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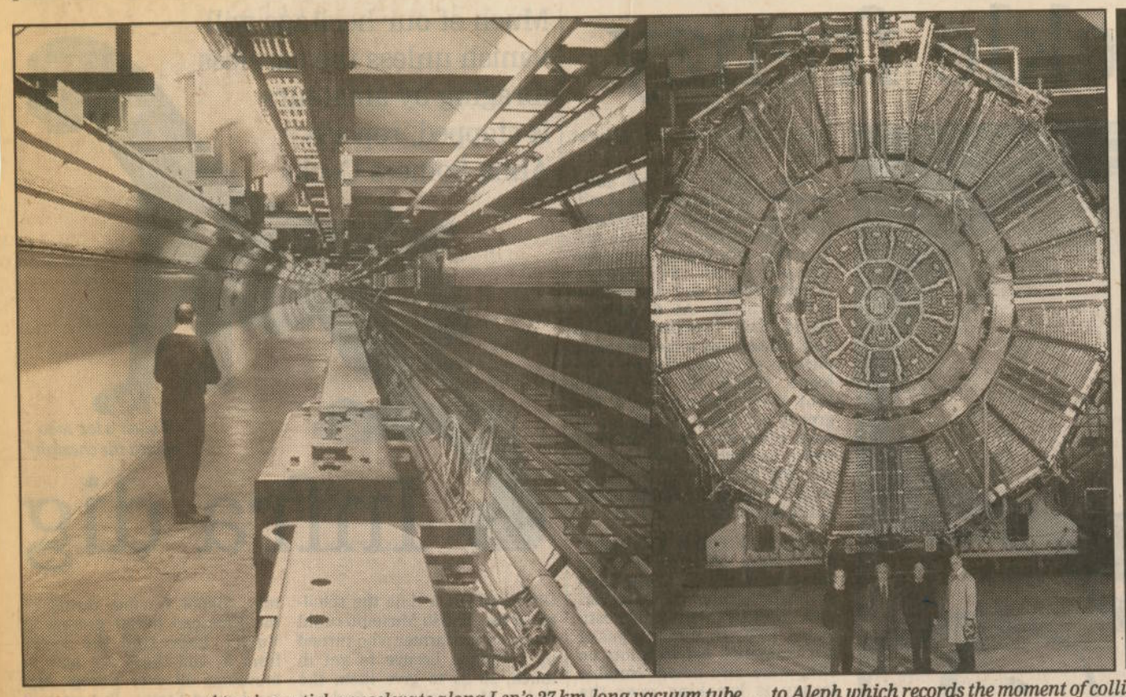
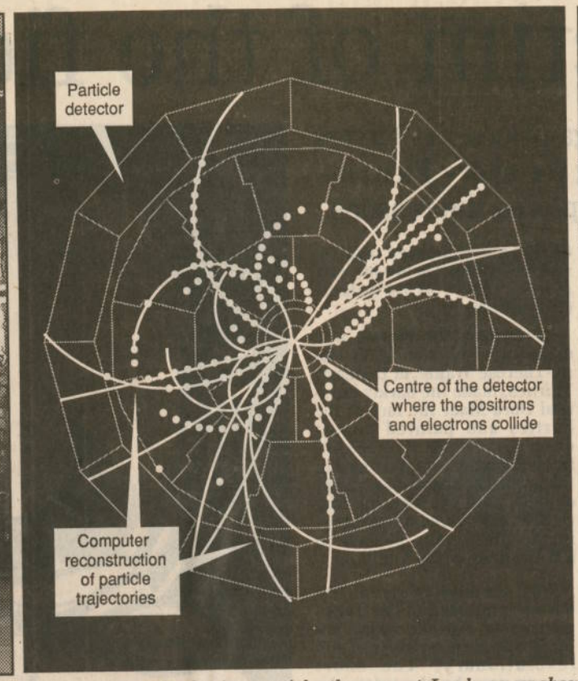
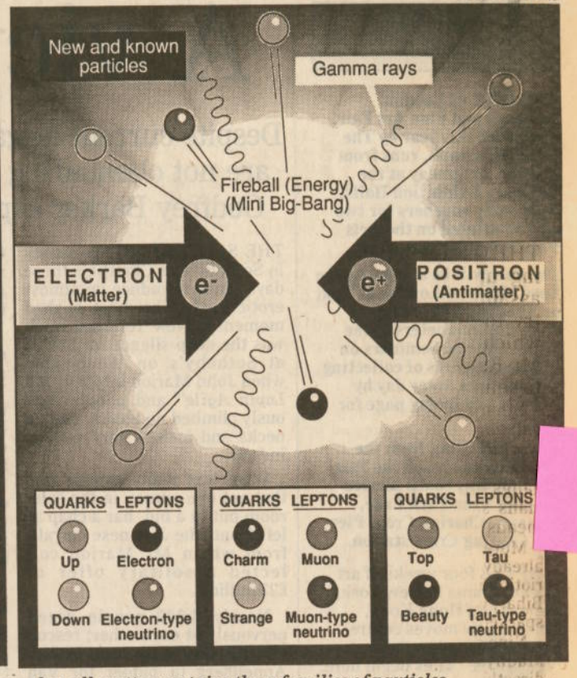
PETER WILLIAMS







Atomic particles accelerate along Lep's 27 km-long vacuum tube . . . to Aleph which records the moment of collision . . . and tracks the tiny particles thrown out. Lep has now shown that all matter contains three families of particles

The biggest bang since the Big One

Science Editor Roger Highfield reports on a £700 m particle accelerator – man's most complex instrument – that allows us to see inside the atom

THE BIGGEST scientific party ever was held last week to celebrate the inauguration of the largest instrument on the planet and the most complex ever devised by man. It allows man to study the fundamental building blocks of all matter.

The new £700 million Large Electron Positron collider in Geneva will ensure that Europe's scientists maintain their world lead in particle physics and help erect a grand theoretical framework for understanding the origins and development of — to quote a familiar science fiction catchphrase — the universe and all its contents.

Lep is a particle accelerator housed in a 27-kilometre circumference tunnel beneath the French and Swiss countryside. Its main competitor is America's Stanford Linear Accelerator Center, a radically different smasher design, although other nations are planning many more accelerators. Now the Americans are planning the ambitious Superconducting Super Collider, an 84-kilometre ring which will cost a colossal $6,000 million.

Lep is run by the 14 member states of Cern, the European Laboratory for Nuclear Research. All were represented in an event more remarkable for its pomp than scientific substance.

The symbolic handing over of the facility to its Nobel prize-winning director general, Prof Carlo Rubbia, was performed by Prof Emilo Picasso, leader of the project to build Lep. Prof Rubbia was given a floppy disk, the "key" to Lep. In his speech, he described how Cern had turned into a magnet for talent, "eloquently attested by the fact that there are now more American physicists coming to work in Europe than Europeans going to the United States".

As each national representative signed the declaration, their scrawl was relayed on to three huge screens in the hall. The strangest signatures received the most enthusiastic applause from those present — some 1,000 scientists, 200 journalists and others from Cern's 3,400-strong staff.

Lep's huge ring tunnel contains a tube the diameter of a human thigh within which two beams of atomic particles move through a vacuum as low as that on the moon. Like a television set, Lep contains hardware to accelerate, bend and focus the beams of particles, which can travel for 3,000 billion kilometres before bumping into a gas molecule.

Lep accelerates electrons, everyday particles, and their antiparticles, positrons, to nearly the speed of light and then causes them to collide head on within its four huge detectors, each the height of a four-storey house. In effect, the more energetic the particle beams the more detail of the innards of atoms are revealed.

In the vast energies of the resulting collisions Z^0 particles are formed. These are associated with the Weak Force, one of nature's four fundamental forces, whose discovery earned Prof Rubbia his Nobel prize in 1984.

Z^0s then decay to groups of quarks, the fundamental particles of matter, producing spectacular events in the physicists' detectors where many track fragments are formed.

The first Z^0 particles were detected within a few weeks of Lep's switch-on and to date it has produced tens of thousands. This has allowed the researchers to weigh the Z^0 with more accuracy than before, which is useful for determining the relative strengths of two of the fundamental forces of nature, known as the Weak and Nuclear Forces.

Less than three months after it collided its first particles, Lep announced it had made a fundamental determination: that three families of particles make up all the matter in the universe.

WHAT'S WHAT INSIDE THE ATOM:
Though physicists have suspected for some time that there are no more than three families of elementary particles, each consisting of a pair of quarks and a pair of leptons, confirmation of this by the experiments on Lep will increase their confidence in their theories, and removed an uncertainty in their favourite one, called the Standard Model.

The first family: Everyday matter is made of the four particles in this family. They are up quarks and down quarks, which make up the protons and neutrons found in the nuclei of atoms, and two leptons: electrons, which orbit the nuclei of atoms, and electron neutrinos, which are produced by exploding stars.

The second family: These particles are the strange and charmed quarks, and leptons named muons and muon neutrinos.

The third family: These are the bottom quark, top quark, the tau lepton and the tau neutrino.

All three families existed naturally a fraction of a second after the Big Bang that created the universe. But those in the second and third families cannot exist naturally on Earth today, save in cosmic rays and atom smashers, because the universe has cooled down.

Future aims of Lep are to find the elusive "top quark" and "tau neutrino" the only members of the three families not yet tracked down.

Even the Holy Grail for particle physicists may be in reach: the "Higgs boson", a particle first postulated by Dr Peter Higgs of Edinburgh University that is believed to be responsible for why matter weighs what it does.

There always remains, however, the chance that completely unexpected discoveries will be made en route to a grand theory of everything, which encompasses the quarks, leptons and all forces in nature.

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AN UNDERGROUND CATHEDRAL-SIZED VAULT DEDICATED TO SMASHING ATOMS

AS LONG AGO as the fifth century BC, Greek philosophers considered that all matter might be made of tiny building blocks which they called *atomos* — indivisible. "Particle physics is the study of matter at its most basic level," said Dr John Ellis, head of the theoretical division dealing with the Lep particle accelerator. "Lep is the most efficient and precise tool for continuing the basic philosophical drive of the Greeks."

Particle smashers like Lep reveal what an atom consists of. In a cathedral-sized vault hewn 150 metres underground lies one of the four "eyes" of the massive machine, in which the serious smashing takes place.

When the Large Electron Positron collider goes into action the eye — a vast cylinder called Aleph which is as big as a four-storey building — gazes upon a splash of matter and energy of a kind not seen since the universe was one tenth of a billionth of a second old and only one thousand million million times smaller than today.

Within Aleph and the other detectors, negatively charged electrons and positively charged antimatter collide at nearly the speed of light to release enormous energy, some of which become extremely short-lived particles of matter.

These tracks of charged particles are recorded in Aleph with a "time projection chamber". From the tracks the kind of particles can be deduced.

In all, eight people work on Aleph during experiments in seven control booths that operate 24 hours a day. Dr Terry Sloan of Lancaster University, one of the 130 British physicists working on Lep, said that Aleph offers better "segmentation" than the other three detectors, which enables a better separation of the tracks of the particles produced in a collision.

The depth of Aleph is about the same as the height of the Blackpool Tower. To anyone gazing up its huge vertical access shaft to the surface, the opening looks like a moon.

Scientists scuttle like troglodytes in the cavern, one of four housing detectors spaced at seven-kilometre intervals around Lep. Dr Sloan said the more athletic compete to see how quickly they can climb the stairs to the surface.

The distances around the Lep ring are so great the scientists resort to a monorail and bicycles to get about. There are also signs around the 27 km tunnel to help them navigate areas where one section looks much like any other. Aleph sits at the end of a siding at the Echenevex station.