Compact Linear Collider (CLIC)

Philip Burrows

John Adams Institute
Oxford University
Outline

- Introduction
- Linear colliders + CLIC
- CLIC project status
- 5-year R&D programme + technical goals
- Applications of CLIC technologies
Large Hadron Collider (LHC)

Largest, highest-energy particle collider

CERN, Geneva
CERN accelerator complex
CLIC vision

• A proposed LINEAR collider of electrons and positrons

• Designed to reach VERY high energies in the electron-positron annihilations: 3 TeV

  \[ 3 \text{ TeV} = 3 \times 10^{12} \text{ eV} \]

• Ideal for producing new heavy particles of matter, such as SUSY particles, in clean conditions
CLIC vision

• A proposed LINEAR collider of electrons and positrons

• Designed to reach VERY high energies in the electron-positron annihilation: $3 \text{ TeV}$

  $$= 3\,000\,000\,000\,000\,000 \text{ eV}$$

• Ideal for producing new heavy particles of matter, such as SUSY particles, in clean conditions

  … should they be discovered at LHC!
CLIC energy staging

- An energy-staging strategy is being developed:
  
  \[ \sim 500 \text{ GeV} \rightarrow 1.5 \text{ TeV} \rightarrow 3 \text{ TeV} \]

  (and realistic for implementation)

- The start-up energy would allow for a Higgs boson and top-quark factory
2013 Nobel Prize in Physics
e+e- Higgs boson factory

e+e- annihilations:

\[ E > 91 + 125 = 216 \text{ GeV} \]

\[ E \sim 250 \text{ GeV} \]

\[ E > 91 + 250 = 341 \text{ GeV} \]

\[ E \sim 500 \text{ GeV} \]
European PP Strategy (2013)

High-priority large-scale scientific activities:

- LHC + High Lumi-LHC
- Post-LHC accelerator at CERN
- International Linear Collider
- Neutrinos
International Linear Collider (ILC)

31 km

c. 250 GeV / beam

31 km
ILC Candidate Location: Kitakami Area

IP: (underground) candidate Location:
   - Level above sea: 111 m (± 50 m)

Proposed by JHEP community
Endorsed by LCC
Not decided by Japanese Government
(presented by A. Yamamoto, AWLC14)
ILC Kitakami Site: IP region
Global Linear Collider Collaboration
CERN should undertake design studies for accelerator projects in a global context, with emphasis on proton-proton and electron-positron high energy frontier machines. These design studies should be coupled to a vigorous accelerator R&D programme, including high-field magnets and high-gradient accelerating structures, in collaboration with national institutes, laboratories and universities worldwide.
CLIC Layout: 3 TeV

Drive Beam Generation Complex

Main Beam Generation Complex

- 326 klystrons
- 33 MW, 139 μs
- drive beam accelerator: 2.38 GeV, 1.0 GHz
- 1 km
- delay loop
- CR1
- CR2
- circumferences delay loop 72.4 m
- CR1 144.8 m
- CR2 434.3 m

- 326 klystrons
- 33 MW, 139 μs
- drive beam accelerator: 2.38 GeV, 1.0 GHz
- 1 km
- delay loop
- decelerator, 24 sectors of 876 m

- BC2
- 245 m
- TA radius = 120 m
- $e^-$ main linac, 12 GHz, 100 MV/m, 21.02 km

- BC2
- 245 m
- TA radius = 120 m
- $e^+$ main linac

- BDS
- 2.75 km
- IP

- Booster linac, 9 GeV

- $e^-$ injector, 2.4 GeV
- BC1
- e$^-$ PDR 365 m
- e$^-$ DR 365 m

- e$^+$ injector, 2.4 GeV
- e$^+$ PDR 365 m
- e$^+$ DR 365 m

CR: combiner ring
TA: turnaround
DR: damping ring
PDR: predamping ring
BC: bunch compressor
BDS: beam delivery system
IP: interaction point
CLIC Collaboration

29 Countries – over 70 Institutes

- Accelerator collaboration
- Detector collaboration
- Accelerator + Detector collaboration
CLIC Collaboration

29 Countries – over 70 Institutes

Accelerator collaboration
Detector collaboration
Accelerator + Detector collaboration

New accelerator collaboration partners joining (2013/4):
The Hebrew University Jerusalem, Vinca Belgrade, ALBA/CELLS, Tartu University, NCBJ Warsaw, Shandong University, Ankara University
Institute of Accelerator Technologies (IAT)

Detector collaboration operative with 22 institutes
CLIC Organisation

CERN LC project leader: Steinar Stapnes

CLIC Accelerator:
Collaboration Spokesperson: PNB
CLIC/CTF3 technical coordinator: Roberto Corsini
Collaboration Board Chair: Lenny Rivkin

CLIC Detector + physics:
Collaboration Spokesperson: Lucie Linssen
Collaboration Board Chair: Frank Simon
This workshop will cover **Accelerator as well as the Detector and Physics studies**, with its present status and programme for the coming years.

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<thead>
<tr>
<th>Overview</th>
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<td>Timetable</td>
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<td>Physics and Detector Study Website</td>
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**306 registered**

**Main elements:**
- Open high energy frontier session session, including hadron options with FCC
- Accelerator sessions focusing on collaboration efforts and plans 2013-2018, parallel sessions and plenary
- High Gradient Applications for FELs, industry, medical
- Physics and detector sessions on current and future activities
- Collaboration and Institute Boards
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**Main elements:**
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Accelerator sessions focusing on collaboration efforts and plans 2013-2018, parallel sessions and plenary

**High Gradient Applications for FELs, industry, medical**

Physics and detector sessions on current and future activities

Collaboration and Institute Boards
CLIC Workshop 2015

January 26-30 @ CERN
A Multi-TeV Linear Collider
based on CLIC Technology

CLIC Conceptual Design Report

PHYSICS AND DETECTORS AT CLIC

CLIC Conceptual Design Report
CDR (2012)

CLIC SCHEMATIC
(not to scale)
CDR (2012)
CLIC detector

- Return yoke with instrumentation for muon ID
- Complex forward region with final beam focusing
- Strong solenoid 4 T - 5 T
- Fine grained (PFA) calorimetry, $1 + 7.5 \Lambda_i$
- All-silicon tracker
- Ultra low-mass vertex detector with 25 μm pixels

Lucie Linssen
CDR (2012)

- Pre-Higgs discovery
- Optimised design for 3TeV, but not lower energies
- First look at power/energy requirements
- Some industrial costing, overall cost not optimised
- Some component reliability studies
- X-band demonstration limited by test capacity
- Initial system tests

→ Already a lot more has been (and will be) done!
Beyond the CDR: next 5 years

Present CLIC project as a credible option for CERN in post-LHC era ( > 2035) – for consideration in next European Strategy update ~ 2018/19

- Update physics studies in light of LHC results
- Complete key technical feasibility R&D
- Perform more system tests + verification
- More advanced industrialisation studies
- Cost/energy-staging strategy with a 20-30 year perspective
CLIC parameters (3 TeV)

Electrons or positrons / bunch  4  10**9
Bunch separation  0.5  ns
### CLIC parameters (3 TeV)

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<td>Wall-plug power</td>
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CLIC accelerating structures

12 GHz (X-band): 100 MV/m

Micron-level surface finish and stacked alignment
High RF power X-band test station XBOX#2. bld. 150.
Future XBOX#3: x4 klystron (6MW) cluster

Should service 4 testing slots in parallel with pulses repetition rate of 100 Hz
CLIC Modules

20760 modules x 2

3 modules to be mechanically characterised + tested:
Active alignment, fiducialisation + stabilisation (PACMAN)
Test-area (simulating the tunnel)

- Range for air temperature and speed:
  - $T_{air} = 20 - 40 \, ^\circ C$
  - $v_{air} = 0.2 - 0.8 \, m/s$

- Air speed sensors installed in the middle of the room
“Nano positioning” CLIC

With piezo actuators, modify position quadrupole in between beam pulses (≈ 5 ms)

Range ± 5 μm, increments 10 to 50 nm, precision ± 0.25 nm
Demonstration of mechanical absolute stability at sub nano metre level

Collocated pair

Type 1

X-y proto

In CLIC this transfer function reduces the luminosity loss due to ground motion from 68 % to 7%
PACMAN = a study on Particle Accelerators Components’ Metrology and Alignment to the Nanometer scale

Metrology
Survey & alignment
Beam instrumentation
Radio Frequency
Nano-positioning
Magnetic measurements

Develop very high accuracy metrology & alignment tools and integrate them in a prototype alignment bench

Extrapolate the tools & methods developed to other projects

Prepare for industrialisation
PACMAN industrial and academic partners

Europe

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<td>DMP</td>
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CLIC Magnets

124 MW power consumed by magnets in 3 TeV baseline

Eg. use of permanent or hybrid magnets for the drive beam

( ~ 50,000 magnets)
Vacuum technology development for CLIC

Development of vacuum windows and chambers in glassy carbon.

Deformable RF fingers in free position

NEG and ion pumping
test accelerator to demonstrate CLIC technology

COMBINER RING

DELAY LOOP

CLEX

DRIVE BEAM LINAC

CLIC Test Facility (CTF3)
CTF3

Delay Loop
Chicane
Linac
Combiner Ring
CALIFES
Probe Beam Injector
TBTS
TBL
Injectot
CLEX
CTF3

Beam loading/BDR experiment

Phase feed-forward, DB stability studies

Two-Beam Module, Wake-field monitors, Two-beam studies RF pulse shaping

Power production, RF conditioning/testing with DB & further decelerator tests

CLIC Diagnostics tests
Drive beam phase FF prototype
(Oxford, CERN, Frascati)
Drive beam phase FF prototype
(Oxford, CERN, Frascati)
Drive beam phase FF prototype
(Oxford, CERN, Frascati)
Executive summary

• The key CLIC technologies have been prototyped + demonstrated → no ‘show-stoppers’

• Currently main effort is on system tests and industrialisation of key technologies

• I only gave a flavour of some of the issues

• There is a lot to do… come and join the fun!
2013-18 Development Phase
Develop a Project Plan for a staged implementation in agreement with LHC findings; further technical developments with industry, performance studies for accelerator parts and systems, as well as for detectors.

4-5 year Preparation Phase
Finalise implementation parameters, Drive Beam Facility and other system verifications, site authorisation and preparation for industrial procurement.
Prepare detailed Technical Proposals for the detector-systems.

2018-19 Decisions
On the basis of LHC data and Project Plans (for CLIC and other potential projects), take decisions about next project(s) at the Energy Frontier.

2024-25 Construction Start
Ready for full construction and main tunnel excavation.

Commissioning
Becoming ready for data-taking as the LHC programme reaches completion.
Applications of CLIC high-gradient technology

Linear collider – CLIC collaboration

Single-room proton therapy for cancer
TERA foundation

Compact XFEL light sources – Horizon2020 proposal
## Horizon 2020 Design Study

### Participant organisation names

<table>
<thead>
<tr>
<th>Participant No</th>
<th>Participant organisation name</th>
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