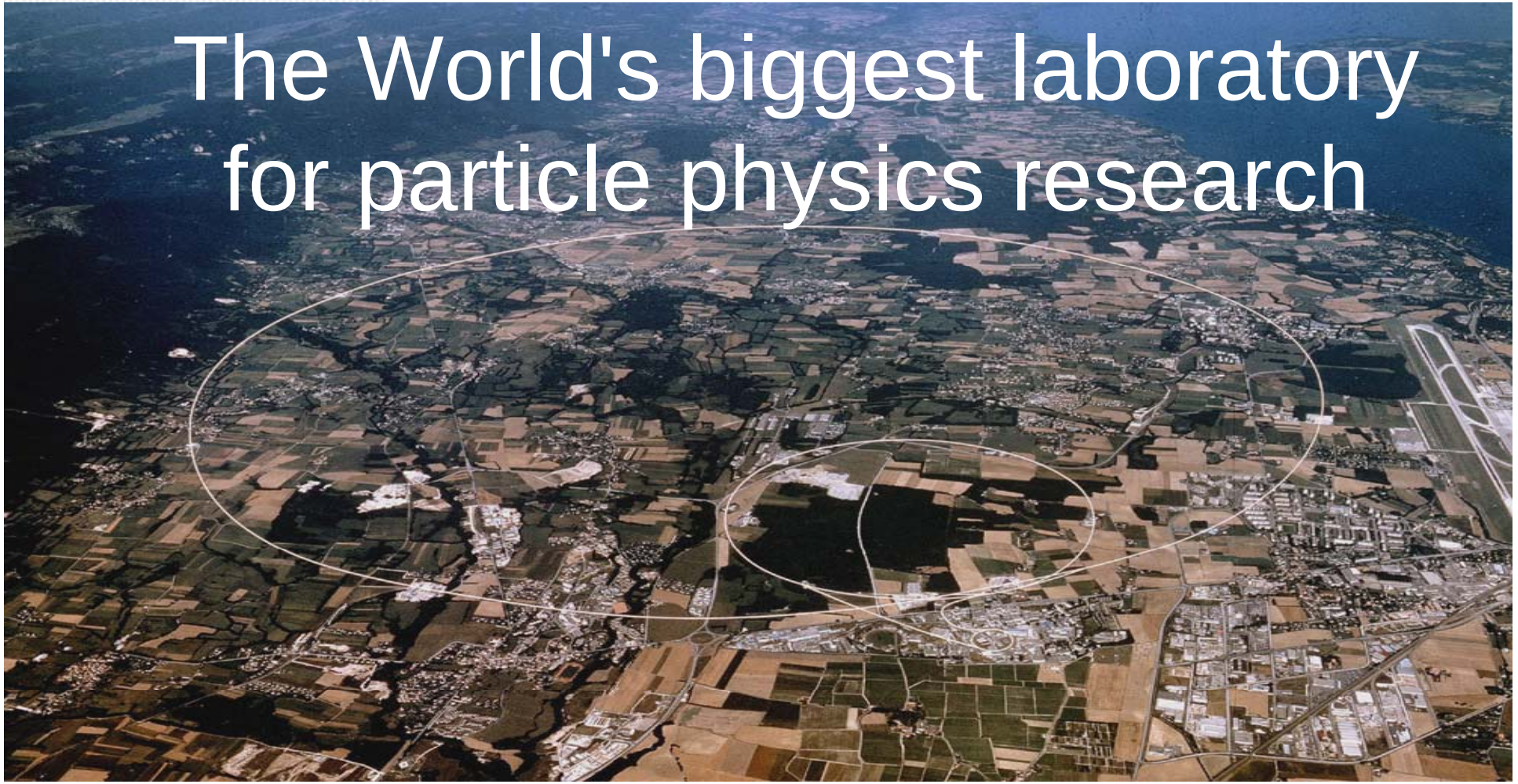
CERN

European Organization for Nuclear Research
Organisation Européenne pour la Recherche Nucléaire

The World's biggest laboratory for particle physics research

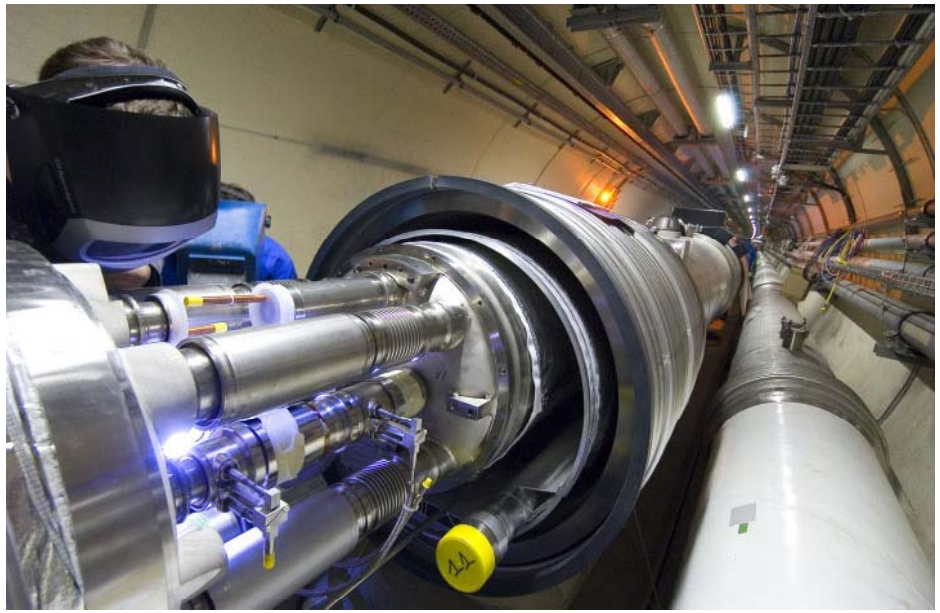


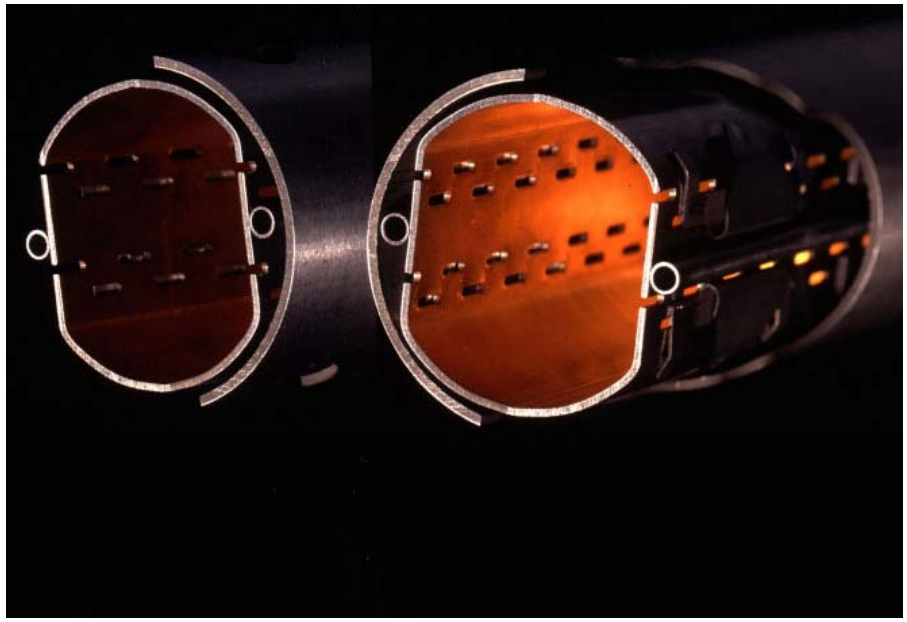
Research and discovery - Education, training, collaboration - Technology and innovation

One of the fastest racetracks on the planet

Several thousand billion protons traveling at 99.9999991% of the speed of light will travel round the 27km ring over 11000 times a second

The emptiest space in the solar system…



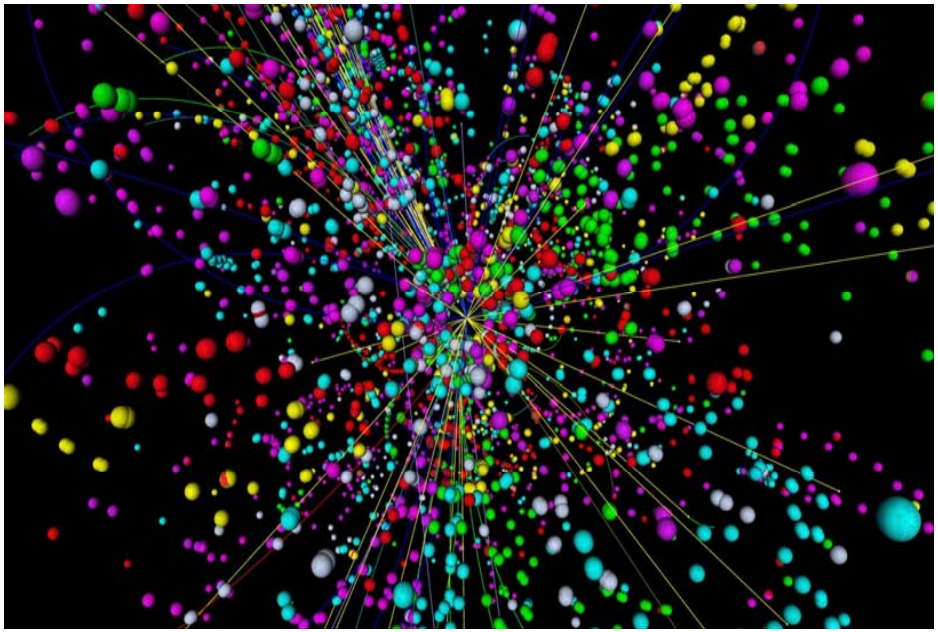


To accelerate protons to almost the speed of light, we need a vacuum similar to interplanetary space. The pressure in the beam-pipes of the LHC will be about ten times lower than on the moon.

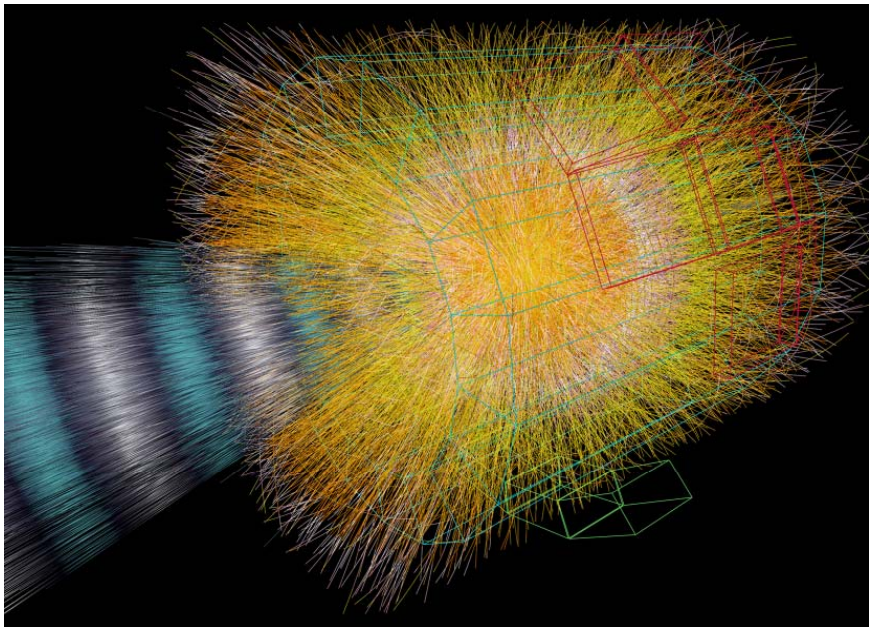
One of the coldest places in the Universe…

With a temperature of around -271 degrees Celsius, or 1.9 degrees above absolute zero, the LHC is colder than interstellar space.

One of the hottest places in the Galaxy…



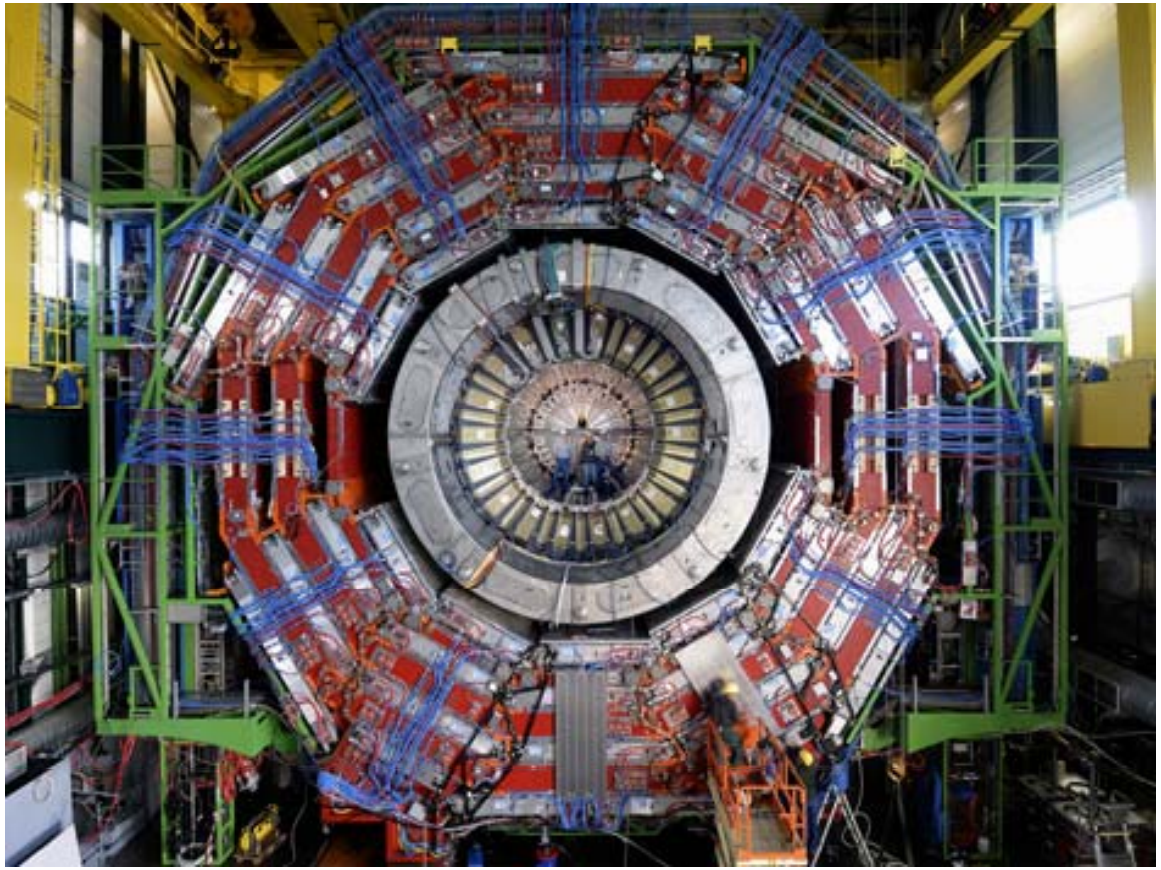
Simulation of a collision in the CMS experiment



Simulation of a collision in the ALICE experiment

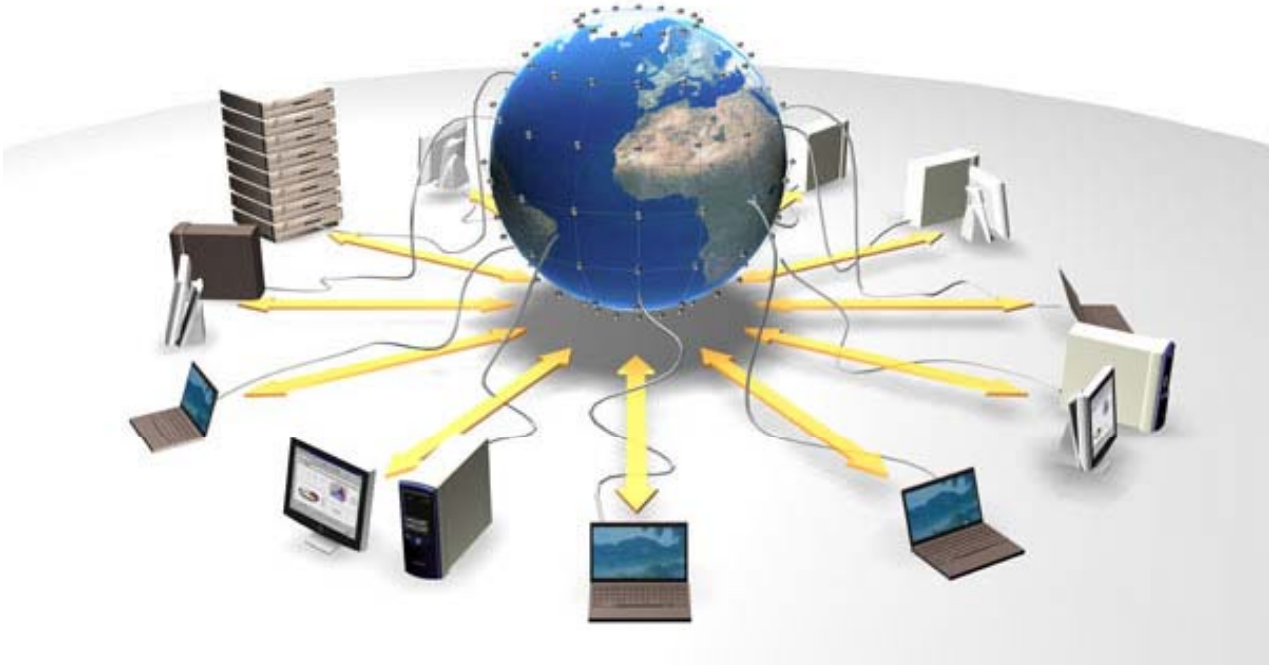
When two beams of protons collide, they generate within a tiny volume, temperatures more than a billion times those in the very heart of the Sun.

The largest and most complex detectors ever built...



To select and record the signals from the 600 million proton collisions every second, CERN scientists are building huge detectors to measure the tiny particles to an extraordinary precision.

The furthest reaching computer in the world...



Tens of thousands of computers based all over the world are used to analyse data from CERN. The computing GRID is the next advance in decentralised computing from the laboratory that brought you the World-Wide Web.

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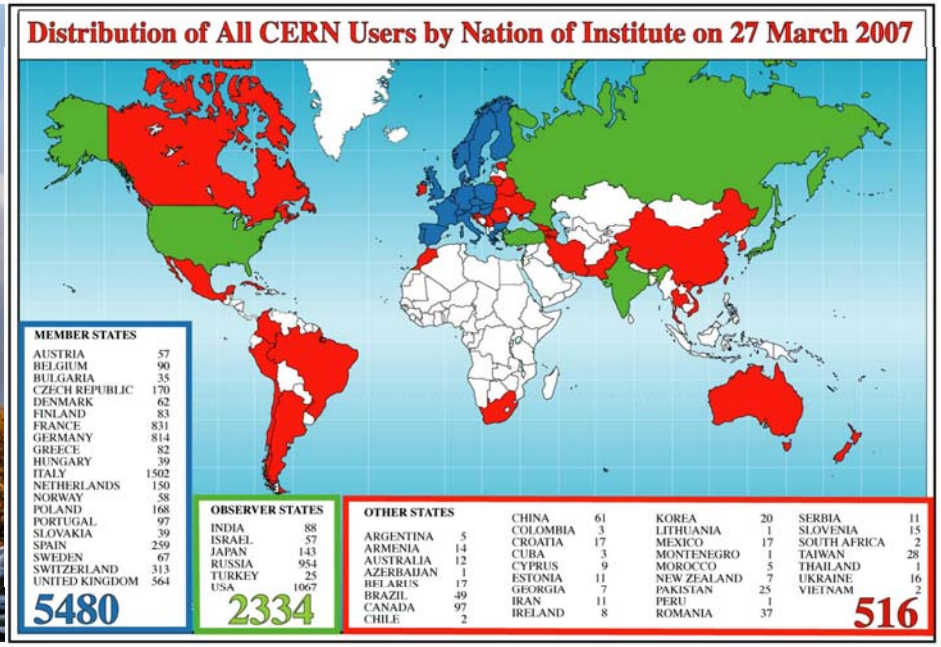
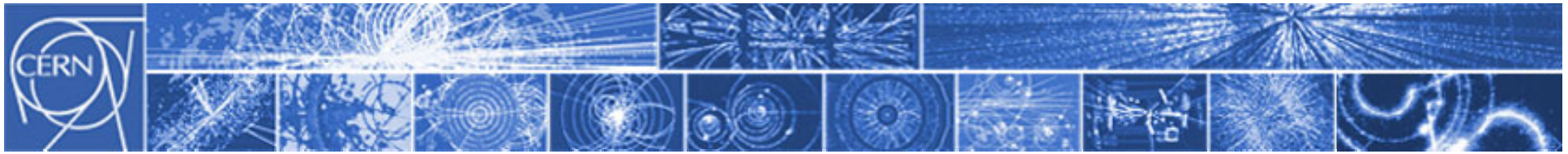
Every day, around 10 000 scientists
from all over the world perform research at CERN

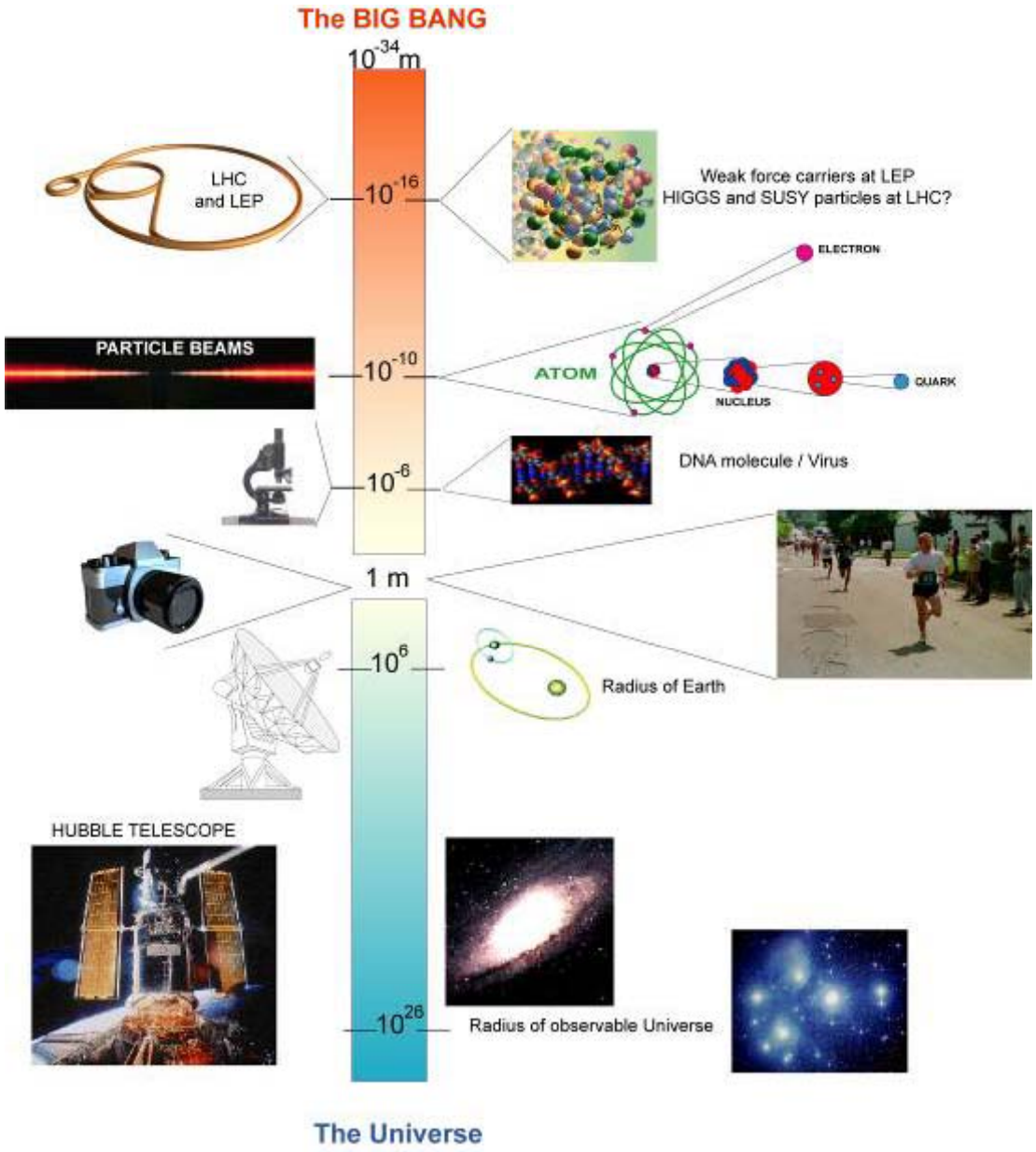
Flags of CERN's Member States



20 European Member States and around 60 additional countries collaborate in our scientific projects.



Why ?



Different types of equipment are needed to observe different sizes of object

Only particle accelerators can explore the tiniest objects in the Universe

After more than 50 years of experiments our present understanding of the Universe

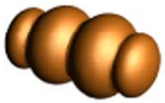
Leptons

Electric Charge

Tau	-1	0	Tau Neutrino
Muon	-1	0	Muon Neutrino
Electron	-1	0	Electron Neutrino

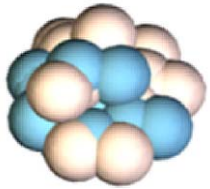
Strong

Gluons (8)



Quarks

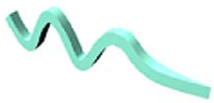
Mesons
Baryons

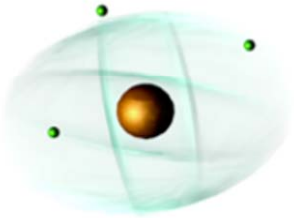


Nuclei

Electromagnetic

Photon





Atoms
Light
Chemistry
Electronics

Quarks

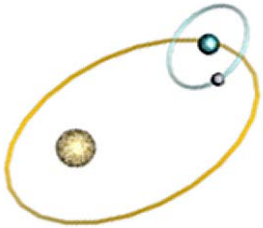
Electric Charge

Bottom	-1/3	2/3	Top
Strange	-1/3	2/3	Charm
Down	-1/3	2/3	Up

each quark: R, B, G 3 colours

Gravitational

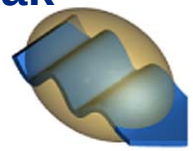
Graviton ?

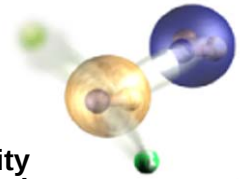


Solar system
Galaxies
Black holes

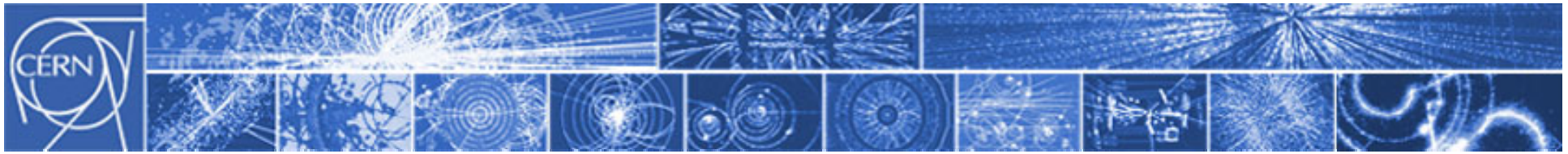
Weak

Bosons (W,Z)





Neutron decay
Beta radioactivity
Neutrino interactions
Burning of the sun



nice ...

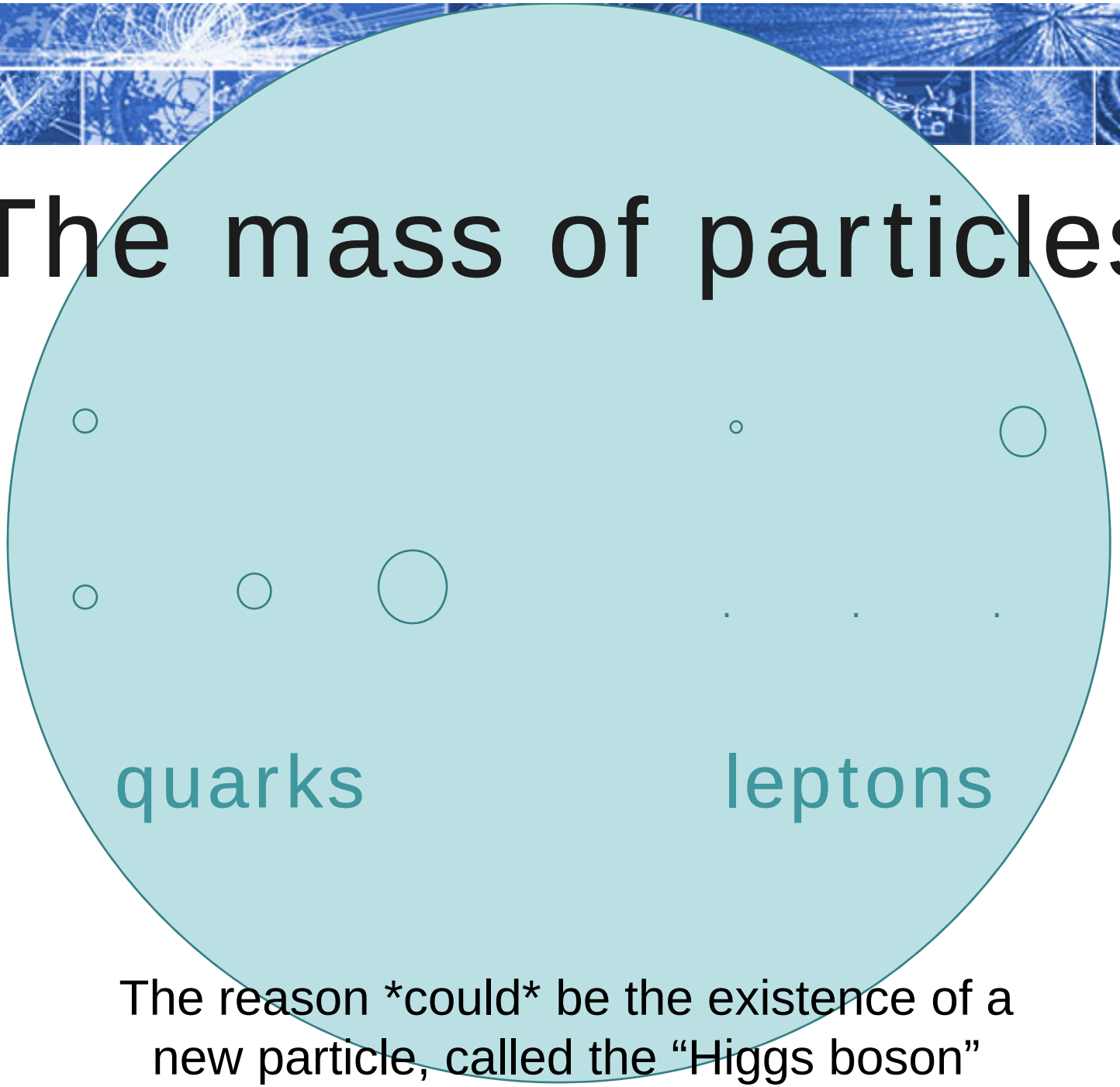
BUT

The mass of particles

quarks leptons

The reason *could* be the existence of a new particle, called the “Higgs boson”

The mass of particles



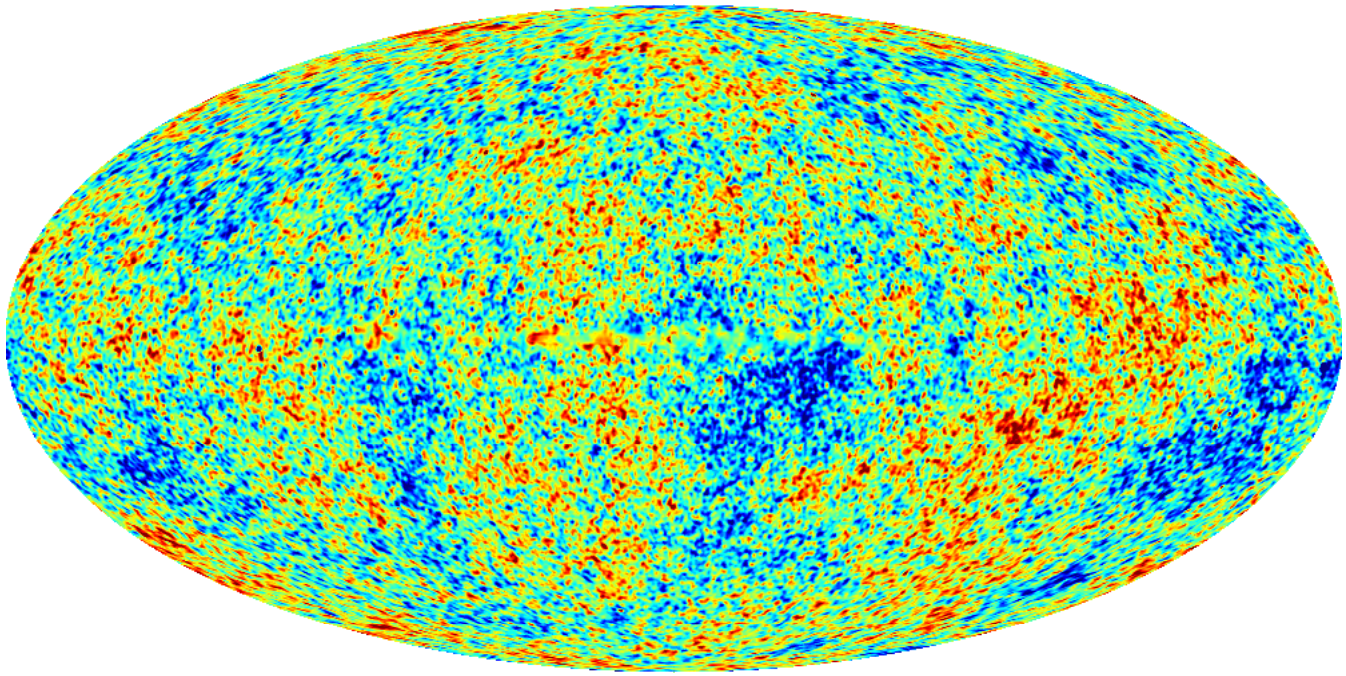
The reason *could* be the existence of a new particle, called the “Higgs boson”

Big Bang: equal amounts of matter and antimatter created

Now: we (matter) exist

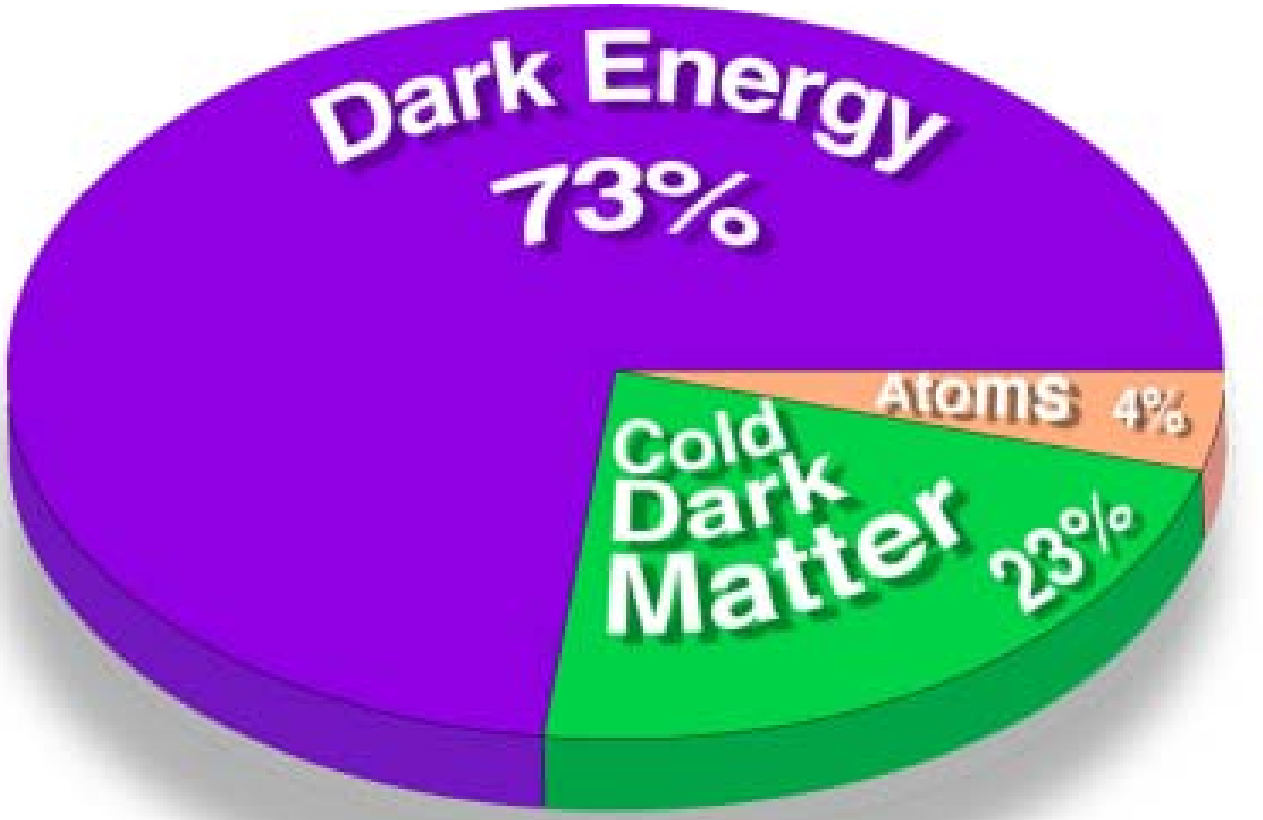
Where did all the antimatter go?

A phenomenon called “CP violation” might explain this



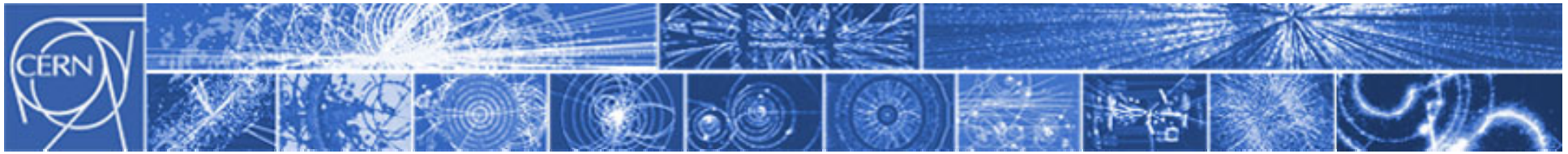
And why is the Universe “clumpy”?

What is our Universe made of?



A “new” set of particles, known as “Supersymmetric particles”, could explain the dark matter (but NOT the dark energy!)

Source: Robert Kirshner
Source: NASA/WMAP Science Team



How ?

The tools of the trade

1. Accelerators : powerful machines capable of accelerating particles up to extremely high energies and bringing them into collision with other particles.

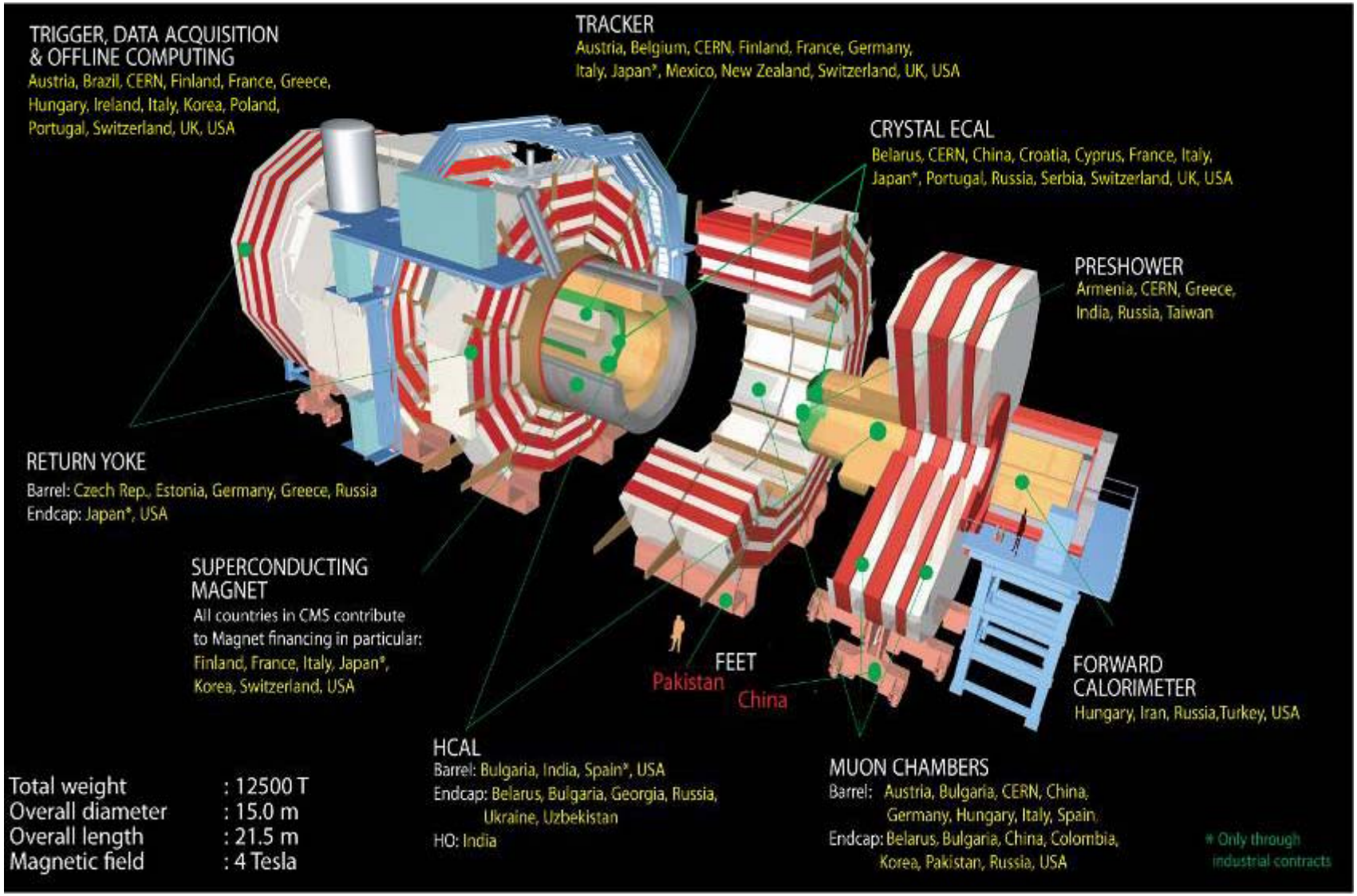
2. Detectors : gigantic instruments recording the particles spraying out from the collisions.

3. Computers : collecting, stocking, distributing and analysing the enormous amounts of data produced by the detectors.

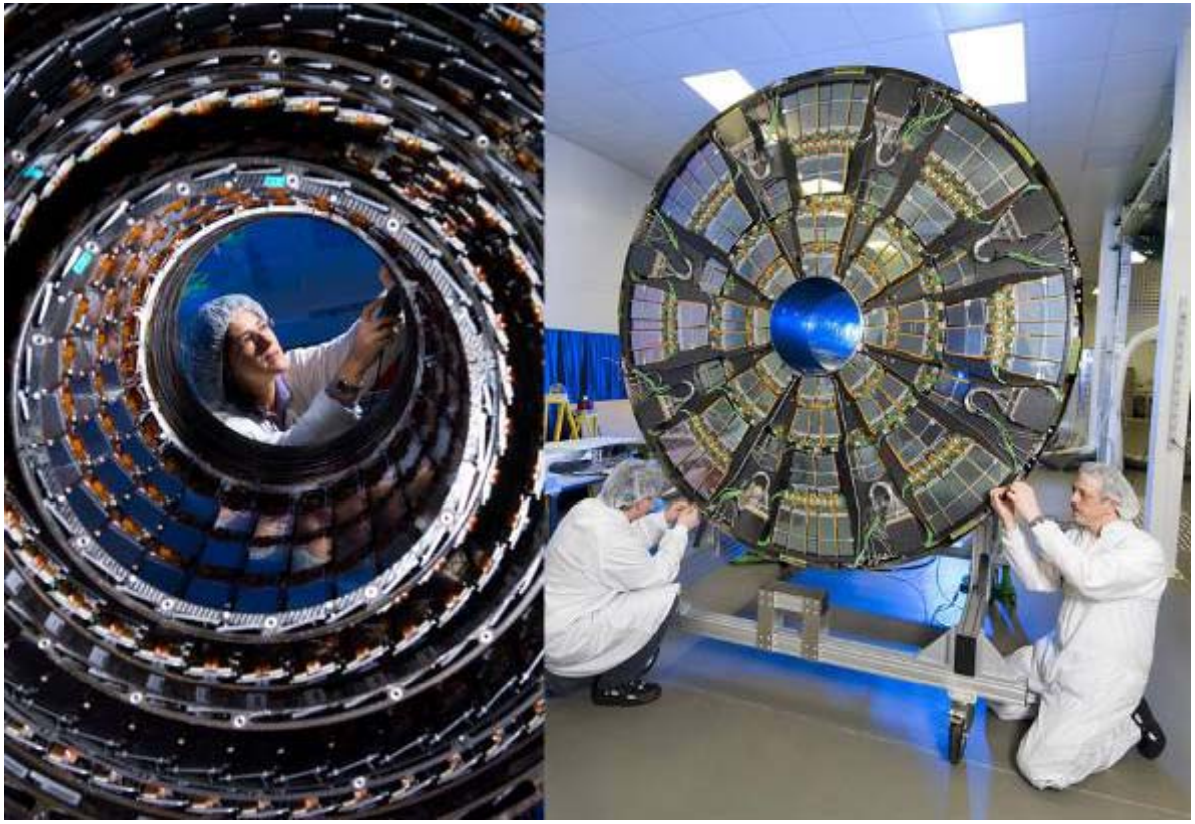
4. People : Only a collaboration of thousands of scientists, engineers, technicians and support staff can design, build and operate these amazing machines

The 27km LHC in its tunnel 100 m underground

The Compact Muon Solenoid (CMS) experiment in Cessy



Silicon Tracker

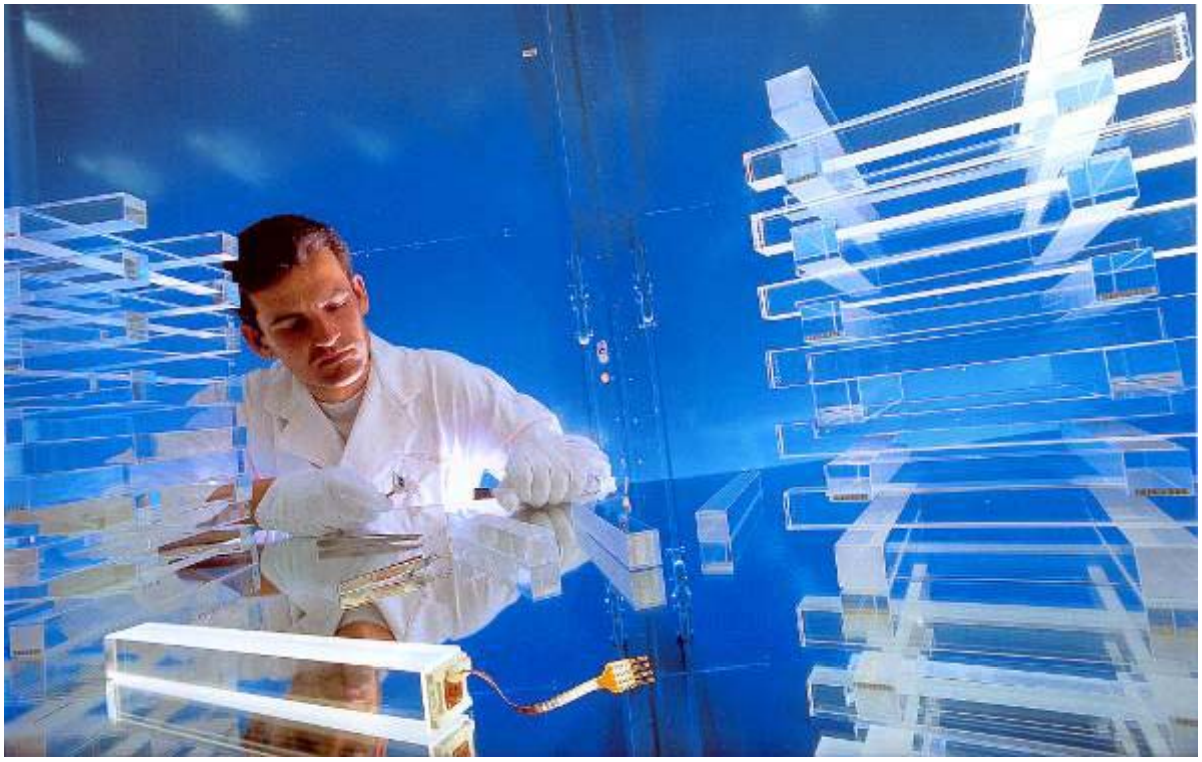


Finely segmented silicon sensors (strips and pixels) enable charged particles to be tracked and their momenta to be measured

Similar to a 70 Megapixel digital camera taking 40 million pictures per second!

Purpose: measure trajectories & momenta of charged particles

Electromagnetic Calorimeter (ECAL)

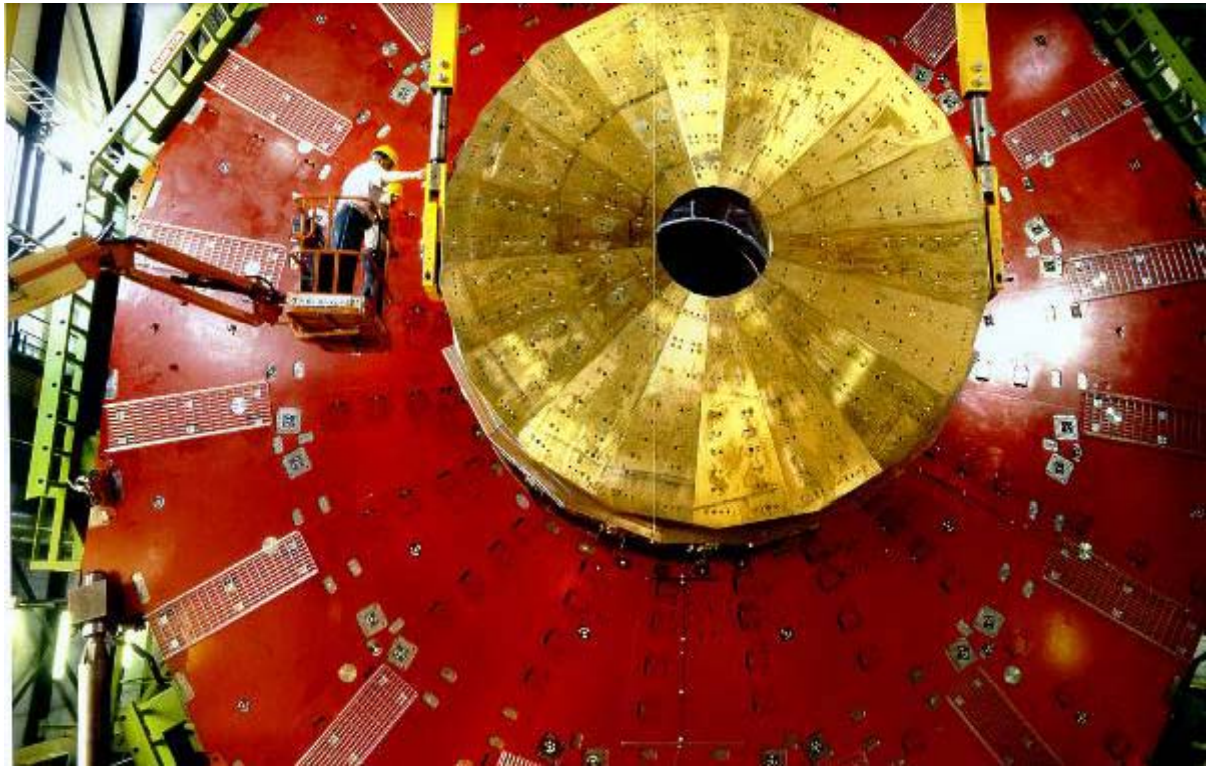


80000 crystals of $PbWO_4$ (lead tungstate) produce light from incident particles. The amount of light depends on the energy of the incoming particle

~80% metal – transparent!

Purpose: measure energy of electrons, positrons and photons

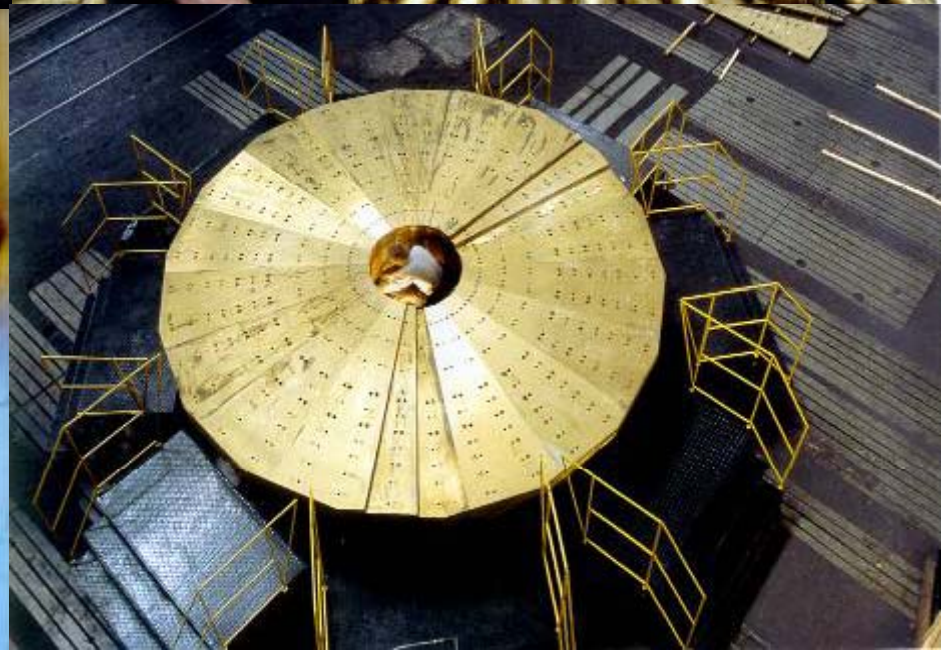
Hadron Calorimeter (HCAL)



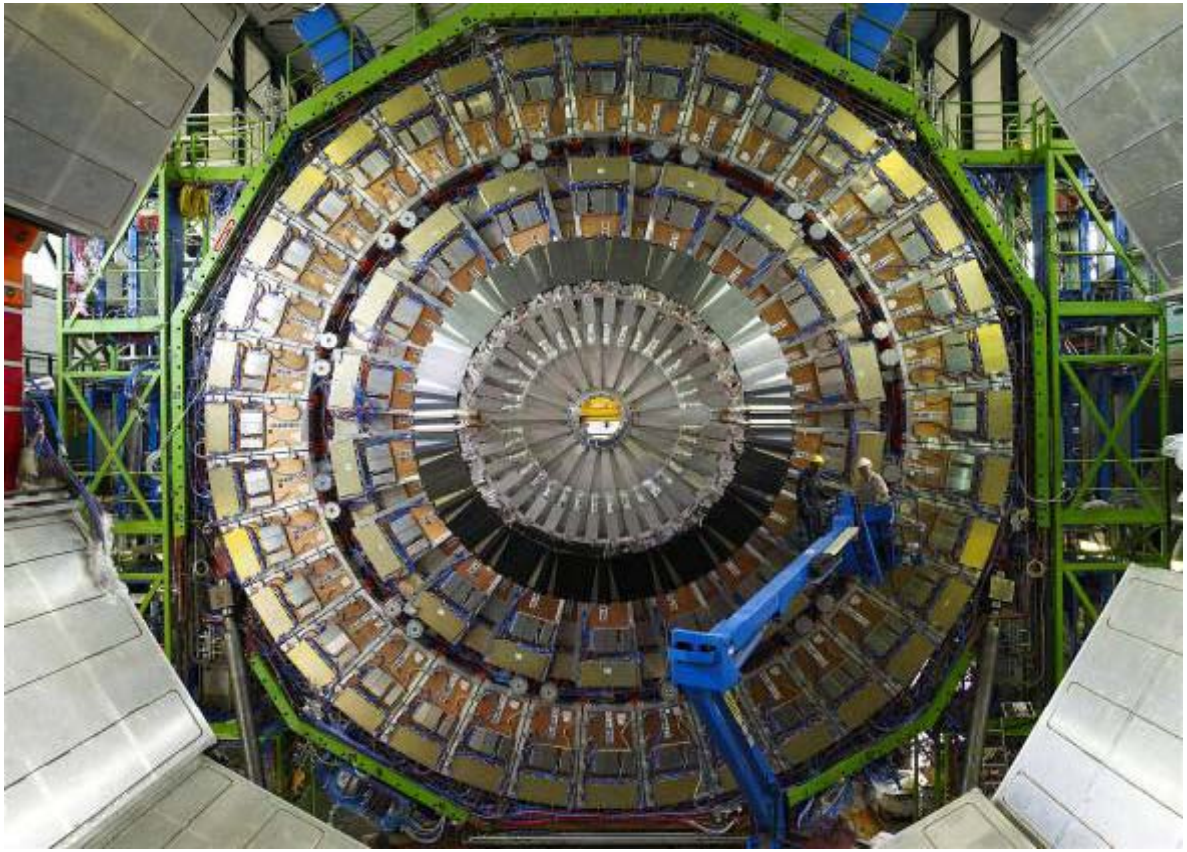
Layers of dense material (brass or steel) interleaved with plastic scintillators or quartz fibres.

Weapons to ploughshares: Brass for endcap HCAL recuperated from Russian warships!

Purpose: measure energy of hadrons (e.g. protons, neutrons..)



Muon Detectors



CMS uses three types of muon detector: drift tubes, cathode strip chambers and resistive plate chambers.

Total area of detectors is about the same as a football pitch – 6000m^2

Purpose: identify muons and measure their momenta

Superconducting Solenoid

13m long, 6m inner diameter largest superconducting solenoid ever made.

Niobium-Titanium wires cooled to -271^{o}C carry 20000 Amps to provide a 4 teslas magnetic field – about 100000 times stronger than that of the earth

Purpose: Provide a magnetic field for bending charged particles

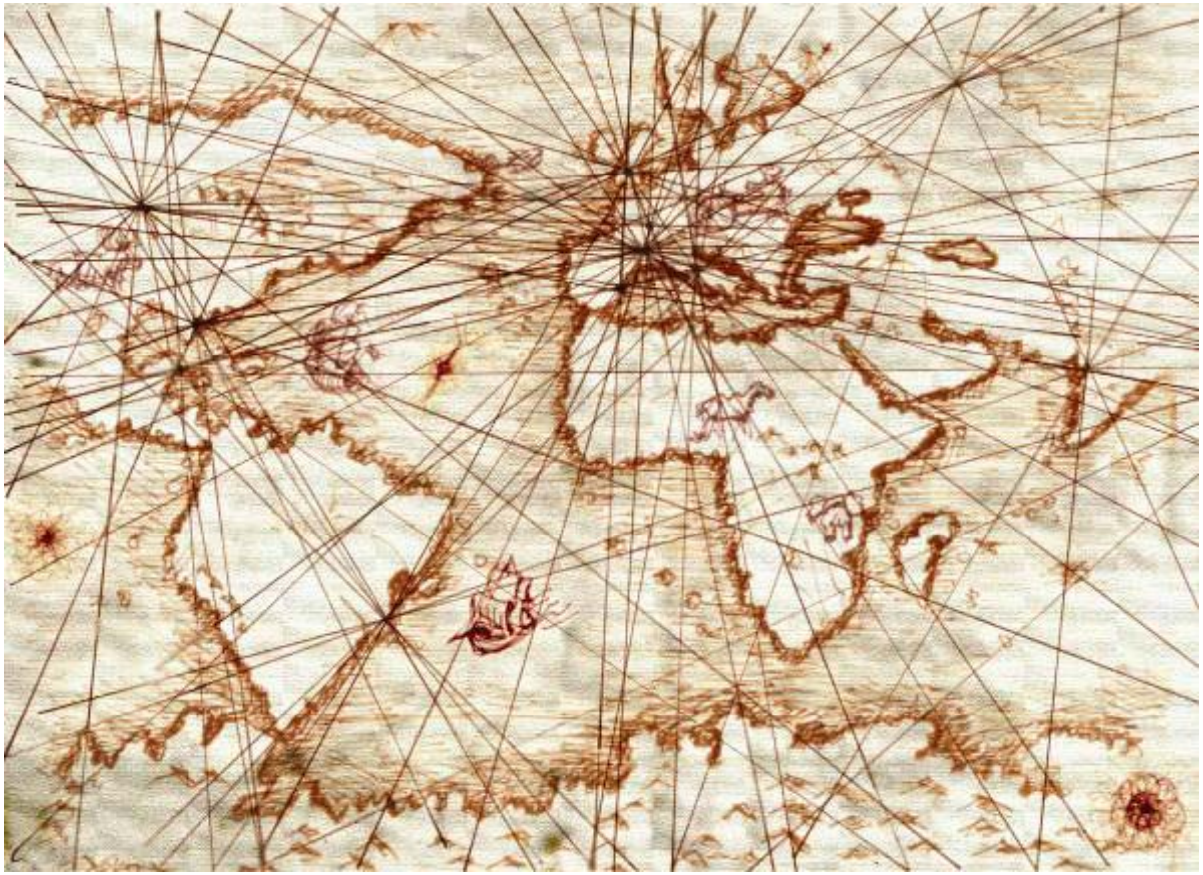
Support Structure

CMS uses more than 10000 tonnes of solid steel – by comparison the Eiffel tower only uses 7000 tonnes!

This “support foot” was made in Pakistan and travelled to CERN via train, ship and truck!

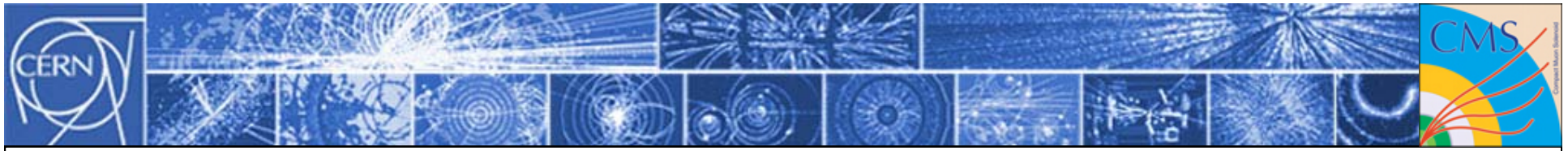
Purpose: Control magnetic field and provide mechanical support

CMS Collaboration – a Worldwide Adventure



38 Countries
155 Institutes
More than 2000 scientists and engineers
About 450 students

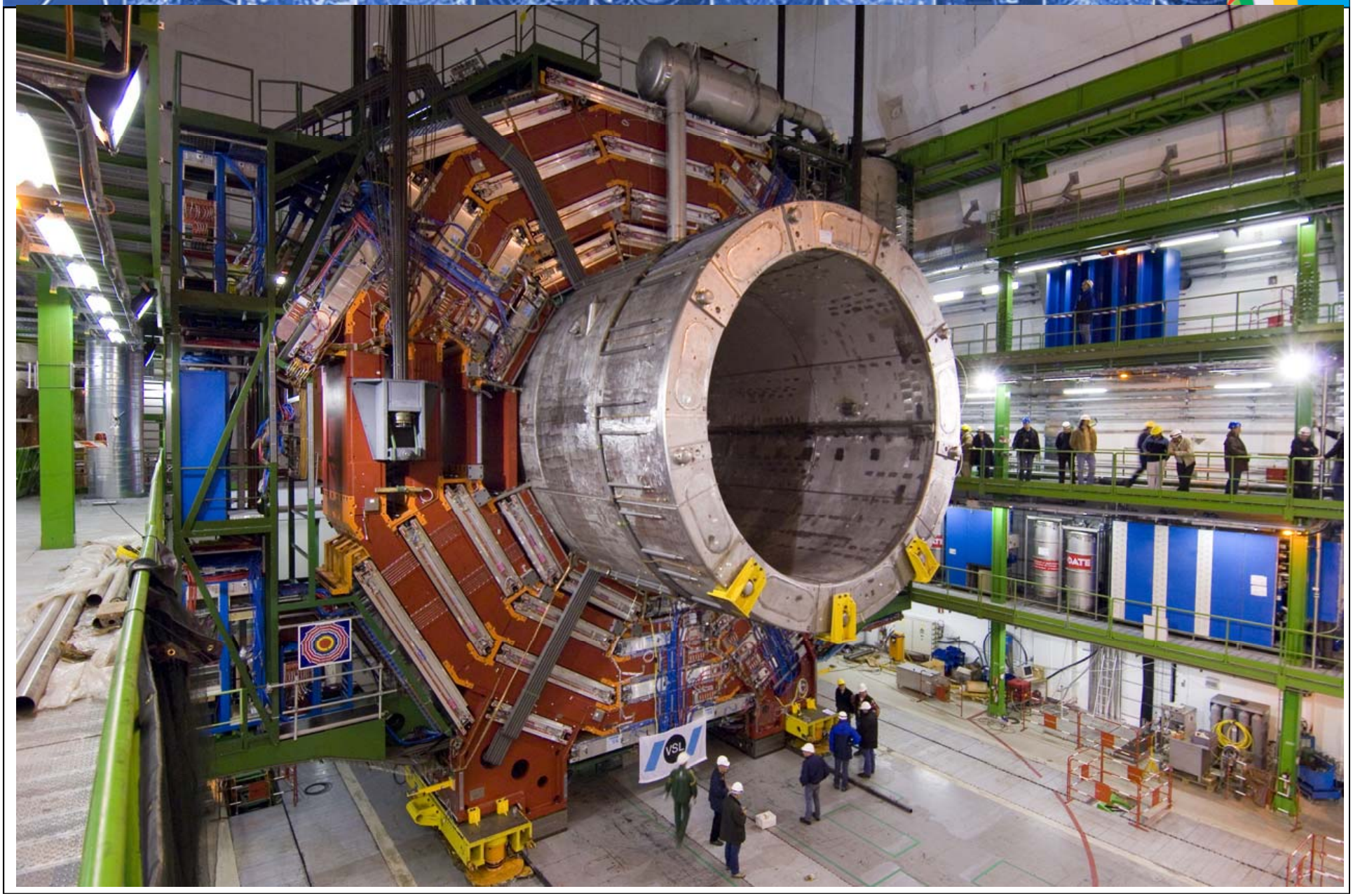
Purpose: Design, construct, assemble, test and operate CMS



Assembly and Lowering

Components were designed, assembled and tested all around the world before being brought to CERN

Large pieces were assembled in the surface hall before being lowered 100m underground


VSL

CMS in the cavern

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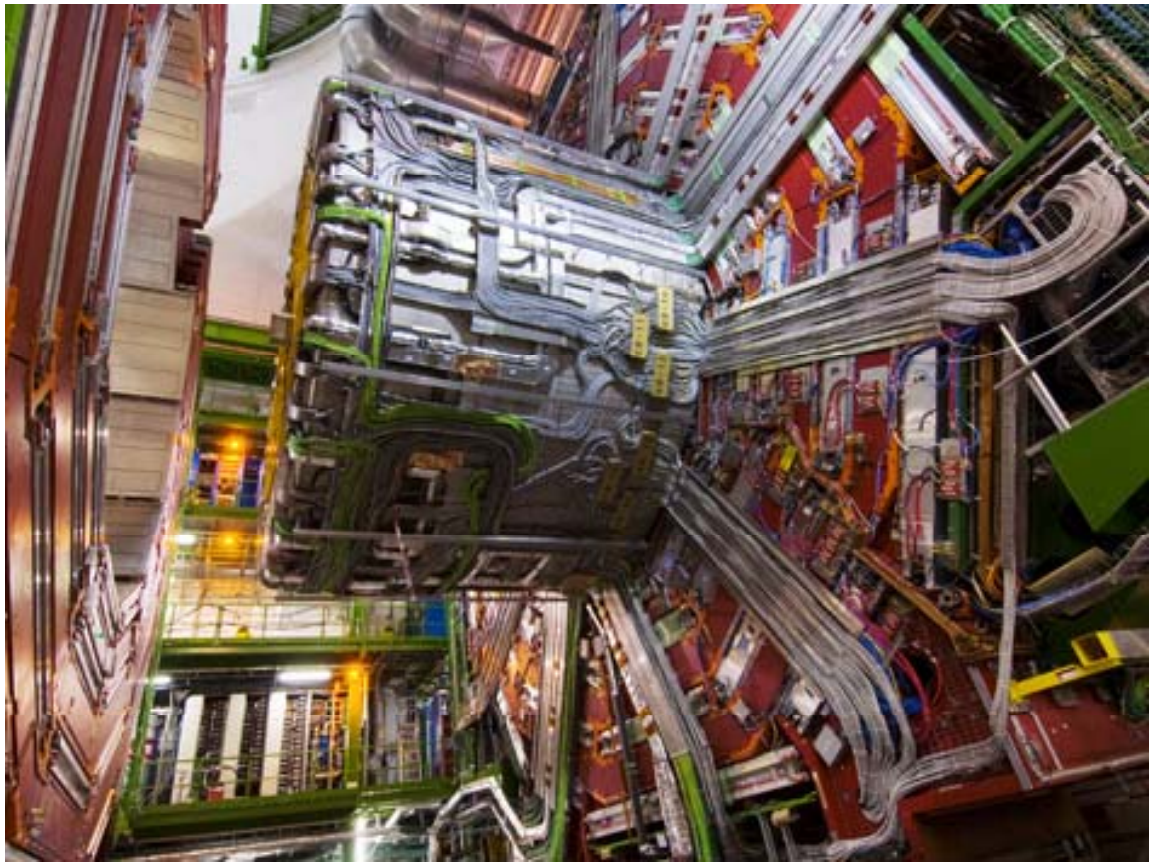


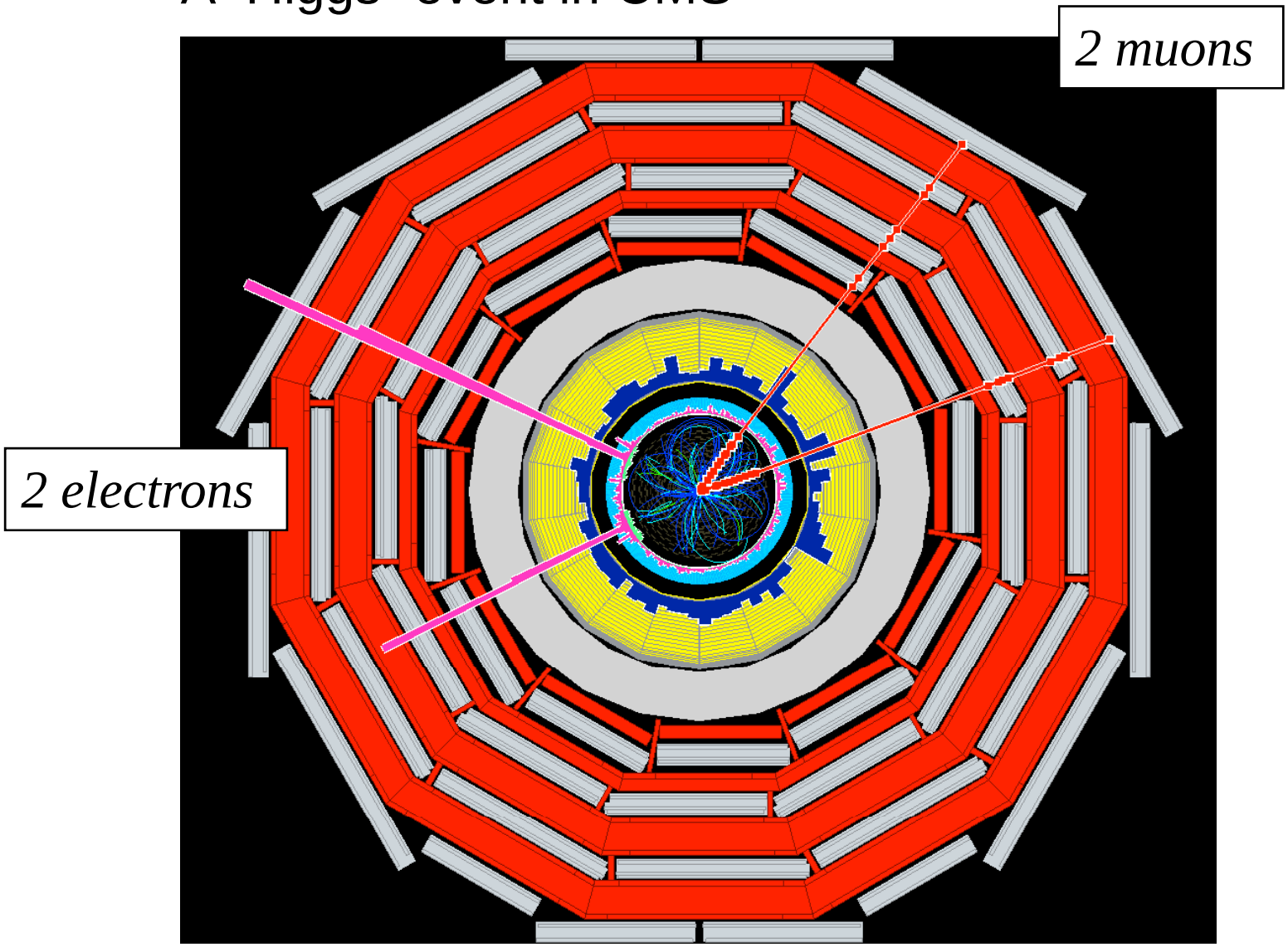
Most parts of CMS are now underground.

Once underground, all cabling, piping etc. takes place – 250km and 50000 man-hours for the central part alone!

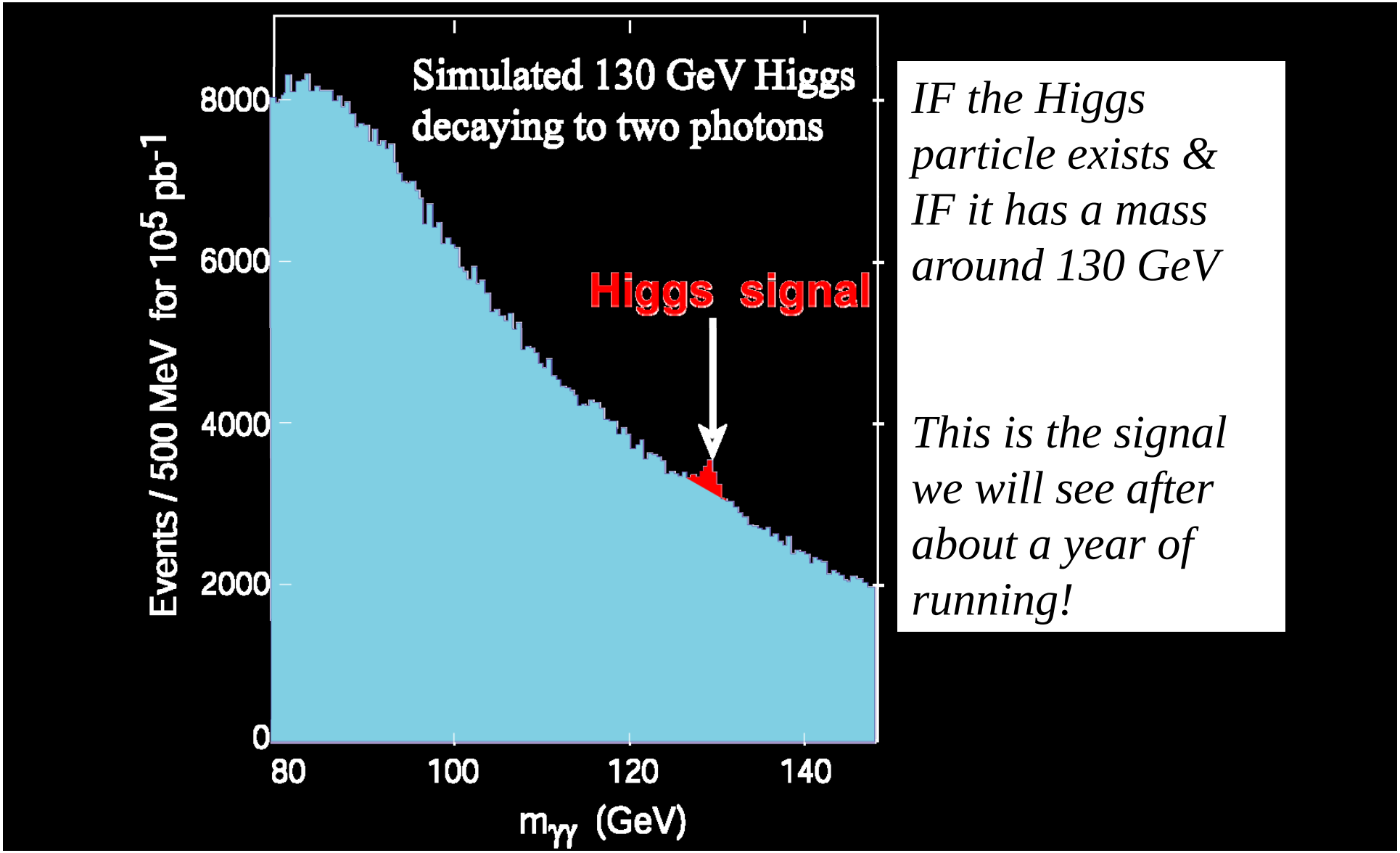
All detectors are then tested extensively with cosmic rays prior to LHC switch-on later this year

Purpose: Prepare for data taking!

A “Higgs” event in CMS

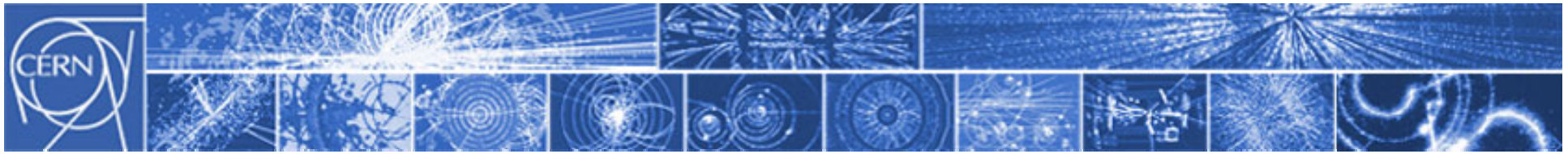


The “physicist’s gold”



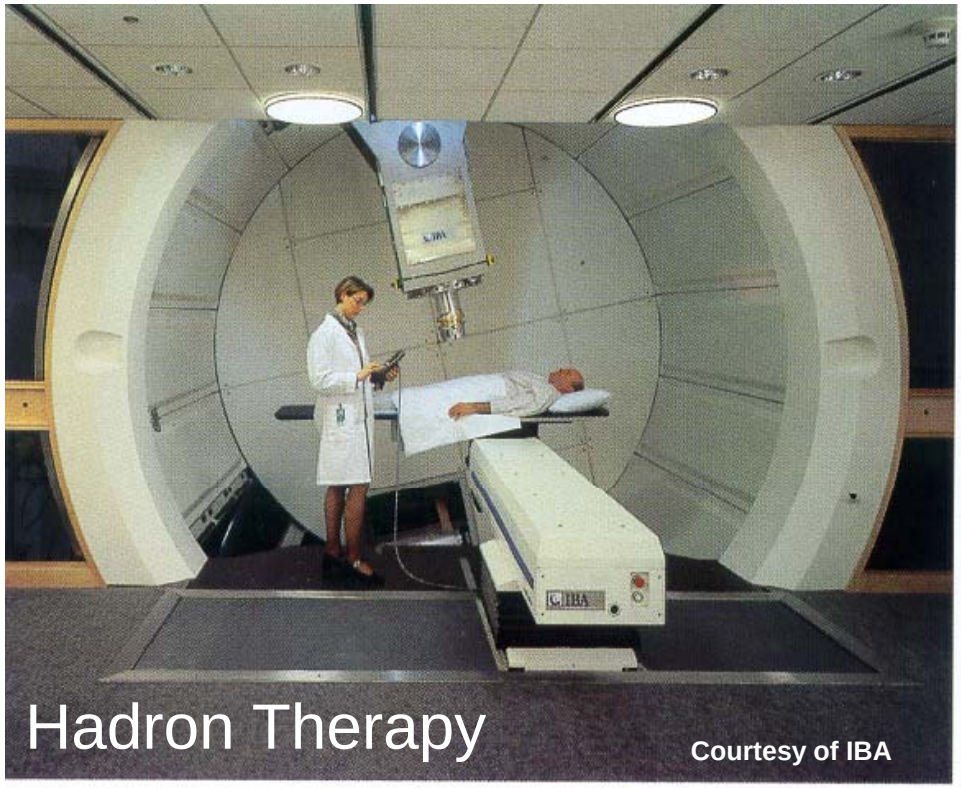
IF the Higgs particle exists & IF it has a mass around 130 GeV

This is the signal we will see after about a year of running!



But what does CERN and its particles, accelerators and detectors have to do with everyday life?

Accelerators: developed in physics labs are used in hospitals

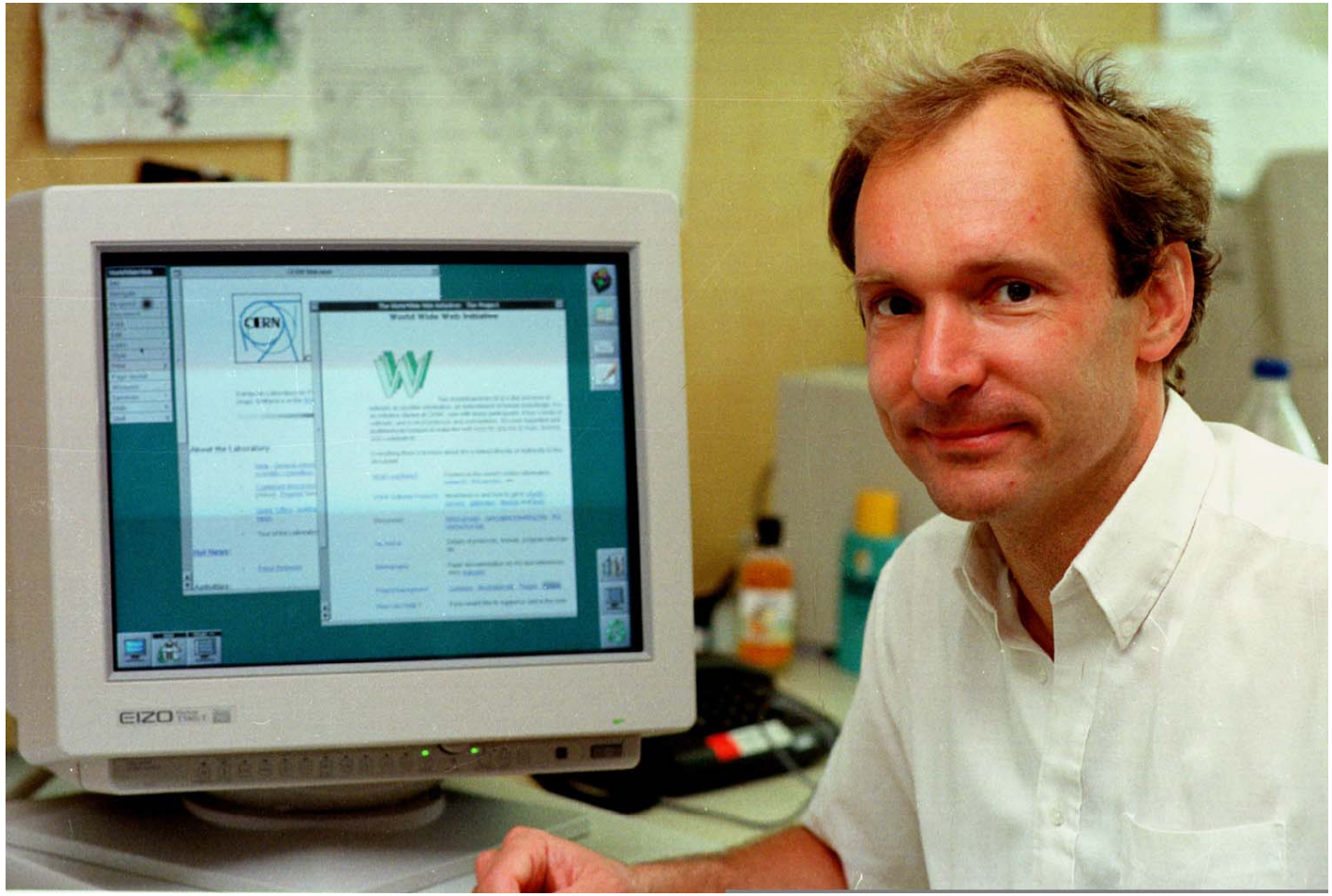


Around 9000 of the 17000 accelerators operating in the World today are used for medicine.

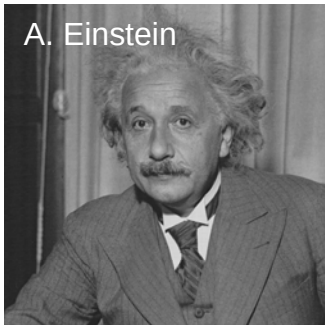
Detectors: developed in physics labs are used for medical imagery

PET (Positron Emission Tomography) is a very important technique for localising and studying certain types of cancer using the Fluor-18 isotope produced by particle accelerators. PET uses antimatter (positrons).

Other spinoffs include… WWW



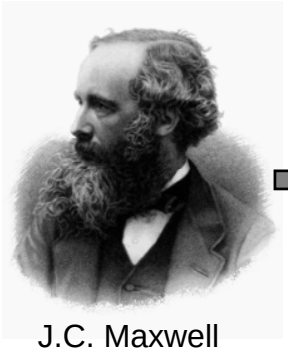
Fundamental research has always been a driving force for innovation



Relativity

100% SCIENCE

For GPS to work, we have to take into account the correction due to time dilation. Otherwise, there would be a position error of around 10m after just 5 minutes of travel-time!

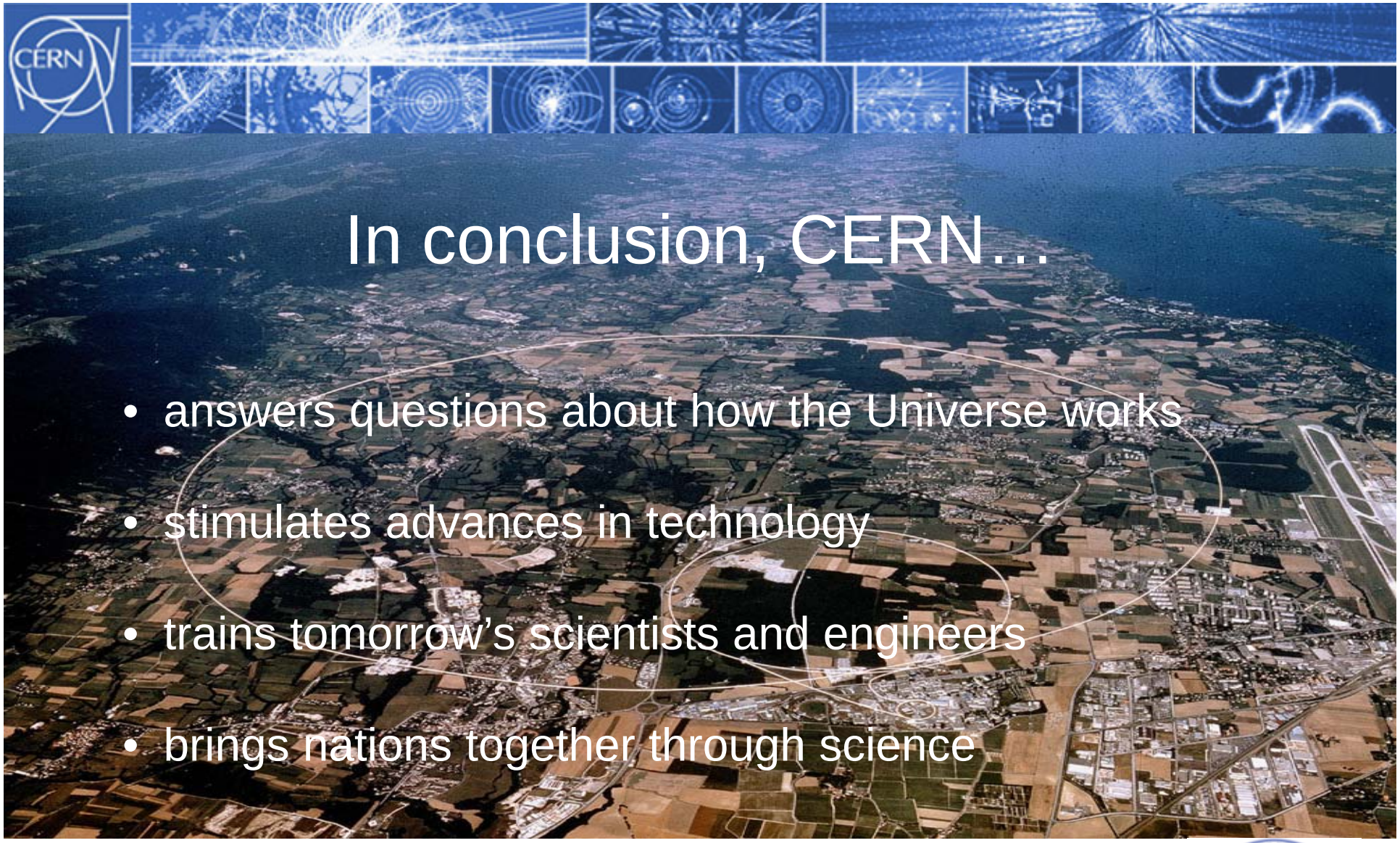


J.C. Maxwell

Electromagnetism

100% SCIENCE

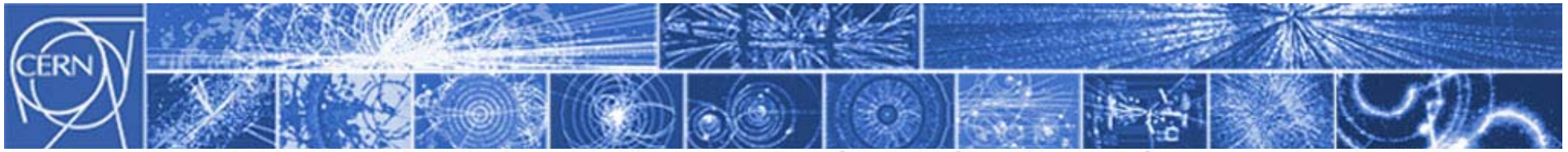
Telephones use electromagnetic waves to communicate



In conclusion, CERN…

- answers questions about how the Universe works
- stimulates advances in technology
- trains tomorrow's scientists and engineers
- brings nations together through science

LHC 2008



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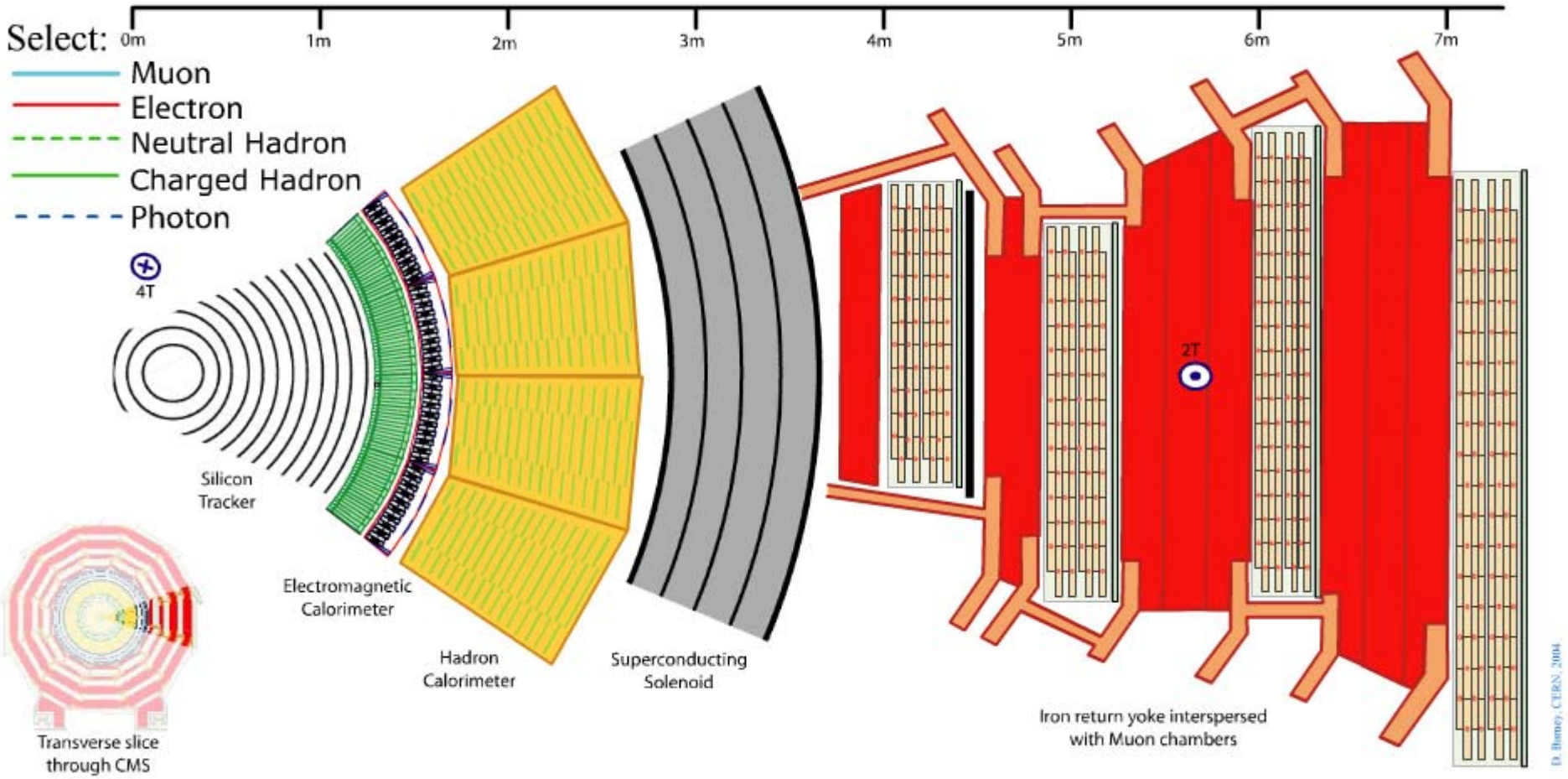
Organisation Européenne pour la Recherche Nucléaire

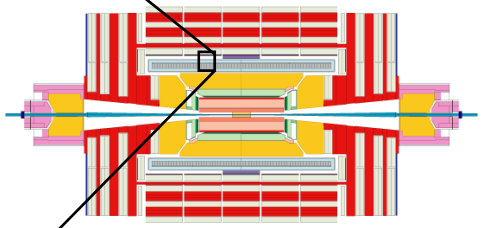
SPARE

Lavered structure of CMS

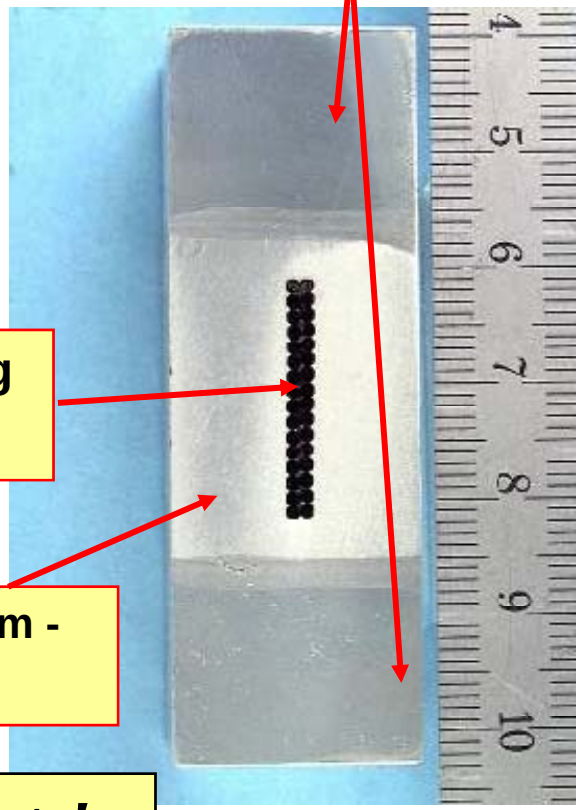


Superconducting Solenoid 1: cable

Solenoid piece at Cessy



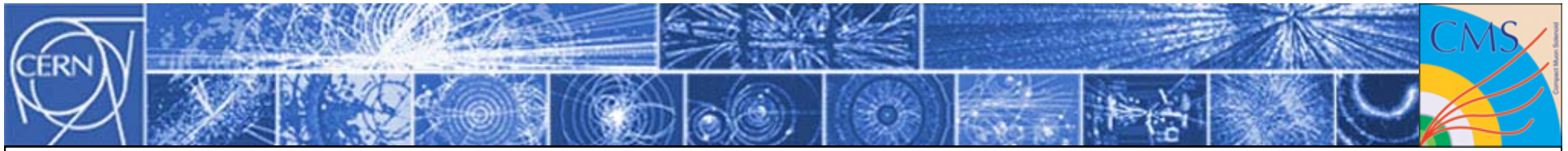
Aluminium alloy - mechanical stabilizer



Superconducting cable - NbTi

Ultra-pure Aluminium - magnetic stabilizer

Approx: 1 million km of NbTi filaments!



Superconducting Solenoid 2: major components

7 main parts:

- Outer vacuum tank: made in 3 pieces, assembled at CERN
- Inner vacuum tank: single piece transported to CERN from ~120km away in the Jura
- Solenoid itself: 5 coils, welded to each other

Also a huge “return yoke”

- ~10500 tonnes of solid steel pieces surround the solenoid to control the magnetic field
- Also act as the “skeleton” of CMS
- Yoke is divided into 5 barrel rings and 6 endcap disks (3 on each side)

Superconducting Solenoid 3: assembly