



Welcome to CERN

Margherita Boselli



C
E
R
N

Conseil
Européen pour
la
Recherche
Nucléaire

European
Organization for
Nuclear
Research



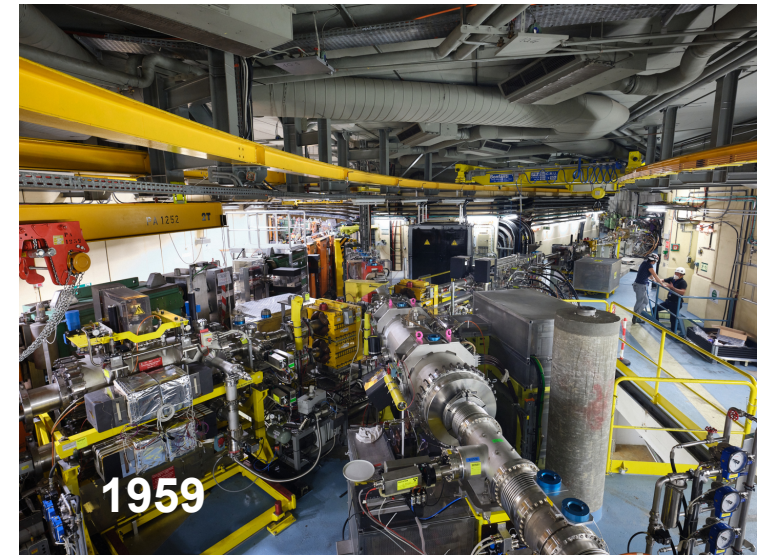
- ◆ **1951** agreement among 11 countries (pioneers - Bohr-DK) - provisional council.
- ◆ **1952** Geneva was selected
- ◆ **29 September 1954** The Organisation is officially born, 12 nations signed the convention. Beginning of construction works.
- ◆ First physics laboratory built across two countries CH and FR

<https://timeline.web.cern.ch>

C
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Research



CERN now

23 member states

10 associate members

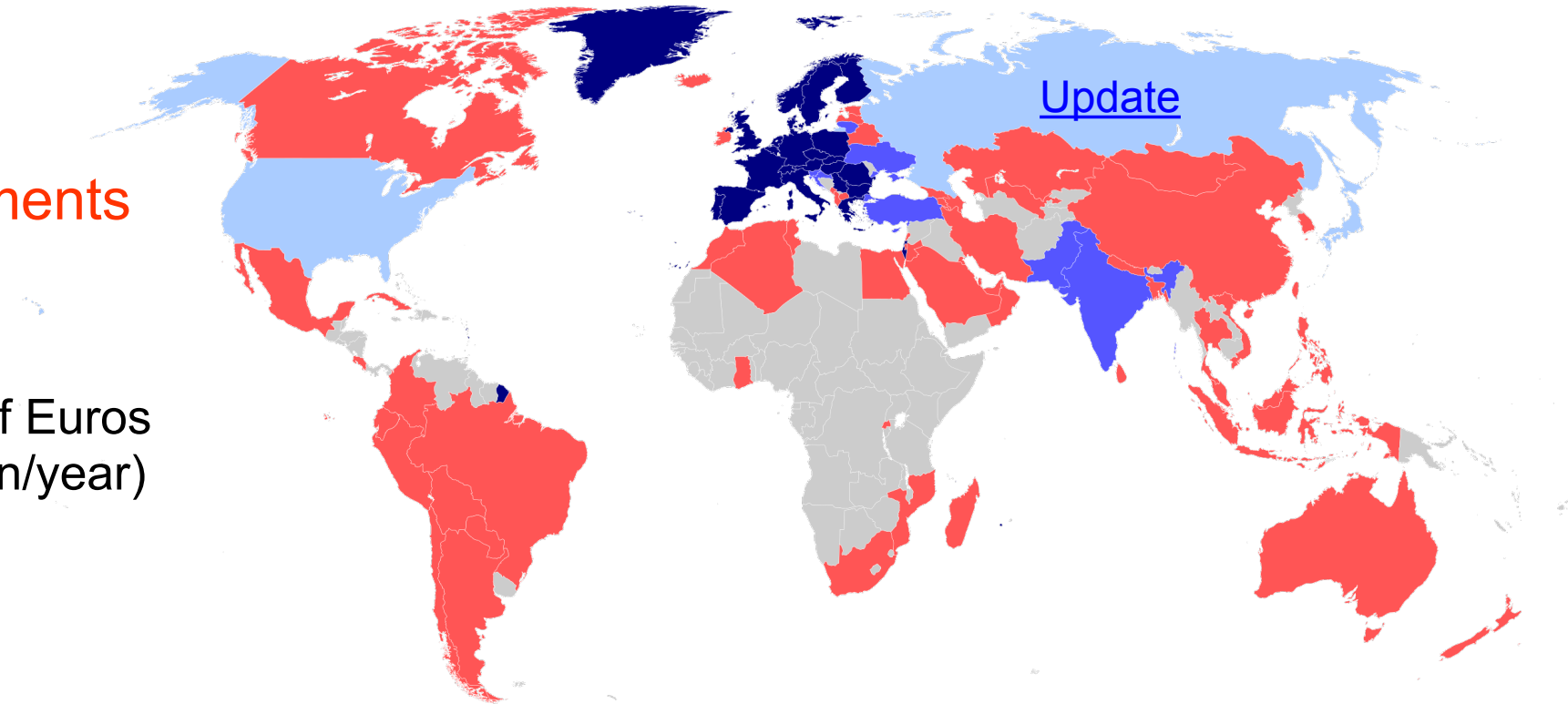
3 observers

61 countries with agreements

Budget in 2023: 1.23 billions of Euros
(123 M Euros IT, 2 Euro/person/year)

3558 members of personnel

13000 users



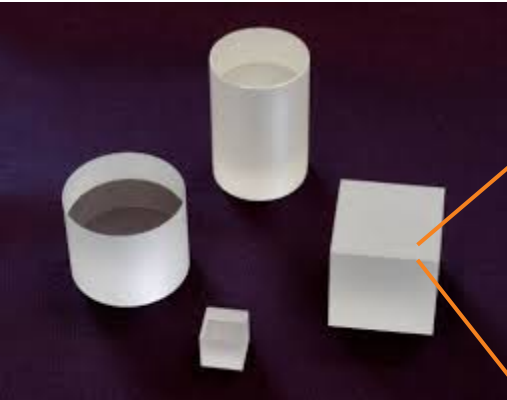
CERN mission

- Provide the facilities for frontend fundamental physics research: accelerators.
- Research in fundamental physics.
- Bring people together and push the frontiers of science and technology for the benefit of all.
- Education of future generations of scientists.

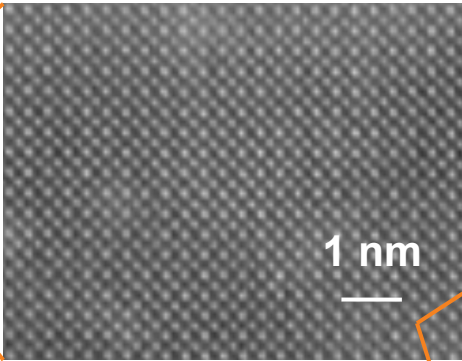


Research at CERN

Macroscopic matter



Atomic structure

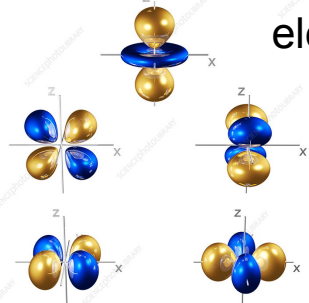


IV-V century BC

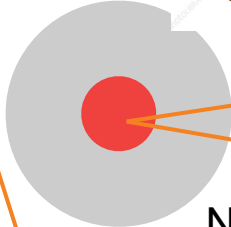
Scale 10^{-10} - 10^{-15}

m

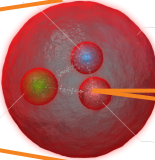
electrons



protons and neutrons



Nucleus



quarks

End of IXX century

Beginning of XX century

1960s

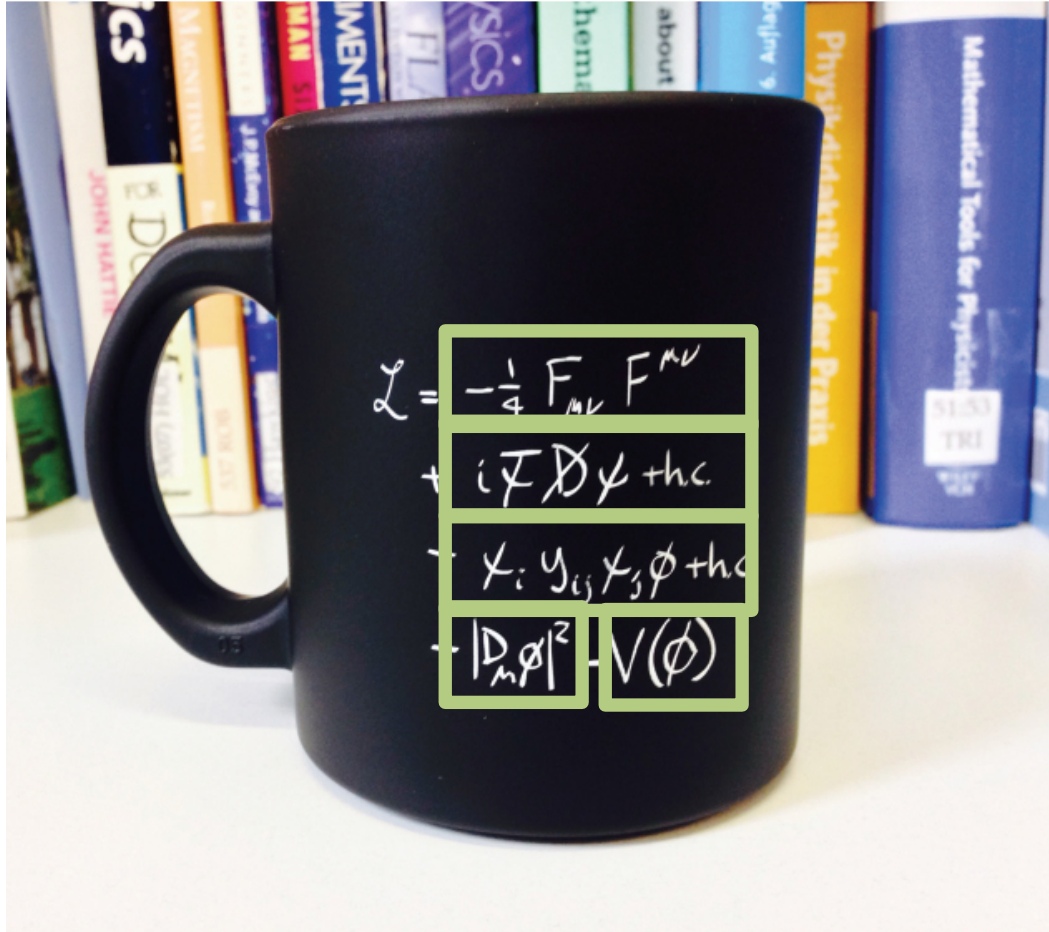
Fundamental constituents of matter and their interactions.

From the periodic table of elements

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18																						
1	H Hydrogen 1.008	Atomic Symbol C Solid Name Weight Hg Liquid H Gas Rf Unknown																	2	He Helium 4.0026																				
2	Li Lithium 6.94	Be Beryllium 9.0122	<table border="1"> <tr> <td rowspan="2">Alkali metals</td> <td colspan="2">Metals</td> <td rowspan="2">Transition metals</td> <td rowspan="2">Post-transition metals</td> <td rowspan="2">Metalloids</td> <td colspan="3">Nonmetals</td> </tr> <tr> <td>Alkaline earth metals</td> <td>Lanthanoids</td> <td>Reactive nonmetals</td> <td>Noble gases</td> </tr> <tr> <td></td> <td></td> <td></td> <td>Actinoids</td> <td></td> <td></td> <td></td> <td></td> <td></td> </tr> </table>										Alkali metals	Metals		Transition metals	Post-transition metals	Metalloids	Nonmetals			Alkaline earth metals	Lanthanoids	Reactive nonmetals	Noble gases				Actinoids						B Boron 10.81	C Carbon 12.011	N Nitrogen 14.007	O Oxygen 15.999	F Fluorine 18.998	Ne Neon 20.180
Alkali metals	Metals		Transition metals	Post-transition metals	Metalloids	Nonmetals																																		
	Alkaline earth metals	Lanthanoids				Reactive nonmetals	Noble gases																																	
			Actinoids																																					
3	Na Sodium 22.990	Mg Magnesium 24.305	Al Aluminium 26.982	Si Silicon 28.085	P Phosphorus 30.974	S Sulfur 32.06	Cl Chlorine 35.45	Ar Argon 39.948																																
4	K Potassium 39.098	Ca Calcium 40.078	Sc Scandium 44.956	Ti Titanium 47.867	V Vanadium 50.942	Cr Chromium 51.996	Mn Manganese 54.938	Fe Iron 55.845	Co Cobalt 58.933	Ni Nickel 58.693	Cu Copper 63.546	Zn Zinc 65.38	Ga Gallium 69.723	Ge Germanium 72.630	As Arsenic 74.922	Se Selenium 78.971	Br Bromine 79.904	Kr Krypton 83.798																						
5	Rb Rubidium 85.468	Sr Strontium 87.62	Y Yttrium 88.906	Zr Zirconium 91.224	Nb Niobium 92.906	Mo Molybdenum 95.95	Tc Technetium (98)	Ru Ruthenium 101.07	Rh Rhodium 102.91	Pd Palladium 106.42	Ag Silver 107.87	Cd Cadmium 112.41	In Indium 114.82	Sn Tin 118.71	Sb Antimony 121.76	Te Tellurium 127.60	I Iodine 126.90	Xe Xenon 131.29																						
6	Cs Caesium 132.91	Ba Barium 137.33	57-71	Hf Hafnium 178.49	Ta Tantalum 180.95	W Tungsten 183.84	Re Rhenium 186.21	Os Osmium 190.23	Ir Iridium 192.22	Pt Platinum 195.08	Au Gold 196.97	Hg Mercury 200.59	Tl Thallium 204.38	Pb Lead 207.2	Bi Bismuth 208.98	Po Polonium (209)	At Astatine (210)	Rn Radon (222)																						
7	Fr Francium (223)	Ra Radium (226)	89-103	Rf Rutherfordium (267)	Db Dubnium (268)	Sg Seaborgium (269)	Bh Bohrium (270)	Hs Hassium (277)	Mt Meitnerium (278)	Ds Darmstadtium (281)	Rg Roentgenium (282)	Cn Copernicium (285)	Nh Nihonium (286)	Fl Flerovium (289)	Mc Moscovium (290)	Lv Livermorium (293)	Ts Tennessine (294)	Og Oganesson (294)																						
For elements with no stable isotopes, the mass number of the isotope with the longest half-life is in parentheses.																																								
	La Lanthanum 138.91	Ce Cerium 140.12	Pr Praseodymium 140.91	Nd Neodymium 144.24	Pm Promethium (145)	Sm Samarium 150.36	Eu Europium 151.96	Gd Gadolinium 157.25	Tb Terbium 158.93	Dy Dysprosium 162.50	Ho Holmium 164.93	Er Erbium 167.26	Tm Thulium 168.93	Yb Ytterbium 173.05	Lu Lutetium 174.97																									
	Ac Actinium (227)	Th Thorium 232.04	Pa Protactinium 231.04	U Uranium 238.03	Np Neptunium (237)	Pu Plutonium (244)	Am Americium (243)	Cm Curium (247)	Bk Berkelium (247)	Cf Californium (251)	Es Einsteinium (252)	Fm Fermium (257)	Md Mendelevium (258)	No Nobelium (259)	Lr Lawrencium (266)																									

From <https://ptable.com>

To the standard model of particles



Mathematical encoding of all interaction particles except for the Higgs boson.

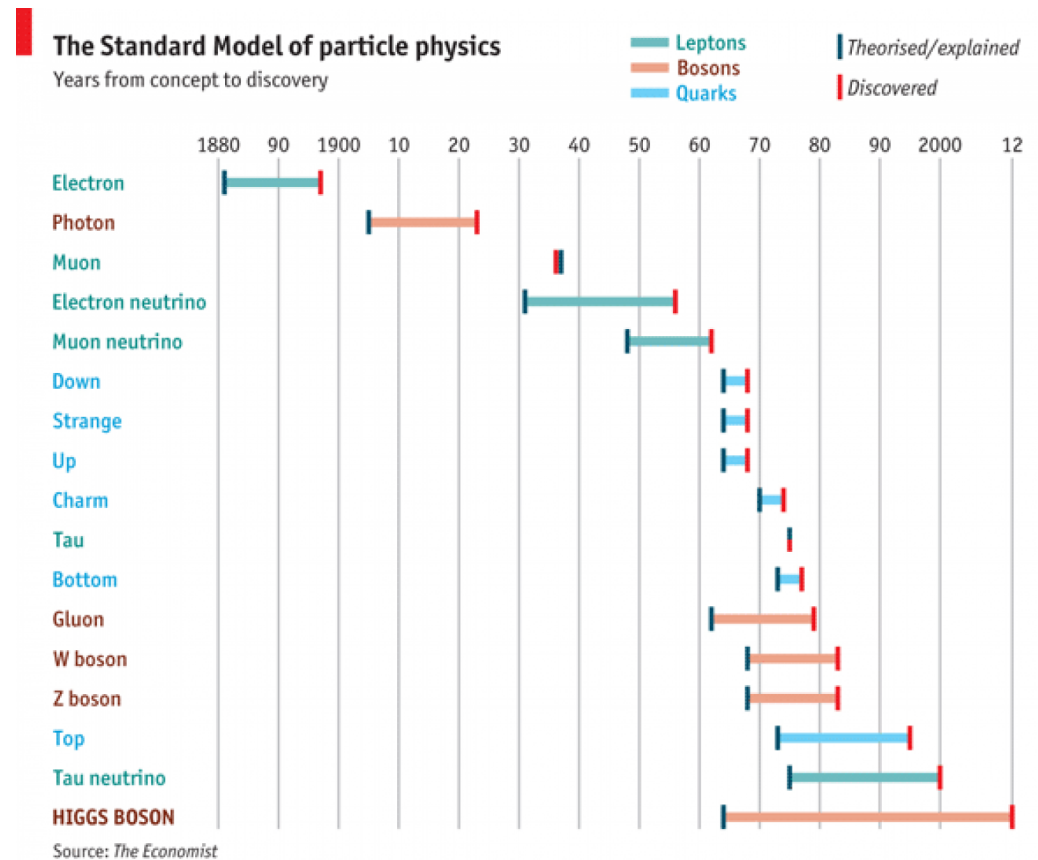
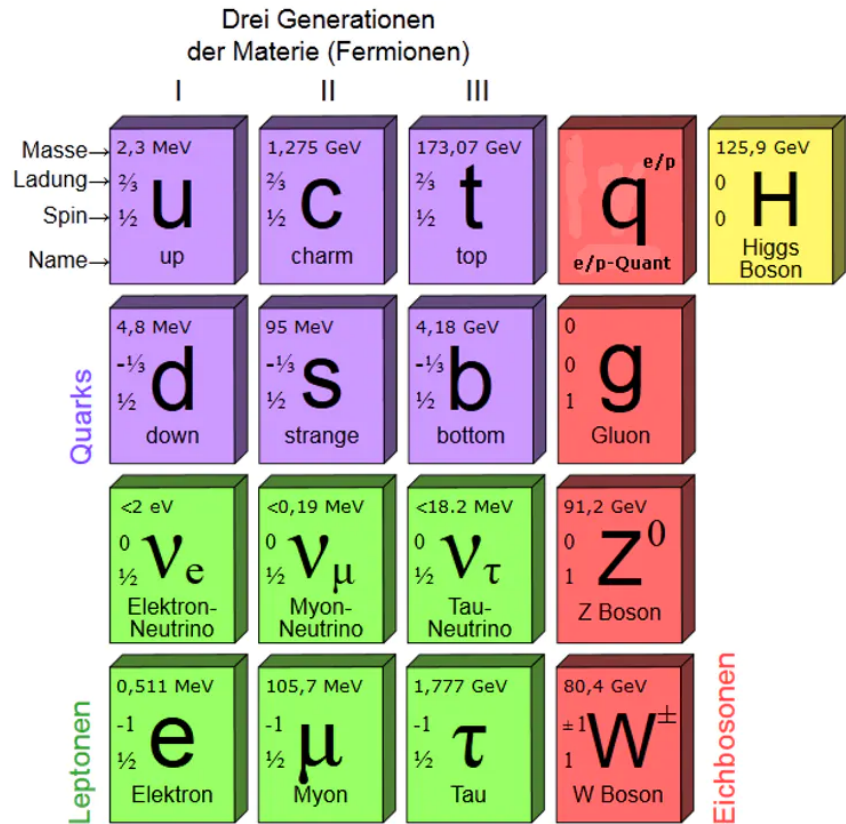
Interactions between interaction particles and mass particles. Radioactive decays are described by this term.

Interaction of mass particles with the Brout-Englert-Higgs field to obtain mass.

Coupling of the interaction particles with BEH field.

Potential of the BEH field.

To the standard model of particles



To the standard model of particles

Drei Generationen
der Materie (Fermionen)

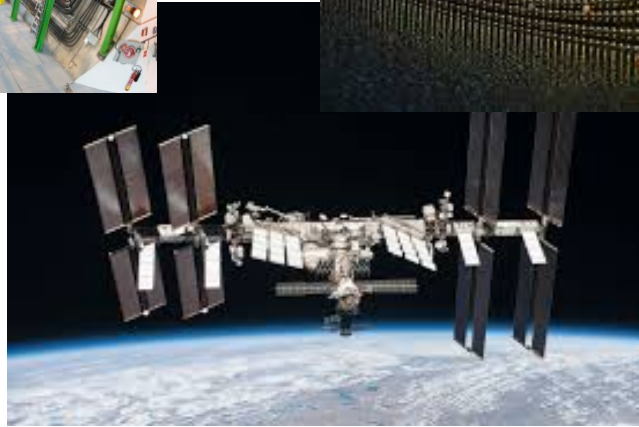
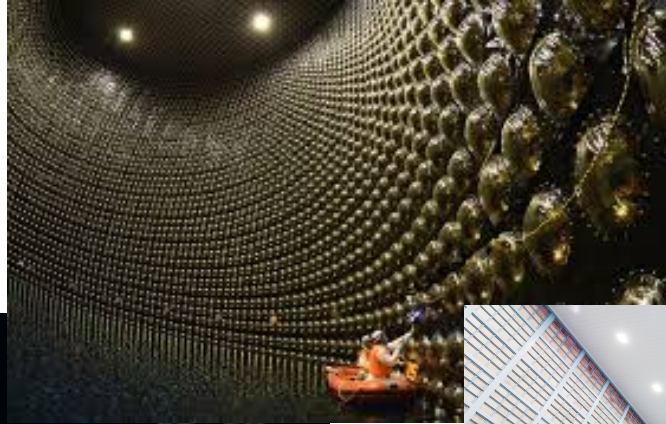
	I	II	III	
Masse	2,3 MeV	1,275 GeV	173,07 GeV	125,9 GeV
Ladung	$\frac{2}{3}$	$\frac{2}{3}$	$\frac{2}{3}$	0
Spin	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	0
Name	u up	c charm	t top	H Higgs Boson
			q e/p-Quant	
Quarks	4,8 MeV	95 MeV	4,18 GeV	0
	$-\frac{1}{3}$	$-\frac{1}{3}$	$-\frac{1}{3}$	0
	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	1
	d down	s strange	b bottom	g Gluon
Leptonen	<2 eV	<0,19 MeV	<18,2 MeV	91,2 GeV
	0	0	0	0
	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	1
	ν_e Elektron- Neutrino	ν_μ Myon- Neutrino	ν_τ Tau- Neutrino	Z⁰ Z Boson
	0,511 MeV	105,7 MeV	1,777 GeV	80,4 GeV
	-1	-1	-1	± 1
	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	1
	e Elektron	μ Myon	τ Tau	W[±] W Boson

Eichbosonen

- The SM is now a theory, confirmed by many experiments.
- Is it all, or there is more?
- How gravity can be integrated?
- Why there is no more antimatter?
- What is the dark matter and the dark energy?

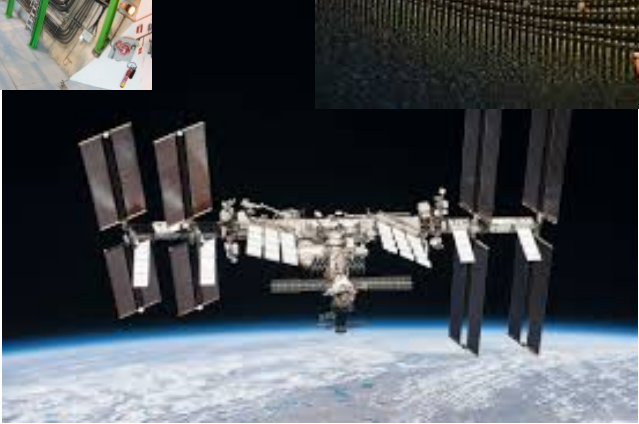
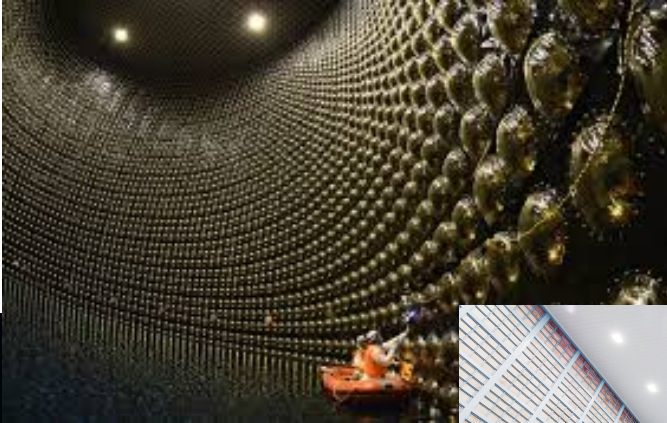
For each of these particles there is an antiparticle !

Different purposes – different laboratories



Particle accelerators have a prominent role in this picture

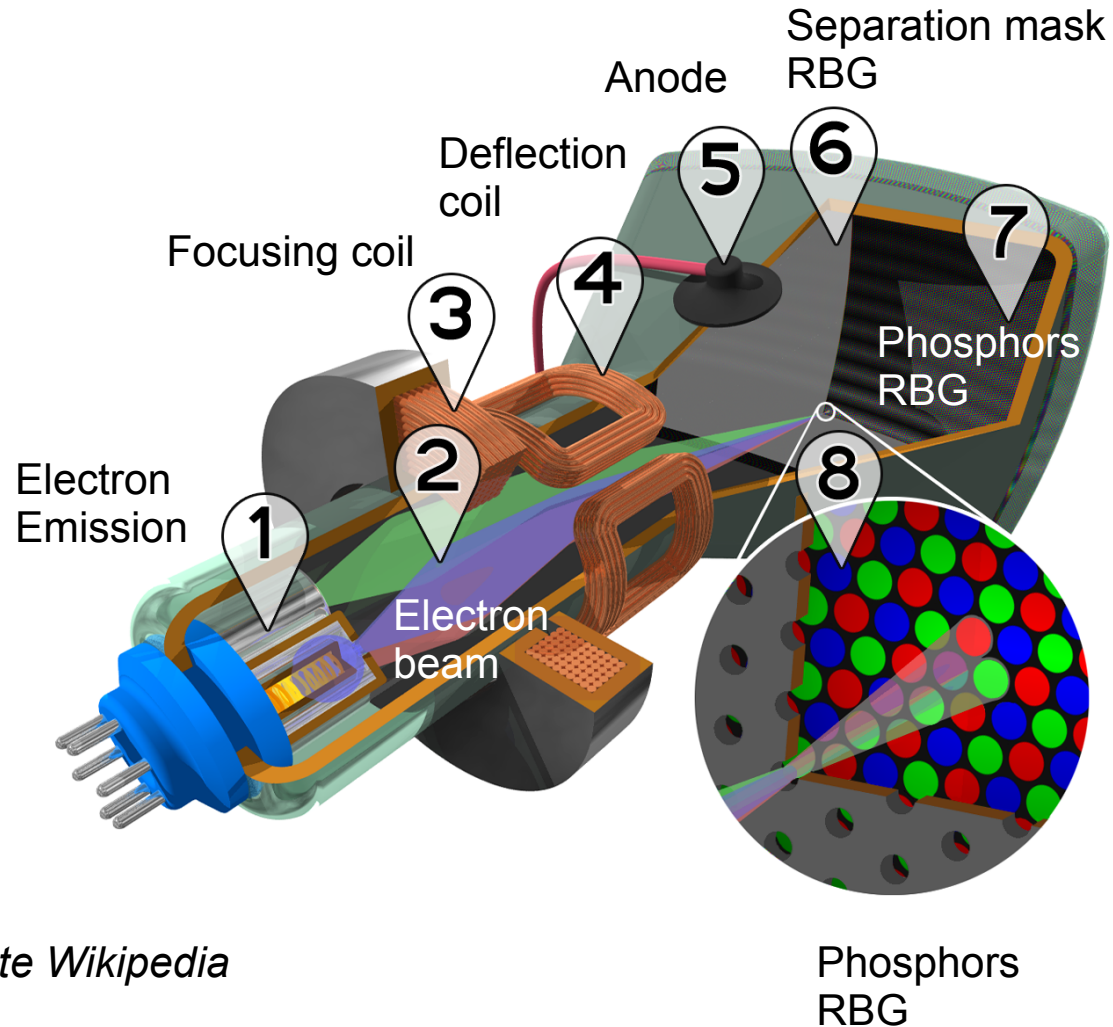
Different purposes – different laboratories



[Latest news!](#)

Particle accelerators have a prominent role in this picture

A particle accelerator



- Electrically charged particle source.
- Electric fields to accelerate.
- Magnetic fields to bend.

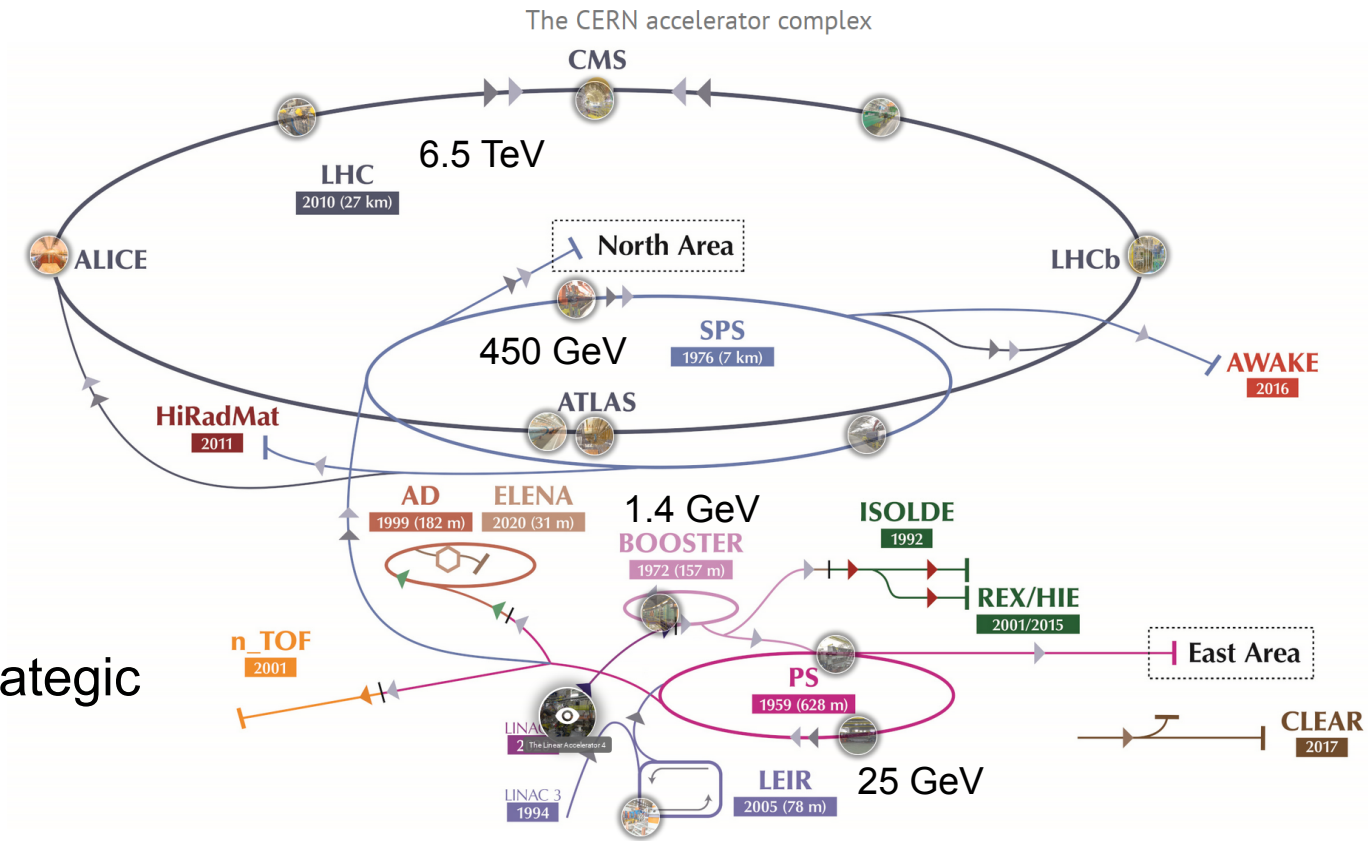
Fonte Wikipedia

CERN Accelerators

CERN has a complex of accelerators produce beams of :

- Protons and anti-protons
- Ions
- Neutrons
- Isotopes

Several experiments are placed in strategic points of the accelerators.

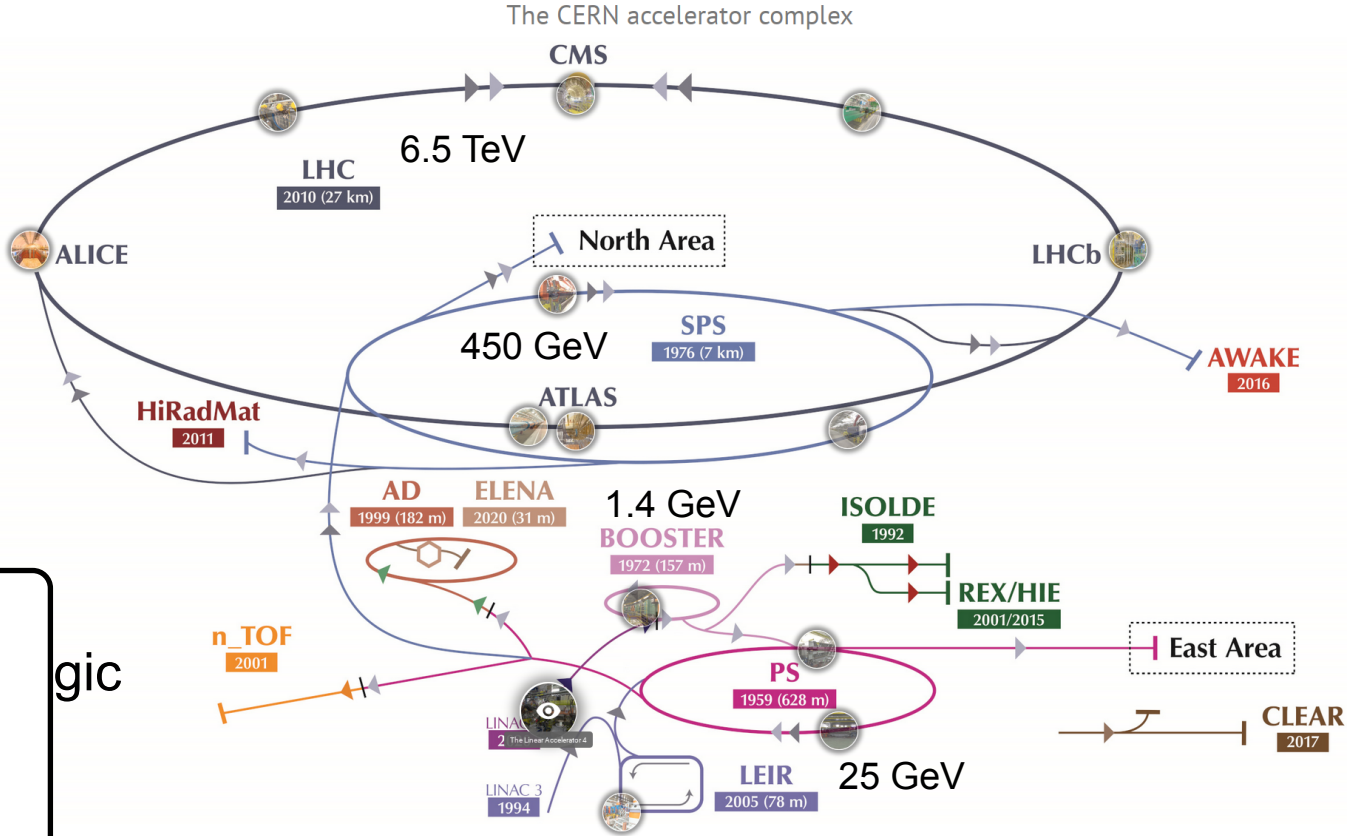


CERN Accelerators

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- Protons and anti-protons
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The eV is a unit of energy.
 $1 \text{ eV} = 1 \text{ e} \cdot 1 \text{ V} = 1.6 \cdot 10^{-19} \text{ J}$



Step 1 : an H2 bottle and a linear accelerator



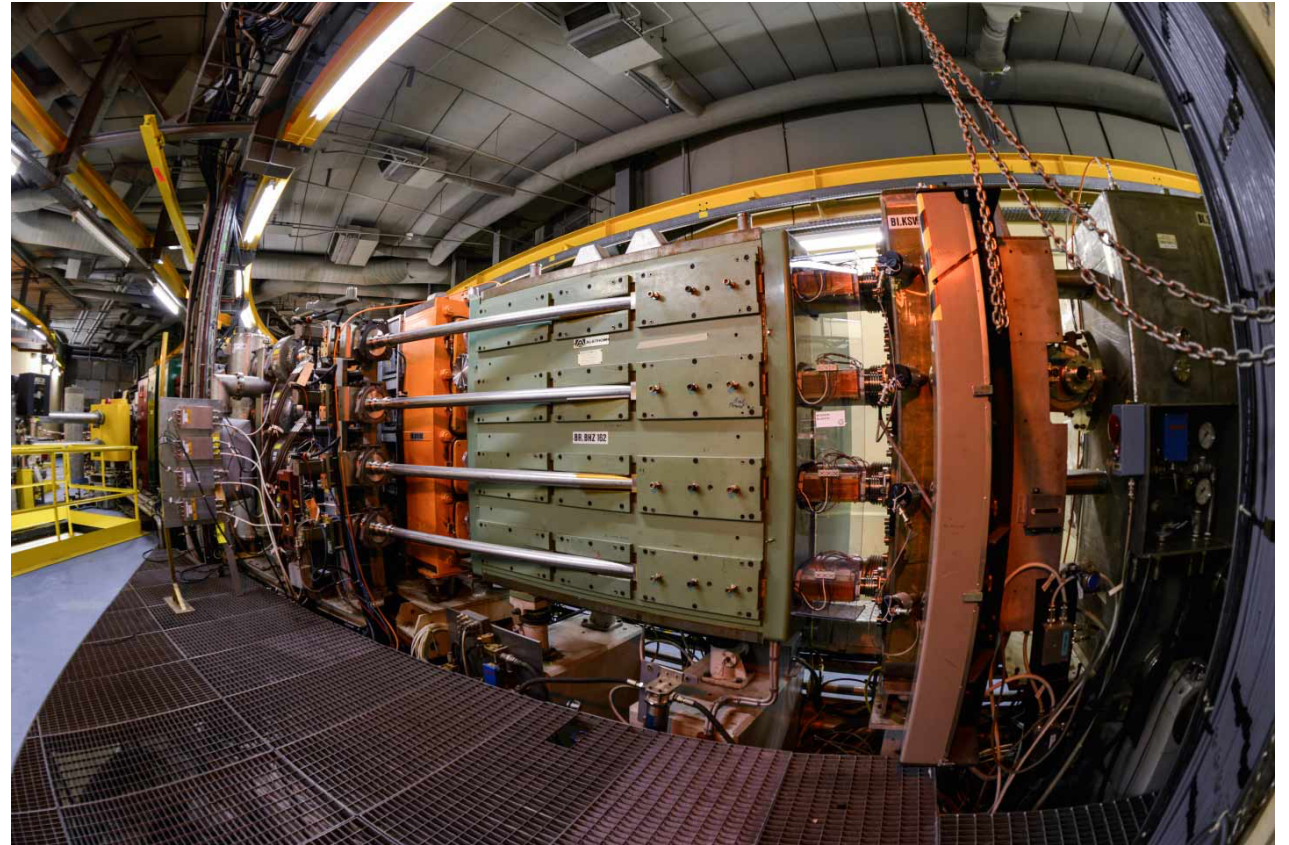
Gas bottle



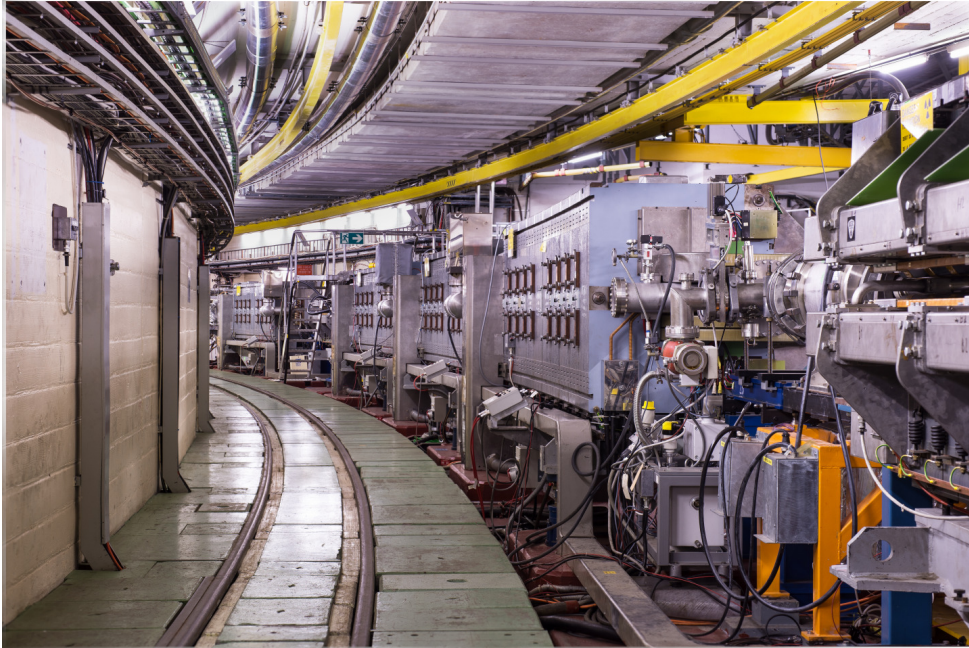
LINAC4 ca. 76 m, up to 160 MeV

Step 2 : The booster

The Booster consists in 4 superimposed synchrotrons that receive protons from the Linac4 at 160 MeV and accelerate them to 2 GeV. Radius 25 m.



Step 3 : The PS and the SPS

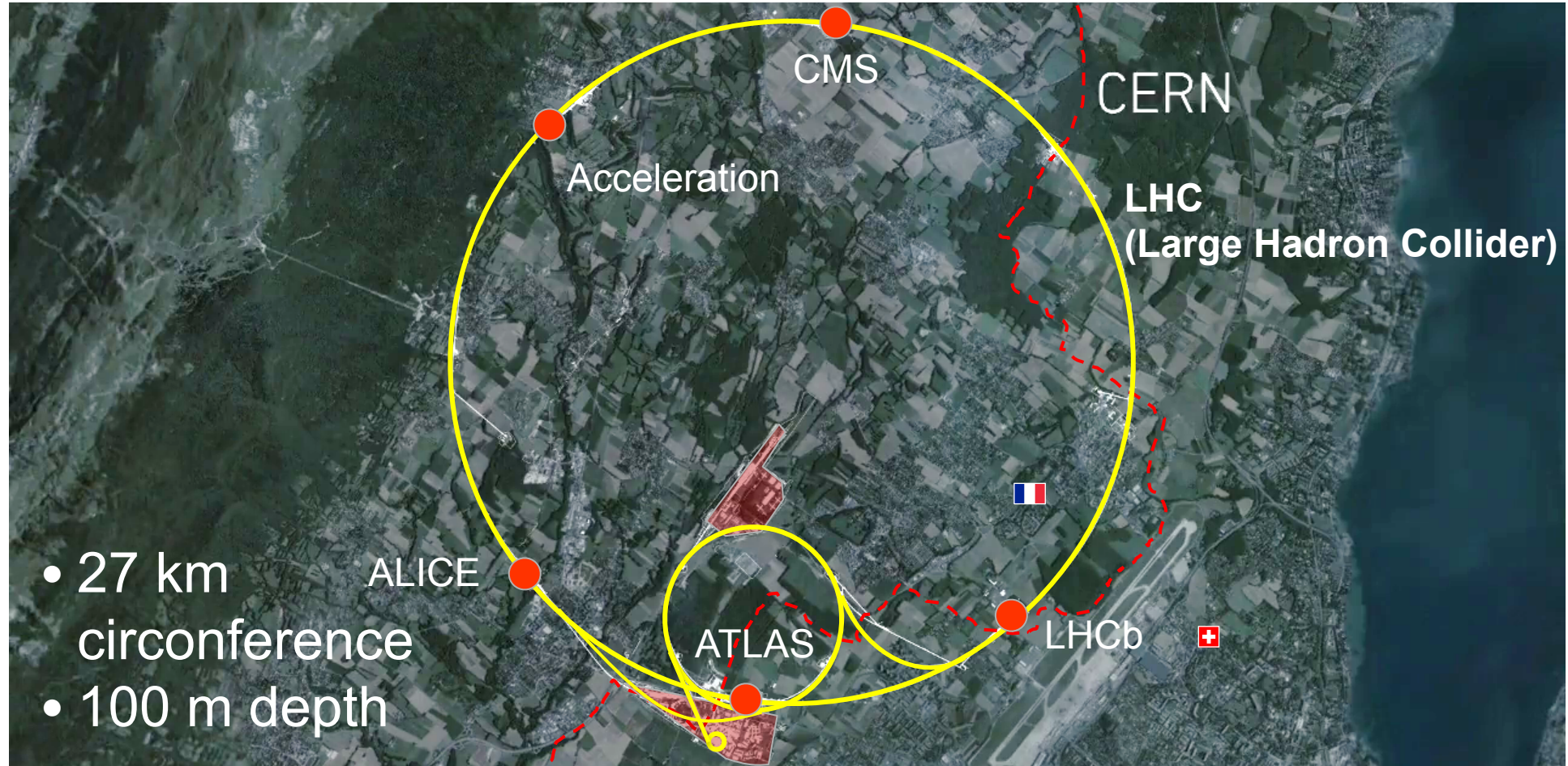


628 m of circumference, protons up to 26 GeV.

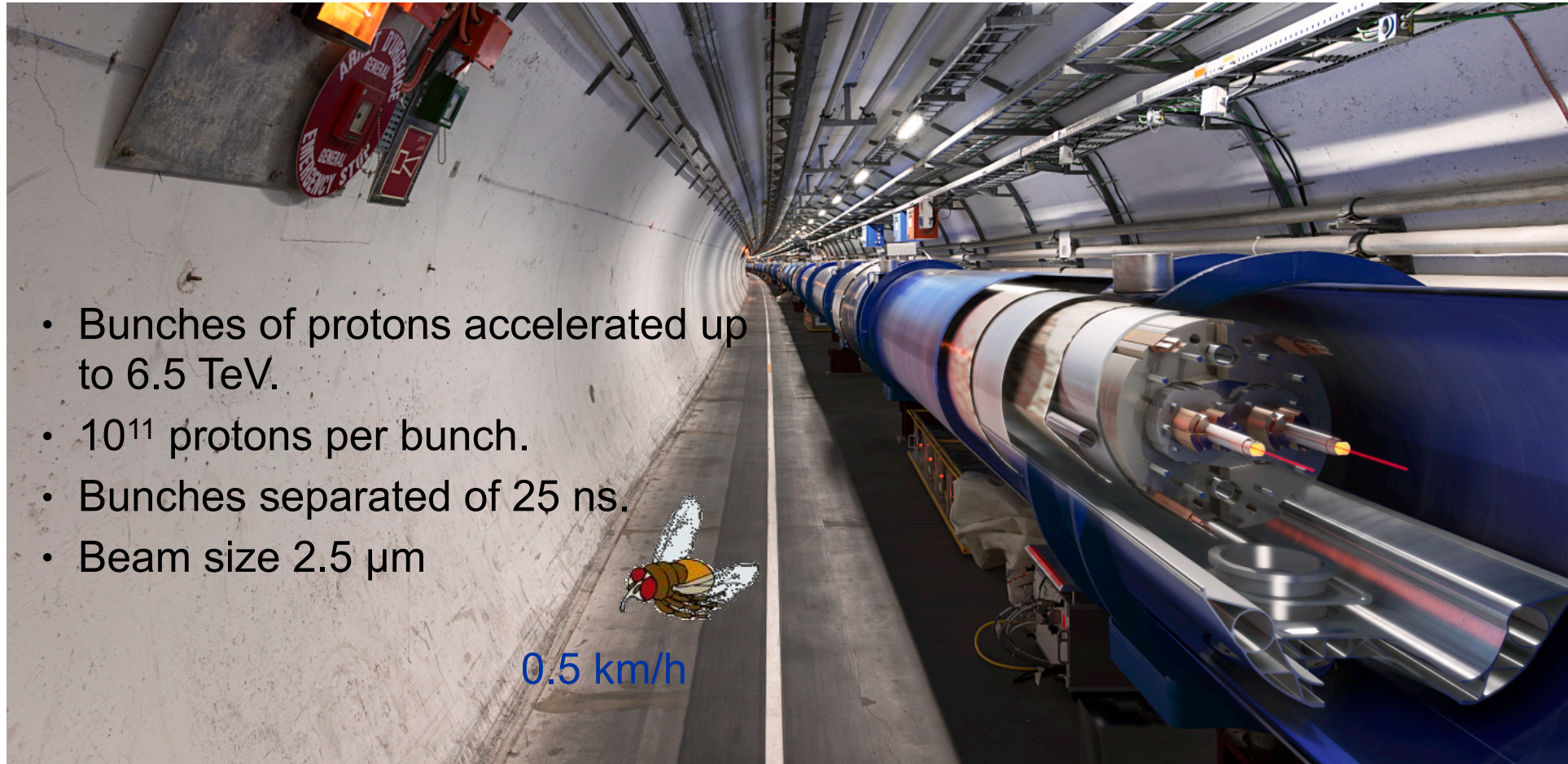


7 km of circumference, last step before the LHC, protons up to 450 GeV.

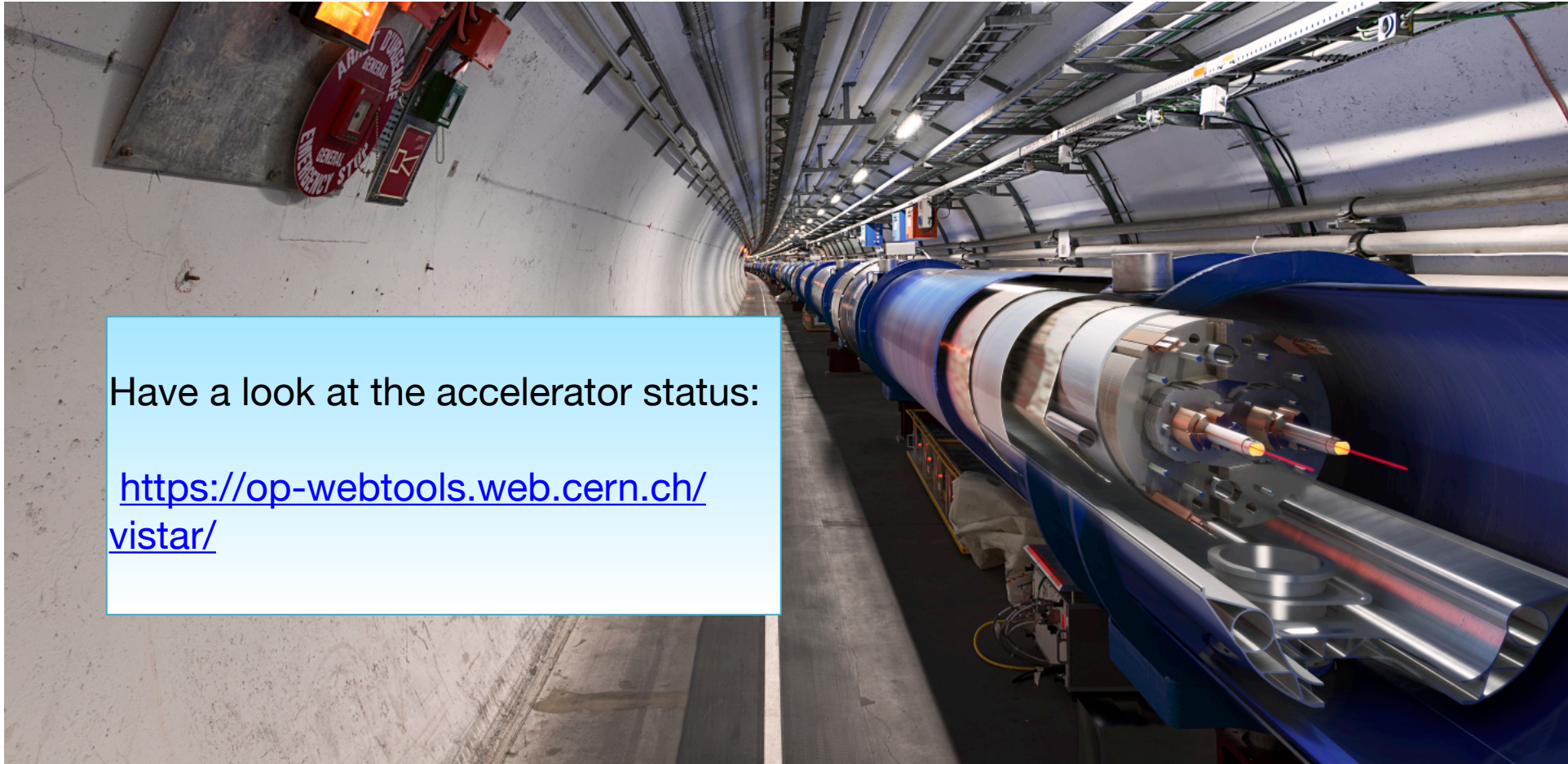
Final step : The Large Hadron Collider



Final step : The Large Hadron Collider



Final step : The Large Hadron Collider



Have a look at the accelerator status:

<https://op-webtools.web.cern.ch/vistar/>

A bit of history

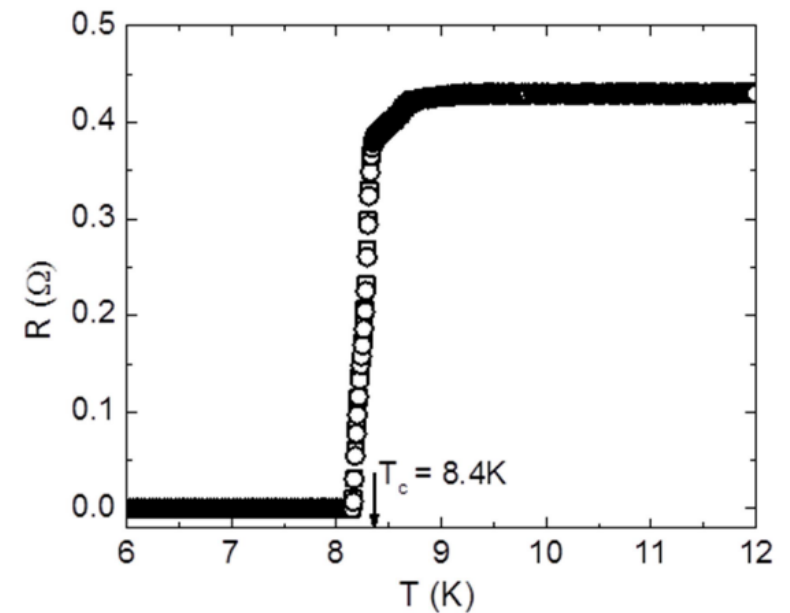
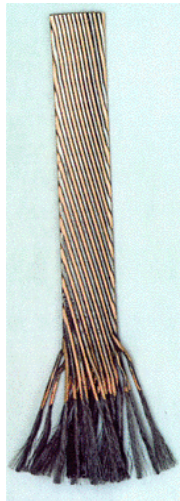


Images from L. Evans presentation 04/07/2022

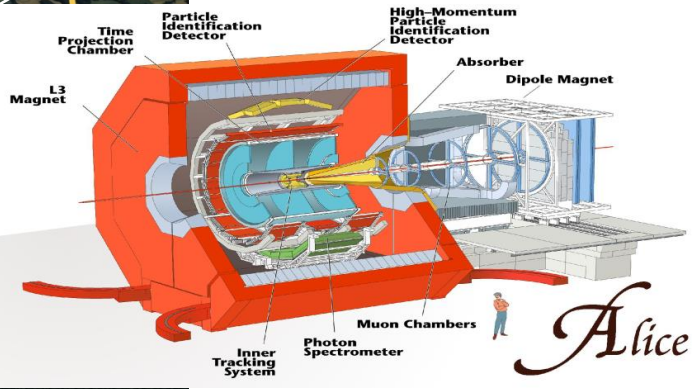
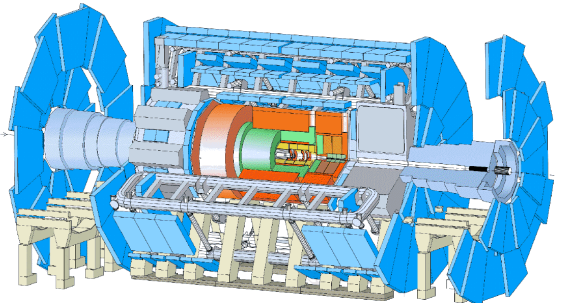
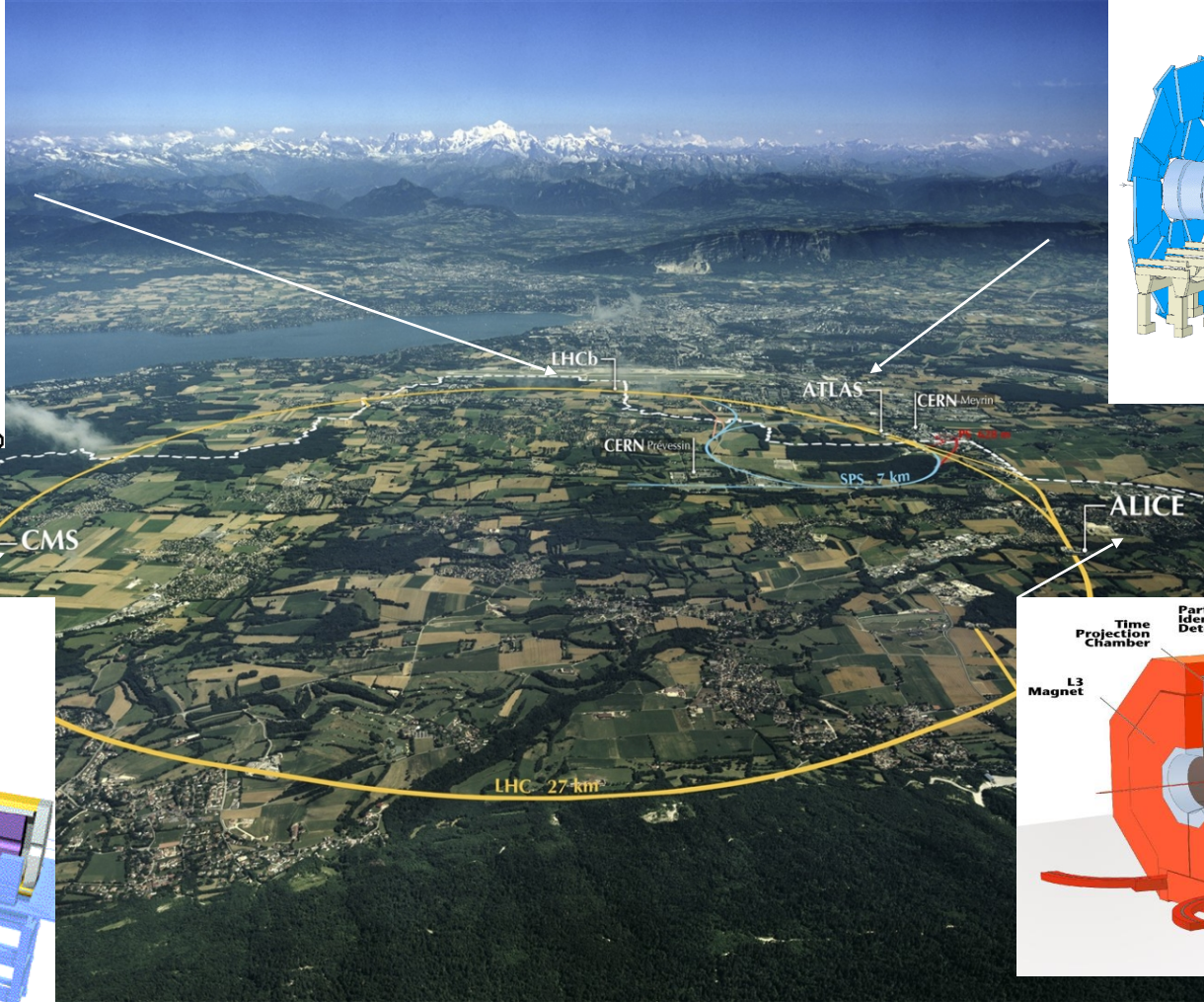
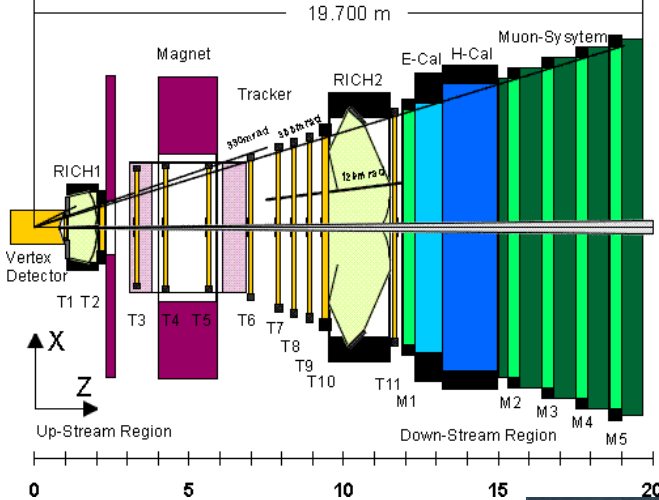
The technology required

One of the main challenge of the LHC is the production and maintenance of the superconducting magnets.

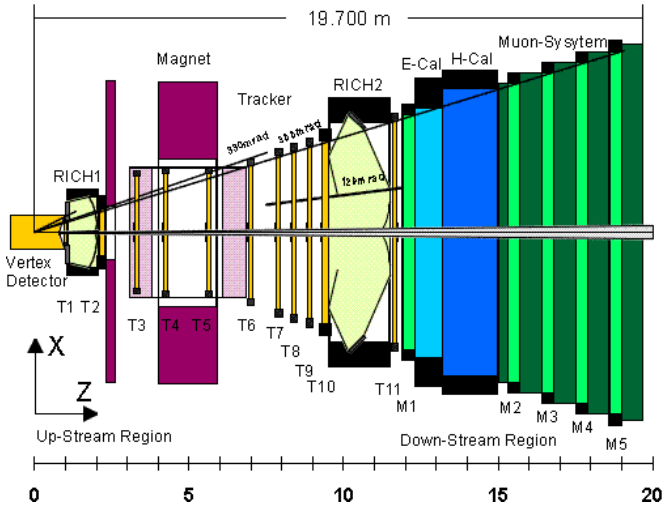
- 1232 magnets to bend the particles.
- 220 000 km of **superconducting wires**.
- Working temperature : 1.9 K (-271.3 C), superfluid Helium.



Experiments at the LHC



Experiments at the LHC

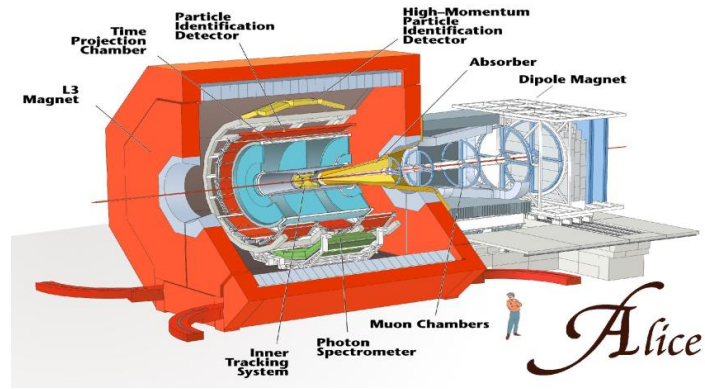
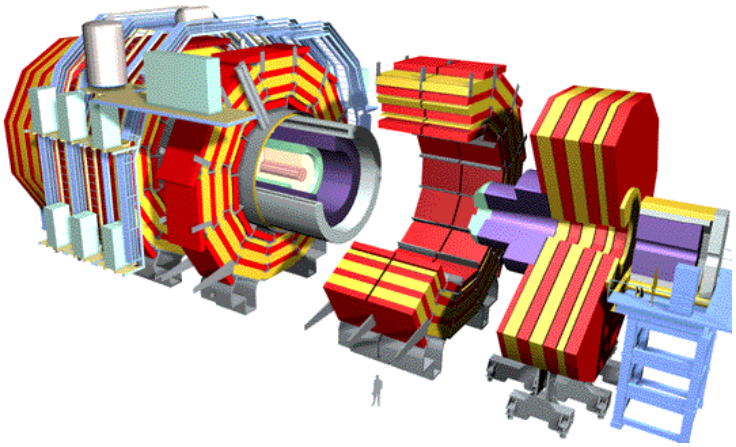
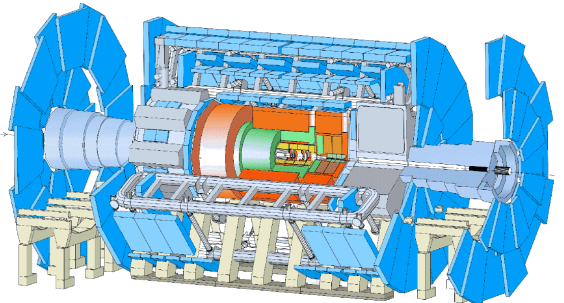


The experiments are international collaborations.

Many research institutions are involved in :

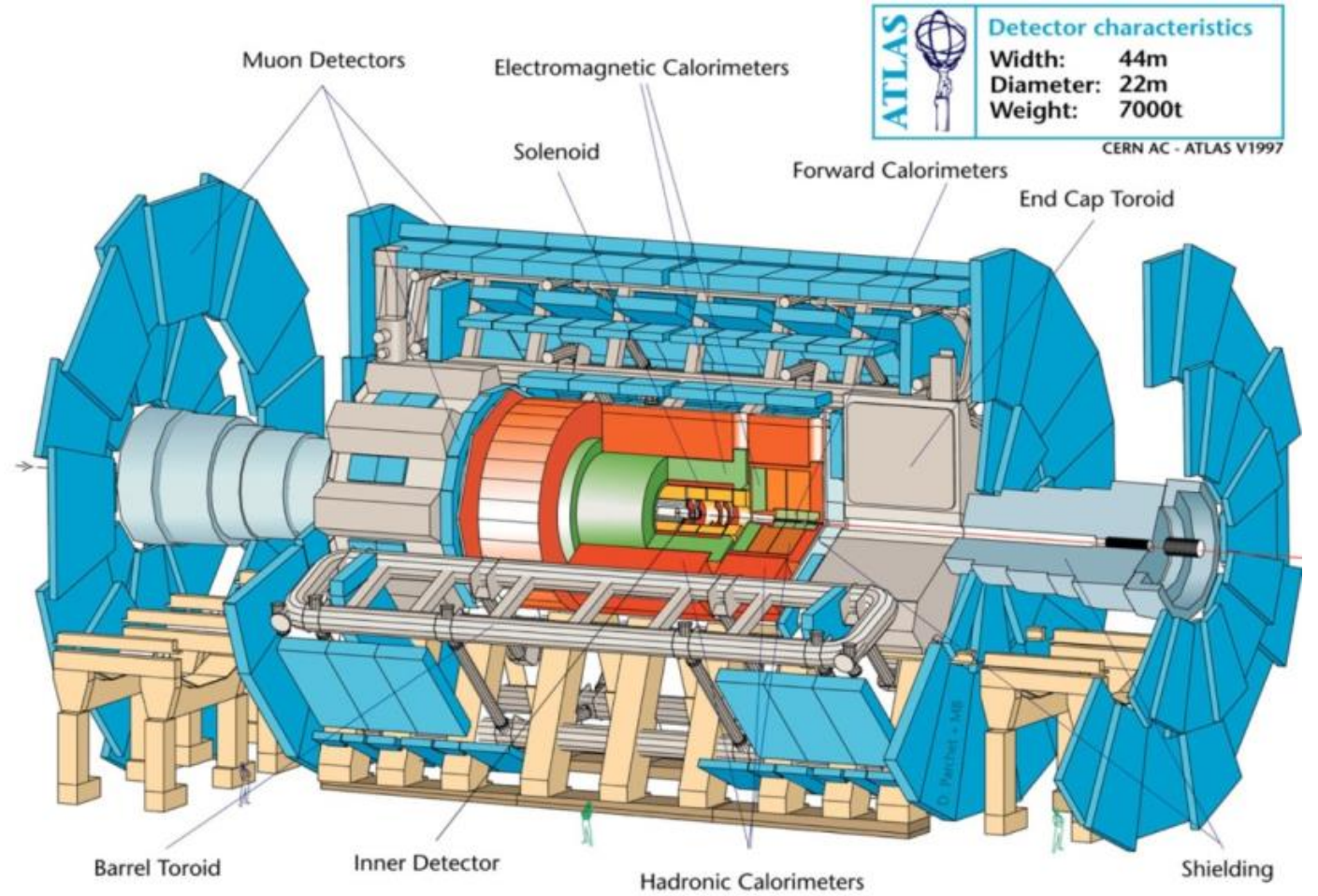
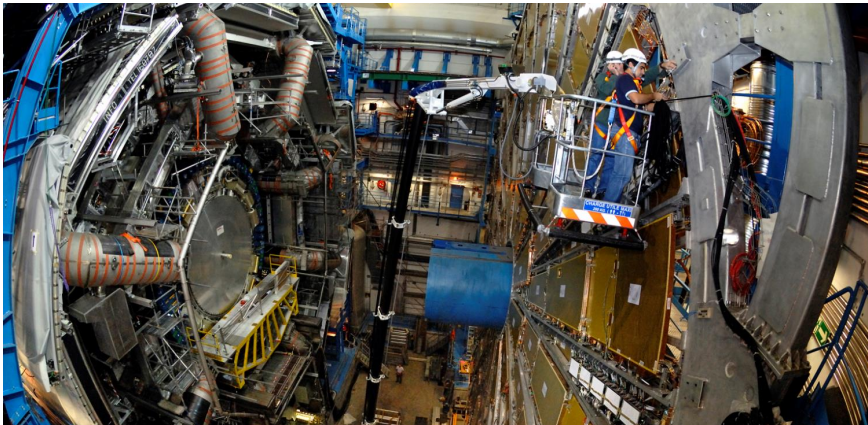
- Design
- Production
- Management
- Resources
- Data analysis etc..

Each experiment has a specific purpose.

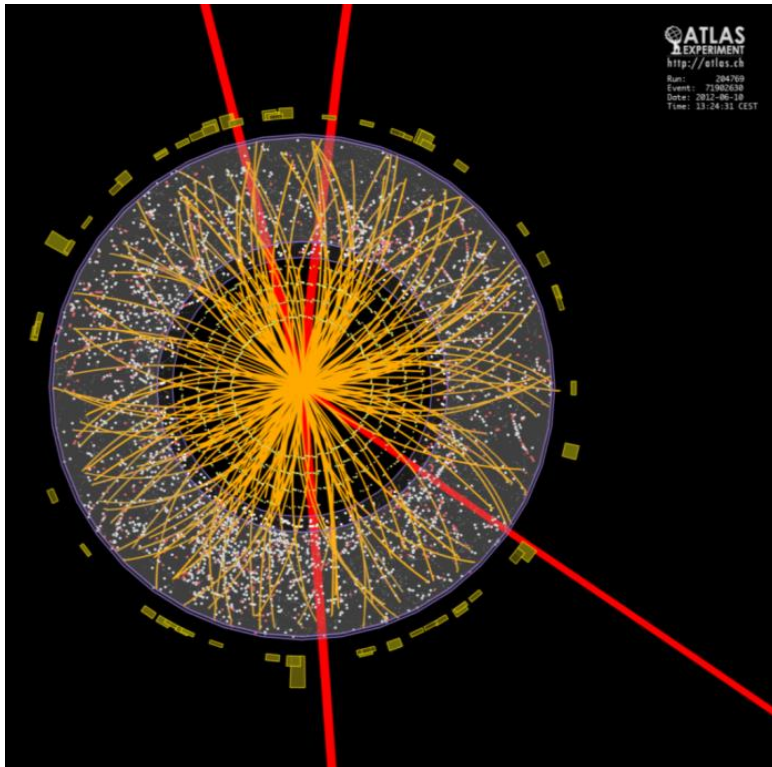


A few words about ATLAS

- Multipurpose detector.
- 46 m long, 25 m in diameter.
- 7000 tons (Eiffel's tower 7300)
- 100 sensors
- 3500 members from 35 countries



Detection of very rare events

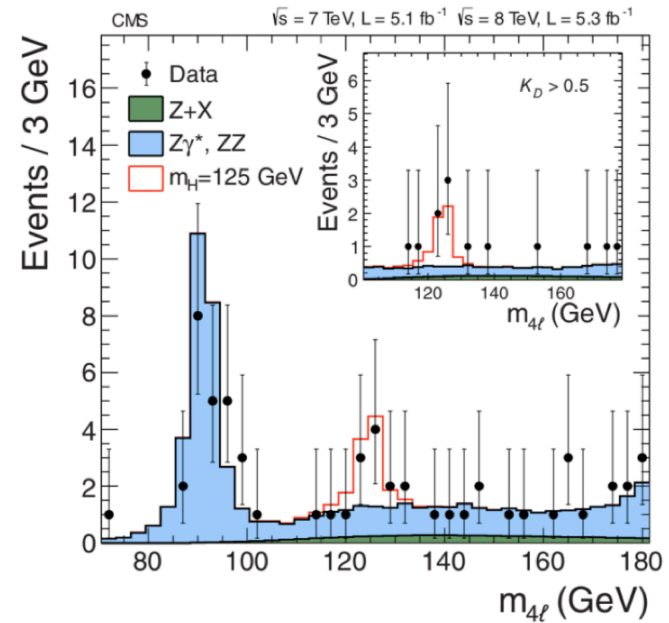
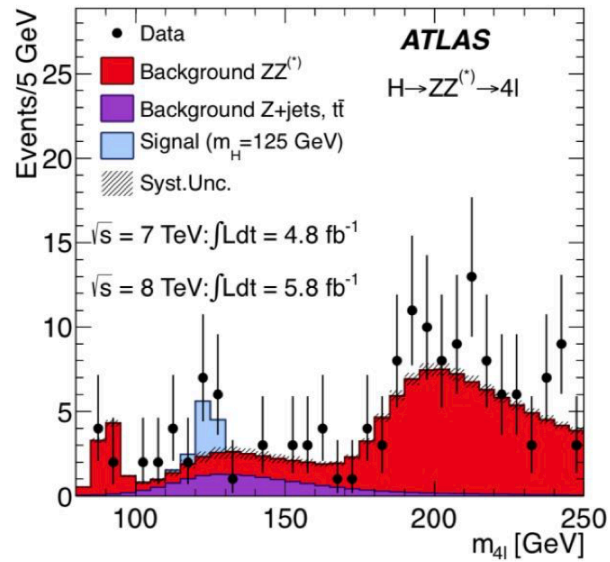


- Inside ATLAS or CMS there are 800 million pairs of protons colliding.
- Higgs events are expected only once for 10^{12} collisions.



41 coins

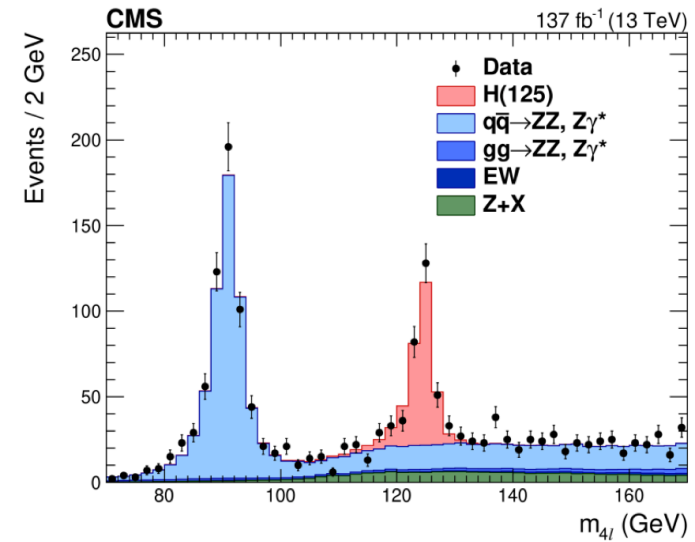
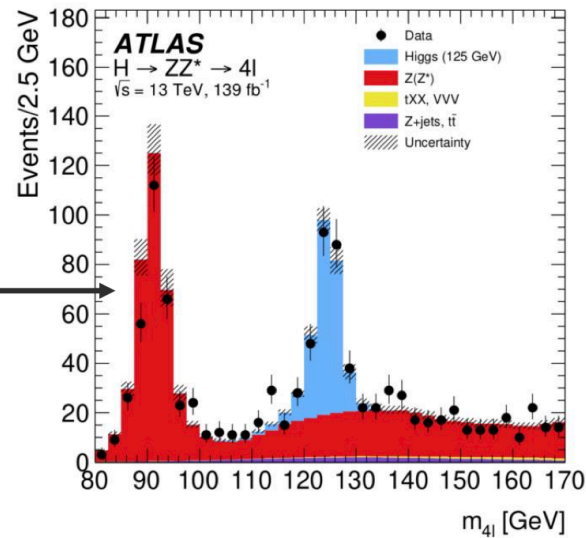
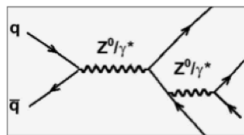
July 2012



Images from F. Gianotti presentation 04/07/2022

Today

Peak at $m_{4l} \sim 90$ GeV from $Z \rightarrow 4l$ production



Data filtering

The raw data of ATLAS comes with a rate of 80 TB/s



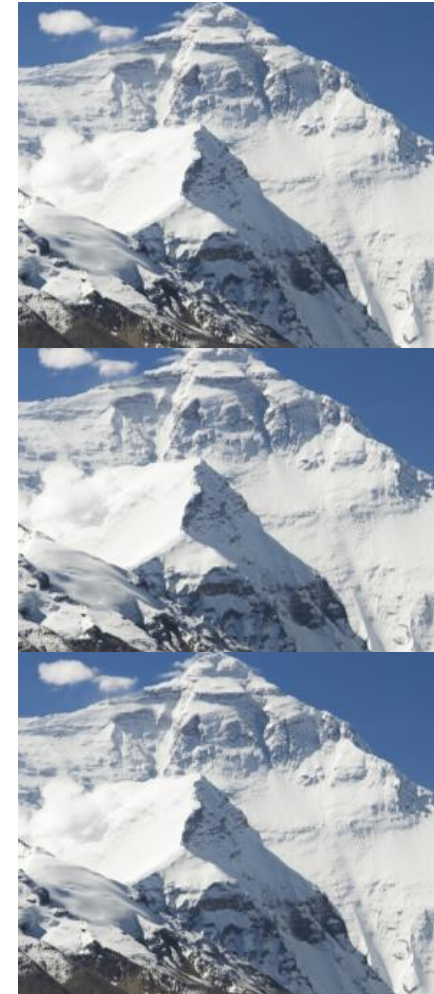
0.1 s



1 day



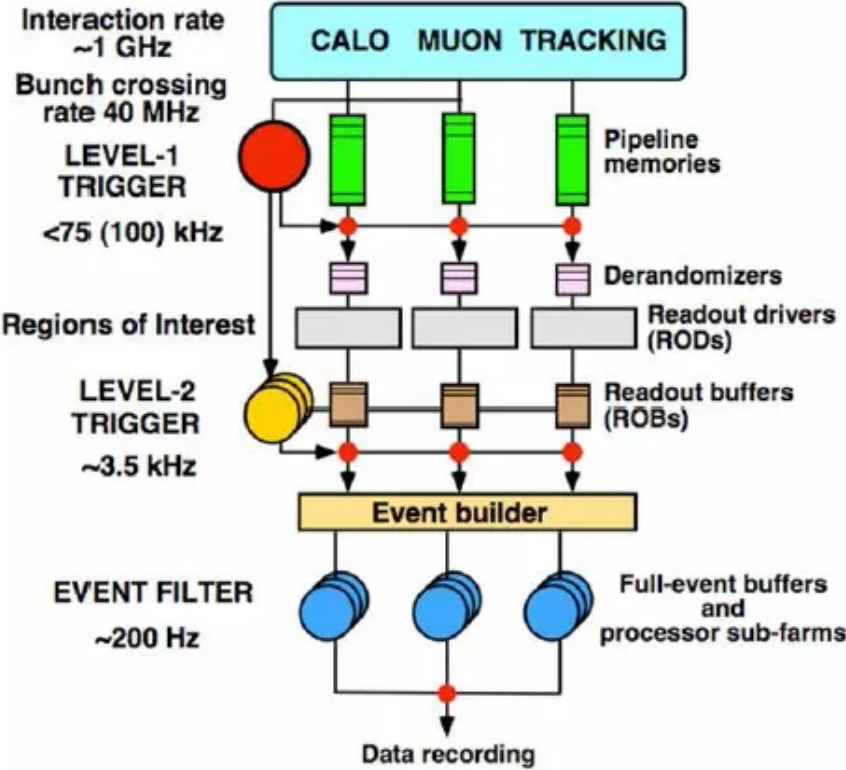
What would be the height ?



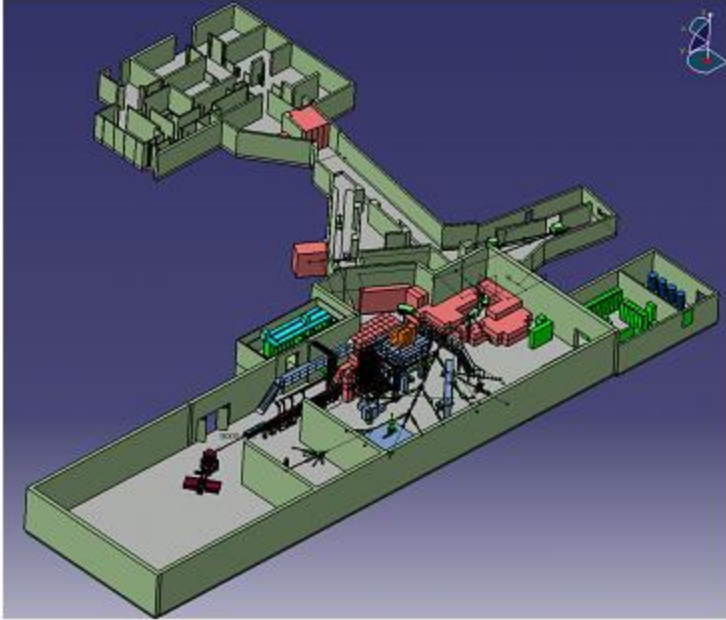
26 km

Data filtering

A system implemented in hardware and software reduces the data of 3 order of magnitudes.

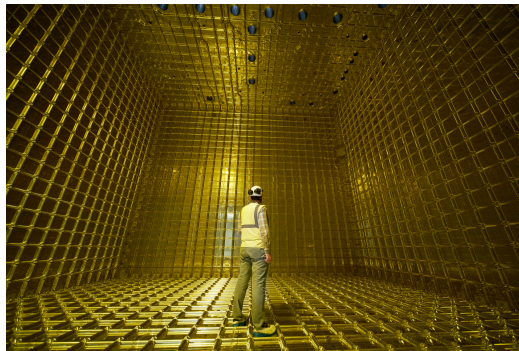
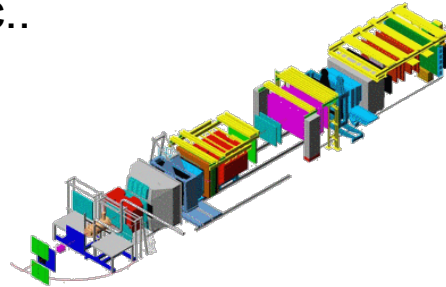


Other CERN experiments



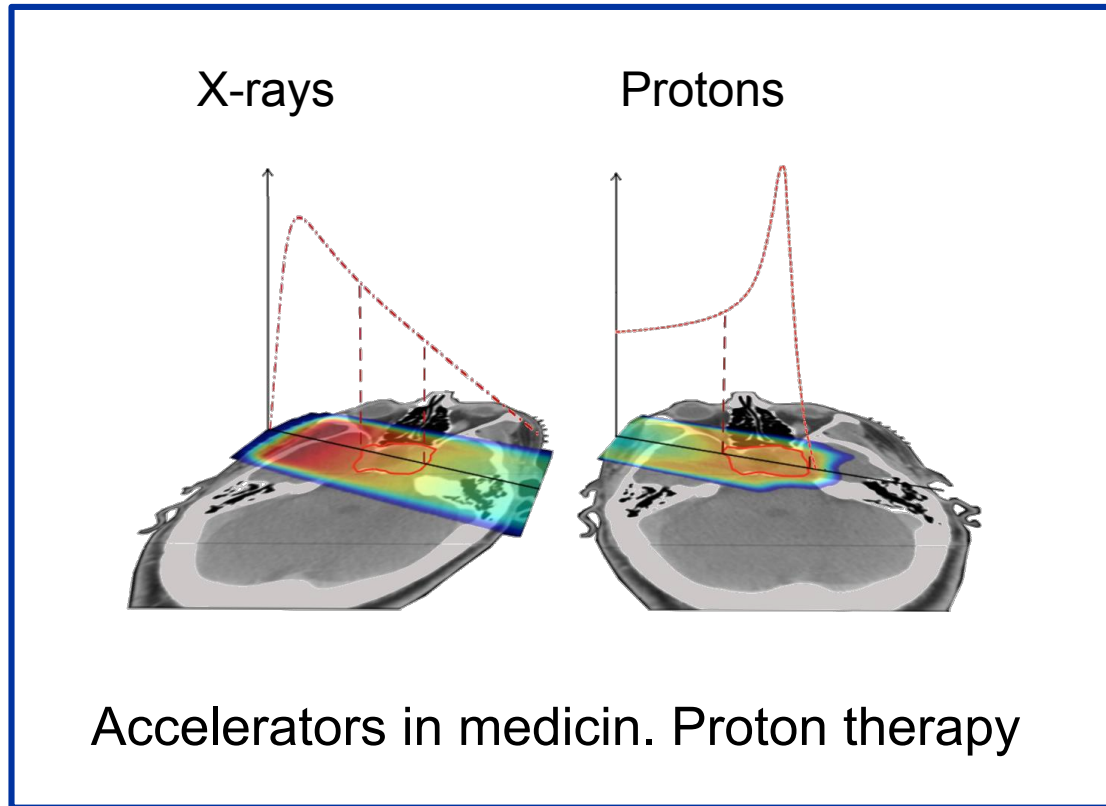
Isolde : Production and research with Isotopes

Fixed target experiments :
R&D for detectors,
COMPASS (Exploration of
hadron structure), The
Neutrino Platform, CLOUD,
etc..



Antimatter Factory

Technological applications



CERN DD/OC
Information Management: A Proposal

Tim Berners-Lee, CERN/DD
March 1989

Information Management: A Proposal

Abstract

This proposal concerns the management of general information about accelerators and experiments at CERN. It discusses the problems of loss of information about complex evolving systems and derives a solution based on a distributed hypertext system.

Keywords: Hypertext, Computer conferencing, Document retrieval, Information management, Project control

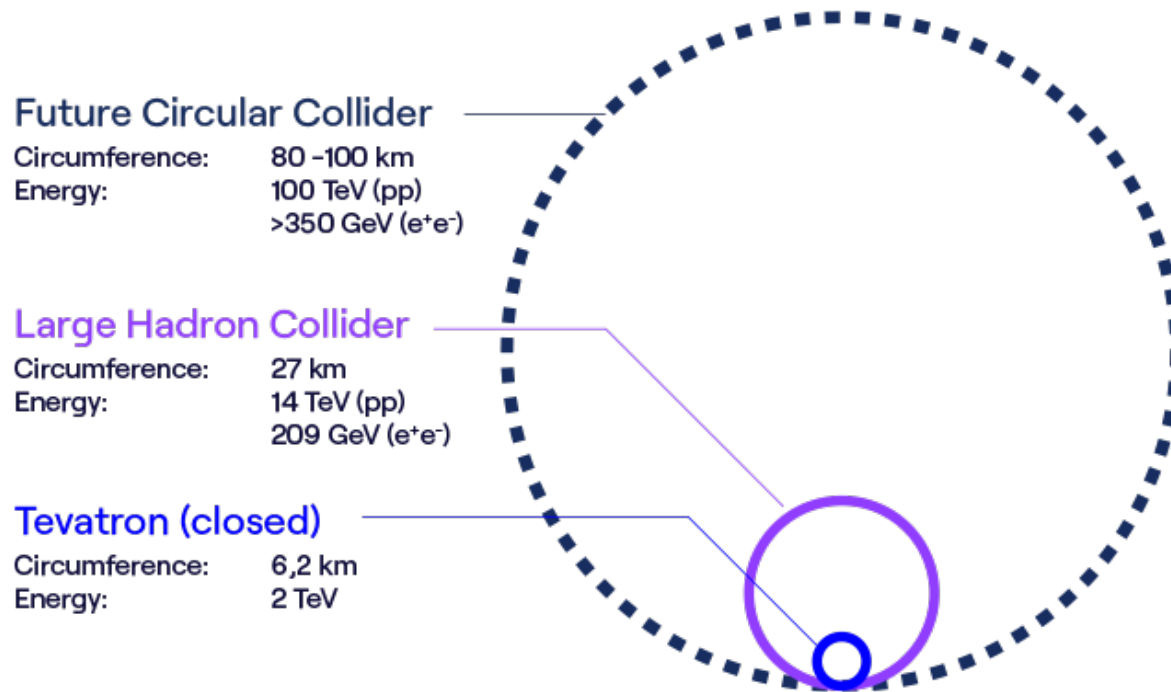
World Wide Web

And many others

The future

LHC will run until appr. 2040

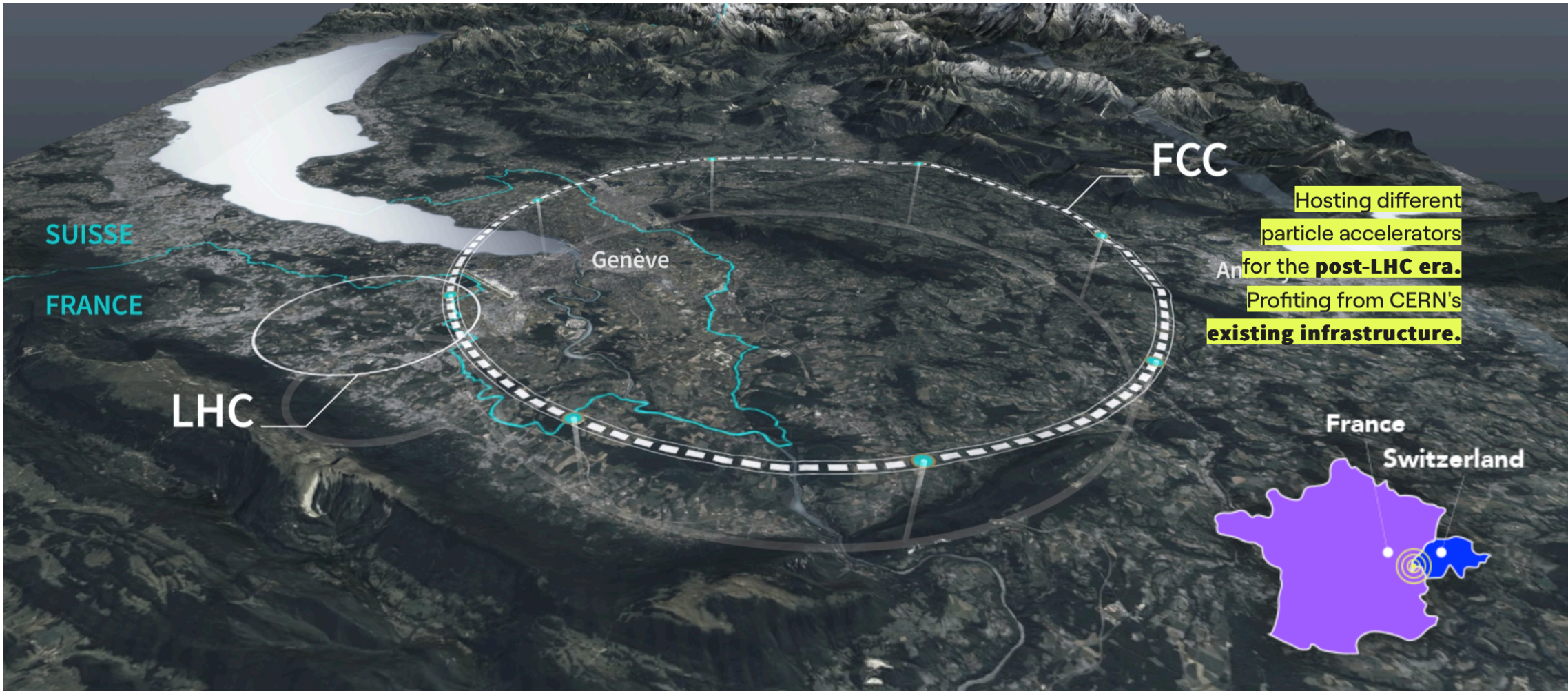
What's next after the LHC? The Future Circular collider - feasibility study on going.



Phase 1: FCC -ee beginning operation around 2045

Phase 2: FCC hh from 2070 on..

The future



The future

The image shows an aerial view of the CERN site in Geneva, Switzerland, with the LHC and FCC rings overlaid. The LHC is a solid line, and the FCC is a dashed line. The map in the bottom right shows France in purple and Switzerland in blue, with the CERN site marked by a target symbol.

- Higher energy and statistics for precision measurements of SM particles looking for deviations.
- Dark matter studies. Some theories predict DM particles having masses ranging from GeV to TeV.
- Investigation of the mechanisms providing a mass to neutrinos.
- Matter-antimatter asymmetry.
- SUSY.

FCC

Hosting different particle accelerators for the **post-LHC era**. Profiting from CERN's **existing infrastructure**.

SUISSE
FRANCE

LHC

France
Switzerland



Enjoy your stay at CERN!

Margherita.boselli@cern.ch



home.cern