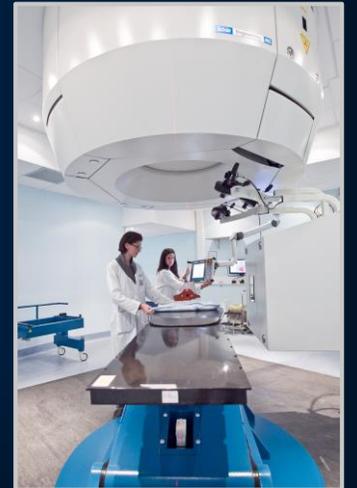
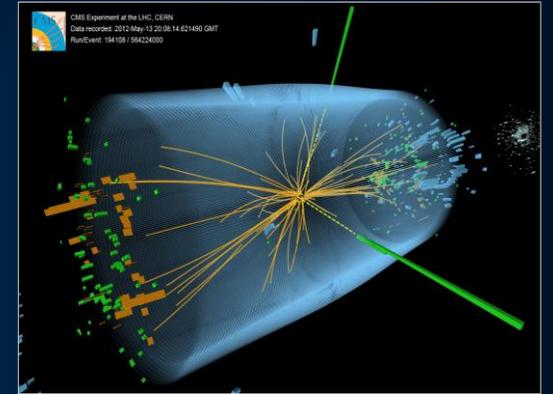
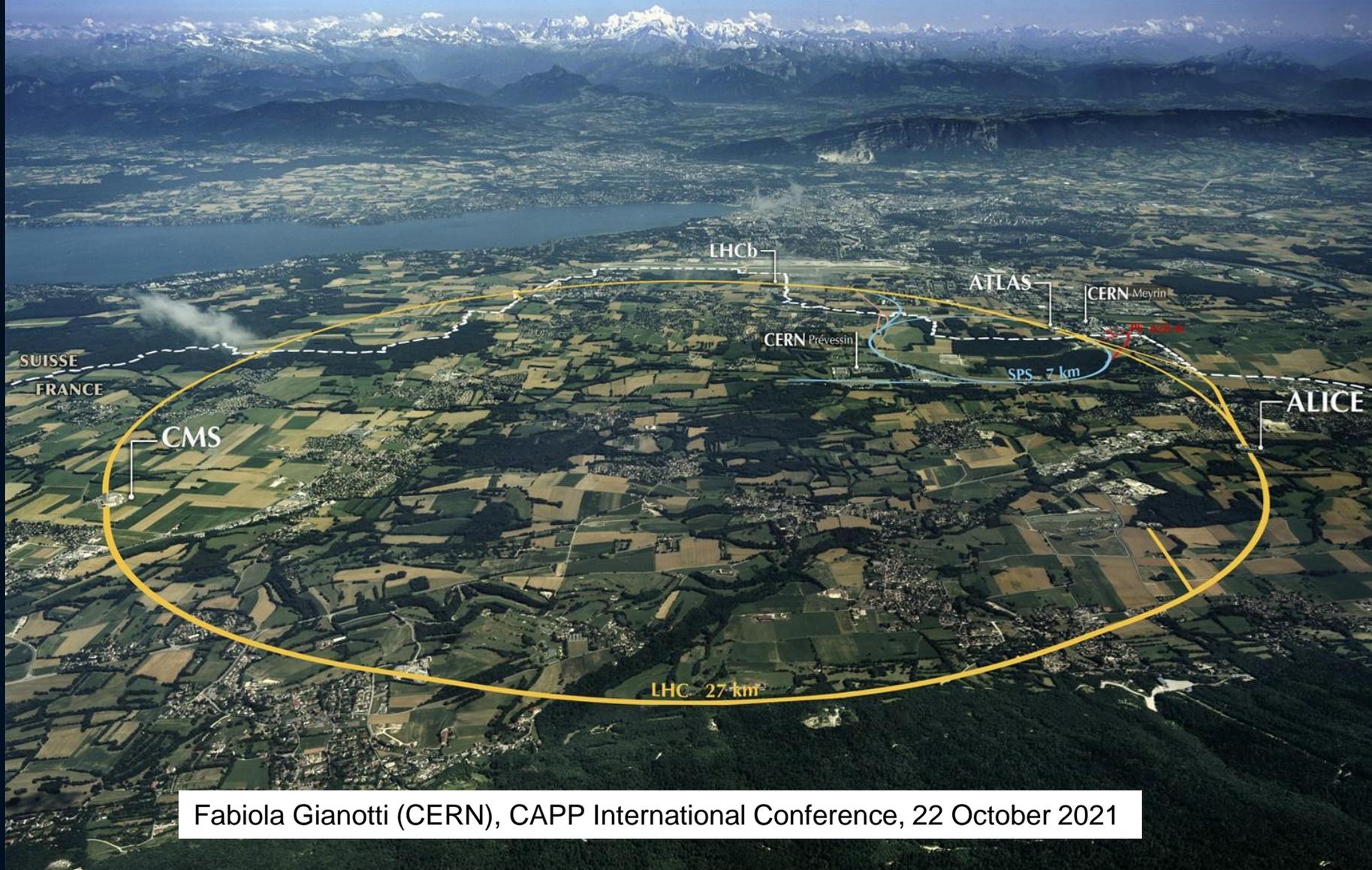


Science as a value system for a sustainable world (CERN as an example)



Fabiola Gianotti (CERN), CAPP International Conference, 22 October 2021

CERN the largest particle physics laboratory in the world

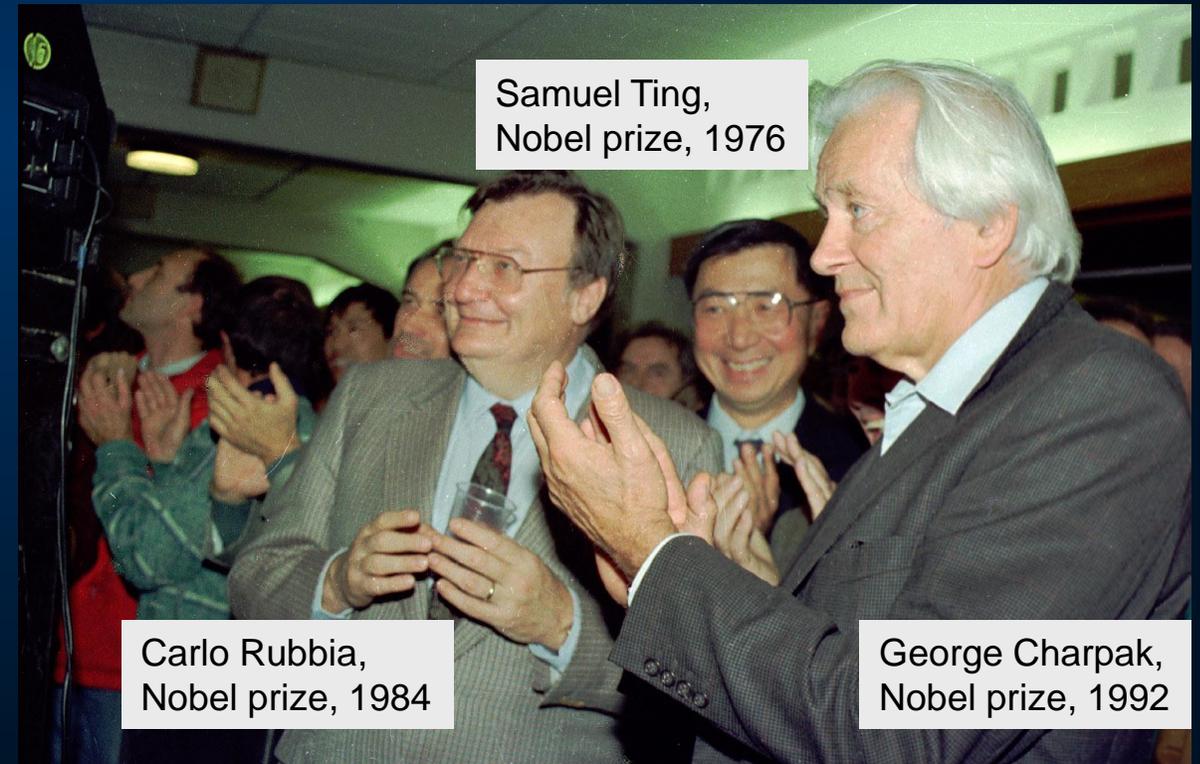
Intergovernmental organisation based in Geneva

Mission:

- science: fundamental research in particle physics → discoveries (e.g. Higgs boson in 2012), Nobel prizes
- technology and innovation → transferred to society (e.g. the World Wide Web, medical applications)
- training and education
- bringing the world together: ~ 17000 scientists, > 110 nationalities



WEB@30 celebration, 12 March 2019 at CERN, with T. Berners-Lee, former CERN staff member



Samuel Ting,
Nobel prize, 1976

Carlo Rubbia,
Nobel prize, 1984

George Charpak,
Nobel prize, 1992

CERN was founded in 1954, in the aftermath of World War II (i.e. after a crisis), with two goals:

- ❑ rebuild scientific research in Europe (→ **awareness that economic recovery also requires investment in science**)
- ❑ foster peaceful collaboration among European countries (→ **awareness that science can break walls**)

Main ingredients of CERN's founding Convention:

- ❑ scientific research of fundamental character with no military purpose
- ❑ results and information should be disseminated and made available to everybody (→ **open science!**)
- ❑ promote international cooperation (→ **science for peace!**)
- ❑ training and education

ORGANISATION EUROPÉENNE POUR LA RECHERCHE NUCLÉAIRE
CERN EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH

CONVENTION

FOR THE ESTABLISHMENT OF A EUROPEAN ORGANIZATION
FOR NUCLEAR RESEARCH

PARIS, 1st JULY, 1953
As amended

CONVENTION

POUR L'ÉTABLISSEMENT D'UNE ORGANISATION EUROPÉENNE
POUR LA RECHERCHE NUCLÉAIRE

PARIS, le 1^{er} JUILLET 1953
Telle qu'elle a été modifiée

ÜBEREINKOMMEN

ZUR ERRICHTUNG EINER EUROPÄISCHEN ORGANISATION
FÜR KERNFORSCHUNG

PARIS, 1. JULI 1953
Revidierte Fassung

Signed by 12 Member States
in Paris on 1st July 1953

La sixième session du Conseil fut organisée à Paris du 29 juin au
1^{er} juillet 1953. C'est à cette occasion que la Convention établissant l'Organisation fut signée, sous réserve de ratification, par douze Etats membres.

For the German Federal Republic <i>H. Heusinger</i> subject to ratification	Pour la République Fédérale d'Allemagne	For the Kingdom of Norway <i>H. Heusinger</i> subject to ratification	Pour le Royaume de Norvège subject to ratification
For the Kingdom of Belgium <i>J. H. H. Heusinger</i> subject to ratification	Pour le Royaume de Belgique	For the Kingdom of the Netherlands <i>H. Heusinger</i> subject to ratification	Pour le Royaume des Pays-Bas
For the Kingdom of Denmark <i>H. Heusinger</i> subject to ratification	Pour le Royaume de Danemark	For the United Kingdom of Great Britain and Northern Ireland <i>H. Heusinger</i> subject to ratification	Pour le Royaume-Uni de la Grande-Bretagne et de l'Irlande du Nord
For the French Republic <i>H. Heusinger</i> subject to ratification	Pour la République Française	For the Kingdom of Sweden <i>H. Heusinger</i> subject to ratification	Pour le Royaume de Suède
For the Kingdom of Greece <i>H. Heusinger</i> subject to ratification	Pour le Royaume de Grèce	For the Confederation of Switzerland <i>H. Heusinger</i> subject to ratification	Pour la Confédération Suisse
For Italy <i>H. Heusinger</i> subject to ratification	Pour l'Italie	For the Federal People's Republic of Yugoslavia <i>H. Heusinger</i> subject to ratification	Pour la République Fédérale Populaire de Yougoslavie

The Sixth Session of the CERN Council took place in Paris on 29 June—1 July 1953. It was here that the Convention establishing the Organization was signed, subject to ratification, by twelve States.

CERN today

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

10 Associate Member States: Croatia, Cyprus, Estonia, India, Latvia, Lithuania, Pakistan, Slovenia, Turkey, Ukraine

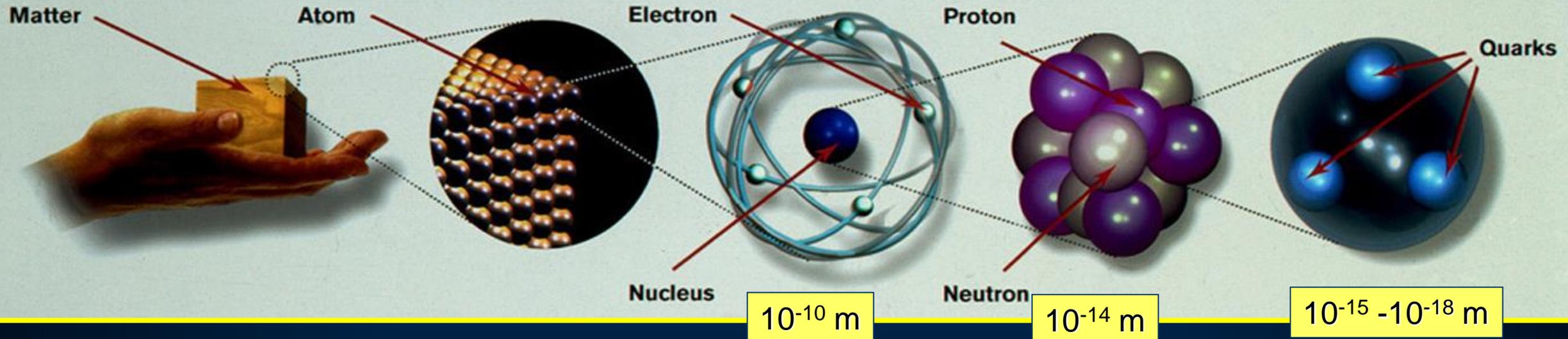
6 Observers to Council: Japan, Russian Federation, USA, EU, JINR/Dubna, UNESCO

~ 50 International Cooperation Agreements: more and more developing countries (recent examples: Paraguay, Sri Lanka, Nepal) sign cooperation agreements with CERN and other research organisations
→ engaging internationally on fundamental research is part of their efforts towards development, building knowledge-based economies and strengthening relations with other countries

Annual budget (2020) ~1200 MCHF (on average: ~ 1 cappuccino/year per European citizen):
Member States contribute in proportion to their income (NNI). Non-Member States contribute “à la carte”.
Budget stability over decades and international cooperation have allowed accomplishment of extremely ambitious and complex projects that no single country could afford alone.

CERN's primary mission is SCIENCE

Study the elementary particles (e.g. the building blocks of matter: electrons and quarks) and the forces that control their behaviour at the most fundamental level



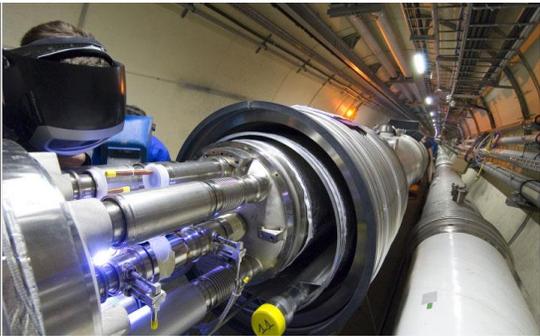
Particle physics at modern accelerators allows us to study the fundamental laws of nature on scales down to smaller than 10^{-18} m

- insight also into the structure and evolution of the Universe
- from the very small to the very big ...

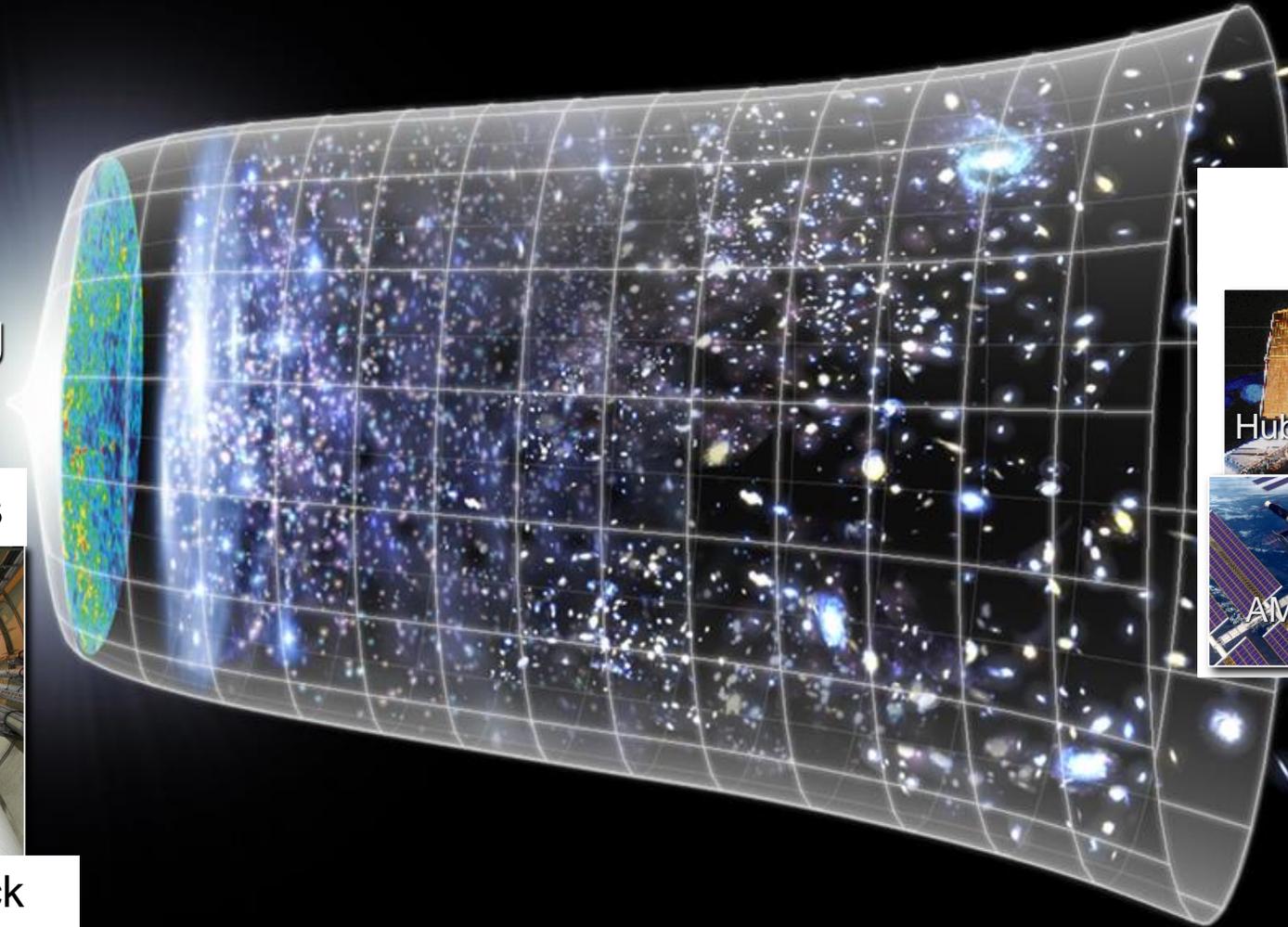
Evolution of the Universe

Big Bang

CERN's accelerators



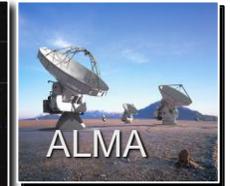
Explore the Universe back to 10^{-12} s from the Big Bang



Telescopes



Hubble



ALMA



AMS



VLT

13.7 Billion Years

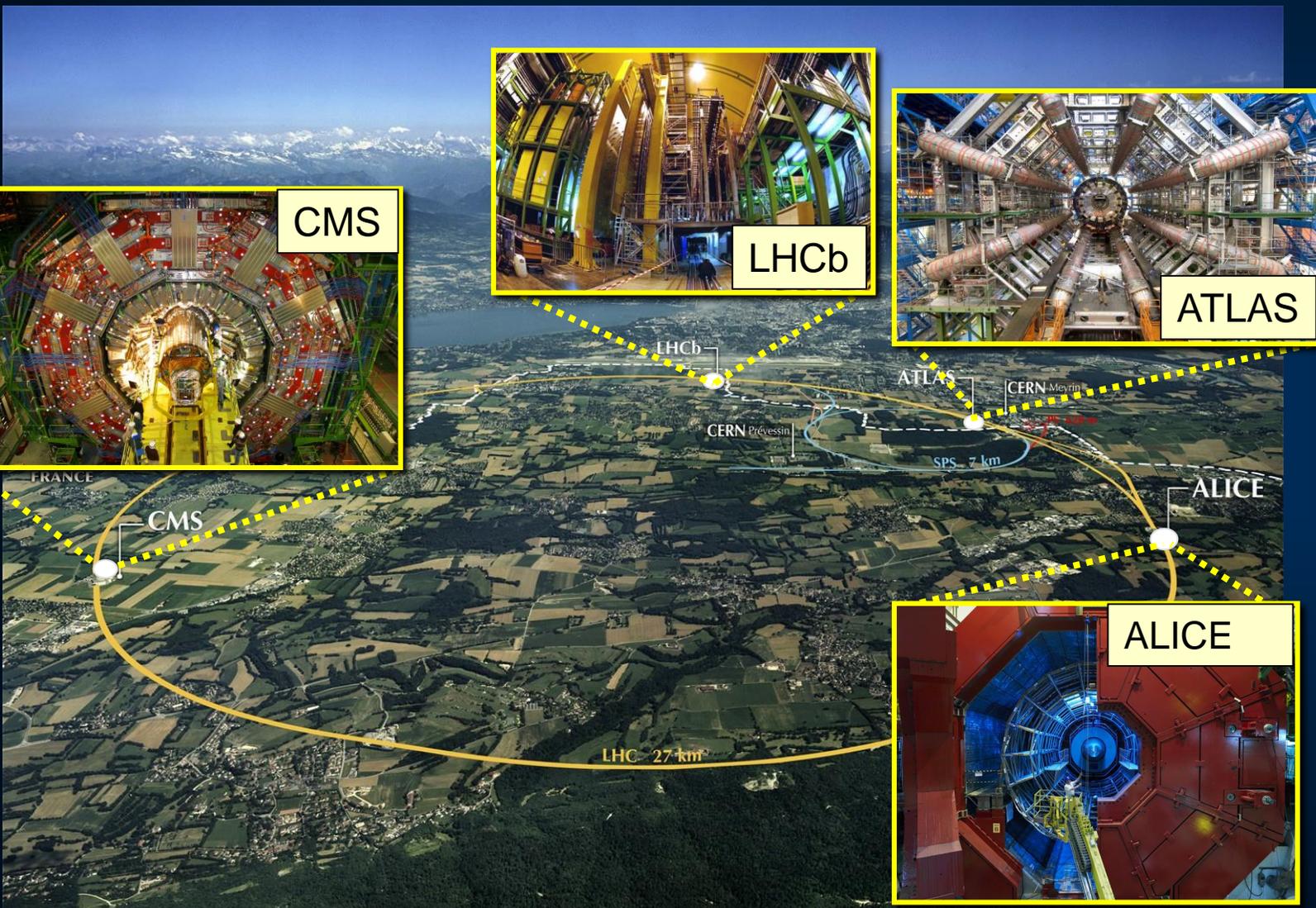
Today

10^{28} cm



Large Hadron Collider (LHC): the most powerful accelerator ever

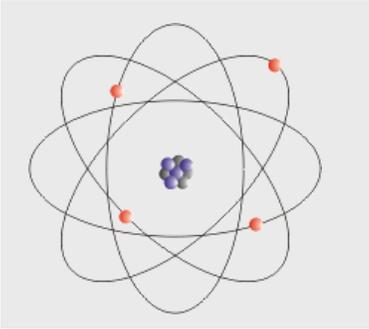
27 km ring, 100 m underground. Operation started in 2010 → exploration of new energy frontier



July 2012, ATLAS and CMS announced the discovery of a new (very special!) particle: the Higgs boson.



Nobel Prize in Physics 2013 awarded to François Englert and Peter Higgs



A world without Higgs boson would be very strange. Atoms would not exist → universe would be very different



Accelerator:

- ❑ 1232 high-tech superconducting magnets (built by Alstom, Ansaldo and Babcock-Noell)
 - a great example of research-industry partnership
- ❑ magnet operation temperature: 1.9 K (-271 °C)
 - LHC is one of coldest places in the universe
- ❑ number of protons per beam: 200000 billions
- ❑ number of turns of the 27 km ring per second: 11000
- ❑ number of beam-beam collisions per second: 40 millions
- ❑ collision “temperature”: 10^{16} K

Distribution of All CERN Users by Nationality on 9 December 2019

MEMBER STATES

7 394

Austria	102
Belgium	116
Bulgaria	75
Czech Republic	223
Denmark	51
Finland	77
France	795
Germany	1 225
Greece	220
Hungary	80
Israel	60
Italy	1 911
Netherlands	171
Norway	62
Poland	328
Portugal	99
Romania	147
Serbia	49
Slovakia	130
Spain	428
Sweden	79
Switzerland	205
United Kingdom	761

OBSERVERS **2 572**

Japan	276
Russia	1 154
USA	1 142

ASSOCIATE MEMBERS IN THE PRE-STAGE TO MEMBERSHIP

54

Cyprus	22
Slovenia	32

ASSOCIATE MEMBERS

798

Croatia	47
India	380
Lithuania	33
Pakistan	66
Turkey	169
Ukraine	103

OTHERS

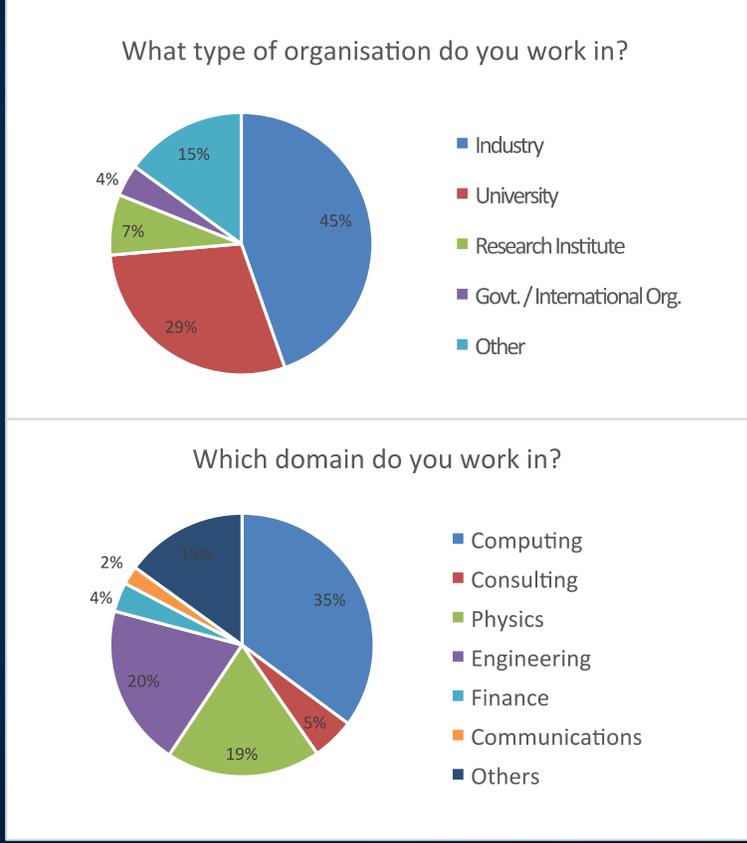
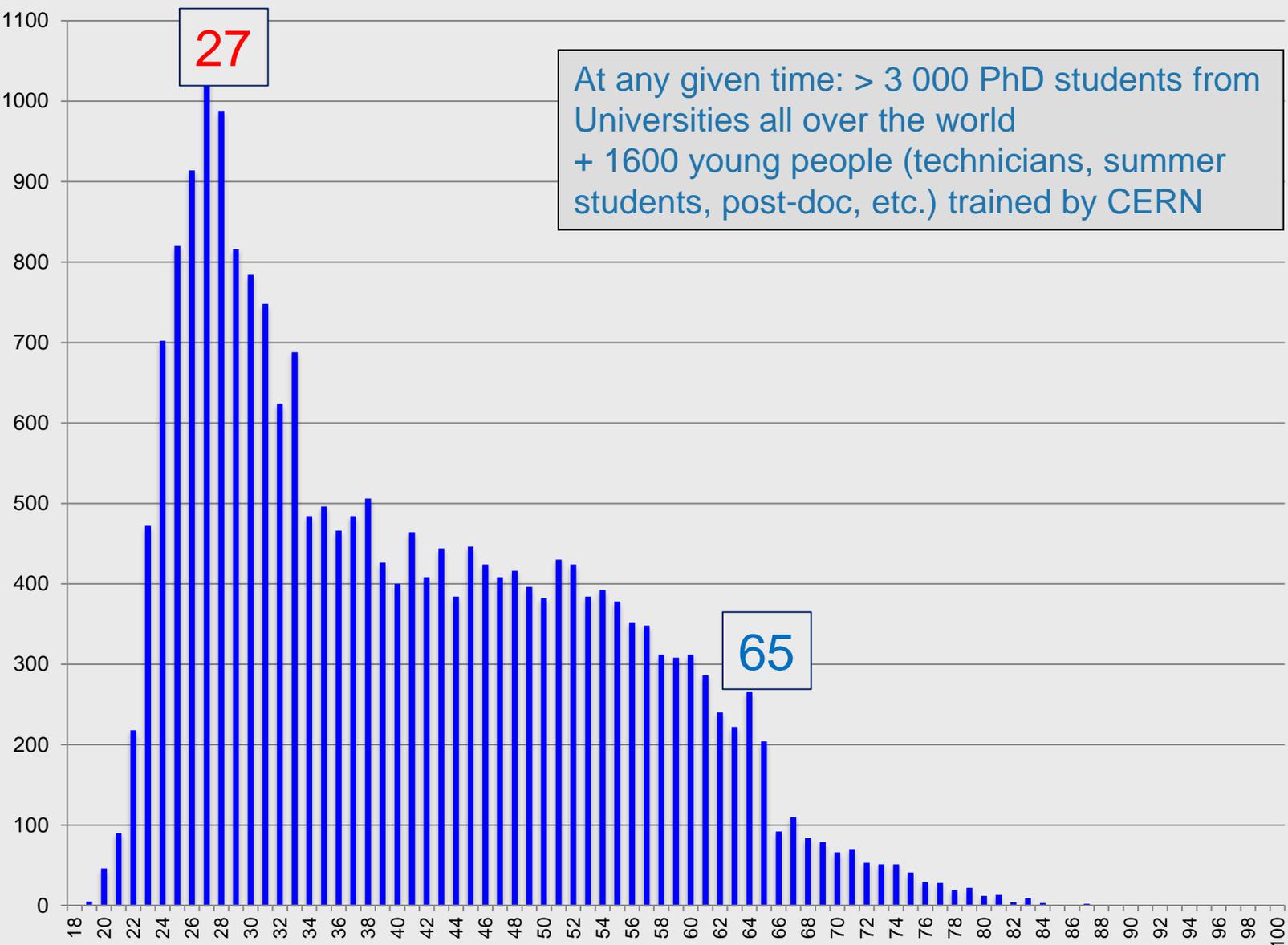
Albania	4	Bolivia	2	Ecuador	11	Iraq	1	Malaysia	19	Palestine	7	Taiwan	49
Algeria	10	Bosnia & Herzegovina	3	Egypt	26	Ireland	14	Malta	5	Paraguay	1	Thailand	25
Argentina	23	Bostwana	1	El Salvador	1	Jamaica	1	Mexico	83	Peru	6	Tunisia	5
Armenia	18	Brazil	123	Estonia	17	Jordan	1	Mongolia	2	Philippines	3	Uruguay	1
Australia	30	Burundi	1	Georgia	53	Kazakhstan	13	Montenegro	9	Saint Kitts and Nevis	1	Venezuela	10
Azerbaijan	8	Cameroon	1	Ghana	1	Kenya	1	Morocco	26	Saudi Arabia	3	Viet Nam	9
Bahrain	3	Canada	164	Gibraltar	1	Korea	166	Myanmar	1	Senegal	1	Yemen	1
Bangladesh	7	Chile	21	Guatemala	1	Kyrgyzstan	1	Nepal	8	Senegal	1	Zambia	1
Belarus	52	China	587	Hong Kong	1	Latvia	4	New Zealand	6	Singapore	4	Zimbabwe	2
Benin	1	Columbia	38	Honduras	1	Lebanon	26	Nigeria	2	South Africa	59		
		Congo	1	Iceland	5	Lesotho	1	North Korea	3	Sri Lanka	6		
		Costa Rica	1	Indonesia	11	Luxembourg	4	North Macedonia	2	Sudan	2		
		Cuba	17	Iran	48	Madagascar	1	Oman	3	Syria	2		

A great example of collaboration across borders

1 898

Age distribution of scientists working at CERN

< 50% of the young people stay in particle physics:
where do the others go?



Fundamental research prepares them also for variety of jobs outside the field

CERN-UNESCO schools on digital libraries

- ❑ Aimed at providing skills for running digital library systems → improve access to information for African researchers, increase global visibility of African research
- ❑ Based on INVENIO open source digital platform developed by CERN
- ❑ Held so far in Rwanda, Morocco, Senegal, Ghana and Kenya

5th school: Oct 2018, University of Nairobi, Kenya: attended by librarians from Kenya, Cameroon, Somalia, Tanzania, Uganda, Zambia and Zimbabwe.

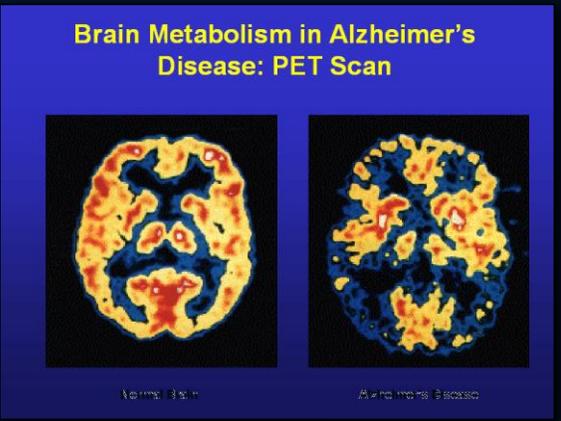




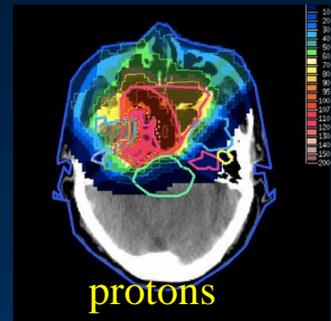
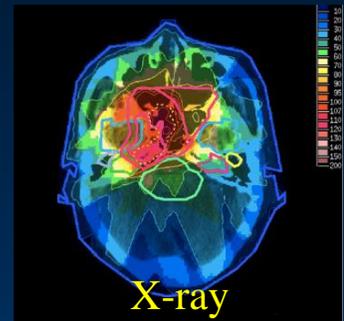
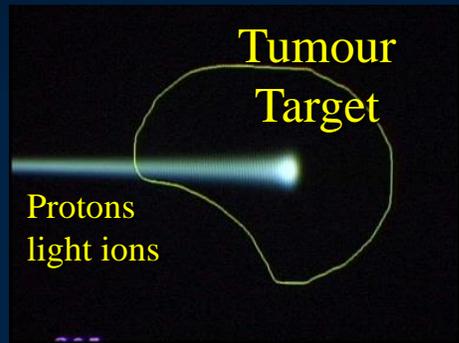
CERN technologies transferred to society free of charge: examples

Medical imaging (PET)

Hadron therapy (e.g. CNAO, Pavia)



Cultural heritage

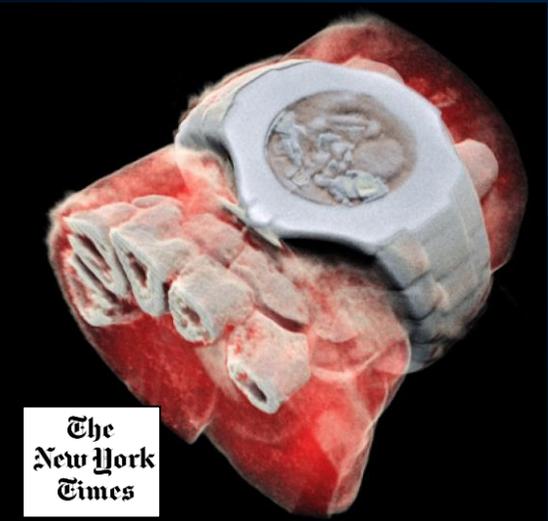


Radiation dosimetry for space missions

Machine learning and FPGA for car automation

	Jun 2019 Jun 2021	Automotive Fast machine learning for autonomous driving	Collaboration R&D ZENUTY (company owned by Volvo Group and Veoneer) is innovating in driver-assistance and autonomous-driving technologies. For this purpose, fast machine learning using FPGAs is relevant to the automotive worlds. Collaboration HSL4ML with CERN.
--	---------------------	---	---

Colour X-ray imaging with CERN's electronics



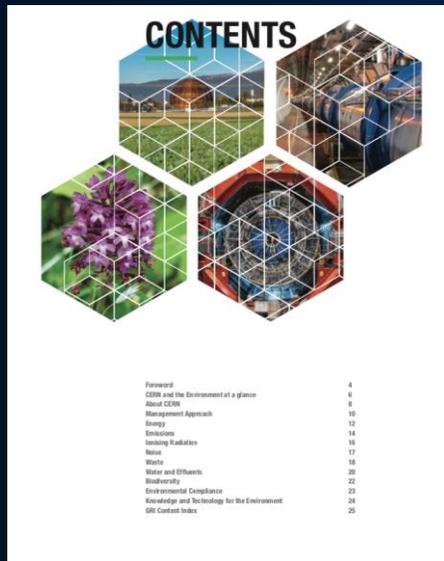
Radon dose monitor for better air quality



The New York Times

Sustainability and environment at CERN (examples)

CERN's first public Environment Report released in 2020, second one now



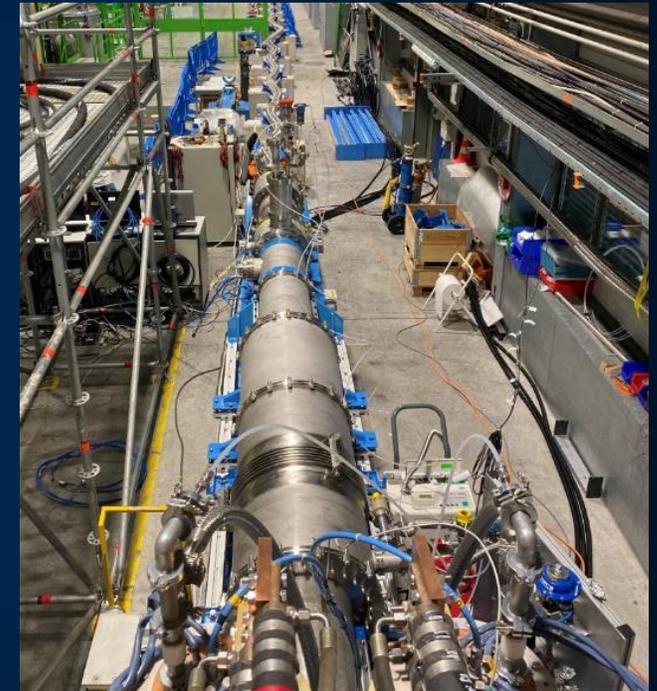
Energy savings and recovery



Heat from LHC cooling towers used to heat a nearby housing (8000 people)

Sets ambitious objectives for the future, e.g. to reduce GHG emissions by ~ 30% by 2024

CERN technologies for zero-loss electricity transport



Using "high temperature" superconducting materials

What can scientific research do for society in the post-COVID era ?

Knowledge

Science is the fuel of progress. Without the innovative ideas and breakthroughs that come from scientific research, progress sooner or later stagnates. History shows that major breakthroughs often come from fundamental research. Electron microscope (also used to study the virus) would not exist without knowledge of quantum mechanics, GPS would not work without knowledge of general relativity, medical diagnosis would not exist without X-rays.

Science gives us the knowledge and tools to address societal and planetary challenges.

Innovation

Science is a driver of innovation as it requires cutting-edge instruments and the development of new technologies

Collaboration across borders, disciplines and sectors

Today's challenges are global and interconnected → require collaboration between countries, disciplines and sectors (research, academia, private/industry, policy makers, etc.) and “holistic approach”.

Science is universal (as based on objective facts and not on opinions) and unifying → can play a key role in connecting people and promoting collaborative work

Training and education

STEM jobs grow 3 times faster than any other job → scientific training is fundamental to prepare tomorrow's workforce

In general: scientific education (problem-solving skills, analytical thinking, scientific method, evidence-based assessment, etc.) is crucial to forming well-rounded citizens and increasing trust in science

Reducing inequalities

Technology and innovation grow fast in modern society → expectations are that majority of current jobs will disappear in next 30 years (replaced by automation, machines, AI); "low-skill" jobs will disappear first

→ Danger of increasing gap between developed and developing countries, rich and poor, those with and those without access to education and technology → exacerbating inequalities → increasing political and social tension

To revert this trend:

- ❑ capacity building through scientific training and education accessible to all
- ❑ implant scientific facilities and tools in developing countries and provide the locals with the skills to operate and improve them
- ❑ open science: open-source HW and SW, data sharing, publishing on open-access journals, open-access education are crucial to spread knowledge around the world, reaching out in particular to people from less privileged regions

Scientific knowledge and scientific education accessible to all are fundamental to reduce inequalities

Conclusions

The COVID-19 crisis has shaken the world, revealing a societal system that is not sustainable
→ the “old normal” is not an option

We need to adopt **a values-first approach** and strive for a world where:

- there is **strong, long-term commitment to knowledge and education for all**
- the **well-being of humanity and the preservation of the planet prevail**
- collaboration, solidarity** and inclusiveness override competition, rivalry and divides
- a **shared long-term vision wins out over individual or national short-term gain**
- hope and trust supplant fear and despair**

These are **values at the foundation of science.**
Promoting them is a task of **responsible science.**



SUISSE
FRANCE

CMS

Thank you

LHC 27 km

LHCb

CERN Prévessin

ATLAS

CERN Meyrin

SPS 7 km

ALICE

Some of the outstanding questions in fundamental physics

What is the origin of the masses of the elementary particles (quarks, electrons, ...) ? → related to the Higgs boson



95% of the universe is unknown (dark): e.g. 25% is dark matter

Why is there so little antimatter in the universe ?

What are the features of the primordial plasma permeating the universe $\sim 10 \mu\text{s}$ after the Big Bang ?

Are there other forces in addition to the known four ?

Etc. etc.