



*Accelerating Science and Innovation*

# The Role of Big Laboratories: CERN Past - Present - Future

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Oles Honchar Dnipro National University,  
Dnipro, Ukraine, 2-4 March, 2020

# CERN

a European Intergovernmental Organization, globally used

→ an infrastructure belonging to all its member states

→ an example of what Europe and its partners can achieve when they are working together



**1954:** European Reconstruction  
1<sup>st</sup> Session of CERN Council



**1980:** The East Meets the West  
Visit of delegation from Beijing



**Today:** Global Collaborations  
The LHC brings together > 10000 scientists and some 100 nationalities

**Today: Global Science & Global Collaborations**



# Today CERN:

## 23 Member States and 8 Associate Member States

~ 2700 staff (250 physicists, 800 Fellows)

~ 1800 other paid personnel

~ 12600 scientific users

Budget (2018) ~ 1200 MCHF

**Member States:** Austria, Belgium, Bulgaria, Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Israel, Italy, Netherlands, Norway, Poland, Portugal, Romania, Serbia, Slovak Republic, Spain, Sweden, Switzerland and United Kingdom

**Associate Member States:** Croatia, India, Lithuania, Pakistan, Turkey, Ukraine

**Associate Members in the Pre-Stage to Membership:** Cyprus, Slovenia

**Applications for Membership or Associate Membership:** Brazil, Estonia

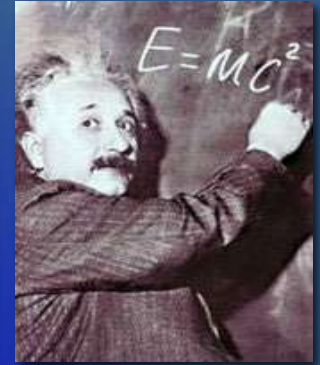
**Observers to Council:** Japan, Russia, United States of America;  
European Union, JINR and UNESCO

# The Mission of CERN

## ❖ **Research**

**Push Forward** the Frontiers of Knowledge

(E.g. the secrets of the Big Bang ...what was the matter like within the first moments of the Universe's existence?)



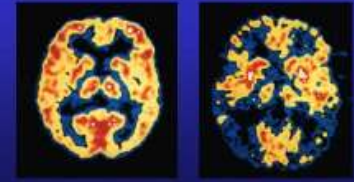
## ❖ **Innovation**

**Advances** the Frontiers of Technology

- Information technology - the Web and the GRID
- Medicine - diagnosis and therapy



Brain Metabolism in Alzheimer's Disease: PET Scan



## ❖ **Education**

**Train** Scientists and Engineers of Tomorrow



## ❖ **Outreach**

**Promote** Science in Society

## ❖ **Science for Piece**

**Unite** people from different countries and cultures through science





## MAJOR DISCOVERIES AND INVENTIONS

1958 Rare pion decays	1968 Wire chamber	1973 Neutral currents	1983 W, Z bosons	1989 World Wide Web	1992 3 generations of particles	2012 Higgs boson
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### NOBEL PRIZES TO CERN STAFF

G. Charpak Wire chamber  
C. Rubbia Discovery of W, Z bosons  
S. van der Meer Beam cooling

### THREE MAIN INSTRUMENTS: ACCELERATORS, DETECTORS, COMPUTING



Large Hadron Collider



LHC detector



CERN Data Centre

### CERN'S SCIENTIFIC OUTPUT PER YEAR

900 peer reviewed research papers  
600 PhD theses

### UNIQUE WORLD-CLASS FACILITIES

LHC, Antimatter Decelerator (AD), ISOLDE

## What is the impact of CERN?

This brochure highlights the main benefits of CERN's activities to science, innovation, the economy, international collaboration, education and people.

**Scientific knowledge.** CERN is one of the world's leading research centres for fundamental physics, and its biggest impact is due to great scientific discoveries. The Large Hadron Collider and other unique facilities at CERN provide the necessary infrastructure for scientists around the world to gain more knowledge about the smallest constituents of matter, their interactions, and the origin and evolution of the Universe.

**Innovation, knowledge transfer, and the economy.** While CERN's research is primarily motivated by curiosity, its impact on society and everyday life is significant. Reaching ambitious scientific objectives requires the development of advanced instruments and new technologies, making CERN and the collaborating institutes and laboratories drivers of innovation. This brings tremendous benefit to society and the economy, through knowledge transfer.

**International collaboration.** CERN is a powerful model for international cooperation. About 16,000 scientists of more than 110 different nationalities work together effectively and peacefully towards a common goal, regardless of ethnical, cultural, political or religious differences. The history of CERN has shown that scientific collaboration can build bridges between nations.

**Education and outreach.** CERN contributes to improving science education from secondary school to postgraduate level, and to a broader understanding of science by the general public. Many of the young physicists, engineers and technicians trained at CERN transfer their expertise to other research projects, to industry or to society at large. CERN engages in many ways with citizens from across the globe through a variety of outreach activities. Learning about the fundamental constituents of the universe and how scientists try to answer fascinating questions inspires young people and increases the attraction of science and technology.

# Organisation Européenne pour la Recherche Nucléaire European Organization for Nuclear Research

Founded in 1954 by 12 European States « Science for Piece »

The CERN “parents”:

a group of farsighted  
scientists, politicians,  
diplomats



After World War 2 the HEP scientific community, rather than politicians or business leaders, has always led the scientific decision process. The pressure of the business sector, indeed, has never been major justification for the large HEP projects

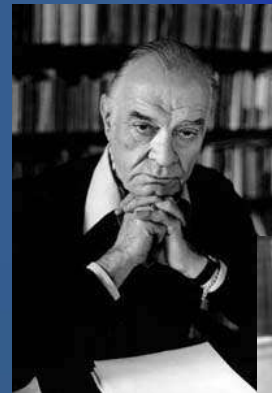
**a Large International Infrastructure  
with Impact Beyond Science and Technology**



# 1949: The origins of CERN, Lausanne



- European science was depleted
- Nuclear scientists wanted to do something for peace
- The word nuclear held promise
- Political and scientific consensus
- Denis de Rougemont: European Cultural Conference, Lausanne, 1949



Louis de Broglie proposed: *"the creation of a laboratory or institution where it would be possible to do scientific work, but somehow beyond the framework of the different participating states [Endowed with more resources than national facilities, **such a laboratory could**] undertake tasks, which, by virtue of their size and cost, were **beyond the scope of individual countries**".*

# 1950: UNESCO General Conference, Florence



American Nobel laureate, Isidor Rabi tables a resolution authorizing UNESCO to: *"assist and encourage the formation of regional research laboratories in order to increase international scientific collaboration..."*



## 1951: UNESCO inter-Governmental meeting, Paris

## 1952: The choice of Geneva

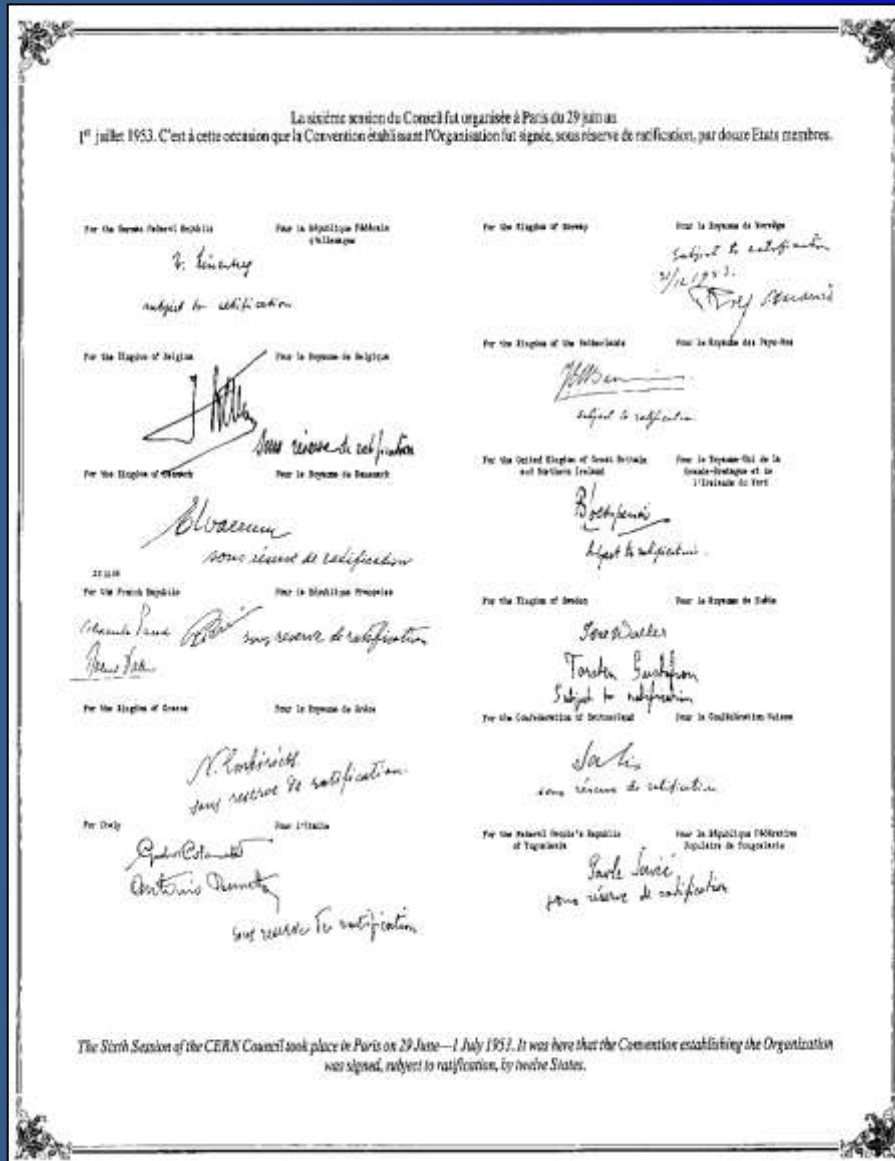
At a meeting of **UNESCO** in Paris in **December 1951**, the 1<sup>st</sup> resolution concerning the establishment of a European Council for Nuclear Research was adopted. Two months later, 11 countries signed an agreement establishing the provisional Council – **the acronym CERN was born.**



At the provisional Council's third session in October 1952, Geneva was chosen as the site of the future Laboratory. This choice was finally ratified in a referendum organized by the Canton of Geneva in June 1953.



# 1954: The organization is born



The CERN Convention, established in July 1953, was ratified by the 12 founding Member States: Belgium, Denmark, France, the Federal Republic of Germany, Greece, Italy, the Netherlands, Norway, Sweden, Switzerland, the UK, and Yugoslavia. **On 29 September 1954, the European Organization for Nuclear Research officially came into being. CERN was dissolved but the acronym remains.**



# 1957: CERN's first accelerator (synchrocyclotron) arrives



The SC provided a beam of 600 MeV for particle physics (until 1964) and nuclear physics (until 1990 for ISOLDE)

33 years of successful operation!



# 1959: CERN's first big machine



Start up of the CERN Proton Synchrotron, assisted by Hildred Blewett from Brookhaven....



1961: ADA at Frascati...

**The late 1950s saw the healthy competitive collaboration between the US and Europe that continues to this day...**



... who shared the technique of strong focusing, invented at Brookhaven, with her European colleagues.



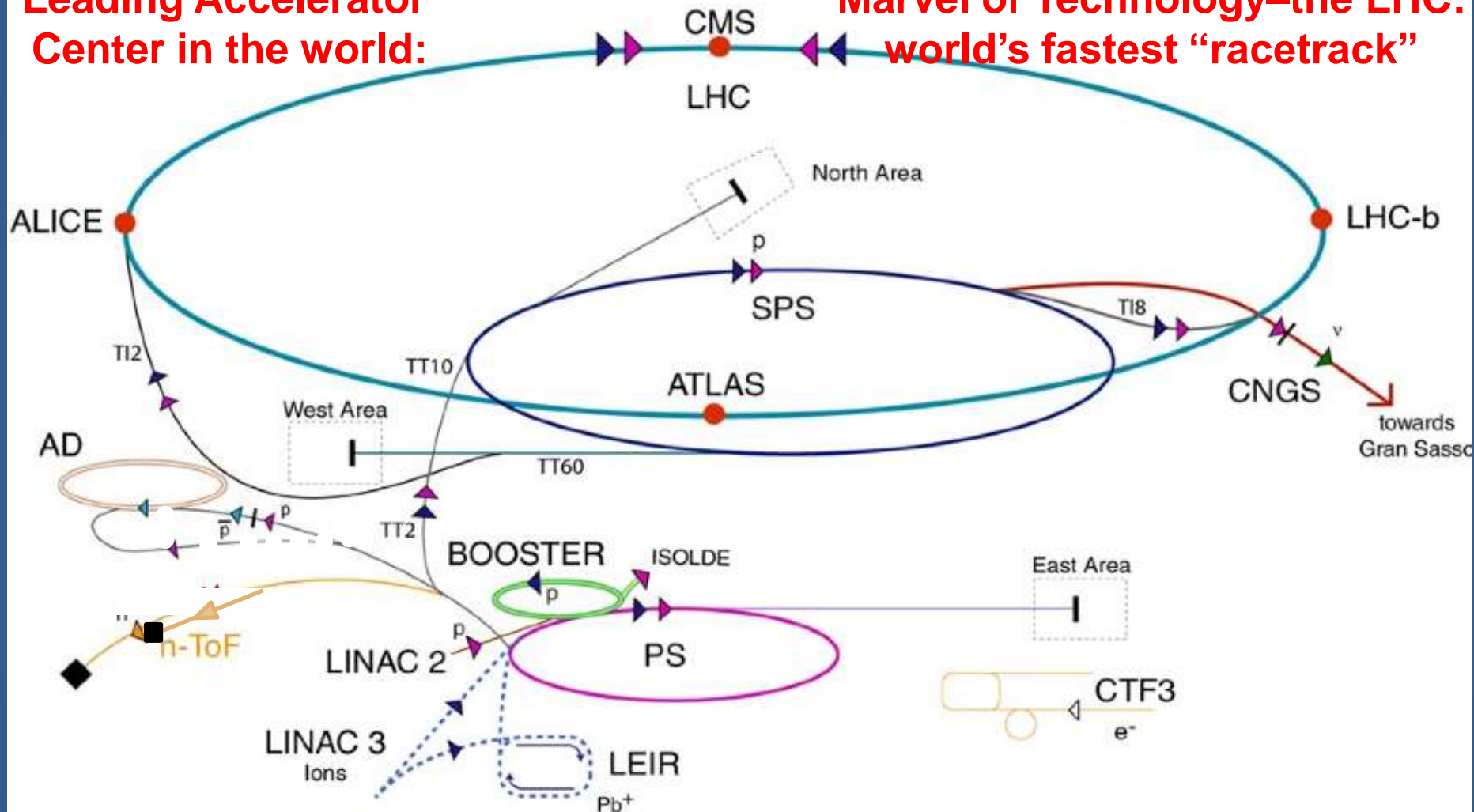
... and VEPP-1 at Novosibirsk



# CERN Accelerator Complex today

Leading Accelerator  
Center in the world:

Marvel of Technology—the LHC:  
world's fastest “racetrack”



▶ protons	▶ antiprotons	AD Antiproton Decelerator	LHC Large Hadron Collider
▶ ions	▶ electrons	PS Proton Synchrotron	n-ToF Neutron Time of Flight
▶ neutrons	▶ neutrinos	SPS Super Proton Synchrotron	CNGS CERN Neutrinos Gran Sasso
			CTF3 CLIC Test Facility 3

# PARTICLE PHYSICS LANDSCAPE AT CERN

High Energy Frontier

**LHC**

Low Energy

**heavy flavours / rare decays**

**neutrino oscillations**

**anti-matter**

Multidisciplinary

**climate, medicine**

Non-accelerator

**dark matter**

**astroparticles**

Hadronic Matter

**deconfinement**

**non-perturbative QCD**

**hadron structure**

**Non-LHC Particle Physics = o(1000) physicists / o(20) experiments**

Scientific Diversity at **UNIQUE FACILITIES**

**CERN maintains and upgrades these facilities**

Complemented and Supported by **THEORY**





# *Accelerating Science and Innovation*

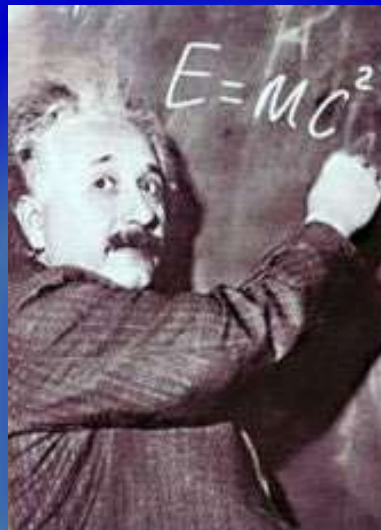
**Fundamental Research:**  
Push forward  
the frontiers of knowledge





# CERN: Push forward the frontiers of knowledge.....

## Seeking answers to questions about the Early Universe:



“Newton’s unfinished business”... **what is mass?**

Science’s little embarrassment... **what is 96% of the Universe made of?**

Nature’s favouritism... **why is there no more antimatter?**

The secrets of the Big Bang... **what was matter like within the first moments of the Universe’s life?**



# Exploration of a new energy frontier Large Hadron Collider (LHC)

CMS

LHCb

- Largest scientific instrument ever built, 27 km of circumference
  - >10 000 people involved in its design, construction, exploitation
  - ATLAS / CMS collaborations: > 3000 people contributed to the construction of the experiments for the Higgs discovery
- can you imagine, 500 full professors from > 200 institutes worldwide working together towards one goal ... 500 personalities – **it is possible !**

LHC ring:

TOTEM  
LHCf  
MOEDAL

ATLAS



# Marvel of Technology – the world's fastest racetrack – LHC

Protons are accelerated around circular orbits by electric fields (superconducting RF cavities) → 1232 superconducting magnets, each 15 m long, operating at 8.3 T (200'000 x Earth's magnetic field) and 1.9K (-271°C) in superfluid helium.



## Energy stored in LHC magnets:

1 dipole magnet  $E_{\text{stored}} = 7 \text{ MJ}$

All magnets  $E_{\text{stored}} = 10.4 \text{ GJ}$

The kinetic energy of an A380 at 700 km/hour



## Energy stored in LHC beams

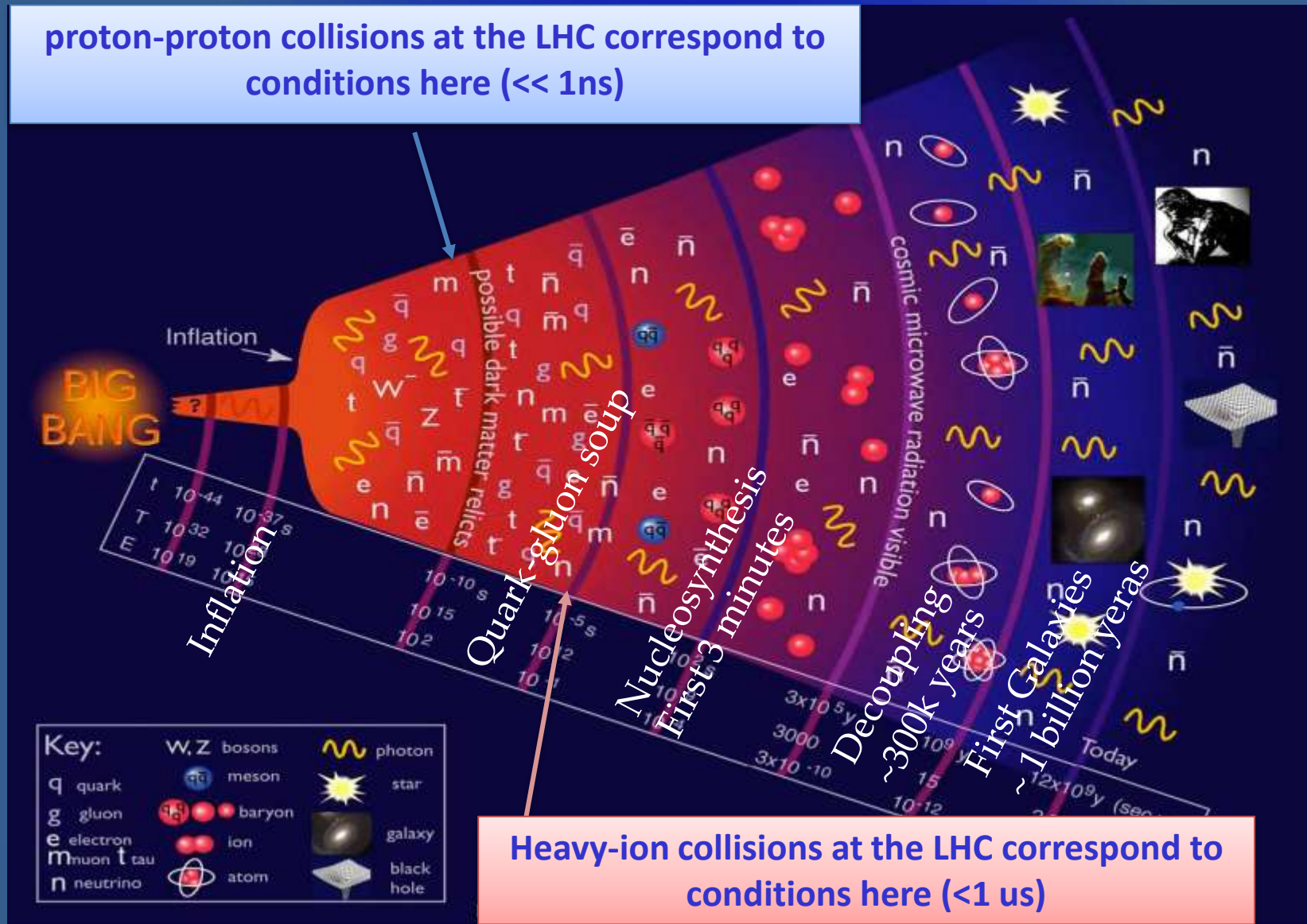
- Kinetic energy of 1 proton bunch:
  - $E_1 = (1.15 \times 10^{11} \text{ protons}) \times 7 \text{ TeV} = 129 \text{ kJ}$
- Kinetic energy of beam = 2808 bunches:
  - $E_{\text{beam}} = k \times E_1 = 2808 \times E_1 = 362 \text{ MJ}$

Enough to melt 5.6 tons of gold



# Brief History of Our Universe and Physics of LHC

proton-proton collisions at the LHC correspond to conditions here ( $\ll 1\text{ns}$ )



Particles (which are very small « objects ») of high energy are instruments to go back in time

## 2000x: Fear and loathing... are they going to end the world?



Has the new CERN project – the LHC - the potential to create a black hole that swallows our planet earth?

<https://www.forbes.com/sites/startswithabang/2016/03/11/could-the-lhc-make-an-earth-killing-black-hole/#2fe64fd02ed5>



# 2013: Nobel Prize in Physics for Higgs Boson Discovery



**CERN and LHC collaborations has been a magnet for scientific talent from around the world.**

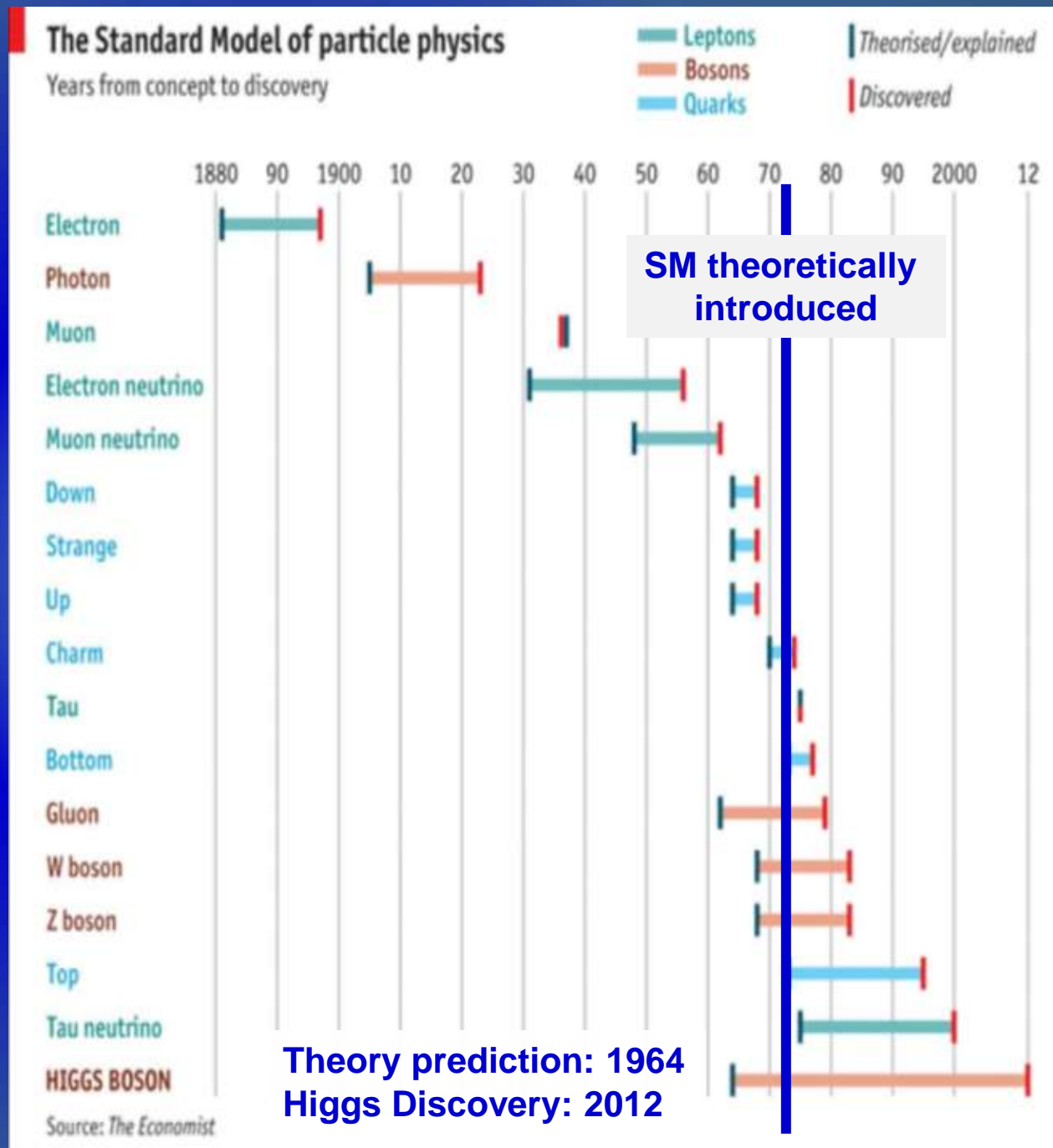


*'The Large Hadron Collider at CERN is the largest most complex machine in the world, possibly the universe. By smashing particles together at enormous energies, it recreates the conditions of the Big Bang. **The recent discovery of what looks like the "Higgs particle" is a triumph of human endeavour and international collaboration.** It will change our perception of the world and has the potential to offer insights into a complete theory of everything.'* **Stephen Hawking**

**Source:**  
**The Economist**  
**July 4th, 2012**

With a well-founded  
theoretical model,  
precision measurements  
can be turned into  
discoveries - and  
precision measurements  
can guide the  
development of new  
models

**The clear need for  
long-term planning  
in our research field**







*Accelerating Science and Innovation*



**Science & Innovation:**  
**Advance the Frontiers of  
Technology**



[https://cds.cern.ch/record/1551933/files/Strategy\\_Report\\_LR.pdf](https://cds.cern.ch/record/1551933/files/Strategy_Report_LR.pdf)



# Particle Physics and Innovation

- **Interfacing** between fundamental science and key technological developments



- **CERN Technology and Innovation** : development and transfer of technology to other fields of research, industry and society

Since 1954, several achievements have been made at CERN, some of which have been rewarded with the Nobel Prize in Physics.



Accelerating particle beams



Detecting particles



Large-scale computing (Grid)



# From Accelerators to Solar Panels

A kind of molecular flypaper was developed to keep perfect vacuum inside the LEP accelerator pipe. This technology, applied to solar collectors, provides ultra-efficient thermal insulation and increases by a factor of 10 the efficiency of standard rooftop solar panels.

Inside the LEP beam pipe.  
The metal ribbon acts as molecular flypaper.



The same technology is at work  
inside solar panels on the roof  
of Geneva airport.



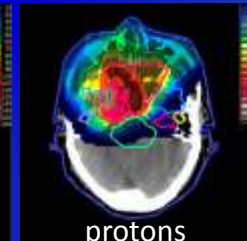
<https://www.forbes.com/sites/jenniferhicks/2012/03/13/geneva-international-airport-gets-largest-solar-energy-system/#53d99fd373af>

# Medical Application as Example of Particle Physics Spin-off

Combining Physics, ICT, Biology and Medicine to fight cancer



## Hadron Therapy



Leadership in Ion Beam Therapy now in Europe and Japan

Accelerating particle beams  
~30'000 accelerators worldwide  
~17'000 used for medicine

>100'000 patients treated worldwide (45 facilities)  
>50'000 patients treated in Europe (14 facilities)



Detecting particles

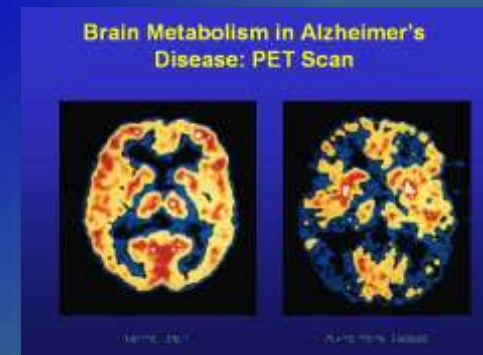
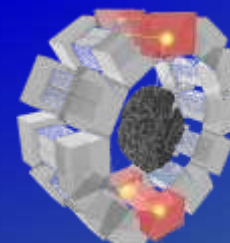


## Imaging

Clinical trial in Portugal, France and Italy for new breast imaging system (ClearPET)



PET Scanner





# Steadily Growing Interest in Hadron Therapy

Low energy synchrotrons and cyclotrons are now commonly used in industry, e.g. food industry (around 20000) and in hospitals (around 10000). Their annual commercial output is valued at up to €500 billion.

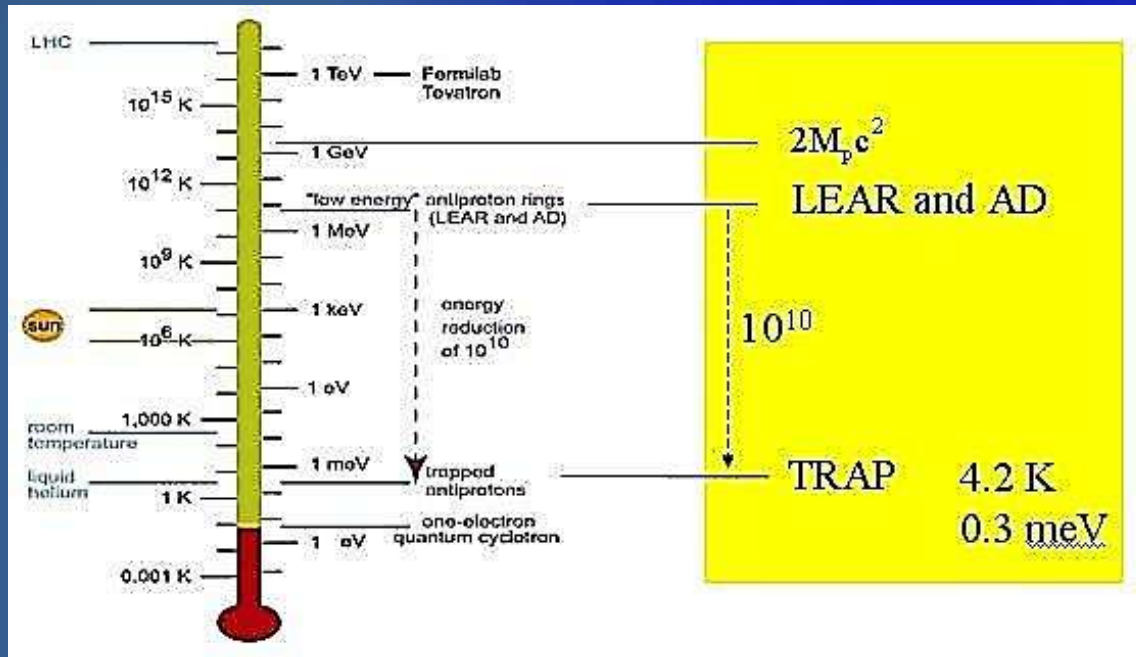
The Proton Ion Medical Machine Study (PIMMS) at CERN produced an accelerator design optimized for hadron therapy, deployed in MedAustron (Austria) and CNAO (Italy)

Interest/plans for new facilities in Bulgaria, Greece, Norway, Denmark, the Netherlands, UK, Spain

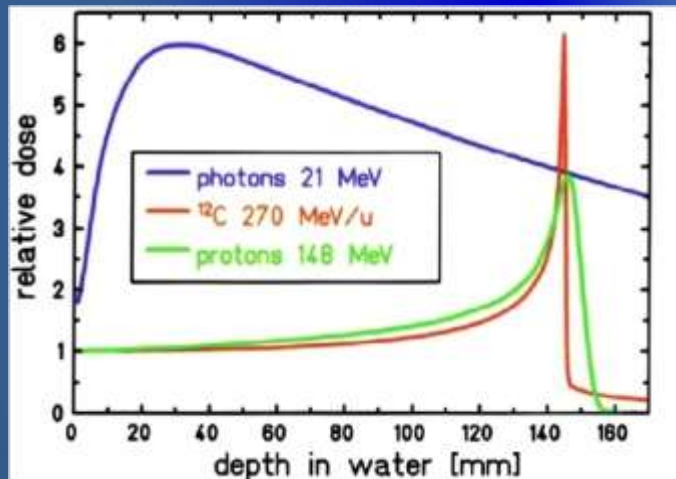
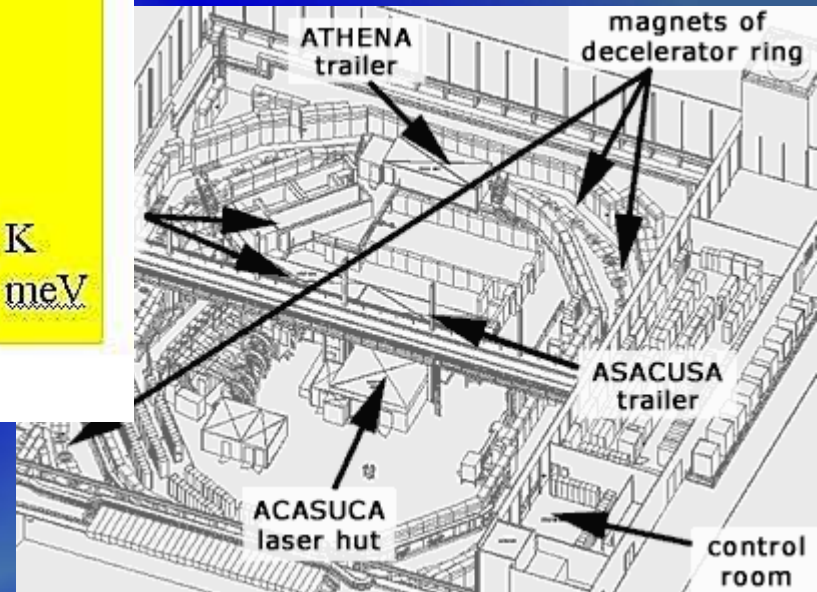
Need more research and biomedical studies with different ions (BioLEIR)



# Anti-Proton Decelerator and ACE Experiment @ CERN



Unique facility to study anti-atoms at CERN



But also for the ACE (anti-proton cell experiment) experiment studying the potential use of antiprotons in cancer therapy (deliver more energy to the tumour)



# 1968: MWPC – revolutionising the way particle physics is done

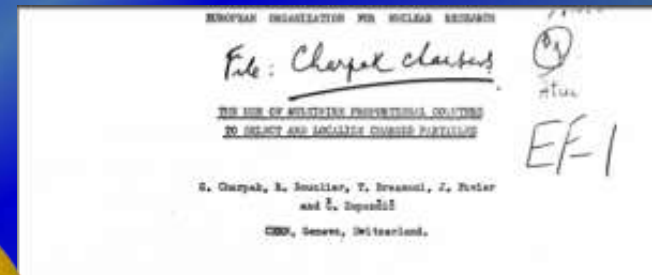


Detecting particles was a mainly a manual, tedious and labour intensive job – unsuited for rare particle decays

**George Charpak developed the MultiWire Proportional Chamber, which revolutionized particle detection and High Energy Physics - which passed from the manual to the electronic era.**



**1992:**

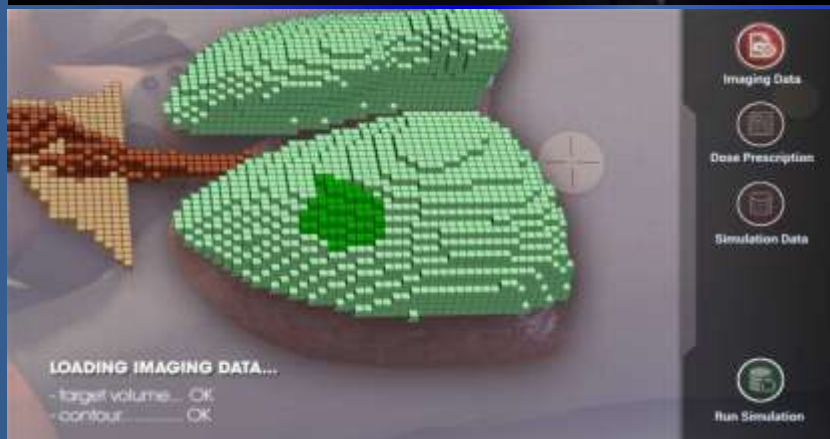
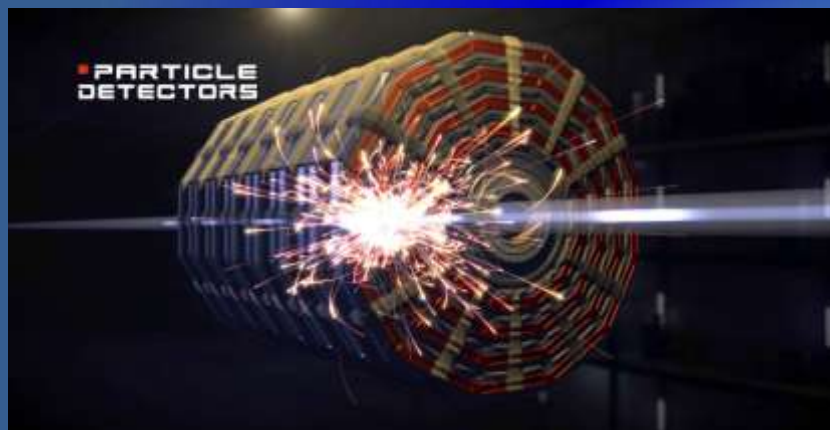


Electronic particle track detection is now standard in all particle detectors

# From LHC Particle Detectors to Medicine

Silicon pixel detectors, and crystals of lead tungstate, used for calorimetry, have already found various applications, especially in medicine:

- Silicon pixels are deployed as Medipix, for medical imaging and diagnosis.
- CMS electronics to read out these crystals in a magnetic field opened the way to combined PET/MRI scanners.



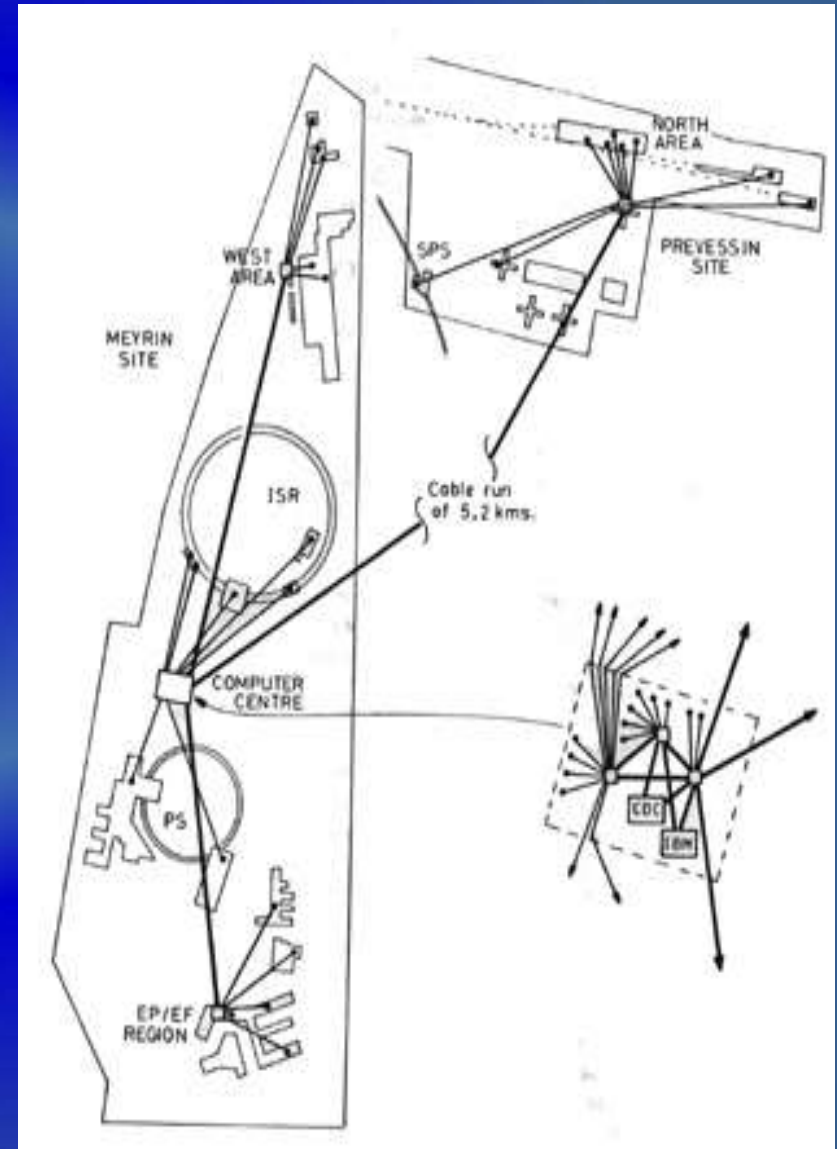
MEDIPIX: <https://medipix.web.cern.ch/>

ClearPET: <https://crystalclear.web.cern.ch/crystalclear/pet.html>



# 1987: CERNET gives way to INTERNET

World Wide Web was developed at CERN to help share information among scientists working at the Large Electron Positron collider, at institutes all around the globe.



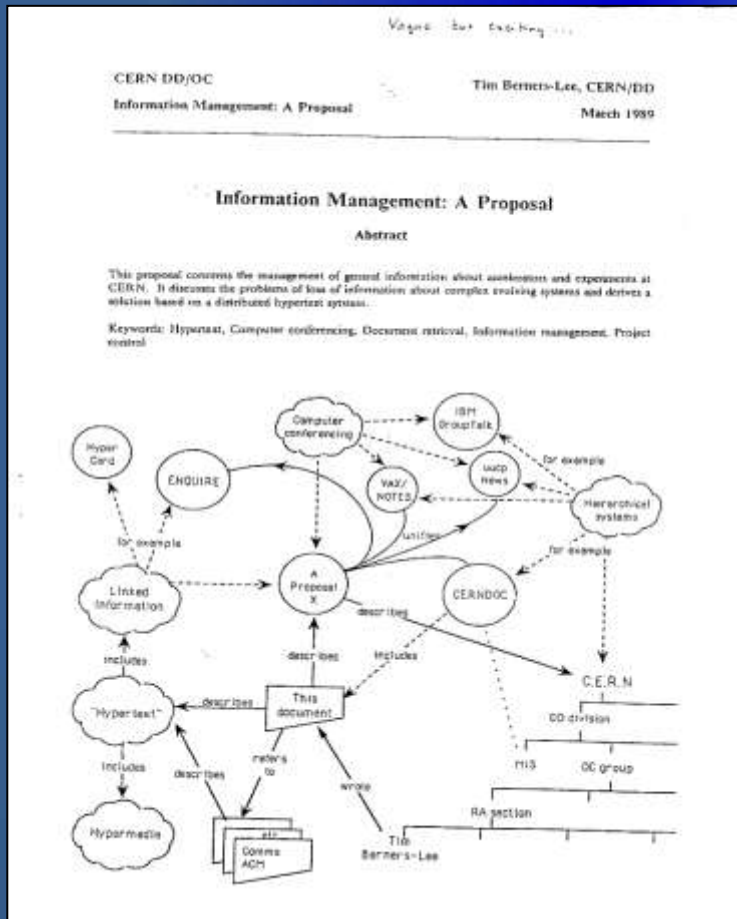
# 1989: The Birth of World Wide Web (WWW)

Tim Berners Lee proposed the web concept

Linking information across  
different computers:

The first web address:

<http://info.cern.ch/hypertext/WWW/TheProject.html>



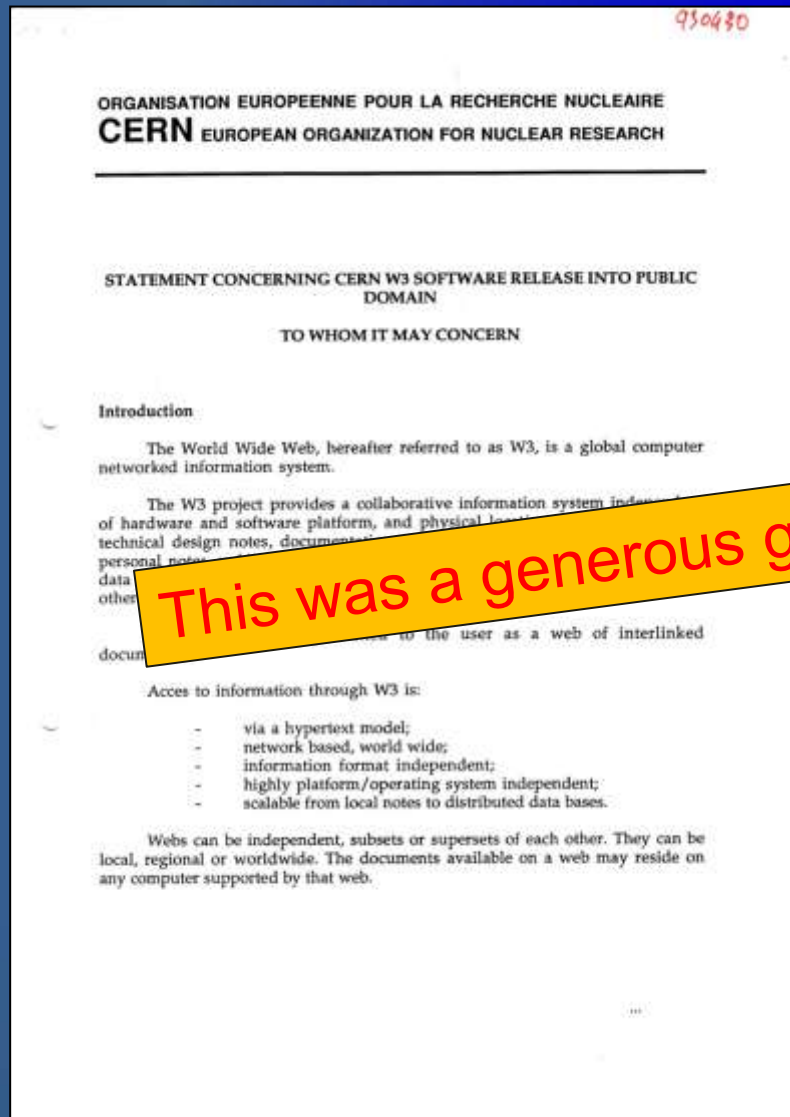
The 30-year Anniversary (Mar. 12, 2019):  
<https://web30.web.cern.ch/>





# 1993: Release of the Web to Public Domain

## The most valuable document for humanity?



An aerial photograph of the CERN facility in Switzerland, showing the landscape with green fields, a large lake, and snow-capped mountains in the background. Overlaid on the image are several colored lines representing particle accelerator tracks: a large yellow oval for the LHC (27 km), a blue circle for the SPS (7 km), and a red line for the ALICE experiment. Other labels include CMS, LHCb, ATLAS, CERN Meyrin, and CERN Provençin. A dashed line separates 'SUISSE' and 'FRANCE'.

# **EDUCATION:** Train Scientists and Engineers of Tomorrow

SUISSE  
FRANCE

CMS

LHCb

ATLAS

CERN Meyrin

CERN Provençin

SPS 7 km

ALICE

LHC 27 km



# Education and Capacity Building at CERN

## Scientists at CERN

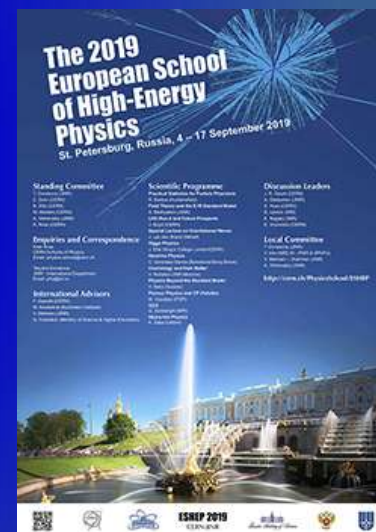
Academic Training Programme

## High School Students

- S'Cool Lab; Beamline for Schools
- Masterclasses  
(complement school visits to CERN)

**Key Message**  
Engage young people with science

## CERN-JINR School:



## Young Researchers

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



## Physics Students

Summer Students  
Programme (address  
University students)

## CERN Teacher Schools

International and National  
Programmes at CERN and  
remotely



# CERN as an Educator

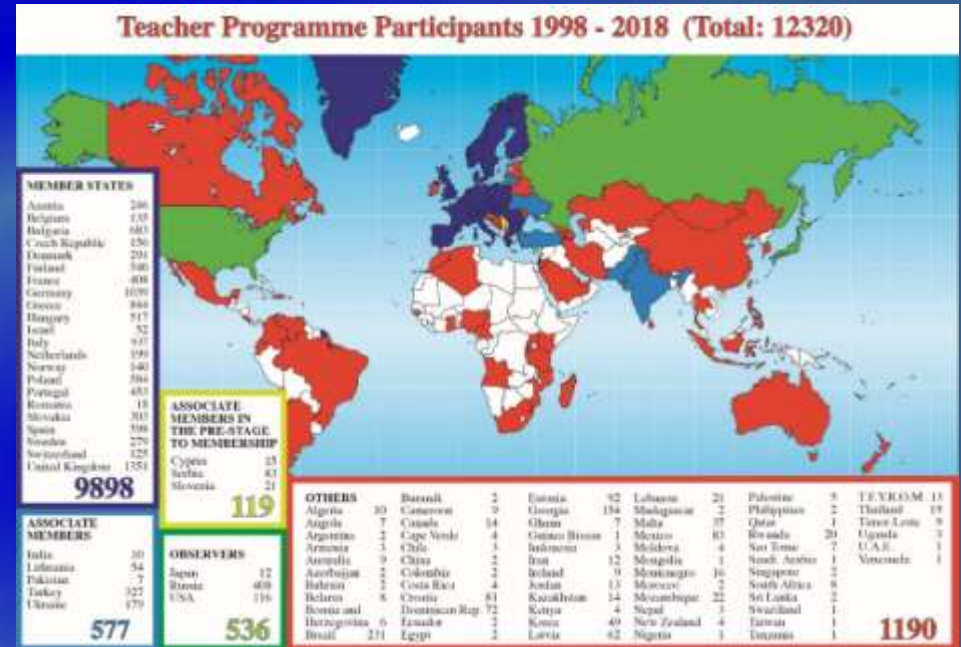




# Education and Capacity Building at CERN

[https://www.lhc-closer.es/taking\\_a\\_closer\\_look\\_at\\_lhc/0.cern\\_education](https://www.lhc-closer.es/taking_a_closer_look_at_lhc/0.cern_education)

- **High-School Teachers Program (national):** courses of one week duration in the mother language
- **CERN Teacher and Student Thematic Forum (international):** share ideas, discuss coherent strategies



<https://indico.cern.ch/category/8635>

# CERN: Promote Knowledge Transfer Through People

Number of Users from MS, AMS and NMS institutes

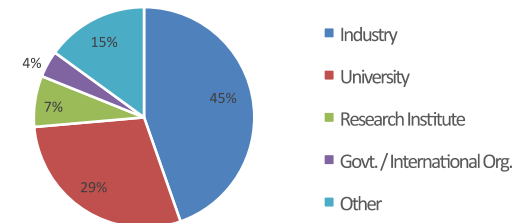


« The Largest PhD Factory in the world »

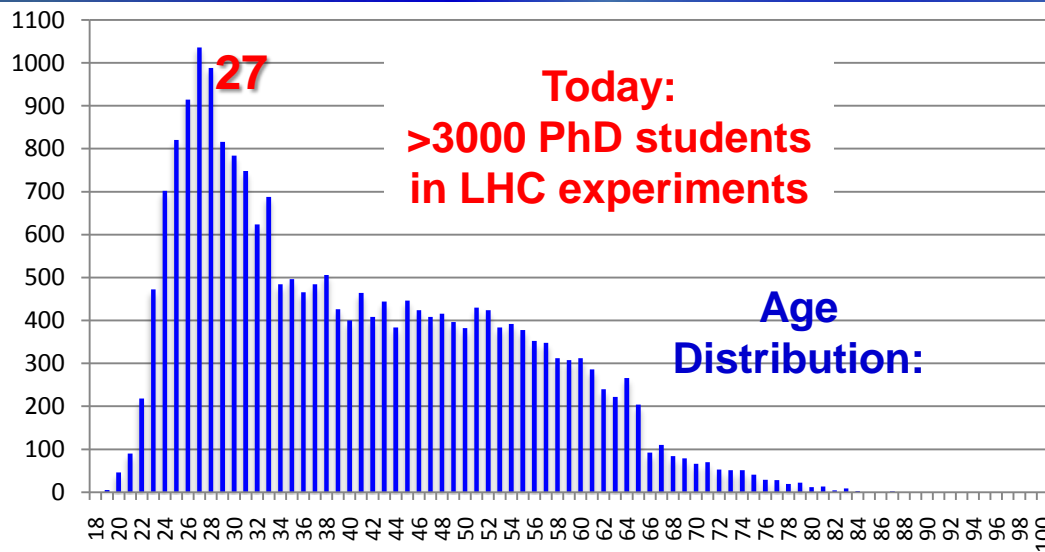
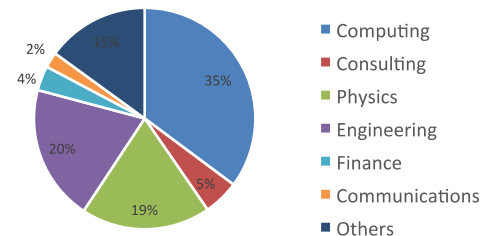
→ ~ 1000 PhD students per year, working @ CERN receives PhD degree from their home universities

Where do they go?

What type of organisation do you work in?



Which domain do you work in?

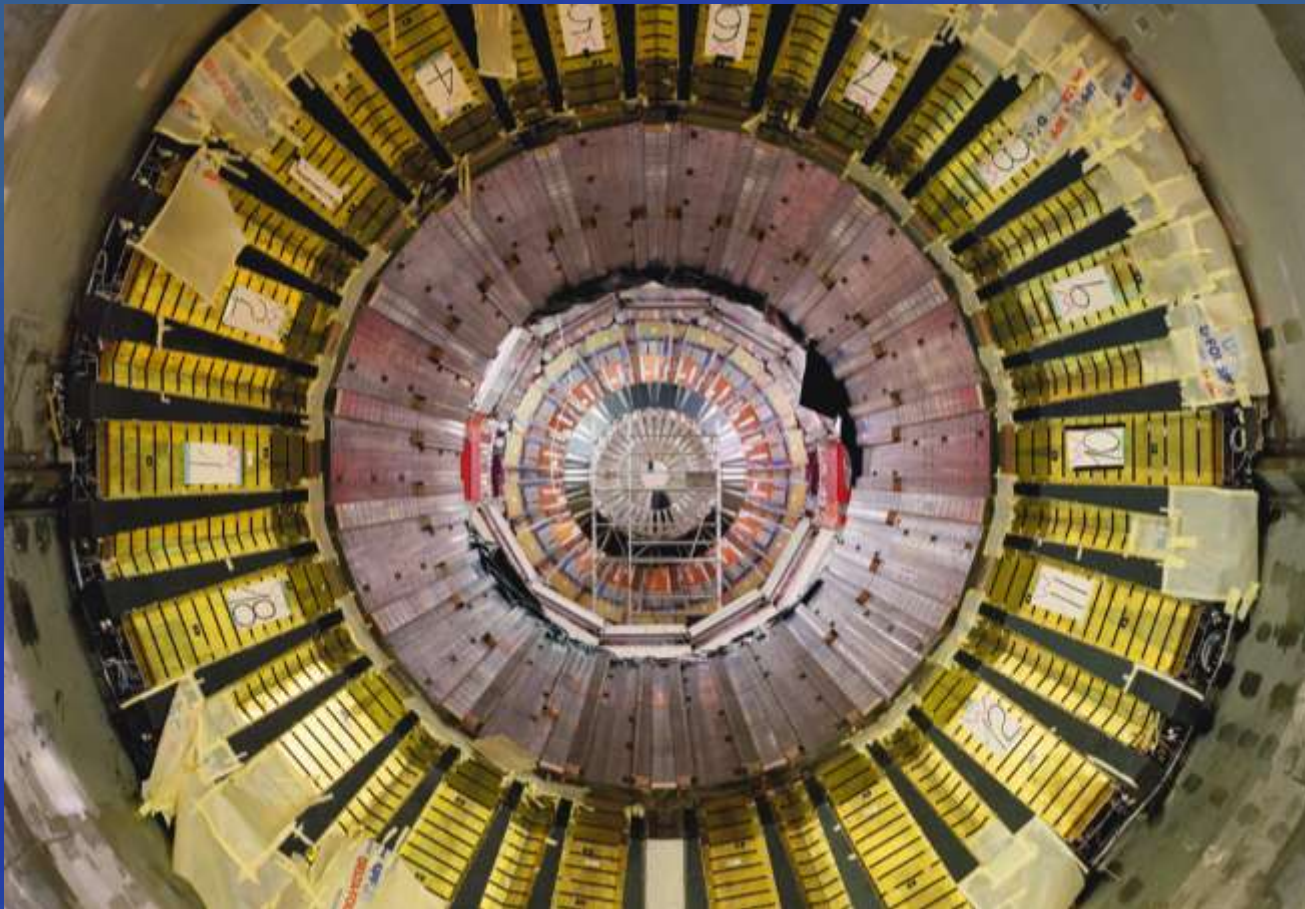






# **OUTREACH:** From Science to Society





*Knowledge is limited. Whereas the Imagination embraces the entire world...*

Albert Einstein

**Bridge the gap between science and society ...**



# CERN Communication Strategy

Today: CERN is a much bigger story than it used to be. Reputational risk is correspondingly higher. The relationship with all our publics requires more careful management. In short – we need a well-defined communication function.

## The vision:

- Maintain CERN's position as a world leading centre for basic research, reinforcing awareness of the importance of basic research for society.

## Key messages:

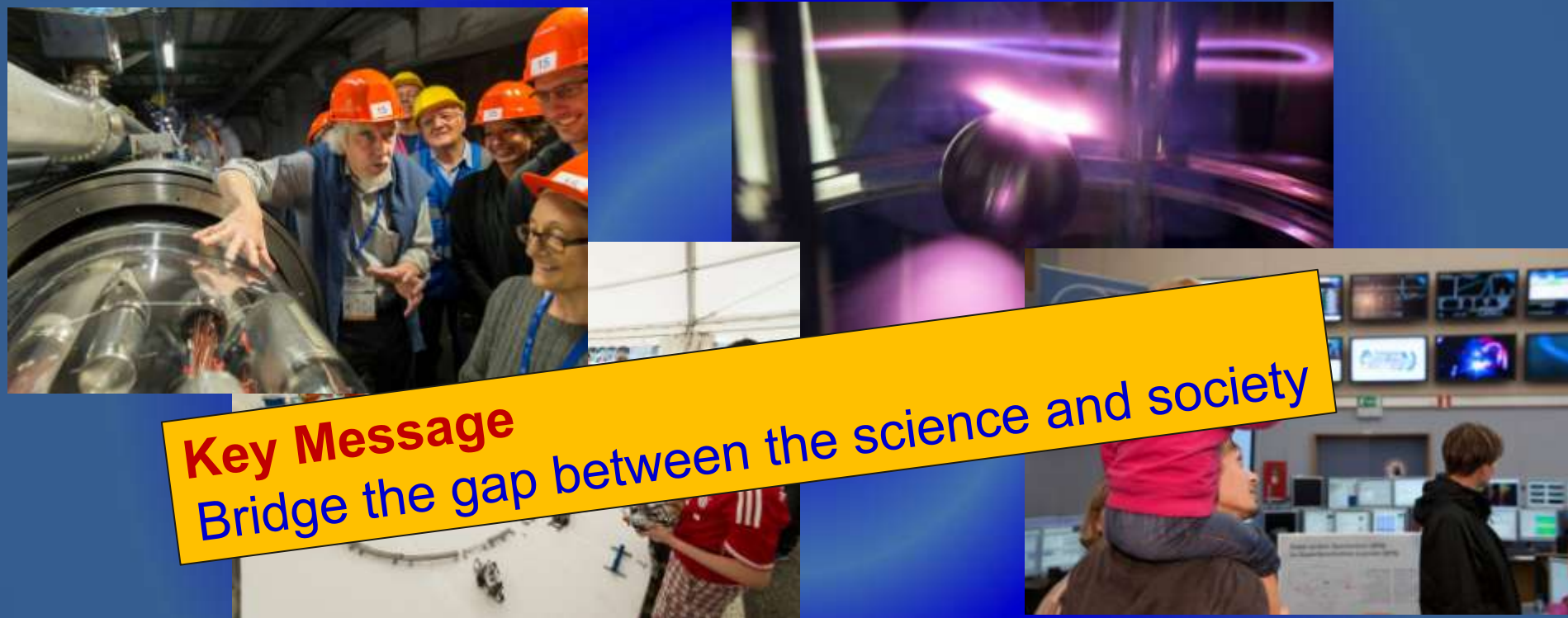
- CERN is a world leading centre for basic research. Basic physics is essential for the progress of society.

## External Challenges:

- Converting the platform into sustained interest in our science, innovation and value to society;
- Engaging with audiences in a positive and constructive manner through social media;
- Providing good quality content to supply all our audiences' needs;

# Society needs to realize and appreciate science

**CERN Open Days - September 2013** – some 70,000 people visited CERN this weekend for the Open Days – and 20,000 of them went underground



**Key Message**

Bridge the gap between the science and society

**CERN Open Days - Explore the future with us ! – Dec. 14, 15, 2019**

<https://home.cern/news/news/cern/cern-open-days-explore-future-us>



Explore the future with us  
Explorez le futur avec nous





# “SCIENCE FOR PIECE”

SUISSE  
FRANCE

CMS

LHCb

ATLAS

CERN Meyrin

CERN Prévessin

SPS 7 km

ALICE

LHC 27 km



# “The CERN Model”: Science for Piece and Development

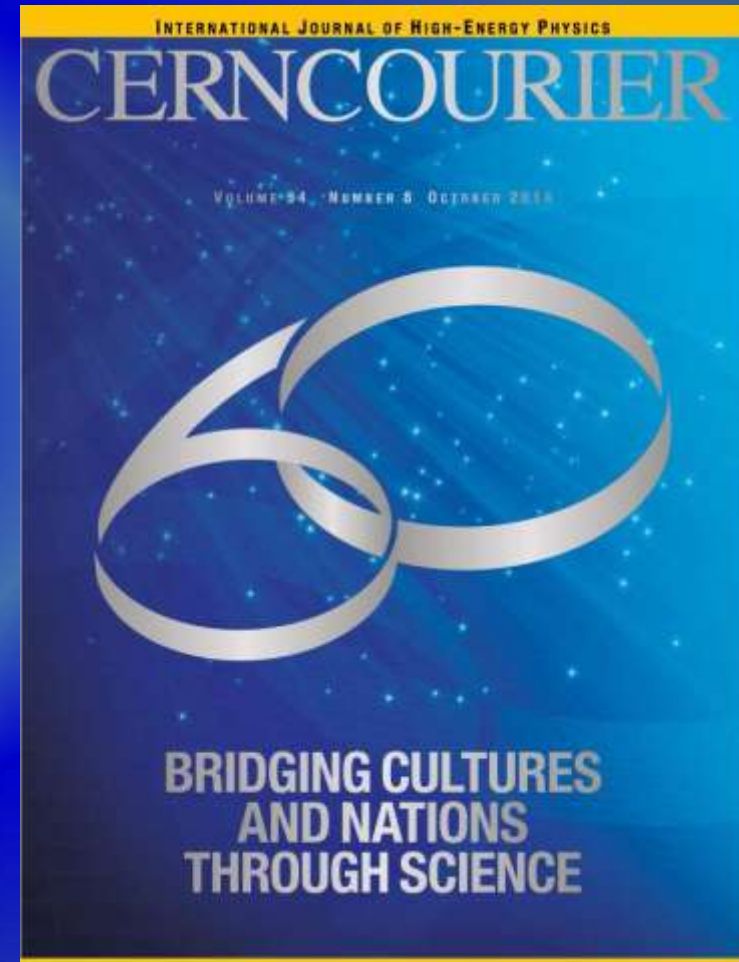
## Science for Peace: an Exportable Model?

And still attractive ...

- In its 60 years of life CERN, with its model, was a positive example of a worldwide platform for science as enabler for dialogue and piece
- CERN is actively engaged to promoting the role of science for the sustainable development of society: knowledge; technology and innovation; education



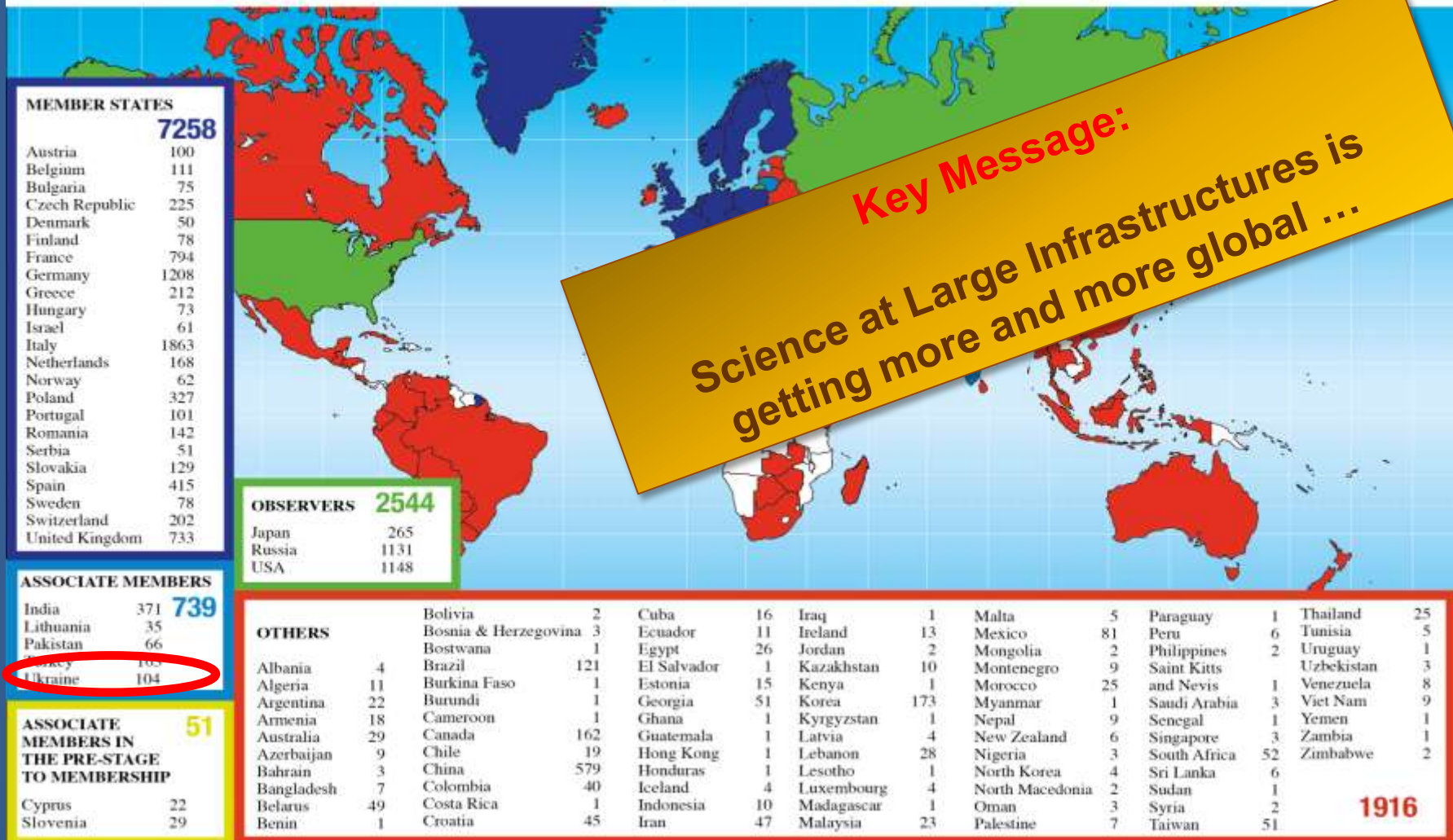
**CERN observer  
status at the UN  
since 2012**





# Breaking the Walls between Cultures and Nations since 1954

## Distribution of All CERN Users by Nationality as of mid-September 2019



# 1967: Looking to the East...



In 1967, CERN signed an agreement with the USSR that led to exchanges of personnel and equipment between CERN and Serpukhov.



## A culture of mutual help:

Earlier in the decade, CERN had been the scene of the first scientific contacts between East and West Germany following the erection of the Berlin wall..





# CERN: Science for Piece

## *Four Seas Conference: « Physique-sans-Frontières »*

- ❖ “**Physique-sans-Frontières**” (PSF) was born in 1992, during the war in Bosnia when many scientists felt the necessity to “do something” for their colleagues of South-Eastern Europe.

- ❖ **Georges CHARLIER**

president of the

sup

the

- ❖ The 1st PSF conference was a real success, despite the renewed war in Bosnia : 150 physicists, half of them from the South-Eastern Europe; **all the countries of the Balkanic area were represented, despite the existing state of war between some of them**

Served as a way to express the solidarity of the scientific community with all those who, under difficult conditions, seek to keep alive the diverse intellectual and cultural links that constitute the essence of our civilization



# CERN: Sixty Years of Science for Piece (2014)

CERN-UN event on “Science for Peace and Development” in New York:  
“CERN, Sixty Years of Science for Peace and Development”

**fostering the dialogue between science, diplomacy and politics**

very rare that the United Nations celebrates another Organization at its Headquarters



*United Nations Headquarters, New York, Oct. 2014*



# Today CERN: opening the door...

- **Scientific Excellence is key**
  - world-class, excellent infrastructures,  
**intellectual challenges are of utmost importance**
- **International scientific cooperation is vital**
  - **CERN: be global (in membership) but keep European component**
    - Membership for Non-European countries
    - New Associate Membership defined
- **CERN participation in global HEP projects independent of location**

# The Role of Big High Energy Physics Laboratories: – innovate, discover, publish, share



... and bring the world together



A serene landscape photograph featuring a calm body of water in the foreground, which perfectly reflects the sky and the surrounding environment. The sky is a mix of soft blue and pale yellow, suggesting dawn or dusk. In the background, majestic mountains with significant snow cover rise above a thick forest of dark evergreen trees. The middle ground shows a misty or foggy area with several small, isolated trees. The overall mood is peaceful and majestic.

# BACK-UP SLIDES

In post-war Europe in the 1940s, the notion of science as a universal and unifying value, transcending boundaries of all kinds, was put forward by a small group of visionary scientists and diplomats as a way to provide a peaceful future for the continent. As a result, the European Organization for Nuclear Research, CERN, was founded in Geneva in 1954. Designed to provide a **centre of excellence** for fundamental research in physics in Europe, CERN also had a second mission: **to foster peaceful collaboration between nations that had recently been at war.**



**CERN's founding convention is a "Work of Genius".** Deceptively simple, it provides a robust, stable and flexible framework for international collaboration. In the more than 60 years of CERN's existence, it has been put to the test on many occasions and has been successfully adopted by other scientific organizations. **The CERN model for international collaboration is all about recognizing the strength of diversity, the power of sharing, and the benefits that accrue when neighbors work together to achieve common goals.**



# Sociology

## Large International Collaborations

- a place where people learn to work together
- collaboration and competition
- diversity: good opportunity to recognize differences, accept them and learn from them

### Key Message

Cooperation (capability to share) AND competition are the path to success

- experience can be used by individuals and in other fields

- management through 'common goals'
- management by 'convincing partners'

... through arts

Collide@CERN

# CREATIVE COLLISIONS

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## BETWEEN THE ARTS AND SCIENCE



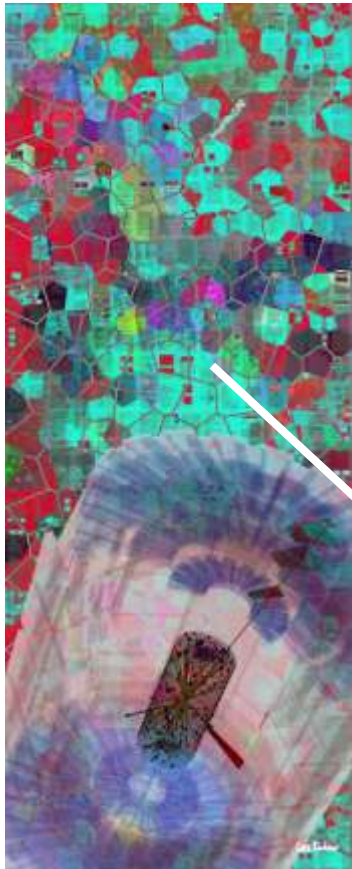
With special thanks to our private donors



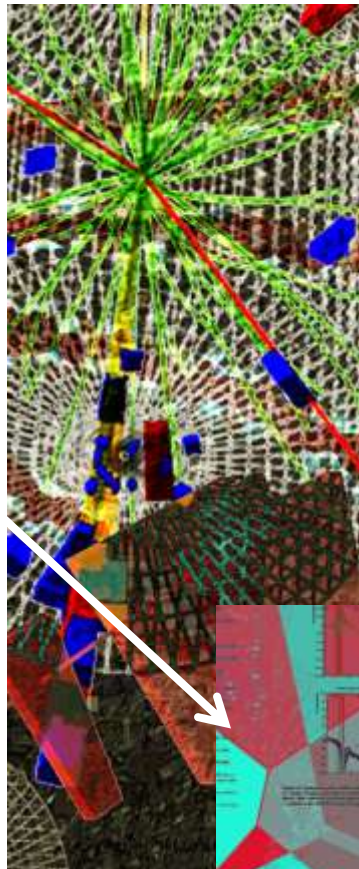
# Art @ CMS Project: In Search of the Higgs Boson

Inspire 'non scientific world' with science instruments & physics topics:  
<http://cern.ch/scienceartschool>

Xavier Cortada (with the participation of physicist Pete Markowitz), digital art, 2013



$H \rightarrow WW$



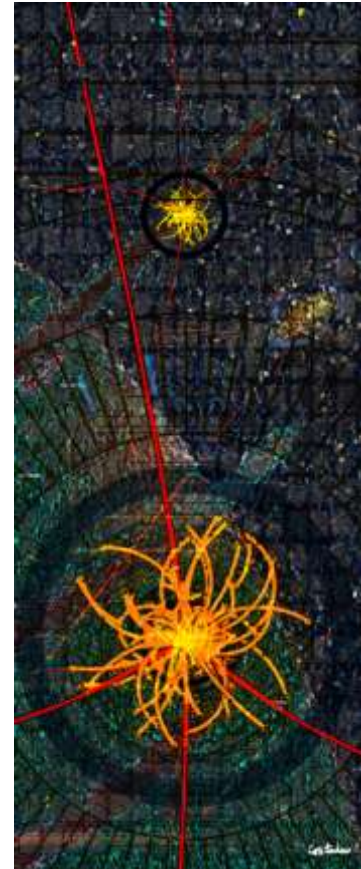
$H \rightarrow \gamma\gamma$



$H \rightarrow b\bar{b}$



$H \rightarrow \tau\tau$



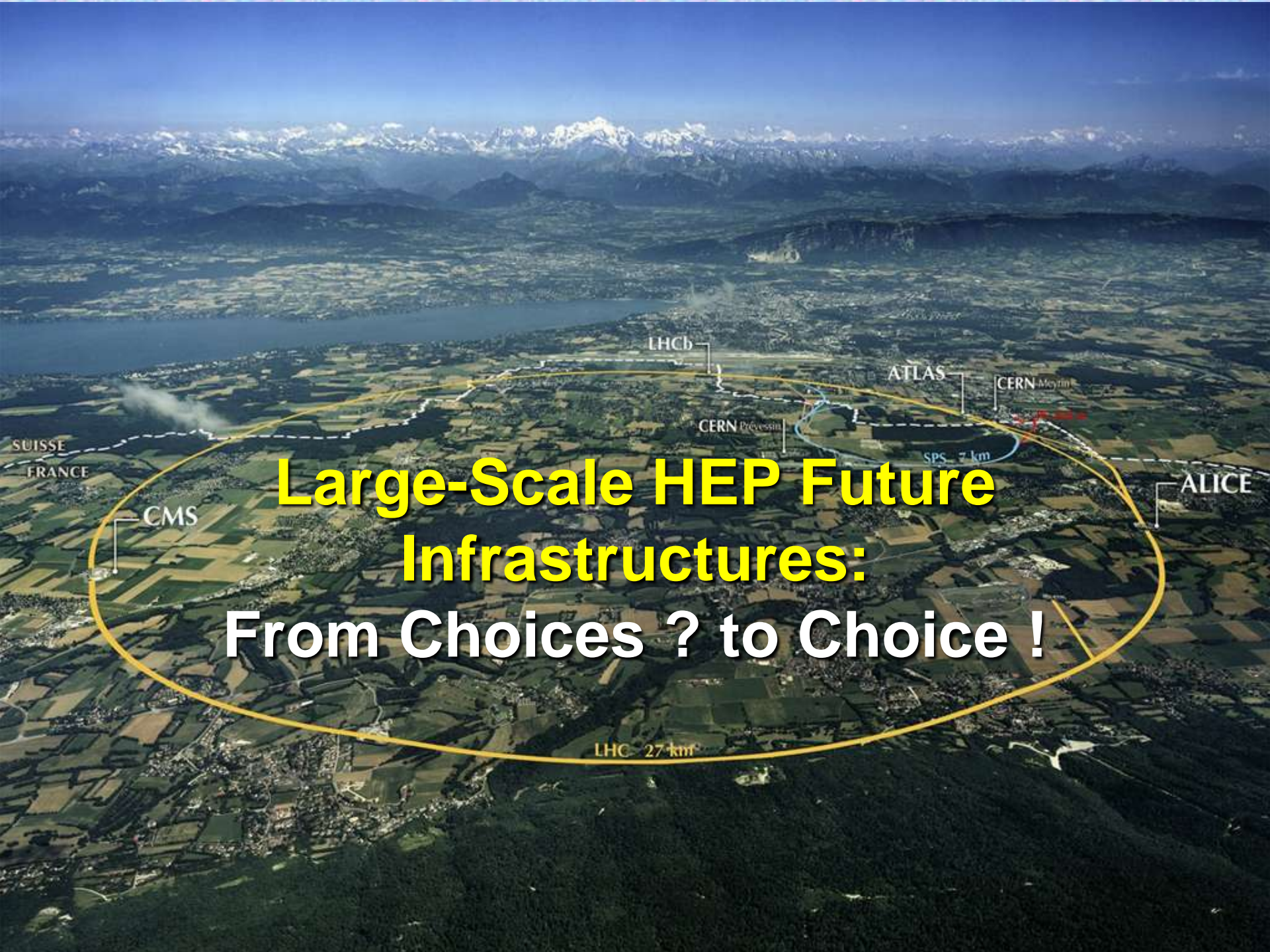
$H \rightarrow ZZ$

CMS Papers in  
Art Design:



Real CMS  
Event Displays:





# Large-Scale HEP Future Infrastructures: From Choices ? to Choice !



# NEW SCIENCE: GLOBAL SCIENCE

- Need to present and discuss new large scale projects in an **international context** before making choices
- Need to present **physics case(s)** always taking into account latest results at existing facilities
- Need to present (additional) **benefits to society** from the very beginning of the project
- Need to have **excellent communication and outreach** accompanying all projects