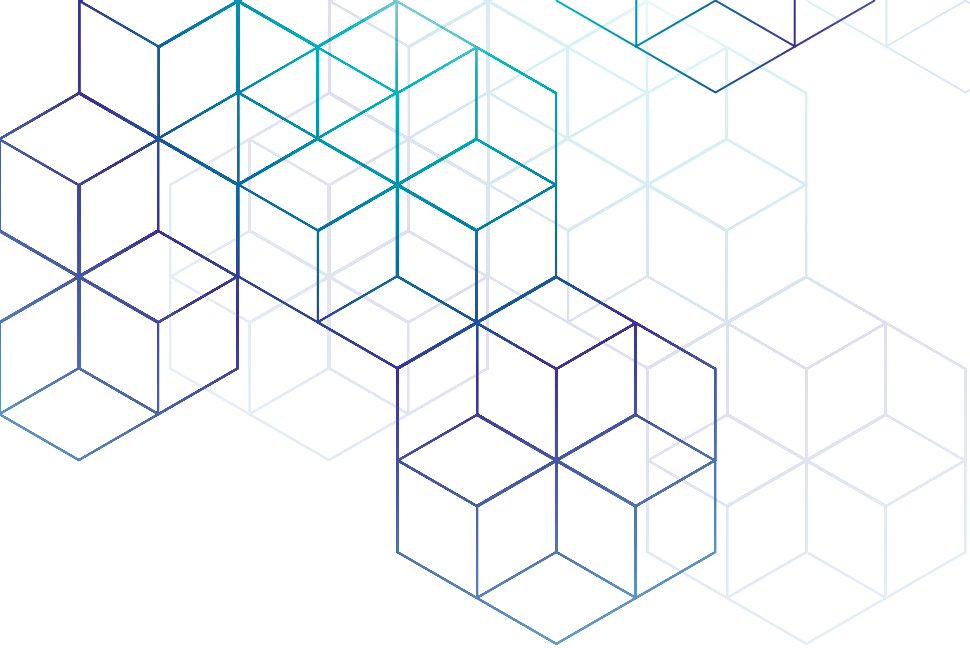


The Impact of CERN

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.

Scientific knowledge

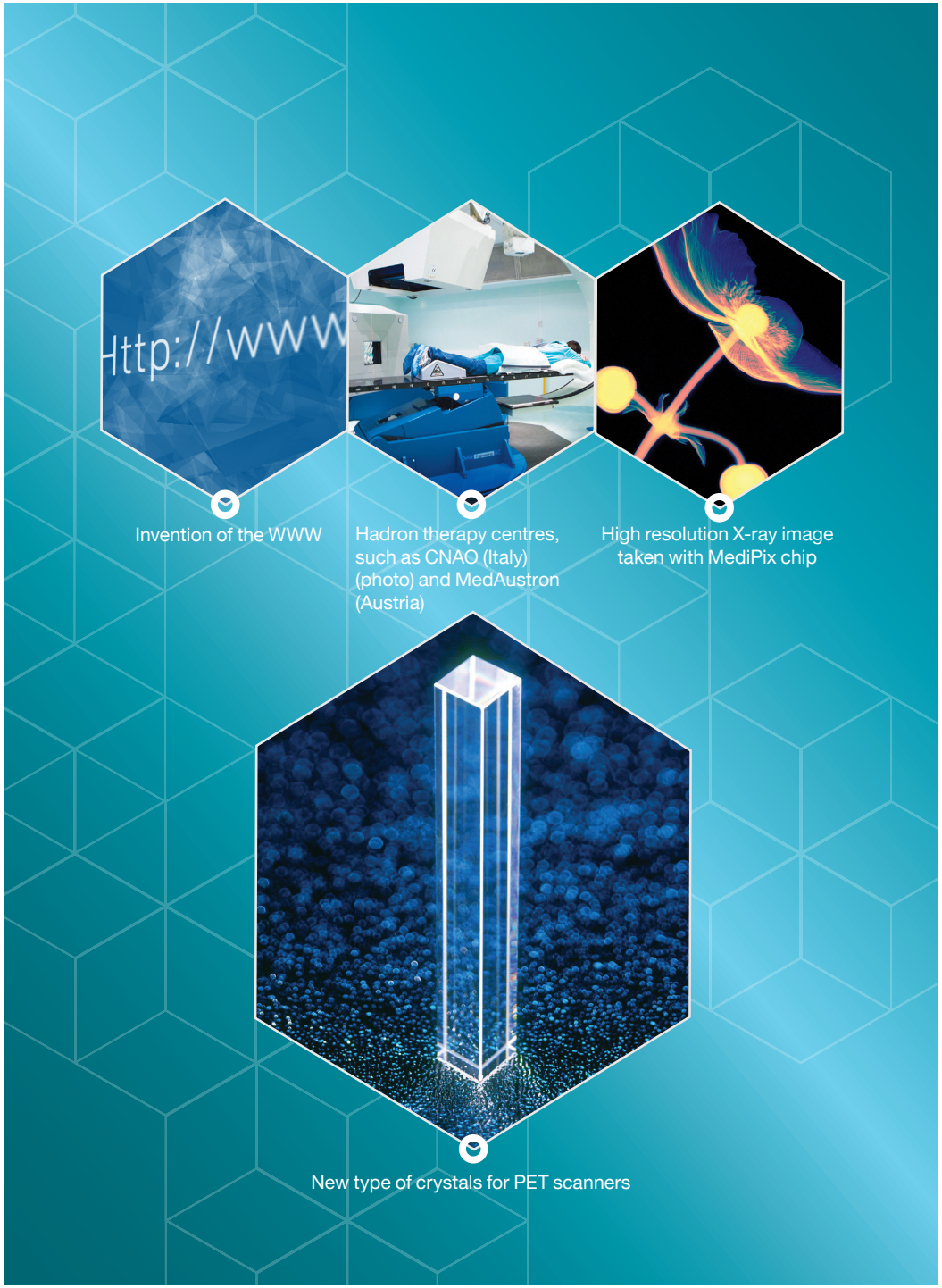
Many important discoveries and technological breakthroughs have been made at CERN.

Since the Organisation was founded in 1954, the discoveries and measurements of the W, Z and Higgs particles and other phenomena have dramatically improved our understanding of fundamental physics. Three CERN researchers obtained Nobel prizes in physics (Carlo Rubbia, Simon van der Meer, Georges Charpak). The discovery of the Higgs boson by the ATLAS and CMS collaboration led to the Nobel prizes for Peter Higgs and Francois Englert.

At CERN, about 70% of the world's particle physicists work together on one of the biggest scientific endeavours in the history of humankind. They use the most complex scientific instrument on Earth - the 27 km long Large Hadron Collider (LHC) - to study nature's most basic constituents and to address questions like: What is the composition of the dark matter, making up 25% of the universe? Why is the universe only made of matter, with almost no antimatter? The LHC accelerates and collides protons or lead ions to reproduce conditions that give new insights into the earliest moments of the universe. Complex detectors the size of six-story buildings record billions of collisions per second, and scientists across the globe use the world-wide LHC computing grid to analyse the data. Every year, researchers at CERN publish about 900 original research papers in peer-reviewed journals.

In addition to the LHC, CERN provides a number of unique research facilities and experiments to researchers around the globe, including: the Antiproton Decelerator, for precision experiments to understand if matter and antimatter behave in the same way; the ISOLDE facility for studies of nuclear physics, using a wide range of exotic nuclei; and the CLOUD experiment, for exploring the influence of cosmic rays on cloud formation in the Earth' atmosphere, giving important input to global climate models.

CERN's Theory Department has been the source of many ideas that have contributed to reshaping our understanding of nature, such as supersymmetry and supergravity. Today, physicists in the Theory Department continue to propose original ideas, contributing to CERN's visibility and inspiring the general public.



Innovation, knowledge transfer, and the economy

The ambitious scientific goals of high energy physics require cutting edge instruments and innovative technologies that have applications in many other fields.

INNOVATION AND KNOWLEDGE TRANSFER

CERN actively engages with experts in science, technology and industry, to transfer its technology and know-how, with the goal of accelerating innovation and maximising the positive impact of CERN on society. This can take the form of encouraging entrepreneurship and spin-offs, public-private R&D partnerships or consultancy. Together with the collaborating institutes and laboratories, CERN develops state-of-the-art technology in 18 different domains. Some examples:

- **The invention of the World-Wide Web at CERN** was driven by the need for better communication among scientists around the world. It is certainly CERN's innovation with the highest impact on our daily life. In addition, CERN was a pioneer in other breakthrough technologies, such as the touchscreen.

- **The World-Wide LHC computing grid** (WLCG) is a distributed computing infrastructure providing more than 500,000 CPUs and 500 PB of data storage in over 200 computer centres in 35 countries [1]. CERN is one of the biggest producers and consumers of big data in the world.

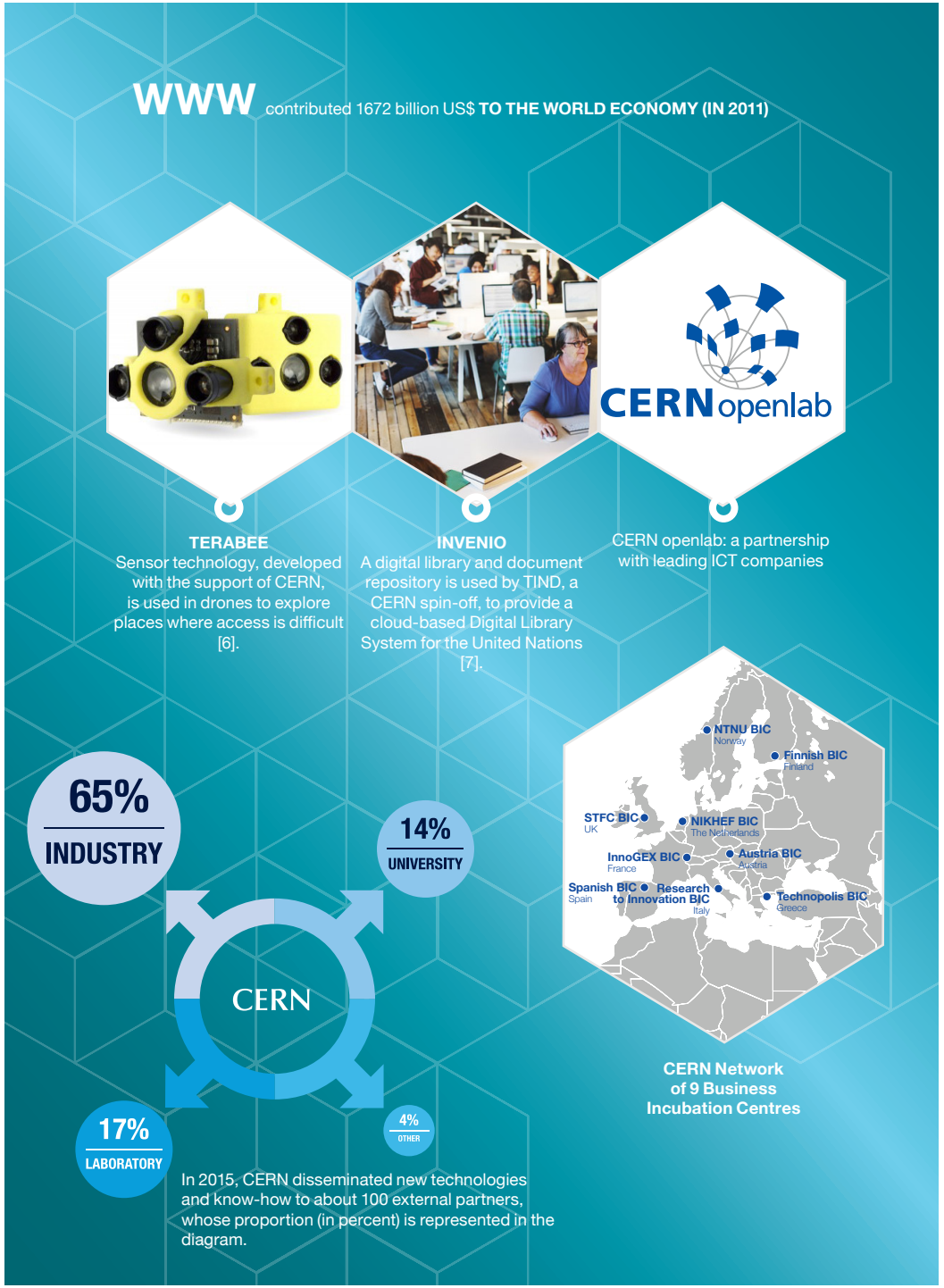
- **Hadron therapy** aims at treating tumours with beams of protons and light ions, to reduce the radiation exposure of healthy tissue. Europe has three cutting-edge therapy centres: two of these, CNAO in Italy and MedAustron in Austria, were built in close cooperation with CERN for accelerator design, construction, testing and further technology developments. CERN also supports the development of miniature linear accelerators for proton therapy [2].

- **Medical imaging** benefits from new types of fast, bright, and dense scintillating crystals for PET scanners [3]. The forerunner of the PET scanner, now used routinely in medical imaging, was another breakthrough technology where CERN made pioneering contributions.

- **Software for simulating particle interactions in detectors** is used e.g. to calculate the precise radiation dose for cancer treatment planning systems and for space applications [4].

- **Pixel detector technologies** developed at CERN ("Medipix") are used e.g. in medical diagnostics, industrial processes, x-ray based material analysis and space missions on the International Space Station [5].

[1] wlcg.web.cern.ch
[2] advancedoncotherapy.com
[3] cern.ch/crystalclear
[4] fluka.org, geant4.cern.ch
[5] medipix.web.cern.ch



INDUSTRIAL AND ECONOMIC RETURN

The World-Wide Web had a huge impact on the global economy since it was made openly available in 1993 by CERN. The number of internet users has skyrocketed from 14 million to 3.2 billion between 1993 and 2015. A study estimated the contribution of the world wide web to the economy at 2.9% of the global 2011 GDP, amounting to 1672 billion US$ [8].

About 50% of CERN's budget (about 500 MCHF) is invested into contracts with industry in its member-state countries. New technologies are developed in-house at CERN through R&D work and prototyping, often in partnership with industry. Industry is then used to build the final products: accelerator, detector and computing components. CERN's procurement policy stimulates contracts with SMEs as they are often very adaptable and reactive, hence ideal industrial partners for CERN's highly specialised technological developments. Companies profit from the gain in know-how when working with CERN: the increase in their turnover (or in cost savings) divided by the value of the CERN contract (the "utility/sales ratio") is typically 3-4, as several studies have found [9]. Member states also benefit from the knowledge acquired by their scientists, engineers, teachers and students while working at CERN. They bring back new experience and methods that contribute to the development of a wide range of activities in their home countries.

Global IT companies (e.g. Huawei, Intel, Oracle, Siemens) collaborate within CERN's "openlab" and profit from the performance demands from particle physics in terms of big-data storage and analysis. Firms use CERN as a test-bed for optimising and stress-testing their latest products [10].

Entrepreneurship. CERN supports personnel and entrepreneurs in creating spin-off companies. As of November 2016, CERN has created a network of nine Business Incubation Centres (BICs), to assist in taking innovative CERN technologies from technical concept to market reality. About 16 start-ups and spin-offs use CERN technologies, with applications in domains as diverse as biotechnology, the oil and gas industry and material science.

[6] teraranger.com
[7] invenio-software.org, tind.io
[8] mckinsey.com/industries/high-tech/our-insights/the-great-transformer, McKinsey Global Institute, May 2011
[9] M. Florio et al., arxiv.org/abs/1507.05638; E. Autio et al.; CERN-2003-005
[10] openlab.cern

International collaboration

CERN is a centre of scientific excellence and provides a framework for peaceful scientific collaboration.

Founded in 1954 by 12 European countries, CERN now has 22 member states and 6 associate member states, including countries from outside Europe. Its scientific excellence attracts about 70% of the world's particle physics community. Based on its spirit of open access, collaboration, tolerance and freedom of thought, the CERN model serves as a 'blueprint' for open global collaboration and evokes calls for similar multinational research efforts in other fields, such as a "CERN for the oceans" [11], genomics [12], agricultural science [13] and human brain research [14].

SCIENCE FOR PEACE

CERN is open to scientists from all nations irrespective of their system of government, some from countries that are opponents on the political stage. During the Cold War, CERN served as a bridge between East and West: the 1968 agreement between CERN and the (Soviet) IHEP laboratory in Moscow later became a model for an agreement between the USA and the Soviet Union [15]. In 2012, CERN became observer to the United Nations (UN), serving as a leading voice for global science. In cooperation with the UN, CERN provides the IT infrastructure that allows the UNOSAT programme to be at the forefront of satellite-analysis technology, e.g. for disaster-risk reduction or regional capacity development. CERN has also helped to build the SESAME [16] light source in Jordan, which follows the CERN model and promotes scientific collaboration in the Middle East (SESAME members are Bahrain, Cyprus, Egypt, Iran, Israel, Jordan, Pakistan, the Palestinian Authority, and Turkey).

MANAGEMENT OF BIG, GLOBAL PROJECTS

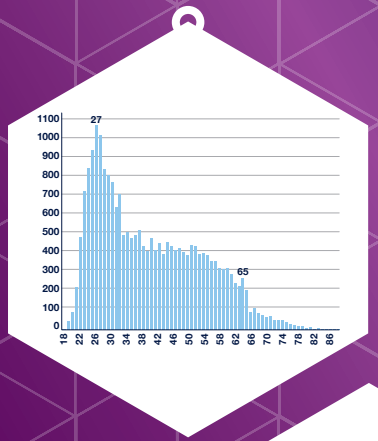
The management of the LHC experimental collaborations has attracted much attention from multinational companies [17]. They are interested in understanding how groups of up to 4000 physicists, engineers and technicians, of more than 110 nationalities, different languages, cultural and educational backgrounds, manage to work together for 20 years to design, build and commission thousands of challenging detector components that have to fit together precisely and operate flawlessly. The answer lies in the shared passion for "noble values" (knowledge) and a common goal that draws collaborators together. All partners are equal, there is no leader country or institution, and everybody, including the youngest collaborators, feels empowered to contribute to the common aim. Decisions are taken on a consensual basis, and competition and cooperation co-exist.

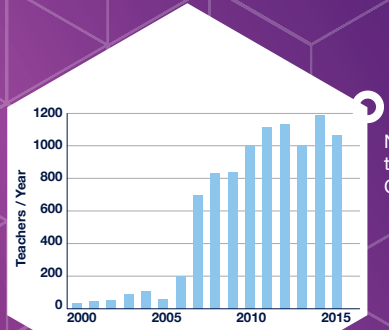
[11] Time, 2015, time.com/4029379/cern-for-the-oceans/
[12] EMBO, 2015, embo.org/news/articles/2015/we-need-a-cern-for-genomics
[13] Phys.Org, 2016, phys.org/news/2016-01-cern-agricultural-science.html
[14] Science, 2015, sciencemag.org/news/2015/03 mediators-propose-cern-organization-human-brain-
[15] H. Schopper, CERN-60 presentation, in: indico.cern.ch/event/328735/contribution/1/material/slides/1.pdf
[16] sesame.org.jo/sesame/
[17] The Economist, 27 April 2013

EVERY YEAR
More than 1,000 highly trained and qualified young physicists and engineers
More than 1,000 school teachers in CERN training programmes
600 PhD theses completed

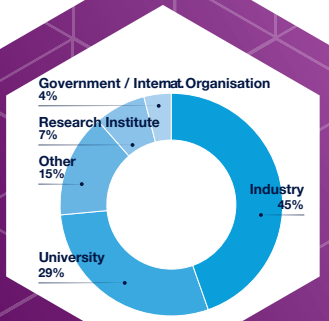
S'COOL LAB
4,000 pupils perform hands-on experiments on modern physics every year

Age distribution of CERN scientists

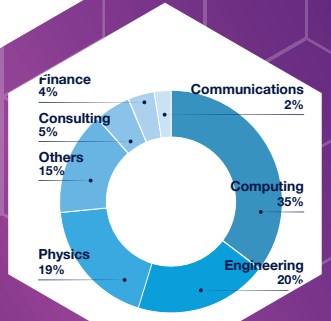




Number of school teachers trained at CERN (per year)



Where do young physicists and engineers find their first job after CERN?



Which domain in industry do they work in?

Education and Open Science

Education and Open Science are CERN's core missions

YOUNG RESEARCHERS

The education of young researchers is an essential part of CERN's impact on society. Over 2,400 PhD students are registered at CERN, and 600 PhD theses are completed every year. About 36% of post-graduates leaving CERN find a first job in research or academia. In the longer term, 20% find permanent jobs in these domains, and about 80% transfer their expertise to industry, finance or other fields. This provides a steady stream of highly qualified young people with excellent technical skills and international experience for business and industry.
Every summer, about 300 undergraduate students from CERN member and non-member states participate in an 8-13 week internship programme. Several hundred young physics students, engineers and technicians receive higher degrees from universities for work carried out at CERN, where they gain problem-solving skills, new knowledge and experience in international collaboration. Specialised CERN schools provide training on particle physics, accelerators and computing to several hundred young researchers each year. CERN hosts more than 500 postdoctoral fellows working in research and applied physics, engineering and IT.

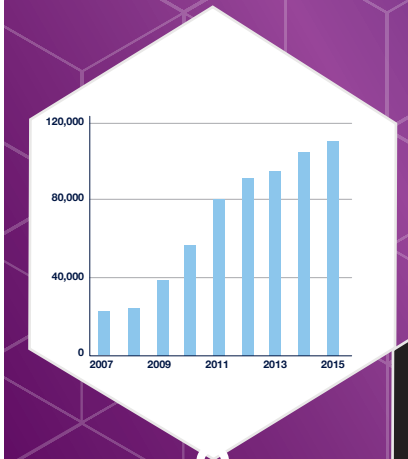
TEACHER AND SCHOOL STUDENT PROGRAMMES

Since 2006, about 10,000 teachers have been trained at CERN in 1-3 week programmes, giving them a first-hand insight into frontier research. The goal is to inspire them to use examples from CERN's research to make their lessons more attractive. Assuming that each participant reaches more than 100 students, these programmes have impacted more than a million students.
About 4,000 school students per year use the "S'cool Lab" at CERN - a hands-on laboratory equipped with experiments in modern physics and state-of-the-art detector technology. The "Beamline for Schools" competition engages 200-300 teams from schools around the world to win a 10-day residency for carrying out a real science experiment at a CERN beam line. The 'International Masterclasses" programme reaches 15,000 pupils in 46 countries and provides an introduction to particle physics and access to the analysis of LHC data.

OPEN SCIENCE

Knowledge dissemination is part of CERN's raison d'être according to its founding convention. Thus CERN provides open access to scientific publications, data and technologies free of charge. CERN participates in the Open Source Software (OSS) initiative, which brings society considerable benefits, including cost savings, improved reliability and adaptability. CERN has extended this model to Open Hardware Licenses (OHL), to enable knowledge-exchange across a wide community of electronic designers. CERN papers are published in Open Access peer-reviewed journals (SCOAP3 initiative).

70,000 SCHOOL CHILDREN VISIT CERN EVERY YEAR



Number of CERN visitors per year

4 July 2012: The Higgs boson discovery

166,000 ARTICLES ON CERN PUBLISHED IN THE WORLD MEDIA (2015)

25 HEADS OF STATE AND 168 MINISTERS HAVE VISITED CERN (2011-2015)

Outreach

CERN engages with society in many ways, notably by attracting and inspiring the public through guided tours and exhibitions.

CERN VISITS AND EXHIBITIONS

CERN has developed a highly successful visits and exhibition programme. 25 heads of state and 168 ministers have made protocol visits between 2011 and 2015. CERN organises guided tours for the public, with the help of more than 200 volunteer guides. About 120,000 visitors per year – among whom 70,000 are school students - have the opportunity to go on a half-day tour, but the demand (300,000 visit requests) is much higher. CERN traveling exhibitions have been shown in 76 locations in 15 countries, with more than one million visitors in the member states.

MEDIA AND THE ARTS

CERN attracts more than 500 visits by the world media per year. The discovery of the Higgs boson on 4 July 2012 was broadcast globally and had the potential to reach over more than 1 billion people. In 2015, the world's newspapers published a total of 166,000 articles related to CERN, with a total of 9.9 billion potential readers. Major TV channels produce more than ten documentaries about CERN every year [18]. The CERN website has typically 20,000 sessions per day, and every year about 4.4 million unique visitors access it. On social media (Twitter, Facebook, etc), there are about 2 million mentions of CERN per year.

CERN's engagement with the arts, through the Arts at CERN programme [19], attracts brilliant artists for 1-3 month residencies, with the goal of bringing arts and science closer together.

[18] VOCUS/CISION media monitoring www.cision.com/us/

[19] Arts-at-CERN: arts.cern

CERN Quick Facts

ACCELERATORS

LHC	7+7 TeV Large Hadron Collider, 27 km in circumference
SPS	450 GeV Super Proton Synchrotron, 6.9 km in circumference
PS	28 GeV Proton Synchrotron
ISOLDE	Booster-ISOLDE isotope separator
AD /ELENA	Antiproton Decelerator (5MeV/100 keV)

ADVANCED ACCELERATOR DEVELOPMENTS

CTF3	150 MeV CLIC test-facility electron beam: accelerator R&D for future linear collider
AWAKE	400 GeV protons to drive plasma wakefield acceleration developments

FINANCIAL CONTRIBUTIONS
(in percent)

Member States	
Austria	2.2
Belgium	2.8
Bulgaria	0.3
Czech Republic	0.9
Denmark	1.8
Finland	1.4
France	14.3
Germany	20.4
Greece	1.2
Hungary	0.6
Israel	1.5
Italy	10.6
Netherlands	4.8
Norway	2.9
Poland	2.8
Portugal	1.1
Romania	1.0
Slovak Republic	0.5
Spain	7.2
Sweden	2.7
Switzerland	3.9
United Kingdom	15.1

Associate Member States	
Cyprus*	0.1
India	
Pakistan	0.1
Serbia*	0.2
Turkey	0.4
Ukraine	0.1

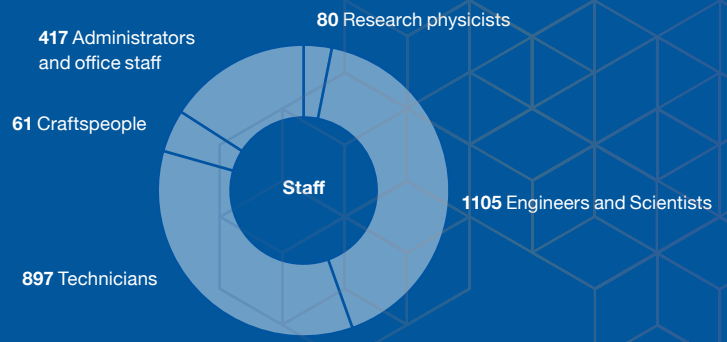
**in the pre-stage to membership*

TOTAL BUDGET
MEMBER STATES AND ADDITIONAL CONTRIBUTIONS

1130 MILLION CHF

MEMBERS OF THE PERSONNEL

Employed members of the personnel	**3312**
Staff	2560
Fellows	752



ASSOCIATED MEMBERS OF THE PERSONNEL 13592
(Users plus participants in scientific exchange and training)

NUMBER OF USERS AND INSTITUTES
(including universities) participating in the research programme

Member States	Users: 6974	Institutes: 424
Austria	97	9
Belgium	152	11
Bulgaria	38	5
Czech Republic	231	11
Denmark	67	6
Finland	117	8
France	876	35
Germany	1282	70
Greece	128	12
Hungary	62	6
Israel	68	6
Italy	1430	93
Netherlands	166	6
Norway	85	4
Poland	252	21
Portugal	100	11
Romania	100	7
Slovak Republic	81	7
Spain	322	26
Sweden	102	10
Switzerland	371	15
United Kingdom	847	45

Associate Member States	Users: 426	Institutes: 52
Cyprus*	15	1
India	197	24
Pakistan	33	2
Serbia*	32	4
Turkey	120	15
Ukraine	29	6

**in the pre-stage to membership*

Observers	Users: 3178	Institutes: 192
Japan	277	40
Russia	981	24
United States of America	1920	128

All other States	Users: 1229	Institutes: 165

Status: December 2016

BREAKTHROUGH DISCOVERIES IN EXPERIMENTAL PHYSICS

16,000 SCIENTISTS OF MORE THAN 110 NATIONALITIES

70% OF THE WORLD'S PARTICLE PHYSICISTS DO RESEARCH AT CERN

PROMOTES OPEN SCIENCE

WWW INVENTED AT CERN

THE LHC IS THE MOST POWERFUL ACCELERATOR BUILT BY HUMANITY

ADVANCED TECHNOLOGIES WITH APPLICATIONS IN 16 DOMAINS

MODEL OF EFFECTIVE AND PEACEFUL INTERNATIONAL COLLABORATION

ABOUT 600 PHD THESES BASED ON WORK AT CERN COMPLETED EVERY YEAR

SEVERAL UNIQUE RESEARCH FACILITIES

166,000
ARTICLES IN THE WORLD PRESS WRITTEN ABOUT CERN

TRAINS ABOUT 1,000 HIGH-SCHOOL TEACHERS, 300 UNDERGRADUATE STUDENTS AND THOUSANDS OF YOUNG PHYSICISTS EVERY YEAR

WELCOMES MORE THAN 120,000 VISITORS EVERY YEAR

CERN
CH-1211 Geneva, Switzerland
home.cern
Education, Communication and Outreach Group

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UNOSAT (p.10)