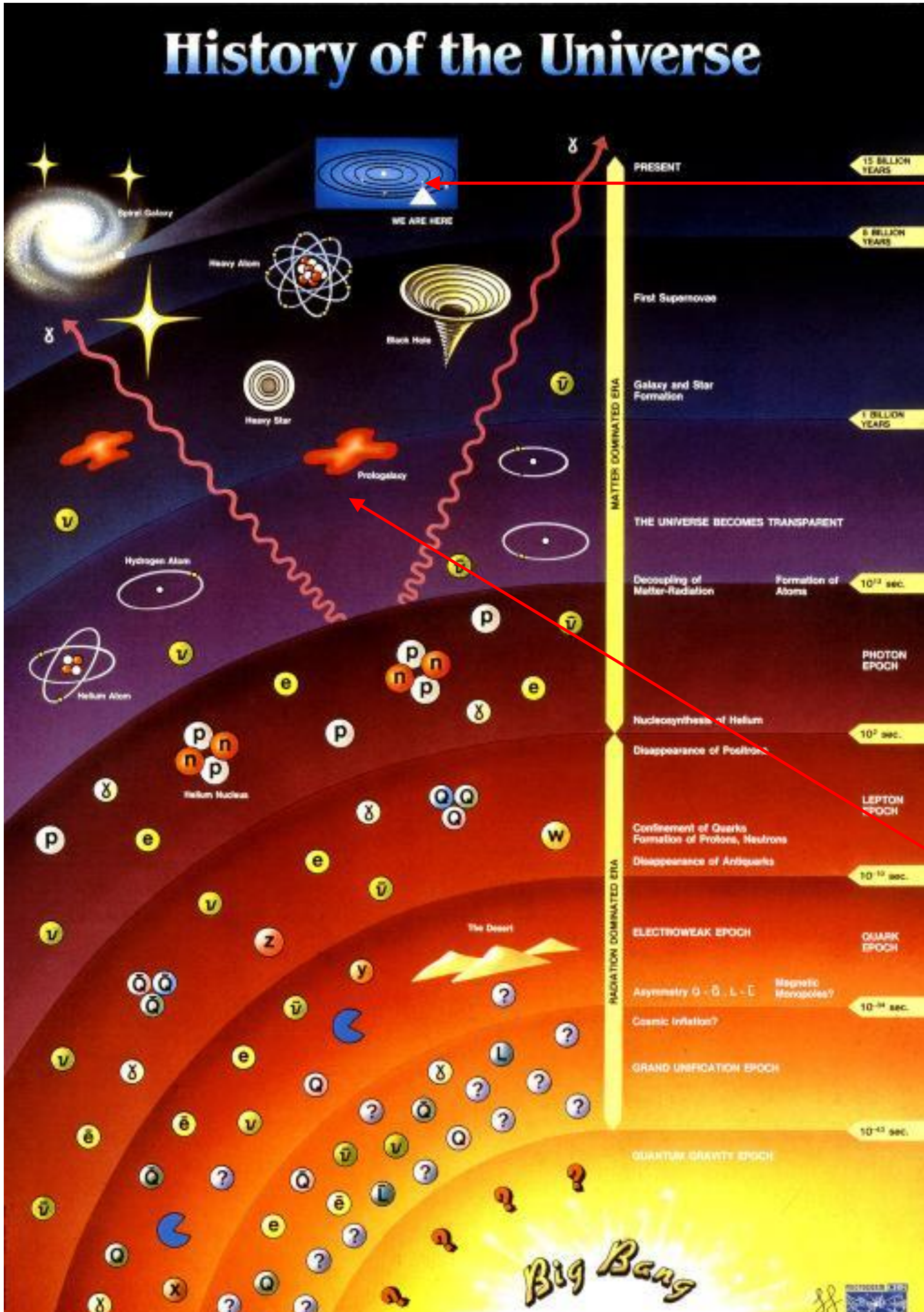
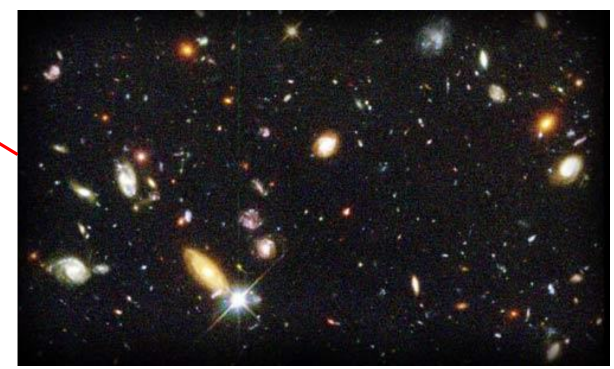
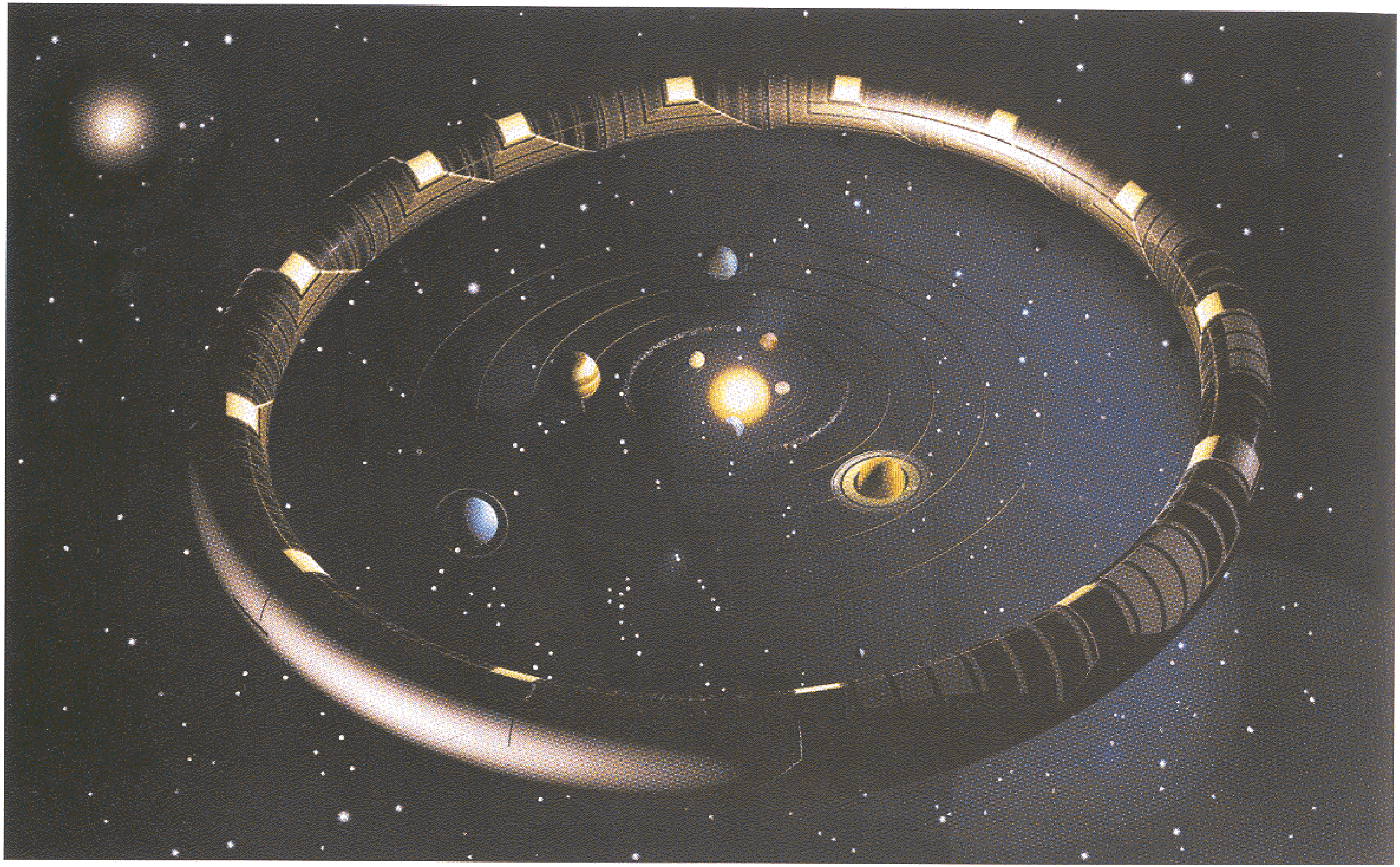
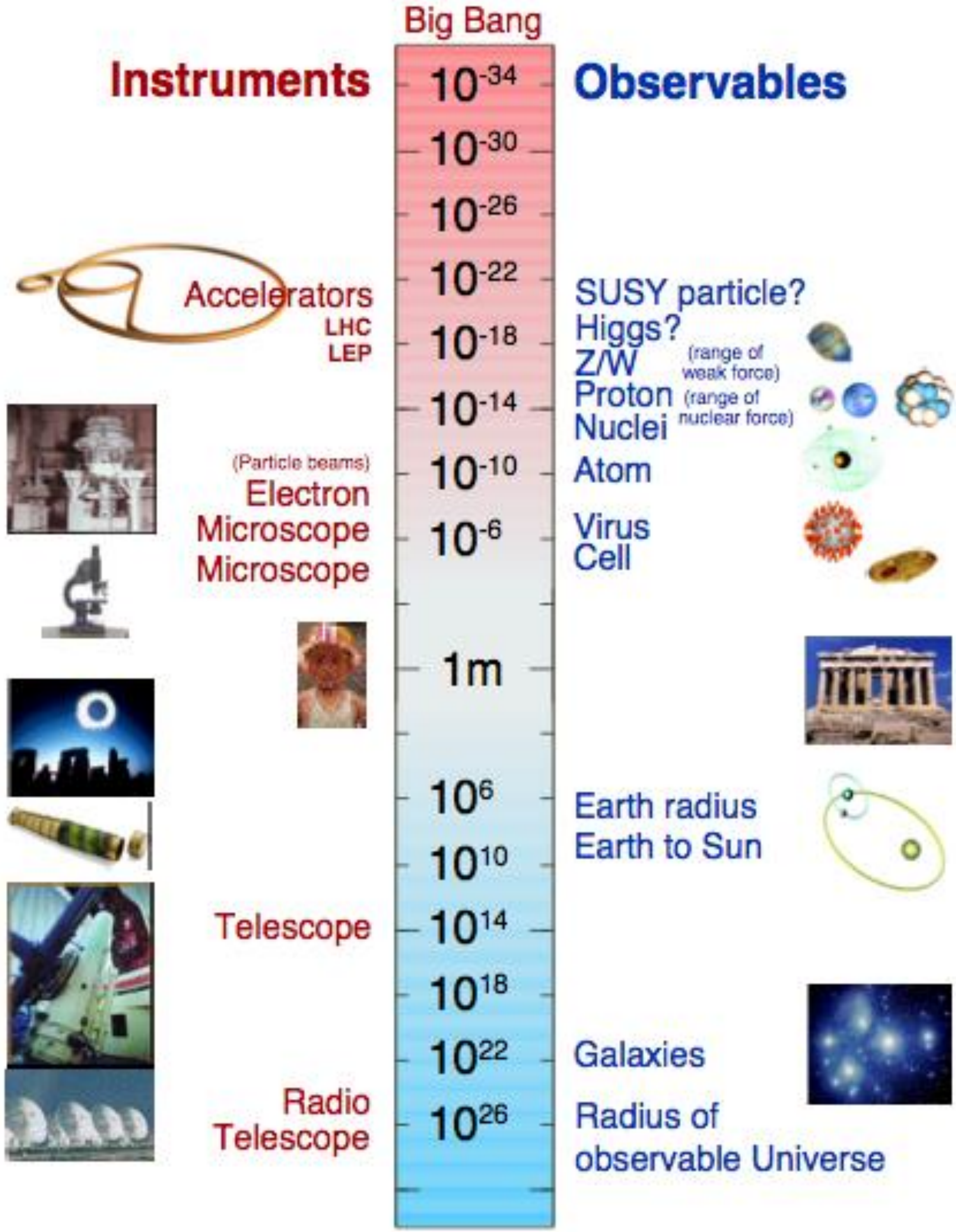
# Tervetuloa CERNiin

**Espoonlahden, Kaitaan, Karjaan ja Leppävaaran lukiot 9.11.2016**

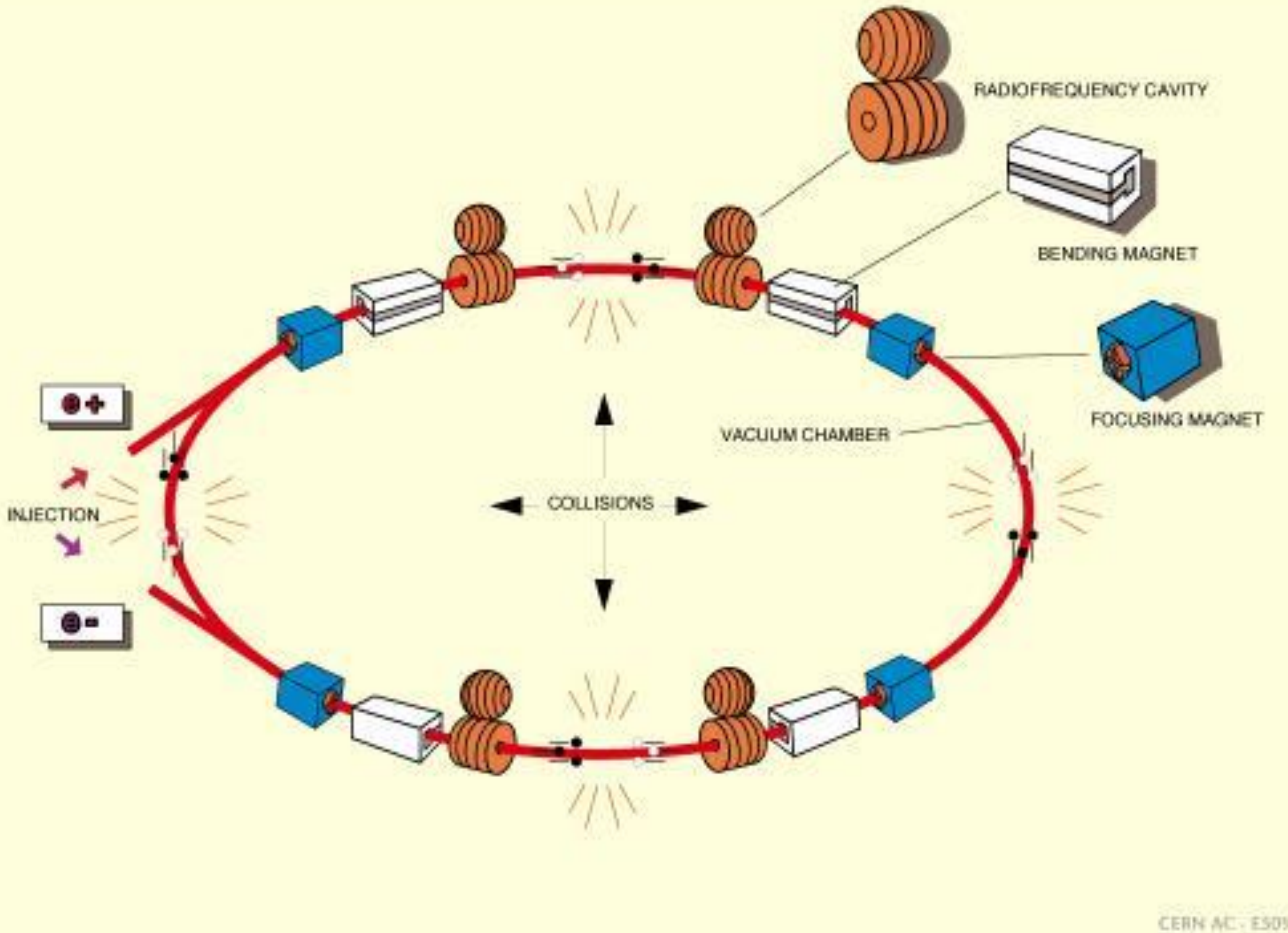

History of the Universe
PRESENT
15 BILLION YEARS
5 BILLION YEARS
First Supernovae
Galaxy and Star Formation
1 BILLION YEARS
THE UNIVERSE BECOMES TRANSPARENT
Decoupling of Matter-Radiation
Formation of Atoms
PHOTON EPOCH
Nucleosynthesis of Helium
$10^2$ sec.
Disappearance of Positrons
LEPTON EPOCH
Confinement of Quarks
Formation of Protons, Neutrons
Disappearance of Antiquarks
ELECTROWEAK EPOCH
QUARK EPOCH
Magnetic Monopoles?
$10^{-34}$ sec.
Cosmic Inflation?
GRAND UNIFICATION EPOCH
$10^{-43}$ sec.
QUANTUM GRAVITY EPOCH
MATTER DOMINATED ERA
RADIATION DOMINATED ERA
Spiral Galaxy
WE ARE HERE
Heavy Atom
Black Hole
Heavy Star
Protogalaxy
Hydrogen Atom
Helium Atom
Helium Nucleus
The Desert
Big Bang



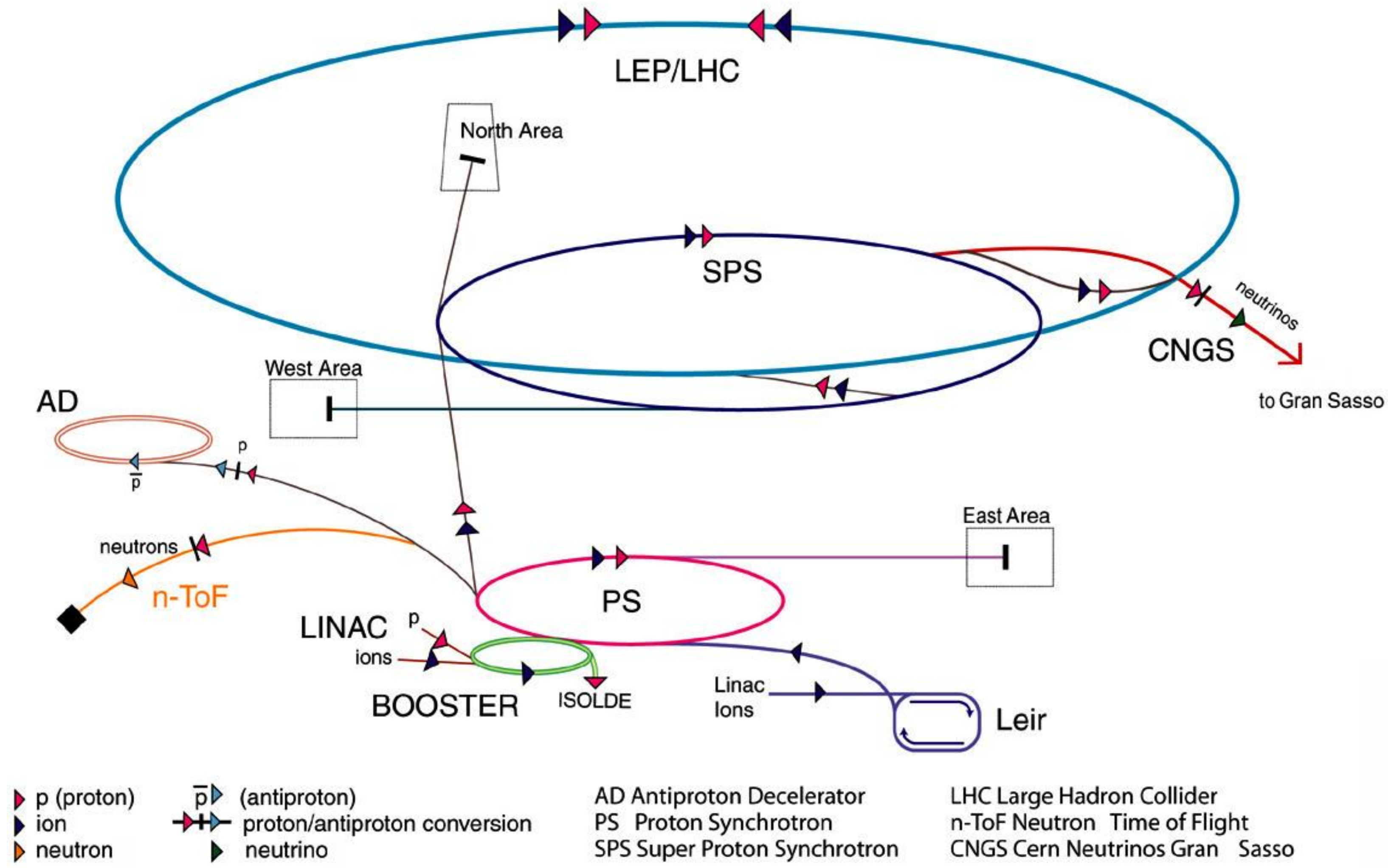



Big Bang
Instruments
Observables
$10^{-34}$
$10^{-30}$
$10^{-26}$
$10^{-22}$
$10^{-18}$
$10^{-14}$
$10^{-10}$
$10^{-6}$
1m
$10^{6}$
$10^{10}$
$10^{14}$
$10^{18}$
$10^{22}$
$10^{26}$
Accelerators
LHC
LEP
(Particle beams)
Electron
Microscope
Microscope
Telescope
Radio
Telescope
SUSY particle?
Higgs?
Z/W
(range of weak force)
Proton
(range of nuclear force)
Nuclei
Atom
Virus
Cell
Earth radius
Earth to Sun
Galaxies
Radius of observable Universe

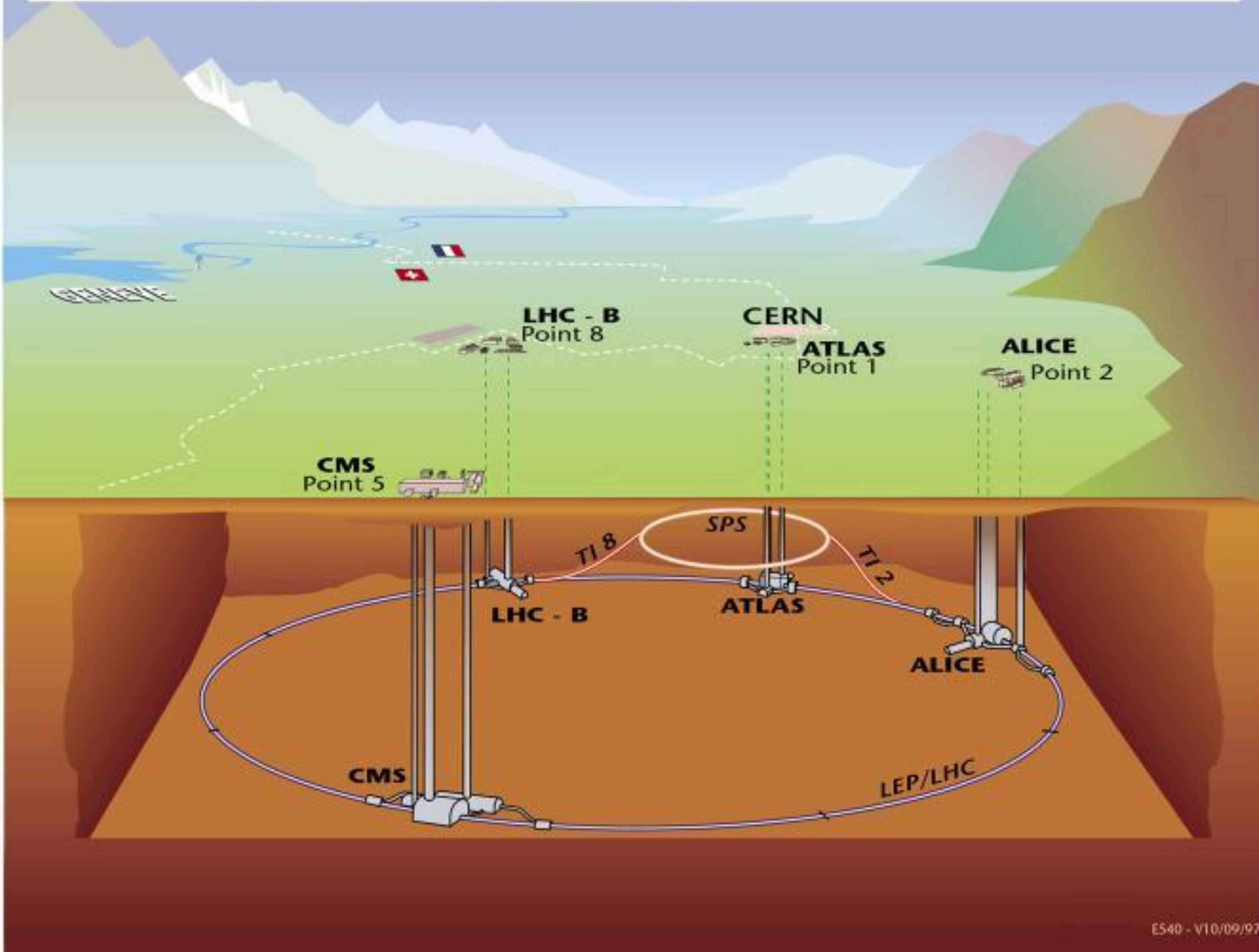
# THE PRINCIPAL MACHINE COMPONENTS OF THE LEP ACCELERATOR.



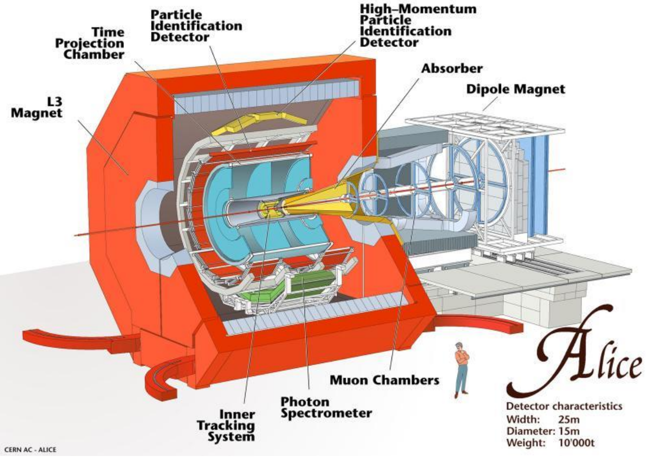
# Accelerator chain at CERN, a complex business

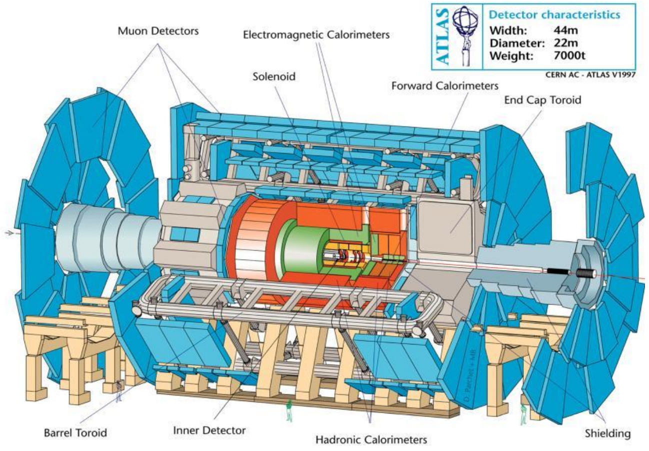


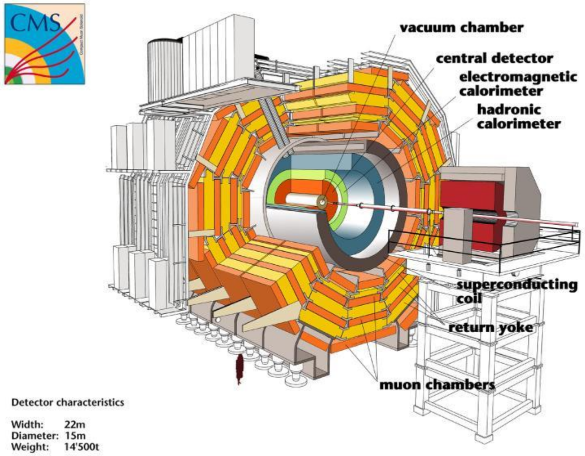
# Overall view of the LHC experiments.

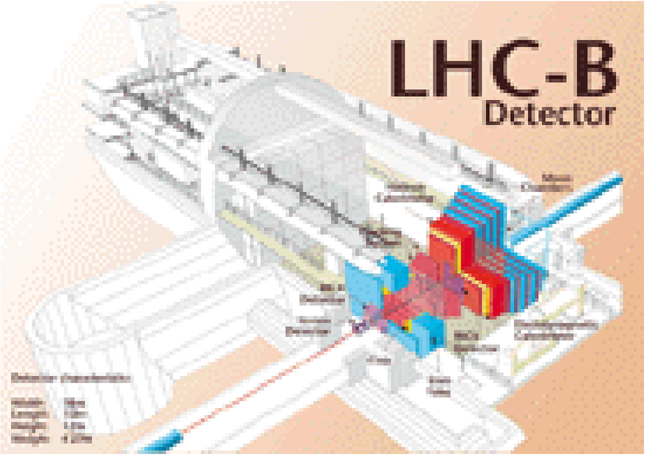


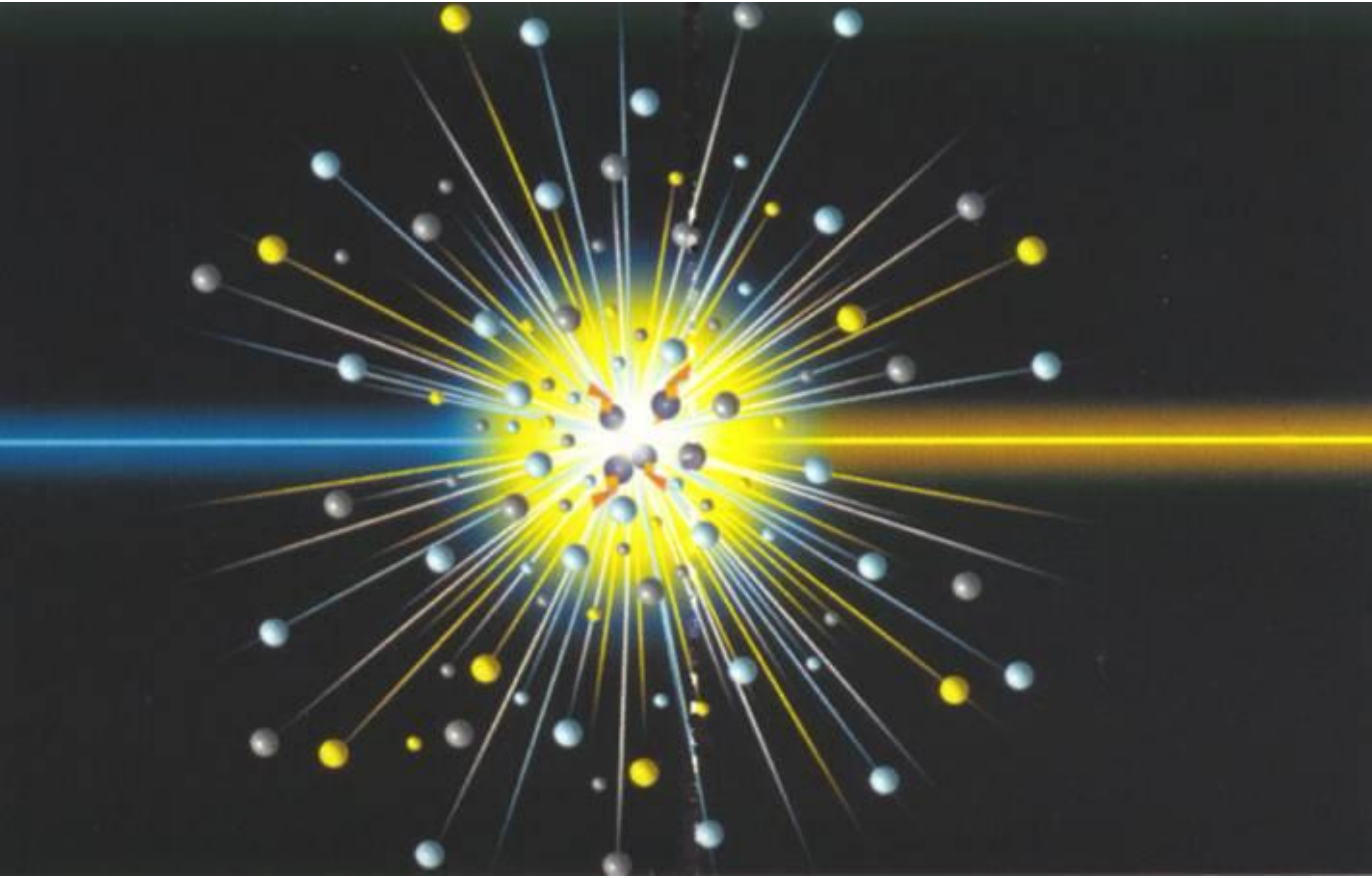
# LHC Experiments

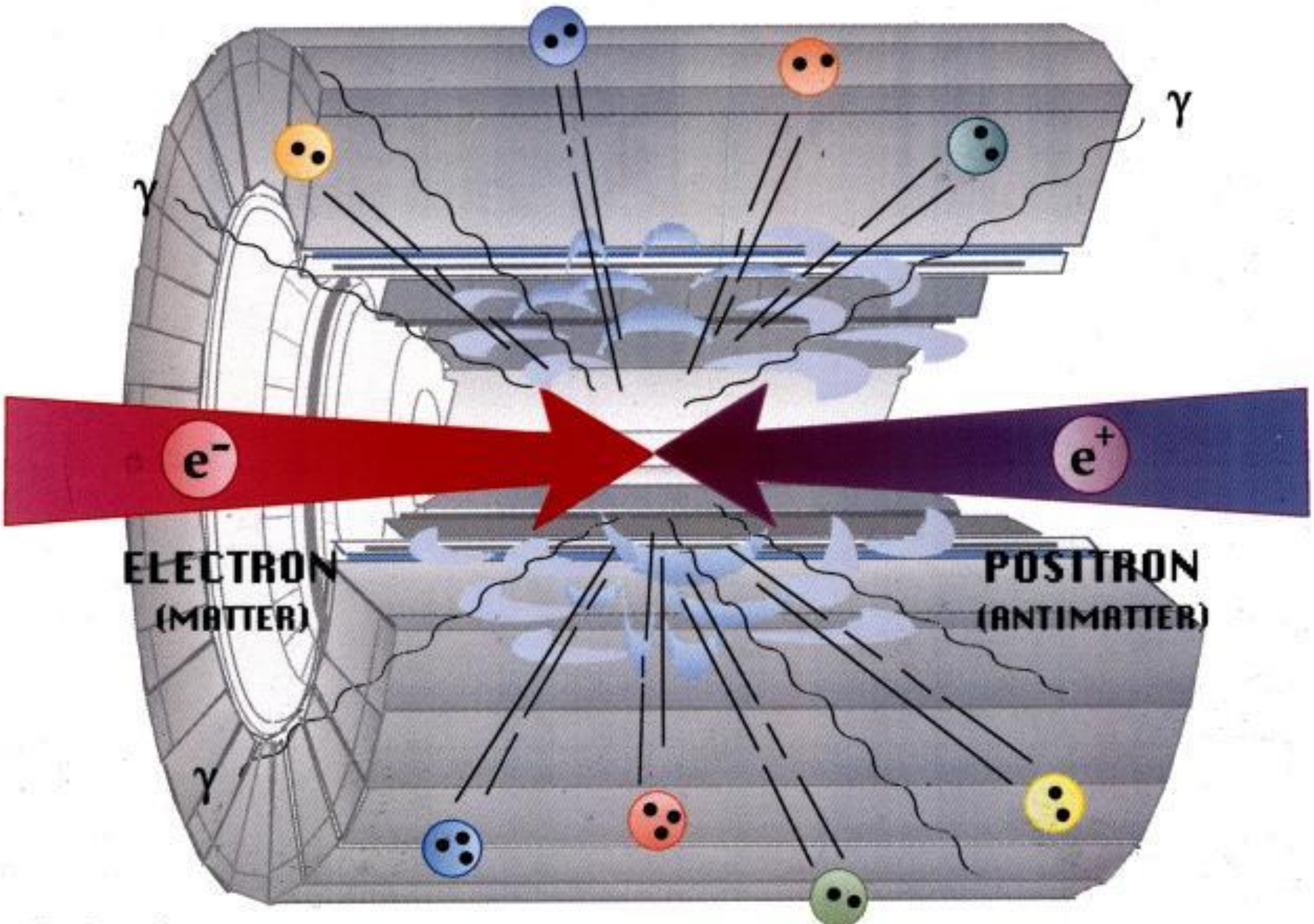


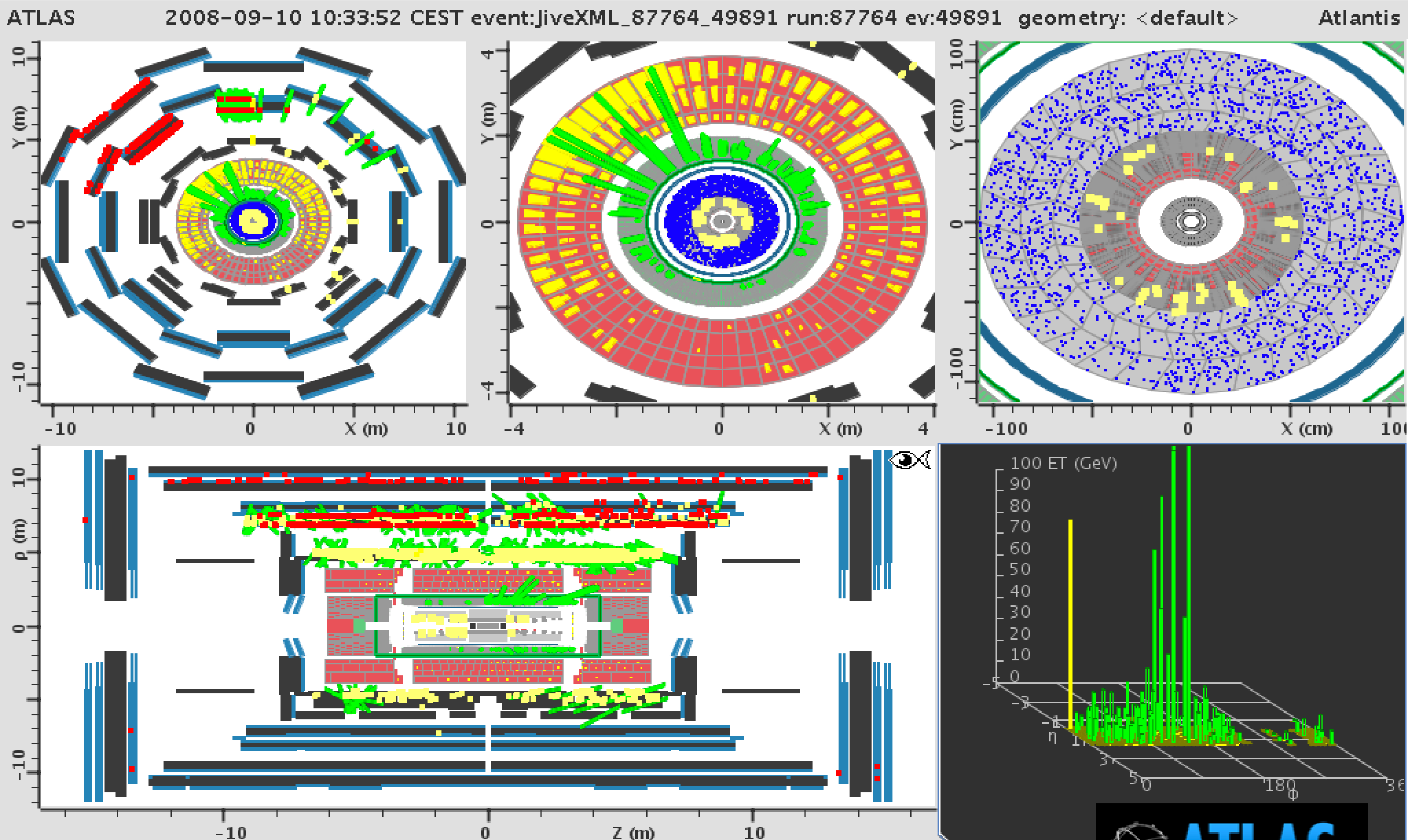



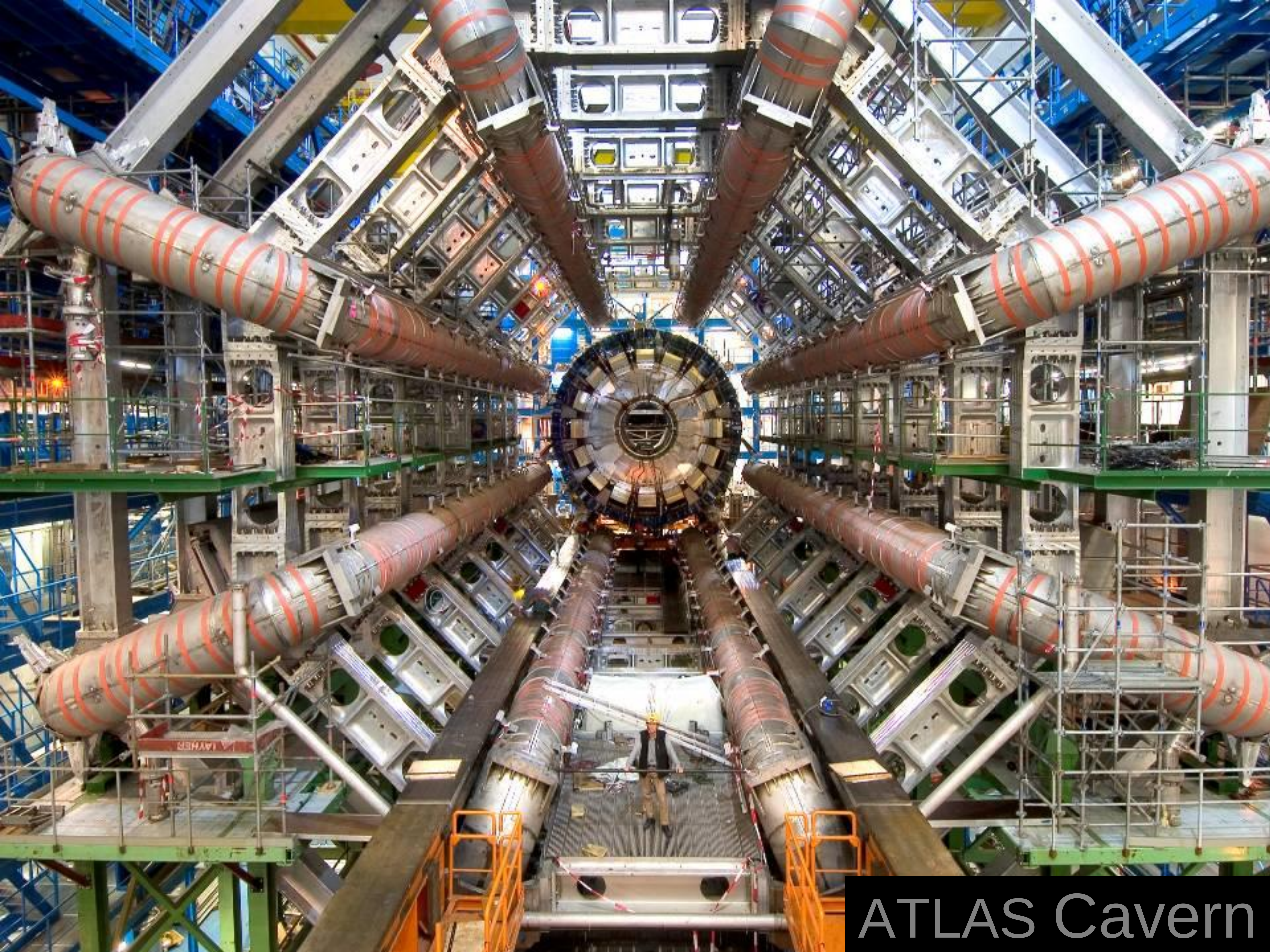



γ
γ
γ
e⁻
e⁺
ELECTRON
(MATTER)
POSITRON
(ANTIMATTER)
Eliane Onursal



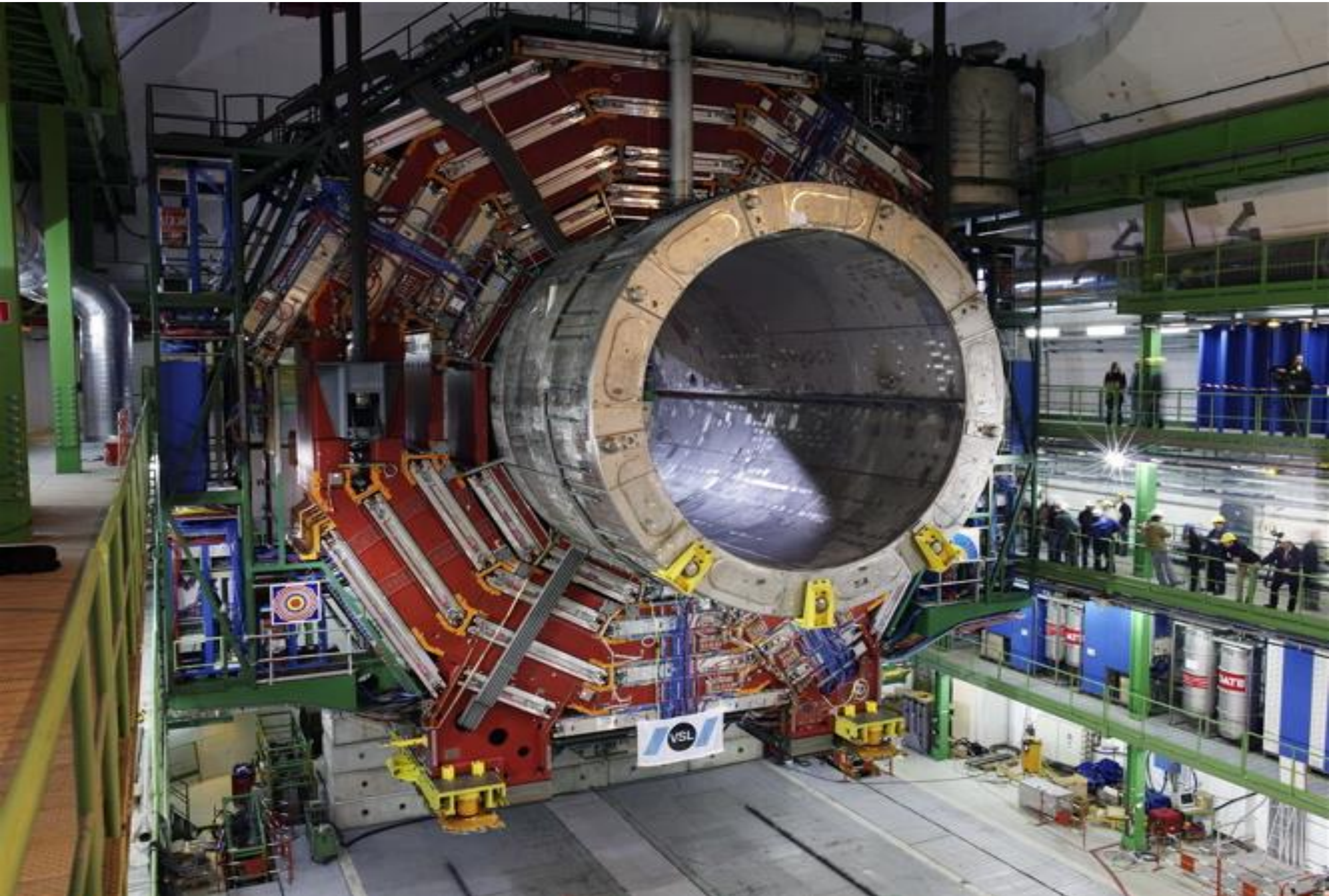

2nd beam event seen in ATLAS

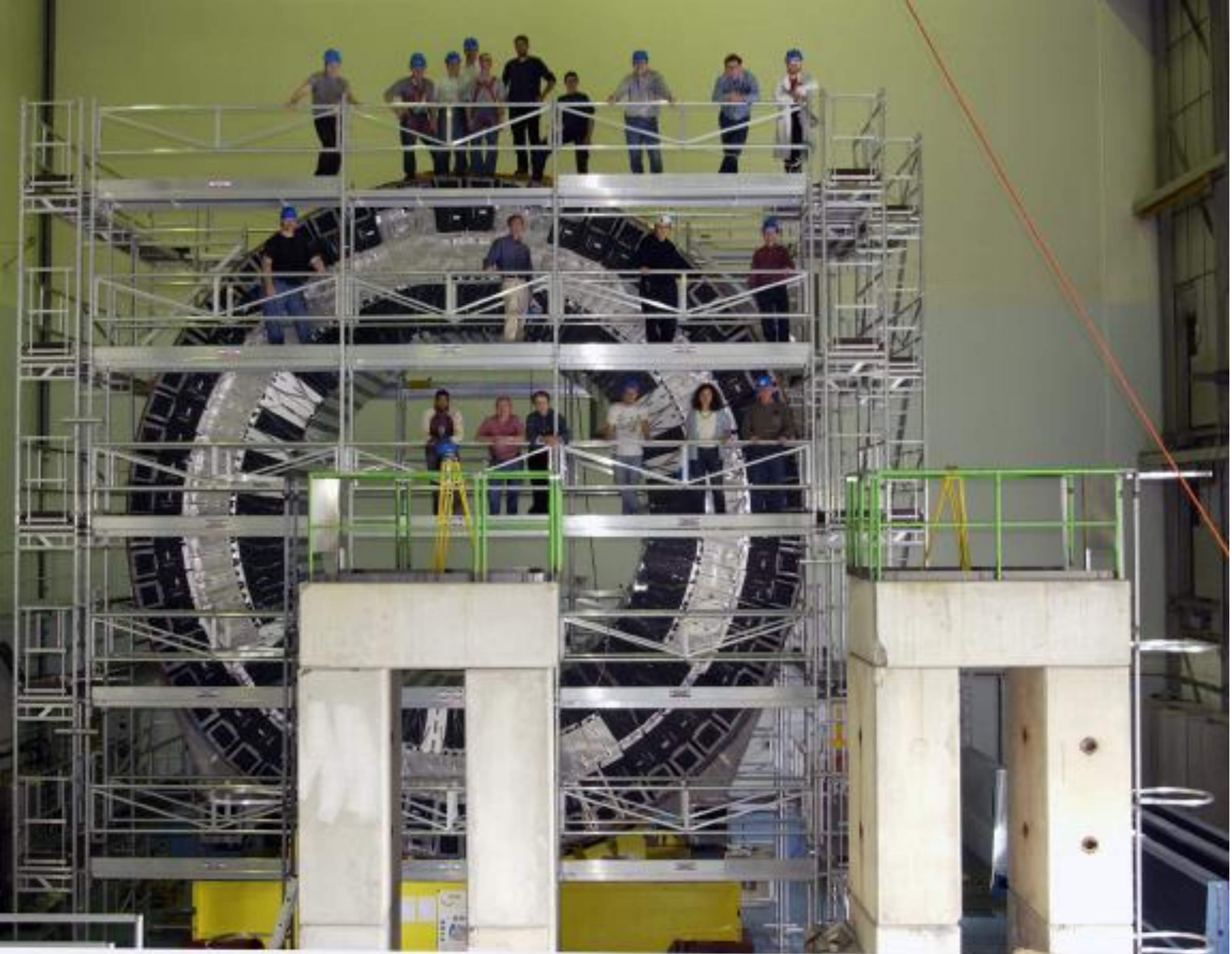
ATLAS EXPERIMENT
http://atlas.ch

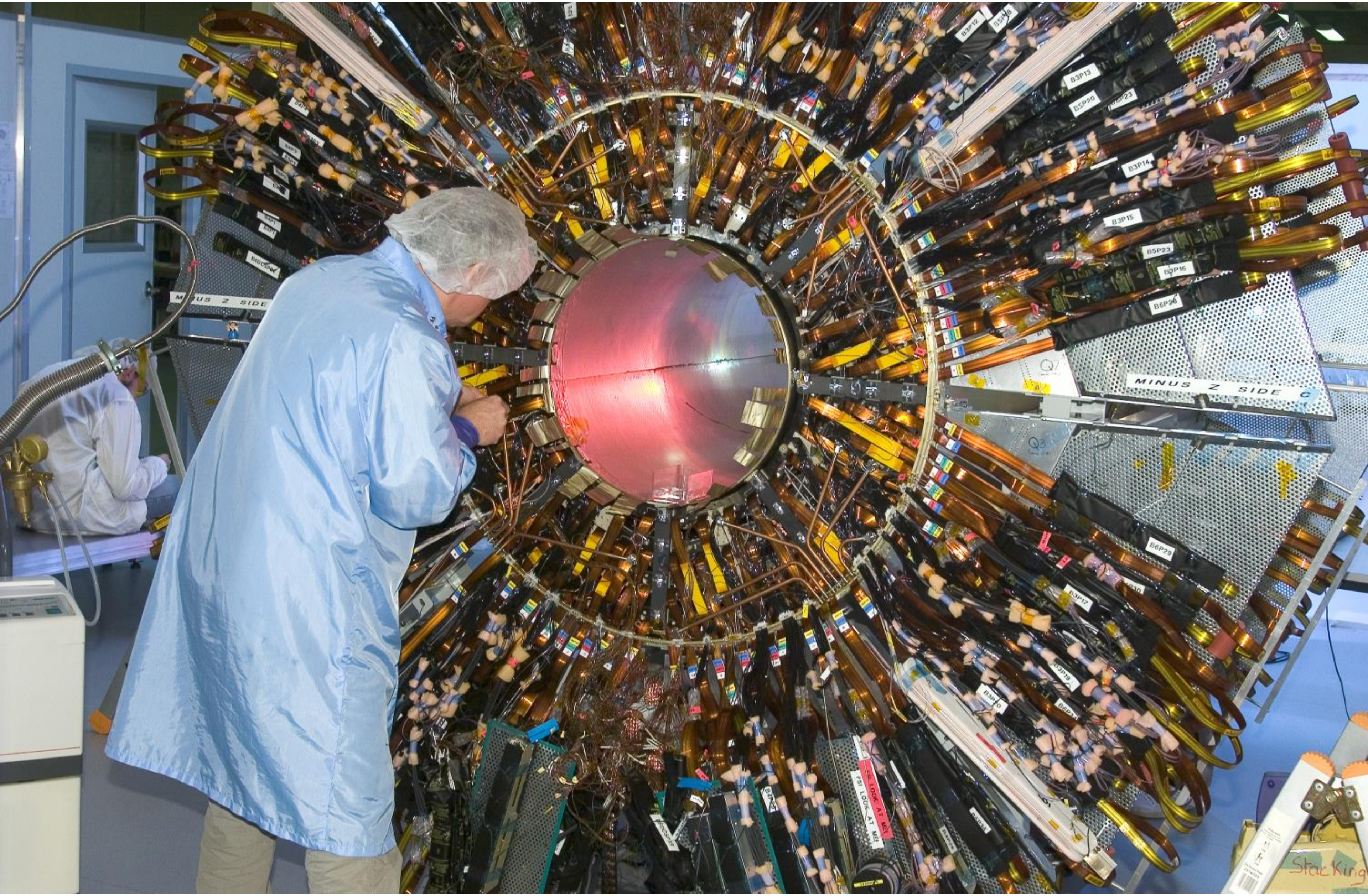


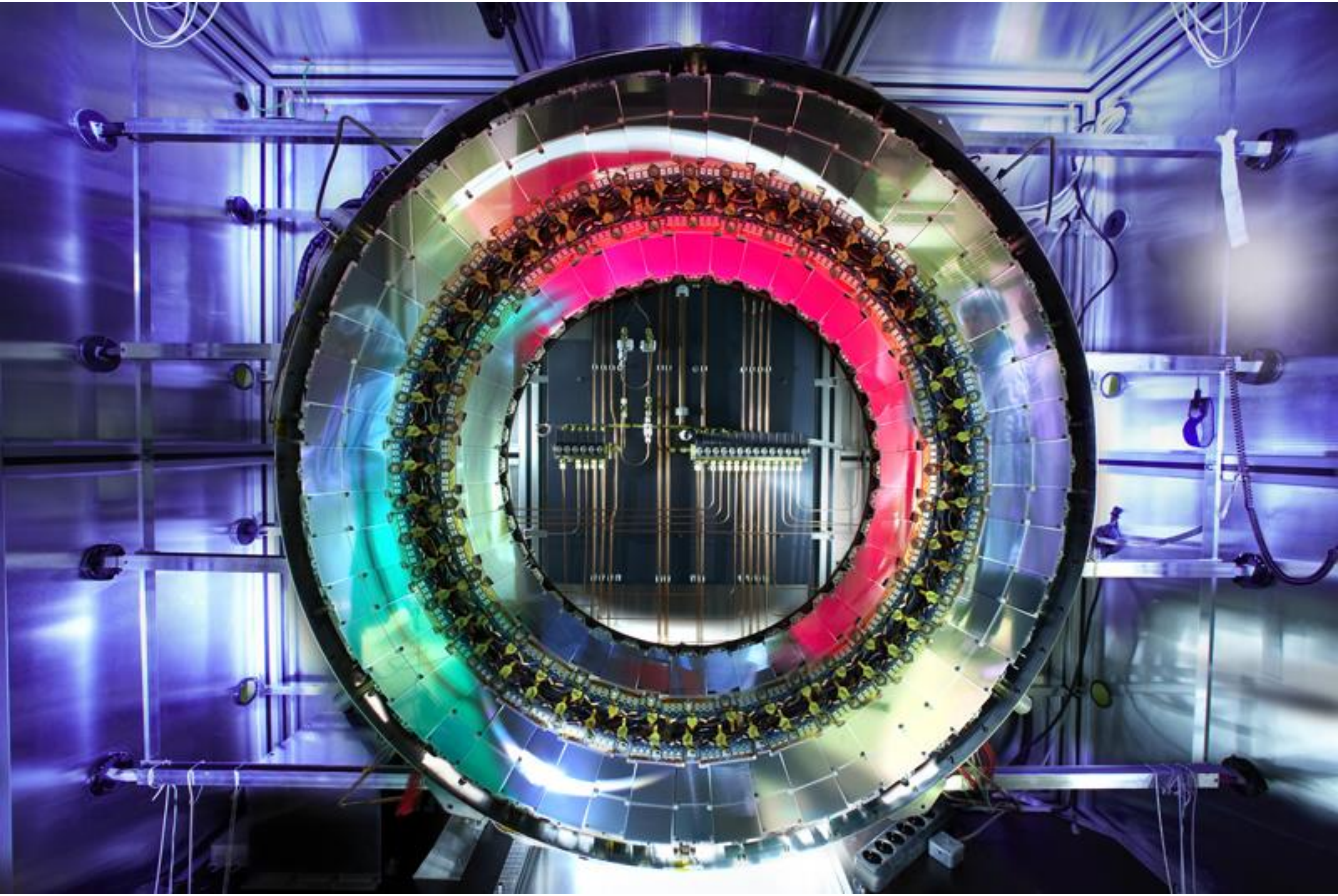
ATLAS Cavern

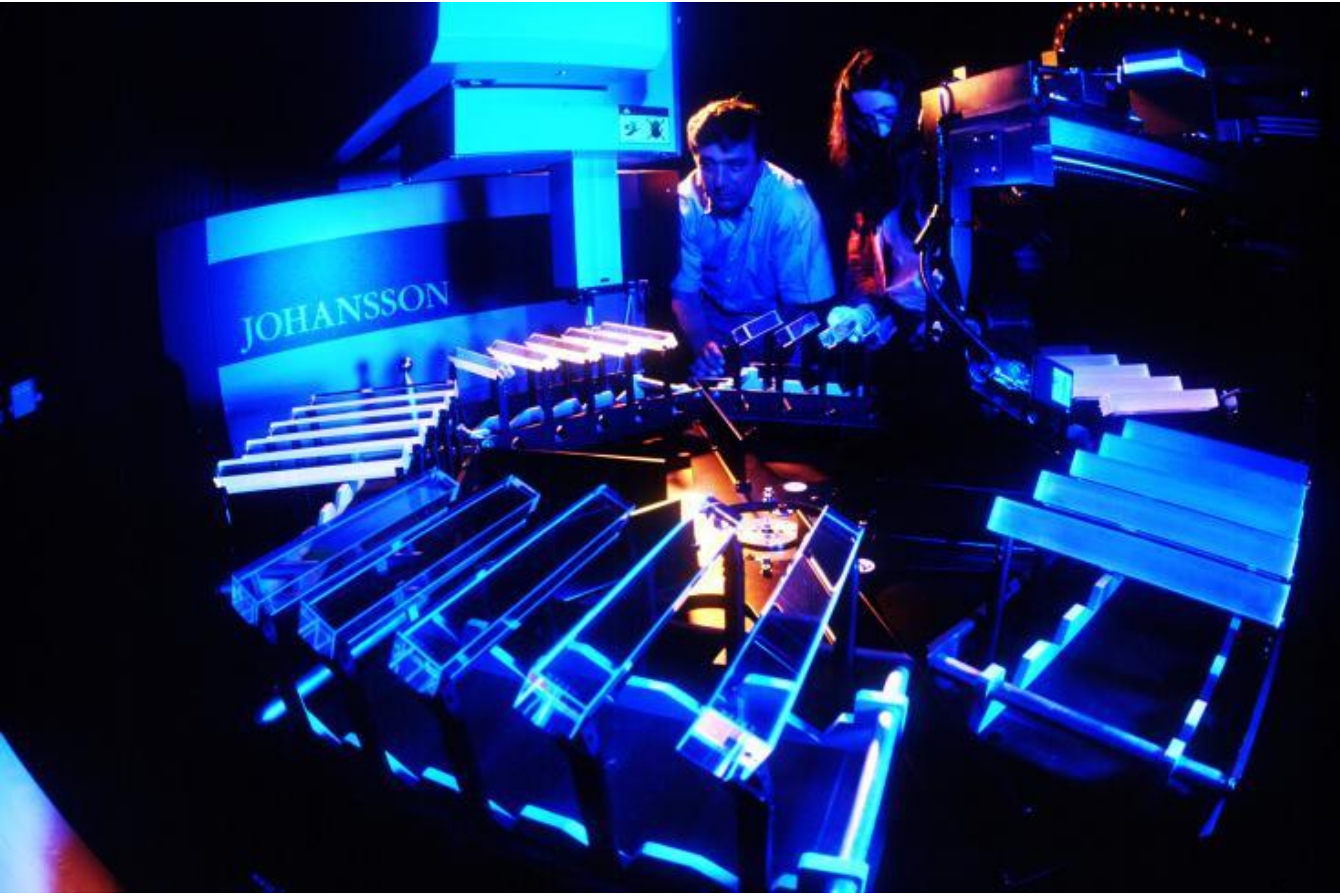
# Building CMS

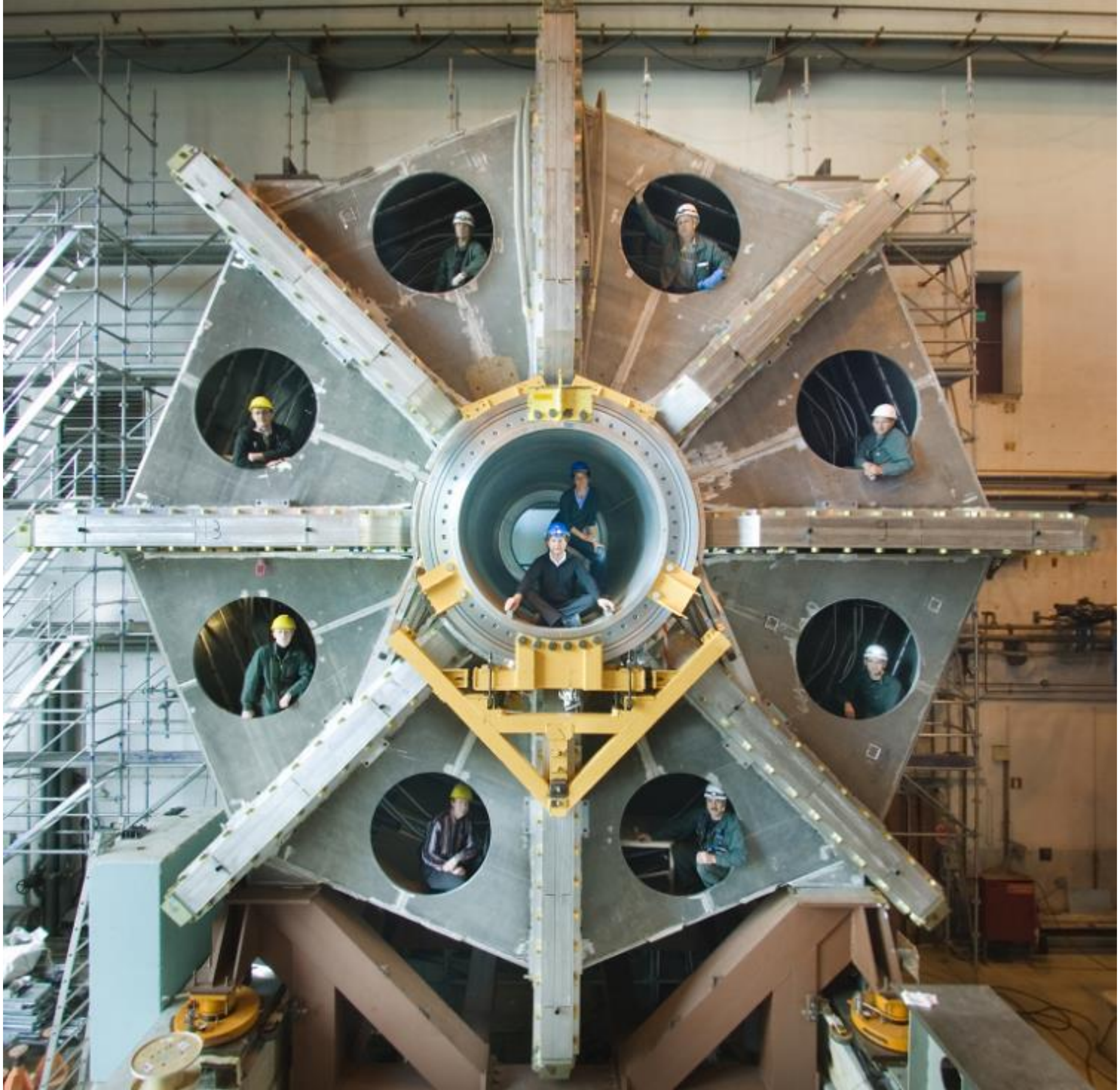





MINUS Z SIDE C
B3P13
B5P20
B3P14
B3P15
B5P23
B6P29



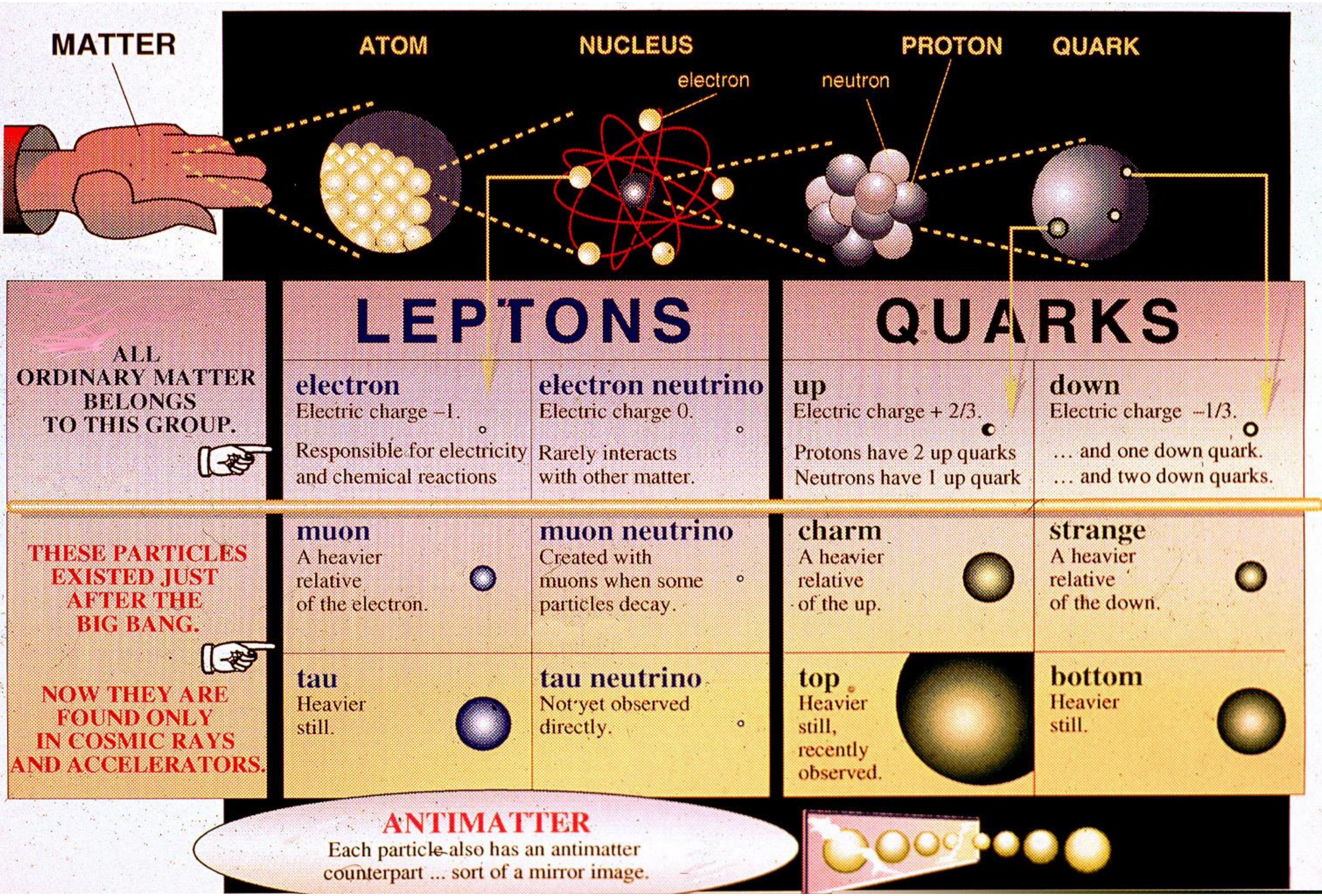

JOHANSSON




C
D


600
17
17


DELPHI Interactive Analysis
Beam:45.6 GeV
Run:26154
DAS :25-Aug-1991
Proc:1-Oct-1991
Evt:3018
21:47:02
Scan:15-Jan-1992
TD TE TS TK TV ST PA
DELPHI
ENDCAPS
BARREL
CENTRAL
Return


MATTER
ATOM
NUCLEUS
electron
neutron
PROTON
QUARK
LEPTONS
QUARKS
ALL ORDINARY MATTER BELONGS TO THIS GROUP.
electron
Electric charge –1.
Responsible for electricity and chemical reactions
electron neutrino
Electric charge 0.
Rarely interacts with other matter.
up
Electric charge + 2/3.
Protons have 2 up quarks
Neutrons have 1 up quark
down
Electric charge –1/3.
… and one down quark.
… and two down quarks.
THESE PARTICLES EXISTED JUST AFTER THE BIG BANG.
NOW THEY ARE FOUND ONLY IN COSMIC RAYS AND ACCELERATORS.
muon
A heavier relative of the electron.
muon neutrino
Created with muons when some particles decay.
charm
A heavier relative of the up.
strange
A heavier relative of the down.
tau
Heavier still.
tau neutrino
Not yet observed directly.
top
Heavier still, recently observed.
bottom
Heavier still.
ANTIMATTER
Each particle also has an antimatter counterpart ... sort of a mirror image.

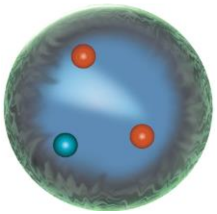
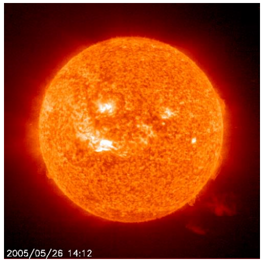
# Mass Ratios of Elementary Particles (MeV)

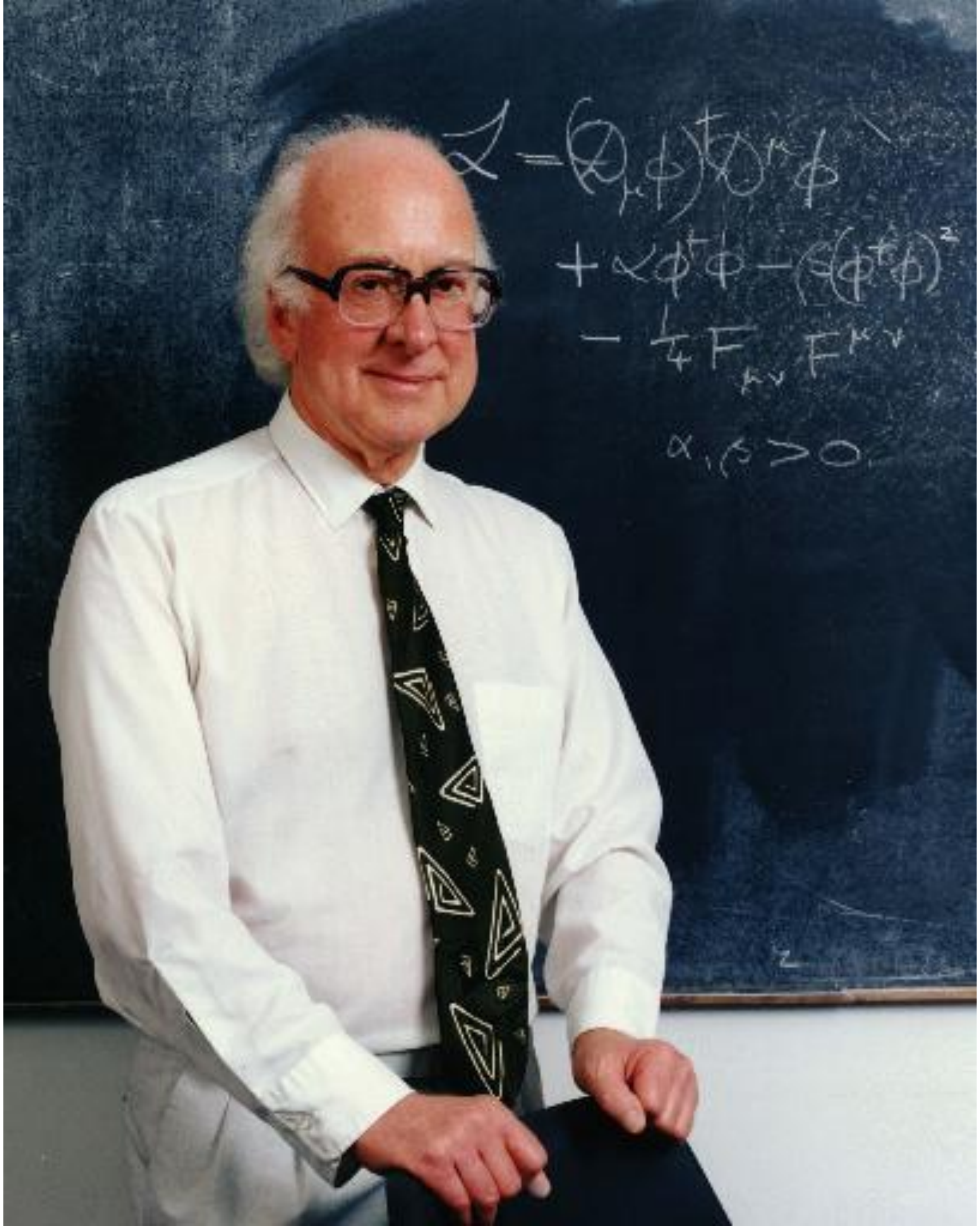
| | Lepton | Neutrino | Quark 1 | Quark 2 |
|---|---|---|---|---|
| 1st Family | 0.5 | 0 | 3 | 6 |
| 2nd Family | 106 | 0 | 1300 | 100 |
| 3rd Family | 1800 | 0 | 175000 | 4500 |

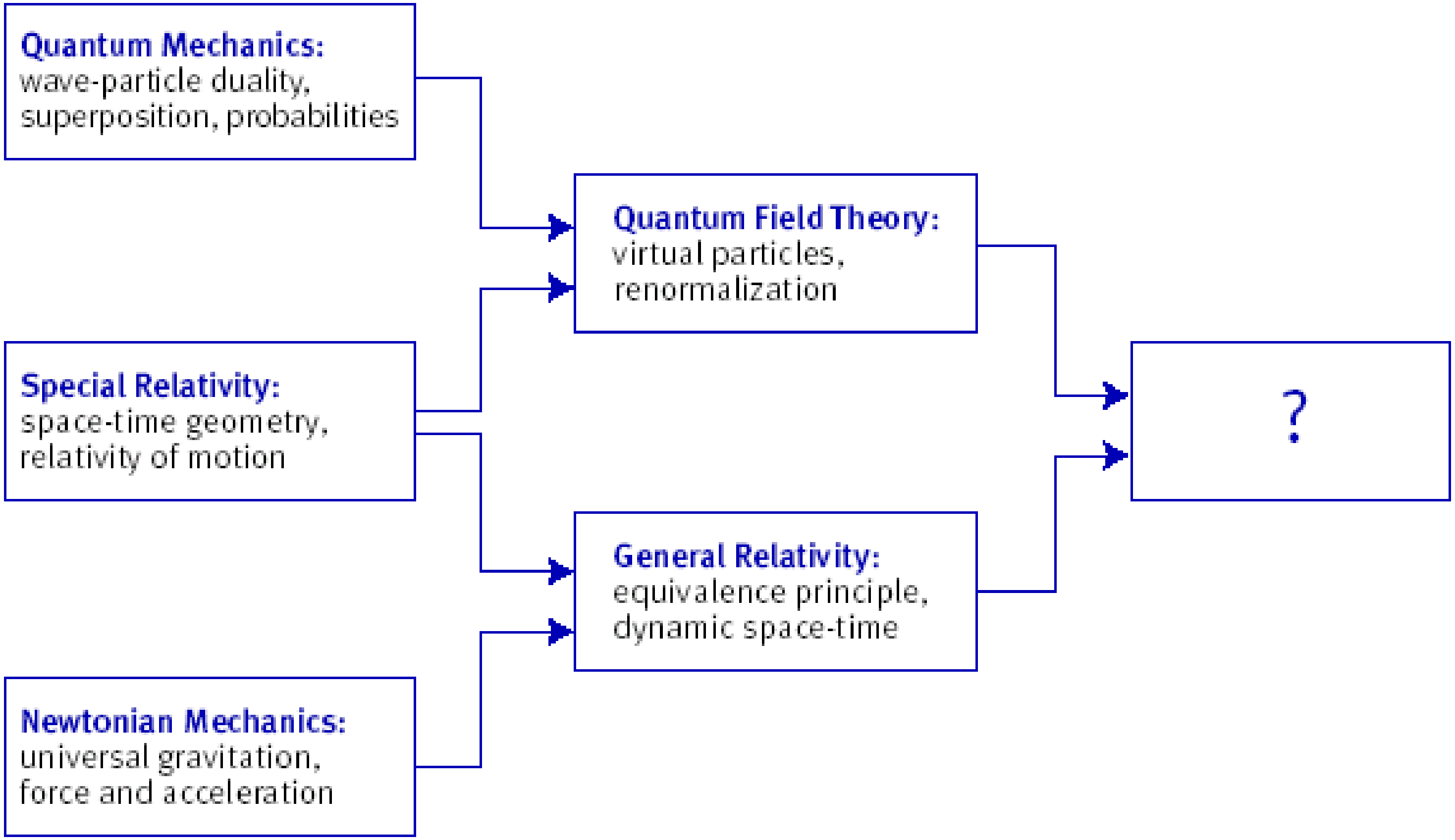
| | Lepton | Neutrino | Quark 1 | Quark 2 |
|---|---|---|---|---|
| 1st Family | 1 | 0 | 1 | 1 |
| 2nd Family | 212 | 0 | 433 | 17 |
| 3rd Family | 3600 | 0 | 58333 | 750 |

| | Lepton | Q1/Q2 | L/(Q1/Q2) |
|---|---|---|---|
| 1st Family | 1 | 1 | 1 |
| 2nd Family | 212 | 26 | 8 |
| 3rd Family | 3600 | 78 | 46 |

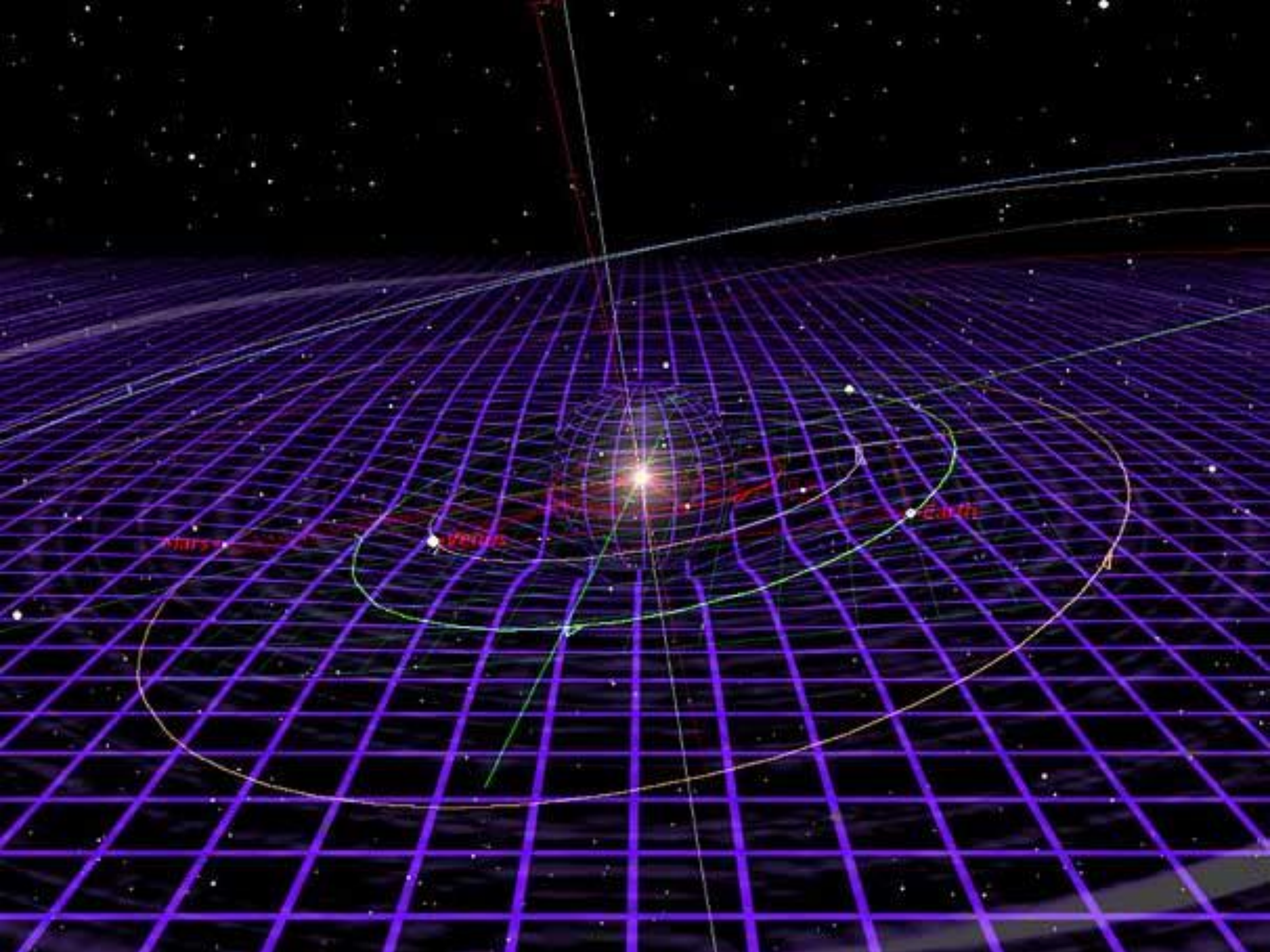
# Basic Forces and their Carriers

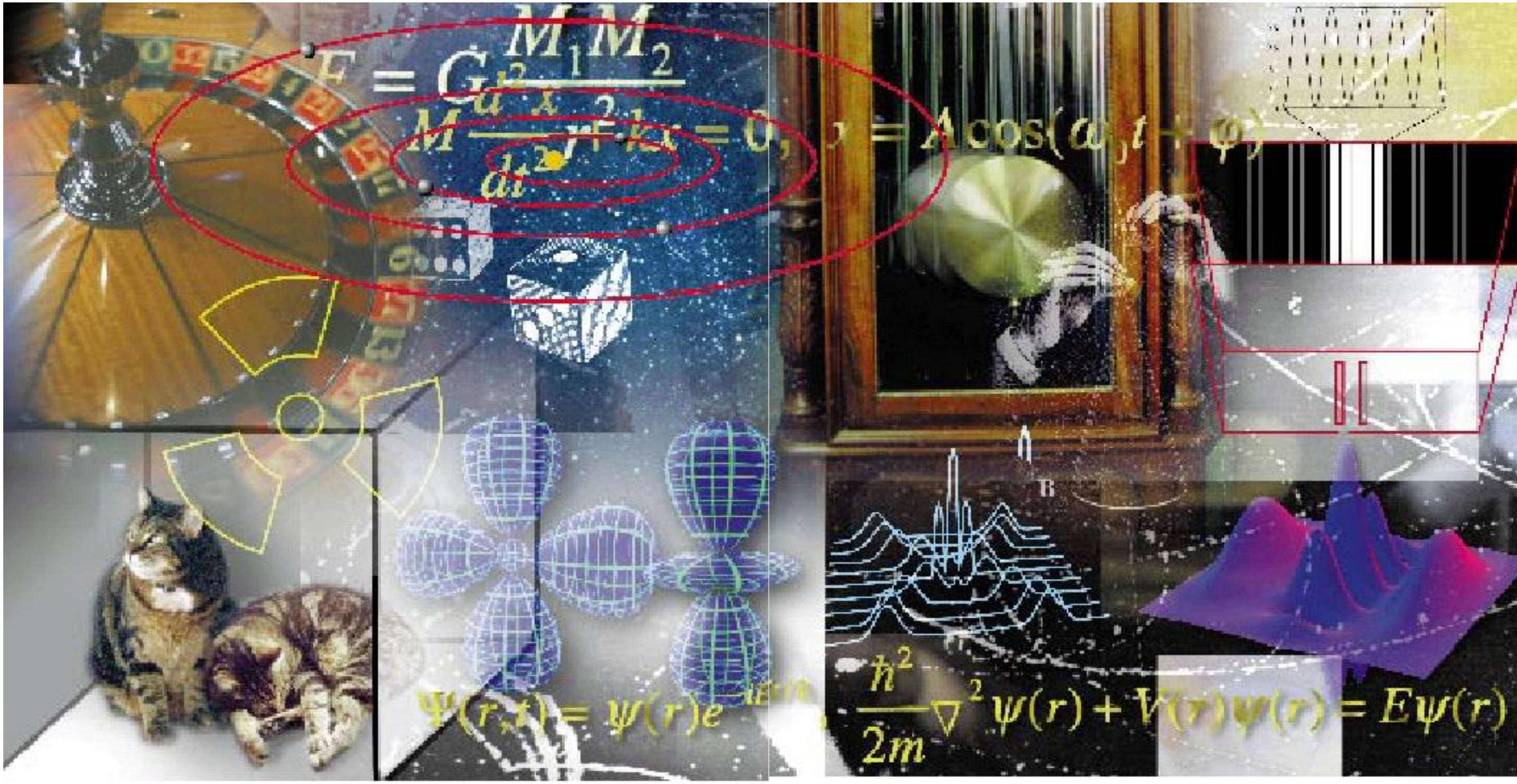
| | | |
|---|---|---|
|  | Strong Force: | Gluon |
|  | Electro-Magnetic Force: | Photon |
|  | Weak Force: | Bosons (W, Z) |
|  | Gravitation:<br>Falling apples, orbiting Moon<br><br>Relative strength ~ $(1/10^{38})$ | Graviton<br><br><br>No mass (?) |


$\mathcal{L} = -(\partial_\mu \phi)^\dagger \partial^\mu \phi$
$+ \alpha \phi^\dagger \phi - \beta (\phi^\dagger \phi)^2$
$- \frac{1}{4} F_{\mu\nu} F^{\mu\nu}$
$\alpha, \beta > 0.$



Quantum Mechanics:
wave-particle duality,
superposition, probabilities
Special Relativity:
space-time geometry,
relativity of motion
Newtonian Mechanics:
universal gravitation,
force and acceleration
Quantum Field Theory:
virtual particles,
renormalization
General Relativity:
equivalence principle,
dynamic space-time
?





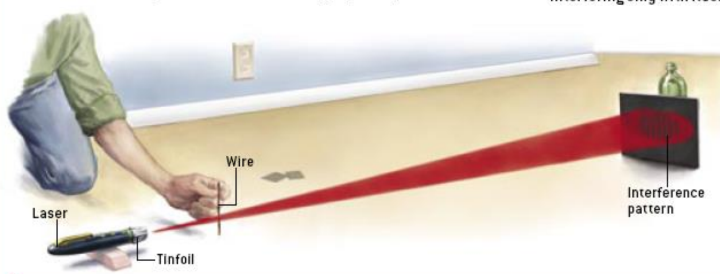
# Quantum Erasing in the Home

The steps presented here outline how to see quantum erasure in action. See www.sciam.com/ontheweb for a fuller description and additional information, such as the basics of how waves interfere and produce fringes.


## 1 SEEING INTERFERENCE

- Wrap the tinfoil around the business end of the laser and put a pinhole in it to let through some of the light beam.
- Set up the laser so it shines on the screen from at least six feet away. It should produce a circular spot of light on the screen.
- Position the wire vertically and centered in the light.

WHAT HAPPENS: As shown, you should see an interference pattern consisting of a row of fringes (bright and dark bands). The interference pattern arises because light passing on the left of the wire is combining, or "interfering," with light passing on the right-hand side. If you hold a piece of paper just after the wire, you will see a lobe of light on each side of the shadow of the wire. The lobes expand and largely overlap by the time they reach the screen. For each individual photon arriving at the screen in the overlap region, it is impossible to tell whether it went on the left or the right side of the wire, and the combination of the two ways it went causes the fringes. Although you are looking at trillions of photons, each of them is interfering only with itself.

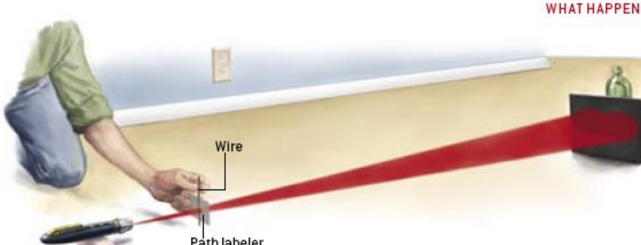


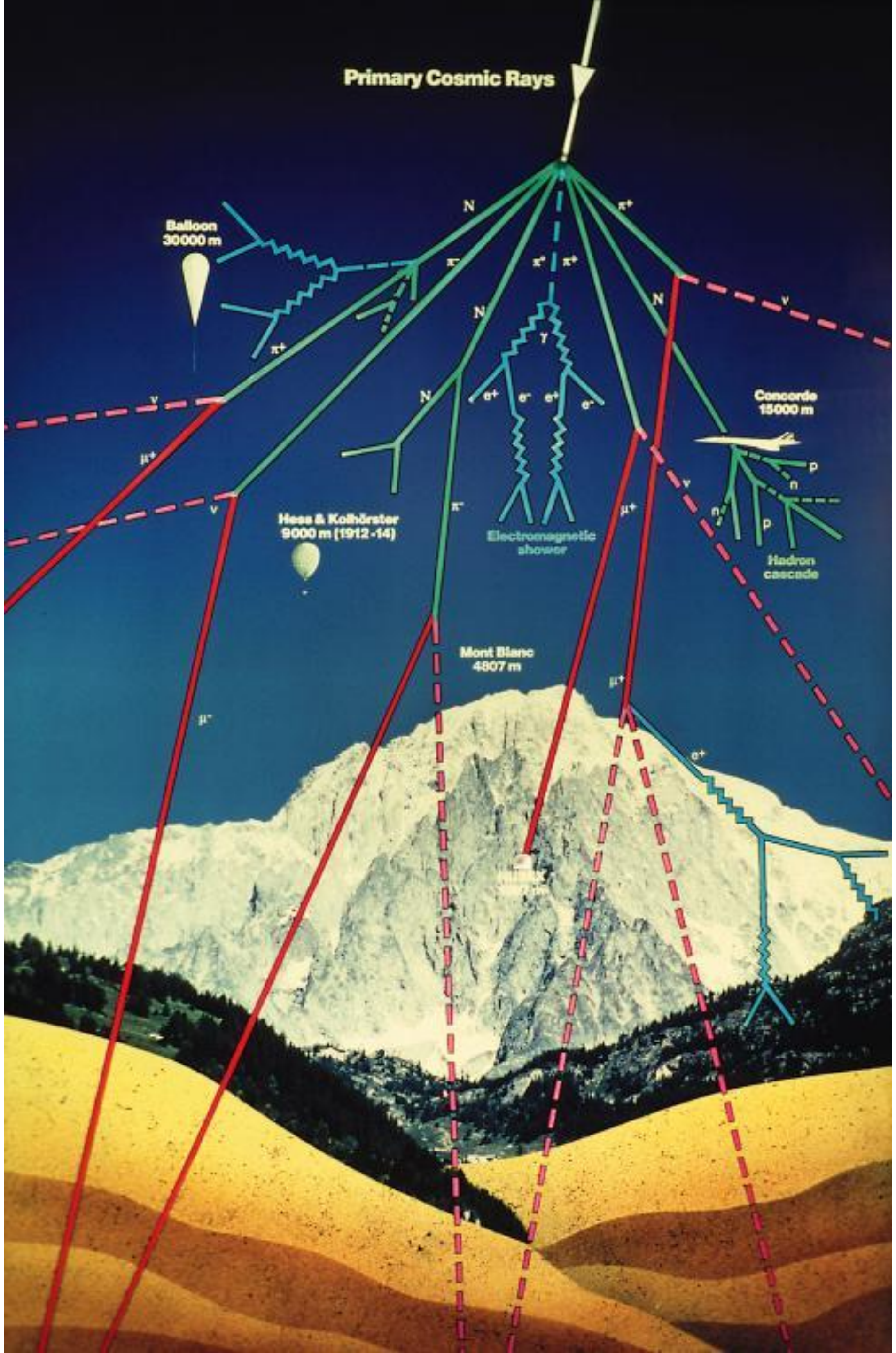

INTERFERENCE seen is captured in this photograph. The size and other features of the patterns depicted in the diagrams are exaggerated.

## 2 LABELING THE PATH

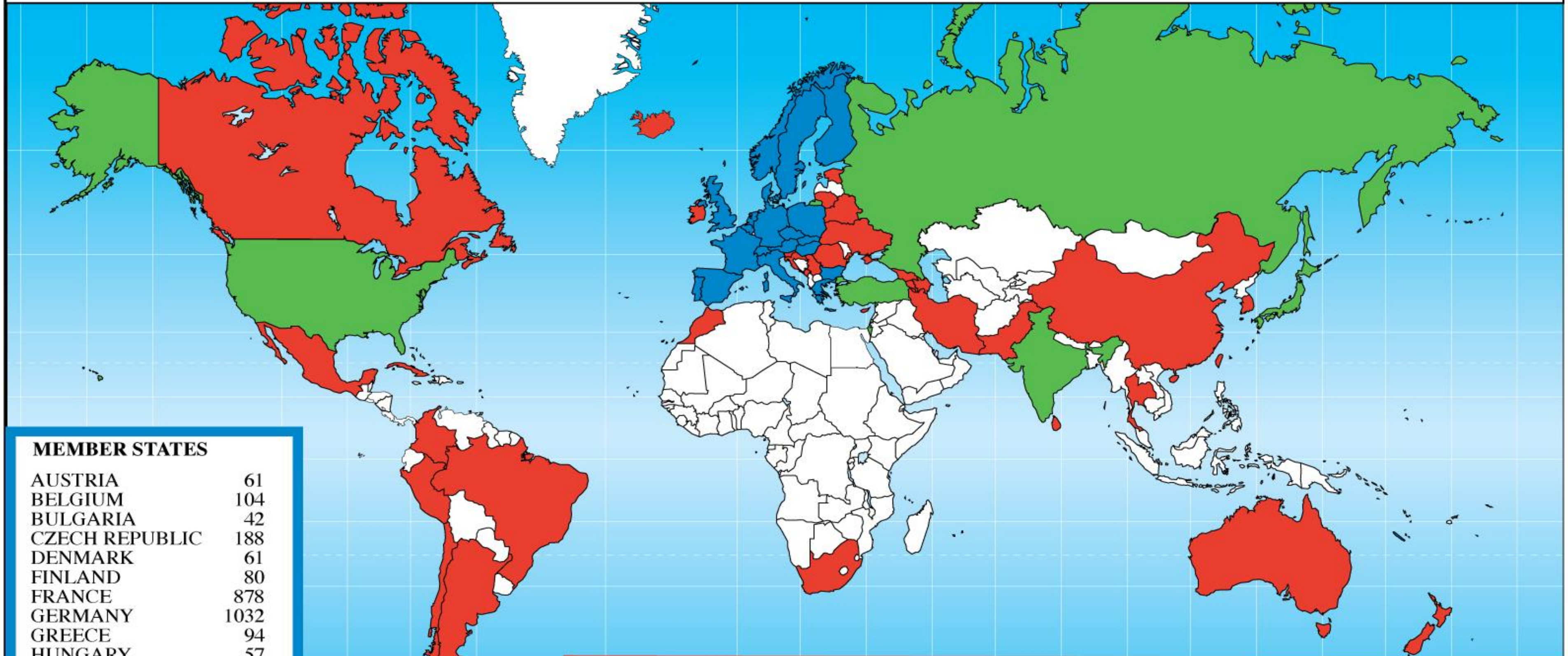
- Take two polarizers and rotate one of them so that their axes are perpendicular; you have done this correctly if when you overlap the film temporarily, no light goes through the overlap region.
- Tape them together side by side with no gap or overlap. Do the taping along the top and bottom so the tape will not block the light. We will call this the path labeler.
- Position the labeler in the beam so that its join is right behind the wire. Attaching the wire to the labeler might be easiest. Wire and labeler will not be moving for the rest of the experiment. We will say that the left-hand polarizer produces vertically polarized light (V), and the right-hand one horizontally polarized (H). It does not matter if we have these labels reversed.

WHAT HAPPENS: Even though the light is again passing on both sides of the wire, the fringes should be gone. If a photon reaches the screen by passing to the left of the wire, it arrives V-polarized; if to the right of the wire, H-polarized. Thus, the labeler has made available the information about which way each photon went, which prevents the interference.





Primary Cosmic Rays
Balloon
30000 m
Hess & Kolhörster
9000 m (1912-14)
Electromagnetic
shower
Concorde
15000 m
Hadron
cascade
Mont Blanc
4807 m

# Distribution of All CERN Users by Nation of Institute on 6 January 2009



**MEMBER STATES**

| | |
|---|---|
| AUSTRIA | 61 |
| BELGIUM | 104 |
| BULGARIA | 42 |
| CZECH REPUBLIC | 188 |
| DENMARK | 61 |
| FINLAND | 80 |
| FRANCE | 878 |
| GERMANY | 1032 |
| GREECE | 94 |
| HUNGARY | 57 |
| ITALY | 1483 |
| NETHERLANDS | 175 |
| NORWAY | 78 |
| POLAND | 174 |
| PORTUGAL | 111 |
| SLOVAKIA | 49 |
| SPAIN | 286 |
| SWEDEN | 73 |
| SWITZERLAND | 330 |
| UNITED KINGDOM | 715 |

**6071**

**OBSERVER STATES**

| | |
|---|---|
| INDIA | 89 |
| ISRAEL | 59 |
| JAPAN | 200 |
| RUSSIA | 883 |
| TURKEY | 52 |
| USA | 1485 |

**2768**

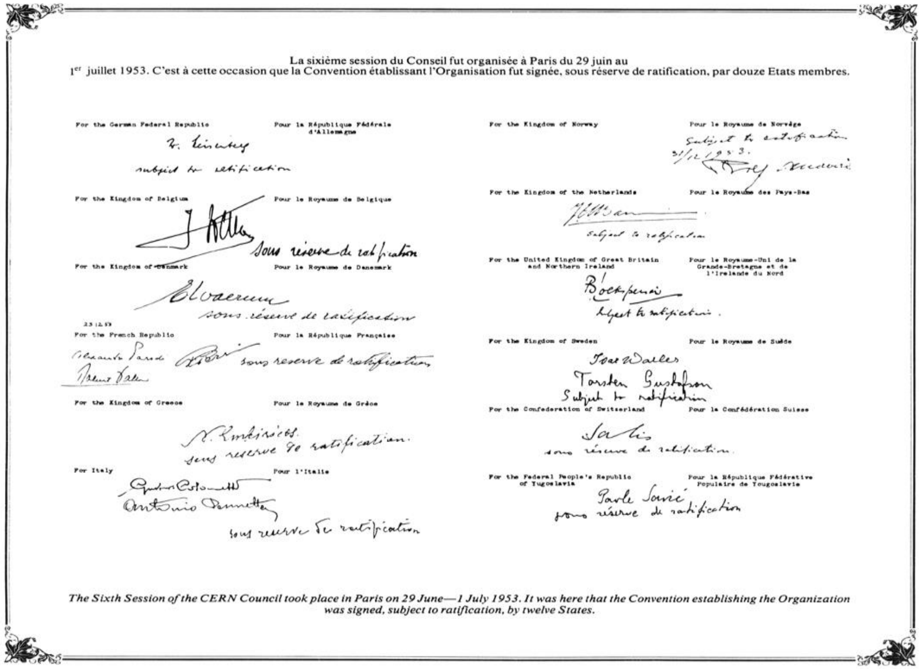
**OTHER STATES**

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| ARGENTINA | 10 | CUBA | 3 | MONTENEGRO | 1 | SRI LANKA | 1 |
| ARMENIA | 15 | CYPRUS | 6 | MOROCCO | 5 | TAIWAN | 42 |
| AUSTRALIA | 14 | ESTONIA | 11 | NEW ZEALAND | 6 | THAILAND | 1 |
| AZERBAIJAN | 1 | GEORGIA | 11 | PAKISTAN | 24 | UKRAINE | 18 |
| BELARUS | 19 | ICELAND | 1 | PERU | 1 | | |
| BRAZIL | 73 | IRAN | 12 | ROMANIA | 49 | | |
| CANADA | 136 | IRELAND | 12 | SERBIA | 17 | | |
| CHILE | 4 | KOREA | 51 | SLOVENIA | 16 | | |
| CHINA | 64 | LITHUANIA | 5 | SOUTH AFRICA | 8 | | |
| COLOMBIA | 11 | MEXICO | 28 | | | | |
| CROATIA | 20 | | | | | | |

**696**

# CERN
## European Organization for Nuclear Research

- Founded in 1954 by 12 countries
- Now: 22 member states, 5 + 2 observers (jp, ru, tr, us, EU, Unesco)
- More than 7000 users from all over the world
- ~1000 Meur / Year budget


La sixième session du Conseil fut organisée à Paris du 29 juin au 1er juillet 1953. C'est à cette occasion que la Convention établissant l'Organisation fut signée, sous réserve de ratification, par douze Etats membres.

For the German Federal Republic — Pour la République Fédérale d'Allemagne

subject to ratification

For the Kingdom of Belgium — Pour le Royaume de Belgique

Sous réserve de ratification

For the Kingdom of Denmark — Pour le Royaume de Danemark

sous réserve de ratification

For the French Republic — Pour la République Française

sous reserve de ratification

For the Kingdom of Greece — Pour le Royaume de Grèce

sous reserve de ratification

For Italy — Pour l'Italie

sous reserve de ratification

For the Kingdom of Norway — Pour le Royaume de Norvège

Subject to ratification

For the Kingdom of the Netherlands — Pour le Royaume des Pays-Bas

Subject to ratification

For the United Kingdom of Great Britain and Northern Ireland — Pour le Royaume-Uni de la Grande-Bretagne et de l'Irelande du Nord

Subject to ratification.

For the Kingdom of Sweden — Pour le Royaume de Suède

Torsten Gustafson

Subject to ratification

For the Confederation of Switzerland — Pour la Confédération Suisse

sous réserve de ratification.

For the Federal People's Republic of Yugoslavia — Pour la République Fédérative Populaire de Yougoslavie

Pavle Savić

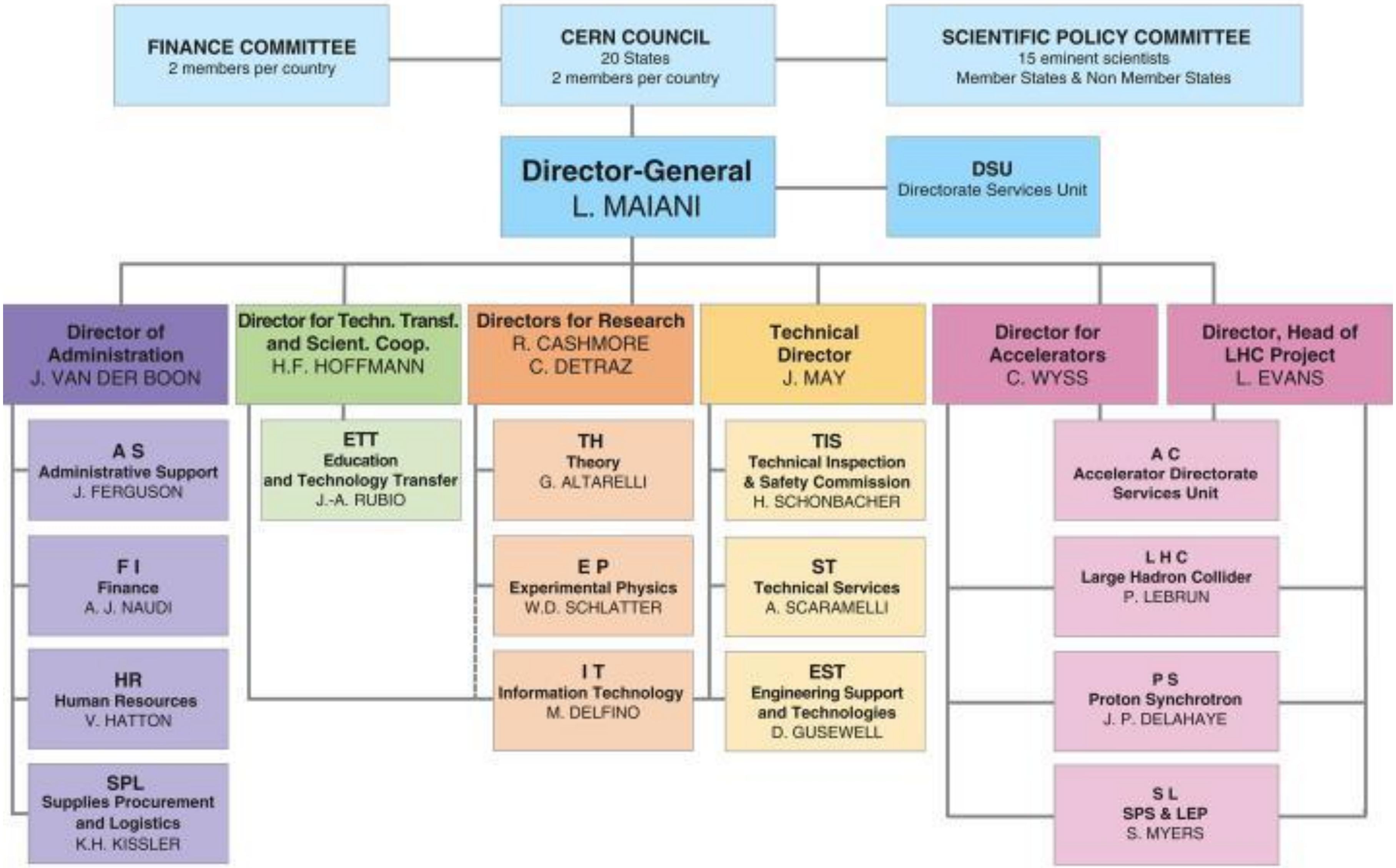
sous réserve de ratification

*The Sixth Session of the CERN Council took place in Paris on 29 June—1 July 1953. It was here that the Convention establishing the Organization was signed, subject to ratification, by twelve States.*

1954: Convention establishing the Organization - original signatures

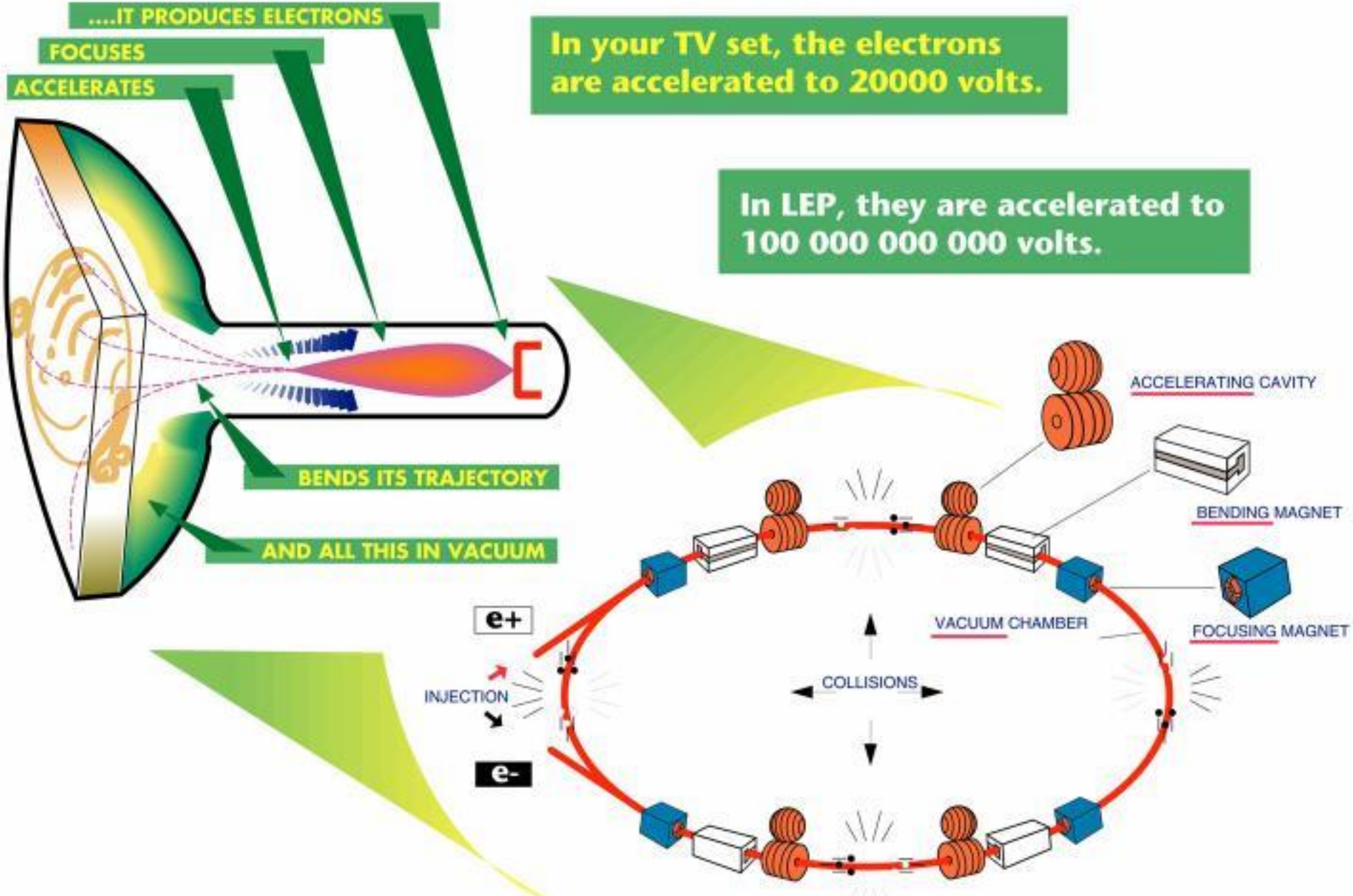
2007: The 20 member states

# CERN ORGANISATIONAL CHART 07/2001

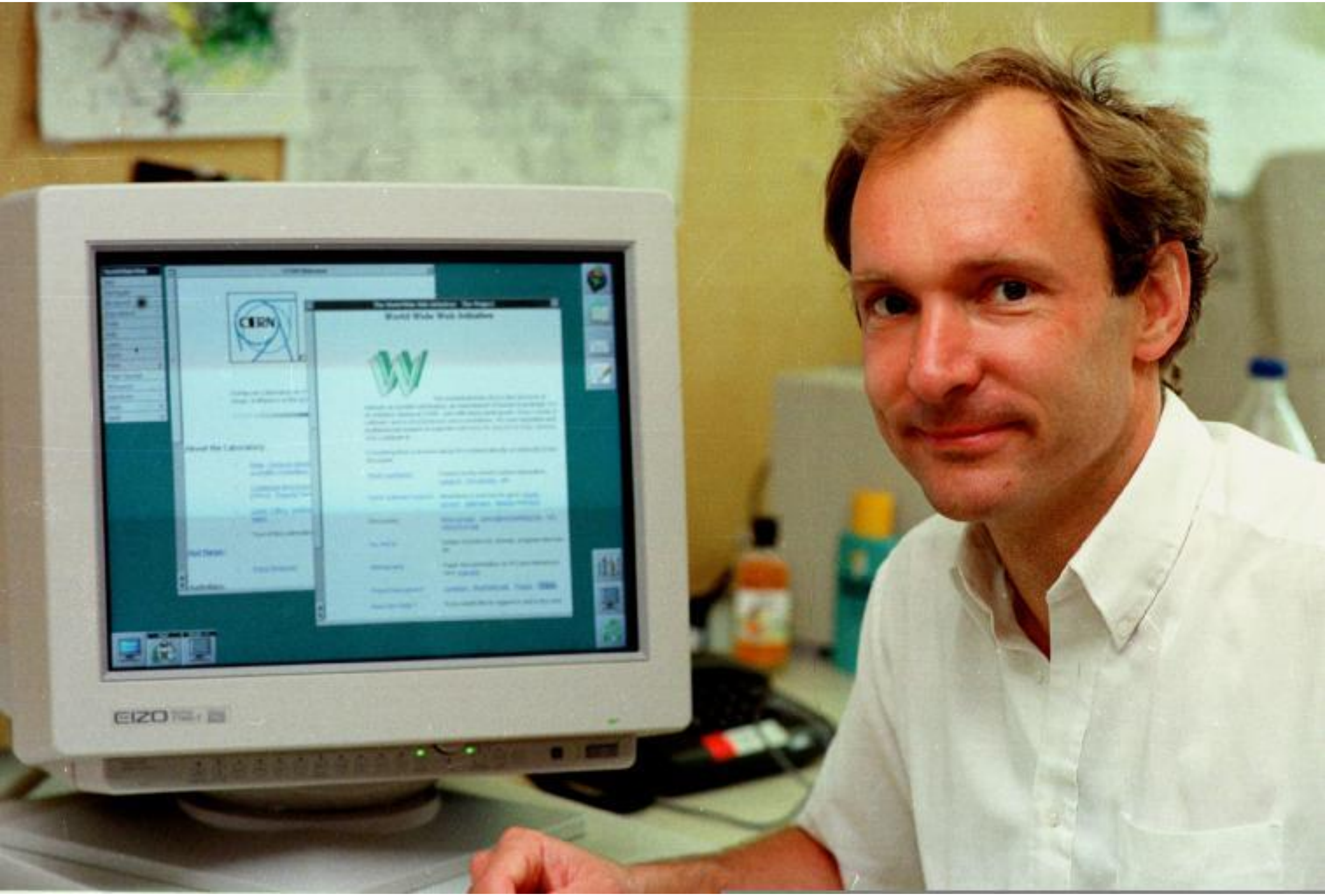



Teilchen

# DID YOU KNOW YOUR TELEVISION SET IS AN ACCELERATOR ?




SIEMENS
ECAT


World Wide Web Initiative
CERN
EIZO

Modern Physics
Relativity
Thermodynamics
Optics
Biology

\+

Quantum Mechanics

**QM describes physics phenomena at very small distances**

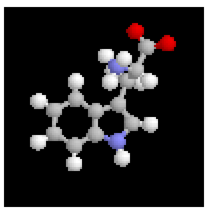
1) Objects described with a wavefunction WF
2) The WF fills the entire (Hilbert) space

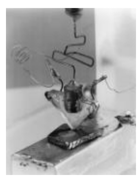
Chemistry

Electronics (transistor)

Optics (lasers)

(Other)





Computer (chip)

Quantum Computing

Bioinformatics

Software

Communi-cations

Teleportation?

Grid