The Large Hadron Collider at CERN: the latest challenge of particle

Chiara Roda – Universita' di Pisa and
Istituto di Fisica Nucleare

About one year ago: September 10th 2008 …

Ricerca avanzata
Preferenze
Strumenti per le lingue

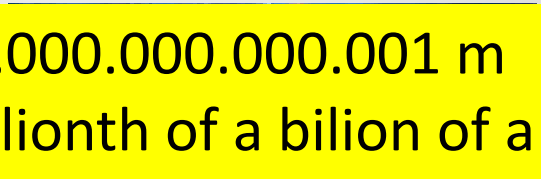
Cerca con Google | Mi sento fortunato

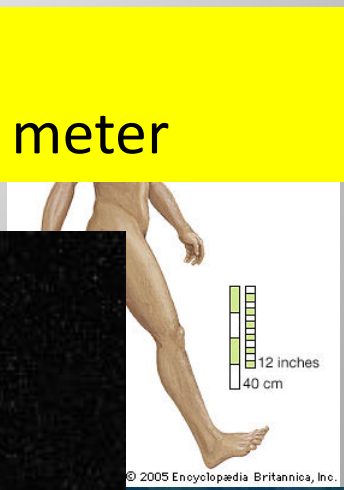
Cerca: nel Web pagine in Italiano pagine provenienti da: Italia

What has happened on September 10th at CERN … and after ?
Why have we started this huge enterprise ?
An example of the pratical esperience of working at this enterprise

What is the Large Hadron Collider used for ?

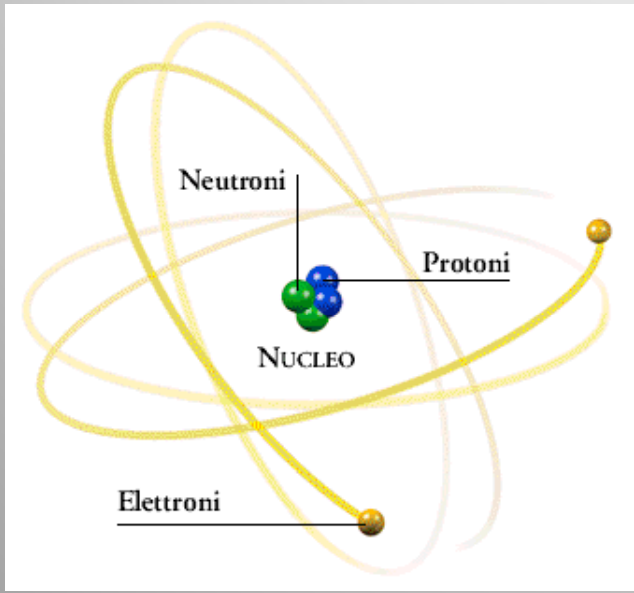
>0.000.000.000.000.001 m
One milionth of a bilion of a meter



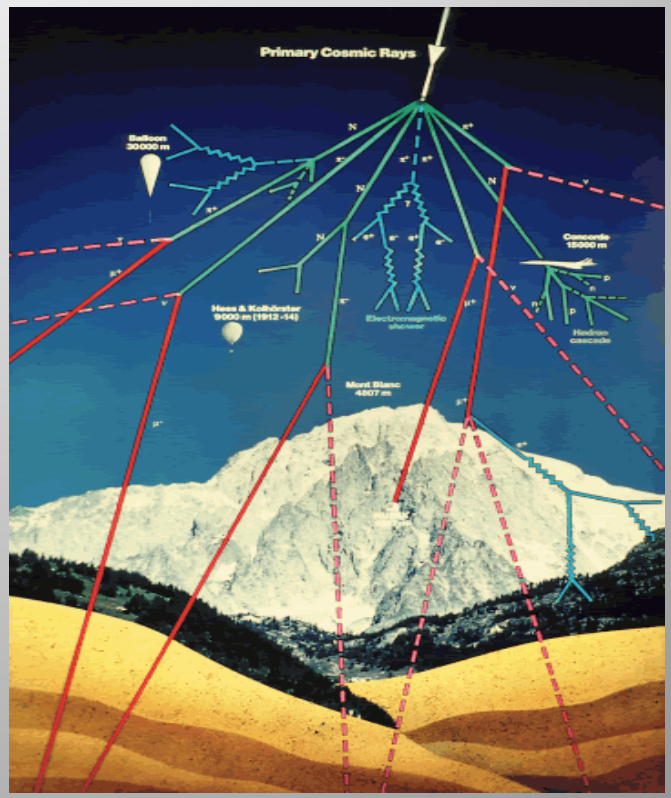


One step back: why have we arrived to the LHC?

Studies on athom



Studies on cosmic rays

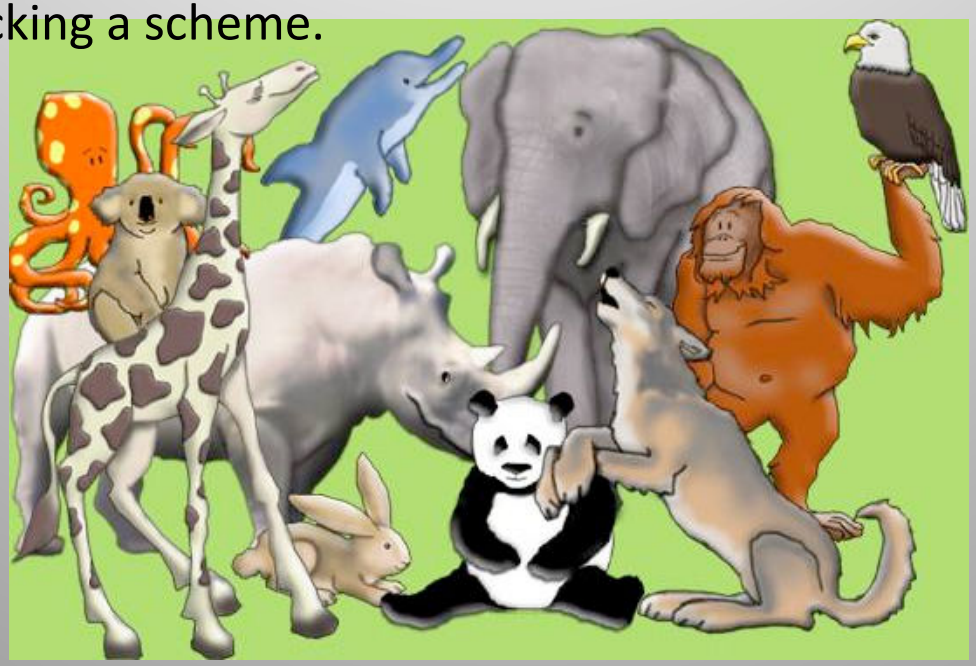


1930 understanding of the athom structure: nucleus + electrons in energy levels

Discovered at the beginning of the century
Carried to the discovery of different particle types: muons, pions

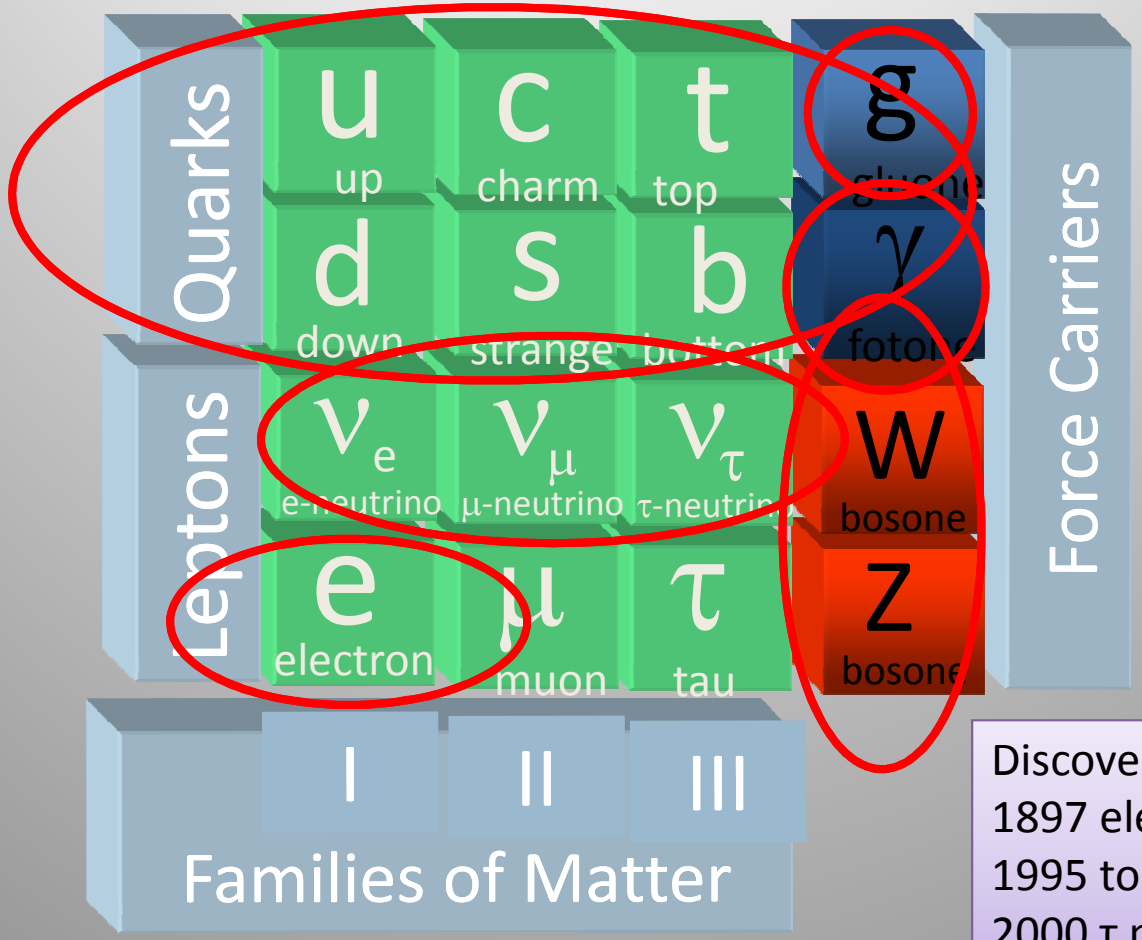
The accelerator era

The born of the accelerators revealed to the physicists a world so rich of particles that looked very much liked a zoo. Not only the variety of particles was really wide but they also showed different “lifetimes”: some of the particles after a certain time decayed producing other particles.
By 1960 the phycisits knew about 100 different particles that were completely lacking a scheme.



A new periodic table…

The Standard Model



Discoveries:
1897 electrons
1995 top quark
2000 τ neutrino

The Standard Model gives us an explanation for all … or almost so

$$
\begin{aligned}
&-\tfrac{1}{2}\partial_\nu g^a_\mu \partial_\nu g^a_\mu - g_s f^{abc}\partial_\mu g^a_\nu g^b_\mu g^c_\nu - \tfrac{1}{4} g_s^2 f^{abc} f^{ade} g^b_\mu g^c_\nu g^d_\mu g^e_\nu + \\
&\tfrac{1}{2} i g_s^2 (\bar{q}^\sigma_i \gamma^\mu q^\sigma_j) g^a_\mu + \bar{G}^a \partial^2 G^a + g_s f^{abc} \partial_\mu \bar{G}^a G^b g^c_\mu - \partial_\nu W^+_\mu \partial_\nu W^-_\mu - \\
&M^2 W^+_\mu W^-_\mu - \tfrac{1}{2}\partial_\nu Z^0_\mu \partial_\nu Z^0_\mu - \tfrac{1}{2c_w^2} M^2 Z^0_\mu Z^0_\mu - \tfrac{1}{2}\partial_\mu A_\nu \partial_\mu A_\nu - \tfrac{1}{2}\partial_\mu H \partial_\mu H - \\
&\tfrac{1}{2} m_h^2 H^2 - \partial_\mu \phi^+ \partial_\mu \phi^- - M^2 \phi^+ \phi^- - \tfrac{1}{2}\partial_\mu \phi^0 \partial_\mu \phi^0 - \tfrac{1}{2c_w^2} M \phi^0 \phi^0 - \beta_h [\tfrac{2M^2}{g^2} + \\
&\tfrac{2M}{g} H + \tfrac{1}{2}(H^2 + \phi^0 \phi^0 + 2\phi^+ \phi^-)] + \tfrac{2M^4}{g^2}\alpha_h - i g c_w [\partial_\nu Z^0_\mu (W^+_\mu W^-_\nu - \\
&W^+_\nu W^-_\mu) - Z^0_\nu (W^+_\mu \partial_\nu W^-_\mu - W^-_\mu \partial_\nu W^+_\mu) + Z^0_\mu (W^+_\nu \partial_\nu W^-_\mu - \\
&W^-_\nu \partial_\nu W^+_\mu)] - i g s_w [\partial_\nu A_\mu (W^+_\mu W^-_\nu - W^+_\nu W^-_\mu) - A_\nu (W^+_\mu \partial_\nu W^-_\mu - \\
&W^-_\mu \partial_\nu W^+_\mu) + A_\mu (W^+_\nu \partial_\nu W^-_\mu - W^-_\nu \partial_\nu W^+_\mu)] - \tfrac{1}{2} g^2 W^+_\mu W^-_\mu W^+_\nu W^-_\nu + \\
&\tfrac{1}{2} g^2 W^+_\mu W^-_\nu W^+_\mu W^-_\nu + g^2 c_w^2 (Z^0_\mu W^+_\mu Z^0_\nu W^-_\nu - Z^0_\mu Z^0_\mu W^+_\nu W^-_\nu) + \\
&g^2 s_w^2 (A_\mu W^+_\mu A_\nu W^-_\nu - A_\mu A_\mu W^+_\nu W^-_\nu) + g^2 s_w c_w [A_\mu Z^0_\nu (W^+_\mu W^-_\nu - \\
&W^+_\nu W^-_\mu) - 2 A_\mu Z^0_\mu W^+_\nu W^-_\nu] - g\alpha [H^3 + H\phi^0\phi^0 + 2H\phi^+\phi^-] - \\
&\tfrac{1}{8} g^2 \alpha_h [H^4 + (\phi^0)^4 + 4(\phi^+\phi^-)^2 + 4(\phi^0)^2 \phi^+\phi^- + 4H^2\phi^+\phi^- + 2(\phi^0)^2 H^2] - \\
&g M W^+_\mu W^-_\mu H - \tfrac{1}{2} g \tfrac{M}{c_w^2} Z^0_\mu Z^0_\mu H - \tfrac{1}{2} i g [W^+_\mu (\phi^0 \partial_\mu \phi^- - \phi^- \partial_\mu \phi^0) - \\
&W^-_\mu (\phi^0 \partial_\mu \phi^+ - \phi^+ \partial_\mu \phi^0)] + \tfrac{1}{2} g [W^+_\mu (H \partial_\mu \phi^- - \phi^- \partial_\mu H) - W^-_\mu (H \partial_\mu \phi^+ - \\
&\phi^+ \partial_\mu H)] + \tfrac{1}{2} g \tfrac{1}{c_w} (Z^0_\mu (H \partial_\mu \phi^0 - \phi^0 \partial_\mu H) - i g \tfrac{1 - 2c_w^2}{2c_w} Z^0_\mu (W^+_\mu \phi^- - W^-_\mu \phi^+) + \\
&i g s_w M A_\mu (W^+_\mu \phi^- - W^-_\mu \phi^+) - i g \tfrac{1 - 2c_w^2}{2c_w} Z^0_\mu (\phi^+ \partial_\mu \phi^- - \phi^- \partial_\mu \phi^+) + \\
&i g s_w A_\mu (\phi^+ \partial_\mu \phi^- - \phi^- \partial_\mu \phi^+) - \tfrac{1}{4} g^2 W^+_\mu W^-_\mu [H^2 + (\phi^0)^2 + 2\phi^+\phi^-] - \\
&\tfrac{1}{4} g^2 \tfrac{1}{c_w^2} Z^0_\mu Z^0_\mu [H^2 + (\phi^0)^2 + 2(2 s_w^2 - 1)^2 \phi^+\phi^-] - \tfrac{1}{2} g^2 \tfrac{s_w^2}{c_w} Z^0_\mu \phi^0 (W^+_\mu \phi^- + \\
&W^-_\mu \phi^+) - \tfrac{1}{2} i g^2 \tfrac{s_w^2}{c_w} Z^0_\mu H (W^+_\mu \phi^- - W^-_\mu \phi^+) + \tfrac{1}{2} g^2 s_w A_\mu \phi^0 (W^+_\mu \phi^- + \\
&W^-_\mu \phi^+) + \tfrac{1}{2} i g^2 s_w A_\mu H (W^+_\mu \phi^- - W^-_\mu \phi^+) - g^2 \tfrac{s_w}{c_w} (2c_w^2 - 1) Z^0_\mu A_\mu \phi^+ \phi^- - \\
&g^1 s_w^2 A_\mu A_\mu \phi^+ \phi^- - \bar{e}^\lambda (\gamma \partial + m^\lambda_e) e^\lambda - \bar{\nu}^\lambda \gamma \partial \nu^\lambda - \bar{u}^\lambda_j (\gamma \partial + m^\lambda_u) u^\lambda_j - \bar{d}^\lambda_j (\gamma \partial + \\
&m^\lambda_d) d^\lambda_j + i g s_w A_\mu [-(\bar{e}^\lambda \gamma e^\lambda) + \tfrac{2}{3}(\bar{u}^\lambda_j \gamma u^\lambda_j) - \tfrac{1}{3}(\bar{d}^\lambda_j \gamma d^\lambda_j)] + \tfrac{ig}{4c_w} Z^0_\mu [(\bar{\nu}^\lambda \gamma^\mu (1 + \\
&\gamma^5) \nu^\lambda) + (\bar{e}^\lambda \gamma^\mu (4 s_w^2 - 1 - \gamma^5) e^\lambda) + (\bar{u}^\lambda_j \gamma^\mu (\tfrac{8}{3} s_w^2 - 1 - \gamma^5) u^\lambda_j) + \\
&(\bar{d}^\lambda_j \gamma^\mu (1 - \tfrac{8}{3} s_w^2 - \gamma^5) d^\lambda_j)] + \tfrac{ig}{2\sqrt{2}} W^+_\mu [(\bar{\nu}^\lambda \gamma^\mu (1 + \gamma^5) e^\lambda) + (\bar{u}^\lambda_j \gamma^\mu (1 + \\
&\gamma^5) C_{\lambda\kappa} d^\kappa_j)] + \tfrac{ig}{2\sqrt{2}} W^-_\mu [(\bar{e}^\lambda \gamma^\mu (1 + \gamma^5) \nu^\lambda) + (\bar{d}^\kappa_j C^\dagger_{\lambda\kappa} \gamma^\mu (1 + \gamma^5) u^\lambda_j)] + \\
&\tfrac{ig}{2\sqrt{2}} \tfrac{m^\lambda_e}{M} [-\phi^+ (\bar{\nu}^\lambda (1 - \gamma^5) e^\lambda) + \phi^- (\bar{e}^\lambda (1 + \gamma^5) \nu^\lambda)] - \tfrac{g}{2} \tfrac{m^\lambda_e}{M} [H (\bar{e}^\lambda e^\lambda) + \\
&i \phi^0 (\bar{e}^\lambda \gamma^5 e^\lambda)] + \tfrac{ig}{2M\sqrt{2}} \phi^+ [-m^\kappa_d (\bar{u}^\lambda_j C_{\lambda\kappa} (1 - \gamma^5) d^\kappa_j) + m^\lambda_u (\bar{u}^\lambda_j C_{\lambda\kappa} (1 + \\
&\gamma^5) d^\kappa_j] + \tfrac{ig}{2M\sqrt{2}} \phi^- [m^\lambda_d (\bar{d}^\lambda_j C^\dagger_{\lambda\kappa} (1 + \gamma^5) u^\kappa_j) - m^\kappa_u (\bar{d}^\kappa_j C^\dagger_{\lambda\kappa} (1 - \gamma^5) u^\kappa_j] - \\
&\tfrac{g}{2} \tfrac{m^\lambda_u}{M} H (\bar{u}^\lambda_j u^\lambda_j) - \tfrac{g}{2} \tfrac{m^\lambda_d}{M} H (\bar{d}^\lambda_j d^\lambda_j) + \tfrac{ig}{2} \tfrac{m^\lambda_u}{M} \phi^0 (\bar{u}^\lambda_j \gamma^5 u^\lambda_j) - \tfrac{ig}{2} \tfrac{m^\lambda_d}{M} \phi^0 (\bar{d}^\lambda_j \gamma^5 d^\lambda_j) + \\
&\bar{X}^+ (\partial^2 - M^2) X^+ + \bar{X}^- (\partial^2 - M^2) X^- + \bar{X}^0 (\partial^2 - \tfrac{M^2}{c_w^2}) X^0 + \bar{Y} \partial^2 Y + \\
&i g c_w W^+_\mu (\partial_\mu \bar{X}^0 X^- - \partial_\mu \bar{X}^+ X^0) + i g s_w W^+_\mu (\partial_\mu \bar{Y} X^- - \partial_\mu \bar{X}^+ Y) + \\
&i g c_w W^-_\mu (\partial_\mu \bar{X}^- X^0 - \partial_\mu \bar{X}^0 X^+) + i g s_w W^-_\mu (\partial_\mu \bar{X}^- Y - \partial_\mu \bar{Y} X^+) + \\
&i g c_w Z^0_\mu (\partial_\mu \bar{X}^+ X^+ - \partial_\mu \bar{X}^- X^-) + i g s_w A_\mu (\partial_\mu \bar{X}^+ X^+ - \partial_\mu \bar{X}^- X^-) - \\
&\tfrac{1}{2} g M [\bar{X}^+ X^+ H + \bar{X}^- X^- H + \tfrac{1}{c_w^2} \bar{X}^0 X^0 H] + \tfrac{1 - 2c_w^2}{2c_w} i g M [\bar{X}^+ X^0 \phi^+ - \\
&\bar{X}^- X^0 \phi^-] + \tfrac{1}{2c_w} i g M [\bar{X}^0 X^- \phi^+ - \bar{X}^0 X^+ \phi^-] + i g M s_w [\bar{X}^0 X^- \phi^+ - \\
&\bar{X}^0 X^+ \phi^-] + \tfrac{1}{2} i g M [\bar{X}^+ X^+ \phi^0 - \bar{X}^- X^- \phi^0]
\end{aligned}
$$

$$
\begin{aligned}
&W^-_\nu \partial_\nu W^+_\mu)] - i g s_w [\partial_\nu A_\mu (W^+_\mu W^-_\nu - W \\
&W^-_\mu \partial_\nu W^+_\mu) + A_\mu (W^+_\nu \partial_\nu W^-_\mu - W^-_\nu \partial_\nu W \\
&\tfrac{1}{2} g^2 W^+_\mu W^-_\nu W^+_\mu W^-_\nu + g^2 c_w^2 (Z^0_\mu W^+_\mu Z^0 \\
&g^2 s_w^2 (A_\mu W^+_\mu A_\nu W^-_\nu - A_\mu A_\mu W^+_\nu W^-_\nu) + \\
&W^+_\nu W^-_\mu) - 2 A_\mu Z^0_\mu W^+_\nu W^-_\nu] - g\alpha [H^3 \\
&\tfrac{1}{8} g^2 \alpha_h [H^4 + (\phi^0)^4 + 4(\phi^+\phi^-)^2 + 4(\phi^0)^2 \phi^+ \phi \\
&g M W^+_\mu W^-_\mu H - \tfrac{1}{2} g \tfrac{M}{c_w^2} Z^0_\mu Z^0_\mu H - \tfrac{1}{2} i g [W \\
&W^-_\mu (\phi^0 \partial_\mu \phi^+ - \phi^+ \partial_\mu \phi^0)] + \tfrac{1}{2} g [W^+_\mu (H \partial_\mu \phi^- \\
&\phi^+ \partial_\mu H)] + \tfrac{1}{2} g \tfrac{1}{c_w} (Z^0_\mu (H \partial_\mu \phi^0 - \phi^0 \partial_\mu H) - i g \\
&i g s_w M A_\mu (W^+_\mu \phi^- - W^-_\mu \phi^+) - i g \tfrac{1 - 2c_w^2}{2c_w} \\
&i g s_w A_\mu (\phi^+ \partial_\mu \phi^- - \phi^- \partial_\mu \phi^+) - \tfrac{1}{4} g^2 W^+_\mu W
\end{aligned}
$$

$$
g M W^+_\mu W^-_\mu H - \tfrac{1}{2} g \tfrac{M}{c_w^2} Z^0_\mu Z^0_\mu H
$$

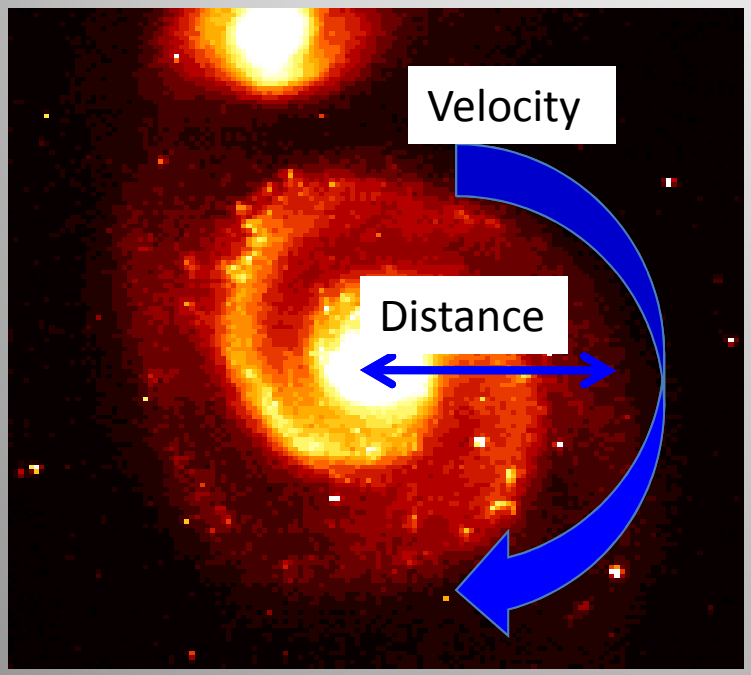
The Higgs boson and the mass

A room full of people like in a party - the crowd represent the Higgs field

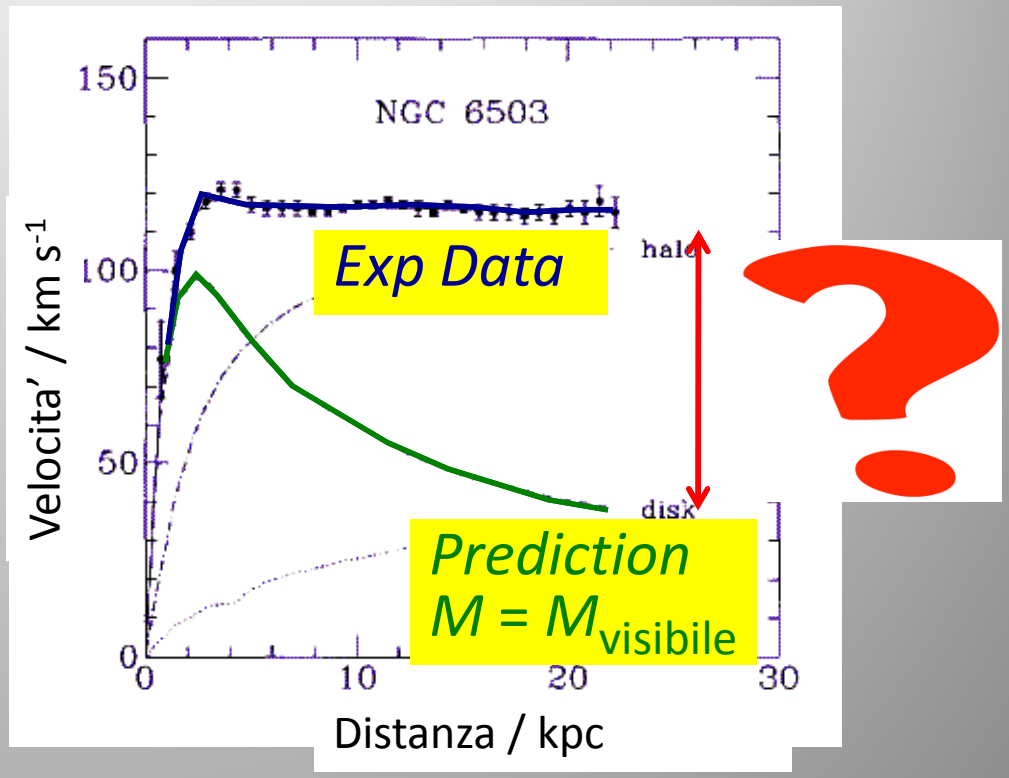
A famous person arrives – this person represent a particle

As the famous person cross the room the crowd concentrate around him slowing him down as if he was becoming heavier – - the particle acquires mass

Another unsolved problem: the existence of dark matter



Measurement of the rotational velocity of the stars at the edge of spiral galaxies.



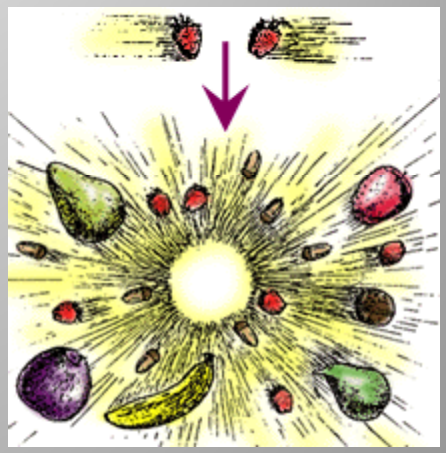
Dark matter would be 5 times larger than standard matter.

How can we find an answer to the open problems ?

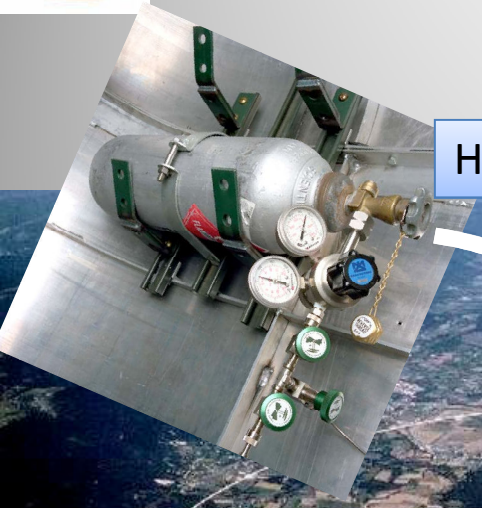
We create in the laboratory the conditions for which the particles we are looking for can be generated.

Needed Ingredients:

- High energy collision of particles: “commonly findable” low mass particles (protons) accelerated to high velocity -> high energy collision -> in the collision different types of particles having high mass may be created thanks to the available energy - the key relation is $E=mc^2$
- High number of collisions: the particles we are looking for are rare
- A precise apparatus to record the collision characteristics

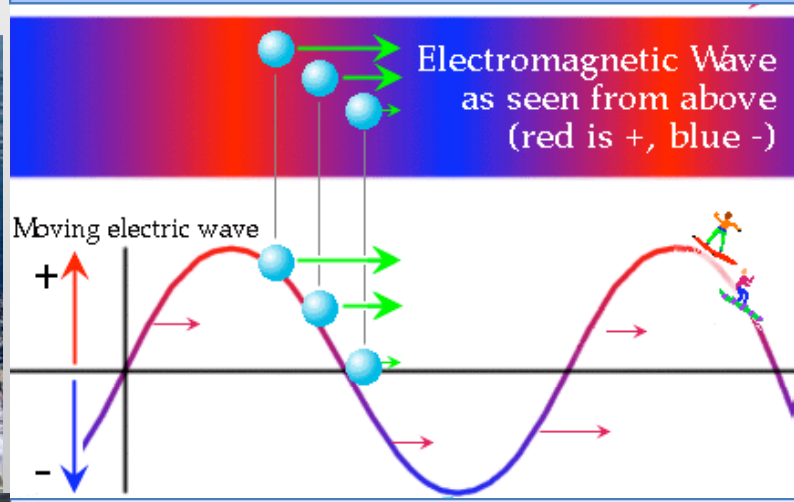


The beam particles and the accelerator

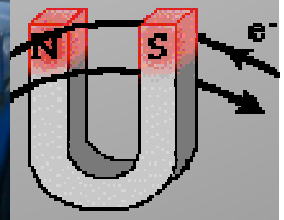


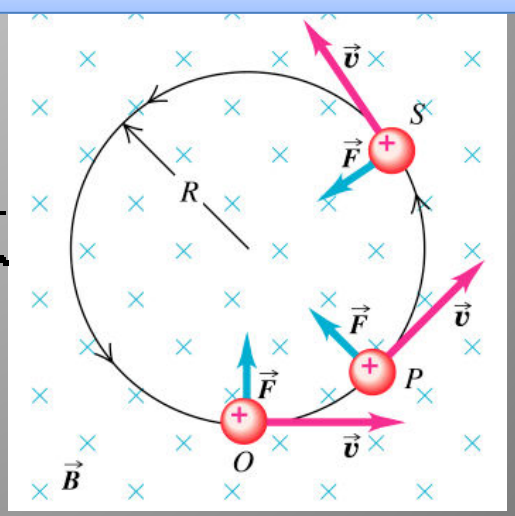
Hydrogen bottle

Electric field to accelerate the protons

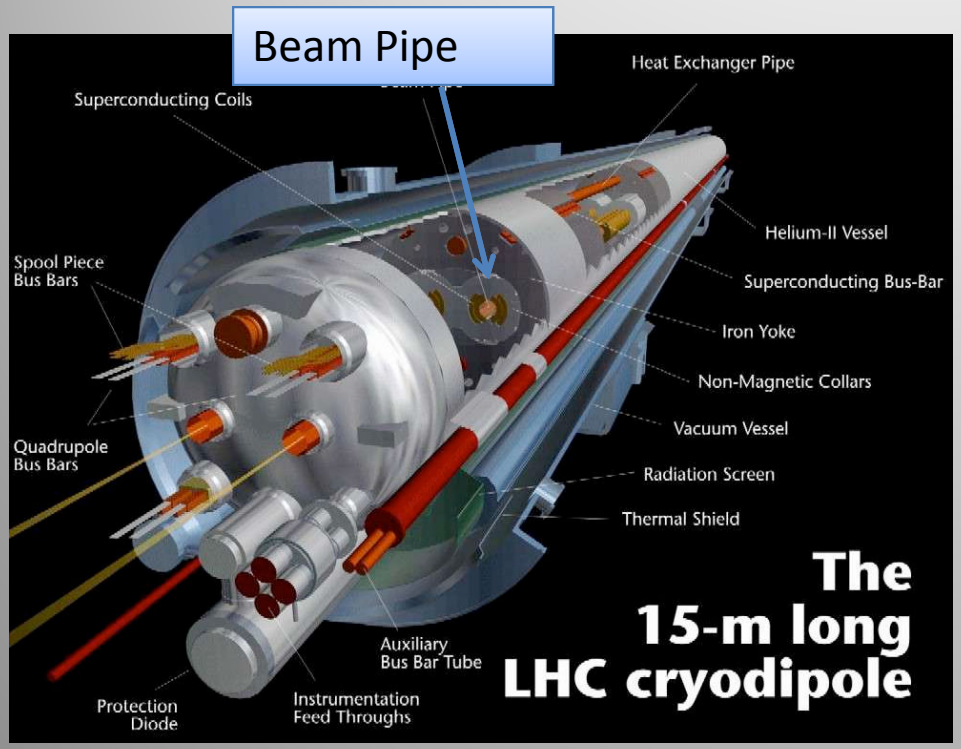


Magnetic fields to circulate them





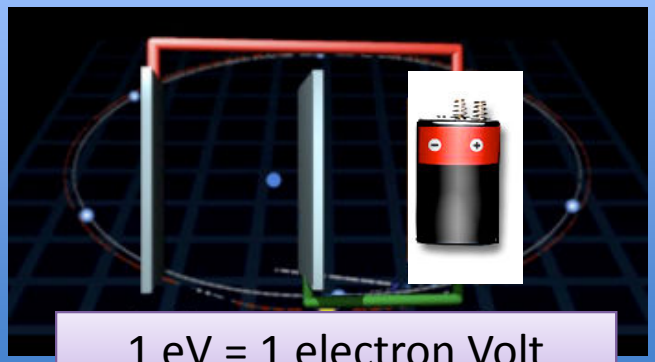
The most challenging part of LHC



- The magnetic field intensity is 8.3 Tesla, 100000 times larger than that of earth, requires to use special magnets called: superconducting magnets
- In order to have superconducting magnets they have to be operated at very low temperature: -271.3 °C about 1 degree colder than the temperature of cosmic space
- The cooling system of LHC is the biggest cooling system ever built and it is based on Helium kept in conditions to be superfluid
- The cool down of the 27 Km of LHC at -271.3 °C requires 3-4 weeks

The proton energy

Proton energy = 7000000000000 eV = 7 TeV

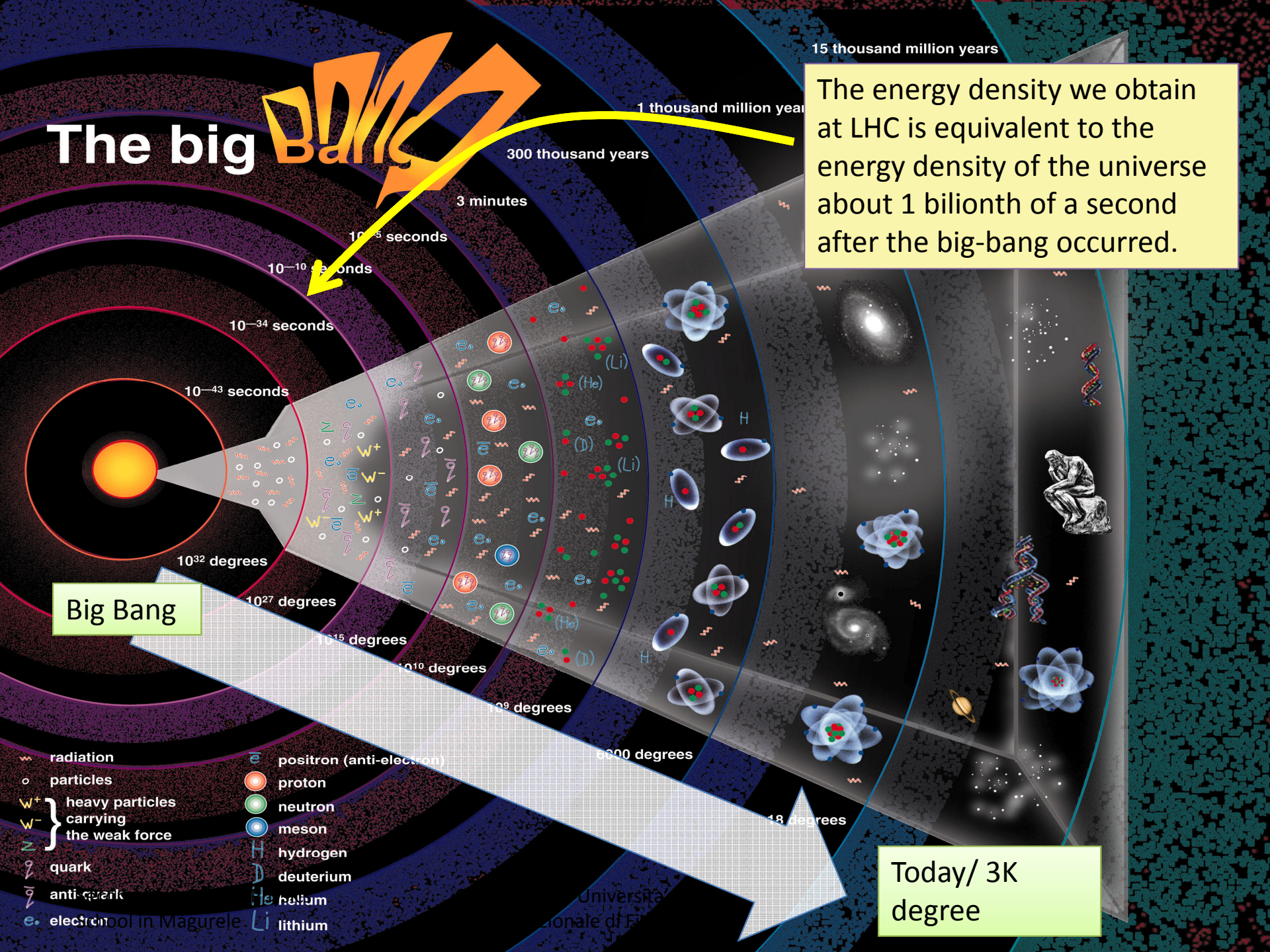


1 eV = 1 electron Volt

7 TeV

High energy ? A 7 TeV proton = energy of a flying mosquito … the real challenge is the energy density…

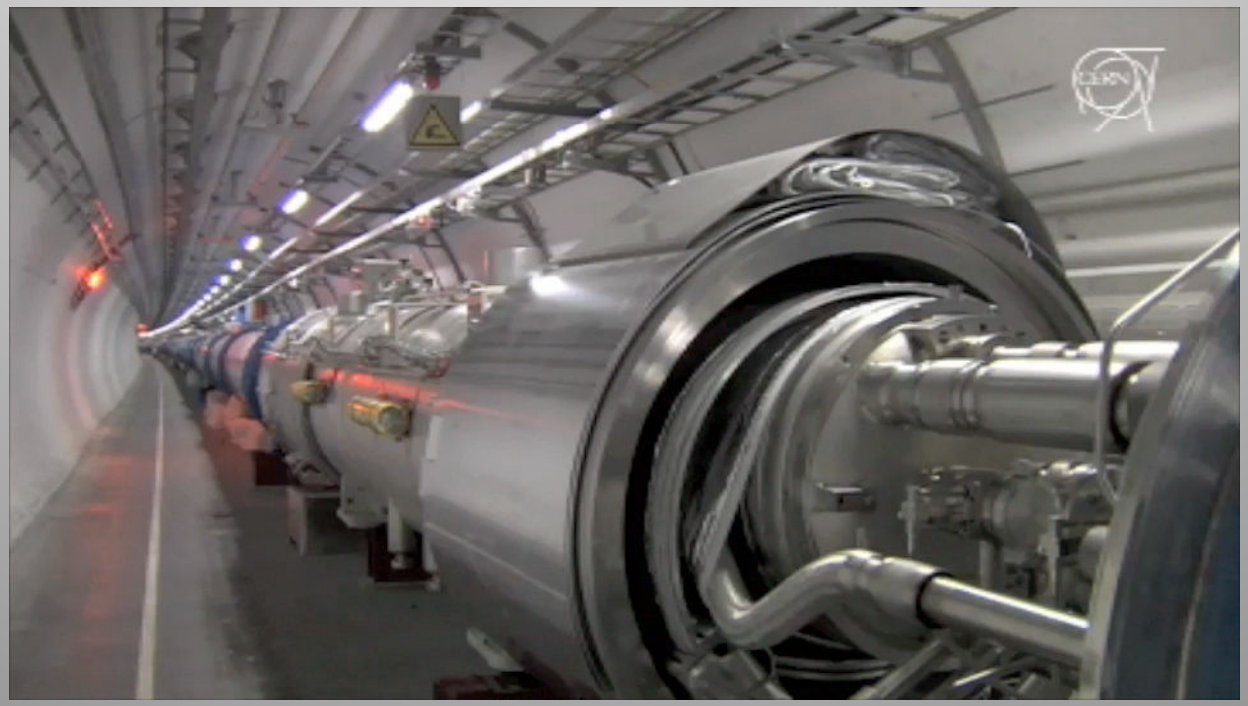
X 0.0000000000001
One thousandth of bilionth of the mosquito volume



The energy density we obtain at LHC is equivalent to the energy density of the universe about 1 bilionth of a second after the big-bang occurred.

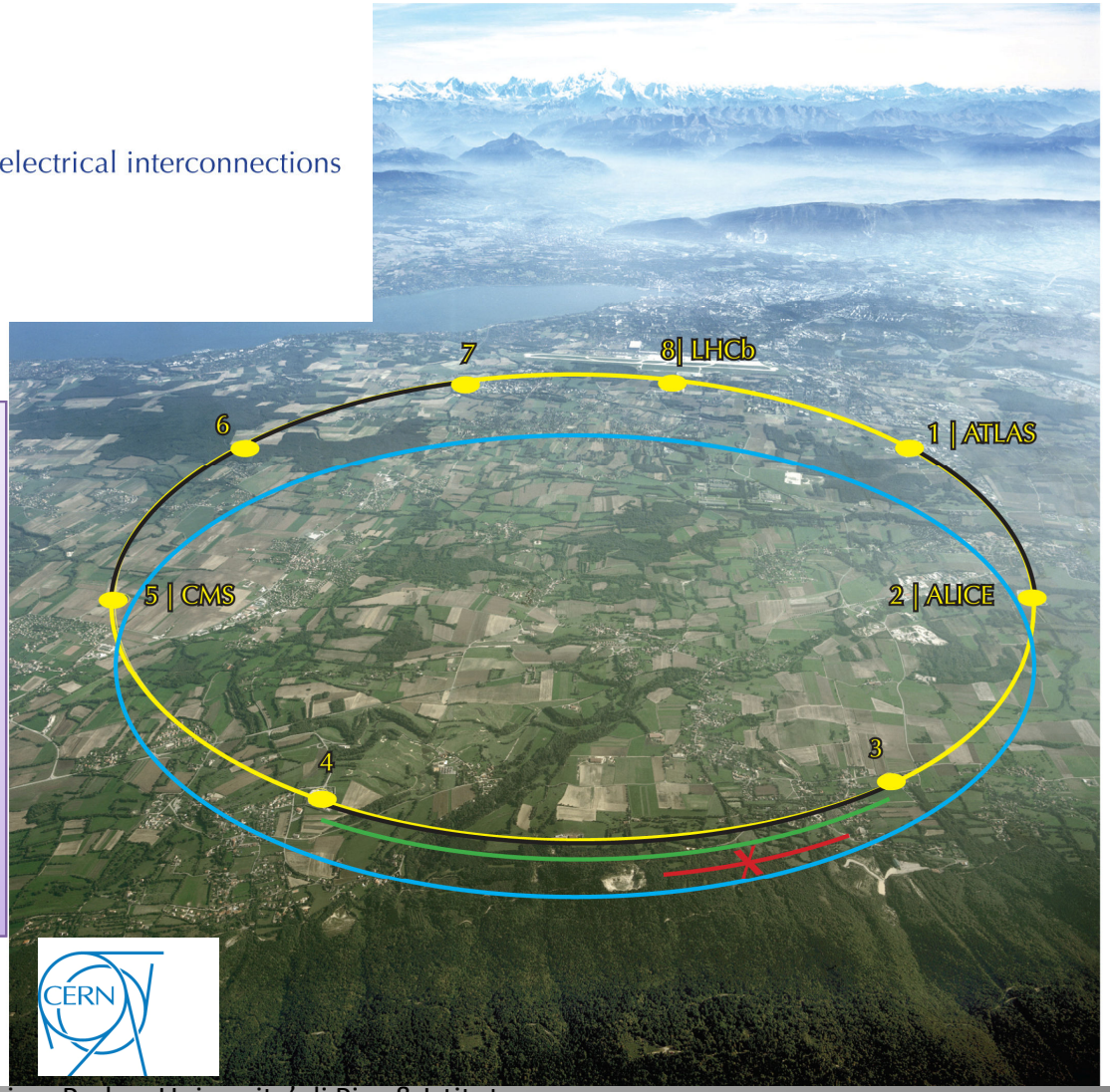
Uncluckly … something went wrong

- The first collisions where expected in the last week of September 2009
- On September 19th LHC suffered a big incident due to and electric fault



LHC Repair

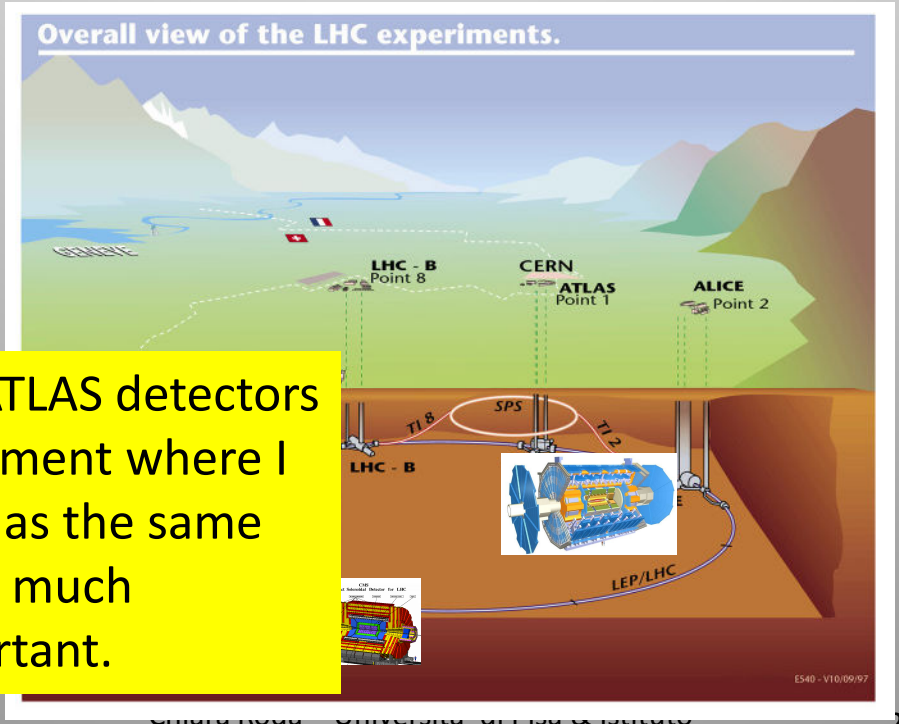
- New pressure release ports fitted
- Upgrade of magnet protection system
- Cleaning ofvacuum beam tube
- Dipole and quadrupole magnets replaced and electrical interconnections
- LHC ring
- X Incident



All the repairs finished and on October 19th the last sector of LHC was cool-down to the operating temperature 1.9K. The coming week are intense commissioning weeks to take LHC back to the first collision early in December.

We have seen that LHC has been designed to generate collision that may produce the particles we are looking for.

Now we need a detector that is able to “see” and record the characteristics of the particles produced in these collisionsAbbiamo visto che LHC



I will talk about the ATLAS detectors because is the experiment where I work however CMS has the same physic goals and is as much interesting and important.

ATLAS

ATLAS is the slang to indicate both the community of people working at the experiment and the apparatus.

2500 physicits, 37 nations

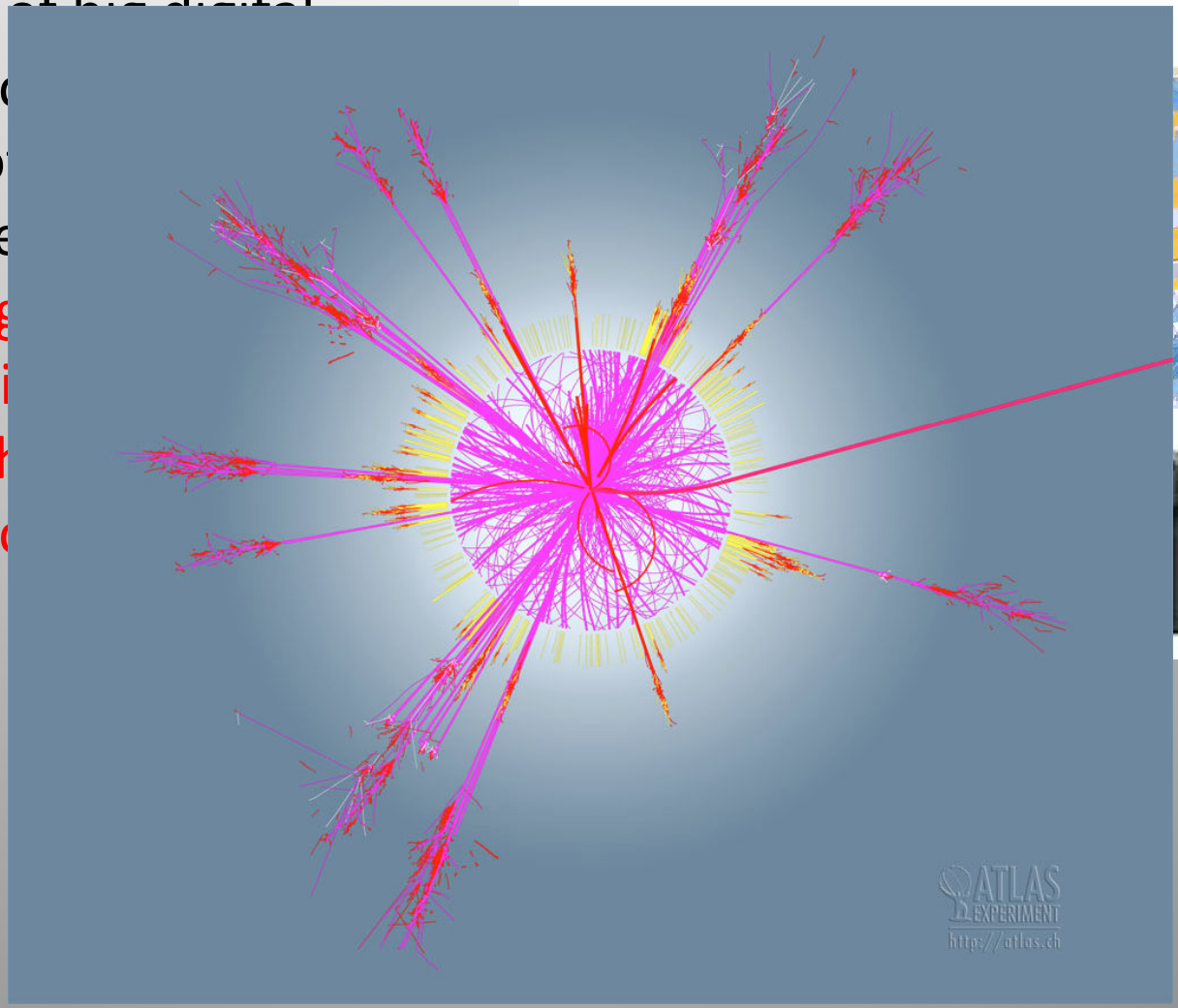
IFIN-HH 23 Physicists

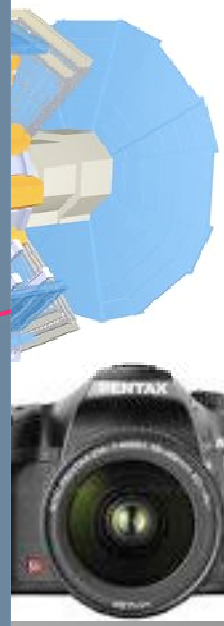
15 Physicists

The national ATLAS groups are small/medium size groups that partecipated to make the design, to build, install and perate part of the detector and to the development of some analysis.

The ATLAS detector

ATLAS is a kind of big digital
camera that all
characteristic o
produced in the
collisions ➔ it g
precise three di
every time we h
proton-proton c





CERN/LHCC/92-4
LHCC/I 2
1 October 1992

ATLAS

Letter of Intent
for a
General-Purpose pp Experiment
at the
Large Hadron Collider at CERN

Abstract

The ATLAS collaboration proposes to build a general purpose proton–proton detector for the Large Hadron Collider, capable of exploring the new energy regime which will become accessible. The detector would be fully operational at the startup of the new accelerator. The detector concept, the research and development work under way to optimize the detector design, and its proposed implementation are described, together with examples of its discovery potential.

An adventure started in 1992 …

1996

Second High Energy Physics School in Măgurele

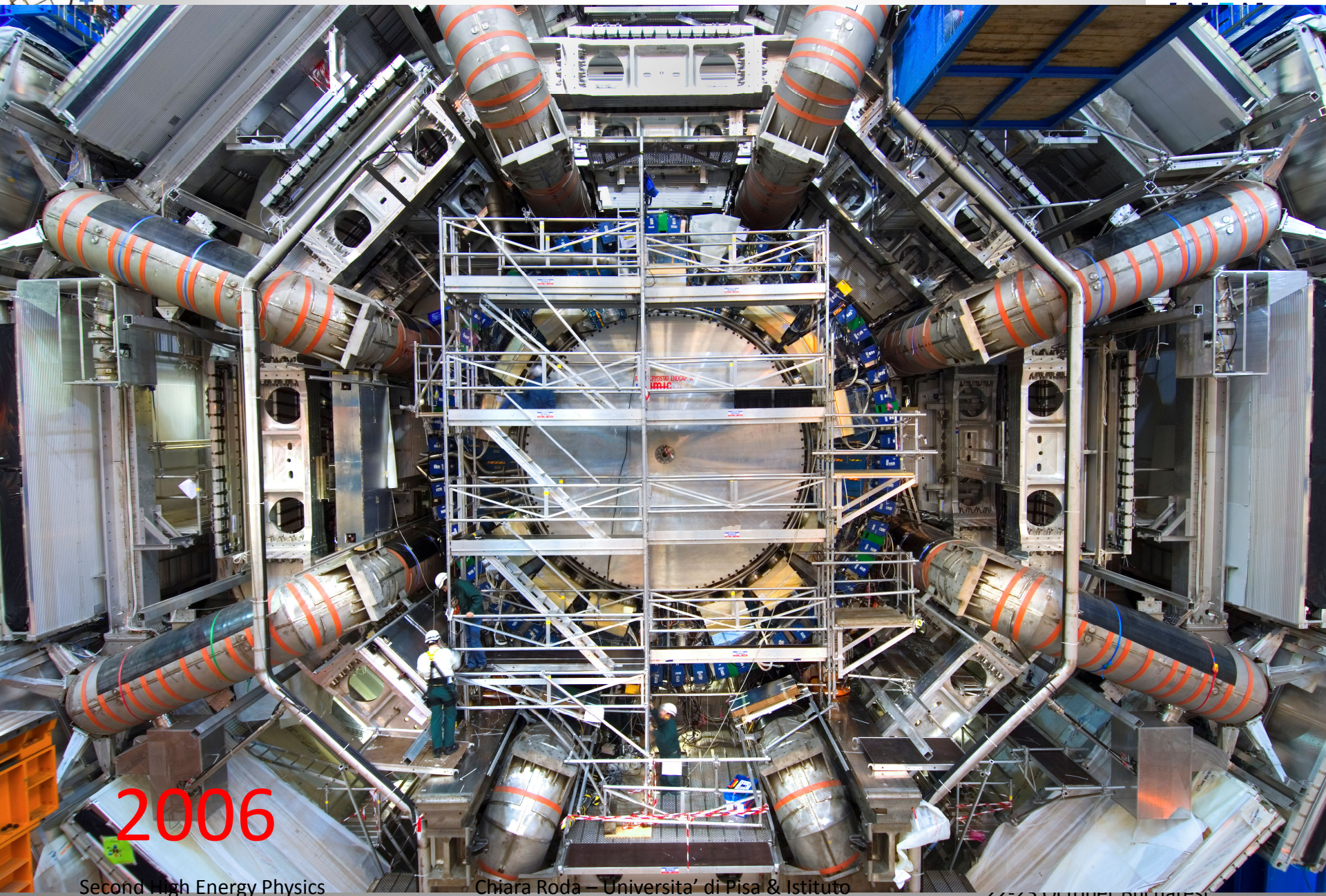
Chiara Roda – Universita' di Pisa & Istituto Nazionale di Fisica Nucleare

2004

Second High Energy Physics School in Măgurele

Chiara Roda – Universita' di Pisa & Istituto Nazionale di Fisica Nucleare

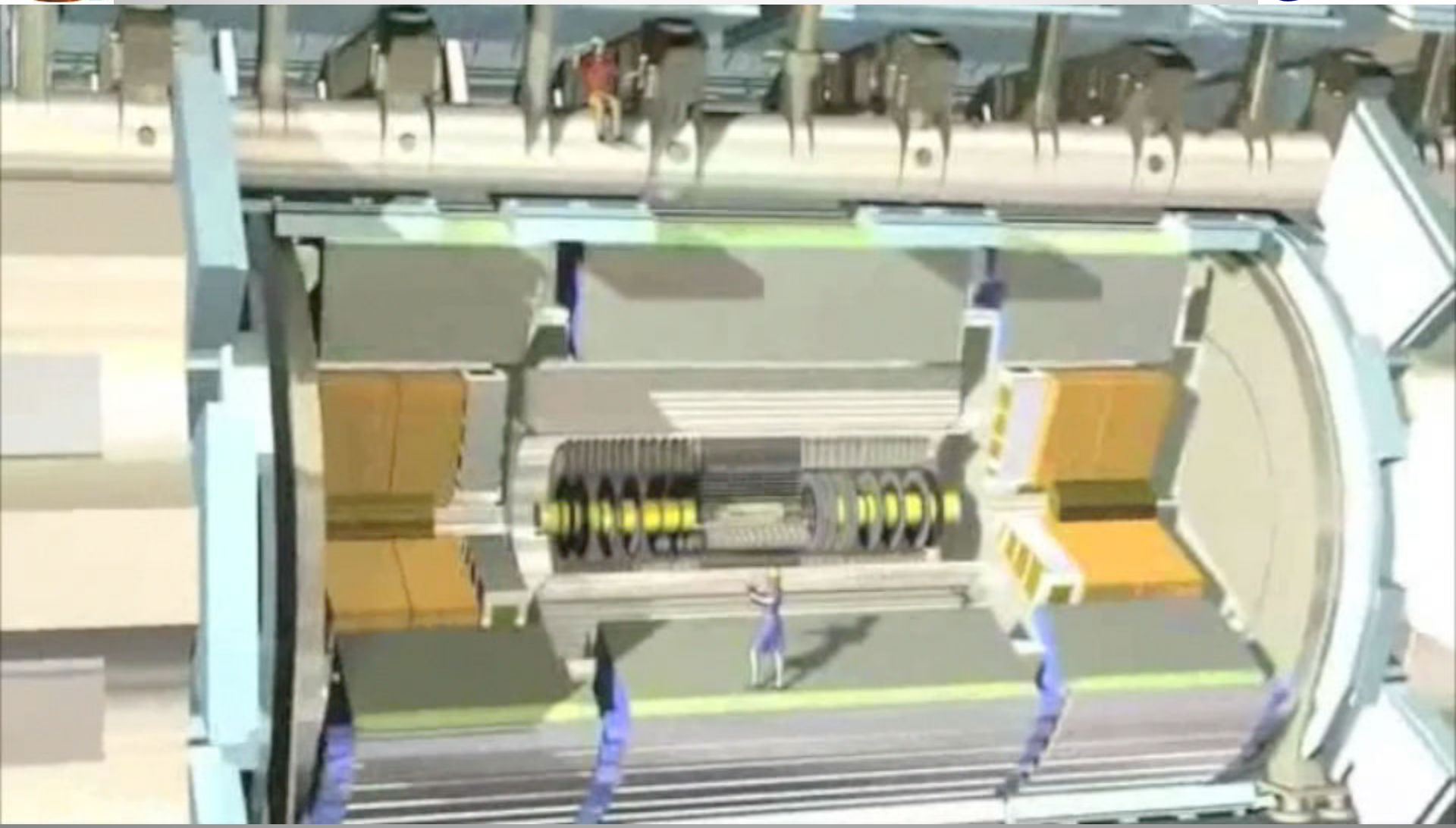
tituto Nazionale
Fisica Nucleare


2006

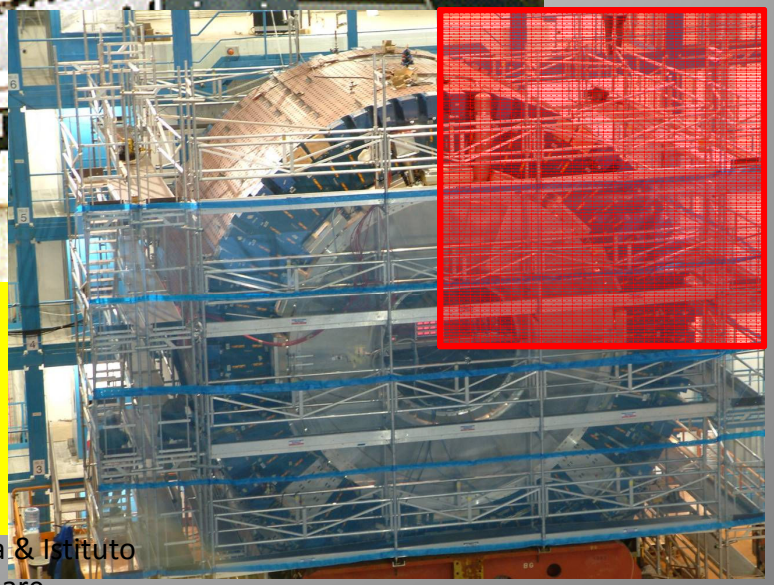
Nazionale
Nucleare

Now

Chiara Roda – Universita' di Pisa & Istituto
Nazionale di Fisica Nucleare



Il primo modulo del calorimetro TileCal



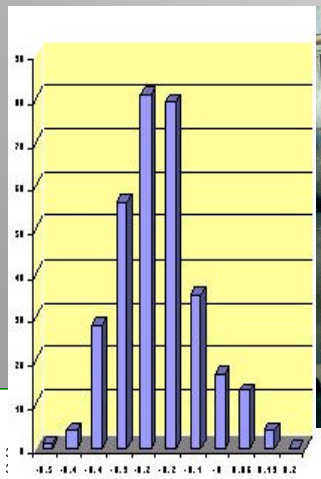
The group of ATLAS Pisa built ¼ of the structure of the central hadronic calorimeter section

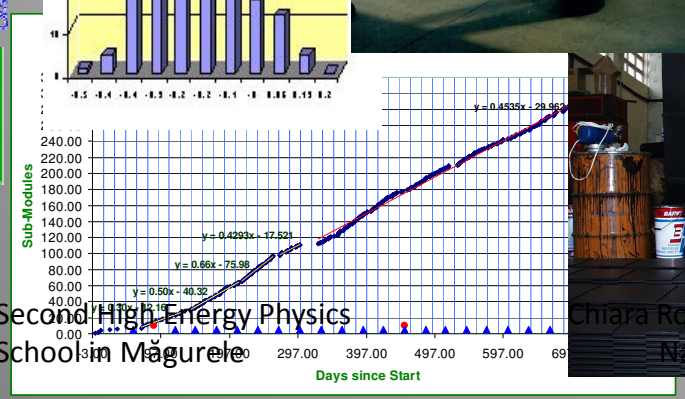
What is the everyday work in research: one example from the group where I work

Module assembling in Pisa

310 components weighting 1200 kg to be mounted with a precision of 1/50000

May 1998:
Arrival of first load

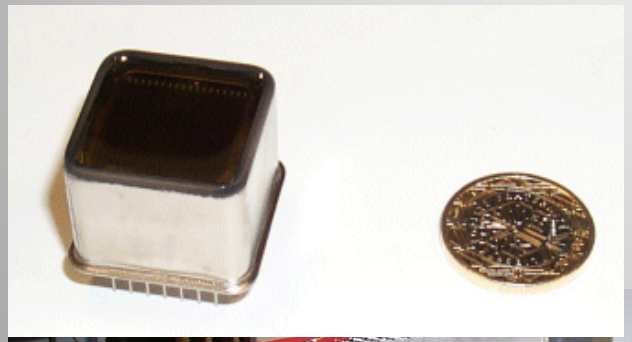


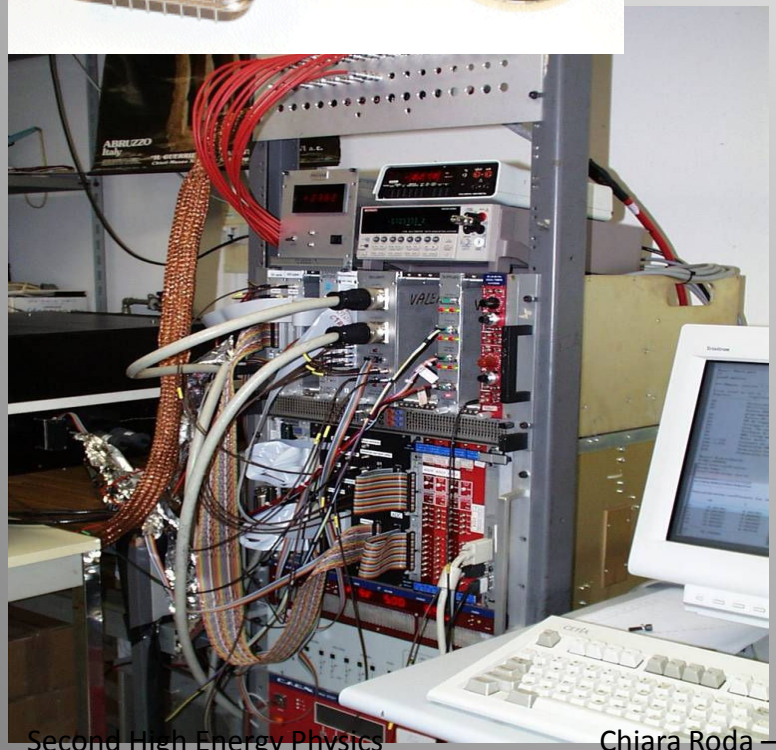


May 2002:
Departure of last load

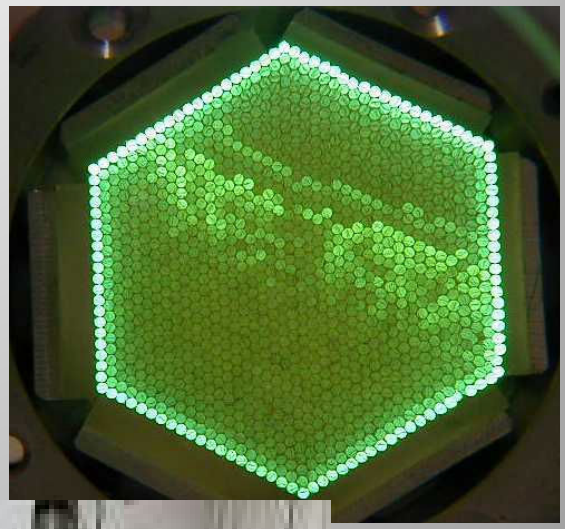
Studies on photomoltipliers and fibres in the laboratories in Pisa

1550 photomultipliers tested and characterized

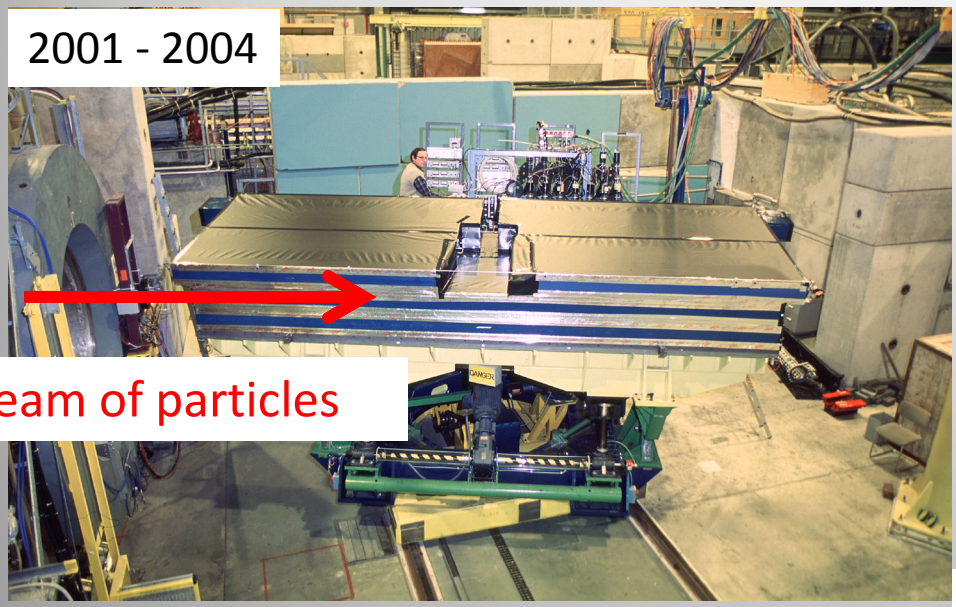




700000 optical fibres for the calorimeter read out tested, qualified and prepared for aluminzation…

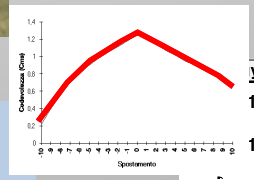


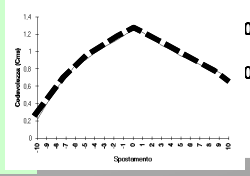
Before building ATLAS: all the possible tests to understand and tune our detector

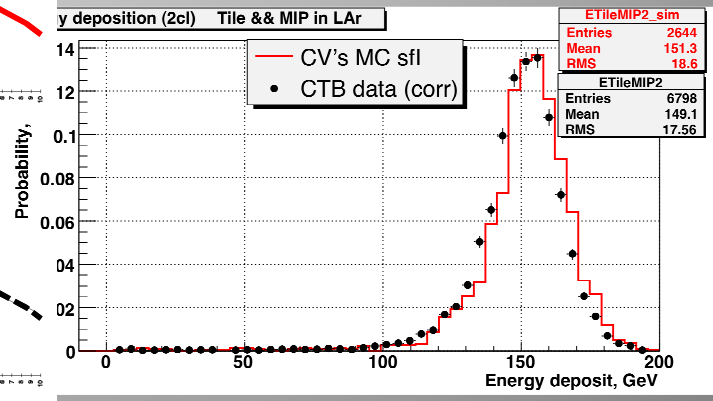


Detector simulator

Analysis of experimental Data





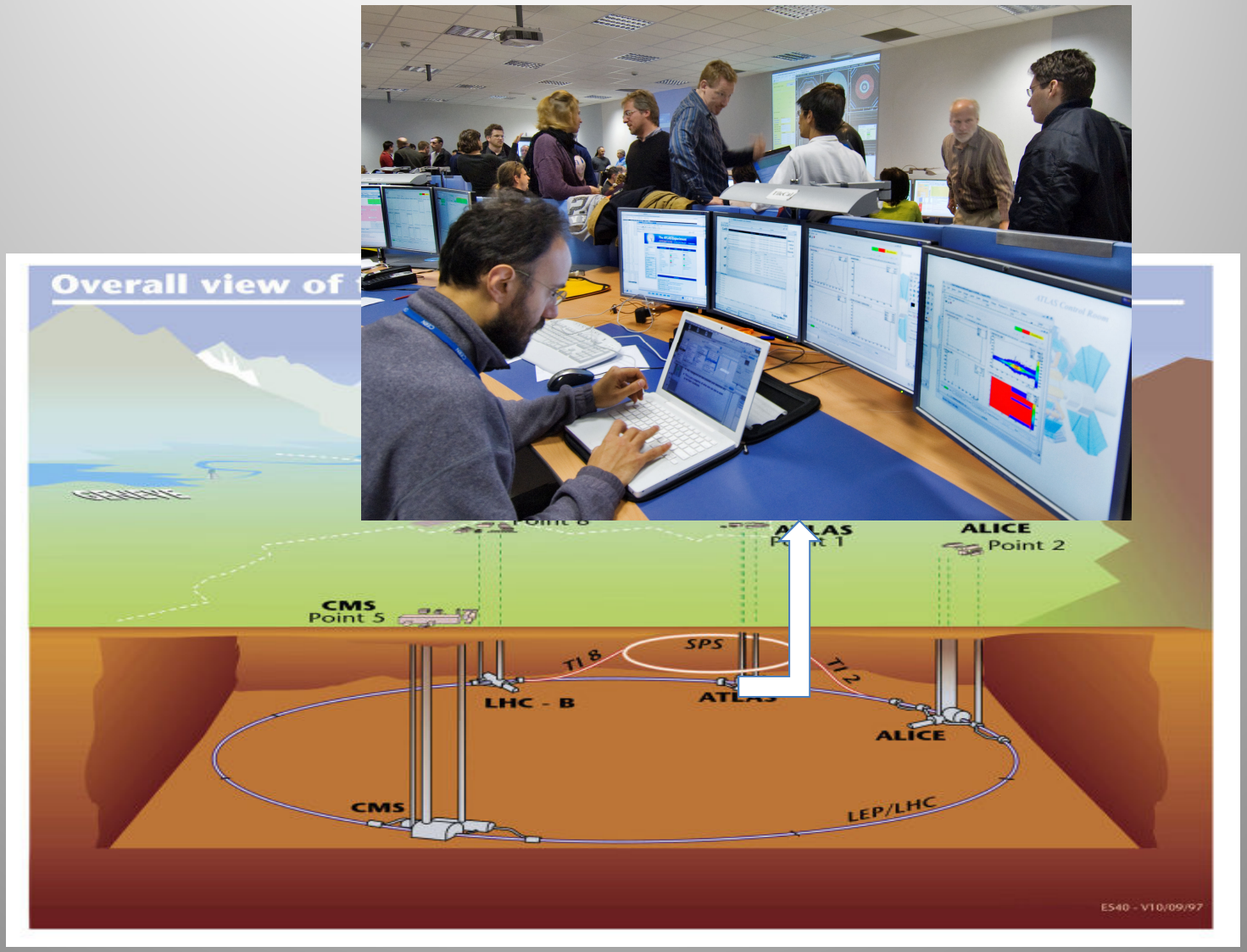


A huge amount of data are arriving

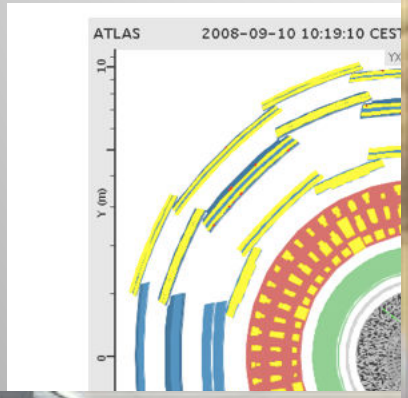
15 milions of Gbyte / year

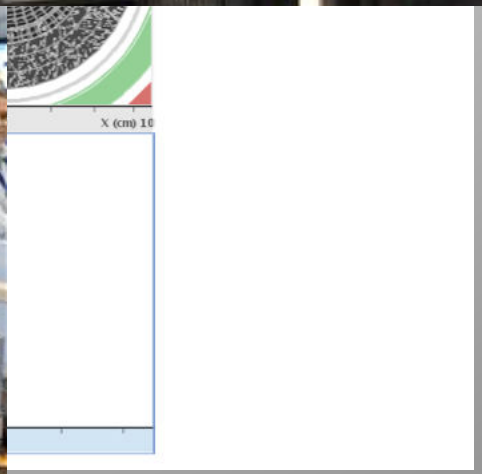
GRID: a grid of CPUS's and data storage spread all over the world to have enough power to analyze all our data

Finally in the control room waiting for LHC



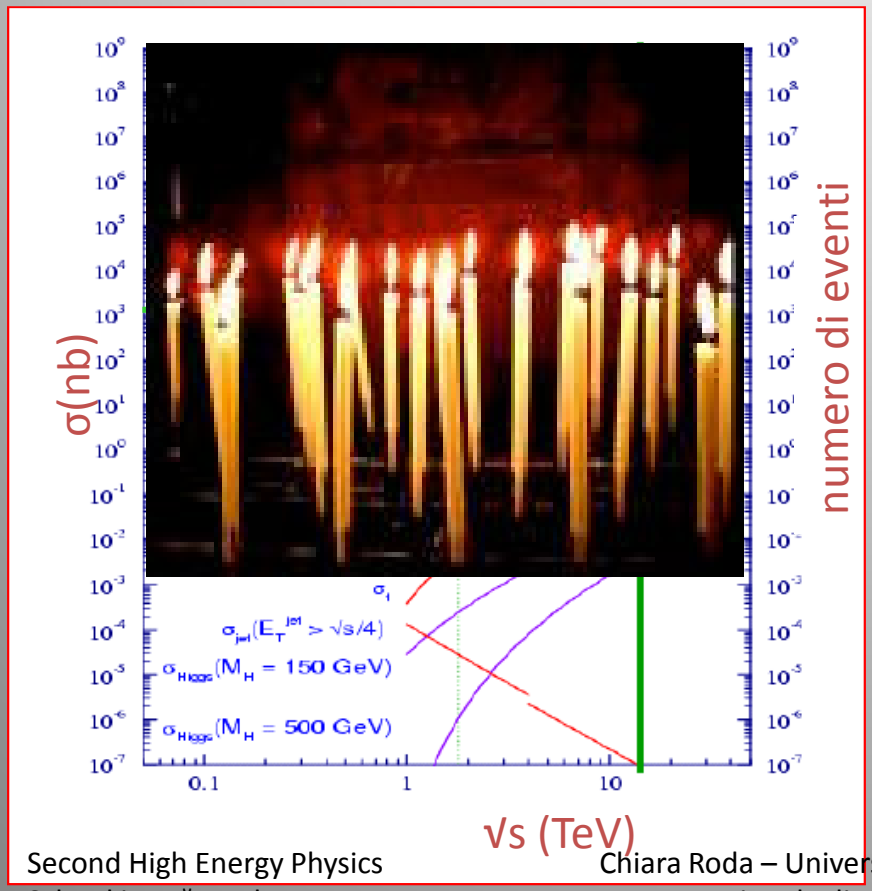
The first event seen in ATLAS
September 10th 2009





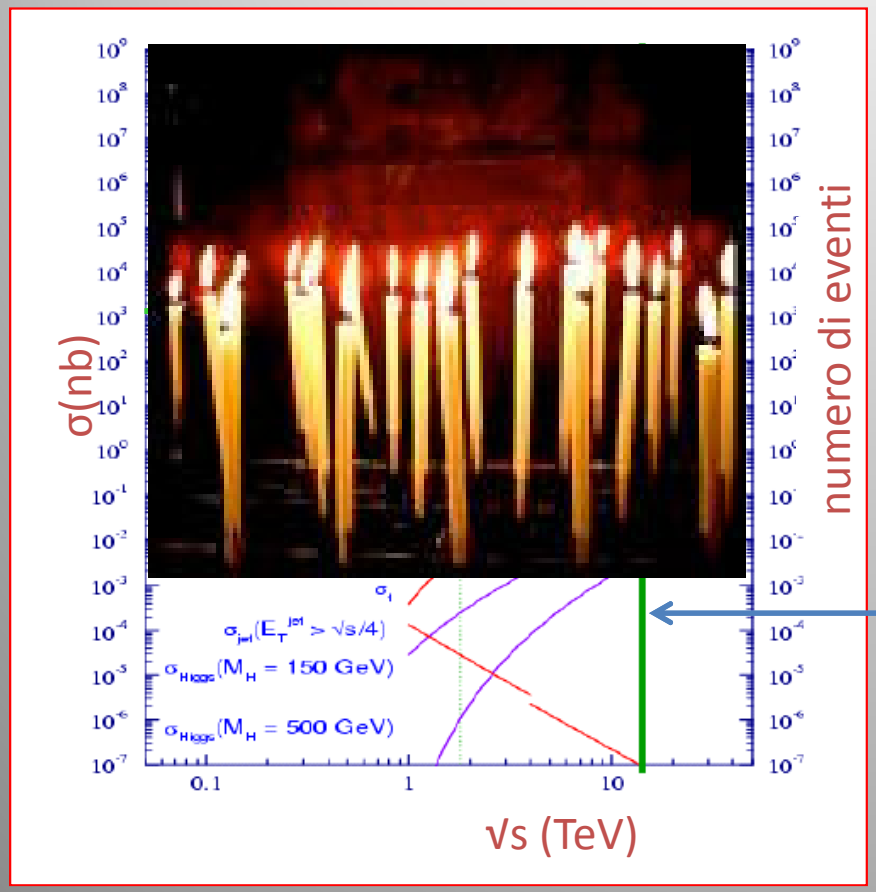
We have been preparing for LHC start up for years…but

As data arrives we have to be cool and wise since before even trying to look for the possible wonders in our data such as Higgs, dark matter, supersimmetry or even something unexpected …

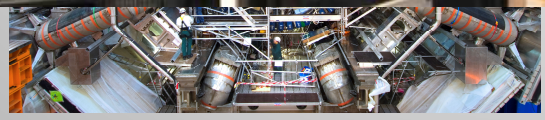


we have to demonstare to have our system well under control. This will done demonstrating to be able to see all the known processes with the expected characteristics.

Our candles ..
Than we can go to the interesting part !



For <u>each event</u> in which we expect new interesting physics we have to get rid of <u>one hundred bilion of ordinary events</u> ….



We have built a kind of modern cathedral !

Most of the work done to built it was due to the hard work of many very young students.

We are very impatient for the data to arrive and the coming years will be very important since we will have new data to better understand the laws of nature. It is like arriving in a new tresaure island …

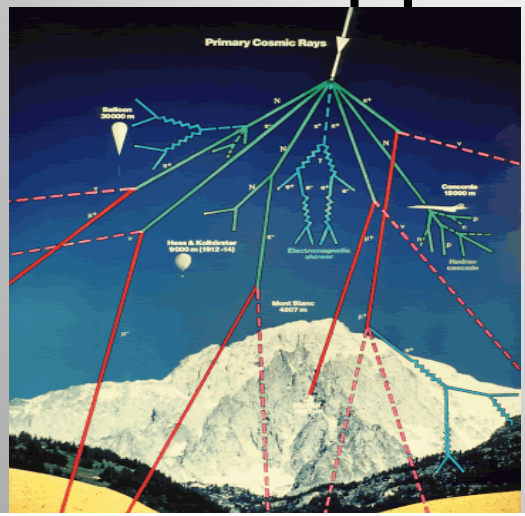
… maybe some of the you will join us to help discovering these tresaures !

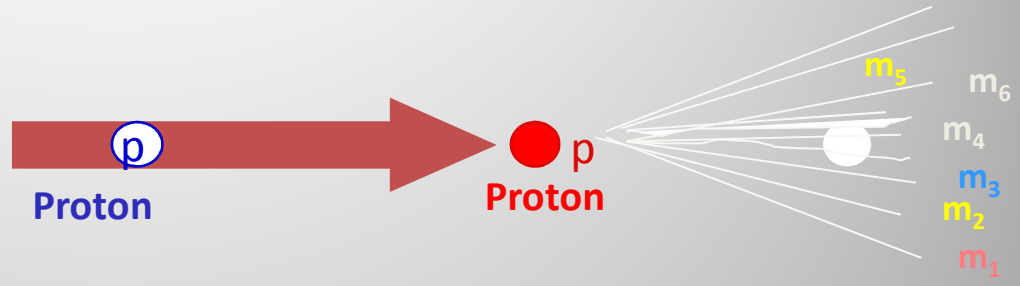
A lot of the material in the presentation was taken from very good outreach sites, where you can find also much more material:

CERN public page http://www.cern.ch/
ATLAS outreach page http://www.atlas.ch/
Gran Sasso National Laboratory outreach page:
http://www.lngs.infn.it/lngs_infn/index.htm?mainRecord=http://www.lngs.infn.it/lngs_infn/contents/lngs_it/public/educational/

Backup Slides

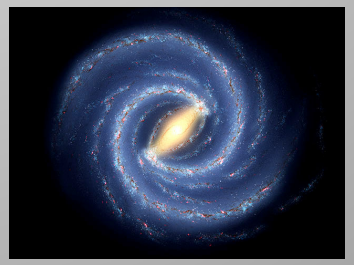
… and what about the fear of disappering in a black hole ?



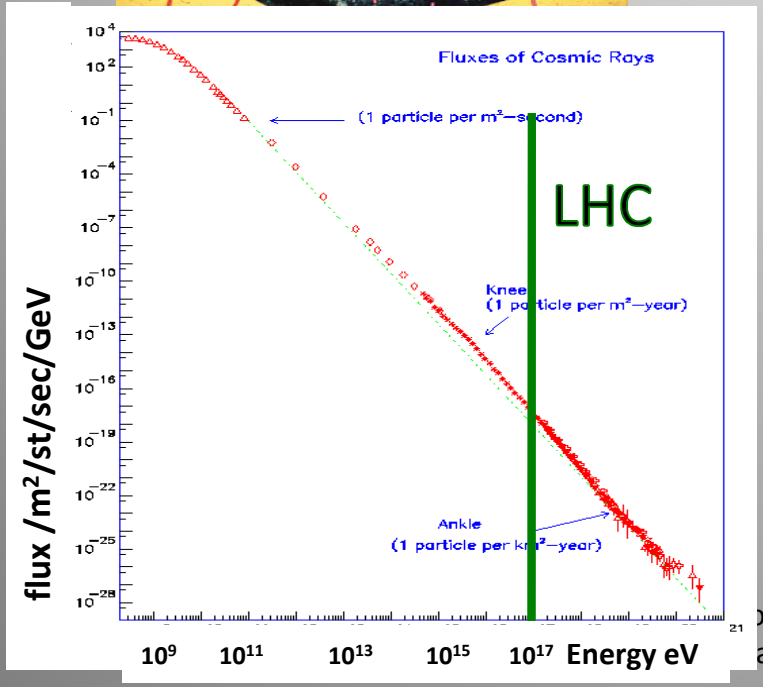


$E \geq E_{LHC}$

= 100000 LHC

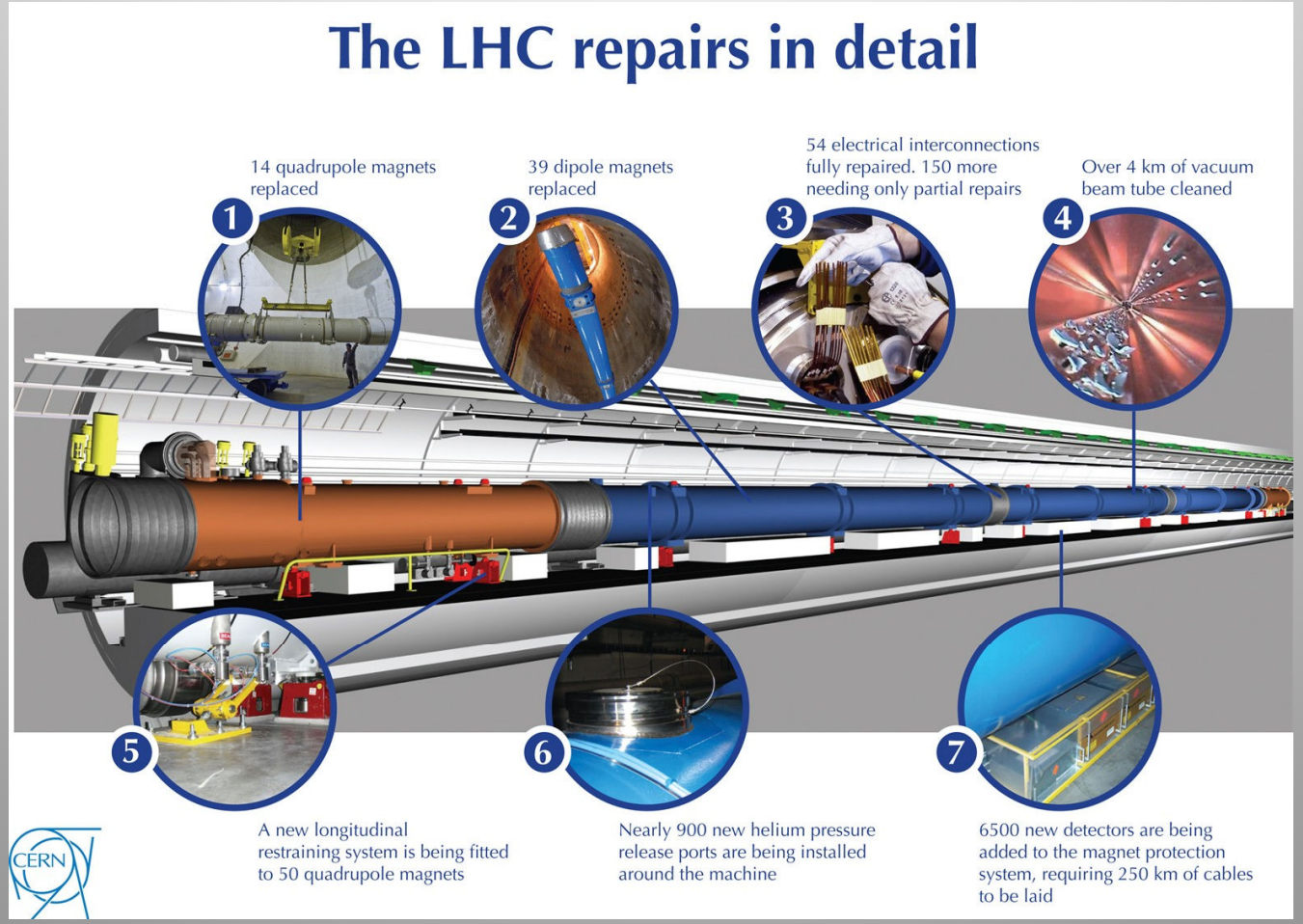


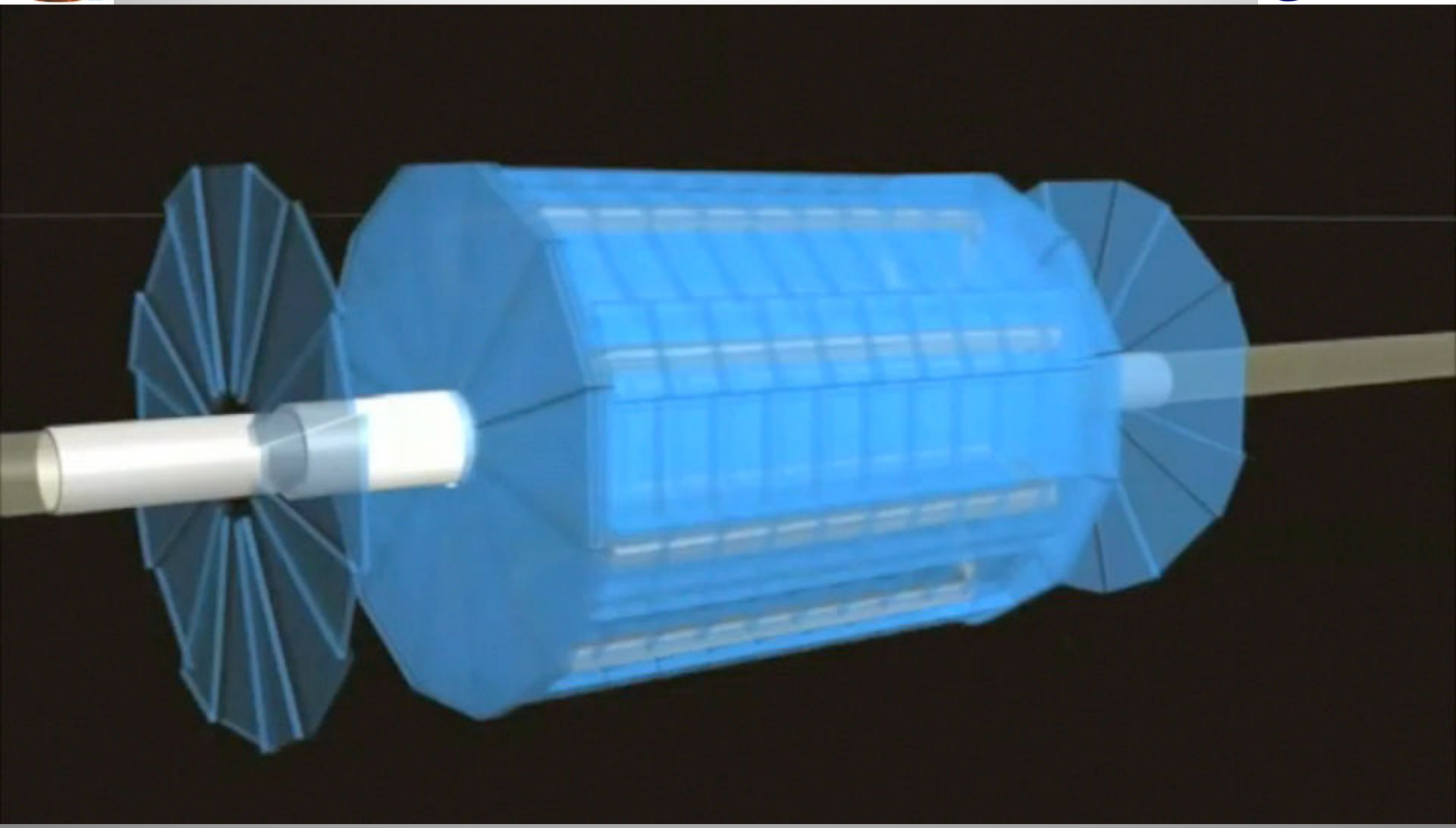
= 10^{31} LHC

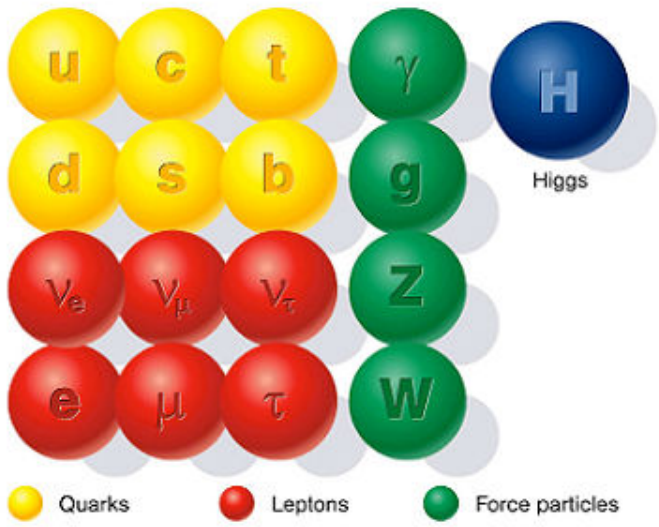


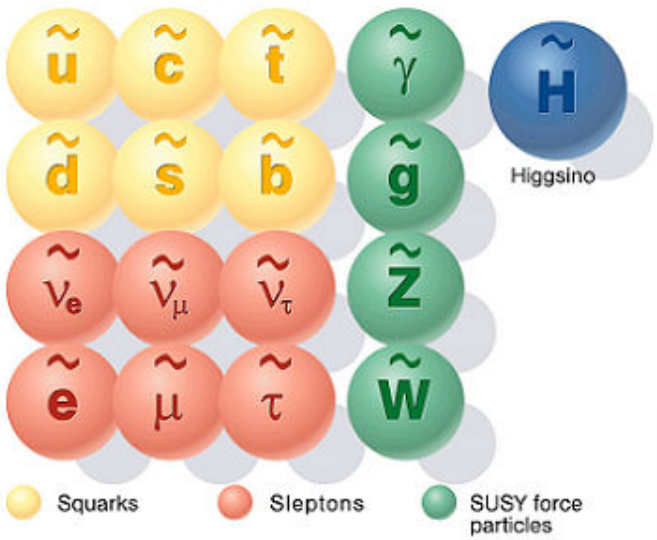
The earth, the sun and the stars exist since bilions of years without being absorbed in a black hole …

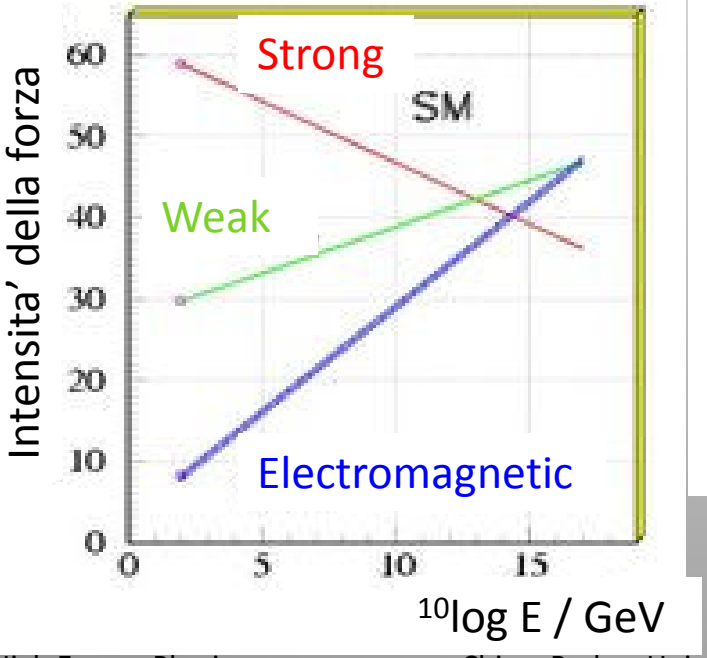
LHC Incident

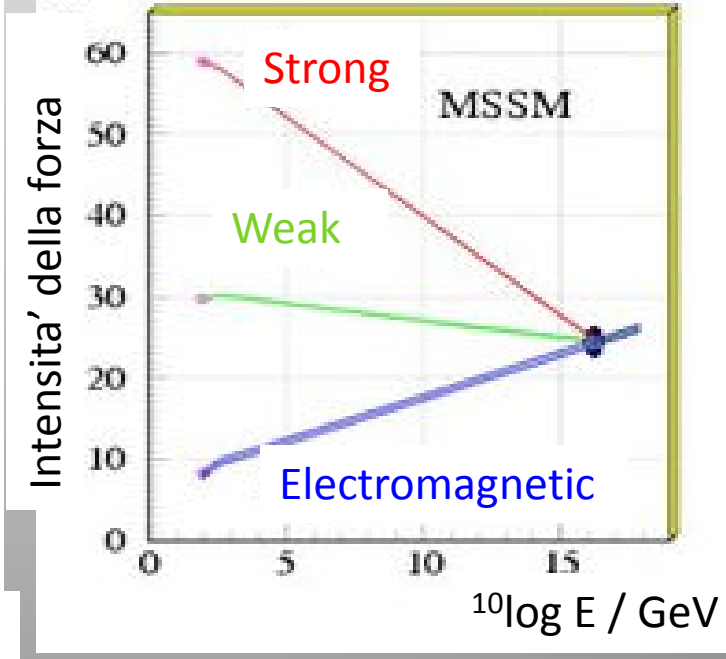





Standard particles
u
c
t
γ
H
Higgs
d
s
b
g
νe
νμ
ντ
Z
e
μ
τ
W
Quarks
Leptons
Force particles


SUSY particles
ũ
c̃
t̃
γ̃
H̃
Higgsino
d̃
s̃
b̃
g̃
ν̃e
ν̃μ
ν̃τ
Z̃
ẽ
μ̃
τ̃
W̃
Squarks
Sleptons
SUSY force particles


Intensita' della forza
Strong
SM
Weak
Electromagnetic
0
10
20
30
40
50
60
0
5
10
15
10log E / GeV

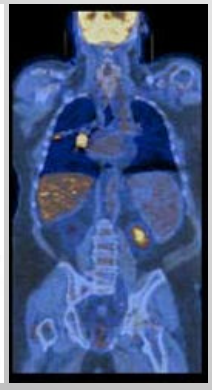

Intensita' della forza
Strong
MSSM
Weak
Electromagnetic
0
10
20
30
40
50
60
0
5
10
15
10log E / GeV

Perchè due rivelatori

- ATLAS e CMS sono due rivelatori progettati per eseguire lo stesso tipo di misure.
- Simili ma tecnicamente diversi un po' come avere una Ferrari ed una MacLaren. La loro diversità e complementarità fornisce una garanzia ai segnali di scoperta "visti" da entrambe i rivelatori

Vi raccontero' di ATLAS perche' e' l'esperimento a cui lavoro, ma CMS e' altrettanto interessante ed importante

Particle Physics Spin-offs

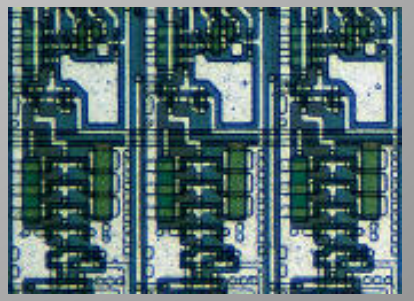


Fisica medica

Investimenti in aziende

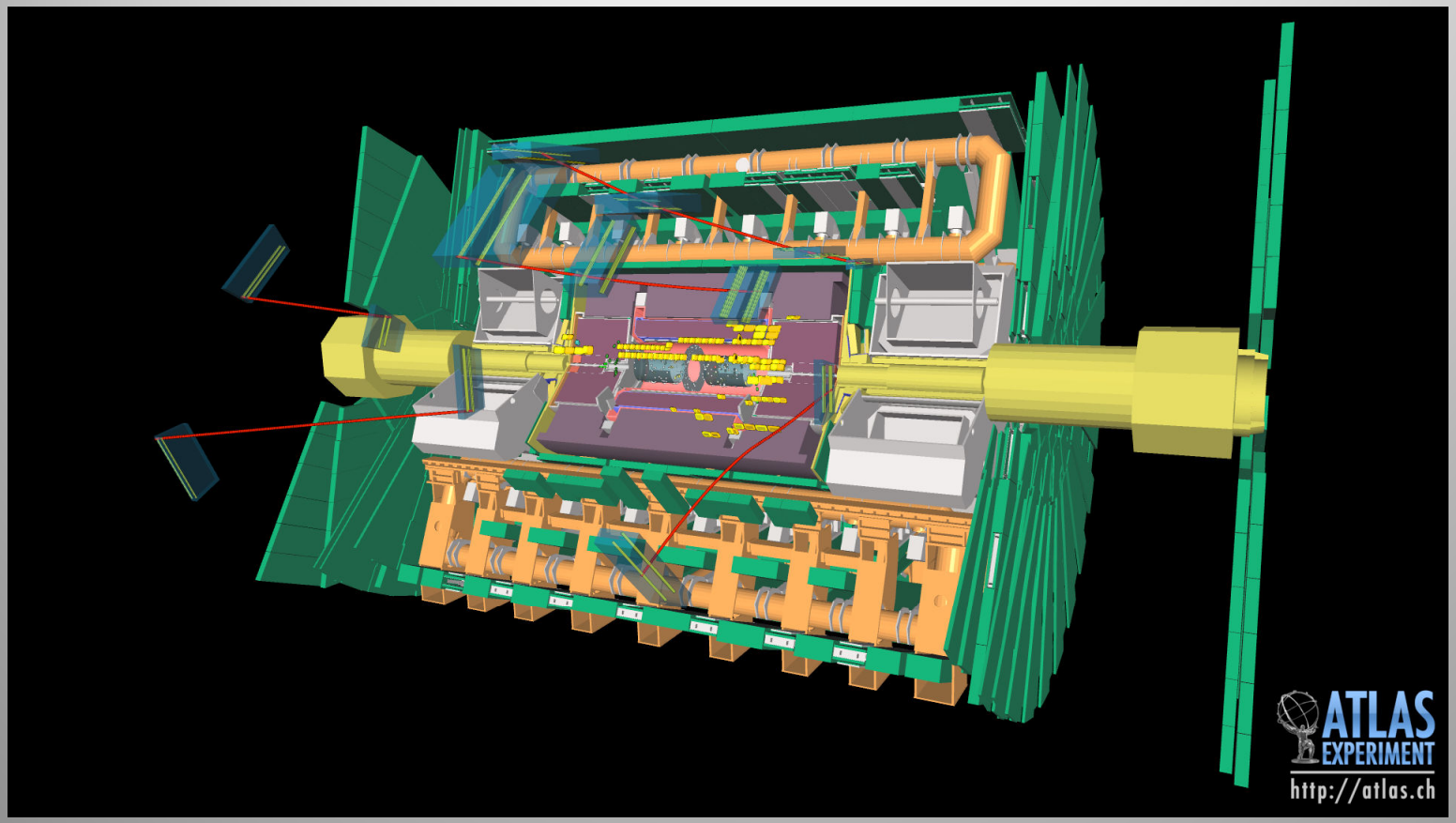
Istruzione

Computer - Web

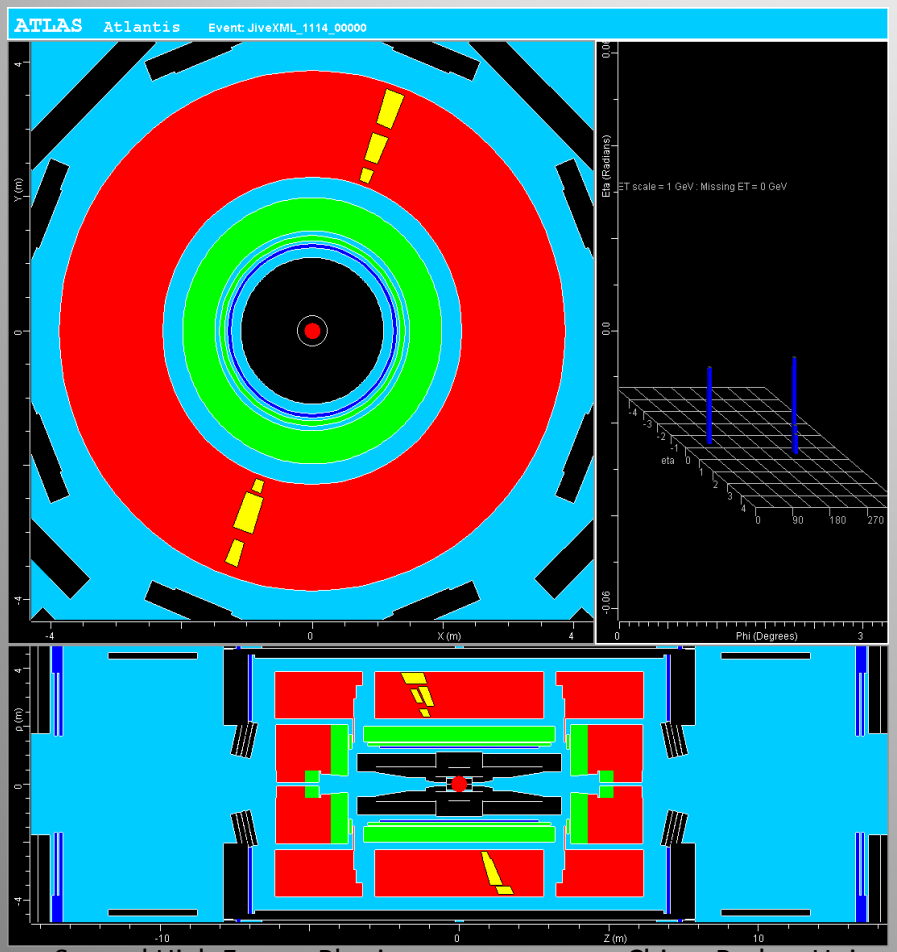


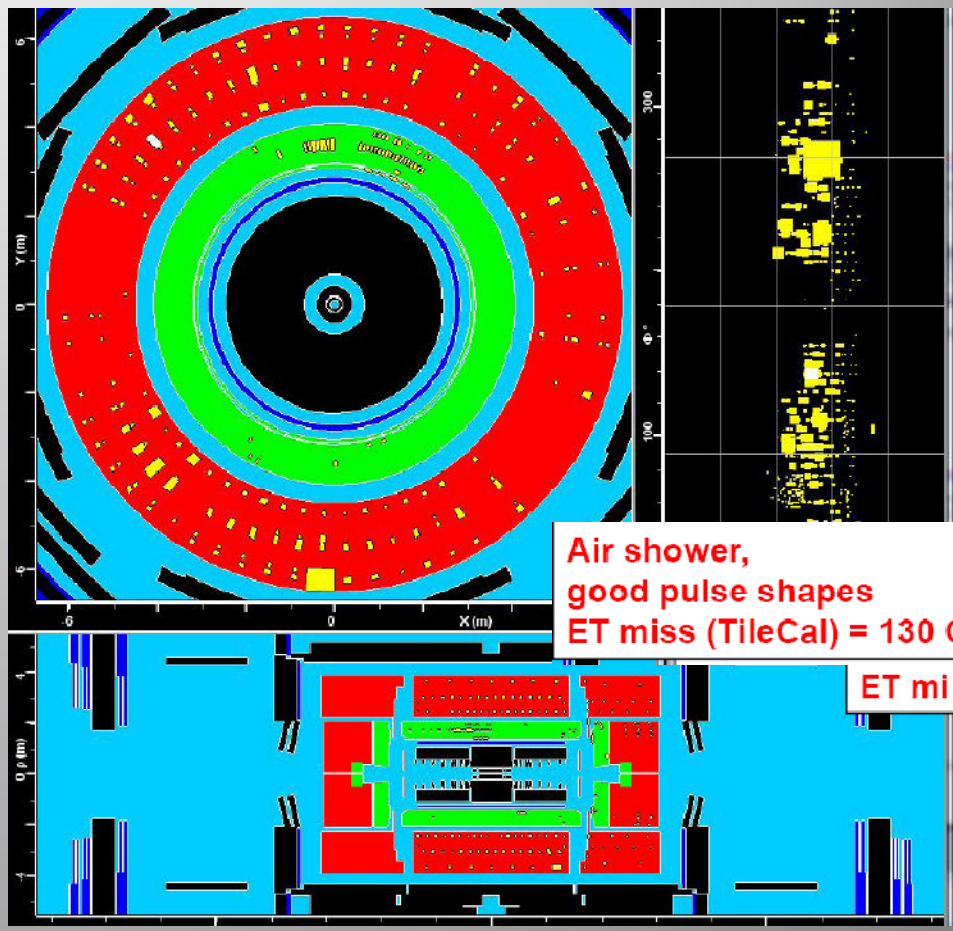
Elettronica

Evento di interazione fascio-gas



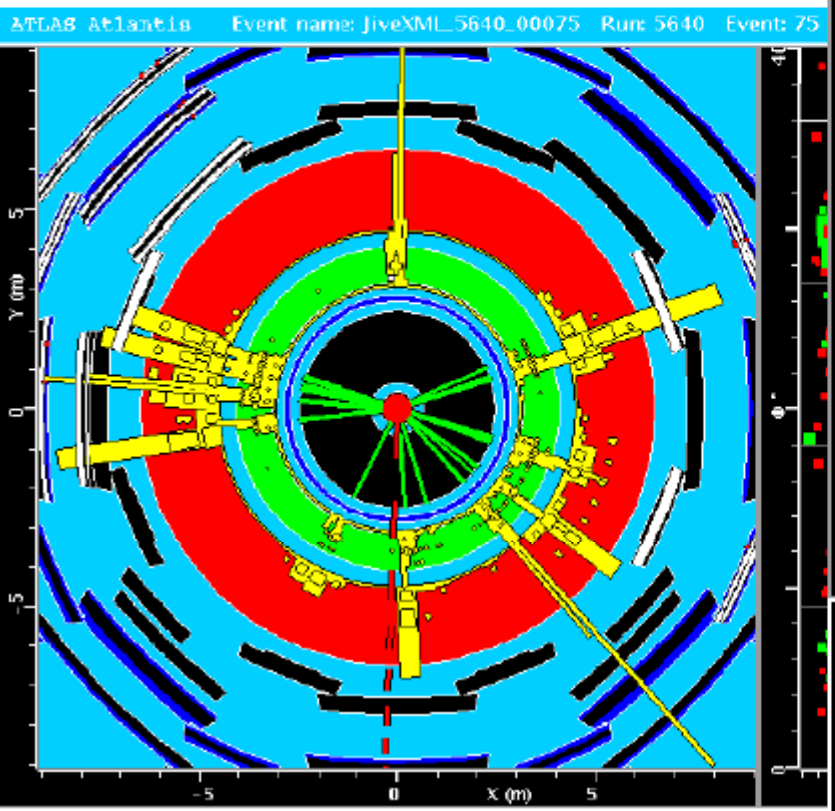
Test con i raggi cosmici

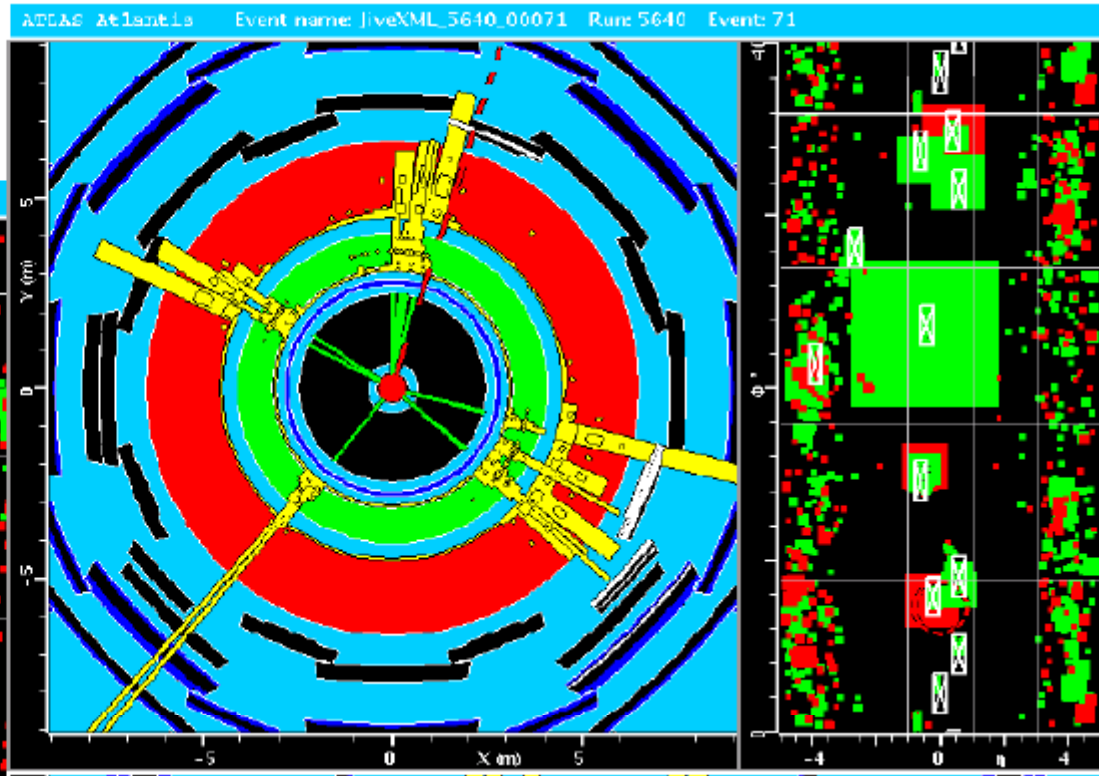


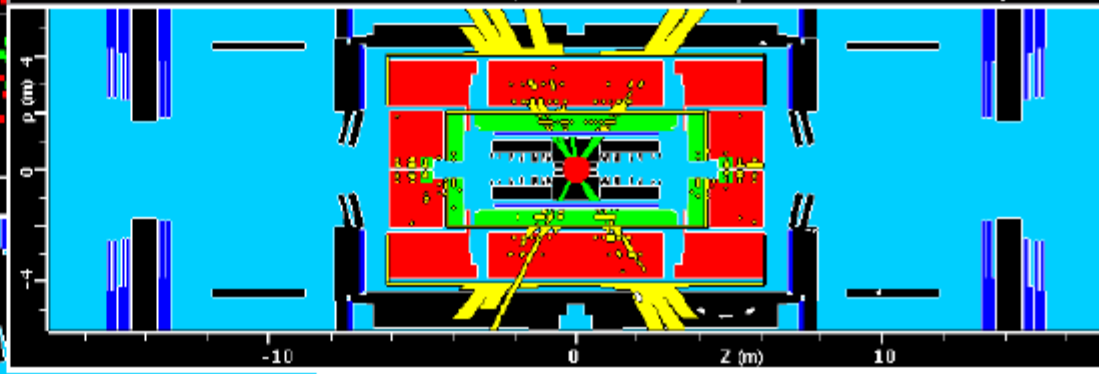


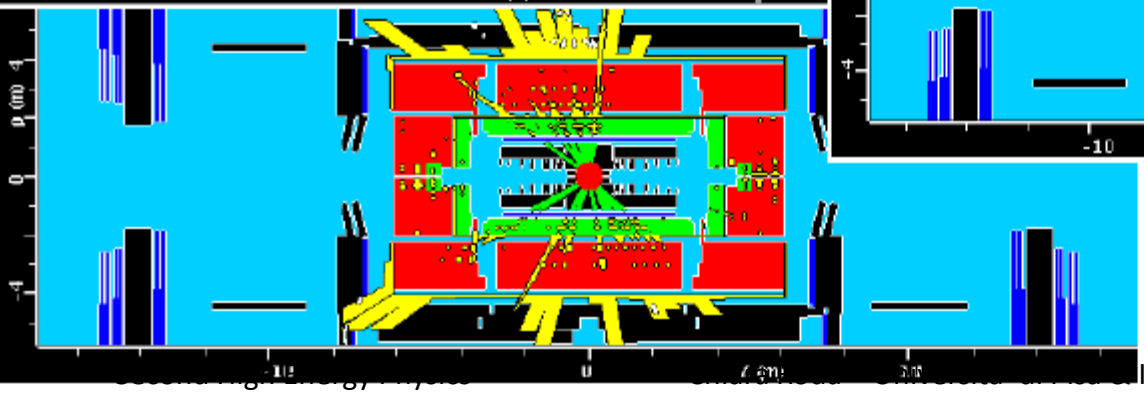
Events can look very busy

…



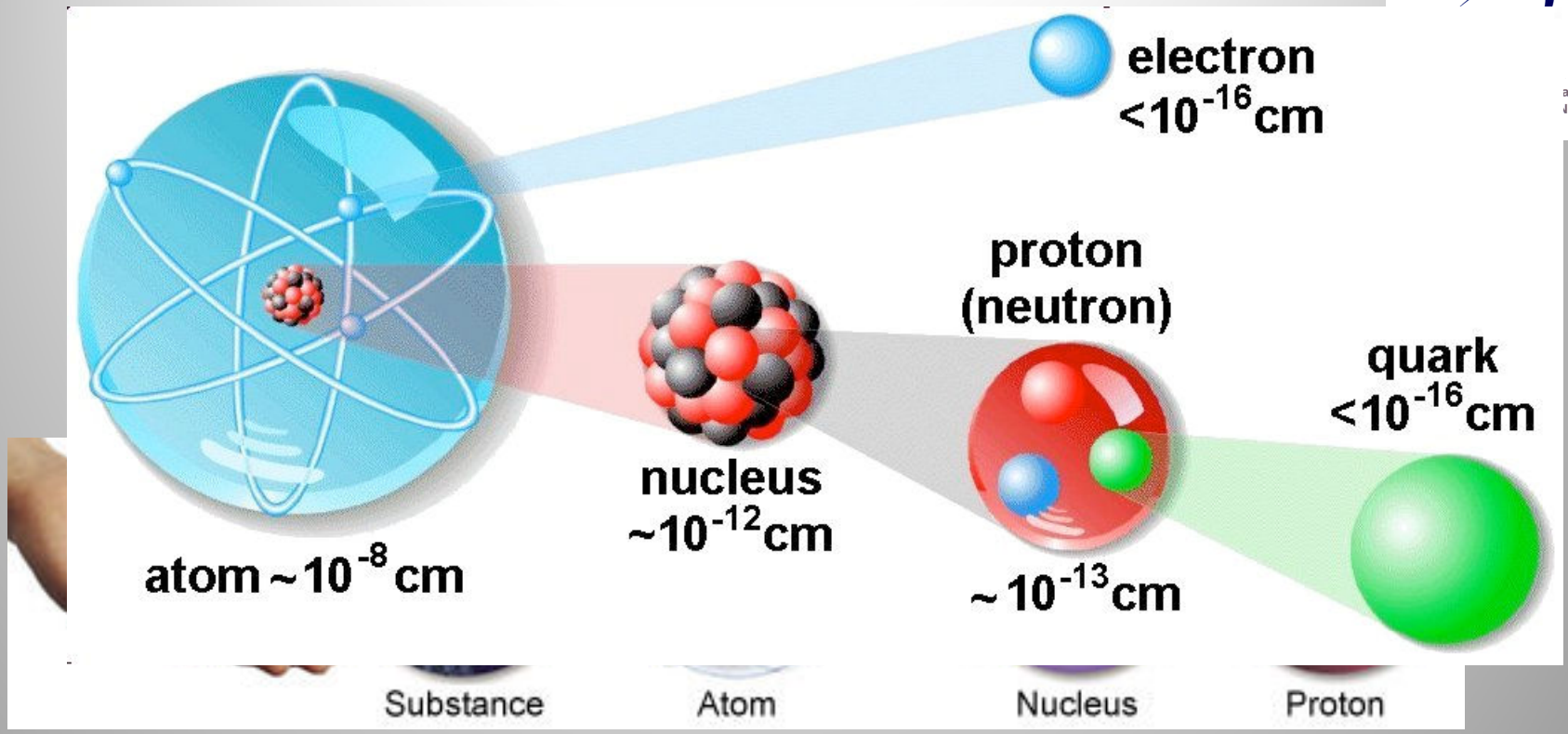






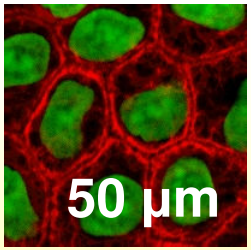
… or not nearly so much so

A black hole!!!



0 . 0000000001

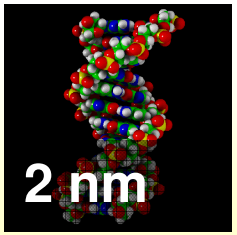
I costituenti della materia



Extra magnification?

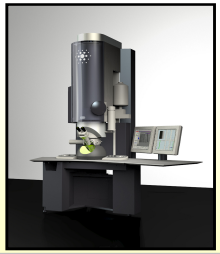
CELLS
Twenty per mm

Microscope

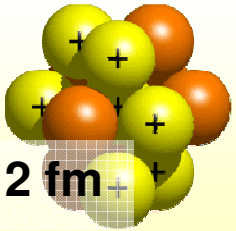


x 25 thousand

DNA
Five hundred thousand per mm



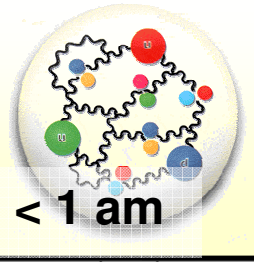
Electron microscope



x 1 million

Nucleus
Five hundred billion per mm

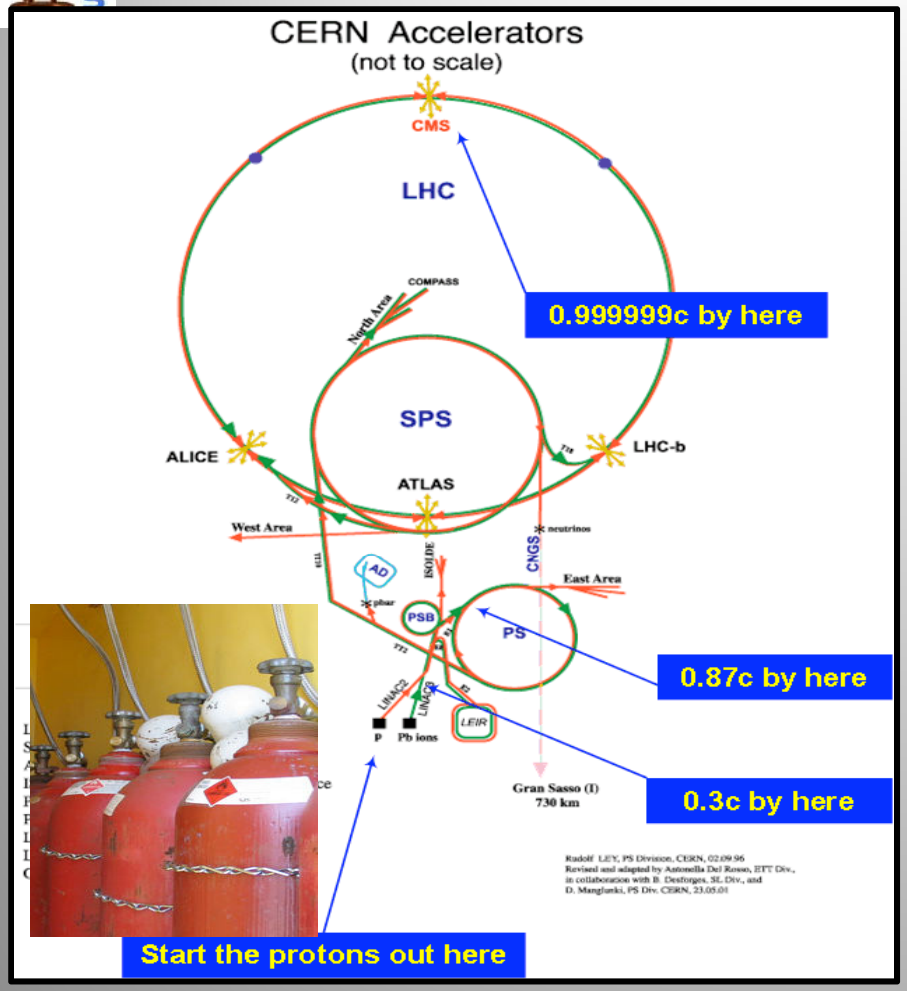
Particle Accelerators



x 2 thousand

Quarks
More than one million billion per mm

Produce the collisions



Energia dei protoni

eV = elettronVolt: energia acquistato da un elettrone che viene accelerato da una batteria di 1 Volt

Energia dei protoni in LHC: 7 TeV = 7 10^{12} eV

Alta energia ? Energia di una zanzara che vola … ma concentrata in un volume piccolissimo

X 0.0000000000001

Alto numero di collisioni

ogni fascio contiene 2808 pacchetti costituiti da 100.000.000.000 di protoni. Si producono un miliardi di collisioni al secondo.

Pre-ATLAS: test con i raggi cosmici