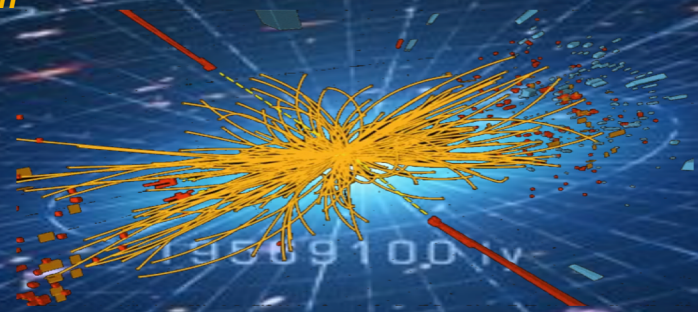
Sonia Natale
Astroparticle Physicist
Science Communication and Outreach

sonia.natale@cern.ch



CERN

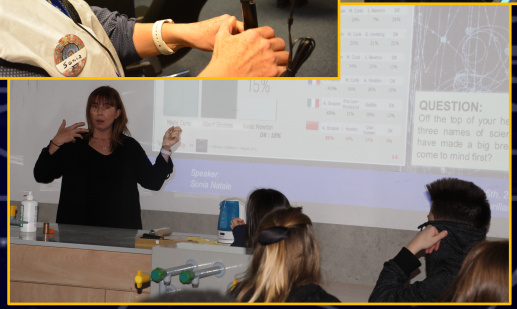
A JOURNEY FROM THE INFINITELY SMALL TO THE INFINITELY LARGE

Jun 6th, 2022

- Conference will start shortly
- Switch off camera and microphone
- Open the *chat* tool (down-right)



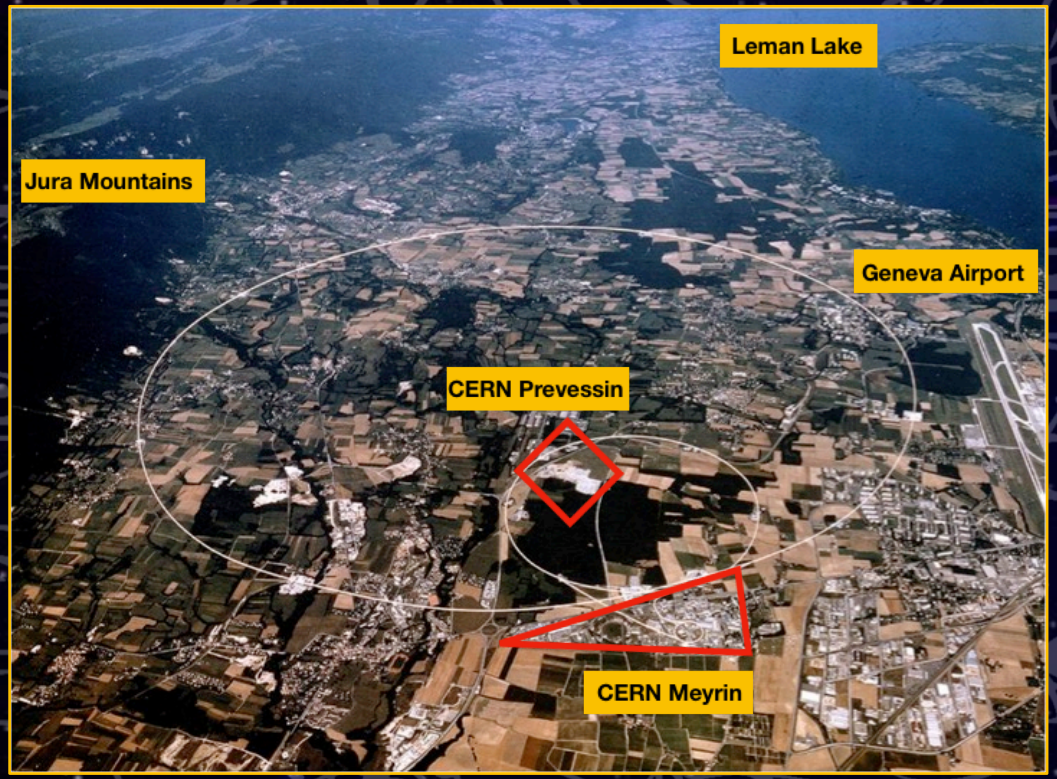


What does an Astroparticle Physicist *(loving phylosophy and arts)* do at CERN ?

A quick journey through CERN

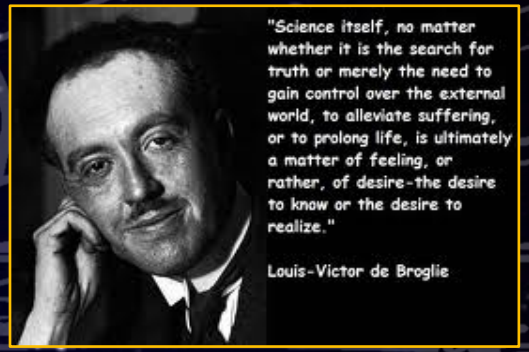
- the location
- the past
- the present
- key messages



The location

The past

•1949 : the French physics theorist and Nobel laureate Louis de Broglie proposed setting up a new European laboratory to halt the exodus of physics talent from Europe to North America;




Sur le terrain du futur institut nucléaire

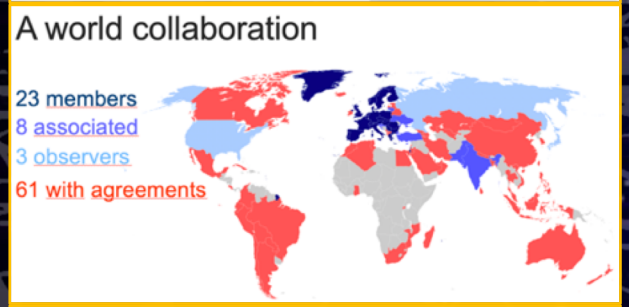
Sous la conduite de M. A. Picot, les membres du Conseil européen pour la recherche nucléaire se sont rendus hier à Meyrin pour reconnaître le terrain où s'élèvera le Centre nucléaire (voir en Dernière heure)

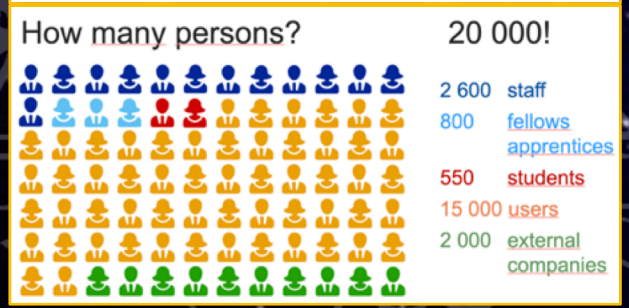
(Photo Freddy Bertrand, Genève)

La Suisse du 30 octobre 1953

•1950 : at a UNESCO conference in Florence, the American Nobel-prize winner Isidor Rabi put forward a resolution calling on UNESCO "*to assist and encourage the formation and organization of regional centres and laboratories in order to increase and make more fruitful the international collaboration of scientists*"

•1953 : European Council for Nuclear Research (only hosts meetings to drive scientific research);
•1954 : European Organization for Nuclear Research (has also labs to perform scientific research).





The present

- CERN employs «only» 3400 persons (Staff, Fellows, Apprentices) and «only» 70 of them are research physicists;
- Depending on the time of the year from 300 up to 600 students come to CERN. They are mostly university students but we also offer programmes for high school pupils;
- The core population of CERN is made of about 15'000 «users», called like that because they are here to «use» CERN's facilities. They are NOT employed by CERN and come in the frame of the collaborations. They spend from 5% up to 100% of their time at CERN;
- Given the size for CERN's population, many services are externalized (mail, transport, restaurants, etc) to firms.

Key messages :

- research of a “*pure scientific and fundamental character*”
- “ *no concern with work for military requirements and the results of its experimental and theoretical work shall be published or otherwise made generally available*”


ORGANISATION EUROPÉENNE POUR LA RECHERCHE NUCLÉAIRE
CERN EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH

CONVENTION

FOR THE ESTABLISHMENT OF A EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH

As amended

CONVENTION

POUR L'ÉTABLISSEMENT D'UNE ORGANISATION EUROPÉENNE POUR LA RECHERCHE NUCLÉAIRE

Telle qu'elle a été modifiée

ÜBEREINKOMMEN

ZUR ERRICHTUNG EINER EUROPÄISCHEN ORGANISATION FÜR KERNFORSCHUNG

Revidierte Fassung

Scientific knowledge

CERN is one of the world’s leading research centres for fundamental physics, and its biggest impact is due to great scientific discoveries.
CERN’s research is primarily motivated by curiosity,

Innovation, knowledge transfer, economy.

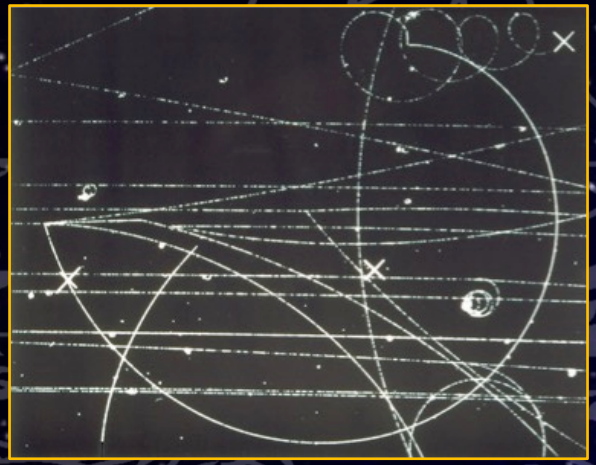
CERN’s research impact on society and everyday life is significant.
The development of advanced instruments and new technologies brings tremendous benefit to society and the economy, through knowledge transfer.

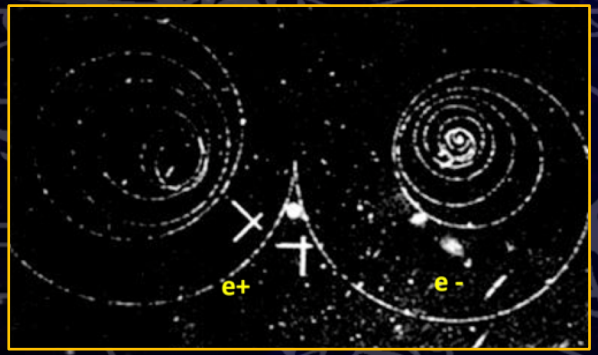
International collaboration

CERN is a powerful model for international cooperation.
More than 110 different nationalities work together effectively and peacefully towards a common goal, regardless of ethnical, cultural, political or religious differences.

Education and outreach

CERN contributes to improving science education from secondary school to postgraduate level, and to a broader understanding of science by the general public.
Learning about the fundamental constituents of the universe and how scientists try to answer fascinating questions inspires young people and increases the attraction of science and technology.

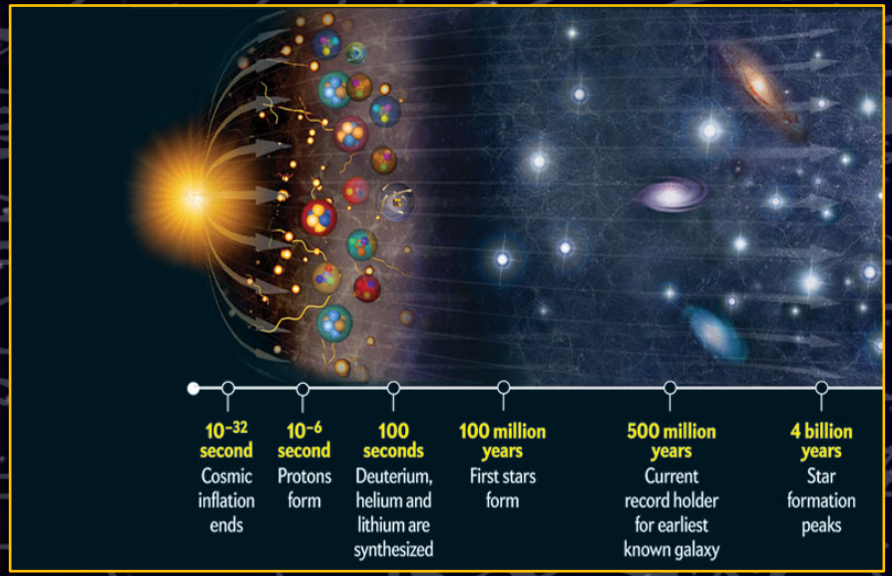


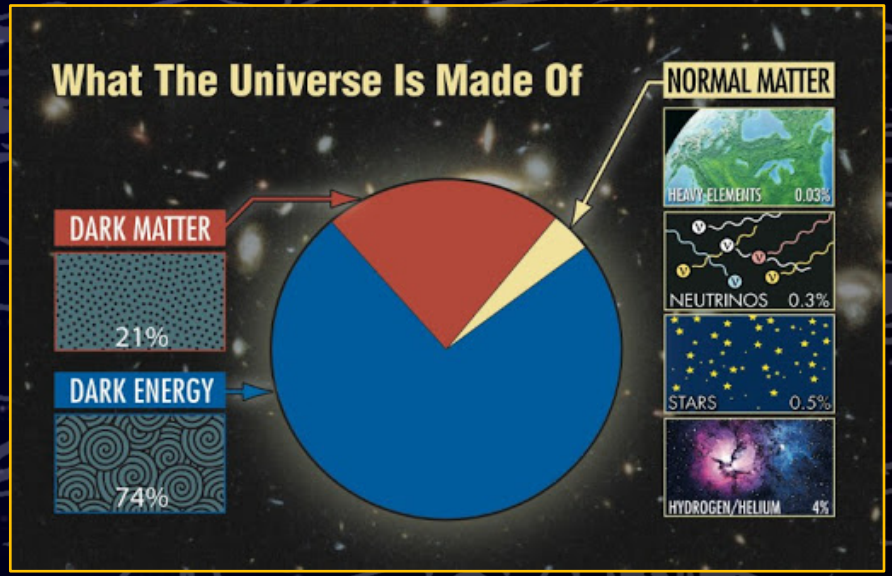


A quick journey through Particle Physics

- the Universe composition
- the Standard Model of Particle Physics
- what we know and what we don't know
- accelerators at CERN: LHC
- Detectors at CERN: ATLAS, ALICE, CMS, LHCb

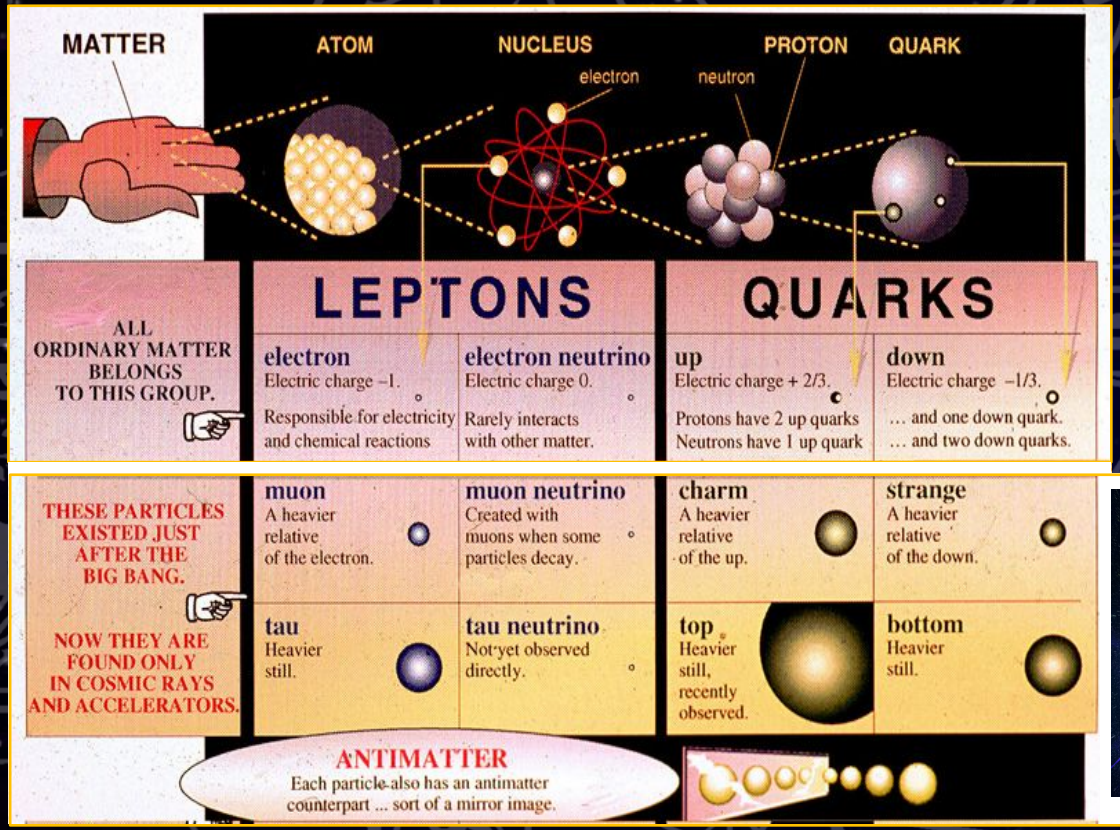
The Universe composition

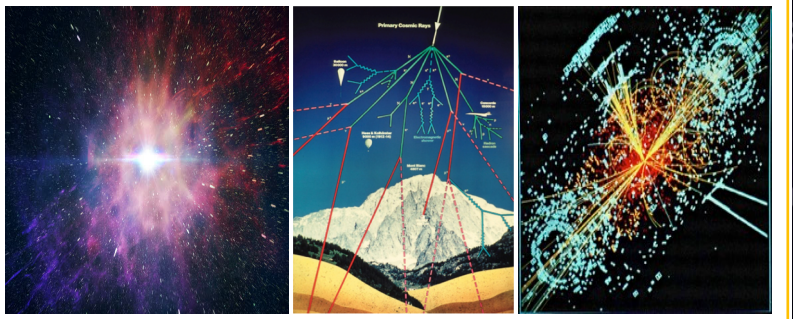


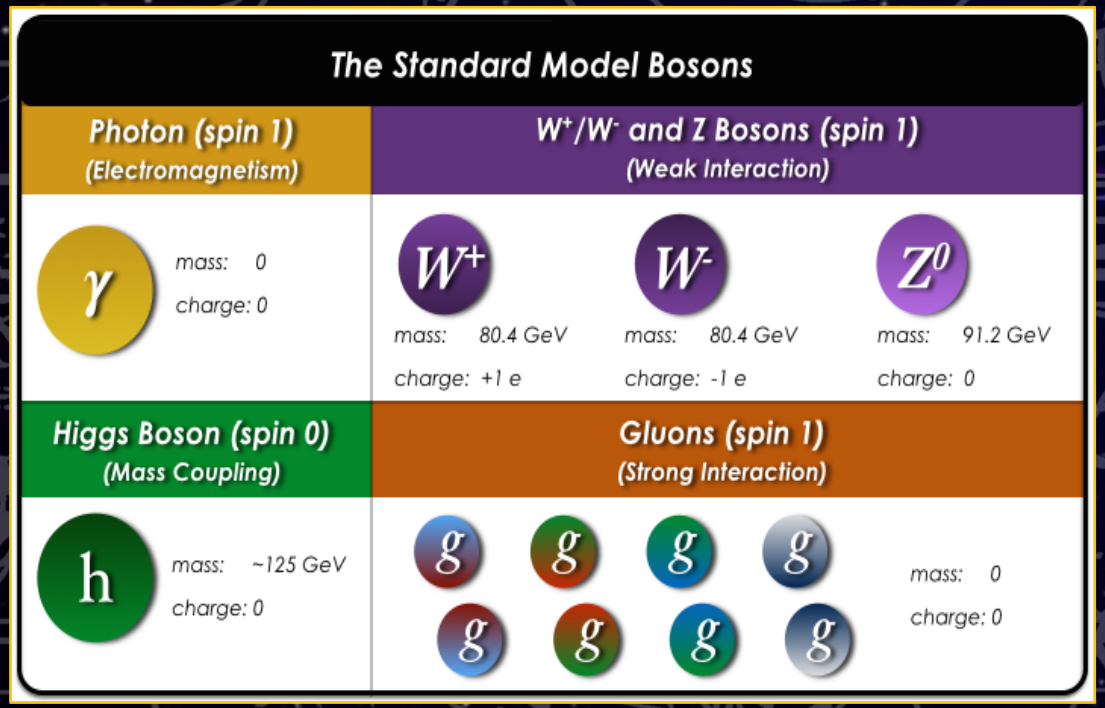


The Standard Model of Particle Physics :

Matter

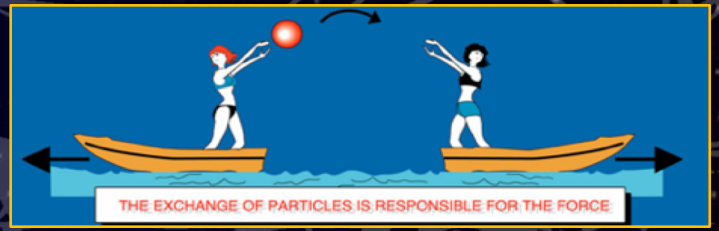






The Standard Model of Particle Physics :

Interactions (Forces)

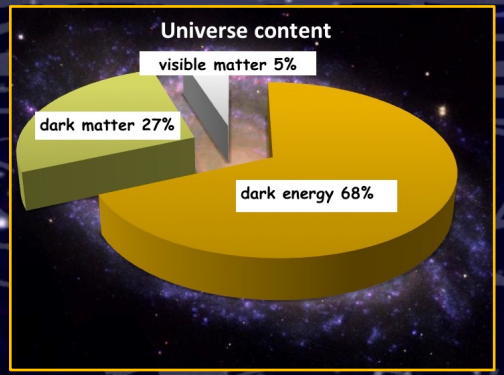


What we know ..... and ..... What we don't know

THE STANDARD MODEL OF PARTICLE PHYSICS

It is a mathematical model describing 12 fundamental particles (and their anti-particles) interacting through 3 forces…….Gravity is not included yet !

Until now all experimental results confirm very precisely *Standard Model* predictions.

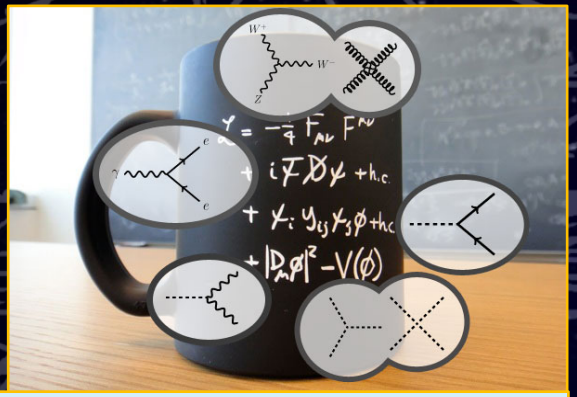


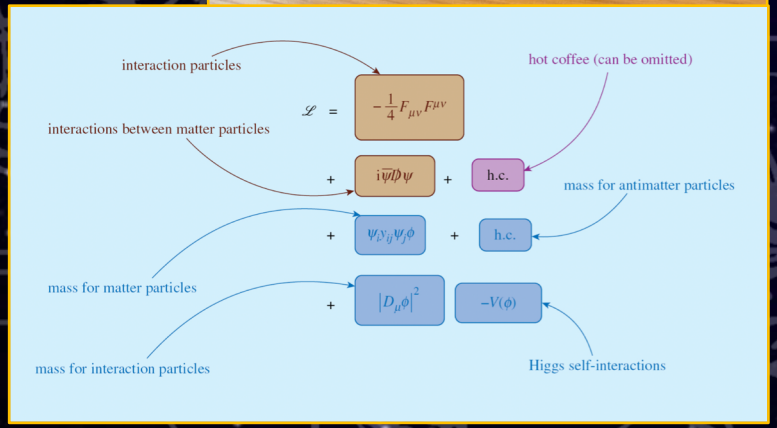
SOME OPEN QUESTIONS IN PARTICLE PHYSICS

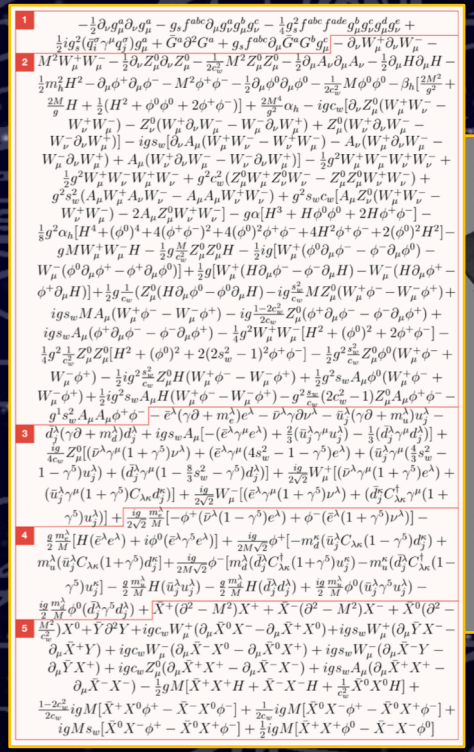
- What the 95% of Universe is made of?
- Why do we live in a world made of matter?
- How was the matter at the very beginning of Universe?
- Why there exist exactly 12 fundamental particles?
- Are they really fundamental or are they composed by other smaller particles?

…. translating into mathematical language …

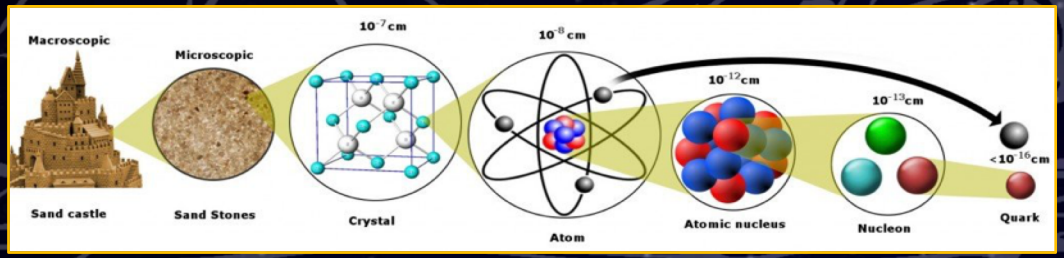
(having the right background, is not that difficult)

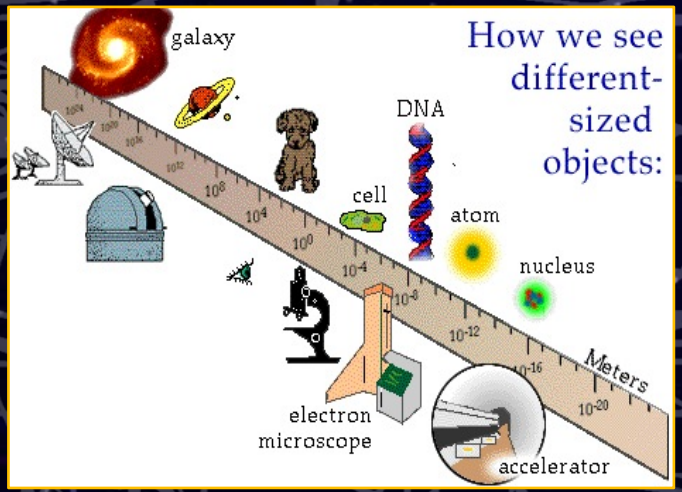


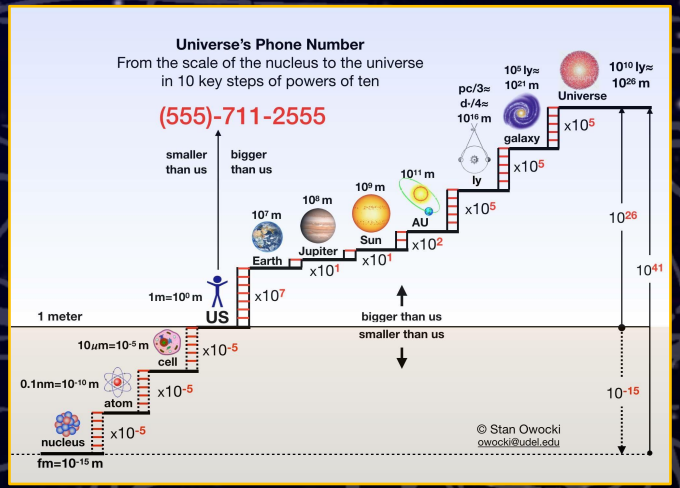




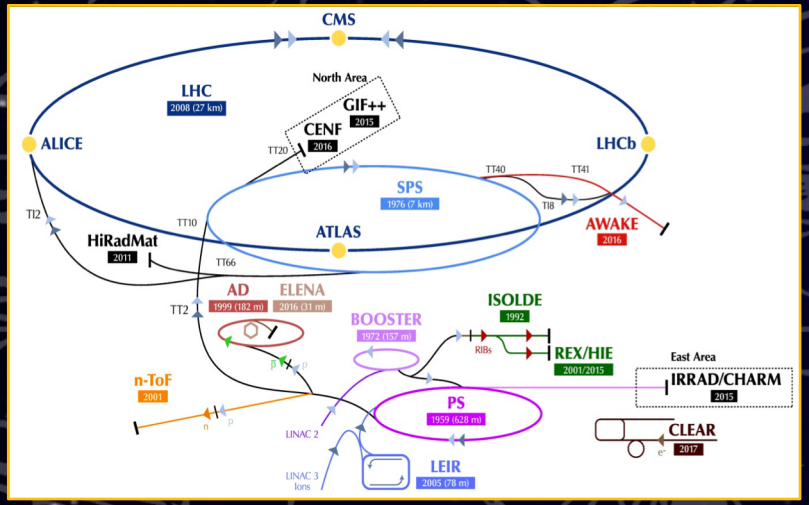
The right ”spectacles” for each size !

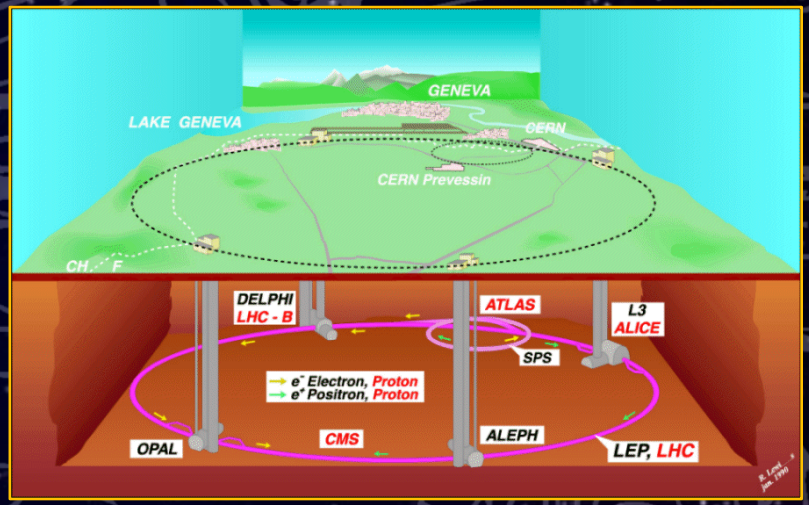






How to investigate the infinitely small

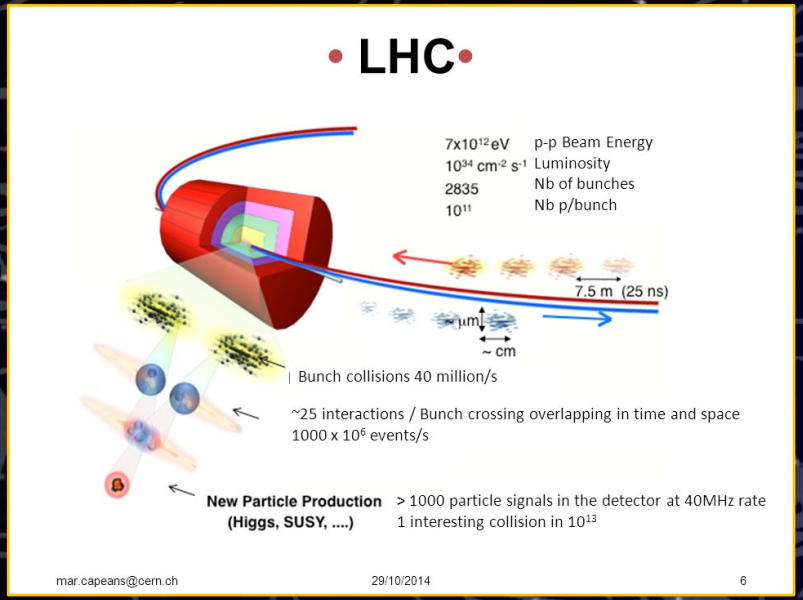


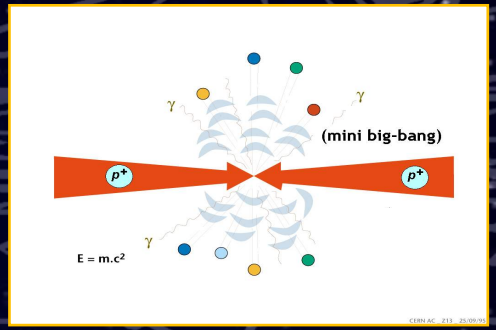


The Large Hadron Collider (LHC) is the most powerful device ever built to investigate particles behavior. It is the last stage of a more complex chain of accelerators (LINAC, PS, SPS).

The first proton beam circulated Sep. 10th,2008 at low energy for a test period.

How does the LHC work?





Energy converted in mass as described by the famous Einsten's equation:

$$E = mc^2$$

More in general:

$$E^2 = m^2c^4 + p^2c^2$$

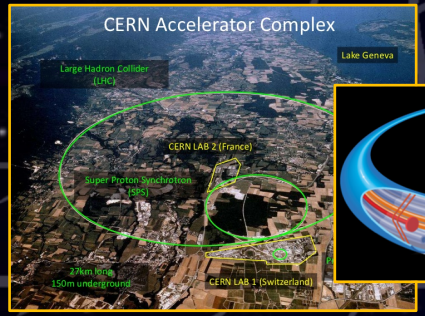
$$E = mc^2 + T$$

$$E = \gamma mc^2$$

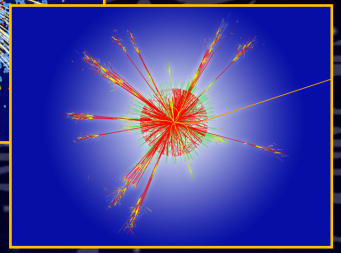
being

m = rest mass
p = momentum
T = kinetic energy
$\gamma = 1/\sqrt{1-\beta^2}$, $\beta = v/c$

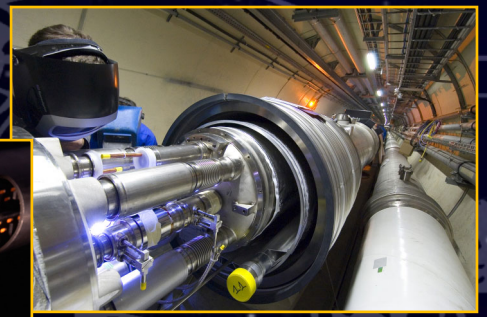
LHC records

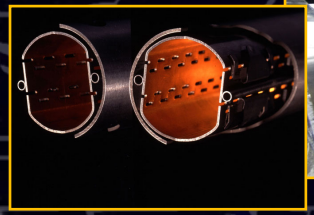


The fastest circuit on the Earth
(40x10^{6} bunch crossing/second)



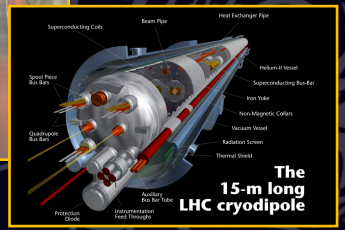
The hottest place in the galaxy (T~ 10^{5} higher than in the Sun but in a much smaller space)





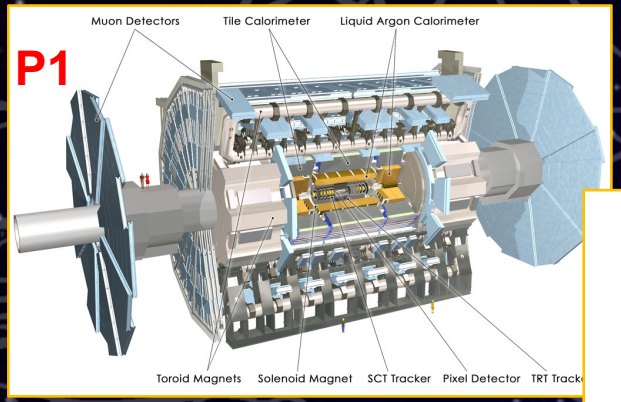
The most empty place in the Solar System
(p~10^{-16} atm ~ 10^{-11}Pa)

The coldest place in the Space (cryomagnets at T ~ 271.3 ^{o}C ~ 1.9K, magnetic field B~8.5T)

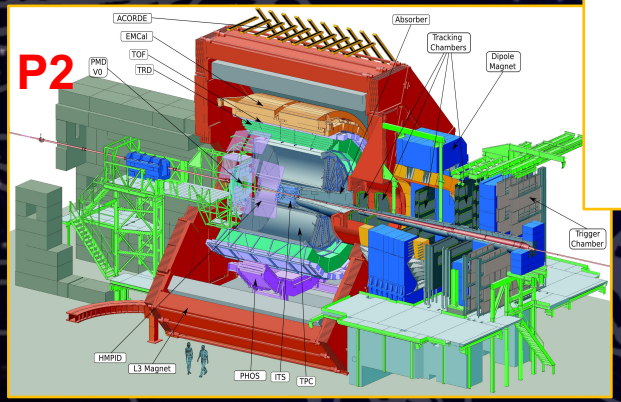


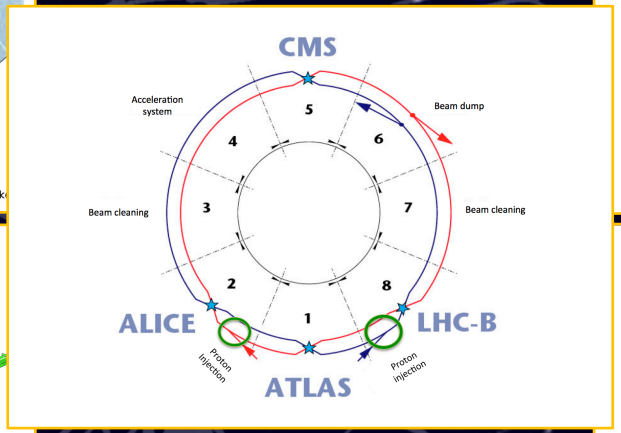
Four detectors operating on LHC

ATLAS

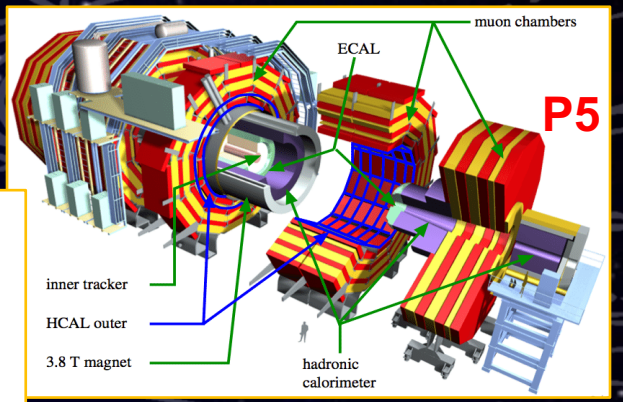


ALICE

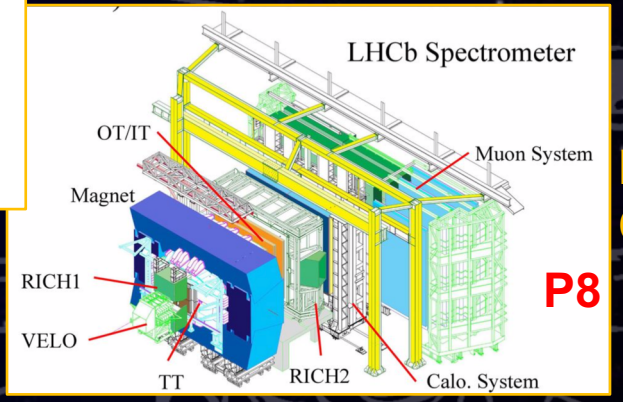




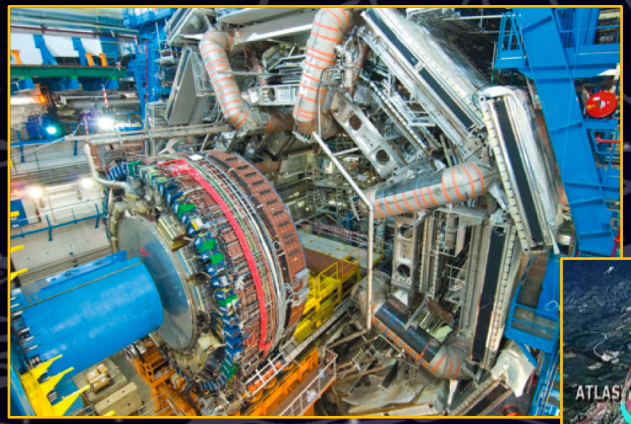
CMS



LHCb



ATLAS



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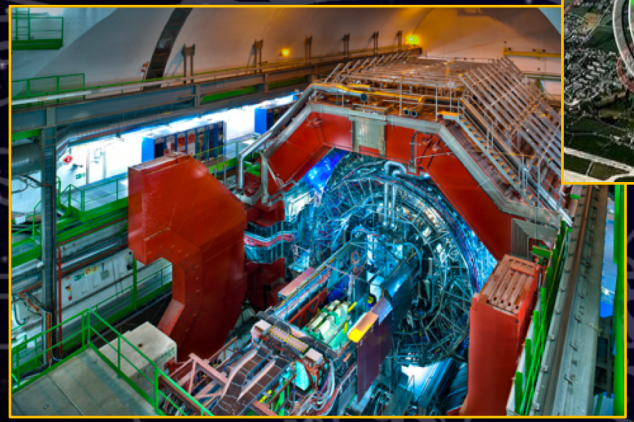
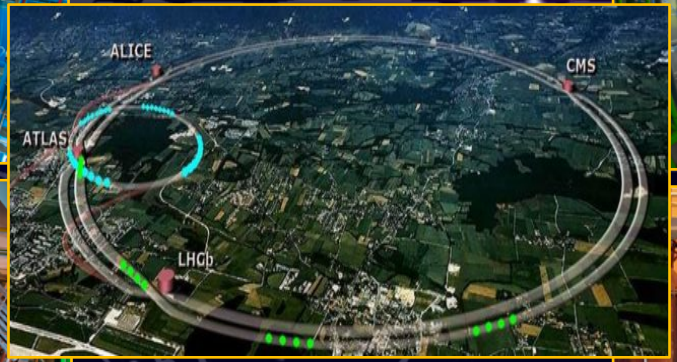
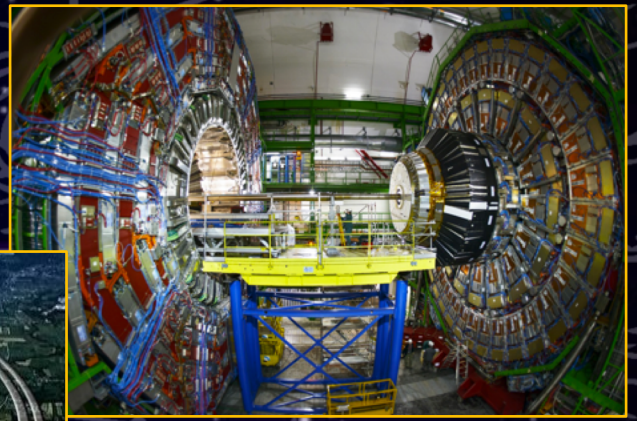
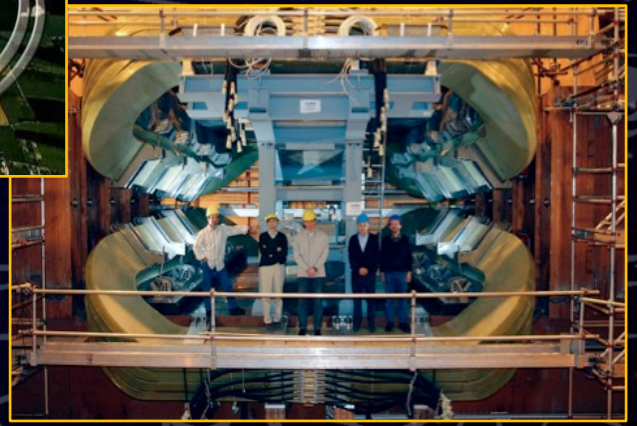


…and now



…for real !





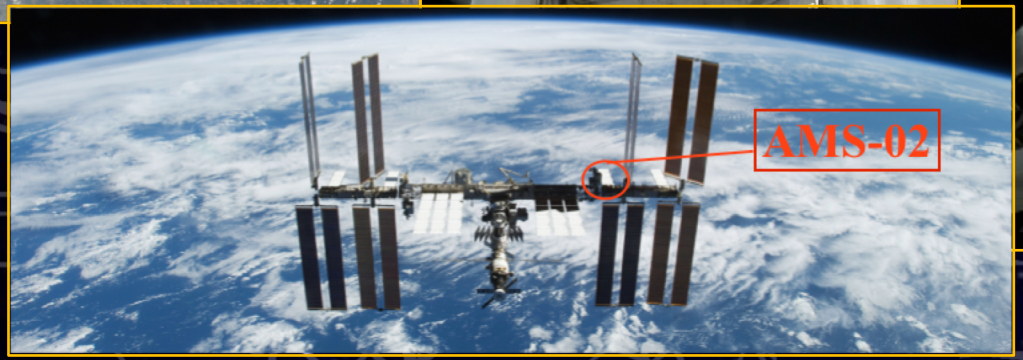
CMS

LHCb

CERN is not only involved in accelerator Physics and its research programme include also:

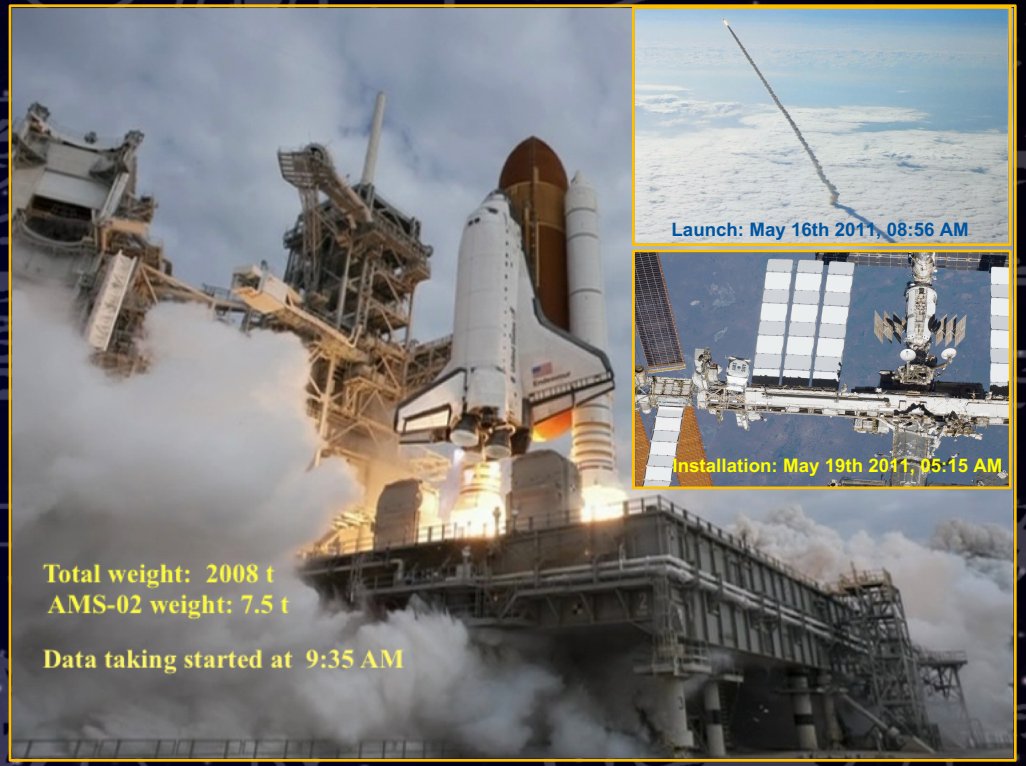
- Astroparticle and Cosmic Rays Physics (AMS-02, CLOUD)
- Nuclear Physics (COMPASS, ALPHA, AEGIS)
- Medical Physics (CERN MEDICIS, GaToroid Magnet, PIMMS and NIMMS)
- Informatics Tecnologies (WEB, GRID)
- ……..

Astroparticle Physics : AMS-02 on the ISS



Alpha Magnetic Spectrometer
International Space Station

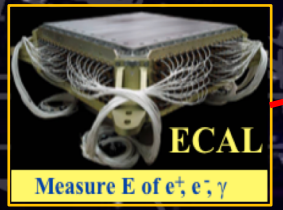
AMS-02 history



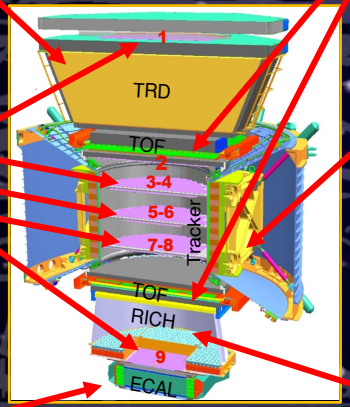
- 1995-1998: proposal and feasibility test (AMS-01);
- 1999-2006: subdetectors productions (institutes);
- 2007–2010: Detector assembly and test at CERN.

- May 16th, 2011: launch at Cape Canaveral (Florida, USA);
- May 19th, 2011: installation on the ISS.

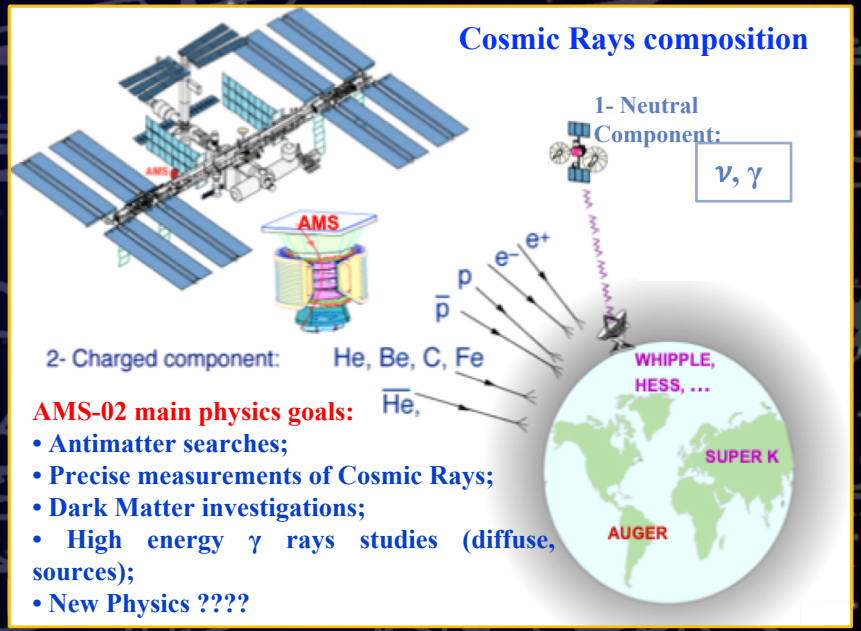
AMS-02 detector and research plan



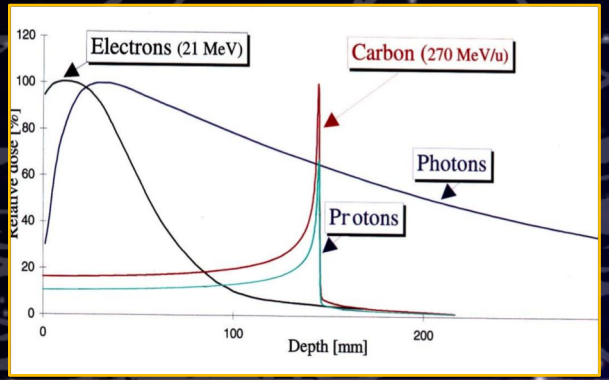
Particles and nuclei are identified by their charge (Z) and energy (E~P)

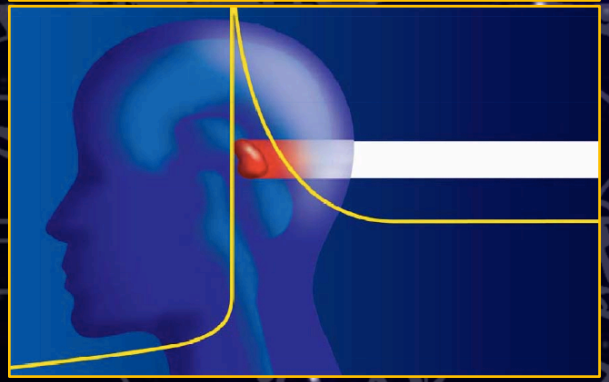


Z, P independently measured by Tracker, RICH, TOF e ECAL



PARTICLE PHYSICS AND MEDICAL APPLICATION





RADIO THERAPY

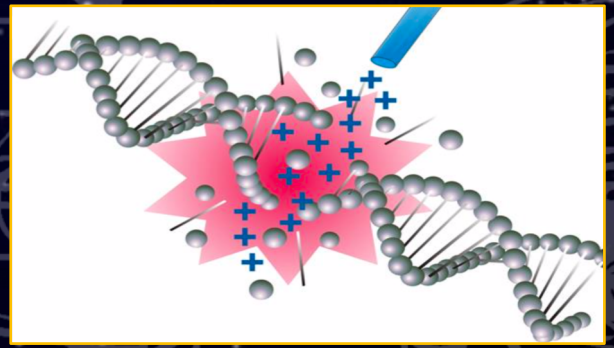
Photons and electrons

- Physical dose high near surface
- DNA damage easily repaired
- Biological effect lower
- Need presence of oxygen
- Effect not localised

HADRON THERAPY

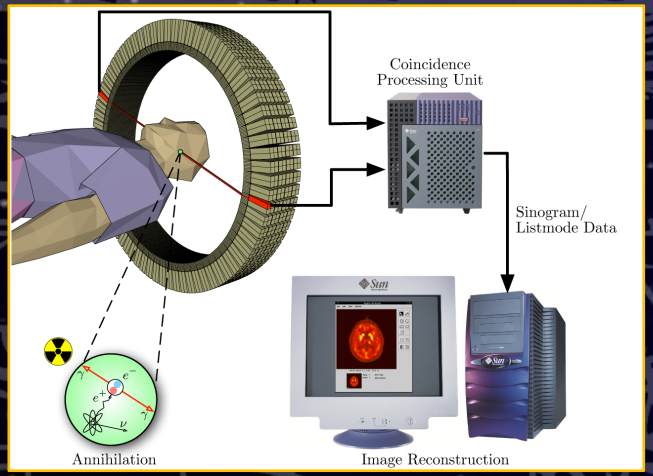
Hadrons (p, n) and C nuclei

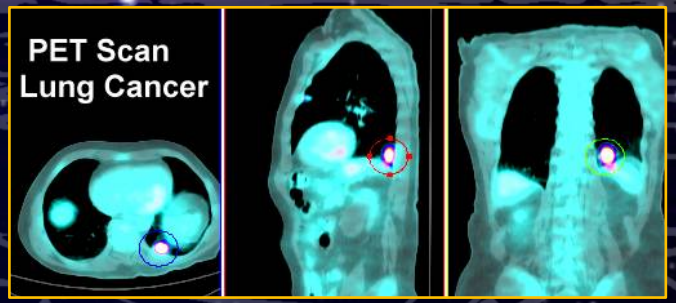
- Dose highest at the Bragg Peak
- DNA damage not repaired
- Biological effect high
- Do not need oxygen
  Effect is localised

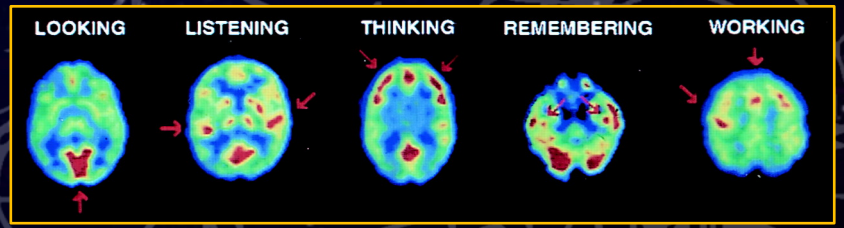


PARTICLE PHYSICS AND MEDICAL APPLICATION

P.E.T. : POSITRON EMISSION TOMOGRAPHY







- Non-invasive screening
- High precision diagnostics

PARTICLE PHYSICS AND TECNOLOGY INFORMATION

WORLD WIDE WEB

TIM BERNERS-LEE

WLCG: LHC Computing Grid

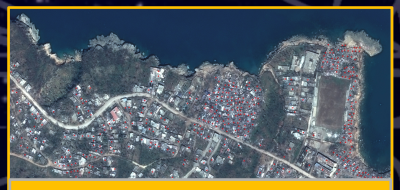
About WLCG:
- A community of 10,000 physicists
- ~250,000 jobs running concurrently
- 600,000 processing cores
- 700 PB storage available worldwide
- 20-40 Gbit/s connect CERN to Tier1s

Tier-0 (CERN)
- Initial data reconstruction
- Data recording & archiving
- Data distribution to rest of world

Tier-1s (14 centres worldwide)
- Permanent storage
- Re-processing
- Monte Carlo Simulation
- End-user analysis

Tier-2s (>150 centres worldwide)
- Monte Carlo Simulation
- End-user analysis

2006: H5N1 VIRUS (Avian Flu)



2016: Hurricane Matthew damages

CERN AGAINST COVID-19

2020: Folding@home Project

In conclusion, being a physicist can be exciting and is for sure useful ……
……..but you will never confine a physicist in doing only physics as they are curious minds always thirsty of knowledge !

Come to join us at CERN !

Thanks for your attention!

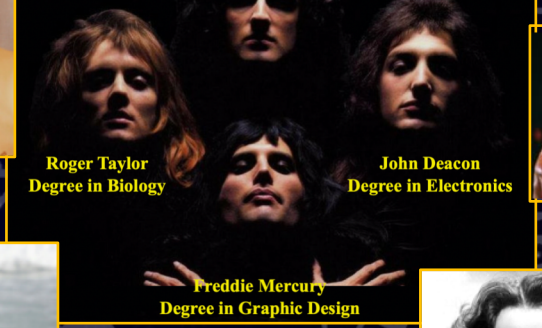
To learn further…

- https://home.cern/
- http://visit.cern/
- https://careers.cern/

- sonia.natale@cern.ch

Please, fill the survey on the Indico

Brian May
Degree in Physics and PhD in Astrophysics



Other Useful Links!

- **Medical**
  https://cds.cern.ch/record/1611721
  https://cds.cern.ch/record/1477954?ln=en
  https://videos.cern.ch/record/2647660
- **AMS-02 at CERN and NASA**
  https://ams02.space/
  https://home.cern/science/experiments/ams
  https://ams.nasa.gov/
- **LHC Magnets**
  https://spectrum.ieee.org/computing/software/analyzing-the-lhc-magnet-quenches
- **Live Cloud Chamber at CERN (Microcosm)**
  https://microcosm.web.cern.ch/en/particles-live-cern
- **NASA Live TV**
  http://www.ustream.tv/nasahdtv