

An introduction to CERN

Mick Storr

CERN and University of Birmingham



Accelerating Science and Innovation

1945 l'Europe après deux guerres dévastatrices en moins de 30 ans



Les chercheurs quittent l'Europe pour USA

30th November 2009 LHC sets new world record

Early this morning CERN's Large Hadron Collider become the world's highest energy particle accelerator, having accelerated its twin beams of protons to an energy of **1.18 TeV**. This exceeds the previous world record of 0.98 TeV, which had been held by the US Fermi National Accelerator



CERN was founded 1954: 12 European States

“Science for Peace”

Today: 21 Member States

~ 2300 staff

~ 1050 other paid personnel

> 11000 users

Budget (2012) ~1000 MCHF

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

Candidate for Accession: Romania

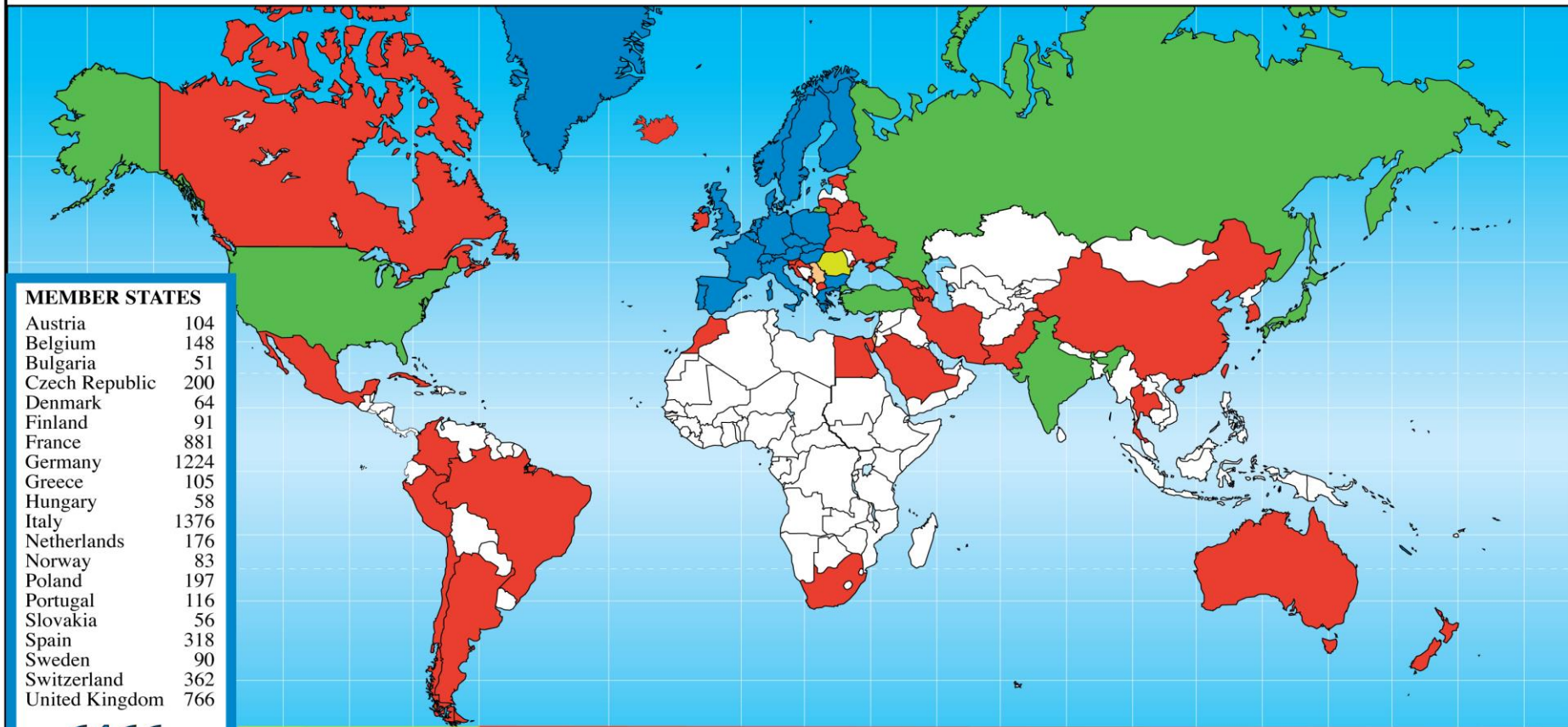
Associate Members in the Pre-Stage to Membership: Serbia

Applicant States: Cyprus, Slovenia, Turkey

Observers to Council: India, Japan, the Russian Federation, the United States of America, Turkey, the European Commission and UNESCO

Science is getting more and more global

Distribution of All CERN Users by Location of Institute on 2 September 2013



MEMBER STATES

Austria	104
Belgium	148
Bulgaria	51
Czech Republic	200
Denmark	64
Finland	91
France	881
Germany	1224
Greece	105
Hungary	58
Italy	1376
Netherlands	176
Norway	83
Poland	197
Portugal	116
Slovakia	56
Spain	318
Sweden	90
Switzerland	362
United Kingdom	766

6466

OBSERVERS

India	154
Japan	224
Russia	899
Turkey	106
USA	1787

3170

CANDIDATE FOR ACCESSION

Romania	82
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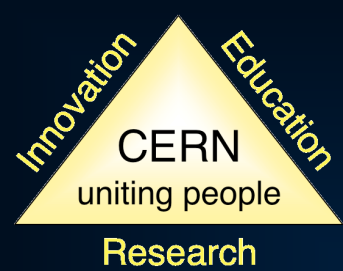
ASSOCIATE MEMBER IN THE PRE-STAGE TO MEMBERSHIP

Israel	57
Serbia	30

OTHERS

Chile	7	Georgia	10	New Zealand	6
China	130	Iceland	4	Pakistan	21
China (Taipei)	70	Iran	22	Peru	2
Colombia	11	Ireland	7	Saudi Arabia	3
Croatia	25	Korea	103	Slovenia	25
Azerbaijan	2	Lithuania	16	South Africa	31
Belarus	23	Mexico	40	Thailand	6
Brazil	110	Montenegro	1	T.F.Y.R.O.M.	1
Canada	154	Morocco	9	Ukraine	26
Estonia	18				

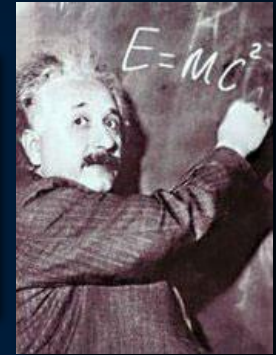
987



The Mission of CERN

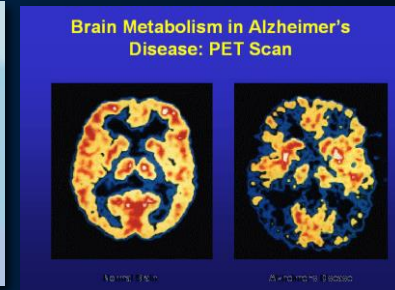
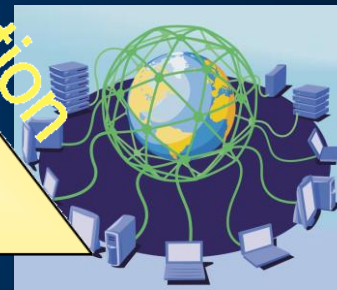
- ❑ **Push forward** the frontiers of knowledge

E.g. the secrets of the Big Bang: what was the matter like within the first moments of the universe's existence?

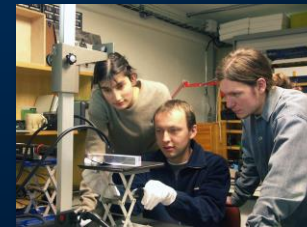


- ❑ **Develop** new technologies, accelerators and detectors

Information technology
Medicine - diagnosis and therapy



- ❑ **Train** scientists and engineers of tomorrow

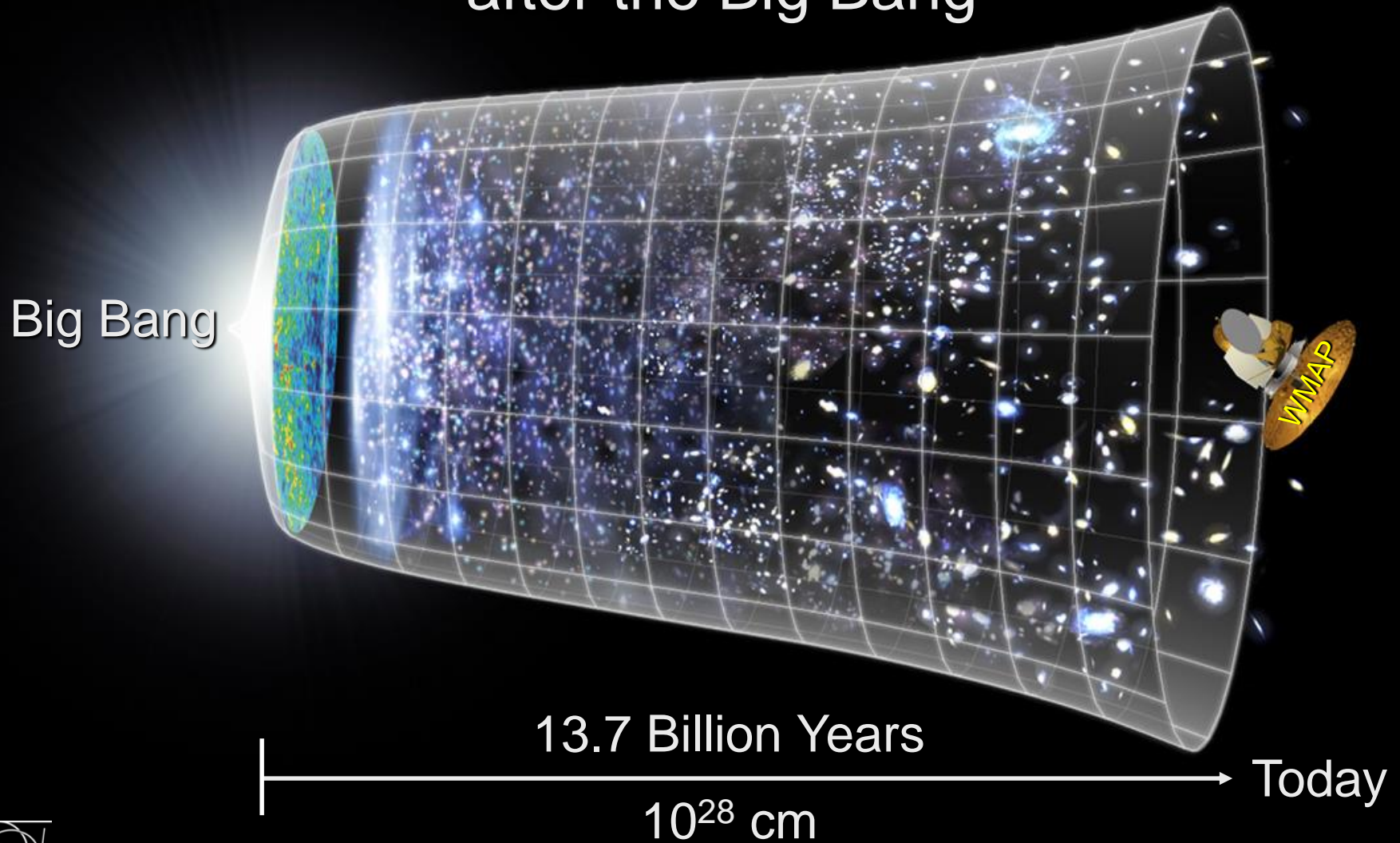


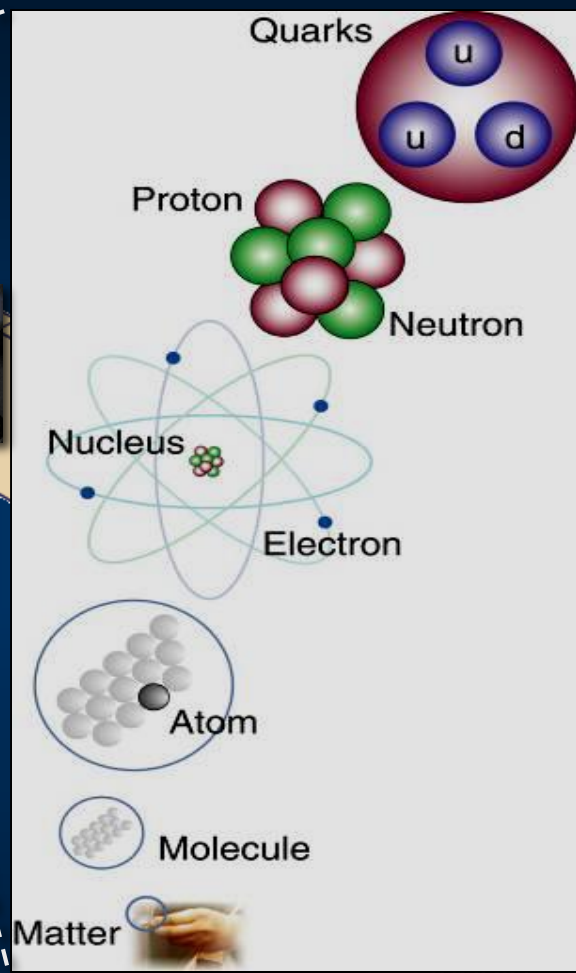
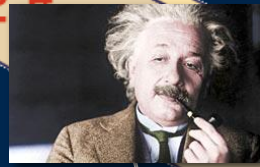
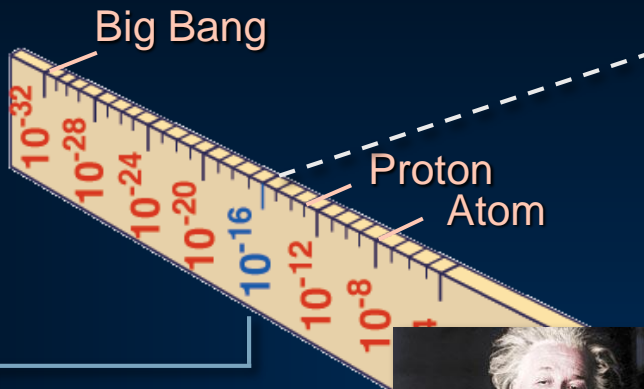
- ❑ **Unite** people from different countries and cultures



Next Scientific Challenge:

to understand the very first moments of our Universe
after the Big Bang





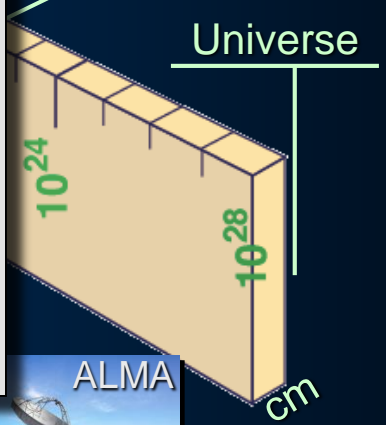
LHC

Super-Microscope



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

Radius of Galaxies



**“Where do we come from?
What are we?
Where are we going?”**



**The aim of particle physics, CERN & the LHC:
What is the Universe made of?**

The Large Hadron Collider (LHC)

Proton- Proton Collider

4 TeV + 4 TeV



1,000,000,000 collisions/second

Total energy over 8,000 proton masses

Primary targets:

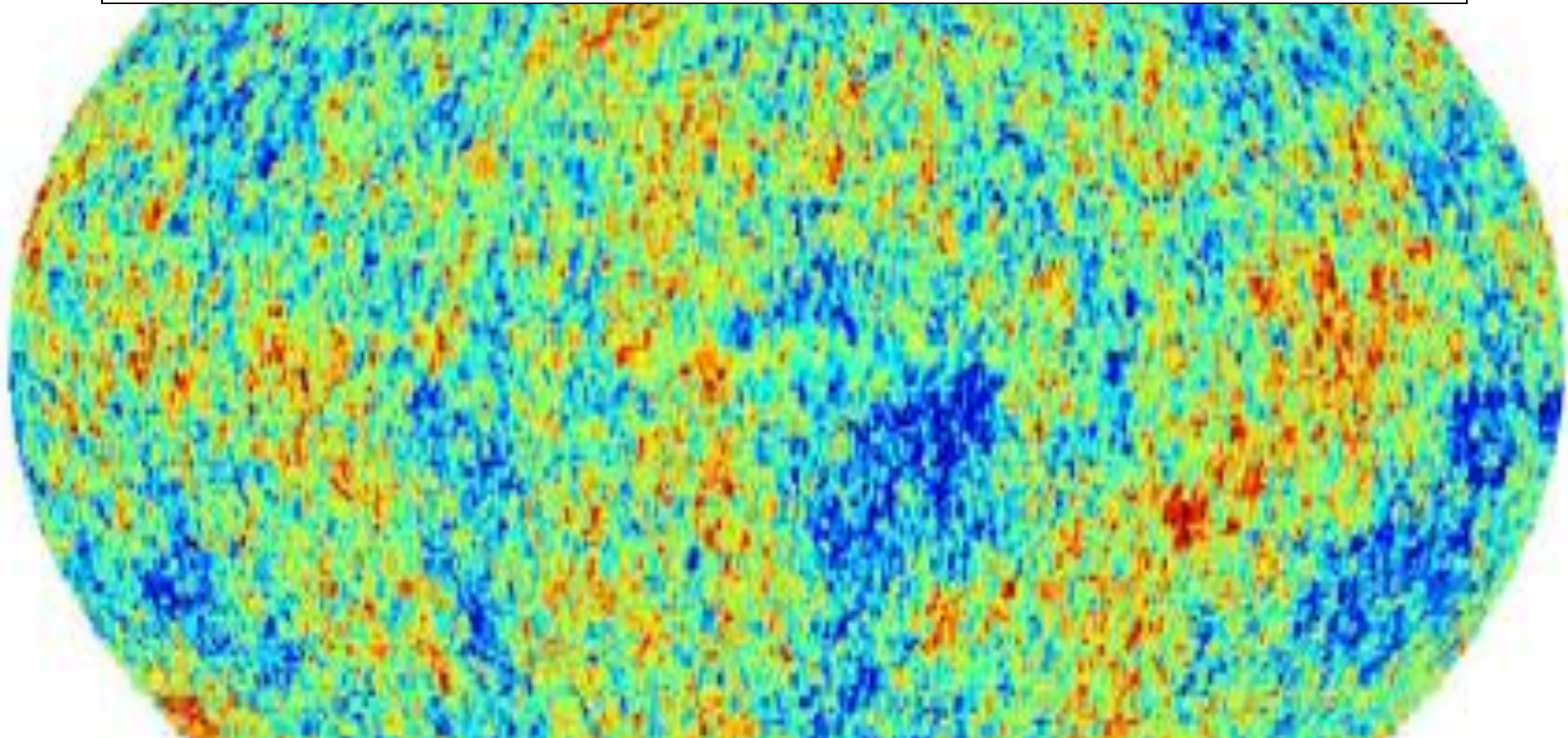
- Origin of mass
- Nature of Dark Matter
- Primordial Plasma
- Matter vs Antimatter

The Emptiest Space in the Solar System

A photograph showing a long, brightly lit tunnel of a particle accelerator. The tunnel is filled with complex machinery, including large cylindrical components and various pipes. The lighting is warm and focused on the equipment, creating a sense of depth and scale. The perspective is from the end of the tunnel, looking down its length.

**Vacuum similar to interplanetary space:
the pressure in the beam-pipes is ten
times lower than on the Moon.**

Colder than Outer Space

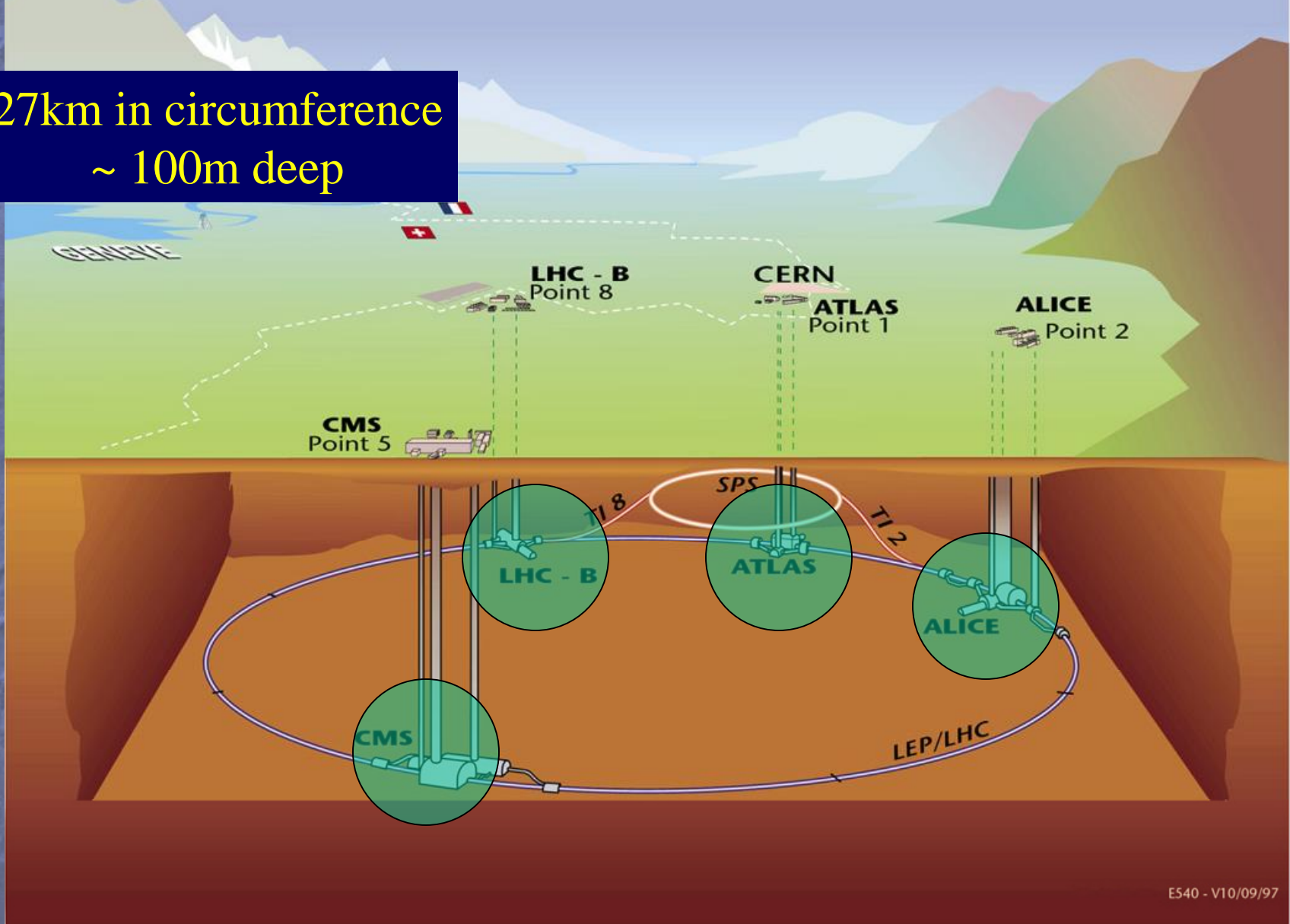


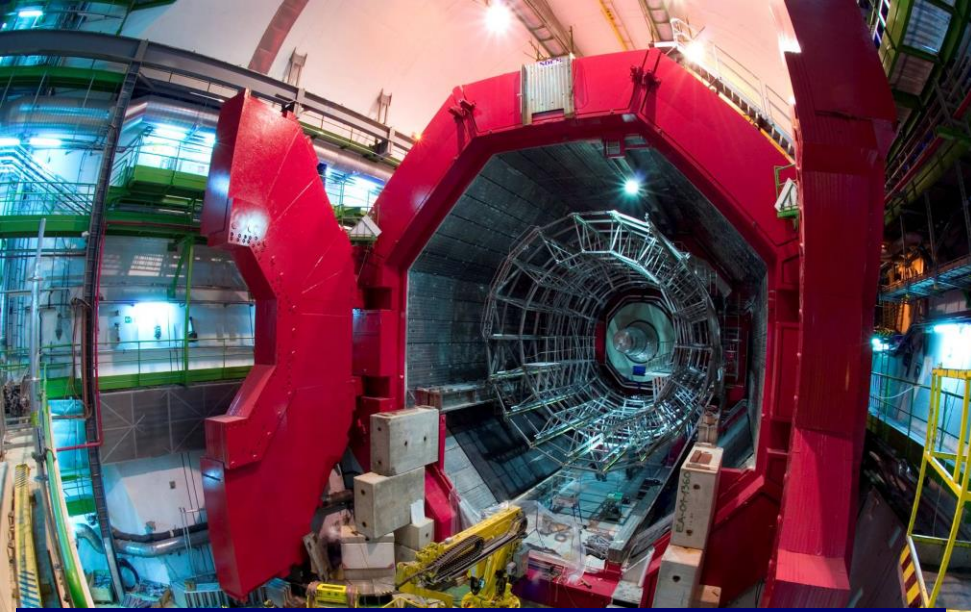
LHC 1.9 degrees above absolute zero = - 271 C

Outer space 2.7 degrees above zero = - 270 C

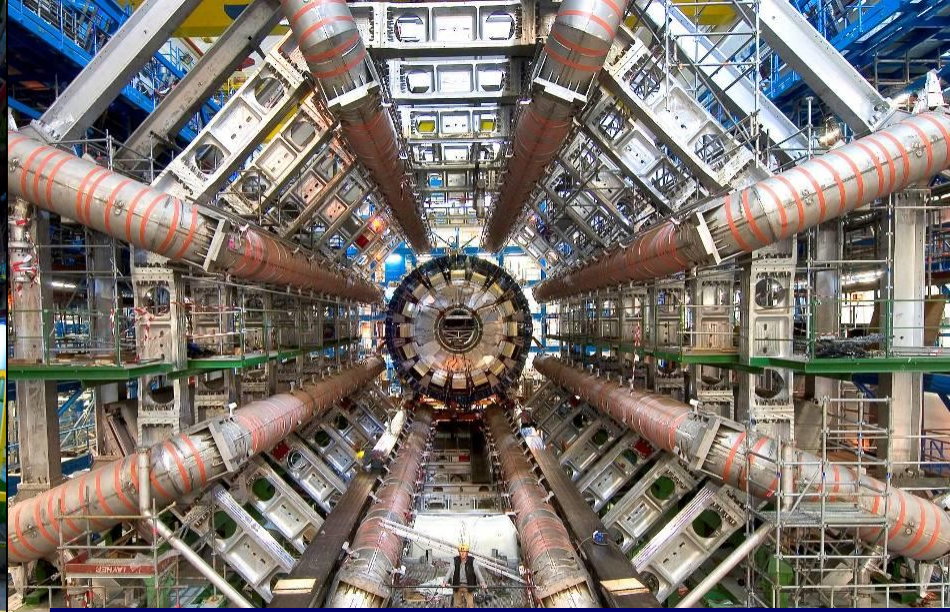
General View of LHC & its Experiments

27km in circumference
~ 100m deep

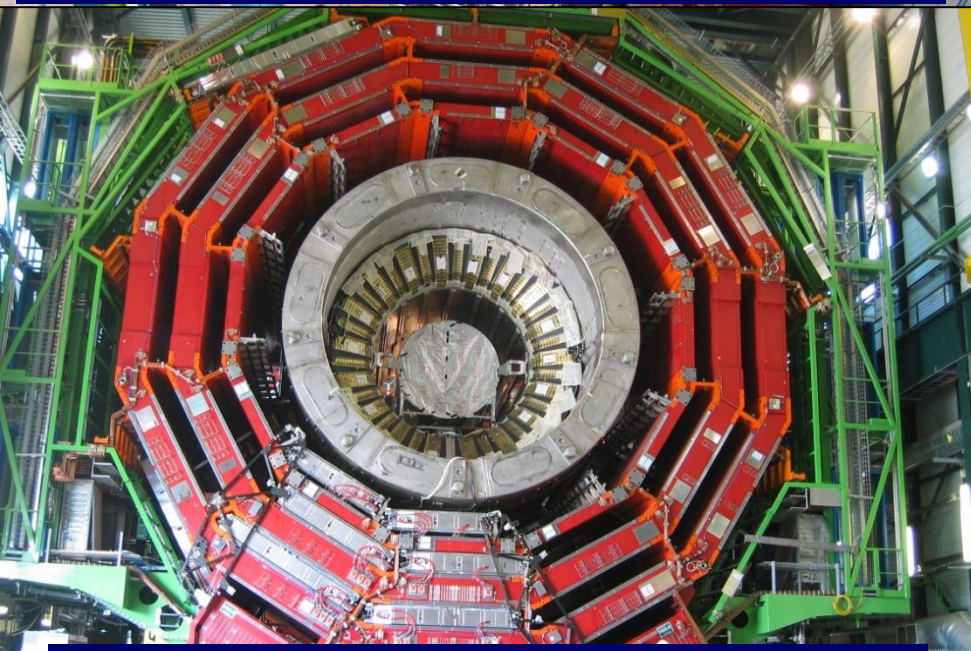




ALICE: Primordial cosmic plasma



ATLAS: Higgs and supersymmetry



CMS: Higgs and supersymmetry



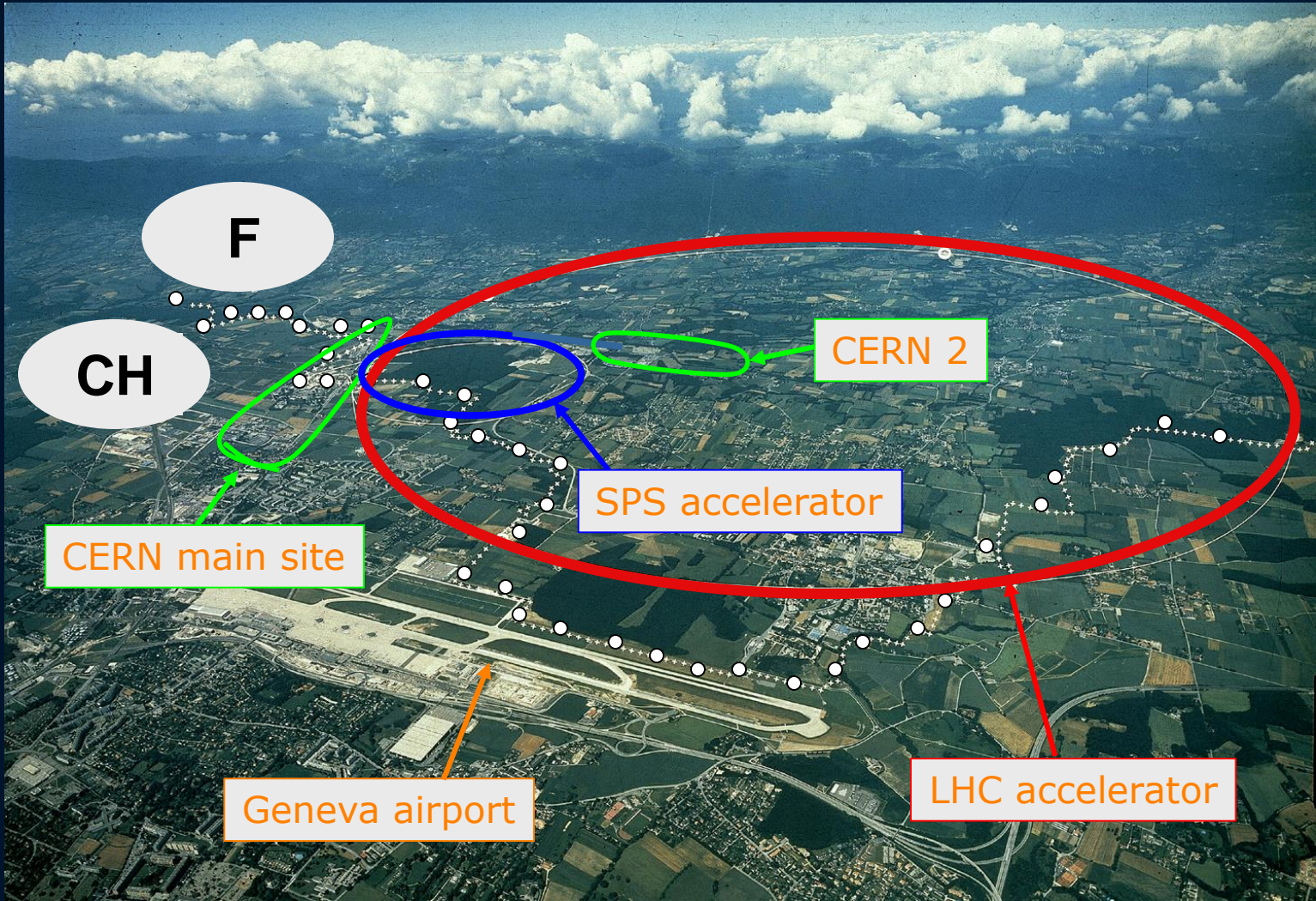
LHCb: Matter-antimatter difference



The Hottest Place in the Galaxy



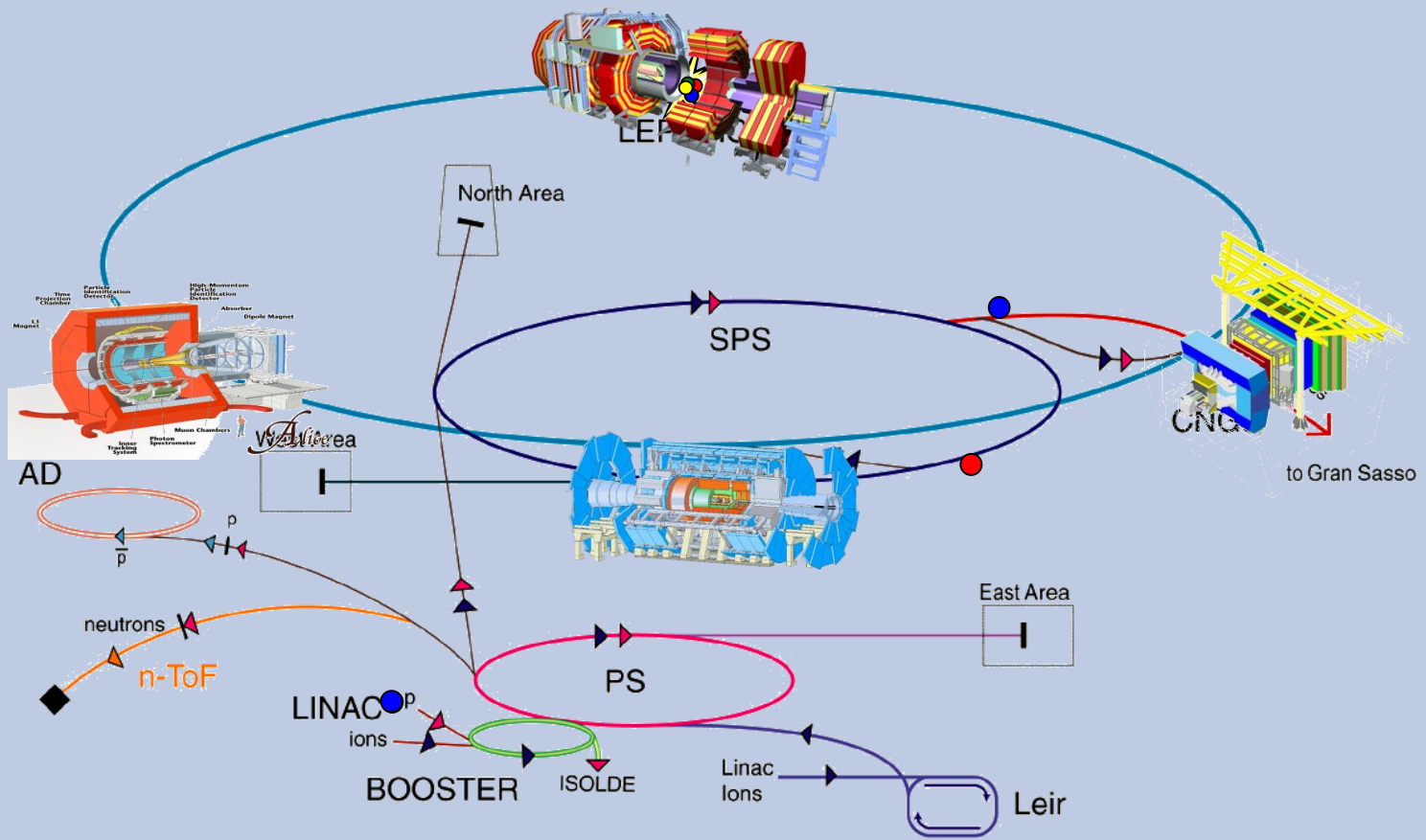
**Particle collisions create
(within a tiny volume)
temperatures a billion times higher than
in the heart of the Sun**



Large Hadron Collider

Collision of proton beams...

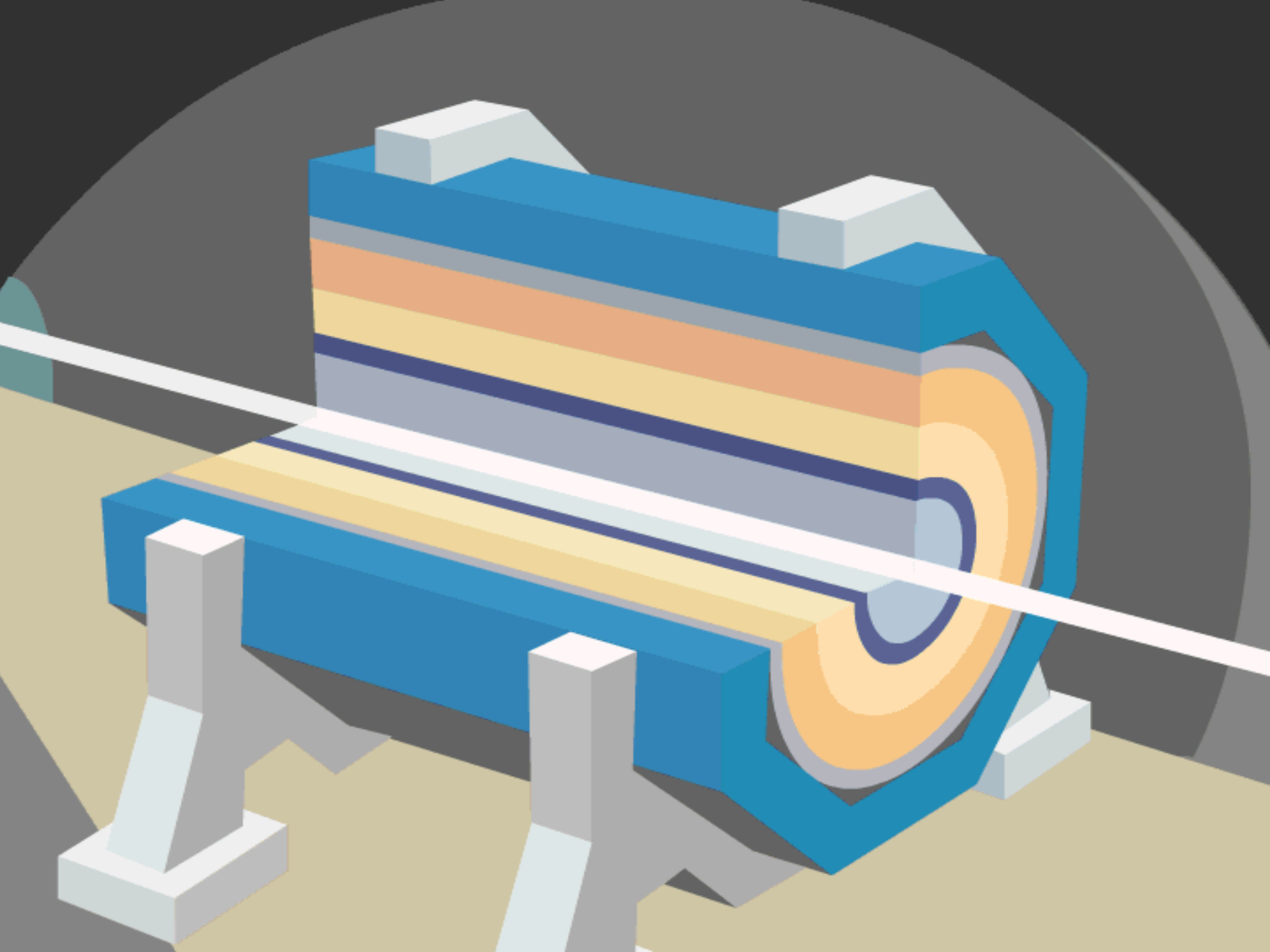
...observed in giant detectors



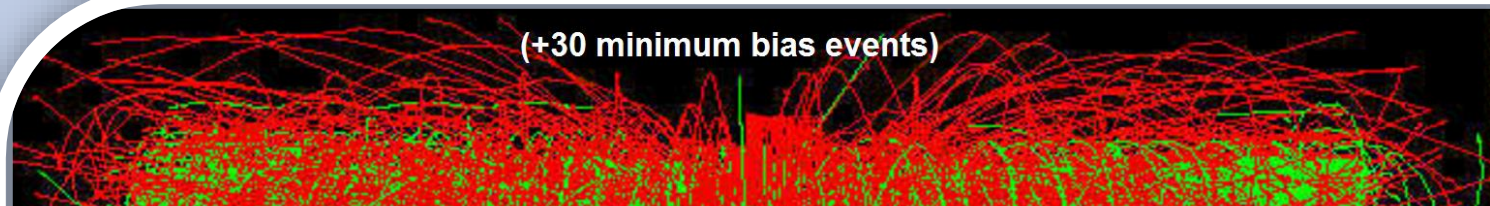
- ▶ p (proton)
- ▶ \bar{p} (antiproton)
- ▶ ion
- ▶ neutron
- ▶ $\bar{\nu}$ (neutrino)
- ▶ ν (neutrino)

- AD Antiproton Decelerator
- PS Proton Synchrotron
- SPS Super Proton Synchrotron

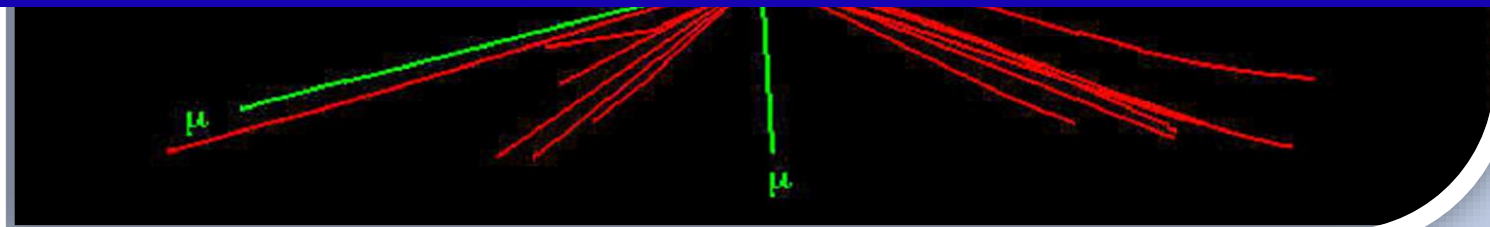
- LHC Large Hadron Collider
- n-ToF Neutron Time of Flight
- CNGS CERN Neutrinos Gran Sasso



❑ Searching for new particles requires selection and analysis of enormous quantity of data from LHC detectors



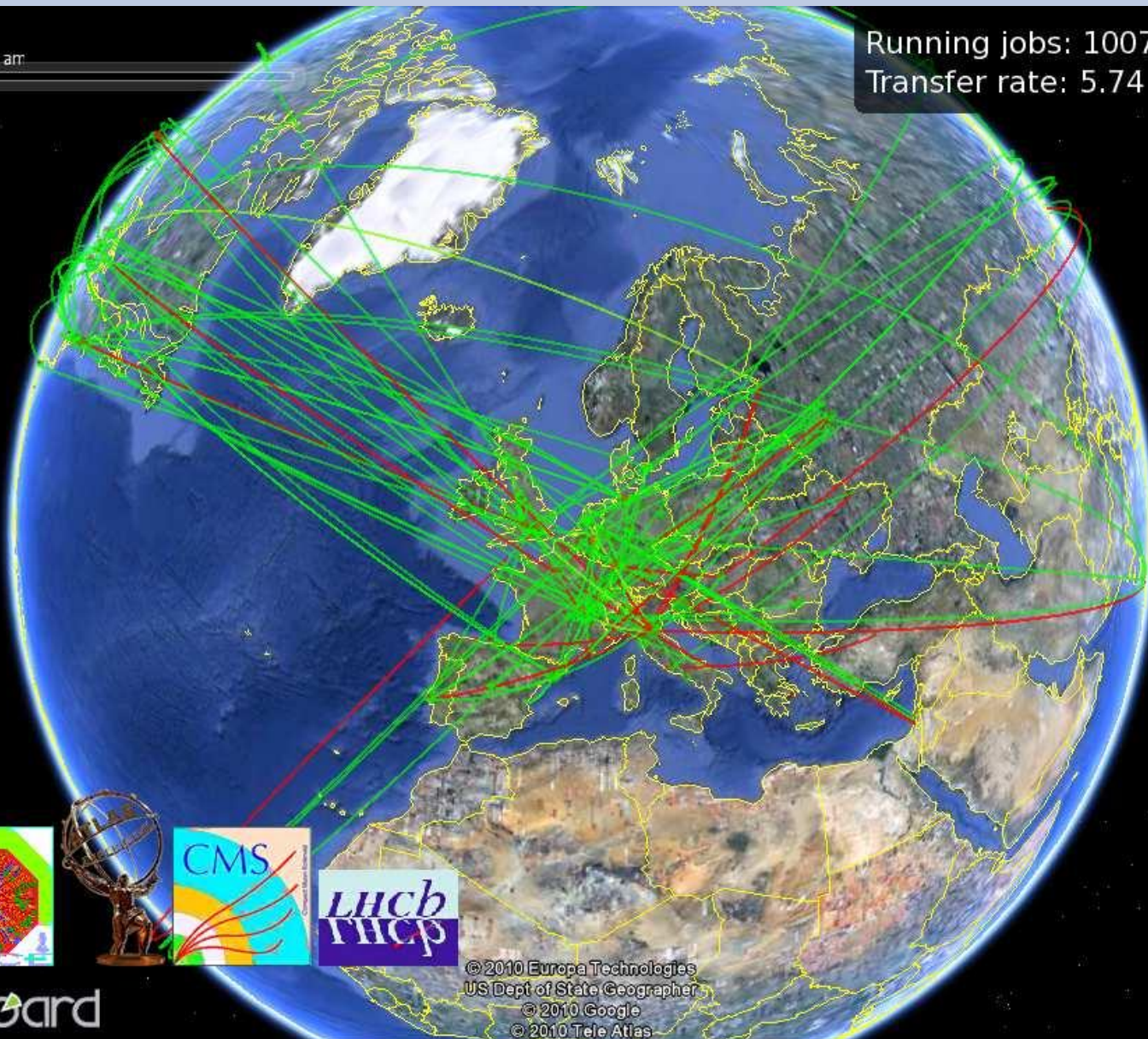
- LHC experiments produce **10-15 million Gigabytes** of data each year (about 20 million CDs!)
- LHC data analysis requires a computing power equivalent to **~100,000 of today's fastest PC processors.**



LCG-LHC Computing GRID

Oct 6, 2010 7:20:00 am

Running jobs: 100767.0
Transfer rate: 5.74 GiB/sec



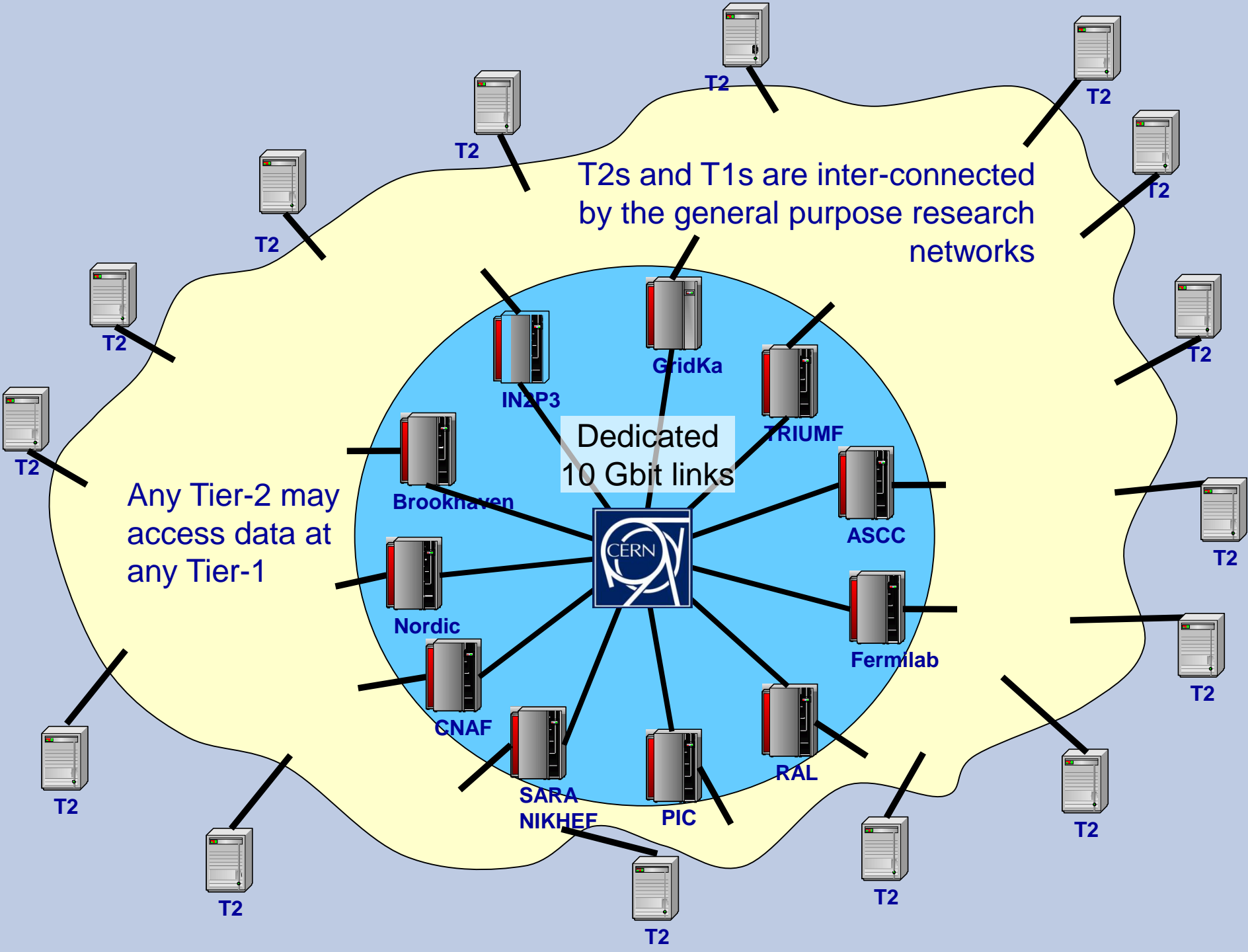
© 2010 Europa Technologies
US Dept of State Geographer

© 2010 Google
© 2010 Tele Atlas

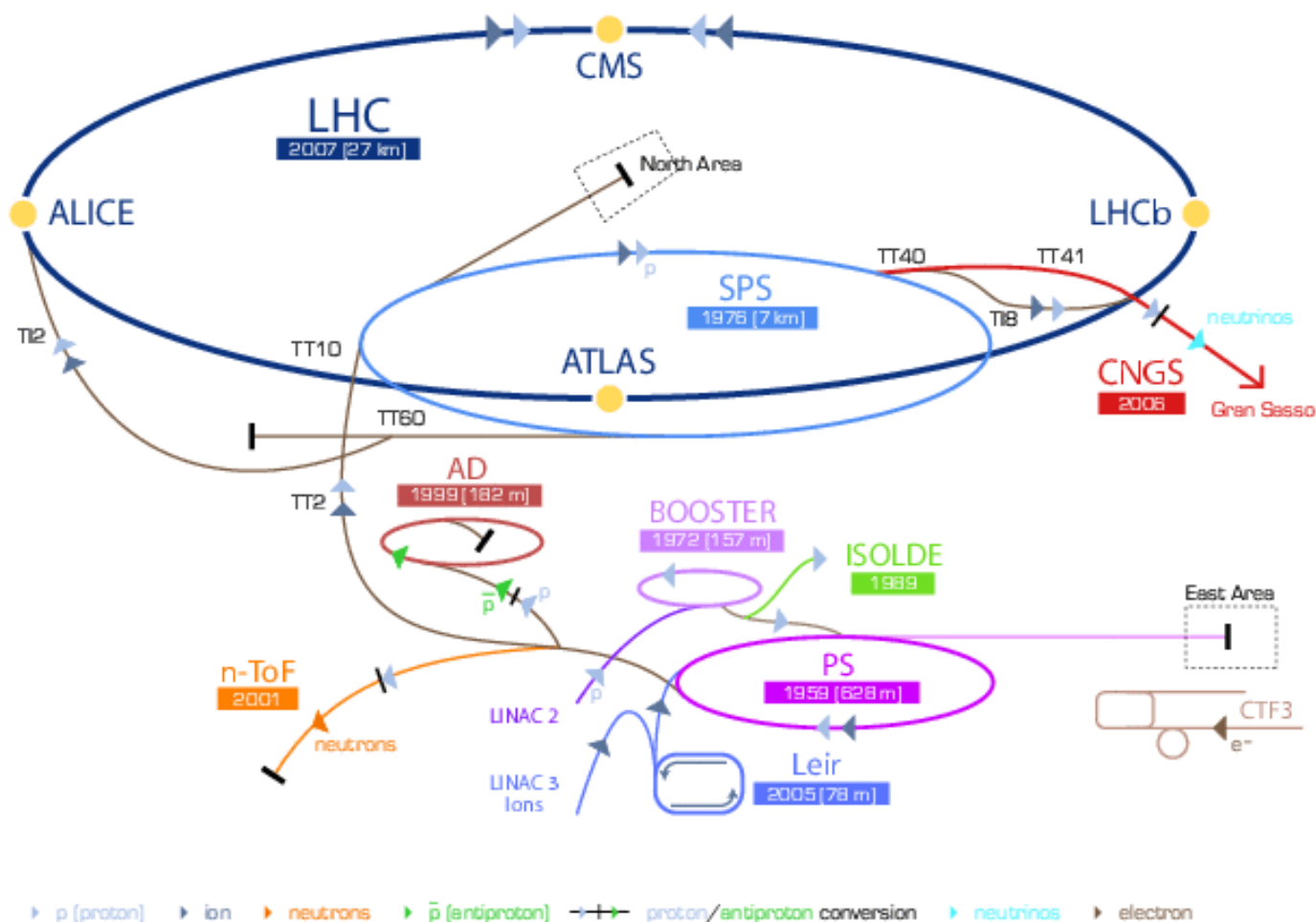
22°34'45.42" N 15°53'35.50" E elev=2326 ft

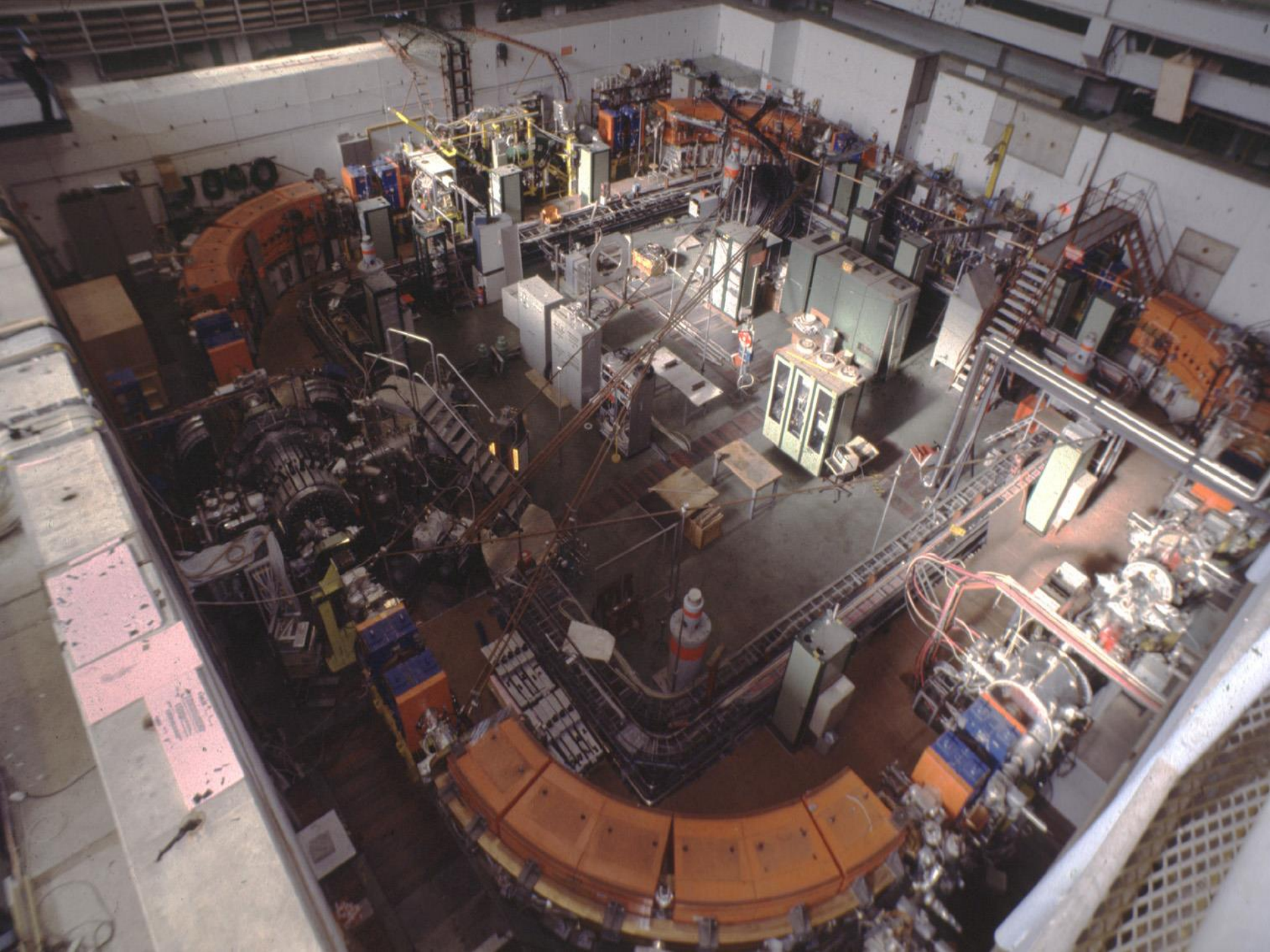
©2010 Google

Eye alt 6720.01 mi



CERN – world biggest accelerator complex





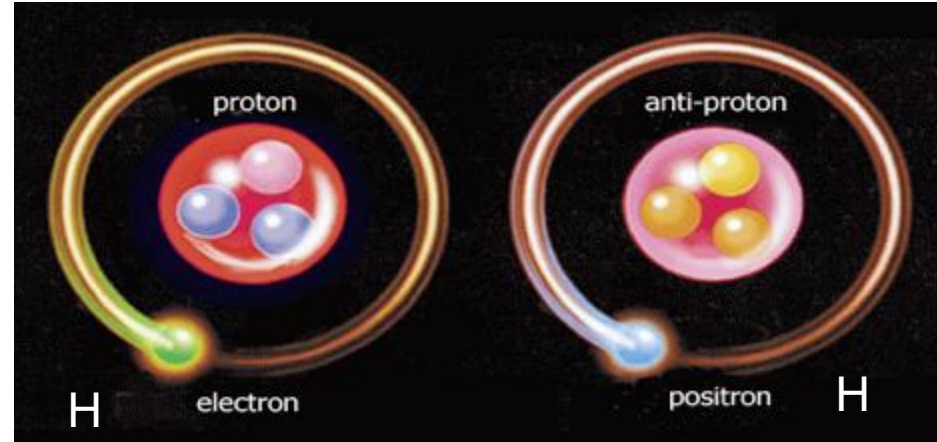


Antimatter Physics

Matter-Antimatter comparison

Very fundamental in our theory of physics

$$m=\bar{m} \quad g=\bar{g}$$



ASACUSA
ATRAP
ALPHA

Trapping \bar{H} in a magnetic bottle

AEGIS

Look at \bar{H} free fall
Galileo's experiment for antimatter !

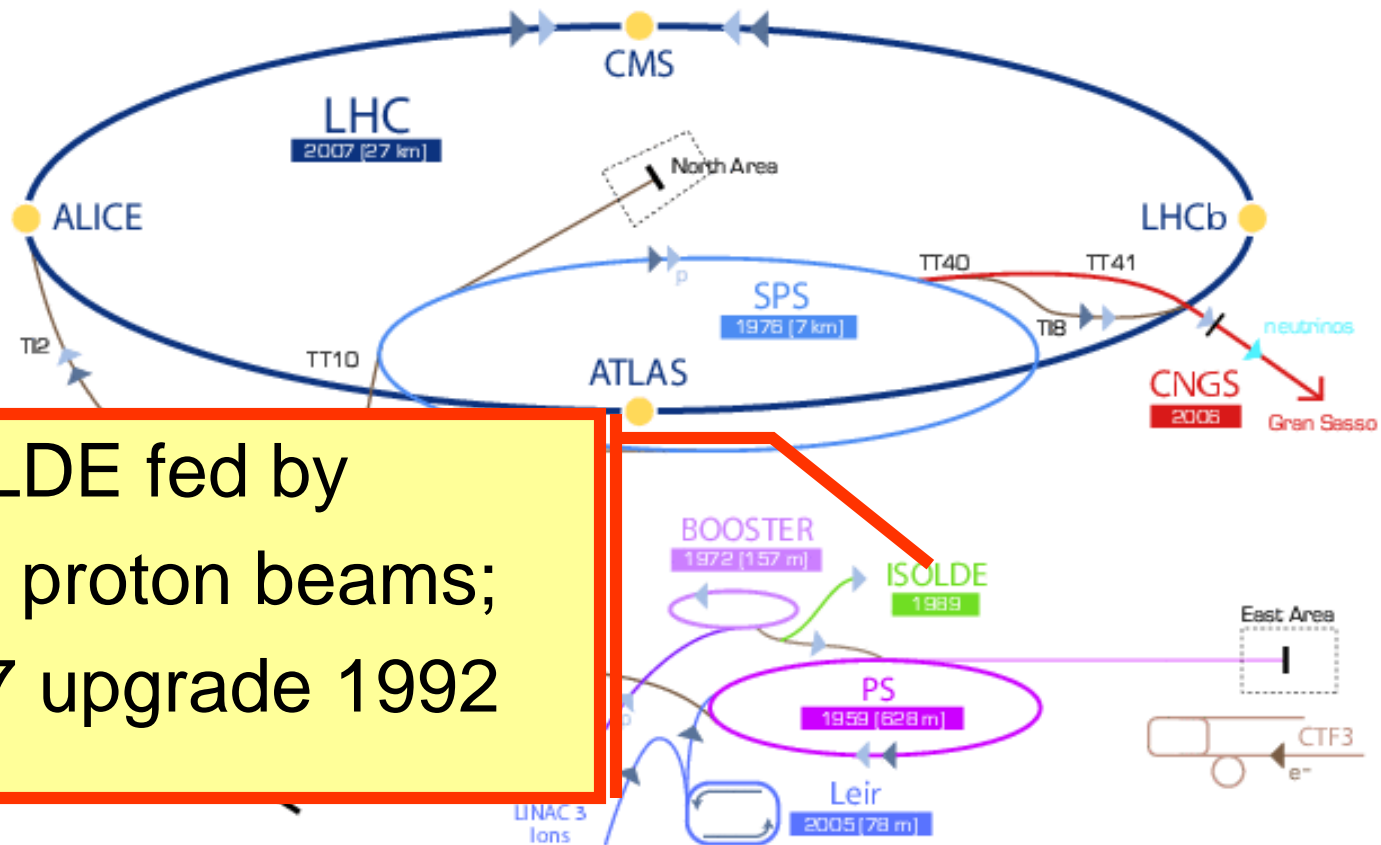


ACE

Biological effect of \bar{p}
Possible use for cancer therapy



CERN accelerator complex, working not only for LHC



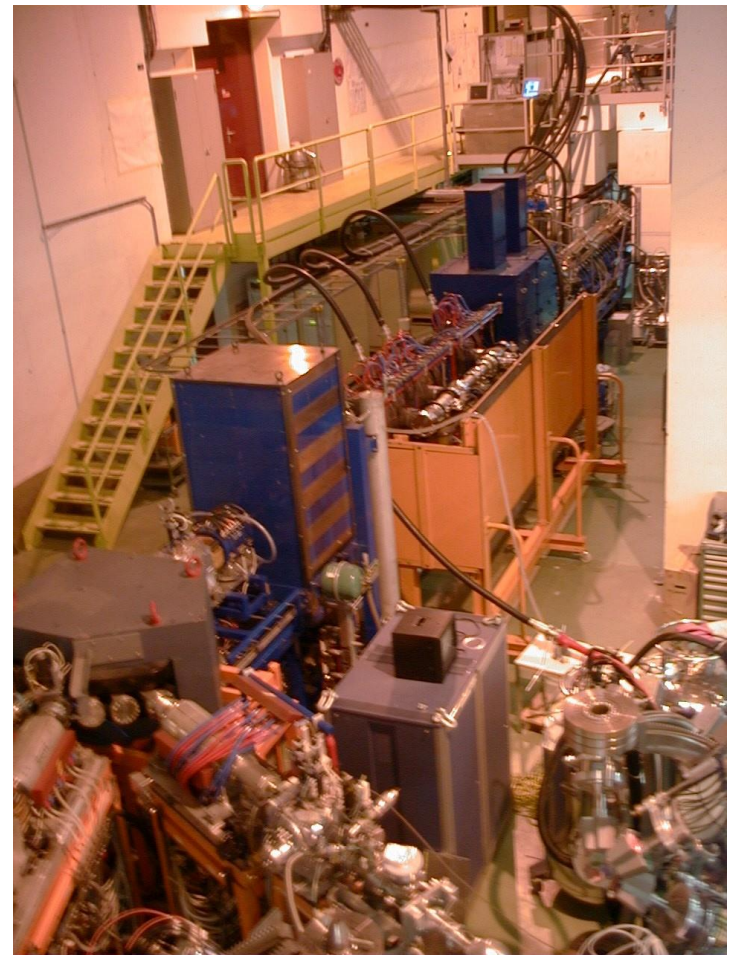
ISOLDE fed by
PSB proton beams;
1967 upgrade 1992

▶ p (proton) ▶ ion ▶ neutrons ▶ \bar{p} (antiproton) ▶ \leftrightarrow proton/antiproton conversion ▶ neutrinos ▶ electron

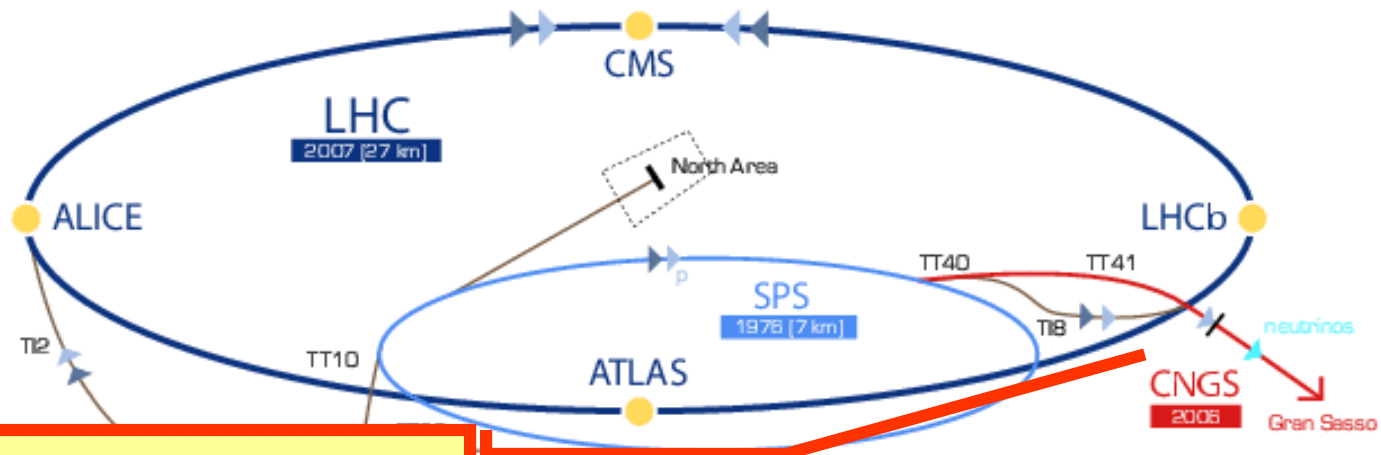
ISOLDE - Isotope Separator On Line, and Radioactive beam EXperiment (REX)

An alchemical factory for nuclear physics

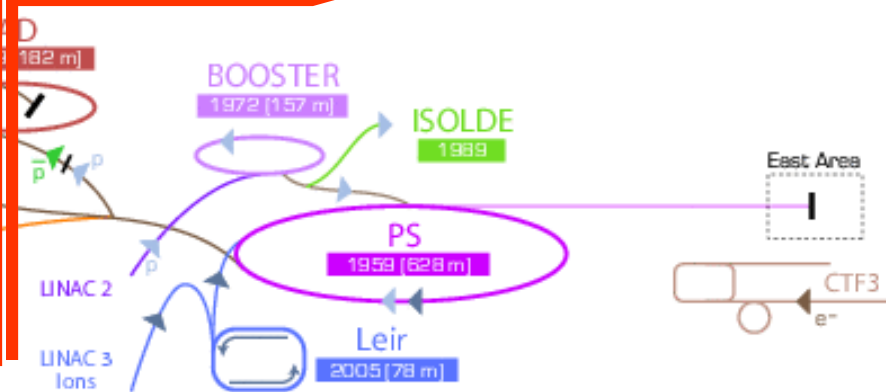
Low-energy beams of radioactive isotopes - atomic nuclei. The facility, located at the Proton-Synchrotron Booster (PSB), is like a small alchemical factory, changing one element to another. It produces a total of more than 1000 different isotopes for a wide range of research.



CERN accelerator complex, working not only for LHC !



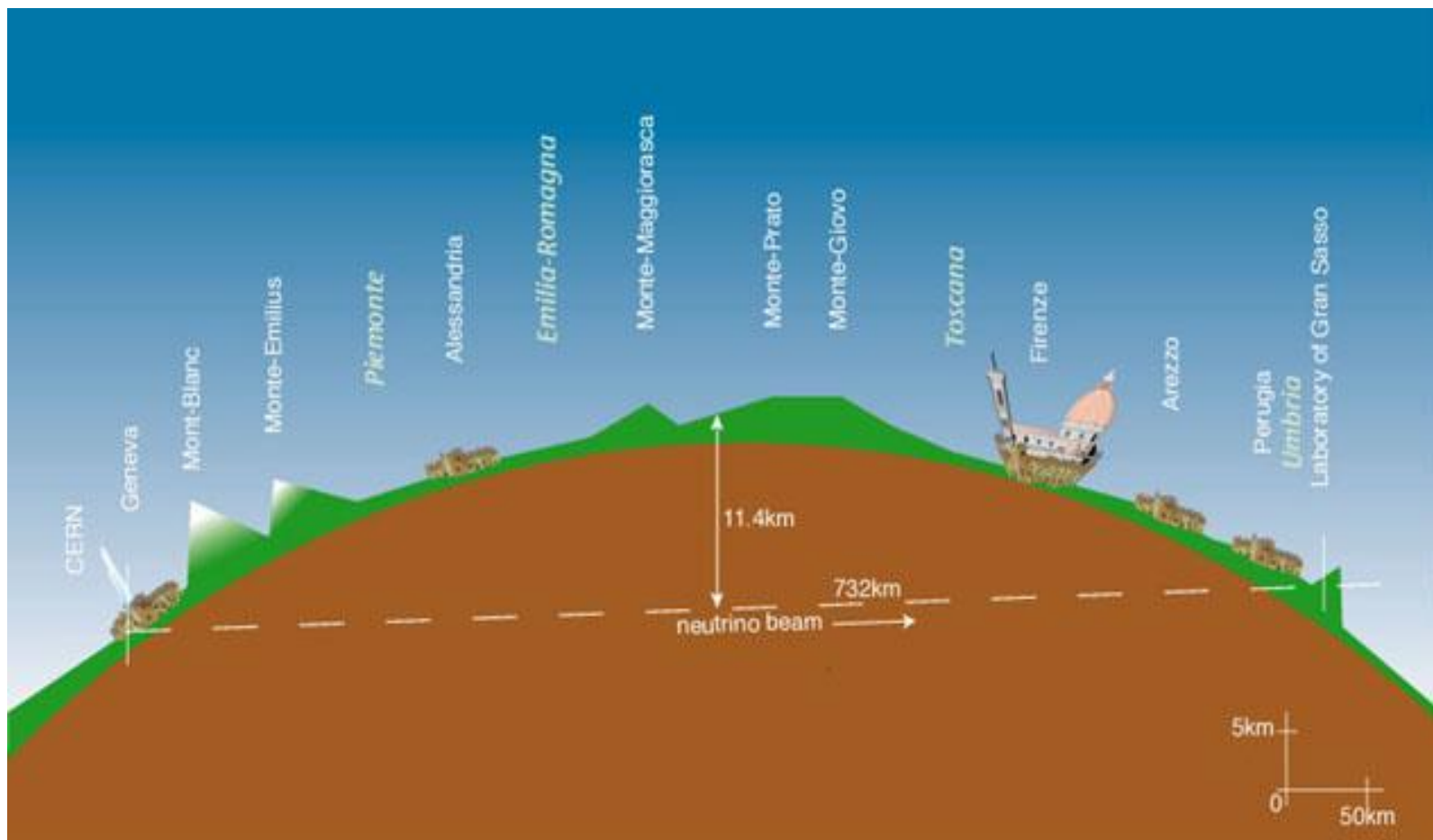
CNGS fed by
SPS proton beams



▶ p (proton) ▶ ion ▶ neutrons ▶ p-bar (antiproton) ▶ proton/antiproton conversion ▶ neutrinos ▶ electron

CNGS – CERN Neutrino to Gran Sasso experiment - investigation of the nature of neutrinos

CERN sends muon neutrinos to the Gran Sasso National Laboratory (LNGS), 732 km away in Italy. There, two experiments, OPERA and ICARUS, wait to find out if any of the muon neutrinos have transformed into tau neutrinos. To create the neutrino beam, a proton beam from the [Super Proton Synchrotron](#) (SPS) is used.



Study effect of cosmic rays on clouds formation
(cosmic rays “simulated “ by T11 beam, clouds
created in a large climatic chamber





CERN: Particle Physics and Innovation

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



- ❑ **CERN Technologies and Innovation**



Accelerating particle beams



Detecting particles



Large-scale computing (Grid)

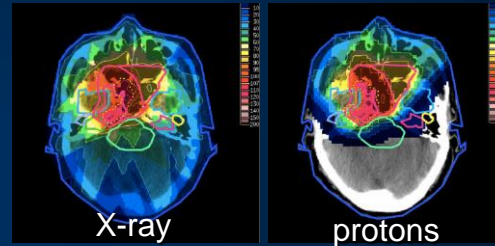
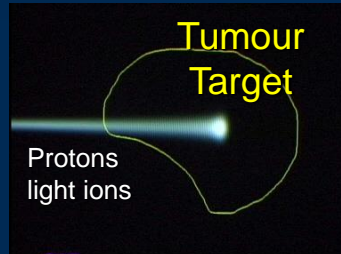
Medical Application as an Example of Particle Physics Spin-off

Combining Physics, ICT, Biology and Medicine to fight cancer



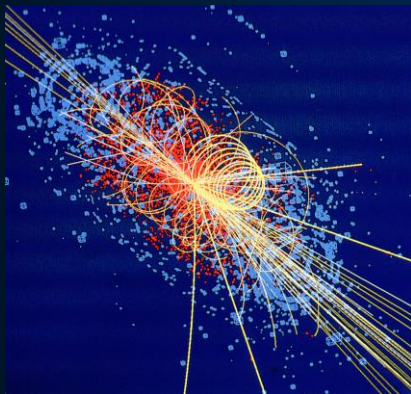
Hadron Therapy

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



Leadership in Ion Beam Therapy now in Europe and Japan

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

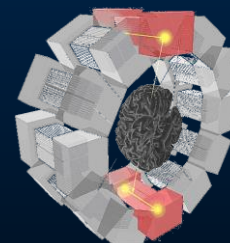


Imaging

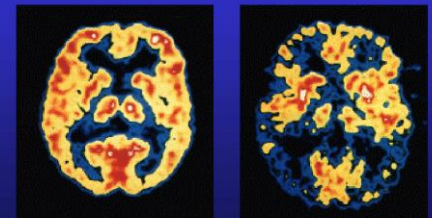
Clinical trial in Portugal for new breast imaging system (ClearPEM)



PET Scanner



Brain Metabolism in Alzheimer's Disease: PET Scan



Normal Brain Metabolism Alzheimer's Disease



Detecting particles

CERN Education Activities

Scientists at CERN
Academic Training Programme



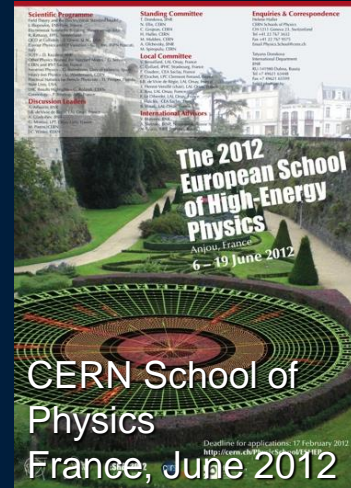
NEW:
Asia-Europe-Pacific School
of High-Energy Physics
Fukuoka, Oct 2012



Latin American School
Natal, Brazil, 2011

Young Researchers

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



CERN School of
Physics
France, June 2012

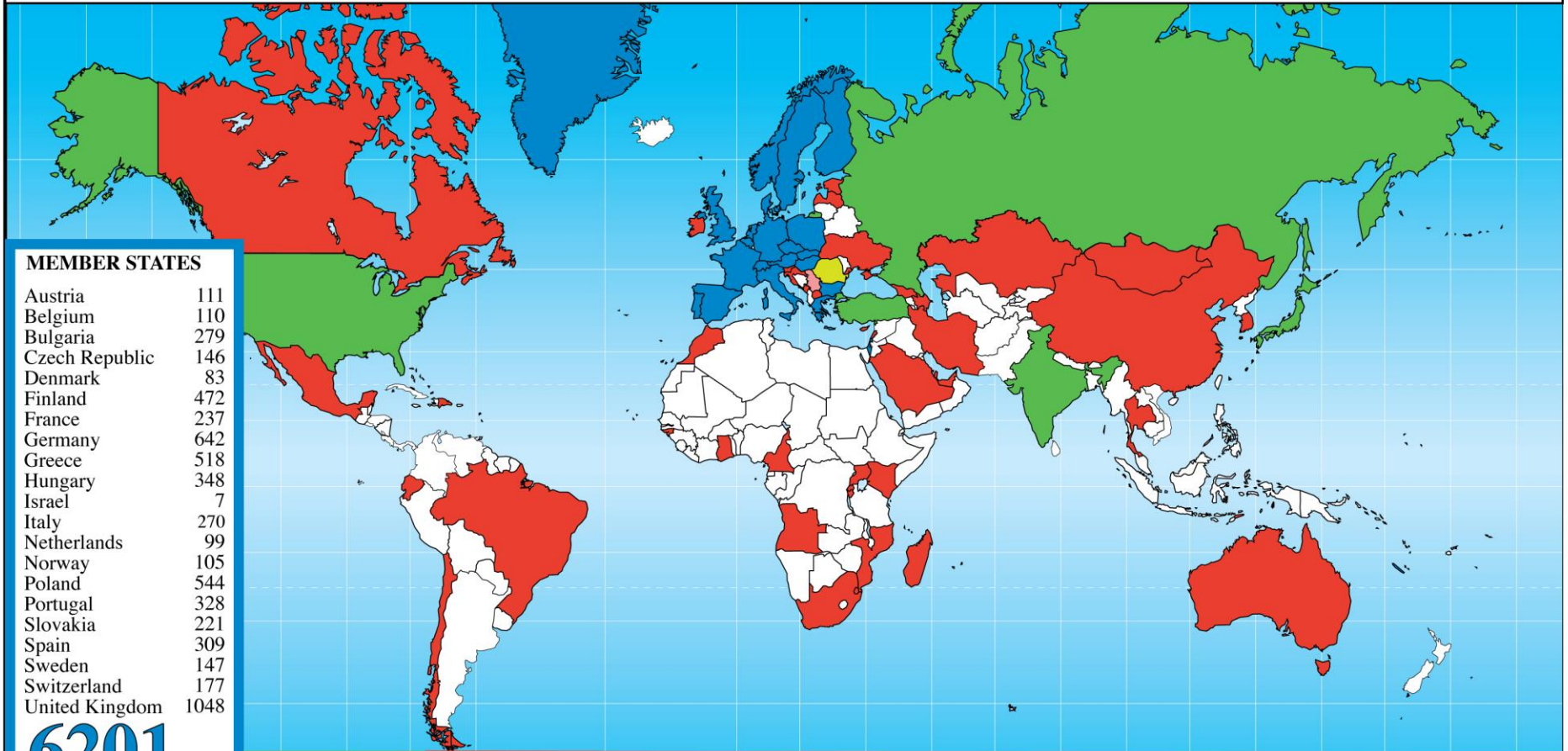


Physics Students
Summer Students
Programme



CERN Teacher Schools
International and National
Programmes

Teacher Programme Participants 1998 - 2013 (Total: 7087)



MEMBER STATES

Austria	111
Belgium	110
Bulgaria	279
Czech Republic	146
Denmark	83
Finland	472
France	237
Germany	642
Greece	518
Hungary	348
Israel	7
Italy	270
Netherlands	99
Norway	105
Poland	544
Portugal	328
Slovakia	221
Spain	309
Sweden	147
Switzerland	177
United Kingdom	1048

6201

OBSERVER STATES

India	2
Japan	5
Russia	193
Turkey	3
USA	65

268

OTHERS

Angola	4
Australia	5
Azerbaijan	1
Brazil	114
Burundi	1
Cameroon	3
Canada	3
Cape Verde	3
Chile	3

China	1
Croatia	1
Cyprus	8
Dominican Rep.	21
Ecuador	2
Estonia	46
Georgia	74
Ghana	6
Guinea Bissau	1
Iran	1
Ireland	5
Kazakhstan	3
Kenya	4
Latvia	1
Lebanon	1
Madagascar	2
Malta	36
Mexico	6
Mongolia	1
Montenegro	13

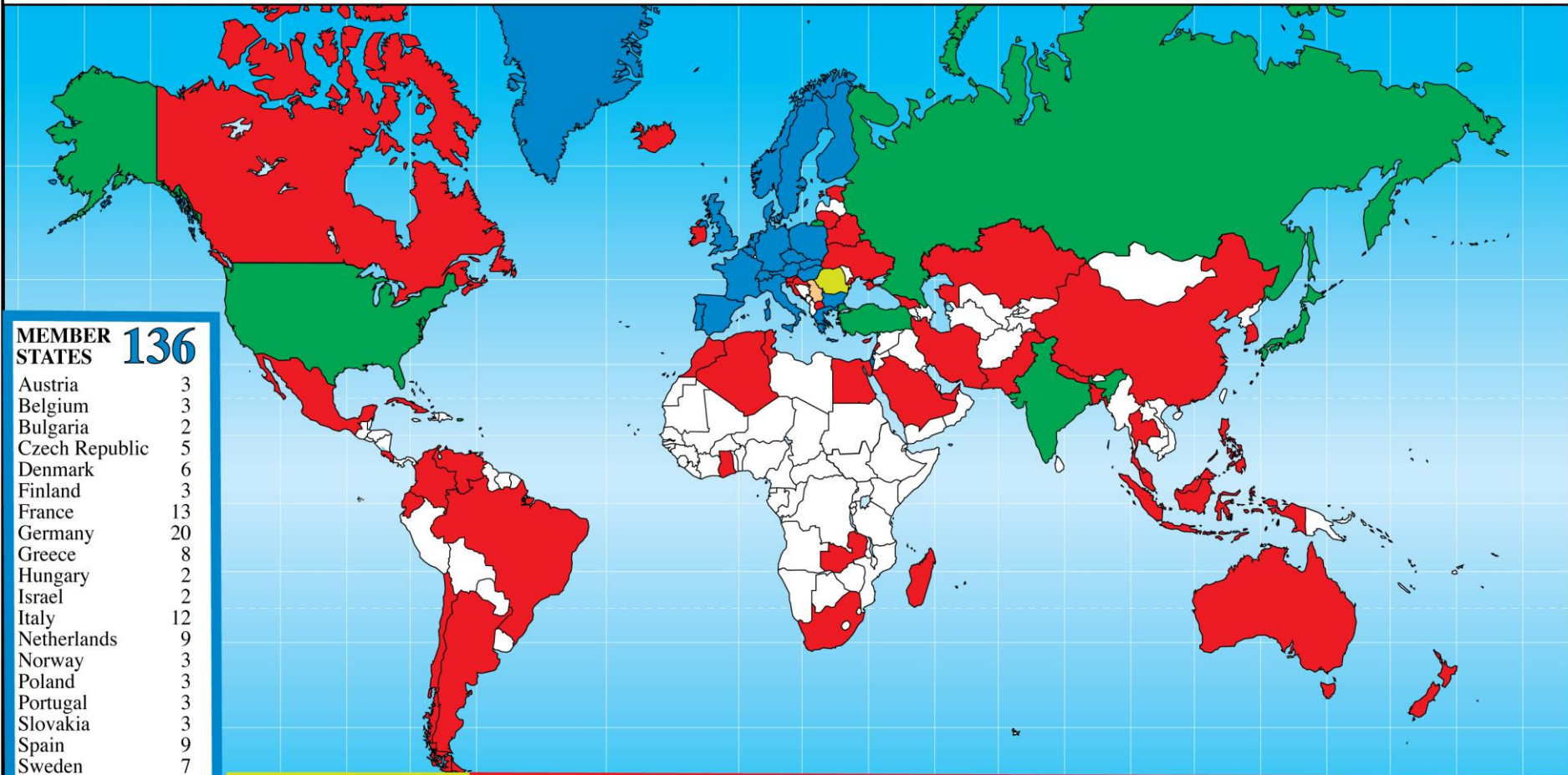
Morocco	2
Mozambique	17
Qatar	1
Rwanda	17
Sao Tome	4
Saudi Arabia	1
Singapore	2
Slovenia	21
South Africa	6
South Korea	44

Swaziland	1
Thailand	7
T.F.Y.R.O.M.	11
Timor-Leste	7
Uganda	3
Ukraine	77
U.A.E.	1

592



Summer Students 2013



MEMBER STATES 136

Austria	3
Belgium	3
Bulgaria	2
Czech Republic	5
Denmark	6
Finland	3
France	13
Germany	20
Greece	8
Hungary	2
Israel	2
Italy	12
Netherlands	9
Norway	3
Poland	3
Portugal	3
Slovakia	3
Spain	9
Sweden	7
Switzerland	4
United Kingdom	16

CANDIDATE FOR ACCESSION

Romania	3
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ASSOCIATE MEMBER IN THE PRE-STAGE TO MEMBERSHIP

Serbia	2
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OBSERVERS 43

India	7
Japan	5
Russia	9
Turkey	6
USA	16

OTHERS

Algeria	2	China	5	Estonia	4	Korea, South	2	New Zealand	1	Tunisia	1
Argentina	1	Colombia	1	Georgia	1	Lebanon	1	Pakistan	4	Ukraine	2
Australia	1	Comoros	1	Ghana	1	Lithuania	2	Palestine	1	U.A.E.	2
Bangladesh	1	Costa Rica	1	Hong Kong	4	Madagascar	1	Philippines	1	Venezuela	1
Belarus	1	Croatia	3	Iceland	1	Malaysia	3	Saudi Arabia	1	Zambia	1
Benin	1	Cuba	1	Indonesia	3	Malta	3	Slovenia	1		
Brazil	1	Cyprus	2	Iran	2	Mexico	2	South Africa	2		
Canada	5	Ecuador	3	Ireland	1	Morocco	2	Thailand	2		
Chile	1	Egypt	4	Kazakhstan	1	Nepal	1	T.F.Y.R.O.M.	2		

Summer Students 2012



Personnel



Workforce

- **Physicists**
 - **Experimental**
 - **Theoretical**
- **Applied Physicists and Engineers**
- **Technicians**
- **Craftsmen**
- **Administrative personnel**
- **Fellows**
- **Doctoral Students**
- **Technical Students**
- **Associates**
- **Summer Students**
- **Employees of CERN**
- **Users**

30th November 2009 LHC sets new world record

Early this morning CERN's Large Hadron Collider become the world's highest energy particle accelerator, having accelerated its twin beams of protons to an energy of **1.18 TeV**. This exceeds the previous world record of 0.98 TeV, which had been held by the US Fermi National Accelerator



What next ?



OPERA experiment invites scrutiny of unexpected results

ATLAS and CMS experiments present Higgs search status

13 December 2011. In a seminar held at CERN¹ today, the ATLAS² and CMS³ experiments presented the status of their searches for the Standard Model Higgs boson.

Their results are based on the analysis of considerably more data than those presented at the summer conferences, sufficient to make significant progress in the search for the Higgs boson, but not enough to make any conclusive statement on the existence or non-existence of the elusive Higgs.

The main conclusion is that the Standard Model Higgs boson, if it exists, is most likely to have a mass constrained to the range 116-130 GeV by the ATLAS experiment, and 115-127 GeV by CMS.

Tantalising hints have been seen by both experiments in this mass region, but these are not yet strong enough to claim a discovery.

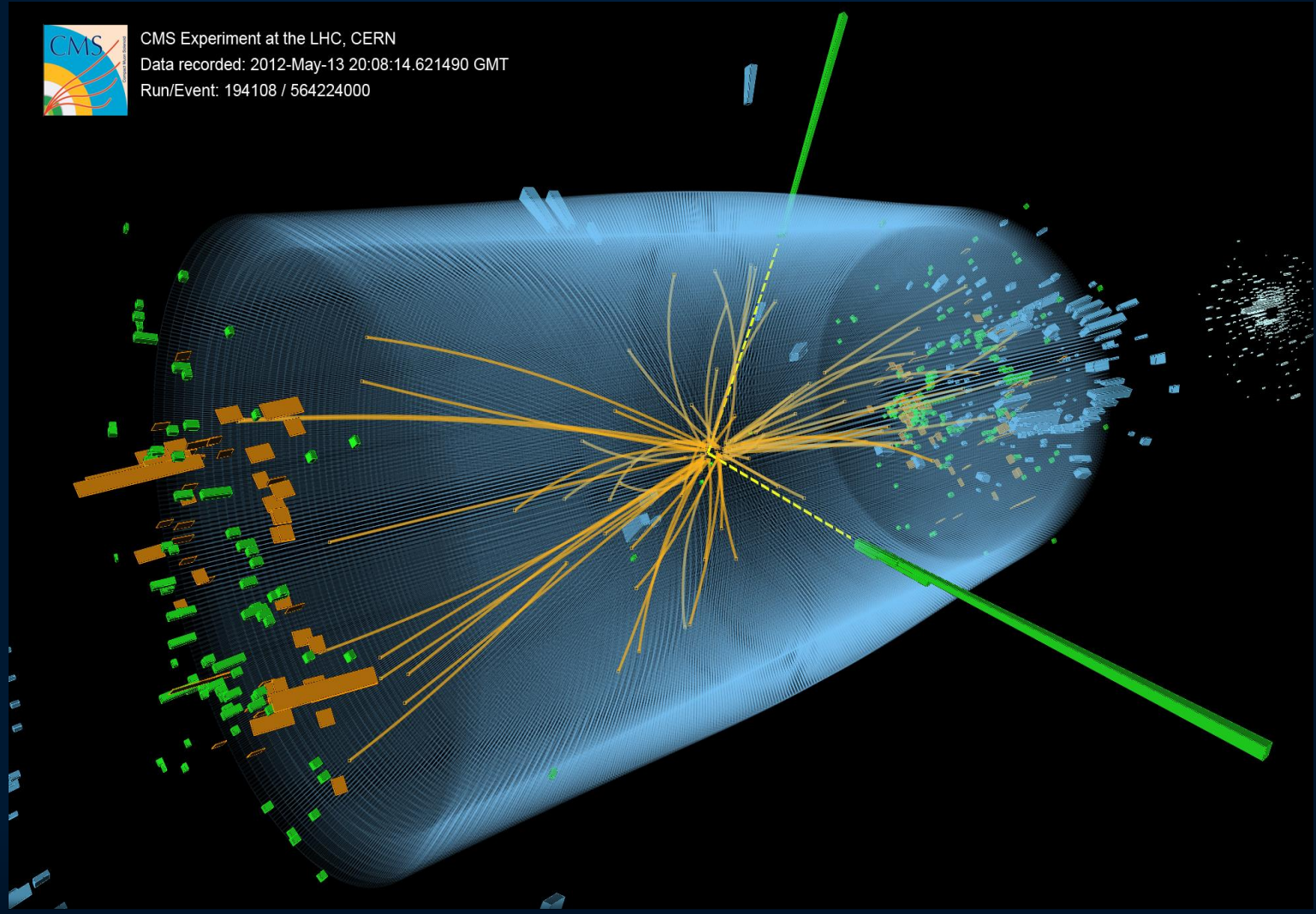




4 July 2012: CERN press conference



“CERN experiments observe particle consistent with long-sought Higgs boson”





4 July 2012: CERN press conference

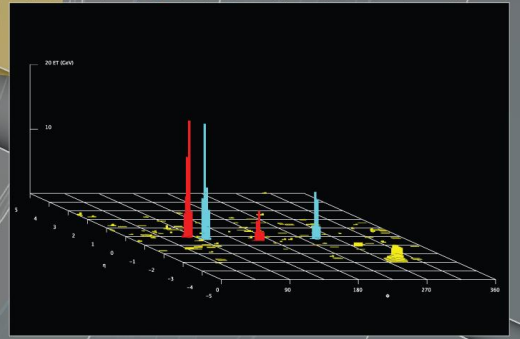
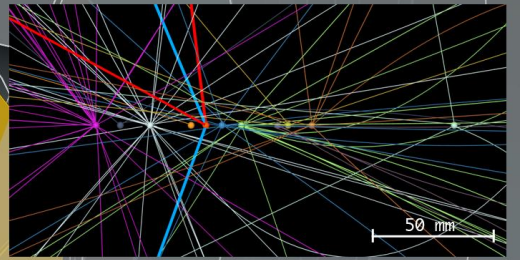
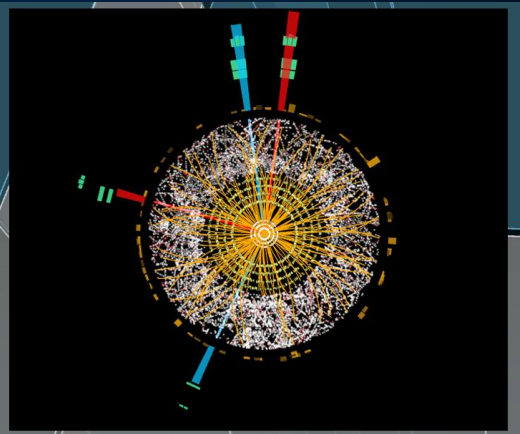
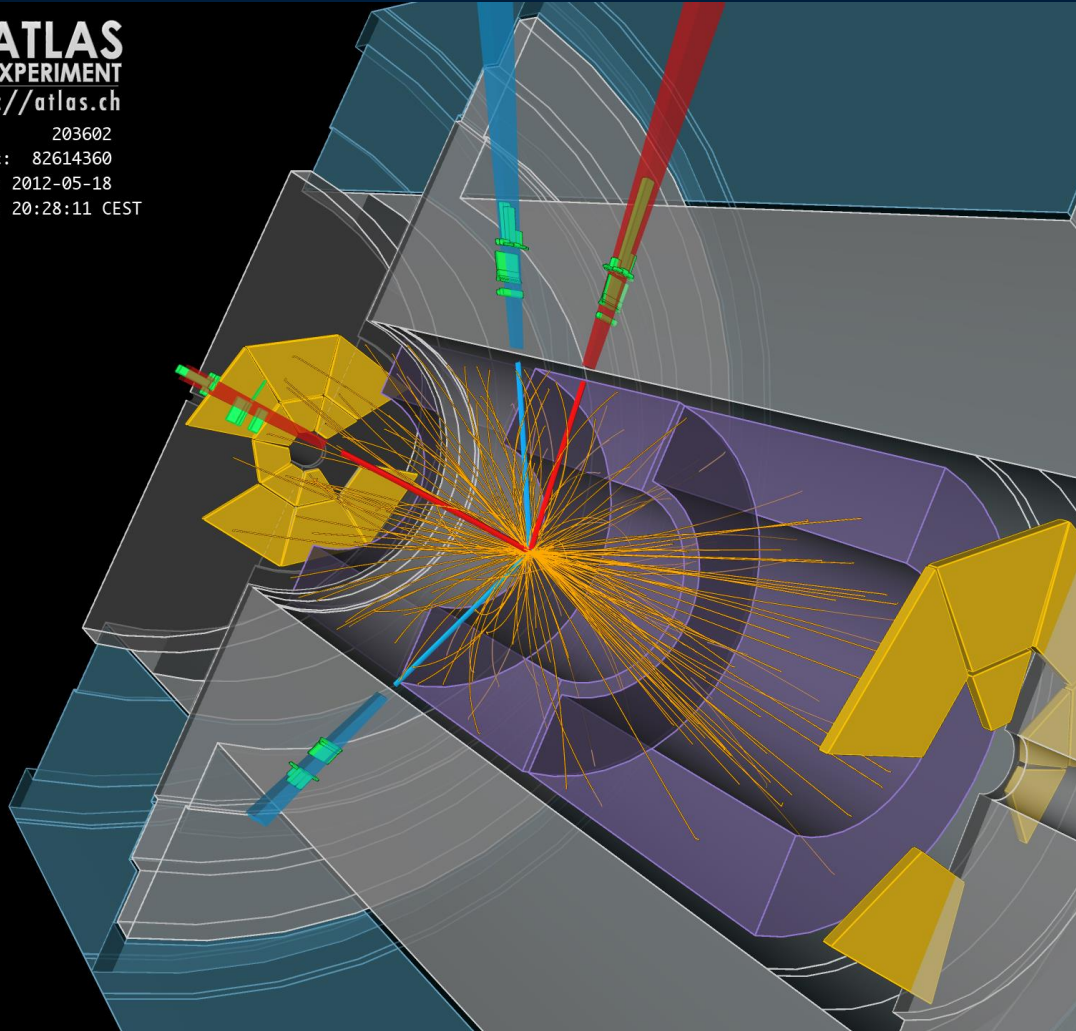


“CERN experiments observe particle consistent with long-sought Higgs boson”

ATLAS
EXPERIMENT

<http://atlas.ch>

Run: 203602
Event: 82614360
Date: 2012-05-18
Time: 20:28:11 CEST



CERN experiments observe particle consistent with long-sought Higgs boson Geneva, 4 July 2012.

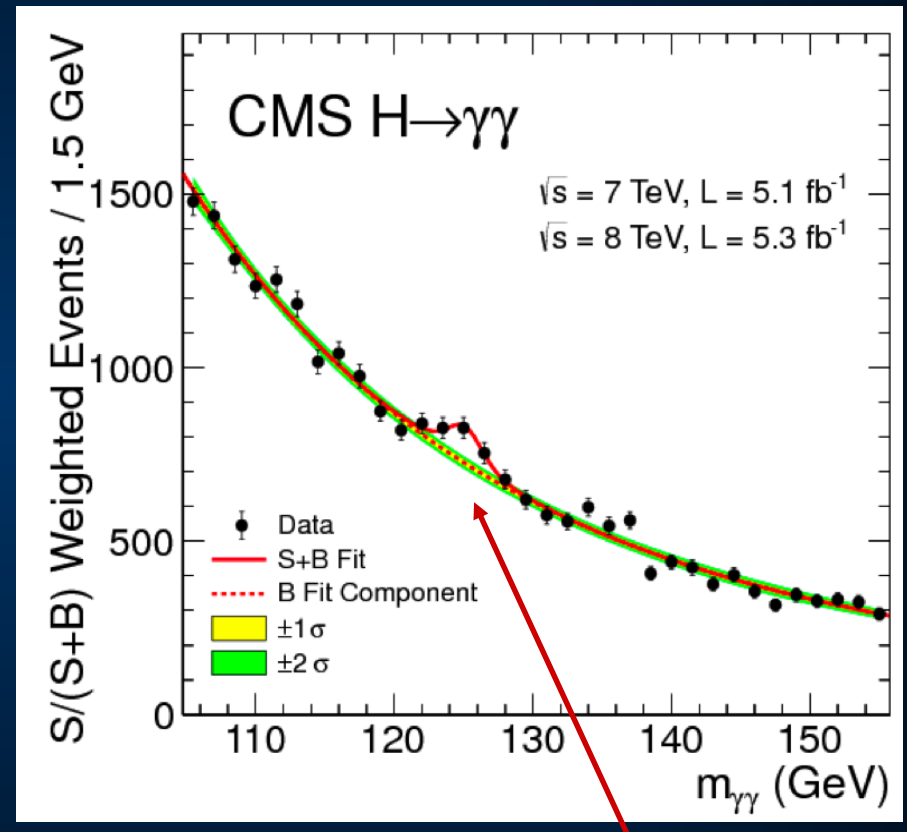
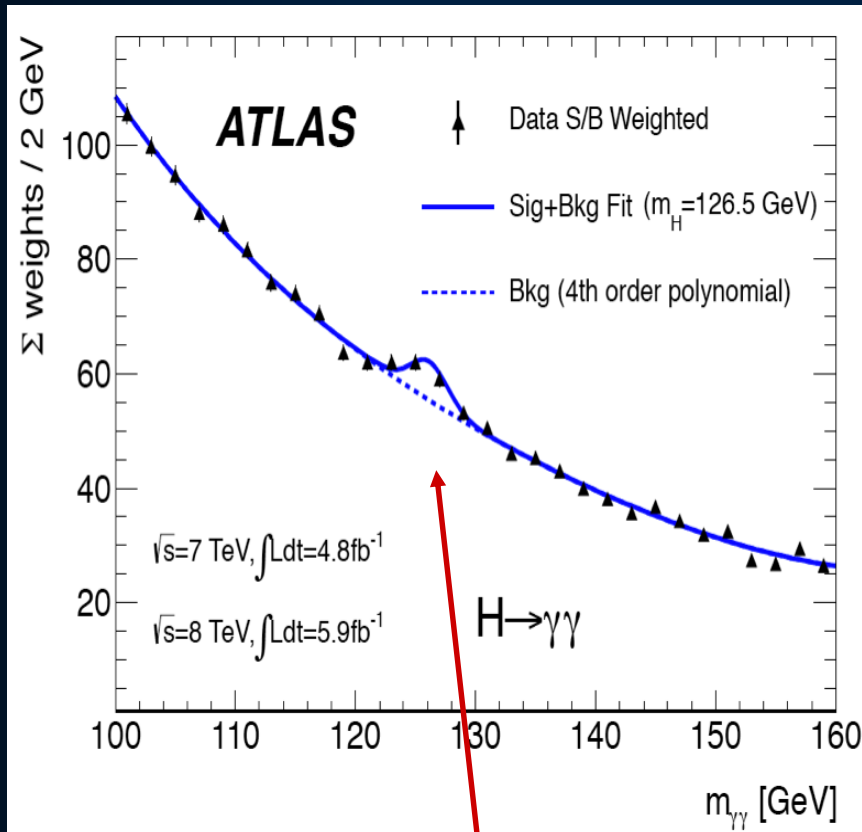
At a seminar held at CERN¹ today as a curtain raiser to the year's major particle physics conference, ICHEP2012 in Melbourne, the ATLAS and CMS experiments presented their latest preliminary results in the search for the long sought Higgs particle. **Both experiments observe a new particle in the mass region around 125-126 GeV.**

“We observe in our data clear signs of a new particle, at the level of 5 sigma, in the mass region around 126 GeV. The outstanding performance of the LHC and ATLAS and the huge efforts of many people have brought us to this exciting stage,” said ATLAS experiment spokesperson Fabiola Gianotti, *“but a little more time is needed to prepare these results for publication.”*

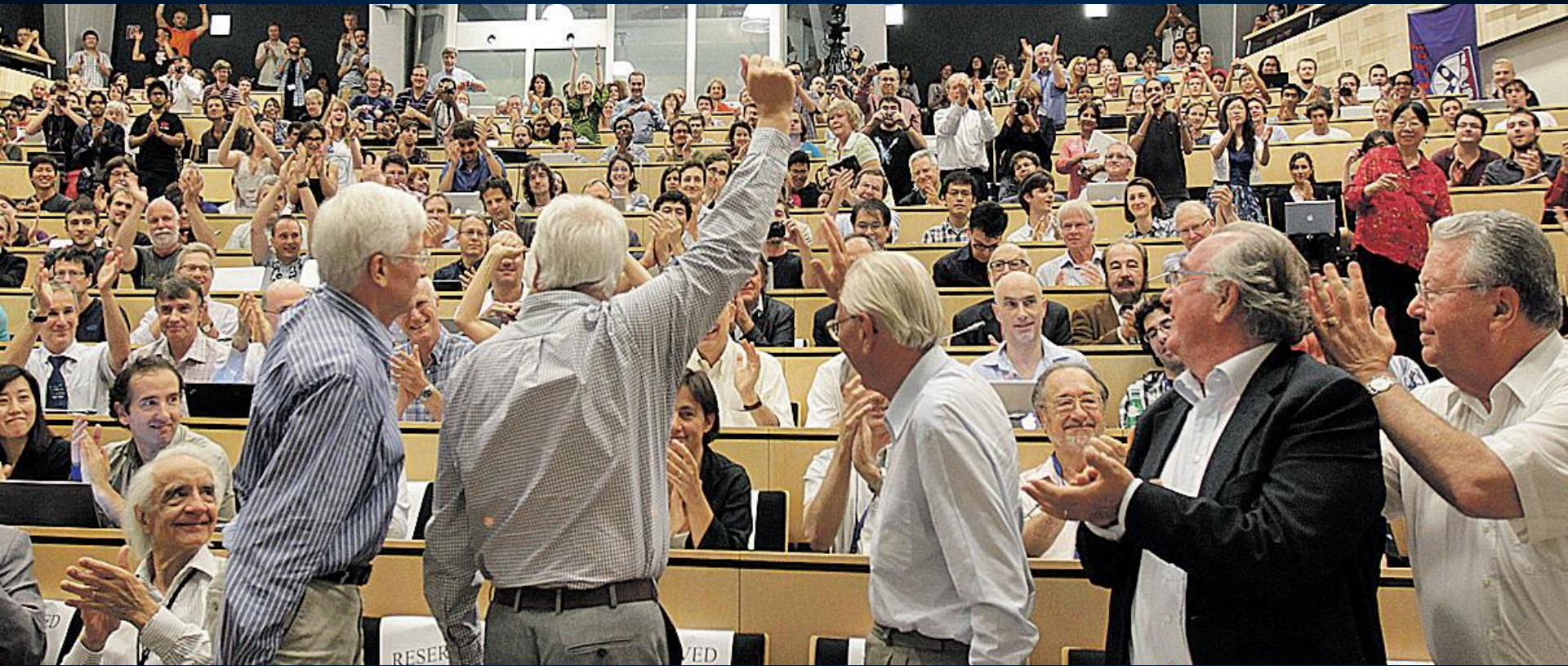
“The results are preliminary but the 5 sigma signal at around 125 GeV we’re seeing is dramatic. This is indeed a new particle. We know it must be a boson and it’s the heaviest boson ever found,” said CMS experiment spokesperson Joe Incandela. *“The implications are very significant and it is precisely for this reason that we must be extremely diligent in all of our studies and cross-checks.”*



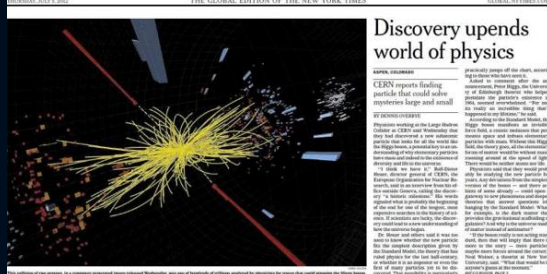
Higgs decay to $\gamma\gamma$, ATLAS and CMS, summer 2012 data



July 4th at CERN, after the Higgs seminar



4 JULY 2012 CERN Press conference



Discovery opens world of physics

CERN reports finding particle that could solve mysteries large and small



Scientists at Geneva on Wednesday applauded the discovery of a subatomic particle that looks like the Higgs boson.

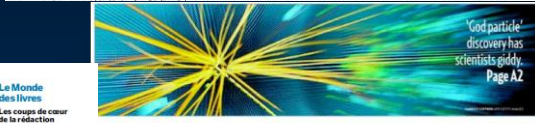
The Economist: A giant leap for science. Finding the Higgs boson.



ヒッグス粒子検出 年内に結論

Le Monde: Science: la matière dévoilée. Milhares de moradores de bairros sociais em risco de perderem RSI.

Le Monde: Science: la matière dévoilée. Une fête sans panache.



The Gazette: EL PAIS

EL PAIS: A solas con la prueba del VIH. De Villota pierde el ojo derecho.

MK: ПОСЛЕДНИЙ КИРПИЧ В СТЕНУ МИРОЗДАНИЯ. «КРЕМЛЕВСКИЕ» САМОЛЕТЫ ПРИШЛОСЬ МЕНЯТЬ НА ПЕРЕГРABE.

AD ALGEMEEN DAGBLAD: Eindelijk gelijk na 48 jaar. Zieke Kaj en zijn moeder toch samen in de VS.

Frankfurter Allgemeine: Masse macht's. GroÙe Mehrheit im Europaparlament.

CHINA DAILY: 大快人心! 科学家发现上帝粒子. 重要消息: 科学家宣称发现上帝粒子.

THE TIMES OF INDIA: Big bang moment: Scientists may have found 'God particle'. Adarsh scam: Finally, CBI chargesheets 13.

THE HINDU: Elusive particle found, looks like Higgs boson. CERN physicists hail evidence of game-changing discovery of subatomic particle.

CORRIERE DELLA SERA: La particella che può svelare i segreti dell'universo. Risultato a oggi il voto sui nuovi consiglieri.

gazeta: Czastke Higgsa fizycy najpierw wymyślili, potem szukali 40 lat. Ukraińcy nie są o Język Rosyjski.

বিশ্বনাথের 'ঈশ্বর' দর্শন. সত্যেন্দ্রনাথকে বিনয় প্রণাম. 'পেয়েছি, যা খুঁজছিলাম'.

Peter Higgs and Francois Englert

