

# Brief Introduction to CERN

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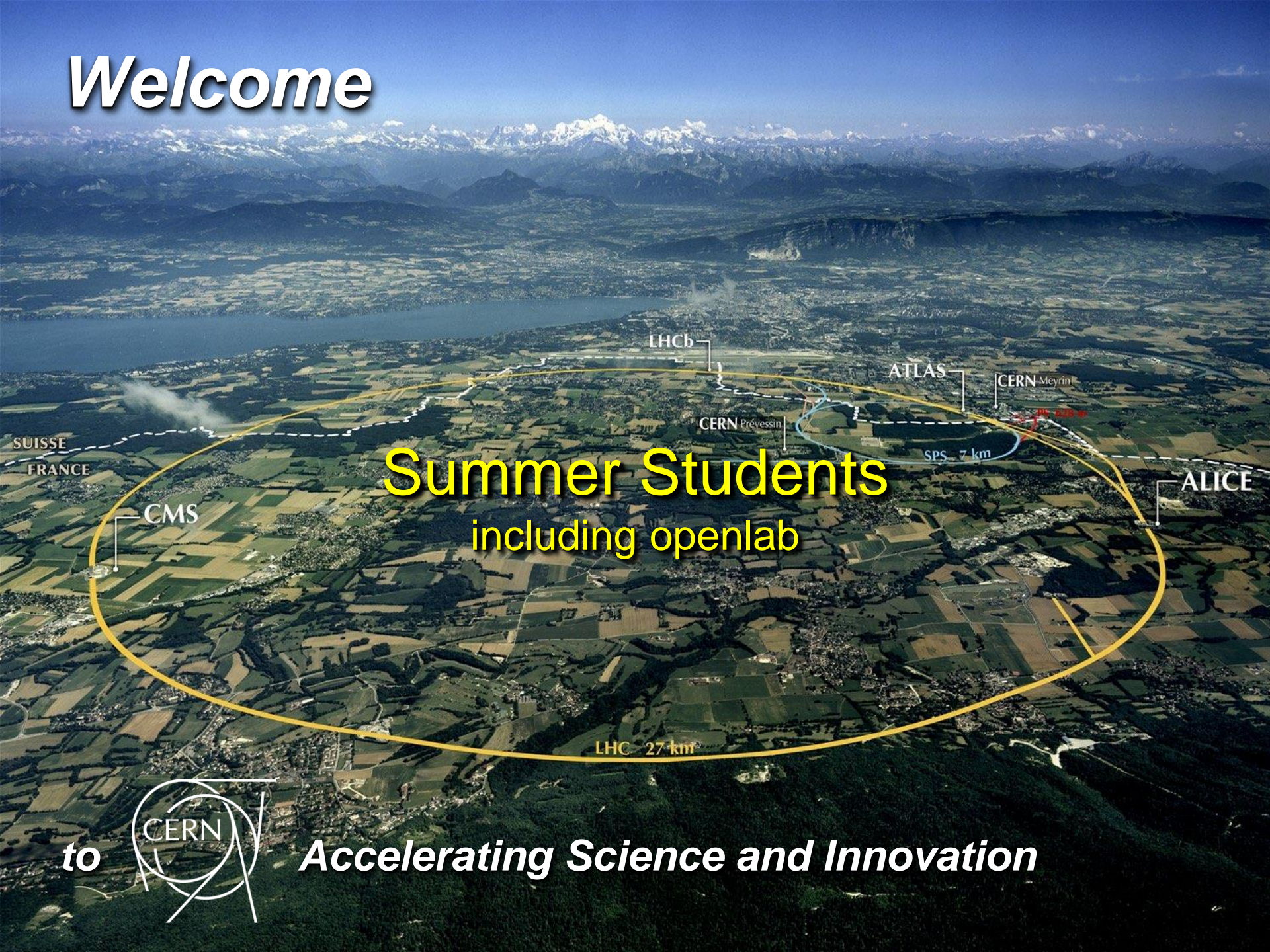
Director for Research and Computing

29.6.2018





# Welcome



## Summer Students including openlab

to



***Accelerating Science and Innovation***

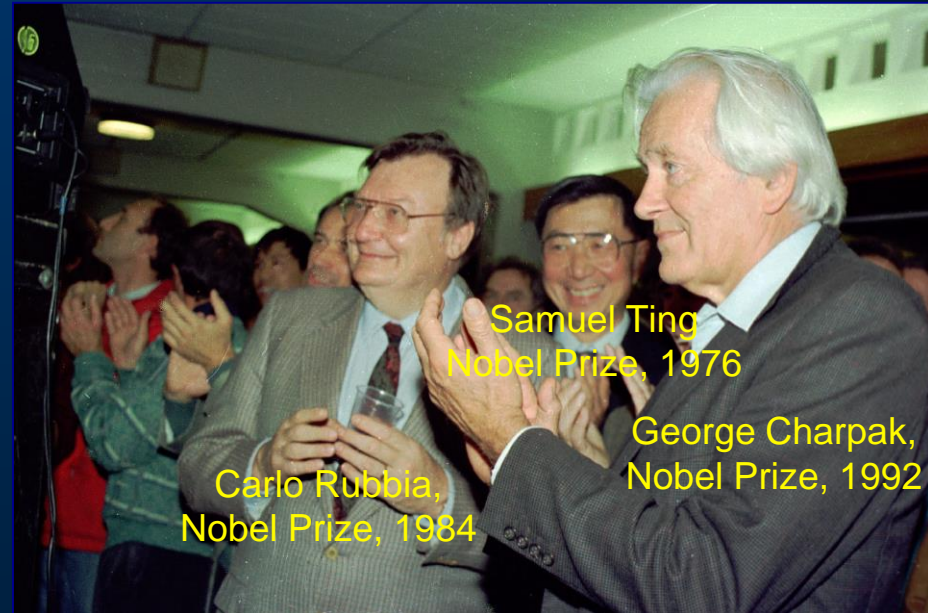


# CERN's Mission

- Fundamental research in particle physics
- Technology and innovation
  - transfer to society (e.g. the World Wide Web)
- Training and education
- Unite people in their quest for knowledge:
  - > 13000 scientists, > 110 nationalities

where the web was born

CERN staff member T. Berners-Lee,  
inventor of the WEB, with Kofi Annan



Samuel Ting  
Nobel Prize, 1976

Carlo Rubbia,  
Nobel Prize, 1984

George Charpak,  
Nobel Prize, 1992

# CERN: founded in 1954: 12 European States

“Science for Peace”

## Today: 22 Member States

~ 2500 staff

~ 1800 other paid personnel

~ 13000 scientific users

Budget (2017) ~ 1100 MCHF

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

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

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

**Applications for Membership or Associate Membership:**

Brazil, Croatia

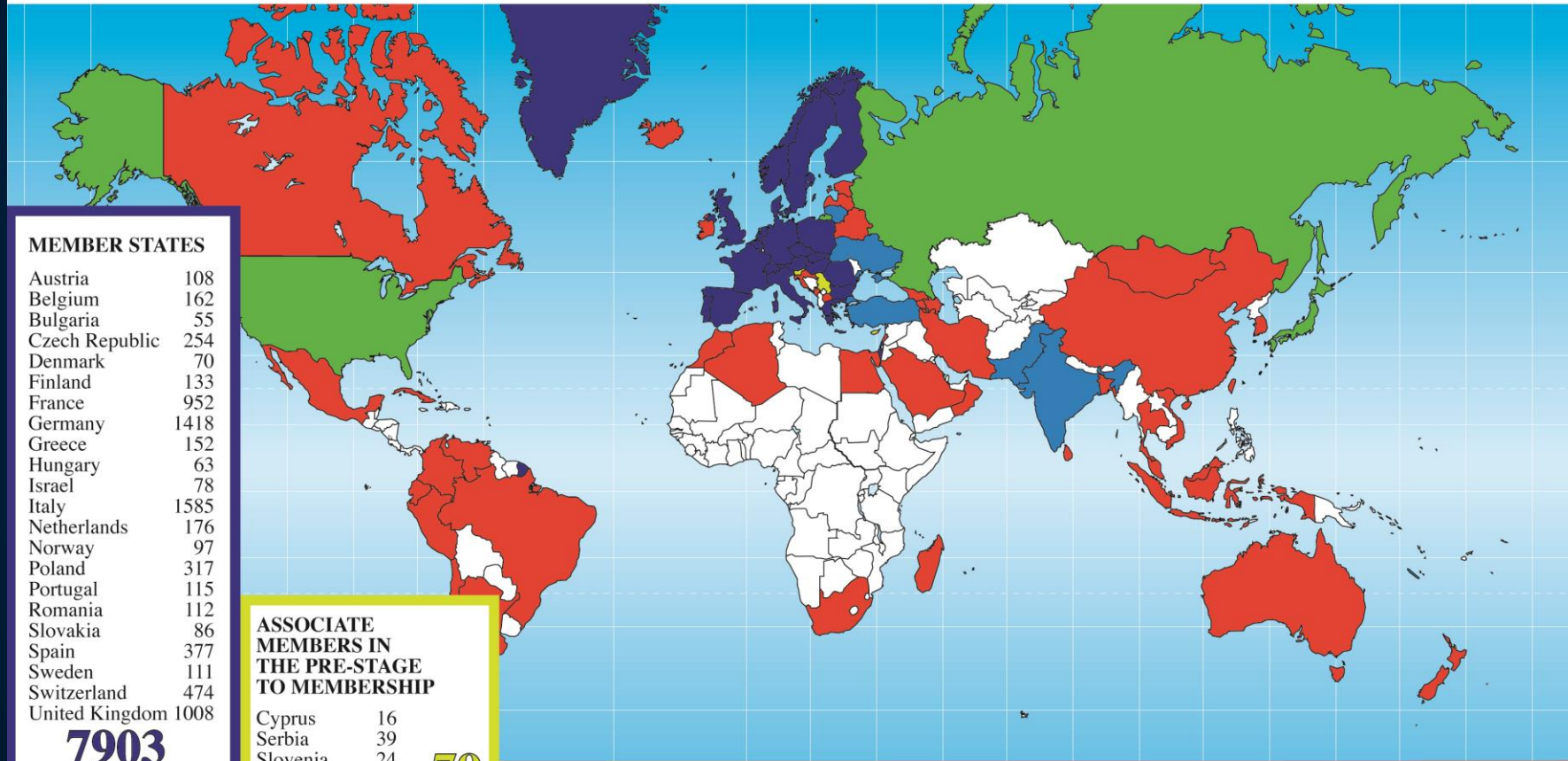
**Observers to Council:** Japan, Russia, United States of America; European Union, JINR and UNESCO





# Science is getting more and more global

## Distribution of All CERN Users by Location of Institute on 24 January 2018



### MEMBER STATES

Austria	108
Belgium	162
Bulgaria	55
Czech Republic	254
Denmark	70
Finland	133
France	952
Germany	1418
Greece	152
Hungary	63
Israel	78
Italy	1585
Netherlands	176
Norway	97
Poland	317
Portugal	115
Romania	112
Slovakia	86
Spain	377
Sweden	111
Switzerland	474
United Kingdom	1008

**7903**

### ASSOCIATE MEMBERS IN THE PRE-STAGE TO MEMBERSHIP

Cyprus	16
Serbia	39
Slovenia	24

**79**

### ASSOCIATE MEMBERS 446

India	221
Lithuania	21
Pakistan	38
Turkey	129
Ukraine	37

### OBSERVERS

Japan	285
Russia	1099
USA	2070

**3454**

### OTHERS

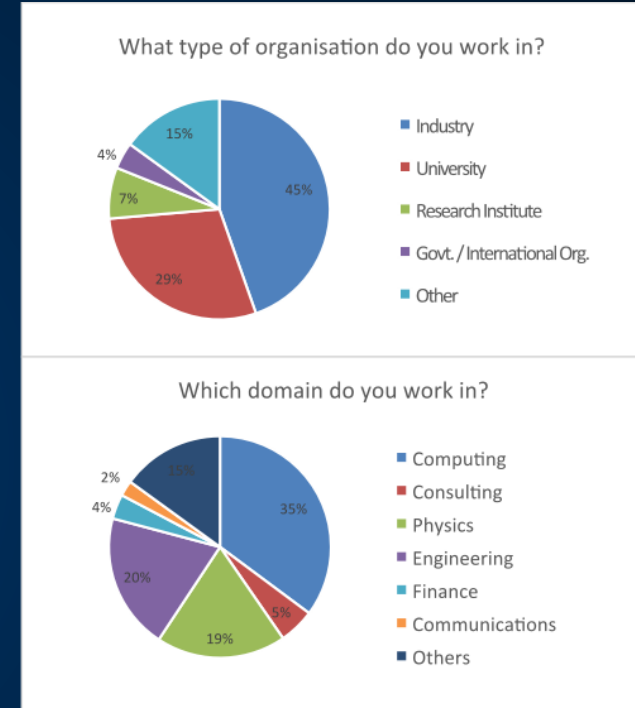
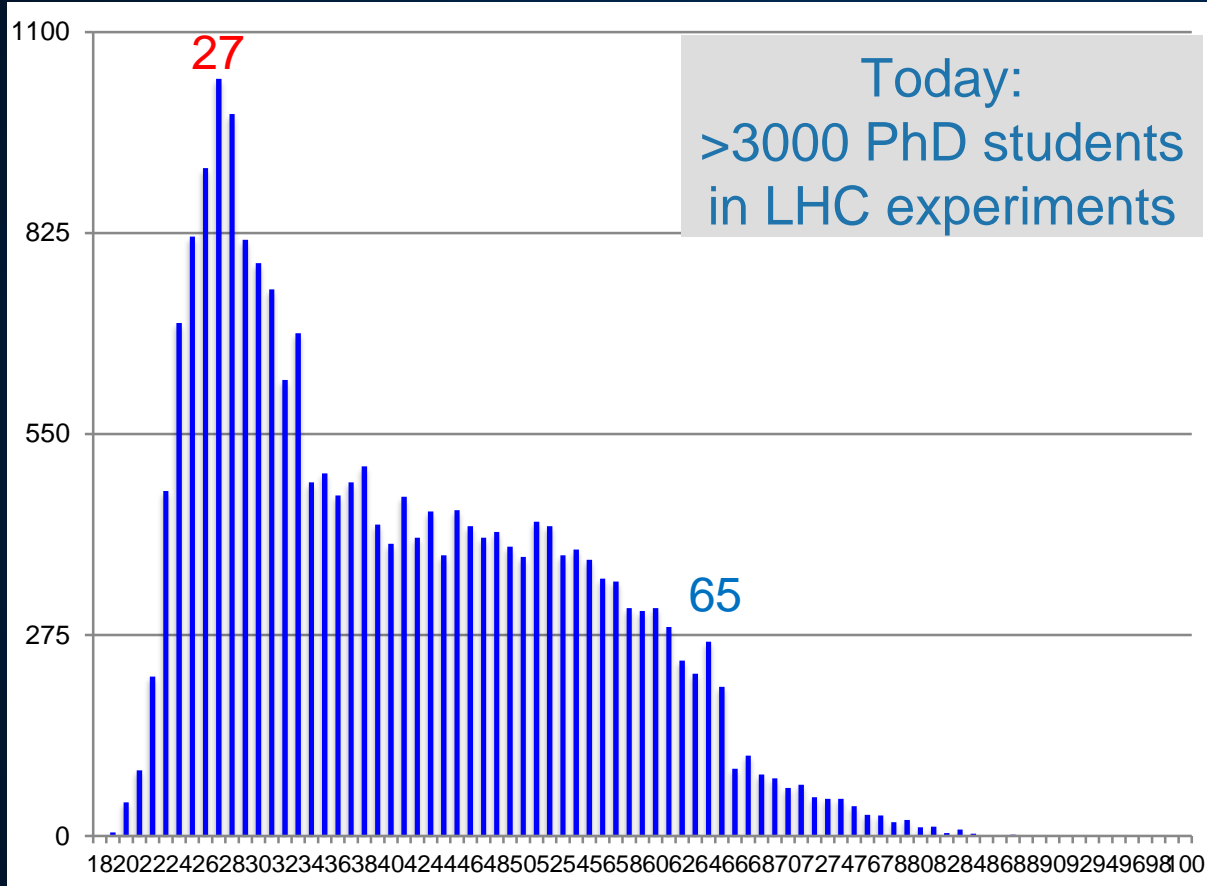
Algeria	1	Chile	23	Iceland	2	Mexico	64	Sri Lanka	3
Argentina	20	China	283	Indonesia	7	Mongolia	2	T.F.Y.R.OM	2
Armenia	14	Colombia	27	Iran	26	Montenegro	7	Taiwan	68
Australia	36	Croatia	31	Ireland	10	Morocco	12	Thailand	19
Azerbaijan	5	Cuba	3	Korea	166	New Zealand	7	Venezuela	1
Bangladesh	3	Ecuador	4	Latvia	1	Oman	4	Viet Nam	1
Belarus	24	Egypt	25	Lebanon	10	Peru	3		
Brazil	135	Estonia	18	Madagascar	3	Saudi Arabia	1		
Canada	190	Georgia	28	Malaysia	7	Singapore	3		
		Hong Kong	19	Malta	8	South Africa	81		

**1407**



# Age Distribution of Scientists

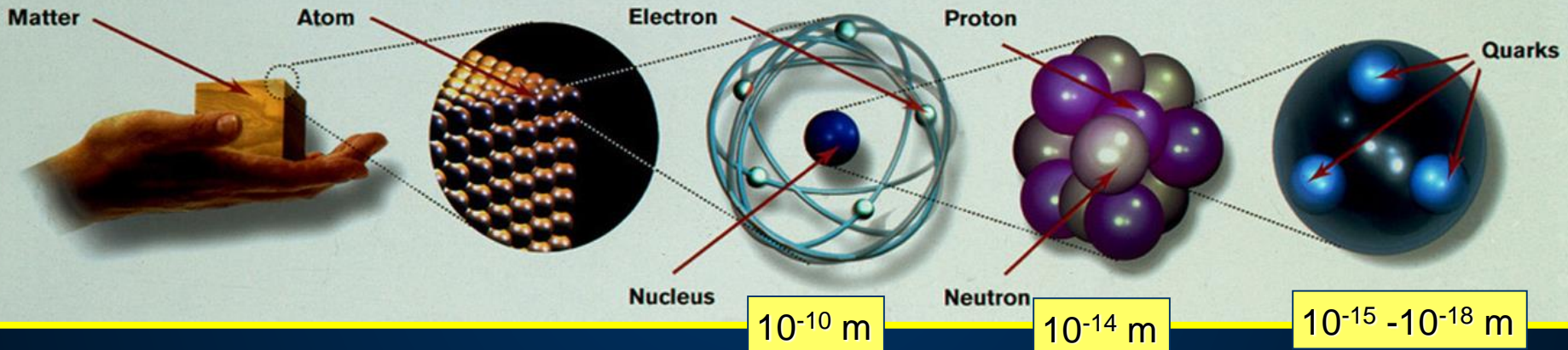
- and where they go afterwards



They do not all stay: where do they go?

# 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



Modern accelerators enable us to study the fundamental laws of nature on scales smaller than  $10^{-18}$  m

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

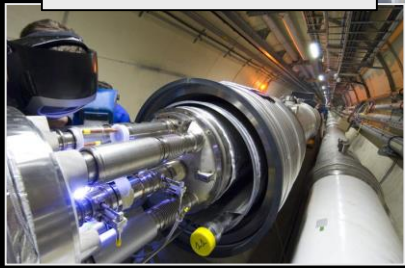


# Evolution of the Universe

Big Bang

Accelerators

Telescopes



380000 years

13.7 Billion Years

$10^{28}$  cm

Today



# 2010: a New Era in Fundamental Science



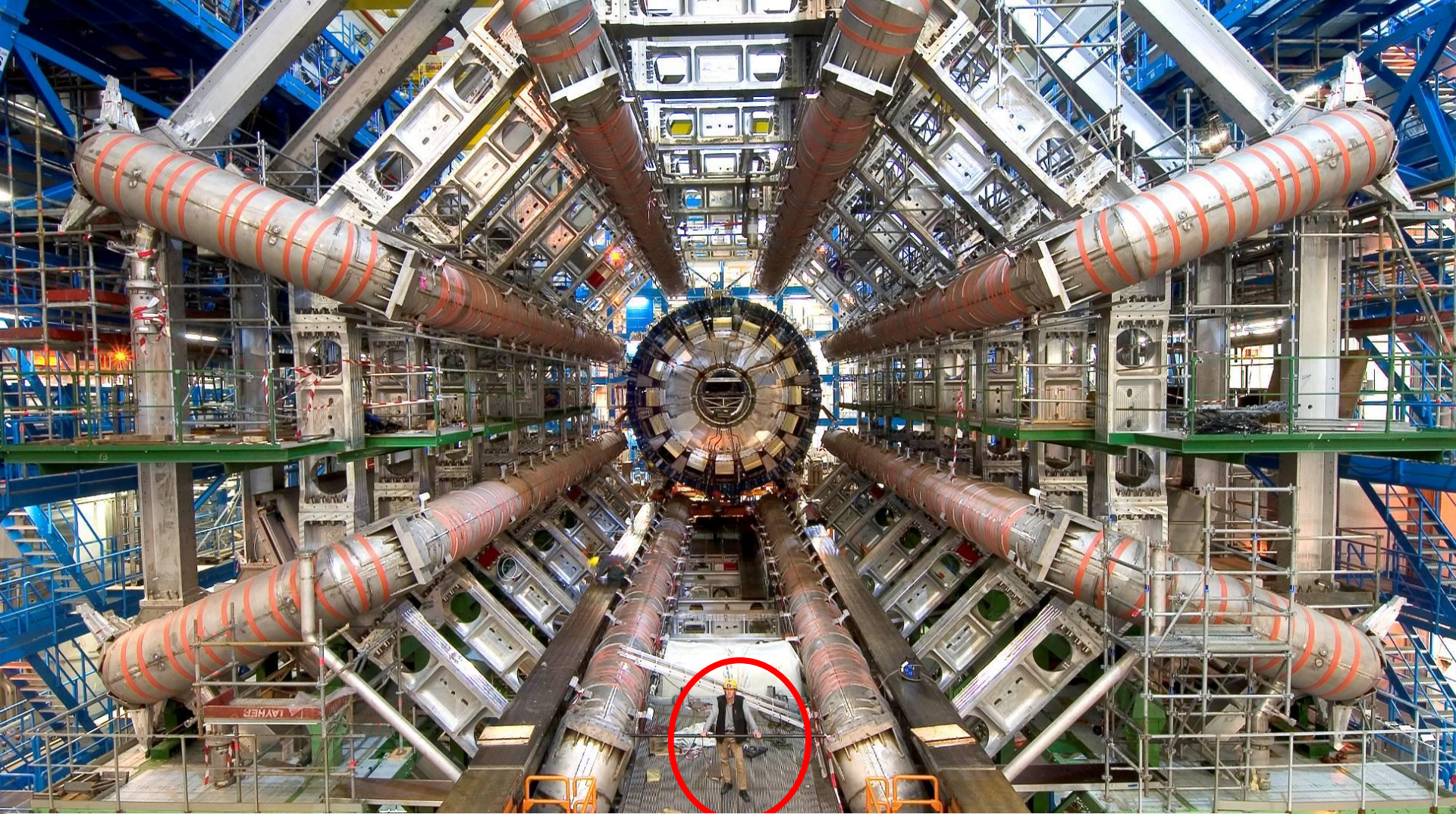




### Accelerator:

- 1232 high-tech superconducting magnets
- magnet operation temperature: 1.9 K (-271 °C)
  - LHC is one of the *coldest* place 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





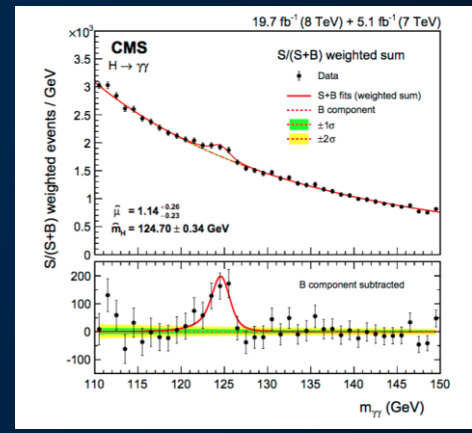
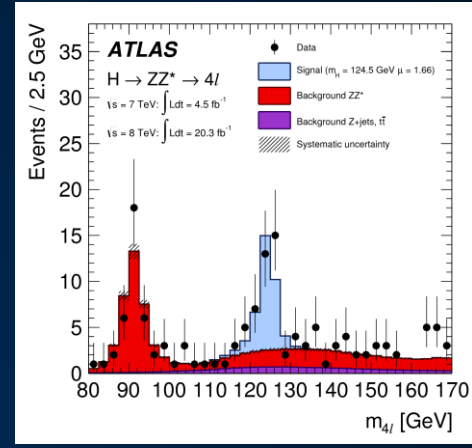
## Detectors:

- ❑ size of ATLAS: ~ half Notre Dame cathedral
- ❑ weight of CMS experiment: 13000 tons (more than Eiffel Tower)
- ❑ number of detector sensitive elements: 100 millions
- ❑ cables needed to bring signals from detector to control room: 3000 km
- ❑ data in 1 year per experiment: ~10 PB (20 million DVD; more than YouTube, Twitter)





The Nobel Prize in Physics 2013 was awarded jointly to François Englert and Peter W. Higgs "for the theoretical discovery of a mechanism that contributes to our understanding of the origin of mass of subatomic particles, and which recently was confirmed through the discovery of the predicted fundamental particle, by the ATLAS and CMS experiments at CERN's Large Hadron Collider".



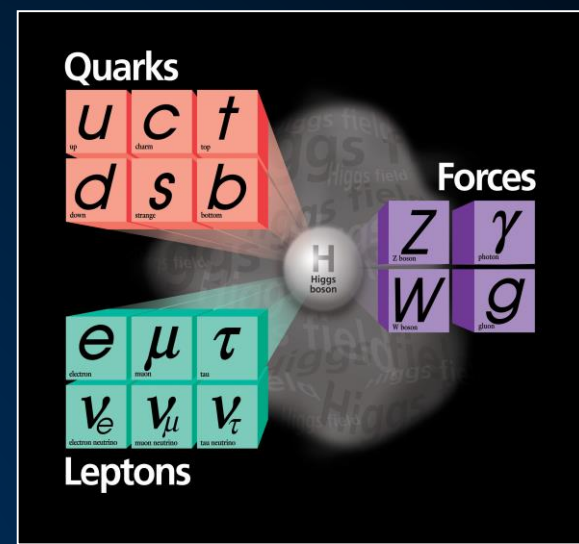
Discovery 2012





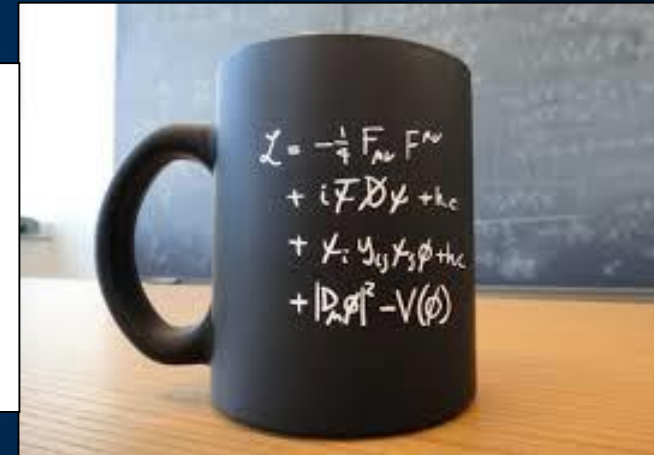
These are very exciting times in particle physics!

With the discovery of the Higgs boson, we have completed the Standard Model (> 50 years of theoretical and experimental efforts !)



We have tested the Standard Model with very high precision (wealth of measurements since early '60s, in particular at accelerators)

- it works BEAUTIFULLY (puzzling ...)
- no significant deviations observed (but difficult to accommodate non-zero neutrino masses)



However: the SM is not a complete theory of particle physics, as several outstanding questions remain (raised also by precise experimental observations) that cannot be explained within the SM.

These questions require NEW PHYSICS

# Key questions in today's particle physics

- Why is the Higgs boson so light (so-called “naturalness” or “hierarchy” problem) ?
- What is the origin of the matter-antimatter asymmetry in the Universe ?
- Why 3 fermion families ? Why do neutral leptons, charged leptons and quarks behave differently ?
- What is the origin of neutrino masses and oscillations ?
- What is the composition of dark matter (23% of the Universe) ?
- What is the cause of the Universe's accelerated expansion (today: dark energy ? primordial: inflation ?)
- Why is Gravity so weak ?

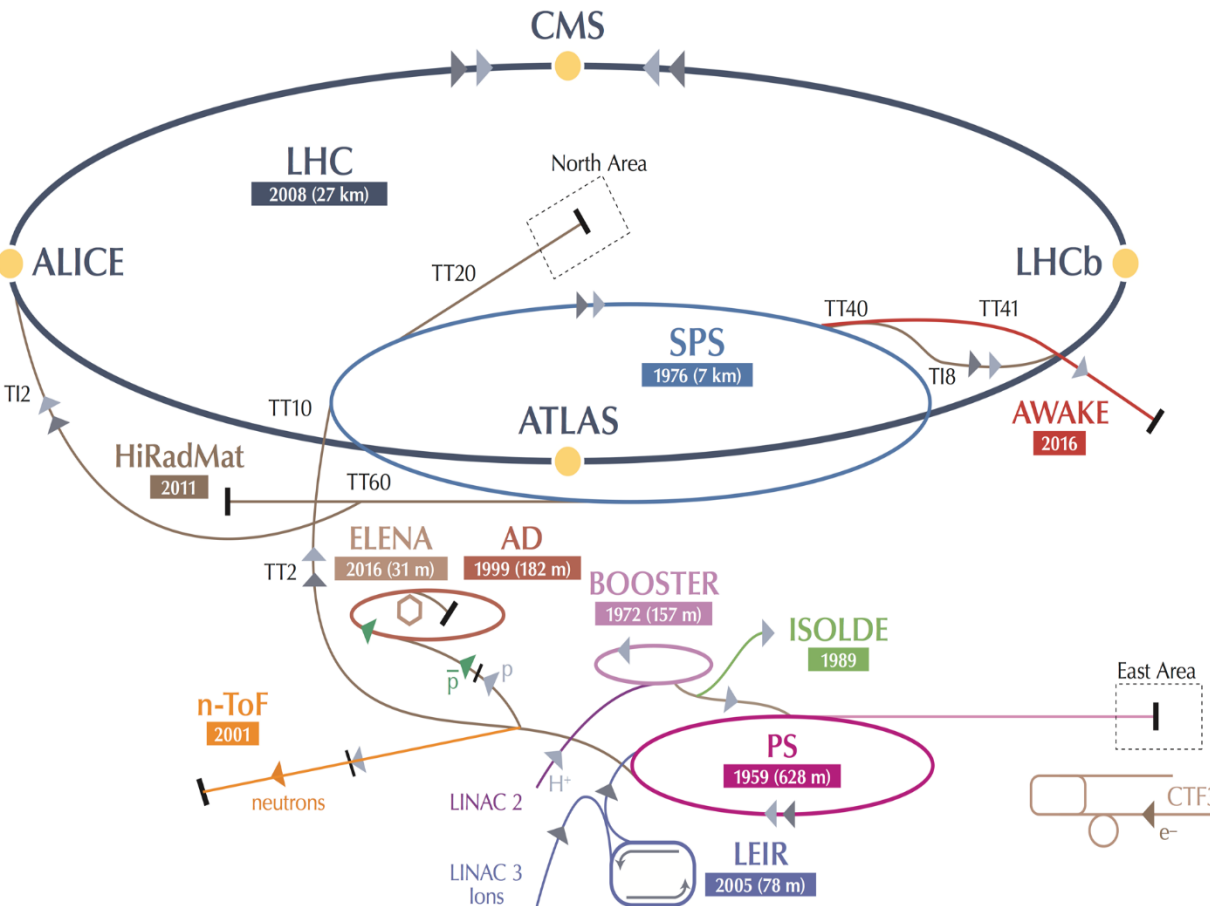
However, there is no direct evidence for new particles (yet...) from the LHC or other facilities.

- Where is the new physics?
- How does it couple?
- What is the (energy) scale?

LHC will be a primary research tool over the next 20 years



# CERN scientific programme...



exploits unique capabilities of CERN's accelerator complex; complementary to other efforts in the world.

~20 projects other than LHC with > 1200 physicists

**AD:** Antiproton Decelerator for antimatter studies

**AWAKE:** proton-induced plasma wakefield acceleration

**CAST, OSQAR:** axions

**CLOUD:** impact of cosmic rays on aerosols and clouds → implications on climate

**COMPASS:** hadron structure and spectroscopy

**ISOLDE:** radioactive nuclei facility

**LHC**

**NA61/Shine:** ions and neutrino targets

**NA62:** rare kaon decays

**NA63:** radiation processes in strong EM fields

**NA64:** search for dark photons

**Neutrino Platform:**  $\nu$  detector R&D for experiments in US, Japan

**n-TOF:** n-induced cross-sections

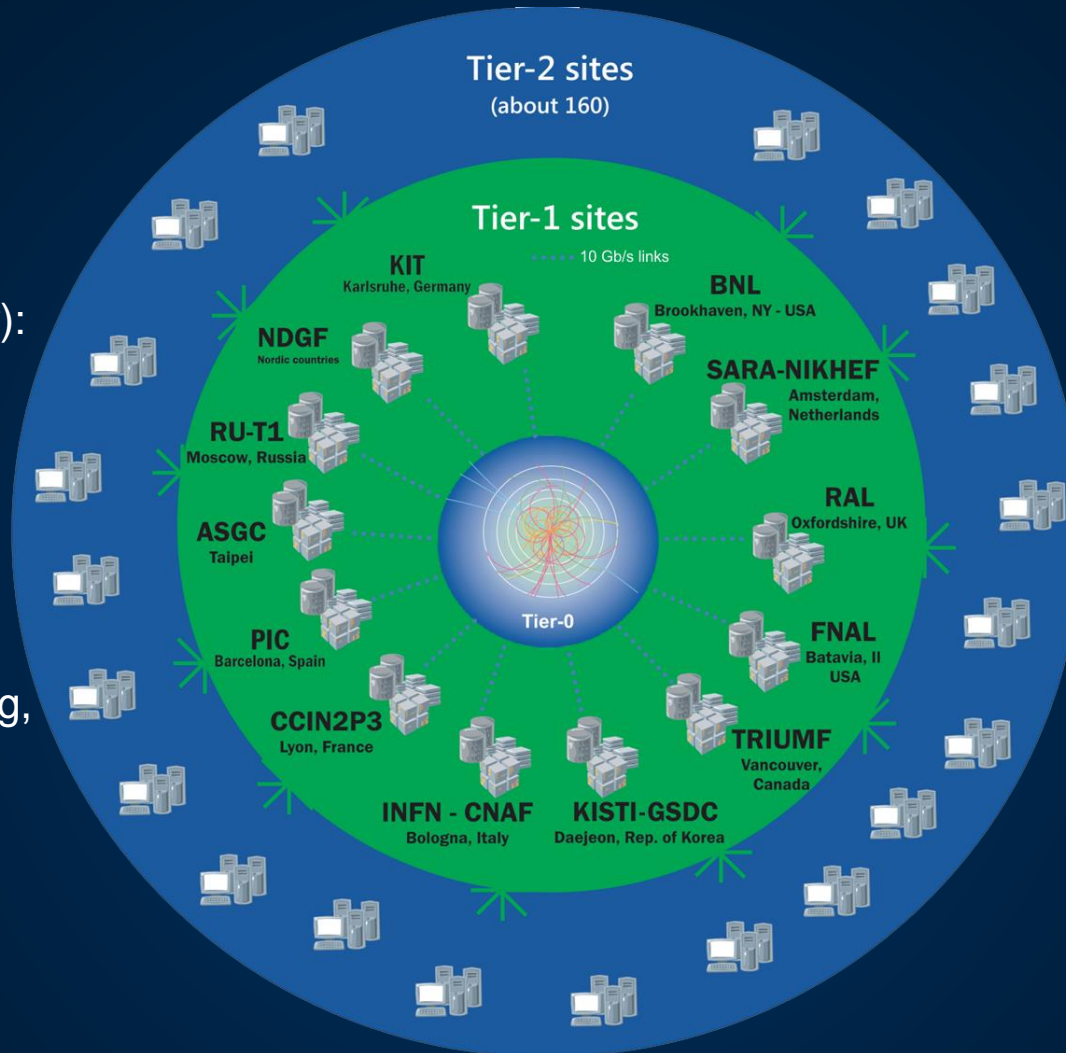
**UA9:** crystal collimation

# The Worldwide LHC Computing Grid

Tier-0  
(CERN and Hungary):  
data recording,  
reconstruction and  
distribution

Tier-1: permanent  
storage, reprocessing,  
analysis

Tier-2: simulation,  
end-user analysis



>170 sites in,  
42 countries

750k CPU cores

800 PB of storage

> 2 million jobs/day

35 GB/s global  
transfers

## WLCG:

An International collaboration to distribute and analyse LHC data

Integrates computer centres worldwide that provide computing and storage resource into a single infrastructure accessible by all LHC physicists





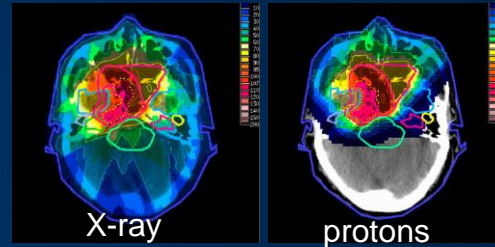
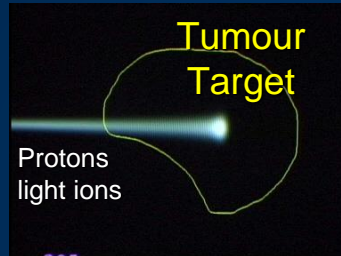
# Medical Application as an Example of Particle Physics Spin-off

Combining Physics, ICT, Biology and Medicine to fight cancer



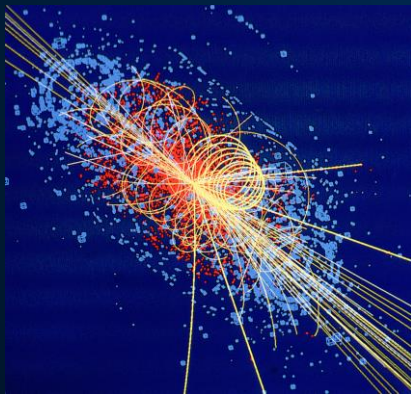
## Hadron Therapy

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



Leadership in Ion Beam Therapy now in Europe and Japan

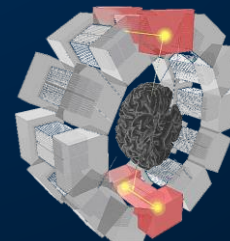
>100'000 patients treated worldwide (45 facilities)  
>50'000 patients treated in Europe (14 facilities)



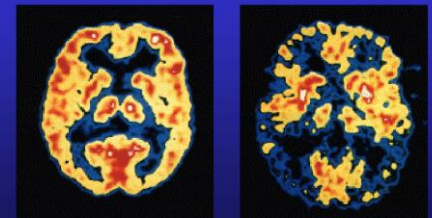
## Imaging

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

PET Scanner



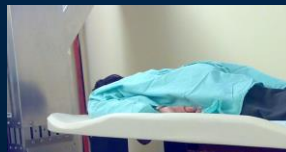
Brain Metabolism in Alzheimer's Disease: PET Scan



Normal Brain

Alzheimer's Disease

Detecting particles



# CERN openlab Summer Student Projects

Machine Learning for Fast Physics Simulation

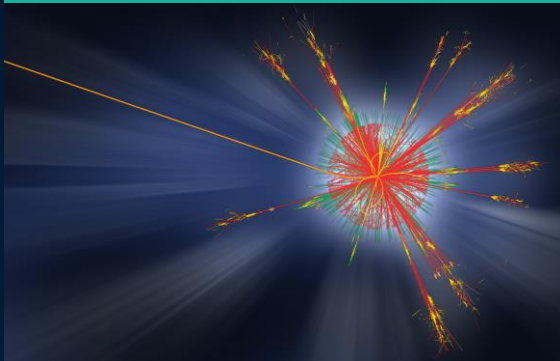
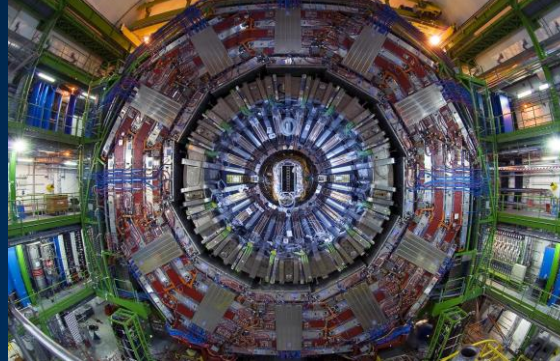
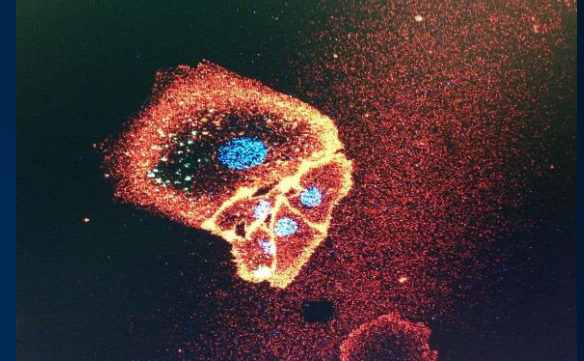


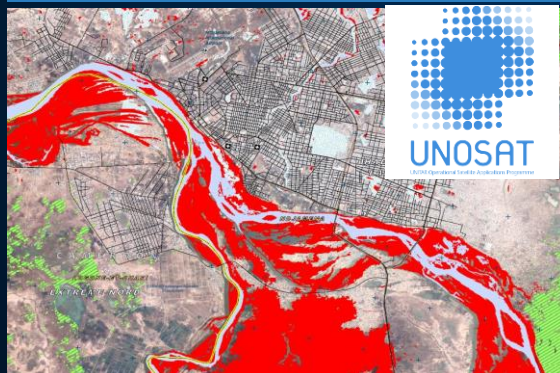
Image Processing for Track Reconstruction



Biology Development Simulation in the Cloud



Deep-Learning Algorithms for Image Feature Extraction



Artificial Intelligence

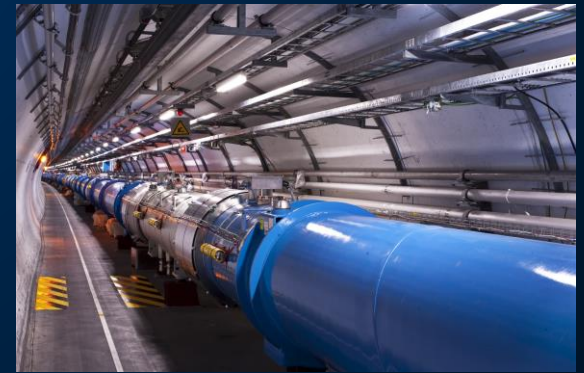
Image Analysis

Code Modernization

HPC in the Cloud

Internet of Things

Internet of Things for Smart Control Systems in the LHC





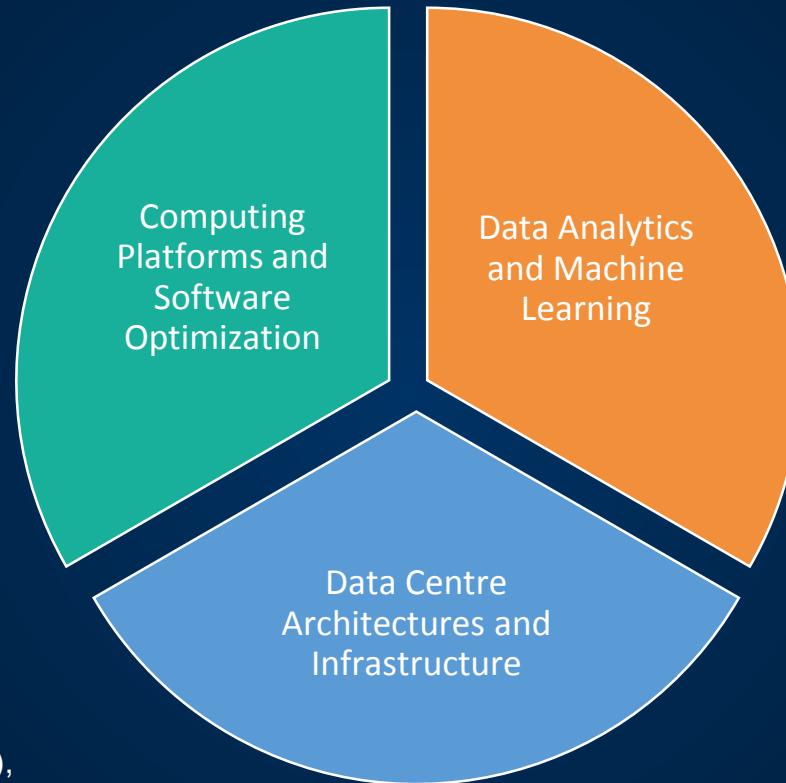
# CERN openlab Research Activities

Accelerated computing platforms for data acquisition and filtering (GPUs, CPU+FPGA)

Specialized platforms for Machine Learning applications

Parallelized Simulation Software (Physics and Medical Research)

Software Defined Networks (SDN), IoT Infrastructures, Sensor Networks, High-Speed Fiber Links



Anomaly Detection (Data Quality and Engineering Systems)

Cloud-based Data Training  
Fast Inference for Triggers,  
Big Data Reduction

Image Processing (Track  
Reconstruction, Medical  
Applications, Maps)

Software Defined Infrastructure (SDI)  
Scalable Hybrid Clouds,  
File Systems as a Service, In-Memory Databases

Enjoy your stay at CERN!

