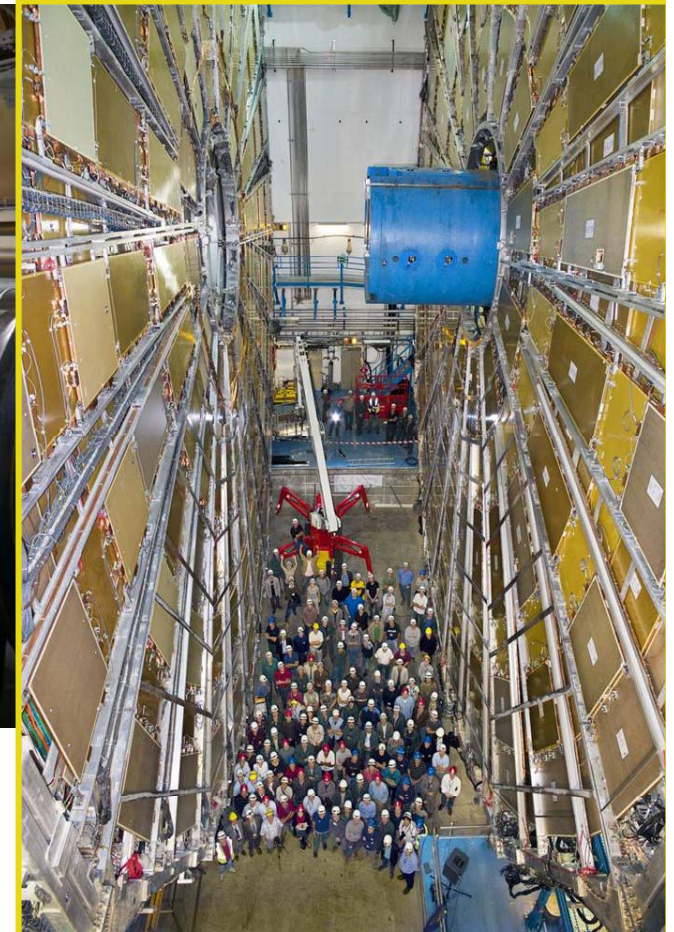
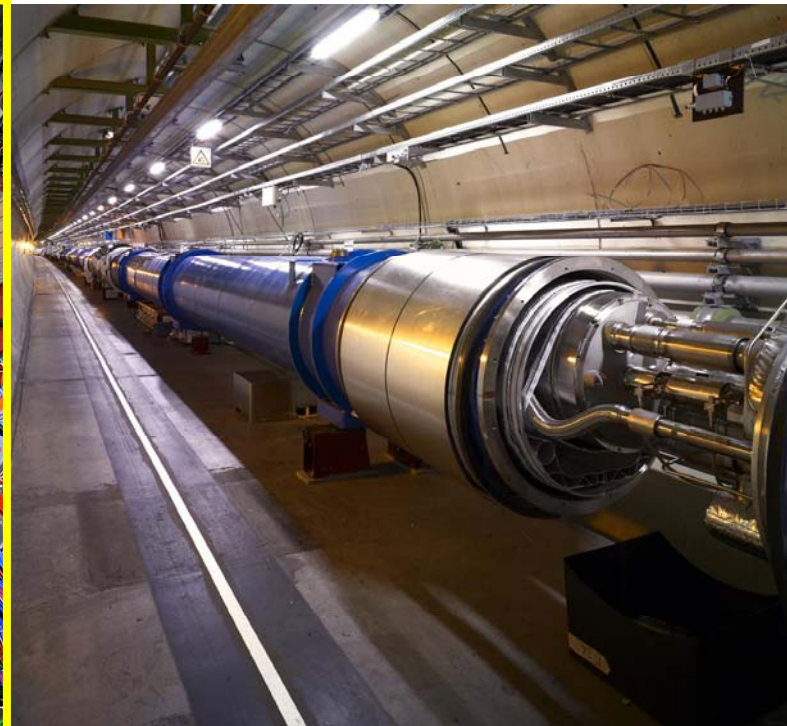




The LHC Experiments



GRID Fest CERN, 3rd October 2008



Introduction
LHC Experiments:
Detectors, Computing
Prospects for Discoveries

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CERN/Imperial College

T. Virdee, GridFest

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Particle Physics



Particle physics is THE modern name for centuries old effort to understand the laws of nature..

Aims to answer the two following questions:

What are the **elementary constituents** of matter ?

What are the **forces** that control their behaviour at the most basic level?

Experimentally

Get particles to interact and study the resulting products and features.
Measure the energy, the direction and the identity of these products as precisely as possible.



This Requires.....



1. Accelerators : powerful machines that accelerate particles to extremely high energies and then bring them into collision with other particles

2. Detectors : gigantic instruments that record the resulting particles as they “stream” out from the point of collision.

3. Computers : to collect, store, distribute and analyse the vast amount of data produced by the detectors

4. People : Only a worldwide collaboration of thousands of scientists, engineers, technicians and support staff can design, build and operate the complex “machines”



CERN Site



Large Hadron Collider
27 km circumference

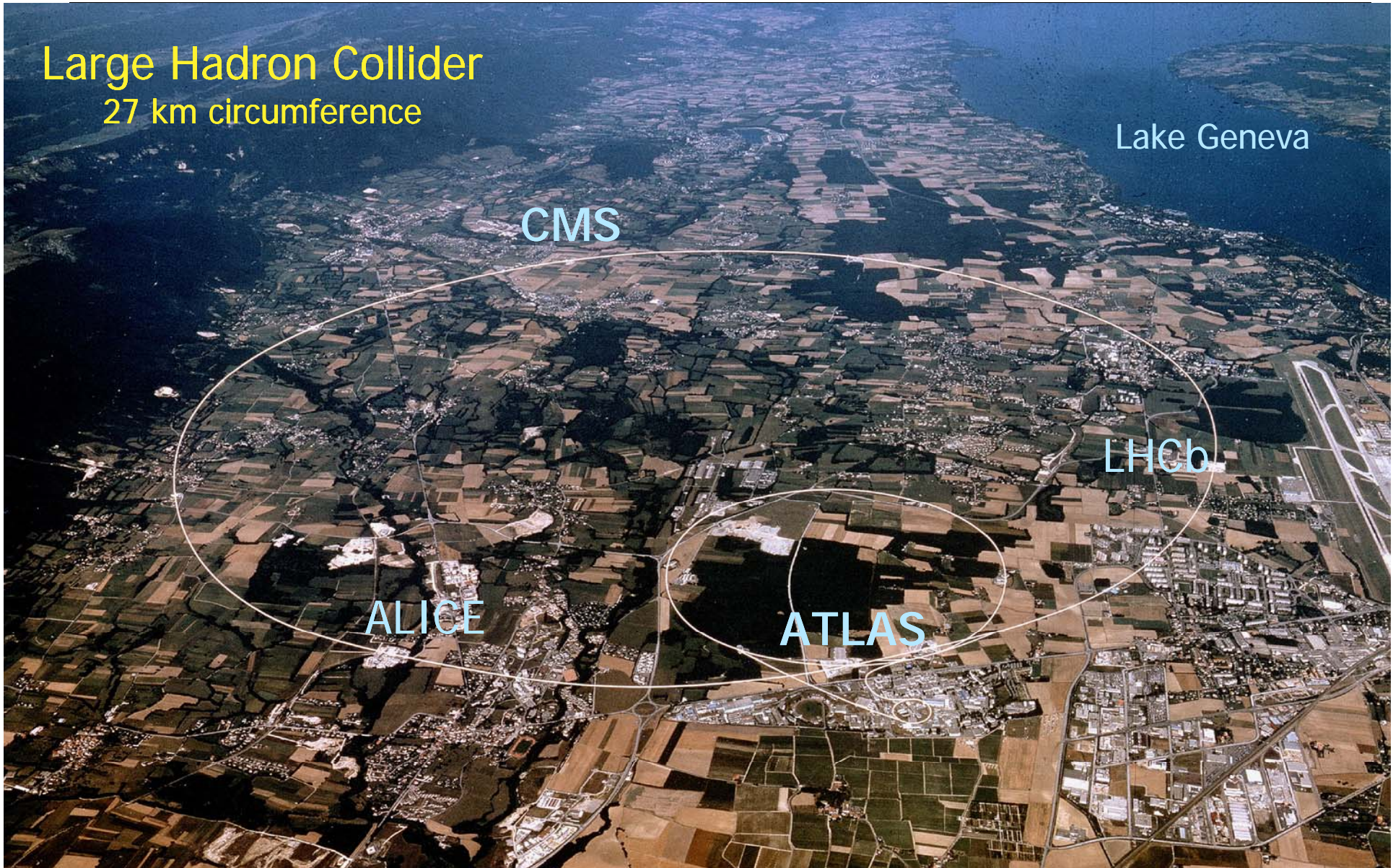
Lake Geneva

CMS

LHCb

ALICE

ATLAS





Experimental Challenge



Bunches, each containing 100 billion protons, cross **40 million times a second** in the centre of each experiment

1 billion proton-proton interactions per second in ATLAS & CMS !

Large Particle Fluxes

~ 1000 tracks stream into the detector every 25 ns

⇒ large number of channels (~ **100 M ch**) ⇒ ~ 1 MB/25ns i.e. **40 TB/s** !

High Radiation Levels

⇒ radiation hard (tolerant) detectors and electronics



General Purpose LHC Experiments



Physics requirements drive the design

Analogy with a cylindrical onion:

Technologically advanced detectors comprising many layers, each designed to perform a specific task.

Together these layers allow scientists to identify and precisely measure the energies/momenta of all the particles produced in collisions.

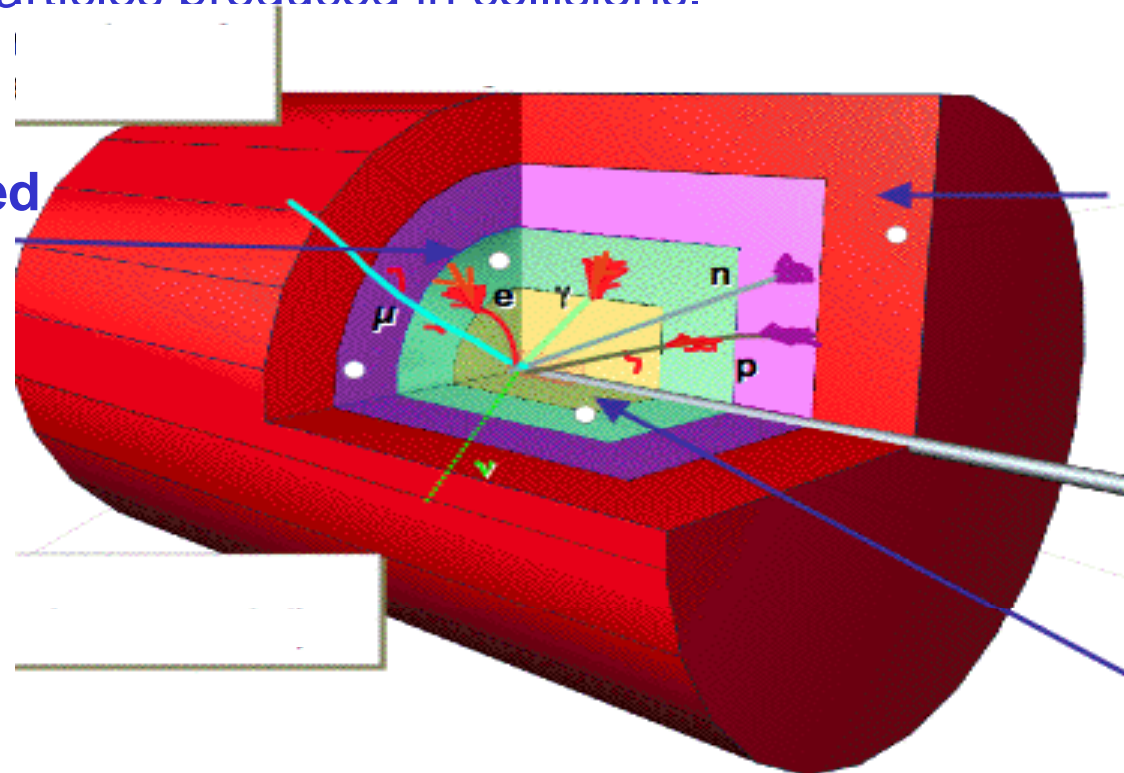
Species of Particles Observed

Photons,
Electrons,
Muons,
Quarks

(as jets of particles)

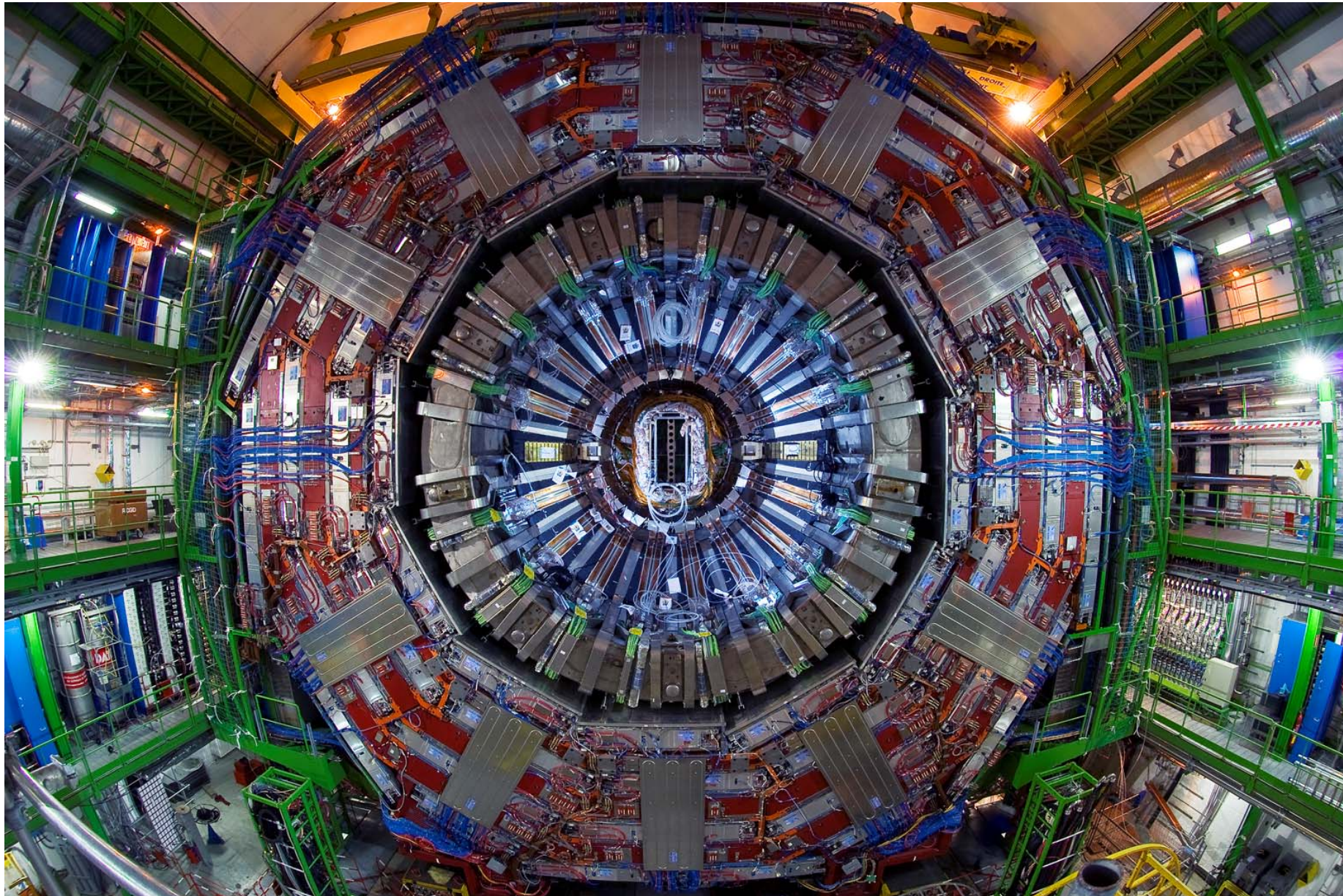
Neutrinos

(as missing energy (E_T))



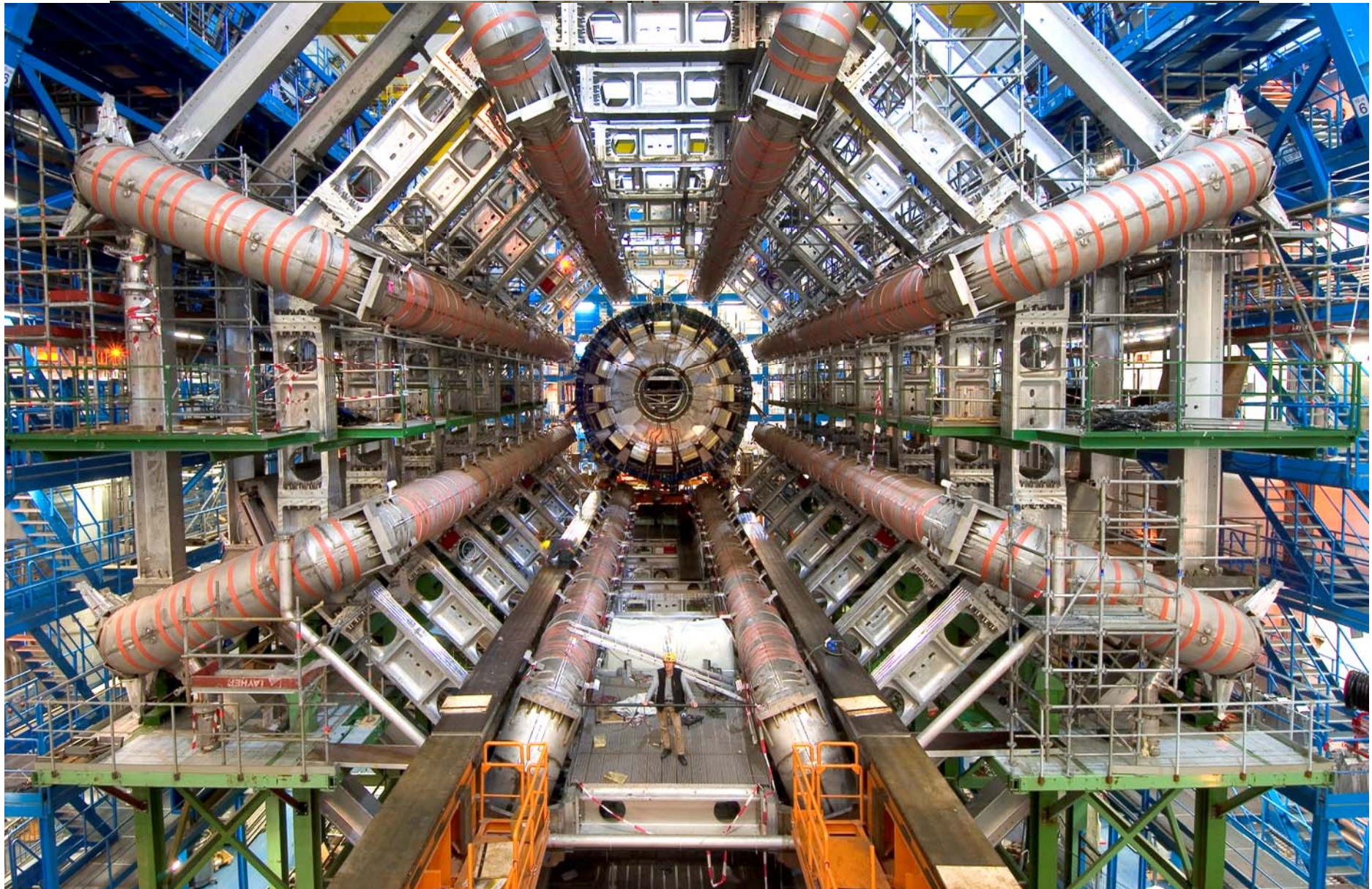


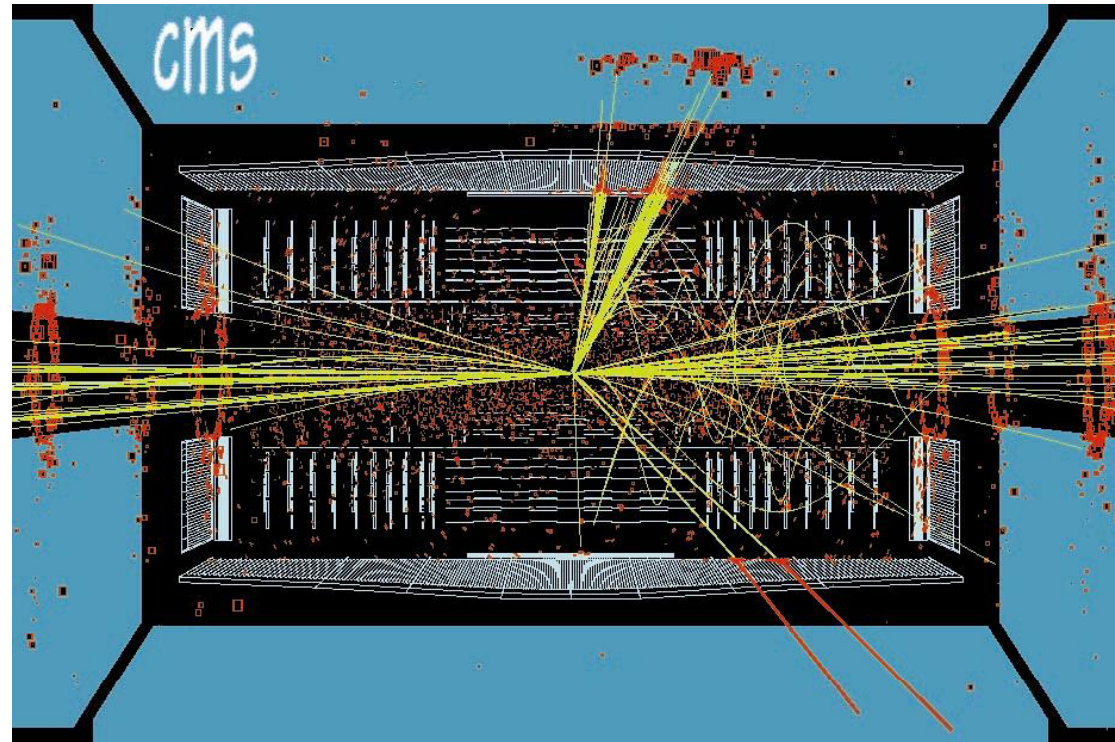
Transverse cut of an LHC Experiment





The Toroidal System of Magnets of ATLAS

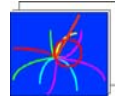




- Cannot possibly extract and record 40 TB/s. Essentially 2 stages of selection
- dedicated custom designed hardware processors \Rightarrow 40 MHz \rightarrow 100 kHz
 - then each 'event' sent to a free core in a farm of \sim 30k CPU-cores \Rightarrow 100 kHz \rightarrow few 10^2 Hz



Acquiring and Recording Data of Interest



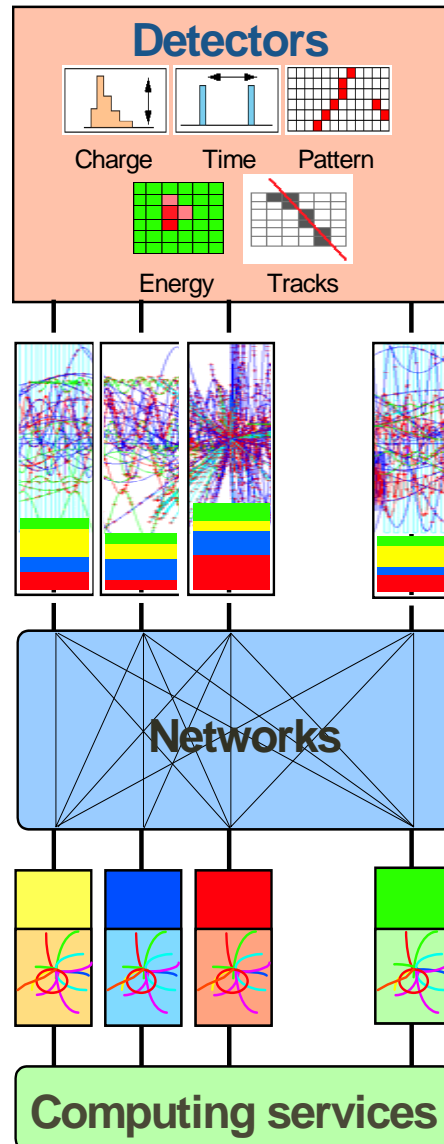
40 MHz
COLLISION RATE

100 kHz
LEVEL-1 TRIGGER

1 Terabit/s
(50000 DATA CHANNELS)

500 Gigabit/s

Gigabit/s SERVICE LAN



Analogy

With a 100 Mpix 3-D digital camera
40M shots/sec (of events occurring 1/100 of
a ns after the Big Bang)

First selection reduces this to 100k shots/s

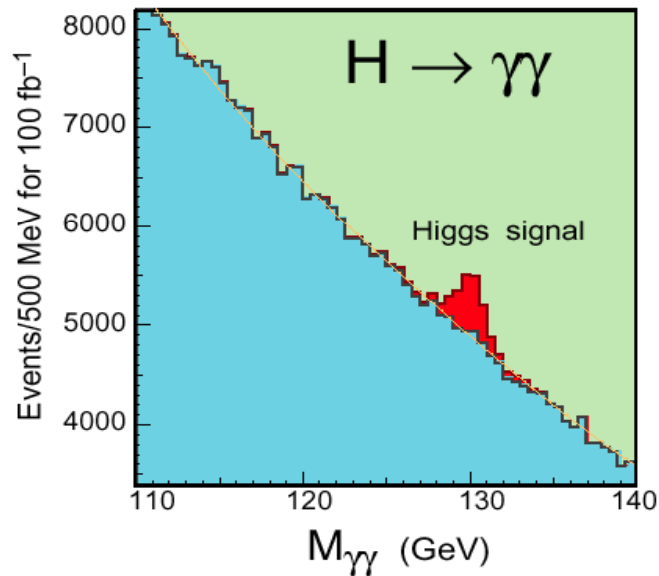
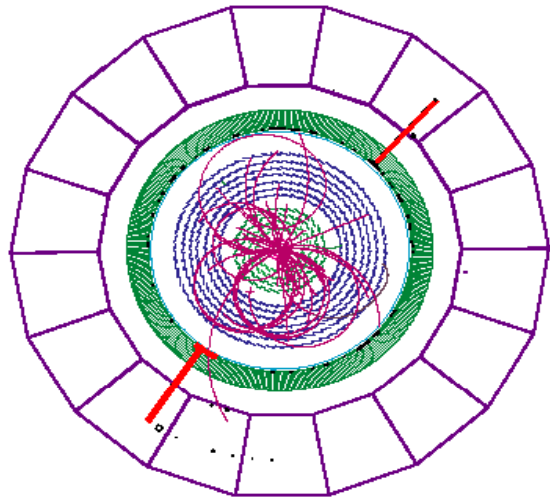
Each photo (~ MB)

- taken in ~ 500 different parts
- put together using a telecommunications 'switch'
- analysed in a CPU
(in a farm of ~ 50000 cores)

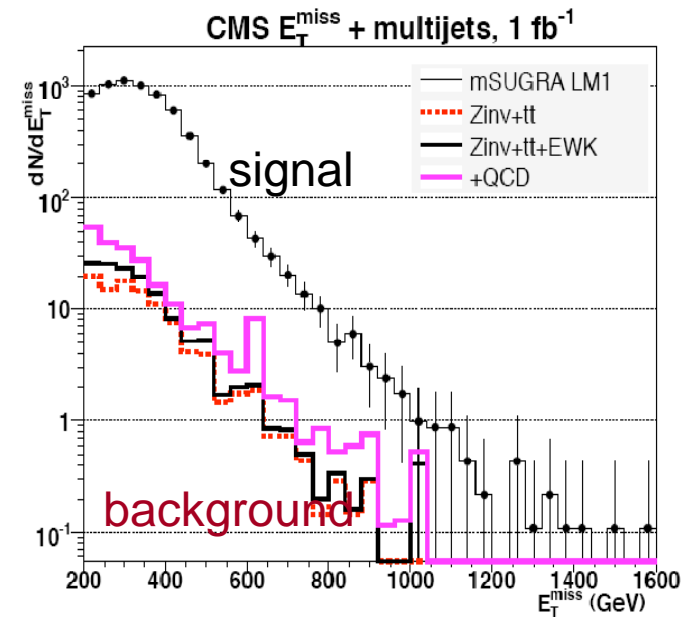
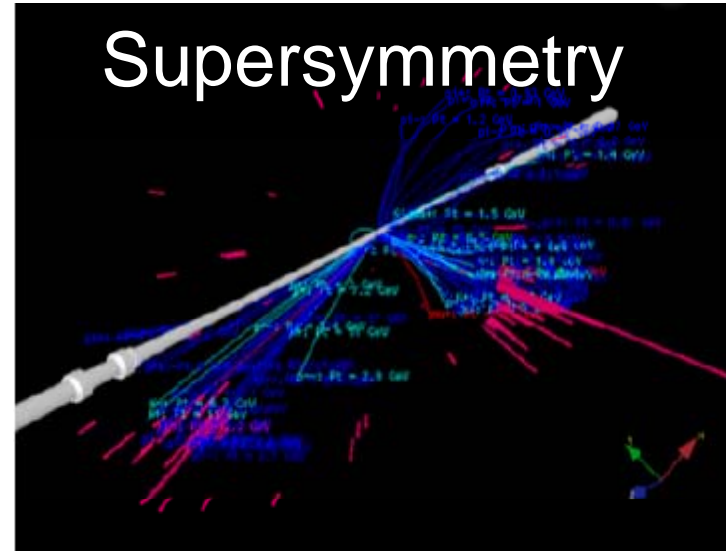
Only a few hundred photos stored on mass
storage.

~ 10 PB/year (3 M DVDs/year)

Higgs Boson



Supersymmetry





Experiment Control Rooms: First Beam

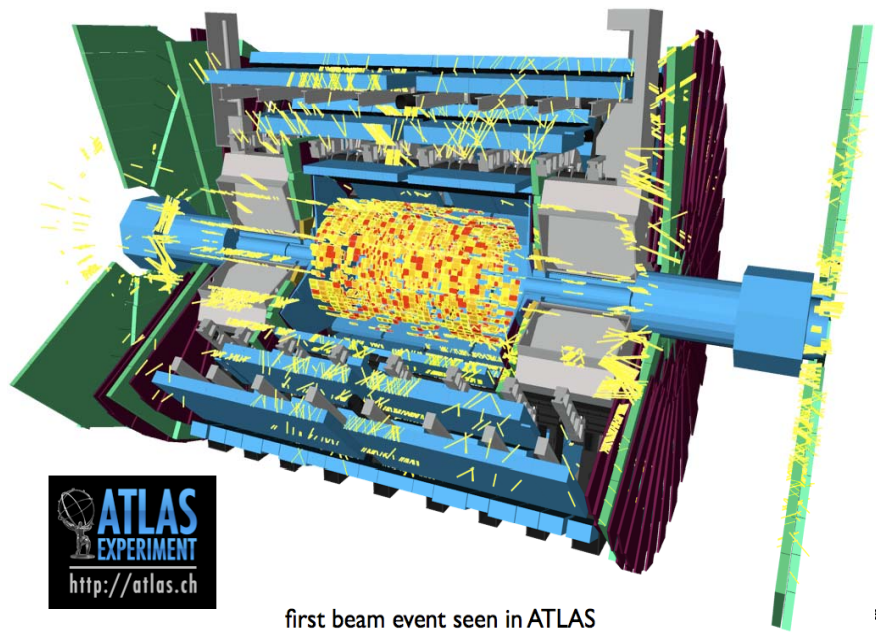
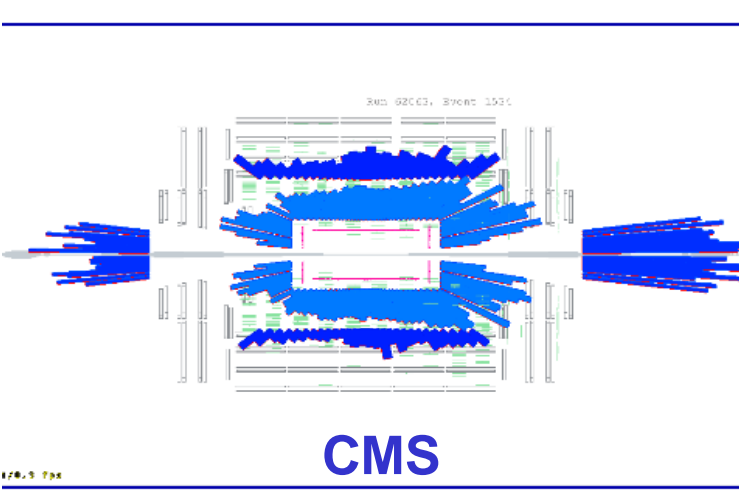
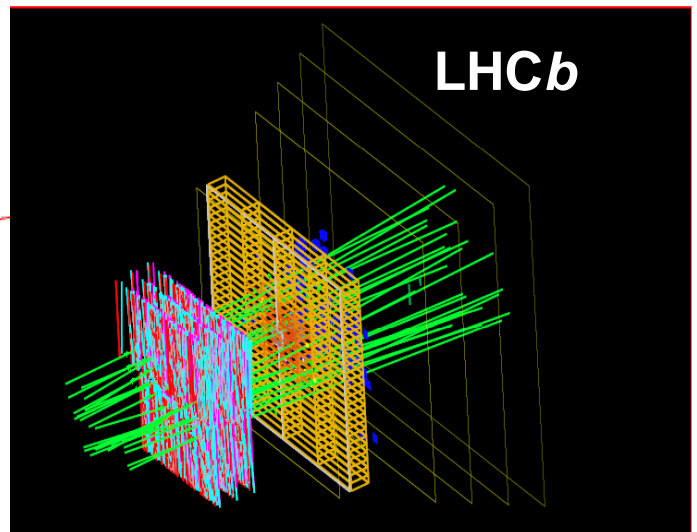
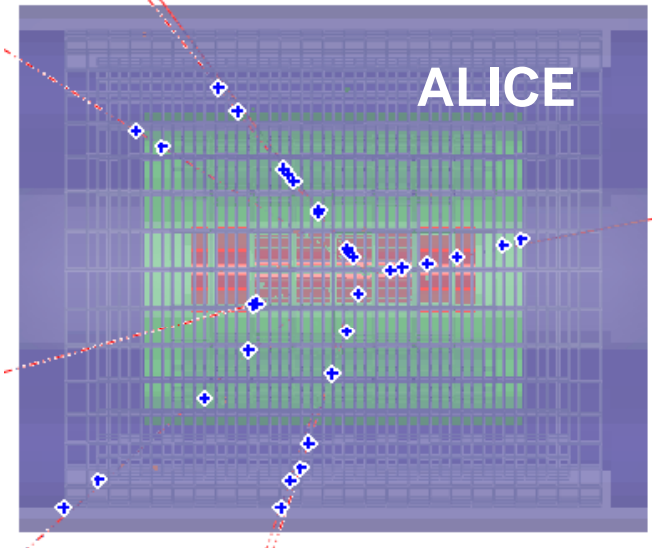


10 Sept. 2008



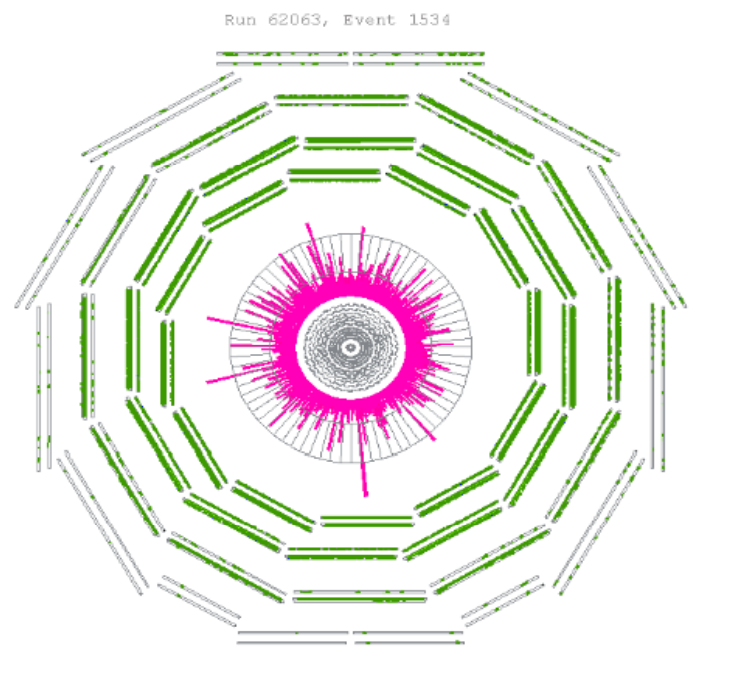


First Events



first beam event seen in ATLAS

e, GridFest





Summary



- The LHC project (the accelerator and experiments) was conceived & designed to attack key questions in particle physics (and science).
- The LHC accelerator and the experiments are unprecedented in complexity and will operate in an unprecedented & hostile environment.
- Driven by the science many technologies have been pushed to their limits.
- The Computing Grid is essential for the extraction of science from the LHC.
- The Project has required a long and painstaking effort on a global scale.
- The accelerator and the experiments are unparalleled scientific instrument(s) - powerful “microscopes” as well as powerful “telescopes”.
- All indications are that the experiments can work well and according to specifications. Data taking will restart in Spring 2009.

All expectations are that what we find at the LHC will reform our understanding of nature at the most fundamental level.

Only experiments reveal/confirm Nature's inner secrets.