# Romania@CERN
# Open Symposium 2023

Măgurele
11 January 2023

## Extreme experiments for fundamental science

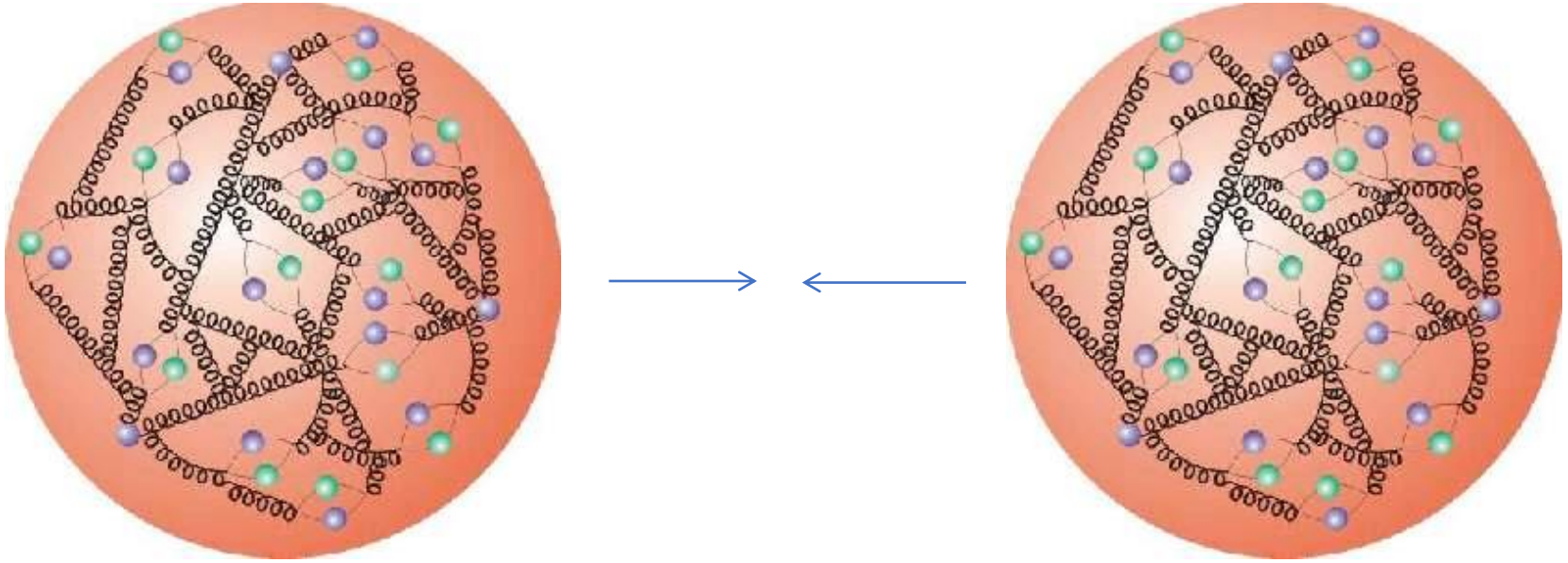
**Cristinel DIACONU**
Centre de Physique des Particules de Marseille

# What is the matter made of?

# How does the matter compose the Universe?

**The large infinity**

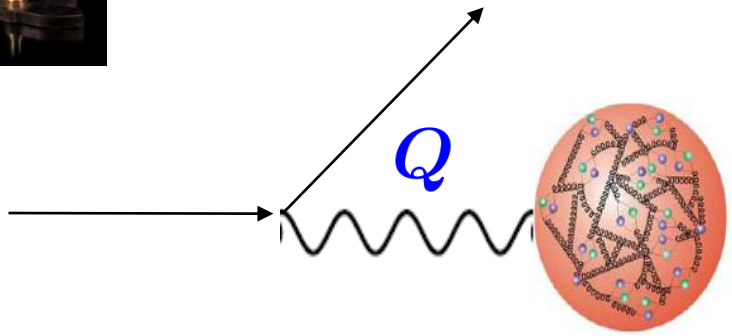
# **The “microscope”**: Particle Accelerators: probe the infinitelly small



Proton

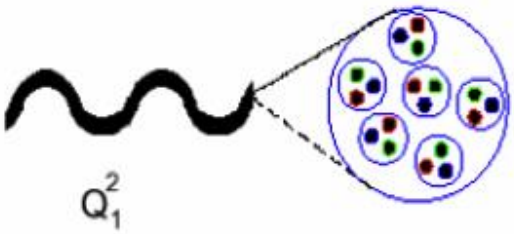
Proton

# Smaller=higher energy

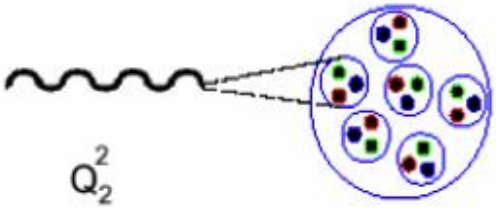



$$\delta\ [\mathrm{fm}] \simeq \frac{200\ \mathrm{MeV}}{Q}$$

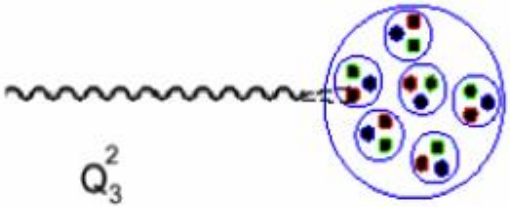
Proton size [1fm=$10^{-15}$ m]




**Nucleus (~1910)**




**Nucleon (p,n) (~1950)**

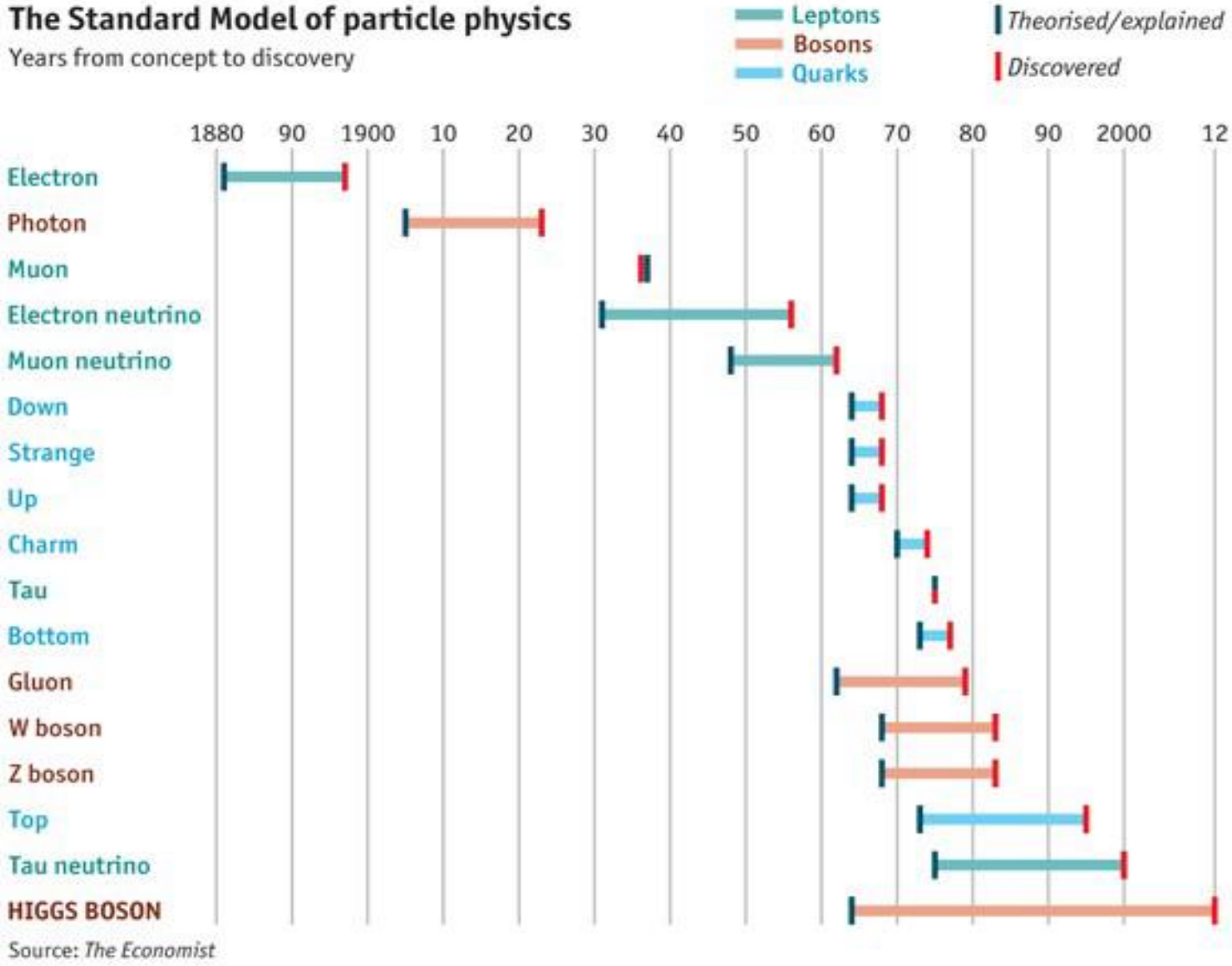



**Quarks (~1970)**

$Q_3^2 > Q_2^2 > Q_1^2$

## The Standard Model of particle physics

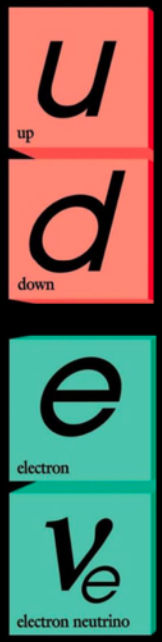
Years from concept to discovery




Source: *The Economist*

# Simple matter

**Fermions de matière** (spin 1/2)



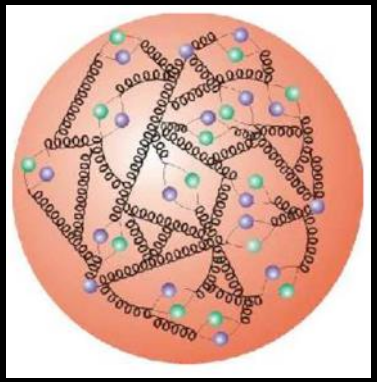

**Bosons vecteurs d'interaction** (spin 1)


Force nucléaire forte

Force électromagnétique

Un vieux rêve réductionniste
Empédocle - Ve siècle av. J.C.

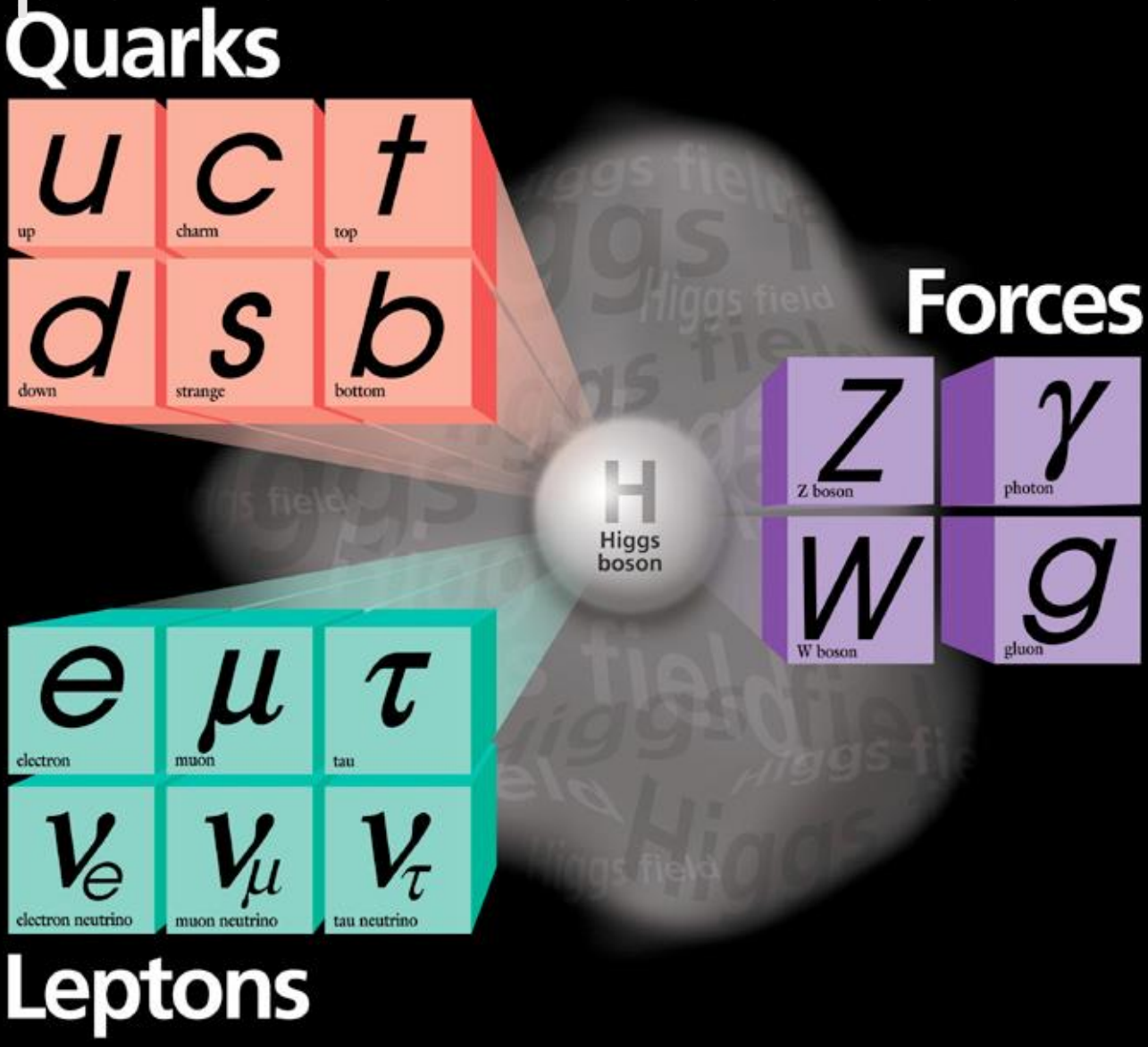
nucleon



⟷

- Il existe aussi une interaction faible
- Le neutrino n'interagit que par cette interaction faible

# Simple Matter: The Standard Model

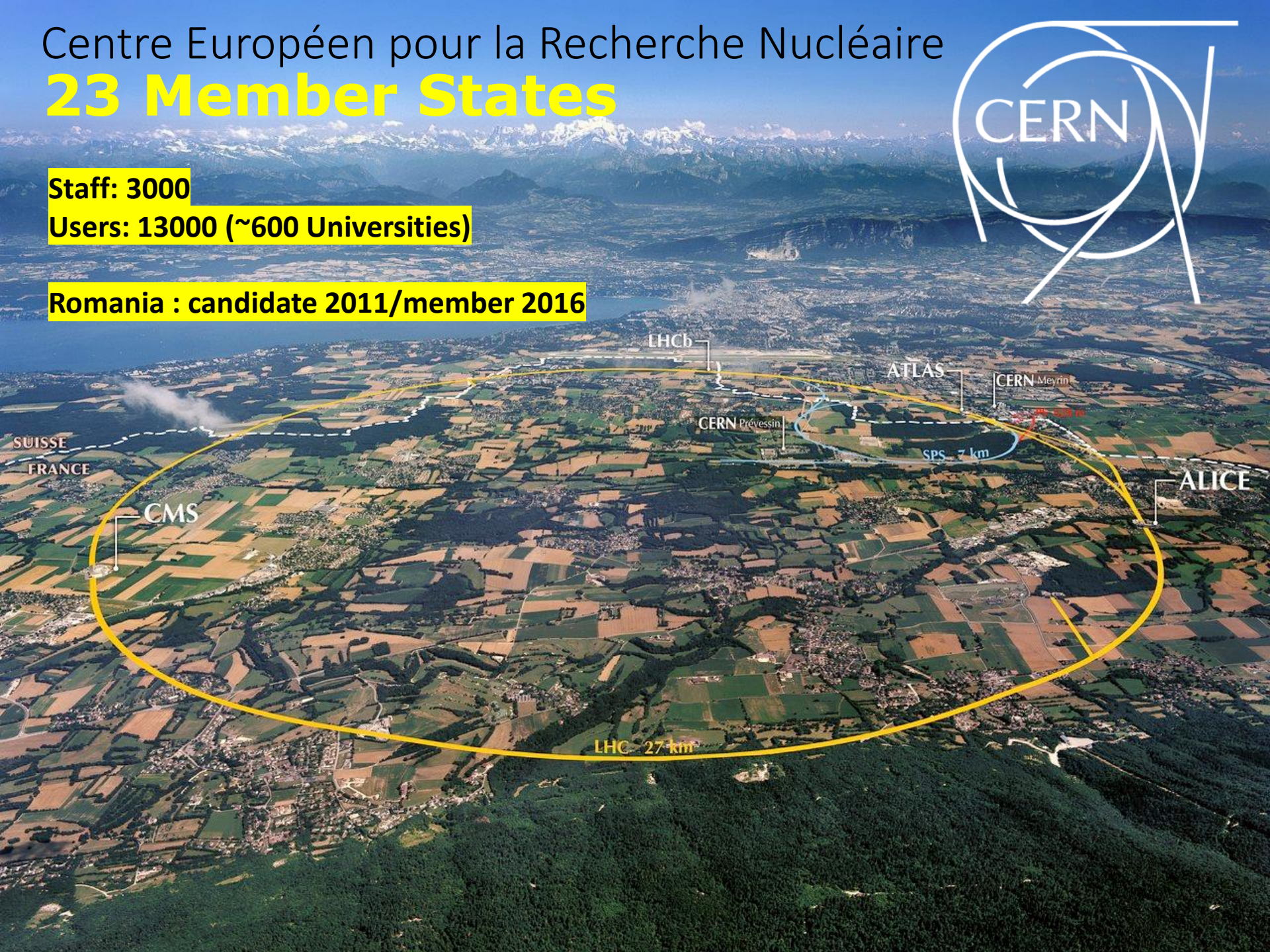


# Centre Européen pour la Recherche Nucléaire

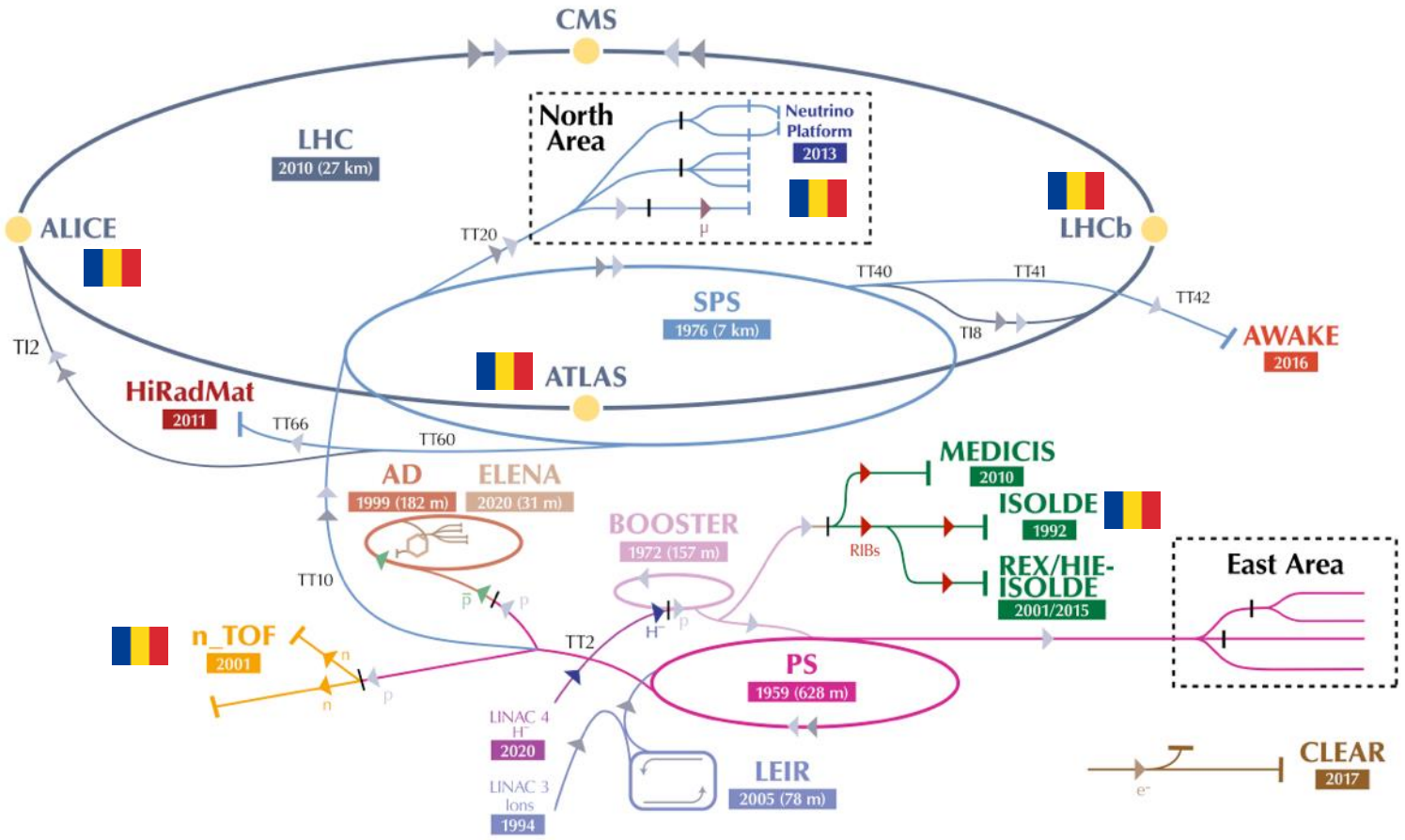
## 23 Member States

**Staff: 3000**
**Users: 13000 (~600 Universities)**

**Romania : candidate 2011/member 2016**



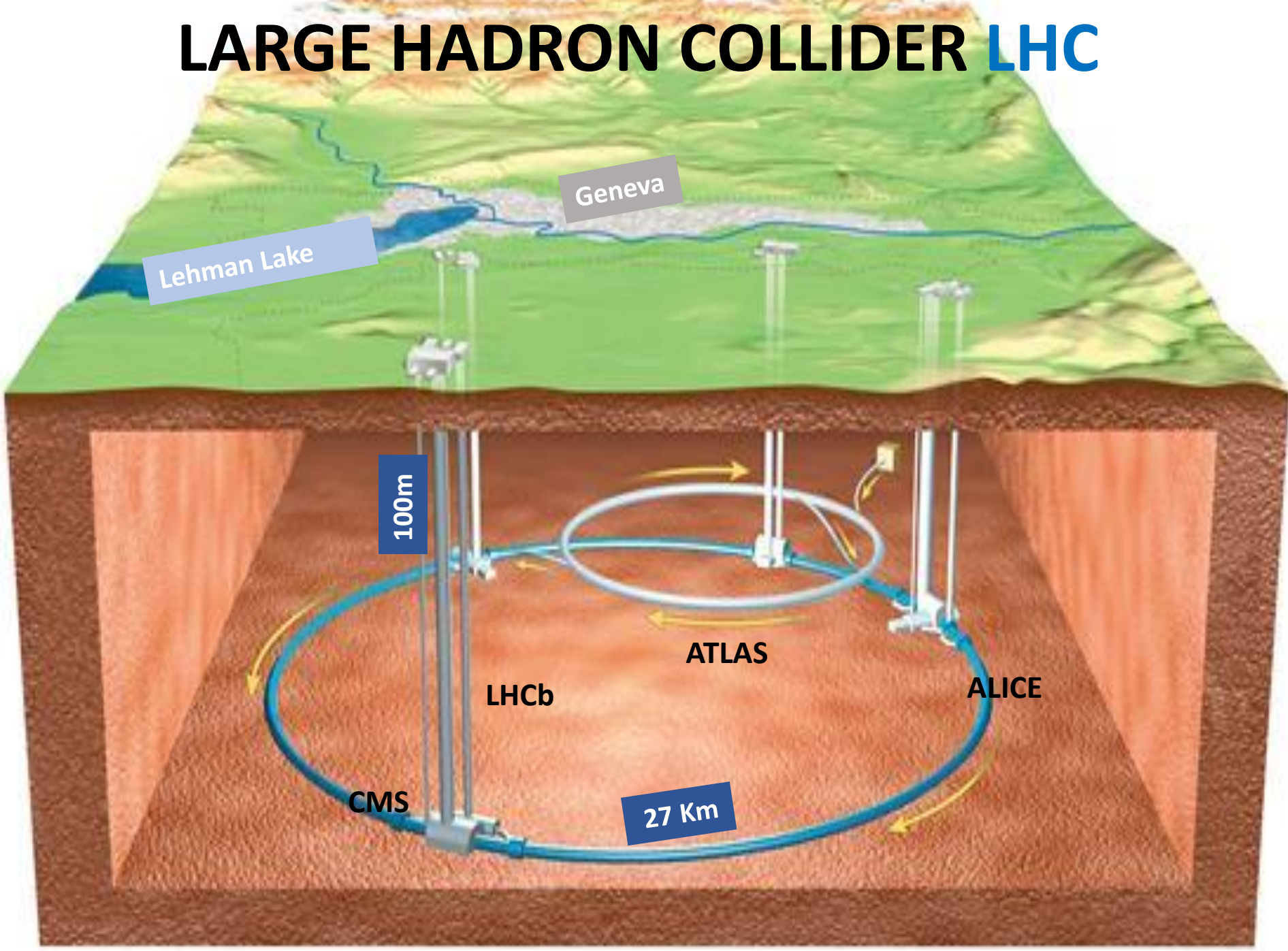
# The CERN accelerator complex
## *Complexe des accélérateurs du CERN*

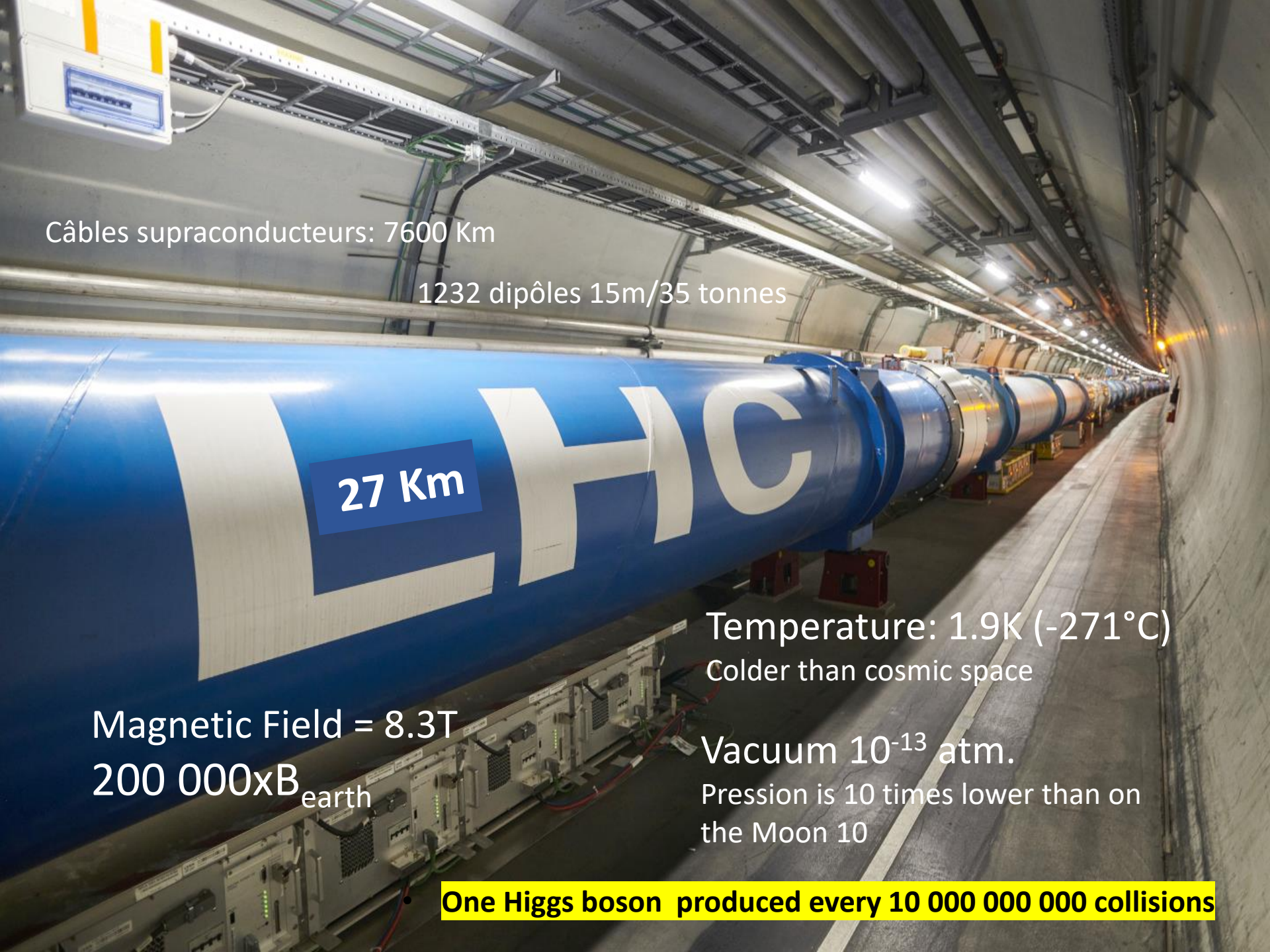


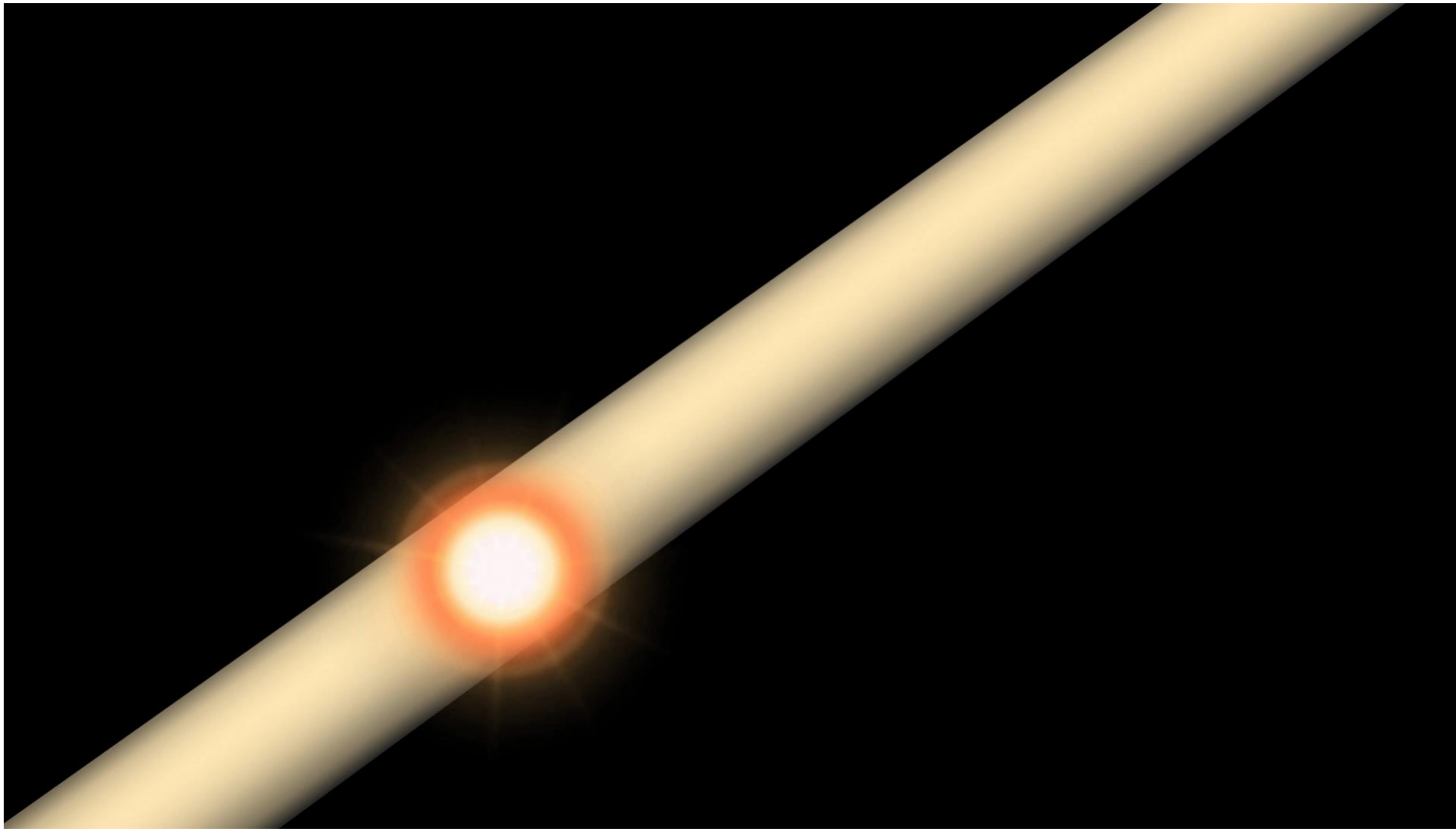

H⁻ (hydrogen anions) · p (protons) · ions · RIBs (Radioactive Ion Beams) · n (neutrons) · p̄ (antiprotons) · e⁻ (electrons) · μ (muons)

LHC - Large Hadron Collider // SPS - Super Proton Synchrotron // PS - Proton Synchrotron // AD - Antiproton Decelerator // CLEAR - CERN Linear Electron Accelerator for Research // AWAKE - Advanced WAKefield Experiment // ISOLDE - Isotope Separator OnLine // REX/HIE-ISOLDE - Radioactive EXperiment/High Intensity and Energy ISOLDE // MEDICIS // LEIR - Low Energy Ion Ring // LINAC - LINear ACcelerator // n_TOF - Neutrons Time Of Flight // HiRadMat - High-Radiation to Materials // Neutrino Platform

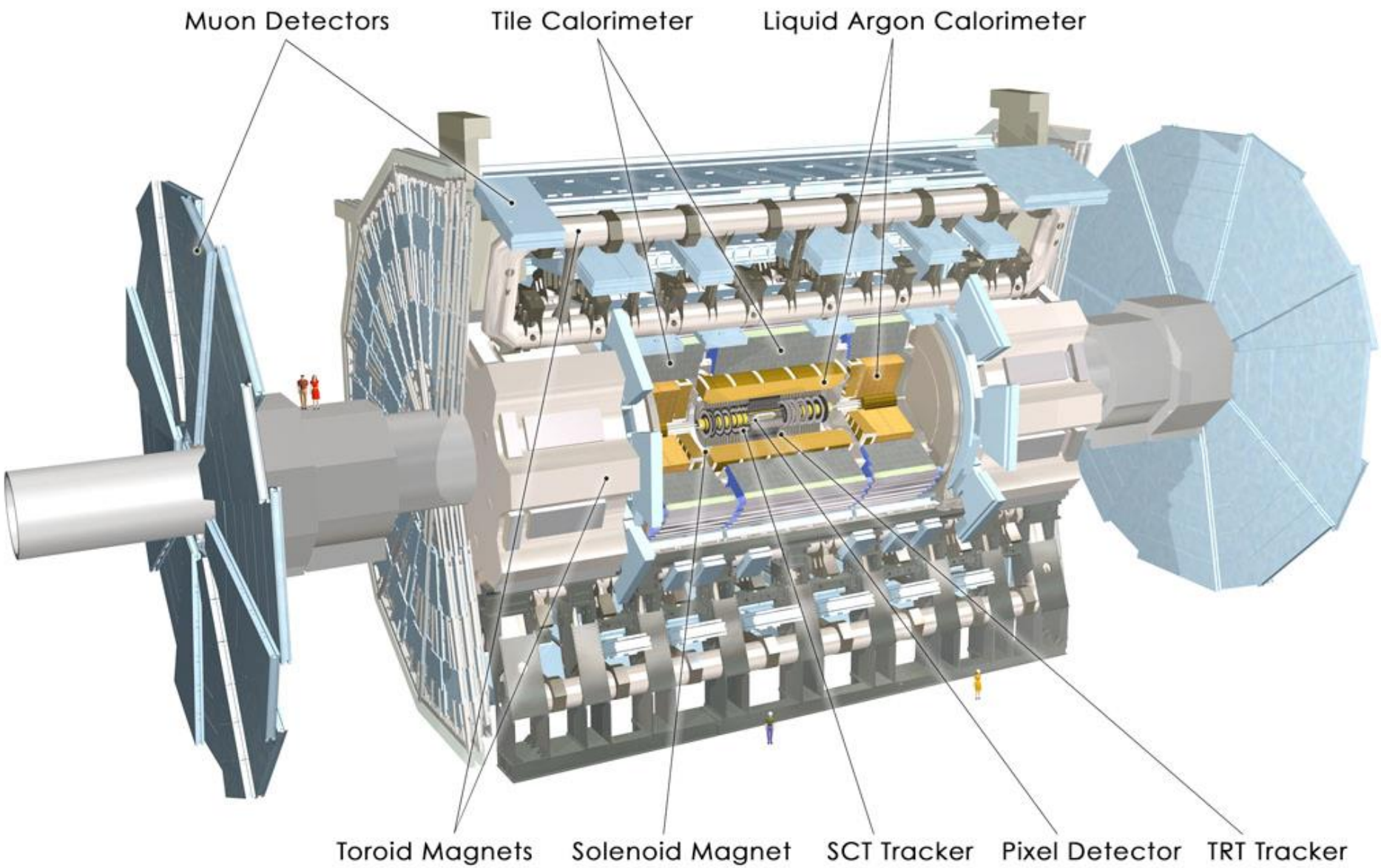
# LARGE HADRON COLLIDER LHC




Câbles supraconducteurs: 7600 Km
1232 dipôles 15m/35 tonnes
LHC
27 Km
Temperature: 1.9K (-271°C)
Colder than cosmic space
Magnetic Field = 8.3T
200 000xB earth
Vacuum 10-13 atm.
Pression is 10 times lower than on the Moon 10
One Higgs boson produced every 10 000 000 000 collisions

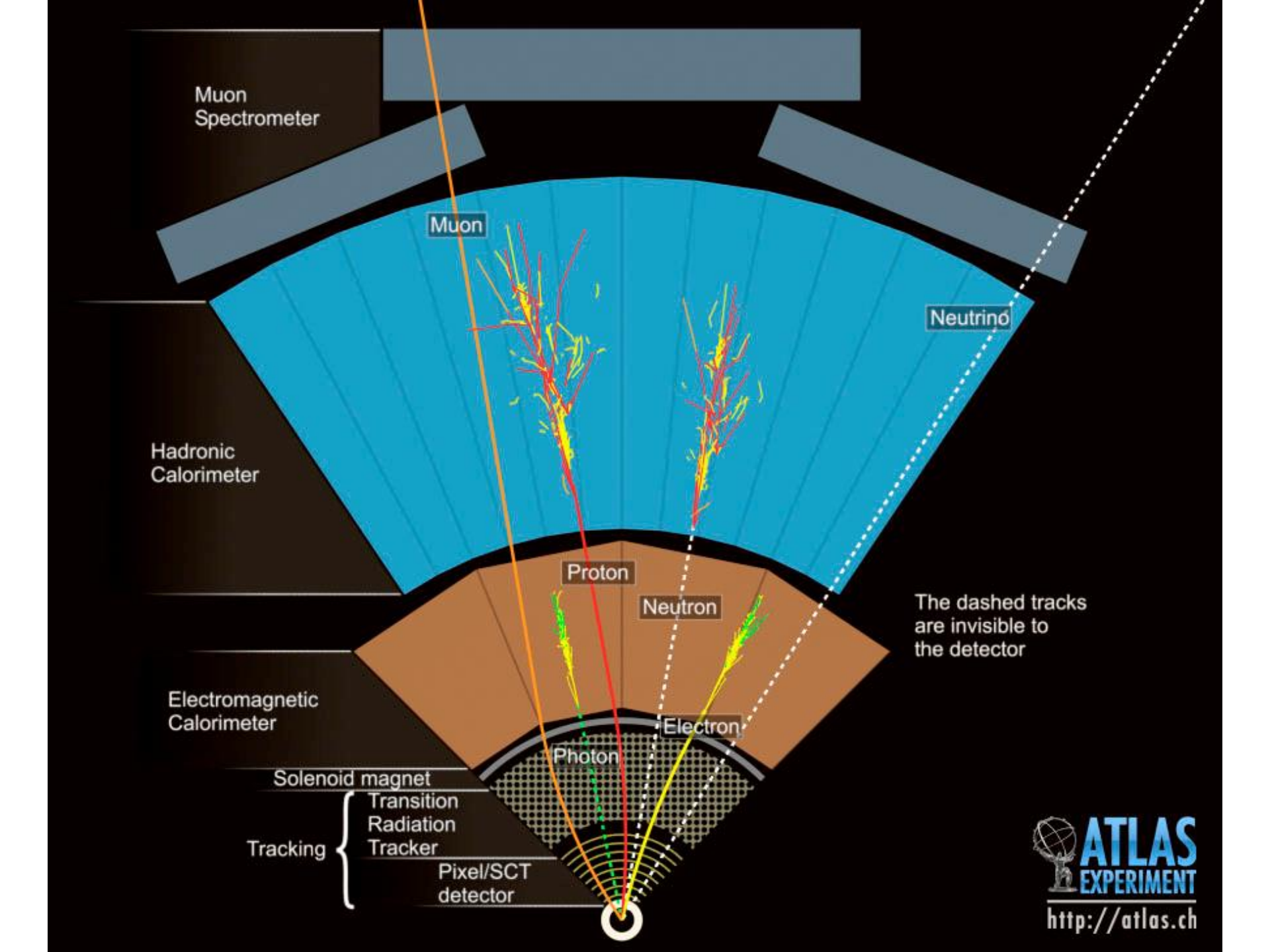


# ATLAS

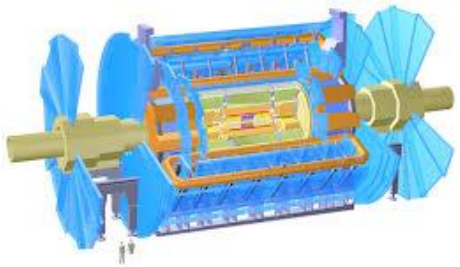

Muon Detectors
Tile Calorimeter
Liquid Argon Calorimeter
Toroid Magnets
Solenoid Magnet
SCT Tracker
Pixel Detector
TRT Tracker

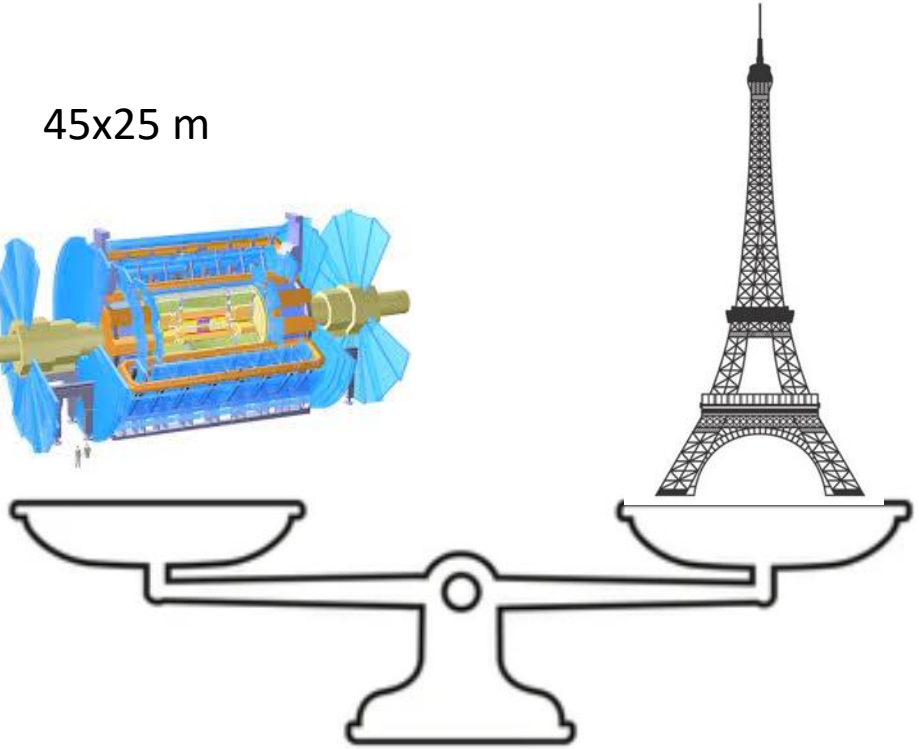
# ATLAS: a human venture too

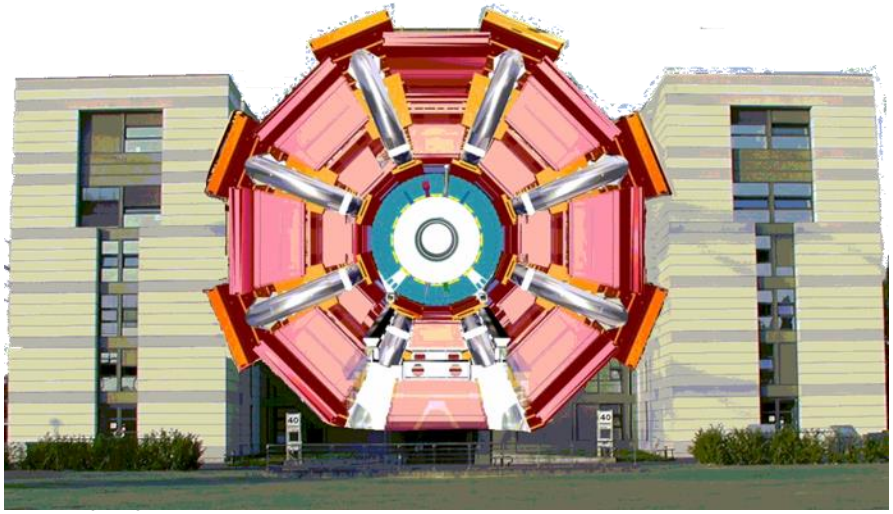
More than 5500 scientists from 245 institutes in 42 countries work on the ATLAS experiment (March 2022).

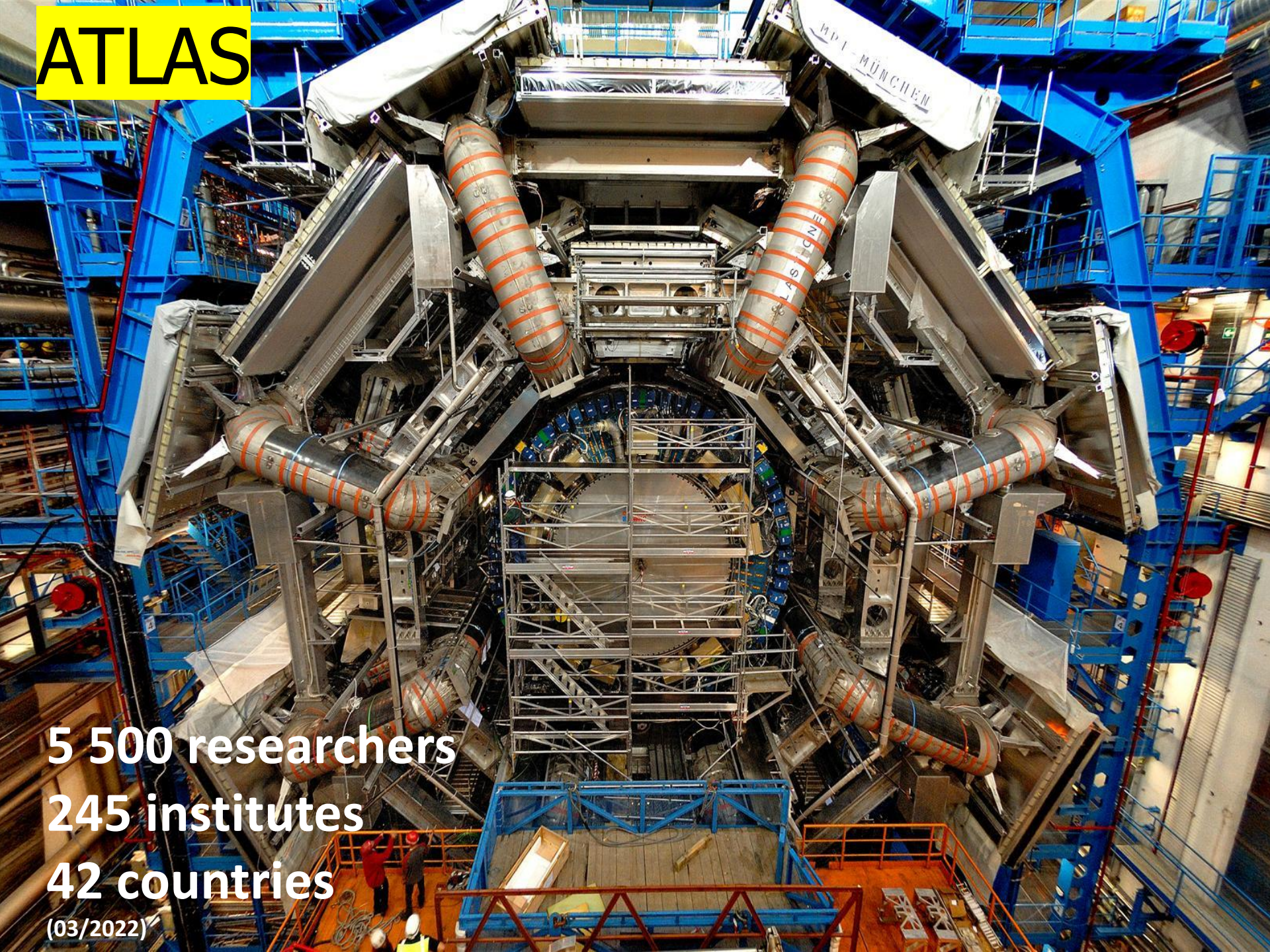

Muon
Spectrometer
Muon
Neutrino
Hadronic
Calorimeter
Proton
Neutron
The dashed tracks
are invisible to
the detector
Electromagnetic
Calorimeter
Electron
Photon
Solenoid magnet
Tracking
Transition
Radiation
Tracker
Pixel/SCT
detector
ATLAS
EXPERIMENT
http://atlas.ch

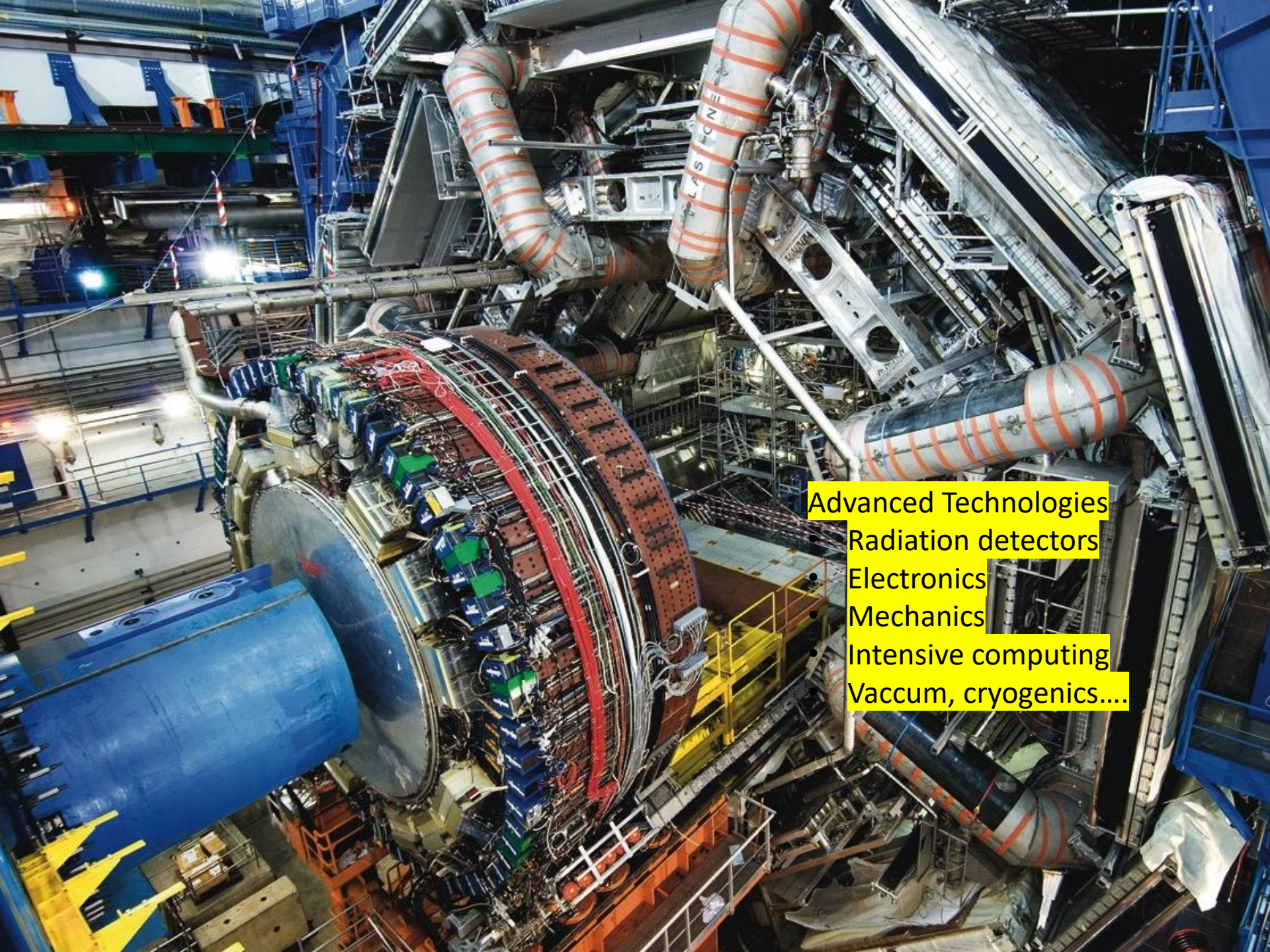
45x25 m



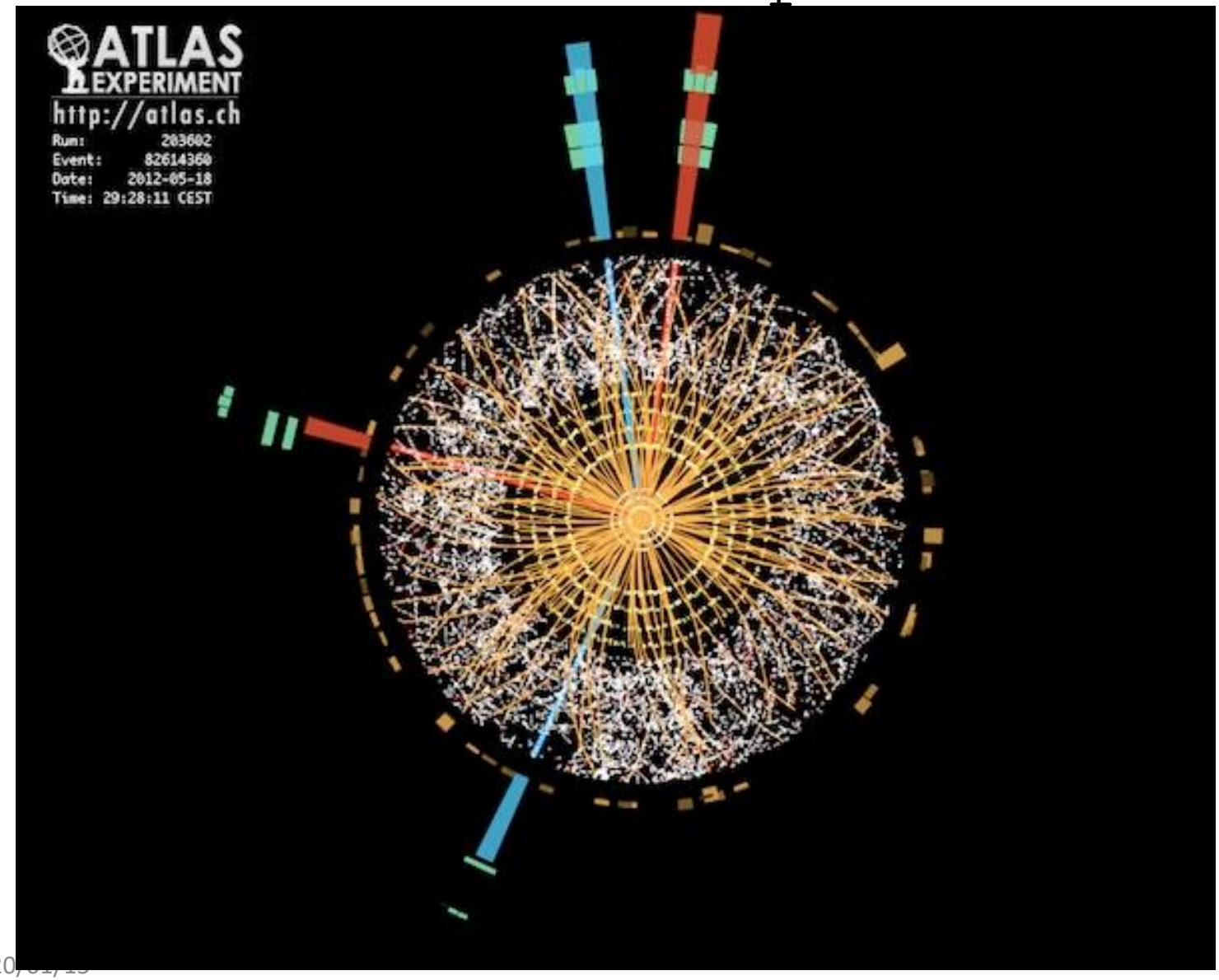


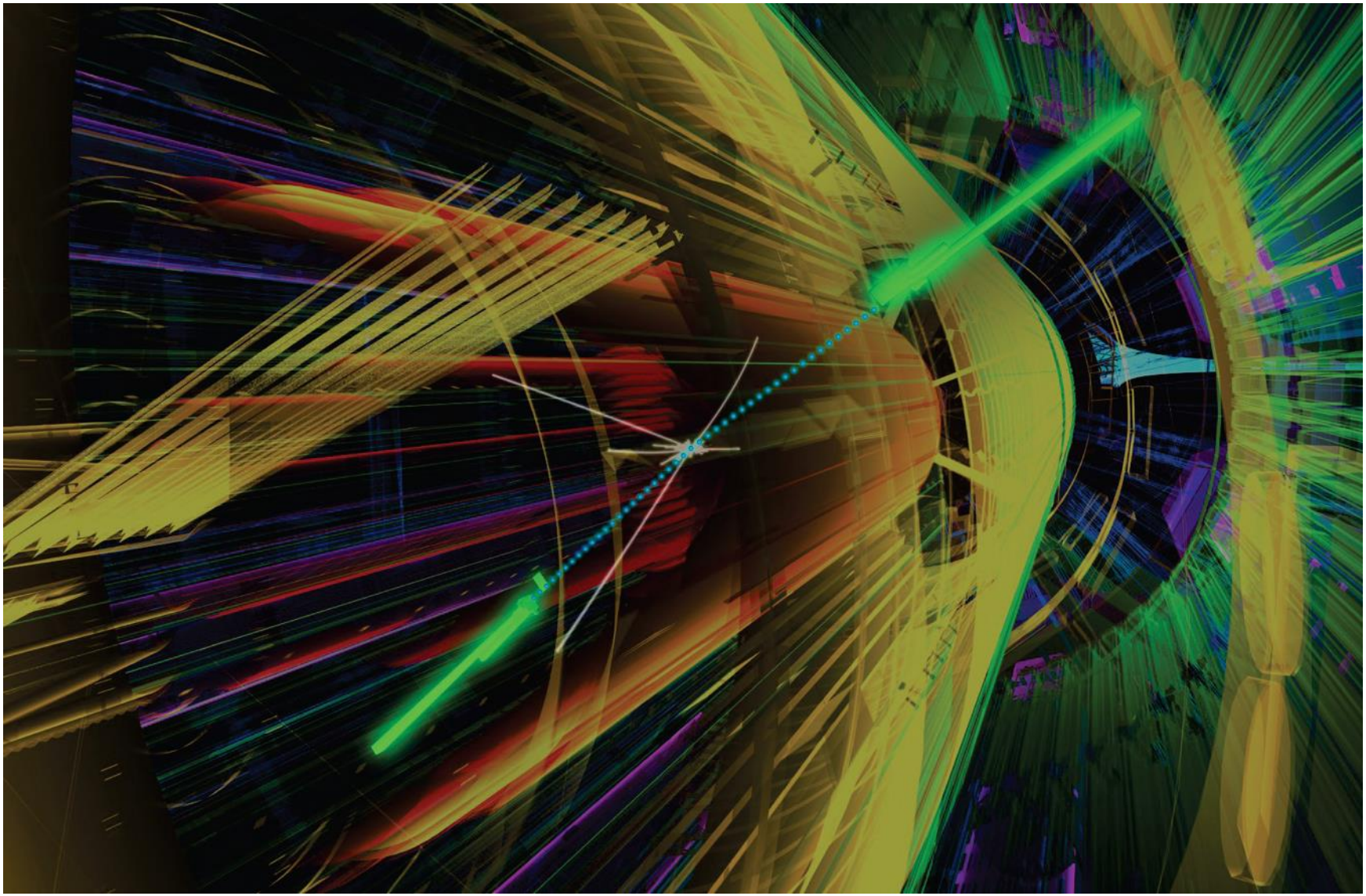



ATLAS
MPI - MÜNCHEN
5 500 researchers
245 institutes
42 countries
(03/2022)

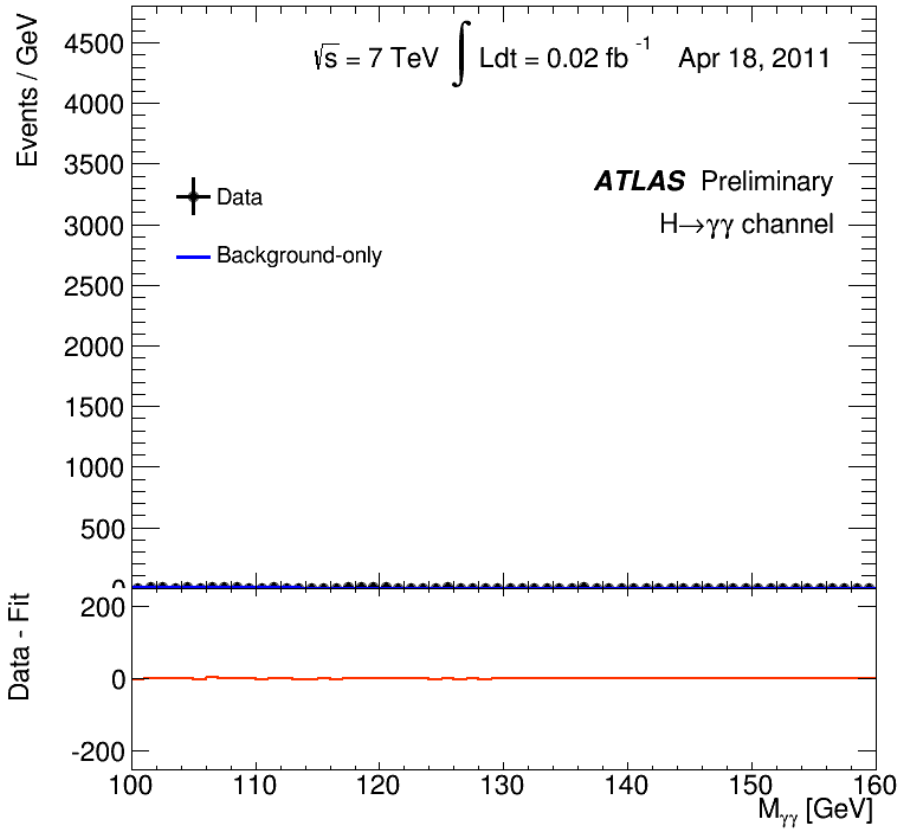

Advanced Technologies
Radiation detectors
Electronics
Mechanics
Intensive computing
Vaccum, cryogenics….

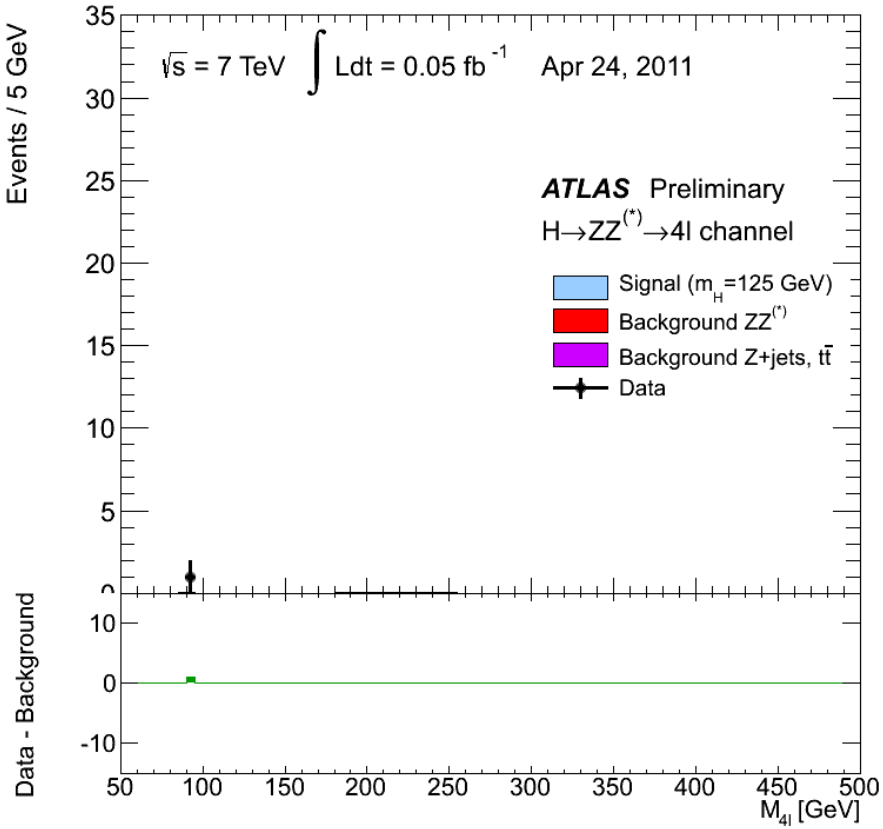
# Data: H➔ZZ➔ 4 leptons

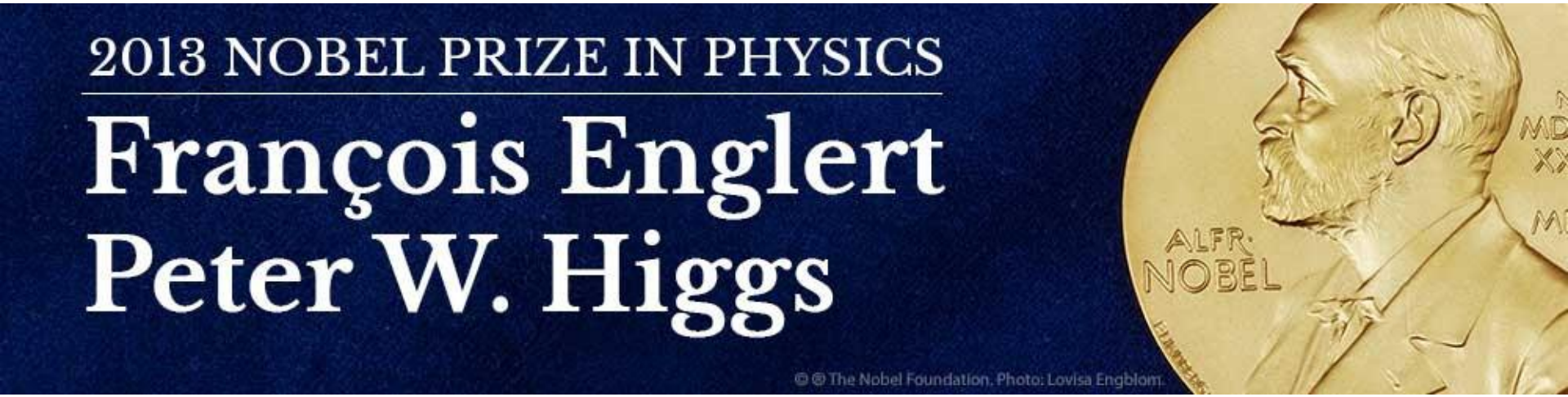




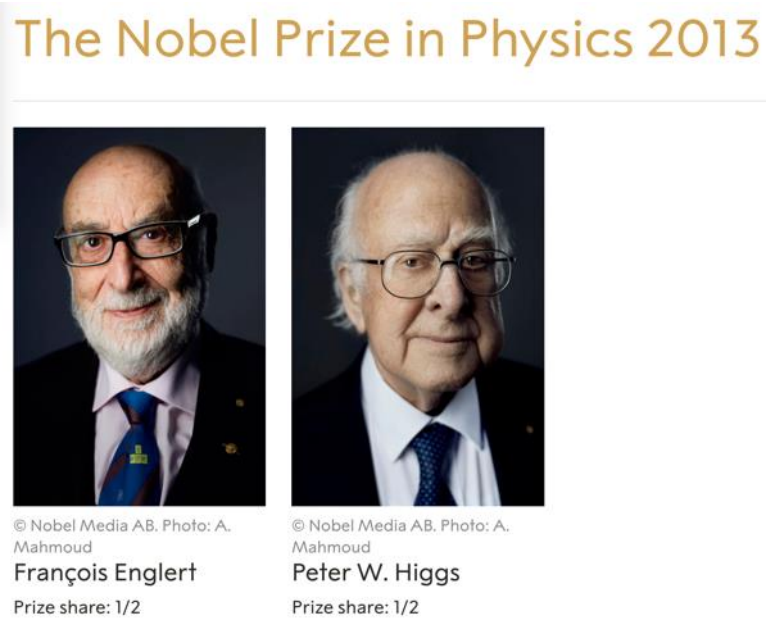
# July 2012 - 10 years ago

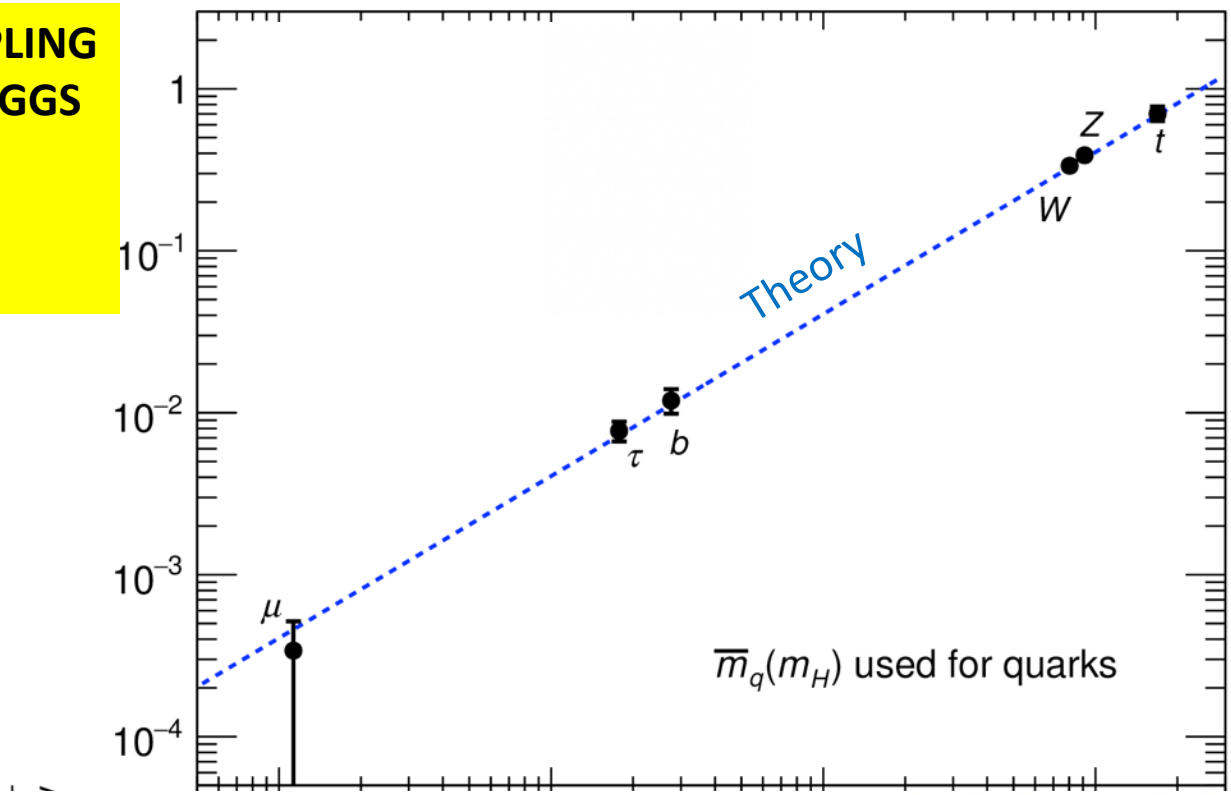






The Nobel Prize in Physics 2013 was awarded jointly to François Englert and Peter W. Higgs "for the theoretical discovery of a mechanism that contributes to our understanding of the origin of mass of subatomic particles, and which recently was confirmed through the discovery of the predicted fundamental particle, by the ATLAS and CMS experiments at CERN's Large Hadron Collider"



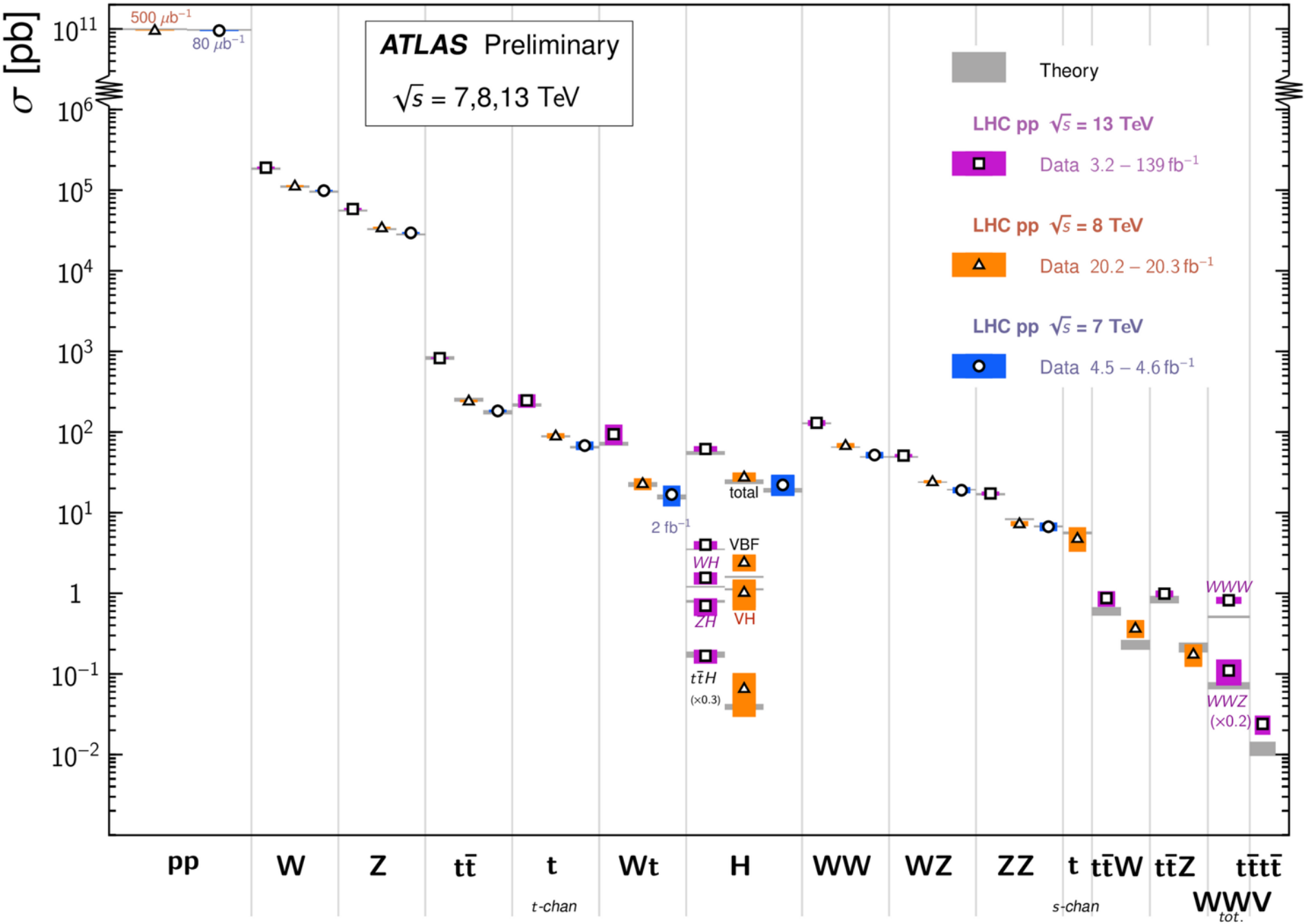
**COUPLING TO HIGGS**



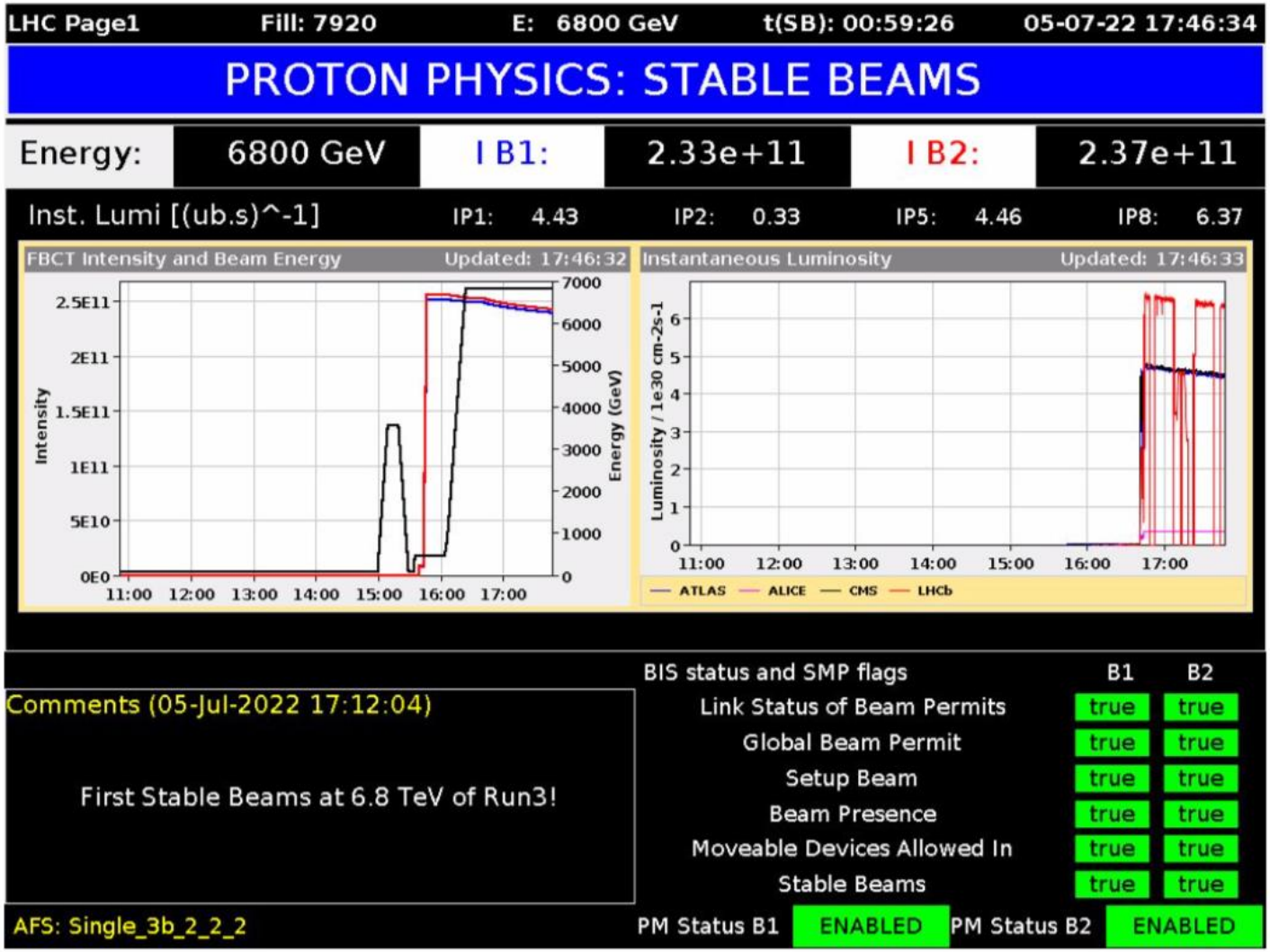

**Particle Mass**

# Standard Model Total Production Cross Section Measurements

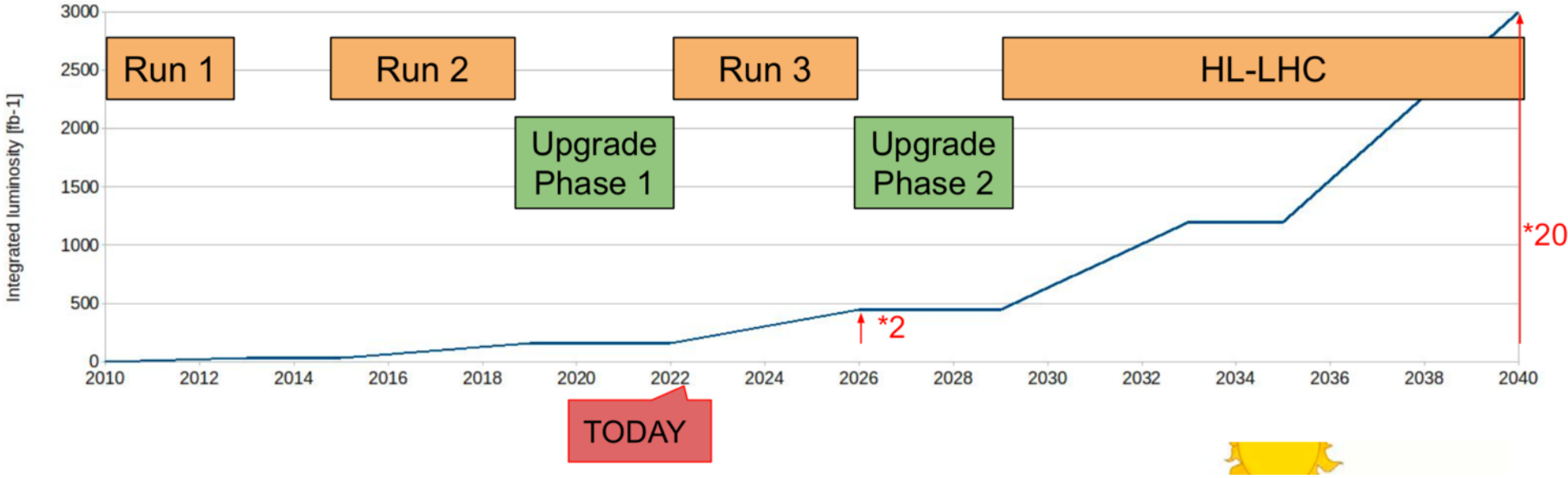
Status: February 2022



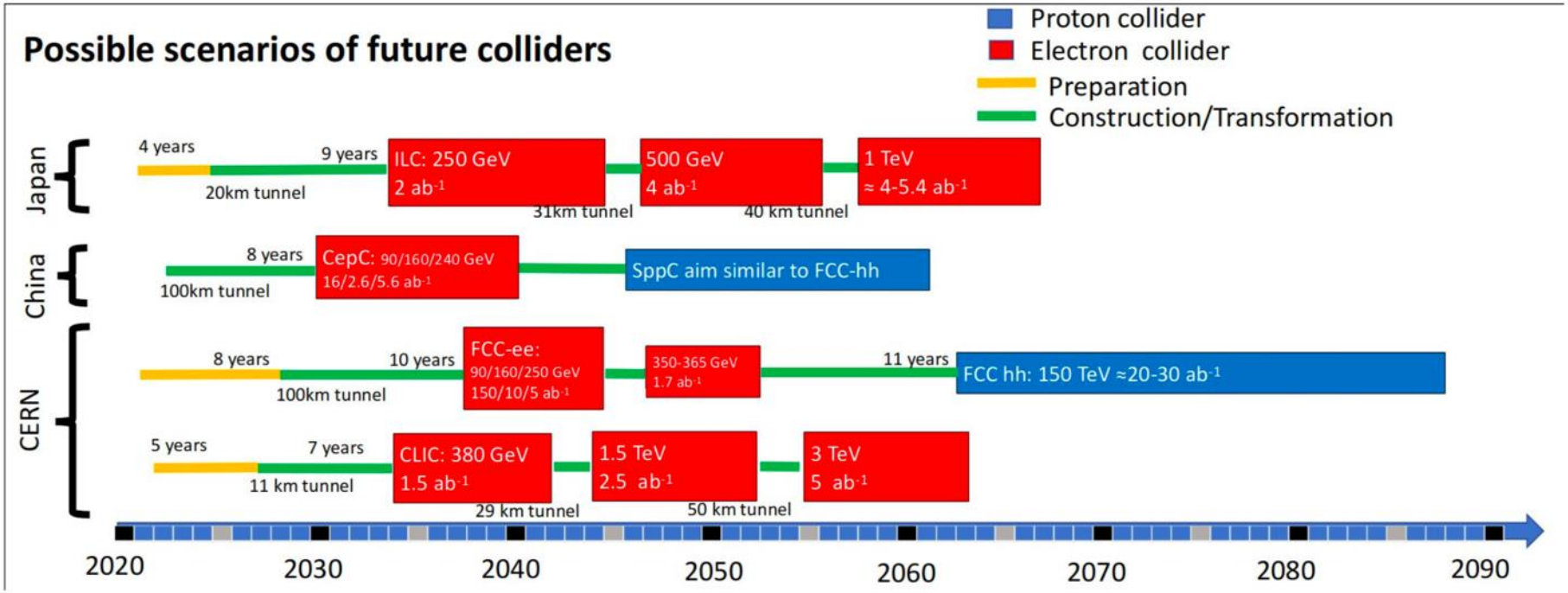
# The future starts now



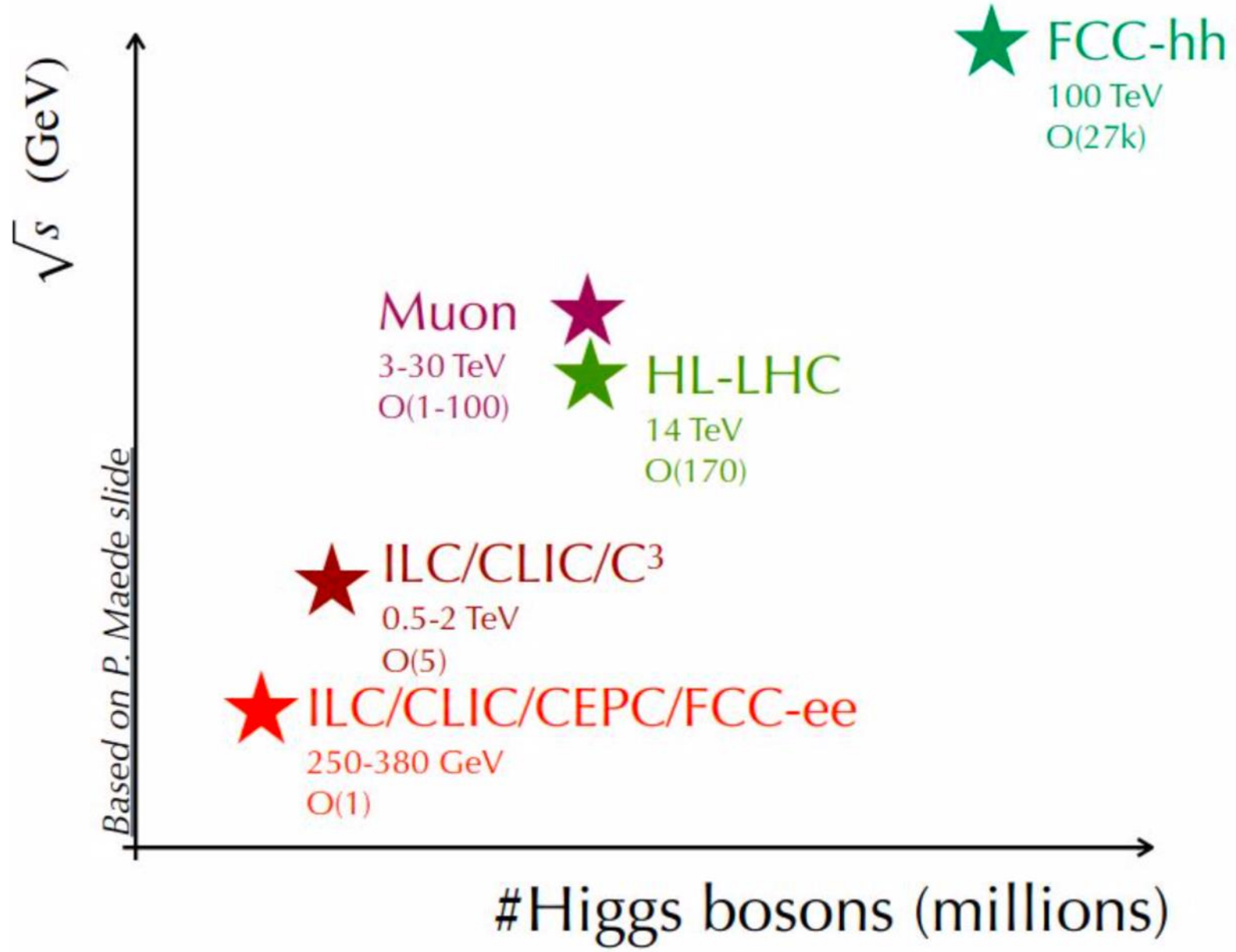
# The future starts now….until 2040 at least



# ....and beyond




*adapted from S. Bethke, ESPP symposium 2019*


FCC-hh
100 TeV
O(27k)
Muon
3-30 TeV
O(1-100)
HL-LHC
14 TeV
O(170)
ILC/CLIC/C3
0.5-2 TeV
O(5)
ILC/CLIC/CEPC/FCC-ee
250-380 GeV
O(1)
√s (GeV)
Based on P. Maede slide
#Higgs bosons (millions)

WHO BENEFITS?

# THE ECONOMIC BENEFITS OF THE LHC RESEARCH PROGRAMME

Is it worth investing in large-scale research facilities?

2

**Students and researchers**
(Education, training, competitiveness)

1

**Scientists**
(basic research and publications)

3

**Industry**
(global network, new Products & Services more efficiency, )

5

**Taxpayers**
(Knowledge as public good)

4

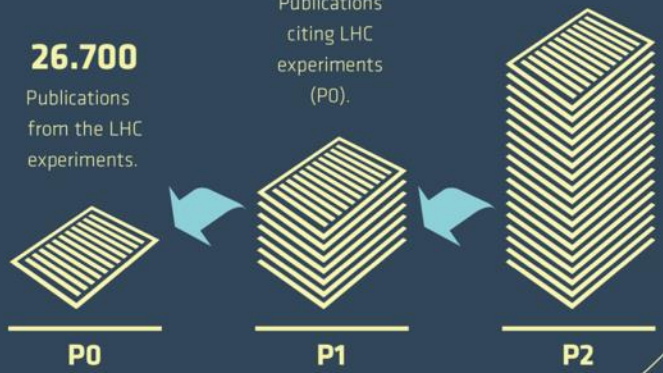
**General Public**
(Culture and Education)

## 1 SCIENTISTS

**862.100**
Publications citing P1.

**242.600**
Publications citing LHC experiments (P0).

**26.700**
Publications from the LHC experiments.



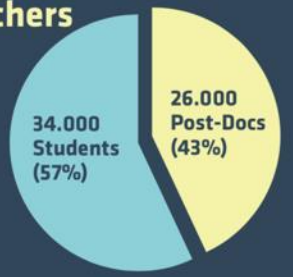

## 2 STUDENTS & RESEARCHERS

Education that goes beyond solving scientific problems.

- Project management
- Teamwork and Networking
- Independent thinking
- Communication
- Problem Solving
- Technical Skills
- Scientific Skills

**€ 150,000 cumulative salary increase per student**

**Young researchers**
(1993-2038)

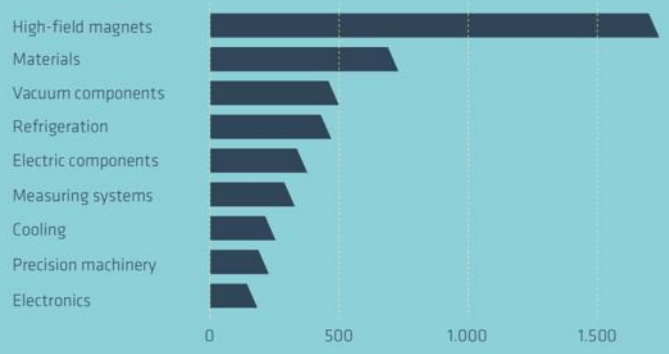


## 3 INDUSTRIAL PARTNERS

**Worldwide participation (1995-2015)**

**4.204 Companies | 47 Countries | 33.414 Contracts**

**Technology orders as a driver of innovation**




**Innovation Orders(1995-2015)**

## 4 PUBLIC

**Cultural value (1993-2038)**

**5,1**
Million
CERN Visitors

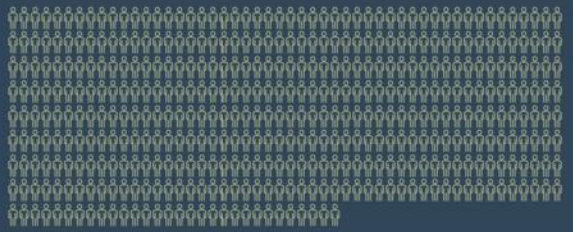
**1,6**
Million Visitors to
CERN's exhibitions

**29,3**
Millions of Social Media
Users

**775**
Million of visitors
to the sites

## 5 TAXPAYERS

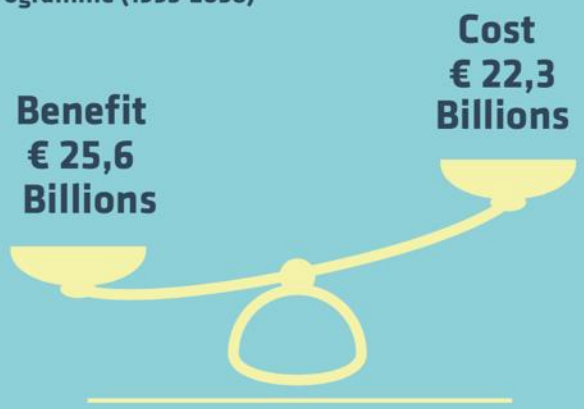
**How much does each one contribute?**



**430 Millions** of taxpayers
in **22 Member states**
**€ 2,50 per Person** and per year

# INVESTING IN FUNDAMENTAL RESEARCH - SHAPING A BETTER FUTURE

**LHC Programme (1993-2038)**




## Economic Impact

The Large Hadron Collider (LHC) research program at CERN generates approximately € 3.3 billion in net present value (investment and operating costs are deducted) for the Society in the period from 1993 to 2038.

In other words, the research infrastructure reimburses its costs with 15% surplus in the form of societal benefits.

The data of this infographic comes from a cost-benefit analysis carried out by the University of Milan and the Center for Industrial Studies in Milan (Italy). The European Union's Investment Projects Guide to Cost Benefit analysis of Investment projects (2014) has been used for the analysis to ensure that a fact-based method is used.

The study is available at the following link: http://cds.cern.ch/record/2319300

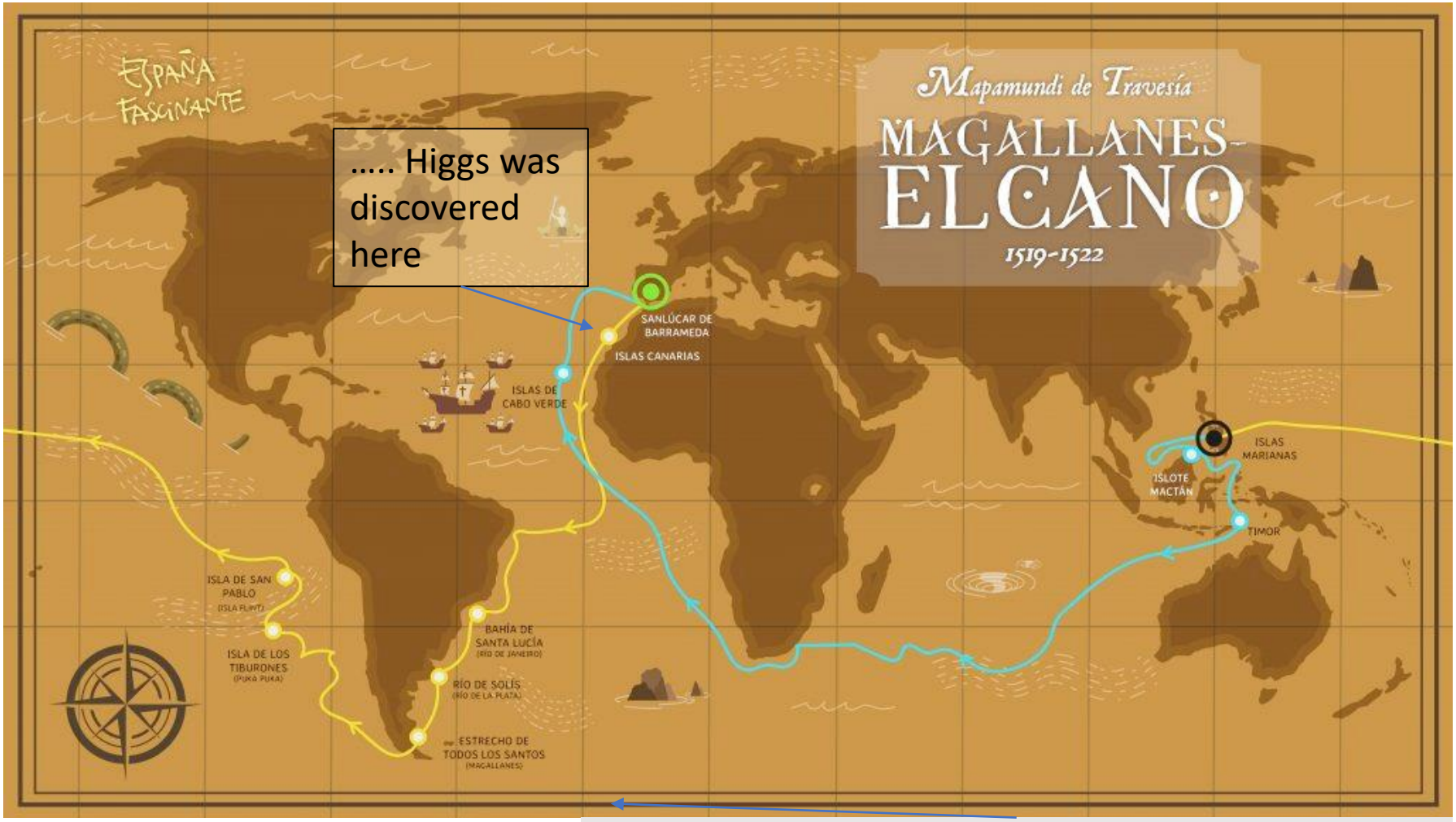

BETTER PLANET
SAFETY
INDUSTRY 4.0
EMERGING TECHNOLOGIES
MEDICAL & BIOMEDICAL
CULTURAL HERITAGE
AEROSPACE
FROM CERN TECHNOLOGY TO SOCIETY

# The world 1502

Gregor Reisch's
Margarita philosophica.
Freiburg, Joh. Schott, 1503

# Magellan-Elcano 1519-1522

If LHC was “Victoria”…..




The World Map before and after Magellan's Voyage
Author(s): Edward Heawood
Source: The Geographical Journal , Jun., 1921, Vol. 57, No. 6 (Jun., 1921), pp. 431-442

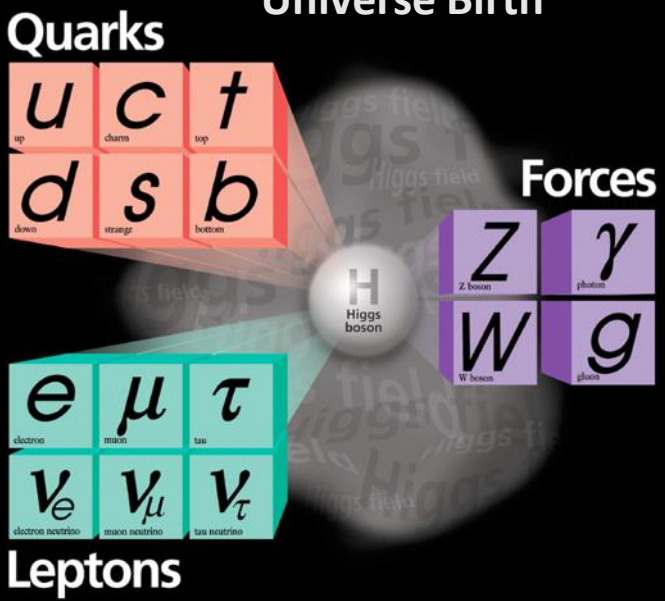
# The two infinites

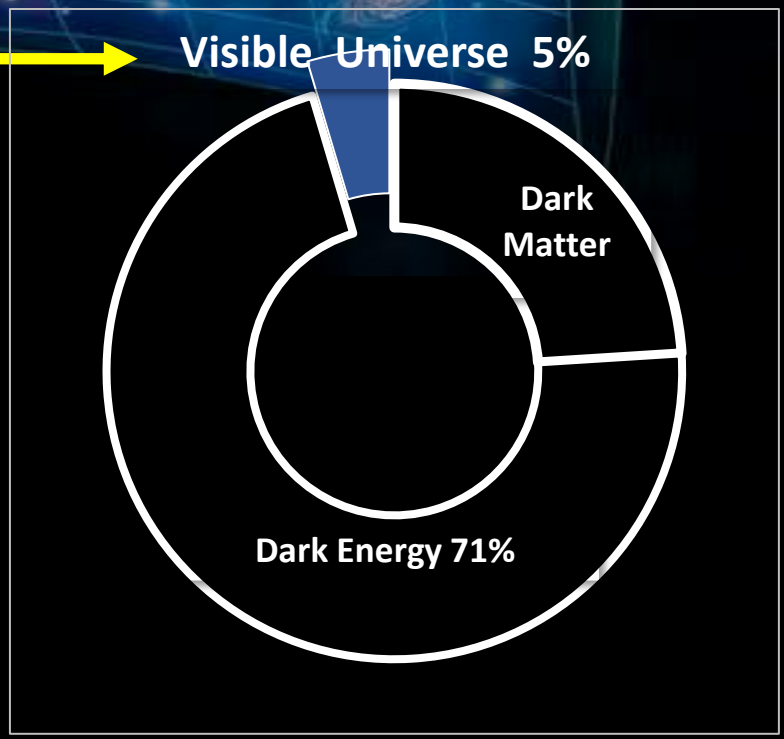
Infinitely small/
Infinimment petit

Infinitely large/
Infinimment grand

13.7 Byears

Universe Birth



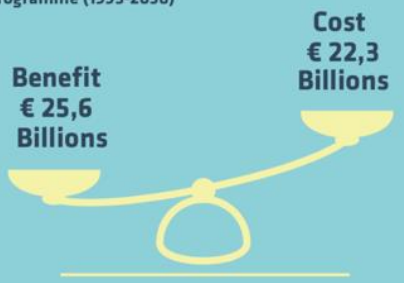



BACKUP

# THE ECONOMIC BENEFITS OF THE LHC RESEARCH PROGRAMME

Is it worth investing in large-scale research facilitie

**LHC Programme (1993-2038)**




## 4 PUBLIC

**Cultural value (1993-2038)**

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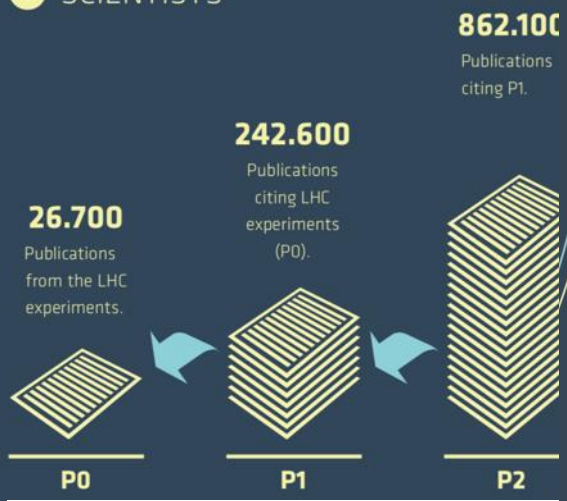
## 1 SCIENTISTS




## 3 INDUSTRIAL PARTNERS

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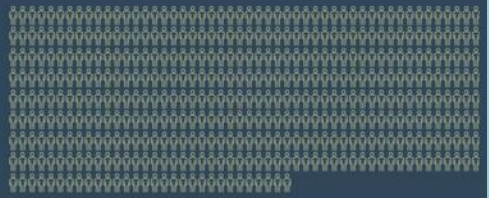
## 5 TAXPAYERS

**How much does each one contribute?**



**430 Millions** of taxpayers
in **22 Member states**
**€ 2,50 per Person** and per year

## STUDENTS & RESEARCHERS

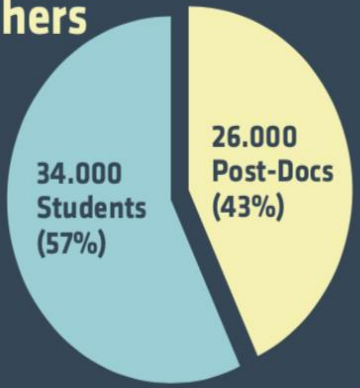
Education that goes beyond solving scientific problems.

- Project management
- Teamwork and Networking
- Independent thinking
- Communication
- Problem Solving
- Technical Skills
- Scientific Skills

**€ 150,000 cumulative salary increase per student**

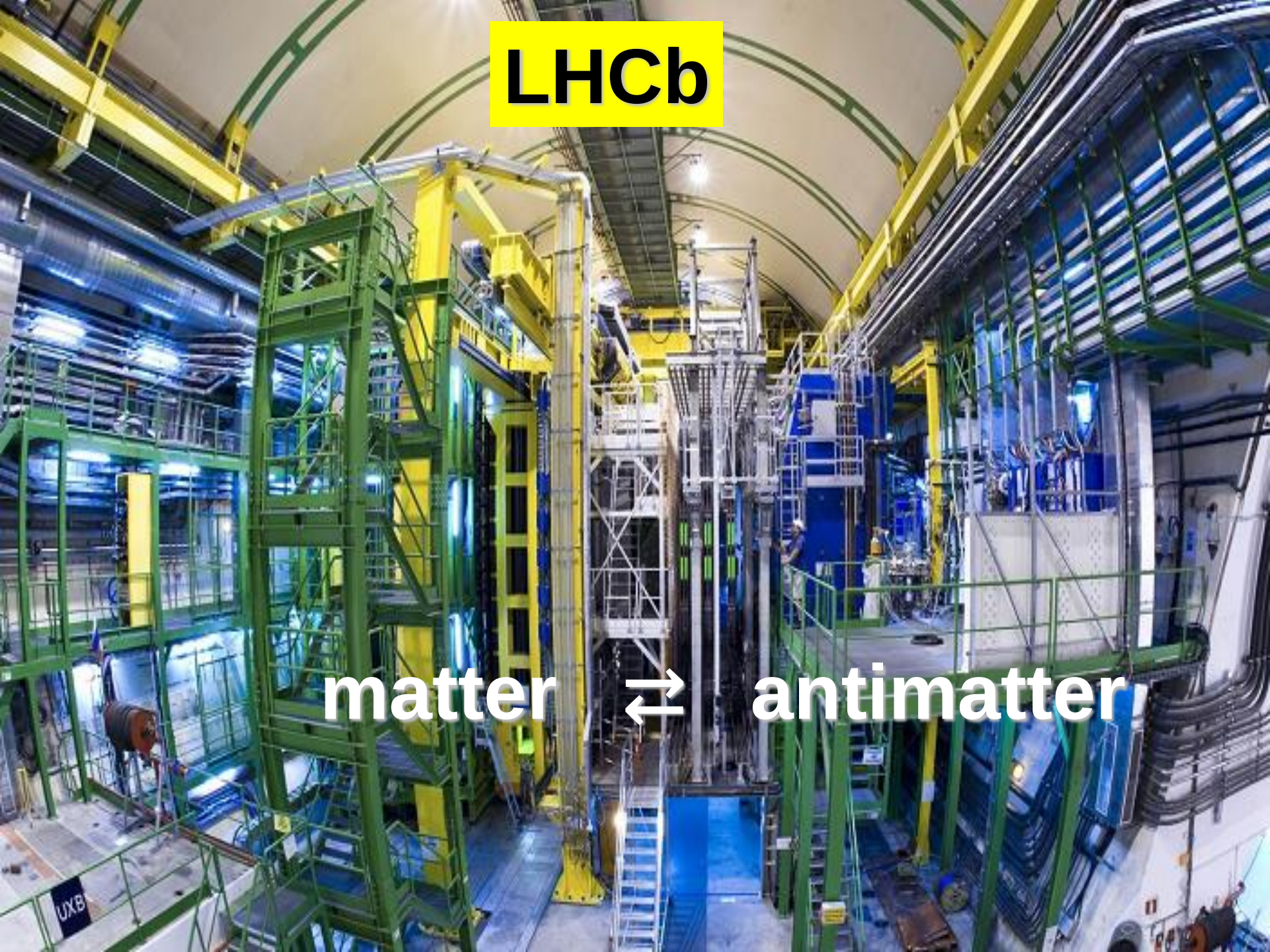
## Young researchers

(1993-2038)



# 2016: Romania becomes the 22nd CERN member state

"Romania is very proud to join the CERN community. We are confident that our country's membership represents **international recognition of the excellence of the Romanian research and scientific community** and of its remarkable results", said Klaus Iohannis, the President of Romania. (flag raising ceremony Sep 2017)

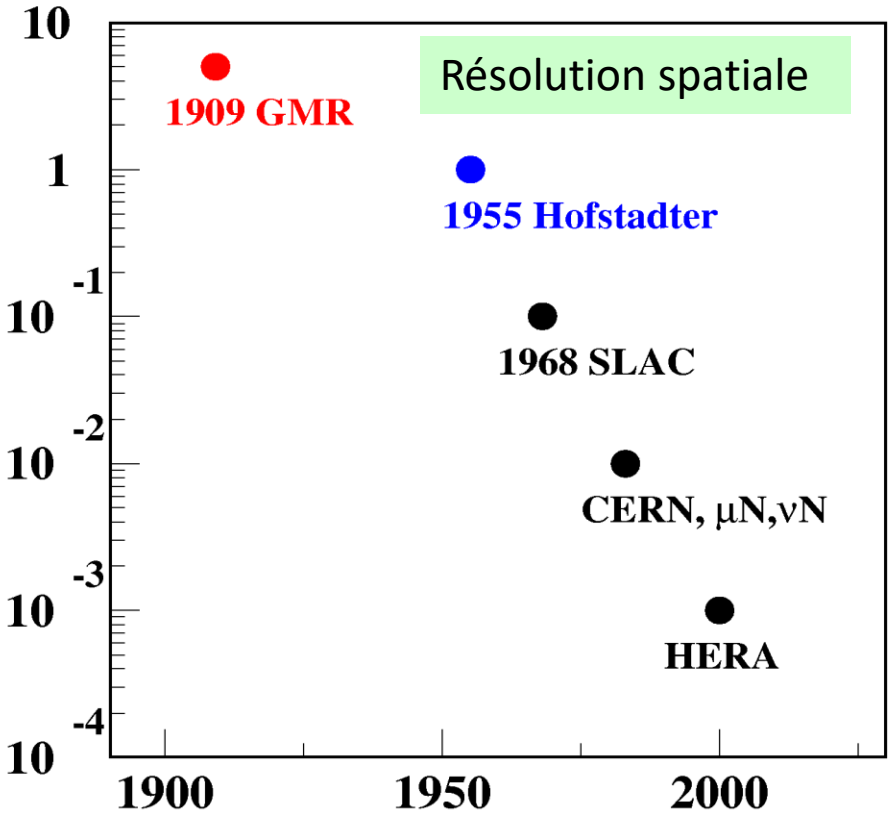

LHCb
matter ⇄ antimatter

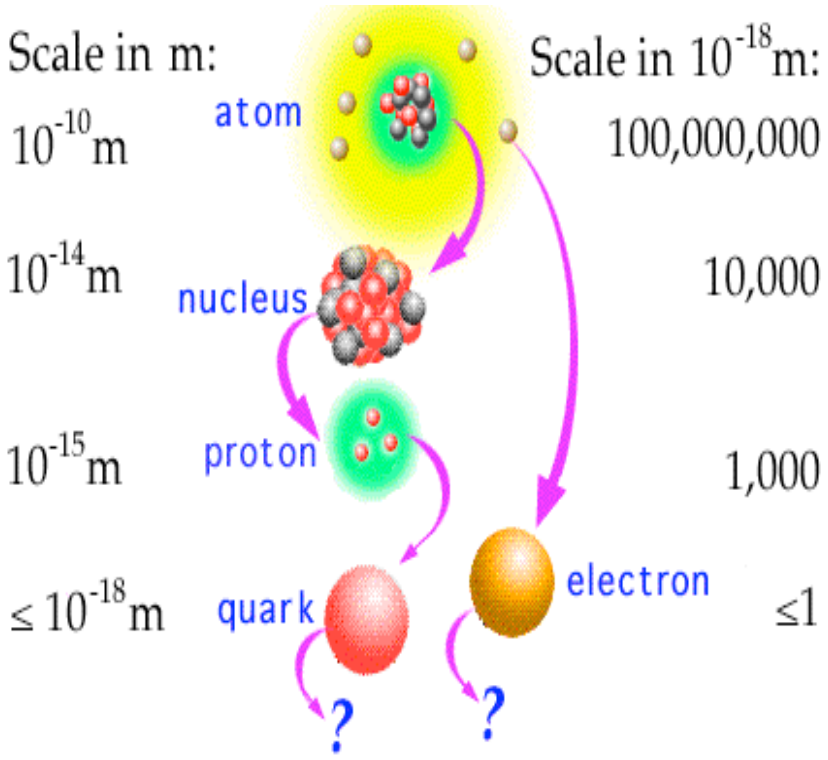

ALICE
plasma quark-gluonp
primordial « soup »
WILL LEAVE THIS FOR JOHN

# Plus d'énergie, plus de finesse

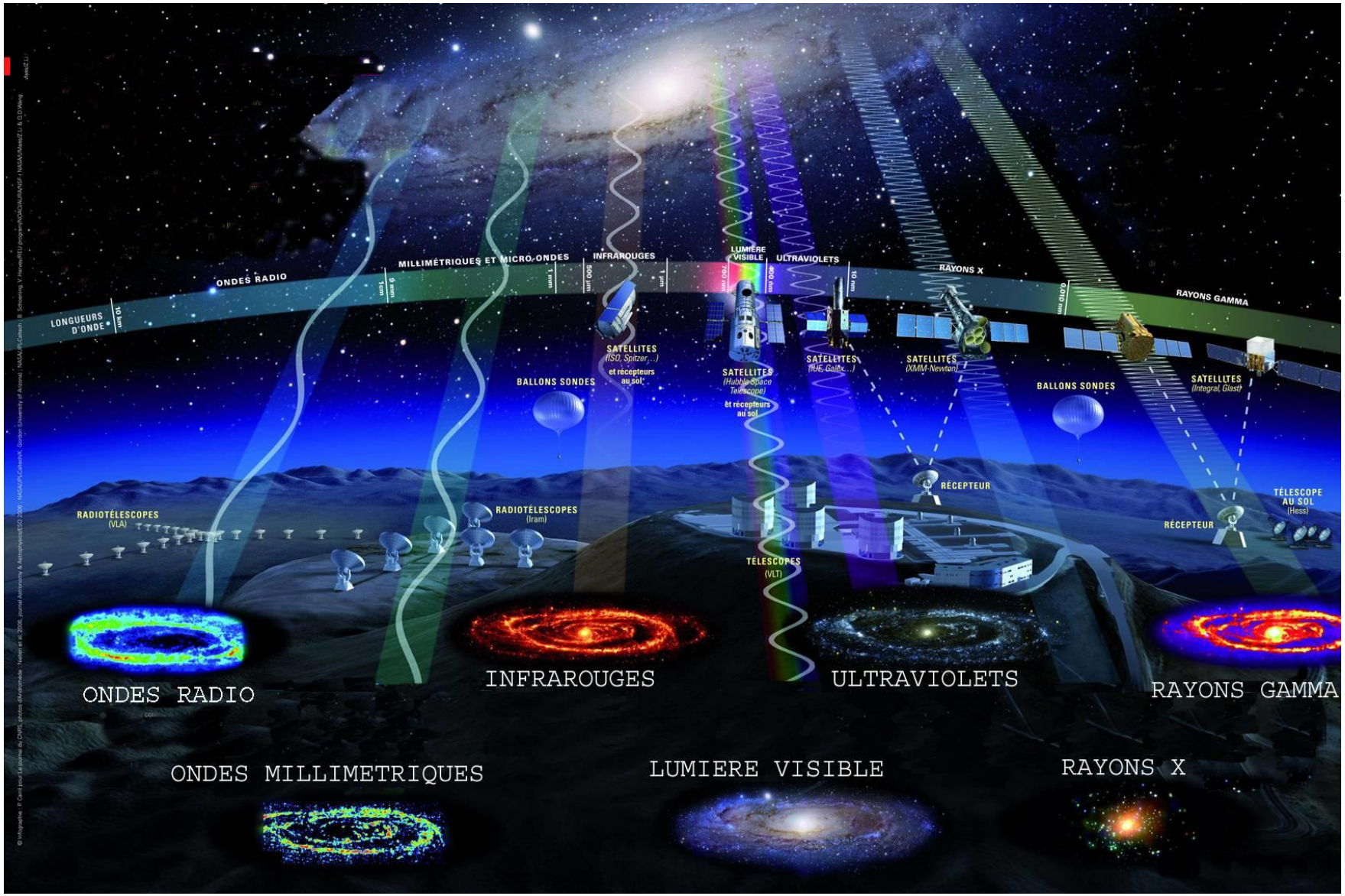
$$\delta\ [\mathrm{fm}] \simeq \frac{200\ \mathrm{MeV}}{Q}$$

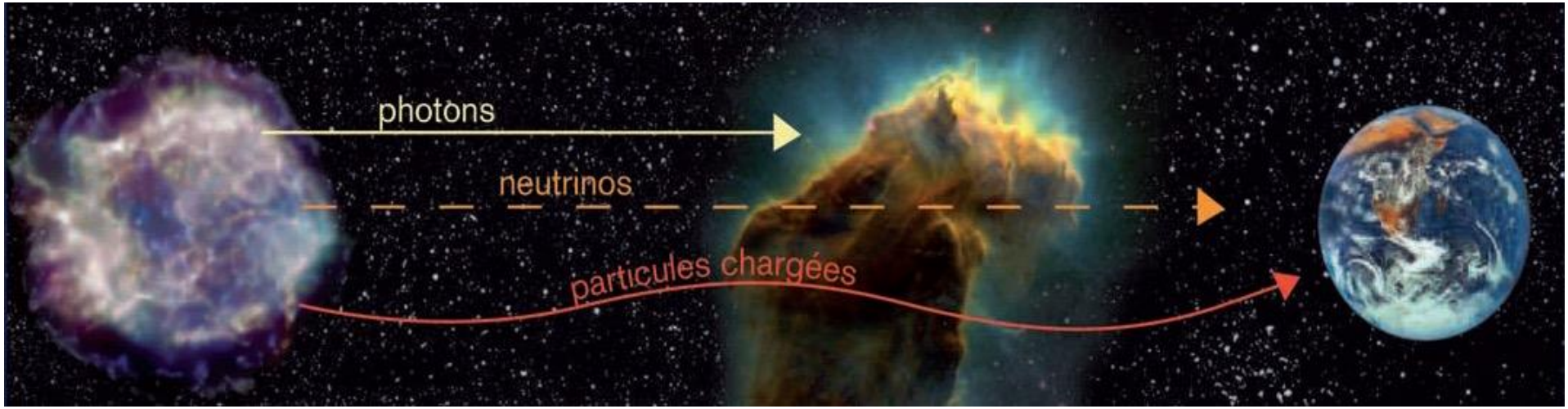
[1fm=$10^{-15}$ m]

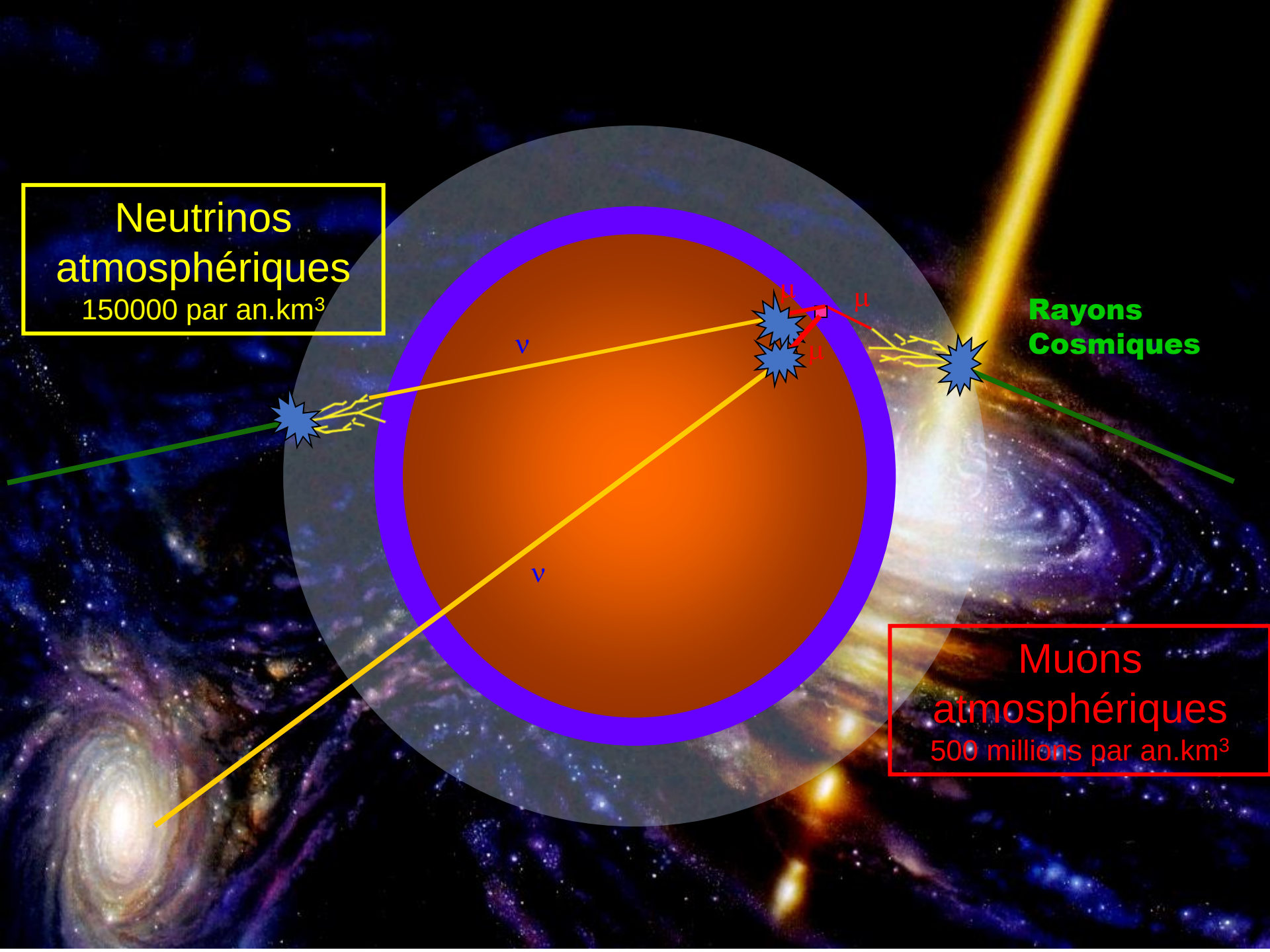


# Astronomie “multicolora”




photons
neutrinos
particules chargées

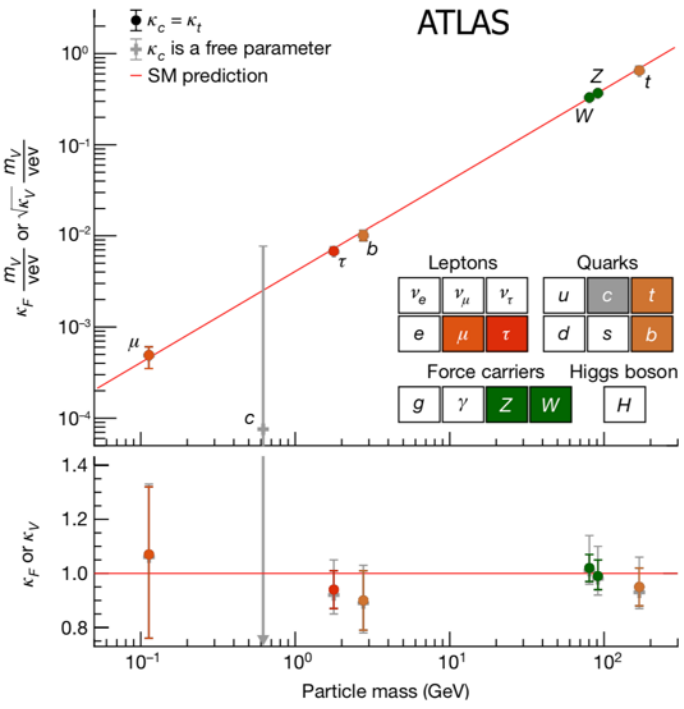

Neutrinos
atmosphériques
150000 par an.km3
ν
ν
μ
μ
μ
Rayons
Cosmiques
Muons
atmosphériques
500 millions par an.km3

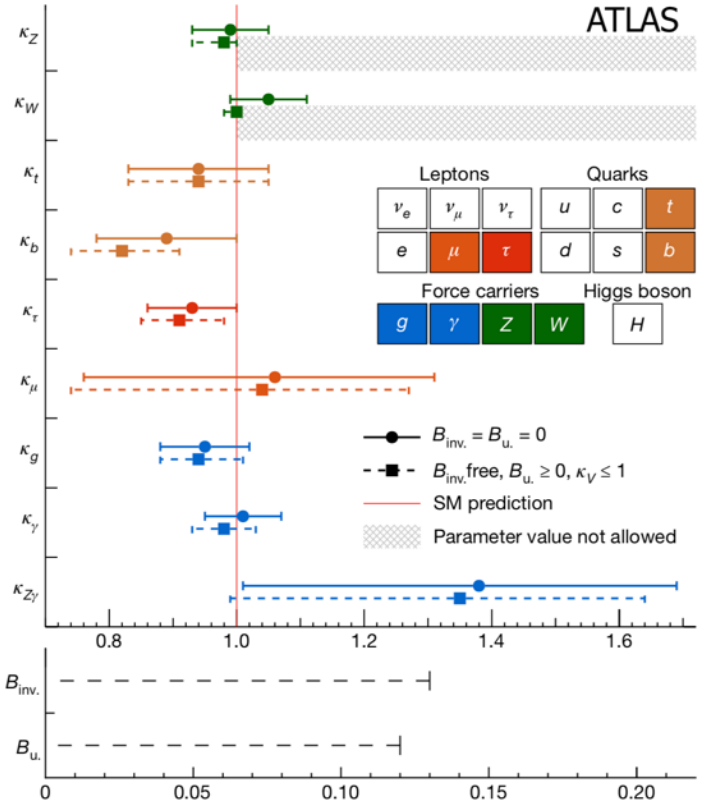
nature

4th of July 2022

Article

# A detailed map of Higgs boson interactions by the ATLAS experiment ten years after the discovery



# The two infinites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