The Linear Collider Collaboration
Lyn Evans
LCC Mandate 2013-2018

The mandate of the LCC (from ICFA) is to support the global design effort to enable the possible realization of a timely electron-positron collider and its detectors based on ILC technology, to support the CLIC technology development for a potential future higher energy machine and to coordinate both efforts in order to exploit synergies between them.
The future of LCC

Japan has made it clear that no decision on ILC will be made before end 2018.
ILL mandate has been extended by ICFA until the end of 2019.
Table 4. Accelerator parameters for the ILC and the CLIC in various modes [27, 28].

<table>
<thead>
<tr>
<th>Parameters</th>
<th>ILC baseline</th>
<th>ILC Hi-lumi</th>
<th>ILC E-upgrade</th>
<th>CLIC staging</th>
<th>CLIC baseline</th>
</tr>
</thead>
<tbody>
<tr>
<td>Accelerating technology</td>
<td>SRF</td>
<td>SRF</td>
<td>SRF</td>
<td>NRF</td>
<td>NRF</td>
</tr>
<tr>
<td>Center-of-mass energy (GeV)</td>
<td>500</td>
<td>500</td>
<td>1,000</td>
<td>500</td>
<td>3,000</td>
</tr>
<tr>
<td>Luminosity (cm$^{-2}$s$^{-1}$)</td>
<td>$1.8 \times 10^{34}$</td>
<td>$3.6 \times 10^{34}$</td>
<td>$4.9 \times 10^{34}$</td>
<td>$2.3 \times 10^{34}$</td>
<td>$5.9 \times 10^{34}$</td>
</tr>
<tr>
<td>Luminosity at top 1% CM energy</td>
<td>$1.1 \times 10^{34}$</td>
<td>$2.2 \times 10^{34}$</td>
<td>$2.2 \times 10^{34}$</td>
<td>$1.4 \times 10^{34}$</td>
<td>$2.0 \times 10^{34}$</td>
</tr>
<tr>
<td>Accelerator length (km)</td>
<td>31</td>
<td>31</td>
<td>50</td>
<td>13.0</td>
<td>48.4</td>
</tr>
<tr>
<td>Acc. gradient loaded (MV/m)</td>
<td>31.5</td>
<td>31.5</td>
<td>31.5/45</td>
<td>80</td>
<td>100</td>
</tr>
<tr>
<td>RF (GHz)</td>
<td>1.3</td>
<td>1.3</td>
<td>1.3</td>
<td>12</td>
<td>12</td>
</tr>
<tr>
<td>Beam power/beam (MW)</td>
<td>5.2</td>
<td>11.0</td>
<td>13.6</td>
<td>4.7</td>
<td>14</td>
</tr>
<tr>
<td>No. of particles/bunch ($10^9$e$^+/-$)</td>
<td>20</td>
<td>20</td>
<td>17.4</td>
<td>6.8</td>
<td>3.72</td>
</tr>
<tr>
<td>No. of bunches/pulse</td>
<td>1,312</td>
<td>2,625</td>
<td>2,450</td>
<td>354</td>
<td>312</td>
</tr>
<tr>
<td>Bunch separation (ns)</td>
<td>554</td>
<td>366</td>
<td>366</td>
<td>0.5</td>
<td>0.5</td>
</tr>
<tr>
<td>Beam pulse duration ($\mu$s)</td>
<td>727</td>
<td>900</td>
<td>900</td>
<td>177</td>
<td>0.156</td>
</tr>
<tr>
<td>Beam pulse current [mA]</td>
<td>5.8</td>
<td>8.8</td>
<td>7.6</td>
<td>2180</td>
<td>1190</td>
</tr>
<tr>
<td>Repetition rate [Hz]</td>
<td>5</td>
<td>5</td>
<td>4</td>
<td>50</td>
<td>50</td>
</tr>
<tr>
<td>H./V. norm. emittance ($10^{-6}/10^{-9}$)</td>
<td>10/35</td>
<td>10/35</td>
<td>10/30</td>
<td>2.4/25</td>
<td>0.66/20</td>
</tr>
<tr>
<td>H./V. IP beam size (nm)</td>
<td>474/5.9</td>
<td>474/5.9</td>
<td>335/2.7</td>
<td>203/2.3</td>
<td>40/1</td>
</tr>
<tr>
<td>Beamstrahlung photon/electron</td>
<td>1.72</td>
<td>1.72</td>
<td>1.97</td>
<td>1.3</td>
<td>2.1</td>
</tr>
<tr>
<td>Wall plug to beam transfer eff. (%)†</td>
<td>6.4</td>
<td>10.2</td>
<td>9.1</td>
<td>3.5</td>
<td>4.8</td>
</tr>
<tr>
<td>Power efficiency in the main linac‡</td>
<td>12</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>6</td>
</tr>
<tr>
<td>Total power consumption (MW)</td>
<td>163</td>
<td>204</td>
<td>300</td>
<td>271</td>
<td>582</td>
</tr>
</tbody>
</table>

* Here the parameter set B for 1 TeV in TDR is adopted.
† Final beam power (two beams) divided by the total site power.
‡ Beam power gain in main linac divided by AC power into main linac, including cryogenics, drive linac, linac magnets, drive beam manipulation, etc.
**ILC500 (TDR) \(\rightarrow\) ILC250**

**ILC 500GeV**

~31km

**ILC 250GeV**

\(\rightarrow\) Cost reduction

~20km

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**SRF Cost-reduction R&D**

*Cost reduction by techn. innovation*

- **Nb material** process \(\rightarrow\) reduce material cost
- **Cavity Surface** process with N-infusion (High-G and –Q): reduce # cavities and cost

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<tr>
<td>C.M. Energy</td>
<td>250 GeV</td>
</tr>
<tr>
<td>Length</td>
<td>20.5 km</td>
</tr>
<tr>
<td>Luminosity</td>
<td>(1.35 \times 10^{34}) cm(^{-2}) s(^{-1})</td>
</tr>
<tr>
<td>Repetition</td>
<td>5 Hz</td>
</tr>
<tr>
<td>Beam Pulse Period</td>
<td>0.73 ms</td>
</tr>
<tr>
<td>Beam Current</td>
<td>5.8 mA (in pulse)</td>
</tr>
<tr>
<td>Beam size (y) at FF</td>
<td>7.7 nm</td>
</tr>
<tr>
<td>SRF Cavity G. (Q_0)</td>
<td>(31.5\sim35) MV/m (Q_0 = 1 \sim1.6\times10^{10})</td>
</tr>
</tbody>
</table>

DIRECTLY SLICED 3-CELL CAVITY SATISFIED THE ILC SPEC.

N-INFUSION SUCCESSFUL AT FERMILAB AND KEK.
ILC250 Acc. Design Overview

Key Technologies

Nano-beam Technology

SRF Accelerating Technology

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**E-XFEL: SRF Cavity Performance (as received)**

- **SRF cavity production/test:**
  - # RI Cavities, 373 (as of Sept. 2015)
  - Final process: 40 μm EP.
  - w/ same recipe to ILC-SRF's
  - Tested at DESY-AMTF

**Notes:**
- “Ultra-pure water rinsing as the 2nd process improving the gradient performance (> ~10%) for lower-performed cavities (not shown here).

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### SRF Cavity Performance

<table>
<thead>
<tr>
<th>G-max</th>
<th>(ILC)</th>
<th>G-usable</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;G&gt;</td>
<td></td>
<td></td>
</tr>
<tr>
<td>MV/m</td>
<td>29.4</td>
<td>33</td>
</tr>
<tr>
<td>YIELD at 28MV/m</td>
<td>66%</td>
<td>86%</td>
</tr>
</tbody>
</table>

22 September 2018
Cryomodule Performance: VT vs. MT

Average gradient gain (HT-VT, MV/m) for individual cavity RF distribution

No degradation, after ~ XM54

1st sample of 34 series CM
$\Delta E_{op} = -2.1$ MV/m

2nd sample of 19 series CM
$\Delta E_{op} = -1.7$ (-0.9) MV/m

Last 42 series CM
$\Delta E_{op} = +0.4$ MV/m

- Significant gradient degradation from XM6 to XM23, while CEA and Alsyom put all their effort in achieving production goal of 1 CM/week: an audit of string and module assembly was conducted by CEA on XM26
- A simplification of the clean room procedures was introduced at XM54: no degradation after...

5 July 2016  TTC Meeting, Saclay  27
Results comparison
"standard" 120C bake vs "N infused" 120C bake

Grassellino/Solyak

- Achieved: 45.6 MV/m \rightarrow 194 mT
  With Q \sim 2\times10^10!

- Q at \sim 35 MV/m \sim 2.3\times10^{10}!

- ILC specs: Q=0.8\times10^{10} @ 35MV/m

Increase in Q factor of two, increase in gradient \sim 15%
Technical Status in 2018

Key Technologies advanced!

Nano-beam Technology:
KEK-ATF2: FF beam size (v): 41 nm at 1.3 GeV (equiv. to 7 nm at ILC)

SRF Technology:
European XFEL completed: <G = ~ 30 MV/m> achieved with 800 cavities and accelerator commissioning/operation reaching > 90 % design energy.

LCLS-II: construction in progress

H-FEL (Shinghai): construction approved

US-Japan: Cost Reduction R&Ds in progress, focusing on “N Infusion” process demonstrated, at Fermilab, for High-Q and High-G

General design updated:
• ILC 250 GeV proposal has been authorized by ICFA/LCB
Progress in FF Beam Size and Stability at ATF2

**Goal 1:** Establish the ILC final focus method with same optics and comparable beamline tolerances
- **ATF2 Goal:** 37 nm $\rightarrow$ 6nm @ILC500GeV
  7.7nm@ILC250GeV
- **Achieved:** 41 nm (2016)

**Goal 2:** Develop a few nm position stabilization for the ILC collision
- **FB latency 133 nsec achieved** (target: < 300 nsec)
- **Position jitter at IP:** 410 $\rightarrow$ 67 nm (2015) (limited by the BPM resolution)

We continue efforts to achieve goal 1 and goal 2.

Nano-meter stabilization at IP

History of ATF2 small beam

- 1 Skew Sextupole Installed
- 4 Skew Sextupole Installed
- 4 FF Sextupoles
- Orbit Stabilization
  5 FF sextupole
  Skew Sextupole Modification
- Sextupole Swapped
- FONT FB ON
- OFF: 0.41 um
- On: 0.067 um
ILC Investigation by SCJ and MEXT

SCJ — Commissioned Survey by NRI (2014-17)

MEXT

ILC Adv. Panel

Physics WG

TDR Valid. WG

Human Res. WG

Organization & Managem. WG

2014-15 & 2018

2014-15 & 2018

2015-16

2017

2014 ~ 2018

1) WW Research trend (FY14)
2) Technology issues (FY15)
3) Large Int’l projects (FY16)
4) Risk/safety issues (FY17)

- Physics WG, and TDR Validation WG re-organized to evaluate ILC-250GeV.
ILC collision energy first stage at 250 GeV, now accepted by the community. The accelerator construction cost is well estimated with a meaningful cost reduction,
Key technologies of “Nano-beam” and “SRF” mature. Thanks for worldwide efforts for SRT technology, with European XFEL, LILS-II, and further.
Polarised positron production is marginal at 250 GeV.
The US-Japan, SRF cost-reduction R&D program in progress with encouraging results.
Our best effort has been made to provide comprehensive information to official WGs and IAP at MEXT is reaching a very critical stage to evaluate the ILC 250 GeV proposal.
The CLIC project

Timeline for the European Strategy ~2019, goal:
- Cost and power optimised 380 GeV machine (~11 km) (drivebeam and klystrons) upgradeable to 3 TeV

Key technical activities in the collaboration:
- Xband statistics and optimisation for cost
- Work with FEL labs for use in smaller machines
- Permanent magnets (power)
- High Efficiency klystrons (power and cost)
- Stability and alignment (lum performance)
- Tests CTF3, CLEAR (next slide), ATF2, Low emittance rings
- Physics and detectors

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Unit</th>
<th>380 GeV</th>
<th>3 TeV</th>
</tr>
</thead>
<tbody>
<tr>
<td>Centre-of-mass energy</td>
<td>TeV</td>
<td>0.38</td>
<td>3</td>
</tr>
<tr>
<td>Total luminosity</td>
<td>$10^{34}$cm$^2$s$^{-1}$</td>
<td>1.5</td>
<td>5.9</td>
</tr>
<tr>
<td>Luminosity above 99% of vs</td>
<td>$10^{34}$cm$^2$s$^{-1}$</td>
<td>0.9</td>
<td>2.0</td>
</tr>
<tr>
<td>Repetition frequency</td>
<td>Hz</td>
<td>50</td>
<td>50</td>
</tr>
<tr>
<td>Number of bunches per train</td>
<td></td>
<td>352</td>
<td>312</td>
</tr>
<tr>
<td>Bunch separation</td>
<td>ns</td>
<td>0.5</td>
<td>0.5</td>
</tr>
<tr>
<td>Acceleration gradient</td>
<td>MV/m</td>
<td>72</td>
<td>100</td>
</tr>
<tr>
<td>Site length</td>
<td>km</td>
<td>11</td>
<td>50</td>
</tr>
</tbody>
</table>
CLIC Layout at 3 TeV

Drive beam time structure - initial

- 240 ns
- 140 μs train length - 24 × 24 sub-pulses
- 4.2 A - 2.4 GeV - 60 cm between bunches

Drive beam time structure - final

- 5.8 μs
- 24 pulses - 101 A - 2.5 cm between bunches

- 240 ns

Main Beam Generation Complex

- Combiner ring
- Turnaround
- Damping ring
- Predamping ring
- Bunch compressor
- Beam delivery system
- Interaction point
- Dump
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.

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

Looking forward
Accelerator collaboration with ~50 institutes
Detector collaboration operative with ~25 institutes

• European Strategy points addressed: High Gradient acceleration, machine studies for high energy frontier e+e- (CLIC), ILC and general accelerator and detector R&D

• Common work with ILC related to several acc. systems as part of the LC coll., also related to initial stage physics and detector developments

• Common physics benchmarking with FCC pp and common detect. challenges (ex: timing, granularity), as well as project
Recently installed 2-beam acceleration module in CTF3 (according to latest CLIC design)
First 2-beam tests stand reached 145 MV/m (2012)

CLIC module review June 22: https://indico.cern.ch/event/393250/

32 September 2018
Timeline

2013 - 2019 Development Phase
Development of a Project Plan for a staged CLIC implementation in line with LHC results; technical developments with industry, performance studies for accelerator parts and systems, detector technology demonstrators

2020 - 2025 Preparation Phase
Finalisation of implementation parameters, preparation for industrial procurement, Drive Beam Facility and other system verifications, Technical Proposal of the experiment, site authorisation

2026 - 2034 Construction Phase
Construction of the first CLIC accelerator stage compatible with implementation of further stages; construction of the experiment; hardware commissioning

2019 - 2020 Decisions
Update of the European Strategy for Particle Physics; decision towards a next CERN project at the energy frontier (e.g. CLIC, FCC)

2025 Construction Start
Ready for construction; start of excavations

2035 First Beams
Getting ready for data taking by the time the LHC programme reaches completion
The goals and plans for 2015-19 are well defined for CLIC, focusing on the high energy frontier capabilities – well aligned with current strategies – also preparing to align with LHC physics as it progresses in the coming years:

• Aim provide **optimized staged** approach up to 3 TeV with costs and power not too excessive compared to LHC.
• Possible klystron driven start version at about 380 GeV

LC general and ILC support:

• LCC common fund and hosting, ATF as mentioned on earlier slide, participation in ILC preparation team (in the areas of BDS, RTML, Cryogenics systems, CFS and SCRF specific studies) ~10% of CERN LC effort
• Common WGs in Beam dynamics, Sources, MDI, DRs, RTML, BDS