

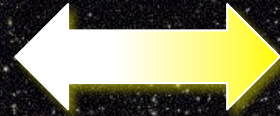
The Archeology of the Universe



Torino, 4 July 2010

Felicitas Pauss
CERN and ETH Zurich

Why?



Physics goals

How?



The instruments

Where?



CERN

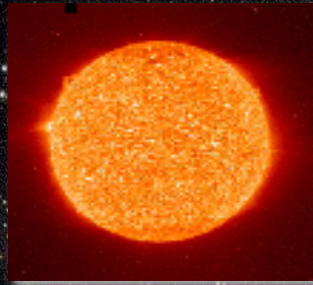


The mission of CERN and the impact
of fundamental science on society

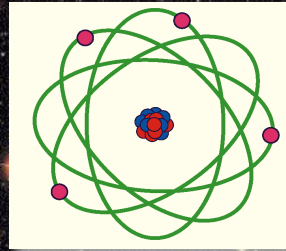
Our Visible Universe



$\sim 10^{11}$ Galaxies



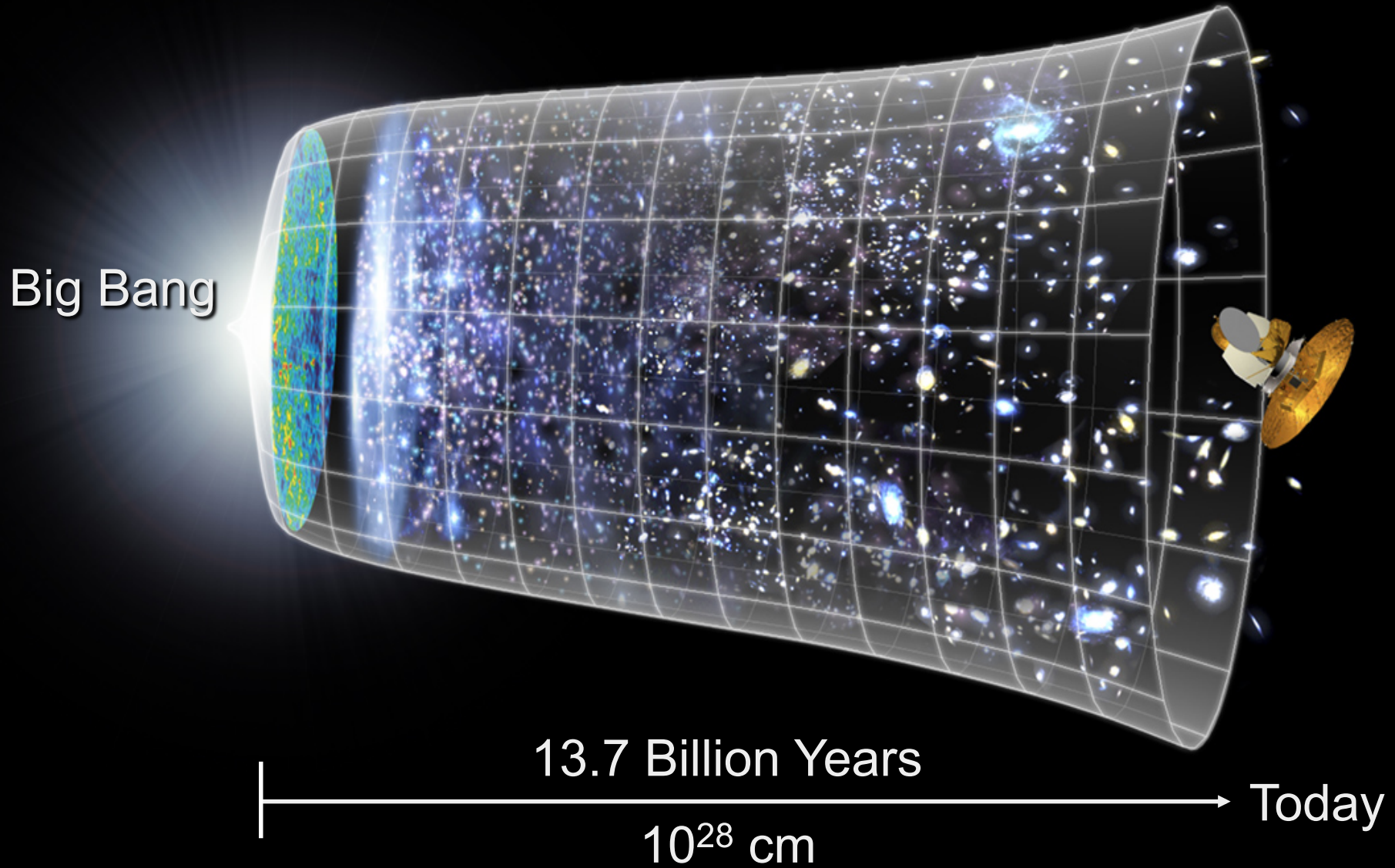
$\sim 10^{21}$ Stars

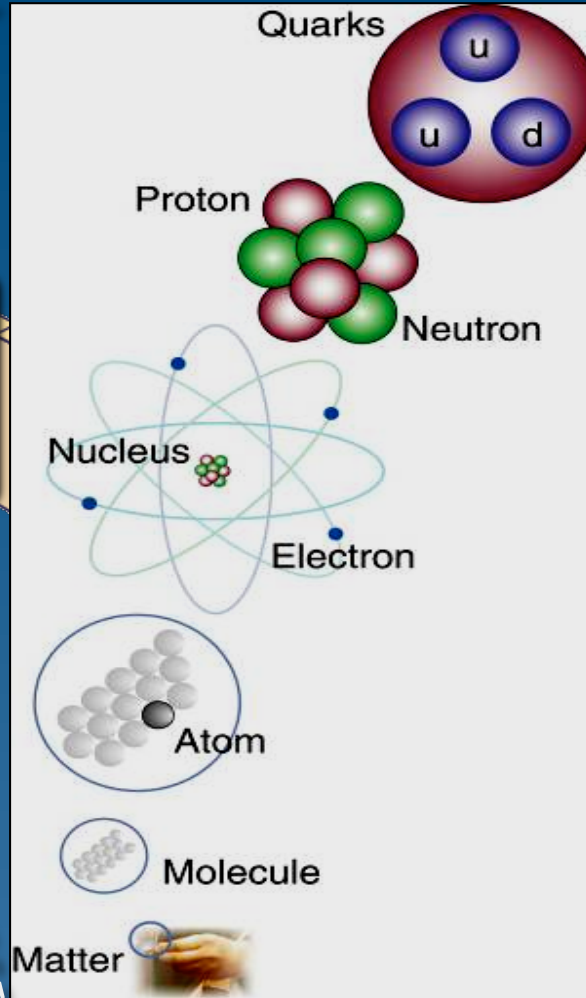
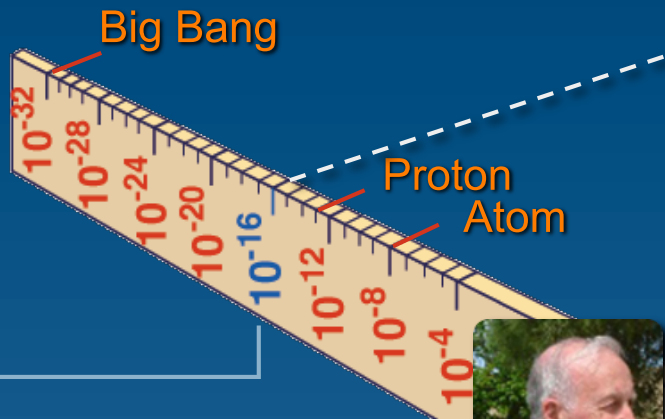


$\sim 10^{78}$ Atoms

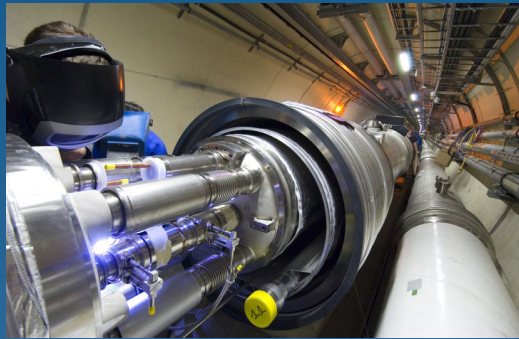
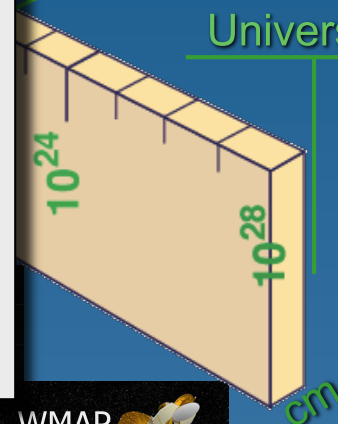
$\sim 10^{88}$ Photons

Evolution of the Universe





Radius of Galaxies
Universe



LHC

Super-Microscope



Study physics laws of first moments after Big Bang
increasing Symbiosis between Particle Physics,
Astrophysics and Cosmology

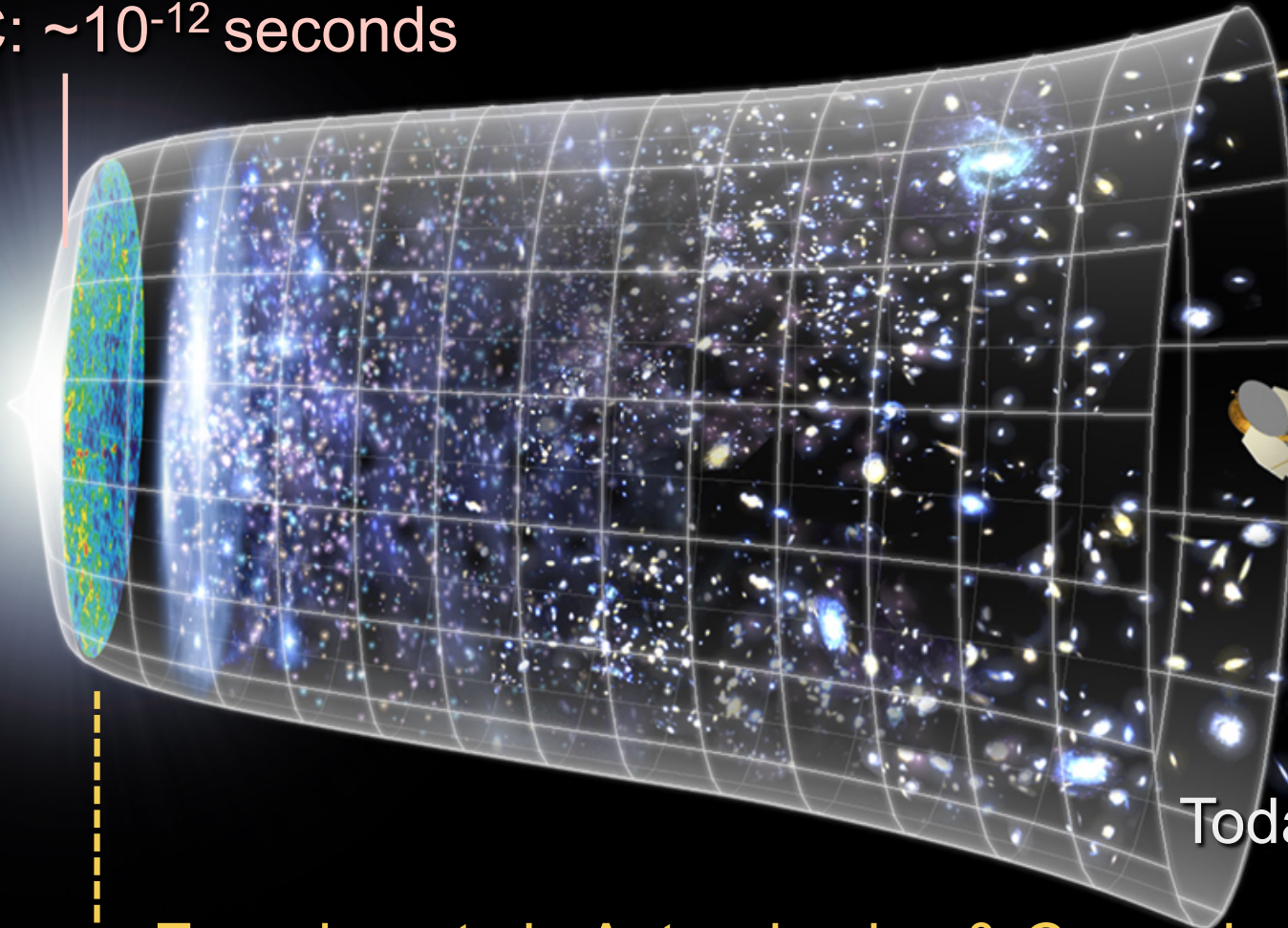


Evolution of the Universe

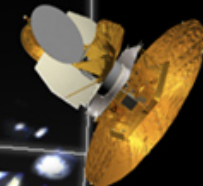


LHC: $\sim 10^{-12}$ seconds

Big Bang



Today



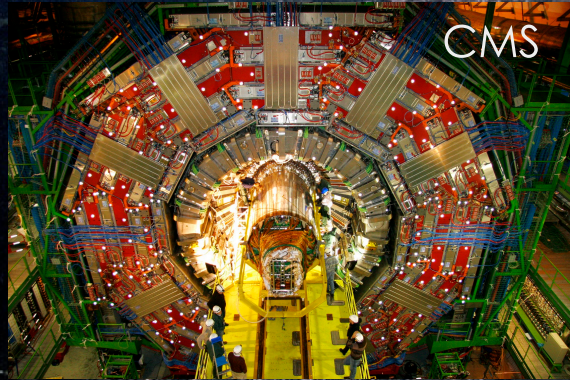
WMAP (2001)
COBE (1989)

Experiments in Astrophysics & Cosmology

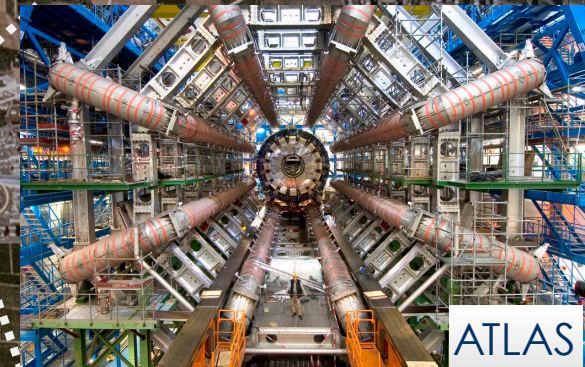
$\sim 300'000$ years

Enter a New Era in Fundamental Science

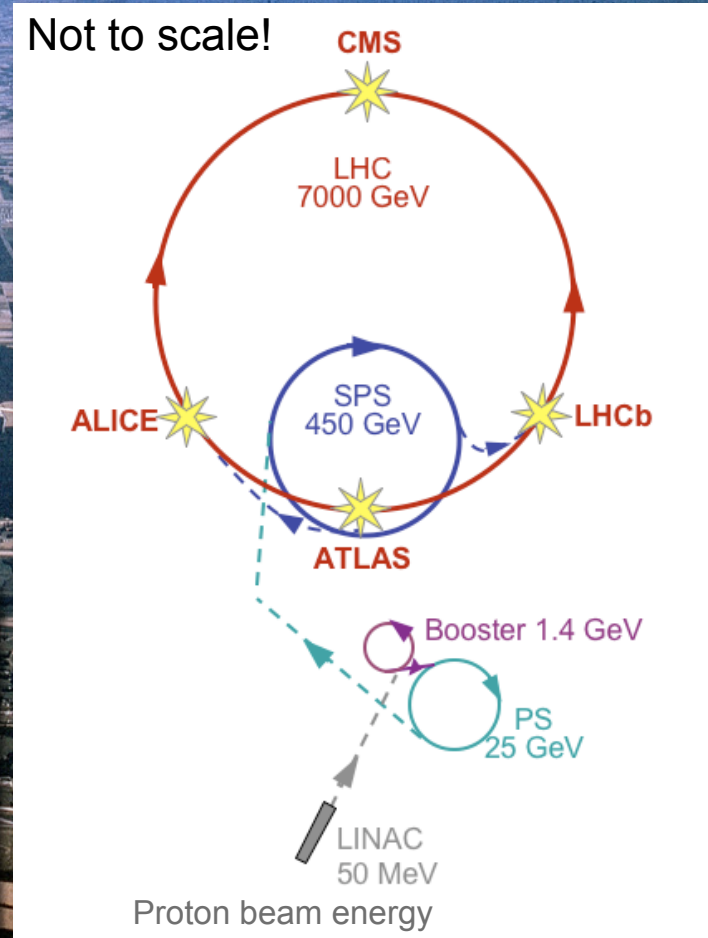
Start-up of the Large Hadron Collider (LHC), one of the largest and truly global scientific projects ever, is the most exciting turning point in particle physics.



Exploration of a new energy frontier



$$E = mc^2$$



10^{11} protons per bunch
~ 3000 bunches
collisions: $40 \cdot 10^6$ per second

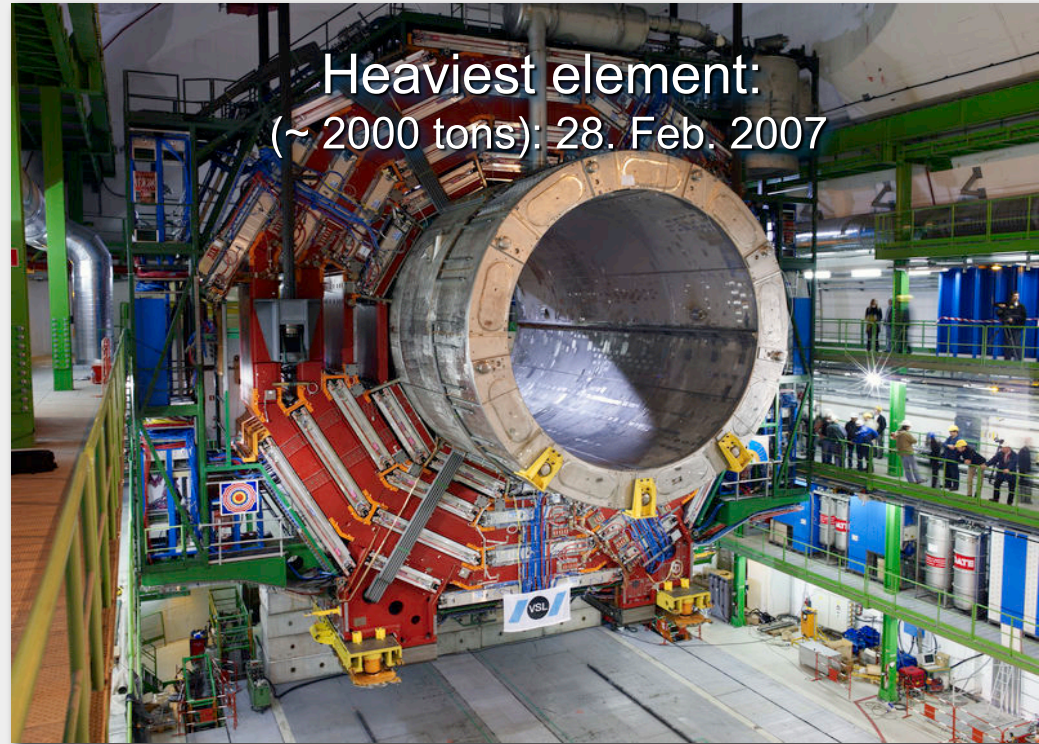


Example of an experiment at LHC: installation in experimental cavern

Installation in cavern started
in Nov 2006

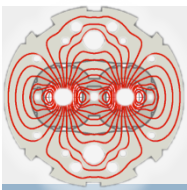


Heaviest element:
(~ 2000 tons): 28. Feb. 2007

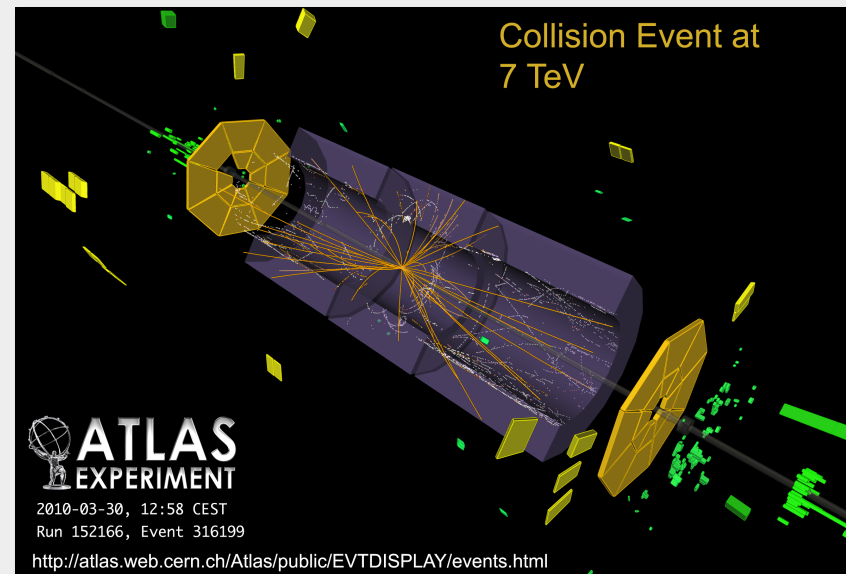
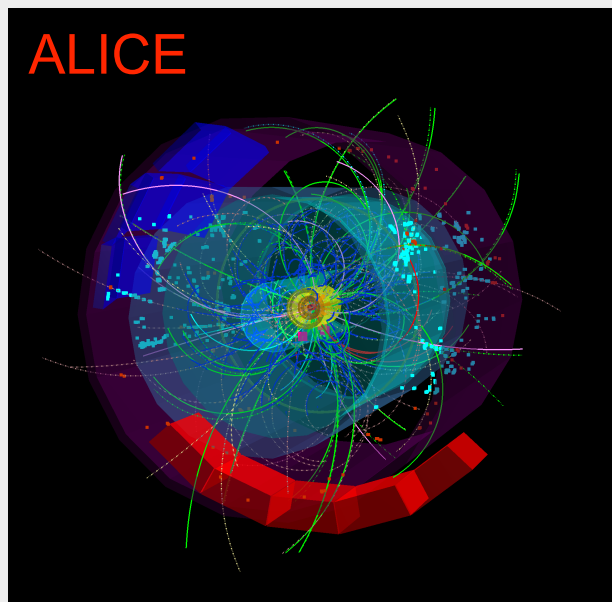


.... About weight of 5 Jumbo jets ,
or 3.5 Airbus380-planes....

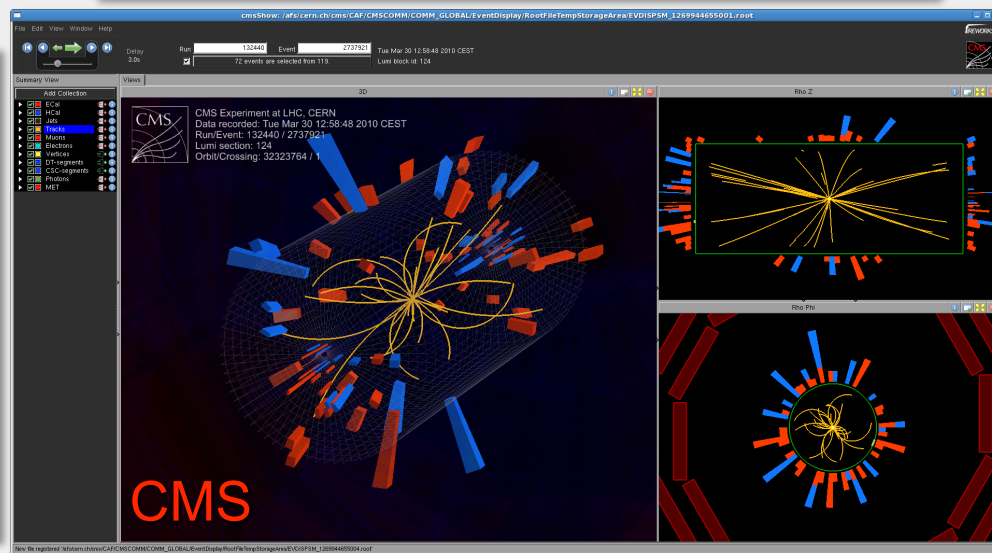
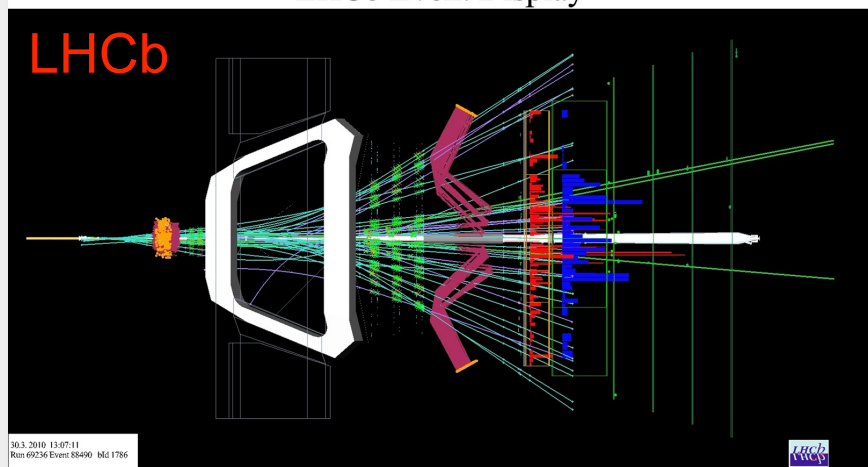


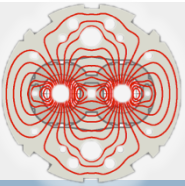


LHC: First collisions at 7 TeV on 30 March 2010

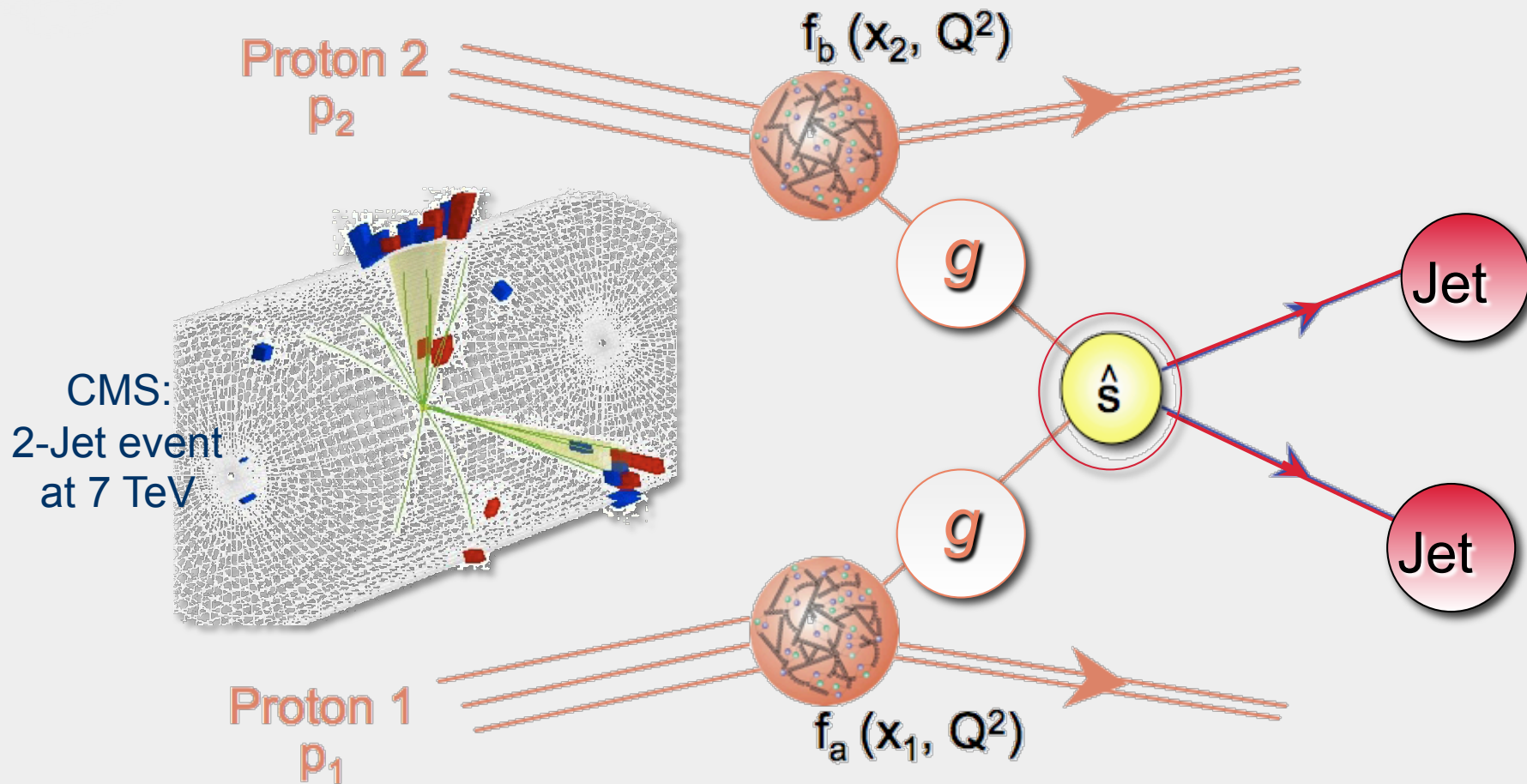


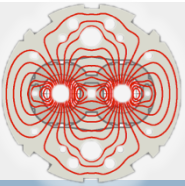
LHCb Event Display



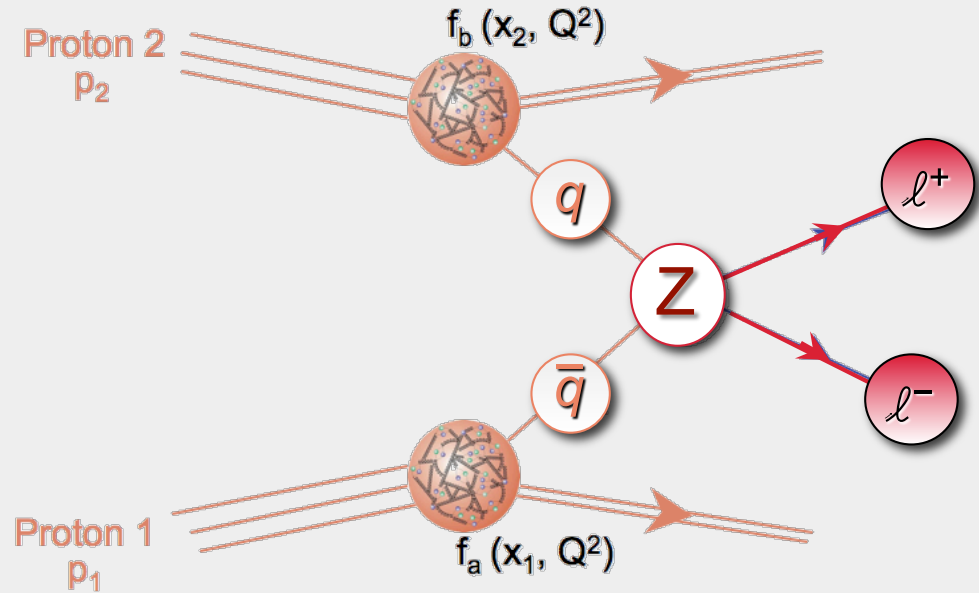
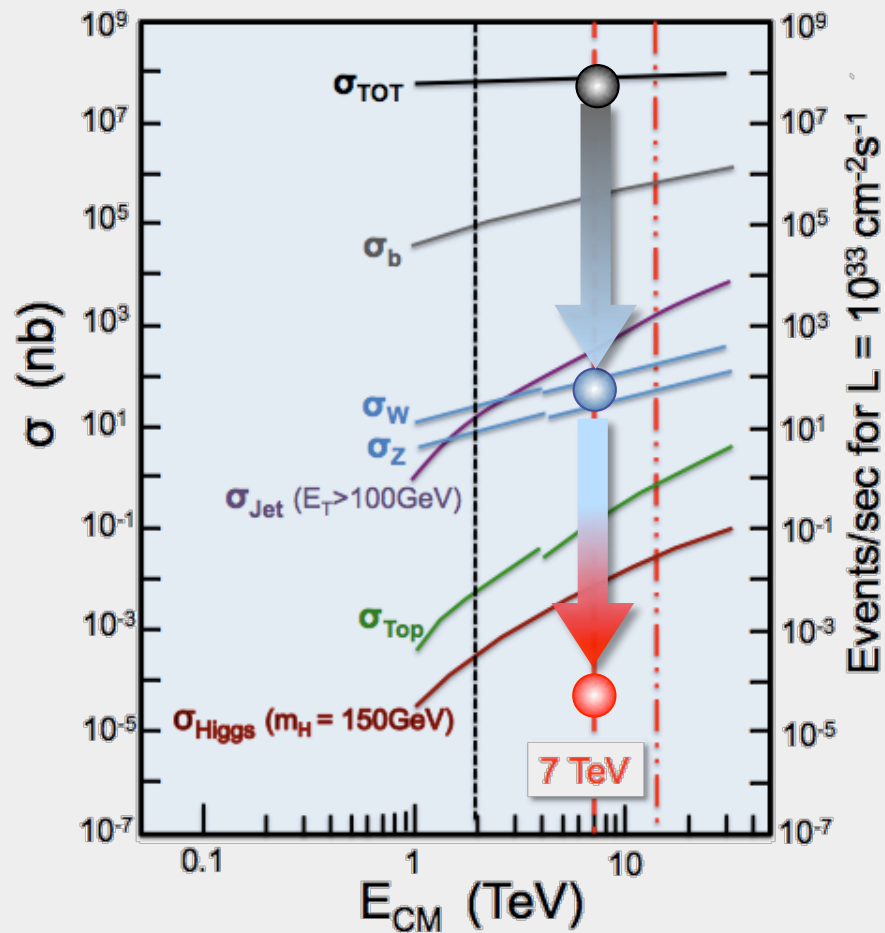


Basic processes at LHC





Basic processes at LHC



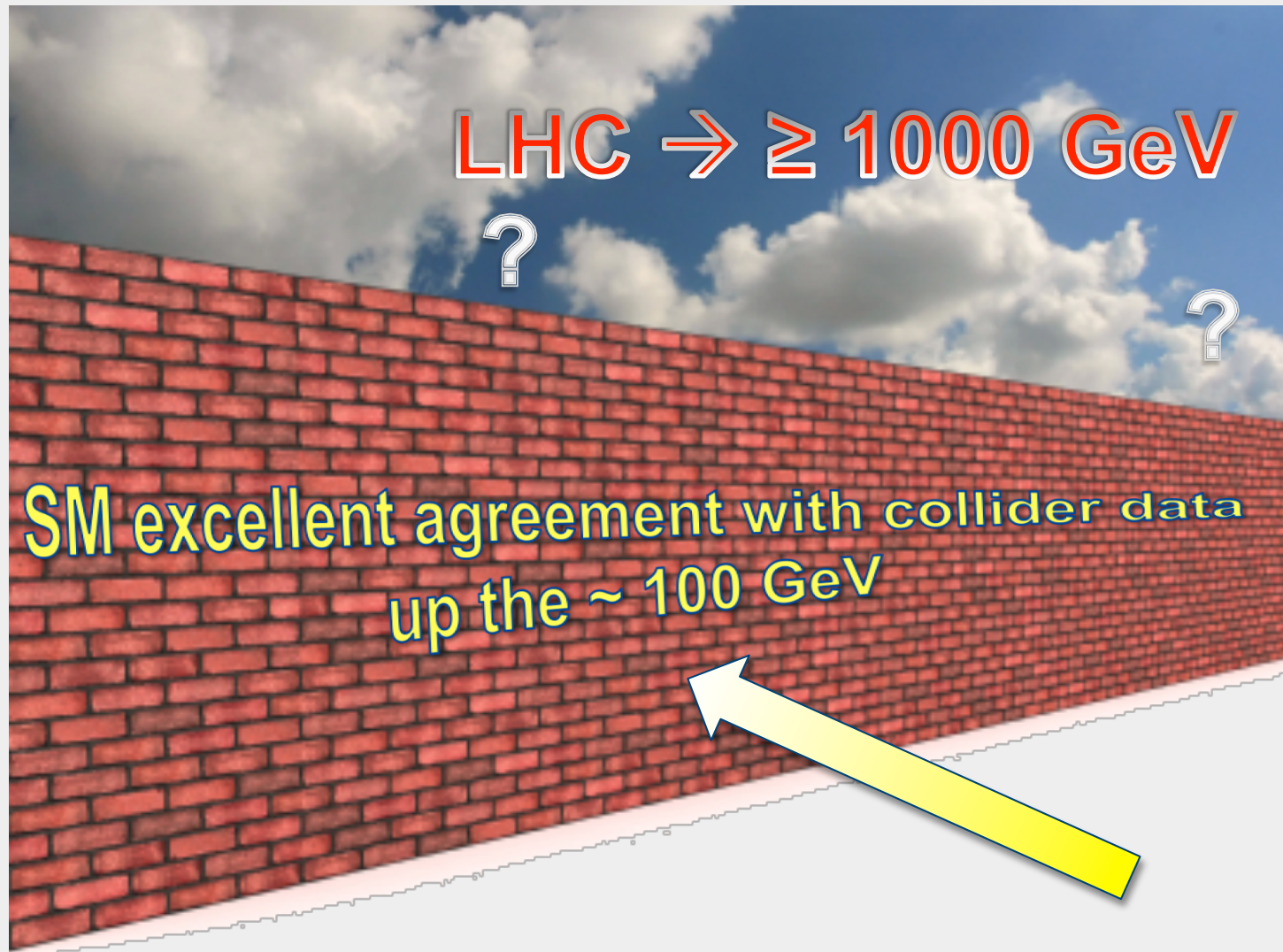
CMS Experiment at LHC, CERN
Run 133877, Event 28405693
Lumi section: 387
Sat Apr 24 2010, 14:00:54 CEST

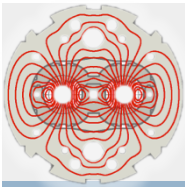
Electrons $p_T = 34.0, 31.9 \text{ GeV}/c$
Inv. mass = $91.2 \text{ GeV}/c^2$

The image shows a 3D reconstruction of the CMS detector with particle tracks. A circular inset provides a magnified view of the vertex region where the Z boson decayed into two electrons.



New Landscape of Physics?





LHC: Exploration of a New Energy Frontier



Innovative technologies developed
Industry participation

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

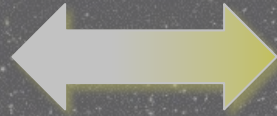
The origin of mass
Unification of fundamental forces
Matter-Antimatter Asymmetry
New forms of matter
Extra dimensions of space-time



Physics exploitation for the next 20 years

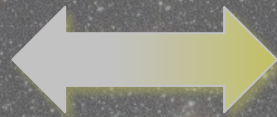


Why?



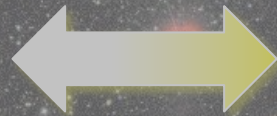
Physics goals

How?

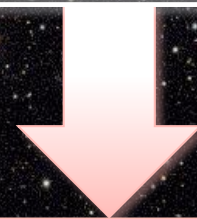


The instruments

Where?



CERN



The mission of CERN and the impact
of fundamental science on society



Founded in 1954 (12 European Member States)

CERN: European Laboratory for Particle Physics

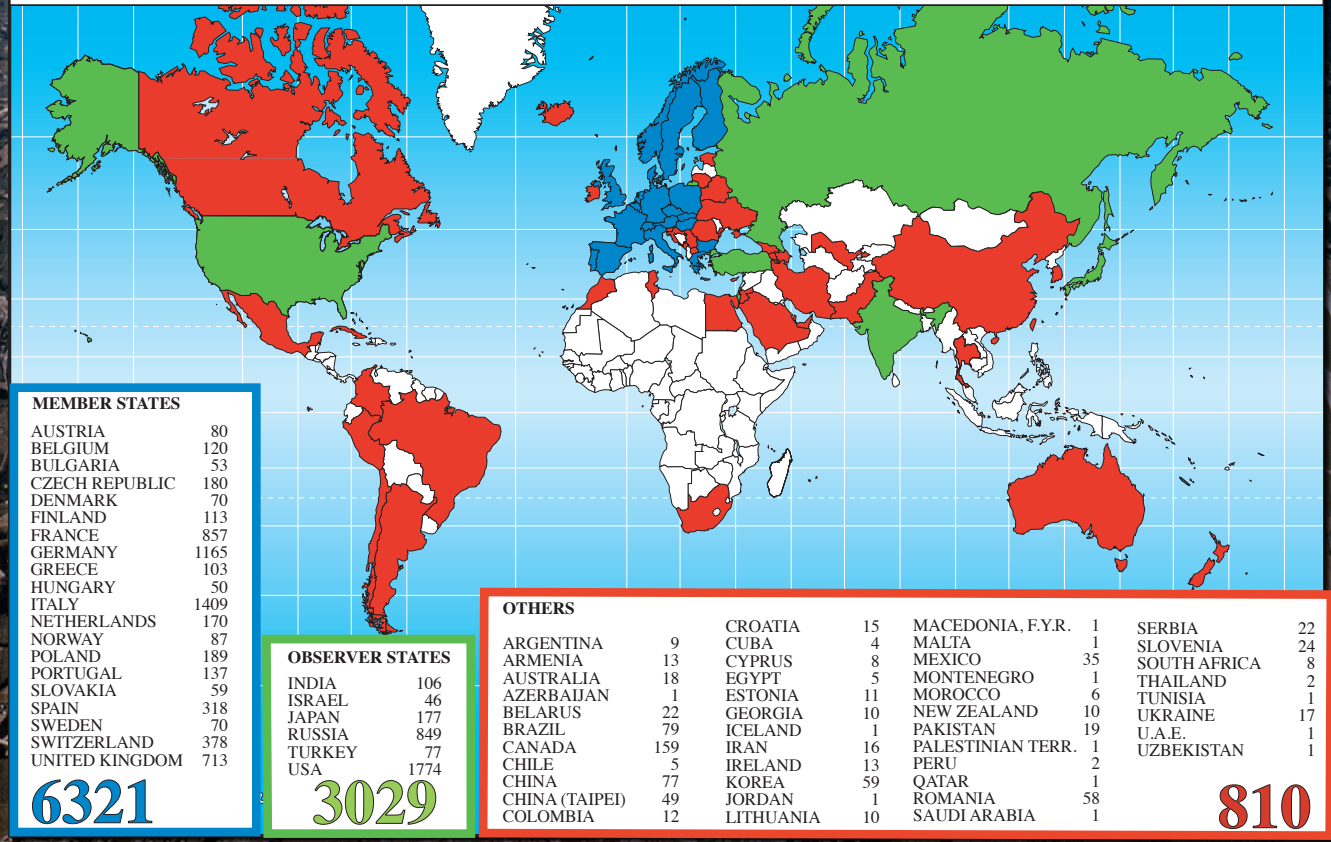
Today:

20 European Member States

8 Observers:

USA, Japan, India, Russia, Israel, Turkey, EU and UNESCO

Distribution of All CERN Users by Nation of Institute on 2 July 2010



World's largest Particle Physics Laboratory:

>10'000 Scientists from >60 countries use CERN's large infrastructures



Founded in 1954 (12 European Member States)

CERN: European Laboratory for Particle Physics

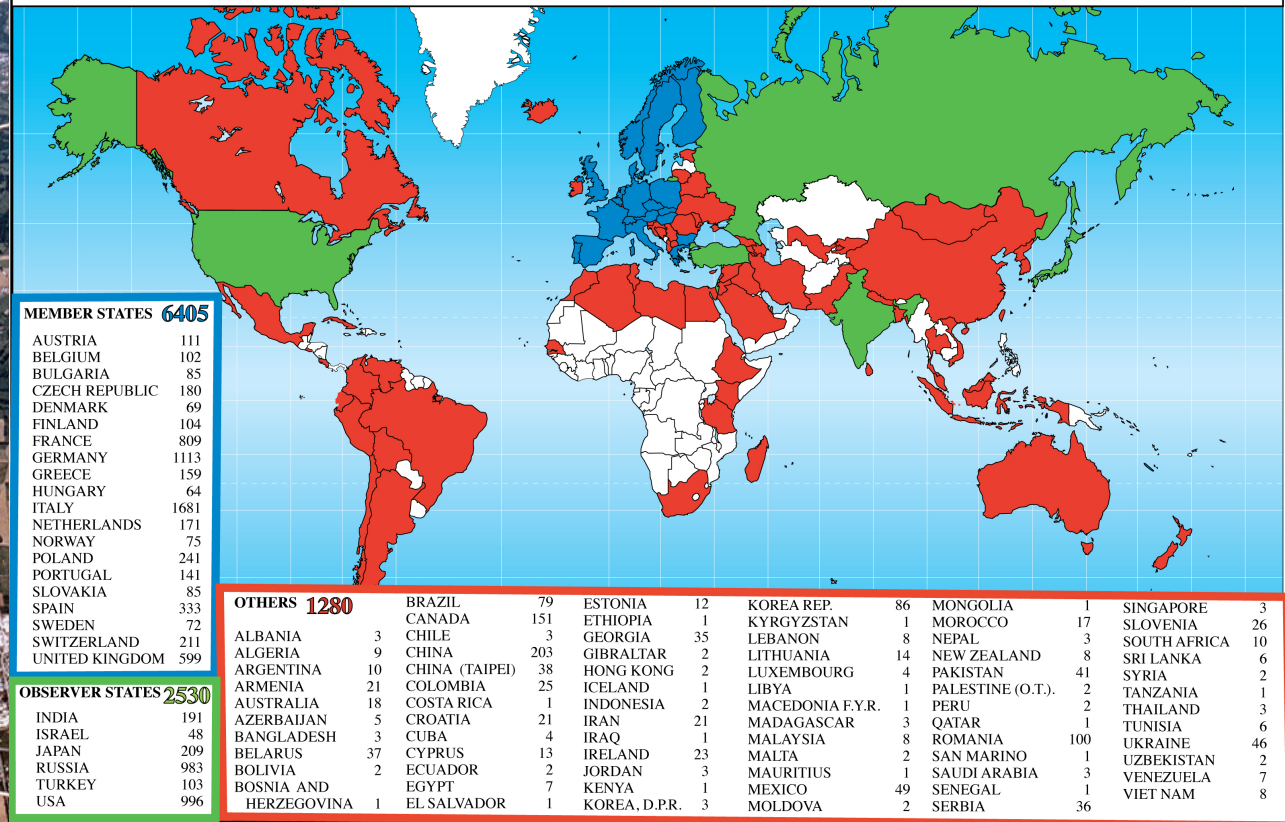
Today:

20 European Member States

8 Observers:

USA, Japan,
India, Russia,
Israel, Turkey,
EU and UNESCO

Distribution of All CERN Users by Nationality on 2 July 2010

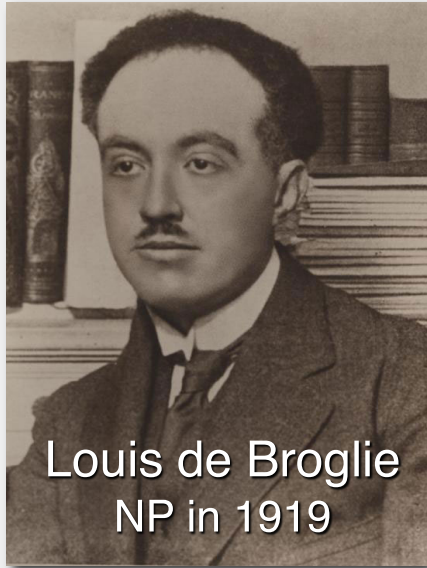


World's largest Particle Physics Laboratory:

>10'000 Scientists from >60 countries use CERN's large infrastructures



The Birth of CERN



Louis de Broglie
NP in 1919

1949: First public airing of the idea for a world class European Laboratory for basic physics

Louis De Broglie:

“A laboratory where it would be possible to carry out scientific work above and beyond the framework of the various nations taking part an engine for peaceful collaboration across borders”

CERN founded in **1954** with a **dual mission**:
Research and collaboration for the betterment of humanity



Start of construction work in Meyrin (Geneva)

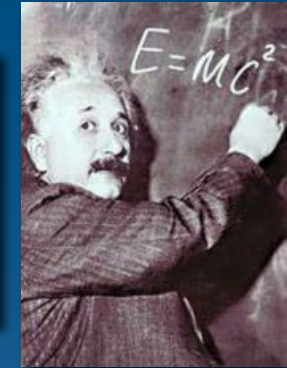




The Mission of CERN

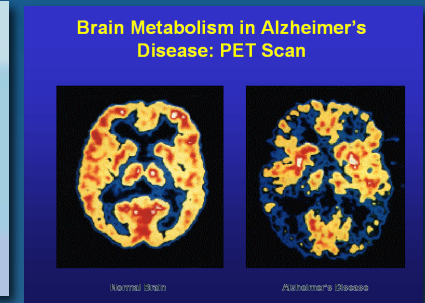
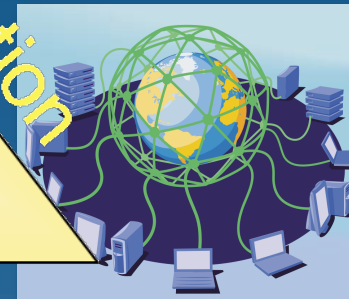
- **Push back** the frontiers of knowledge

E.g. the secrets of the Big Bang, what is the matter like within the first moments of the universe's existence?

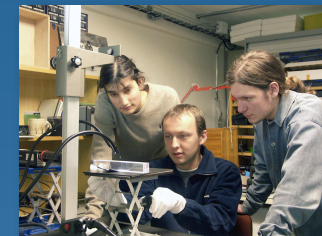


- **Develop** new technologies, accelerators and detectors

Information technology
Medicine - diagnosis and therapy



- **Train** scientists and engineers of tomorrow



- **Unite** people from different countries and cultures





CERN's Core Mission

CERN is a Laboratory devoted to **basic research**, pushing forward the **frontiers** of human **knowledge**.
CERN's scientists have made important contributions in many areas



Carlo Rubbia
Simon van der Meer

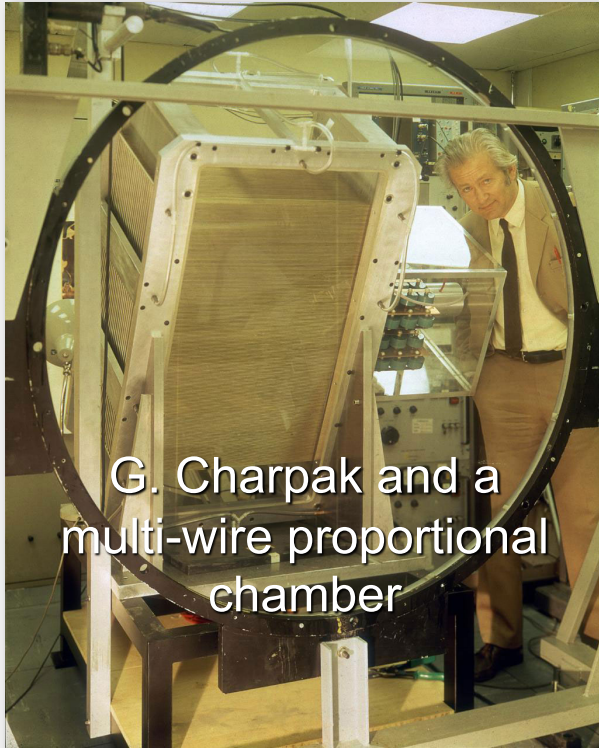
Nobel Prize in 1984:

- C. Rubbia for **basic research**
- S. van der Meer for a **technical innovation**





Particle Detection Techniques



G. Charpak and a multi-wire proportional chamber

Georges Charpak transforming particle detection techniques from optical to electronic in the 1960s
Revolutionising many other areas as well

1992: NP in Physics

Walter Le Croy: *“Charpak’s invention had transformed the world of the electronics developer”*



2006: IEEE Milestone Award

G. Charpak and W. Cleon Anderson

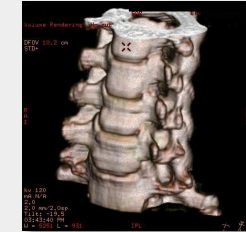




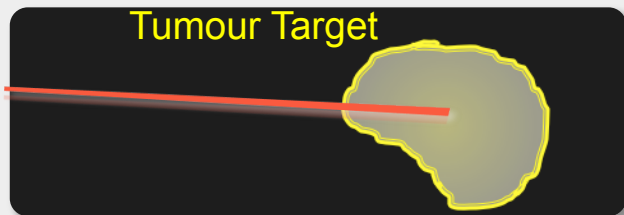
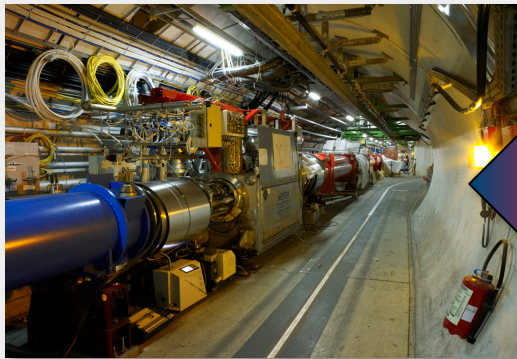
CERN Technologies - Innovation

Example: medical application

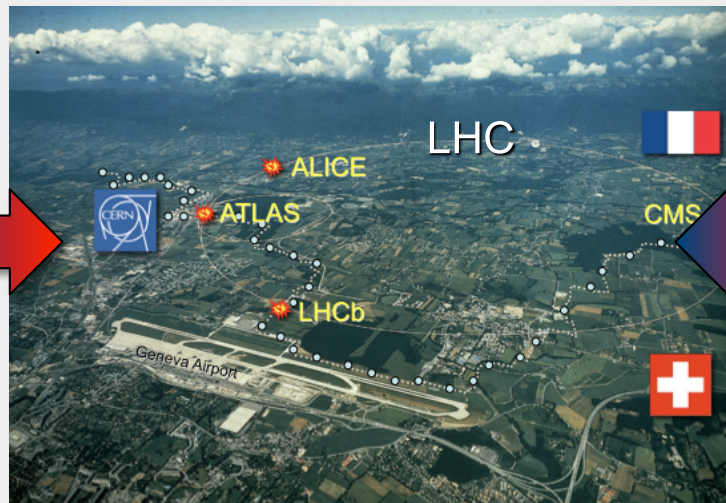
Medical imaging



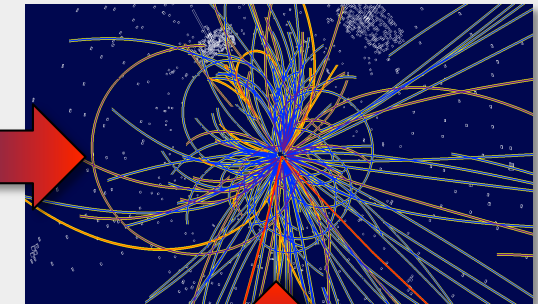
Accelerating particle beams



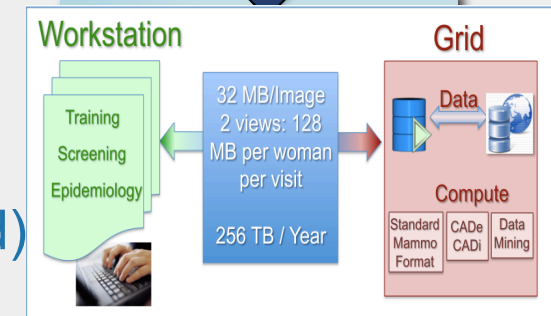
Charged hadron beam that loses energy in matter



Detecting particles



Large-scale computing (Grid)



Grid computing for medical data management and analysis



CERN Education Activities



Scientists at CERN
Academic Training Programme



2nd Latin American School
of High Energy Physics
Mexico, 2003

Young Researchers

CERN School of High Energy Physics
CERN School of Computing
CERN Accelerator School



School of Computing
Norway, 2008



Physics Students

Summer Students
Programme



CERN Teacher Schools

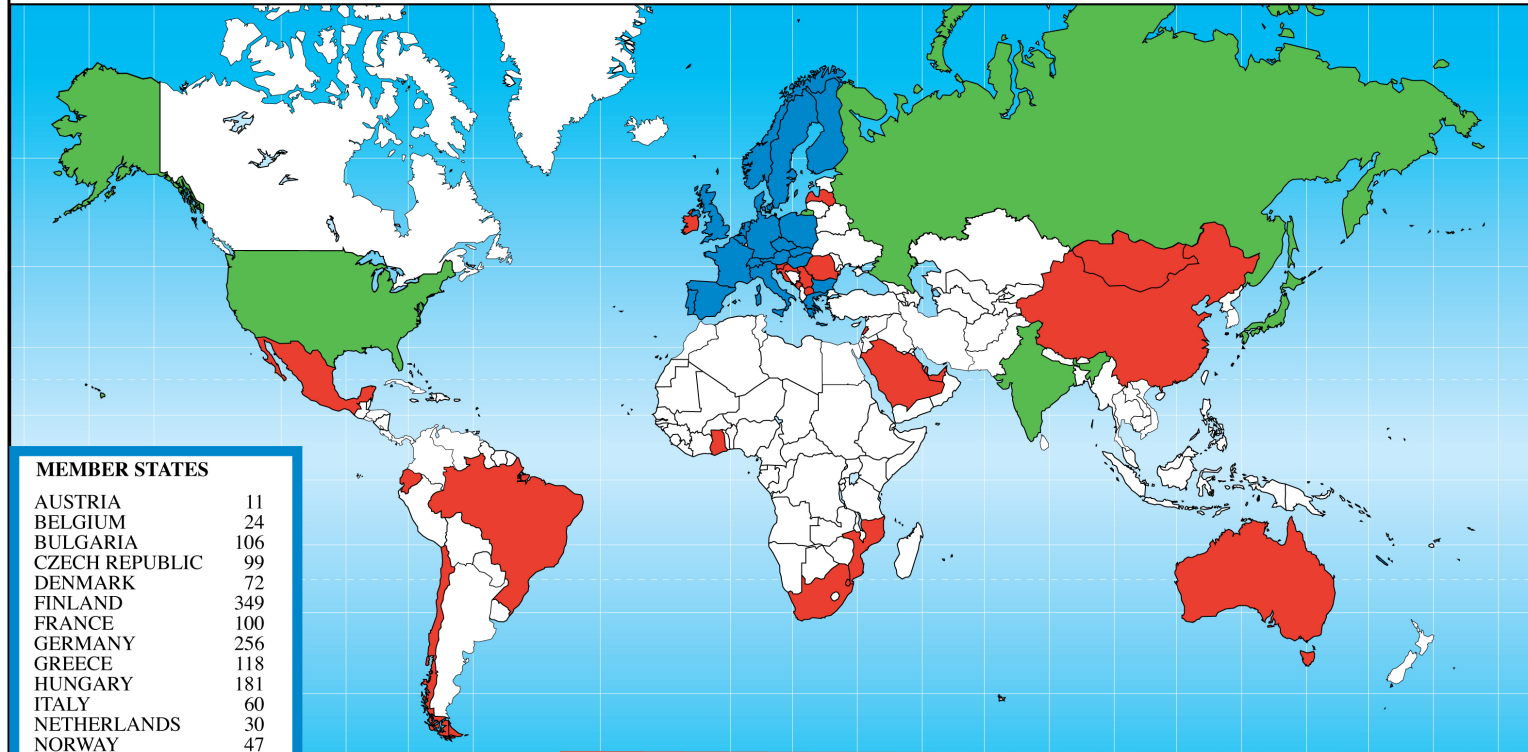
International and National
Programmes



CERN Education Activities



CERN Teacher Programme Participants 1998 - 2009



MEMBER STATES

AUSTRIA	11
BELGIUM	24
BULGARIA	106
CZECH REPUBLIC	99
DENMARK	72
FINLAND	349
FRANCE	100
GERMANY	256
GREECE	118
HUNGARY	181
ITALY	60
NETHERLANDS	30
NORWAY	47
POLAND	406
PORTUGAL	165
SLOVAKIA	145
SPAIN	122
SWEDEN	79
SWITZERLAND	12
UNITED KINGDOM	344

2726

OBSERVER STATES

INDIA	2
JAPAN	1
RUSSIA	48
USA	46

97

OTHERS

AUSTRALIA	1	IRELAND	3	MONTENEGRO	13	SLOVENIA	21
AZERBAIJAN	1	LATVIA	1	MOZAMBIQUE	5	SOUTH AFRICA	6
BRAZIL	12	LEBANON	1	QATAR	1	SWAZILAND	1
CHILE	3	MACEDONIA	10	ROMANIA	5	U.A.E.	1
CHINA	1	MALTA	36	SAUDI ARABIA	1		
CROATIA	1	MEXICO	5	SERBIA	10		
EQUADOR	1	MONGOLIA	1	SINGAPORE	2		
GHANA	1						

144





Concluding remarks (1)

European scientific and political leaders with visionary minds created CERN more than 50 years ago:

- ❑ Tying together human and financial resources for a **common scientific goal** that only could be realized by constructing large infrastructures (accelerators)
- ❑ Building **strong links** between scientists of large and small countries
- ❑ Realization of **long-term goals** with strong support from all Member States

Sir Ben Lockspeiser, first president of the CERN Council:

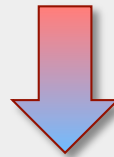
*“Scientific research lives and flourishes in an **atmosphere of freedom** – freedom to **doubt**, freedom to **enquire** and freedom to **discover**. These are the conditions under which this new laboratory has been established.”*





Concluding remarks (2)

- ❑ Basis science as carried out at CERN provides the foundations for future knowledge and innovation
- ❑ CERN became a world-class centre of excellence, attracting the best scientists and connecting Europe to the rest of the world
→ CERN became a GLOBAL LABORATORY



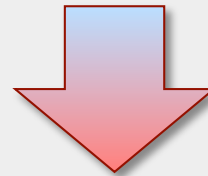
The CERN Council recognizes the increasing globalization of the field, and the important role played by CERN and thus decided in its June Session to open the door to establish more formal institutional links for any State, independent on its geographical location.





Concluding remarks (3)

I wonder whether the European scientific and political leaders who founded CERN dared to dream what more than half a century of fundamental research at CERN might bring



a very powerful engine for peaceful collaboration across borders in fundamental research

mastering forefront technologies leading to innovation

education and training of next generation of scientists and engineers → investment into the future





Thank You!
Molte Grazie!

