The Higgs boson: what, why, how?

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To make and detect massive Higgs Bosons:

- Accelerate protons to gain kinetic energy
  (7 TeV = 7500 times rest mass.)
- Head-on collisions (7+7 TeV) destroy energy to create mass. ($mc^2 = E$) B Touschek (Glasgow)
- Detect events to capture characteristic Higgs signatures (depends on unknown Higgs mass e.g. 4μ)
- Analyse events to isolate rare Higgs production
  (1 in 10^{11} – need 40 MHz rate.)
  use computer grid = organised WWW

- Most of these figures are taken from a talk given earlier at the Royal Society of Edinburgh by Fabiola Gianotti, now spokesman of the ATLAS collaboration

- Gianotti's talk may be found at

  http://www.ippp.dur.ac.uk/Workshops/08/FRSE/gianotti.pdf

  (87 Mb)

Tevatron (USA) now taking data at 1+1 TeV.
Includes Glasgow team.

LHC startup autumn 2009 after incident

The Large Hadron Collider (LHC) at CERN

the most powerful accelerator

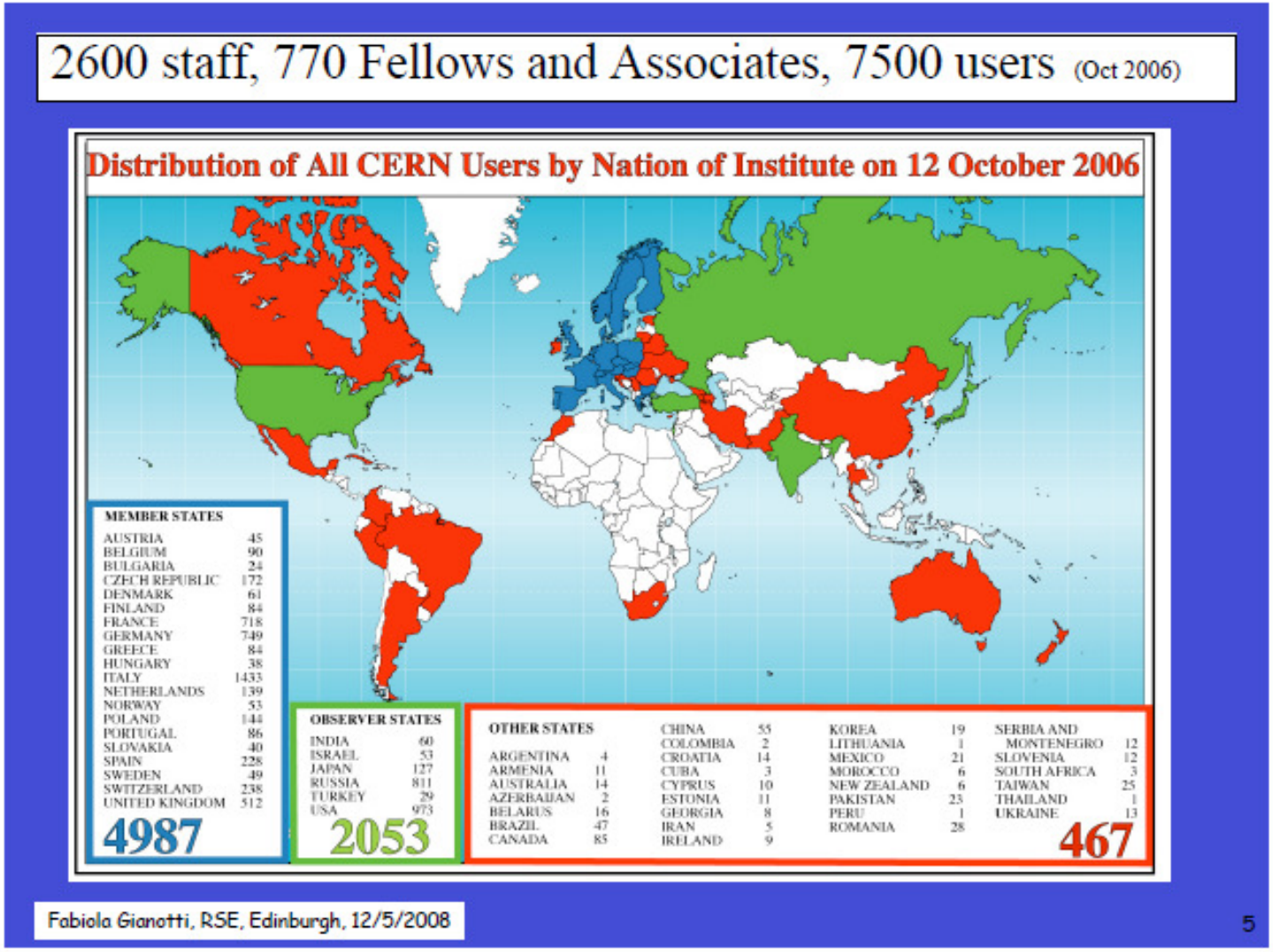
…. and also ….

the most powerful detectors
the most powerful computing infrastructure
the widest international collaboration
the most innovative concepts and technologies
(cryogenics, new materials, electronics, data transfer and storage, etc. etc…)

ever achieved in particle physics and one of the most ambitious projects in science in general !

CERN (1954 -) 20 member states + 8 observers

budget 1000 MCHF pays for facilities. We pay for detectors+exploitation

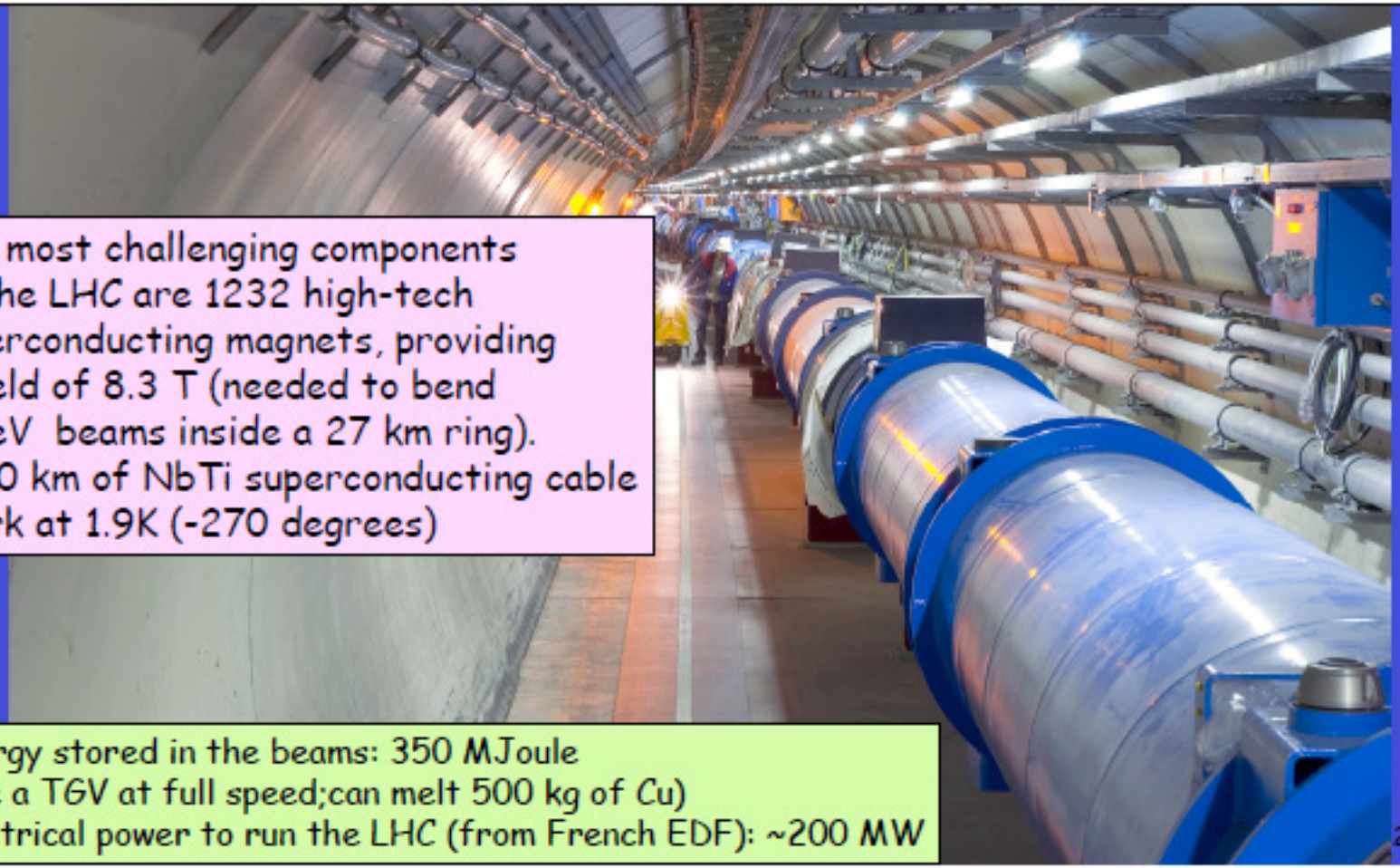


The LHC is a 27 km accelerator ring, 100 m below ground, across the French-Swiss border
Two proton beams will be accelerated in opposite directions up to speed of light.
They will collide at four points, where four big experiments have been installed.

Unprecedented energy: 7 TeV per beam particle → collision energy = 14 TeV

(1 TeV= 10^{-7} Joule)

Note: huge amount of energy concentrated in the collision point
(14 TeV corresponds to 20 1-Volt batteries for each star of our galaxy and to 10^{14} times the temperature in this room)
However: small energy on macroscopic scale (1 μJoule is just enough to swat a mosquito)



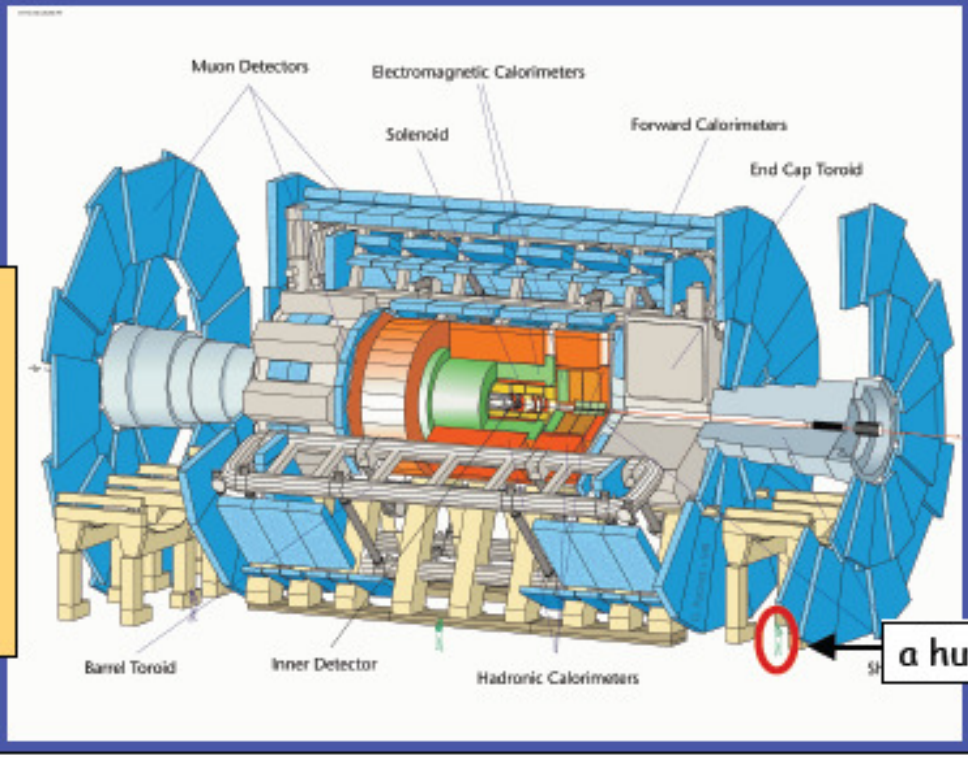
The most challenging components of the LHC are 1232 high-tech superconducting magnets, providing a field of 8.3 T (needed to bend 7 TeV beams inside a 27 km ring).
7600 km of NbTi superconducting cable
Work at 1.9K (-270 degrees)

Energy stored in the beams: 350 MJoule
(like a TGV at full speed;can melt 500 kg of Cu)
Electrical power to run the LHC (from French EDF): ~200 MW

Detectors are like giant digital cameras

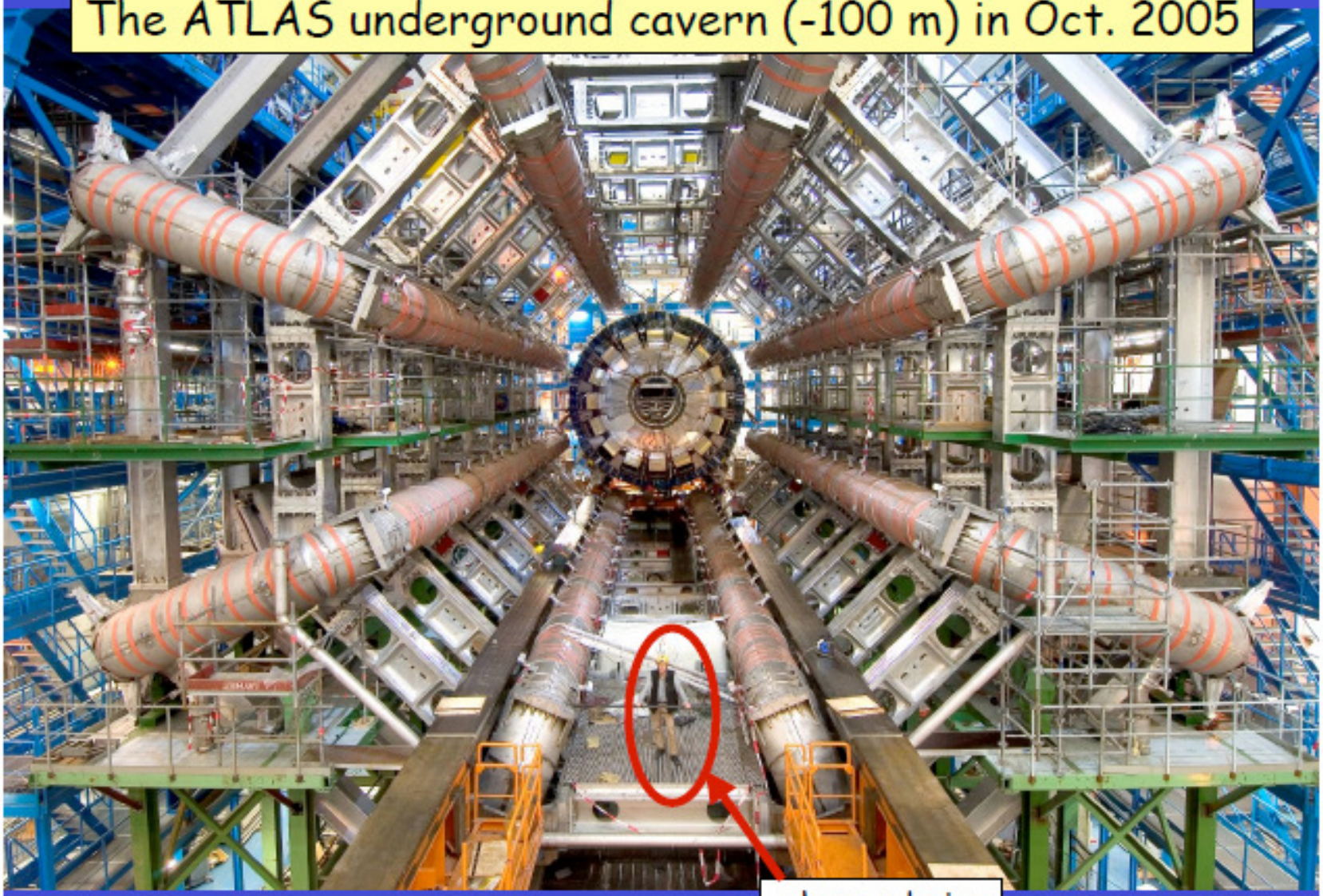
One example: the ATLAS detector

LHC detectors are much more complex, performing and challenging than those at previous/present accelerators
→ a big jump in concepts and technologies

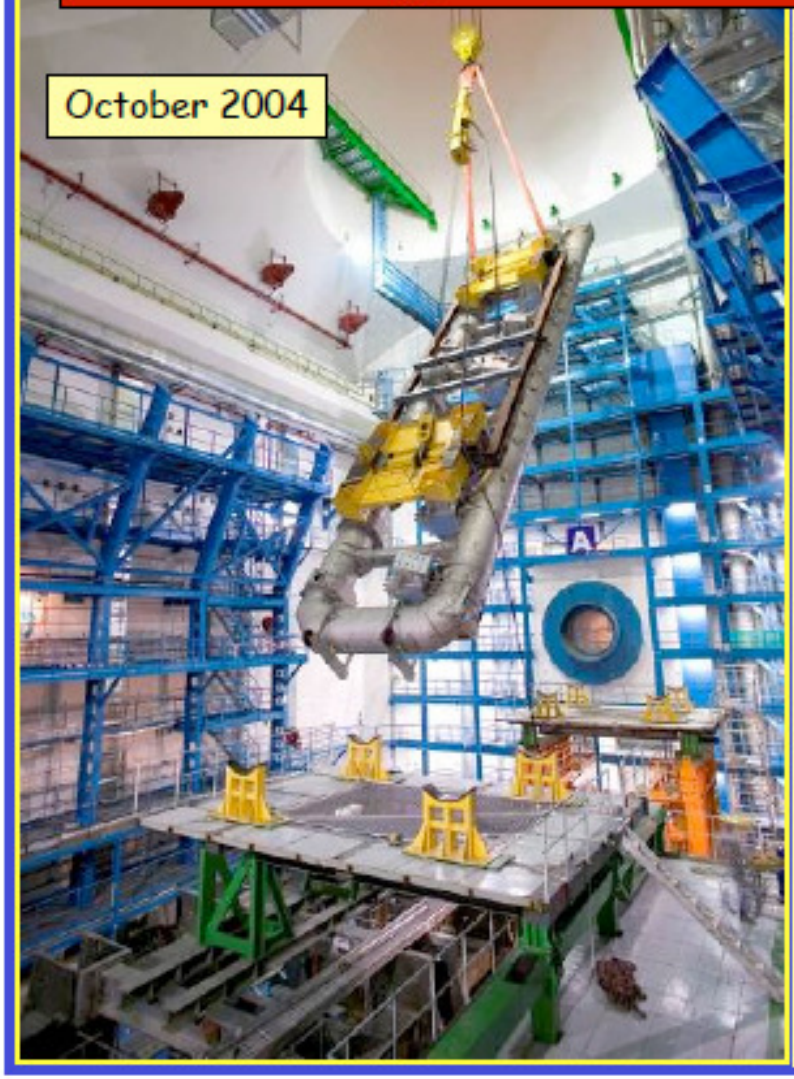


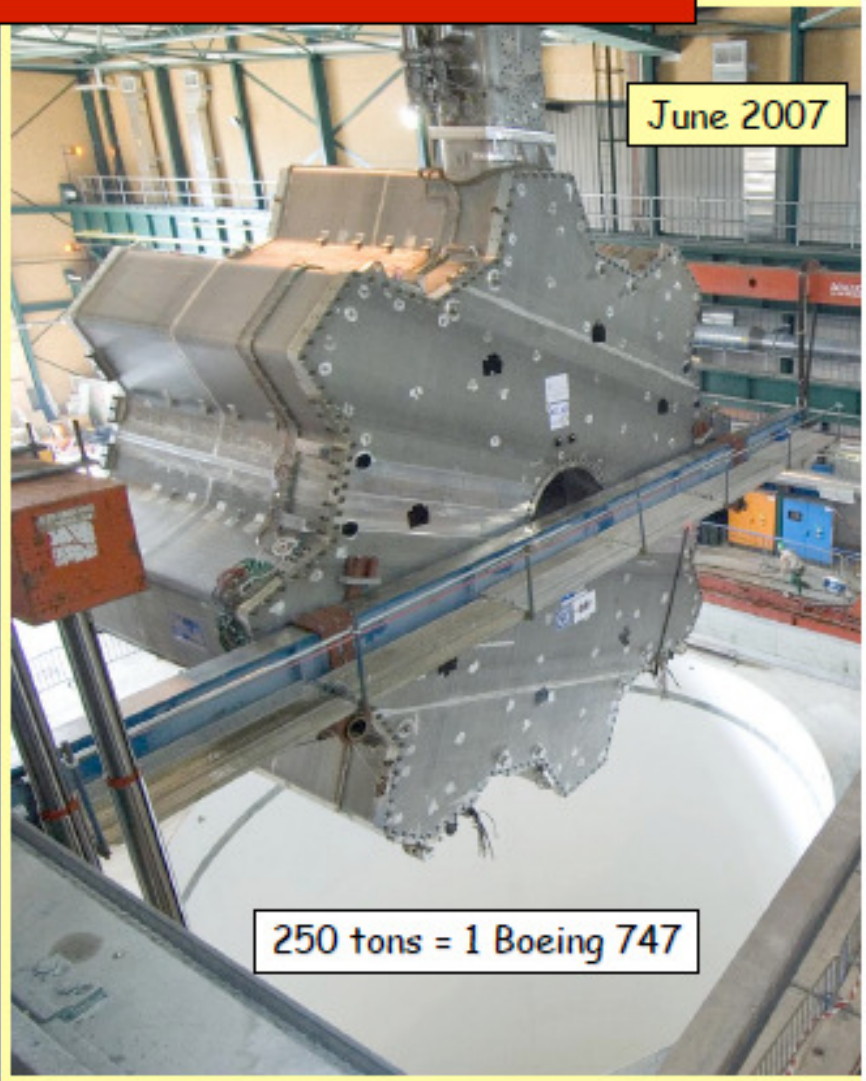
- Size (length 45m, diameter 25m): to measure and absorb high-energy particles
- Fast response (~50 ns): 40 million beam-beam collisions per second (1 ns = 10^{-9} s)
- 10^8 electronic channels ("individual signals"): to track ~1000 particles per event
- 3000 km of cables to transfer the detector signals
- Radiation hard: up to 10^6 Gy in the hottest regions after 10 years of operation
- Collaboration: ~ 2100 physicists from 167 Institutions/Universities, from 35 countries from 5 continents (12 UK groups, ~ 220 physicists)

The ATLAS underground cavern (-100 m) in Oct. 2005



Spectacular operations … installing detector pieces in the underground cavern



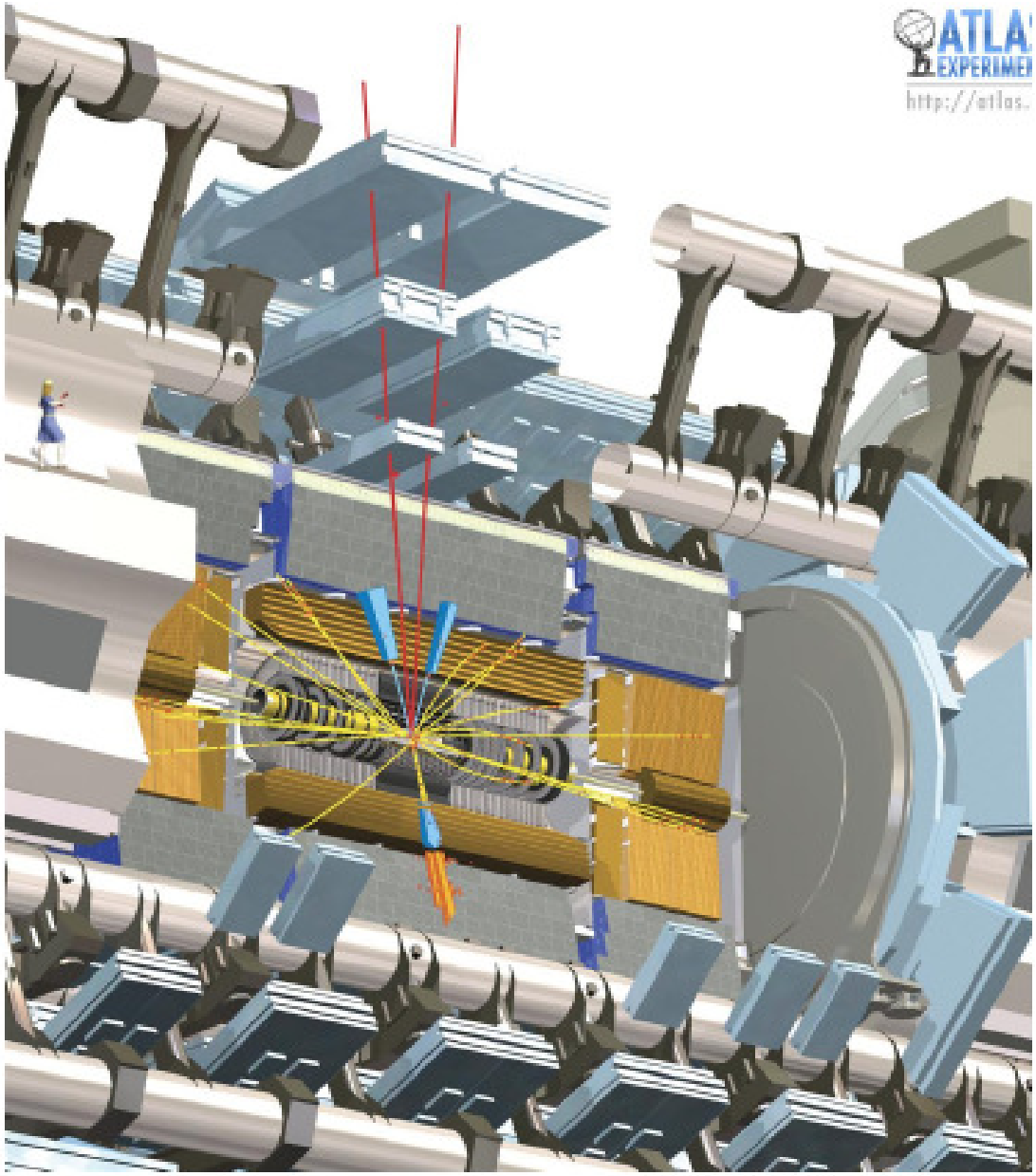


Finding Higgs events is tricky. An easy example:

A Higgs boson plus a jet in the opposite direction where the Higgs boson decays to two Z bosons with one Z boson decaying to e+ e- and the other to μ+μ-

Have to study many different possible signatures

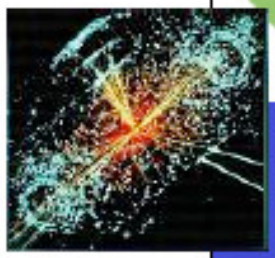
Photograph: Joao Pequenao



Computing

Each LHC experiment will produce ~ 10 PB of data per year 1 PB=10^6 GB
This corresponds to ~ 20 million DVD (a 20 km stack …)

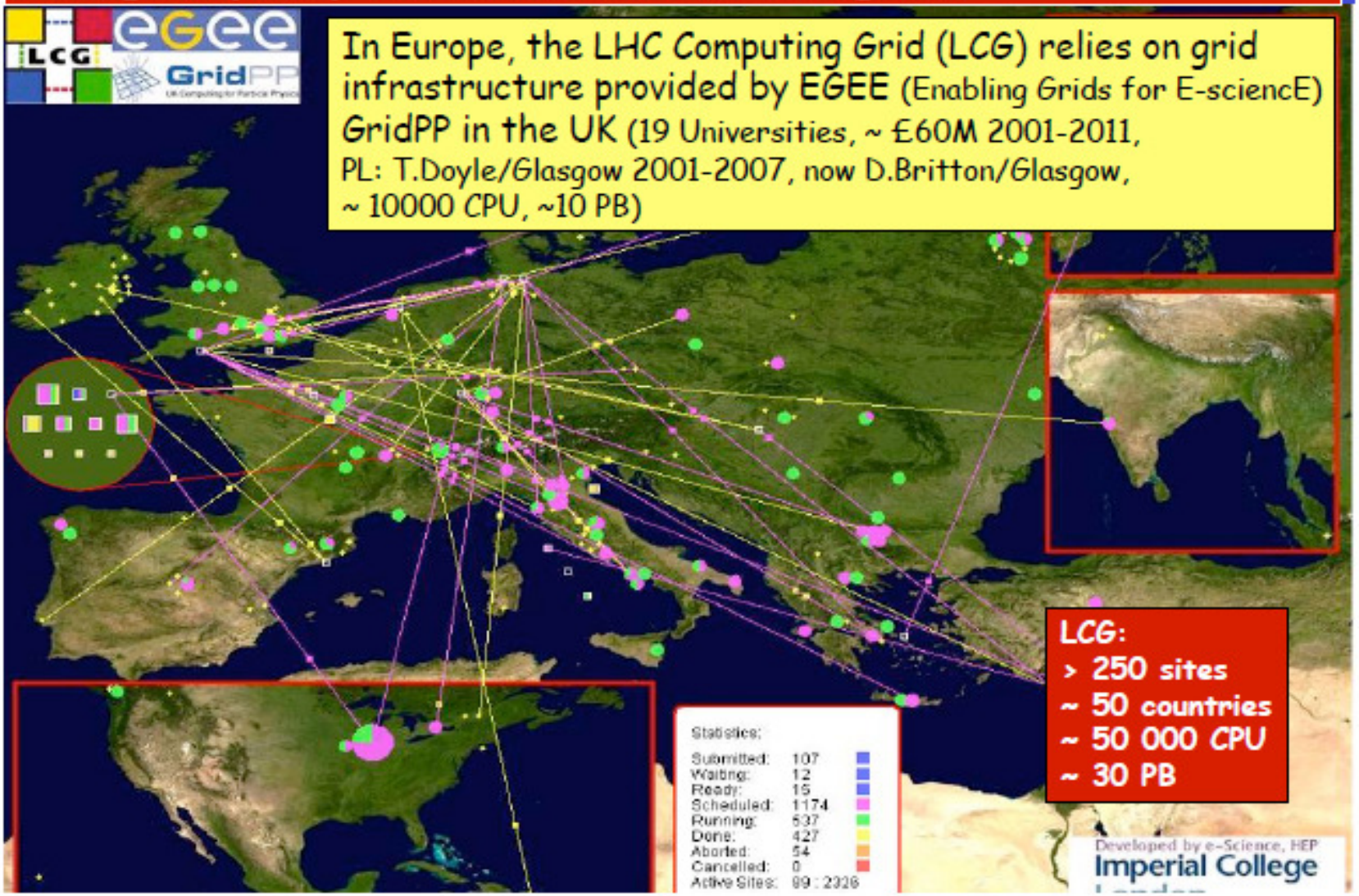
Data analysis requires computing power equivalent to ~100 000 today's fastest PC processors.



The experiment international Collaborations are spread all over the world → computing resources must be distributed.

Cooperation of many computer centres all over the world is needed →

The Grid provides seamless access to computing power and data storage capacity distributed all over the globe



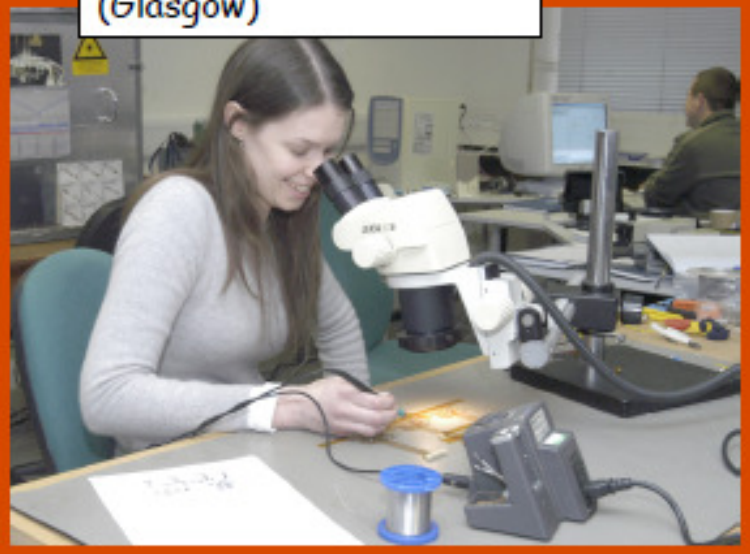
Scottish contributions to the LHC: examples …

ScotGrid

Scottish Grid Service

- Durham, Edinburgh, Glasgow
- Supports Scottish research in growing number of disciplines
- ~ 1000 CPU, ~100 TB
- Funded by Scottish Funding Council

ATLAS Si strip detector (Glasgow)



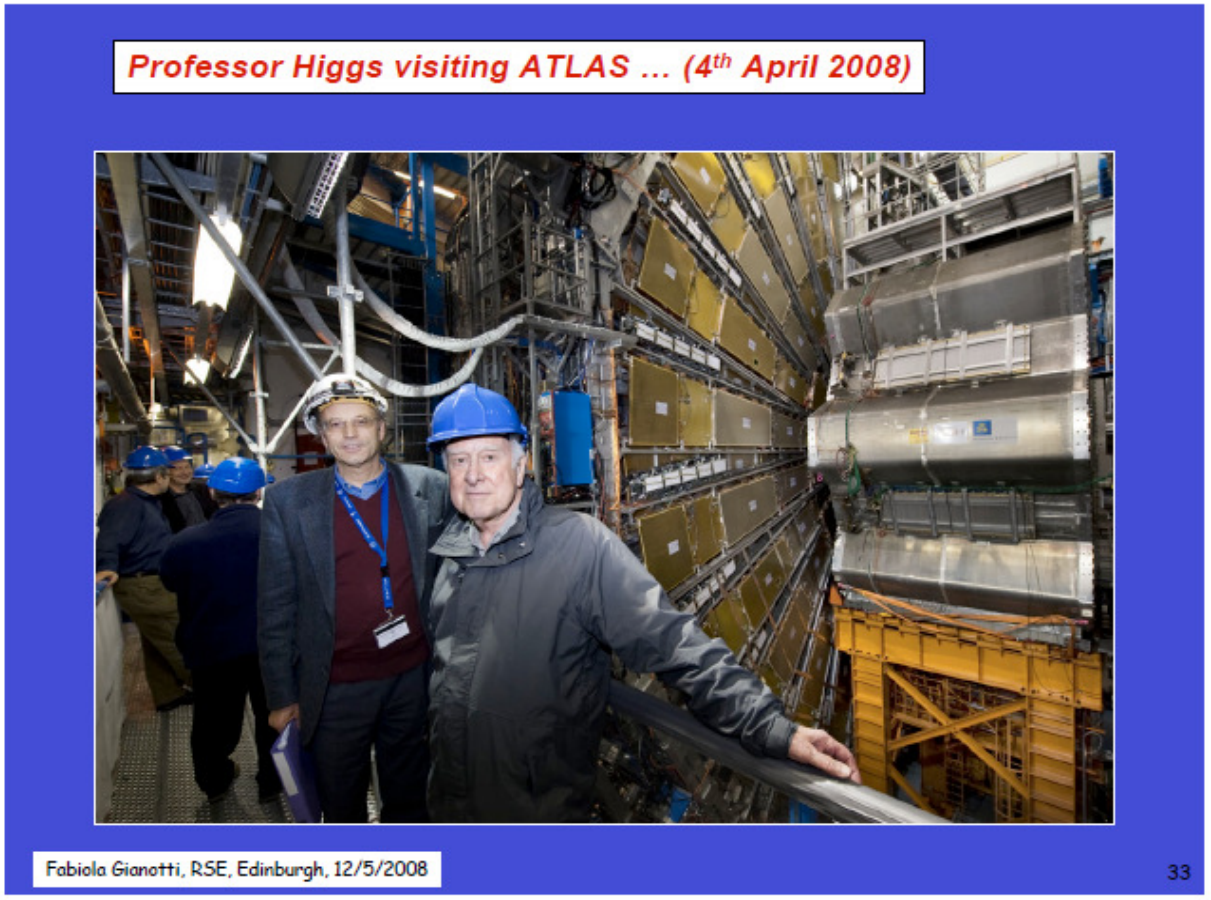
LHCb RICH detector (Edinburgh)

Higgs or what? No-lose theorem

Experiment: Higgs mass between 114 and 200 GeV (minimal theory)

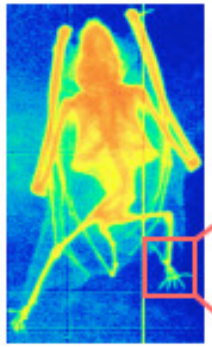
Theory violates unitarity if nothing found in LHC range(<1000 GeV)

Higgs/higgs-like MUST occur. Related to dark matter in cosmology

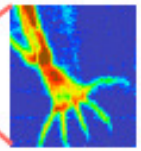


Technology transfer and spin-offs: from fundamental science to everyone's life

Extreme performance required in particle physics → cutting-edge technologies developed at CERN and collaborating Institutes and then transferred to society.

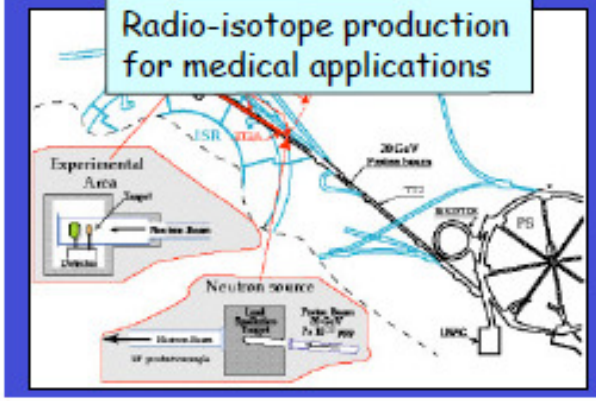


Radiography of a bat, recorded with a GEM detector



Applications: medical imaging (e.g. PET), cancer therapy, materials science, airport scanners, cargo screening, food sterilization, nuclear waste transmutation, etc. ...
Not to mention the WEB and the GRID ...

Radio-isotope production for medical applications



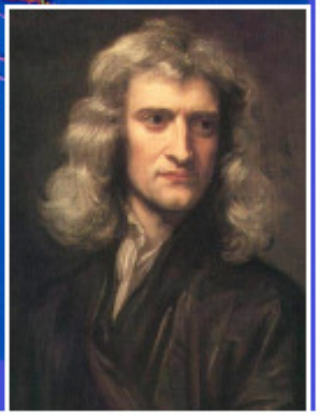
Hadrontherapy for cancer treatment

CERN and the LHC

- Seeking answers to fundamental questions about elementary particles and the Universe. A new era of discoveries will start with the exploration of an unprecedented energy scale at the LHC
- Advancing the frontiers of technology (also to the benefit of society)
- Training (students, high-school teachers, young scientists)
- Bringing nations together through science

"Nati non fummo a viver come bruti ma per seguir virtute et conoscenza",
Dante Alighieri (1265-1321),
Divina Commedia, Inferno, Canto XXVI

"What we know is a droplet, what we don't know is an Ocean",
Isaac Newton (1643-1727)



Thanks to Fabiola Gianotti for beautiful slides.