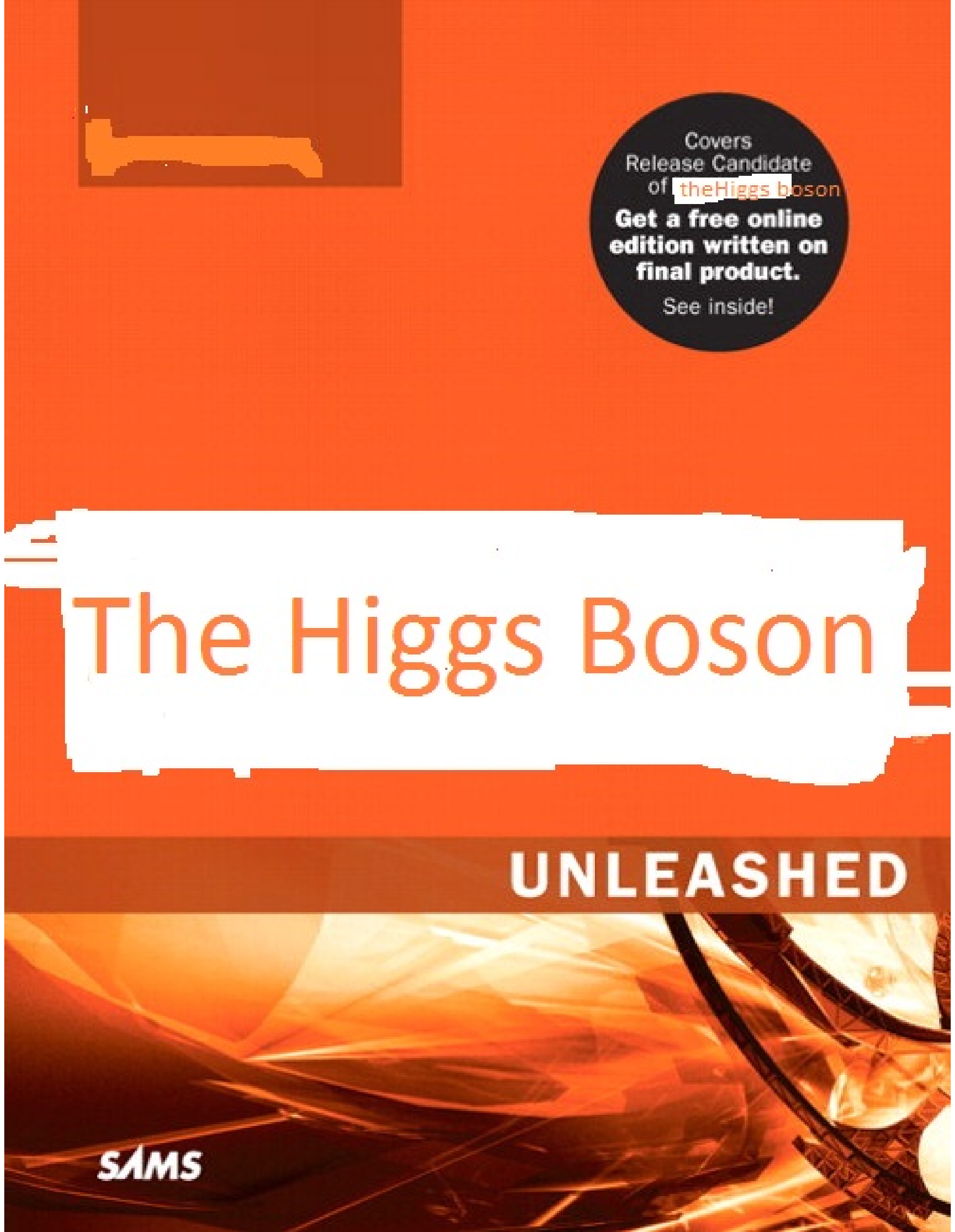
Covers
Release Candidate
of theHiggs boson
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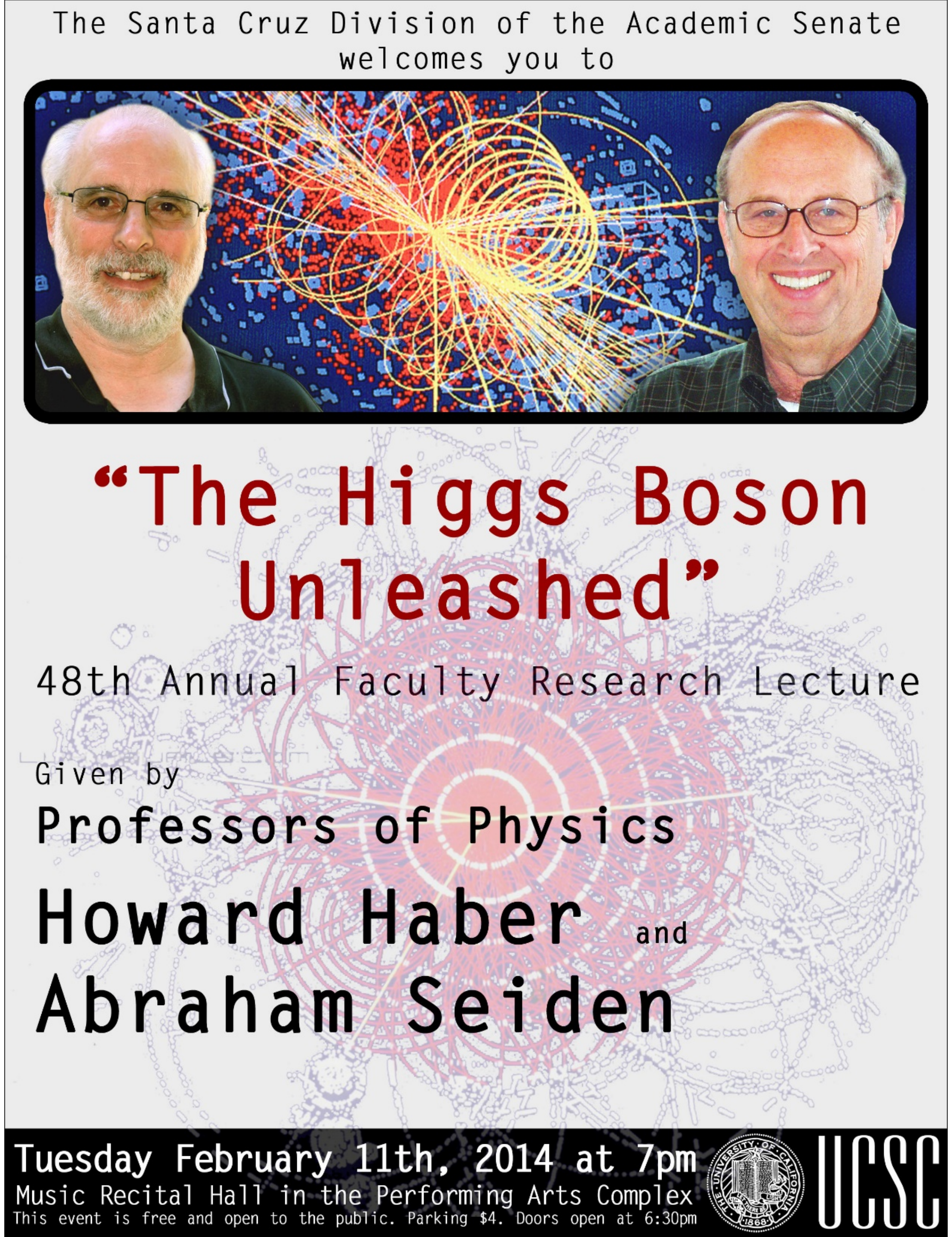
See inside!
The Higgs Boson
UNLEASHED
SAMS


The Santa Cruz Division of the Academic Senate
welcomes you to
“The Higgs Boson
Unleashed”
48th Annual Faculty Research Lecture
Given by
Professors of Physics
Howard Haber and
Abraham Seiden
Tuesday February 11th, 2014 at 7pm
Music Recital Hall in the Performing Arts Complex
This event is free and open to the public. Parking $4. Doors open at 6:30pm
UCSC

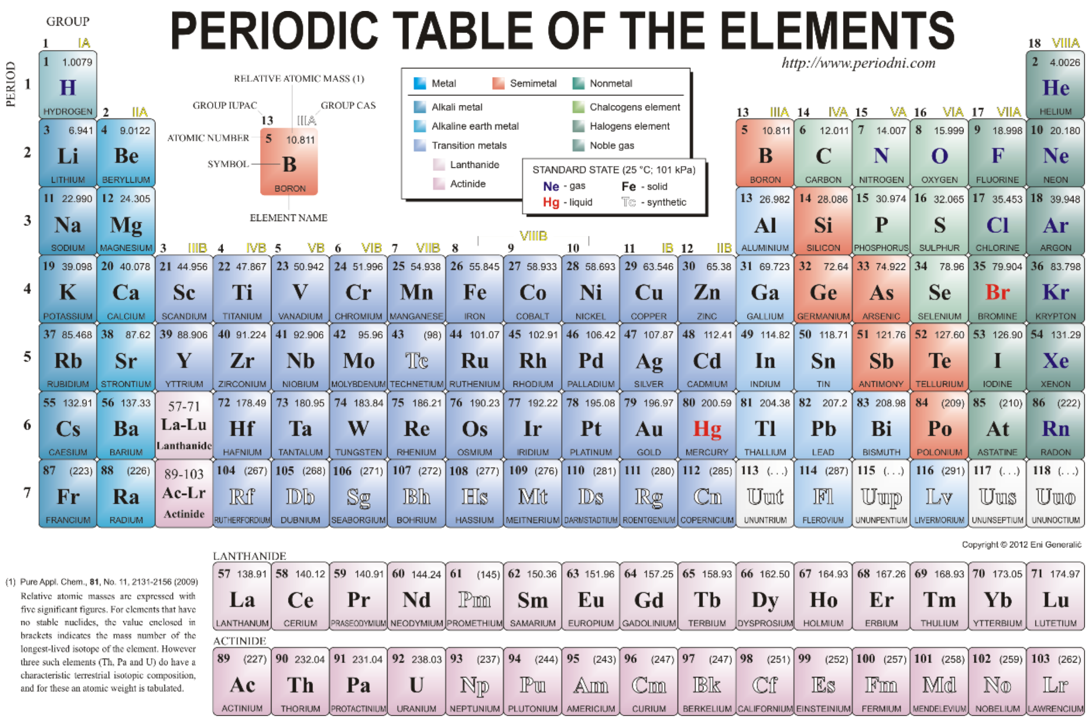
Part I: The Higgs Boson—A Theoretical Journey

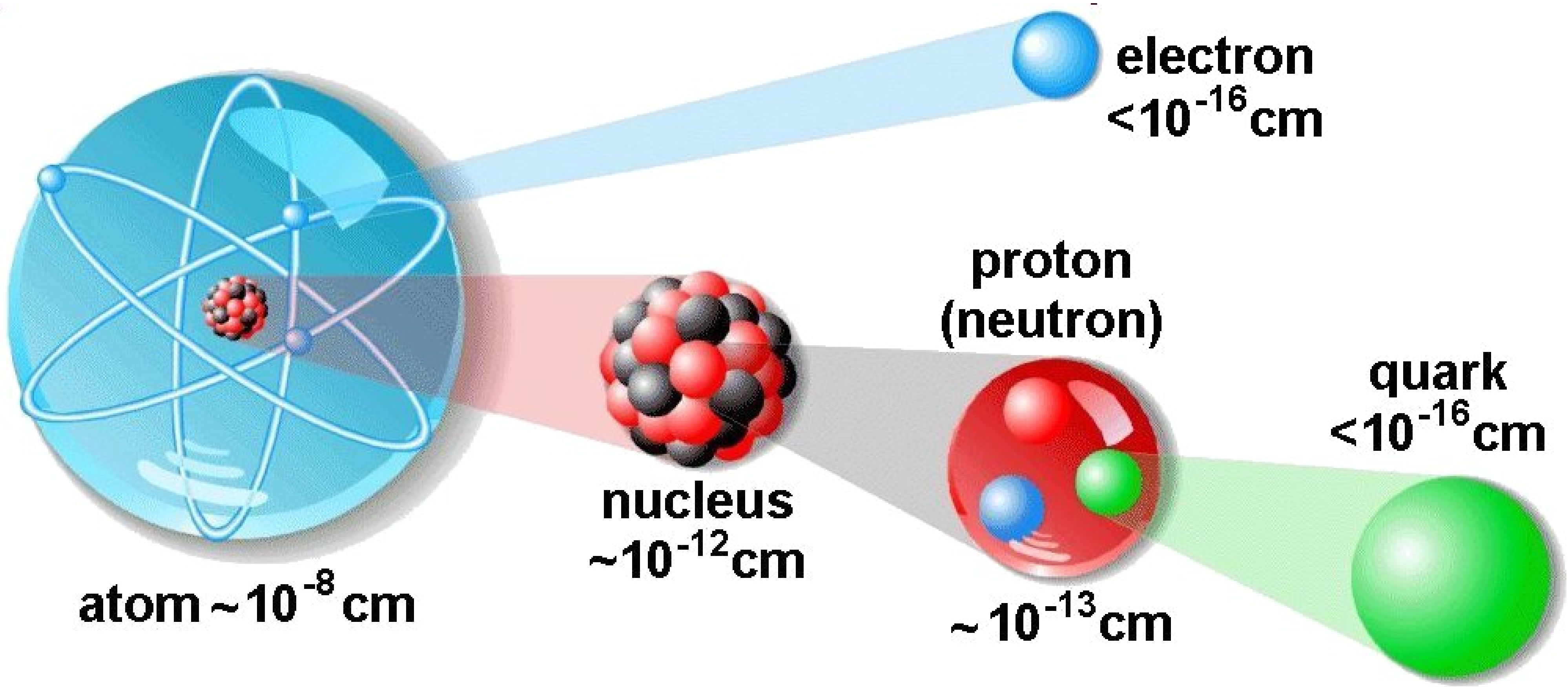
- The search for the fundamental particles and forces of nature
  - Revolutions of 20th century physics: relativity and quantum theory
- Quantum fields and waves/particles
  - A quantum view of the vacuum
- Role of symmetry in physics
- The remarkable Higgs mechanism
  - Generating mass for the fundamental particles
- Introducing the Higgs boson
  - A theorist invents a new fundamental particle
  - Hunting the Higgs boson
- End of an era or a new beginning?

The search for fundamental particles and forces of nature

- More than 25 centuries ago, the Ionian Greeks argued (based on philosophy) that the apparent complexity of the universe could be understood in terms of a few simple underlying laws. Similar developments also occurred in India around the same time period.
- Democritus coined the term *átomos* around the year 450 BC.
- The scientific theory of the atom arose in the 19th century culminating in the periodic table of elements (Mendeleev).
- The final experimental confirmation of the atomic theory only took place in the 20th century.

The discoveries of the 20th century revealed that atoms were not truly fundamental particles but were composed of smaller constituents.



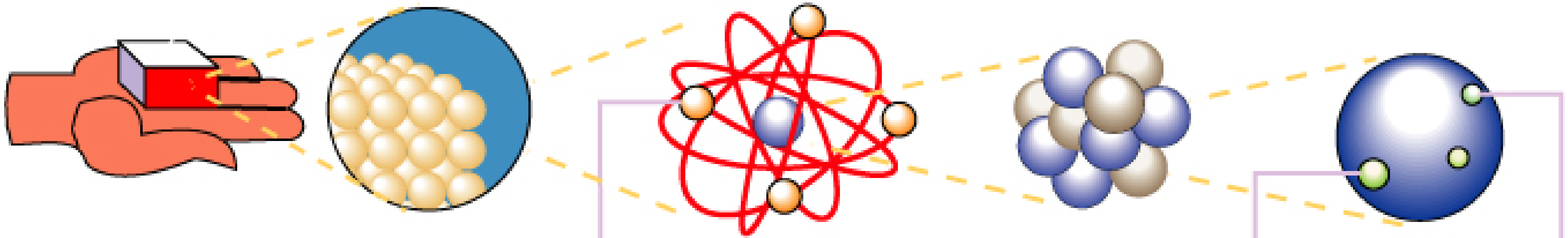

electron
<10^{-16}cm
proton
(neutron)
quark
<10^{-16}cm
nucleus
~10^{-12}cm
atom ~10^{-8} cm
~10^{-13}cm

Quarks

- Invented by theorists Murray Gell-Mann and George Zweig in 1964.
  - At the time of its invention only three types of quarks (u,d,s) were required to describe all known strongly-interacting sub-atomic particles.
- Gell-Mann chose the name "quark" inspired by James Joyce.

Three quarks for Muster Mark!
Sure he has not got much of a bark
And sure any he has it's all beside the mark.
—James Joyce, *Finnegans Wake*

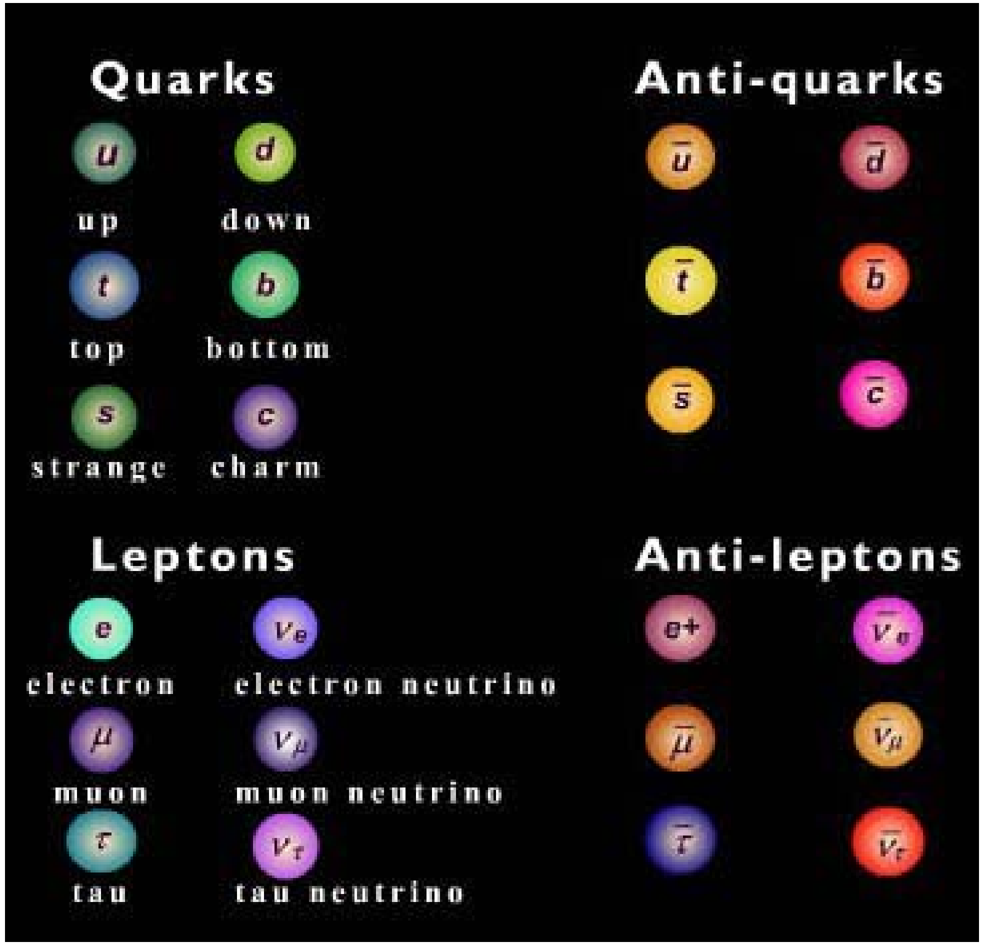
- Although not obviously related to the German cheese product called quark, it is said that there was a German commercial slogan in the 1920s: "Drei Quark für eine Mark."
(Indeed, James Joyce was known for multilingual puns.)



	LEPTONS		QUARKS	
Mass Particles All ordinary particles belong to this group	**Electron** Responsible for electricity and chemical reactions It has a charge of -1 Its anti-particle, the positron,has a charge of +1	**Electron Neutrino** Particle with no electric charge, and possibly no mass. Billions fly through your body every second.	**Up** It has an electric charge of +2/3. Protons contain 2, neutrons contain 1.	**Down** It has an electric charge of -1/3 Protons contain 1, neutrons contain 2.
These particles only existed just after the Big Bang. Now they are found in cosmic rays or produced in scientific laboratories such as CERN.	**Muon** It is heavier than the electron. It lives for two millionths of a second It has a charge of ±1	**Muon Neutrino** Created along with muons when some particles decay. It has no electric charge.	**Charm** Discovered in 1974. It is heavier than the Up. It has a charge of +2/3	**Strange** Discovered in 1963. It is heavier than the Down. It has a charge of -1/3
	Tau Heavier still; it is extremely unstable. It was discovered in 1975. It has a charge of ±1	**Tau Neutrino** Discovered in 2000. It has no electric charge.	**Top** Heavier still. Discovered in 1995. Electric charge +2/3	**Bottom** Heavier still; measuring bottom quarks is an important test of electroweak theory. Discovered in1977. Electric charge -1/3

Anti-particles

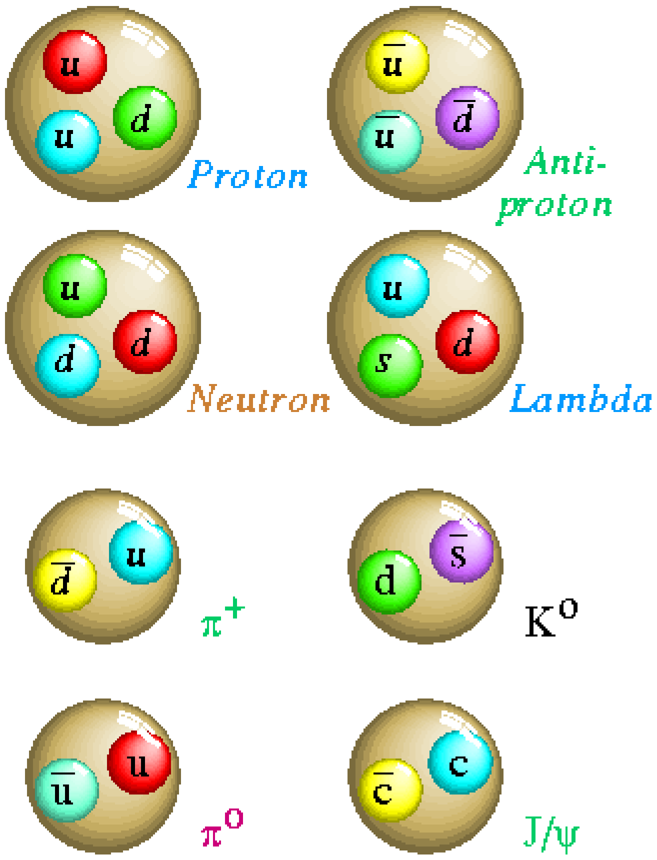
The theoretical physicist Paul Dirac proposed the existence of antimatter in 1928 based on an interpretation of his relativistic quantum theory of the electron. The anti-electron (now called the positron) was subsequently discovered in an experiment by Carl Anderson in 1932.

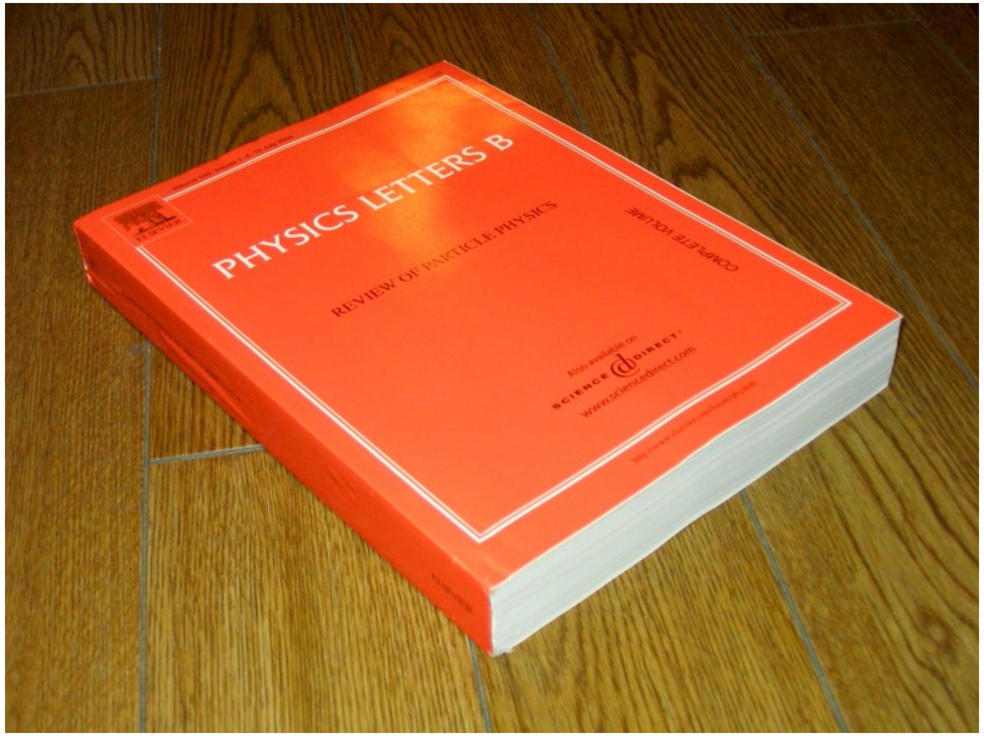


- An anti-particle has the same mass as a particle but has the opposite electric charge.

- An anti-particle that collides with a particle can annihilate it, resulting in pure radiation.

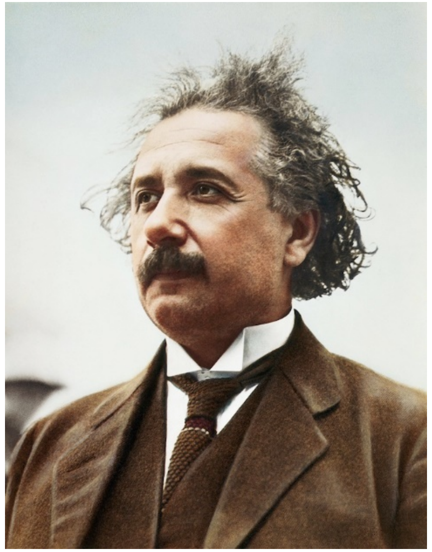
A zoo of new sub-atomic particles





A very thick book (updated every other year) is needed to describe the properties of all the observed sub-atomic particles.

Revolutionary ideas of 20th century physics



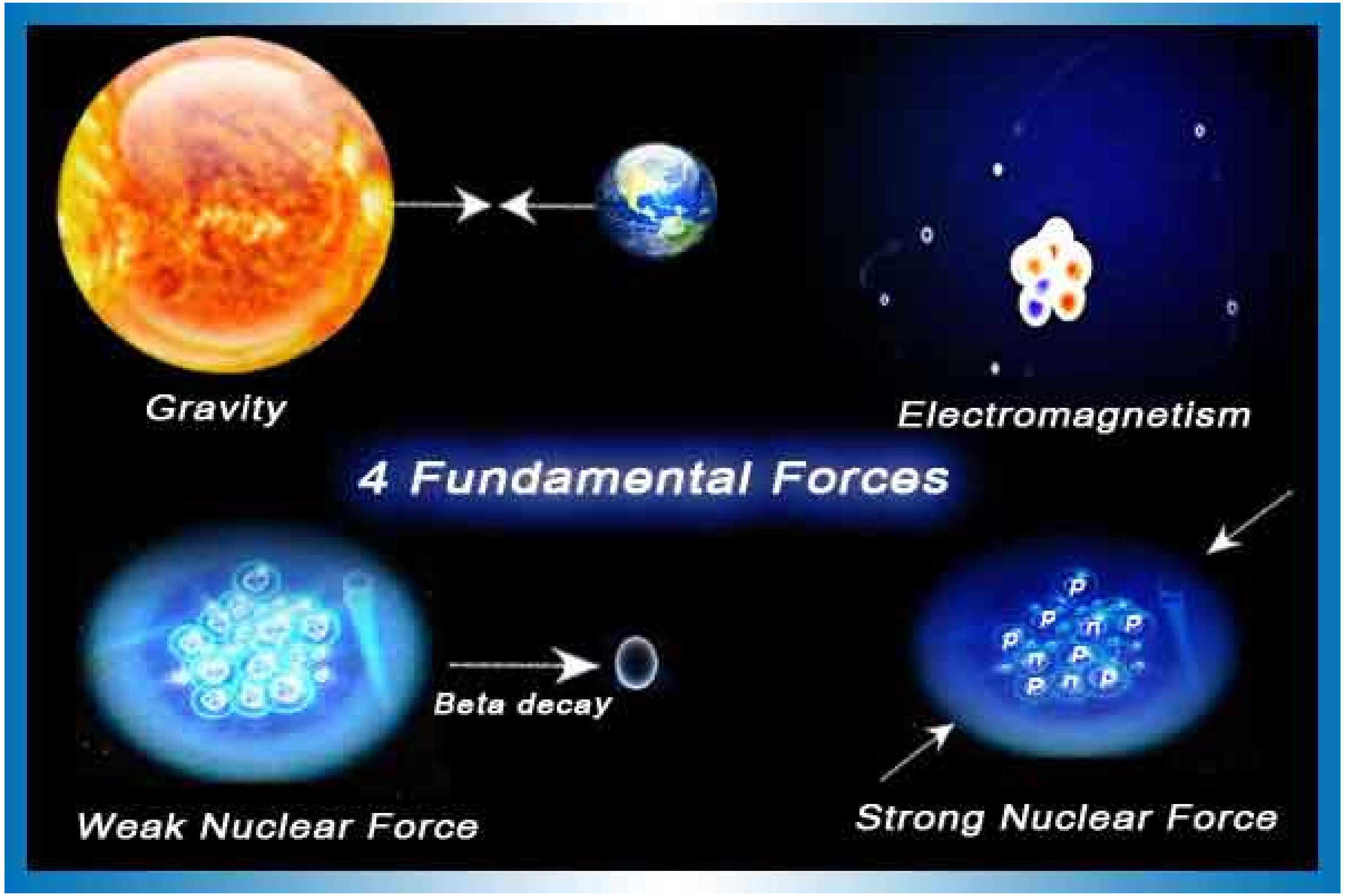
- Relativity (Einstein)
  - The speed of light is the ultimate speed limit.
  - $E=mc^2$ (that is, energy can be converted into matter and vice versa).

- Quantum theory (Heisenberg, Schrodinger, …)
  - Electromagnetic waves come in a smallest unit ("the quantum") with particle properties.
  - A particle can be interpreted as the smallest unit of a wave, and thus can exhibit wave-like properties.
  - Heisenberg's Uncertainty principle allows for quantum "fluctuations".
  - To probe shorter distance scales in the sub-atomic world requires probes of higher energy. Hence the need for more powerful colliders.

The fundamental forces of nature

Isaac Newton introduced the theory of gravity in 1687, which was refined by Einstein in 1915.

Governs nuclear fusion (origin of solar energy) and certain radioactive decays (e.g., $n \to p\, e^-\, \bar{\nu}_e$).



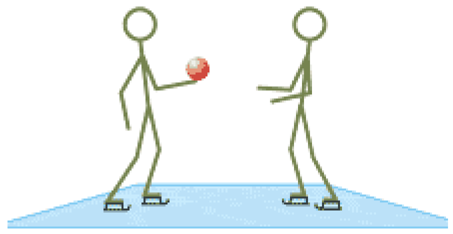
Electric and magnetic forces were unified by electromagnetic theory of James Clerk Maxwell in 1865.

Responsible for holding the atomic nucleus together.

A puzzle in beta decay led Wolfgang Pauli in 1930 to invent a new particle—the neutrino, a particle that interacted so weakly that it took 26 years to discover it in the laboratory.

How are fundamental forces transmitted?

- Forces cannot be transmitted instantaneously (Einstein's relativity).
- Quantum mechanics and relativity provide a consistent framework for the mechanism of transmission of forces (through "virtual particle exchange").

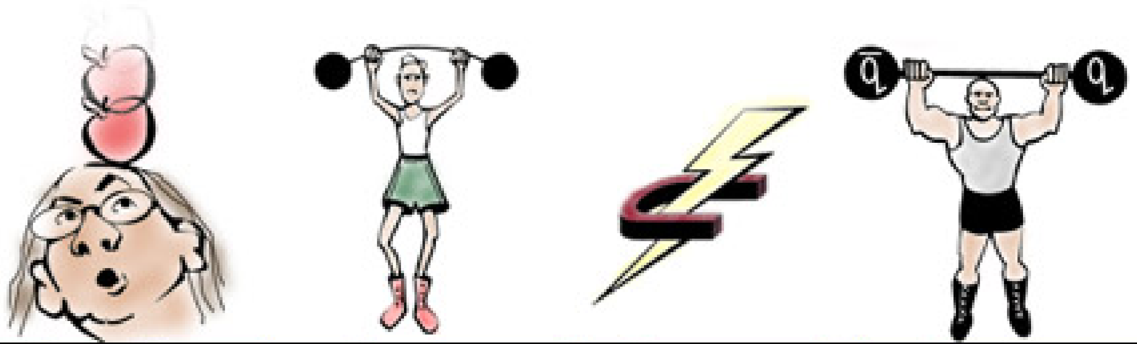


The ice skaters metaphor

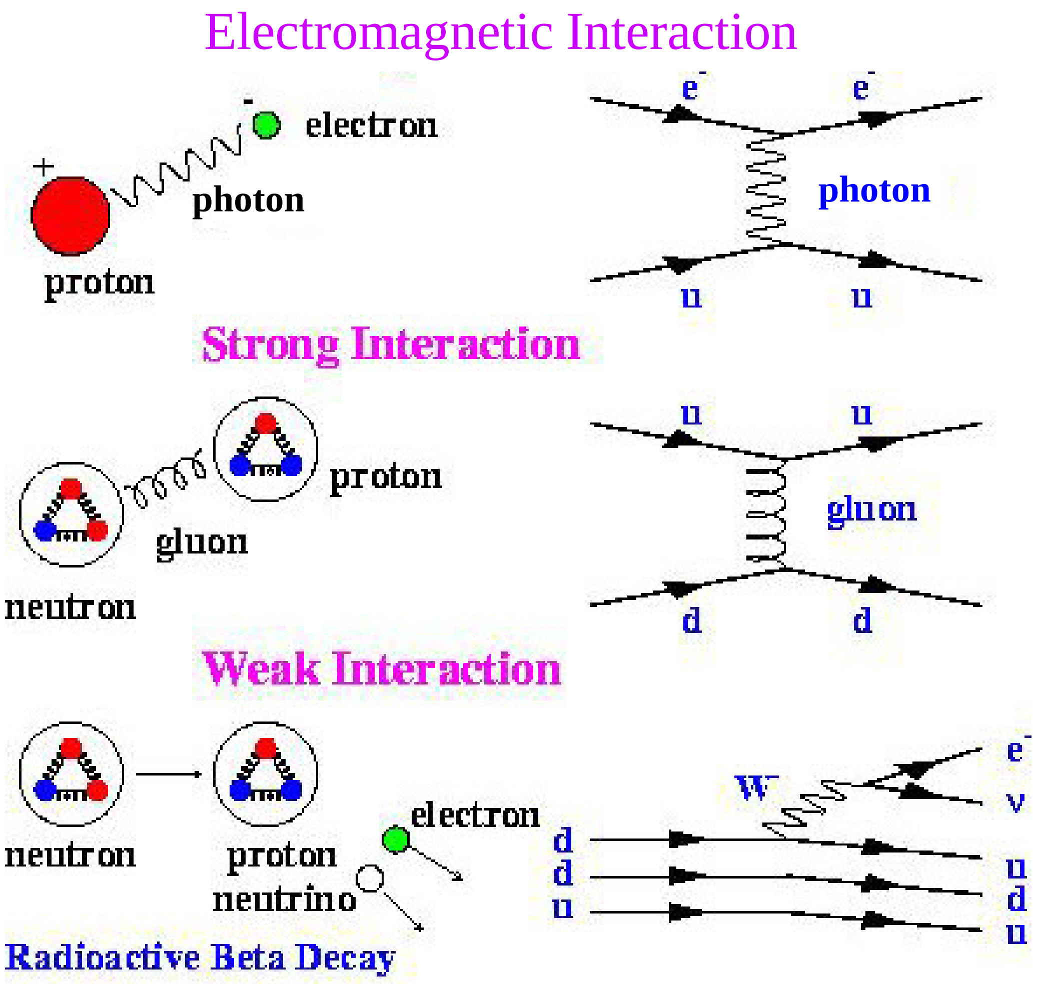
Electromagnetic repulsion of two electrons (via exchange of a photon)

- Each of the four fundamental forces are mediated by particles (quanta of radiation).

The fundamental forces in action (represented in Feynman diagrams)



	Gravity	Weak (Electroweak)	Electromagnetic (Electroweak)	Strong
Carried By	Graviton (not yet observed)	W^+ W^- Z^0	Photon	Gluon
Acts on	All	Quarks and Leptons	Quarks and Charged Leptons and W^+ W^-	Quarks and Gluons



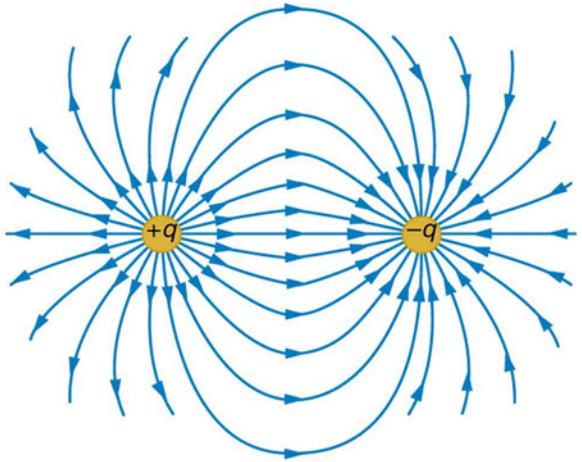
The gravitational force between two quarks inside the proton is utterly negligible (roughly 10^{-41} relative to the electromagnetic force).

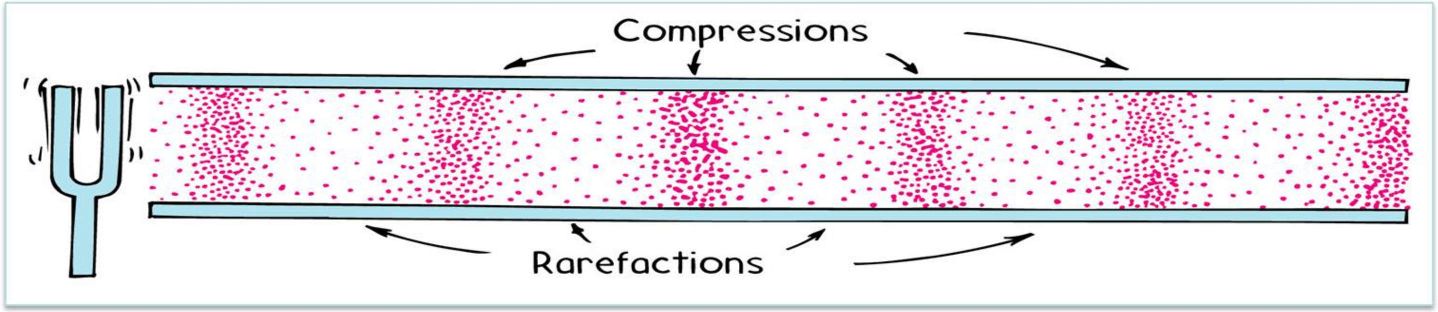
Thus, we focus only on the other three forces, which have significant effects on sub-atomic phenomena.

An aside: fields and waves

- A field is a quantity that varies over space and time.

  Example: the electric force field due to a pair of charges (of opposite sign). The arrow indicates the force experienced at a given point in space by a positive test charge.



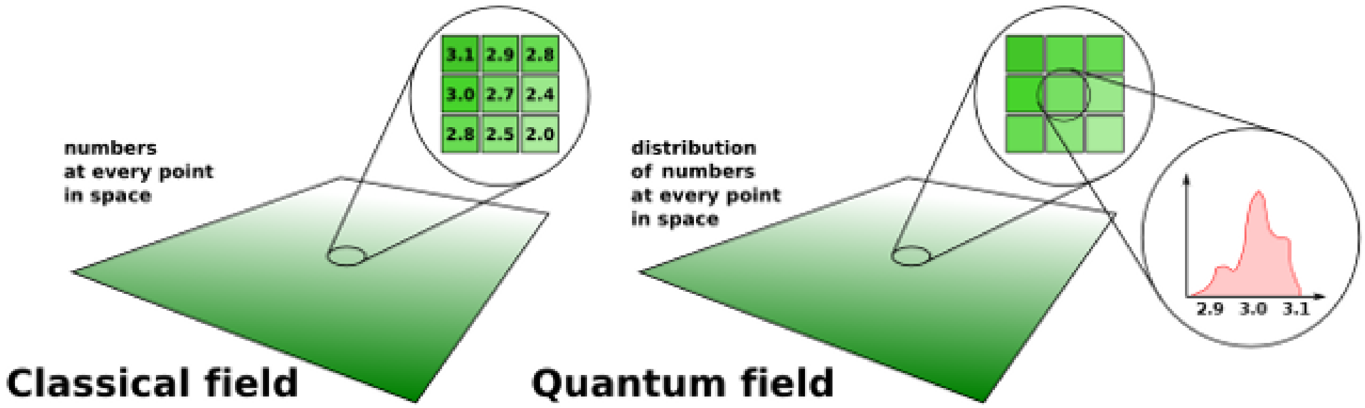


- A disturbance can propagate from one point to another. For example, consider a field that consists of the air density at any point in space. A sound wave corresponds to a periodic variation of the density field along the direction of propagation.

Quantum fields and waves/particles

- The unification of quantum mechanics and Einstein relativity led to the development of quantum field theory, which describes the behavior of the fundamental fields and forces (excluding gravity).

- For each fundamental particle, there is an associated quantum field. Disturbing that quantum field creates a wave. The minimal disturbance (one "quantum") has particle-like properties.

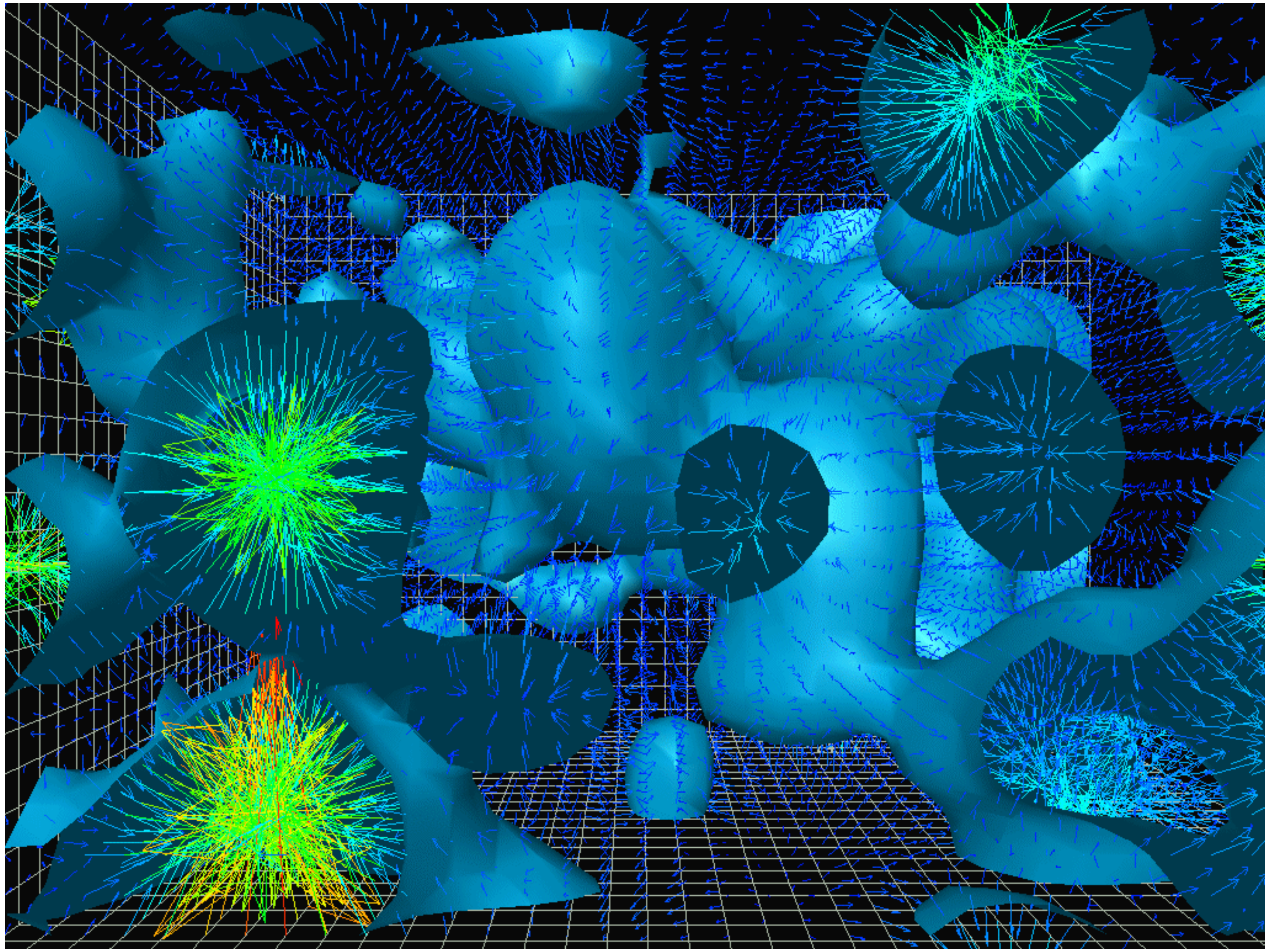


The quantum vacuum

In classical physics, the vacuum is the lowest energy state possible—complete emptiness.

In quantum physics, random quantum field oscillations fluctuate in and out of existence within the lowest energy state of the quantum vacuum.

Pumping energy into the quantum vacuum can excite the quantum fields of the vacuum thereby creating particles.



Field values can be positive or negative—on average they cancel out.

What are the characteristics of a fundamental particle?

- Point-like (no discernable size)
- Mass
- Spin
- Charge (electric, weak, strong)

The Earth spins (i.e. rotates about its own axis once every 24 hours). But how does a point-like object spin? This is purely a quantum mechanical effect (and should not be viewed as a physical spinning process). The spin is an intrinsic property of the particle (like mass and charge). Quantum mechanics dictates that the only allowed values of the spin (in appropriate units) are n/2, where n=0,1,2,3,4,…. Particles with even n and odd n behave quite differently in quantum mechanics, and thus are given special names.

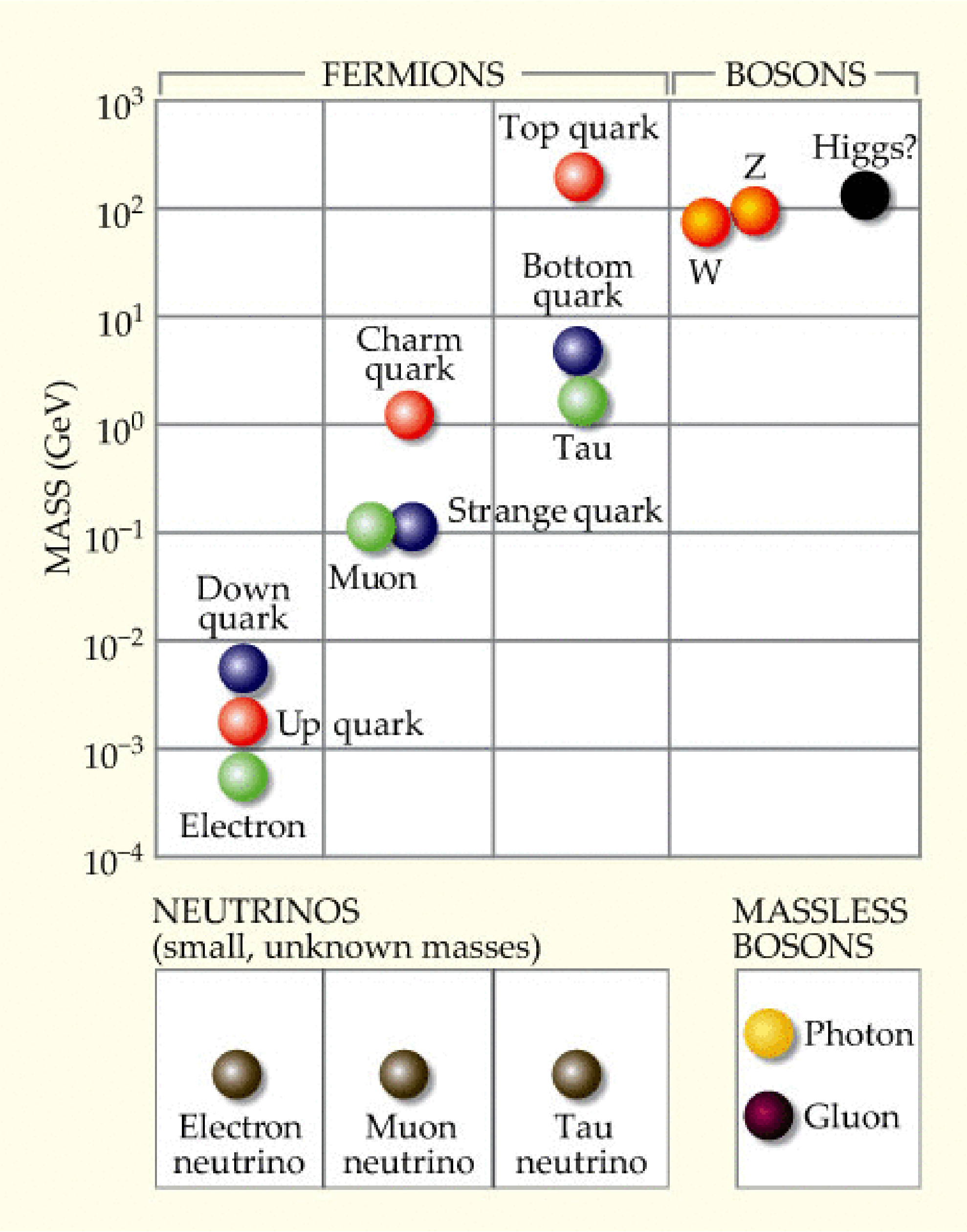
Fermions (n odd): examples—the quarks and leptons have spin ½.
Bosons (n even): examples—the photon, gluon, W^+, W^- and Z all have spin 1; the graviton has spin 2.

The mass puzzle

- ➢ What is the origin of the masses of the fundamental particles?

The Standard Model of Particle Physics based on the principles of relativity and quantum mechanics has been remarkably successful in describing sub-atomic phenomena.

Nevertheless, a naïve implementation of this theory seemed to imply that all the fundamental particles should be massless. In contrast, the W^+, W^- and Z bosons, which mediate the weak interactions, are roughly 100 times heavier than a proton.



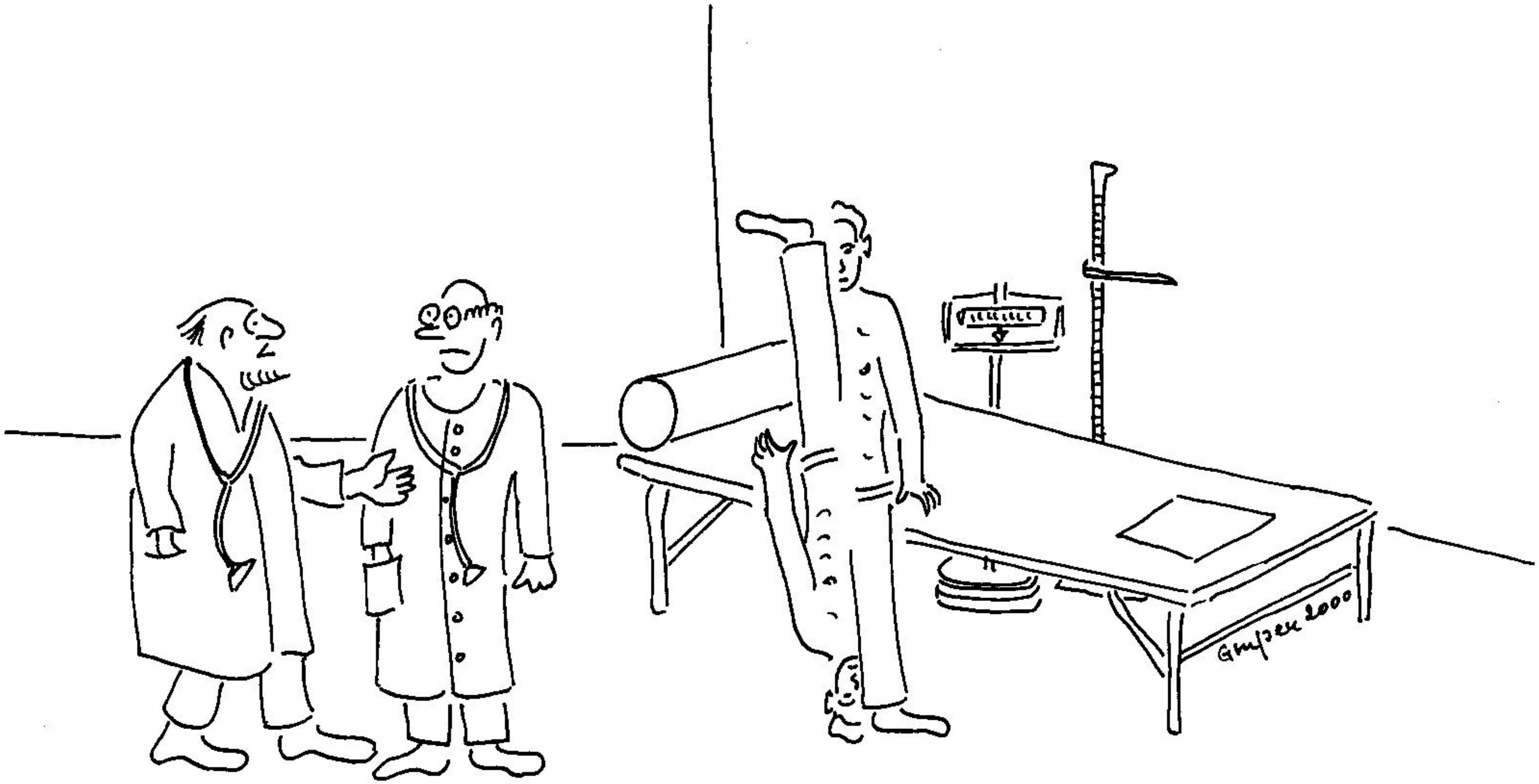
The beauty of symmetry

The role of symmetry in physics

In physics, symmetry plays a very important role. For example, the fact that the laws of physics do not depend on location or orientation ("translational and rotational invariance") places strong constraints on the form of the equations that describe those physical laws.

A more abstract symmetry principle underlies the laws of electromagnetism. This symmetry principle guarantee that the photon is massless. A similar application of this symmetry principle would predict that the W^+, W^- and Z bosons that mediate the weak force should also be massless.

However, if you naively try to "break the symmetry" to allow for massive W^+, W^- and Z bosons, the resulting theory is mathematically inconsistent.



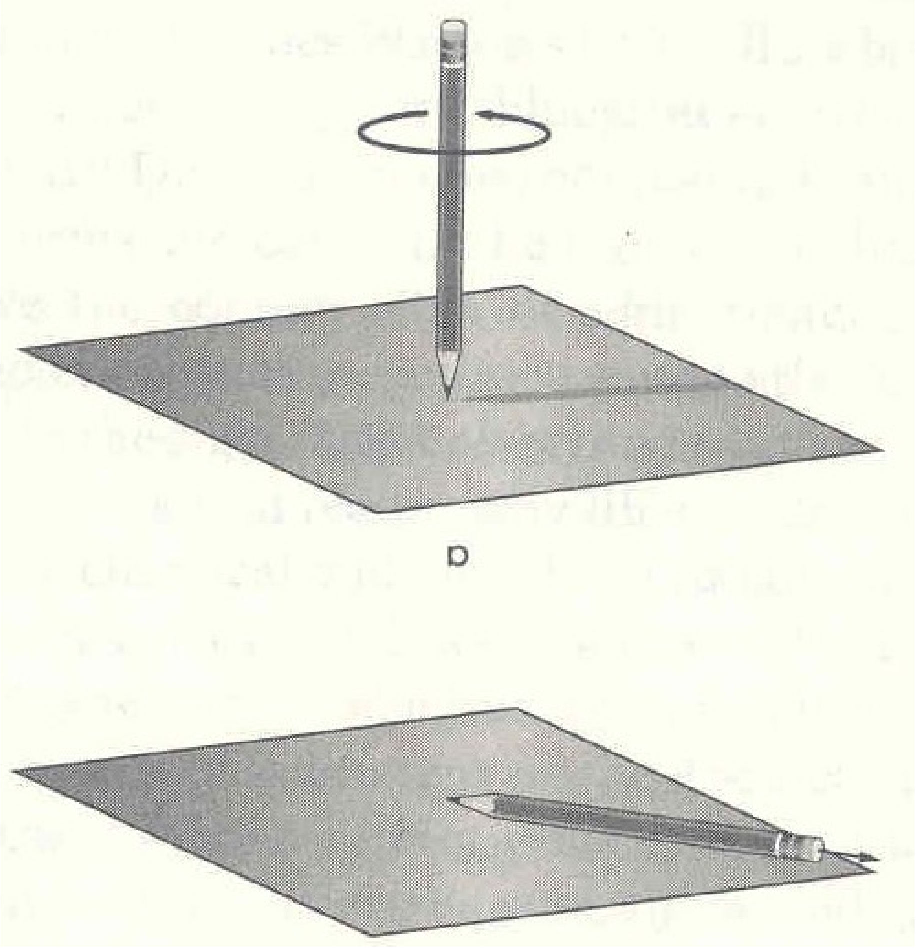
“A severe case of symmetry breaking!”

Symmetry-breaking without breaking the symmetry

- The rotational symmetry of the pencil around its axis implies that the pencil is equally likely to fall in any direction.

- However, perform the experiment once, and the pencil must fall in some direction.

- The resulting state of the pencil breaks the rotational symmetry, although the rotational symmetry of the laws that govern the falling pencil remain intact.



The remarkable Higgs mechanism

- Key ingredients by Yoichiro Nambu and Philip Anderson.
- Adapted to relativistic quantum field theory in 1964 by Robert Brout and Francois Englert and independently by Peter Higgs. Important clarifications by Gerald Guralnik, Carl Hagen and Tom Kibble followed.
- The history is wonderfully told by Frank Close in *The Infinity Puzzle*.

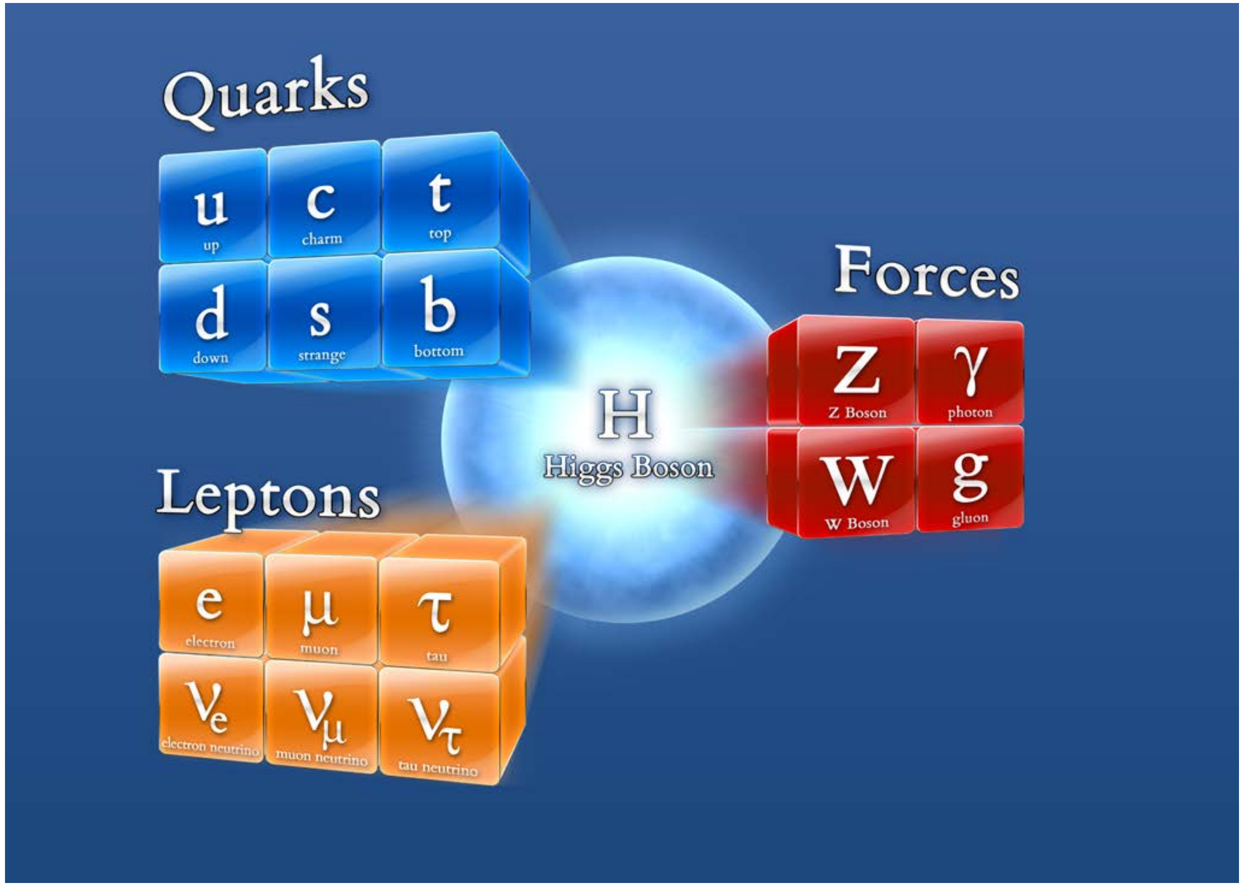
The essential idea: Postulate the existence of a spinless quantum field, now called the Higgs field, which (in average) is non-zero in the quantum vacuum. In contrast, other quantum fields (which have nonzero spin) that fluctuate in the quantum vacuum still must average out to zero.

The physical laws which govern the Higgs field respect the symmetry that require massless W^+, W^- and Z bosons. However, like the fallen pencil, the vacuum state of the Higgs field breaks the symmetry. Since the W^+, W^- and Z reside in the symmetry-broken Higgs vacuum, their masses need not be zero.

The Standard Model of Particle Physics

- The Higgs mechanism provides the only known mathematically consistent formulation of the theory of fundamental particles that accounts for their masses.

- The simplest implementation of the Higgs mechanism (due to Steve Weinberg in 1967 1967 and Abdus Salam in 1968) incorporates a new spin-0 (scalar) particle called the Higgs boson.



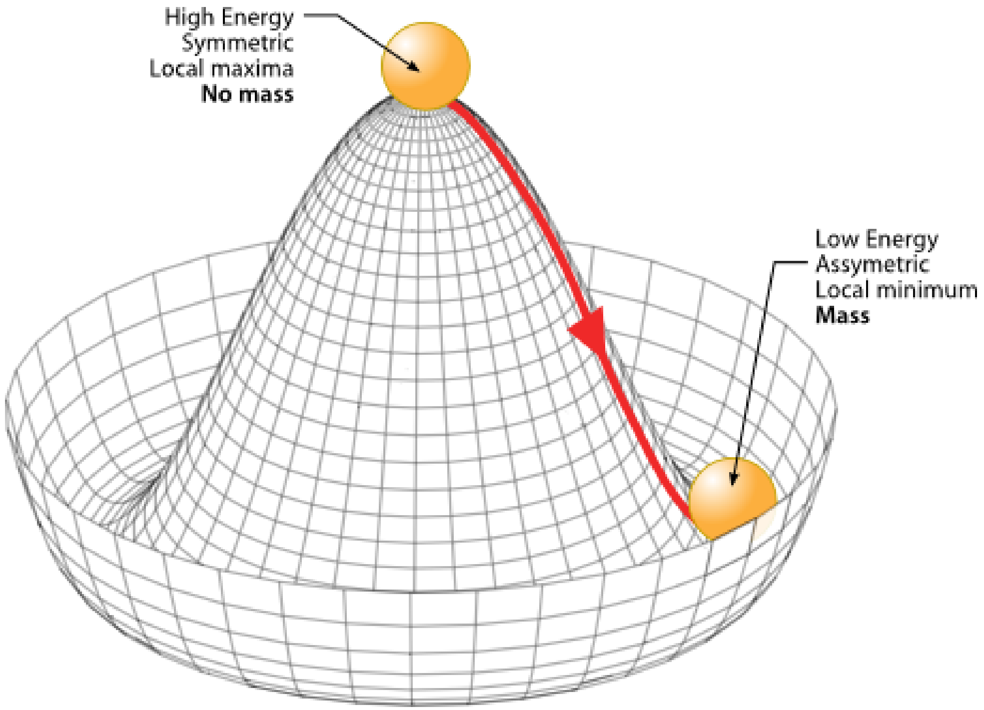
The Higgs boson is a result of disturbing the Higgs field. The theoretical existence of such a particle (in the context of the Higgs mechanism) was first proposed by Peter Higgs in 1964.

Generating mass for the fundamental particles

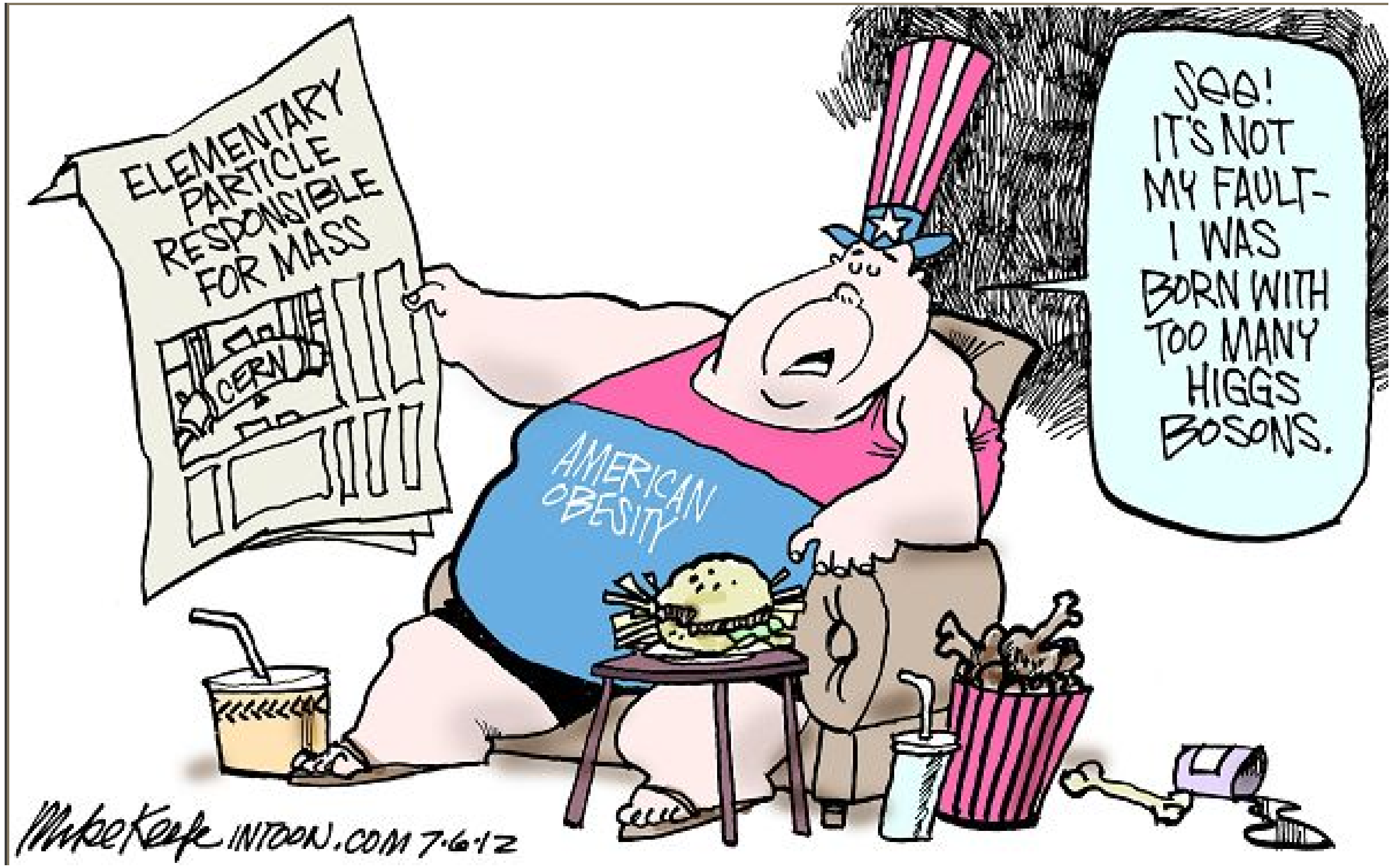
- In the Standard Model, the abstract symmetry that governs the weak and electromagnetic interactions (called the electroweak symmetry) governs the dynamics of the quarks, leptons and Higgs fields.

- The symmetric point of the Higgs field is at a Higgs field configuration of higher energy than the vacuum state. Thus, in the vacuum, the Higgs field breaks the electroweak symmetry.

- As a result, all Standard Model particles propagating through the vacuum that interact with the omnipresent Higgs field acquire their observed masses.



A video made by Phil Owen (not to be taken literally, but the graphics are cool!)



Warning: Most of your mass does not come from the Higgs mechanism. Your mass arises from the protons and neutrons contained in the atoms of your body. Most of this mass arises from the "binding energy" involved in constructing the proton and neutrons from their constituent quarks (and gluons).

The hunt for the Higgs boson begins

- By the end of the 1970s, the Standard Model was firmly established as the theory of the strong and electroweak interactions. Further experimental confirmation followed with the discovery of the W^+, W^- and Z in 1983 and the top quark in 1995. All that was missing was the Higgs boson.

- The Standard Model predicts all the properties of the Higgs boson except for its mass, which is a free parameter. Thus, one had to devise experimental searches that would apply for all possible masses accessible to your collider.

- If the Higgs boson did not turn up in your experiment, then perhaps your collider was not energetic enough to produce it (remember $E=mc^2$). Time to design a higher energy collider and continue the search.

1976: The first comprehensive study of how to search for the Higgs boson

Nuclear Physics B106 (1976) 292–340

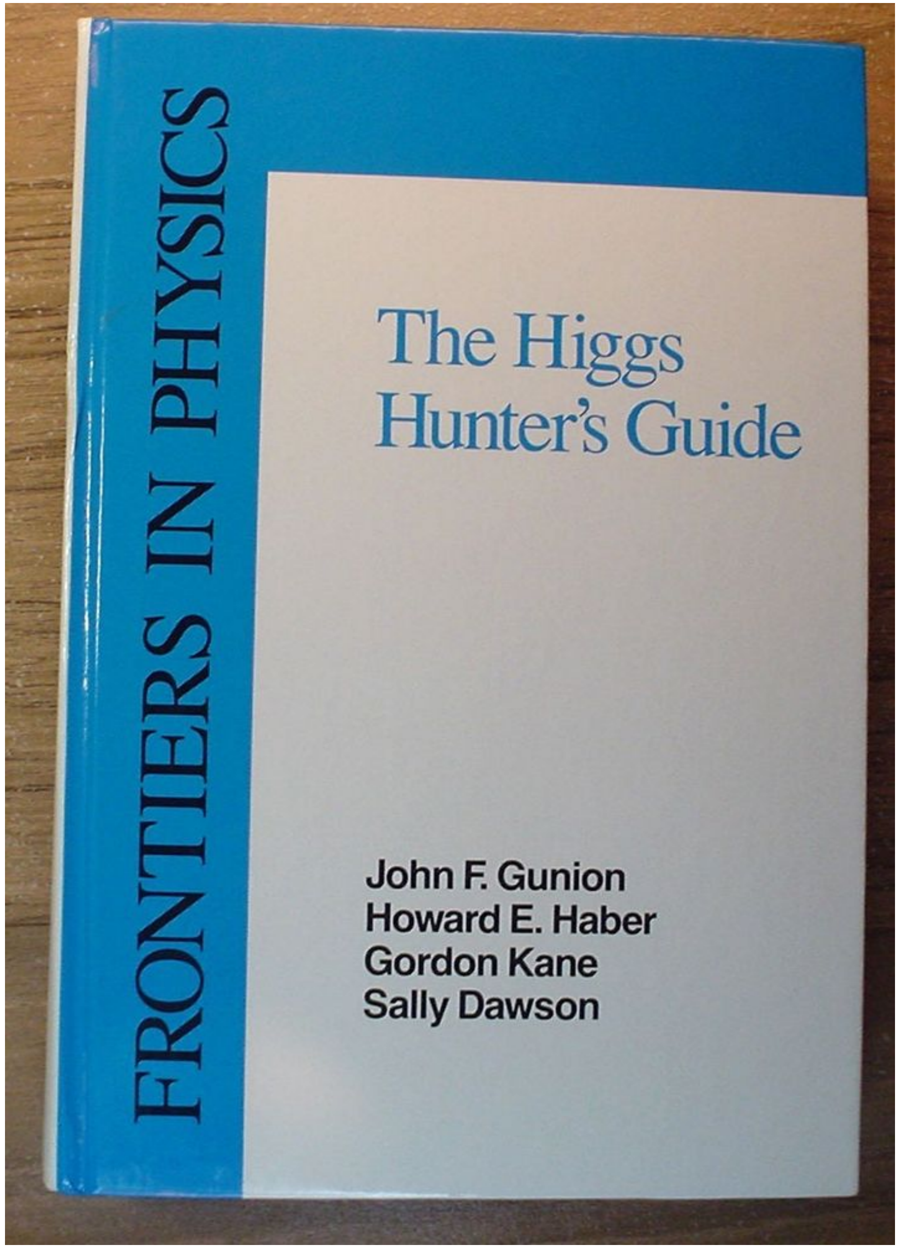
A PHENOMENOLOGICAL PROFILE OF THE HIGGS BOSON

John ELLIS, Mary K. GAILLARD * and D.V. NANOPOULOS **
CERN, Geneva

Received 7 November 1975

A discussion is given of the production, decay and observability of the scalar Higgs boson H expected in gauge theories of the weak and electromagnetic interactions such as the Weinberg-Salam model. After reviewing previous experimental limits on the mass of

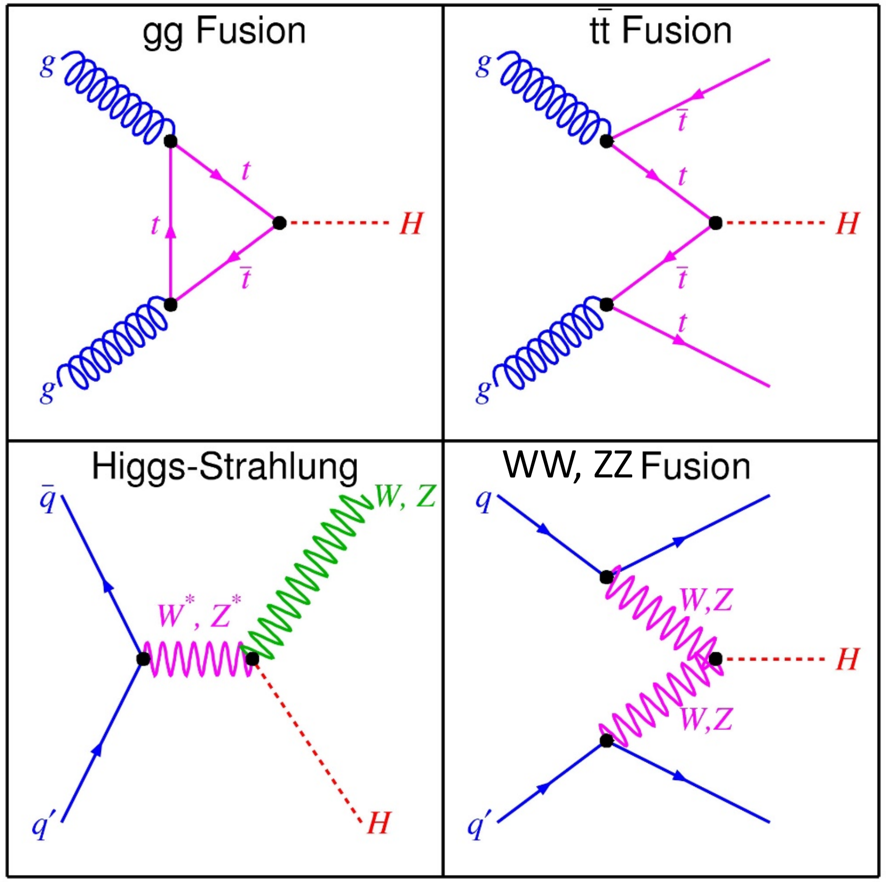
We should perhaps finish with an apology and a caution. We apologize to experimentalists for having no idea what is the mass of the Higgs boson, unlike the case with charm [3,4] and for not being sure of its couplings to other particles, except that they are probably all very small. For these reasons we do not want to encourage big experimental searches for the Higgs boson, but we do feel that people performing experiments vulnerable to the Higgs boson should know how it may turn up.



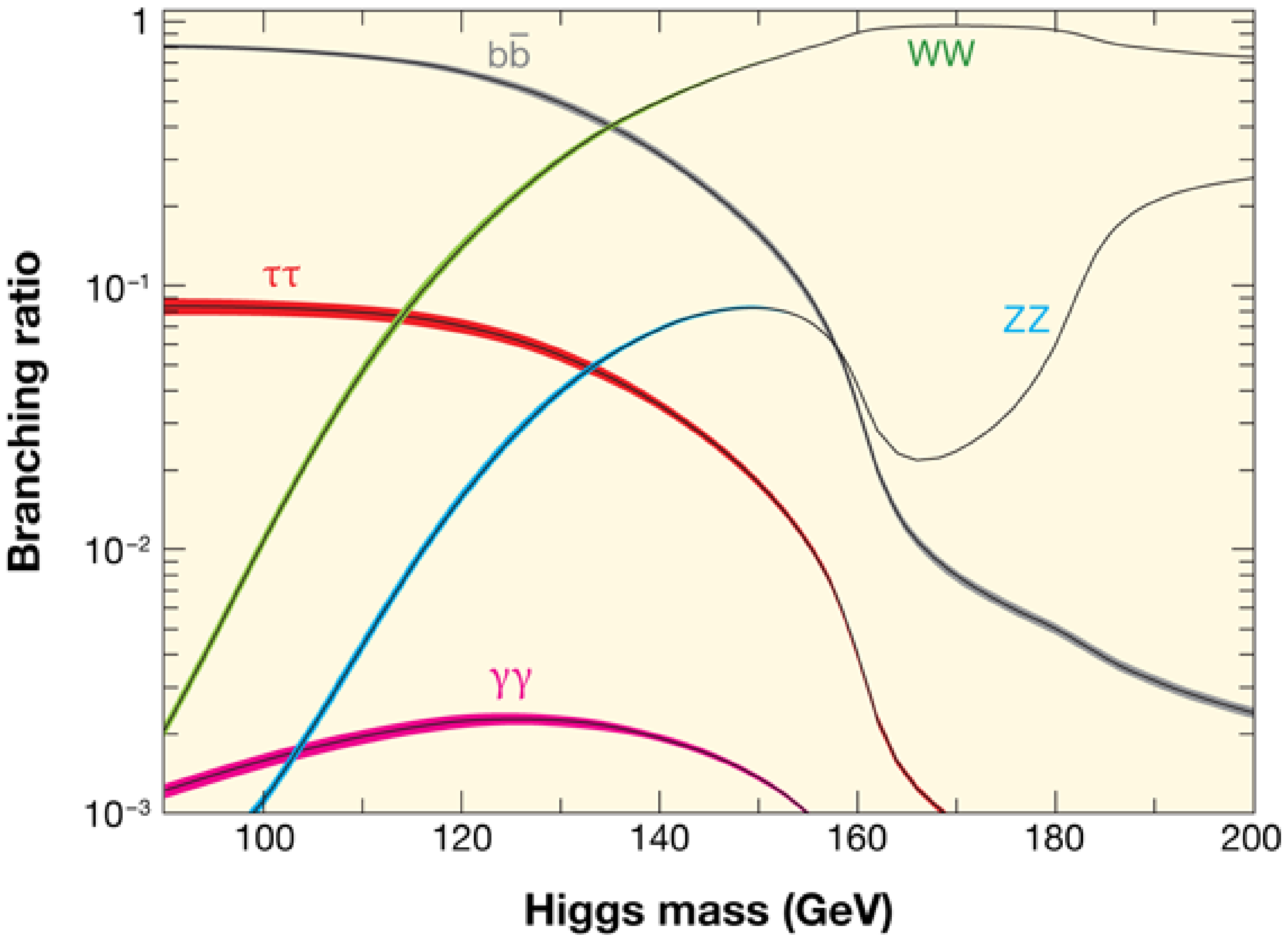
In 1990, the Higgs Hunter's Guide was published. It served as the definitive reference, guiding both theorists and experimentalists as the Higgs boson search was extended to more powerful colliders.

At the Symposium on Higgs Boson Physics in Ann Arbor, MI (May, 2010)

When two protons collide at the Large Hadron Collider, the violent collision of the quark (q) and/or gluon (g) constituents of the two protons can sometimes generate enough energy to create a Higgs boson (H), along with other particles.



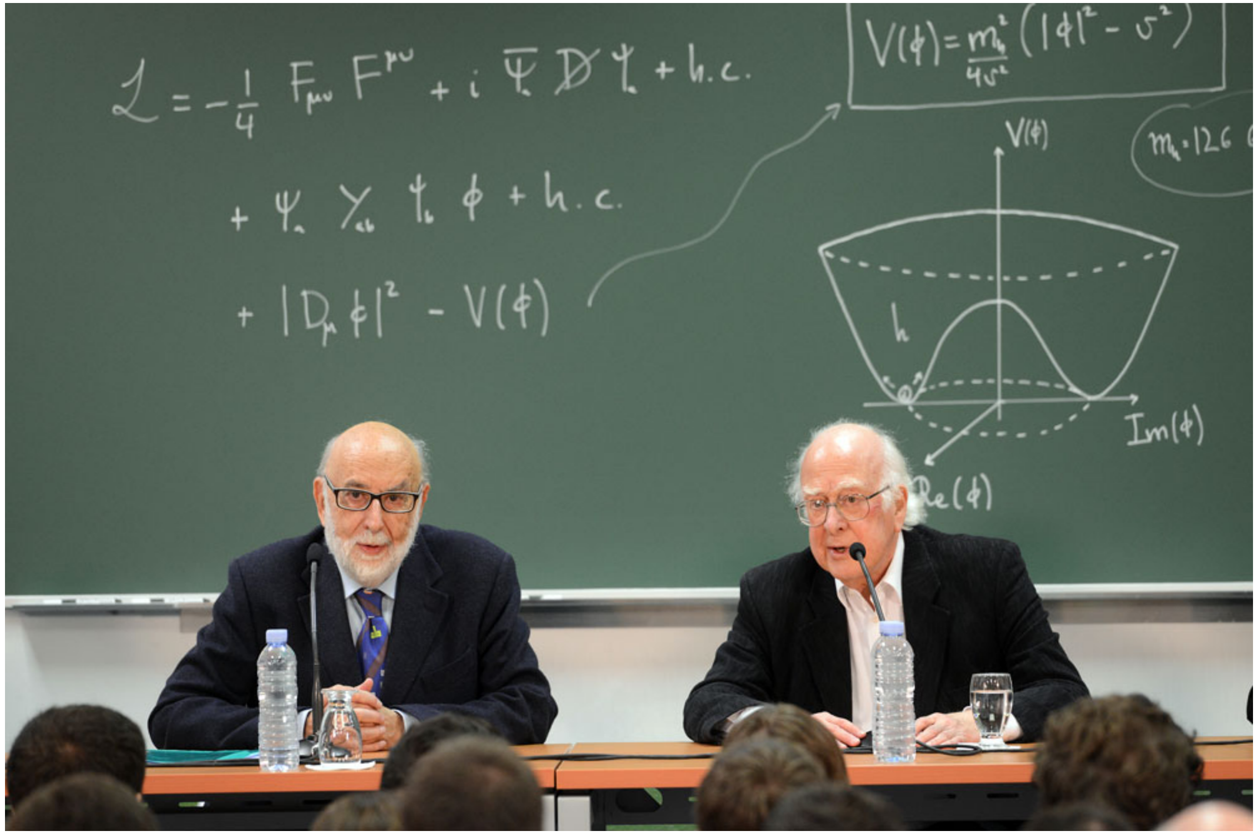
Probability for a Higgs boson decay into various final states as a function of its mass



The Discovery of the Higgs boson is announced on July 4, 2012

The CERN update of the search for the Higgs boson, simulcast at ICHEP-2012 in Melbourne, Australia

Winners of the 2013
Nobel Prize in Physics



François Englert

and

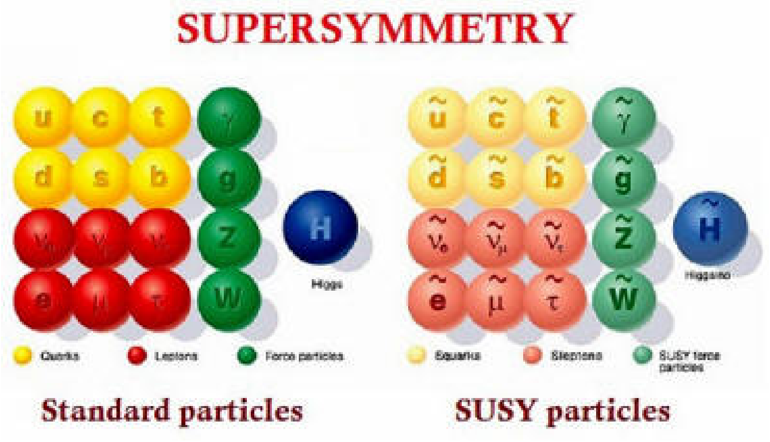
Peter Higgs

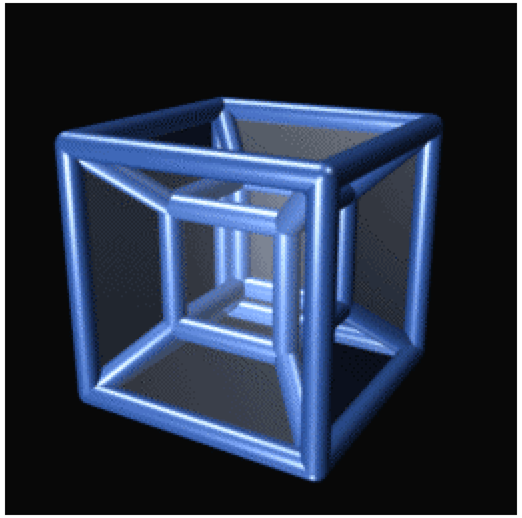
End of an era or a new beginning?

➢ The discovery of the Higgs boson is remarkable in another sense. Just like the photon and its friends, the Higgs boson mediates a fundamental force. That is, a new (fifth) fundamental force of nature has been discovered!!

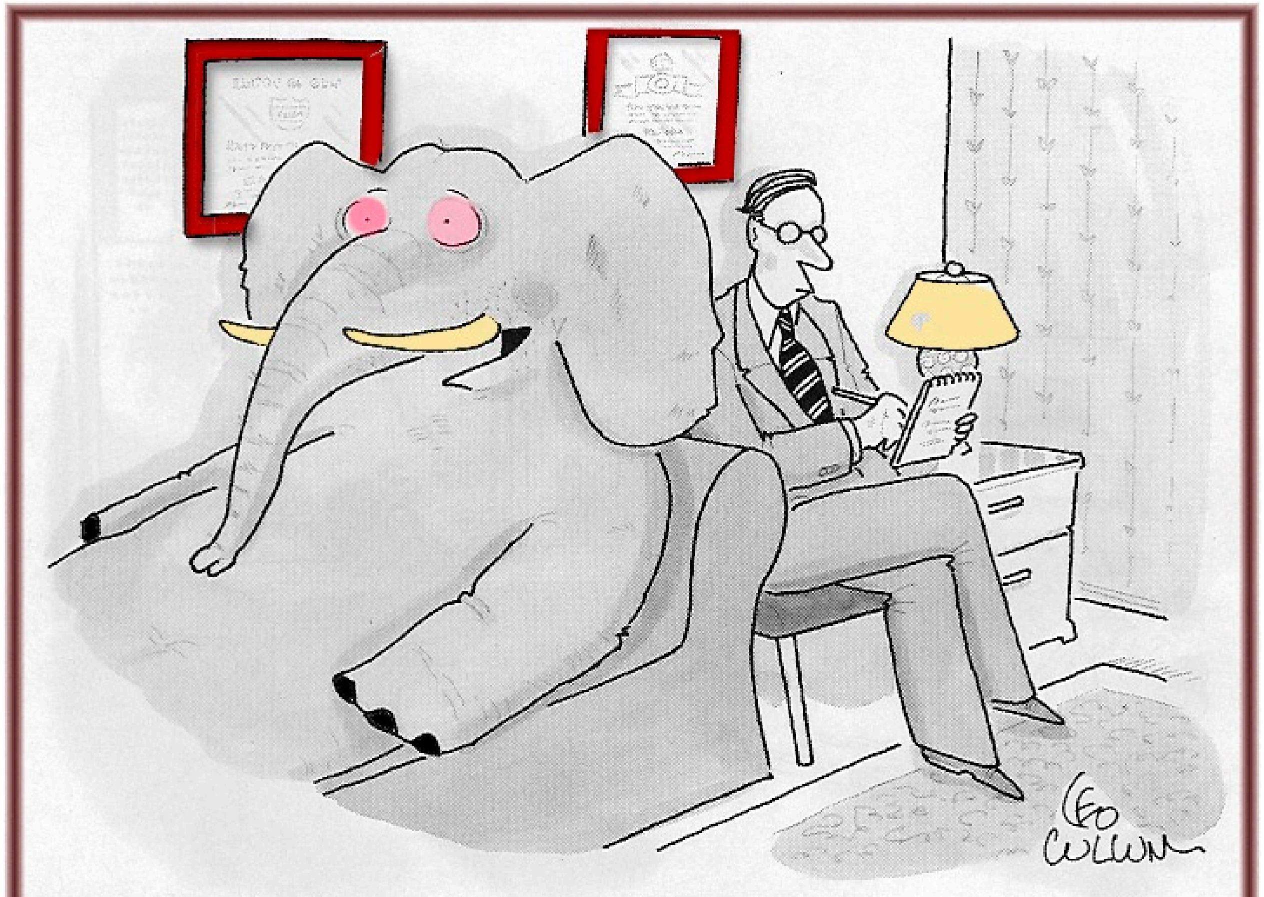
➢ The discovery of the Higgs boson finally completes the Standard Model of particle physics. Or does it??

- The Higgs boson mass is not really a consequence of the Higgs mechanism. So how does one account for the origin of the Higgs boson mass? This turns out to be a profound question, whose answer may require new exotic phenomena (supersymmetry? extra dimensions?), which if we are lucky could turn up at the Large Hadron Collider.





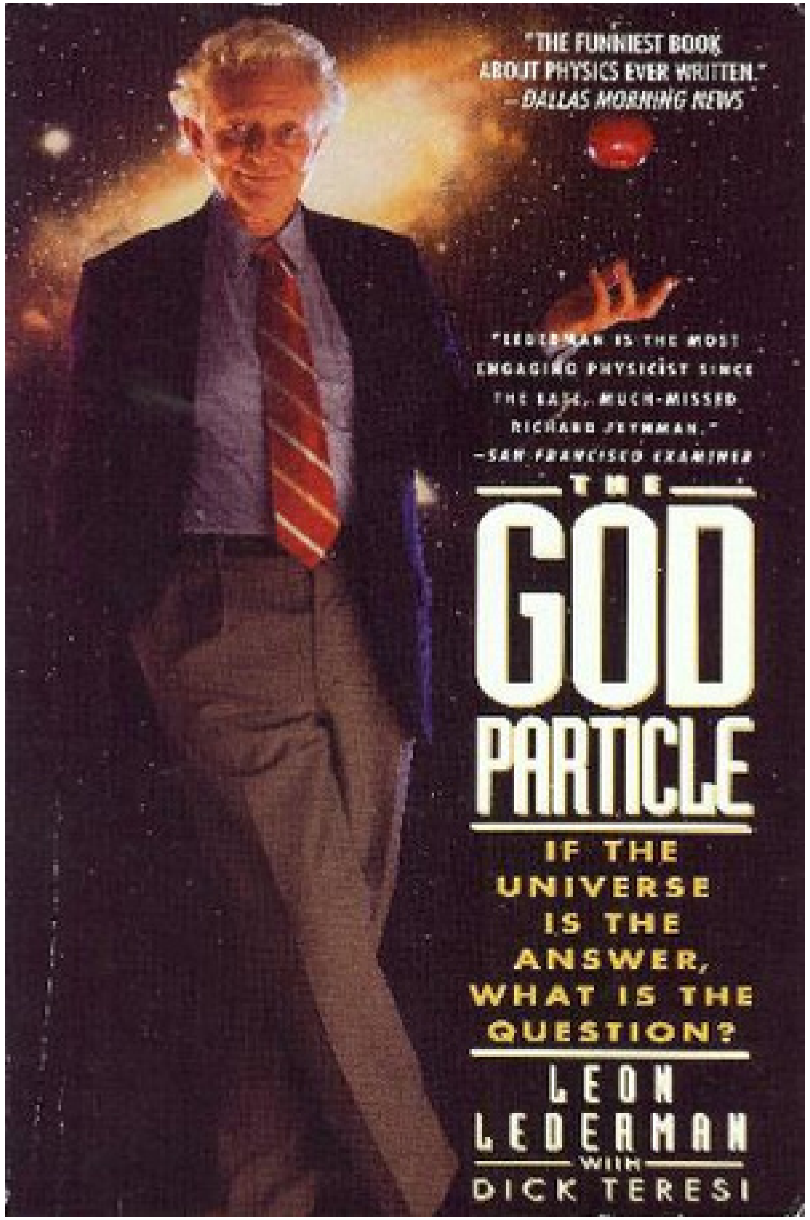
Before handing the baton over to Abe Seiden, I have to admit that there is an elephant in the room. I have been trying to avoid it, but someone is bound to ask…



"I'm right there in the room, and no one even acknowledges me."

The New Yorker, 9/18/06

This goes way beyond *Angels and Demons*. This phrase caught the fancy of the popular press. We have Leon Lederman's editor to thank (he thought it would sell more books).



Leon Lederman shared the 1988 Nobel prize for Physics for the discovery of the mu-neutrino. He also led the experimental team that discovered the b quark and served for many years as the director of Fermilab.
He published *The God Particle* in 1993.

Standard reactions of physicists when the God particle is mentioned

Angels and Demons at CERN. But will there be a Higgs boson?

Part II: Hunting the Higgs Boson!

Importance of Particle Masses

Particle masses and interaction strengths determine much of the behavior of our world. For example the mass of the electron and the value of its electric charge determine the size of atoms and binding energies in atoms and molecules. The small difference in mass between the neutron and proton, combined with the very heavy mass of the particles responsible for the weak nuclear force, control many aspects of how the sun works, allowing it to shine very slowly, so that it shines for billions of years.

But how does the mass come about? The idea, presented in a series of papers in 1964, is that the fundamental particle masses are due to an interaction with a field (now called the Higgs field) that fills all of space.

Everywhere we look, using light from objects in the cosmos, we see that particles have the same mass and that their interactions in stars seem to be identical. So we can't see the Higgs field directly since it doesn't vary in space and time, it is what we think of as the vacuum.

So Can We Ever Tell if this Idea is Correct?

Since the vacuum is everywhere the same, can we ever tell for sure that the Higgs idea is correct? The answer is yes. It can be verified by excitation of the field, which is manifest as a particle called the Higgs boson – that is actually what we look for. It turns out that the mass of the Higgs boson is not given by the theory, but once its mass is specified all of its other properties are determined. For example its interaction with other particles is determined by the mass of the other particles. This is due to its relation to the Higgs field and the generation of mass. It is unstable and how often it decays to other particles is also specified. So we can plan experiments to look for the particle since its properties are very well specified.

Progress Over Time

However, these experiments turn out to be very difficult. In 1964, when the Higgs boson idea was presented, we had neither the accelerator nor the particle detector and data collection capability up to the task of finding it. The building of a suitable accelerator became possible with the development of powerful superconducting magnets. The accelerator would be large but still within the realm of possibility. The collection of vast amounts of data, as needed to find a small number of Higgs boson events produced in beam collisions, became possible with the enormous advances in computing and data storage coming from industry.

The Accelerator at CERN, 27 km in Circumference:
The LHC (proton-proton collider) near Geneva, Switzerland

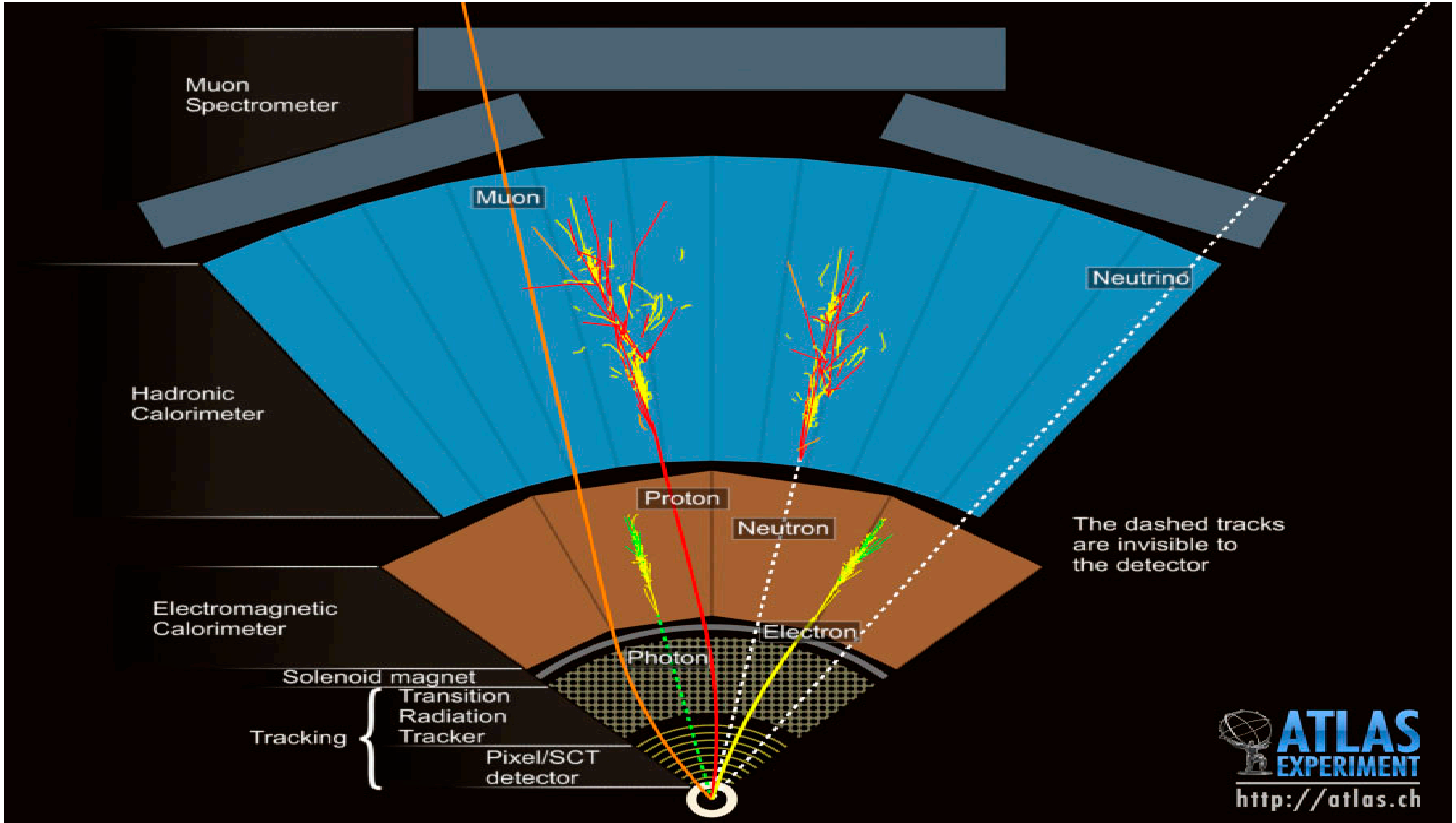
We Still Need a Particle Detector!

The challenge of building a suitable particle detector remained and a small group of us at UCSC decided to take up this challenge in 1986. The work built on several years of building major detectors for particle physics experiments by the Santa Cruz group, but significant advances were required.

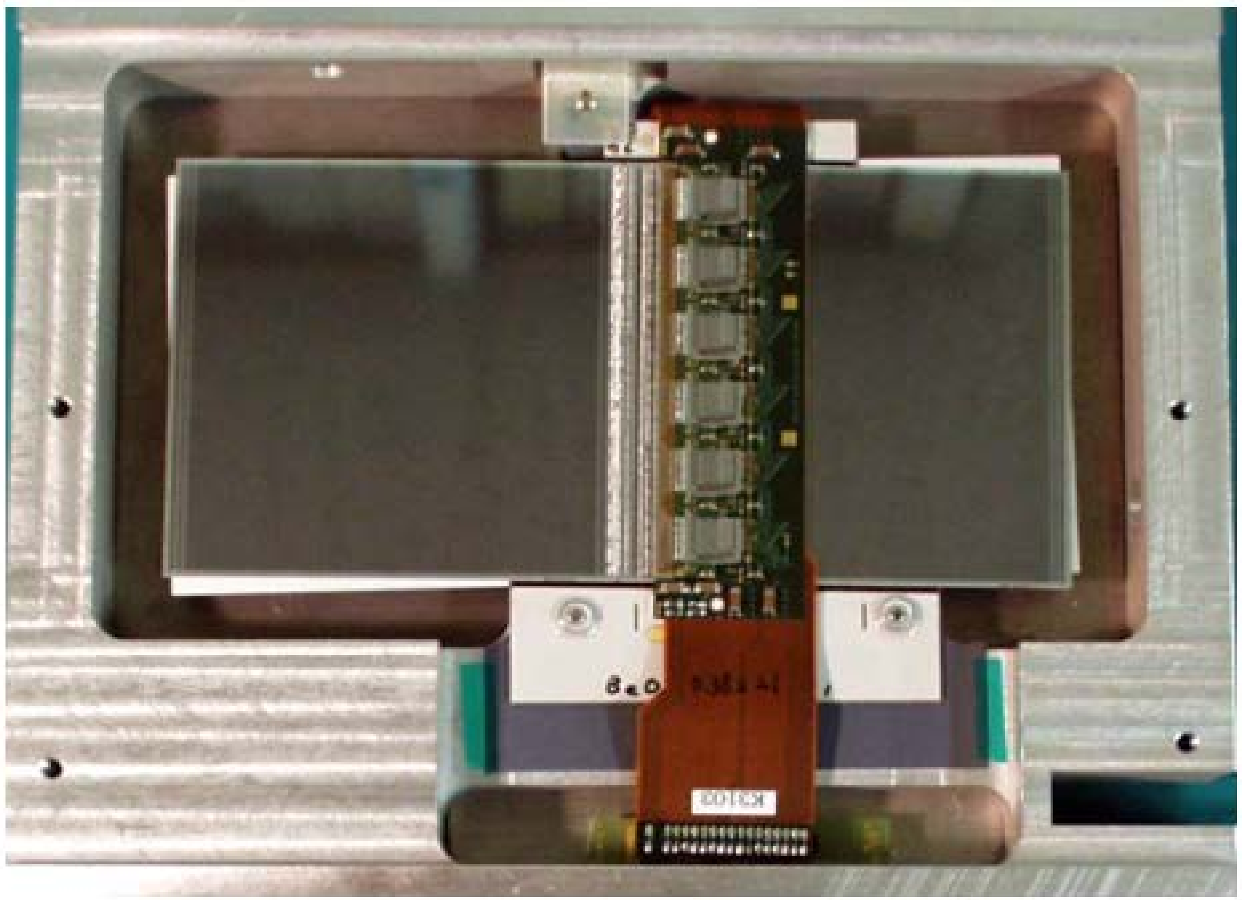
In particular, a suitable sensor was required that could determine the passage of individual particles produced in a collision. Each collision would create very many particles and we wanted to find each one. We had to also show that the sensor could survive the intense radiation from the particles produced by the colliding beams, and we had to develop the electronics to read out signals generated by the passing particles. At the accelerator, collisions would occur every 25 nanoseconds, so the electronics was a large challenge. We also had to prove to the community by simulations that an array of such sensors could in fact provide an excellent and efficient detector of particles.

A Detector Organized as "Concentric Shells",

Each Shell with a Specific Detection Task.

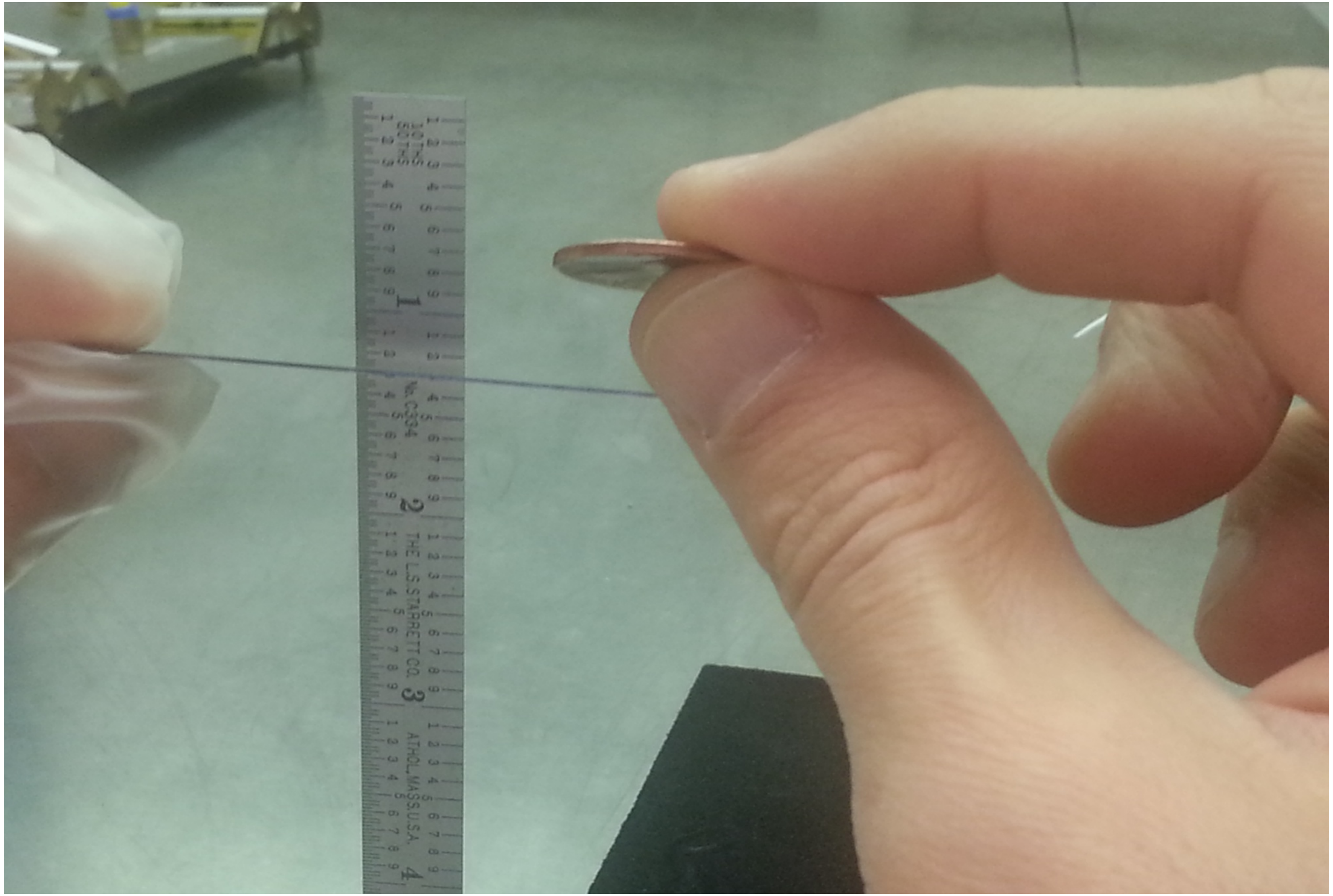


Module Made of Silicon Wafers, Electronics Directly On Top. Each Wafer is Actually 768 Individual Sensors.

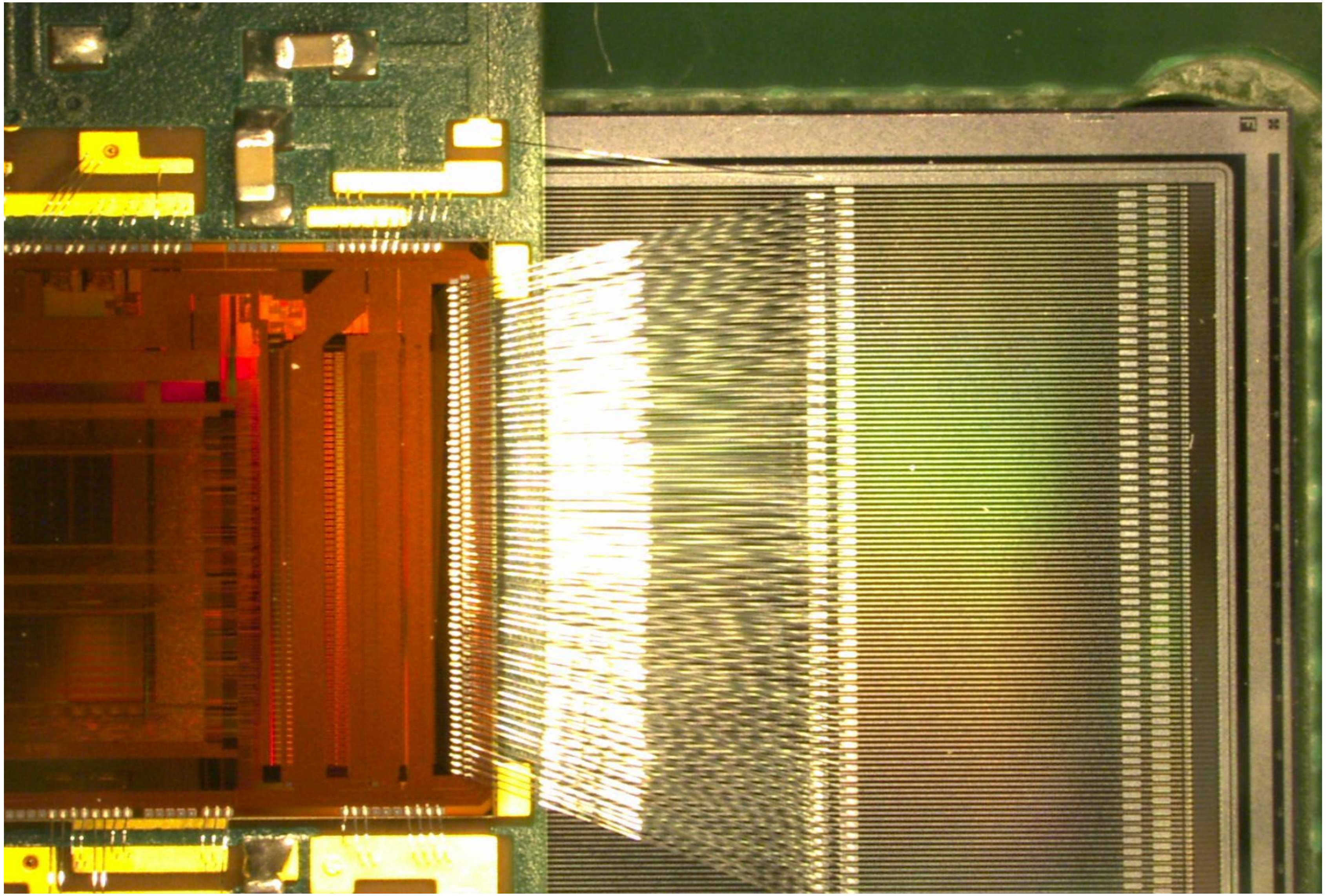


12 cm

Wafer is Thin Enough to Minimally Disrupt Particles Passing Through



Blow-up of Region of a Silicon Wafer. Spacing of Sensor Lines about ¼ of Sensor Thickness



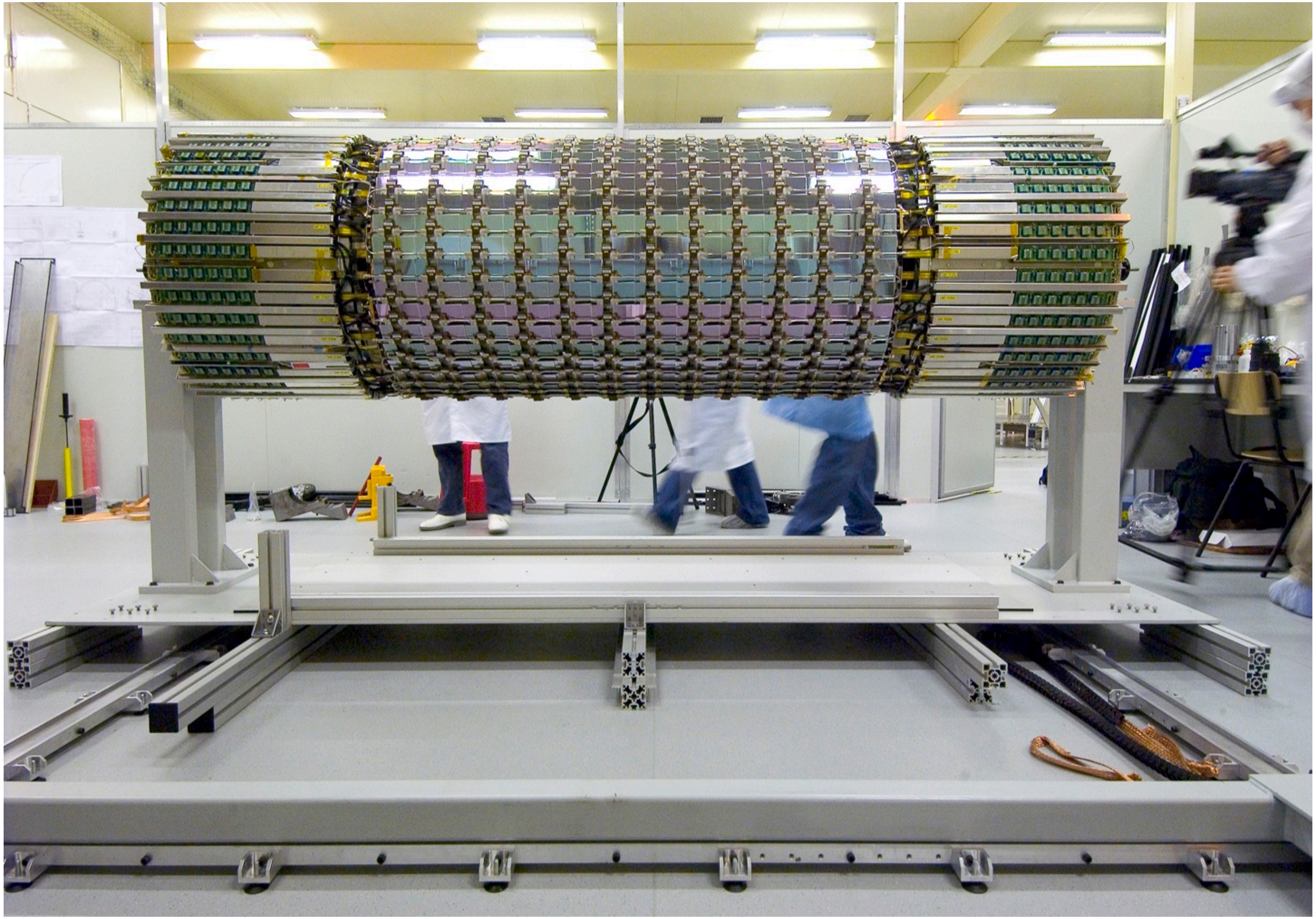
Using Our Ideas in a Real Experiment

In 1994 we joined the ATLAS experiment to be built at the CERN accelerator center in Geneva, Switzerland.

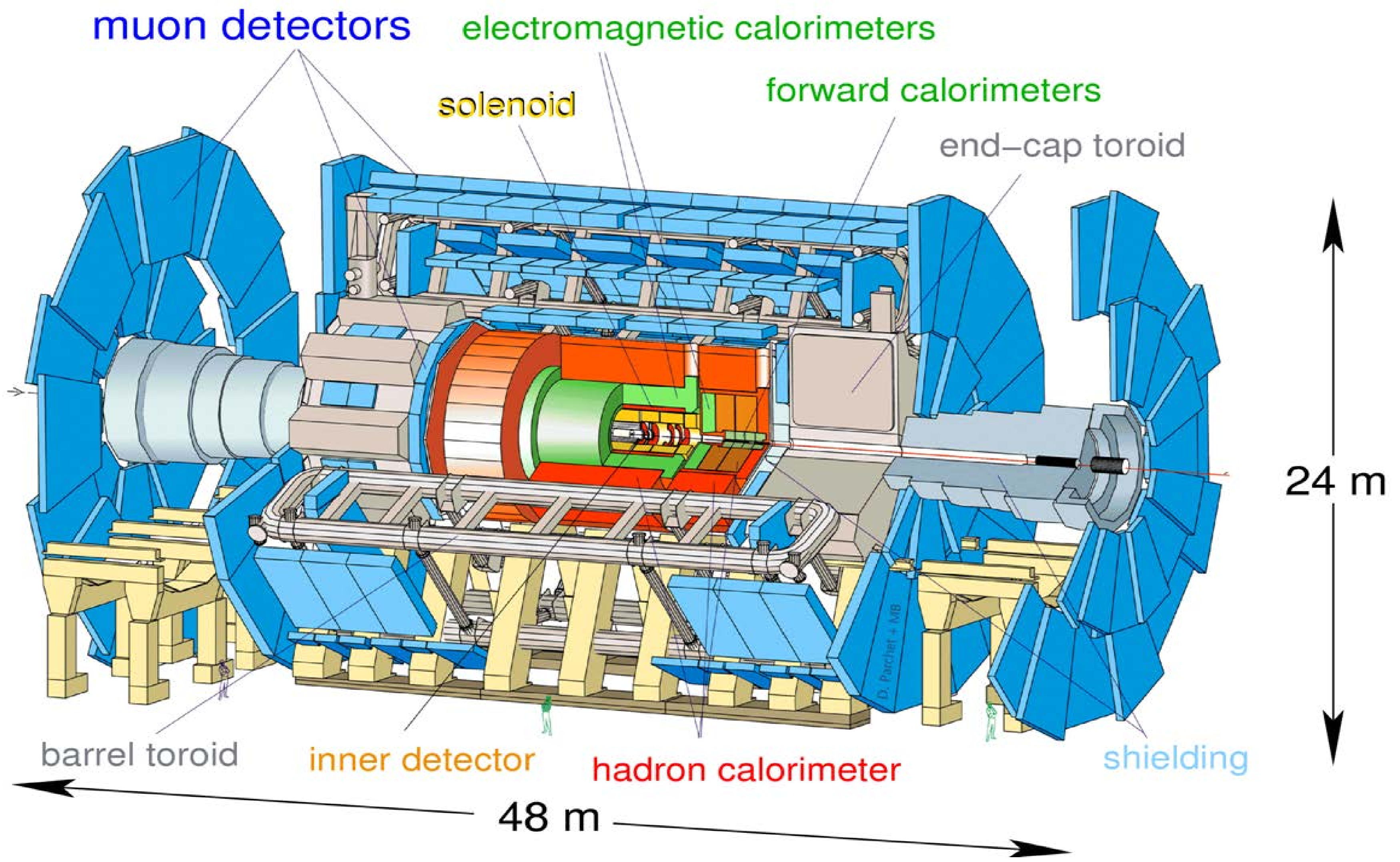
An array of silicon sensors would lie at the center of a very large detector (called ATLAS), which would have all of the detection devices needed to figure out what were the underlying particles produced in a given collision. The experiment would have to be very large and an international effort was required to achieve the financial and human resources required to realize the experiment. The accelerator was provided by the CERN laboratory but the experiment would have to be provided by the scientists who wanted to search for the Higgs boson.

ATLAS is a Very Large International Undertaking

One of Four Barrel Detectors Made of Silicon Strip Sensors

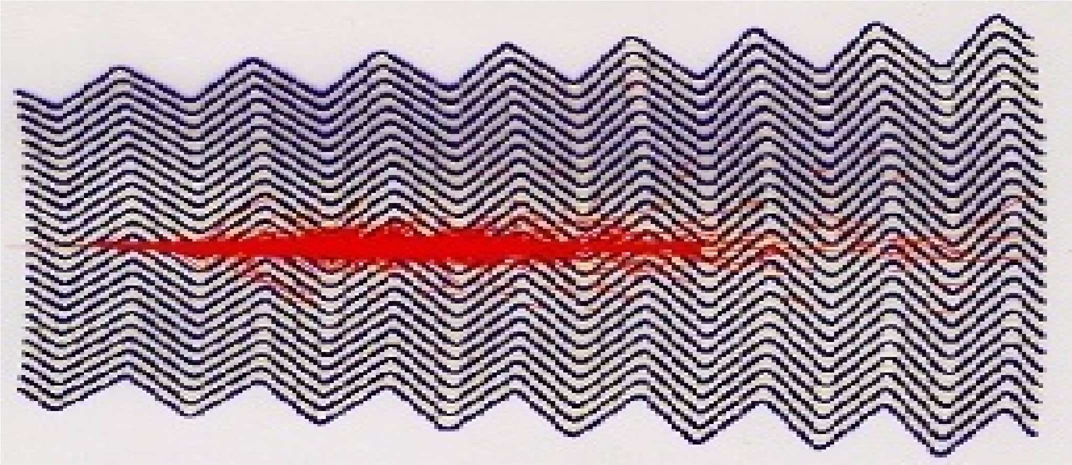


ATLAS Experiment



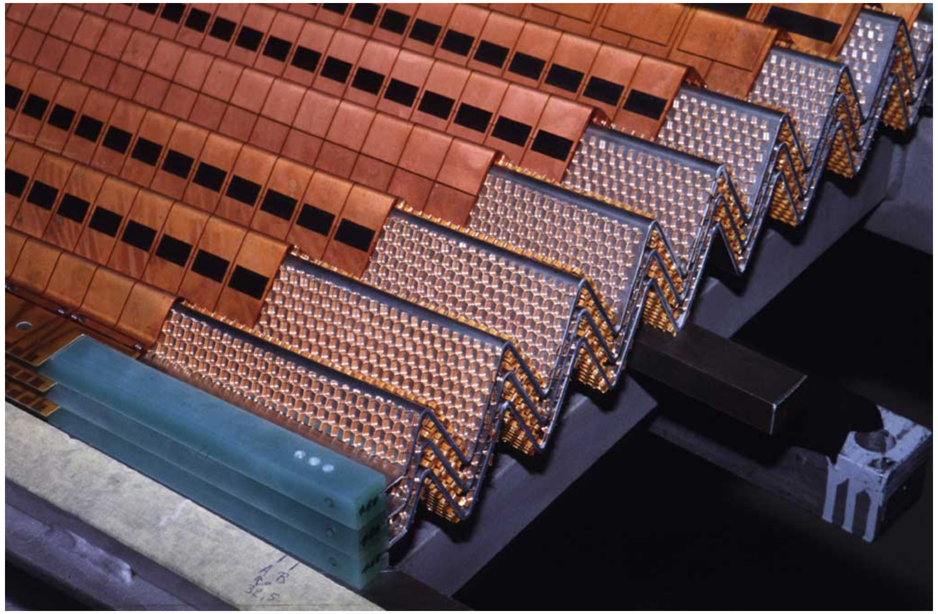
ATLAS Electromagnetic Calorimeter

Calorimeter concept: shower of particles created by lead; ionization in liquid argon between the lead radiators is collected by electrodes. This is the signal used to measure the shower energy.

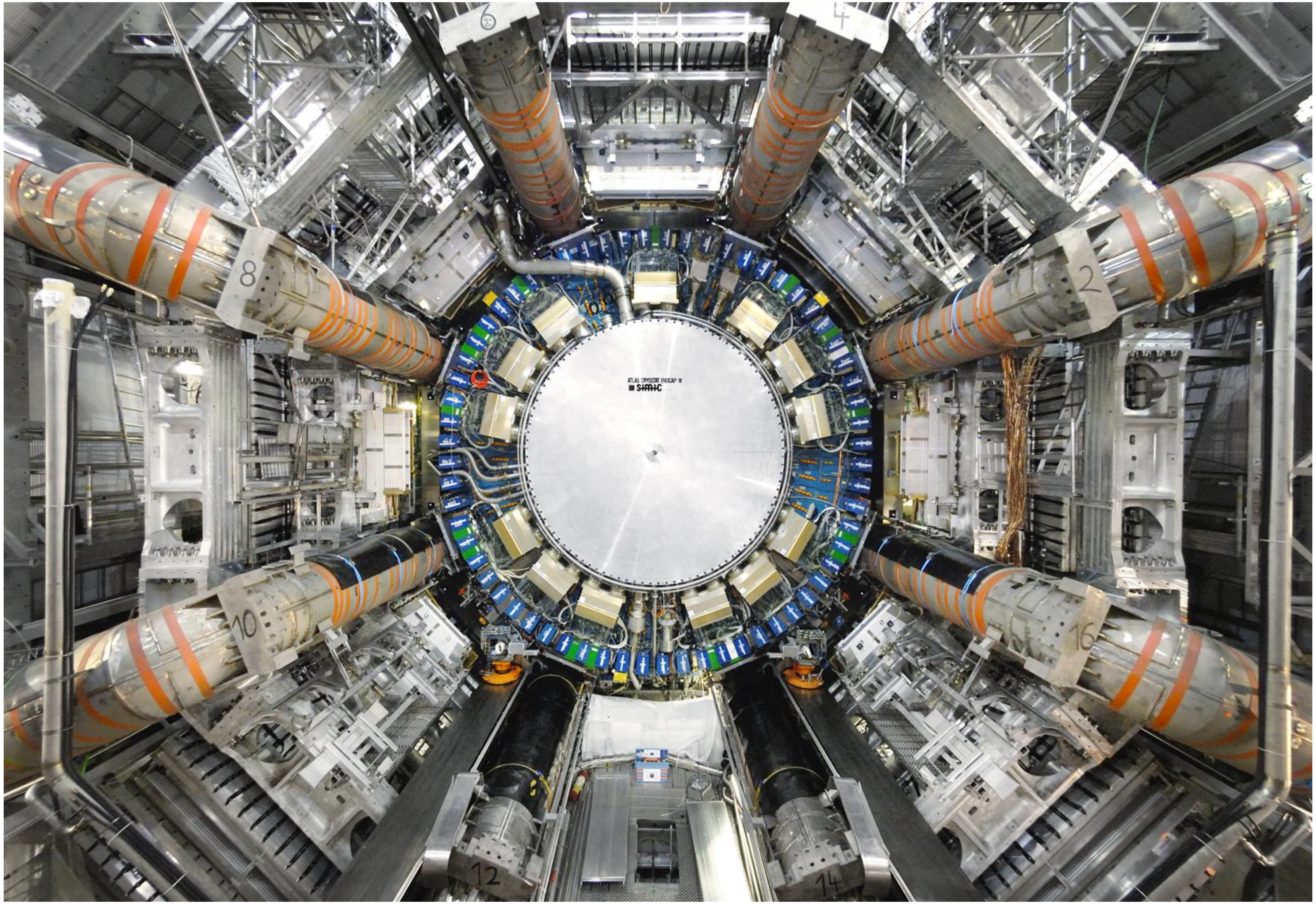


Lead Radiator Material

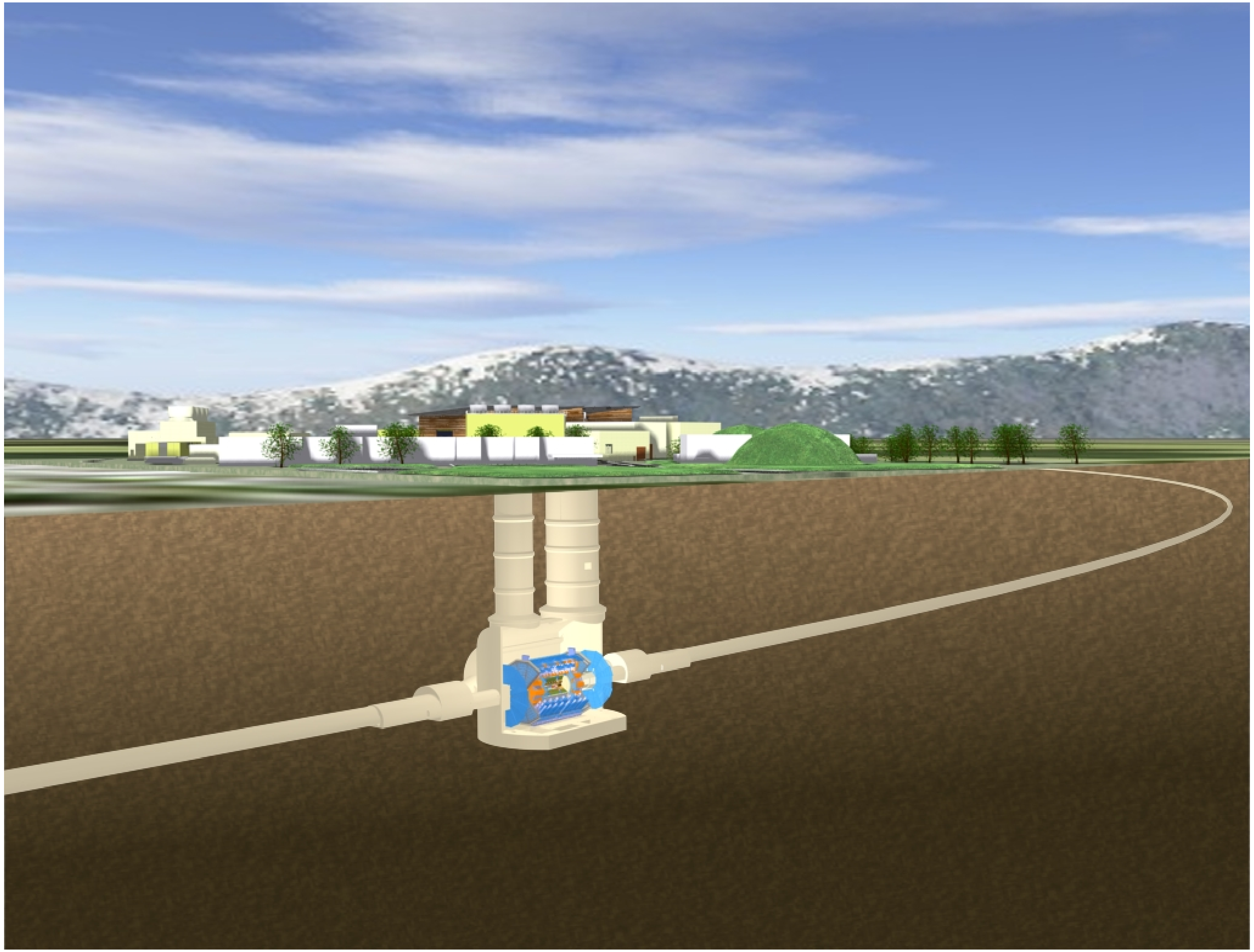
Electrodes for Collection of Ionization



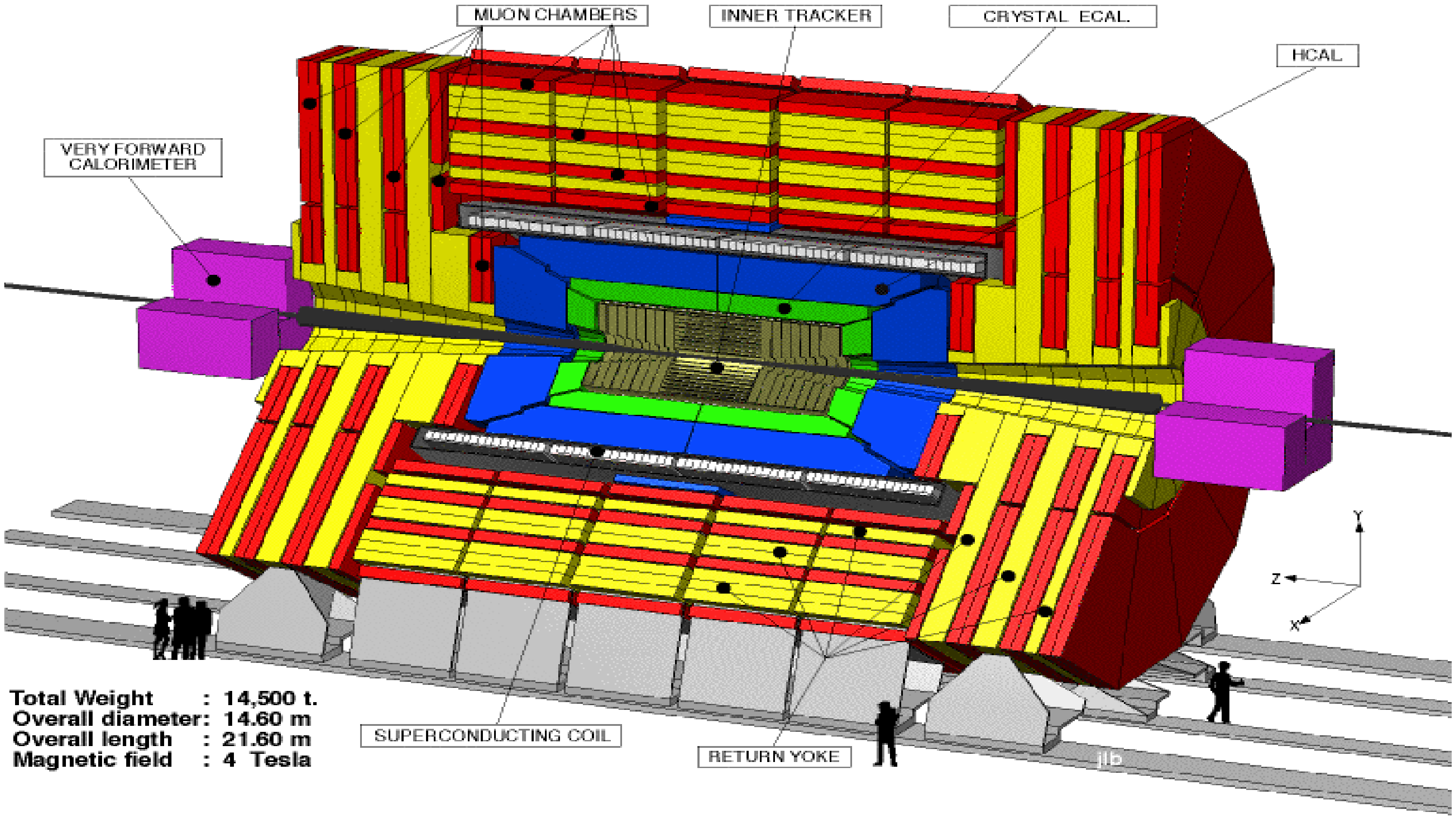
Muon Toroids, While ATLAS is Being Assembled



ATLAS Detector Deep Underground

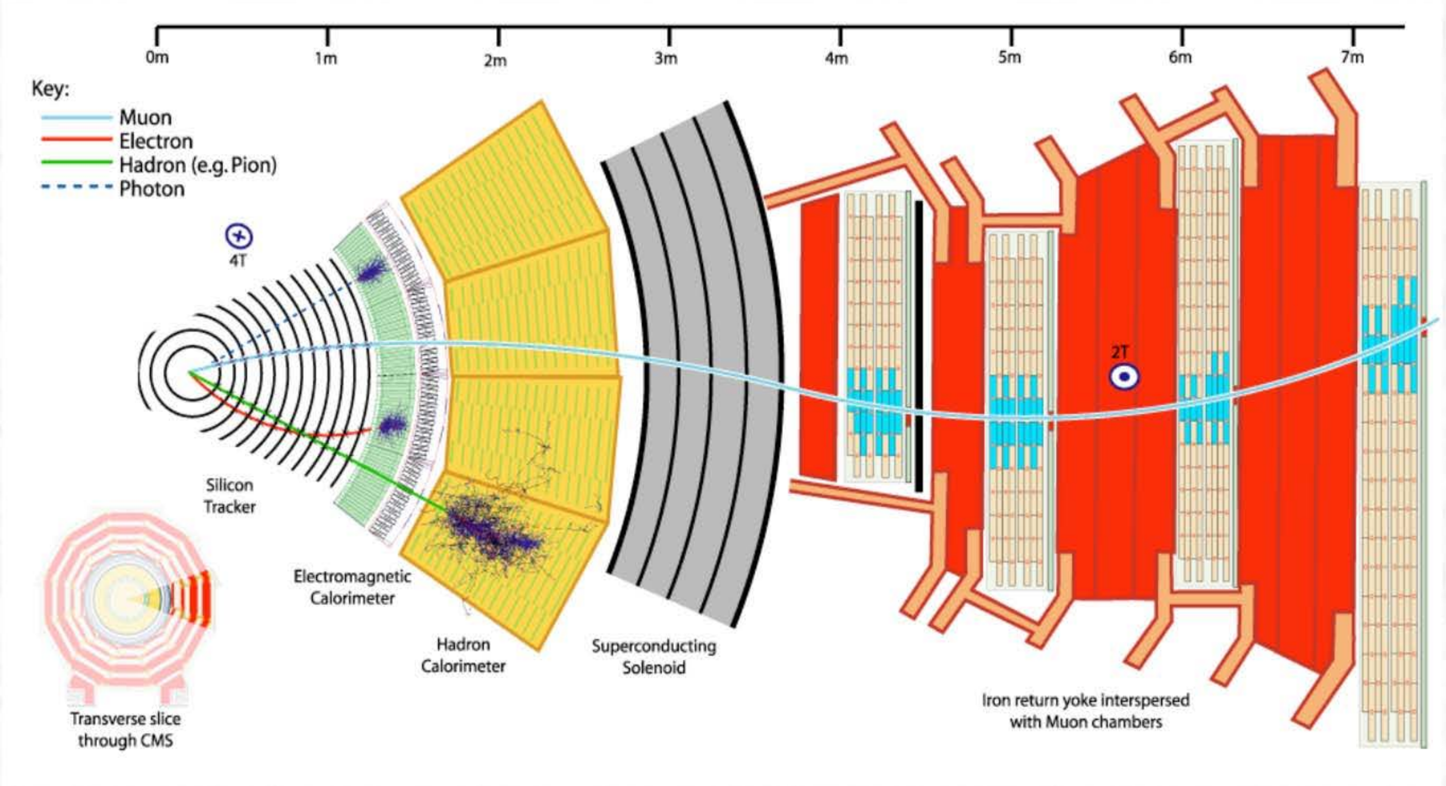


Second Detector Called CMS



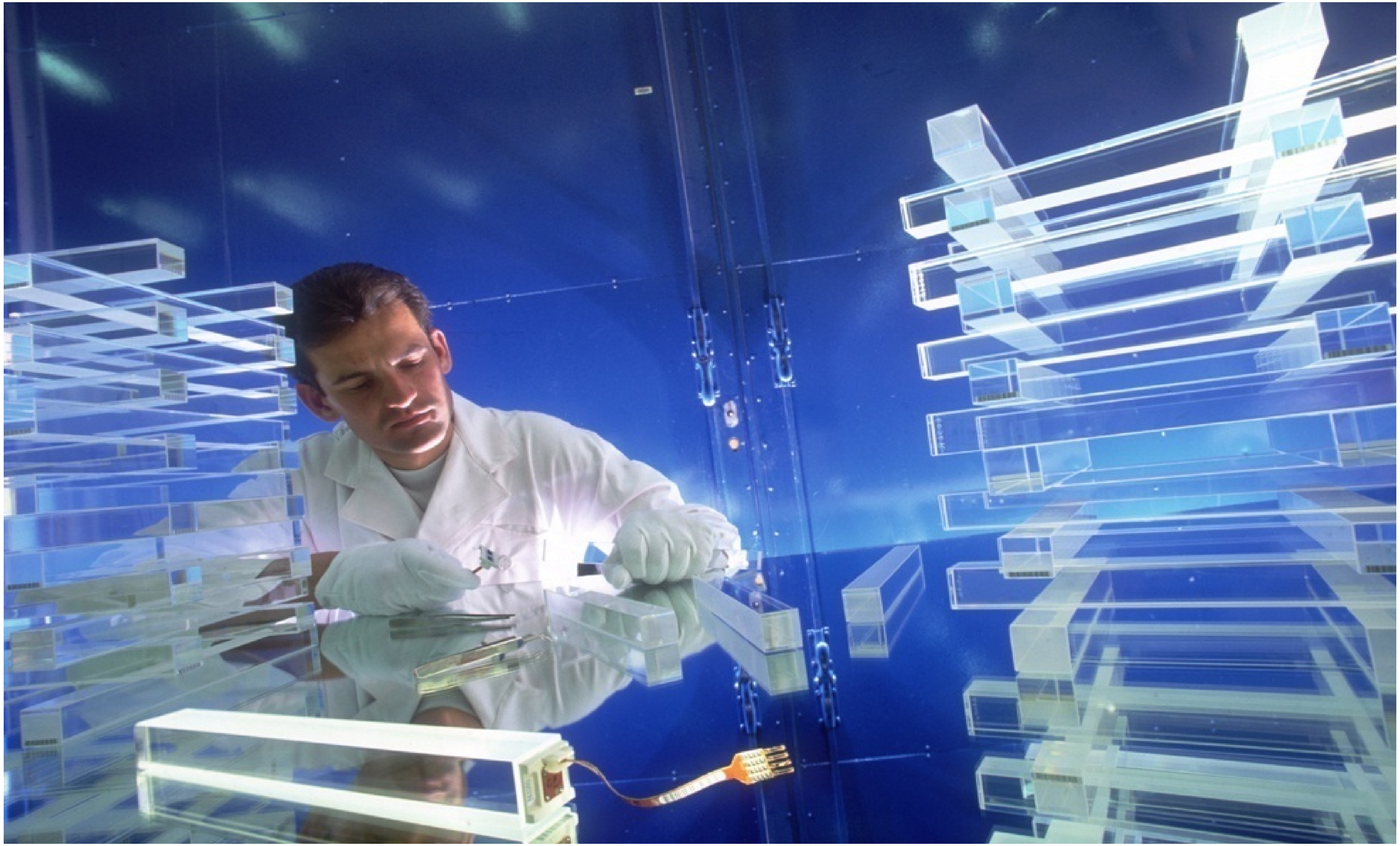
Almost all the detection elements for CMS are different from those in ATLAS except for a silicon detector at the center of the experiment.

CMS Detector Concept



Tracker Calorimeter Coil Muon Detector and iron return yoke

Novel Lead Tungstate Scintillating Crystals for Electromagnetic Calorimeter: Very dense, about 25cm long, very fast signals. About 76,000 crystals in the CMS detector.



The Detectors are Very Large Devices Filled With Electronics

Object	Approx. Weight (Tons)
Boeing 747 (fully loaded)	500
Space Shuttle (fully loaded)	2,200
ATLAS Detector	7,000
Eiffel Tower (metal only)	7,300
USS John McCain (navy destroyer)	8,300
CMS Detector	14,500

Take Data!

A very large amount of effort was required to build ATLAS: about 10 years of work for construction, involving thousands of people. After calibrating the very complicated detectors and learning how to collect and analyze the data, we were ready to receive the large amounts of data delivered in the second half of 2011 and in 2012. From a very large collection of events, special events of interest are selected for examination based on the particles detected. Plots are then made to see if we have evidence of a new particle in any of the final states of interest. Generally, final states have contributions from processes other than a Higgs boson but these produce smooth distributions in mass. We look for events clustered at a fixed mass indicating contributions from one particle at that mass.

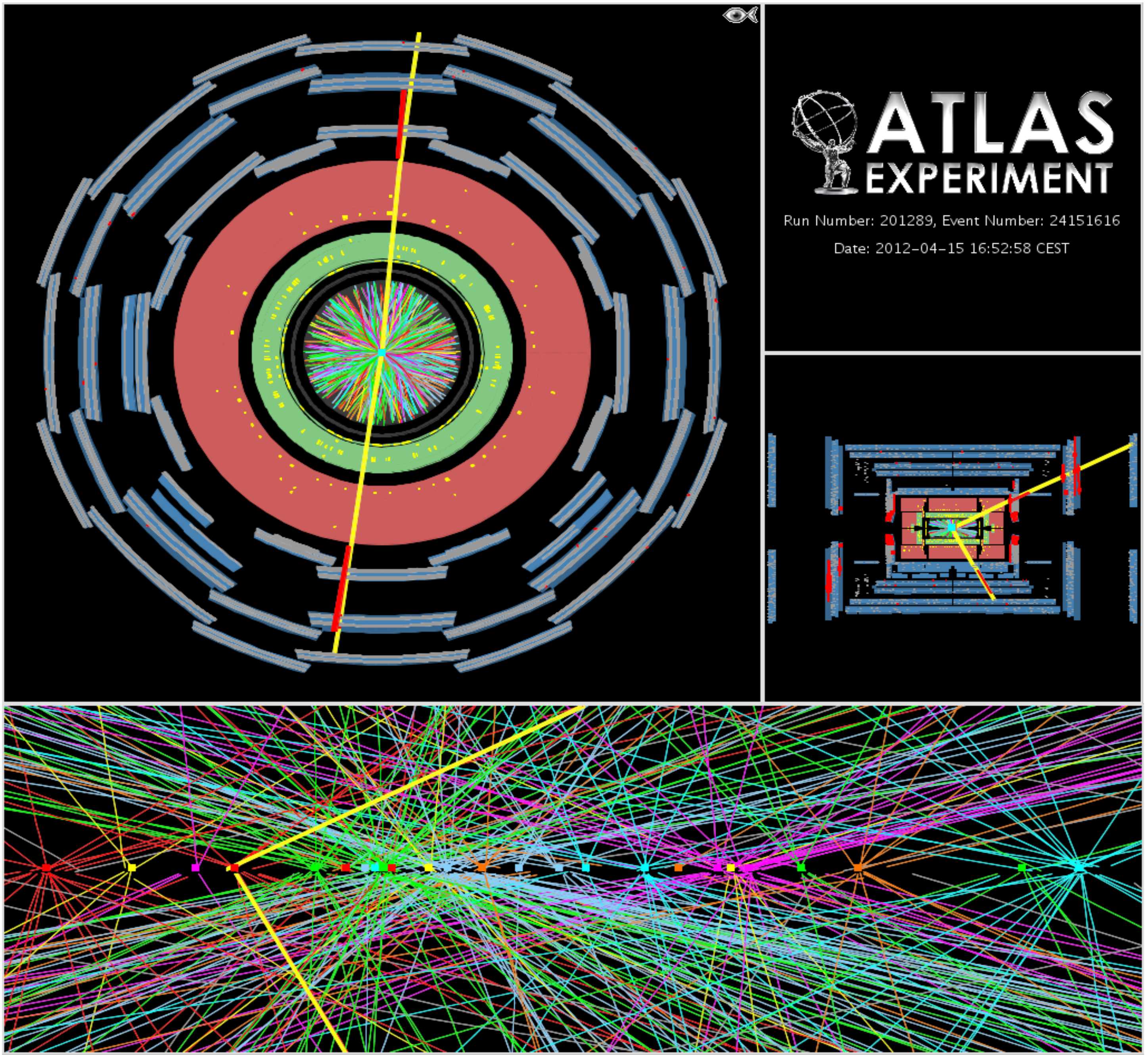
ANGELS & DEMONS

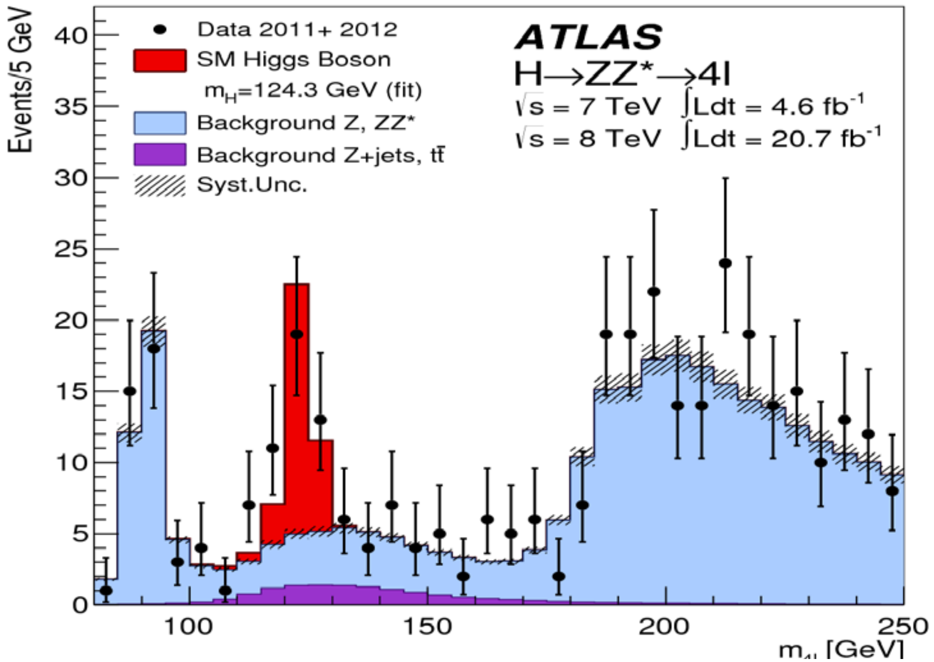
Film Clip

Atomic Collision
(Zurer)

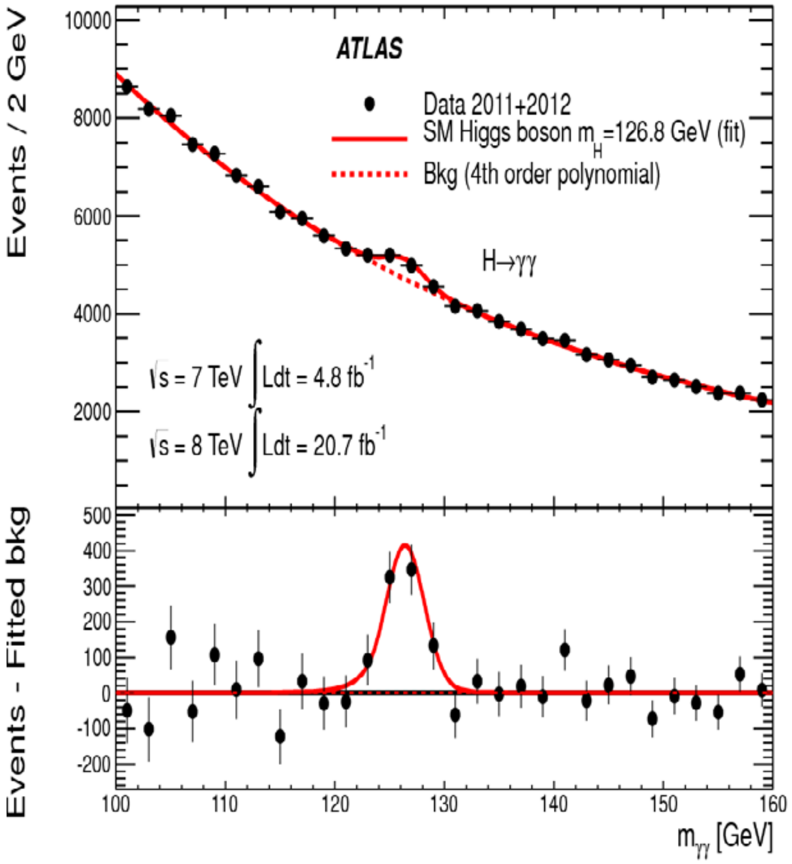
Appropriate Placement Only

TRT 1:03

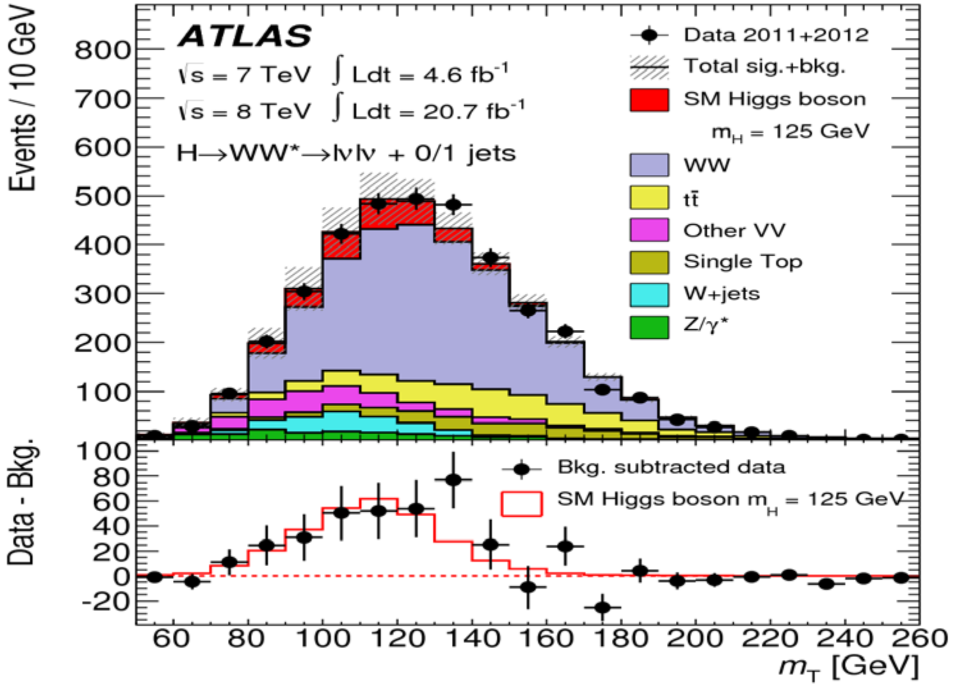

ATLAS
EXPERIMENT
Run Number: 201289, Event Number: 24151616
Date: 2012-04-15 16:52:58 CEST



Data 2011+ 2012
SM Higgs Boson
m_H=124.3 GeV (fit)
Background Z, ZZ*
Background Z+jets, $t\bar{t}$
Syst.Unc.
ATLAS
$H\rightarrow ZZ^*\rightarrow 4l$
$\sqrt{s}$ = 7 TeV $\int Ldt$ = 4.6 fb^{-1}
$\sqrt{s}$ = 8 TeV $\int Ldt$ = 20.7 fb^{-1}
Events/5 GeV
m_{4l} [GeV]



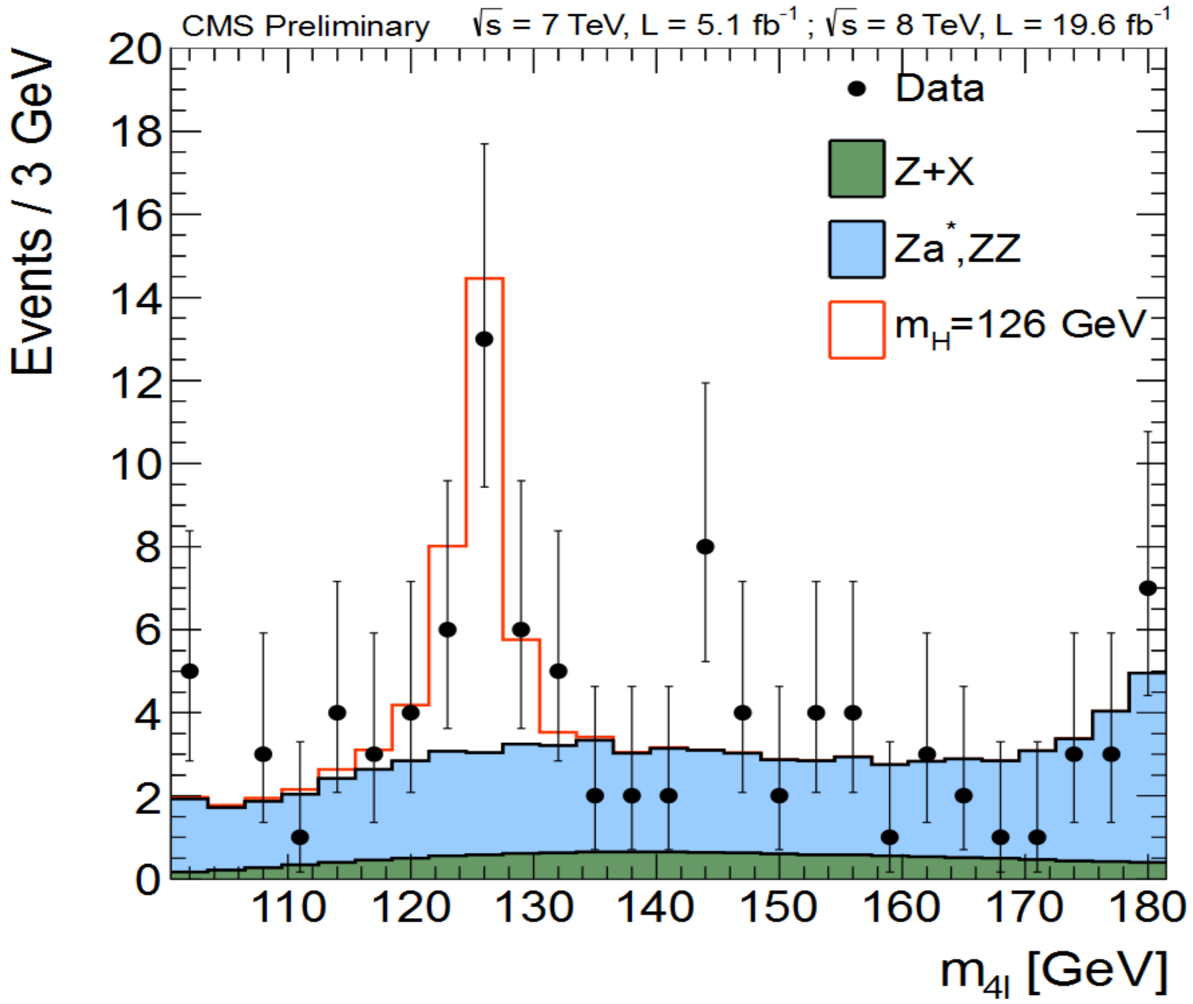
ATLAS
Data 2011+2012
SM Higgs boson m_H=126.8 GeV (fit)
Bkg (4th order polynomial)
$H\rightarrow\gamma\gamma$
$\sqrt{s}$ = 7 TeV $\int Ldt$ = 4.8 fb^{-1}
$\sqrt{s}$ = 8 TeV $\int Ldt$ = 20.7 fb^{-1}
Events / 2 GeV
Events - Fitted bkg
$m_{\gamma\gamma}$ [GeV]



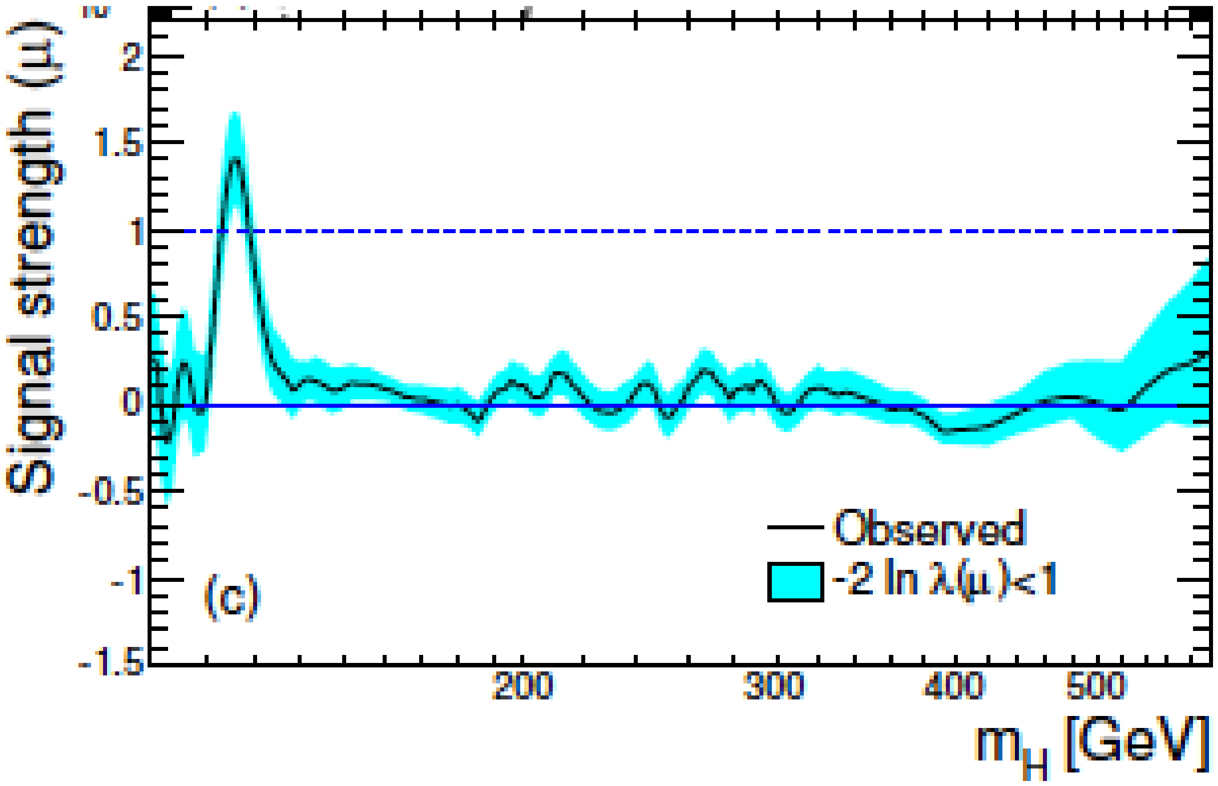
ATLAS
$\sqrt{s}$ = 7 TeV $\int Ldt$ = 4.6 fb^{-1}
$\sqrt{s}$ = 8 TeV $\int Ldt$ = 20.7 fb^{-1}
$H\rightarrow WW^*\rightarrow l\nu l\nu$ + 0/1 jets
Data 2011+2012
Total sig.+bkg.
SM Higgs boson
m_H = 125 GeV
WW
$t\bar{t}$
Other VV
Single Top
W+jets
Z/γ^*
Events / 10 GeV
Data - Bkg.
Bkg. subtracted data
SM Higgs boson m_H = 125 GeV
m_T [GeV]


We found it!
We found the
Higgs boson!
SCIENCE

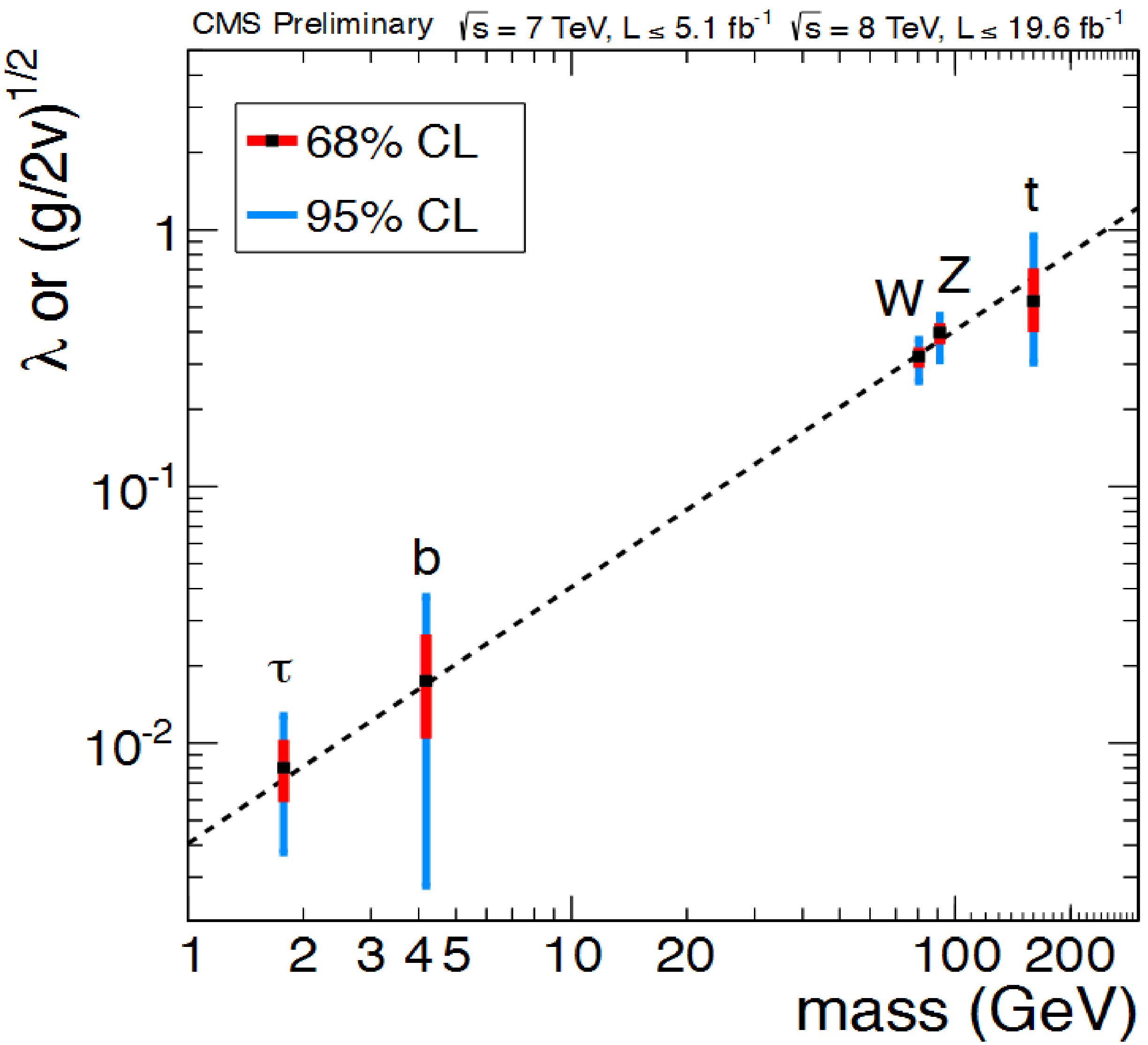
Confirmation!



Search for Higgs Boson Signal Over Broad Mass Range



It is a new type of particle, but is it a Higgs Boson?



What is Next for the Higgs

1) The accelerator energy is being nearly doubled to increase the rate of Higgs production and also to extend the mass range over which we can search for surprise phenomena. Will startup in about a year.
2) An additional silicon layer is being added inside all the others and very close to the colliding beams to improve the measurement of charged particle trajectories. It will be installed in a few months.
3) The accelerator has a program of increasing the number of interactions per second over time. We have to improve the experiment to keep up with the accelerator. We are working on this!

Plan to collect about 500 times the number of Higgs boson decay events to very carefully check the theory!

If you want to know more about the Higgs boson and related subjects, be sure to check out the exciting new documentary film, *Particle Fever*, coming in mid-March to one of the Nickelodeon Theatres in Santa Cruz for a limited one-week run.

http://particlefever.com