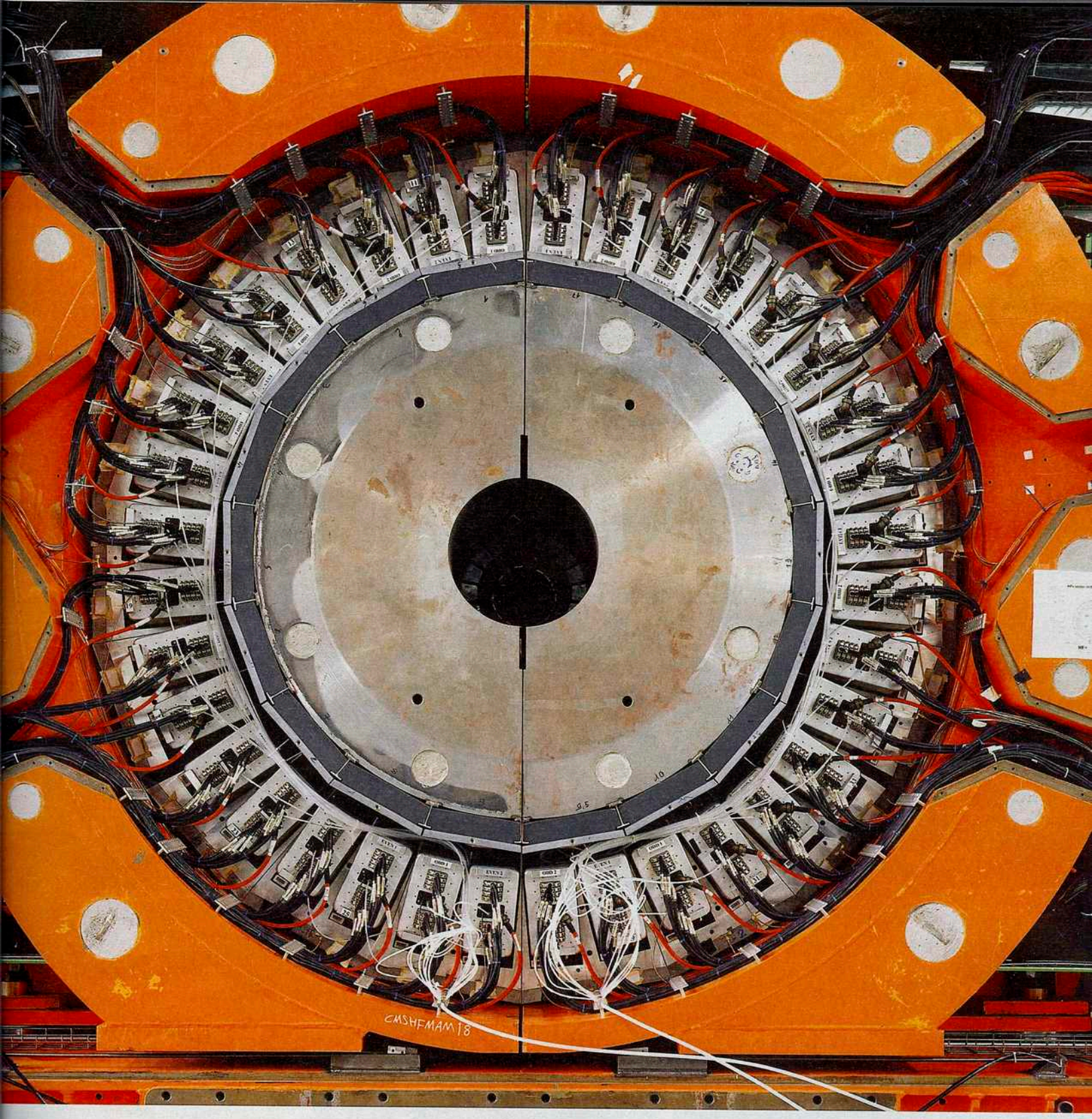
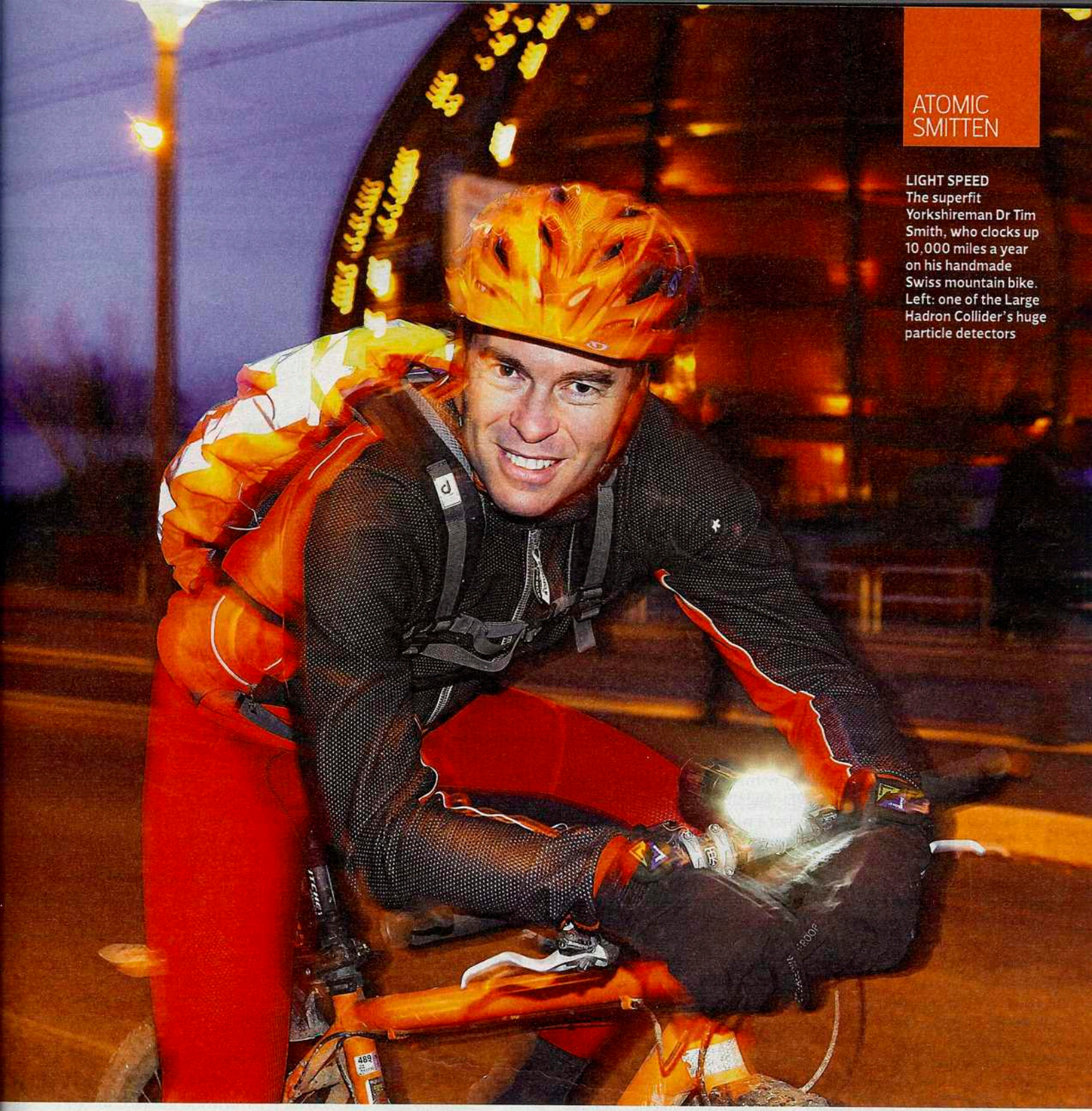


HIGGS AND MISSES

Home to the Large Hadron Collider, Cern keeps physicists such as Dr Tim Smith on their toes. **Michael Hanlon** followed their quest for the ever-elusive Higgs boson

ATOMIC SMITTEN



LIGHT SPEED The superfit Yorkshireman Dr Tim Smith, who clocks up 10,000 miles a year on his handmade Swiss mountain bike. Left: one of the Large Hadron Collider's huge particle detectors

The atom-smashers of Geneva are a breed apart. Cern is not just a place where they pulverise protons, break Einstein's laws and find elusive particles; it is a way of life. Cern, which has carved out a supranational, United Nations-style niche, has its own laws; its polite, diligent and workaholic citizens pay no state income tax and enjoy perks such as cheap cars and subsidised sauvignon.

The European Organisation for Nuclear Research is a temple to science, and the people who work here are the high priests of knowledge. Physicists, the rock gods of science, are on a roll, in the news more than at any time since the days of Einstein and Fermi. The feeling in the air is that after 30 years of dead ends and wrong turnings, science's senior service is on the verge of a series of breakthroughs.

If all goes well, we have a chance of understanding what the universe is, how it came about and even why we are here. Late last year, Cern was in the news for finding hints of the elusive Higgs boson and for getting a stream of neutrinos (some of the tiniest subatomic particles of all) to hurtle through the Alps at a whisper over the speed of light, potentially overturning Einstein's cardinal law that nothing may travel this fast. This caused great excitement at the time, but Cern now believes ⟩⟩⟩→

HEART OF THE MATTER Left: the cathedral-like Compact Muon Solenoid cavern, part of the LHC. Below: Val Gibson and Andy Parker. Right: Dr Pippa Wells's interests outside Cern include playing the violin to concert standard

that the "discovery" was down to faulty wiring causing an error in timing. This month Cern's star turn, the magnificent Large Hadron Collider (LHC), is switched on again after a winter service to resume its search for the Higgs boson. The LHC, which cost you the taxpayer about £6 billion and counting, has been working flat out (save a couple of breakdowns) since it was inaugurated and I have been granted unprecedented access to the machine's underground workings during this brief hiatus. Once it is in operation again, nobody will be able to come down here for months until it is turned off towards the end of this year for a refurbishment. The Higgs boson is the near-mythical particle that endows the rest of matter — the stuff we are made of — with mass, heft, call it what you will. This is the most fundamental property of matter. In the words of the British physicist Andy Parker, the Higgs boson "makes stuff stuff".

Cern is an odd place. I am reminded of how the writer Michael Moorcock described the utopian futures imagined by his friend Arthur C Clarke, populated by "brainy people sitting about in togas swapping theorems". The *Cernois* are mostly fit, highly intelligent workaholics; there are plenty of brainy women as well as men (and nobody wears togas — at least not in public).

Nearly everyone skis, some cycle 30 miles to work and back, most commuting from Jura villages over the French border, where prices are half those in Switzerland. In the car park are sports cars and expensive carbon road bikes. Yorkshireman Dr Tim Smith, like many people at Cern, lives for the mountains. Terrifyingly fit, he commutes to work on his handmade Swiss mountain bike, clocking up 10,000 miles a year. These people are also Olympic athletes in cerebral terms.

The air does not exactly crackle with sexual tension — this isn't Mad Men. But there must be something in the air.

The scientists work long hours in close proximity. And if you spend most of your waking hours thinking about neutrinos, it must be hard to spend your life with someone motivated by money, football or fashion. No wonder that so many of these people pair off. If you work in particle physics, this is a good time to be alive, with the discipline increasingly seen by the outside world as sexy and cutting edge.

The British couple Val Gibson and Andy Parker both work at Cern. "Ten years ago, if you said at a party that you were a particle physicist, that was the end of the conversation," says Professor Parker. "Now it's, 'Have you found the Higgs?'." They divide their time between Geneva and Cambridge, but are specialists in different fields and try not to talk shop at home. "I am a matter-antimatter person," says Professor Gibson (one of physics's loose ends is why there was slightly more matter than antimatter — the same as matter but whose particles have opposite electrical charges — at the beginning of the universe. Equations show that equal amounts of both should have emerged, annihilating each other, but clearly this did not happen, otherwise we would not be here). "And I do black-hole stuff," Parker adds.

He admits he may have been partly responsible for a scare story in 2008, just before the LHC was switched on. Internet rumours had it that the collider was powerful enough to create a mini black hole that would punch a hole through to the Earth's core and devour our planet. "I went round saying, isn't this fun? Maybe we could create a black hole in the lab. But not a destructive one, of course — it would evaporate instantly."

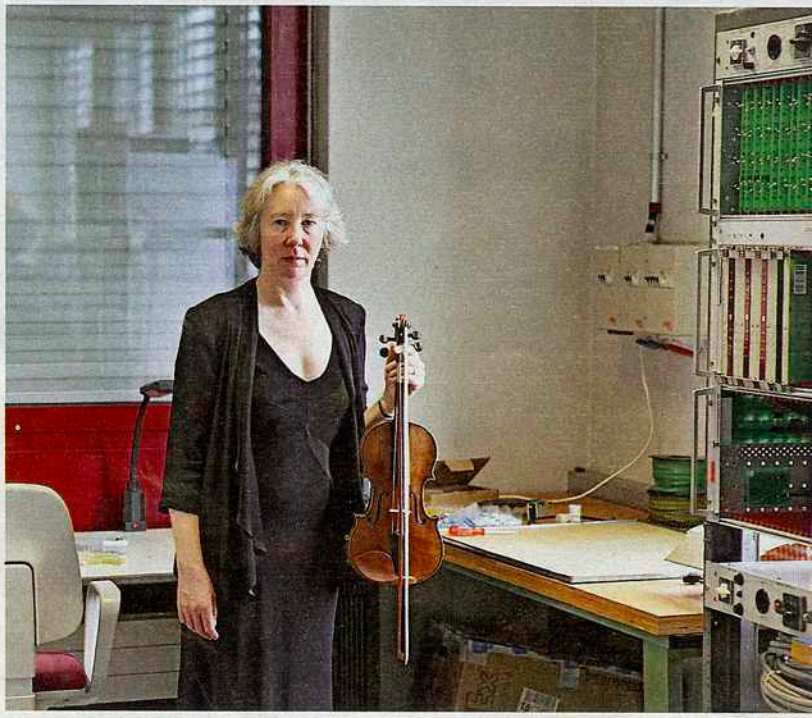
While it is possible to visualise genes or galaxies, the Alice in Wonderland nature of quantum physics is outside our imagining. This is a world where objects vanish like Cheshire cats into waves, where things can be in two places at once, where ordinary words are pressed into service to describe the indescribable. At one point, the British physicist Dr Pippa Wells says to me: "We might find the Higgs, but it may not be a standard Higgs — it might be a Susy Higgs." She is referring to Susy, or rather SUSY, short for "supersymmetry", another impossible-to-visualise concept that hypothesises the existence of

P44, P46 TOP LEFT AND P48 TOP LEFT: SIMON NORFOLK/NB PICTURES. ALL PORTRAITS: STEEVE IUNCKER/YU FOR THE SUNDAY TIMES MAGAZINE

shadowy "partners" for the elementary particles we know of. Wells, a girlishly enthusiastic fortysomething with three children, does a better job than anyone else I meet of explaining what is going on here. She has a life outside physics — playing violin to concert standard with the Orchestre Symphonique Genevois. This is a civilised place. "We are rivals, but friendly rivals," I am told time and again. Surely there must be petty feuds, absurd jealousies? Perhaps, but this work demands an unusual combination of team spirit and fierce individualism.

There are some intense people here, but Richard Jacobsson, 43, from near Stockholm, takes this to an extreme. He works on the LHCb, one of the four LHC detectors, which manipulates the beam to explore antimatter. Though affable, this man takes no prisoners as he explains the intricacies of the machine. His free time is pretty intense too. Jacobsson's honeymoon, in 2004, was spent on a tiny island called Tofua, in the Pacific, where an active volcano belches poison gas. Every day when he and his bride walked to a lake on top of the volcano to scuba-dive, they had to wear gas masks. Since then he has designed and built his own house, in the Jura Mountains. "People say they don't have time but then they watch television," he says.

Three hundred feet down, carved into the rock, you will find the Large Hadron Collider, which gets its name because it is huge, the subatomic particles it uses are "heavy" (or hadronic) as opposed to fleeting will-o'-the-wisps such as electrons, and because it gets them to collide as they fly rather than smash into a stationary target.



THE LHC IS THE MOST POWERFUL PARTICLE ACCELERATOR EVER BUILT. IT TOOK 20 YEARS TO DESIGN AND 10 YEARS TO CONSTRUCT

The LHC is the largest, most powerful particle accelerator ever built. It took 20 years to design and 10 years to construct; running costs are £690m a year. It is housed in the 17-mile, roughly circular tunnel under the Franco-Swiss border that was built for its predecessor, the much less powerful Large Electron-Positron Collider. Using more than 9,000 supercooled magnets of unimaginable power, the LHC can accelerate two opposing beams of protons or lead ions (lead atoms stripped of electrons) at energies of up to 14 trillion electronvolts, equivalent to those seen a fraction of a nanosecond after the Big Bang.

It's a wonderful machine, but there have been problems. Soon after it was turned on, a pigeon caused a power cut by dropping a piece of bread onto an outside electronic component. Then, 10 days into operation, a soldered joint in one of the beam-steering magnets failed, leading to the release of six tons of boiling helium gas into the tube. This created a pressure wave powerful enough to knock several 35-ton magnets off their mountings.

I take the elevator down to the Atlas detector, one of the most jaw-dropping pieces of machinery ever created. One of the four main "stations" on the Circle Line of the LHC, it is here that 4in-long packets of hydrogen ions 10 times thinner than a human hair are smashed together at 600m mph. The energy of the two beams combined is about the same as two freight trains travelling at 100mph.

This is the world where the sub-submicroscopic meets the gargantuan. Atlas, which sits in an artificial cavern that could swallow a cathedral, looks like a James Bond villain's wildest fantasy. Here are tens of thousands of miles of wiring, blinking computers, lumps of pig iron weighing as much as freighters and delicate instruments. Brunel meets the Death Star: at full tilt, the LHC gobbles as much power as the domestic consumption of Geneva. ⋙→

GHOST IN THE MACHINE: CHASING THE GOD PARTICLE

In the early 1960s the British physicist Peter Higgs proposed a complex mechanism to explain where mass comes from. In 1993 the minister William Waldegrave offered a bottle of champagne to anyone who could explain the "Higgs mechanism" on a single sheet of paper. The winner used an analogy involving a cocktail party and Margaret Thatcher.

A heavy particle (such as a proton) resembles an important person, such as the former prime minister. If Mrs T walks into the party, she will attract a larger crowd of followers than a lightweight, spotty neutrino. "Mass" is the drag imparted by the hangers-on, or Higgs field — an invisible gloopy ether that permeates the universe. Imagine that instead of Mrs T walking in, a rumour starts that she is about to walk in. Suddenly, there is a cluster of people around the door. This cluster is the Higgs boson.

So how do you catch a Higgs? First, take protons and accelerate them using magnets, then send two beams of them whirling round the LHC tunnel in opposite directions. You steer the beams so that the protons collide at four points. Then you examine the complex shower of debris that results. In late 2011, tantalising glimmers of the Higgs were spotted, but months more of continuous operation are needed to confirm this discovery.

This will be a triumph, but still leaves the small matter of reconciling quantum physics with Einstein's relativity. The best candidate is string theory, but to confirm it requires an accelerator the size of planet Earth. And there isn't the money for that right now.

TUNNEL VISION
Right: the 17-mile tunnel under the Franco-Swiss border is used to accelerate subatomic particles. Far right: the physicist Richard Jacobsson. Below: Alison Lister, who works on the Atlas detector, enjoys jogging and skiing in the Alps

As I stare in reverential silence, Dr Alison Lister, who works on Atlas, says: "It really is amazing to think this is all here for curiosity's sake. It gives you faith in humanity." Lister embodies Cern. Her boyfriend, a Pole, is also a physicist — at the LHC. And, like most people here, she takes full advantage of living in one of Europe's playgrounds, skiing in the Alps and pounding the running trails through the countryside. She observes that while many of the male employees are married to non-physicists, the female scientists here nearly always pair off with close colleagues. "I can think of only one woman physicist here who is not with another physicist — and he is an engineer."

It is make-or-break time for Cern. The scientists here know that their paymasters — us — want results, which means snaring the Higgs. After the LHC is turned on again, they will have the best part of a year to find the Higgs (or confirm it does not exist — equally exciting) and get hints as to the nature of dark matter, the weird invisible substance that forms the bulk mass of the universe. We will also know whether neutrinos really can break the light-speed limit — faulty wiring permitting.

Cern's chief scientist, a 62-year-old Italian bon viveur, motorcyclist and yachtsman called Sergio Bertolucci, is bullish. "We will definitely find something this year," he says. This anti-geek, who scythes his Honda over the Alpine passes to his beloved boat on the Med at La Spezia, is bullish too about the tens of billions of euros spent on what many criticise as esoteric research. "About 20% of global business is done on the web. And Cern invented the web. This alone justifies our existence for three or four hundred years." Back in the late 1980s a Cern staffer, Tim Berners-Lee, frustrated at the user-unfriendliness of the nascent internet, decided to improve it and invented the World Wide Web.

Physics is not only in the news: it is sexy, with applications in some British universities up 40%. Fifty per cent of engineers in the control rooms of Cern's particle accelerators are women, an unusually high proportion in a scientific establishment. Dr Edda Gschwendtner, a vivacious Austrian blonde, was responsible for sending a beam of neutrinos (ghostlike subatomic particles that have almost no mass) 450 miles under the Alps to detectors at Gran Sasso in Italy. Much to her (and everyone else's) surprise, the neutrinos appeared to have arrived 60 nanoseconds too early, implying they had travelled a little faster than light. Since then, she has sent smaller packets of neutrinos with the same result. "I was sceptical. I am sceptical, but it would be extremely cool if the result is confirmed," she says.

Fellow Austrian Dr Verena Kain, who sits in the control room and drives the LHC, has never lost touch with the sense of wonder she first felt as a child. Her wonder started not with the impossibly small and close but with the unimaginably large and distant. "I was always fascinated with what is going on far away from planet Earth," she says.

Perhaps the most unlikely physicist in Cern is Dr Steve Myers, who grew up in Catholic north Belfast and became a serious boxer after attacks by Protestant thugs on his walk to St Malachy's College on the Antrim Road. Certainly, few senior staff will have been shot at "several times" and nearly blown up by the IRA. Myers probably knows more about operating a particle collider than anyone else alive, having been a key player in Cern's biggest projects for 40 years. In 2009 he became director of accelerators and technology, "responsible for the operation and exploitation of the whole Cern accelerator complex", but it was touch and go at first. "My wife hated it. We had a new baby. There was no social life, nothing on the telly — have you seen Swiss telly? I hated it. I missed my friends and I missed the craic," he says.

So, what is the point of it all? We got the web, but that isn't what this is all about. If there is a point to our existence, it is surely to discover the fundamental nature of the universe. The great flowering of the Renaissance, which begat the Enlightenment, saw revolutions in the arts and sciences. It is only for a few hundred years that we have been asking questions about space, time and matter, and we have the wherewithal to find the answers. How did the universe begin? What is it made of? How will it end? Could it be any other way? And why is it here at all?

To these questions we have as yet no answers, but it is not for the want of trying. Thanks to Cern and similar establishments, a great deal of meat has been placed upon the theoretical bones of the breakthroughs made by 20th-century physics gods. Like the great telescopes that are discovering planets orbiting distant stars and colliding galaxies on the edge of the universe, Cern is one of science's great temples, a cathedral of knowledge. And for all that, less than £700m a year is surely something of a bargain ■

To watch a video of how antimatter atoms are produced and trapped at Cern, visit thesundaytimes.co.uk/hadroncollider