CLIC - The Compact Linear Collider

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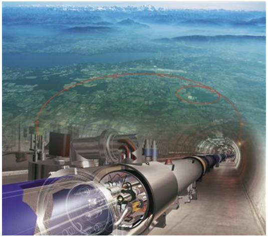
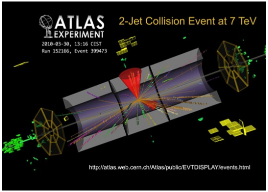
Particle accelerator:

- Uses electric fields to accelerate charged particles and normally magnetic fields to bend their paths
- Many applications, including
  - High energy physics (understand nature's building blocks and their interactions)
  - Synchrotron light sources (analysis of atoms, molecules etc.)
  - Medical accelerators (hadron therapy)



Particle collider:

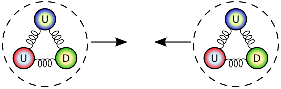
- Fundamental particles collide at velocities close to the speed of light
- Original particles may be annihilated while new particles are produced
- Many different collision events possible - some common, some rare
  - For statistical reasons, a very high number of collisions is needed
  - A discovery is claimed at 5σ evidence (the chance that it is wrong is 1 in 500 million)
  - Billions of collisions are recorded in particle detectors
  - Colliders usually collect data for several years
- In high-energy colliders, particles are packed into bunches. As an example, the LHC can have up to 2808 bunches in the ring, each with 100 billion protons.
- In the search for new physics, the energy frontier is pushed further



Why build a new collider?

Need for a lepton collider after the LHC

- Hadron (like proton): Each particle consists of quarks and gluons
- Hadron colliders: Constituents have varying momenta - collision energy for the whole hadron is constant
- Lepton (like electron): Fundamental, indivisible particle
- Lepton colliders: More suited to precision physics, less background particles

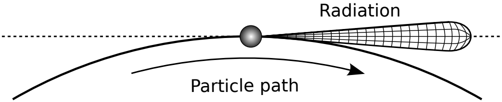


Lepton collider options

- Linear e^+e^- collider: CLIC, ILC
- Muon collider
- Plasma-driven acceleration

For electrons, a ring is ruled out because of *synchrotron radiation*. The energy loss per turn is:

$$\Delta E \propto \frac{1}{m_0^4}\frac{E^4}{\rho}$$



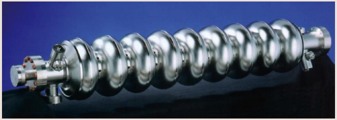
- Electrons have $1836^4 \approx 10^{13}$ higher losses than protons
- Based on energy loss per turn, a scaled-up LEP accelerator at 1 TeV would have a diameter of 5400 km, reaching from Geneva to the US east coast...
- Therefore, the consensus is to build a linear electron/positron collider

Acceleration and gradient

- Gradient: Accelerating field per meter
- Especially important in linear accelerators (directly related to accelerator length)
- Traditional radiofrequency technology: ~ 20 MV/m (SLC in Palo Alto, California)
  $\Rightarrow$ A 1 TeV machine would need about 75 km

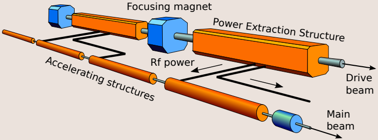
The International Linear Collider (ILC)

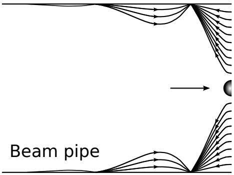
- 0.5 TeV electron/positron collider (possible upgrade to 1 TeV)
- Superconducting accelerating cavities
- Gradient: 31.5 MV/m
- Length: 31 km



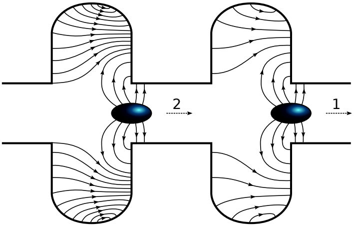
The Compact Linear Collider (CLIC)

- 3 TeV electron/positron collider (will possibly start at 0.5 TeV)
- 2-beam scheme: Power is transferred from a secondary drive beam
- Gradient: 100 MV/m
- Length: 48.3 km

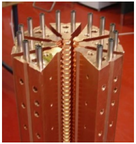


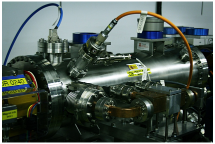


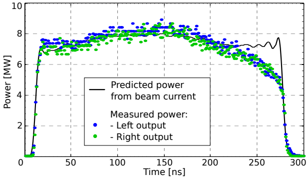
- After particle bunches there is a trailing wake field
- In a cavity, a field is left behind
- A certain bunch spacing leads to a constructive build-up of the field



Power Extraction and Transfer Structure (PETS): A periodically loaded waveguide that exploits this.







- The field travels down the structure at 0.46c (group velocity)
- Up to 135 MW of radiofrequency power is coupled out
- This is used to accelerate the main beam bunches
- The drive beam bunches are decelerated (by conservation of energy)

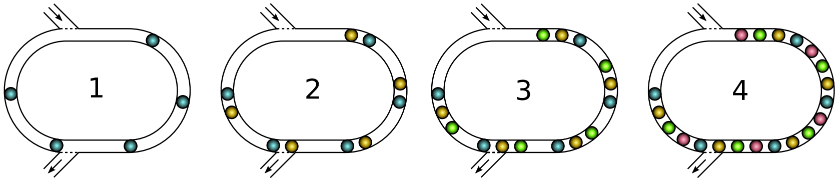
Achieving a high beam current

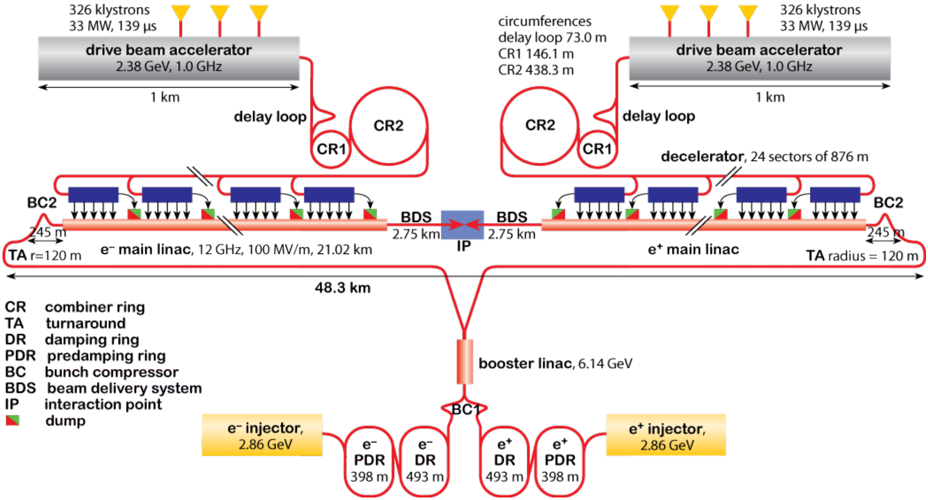
The power produced in a PETS goes as $P \propto I^2$

- Strong dependence on the beam current I (flow of charged particles)
- A high current is vital for a strong accelerating field

To achieve a high beam current $\Rightarrow$ high power:

- Bunches are packed closely together in short pulses
- This is done in *delay loops* and *combiner rings*
- In CLIC, the beam current and the frequency is multiplied 24 times

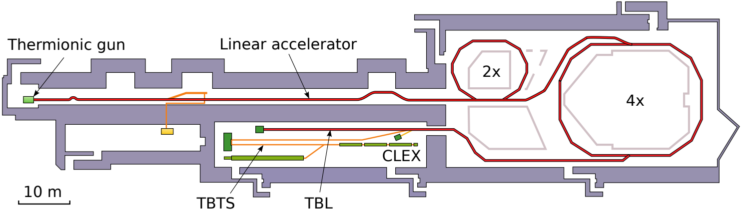




326 klystrons
33 MW, 139 μs
drive beam accelerator
2.38 GeV, 1.0 GHz
1 km
delay loop
CR2
CR1
circumferences
delay loop 73.0 m
CR1 146.1 m
CR2 438.3 m
326 klystrons
33 MW, 139 μs
drive beam accelerator
2.38 GeV, 1.0 GHz
1 km
delay loop
CR2
CR1
decelerator, 24 sectors of 876 m
BC2
245 m
TA r=120 m
e⁻ main linac, 12 GHz, 100 MV/m, 21.02 km
BDS
2.75 km
IP
BDS
2.75 km
e⁺ main linac
BC2
245 m
TA radius = 120 m
48.3 km
CR combiner ring
TA turnaround
DR damping ring
PDR predamping ring
BC bunch compressor
BDS beam delivery system
IP interaction point
dump
booster linac, 6.14 GeV
BC1
e⁻ injector, 2.86 GeV
e⁻ PDR 398 m
e⁻ DR 493 m
e⁺ DR 493 m
e⁺ PDR 398 m
e⁺ injector, 2.86 GeV

CLIC Test Facility 3 (CTF3): Set up to verify key technology concepts

- 1 delay loop (factor 2 combination)
- 1 combiner ring (factor 4 combination)
- Power production and tests of PETS
- Two-beam acceleration and tests of accelerating structures: Two-Beam Test Stand (TBTS)
- Energy extraction in several PETS: The Test Beam Line (TBL)



Some things demonstrated so far:

- Drive beam generation with factor 8 frequency multiplication
- Two-beam acceleration with 106 MV/m in TBTS
- 9 % energy extraction in TBL so far (55 % when fully installed)