Introduction to (LHC) High Energy Physics

Dr Clara Nellist

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Liverpool@CERN Particle Physics School

Nikhef

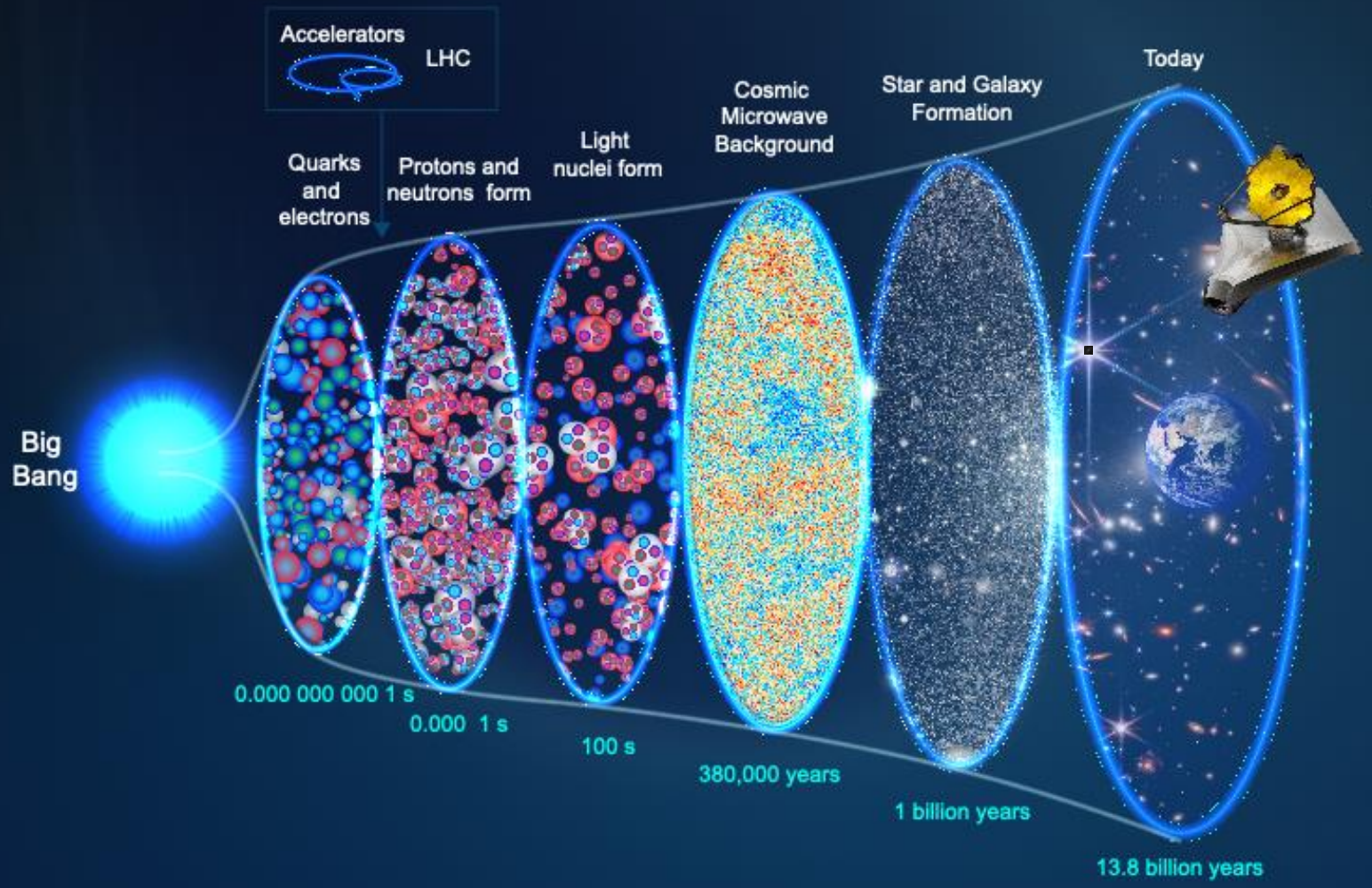
ATLAS EXPERIMENT

Universiteit van Amsterdam


CERN

Voyage into the world of atoms

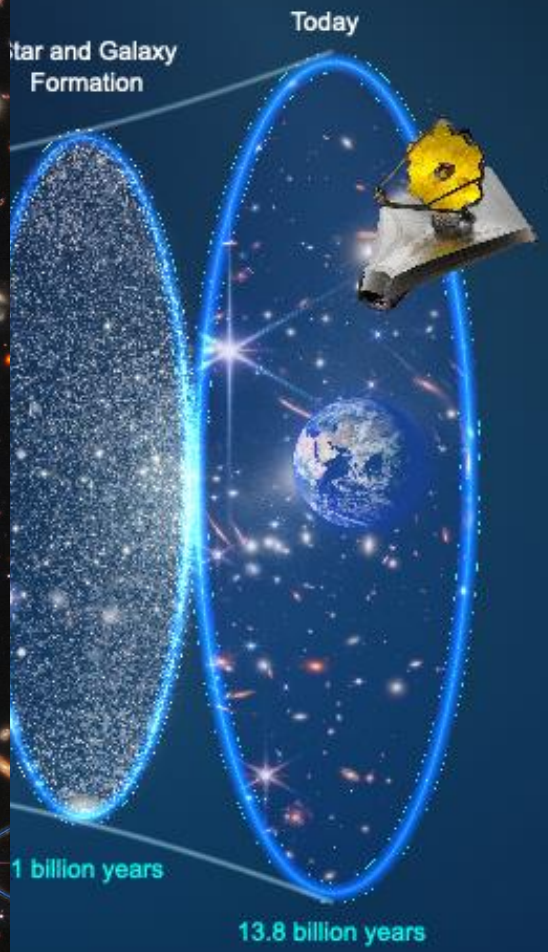
Studying nature's building blocks and the forces that govern them



ESA & NASA

Image: CERN

uilding blocks govern them



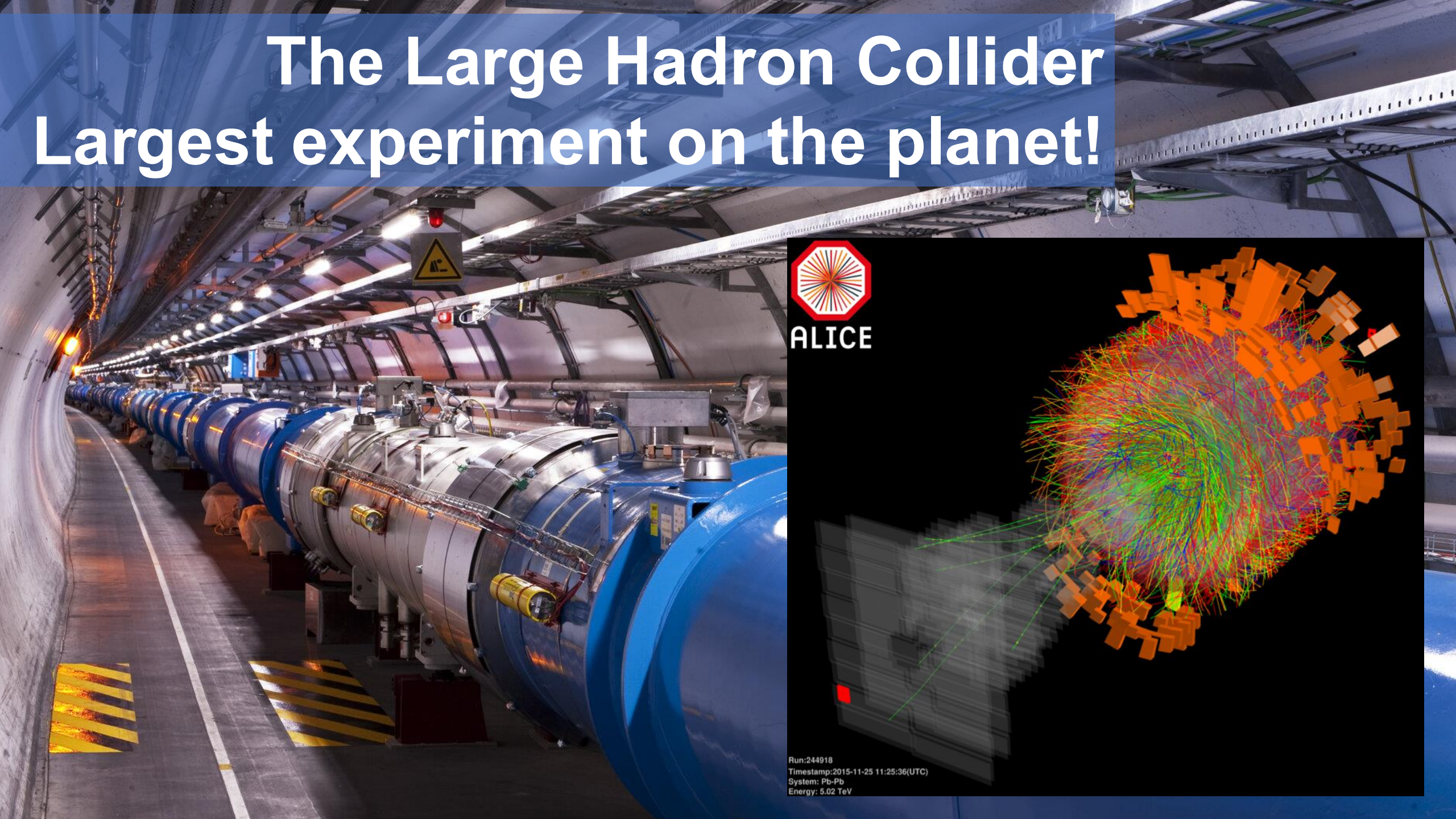
ESA & NASA

Studying nature's building blocks and the forces that govern them

CERN

Image: CERN

The Large Hadron Collider
Largest experiment on the planet!



Introduction to me

Particle physicist working on the ATLAS experiment

My job is to smash things for a living!

I studied: Physics, Maths, Chemistry and English Language & Literature (+ Film Studies).

My career path

MANCHESTER 1824
The University of Manchester

Masters on the D0 at Fermilab

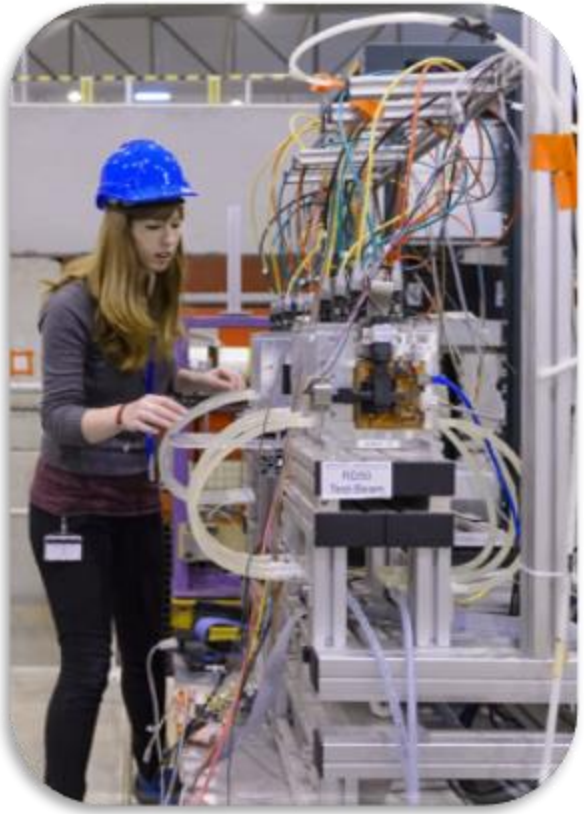
PhD in particle physics working on the ATLAS Experiment at CERN

LABORATOIRE DE L'ACCÉLÉRATEUR LINÉAIRE

GEORG-AUGUST-UNIVERSITÄT GÖTTINGEN

Radboud University

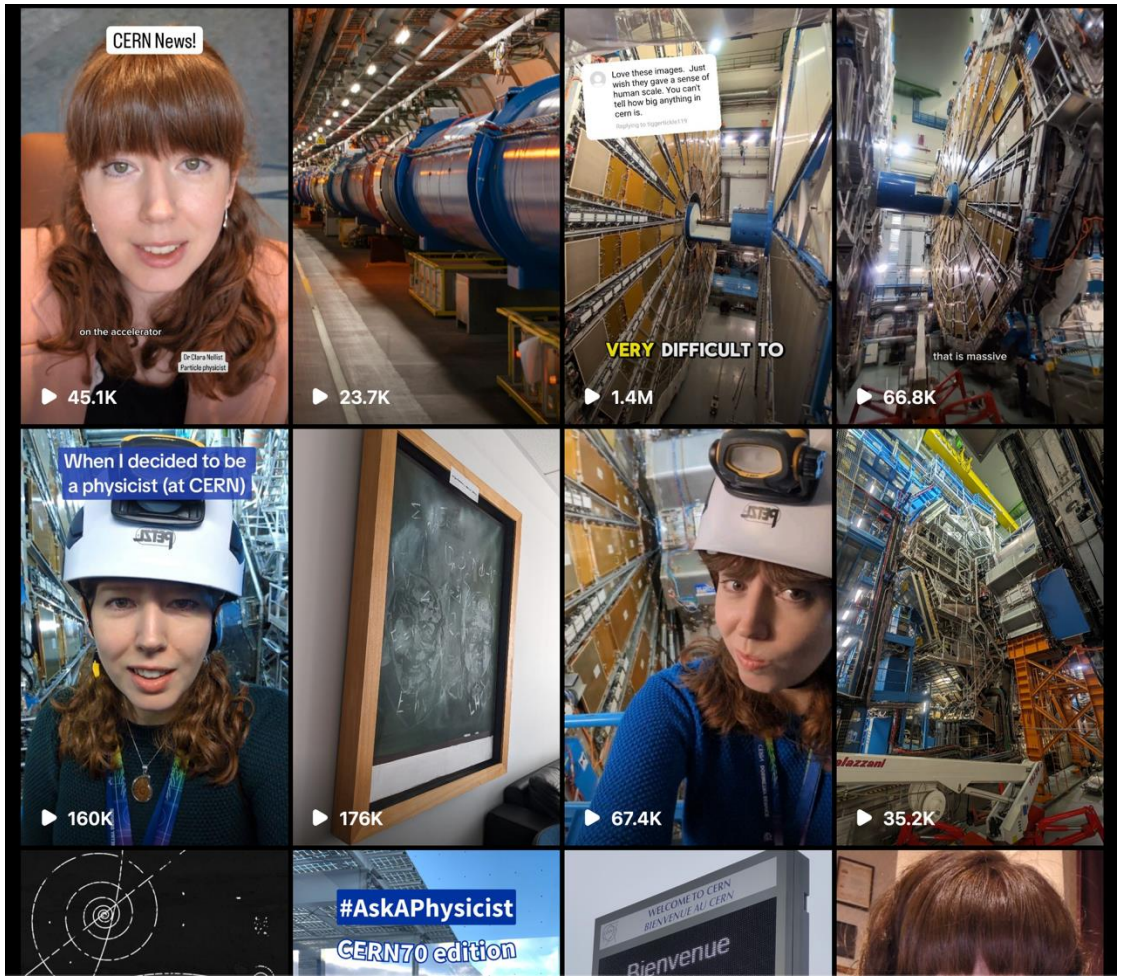
Postdoctoral research positions: LAL in France, Göttingen in Germany and Radboud in the Netherlands



Currently: UNIVERSITEIT VAN AMSTERDAM

Assistant Professor, University of Amsterdam & Nikhef

Science Communicator



@ParticleClara everywhere

$$-\tfrac{1}{2}\partial_\nu g^a_\mu \partial_\nu g^a_\mu - g_s f^{abc}\partial_\mu g^a_\nu g^b_\mu g^c_\nu - \tfrac{1}{4}g_s^2 f^{abc}f^{ade}g^b_\mu g^c_\nu g^d_\mu g^e_\nu +$$

$$\tfrac{1}{2}ig_s^2(\bar{q}^\sigma_i\gamma^\mu q^\sigma_j)g^a_\mu + \bar{G}^a\partial^2 G^a + g_s f^{abc}\partial_\mu \bar{G}^a G^b g^c_\mu - \partial_\nu W^+_\mu \partial_\nu W^-_\mu -$$

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

$$\tfrac{1}{2}m_h^2 H^2 - \partial_\mu \phi^+ \partial_\mu \phi^- - M^2\phi^+\phi^- - \tfrac{1}{2}\partial_\mu\phi^0\partial_\mu\phi^0 - \tfrac{1}{2c_w^2}M\phi^0\phi^0 - \beta_h[\tfrac{2M^2}{g^2} +$$

$$\tfrac{2M}{g}H + \tfrac{1}{2}(H^2+\phi^0\phi^0+2\phi^+\phi^-)] + \tfrac{2M^4}{g^2}\alpha_h - igc_w[\partial_\nu Z^0_\mu(W^+_\mu W^-_\nu -$$

$$W^+_\nu W^-_\mu) - Z^0_\nu(W^+_\mu\partial_\nu W^-_\mu - W^-_\mu\partial_\nu W^+_\mu) + Z^0_\mu(W^+_\nu\partial_\nu W^-_\mu -$$

$$W^-_\nu\partial_\nu W^+_\mu)] - igs_w[\partial_\nu A_\mu(W^+_\mu W^-_\nu - W^+_\nu W^-_\mu) - A_\nu(W^+_\mu\partial_\nu W^-_\mu -$$

$$W^-_\mu\partial_\nu W^+_\mu) + A_\mu(W^+_\nu\partial_\nu W^-_\mu - W^-_\nu\partial_\nu W^+_\mu)] - \tfrac{1}{2}g^2 W^+_\mu W^-_\mu W^+_\nu W^-_\nu +$$

$$\tfrac{1}{2}g^2 W^+_\mu W^-_\nu W^+_\mu W^-_\nu + g^2c_w^2(Z^0_\mu W^+_\mu Z^0_\nu W^-_\nu - Z^0_\mu Z^0_\mu W^+_\nu W^-_\nu) +$$

$$g^2 s_w^2(A_\mu W^+_\mu A_\nu W^-_\nu - A_\mu A_\mu W^+_\nu W^-_\nu) + g^2 s_w c_w[A_\mu Z^0_\nu(W^+_\mu W^-_\nu -$$

$$W^+_\nu W^-_\mu) - 2A_\mu Z^0_\mu W^+_\nu W^-_\nu] - g\alpha[H^3 + H\phi^0\phi^0 + 2H\phi^+\phi^-] -$$

$$\tfrac{1}{8}g^2\alpha_h[H^4+(\phi^0)^4+4(\phi^+\phi^-)^2+4(\phi^0)^2\phi^+\phi^-+4H^2\phi^+\phi^-+2(\phi^0)^2H^2] -$$

$$gMW^+_\mu W^-_\mu H - \tfrac{1}{2}g\tfrac{M}{c_w^2}Z^0_\mu Z^0_\mu H - \tfrac{1}{2}ig[W^+_\mu(\phi^0\partial_\mu\phi^- - \phi^-\partial_\mu\phi^0) -$$

$$W^-_\mu(\phi^0\partial_\mu\phi^+ - \phi^+\partial_\mu\phi^0)] + \tfrac{1}{2}g[W^+_\mu(H\partial_\mu\phi^- - \phi^-\partial_\mu H) - W^-_\mu(H\partial_\mu\phi^+ -$$

$$\phi^+\partial_\mu H)] + \tfrac{1}{2}g\tfrac{1}{c_w}(Z^0_\mu(H\partial_\mu\phi^0 - \phi^0\partial_\mu H) - ig\tfrac{s_w^2}{c_w}MZ^0_\mu(W^+_\mu\phi^- - W^-_\mu\phi^+) +$$

$$igs_w MA_\mu(W^+_\mu\phi^- - W^-_\mu\phi^+) - ig\tfrac{1-2c_w^2}{2c_w}Z^0_\mu(\phi^+\partial_\mu\phi^- - \phi^-\partial_\mu\phi^+) +$$

$$igs_w A_\mu(\phi^+\partial_\mu\phi^- - \phi^-\partial_\mu\phi^+) - \tfrac{1}{4}g^2 W^+_\mu W^-_\mu[H^2 + (\phi^0)^2 + 2\phi^+\phi^-] -$$

$$\tfrac{1}{4}g^2\tfrac{1}{c_w^2}Z^0_\mu Z^0_\mu[H^2 + (\phi^0)^2 + 2(2s_w^2-1)^2\phi^+\phi^-] - \tfrac{1}{2}g^2\tfrac{s_w^2}{c_w}Z^0_\mu\phi^0(W^+_\mu\phi^- +$$

$$W^-_\mu\phi^+) - \tfrac{1}{2}ig^2\tfrac{s_w^2}{c_w}Z^0_\mu H(W^+_\mu\phi^- - W^-_\mu\phi^+) + \tfrac{1}{2}g^2 s_w A_\mu\phi^0(W^+_\mu\phi^- +$$

$$W^-_\mu\phi^+) + \tfrac{1}{2}ig^2 s_w A_\mu H(W^+_\mu\phi^- - W^-_\mu\phi^+) - g^2\tfrac{s_w}{c_w}(2c_w^2-1)Z^0_\mu A_\mu\phi^+\phi^- -$$

$$g^1 s_w^2 A_\mu A_\mu\phi^+\phi^- - \bar{e}^\lambda(\gamma\partial + m^\lambda_e)e^\lambda - \bar{\nu}^\lambda\gamma\partial\nu^\lambda - \bar{u}^\lambda_j(\gamma\partial + m^\lambda_u)u^\lambda_j -$$

$$\bar{d}^\lambda_j(\gamma\partial + m^\lambda_d)d^\lambda_j + igs_w A_\mu[-(\bar{e}^\lambda\gamma^\mu e^\lambda) + \tfrac{2}{3}(\bar{u}^\lambda_j\gamma^\mu u^\lambda_j) - \tfrac{1}{3}(\bar{d}^\lambda_j\gamma^\mu d^\lambda_j)] +$$

$$\tfrac{ig}{4c_w}Z^0_\mu[(\bar{\nu}^\lambda\gamma^\mu(1+\gamma^5)\nu^\lambda) + (\bar{e}^\lambda\gamma^\mu(4s_w^2 - 1 - \gamma^5)e^\lambda) + (\bar{u}^\lambda_j\gamma^\mu(\tfrac{4}{3}s_w^2 -$$

$$1 - \gamma^5)u^\lambda_j) + (\bar{d}^\lambda_j\gamma^\mu(1 - \tfrac{8}{3}s_w^2 - \gamma^5)d^\lambda_j)] + \tfrac{ig}{2\sqrt{2}}W^+_\mu[(\bar{\nu}^\lambda\gamma^\mu(1+\gamma^5)e^\lambda) +$$

$$(\bar{u}^\lambda_j\gamma^\mu(1+\gamma^5)C_{\lambda\kappa}d^\kappa_j)] + \tfrac{ig}{2\sqrt{2}}W^-_\mu[(\bar{e}^\lambda\gamma^\mu(1+\gamma^5)\nu^\lambda) + (\bar{d}^\kappa_j C^\dagger_{\lambda\kappa}\gamma^\mu(1 +$$

$$\gamma^5)u^\lambda_j)] + \tfrac{ig}{2\sqrt{2}}\tfrac{m^\lambda_e}{M}[-\phi^+(\bar{\nu}^\lambda(1-\gamma^5)e^\lambda) + \phi^-(\bar{e}^\lambda(1+\gamma^5)\nu^\lambda)] -$$

$$\tfrac{g}{2}\tfrac{m^\lambda_e}{M}[H(\bar{e}^\lambda e^\lambda) + i\phi^0(\bar{e}^\lambda\gamma^5 e^\lambda)] + \tfrac{ig}{2M\sqrt{2}}\phi^+[-m^\kappa_d(\bar{u}^\lambda_j C_{\lambda\kappa}(1-\gamma^5)d^\kappa_j) +$$

$$m^\lambda_u(\bar{u}^\lambda_j C_{\lambda\kappa}(1+\gamma^5)d^\kappa_j] + \tfrac{ig}{2M\sqrt{2}}\phi^-[m^\lambda_d(\bar{d}^\lambda_j C^\dagger_{\lambda\kappa}(1+\gamma^5)u^\kappa_j) - m^\kappa_u(\bar{d}^\lambda_j C^\dagger_{\lambda\kappa}(1 -$$

$$\gamma^5)u^\kappa_j] - \tfrac{g}{2}\tfrac{m^\lambda_u}{M}H(\bar{u}^\lambda_j u^\lambda_j) - \tfrac{g}{2}\tfrac{m^\lambda_d}{M}H(\bar{d}^\lambda_j d^\lambda_j) + \tfrac{ig}{2}\tfrac{m^\lambda_u}{M}\phi^0(\bar{u}^\lambda_j\gamma^5 u^\lambda_j) -$$

$$\tfrac{ig}{2}\tfrac{m^\lambda_d}{M}\phi^0(\bar{d}^\lambda_j\gamma^5 d^\lambda_j) + \bar{X}^+(\partial^2 - M^2)X^+ + \bar{X}^-(\partial^2 - M^2)X^- + \bar{X}^0(\partial^2 -$$

$$\tfrac{M^2}{c_w^2})X^0 + \bar{Y}\partial^2 Y + igc_w W^+_\mu(\partial_\mu\bar{X}^0X^- - \partial_\mu\bar{X}^+X^0) + igs_w W^+_\mu(\partial_\mu\bar{Y}X^- -$$

$$\partial_\mu\bar{X}^+Y) + igc_w W^-_\mu(\partial_\mu\bar{X}^-X^0 - \partial_\mu\bar{X}^0X^+) + igs_w W^-_\mu(\partial_\mu\bar{X}^-Y -$$

$$\partial_\mu\bar{Y}X^+) + igc_w Z^0_\mu(\partial_\mu\bar{X}^+X^+ - \partial_\mu\bar{X}^-X^-) + igs_w A_\mu(\partial_\mu\bar{X}^+X^+ -$$

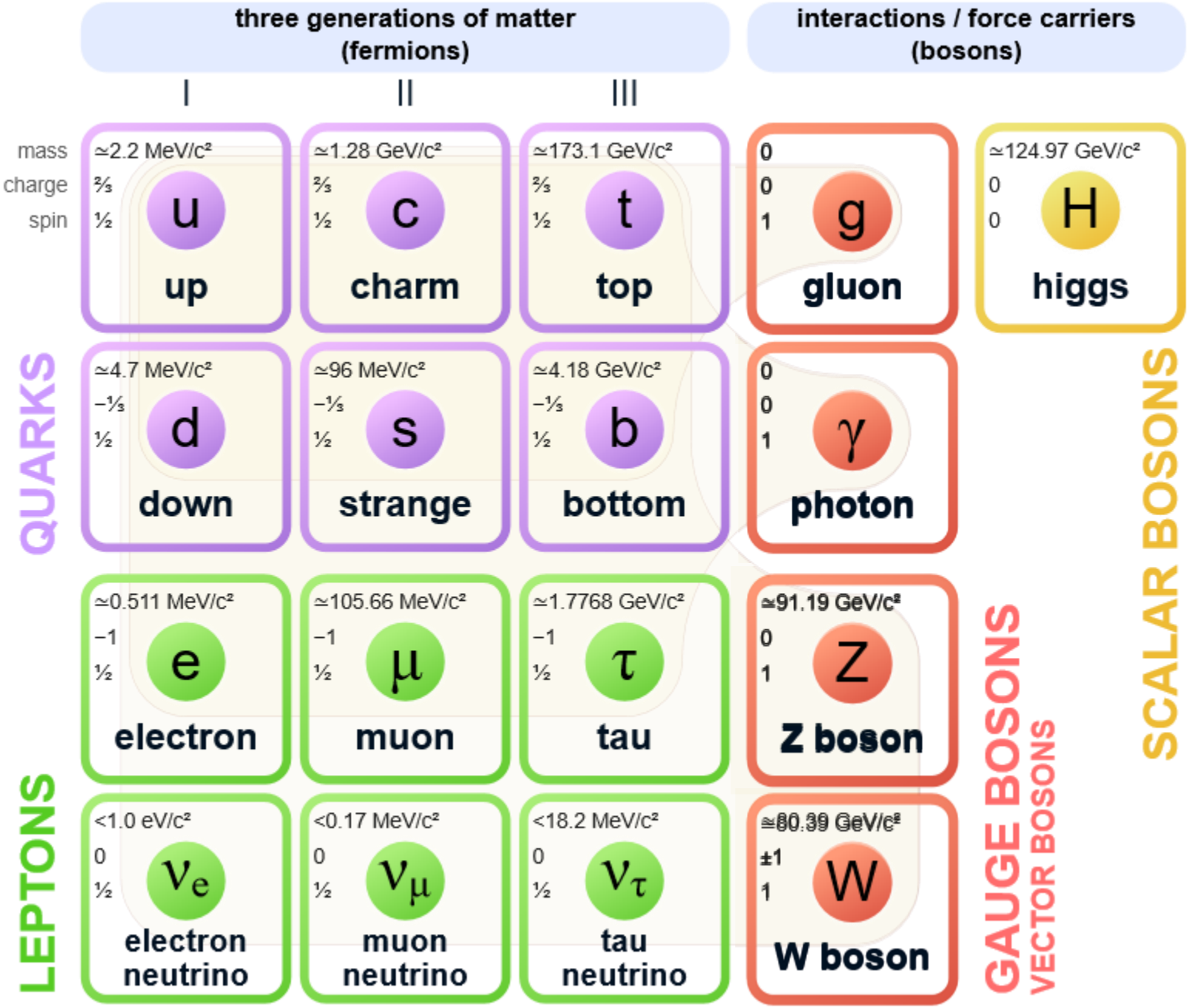
$$\partial_\mu\bar{X}^-X^-) - \tfrac{1}{2}gM[\bar{X}^+X^+H + \bar{X}^-X^-H + \tfrac{1}{c_w^2}\bar{X}^0X^0H] +$$

$$\tfrac{1-2c_w^2}{2c_w}igM[\bar{X}^+X^0\phi^+ - \bar{X}^-X^0\phi^-] + \tfrac{1}{2c_w}igM[\bar{X}^0X^-\phi^+ - \bar{X}^0X^+\phi^-] +$$

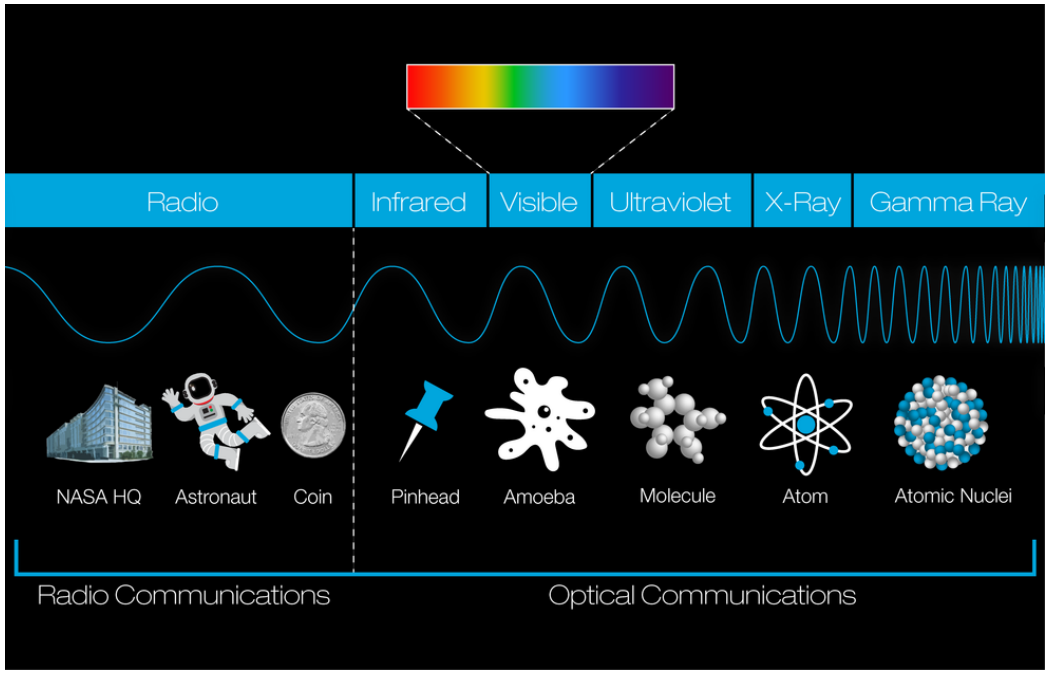
$$igMs_w[\bar{X}^0X^-\phi^+ - \bar{X}^0X^+\phi^-] + \tfrac{1}{2}igM[\bar{X}^+X^+\phi^0 - \bar{X}^-X^-\phi^0]$$

But what are we looking for?

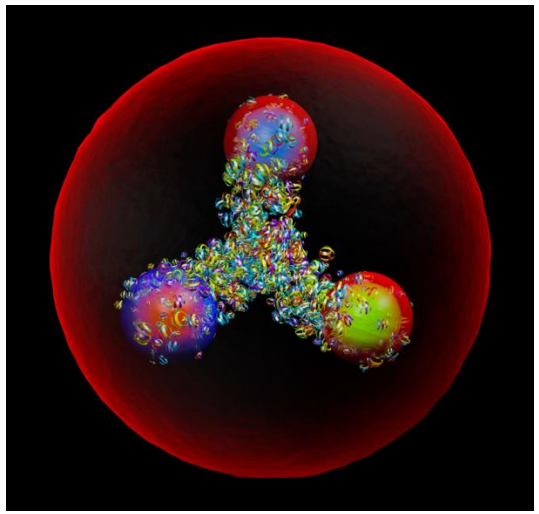
The Standard Model

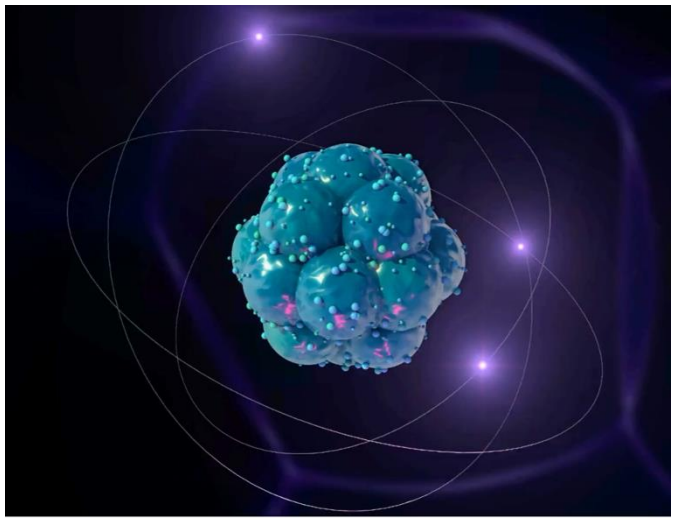


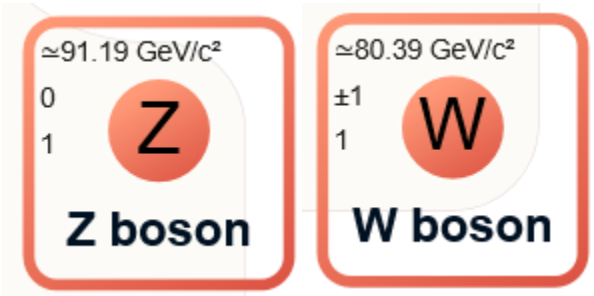

0
0
1
g
gluon

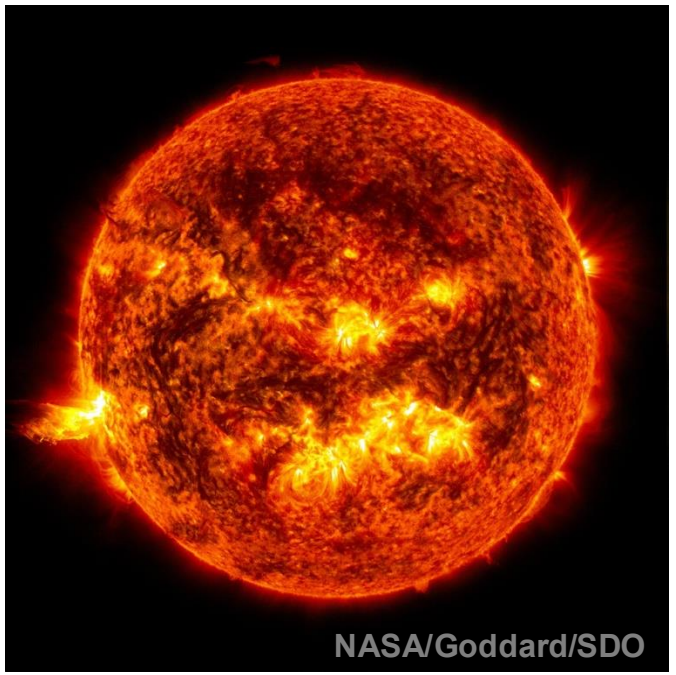

Radio
Infrared
Visible
Ultraviolet
X-Ray
Gamma Ray
NASA HQ
Astronaut
Coin
Pinhead
Amoeba
Molecule
Atom
Atomic Nuclei
Radio Communications
Optical Communications


0
0
1
γ
photon

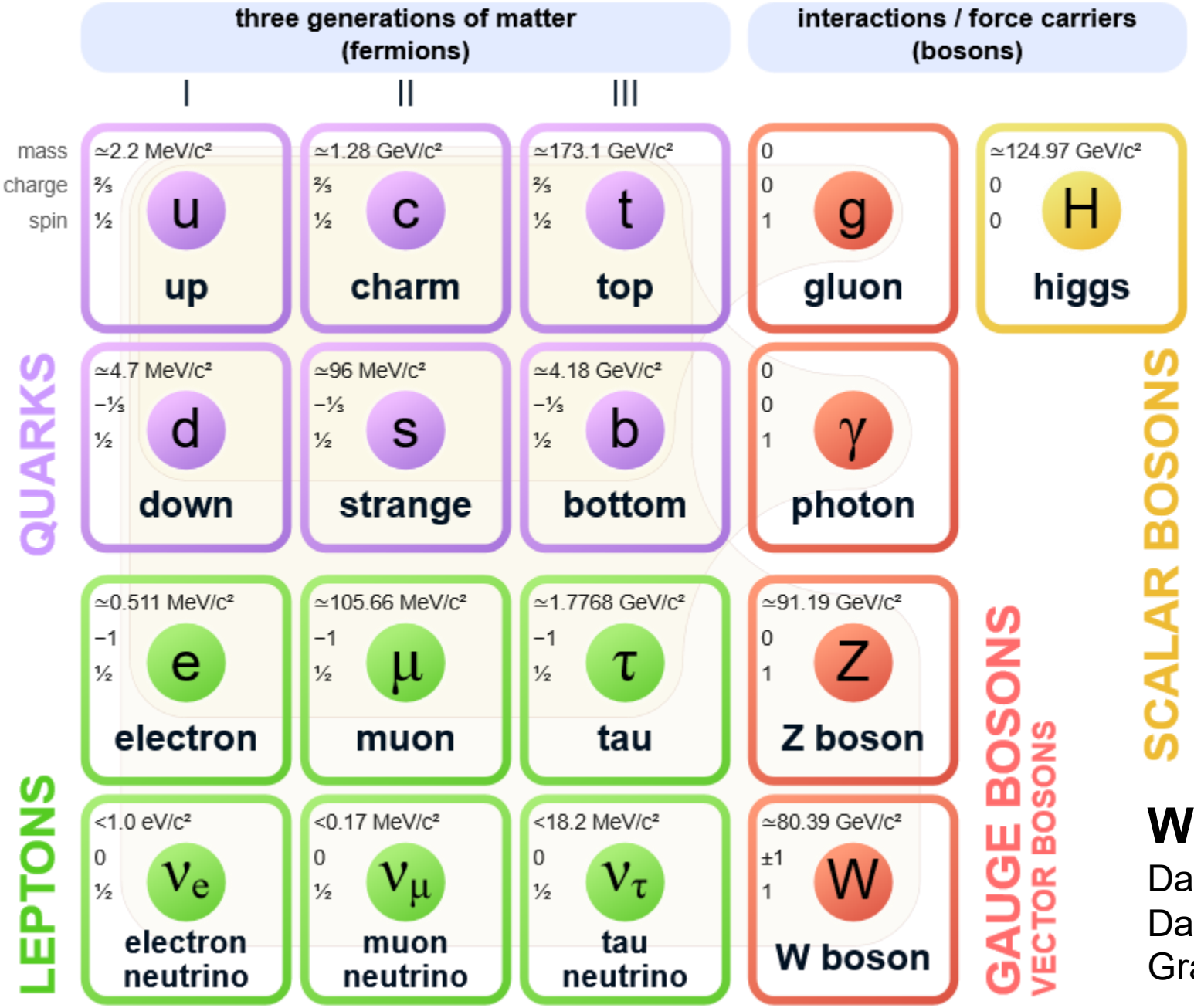





≃91.19 GeV/c²
0
1
Z
Z boson
≃80.39 GeV/c²
±1
1
W
W boson


NASA/Goddard/SDO

The Standard Model



What's missing?

Dark matter
Dark energy
Gravity!

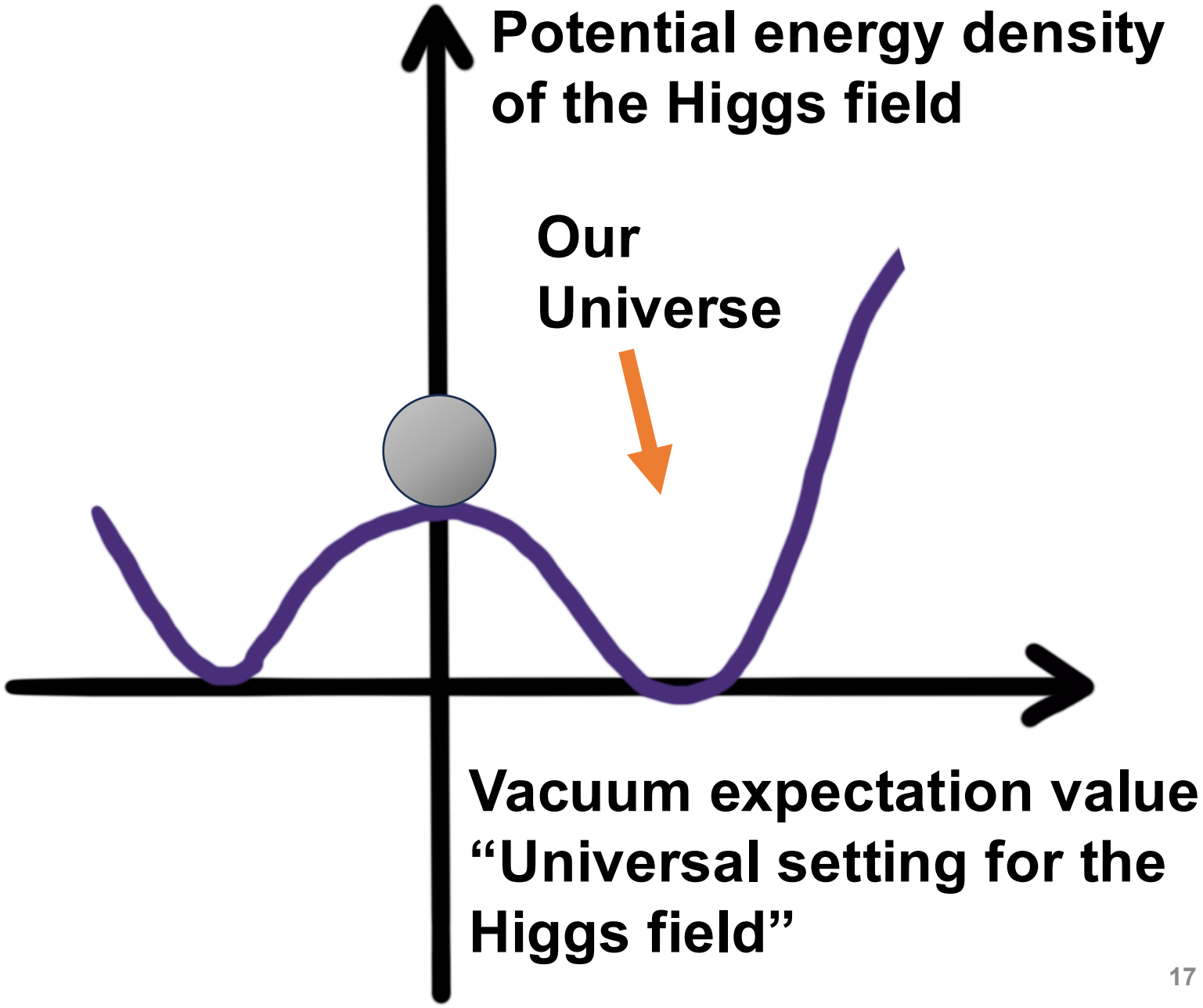
The Big Questions in Physics

The search for the Higgs boson

Image: Jorge Cham / PhD Comics

The Higgs boson

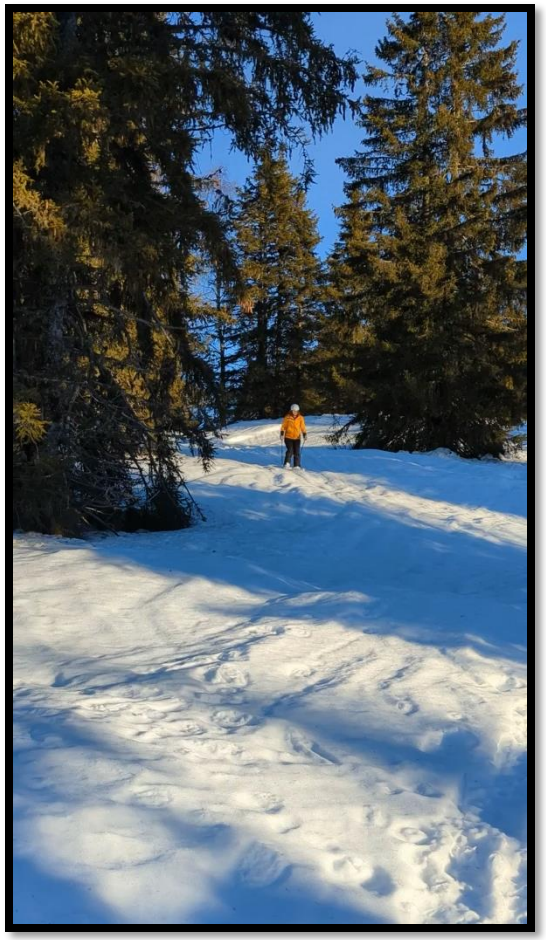
Aim: to understand the origin of the mass of elementary particles.



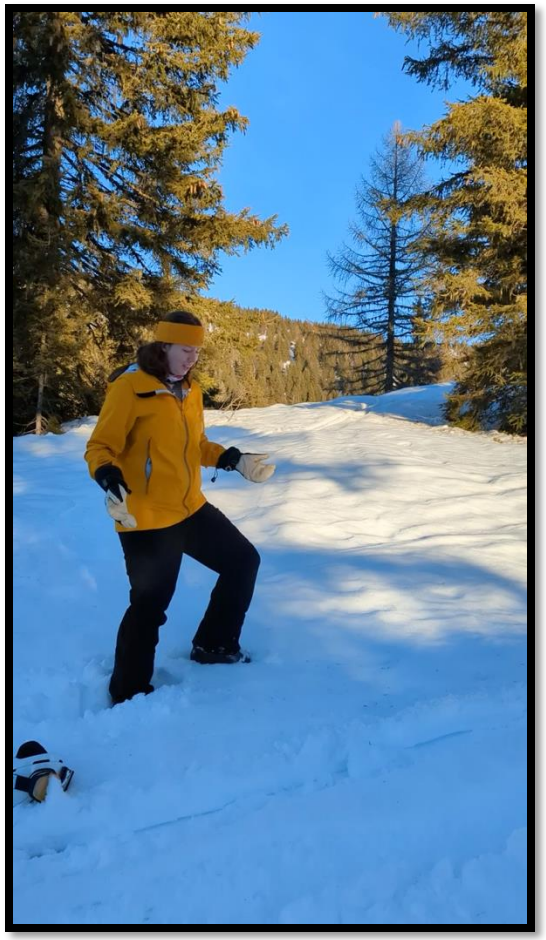
The Higgs boson

Image: Jorge Cham / PhD Comics

Low mass particle (electron)



High mass particle (top quark)



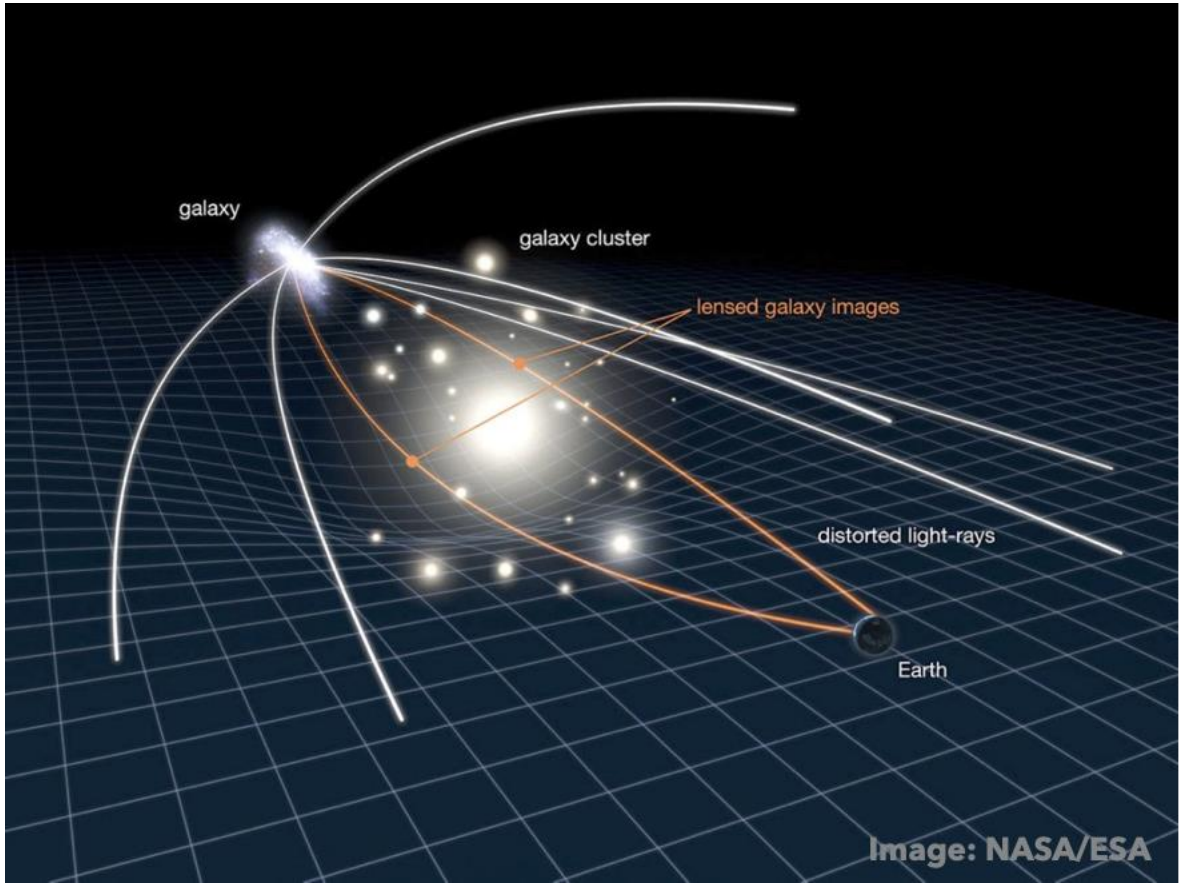
The Higgs boson

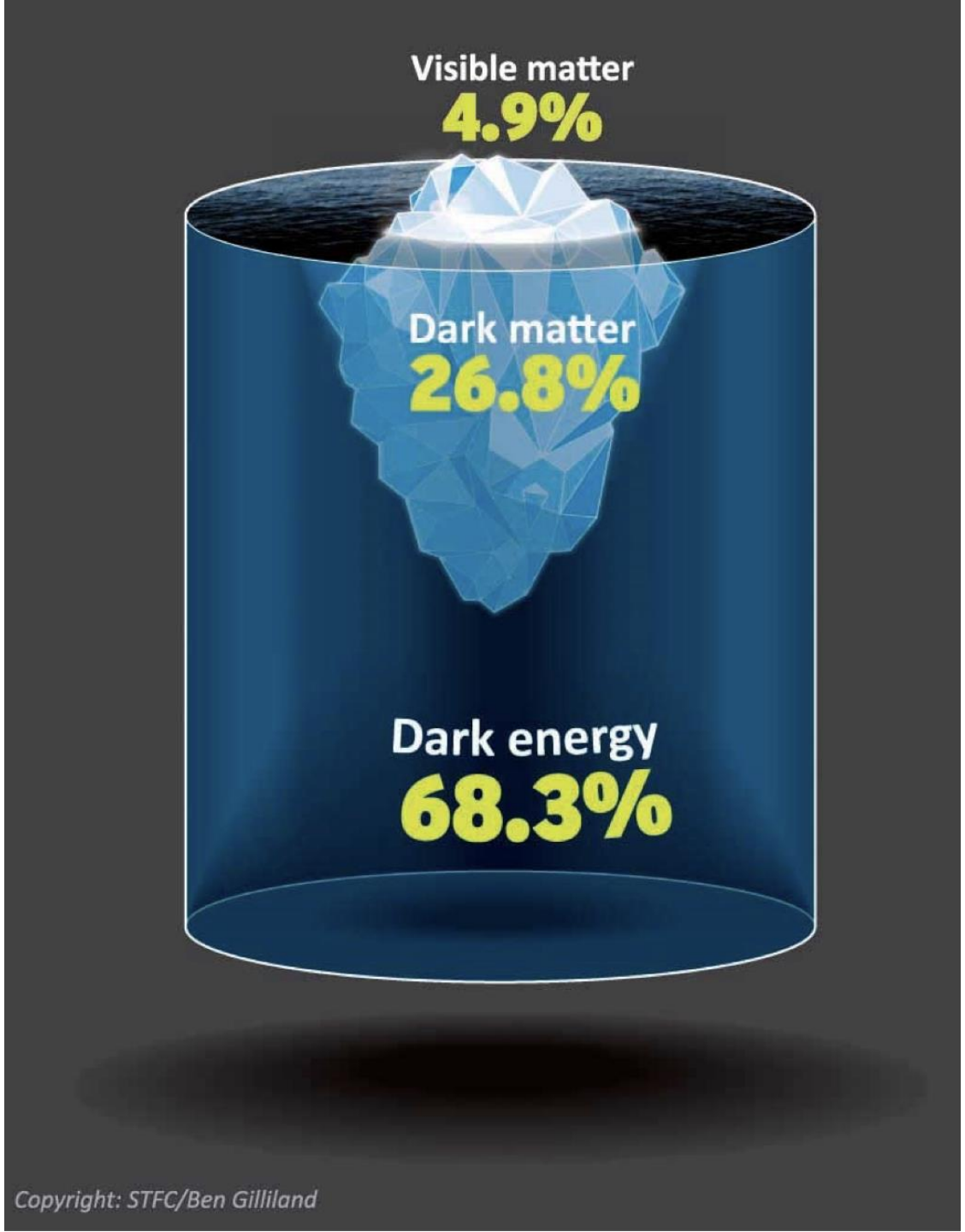
The Higgs boson

Image: Jorge Cham / PhD Comics

Zero mass particle (photon)

The search for new particles (dark matter?)

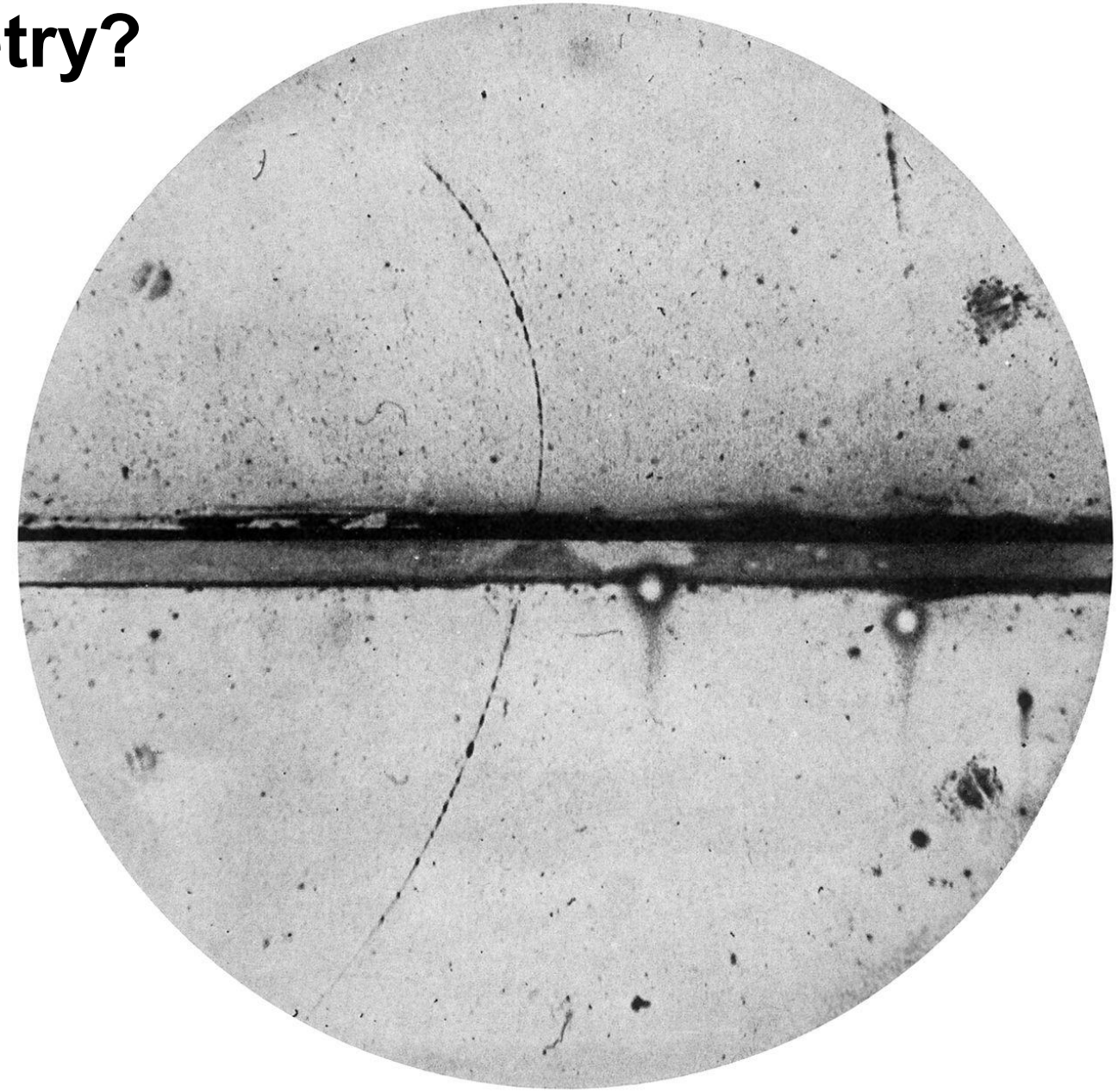




The search for

Illustration by Sandbox Studio, Chicago with Ana Kova for Symmetry magazine

Matter-Antimatter asymmetry?



The Strength of Gravity?

- Is there a graviton?
- Are there extra dimensions that gravity is leaking into?
- What is the strength of gravity for antimatter?

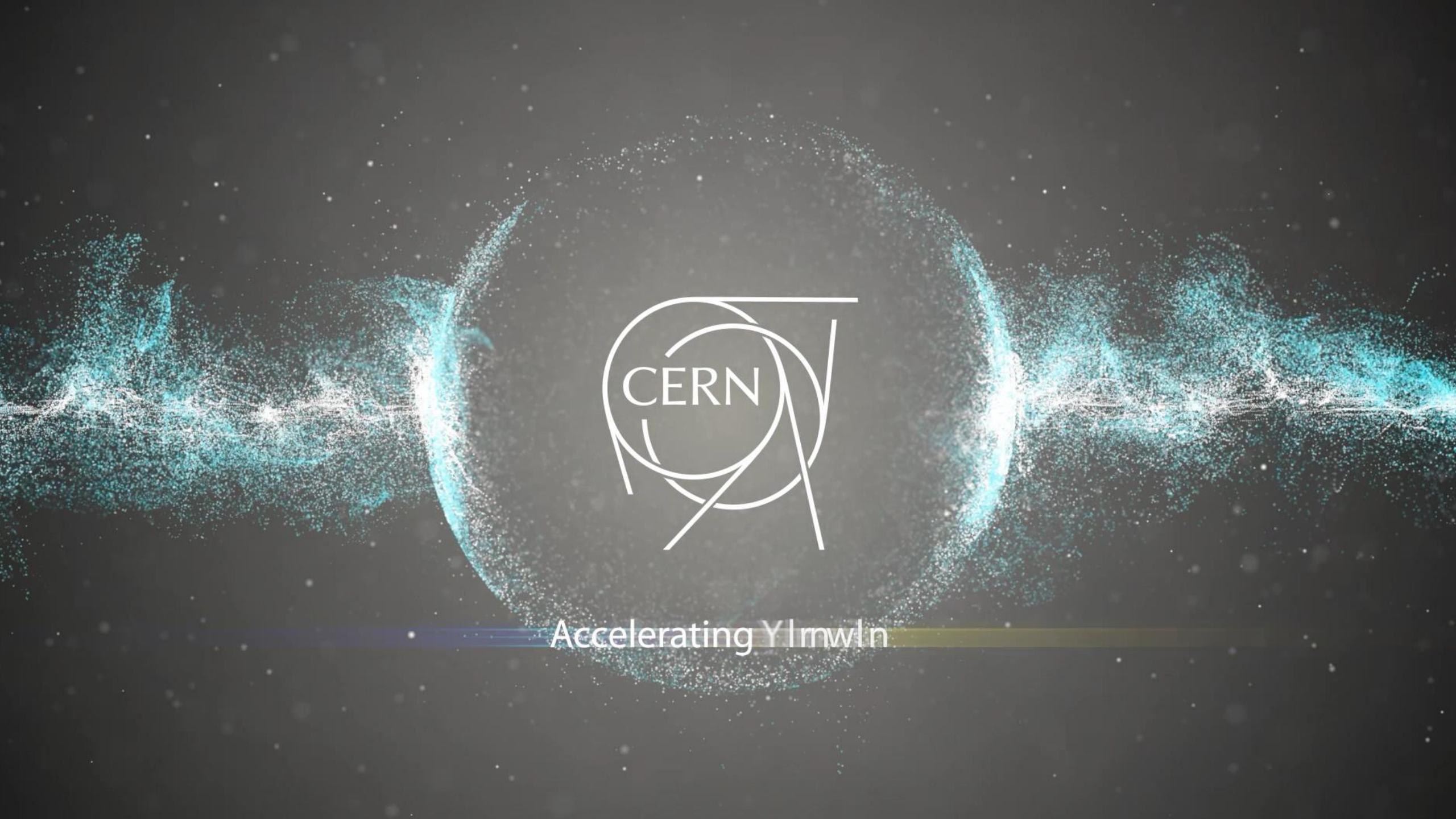
Neutrino note

Not going to talk much about them today because in LHC physics, we mostly just deal with them as missing momentum in our data.

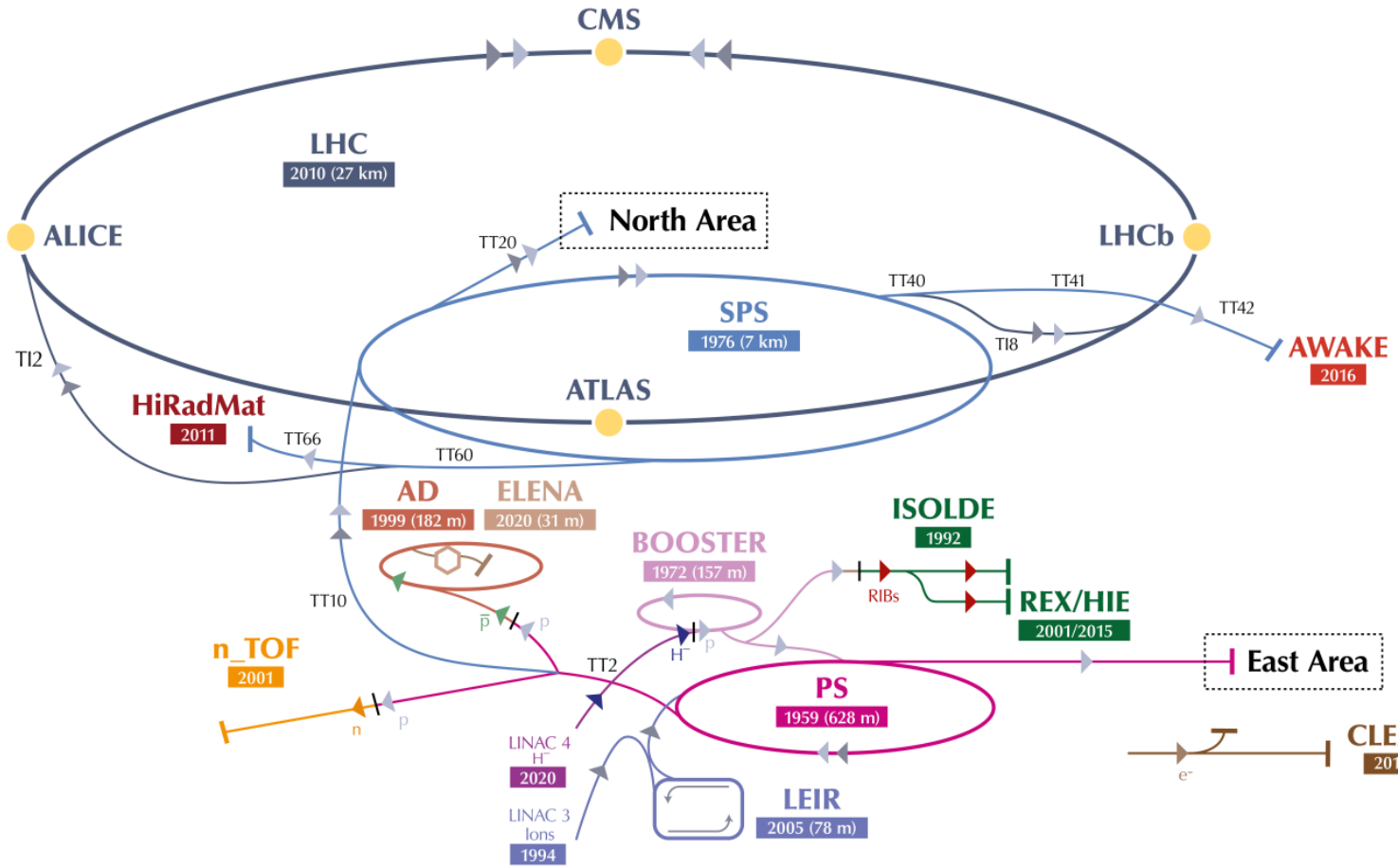
But, there are big questions still: **What are the neutrino masses** and **where do they get their mass from**?

We still don't know.

So how do we go about answering these questions?


CERN
Accelerating

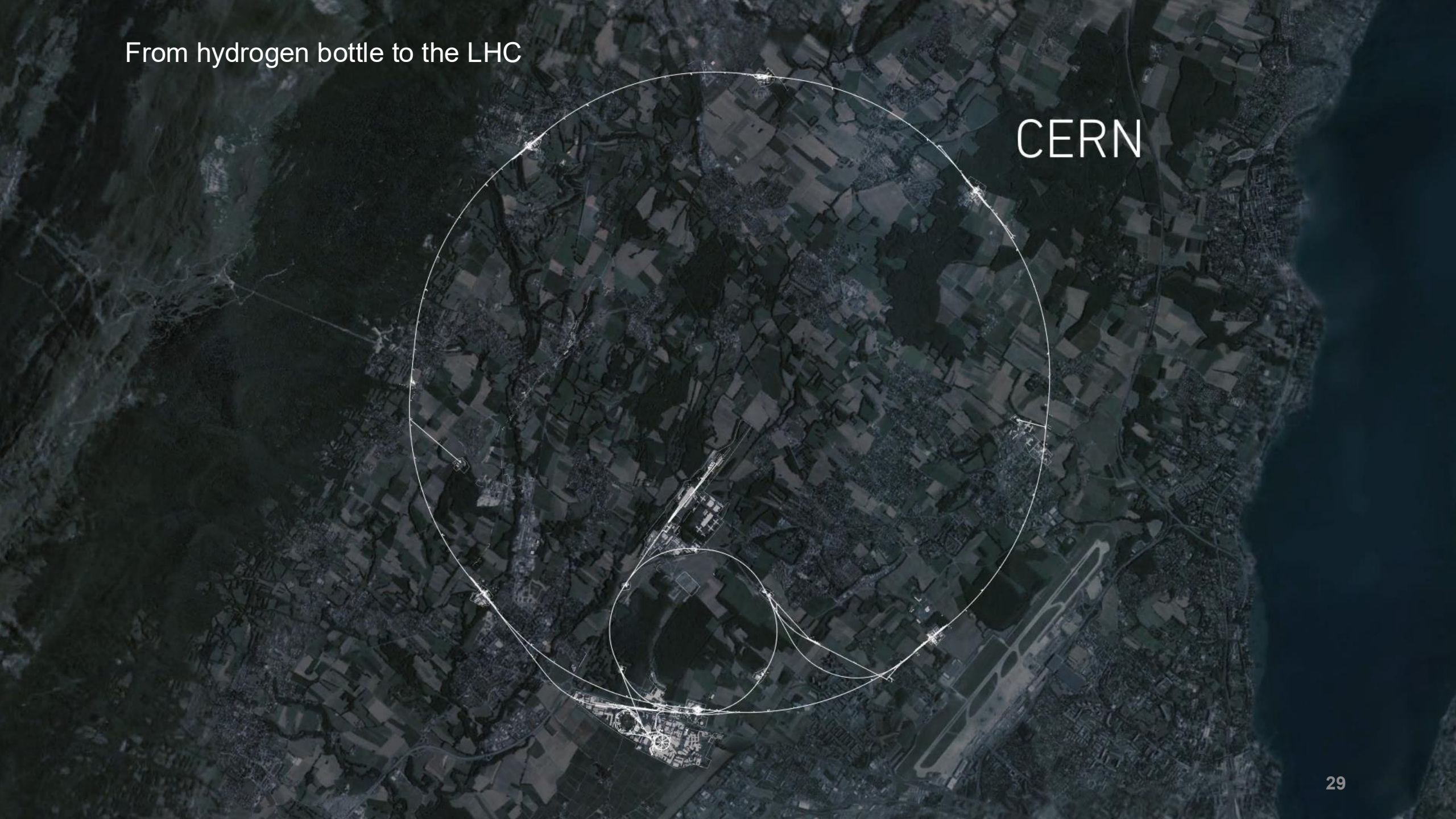
The CERN accelerator complex
Complexe des accélérateurs du CERN



H⁻ (hydrogen anions) · p (protons) · ions · RIBs (Radioactive Ion Beams) · n (neutrons) · $\bar{p}$ (antiprotons) · e^- (electrons)

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 - Radioactive EXperiment/High Intensity and Energy ISOLDE // LEIR - Low Energy Ion Ring // LINAC - LINear ACcelerator // n_TOF - Neutrons Time Of Flight // HiRadMat - High-Radiation to Materials

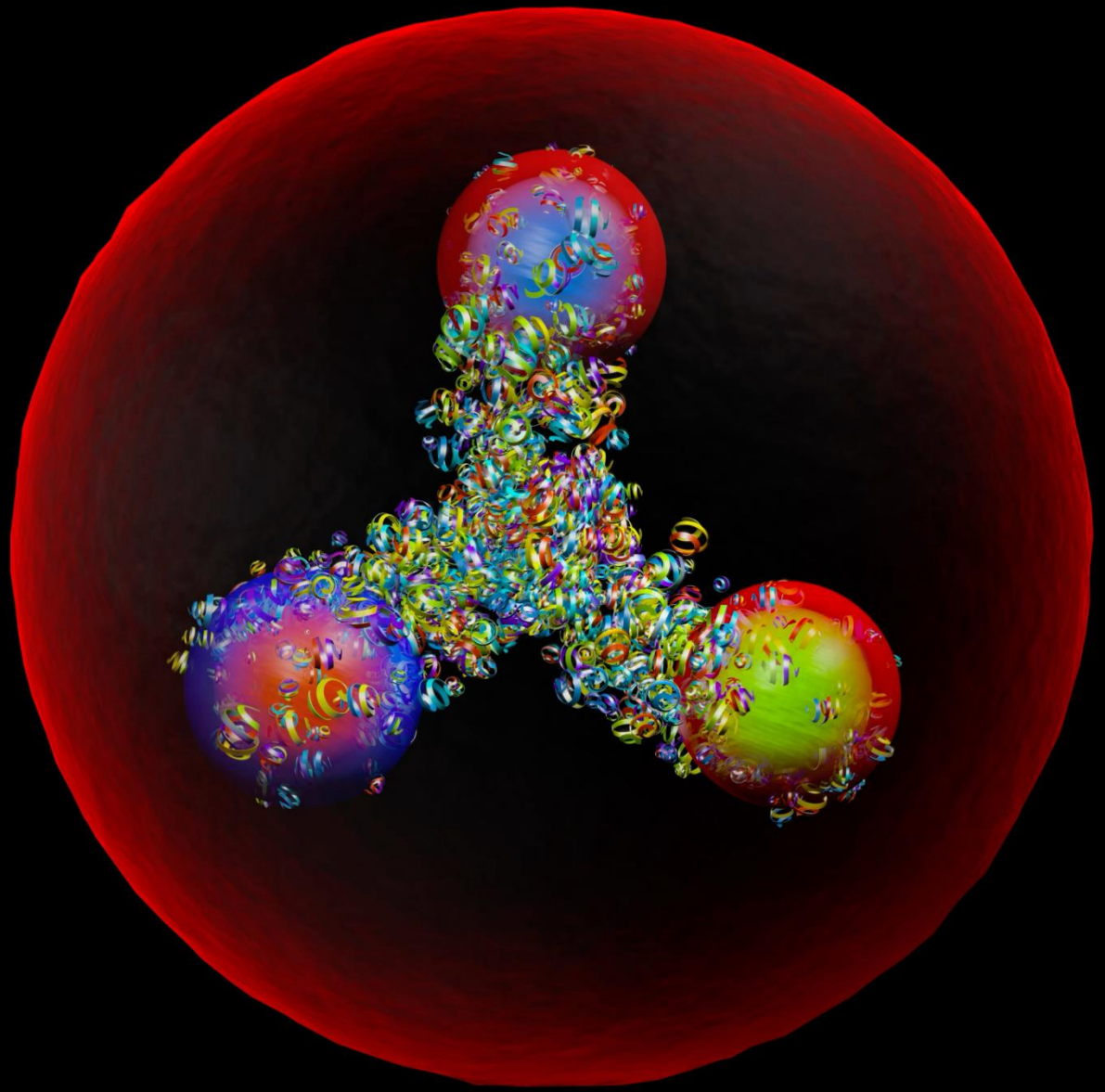
From hydrogen bottle to the LHC



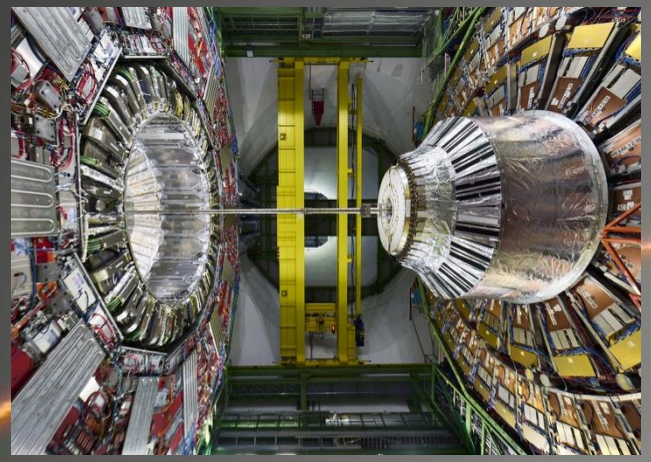

Colder than outer space!

Superconducting magnets

Colliding protons



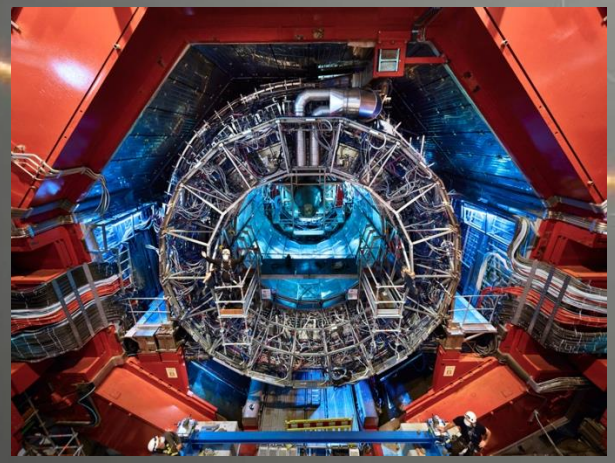
The LHC detectors



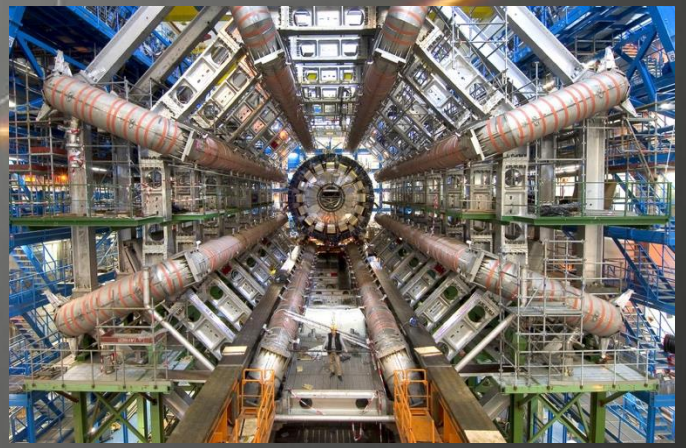
CMS

LHCb

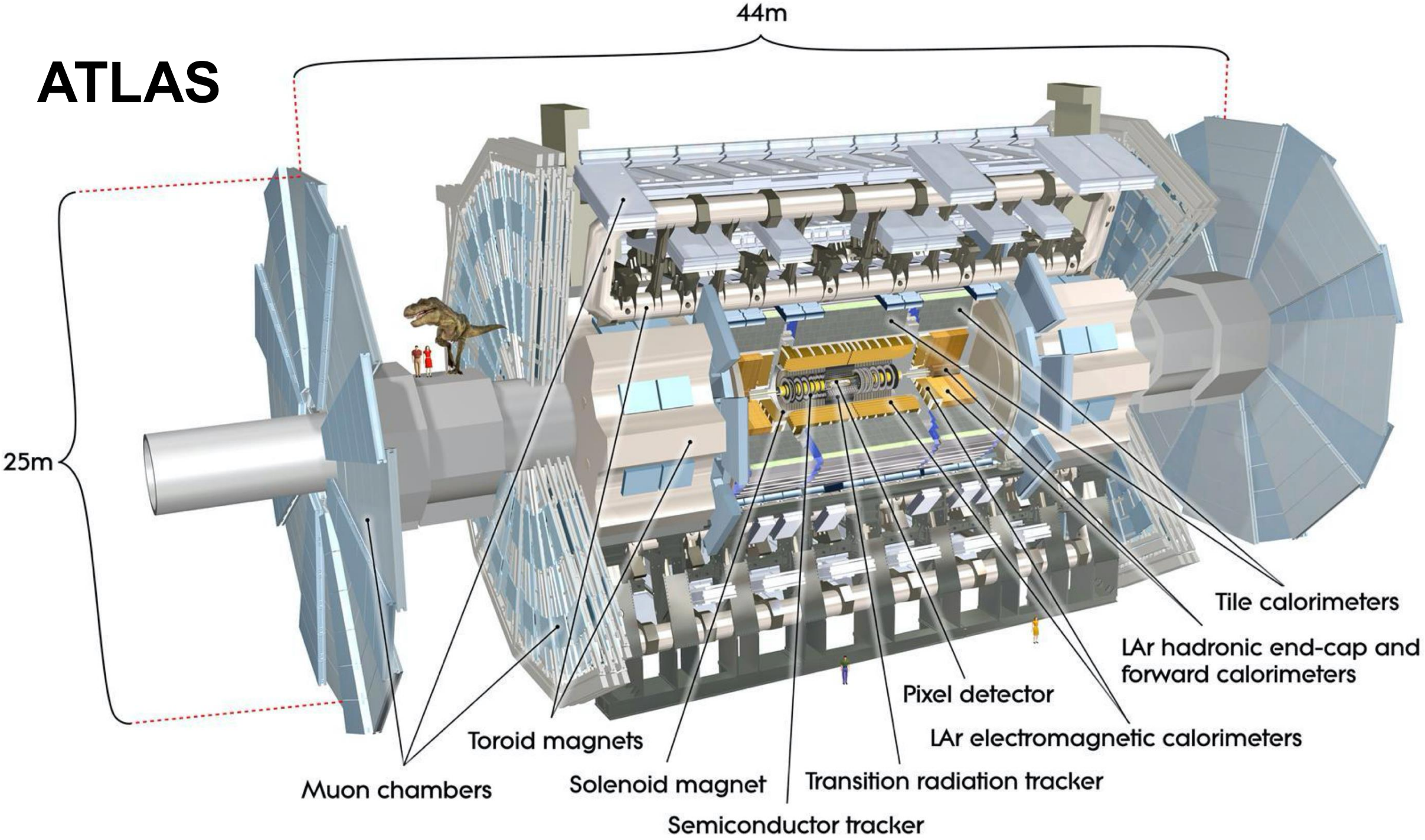
ALICE

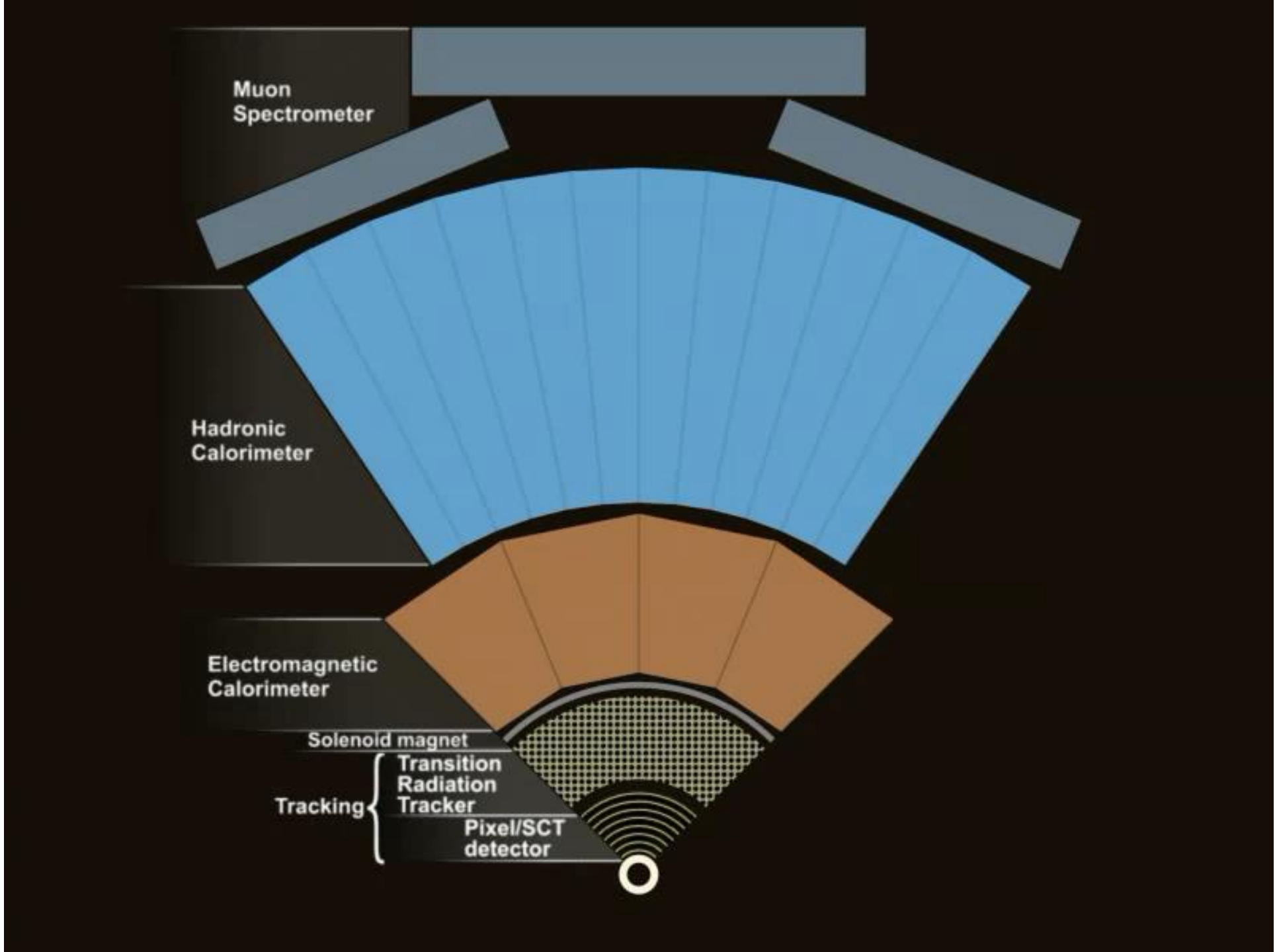


ATLAS



ATLAS


44m
25m
Tile calorimeters
LAr hadronic end-cap and forward calorimeters
Pixel detector
LAr electromagnetic calorimeters
Toroid magnets
Muon chambers
Solenoid magnet
Transition radiation tracker
Semiconductor tracker

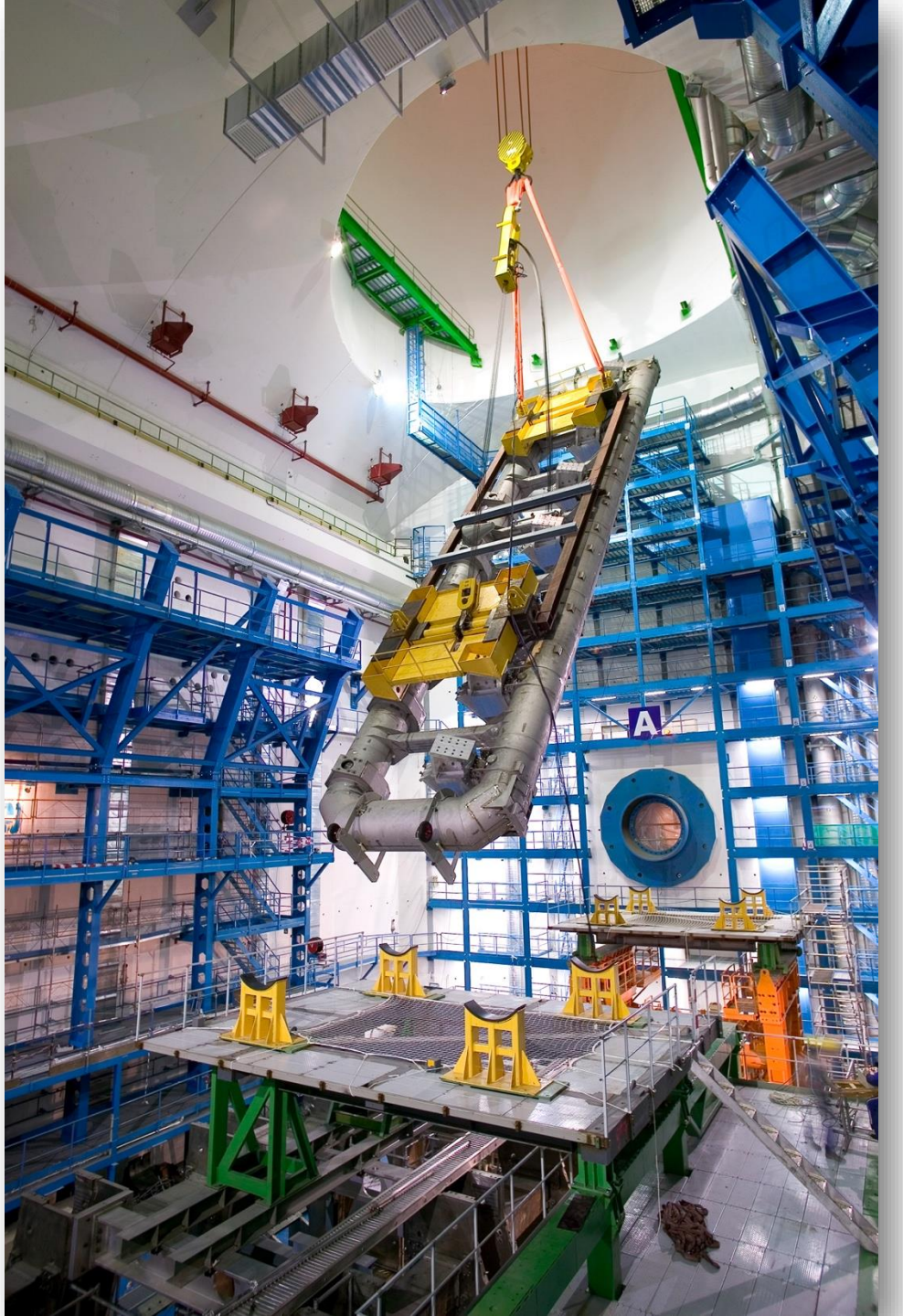

Muon
Spectrometer
Hadronic
Calorimeter
Electromagnetic
Calorimeter
Solenoid magnet
Tracking
Transition
Radiation
Tracker
Pixel/SCT
detector

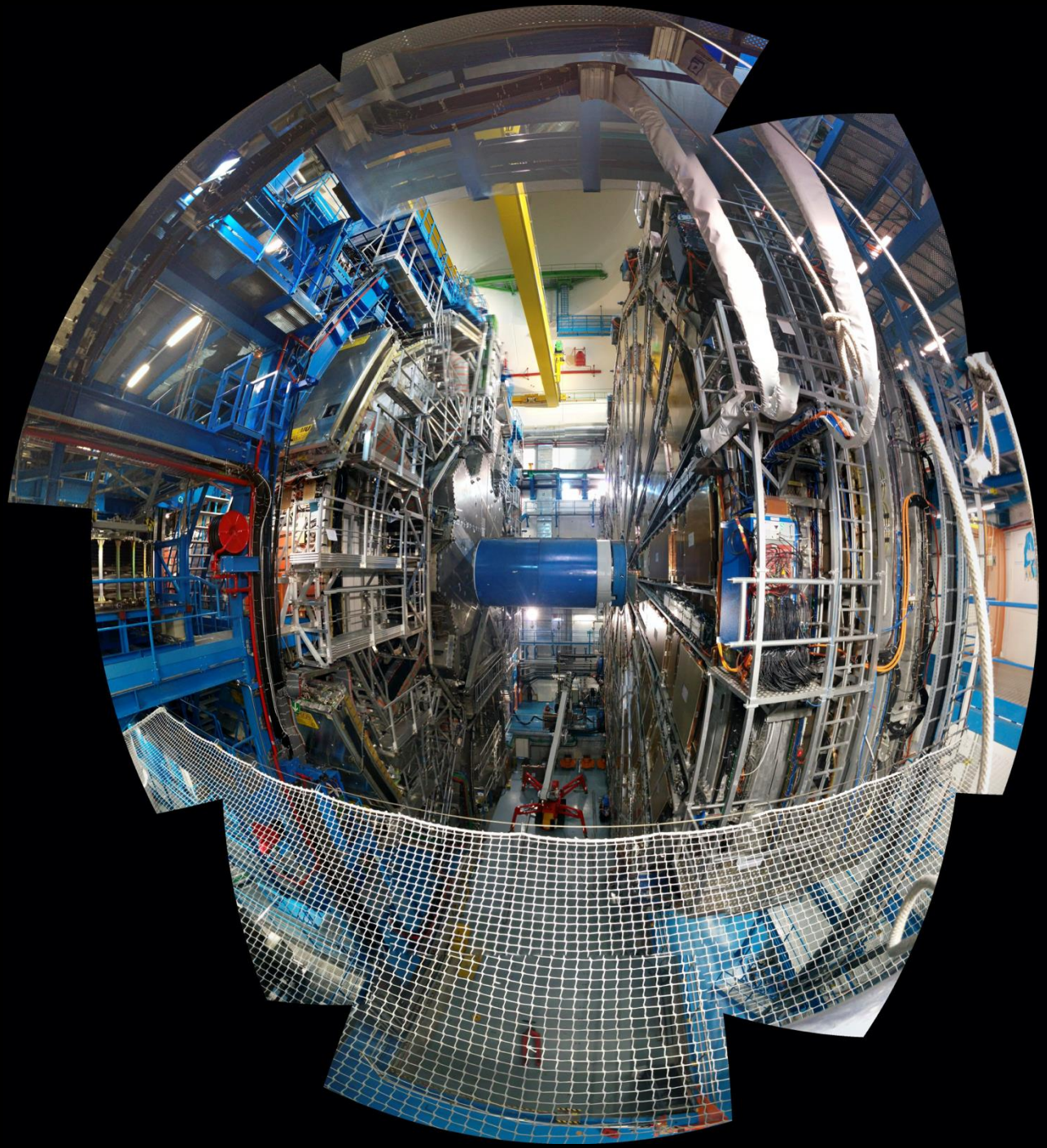
2002

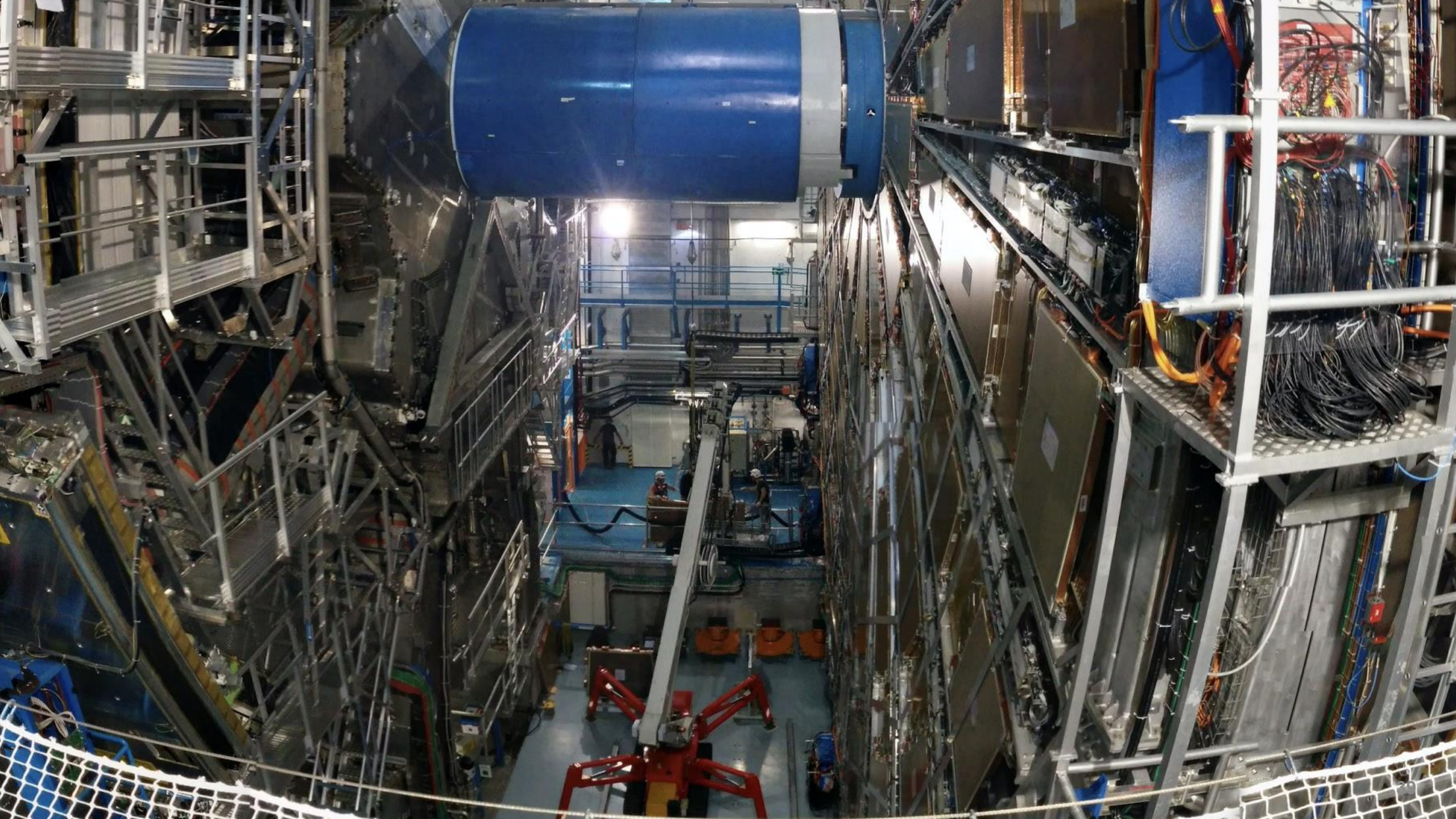
ATLAS Installation in the cavern

2004

ATLAS Installation in the cavern





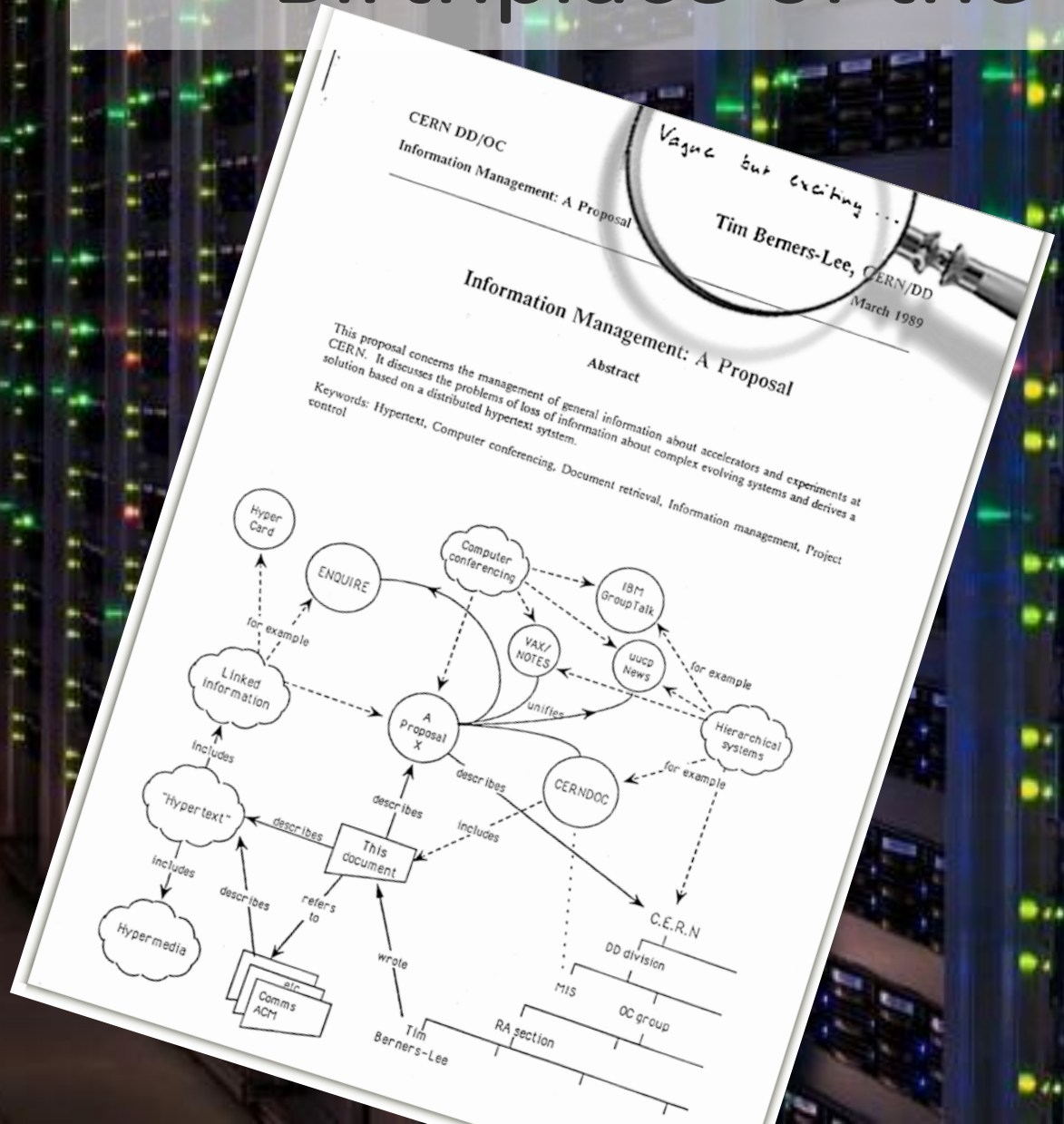



Status: November 2018
Albania
Algeria
Argentina
Armenia
Australia
Austria
Azerbaijan
Bangladesh
Belarus
Belgium
Bosnia and Herzegovina
Botswana
Brazil
Bulgaria
Burundi
Canada
Chile
China
Colombia
Costa Rica
Croatia
Cuba
Cyprus
Czech Republic
Denmark
Ecuador
Egypt
Finland
France
Georgia
Germany
Ghana
Greece
Honduras
Hong Kong
Hungary
Iceland
India
Indonesia
Iran
Iraq
Ireland
Israel
Italy
Japan
Jordan
Kazakhstan
Kenya
Kyrgyzstan
Latvia
Lebanon
Lithuania
Luxembourg
Madagascar
Malaysia
Malta
Mauritius
Mexico
Mongolia
Montenegro
Morocco
Nepal
Netherlands
New Zealand
Niger
Nigeria
Norway
Pakistan
Palestine
Peru
Philippines
Poland
Portugal
Romania
Russia
Saudi Arabia
Senegal
Serbia
Slovakia
Slovenia
South Africa
South Korea
Spain
Sri Lanka
Sudan
Swaziland
Sweden
Switzerland
Syria
Taiwan
Thailand
Tunisia
Turkey
Ukraine
UAE
UK
USA
Uruguay
Uzbekistan
Venezuela
Vietnam
Zambia
Zimbabwe
ATLAS Collaboration member nationalities
Over 5500 members of 103 nationalities
ATLAS EXPERIMENT


LHCb


ATLAS
EXPERIMENT

Birthplace of the World Wide Web



Birthplace of the World Wide Web

Vague but exciting ...

D/OC

on Management: A Proposal

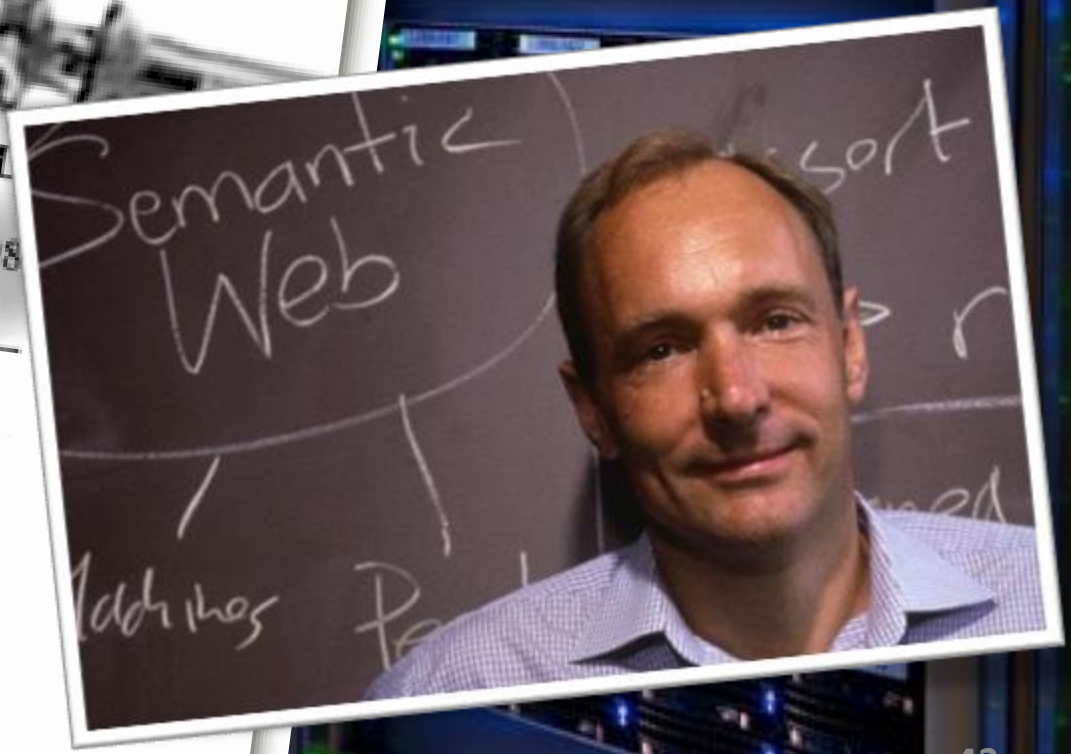
Tim Berners-Lee, CERN/D

March 198

Information Management: A Proposal

Abstract

ncerns the management of general information about accelerators and experiments at
es the problems of loss of information about complex evolving
a distributed hypertext sytstem.



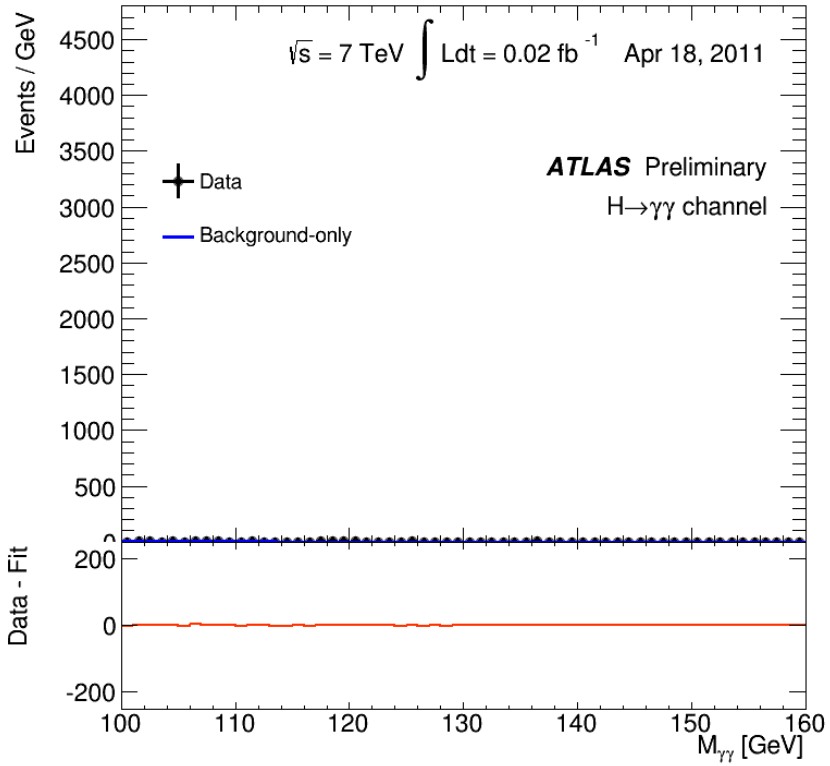

600 million collisions
every second

2012

The discovery of a new boson!

The Higgs boson – a major success of the first LHC run.

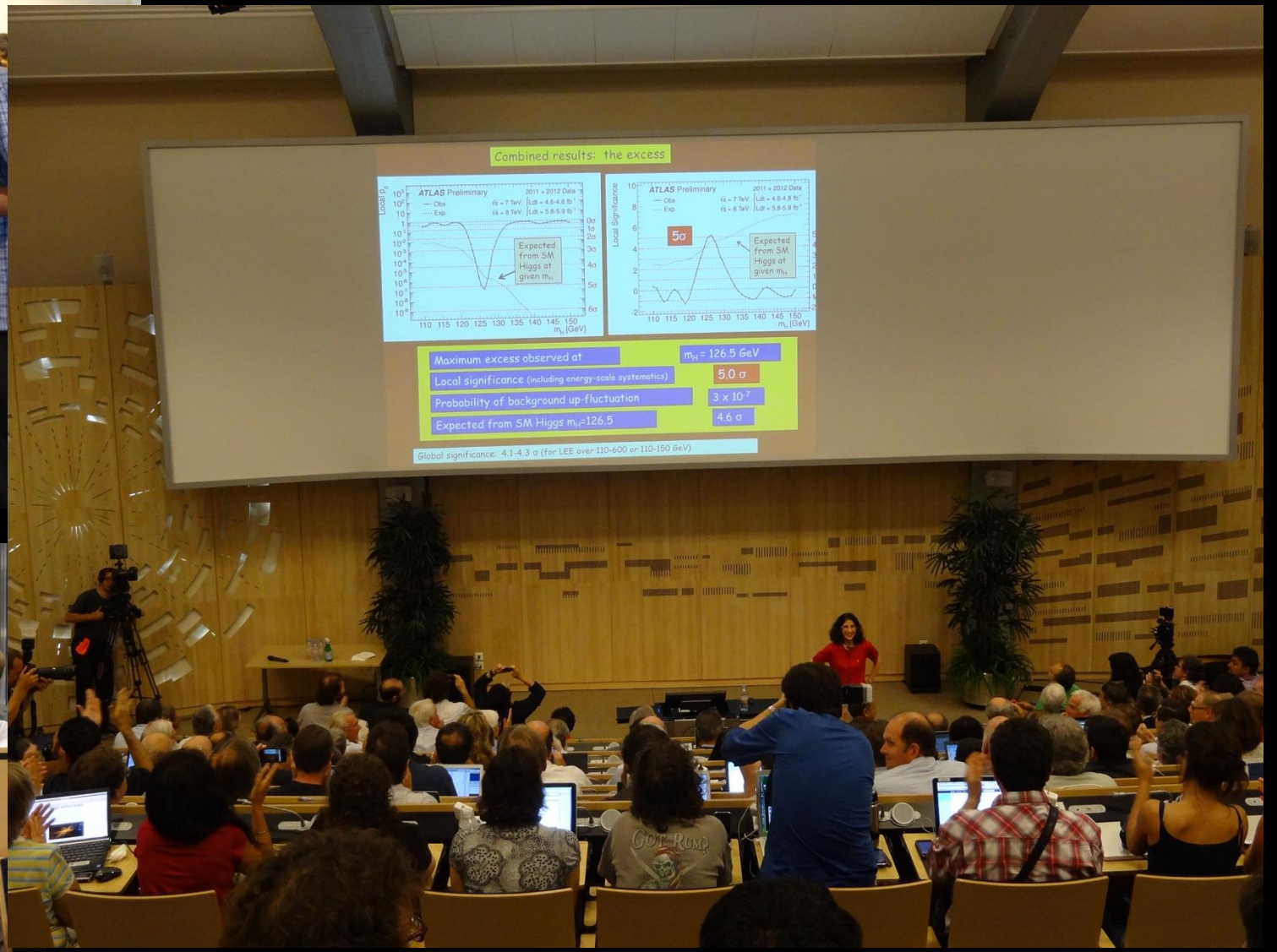
Image: Jorge Cham / PhD Comics



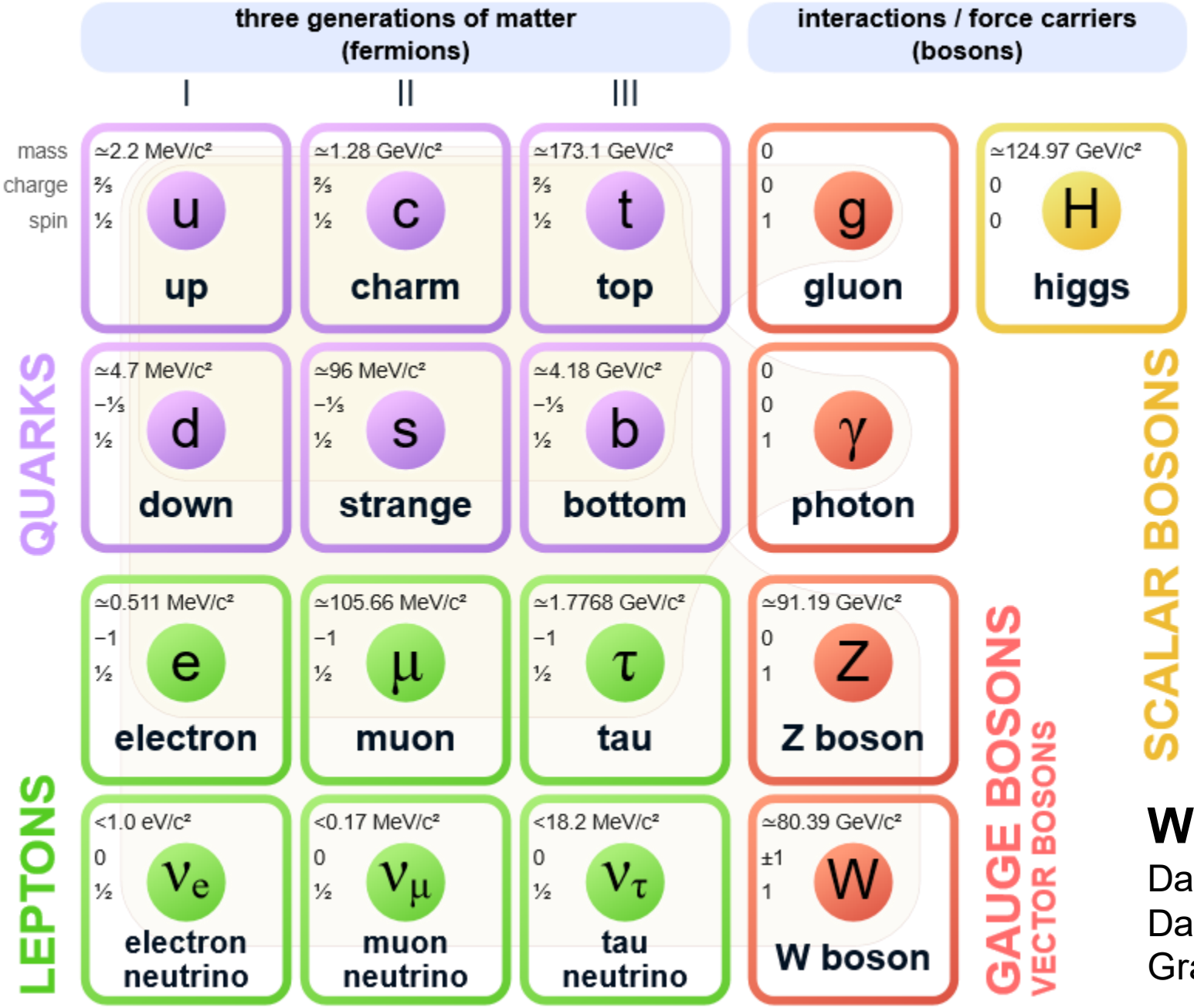
Physicists Find Elusive Particle Seen as Key to Universe

By **DENNIS OVERBYE** JULY 4, 2012

Scientists in Geneva on Wednesday applauded the discovery of a subatomic particle that looks like the Higgs boson. Pool photo by Denis Balibouse


Combined results: the excess
ATLAS Preliminary
2011 + 2012 Data
Obs.
Exp.
√s = 7 TeV ∫Ldt = 4.6-4.8 fb⁻¹
√s = 8 TeV ∫Ldt = 5.8-5.9 fb⁻¹
Expected from SM Higgs at given m_H
Local p_0
Local Significance
5σ
m_H [GeV]
Maximum excess observed at
m_H = 126.5 GeV
Local significance (including energy-scale systematics)
5.0 σ
Probability of background up-fluctuation
3 x 10⁻⁷
Expected from SM Higgs m_H=126.5
4.6 σ
Global significance: 4.1-4.3 σ (for LEE over 110-600 or 110-150 GeV)

The Standard Model (today)

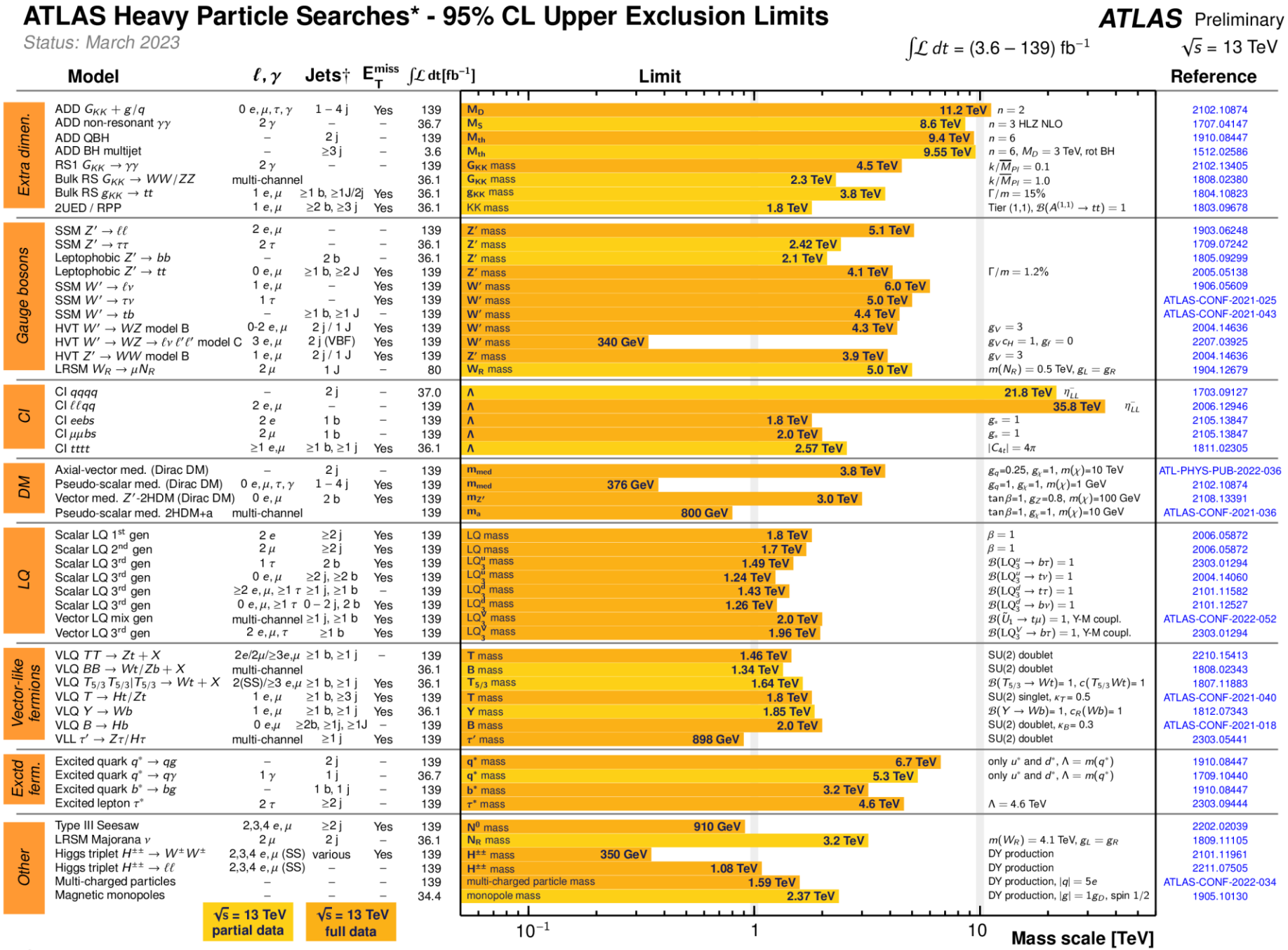


What's missing?

Dark matter
Dark energy
Gravity!

So, we keep searching

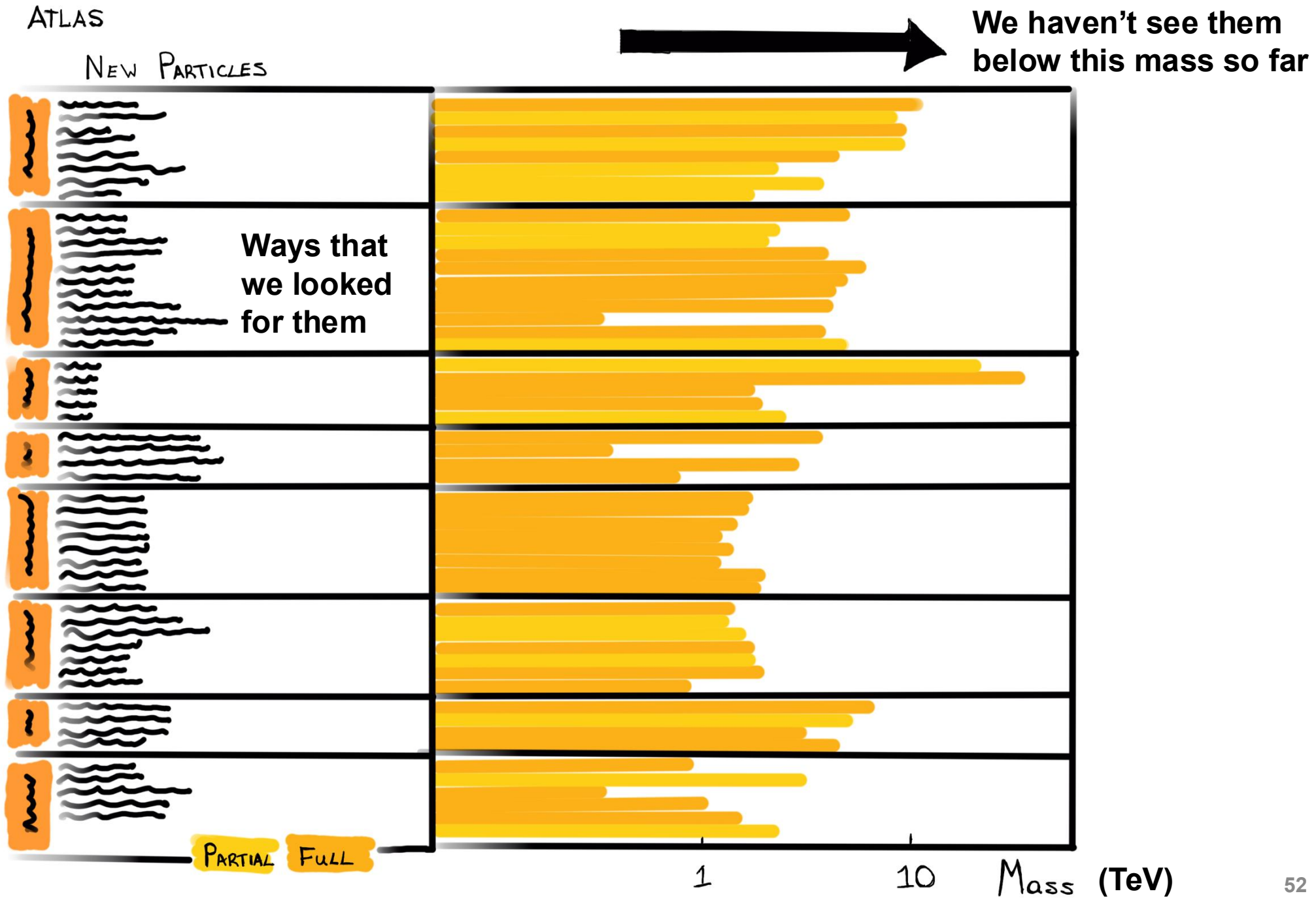
Searches

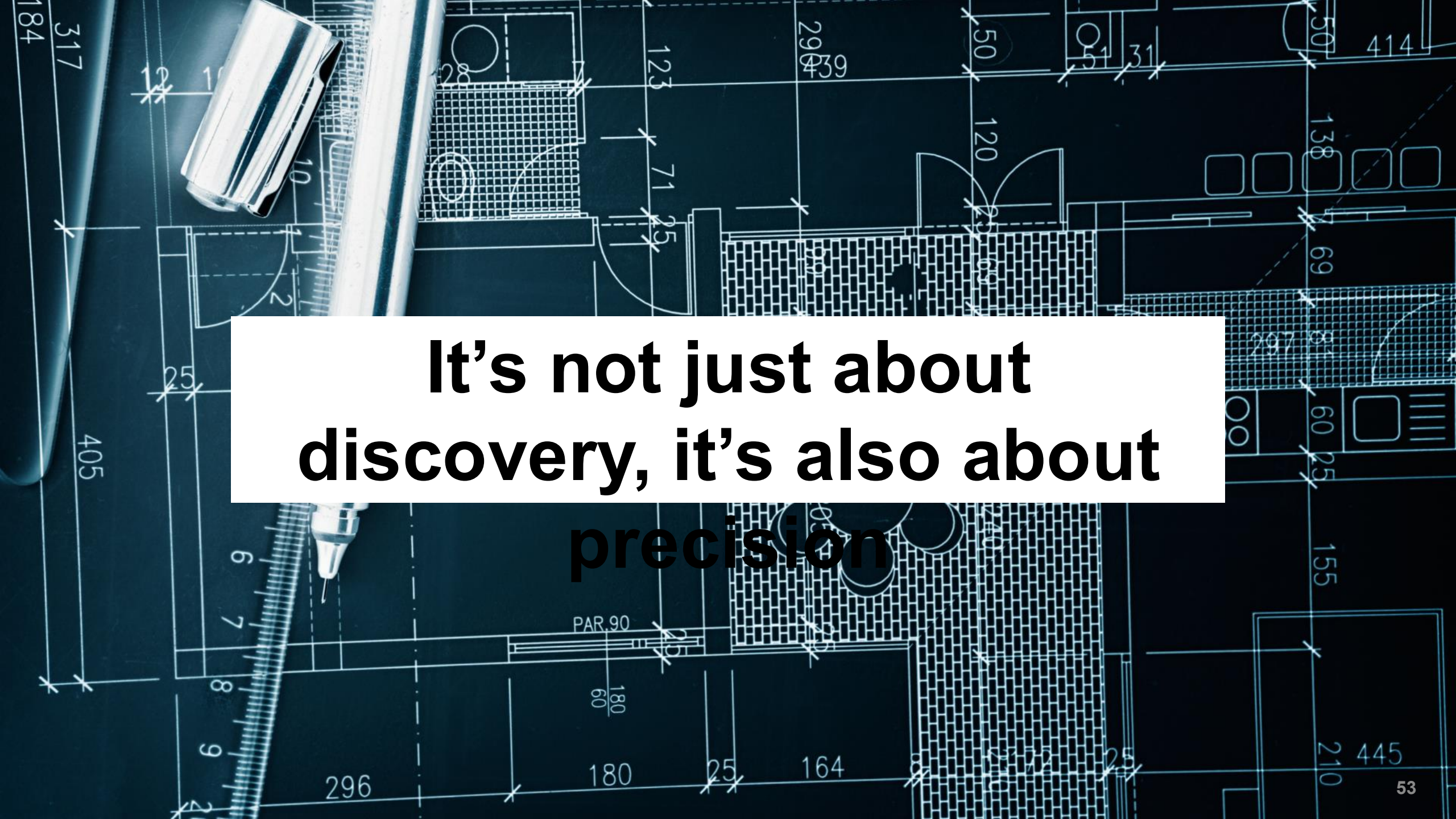


*Only a selection of the available mass limits on new states or phenomena is shown.

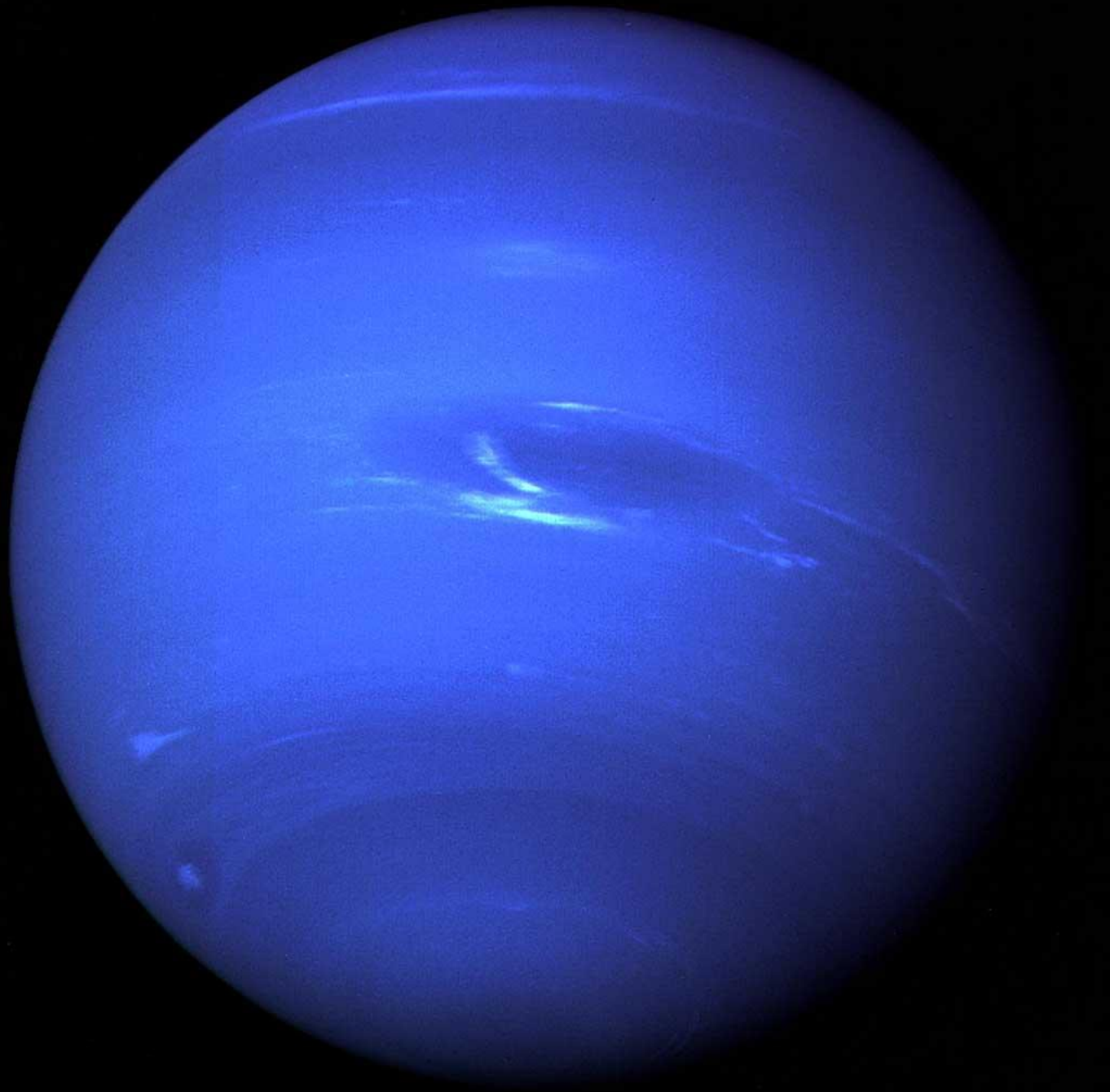
†Small-radius (large-radius) jets are denoted by the letter j (J).

Searches


ATLAS
NEW PARTICLES
We haven't see them below this mass so far
Ways that we looked for them
PARTIAL
FULL
1
10
Mass (TeV)



It’s not just about discovery, it’s also about precision

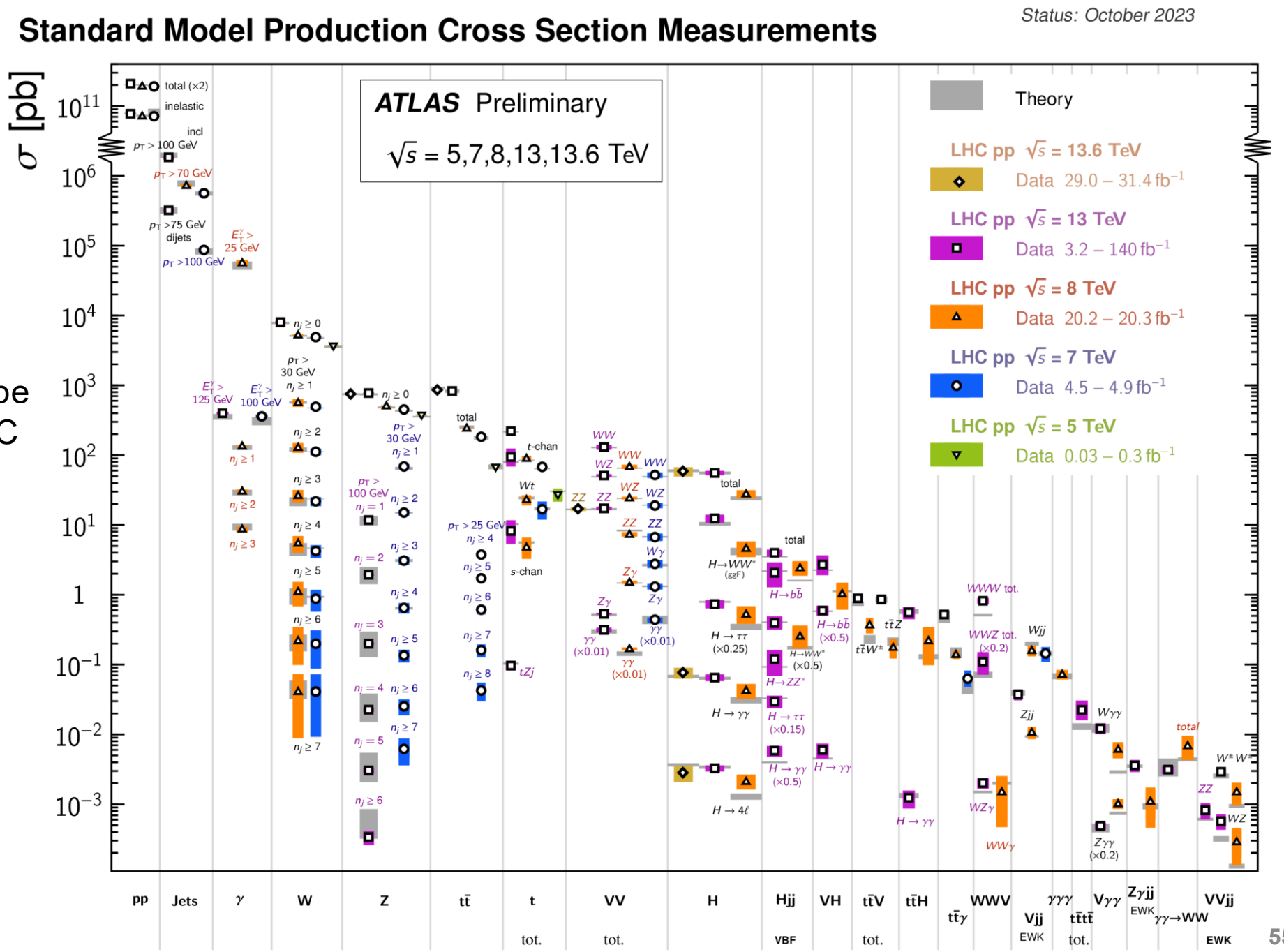


NASA/JPL-Caltech

Precision measurements

How likely a process is to be created in LHC collisions

A rarer process

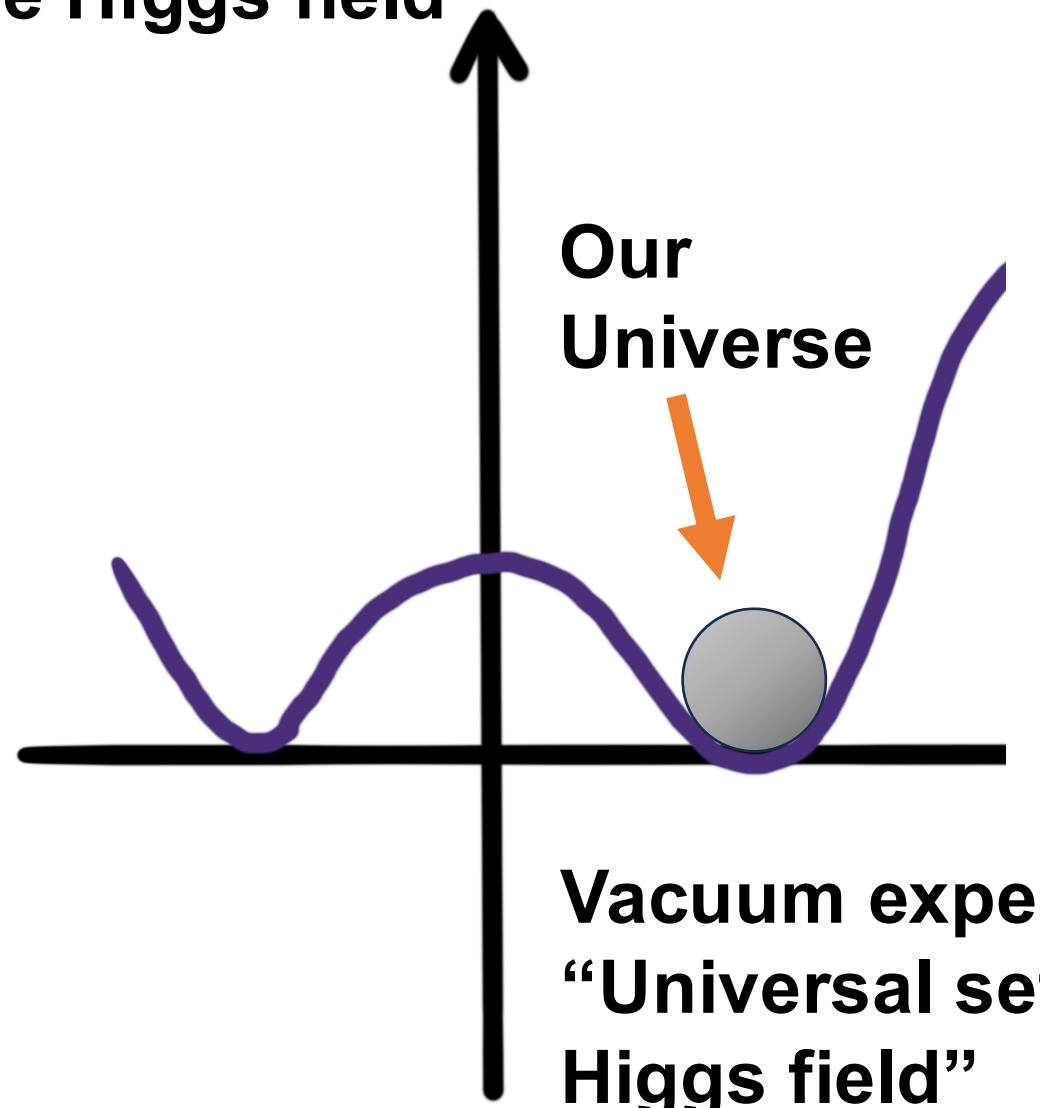


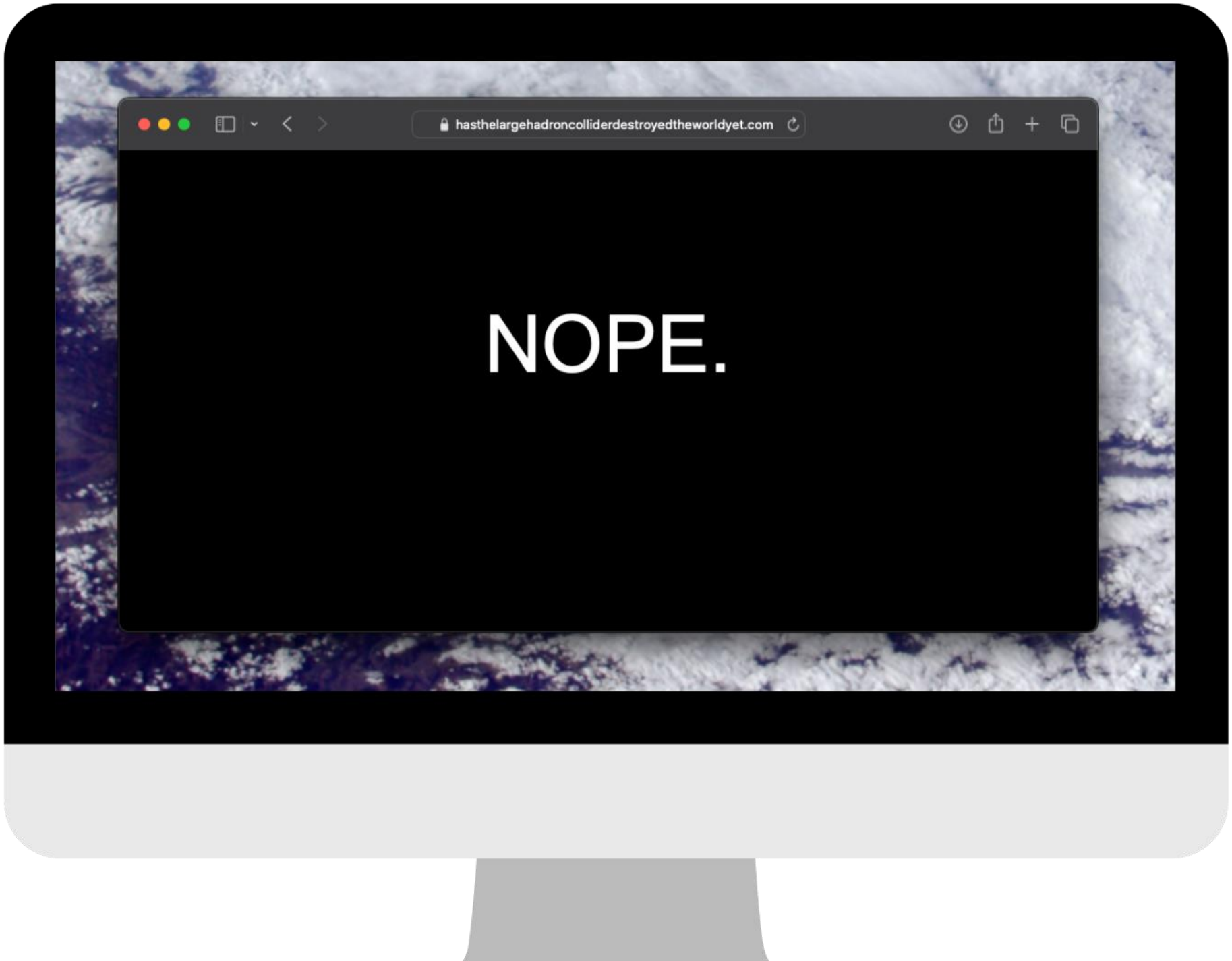
The stability of the universe depends on it!

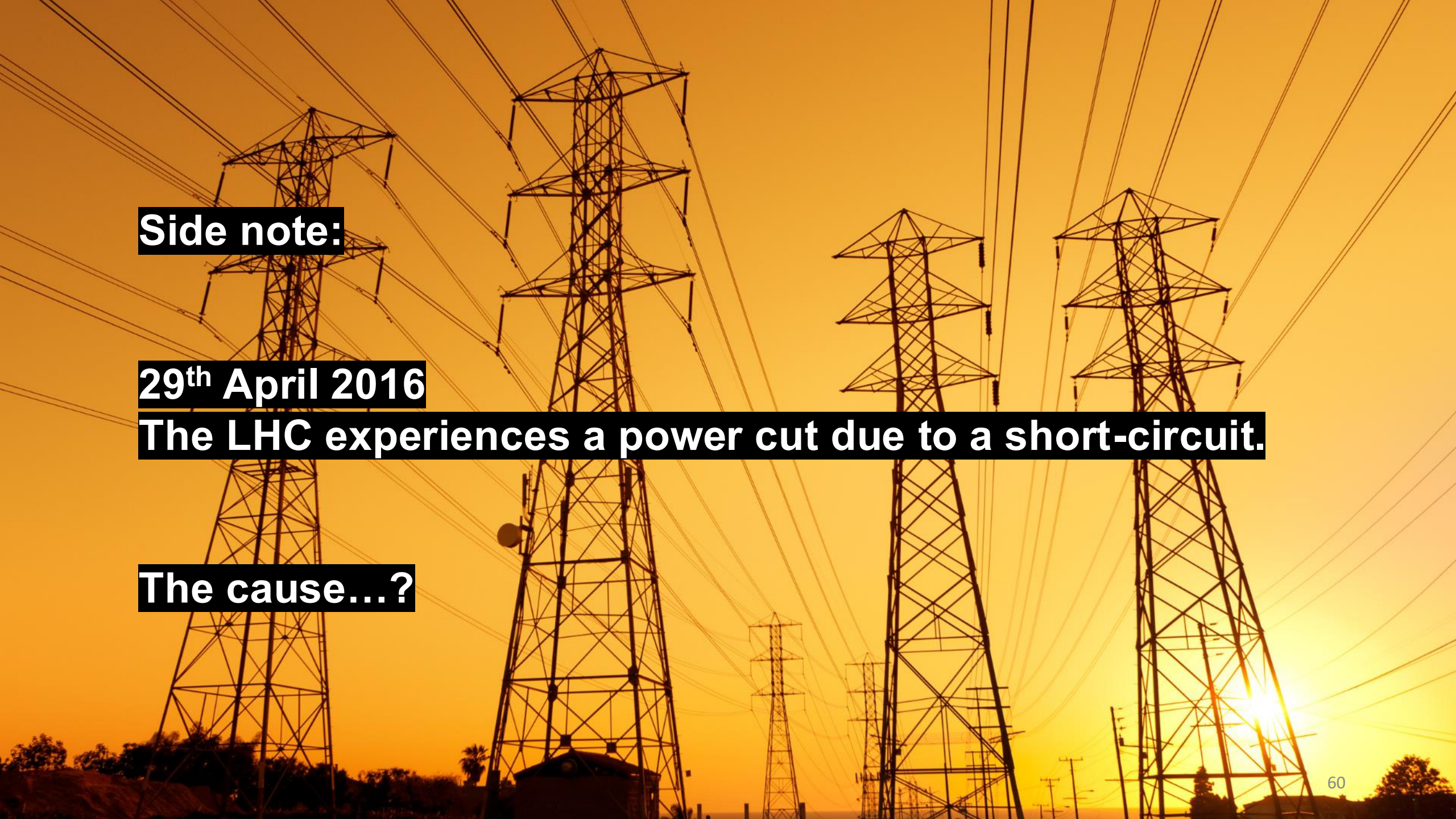
Please note:

measuring this at CERN doesn’t affect the stability.
We’re a passive observer :)

Potential energy density of the Higgs field




hasthelargehadroncolliderdestroyedtheworldyet.com
NOPE.



Side note:

29th April 2016
The LHC experiences a power cut due to a short-circuit.

The cause…?


Illustration purposes only.
A pine marten!

Illustration purposes only.

Large Hadron Collider on paws after creature chews through wiring

The Guardian

LHC to be out of action for a week while connections to transformer are replaced following visit from hungry fouine

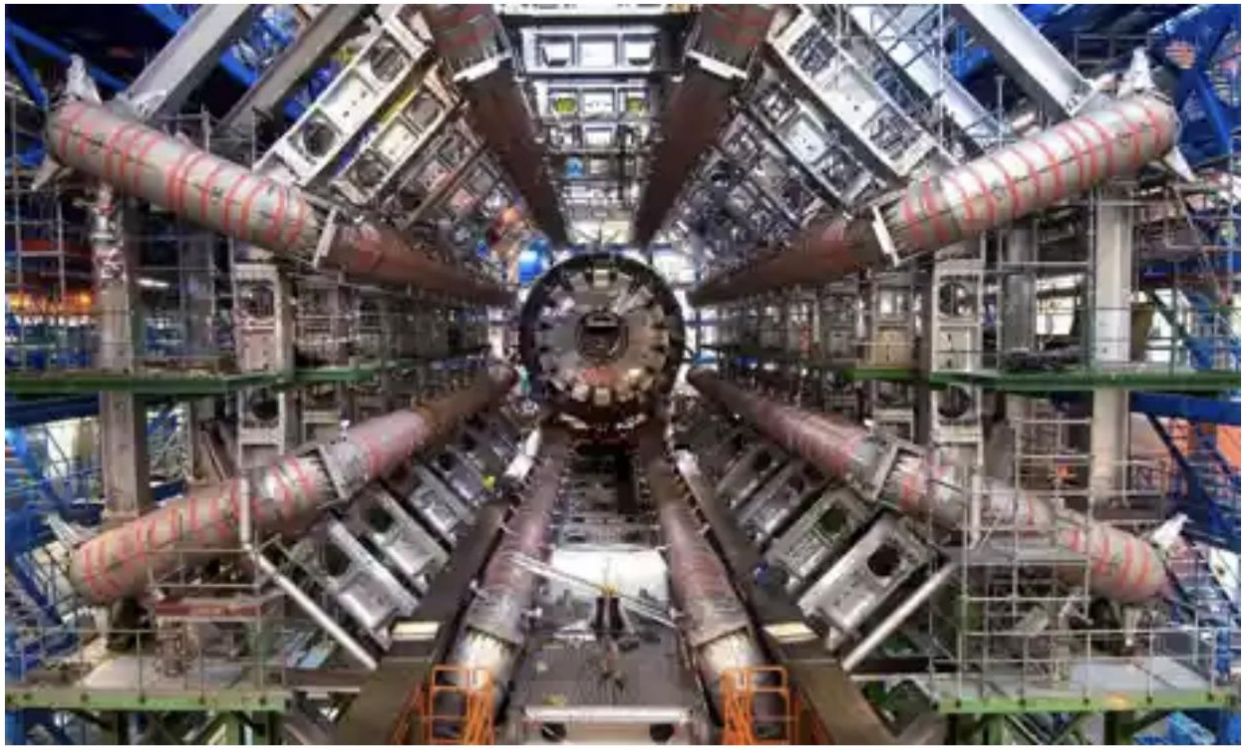
A young beech marten, or fouine. Photograph: Alamy

The world's largest and most powerful particle accelerator has been brought to its knees by a beech marten, a member of the weasel family, that chewed through wiring connected to a 66,000-volt transformer.

Big bang goes phut as bird drops baguette into Cern machinery

The Guardian

- **Hadron collider halted again by power cut**
- **Scientists stop testing for relaunch after fowl play**



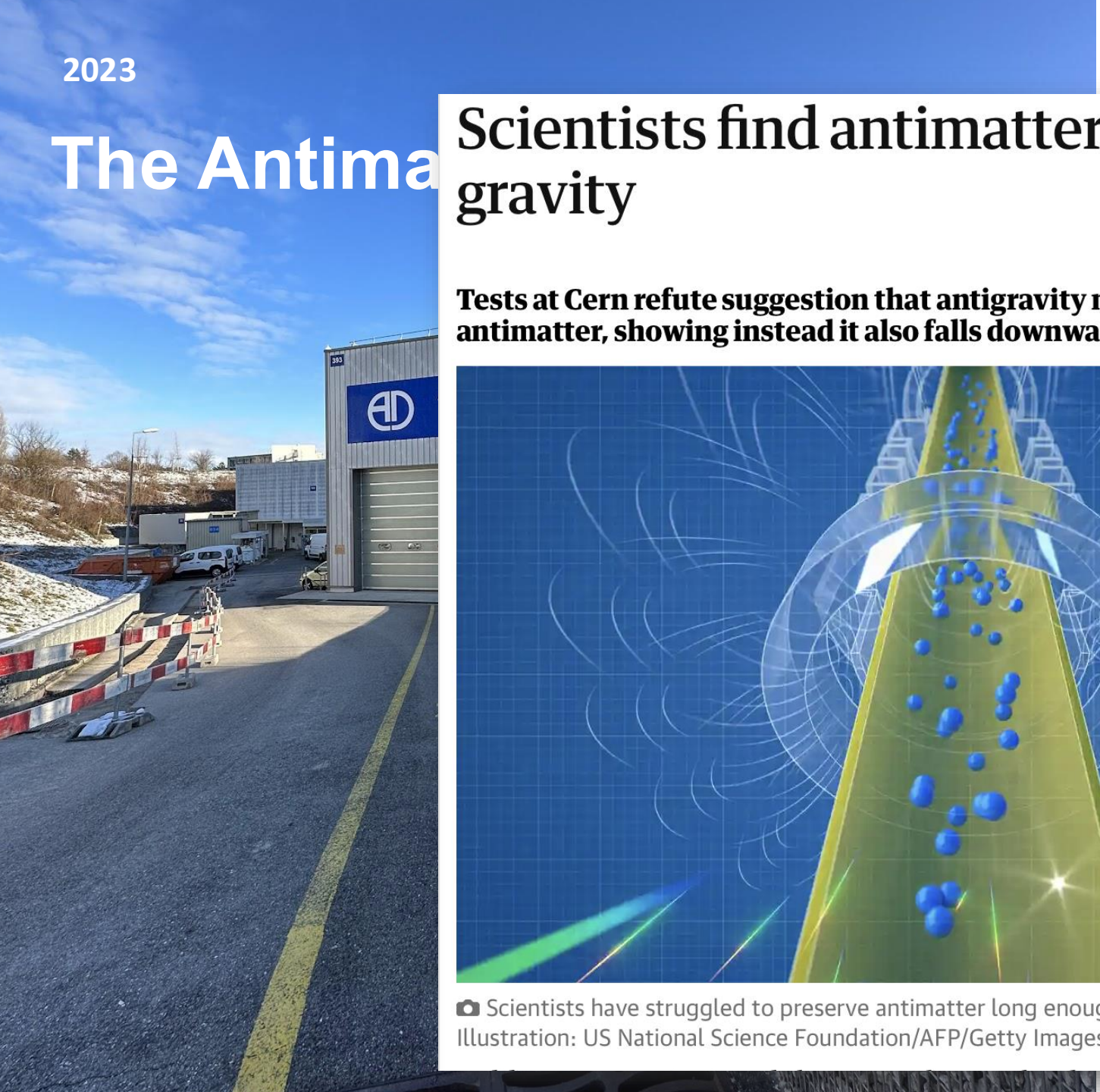
Cern: View from the central axis of the LHC (Large Hadron Collider) tunnel of the ATLAS underground facility with the eight toroids surrounding the calorimeter

It is the machine that scientists hope will recreate the conditions present at the beginning of time. But scientists at the £3.6bn Large Hadron Collider (LHC) found their plans to emulate the big bang postponed this week when a passing bird dropped a "bit of baguette" into the machine, causing it to overheat.

2023

The Antima

ore antimatter roperties



Scientists find antimatter is subject to gravity

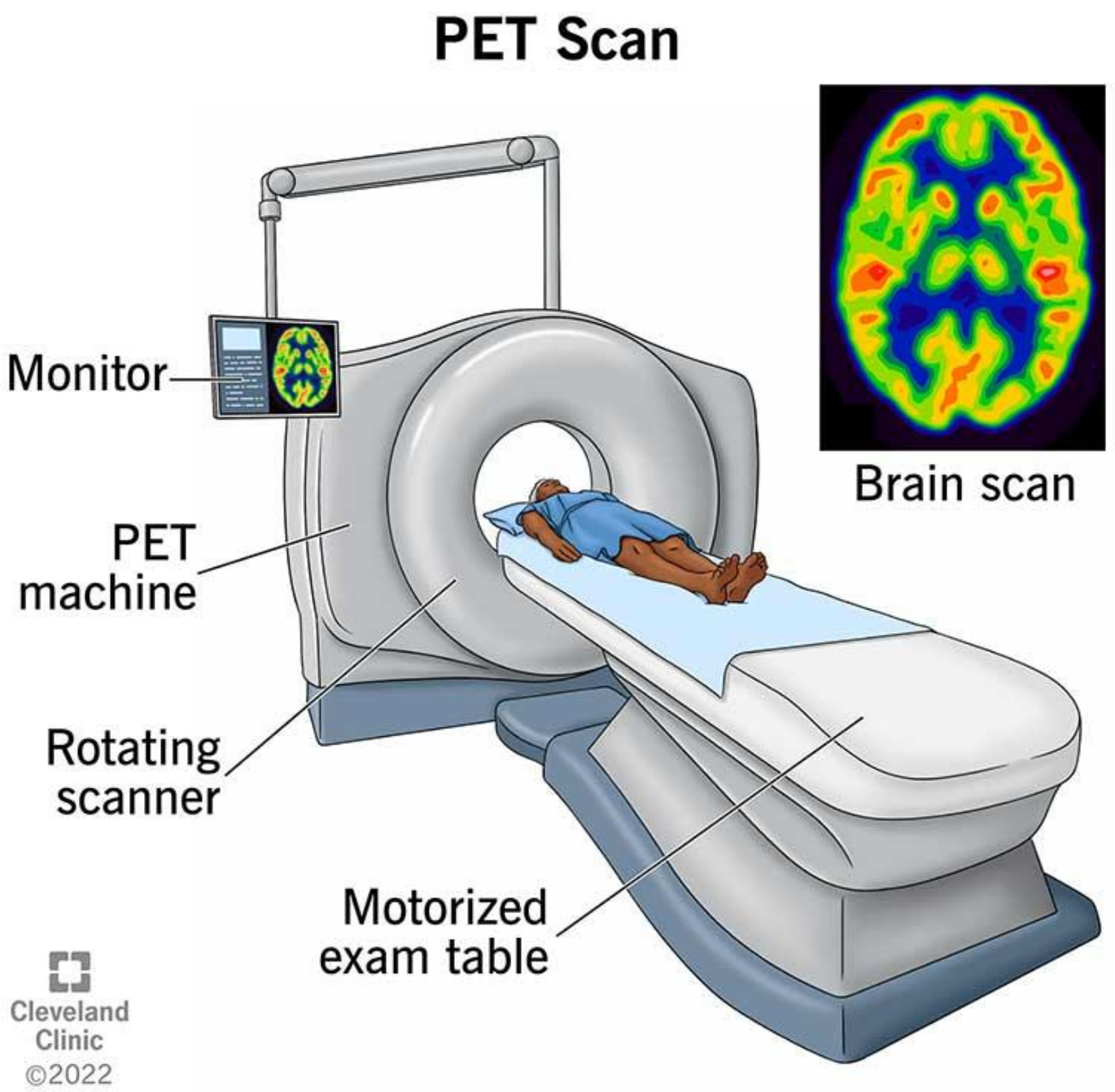
Tests at Cern refute suggestion that antigravity might apply to antimatter, showing instead it also falls downwards

Scientists have struggled to preserve antimatter long enough to carry out experiments on it. Illustration: US National Science Foundation/AFP/Getty Images

How does this affect you?

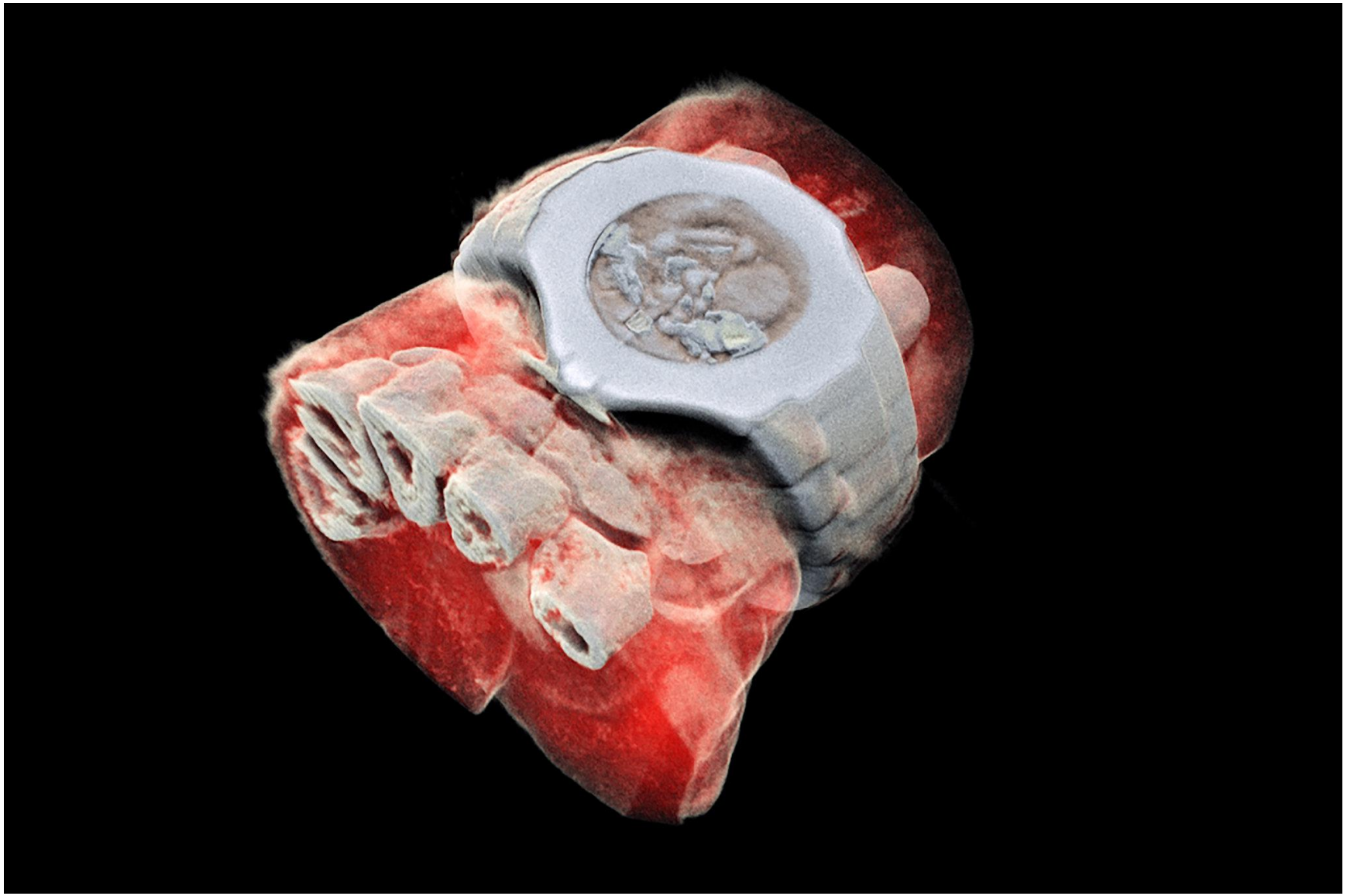
Learning more about our universe is a fundamental human curiosity

Doing difficult things gives us better technology that improves our lives and tells us interesting things right now!

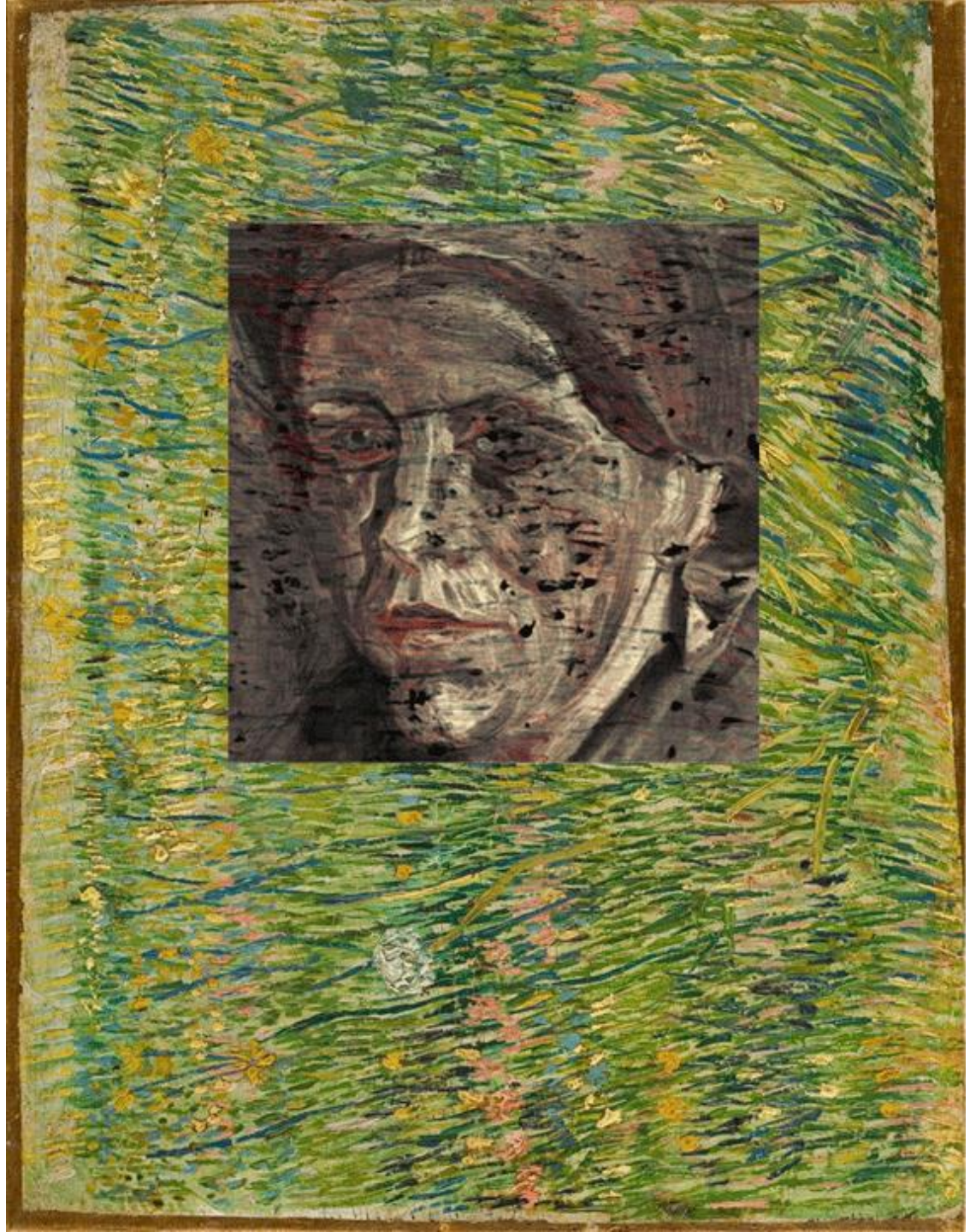


Even 3D colour x-rays using CERN technology!

X-rays have wavelengths just like visible light does



Synchrotron Radiation Based X-ray Fluorescence Elemental Mapping

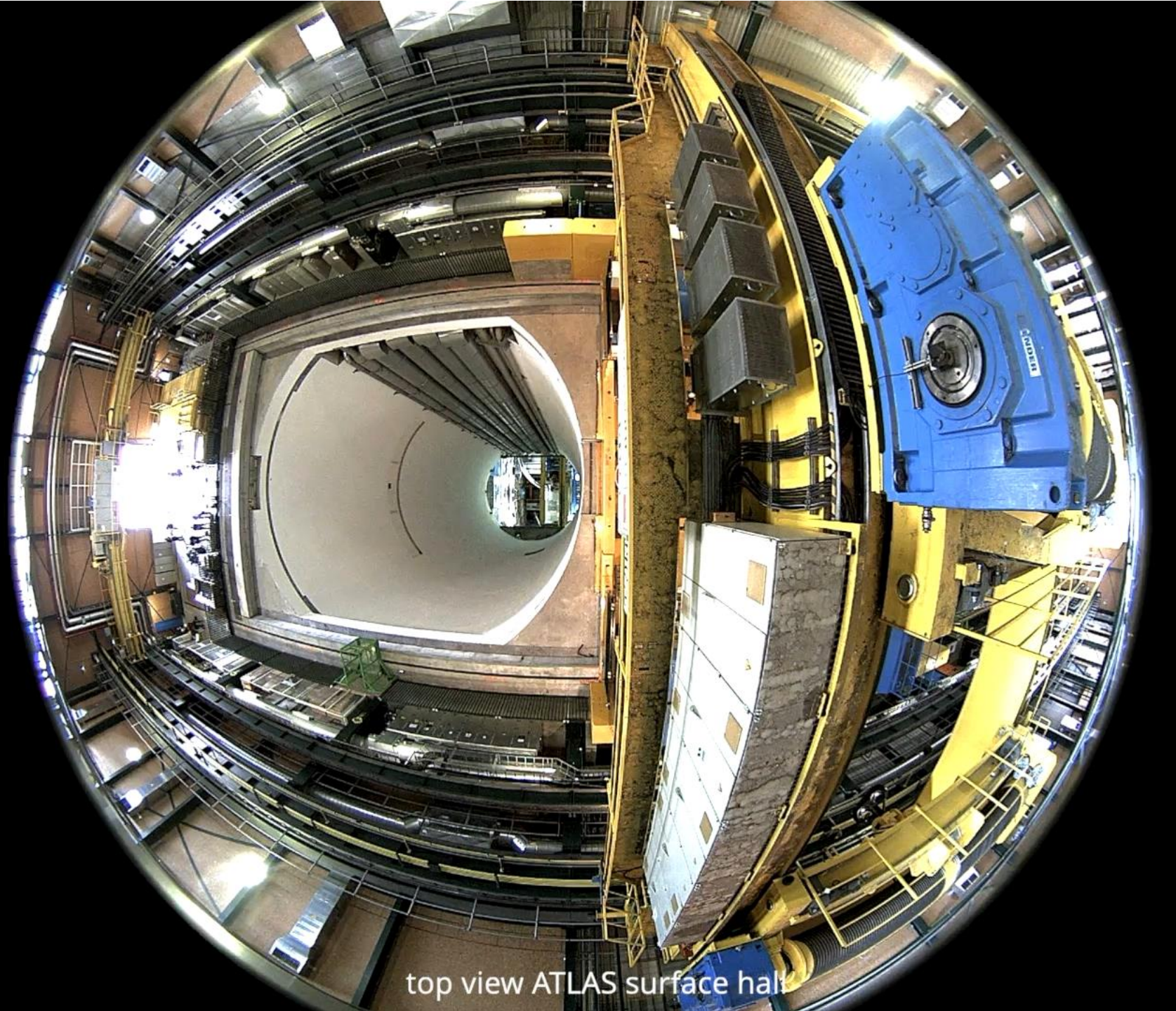


Muon tomography for pyramids

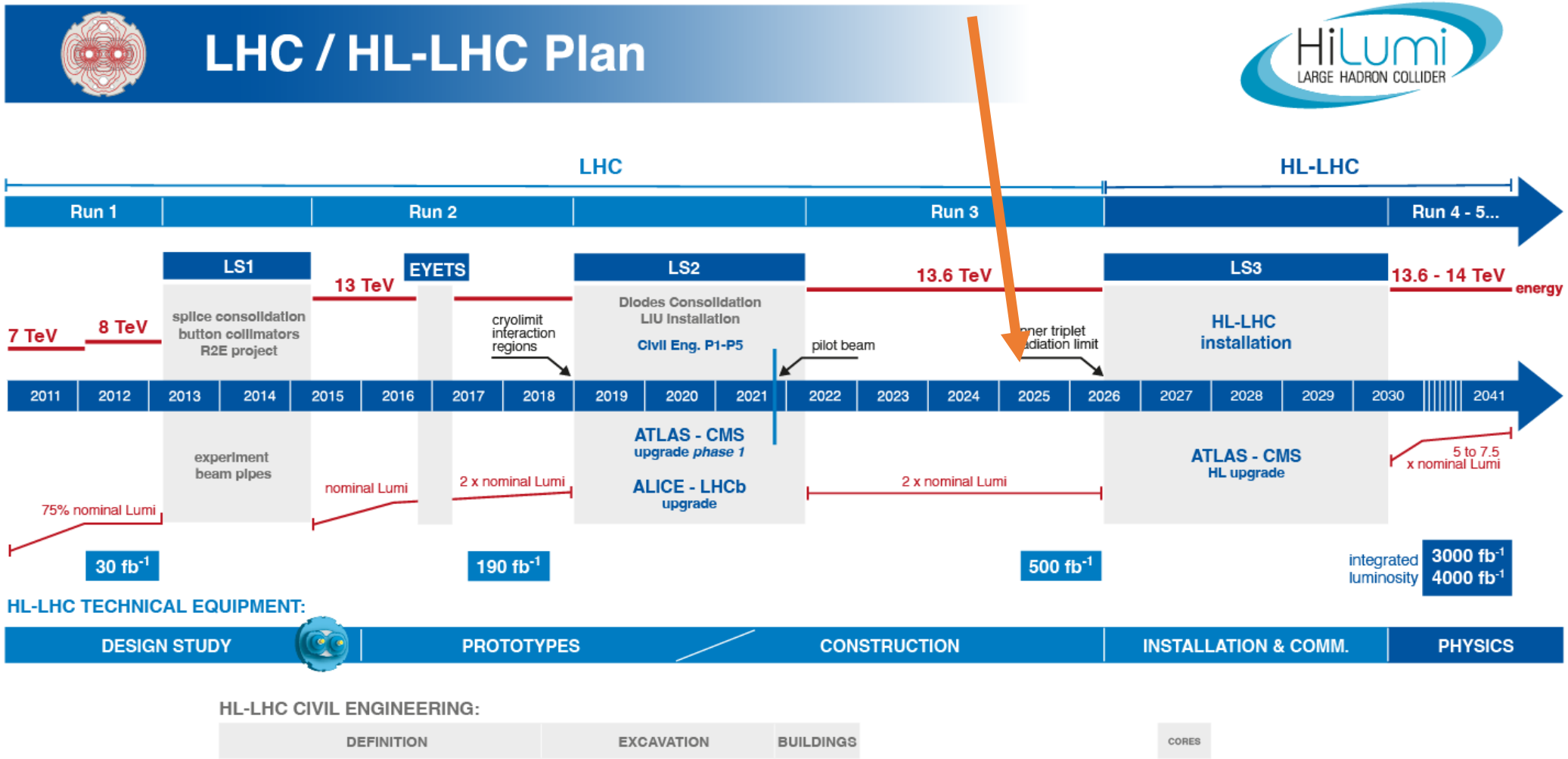

FUTURE


top view ATLAS cavern


level 6 ATLAS cavern


top view ATLAS surface hall

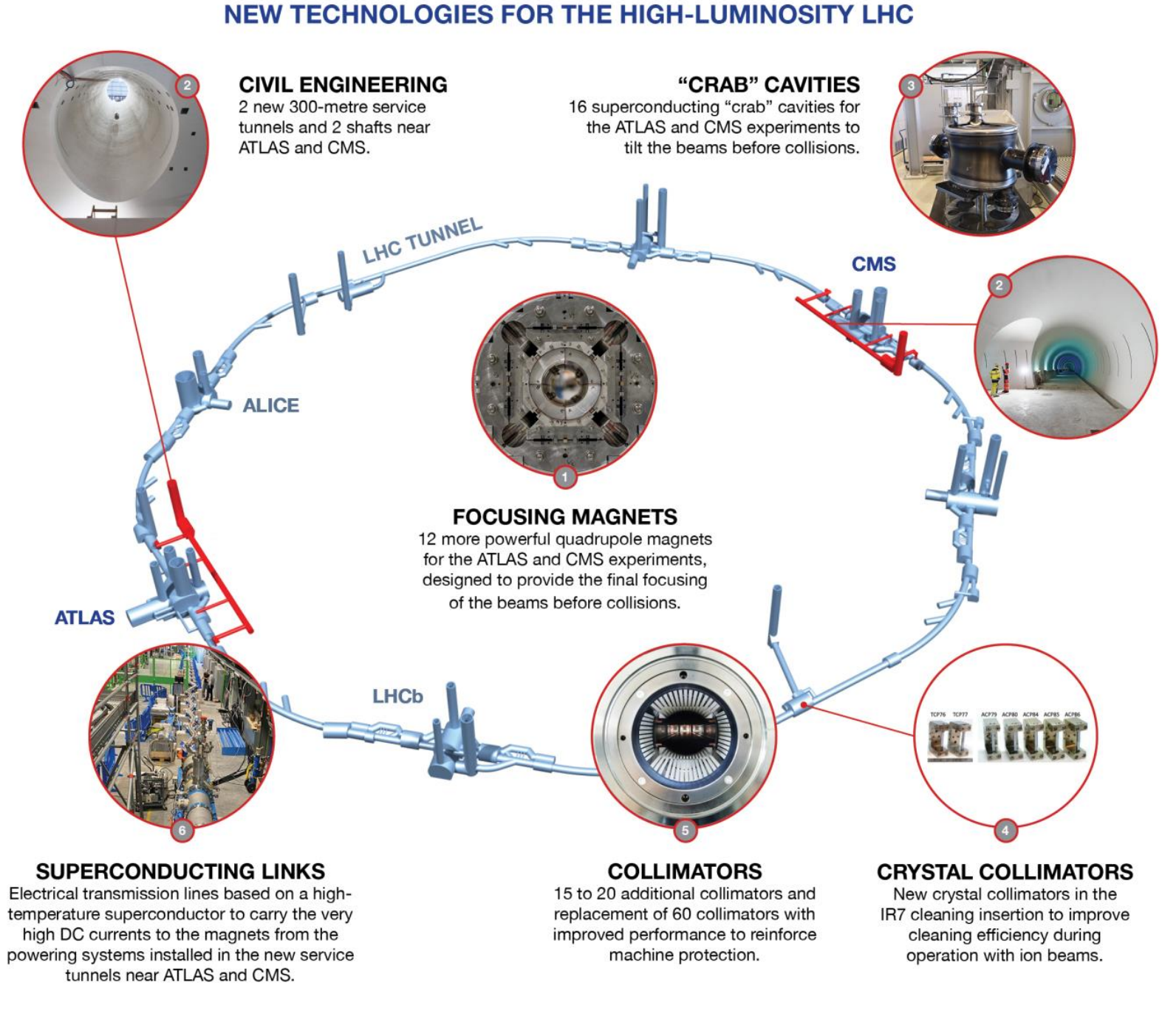
We are here



Have only taken ~ 10% of planned data so far

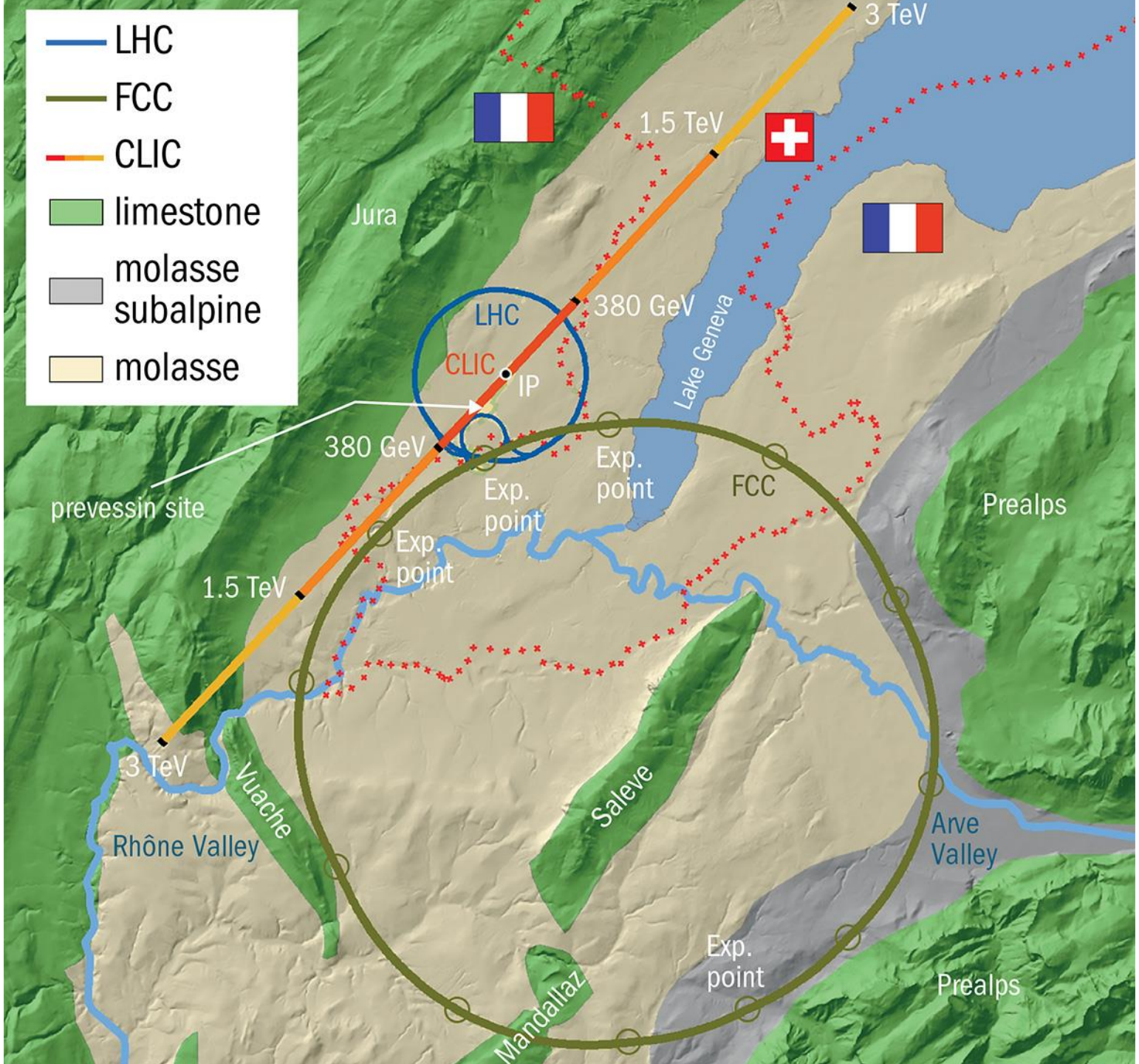
2026

A new LHC Towards high luminosity



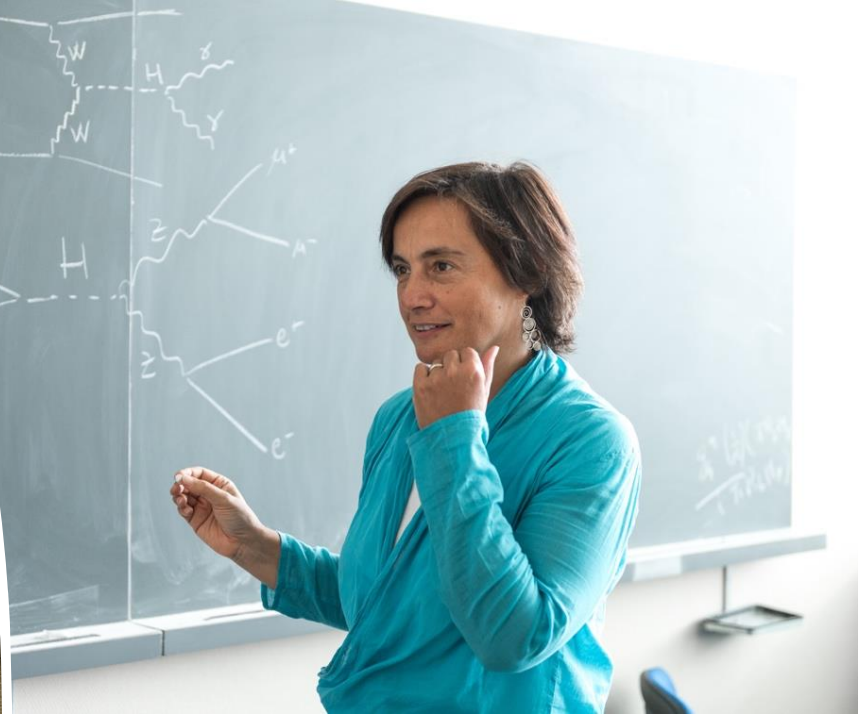
The Future

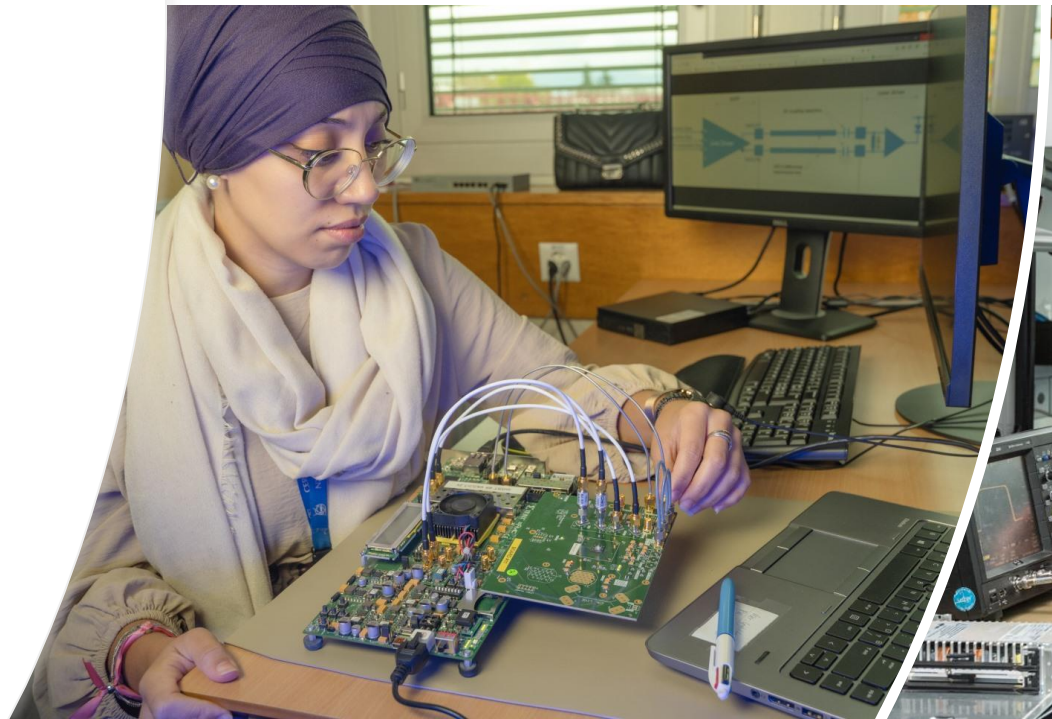
2040 and after



Challenges at CERN

- Huge data processing challenge
  - Programming skills are very important to being a particle physicist.
- Or you can be more hands on in the laboratory, building new detector components.
- Or you can be more theoretical and work on the calculations.





So much more than physics...

ROBOTICS

COMPUTING

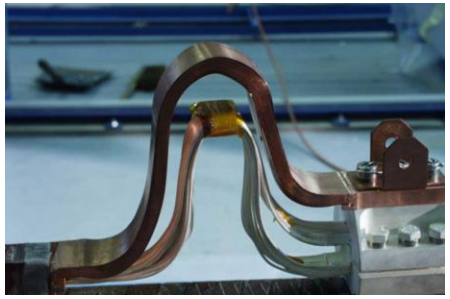
COMMUNICATION

RADIO FREQUENCY

ELECTRONICS

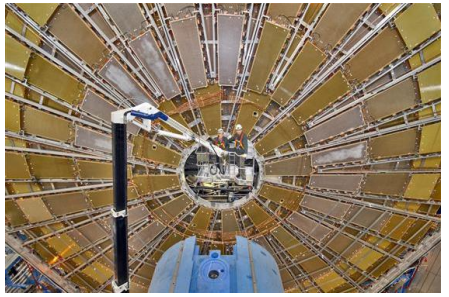
VACUUM AND CRYOGENICS

ELECTRICAL ENGINEERING

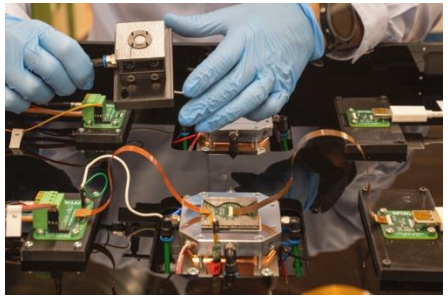


CIVIL ENGINEERING

MECHANICAL ENGINEERING



MATERIALS SCIENCE



Science and Technology Facilities Council

home | about the programme | contact | after work experience

For years 10, 11, 12, 13

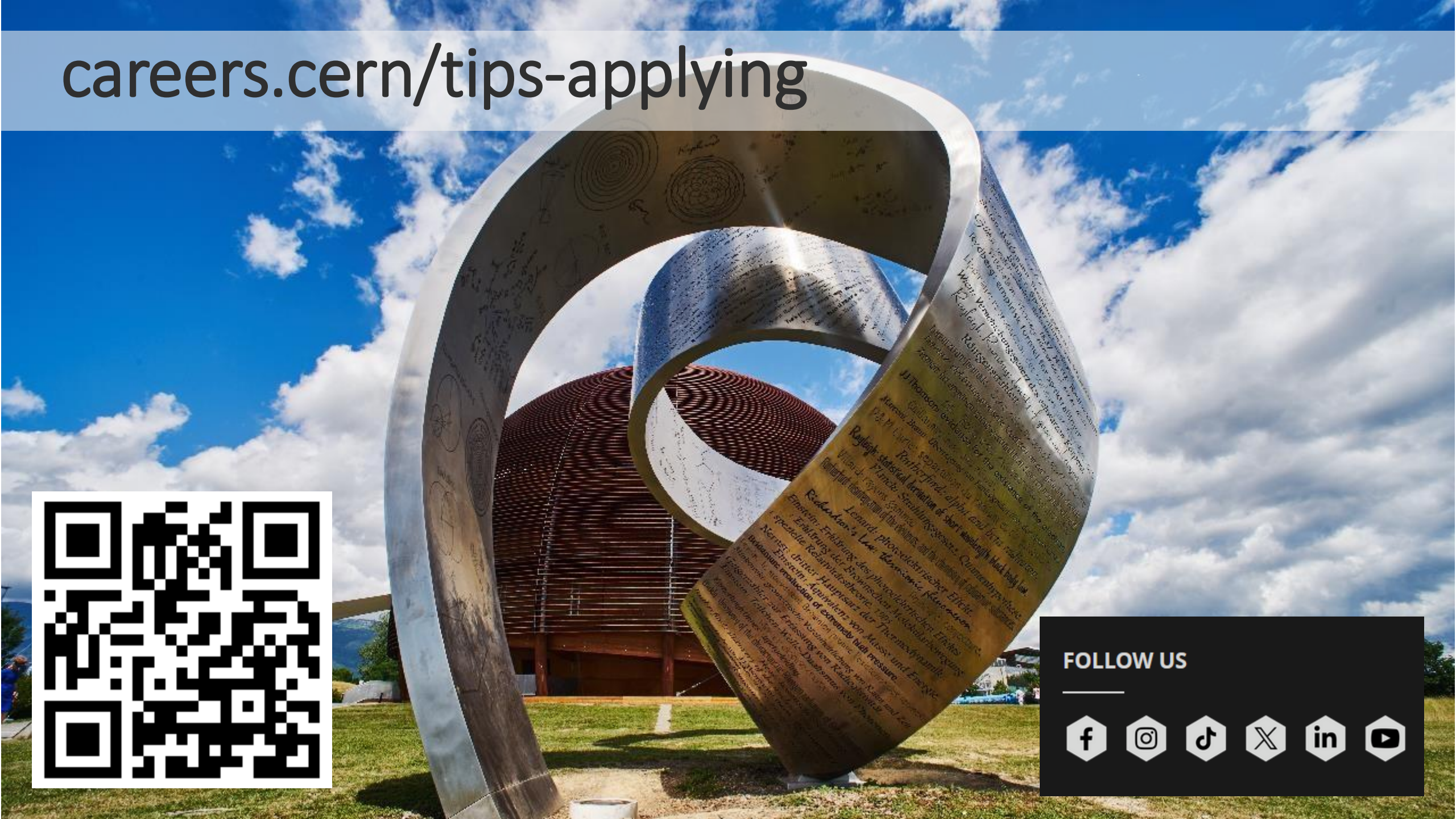
Possible placements in Cheshire, Oxfordshire or Edinburgh

Work Experience

Science and Technology Facilities Council

about the programme →

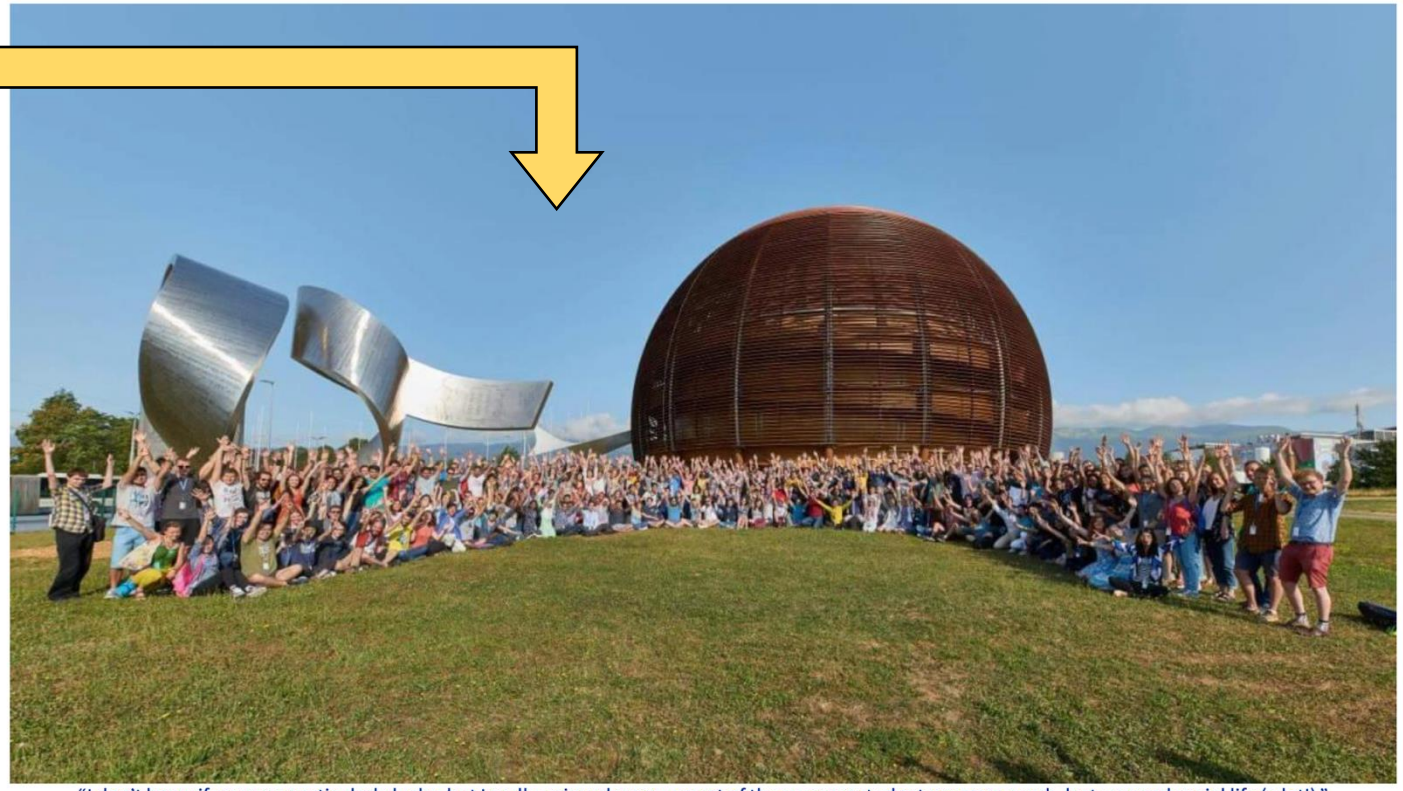
careers.cern/tips-applying



FOLLOW US

The future

There are a number of summer programmes and internships students can apply to throughout their undergraduate programme.



"I don't know if we were particularly lucky, but I really enjoyed every aspect of the summer student program: work, lectures and social life (a lot!)."

Summer programmes:

CERN Summer Student Programme
DESY Summer Student Programme
HASCO Summer School

Internships:

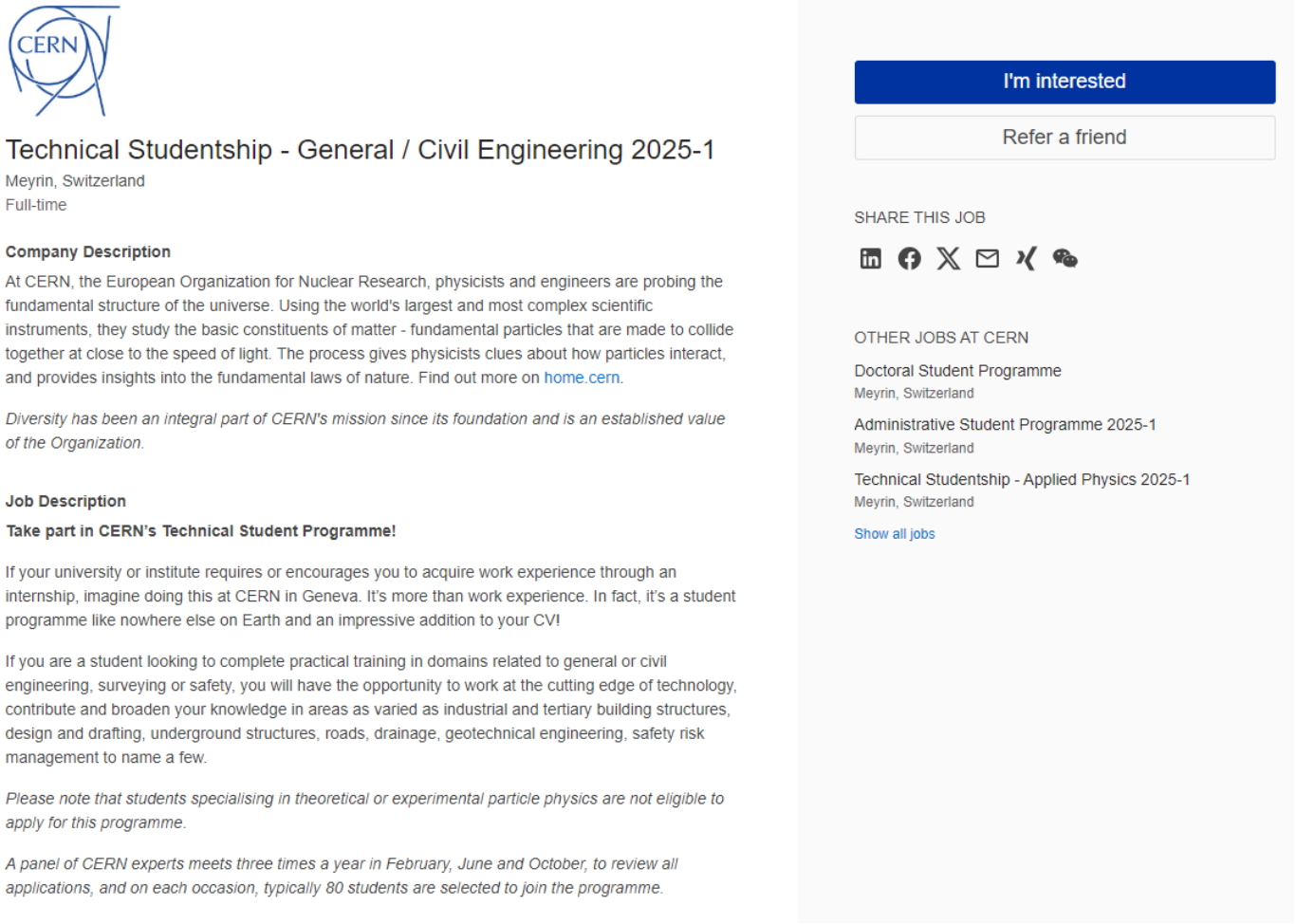
CERN Technical Student programme
ESA Student Internships

thank you!

Backup

Here's one I prepared earlier

How can I apply?



Technical Studentship - General / Civil Engineering 2025-1

Meyrin, Switzerland
Full-time

Company Description

At CERN, the European Organization for Nuclear Research, physicists and engineers are probing the fundamental structure of the universe. Using the world's largest and most complex scientific instruments, they study the basic constituents of matter - fundamental particles that are made to collide together at close to the speed of light. The process gives physicists clues about how particles interact, and provides insights into the fundamental laws of nature. Find out more on home.cern.

Diversity has been an integral part of CERN's mission since its foundation and is an established value of the Organization.

Job Description

Take part in CERN's Technical Student Programme!

If your university or institute requires or encourages you to acquire work experience through an internship, imagine doing this at CERN in Geneva. It's more than work experience. In fact, it's a student programme like nowhere else on Earth and an impressive addition to your CV!

If you are a student looking to complete practical training in domains related to general or civil engineering, surveying or safety, you will have the opportunity to work at the cutting edge of technology, contribute and broaden your knowledge in areas as varied as industrial and tertiary building structures, design and drafting, underground structures, roads, drainage, geotechnical engineering, safety risk management to name a few.

Please note that students specialising in theoretical or experimental particle physics are not eligible to apply for this programme.

A panel of CERN experts meets three times a year in February, June and October, to review all applications, and on each occasion, typically 80 students are selected to join the programme.

Direct link to application

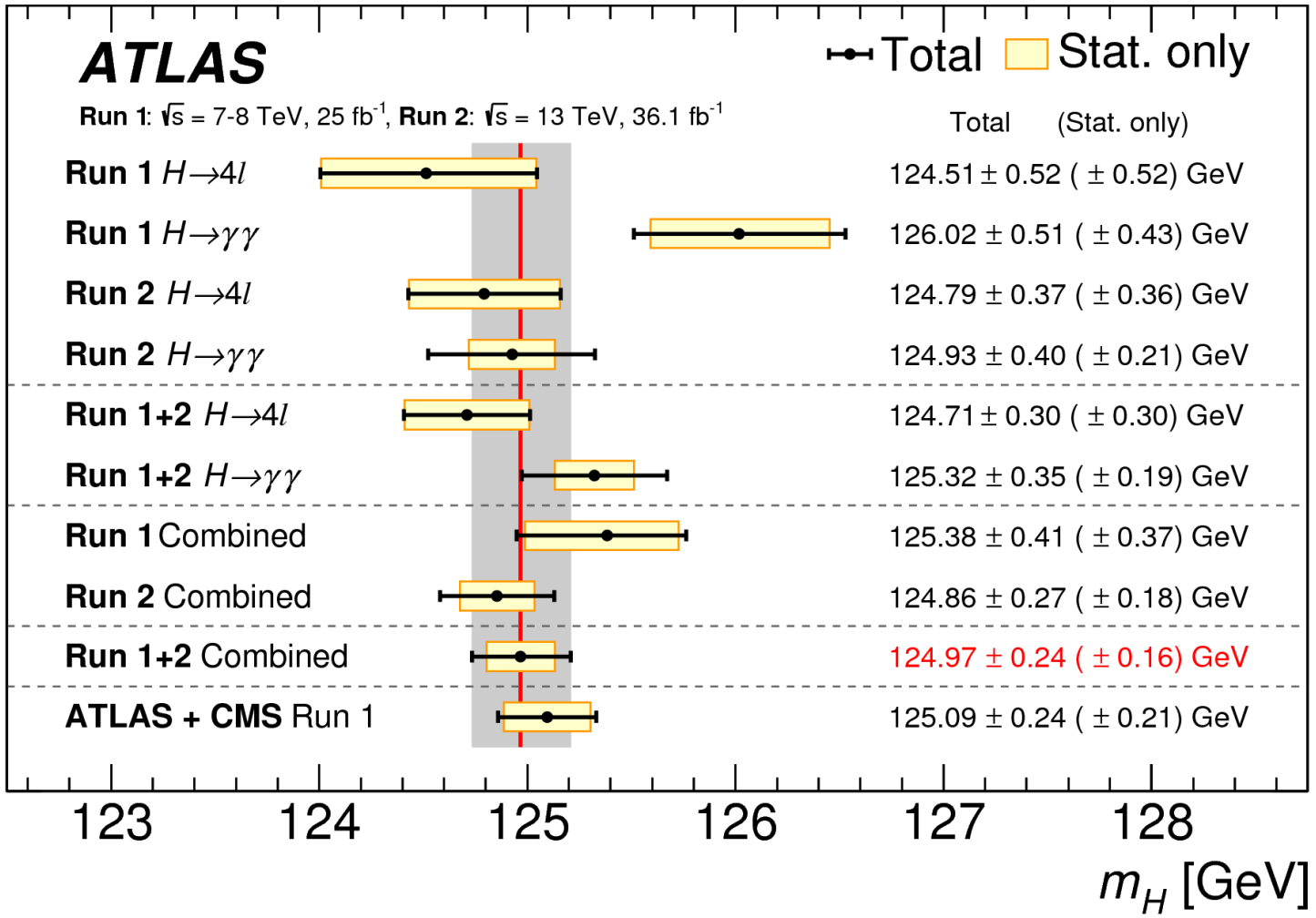
Direct links to apply:

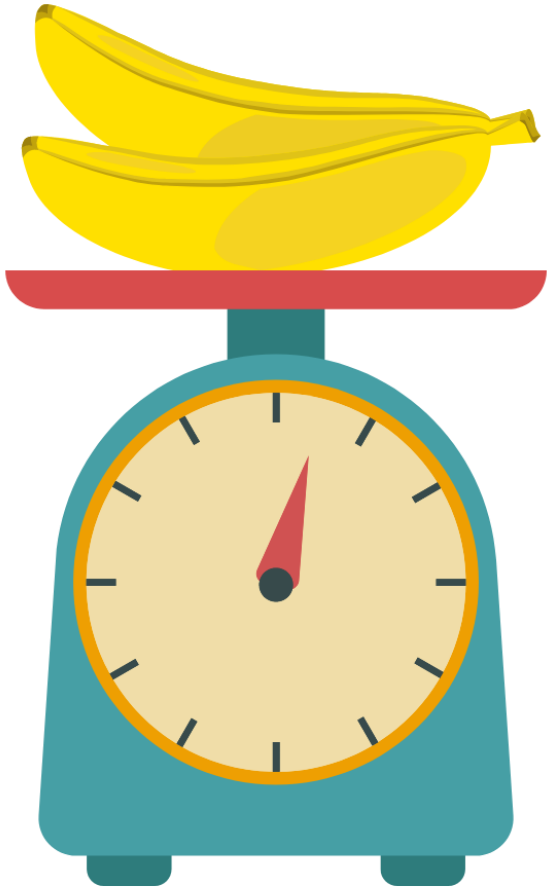
- Electrical/Electronics Engineering
- Mechanical Engineering
- IT, Mathematics & Robotics
- Material & Surface Science
- Applied Physics
- General/Civil Engineering

2023

Highest energy observation of quantum entanglement, looking at top quarks in the ATLAS Experiment

Precision Higgs measurements

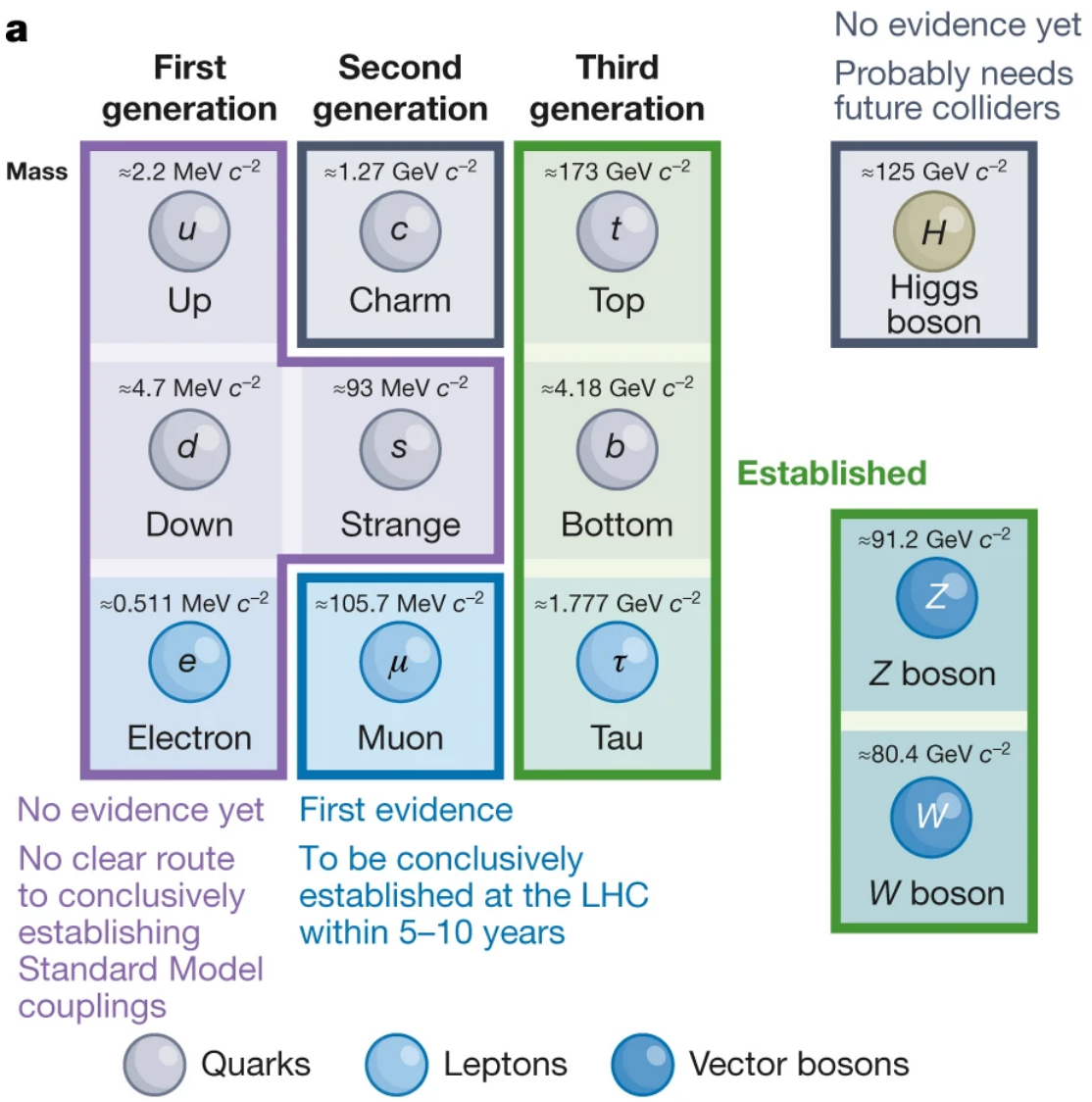


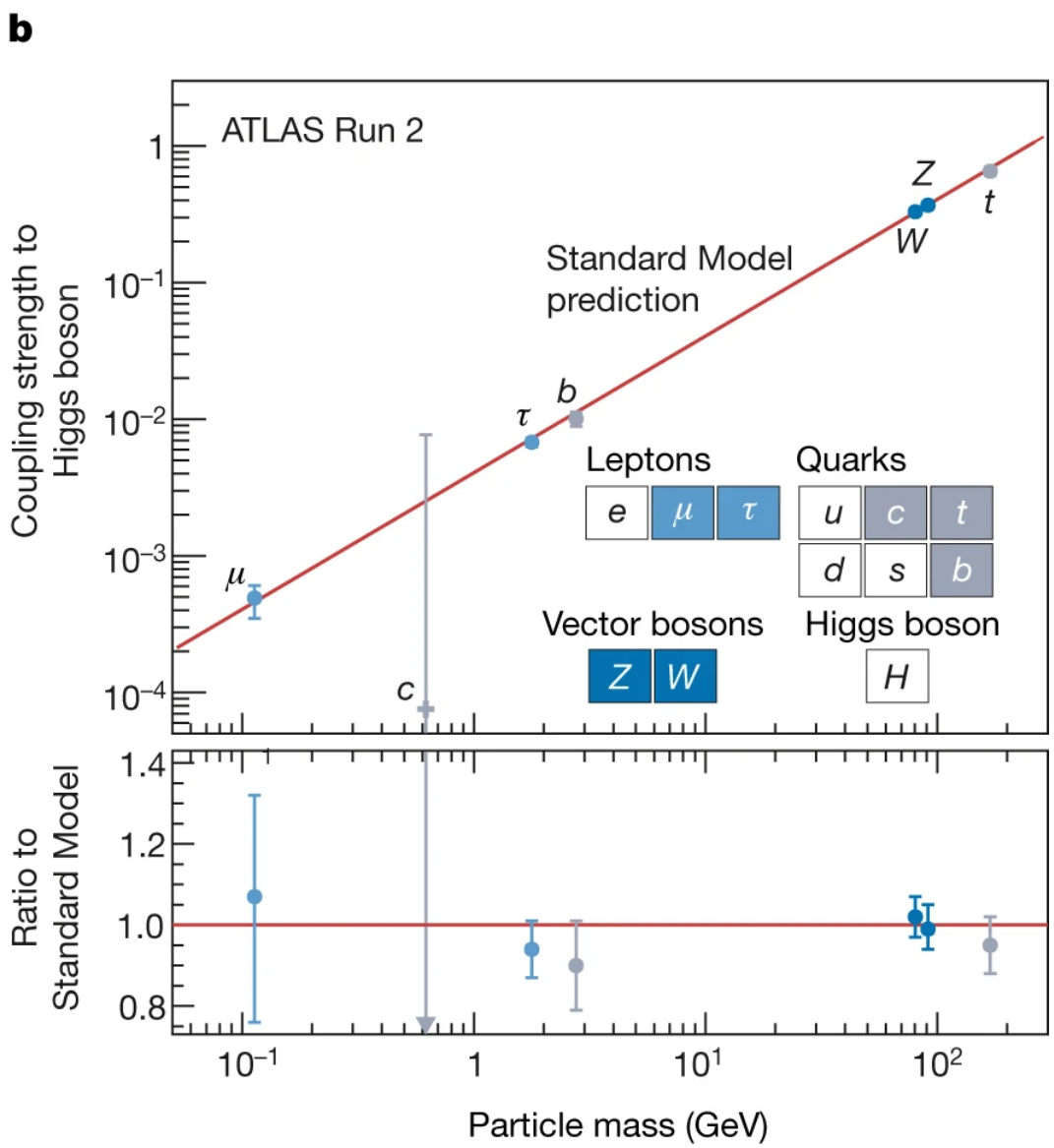


Mass measurements

Precision Higgs measurements

Nature 607, p41-47 (2022), G. Salam et al.

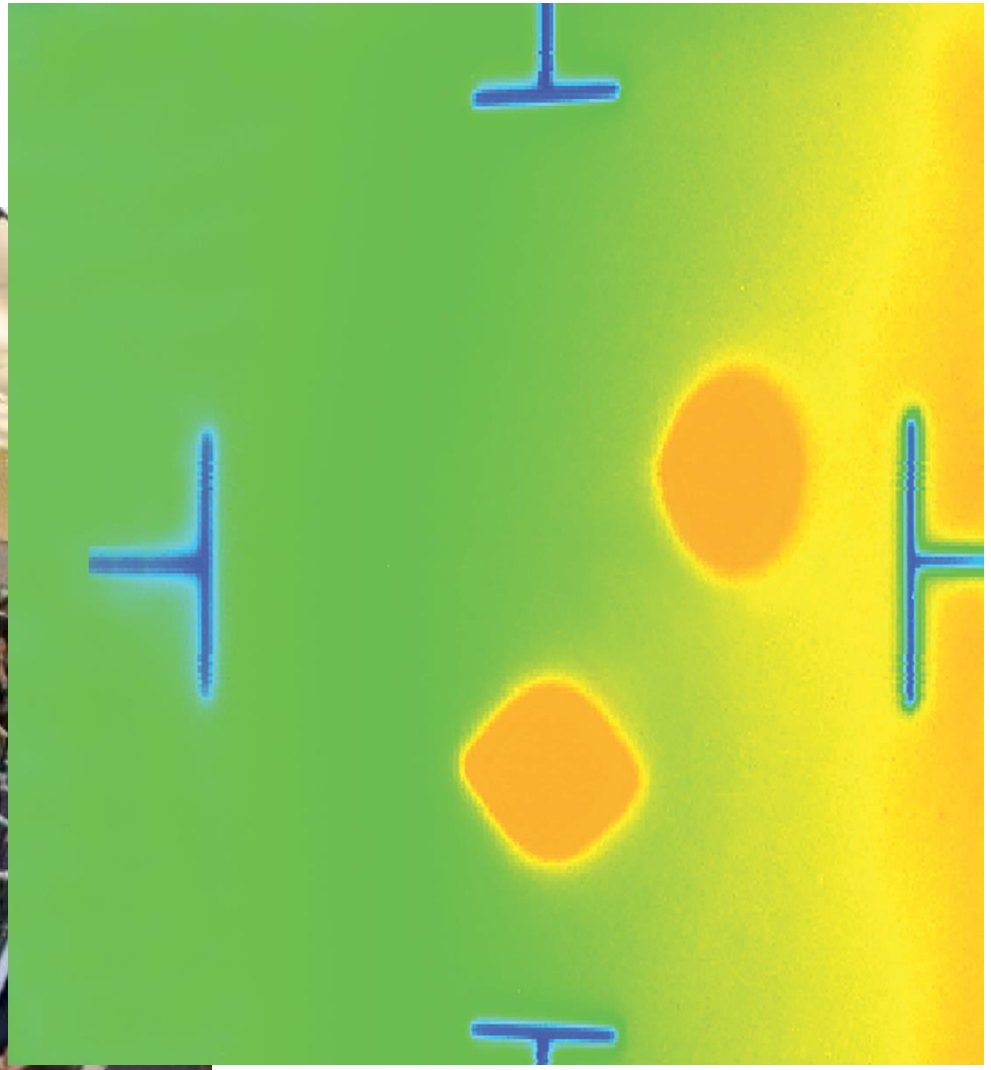




Dark matter ?

2008 First beams in the LHC

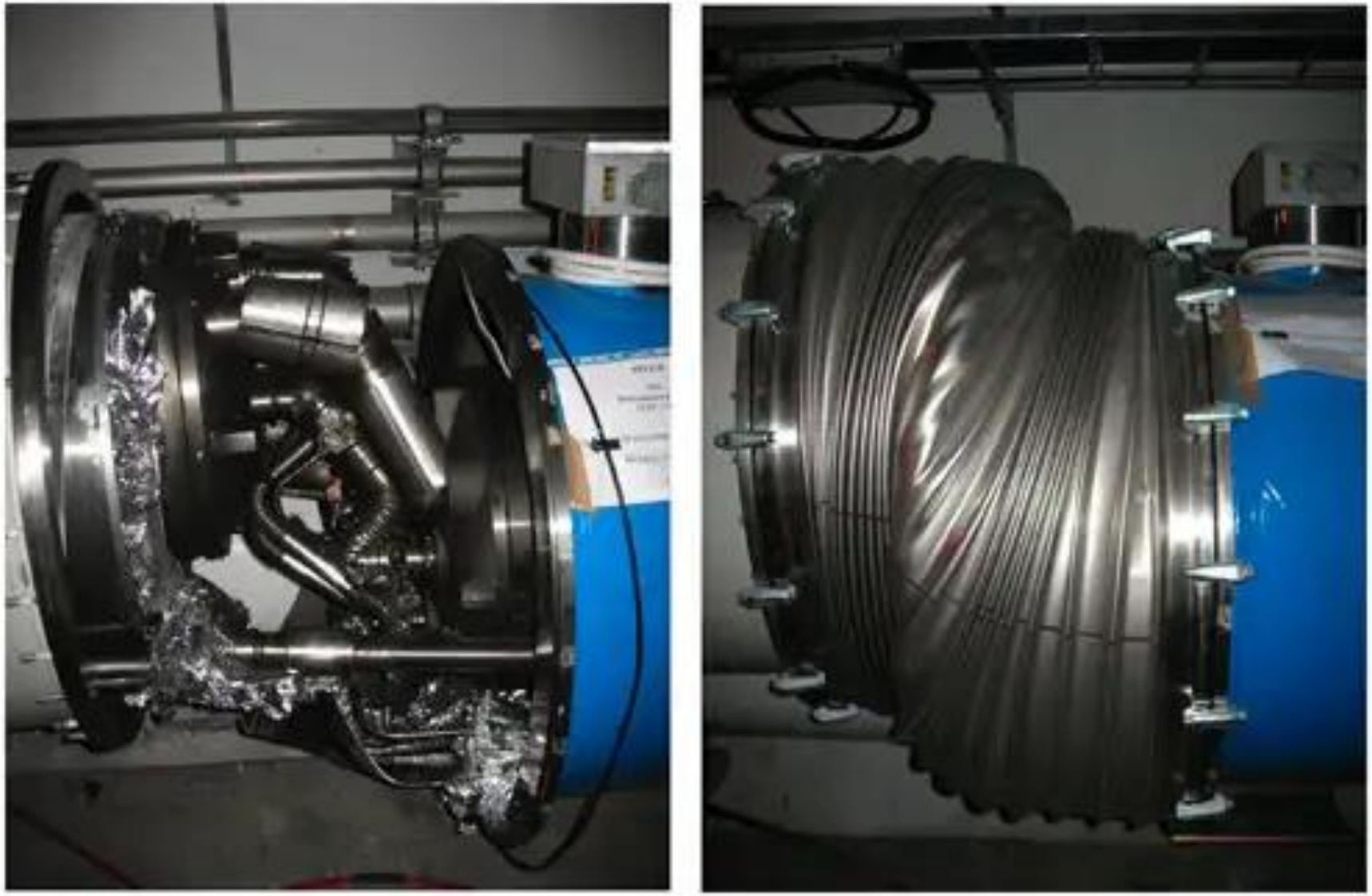
10th September



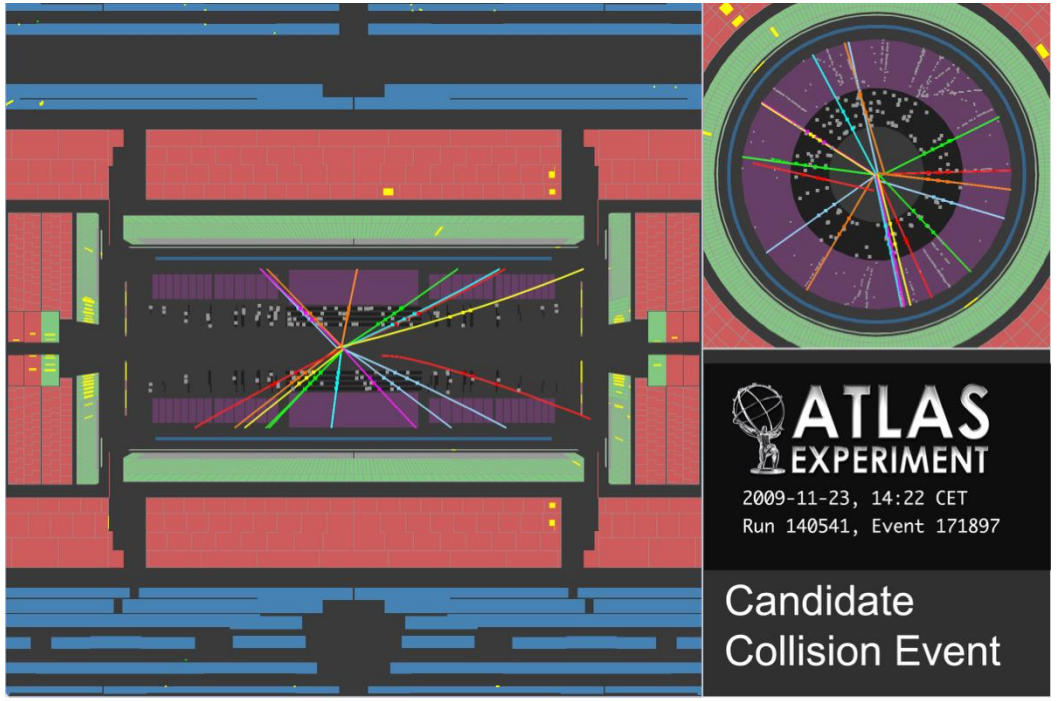
Images: CERN

2008 Magnet incident - QUENCH

19th September, 11.45am



2009 First collisions in the LHC!



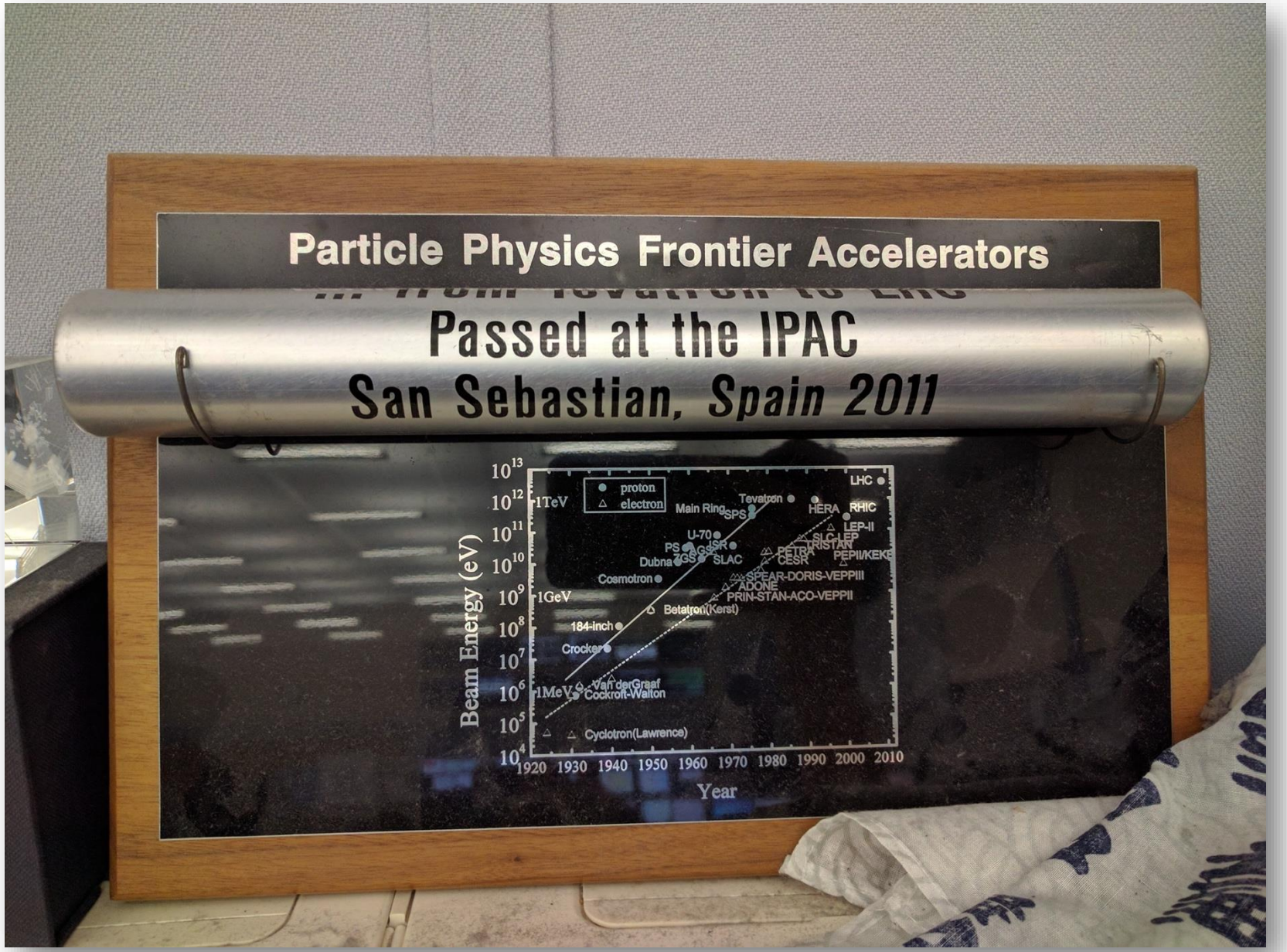
http://atlas.web.cern.ch/Atlas/public/EVTDISPLAY/events.html

2009 Highest energy particle collider in the world!

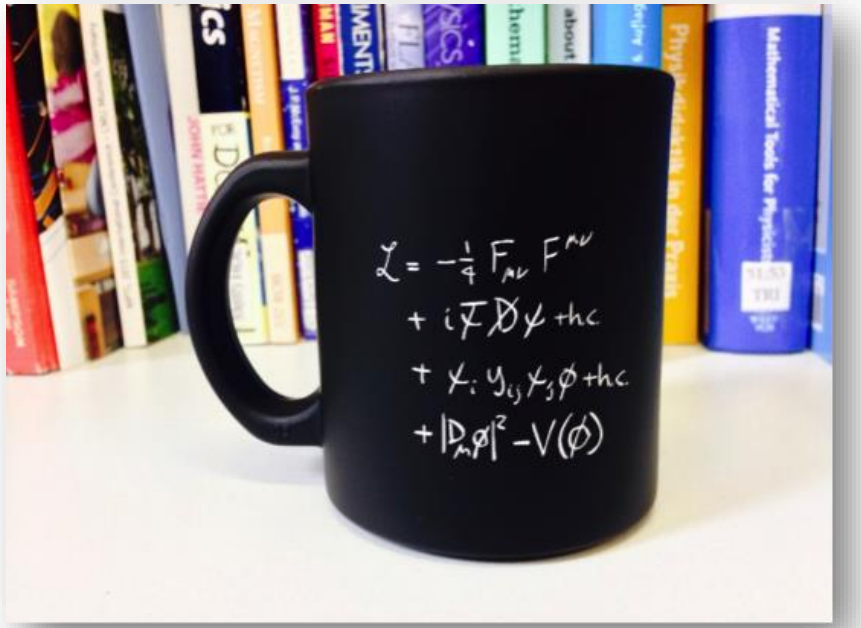
First collisions at 900 GeV. Then to 2.36 TeV - a new record!

Continued ramping up through to 2010 to reach 7 TeV centre of mass.

From Fermilab to CERN



Coffee



~10 million

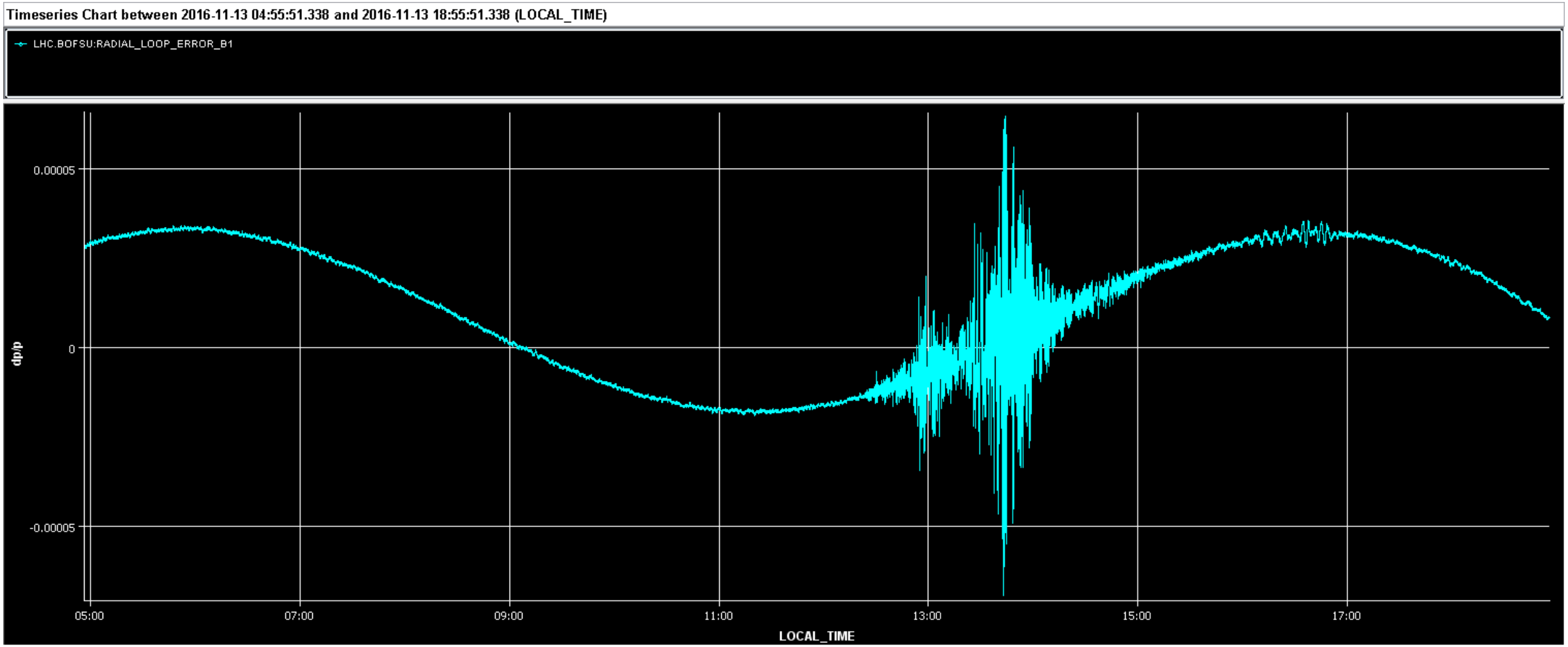
cups of coffee

The restaurants at CERN go through about 30 kilograms of coffee a day. Considering every kilogram of coffee generally makes between 120 and 140 cups, that's roughly 4,000 cups a day!

- Symmetry Magazine

2016

The LHC as an earth-quake detector



The top quark

- The **heaviest fundamental particle.**
  - **~170 GeV** (but we don't know why it's so heavy).
  - **Very short lifetime**.
- Expected to **couple strongly to the Higgs boson** (~1).
  - A possible connection to new physics!
  - Need to measure its properties and interactions with other particles in further detail to find out!