LC studies

Outline:
- ILC and CLIC – project overview
- Why LCs – brief physics consideration
- Recent results
- Realization of the projects
- Summary
- Electron and Positron Sources (e-, e+):
- Damping Ring (DR):
- Ring to ML beam transport (RTML)
- Main Linac (ML): SCRF Technology
- Beam Delivery System (BDS)

Production yield: 94% at > 35+/−20%
Average gradient: 37.1 MV/m
> R&D goal of 35 MV/m reached (2012)
# ILC parameters

Table 2.1. Summary table of the 200–500 GeV baseline parameters for the ILC. The reported luminosity numbers are results of simulation [12]

<table>
<thead>
<tr>
<th>Centre-of-mass energy</th>
<th>$E_{CM}$ GeV</th>
<th>200</th>
<th>230</th>
<th>250</th>
<th>350</th>
<th>500</th>
</tr>
</thead>
<tbody>
<tr>
<td>Luminosity pulse repetition rate</td>
<td>Hz</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>Positron production mode</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>nom.</td>
<td>nom.</td>
</tr>
<tr>
<td>Estimated AC power</td>
<td>$P_{AC}$ MW</td>
<td>114</td>
<td>119</td>
<td>122</td>
<td>121</td>
<td>163</td>
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<tr>
<td>Bunch population</td>
<td>$N \times 10^{10}$</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Number of bunches</td>
<td>$n_b$</td>
<td>1312</td>
<td>1312</td>
<td>1312</td>
<td>1312</td>
<td>1312</td>
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<tr>
<td>Linac bunch interval</td>
<td>$\Delta t_b$ ns</td>
<td>554</td>
<td>554</td>
<td>554</td>
<td>554</td>
<td>554</td>
</tr>
<tr>
<td>RMS bunch length</td>
<td>$\sigma_z$ $\mu$m</td>
<td>300</td>
<td>300</td>
<td>300</td>
<td>300</td>
<td>300</td>
</tr>
<tr>
<td>Normalized horizontal emittance at IP</td>
<td>$\gamma_{e\times}$ $\mu$m</td>
<td>10</td>
<td>10</td>
<td>10</td>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td>Normalized vertical emittance at IP</td>
<td>$\gamma_e_{y}$ nm</td>
<td>35</td>
<td>35</td>
<td>35</td>
<td>35</td>
<td>35</td>
</tr>
<tr>
<td>Horizontal beta function at IP</td>
<td>$\beta_x^*$ mm</td>
<td>16</td>
<td>14</td>
<td>13</td>
<td>16</td>
<td>11</td>
</tr>
<tr>
<td>Vertical beta function at IP</td>
<td>$\beta_y^*$ mm</td>
<td>0.34</td>
<td>0.38</td>
<td>0.41</td>
<td>0.34</td>
<td>0.48</td>
</tr>
<tr>
<td>RMS horizontal beam size at IP</td>
<td>$\sigma_x^*$ nm</td>
<td>904</td>
<td>789</td>
<td>729</td>
<td>684</td>
<td>474</td>
</tr>
<tr>
<td>RMS vertical beam size at IP</td>
<td>$\sigma_y^*$ nm</td>
<td>7.8</td>
<td>7.7</td>
<td>7.7</td>
<td>5.9</td>
<td>5.9</td>
</tr>
<tr>
<td>Vertical disruption parameter</td>
<td>$D_y$</td>
<td>24.3</td>
<td>24.5</td>
<td>24.5</td>
<td>24.3</td>
<td>24.6</td>
</tr>
<tr>
<td>Fractional RMS energy loss to beamstrahlung</td>
<td>$\delta_{BS}$ %</td>
<td>0.65</td>
<td>0.83</td>
<td>0.97</td>
<td>1.9</td>
<td>4.5</td>
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<tr>
<td>Luminosity</td>
<td>$L \times 10^{34}$ cm$^{-2}$ s$^{-1}$</td>
<td>0.56</td>
<td>0.67</td>
<td>0.75</td>
<td>1.0</td>
<td>1.8</td>
</tr>
<tr>
<td>Fraction of $L$ in top 1% $E_{CM}$</td>
<td>$L_{0.01}$ %</td>
<td>91</td>
<td>89</td>
<td>87</td>
<td>77</td>
<td>58</td>
</tr>
<tr>
<td>Electron polarisation</td>
<td>$P_e$ %</td>
<td>80</td>
<td>80</td>
<td>80</td>
<td>80</td>
<td>80</td>
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<tr>
<td>Positron polarisation</td>
<td>$P_+^*$ %</td>
<td>30</td>
<td>30</td>
<td>30</td>
<td>30</td>
<td>30</td>
</tr>
<tr>
<td>Electron relative energy spread at IP</td>
<td>$\Delta p/p$ %</td>
<td>0.20</td>
<td>0.19</td>
<td>0.19</td>
<td>0.16</td>
<td>0.13</td>
</tr>
<tr>
<td>Positron relative energy spread at IP</td>
<td>$\Delta p/p$ %</td>
<td>0.19</td>
<td>0.17</td>
<td>0.15</td>
<td>0.10</td>
<td>0.07</td>
</tr>
</tbody>
</table>

Upgradeable to 1 GeV – parameters sets also available
CLIC Layout at 3 TeV

Drive Beam Generation

**Drive beam time structure - initial**

- 140 μs train length - 24 × 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 - 101 A - 2.5 cm between bunches

**Main Beam Generation Complex**

- e⁻ main linac, 12 GHz, 100 MV/m, 21 km
- CR combiner ring
- TA turnaround
- DR damping ring
- PDR predamping ring
- BC bunch compressor
- BDS beam delivery system
- IP interaction point
- dump

**e⁻ injector, 2.86 GeV**
### Possible CLIC stages studied in the CDR

#### Key features:
- High gradient (energy/length)
- Small beams (luminosity)
- Repetition rates and bunch spacing (experimental conditions)

### Table 1: Parameters for the CLIC energy stages of scenario A.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Symbol</th>
<th>Unit</th>
<th>Stage 1</th>
<th>Stage 2</th>
<th>Stage 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Centre-of-mass energy</td>
<td>$\sqrt{s}$</td>
<td>GeV</td>
<td>500</td>
<td>1400</td>
<td>3000</td>
</tr>
<tr>
<td>Repetition frequency</td>
<td>$f_{repl}$</td>
<td>Hz</td>
<td>50</td>
<td>50</td>
<td>50</td>
</tr>
<tr>
<td>Number of bunches per train</td>
<td>$n_b$</td>
<td></td>
<td>354</td>
<td>312</td>
<td>312</td>
</tr>
<tr>
<td>Bunch separation</td>
<td>$\Delta t$</td>
<td>ns</td>
<td>0.5</td>
<td>0.5</td>
<td>0.5</td>
</tr>
<tr>
<td>Accelerating gradient</td>
<td>$G$</td>
<td>MV/m</td>
<td>80</td>
<td>80/100</td>
<td>100</td>
</tr>
<tr>
<td>Total luminosity</td>
<td>$\mathcal{L}$</td>
<td>$10^{34}$ cm$^{-2}$s$^{-1}$</td>
<td>2.3</td>
<td>3.2</td>
<td>5.9</td>
</tr>
<tr>
<td>Luminosity above 99% of $\sqrt{s}$</td>
<td>$\mathcal{L}_{0.01}$</td>
<td>$10^{34}$ cm$^{-2}$s$^{-1}$</td>
<td>1.4</td>
<td>1.3</td>
<td>2</td>
</tr>
<tr>
<td>Main tunnel length</td>
<td></td>
<td>km</td>
<td>13.2</td>
<td>27.2</td>
<td>48.3</td>
</tr>
<tr>
<td>Charge per bunch</td>
<td>$N$</td>
<td>$10^9$</td>
<td>6.8</td>
<td>3.7</td>
<td>3.7</td>
</tr>
<tr>
<td>Bunch length</td>
<td>$\sigma_z$</td>
<td>$\mu$m</td>
<td>72</td>
<td>44</td>
<td>44</td>
</tr>
<tr>
<td>IP beam size</td>
<td>$\sigma_x/\sigma_y$</td>
<td>nm</td>
<td>200/2.6</td>
<td>$\sim$ 60/1.5</td>
<td>$\sim$ 40/1</td>
</tr>
<tr>
<td>Normalised emittance (end of linac)</td>
<td>$\varepsilon_x/\varepsilon_y$</td>
<td>nm</td>
<td>2350/20</td>
<td>660/20</td>
<td>660/20</td>
</tr>
<tr>
<td>Normalised emittance (IP)</td>
<td>$\varepsilon_x/\varepsilon_y$</td>
<td>nm</td>
<td>2400/25</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>Estimated power consumption</td>
<td>$P_{wall}$</td>
<td>MW</td>
<td>272</td>
<td>364</td>
<td>589</td>
</tr>
</tbody>
</table>

### Table 2: Parameters for the CLIC energy stages of scenario B.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Symbol</th>
<th>Unit</th>
<th>Stage 1</th>
<th>Stage 2</th>
<th>Stage 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Centre-of-mass energy</td>
<td>$\sqrt{s}$</td>
<td>GeV</td>
<td>500</td>
<td>1500</td>
<td>3000</td>
</tr>
<tr>
<td>Repetition frequency</td>
<td>$f_{repl}$</td>
<td>Hz</td>
<td>50</td>
<td>50</td>
<td>50</td>
</tr>
<tr>
<td>Number of bunches per train</td>
<td>$n_b$</td>
<td></td>
<td>312</td>
<td>312</td>
<td>312</td>
</tr>
<tr>
<td>Bunch separation</td>
<td>$\Delta t$</td>
<td>ns</td>
<td>0.5</td>
<td>0.5</td>
<td>0.5</td>
</tr>
<tr>
<td>Accelerating gradient</td>
<td>$G$</td>
<td>MV/m</td>
<td>100</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>Total luminosity</td>
<td>$\mathcal{L}$</td>
<td>$10^{34}$ cm$^{-2}$s$^{-1}$</td>
<td>1.3</td>
<td>3.7</td>
<td>5.9</td>
</tr>
<tr>
<td>Luminosity above 99% of $\sqrt{s}$</td>
<td>$\mathcal{L}_{0.01}$</td>
<td>$10^{34}$ cm$^{-2}$s$^{-1}$</td>
<td>0.7</td>
<td>1.4</td>
<td>2</td>
</tr>
<tr>
<td>Main tunnel length</td>
<td></td>
<td>km</td>
<td>11.4</td>
<td>27.2</td>
<td>48.3</td>
</tr>
<tr>
<td>Charge per bunch</td>
<td>$N$</td>
<td>$10^9$</td>
<td>3.7</td>
<td>3.7</td>
<td>3.7</td>
</tr>
<tr>
<td>Bunch length</td>
<td>$\sigma_z$</td>
<td>$\mu$m</td>
<td>44</td>
<td>44</td>
<td>44</td>
</tr>
<tr>
<td>IP beam size</td>
<td>$\sigma_x/\sigma_y$</td>
<td>nm</td>
<td>100/2.6</td>
<td>$\sim$ 60/1.5</td>
<td>$\sim$ 40/1</td>
</tr>
<tr>
<td>Normalised emittance (end of linac)</td>
<td>$\varepsilon_x/\varepsilon_y$</td>
<td>nm</td>
<td>—</td>
<td>660/20</td>
<td>660/20</td>
</tr>
<tr>
<td>Normalised emittance (IP)</td>
<td>$\varepsilon_x/\varepsilon_y$</td>
<td>nm</td>
<td>—</td>
<td>660/25</td>
<td>—</td>
</tr>
<tr>
<td>Estimated power consumption</td>
<td>$P_{wall}$</td>
<td>MW</td>
<td>235</td>
<td>364</td>
<td>589</td>
</tr>
</tbody>
</table>

Fig. 3.6: Simplified upgrade scheme for CLIC staging scenario B.
Vol 1: The CLIC accelerator and site facilities
- CLIC concept with exploration over multi-TeV energy range up to 3 TeV
- Feasibility study of CLIC parameters optimized at 3 TeV (most demanding)
- Consider also 500 GeV, and intermediate energy range
- https://edms.cern.ch/document/1234244/

Vol 2: Physics and detectors at CLIC
- Physics at a multi-TeV CLIC machine can be measured with high precision, despite challenging background conditions
- External review procedure in October 2011
- http://arxiv.org/pdf/1202.5940v1

Vol 3: “CLIC study summary”
- Summary and available for the European Strategy process, including possible implementation stages for a CLIC machine as well as costing and cost-drives
- Proposing objectives and work plan of post CDR phase (2012-16)
- http://arxiv.org/pdf/1209.2543v1

In addition a shorter overview document was submitted as input to the European Strategy update, available at: http://arxiv.org/pdf/1208.1402v1

Physics at LC from 250 GeV to 3000 GeV

- Physics case for the Linear Collider:
  - Higgs physics (SM and non-SM)
  - Top
  - SUSY
  - Higgs strong interactions
  - New Z’ sector
  - Contact interactions
  - Extra dimensions
  - .... AOP (any other physics) ...

Specific challenges for CLIC studies:
- Need to address Higgs-studies, including gains for measurements at higher energies
- Reach for various “new physics” (list above) options; comparative studies with HiLumi LHC and proton-proton at higher energies (FCC).
**ILC: SCRF Linac Technology**

**1.3 GHz Nb 9-cell Cavities**
- Quantity: 16,024

**Cryomodules**
- Quantity: 1,855

**SC quadrupole pkg**
- Quantity: 673

**10 MW MB Klystrons & modulators**
- Quantity: 436 *

* site dependent

Approximately 20 years of R&D worldwide
→ Mature technology, overall design and cost
Cryomodule System Tests

**DESY: FLASH**
- 1.25 GeV linac (TESLA-Like tech.)
- ILC-like bunch trains:
  - 600 ms, 9 mA beam (2009);
  - 800 ms, 4.5 mA (2012)
- Quantum Beam Accelerator (Inverse Laser Compton): 6.7 mA, 1 ms
- CM1 test with beam (2014 ~2015)
- STF-COI: Facility to demonstrate CM assembly/test in near future

**KEK: STF/STF2**
- S1-Global: completed (2010)
- Quantum Beam Accelerator (Inverse Laser Compton): 6.7 mA, 1 ms
- CM1 test with beam (2014 ~2015)
- STF-COI: Facility to demonstrate CM assembly/test in near future

**FNAL: ASTA**
(Advanced Superconducting Test Accelerator)
- CM1 test complete
- CM2 operation (2013)
- CM2 with beam (soon)
Technology: STF cryostring - KEK

2011
  disassemble S1-Global,
  start construction of STF accelerator(Injector + QB)

2012
  Feb: QB accelerator commissioning
  Apr: beam acceleration
  Jun: beam focus for Laser-Compton
  Jul to Mar: experiment of Laser-Compton (QB)

2013
  Apr: disassemble Laser-Compton
  start installation of CM-1
  Sep: two set of 4-cavity train completed
  Oct: Cryomodule assembly in STF tunnel
  Dec: CM-1 completed

2014
  Apr: start CM-2a assembly
  Jul: CM-1 and CM-2a connection will be completed
  Oct: Cool-down test
Technology: STF cryostring - KEK

A High Performance cryostring
## Progress in 1.3 GHz 9-cell Cavity Production

<table>
<thead>
<tr>
<th>Year</th>
<th>Capable Lab.</th>
<th>Capable Industry</th>
</tr>
</thead>
<tbody>
<tr>
<td>2006</td>
<td>1 DESY</td>
<td>2 ACCEL, ZANON</td>
</tr>
<tr>
<td>2011</td>
<td>4 DESY, JLAB, FNAL, KEK</td>
<td>4 RI, ZANON, AES, MHI,</td>
</tr>
<tr>
<td>2012</td>
<td>5 DESY, JLAB, FNAL, KEK, Cornell</td>
<td>5 RI, ZANON, AES, MHI, Hitachi</td>
</tr>
</tbody>
</table>

- One lab (2 vendors) in 2006
- 5 labs (5 vendors) in 2012 (maybe more)
<table>
<thead>
<tr>
<th>Category</th>
<th>Work-base</th>
<th>Specific subject</th>
<th>Global Collaboration w/</th>
</tr>
</thead>
<tbody>
<tr>
<td>Positron Source</td>
<td></td>
<td>Positron source</td>
<td>PosiPol Collaboration</td>
</tr>
<tr>
<td>Nano Beam</td>
<td>ATF</td>
<td>37 nm beam 2 nm stability</td>
<td>ATF collaboration</td>
</tr>
<tr>
<td>SCRF Cavity Integration</td>
<td>STF</td>
<td>Power Input Coupler Tuner He-Vessel</td>
<td>CERN-DESY-KEK CEA-Fermi/SLAC-KEK DESY-KEK (WS at CERN? Autumn. 2014)</td>
</tr>
<tr>
<td>CM integration</td>
<td>STF, ILC</td>
<td>Conduction-cooled SC Quadrupole</td>
<td>Fermilab-KEK</td>
</tr>
<tr>
<td>Cryogenics</td>
<td>ILC</td>
<td>Cryog. Underground He inventory High p. Gas Safety</td>
<td>CERN-Fermilab-KEK (WS at CERN, 18 June)</td>
</tr>
<tr>
<td>CFS</td>
<td>ILC</td>
<td>CFS design prep.</td>
<td>CERN-Fermilab-KEK</td>
</tr>
<tr>
<td>Radiation Safety</td>
<td>ILC</td>
<td>ML radiation shield</td>
<td>SLAC-DESY-CERN-KEK</td>
</tr>
</tbody>
</table>
Parameters, Design and Implementation
• Integrated Baseline Design and Parameters
• Feedback Design, Background, Polarization
• Machine Protection & Operational Scenarios
• Electron and positron sources
• Damping Rings
• Ring-To-Main-Linac
• Main Linac - Two-Beam Acceleration
• Beam Delivery System
• Machine-Detector Interface (MDI) activities
• Drive Beam Complex
• Cost, power, schedule, stages

Experimental verification
• Drive Beam phase feed-forward and feedbacks
• Two-Beam module string, test with beam
• Drive-beam front end including modulator development and injector
• Modulator development, magnet converters
• Drive Beam Photo Injector
• Low emittance ring tests
• Accelerator Beam System Tests (ATF and FACET, others)

Technical Developments
• Damping Rings Superconducting Wiggler
• Survey & Alignment
• Quadrupole Stability
• Warm Magnet Prototypes
• Beam Instrumentation and Control
• Two-Beam module development
• Beam Intercepting Devices
• Controls
• Vacuum Systems

Detector and Physics
• Physics studies and benchmarking
• Detector optimisation
• Technical developments

X-band Technologies
• X-band Rf structure Design
• X-band Rf structure Production
• X-band Rf structure High Power Testing
• Novel RF unit developments (high efficiency)
• Creation and Operation of x-band High power Testing Facilities
• Basic High Gradient R&D
High-gradient accel. structure test status

Results very good, design/performance more and more understood – but:
• numbers limited, industrial productions also limited
• basic understanding of BD mechanics improving
• condition time/acceptance tests need more work
• use for other applications (e.g. FELs) needs verification
In all cases test-capacity is crucial
Very significant increase of test-capacity
First commercial 12 GHz klystron systems
becoming available
Confidence that one can design for good (and
possibly better) gradient performance
As a result; now possible to use Xband
technology in accelerator systems – at smaller
scale
Automatic procedure scanning over many structures (parameter sets)

Structure design fixed by few parameters

\[ a_1, a_2, d_1, d_2, N_c, f, G \]

Beam parameters derived automatically

Cost calculated

Luminosity goal significantly impact minimum cost
For \( L=1 \times 10^{34} \text{cm}^{-2} \text{s}^{-1} \) to \( L=2 \times 10^{34} \text{cm}^{-2} \text{s}^{-1} \) costs 0.5 a.u.
Beyond the parameter optimization there are other on-going developments (design/technical developments):

- Use of permanent or hybrid magnets for the drive beam (order of 50,000 magnets)
- Optimize drive beam accelerator klystron system
- Electron pre-damping ring can be removed with good electron injector
- Dimension drive beam accelerator building and infrastructure are for 3 TeV, dimension to 1.5 TeV results in large saving
- Systematic optimization of injector complex linacs in preparation
- Power consumption:
  - Optimize and reduce overhead estimates

**Goal:**
- Rebaseline project at ~350 GeV, ~1.5 TeV, 3 TeV
- Optimised cost and power for given luminosity
- End year – hopefully needed to redo with new LHC results at some point
CTF3 programme 2013-2016

Beam loading/BDR experiment

Delay Loop

Chicane

Combiner Ring

Linac

TBL

CLIC Diagnostics tests

Phase feed-forward, DB stability studies

Two-Beam monitors, RF pulse shaping

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

Drive beam, 1-3 A, 100-50 MeV

50 mm circular waveguide
Technology example: CLIC module

- Test within laboratory (tunnel model with air flow)
- Test in CTF3 with beam (earlier slide)
- Transport test

- First module is under test, data under evaluation
- For second and third module many components have been received
- Tunnel environment modeled in experimental hall

- Range for air temperature and speed:
  - $T_{\text{air}} = 20 - 40 \, ^\circ\text{C}$
  - $v_{\text{air}} = 0.2 - 0.8 \, \text{m/s}$
  - Air speed sensors installed in the middle of the room
Technology examples: Magnets and Instrumentation

Magnet developments:
- Main Beam Quadrupole (MBQ)
- Drive Beam Quadrupoles (DBQ)
- Steering correctors
- QD0
- SD0
- Other studies (ILC and ATF studies)

- Development of OTR/ODR simulation tools well advanced and experimental validation has already shown promising results
- Proposing future beam test at ATF2 of a combined OTR/ODR Linear collider beam size monitor
- EO SD commissioned successfully on Califes with time resolution and S/N ratio better than streak camera
- EO Transposition is currently being studied at Daresbury to provide 20fs resolution bunch length monitor
- R&D on CLIC BPMs is progressing well expecting with 2nd generation of BPM prototypes being built now
- CLIC BLM monitor are being tested intensively with the aim to select the best possible sensor with respect to sensitivity, time response and cost

<table>
<thead>
<tr>
<th>BI Type</th>
<th>CLIC-3-DB</th>
<th>CLIC-3-MB</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intensity</td>
<td>278</td>
<td>184</td>
</tr>
<tr>
<td>Position</td>
<td>46054</td>
<td>7187</td>
</tr>
<tr>
<td>Size</td>
<td>800</td>
<td>148</td>
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<tr>
<td>Energy (spread)</td>
<td>210 (210)</td>
<td>73 (23)</td>
</tr>
<tr>
<td>Bunch length</td>
<td>312</td>
<td>75</td>
</tr>
<tr>
<td>Beam loss / halo</td>
<td>45950</td>
<td>7790</td>
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<td>Beam phase</td>
<td>208</td>
<td>96</td>
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<tr>
<td>Polarization</td>
<td></td>
<td>17</td>
</tr>
<tr>
<td>Tune</td>
<td></td>
<td>6</td>
</tr>
<tr>
<td>Luminosity</td>
<td></td>
<td>2</td>
</tr>
</tbody>
</table>
Performance verifications – example CLIC

Stabilise quadrupole O(1nm) @ 1Hz

FACET (Dispersion-Free Steering and Wakefield-FS)

More in this conference:
THPP034 – “Experimental Results of Beam-based Alignment Tests”, A.Latina et al.
Final focus: ATF 2 at KEK

Goal 1: demonstrate optics, tunability

Goal 2: beam stabilisation through feedback

Local chromatic corrections

Similar optics, similar tolerances ATF and ILC
ATF-2 beam size development

June: reaching 44 nm, very close to ILC goal (37 nm corr. to 6nm at ILC)

Field quality improvements, orbit stabilisation through feedback, shorted turn in 6-pole magnet, beam size monitor improvements

ATF 2 Future program – next Run October
In general the CLIC coll. is very interested in a longer term programme at ATF2 and ideas exist for:

- Building 2 octupoles for ATF2 (to study FFS tuning with octupoles)
- Test of OTR/ODR system at ATF2
- Test and use of accurate kicker/amplifier system is considered
- General support for ATF2 operation
US and EU (industrial) production and test capacity. Perfectly placed for start of ILC construction end of this decade.

Largest deployment of this technology to date:
- 100 cryomodules
- 800 cavities
- 17.5 GeV (pulsed)

Kitakami proposed site

US infrastructure for:
- 35 cryomodules
- 280 cavities
- 4 GeV (CW)

Preliminary data; results are not published

Maximum field

ILC usable gradient (FE limited)

ILC TDR acceptance

XFEL industrial production following ILC baseline process
Drive beam development beyond CTF3

- RF unit prototype with industry using CLIC frequency and parameters
- Drive beam front-end (injector), to allow development into larger drivebeam facility beyond 2018

Damping rings
- Tests at existing damping rings, critical component development (e.g. wigglers) ... large common interests with light source laboratories

Main beam (see slides later)
- Steering tests at FACET, FERMI, ...

Beam delivery system (see slide later)
- ATF/ATF2

---

**Super-conducting wigglers**
- Demanding magnet technology combined with cryogenics and high heat load from synchrotron radiation (absorption)

**High frequency RF system**
- 1 GHz RF system respecting power and transient beam
- Coatings, chamber design and ultra-low vacuum
  - Electron cloud mitigation, low-impedance, fast-ion instability

**Kicker technology**
- Extracted beam stability
- Diagnostics for low emittance

---

**Parameters**

<table>
<thead>
<tr>
<th>Parameters</th>
<th>BINP</th>
<th>CERN/Karlsruhe</th>
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<td>2.8</td>
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<td>$\lambda_0$ [mm]</td>
<td>50</td>
<td>40</td>
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<td>13</td>
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<td>Operating temperature [K]</td>
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<td>4.2</td>
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</table>

---

Experimental program set-up for measurements in storage rings and test facilities:

- ALBA (Spain), ANKA (Germany), ATF (Japan), CESR-TA (USA), ALS (Australia) ...
X-band technology appears interesting for compact, relatively low cost FELs – new or extensions
- Logical step after S-band and C-band
- Example similar to SwissFEL: E=6 GeV, Ne=0.25 nC, σz=8μm

Use of X-band in other projects will support industrialisation
- They will be klystron-based, additional synergy with klystron-based first energy stage

Started to collaborate on use of X-band in FELs
- Australian Light Source, Turkish Accelerator Centre, Elettra, SINAP, Cockcroft Institute, TU Athens, U. Oslo, Uppsala University, CERN

Share common work between partners
- Cost model and optimisation
- Beam dynamics, e.g. beam-based alignment
- Accelerator systems, e.g. alignment, instrumentation...

Define common standard solutions
- Common RF component design, -> industry standard
- High repetition rate klystrons (500Hz soon to be ordered for CLIC)

Great potential for collaboration (G.D’Auria et al., “X-band technology for FEL sources”)
ILC Timeline

• **2013 - 2016**
  – Accelerator detailed design, R&Ds for cost-effective production, site study, CFS designs etc.
  – Negotiations among governments
  – Prepare for the international lab.

• **2016 – 2018**
  – ‘Green-sign’ for the ILC construction to be given (in early 2016)
  – International agreement reached to go ahead with the ILC
  – Formation of the ILC lab.
  – Preparation for biddings etc.

• **2018**
  – Construction start (9 yrs)

• **2027**
  – Construction (500 GeV) complete, (and commissioning start)
    (250 GeV time-scale is slightly shorter)
<table>
<thead>
<tr>
<th>Sub-Group</th>
<th>Global Leader Deputy/Contact p.</th>
<th>KEK-Leader* Deputy</th>
<th>Sub-Group</th>
<th>Global Leader Deputy/Contact P.</th>
<th>KEK-Leader* Deputy</th>
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</thead>
</table>
| Acc. Design Integr. | **N. Walker (DESY)**  
K. Yokoya (KEK) | K. Yokoya | SRF | **H. Hayano (KEK)**  
C. Ginsburg (Fermi),  
E. Montesinos (CERN) | H. Hayano  
Y. Yamamoto |
| Sources (e-, e+) | **W. Gai (ANL)**  
M. Kuriki (Hiroshima U.) | J. Urakawa  
T. Omori | RF Power & Cntl | **S. Michizono (KEK)**  
TBD (AMs, EU) | Michizono  
T. Matsumoto |
| Damping Ring | **D. Rubin (Cornell)**  
N. Terunuma (KEK) | N. Terunuma | Cryogenics (incl. HP gas issues) | **H. Nakai: KEK**  
T. Peterson (Fermi),  
D. Delikaris (CERN) | H. Nakai  
Cryog. Center |
| RTML | **S. Kuroda (KEK)**  
A. Latina (CERN) | S. Kuroda | CFS | **A. Enomoto (KEK)**  
V. Kuchler (Fermi),  
J. Osborne (CERN),  
| A. Enomoto  
M. Miyahara |
| Main Linac (incl. B. Compr. & B. Dynamics) | **N. Solyak (Fermi)**  
K. Kubo (KEK) | K. Kubo | Radiation Safety | **T. Sanami (KEK)**  
TBD (AMs, EU) | T. Sanami  
T. Sanuki |
| BDS | **G. White (SLAC),**  
R. Tomas (Cern)  
T. Okugi (KEK) | T. Okugi | Electrical Support (Power Supply etc.) | TBD | TBD |
| MDI | **K. Buesser (DESY)**  
T. Tauchi (KEK) | T. Tauchi | Mechanical S. (Vac. & others) | TBD | TBD |

**ILC Accelerator Organization**

LCC-ILC Director: M. Harrison, Deputies: N. Walker and H. Hayano  
*KEK LC Project Office Head: A. Yamamoto
Site specific studies

Establish a site-specific Civil Engineering Design - map the (site independent) TDR baseline onto the preferred site - assuming “Kitakami” as a primary candidate

Need to finalize:
- IP / Linac orientation and length
- Access points and IR infrastructure
- Conventional Facilities and Siting (CFS)
- ...

Proposed by JHEP community
Endorsed by LCC
Not yet decided by Japanese Government
ILC preferred site - Kitakami
## ILC pre-construction work scope

### Current Status: Facility Planning Progress – CFS View

<table>
<thead>
<tr>
<th>Work</th>
<th>Underground Facilities</th>
<th>Surface Facilities</th>
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<tbody>
<tr>
<td>Facility Arrangement</td>
<td>ML B/C</td>
<td>AY D</td>
</tr>
<tr>
<td>Basic Shape, Dimension</td>
<td>AH B/C</td>
<td>CS C</td>
</tr>
<tr>
<td>Civil/Architectural Design</td>
<td>DR C</td>
<td>CC D</td>
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<td>Electronic Design</td>
<td>BDS B/C</td>
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<tr>
<td>Mechanical Design</td>
<td>DH C</td>
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</table>

<table>
<thead>
<tr>
<th>Legend: Progress degree</th>
<th>Requirement</th>
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<tbody>
<tr>
<td>A</td>
<td>Clear</td>
</tr>
<tr>
<td>B</td>
<td>Clear</td>
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<tr>
<td>C</td>
<td>Unclear(50%)</td>
</tr>
<tr>
<td>D</td>
<td>Unclear</td>
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</tbody>
</table>

**Timeline:**

- **2014:** Planning, Basic Survey, Topographical Survey
- **2015:** Basic Design, Detailed Survey, Land Acquisition
- **2016:** Detailed Design, Environmental Impact Survey
- **2017:** Tendering, Compensation, Acquisition
- **2018:** Cost Estimate, Additional
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.

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.

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

Construction Phase
Stage 1 construction of CLIC, in parallel with detector construction. Preparation for implementation of further stages.

Commissioning
Becoming ready for data-taking as the LHC programme reaches completion.
Seven new collaboration partners joined in 2013 (The Hebrew University Jerusalem, Vinca Belgrade, ALBA/CELLS, Tartu University, NCBJ Warsaw, Shandong University, Ankara University Institute of Accelerator Technologies (IAT)). In 2014 two (SINAP Shanghai and IPM Tehran) more Detector collaboration operative with 23 institutes.
The ILC and CLIC accelerator studies are organised under the heading of LCC with goals:

- Strongly support the Japanese initiative to construct a linear collider as a staged project in Japan
- Prepare CLIC machine and detectors as an option for a future high-energy linear collider at CERN
- Further improve collaboration between CLIC and ILC machine experts
- Beyond the significant progress on the basic RF studies, increased and successful effort on system-studies of various types (FACET, ATF, etc)
- Many common challenges with 3rd generation light sources and FELs, the latter providing very important industrial/lab production experiences
- Slides/figures from LCC collaboration members and others
- Knowingly from M.Harrison, A.Yamamoto, A. Latina, K.Kubo and ATF colleagues, D.Schulte, Y.Yamamoto, W.Fang, W.Wuensch and Xband team, M. Miyahara, N.Walker, T.Lefevre, M.Modena, R.Tomas, G.D’Auria ... probably several more unknowingly