Wolfgang Pauli, CERN, and the LHC

Rüdiger Voss – Physics Department, CERN

Pauli and the origins of CERN

- Letter to Oppenheimer (1952):
  "I am more urgently needed ... here, particularly in connection with the new plans for a European Research Institute of Physics"
- Letter to Stern (1952):
  (the CERN project is) "... not entirely stupid ... since there also jobs for theoreticians will be available."

Practical involvement?

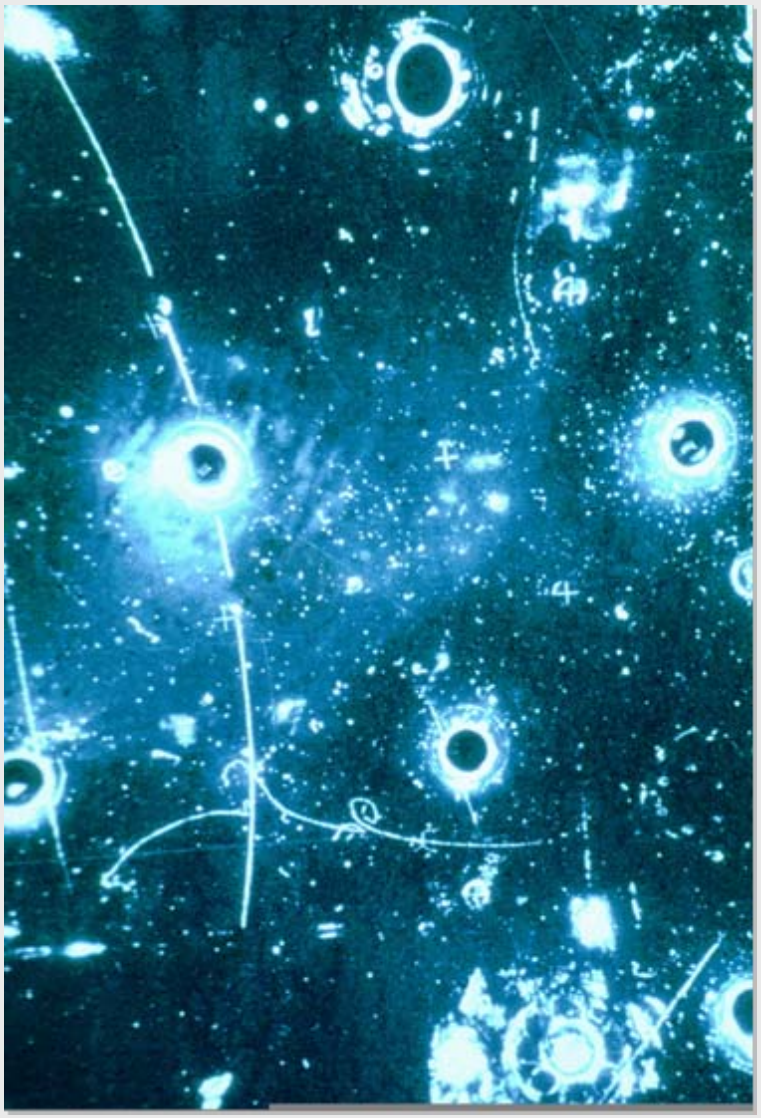
- 1953-1957: (Vice-)President of the Swiss Physical Society: Strong support to CERN and the Geneva site
- 1955: Lectures at CERN Theory Division in Copenhagen

The legacy

- Pauli's impact on CERN has been through his impact on physics
- The lasting link: 1959, Franca Pauli donated the Pauli Archive to CERN

From modest beginnings in 1954 ...

... through ground-breaking milestones ...



- Discovery of the weak neutral current in 1973

... a couple of Nobel Prizes ...

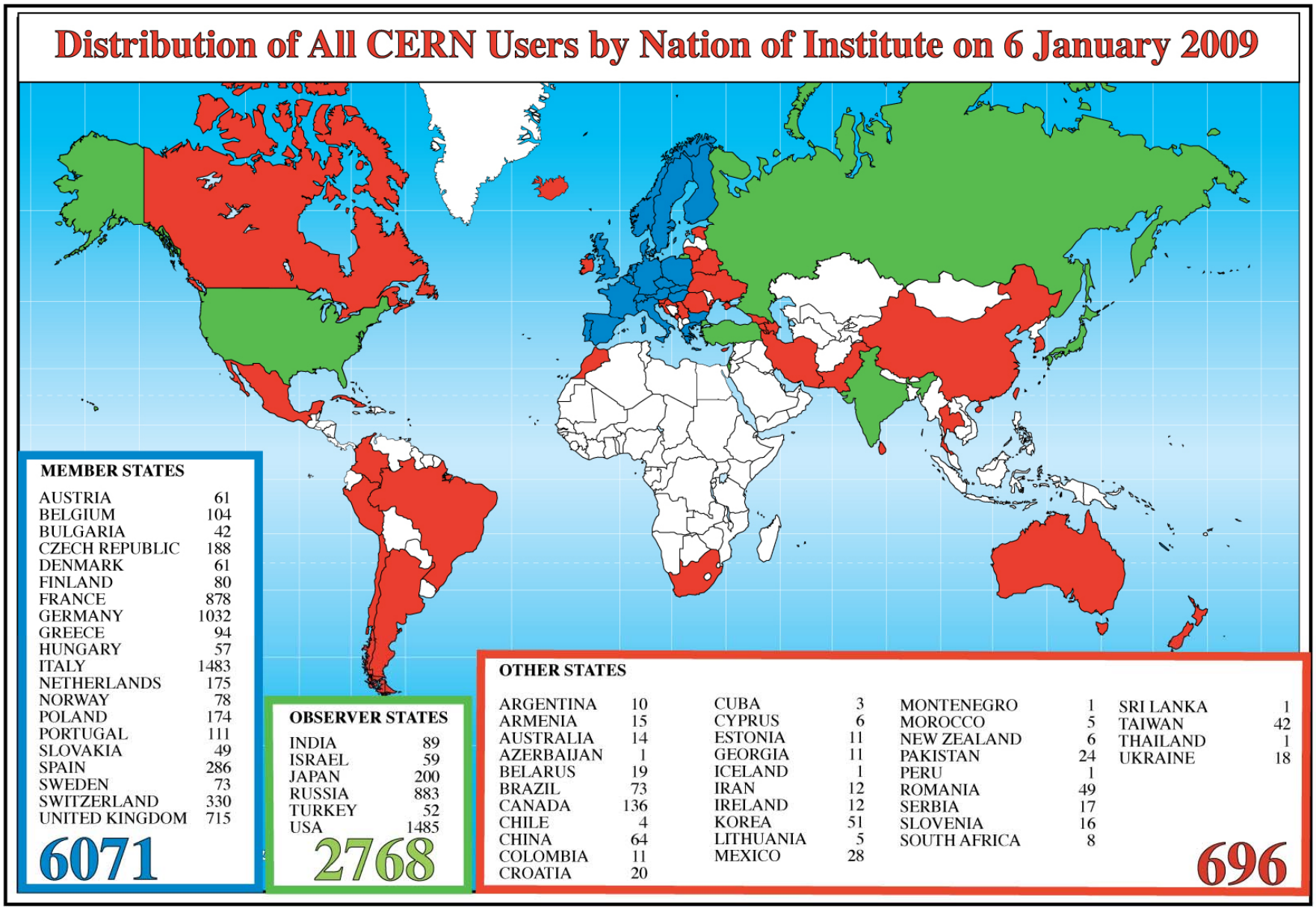
Carlo Rubbia

Simon van der Meer

Nobel Prize for Physics 1984

... to the world's largest research laboratory:

Distribution of All CERN Users by Nation of Institute on 6 January 2009



MEMBER STATES

AUSTRIA	61
BELGIUM	104
BULGARIA	42
CZECH REPUBLIC	188
DENMARK	61
FINLAND	80
FRANCE	878
GERMANY	1032
GREECE	94
HUNGARY	57
ITALY	1483
NETHERLANDS	175
NORWAY	78
POLAND	174
PORTUGAL	111
SLOVAKIA	49
SPAIN	286
SWEDEN	73
SWITZERLAND	330
UNITED KINGDOM	715

6071

OBSERVER STATES

INDIA	89
ISRAEL	59
JAPAN	200
RUSSIA	883
TURKEY	52
USA	1485

2768

OTHER STATES

ARGENTINA	10	CUBA	3	MONTENEGRO	1	SRI LANKA	1
ARMENIA	15	CYPRUS	6	MOROCCO	5	TAIWAN	42
AUSTRALIA	14	ESTONIA	11	NEW ZEALAND	6	THAILAND	1
AZERBAIJAN	1	GEORGIA	11	PAKISTAN	24	UKRAINE	18
BELARUS	19	ICELAND	1	PERU	1		
BRAZIL	73	IRAN	12	ROMANIA	49		
CANADA	136	IRELAND	12	SERBIA	17		
CHILE	4	KOREA	51	SLOVENIA	16		
CHINA	64	LITHUANIA	5	SOUTH AFRICA	8		
COLOMBIA	11	MEXICO	28				
CROATIA	20						

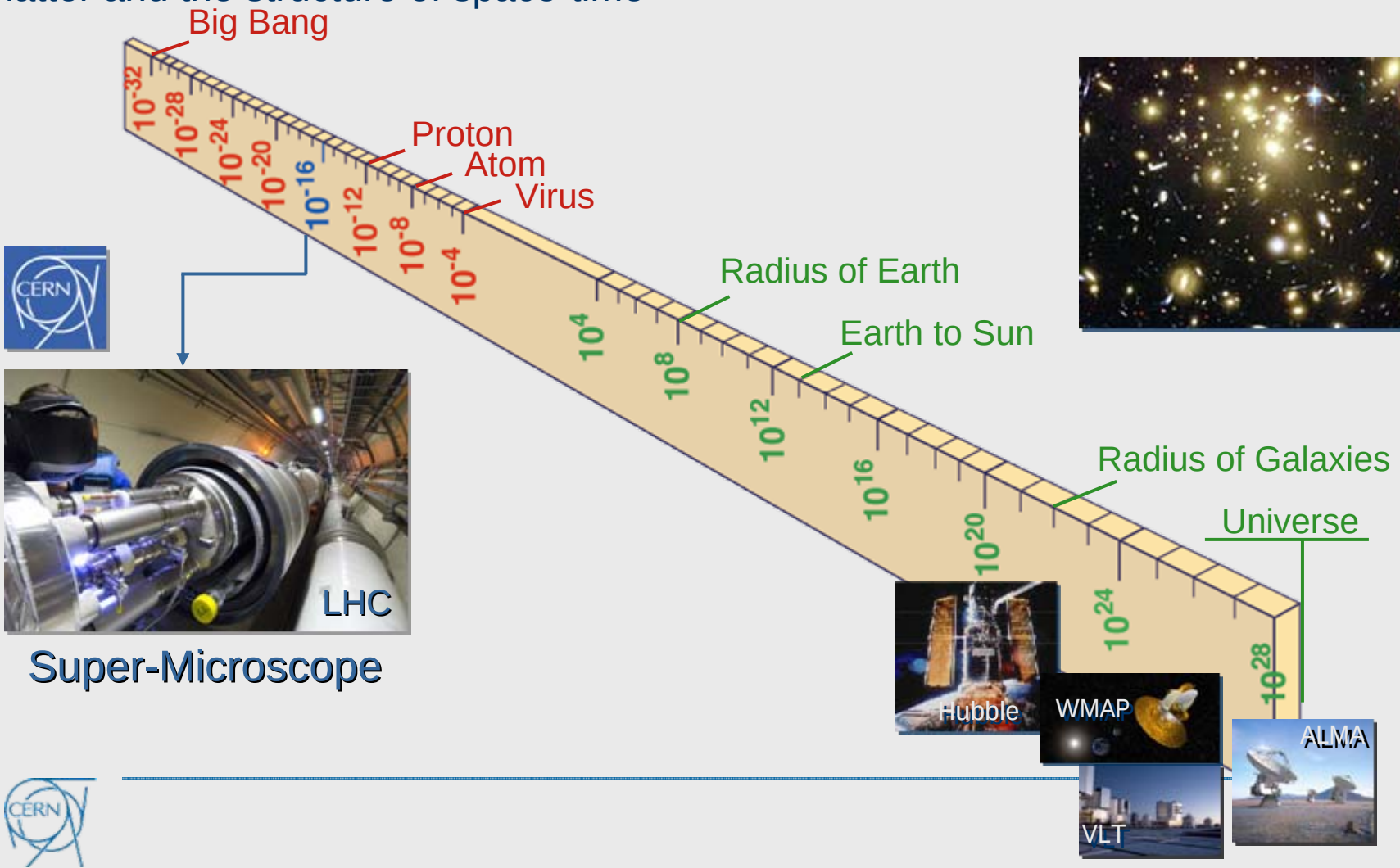
696

Hungary at CERN

- CERN Member State since 1992 ...
- ... but strong scientific participation has a much longer tradition! (NA4 [through JINR], OPAL experiment @ LEP)
- Today's focal points in Hungary:
  - Budapest (RMKI and Eötvös University)
  - Debrecen (ATOMKI and University)
- Today's focal points at CERN:
  - CMS and ALICE at the LHC
  - Smaller fixed-target experiments

Particle Physics

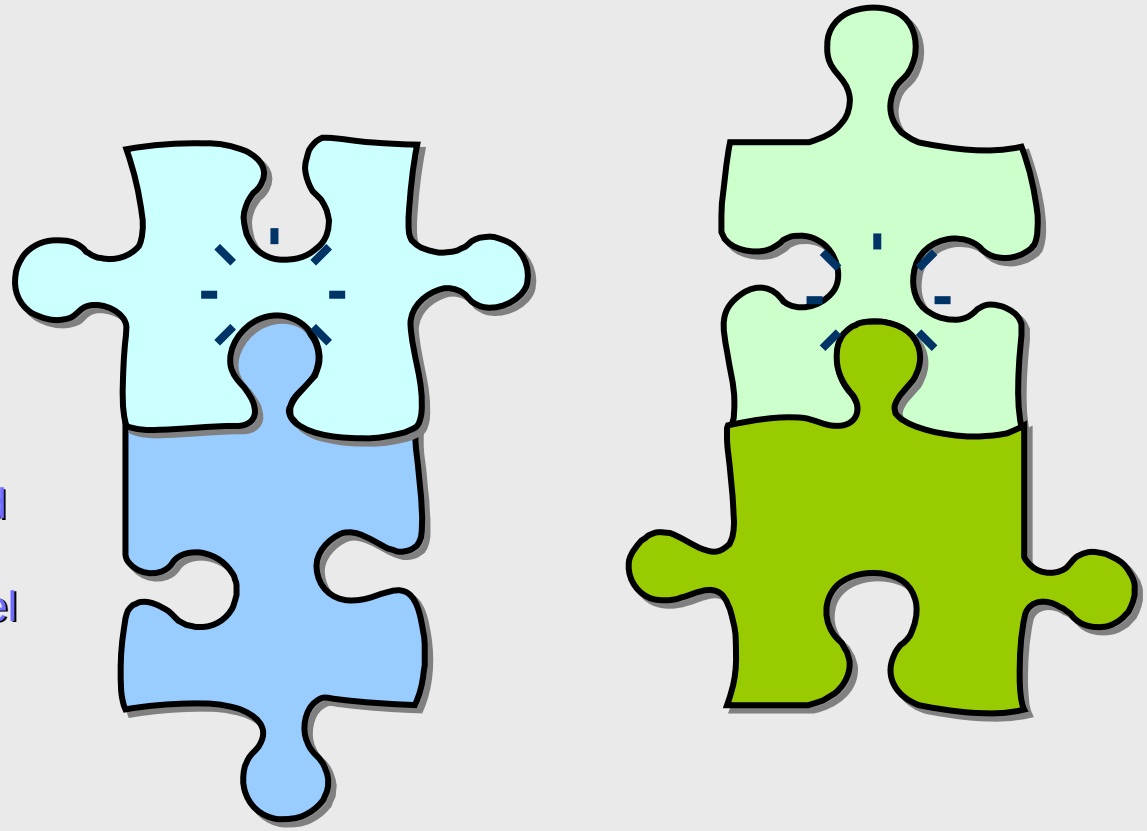
Study the structure of the Universe at its most fundamental level:
explore the basic physics laws which govern the fundamental building blocks of matter and the structure of space-time



Describing the Universe

Particle Physics
Experiments
Accelerators
Underground

Quantum Field
Theory
Standard Model



Astrophysics
Experiments
Telescopes
Satellites

Standard
Cosmology
Model

10^{-18} m

10^{26} m

Describing the Universe

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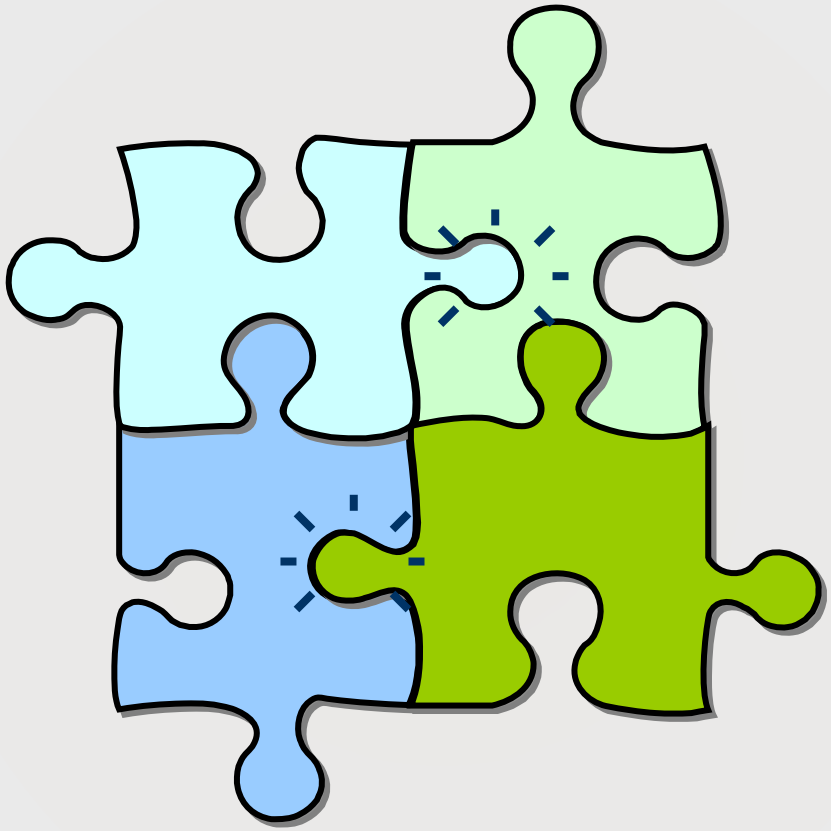


Astrophysics
Experiments
Telescopes
Satellites

Standard
Cosmology
Model

Consistent understanding ?

10^{-18} m

10^{26} m

LHC: Exploration of a new energy frontier

Proton-proton collisions at E_{CM} = 14 TeV
Heavy Ions: Lead-lead collisions: **Energy/nucleon = 2.76 TeV/u**

The LHC will **illuminate a new landscape of physics**, possibly answering some of the most **fundamental questions in modern physics**, like e.g.

- The origin of mass
- Unification of fundamental forces
- New forms of matter
- Extra dimensions of spacetime

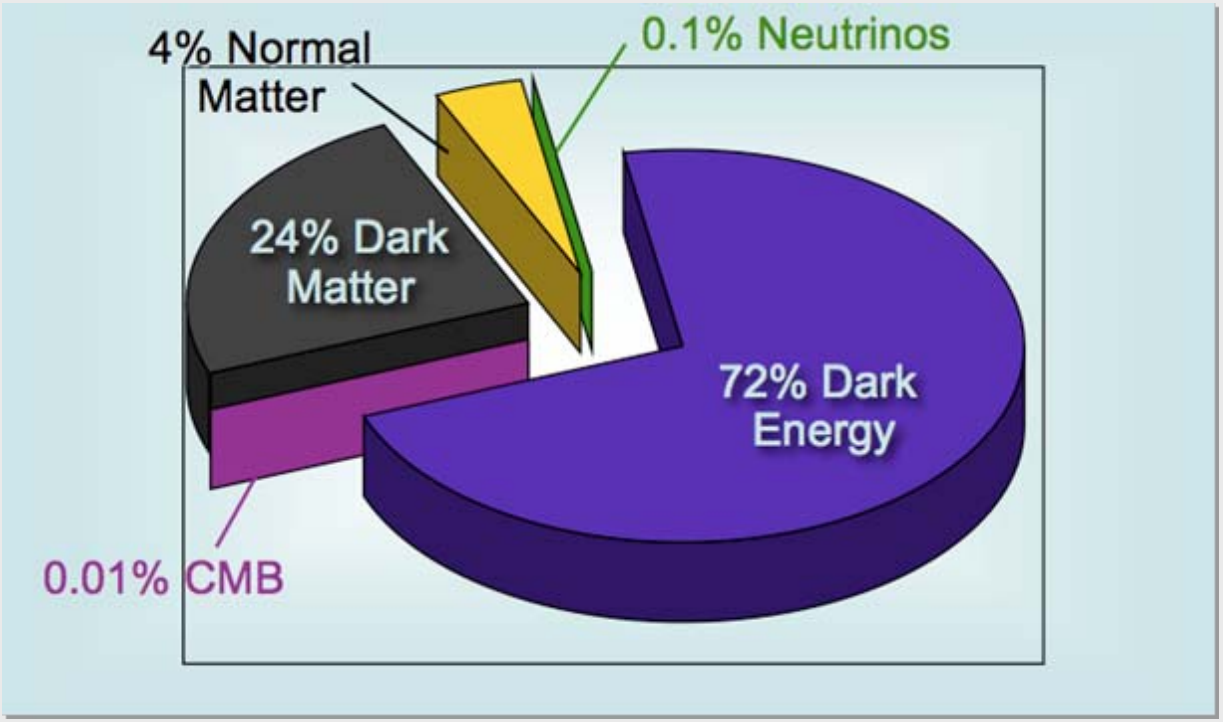
The Higgs particle

Manifestation of the Higgs mechanism, which explains the origin of mass in the Universe

Peter Higgs
Visit to CERN
April 2008

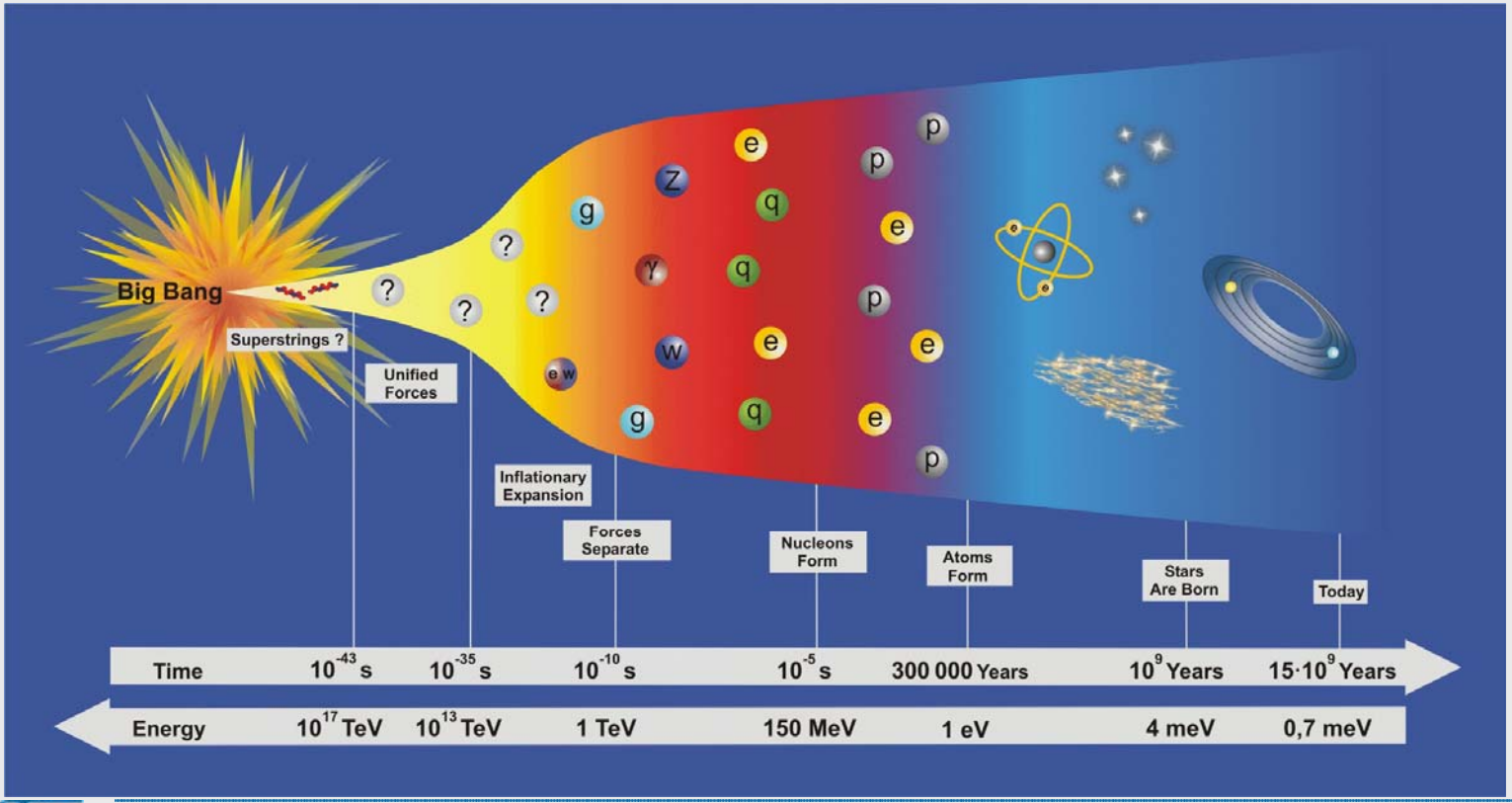
Supersymmetry

- The candidate theory for unification of fundamental forces
- Lightest supersymmetric particles can explain dark matter in the universe

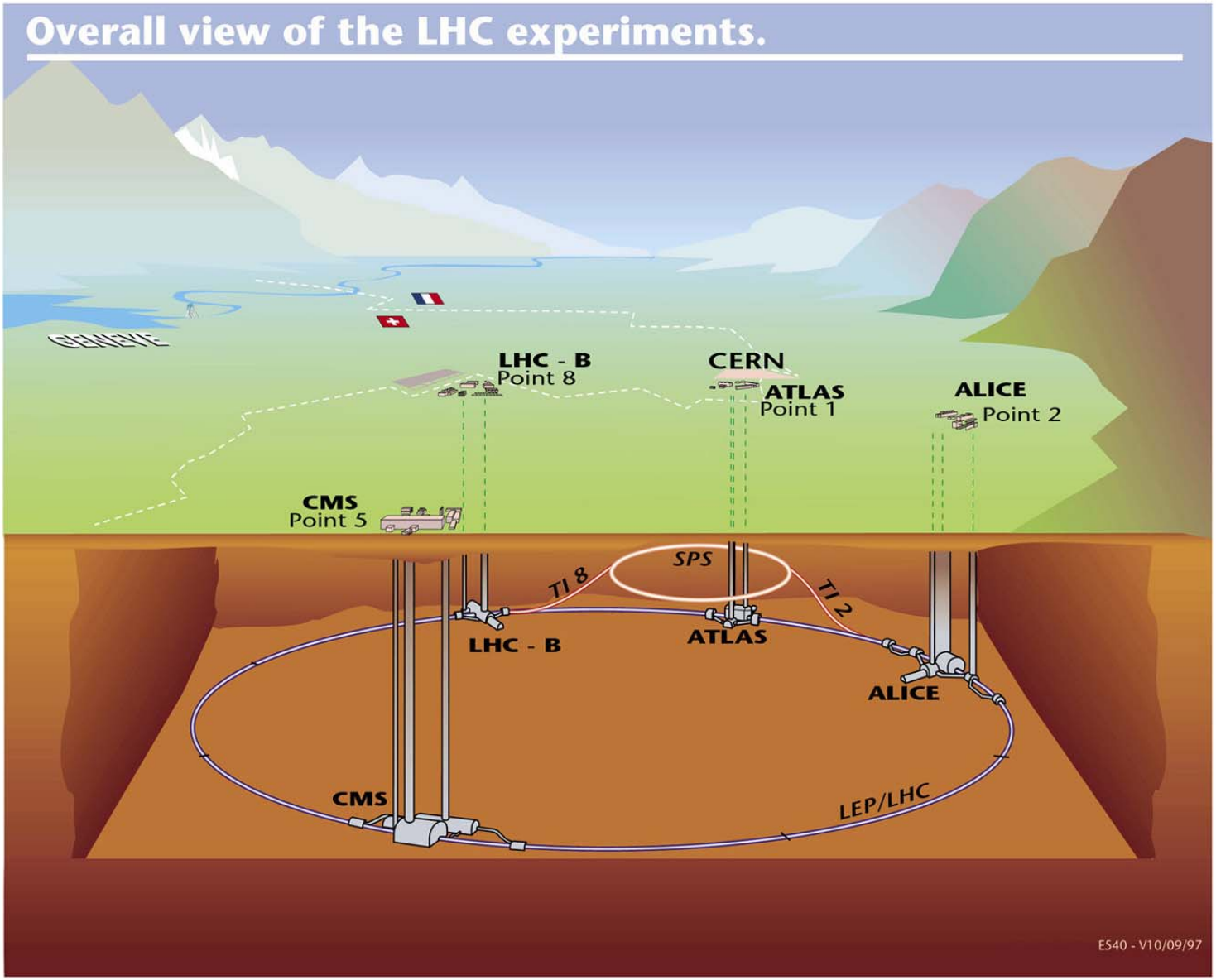


CP Violation

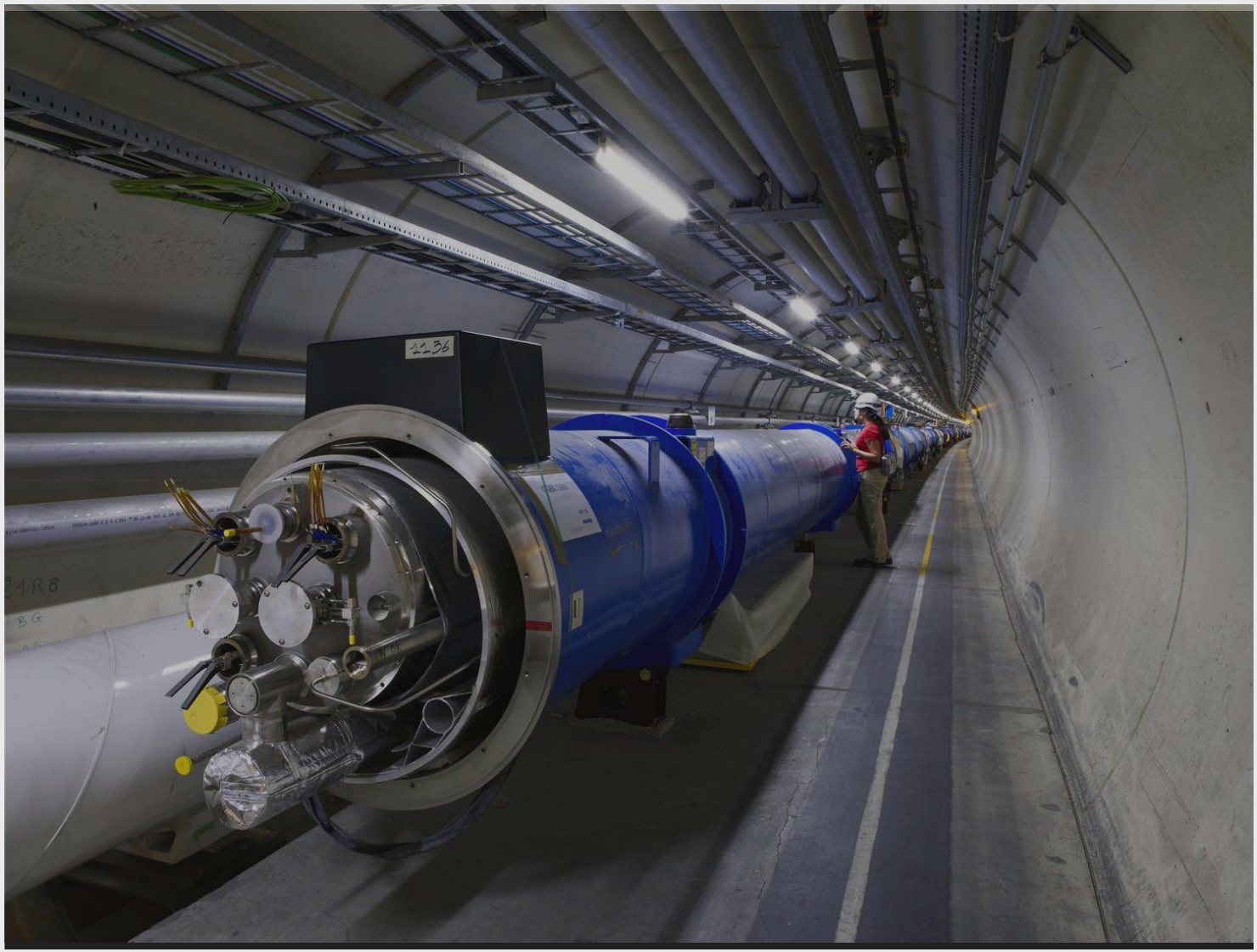
- The mystery of matter-antimatter asymmetry in the Universe



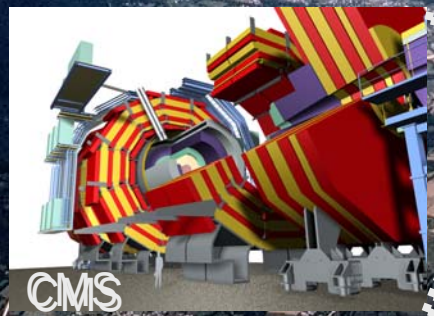
The LHC Tunnel



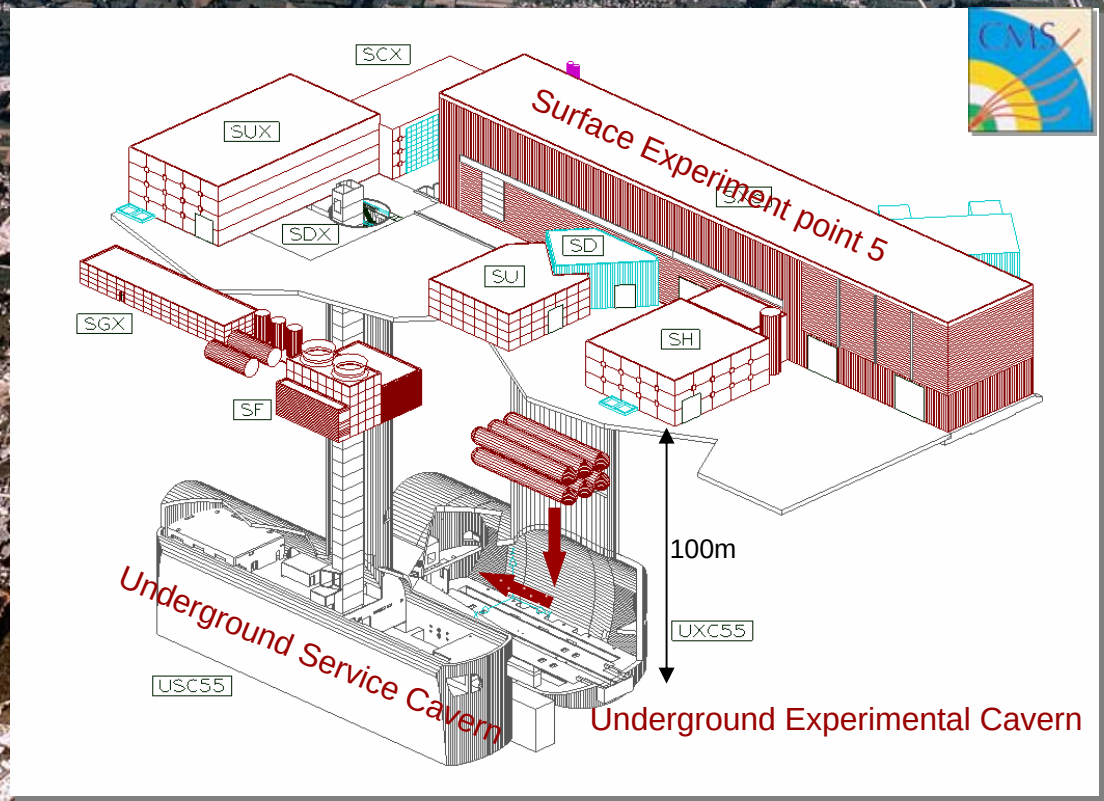
LHC superconducting dipole magnets



Construction of CMS at point 5 of LHC



Construction at point 5 started end of 1999

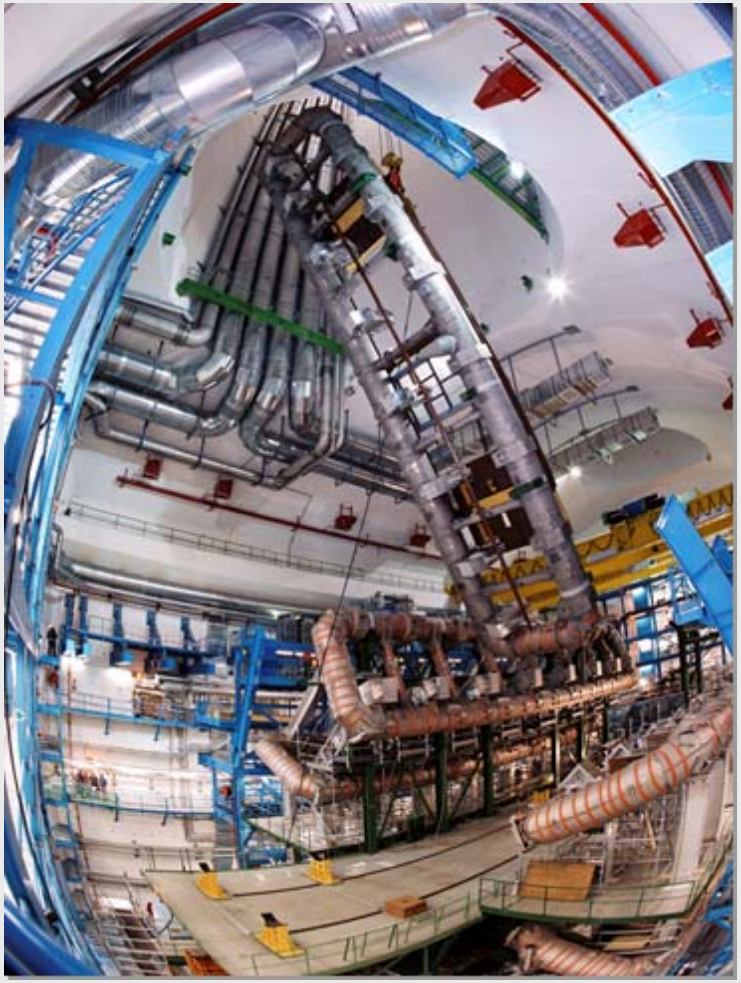


Lowering of heavy elements into cavern

Lowering of central and heaviest element (~ 2000 t) on **February 28, 2007** ……

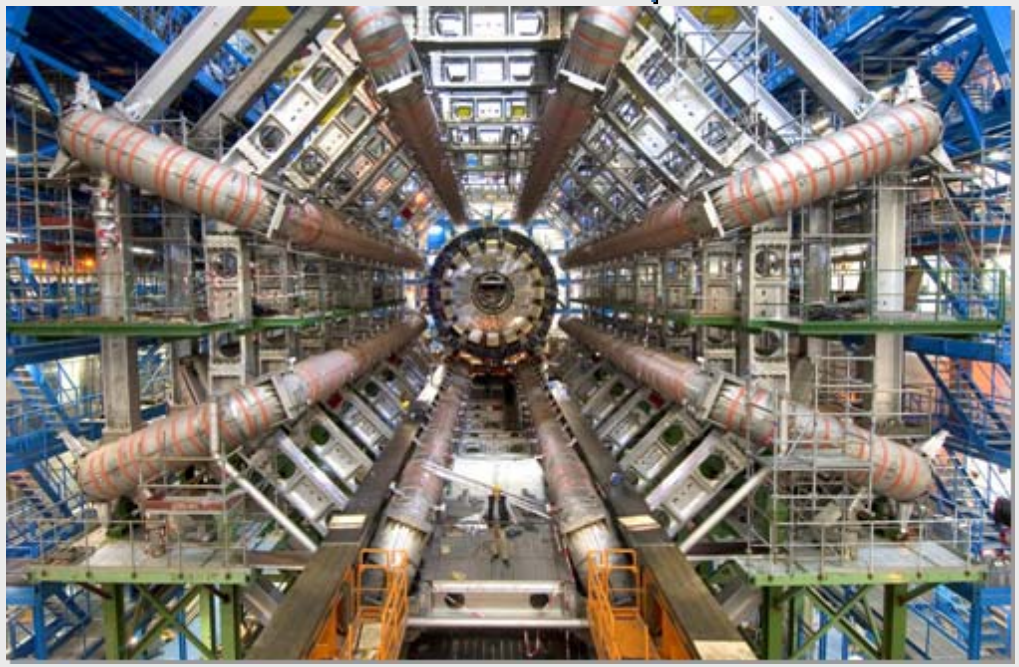
Lowering of the last heavy element on
January 22, 2008

ATLAS: assembly in cavern



Barrel toroid system: eight 25m-long, 100 ton superconducting coils

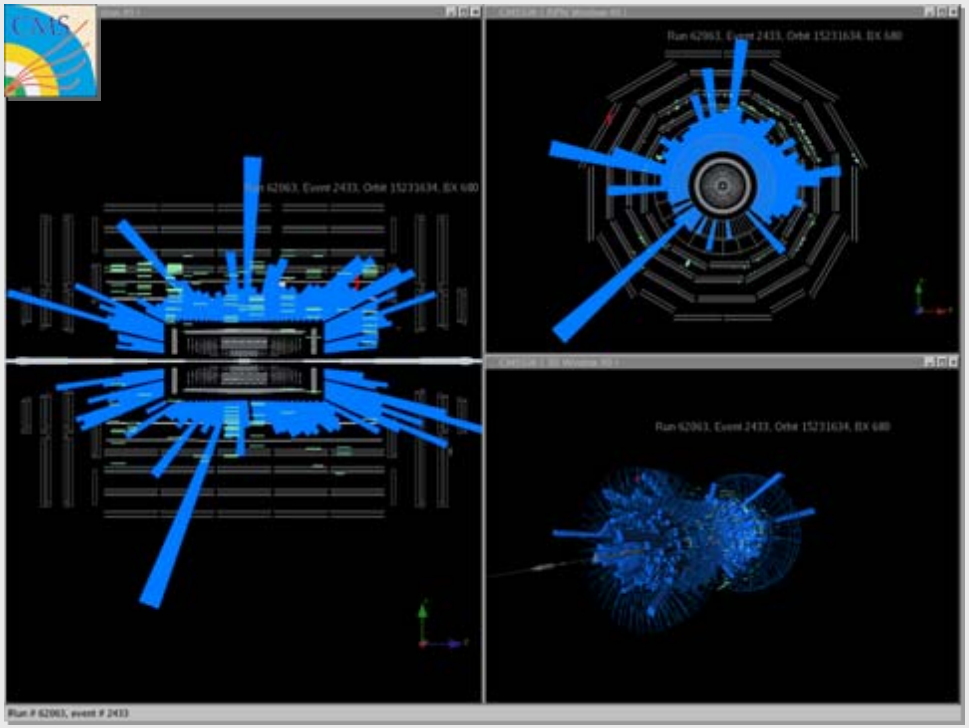
The famous ATLAS picture

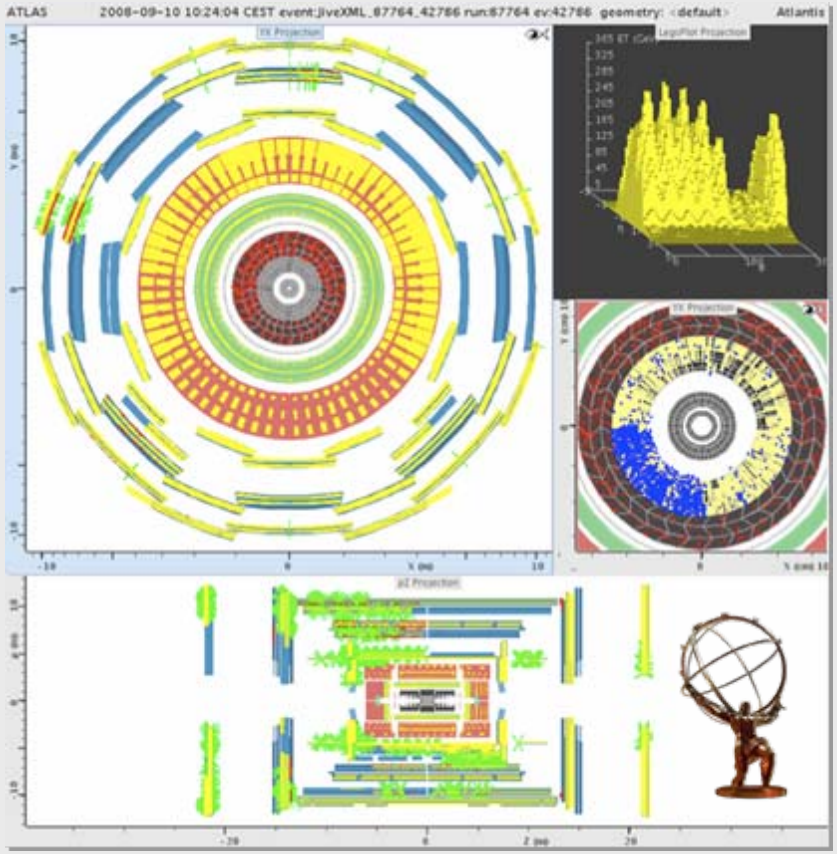


September 10, 2008: Experiment ready to take data

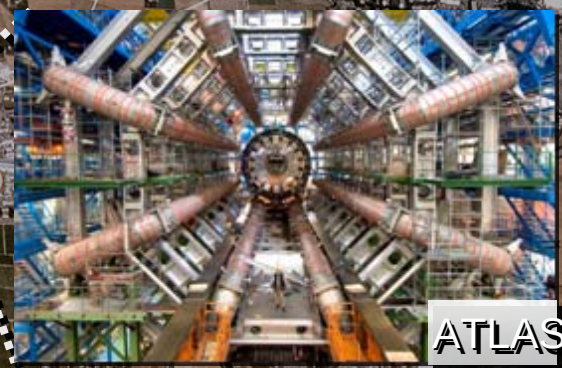
First protons circulating in the LHC ring

The beam was initially intentionally stopped by blocks around 150 metres before experiments, producing these images of the debris or "splash" from the particles hitting the blocks.



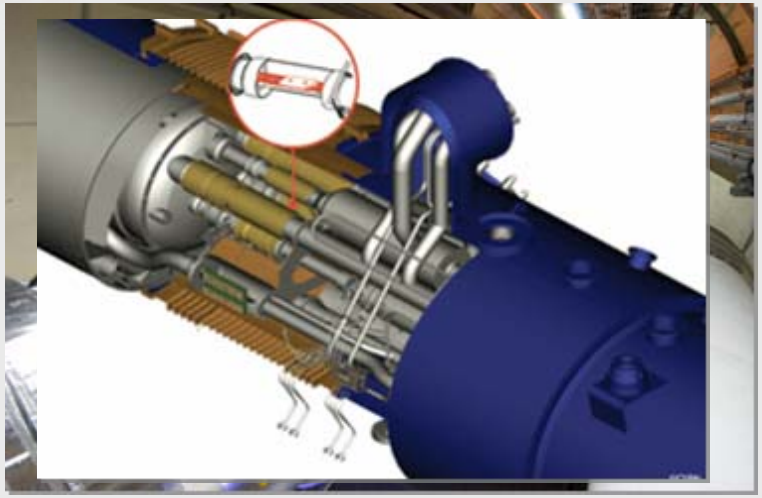


Very exciting years are ahead of us

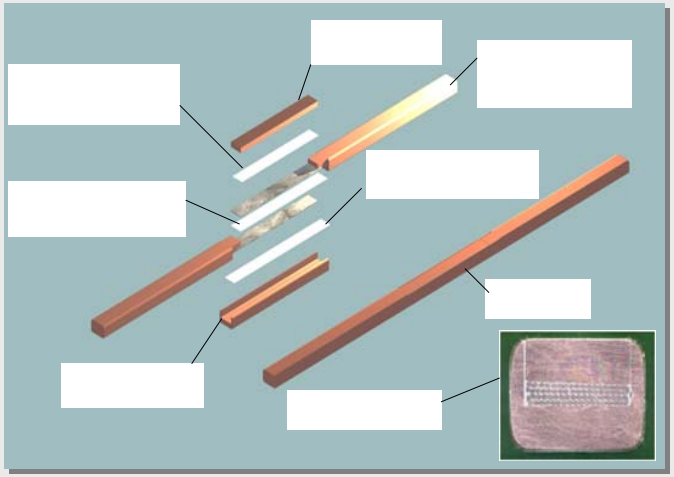


Spare slides...

September 19, 2008: incident in sector 3-4



The incident was traced to a faulty electrical connection between segments of the LHC's superconducting cable
(busbars)
High impact was caused by collateral damage



2 most severely damaged interconnects

53 Magnets (along a zone of about 700 m) to be removed from tunnel and repaired/exchanged (a few % of entire LHC)

Repairs and Restart

- Enhanced quench protection system (QPS):

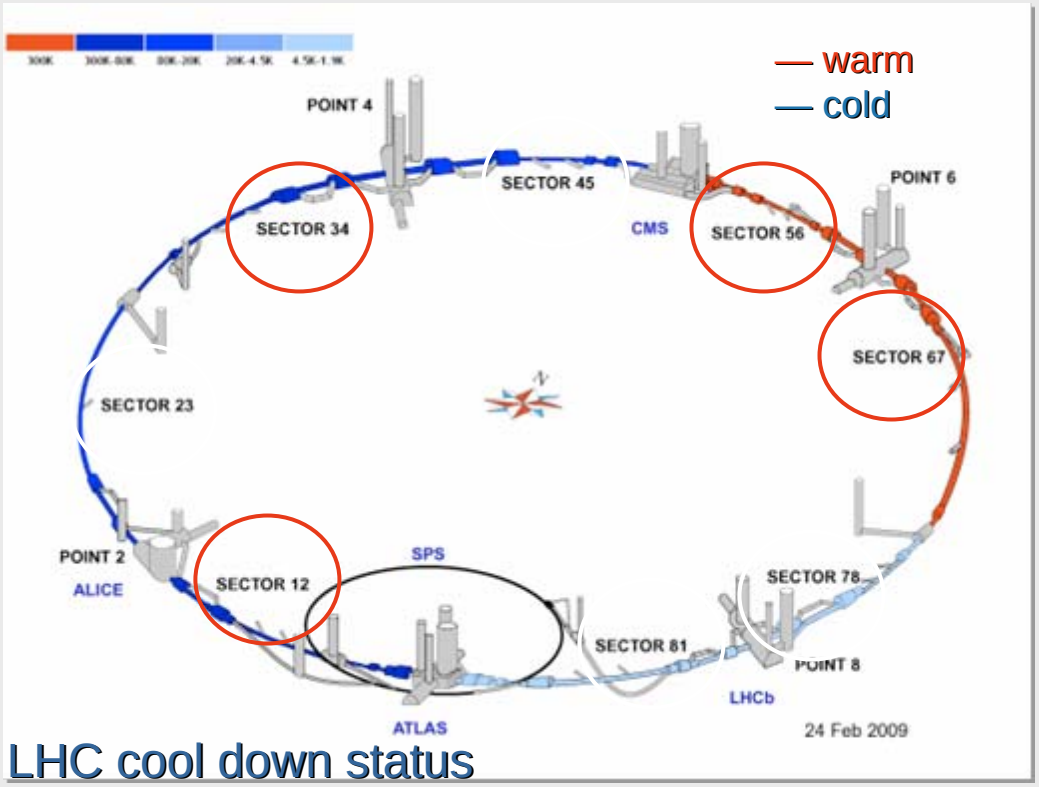
  More precise system to monitor (and protect) anomalously high resistance in a joint (splice) near the magnets.
  - A QPS threshold of 0.3mV is needed
  - The QPS will be upgraded everywhere to cover all busbar splices

- Improve pressure relief devices:
  - The four warm sectors will be equipped with extra pressure relief valves (PRVs) on all dipole cryostats
  - The four cold sectors will get extra PRVs on all short straight section cryostats. This can be done with the sectors cold and is adequate for 5 TeV operation

- The whole machine will be cold by mid August, ready for first injected beam in late September

- The machine will run at 5 TeV until autumn 2010 after which the remaining 4 sectors will be equipped with PRVs and will be prepared for high energy operation

Repairs: Present Status



LHC cool down status

Repair for 27 magnets completed
(out of 53)
End of March:
last magnet into tunnel

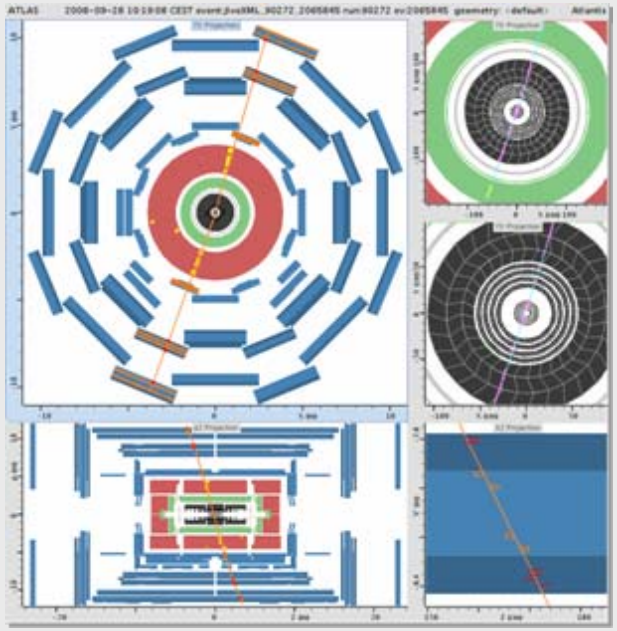
The LHC is an unprecedented adventure
Imperative to progress with care

Present Status of Experiments

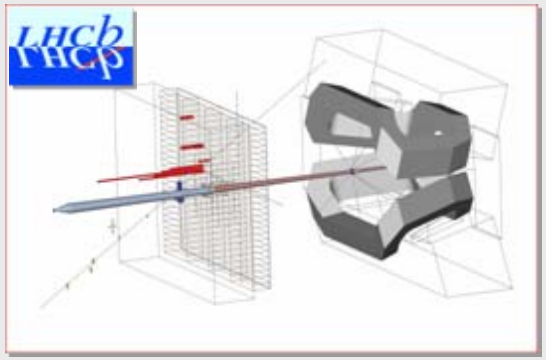
Use time in most efficient way:

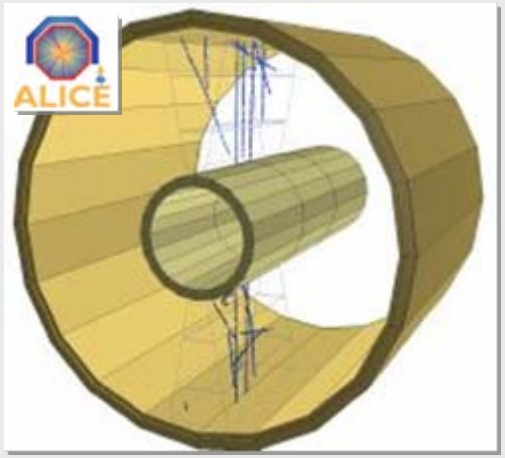
Installation of some detector components, some repairs, commissioning using cosmics

Gain operation experience in situ before collisions start

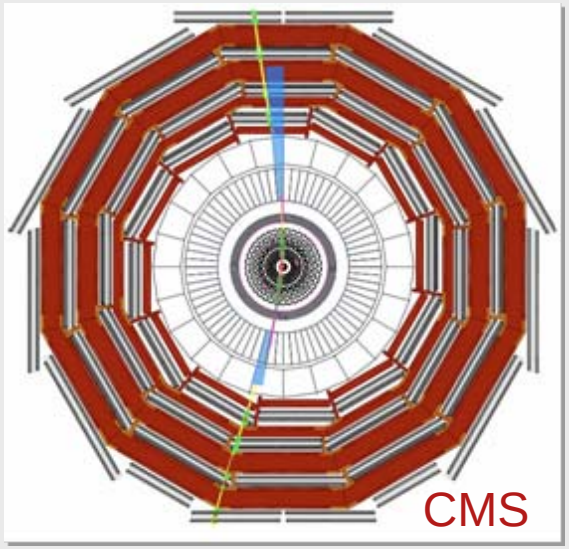


ATLAS: 216 million cosmic events





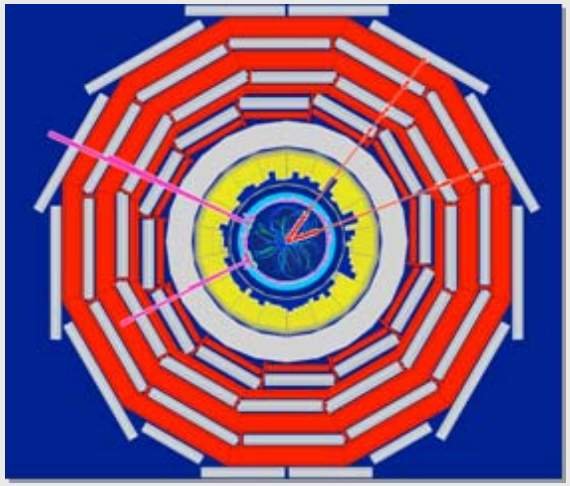
CMS: 300 million cosmic events



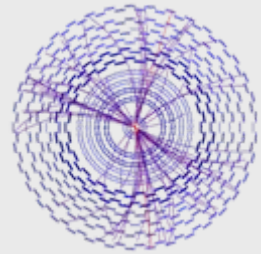
Beam Conditions for Physics

- Machine protection will be tested with beam (at 0.45 TeV energy levels)
- **Beam energy limit in 2010: 5 TeV**
- **Estimated integrated luminosity**
  - **The during first 100 days of operation.. ≈100pb^{-1}**
    Peak L of 5.10^{31} η (overall) = 10% gives 0.5pb^{-1}/day
    Peak L of 2.10^{32} η (overall) = 10% gives 2.0pb^{-1}/day
  - **During next 100 days of operation ≈ 200pb^{-1}?**
- Towards end of year (2010) **heavy ion run**

Basic processes at LHC

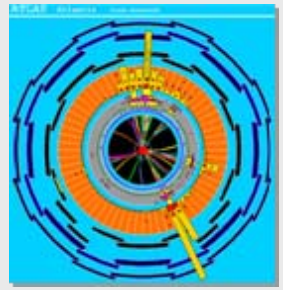


LHC Physics in 2009/2010



First beams: very early physics - **rediscover SM physics**

Detector synchronization, in-situ alignment and calibration



10 pb^{-1}: Standard Model processes

measure jet and lepton rates, observe W, Z bosons

first look at possible **extraordinary signatures**…

30 pb^{-1}

Measure Standard Model Processes (at 10TeV need ~ 30pb^{-1}):

~ 10^4 Z $\rightarrow$ e+e- (golden Z's for detector studies (1%))

~ 10^5 W $\rightarrow$ eν

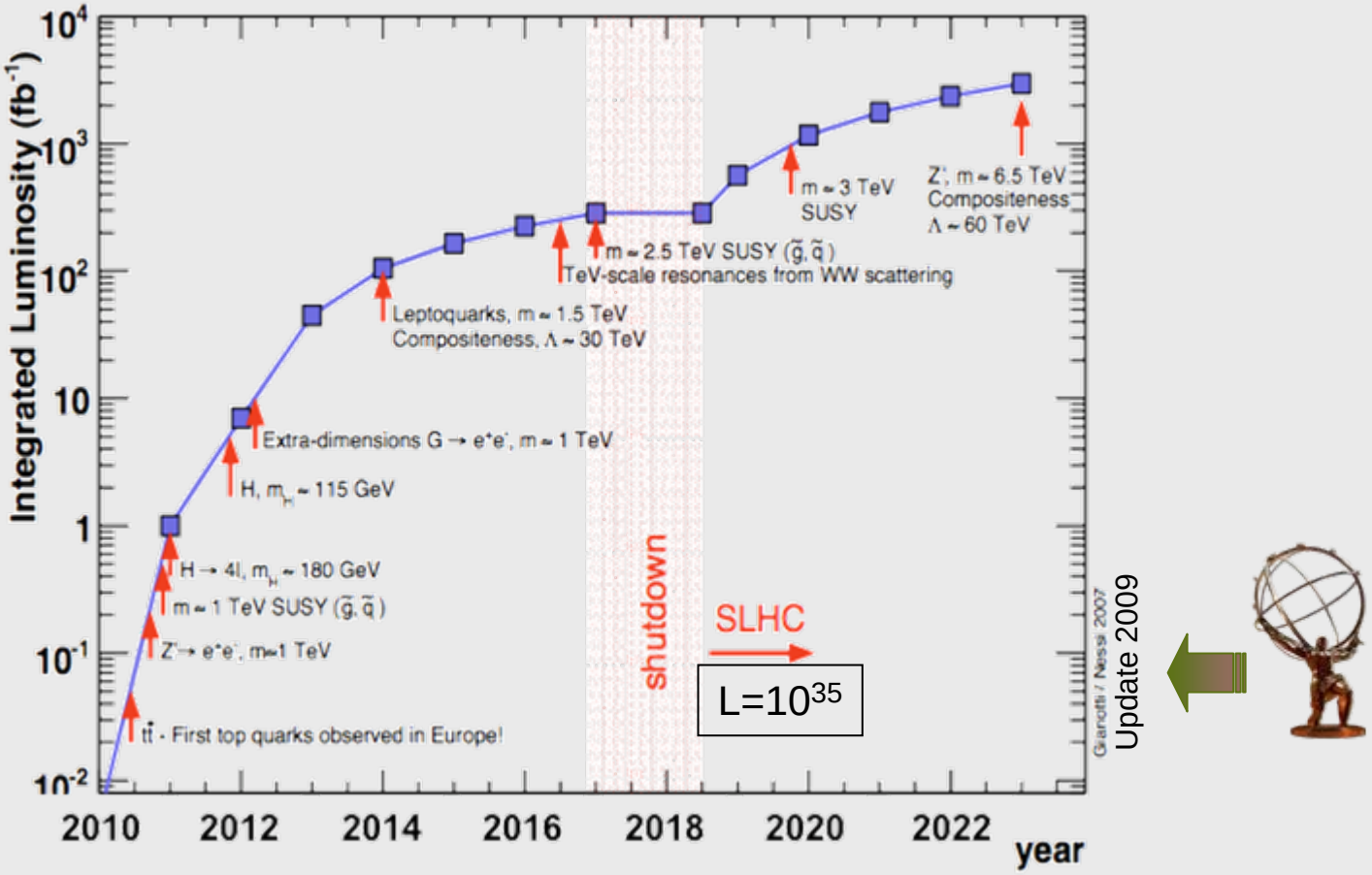
~ 10^3 ttbar (measure σ to 10%)

} Background for new physics; Need to understand very well

Initial Higgs searches and searches for physics beyond the SM

> 200 pb^{-1} Entering Higgs discovery era and explore large part of SUSY and new resonances at ~ few TeV

LHC discoveries vs. time: we can dream !!



" We are ready for an unforeseen event that may or may not occur"
(A. Gore)