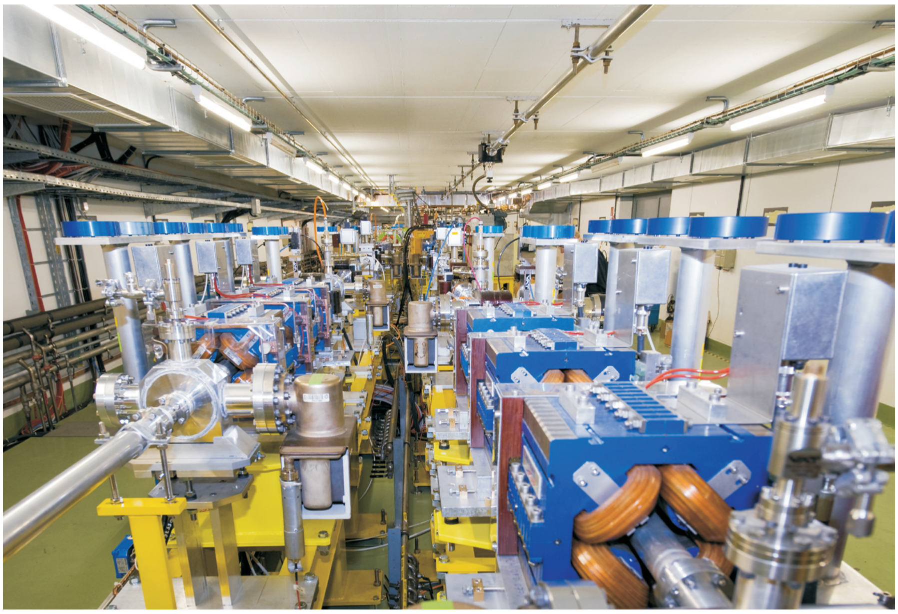
Next Generation Particle Accelerators

– CLIC

If particle detectors are the "payload" of particle physics, the particle accelerators are the "spacecraft". Each new generation of particle accelerators has lifted us up to an energy level where we have been able to explore a flora of new particles and phenomena.

While the world's largest accelerator, the LHC, is preparing for the first collisions, CERN is already designing the next generation, and its name is CLIC – the Compact Linear Collider.

Compact might not be the first word that comes to mind when the baseline design shows an almost 50 km long linear collider – but we are about to see that the ingenious CLIC design does merit the word "compact".



In the CLIC experimental area the world's first tests of 12 GHz Two-Beam Acceleration will take place in 2009. Photo by Claudia Marcelloni

The Next Step after LHC

Firstly, why do we need a 50 km long new collider? Secondly, why do we need a new collider at all after LHC? The answers lie in the type of particles being collided. LHC will be a proton-proton collider. From the particle-physics' viewpoint protons are heavy, composite objects, constituted of quarks and gluons. Their large mass makes them relatively easy to accelerate, because heavy particles radiate much less synchrotron radiation when they are accelerated, than lighter particle (e.g. electrons). This means that one can use a circular accelerator, like LHC, for acceleration up to very high energies.

However, since protons are not point-like objects, precision measurements will be difficult at the LHC. An electron-positron collider, on the other hand, produces "clean" collisions between point-like objects, and a lot of complementary information about particles, detected in e.g. the LHC, will be found. As an example: imagine that the LHC discovers a Higgs particle with a certain mass. The Higgs is not described by its mass alone, but by its spin, its coupling to other particles, and its coupling to itself. In many ways the Higgs is a very special particle. To measure these parameters and find out whether the particle found really is the Higgs as predicted by the standard model, one needs electron-positron collisions with an energy reach comparable to that of new physics found at the LHC.

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Erik Adli (33) from Steinkjer, Norway, started his career in the Aerospace Industry. From having worked three years for ESA at ESTEC, dealing mostly with Space Robotics and Technology Transfer, he then moved on to the particle-physics experiment ATLAS under a CERN Fellowship. He is now working towards the end of his Ph.D. studying Next Generation Particle Accelerators at CERN.

Getting Straight

At LHC-like energy levels the electrons and positrons have to be accelerated in a straight line to avoid enormous synchrotron radiation being radiated if moving on a curved orbit. Unfortunately, the electric field one can build up in an accelerating structure is limited, and the length of a linear electron-positron collider will be driven by the achievable maximum accelerating field.

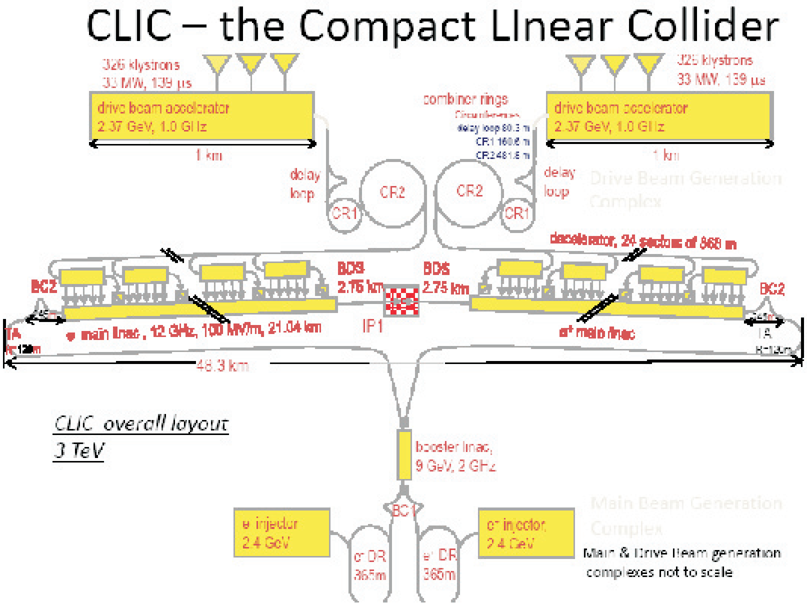
CLIC is aiming to achieve a world record in accelerator accelerating field - 100 MV/m – which will give a collision energy of 3 TeV – covering well the LHC range. However, " conventional" linear accelerators typically use pulsed-power Klystron technology to feed the accelerating structures. Klystrons producing pulsed power can be complex, expensive beasts, with a large need for maintenance. If CLIC would be build with this technology, it would require tens of thousands of klystrons operating at X-band frequencies, along the full length of the electron and positron accelerators.

CLIC – the Electron Peeler

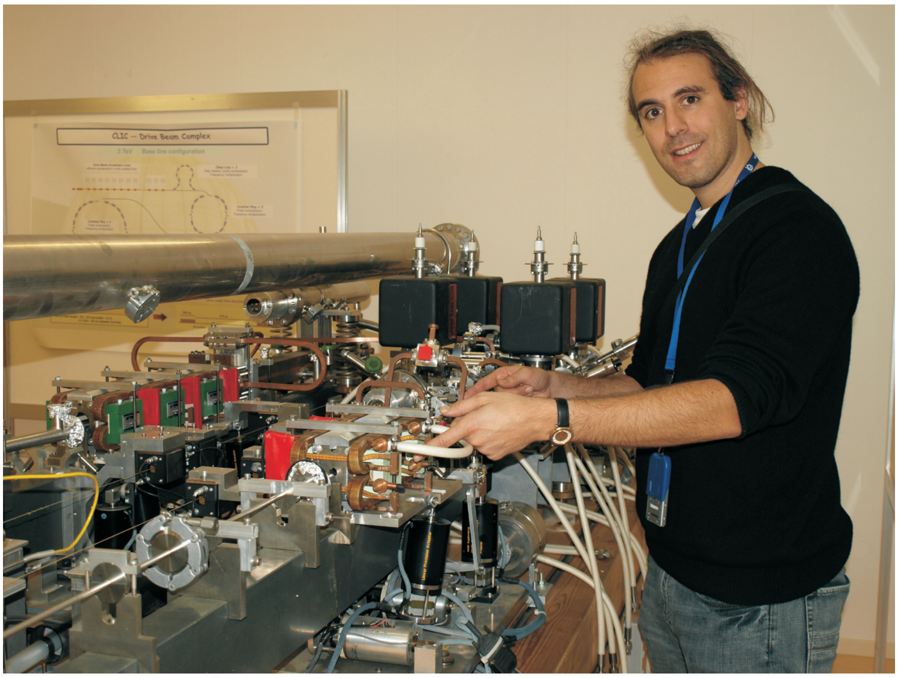
What CLIC does is instead to take on a novel approach for providing RF-power for the accelerating structures. In parallel to the electron and positron accelerator beams, a very intense electron Drive Beam will be sent. Special power extraction structures will mercilessly peel the electromagnetic field off the electrons in the Drive Beam, and transfer the RF-field generated from this process to the Main Beam accelerating structures.

Located close to the CLIC central complex, the Drive Beam will be accelerated to a relatively low energy (2 GeV) before being sent off towards the electron and positron main accelerators. Thus one transfers the power of a high intensity, low energy Drive Beam to the low intensity but high energy main beams –using purely passive components, operating at room temperature. This makes the accelerator technology both robust and compact.

This advanced acceleration concept is called Two-Beam Acceleration , and prototypes to verify these principles have been built at CERN, first on a small scale and then planned for the next few years: a full feasibility test in the new CLIC Test Facility 3. An intense research and development scheme will be needed to fulfill the technological challenges, and the full CLIC machine can possibly start operating somewhere in the 2020s.



Principal sketch of the Compact Linear Collider. Source: CERN



Erik Adli explains the principle of Two-Beam Acceleration using an early CLIC module prototype. Photo NordicSpace

Once the LHC is up and running, indicating to us what new phenomena that wait on the energy frontier of particle physics, the electron-peeler CLIC might thus be the our next spacecraft launching us ever more deeply into inner space.