VELAN

World Leader for Cryogenic Valve Applications

Cryogenic Bellows Seal Control and Quench Relief Valves in the world's largest, fastest, and coldest accelerator of nuclear particles at CERN, Geneva

(Conseil Européen pour la Recherche Nucléaire)


In production


In service

2500 Velan Cryogenic Valves for liquid Helium at 1.5° K above absolute zero (-271.5°C) in the world's largest Hadron collider, LHC at CERN, Geneva.

CERN LHC Inauguration

21 October 2008

Inauguration du LHC

21 octobre 2008

On 10 September the world watched as protons travelled around the Large Hadron Collider for the very first time. This event marked the latest stage in a journey that began in 1984 with a debate on the possible objectives of a future accelerator. The CERN Council then approved the construction of the LHC in 1996.

For the past 12 years, physicists, engineers and technicians from CERN and its associated institutes have been engaged in constructing the three pillars of the LHC: the accelerator, the four experiments, and the computing infrastructure needed to store and analyse the data.

As Director-General I feel tremendous pride in the commitment and dedication shown by everyone at CERN, at its partner institutions in the Member States and non-Member States, and at the many contractors involved, in completing this unique endeavour.

Now the LHC is poised to generate new knowledge that we will share with the whole of mankind. This is precisely why CERN was founded — to restore Europe to its place at the forefront of science and, in particular, at the forefront of physics.

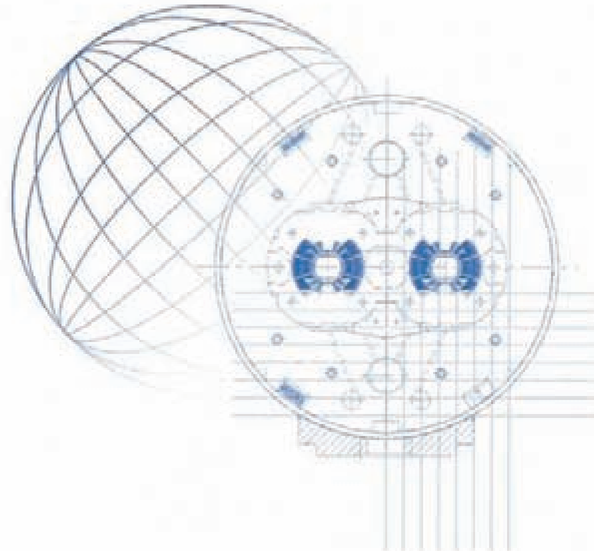
Le 10 septembre, le monde entier suivait la progression des protons qui circulaient pour la première fois dans le Grand collisionneur de hadrons (LHC). Cet événement représentait la dernière étape d'un voyage débuté en 1984 avec un débat sur les objectifs éventuels d'un futur accélérateur. Puis, en 1996, le Conseil du CERN a approuvé la construction du LHC.

Durant les douze dernières années, les physiciens, les ingénieurs et les techniciens du CERN et des instituts associés ont travaillé à la construction des trois piliers du LHC : l'accélérateur, les quatre expériences et l'infrastructure informatique nécessaire au stockage et à l'analyse des données expérimentales.

En tant que Directeur général, je suis extrêmement fier de l'engagement et du dévouement de tous, que ce soit au CERN, dans les institutions partenaires des États membres et des États non-membres, ou dans les nombreuses entreprises qui ont pris part à cette aventure exceptionnelle.

Le LHC est maintenant prêt à produire de nouvelles connaissances que nous partagerons avec l'humanité entière. C'est bien pour cela que le CERN a été créé : pour que l'Europe retrouve sa place à la pointe de la science, et en particulier à la pointe de la physique.

Director-General | Directeur général



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Geneva, 9 October 2008

Dear Mr Velan,

CERN is pleased to invite you to the Large Hadron Collider (LHC) Industry Award Day on Monday, 20 October 2008.

We hope that you will be able to attend this special event, which will take place the day before the official LHC Inauguration Ceremony to celebrate the excellent collaboration between CERN and Industry during the construction phase of the machine and its experiments.

The programme is enclosed with this invitation.

All details of the venue can be found on the LHC2008 website:
http://lhc2008.web.cern.ch/LHC2008/industry/index.html#

We look forward to meeting you on 20 October.

Yours sincerely,

Lucio Rossi

Head of LHC 2008 events

Le Directeur général du CERN,
Robert Aymar,

prie Monsieur Karel Velan

de lui faire l'honneur d'assister à
la cérémonie d'inauguration du LHC,

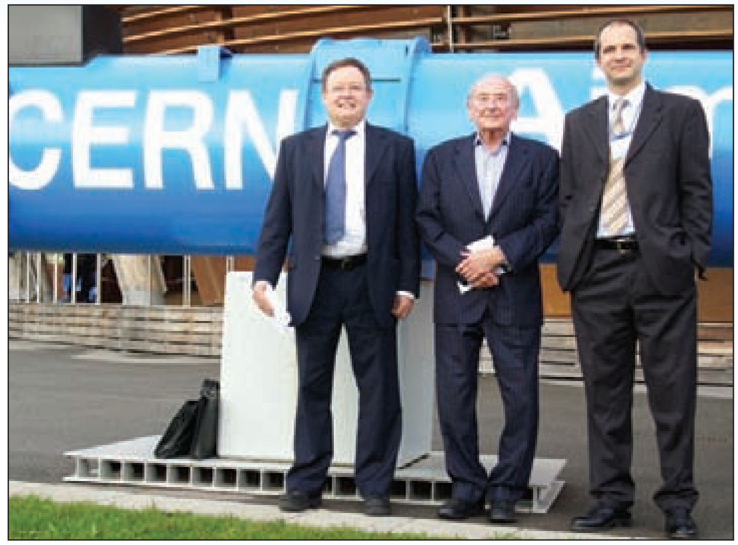
le mardi 21 octobre 2008

R.S.V.P. Pour mémoire

Enregistrement au **Globe de la science et de l'innovation**
de 12h15 à 12h45 sur présentation de ce carton et d'une pièce d'identité

CERN LHC INAGURATION - OCTOBER 20 & 21, 2008

Mr. A.K. Velan, founder and CEO of Velan Inc. with Mr. Robert Aymar, General Manager of CERN.



Mr. Patrick Henry, Manager of Velan SAS and Mr. A.K. Velan with Mr. Antonio Perin in charge of cryogenic systems at CERN.

Mr. Raphaël Couturier, Sales Manager of cryogenic and control valves at Velan SAS with Mr. Antonio Perin and Mr. A.K. Velan.

Mr. A.K. Velan and Mr. Raphaël Couturier.

INTERNATIONAL JOURNAL OF HIGH-ENERGY PHYSICS

CERN COURIER

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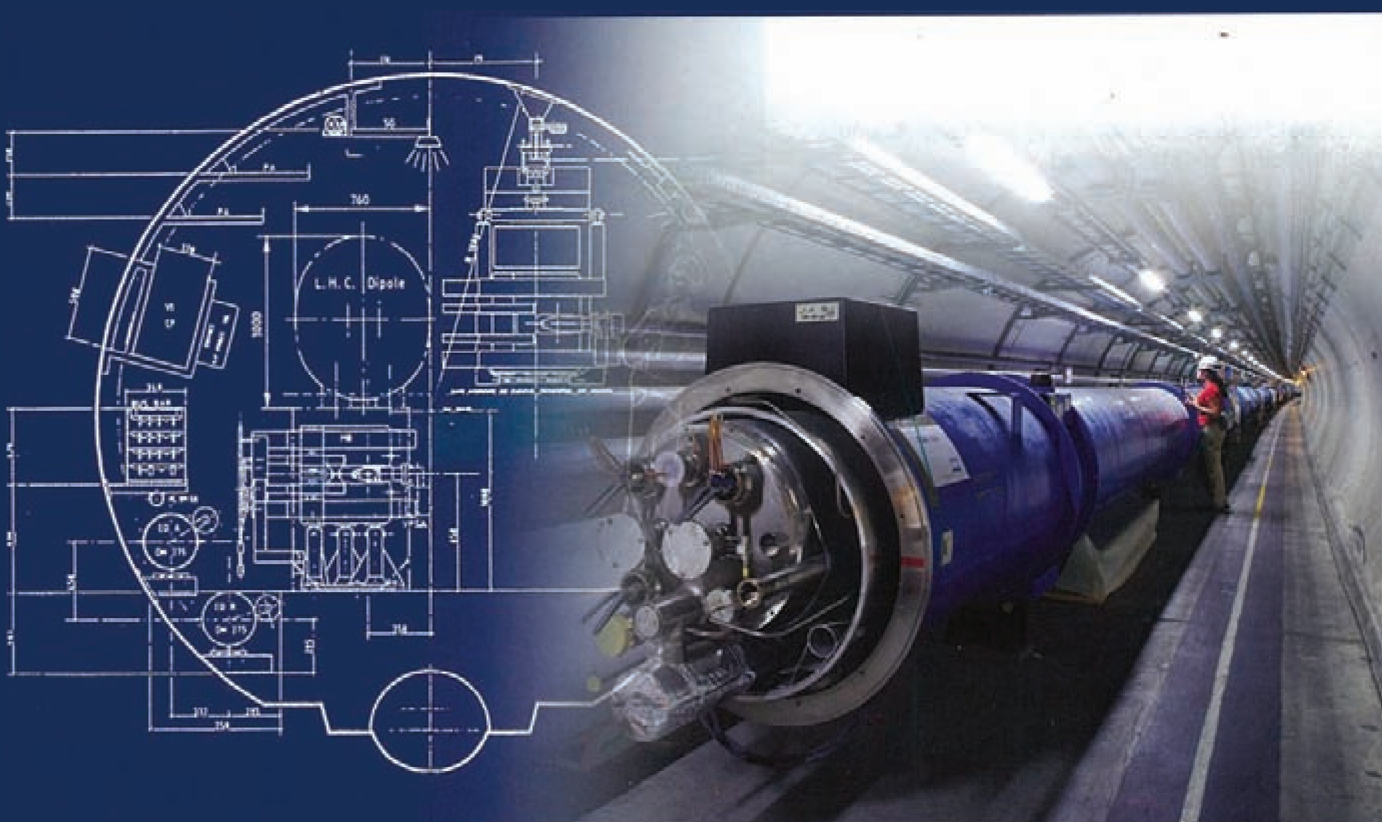
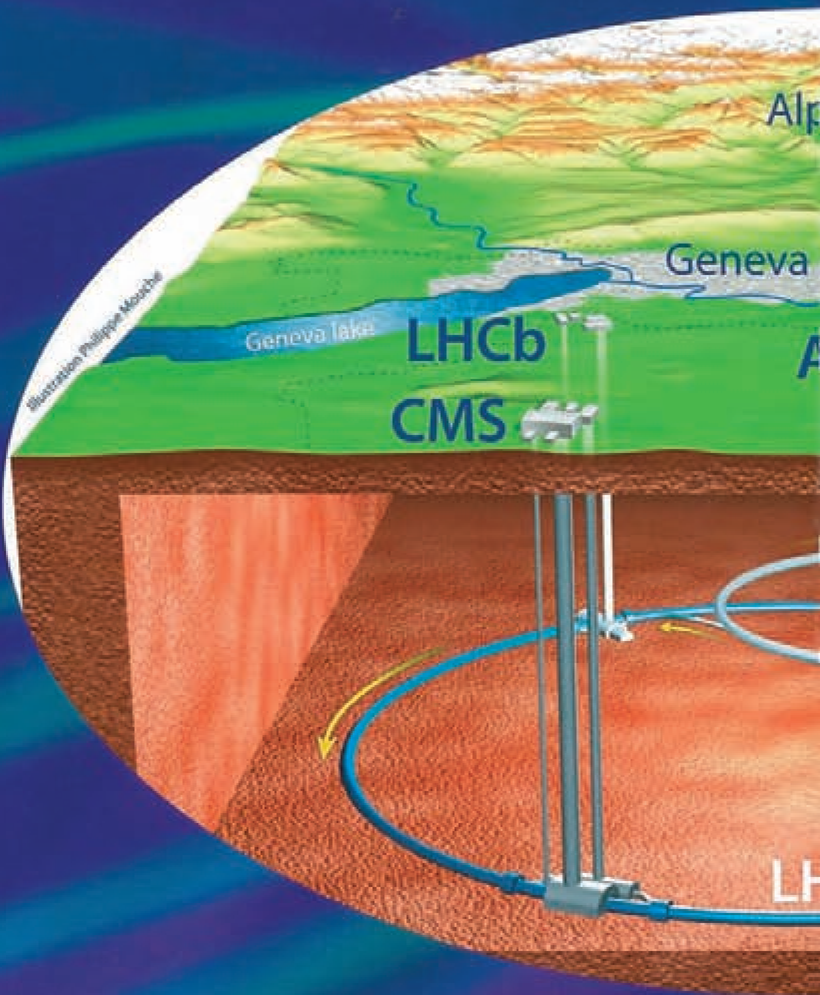


The LHC: from dream to reality

LHC >>> the world's

Where is it?

The LHC is being installed in a tunnel 27 km in circumference, buried 50-150 m below ground. Located between the Jura mountain range in France and Lake Geneva in Switzerland, the tunnel was built in the 1980s for the previous big accelerator, the Large Electron–Positron collider (LEP).



What will it do?

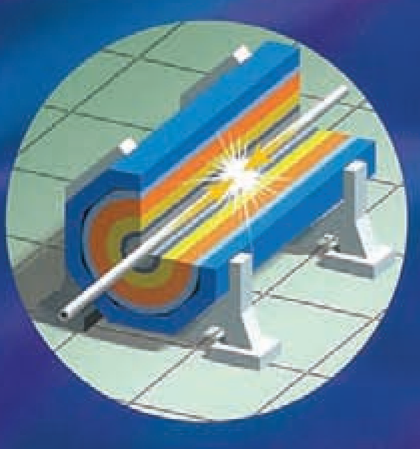
The LHC will produce head-on collisions between two beams of particles of the same kind, either protons or lead ions. The beams will be created in CERN's existing chain of accelerators and then injected into the LHC, where they will travel through a vacuum comparable to outer space. Superconducting magnets operating at extremely low temperatures will guide the beams around the ring.

Each beam will consist of nearly 3000 bunches of particles and each bunch will contain as many as 100 billion particles. The particles are so tiny that the chance of any two colliding is very small. When the bunches cross, there will be only about 20 collisions among 200 billion particles. However, bunches will cross about 30 million times per second, so the LHC will generate up to 600 million collisions per second.

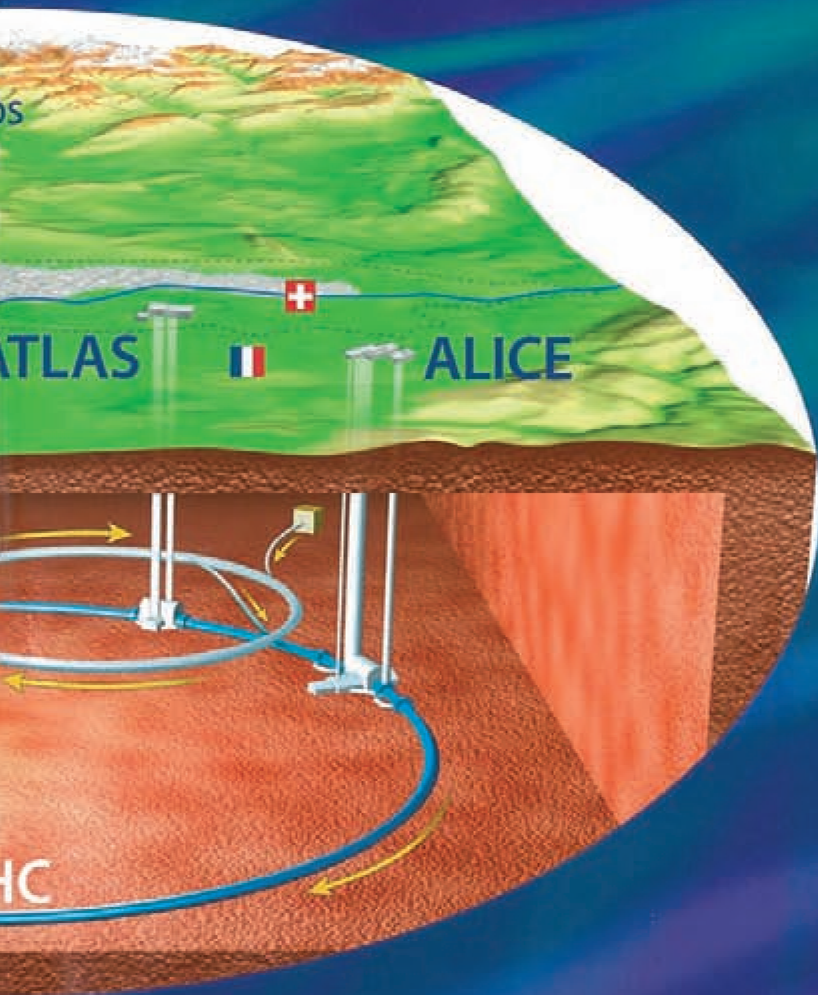
At near light-speed, a proton in the LHC will make 11 245 turns every second. A beam might circulate for 10 hours, travelling more than 10 billion kilometres—far enough to get to the planet Neptune and back again.

What is it for?

Due to switch on in 2008, the LHC will provide collisions at the highest energies ever observed in laboratory conditions and physicists are eager to see what they will reveal. Four huge detectors—ALICE, ATLAS, CMS and LHCb—will observe the collisions so that the physicists can explore new territory in matter, energy, space, and time.



most powerful accelerator



How powerful?

The LHC is a machine for concentrating energy into a very small space. Particle energies in the LHC are measured in tera-electronvolts (TeV). 1 TeV is roughly the energy of a flying mosquito, but a proton is about a trillion times smaller than a mosquito.

Each proton flying round the LHC will have an energy of 7 TeV, so when two protons collide the collision energy will be 14 TeV. Lead ions have many protons, and together they give an even greater energy: the lead ion beams will have a collision energy of 1150 TeV.

At full power, each beam will be about as energetic as a car travelling at 1600 kph. The energy stored in the magnets would be enough to melt 50 tonnes of copper.

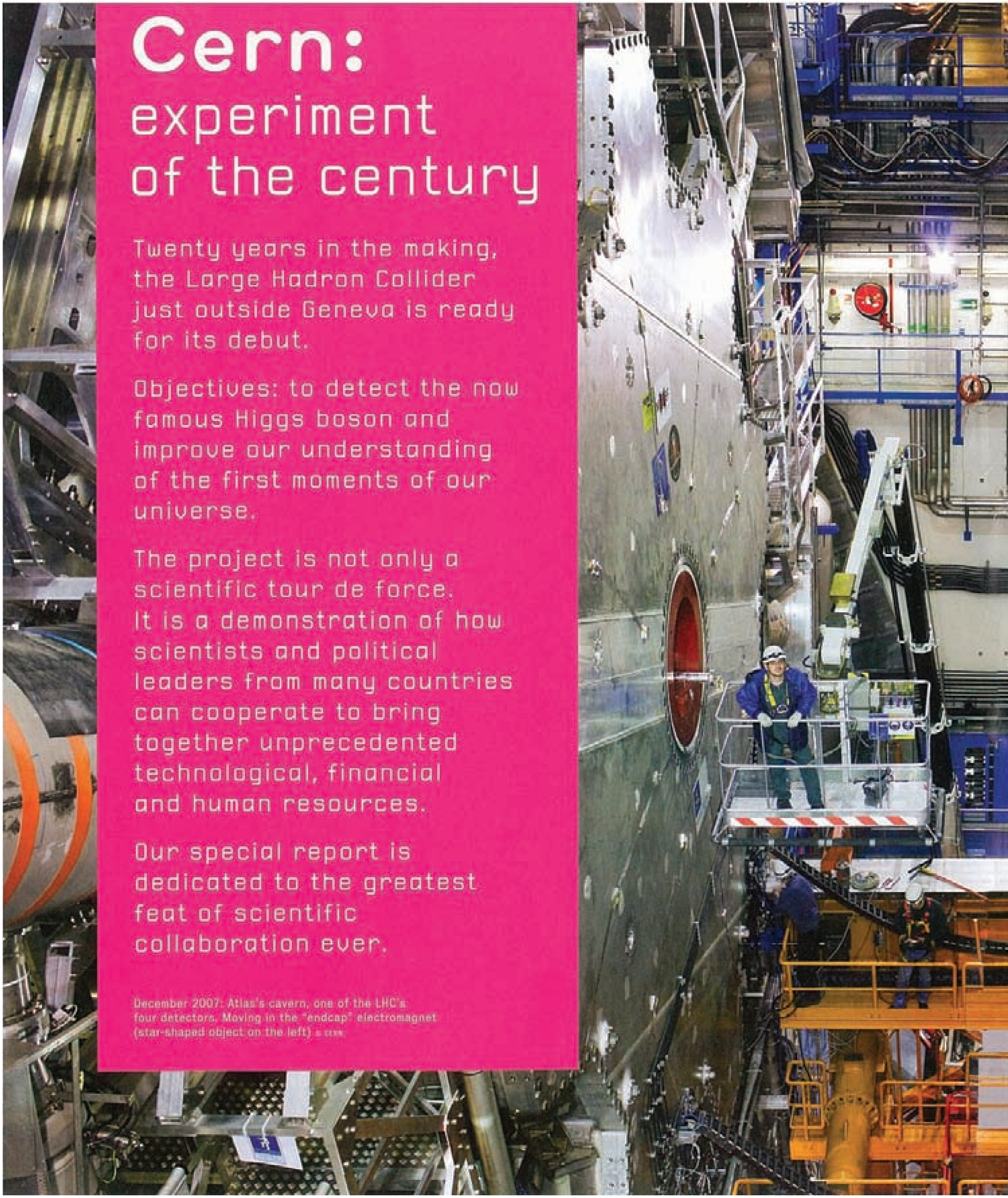
How will it work?

After reaching an energy of 0.45 TeV in CERN's accelerator chain, the beams will be injected into the LHC ring, where they will make millions of circuits. On each circuit, the beams will receive an additional impulse from an electric field contained in special cavities, until they reach the final energy of 7 TeV. To control beams at such high energies, the LHC will use some 1800 superconducting magnet systems. These electromagnets are built from superconducting materials.

At low temperatures they can conduct electricity without resistance and so can create much stronger magnetic fields than ordinary electromagnets. The LHC's niobium-titanium magnets operate at a temperature of only 1.9 K (–271°C).

The strength of a magnetic field is measured in units called tesla. The LHC will operate at about 8 tesla, whereas ordinary "warm" magnets can achieve a maximum field of about 2 tesla.

If the LHC used ordinary "warm" magnets instead of superconductors, the ring would have to be at least 120 km in circumference to achieve the same collision energy and it would consume 40 times more electricity.



Cern:

experiment of the century

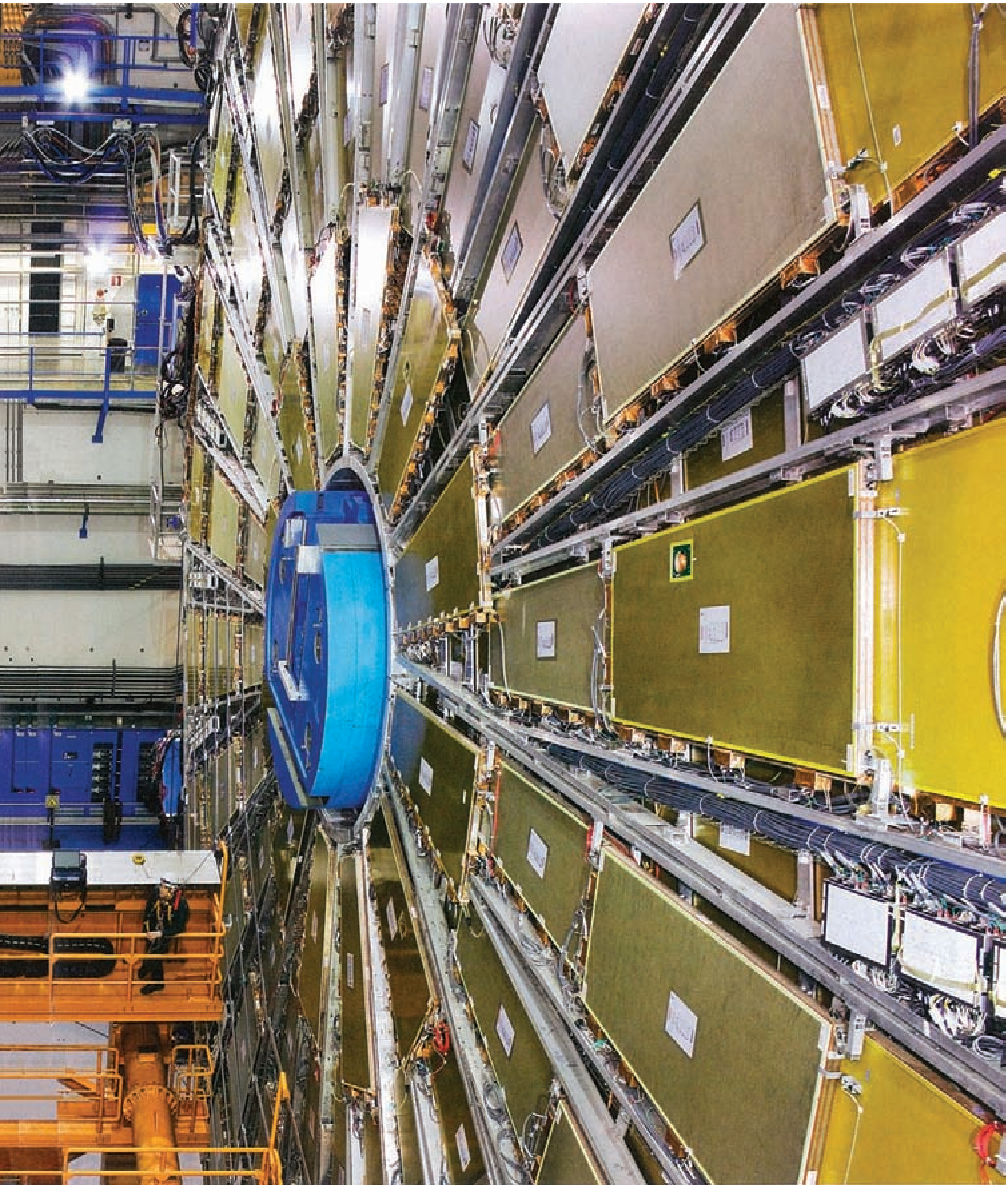
Twenty years in the making, the Large Hadron Collider just outside Geneva is ready for its debut.

Objectives: to detect the now famous Higgs boson and improve our understanding of the first moments of our universe.

The project is not only a scientific tour de force. It is a demonstration of how scientists and political leaders from many countries can cooperate to bring together unprecedented technological, financial and human resources.

Our special report is dedicated to the greatest feat of scientific collaboration ever.

December 2007: Atlas's cavern, one of the LHC's four detectors. Moving in the "endcap" electromagnet (star-shaped object on the left) © CERN



The extraordinary quest for our origins

BY DANIEL SARAGA ILLUSTRATIONS: NO DO/DANIEL SARAGA

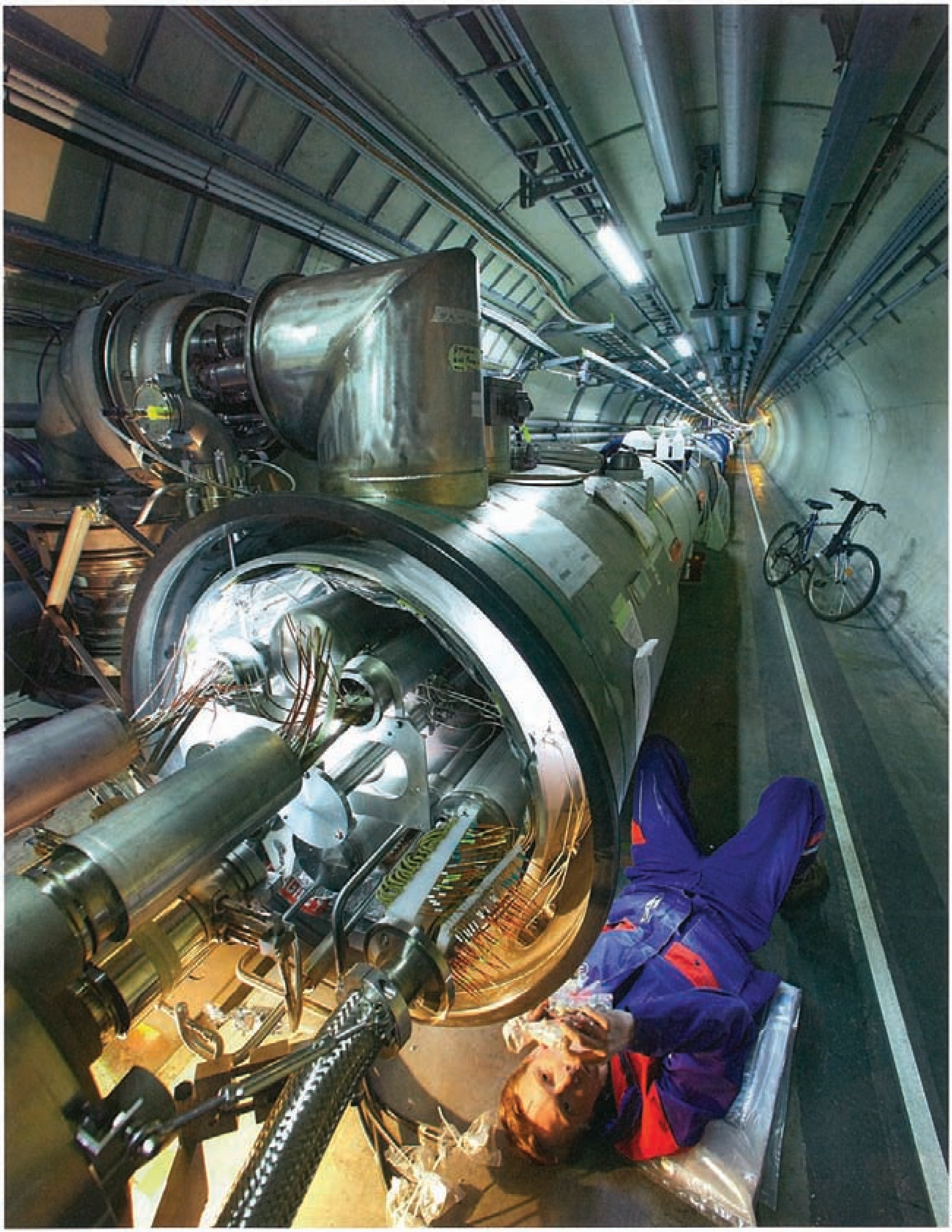
Shortly the LHC will set off on a journey toward the infinitely small, with 10,000 scientists aboard.

CERN's physicists will return from this expedition with evidence of the very first moments in the life of our universe, snapshots of the most ephemeral particles, and a few pieces that are missing from our jigsaw puzzle of the cosmos.

One hundred meters beneath the Franco-Swiss countryside, the biggest physics experiment of all time is about to begin at CERN. Detectors weighing thousands of tons will follow the tracks of half a billion collisions a second and broadcast millions of gigabytes of data per year to thousands of physicists around the world.

The goal is to detect at last the famous Higgs boson, a particle first imagined more than 40 years ago but as yet never observed. And also to discover new particles that may well provide the answers to two fundamental questions. The first is: how did it come about that matter won the battle with anti-matter during the first instants of the life of our universe? And the second: what is the composition of "dark matter," which makes up 85% of all the matter in the cosmos?

Welcome to the world of the Large Hadron Collider (LHC), CERN's new particle accelerator: the most effective scalpel in the world, which smashes and tears to shreds protons accelerated to almost a billion km/h in order to reveal their most intimate parts.



Inside the accelerator are two tubes each containing a bundle of protons driven by 1700 superconducting electromagnets cooled by liquid helium.

FASTER, COLDER

The protons move at phenomenal speed: 99.9999991% of the speed of light, which is equivalent to going seven times round the world in a second. The energy of the frontal collisions between protons results in "particle chemistry" whereby successive disintegrations and transformations alter and transmute these elementary specks of matter. And here the most celebrated equation in physics comes on stage: $E=mc^2$. Its significance is that a certain amount of energy is capable of creating a particle of a corresponding mass from nothing. In the LHC this energy will come from the proton collisions. To guide the protons, the engineers have installed 1700 superconducting electromagnets along 23 km of the 27-km LHC loop. These magnets, whose field strength reaches 8 Teslas, have to be cooled to -271°C, at which temperature their coils become superconducting. This is done with 700,000 liters of liquid helium. At this temperature the magnets consume little or no energy because the coils have almost no electrical resistance.

The next layer is the calorimeter, a succession of lead and plastic layers, which stops most of the particles and measures their energy. However the muons (a kind of electron, but much heavier) continue on their way to cross the last detector at about 10 meters from the proton beam, and end up underground. As for the neutrinos, they cannot be stopped, but continue to travel the cosmos at the speed of light.

AN AVALANCHE OF INFORMATION

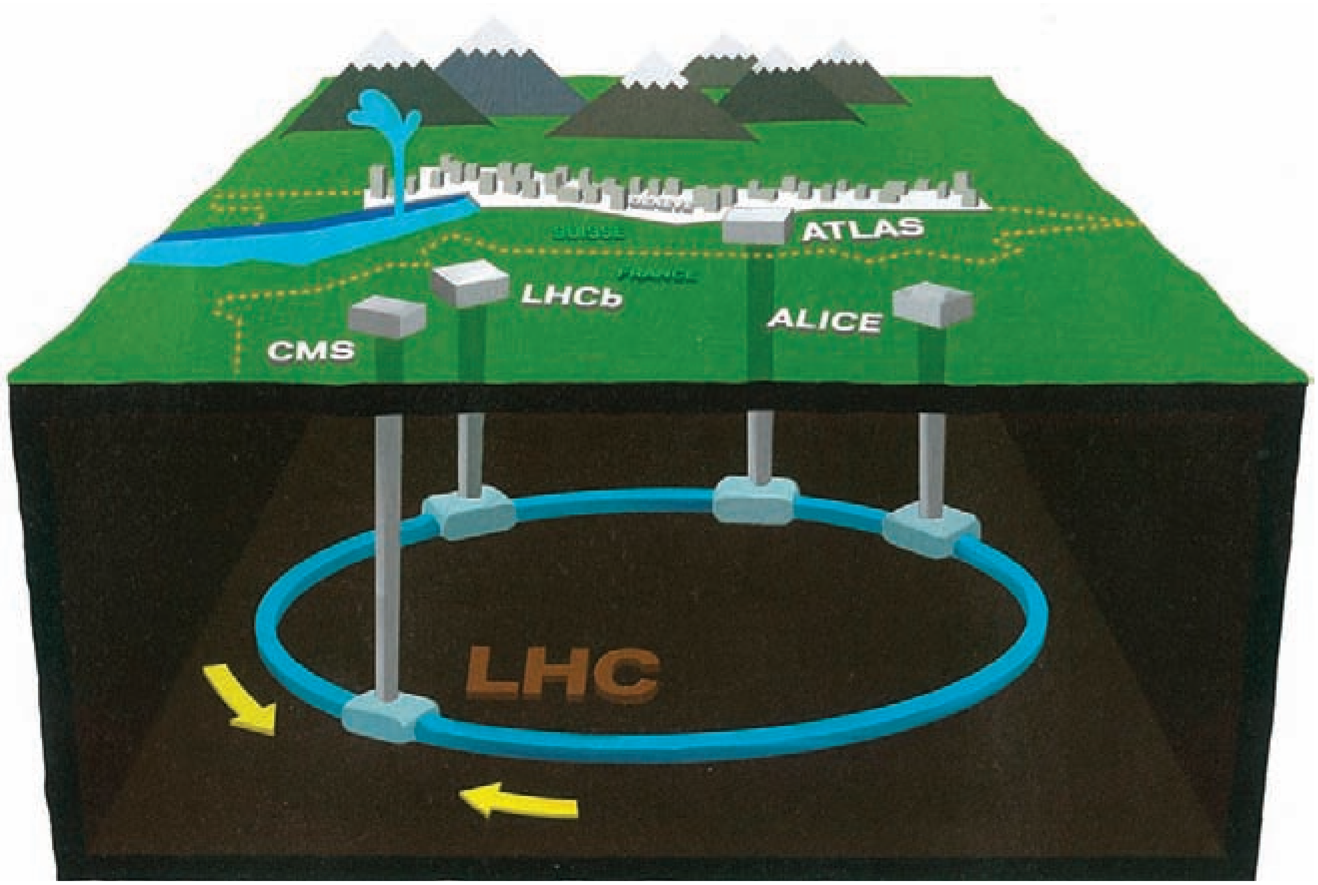
The sheer volume of data from the LHC and Atlas makes you dizzy. Some 2800 packets each thinner than a human hair and containing a hundred billion protons cross each other 40 million times a second. Each time the packets cross there are a score of collisions each creating a multitude of ephemeral particles, tracked by Atlas's hundred million pixels. The total amount of raw data resulting is phenomenal: every second 70,000 GB, which would fill a stack of CDs 150 meters high. It is impossible to store data at this rate. The raw data are

The 1,700 superconducting electromagnets along 23 km are cooled to -271°C with the help of 700,000 liters of liquid helium

The task of analyzing the particle collisions is like that of a ballistics expert who must determine from where a shot was fired by analyzing the impact of the bullet. The physicists retrace the trajectories of the particles from the traces they leave in the detectors, which are built around the proton beams like the layers of an onion. At the centre of the main detector, Atlas, there is a giant ultra-rapid digital camera with millions of silicon pixels, each of which emits an electrical impulse when hit by a charged particle. From the chain of such impulses the track of the particle can be calculated. After this the particles cross a second detector made up of hundreds of thousands of tubes containing xenon, a noble gas similar to the neon in an ordinary fluorescent tube. The passage of the particle ionizes the gas, i.e. it causes the gas to lose electrons which are collected by a metal wire running through the center of the tube. It's the same principle as that of the Geiger counter measuring the level of radioactivity.

filtered electronically by devices known as "triggers," which keep only the data from the most promising collisions. Further, they take account of only a part of the pixels so as to speed things up. This is enough to indicate the presence of an interesting particle, as for example a muon leaving the collision at a wide angle. The triggers have only 25 billionths of a second to do their work.

The second stage of filtering is done by a bank of about 2000 computers sitting beside Atlas. They partially reconstruct the particles' trajectories in order to select those of greatest interest, sending on to CERN's computing center the data on only about 100 collisions per second, a rate of 300 MB/s. The data are then stored on thousands of magnetic tapes and distributed to hundreds of computing centers around the world, which reconstruct each particle's exact trajectory in order to identify the particle and calculate its mass.



The greatest experiment of all time in particle physics. Astride the Franco-Swiss frontier, CERN's new particle accelerator, the LHC, is installed in a circular tunnel 27 km in circumference. It is equipped with four detectors: Atlas, Alice, CMS and LHCb.

The amount of data to be analyzed is still gigantic, amounting to about 10 million GB a year. In order to share the computing resources the physicists need, CERN has perfected a new technology for shared computation, known as the GRID. It is the heir to the World Wide Web, itself developed at CERN to facilitate the exchange of data. In all, 1900 scientists will take part in the ATLAS experiment.

A RETURN TO THE ORIGIN OF THINGS

To understand what CERN is after, it's simplest to begin at the beginning, when the universe was born.

> At the beginning was the Big Bang. The entire universe, concentrated in one infinitesimally small point, began to expand and cool, liberating particles of matter and the fundamental forces. The first atoms appeared, and there was light. The atoms accumulated to form the stars, which created all the known atoms, and then exploded to form the planets.

We owe this modern cosmogony (p. 17) to the combined efforts of cosmology, which indicates that it all started 13.7 billion years ago with the Big Bang; of astrophysics, which explains how nuclear fusion in the heart of the stars generated all the atoms; and of particle physics, which discovered the 12 elementary particles and the forces that bind them. The goal of the LHC is to find out exactly what happened right at the beginning, when the fundamental forces separated. The physicists will study the collisions of protons at energies that have never been equaled, which will recreate for an instant the conditions prevailing when the universe began. The researchers hope that the proton collisions will result in new particles never yet observed, for example the Higgs boson, but also particles that may serve to explain dark matter (p. 12).

"The Higgs boson plays an essential role in particle physics and in the history of the universe," explains Géraldine Servant, a physicist at CERN. In the 1960s physicist Peter Higgs described how an extra-force

A little light on dark matter

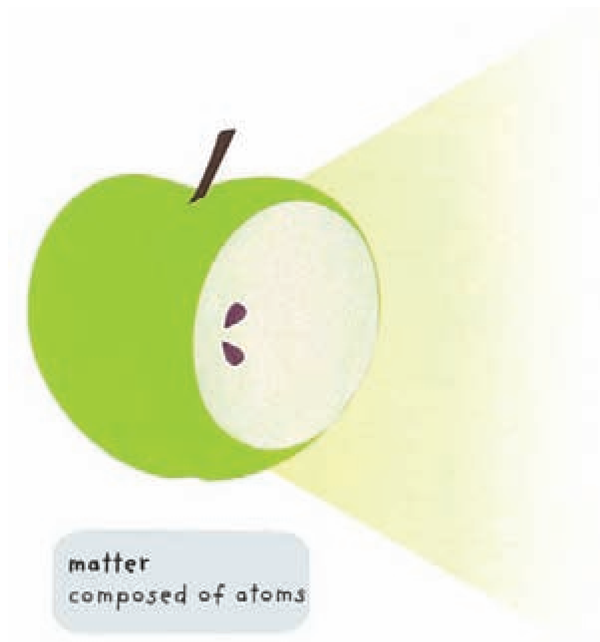
Dark matter is invisible despite its colossal mass, which is estimated to be 85% of the total in the universe. The destiny of the universe itself depends on it: if the universe is light enough, it will keep on expanding forever; if not, it will end up collapsing on itself in a smashing big crunch – a kind of inverted Big Bang. And it's the amount of dark matter that will decide the issue.

How do we know that this invisible matter exists at all? Simply because the galaxies observed in the cosmos do not rotate as they should. If we take account only of visible matter (the stars and the interstellar gases) the stars located at the edge of the galaxies should rotate more slowly than those near the center, like coffee stirred in a cup. But astronomic measurements show that those at the edge rotate as quickly as those at the center, as if all were mounted on a rigid disk. The preferred explanation is that there exists an enormous amount of extra mass forming a halo around the galaxies; this is dark matter.

The questions remain: what is this matter made of and is there a type of particle at once massive and invisible? In order to be "invisible" this particle must interact very weakly with the other particles, which would be so if for instance it was sensitive only to the weak force. Such wimps (for weakly interacting massive particles) are predicted by recent theories such as supersymmetry or technicolor. The energy of the new particle accelerator LHC should be sufficient to create them – if indeed they do exist.

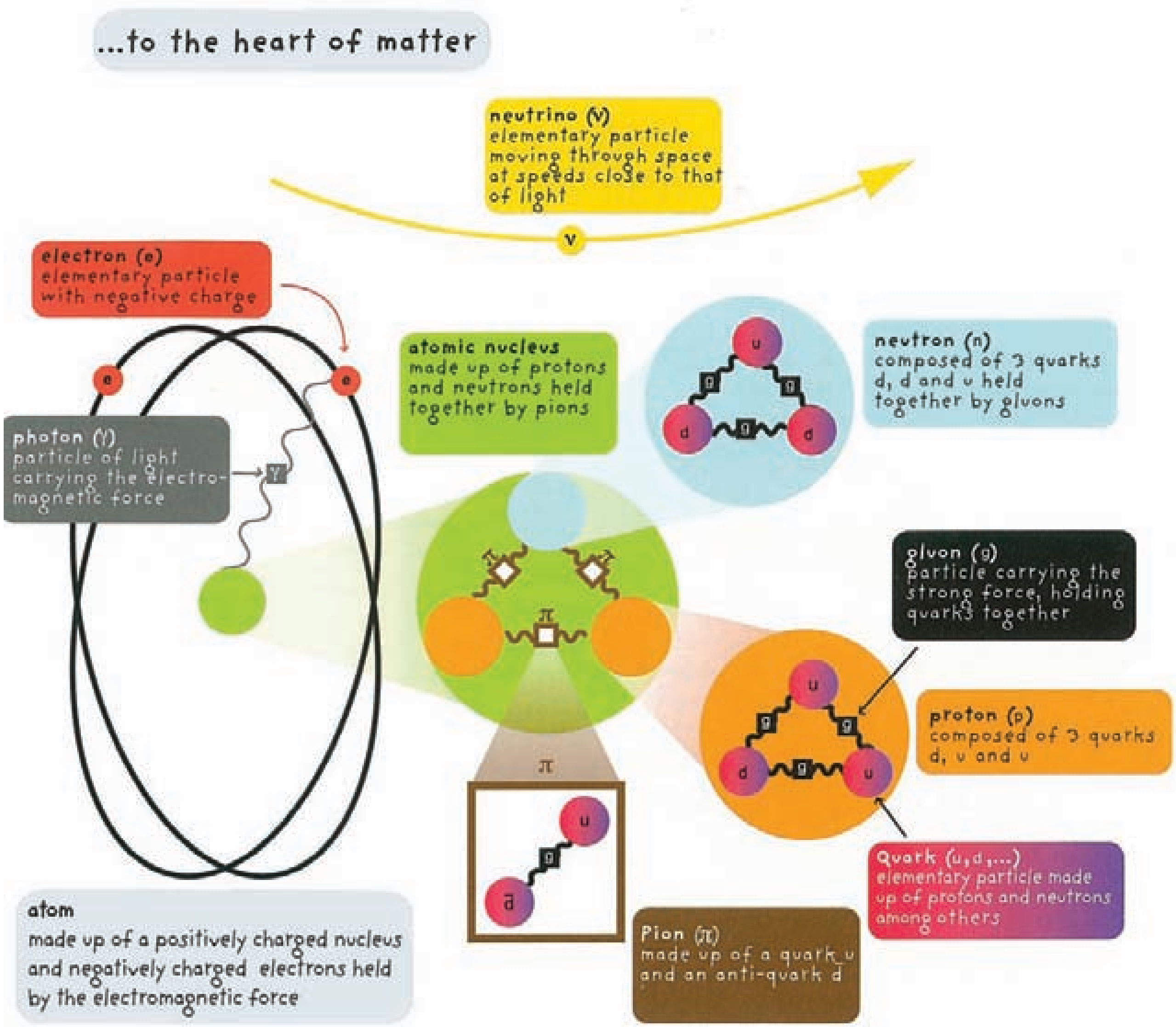
Since these particles by definition hardly interact with the others, it is extremely difficult to observe them. An indirect method has to be used, which one may compare to a game of billiards with one invisible ball. If a wimp were created as a result of a collision, the paths of the other particles would be changed and the nature of the changes would allow physicists to determine the characteristics of the wimp. With a bit of luck, the wimp might then turn out to have enough mass to account for the cosmos's dark mass, and so relieve the physicists of a problem that has taunted them for more than 30 years.

A trip...



particle could help to better understand one particular instant in our history, about a picosecond (10^{-12} s) after the Big Bang, when the electromagnetic force separated from the weak nuclear force. "The Higgs boson explains how the particles responsible for the weak force, the W and Z bosons, acquired mass while the photon, carrying the electromagnetic force, has none. The physicists realized that the Higgs particle could not only explain the mass of the W and Z bosons but also that of all the particles of matter like the quarks and the electrons."

The Higgs boson exerts a force on particles that slows them down when they move, rather like the way a crowd



of hysterical fans hinder the physical progress of a celebrity.

Such resistance corresponds exactly to the notion of mass, in that the heavier the object the more difficult it is to get it moving. The only particles insensitive to the Higgs particle and hence spared this sluggishness are the gluons, responsible for the strong nuclear force, and the photons.

So far the detectors at CERN and Fermilab in the U.S. have failed to detect the Higgs particle, but the physicists are optimistic that it will be found thanks to the LHC. "The Higgs boson ought to have a mass of less than 1 TeV," declares Servant who, like all particle physicists, measures mass in electron-volts – a unit of energy. "This limit derives from both experimental and theoretical results." With an energy of 14 TeV the new particle accelerator should thus be able to create the Higgs boson. However, detecting this particle is by no means the only goal of CERN's new experiments.

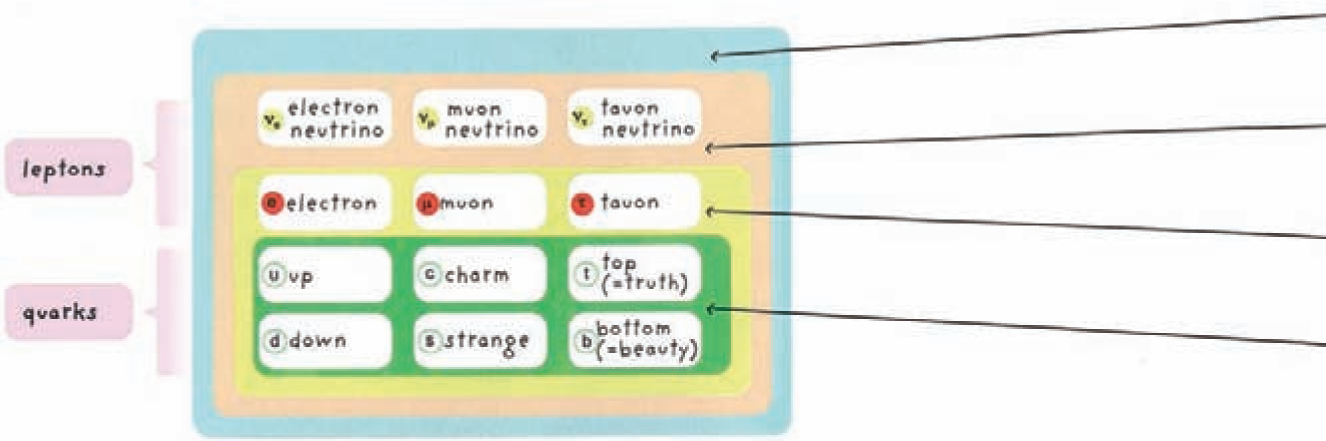
A MATTER FOR DISCUSSION

"Theorists are amusing themselves discussing which would be worse: to discover a Higgs boson with exactly the properties predicted in the standard model or to discover that there is no Higgs boson," writes physicist John Ellis, who works at CERN. In the first case the

The universe is made up of matter

Matter
is made of fermions, which are divided into leptons and quarks. At the moment 12 fermions are known.

12 fermions

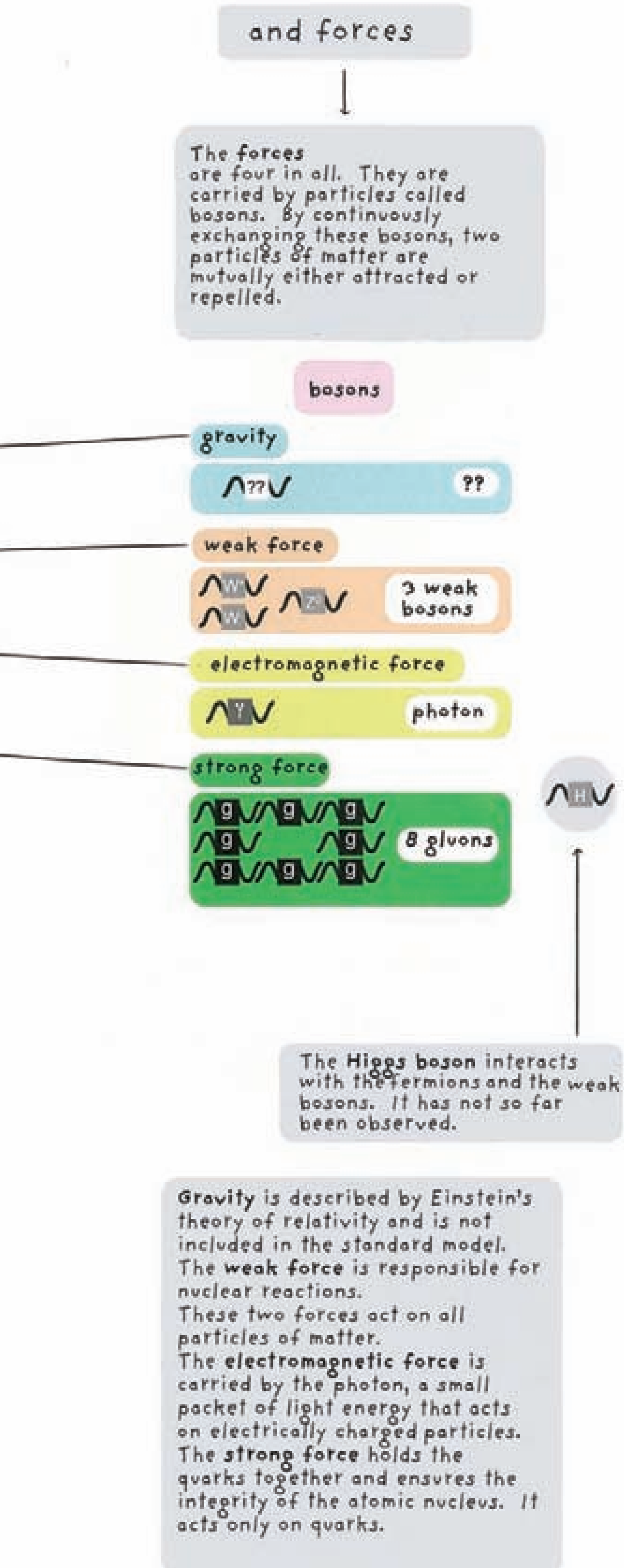


Quarks are always held together by gluons in composite particles called hadrons. They are found either in threes in baryons like the proton and the neutron, or in pairs in mesons such as the pion.

Atoms are composed only of fermions of the first column: electrons and up and down quarks. The other elementary particles are too unstable to exist for more than a fraction of a second, or else traverse the cosmos at very high speed.

The **standard model** describes how the weak forces, the electromagnetic force and the strong force act between the 12 fermions and their anti-particles. It ignores gravitation and does not explain the values of certain parameters such as the masses of the particles and the strength of the forces.

Antimatter
Each particle has its anti-particle, which has the same mass but with a charge of the opposite sign.



theoretical predictions would be confirmed, the Nobel Prizes would fall like manna, but there would still be some problems left to be solved. The absence of a Higgs boson would in fact be most interesting for the researcher, but a lot more dicey to explain to the politicians who financed the LHC.

"The theoreticians don't really understand how the Higgs boson can have so little mass, and hence be so insensitive to high energy physics," explains Servant. "A priori, its mass ought to correspond to the energy of the very first moments of the universe, when all the forces were still unified – energy a trillion times greater than that of the LHC. How can we understand that its mass could be so low and that the Higgs boson could be observed at CERN?" Resolving this contradiction requires a mathematical development going beyond the standard model.

70'000 GB every second, or a stack of CDs 150 meters high.

In short, the Higgs boson is not enough. For 50 years, theoretical and experimental physicists have gone forward hand in hand, with the former predicting the existence of new particles and the latter providing confirmation through experiments on ever more powerful particle accelerators.

The standard model is the fruit of this collaboration (see opposite). Yet despite its success, it has a certain number of problems, as for instance the absence of a particle that might explain dark matter, or one to account for the difference between matter and antimatter (p. 52). The standard model also does not explain the mechanism responsible for the mass of the Higgs boson, and does not say whether the Higgs is an elementary particle or an agglomeration of particles. Over several decades the theoreticians have therefore developed new models that deal with these problems: supersymmetry, technicolor, and theories based on more dimensions.

"Each theory predicts the existence of new particles," says Servant. "If the LHC finds them, we'll have some solid clues as to which theory is the right one." What the physicists want, then, is a "new physics" that will take them over and beyond the standard model. If the Higgs boson is detected, it will be the acid test for these theories, for they also predict its mass.

AN ARMY OF RESEARCHERS

But let's come back to earth, for it's here that these discoveries will – or will not – be made. Atlas's direct competitor is called CMS and is located diametrically opposite Atlas. Twenty-one meters long and 16 meters high, the Compact Muon Solenoid is certainly smaller, but at 12,500 tons it is even heavier than Atlas. This instrument, containing more metal than the Eiffel tower, is a "general" detector like Atlas, and with the same goals – to find the Higgs boson and any new particles. Its strategy is different, however. It has three muon detectors and concentrates on their trajectories, in the hope that these electron-like particles (though 200 times heavier) will appear during the process of creating the Higgs boson. With an army of 2000 researchers, CMS is a serious rival to Atlas.

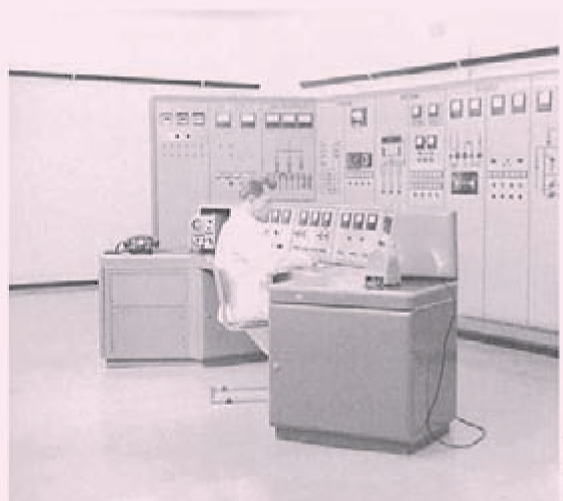
The third detector is called LHCb, for LHC beauty. It aims at finding the difference between matter and antimatter by studying the disintegration of particles containing quarks "beauty" (p. 56).

The fourth detector, Alice, will operate only for one month a year, when the LHC is emptied of protons and will instead accelerate atoms of ionized lead. The collisions of these much heavier particles will generate temperatures of a trillion degrees, creating a plasma of quarks and gluons, which was the state of the universe during the first millionth of a second of its life. Two more modest experiments, Totem and LHCf, will measure the size of the proton and study the cosmic radiation produced by the LHC.

The LHC program is extremely ambitious. The vast majority of physicists are convinced that it will lead to many discoveries, justifying the investments made. If that happens, the CERN adventure will once again have demonstrated man's extraordinary capacity for rolling back the frontiers of knowledge and his ability to organize and bring projects of unprecedented complexity to fruition. If it doesn't, then the politicians may look the other way when they are again asked to dip into their pockets. Only the future, hidden among the billions of gigabytes of data that the LHC will generate, will tell. ■

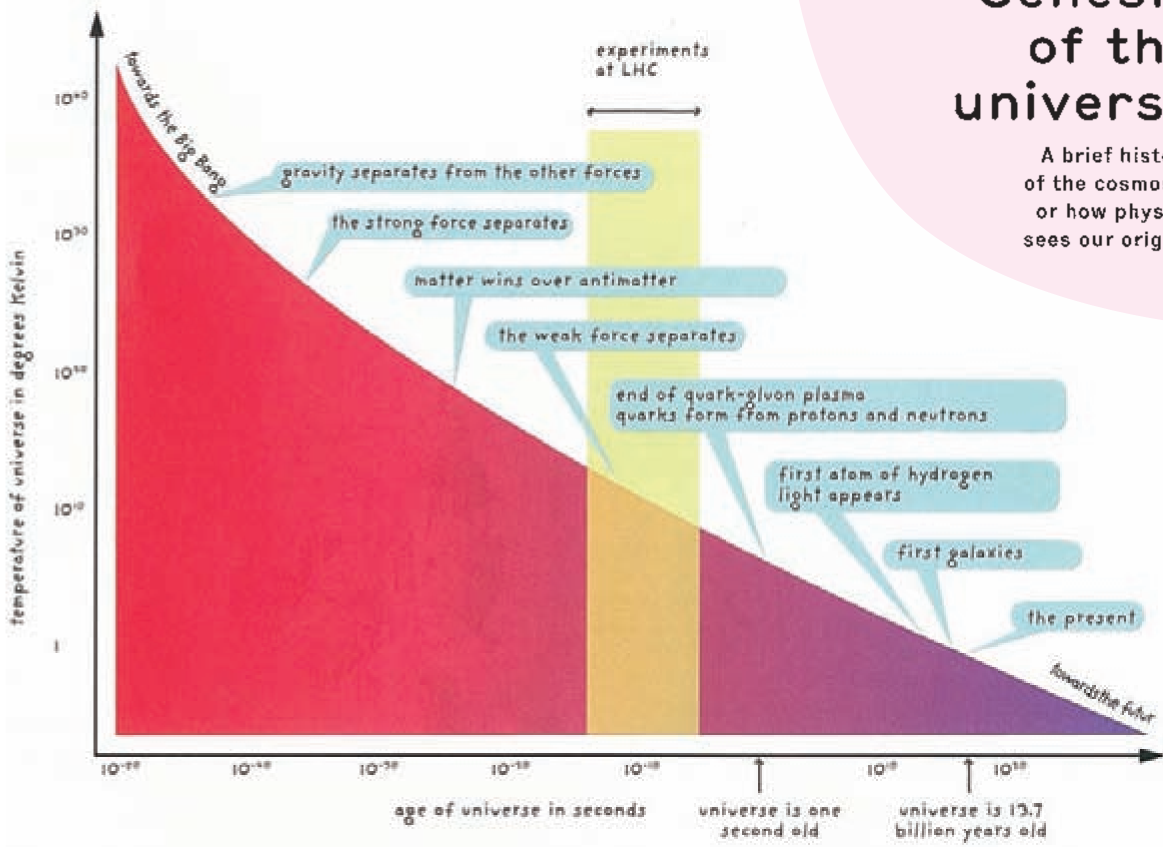
LE LHC EN CHIFFRES

Circumference	26.7 km
Speed of protons	1,079,000,000 km/h (99.9999991% of the speed of light)
Duration of a proton beam	10 hours
Collisions per second	600 million
Maximum temperature of collision	1,000,000,000,000°C
Temperature of the superconducting magnets	-271.3°C
Amount of liquid helium	700,000 liters
Weight of the CMS detector	12,000 tons
Dimensions of the Atlas detector	46 x 25 meters
Raw data rate of the detectors	70,000 GB/s
Data storage rate	700 MB/s (20,000,000 GB/y)
Power required by the LHC	120 MW (7% of Geneva's consumption)
Cost of the LHC with its detectors	about 6 billion Swiss francs
Number of scientists working with the LHC	more than 10,000
Research Institutes	more than 500
CERN's budget for 2007	981 million Swiss francs
Number of people working at CERN	2645



Genesis of the universe

A brief history of the cosmos — or how physics sees our origins



The universe began with the Big Bang about 13.7 billion years ago. During the first few moments it was no more than 10^{-30} meters in diameter and had a temperature of 10^{32} degrees. At this point the universe was very simple: there was only one force and just as much matter as antimatter. At 10^{-44} seconds the gravitational force separated from the primordial force, i.e. it took its own distinct form.

This separation of the gravitational force completely mystifies the physicists, who can only speculate with the help of extremely complicated models such as superstring theory, which requires a universe in ten dimensions. Indeed, one of the Holy Grails of modern physics is to build a "theory of everything" which would explain how the four fundamental forces began as one. Studying this primeval state directly would require a particle accelerator more than a billion billion times more powerful than the LHC, which would be so big that our entire solar system couldn't hold it.

But the universe didn't wait; it continued to cool down, and at 10^{-35} seconds a second force appeared: the strong nuclear force, applied by the gluons and holding quarks together. Matter then triumphed over antimatter in a universe made up entirely of a plasma of quarks and gluons. At a picosecond (10^{-12} s) the final separation of forces took place, releasing the weak nuclear force (responsible for nuclear reactions) and the electromagnetic force. The new experiments at CERN will clarify the events of this stage, when the Higgs boson is supposed to have endowed the particles with mass.

Then matter began to take shape. At one second after the Big Bang the quarks separated from the plasma and combined in threes to form stable nucleons, protons and neutrons. Nuclear fusion over the next few minutes gave birth to new nuclei, notably that of helium. Now things slowed down a bit: it took another 380,000 years before the first atoms appear, when the universe was cool enough to allow the nuclei to capture electrons. At last photons could escape, and there was light. This primordial light can still be seen today, and is known as "fossil radiation." The atoms agglomerated under gravitational attraction and condensed to form stars. At the center of the stars, the temperature was high enough to enable nuclear reactions to take place and transmute the atoms, creating all the elements of the periodic table. Some stars exploded as supernovae and the resulting debris spread throughout space. This "stardust" condensed under gravity and ended up forming the planets some billions of years after the Big Bang. All that now remained was for the earliest life-forms to appear, and evolution did the rest.

THE MULTI-UNIVERSE COSMOS

The First Complete Story of the Origin of the Universe

Karel Velan

Karel Velan was raised and educated in Czechoslovakia, where he earned a master's degree in mechanical engineering. He emigrated to Canada from his home country and in 1950 founded Velan, Inc., in Montreal. He is now the CEO of this international manufacturer of industrial and nuclear valves and Tom Velan, his son, is President. Since his early youth, Velan has been facinated with astrophysics and cosmology, and has written many articles and two books on these subjects.

THE LANGUAGE OF SCIENCE Plenum PUBLISHING CORPORATION

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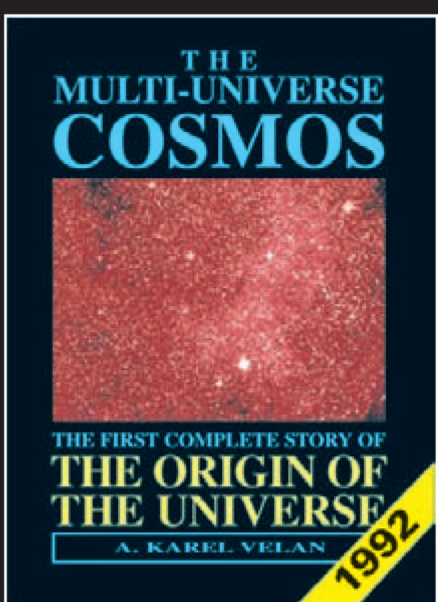
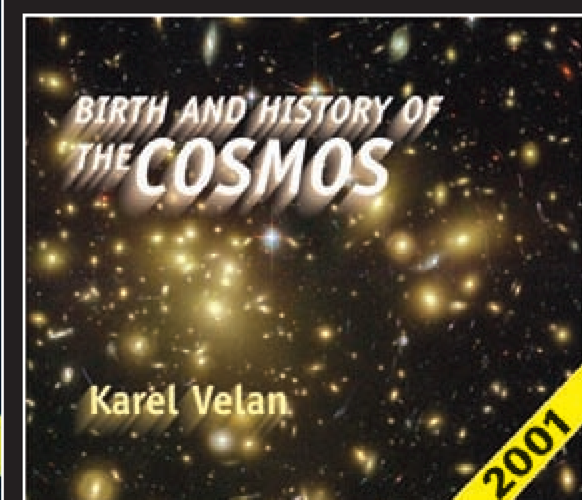
"Karel Velan's book is a remarkable achievement"
– **Sir Martin Rees,** University of Cambridge, Institute of Astronomy, Cambridge, United Kingdom

"The author of the *Multi-Universe Cosmos* does a good job making clear what it is about conventional models of the early universe that is likely to bother most people."
– **Virginia Trimble,** Department of Physics, University of California, Irvine; Astronomy Program, University of Maryland, College Park; and Editor, *Comments on Astrophysics*





"We are not just manufacturers of cryogenic valves but we also share, with the 10,000 scientists working for CERN, their passion for cosmology, in order to discover more details about the birth of the cosmos."

Karel Velan
Founder and CEO of Velan Inc.

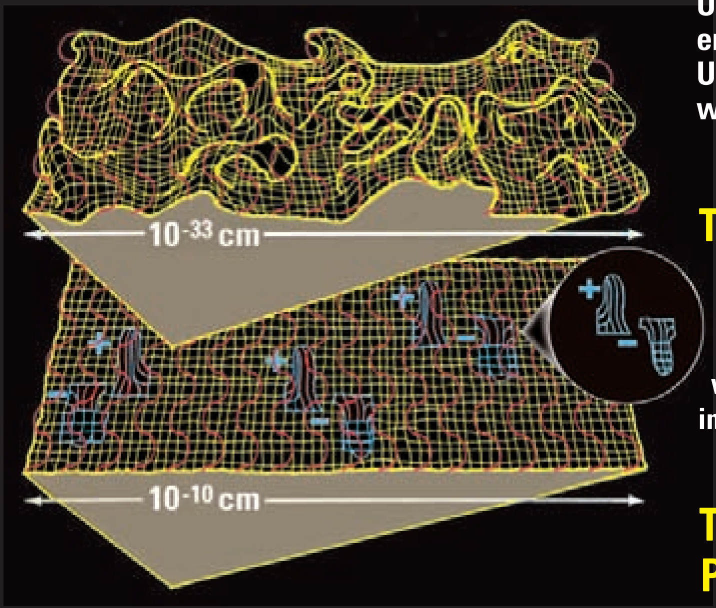
PRESENT COSMOLOGICAL THEORIES ARE IN CONSTANT EVOLUTION

The present leading cosmological theory of the classical Big Bang with its various refinements, as well as the prevailing theory of chaotic inflation, do not provide any explanation on the creation of the Singularity, matter and energy, the explosion process of the Singularity or an acceptable explanation for the creation of galaxies without the introduction of mysterious and unproven dark non-baryonic matter.

THE MULTI-UNIVERSE COSMOS

Karel Velan

I propose an entirely new approach to the origin of the Cosmos and our universe, one of many in a Multi-Universe Cosmos.



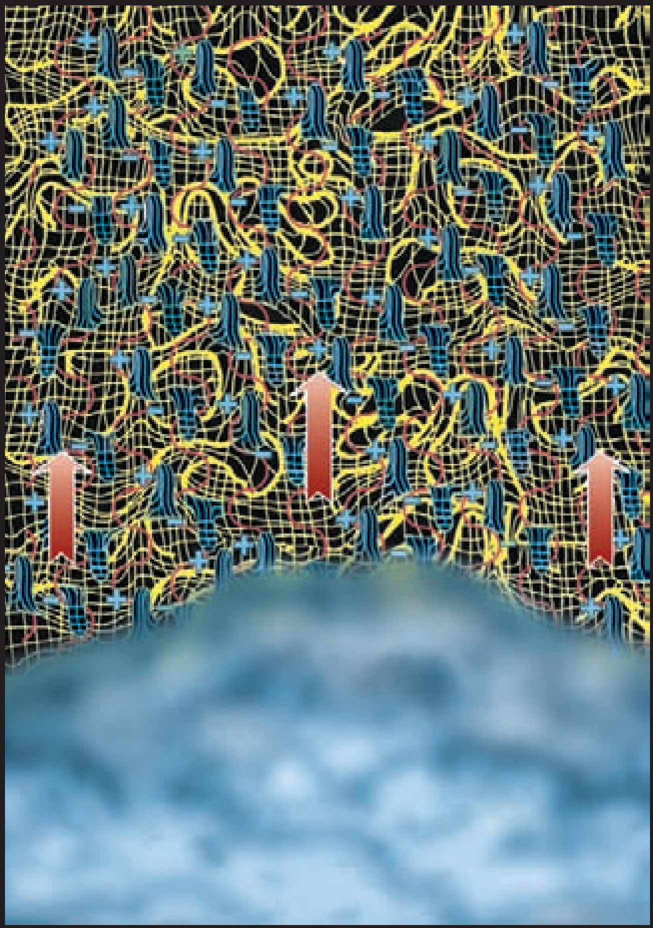
The new model eliminates the mysterious singularity at time 0, the origin of which and its explosion no one can explain. It is the first theory which describes the creation of the Universe using laws of physics which hold everywhere and embody the conservation law of energy. Long before any Universe was born, the 4-dimensional cosmic space-time was created and all laws of physics established.

The Inter-universe Space-time Continuum

THE 4-DIMENSIONAL COSMIC SPACE-TIME *(shown left)*

Quantum fluctuations of space are depicted graphically and the primordial radiation field (waves) is shown together with virtual particle pairs appearing spontaneously, interacting and annihilating.

The Particle Creation Process from Virtual Particles and Primordial Radiation



THE PARTICLE CREATION PROCESS
A cloud of elementary particle pairs is being borne from virtual particles (+, –) acquiring their rest mass from the primordial radiation field (red waves).

About 18 billion years ago, an area of the cosmic space-time vacuum underwent sudden dynamic quantum fluctuations of extreme intensity. Small space-time cells of 10^{-33} cm vibrated, expanded, attained maximum size, collapsed and exploded most actively.

The powerful topological distortions were passed on from one area to another like tidal waves. This wave effect caused the simultaneous, widespread appearance of virtual particle pairs of electrons, electron-neutrinos, up & down quarks (u, d) and their anti-particles. These were all swept up by the primordial radiation field, and a great transformation of virtual particles to real particles ensued.

Many other types of particles and anti-particles appeared but were quickly annihilated, due to their very short lifetimes into photons. The powerful cosmic radiation field provided the virtual particles with their rest mass necessary to release them into the real world following the equivalent formula of Einstein $M = E/c^2$. Meanwhile, a sea of photons originated from the primordial radiation and from the annihilation of particle-antiparticle pairs. In seconds, a vast dense cloud of radiation and elementary particles had formed.

The photons, electrons, electron-neutrinos, and quarks (which were later confined in protons and neutrons) became the building blocks of our universe.

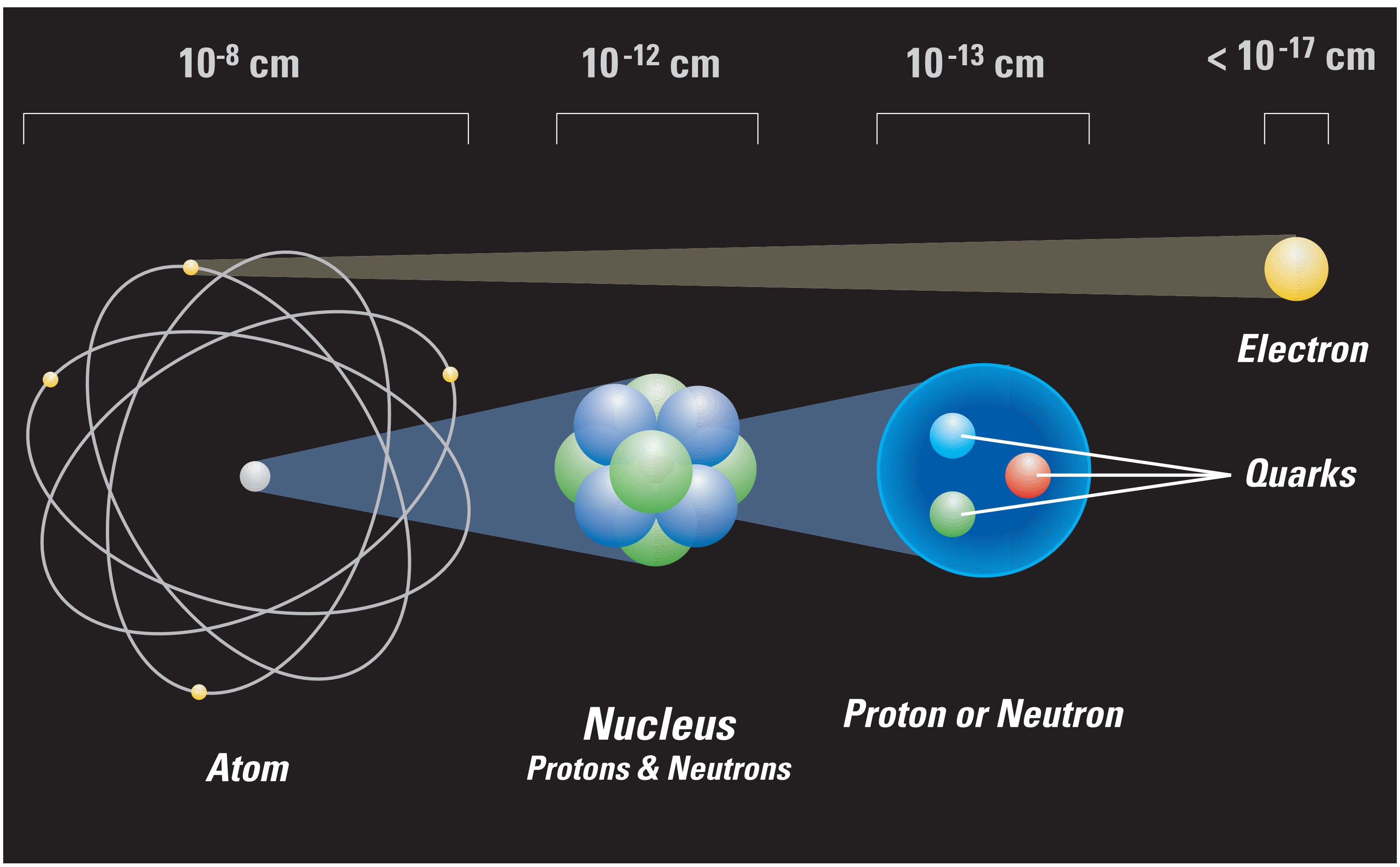
As there was no other justification established, so far, for the presence of virtual particles in the cosmic space-time, it is logical to conclude that their high density presence together with the cosmic primordial radiation field was assigned a major role in the creation process of universes. Space-time in our Universe is an extension of the cosmic space-time.

THE ELEMENTARY PARTICLES

Pages 11–18 only from Karel Velan's book on his cosmological theory; *The Birth and History of the Cosmos* (2001).

Newton showed that the laws of physics, which apply here on Earth, operate in exactly the same way throughout the known universe. Today we know this is true for the building blocks of nature as well. The structure and behavior of matter follow essentially the same laws whether in the cores of distant stars and galaxies, or in a laboratory right here on Earth.

All atoms everywhere are composed of quarks in protons and neutrons and electrons, which combine to form the hundred-or-so chemical elements (hydrogen, oxygen, nitrogen, carbon, iron, copper, etc.) found in the universe. These elements then combine to form an endless variety of molecules, which constitute both living and non-living matter.

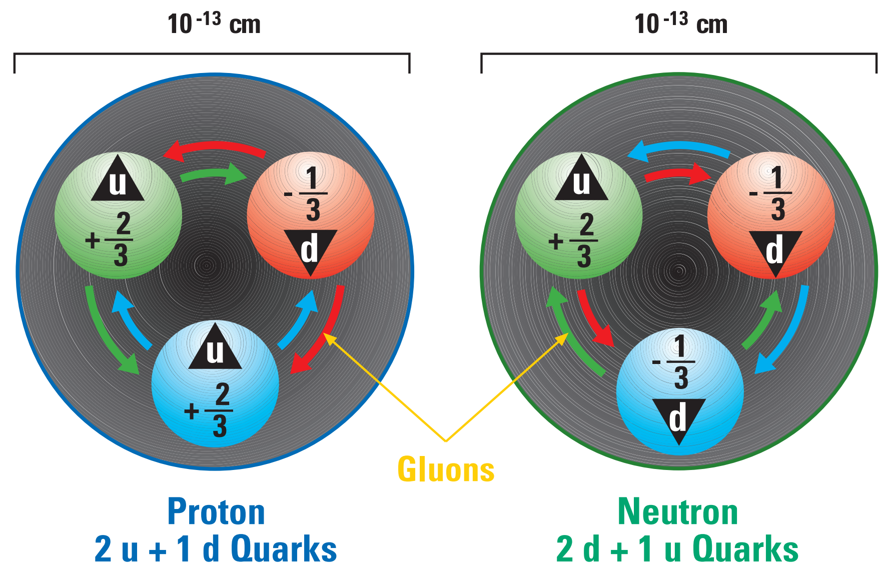


Structure of an atom and its components

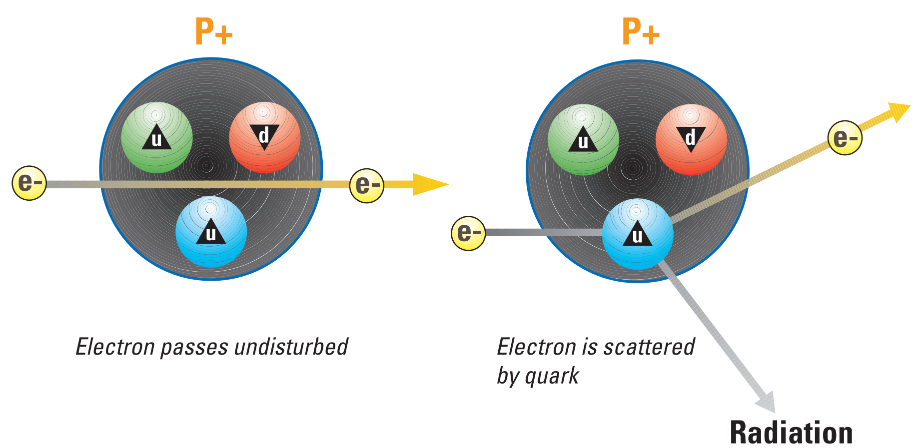
Properties of protons and neutrons

Protons and neutrons are built from smaller particles called quarks. One proton has two quarks **u** (up) and one quark **d** (down), while a neutron possesses two quarks **d** and one quark **u**. The quarks are held together by gluons, particles of the strong nuclear force.

As they both consist of three quarks, they have nearly the same mass. The quark **u** has an electric charge of **+2/3** and the **d**, **-1/3**, resulting in a proton charge of **+1** and zero for the neutron.



Experimental proof for the gluon-quark structure of protons and neutrons



Electron passes undisturbed

Electron is scattered by quark

Nucleons		
Particle	**Proton P+**	**Neutron N**
Mass in MeV*	938.2	939.6
Electric charge	+1	0
Half-lifetime	Stable	10.3 min. (if free)

** According to Einstein's famous equation $E = mc^2$, mass can be expressed as energy when multiplied by the speed of light squared. These units are expressed in millions of electron volts (MeV). One electron volt is about equal to the average energy of a solar photon. 1 MeV = 10^6 eV, 1 GeV = 10^9 eV.*

The four building blocks of the universe

form what is called the electron family

Two types of quark

(up and down)

These quarks combine in groups of three to form protons and neutrons, which in turn combine in various numbers to form the nuclei of atoms. A hydrogen nucleus contains a single proton, while it takes about 240 protons and neutrons to form the nucleus of heaviest atoms like uranium.

Electrons

Electrons are very light and since their charge is opposite that of the protons, they are held in orbit about the atomic nucleus. Stripped from atoms, moving electrons produce electrical currents and magnetic fields familiar to us all.

Electron neutrinos

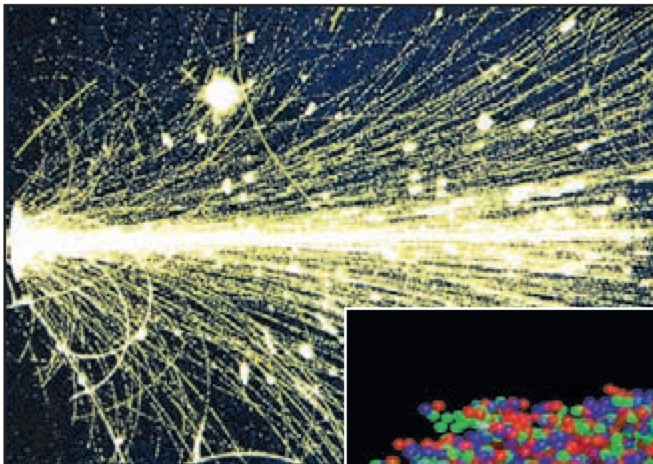
These mysterious particles have no electrical charge and possess an infinitesimal amount of mass or perhaps no mass at all. They are therefore very hard to detect even though they play an essential role in many nuclear reactions.

The electron family

Particle	Electron	Quark u up	Quark d down	Electron neutrino
Symbol	e-	u	d	ν_e
Mass in MeV	0.511	~312	~312	1 eV ?
Mass in grams	0.9×10^{-27}	$\sim 0.535 \times 10^{-24}$	$\sim 0.535 \times 10^{-24}$	1.78×10^{-33} ?
Electric charge	-1	+ 2/3	- 1/3	0
Free particle	yes	no	no	yes

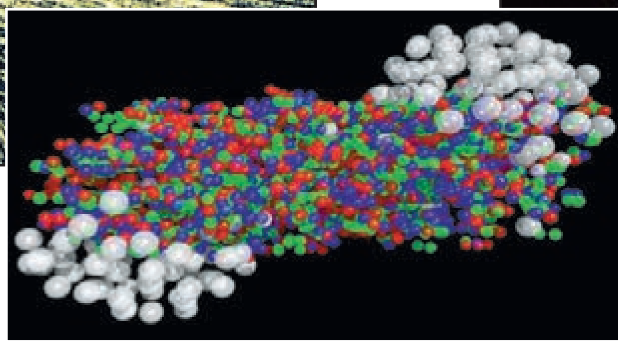
For more details see pages 119-135 in Velan's book, *The Birth and History of the Cosmos (2001).*

The existence of free quarks proven already in 1988 and 1993-1999 at CERN

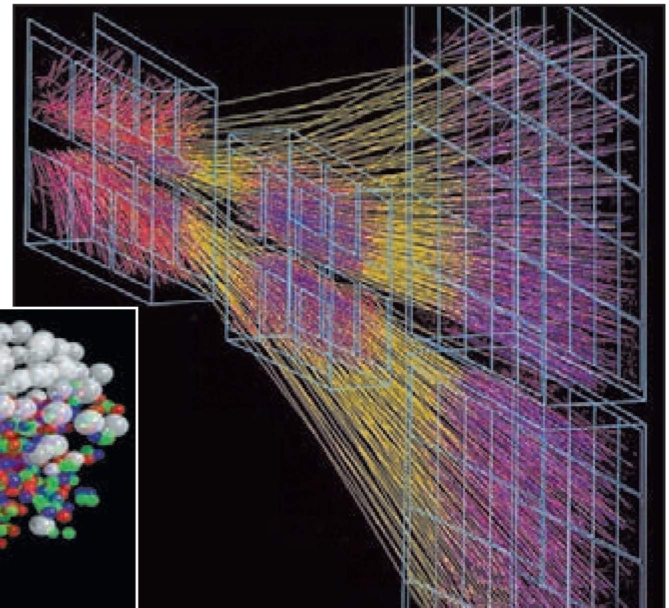


1988

Quark-gluon plasma at CERN, Geneva



Soup of quarks (coloured balls) is set free from protons and neutrons (grey balls) when they collided.



1993–1999

Quark-gluon plasma at CERN, Geneva

Free quarks and gluons, which play an important role in the Velan cosmological model had not been detected anywhere in the universe when the multi-universe theory was first announced in 1985.

Three years later, in 1988, there was a breakthrough at CERN (Centre européen pour la recherche nucléaire). A quark-gluon plasma was created by colliding relativistic sulfur ions against stationary ions of gold. The resulting "fireball" of quarks and gluons was extremely dense and short-lived, lasting only 6.5×10^{-23} second.

Similar experiments have been repeated in recent years (1993 – 1999 at CERN), confirming that at extreme energy densities, quarks can exist freely without confine-ment in protons, neutrons and mesons.

Colliding nuclei of lead (208 protons and neutrons) at near speed of light with a thin stationary foil of lead has shown (diagram above, right) that more than 1,600 particles sprayed out from a single collision, carrying evidence of a quark-gluon plasma. The tremendous energy and pressure of the plasma caused it to explode outward. When temperature and density dropped, the quarks rapidly paired off again into protons and neutrons.

Much smaller Hadron colliders at CERN enabled in 1985 and 1993–1999 already to create a quark-gluon plasma to prove the theory

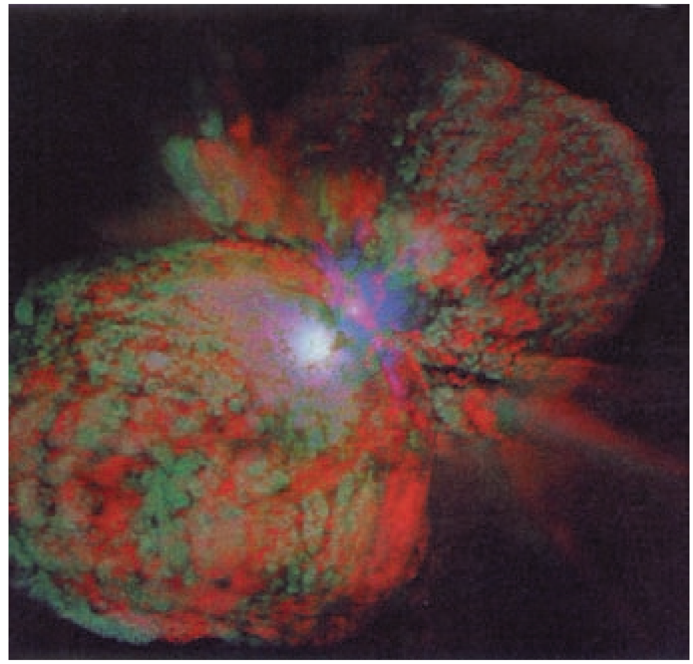
It takes tremendous energy to reproduce the reactions that occur on a cosmic scale. To reach these energy levels, larger and larger particle accelerators are built. Thanks to these instruments, we can generate collisions between particles travelling at nearly the speed of light, and study in detail what happens when they interact.

Over the years, we have discovered hundreds of extremely short-lived elementary particles, which however do not play a fundamental role in the evolution of the universe itself.

THE FOUR FORCES OF NATURE

Just as matter and the laws of physics are the same throughout the universe, the forces operating in nature are the same everywhere. They are universal, and all physical interactions stem from the four known forces.

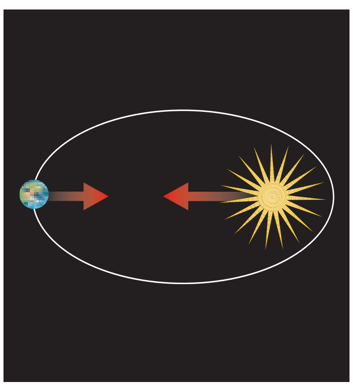
Apart from determining the behavior of the universe, these fundamental forces also played a crucial role in its formation. Their study, like the study of elementary particles, helps us understand what took place when the universe formed billions of years ago, and how it has evolved ever since.



The fundamental forces at work are seen in this image of Eta Carinae, observed by the Hubble Space Telescope. Eta Carina was the second brightest star in the sky when it last exploded in 1843. (NASA).

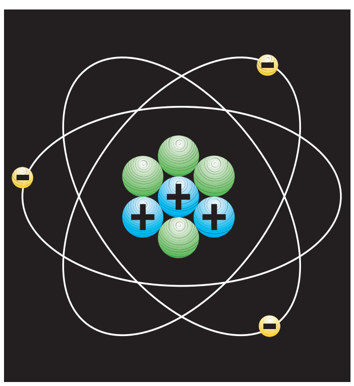
The four forces of Nature

Four separate forces are responsible for all the interactions that exist in the universe:



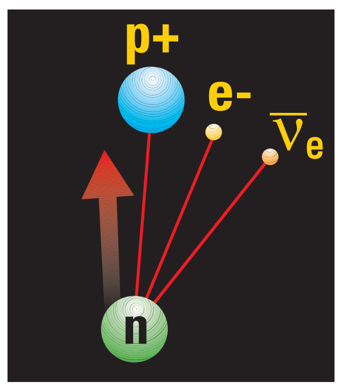
The gravitational force

Causes bodies to fall, regulates the movement of planets, binds together large structures like stars and galaxies, and governs the course of the entire universe.



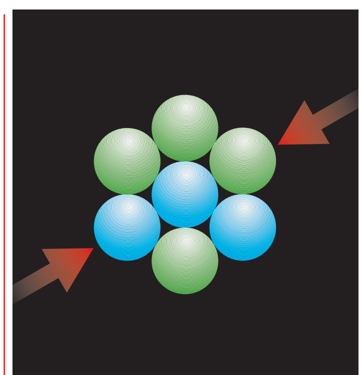
The electromagnetic force

Responsible for electrical phenomena, the emission and absorption of light, and the cohesion of atoms and molecules.



The weak nuclear force

Governs the radioactive decay of some atomic nuclei when neutrons decompose into protons, electrons and neutrinos.



The strong nuclear force

Binds quarks to form protons and neutrons, and holds protons and neutrons together to form atomic nuclei.

The strong and weak nuclear forces operate over an extremely short range, while the gravitational and electromagnetic forces extend infinitely, though their strength decreases rapidly with distance.

For more details see pages 135-160 in Velan's book, *The Birth and History of the Cosmos (2001).*

Basic data of the fundamental forces

Force	Range (cm)	Relative[(1)] strength	Mediator particle (Boson)	Mass	Spin	Particles governed
Gravitation	Infinite ∞	10^{-40}	Graviton	0	2	All
Electromagnetic	Infinite ∞	10^{-4}	Photon	0	1	Electrons, Quarks, Protons
Weak nuclear	10^{-15}	10^{-5}	W±	~80.4 GeV[(2)(3)]	1	Neutrinos, Electrons, Quarks, Neutrons
			Z^0	~91.2 GeV[(3)]	1	
Strong nuclear	10^{-13}	1	Gluon	0	1	Quarks, Protons and Neutrons in cores of atoms

Note:

(1) The relative strength indicated for the forces is only valid for particles with mass and over distances of less than 10^{-13} cm.

(2) 1 GeV = 10^9 eV (1 billion of eV)

(3) The theory of Higgs predicts that the mass of the weak nuclear force Bosons has been provided to the Bosons W± by the Higgs field of energy and to the Z^0 Boson by a Higgs neutral particle, both present in the vacuum of space-time. None have been discovered so far. However, one of the many fields and predicted particles such as the Higgs field and Higgs particles maybe discovered during the collisions in the LHC in CERN.

In the Velan theory of the Multi-Universe Cosmos the mass to all particles as well the bosons of the weak nuclear force has been provided by the cosmic primordial energy field with an energy density of $10^{12} – 10^{14}$ GeV/cm³ which permeates the inter-universe cosmic space-time and provides the missing link to any theory of creation that is consistent with energy conservation. Virtual particle pairs are transformed into real matter-antimatter particle pairs when the primordial radiation field interacts.

Direct detection of the primordial radiation field in our universe is difficult because it is shielded by a curved region of space-time outside our universe, created by the tremendous amount of mass-energy contained within.

However, as I first predicted in 1985, the primordial gamma radiation can occasionally enter our universe from the cosmic space-time by penetrating the surrounding space-time shell and in my view accounts for the super energetic ray bursts.

It is expected by the promoters of the Big Bang theory that in the analysis of the billions of information recorded during the collision of the billions of protons some of the undiscovered data for fields, particles, and bosons will be confirmed.

For more details see pages 135-160 in Velan's book,
The Birth and History of the Cosmos (2001).

The unification of forces

In the big bang theory (Chapters 14, 15), the Birth and History of the Cosmos (2001)

For some time now, we have known that electrical and magnetic interactions are two aspects of the same force, called the electromagnetic force.

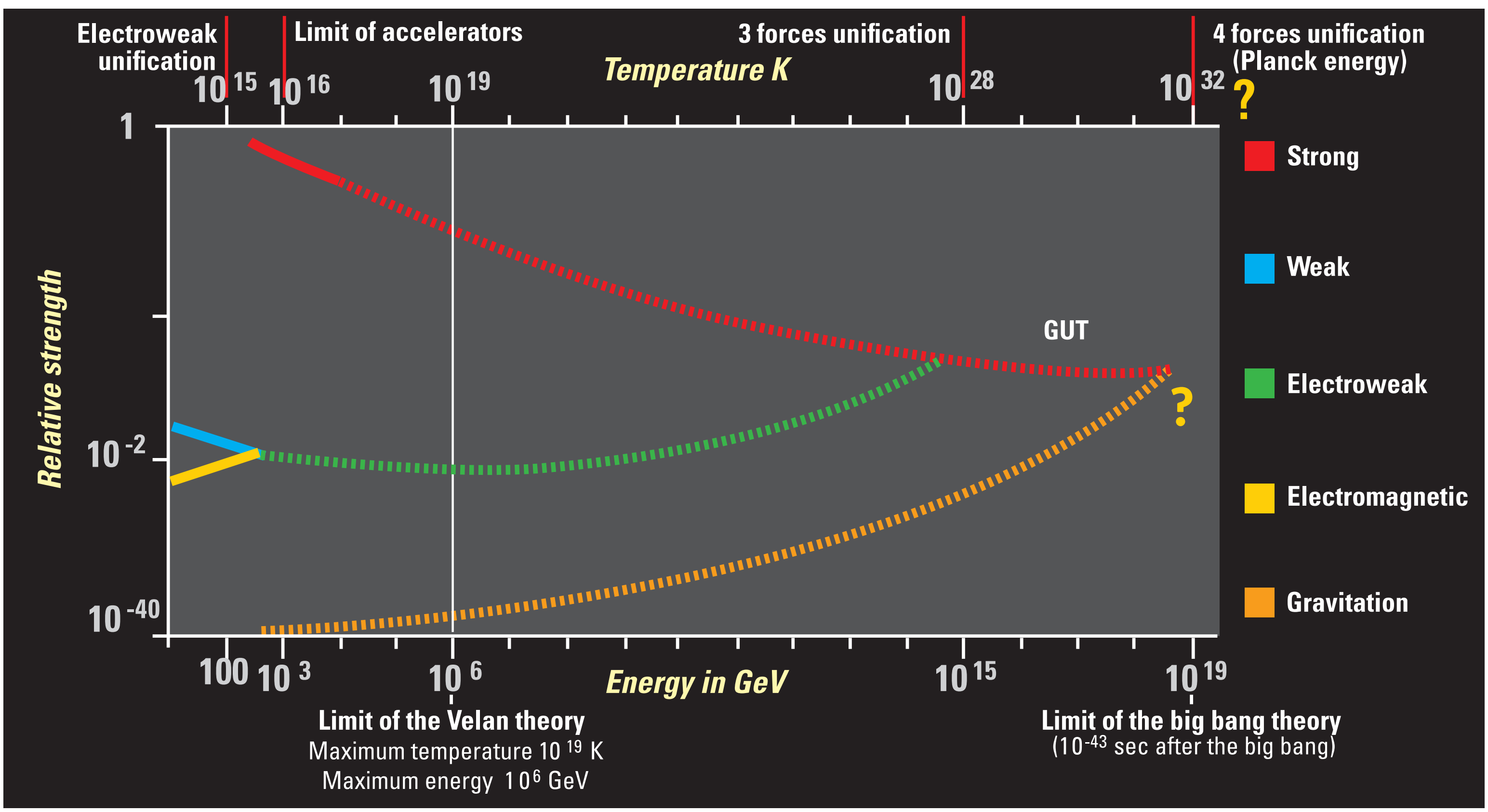
Likewise, physicists have shown that at high energies (100 GeV/ 10^{15} K) the electromagnetic and weak forces unite to form the electroweak force. In the same way, the remaining fundamental forces are thought to merge as energy levels or temperatures increase. The strong force at 10^{15} GeV/10^{28} K and maybe gravitation at 10^{19} GeV/10^{32} K.

These energy levels necessary for unification are so high they cannot be attained in laboratories, even using the largest particle accelerators imaginable. In fact, the only time temperatures were high enough to achieve a grand unification of forces was at the origin of the universe at 10^{32} K and at 10^{19} GeV.

The diagram illustrates the idea that the four forces of nature merge when energy and temperature increases.

In the Velan theory described in *The Multi-Universe Cosmos (1992)* and *The Birth and History of the Cosmos (2001), Chapters 20 and 21*

In the Velan cosmological theory the highest energy and temperature achieved was 10^6 GeV/10^{19} K and only the weak and electromagnetic forces were unified at 100 GeV/10^{15} K. Gravitation and the strong force were always active.



For more details see pages 158-160 in Velan's book, *The Birth and History of the Cosmos (2001).*

The challenges of the LHC

The Large Hadron Collider project has had to overcome challenges at every stage. **Lyn Evans** focuses on the three phases of approval, construction and operation.

It is generally considered that the starting point for the Large Hadron Collider (LHC) was an ECFA meeting in Lausanne in March 1984,although many of us had begun work on the design of the machine in 1981. It took a very long time – 10 years – from this starting point for the project to be approved. During most of this time Giorgio Brianti led the LHC project study. However, we should not forget the enormous debt we owe to Carlo Rubbia in the second half of that decade for holding the community together behind the LHC against all the odds.

The first project approval came in December 1994, although under such severe financial constraints that we were obliged to make a proposal for building the machine in two stages. This would have been a terrible thing to do, but at that point we had no alternative. However, after a major crisis in 1996, when CERN had a rather severe budget cut, at least the constraints on borrowing were relaxed and a single-stage machine was approved (p24).

It is clear that building the LHC is a very challenging project. It is based on 1232 double-aperture superconducting dipole magnets – equivalent to 2664 single dipoles – which have to be capable of operating at up to 9T. We were doing R&D on these magnets in parallel with constructing the machine and the experimental areas. This was not just a question of building a 1m scale model with the very skilled people here at CERN, but of being able to build the magnets by mass production, in an industrial environment, at an acceptable price. This is something we believe we have achieved.

The machine also incorporates more than 500 "two-in-one" superconducting quadrupole magnets operating at more than 250T/m. Here, our colleagues at Saclay have taken on a big role in designing and prototyping the quadrupoles very successfully. There are also more than 4000 superconducting corrector magnets of many types. Moreover, operating the machine will involve cooling 40000 tonnes of material to 1.9K, when helium becomes superfluid. An additional challenge has been to build the machine in an international collaboration. Although usual for detectors, this was a first for the accelerator community, and it has proved to be an enriching experience.

The production of the superconducting cable for the dipoles has driven the final schedule for the LHC, because we have to supply the cable to the magnet manufacturers. We could not risk starting magnet production too early when we were not sure that we could follow it with cable production. Figure 1 shows the ramp-up of cable production in 2002–2003.

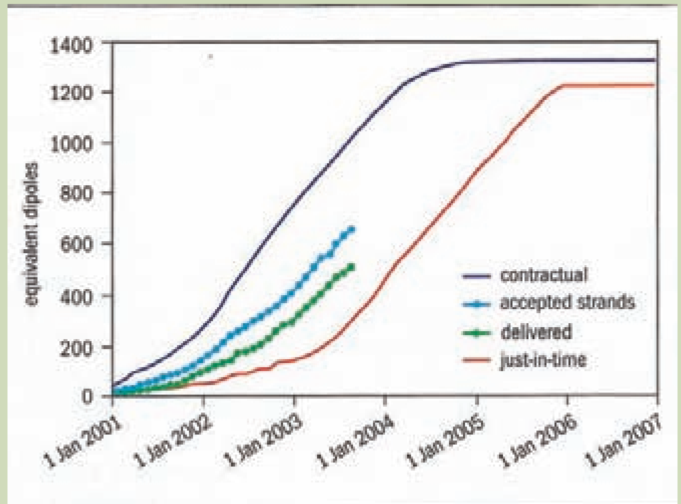


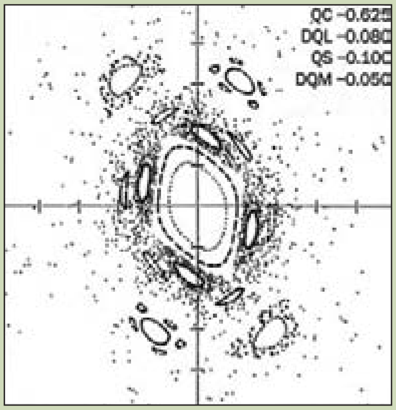
Fig. 1. The delivery of the superconducting cable for the LHC comfortably above the "just-in-time" line in 2003.

A computer-generated image of the Large Hadron Collider.

The next step is the series production of the dipoles, with installation in the tunnel starting in January 2004 and finishing in summer/autumn 2006. The "collared coils" – more than half the work on the dipoles – are now being made at the rate we need. These are assembled into the cold masses, which are delivered to CERN where they are installed in their cryostats, tested and stored.

At the same time the infrastructure of the tunnel is being prepared for the installation of the superconducting magnets. Sector 7-8, the first sector to be instrumented, now has its piping and cabling installed. The next step is the installation of the cryoline, to provide the liquid-helium refrigeration. We are now looking forward to as smooth a passage as possible from installation into commissioning.

The LHC is a very complicated machine, and its operation presents many challenges. The most fundamental concern is >



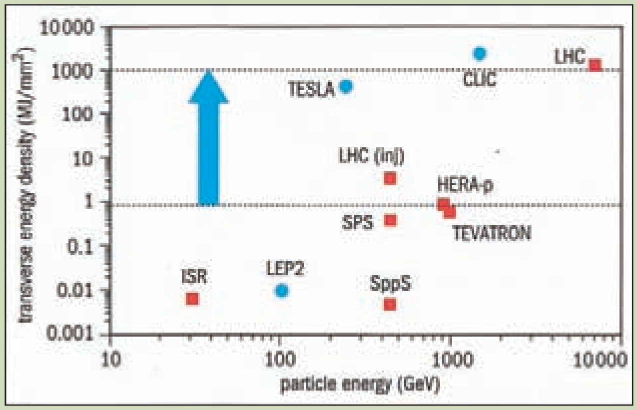


Fig. 2 (left). Simulation showing the chaotic effect of the beam–beam interaction on the position–velocity space of a particle in one of the beams. Fig. 3 (right). At less than 1% of nominal intensity the collimation system enters new territory. The collimators must survive under very punishing conditions.

the beam–beam interaction and collimation. In designing a particle accelerator, we try to make sure that the magnets have as little nonlinearity as possible: that is, they have pure dipole and quadrupole fields. We then introduce controlled non-linearities – sextupoles to control chromatic aberrations and octupoles to give beam stability (Landau damping). We want smooth, distributed non-linearity, not a "lumped" linearity at one point in the ring. So we take a great deal of care, but then we are stuck with what we absolutely do not want – the beam–beam interaction itself. When the beams are brought into collision, a particle in one beam sees the Coulomb field of the other beam, which is strongly non-linear and is lumped – in every revolution the particle sees the beam–beam interaction at the same place. This produces very important effects, which I shall describe.

First, however, I should mention that the conversion of the Super Proton Synchrotron (SPS) into a proton–antiproton collider was a vital step in understanding this phenomenon. Indeed, it is not generally known what a step into the unknown we took with the collider. In this machine the strength of the beam–beam interaction, which we call the beam–beam "tune shift", was very large, much larger than at the Intersecting Storage Rings (ISR). The collider was to operate in a domain where only electron–positron machines had worked, and these machines have the enormous advantage of strong synchrotron-radiation damping: particles that go through large amplitudes are "damped" into the core of the beam again. So we were going to operate a machine with no damping and a strong beam–beam effect. (Indeed, tests at SPEAR at lower and lower energies with reduced damping showed catastrophic effects, which when extrapolated indicated that the proton–antiproton collider could never work!)

Figure 2 shows the effects in a simulation of the transverse phase space (the position–velocity space) of a particle in a perfect machine, apart from the beam–beam interaction. Because of the strong nonlinearity of the beam–beam interaction, particle motion can become chaotic and unstable at large amplitude. This was a real worry at the proton–antiproton collider, which proved to be an absolutely essential prototype for defining the parameters of the LHC. We have designed the LHC to beat this effect by sitting in a very small corner of "tune space" with very precise control in order to stay away from high-order resonances, although the beam–beam interaction will always be a fundamental limit.

A second major challenge of operating the LHC concerns collimation, which is needed to remove halo particles from the beams to avoid their touching the superconducting magnets, and to control the background in the detectors. We also need collimation to protect against fault conditions – the stored energy in the nominal LHC beam is equivalent to 60 kg of TNT! If there is a fault the beam will be kicked out, and for that there is a 3 μs hole in the bunch spacing to allow the field in the kicker magnets to rise. If there is a misfiring particles will be lost as the kickers rise, and the collimators can melt, so they have to be very carefully designed.

Already, at less than 1% of its nominal intensity, the LHC will enter new territory in terms of stored energy. It is two orders of magnitude more in stored beam energy, but the beam-energy density is three orders of magnitude higher (figure 3) because as the beam is accelerated it becomes very small. To cope with this we have designed a very sophisticated collimation system. At injection the beam will be big, so we will open up the collimators to an aperture of about 12 mm, while in physics conditions the aperture of the beam will be 3 mm – the size of the Iberian Peninsula on a €1 coin. The beam will be physically close to the collimator material and the collimators themselves are up to 1.2 m long.

We are now on the final stretch of this very long project. Although there are three-and-a-half years to go, they will be very exciting years as we install the machine and the detectors. It is going to be a big challenge both to reach the design luminosity and for the detectors to swallow it. However, we have a competent and experienced team, and we have put into the design 30 years of accumulated knowledge from previous projects at CERN, through the ISR and proton–antiproton collider. We are now looking forward to the challenge of commissioning the LHC.

● January/February 2004 p27 (abridged).

Based on a talk given at a symposium at CERN, published in *Prestigious Discoveries at CERN. 1973 Neutral Currents. 1983 W & Z Bosons* (Springer 2003).

Résumé

Le Grand collisionneur de hadrons a dû surmonter des obstacles à chaque étape de sa réalisation. Dans cet article, Lyn Evans, chef du projet LHC, examine les trois phases du projet – approbation, construction et exploitation – et, en particulier, les nombreux défis que représente l'exploitation d'une machine aussi complexe.

Lyn Evans, *CERN.*

The high-energy frontier

The discoveries that are expected to come from the LHC should revolutionize our understanding of matter, forces and space.

The principal goal of the experimental programme at the LHC is to make the first direct exploration of a completely new region of energies and distances, to the tera-electron-volt scale and beyond. The main objectives include the search for the Higgs boson and whatever new physics may accompany it, such as supersymmetry or extra dimensions, and also – perhaps above all – to find something that the theorists have not predicted.

The Standard Model of particles and forces summarizes our present knowledge of particle physics. It extends and generalizes the quantum theory of electromagnetism to include the weak nuclear forces responsible for radioactivity in a single unified framework; it also provides an equally successful analogous theory of the strong nuclear forces.

The conceptual basis for the Standard Model was confirmed by the discovery at CERN of the predicted weak neutral-current form of radioactivity and, subsequently, of the quantum particles responsible for the weak and strong forces, at CERN and DESY respectively. Detailed calculations of the properties of these particles, confirmed in particular by experiments at the LEP collider, have since enabled us to establish the complete structure of the Standard Model; data taken at LEP agreed with the calculations at the *per mille* level.

These successes raise deeper problems, however. The Standard Model does not explain the origin of mass, nor why some particles are very heavy while others have no mass at all; it does not explain why there are so many different types of matter particles in the universe; and it does not offer a unified description of all the fundamental forces. Indeed, the deepest problem in fundamental physics may be how to extend the successes of quantum physics to the force of gravity. It is the search for solutions to these problems that define the current objectives of particle physics – and the programme for the LHC.

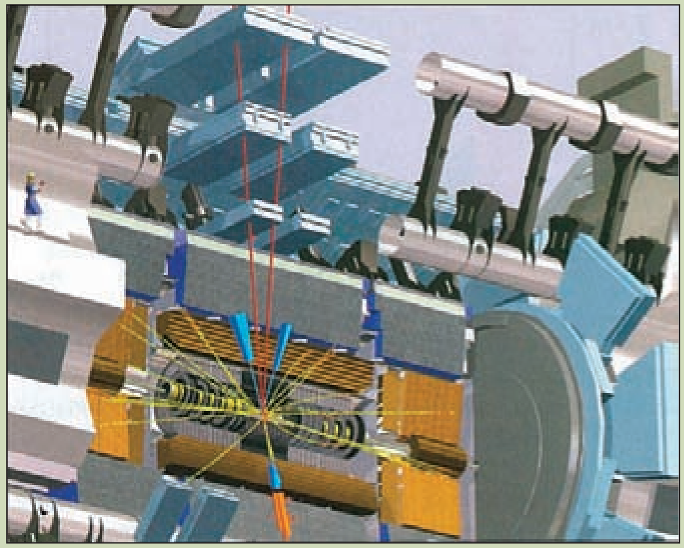


Fig. 1. Simulation in the ATLAS detector where a Higgs boson decays to two Z bosons. One of these decays to two muons (the red tracks going to the top) while the other decays to an electron–positron pair, depositing energy in the electromagnetic calorimeter in the opposite direction.

Higgs, hierarchy and extra dimensions

Understanding the origin of mass will unlock some of the basic mysteries of the universe: the mass of the electron determines the sizes of atoms, while radioactivity is weak because the W boson weighs as much as a medium-sized nucleus. Within the Standard Model the key to mass lies with an essential ingredient that has not yet been observed, the Higgs boson; without it the calculations would yield incomprehensible infinite results. The agreement of the data with the calculations implies not only that the Higgs boson (or something equivalent) must exist, but also suggests that its mass should be well within the reach of the LHC.

Experiments at LEP at one time found a hint for the existence of the Higgs boson, but these searches proved unsuccessful and told us only that it must weigh at least 114 GeV (*CERN Courier* November 2005 p23). At the LHC, the ATLAS and CMS experiments will be looking for the Higgs boson in several ways. The particle is predicted to be unstable, decaying for example to photons, bottom quarks, tau leptons, W or Z bosons (figure 1). It may well be necessary to combine several different decay modes to uncover a convincing signal, but the LHC experiments should be able to find the Higgs boson even if it weighs as much as 1 TeV.

While resolving the Higgs question will set the seal on the Standard Model, there are plenty of reasons to expect other, related new physics, within reach of experiments at the LHC. In particular, the elementary Higgs boson of the Standard Model seems unlikely to exist in isolation. Specifically, difficulties arise in calculating quantum corrections to the mass of the Higgs boson. Not only are these corrections infinite in the Standard Model, but, if the usual procedure is adopted of controlling them by cutting the theory off at some high energy or short distance, the net result depends on the square of the cut-off scale. This implies that, if the Standard Model is embedded in some more complete theory that kicks in at high energy, the mass of the Higgs boson would be very sensitive to the details of this high-energy theory. This would make it difficult to understand why the Higgs boson has a (relatively) low mass and, by extension, why the scale of the weak interactions is so much smaller than that of grand unification, say, or quantum gravity.

This is known as the "hierarchy problem". One could try to resolve it simply by postulating that the underlying parameters of the ▷

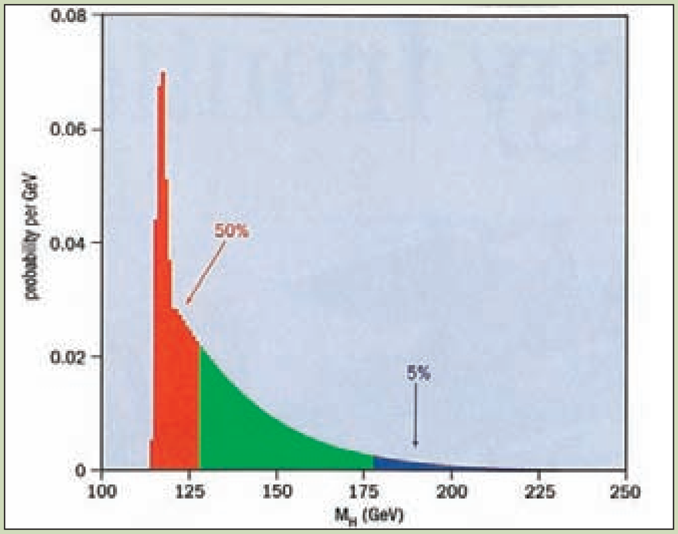


Fig. 2. A graph showing the probability distribution for the mass of the Higgs boson in the Standard Model found by combining direct search information from LEP with an analysis of precision electroweak data (Erler 2007).

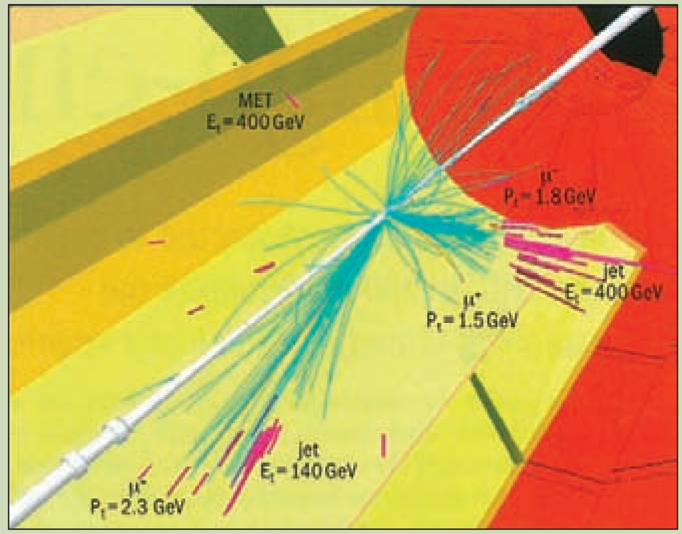


Fig. 3. Simulation of a supersymmetric event in the CMS detector in which a pair of gluinos decay into muons and quark jets and dark-matter particles that carry away a large amount of "missing" invisible energy (MET).

theory are tuned very finely, so that the net value of the Higgs boson mass after adding in the quantum corrections is small, owing to some suitable cancellation. However, it would be more satisfactory either to abolish the extreme sensitivity to the quantum corrections, or to cancel them in some systematic manner.

One way to achieve this would be if the Higgs boson is composite and so has a finite size, which would cut the quantum corrections off at a relatively low energy scale. In this case, the LHC might uncover a cornucopia of other new composite particles with masses around this cut-off scale, near 1 TeV.

The alternative, more elegant, and in my opinion more plausible, solution is to cancel the quantum corrections systematically, which is where supersymmetry could come in. Supersymmetry would pair up fermions, such as the quarks and leptons, with bosons, such as the photon, gluon, W and Z, or even the Higgs boson itself. In a supersymmetric theory, the quantum corrections due to the pairs of virtual fermions and bosons cancel each other systematically, and a low-mass Higgs boson no longer appears unnatural. Indeed, supersymmetry predicts a mass for the Higgs boson probably below 130 GeV, in line with the global fit to precision electroweak data.

The fermions and bosons of the Standard Model, however, do not pair up with each other in a neat supersymmetric manner. The theory, therefore, requires that a supersymmetric partner, or sparticle, as yet unseen, accompanies each of the Standard Model particles. Thus, this scenario predicts a "scornucopia" of new particles that should weigh less than about 1 TeV and could be produced by the LHC (figure 3).

Another attraction of supersymmetry is that it facilitates the unification of the fundamental forces. Extrapolating the strengths of the strong, weak and electromagnetic interactions measured at low energies does not give a common value at any energy, in the absence of supersymmetry. However, there would be a common value, at an energy around 10^{16} GeV, in the presence of supersymmetry. Moreover, supersymmetry provides a natural candidate, in the form of the lightest supersymmetric particle (LSP), for the cold dark matter required by astrophysicists and cosmologists to explain the amount of matter in the universe and the formation of structures within it, such as galaxies. In this case, the LSP should have neither strong nor electromagnetic interactions, since otherwise it would bind to conventional matter and be detectable. Data from LEP and direct searches have already excluded sneutrinos as LSPs. Nowadays, the "scandidates" most considered are the lightest neutralino and (to a lesser extent) the gravitino.

Assuming that the LSP is the lightest neutralino, the parameter space of the constrained minimal supersymmetric extension of the Standard Model (CMSSM) is restricted by the need to avoid the stau being the LSP, by the measurements of $b \rightarrow s\gamma$ decay that agree with the Standard Model, by the range of cold dark-matter density allowed by astrophysical observations, and by the measurement of the anomalous magnetic moment of the muon ($g_\mu - 2$). These requirements are consistent with relatively large masses for the lightest and next-to-lightest visible supersymmetric particles, as figure 4 indicates. The figure also shows that the LHC can detect most of the models that provide cosmological dark matter (though this is not guaranteed), whereas the astrophysical dark matter itself may be detectable directly for only a smaller fraction of models.

Within the overall range allowed by the experimental constraints, are there any hints at what the supersymmetric mass scale might be? The high precision measurements of m_W tend to favour a relatively small mass scale for sparticles. On the other hand, the rate for $b \rightarrow s\gamma$ shows no evidence for light sparticles, and the experimental upper limit on $B_s \rightarrow \mu^+\mu^-$ begins to exclude very small masses. The strongest indication for new low-energy physics, for which supersymmetry is just one possibility, is offered by $g_\mu - 2$. Putting this together with the other precision observables gives a preference for light sparticles.

Other proposals for additional new physics postulate the existence of new dimensions of space, which might also help to deal with the hierarchy problem. Clearly, space is three-dimensional ▷

Cryogenic unit keeps its cool

The cryogenic system for the LHC reached a major milestone on 7 April by achieving operation of the unit at Point 8 at its nominal temperature of 1.8 K. The LHC and its superconducting magnets are designed to operate at this very low temperature, making the 27 km accelerator the coldest large-scale installation in the world. Although acceptance tests performed on the surface had already reached the required temperature in 2002, this is the first time that the nominal temperature has been achieved *in situ*.

The LHC cryogenics system is hugely complex, with 31 kt of material (compressor stations, cold boxes with expansion turbines and heat exchangers, and interconnecting lines) requiring 700 kl of liquid helium passing through 40 000 pipe junctions.

Although normal liquid helium at 4.5 K would be able to cool the magnets so that they became superconducting, the LHC will use superfluid helium at the lower temperature of 1.8 K. Superfluid helium has unusually efficient heat-transfer properties, allowing kilowatts of refrigeration to be transported over more than 1 km with a temperature drop of less than 0.1 K.

Eight cryogenic installations distributed around the LHC ring, with a total power exceeding 140 kW, will cool the helium in two stages, first to 4.5 K and then to the final 1.8 K. Four units built by the Japanese-Swiss consortium IHI-Linde have already been installed; the other four units, made by the French company Air Liquide, are currently being installed and will be tested in 2006.

● June 2005 p5 (extract).

The cryogenic unit at Point 8 has reached its nominal temperature of 1.8 K.

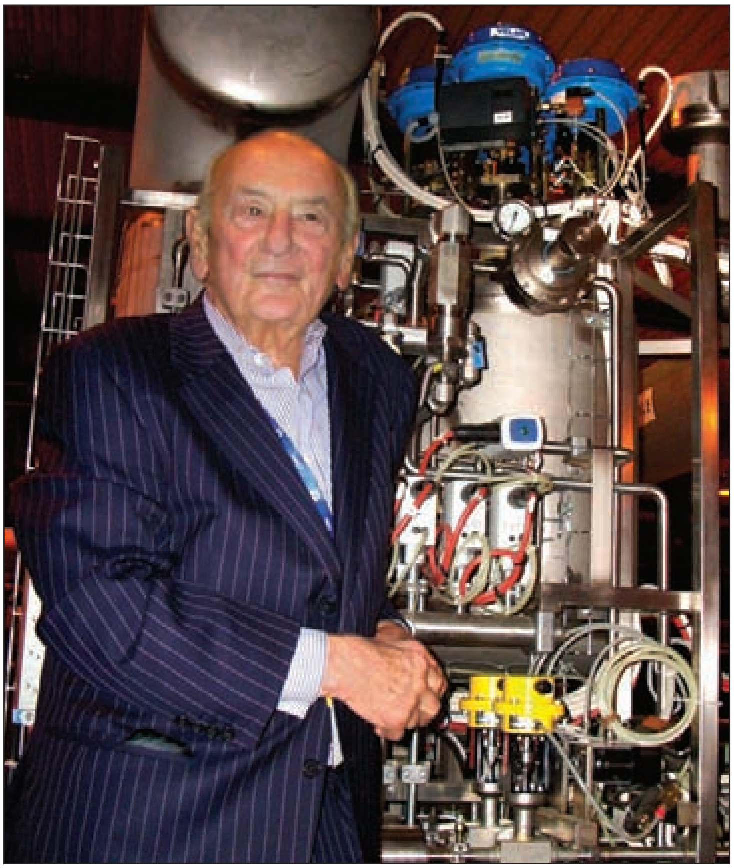
The first section of the cryogenic distribution line, corresponding to an eighth of the accelerator, has been tested at a temperature of 10 K since the end of November 2005.

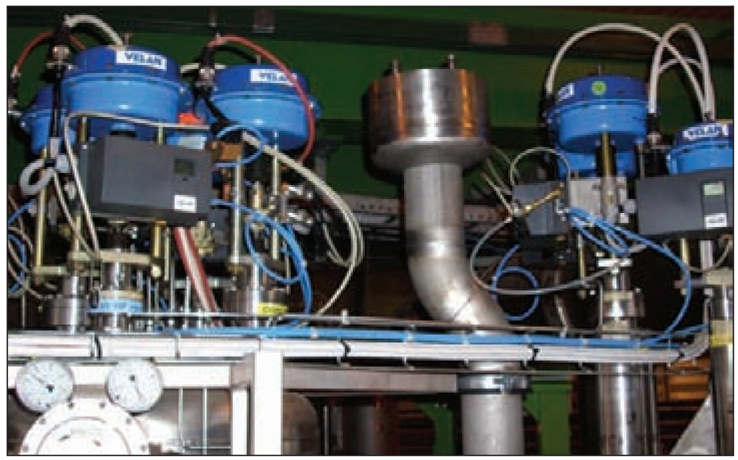
<u>Remark by Velan:</u> To prove that the double shell vacuum insulation of Velan control valves is satisfactory, the CERN Scientists in both photographs put their hand on the outside shell of the Velan control valves.

● January/February 2006 p6.

2500 VELAN BELLOWS SEAL CRYOGENIC CONTROL VALVES AT CERN, GENEVA

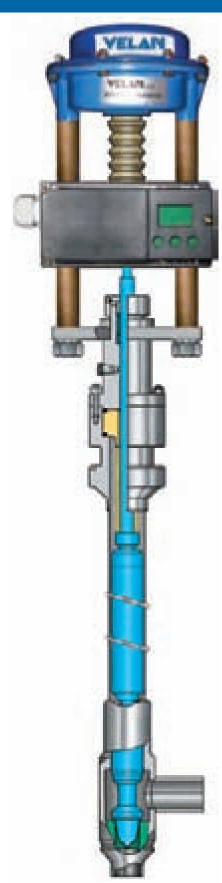
2500 Velan Control Valves control the flow of 700,000 liters of liquid Helium to cool down and optimize the performance of 1,700 magnets to -271°C and accelerate billions of protons in the vacuum of the accelerator to 1 billions of a second less than the speed of light. All valves are bellows sealed with 0 fugitive emissions and generally with a double shell to provide vacuum insulation.





2003–2005
INSTALLATION OF VELAN VALVES AT CERN, GENEVA

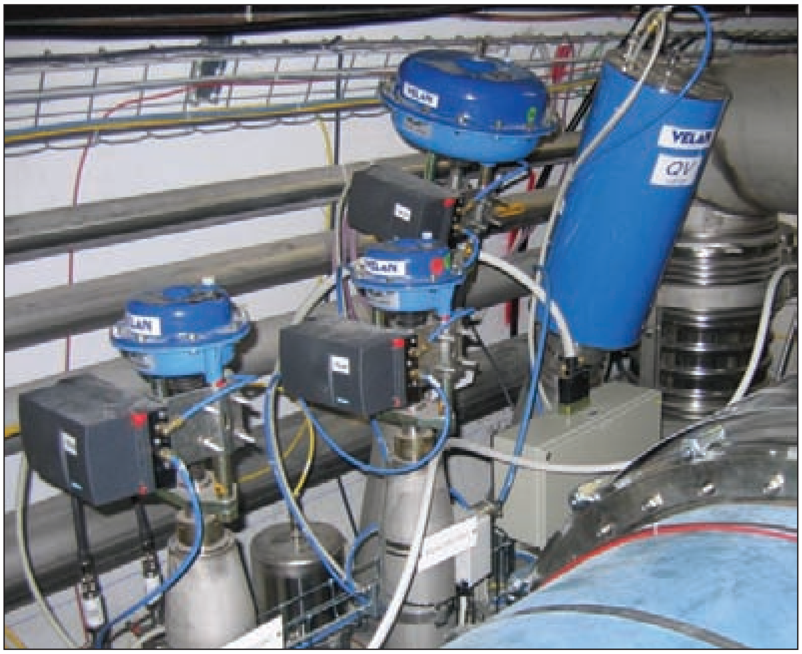
VELAN CONTROL VALVE



Velan Bellow Seal Control valves with vacuum jacketed insulation installed along the 27 Km accelerator lines.

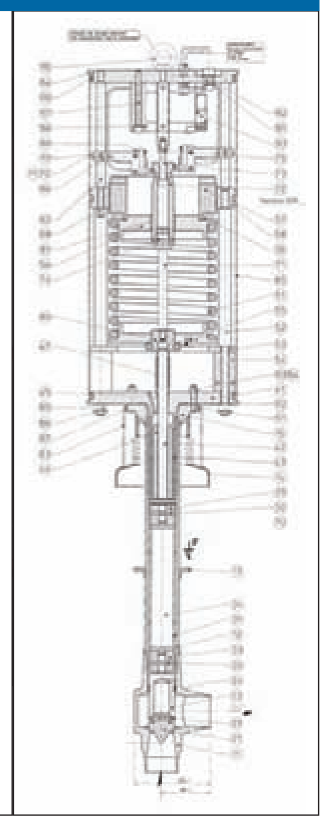
Alternative with Bellow Seal jacketed double shell. →

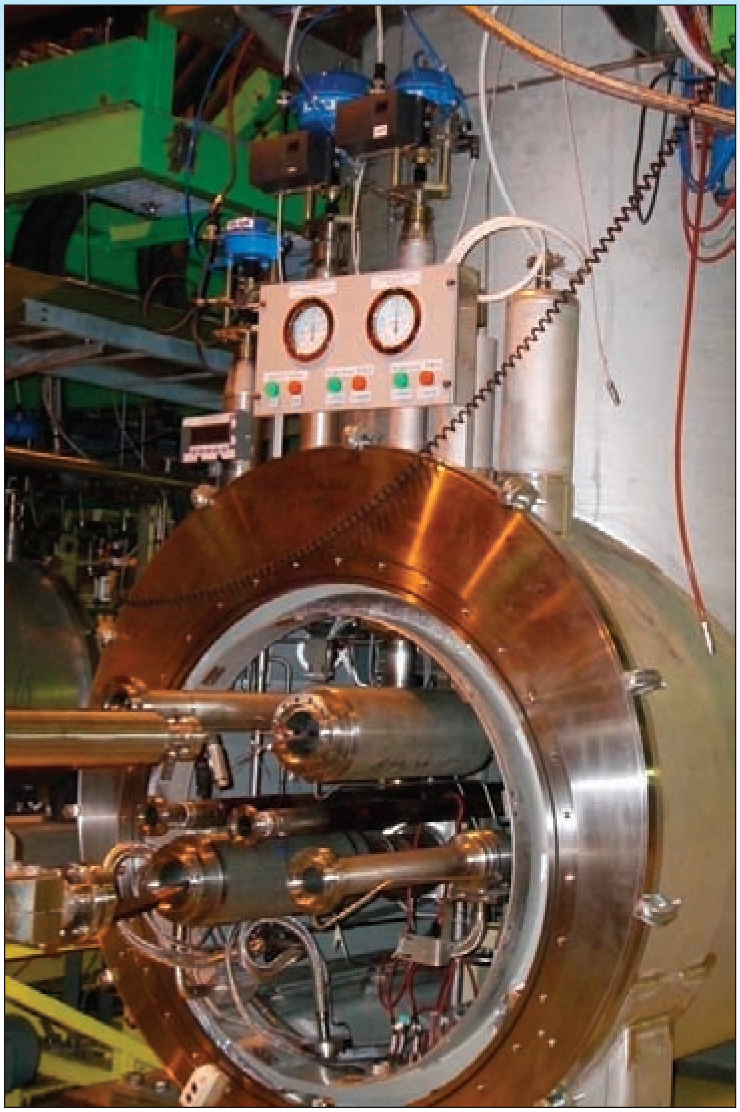
All jacketed valves provide perfect vacuum insulation against -271°C Helium.

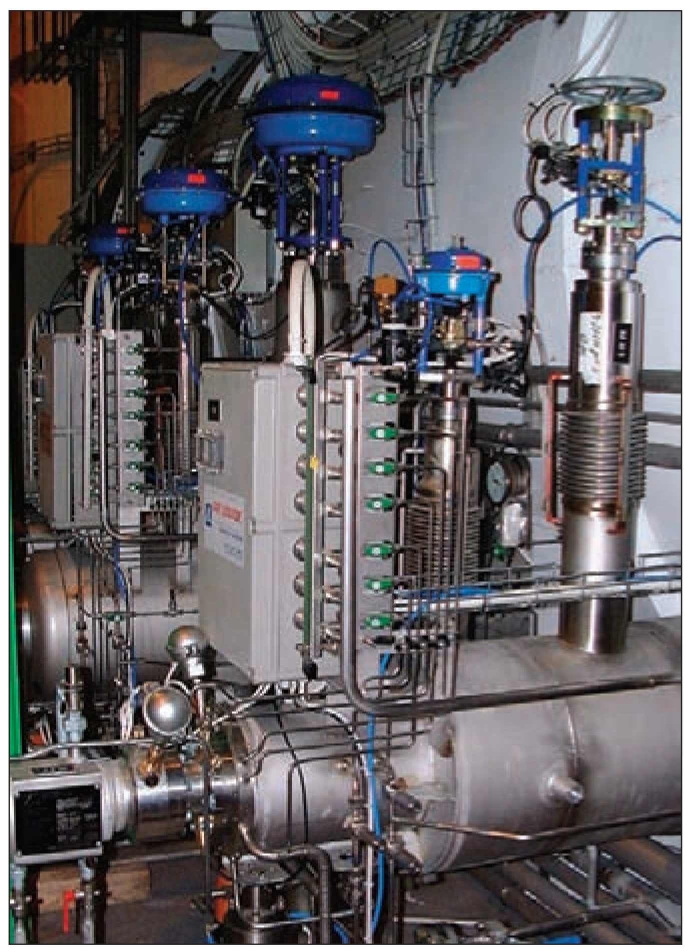


Velan Cryogenic control valves all with jacketed vacuum double shell insulation and Velan cryogenic safety valves to protect against over-pressure of the super fluid helium enclosures of the superconducting magnet resulting from resistive transitions (Quench phenomenon).

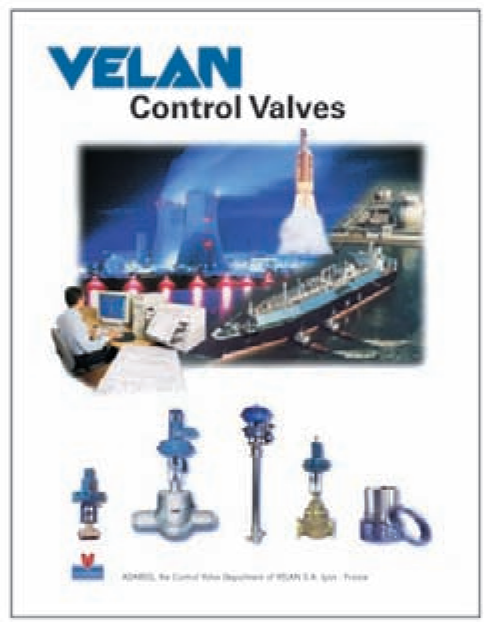
VELAN QUENCH RELIEF VALVE







Velan's complete range of Cryogenic Valves up to close to absolute 0°K



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Co2	-78.50	-109.30
Ethylene	-103.70	-154.66
LNG	-161.60	-258.88
Oxygen	-182.96	-297.33
Nitrogen	-195.80	-320.44
Hydrogen	-252.87	-423.17
Helium	-271.50	-454.20

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