

**LIP in the finalization
of the CMS detector
after 17 years of work
after 45 persons**

André David, LIP-Lisbon



Portugal in CMS

Letter of Intent - 1992

CERN/LHCC 92-3
LHCC/I1
1 October 1992

Letter of Intent
by the
CMS Collaboration

for a General Purpose Detector at the LHC

Inst. of Experimental Physics, University of Warsaw, Warszawa, POLAND

W. Dominik, J. Królikowski, M. Konecki, L. Ropelewski,

Institute for Nuclear Studies, Warszawa, POLAND

M. Górski, M. Szeptycka

LIP, Lisbon, PORTUGAL

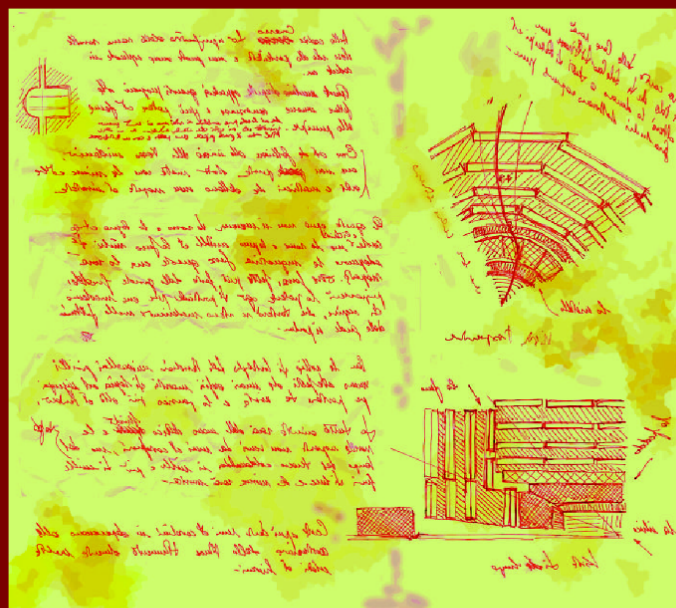
P. Bordalo, C. Lourenço, R. Nóbrega, S. Ramos, J. Varela

JINR, Dubna, RUSSIA

P. Akishin, S. Andreev, A. Bel'kov, M. Bondila, V. Chalyshev,

Technical Proposal - 1994

CERN/LHCC 94-38
LHCC/P1
15 December 1994



The Compact Muon Solenoid Technical Proposal

Laboratório de Instrumentação e Física Experimental de
Partículas, Lisboa, PORTUGAL

A. Almeida, P. Bordalo, J. Gomes, P. Gomes, E. Machado, M. Mota,
R. Nobrega, S. Ramos, S. Silva, J. Varela

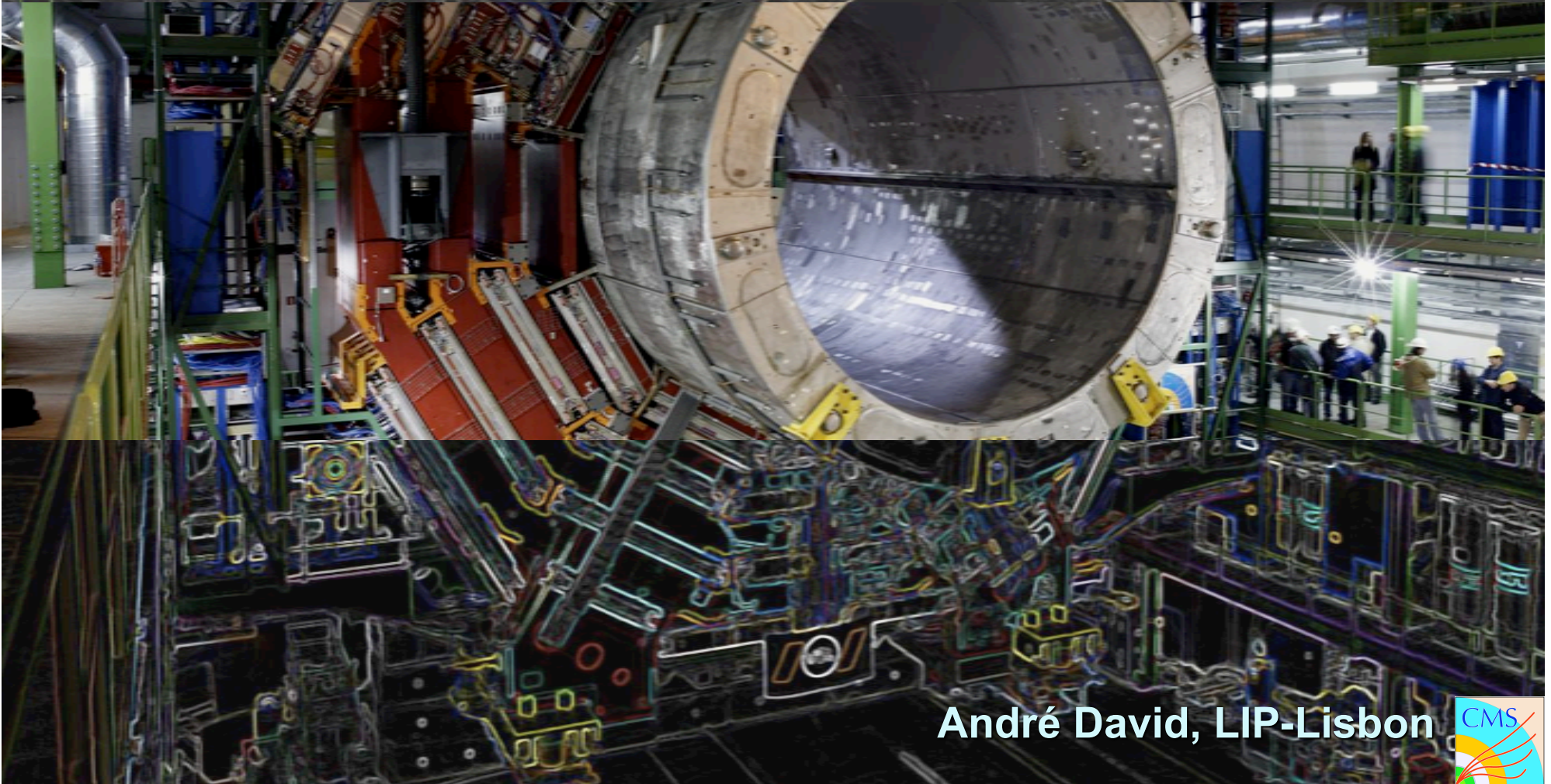
“since 1992”

LIP participants to CMS

R. Alemany-Fernandez	C. Lourenço	H. Sarmento
A. Almeida	E. Machado	J. Semiao
C. Almeida	J. Martins	I. Teixeira
N. Almeida	A. Mishev	J. Teixeira
J. Augusto	J. Morgado	G. Varner
T. Barata Monteiro	M. Mota	I. Videira
L. Berger	S. da Mota Silva	J. Varela
P. Bordalo	P. Musella	
M. Calha	A. Nikitenko	
N. Vaz Cardoso	R. Nobrega	
O. Dias	G. Ordóñez	
M. Ferreira	A. Pierce	
M. Gallinaro	V. Popov	
J. Gomes	P. Q. Ribeiro	
P. Gomes	R. Ribeiro	
F. M. Goncalves	S. Ramos	
M. Husejko	J. C. Silva	
A. Jain	S. Silva	
M. Kazana	P. F. da Silva	
N. Leonardo	M. Santos	

**47 persons
since 1995**

LIP in the finalization of the CMS detector



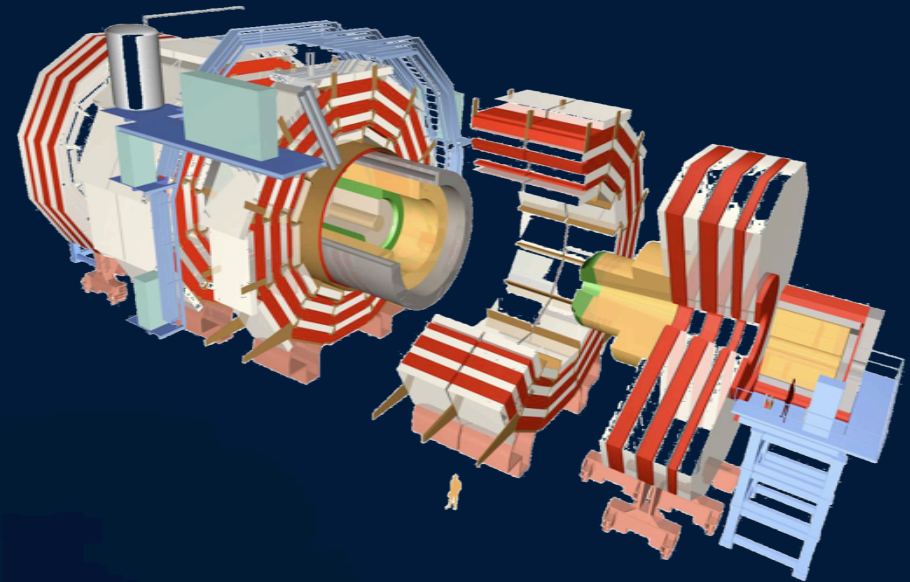
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CMS is...

- 4 Tesla superconductor solenoid
- **Excellent muon detection**
 - multiple detection layers
- **Crystal calorimeter**
 - the best possible photon and electron measurement
- **Charged particle Si tracker**
 - the most reliable technology
- **Hermetic and compact detector**
 - essential for neutrino identification
- Material cost ~ 400 MEUR

36 Countries
160 Institutes
2000 Collaborators



Total weight	12500 tonnes
Diameter	15 m
Length	21.6 m
Magnetic field	4 Tesla

In project since 1992

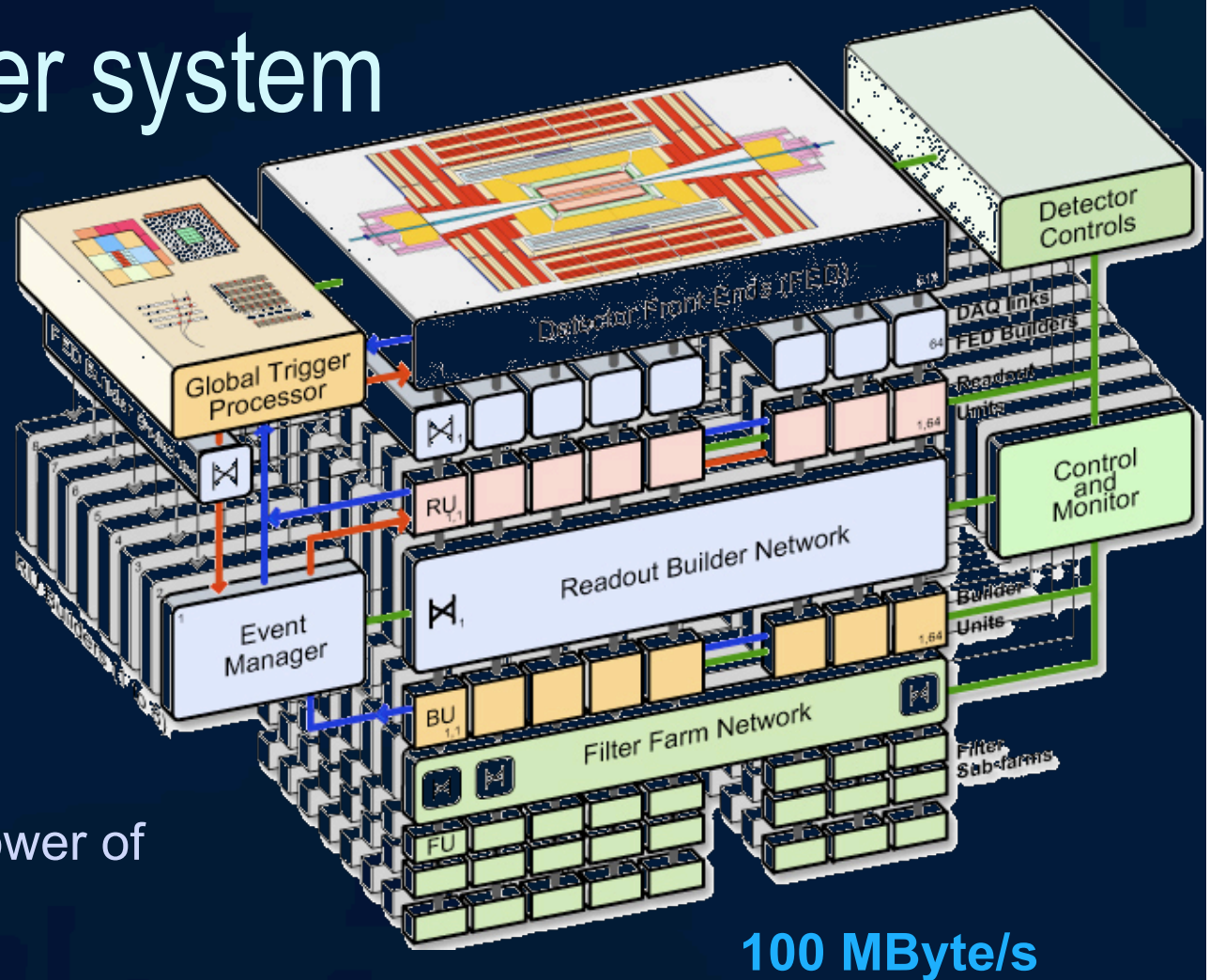
Trigger and data acquisition

- Proton **bunches collide in CMS every 25ns** (~ 40 million times per second)
- Each collision produces ~ 1 MByte of data
- The trigger system decides (**in ~ 3 μ s**) if the collision is to be kept
- **10^7 trigger rejection factor**
- Yearly data volume ~ 10^6 GByte = 1 PByte

The CMS Trigger system

100 TByte/s

100 GByte/s



100 MByte/s

Level 1 Trigger

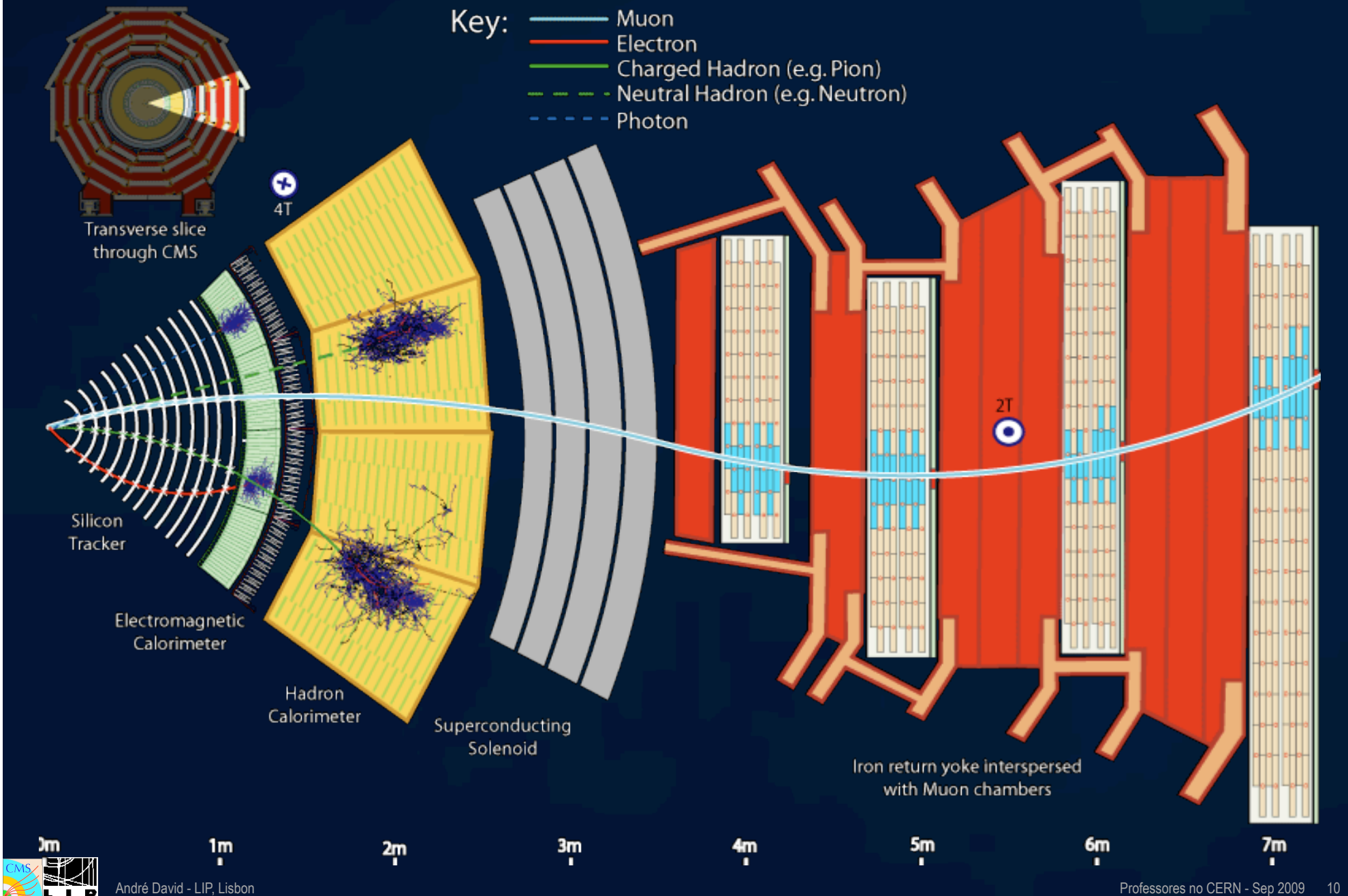
- Dedicated processors
- Equivalent processing power of 50 000 PCs

High Level Triggers

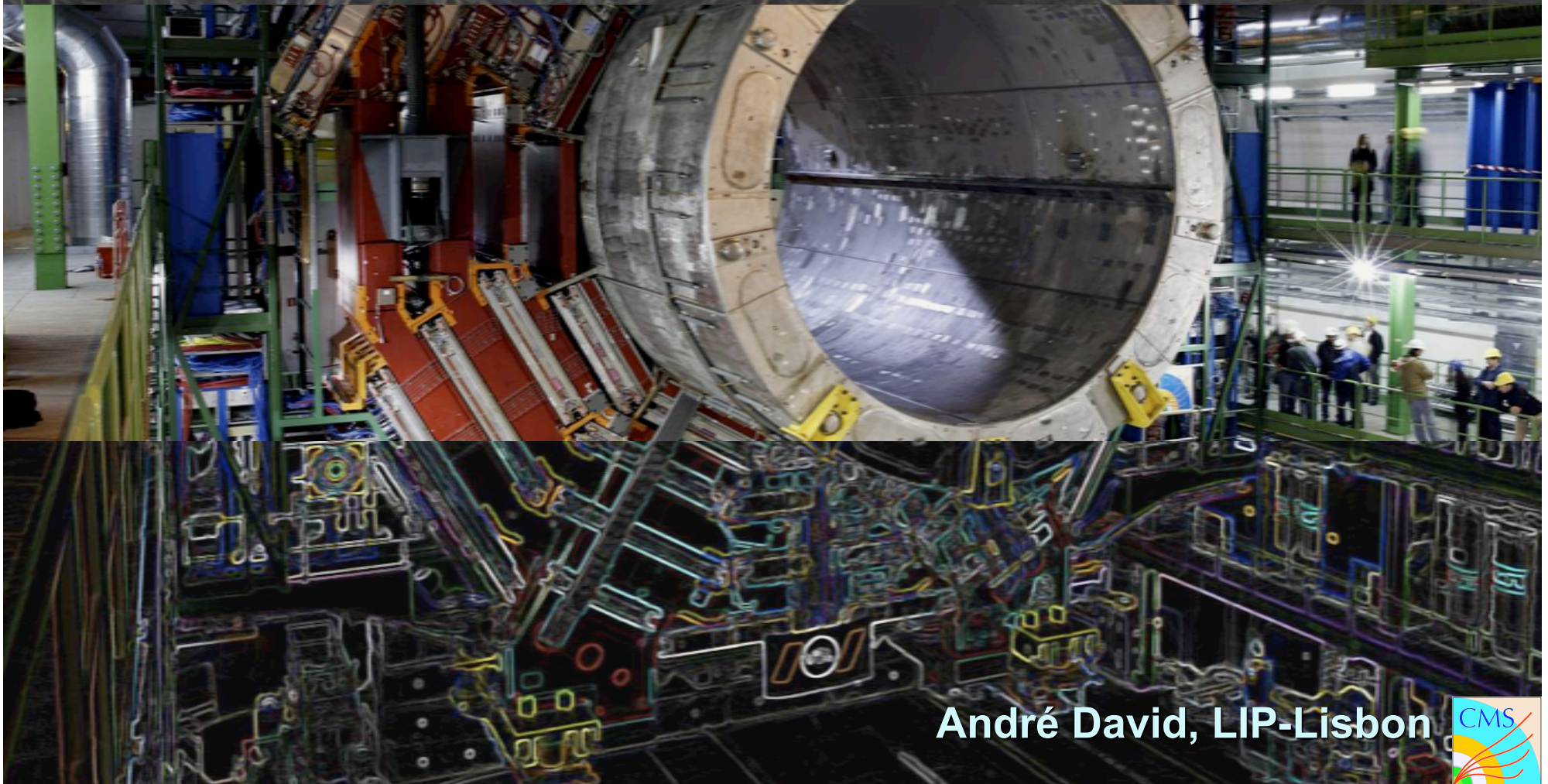
- PC farm with 5000 PCs

One of the most complex electronics systems ever built !

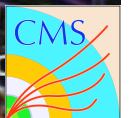
Hadrons, e^\pm , γ and μ^\pm in the barrel



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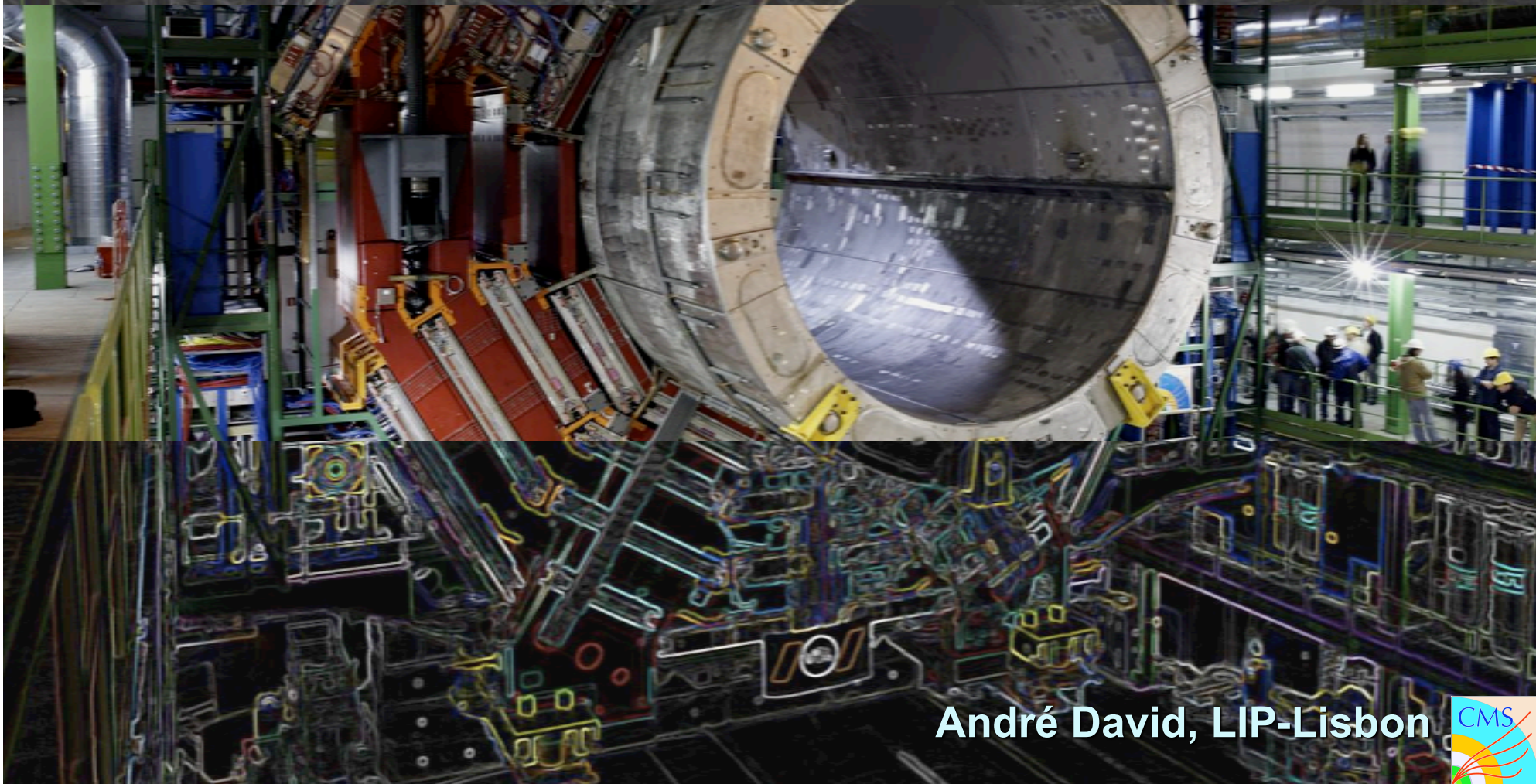
<LIP-CMS> - an average

M.Gallinaro	M.Bluj	J.Seixas	J.Pela	M.Jordão	M.Ferreira	P.Ribeiro	N.Almeida	J.Varela	M.Kazana	J.C.Silva	A.Verde	A.David	M.Husejko	P.Musella	P.Silva
Lisboa			Lisboa			CERN			Lisboa			CERN			
Senior	Postdoc	Senior	MSc	Tech	PhD	Postdoc	Senior	Postdoc	Eng	Tech	Postdoc	Tech	PhD		

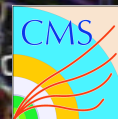
Physics			Hardware			Computing			Trigger DAQ			Hardware		
Physics			Hardware			Computing			Trigger DAQ			Hardware		
Physics			Hardware			Computing			Trigger DAQ			Hardware		

- 16 persons presently involved
 - Recent reinforcement: L. Raposo (MSc)

LIP in the finalization of the CMS detector



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Main responsibilities since 2006



made in LIP

- **ECAL**

- Data Concentrator Card
- ECAL DAQ software
 - Calibration test beams
 - Commissioning and testing of the detector
- Off-detector electronics integration and test system
- Non-event data monitoring system

- **Trigger**

- Synchronization Link Board
- ECAL trigger pattern tests
- ECAL trigger cabling

- **CMS posts held by group members**

- CMS Trigger and DAQ Project Manager (J. Varela)
- ECAL Electronics Coordinator (J.C. Silva)
- ECAL DAQ Coordinator (A. David)



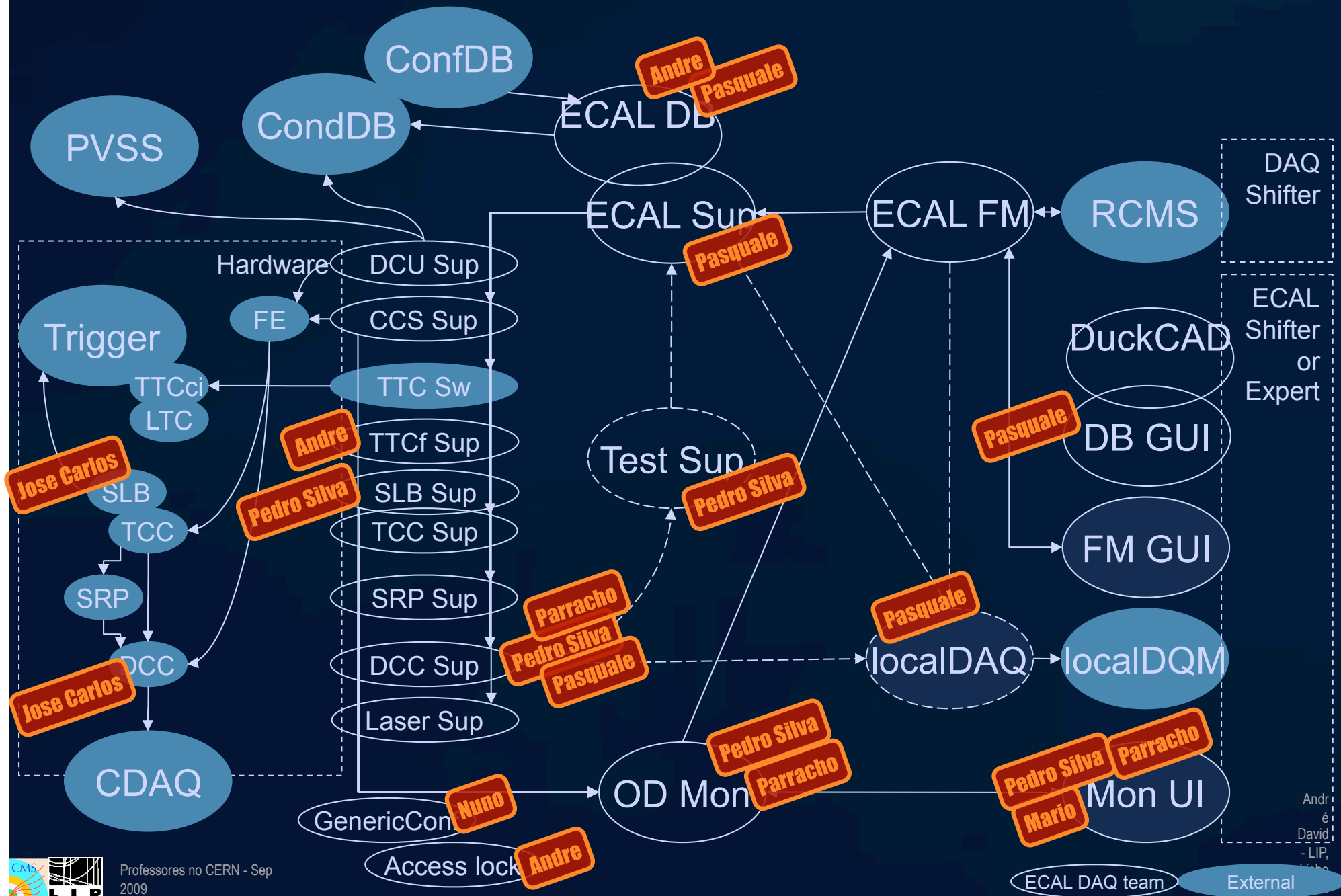
LIP in CMS top management



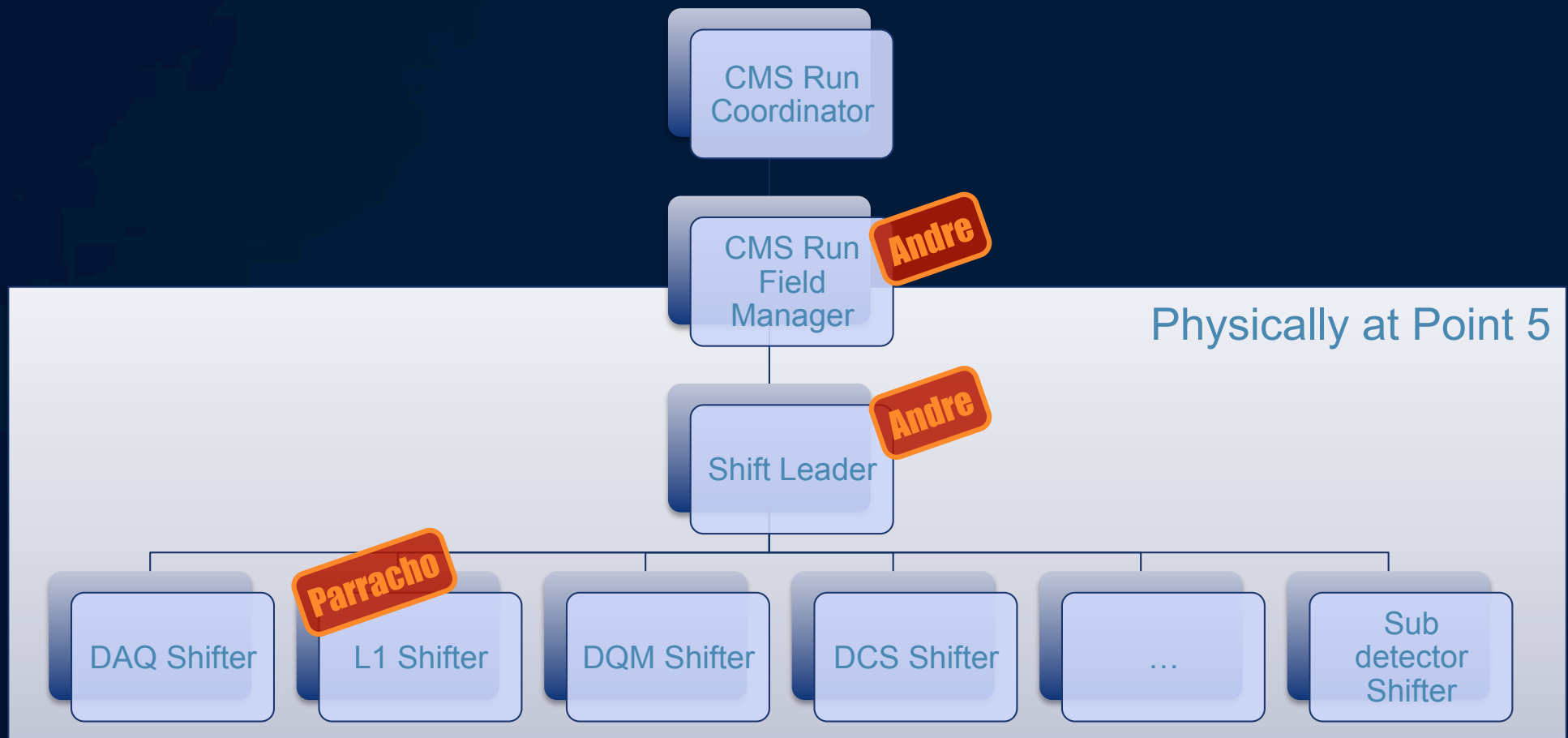
LIP in ECAL management



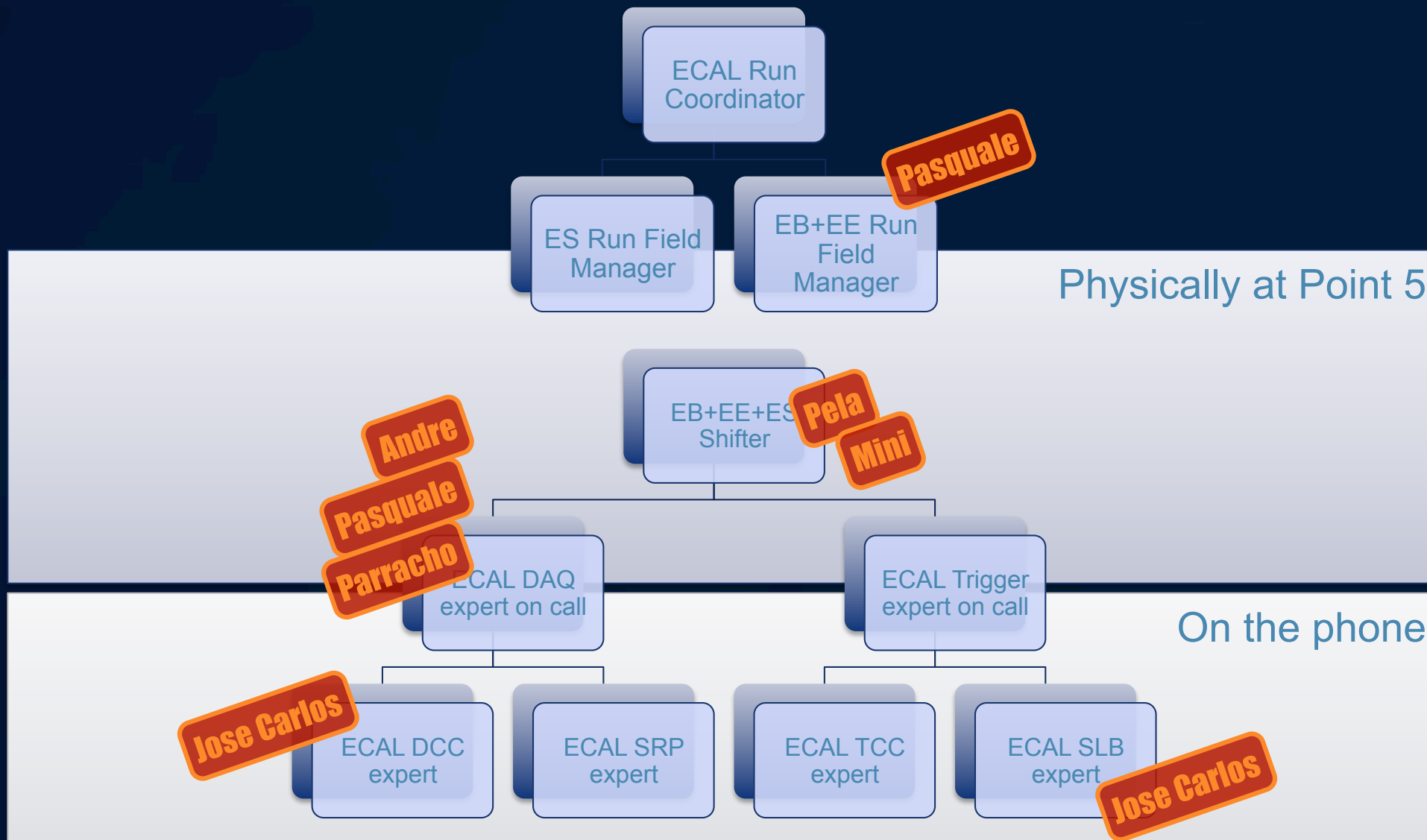
LIP in ECAL DAQ and Trigger



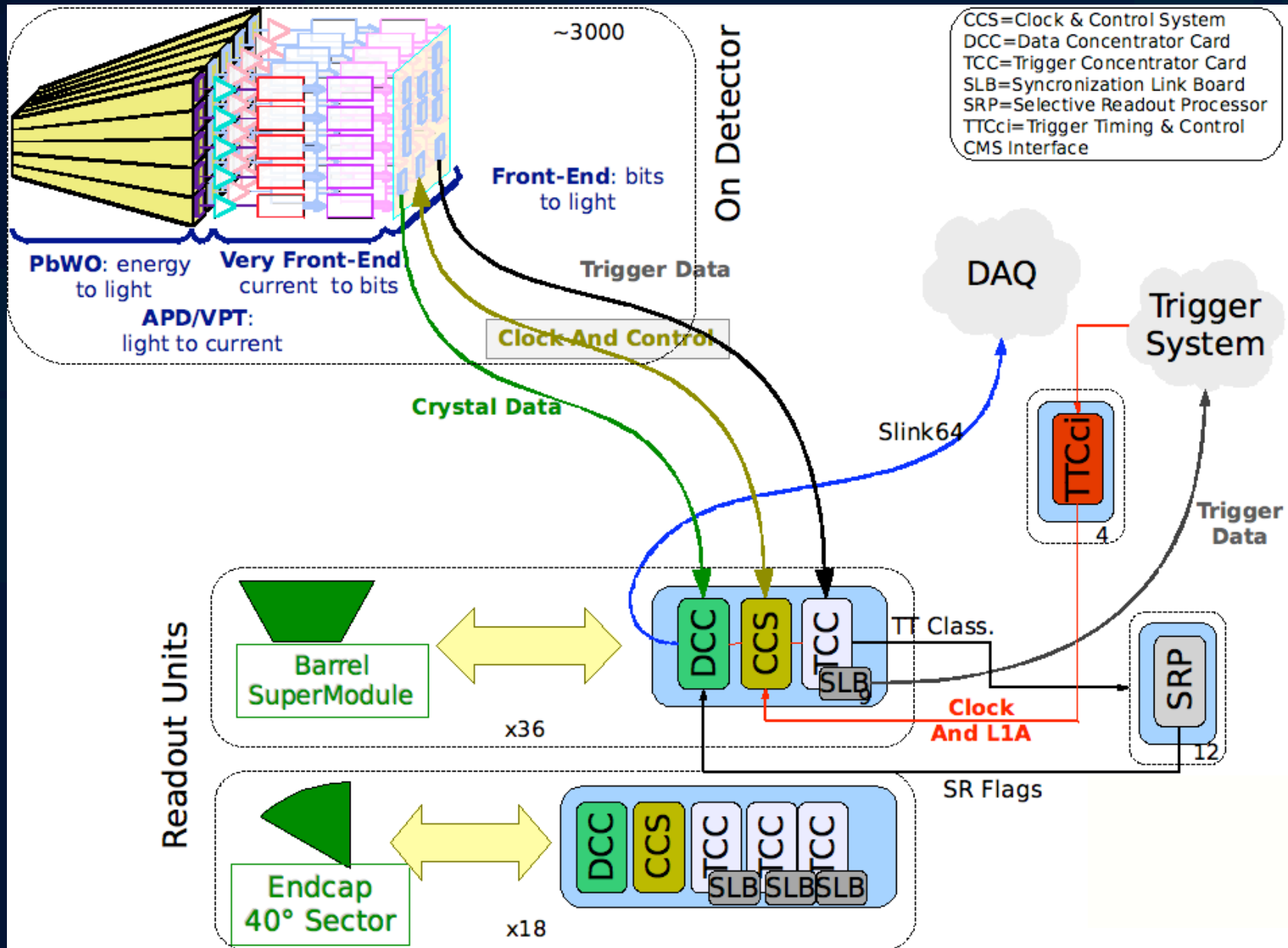
LIP in CMS operations



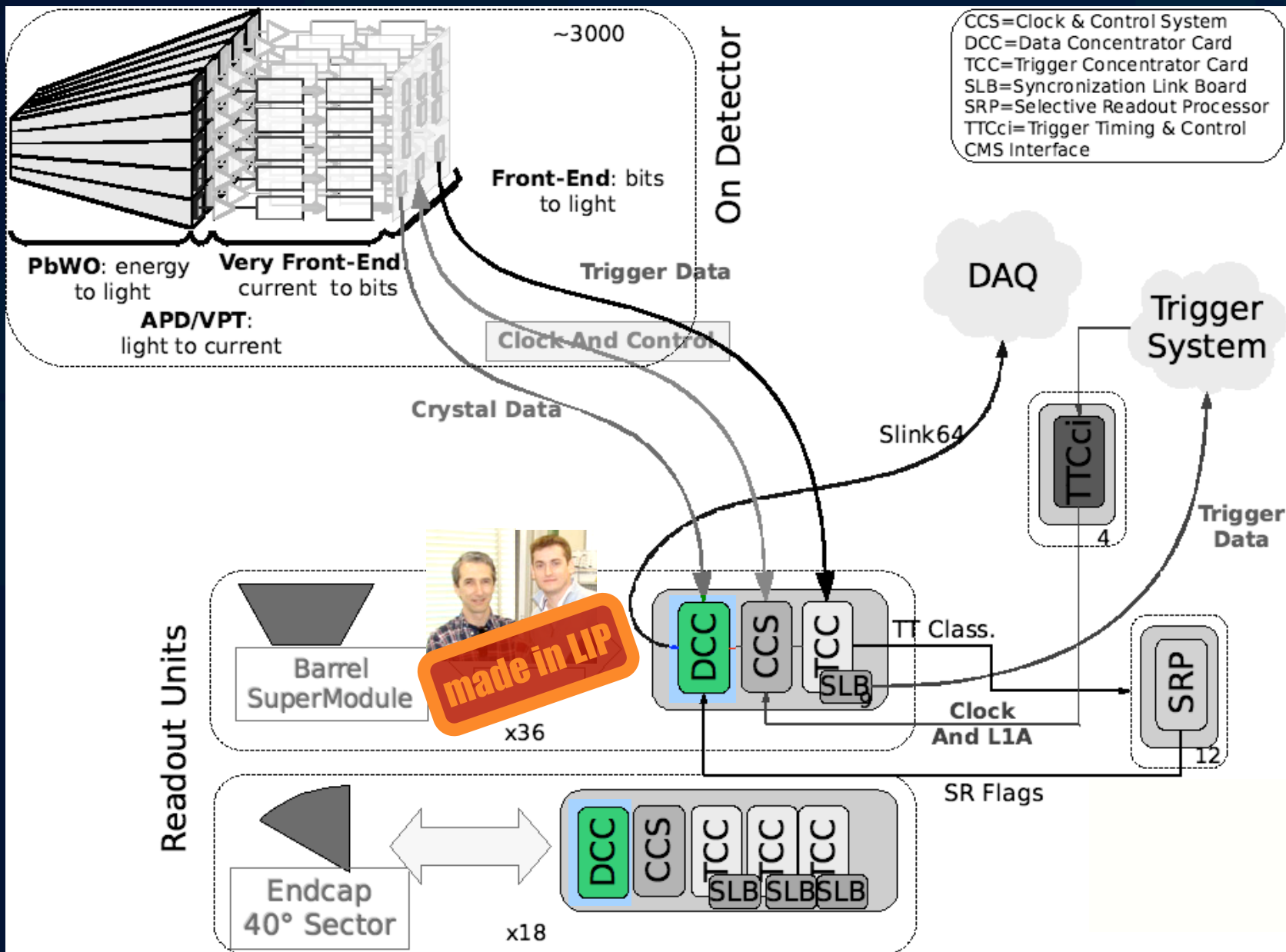
LIP in ECAL operations



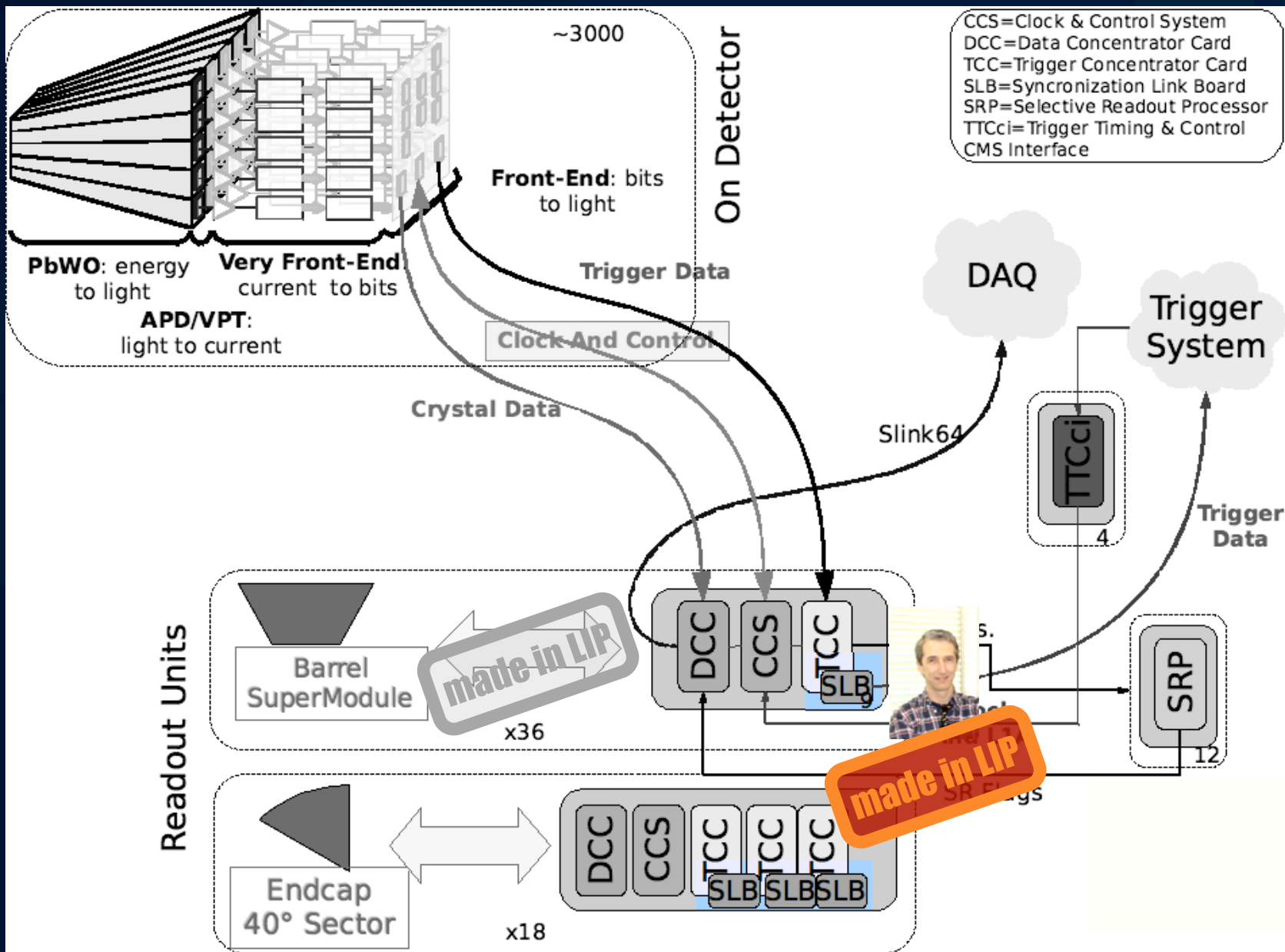
An overview of the ECAL readout



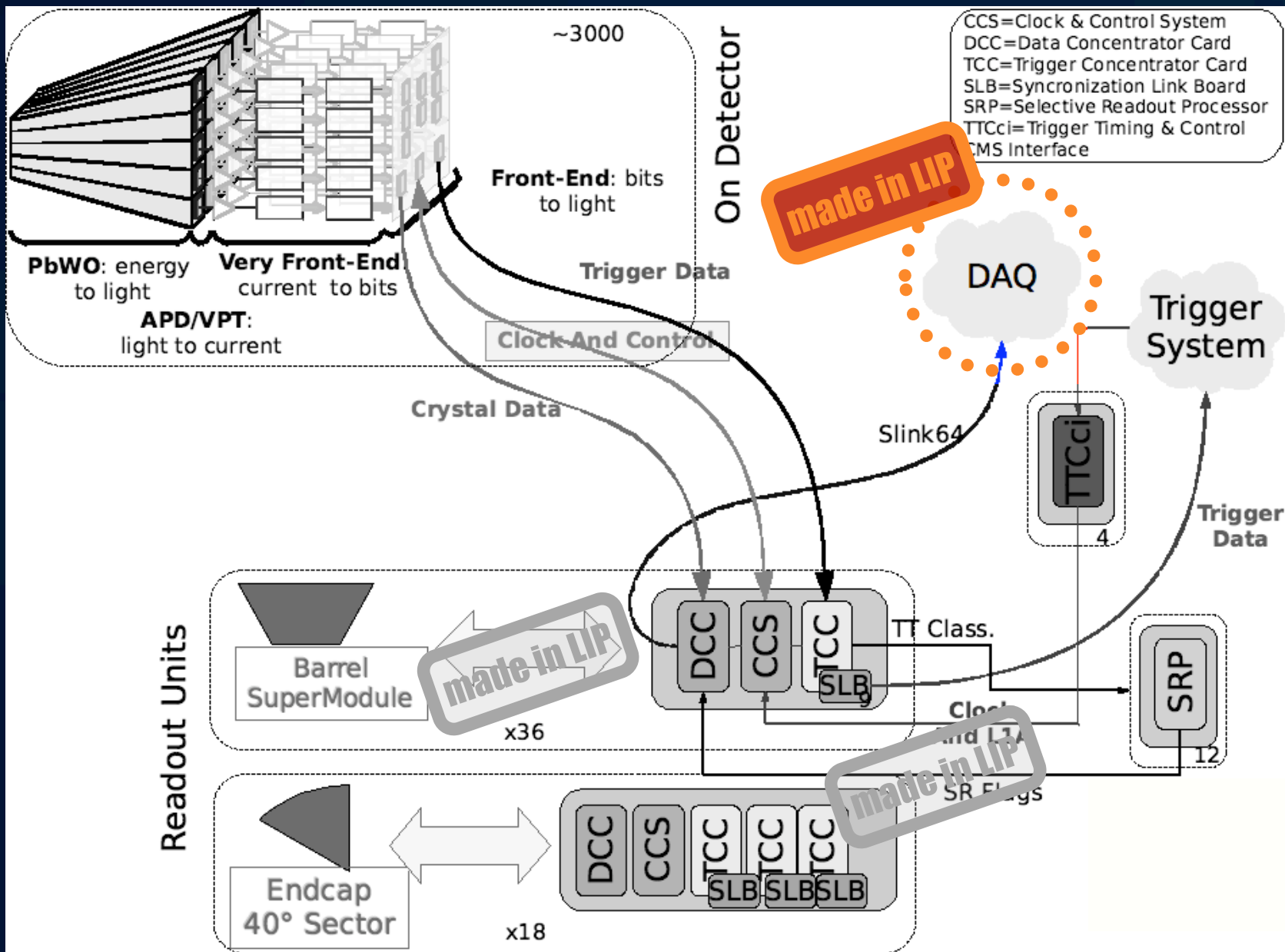
An overview of the ECAL readout



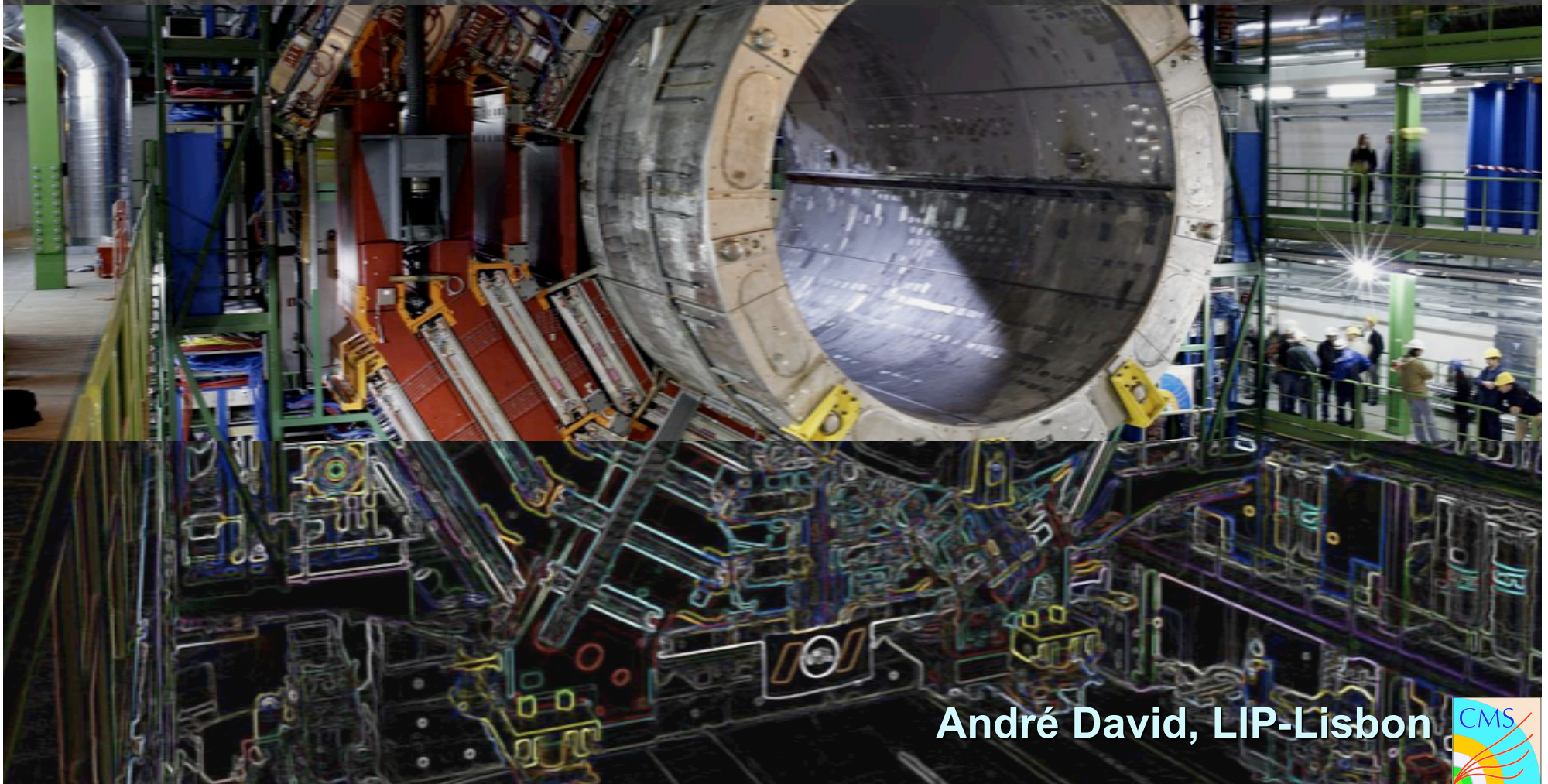
An overview of the ECAL readout



An overview of the ECAL readout



LIP in the finalization of the CMS detector



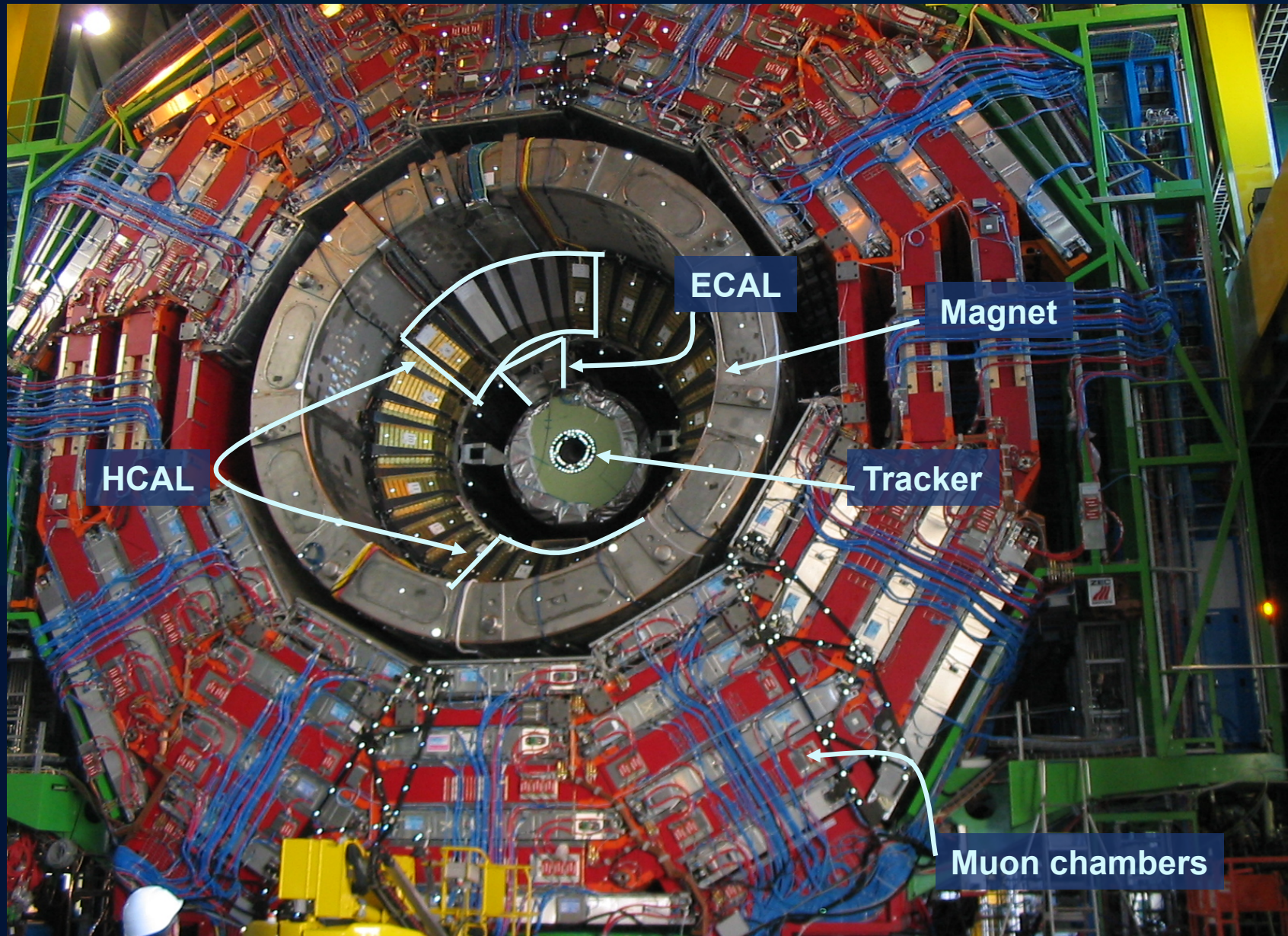
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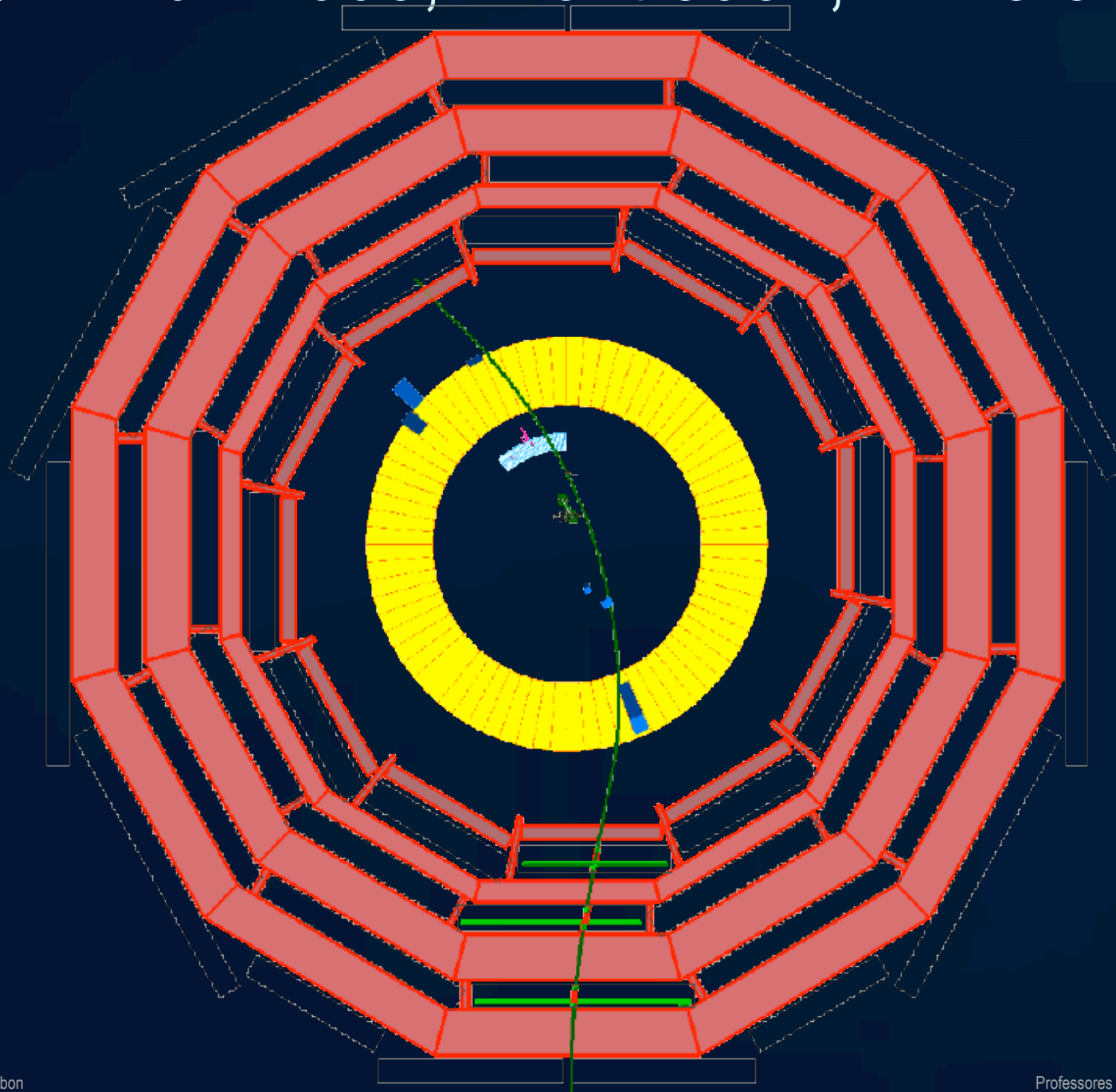
2006: first closure of the CMS experiment



2006: Magnet Test and Cosmic Challenge



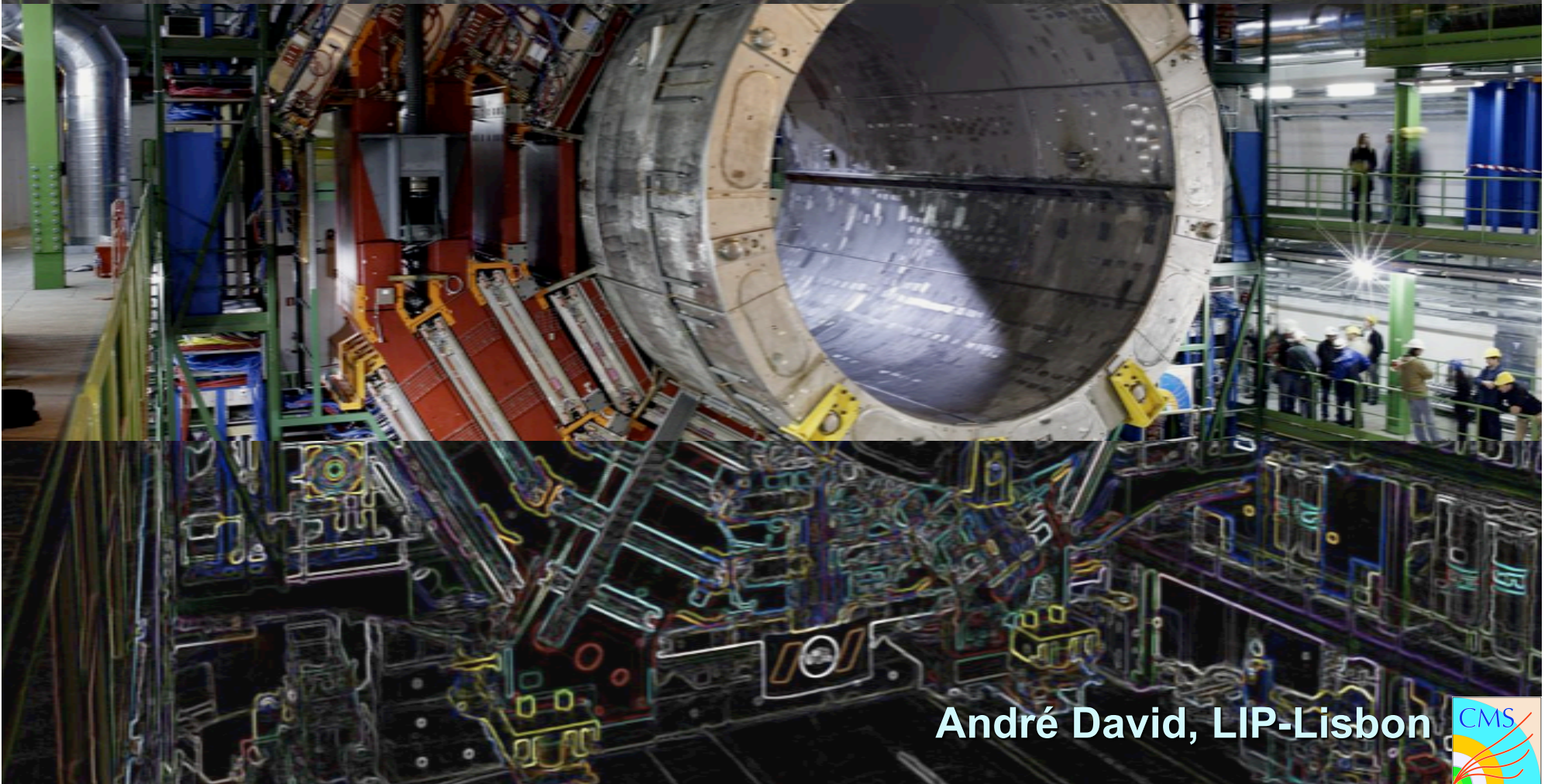
2006/08/27: run 2605, Event 3981, $B = 3.8 \text{ T}$



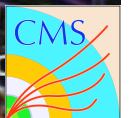
2006: cavern foam test



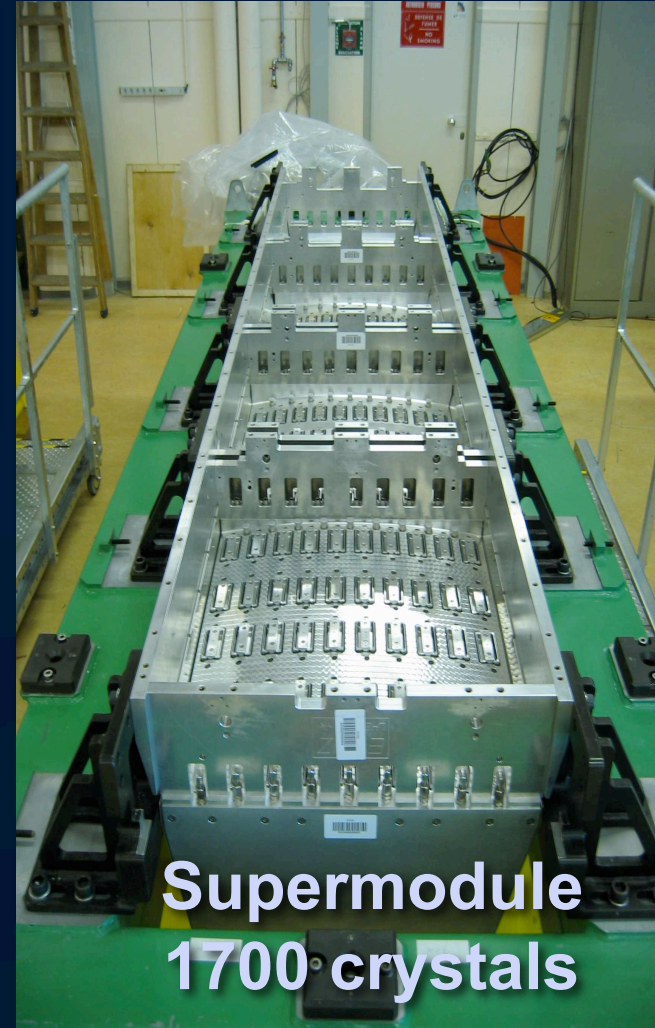
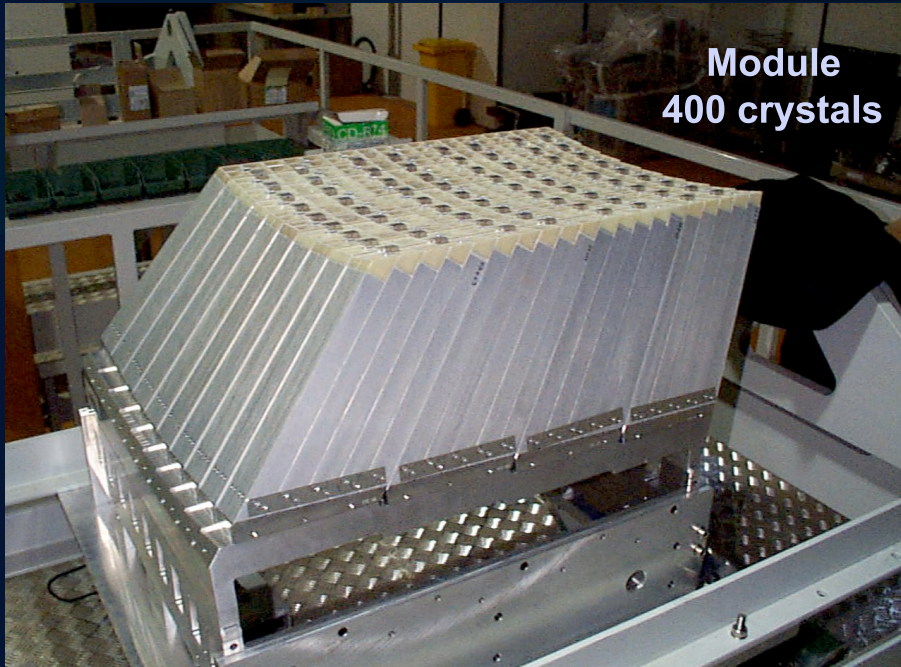
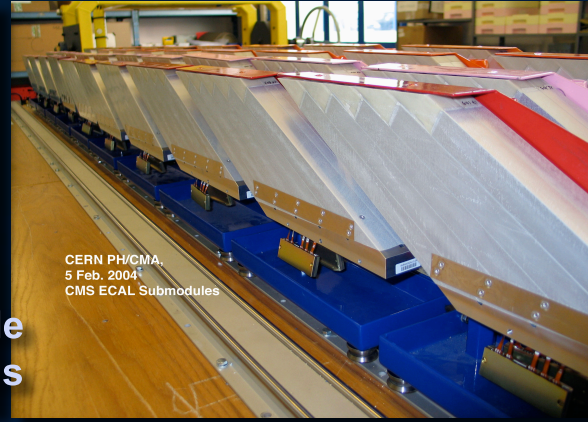
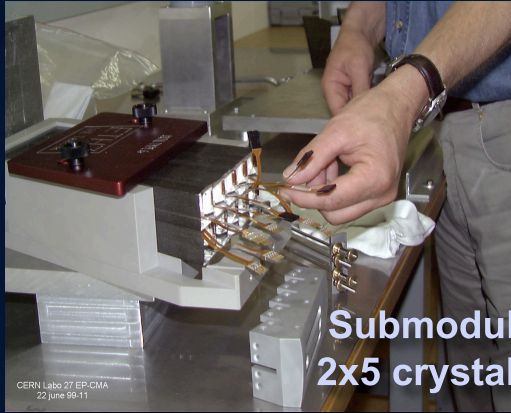
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Assembly of ECAL barrel supermodules



Total 36 Supermodules

Assembly of front-end electronics

- Readout system to check assembly problems

made in LIP



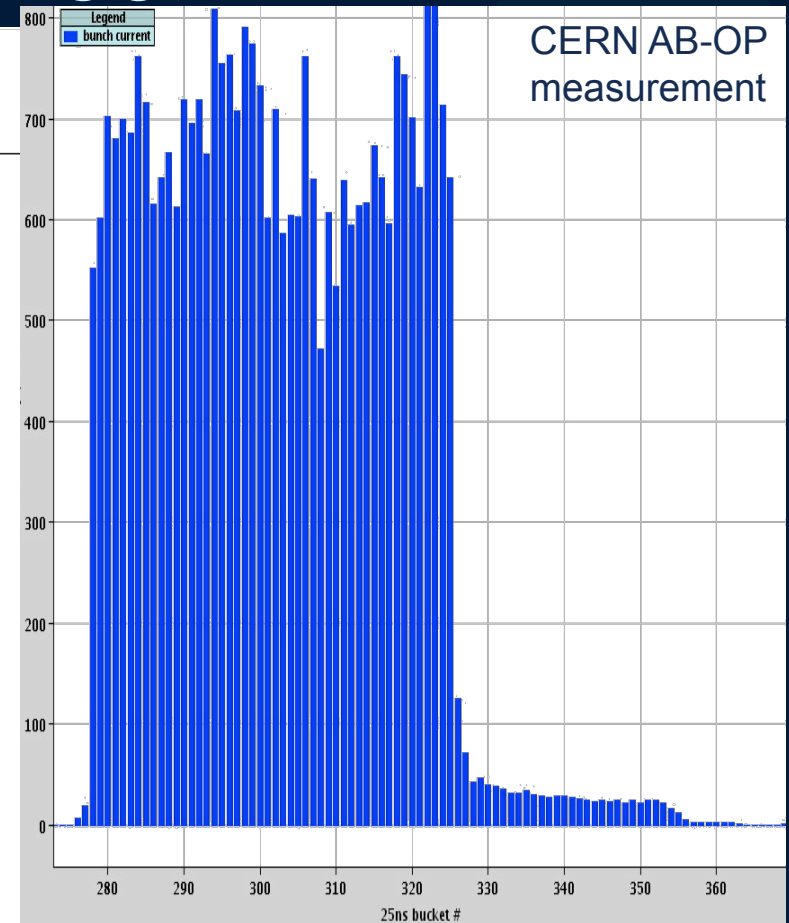
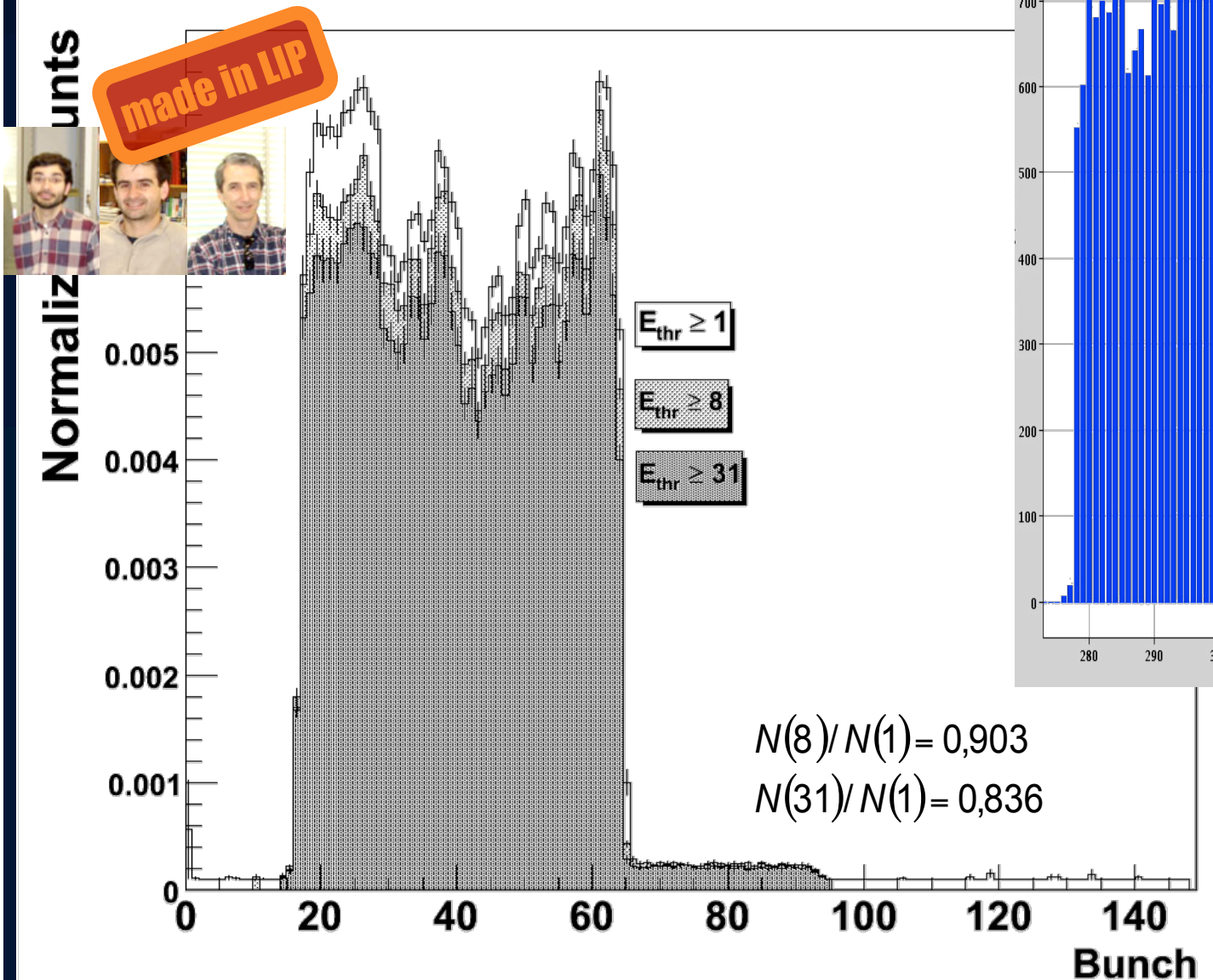
Summer 2006/7: ECAL barrel calibration



- First operation of the trigger electronics of the ECAL
- Large fraction of ECAL barrel intercalibrated with **electron beam**
- All ECAL barrel collected **cosmic muon data**
- **{E,H}CAL combined performance test beams**

Beam structure using the trigger electronics

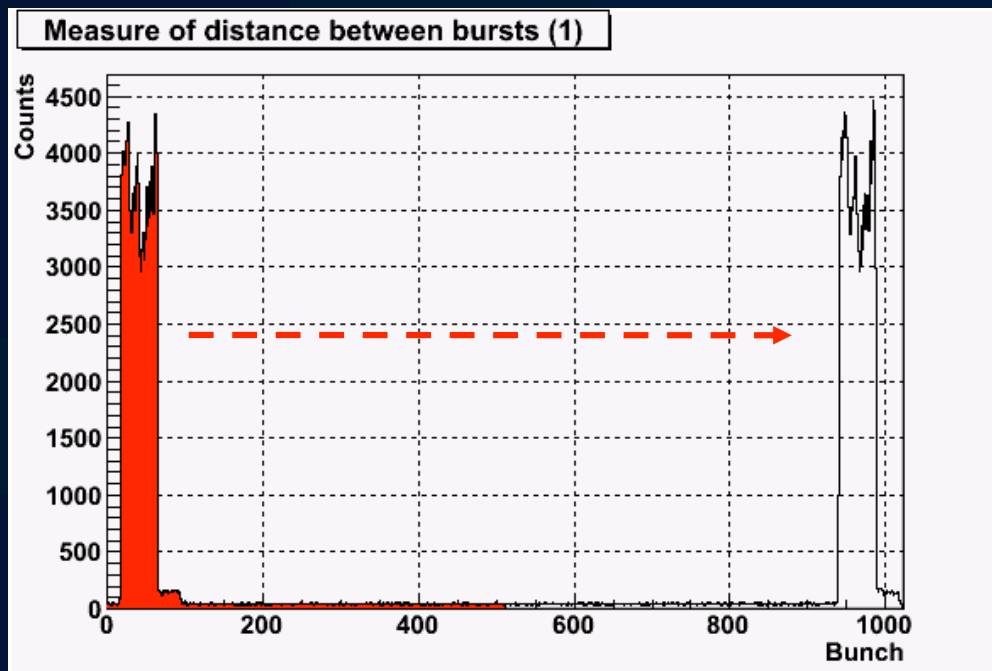
Bunch structure measured at TT=59 by SLB 742



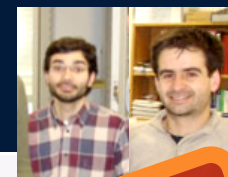
Beam timing analysis using trigger electronics

Time structure of the trigger primitive distribution: $T = 23.1 \mu\text{s}$ (SPS revolution)

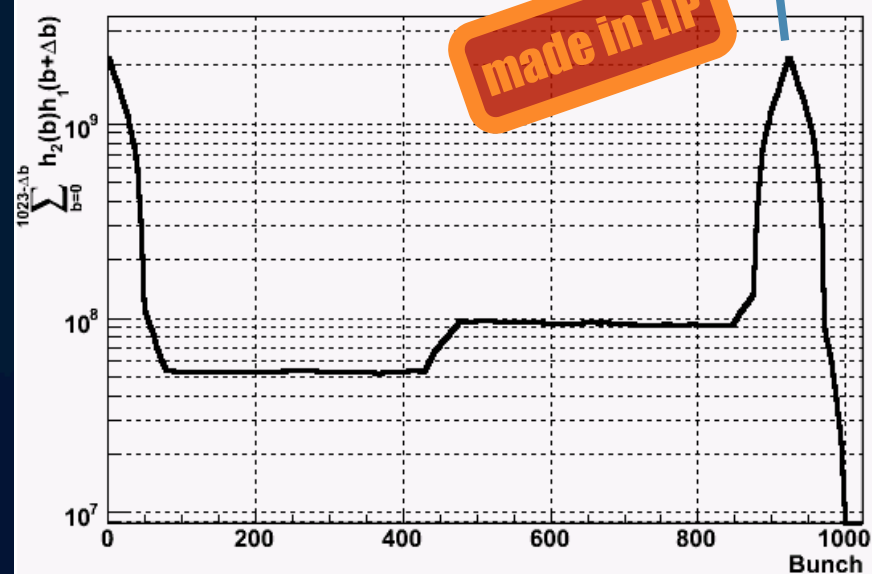
Contents of the accumulator for the Trigger Tower under the beam



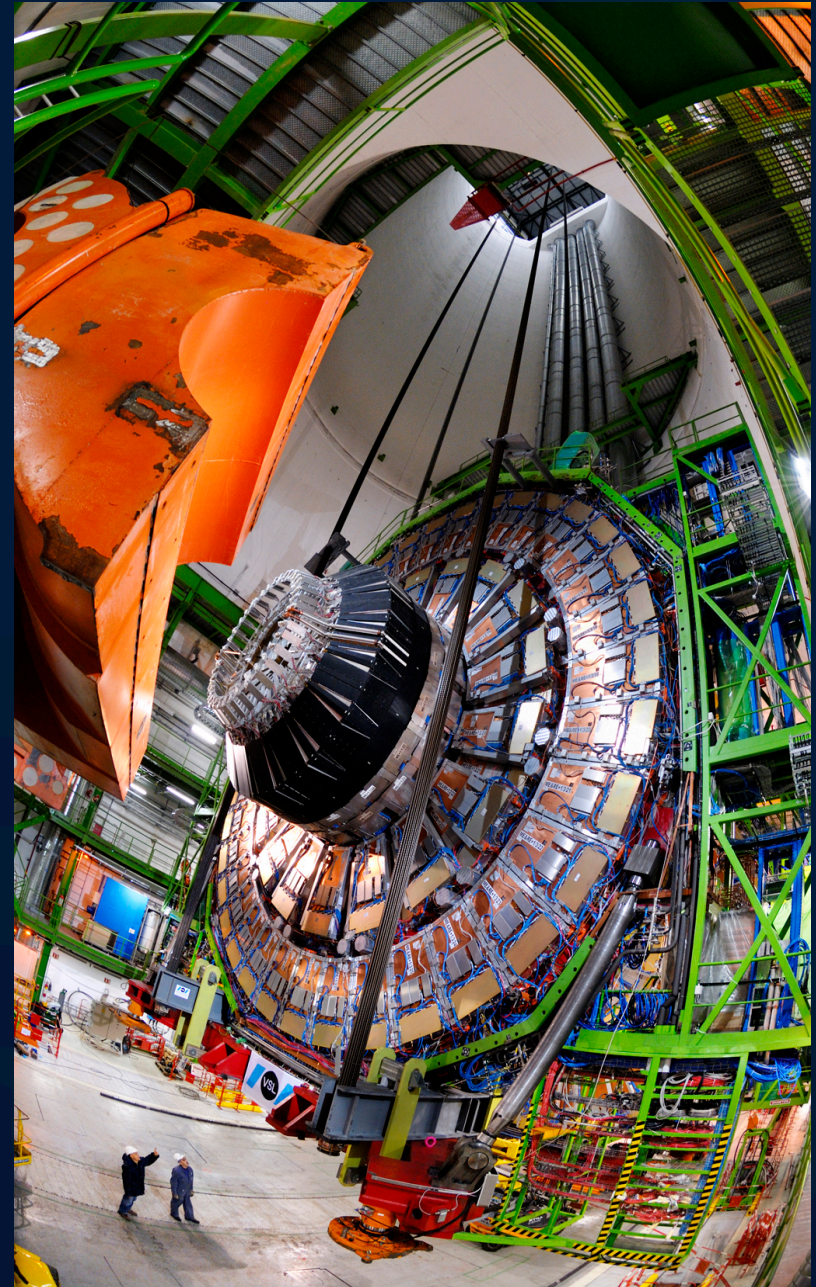
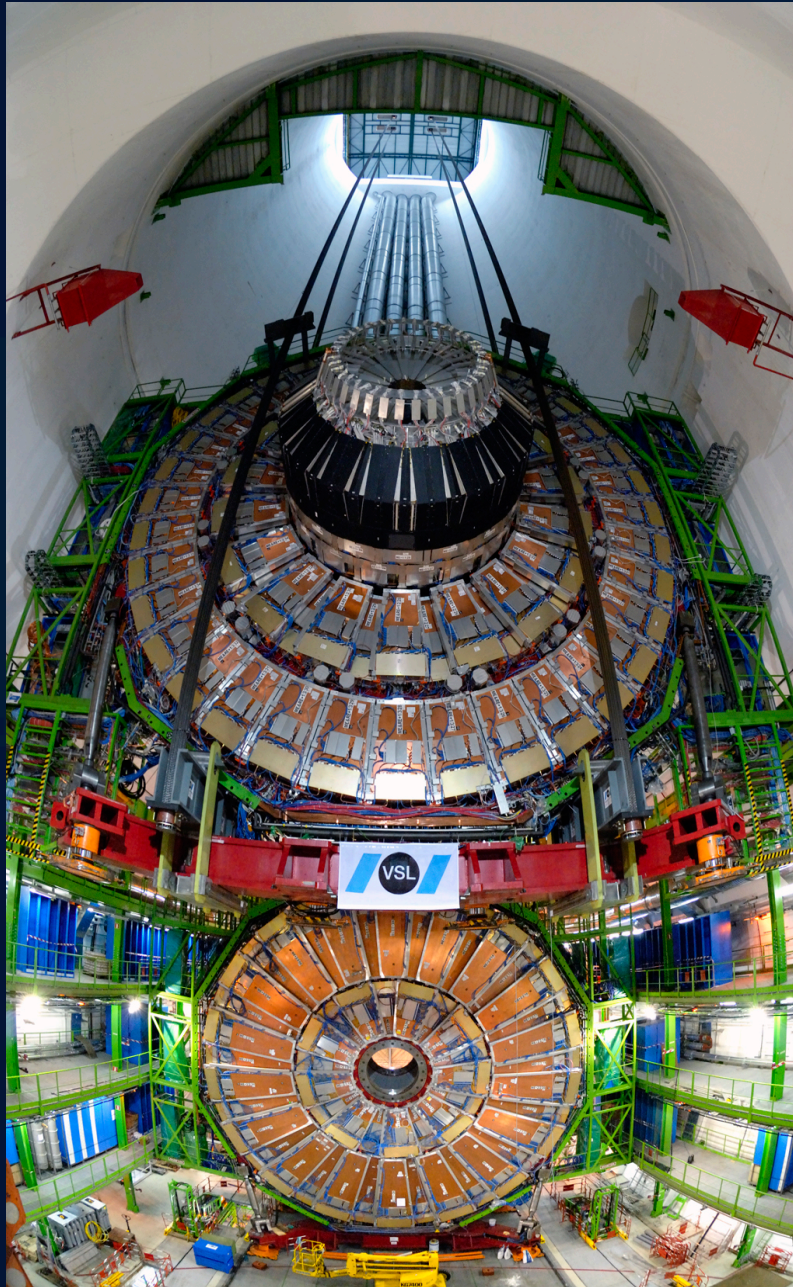
$$\text{Corr}(\Delta b) = \sum_{b=0}^{1023-\Delta b} h_2(b) h_1(b + \Delta b)$$



Self correlation histogram



Jan 2007: lowering the first endcap wheel

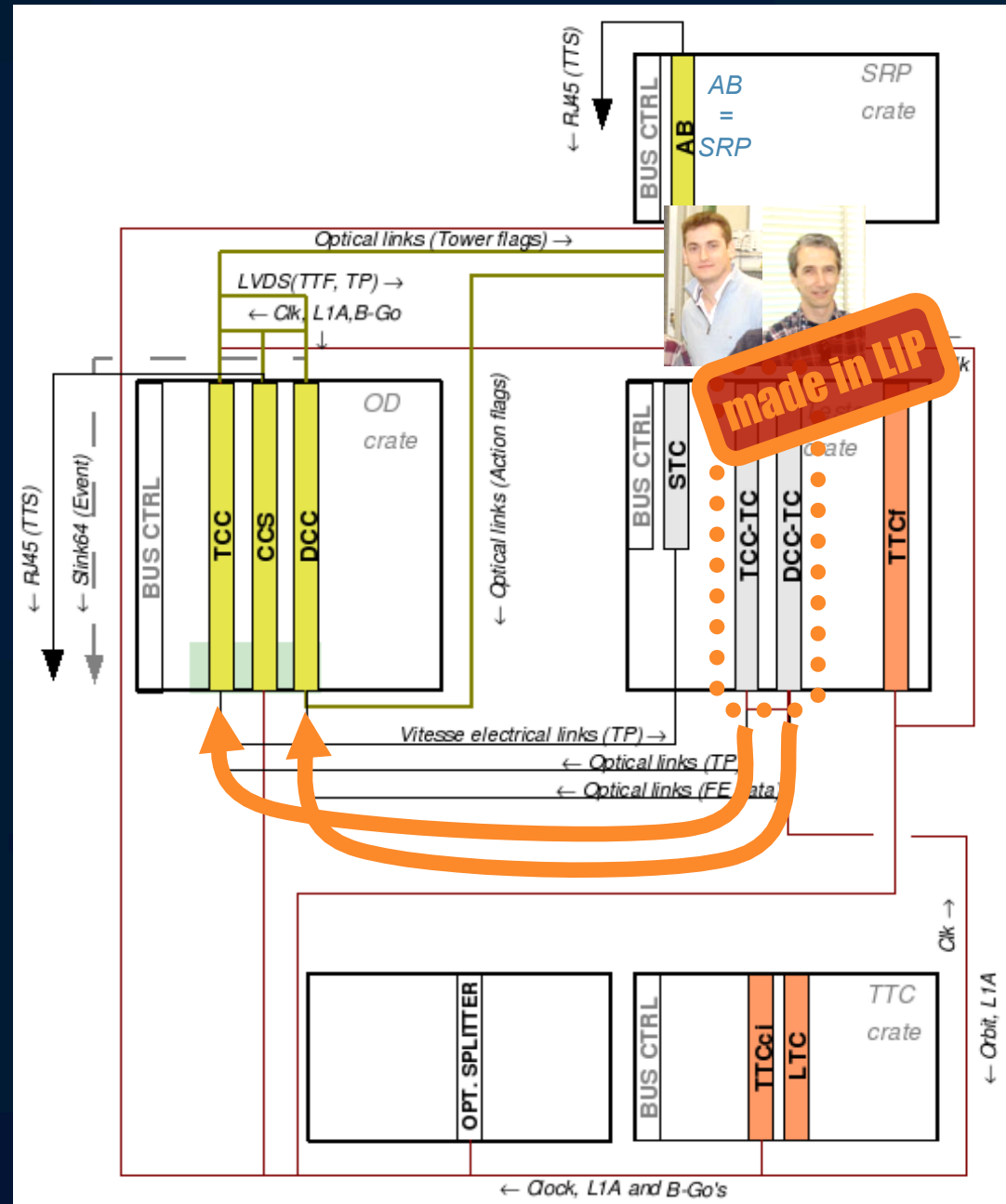
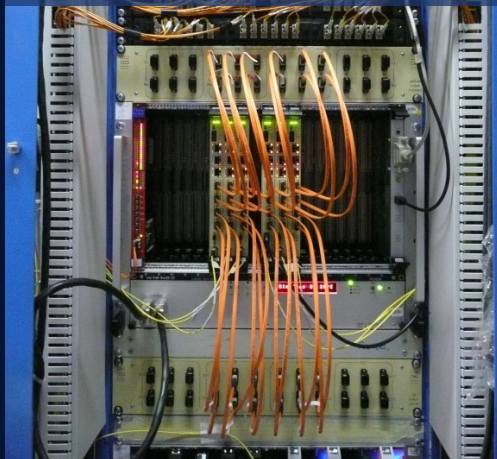


Electronics to test the electronics



Barrel OD electronics triplets in the CMS Electronics Integration Area (904) January-March 2007

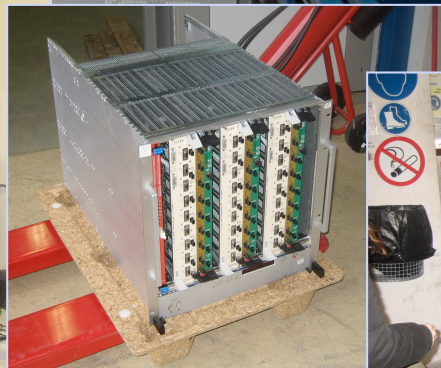
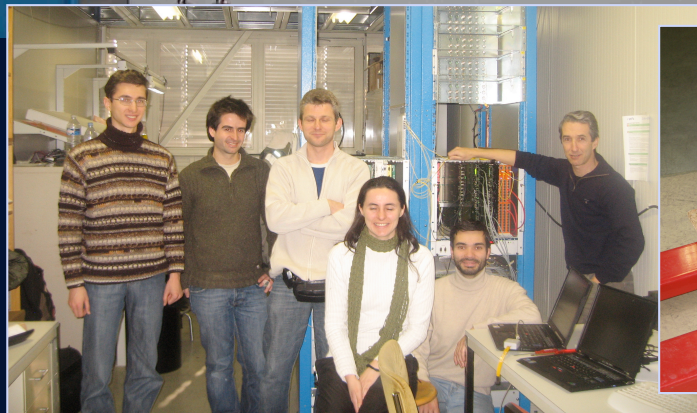
Selective Readout Processor installed in CMS October 2007



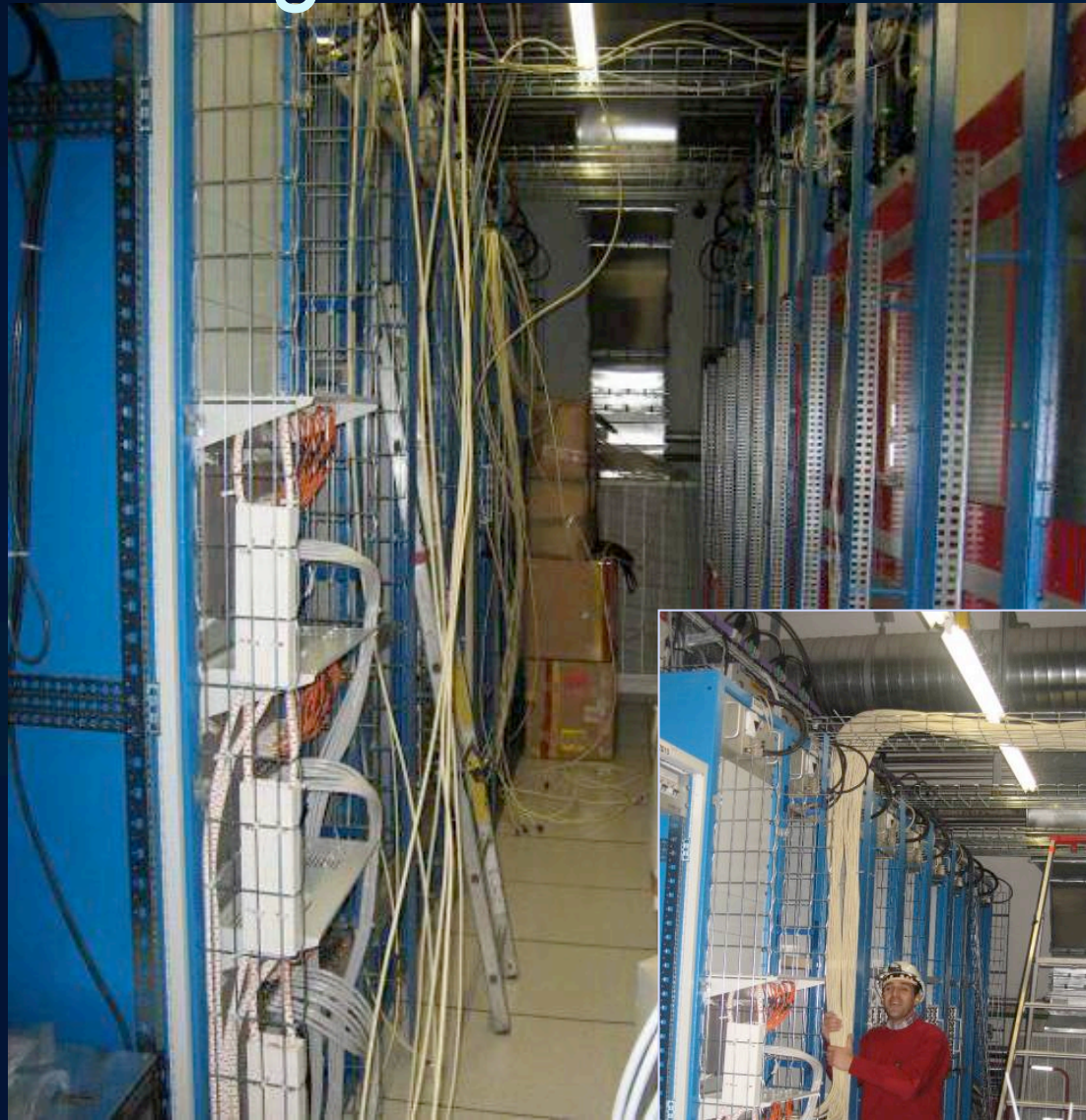
April 2007: ECAL OD electronics integration

- Integrated tests of Data, Trigger and Control cards prior to installation
- 12 crates with **110 cards** intensively tested
- **>10 hours of continuous testing** per crate

made in LIP



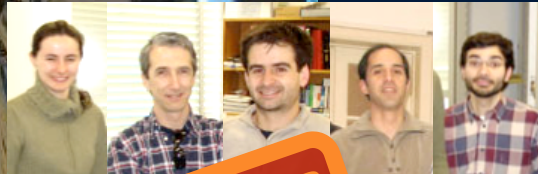
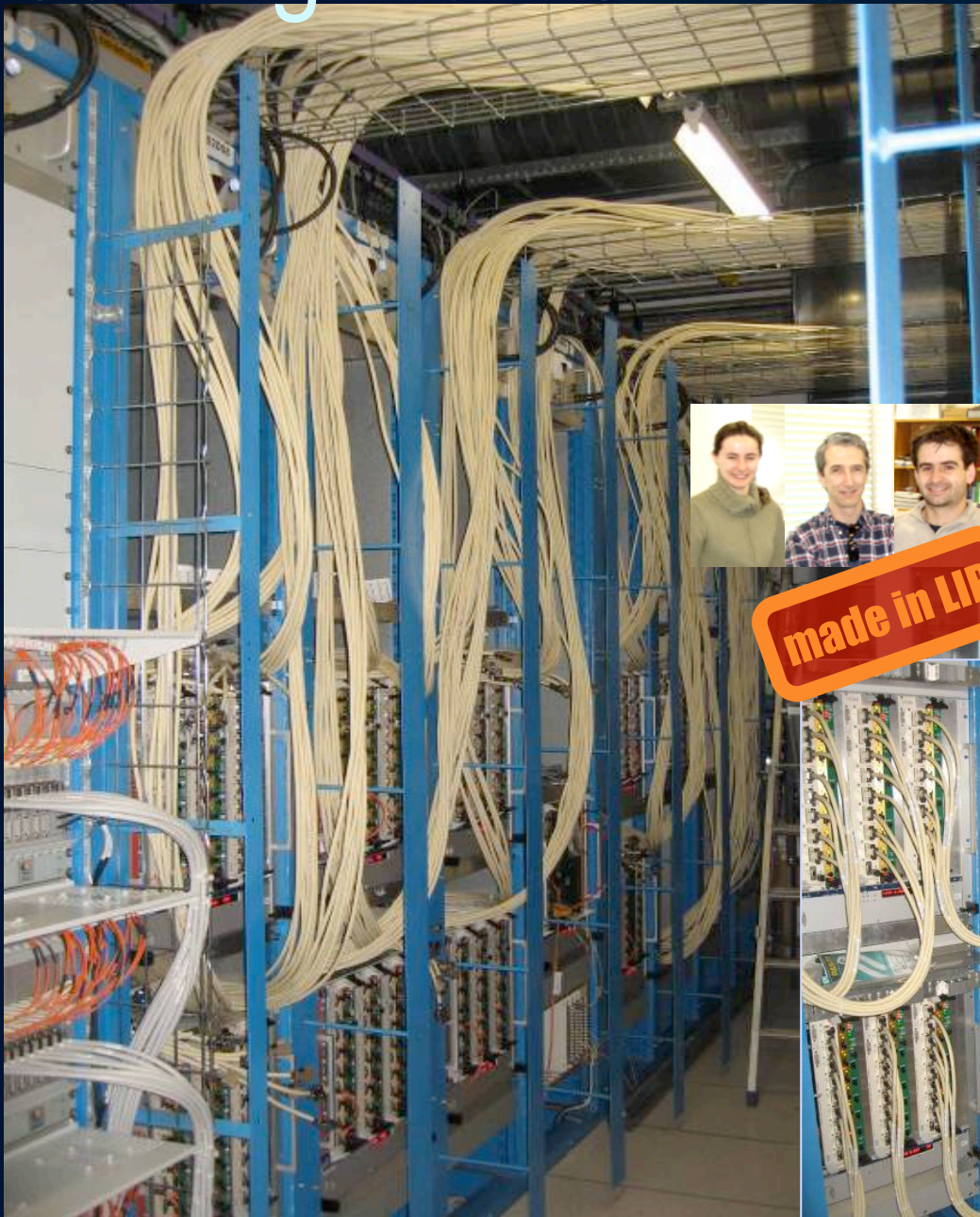
Cabling the ECAL to the Calorimeter Trigger



- ~ 500 cables to connect the ECAL Trigger outputs to the Regional Calorimeter Trigger

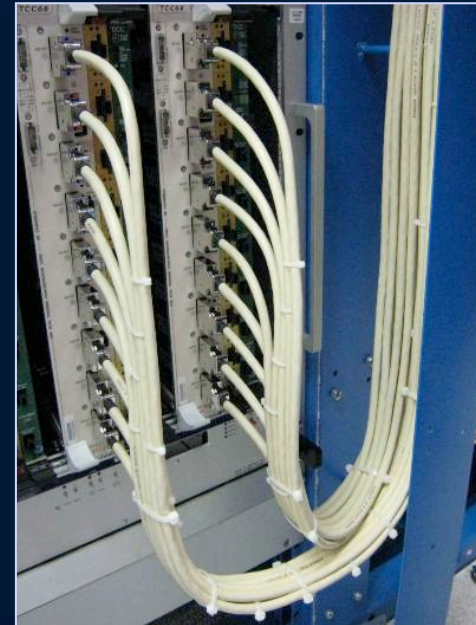
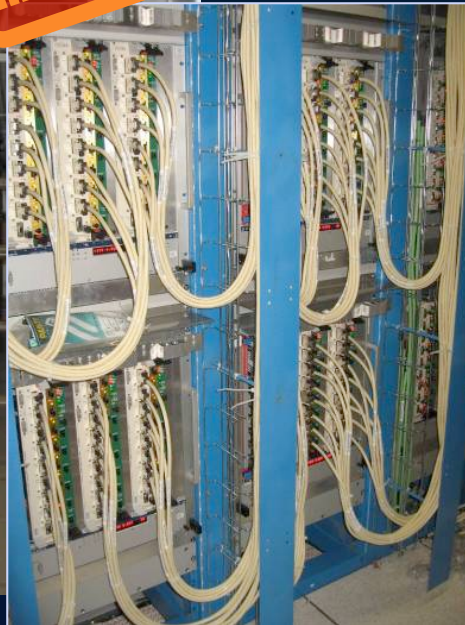


Cabling the ECAL to the Calorimeter Trigger



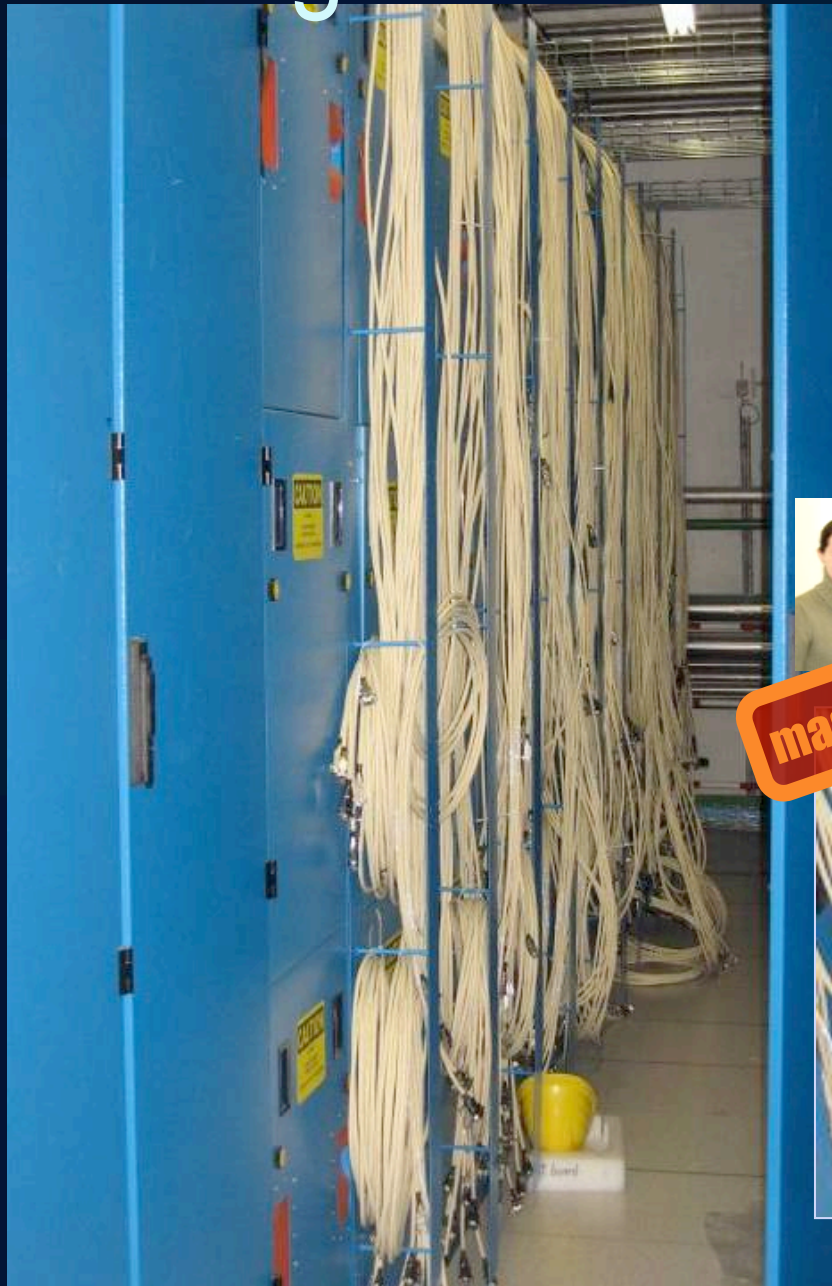
made in LIP

- ~ 500 cables **connecting** the ECAL Trigger outputs to the Regional Calorimeter Trigger



Cabling the ECAL to the Calorimeter Trigger

- ~ 500 cables delivered with the wrong screws
- ~ **1000 screws** had to be changed...

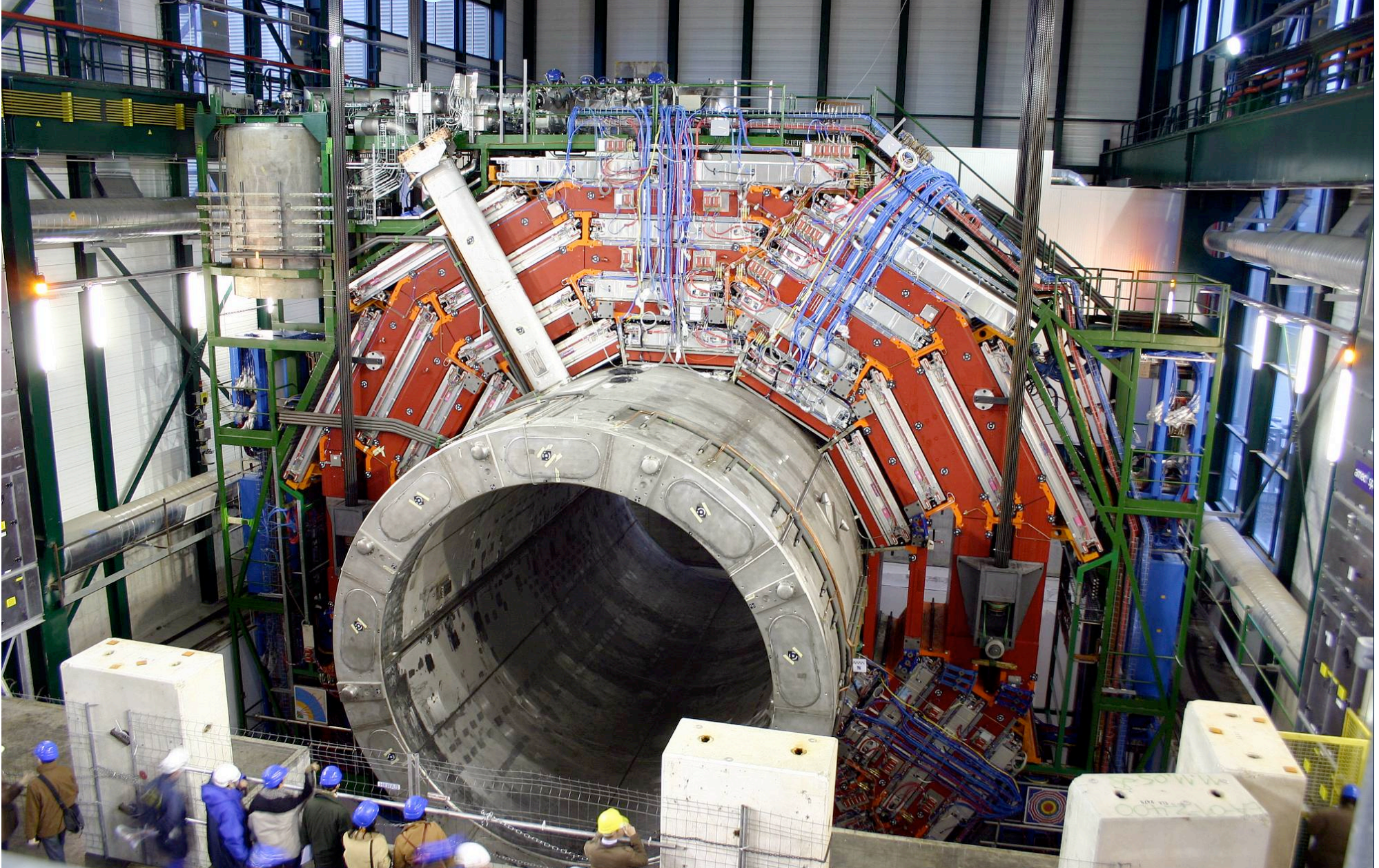


made in LIP

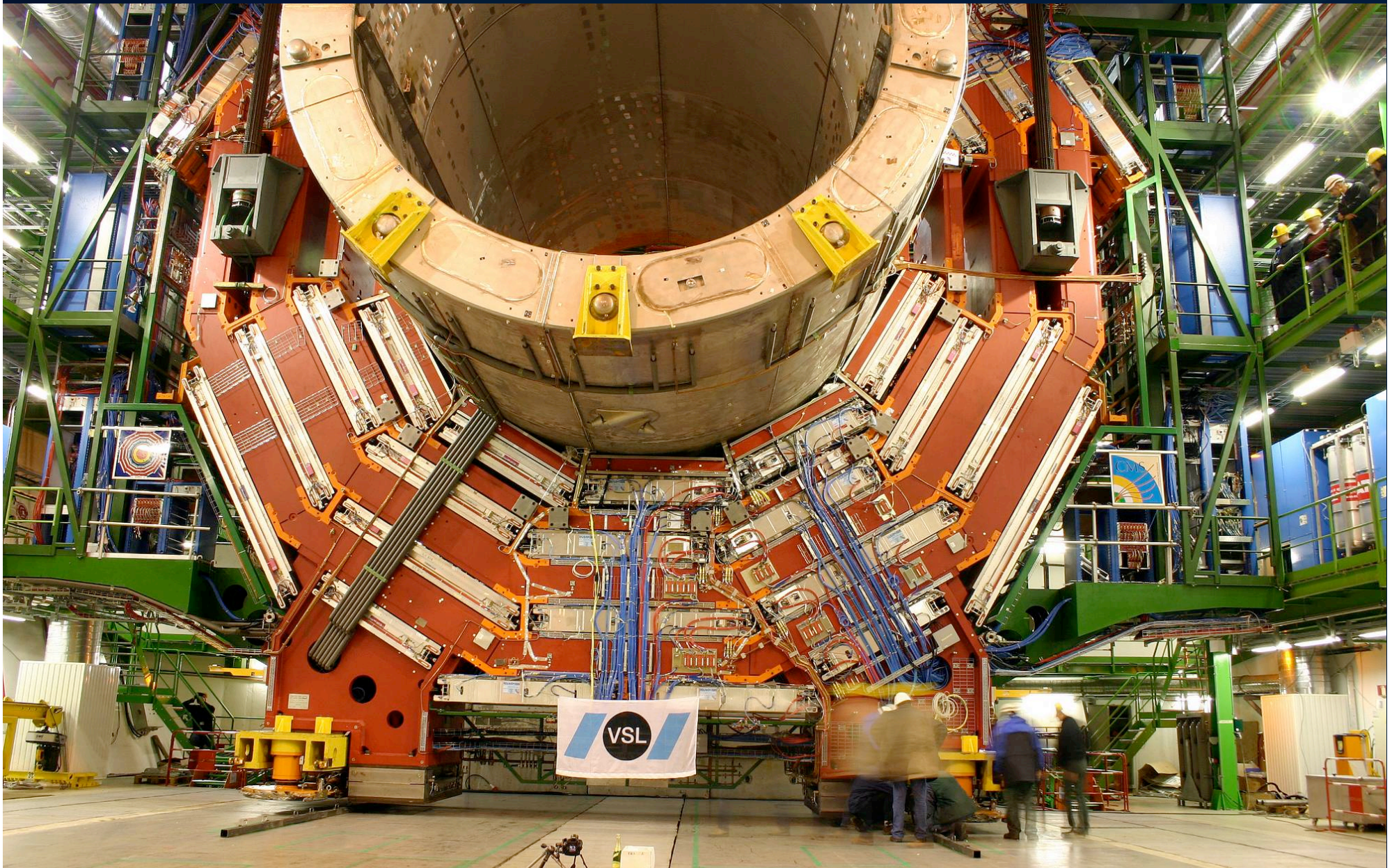


“paciência de Português”

2007: lowering of the central barrel



Touch down !



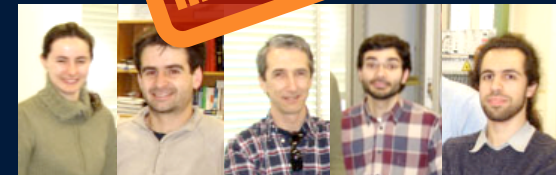
May 2007: ECAL barrel installation



ECAL Barrel installation

- **36 Supermodules** tested before and after insertion in the central barrel:

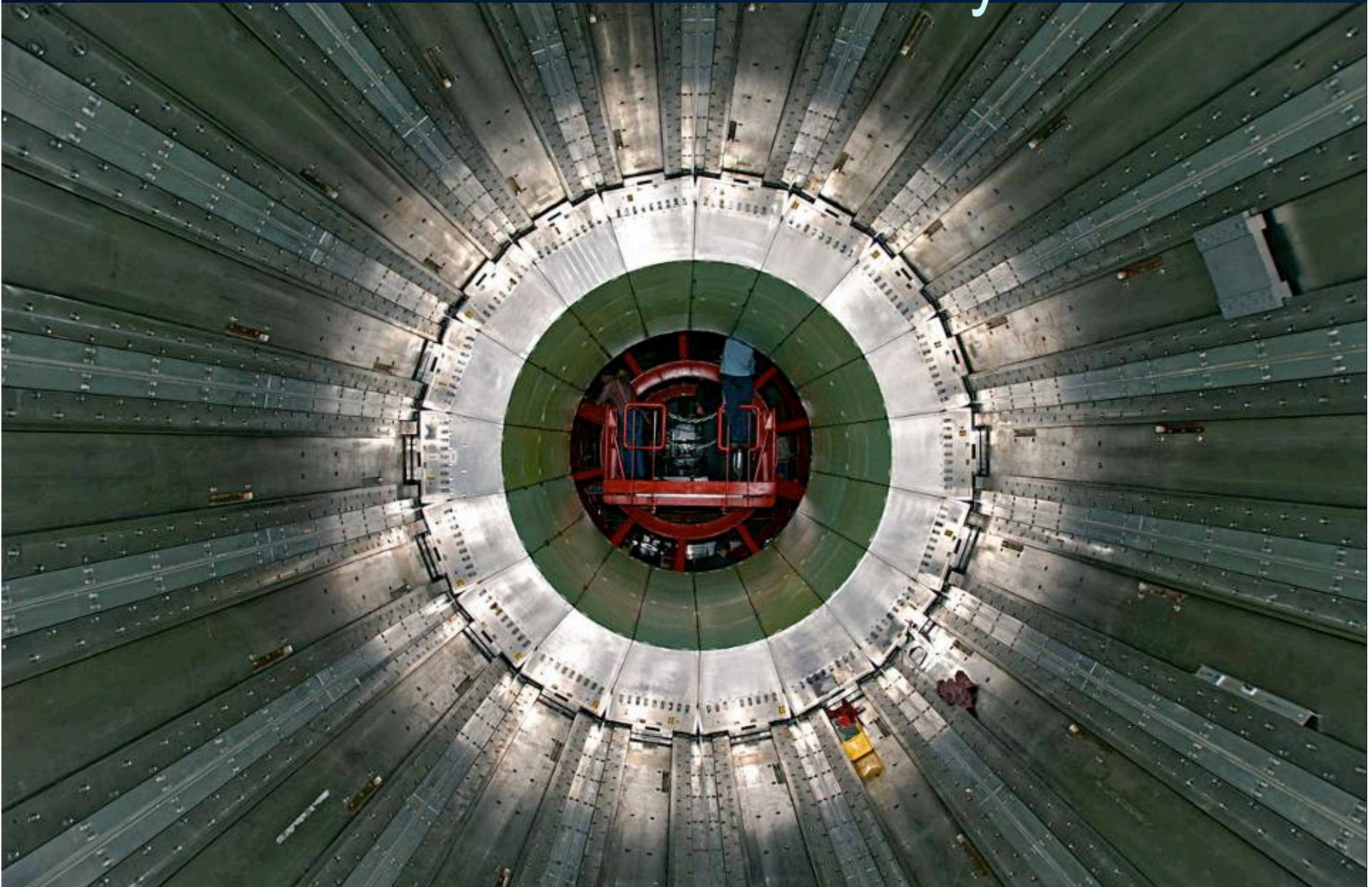
- Front-end functionality
- Data acquisition functionality
- Trigger primitive generation functionality



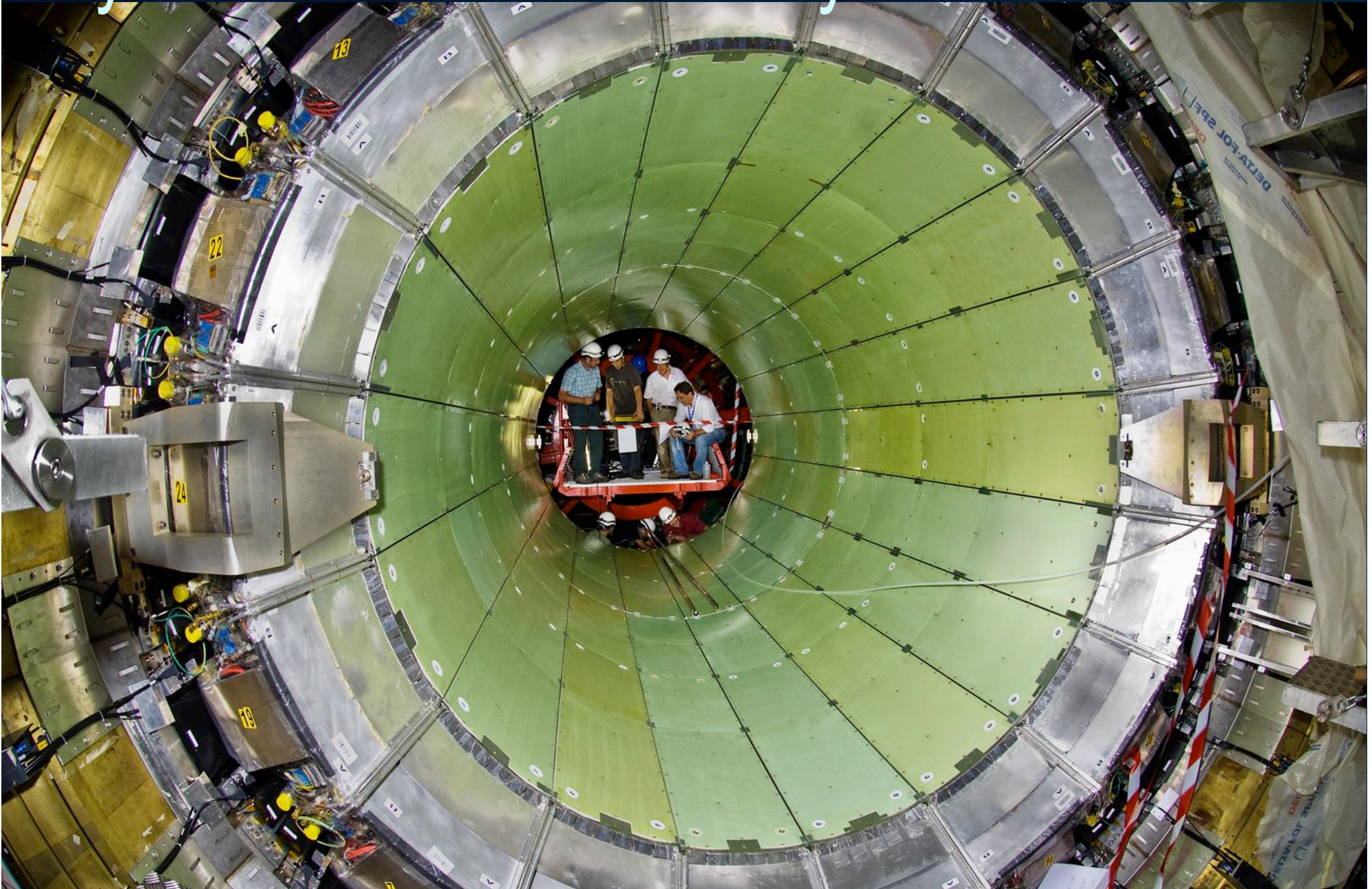
- **Sample logbook entry**

- 1) Token rings - OK
- 2) I2c devices access - OK
- 3) HV - TT57 and TT58 draw high current ($\sim 200\mu\text{A}$),
this problem has appeared on the floor, current was $50\mu\text{A}$.
- 4) DCU - OK, except channel 1427 (TT58) has high APD current ($\sim 200\mu\text{A}$)
except APD temperature TT9, cry245 bad DCU measurement (known from floor)
except APD temperature TT57, cry1441 bad DCU measurement ($\sim 15\text{ C}$, known from floor)
- 6) Pedestal run 1591 - OK, except
ch 1427 (TT58) is noisy ($\text{RMS}_{12}=41.2$),
ch 115 has $\text{rms}_6=1.8$ $\text{rms}_{12}=4.2$ (new problem)
all MEM box channels are noisy in gain 16, as before
- 7) Test pulse run 1592 - OK, except channel 331 (TT15);
it had big HV current and has been disconnected from the HV in 867
- 8) Pedestal HV off run 1593 - OK, except channel 331 (TT15) as explained above
- 9) Trigger links - OK

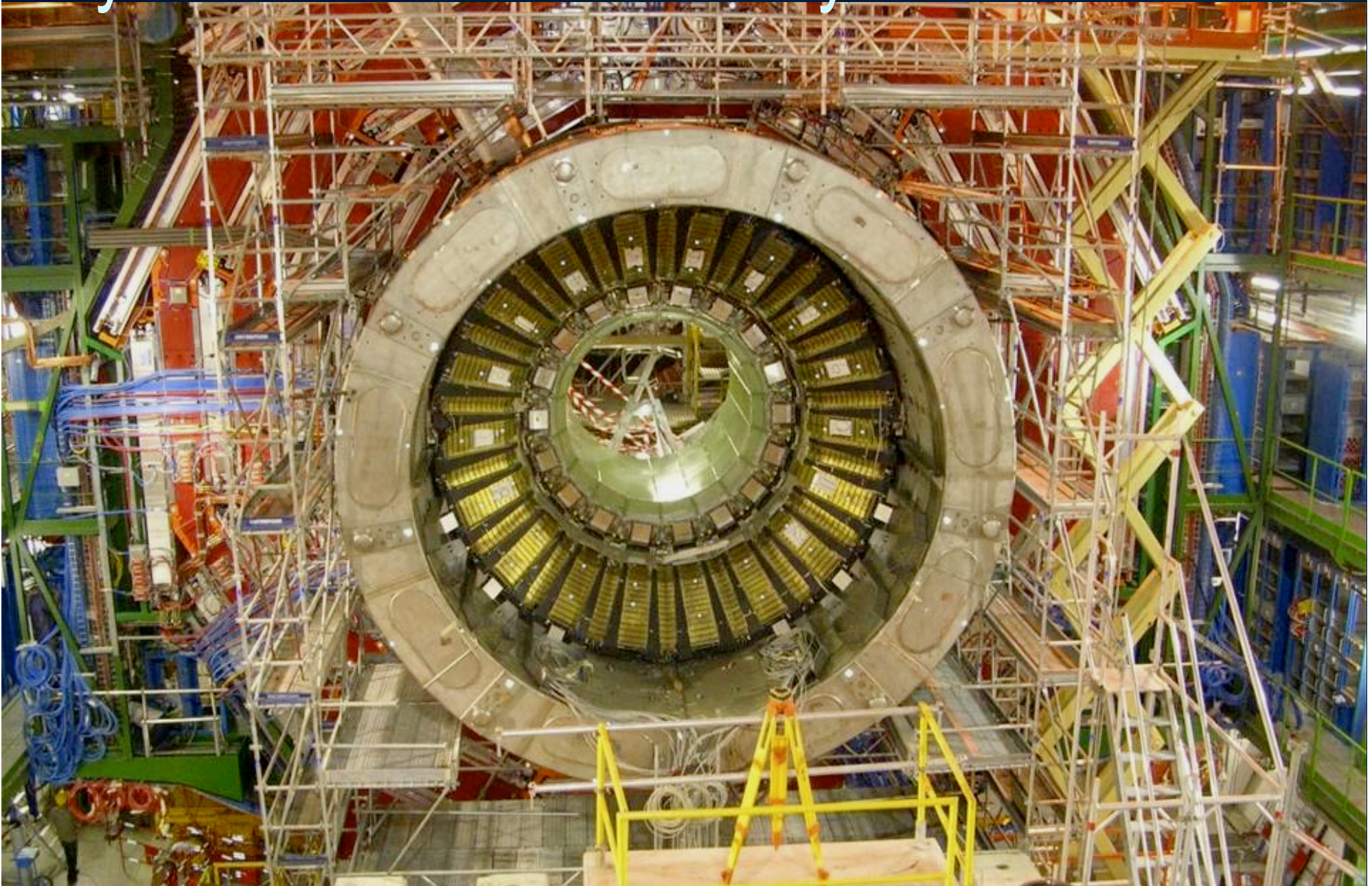
ECAL Barrel installation half-way



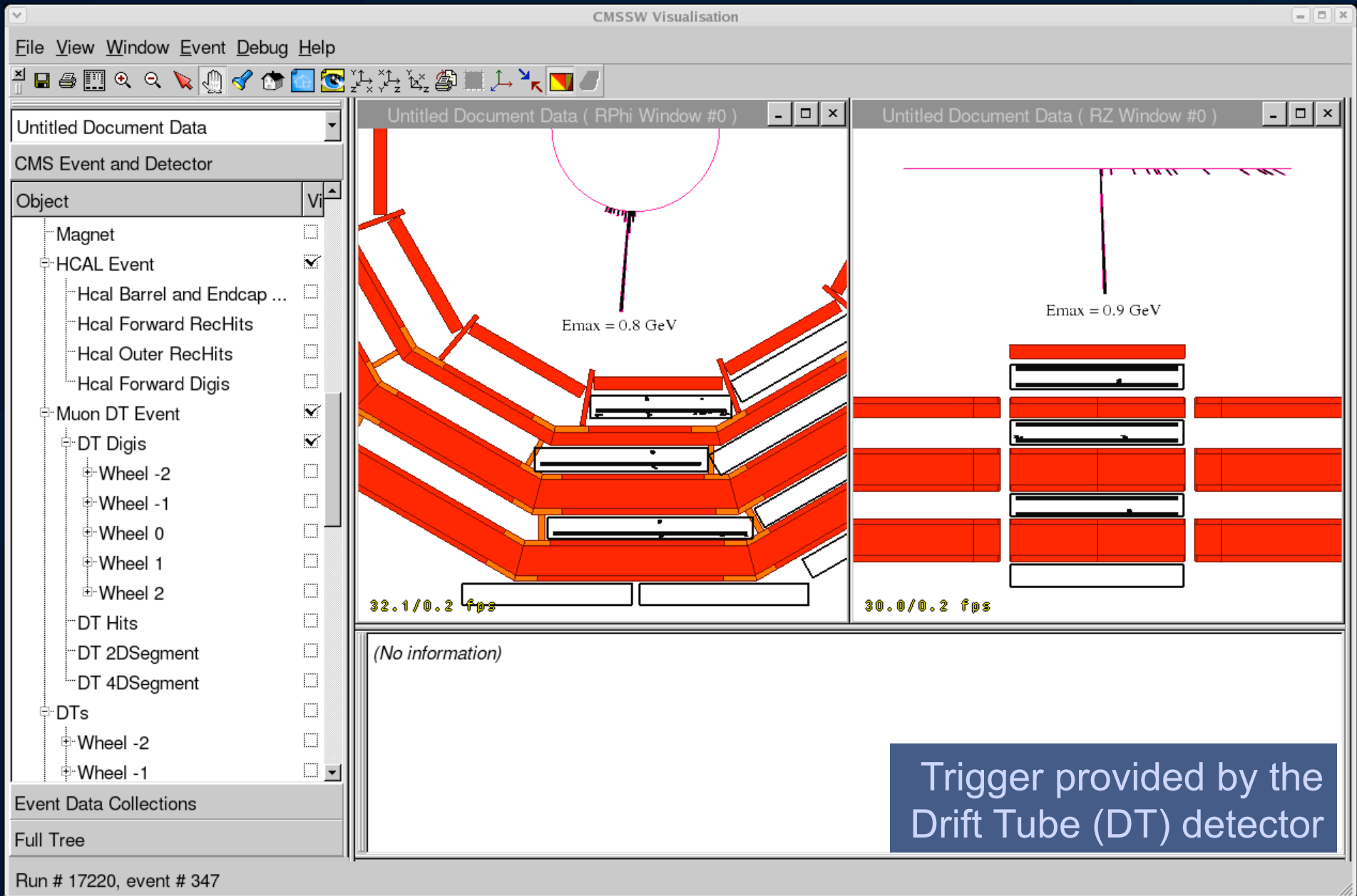
July 2007: ECAL barrel fully installed



July 2007: ECAL barrel fully installed



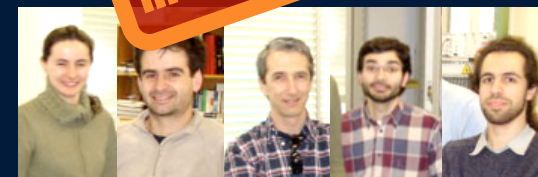
August 2007: muons seen in the ECAL



Sep 2007: ECAL final cabling

- **36 Supermodules** tested with final optical fibres:

- Front-end functionality
- Data acquisition functionality
- Trigger primitive generation functionality
- **Laser monitoring system functionality**



- Tests also **repeated** after Tracker cabling

- **Sample logbook entry**

EB+13 SM35 LASER test, DCU test
after Tracker coverage:

+++++

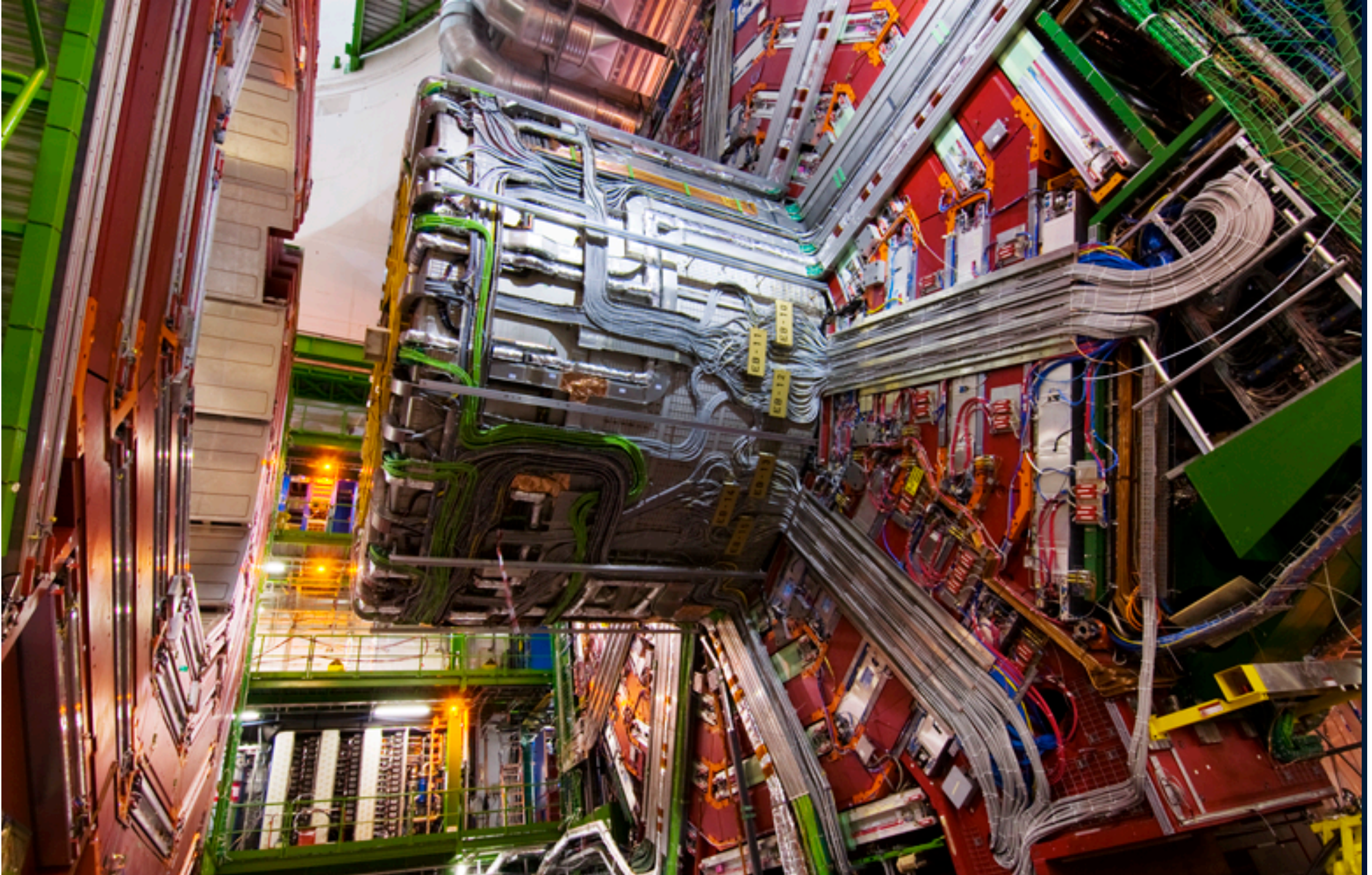
Laser - HV=gain 50 , Side A run 31147 Ampl ~ 1700-2200 ADC counts -
a channel on TT24 is masked (Ampli was ~60% at B867)

Side B run 31151 Ampl ~ 1800-2700 ADC counts
crystal 1023 on TT41 is masked, known dead from B867 (disconnected from HV)

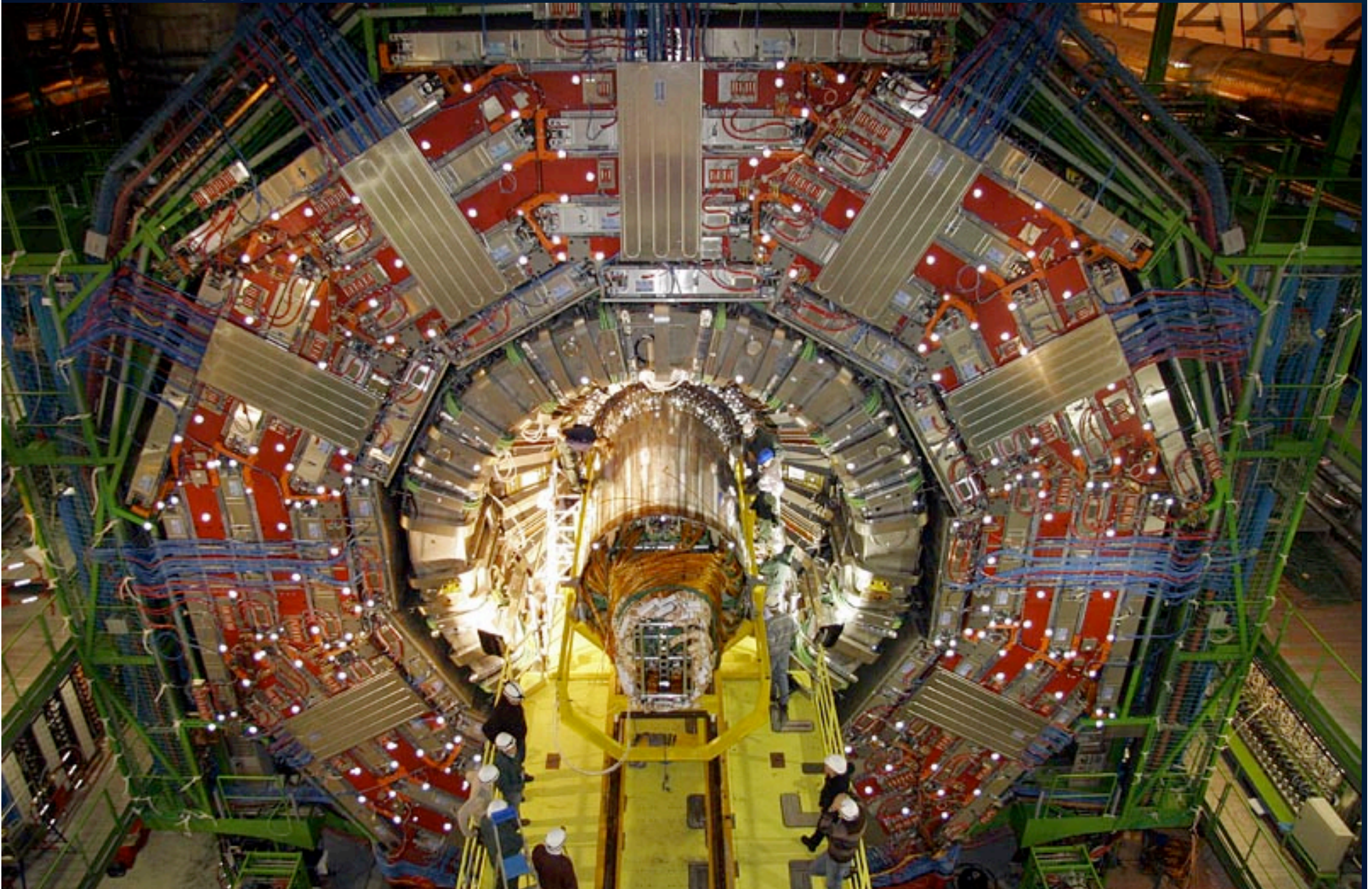
In this moment condition database is not reachable so we can not go in more details about channels low.

DCU run ok - thermistor on TT60,67,68 are dead and LVR low (~3.85V) on TT37-38-41-42 and 61-65-66

Nov 2007: barrel ready for tracker



Dec 2007: tracker inserted in CMS



About *real magic* and magic that is real

6/17/87 (Delhi)

“I’m writing a book on magic,” I explain, and I’m asked, “Real magic?” By *real magic* people mean miracles, thaumaturgical acts, and supernatural powers.

“No,” I answer: “Conjuring tricks, not real magic.”

Real magic, in other words, refers to the magic that is not real, while the magic that is real, that can actually be done, is not *real magic*.

Lee Siegel, Net of Magic (p. 425)

About *real data* and data that is real

6/01/09 (Geneva)

“I’m writing slides on data,” I explain, and I’m asked, “Real data?” By *real data* people mean high-energy collisions, SM physics and BSM physics.

“No,” I answer: “Cosmic muon data.”

Real data, in other words, refers to the data that is not **yet** real, while the data that is real, that can actually be analyzed, is not *real data*.

This talk offers **data that is real**, not **yet *real data***.

September 3, 2008 at 20:30

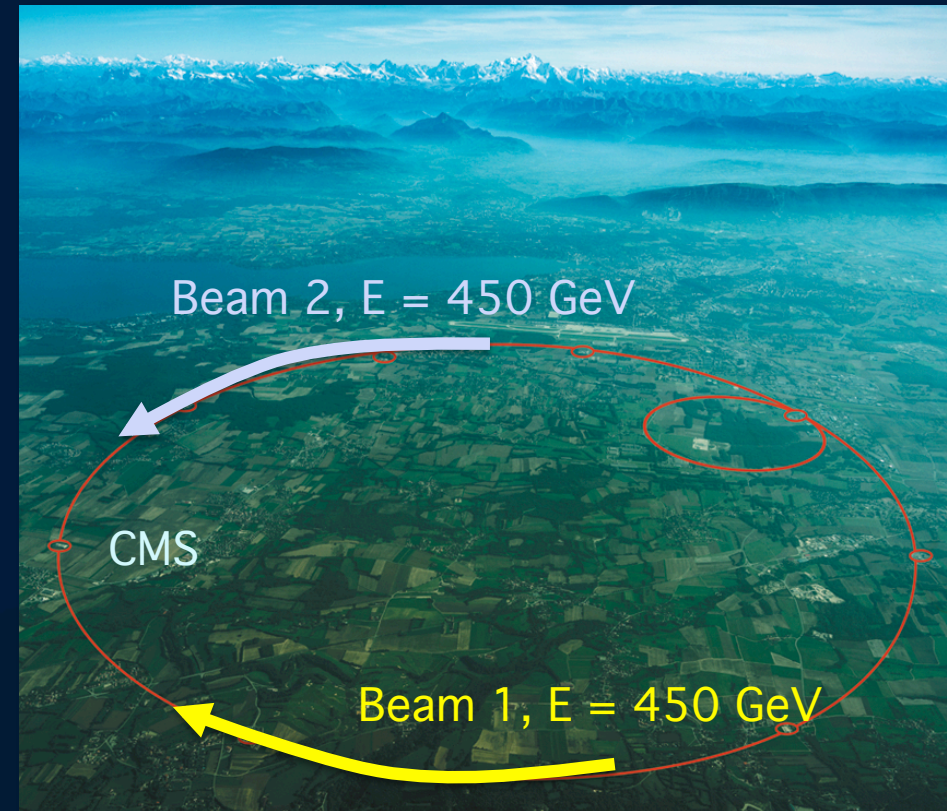


CMS closed and
ready for beam

B field OFF (beam)
All silicon OFF (safety)

Last year beams in the LHC

- September 7
 - Beam 1 on collimators (upstream of CMS)
- September 10 (D-day)
 - Beam 1, then Beam 2 circulating (hundreds of turns)
- September 11
 - RF capture (millions of orbits)
 - Beam halo through CMS
 - Beam-gas events
- About 40 hours of beam at or through CMS
 - All systems ON except Tracker and Solenoid

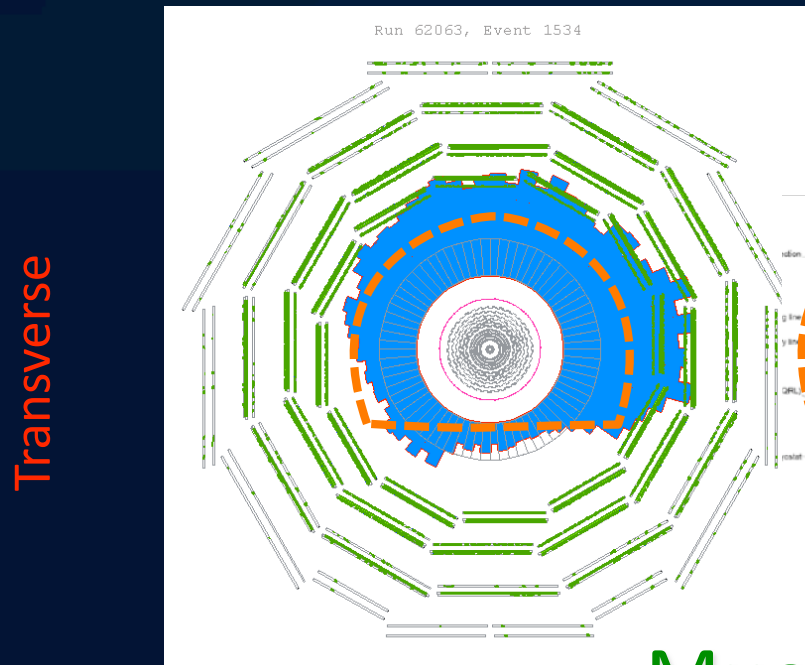
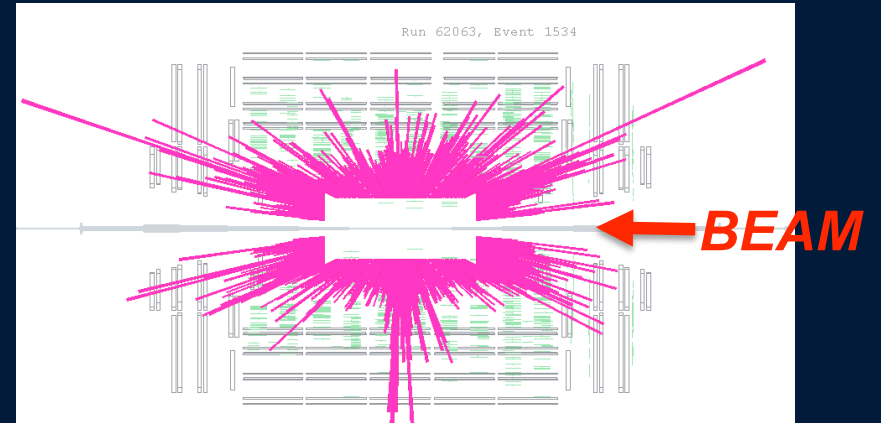
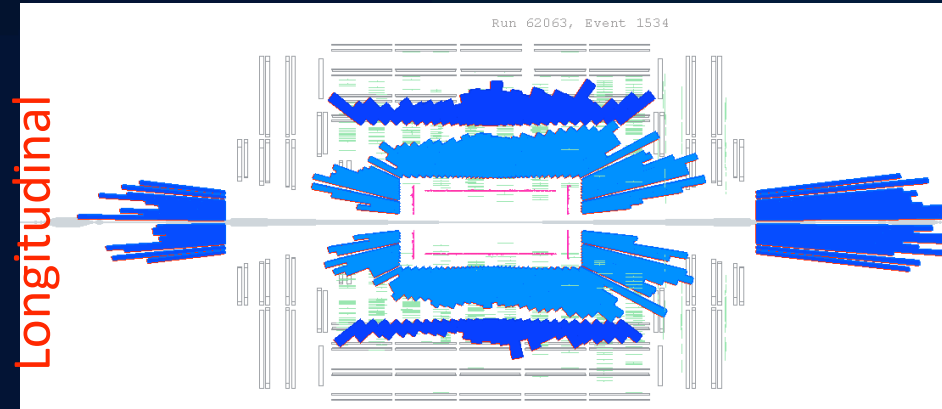


□ CMS Trigger and DAQ fully functional: millions of beam events recorded

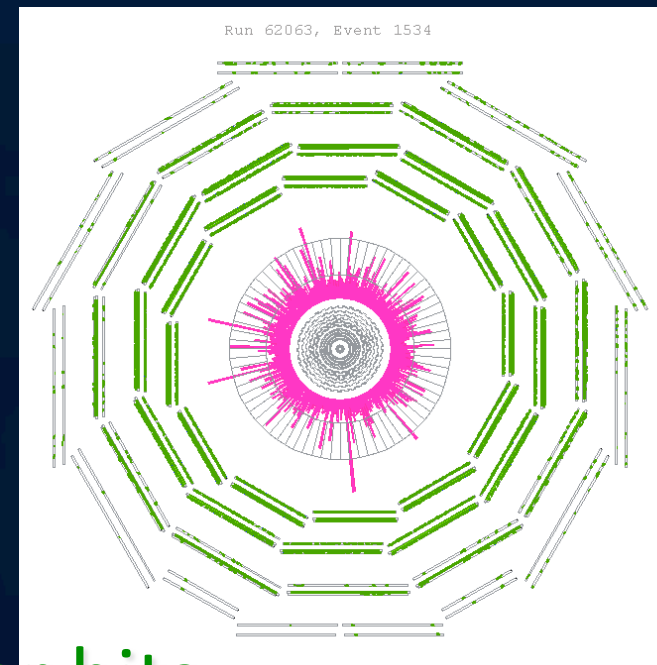
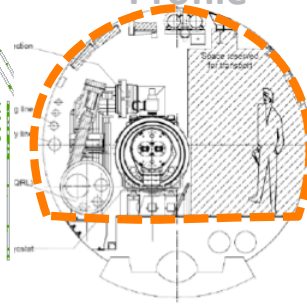
Beam Splash Event Display

HCAL energy

ECAL energy

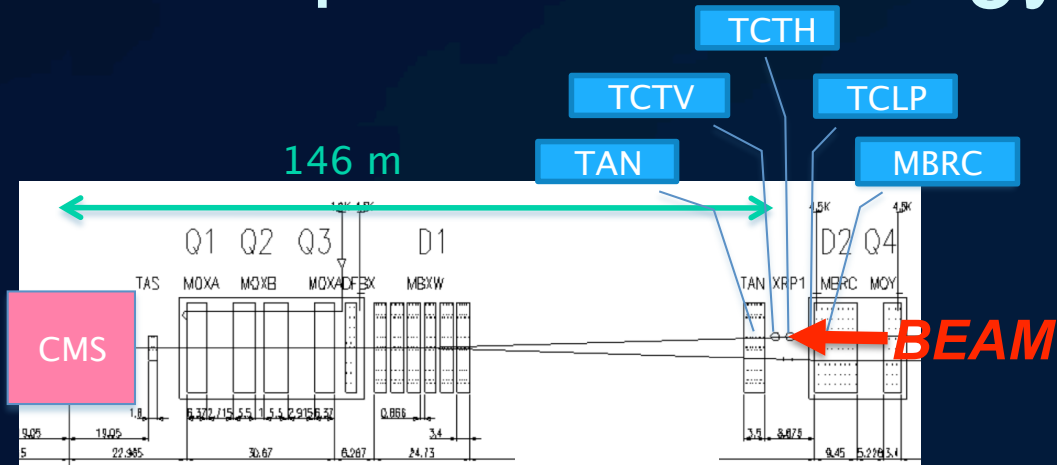


LHC Tunnel Profile

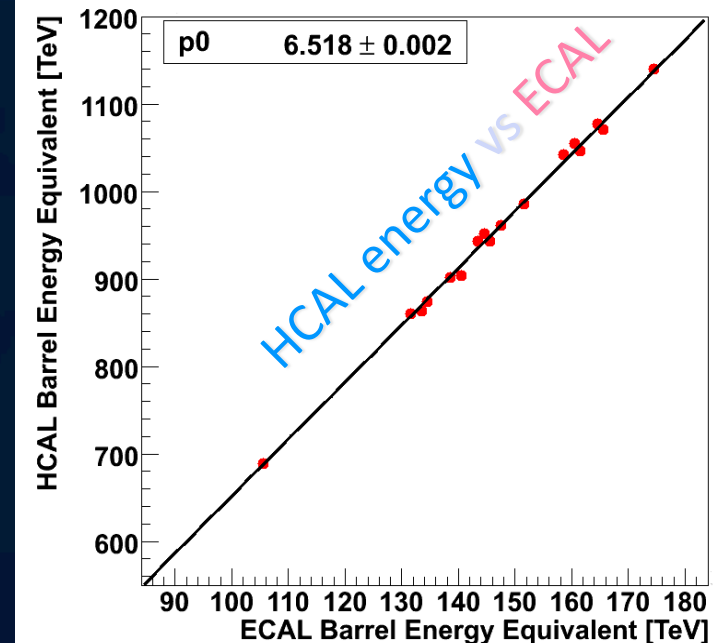
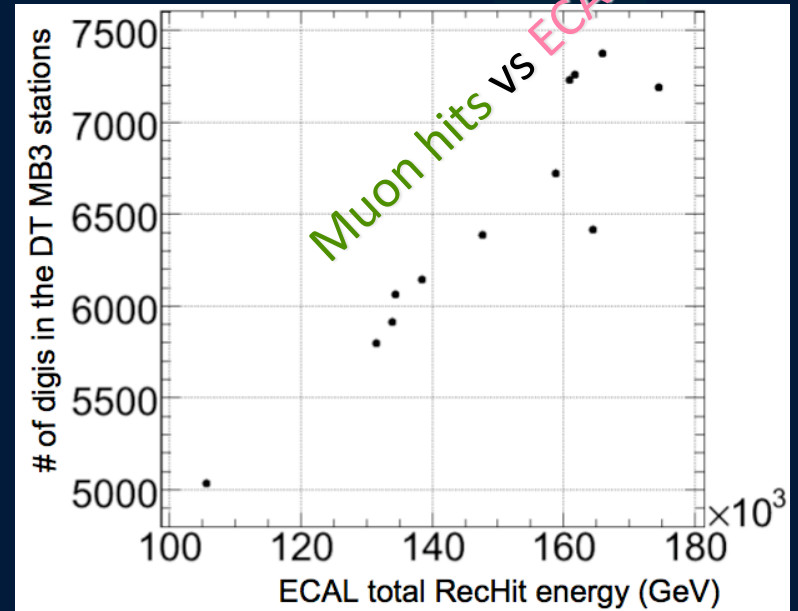
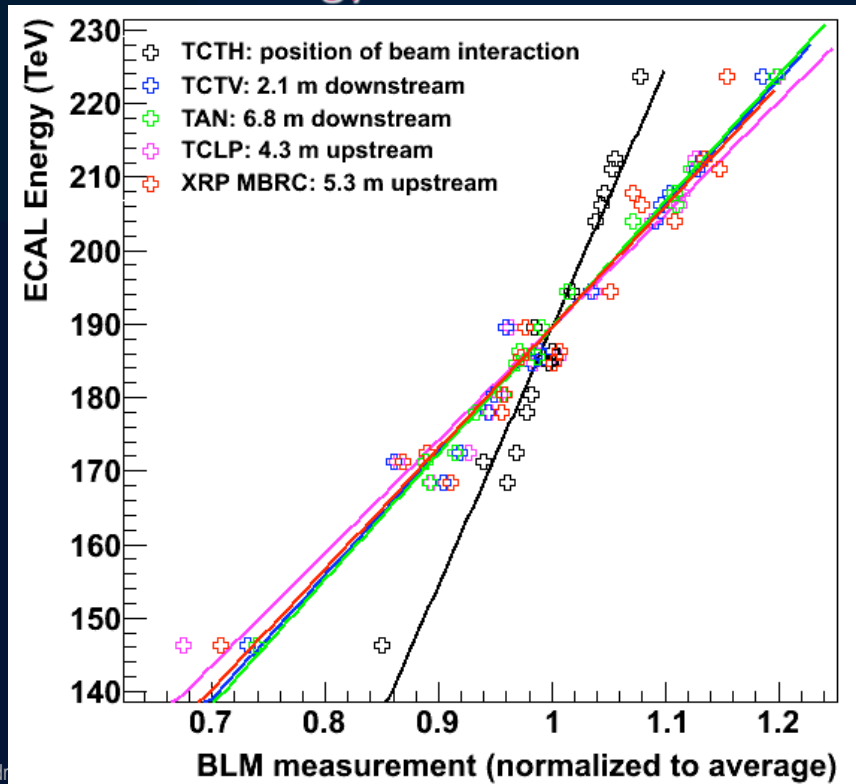


Muon chamber hits

Beam Splashes – energy in CMS

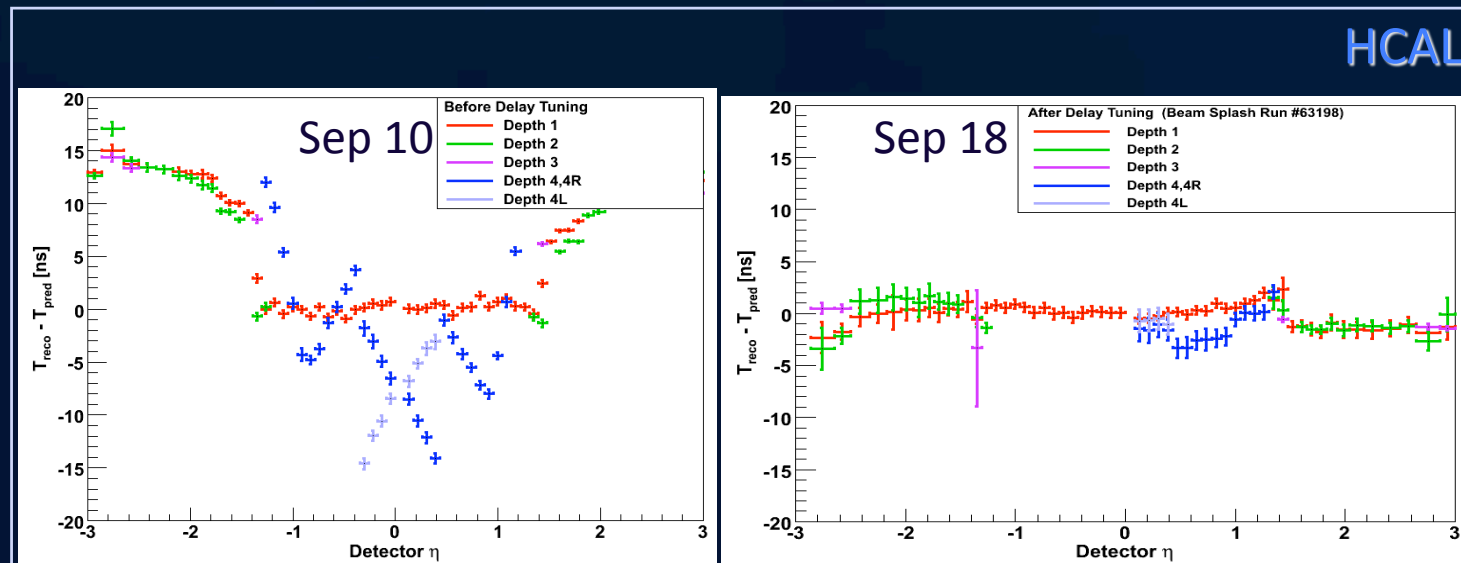
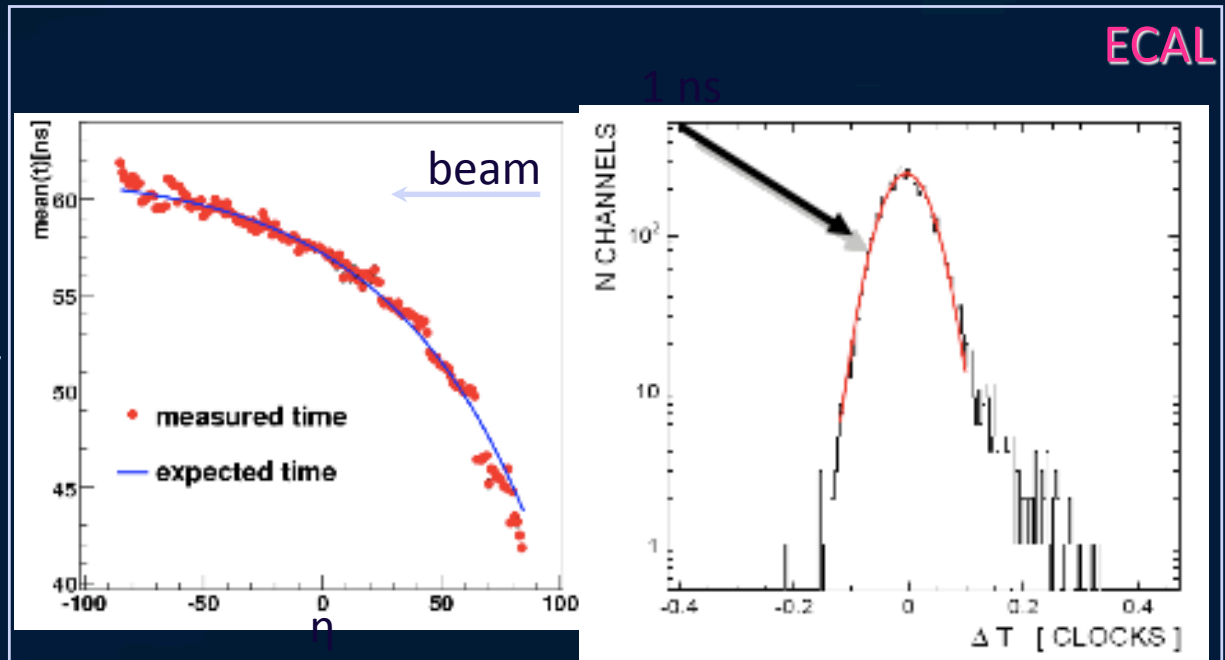


ECAL energy vs Beam Loss Monitors

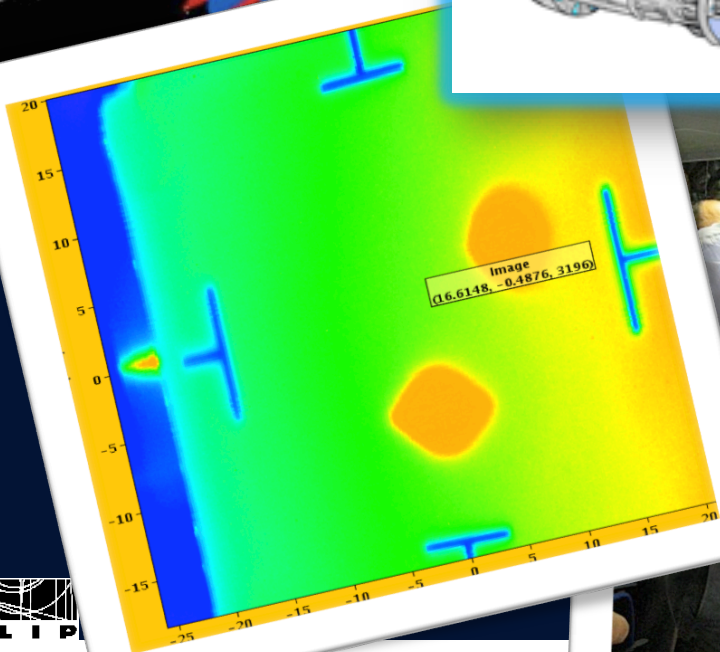
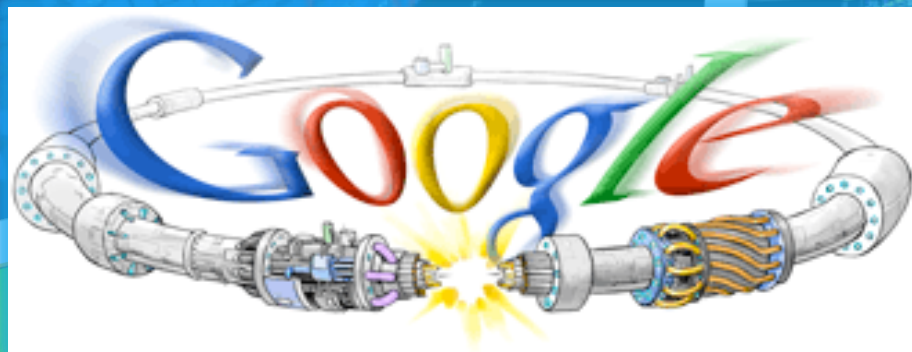
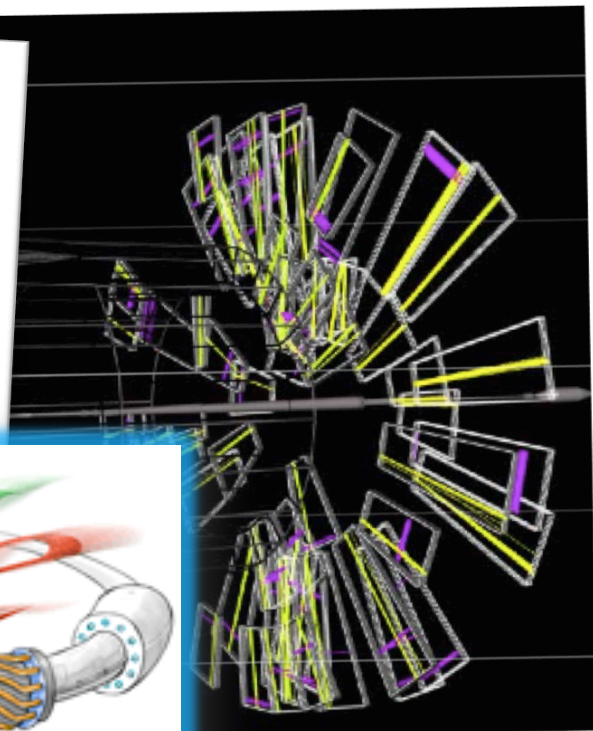
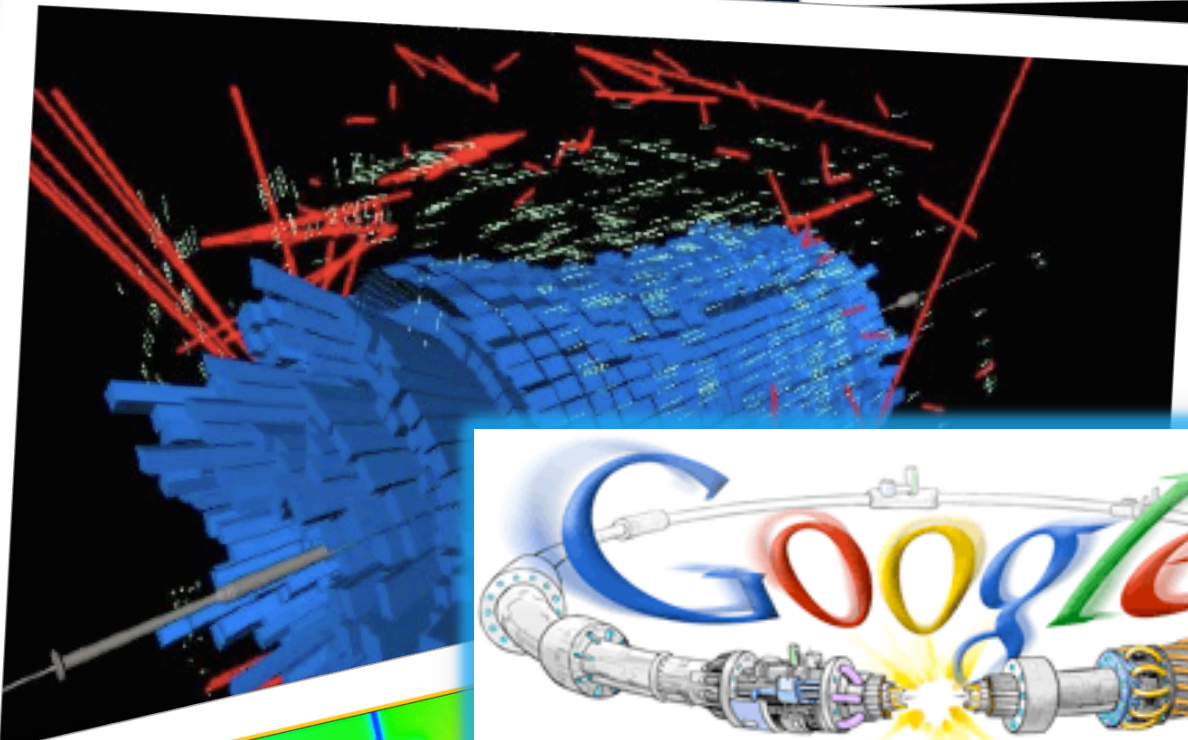


Splash synchronization of calorimeters

- In splash events all channels fire
- synchronize in one go all the calorimeters
 - time of arrival follows geometry

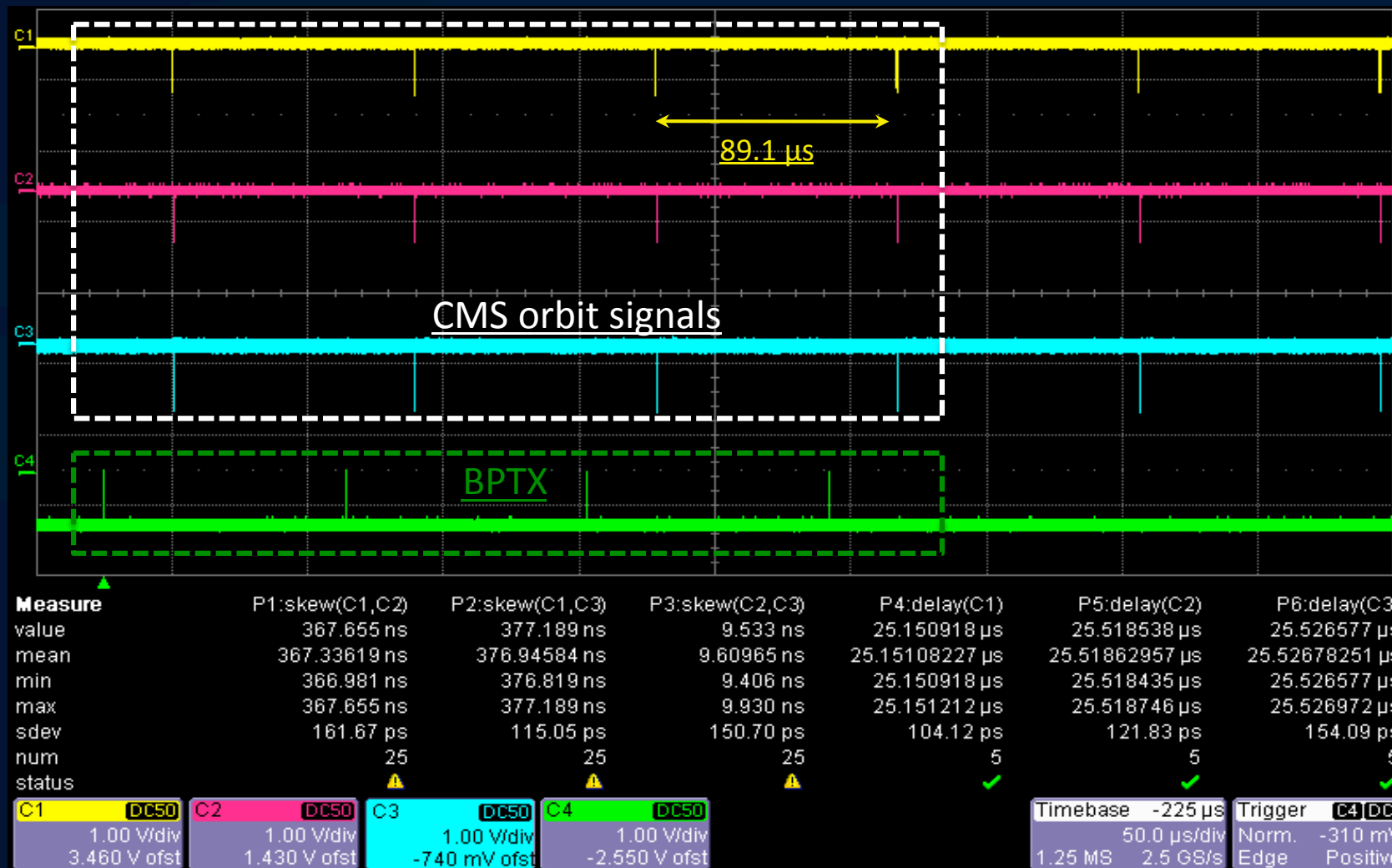


Cometh September 10



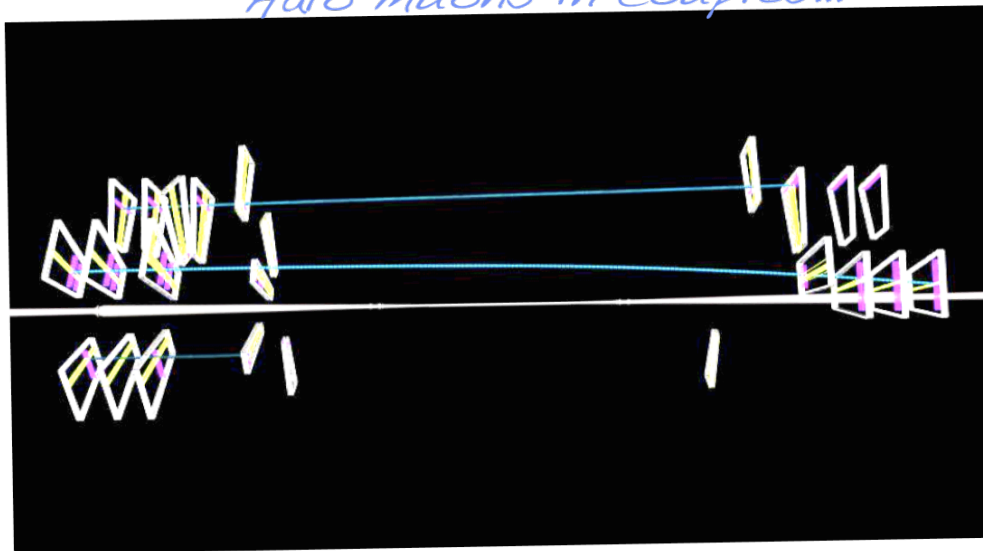
Circulating beams

Multiple orbits detected in the CMS beam monitoring system (BPTX)

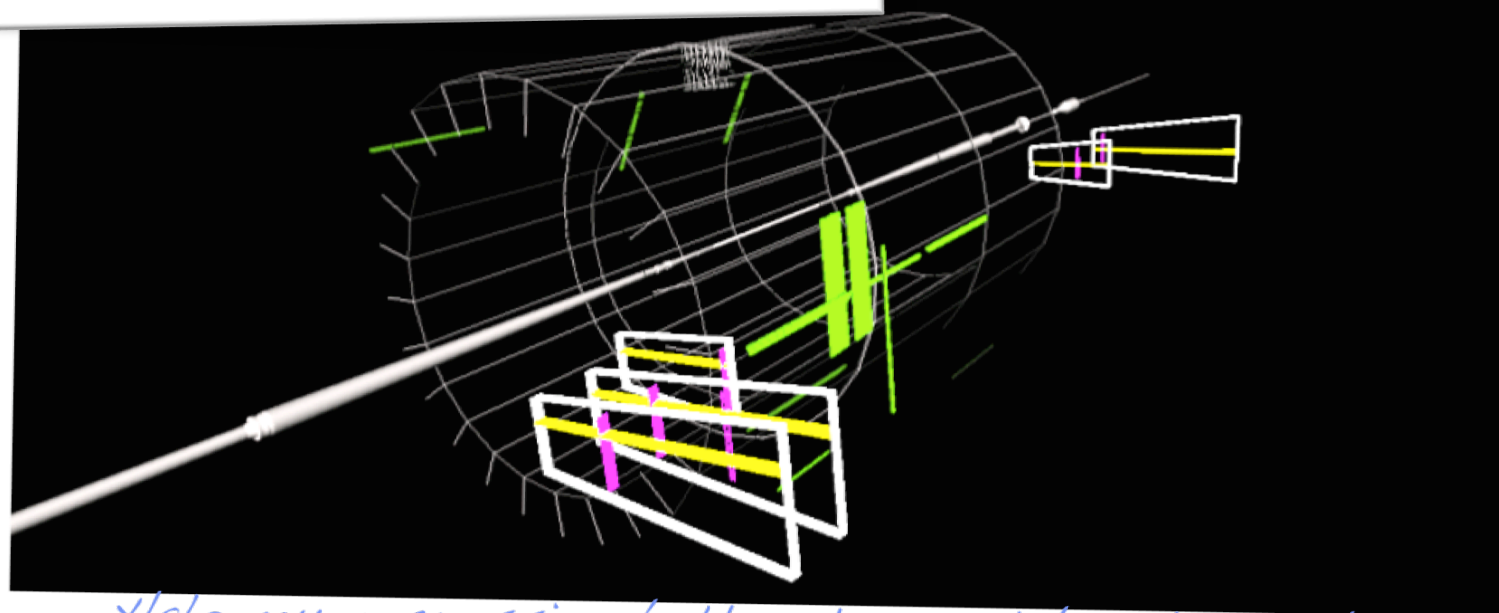
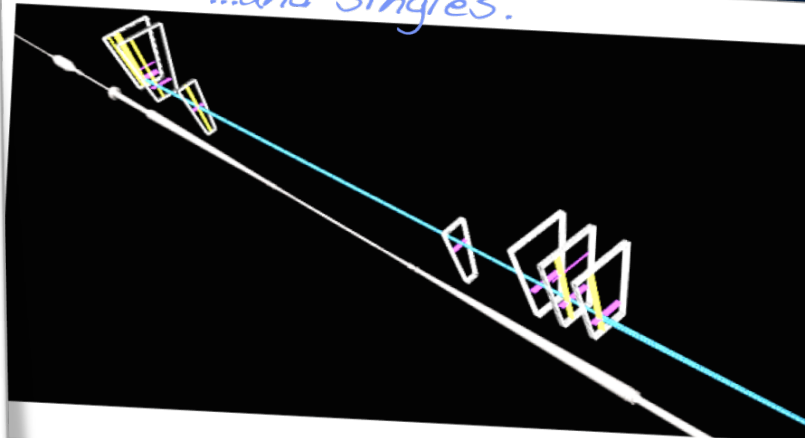


From the CMS Album

Halo muons in couples...



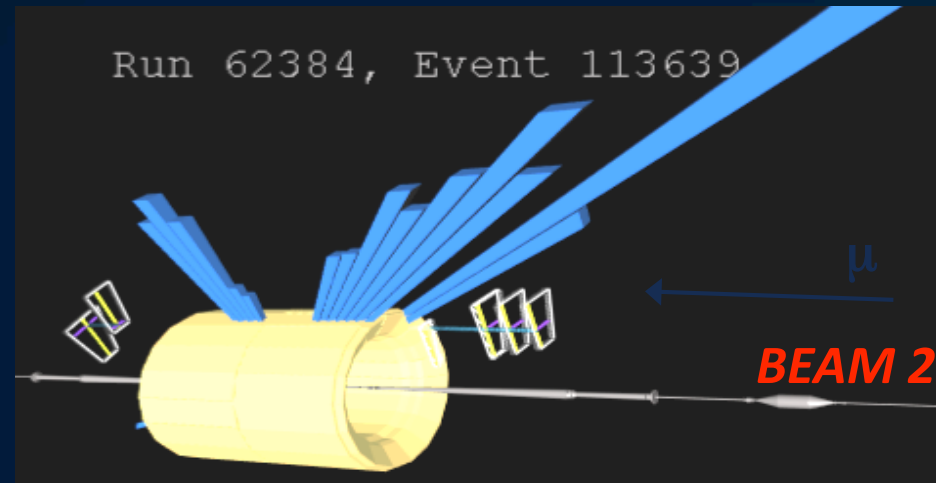
...and singles.



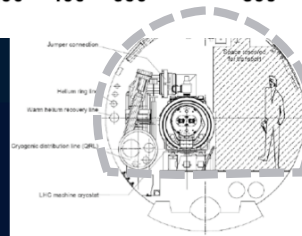
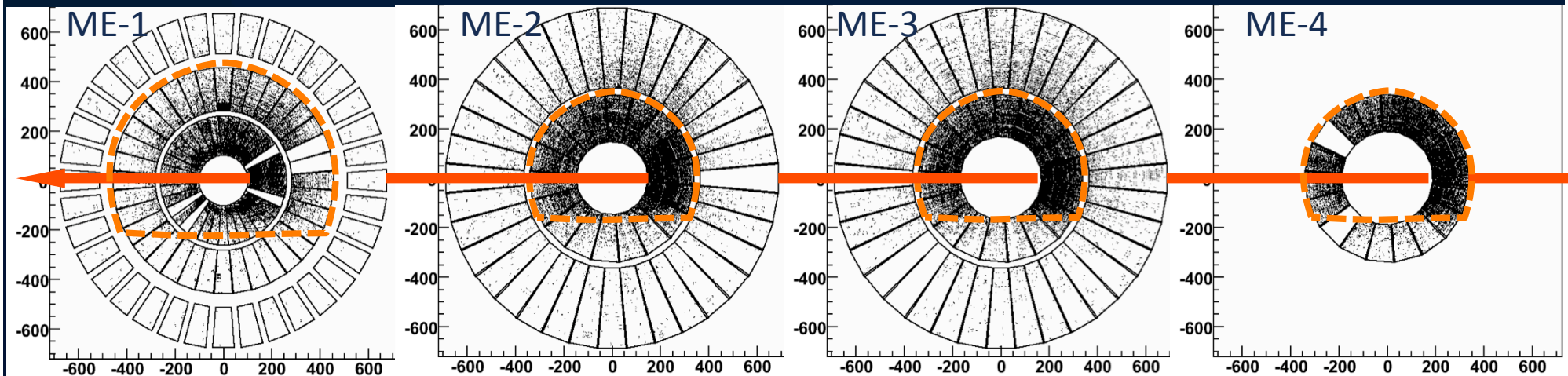
Halo muon crossing both endcap and barrel chambers

Beam Halo Muons

Beam Halo: muons outside of beam-pipe, arising from decays of pions created when off-axis protons scrape collimators or other beamline elements



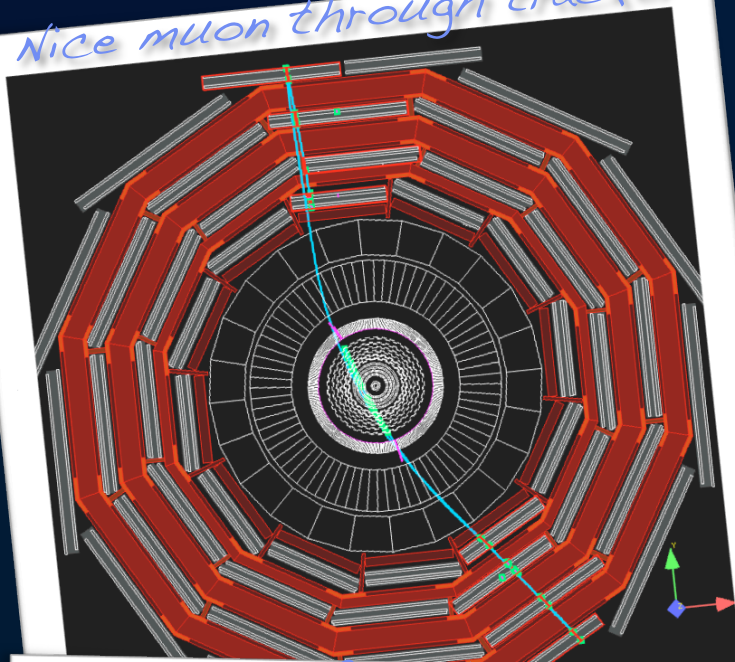
CSC Hit Distribution from Beam Halo Events



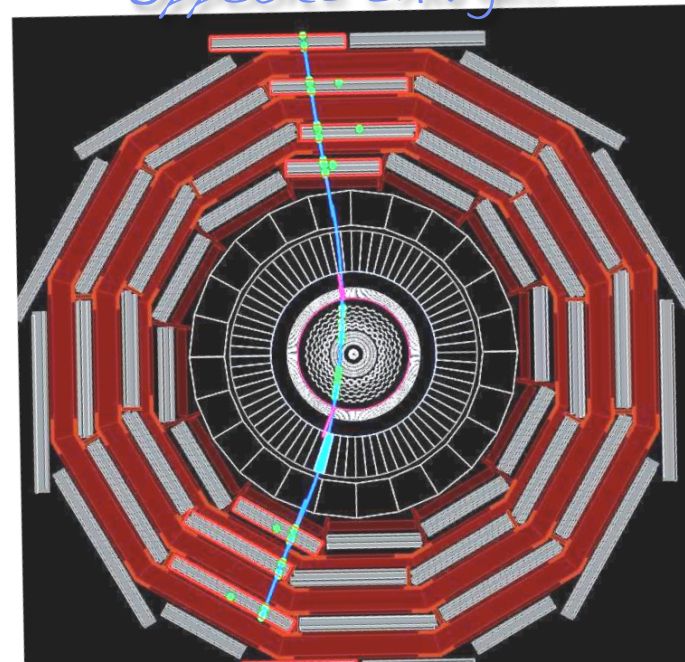
LHC Tunnel Profile

From the CMS Album

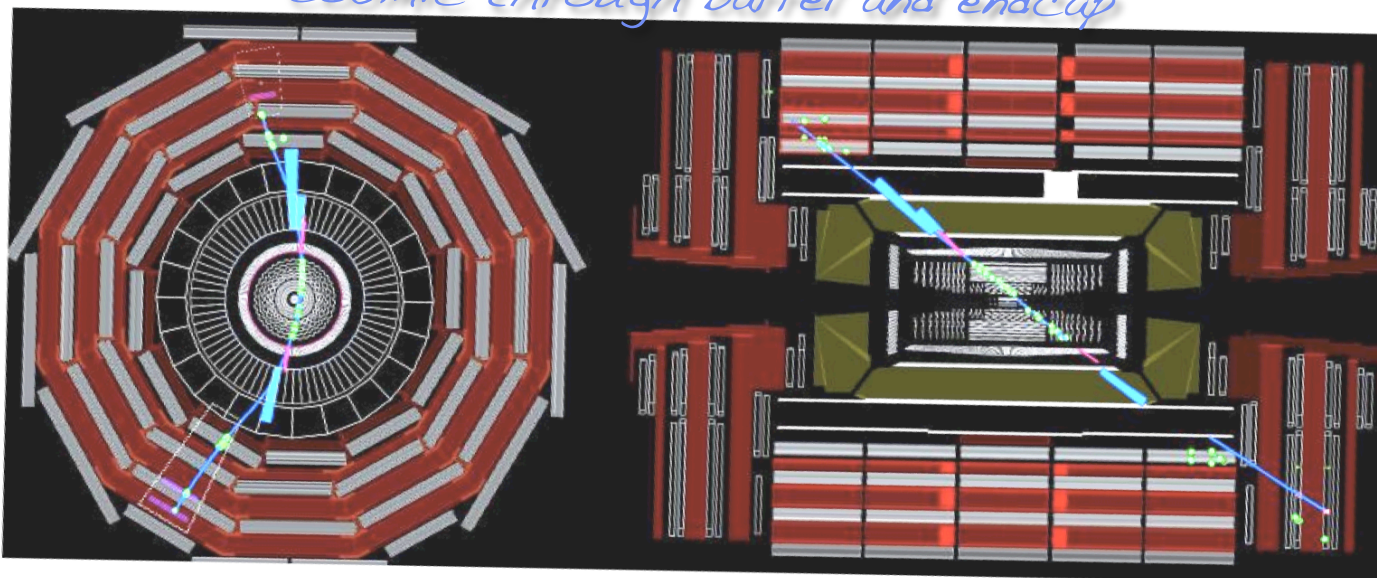
Nice muon through tracker



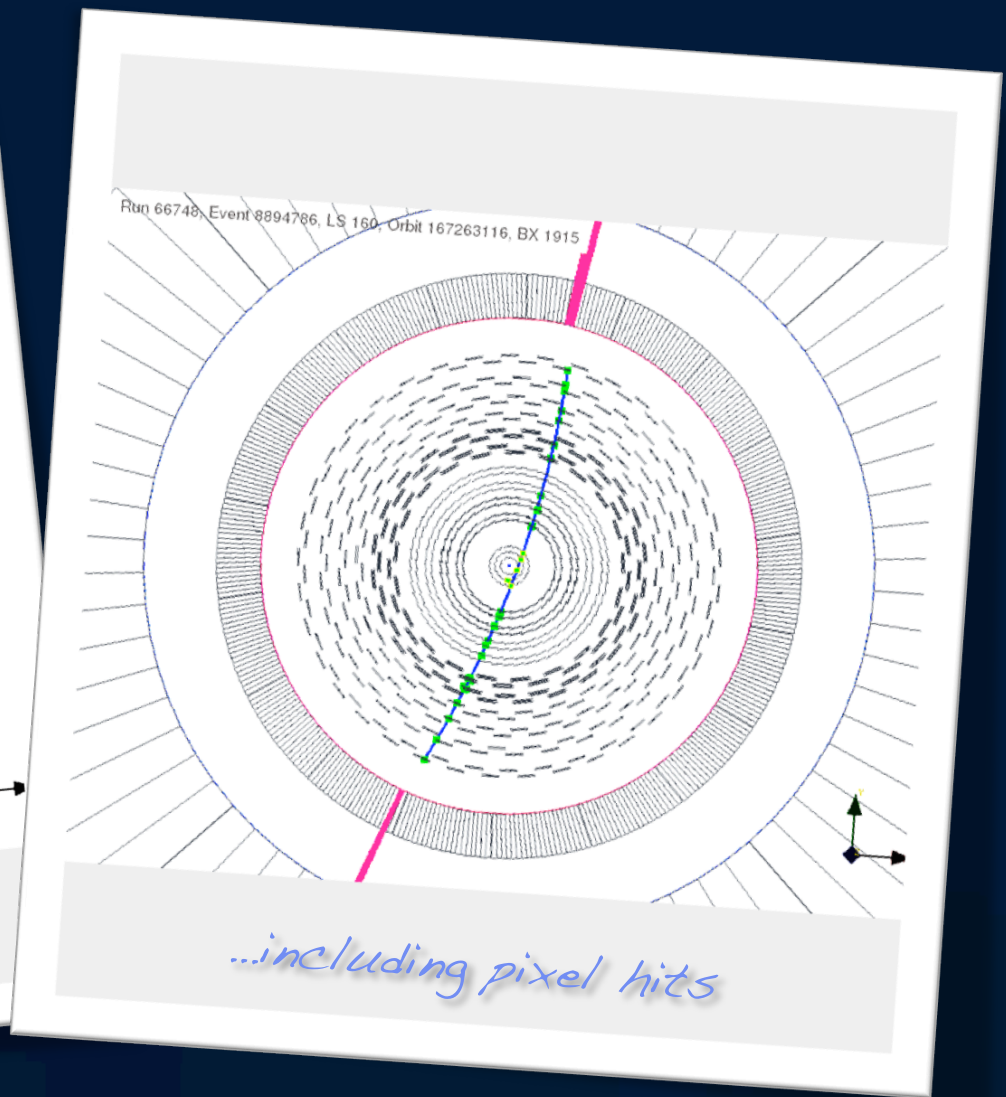
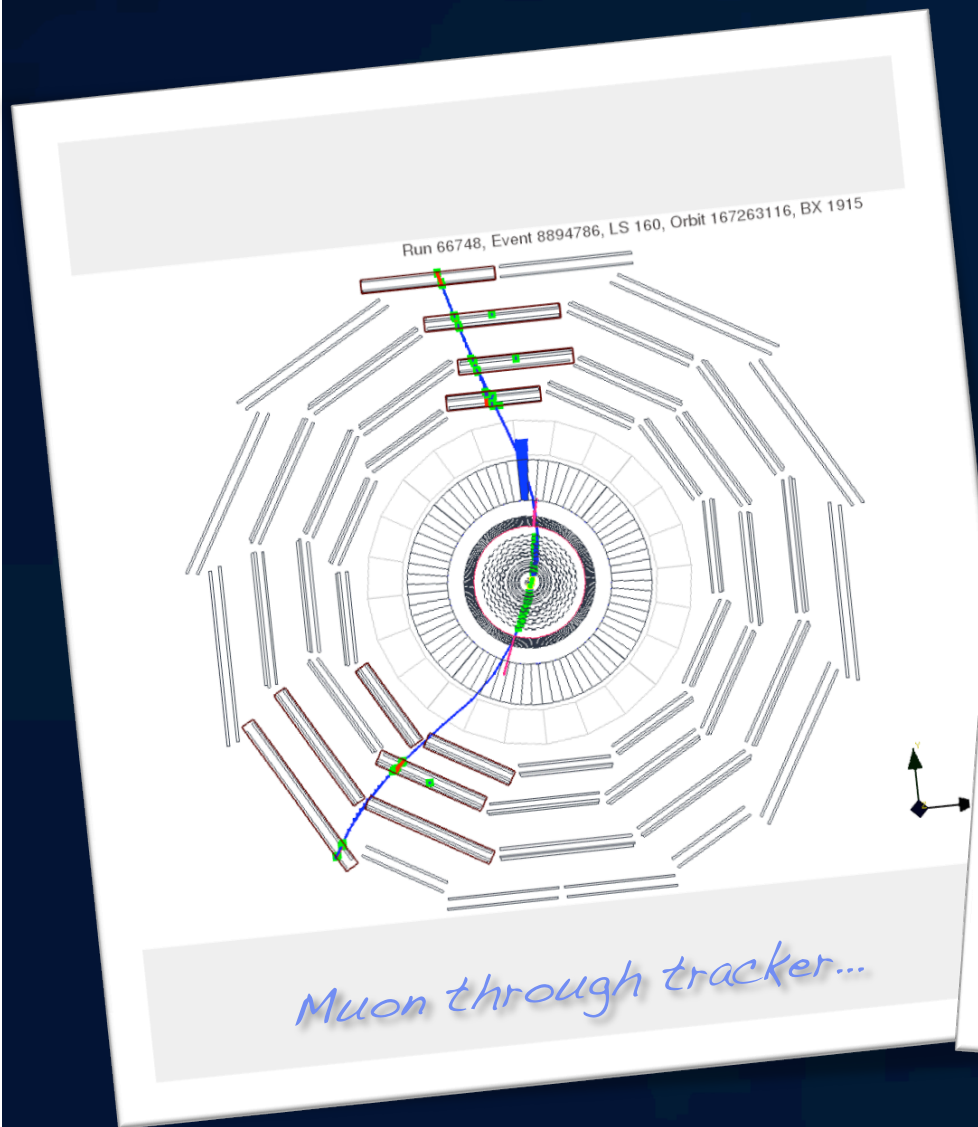
Opposite charge...



Cosmic through barrel and endcap

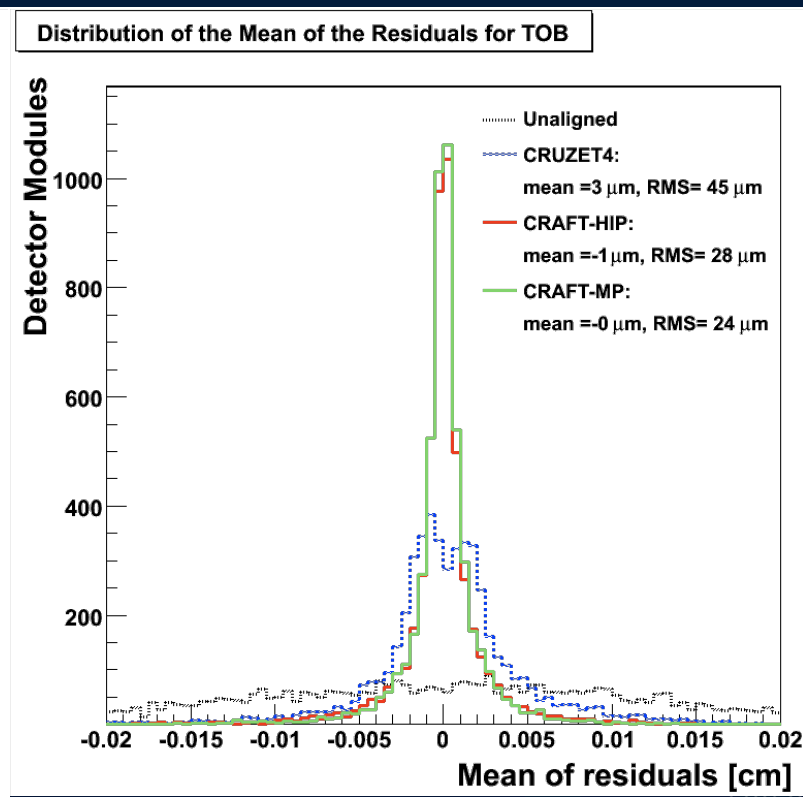
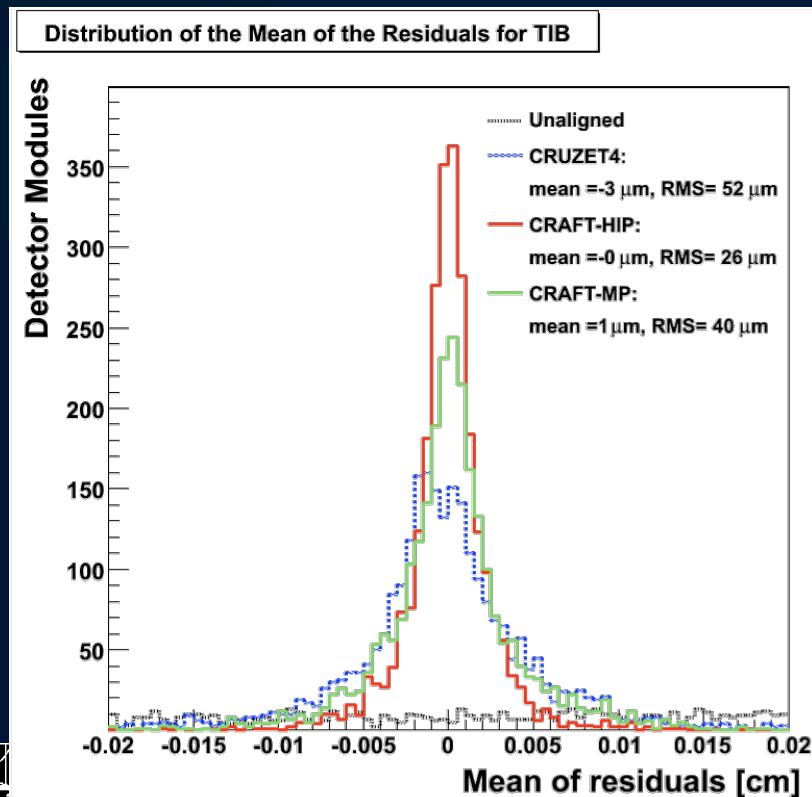


From the CMS Album



Tracker Barrel Alignment

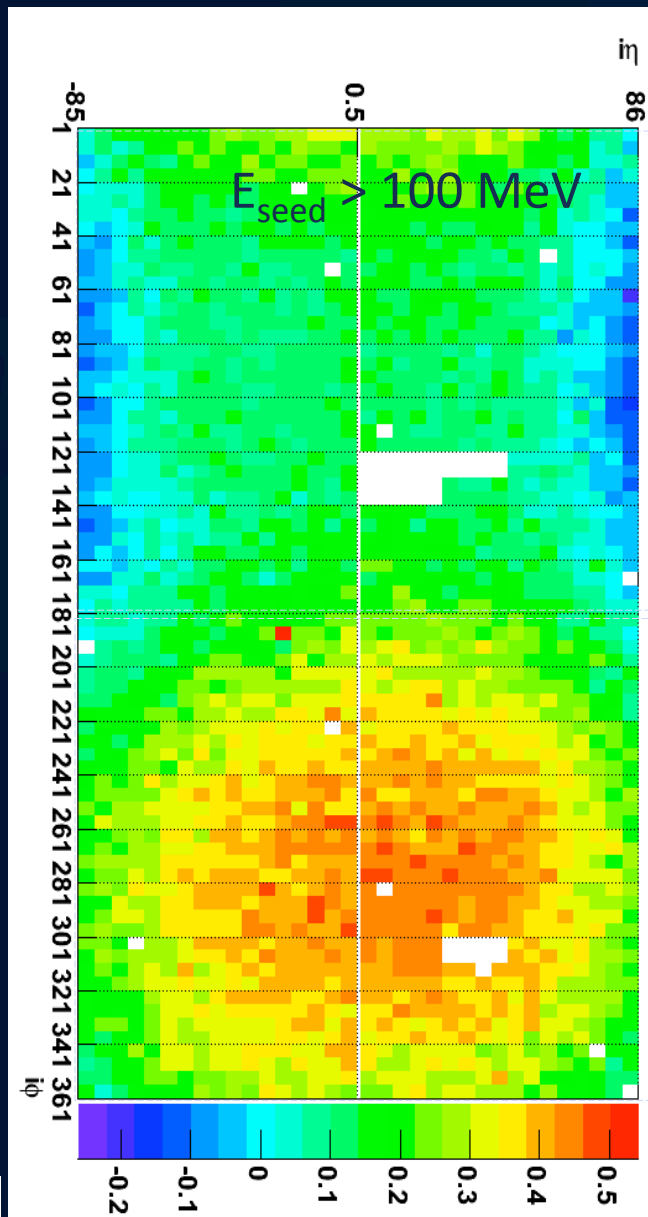
- Mean of residual distributions (cm)
 - Sensitive to module displacements
- Only modules with 30+ hits considered
 - 96 % TIB, 98 % TID, 98 % TOB, 94 % TEC
- HIP algorithm: **TIB RMS = 26 μm , TOB RMS = 28 μm**



ECAL Timing and occupancy

Timing – bottom is late ✓

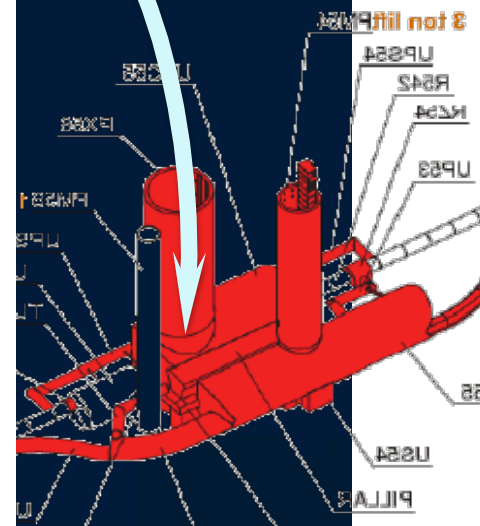
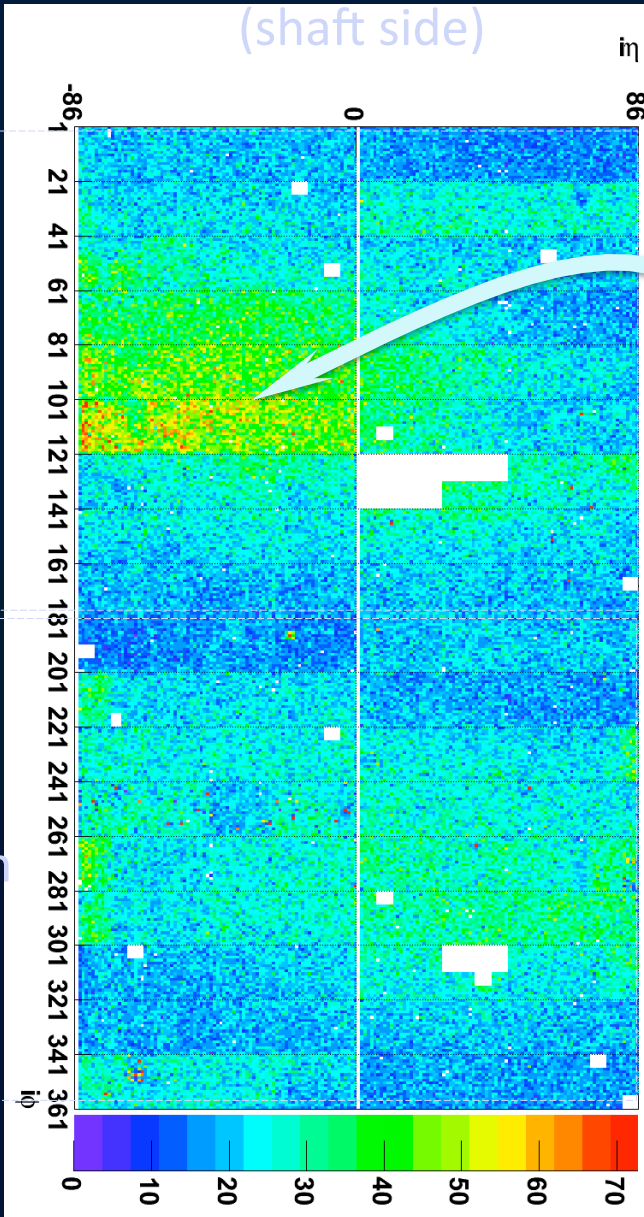
Occupancy – top is busier ✓



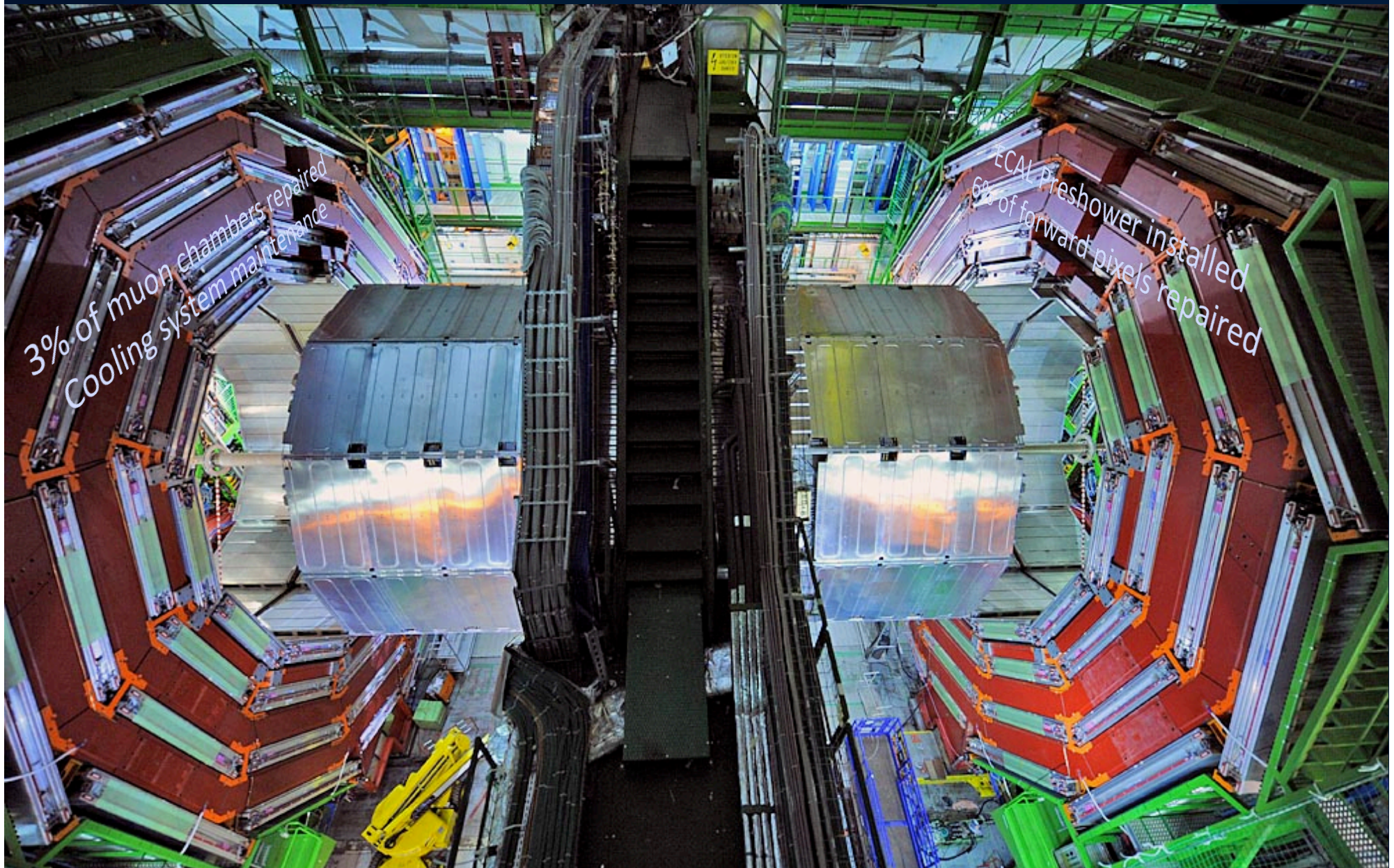
Top

Bottom

(shaft side)



After the cosmic campaign



3% of muon chambers repaired
Cooling system maintenance

ECAL Preshower installed
6% of forward pixels repaired

Preparing for collisions



CMS CRAFT09 RTL Efficiency Summary

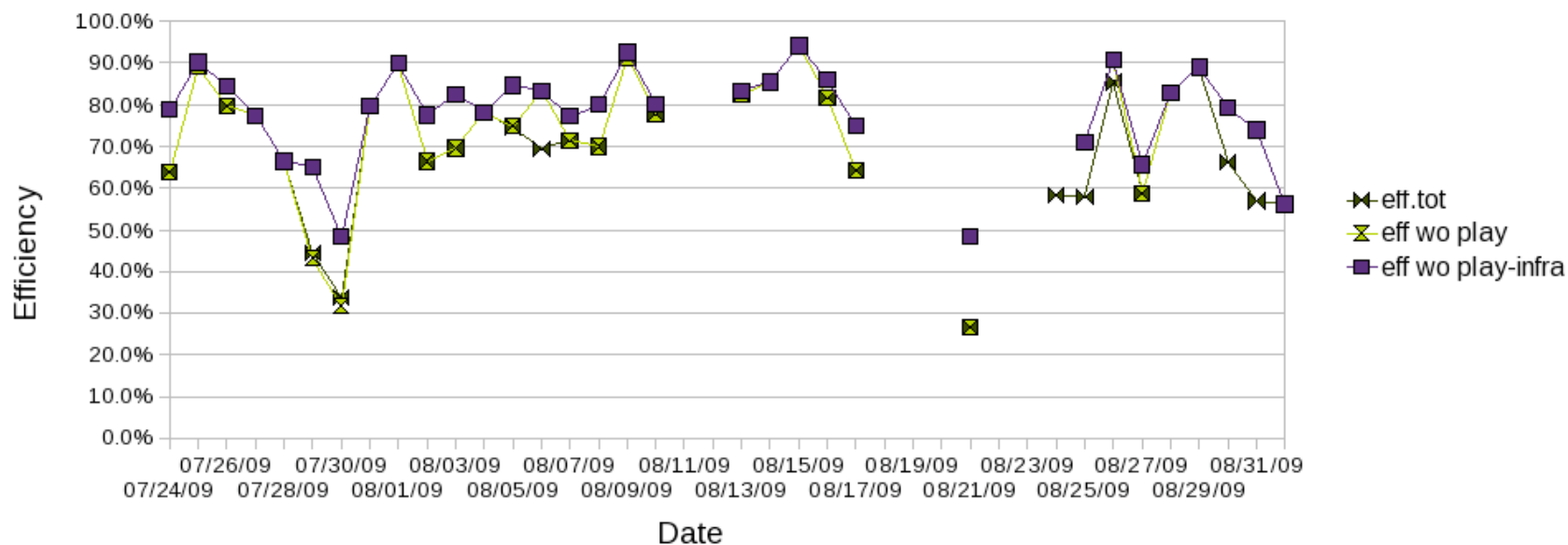


Grand Summary to date (times in UTC)

Started mo.day time	Up-to mo.day time	Days (hours)	Live Time (hr:min)	PlayTime (hr:min)	Infra.Down (hr:min)	Eff_tot (%)	Eff(-PT) (%)	Eff(-PT-Infr) (%)
Fri 07.24 07h	Tue 09.01 13:30	40 (765.5)*	549:03	76:00*	48:16*	71.7	74.6	80.2

Efficiency vs Date

CRAFT09



Summary

- **Portugal has an important role in CMS**
 - E não só...
- **The LHC start is here**
 - Será que é desta?
- **CMS is ready**
 - Just finished 1.5 month long run
 - 80% running efficiency over 24/7
- **Let's visit it !**

