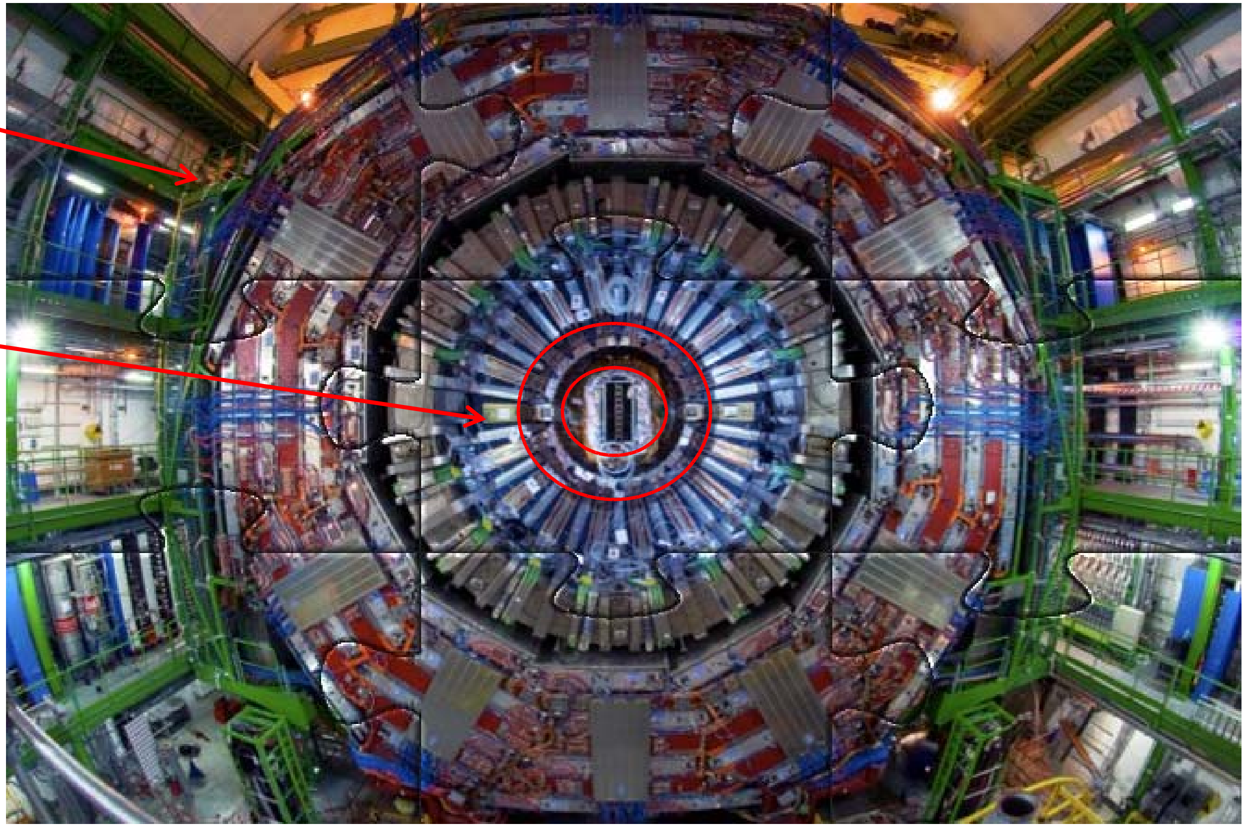
Installation, Commissioning and Performance of the CMS Electromagnetic Calorimeter (ECAL) Electronics

How to compose a very very large jigsaw-puzzle

CMS

ECAL

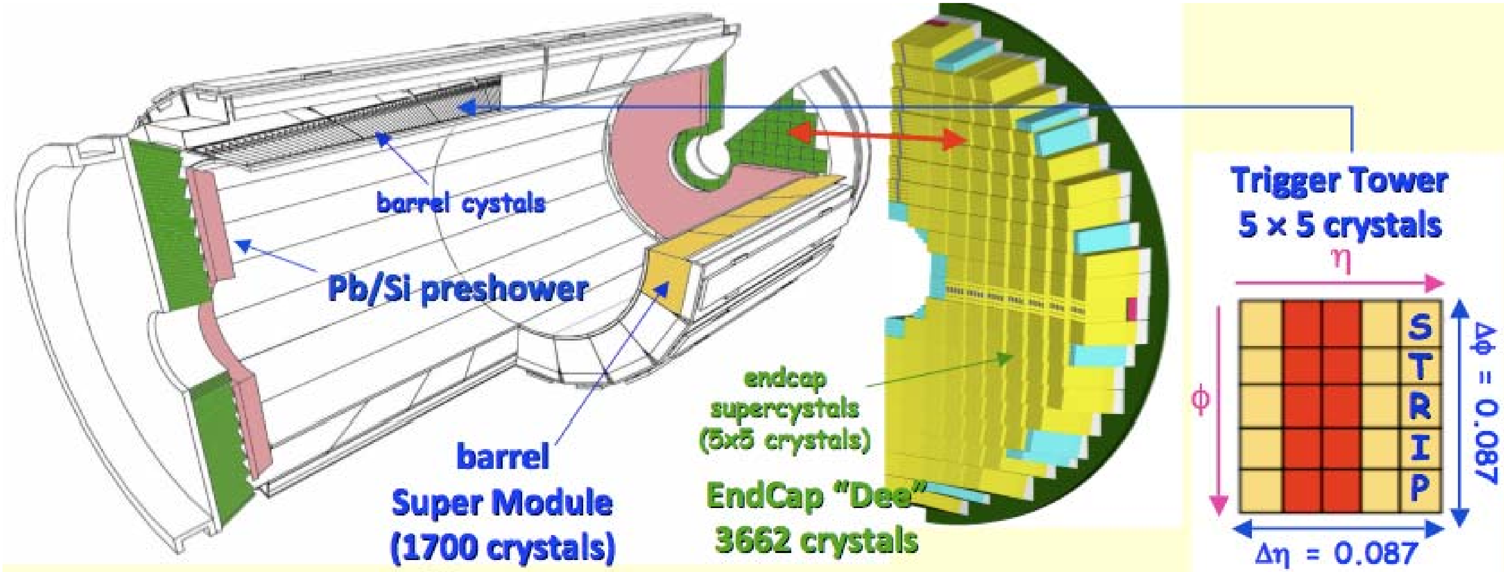


Nicolo Cartiglia, INFN, Turin, Italy

The CMS electromagnetic calorimeter

- 36 Supermodules, 1700 Crystal each
- 4 Endcap Dees, 3662 Crystals each
- 8 meters long
- 90 Tons of Crystal

In total, more than 75,000 channels



Construction

Before being sent to the CMS cavern, ECAL HW has been assembled and tested in many laboratories with final construction in several CERN sites.

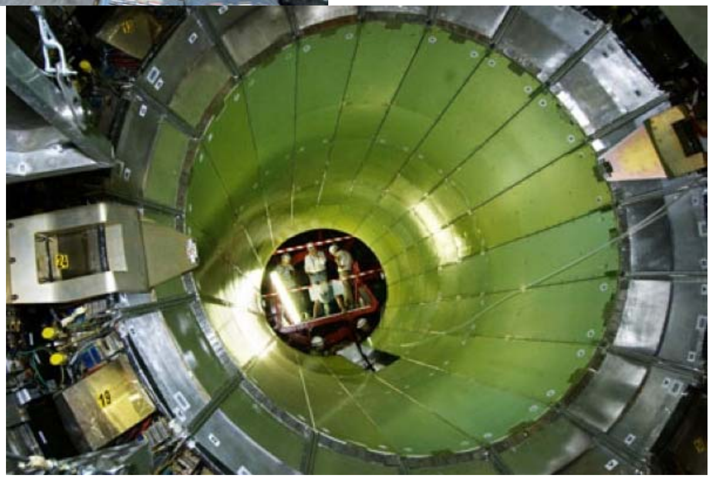
- Modules are produced in Rome and CERN
- SM are assembled at CERN
- On-detector electronics is installed and tested at CERN Prevessin.

CERN integration center:
4 SMs in preparation

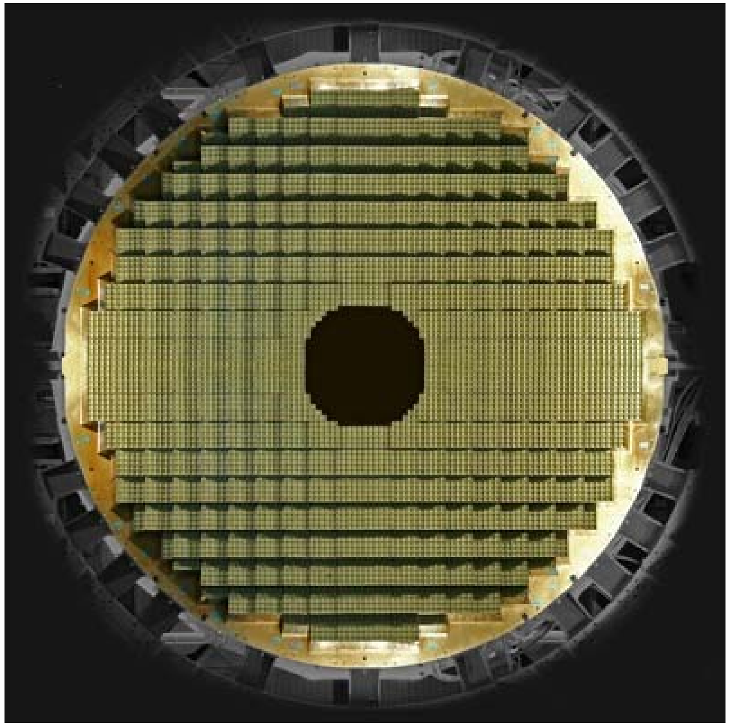
Detector Installation

After many years of work ECAL is inside CMS

April 2007:
first SM



July 2007:
Barrel Done



July 2008: Endcap Done

Ancillary Systems

The very first step is the final commissioning of the ancillary sub-systems (which happened concurrently with the installation):

- CMS & ECAL Safety System (poster pres.)
- Cooling
- Nitrogen flow
- Detector Control System (poster pres.)

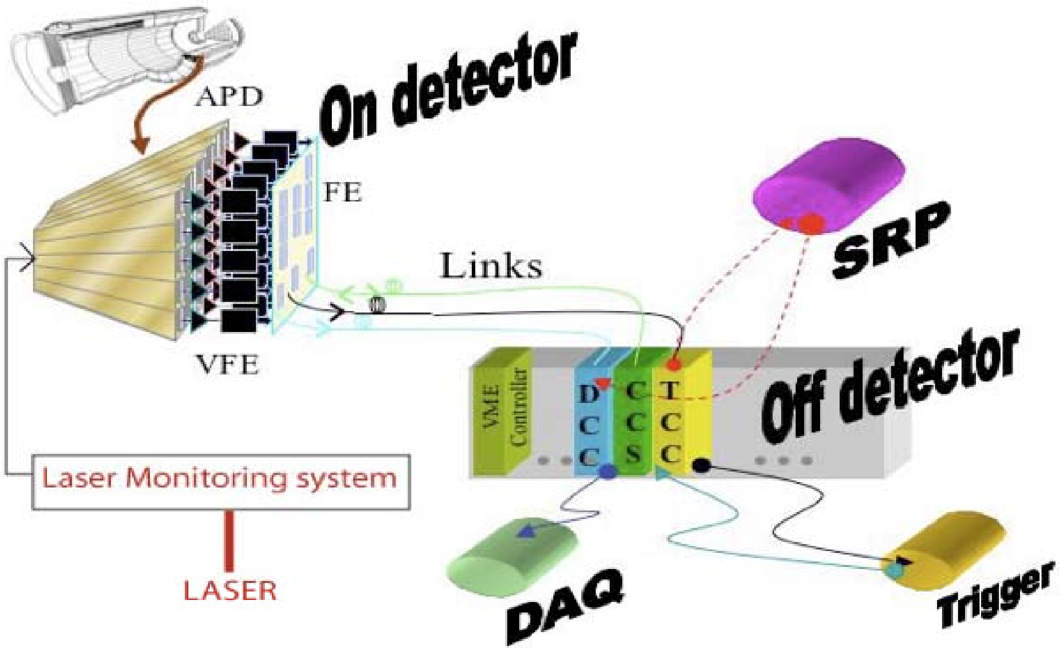
These sub-systems have been running now for ~ year and they are very reliable. We are still suffering occasionally from ‘infrastructure’ problems such as the lack of cold water, power cuts, evacuation alarms which provide us with a few hours of rest….

Commissioning

The commissioning of the electronics has two main aspects

- Hardwar
  On- & off-detect
  High and Low vo
  Laser monitori
  Fiber optic

- DAQ:
  Necessary softwa
  syste

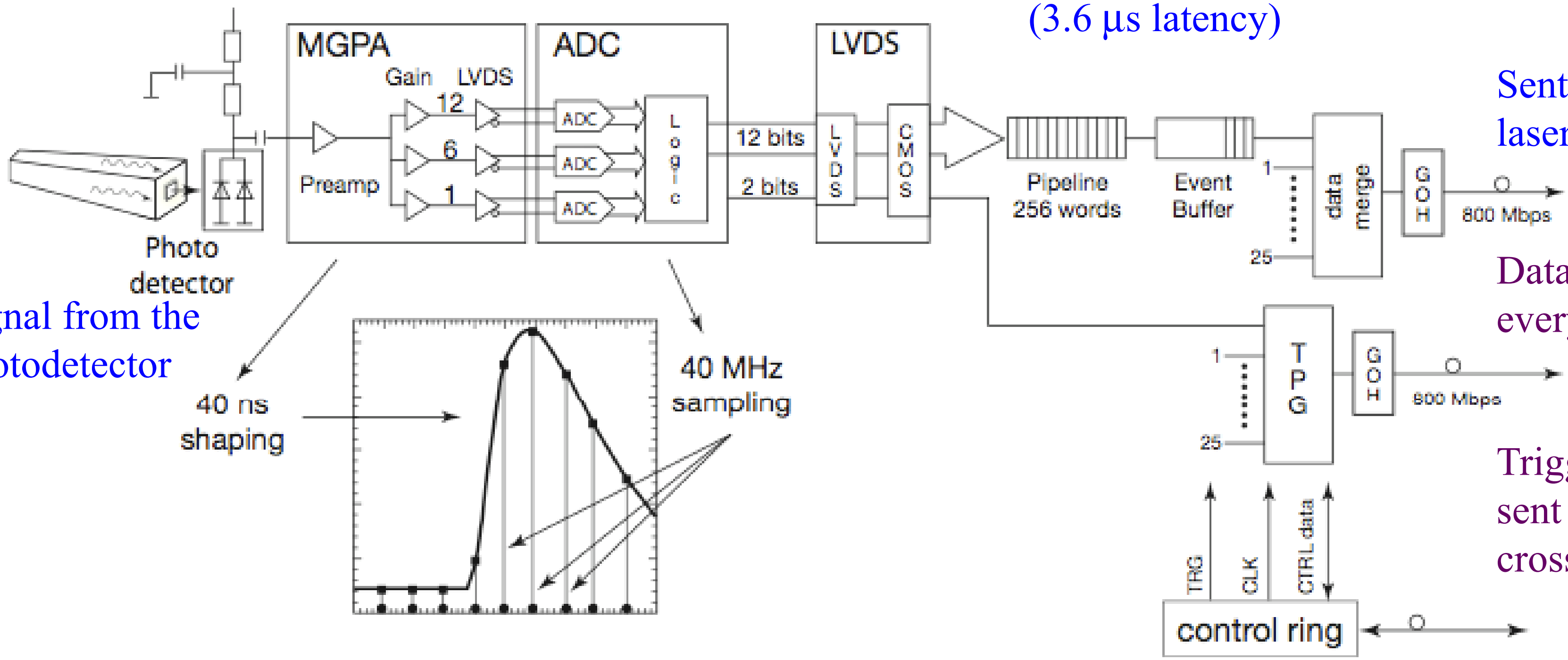


On-Detector Electronics

MGPA: Multi-Gain-Pre-Amplifier with 3 gains (1, 6 and 12)

ADC: 4 40-MHz 12 bit digitize the 3 outputs

The highest, non-saturated gain is selected and kept in memory waiting for a L1-trigger signal (3.6 μs latency)



Sent off detector via laser fibers

Data information sent every L1

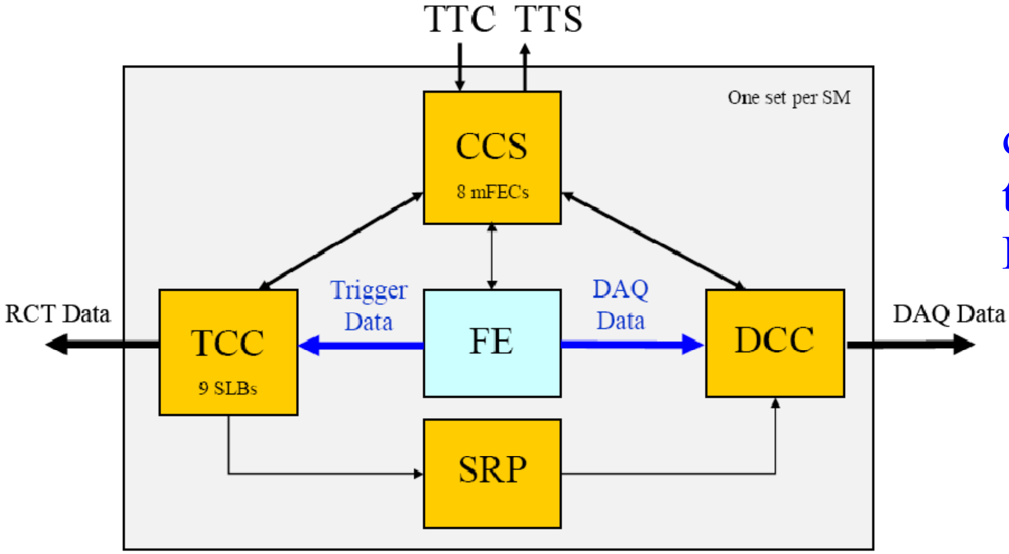
Signal from the photodetector

Trigger information sent every bunch crossing

Overall the on-detector electronics is made by ~ 21,000 custom made boards, 2.3 W/ch => 180kW total

Off-Detector Electronics

CCS: reception/distribution of LHC clock and control signals + front-end initialization



TCC: encoding of trigger primitives and transmission to Regional Calorimeter Trigger at 40 MHz + classification of trigger tower importance and transmission to SRP at Level 1 rate

DCC: integrity check + data reduction + transmission to central DAQ at Level 1 rate

SRP: send to the DCC the list of trigger towers to be read out

Overall the off-detector electronics is made by 18 VME-9U and 1 VME-6U crates controlled by 28 crate mounted PCs

High and Low Voltage systems

The HV system provides the necessary voltages to the photo-detectors (APD in the barrel and VPT in the Endcap)

- Barrel: 18 CAEN crates, each equipped with 4 HV modules. A total of 1224 independent channels providing 350-400 Volt to groups of 50 crystals are installed
- EndCap: 2 CAEN crates provide 8 independent channels supplying 800-1000V for the anodes, and 600-800V for the dynodes to groups of ~1800 photodetectors. All VPTs in a quadrant have the same bias voltages.

The LV system supplies the voltages to the front-end .

The system is produced by Wiener and it comprised a total of ~ 680 LV channels in the Barrel and ~ 150 for the Endcaps

Laser monitoring system

A laser system is used to check transparency changes in crystals:

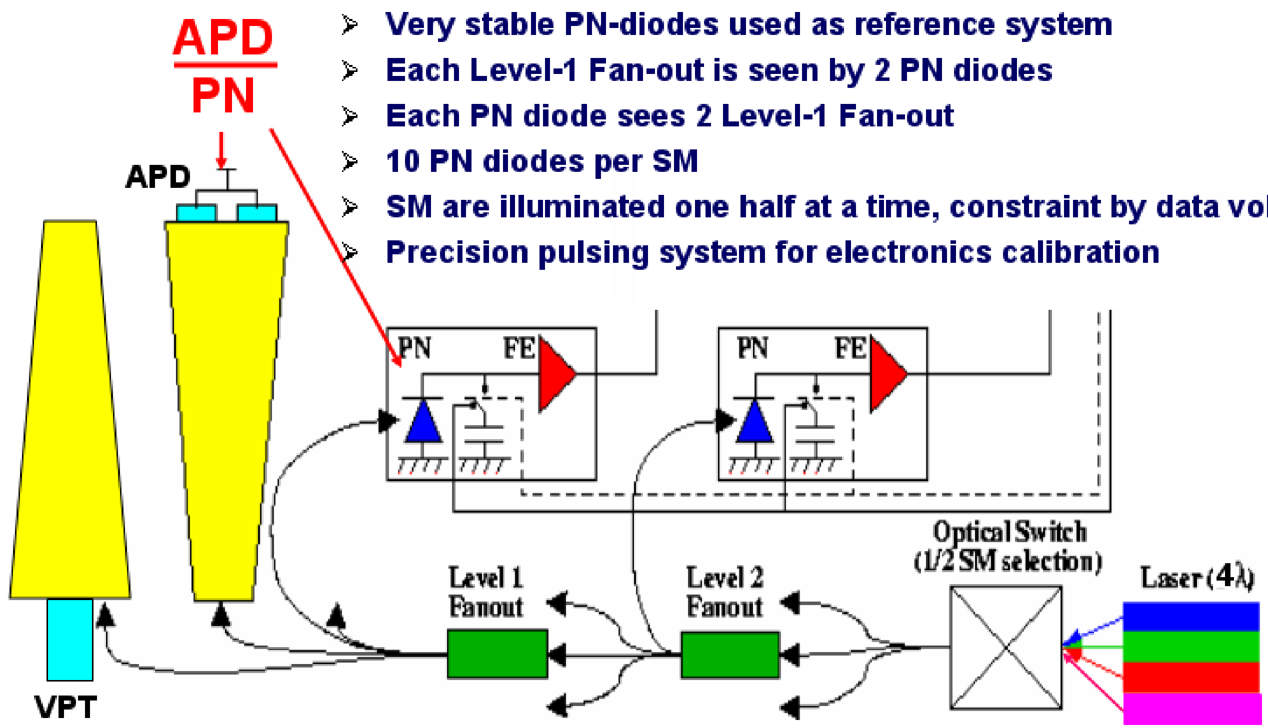
- Changes is dose-rate dependent,
- 1 or 2 per cent at low luminosity
- Oscillation due to LHC cycle O(10%) at eta=2.5, nominal luminosity

Two wavelengths:

λ=440 nm, to follow the changes in transparency due to radiation

λ=796 nm to verify the stability of other elements

- **Very stable PN-diodes used as reference system**
- **Each Level-1 Fan-out is seen by 2 PN diodes**
- **Each PN diode sees 2 Level-1 Fan-out**
- **10 PN diodes per SM**
- **SM are illuminated one half at a time, constraint by data volume**
- **Precision pulsing system for electronics calibration**



Fiber optic links

Data transmission between the on- and off- detector electronics uses optical fibers:

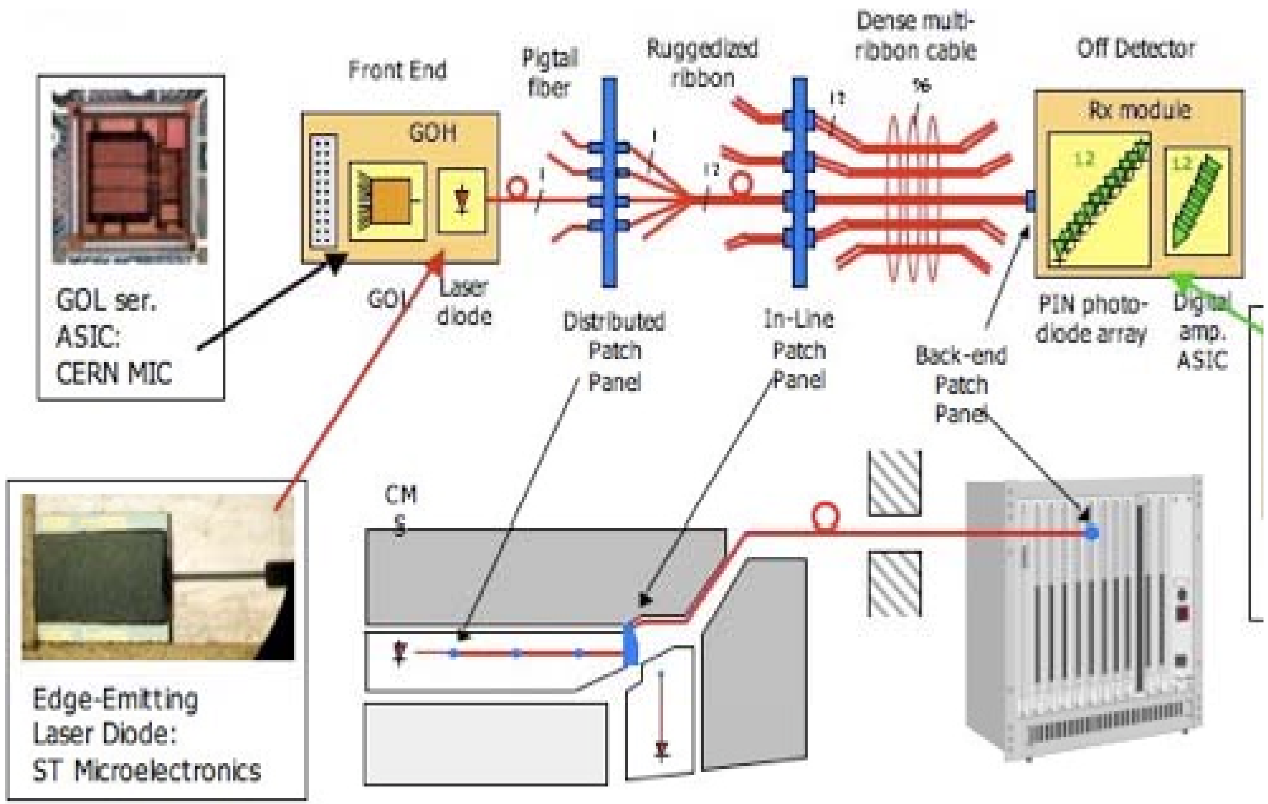
•Data: 1 link / trigger tower

•Trigger:

barrel:1 link / trigger tower;

endcap: 5 links / trigger tower

•Total capacity ~640Mb/s

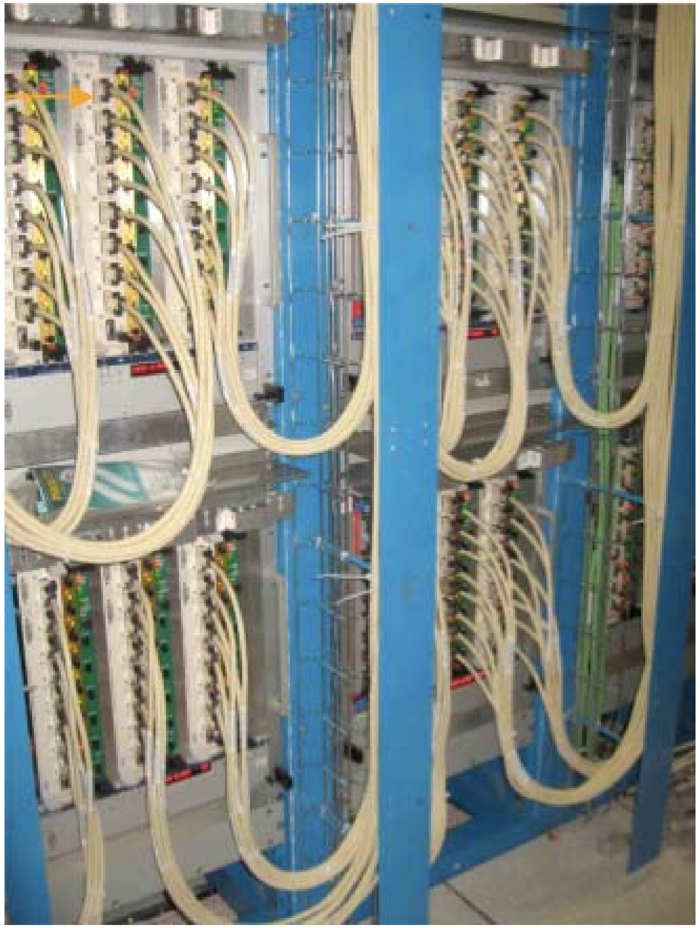


Total data + trigger: ~9000 links

DAQ commissioning

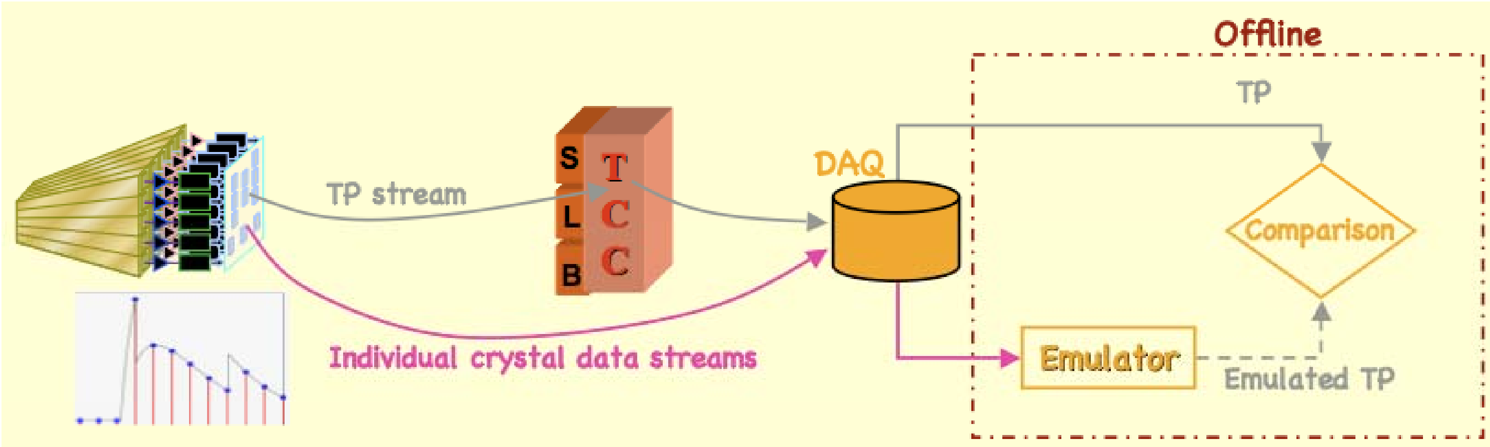
DAQ commissioning deals with all necessary aspects to run the whole ECAL system:

- Trigger
- Selective readout Protocol
- Laser
- Detector Control Units
- Condition and Configuration Databases
- Non-event monitoring
- Run Control
- DQM

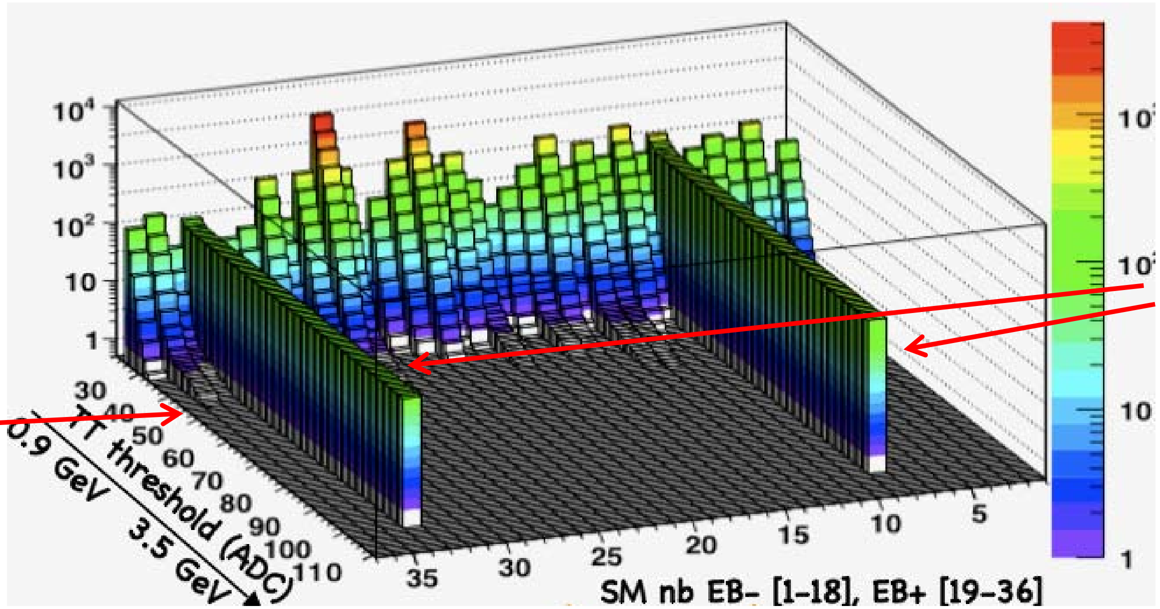


Trigger

Comparison of trigger decision with off-line emulator



Study of trigger rate as a function of threshold



Good SMs: very quite above 1.75 GeV

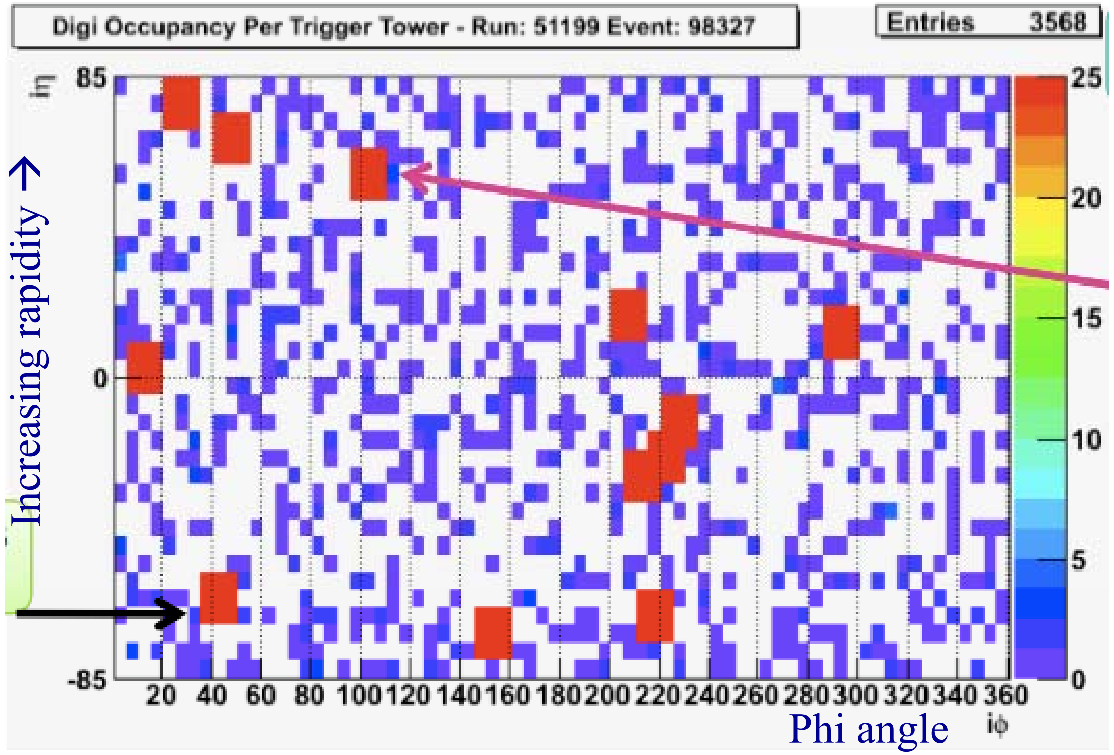
SMs with problems (for that run): trigger rate independent of threshold

Selective Readout Protocol (SRP)

The SRP receives from the TCC the list of ‘interesting towers’ and builds around each of them a 3x3 TT matrix which is read-out in full (each TT = 25 crystals)

This is the map of the TTs read out in a single event: most of them have only one crystal while the 3x3 groups have all 25 crystals

25 x 9 TT = 225 Crystals

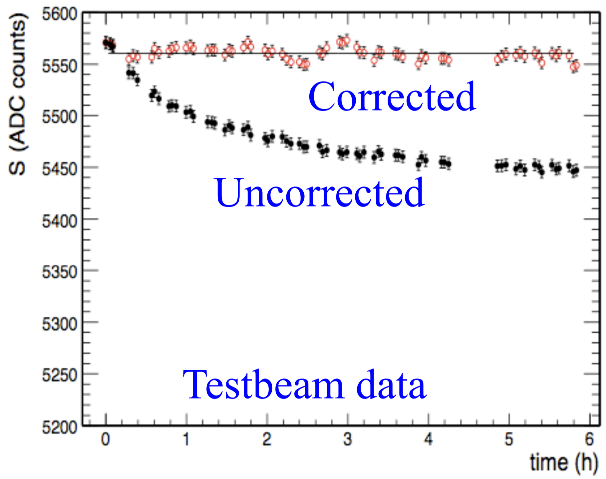


Unrolled Barrel view

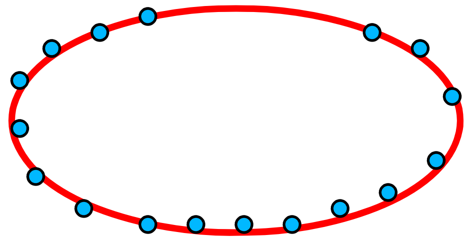
Laser commissioning

The laser calibration works routinely in local runs while in global runs we still have to finalize the sequence

- 600 laser shots for one transparency measurement
- whole ECAL in ~ 1/2 hour
- 40 Gb of laser data a day



Laser data in global runs



During each LHC orbit (96 μs) there is a short period (~1 %) with no bunches (abort gap). ECAL uses this gap to fire the laser and take calibration events while running

ECAL status

ECAL runs routinely with CMS and almost all ECAL sub-systems are operational:

Noise level and performance as expected

Number of masked (i.e. not used) channels ~ few per mille.
➔ Of those, a small fraction has been declared dead (link/clock no working)
➔ The remaining masked channels have a variety of problems. We hope to recover a large part of them (it will requite time)

Local and global runs

Global Run :

•Coherent exercise of CMS data taking in preparation for collisions

•1 week of intense activity

• 6 GR in 2007, 8 in 2008

•Involves more and more subsystems

• ~ 100 ml cosmic triggers acquired

Local Runs :

• Use to debug the system, test configuration

•ECAL only + additional Trigger chain

•Readout can be local (VME with low rate) or global

Beam Run :

•Since September 10^{th} LHC has beam!

•The run structure has deeply changed with a lot of attention given to beam related problems

•Sub-system time for development restricted

Global Cosmic runs

During global cosmic runs a very large number of cosmic ray signals have been acquired

ECAL is able to:

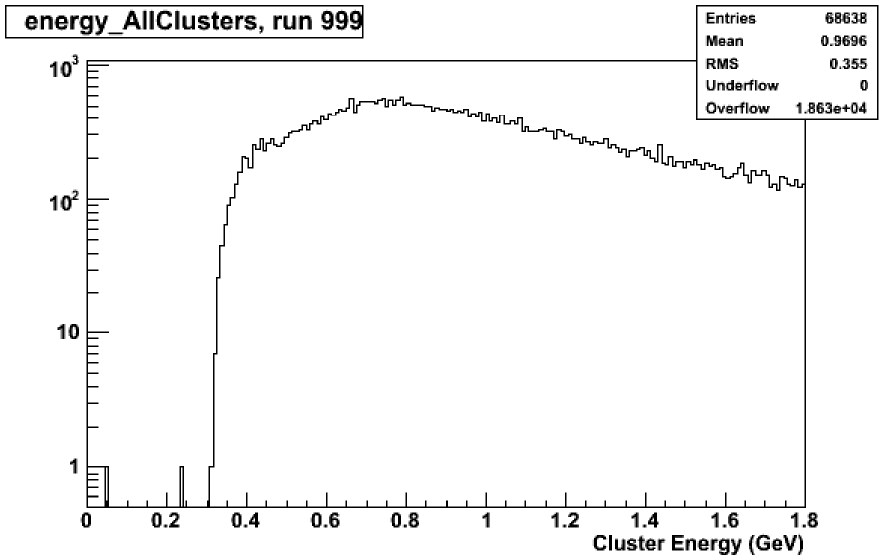
- Clearly see the signal deposited by a mip, 250 MeV (with photodector gain raised from 50 → 200)
- Trigger on mip signal both using single tower or coincidence

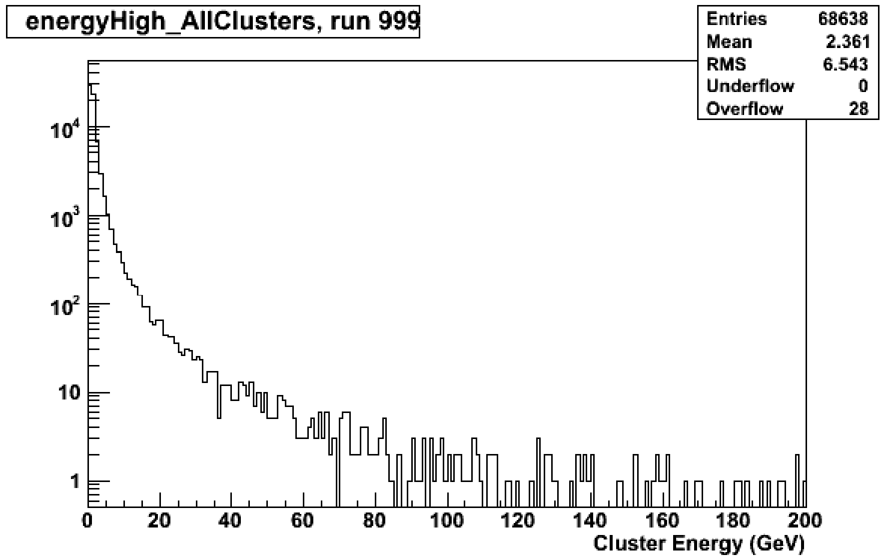
Note: we are using ECAL to measure very low energy deposition, far from its optimization => this was very useful

Measuring signal so small made us understand ECAL very well

Cosmic runs - Signal

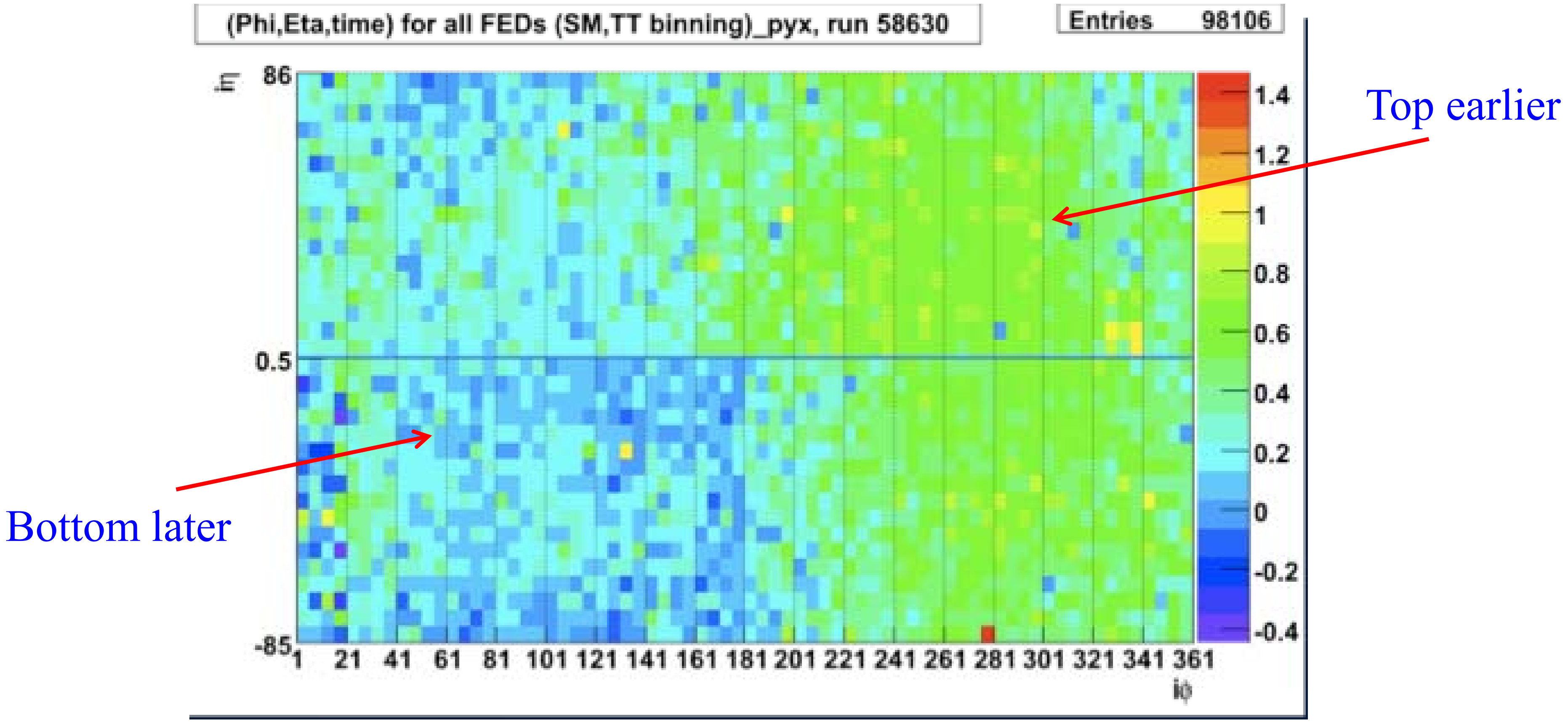
The signal in cosmic ray runs varies a lot since they come with every angle. There is also a high energy component due to muon bremsstrahlung





Cosmic runs - Timing

Using cosmic signals we had timed-in all ECAL-barrel crystals

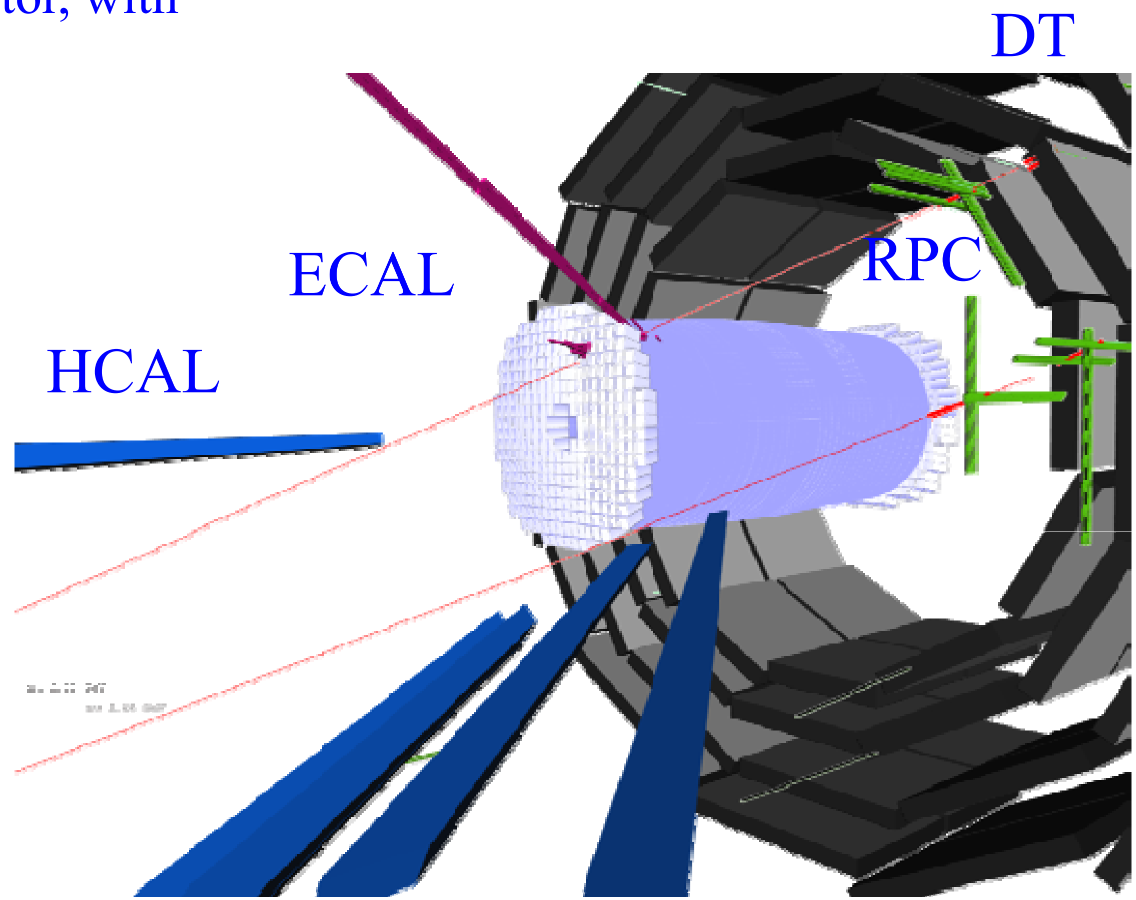


Cosmic runs – Event Display

CMS is now working as a single detector, with correlation between sub-detector.

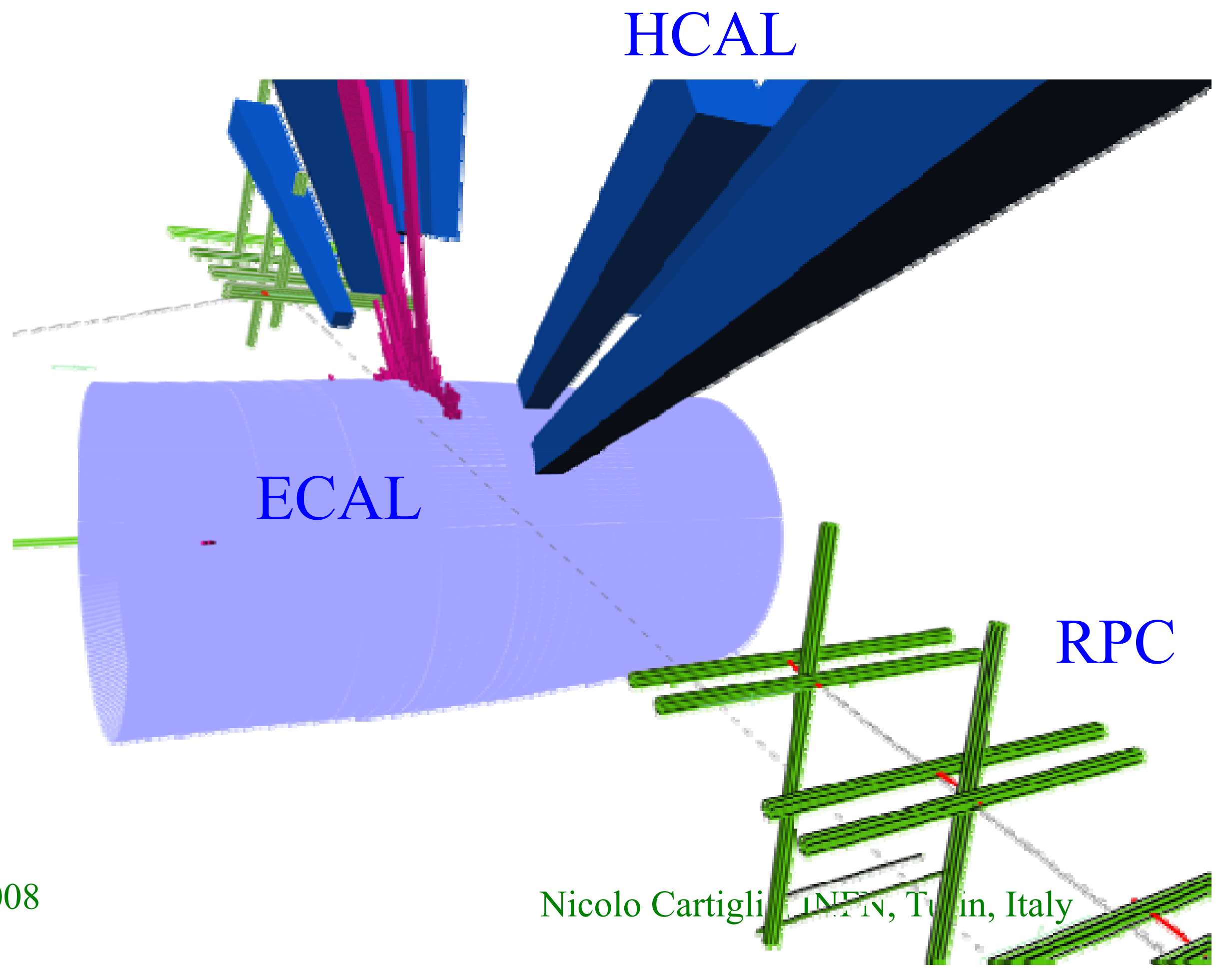
In this picture:

- DT,Muon Drift Tube
- RPC, Muon
- ECAL Barrel
- ECAL Endcaps
- HCAL, Hadronic Calo.



Global runs – Event Display

Calorimeter tracking…..



Beam runs !

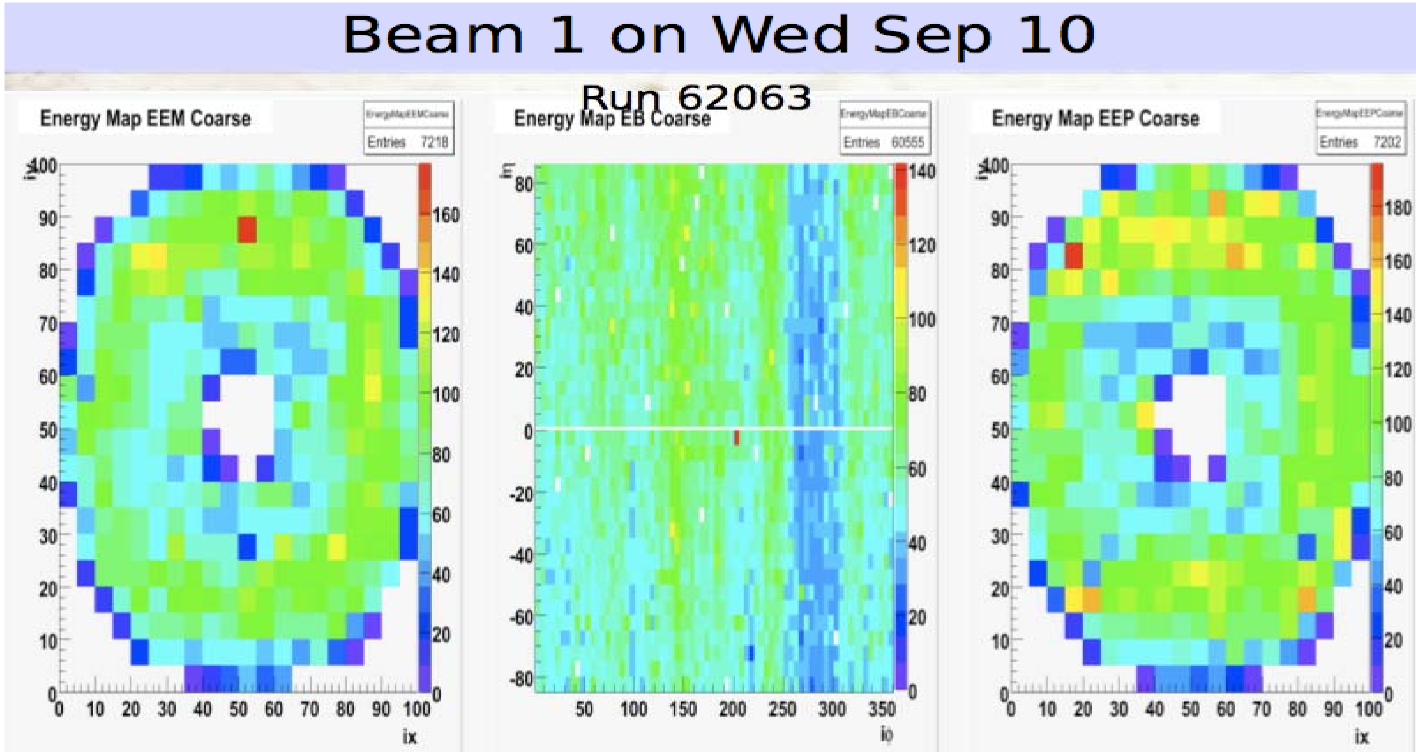
Starting September 10th LHC has beam!

LHC dumped single shot beam (~ 10^9 proton) on the collimators 150 m away from CMS:

Total energy in excess of ~ 100 TeV

98% of crystals hit

~ 1-300,000 muons in one hit



Incredible opportunity to time-in the whole ECAL with just few events

Conclusion and outlook

A very personal ECAL timeline:

Concept — -10

Construction — -5

Commissioning — -2

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b.c.

b.c. = before collisions

You are here

a.c.

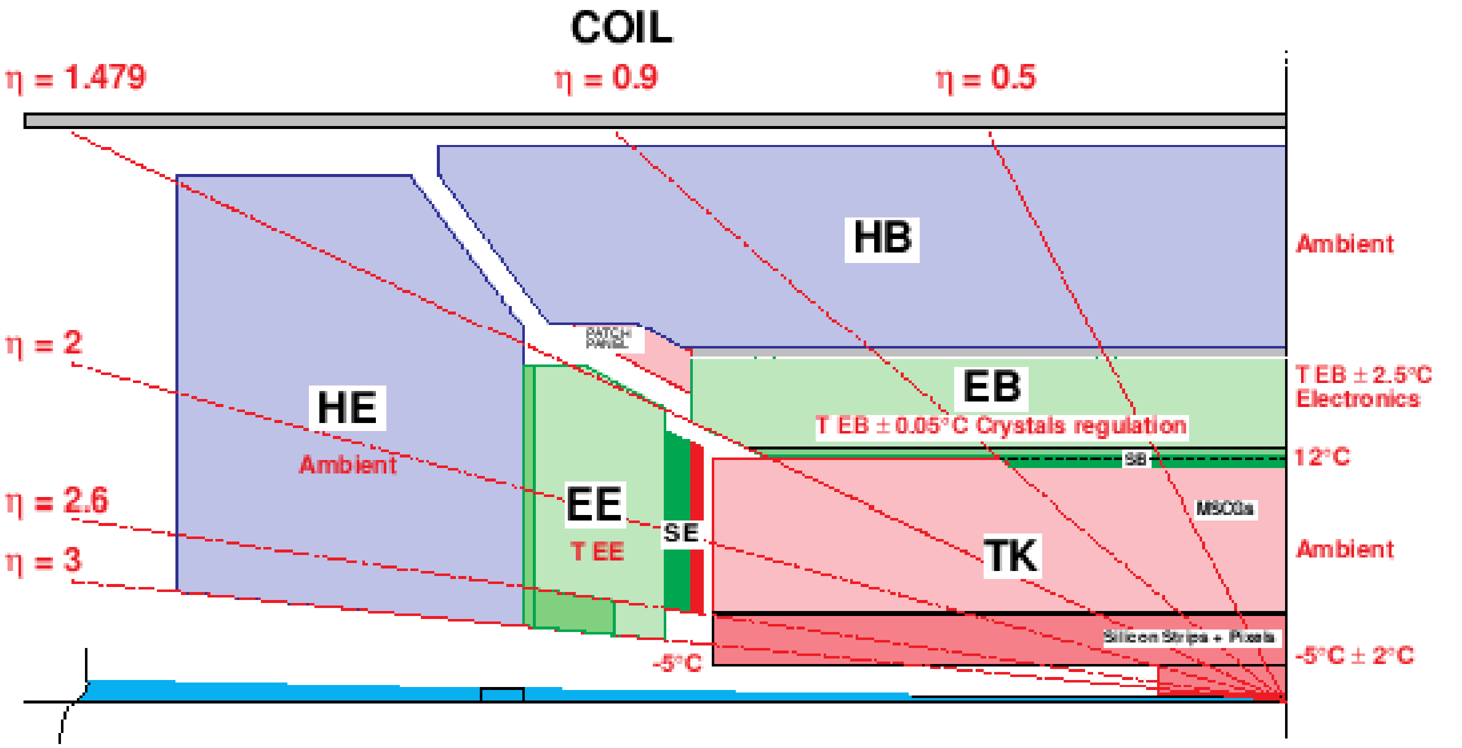
a.c. = after collision

Every time we go from b.c. ➔ a.c. there is a dramatic change:

I think we are ready

EXTRA

CMS rapidity coverage



Detector ambient air temperature 18°C
Dew point 9°C ± 1°C
T EB = <12 ; 18°C>
T EE =18°C ± 0.1°C