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CERN: 70 years of research and discovery

Particle laboratory CERN in Geneva has been a source of discoveries since 1954, and it is also a magnet for researchers.

Jos Engelen, former director of Nikhef and former research director of CERN, looks at Wikipedia's list of historical achievements of the lab in Geneva. The discovery of the Higgs particle. The discovery of the W and Z bosons. Antihydrogen. CP violation. First quark-gluon plasma. Neutral currents. And the World Wide Web, too, of course.

A pretty successful series, full of exciting physics, stretching from the 1950s to the present day. 'Yet also a bit one-sided. CERN work is not only about breakthroughs, but also about sharpening and refining what we already know and are technically able to do. But what you mostly fail to see from the list is how the existence of CERN has given a huge boost to particle physics itself.'

'Certainly also for the Netherlands,' says Engelen. 'Thanks to CERN, as a small country, we have been able develop into a country that matters in particle physics. Look at Nikhef's current research agenda, which is at once broad and ironclad, from LHC to astroparticles and gravitational waves.'

CERN, the *Conseil Européen pour la Recherche Nucléaire*, was founded in 1954, partly by the Netherlands, to rebuild European science after the war and as a centre for peaceful cooperation. International cooperation has been paramount from the outset, and this remained so even during the Cold War, during which east and west were so vehemently opposed elsewhere.

Merits

Jos Engelen was CERN's research director and deputy Director-General from 2004 to 2008. Like no other, he knows the scientific merits of 70 years of CERN, and in particular the Dutch perspectives.

Engelen: 'As a young student in Nijmegen, I attended Van de Walle's lectures. He talked about the strong nuclear force and told me bluntly that there was no theory for it yet. That remark drew me into the profession. I thought: I'm going to create that theory.'

Bubble chambers

Engelen ended up in particle physics and as a student first arrived at CERN around 1970, where, together with Amsterdam, Nijmegen had started its own bubble chamber experiment at the time. 'I still remember the thundering noise those things made with every recording. Very impressive. The window of the vessel lit up in blue and maybe I'm imagining it now, but you could actually see particle tracks in white light.'

Bubble chambers were the best particle detectors available at the time. In those days, the tracks of charged particles in the supercritical fluid were photographed and viewed one by one with the naked eye.

CERN built the world's largest 12 cubic metres bubble chamber, called Gargamelle. And later the even larger BEBC, partly with the help of Nikhef researchers. Gargamelle and BEBC still stand today like strange spaceships on pedestals in CERN's particle garden in Geneva.

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BEBC (left) and Gargamelle (right) in the Miscrocosm garden at CERN

An accelerator innovation in the 1970s were the Intersecting Storage Rings. This ISR (1971) consisted of two rings with proton beams in opposite directions colliding with each other. This is much more efficient than shooting beams at fixed targets. It didn't yield any real discoveries, says Engelen. 'In fact, it was a fantastic new technique, which researchers were still kind of wondering what to actually do with.' Dutch Nobel laureate Martinus Veltman later said they could have used it to find the J/psi particle (a Nobel Prize for Richter and Ting) before the Americans did in 1974. 'A missed opportunity, at that time,' Engelen also thinks.

Neutral currents

In 1973, bubble chamber Gargamelle provided the first evidence for so-called neutral currents, interactions that play a central role in the weak nuclear force. The weak interaction is a nuclear force that controls radioactive beta decay of atomic nuclei. Some theorists suspected that this must involve exchanges of unknown particles, similar to photons in electromagnetism. They are called neutral currents.

The tens of thousands of recordings from Gargamelle sometimes showed events without a muon with only traces of hadrons that seemed to appear out of nowhere. In the summer of 1973, researchers drew the conclusion from 170 such events that neutral currents must really be at work here.

That result became the basis for a continued search for the nature of these interactions. Importantly in this respect, for detectors, since the late 1960s entirely new techniques had been developed, in which pictures of particle tracks in a liquid no longer played a role. The wire chambers of George Charpak (Nobel Prize 1992) meant that fast detectors with the corresponding electronics and 'triggers' made their appearance in particle physics.

Workhorse

In 1976, says Engelen, CERN finally became a large-scale scientific facility with the arrival of the Super Proton Synchrotron, a seven-kilometre underground accelerator ring (for the first time under Switzerland and France). The particle physicists' workhorse attracted researchers from across Europe and around the world.

CERN's new wire detectors plus this SPS accelerator enabled further investigation of neutral currents. Theorists like Glashow, Salam and Weinberg suspected that this involved an uncharged Z particle, which acted as a force carrier in that process. In 1983, two CERN experiments, called UA1 and UA2, found sufficient evidence for such a Z particle in proton-antiproton collisions, and also for a similar but charged W particle. Unlike photons in electromagnetism, such force carriers have mass. Some of the electronics for UA1 were devised by a young researcher at Nikhef, Bob Hertzberger, later a leading pioneer in computer science in the Netherlands in particular.

Simon van der Meer

The UA1 and UA2 experiments used colliding protons and antiprotons for their measurements. There was a Dutch touch to this. At CERN, Delft-trained engineer Simon van der Meer invented the techniques to deliver beams of protons and antiprotons in the SPS accelerator that was extended to become a colliding-beam facility. He was awarded a Nobel Prize in 1984 along with Carlo Rubbia for the W and Z discoveries that his idea had made possible.

Under Nikhef director Walter Hoogland, the Netherlands collaborated on the ACCMOR detector at CERN, which studied collisions at SPS on a fixed target. The A in ACCMOR stood for Amsterdam, where the mechanical workshops got busy with the project, but eventually the experiment at CERN went by the somewhat more prosaic name NA32.

Engelen: 'It was a crucial step for Nikhef to participate prominently in an electronic 'counter experiment'. Thus, large wire chambers were built and corresponding electronics developed in Amsterdam for the first time. This laid the foundation for today's Nikhef.'

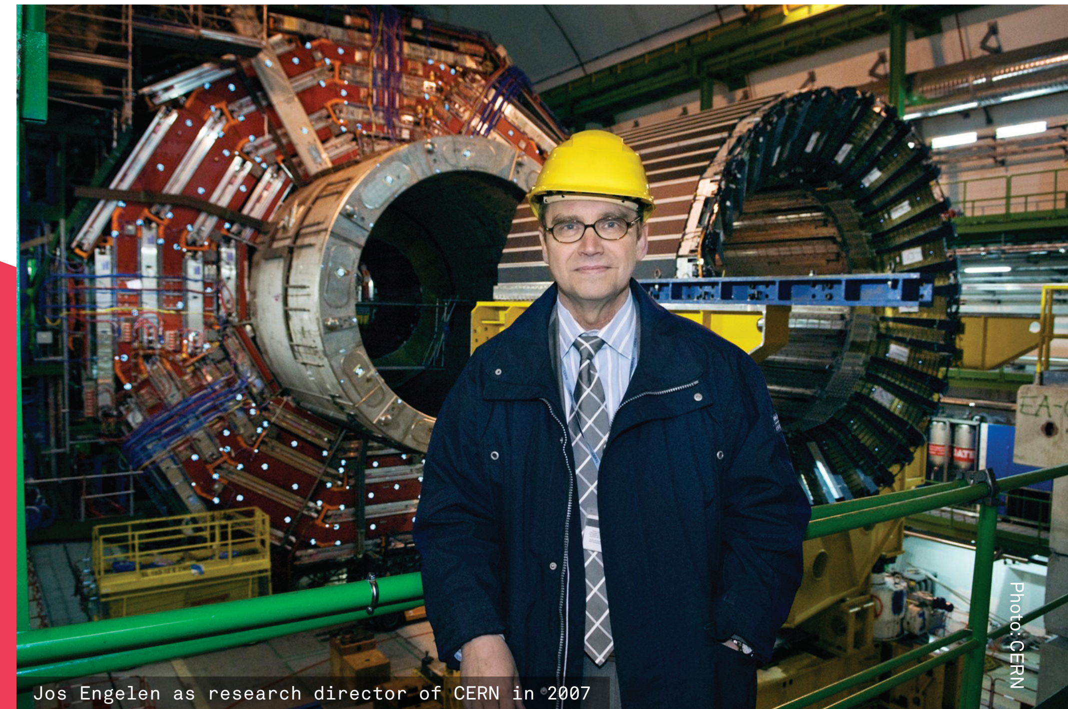

Photo: CERN

Jos Engelen as research director of CERN in 2007

LEP accelerator

This practical contribution was also the reason Nikhef was able to take a leading role in CERN's next project, the Large Electron Positron collider, or LEP accelerator. For this, the largest accelerator in the world was built in an underground tunnel: 27 kilometres in circumference with 5,176 magnets and 128 accelerator cavities. The complex housed four experiments: ALEPH, OPAL, L3 and DELPHI, each with its own design. Through Nikhef, the Netherlands was closely involved in both L3 and DELPHI.

The LEP accelerator came into operation in 1989 and was used for 11 years. This was the same year that software expert Tim Berners-Lee at CERN devised the World Wide Web protocol, perhaps the most influential thing CERN ever produced. Once conceived to allow scientists to collaborate remotely, it is now impossible to imagine society and the economy without it.

Engelen: 'Cynics say: LEP did not discover something totally new or unexpected. Strictly speaking, this is true; we had hoped for clues to the Higgs boson or supersymmetry, for example, back then. The great success of the accelerator and the experiments is that they were able to test the Standard Model in fantastic detail. The work was a crucial check for the work of Veltman and 't Hooft from the 1970s, and contributed to them being awarded the Nobel Prize in 1999.'

As a member of one of CERN's science committees, Engelen witnessed up close the announcement of a totally new form of matter, the plasma of quarks and gluons as heavy nuclei collide.

Higgs particle

But early this century, Engelen was especially closely involved in the run-up to an even more ambitious facility for particle physics: the Large Hadron Collider, today's LHC. A fully superconducting collider for protons at a record energy, with four new large detectors, all replacing the existing LEP accelerator in the same 27-kilometre circumference tunnel.

LEP stopped in 2000 and was decommissioned, the LHC became a reality in 2008, delivering the first usable beams of protons in 2010.

From the outset, the main commitment of the LHC was to find the Higgs particle, named after the theorist Peter Higgs, who died in early April of this year. The particle was predicted in the 1960s in an explanation of why elementary particles have mass at all. From the design phase, Nikhef researchers were involved in no fewer than three of the four detector projects at CERN: ATLAS, ALICE and LHCb. Of those three, ATLAS is a so-called 'multi-purpose' detector, and was more or less built to discover the Higgs particle.

When, on 4 July 2012, ATLAS and CMS jointly report the discovery of the Higgs particle, former director Engelen sits in the CERN auditorium in Geneva next to Peter Higgs, who in turn sits next to his colleague François Englert. 'I think we have it,' says CERN director Rolf Heuer with a great sense of understatement.

It was an emotional moment for many, including at Nikhef, where many were authors on the discovery paper. Engelen: 'A triumph. And proof of how well CERN's concept works: a fantastic central facility where the world comes together to make the most of it and then makes it happen. A place you want to go as a physics student with big questions. Just like me back in the day.' ◂