

The Compact Muon Solenoid Detector

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Torino/CERN

Compact Muon Solenoid

In three parts:

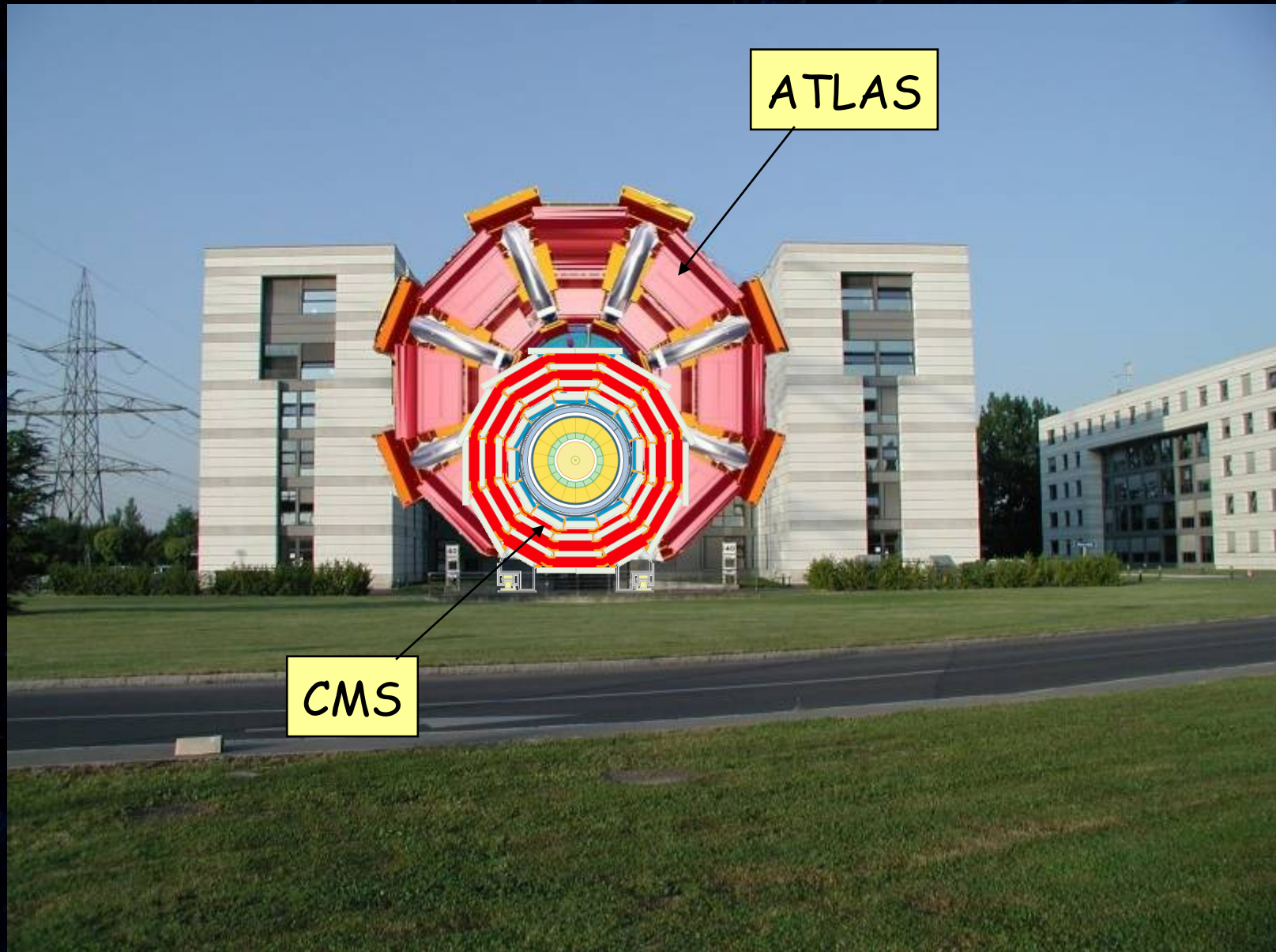
1. What is it
2. How it works
3. How it was built

Compact Muon Solenoid

In three parts:

1. What is it
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Compact

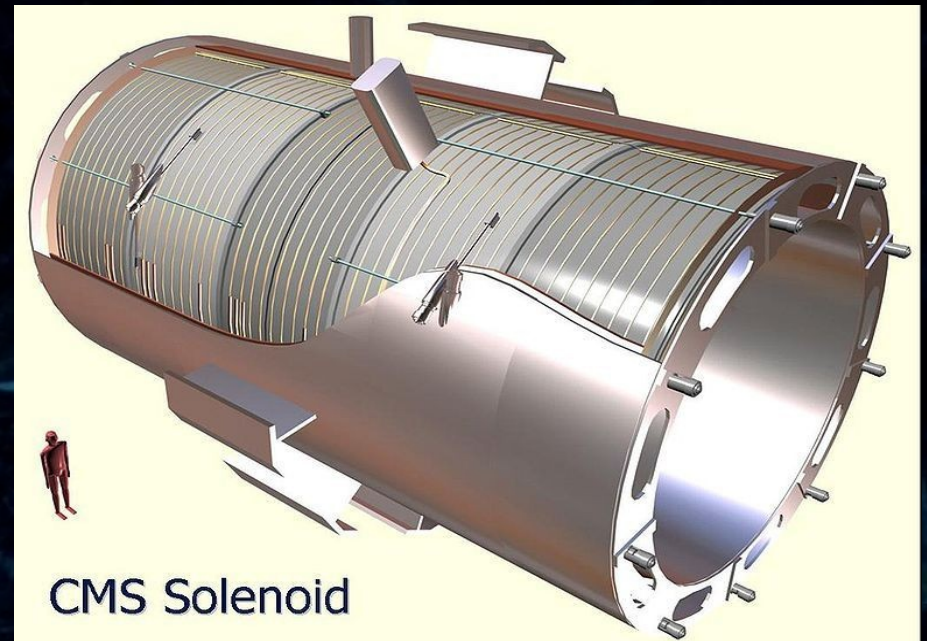


Muon

- The CMS detector was designed to provide optimal measurement of muons
- Muons give a relatively „clean“ signal
- They appear as decay products of other particles in many of the processes we want to study

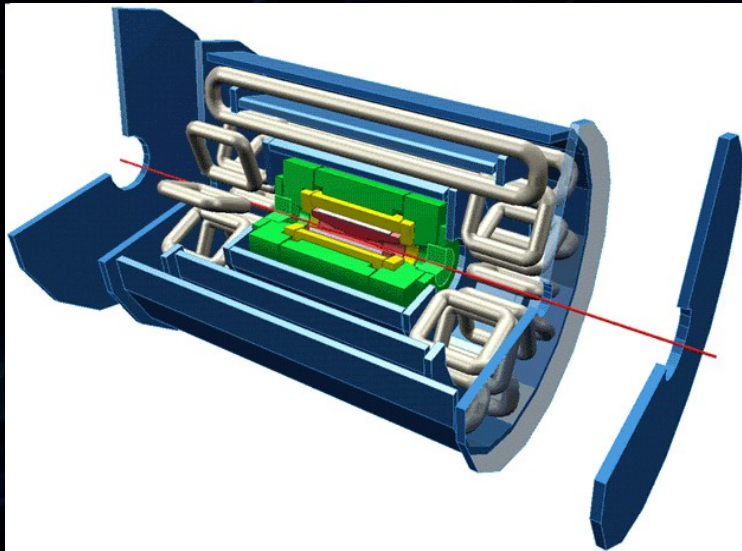
Solenoid

- CMS is built around a superconducting solenoid generating a magnetic field of 4 Tesla
- The current necessary for this - 20 kA...
- Superconducting NbTi wire cooled to $\sim 4\text{K}$
- 13m length, 6m inner diameter - enough to fit the tracker and calorimeters inside
- (cost ~ 80 MCHF)

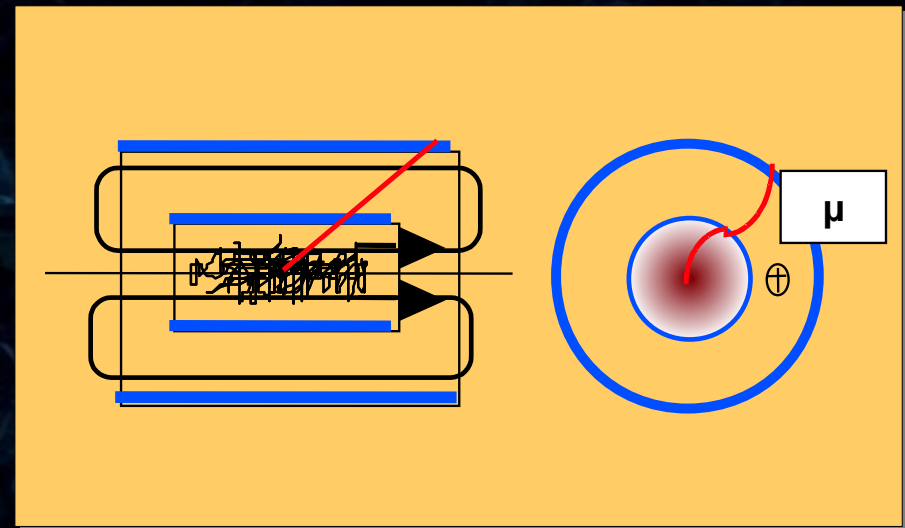
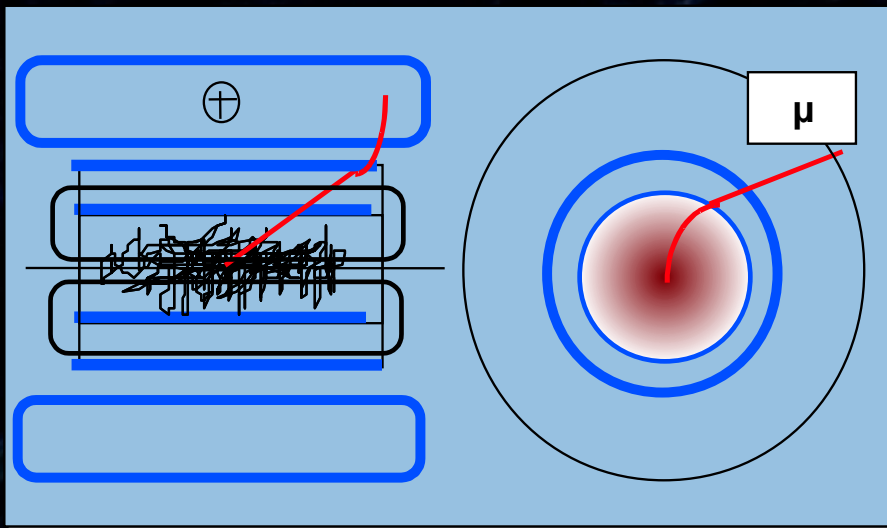
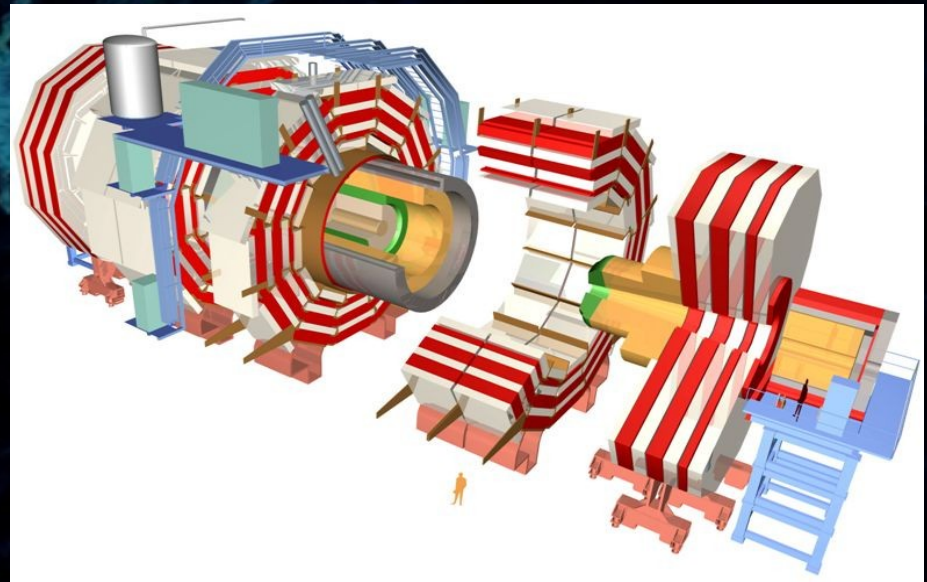


Magnets in particle detectors

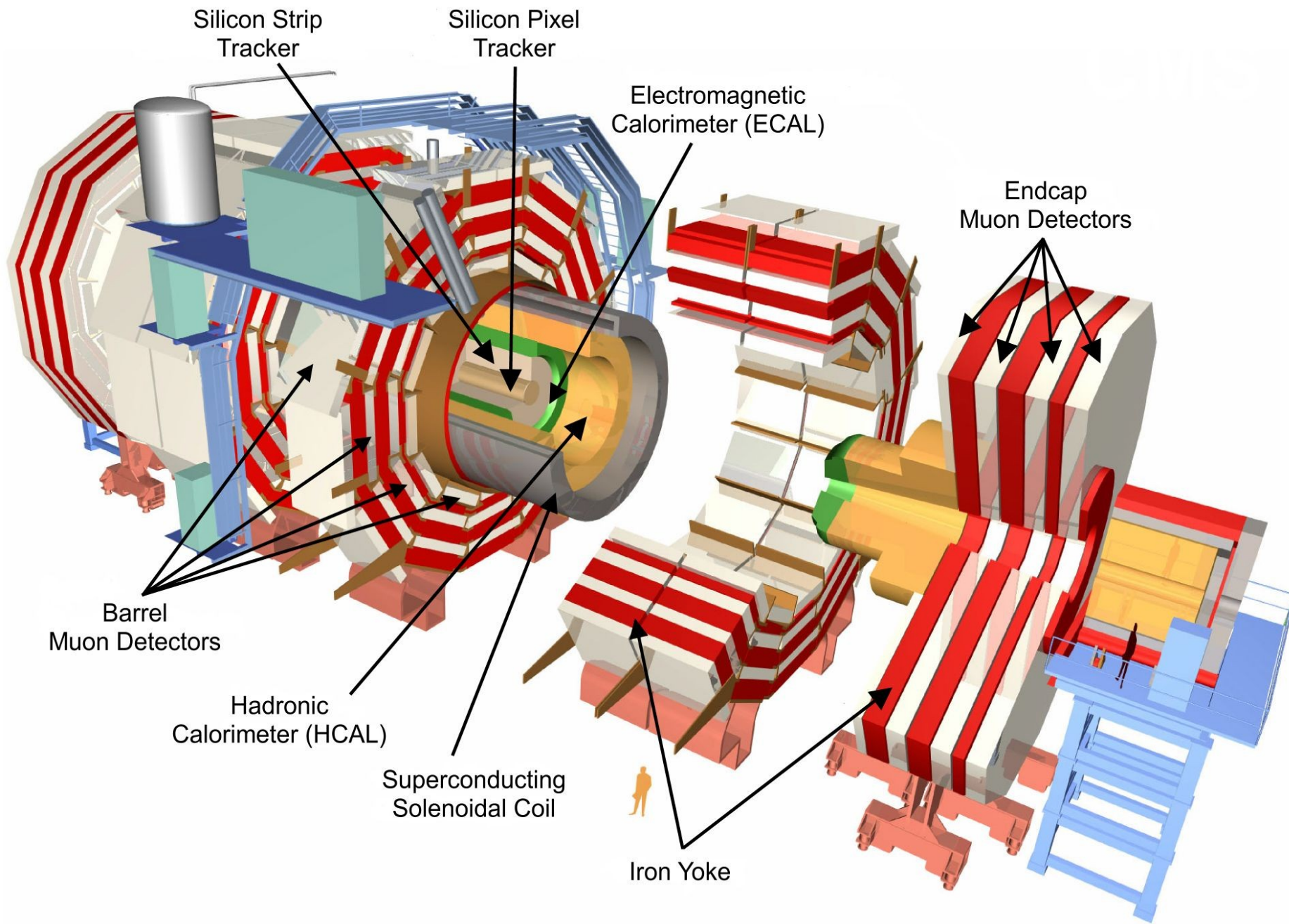
ATLAS A Toroidal LHC Apparatus



CMS Compact Muon Solenoid



CMS detector overview



Compact Muon Solenoid

In three parts:

1. What is it
2. How it works
3. How it was built

Two ways to detect a particle

(in CMS)

Two ways to detect a particle

(in CMS)

See the track



Or

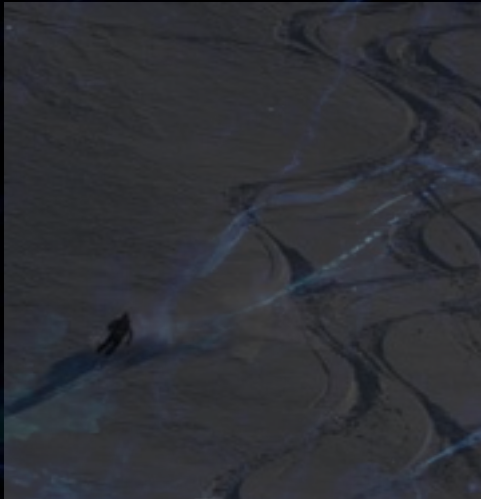
Catch



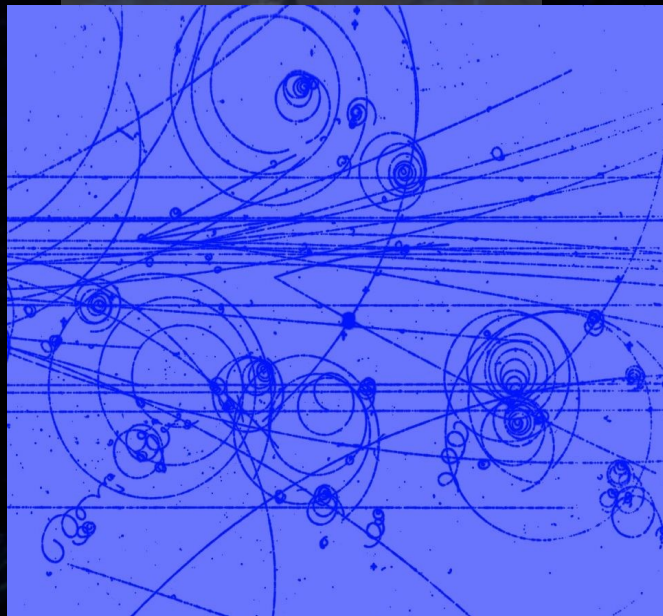
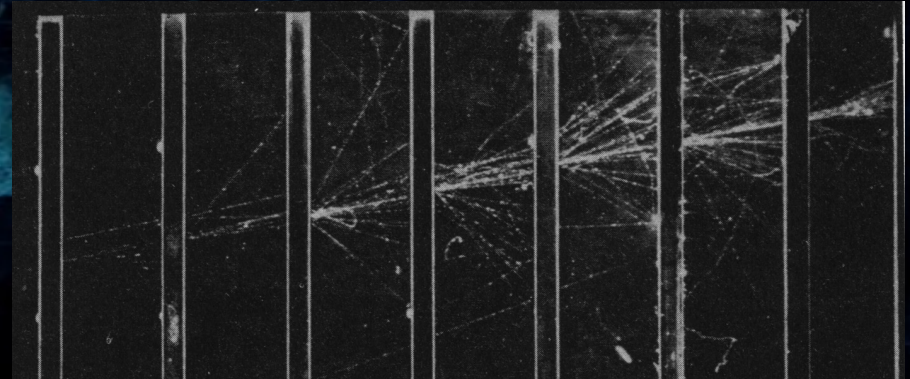
Two ways to detect a particle

(in CMS)

Tracking detector



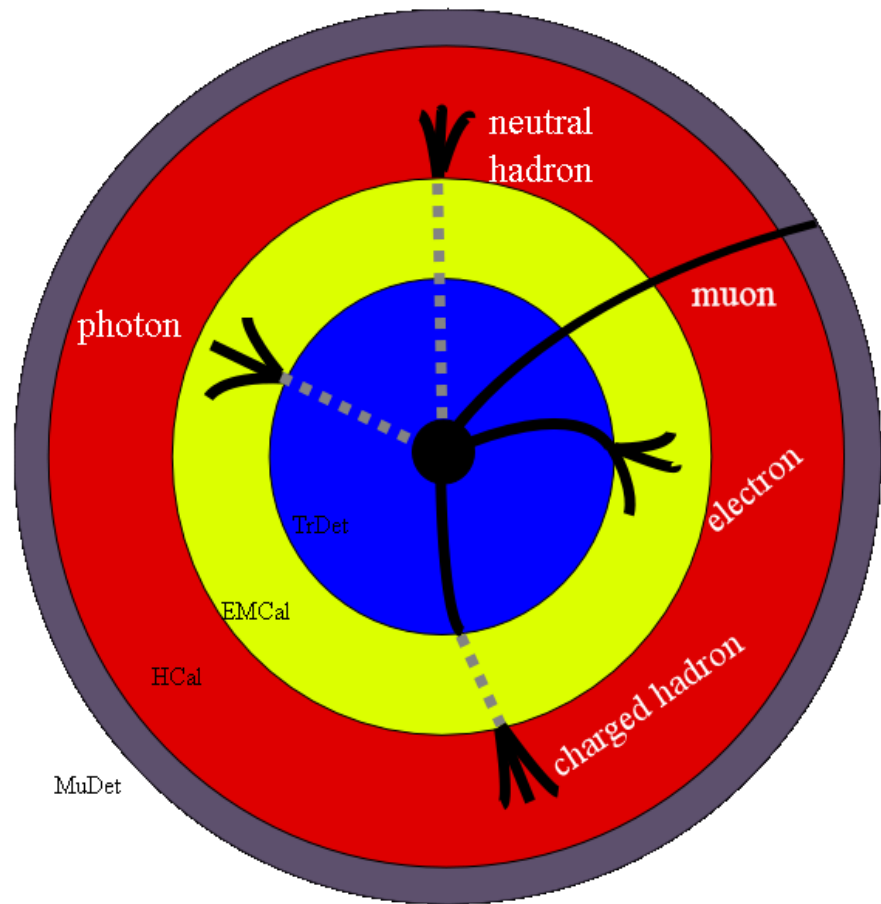
Or



Calorimeter



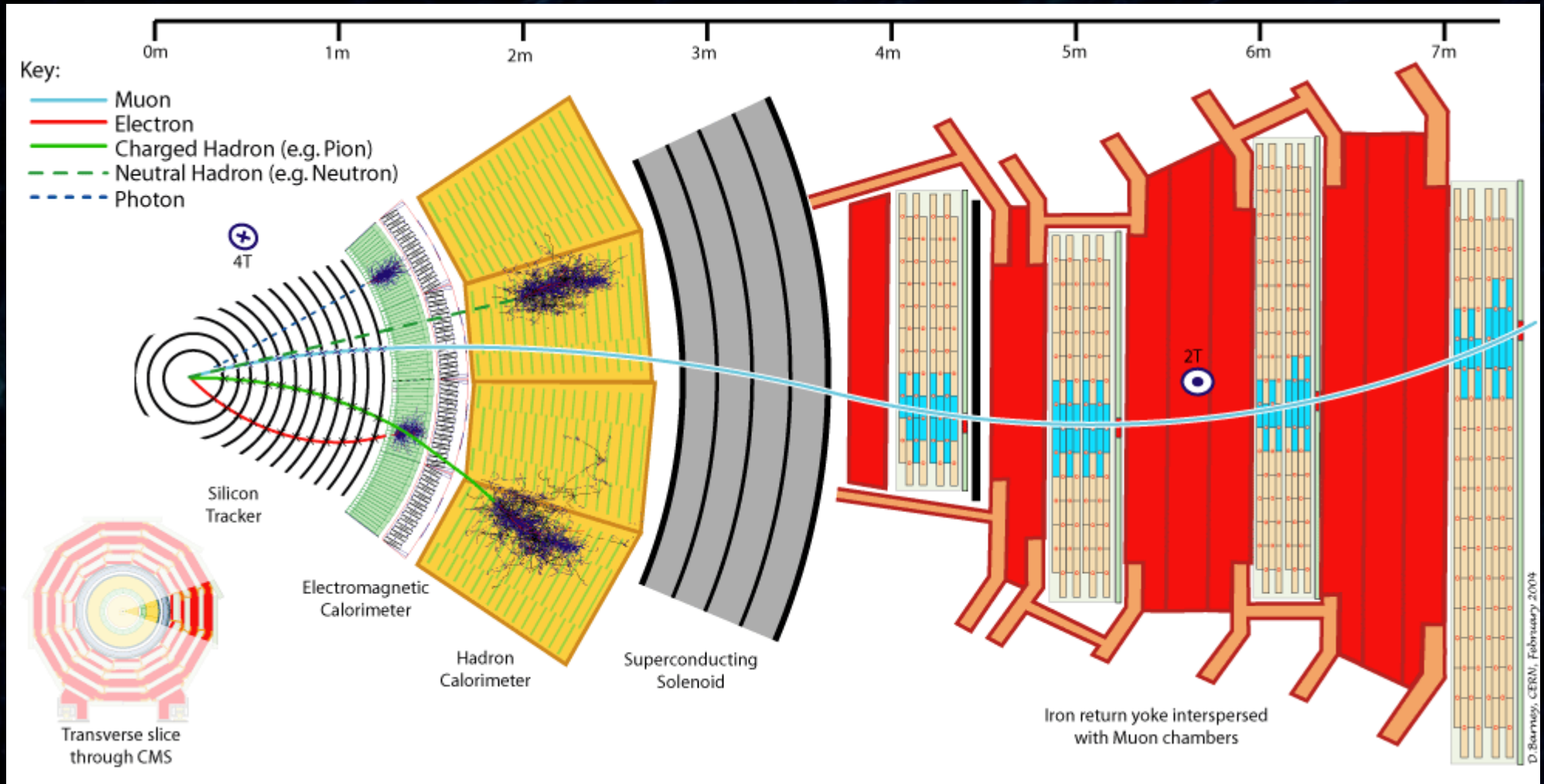
Particle detectors are like...



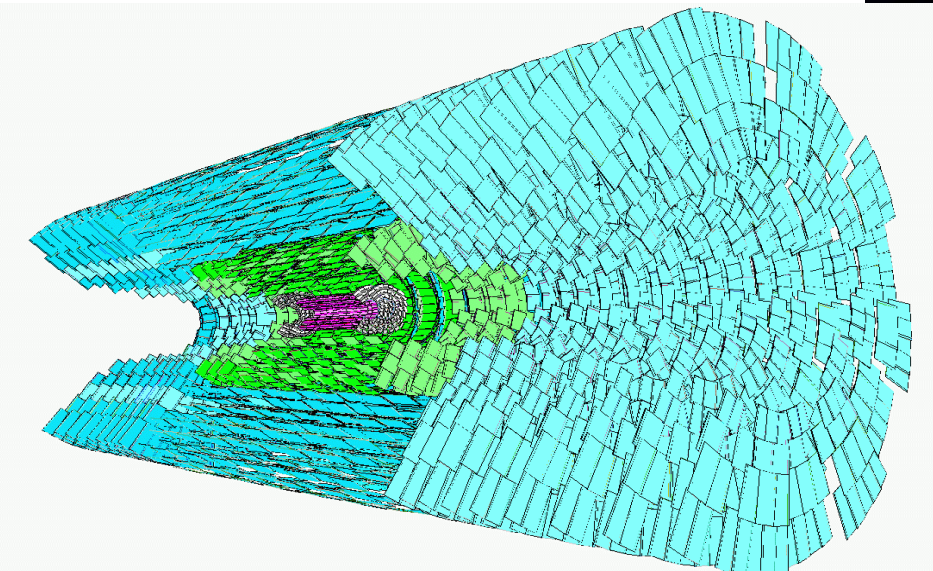
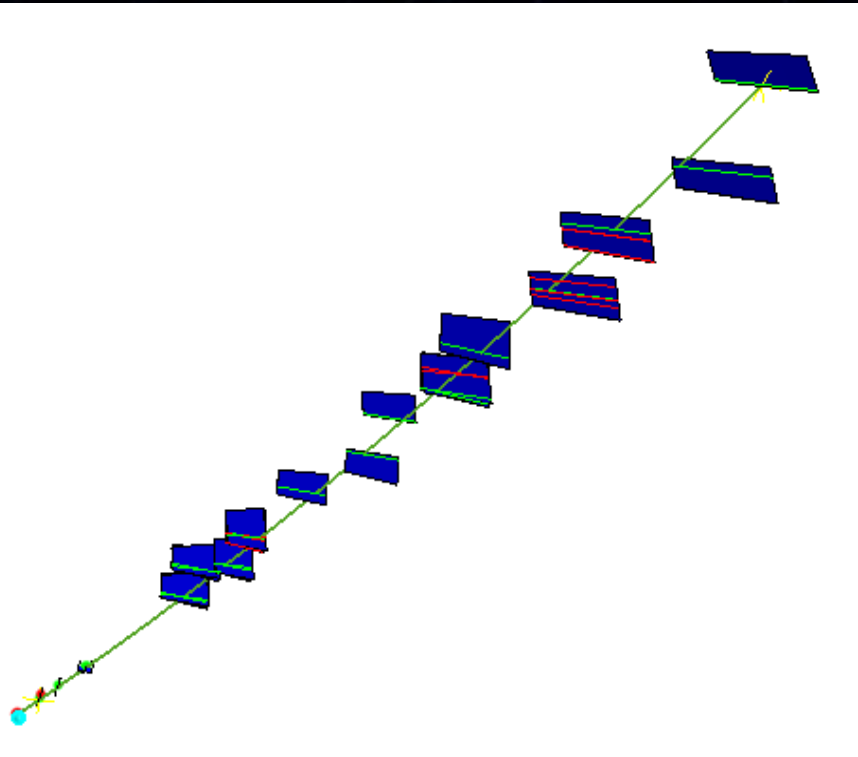
MuDet: muon detectors
TrDet: trace detector + vertex detector
EMCal: elektromagnetický kaloriméter
HCal: hadron kaloriméter



Particle identification in CMS

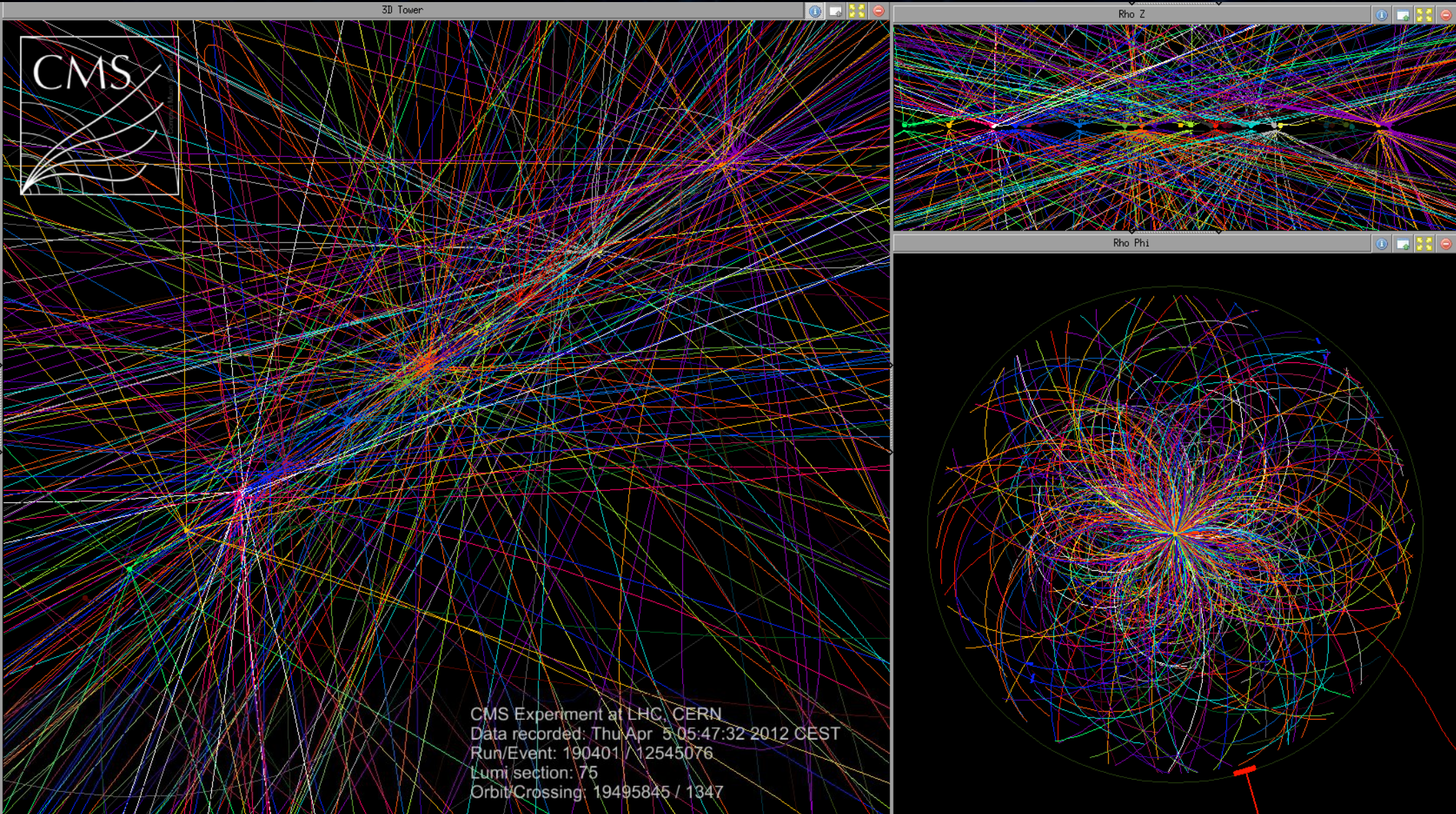


The Inner Tracker



- Measures the trajectories of charged particles
momentum = 1/curvature
- The biggest silicon detector in history, over 220m² of silicon
- Inner part - 3 layers of pixel detectors, outer part 10-11 layers of silicon microstrips
- 75 millions of read-out channels

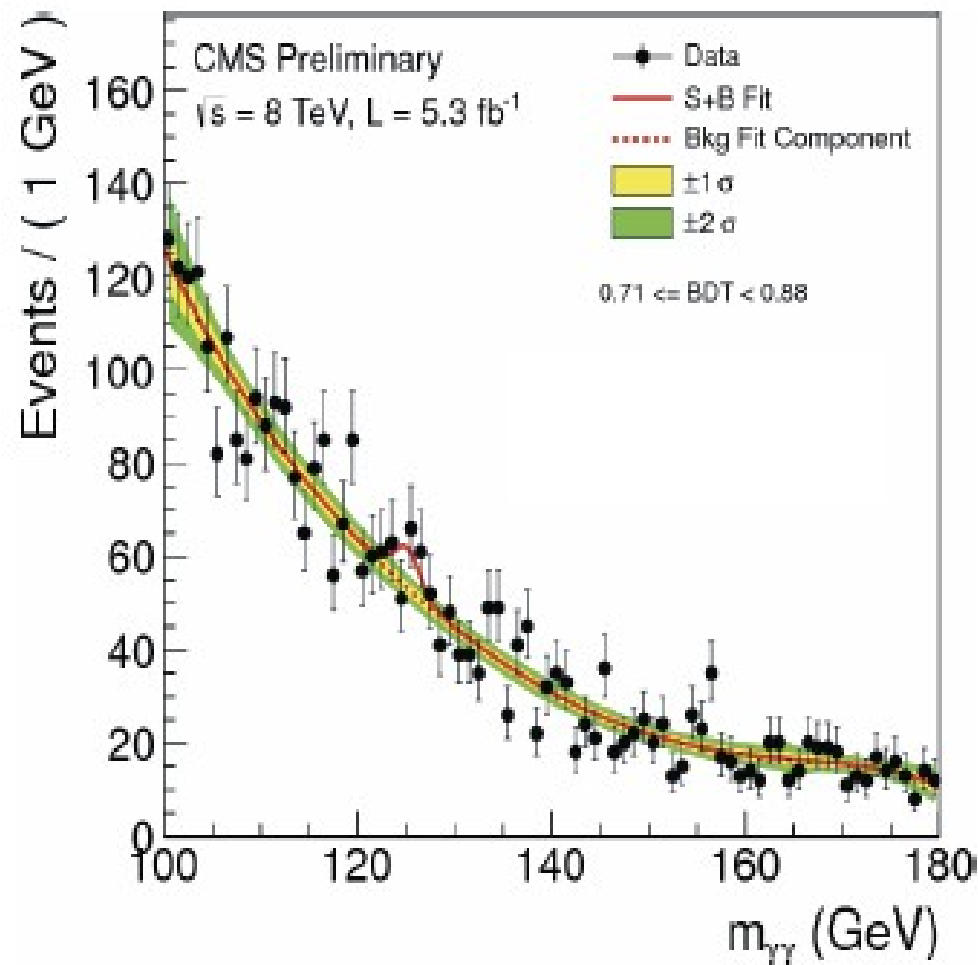
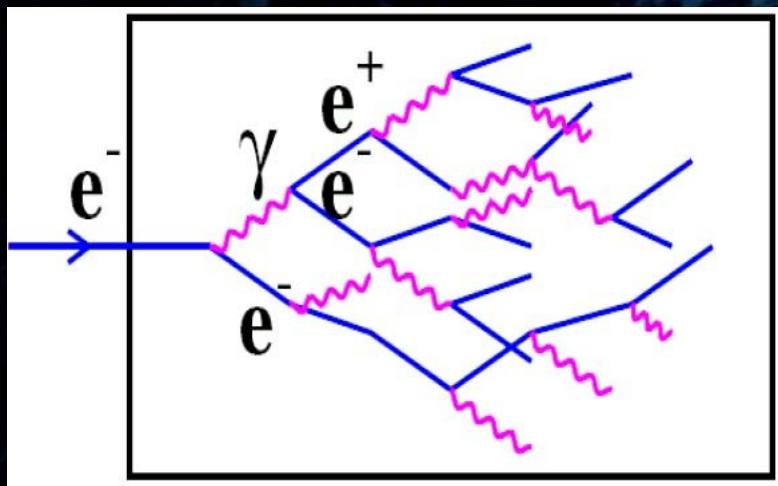
Event „pile-up“



In the LHC, several proton-proton collisions can occur in a single bunch crossing (The image shows an event with 29 reconstructed vertices)

Electromagnetic Calorimeter

- Electron and photon energy measurement
- $\sim 80\,000$ PbWO_4 crystals
- Homogeneous detector - crystals act as both the absorber and the scintillator
- Very good energy resolution



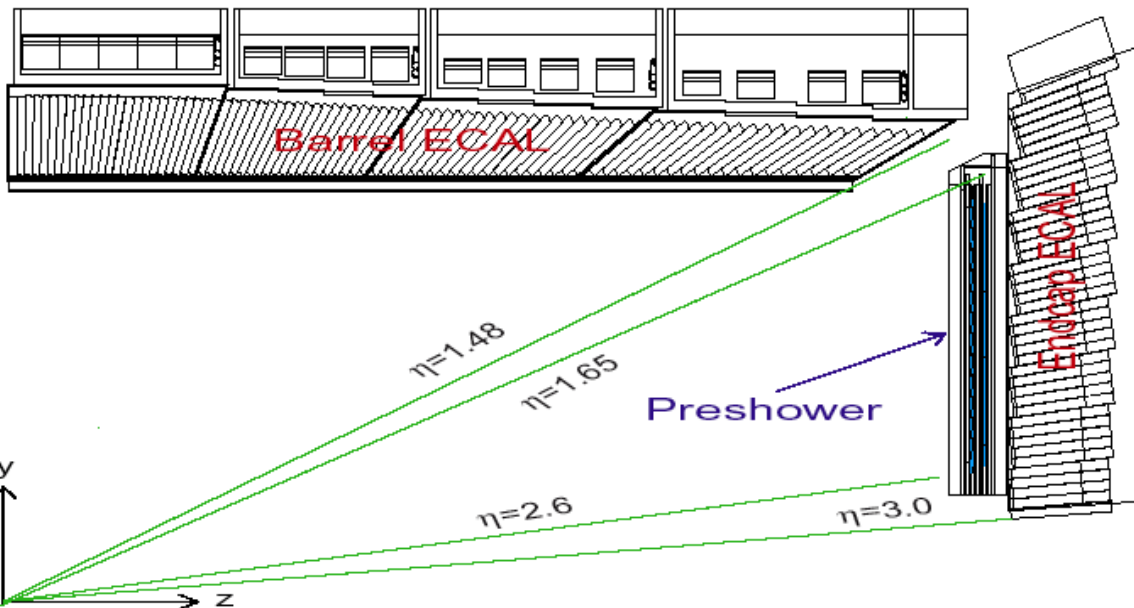
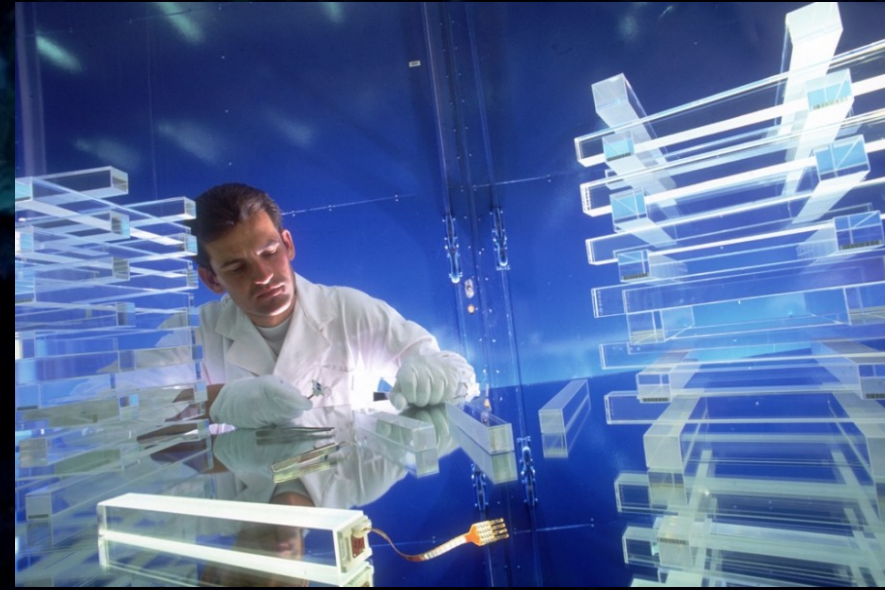


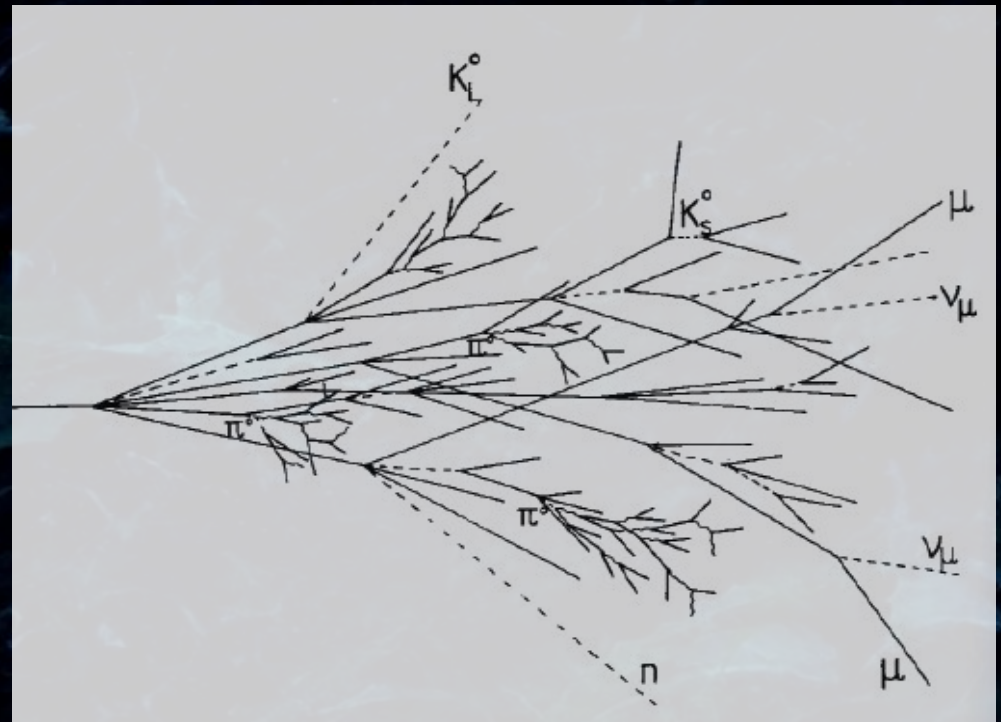
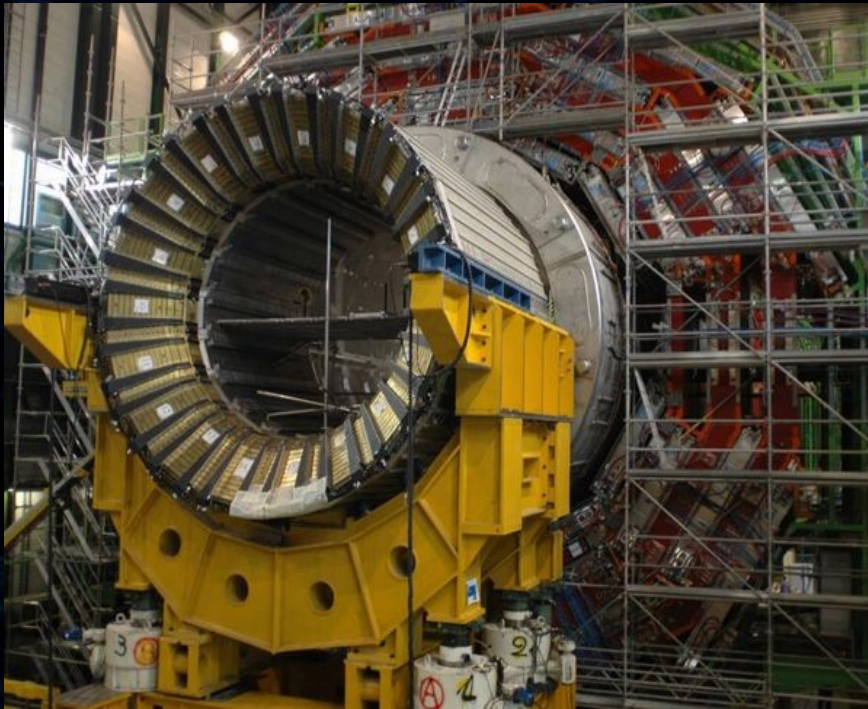
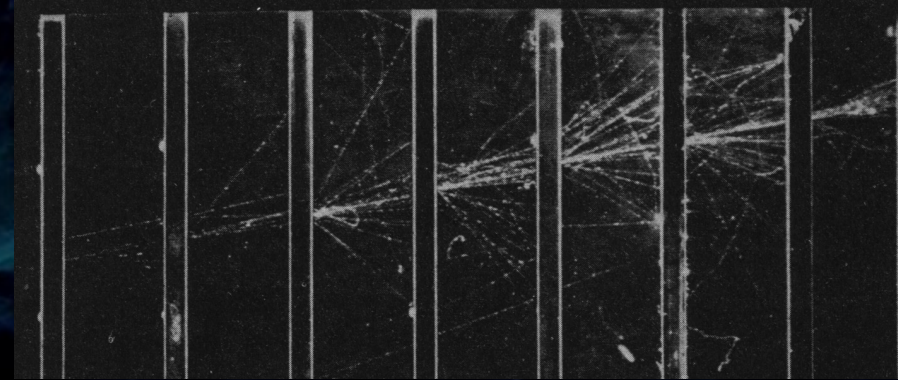
Figure 2: A section through one quadrant of the ECAL.



CMS
Lab 27
PH.CMA
CERN

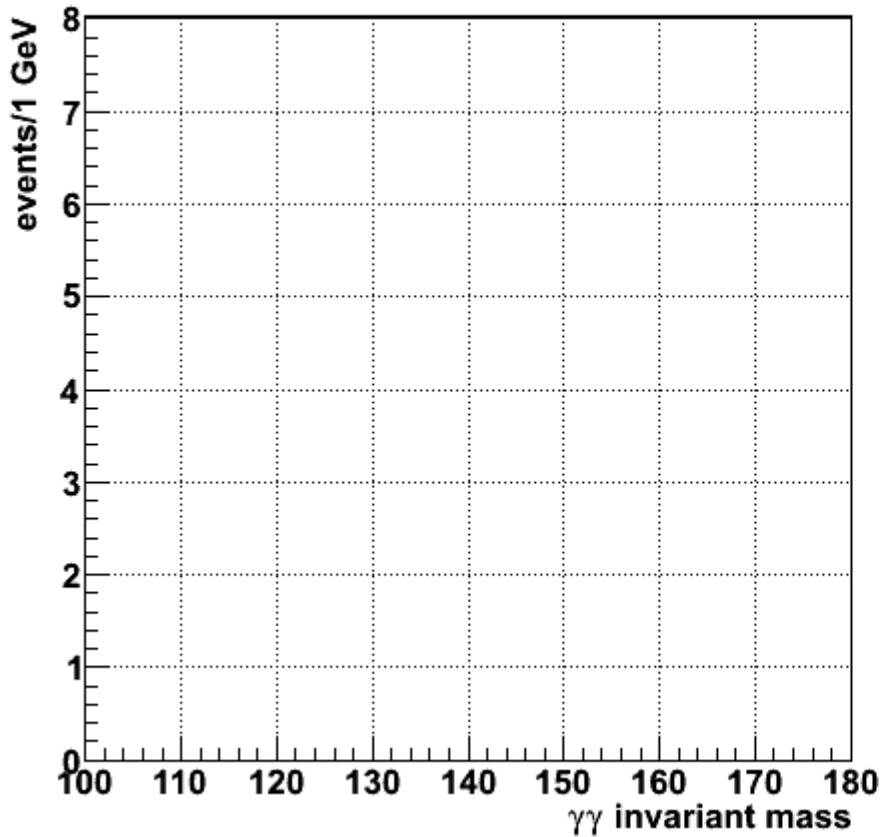
Hadron Calorimeter

- Jet energy measurement
- Brass absorber interleaved with scintillator layers
- Steel blocks with embedded quartz fibers in the „forward“ part

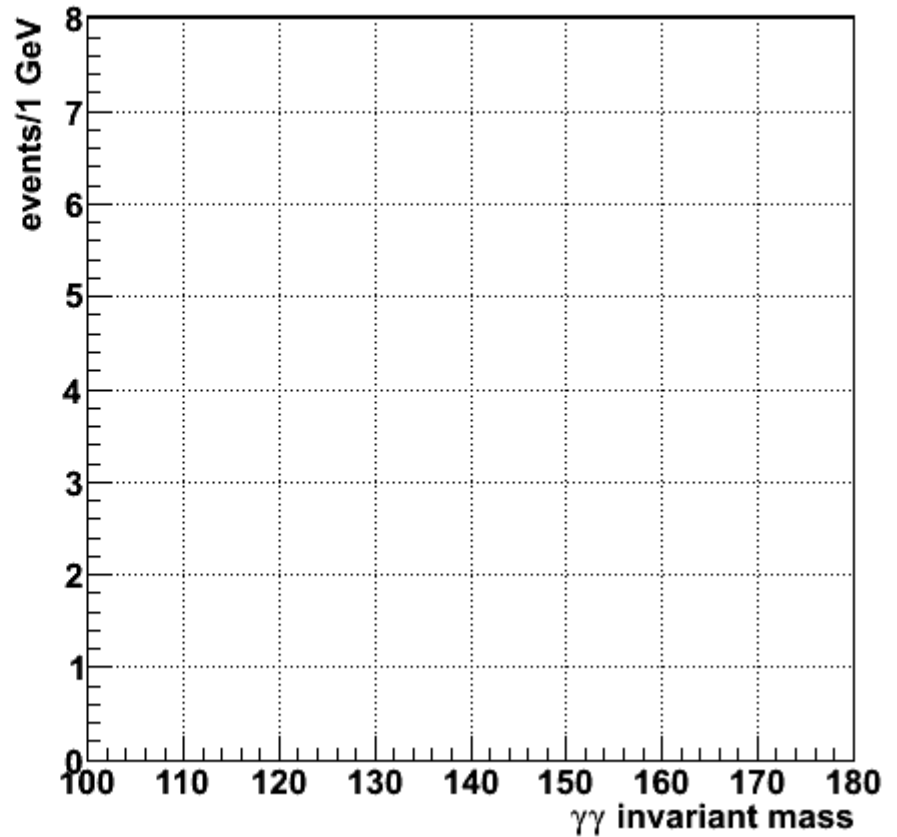


The $H \rightarrow \gamma\gamma$ channel

$L=0.00 \text{ fb}^{-1}$



$L=0.00 \text{ fb}^{-1}$

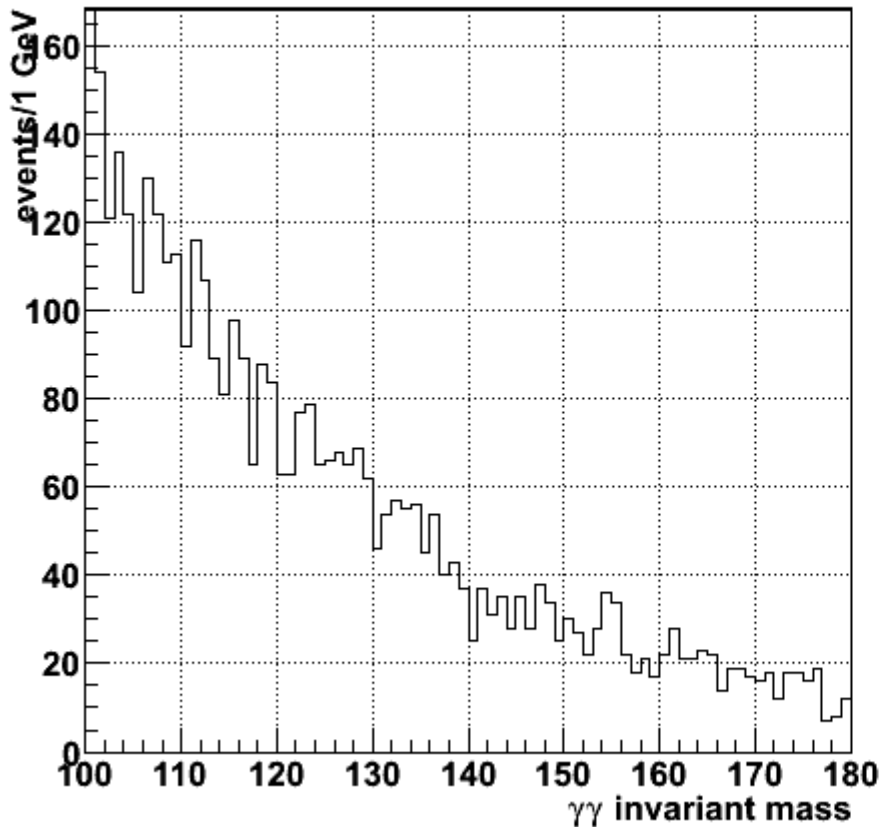


One of these plots contains the (simulated) Higgs boson signal.

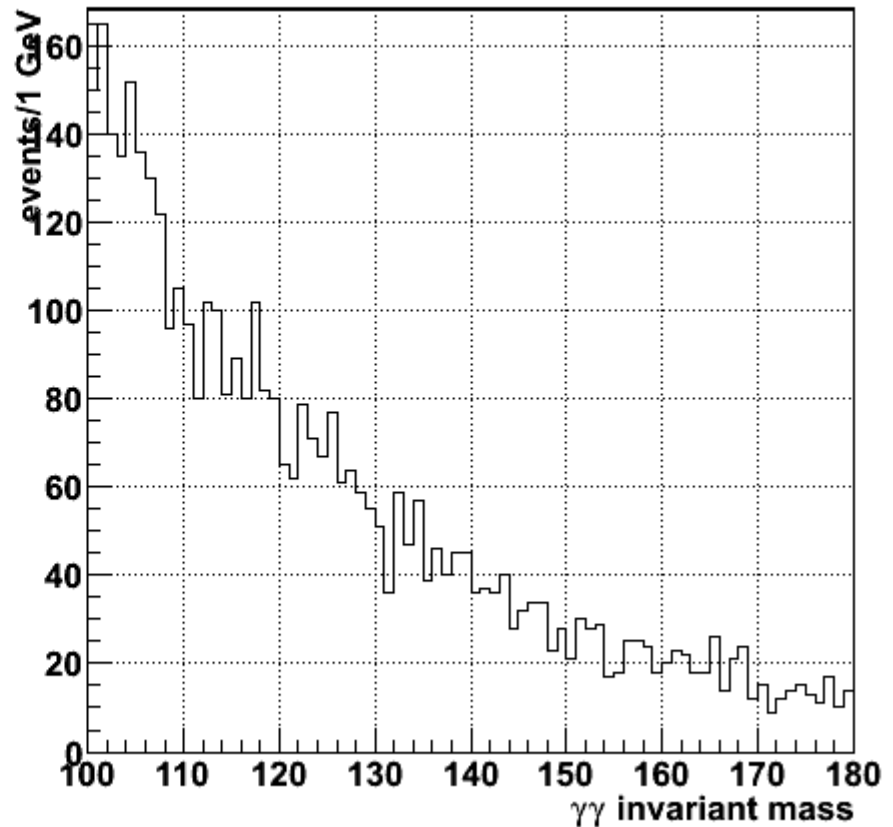
Can you spot it?

The $H \rightarrow \gamma\gamma$ channel

$L=1.00 \text{ fb}^{-1}$



$L=1.00 \text{ fb}^{-1}$

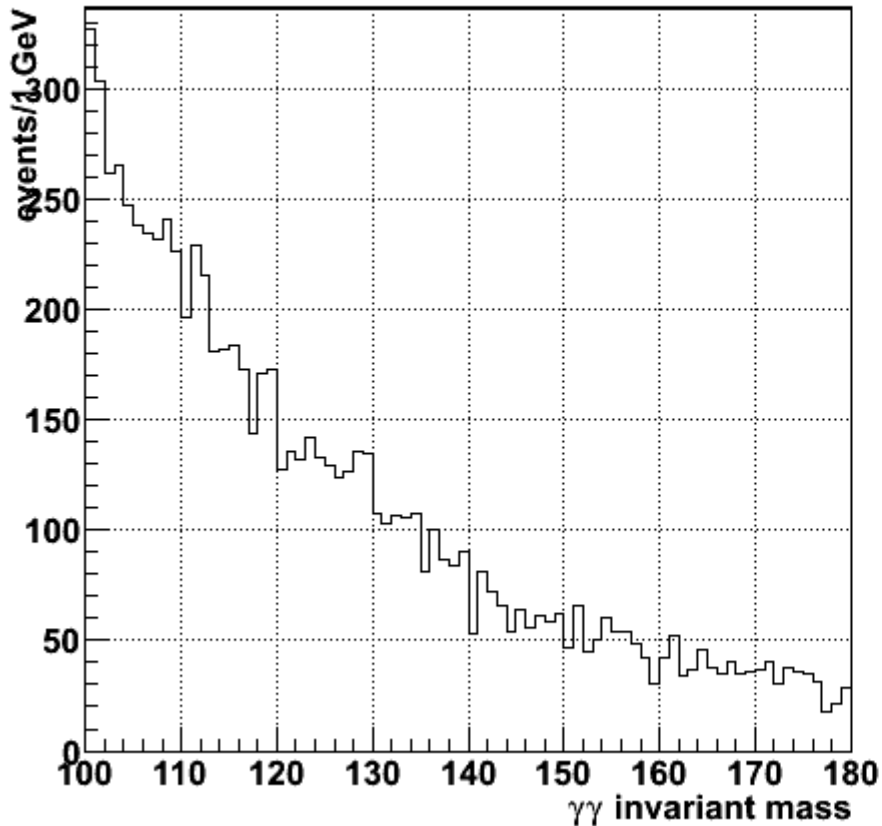


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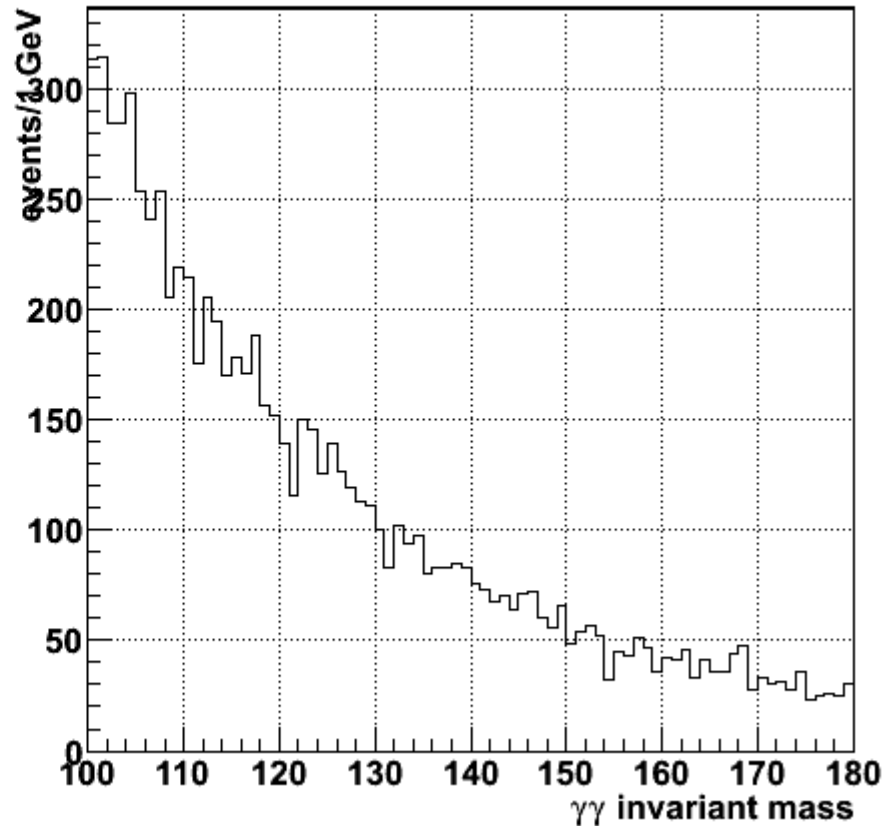
Can you spot it?

The $H \rightarrow \gamma\gamma$ channel

$L=2.00 \text{ fb}^{-1}$



$L=2.00 \text{ fb}^{-1}$

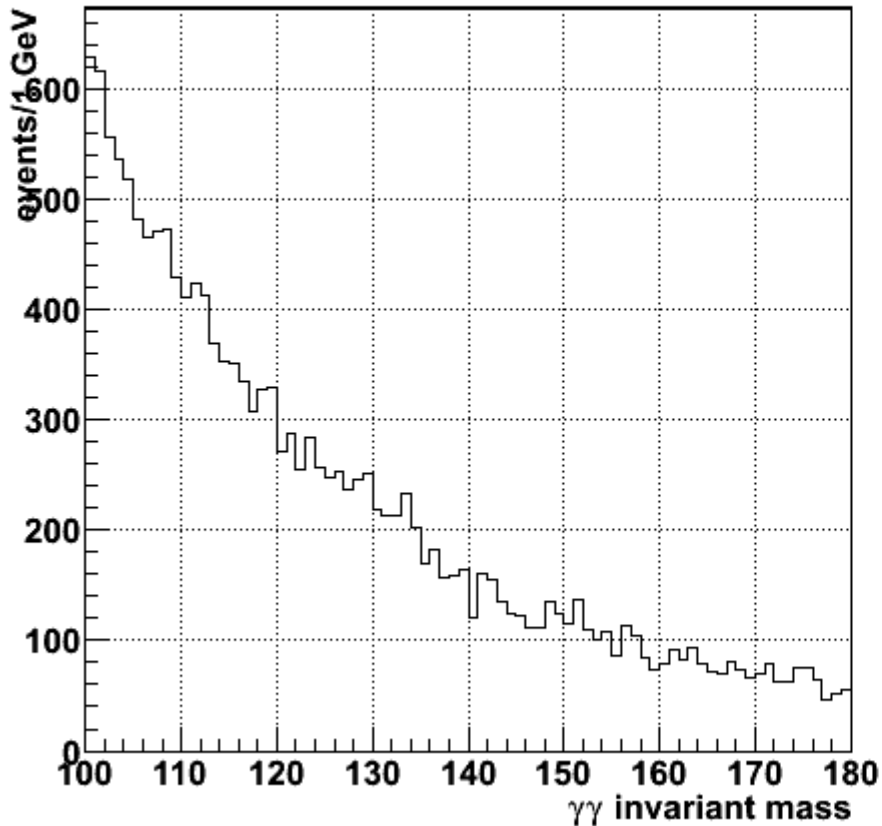


One of these plots contains the (simulated) Higgs boson signal.

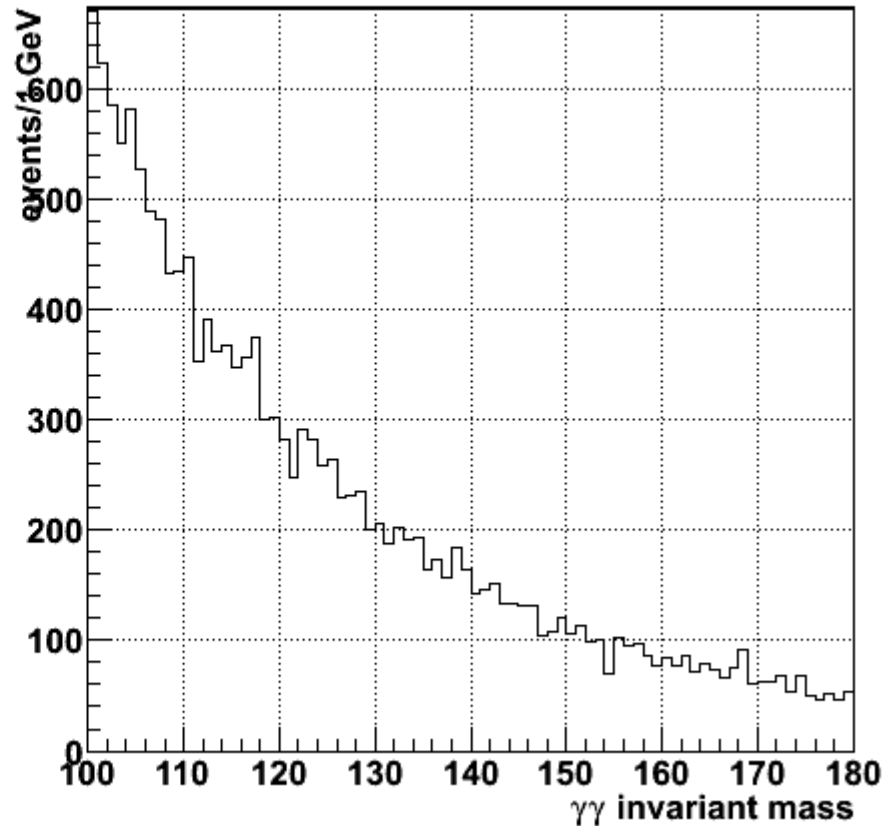
Can you spot it?

The $H \rightarrow \gamma\gamma$ channel

$L=4.00 \text{ fb}^{-1}$



$L=4.00 \text{ fb}^{-1}$

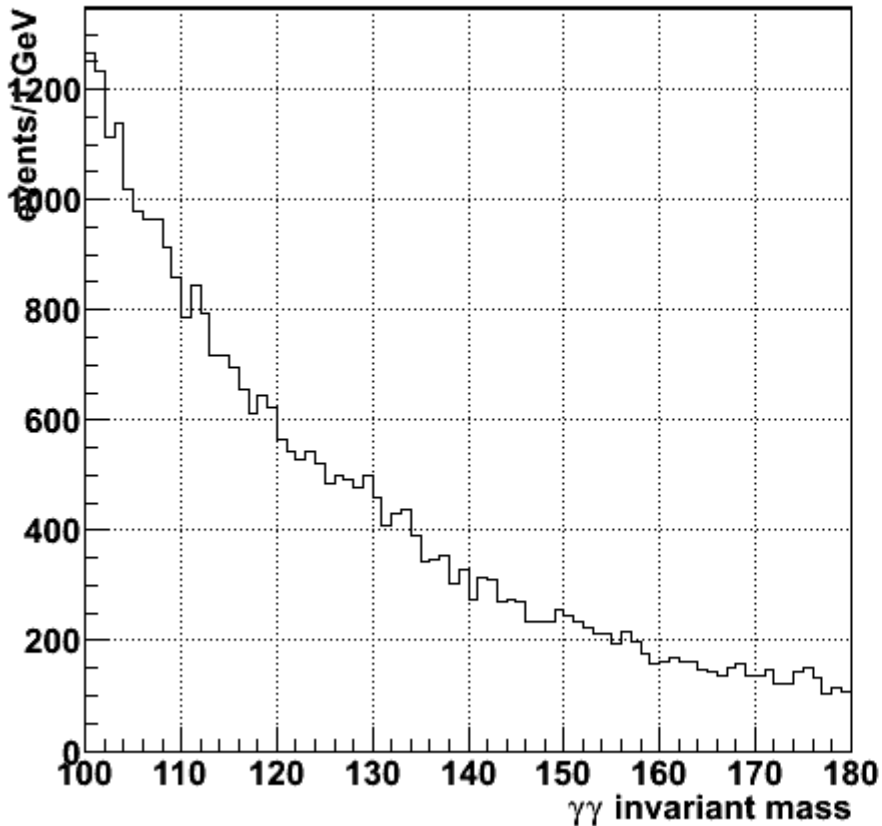


One of these plots contains the (simulated) Higgs boson signal.

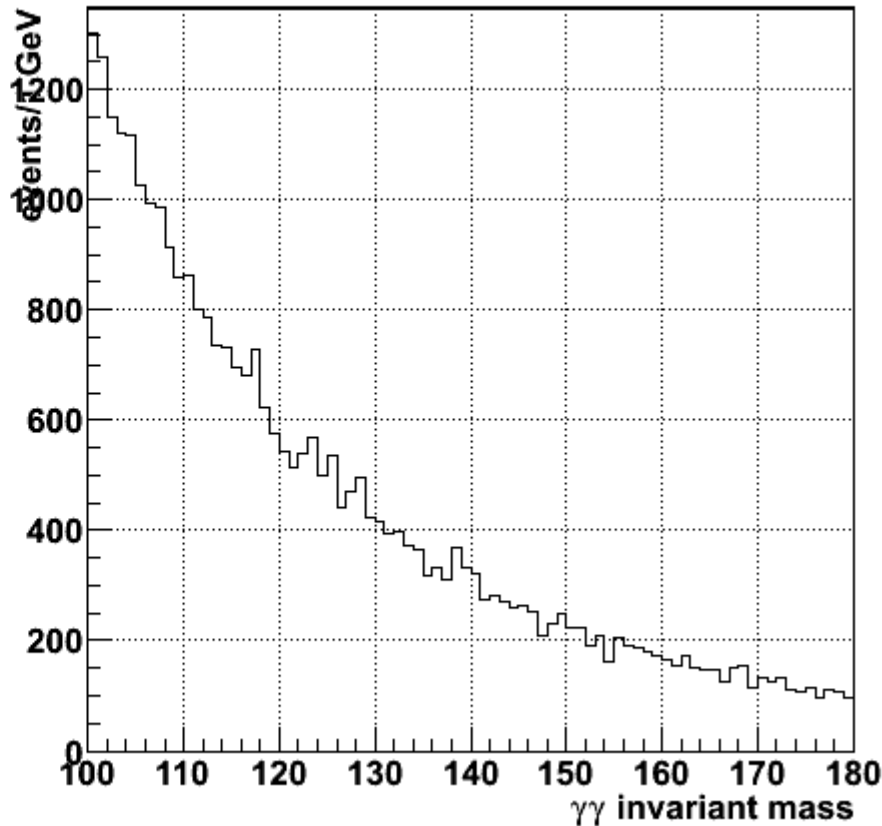
Can you spot it?

The $H \rightarrow \gamma\gamma$ channel

$L=8.00 \text{ fb}^{-1}$



$L=8.00 \text{ fb}^{-1}$

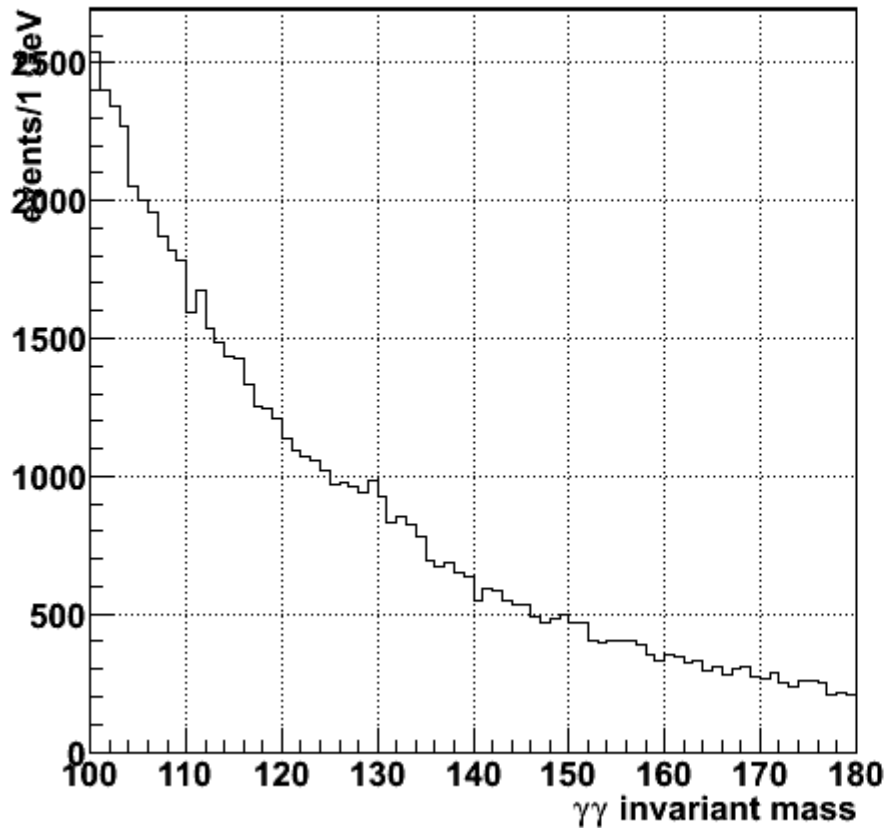


One of these plots contains the (simulated) Higgs boson signal.

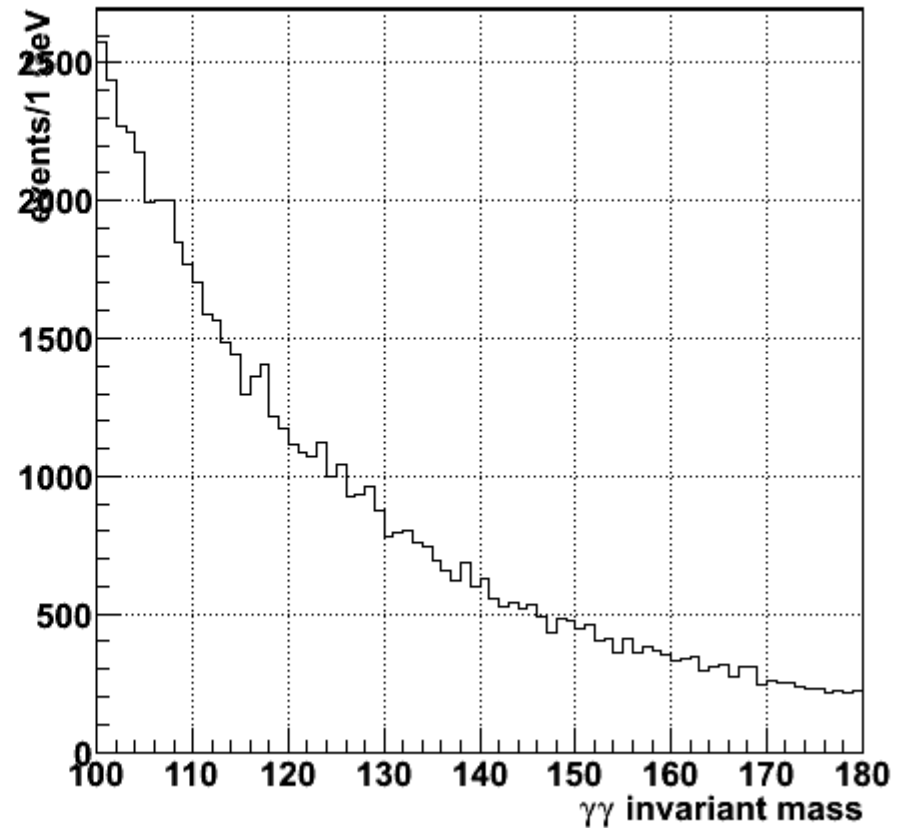
Can you spot it?

The $H \rightarrow \gamma\gamma$ channel

$L=16.00 \text{ fb}^{-1}$



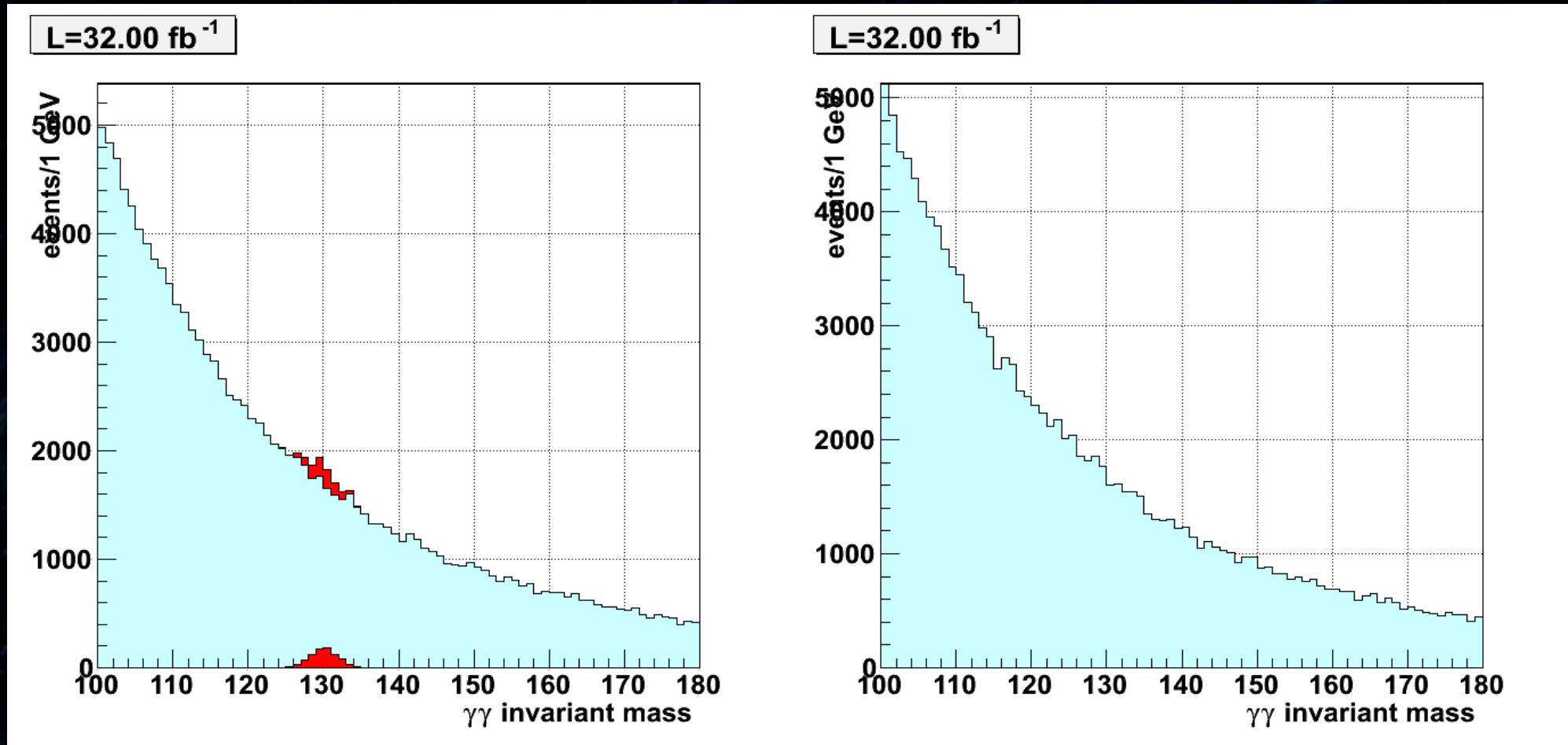
$L=16.00 \text{ fb}^{-1}$



One of these plots contains the (simulated) Higgs boson signal.

Can you spot it?

The $H \rightarrow \gamma\gamma$ channel

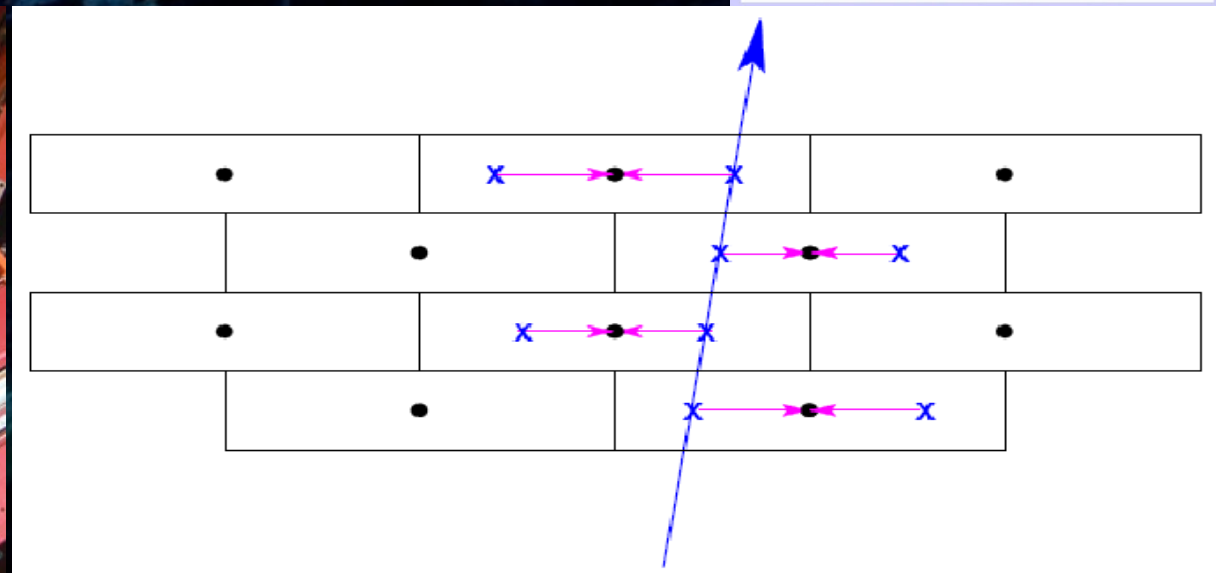
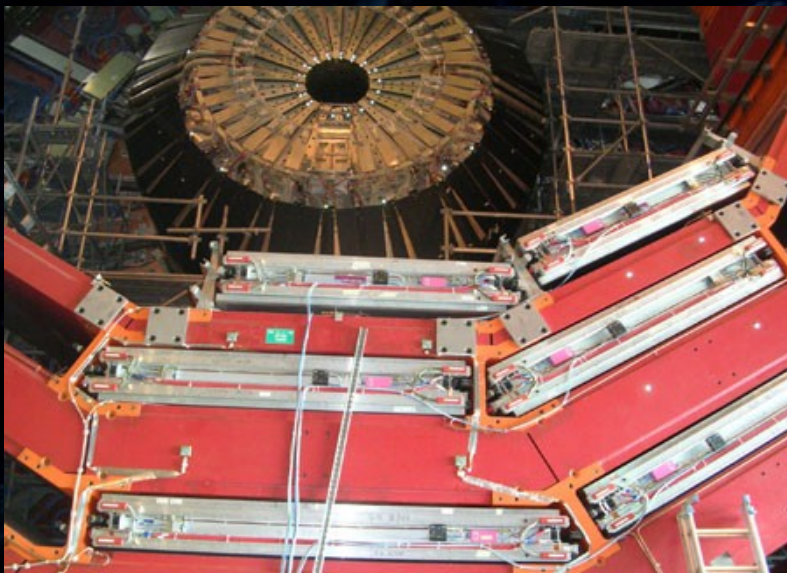
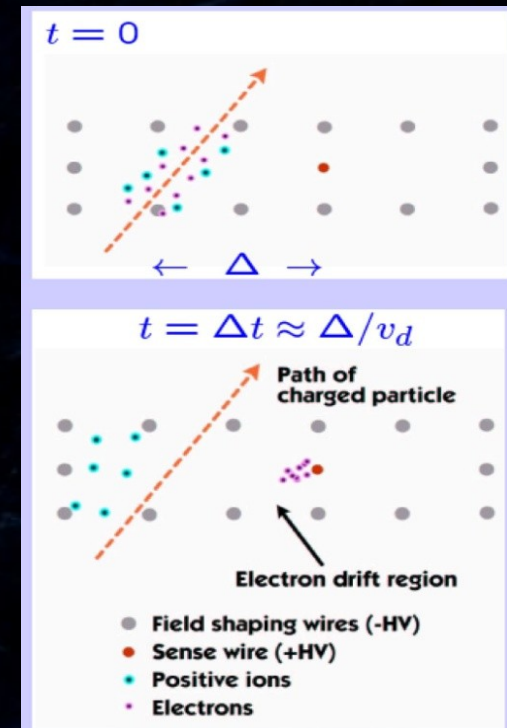


One of these plots contains the (simulated) Higgs boson signal.

Can you spot it?

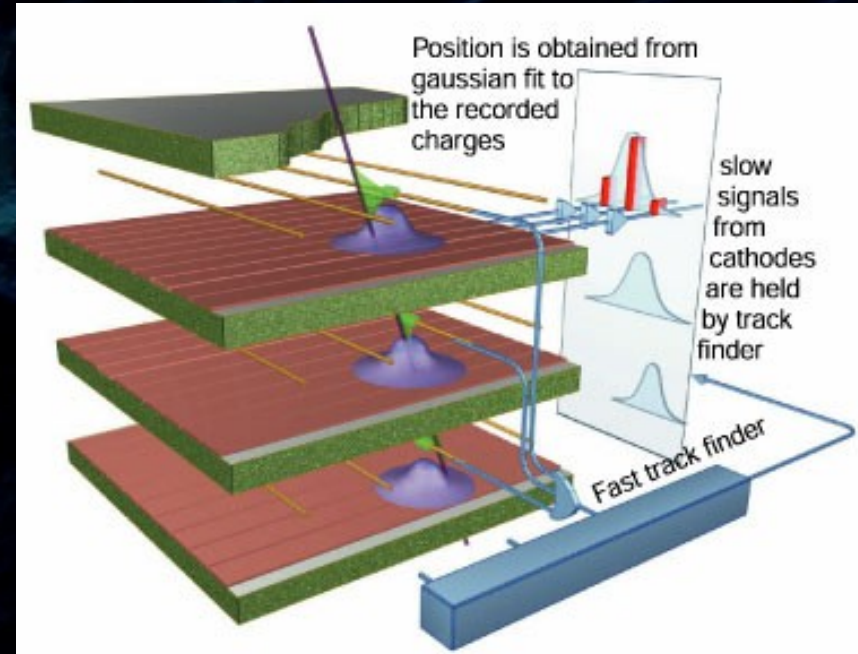
The Muon System - Drift Tubes

- Muon trajectory measurement (barrel)
- Measured quantity - drift time of electrons produced by the passing muon
- Known drift velocity \rightarrow distance measurement ($\sim 50\text{-}200\mu\text{m}$ precision)
- Alignment very important

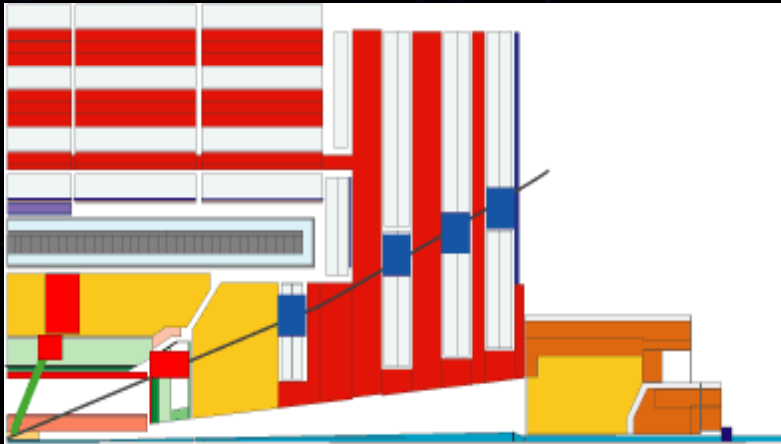


Cathode Strip Chambers (CSC)

- Muon trajectory measurement in the endcaps
- Gaseous detector with layers of anode wires and cathode strips

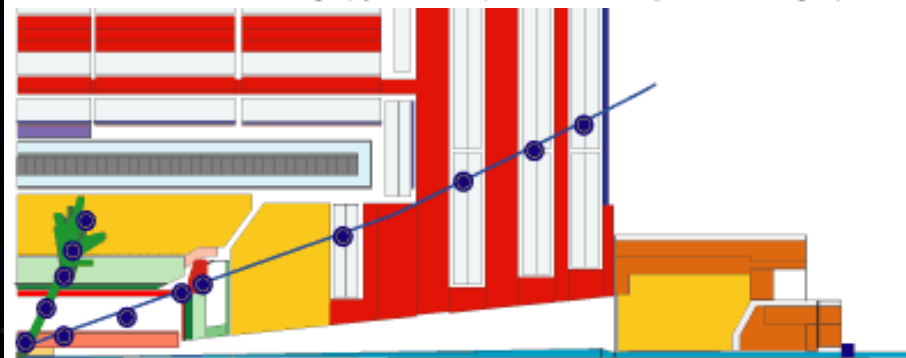


Trigger



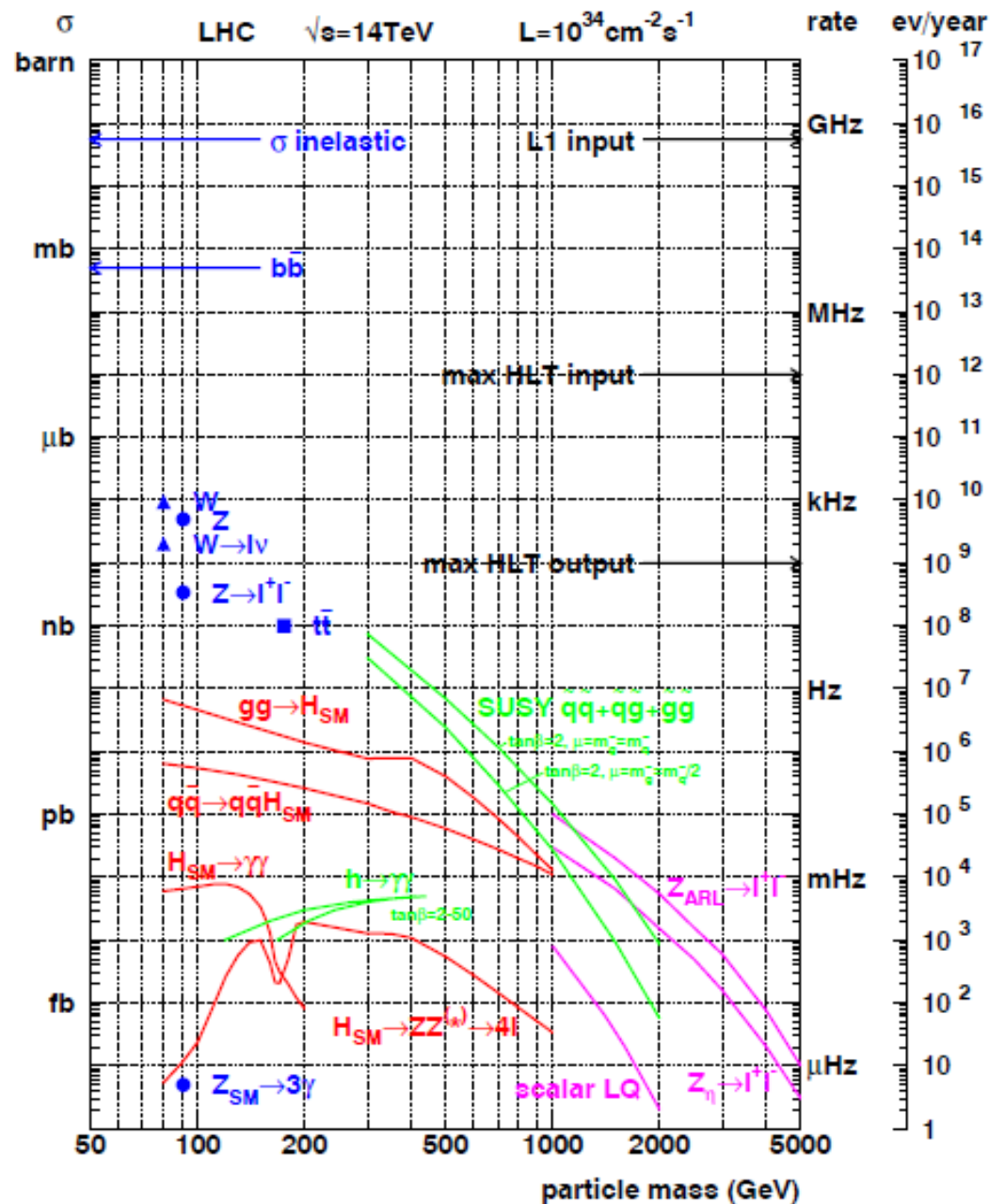
Level-1 trigger. 40 MHz input :

- Specialized processors (25 ns pipelined, latency < 1 μ s)
- Local pattern recognition and energy evaluation on prompt macro-granular information from calorimeter and muon detectors
- Particle identification: high p_t electron, photon, muon, jets, missing E_T



High trigger levels (>1). 100 kHz input :

- Large network of processor farms
- Clean particle signature. All detector data
- Finer granularity precise measurement
- Effective mass cuts and event topology
- Track reconstruction and detector matching
- Event reconstruction and analysis



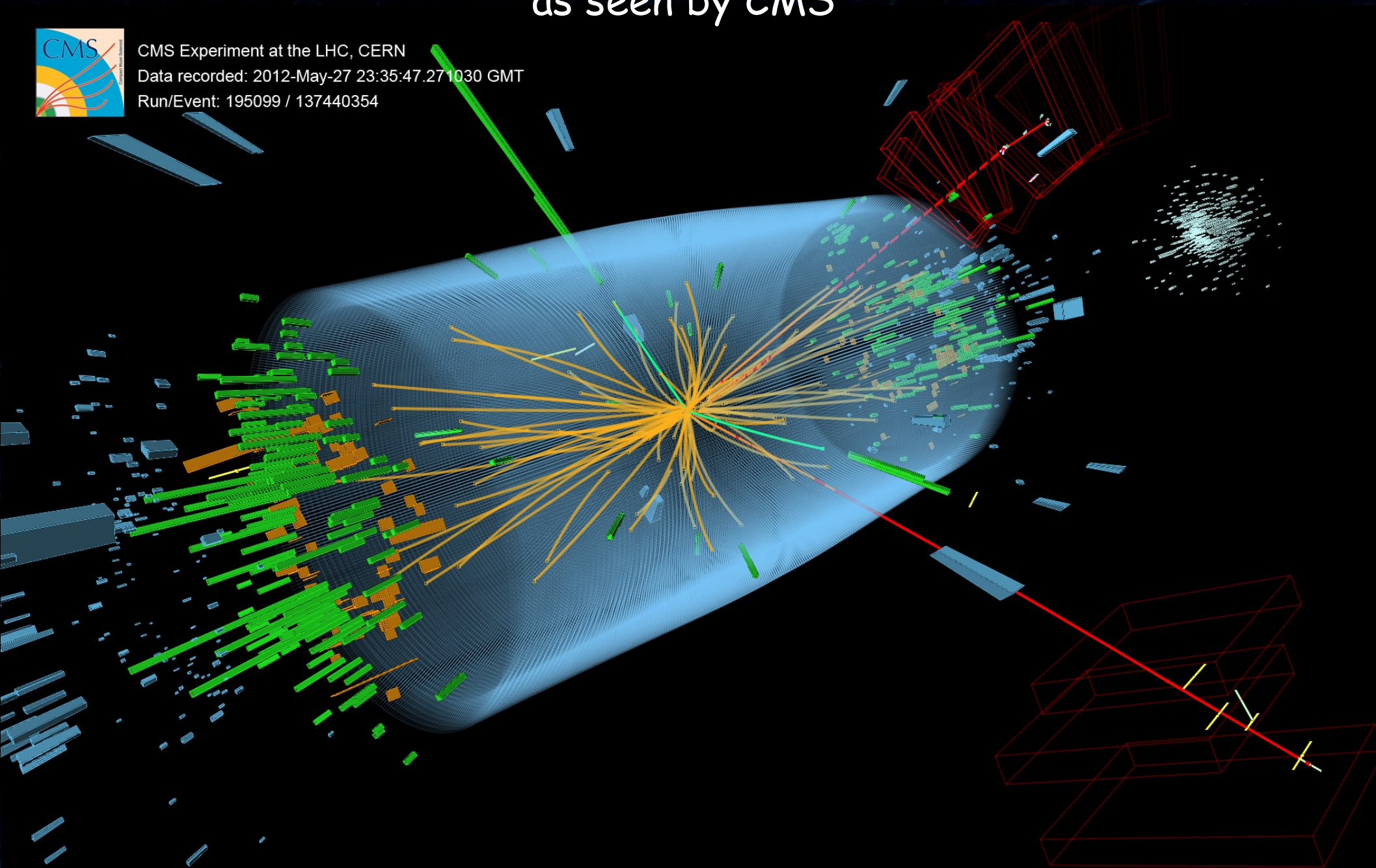
A proton-proton collision as seen by CMS



CMS Experiment at the LHC, CERN

Data recorded: 2012-May-27 23:35:47.271030 GMT

Run/Event: 195099 / 137440354



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1998

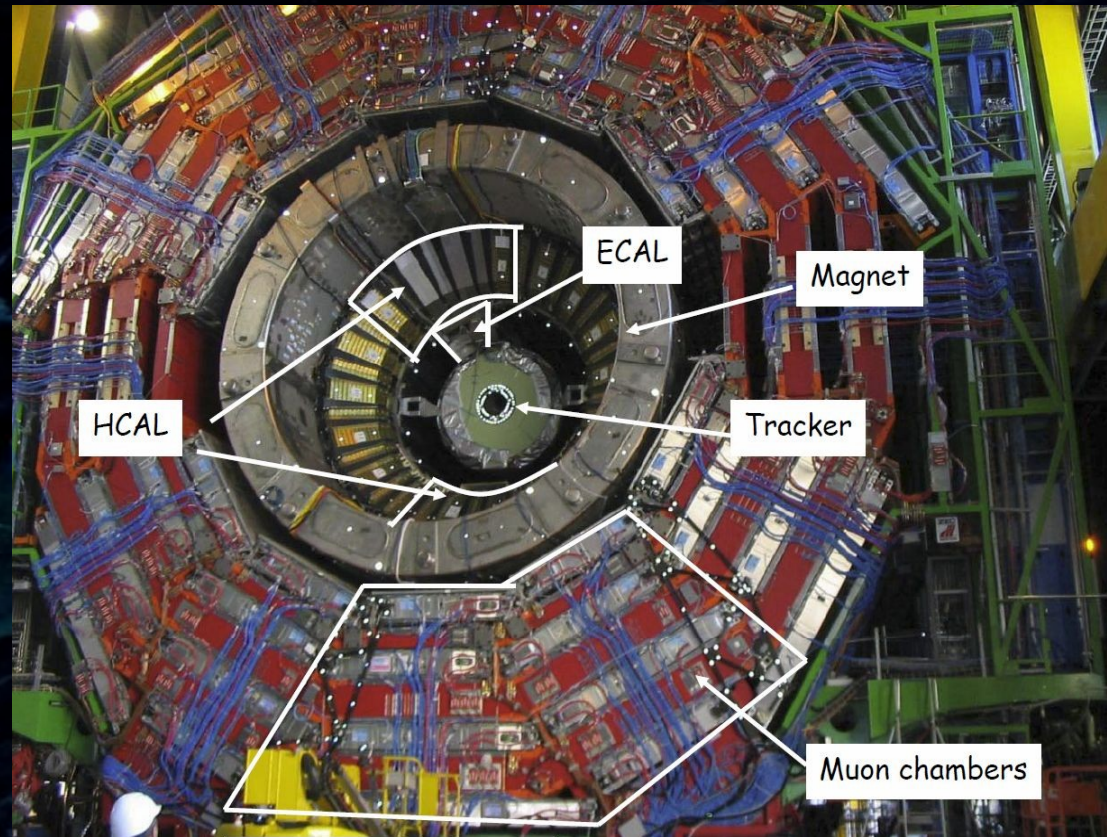
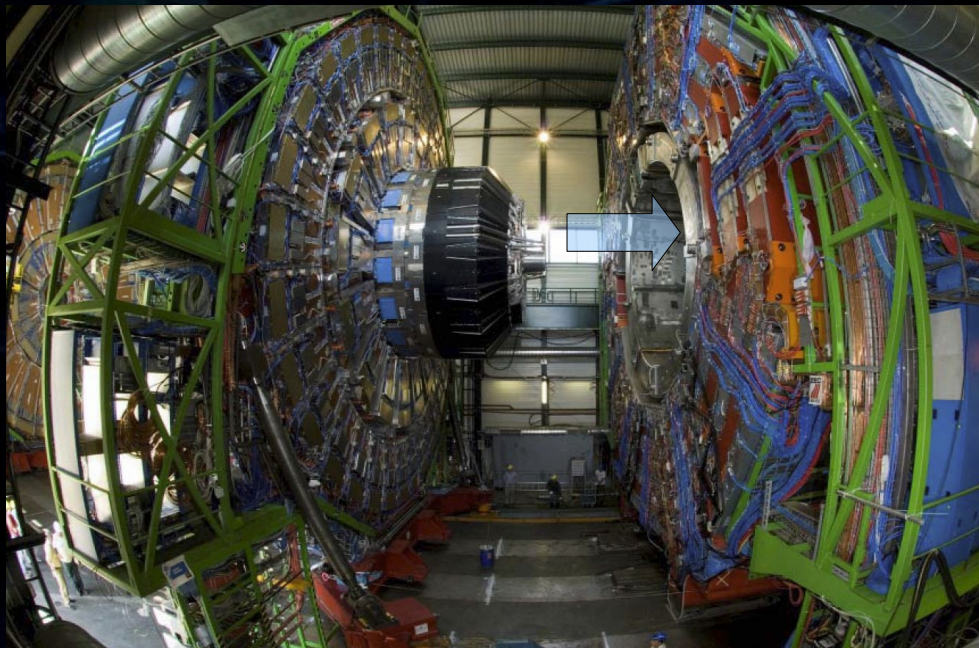


2000

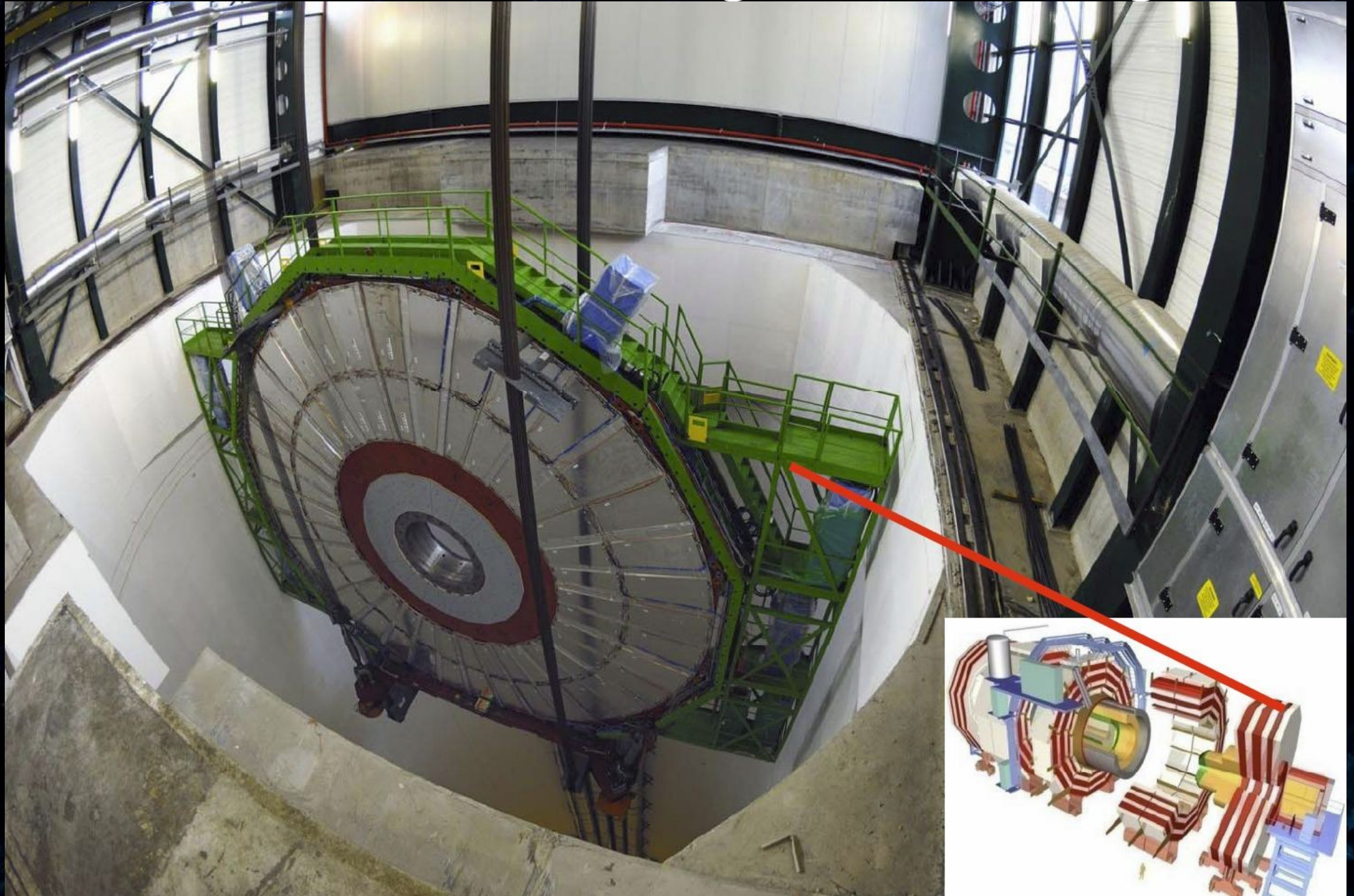


2006

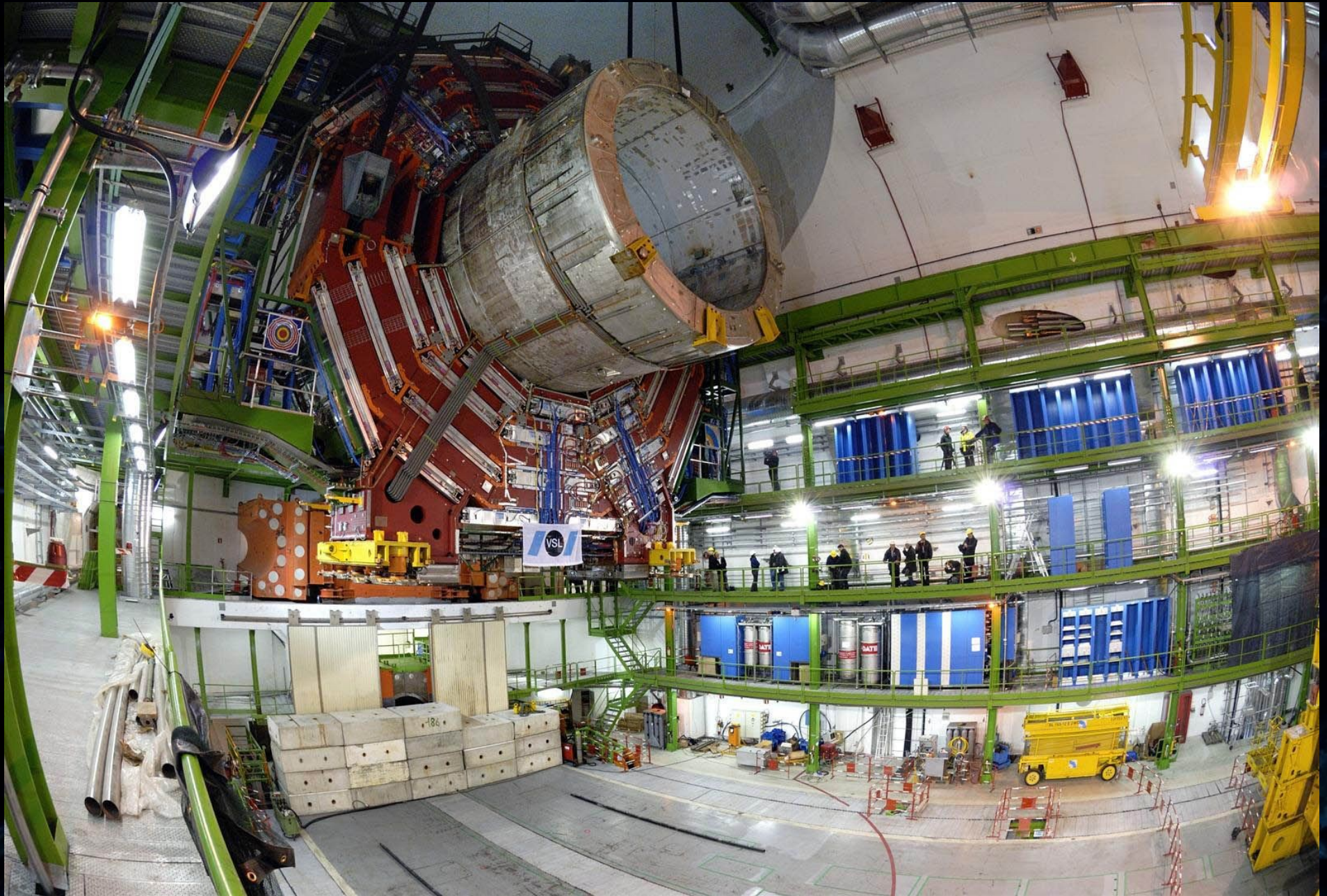
- The detector was assembled and operated still in the surface hall
- MTCC - Magnet Test and Cosmic Challenge



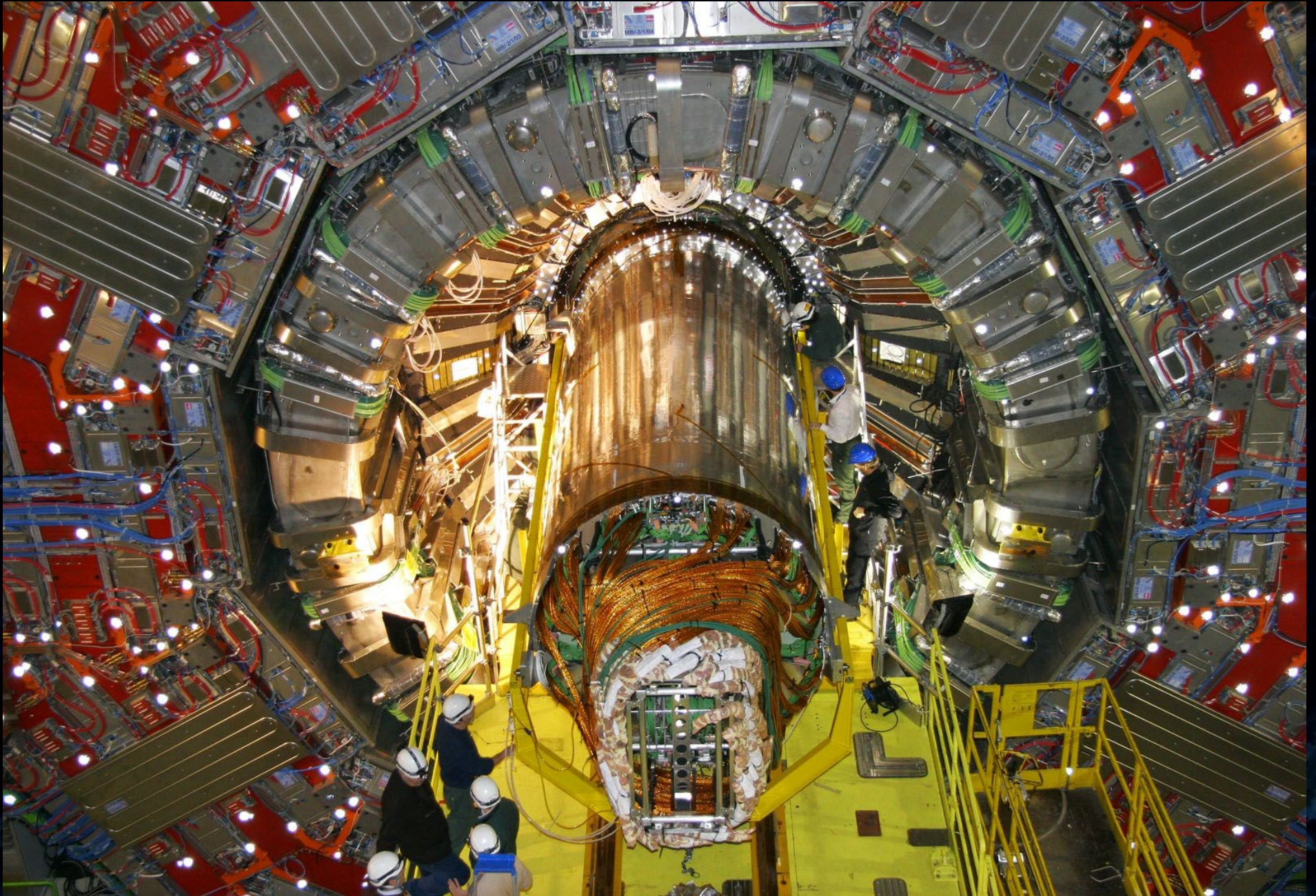
End of 2006 - lowering 100m underground



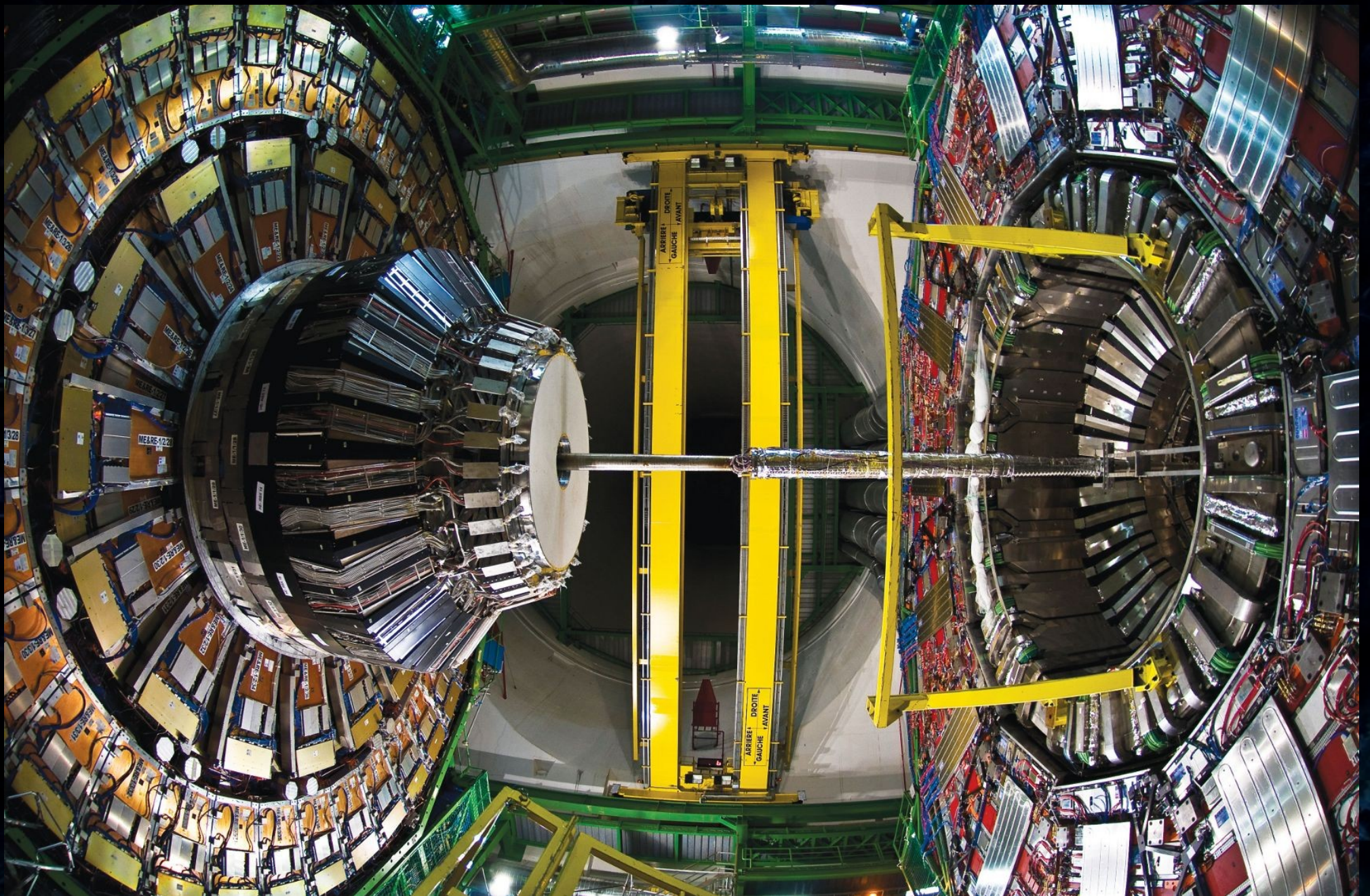
Feb 2007 - lowering the central wheel



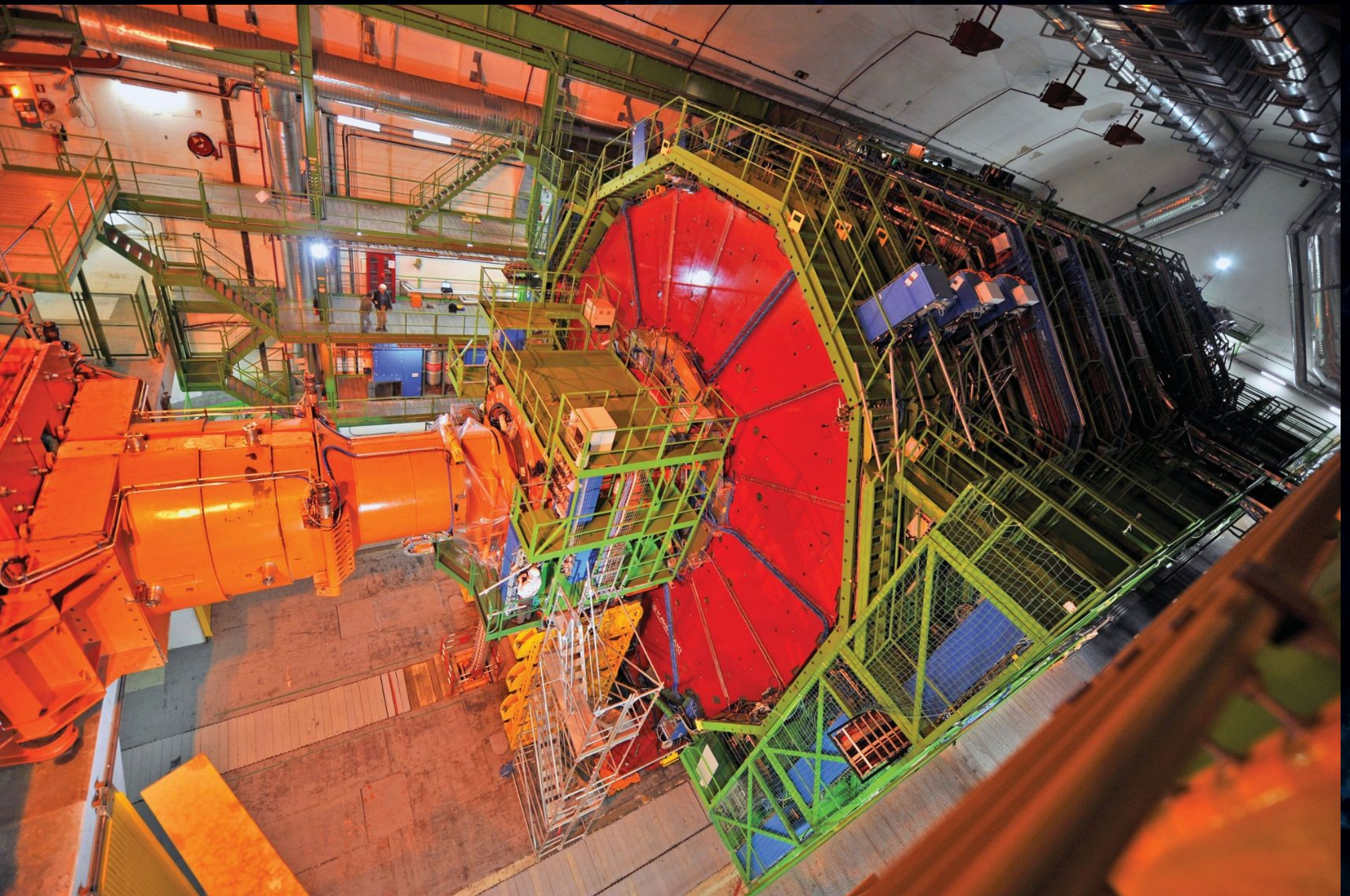
March 2008 - inserting the Tracker



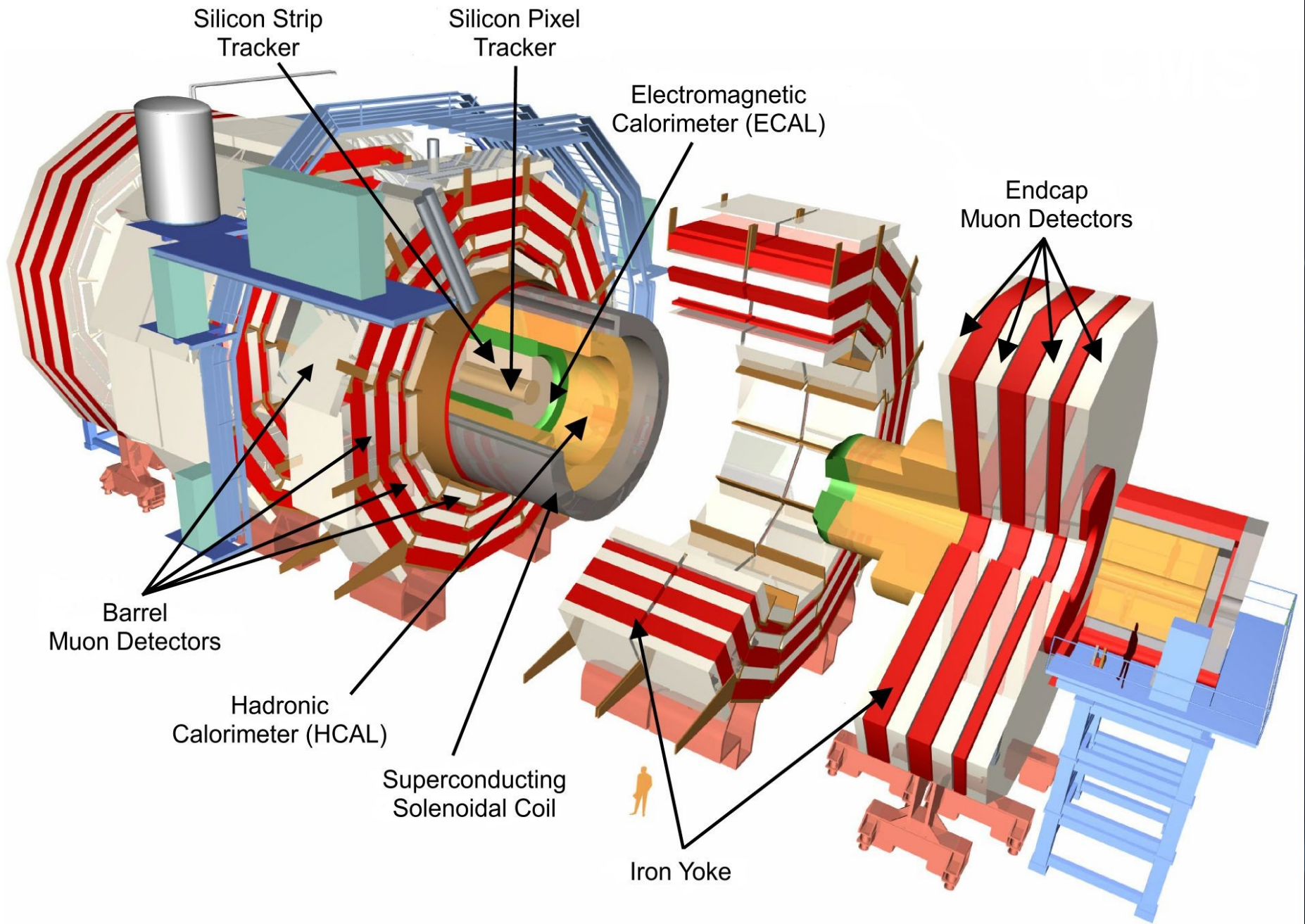
June 2008 - installation of the beam pipe



Sept 3rd, 2008 - Final closure



Once more:



The End

