



# CERN – A Gateway to Science and Technology

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March 2015

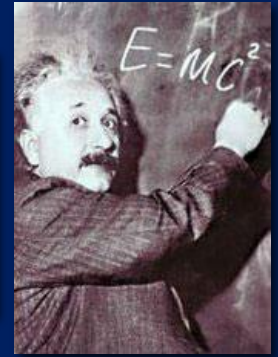


# The Mission of CERN



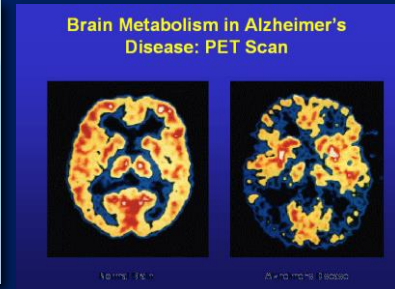
- Push forward the frontiers of knowledge

E.g. the secrets of the Big Bang, the matter like within the first moments of the universe?



- Develop new technologies, accelerators and information technology

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



- Train scientists and engineers of tomorrow



- Unite people from different countries and cultures



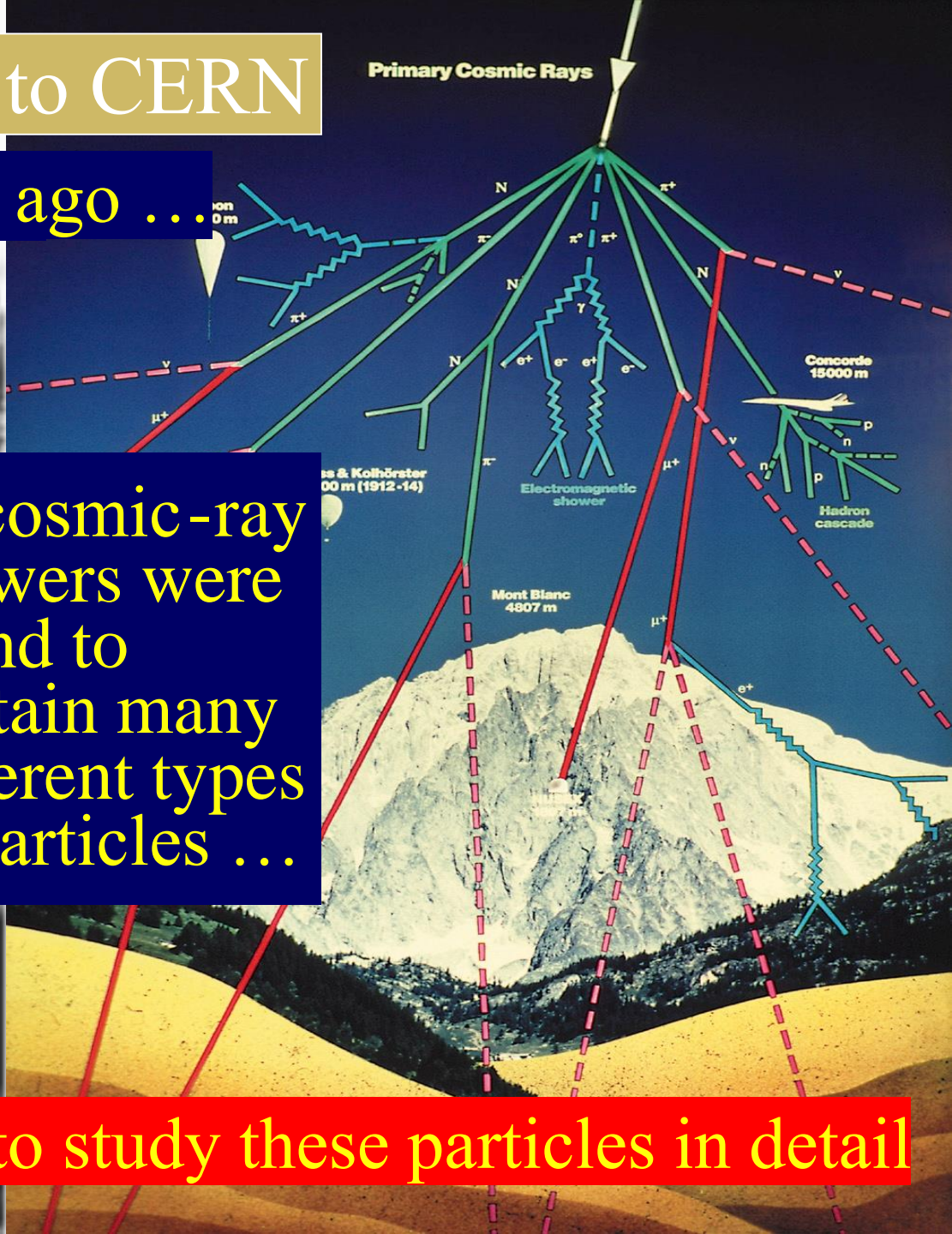
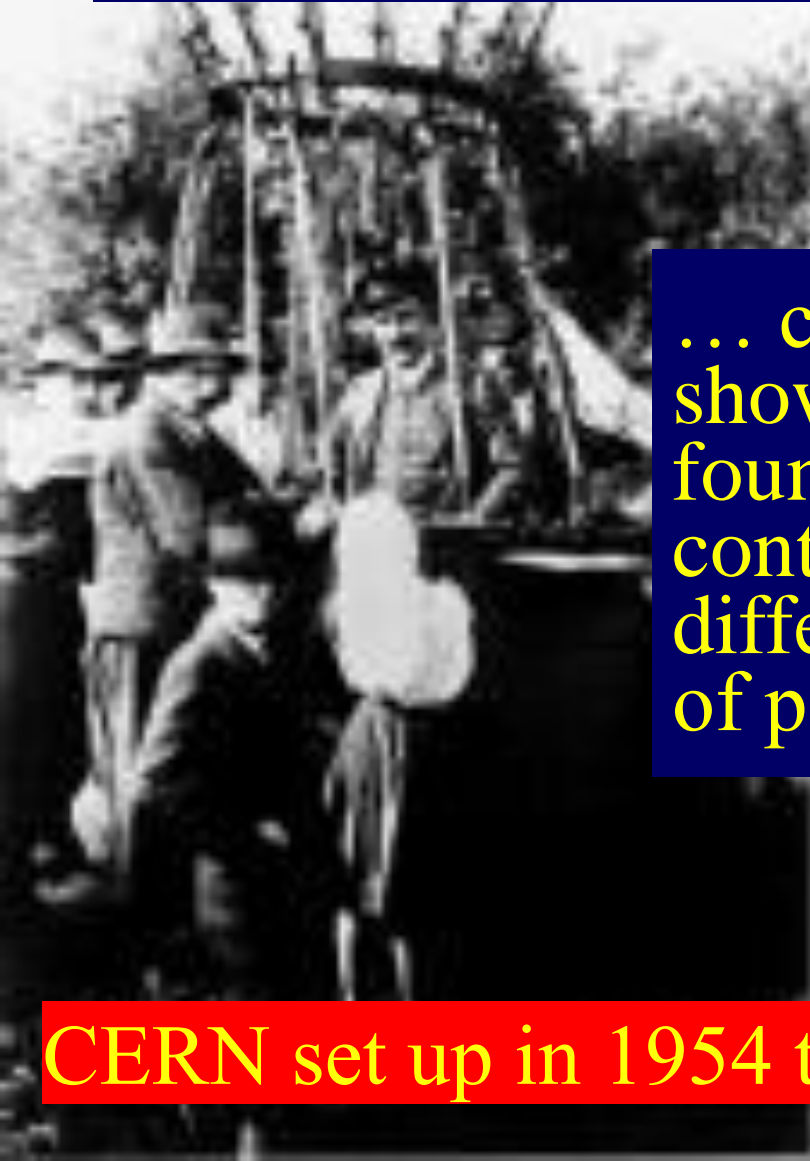
# Discovery Science

# From Cosmic Rays to CERN

Discovered a century ago ...

... cosmic-ray showers were found to contain many different types of particles ...

CERN set up in 1954 to study these particles in detail



# The Standard Model of



# Particle Physics = Cosmic DNA

## The matter particles



## The fundamental interactions



Gravitation

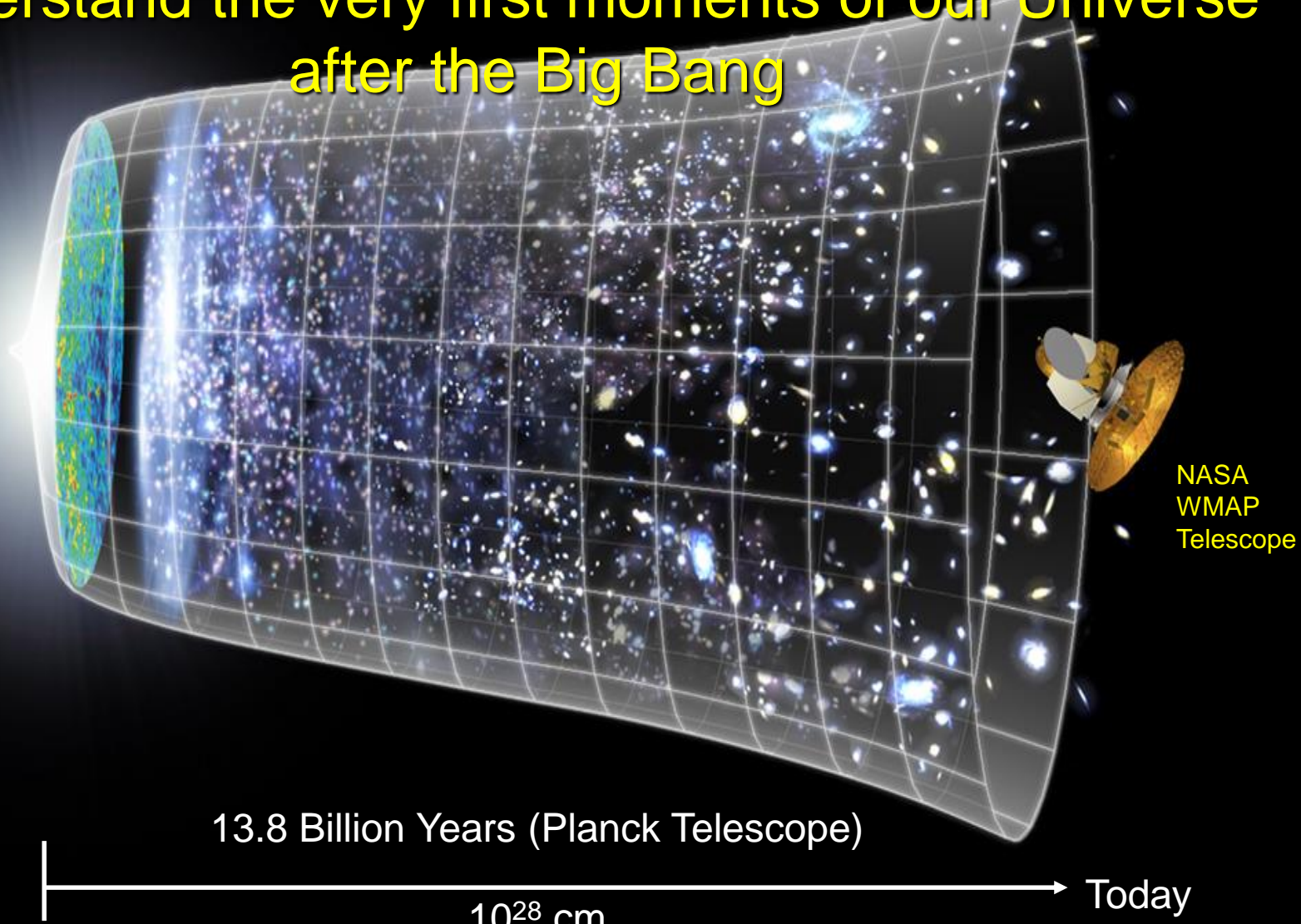
electromagnetism

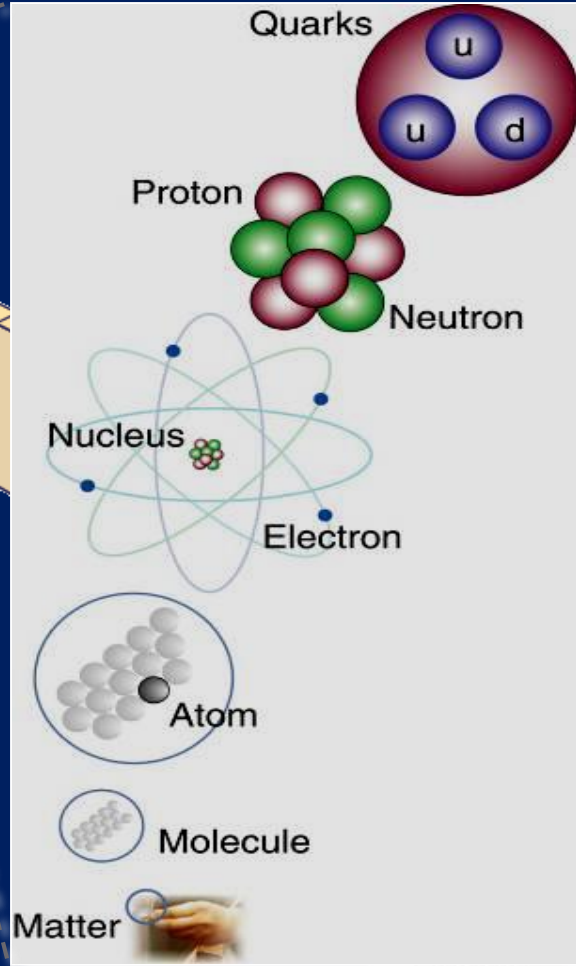
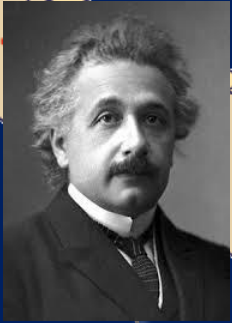
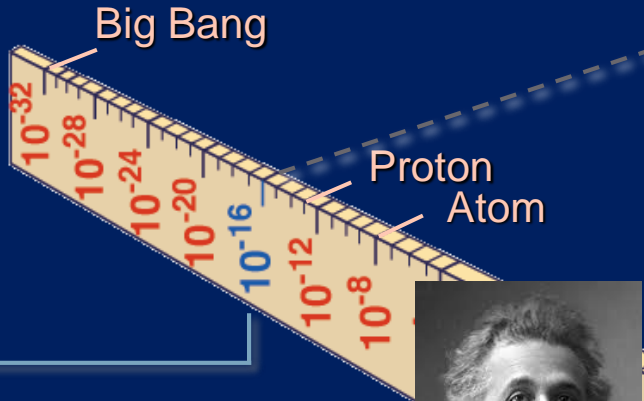
weak nuclear force

strong nuclear force

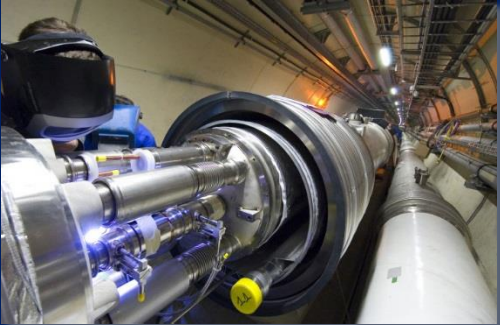
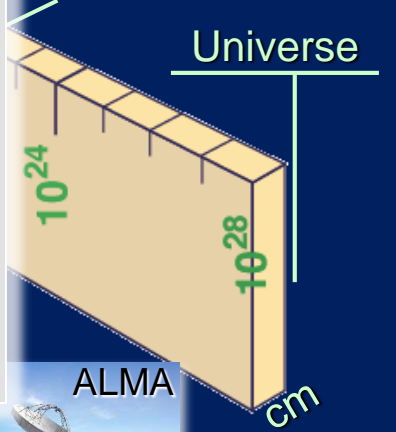
# Scientific Challenge: to understand the very first moments of our Universe after the Big Bang

Big Bang





Radius of Galaxies



LHC

Super-Microscope



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



AMS



ALMA



VLT

# The Large Hadron Collider

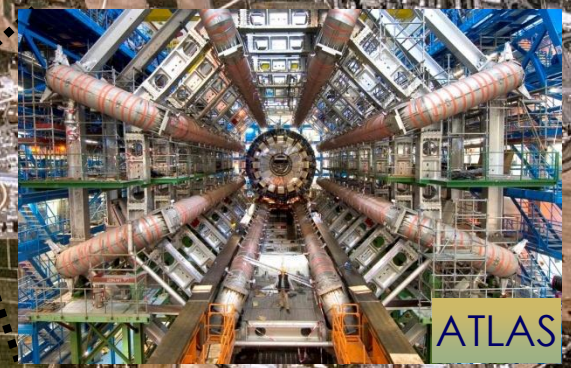
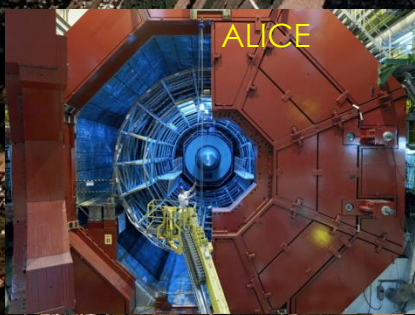


# Enter a New Era in Fundamental Science

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  
Proton-proton collisions at  $E_{\text{CM}} = 14 \text{ TeV}$





**The LHC Arcs**

# The Discovery of the Higgs Boson

# Why do things weigh?

Newton:

Weight proportional to Mass

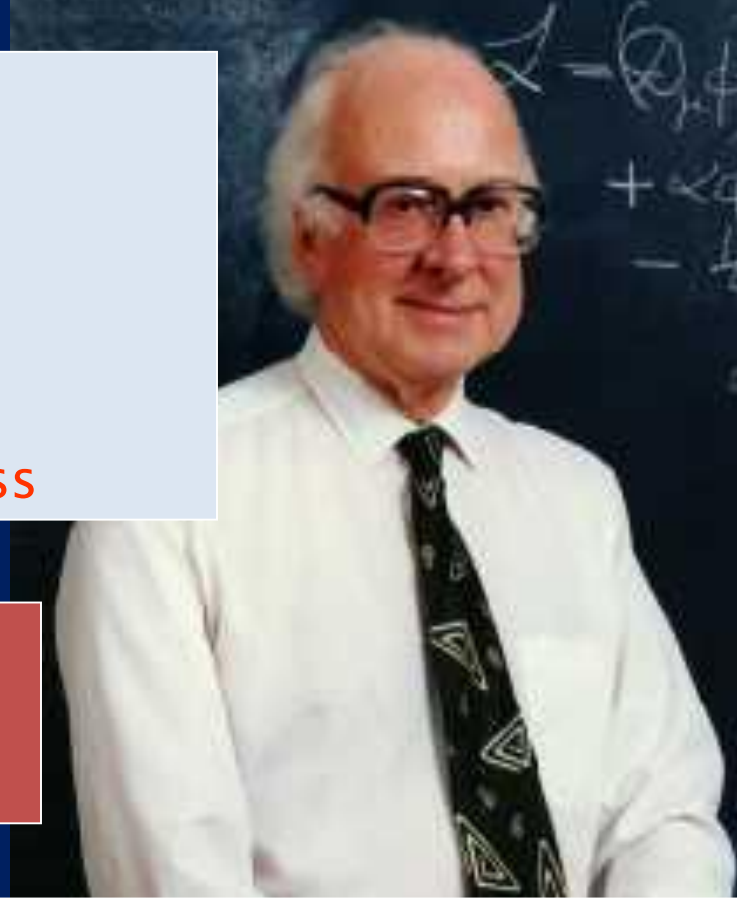
Einstein:

Energy related to Mass

Neither explained origin of Mass


Where do the masses come from?

Are masses due to the Brout-Englert-Higgs (BEH) Mechanism & the Higgs Boson?  
(the physicists' Holy Grail)



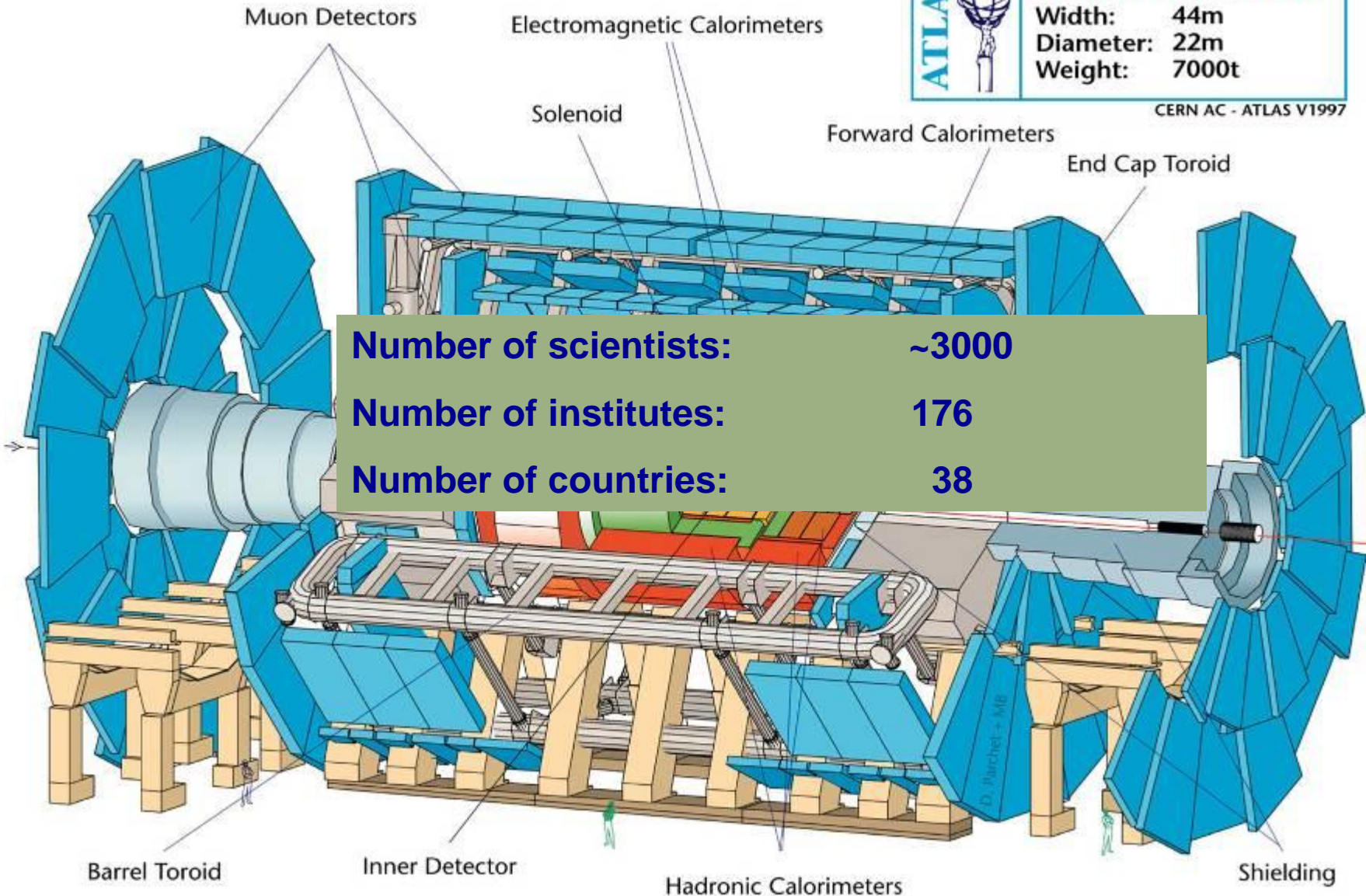
# The ATLAS Experiment



**ATLAS** 

**Detector characteristics**  
Width: 44m  
Diameter: 22m  
Weight: 7000t

CERN AC - ATLAS V1997



**Number of scientists: ~3000**  
**Number of institutes: 176**  
**Number of countries: 38**



**The ATLAS Experiment**

# The Highlight of a Remarkable Year 2012



Volume 712, Issue 3, 6 June 2012 ISSN 0370-2693

ELSEVIER

## PHYSICS LETTERS B

Available online at [www.sciencedirect.com](http://www.sciencedirect.com)  
SciVerse ScienceDirect

$S/(S+B)$  Weighted Events / 1.5 GeV

$m_H$  (GeV)

Legend:  
• Data  
— S+B Fit  
--- Big Fit Component  
■ 1 $\sigma$   
■ 2 $\sigma$

Parameters:  
 $\sqrt{s} = 7$  TeV,  $L = 5.1 \text{ fb}^{-1}$   
 $\sqrt{s} = 8$  TeV,  $L = 5.3 \text{ fb}^{-1}$

ATLAS 2011-12  $\sqrt{s} = 7-8$  TeV

Local  $p_0$

$m_H$  [GeV]

Legend:  
— Observed  
■ Expected Signal: 1 $\sigma$

Significance levels: 2 $\sigma$ , 3 $\sigma$ , 4 $\sigma$ , 5 $\sigma$ , 6 $\sigma$

<http://www.elsevier.com/locate/physletb>

## The Economist

JULY 7TH - 13TH 2012 Economist.com

In praise of charter schools  
Britain's banking scandal spreads  
Volkswagen overtakes the rest  
A power struggle at the Vatican  
When Lonesome George met Nora

# A giant leap for science

**Finding the Higgs boson**

# Nobel Prize in Physics 2013



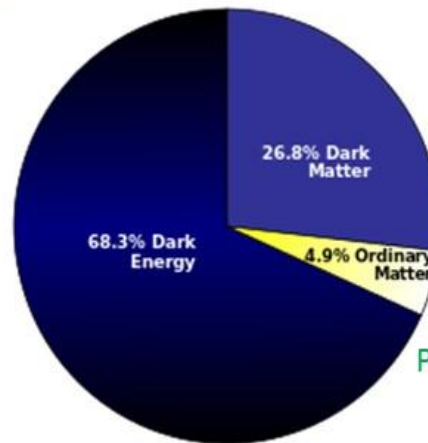
The Nobel Prize in Physics 2013 was awarded jointly to François Englert and Peter W. Higgs "for the theoretical discovery of a mechanism that contributes to our understanding of the origin of mass of subatomic particles, and which recently was confirmed through the discovery of the predicted fundamental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



# The Higgs boson discovery is only the beginning!

## *What's next?*

- Is it *the* Higgs boson...or one of many?
- Measure with precision the properties of the discovered Higgs boson
  - ...its properties could give information on Dark Matter
  - ...its properties could give first indications on Dark Energy



Planck Space Observatory, ESA (2013)

***Our understanding of the Universe is changing!***

# Dark Matter in the Universe

The background of the slide is a composite image. On the left, there is a close-up of the lunar surface showing craters. On the right, there is a deep space image featuring a prominent spiral galaxy with a bright central core and several other stars and galaxies in the distance.

Astronomers say  
that most of the  
matter in the  
Universe is  
invisible  
Dark Matter

**‘Supersymmetric’ particles ?**

We shall look for  
them with the  
LHC

# The Predictable Future - *LHC Timeline*



2009

Start of LHC

Run 1: 7 and 8 TeV centre-of-mass energy, luminosity ramping up to several  $10^{33}$   $\text{cm}^{-2} \text{s}^{-1}$ ,  $\sim 25 \text{ fb}^{-1}$  delivered

2013/14

LS1: LHC shut-down to prepare machine for design energy and nominal luminosity

Run 2: Ramp up luminosity to  $2 \times 10^{34}$   $\text{cm}^{-2} \text{s}^{-1}$  (50 to 100  $\text{fb}^{-1}$ ) and centre-of-mass energy to 13 TeV

2018

LS2 - Injector and LHC upgrade to reach ultimate luminosity

Run 3: Increase luminosity to 2.2 x nominal, reaching  $\sim 100 \text{ fb}^{-1}$  / year accumulated  $\text{fb}^{-1}$

$\sim 2023$

LS3: High luminosity LHC. New focusing magnets and CRAB cavities for very high luminosity with levelling

Run 4: Collect data until  $>3000 \text{ fb}^{-1}$

$>2035$

Study of the properties of the Higgs Boson and Physics beyond the Standard Model

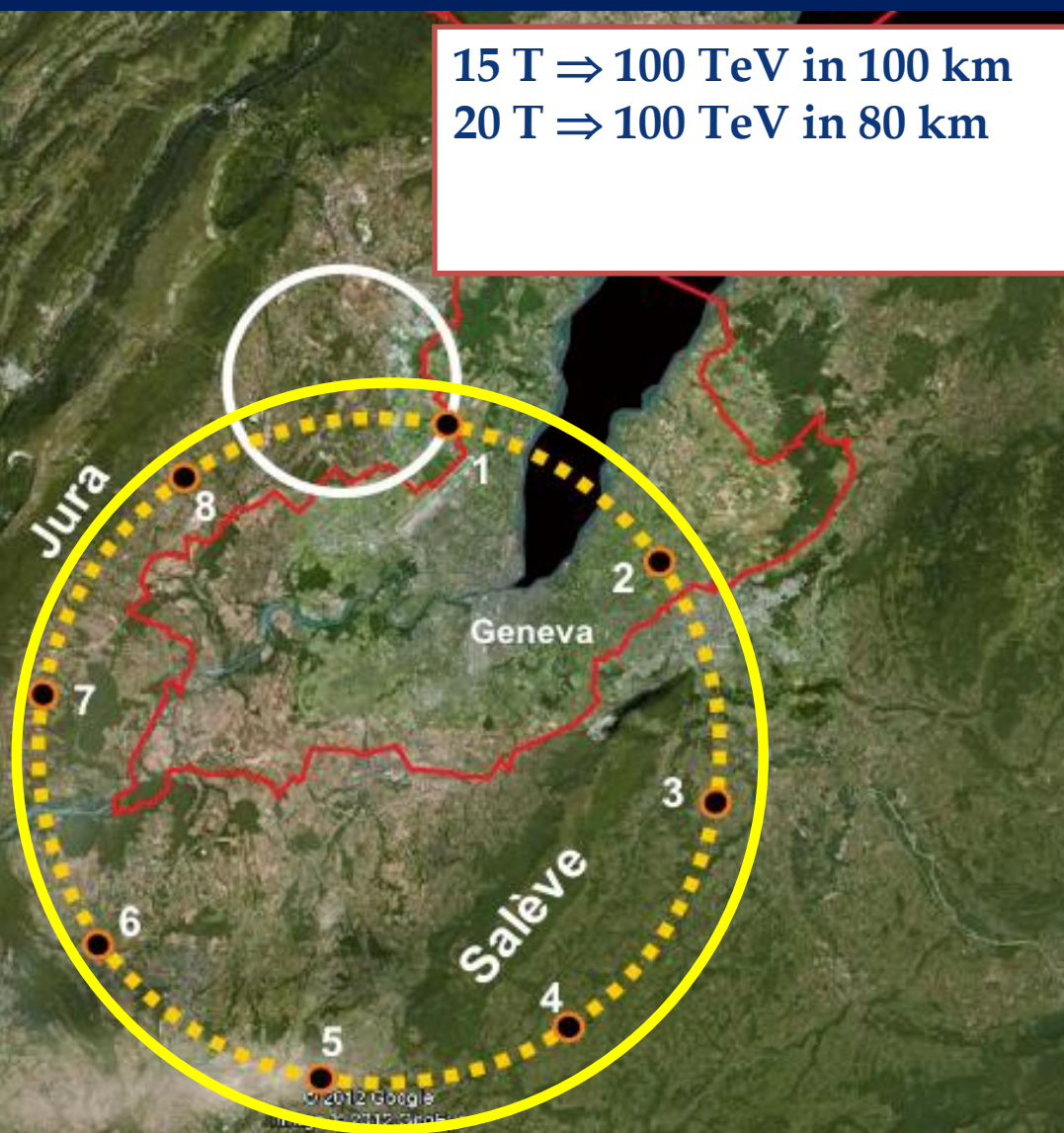


# 80-100 km tunnel infrastructure in Geneva area – design driven by pp-collider requirements with possibility of e<sup>+</sup>-e<sup>-</sup> (TLEP) and p-e (VLHeC)

**FCC Design Study  
Kick-off Meeting:  
12-14. February 2014  
at Geneva University**

- *Establishing international collaborations*
- *Set-up study groups and committees*

15 T ⇒ 100 TeV in 100 km  
20 T ⇒ 100 TeV in 80 km



## LEGEND

- LHC tunnel
- ⋯ HE\_LHC 80km option
- potential shaft location

# CLIC near CERN



## Legend

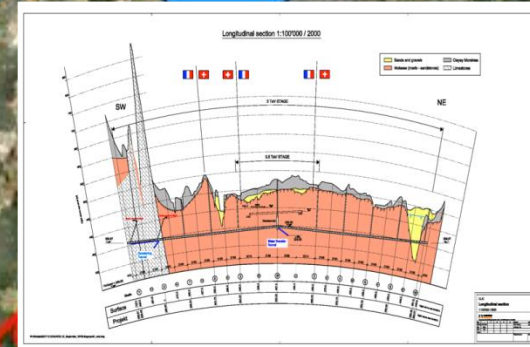
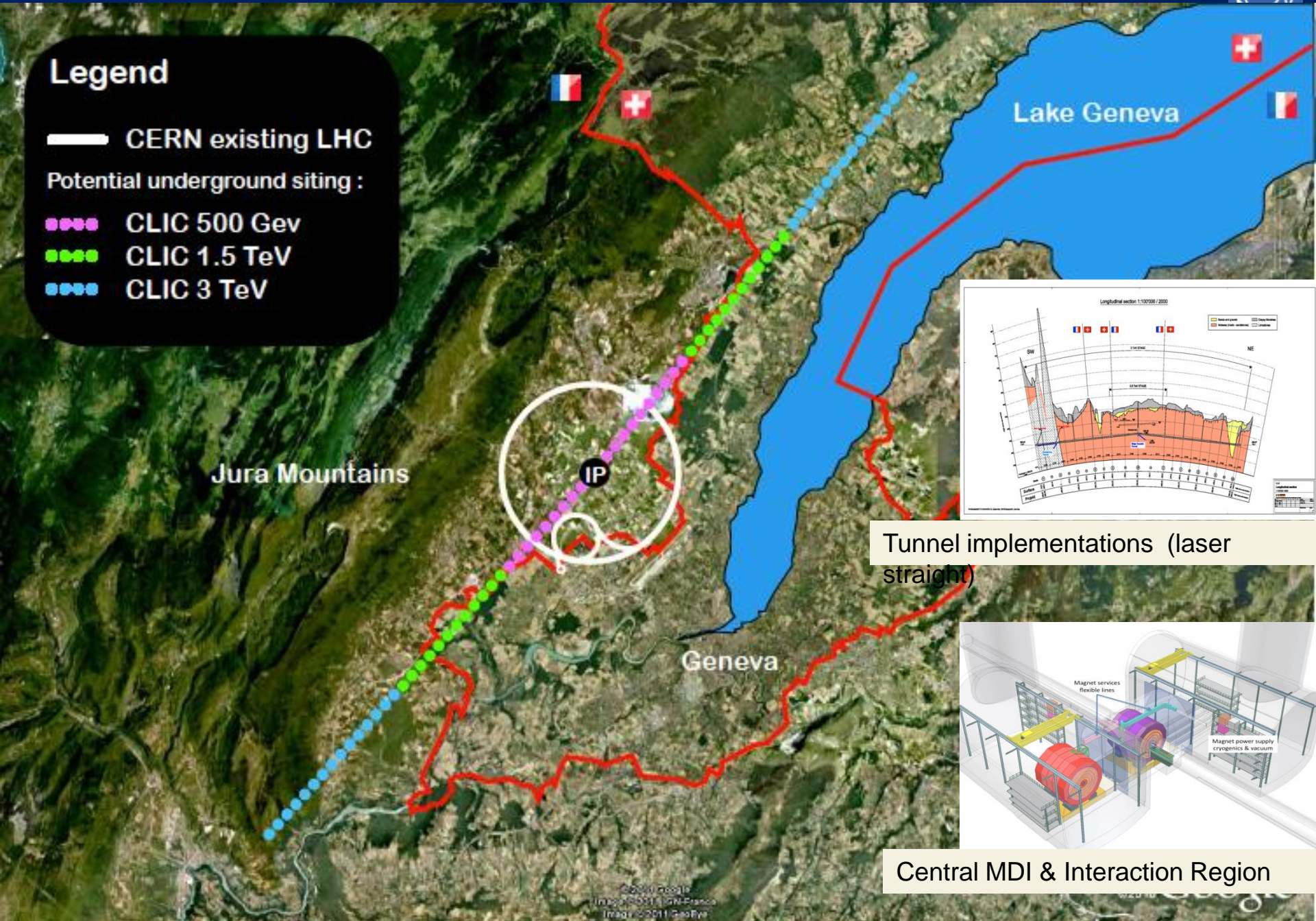
— CERN existing LHC

Potential underground siting :

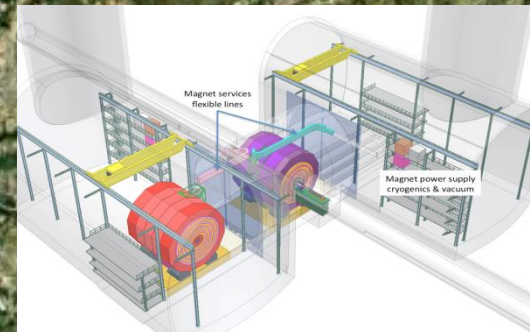
●●●● CLIC 500 GeV

●●●● CLIC 1.5 TeV

●●●● CLIC 3 TeV



Tunnel implementations (laser straight)



Central MDI & Interaction Region

# Knowledge and Technology Transfer



# CERN Technologies and Innovation

## *Example – Medical Applications*

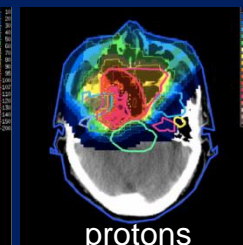
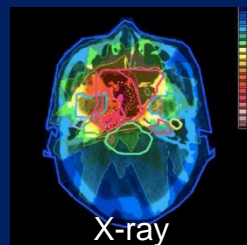
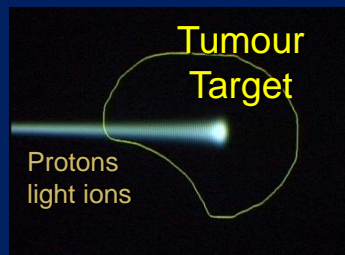


Combining Physics, ICT, Biology and Medicine to fight cancer



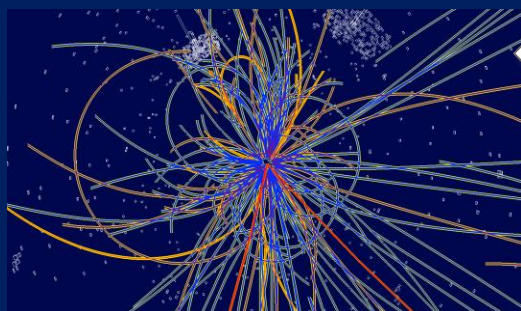
## Hadron Therapy

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



Leadership in Ion Beam Therapy now in Europe and Japan

>70' 000 patients treated worldwide (30 facilities)  
>21' 000 patients treated in Europe (9 facilities)



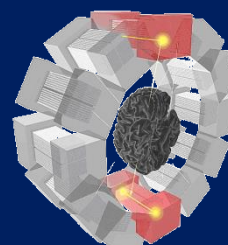
Detecting particles

## Imaging

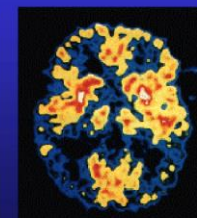
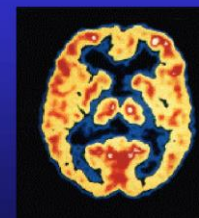
Clinical trial in Portugal for new breast imaging system (ClearPEM)



PET Scanner



Brain Metabolism in Alzheimer's Disease: PET Scan





# Breaking the Wall of Communication

26 years ago: the Web was born



... and today ?



# The LHC Data Challenge

- ▣ Experiments were anticipated to produce about **25 Million Gigabytes** of data each year (~30 million CDs!).
- ▣ LHC data analysis requires a computing power equivalent to **~100,000 of today's fastest PC processors.**
- ▣ => Requires many cooperating computer centres, as CERN can only provide ~20% of the capacity.



 **GRID Computing**

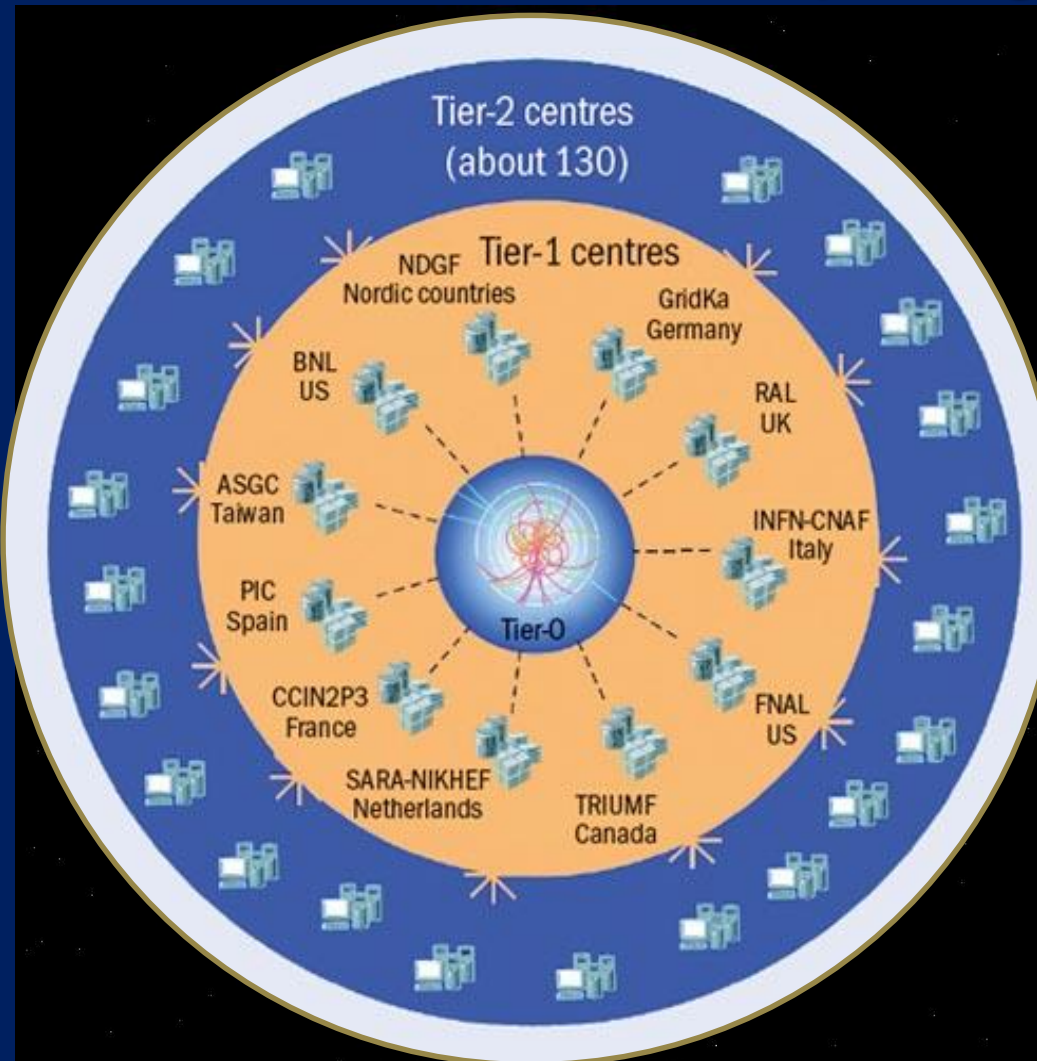
# The Worldwide LHC Computing Grid



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

Tier-1: permanent  
storage, re-  
processing,  
analysis

Tier-2: Simulation,  
end-user analysis



nearly 160 sites,  
35 countries

~250'000 cores

173 PB of storage

> 2 million jobs/day

10 Gb links

**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

# CERN Education Activities

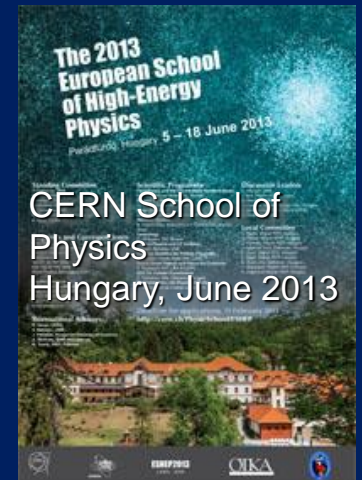


**Scientists at CERN**  
Academic Training Programme



**Young Researchers**

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



**Physics Students**  
Summer Students  
Programme

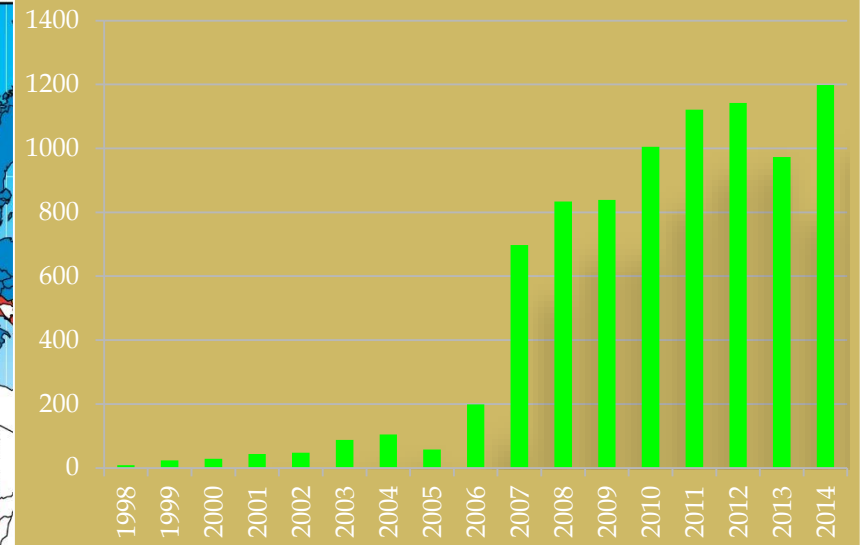
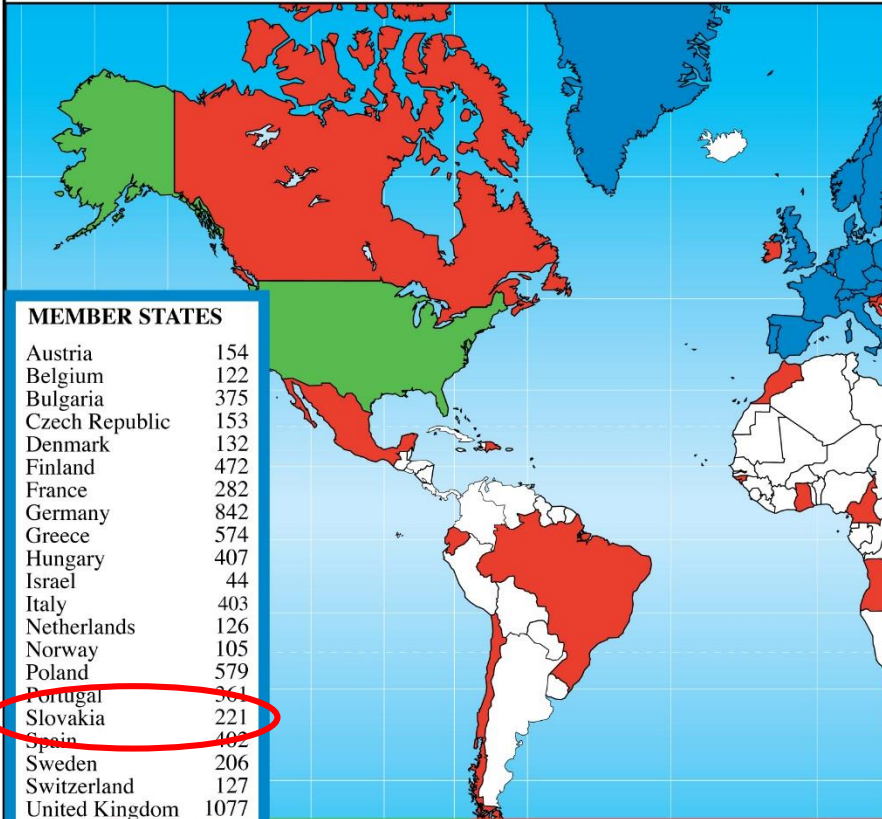


**CERN Teacher Schools**  
International and National  
Programmes

# CERN Teacher Programme



## Teacher Programme Participants 1998 - 2014 (Total: 8430)



MEMBER STATES	
Austria	154
Belgium	122
Bulgaria	375
Czech Republic	153
Denmark	132
Finland	472
France	282
Germany	842
Greece	574
Hungary	407
Israel	44
Italy	403
Netherlands	126
Norway	105
Poland	579
Portugal	361
Slovakia	221
Spain	482
Sweden	206
Switzerland	127
United Kingdom	1077

**7164**

CANDIDATE FOR ACCESSION	
Romania	13
Serbia	47

**60**

OBSERVER STATES	
India	3
Japan	6
Russia	279
Turkey	74
USA	92

**454**

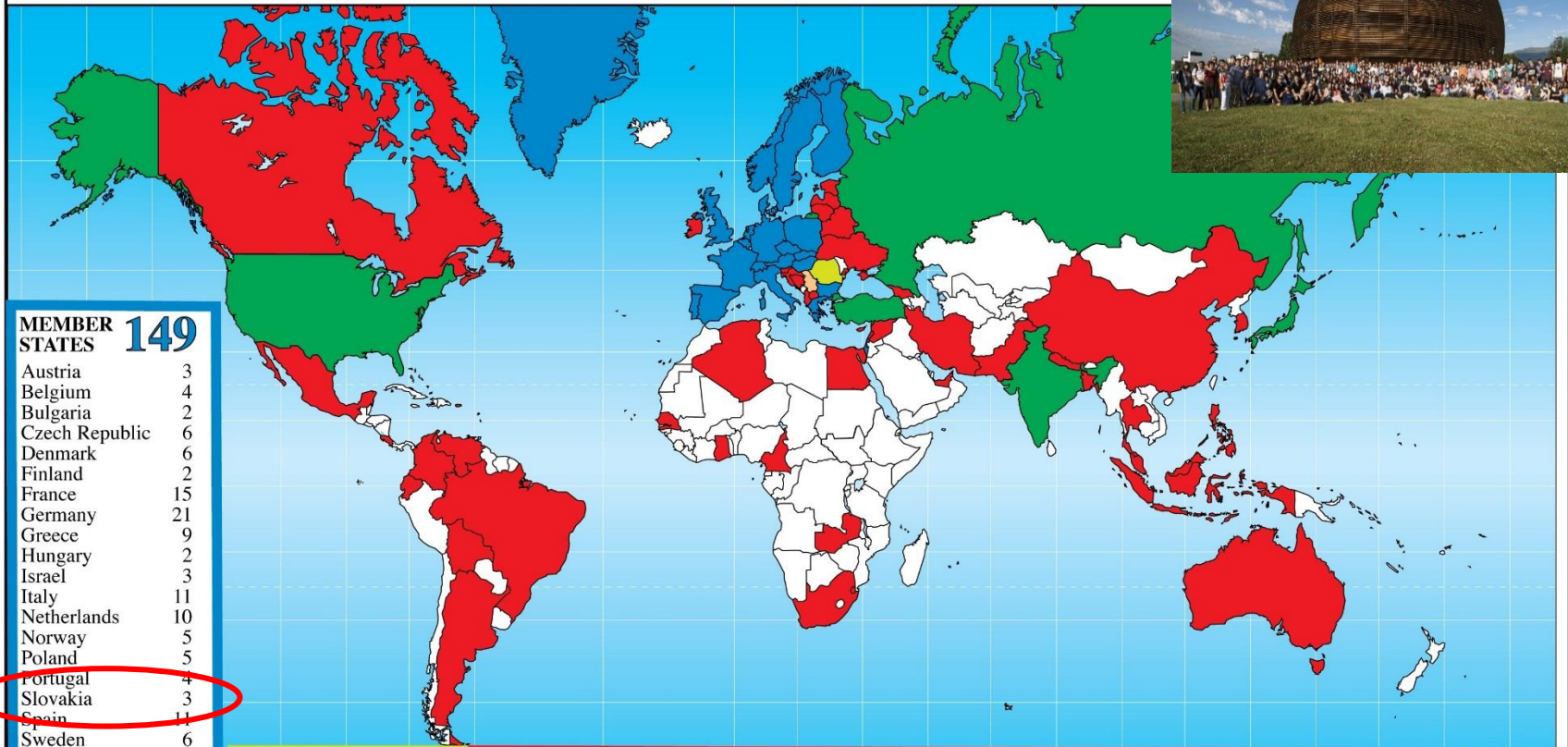
OTHERS	
Chile	3
Angola	7
Armenia	1
Australia	6
Azerbaijan	1
Belarus	2
Brazil	144
Burundi	2
Cameroon	4
Canada	7
Cape Verde	4
China	2
Croatia	2
Cyprus	8
Dominican Rep.	24
Ecuador	2
Estonia	54
Georgia	88
Ghana	6
Guinea Bissau	1
Iran	3
Ireland	7
Jordan	11
Kazakhstan	5
Kenya	4
Latvia	1
Lebanon	1
Lithuania	16
Madagascar	2
Malta	36
Mexico	10
Mongolia	1
Montenegro	13
Morocco	2
Mozambique	19
Nepal	1
New Zealand	1
Lebanon	1
Palestine (O.T.)	1
Qatar	1
Rwanda	20
Sao Tome	5
Saudi Arabia	1
Singapore	2
Slovenia	21
South Africa	6
South Korea	48
Swaziland	1
Thailand	10
T.F.Y.R.O.M.	11
Timor-Leste	7
Uganda	3
Ukraine	113
U.A.E.	1

**752**

# Summer Students 2014



## Summer Students 2014



### MEMBER STATES 149

Austria	3
Belgium	4
Bulgaria	2
Czech Republic	6
Denmark	6
Finland	2
France	15
Germany	21
Greece	9
Hungary	2
Israel	3
Italy	11
Netherlands	10
Norway	5
Poland	5
Portugal	4
Slovakia	3
Spain	11
Sweden	6
Switzerland	4
United Kingdom	17

### OBSERVERS 45

India	10
Japan	5
Russia	10
Turkey	7
USA	13

### CANDIDATE FOR ACCESSION

Romania	2
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### ASSOCIATE MEMBER IN THE PRE-STAGE TO MEMBERSHIP

Serbia	2
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### OTHERS

Albania	1	Cameroun	1	Estonia	5	Lithuania	4	Senegal	1	U.A.E.	2
Algeria	3	Canada	3	Georgia	1	Malaysia	4	Singapore	1	Venezuela	1
Argentina	1	China	8	Ghana	1	Malta	3	Slovenia	1		
Australia	1	Colombia	1	Indonesia	2	Mexico	1	South Africa	2		
Bangladesh	1	Costa Rica	2	Iran	3	Nepal	1	Swaziland	1		
Belarus	1	Croatia	1	Ireland	1	Pakistan	3	Syria	1		
Bolivia	1	Cyprus	2	Korea, South	1	Palestine	1	Thailand	4		
Bosnia	1	Ecuador	3	Latvia	1	Philippines	1	T.F.Y.R.O.M.	2		
Brazil	1	Egypt	5	Lebanon	2	Puerto Rico	1	Ukraine	4		

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# CERN – The European Organization for Nuclear Research

# CERN: founded in 1954: 12 European States

“Science for Peace”

## Today: 21 Member States

~ 2300 staff

~ 1300 other paid personnel

~ 11500 scientific users

Budget (2015) ~1000 MCHF

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

**States in accession to Membership:** Romania, Serbia

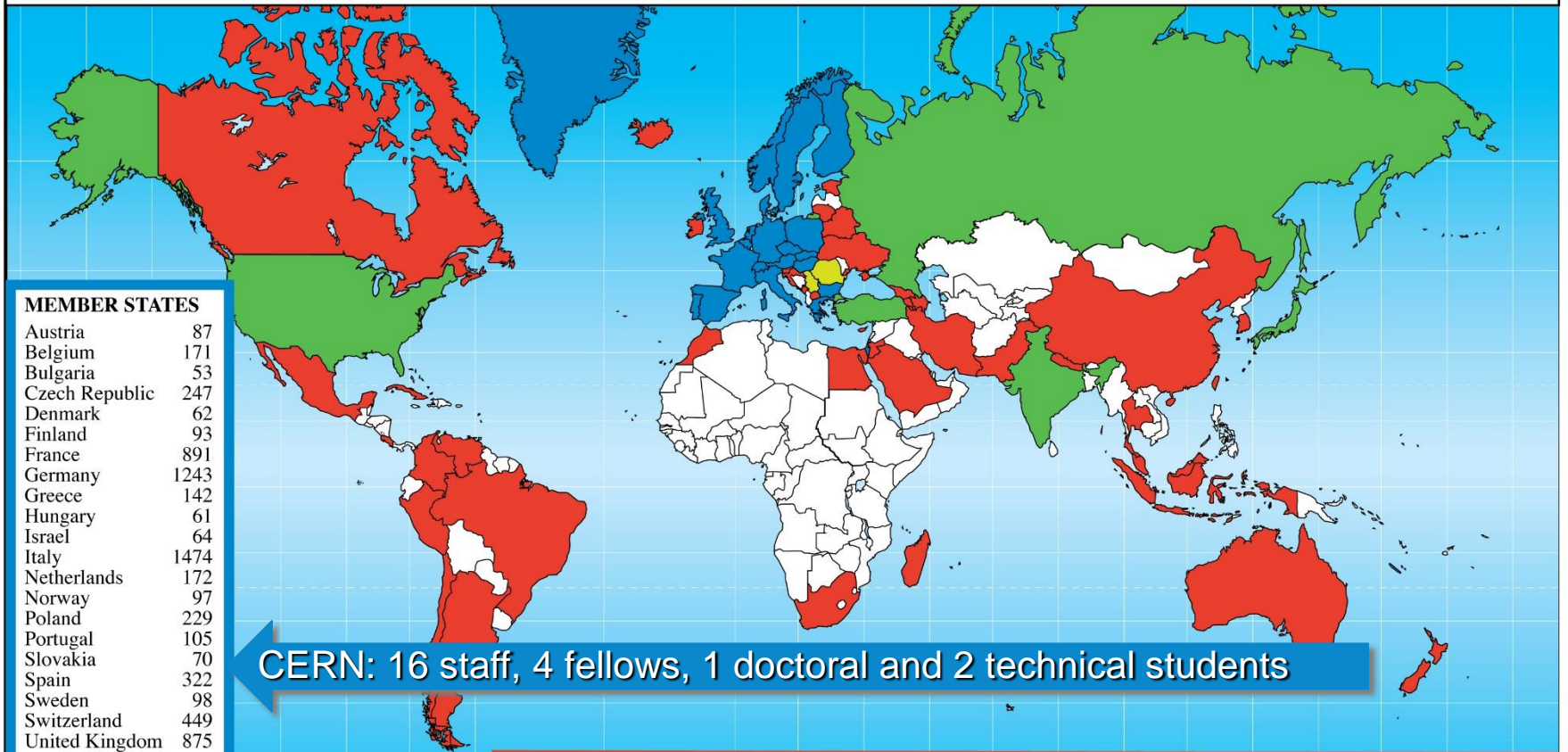
**Applications for Membership or Associate Membership:**  
Brazil, Croatia, Cyprus, Pakistan, Russia, Slovenia, Turkey, Ukraine

**Observers to Council:** India, Japan, Russia, Turkey, 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 13 January 2015



### MEMBER STATES

Austria	87
Belgium	171
Bulgaria	53
Czech Republic	247
Denmark	62
Finland	93
France	891
Germany	1243
Greece	142
Hungary	61
Israel	64
Italy	1474
Netherlands	172
Norway	97
Poland	229
Portugal	105
Slovakia	70
Spain	322
Sweden	98
Switzerland	449
United Kingdom	875

**7005**

### OBSERVERS

India	182
Japan	261
Russia	917
Turkey	127
USA	1731

**3218**

### STATES IN ACCESSION TO MEMBERSHIP

Romania	97
Serbia	35

**132**

**CERN: 16 staff, 4 fellows, 1 doctoral and 2 technical students**

### OTHERS

Argentina	22	China	150	Iceland	3	Montenegro	1	Taiwan	77
Armenia	17	Colombia	15	Indonesia	8	Morocco	8	Thailand	13
Australia	37	Costa Rica	1	Iran	29	Nepal	1	TFYROM	2
Azerbaijan	3	Croatia	22	Ireland	7	New Zealand	7	Ukraine	29
Belarus	26	Cuba	3	Jordan	2	Pakistan	26	Venezuela	1
Brazil	138	Cyprus	12	Korea	130	Peru	3		
Canada	165	Egypt	22	Lithuania	12	Saudi Arabia	1		
Chile	11	Estonia	17	Madagascar	3	Singapore	1		
		Georgia	14	Malaysia	8	Slovenia	21		
		Hong Kong	11	Mexico	56	South Africa	42		

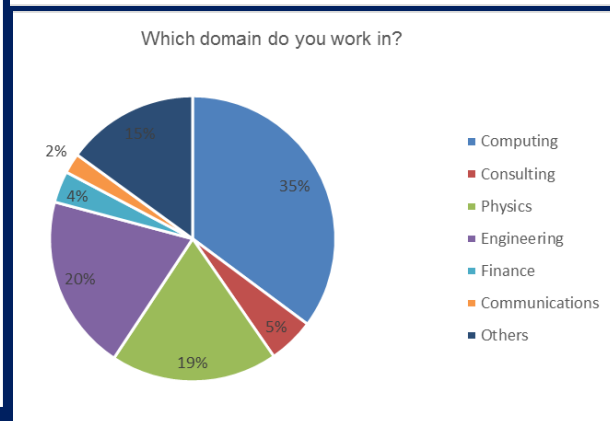
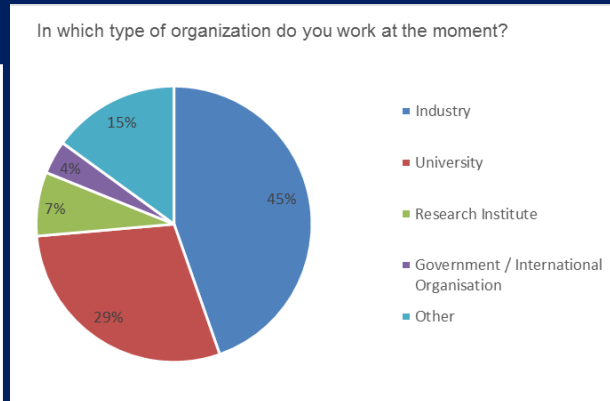
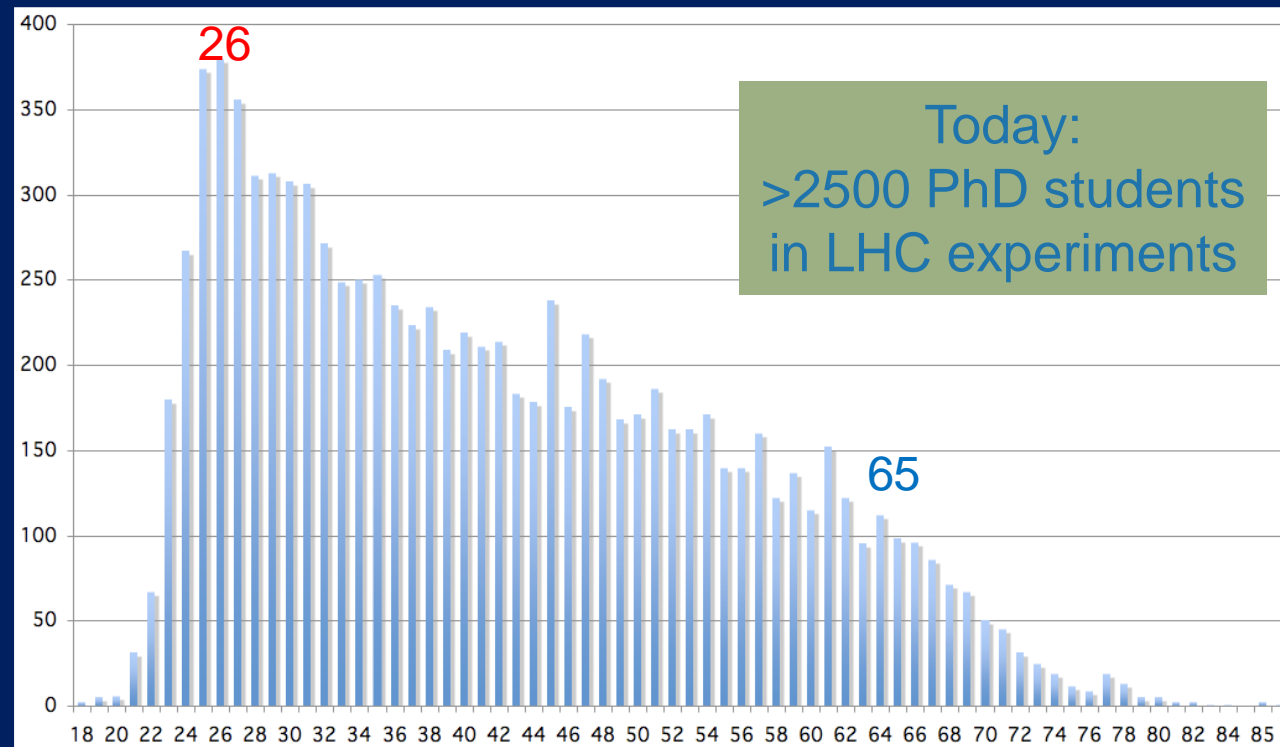
**1177**





# Age Distribution of Scientists

- and where they go afterwards



They do not all stay: where do they go?



# Slovakia and CERN



- Slovakia became CERN Member State in 1993
- Today research in particle physics is carried out mainly at 4 Institutes:
  - Comenius University Bratislava
  - Institute of Experimental Physics of the Slovak Academy of Sciences, Košice
  - Institute of Physics of the Slovak Academy of Science, Bratislava
  - Šafárik University Košice



Concentrated effort to participate in the LHC experiments **ALICE** and **ATLAS**:  
Membership from **Comenius University** and **Institute of Experimental Physics of the Slovak Academy of Sciences, Košice**

Also participation in several fixed-target experiments – **NA62, ISOLDE**

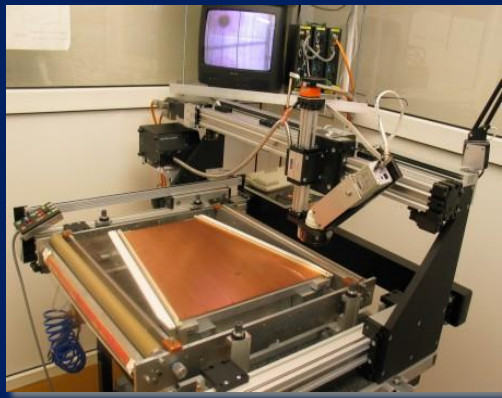


# Slovakia and CERN



## Contributions to ALICE

16 members



TPC **Bratislava**  
Production and test  
of 26 readout  
chambers at  
Bratislava Detector  
Laboratory



Pixel detector:  
**Košice**  
Electronics for  
readout



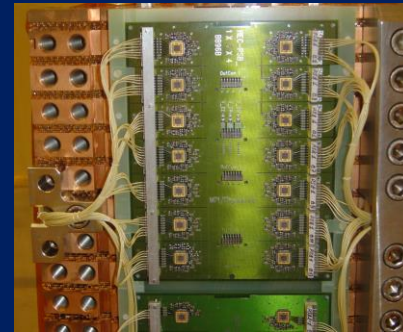
## Contributions to ATLAS

15 members



Tile calorimeter in test beam

Tile calorimeter:  
**Bratislava**  
Iron tiles produced  
in Dubnica



Electronics cards for LAr  
endcap calorimeter:  
**Košice**

Lifting devices for calorimeter modules produced in Prešov



# Slovakia and CERN



## Contributions to LHC project from Industry in Slovakia



Blue cryostat for LHC dipoles produced at SES (Slovenské energetické strojárne) in **Tlmače**

Robots carry LHC magnets and align them with magnet support jacks made by ZTS (Závody ťažkého strojárnenstva) in **Košice**



LHC award to ZTS

# CERN – innovate, discover, publish, share



... and bring the world together



SUISSE  
FRANCE

LHCb

ATLAS

CERN Meyrin

CERN Prévessin

SPS 7 km

CMS

ALICE

Thank You!  
Ďakujem!

LHC 27 km



***Accelerating Science and Innovation***