By reading this you agree with the terms and conditions below

Please ask questions. Be critical. Too much thinking may actually do you good. Results may vary depending on your beliefs. Be open to other points of view. Knowledge does not generate unhappiness but can help combat it. Science may disillusion you and help you align yourself with reality.

a.david@cern.ch

The Higgs boson we cannot unsee

an excuse to discuss
Particle Physics and Society
(with one mention of the word Psychology)

a.david@cern.ch

Things you can't "unsee"

[http://cern.ch/go/Dxh7]

Things you can’t “unsee”

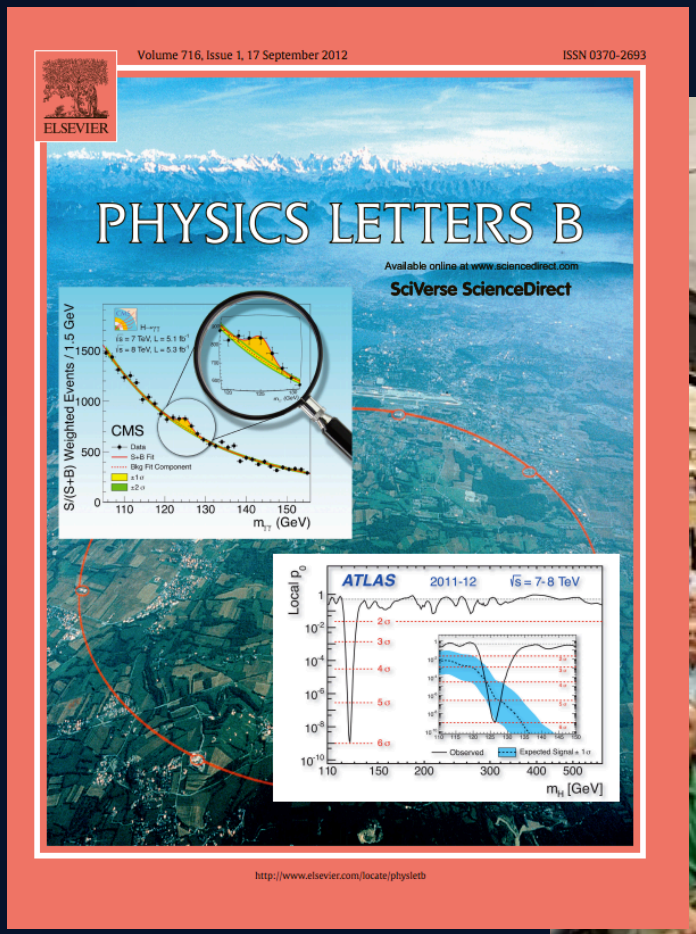
[http://cern.ch/go/Dxh7]

Things you can't "unsee"

[http://cern.ch/go/Dxh7]

July 2012: looking up to a new boson

[http://cern.ch/go/q8jx]



A 2012 hit

[http://goo.gl/49c0c] [http://goo.gl/suJzZ] [http://goo.gl/ShJJG]

symmetry dimensions of particle physics

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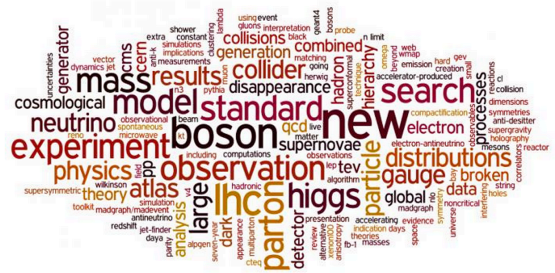

signal to background

May 12, 2013

The top 40 physics hits of 2012

The Higgs boson is a popular subject among the most-cited physics papers of 2012, but a particle simulation manual takes the top spot.

2012 reports for eprints

1. 568 citations in 2012
Observation of a new particle in the search for the Standard Model Higgs boson with the ATLAS detector at the LHC
ATLAS Collaboration (Georges Aad (Freiburg U.) *et al.*). Jul 2012. 24 pp.
Published in **Phys.Lett. B716 (2012) 1-29**
CERN-PH-EP-2012-218
DOI: 10.1016/j.physletb.2012.08.020
e-Print: **arXiv:1207.7214 [hep-ex]** | PDF
References | BibTeX | LaTeX(US) | LaTeX(EU) | Harvmac | EndNote
ADS Abstract Service; Link to all figures including auxiliary figures

2. 558 citations in 2012
Observation of a new boson at a mass of 125 GeV with the CMS experiment at the LHC
CMS Collaboration (Serguei Chatrchyan (Yerevan Phys. Inst.) *et al.*). Jul 2012.
Published in **Phys.Lett. B716 (2012) 30-61**
CMS-HIG-12-028, CERN-PH-EP-2012-220
DOI: 10.1016/j.physletb.2012.08.021
e-Print: arXiv:1207.7235 **[hep-ex]** | PDF
References | BibTeX | LaTeX(US) | LaTeX(EU) | Harvmac | EndNote
CERN Document Server ; ADS Abstract Service; Link to PRESSRELEASE

3. 433 citations in 2012
Combined results of searches for the standard model Higgs boson in pp collisions at $\sqrt{s}=7$ TeV
CMS Collaboration (Serguei Chatrchyan (Yerevan Phys. Inst.) *et al.*). Feb 2012.
Published in **Phys.Lett. B710 (2012) 26-48**
CMS-HIG-11-032, CERN-PH-EP-2012-023
DOI: 10.1016/j.physletb.2012.02.064
e-Print: **arXiv:1202.1488 [hep-ex]** | PDF
References | BibTeX | LaTeX(US) | LaTeX(EU) | Harvmac | EndNote
CERN Document Server ; ADS Abstract Service

4. 381 citations in 2012
Combined search for the Standard Model Higgs boson using up to 4.9 fb^{-1} of pp collision data at $\sqrt{s}=7$ TeV with the ATLAS detector at the LHC
ATLAS Collaboration (Georges Aad (Freiburg U.) *et al.*). Feb 2012. 8 pp.
Published in **Phys.Lett. B710 (2012) 49-66**
CERN-PH-EP-2012-019
DOI: 10.1016/j.physletb.2012.02.044
e-Print: **arXiv:1202.1408 [hep-ex]** | PDF
References | BibTeX | LaTeX(US) | LaTeX(EU) | Harvmac | EndNote
CERN Document Server ; ADS Abstract Service; Link to all figures including auxiliary figures

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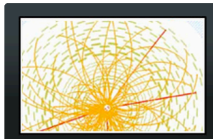
Home > Collections > Online Extras > Special Issues 2012 > Breakthrough of the Year, 2012

Breakthrough of the Year, 2012

Every year, crowning one scientific achievement as Breakthrough of the Year is no easy task, and 2012 was no exception. The year saw leaps and bounds in physics, along with significant advances in genetics, engineering, and many other areas. In keeping with tradition, *Science*'s editors and staff have selected a winner and nine runners-up, as well as highlighting the year's top news stories and areas to watch in 2013.



FREE ACCESS

The Discovery of the Higgs Boson

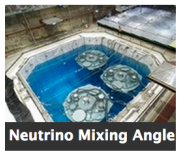
A. Cho

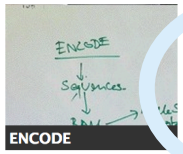
Exotic particles made headlines again and again in 2012, making it no surprise that the breakthrough of the year is a big physics finding: confirmation of the existence of the Higgs boson. Hypothesized more than 40 years ago, the elusive particle completes the standard model of physics, and is arguably the key to the explanation of how other fundamental particles obtain mass. The only mystery that remains is whether its discovery marks a new dawn for particle physics or the final stretch of a field that has run its course.

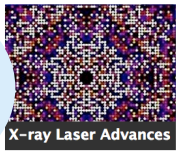
Read more about the Higgs boson from the research teams at CERN.

Runners-Up FREE WITH REGISTRATION

This year's runners-up for Breakthrough of the Year underscore feats in engineering, genetics, and other fields that promise to change the course of science.







Who Should Be TIME's Person of the Year 2012?

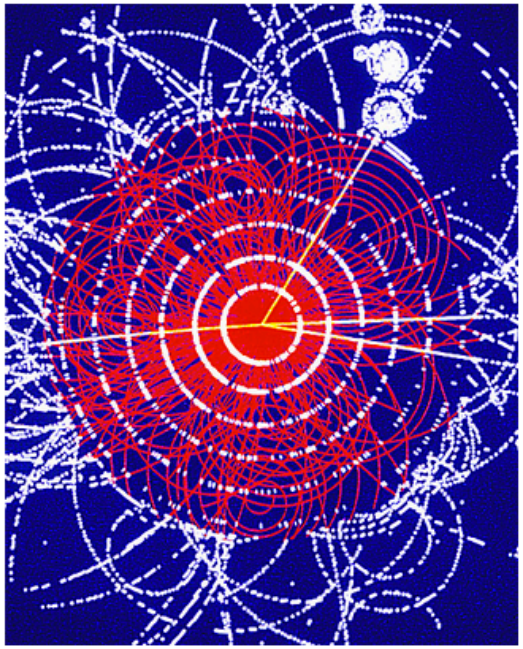
As always, TIME's editors will choose the Person of the Year, but that doesn't mean readers shouldn't have their say. Cast your vote for the person you think most influenced the news this year for better or worse. Voting closes at 11:59 p.m. on Dec. 12, and the winner will be announced on Dec. 14.

THE CANDIDATES

The Higgs Boson

18 of 40

By Jeffrey Kluger | Monday, Nov. 26, 2012



SSPL/GETTY IMAGES

Simulation of a Higgs-Boson decaying into four muons, CERN, 1990.

What do you think?

Should **The Higgs Boson** be TIME's Person of the Year 2012?

Definitely No Way

VOTE

Take a moment to thank this little particle for all the work it does, because without it, you'd be just inchoate energy without so much as a bit of mass. What's more, the same would be true for the entire universe. It was in the 1960s that Scottish physicist Peter Higgs first posited the existence of a particle that causes energy to make the jump to matter. But it was not until last summer that a team of researchers at Europe's Large Hadron Collider — Rolf Heuer, Joseph Incandela and Fabiola Gianotti — at last sealed the deal and in so doing finally fully confirmed Einstein's general theory of relativity. The Higgs — as particles do — immediately decayed to more-fundamental particles, but the scientists would surely be happy to collect any honors or awards in its stead.

Photos: Step inside the Large Hadron Collider.

WHO SHOULD BE TIME'S PERSON OF THE YEAR 2012?
The Candidates
Video
Poll Results

PAST PERSONS OF THE YEAR

2011: The Protester

2010: Facebook's Mark Zuckerberg

2009: Ben Bernanke

2008: Barack Obama

Most Read | Most Emailed

1 Who Should Be TIME's Person of the Year 2012?
2 LIFE Behind the Picture: The Photo That Changed the Face of AIDS
3 Nativity-Scene Battles: Score One for the Atheists
4 The $7 Cup of Starbucks: A Logical Extension of the Coffee Chain's Long-Term Strategy

TIME

Person of the Year

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2012 2011 2010 2009 2008

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Like 1.5k | Tweet 536 | +1 20 | Share 7

THE CANDIDATES

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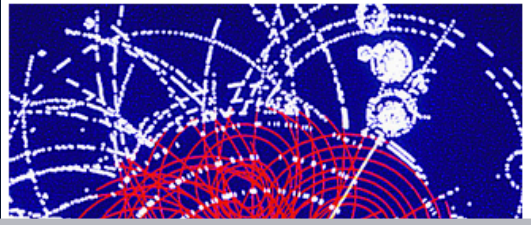

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Definitely No Way

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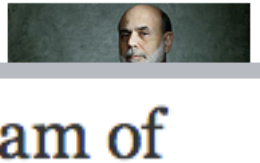
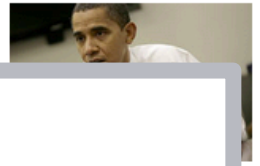


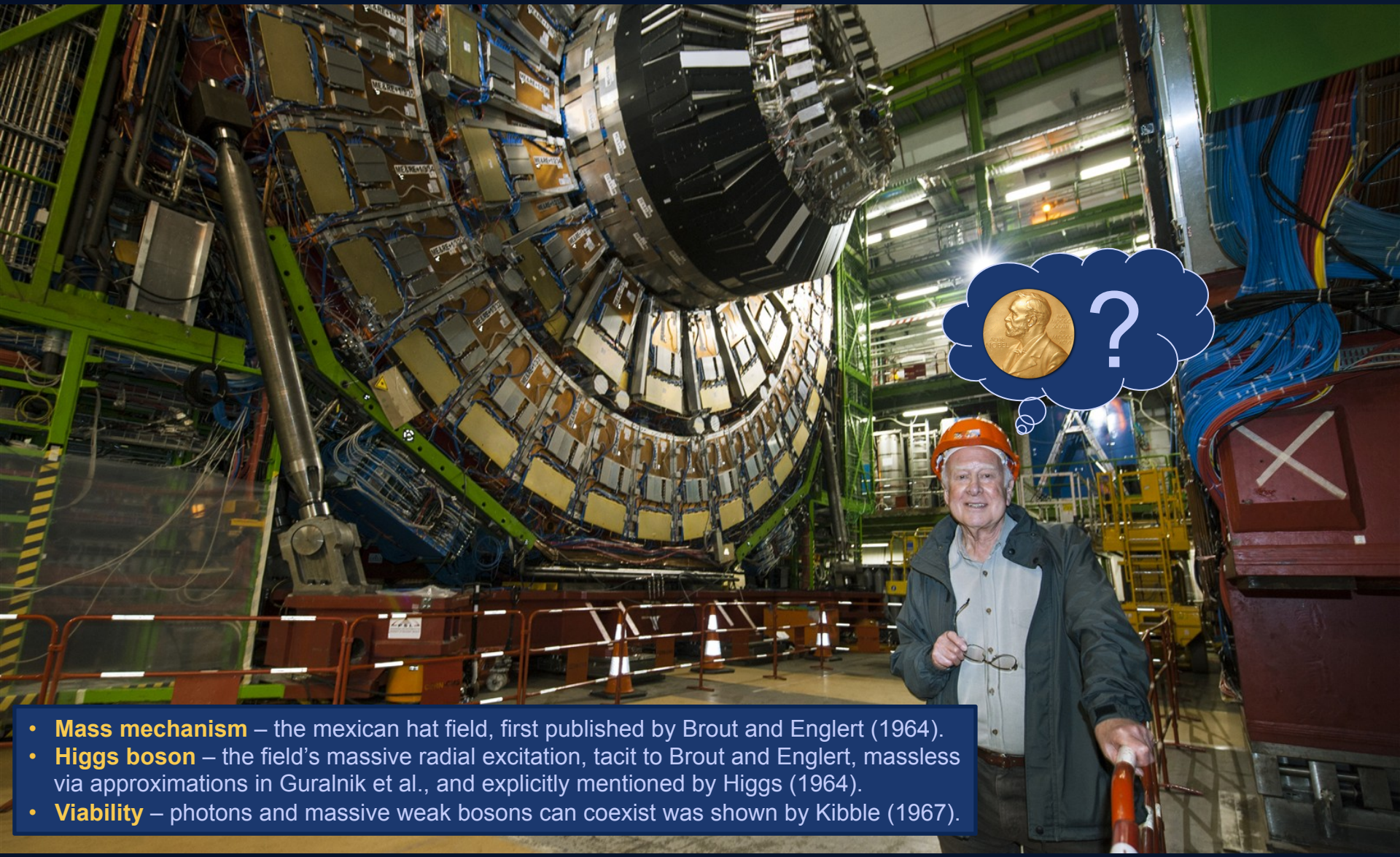


last summer that a team of researchers at Europe's Large Hadron Collider — Rolf Heuer, Joseph Incandela and Fabiola Gianotti — at last sealed the deal and in so doing finally fully confirmed Einstein's general theory of relativity. The

Photos: Step inside the Large Hadron Collider.

Higgs in CMS – ca. 2008

[http://cern.ch/go/dJf7] [http://cern.ch/go/Sx8m]



- **Mass mechanism** – the mexican hat field, first published by Brout and Englert (1964).
- **Higgs boson** – the field's massive radial excitation, tacit to Brout and Englert, massless via approximations in Guralnik et al., and explicitly mentioned by Higgs (1964).
- **Viability** – photons and massive weak bosons can coexist was shown by Kibble (1967).

October 2013: experimentalists hear Nobel

Progress – stepping through paradigms

- **Discovery of fire**
- Candle invention
- Candle ubiquity
  - Applied research: Animal fat, Bee's wax, Oil lamps,…

- **Discovery of electricity**
- Light bulb invention
- Light bulb ubiquity
  - Applied research: Carbon filament, Tungsten filament, inert gas filling…

- **Discovery of plasmas** (electrical discharges in gases)
- Fluorescent tube invention
- Fluorescent tube ubiquity
  - Applied research: Long rod, Compact fluorescent,…

- **Discovery of band gap semiconductors**
- Light-emitting diode invention
- Ubiquity? Stay tuned, work in progress
  - Applied research: white LED, high-power LED,…

No discoveries, no inventions

- **Discoveries enable inventions**
  that *can* become ubiquitous

- No fire, no candles
- No electricity, no light bulbs
- No plasmas, no fluorescent tubes
- No semiconductors, no LEDs

Society – the link to ubiquity

- Discoveries enable **inventions**
  that can become ubiquitous

- **Ubiquity** hinges on the **perceived value for society**
  - Candles
    provided light when the sun was down
  - Light bulbs
    prevented candle fires and gas emissions
  - Fluorescent tubes
    produced less heat than light bulbs
  - LED light bulbs
    provides improved energy efficiency and longevity

Enabling discoveries

- **Discoveries more often than not stem from research with**
  - no direct practical purpose
  - no immediate profit or gain
  - no clear path ahead
  - **no support from society**
  - **no intention of making discoveries**

- In order to make **discoveries** societies must invest on **diverse research**

Experimental Particle Physics

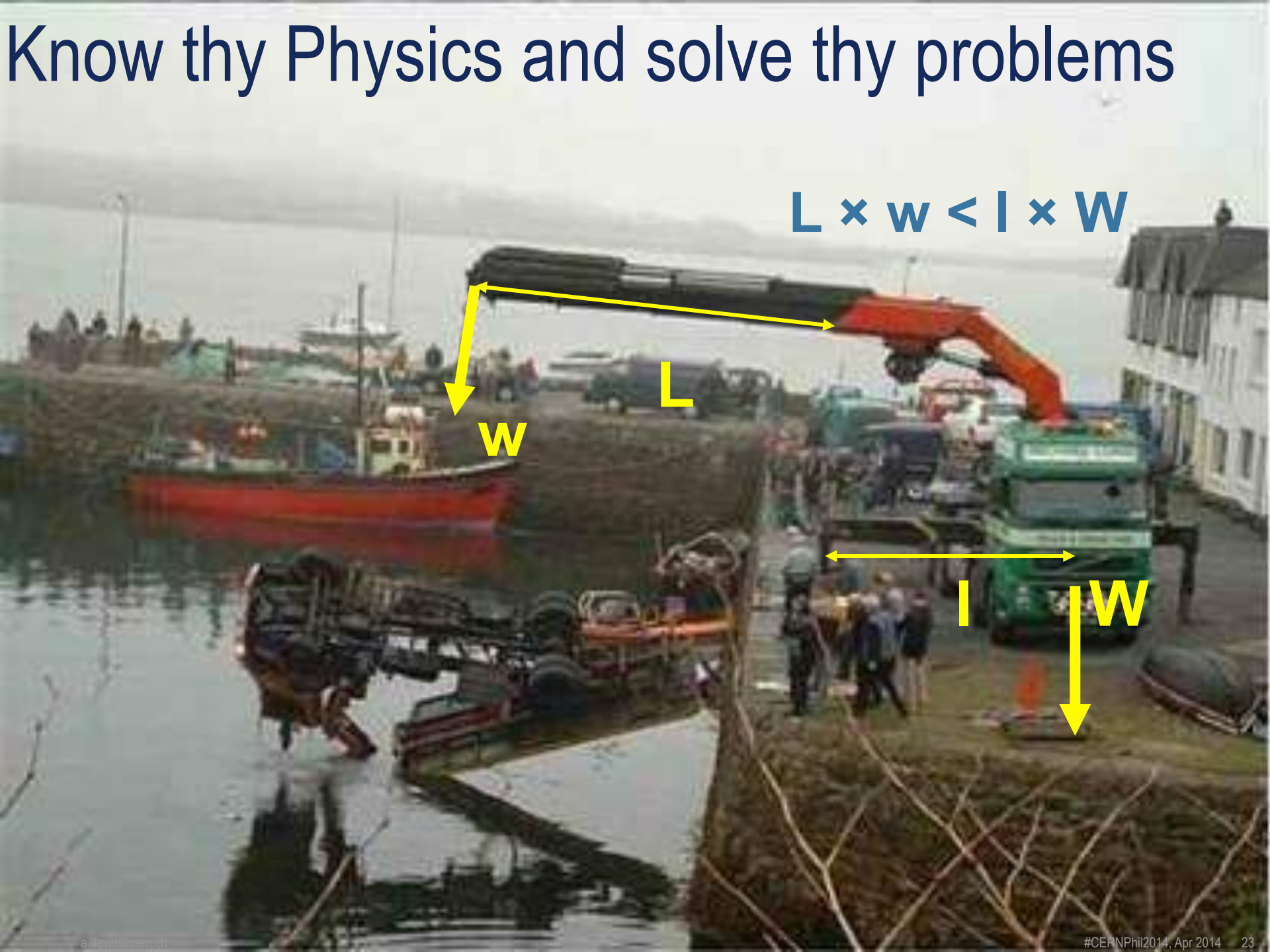
Experimental Particle Physics

To solve problems...

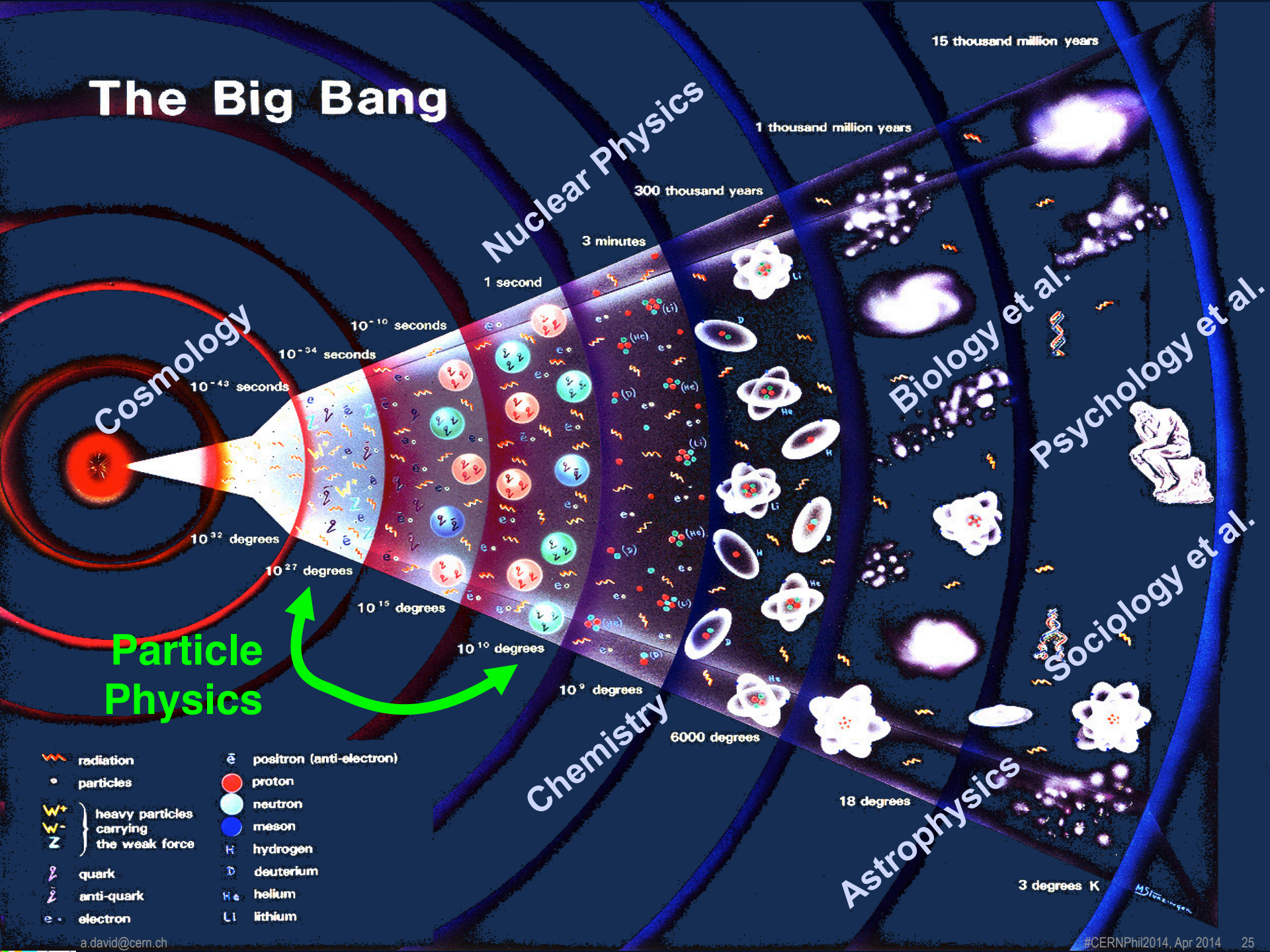
To solve larger problems…


MICHAEL LONG
TRUCK & CRANE HIRE

Know thy Physics and solve thy problems

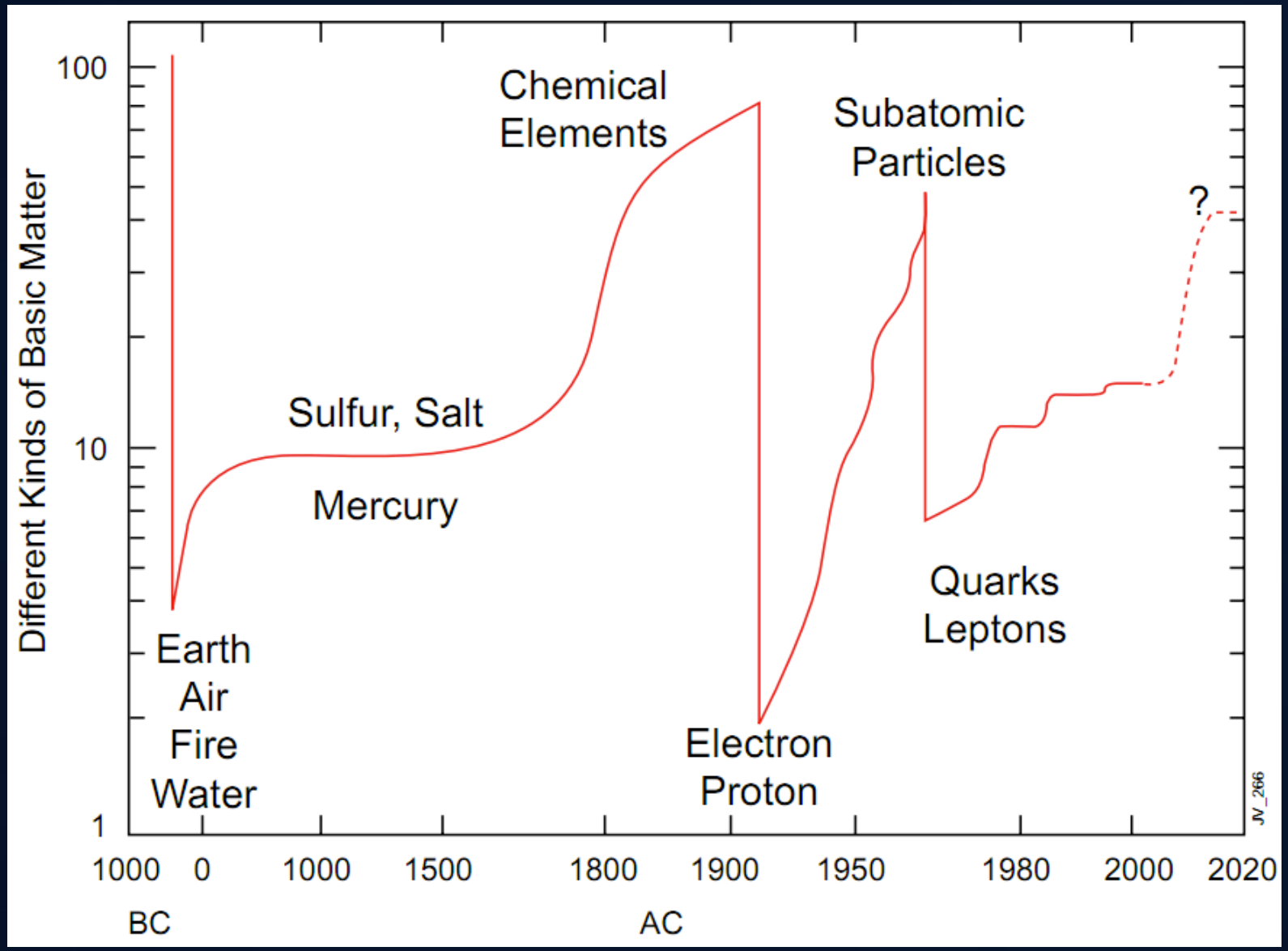


Experimental Particle Physics

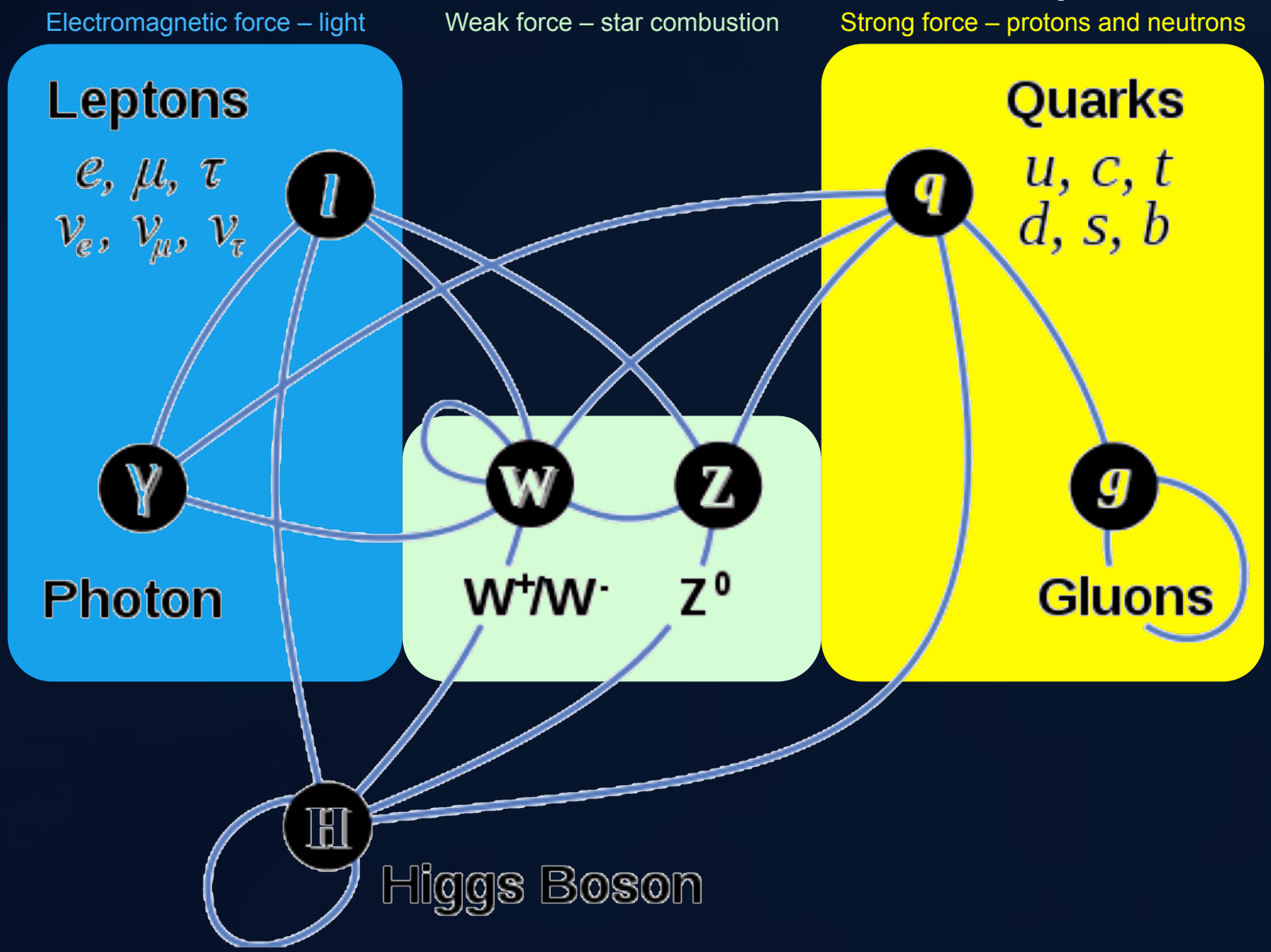

The Big Bang
15 thousand million years
1 thousand million years
300 thousand years
3 minutes
1 second
10^{-10} seconds
10^{-34} seconds
10^{-43} seconds
10^{32} degrees
10^{27} degrees
10^{15} degrees
10^{10} degrees
10^{9} degrees
6000 degrees
18 degrees
3 degrees K
Cosmology
Nuclear Physics
Chemistry
Astrophysics
Biology et al.
Psychology et al.
Sociology et al.
Particle Physics
radiation
particles
heavy particles carrying the weak force
quark
anti-quark
electron
positron (anti-electron)
proton
neutron
meson
hydrogen
deuterium
helium
lithium

Experimental Particle Physics

Evolutions and revolutions of the elements



The Standard Model of Particle Physics



Experimental Particle Physics

Up the energy scale

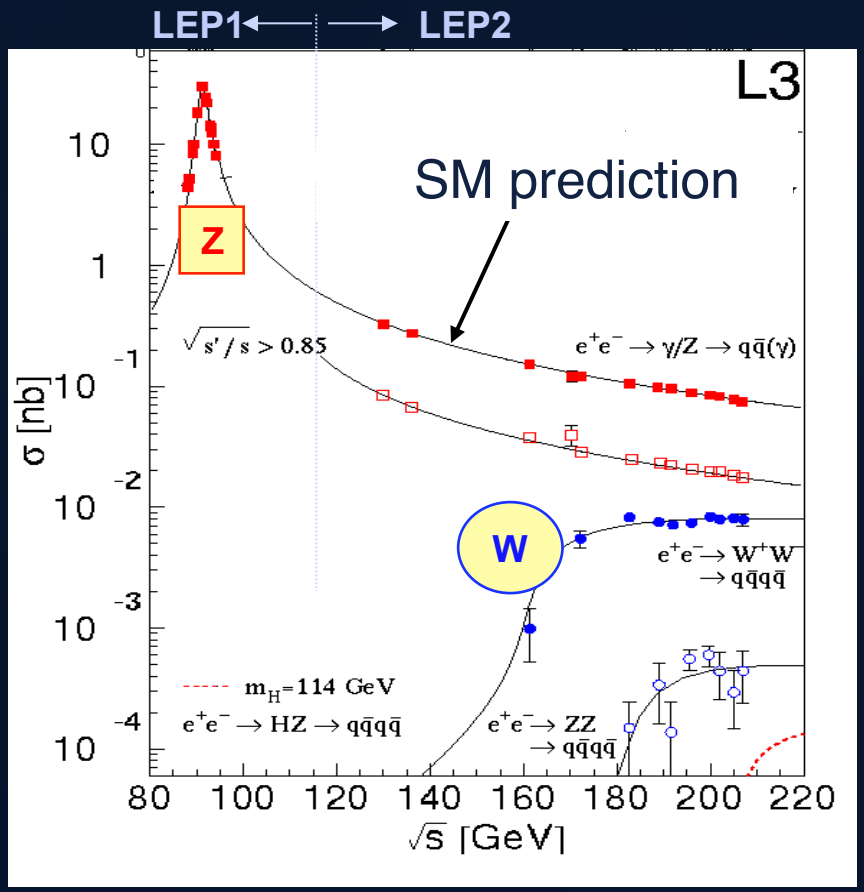
- eV — typical energy in an atom

- keV — kilo — X rays
- MeV — mega — nucleus, nuclear physics
- GeV — giga — particle physics m_{proton} = 1 GeV

- TeV — tera — limit of present accelerators

The success of the Standard Model

The previous generation of accelerators (LEP, SLC, Tevatron) established that we understand Physics up to an energy of ~ 100 GeV



The Standard Model is a very successful theory
BUT we know that it is incomplete !

Issues with the Standard Model

- The SM does not explain **how mass appears**
  - Higgs Mechanism? If so, the Higgs boson should have a mass < 200 GeV.
  - New Physics?

- The SM **without a mechanism like the Higgs boson** would give **inconsistencies at high energies** (~ TeV)
  - Some reaction probabilities become larger than 1…

- 96% of the Universe is made of **unknown "stuff"**
  - Dark matter, Dark energy. What are they ?

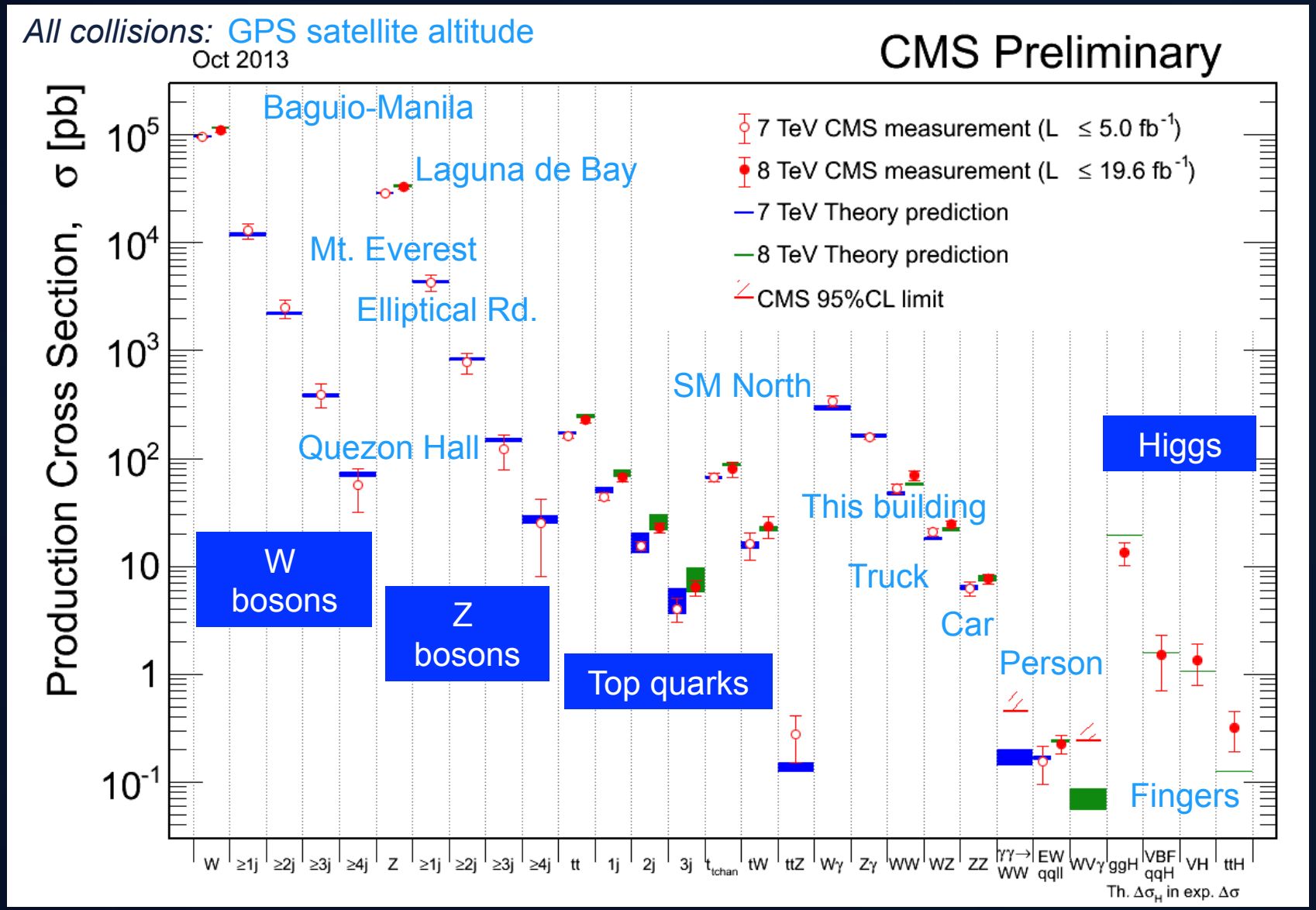
LHC – an answer machine

Such questions made us think that something new awaited us in the **TeV** energy region

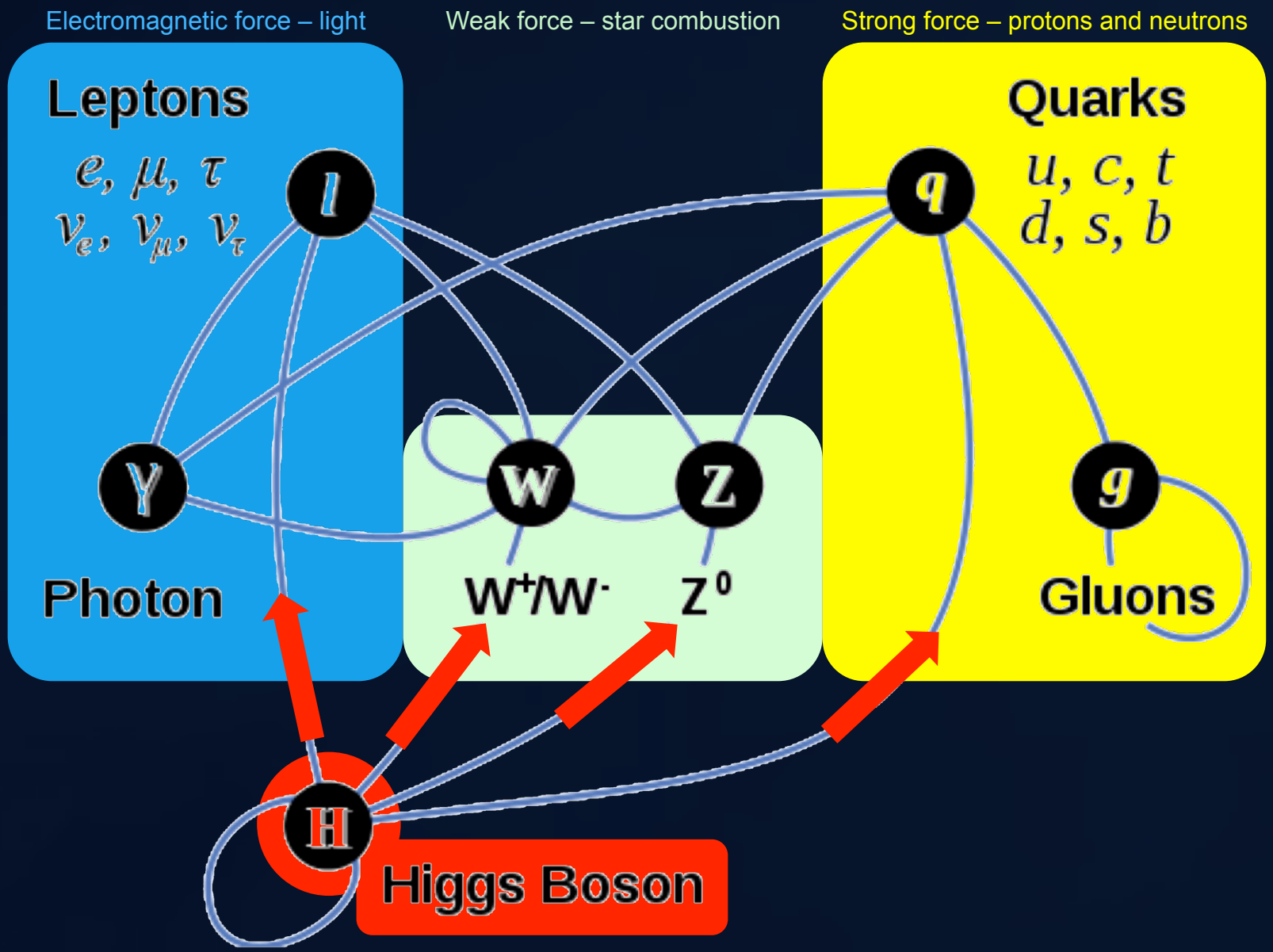
The LHC experiments were conceived to answer such questions
And they might still come across the unknown !

Digging needles out of haystacks at the LHC

[Equivalent height of haystack]



And the LHC found a rather central piece



A recipe for Experimental Particle Physics

1. Accelerators : machines able to accelerate particles to high energy and bring them into collisions,

2. Detectors : instruments which detect the particles produced in the collisions,

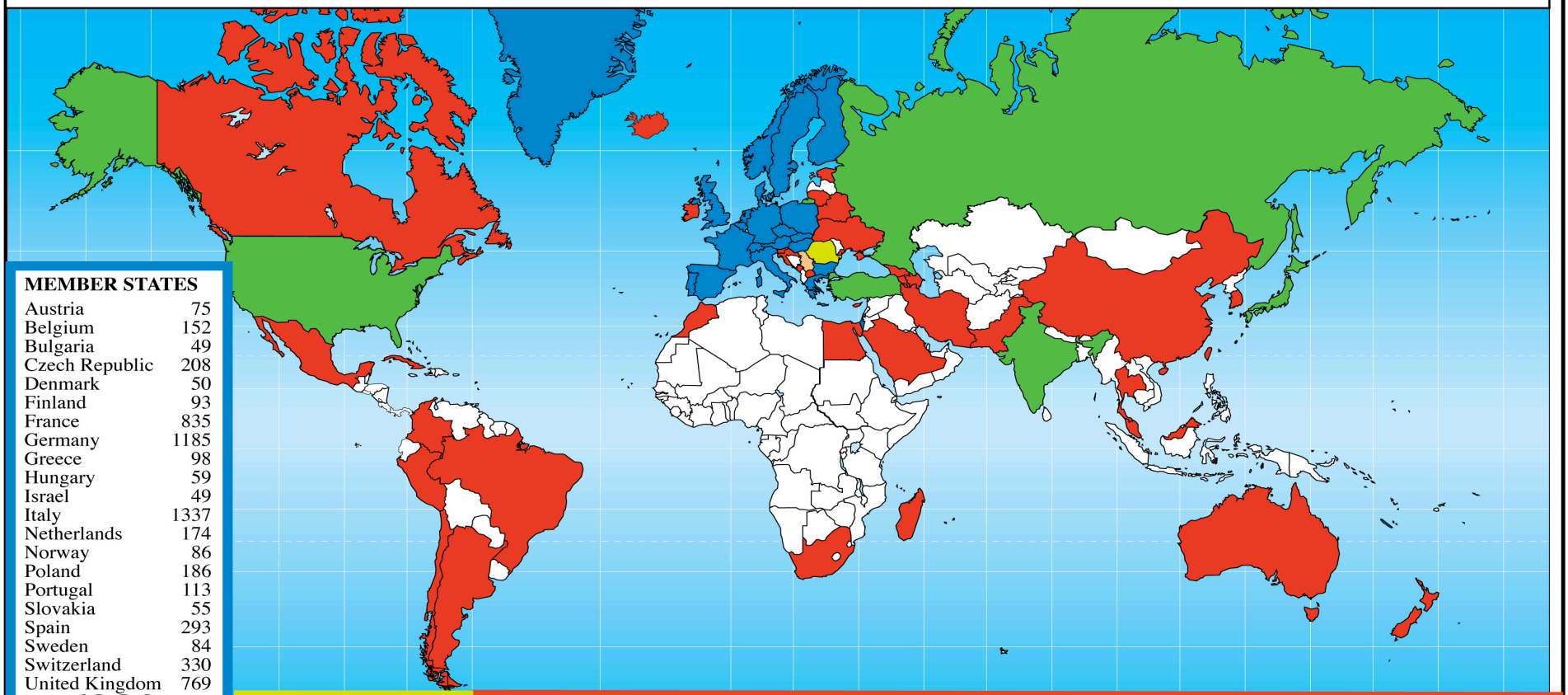
3. Computing infrastructure : to collect, save, distribute and analyse the data produced by the detectors,

4. Researchers, engineers and technicians : only an international collaboration of thousands of people can build and run such complex tools.

CERN – fostering particle physics

Who uses CERN ?

Distribution of All CERN Users by Location of Institute on 14 January 2014



MEMBER STATES	
Austria	75
Belgium	152
Bulgaria	49
Czech Republic	208
Denmark	50
Finland	93
France	835
Germany	1185
Greece	98
Hungary	59
Israel	49
Italy	1337
Netherlands	174
Norway	86
Poland	186
Portugal	113
Slovakia	55
Spain	293
Sweden	84
Switzerland	330
United Kingdom	769

6280

OBSERVERS	
India	153
Japan	217
Russia	890
Turkey	110
USA	1724

3094

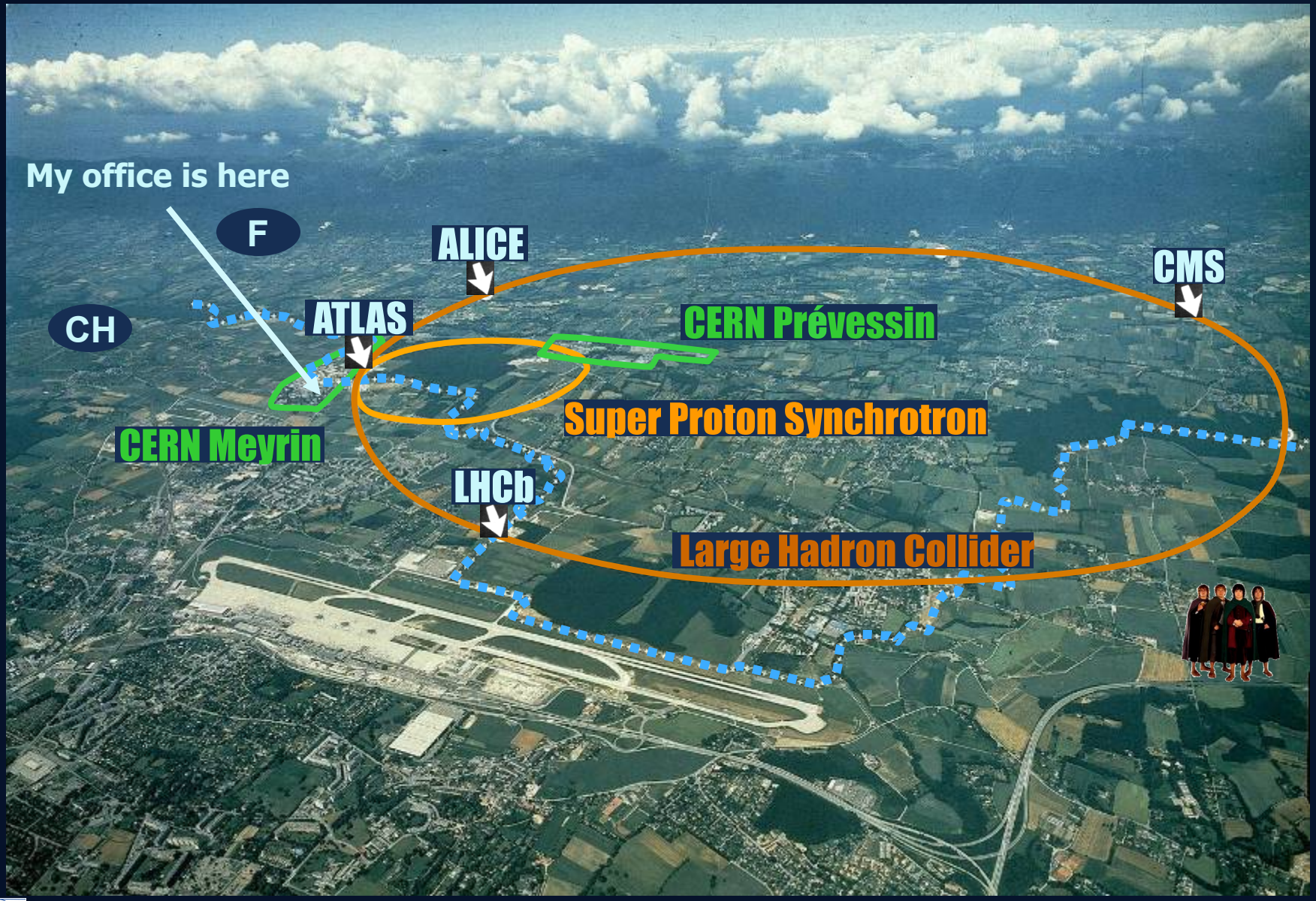
CANDIDATE FOR ACCESSION	
Romania	86

ASSOCIATE MEMBER IN THE PRE-STAGE TO MEMBERSHIP	
Serbia	30

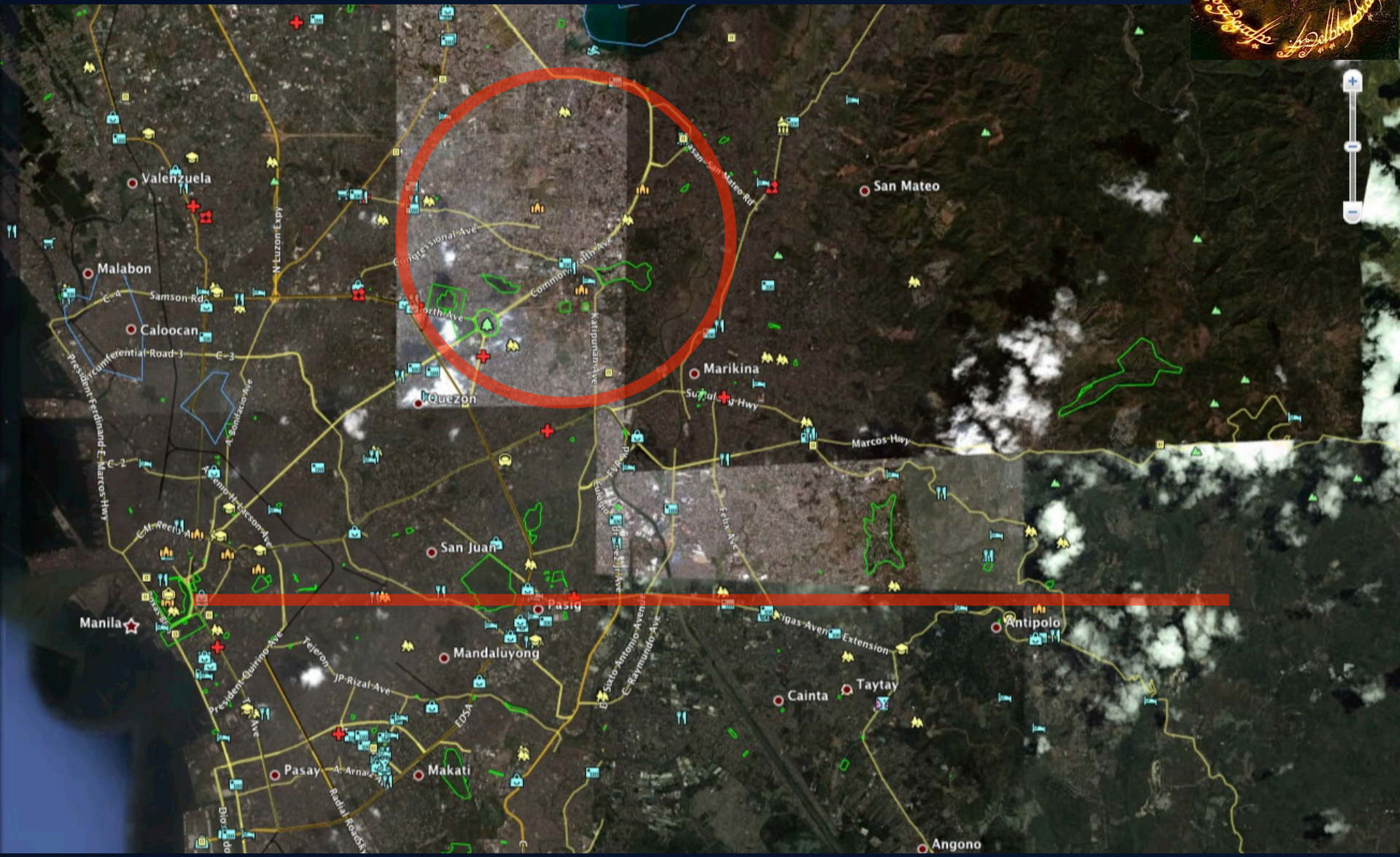
OTHERS									
Argentina	13	China	122	Iran	20	Pakistan	18		
Armenia	16	China (Taipei)	71	Ireland	5	Peru	2		
Australia	39	Colombia	10	Korea	105	Saudi Arabia	3		
Azerbaijan	2	Croatia	23	Lithuania	13	Slovenia	25		
Belarus	24	Cuba	3	Madagascar	3	South Africa	32		
Brazil	116	Cyprus	13	Malaysia	8	Thailand	8		
Canada	147	Egypt	18	Mexico	46	T.F.Y.R.O.M.	1		
Chile	8	Estonia	17	Montenegro	1	Ukraine	24		
		Georgia	11	Morocco	6				
		Iceland	4	New Zealand	5				

982

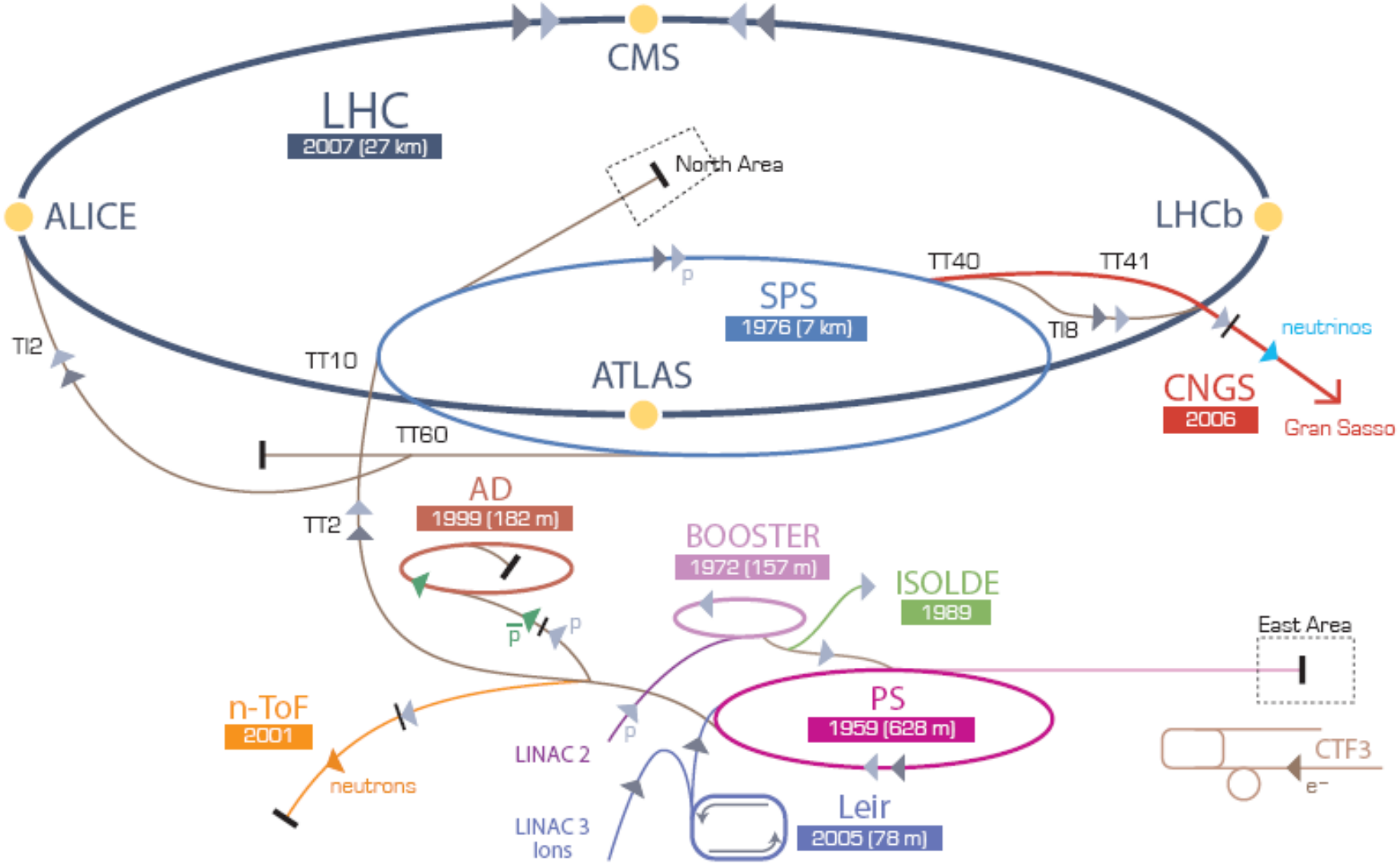
The physical extents of CERN



Metro Manila, The Philippines



Accelerators



p (proton) ion neutrons p̄ (antiproton) proton/antiproton conversion neutrinos electron

LHC Large Hadron Collider SPS Super Proton Synchrotron PS Proton Synchrotron

AD Antiproton Decelerator CTF3 Clic Test Facility CNGS Cern Neutrinos to Gran Sasso ISOLDE Isotope Separator OnLine DEvice

LEIR Low Energy Ion Ring LINAC LINear ACcelerator n-ToF Neutrons Time Of Flight

A ~~word~~ number on the LHC bill(ions)

- ~ 6×10^9 US dollars

  Cf. Bataan Nuclear Power Plant
  ~ 2×10^9 US dollars (1984)

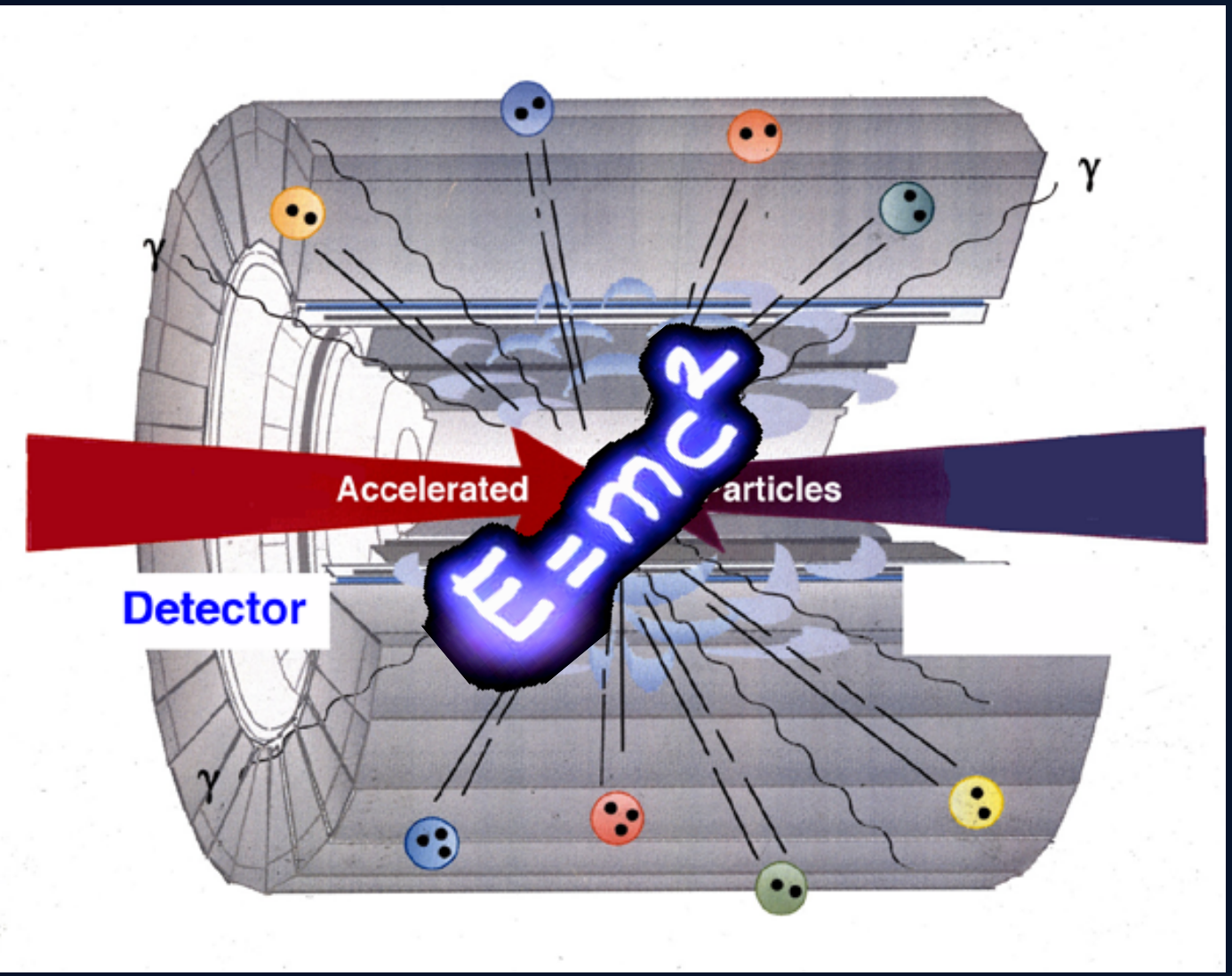
- ~ 20 years of investment

- ~ 463×10^6 member state citizens

- **~ 30 PHP**
  per citizen
  per year

Detectors

Detectors in Particle Physics

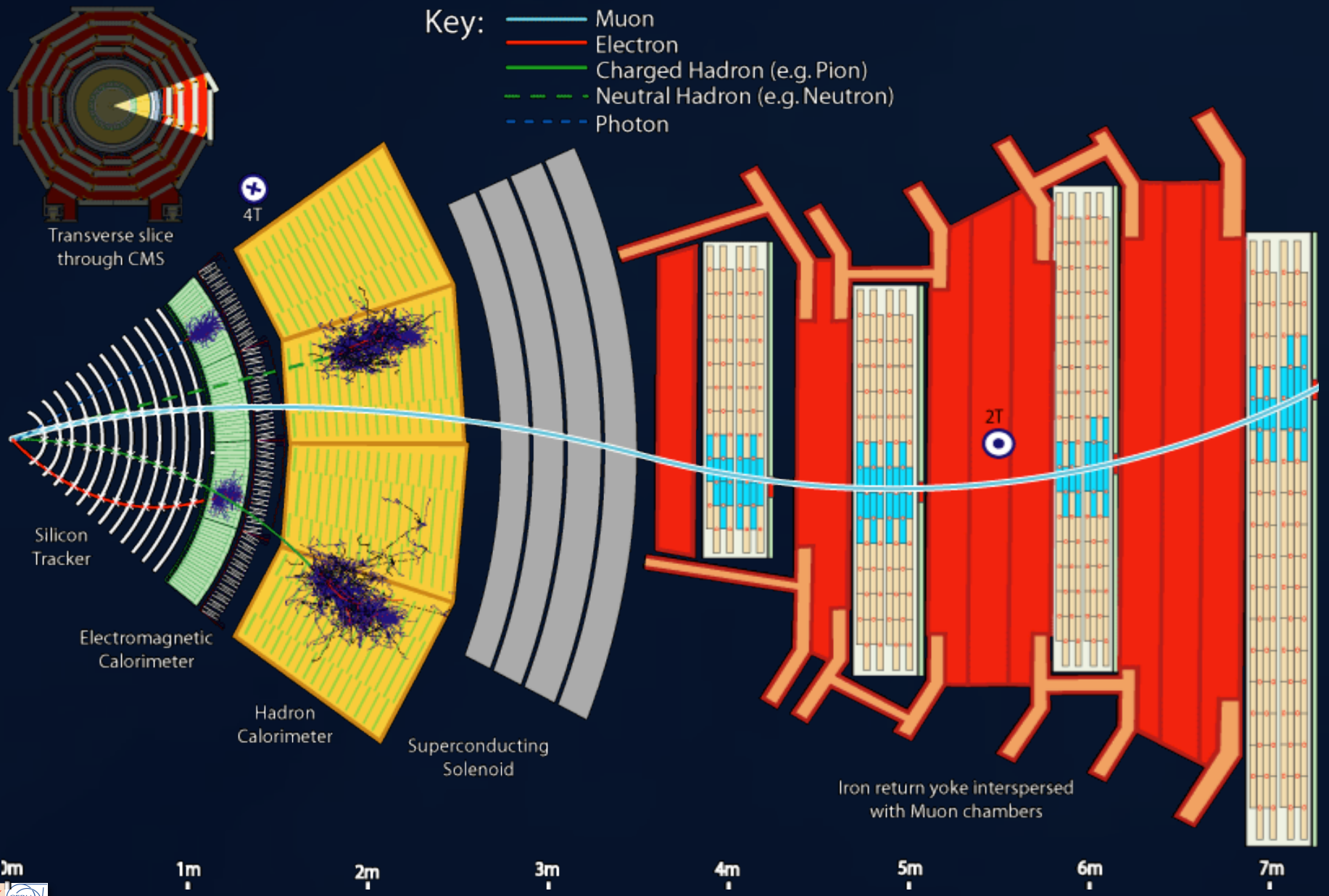


Particles with very high energy of movement are produced.

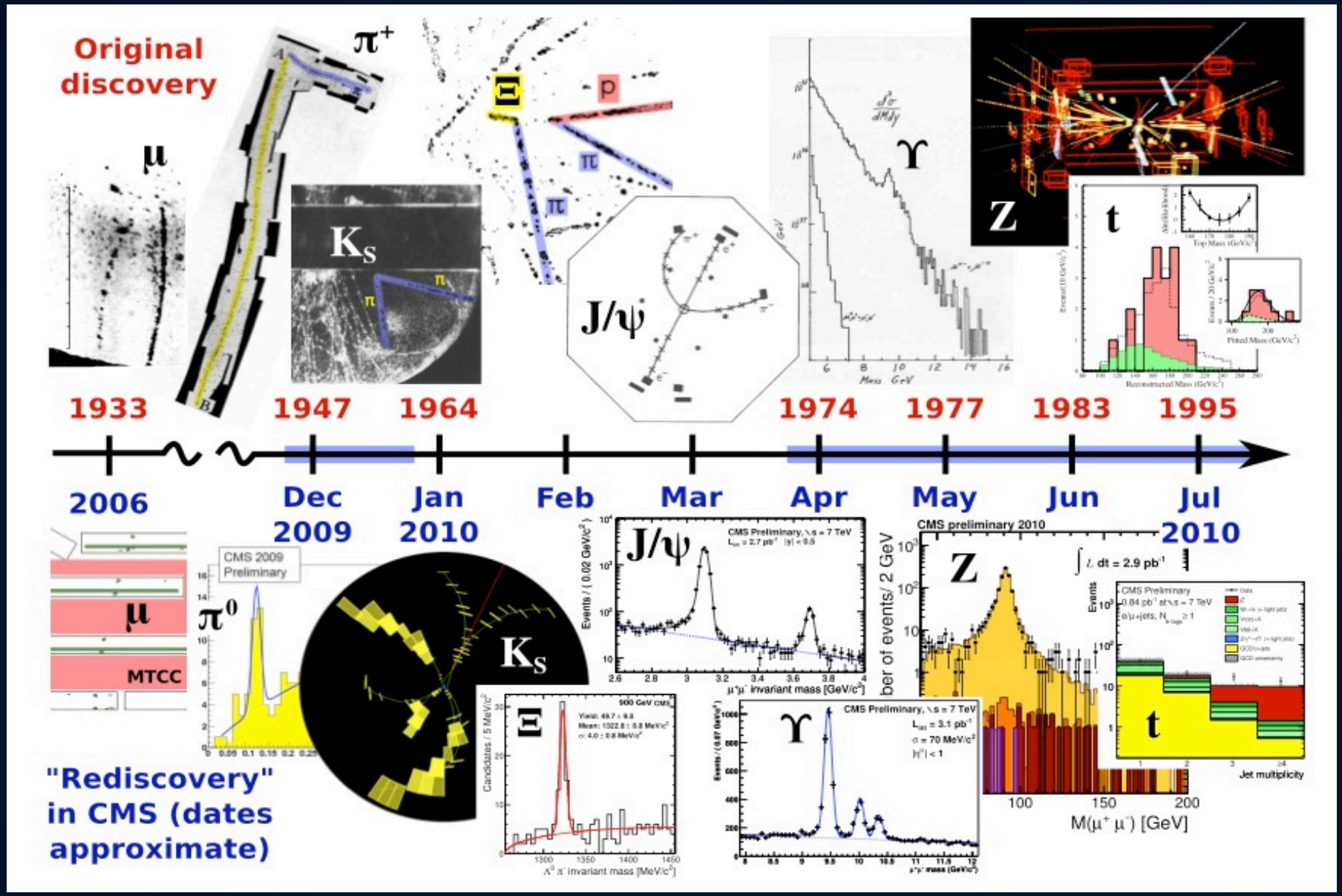
The particles are brought to collision (similar conditions as in the big bang).

The particles that are created are recorded by detectors.

Hadrons, $e^{\pm}$, γ and $\mu^{\pm}$ in the barrel



Rediscovering Particle Physics



Computing

Online and offline

Computing is needed in two levels:

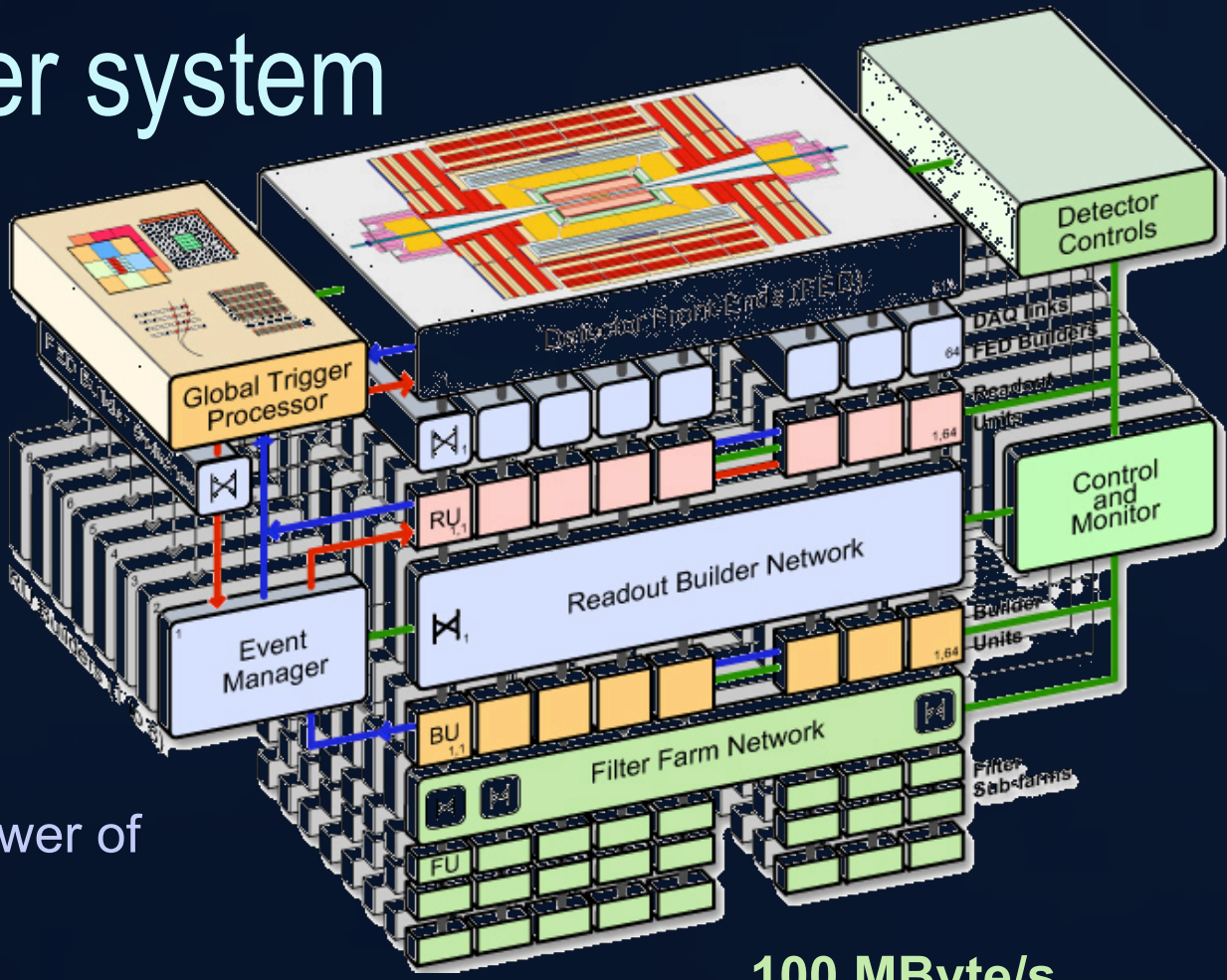
- **In real time**
  select ~ 1'000 events from 40 million collisions / s, without missing interesting events.
  (a needle in a haystack)
  - For that we use **special electronics** and **local computer farms ~ 10'000 PCs**

- **Later, with more time**
  reconstruct and analyse the ~10 million events stored every day.
  - For this we use ~ 100'000 PCs distributed over the whole world **: the computing grid**

The CMS Trigger system

100 TByte/s

100 GByte/s



100 MByte/s

Level 1 Trigger

- Custom processors
- Equivalent processing power of 50’000 PCs

High Level Triggers

- PC farm with 10’000 PCs

One of the most complex electronics systems ever built !

The LHC computing grid

A grid with all the computing resources of all the Particle Physics laboratories in the world

The **World Wide Web** gives access to the *information* stored in millions of different places.

The Grid is an infrastructure giving access to *computing power* and *data storage* distributed in the whole world.

The lightbulb did not come from perfecting the candle,

nor the telephone from making better drums,

nor the computer from more sophisticated slide rules.

Added value to society

(none of the following would exist without CERN)

CERN – *where the web was born*

- HTTP – the hypertext transfer protocol
  - Originally developed to help navigate information
  - Click on word to go to page developing the concept

- Presently the boundless information highway !
  - Web 2.0
  - Online shopping
  - Social networking
  - Email
  - Video chatting
  - Wikileaks
  - …

Pharmaceutical research on the GRID

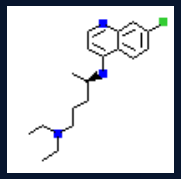
Enabling Grids for E-sciencE

Millions of potentially active molecules

Lab trials
1 to 10 $ per trial,
several hours per trial

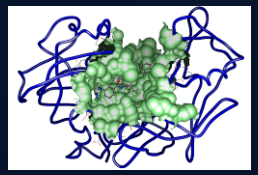
Too expensive !

Library of active molecules



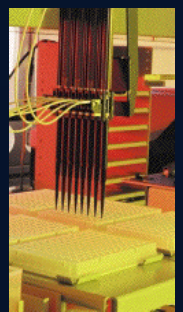
Computation of molecular attachment
1 to 15 minutes per combination

Target protein in 3D



20 to 30 days on 5'000 PCs
Many millions of trials

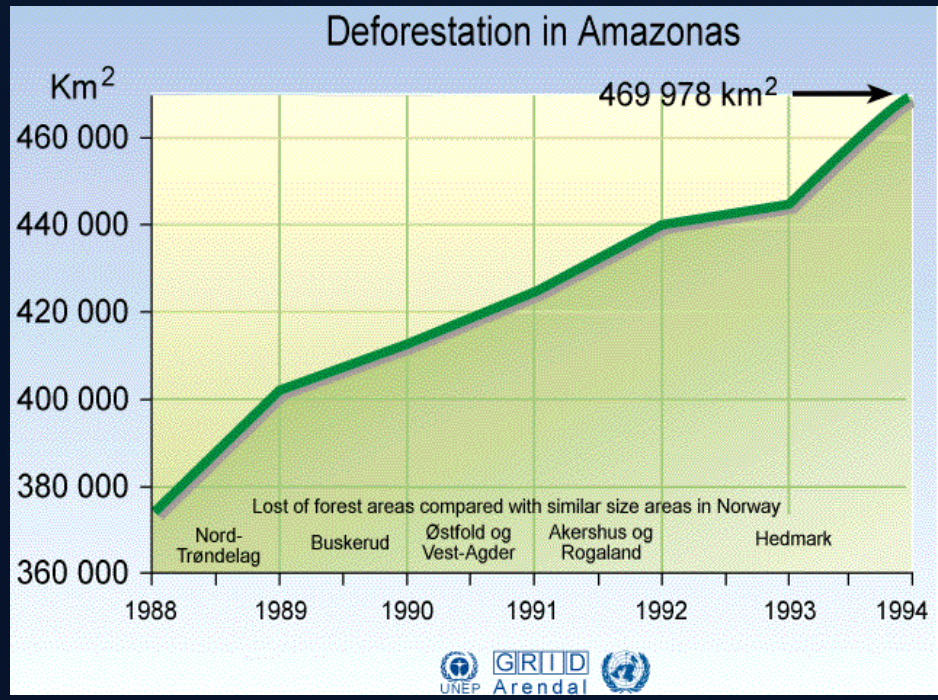
Cost effective and fast !

Select the best →  **in vitro trials** → **Clinical trials**

GIS data on the GRID

- **Disaster management** (UN agencies)
  - Large amounts of satellite data are mined in the GRID to select the best
    - Camp sites
    - Aid routes
    - Airstrip placements

- **Amazonas deforestation**
  - Mine data to find the areas affected



Cryogenics for energy

Developments in cryogenics (in particular on the usage of superfluid helium) : synergy with the research on new sources of energy

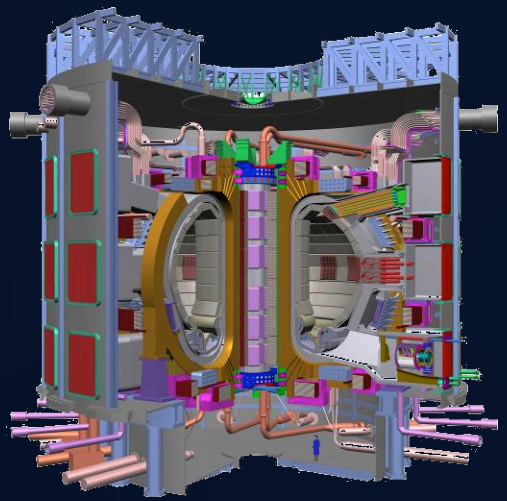
Tore-Supra (1989)

↓

LHC (2008)

↓

ITER (2016)



12 & 13, 13 Mar 2008

Coopération entre le CERN et ITER

Le CERN et l'Organisation internationale ITER pour l'énergie de fusion viennent de signer un premier accord de coopération.

(http://cdsweb.cern.ch/record/1093639)

Kaname Ikeda, Directeur général de l'Organisation internationale ITER pour l'énergie de fusion (à droite) et Robert Aymar, Directeur général du CERN lors de la signature.

Au cours d'une rencontre sur le site de Meyrin, jeudi 6 mars, Kaname Ikeda, le Directeur général de l'Organisation internationale ITER (http://www.iter.org/) pour l'énergie de fusion et Robert Aymar, Directeur général du CERN, ont signé un accord de coopération.

Cet accord prévoit, en particulier, qu'ITER puisse bénéficier de l'expérience du CERN sous forme de services de conseils, non seulement dans le domaine de la technologie mais également dans les secteurs administratifs des finances,

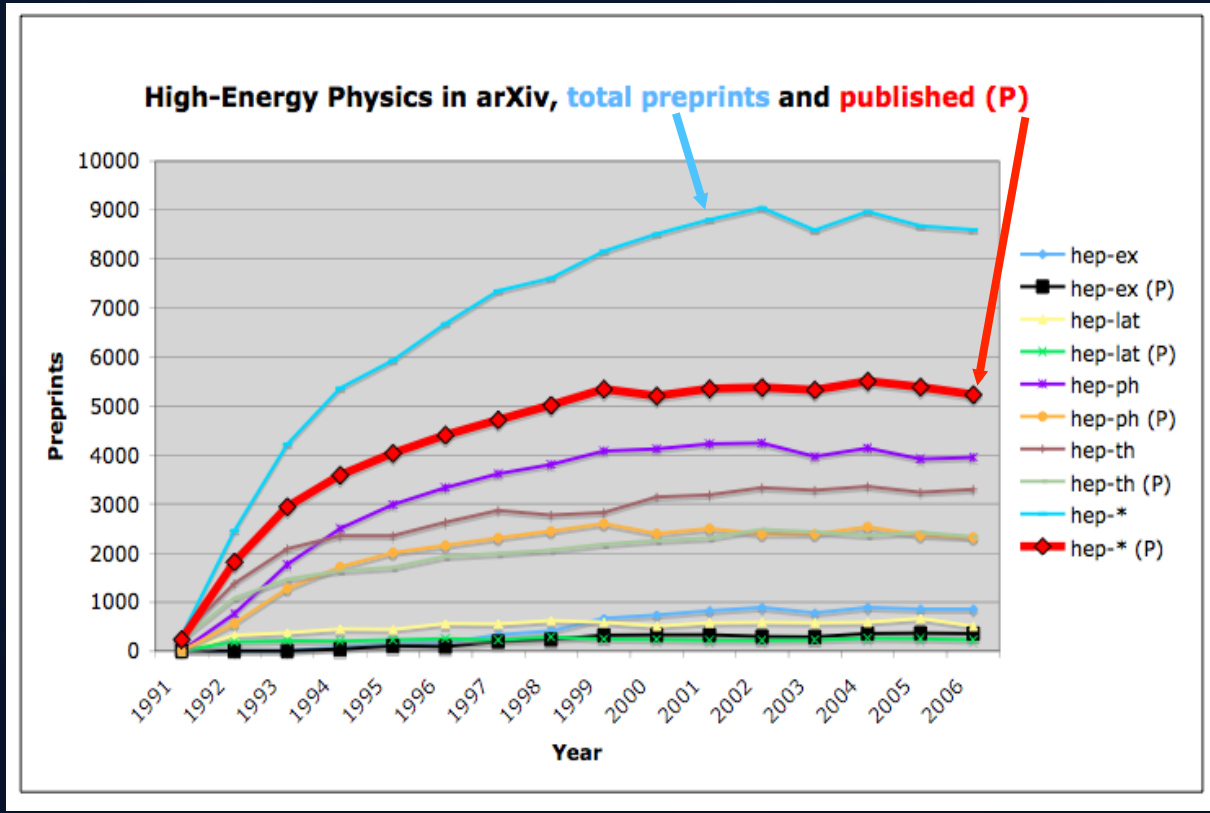
Other international organizations

- **EMBL** – European Molecular Biology Laboratory
- **ESO** – European Southern Observatory
- **SESAME** – a Middle East synchrotron
  - All had offices at CERN at some point
  - All modeled their constitution after CERN's

- **ILC** – International Linear Collider
- **ITER** – International Fusion Reactor
- **FAIR** – Antiproton and Ion Facility
  - All have had or will have seconded experts from CERN in engineering and administrative areas

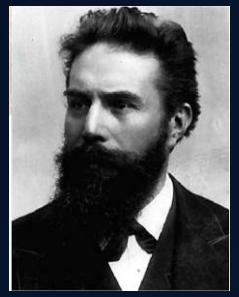
Open Access publishing

- **Grant anybody, anywhere, and anytime access** to the (peer-reviewed) results of (publicly-funded) research
- High Energy Physics has a preprint culture since the 1960s
- Summer 1992, SPIRES links to the full-text documents on arXiv



Medical imaging

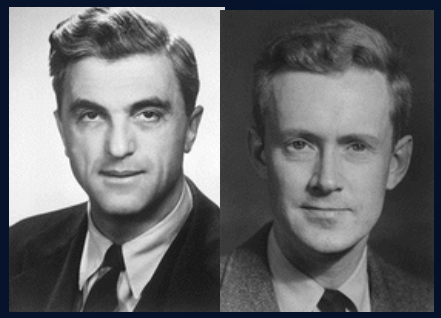
Has always benefited from fundamental research in physics



Röntgen

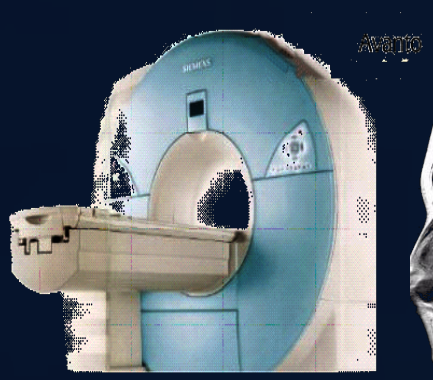
X rays

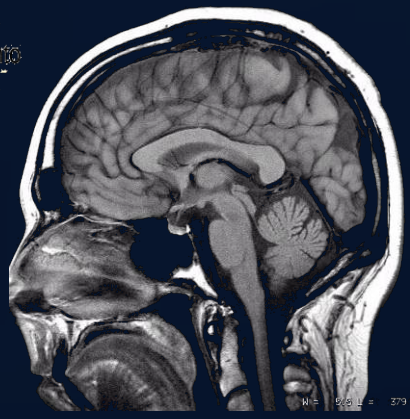
Radiography, scanners



Bloch & Purcell

Nuclear Magnetic Resonance





Resonance

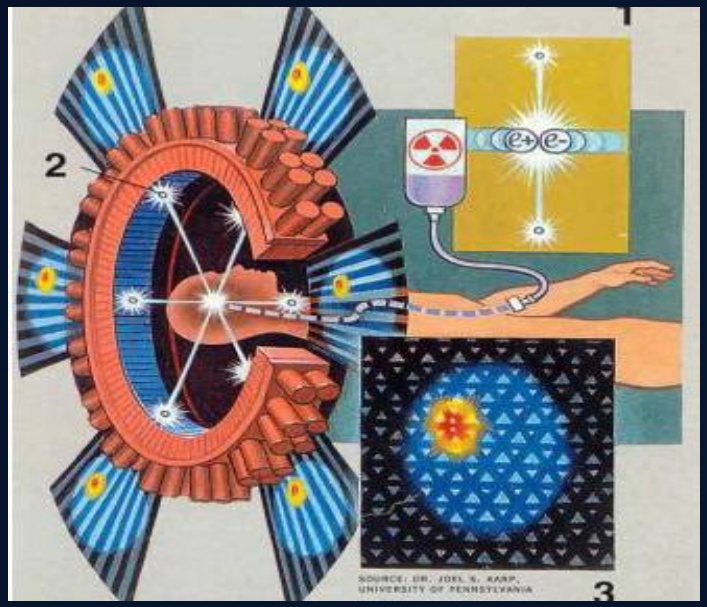
Customs – large area imaging

…drugs hidden inside the gas tank.

A truck, carrying two cars in a container and…

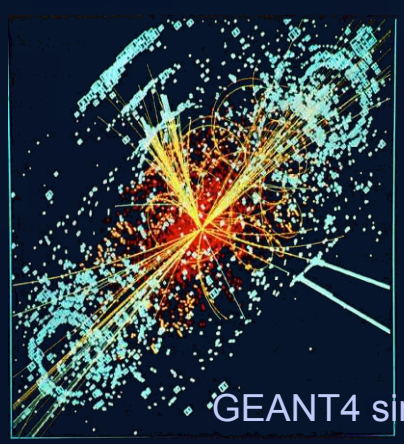
Medical imagery - PET

9’216 LSO crystals
Full body scan in 20 min

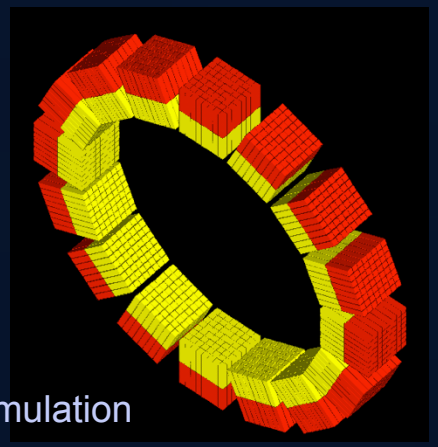


PET (positron emission tomography) uses crystals similar to those developed to the LHC.

The light detectors, the electronics, and the simulation software are also reused.



GEANT4 simulation



Medical imaging – PET mammography

Consortium PET-Mammography

LIP - Laboratório de Instrumentação e Partículas

Hospital Garcia Orta - Serviço Medicina Nuclear

IBEB - Instituto Biofisica e Engenharia Biomédica

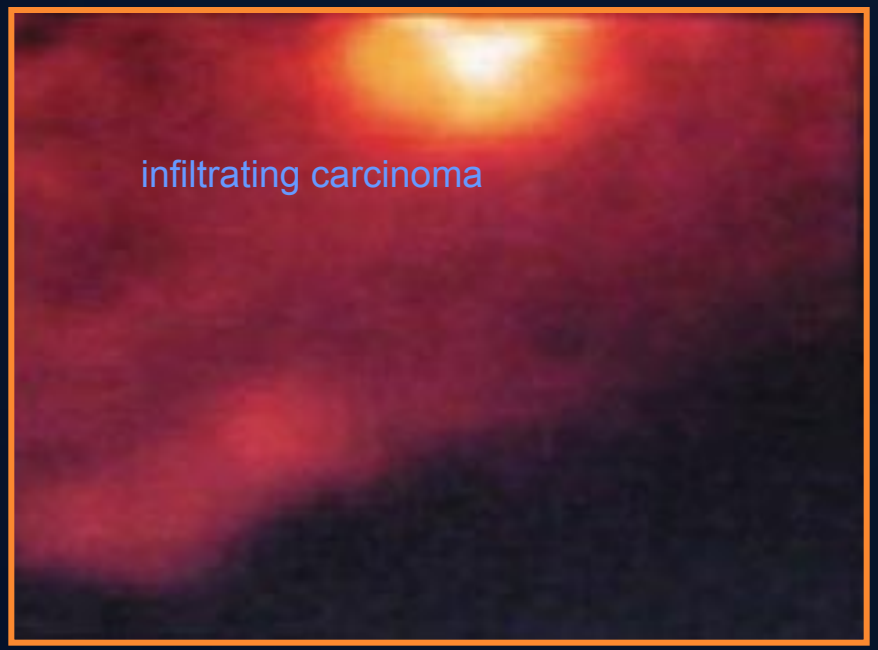
IBILI - Instituto Biomédico de Investigação da Luz e Imagem

INOV- INESC Inovação

INESC-ID - Instituto de Engenharia de Sistemas e Computadores

INEGI - Instituto de Engenharia Mecânica e Gestão Industrial

TAGUSPARK – Parque de Ciência e Tecnologia



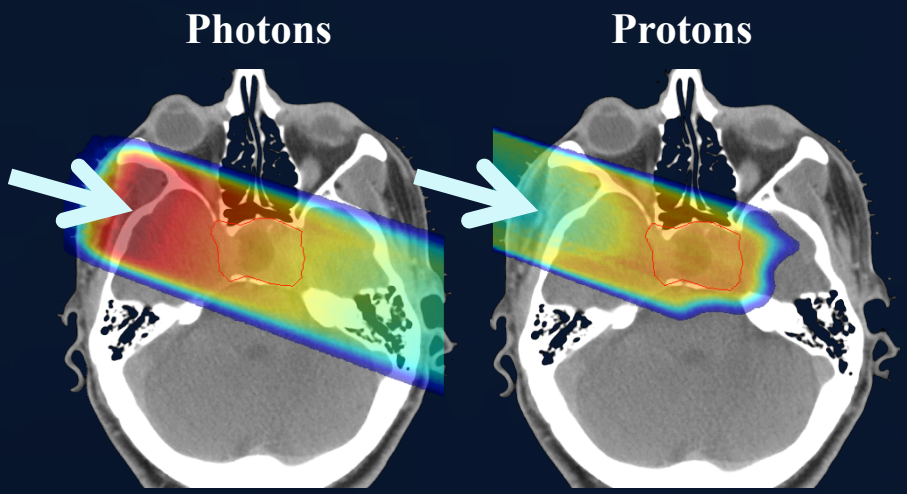
PET: physiological functions of the tissue

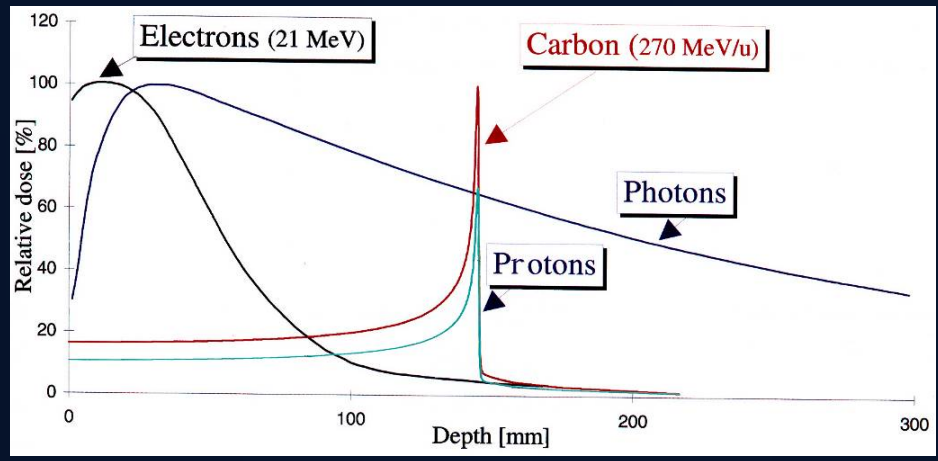
X-ray: lesion size, shape and tissue density

Medical therapy

Developed in physics laboratories, used in hospitals.

Hadron therapy



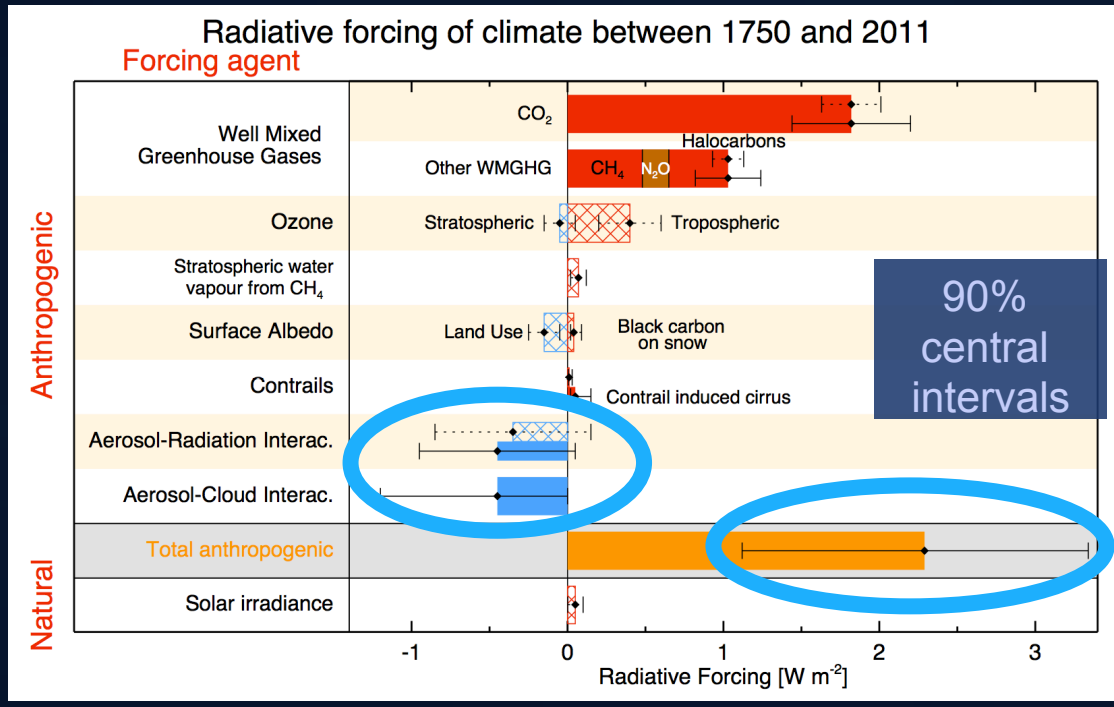


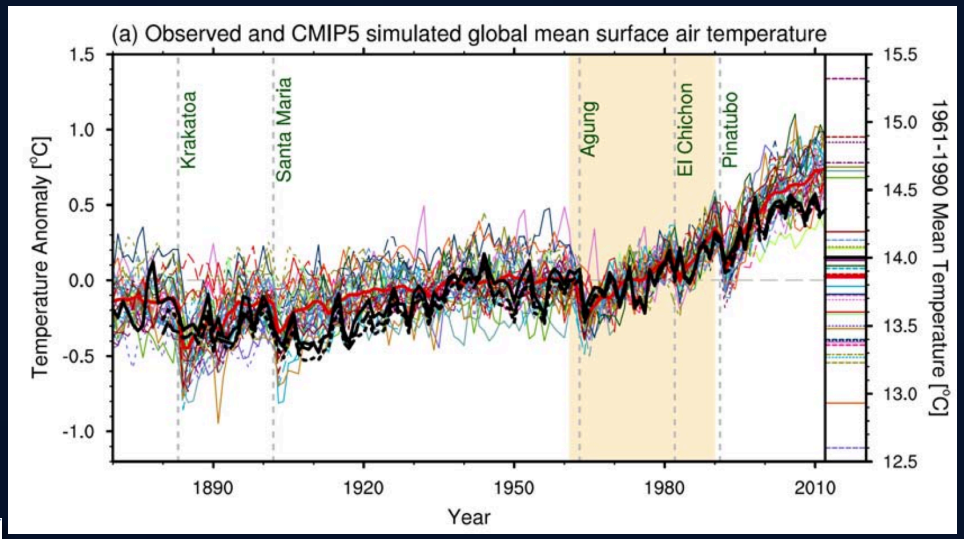
Of the 17'000 accelerators in the world, 9'000 are used for medical applications.

Climate forcings - the state of the art

- IPCC AR5 2013
  - Total anthropogenic: ~ 2.3 W/m^2
  - Negligible solar contribution
  - Non-uniform 0.7 ºC rise since 1900

- **What about before the 20th century ?**

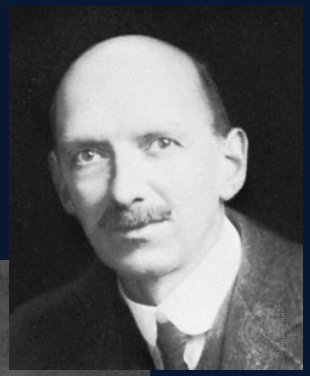


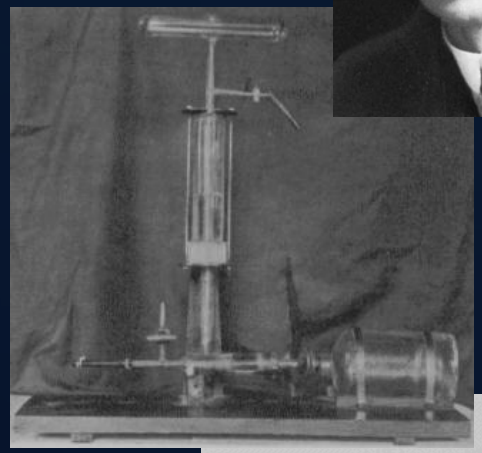


"Radiative forcing is the net change in the energy balance of the Earth system due to some imposed perturbation." - IPCC AR5

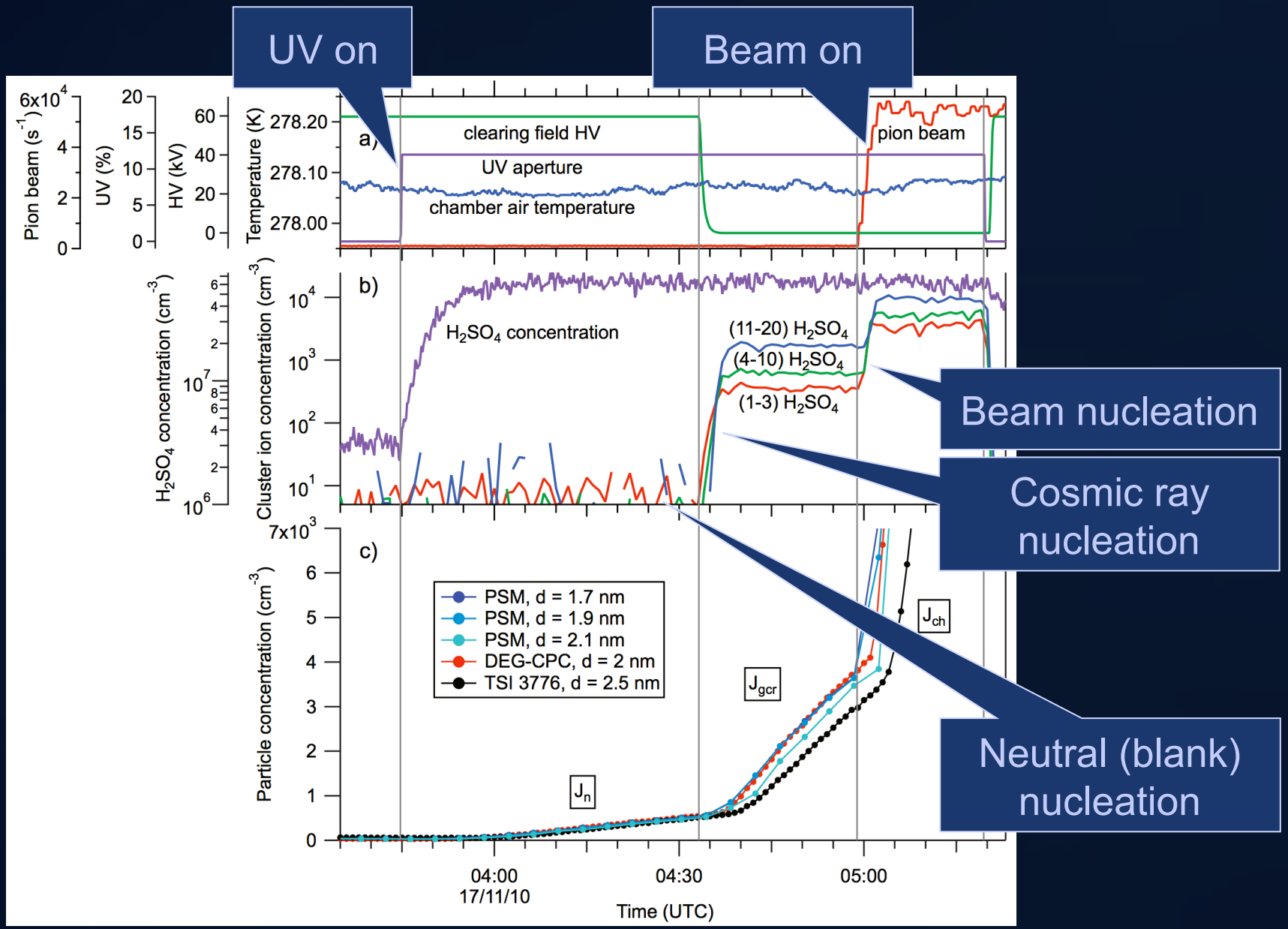
Cloud chambers and cosmic rays

- 1911 - **C.T.R. Wilson**
  - Makes a cloud chamber for experiments on the formation of rain clouds
  - *1927 Nobel Prize*
- 1912 - **Victor Hess**
  - On a hot air balloon sees that the higher, the more radiation
  - *1936 Nobel Prize*

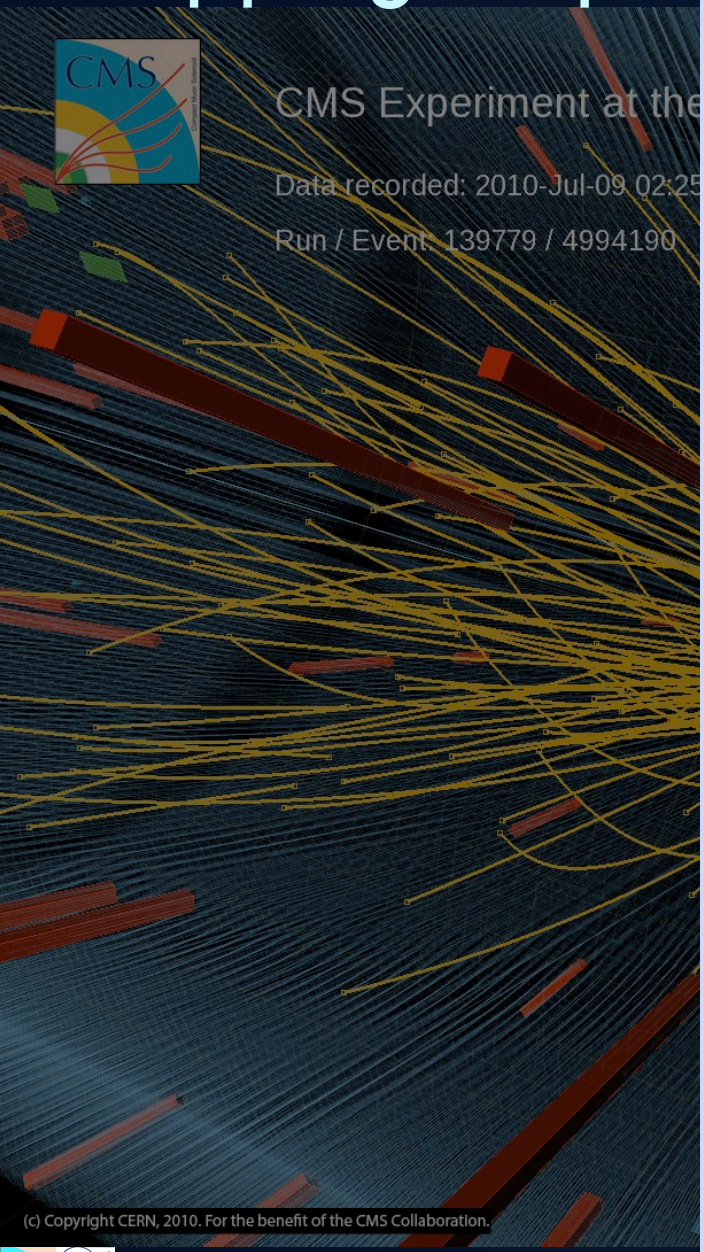




CLOUD - nucleation using pion beams

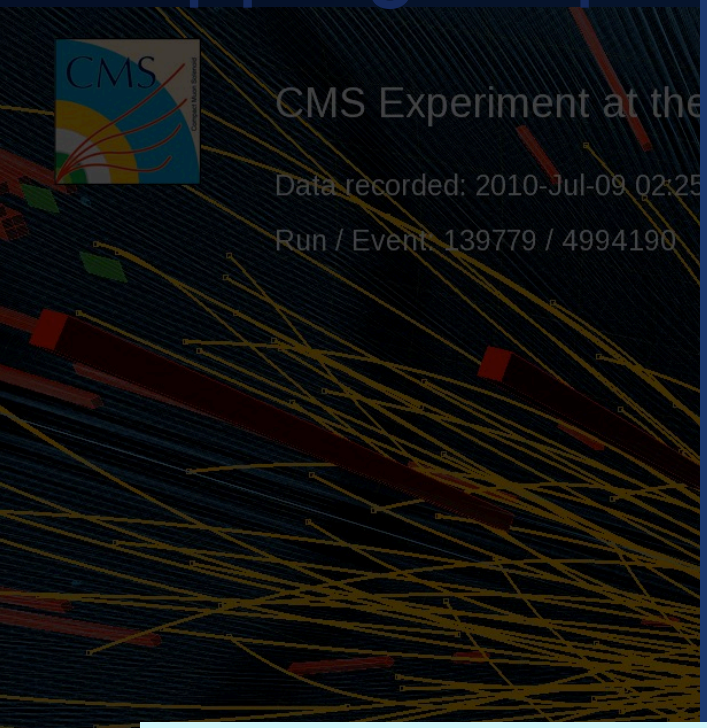


Wrapping it up



- **No discovery, no invention**
  - No invention, no benefit to society
  - The seemingly useless may uncover the extremely useful
- Experimental Particle Physics
  - What is matter made of ?
  - CERN – a knowledge center
    - 21+ countries, 12’000 people
    - State-of-the-art R&D
    - Training and Technology Transfer
    - ~ 2 USD / “CERN citizen” / year
  - Return to society
    - World wide web, http protocol
    - Grid computing: drug discovery, GIS
    - Open Access publishing model
    - Imaging: medical PET, customs
    - Cancer hadro-therapy
    - Climate change

Wrapping it up



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  - What is matter made of ?
- CERN – a knowledge center
  - 20+ countries, 10'000 people
  - Training
  - State-of-the-art technology
  - ~ 1 USD / European / year

- **Time for questions**
  1. There is no such thing as a stupid question.
  2. There are no secrets in our work.
  3. If I do not know the answer, we can always try to find it out.

Rolf Heuer, CERN Director-General since 2009

December 12, 2008

"In the future we need to go further, working together with our partners around the world. Now is the time for us to lay the foundations for future programmes, which will be built on strong national and regional pillars in the Americas, Europe and Asia."

http://press.web.cern.ch/press/PressReleases/Releases2008/PR18.08E.html