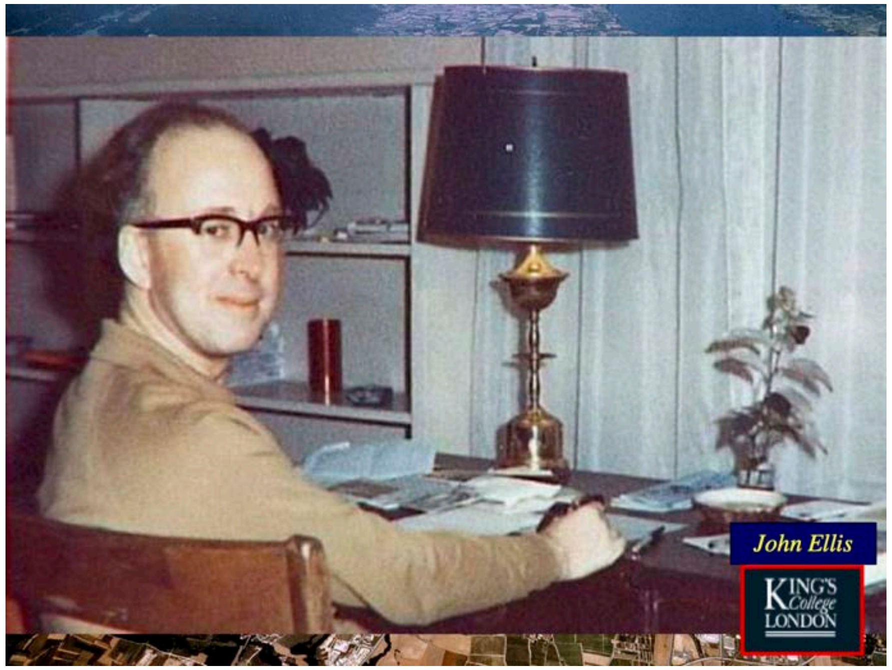
CERN and the future of particle physics

N. Srimanobhas
(Chulalongkorn U., THAILAND; CMS Collaboration, CERN)

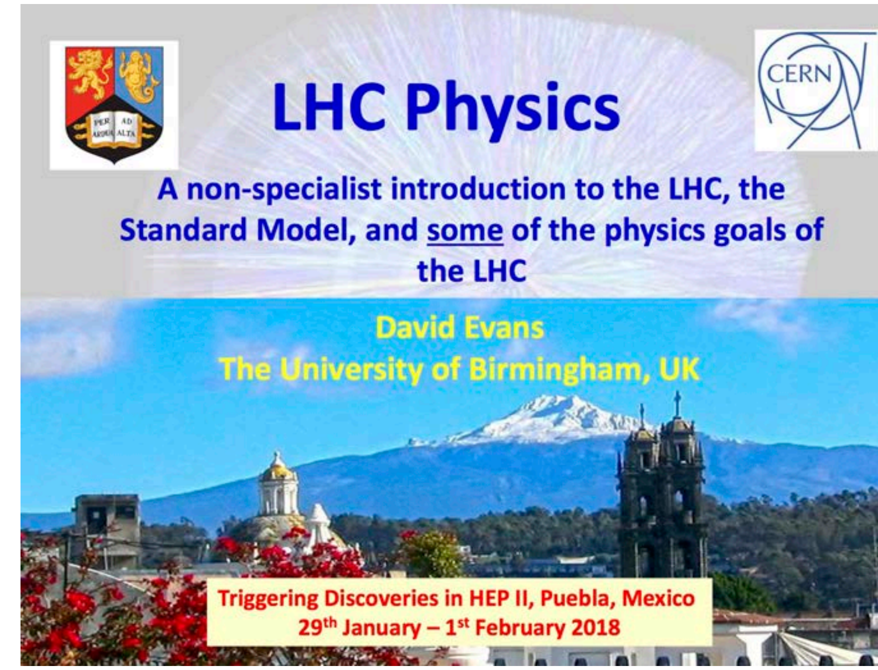
22 April 2018, King Mongkut's University of Technology Thonburi, THAILAND

Credits

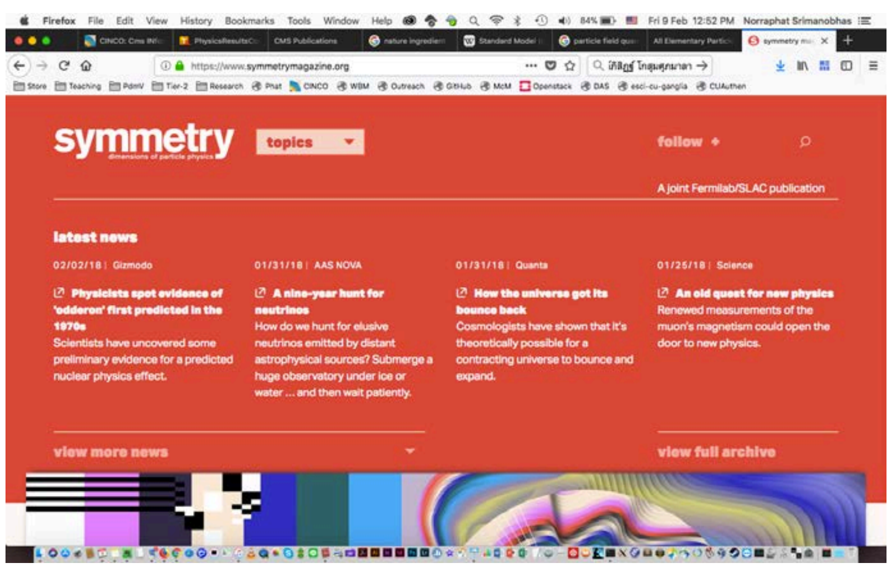


Talk by Prof. John Ellis (KCL)

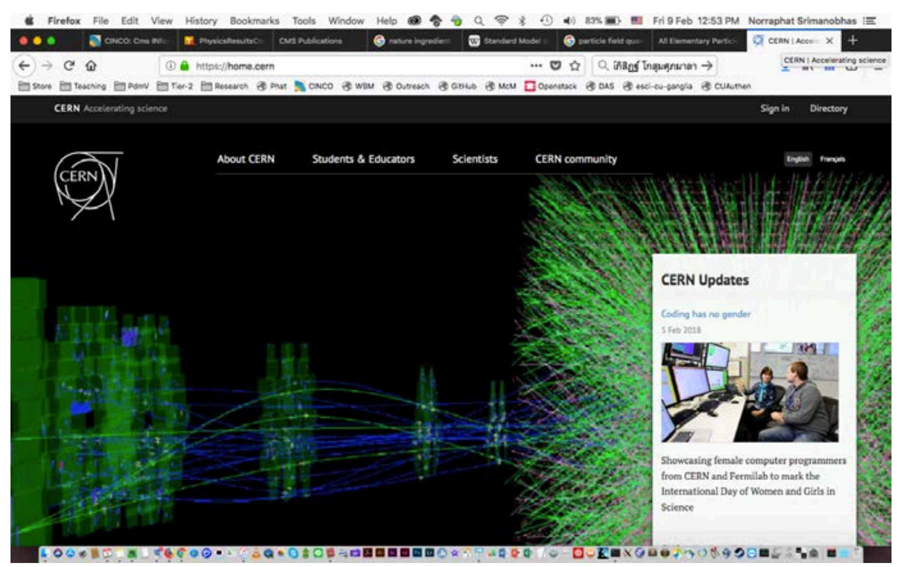
Talk by Prof. Albert De Roeck (CERN, UA, UC-Davis, NTU)



Talk by Prof. David Evans (U. of Birmingham)



www.symmetrymagazine.org



home.cern

and several public talks and websites.

We choose to go to the Moon

"We choose to go to the Moon, we choose to go to the Moon in this decade and do the other things, not because they are easy, but because they are hard, because that goal will serve to organise and measure the best of our energies and skills"

John F. Kennedy, Rice University, Sept. 12, 1962

https://www.nasa.gov/content/president-john-f-kennedy-at-rice-university

CERN: Conseil Européen pour la Recherche Nucléaire

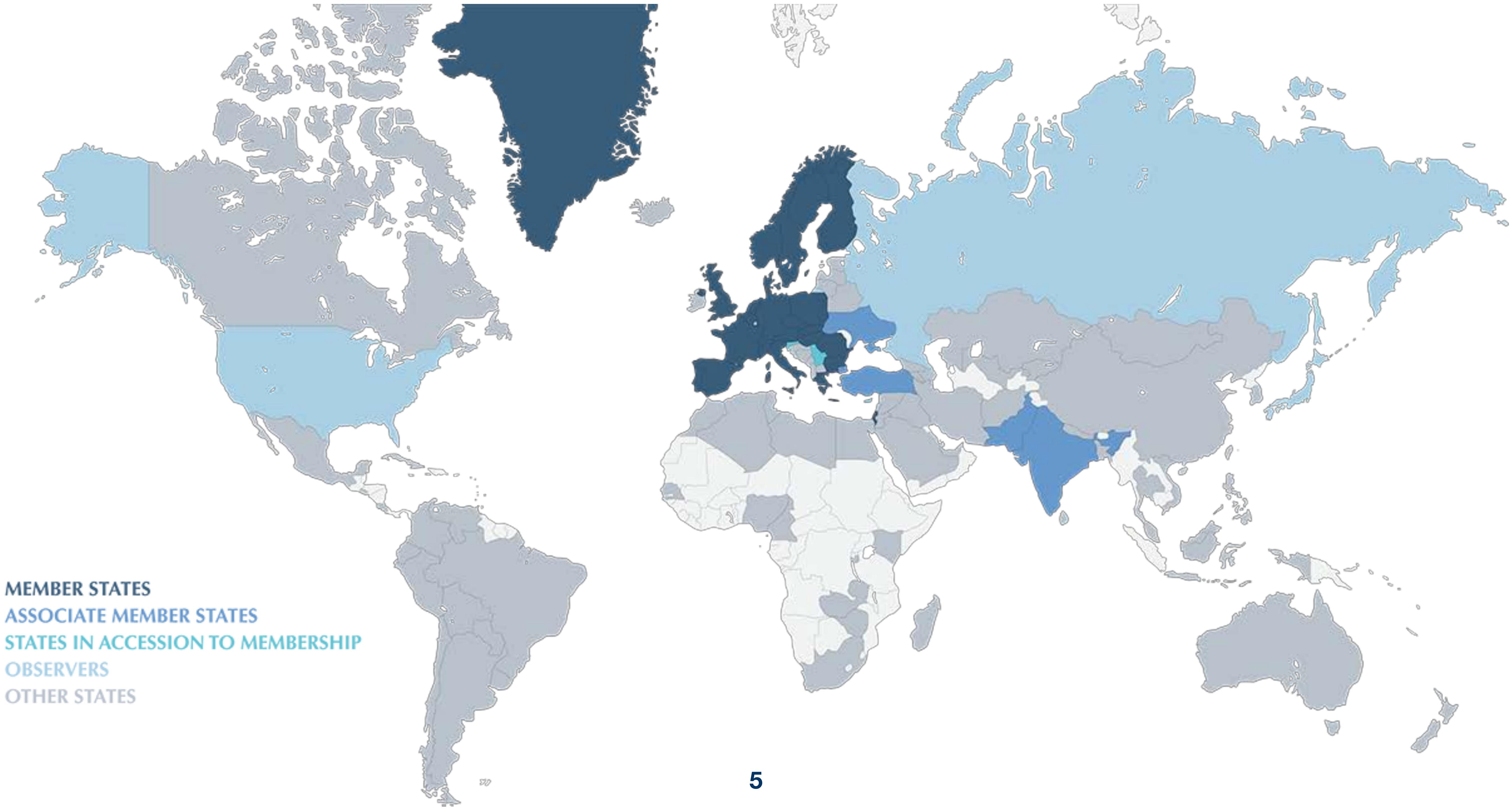
- At the end of the Second World War, European science was no longer world-class.
- A handful of visionary scientists, including *Raoul Dautry, Pierre Auger, Lew Kowarski, Edoardo Amaldi, Niels Bohr*, imagined creating a European atomic physics laboratory.
- *Louis de Broglie* put forward the first official proposal for the creation of a European laboratory at the European Cultural Conference, Lausanne on 9 Dec 1949.
- At the fifth UNESCO General Conference, held in Florence in June 1950, where American physicist and Nobel laureate *Isidor Rabi* tabled a resolution authorizing UNESCO to "assist and encourage the formation of regional research laboratories in order to increase international scientific collaboration…"
- Geneva was selected as the site for the CERN.


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.

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.

CERN: Conseil Européen pour la Recherche Nucléaire

- Found in 1954 with 12 European member states.
- Today 22 member states
- CERN employs just over 2500 people and Some 12,000 visiting scientists from over 70 countries and with 120 different nationalities come to CERN for their research.



CERN Missions

Research
Seeking and finding answers to questions about the Universe

Technology
Advancing the frontiers of technology

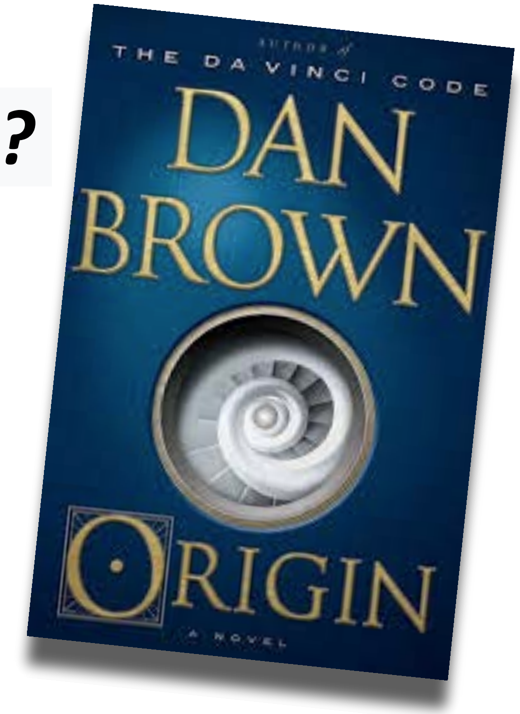
Education
Training the scientists of tomorrow

Collaborating
Bringing nations together through science

Fundamental questions

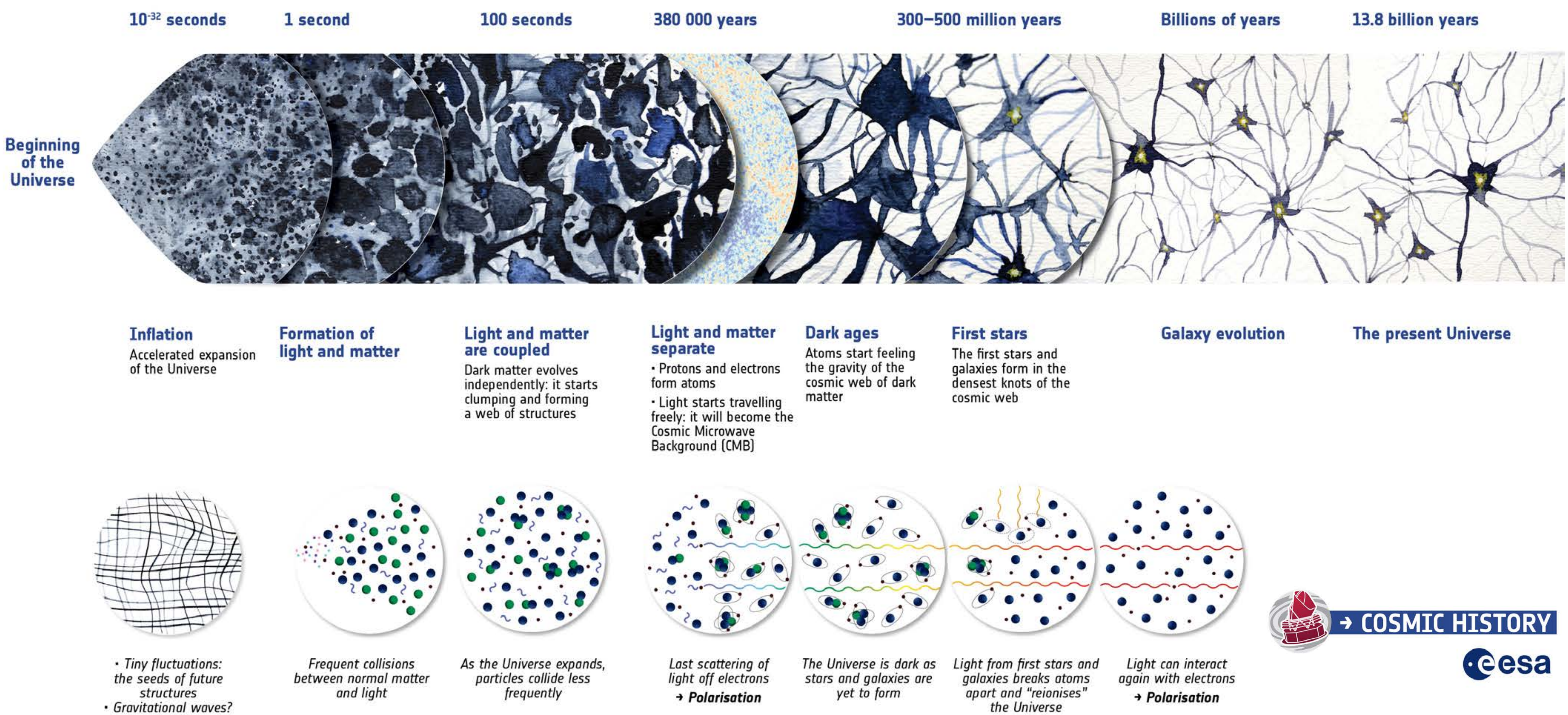
Painting by Paul Gauguin

Where Do We Come From? What Are We? Where Are We Going?
Note that this painting should be read from right to left.

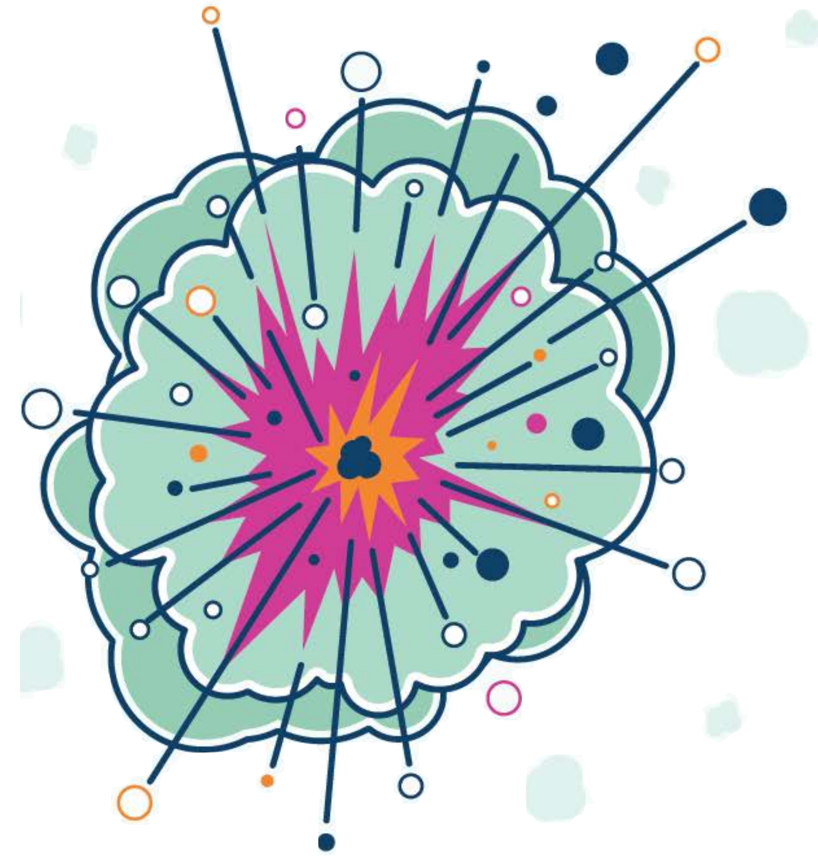


What are we looking for together?

Basic research in the field of experimental and theoretical particle physics, finding out what the Universe is made of and how it works.



Accelerators are our tools to find the answers



Two main ideas behind the accelerator

- **Create matter by increasing energy**

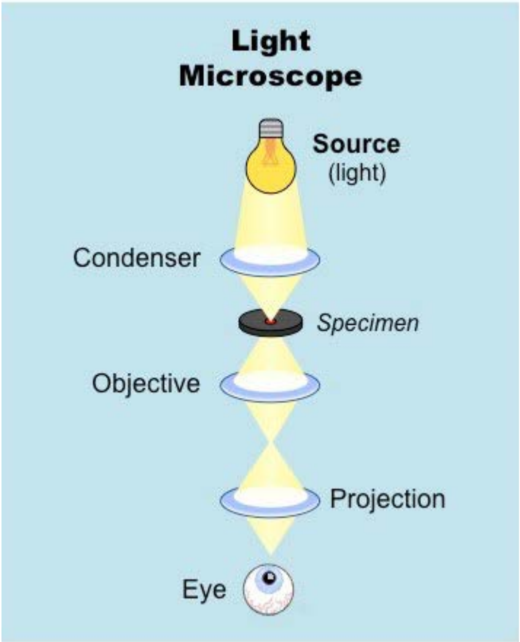
$$E = mc^2$$

- **Provide insight in particle structure**

$$\lambda = \frac{hc}{E}$$

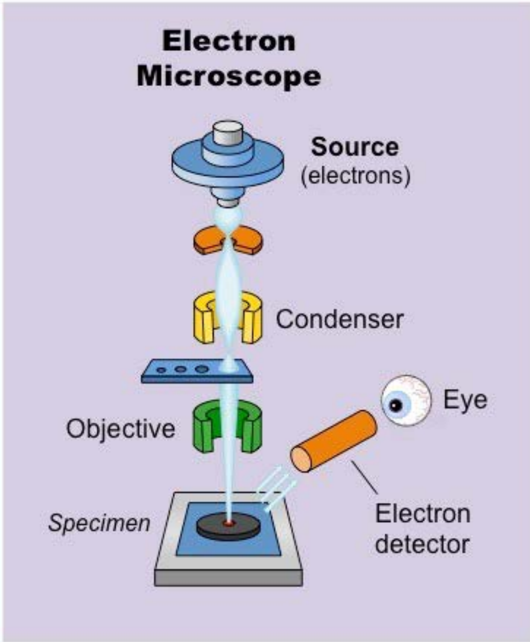
Visible light

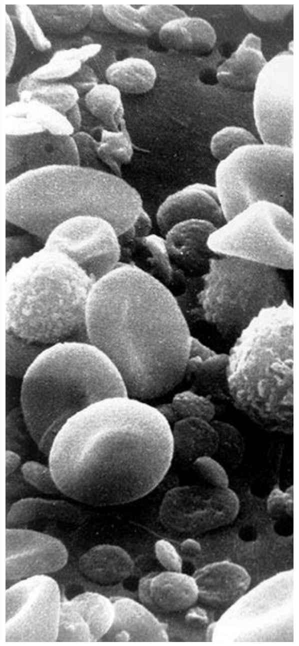
400-500 nm



X-Ray

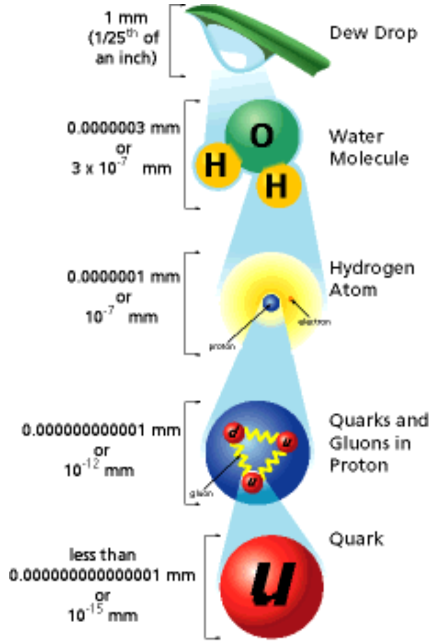
0.01-10 nm





Particle Accelerator

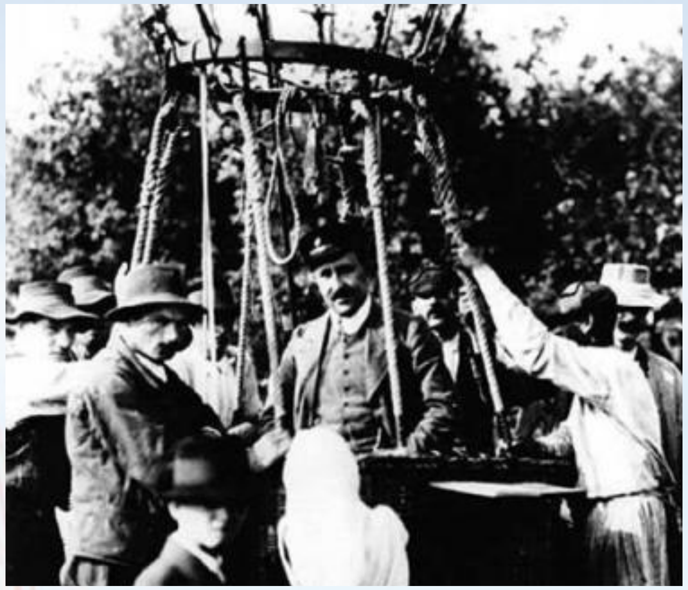
<0.01 nm

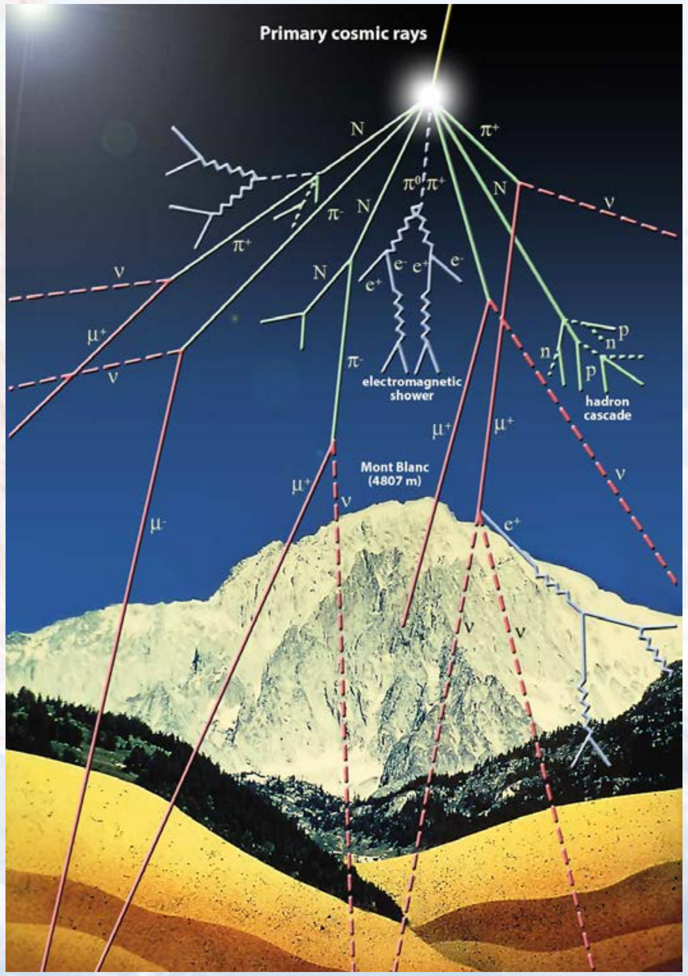


Cosmic rays: Particles from outer space accelerators

In 1912, Austrian physicist **Victor Hess** took an ionization chamber aloft in balloon and measured background radiation. He found that from 2000 meters to 5300 meters the amount of radiation increased, indicating the radiation came from space (Hess ruled out the Sun as the radiation's source by making a balloon ascent during a near-total eclipse). He had discovered "**Cosmic Rays**".

Hess shared the 1936 Nobel prize in physics for his discovery, and cosmic rays have proved useful in physics experiments – including several at CERN – since. Cosmic-ray showers were found to contain many different types of particles. Accelerators study these particles in detail.

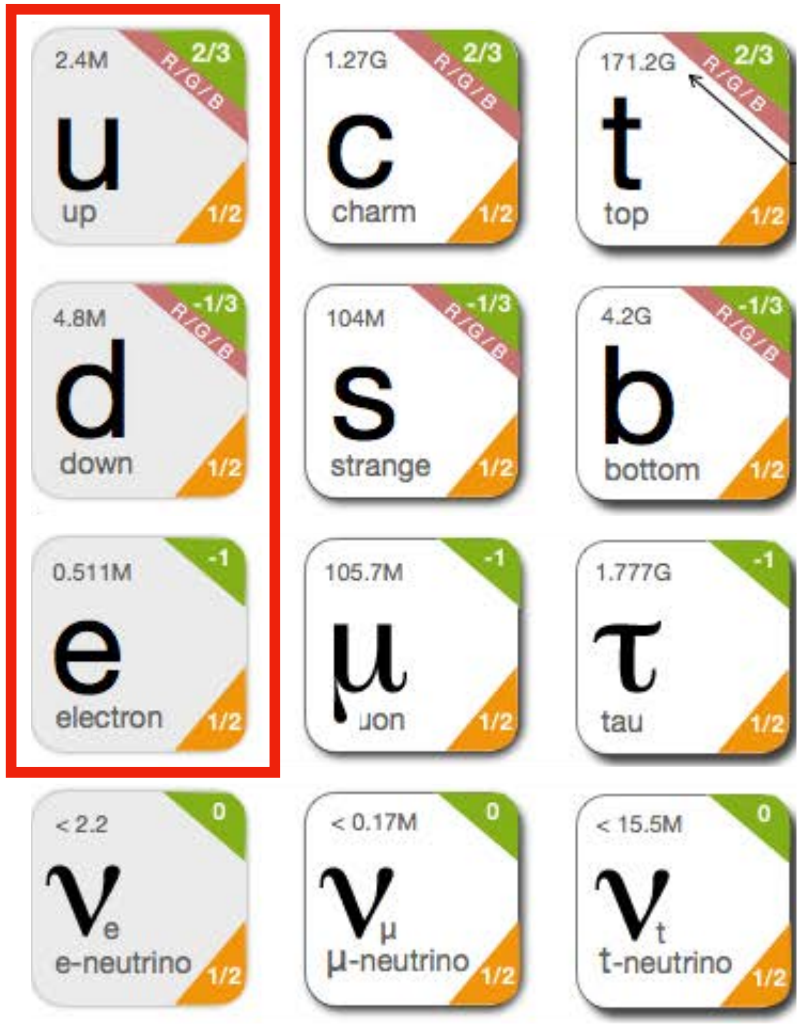




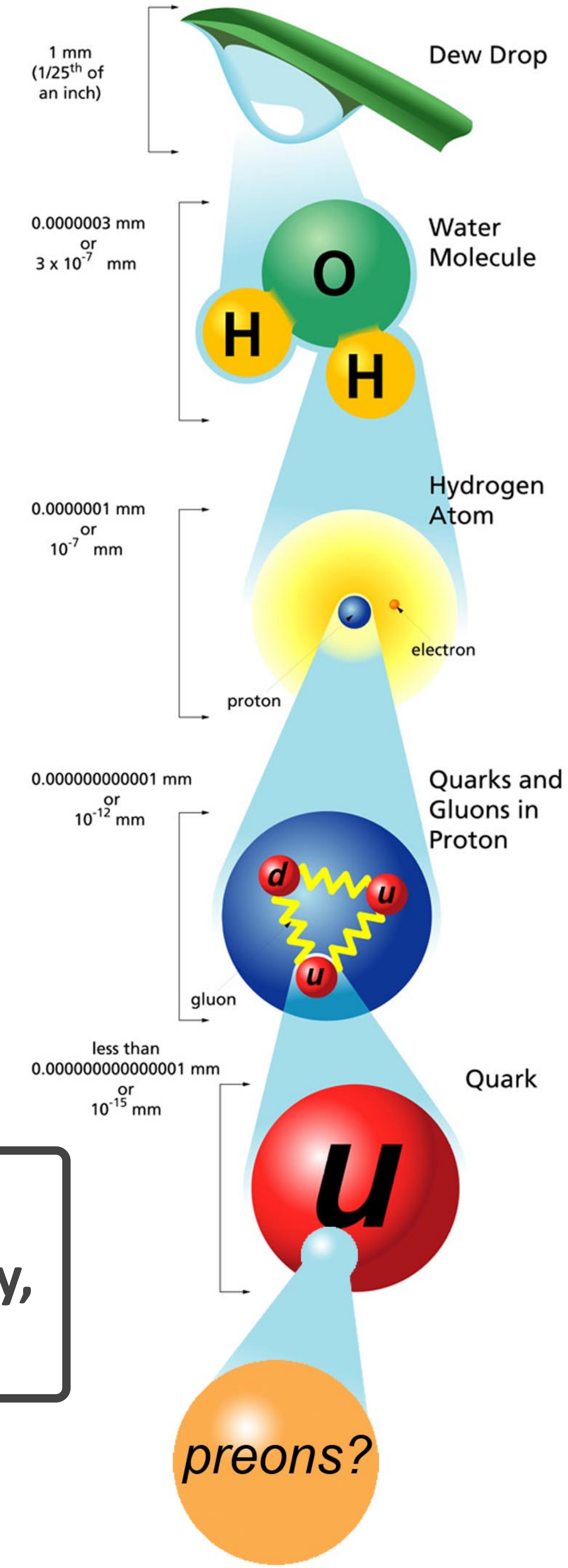
Known universe's ingredients

Everything around us (the whole Periodic Table) is made up of the **first three particles (u, d, electron)**. But somehow nature

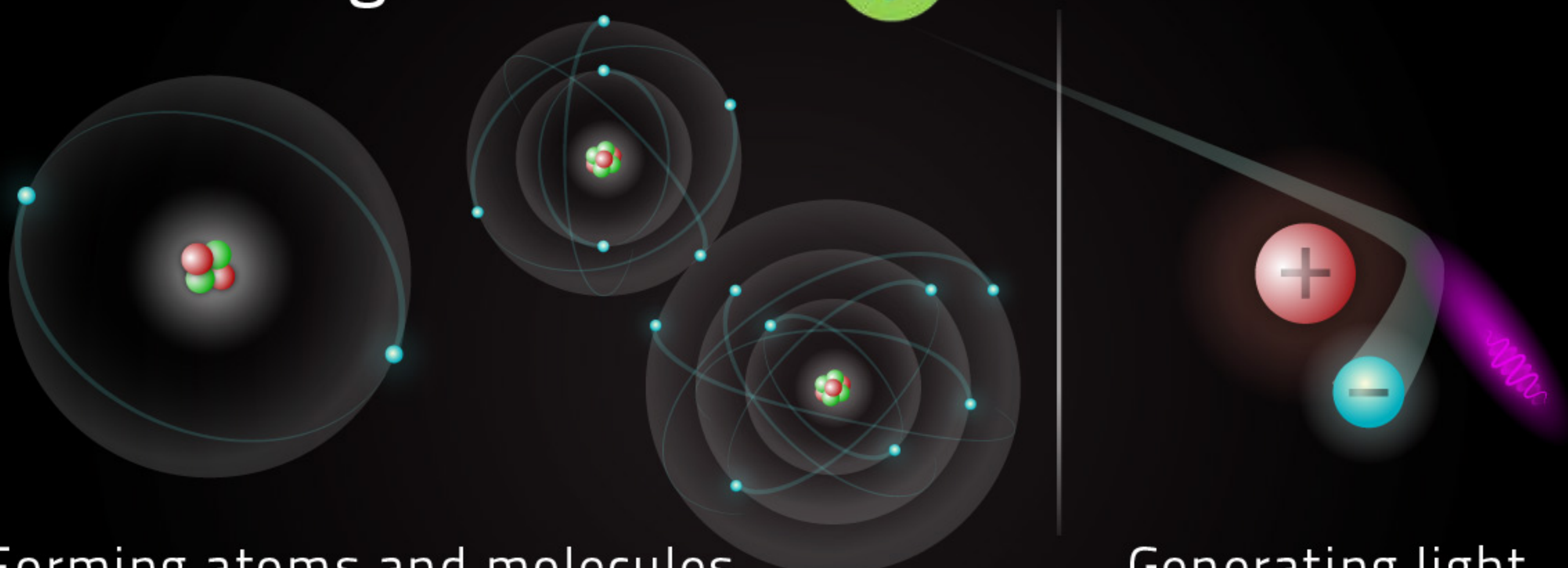
- supplies us with two extra families that are very much heavier,
- doesn't allow us to see free quarks (or maybe we don't see it yet),
  - group of 3 quarks: **Baryon** (e.g. proton),
  - quark-antiquark pairs: **Meson** (e.g. pion),
- describes interactions between these particles particles by **three (out of four) fundamental forces**.



So simple, compared to Periodic Table in Chemistry, or Biological taxonomy!



Electromagnetic Force



Forming atoms and molecules

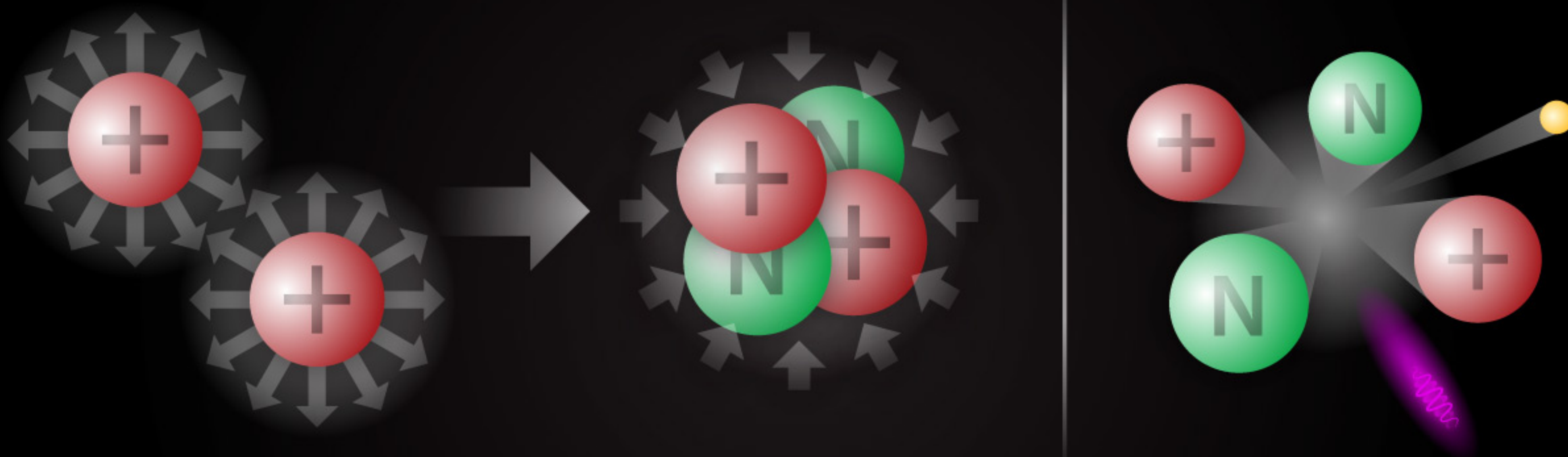
The electromagnetic force pulls negatively charged electrons into bound orbits around positively charged nuclei to form atoms and molecules. As a gas cools, electrons will find their way into the presence of atomic nuclei. Larger nuclei with a greater positve charge pull in more electrons until atoms and molecules have a balance of charges.

Generating light

When a negative electron interacts with a positive proton, the electromagnetic force adds energy to the electron generating a photon.

http://ecuip.lib.uchicago.edu/multiwavelength-astronomy/astrophysics/03.html

Strong Nuclear Force



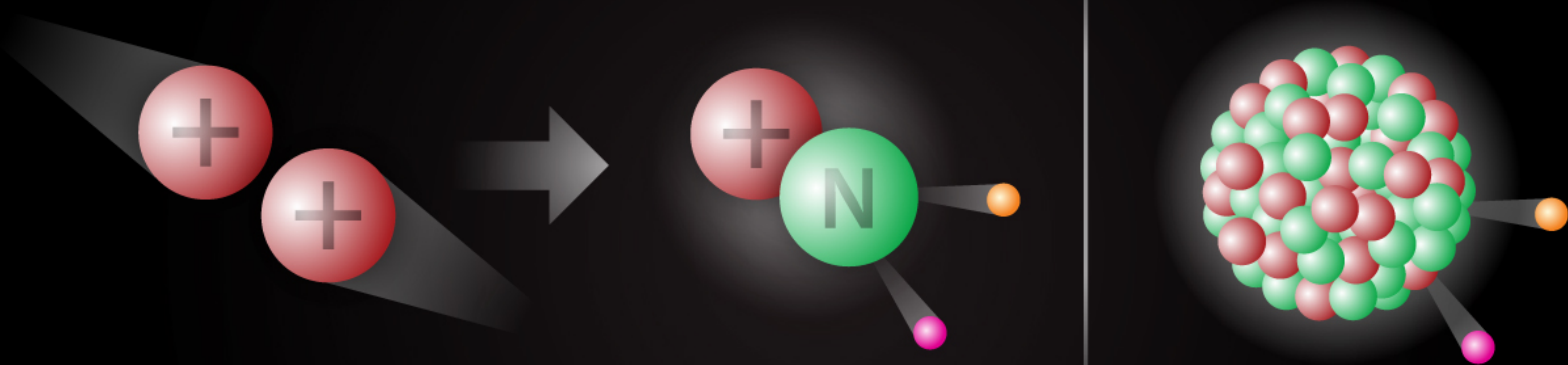
Binding protons in atomic nuclei

Positively charged particles naturally repel each other, it takes an extreme amount of force to hold protons together. The strong nuclear force overcomes the repulsion between protons to hold together atomic nuclei. Without the strong nuclear force, complex nuclei cannot form.

Breaking the bond

Enormous energy is released as gamma rays and nuetrinos when the strong nuclear force is broken between protons and neutrons.

Weak Nuclear Force



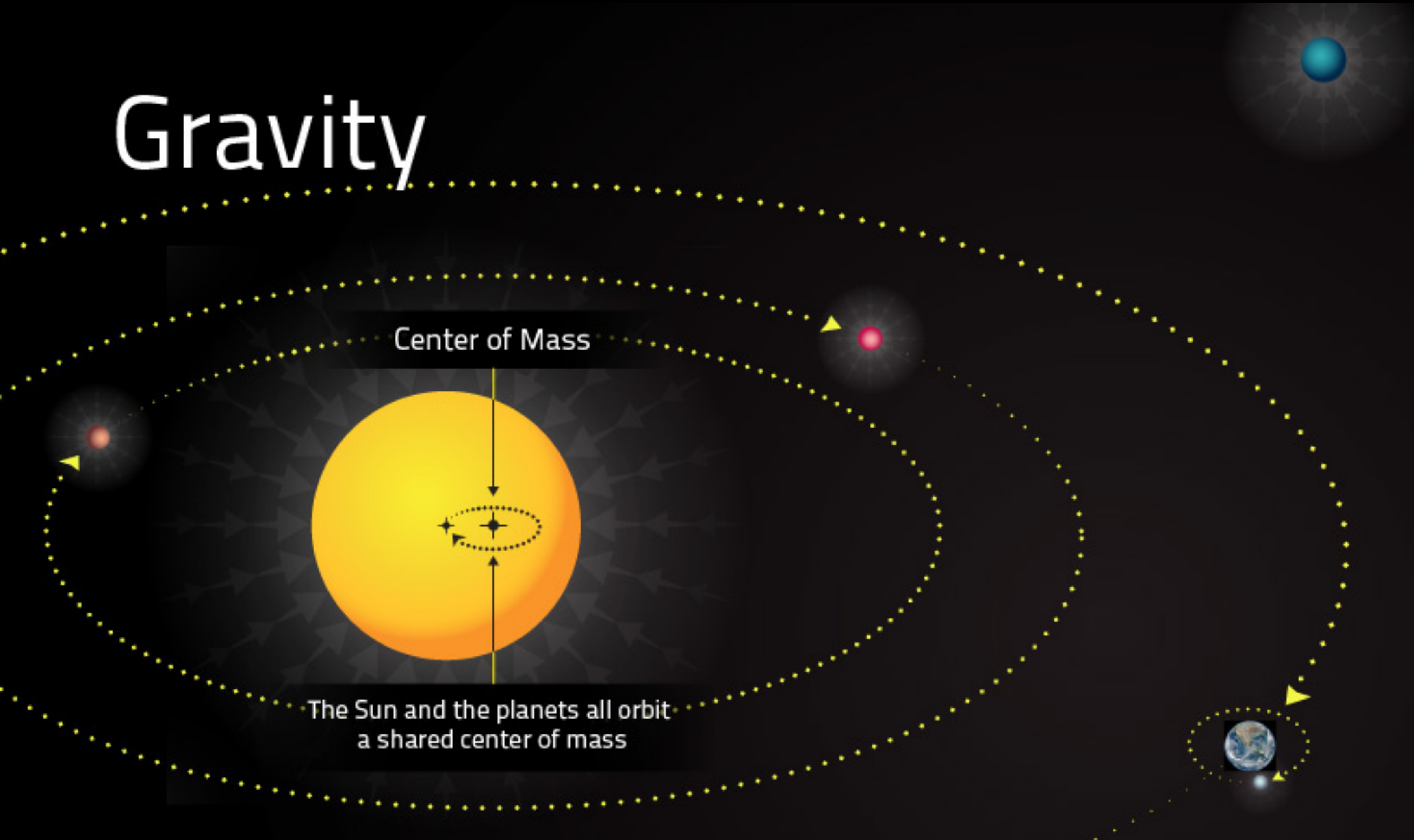
Converting protons into neutrons

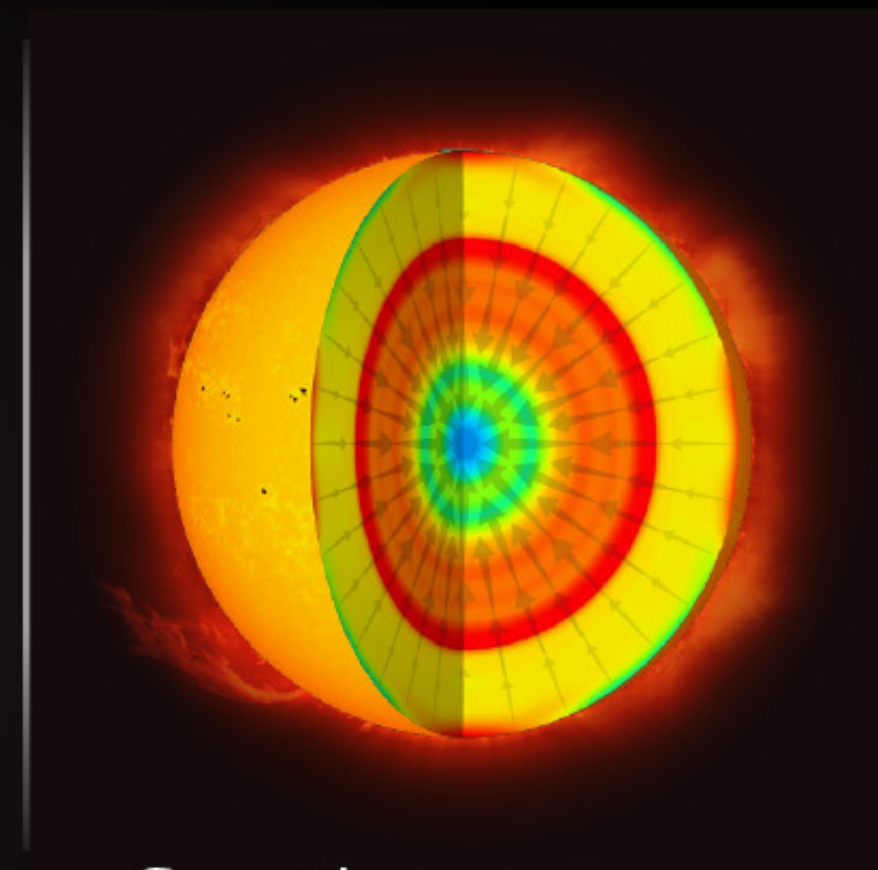
When two protons collide and fuse, a disruption in the weak nuclear force emits a positron and neutrino, which converts one of the positively charged proton to a neutrally charged Nuetron. Without the weak nuclear force converting protons into nuetrons, certain complex nuclei cannot form.

Releasing radiation

Heavy atoms have an imbalance of protons and nuetrons, so the weak nuclear force converts protons to nuetrons releasing radiation.

Gravity





Adding motion to the Universe

Gravity forms stars, planets, and moons, and forces these objects to spin on an axis and move along an orbital path. The planets appear to be orbiting the center of the Sun, but the Sun and planets all orbit a shared center of mass. Planets with enough mass can develop orbiting moons or rings of debris.

Creating energy

Gravity is the force that creates pressure and fusion energy in the core of stars allowing them to burn for millions of years.

Just for completion, not include in what we discuss today.

Mass of elementary particles?

One missing piece was the way to explain the mass of elementary particles. In the mid 1960s, the mechanism to explain the mass generation came out by three independent groups,

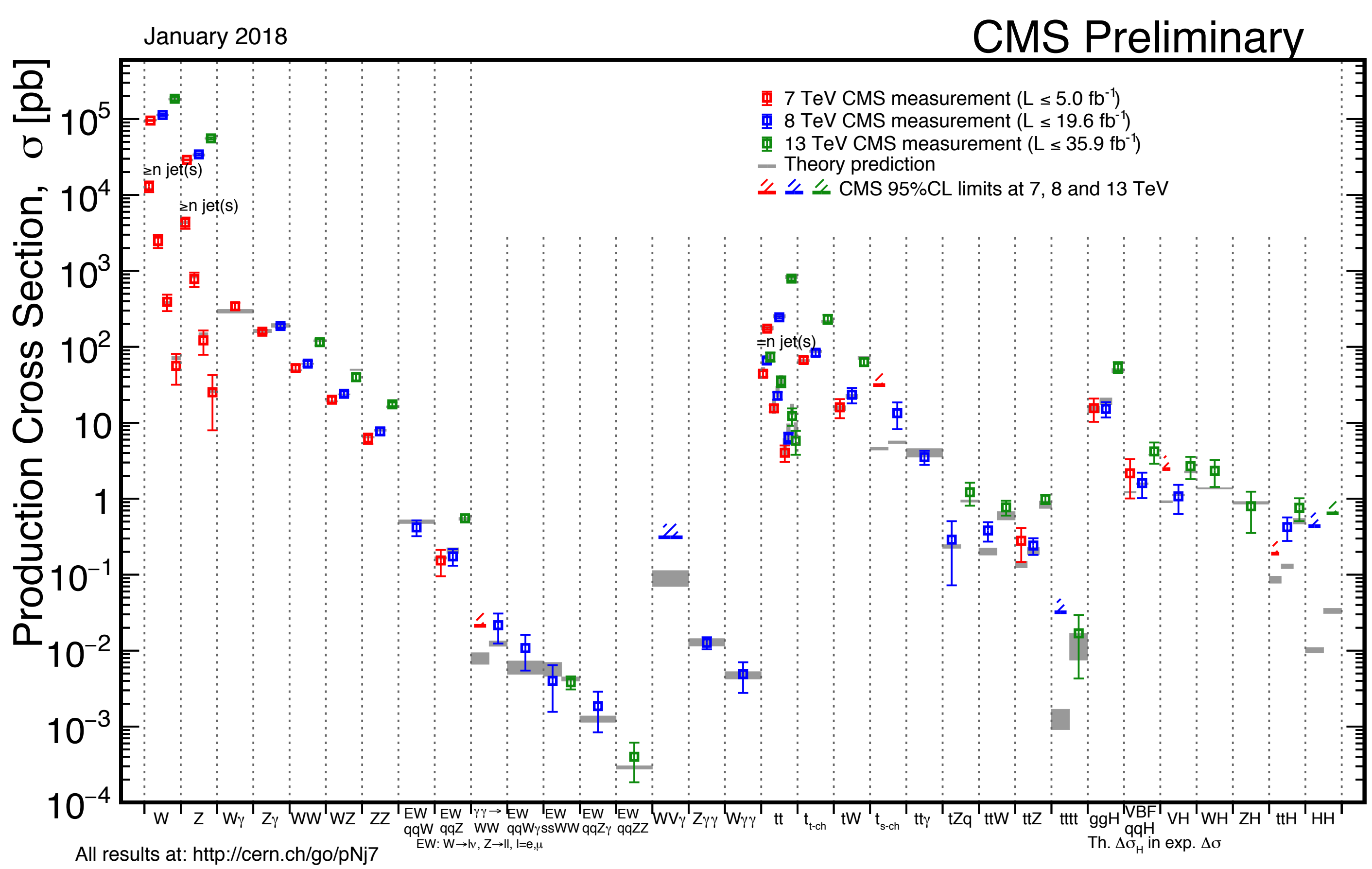
- by Robert Brout and François Englert;
- by Peter Higgs;
- by Gerald Guralnik, C. R. Hagen, and Tom Kibble.

Higgs's original article presenting the model was rejected by Physics Letters. When revising the article before resubmitting it to Physical Review Letters, he added a sentence at the end, mentioning that it implies the existence of one or more new, massive scalar bosons.

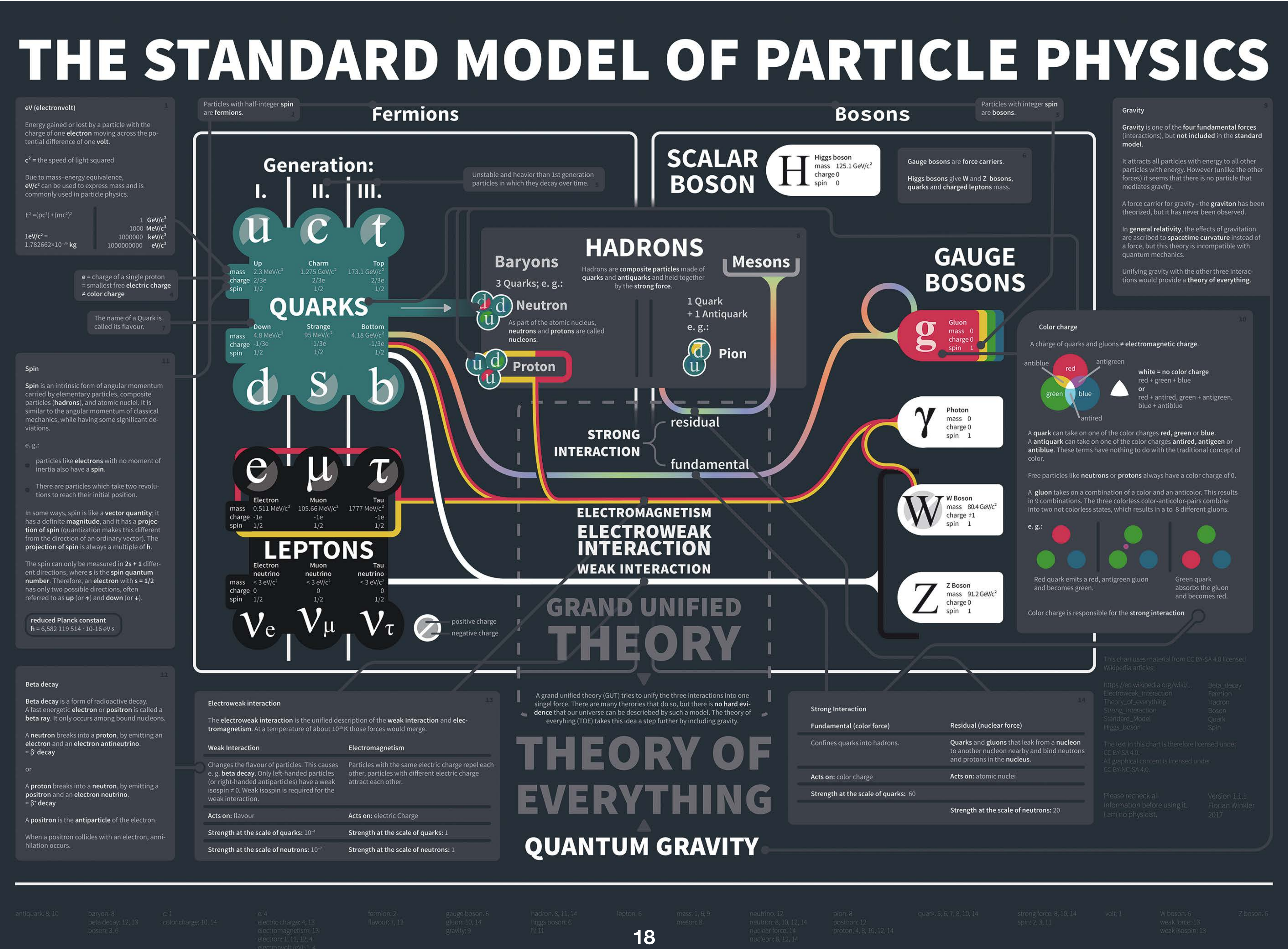
Standard Model

The **Standard Model (SM)** of particle physics is the theory describing three of the four known fundamental forces (the electromagnetic, weak, and strong interactions, and *not including the gravitational force*) in the universe, as well as classifying all known elementary particles.

Steven Weinberg Sheldon Glashow Abdus Salam



SM still show the perfect agreement between theory and experiments in all laboratories around the world. Precise SM measurements, which span 9 order of magnitude, are very important for testing wide-range of SM predictions, and searching for **Beyond SM**.


THE STANDARD MODEL OF PARTICLE PHYSICS
eV (electronvolt) 1
Energy gained or lost by a particle with the charge of one electron moving across the potential difference of one volt.
c² = the speed of light squared
Due to mass-energy equivalence, eV/c² can be used to express mass and is commonly used in particle physics.
E² =(pc²) +(mc²)²
1eV/c² = 1.782662×10⁻³⁶ kg
1 GeV/c² = 1000 MeV/c² = 1000000 keV/c² = 1000000000 eV/c²
e = charge of a single proton = smallest free electric charge ≠ color charge 4
The name of a Quark is called its flavour. 7
Particles with half-integer spin are fermions. 2
Fermions
Bosons
Particles with integer spin are bosons. 3
Generation:
I. II. III.
Unstable and heavier than 1st generation particles in which they decay over time. 5
u c t
Up: mass 2.3 MeV/c², charge 2/3e, spin 1/2
Charm: mass 1.275 GeV/c², charge 2/3e, spin 1/2
Top: mass 173.1 GeV/c², charge 2/3e, spin 1/2
QUARKS
Down: mass 4.8 MeV/c², charge -1/3e, spin 1/2
Strange: mass 95 MeV/c², charge -1/3e, spin 1/2
Bottom: mass 4.18 GeV/c², charge -1/3e, spin 1/2
d s b
e μ τ
Electron: mass 0.511 MeV/c², charge -1e, spin 1/2
Muon: mass 105.66 MeV/c², charge -1e, spin 1/2
Tau: mass 1777 MeV/c², charge -1e, spin 1/2
LEPTONS
Electron neutrino: mass <3 eV/c², charge 0, spin 1/2
Muon neutrino: mass <3 eV/c², charge 0, spin 1/2
Tau neutrino: mass <3 eV/c², charge 0, spin 1/2
νe νμ ντ
positive charge
negative charge
SCALAR BOSON
H Higgs boson: mass 125.1 GeV/c², charge 0, spin 0
Gauge bosons are force carriers. 6
Higgs bosons give W and Z bosons, quarks and charged leptons mass.
HADRONS 8
Hadrons are composite particles made of quarks and antiquarks and held together by the strong force.
Baryons
3 Quarks; e. g.:
Neutron
As part of the atomic nucleus, neutrons and protons are called nucleons.
Proton
Mesons
1 Quark + 1 Antiquark e. g.:
Pion
GAUGE BOSONS
g Gluon: mass 0, charge 0, spin 1
γ Photon: mass 0, charge 0, spin 1
W W Boson: mass 80.4 GeV/c², charge ±1, spin 1
Z Z Boson: mass 91.2 GeV/c², charge 0, spin 1
STRONG INTERACTION
residual
fundamental
ELECTROMAGNETISM
ELECTROWEAK INTERACTION
WEAK INTERACTION
GRAND UNIFIED THEORY
A grand unified theory (GUT) tries to unify the three interactions into one singel force. There are many theories that do so, but there is no hard evidence that our universe can be descriebed by such a model. The theory of everyhing (TOE) takes this idea a step further by including gravity.
THEORY OF EVERYTHING
QUANTUM GRAVITY
Gravity 9
Gravity is one of the four fundamental forces (interactions), but not included in the standard model.
It attracts all particles with energy to all other particles with energy. However (unlike the other forces) it seems that there is no particle that mediates gravity.
A force carrier for gravity - the graviton has been theorized, but it has never been observed.
In general relativity, the effects of gravitation are ascribed to spacetime curvature instead of a force, but this theory is incompatible with quantum mechanics.
Unifying gravity with the other three interactions would provide a theory of everything.
Color charge 10
A charge of quarks and gluons ≠ electromagnetic charge.
antiblue red antigreen green blue antired
white = no color charge
red + green + blue
or
red + antired, green + antigreen, blue + antiblue
A quark can take on one of the color charges red, green or blue.
A antiquark can take on one of the color charges antired, antigreen or antiblue. These terms have nothing to do with the traditional concept of color.
Free particles like neutrons or protons always have a color charge of 0.
A gluon takes on a combination of a color and an anticolor. This results in 9 combinations. The three colorless color-anticolor-pairs combine into two not colorless states, which results in a to 8 different gluons.
e. g.:
Red quark emits a red, antigreen gluon and becomes green.
Green quark absorbs the gluon and becomes red.
Color charge is responsible for the strong interaction
Spin 11
Spin is an intrinsic form of angular momentum carried by elementary particles, composite particles (hadrons), and atomic nuclei. It is similar to the angular momentum of classical mechanics, while having some significant deviations.
e. g.:
particles like electrons with no moment of inertia also have a spin.
There are particles which take two revolutions to reach their initial position.
In some ways, spin is like a vector quantity; it has a definite magnitude, and it has a projection of spin (quantization makes this different from the direction of an ordinary vector). The projection of spin is always a multiple of h.
The spin can only be measured in 2s + 1 different directions, where s is the spin quantum number. Therefore, an electron with s = 1/2 has only two possible directions, often referred to as up (or ↑) and down (or ↓).
reduced Planck constant
h = 6,582 119 514 · 10-16 eV s
Beta decay 12
Beta decay is a form of radioactive decay. A fast energetic electron or positron is called a beta ray. It only occurs among bound nucleons.
A neutron breaks into a proton, by emitting an electron and an electron antineutrino. = β⁻ decay
or
A proton breaks into a neutron, by emitting a positron and an electron neutrino. = β⁺ decay
A positron is the antiparticle of the electron.
When a positron collides with an electron, annihilation occurs.
Electroweak interaction 13
The electroweak interaction is the unified description of the weak Interaction and electromagnetism. At a temperature of about 10¹⁵ K those forces would merge.
Weak Interaction
Changes the flavour of particles. This causes e. g. beta decay. Only left-handed particles (or right-handed antiparticles) have a weak isospin ≠ 0. Weak isospin is required for the weak interaction.
Acts on: flavour
Strength at the scale of quarks: 10⁻⁴
Strength at the scale of neutrons: 10⁻⁷
Electromagnetism
Particles with the same electric charge repel each other, particles with different electric charge attract each other.
Acts on: electric Charge
Strength at the scale of quarks: 1
Strength at the scale of neutrons: 1
Strong Interaction 14
Fundamental (color force)
Confines quarks into hadrons.
Acts on: color charge
Strength at the scale of quarks: 60
Residual (nuclear force)
Quarks and gluons that leak from a nucleon to another nucleon nearby and bind neutrons and protons in the nucleus.
Acts on: atomic nuclei
Strength at the scale of neutrons: 20
This chart uses material from CC BY-SA 4.0 licensed Wikipedia articles:
https://en.wikipedia.org/wiki/...
Electroweak_interaction
Theory_of_everything
Strong_interaction
Standard_Model
Higgs_boson
Beta_decay
Fermion
Hadron
Boson
Quark
Spin
The text in this chart is therefore licensed under CC BY-SA 4.0.
All graphical content is licensed under CC BY-NC-SA 4.0.
Please recheck all information before using it. I am no physicist.
Version 1.1.1
Florian Winkler
2017
antiquark: 8, 10
baryon: 8
beta decay: 12, 13
boson: 3, 6
c: 1
color charge: 10, 14
e: 4
electric charge: 4, 13
electromagnetism: 13
electron: 1, 11, 12, 4
electronvolt (eV): 1, 4
fermion: 2
flavour: 7, 13
gauge boson: 6
gluon: 10, 14
gravity: 9
hadron: 8, 11, 14
higgs boson: 6
h: 11
lepton: 6
mass: 1, 6, 9
meson: 8
neutrino: 12
neutron: 8, 10, 12, 14
nuclear force: 14
nucleon: 8, 12, 14
pion: 8
positron: 12
proton: 4, 8, 10, 12, 14
quark: 5, 6, 7, 8, 10, 14
strong force: 8, 10, 14
spin: 2, 3, 11
volt: 1
W boson: 6
weak force: 13
weak isospin: 13
Z boson: 6

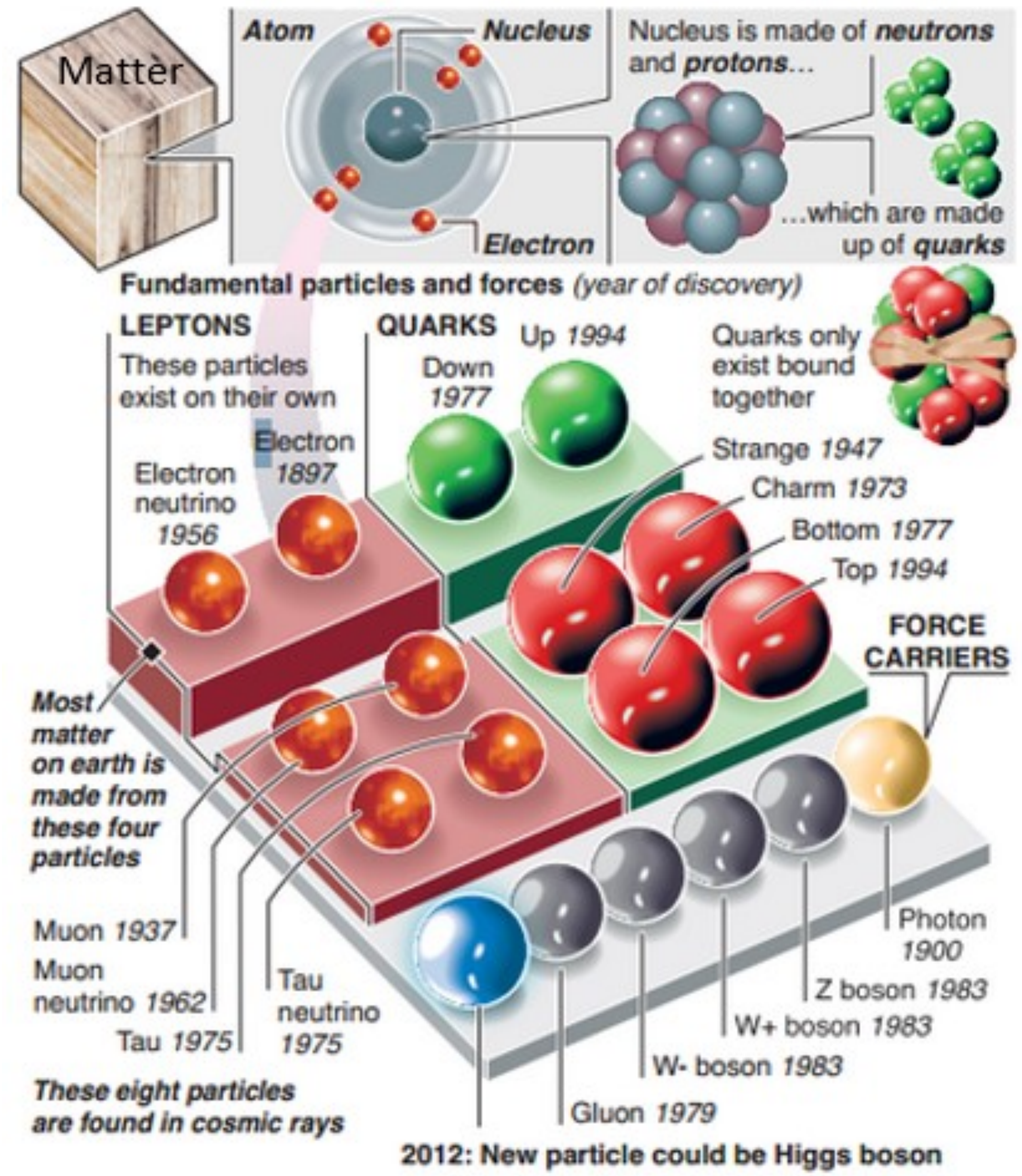
Mathematical tools of the Standard Model

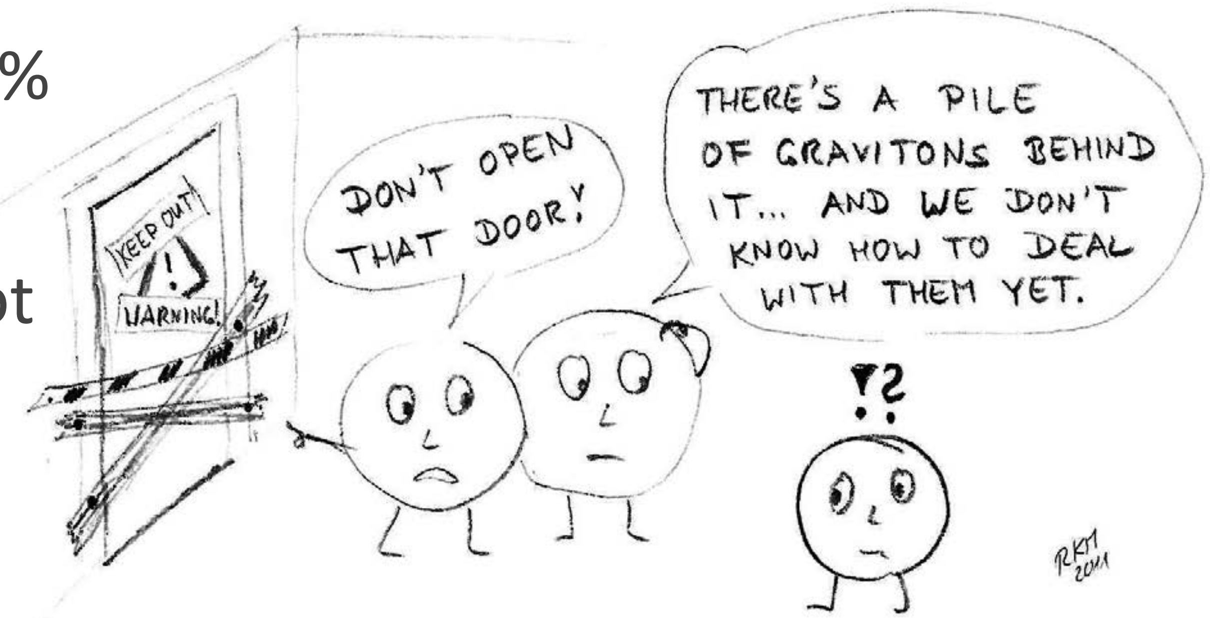
- 12 matter particles (and 12 anti-particles)
  - in 3 generations (all fermions i.e. 1/2 integer spin)
- 4 types of force carriers (all bosons i.e. integer spin)
- 1 Higgs Boson (spin 1)
- The mathematics is called a **Quantum Field Theory** (QFT)
  - combines classical fields, special relativity and quantum mechanics.
- In QFT, the particles are excited states of the field.
- The QFT contains the internal symmetries which form the product group SU(3) x SU(2) x U(1) [QCD x Weak x QED]

The Standard Model is not enough

The SM is one of the most successful models in physics. However, it does have some short comings. Perhaps it is a low-energy approximation to a more complete theory (in the way Newton's laws are a low speed approximation to SR).

- **SM tells you how, but not why:**
  - **Families** – 3 families of quarks and leptons.
  - **Number of parameters** – 19 free parameters.
- **Some phenomenon not explained by the SM:**
  - **Gravity** – not explained, why so weak?, SM incompatible with general relativity
  - **Dark Matter & Dark Energy** – accounts for 95% mass of universe but not included in SM
  - **Matter/anti-matter asymmetry** – SM does not explain the amount of matter/anti-matter asymmetry at Big Bang.

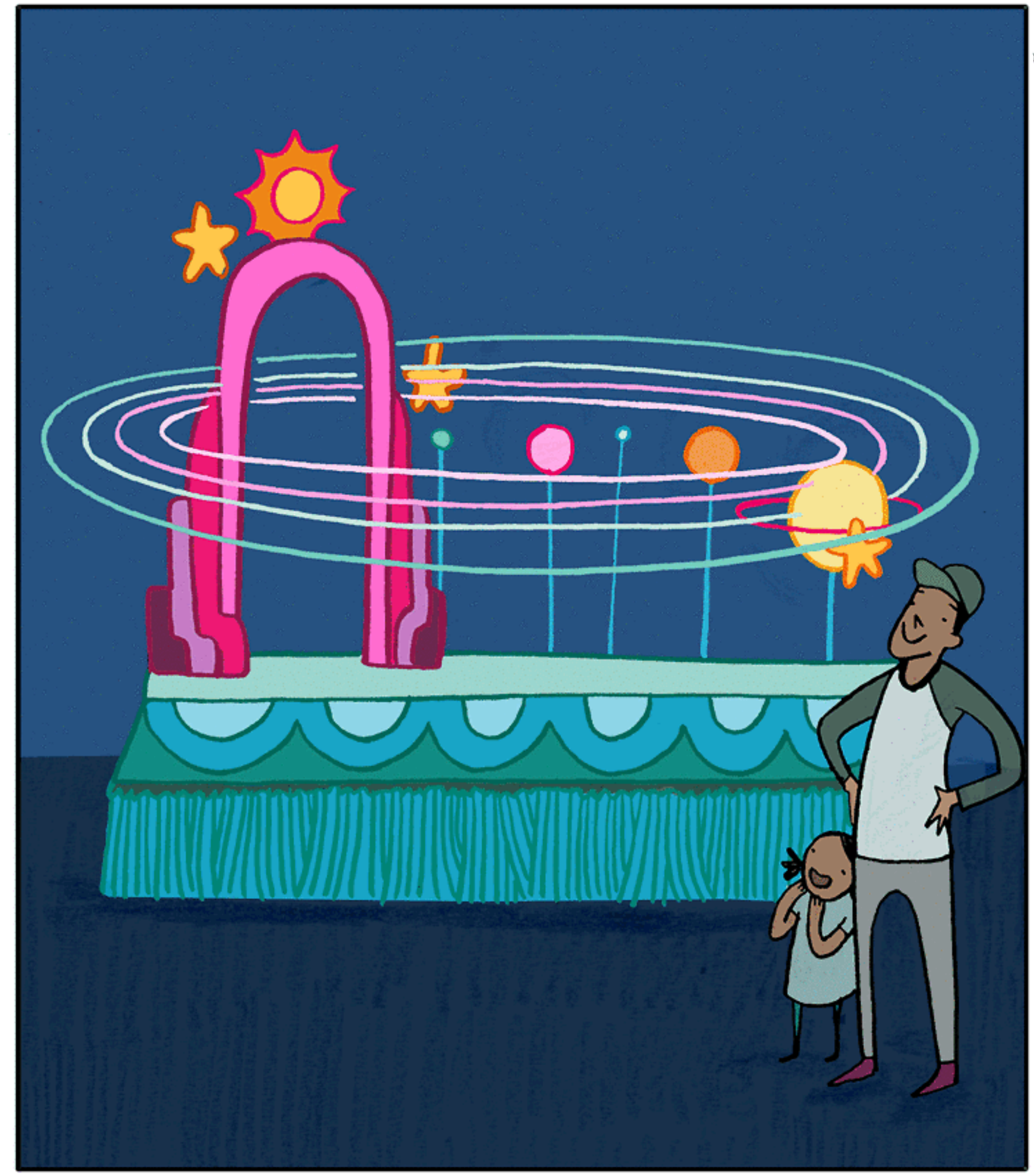




Matter and antimatter asymmetry

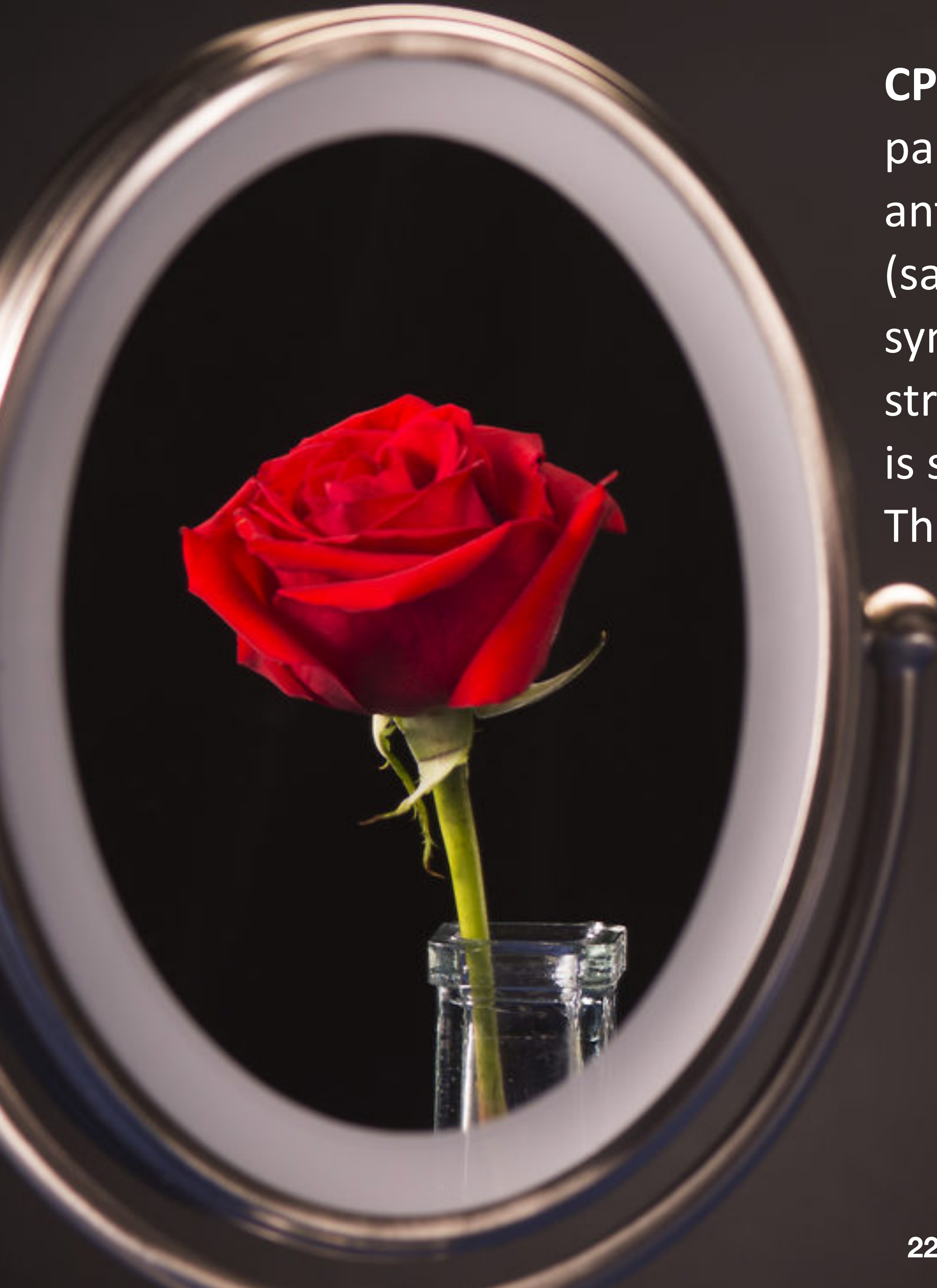
Proto: Symmetry Magazine

Cosmologists predict that the Big Bang produced an **equal amount of matter and antimatter**, which is a conundrum because matter and antimatter annihilate into pure energy when they come into contact.



Particle physicists are looking for any minuscule **differences between matter and antimatter**, which might explain why our universe contains planets and stars and not a sizzling broth of light and energy instead.

CP Symmetry



CP symmetry (where C is charge and P is parity) basically states that a particle and its anti-particle should behave exactly the same (same lifetime, symmetric decays etc.). CP-symmetry seems to be conserved in the strong and electromagnetic interactions but is slightly violated in certain weak decays. This violation is add-on to the SM.

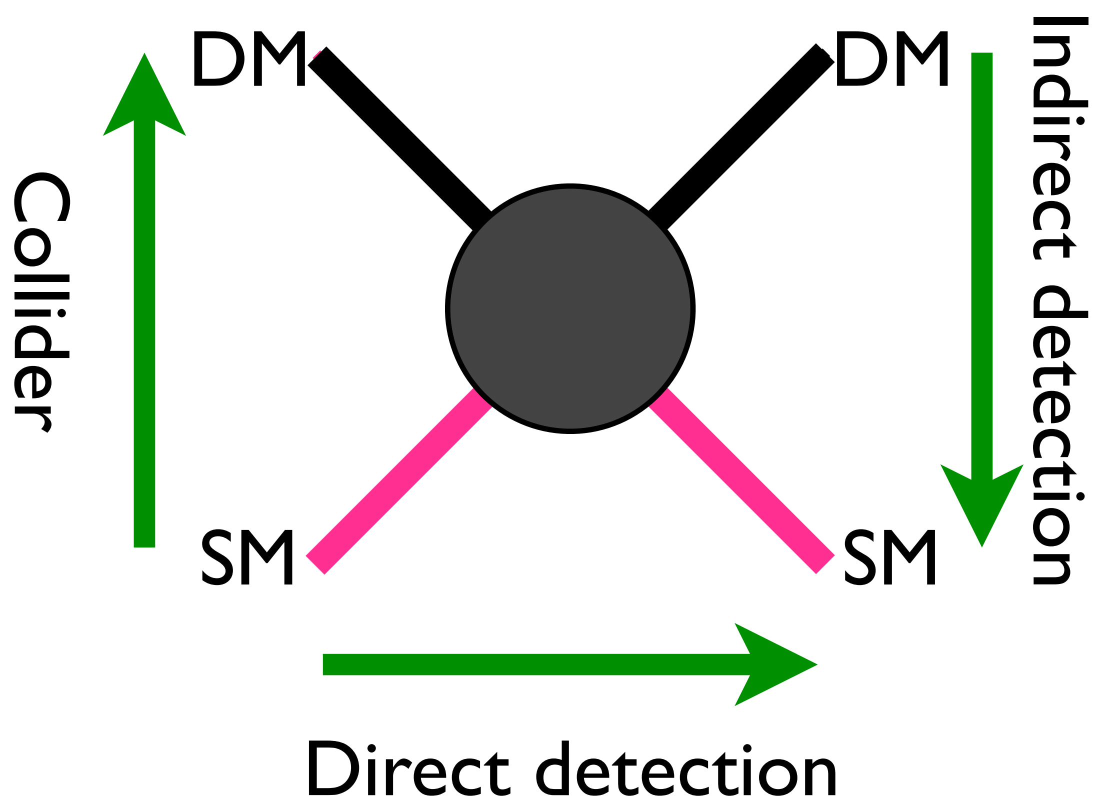
Dark sector

The main point for the dark sector is that the theories comprehensively confront the problem of dark matter. Dark matter is a term physicists coined to explain bizarre gravitational effects they observe in the cosmos. Distant starlight appears to bend around invisible objects as it traverses the cosmos, and galaxies spin as if they had five times more mass than their visible matter can explain.

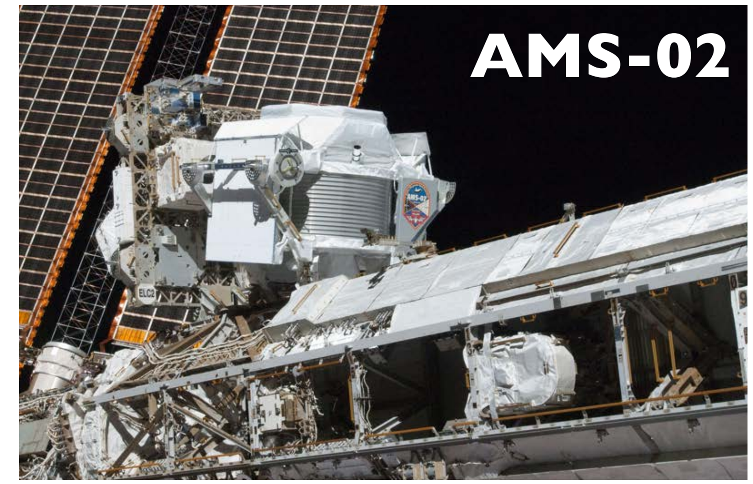
https://www.symmetrymagazine.org/article/voyage-into-the-dark-sector

Dark matter searches

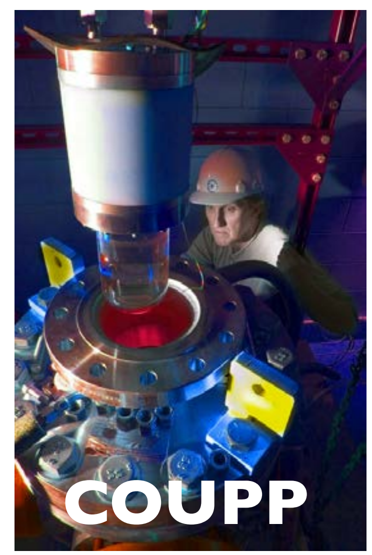
- Identify DM is one of the most important in physics.
- DM is likely to be (direct-)undetected particles.

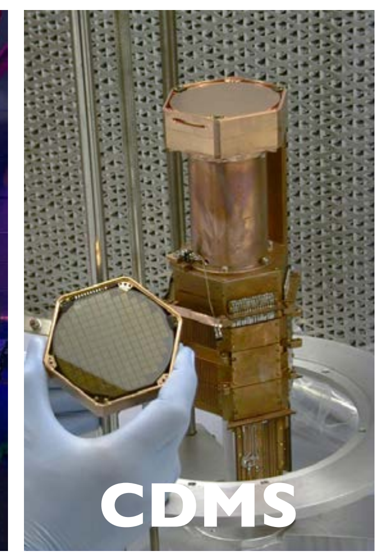


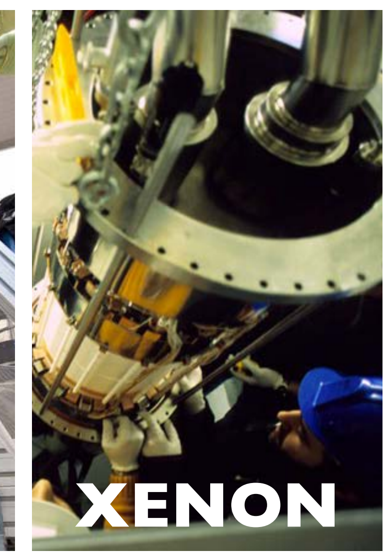
Observe DM annihilation products



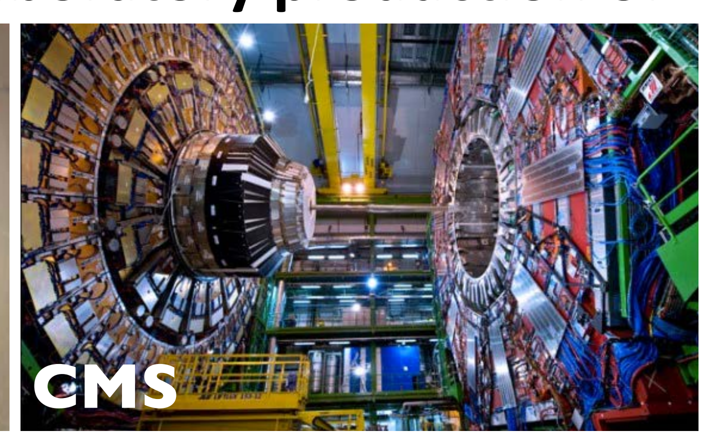
Dark Matter-nucleus scattering

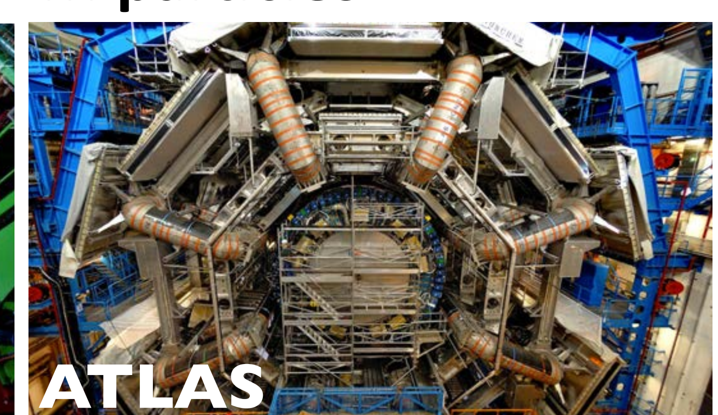




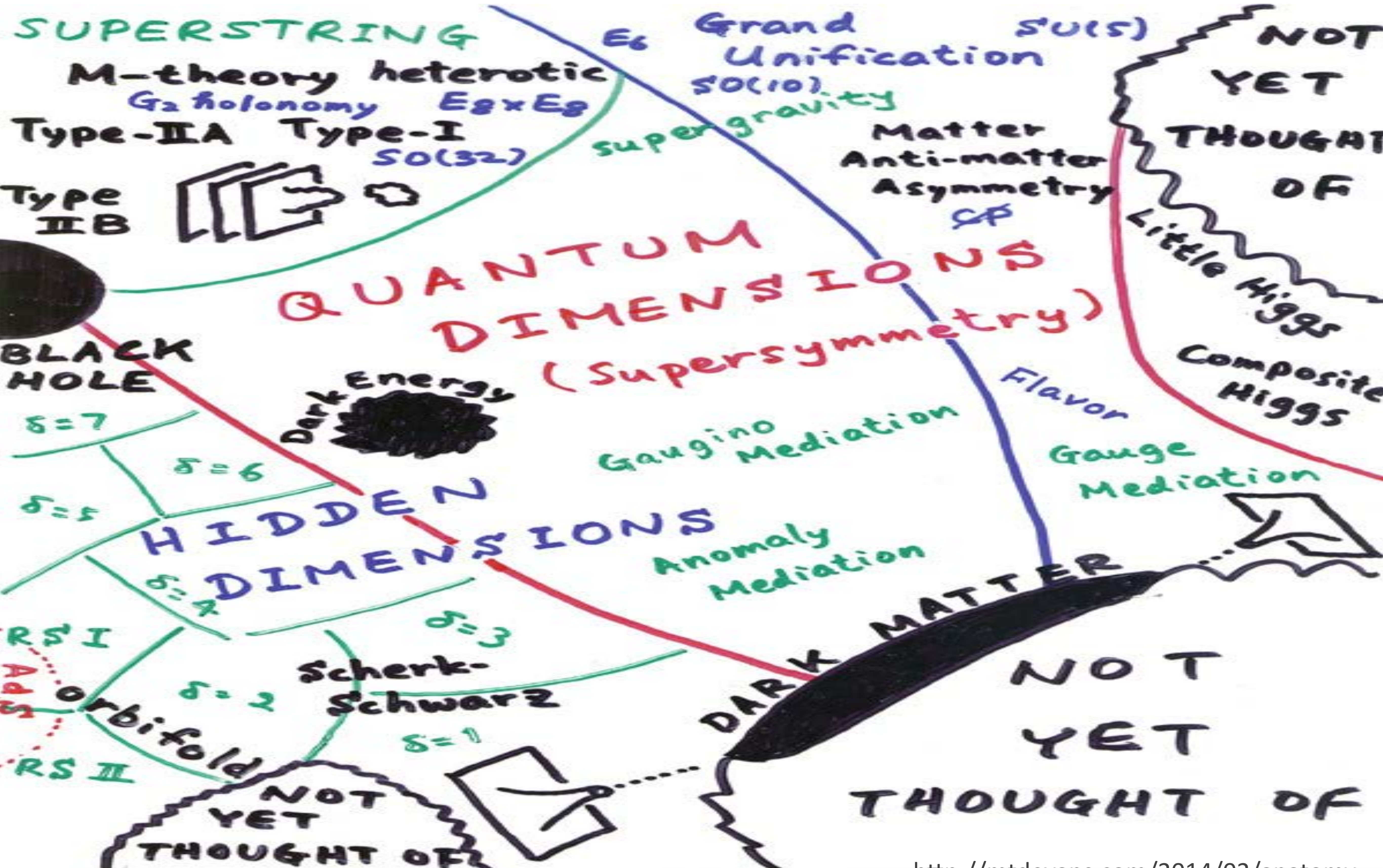


Laboratory production of DM particles





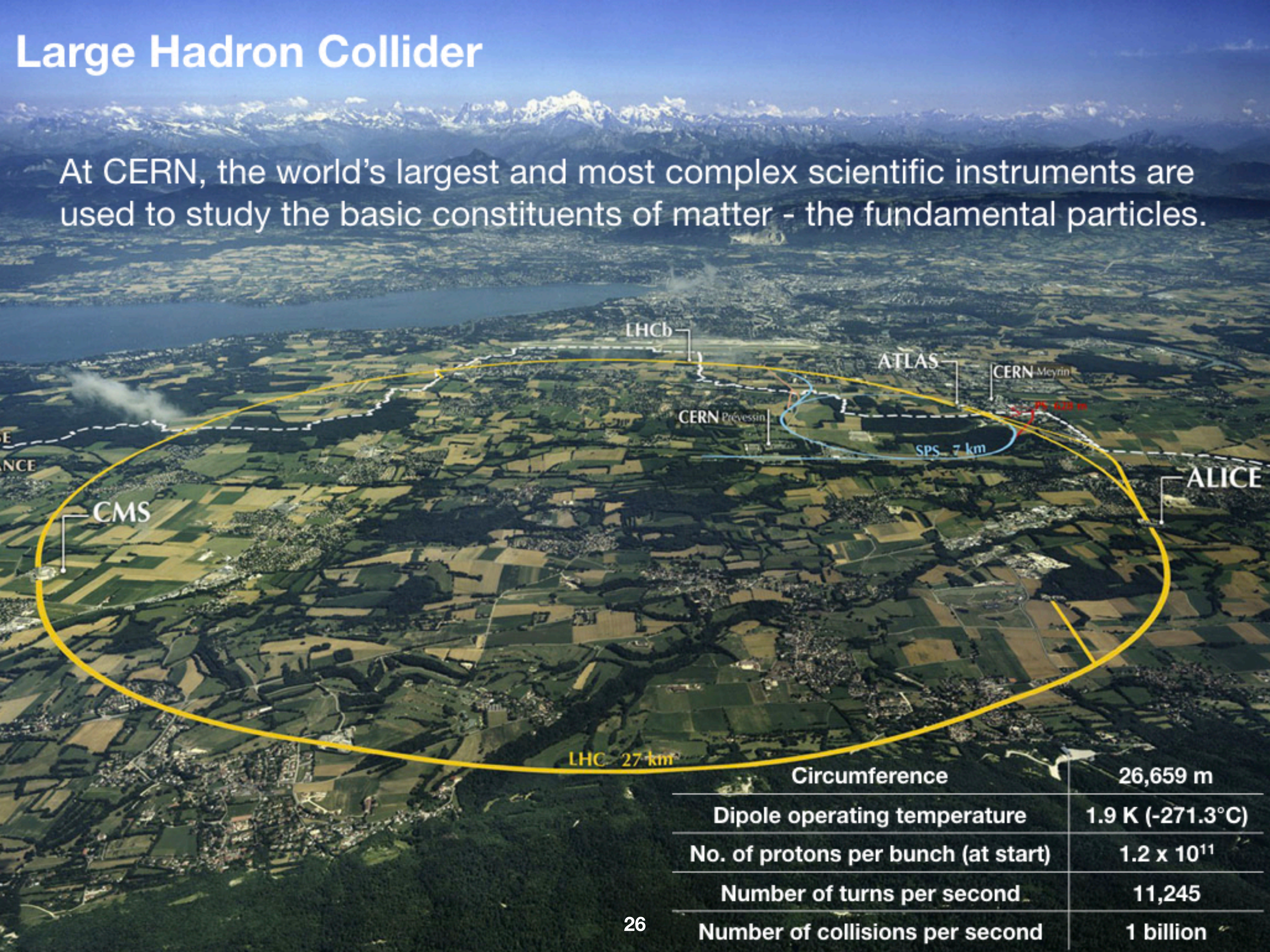
And more that we don't discuss here



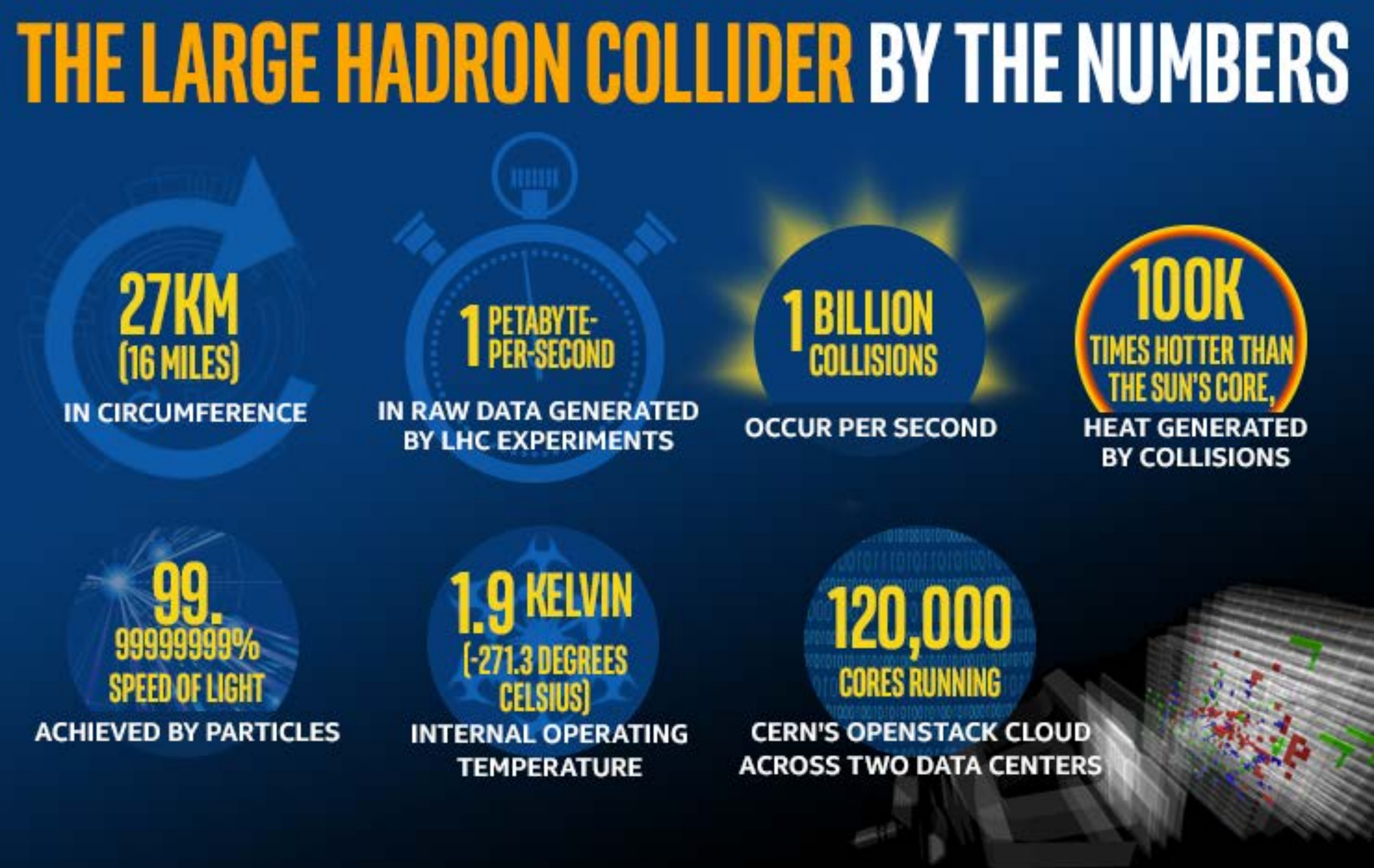
http://mtdevans.com/2014/02/anatomy-of-a-particle-physics-experiment/

Large Hadron Collider

At CERN, the world's largest and most complex scientific instruments are used to study the basic constituents of matter - the fundamental particles.



Circumference	26,659 m
Dipole operating temperature	1.9 K (-271.3°C)
No. of protons per bunch (at start)	1.2×10^{11}
Number of turns per second	11,245
Number of collisions per second	1 billion



http://www.intelfreepress.com/news/cern-upgrades-data-center-and-restarts-large-hadron-collider/9819/

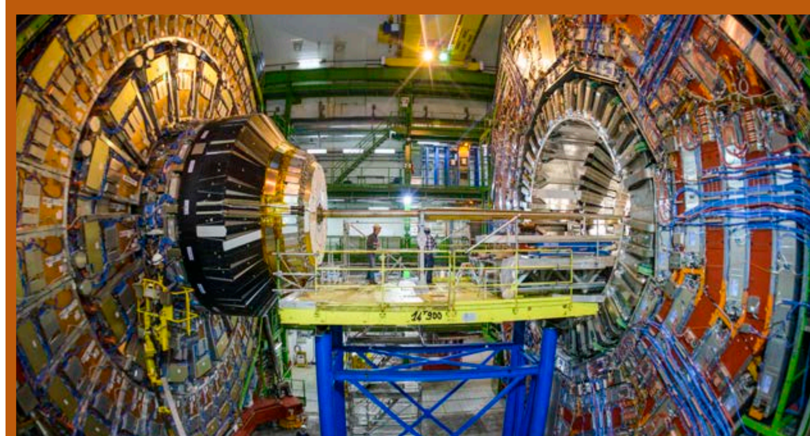
LHC experiments

At CERN, there are seven experiments have been setup around the LHC. These experiments use different designs and techniques of particle detection to detect the myriad of particles produced by collisions in the accelerator, and they run by collaborations of scientists from institutes all over the world.

ALICE

ATLAS

CMS



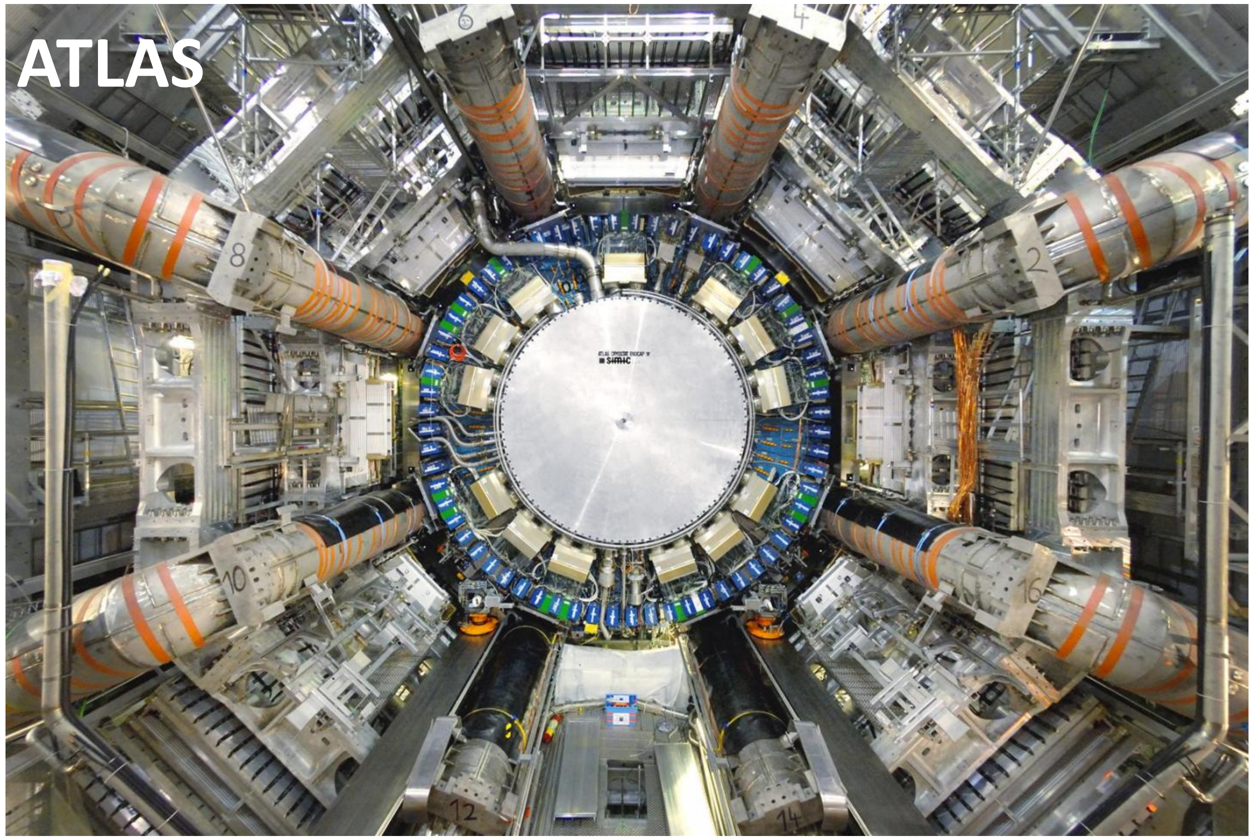
LHCb

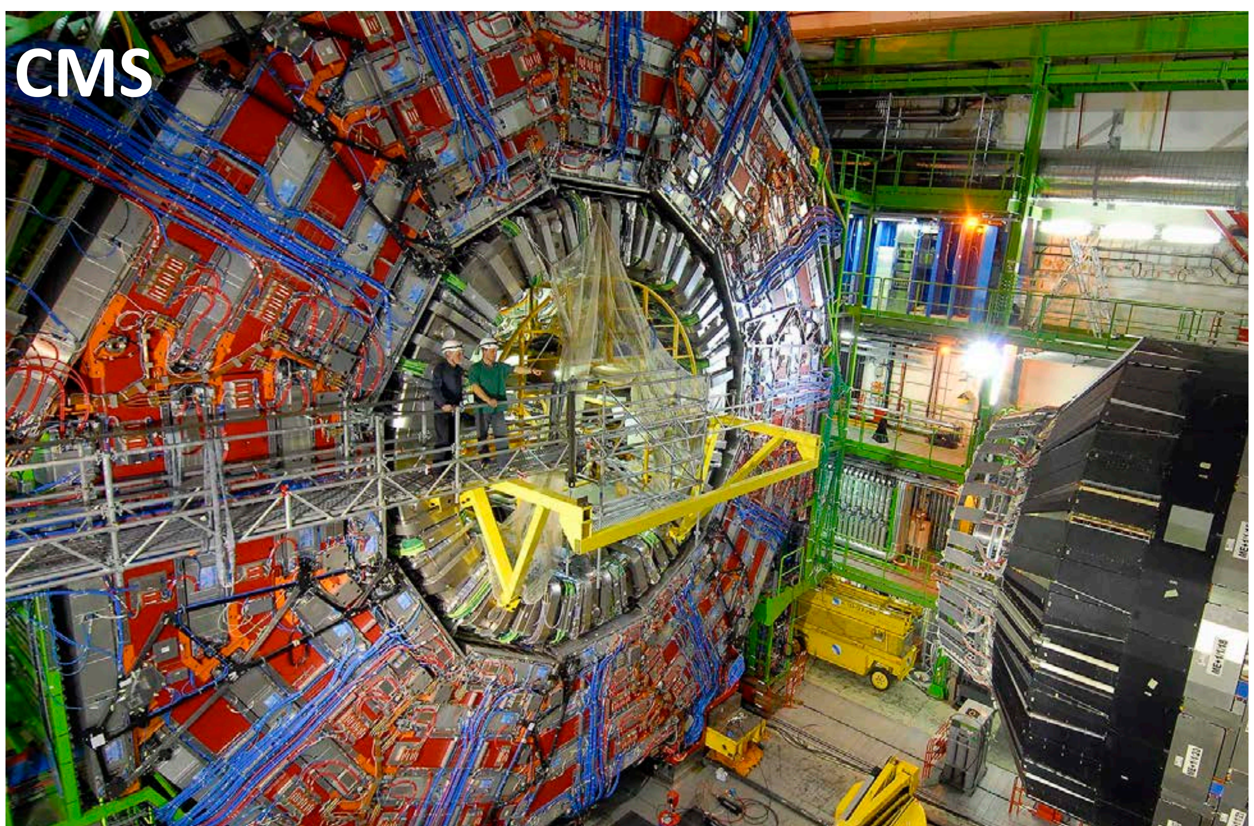
LHCf

MoEDAL

TOTEM

LHC experiments

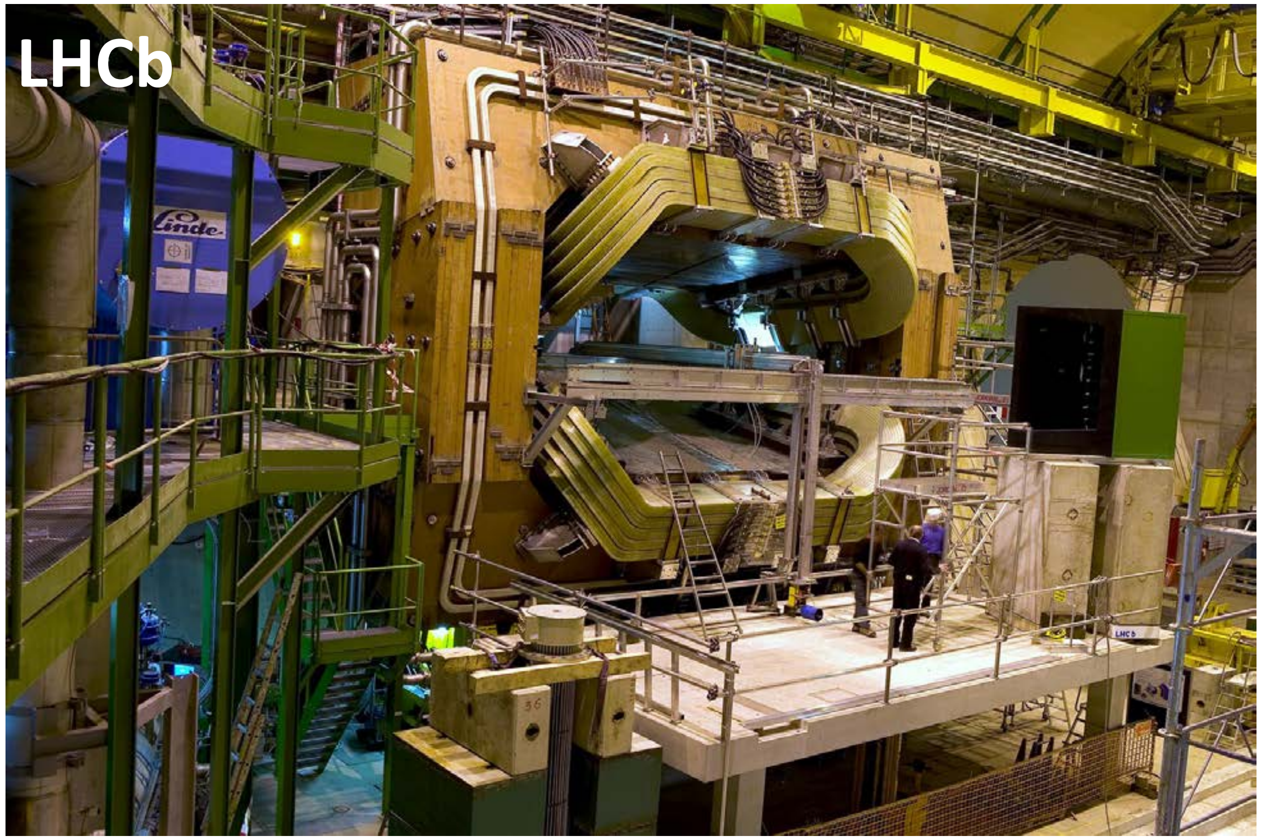




ATLAS (A Toroidal LHC Apparatus) and **CMS** (Compact Muon Solenoid), the two general propose detectors to investigate wide range of physics phenomena where the highly massive particles can be produced from the proton-proton collisions. Having two of them are important key to confirm new discoveries.

- Discover and study the **Higgs Boson**
- Direct searches for new heavy particles **beyond SM** (e.g. **SUSY**)
- The origin of **dark matter**
- Other **new physics** e.g. **extra dimensions**
- … etc.

LHC experiments



LHCb (Large Hadron Collider beauty), a special design detector to focus on

- Find new sources of CP violation
- Indirect search for physics beyond SM
- Precision measures of b- decays
- Search for exotic states of matter

ALICE (A Large Ion Collider Experiment), a detector which is designed to be the heavy-ion detector used to study

- the Quark-Gluon Plasma (by colliding lead ions)
- Study of QCD under extreme conditions

ALICE

And several non-LHC experiments, i.e.

AEGIS

AEGIS uses a beam of antiprotons from the Antiproton Decelerator to measure the value of Earth's gravitational acceleration.

DIRAC

A collaboration of CERN physicists are studying the decay of unstable “pionium atoms” to gain insight into the strong force.

AMS

The Alpha Magnetic Spectrometer looks for dark matter, antimatter and missing matter from a module on the International Space Station.

And several non-LHC experiments, i.e.

AWAKE

AWAKE explores the use of plasma to accelerate particles to high energies over short distances.

CLOUD

Could there be a link between galactic cosmic rays and cloud formation? An experiment at CERN is using the cleanest box in the world to find out.

ISOLDE

ISOLDE studies the properties of atomic nuclei, with further applications in fundamental studies, astrophysics, material and life sciences.

CERN Missions

Research
Seeking and finding answers to questions about the Universe

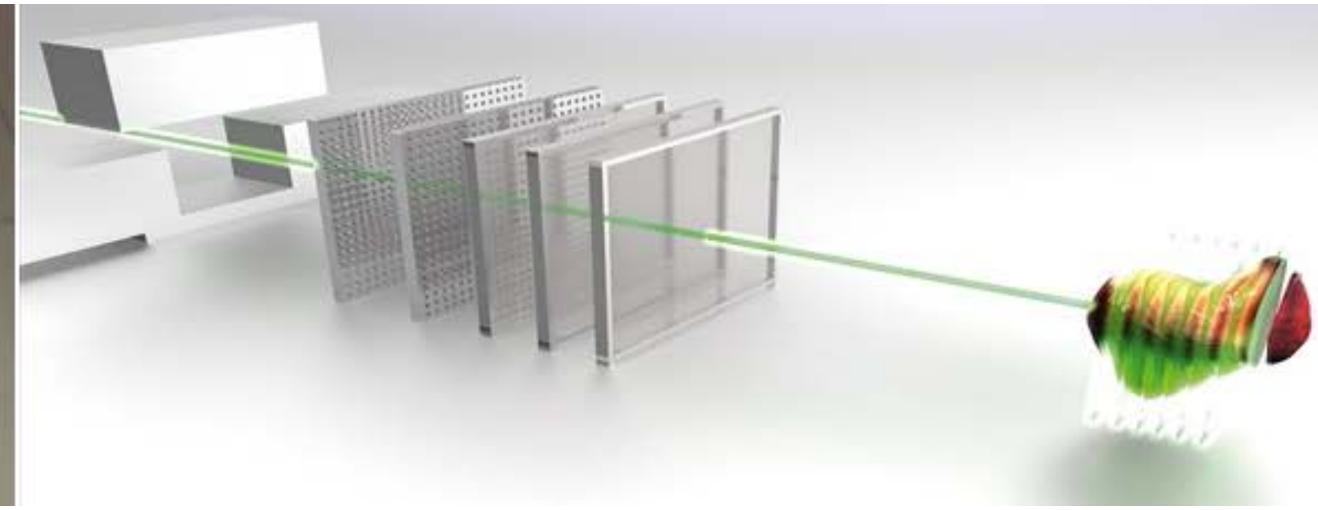
Technology
Advancing the frontiers of technology

Education
Training the scientists of tomorrow

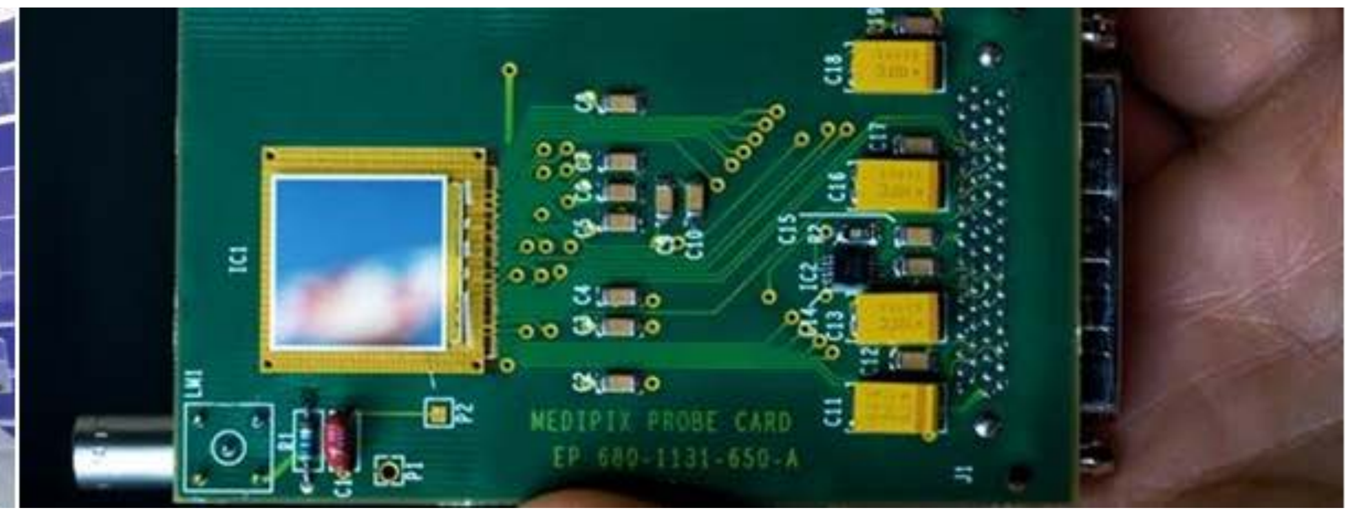
Collaborating
Bringing nations together through science

http://kt.cern

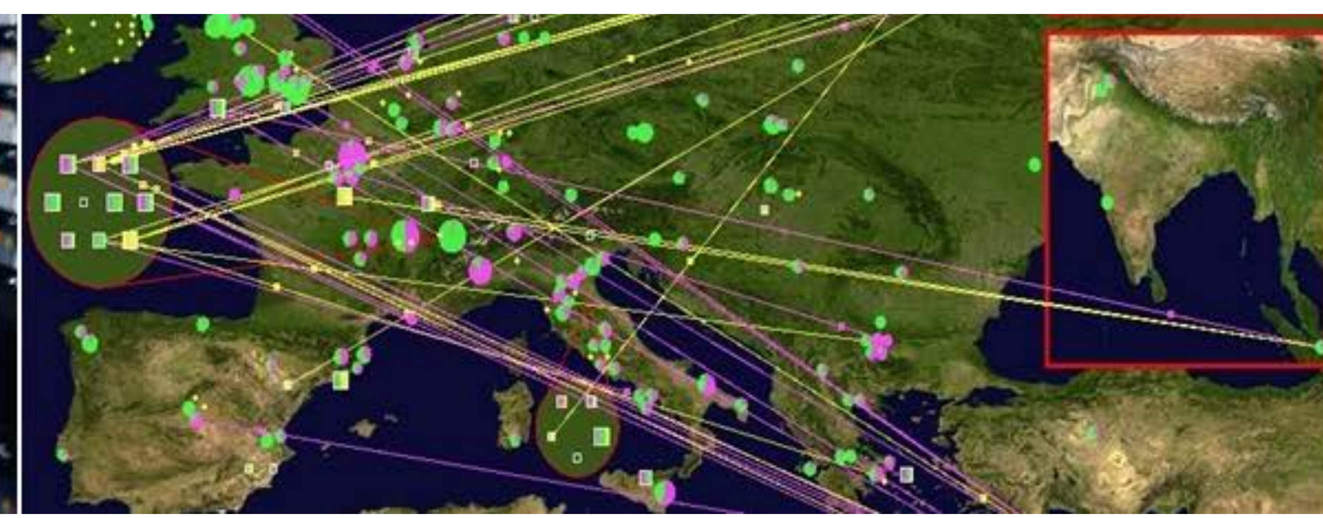
Accelerators



Detectors

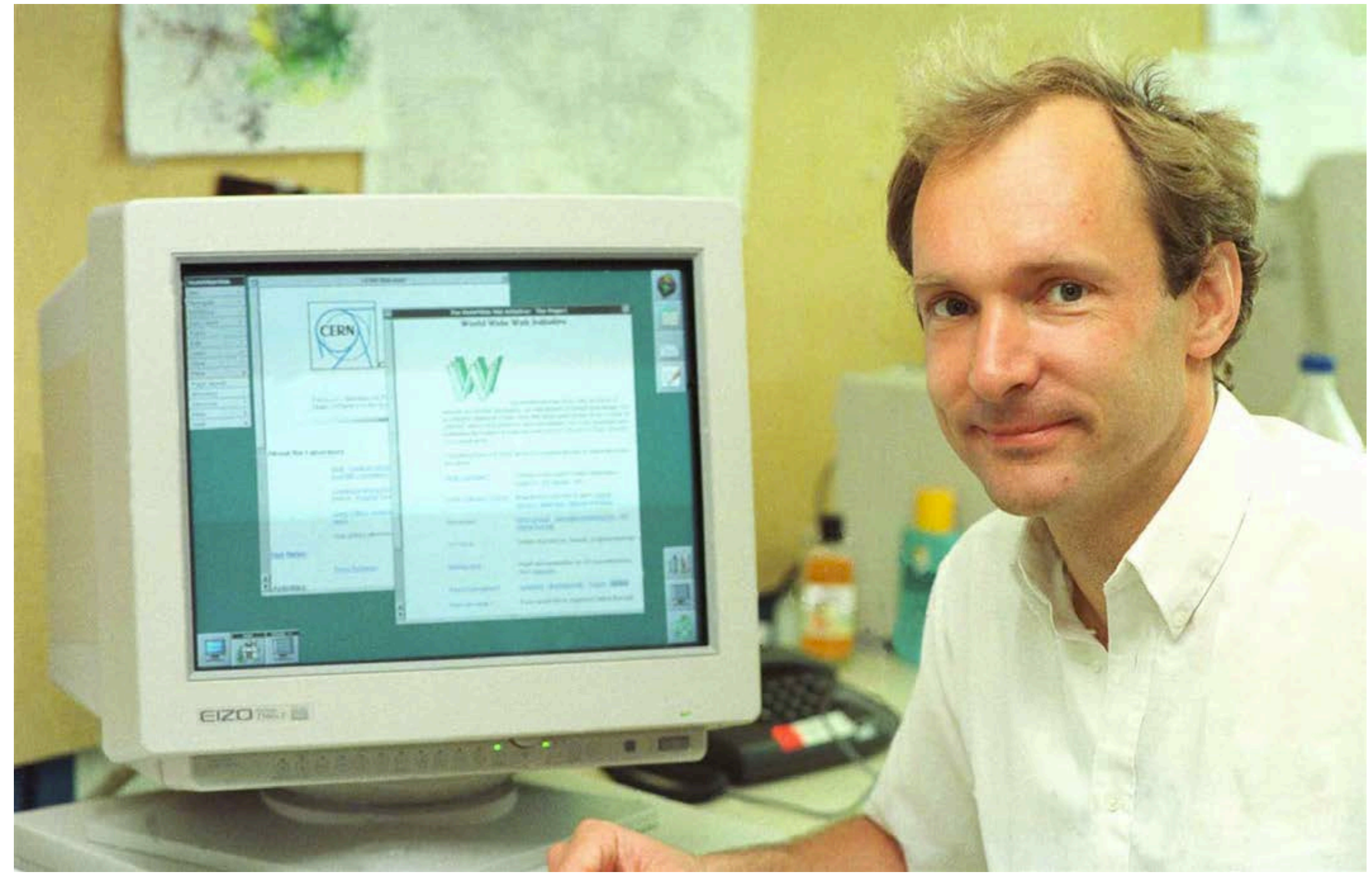


Computing



Where the WWW was born

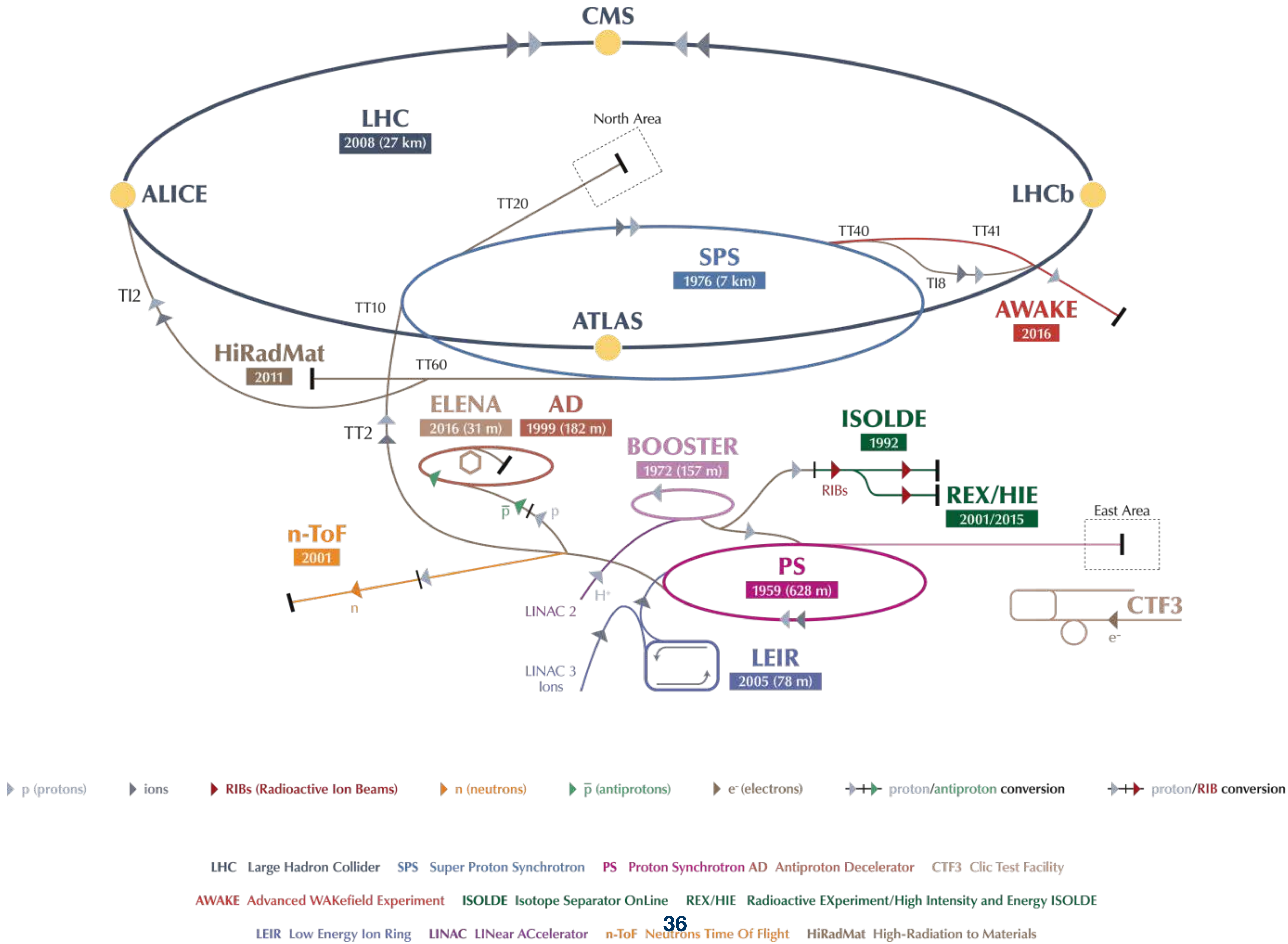
https://home.cern/topics/birth-web



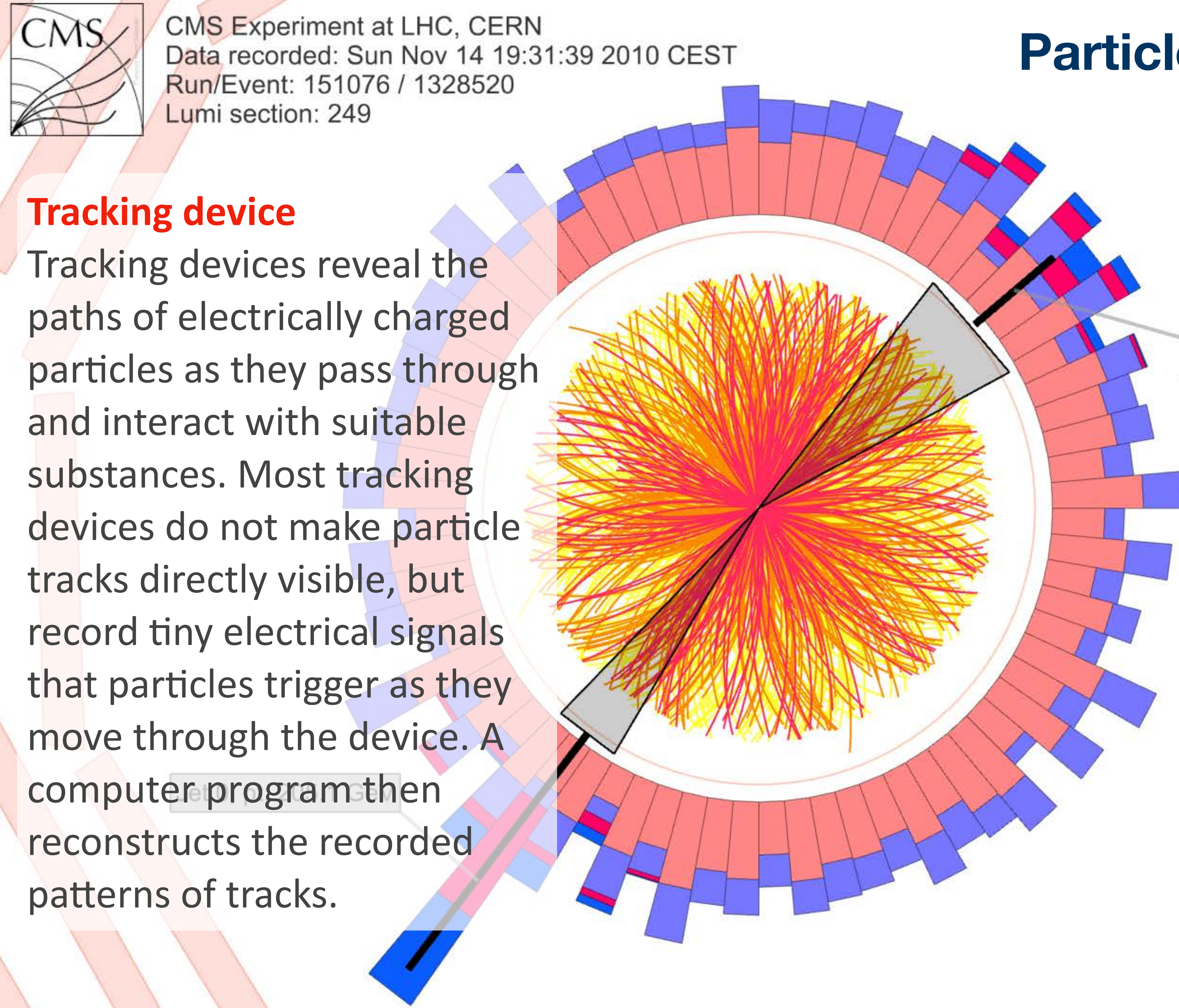
The Touch Terminal as developed for the Antiproton Accumulator (AA).

http://cerncourier.com/cws/article/cern/42092
https://www.symmetrymagazine.org/article/june-2010/cern-touch-screen

CERN accelerator complex



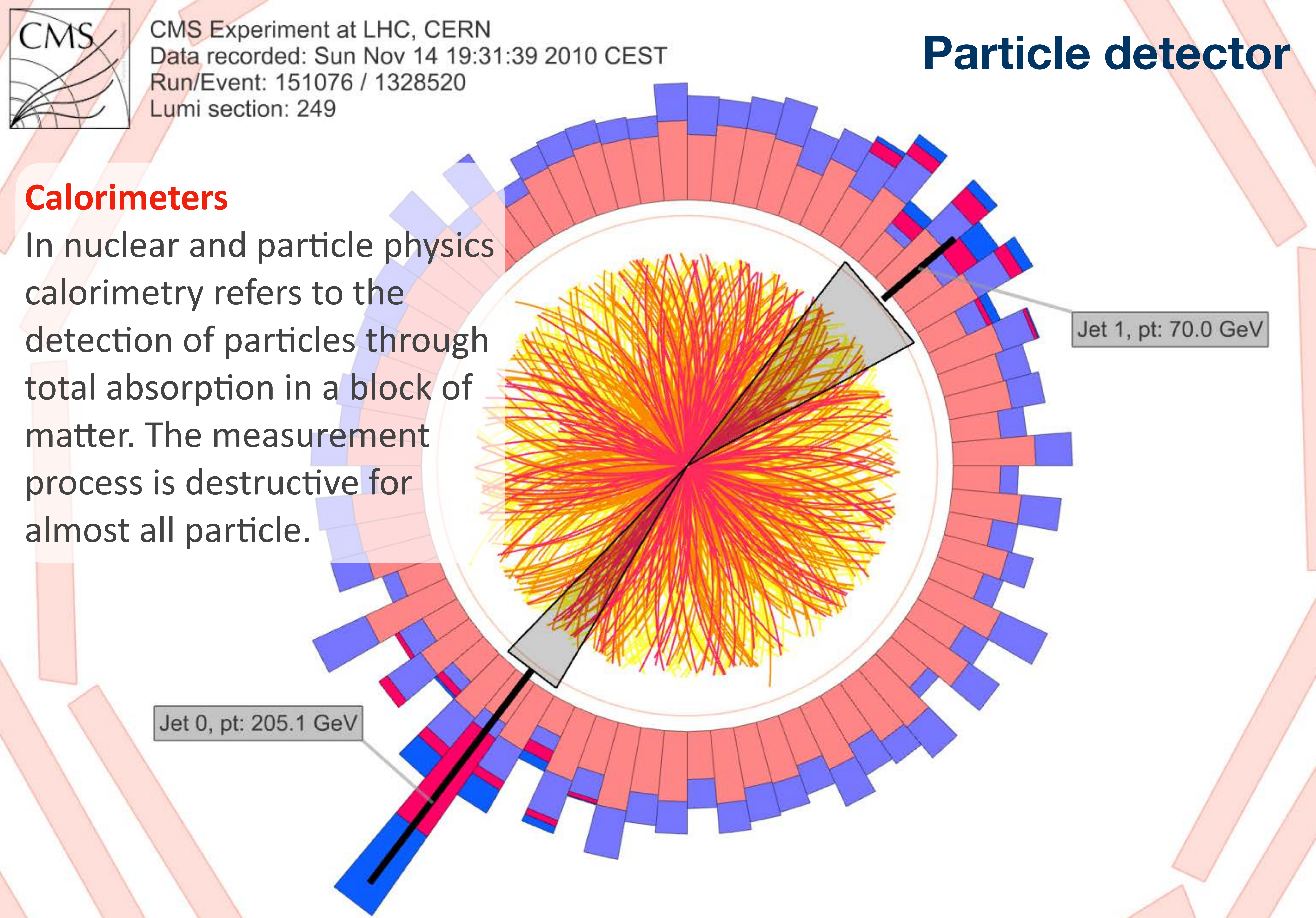
Particle detector



Tracking device

Tracking devices reveal the paths of electrically charged particles as they pass through and interact with suitable substances. Most tracking devices do not make particle tracks directly visible, but record tiny electrical signals that particles trigger as they move through the device. A computer program then reconstructs the recorded patterns of tracks.

Particle detector

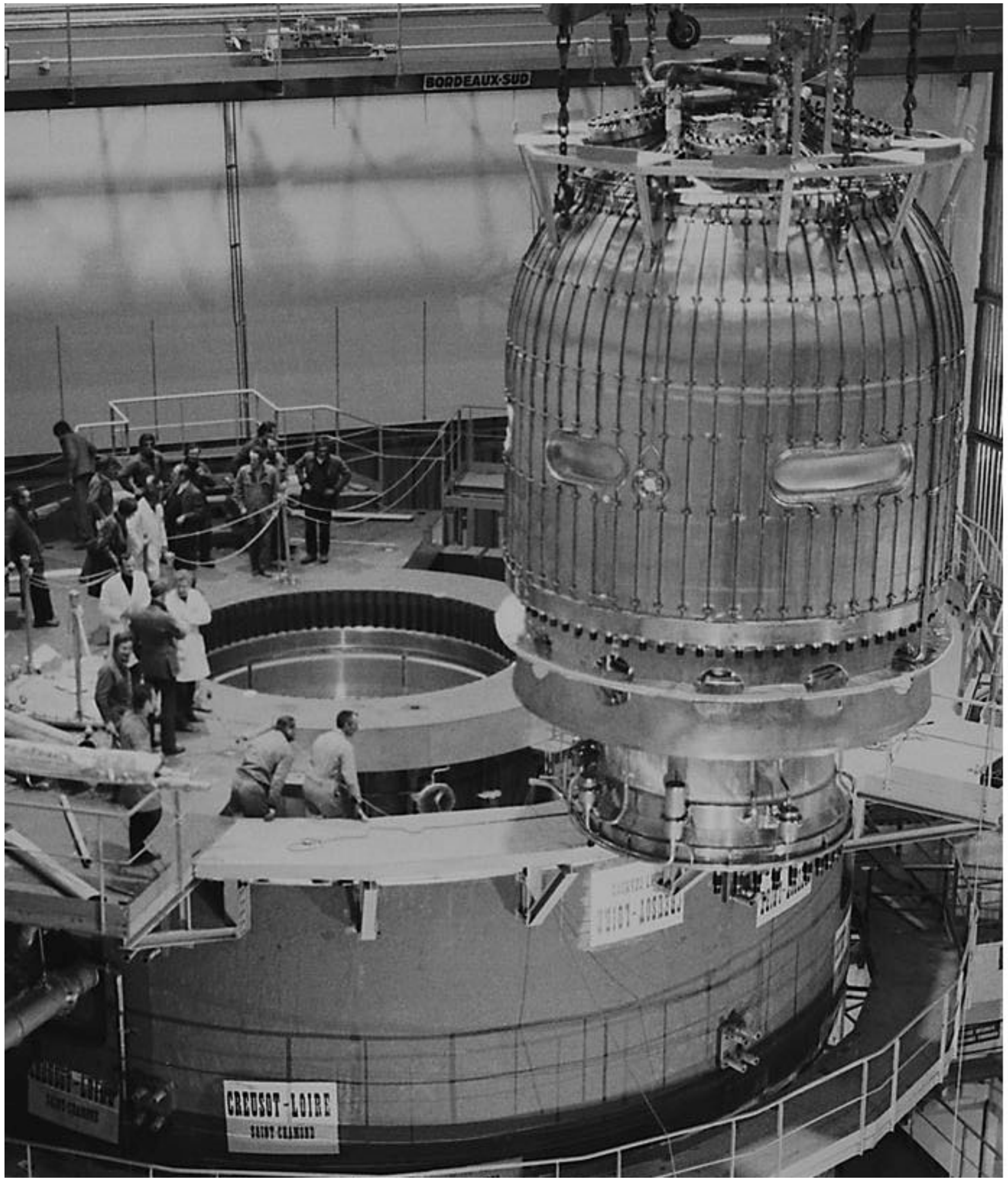


Calorimeters

In nuclear and particle physics calorimetry refers to the detection of particles through total absorption in a block of matter. The measurement process is destructive for almost all particle.

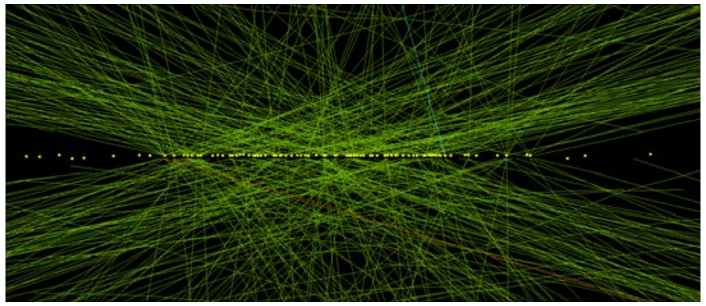
Challenges of particle detector

The Big European Bubble Chamber (BEBC) operated from 1973 -1985. It produced 6.3M photographs (~3,000 km of films).

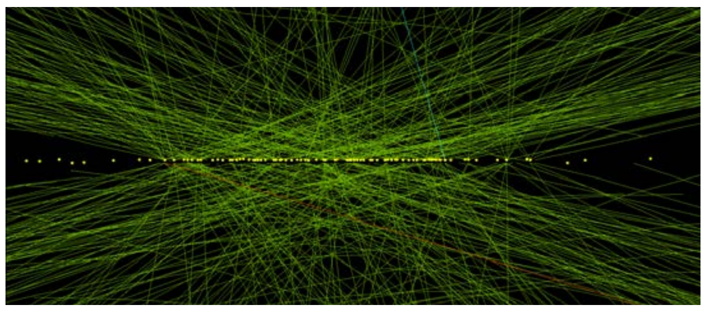


Beautiful but slow and tedious to analyse

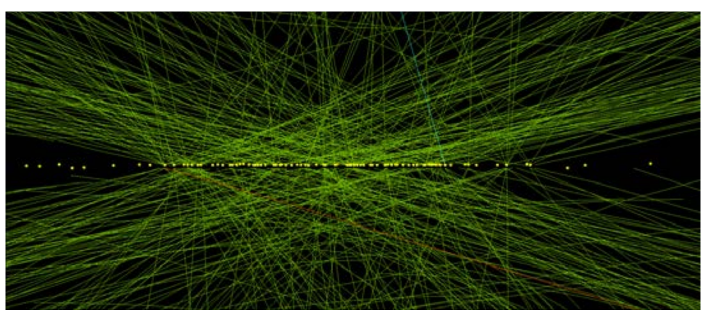
Challenges of particle detector



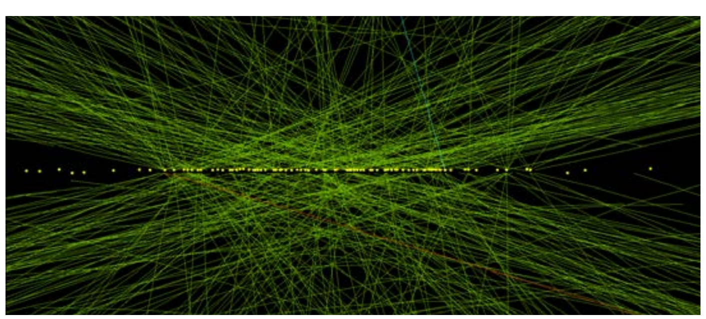
↓ 25 ns



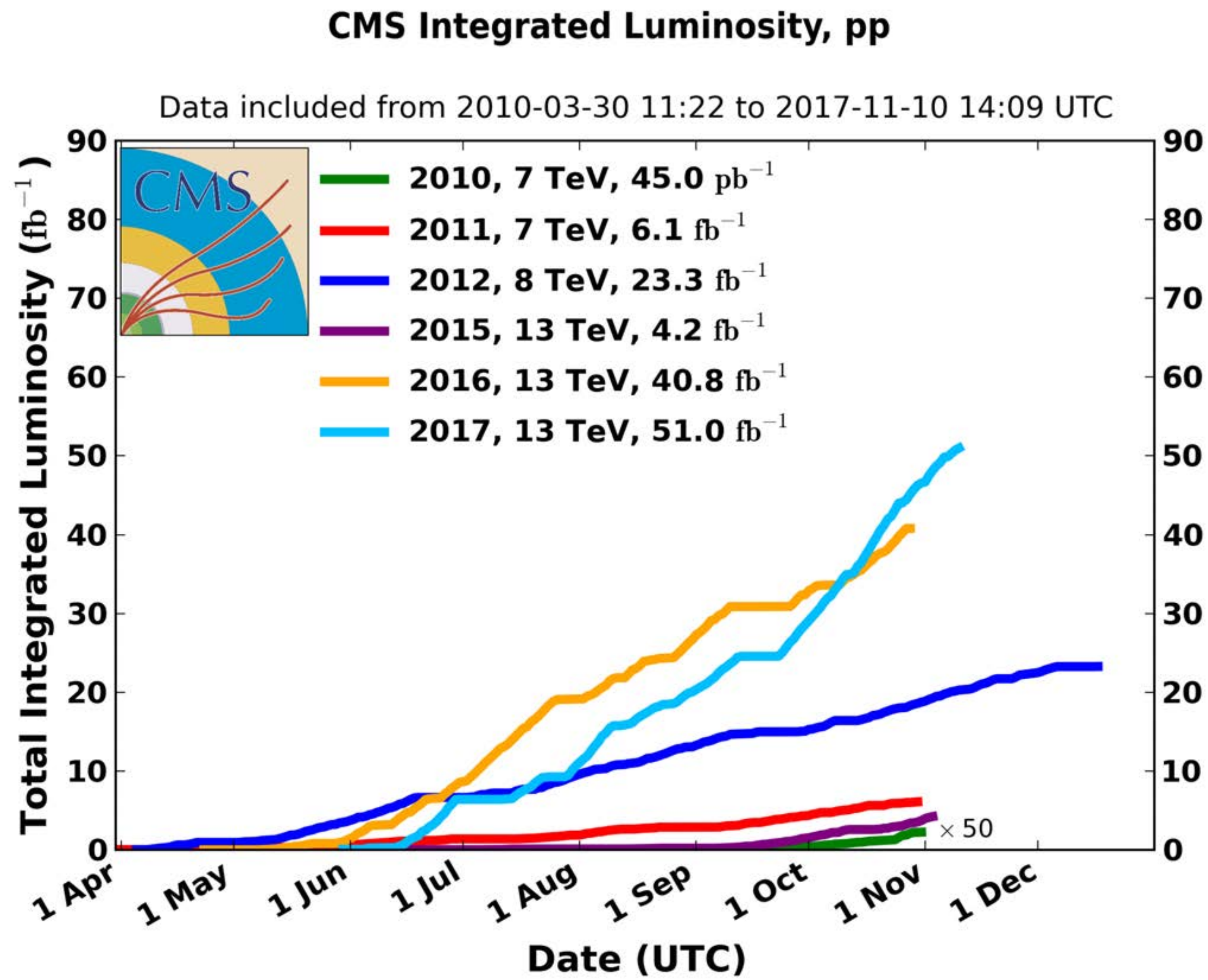
↓ 25 ns



↓ 25 ns



↓ 25 ns

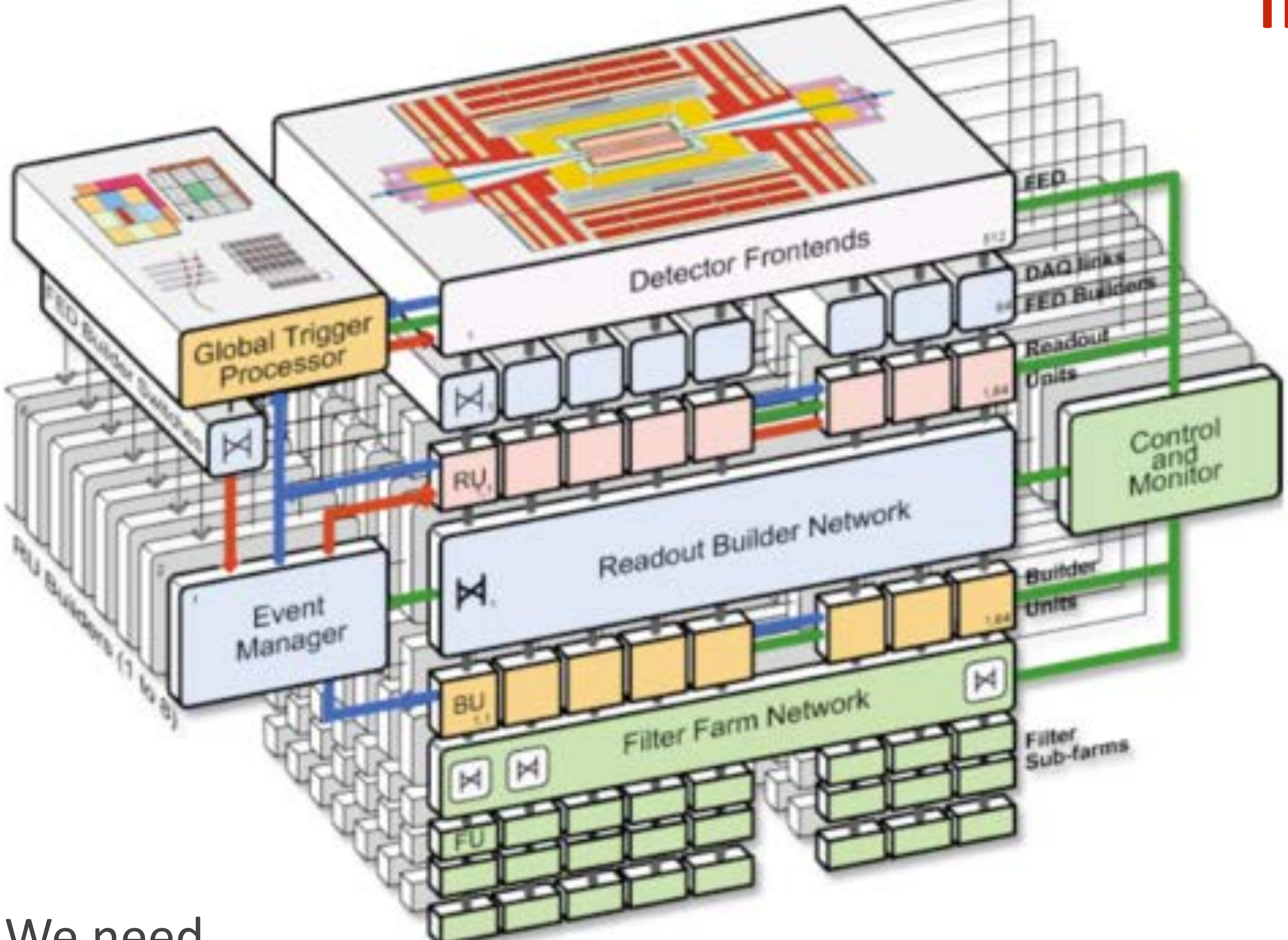


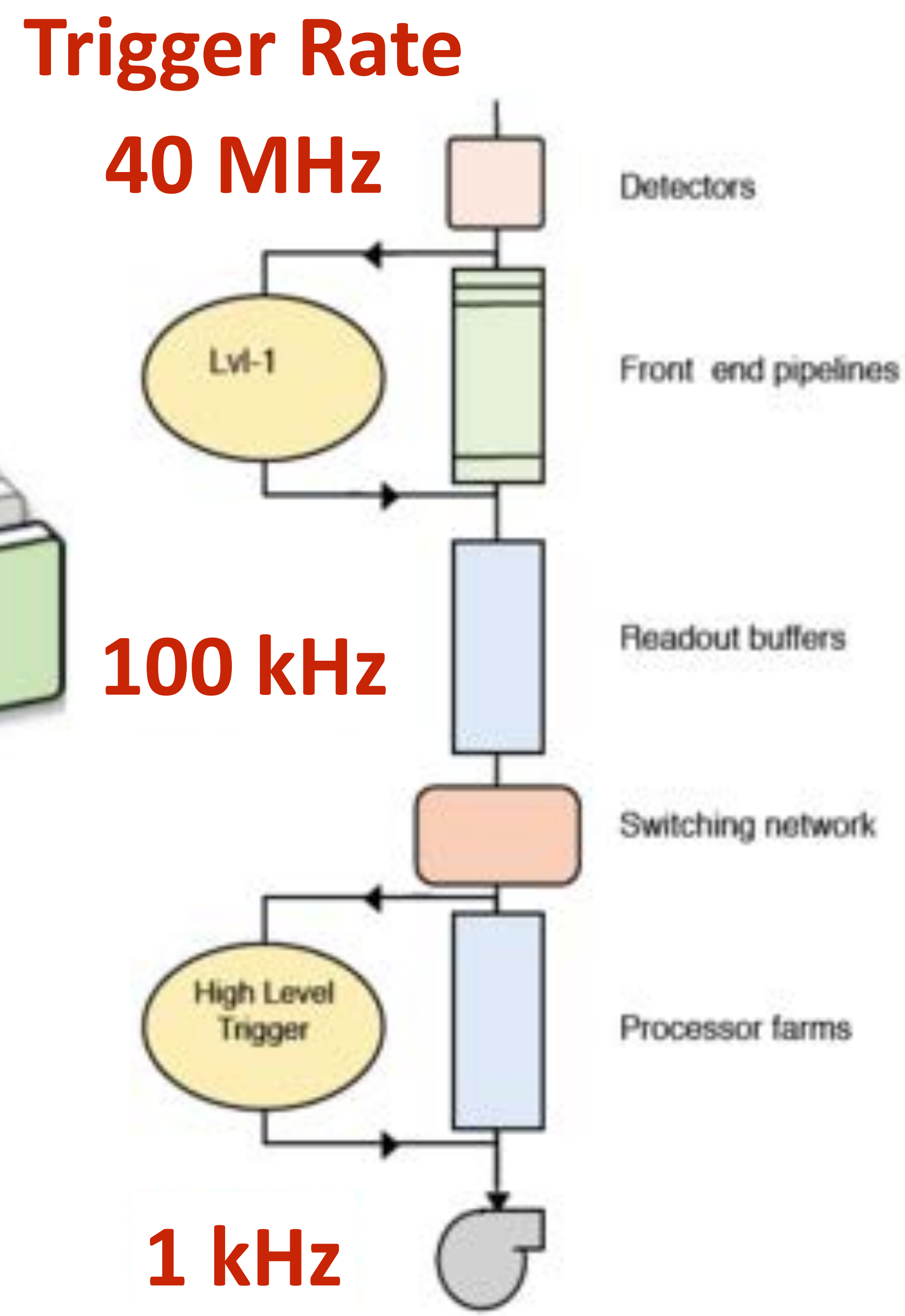
- 2012, collision every 50 ns (20M events per sec)
- 2016, collision every 25 ns (40M events per sec)
- With 1-2 MB/sec, LHC can produce more than 1 TB/sec!

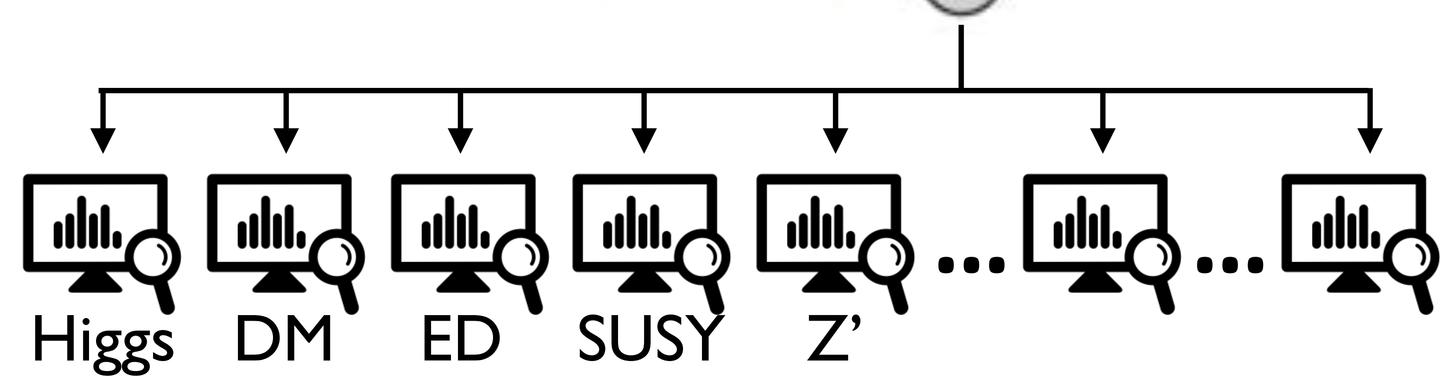
Impossible to store and process all events!

- Triggers (Electronics, Computing) to select events of interest (depend on physics signatures)

Challenges of particle detector







We need

- Fast electronic devices
- Fast computing algorithms to make a trigger system
- Timing accuracy and synchronisation in order of picoseconds

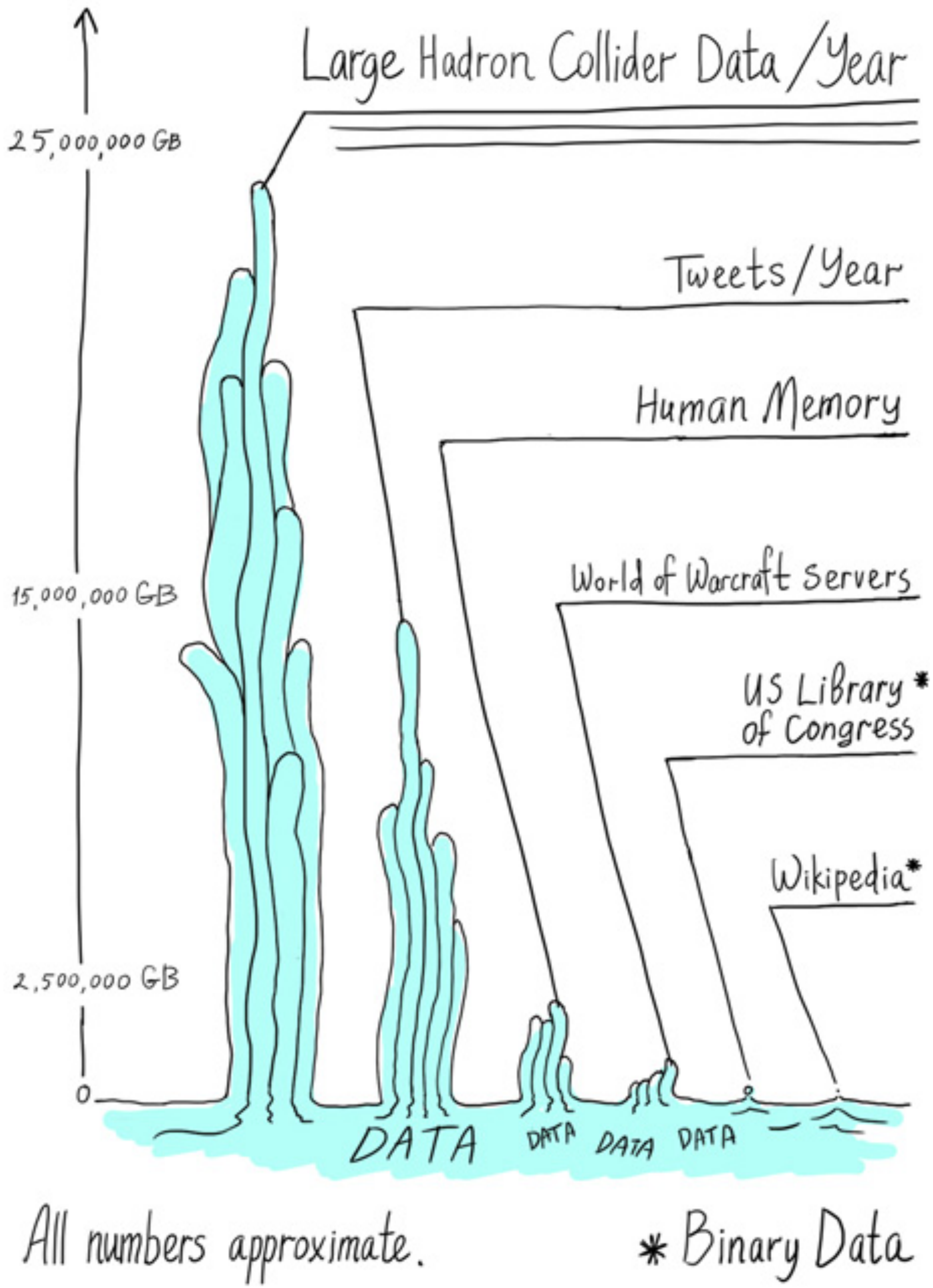
Computing technology

Proto: Symmetry Magazine

High Energy Physics is a statistical science:
Processes have a probability to happen.

The smaller it is, the more data (collisions) are needed for an observation, discovery or finally precision measurement.

Computing technology



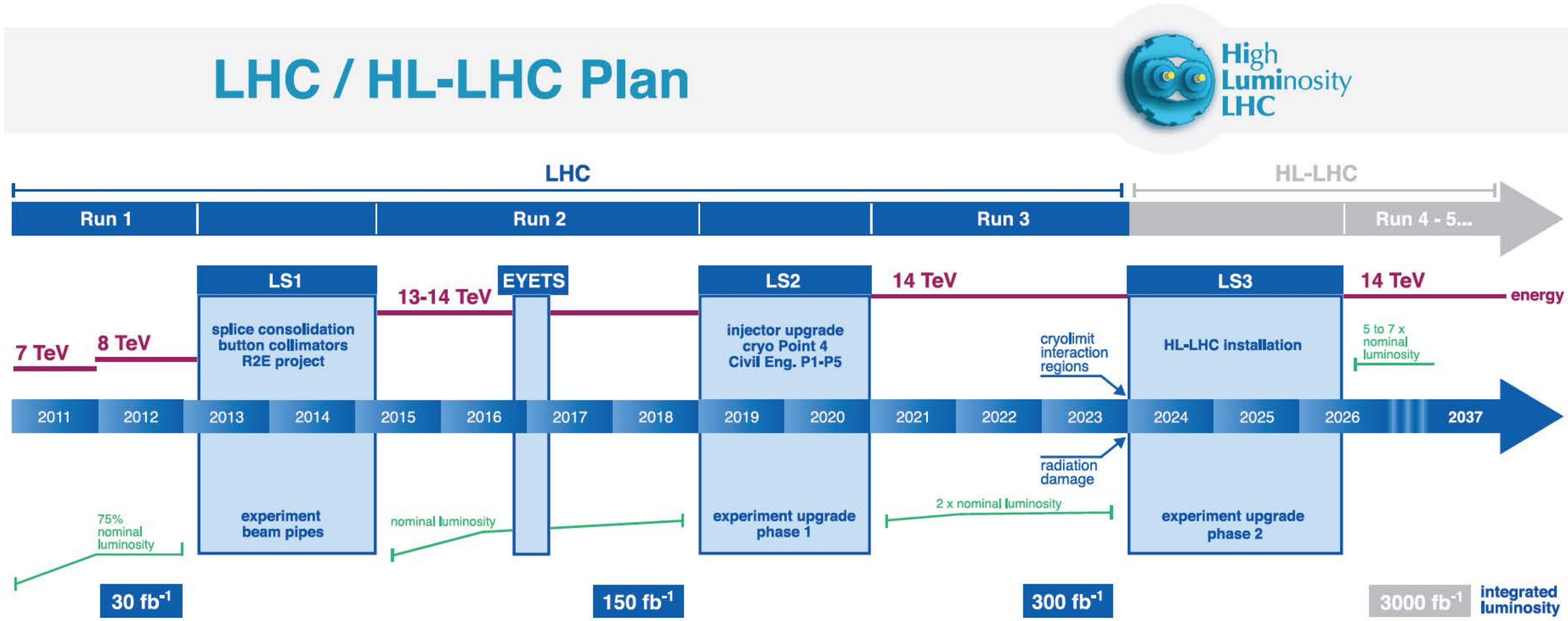
https://www.symmetrymagazine.org/article/august-2012/particle-physics-tames-big-data

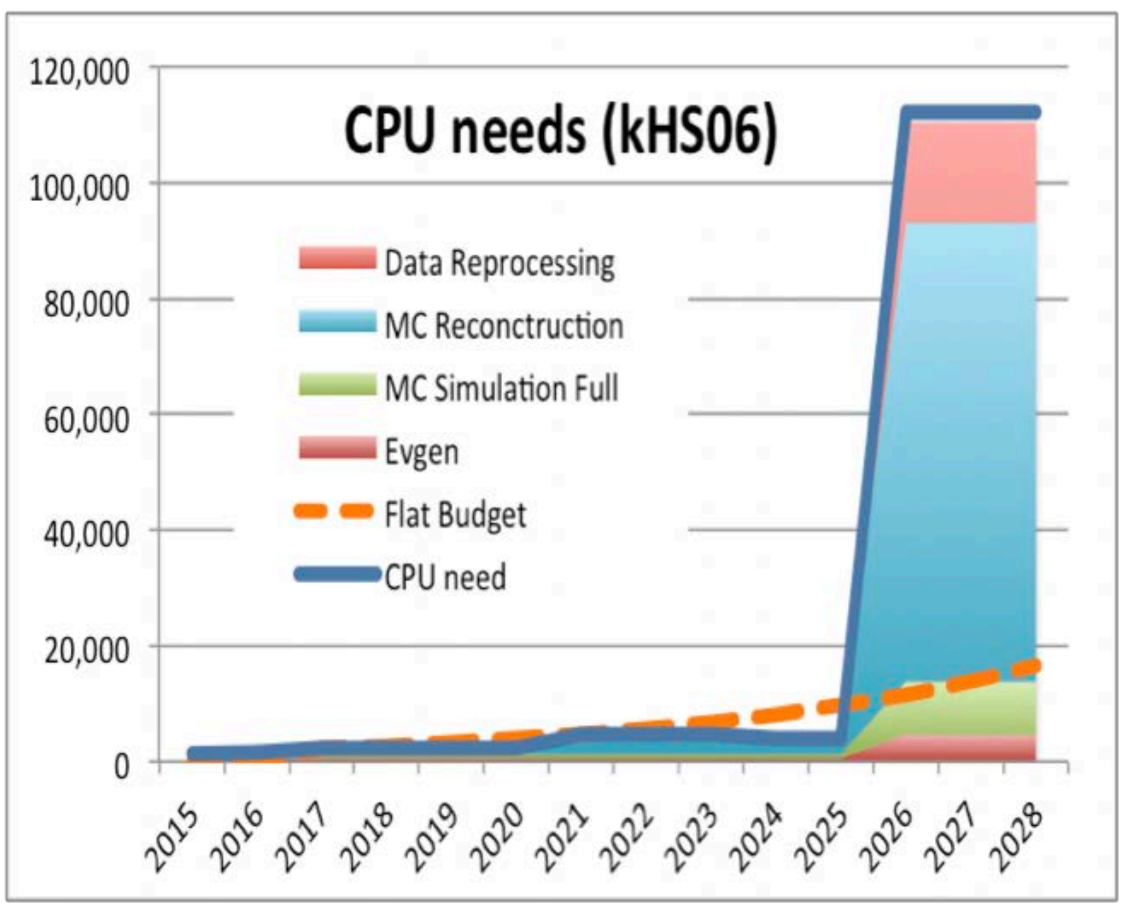
How big is our data?

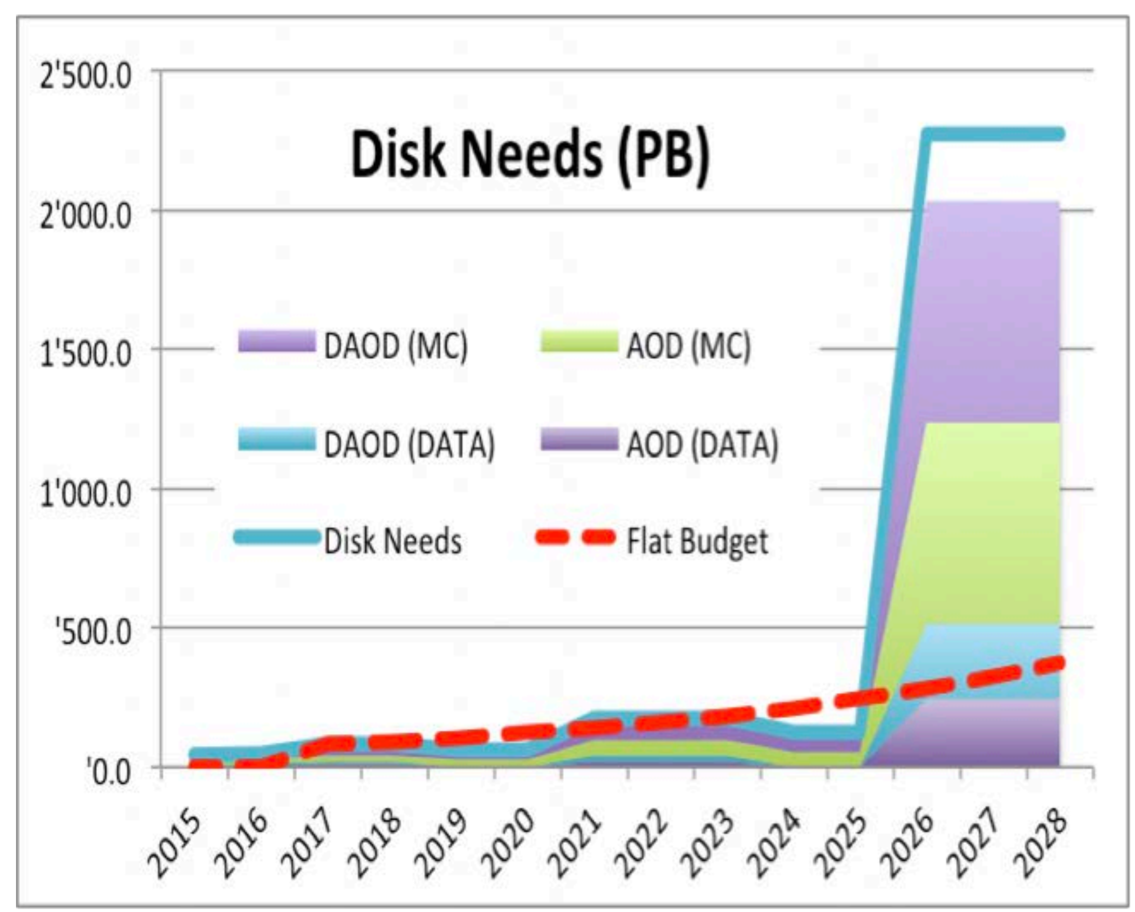
Why our data is so big?

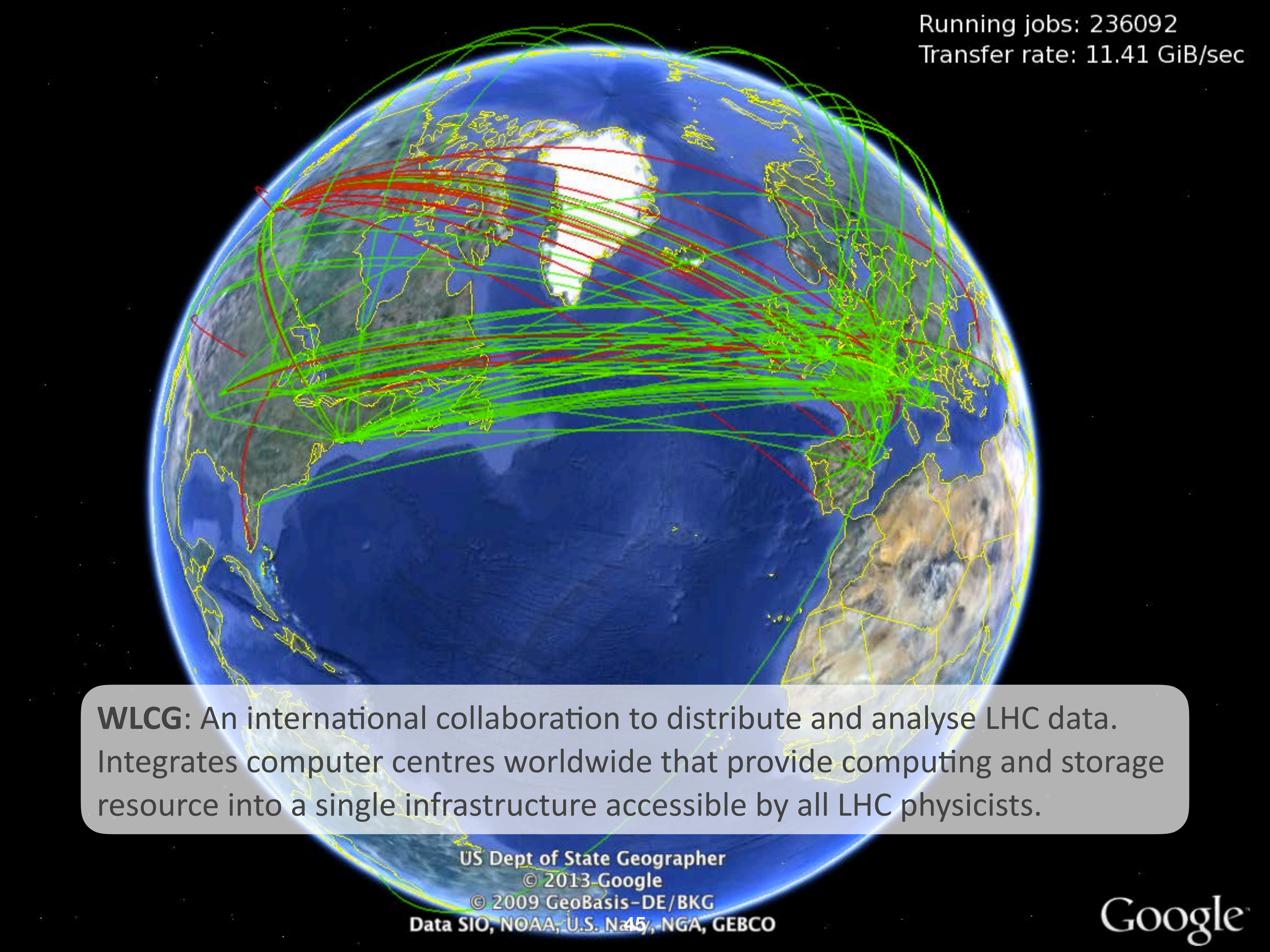
- Enormous **numbers of collisions** of proton bunches with each other. It should be noted that
  - Data from each collision are small (order 1-10 MB)
  - Each collision independent of all others
- **Pile-up:** multiple collisions per bunch crossing

Computing technology: High Luminosity LHC



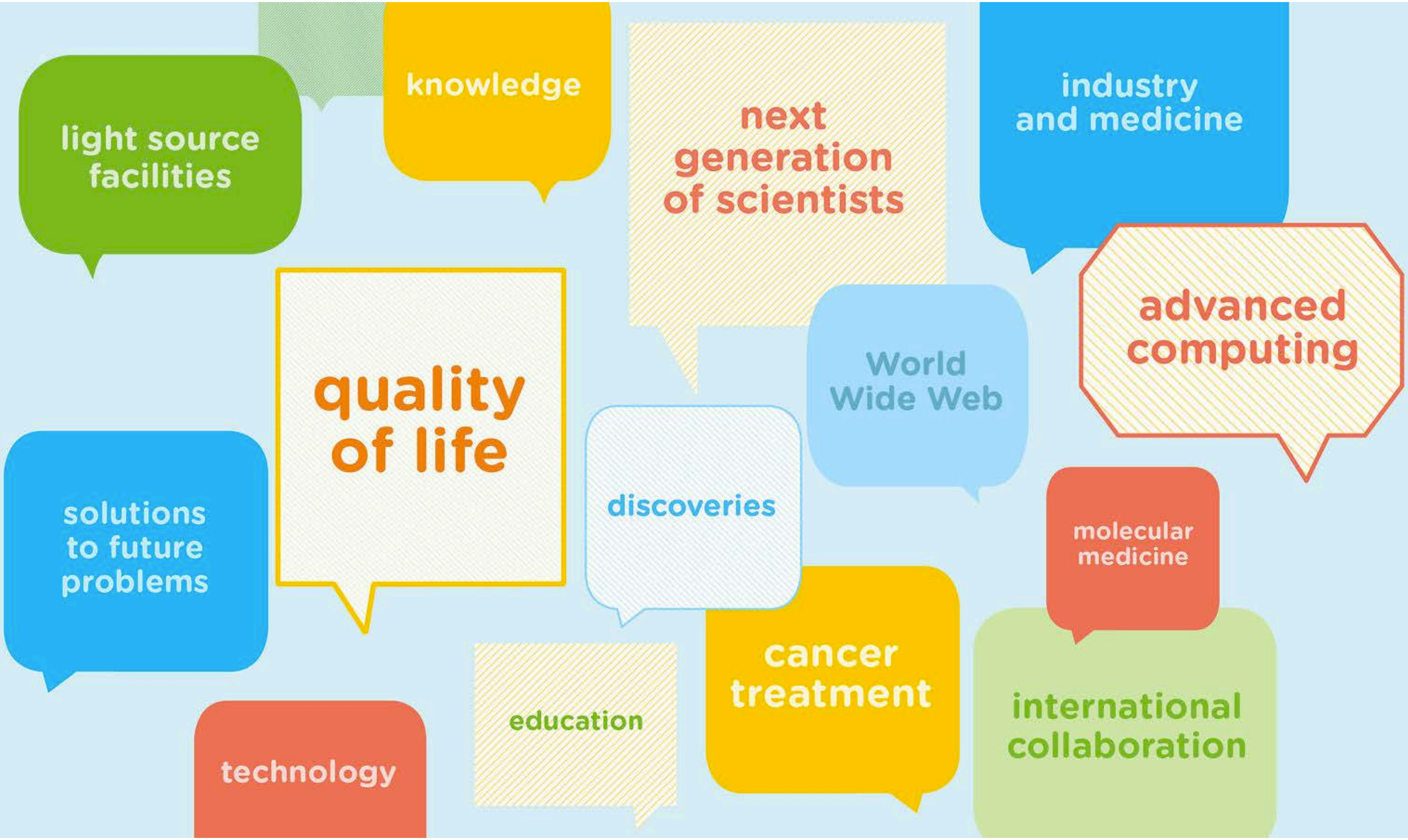






WLCG: An international collaboration to distribute and analyse LHC data. Integrates computer centres worldwide that provide computing and storage resource into a single infrastructure accessible by all LHC physicists.

Why particle physics matters



http://www.symmetrymagazine.org/article/october-2013/why-particle-physics-matters

Applications from accelerator technology

Intense light for research

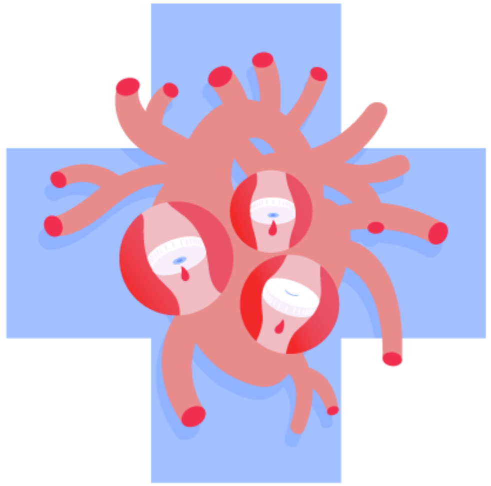
Circular particle accelerators bend the paths of speeding electrons, causing the electrons to emit light. This light is a powerful research tool with many applications. Dedicated synchrotron accelerators known as light sources allow scientists to control the intensity and wavelength of light for research that's led to better batteries, greener energy, new high-performance materials, more effective drug treatments and a deeper understanding of nature.

https://www.symmetrymagazine.org/article/march-2013/how-particle-physics-improves-your-life

Magnetic Resonance Imaging (MRI)

The life-saving medical technology known as MRI makes detailed images of soft tissue in the body. Unlike X-rays, MRIs can distinguish grey matter from white matter in the brain, cancerous tissue from noncancerous tissue, and muscles from organs, as well as reveal blood flow and signs of stroke.

Applications from accelerator technology



Heart valves

Physicists and biologists are improving the safety of artificial heart valves by designing a new material bombarded with silver ions from a particle accelerator using the Alabama A&M.

http://www.symmetrymagazine.org/article/august-2009/accelerator-applications-heart-valves

Shrink wrap

Particle accelerators, electron beam, tie the molecules of plastic together by knocking hydrogen atoms off the polymer chains. If conditions are right, the carbon atoms in one chain bond with carbons in neighboring chains — and make the film tougher mechanically

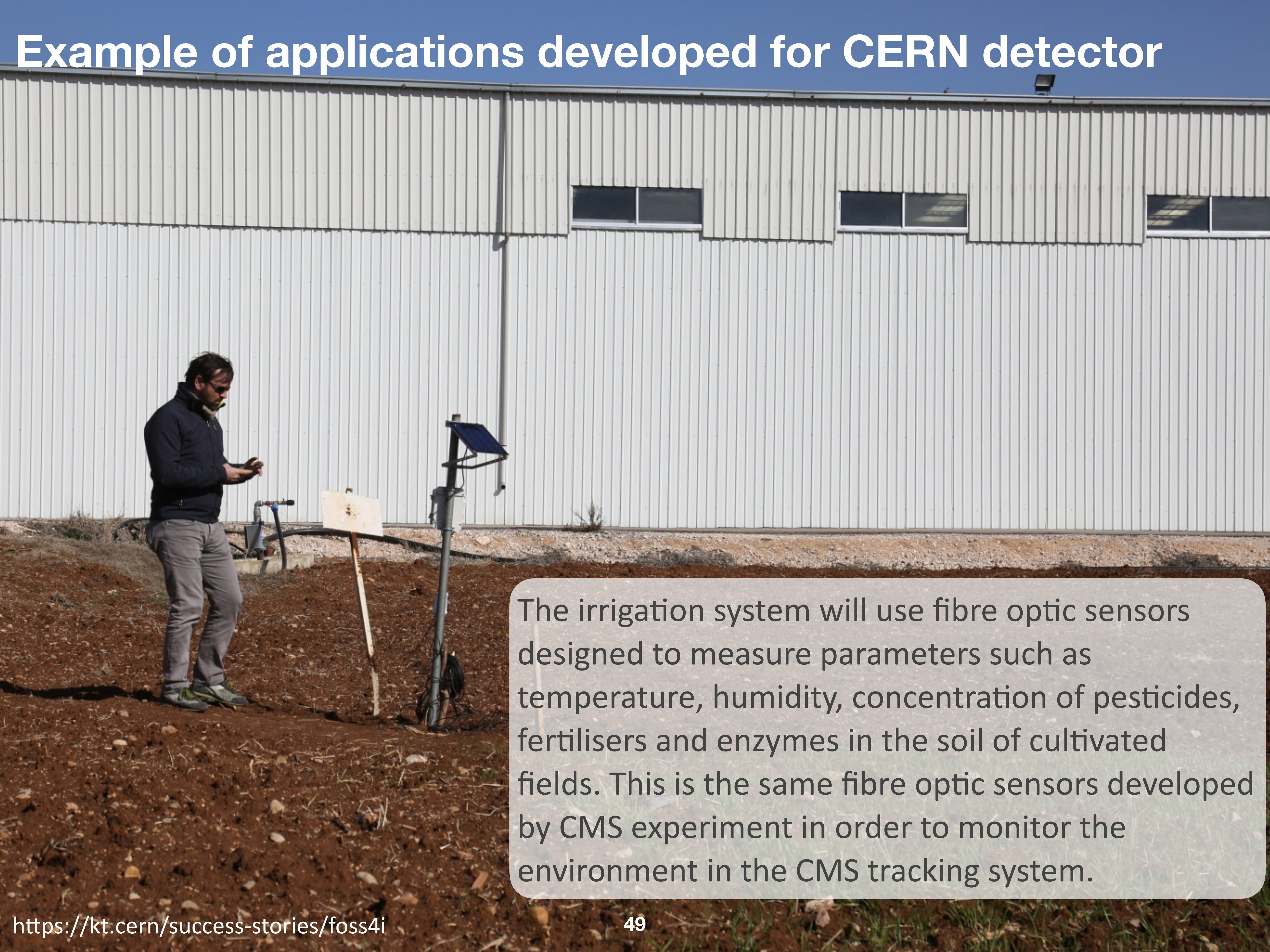
http://www.symmetrymagazine.org/article/october-2009/accelerator-application-shrink-wrap

Diaper

Using X-ray microscopy at ALS Berkeley, chemists were able to see the detailed structure of the superabsorbent polymer material while wet. This help them to adjust and improve the formula for the superabsorbent polymers until they had the perfect diaper.

http://www.symmetrymagazine.org/article/may-2011/accelerator-apps-diapers

Example of applications developed for CERN detector

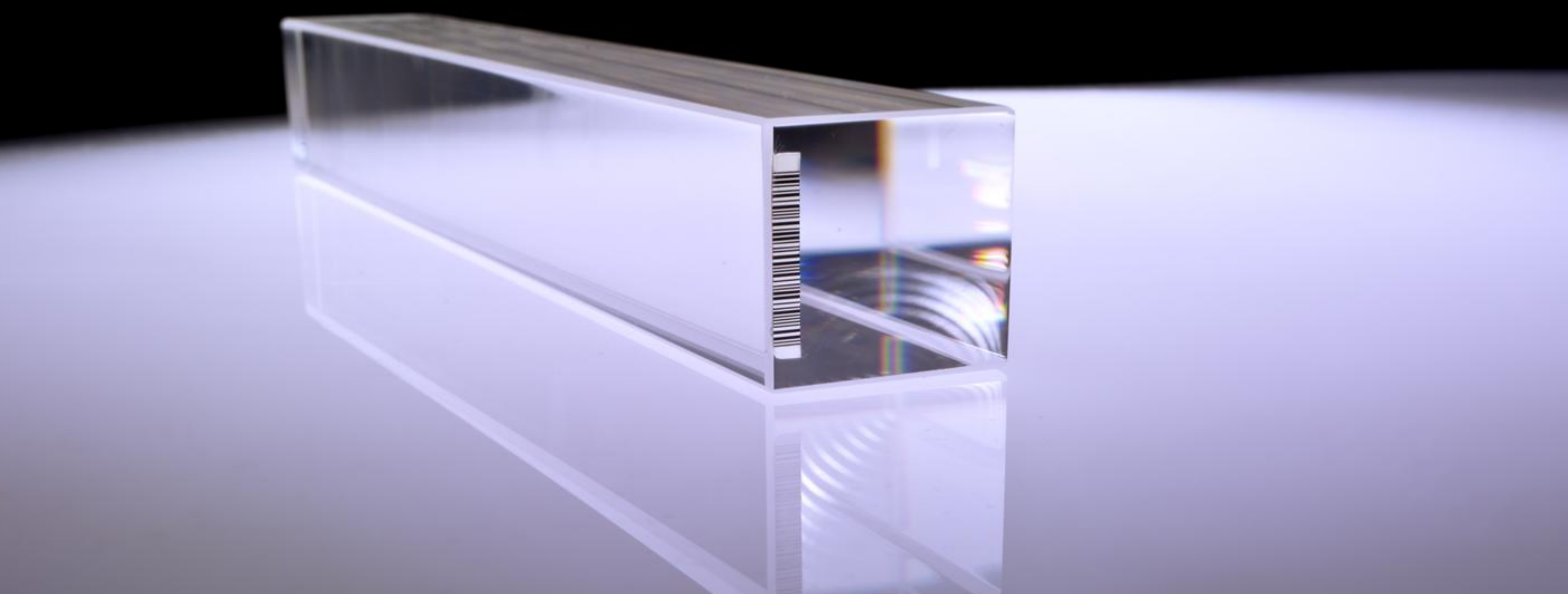


The irrigation system will use fibre optic sensors designed to measure parameters such as temperature, humidity, concentration of pesticides, fertilisers and enzymes in the soil of cultivated fields. This is the same fibre optic sensors developed by CMS experiment in order to monitor the environment in the CMS tracking system.

https://kt.cern/success-stories/foss4i

Example of applications developed for CERN detector

The scintillating crystal detector is used to measure the energy of photons and electrons produced in high-energy proton and ion collisions.
The CERN group of the Crystal Clear Collaboration is developing new fast detector prototypes for use in both high-energy physics experiments and medical imaging, with particular emphasis on Positron Emission Tomography (PET).



https://cms.cern/content/medical-imaging

Applications from computing technology and software

Example: Hardware
A new memory system has been developed to solve the problem of CERN computing in harsh environments, such as extreme temperatures or ionising radiation to protect the corruption in the configuration which can lead to a system malfunction.

Example: Software
Simulation of particle transport and interaction in matter is not only topics in particle physics, but also in a wide range of other domains including medical. In 2016, FLUKA was used to study the possible advantages of radioactive beams of Carbon 11 or Oxygen 15 for hadron therapy.

https://kt.cern/cern-technologies-society

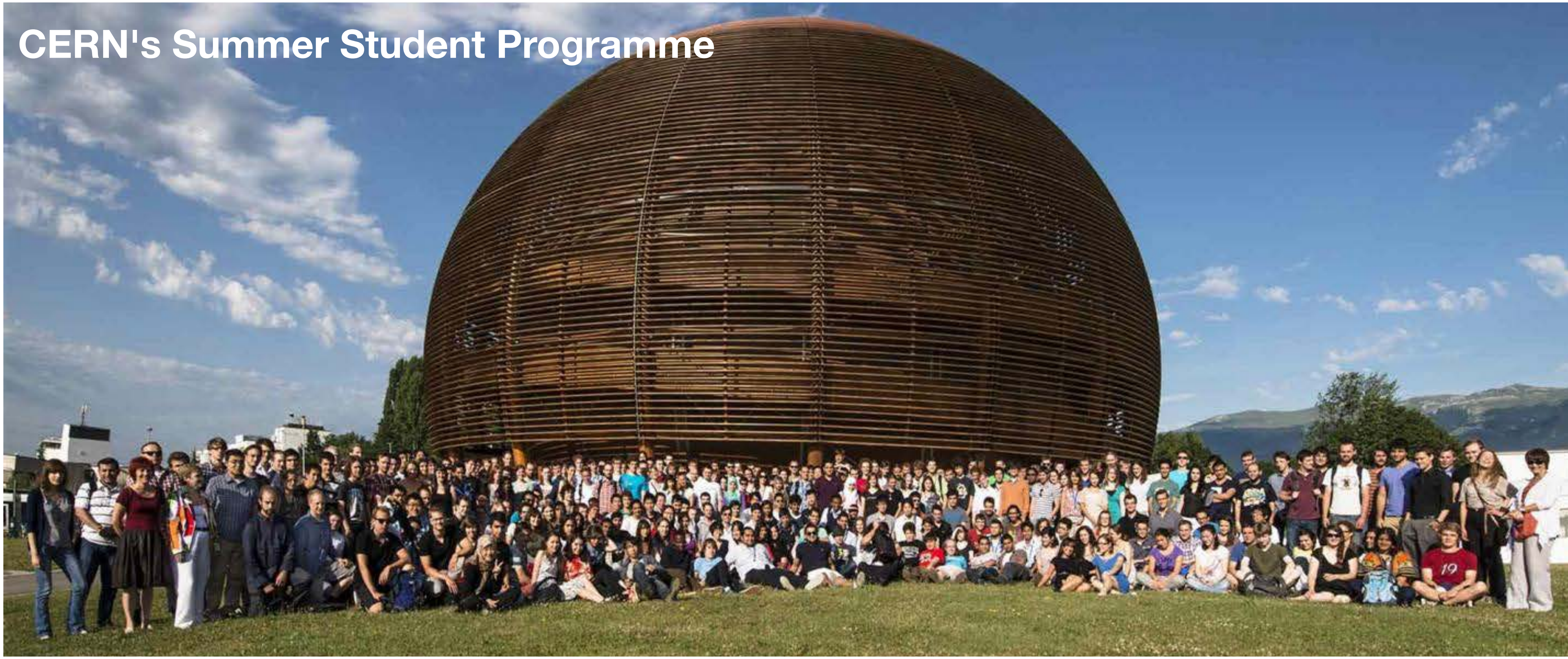
CERN Missions

Research
Seeking and finding answers to questions about the Universe

Technology
Advancing the frontiers of technology

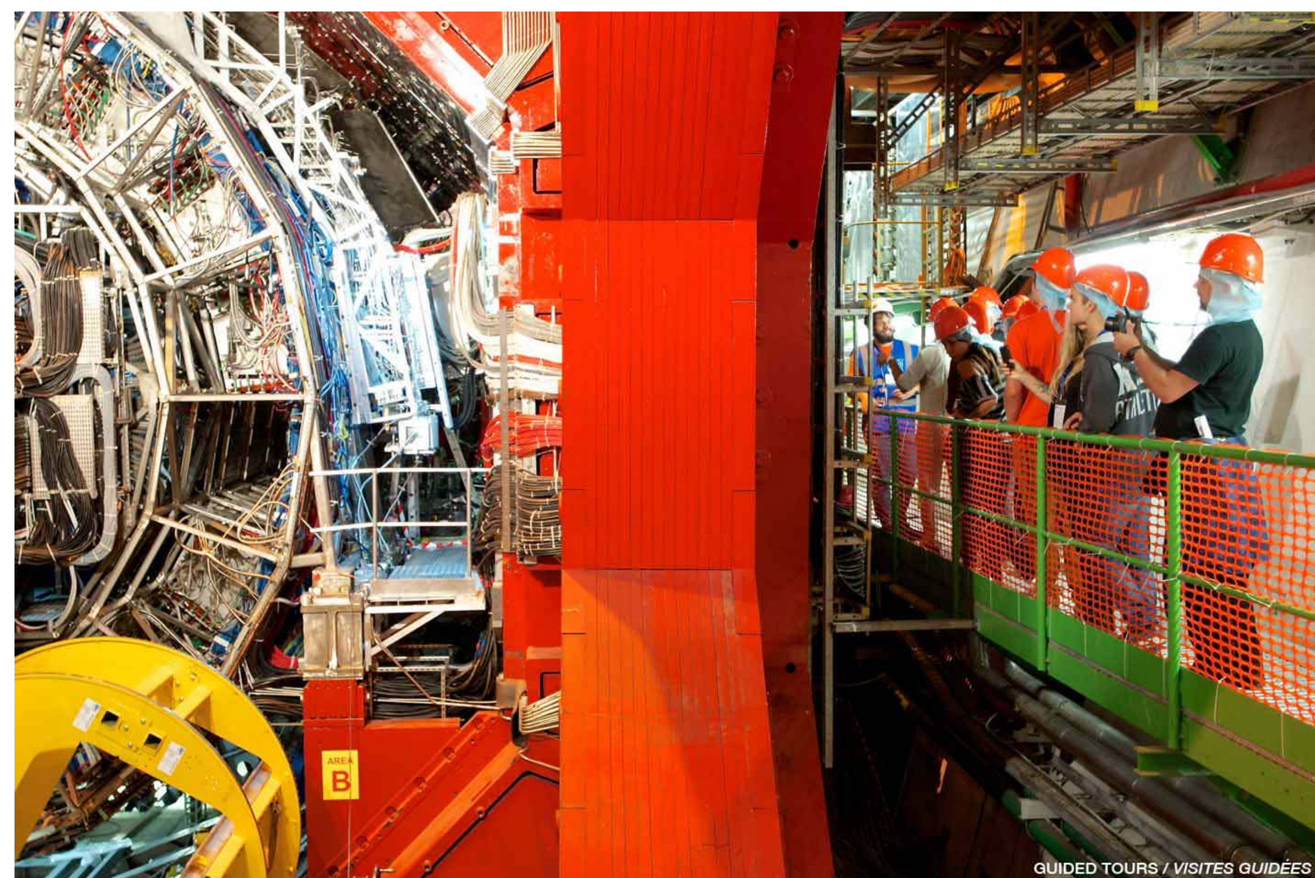
Education
Training the scientists of tomorrow

Collaborating
Bringing nations together through science


CERN's Summer Student Programme


CERN's High School Teachers Programme


UNIVERSE OF PARTICLES / *UNIVERS DE PARTICULES*


GUIDED TOURS / *VISITES GUIDÉES*

Future collider(s) are in new generation hands

Wherever the new colliders will be (China, Switzerland, Japan, …, Thailand), they are in hands of the new generations. One of important job is to make sure that the knowledge will be transferred, training will be done for them.

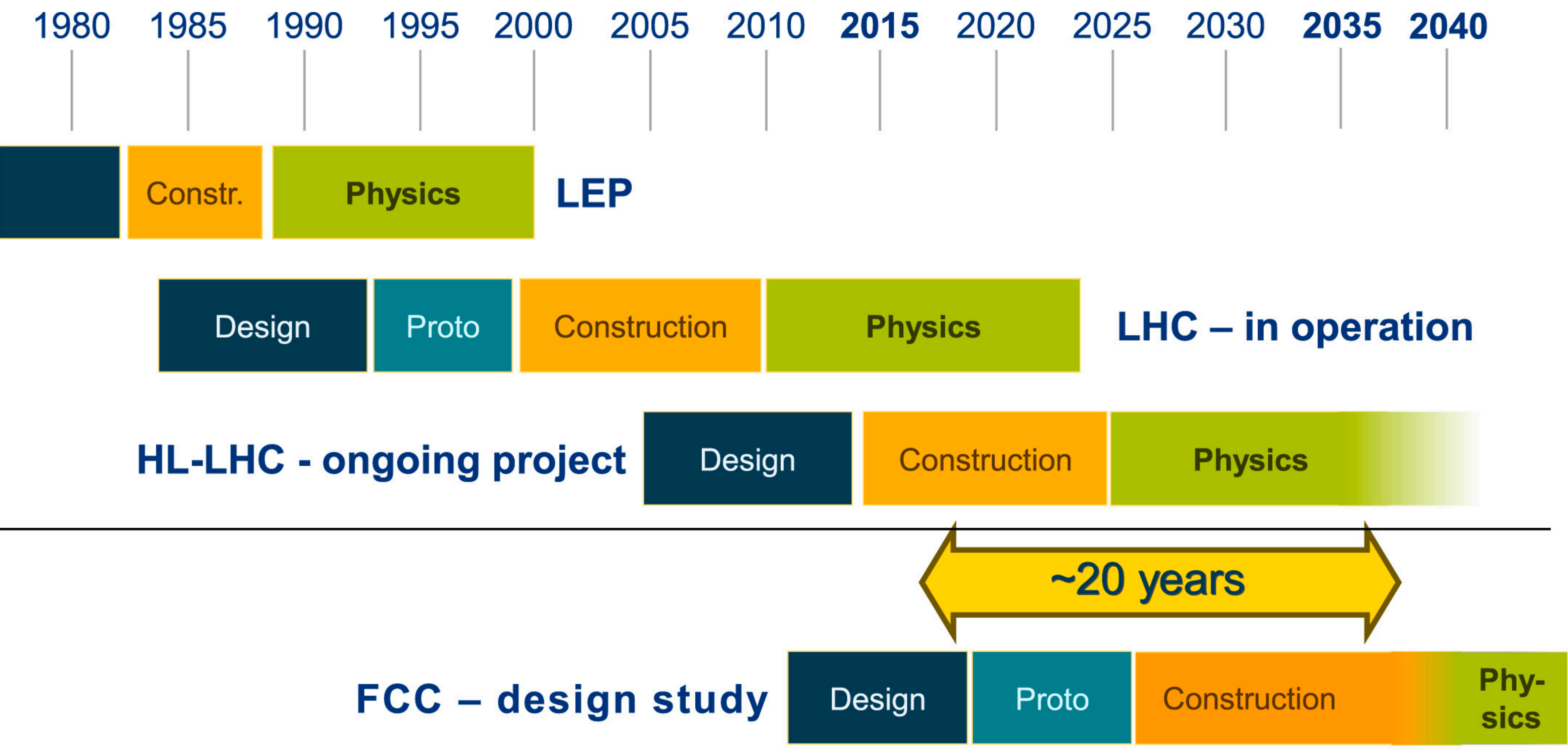


Figure from https://doi.org/10.1016/j.nima.2018.01.034

CERN Missions

Research
Seeking and finding answers to questions about the Universe

Technology
Advancing the frontiers of technology

Education
Training the scientists of tomorrow

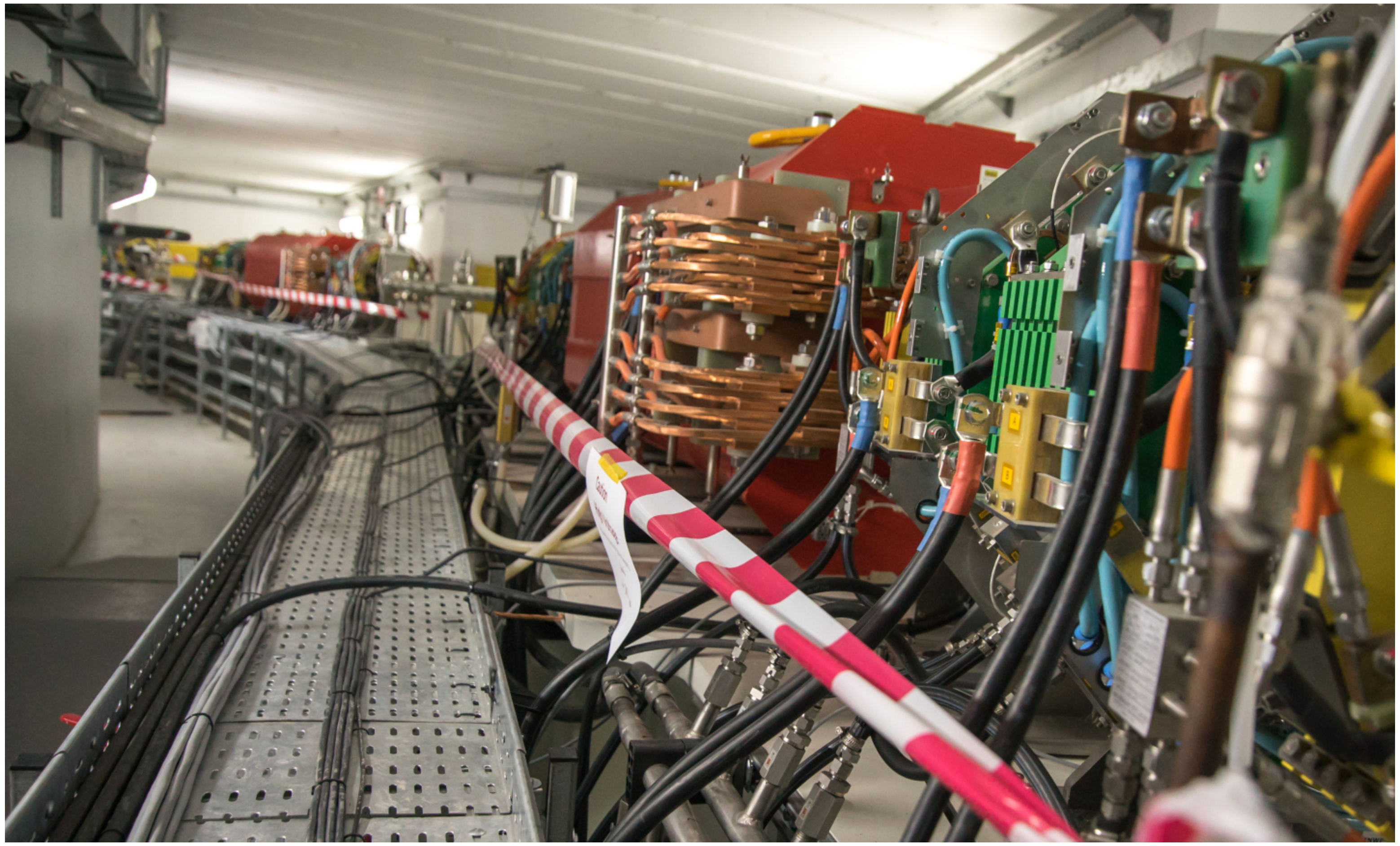
Collaborating
Bringing nations together through science

Science for peace

During the past 64 years, CERN fulfils the dreams of its founders as summarized in the convention, which states that "*The Organization shall provide for collaboration among European States in nuclear research of a pure scientific and fundamental character, and in research essentially related thereto. The Organization shall have no concern with work for military requirements and the results of its experimental and theoretical work shall be published or otherwise made generally available.*"

Thinking about

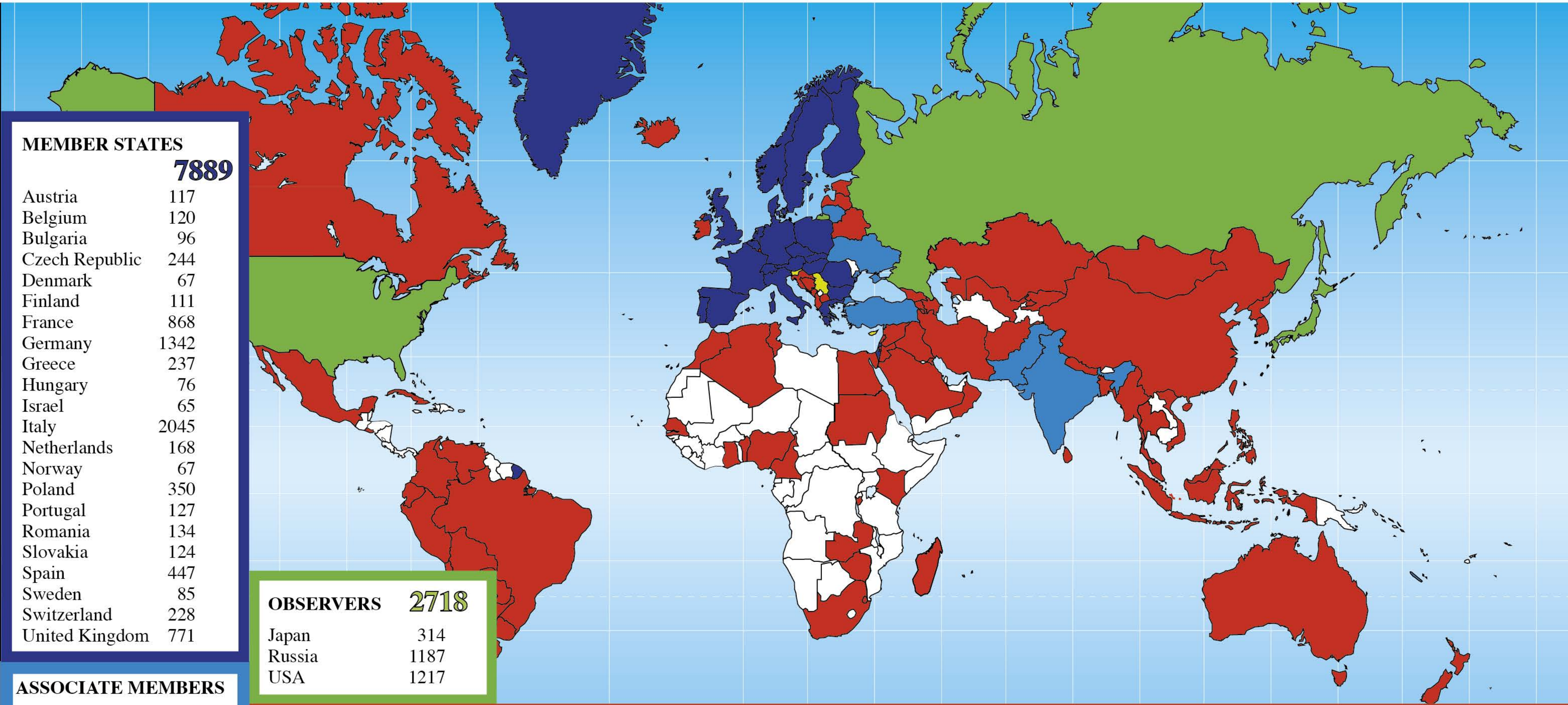
- German in early days at CERN.
- European, US, Soviet scientists worked together during cold war.
- Israelis and Palestinians can work together
- Joining common scientific effort in Middle East.
- …



Synchrotron-Light for Experimental Science and Applications in the Middle East (SESAME). Members include Bahrain, Cyprus, Egypt, Iran, Israel, Pakistan, the Palestinian Authority, and Turkey.

https://home.cern/about/updates/2017/01/first-beam-sesame-light-source

Distribution of All CERN Users by Nationality on 24 January 2018



MEMBER STATES **7889**

Austria	117
Belgium	120
Bulgaria	96
Czech Republic	244
Denmark	67
Finland	111
France	868
Germany	1342
Greece	237
Hungary	76
Israel	65
Italy	2045
Netherlands	168
Norway	67
Poland	350
Portugal	127
Romania	134
Slovakia	124
Spain	447
Sweden	85
Switzerland	228
United Kingdom	771

OBSERVERS **2718**

Japan	314
Russia	1187
USA	1217

ASSOCIATE MEMBERS **745**

India	357
Lithuania	35
Pakistan	65
Turkey	173
Ukraine	115

ASSOCIATE MEMBERS IN THE PRE-STAGE TO MEMBERSHIP **118**

Cyprus	26
Serbia	57
Slovenia	35

OTHERS **1872**

Afghanistan	1
Albania	3
Algeria	14
Argentina	27
Armenia	19
Australia	31
Azerbaijan	10
Bangladesh	11
Belarus	48
Benin	1
Bolivia	4
Bosnia & Herzegovina	2
Brazil	135
Burundi	1
Cameroon	1
Canada	161
Chile	20
China	510
Colombia	45
Croatia	41
Cuba	12
Ecuador	6
Egypt	31
El Salvador	1
Estonia	15
Georgia	46
Ghana	1
Hong Kong	1
Iceland	3
Indonesia	11
Iran	51
Iraq	1
Ireland	16
Jordan	1
Kazakhstan	5
Kenya	3
Korea Rep.	185
Kyrgyzstan	1
Latvia	2
Lebanon	23
Luxembourg	2
Madagascar	4
Malaysia	15
Malta	9
Mauritius	1
Mexico	82
Mongolia	2
Montenegro	11
Morocco	20
Myanmar	1
Nepal	10
New Zealand	5
Nigeria	3
North Korea	1
Oman	3
Palestine (O.T.).	7
Paraguay	2
Peru	7
Philippines	3
Saint Kitts and Nevis	1
Saudi Arabia	2
Senegal	1
Singapore	4
South Africa	56
Sri Lanka	6
Sudan	1
Swaziland	1
Syria	1
Taiwan	51
Thailand	22
T.F.Y.R.O.M.	2
Tunisia	5
Uruguay	1
Uzbekistan	4
Venezuela	10
Viet Nam	13
Zambia	1
Zimbabwe	2

CERN

Thank you.

Research

- CMS
- ALICE

Training

- High school student program
- CERN summer student program
- CERN summer teacher program

Collaboration between 13 Thai Universities/Institutes

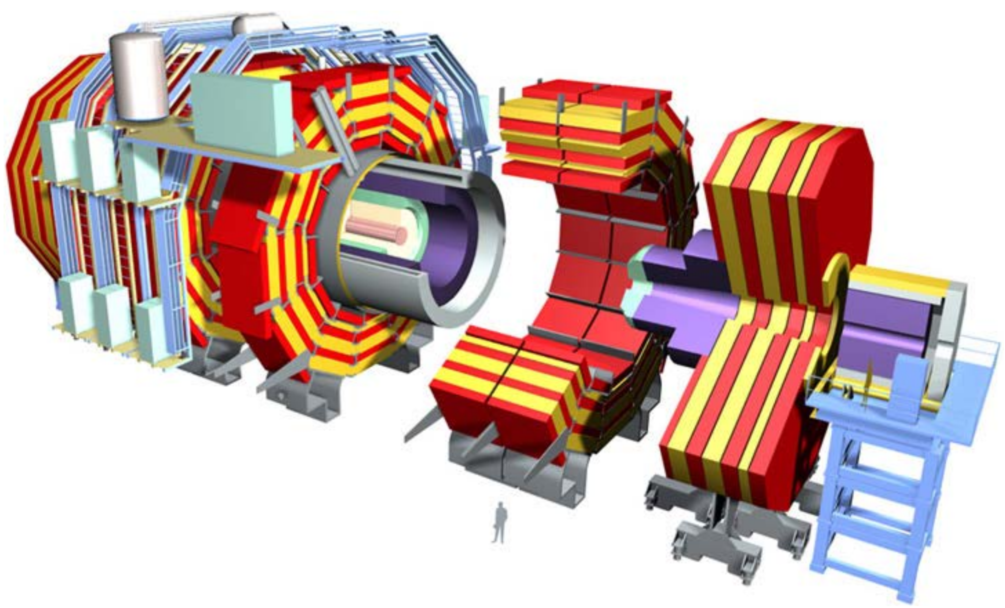
Education

- Schools and workshops in Thailand

National eScience Infrastructure Consortium

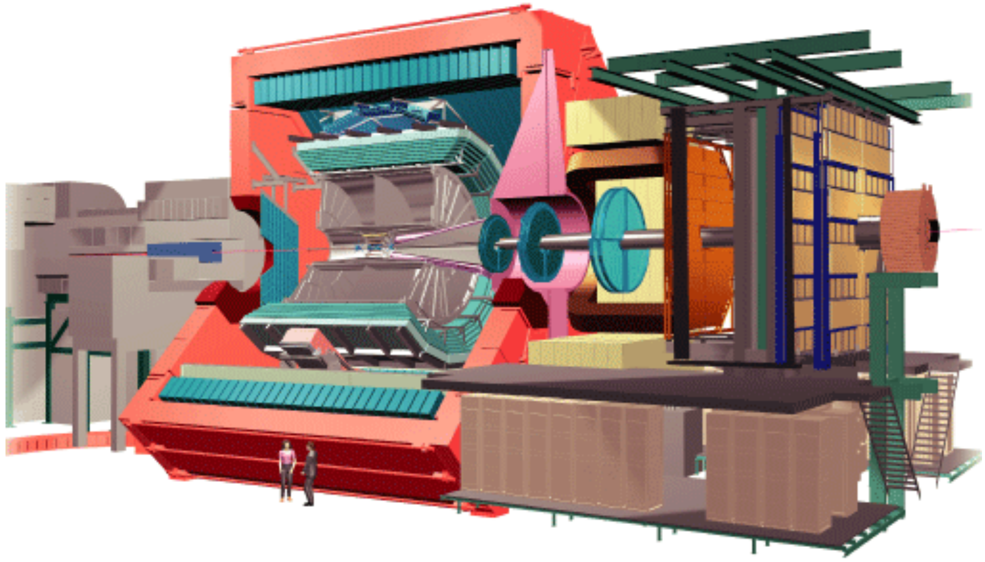
- WLCG

Research



Compact Muon Solenoid (CMS)

- General propose detector
- The CMS Collaboration has a broad physics program, ranging from measurements of the Standard Model and the recently discovered Higgs boson, to studies of heavy-ion collisions, to searches for new particles, phenomena, and even extra dimensions in the Universe.
- Thai institute: CU



A Large Ion Collider Experiment (ALICE)

- To answer
  - What happens to matter when it is heated to 100,000 times the temperature at the centre of the Sun?
  - Why do protons and neutrons weight 100 times more than the quarks they are made of?
  - Can the quarks inside the protons and neutrons be freed?
- Thai institutes: KMUTT, SUT, SLRI, TMEC

Research topics include Physics, Engineering (Computer, Electrical, Mechanical)

Visit of Her Royal Highness Princess Maha Chakri Sirindhorn, Thailand

2000

2003

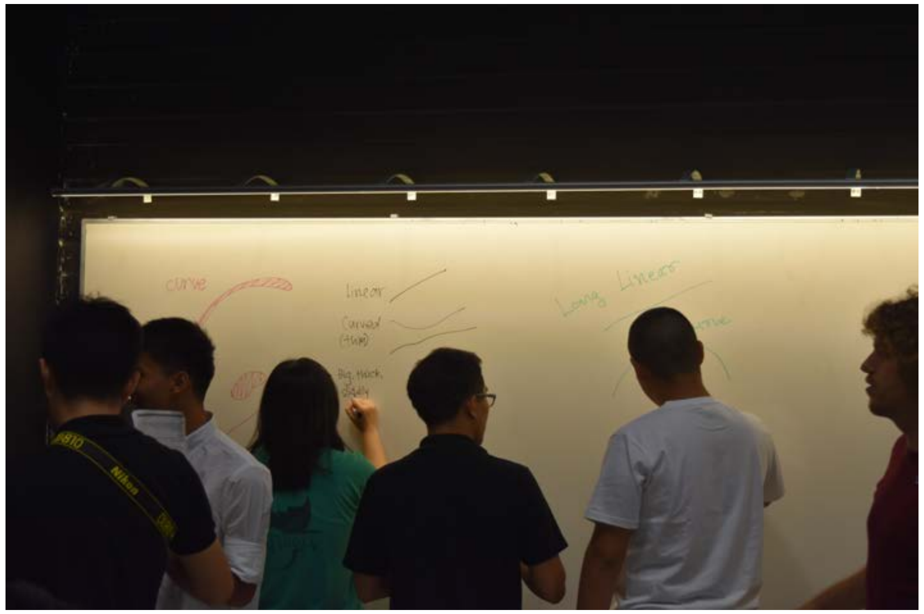
2009

2010

2015

Training: High school student program

- Started in 2013 (together with Singapore)
- 5 days program for high school students
- 12 students
- Lectures include
  - Intro. to CERN
  - Intro. to particle accelerator
  - Intro. to particle physics: theory
  - Intro. to particle physics: experiment
  - Applications
  - Selected topics
- Visit several CERN sites including SC, CMS, ATLAS, SM18, AD, CCC, Data Centre



Training: CERN summer student program

- Officially joined the program since 2010
- 8-12 weeks
- In 2018, 4 students (2 Physics, 2 Engineering)
  - 2 students fully supported by CERN (max. 8 weeks per student) with extension period (max. 4 weeks) supported by Thailand
  - 2 students fully supported by Thailand (max. 12 weeks per student)
- Lectures + summer research project

Training: CERN summer teacher program

- Officially joined the program since 2010
- 3 weeks
- 2 teachers
  - 1 teacher fully supported by CERN
  - 1 teacher fully supported by Thailand
- Lectures + workshops

Education

- Several schools and workshops organized in Thailand including
  - **General audience / High school students (yearly)**
    - Intro. to particle physics and its application
    - Visit (Synchrotron, Chulabhon Hospital)
    - **22-25 April 2018 at KMUTT, https://indico.cern.ch/e/thaihep2018**
  - **Undergraduate students**
    - Varied topics, i.e. particle physics, data analysis, relativety, quantum field theory
    - **23-27 July 2018 at CU**
  - **Graduate students**
    - Advance particle physics and related theories
    - Helps from CERN/CMS/ALICE to find speakers for advance topics

National eScience Infrastructure Consortium

- Follow the "Expression of Interest in The Participation of Physicists from Universities and Research Institutes from Thailand in the CMS Experiment at the CERN LHC Accelerator"
  - To build Thailand Tier-2 to support CMS
  - Become a national infrastructure to support several research areas including
    - Particle physics
    - Climate change
    - Water resource, energy and environment management
    - Computational science and engineering