The first results

Thanks to the Large Hadron Collider, physics seems one step closer to a way out of an impasse, says s ananthanarayanan

THE last results in from the Large Hadron Collider, the 27-km, $9 billion underground facility on the Franco-Swiss border near Geneva indicate that the Higgs Boson, the much sought after elementary particle that would tie loose ends in physical theory, is not to be found in a large part of where it could be. This is a step forward in that it leads researchers, who had looked at the easiest places first, to now search in the remaining places. Scientists at Cern (the European nuclear research establishment at Geneva) believe they will be able to say whether the Higgs Boson exists or not by the end of 2012.

Physics has now reached incredible precision in working out the outcome of reactions — on one hand, at the atomic or sub-atomic level; and, on the other, at the level of the cosmos or the motion of planets, stars and galaxies. Over the last three centuries, science has advanced in mechanics, optics, electromagnetism, thermodynamics, atomic physics and quantum physics.

Newton's discoveries of the laws of motion led to a formal description of processes and, hence, the bases of the gas laws and, later, the steam engine and the petrol engine. Electromagnetic theory explained both the laws of optics and led to marvels of electronics. The structure of the atom was discovered and the new rules of quantum mechanics, which apply at very small dimensions, were discovered.

The theory of relativity refined our understanding of space and time and the force of gravity was considered as arising from the presence of a mass acting to modify the shape of space itself. This formulation led to precise calculation of the trajectories of the cosmos, which do not follow the simpler rules of Newtonian mechanics. Integrating the new rules into quantum mechanics made the latter even more powerful and led to an understanding of subatomic processes with astounding accuracy.

The current description of the elementary particles that make up all matter is the *Standard Model* and it includes the protons, neutrons and electrons which make up atoms and a number of other elementary particles which arise in the interaction of particles, and also the photon, or the packet of light energy, which also behaves like a particle. One difficulty in the early physics had been that in electric and magnetic phenomena, charged particles affected other particles over a distance, which seemed somewhat "magical".

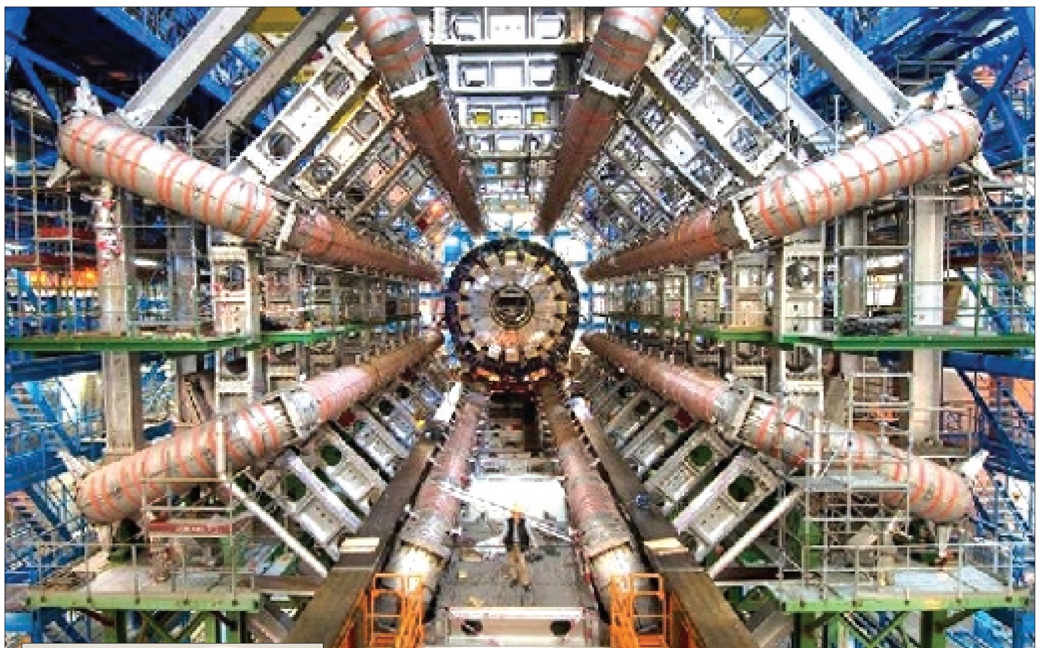
Electromagnetic theory found a way out by the idea of a "field" or a model of the influence of a charge or a charge in motion, so that the effect on an external particle was viewed not as directly by the first particle but by the local value of the "field" due to that particle. The result from quantum theory, that energy of this field should consist of discrete packets or "quanta", was happily confirmed by the existence of photons, which were viewed as the carriers of the electromagnetic force.

But the trouble with the Standard Model, which is so successful in its range of application, is that it does not account for the force of gravity and the nature of the mass of things. On the same lines as with electrical and magnetic forces, one approach was to consider gravity to arise out of a gravitational "field".

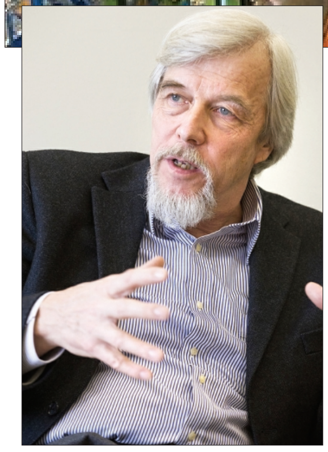
Following through with this idea, in keeping with the laws of quantum physics, then suggests that there would be an elementary particle whose exchange would mediate transmission of the gravitational force. This is the particle called the *Higgs Boson*, after Peter Higgs, who proposed it in the 1960s, and the word "Boson" means a particle with a "whole number" spin, as it is found that this is what the particle would have, like the photon, for its properties.

There are no direct ways to theoretically work out the mass of the Higgs Boson, but it can be estimated, although without much certainty, to keep theory and observation in agreement, to be lighter than about 160 "Giga electron Volts" (Giga eV = 1,000 million eV).

Masses of subatomic particles are expressed as the equivalent energy, in units of the electron Volts. In this case, 160 GeV is about 170 proton masses. Such a massive particle, to be created, for observation, would require huge energy — far beyond the reach of normal experimental resources. Some studies were first done with collisions of very energetic cosmic rays and then, more fruitfully, with the *Large Electron Positron Collider* at Cern. But the results have been inconclusive and much hope has been pinned on the *Large Hadron Collider*, the largest facility so far attempted.



The Large Hadron Collider – still on track to rewrite textbooks.



Cern director, Dr Rolf-Dieter Heuer

The LHC

The LHC is a 27-km circular tube that uses synchronised magnetic fields to accelerate two streams of charged particles, mainly protons, in opposite directions. Very high energies can be attained and the collision of particles of the two streams can create interactions of up to seven Tera eV (or seven million million eV). At the place where the two contrarily moving beams intersect, there is placed a brace of detectors to map the products of the collisions, head on or glancing, which take place. As the energy of the colliding particles would be high, there is a chance that among the products of the collision of two protons would be the elusive Higgs, with mass, just by itself, of about 170 protons masses. With a flux of billions of particles circulating and long spells of interaction, huge data can be collected for analysis.

The LHC first started up in 2009 and reached 0.9 TeV and later 2.36 TeV. In 2010, it reached seven TeV and large data was collected in March 2011, after the winter shutdown in December-February. In reports in April 2011 there were indications of some promising "blips" and some euphoria that something had been found. But the quantity of data is huge; if all the data were recorded it would fill 100,000 CDs every second. In fact, there is some "on the spot" filtering and only "promising" data is recorded at the rate of 27 CDs a second. But LHC is a large international collaboration and there are hundreds of laboratories and universities that join in data analysis.

Results

The data that was collected for the "mid-range" of 145 to 466 GeV has been analysed and on 23 August the results were presented at a conference at the Tata Institute of Fundamental Research, Mumbai. The results, with 95 per cent certainty, rule out the existence of the Higgs in this energy window. This window had been selected for the first round search because it is the range where the particle may be most readily detected. At lower energies, there is much "glare" and detecting anything meaningful would take longer runs and more analysis. But this window selected has now been shown to not contain the Higgs.

"The particle is running out of places to hide," Rolf-Dieter Heuer, Cern director, told a press conference in Mumbai on 25 August.
The continuing search, at lower energies, would be challenging. But researchers say that an answer, one way or the other, will be found by the end of 2012. If there is a Higgs Boson, it would validate the Standard Model and spur the search for other high mass particles that are predicted by String Theory, which is a theoretical framework that explains the Standard Model. If there is no Higgs Boson, then it is back to the drawing board to break a new path!

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Immune attack

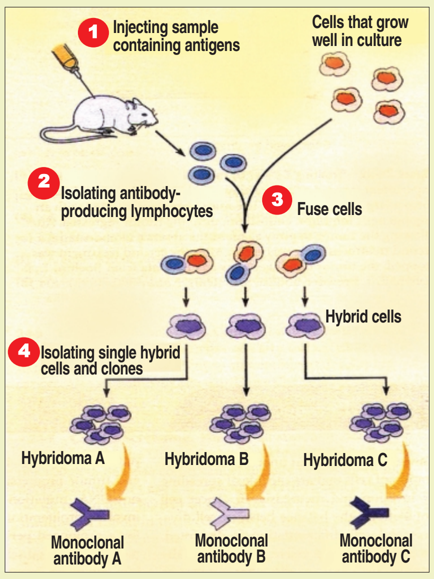
Only monoclonal antibodies can offer a clue to cancer treatment, writes tapan kumar maitra

ONE way in which the immune system operates is by producing antibodies, which are soluble proteins that bind to and inactivate substances, referred to as antigens that provoke an immune response. To function as an antigen, a substance must usually be recognised as being "foreign" — that is, different from molecules normally found in a person's body.

Antibody molecules recognise and bind to specific antigens with extraordinary precision, making them ideally suited to serving as "magic bullets" that selectively target antigens that are unique to, or preferentially concentrated in, cancer cells.

For many years, the use of antibodies for treating cancer was hampered by the lack of a reproducible method for producing large quantities of pure antibody molecules directed against the same antigen. Then in 1975, Georges Kohler and Cesar Milstein solved the problem by devising the procedure. According to their technique, animals are first injected with an antigen of interest and antibody-producing lymphocytes are isolated from the animal a few weeks later. Within such a lymphocyte population, each lymphocyte produces a single type of antibody directed against one particular antigen. To facilitate the selection and growth of individual lymphocytes, they are fused with cells that divide rapidly and have an unlimited lifespan when grown in culture. Individual hybrid cells are then selected and grown to form a series of clones called hybridomas. The antibodies produced by hybridomas are referred to as monoclonal antibodies because each is a pure antibody produced by a cloned population of lymphocytes.

To obtain monoclonal antibodies that might be useful for treating cancer, human cancer tissue is injected into mice to stimulate an immune response. Hybridomas are then created using lymphocytes from the immunised animals and the hybridomas are analysed to determine which ones produce antibodies directed against antigens present in the cancer tissue. Because the antibodies are derived from mice and might be destroyed by a person's immune system, they are usually made more humanlike by replacing large parts of the mouse antibody molecule with corresponding sequences derived from human antibodies. When such antibodies are injected into individuals with cancer, they bind to cancer cells and their presence triggers an immune attack that destroys only those cells to which the antibody is attached.



The monoclonal antibody procedure produces pure populations of antibody molecules, each directed against a single antigen.

The preceding approach is just beginning to be applied to human cancers. For example, antibodies that target the CD20 antigen found on the surface of non-Hodgkins lymphoma cells are now among the standard treatments for this particular type of cancer. Antibodies can also serve as delivery vehicles by linking them to radioactive molecules or to other toxic substances that are too lethal to administer alone. Attaching such substances to antibodies allows the toxins to be selectively concentrated at tumor sites without accumulating to toxic levels elsewhere in the body.

Antibodies are being developed that bind to and inactivate specific proteins involved in the signalling pathways that drive cancer cell proliferation. The monoclonal antibody Herceptin is an example of an anti-cancer drug that works this way.

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Twisted light from the galactic centre

A new phenomenon might aid in seeing the monster black hole at the centre of the Milky Way and provide a way to see Hawking radiation, writes saswato r das

ALBERT Einstein's general theory of relativity, put forward in 1915 to explain how gravity works, is notoriously hard to test through experiments. It was first verified in 1919 when two teams of astronomers led by Sir Arthur Eddington went to the Southern hemisphere to observe a total solar eclipse. General relativity predicts that a massive object like the sun will bend light that passes close to it. (Much like a lead weight placed on a rubber sheet will produce a trough, the sun's mass produces a distortion in the fabric of spacetime, and any light travelling nearby gets bent.)

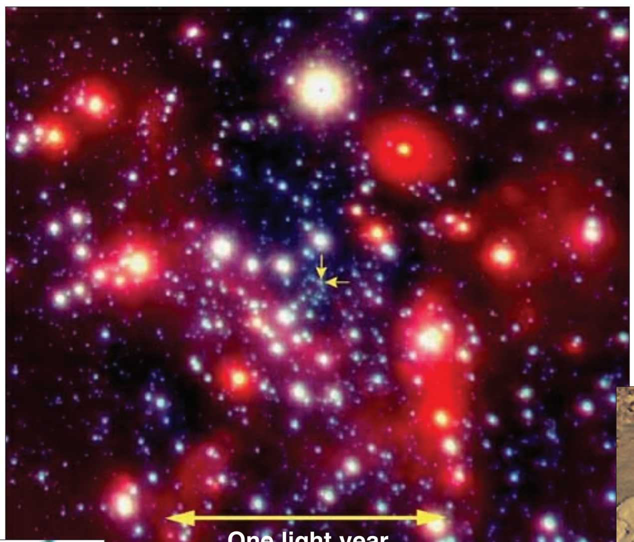
Given the usual brightness of the sun's disc, this effect is impossible to observe. During a solar eclipse, however, the sun's disc is covered by the moon, and Eddington and his colleagues were able to observe the bending of light (it resulted in stars near the sun appearing out of place). Eddington's observations made Einstein world famous almost overnight.

Since then, there have been a few other successful experimental tests of general relativity. Now a recent paper by Dr Bo Thide at the Swedish Institute of Space Physics in Uppsala and Dr Fabrizio Tamburini at the University of Padova, Italy, suggests that we may be able to observe light coming from near the black hole at the centre of our Milky Way galaxy, in the process testing general relativity once more.

Astronomers have known for some time that the centres of galaxies such as our own contain monstrously large black holes. Such "supermassive" black holes have masses that are a few million times that of the sun. (A recent estimate of the mass of Sagittarius A, the black hole at the centre of the Milky Way, puts it at around 3.7 million solar masses.) General relativity predicts that black holes will have intense gravitational fields, so strong that not even light can escape from their confines. Unfortunately for astronomers, black holes' light swallowing abilities make them extremely difficult to observe.

Working with colleagues, Drs Thide and Tamburini say they have found a new phenomenon that may make it possible to observe spinning black holes. (They point out that most objects in the universe rotate, so a non-spinning black hole would be very rare.) General relativity predicts that a spinning supermassive black hole would cause the surrounding spacetime to be dragged around. (In fact, so-called "frame-dragging" around massive objects has been detected by gyroscopes on satellites.) Astronomers believe that a spinning black hole is surrounded by an "accretion disc" – a ring of matter that is being spun around by the black hole's gravitational pull.

A photon produced close to a spinning black hole will have an inherent corkscrew-like property called "orbital angular momentum" that will differentiate it from other light, according to the researchers.
They say it's almost as if the photons from near the spinning black hole will produce a beam of radiation "that will spiral around its axis in a vortex like a tornado".



Dr Bo Thide

What's more, they have calculated that this twisted light effect should be observable on earth for Sagittarius A, which can't be seen through telescopes in visible light because it is obscured by thick clouds of dust near the galactic centre. But radio telescopes can see it through the dust and Dr Thide says that the Very Large Array radio telescope in New Mexico should be able to see the twisted light from Sagittarius A. In fact, he is already working with Dr Nicholas Elias, an astronomer at the Very Large Array, to see if the light can indeed be detected.

Another exotic application of twisted light is that it might one day allow astronomers to see Hawking radiation from a black hole. In 1974, Dr Stephen Hawking, a physicist at Cambridge University, used quantum mechanics to predict that black holes are not, in fact, completely black. Heisenberg's uncertainty principle, one of the central tenets of quantum mechanics, maintains that you cannot pin down all the physical properties of a particle at the same time. Among other curiosities, this leads to the startling idea (which has been proved experimentally) that a vacuum is not empty space. Instead, it is filled with pairs of "virtual" particles and their antiparticles, which pop into existence for a fraction of a second before recombining with one another and disappearing again.

But near a black hole's event horizon – the boundary within which gravity is so intense that nothing can escape – things can go wrong. A virtual particle or antiparticle may be captured by the black hole's gravity. Once within the event horizon, it cannot escape and its abandoned partner has no option but to become real. After a while, the newly real particles decay, giving off (among other things) light, X-rays and gamma rays.

Dr Fabrizio Tamburini

Unfortunately, the typical temperature at which a black hole radiates Hawking radiation is a tiny fraction of the background radiation left over from the Big Bang itself. Proving Dr Hawking's prediction by observing actual Hawking radiation from a black hole in space has, therefore, remained elusive, although recently scientists have observed analogous processes in the laboratory.

Now with twisted light, there is (in theory at least) a way to distinguish the faint Hawking radiation photons (which will be twisted) from the background radiation from the Big Bang (which won't). Whether our telescopes will ever live up to that task is still unknown.

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