

From Pudsey to CERN

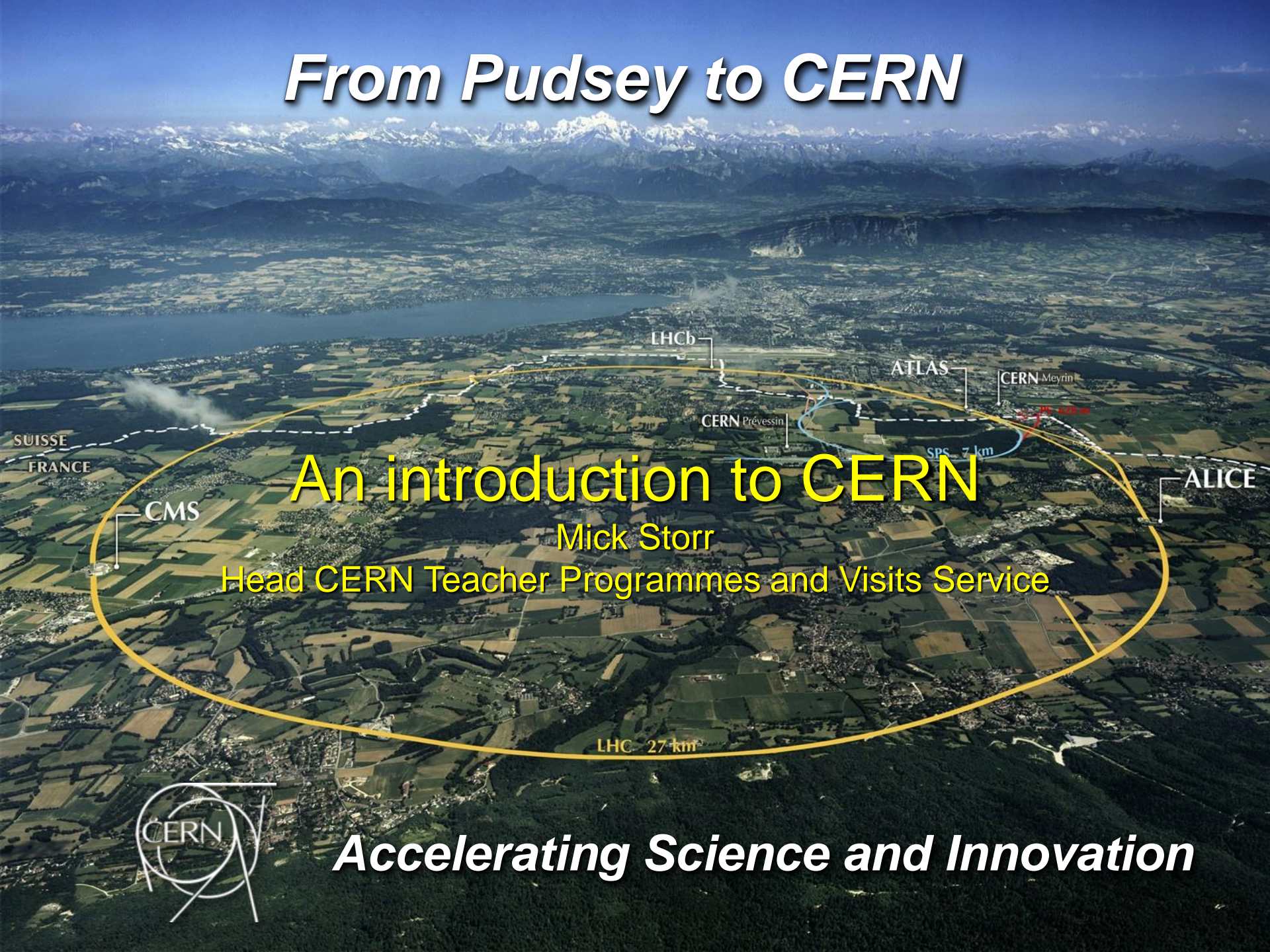
An introduction to CERN

Mick Storr

Head CERN Teacher Programmes and Visits Service

CERN

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: 20 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, Italy, the Netherlands, Norway, Poland, Portugal, Slovakia, Spain, Sweden, Switzerland and the United Kingdom

Candidate for Accession: Romania

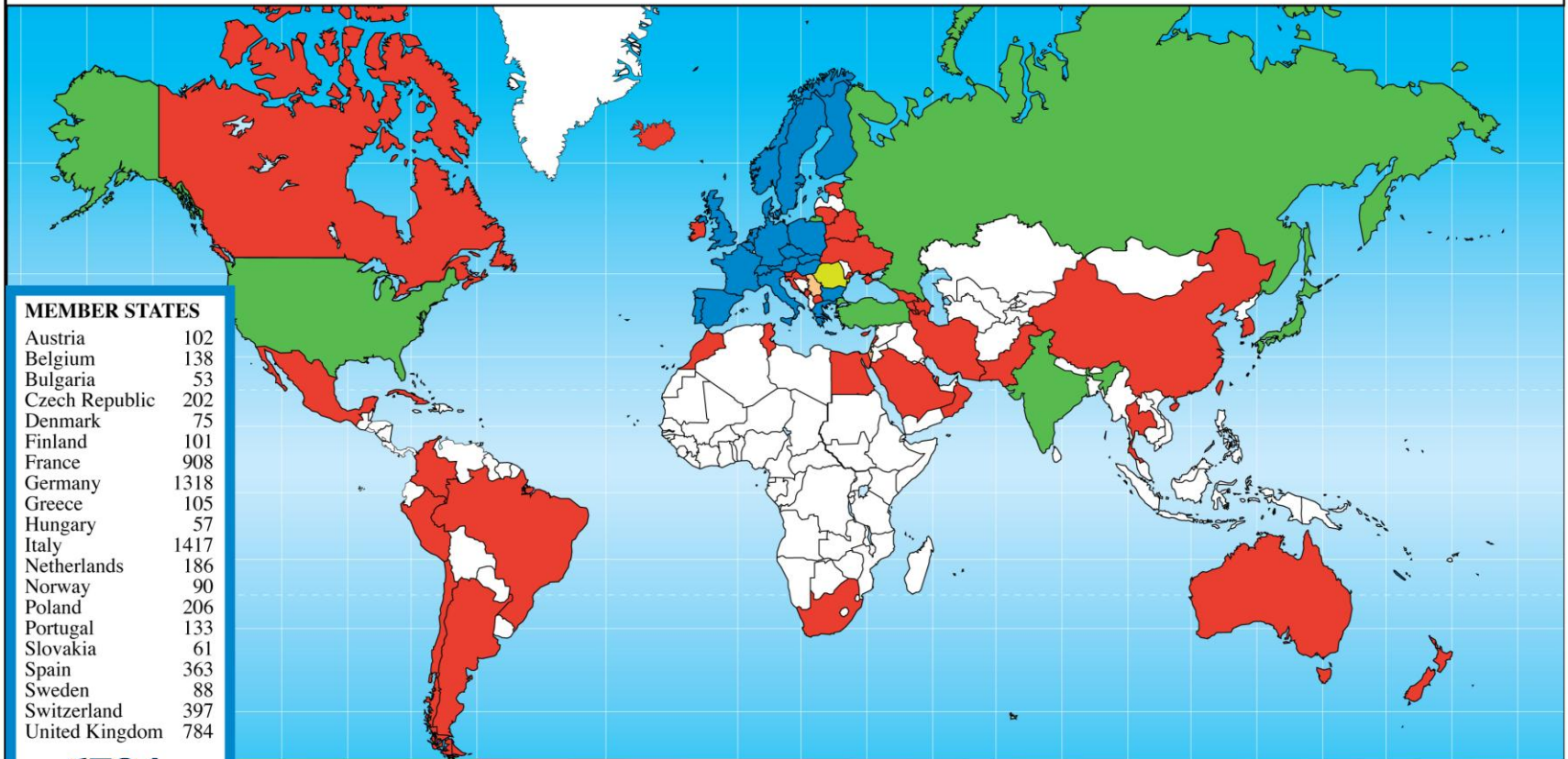
Associate Members in the Pre-Stage to Membership: Israel, Serbia

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 Nation of Institute on 4 April 2012



MEMBER STATES

Austria	102
Belgium	138
Bulgaria	53
Czech Republic	202
Denmark	75
Finland	101
France	908
Germany	1318
Greece	105
Hungary	57
Italy	1417
Netherlands	186
Norway	90
Poland	206
Portugal	133
Slovakia	61
Spain	363
Sweden	88
Switzerland	397
United Kingdom	784

6784

OBSERVERS

India	134
Japan	225
Russia	859
Turkey	83
USA	1749

3050

CANDIDATE FOR ACCESSION

Romania	78
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ASSOCIATE MEMBER IN THE PRE-STAGE TO MEMBERSHIP

Israel	67
Serbia	26

OTHERS

Argentina	18
Armenia	13
Australia	28
Azerbaijan	1
Belarus	22
Brazil	102
Canada	170
Chile	4

China	115
China (Taipei)	70
Colombia	10
Croatia	21
Cuba	4
Cyprus	9
Egypt	7
Estonia	17
Georgia	10
Iceland	3

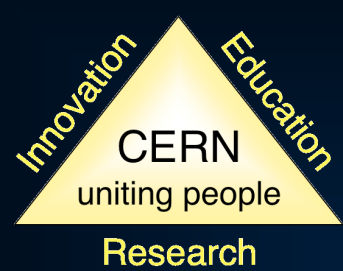
Iran	16
Ireland	10
Korea	91
Lebanon	1
Lithuania	13
Malta	1
Mexico	43
Montenegro	1
Morocco	6
New Zealand	11

Oman	1
Pakistan	22
Peru	2
Qatar	1
Saudi Arabia	3
Slovenia	38
South Africa	21
Thailand	5
T.F.Y.R.O.M.	2
Tunisia	1

Ukraine	21
Uzbekistan	1

934

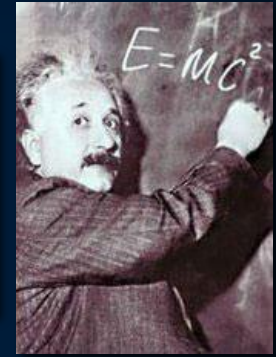




The Mission of CERN

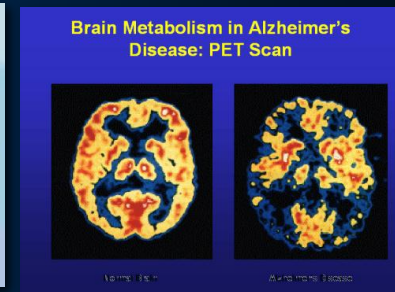
- ❑ **Push forward** the frontiers of knowledge

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

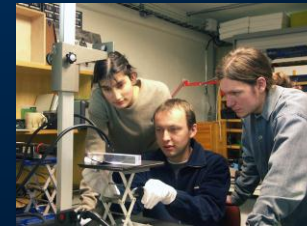


- ❑ **Develop** new technologies, accelerators and detectors

Information technology
Medicine - diagnosis and therapy



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

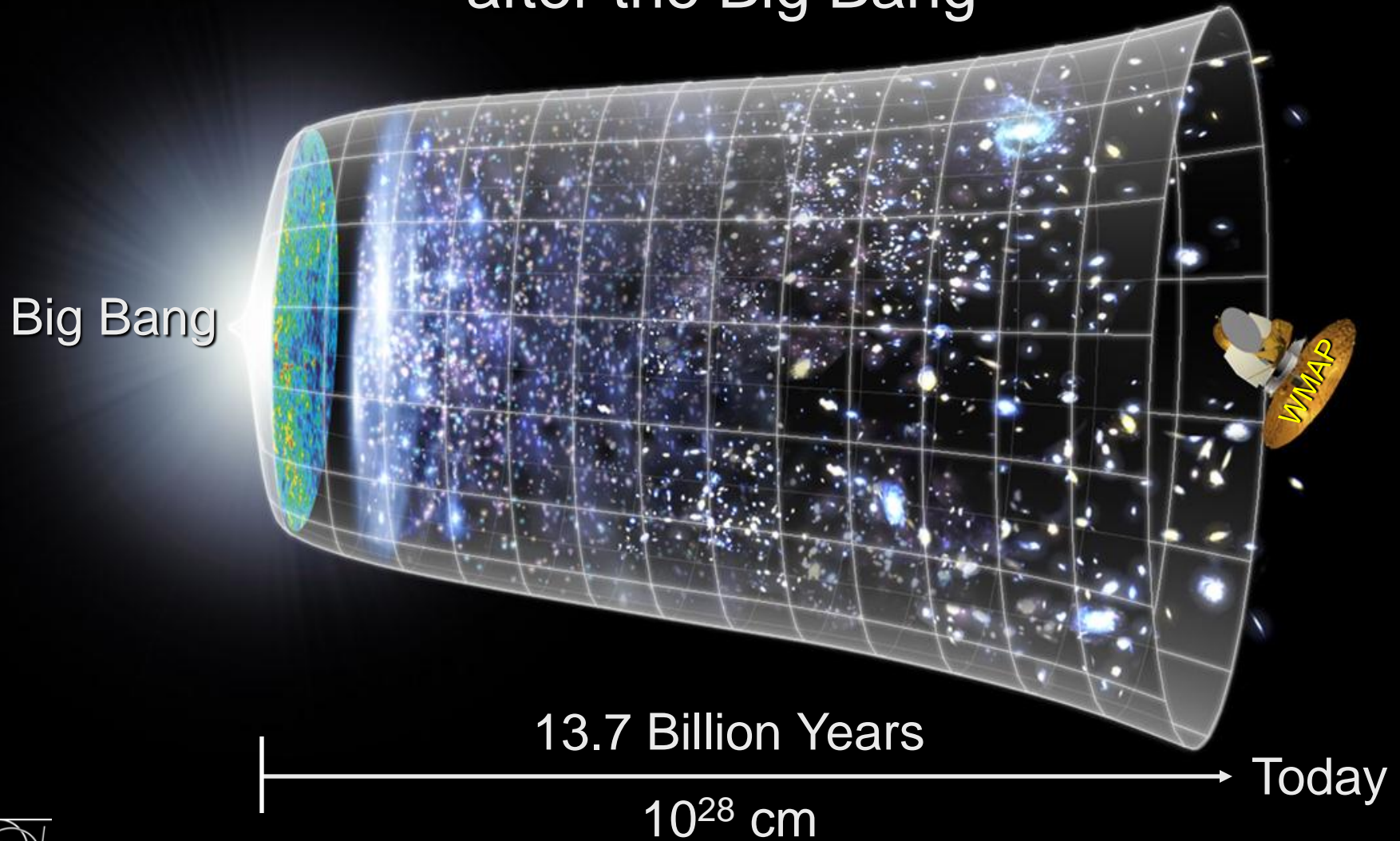


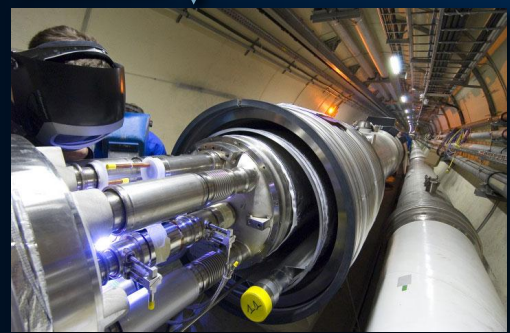
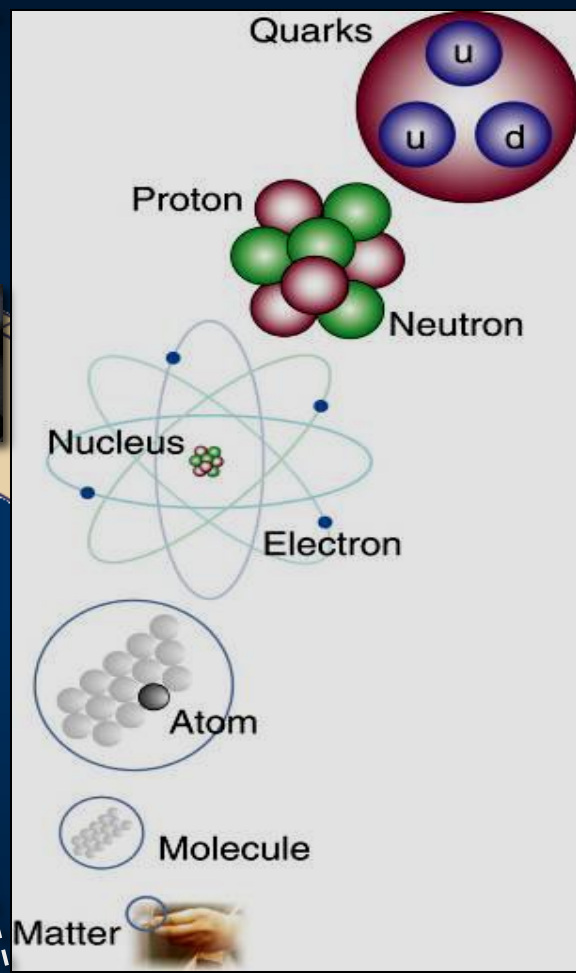
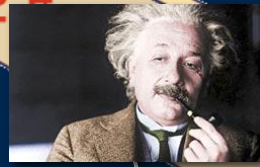
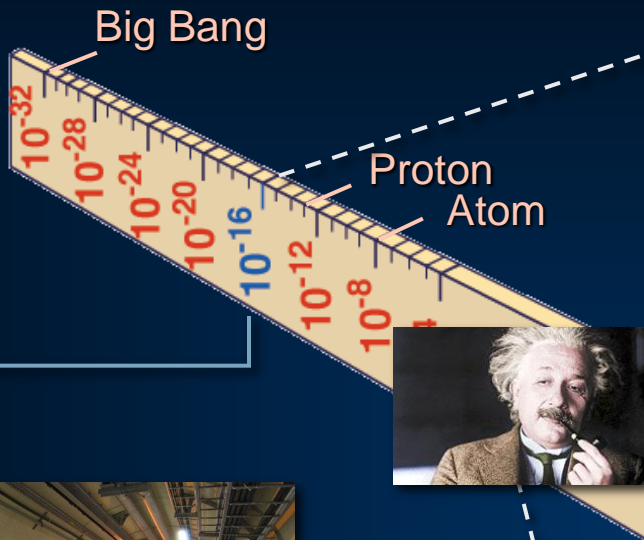
- ❑ **Unite** people from different countries and cultures



Next Scientific Challenge:

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





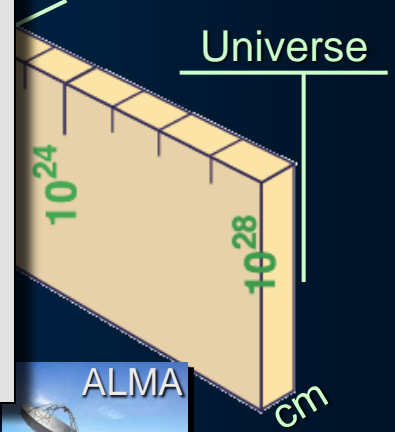
LHC

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



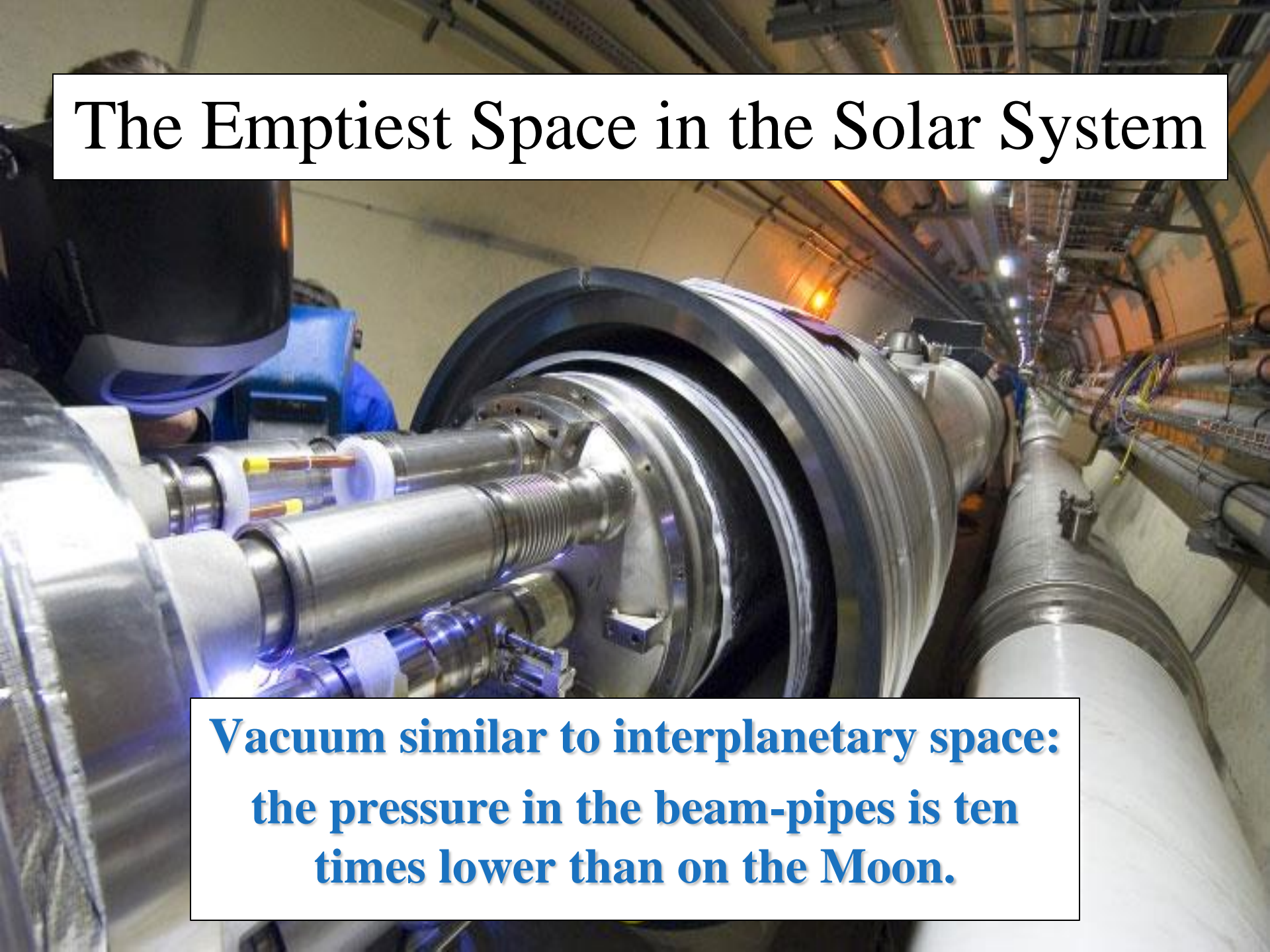
1,000,000,000 collisions/second

Total energy over 8,000 proton masses

Primary targets:

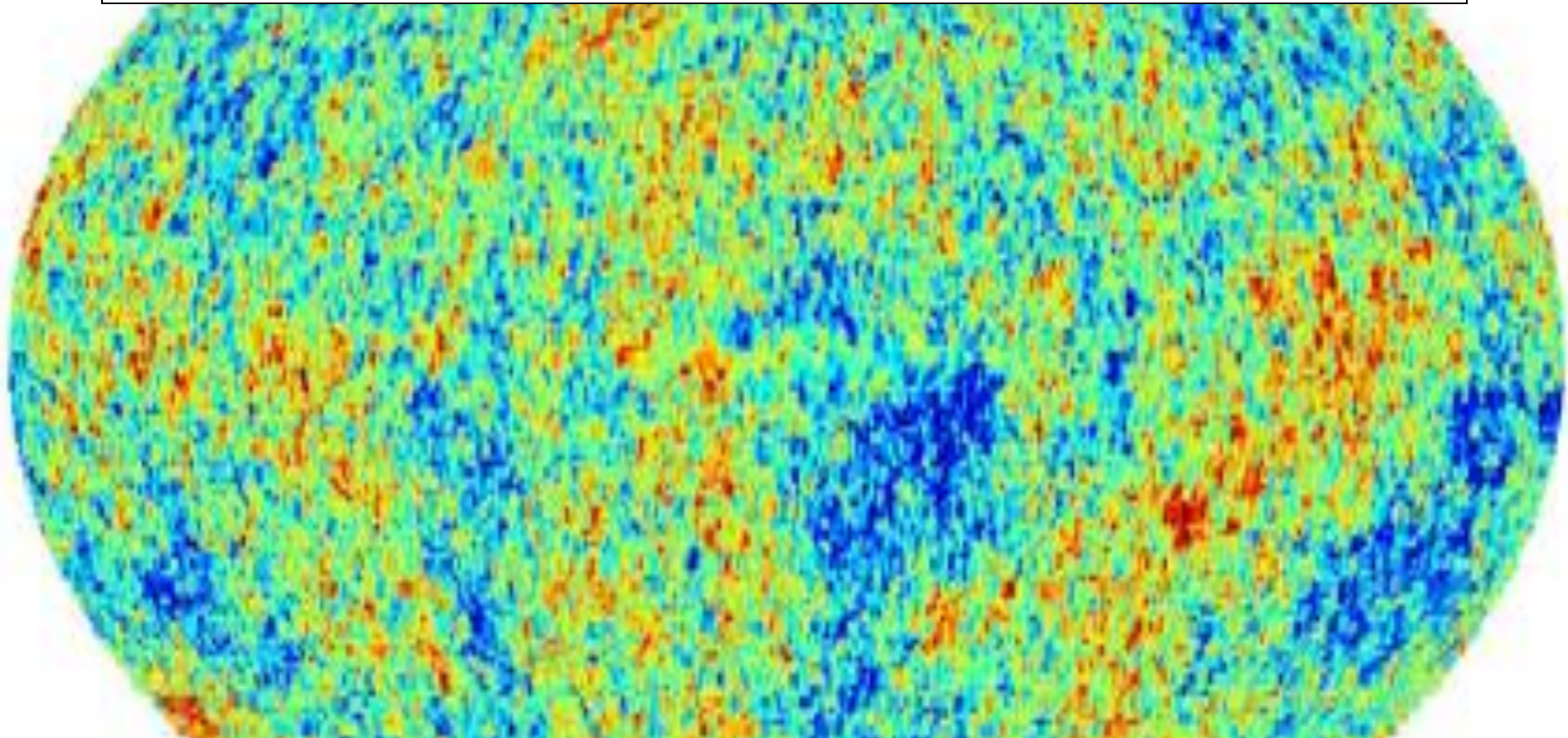
- Origin of mass
- Nature of Dark Matter
- Primordial Plasma
- Matter vs Antimatter

The Emptiest Space in the Solar System

A photograph of a long, brightly lit tunnel, likely a particle accelerator. The tunnel is filled with various pipes, machinery, and structural elements. The lighting is warm and focused on the central axis of the tunnel, creating a sense of depth and scale. The machinery appears to be highly complex and precise, typical of a high-energy physics facility.

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

Colder than Outer Space

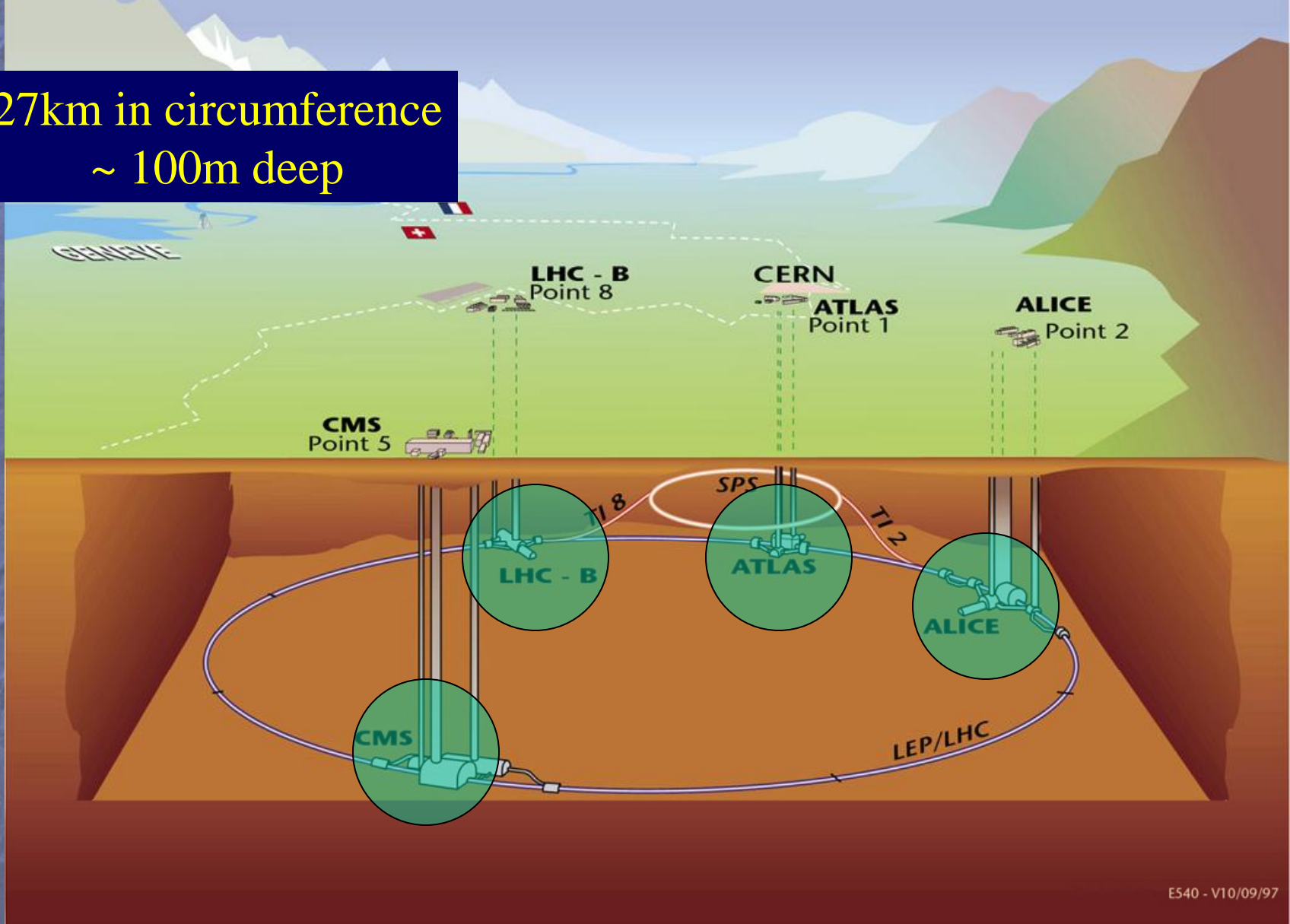


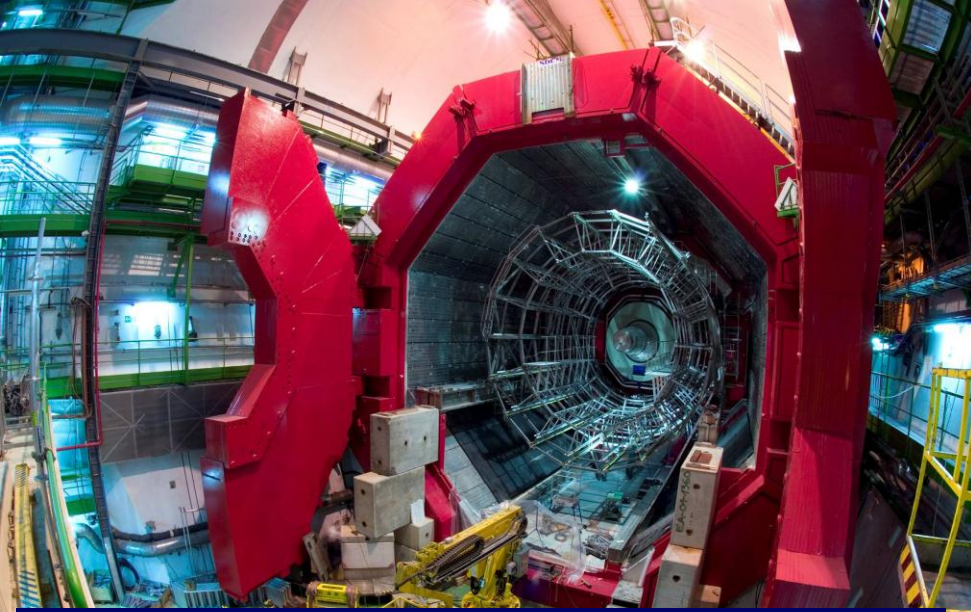
LHC 1.9 degrees above absolute zero = - 271 C

Outer space 2.7 degrees above zero = - 270 C

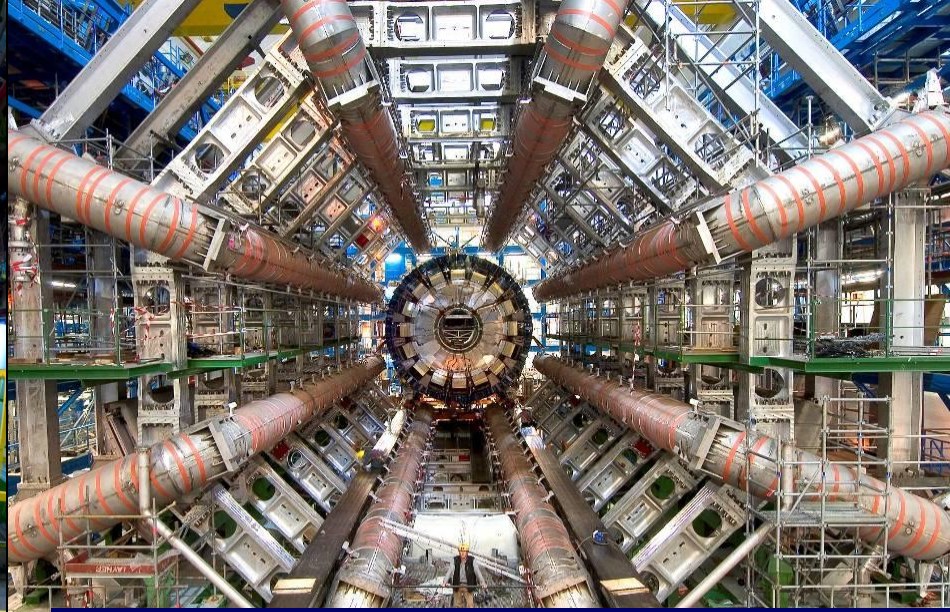
General View of LHC & its Experiments

27km in circumference
~ 100m deep

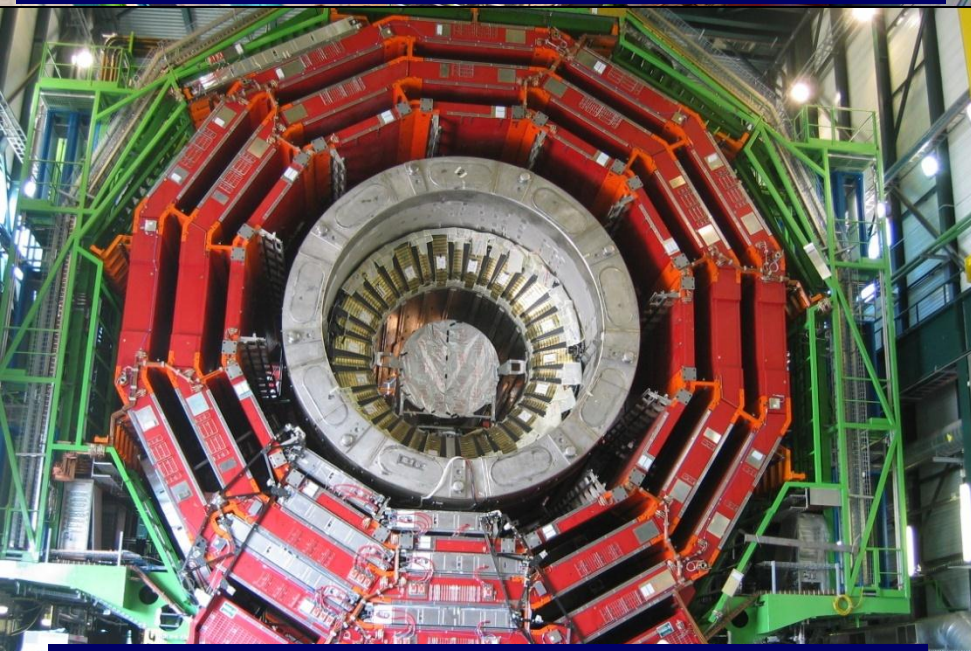




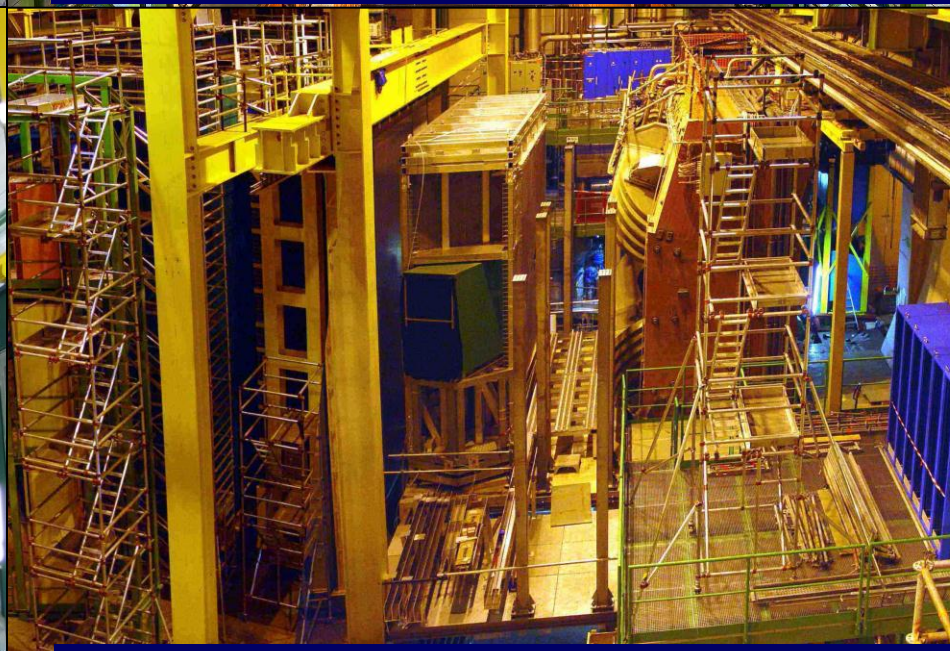
ALICE: Primordial cosmic plasma



ATLAS: Higgs and supersymmetry




CMS: Higgs and supersymmetry



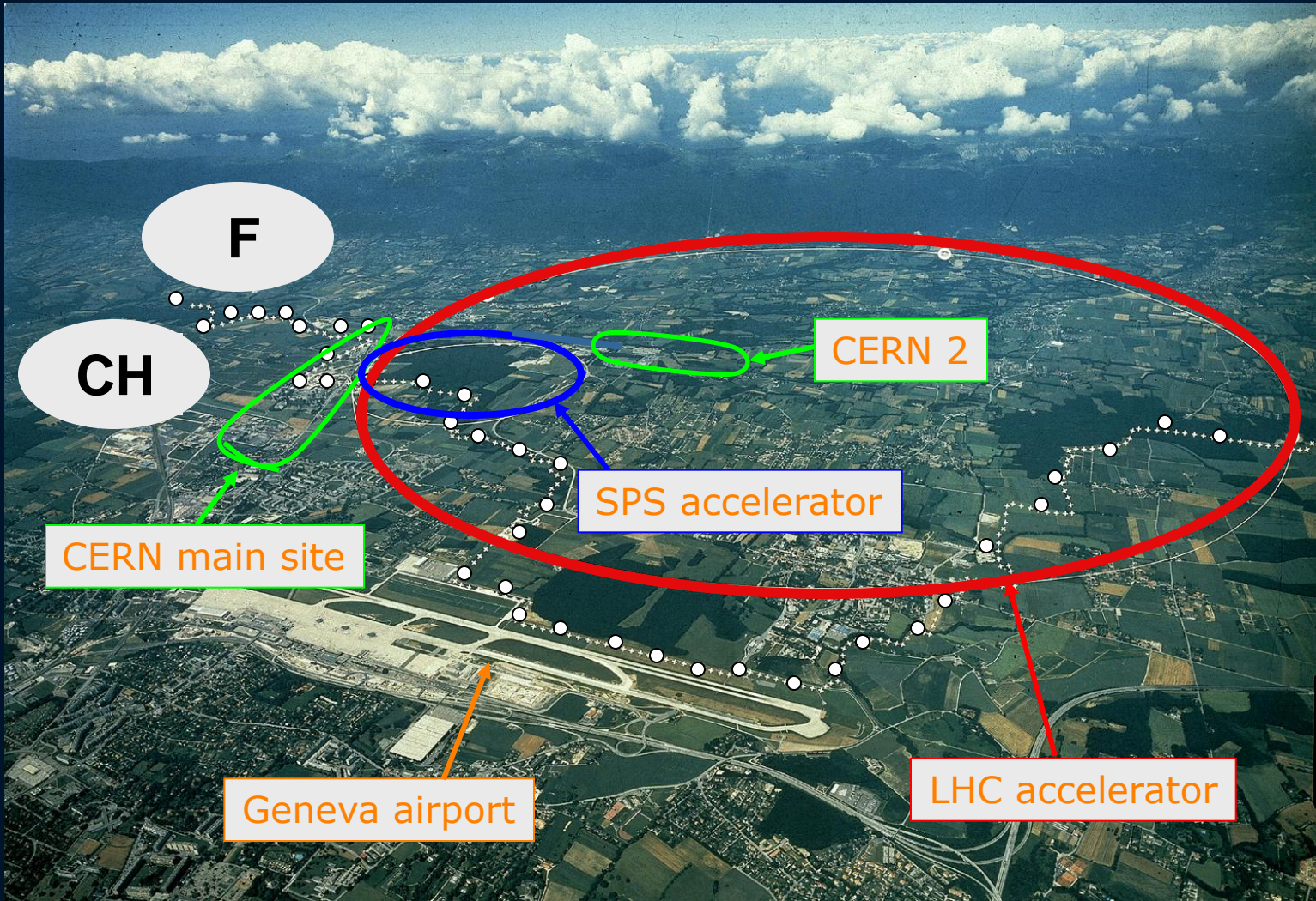
LHCb: Matter-antimatter difference



The Hottest Place in the Galaxy



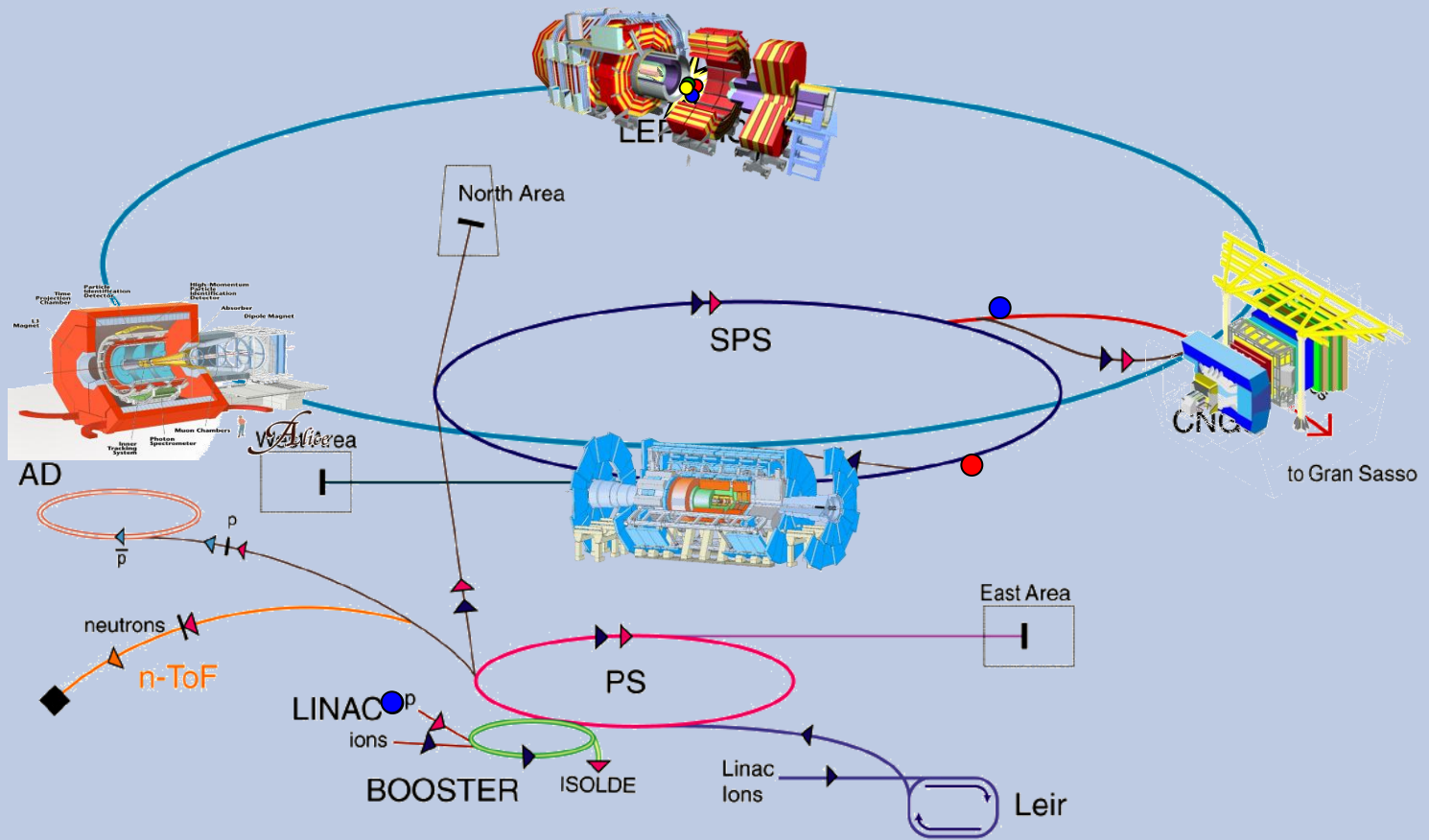
**Particle collisions create
(within a tiny volume)
temperatures a billion times higher than
in the heart of the Sun**



Large Hadron Collider

Collision of proton beams...

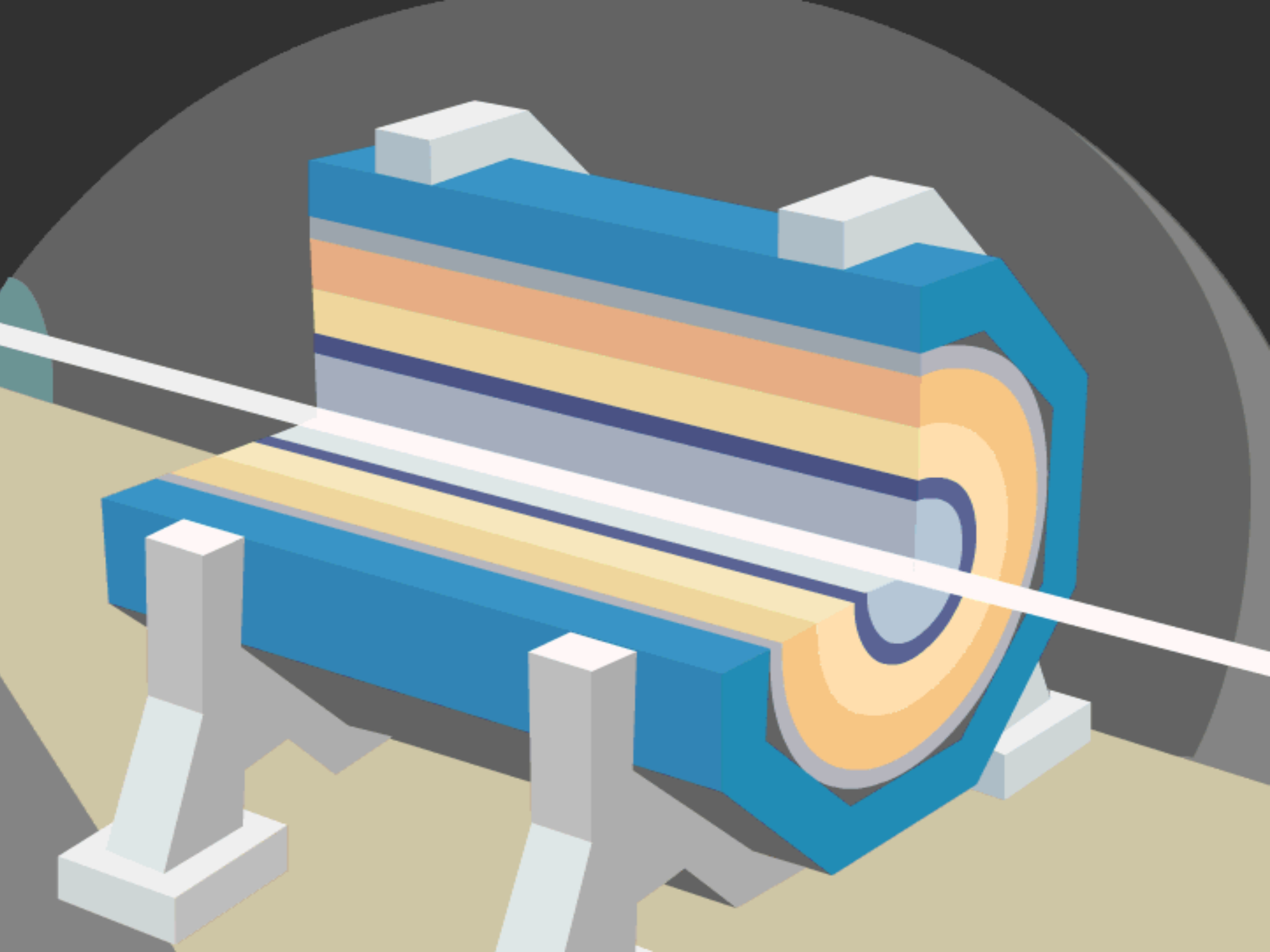
...observed in giant detectors



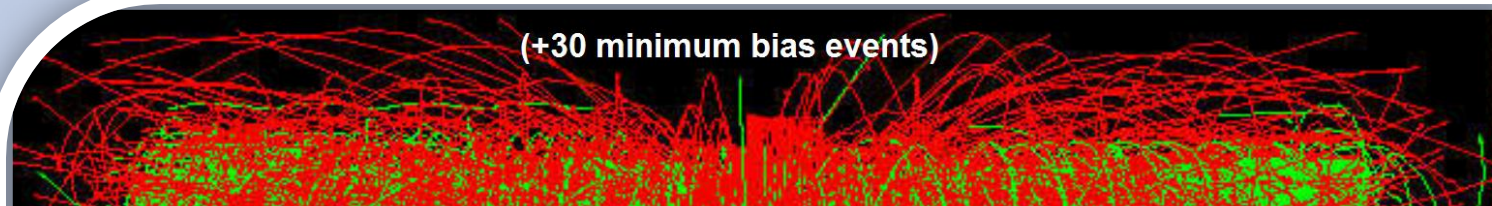
- ▶ p (proton)
- ▶ ion
- ▶ neutron
- ▶ \bar{p} (antiproton)
- ▶ $\bar{\nu}$ proton/antiproton conversion
- ▶ neutrino

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

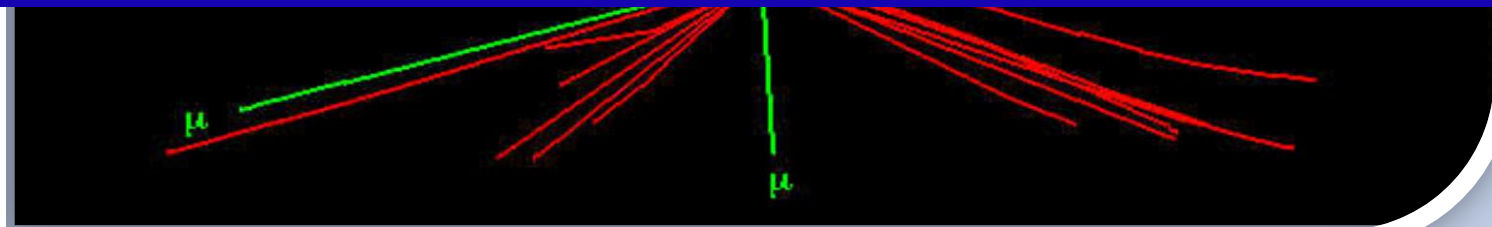
- LHC Large Hadron Collider
- n-ToF Neutron Time of Flight
- CNGS CERN Neutrinos to Gran Sasso



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



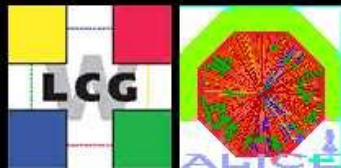
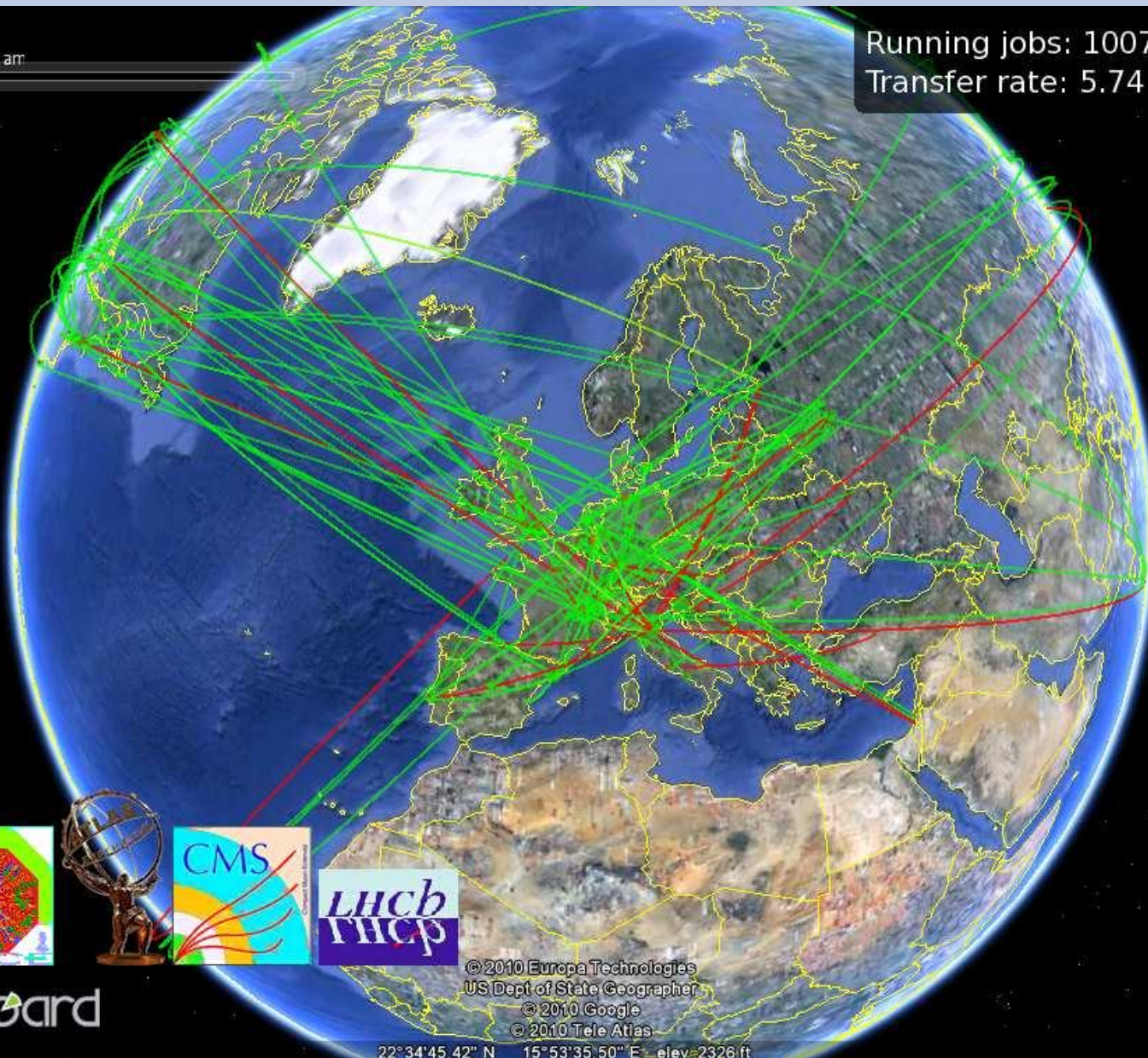
- LHC experiments produce **10-15 million Gigabytes** of data each year (about 20 million CDs!)
- LHC data analysis requires a computing power equivalent to **~100,000 of today's fastest PC processors.**



LCG-LHC Computing GRID

Oct 6, 2010 7:20:00 am

Running jobs: 100767.0
Transfer rate: 5.74 GiB/sec



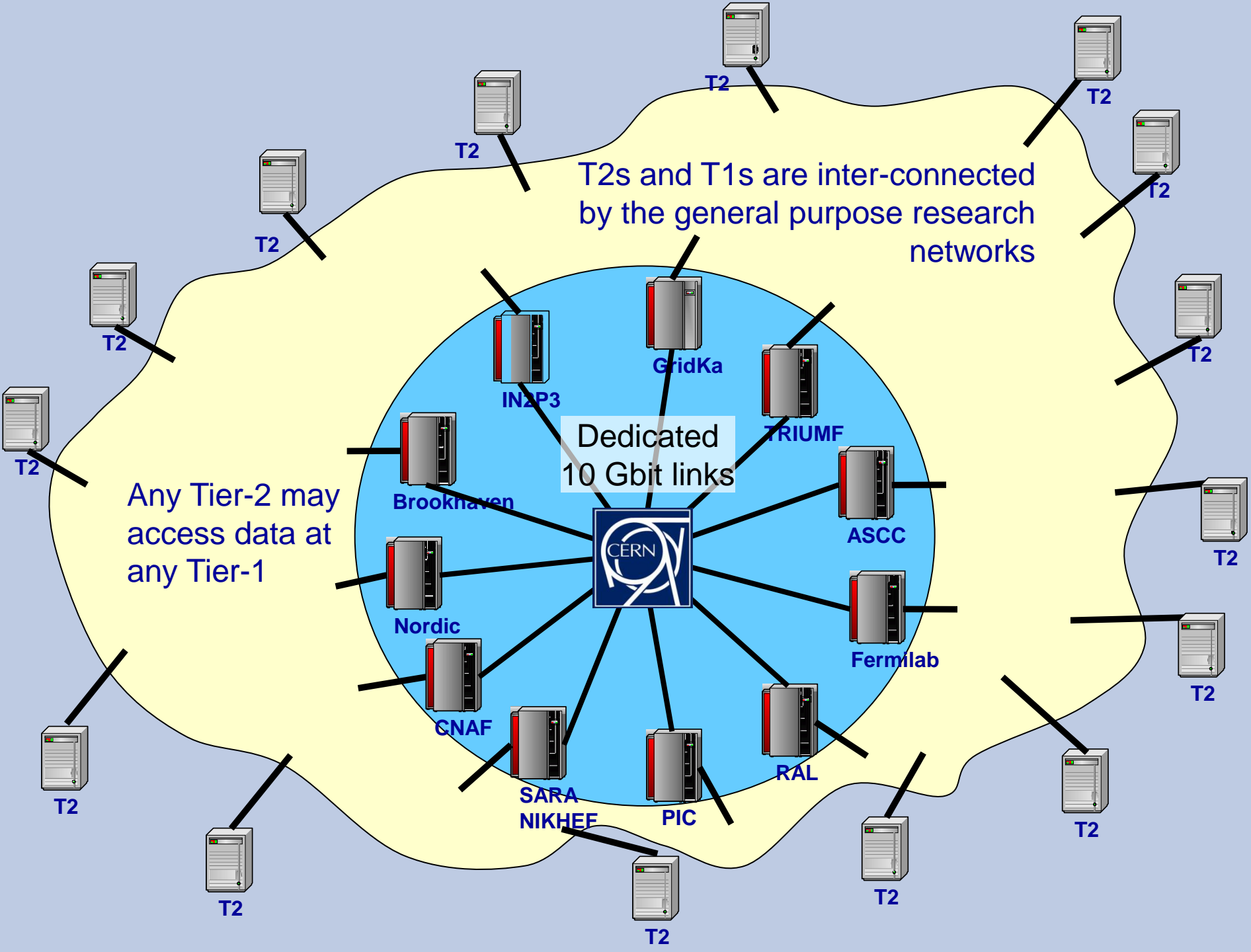
© 2010 Europa Technologies
US Dept of State Geographer

© 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



T2s and T1s are inter-connected by the general purpose research networks

Dedicated 10 Gbit links

Any Tier-2 may access data at any Tier-1



IN2P3

GridKa

TRIUMF

Brookhaven

ASCC

Nordic

Fermilab

CNAF

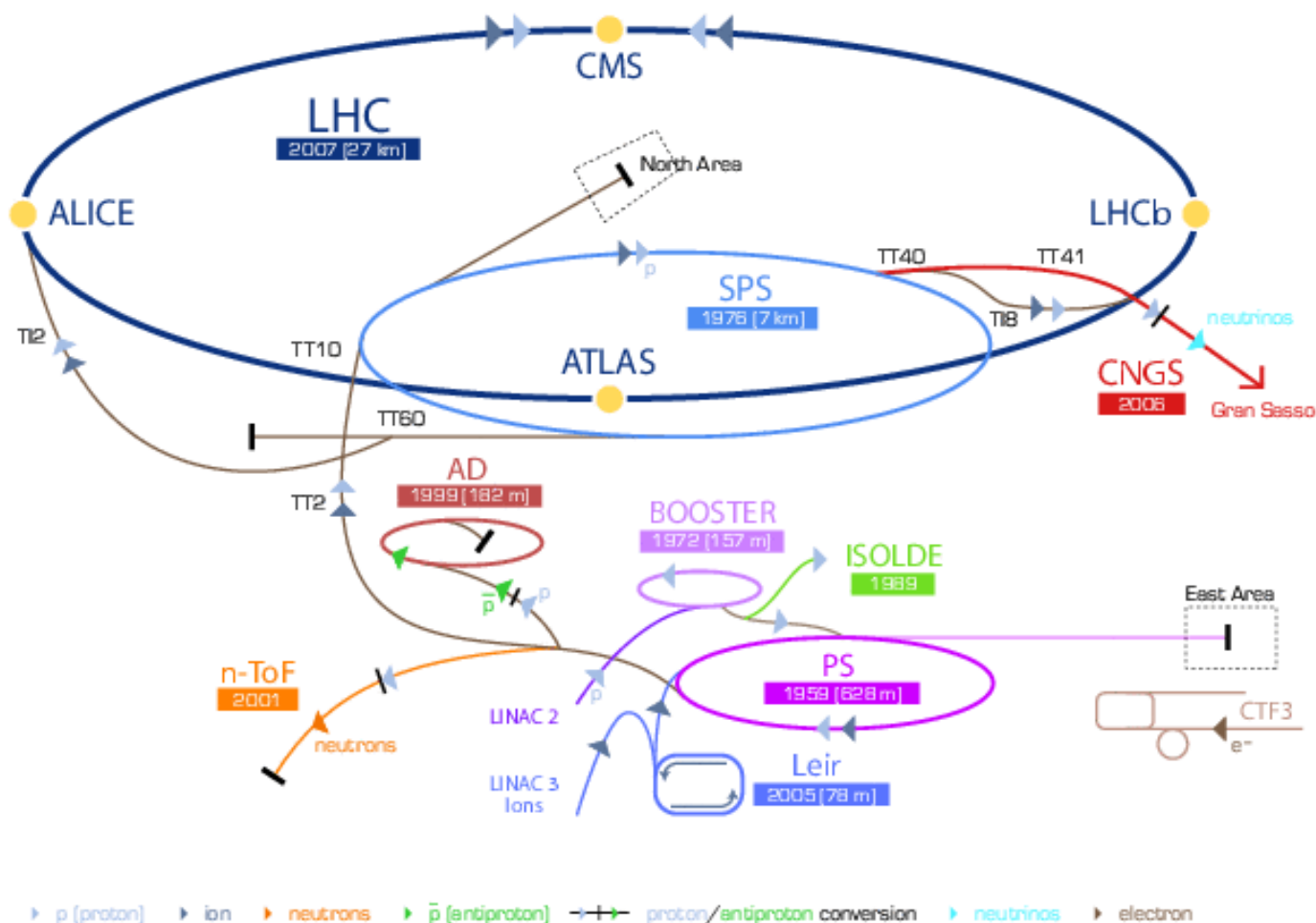
RAL

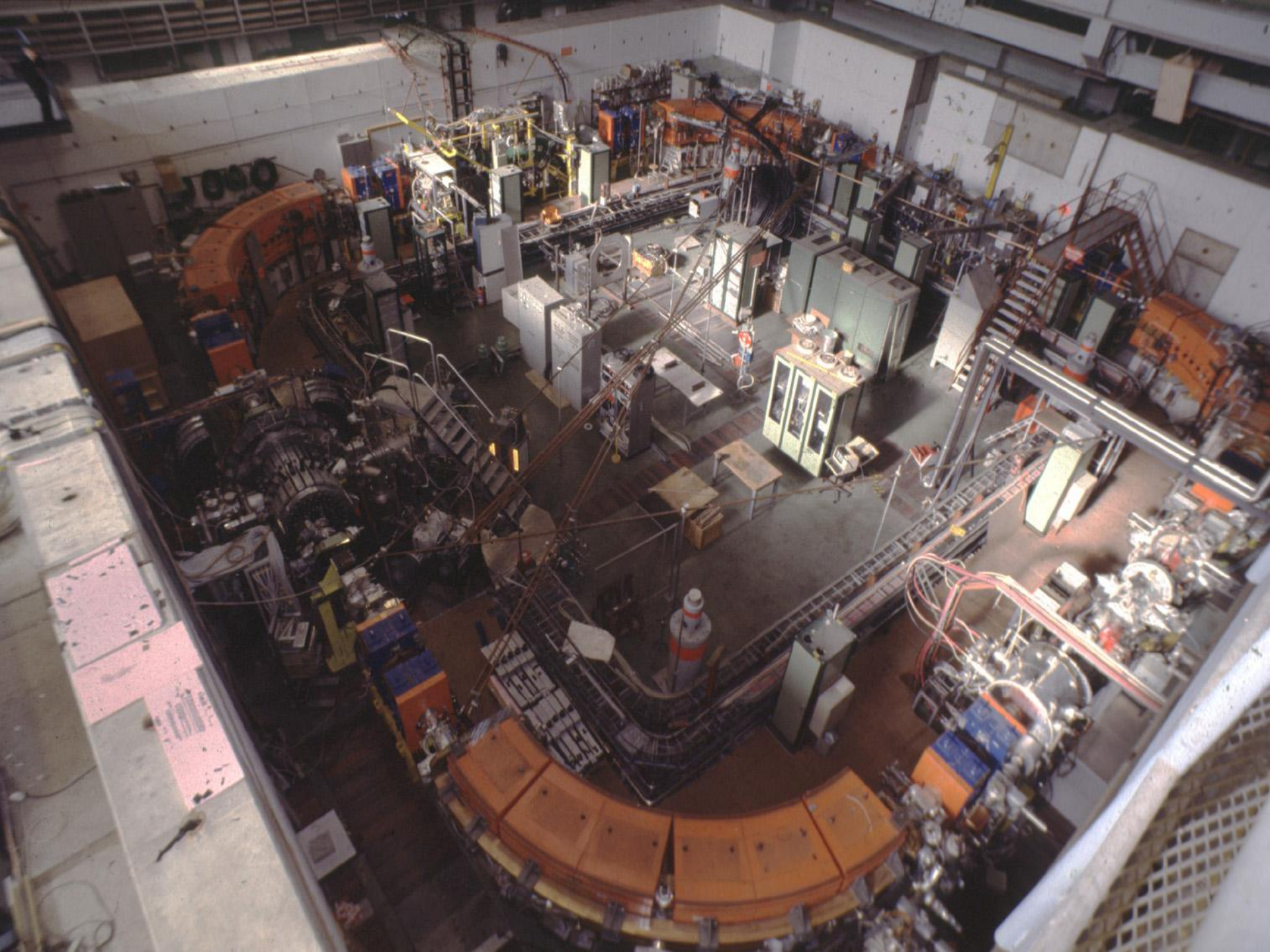
SARA

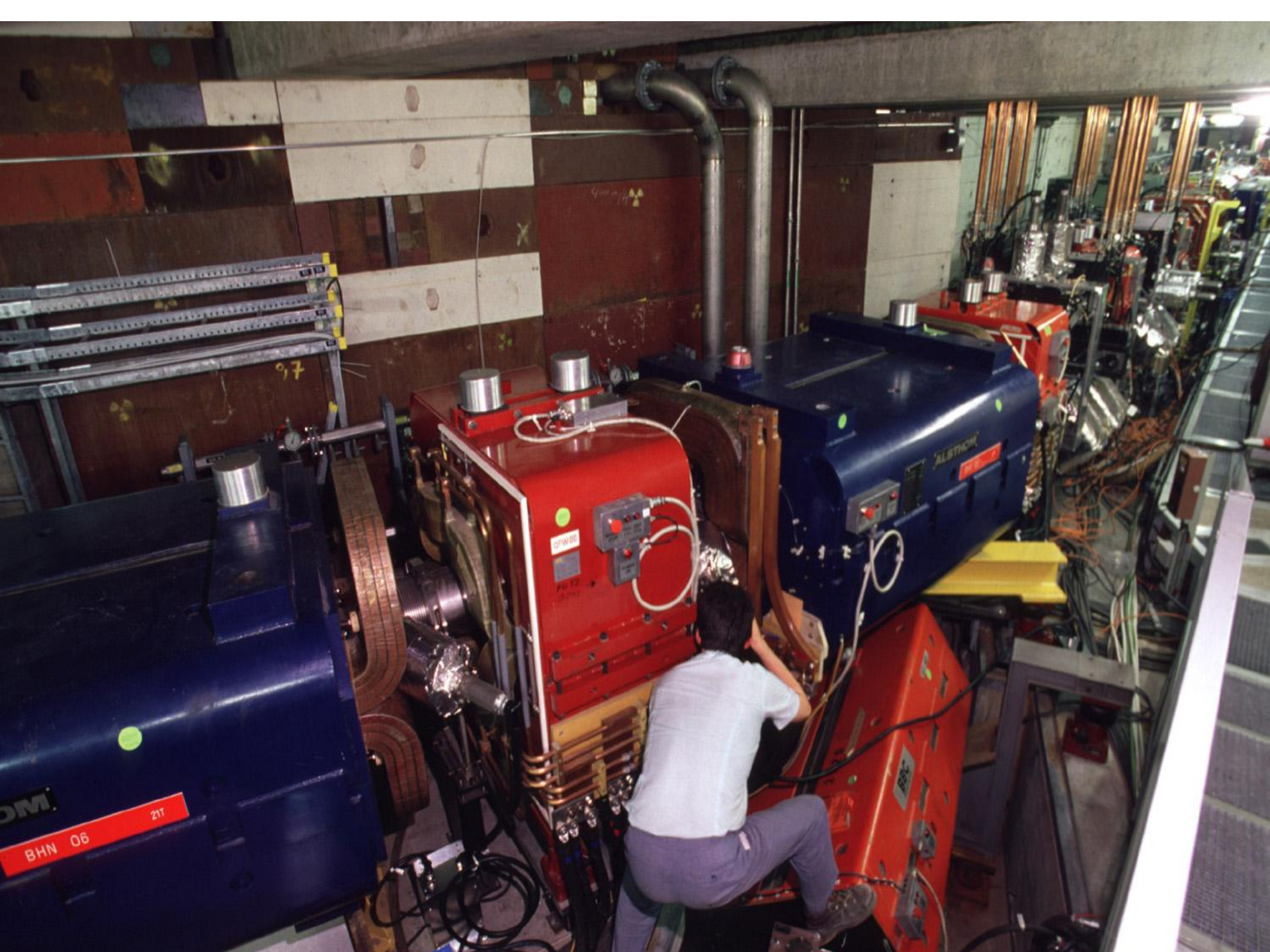
NIKHEF

PIC

CERN – world biggest accelerator complex





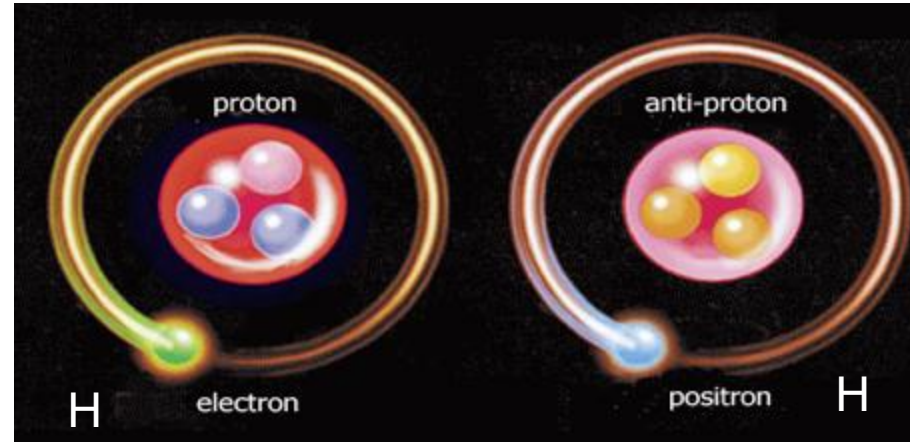


Antimatter Physics

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 !

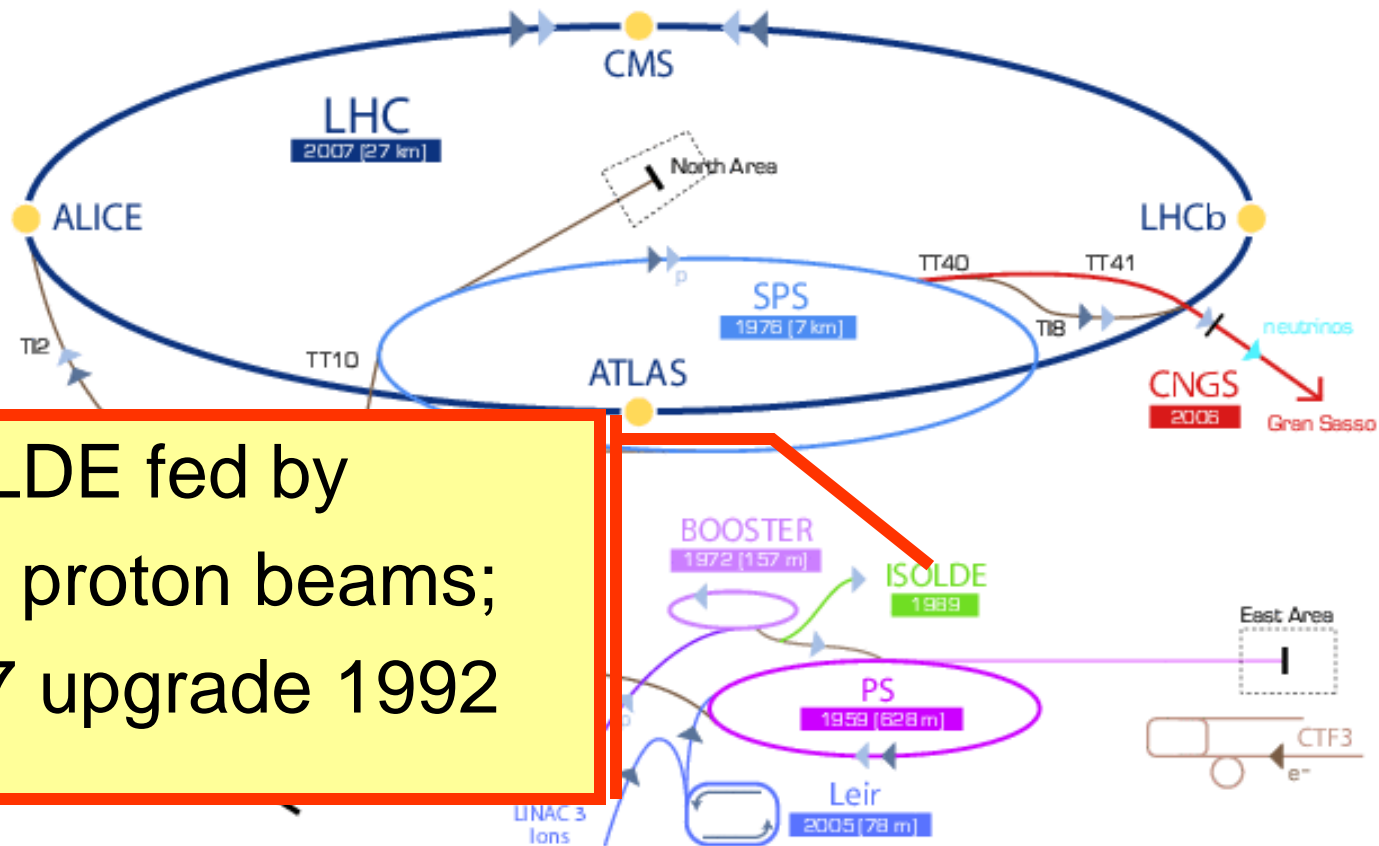


ACE

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



CERN accelerator complex, working not only for LHC



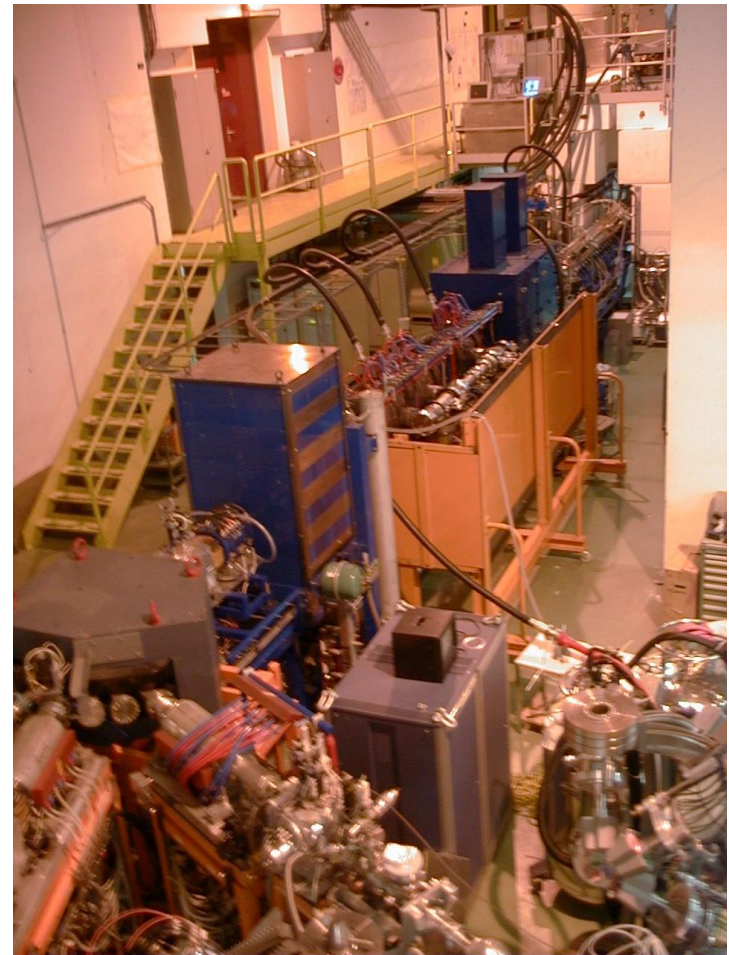
ISOLDE fed by
PSB proton beams;
1967 upgrade 1992

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

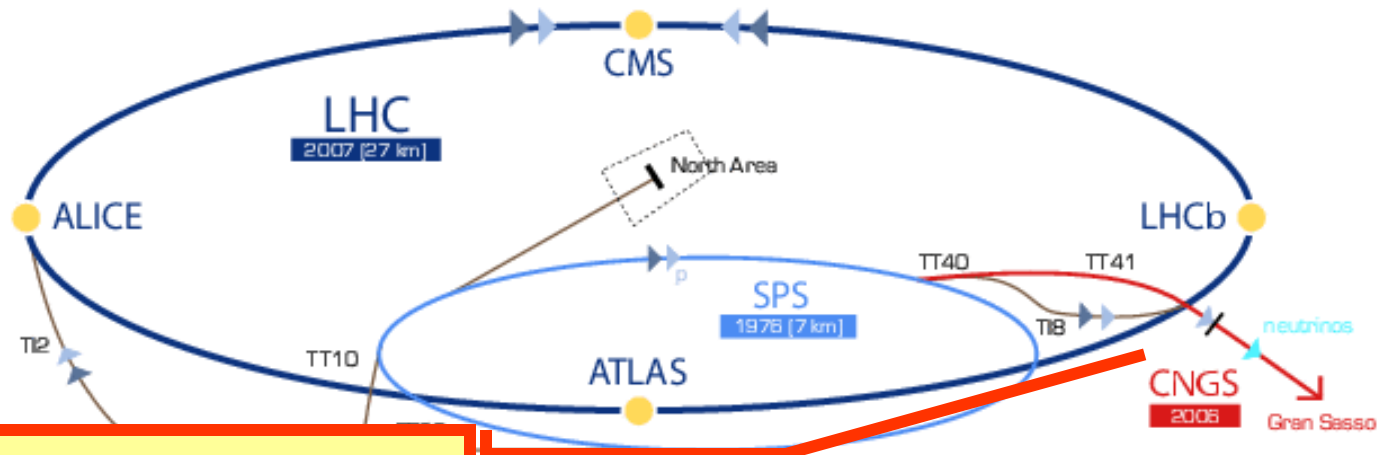
ISOLDE - Isotope Separator On Line, and Radioactive beam EXperiment (REX)

An alchemical factory for nuclear physics

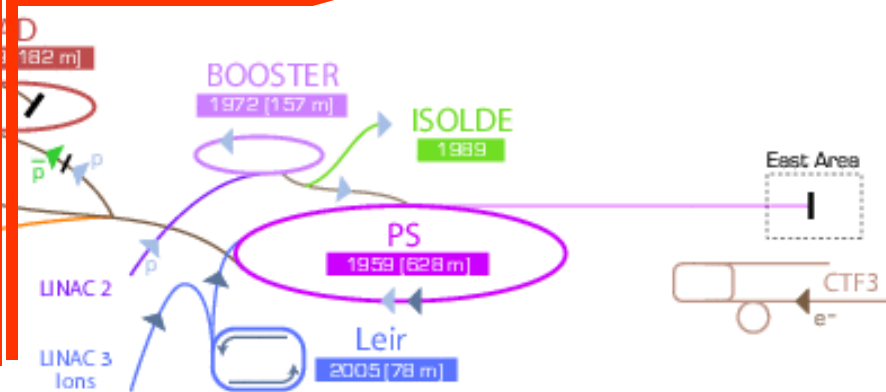
Low-energy beams of radioactive isotopes - atomic nuclei. The facility, located at the Proton-Synchrotron Booster (PSB), is like a small alchemical factory, changing one element to another. It produces a total of more than 1000 different isotopes for a wide range of research.



CERN accelerator complex, working not only for LHC !



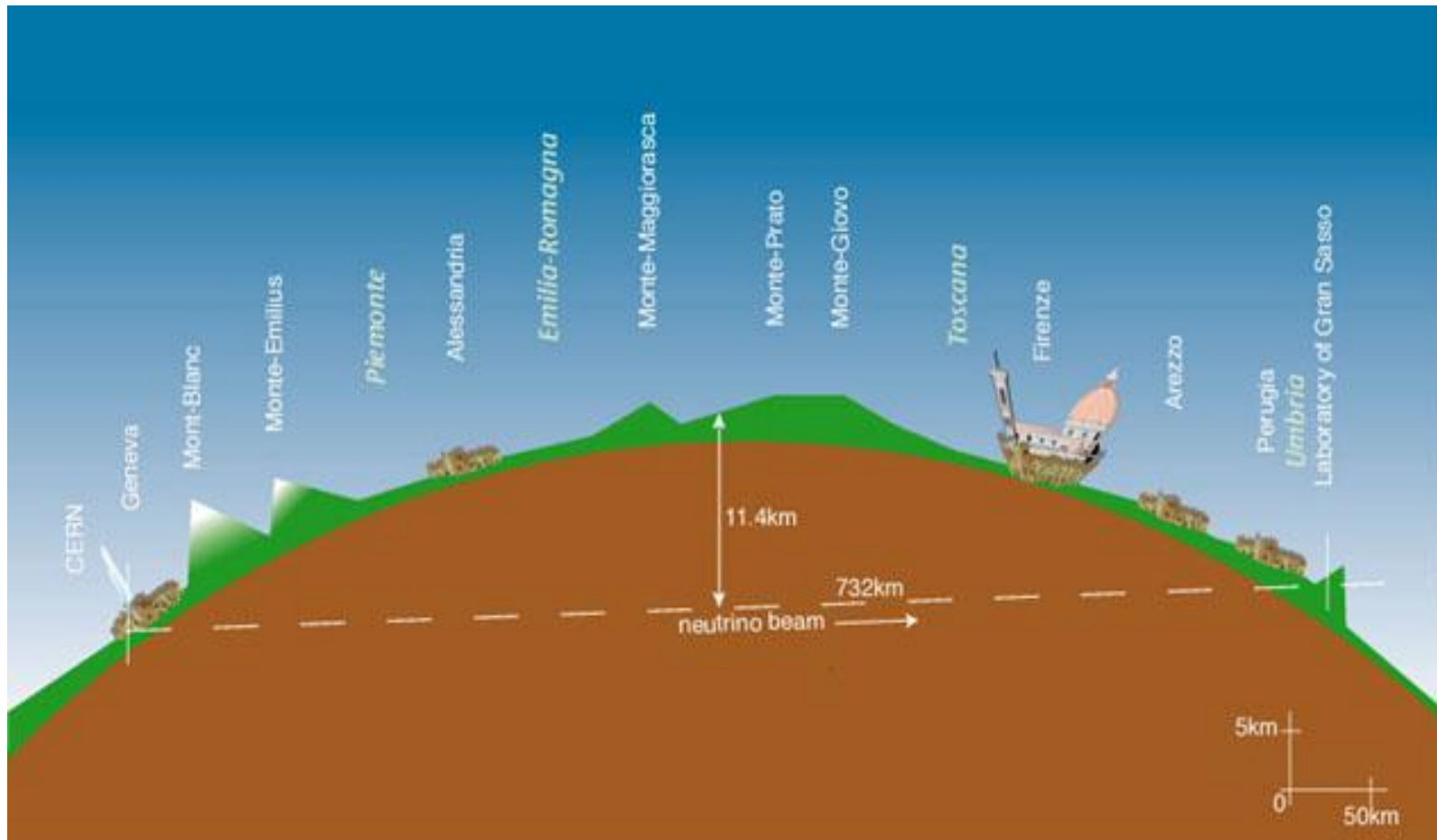
CNGS fed by
SPS proton beams



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

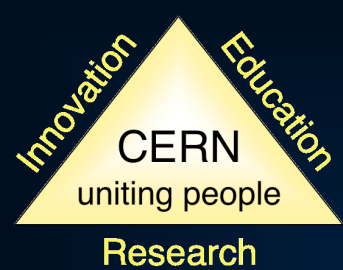
CNGS – CERN Neutrino to Gran Sasso experiment - investigation of the nature of neutrinos

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

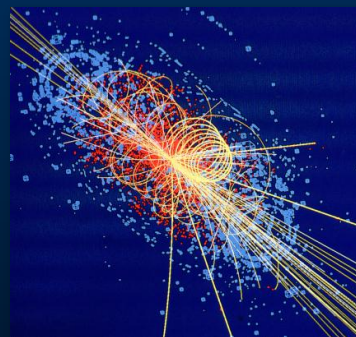
- ❑ **Interfacing** between fundamental science and key technological developments



- ❑ **CERN Technologies and Innovation**



Accelerating particle beams



Detecting particles



Large-scale computing (Grid)

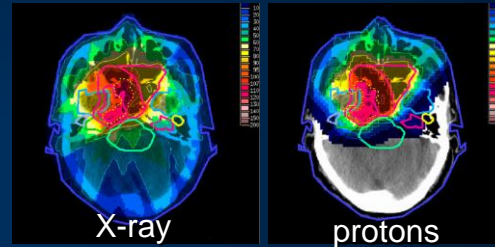
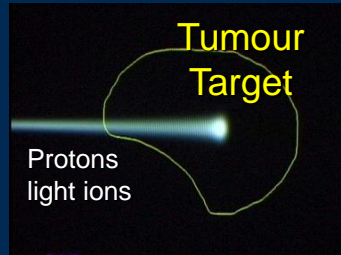
Medical Application as an Example of Particle Physics Spin-off

Combining Physics, ICT, Biology and Medicine to fight cancer



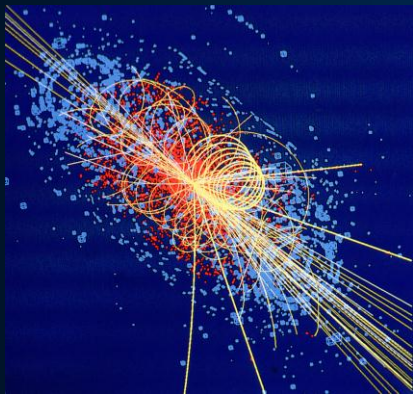
Hadron Therapy

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)

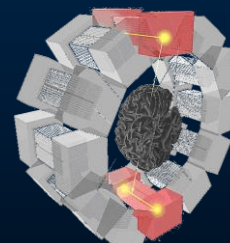


Imaging

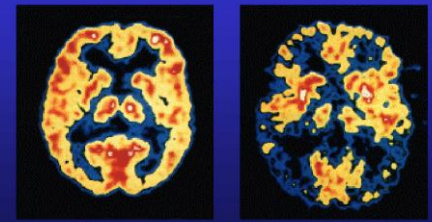
Clinical trial in Portugal for new breast imaging system (ClearPEM)



PET Scanner



Brain Metabolism in Alzheimer's Disease: PET Scan



Detecting particles

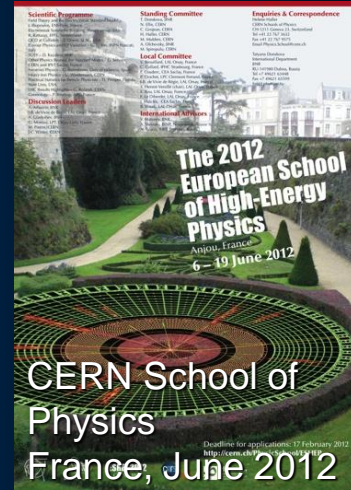
CERN Education Activities

Scientists at CERN
Academic Training Programme



Young Researchers

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



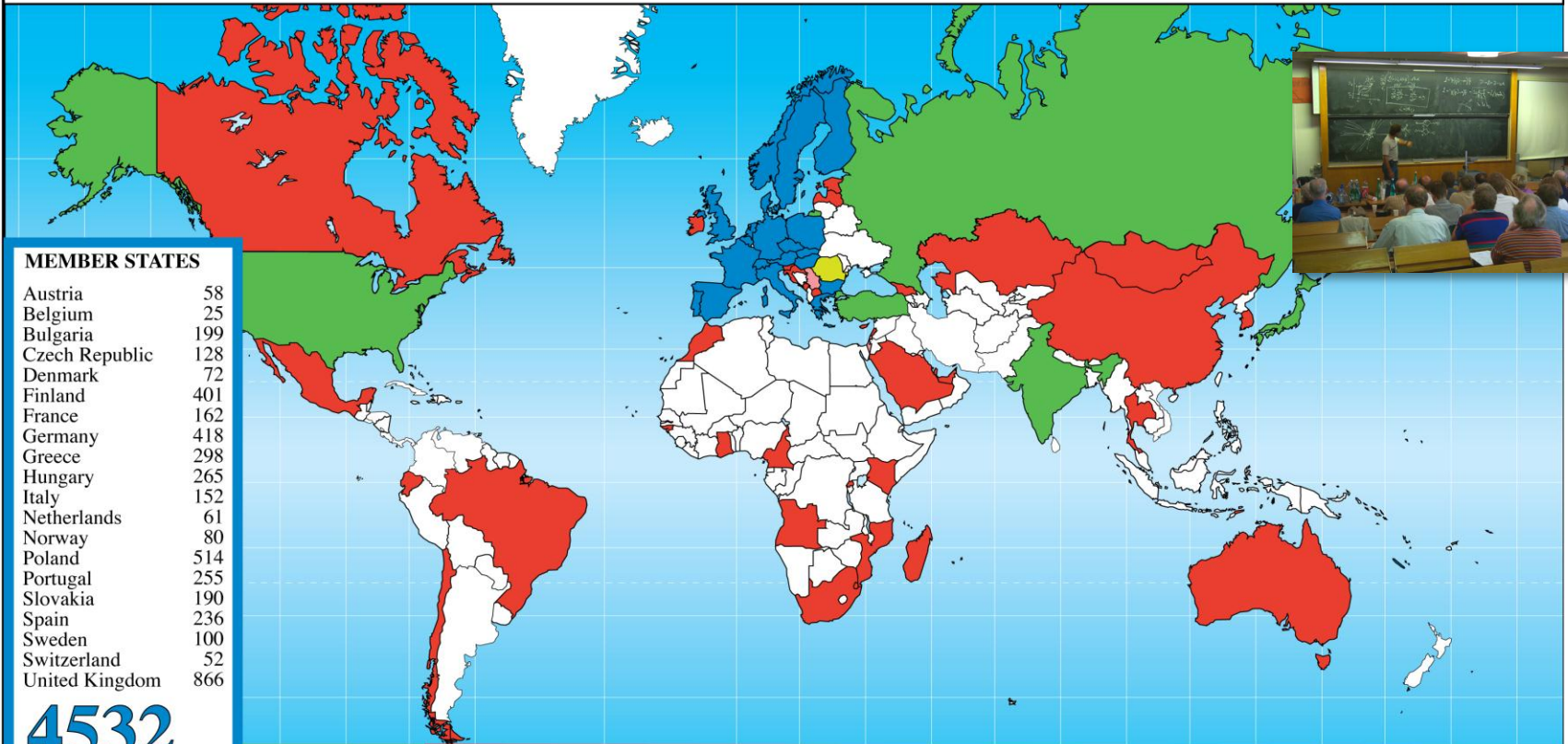
Physics Students
Summer Students
Programme



CERN Teacher Schools
International and National
Programmes

CERN Teacher Programme

CERN Teacher Programme Participants 1998 - 2011



MEMBER STATES

Austria	58
Belgium	25
Bulgaria	199
Czech Republic	128
Denmark	72
Finland	401
France	162
Germany	418
Greece	298
Hungary	265
Italy	152
Netherlands	61
Norway	80
Poland	514
Portugal	255
Slovakia	190
Spain	236
Sweden	100
Switzerland	52
United Kingdom	866

4532

CANDIDATE FOR ACCESSION

Romania	10
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ASSOCIATE MEMBER IN THE PRE-STAGE TO MEMBERSHIP

Israel	2
Serbia	10

OBSERVER STATES

India	2
Japan	3
Russia	132
Turkey	3
USA	56

196

OTHERS

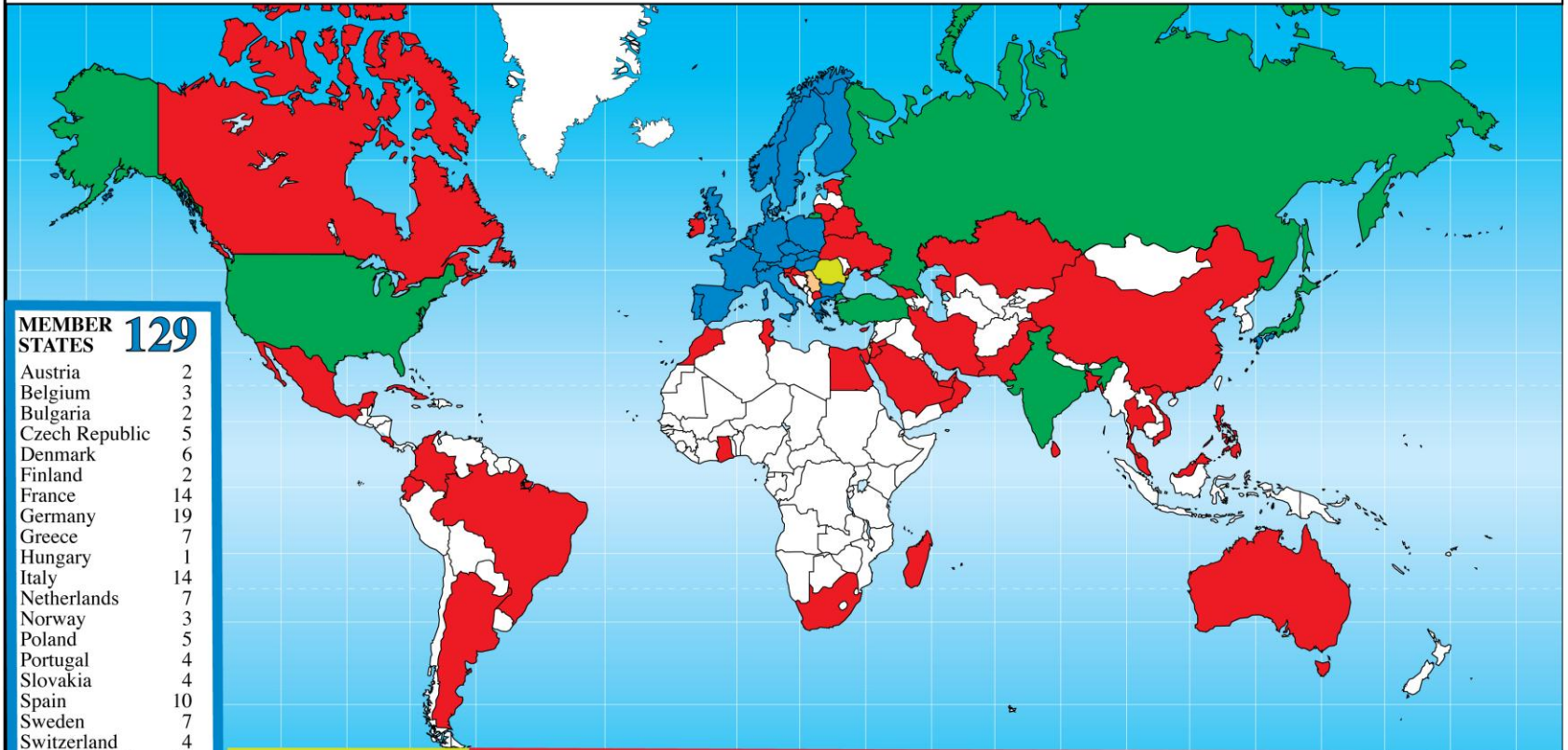
Angola	4	China	1	Kenya	2	Qatar	1	Thailand	4
Australia	3	Croatia	1	Latvia	1	Rwanda	15	T.F.Y.R.O.M.	11
Azerbaijan	1	Cyprus	4	Lebanon	1	Sao Tome	2	Timor-Leste	1
Brazil	53	Ecuador	1	Madagascar	1	Saudi Arabia	1	Ukraine	30
Cameroon	1	Estonia	18	Malta	36	Singapore	2	U.A.E.	1
Canada	1	Georgia	16	Mexico	5	Slovenia	21		
Cape Verde	2	Ghana	4	Mongolia	1	South Africa	6		
Chile	3	Guinea Bissau	1	Montenegro	13	South Korea	22		
		Ireland	3	Morocco	2	Swaziland	1		
		Kazakhstan	3	Mozambique	13				

343



Summer Students 2012

Nationality of Summer Students 2012



MEMBER STATES 129

Austria	2
Belgium	3
Bulgaria	2
Czech Republic	5
Denmark	6
Finland	2
France	14
Germany	19
Greece	7
Hungary	1
Italy	14
Netherlands	7
Norway	3
Poland	5
Portugal	4
Slovakia	4
Spain	10
Sweden	7
Switzerland	4
United Kingdom	10

OBSERVERS 41

India	5
Japan	5
Russia	11
Turkey	6
USA	14

CANDIDATE FOR ACCESSION

Romania	6
---------	---

ASSOCIATE MEMBER IN THE PRE-STAGE TO MEMBERSHIP

Israel	2
Serbia	2

OTHERS

Argentina	1	Croatia	6	Iran	4	Morocco	2	Sri Lanka	1
Australia	2	Cuba	2	Ireland	1	Oman	1	Thailand	2
Bangladesh	1	Cyprus	3	Jordan	1	Pakistan	5	Tunisia	1
Belarus	1	Ecuador	2	Kazakhstan	1	Palestinian Territories	1	T.F.Y.R.O.M.	3
Brazil	1	Egypt	3	Lithuania	1	Philippines	1	Ukraine	1
Canada	5	Estonia	5	Madagascar	1	Saudi Arabia	1	U.A.E.	2
China	8	Georgia	1	Malaysia	3	Singapore	2	Vietnam	1
Colombia	1	Ghana	1	Malta	3	Slovenia	1		
Costa Rica	1	Hong Kong	2	Mexico	1	South Africa	2		

89



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.



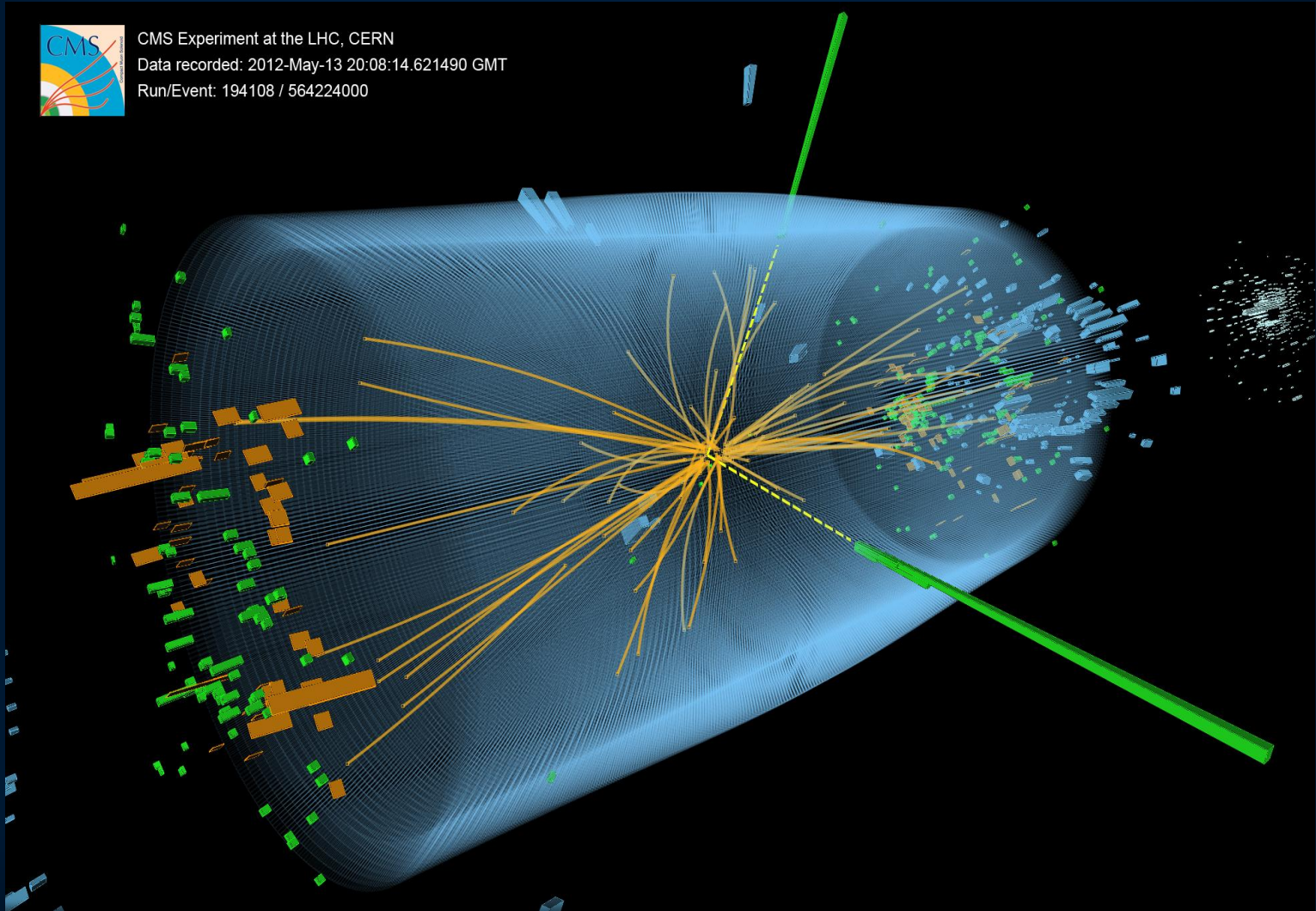
4 July 2012: CERN press conference



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



CMS Experiment at the LHC, CERN
Data recorded: 2012-May-13 20:08:14.621490 GMT
Run/Event: 194108 / 564224000



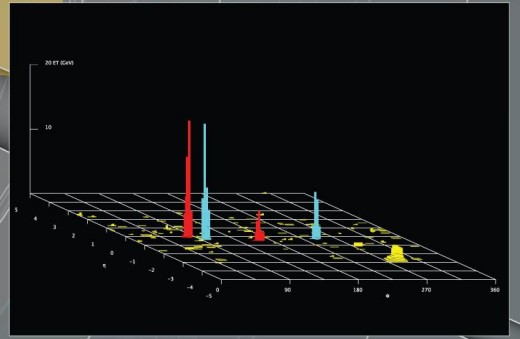
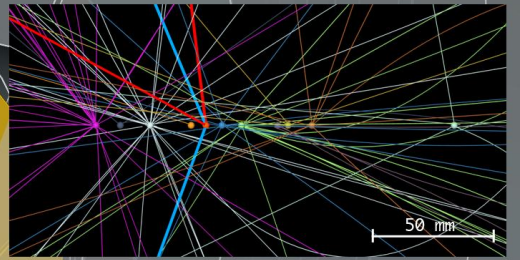
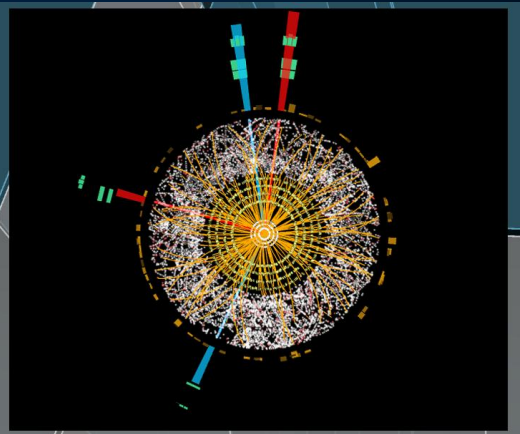
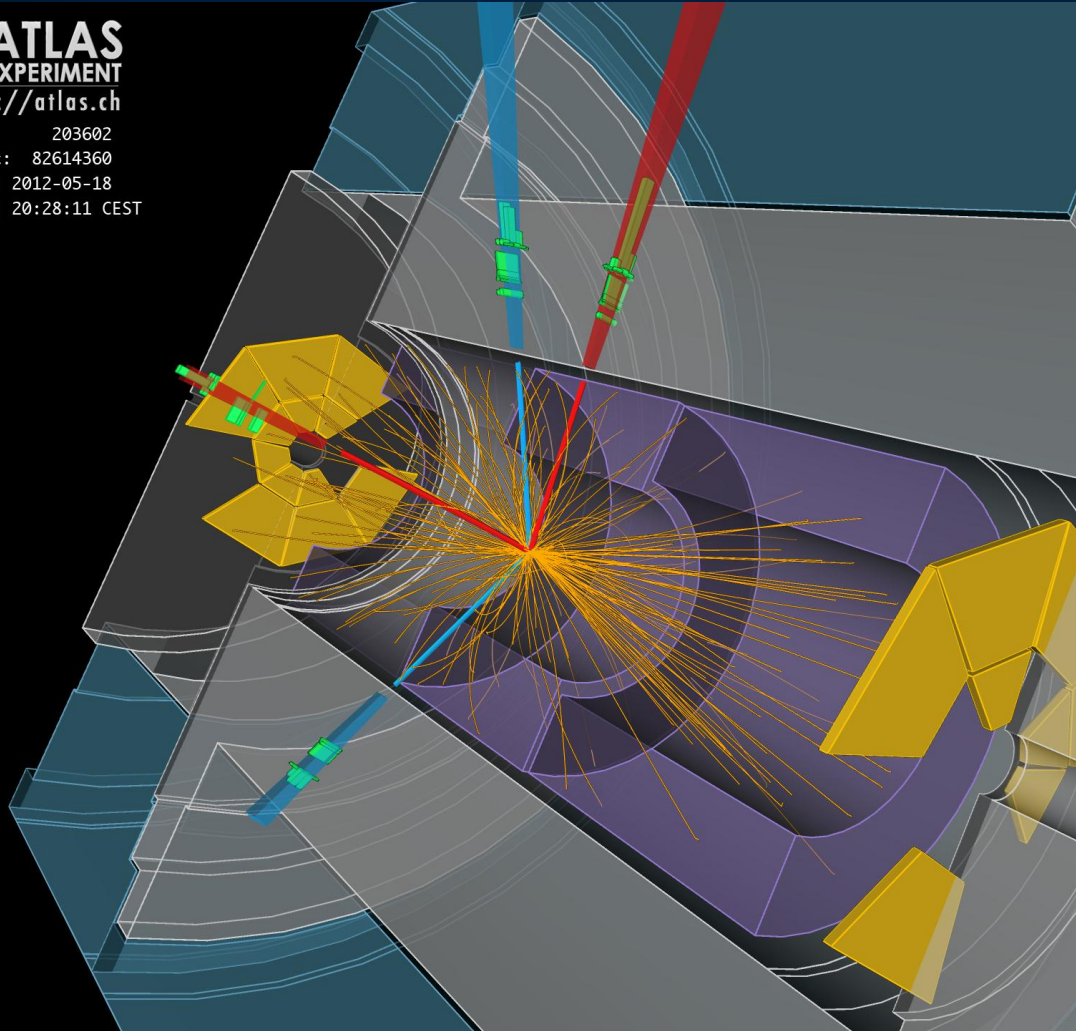


4 July 2012: CERN press conference



“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.

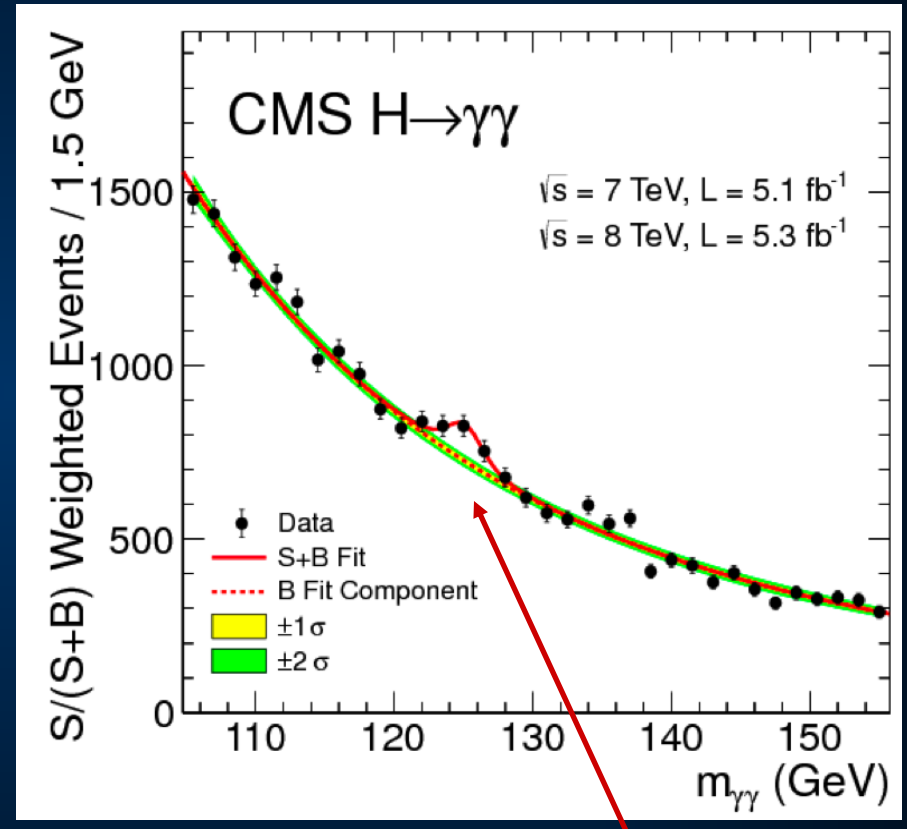
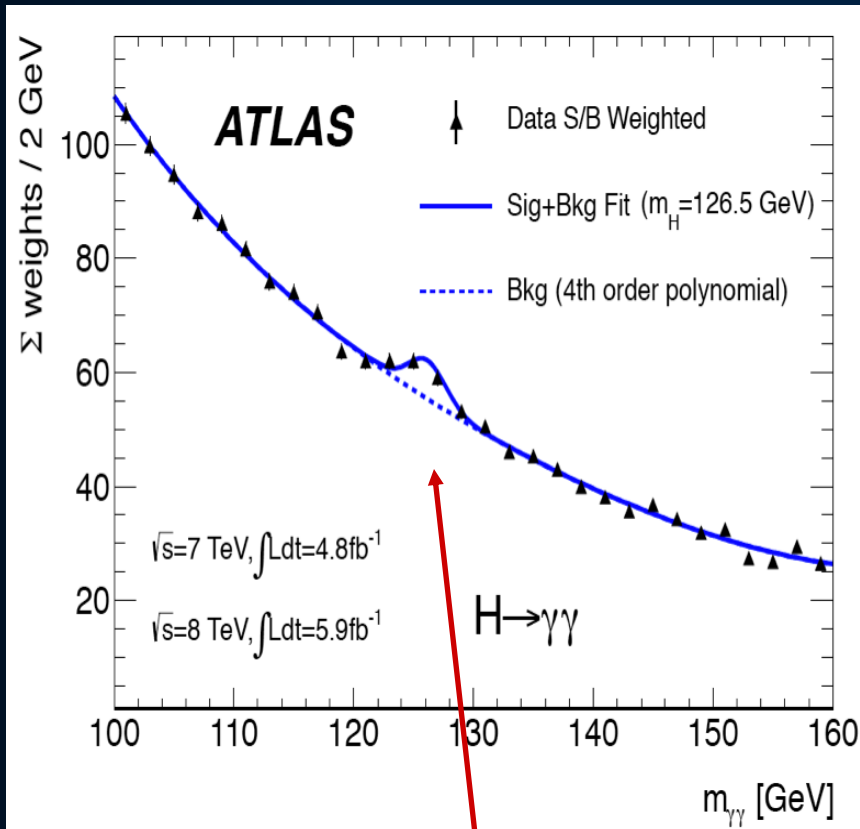
At a seminar held at CERN¹ today as a curtain raiser to the year's major particle physics conference, ICHEP2012 in Melbourne, the ATLAS and CMS experiments presented their latest preliminary results in the search for the long sought Higgs particle. **Both experiments observe a new particle in the mass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



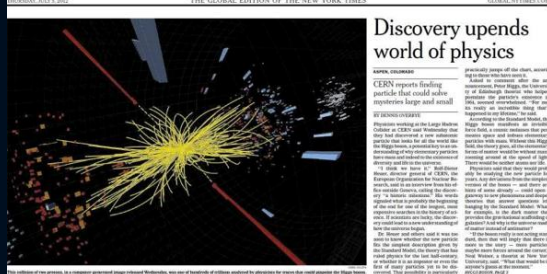
Higgs decay to $\gamma\gamma$, ATLAS and CMS, summer 2012 data



July 4th at CERN, after the Higgs seminar



4 JULY 2012 CERN Press conference



Discovery upends 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.

ヒッグス粒子発見か 新素粒子検出 年内に結論

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

Le Monde: Une fête sans panache. Réforme fiscale à tout risque.

Yodparticle discovery has scientists giddy. Page A2.

The Gazette: EL PAIS. EL PERIÓDICO GLOBAL EN ESPAÑOL.

MK: ПОСЛЕДНИЙ КИРПИЧ В СТЕНУ МИРОЗДАНИЯ. МЕТРО СПУСКАЕТ НА ВОДУ.

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

Frankfurter Allgemeine: Masse macht's. Große Mehrheit im Bundestag.

La Nación: fallada la partícula clave para a comprensión del universo.

CHINADAILY: MOVIE PLOT Iron Man film company looks to China for screen success.

THE HINDU: Elusive particle found, looks like Higgs boson.

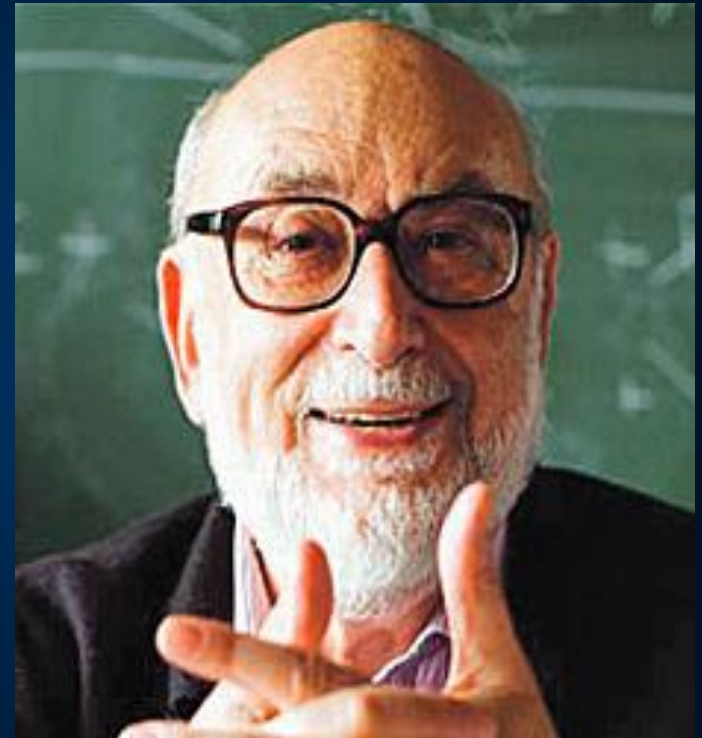
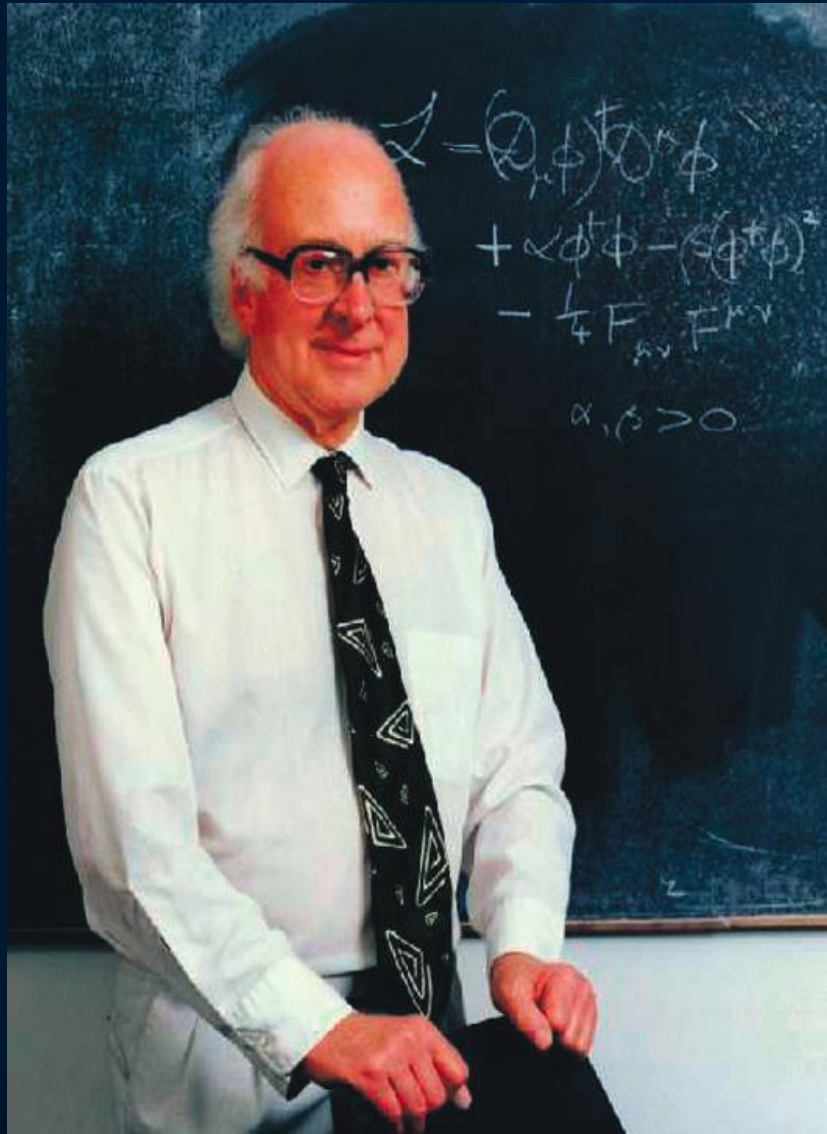
CORRIERE DELLA SERA: La particella che può svelare i segreti dell'universo.

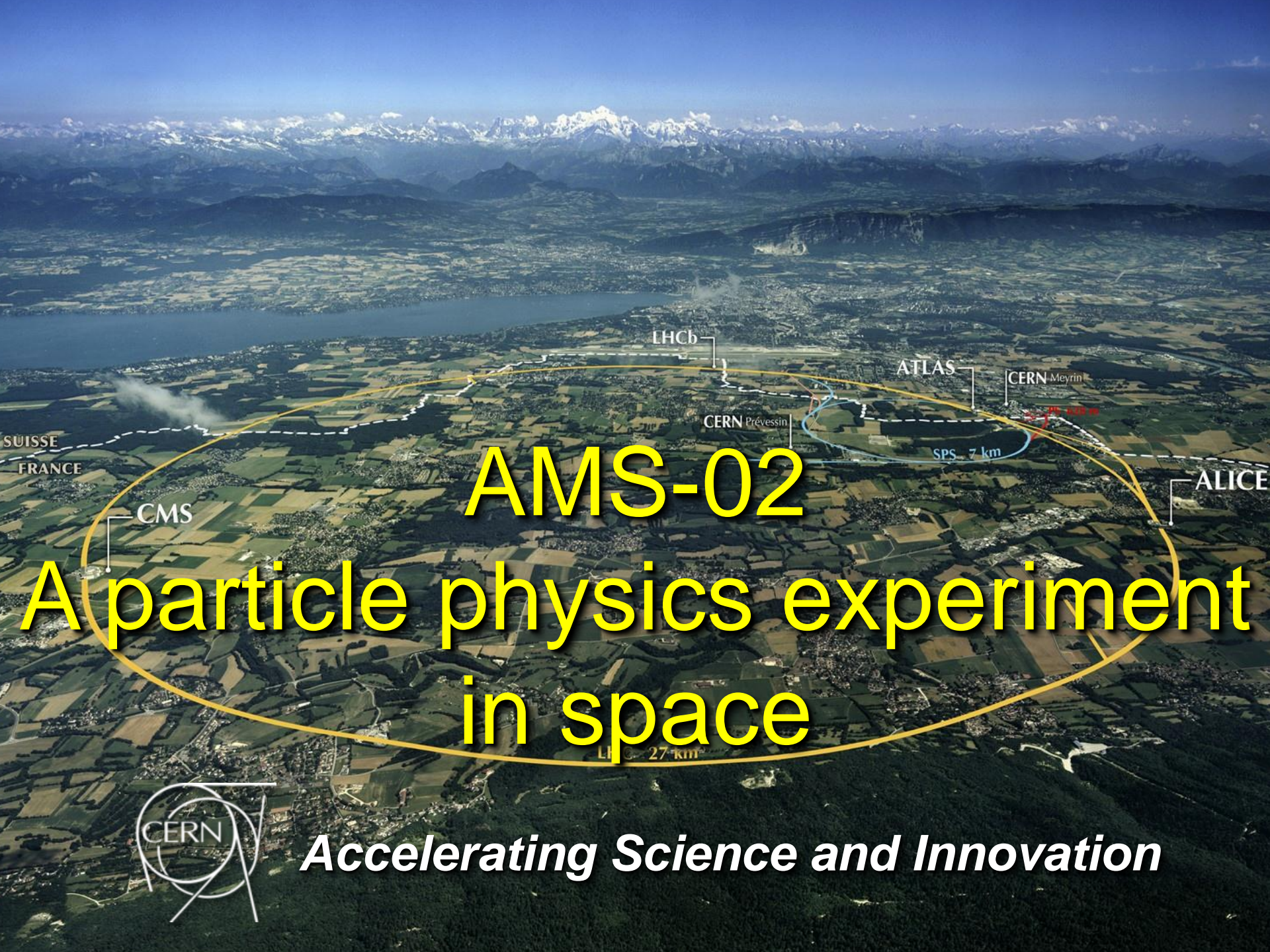
gazeta WYBORCZA.PL: Cząstke Higgsa fizycy najpierw wymyślił, potem szukali 40 lat.

THE TIMES OF INDIA: Big bang moment: Scientists may have found 'God particle'.

বিশ্বজ্ঞানের 'স্বপ্ন' দর্শন: আনন্দবাজার পত্রিকা.

Peter Higgs and Francois Englert





AMS-02

A particle physics experiment in space



Accelerating Science and Innovation