Short Introduction to CLIC and CTF3, Technologies for Future Linear Colliders

Explanation of the Basic Principles and Goals
Visit to the CTF3 Installation

Roger Ruber
Collider History

• **hadron collider** at the frontier of physics
  – huge QCD background
  – not all nucleon energy available in collision

• **lepton collider** for precision physics
  – well defined CM energy
  – polarization possible

• **next machine after LHC**
  – $e^+e^-$ collider
  – energy determined by LHC discoveries
    consensus $E_{cm} \geq 0.5$ TeV
Circular versus Linear Collider

Circular Collider
- many magnets, few cavities, stored beam
- higher energy $\rightarrow$ stronger magnetic field
- $\rightarrow$ higher synchrotron radiation losses ($\propto E^4/R$)

Linear Collider
- few magnets, many cavities, single pass beam
- higher energy $\rightarrow$ higher accelerating gradient
- higher luminosity $\rightarrow$ higher beam power (high bunch repetition)
Cost of Circular & Linear Accelerators

Circular Collider
- $\Delta E \sim (E^4/m^4R)$
- cost $\sim aR + b \Delta E$
- optimization: $R \sim E^2 \rightarrow$ cost $\sim cE^2$

Linear Collider
- $E \sim L$
- cost $\sim aL$
Linear Collider R&D

CTF3 goals:
1. high accelerating gradient
2. efficient power production
3. feasibility demonstration
Acceleration of Charged Particles

- Lorenz (EM) force most practical
  \[ \mathbf{F} = e(\mathbf{v} \times \mathbf{B} + \mathbf{E}) \]

- increasing particle energy
  \[ \Delta E = e \int \mathbf{E} \cdot d\mathbf{r} = eU \]

- to gain 1 MeV energy requires a 1 MV field

Direct-voltage acceleration used in
- TV tube: 20~40 kV
- X-ray tube: ~100 kV
- tandem van de Graaff: up to ~25 MV
Drift Tube Linac: Higher Integrated Field

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Courtesy E. Jensen
electrons $\beta \sim 1$ ($v \sim c$)

short pulses

high frequency $>3$ GHz

typical $10 \sim 20$ MV/m

CLIC:
- 12 GHz
- 240 ns
- 100 MV/m
Accelerating Cavities

CERN PS 19 MHz Cavity (prototype 1966)

ILC 1.3 GHz Cavity (prototype 2005)

CLIC 30 GHz Cavity (prototype 2006)
Surfing: or How to Accelerate Particles

DC Accelerator

RF Accelerator

synchronize particle with an electromagnetic wave!
Challenges:
1. high accelerating gradient
2. **efficient power production**
3. feasibility demonstration
Electromagnetic Waves

• static electron → electric field

• moving electron → electromagnetic wave

• constant electron beam → static electric field + static magnetic field

• bunched electron beam → electromagnetic wave
CLIC Two-beam Acceleration Concept

• 12 GHz modulated and high power drive beam

• RF power extraction in a special structure (PETS)

• use RF power to accelerate main beam
Recombination to Increase Peak Power & Frequency

**Drive Beam Accelerator**
- efficient acceleration in fully loaded linac

**Delay Loop x 2**
- gap creation, pulse compression & frequency multiplication

**Combiner Ring x 3**
- pulse compression & frequency multiplication

**Combiner Ring x 4**
- pulse compression & frequency multiplication

**RF Transverse Deflectors**

**Drive Beam Decelerator Sector**
- Power Extraction

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**Drive beam time structure - initial**
- 240 ns
- 140 µs train length - 24 x 24 sub-pulses - 4.2 A
- 2.4 GeV - 60 cm between bunches

**Drive beam time structure - final**
- 240 ns
- 5.8 µs
- 24 pulses – 100 A – 2.5 cm between bunches
Drive Beam Generation Scheme
Linear Collider R&D

Challenges:
1. high accelerating gradient
2. efficient power production
3. feasibility demonstration
CLIC: Compact Linear Collider

- **Main Linac**
  - C.M. Energy: 3 TeV
  - Peak luminosity: $2 \times 10^{34} \text{ cm}^{-2} \text{s}^{-1}$
  - Beam Rep. rate: 50 Hz
  - Pulse time duration: 156 ns
  - Average field gradient: 100 MV/m
  - # accelerating cavities: $2 \times 71,548$

- **Tunnel**
  - $\Phi 4.5 \text{ m}$

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CTF3 Test Facility

- demonstration **drive beam generation**
- evaluate **beam stability & losses** in deceleration
- develop **power production & accelerating structures**

![Diagram of CTF3 Test Facility](image_url)

- **Drive Beam Accelerator**
  - Drive Beam Injector
  - CLEX

- **Decelerator Test Beam Line**
  - Two-Beam Test-stand
  - 180 MeV Probe Beam Injector

- **Delay loop**
  - 42 m

- **Combiner Ring**
  - 84 m

- **CLEX**
  - Drive beam stability bench marking

- **Drive beam generation scheme**

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