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Technology for ILC is settled, now exploring some tweaks to reduce costs (with promising results). Consistency of overall plan since TDR (and before) shows the strength of the proposal.

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LCWS accelerator sessions showcase sophistication of accelerator expertise worldwide – crucial that these skills exist in all regions for large “international-scale” accelerator projects.
Thank you to Accelerator Conveners!

• **ATF**
  Nobuhiro Terunuma (KEK)
  Phil Burrows (Oxford)

  Edu Marin (Alba-Cells)
  Rogelio Tomas (CERN)
  Glen White (SLAC)

• **Damping Rings**
  Nobuhiro Terunuma (KEK)
  Yannis Papaphilippou (CERN)
  Eliana Gianfelice (FNAL)

  Hitoshi Hayano (KEK)
  Saeki (KEK)
  John Osborne (CERN) & Matthew Stuart

• **Sources**
  Masao Kuriki (U. Hiroshima)
  Steffen Doebert (CERN)
  Sabine Riemann (DESY)
  Manoel Conde (ANL)

• **(SCRF) Superconducting Radio Frequency**
  Sam Posen (FNAL)
  Yasuchika "Kirk" Yamamoto (KEK)

• **Beam Dynamics and RTML**
  Kaoru Yokoya (KEK)
  Andrea Latina (CERN)
  Nikolay Solyak (FNAL)

• **Warm RF**
  Walter Wuensch (CERN)
  Emilio Nanni (SLAC)

• **Beam Delivery System**
  Toshiuki Okugi (KEK)

• **Industry**
  Hugh Montgomery (JLab)
Warm rf session – News from CLIC testing program and linac technology development from SLAC, LANL and UCLA.

- Xbox test stand operation and prototype testing – steady operation of structures above 100 MV/m and validation of new components.
- Power source development – High-efficiency X and L-band klystron development for CLIC and ILC, low-cost fabrication concepts and prototype superconducting focusing solenoid.
- New directions for accelerating structures – Manifold-fed structures, LN2 temperature operation (also for low emittance rf gun), dielectric structures and atomic-level high-field simulations.
- Linac development – LN2 alternative for linear collider

Four prototype CLIC accelerating structures under test in Xbox-3

New structure topologies and cryogenic operation
Warm RF

MgB2 superconducting solenoid for X-band klystrons

High-efficiency klystron design for the ILC courtesy of CLIC.

High-efficiency X-band klystron design for CLIC.

Exploring modular and commoditized source concepts

Overall theme – Solidifying the 100 MV/m and higher baseline and investigating new ideas for higher performance, higher efficiency and lower cost!
Cavity treated with “modified 120 C bake” treatment developed this year at Fermilab was sent to Cornell. Measurement by Cornell confirms achievement of 49 MV/m, a new record for ILC-style single cell cavity – next reproduce at other labs and multicells – studying possible role of hydrides in performance improvement.

While Fermilab has consistent performance in nitrogen infusion treatment, success has been intermittent at other labs (see reports from KEK and DESY). It seems that a very clean furnace is needed.
Superconducting RF

- Updates given on a number of paths towards **high gradient/high Q₀** including low surface field shapes, plasma processing, flux expulsion, and (long term) Nb₃Sn

- **STF upgrades and plans for the future**

- **Reducing costs** in cavity fabrication/processing: large grain material, hydroforming, vertical electropolishing

- Updates on **couplers/tuners** from KEK and LCLS-II, **clean** assembly at KEK

- **Success in large SRF linacs is extremely encouraging as we look forward to ILC.**

  European XFEL is now at design energy! LCLS-II is producing cryomodules meeting all specifications, many with average \( Q₀ > 3 \times 10^{10} \)

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**CM Q₀ Performance**

<table>
<thead>
<tr>
<th>Cryomodule Heat-Load (Average Q₀) Test Results</th>
<th>A (mm)</th>
<th>B (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>FNAL pCM</td>
<td>2.9</td>
<td>*</td>
</tr>
<tr>
<td>* tested at Fermilab</td>
<td>2.7</td>
<td>*</td>
</tr>
<tr>
<td>F1.3-02</td>
<td>3.4</td>
<td>J1.3-02</td>
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<tr>
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<td>J1.3-03</td>
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<tr>
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<td>J1.3-04</td>
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<td>1.9</td>
<td>J1.3-05</td>
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<td>F1.3-06</td>
<td>1.9</td>
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<tr>
<td>F1.3-12</td>
<td>3.5</td>
<td>J1.3-12</td>
</tr>
</tbody>
</table>

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**LSF5-1**

**STF@KEK**

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**European XFEL**

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**Plasma processing**

**Cavity Shape**
Conventional Facilities (CFS)

Green-ILC

- Energy saving on RF system
  (PM-focus-klystron, Q-switch RF filling, thin-film coating High-Q/High-G)
- Reducing beam energy by strong laser interaction
- Green-ILC activities in Kitakami-site
  Use of ILC waste heat, Use of local wood

Tunnel Design

- Design of beam dumps
  (Main beam dump, other dumps)
- Dump-room widening consideration
- Cryomodule Power Distribution System
  cryomodule, PDS, separate installation in the tunnel
- CFS status on CLIC/FCC/HL-LHC
CFS Risks

- CFS Risks at Science-Council-Japan discussion (Radiation Safety, AC power black-out, Spring-water around tunnel, Environmental assessment)
- Gantry crane and Detector Platform Cost discussion and Risks during earthquake
- Experience of CMS Gantry crane CMS Detector lowering into the tunnel, how was it.
- Base isolation from big earthquake for Detector/Accelerator Rubber+rigid-sliding+damper may have good isolation.
ATF2 & BD/RTML

ATF2 (Accelerator Test Facility 2) session: Focus on intensity dependent effects and extrapolations to ILC and CLIC

• A dedicated Report on intensity dependence is being written
• Progress in the characterization and understanding of the effects of intensity dependence at ATF2 -
• Increasing confidence in the extrapolations to ILC BDS – simulations of global mitigation strategies are reassuring

Beam Dynamics & RTML (Ring to Main Linac): Performance optimizations; design updates; super-short bunches for LC

• ILC 250 GeV CoM lattice decks – being updated and completed of missing parts
• LCLS-II Cryomodule performance – exceeded requirements, e.g. gradients -
• Stray fields in CLIC – accurate modeling and countermeasures -
• Beam performance optimization in CLIC Stage 380 GeV CoM – energy spread and transverse stability -
• Ultra-compressed low-power beam parameter options for a future LC – Non-perturbative strong field QED with linear collider parameters -
Suppression of magnetic stray fields

Simulation of spent beams after collision

Feedback On Nano-Second Timescales

IP angle jitter reduction with upstream FONT FB at ATF2

Ultra-short bunches push the limits of QED models

Suppression of magnetic stray fields

C. Gohil’s phase (0.35% energy spread):
sector 1: 6°
sector 2: 6°
sector 3: 14°
sector 4: 30°

CLIC 380 GeV ML RF phase optimization for emittance and energy spread

Emittance vs. energy spread for a range of RF phases (bunch length: 70 μm; bunch charge: 52 x 10^11)

LCLS-II CM gradient performance

Average Gradient of Cryomodule

- VTS: Emax
- VTS: Onset
- CMTS: Emax
- CMTS: Eusable
- CMTS: Eonset
- CMTS Administrative Limit

LCLS-II nominal gradient
6 contributions for E-Driven Positron Source,
5 contributions for Undulator Positron Source.

E-Driven:
- Confirmation that positrons can be generated without any damage on Target with a realistic AMD (Adiabatic Matching Device) field.
- Study showing positron yield can be enhanced by improving AMD and solenoid field.
- Report on the progress of the target prototype. The ferro-fluid seal shows an excellent performance corresponding to $4.0 \times 10^{-9}$ Pa at accelerator.
- Estimate that the highest RF detuning of capture linac by beam loss is much less than bandwidth of RF structure determined by Q value.
- Report that polarized positron can be generated with polarized E-driven method but with low efficiency. Application at ILC requires detailed studies and essential effort.

Undulator
- A summary of the status of R&D was presented. The stress on the target is manageable.
- Report on the target damage test at MAMI. There was no significant damage on test pieces even for load exceeding that expected for the ILC.
- Two independent studies of photon spectra from Undulator.
  - There is a discrepancy on positron yield between two studies - enough positron yield ($>1.5$) with QWT (quarter wave transformer) should be confirmed with a full tracking simulation.
Electron beam

Target wheel

Water-cooled cooler

Photons

Disco

Target

Capture Section

Chicane

Booster Linac

ECS

DR

Destruction limit
35 [J/g]

PEDD [J/g]

Yield

Electron beam

copper disk

ferrofluid seal

Disk D=500 mm 70 kg

Helical undulator

Capture + preacc.

Preacc.

Booster

Spin rotation and flip

Photons to dump

e- to IP

ILC Polarized E-Driven Positron source

\[ e^- \rightarrow \gamma \rightarrow e^+ (\rightarrow e^-) \]

A. Ushakov

M. Fukuda

<table>
<thead>
<tr>
<th>E(e+)</th>
<th>N(e+)/N(e-)</th>
<th>&lt;Sz&gt;</th>
<th>P (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>150 MeV</td>
<td>0.436</td>
<td>0.23</td>
<td>21</td>
</tr>
<tr>
<td>350 MeV</td>
<td>0.056</td>
<td>0.41</td>
<td>37</td>
</tr>
</tbody>
</table>
Damping Ring Session.
Focus: Updates, new ideas for low emittance rings and means to preserve it in practice (alignment, knobs for optics correction).

Key takeaways:
- ILC TDR optics were revisited. It was found that basic checks were okay, but some disagreement on the dynamic aperture. Bending magnet length changed from 3 to 5 m for reducing $\varepsilon_x$ from 6 to 4 $\mu$m w/o deteriorating DA.
- A study was performed of achieving ultra low emittances ($\varepsilon_x \approx 0.1$ nm, $\varepsilon_y \approx 1$ pm, $\varepsilon_s \approx 5$ KeV m) in the CLIC damping ring using TME arcs and FODO straights with wigglers. Revisions: e- pre-DR eliminated, e+ pre-DR may be replaced by a booster. DRs getting reviewed for new baseline. SC wiggler prototype being tested at ANKA.

- Methods for correcting LHC optics were shown. Measurements rely on a AC dipole and turn-by-turn capable BPMs. Beta-beating was corrected below the required 18%. Nonlinear octupole and decapole corrections for chromaticity.
Damping Ring Session – Key takeaways

- To minimize horizontal emittance, a “complex bend” was proposed with possibly SC magnets for strong focusing or by displacing the quads (more compact). A lattice for NSLS-II upgrade is being developed. It needs a special insertion for chromaticity correction.

- It was shown that with proper instruments, numerical models of machine impedance can be inferred by measurements of beam parameters dependence on intensity. Results were shown for many rings. Reasons were suggested for differences between computation and measurements of machine impedance budget.

- Advanced Photon Source lattice upgrade aiming to $\varepsilon_x = 42$ pm was described. APS results of on-line coupling and chromaticity correction resorting to “brute force” optimization were shown.

- At CLIC, nm beam size at the IP translates in very stringent alignment requirements for emittance preservation ($\approx 14 - 17 \mu m$ over 200 m). The fiducialization process for CLIC quad and cavity BPM was described using the stretched-wire measurement method.
SuperKEKB has similar FFS optics requirements to ILC & ATF2
Lots to learn from SuperKEKB tuning -> now looking at $\beta^*$ measurements

Muons rates from halo interception in ILC collimation system studied
Rates low enough that “muon wall” may not be initially required
- need to consider other background processes carefully

Machine learning applied to beam parameter reconstruction of ILC beam collision parameters
Early work shows promise - will be developed further

BPM processing electronics demonstrated @ ATF2
Capable of ~1ns latency for CLIC, resolution = 325 nm
Suitable for IP intra-train feedback

Wakefields measured & mitigation procedures developed @ ATF2
Applied to ILC in simulation -> expect 2.4% effect on luminosity
• CLIC tuning simulations with static & dynamic show 90% cases > 97% lumi
• Work towards improving realism, reducing tuning time

• Study of optics @ ATF2 to reach CLIC-level FFS (final focus system) chromaticity under way
• Ongoing effort to understand systematics and reduce beam size <60 nm - level

• Improved tuning performance by optimized sextupole alignment
• Crystal focusing system considered
• High order aberrations currently significantly limit available luminosity

• Smaller IP beta-function studied for L*=6m CLIC optics to reduce non-linear aberration contribution
• Work ongoing to optimize energy bandwidth
Industry Session
Industry Session - Takeaways

ILC does include numerous challenges for technological industry

Despite explicit funding for ILC being constrained, there are extensive activities in all regions fairly directly related to eventual ILC construction—cost reduction through performance improvement—based on ubiquitous use of SRF technology

Interactions between (scientific) clients and industry demands excellent communications and frequent understanding of goals on both sides

In several countries, organizations encouraging interactions between individual companies prove to be beneficial

Also (in several countries) strong encouragement from labs is bringing industry along at an enormous rate (China)
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Overall Takeaways from Accelerator Sessions