Coisas e anti-coisas

UP QUARK u

The **UP QUARK** along with the **DOWN QUARK**, make up protons and neutrons. Considered by physicists to be an elementary particle, quarks experience the strong force and come in six "flavors": up, down, charm, strange, top and bottom. Everyday physical

ANTIUP QUARK $\bar{u}$

Acrylic felt with poly fill for minimum mass.

$9.75 PLUS SHIPPING

CHARM QUARK c

Heavier than a strange quark, but not as heavy as a bottom quark, the **CHARM QUARK** was discovered in 1974. Particles that contain charm and anticharm quarks are called "charmed matter."

ANTICHARM QUARK $\bar{c}$

Acrylic felt with a mix of poly beads and gravel for medium-heavy mass.

$9.75 PLUS SHIPPING

TOP QUARK t

Discovered at Fermilab in 1995, the **TOP QUARK** is as short-lived as it is massive. Weighing in at a hefty 175 GeV, its lifetime, a mere 10^{-23} second, is the briefest of the six quarks. Top Quarks are an enigmatic particle whose personal life is sought after by

ANTITOP QUARK $\bar{t}$

Acrylic felt/fleece with gravel fill for maximum mass.

$9.75 PLUS SHIPPING

DOWN QUARK d

No, it is not a carrot! The **DOWN QUARK** along with the **UP QUARK**, make up protons and neutrons. Considered by physicists to be an elementary particle, quarks experience the strong force and come in six "flavors": up, down, charm, strange,

ANTIDOWN QUARK $\bar{d}$

Acrylic felt with poly fill for minimum mass.

$9.75 PLUS SHIPPING

STRANGE QUARK s

The 2nd generation of down quark, **STRANGE QUARK** weighs about the same as a muon and was discovered in 1968.

Acrylic felt/fur with poly bead fill for

ANTISTRANGE QUARK $\bar{s}$

Acrylic felt/fur with poly beads for medium mass.

$9.75 PLUS SHIPPING

BOTTOM QUARK b

Nine times heavier than a proton, the short-lived **BOTTOM QUARK** is the 3rd generation of the down and charm quarks, all sharing a -1/3 charge. It was discovered at Fermilab in 1977.

Felt/fleece with

ANTIBOTTOM QUARK $\bar{b}$

Acrylic felt/fleece with gravel fill for maximum mass.

$9.75 PLUS SHIPPING

Loisas e anti-loisas

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/I 1
1 October 1992

Letter of Intent
by the

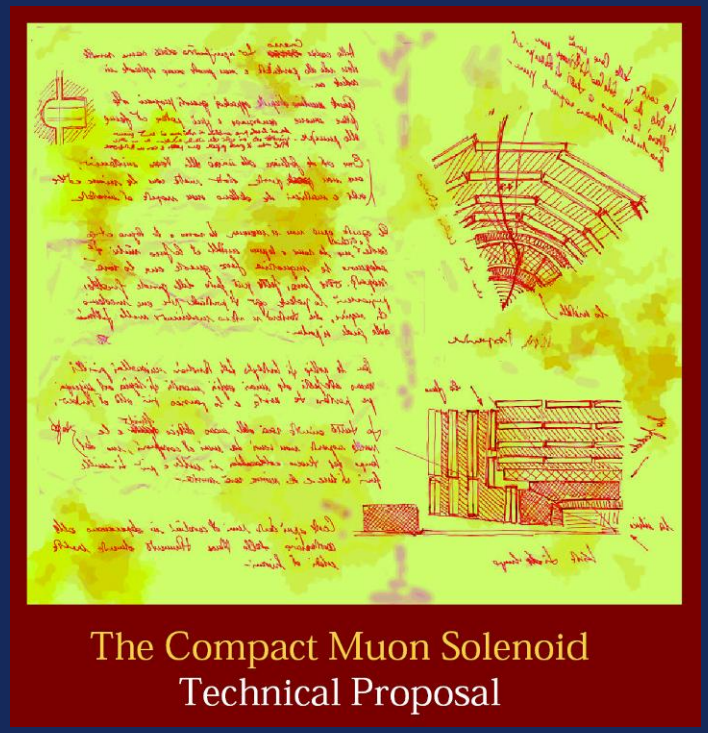
CMS Collaboration

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



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

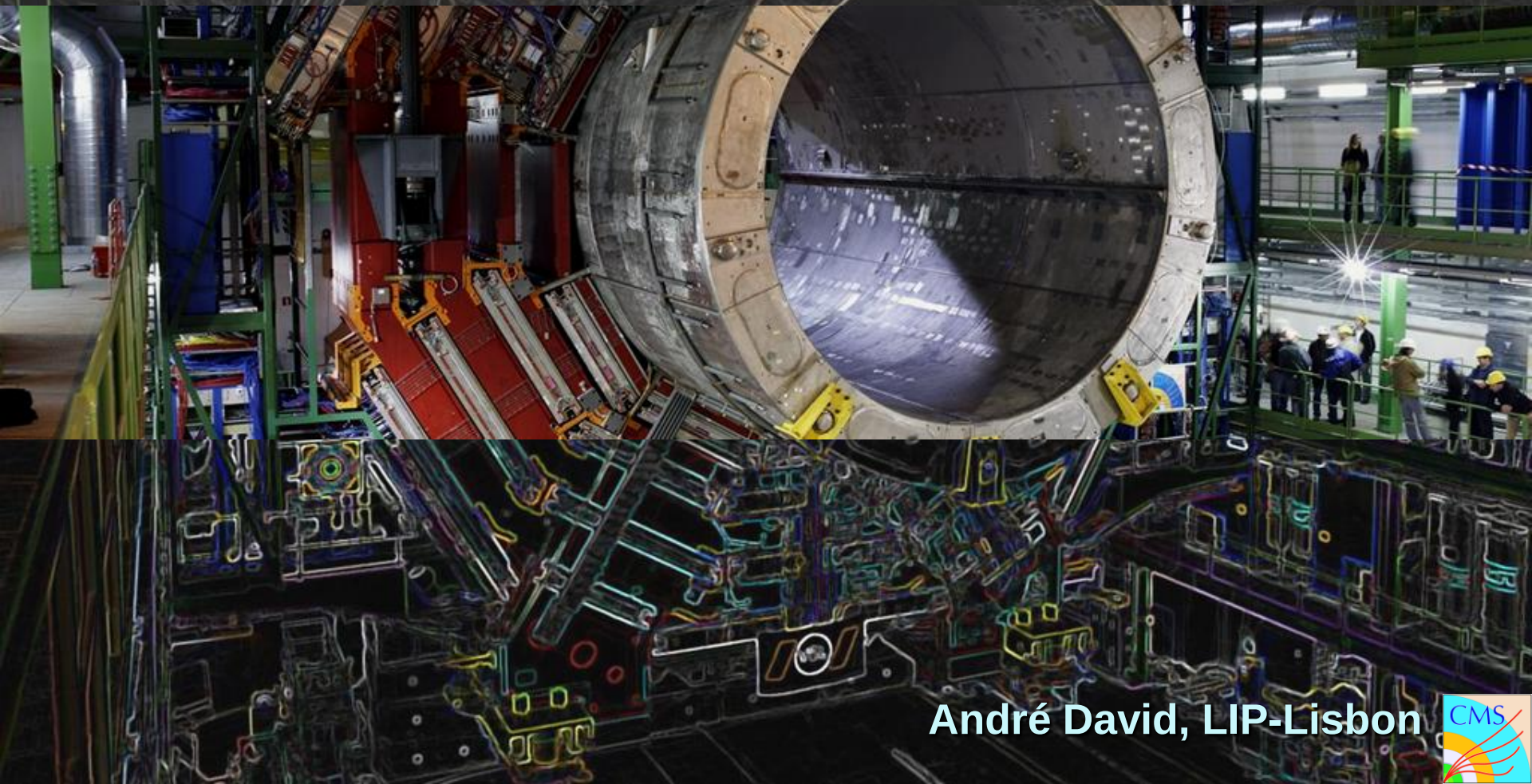
“since 1992”

LIP participants to CMS

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

47 persons since 1995

LIP in the finalization of the CMS detector

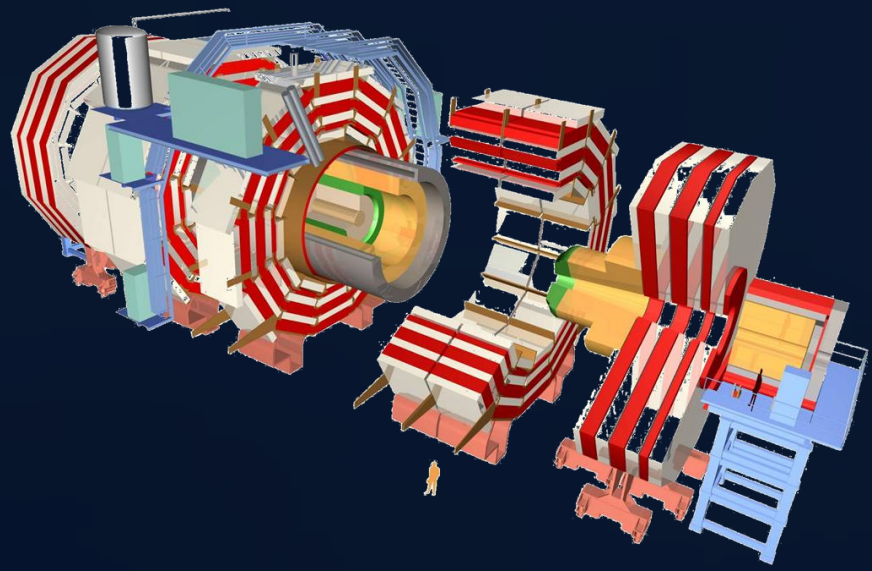


André David, LIP-Lisbon

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

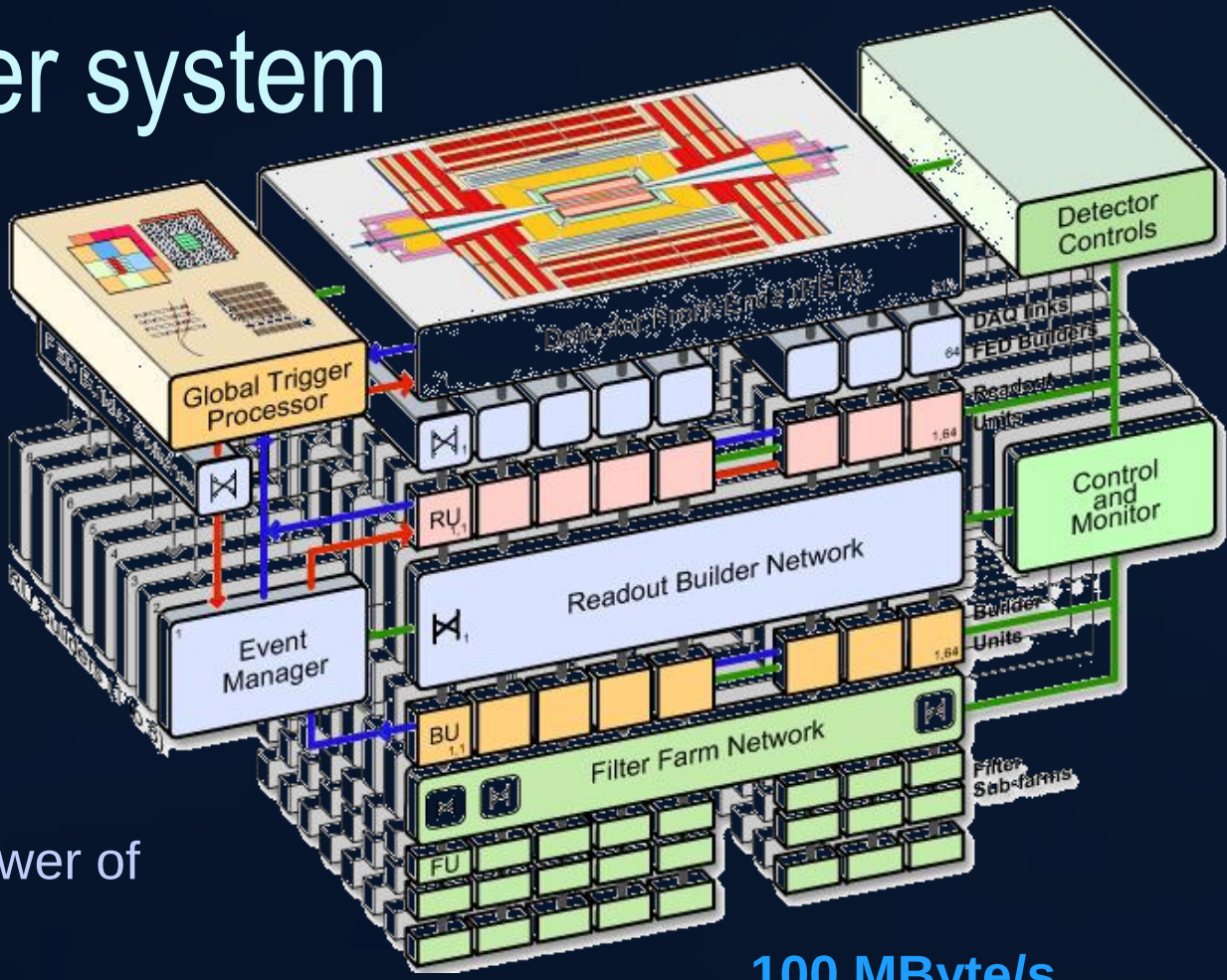
Trigger and data acquisition

- 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 μs)** 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

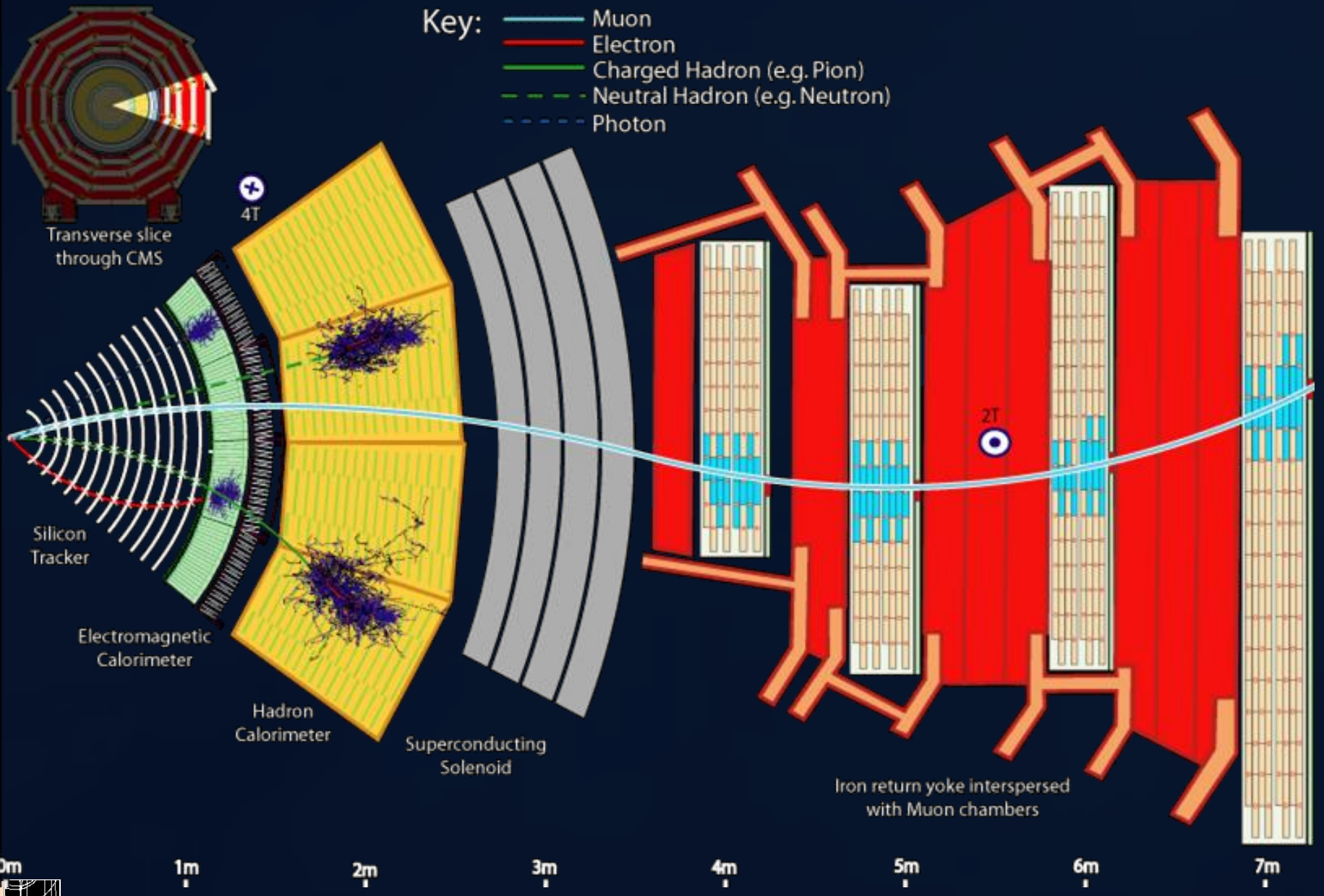
- Dedicated processors
- Equivalent processing power of 50 000 PCs

High Level Triggers

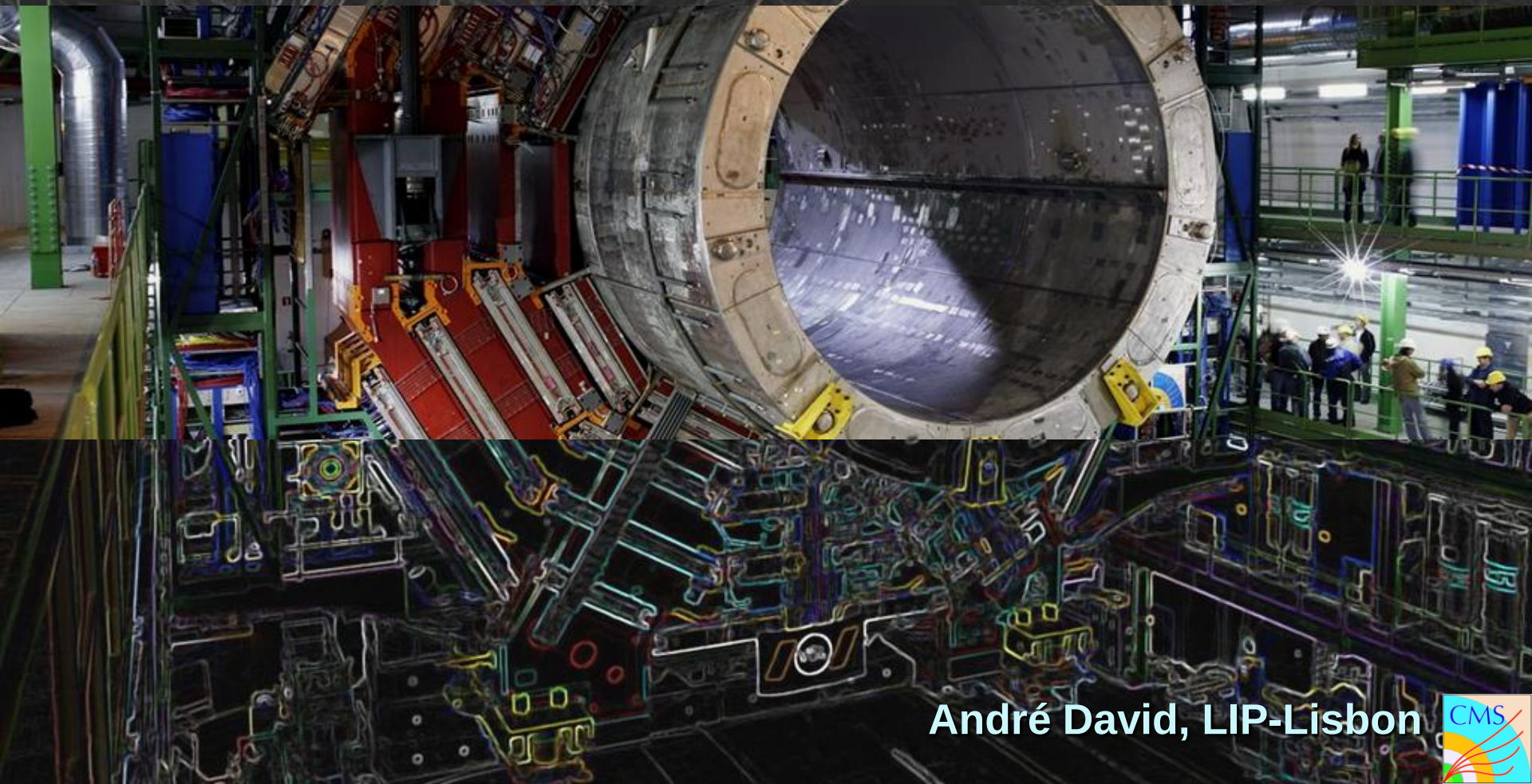
- PC farm with 5000 PCs

One of the most complex electronics systems ever built !

Hadrons, $e^{\pm}$, γ and $\mu^{\pm}$ in the barrel



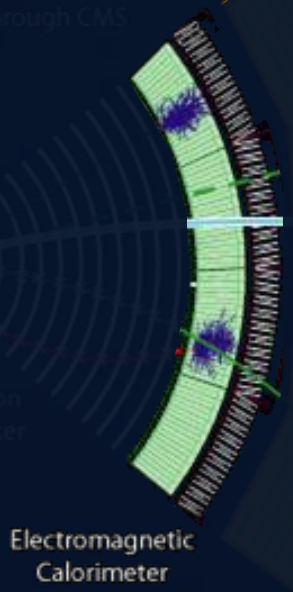
LIP in the finalization of the CMS detector



André David, LIP-Lisbon

Main responsibilities since 2006

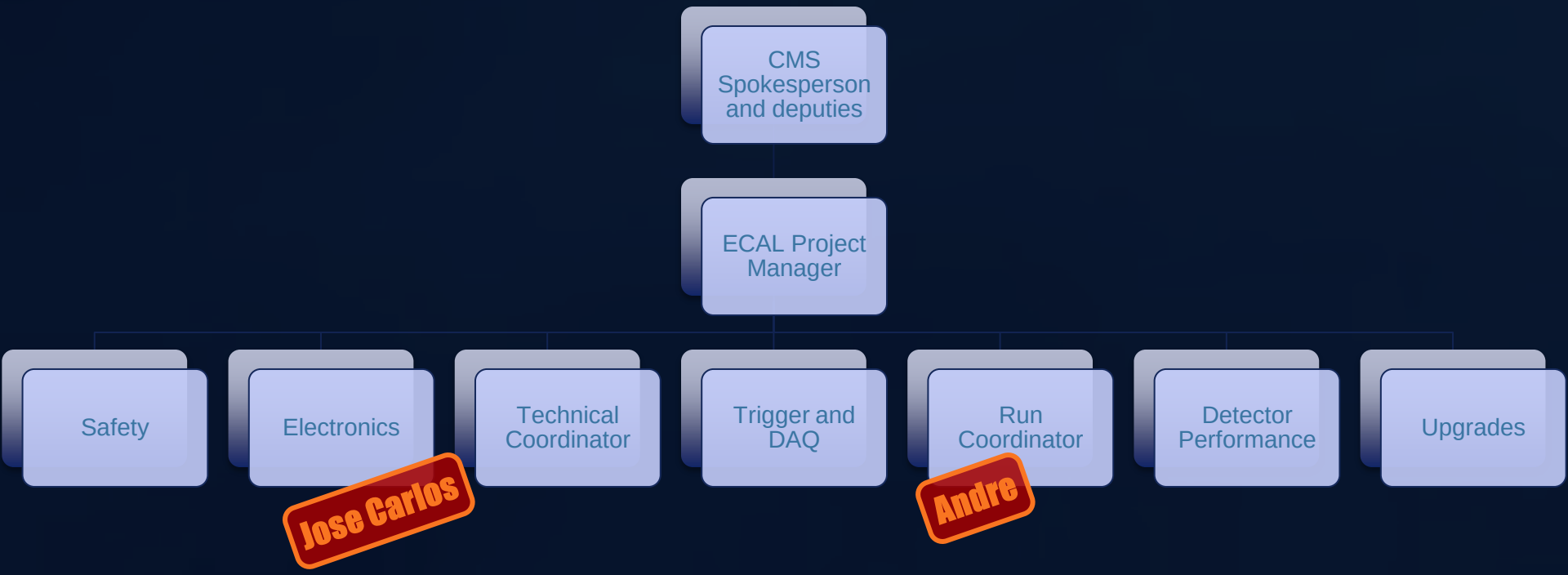
made in LIP



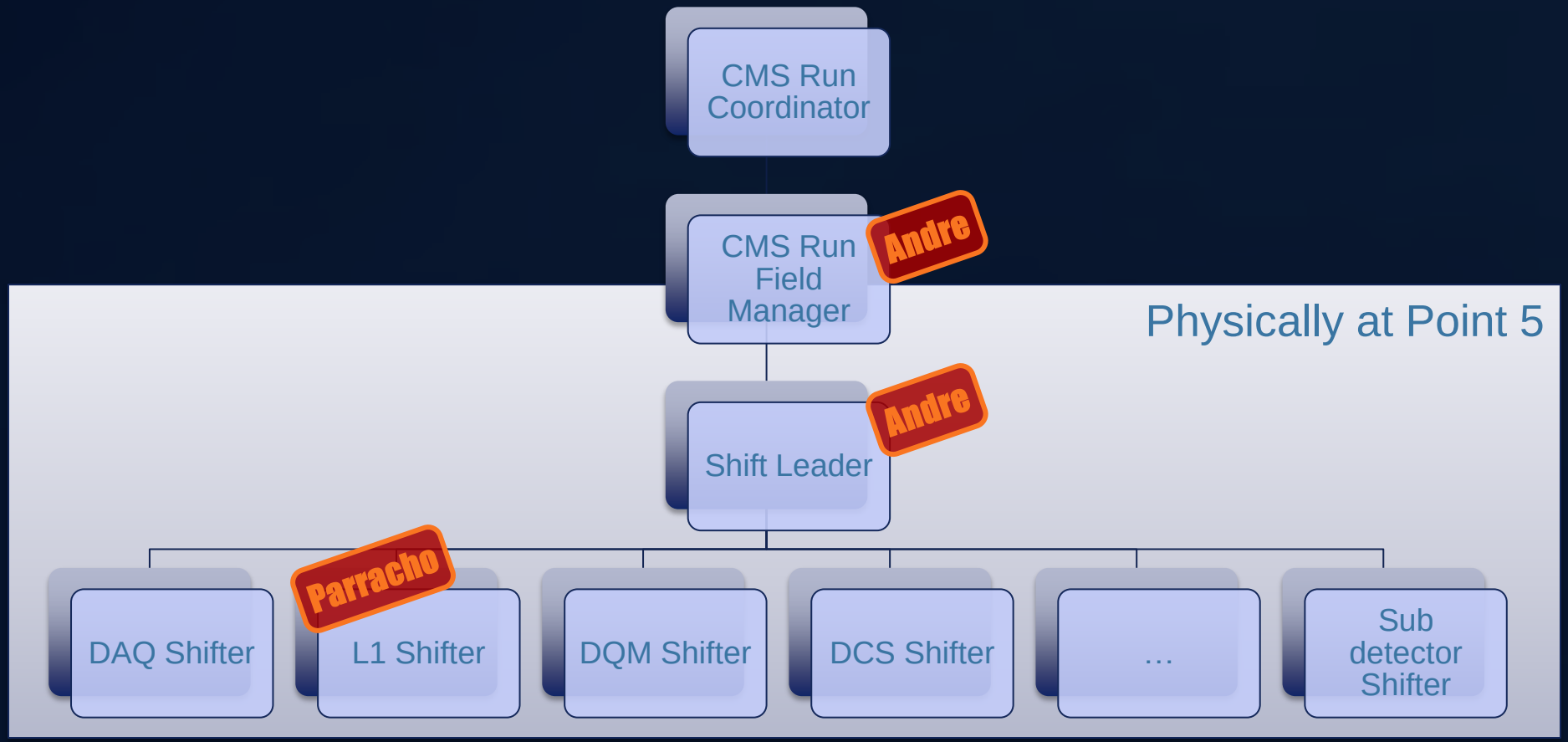
- **ECAL**
  - Data Concentrator Card
  - ECAL DAQ software
    - Calibration test beams
    - Commissioning and testing of the detector
  - Off-detector electronics integration and test system
  - Non-event data monitoring system
- **Trigger**
  - Synchronization Link Board
  - ECAL trigger pattern 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

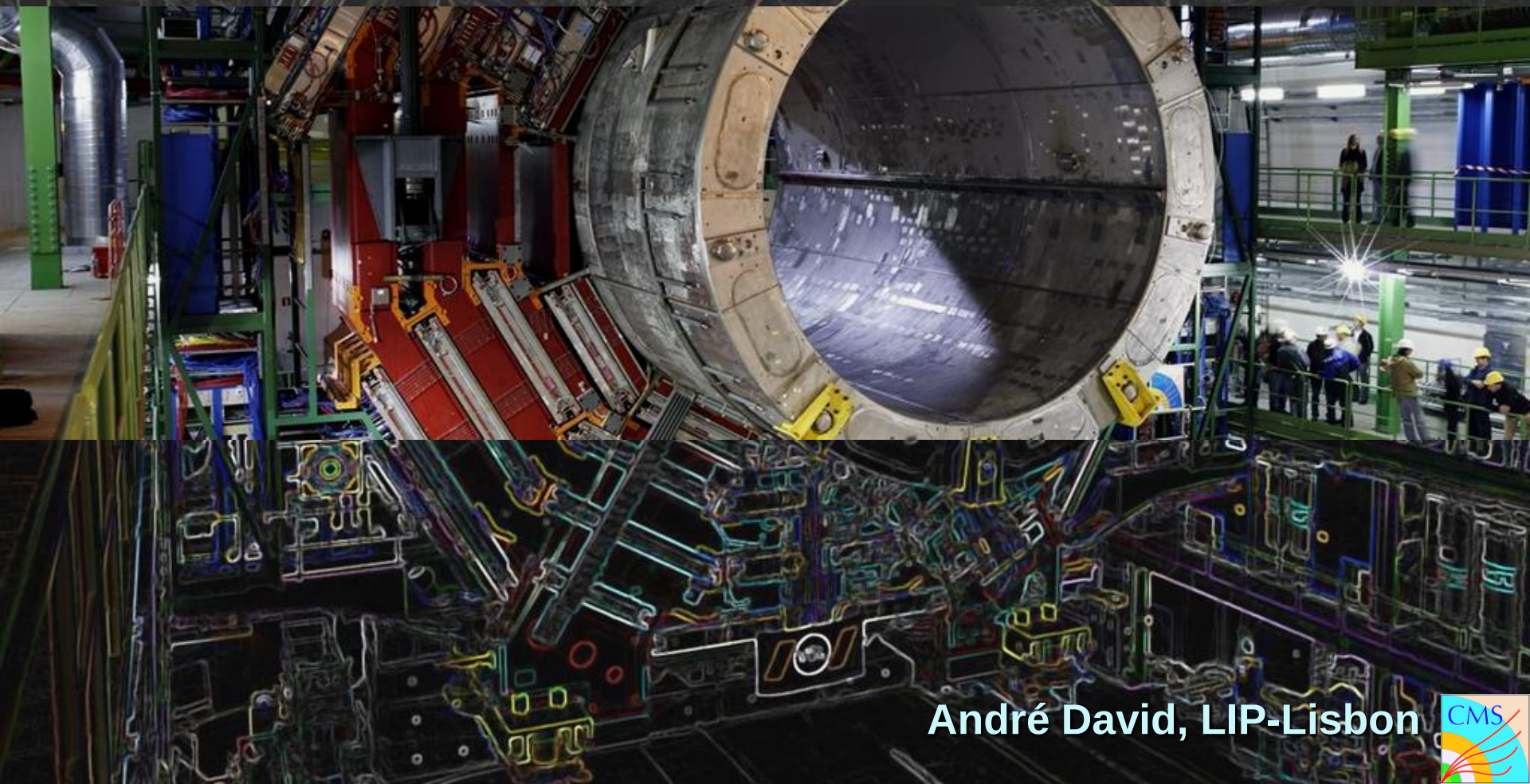
LIP in ECAL management



LIP in CMS operations



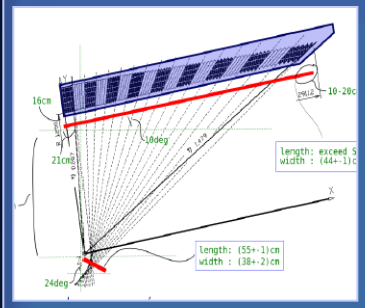
LIP in the finalization of the CMS detector



André David, LIP-Lisbon

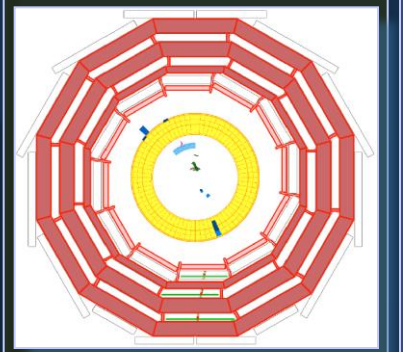
Highlights from the CMS ECAL Timeline

2006-2007
Commissioning & calibration of each SM with cosmics on surface

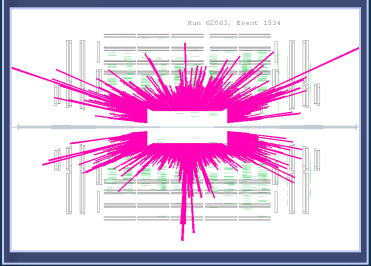


2006
H4 Test Beam: 9 SM calibrated; H2 Combined Test Beam: ECAL+HCAL

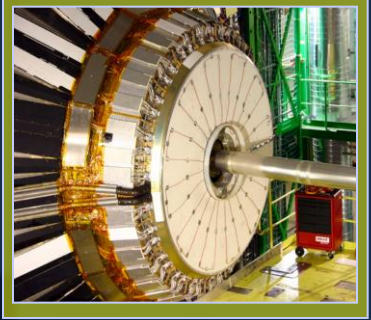
2006
22 SM tested with B-field on surface (MTCC)



2008
Endcap Installation. Commissioning with cosmics and first beam in-situ



2009
Installation of preshower and commissioning of Endcap trigger

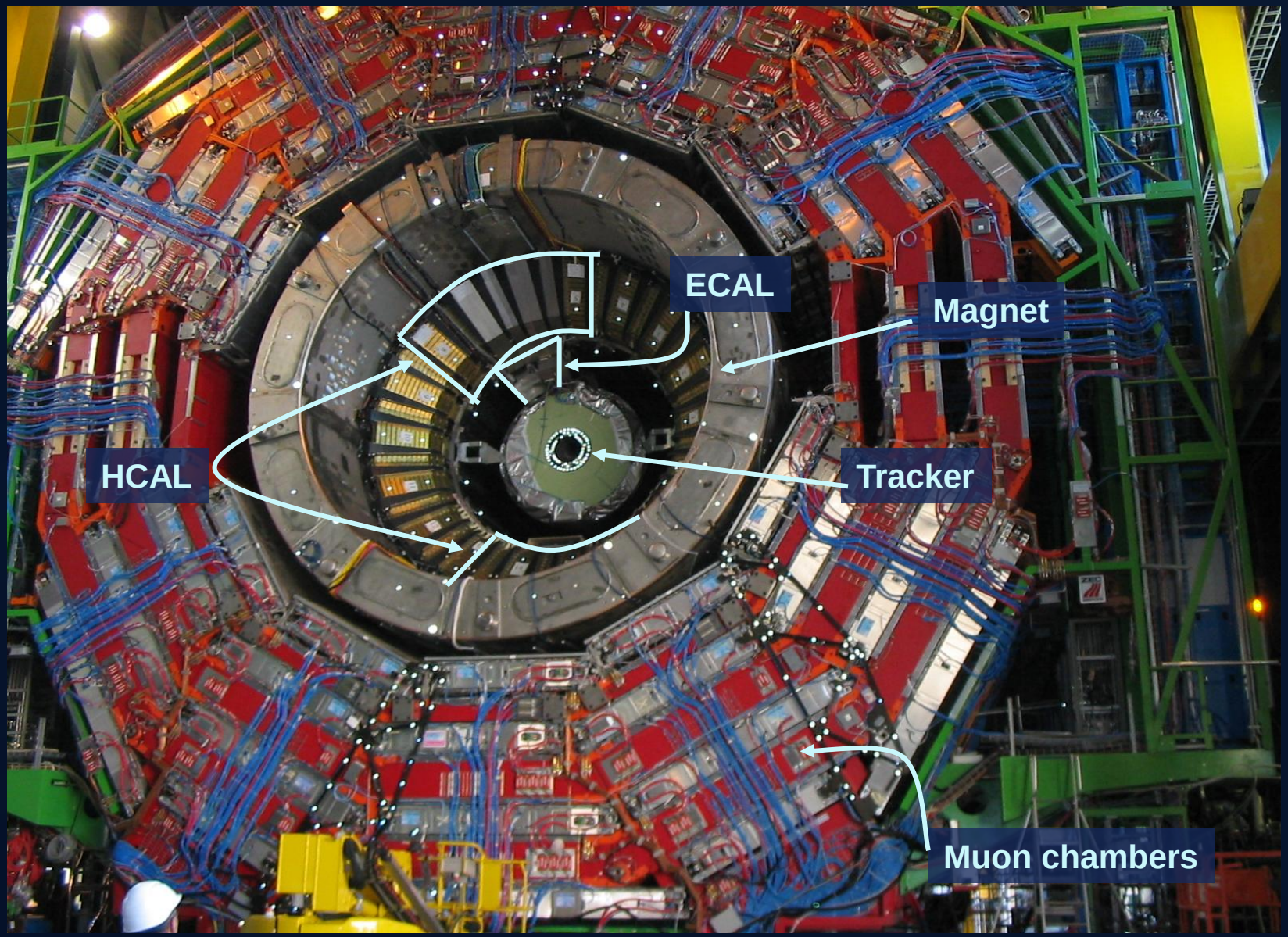


2007
H4 EE Test Beam; Individual signoff of each SM during installation

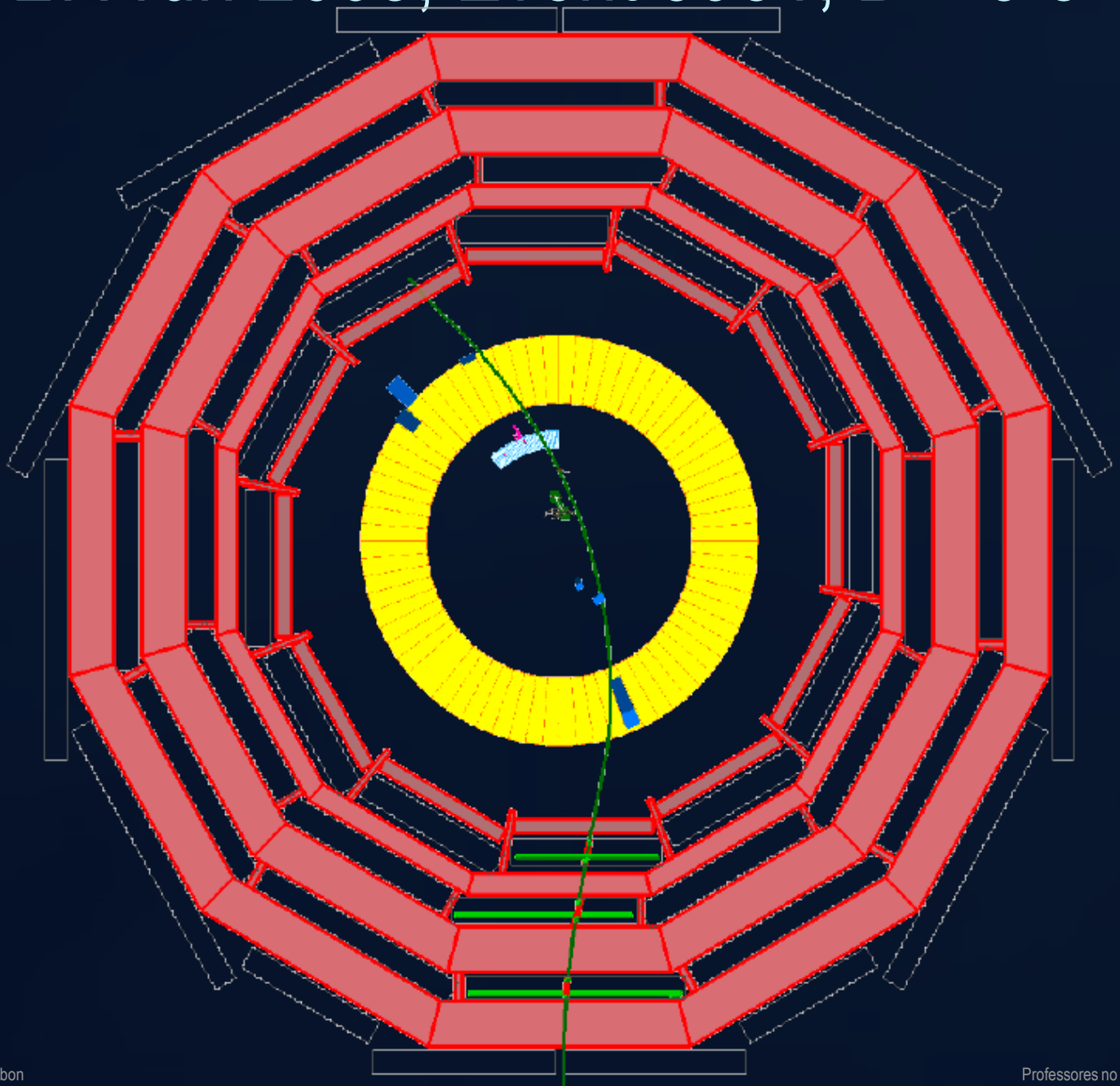
2006 2007 2008 2009

2006: first closure of the CMS experiment

2006: Magnet Test and Cosmic Challenge

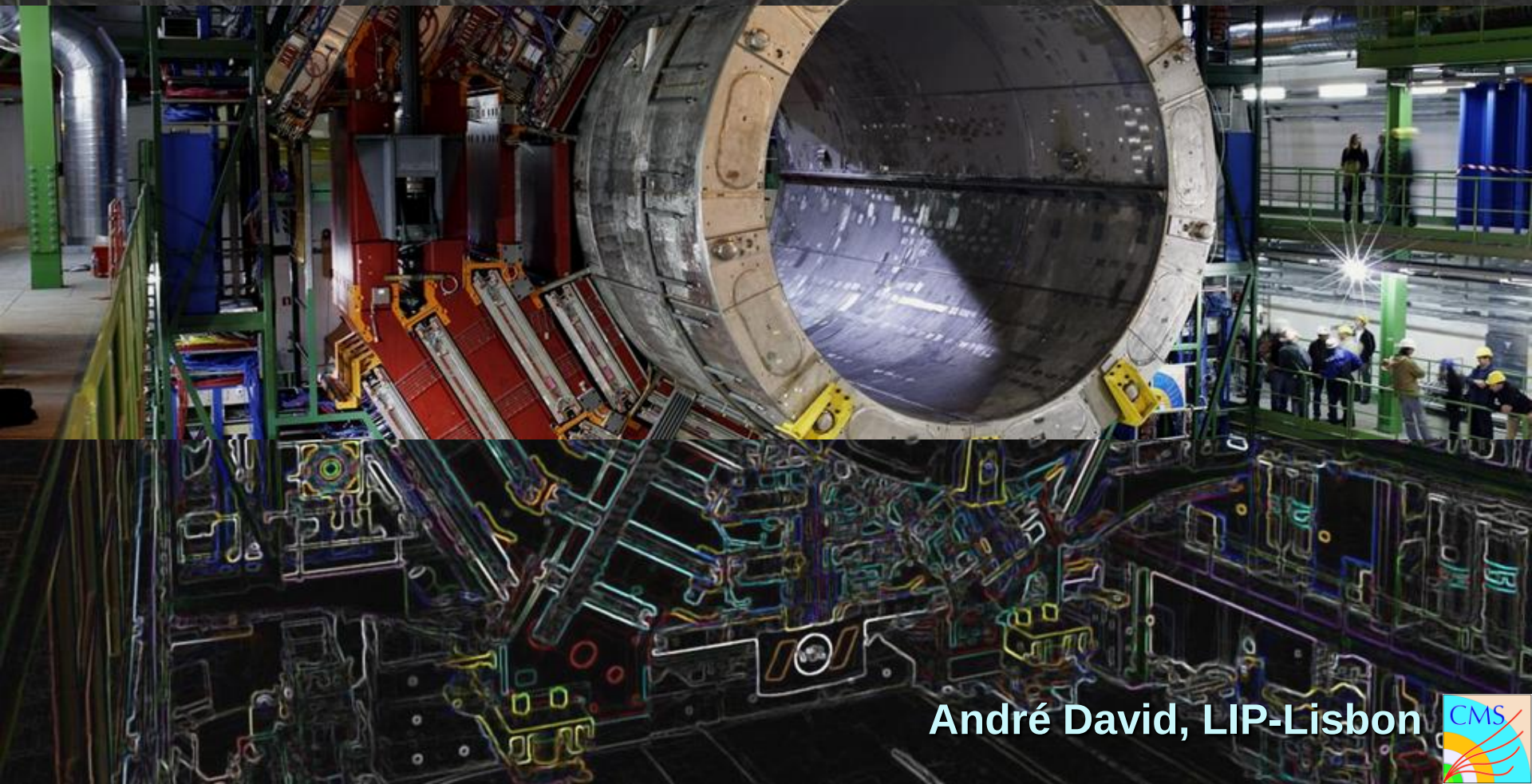


2006/08/27: run 2605, Event 3981, B = 3.8 T



2006: cavern foam test

LIP in the finalization of the CMS detector



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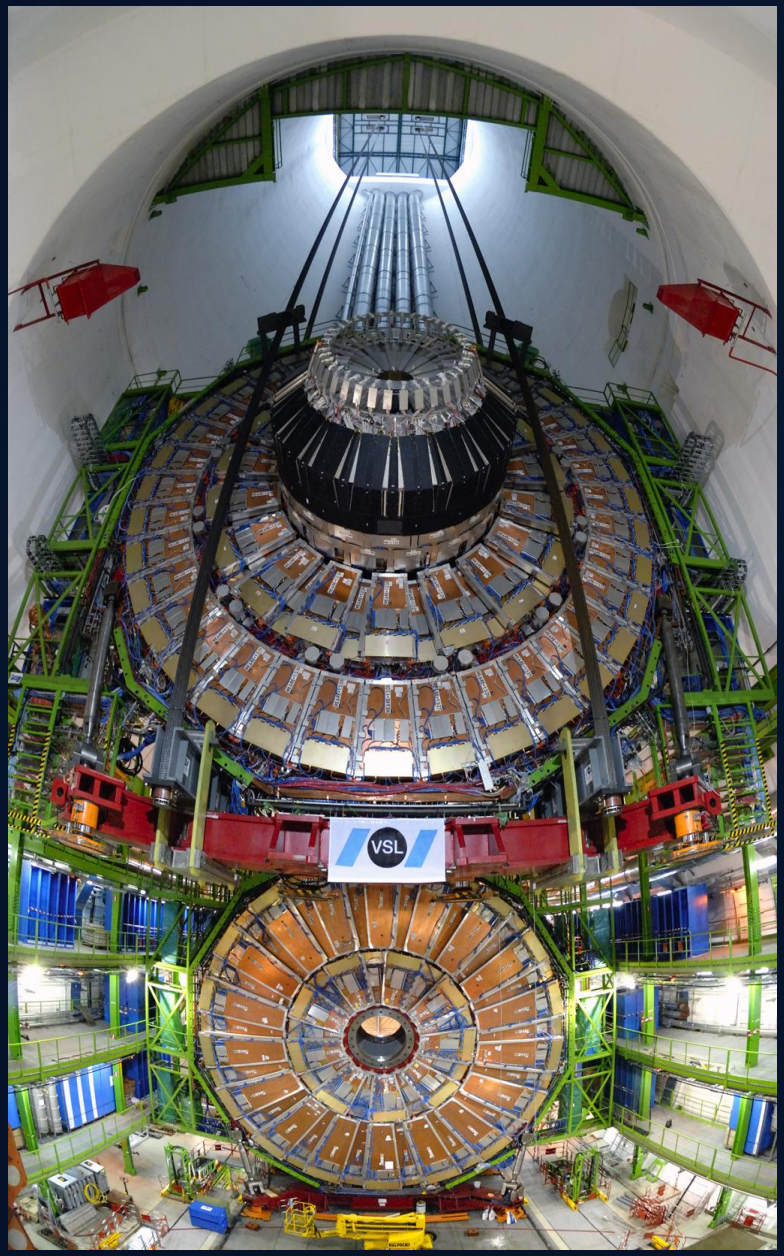
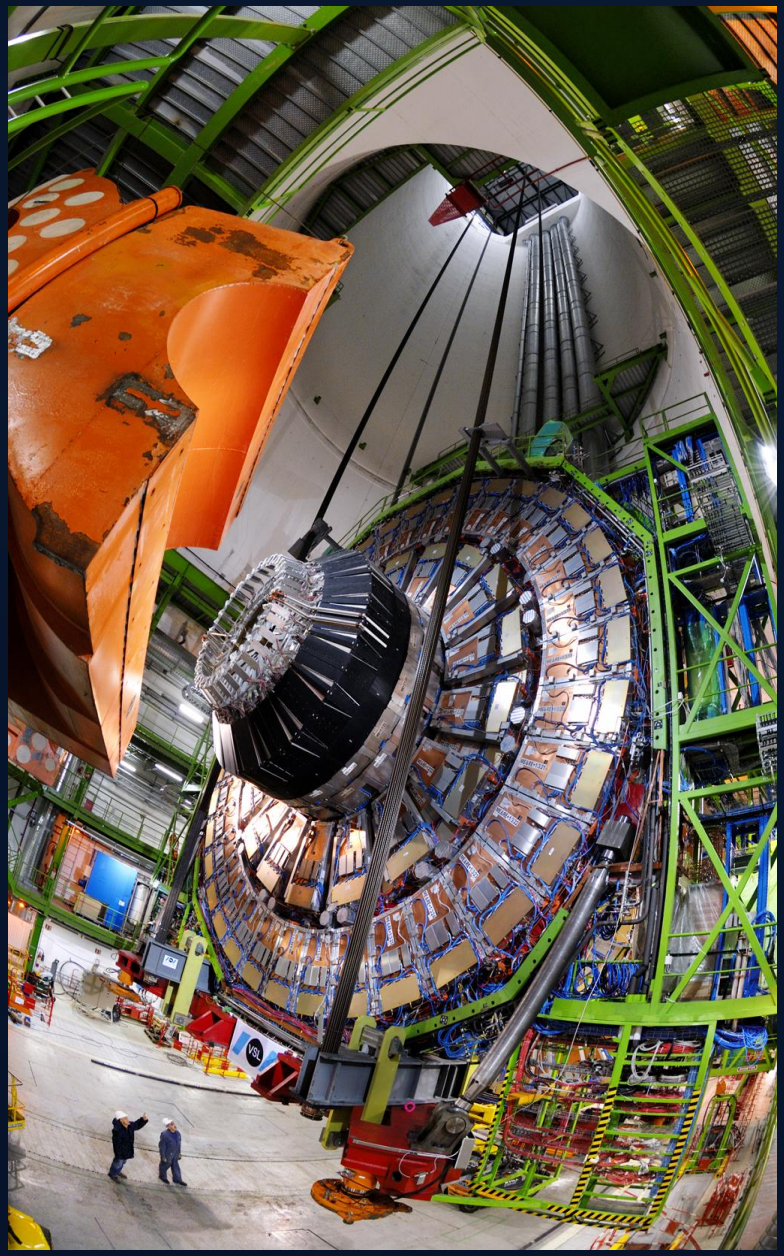
Jan 2007: lowering the first endcap wheel

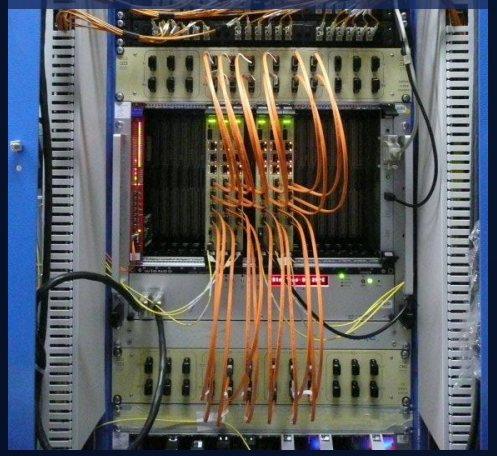


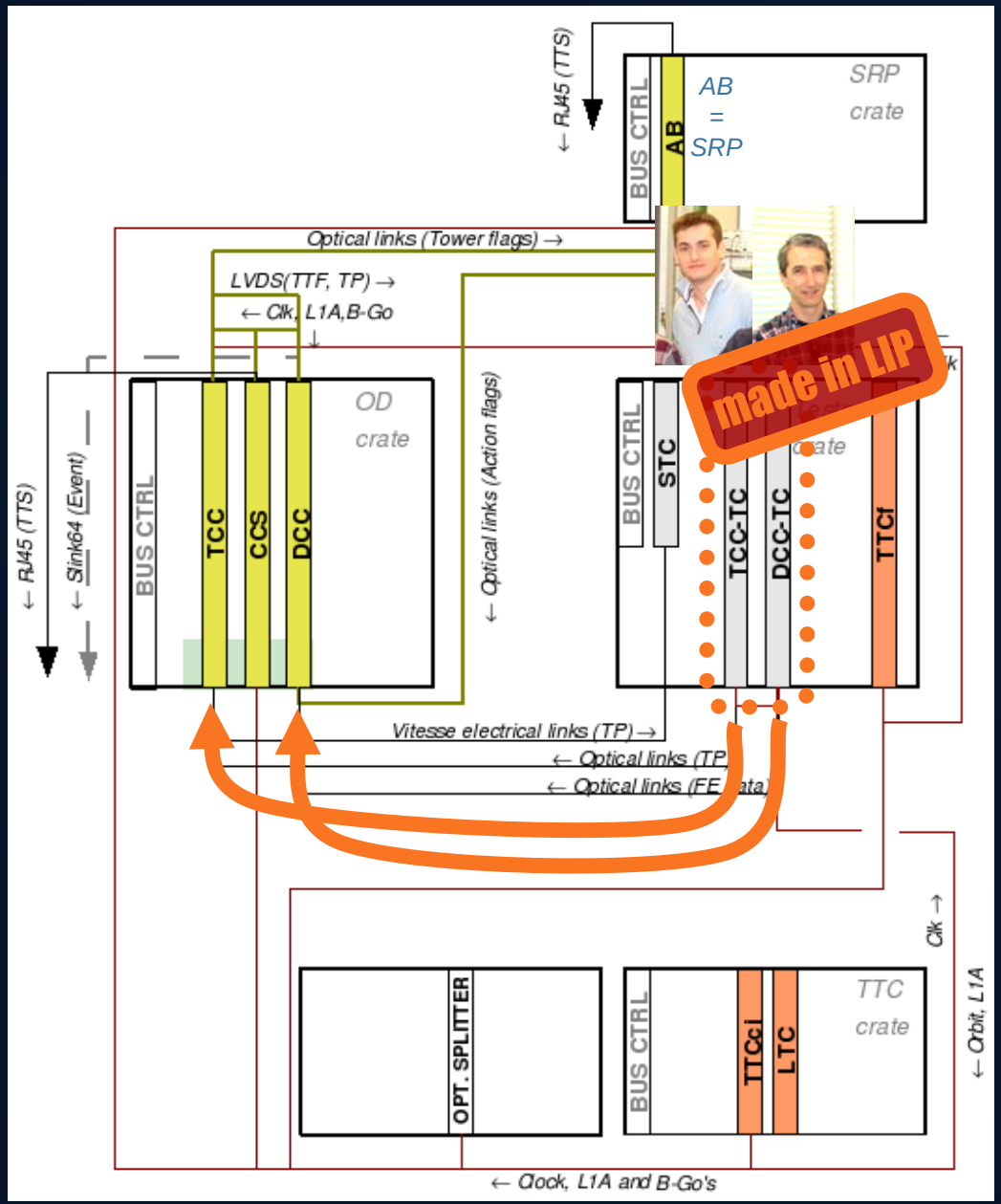


Electronics to test the electronics

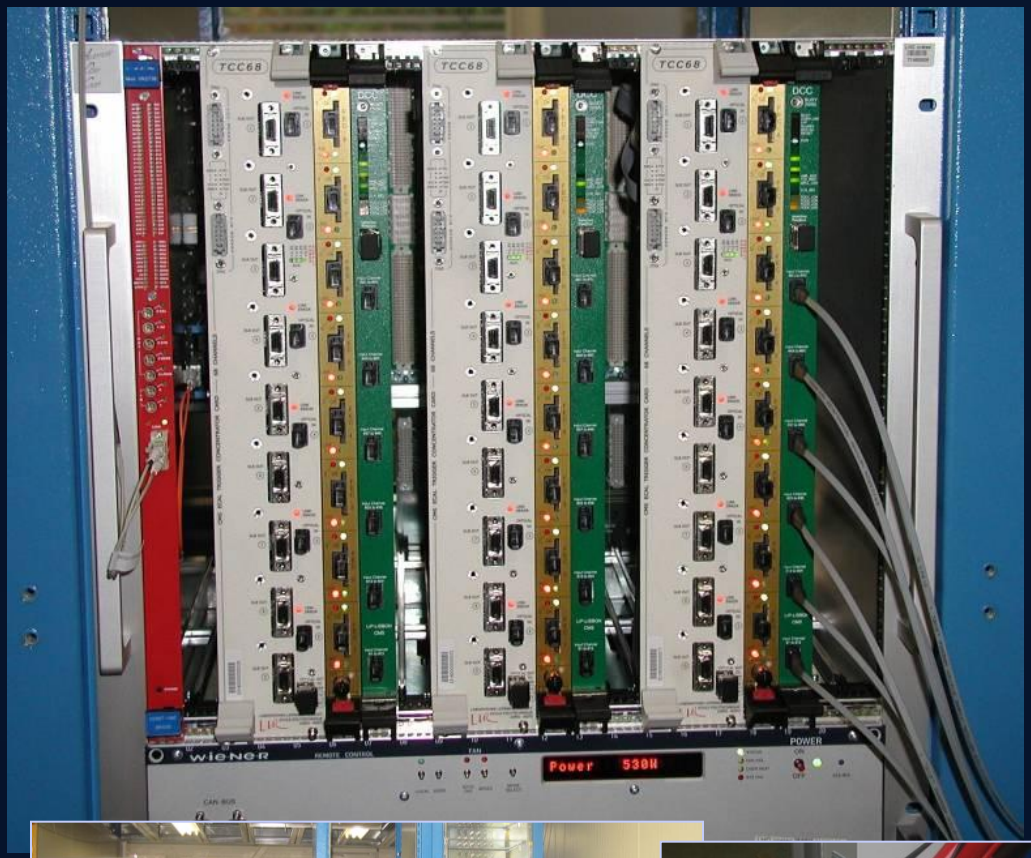
Barrel OD electronics triplets in the CMS Electronics Integration Area (904) January-March 2007

Selective Readout Processor installed in CMS October 2007

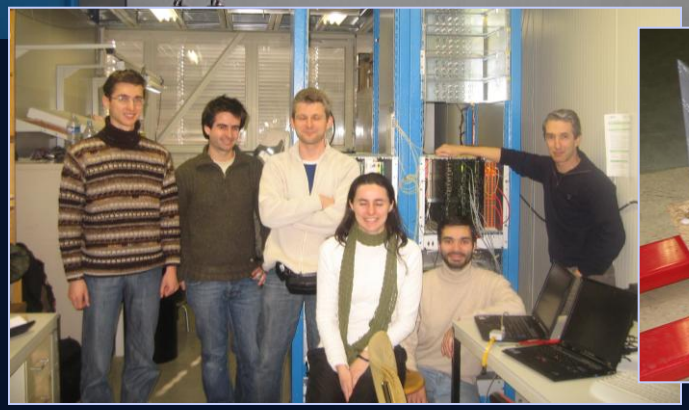




April 2007: ECAL OD electronics integration

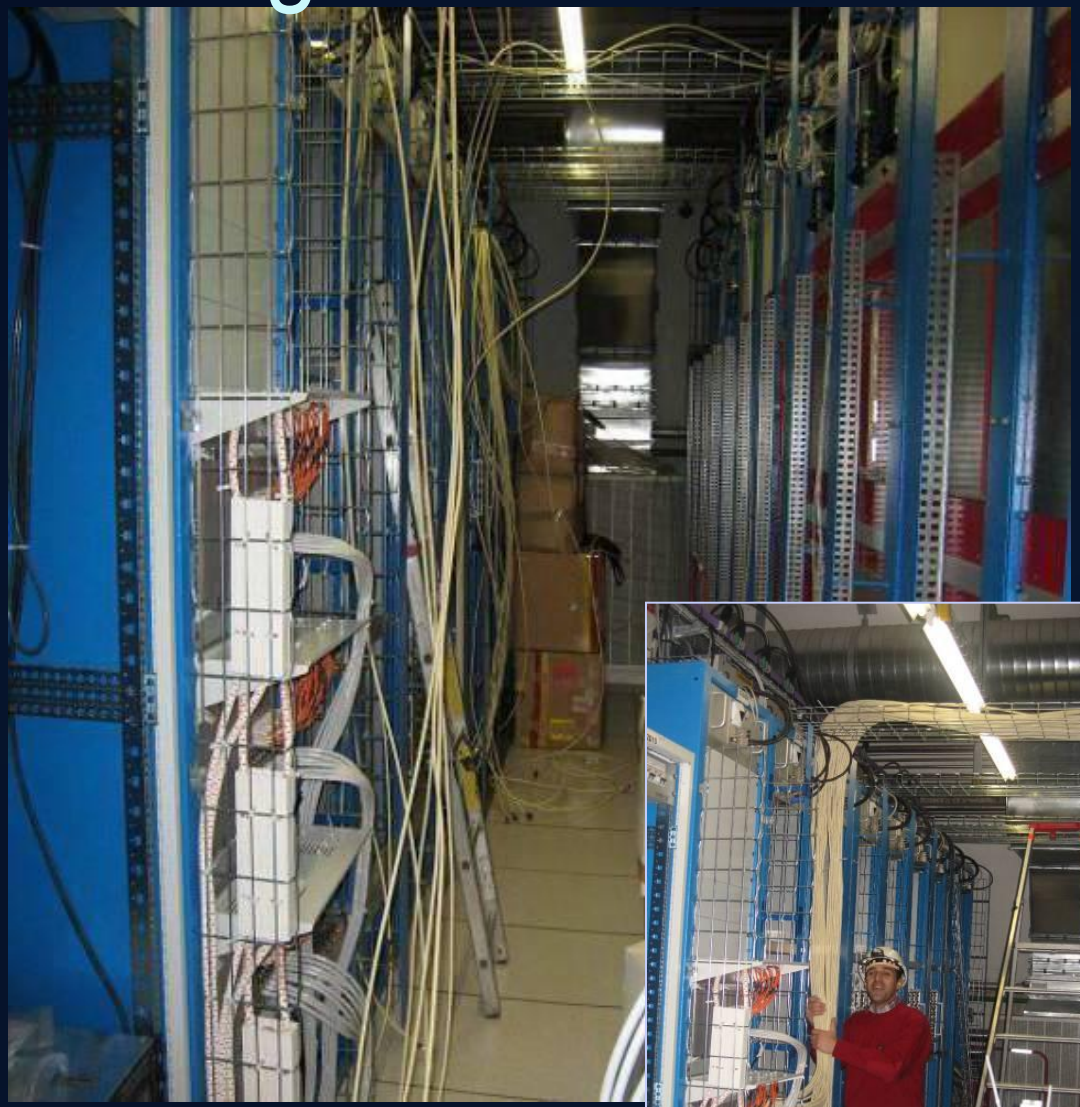


- **Integrated tests** of Data, Trigger and Control cards prior to installation
- 12 crates with **110 cards** intensively tested
- **>10 hours of continuous testing** per crate



made in LIP

Cabling the ECAL to the Calorimeter Trigger

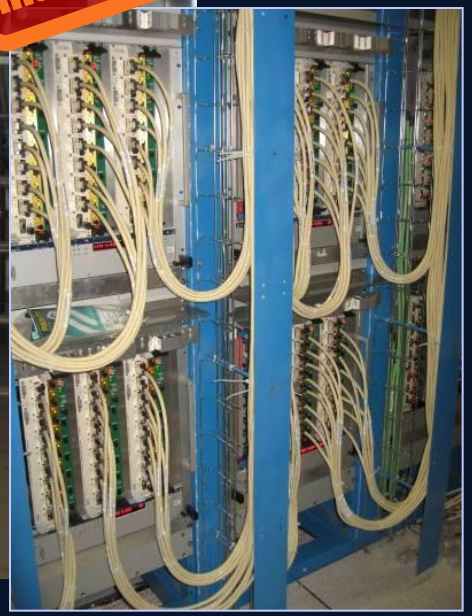


- ~ 500 cables to connect the ECAL Trigger outputs to the Regional Calorimeter Trigger

Cabling the ECAL to the Calorimeter Trigger

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

made in LIP



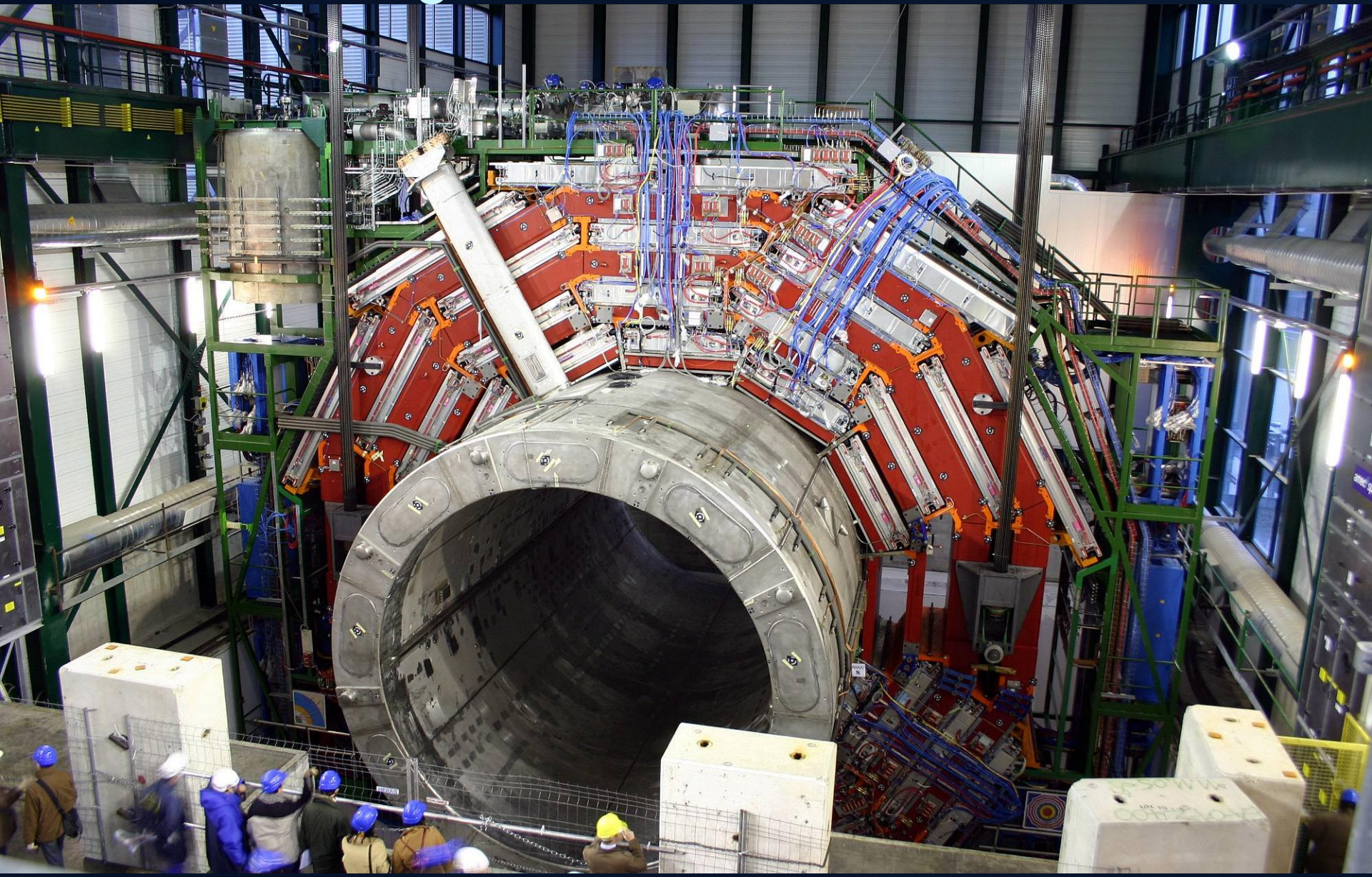
Cabling the ECAL to the Calorimeter Trigger

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

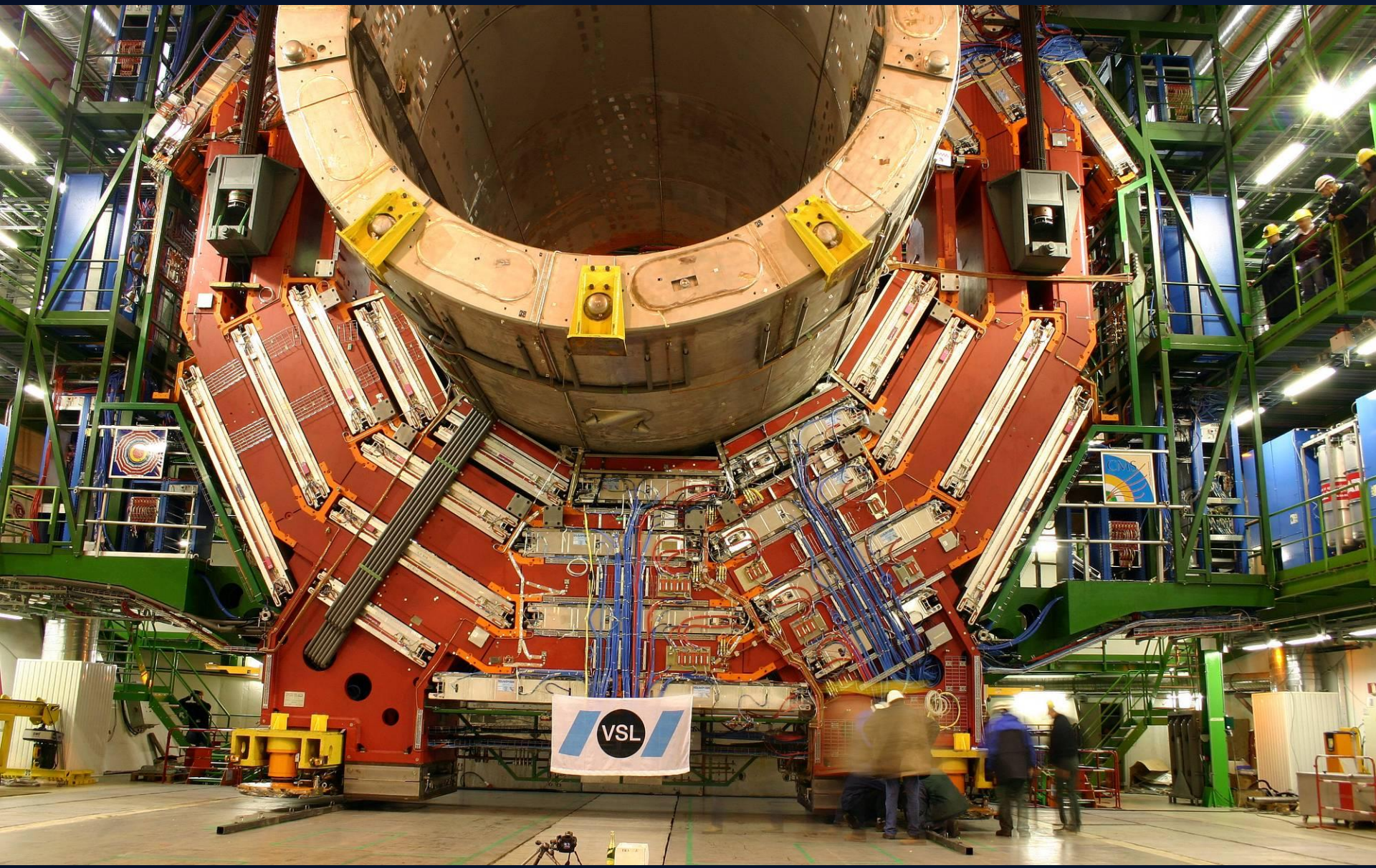
made in LIP

"paciência de Português"

2007: lowering of the central barrel



Touch down !



May 2007: ECAL barrel installation

ECAL Barrel installation

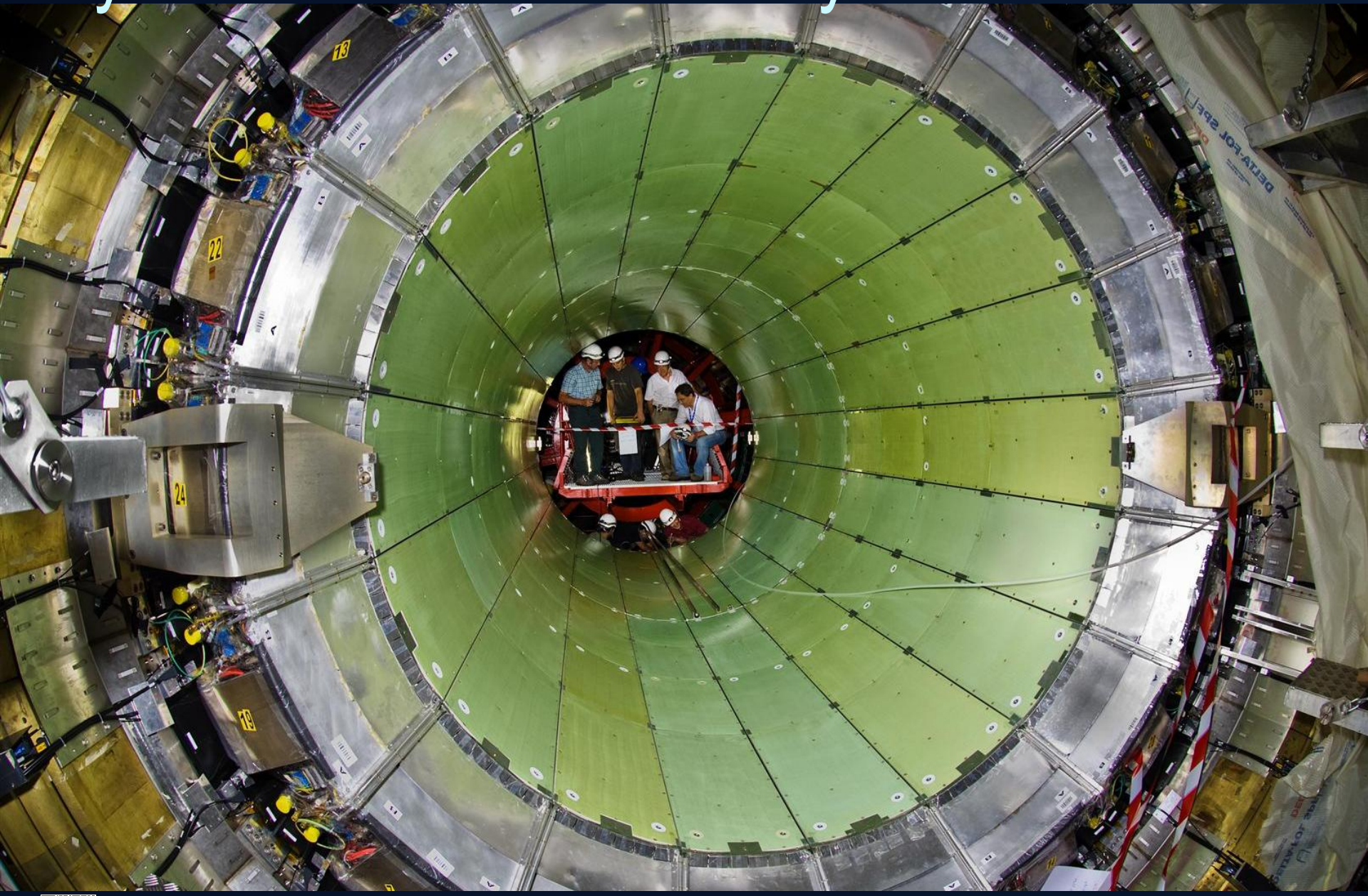
- **36 Supermodules** tested before and after insertion in the central barrel:
  - Front-end functionality
  - Data acquisition functionality
  - Trigger primitive generation functionality

- Sample logbook entry

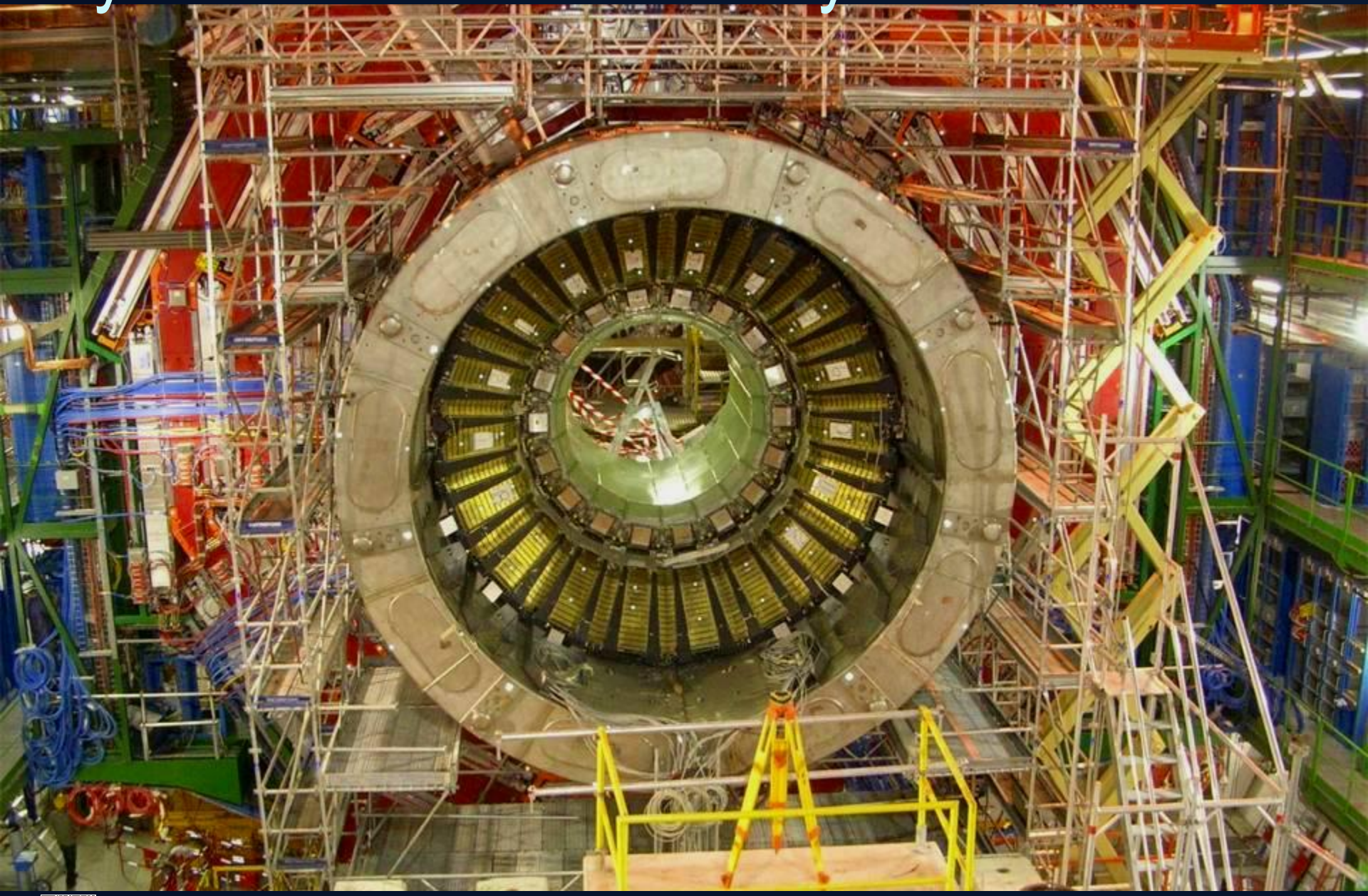
1) Token rings - OK
2) I2c devices access - OK
3) HV - TT57 and TT58 draw high current (~200uA),
   this problem has appeared on the floor, current was 50uA.
4) DCU - OK, except channel 1427 (TT58) has high APD current (~200uA)
   except APD temperature TT9, cry245 bad DCU measurement (known from floor)
   except APD temperature TT57, cry1441 bad DCU measurement (~15 C, known from floor)
6) Pedestal run 1591 - OK, except
   ch 1427 (TT58) is noisy (RMS12=41.2),
   ch 115 has rms6=1.8 rms12=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

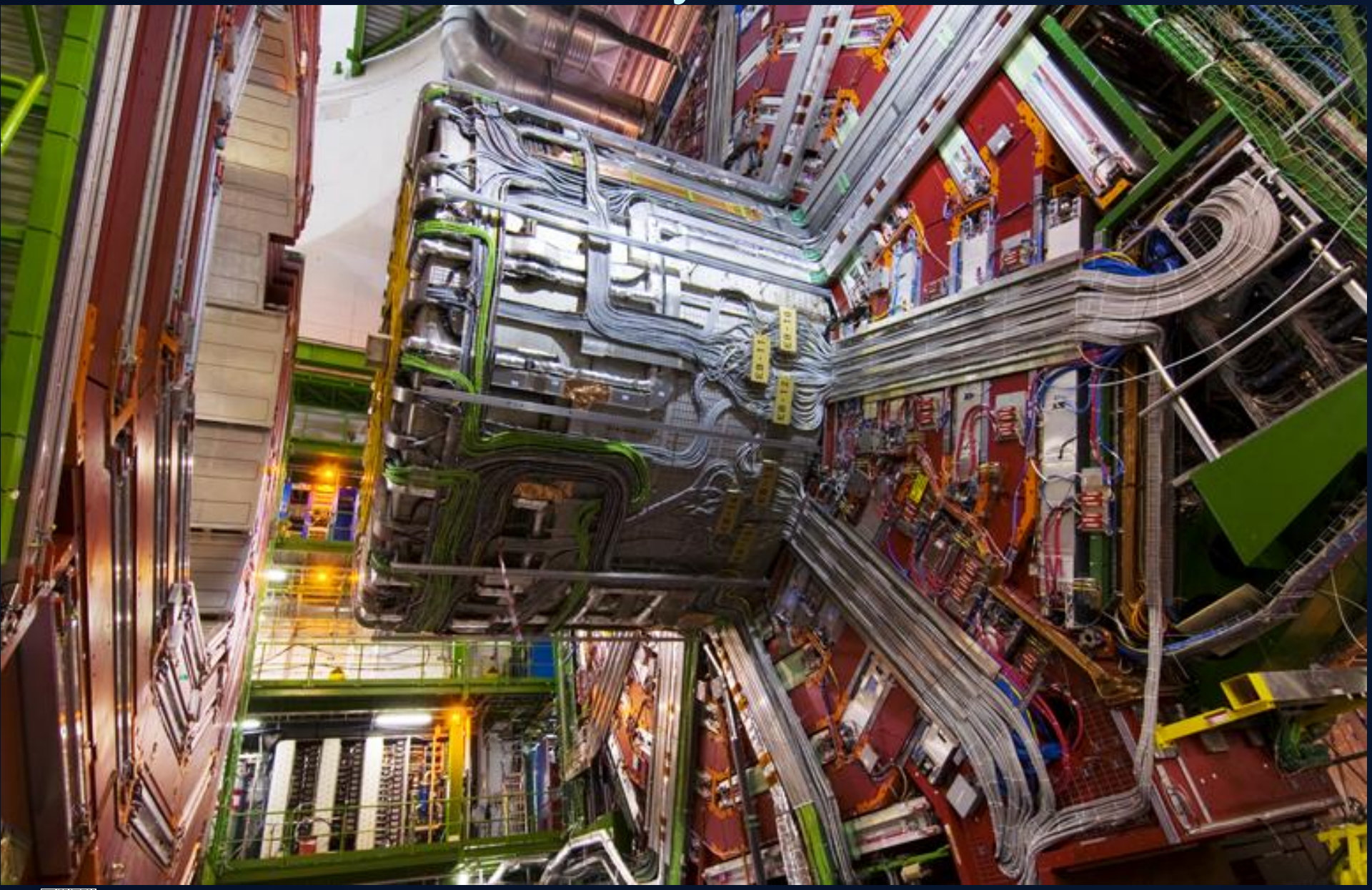
July 2007: ECAL barrel fully installed



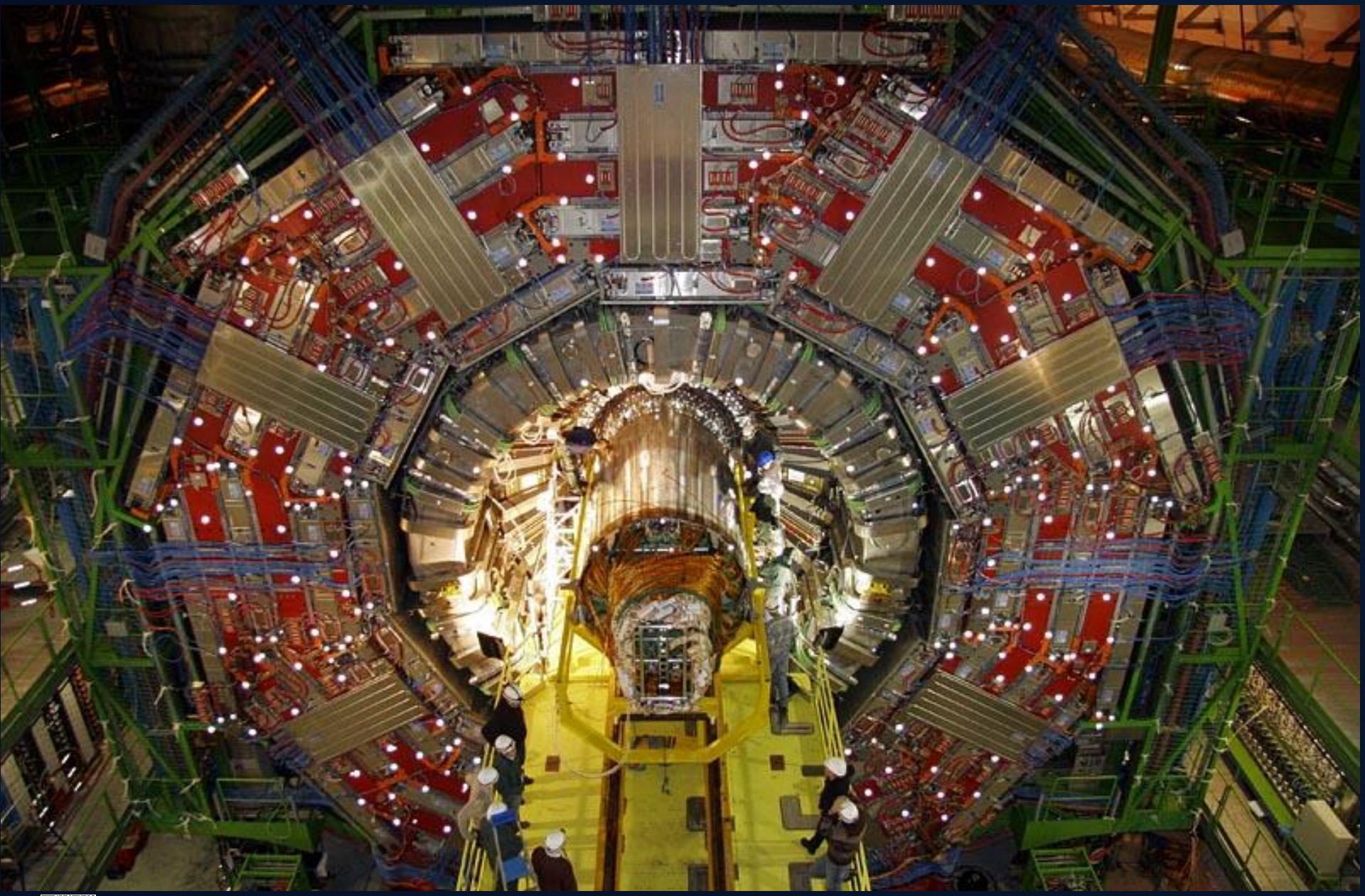
July 2007: ECAL barrel fully installed



Nov 2007: barrel ready for tracker



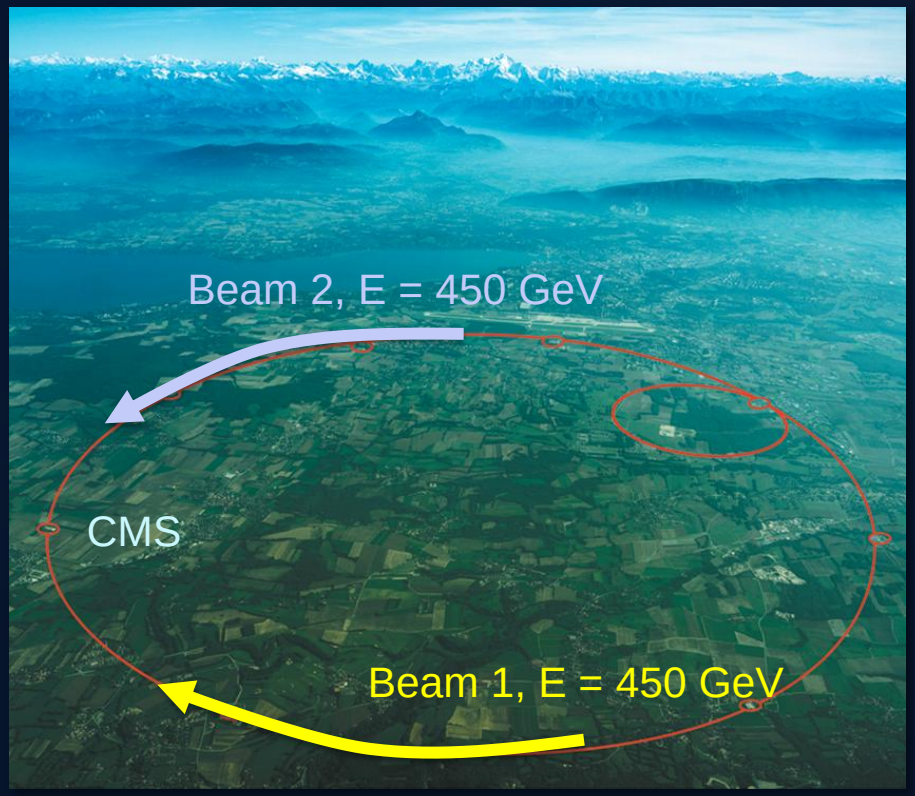
Dec 2007: tracker inserted in CMS



September 3, 2008 at 20:30

2008 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

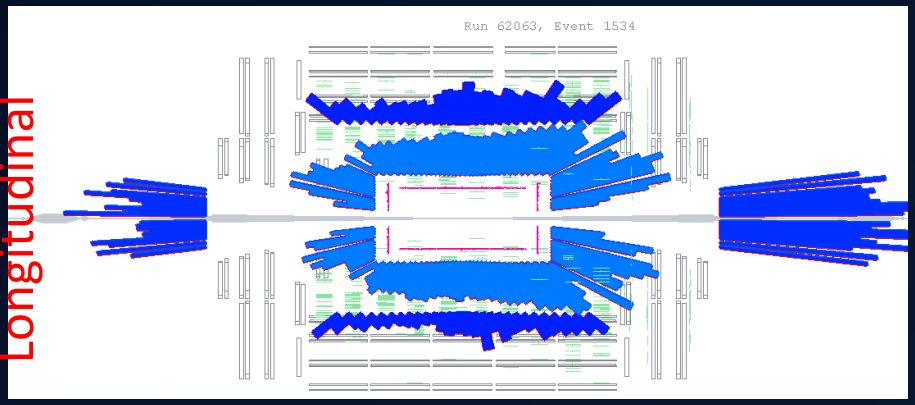
❑ CMS Trigger and DAQ fully functional: millions of beam events recorded

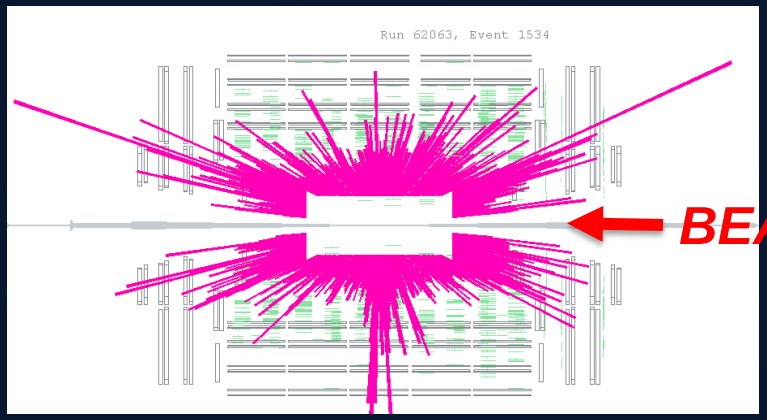
2008 Beam Splashes

HCAL energy

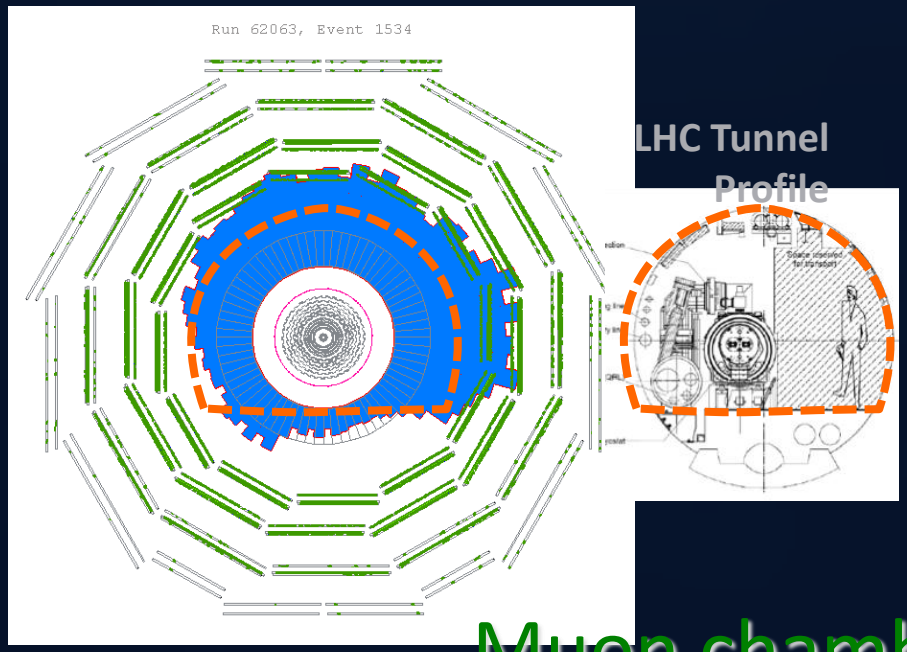
ECAL energy

Longitudinal

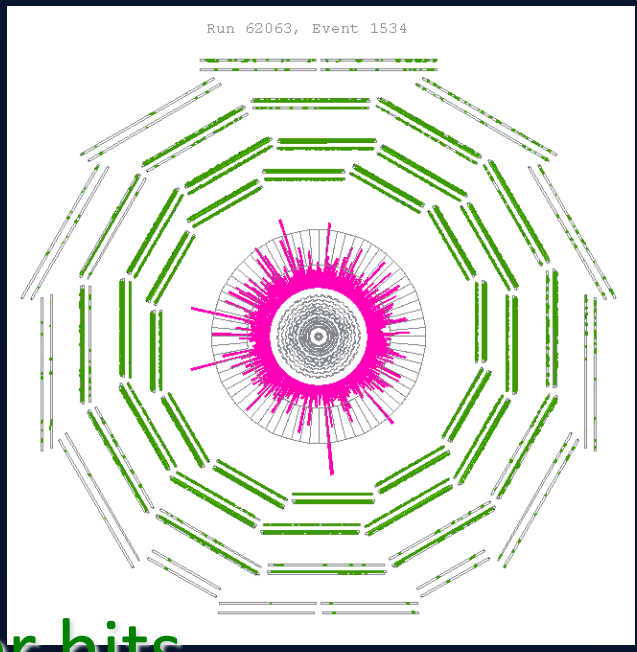




Transverse

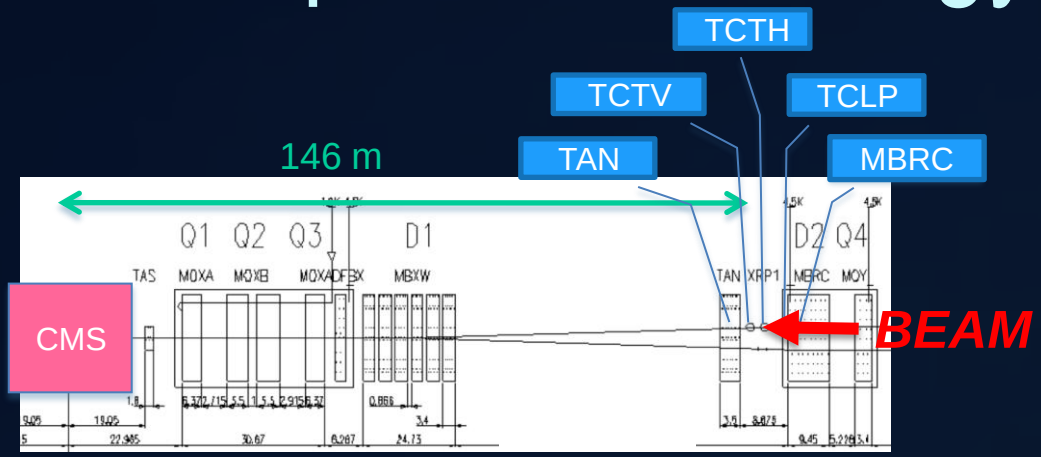


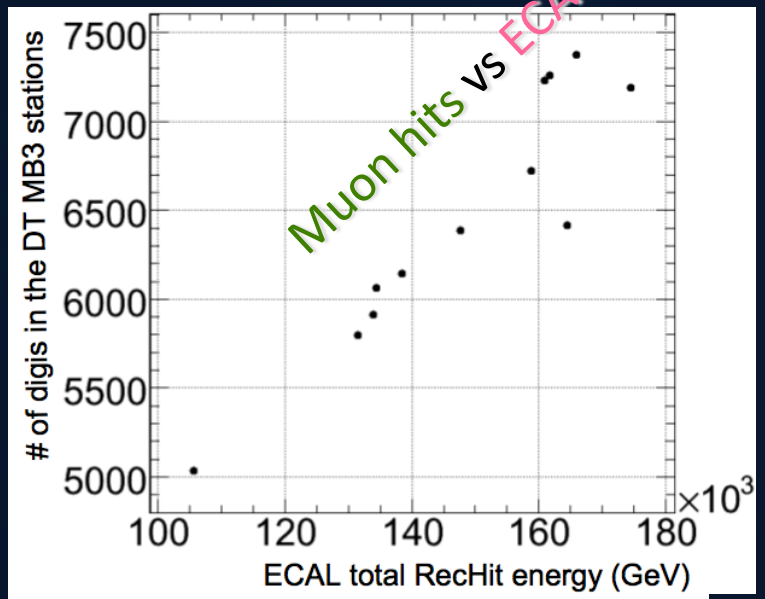
LHC Tunnel Profile



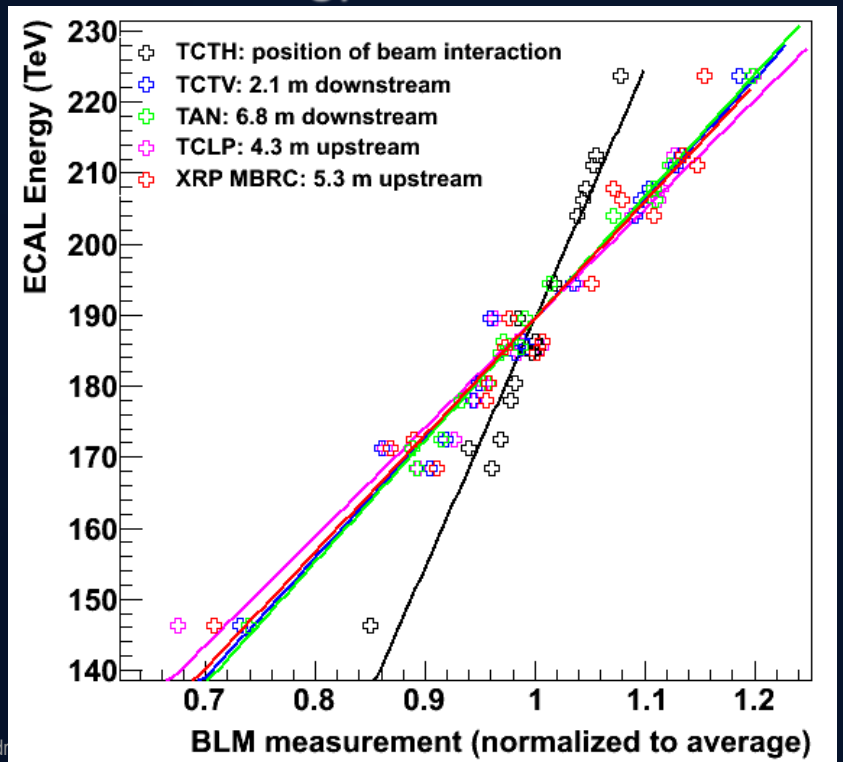
Muon chamber hits

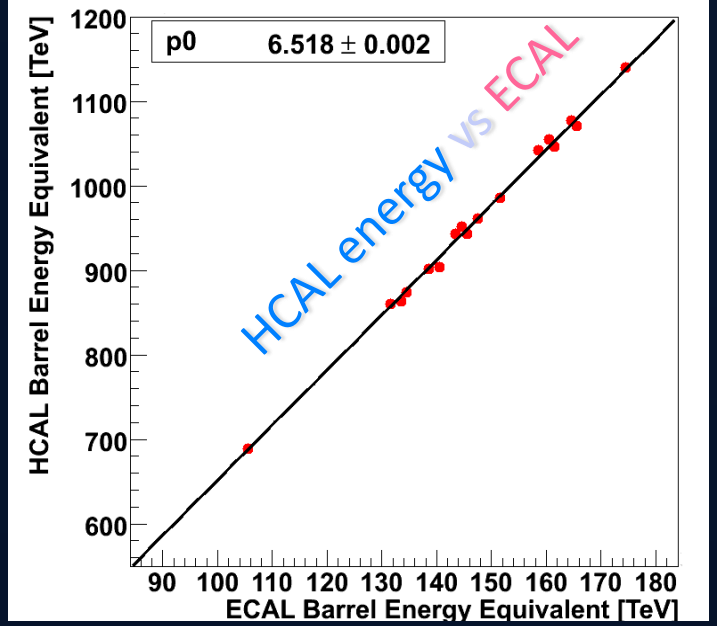
Beam Splashes – energy in CMS



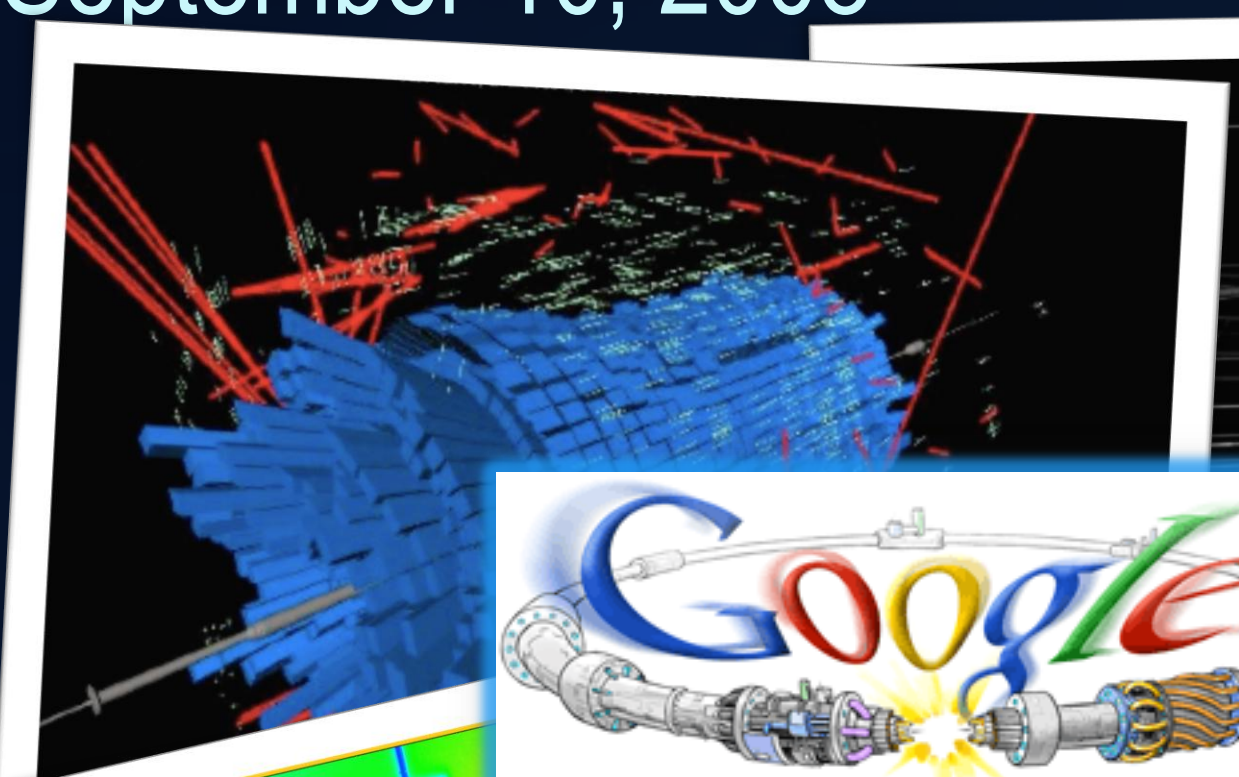


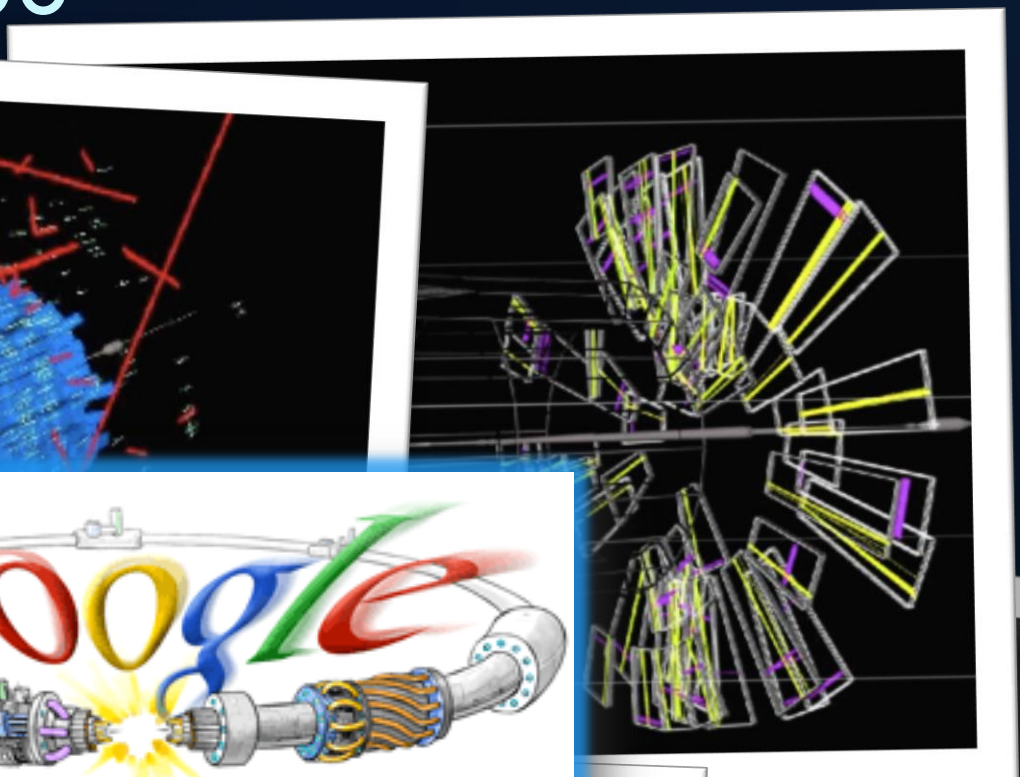
ECAL energy vs Beam Loss Monitors

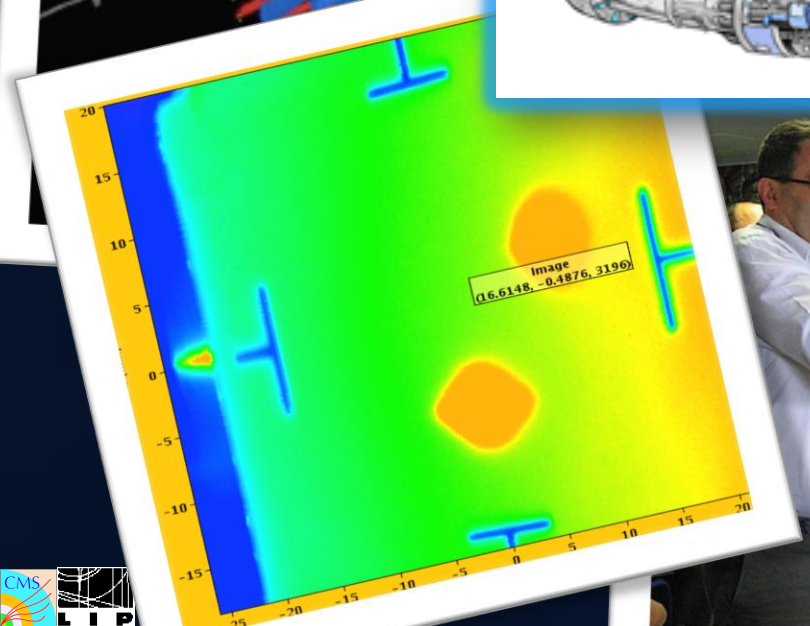




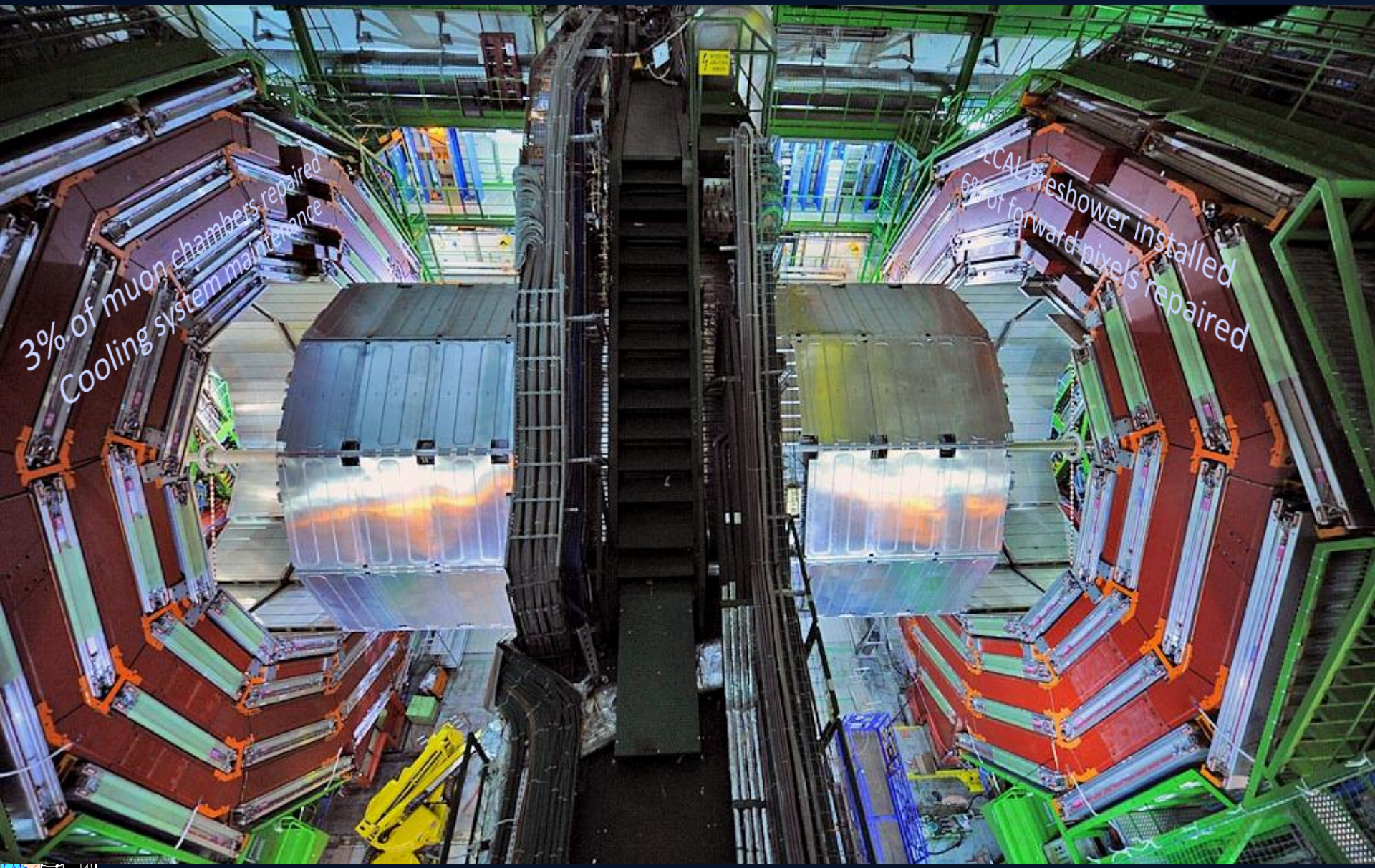
September 10, 2008





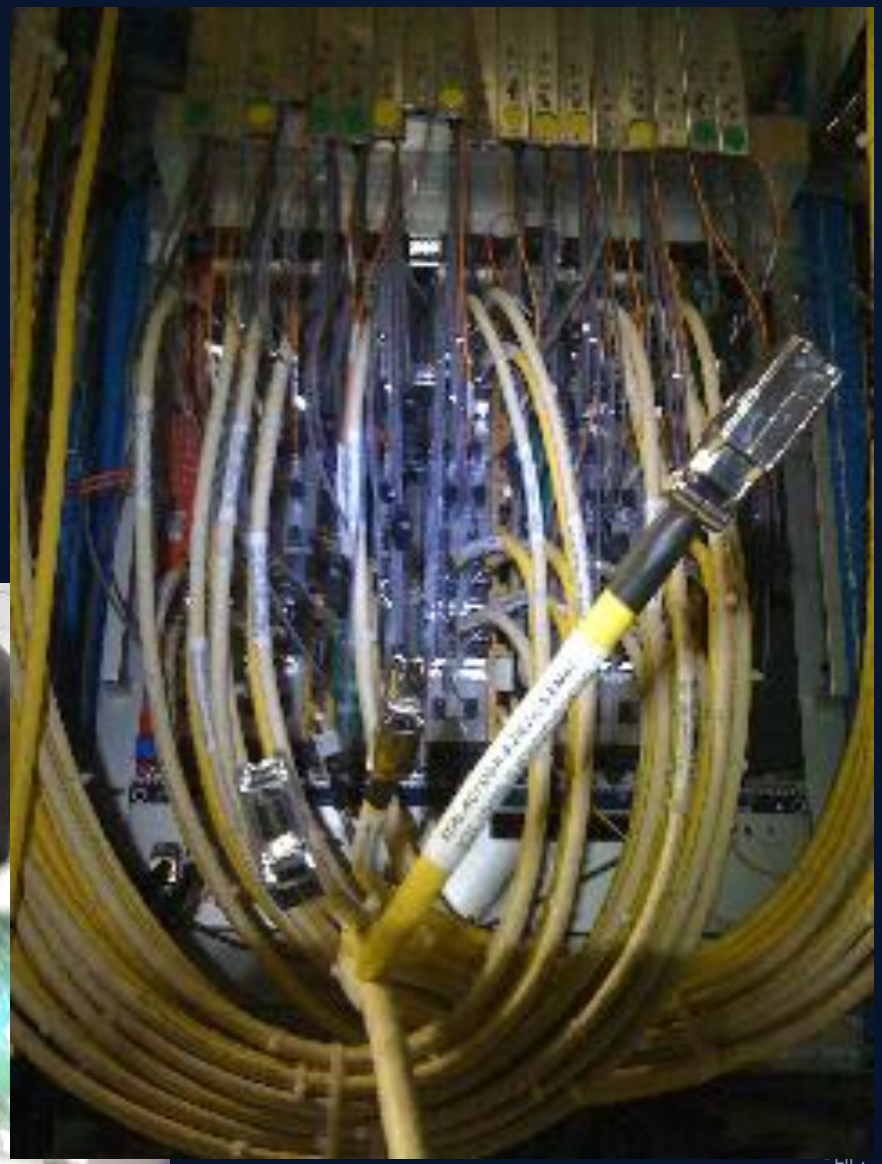


2009 was not an idle year



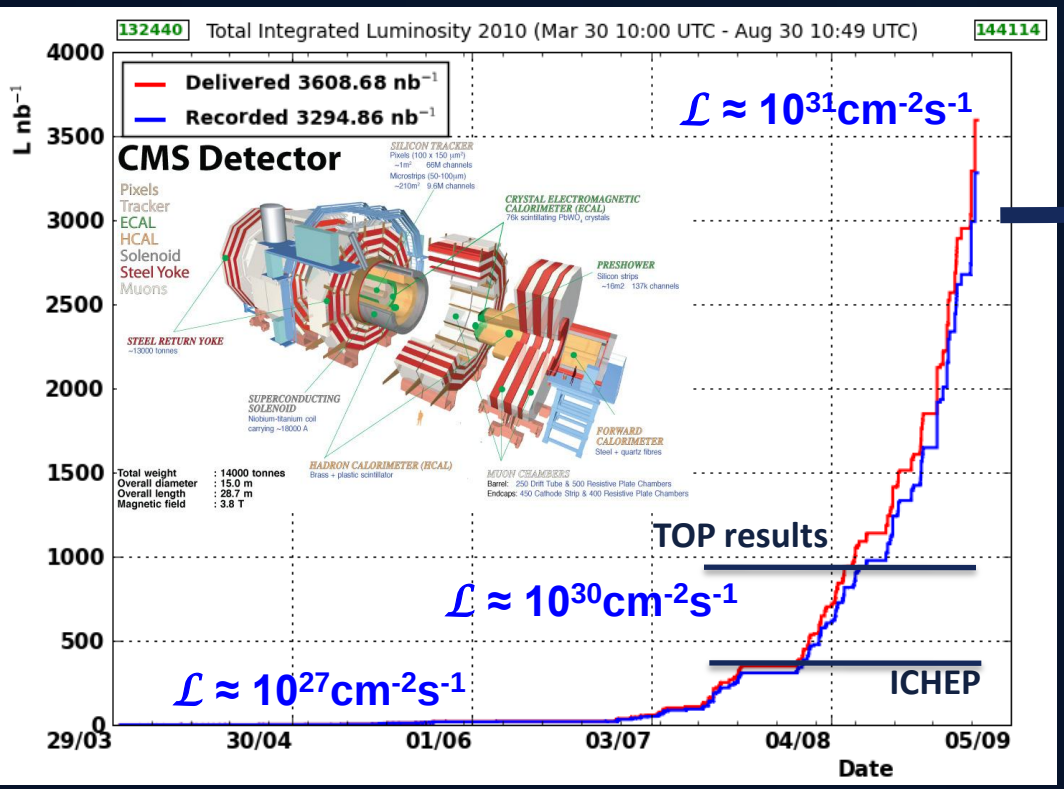
ECAL Endcap Trigger commissioning

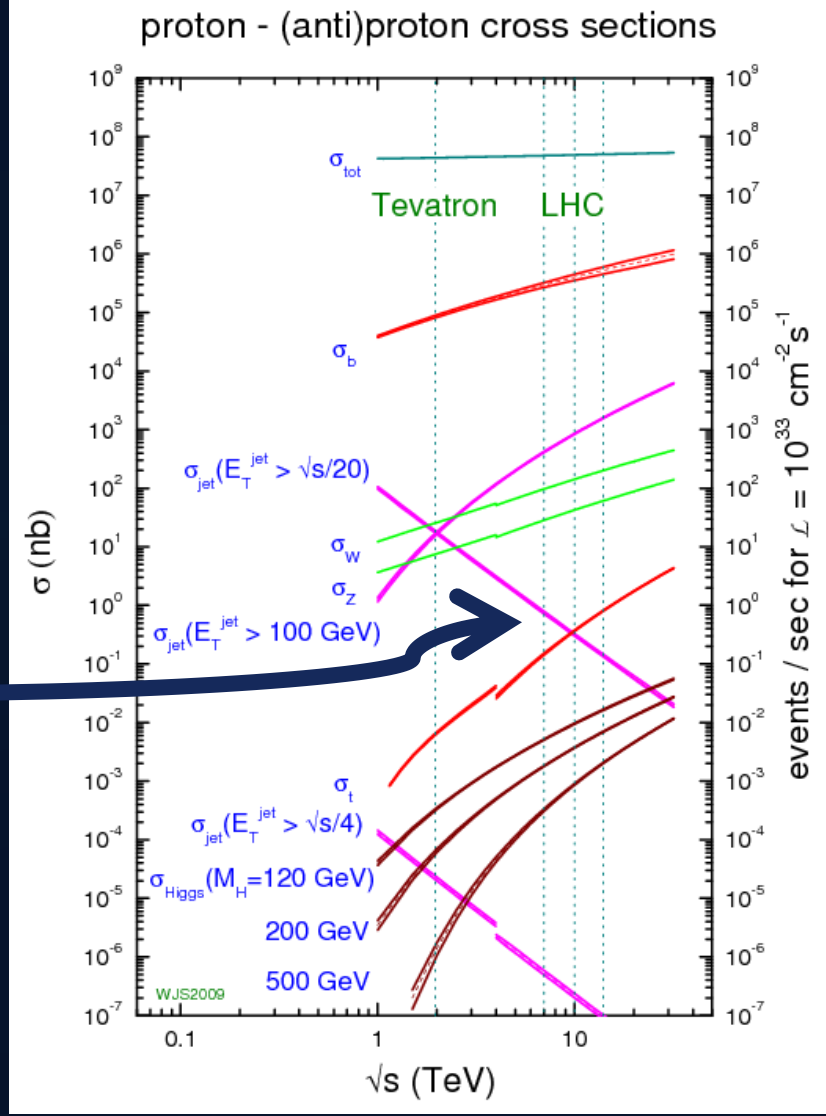
Jose Carlos



March 30, 2010 – *odisseia no LHC*

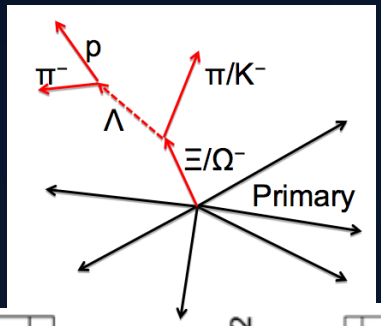
Let's go for Physics



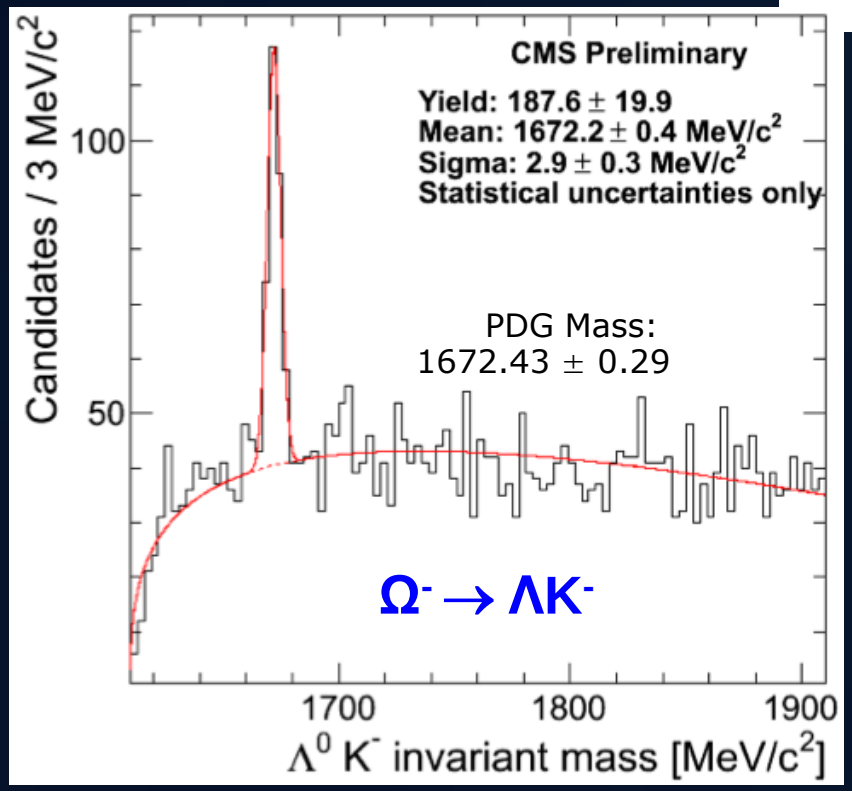


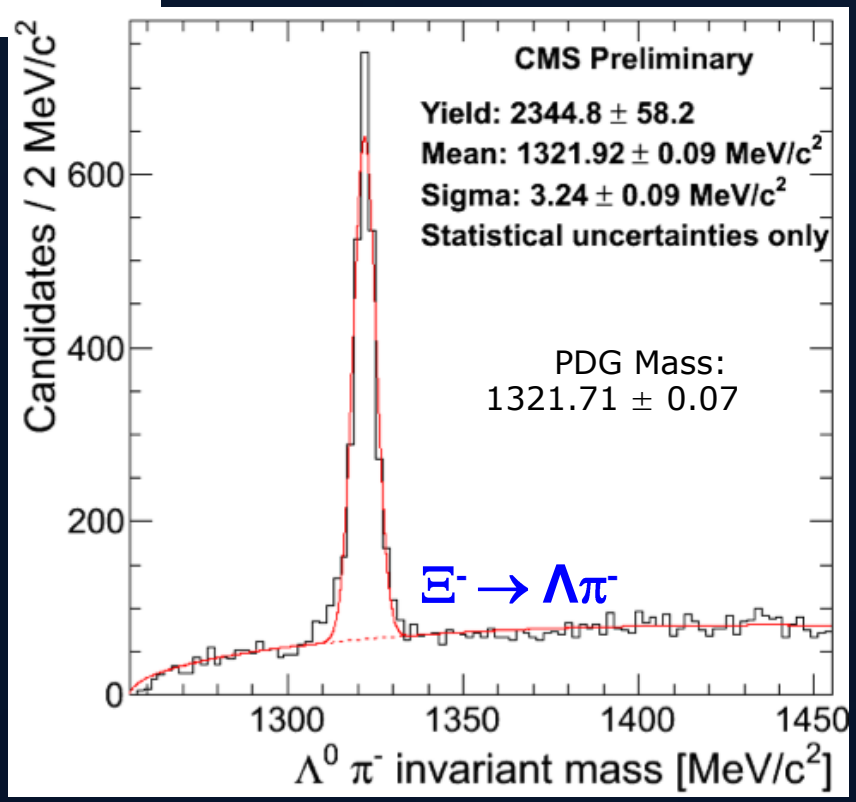
Low mass resonances

- Tracks displaced from primary vertex ($d_{3D} > 3\sigma$)
- Common displaced vertex ($L_{3D} > 10\sigma$)



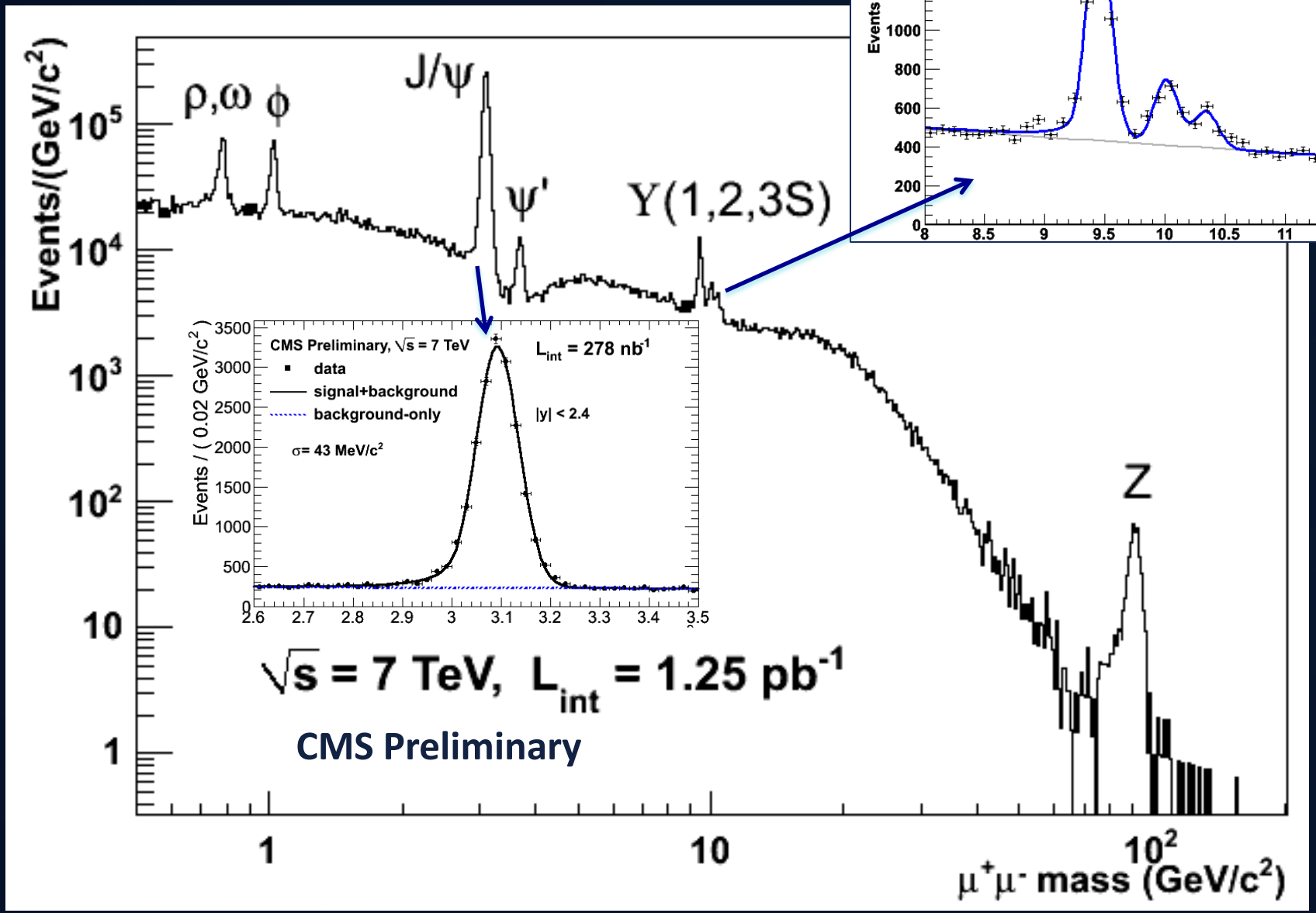
Invariant mass distribution for different combinations ($\Omega^{\pm} \to \Lambda K^{\pm}$ or $\Xi^{\pm} \to \Lambda\pi^{\pm}$) fit to a common vertex.



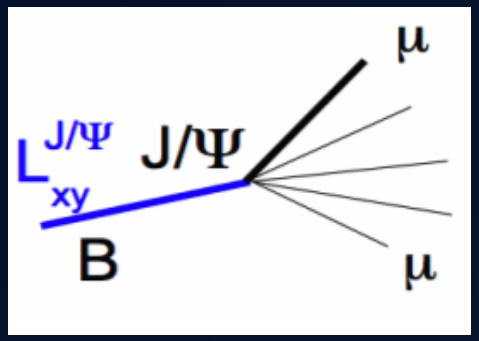


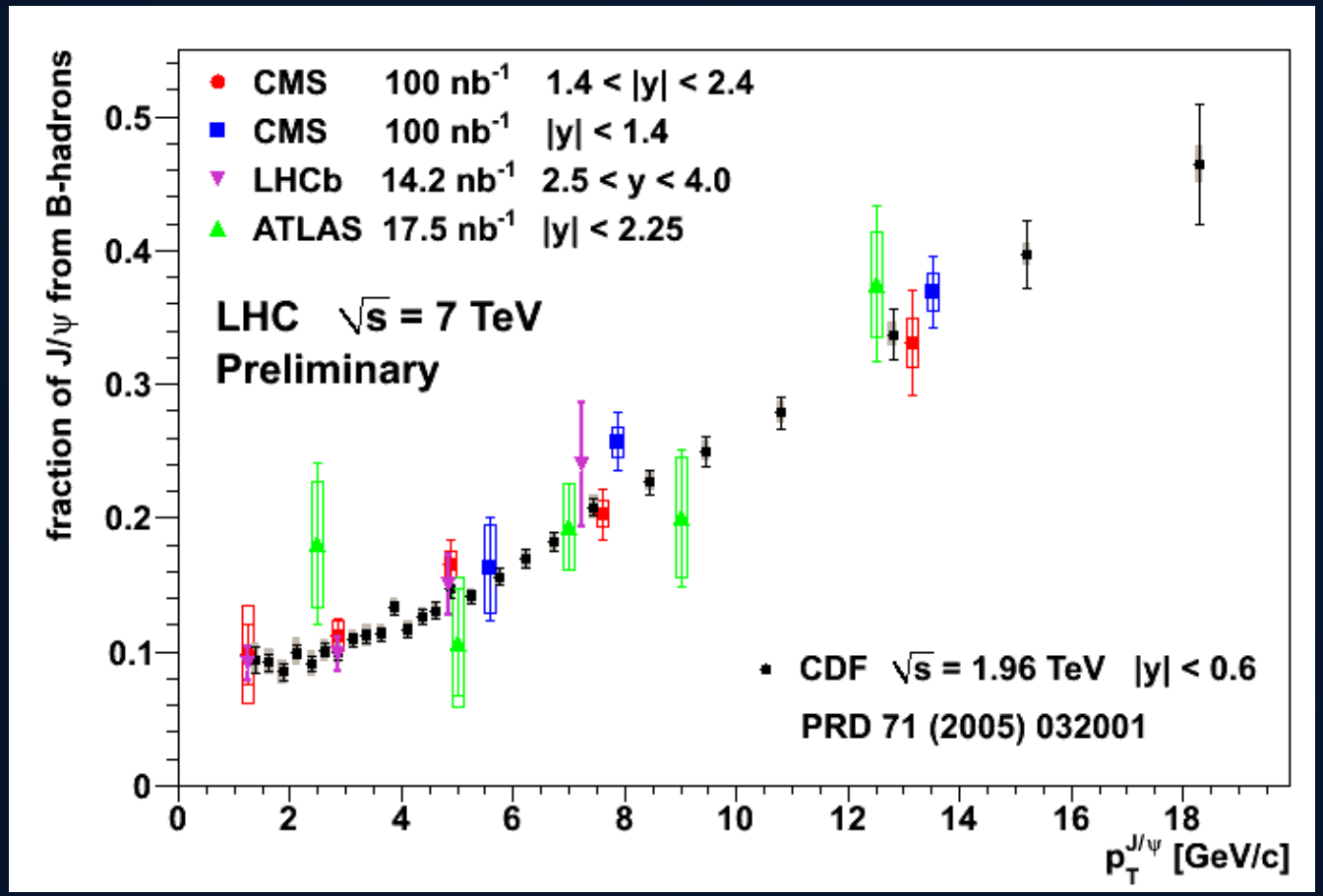
Mass accuracy at the level of 10^{-4} ➔ good alignment of Si-strip and pixels

Di-muon spectrum



J/ψ from B hadrons

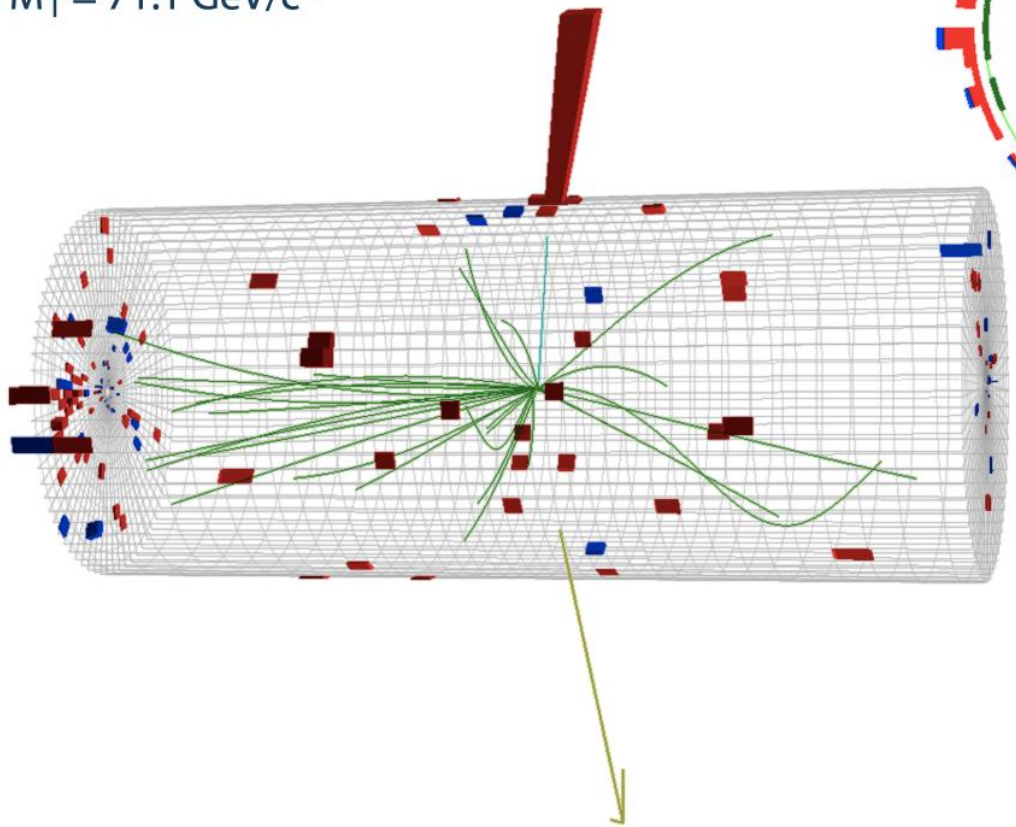


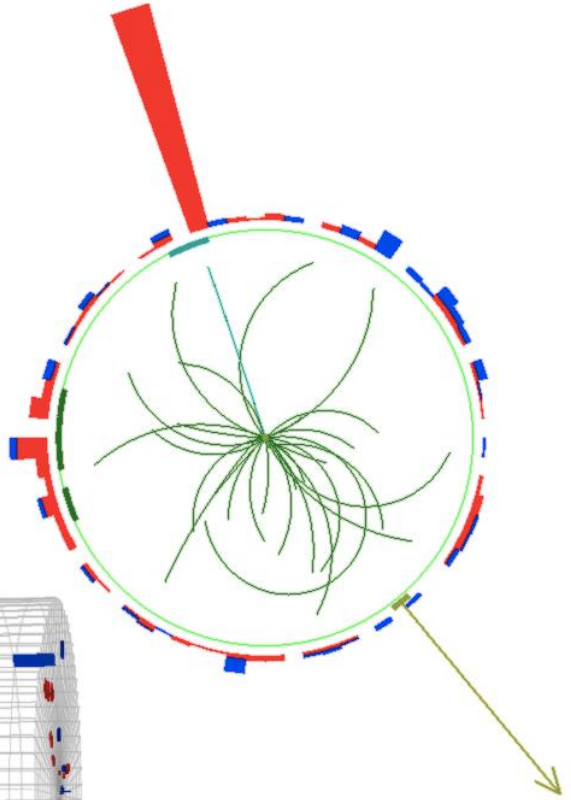


W candidate

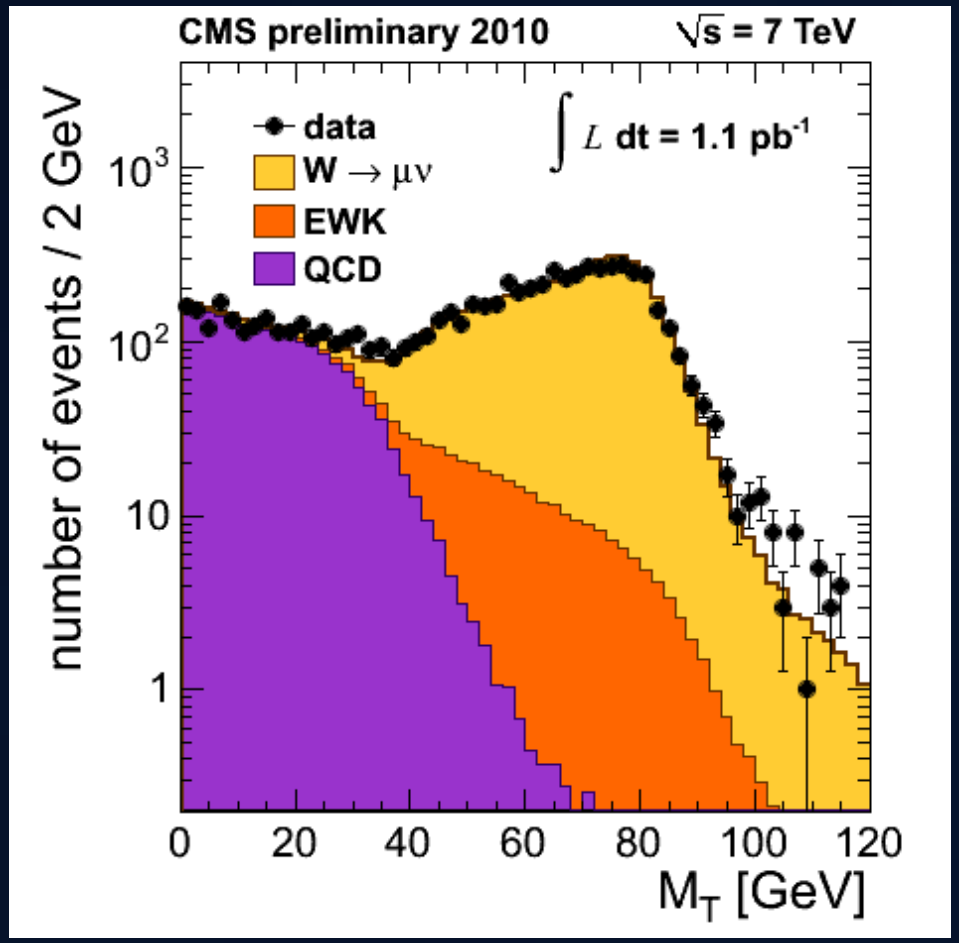
CMS Experiment at LHC, CERN
Run 133874, Event 21466935
Lumi section: 301
Sat Apr 24 2010, 05:19:21 CEST

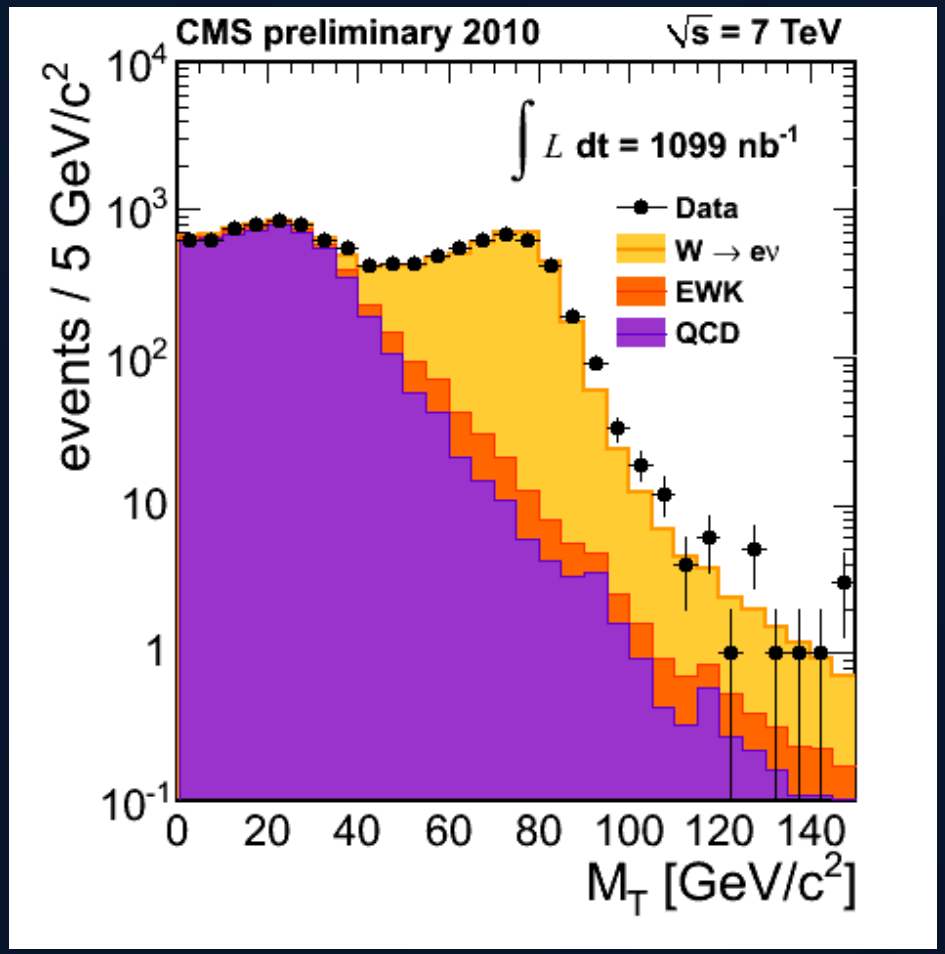
Electron $p_T = 35.6$ GeV/c
$ME_T = 36.9$ GeV
$M_T = 71.1$ GeV/c^2



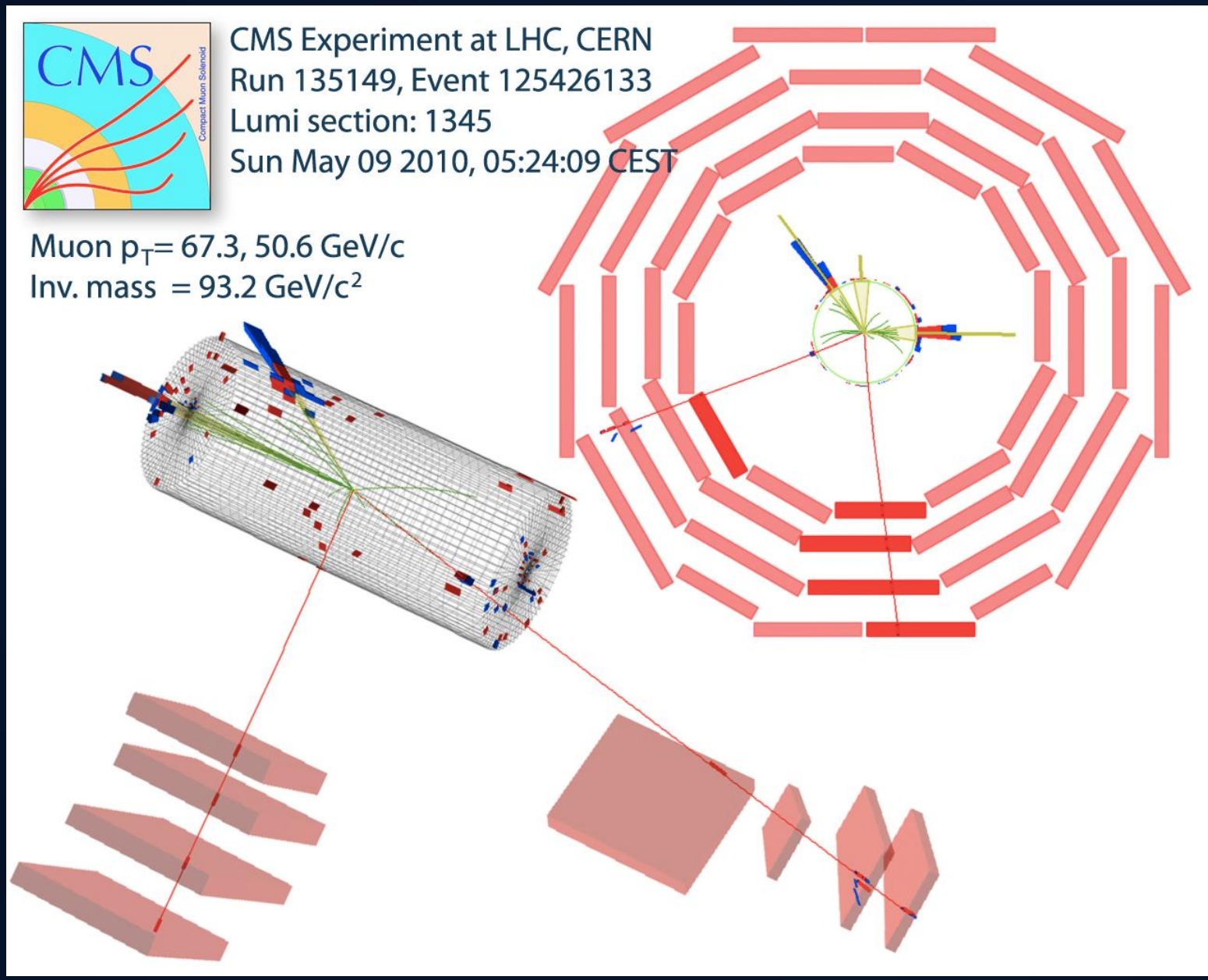


W decays

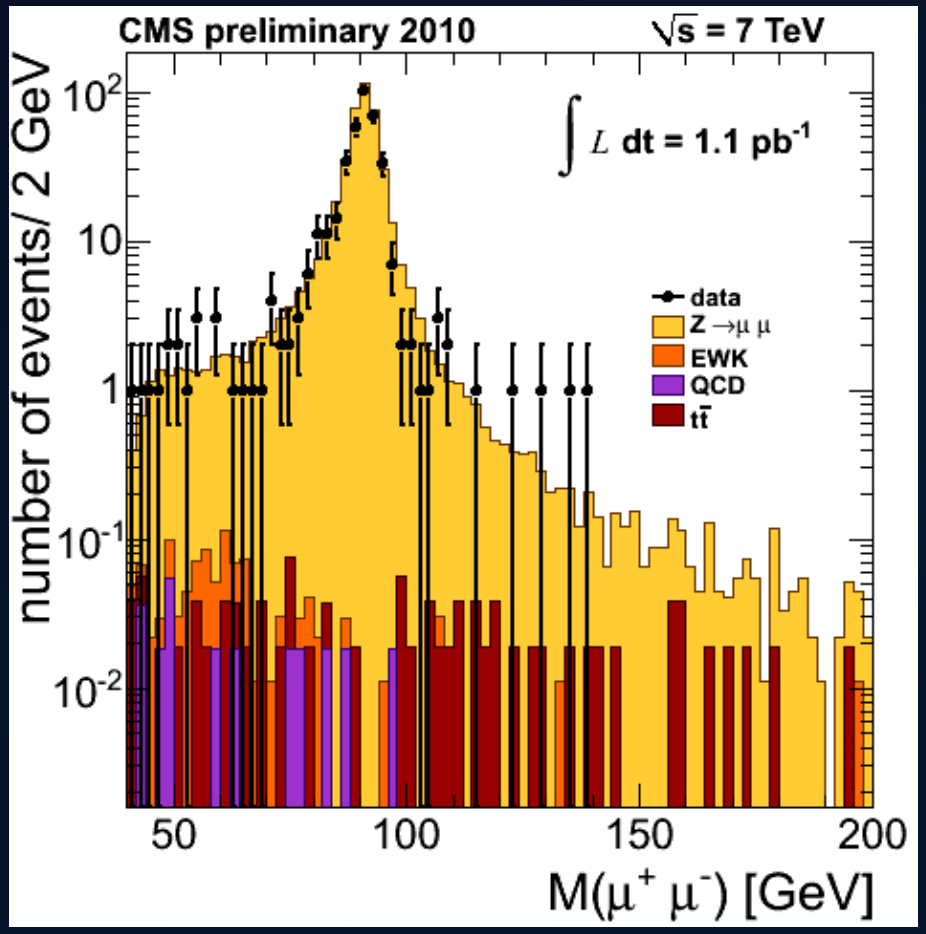

CMS preliminary 2010
√s = 7 TeV
data
W → μν
EWK
QCD
∫ L dt = 1.1 pb-1
number of events / 2 GeV
M_T [GeV]

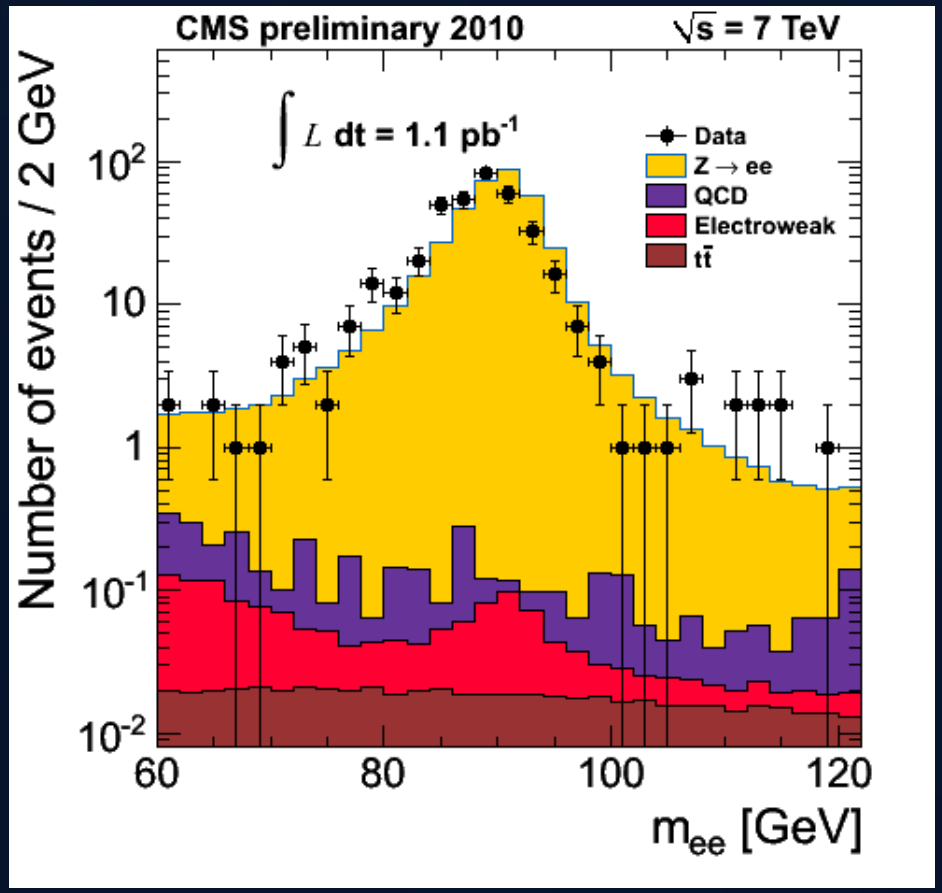

CMS preliminary 2010
√s = 7 TeV
∫ L dt = 1099 nb-1
Data
W → eν
EWK
QCD
events / 5 GeV/c2
M_T [GeV/c2]

Z candidate

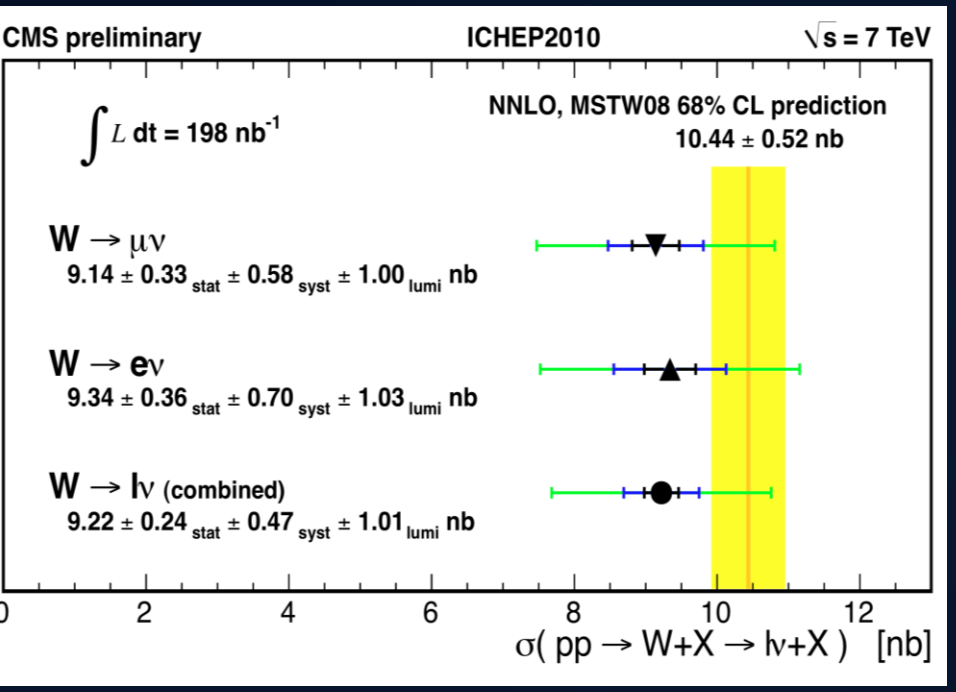

CMS
Compact Muon Solenoid
CMS Experiment at LHC, CERN
Run 135149, Event 125426133
Lumi section: 1345
Sun May 09 2010, 05:24:09 CEST
Muon p_T= 67.3, 50.6 GeV/c
Inv. mass = 93.2 GeV/c^2

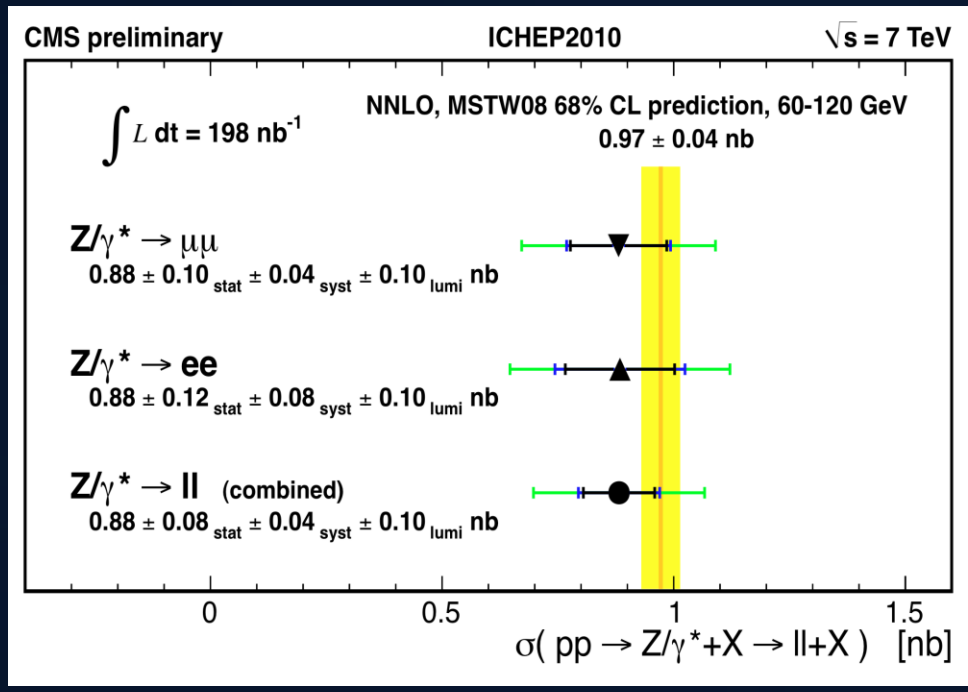
Z decays

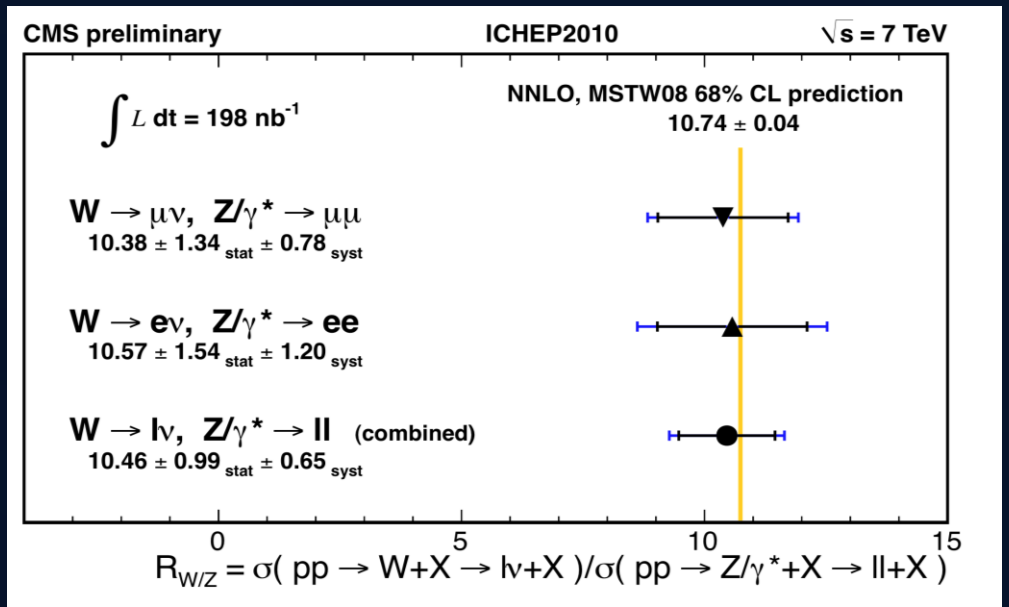

CMS preliminary 2010
√s = 7 TeV
∫ L dt = 1.1 pb-1
data
Z →μ μ
EWK
QCD
tt̄
number of events/ 2 GeV
M(μ+ μ-) [GeV]


CMS preliminary 2010
√s = 7 TeV
∫ L dt = 1.1 pb-1
Data
Z → ee
QCD
Electroweak
tt̄
Number of events / 2 GeV
mee [GeV]

W and Z cross-sections





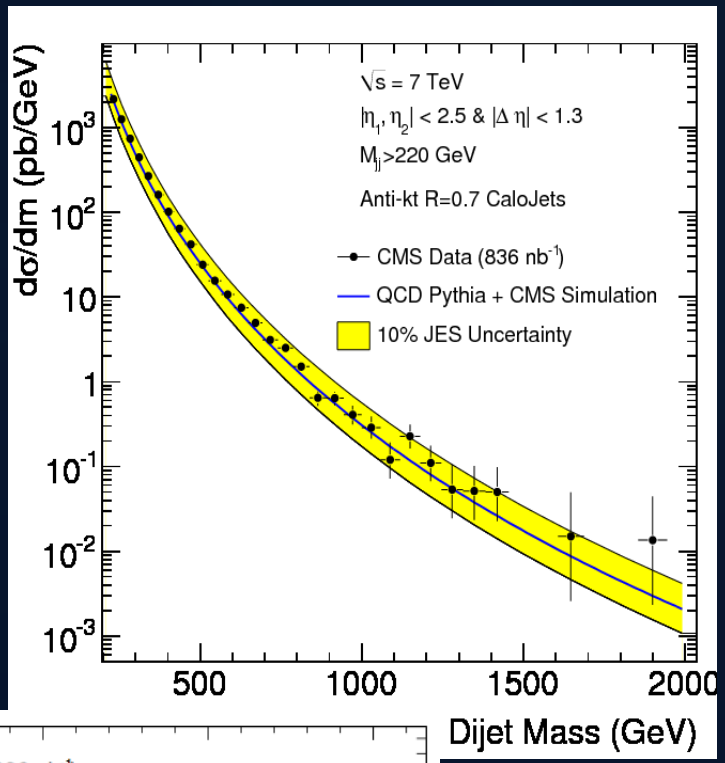


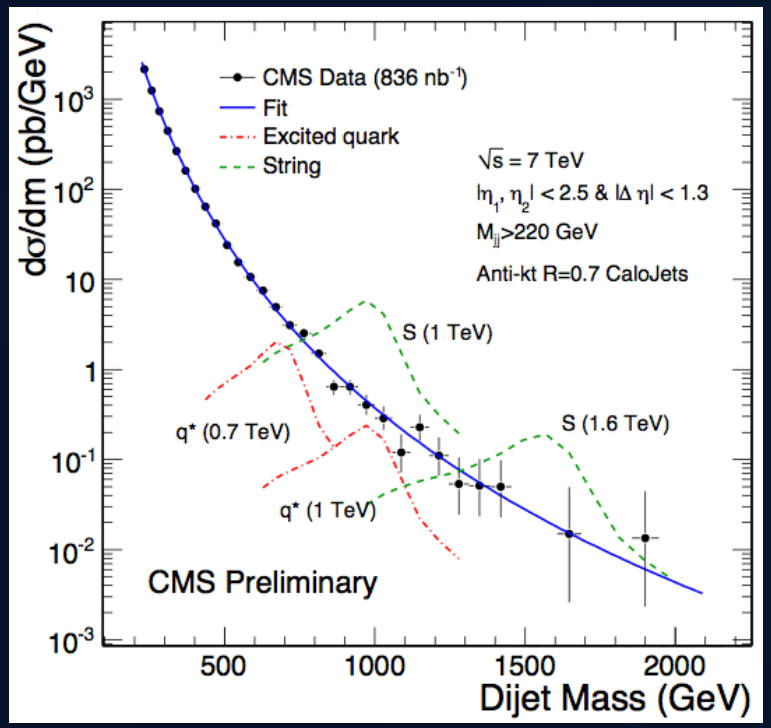
Search for dijet resonances

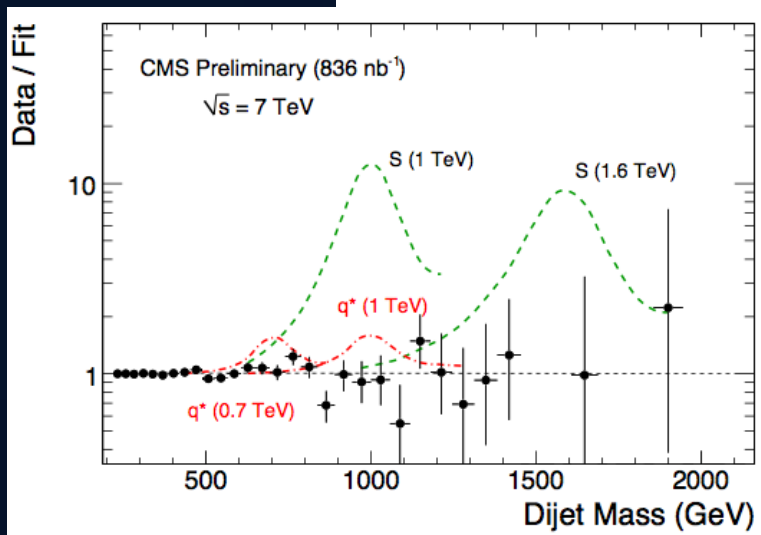
dijet mass differential cross section:

2 anti-k_t ($\Delta R<0.7$) calorimetric jets with $|\eta_1,\eta_2|<2.5$ and $|\Delta\eta_{12}|<1.3$

Distribution sensitive to the coupling of any new massive object to quarks and gluons





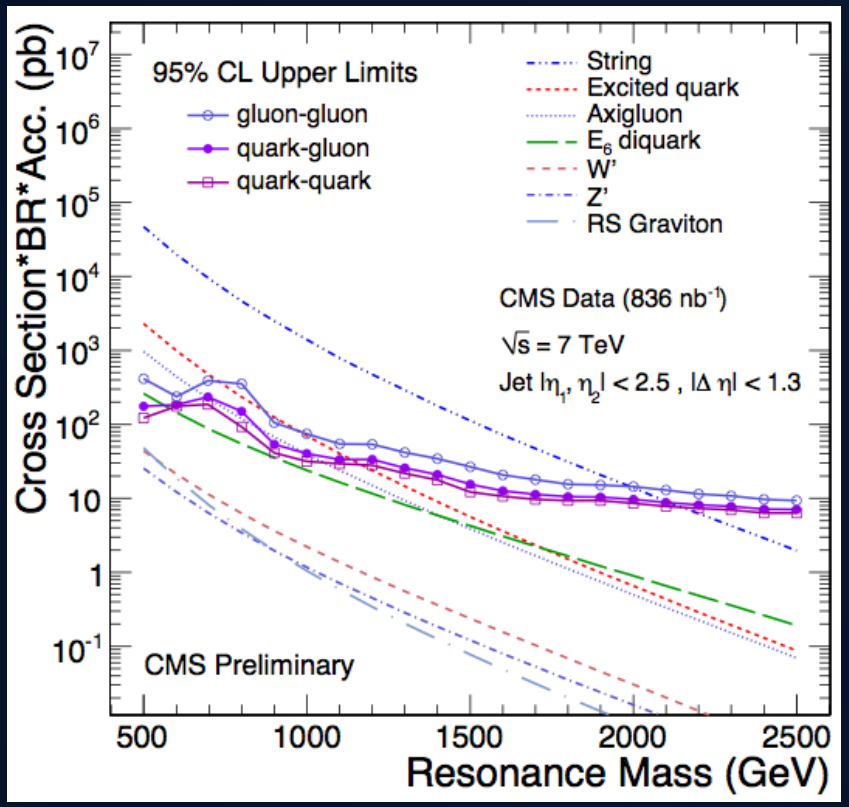


NO indication of New Physics

Limits on resonances

Several models of parton resonances, massive qq, qg,gg decaying to di-jets, to be compared to cross section limits on qq, qg, gg obtained from data

Model Name	X	Color	J^P	$\Gamma/(2M)$	Final-state Partons
String	S	mixed	mixed	0.003-0.037	qq, qq, gg and qg
Axigluon	A	Octet	1^+	0.05	$q\bar{q}$
Coloron	C	Octet	1^-	0.05	$q\bar{q}$
Excited Quark	q*	Triplet	$1/2^+$	0.02	qg
E_6 Diquark	D	Triplet	0^+	0.004	qq
RS Graviton	G	Singlet	2^+	0.01	$q\bar{q}$, gg
Heavy W	W'	Singlet	1^-	0.01	$q\bar{q}$
Heavy Z	Z'	Singlet	1^-	0.01	$q\bar{q}$



95% C.L. Mass Limit [TeV] using CTEQ6L

Model	CMS (836 nb^{-1})	CDF (1.13 fb^{-1})
String	> 2.10	> 1.4
q*	> 1.14	> 0.87
Axigluon/Coloron	> 1.06	> 1.25
E_6 Diquark	> 0.58	> 0.63

Sumário

- **Portugal tem um papel importante em CMS**
  - E não só…

- **O LHC começou…**
  …com o pé direito
  - Uma a uma, estamos a redescobrir todas as partículas do século XX
  - Primeira vez que se vê o quark *top* na Europa

- **CMS está pronta para mais**
  - >90% de eficiência na tomada de dados desde Março

- **Vamos visitar a caverna!**

Natal 2011?


SO, WHAT DOES THE LITTLE HADRON COLLIDER SCIENTIST WANT?
THE HIGGS BOSON PARTICLE!
CAM
OTTAWA CITIZEN