The CMS experiment at the Large Hadron Collider

Michele Gallinaro

Apr. 21, 2012

- Long term planning: 1992-2012
- Technical challenges, preparation
- Exploring the infinitesimally small world
- 2012 and beyond

CMS detector

July 2010

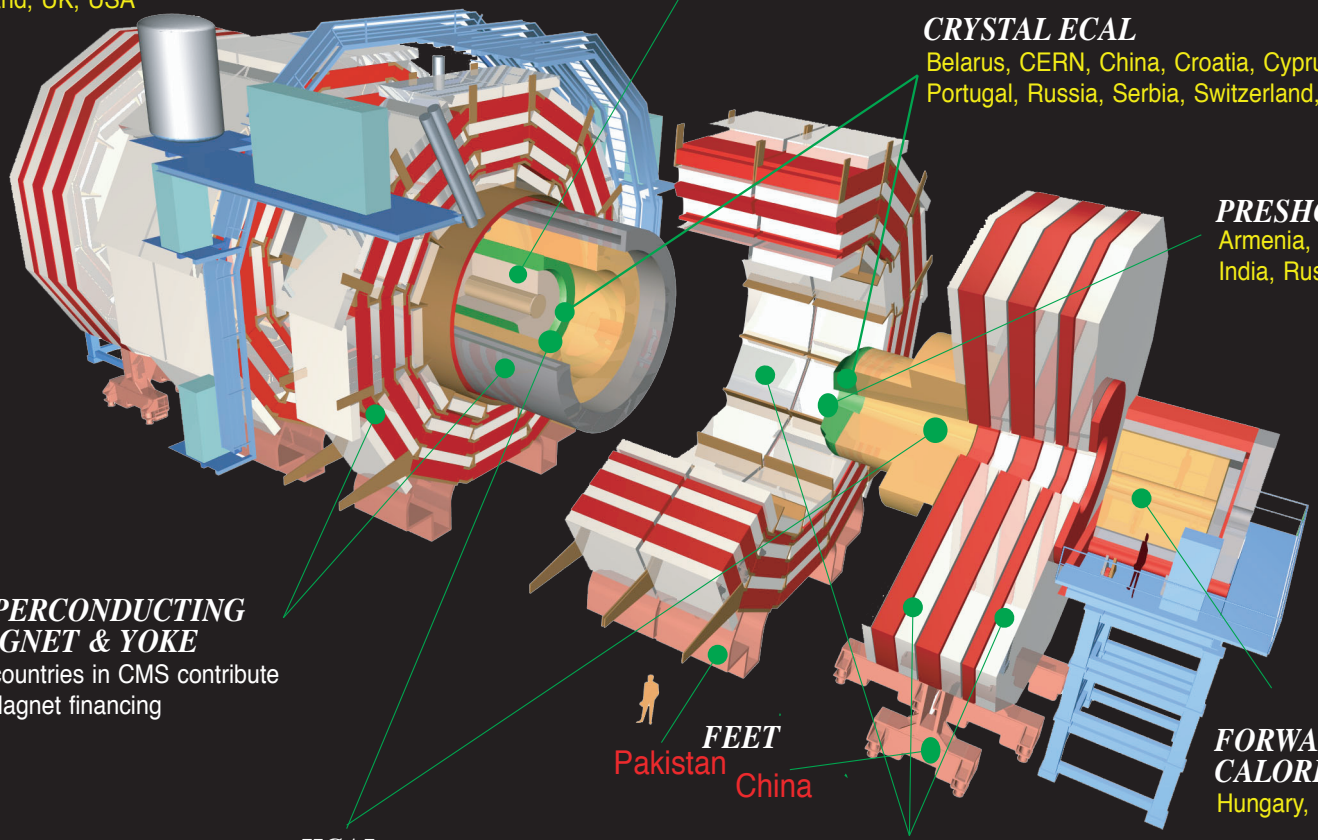
39 Countries, 169 Institutes, 3170 scientists and engineers (including about 800 students)

TRIGGER, DATA ACQUISITION & OFFLINE COMPUTING
Austria, Brazil, CERN, Finland, France, Greece, Hungary, Ireland, Italy, Korea, Lithuania, New Zealand, Poland, Portugal, Switzerland, UK, USA

TRACKER
Austria, Belgium, CERN, Finland, France, Germany, Italy, Mexico, New Zealand, Switzerland, UK, USA

CRYSTAL ECAL
Belarus, CERN, China, Croatia, Cyprus, France, Italy, Portugal, Russia, Serbia, Switzerland, UK, USA

PRESHOWER
Armenia, CERN, Greece, India, Russia, Taiwan



SUPERCONDUCTING MAGNET & YOKE
All countries in CMS contribute to Magnet financing

FEET
Pakistan
China

FORWARD CALORIMETER
Hungary, Iran, Russia, Turkey, USA

HCAL
Barrel: Bulgaria, India, USA
Endcap: Belarus, Bulgaria, Georgia, Russia, Ukraine, Uzbekistan
HO: India

MUON CHAMBERS
Barrel: Austria, Bulgaria, CERN, China, Germany, Hungary, Italy, Spain
Endcap: Belarus, Bulgaria, China, Colombia, Egypt, Korea, Pakistan, Russia, USA

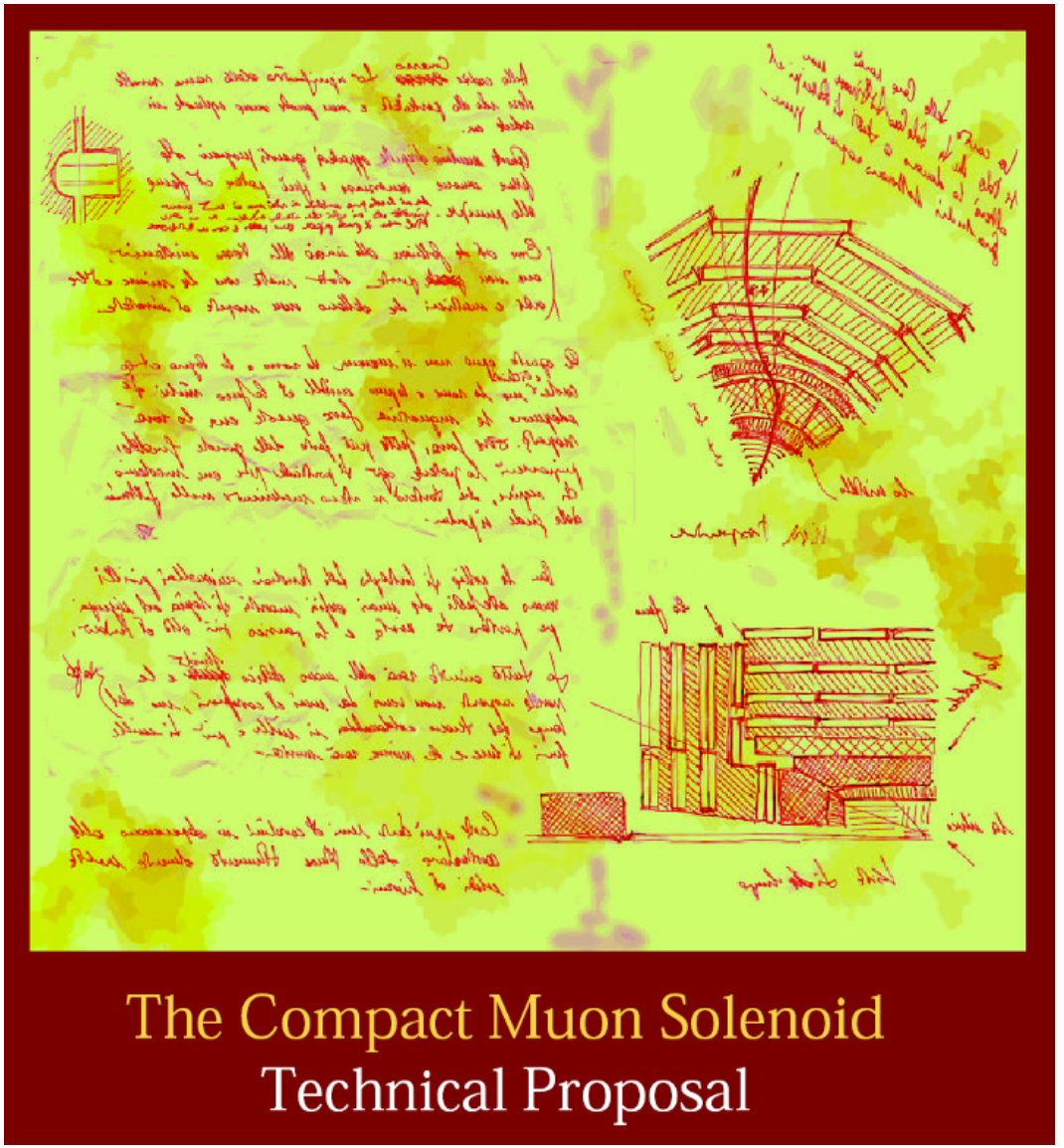
Total weight	**: 14000 tonnes**
Overall diameter	**: 15.0 m**
Overall length	**: 28.7 m**
Magnetic field	**: 3.8 T**

Original proposal (1994)

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

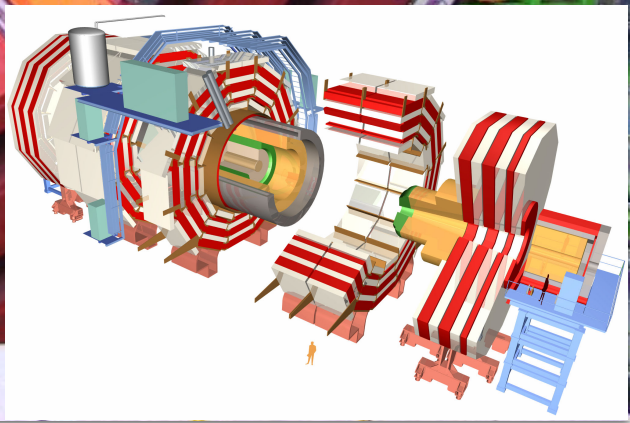
Laboratório de Instrumentação e Física Experimental de Partículas, Lisboa, Portugal

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

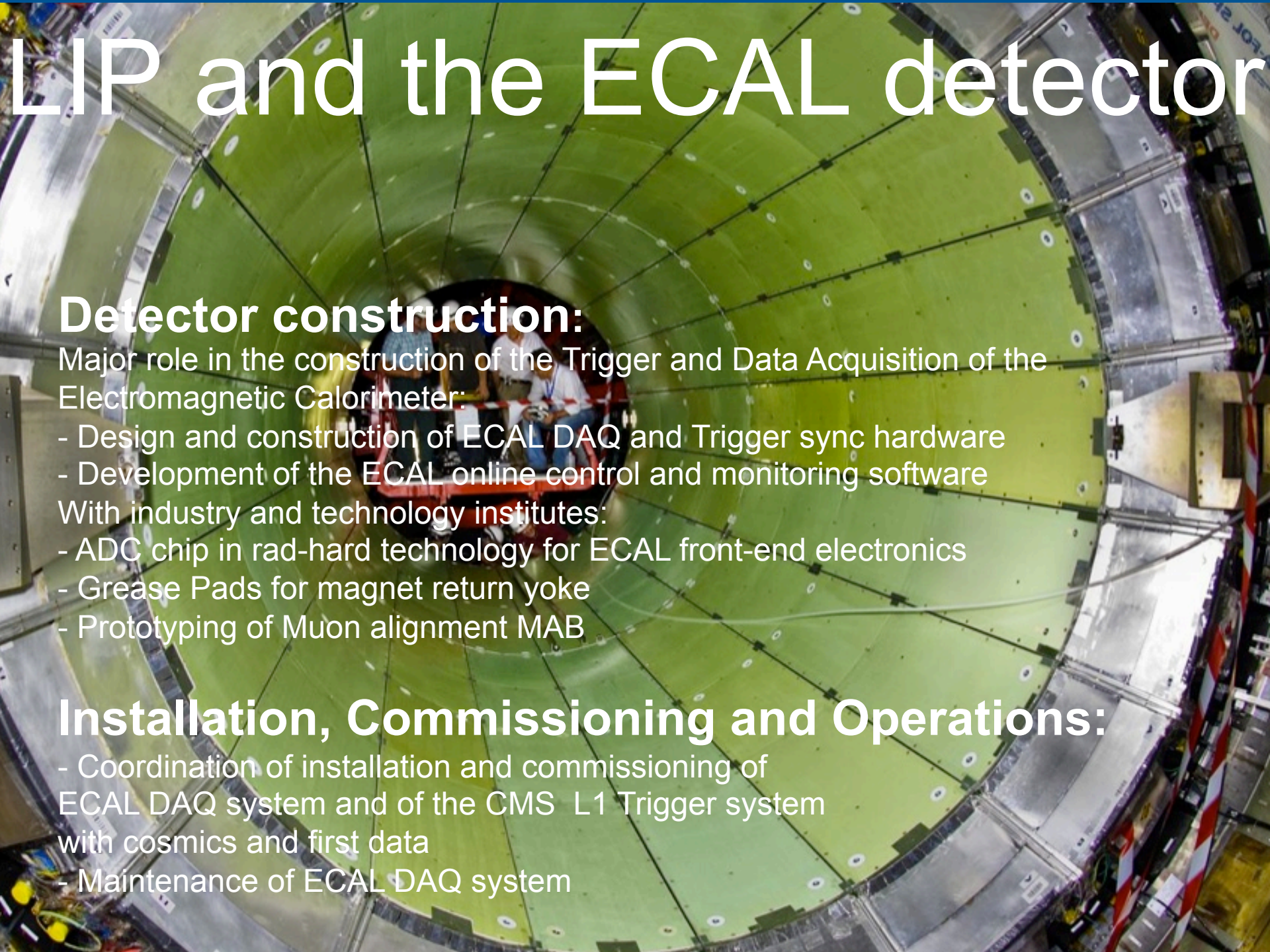


CMS: Surface site in 2000

CMS: Surface hall in 2006



LIP and the ECAL detector



Detector construction:

Major role in the construction of the Trigger and Data Acquisition of the Electromagnetic Calorimeter:

- Design and construction of ECAL DAQ and Trigger sync hardware
- Development of the ECAL online control and monitoring software

With industry and technology institutes:

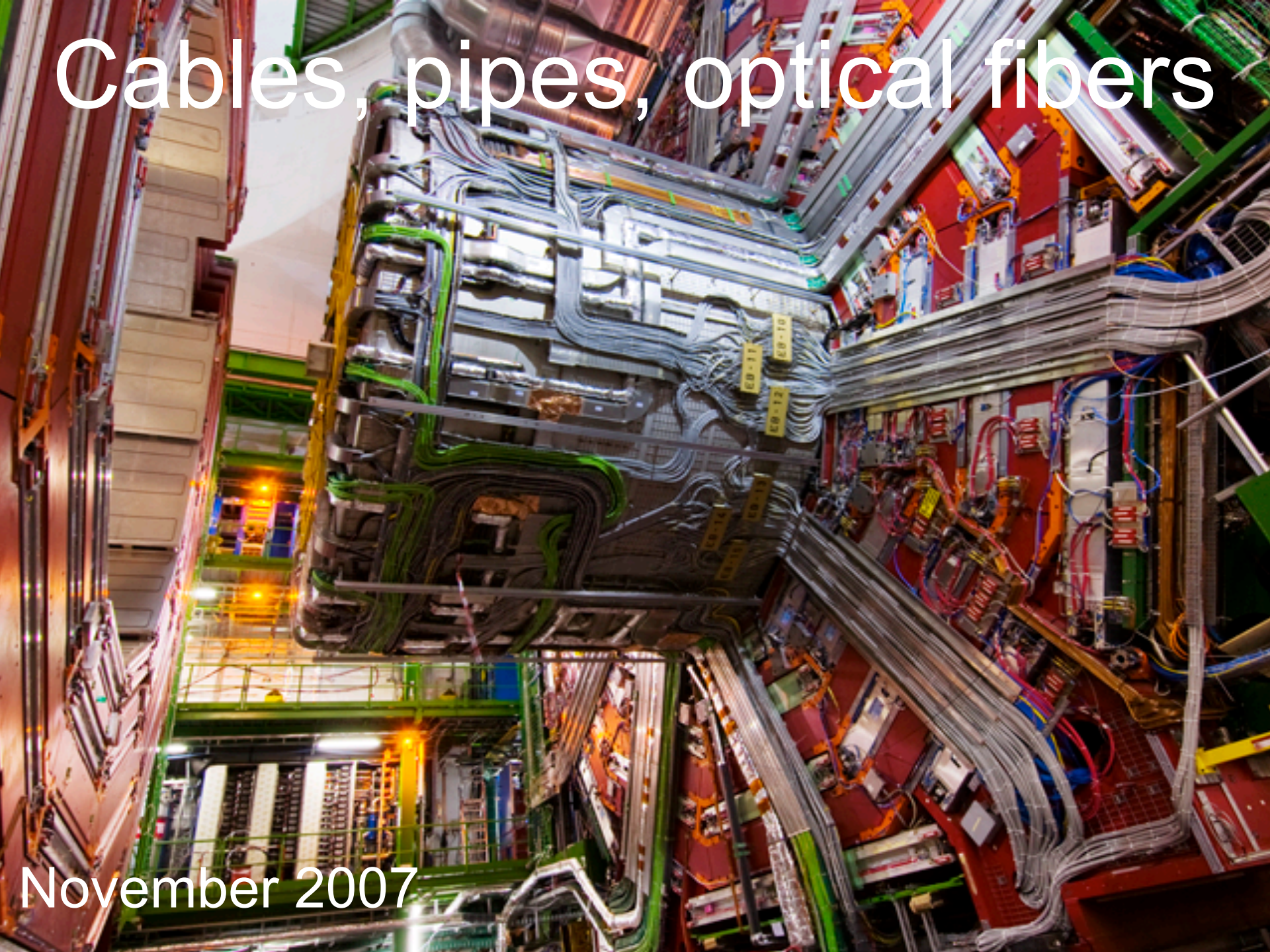
- ADC chip in rad-hard technology for ECAL front-end electronics
- Grease Pads for magnet return yoke
- Prototyping of Muon alignment MAB

Installation, Commissioning and Operations:

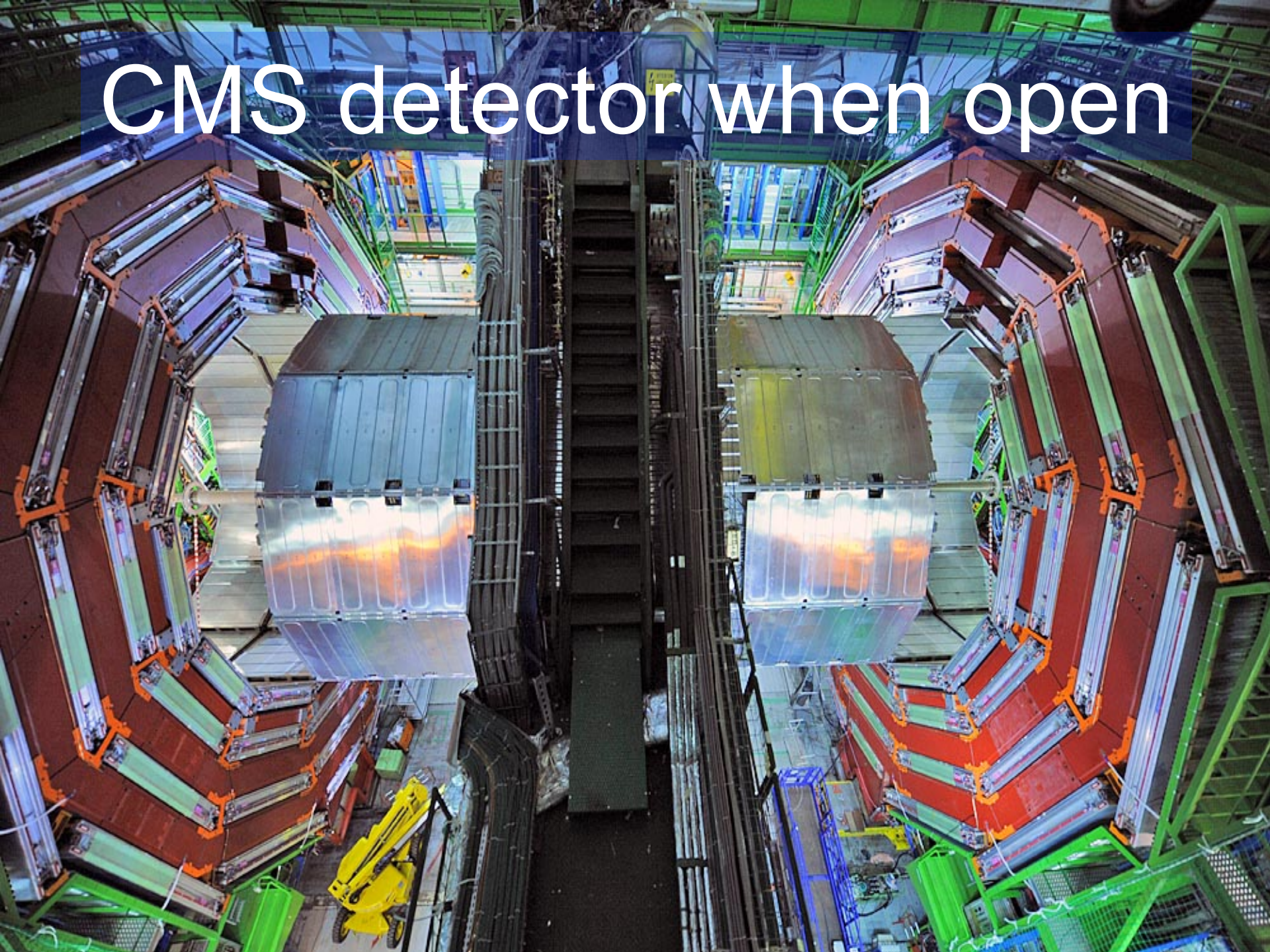
- Coordination of installation and commissioning of ECAL DAQ system and of the CMS L1 Trigger system with cosmics and first data
- Maintenance of ECAL DAQ system

Spectacular operation in 2007

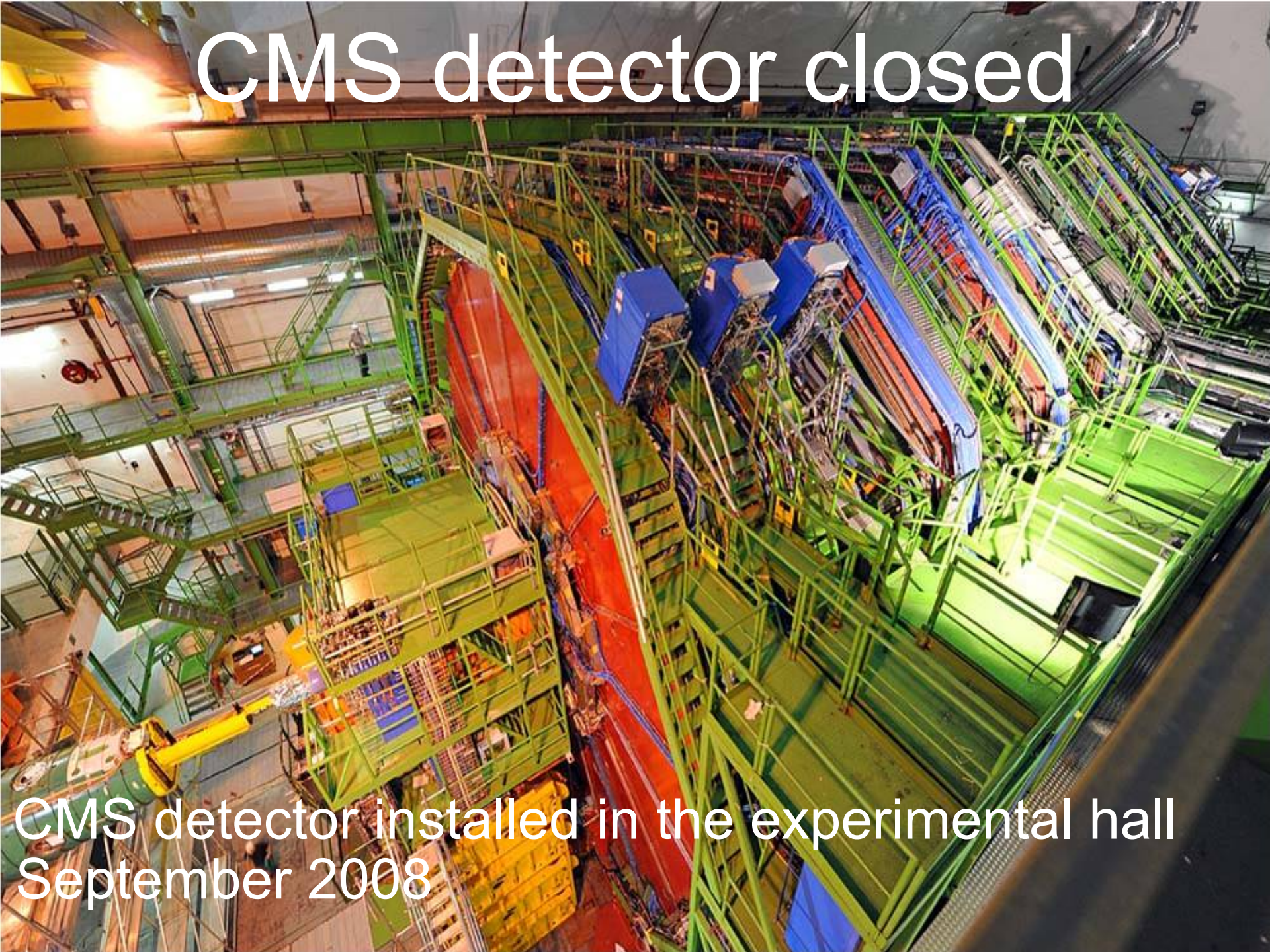
The CMS was lowered to the collision hall in Feb. 2007


Cables, pipes, optical fibers
November 2007

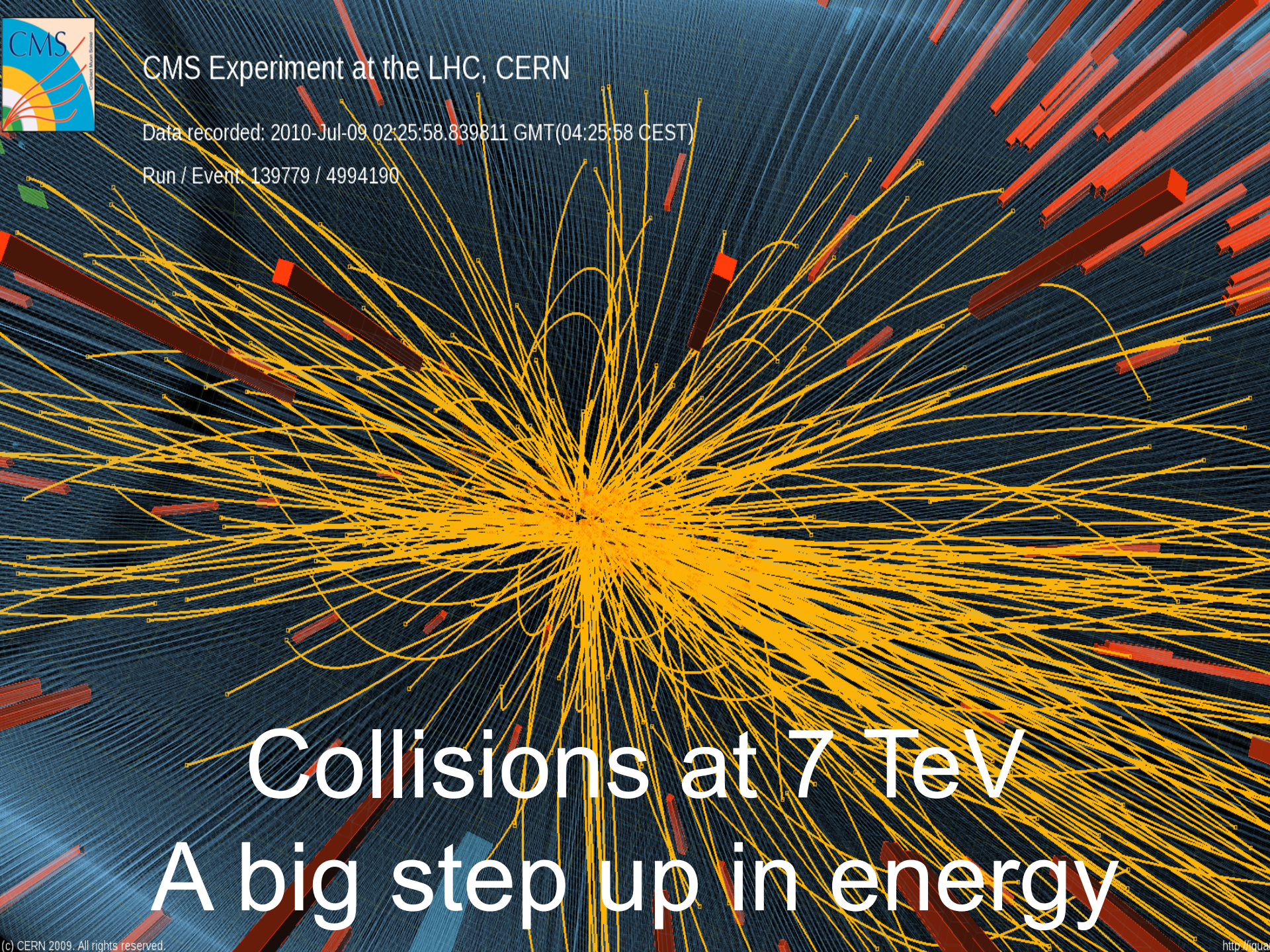
CMS detector when open



CMS detector closed



CMS detector installed in the experimental hall
September 2008



CMS control room when first proton beams collided: 2009

Portuguese participation in CMS

LIP is a founding member of the CMS Experiment (in since 1992)
Contributions from other institutes (IST, INESC, INEGI) and Industry
About 60 physicists, post-docs, engineers, students involved

Detector construction:

Major role in the construction of the Trigger and Data Acquisition of the Electromagnetic Calorimeter:

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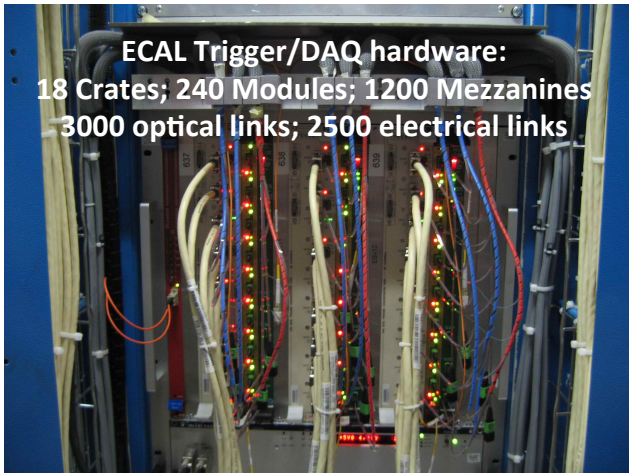
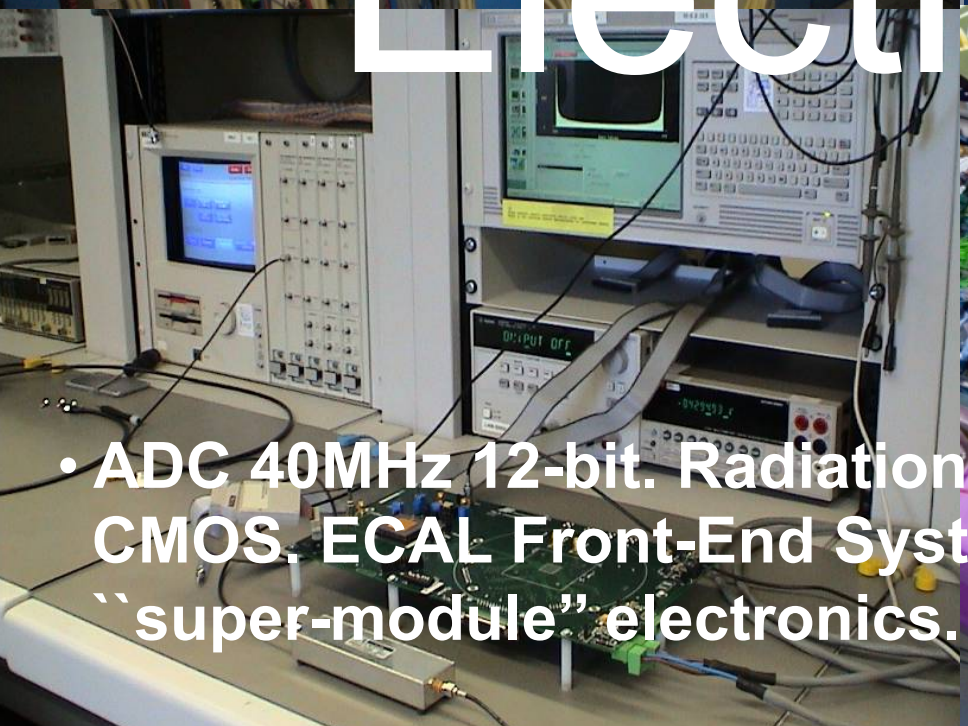


Installation, Commissioning and Operations:

- Coordination of installation and commissioning of ECAL DAQ system and of the CMS L1 Trigger system with cosmics and first data
- Maintenance of ECAL DAQ system

Electronics

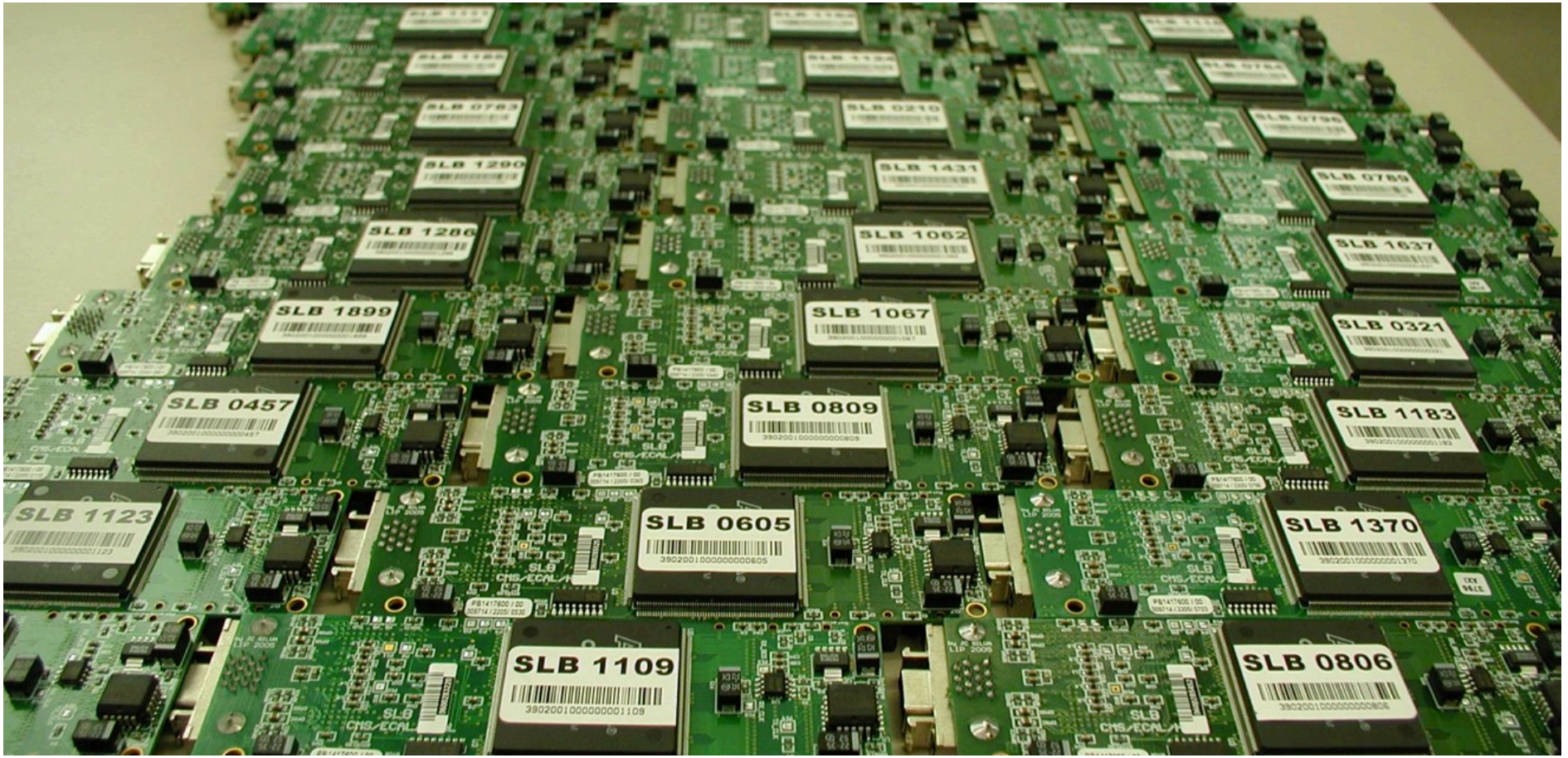
- ECAL data acquisition and trigger crates.
- The full system is composed of 18 crates



- ADC 40MHz 12-bit. Radiation-hard technology 0.25μm CMOS. ECAL Front-End System (80,000 chips). ECAL ``super-module'' electronics.

Trigger and Data Acquisition

Synchronization and Link Board (SLB). About one thousand SLB modules are used in CMS to synchronize the trigger of the ECAL and HCAL calorimeters.



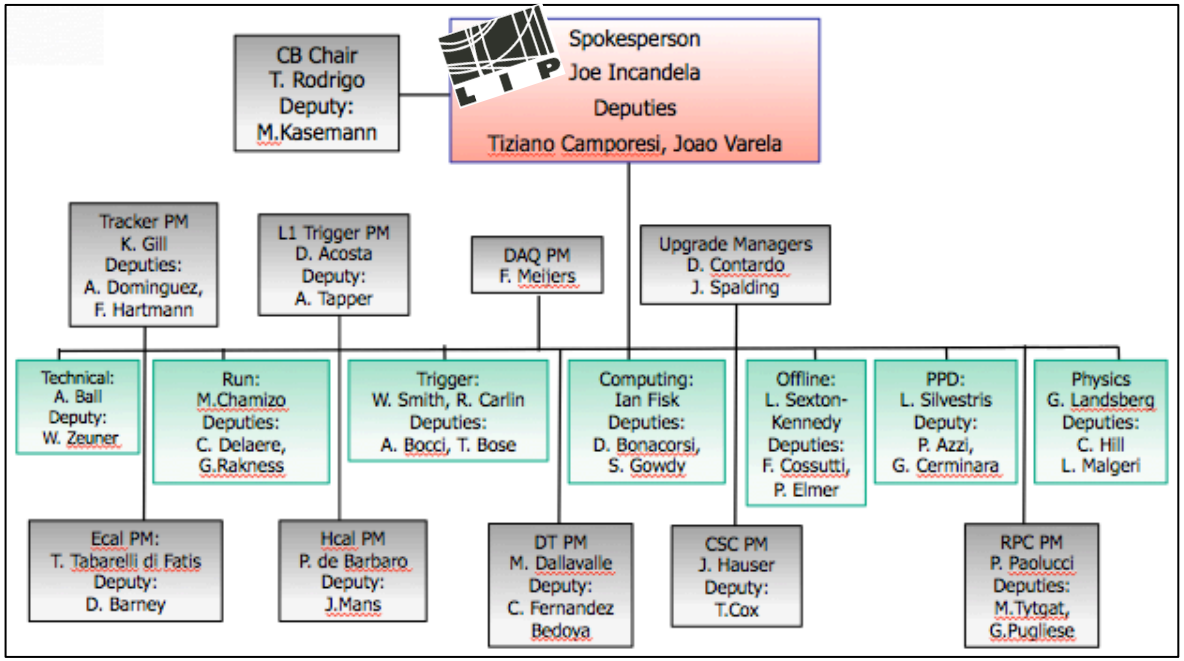
Portuguese Industry at CMS

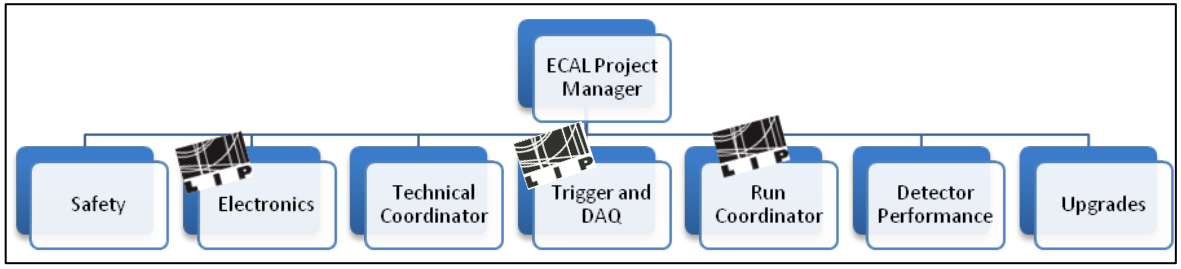
Grease Pads allow fine displacement for final positioning of the detector. Ten pads were fabricated at Euroiso and installed in CMS.

- **Muon Alignment Supports (MAB). High precision carbon fiber.**
- **Construction of the MAB prototype and its full static and dynamic characterization performed by LIP in collaboration with INEGI Porto.**

Responsibilities and management

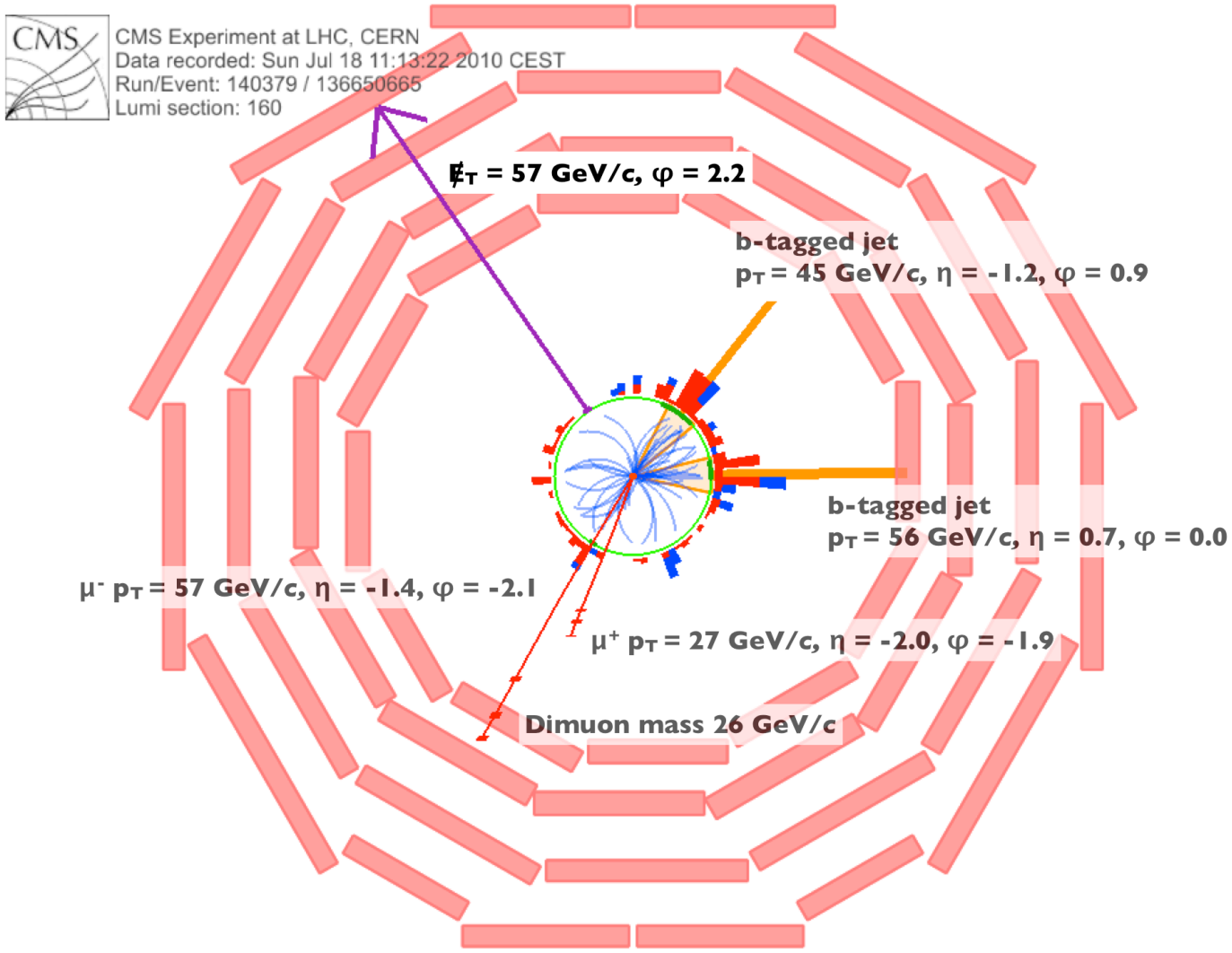
Responsibilities held by members of LIP/CMS group in top CMS management



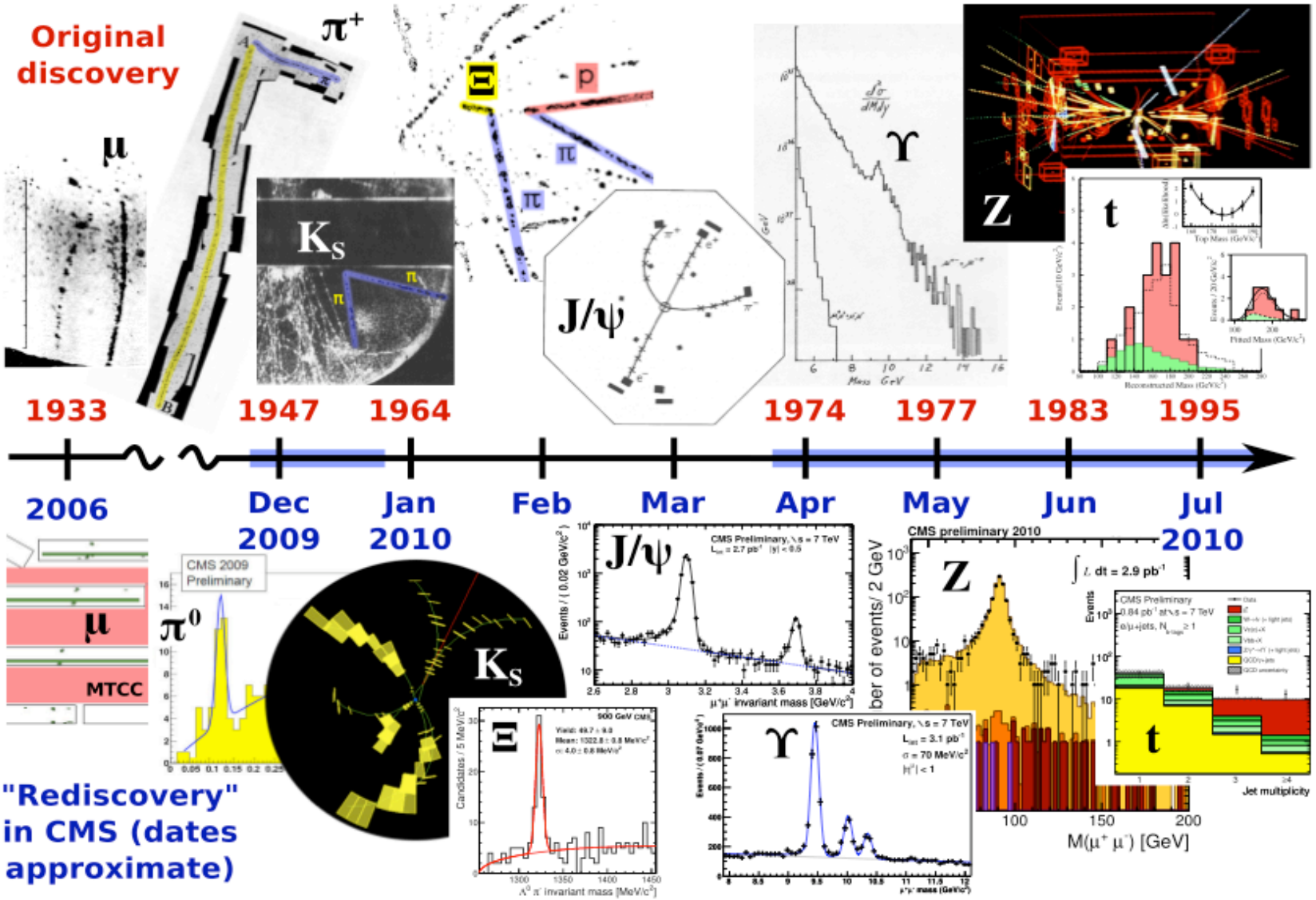


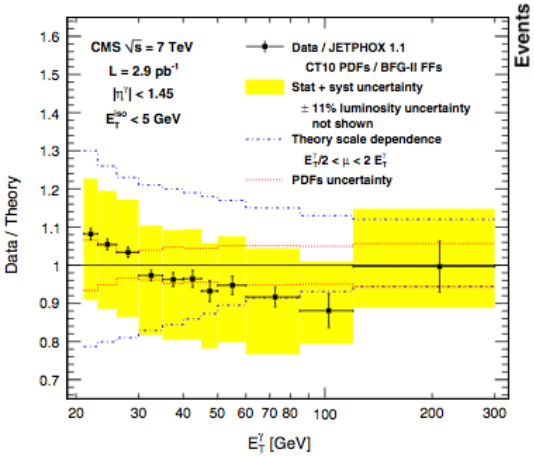
Responsibilities held by members of the LIP-CMS group in CMS ECAL management

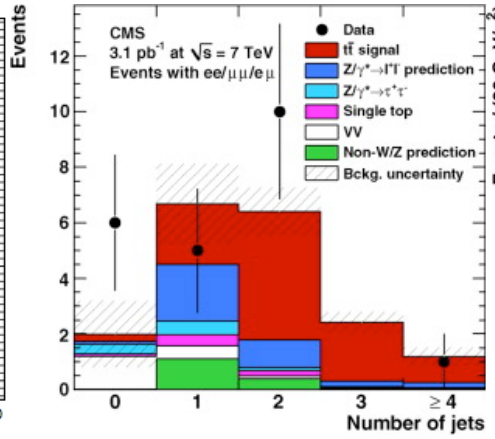
An amazing microscope

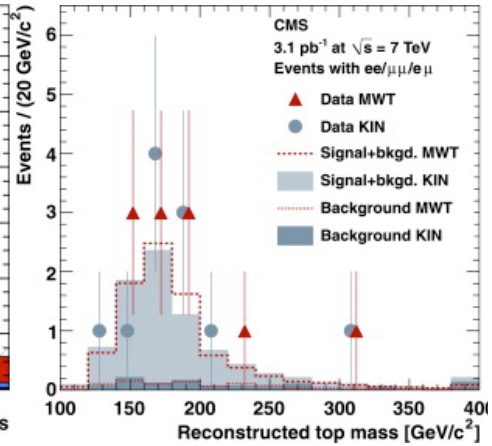


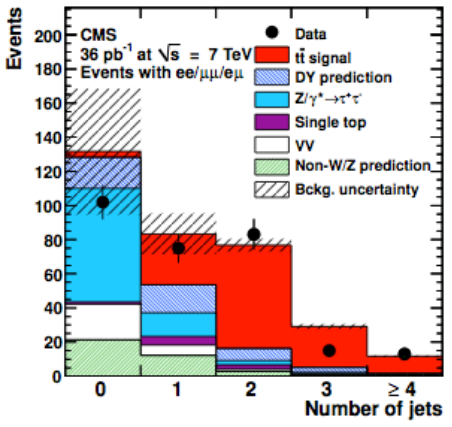
Particle physics (as we know it)

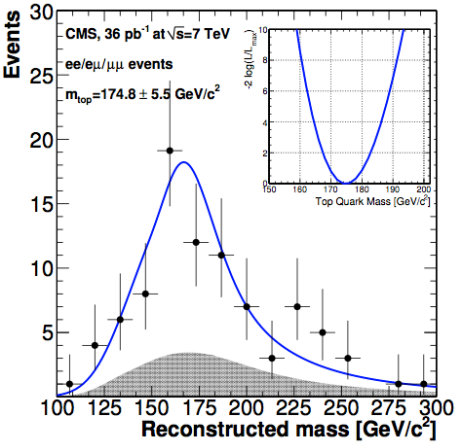


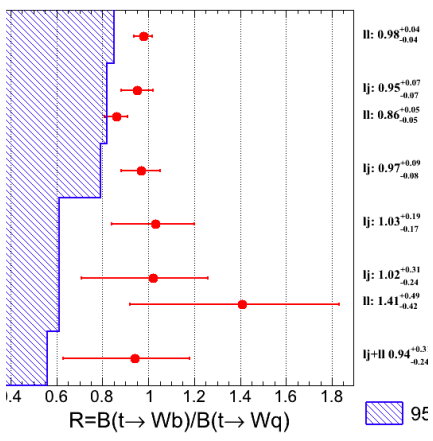

CMS √s = 7 TeV
L = 2.9 pb⁻¹
|η^γ| < 1.45
E_T^iso < 5 GeV
Data / JETPHOX 1.1
CT10 PDFs / BFG-II FFs
Stat + syst uncertainty
± 11% luminosity uncertainty not shown
Theory scale dependence
E_T^γ/2 < μ < 2 E_T^γ
PDFs uncertainty
Data / Theory
E_T^γ [GeV]

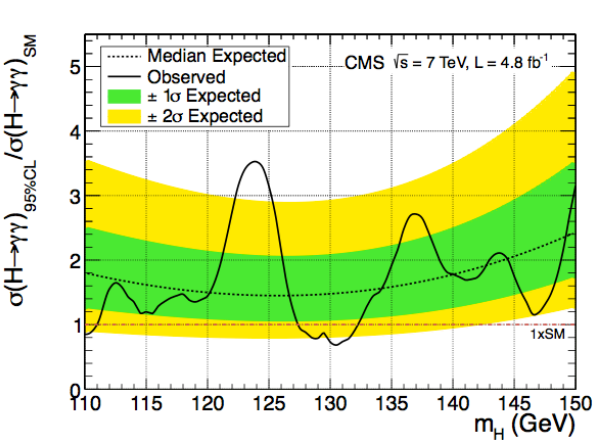

CMS
3.1 pb⁻¹ at √s = 7 TeV
Events with eeμμ/eμ
Data
tt̄ signal
Z/γ*→l⁺l⁻ prediction
Z/γ*→τ⁺τ⁻
Single top
VV
Non-W/Z prediction
Bckg. uncertainty
Events
Number of jets

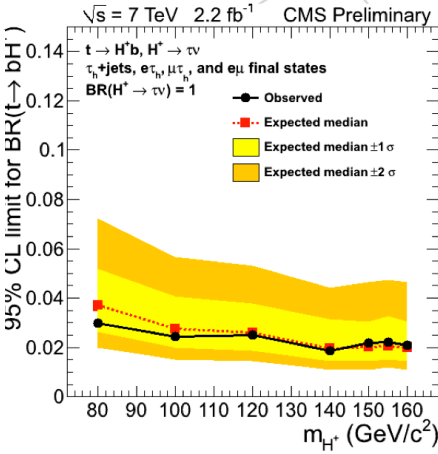

CMS
3.1 pb⁻¹ at √s = 7 TeV
Events with eeμμ/eμ
Data MWT
Data KIN
Signal+bkgd. MWT
Signal+bkgd. KIN
Background MWT
Background KIN
Events / (20 GeV/c²)
Reconstructed top mass [GeV/c²]

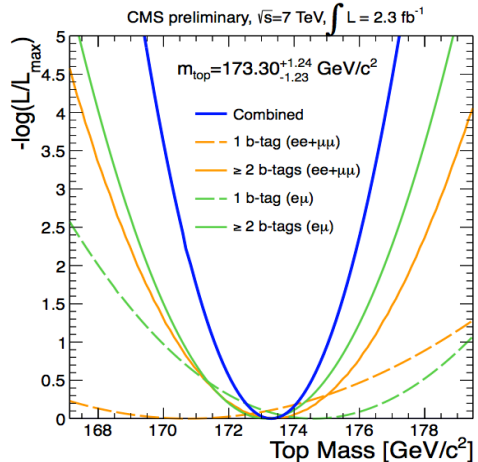

CMS
36 pb⁻¹ at √s = 7 TeV
Events with eeμμ/eμ
Data
tt̄ signal
DY prediction
Z/γ*→τ⁺τ⁻
Single top
VV
Non-W/Z prediction
Bckg. uncertainty
Events
Number of jets

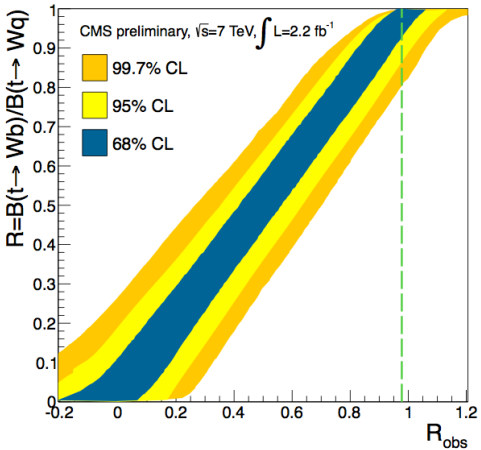

CMS, 36 pb⁻¹ at √s=7 TeV
ee/eμ/μμ events
m_top=174.8 ± 5.5 GeV/c²
Top Quark Mass [GeV/c²]
Events
Reconstructed mass [GeV/c²]

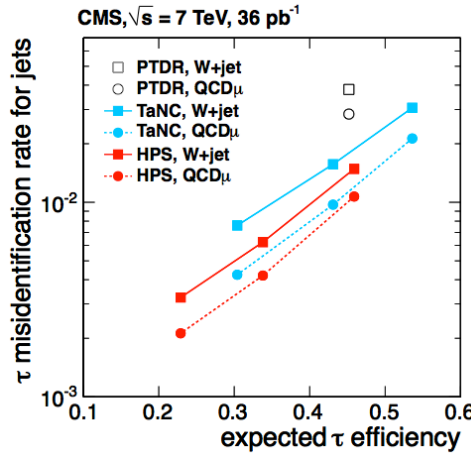

ll: 0.98
lj: 0.95
ll: 0.86
lj: 0.97
lj: 1.03
lj: 1.02
ll: 1.41
lj+ll 0.94
R=B(t→ Wb)/B(t→ Wq)

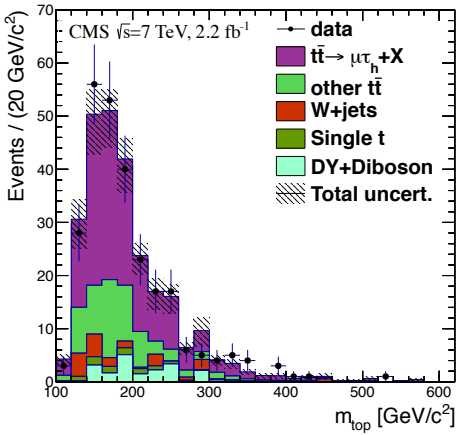

Median Expected
Observed
± 1σ Expected
± 2σ Expected
CMS √s = 7 TeV, L = 4.8 fb⁻¹
σ(H→γγ)/σ(H→γγ)_SM
1xSM
m_H (GeV)


√s = 7 TeV 2.2 fb⁻¹ CMS Preliminary
t → H⁺b, H⁺ → τν
τ_h+jets, eτ_h, μτ_h, and eμ final states
BR(H⁺ → τν) = 1
Observed
Expected median
Expected median ±1 σ
Expected median ±2 σ
95% CL limit for BR(t→ bH⁺)
m_H⁺ (GeV/c²)

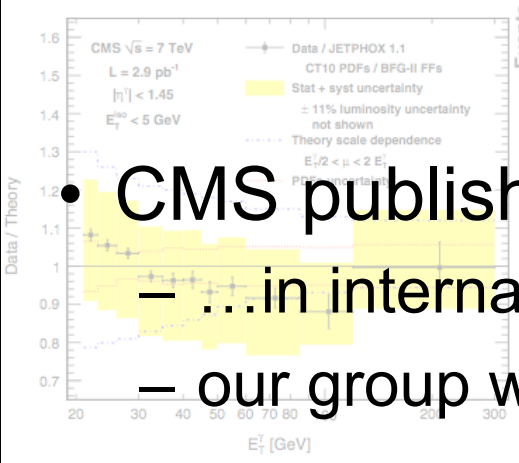

CMS preliminary, √s=7 TeV, ∫ L = 2.3 fb⁻¹
m_top=173.30^+1.24_-1.23 GeV/c²
Combined
1 b-tag (eeμμ)
≥ 2 b-tags (eeμμ)
1 b-tag (eμ)
≥ 2 b-tags (eμ)
-log(L/L_max)
Top Mass [GeV/c²]

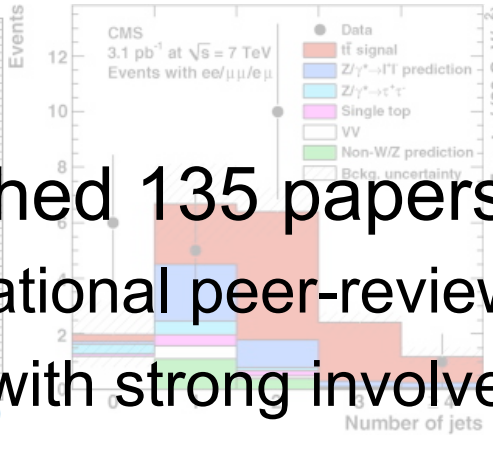

CMS preliminary, √s=7 TeV, ∫ L=2.2 fb⁻¹
99.7% CL
95% CL
68% CL
R=B(t→ Wb)/B(t→ Wq)
R_obs

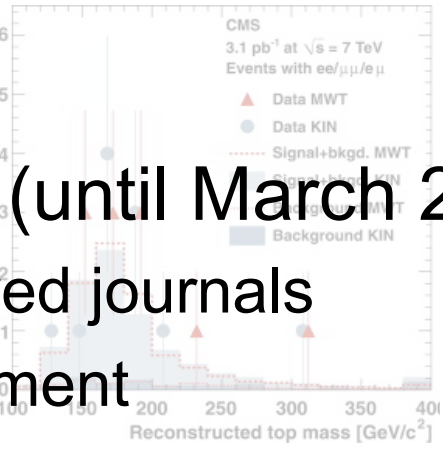

CMS, √s = 7 TeV, 36 pb⁻¹
PTDR, W+jet
PTDR, QCDμ
TaNC, W+jet
TaNC, QCDμ
HPS, W+jet
HPS, QCDμ
τ misidentification rate for jets
expected τ efficiency

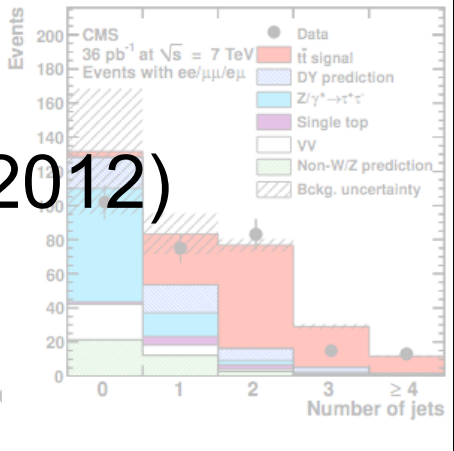

CMS √s=7 TeV, 2.2 fb⁻¹
data
tt̄→ μτ_h+X
other tt̄
W+jets
Single t
DY+Diboson
Total uncert.
Events / (20 GeV/c²)
m_top [GeV/c²]

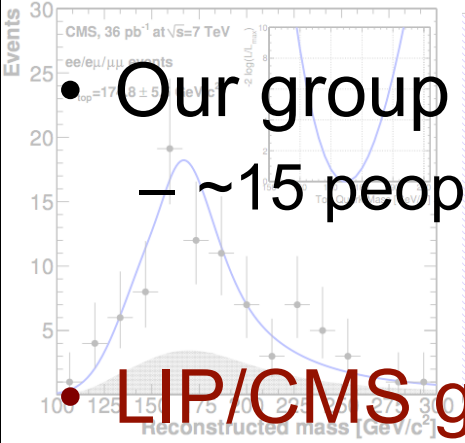
- CMS published 135 papers (until March 2012)
  - …in international peer-reviewed journals
  - our group with strong involvement
- Our group is 0.5% of CMS collaboration
  - ~15 people, i.e. 0.5% of collaborators (~3000 people)
- LIP/CMS group main contributor to 6% of papers
  - fully responsible for 4 papers (i.e. 3%)
  - made important contributions to 4 papers (i.e. 3%)

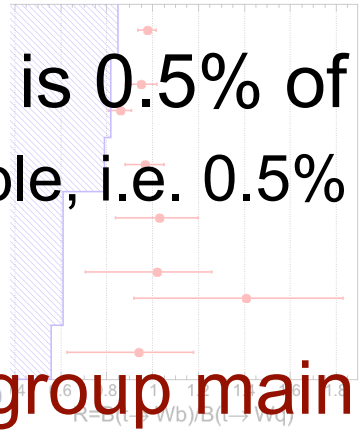


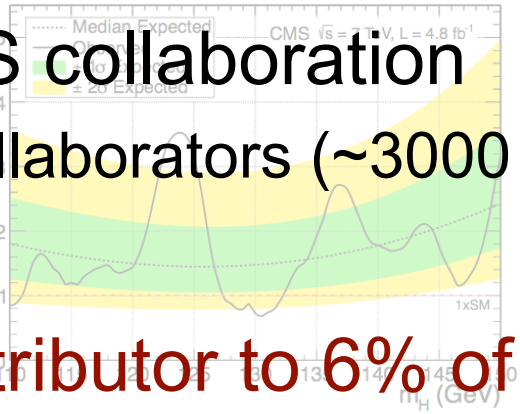


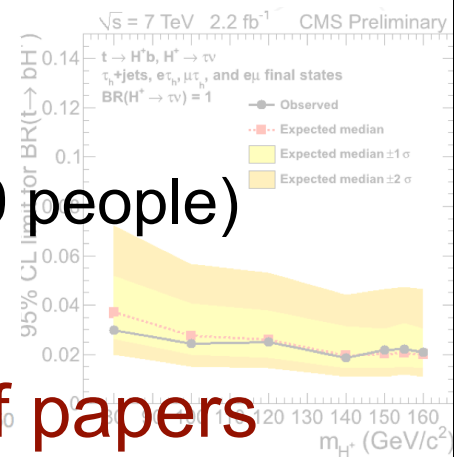


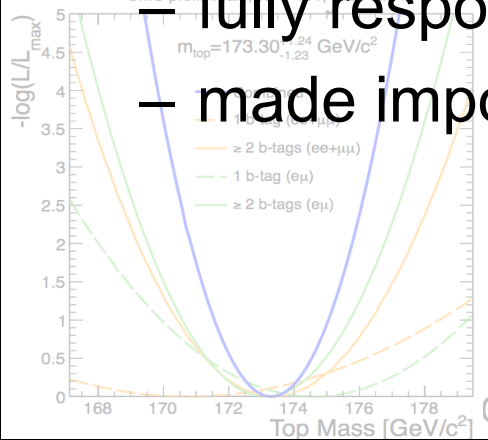


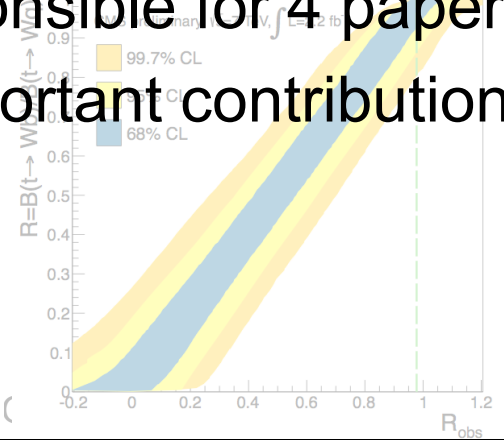


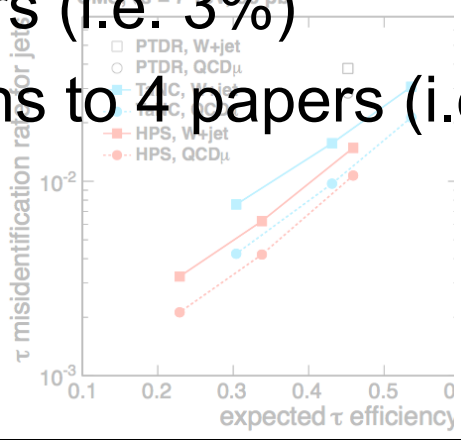


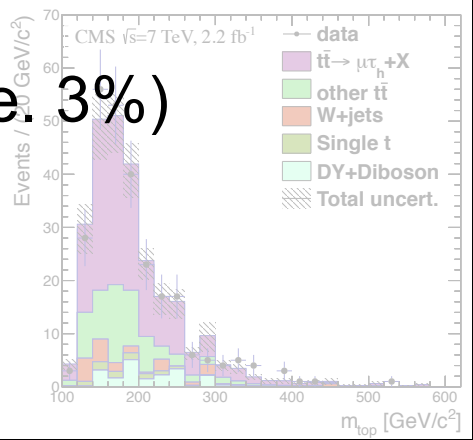












Summary and outlook beyond 2012

CMS is recording high energy collisions

- After twenty years of preparation
- All systems are performing very well

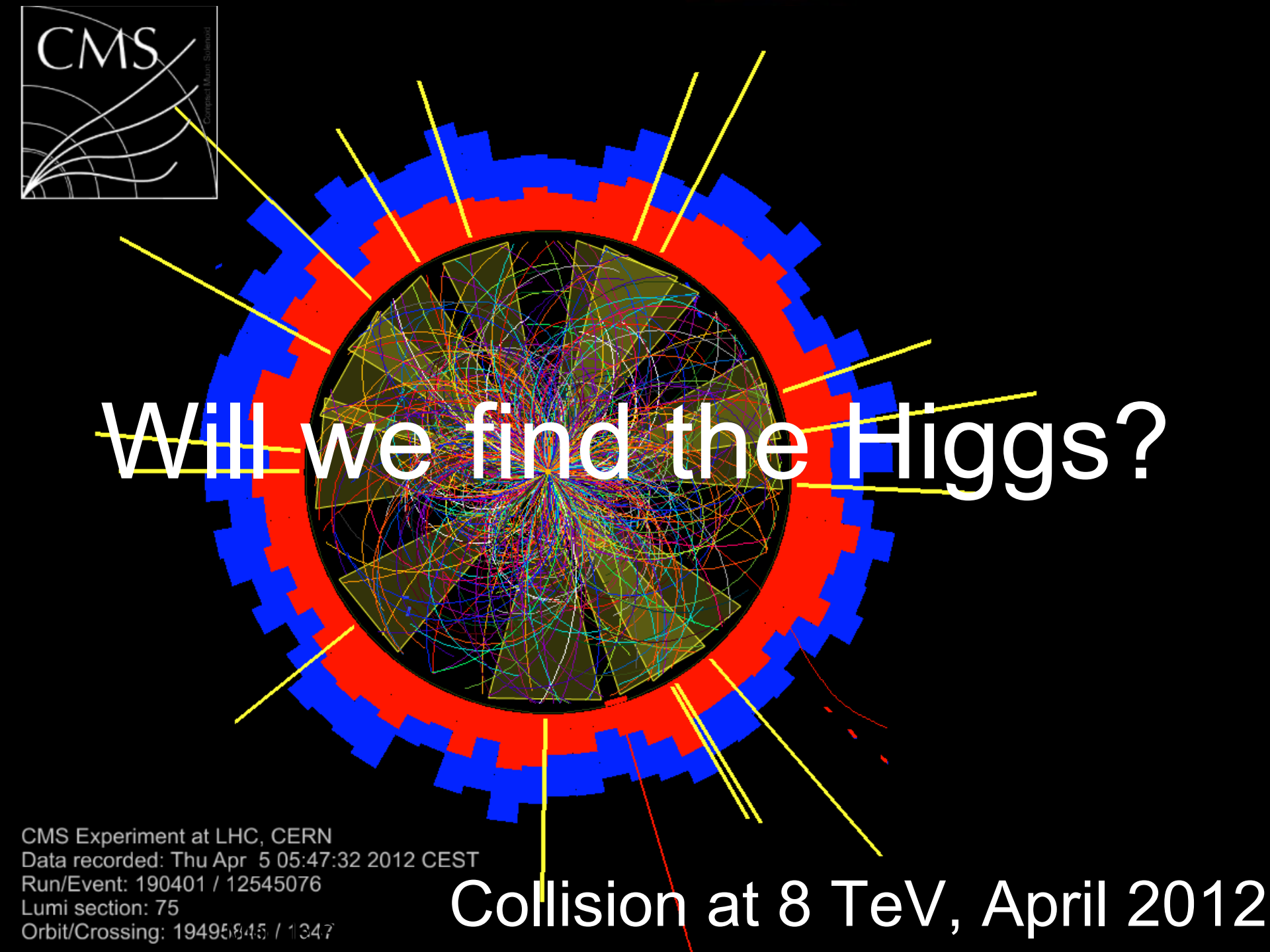
LIP has a strong involvement in the experiment

- Impressive set of results/measurements have been obtained
- New physics searches are being performed

We are only just beginning…

- Observed physics performance justifies setting more ambitious physics goals
- Excellent prospects for the future

What (if) we shall discover at the LHC will alter the way we view our universe!


CMS
Will we find the Higgs?
CMS Experiment at LHC, CERN
Data recorded: Thu Apr 5 05:47:32 2012 CEST
Run/Event: 190401 / 12545076
Lumi section: 75
Orbit/Crossing: 19495845 / 1347
Collision at 8 TeV, April 2012