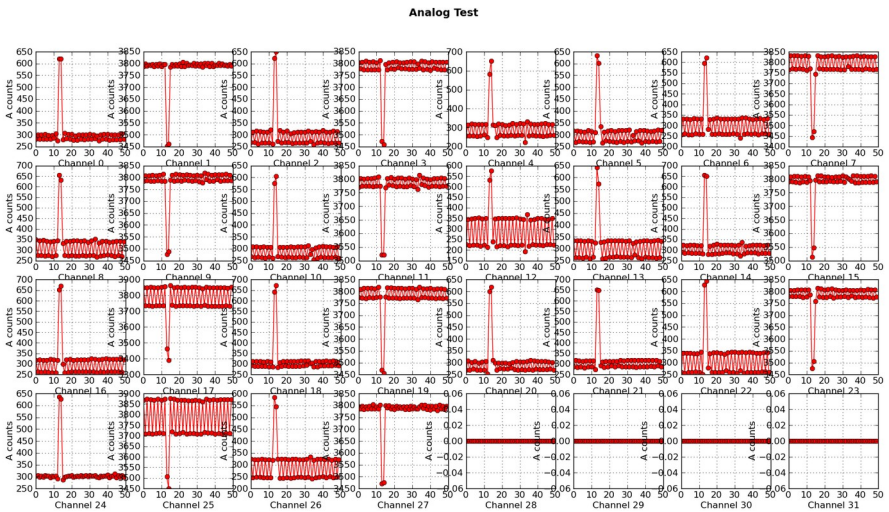


ACQUISITIONS



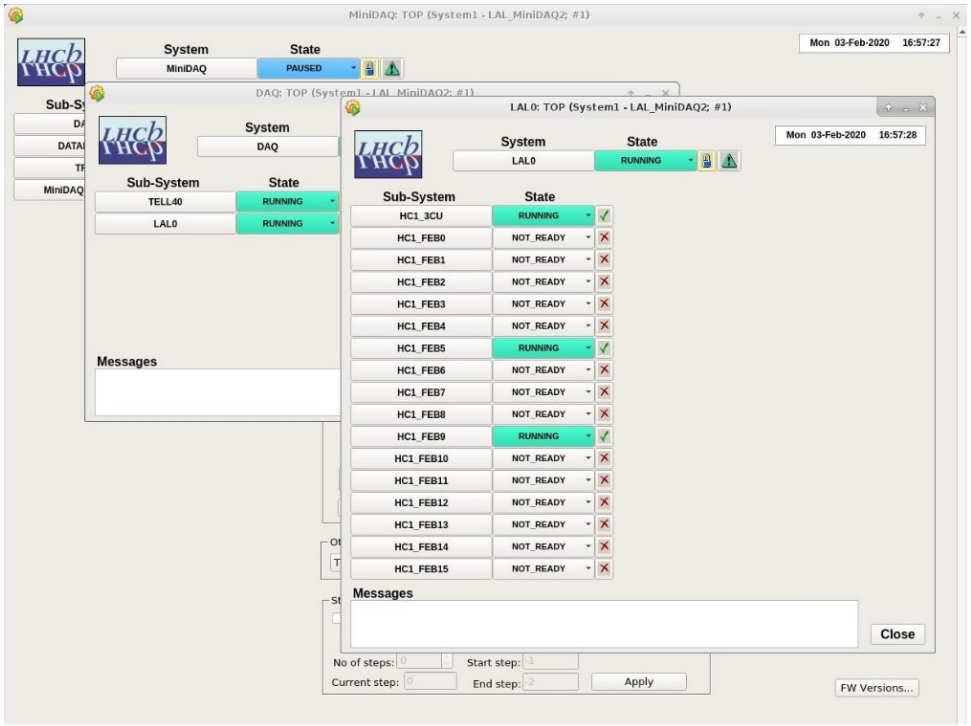


- We had our own acquisition based on a USB port and some C++/python programs
- We received a MINIDAQ early
  - But not ready yet / in heavy development
    - not easy to use
  - We needed a “stable” acquisition while the optical link acquisition was still under development → USB
  - What do you do when you have a failure of the optical part ?



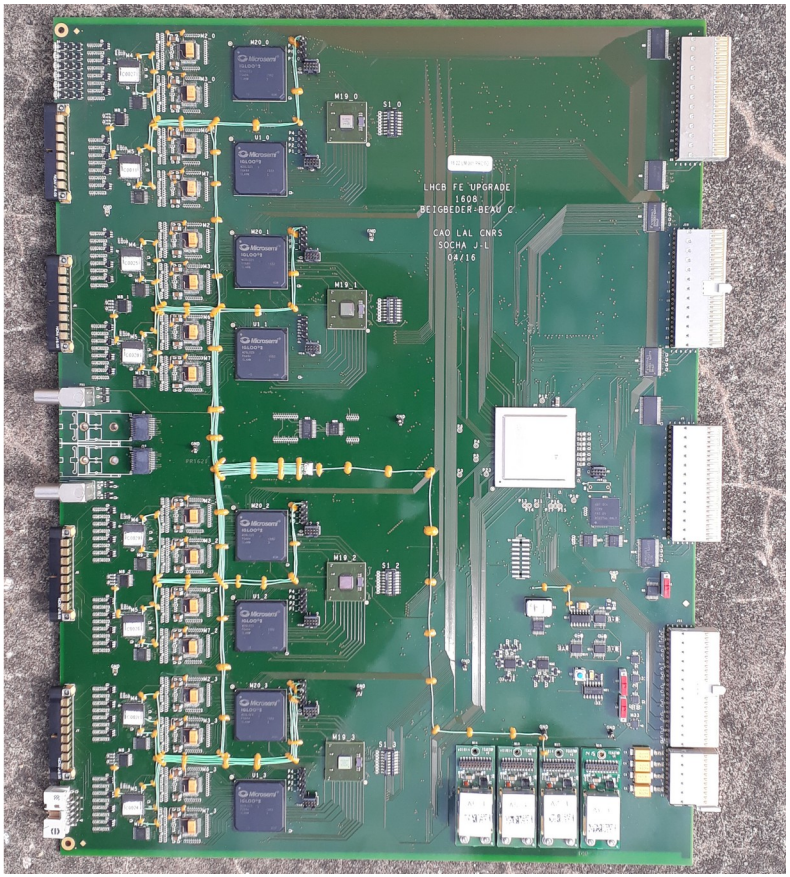
SOFTWARE FOR THE DETECTOR

- We had the chance of having from the beginning computing engineers interested in detector design and detector engineers interested by the software
  - Could fill the gap between the software and the hardware
  - Helped a lot in every day debugging of the hardware



MARKETS

- 2 big markets for the upgrade
  - FPGA (CERN)
  - The FEBs (CNRS)
    - Could avoid market for the 3CU
- FPGA
  - No choice in the components
    - One company… but several distributors
  - SciFi had a (very) bad experience,
    we (CERN) benefited a lot from their difficulties
- Concerning the FEB
  - 5 companies responded to the market survey
    - We had worked with one of them → made our first proto, our preference
    - One company was very aggressive in term of cost and schedule
  - We can imagine that the one we had "choosen" thought CNRS would accept an important overcost
  - Tried to reduce to the minimum the impact of the cost on the choice of company, but this was not sufficient
  - No possibility to visit or contact any company after the market was launched and until it was closed !
    - Our visit of the "winner" increased our worries

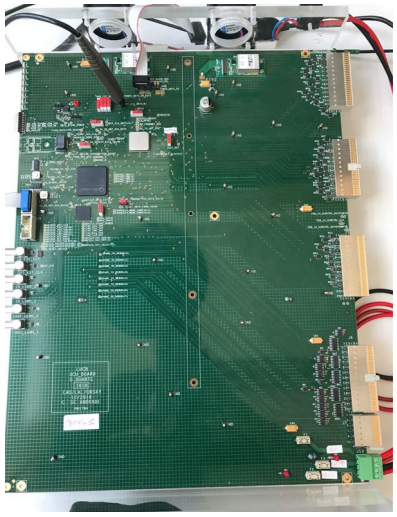


MARKETS

- At the end of the first visit, they called a taxi to take us back to the airport… a Maserati
  - First time I seat in such a car
  - This was a bad sign : be careful if this happens to you

- A dark cloud appeared when they presented the detailed schedule of the production a couple of months later
  - Incompatible with the LHC schedule
  - In complete violation with the contract they had just signed !
  - We took a bus to go back to the airport

- We had to keep the dialogue without allowing any drift of the schedule
  - Conflictual situation and meetings every one/two week(s) until the production ended
  - We had to follow the production and watch out carefully for its quality



- We could avoid launching a market for the 3CU…
- Having some market experts nearby is a clear asset

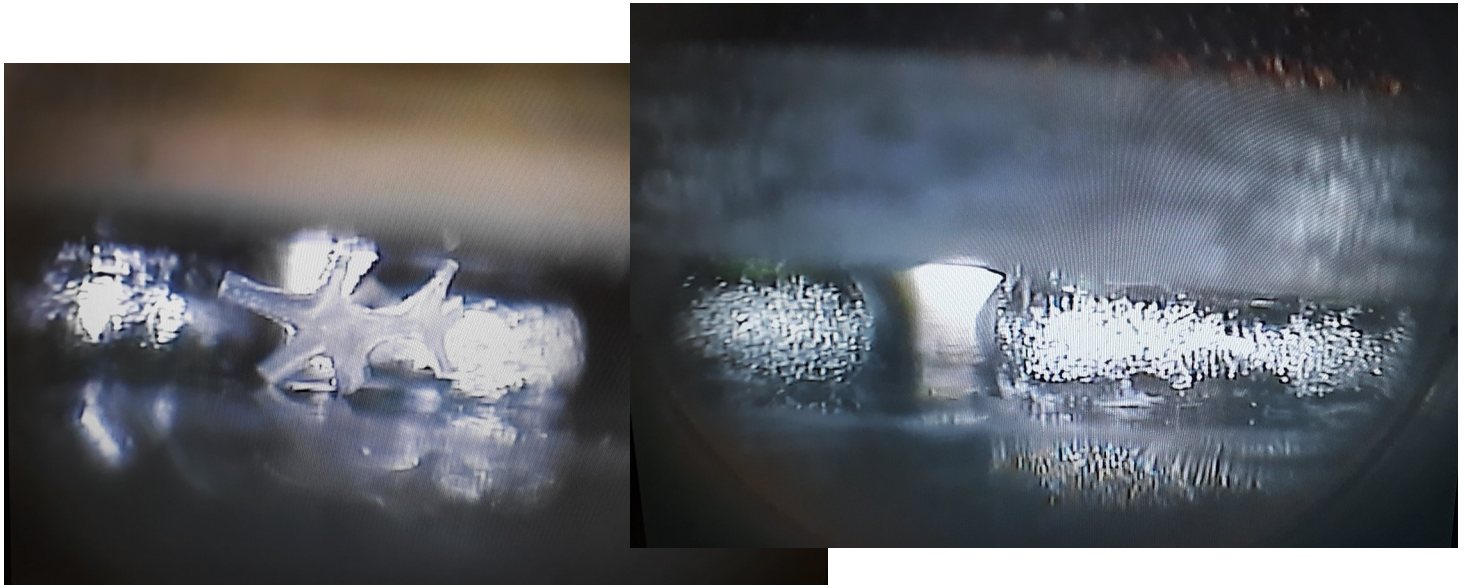
REVIEWS

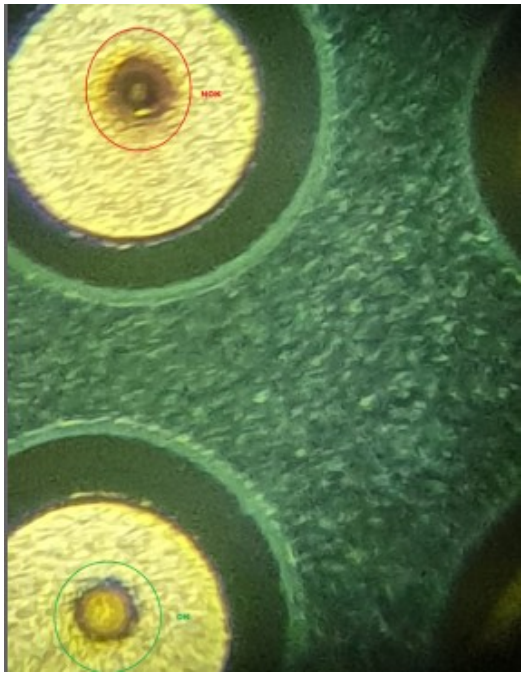
- **The CERN reviews (EDR, PRR, etc…) have been very beneficial to the projet**
  - We closely followed the advices and comments of the referees
  - Not following some remarks would have clearly led to serious difficulties
  - We have always been impressed by the competence of the reviewers
- **However, we have been asked to participate to other reviews (not @CERN)**
  - Those reviews did not aim at improving the project
  - No experts in the panels → would have been a waste of time
  - The aim was to give some activity to the administration → deny if you can !
- **We did not document the project enough and regularly**
  - We had good intentions, but by lack of time and laziness, we did not follow them
  - We clearly pay that now and recovering from this situation is painful

PRODUCTION

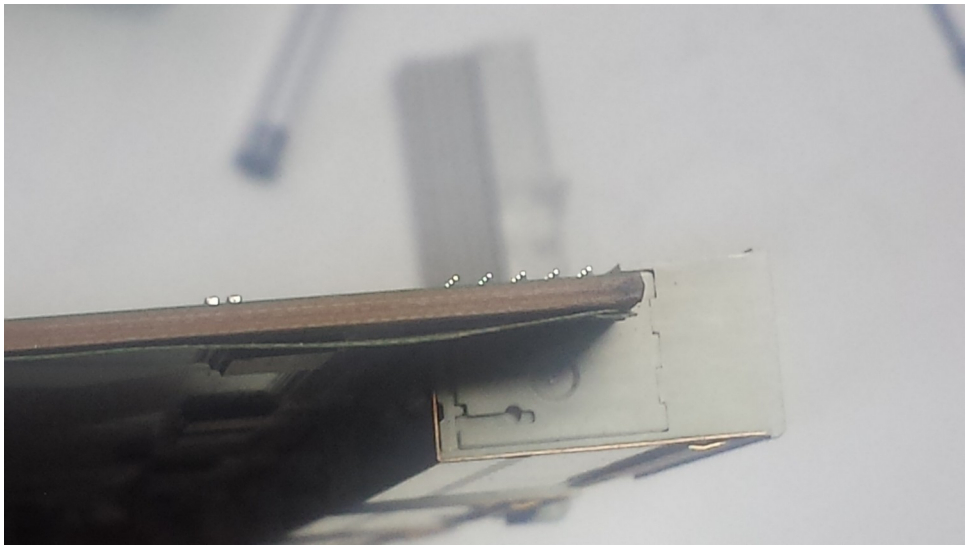
- Should we have produced with the company that made our first prototypes, we would have produced 16 + 280 boards
- We asked for 2 + 16 + 280 boards
  - 2 extra boards requested ASAP to check the competence of the new company
- The pre-production 16 boards (a crate) has been crucial
  - Discovery of a problem affecting ~13% of our optical light emitters
  - Could not be seen with a prototype or 2 boards
- For the Run I & II we had only 16 spares (~5%)
  - This was too few. Moreover, some boards could not be debugged after production → we started the Run I with ~ 12 spare FEB
- For the Run III we decided to make 32 spare boards (~10%)
  - It was a good idea : we could give a fraction of our boards for Plume
- We missed the *electronics meetings at CERN* that gathered ALL the sub-detectors during the Run I preparation (Jorgen Christianssen)

PRODUCTION PROBLEMS

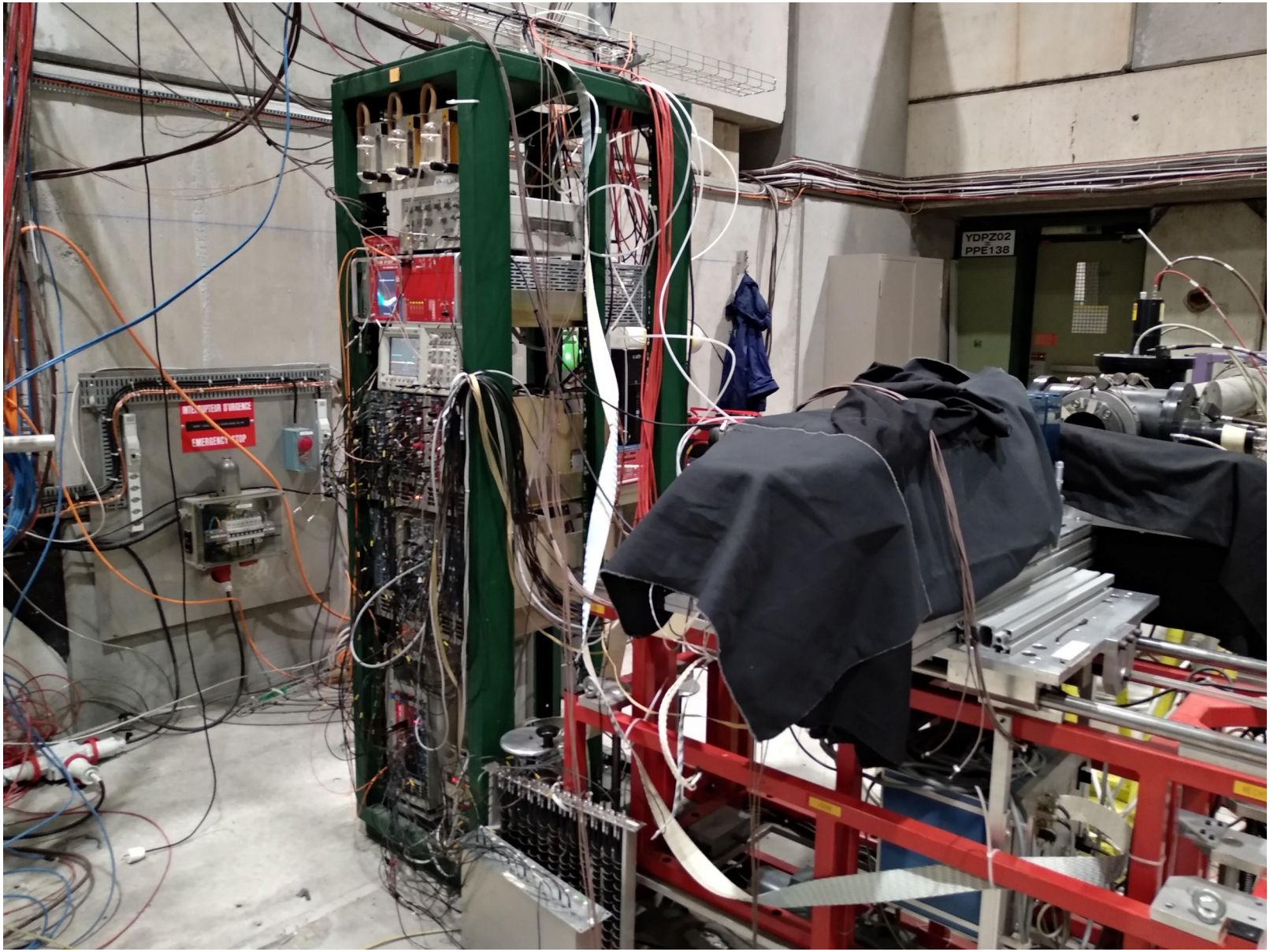




- We had some problems
  - Oxydation on the contacts,
  - Layers of boards not well glued,
  - Bad soldering, ...
- We started with a comfortable margin, we finished just on time !



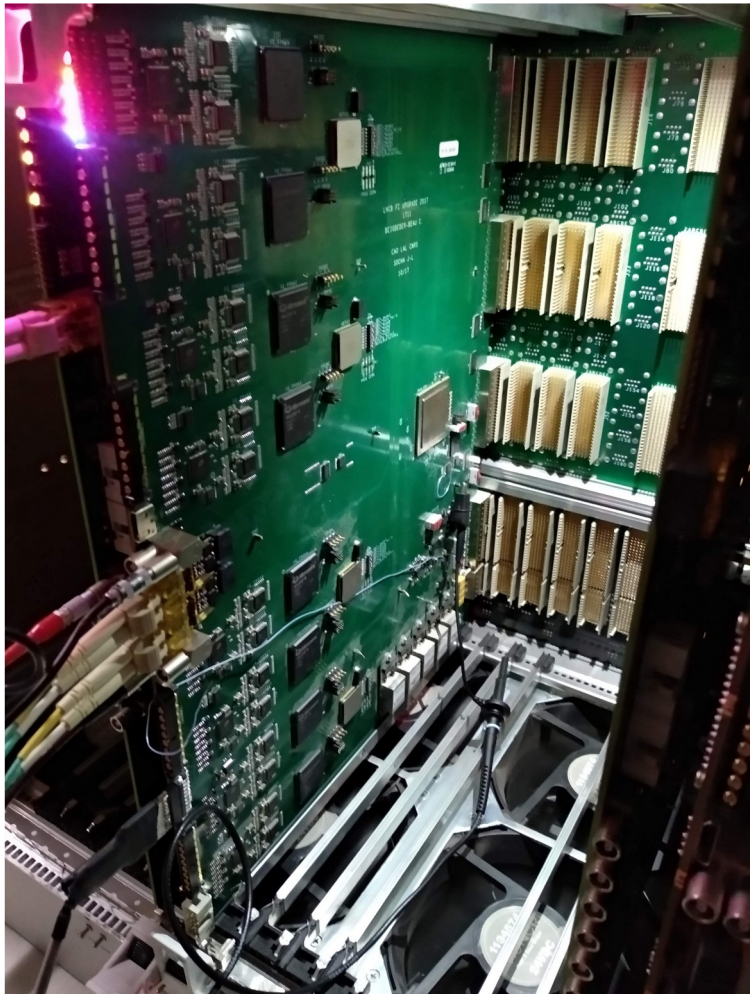
TEST BEAM WITH THE FINAL DESIGN

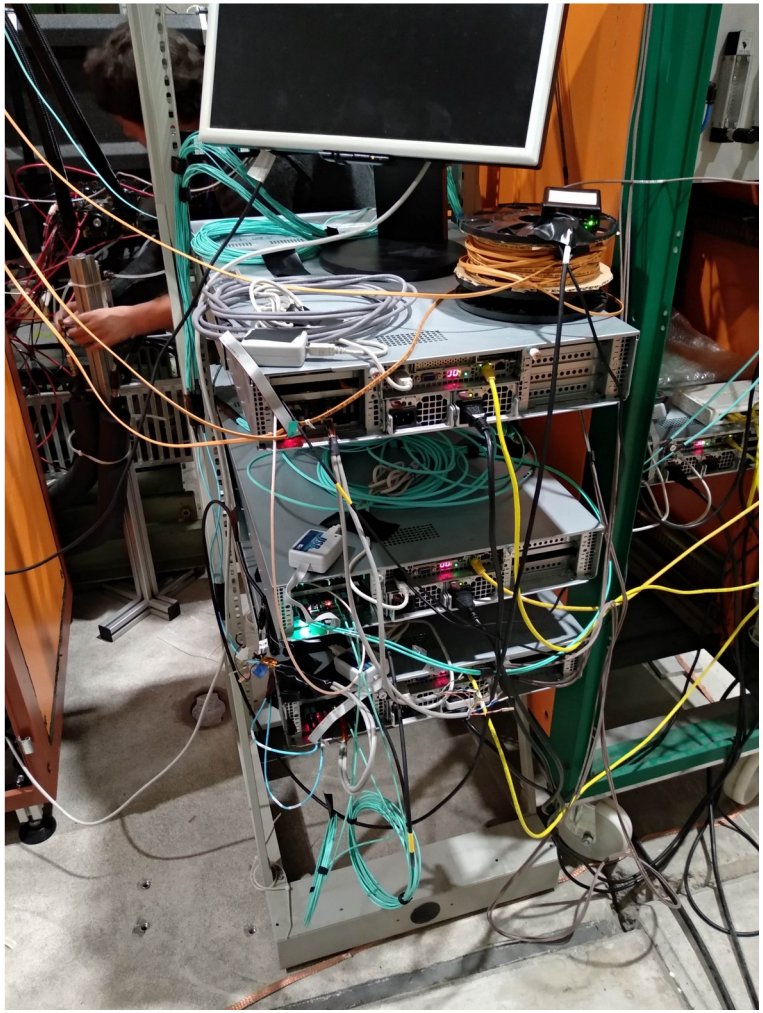


TEST BEAM WITH THE FINAL DESIGN

… a realistic acquisition (Minidaq3) and the online experts (big thanks !)

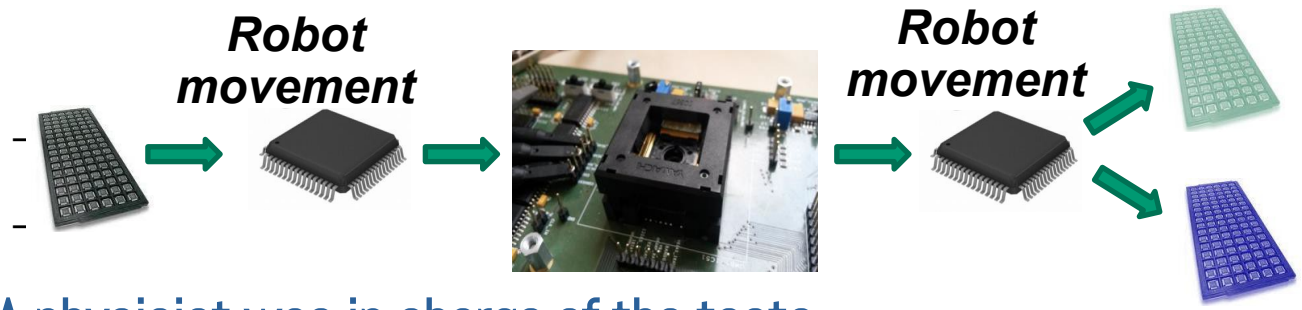
- Nothing would have replaced such a test !

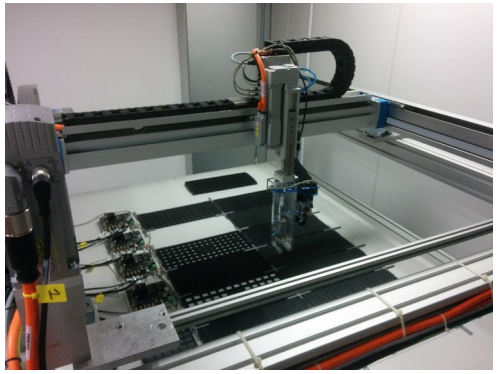




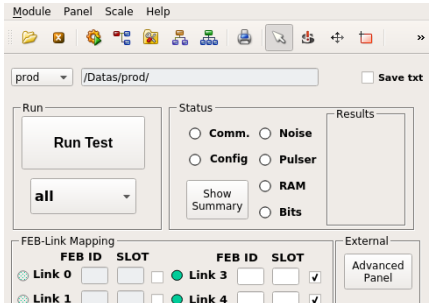
TEST OF THE PRODUCTION

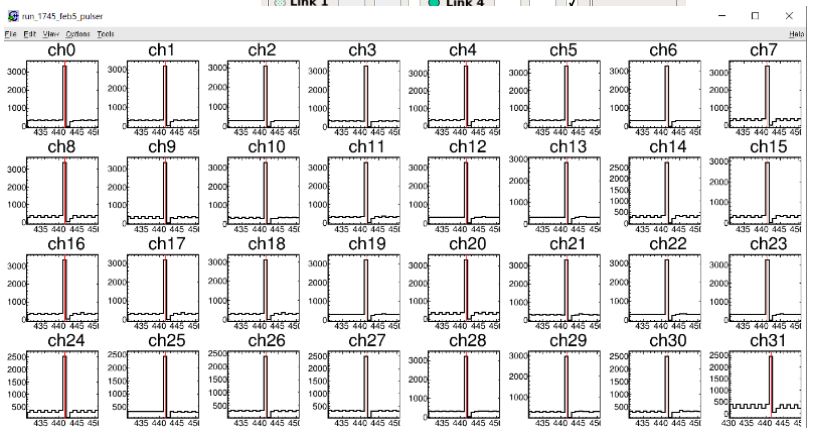
- Barcelona fully automatized the test procedure of the more than 3000 ICECAL chips





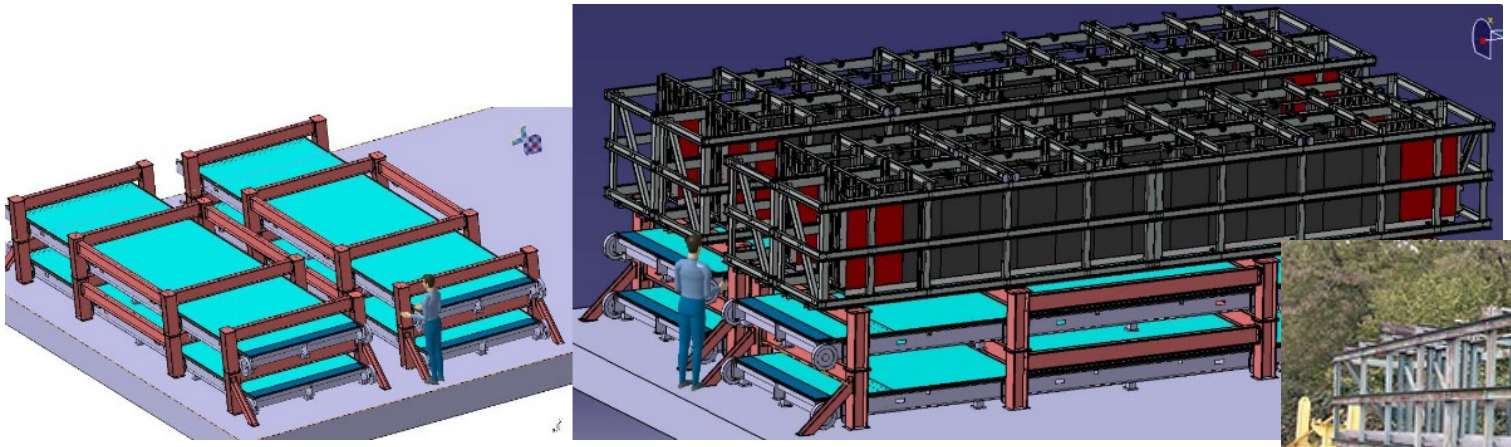
- A physicist was in charge of the tests of the production of the FEB
  - The efficiency of the software tools has been important to speed up the validation of the production (~300 complex board to test)
  - Contributions of the members of the groups for the test





- The organisation was such that from the early development to the end of the projects, we had physicists and engineers working together in the lab

DISMANTLING OF THE SPD / PS

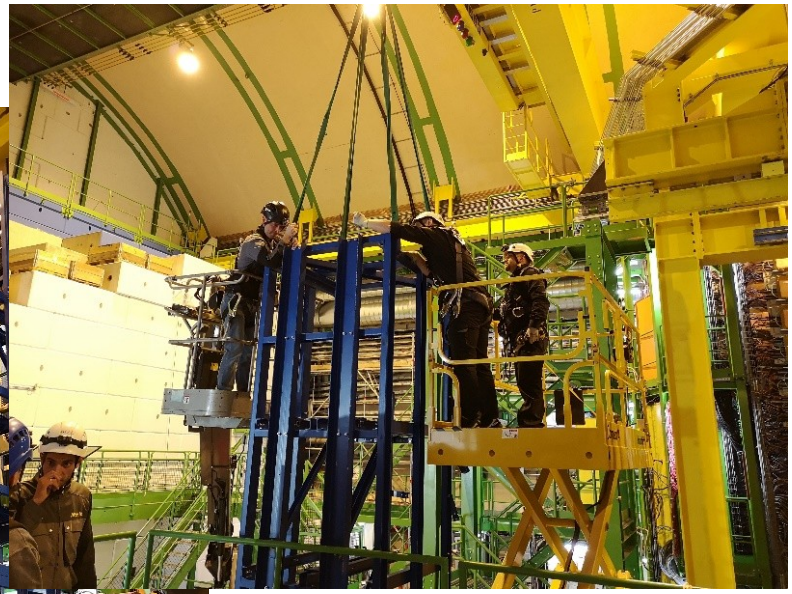


- The dismantling of the SPD – PS has been a heavy task
- Require human resources from several groups
  - It was important to have people from CERN / the pit and people knowing perfectly the detectors and how they had been built more than 10 years earlier
- Several tools used for the construction have been re-used / fixed / adapted / copied / developed
  - It was a good idea to keep the old tools !
- A precise schedule had been prepared
  - A delay may shift the activities of other teams
  - Dismantling was followed closely by the installation

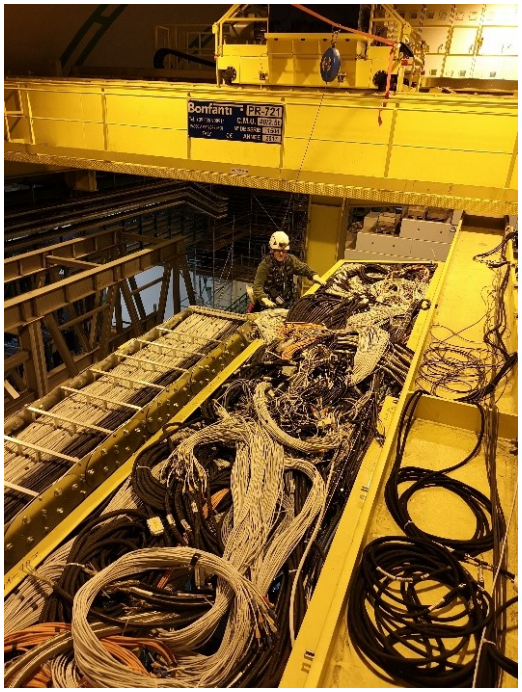
TESTS OF THE TOOLS

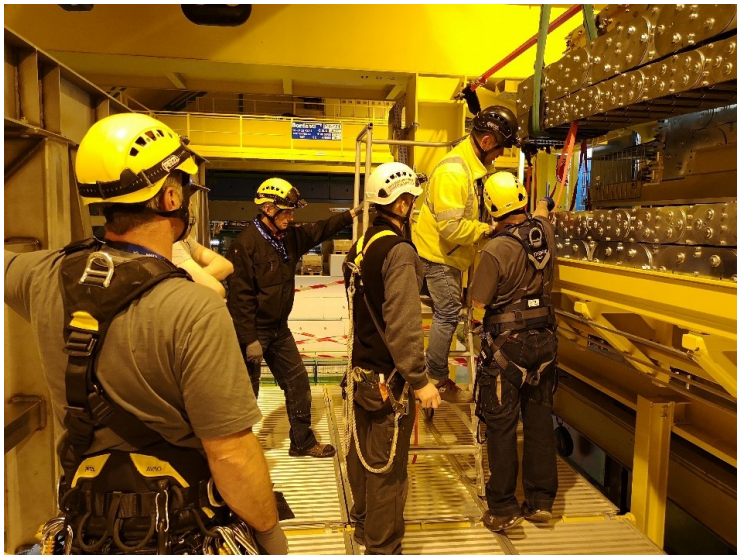
- Tools tested with a 3t load

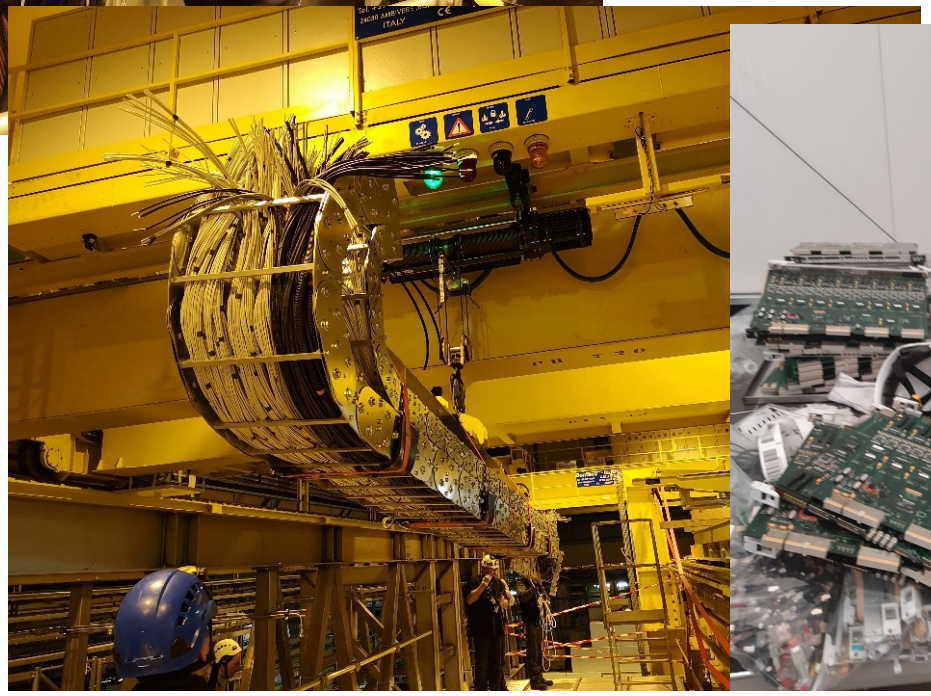
DISMANTLING

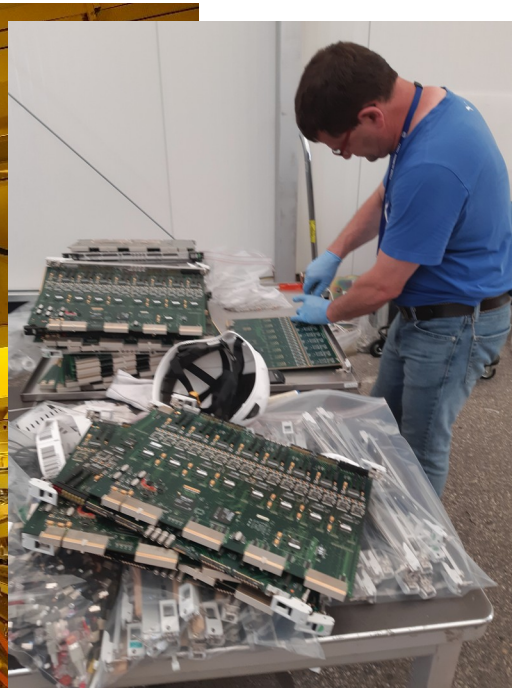


DISMANTLING



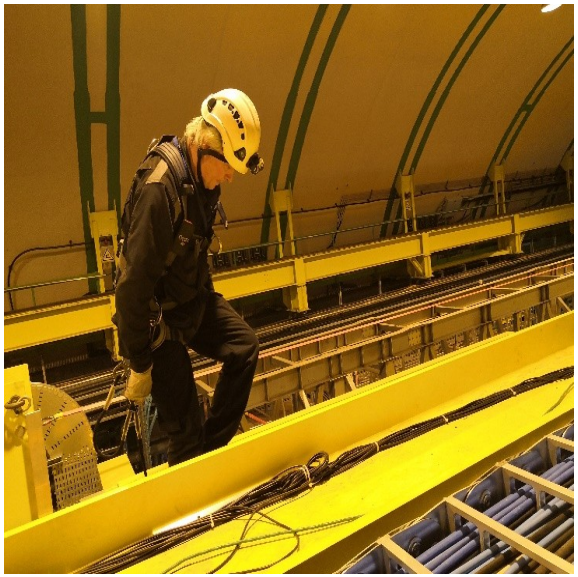






CABLES AND OPTICAL LINKS

- This is probably the only field were the activity was properly documented… thanks to the CERN teams that were in charge of the installation

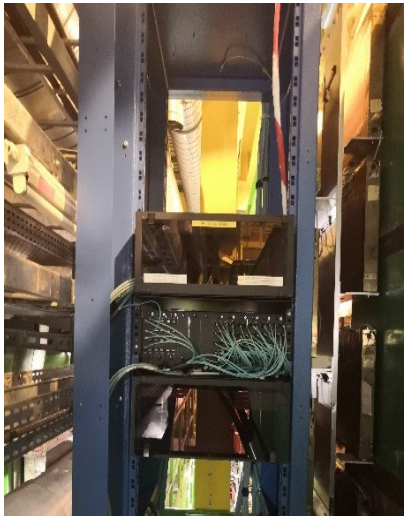


INSTALLATION OF THE ELECTRONICS

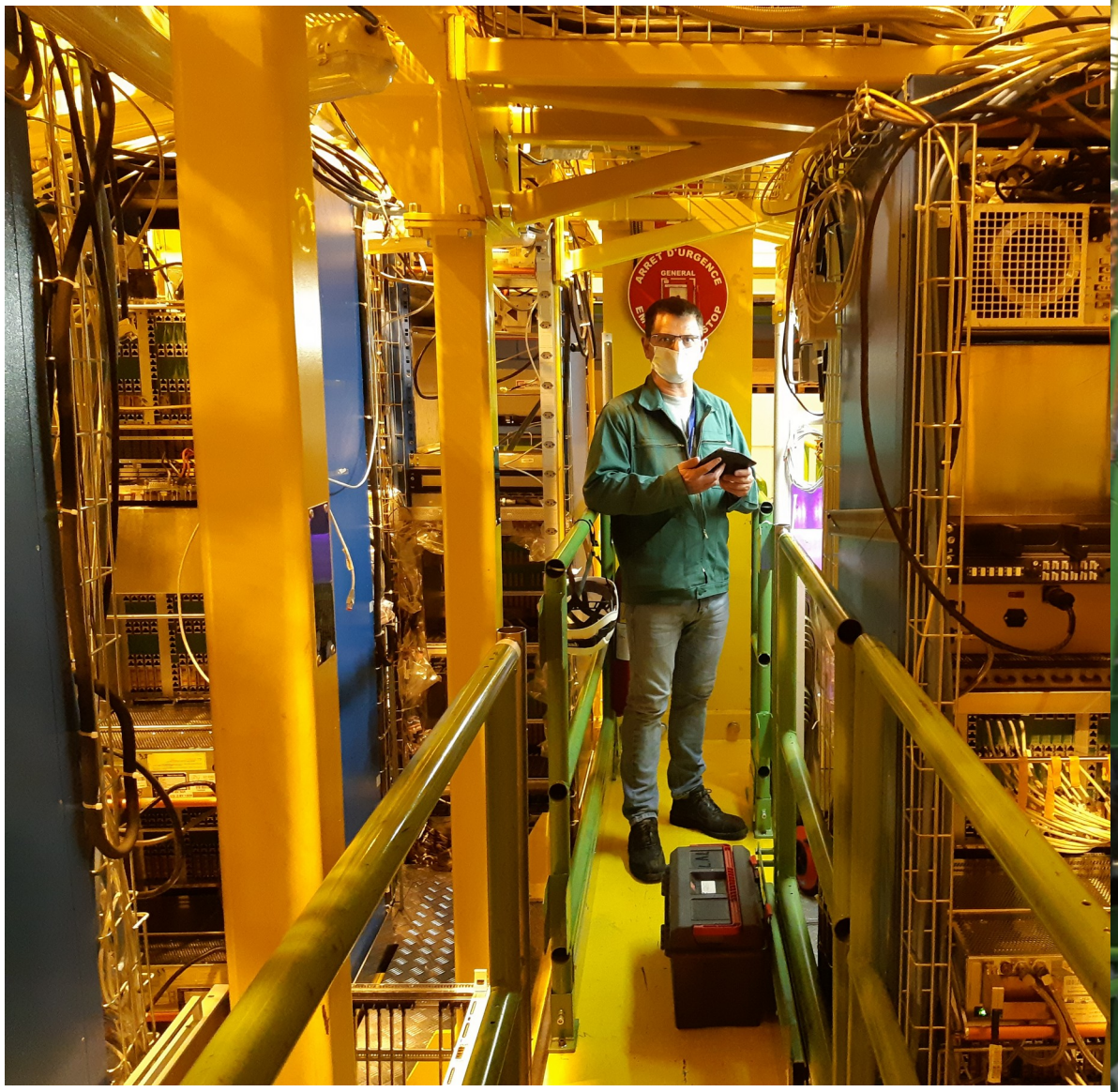
- It was important to put labels on the hardware
  - And it is even nicer to have labels that stay glued on the device and that you don't find on the floor after a while !

ECAL

HCAL



INSTALLATION OF THE ELECTRONICS

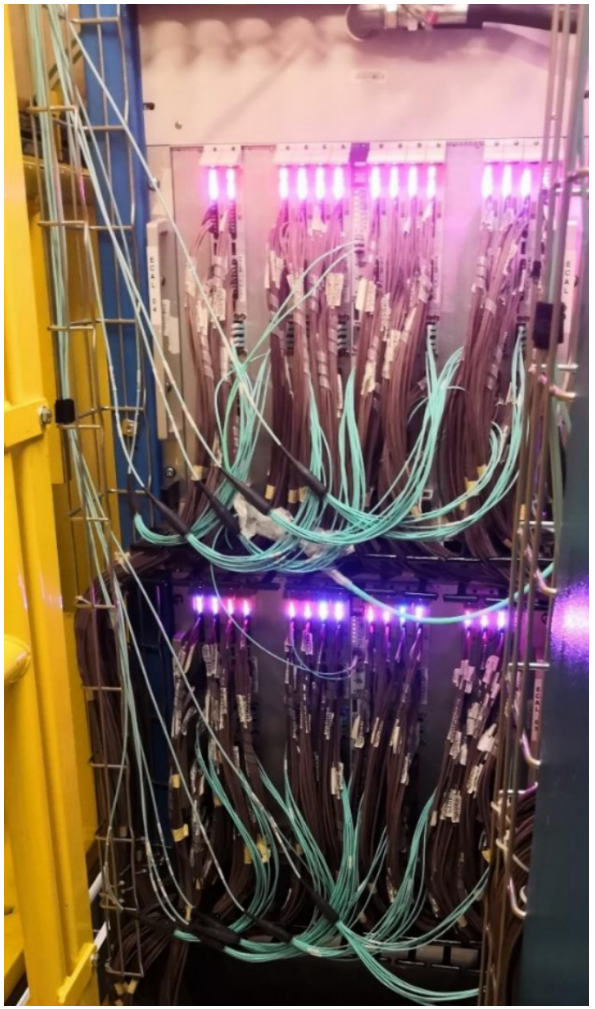


INSTALLATION OF THE ELECTRONICS

... Cabling could start

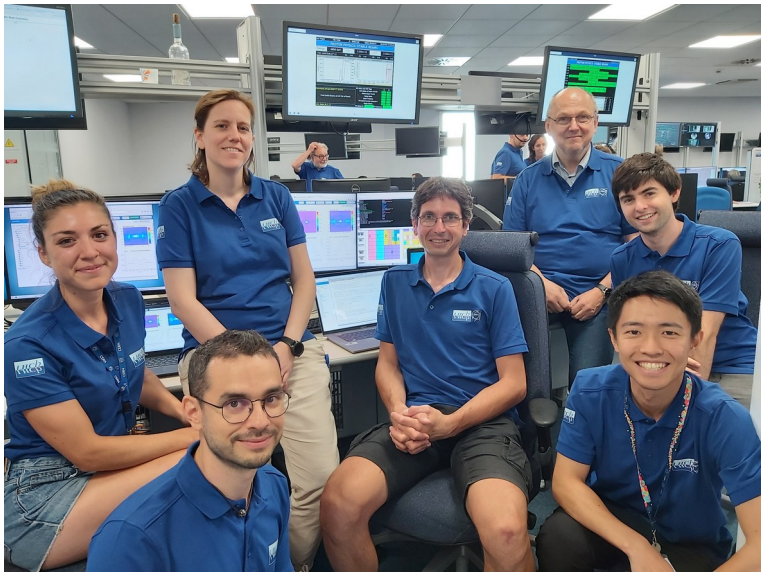
EVERYTHING READY IN 2021

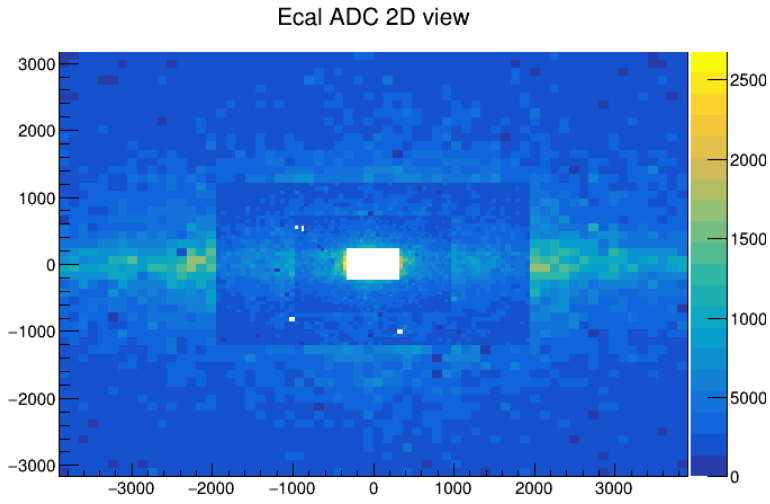
AND COMMISSIONING STARTS



COMMISSIONING

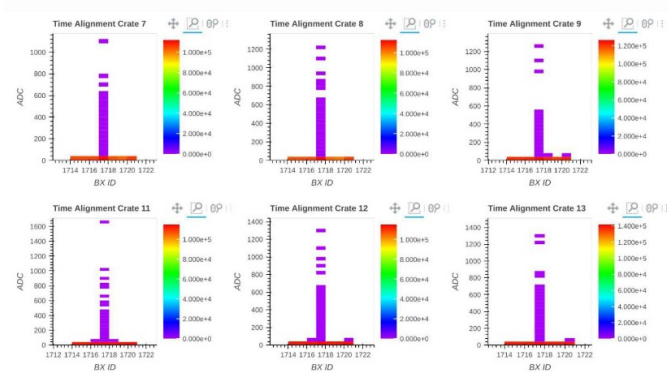
- With the commissioning the need for software experts (~young people) became more important
  - It is important to involve young people early in the project
  - We benefit from the methods developped for the Runs I & II
  - Still a huge work to adapt to the new systems
    - new acquisition, new framework, new constraints, …
    - rewriting everything from scratch could have been more efficient
  - It is important to start the software development early
    - The reconstruction, simulation (DD4HEP) developments started late
    - Thank to some extra-contribution we could catch up
    - Automatic test of the code is crucial
- The project relies on a VERY SMALL number of people
  - Not many exchanges between the upgrade I and upgrade II communities
- LHCb Upgrade II will depend on the success of the Upgrade I

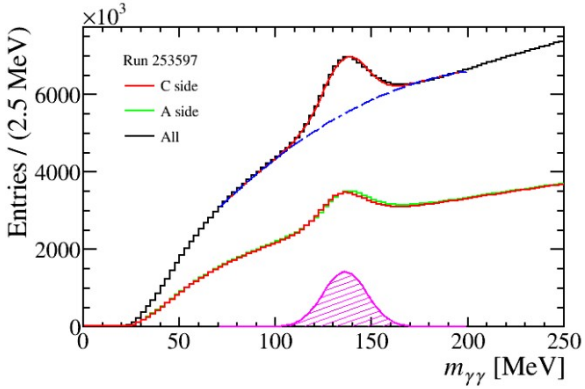


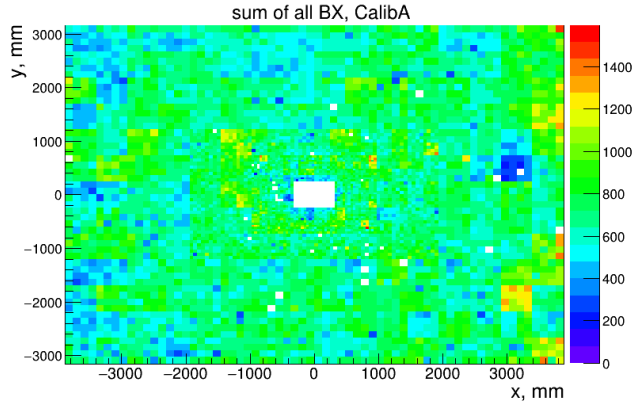


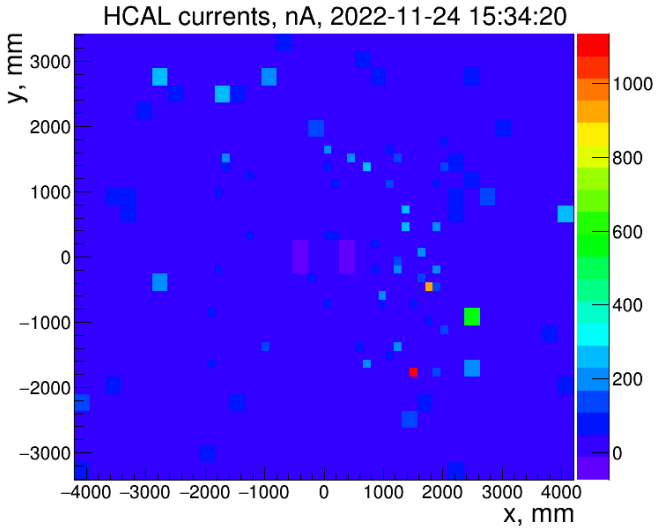
COMMISSIONING

- We rely on a small group of "old" experts for the maintenance
  - PMT / CW replacement, fixing the FEBs
- Younger people are essentially involved in detector tuning, analyzing the data









  - There are doing the most important work now
  - This dichotomy reflects probably our unability to involve new / young people early in the design of the detector and in the "hardware" activities
    - The control room/pit are the best places to learn how the detector works
    - We suffer from a distance between the people who made the detectors and the people who look at the data produced
    - We do not benefit enough from the experience of those who were analyzing data a couple of years ago !
  - My feeling is that this is not true ONLY for the Calorimeter system of LHCb
    - I don't think this was so true for the preparation of the Run I