Linear Collider R&D Status in cooperation with CERN and KEK focusing on the ILC

Akira Yamamoto (KEK-CERN)

CERN-KEK Committee held at KEK, 21 November, 2014
ILC “Design to Realization”

1980’ ~ Basic Study

2004


ILC-GDE

Ref. Design (RDR)

Tech. Design: TDP1

TDP 2

LHC

Selection of SC Technology

Collider Technology Conference 2004 Beijing

126 GeV

Higgs discovered

2012.12.15

2013.6.12

TDR completion

LCC

Progress towards the ILC in Japan

A. Yamamoto, 14/05/16
Damping Rings

Polarised electron source

Ring to Main Linac (RTML) (including bunch compressors)

Parameters

<table>
<thead>
<tr>
<th></th>
<th>Value</th>
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</thead>
<tbody>
<tr>
<td>C.M. Energy</td>
<td>500 GeV</td>
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<tr>
<td>Peak luminosity</td>
<td>$1.8 \times 10^{34}$ cm$^{-2}$s$^{-1}$</td>
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<tr>
<td>Beam Rep. rate</td>
<td>5 Hz</td>
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<tr>
<td>Pulse duration</td>
<td>0.73 ms</td>
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<tr>
<td>Average current</td>
<td>5.8 mA (in pulse)</td>
</tr>
<tr>
<td>E gradient in SCRF acc. cavity</td>
<td>$31.5$ MV/m $\pm$ 20% $Q_0 = 1\times 10^{10}$</td>
</tr>
</tbody>
</table>
ILC Time Line: Progress and Prospect

Preparation Phase

We are here, 2014

Site-dependent design

Expecting ~ (2+4) year
Being re-studied
ILC Accelerator Concept

- Electron and Positron Sources (e-, e+): 
- Damping Ring (DR): 
- Ring to ML beam transport (RTML): 
- Main Linac (ML): SRF Technology 
- Beam Delivery System (BDS)
Remaining Works in Preparation Phase

Key Examples

- Accelerator Design and Integration with EDMS:
- CFS: Site specific work including Central Campus design and others,
- Positron Source: vacuum sealing technology for rotating target,
- Damping Ring: Ultra low emittance, Undulators, 650 MHz SCRF,
- RTML: residual magnetic field effect in long beam transport-line,
- ML: Cavity, CM, Cryogenics integration, to be best cost-effective,
- BDS: Final focusing w/ nano-beam, and beam optics update
To prepare for the ILC project realization
- Detailed design study
- Cost-effective project realization

**Program Adv. Committee**
PAC – Chair: N. Holtkamp

**Linear Collider Board**
LCB – Chair: S. Komamiya

**Regional Directors**
- B. Foster (EU)
- H. Weerts (AMs)
- A. Yamamoto (AS)

**Linear Collider Collab.**
**LCC Directorate**
- Director: L. Evans

**ILC**
- M. Harrison
  - (Deputy) H. Hayano

**CLIC**
- S. Stapnes

**Physics & Detectors**
- H. Yamamoto

**KEK**
KEK LC Project Office

**Acc.**
**Tech. S.**
Phys. & Detector
To be linked to LCC-Phys

**Tech. Board**

**Acc. Design & Integration (ADI)**

**Technical Support**

**ICFA**
Chair: TBD

**FALC**
Chair: Y. Okada

**KEK**

**AWLC14** 7
# LCC-ILC Accelerator Organization

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

<table>
<thead>
<tr>
<th>Sub-Group</th>
<th>Global Leader</th>
<th>KEK-Leader*</th>
<th>Sub-Group</th>
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<th>KEK-Leader*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acc. Design Integr.</td>
<td><strong>N. Walker (DESY)</strong></td>
<td>K. Yokoya</td>
<td>SRF</td>
<td><strong>H. Hayano (KEK)</strong></td>
<td>H. Hayano</td>
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<td></td>
<td>K. Yokoya (KEK)</td>
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<td><strong>C. Ginsburg (Fermi),</strong></td>
<td>Y. Yamamoto</td>
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<td><strong>E. Montesinos (CERN)</strong></td>
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<td>Sources (e-, e+)</td>
<td><strong>W. Gai (ANL)</strong></td>
<td>J. Urakawa</td>
<td>RF Power &amp; Cntl</td>
<td><strong>S. Michizono (KEK)</strong></td>
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<td>M. Kuriki (Hiroshima U.)</td>
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<td>T. Matsumoto</td>
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<td><strong>D. Rubin (Cornell)</strong></td>
<td>N. Terunuma</td>
<td>Cryogenics (incl. HP gas issues)</td>
<td><strong>H. Nakai: KEK</strong></td>
<td>H. Nakai</td>
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<td><strong>S. Kuroda (KEK)</strong></td>
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<td>M. Miyahara</td>
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<td>Main Linac (incl. B. Compr. &amp; B. Dynamics)</td>
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Authorized by CERN Acc. Director, F. Bordry
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</table>

**Authorized by CERN Acc. Director, F. Bordry**

Dear Colleagues,

Following your request for CERN support during the preparation phase of ILC, we are pleased to announce that the following CERN staff have been identified on our side:

Andrea Latina in the area of Ring To Main Linac
Rogelio Tomas Garcia in the area of Beam Delivery System
Eric Montesinos in the area of tuners and couplers
Dimitri Delikaris in the area of Cryogenics
John Osborne in the area of Civil Engineering / Conventional Facilities and Siting

The typical estimated load is 10% or below, and we consider that it is realistic to mention these persons in the preparation team as contact persons for specific technical areas. Increased effort from these people, or additional involvement in terms of fellows and supporting staff, would need to be agreed and discussed case by case.

Steinar Stapnes should be used as contact point ensuring that the appropriate line structure at CERN has been involved in each case.

Yours sincerely,

Frédéric Bordry
Director for Accelerators and Technology
## Further Global Cooperation to be emphasized

<table>
<thead>
<tr>
<th>Category</th>
<th>Work-base</th>
<th>Specific subject</th>
<th>Global Collaboration w/</th>
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<td>Positron Source</td>
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<td>Positron source</td>
<td>PosiPol Collaboration</td>
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<td>Nano Beam</td>
<td>ATF</td>
<td>37 nm beam 2 nm stability</td>
<td>ATF collaboration with CERN</td>
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<td>SCRF Cavity Integration</td>
<td>STF</td>
<td>Power Input Coupler Tuner He-Vessel</td>
<td>CERN-DESY-KEK</td>
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<td>CEA-Fermi/SLAC-KEK</td>
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<td>DESY-KEK</td>
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<td>CM integration</td>
<td>STF, ILC</td>
<td>Conduction-cooled SC Quadrupole</td>
<td>Fermilab-KEK</td>
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<td>Cryog. Underground He inventory High p. Gas Safety</td>
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<td>ILC</td>
<td>ML radiation shield</td>
<td>SLAC-DESY-CERN-KEK</td>
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Cooperation with CERN and KEK

• Nano-beam handling technology  >> to be reported by R. Tomas
  – Nano-beam and the stability as a common subject for both ILC and CLIC, through ATF collaboration
  – Final focusing including magnet and the mechanical stability, as well as commissioning technology, still to be investigated

• SCRF cavity integration technology,
  – Specially on input-power couplers and tuners, as a common subject for both ILC and SPL for LHC injector upgrade,

• Cryogenic engineering
  – Specially on handling of large amount of helium inventory, as a specially crucial issue in mountain region,

• Civil engineering study
  – specially for the detector-hall design,

• Radiation Safety
  – Radiation safety design and optimization
Progress in Beam Size at ATF2

To be reported by G. Tomas

Beam Size 44 nm observed,
(Goal: 37 nm corresponding to 6 nm at ILC)
Extension of the FY2014 Operation to be realized w/ specially contribution by CERN

• In addition to the operation in October and November, the operation can be extended in December,
  – 10/20-10/31 Beam Operation
  – 11/3-11/7 Maintenance
  – 11/10-11/21 Beam Operation
  – 11/24-11/28 Maintenance
  – 12/1-12/19 Beam Operation Extension

• Special thanks for the CERN’s cooperation!
Cooperation with CERN and KEK

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  – Radiation safety design and optimization
ILC CM Assembly

- Cavities (8)
- SC quad package
- Type-B module
  - Type-A has 9 cavities and no quadrupole

12.652 m (slot length)

Type 4 Cryomodule

- 2K HQR
- 85K RETURN
- 40K RETURN
- 2K 2-Phase
- 2.2K SUPPLY
- 5K SUPPLY
- COOL DOWN WARM UP
- BEAM AXIS

Baseline
39 cavity RF unit

Progress towards the ILC in Japan
STF2; SCRF ACCELERATOR PLAN AT KEK

**Objective**
- High Gradient (31.5 MV/m) ➔ Demonstration of full cryomodule
  - Pulse and CW operation (for effective
- Training for next generation s

**Plan:**
- Multiple CM for system study
- In-house Cavity to be installed in cooperation with industry
- Wide range application including Photon Science

Electron Gun   Full Cryomodule s   Undulators   Detector

Beam Acceleration to be in 2015

Gradient achieved at KEK-STF: > ~ 35 MV/m
Progress: > 90 %, at individual vertical test
S1-Global Cavity Packages

**FNAL cavity**
- Blade tuner
- TTF-III coupler

**DESY cavity**
- Lever-arm tuner
- TTF-III coupler

**KEK-type1 cavity**
- Slide-jack tuner (center)
- STF-2 coupler

**KEK-type2 cavity**
- Slide-jack tuner (end)
- STF-2 coupler

**TESLA-ILC cavity**

**TESLA-XFEL cavity**

H.Hayano
A. Yamamoto, 14/05/16
Cavities, Tuners, Couplers in S1-G Cryomodule

TESLA Cavity (DESY/FNAL)

Blade Tuner (INFN/FNAL)

Saclay Tuner (DESY)

TTF-III Coupler (DESY/FNAL/SLAC)

Tesla-like Cavity (KEK)

Slide-Jack Tuner (KEK)

STF-II Coupler (KEK)
LCLS-II Cavity: a Tuner Design Option to be investigated

LCLS Tuner design covering the beam Pipe flanges, overcoming a constraint with a shorter beam pipe
T. Peterson, C. Grimm, et al.,

EXFEL, Tesla type tunder assembly
PHoto, at Fermilab
- 5 LVDT’s HBM® – WI +/- 2.5mm
- 5 Displacement sensors based on bending stress measurements
- Custom force sensors on rods
- HBM® load cells
- DAQ QuantumX from HBM ® – Fs 50 Hz
SRF Tuner Workshop at CERN, 5 Sept. 2014
S1-Global Cavity Packages

FNAL cavity

TESLA-ILC cavity

Blade tuner

TTF-III coupler

TESLA-like KEK cavity

KEK-type1 cavity

TESLA-like KEK cavity

Slide-jack tuner (center)

STF-2 coupler

A. Yamamoto, 14/05/16

DESY cavity

TESLA-XFEL cavity

Lever-arm tuner

TTF-III coupler

TESLA-like KEK cavity

KEK-type2 cavity

Slide-jack tuner (end)

STF-2 coupler

H. Hayano
## Plug-compatible Conditions

<table>
<thead>
<tr>
<th>Item</th>
<th>Variation</th>
<th>TDR Baseline</th>
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</thead>
<tbody>
<tr>
<td>Cavity shape</td>
<td>TESLA / LL</td>
<td>TESLA</td>
</tr>
<tr>
<td>Length</td>
<td>Fixed</td>
<td></td>
</tr>
<tr>
<td>Beam pipe flange</td>
<td>Fixed</td>
<td></td>
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<tr>
<td>Suspension pitch</td>
<td>Fixed</td>
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<tr>
<td>Tuner</td>
<td>Blade/Slide-Jack</td>
<td>Blade (→ Lever Tuner as alternate)</td>
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<tr>
<td>Coupler flange (cold end)</td>
<td>40 or 60</td>
<td>40 mm</td>
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<tr>
<td>Coupler pitch</td>
<td>Fixed</td>
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<tr>
<td>He –in-line joint</td>
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</tr>
<tr>
<td>Magnetic shield</td>
<td>Inside/outside</td>
<td>Inside</td>
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</tbody>
</table>

### 相対コスト（現状）：
- **Coupler:** STF > TTF-III coupler (XFEL)
- **Tune/He-V:** S-Jack >> Blade >> Lever (XFEL)
- **Mag. Shield:** Inside > Outside (XFEL)
SCRF Power-Input Coupler

- Cold-end half/element
- Ceramic window
An approach with lower SEE and Lower Resistance Ceramic Window

**Material Design Concept**

- **Purpose**
  - High Resistance for Creeping Discharge

- **Discharge Effecting Factor**
  - Electron Multiplication
  - Charge Up

- **Material Approach**
  - Low Secondary Electron Emission Coefficient (SEEC)
  - Low Resistance

**Status for Material**

- Low SEE
  - SEEC: 11.2 \(10^{14}\) Ω•cm
  - 99% Alumina
  - KYOCERA A479

- Low Resistant
  - SEEC: 4.6 \(10^{14}\) Ω•cm
  - New Alumina
  - KYOCERA AH100A

- On a commercial basis

- Introduction of AH100A

Low Surface Resistivity
- \(10^8\) Ω/sq
Lower Secondary Electron Emission and lower surface resistance

**SEE (Secondary Electron Emission) Coefficient Measurement Method**

- Primary Electron → Secondary Electron
- Detector → Test Piece

**SEE Coefficient Measurement Result**

- AH100A has a factor 5 smaller SEE Coefficient than that of 99% alumina.
- Sample material can make SEE coefficient less than AH100A, however still higher than TiN coated alumina surface.

After Annealing at 1200 degree C
### Trial/Sample Ceramic compared with conventional Ceramic

#### Comparison of Measurement Value for Evaluated Ceramic

<table>
<thead>
<tr>
<th>Property</th>
<th>99.8% Alumina for RF Application (A479B)</th>
<th>AH100A</th>
<th>Sample Material</th>
</tr>
</thead>
<tbody>
<tr>
<td>Volume Resistivity (ohm·cm)</td>
<td>min. $1 \times 10^{14}$</td>
<td>min. $1 \times 10^{14}$</td>
<td>-</td>
</tr>
<tr>
<td>Surface Resistivity (ohm/□)</td>
<td>確認中</td>
<td>$7.4 \times 10^{15}$</td>
<td>$1.2 \times 10^{14}$</td>
</tr>
<tr>
<td>SEE Coefficient</td>
<td>11.4</td>
<td>4.6</td>
<td>3.2</td>
</tr>
<tr>
<td>Dielectric Constant (1MHz)</td>
<td>9.9</td>
<td>10.2</td>
<td>-</td>
</tr>
<tr>
<td>Dielectric Constant (8GHz)</td>
<td>9.9</td>
<td>10.0</td>
<td>10.0</td>
</tr>
<tr>
<td>Dielectric Loss Angle (1MHz)</td>
<td>$1 \times 10^{-4}$</td>
<td>$1 \times 10^{-4}$</td>
<td>-</td>
</tr>
<tr>
<td>Dielectric Loss Angle (8GHz)</td>
<td>$4 \times 10^{-5}$</td>
<td>$1 \times 10^{-4}$</td>
<td>$3 \times 10^{-3}$</td>
</tr>
<tr>
<td>Mechanical Property</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ave. Flexural Strength (MPa)</td>
<td>300</td>
<td>330</td>
<td>-</td>
</tr>
<tr>
<td>Young’s Modulus (GPa)</td>
<td>370</td>
<td>380</td>
<td>-</td>
</tr>
<tr>
<td>Poisson Ratio</td>
<td>0.23</td>
<td>0.25</td>
<td>-</td>
</tr>
<tr>
<td>Thermal Conductivity (W/mK)</td>
<td>29</td>
<td>24</td>
<td>-</td>
</tr>
<tr>
<td>Coeff. Thermal Expansion (ppm/K)</td>
<td>RT-400deg.C</td>
<td>7.0</td>
<td>7.4</td>
</tr>
</tbody>
</table>

*1: Lower limitation of measurement method

S-band RF Transmission Test Sample
New SCRF Power-Input Coupler under development

A pair of new coupler using the new ceramic insulator being developed with CERN’s contribution
Cooperation with CERN and KEK

- **Nano-beam handling technology** >> to be reported by G. Thomas
  - Nano-beam and the stability as a common subject for both ILC and CLIC, through ATF collaboration
  - Final focusing including magnet and the mechanical stability, as well as commissioning technology, still to be investigated
- **SCRF cavity integration technology**,  
  - Specially on input-power couplers and tuners, as a common subject for both ILC and SPL for LHC injector upgrade,
- **Cryogenic engineering**
  - Specially on handling of large amount of helium inventory, as a specially crucial issue in mountain region,
- **Civil engineering study**
  - specially for the detector-hall design,
- **Radiation Safety**
  - Radiation safety design and optimization
ILC Cryogenics

Cryogenics scale is very similar to the LHC Cryogenics

~ 20 kW at 4.5 K /each

Cited from ILC-TDR
CERN-LHC Cryogenics Diagram

Steady state operation modes:

- Installed pumping capacity 125 g/s at 15 mbar (i.e. ~2.4 kW @ 1.8 K)
- Turndown capability: 1 to 3 without extra liquid burning
- Cold return temperature to the 4.5 K refrigerator below 30 K (reduced capacity) to 20 K (installed capacity).
- Capacity check in standalone mode (Interface B closed)
LHC helium storage & Distribution (high grade helium ring line, 2 MPa, 27 km long, for LHC operation)

[Completing the existing CERN helium recovery system: high grade, 20 MPa, 5 km long and low grade, 3 kPa & 20 MPa, 3 km long each]
ILC Cryogenics Layout Investigated
Cooperation with CERN and KEK

- **Nano-beam handling technology** >> to be reported by G. Thomas
  - Nano-beam and the stability as a common subject for both ILC and CLIC, through ATF collaboration
  - Final focusing including magnet and the mechanical stability, as well as commissioning technology, still to be investigated

- **SCRF cavity integration technology,**
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- **Civil engineering study**
  - specially for the detector-hall design,

- **Radiation Safety**
  - Radiation safety design and optimization
ILC Candidate Location: Kitakami Area

High-way

Express-Rail

IP Region

Hitokabe Granite

Senmaya Granite

Orikabe Granite

BDS, DR, DH
Geological Investigation

Profiles of Geological Surveys along the project

Borehole Survey

New IR point?

Hitokabe Granite  Senmaya Granite  Orikabe Granite

Seismic Exploration Survey

Survey area: @Bedrock boundary, Riverbed part

Geological Survey at pre-construction stage

<table>
<thead>
<tr>
<th></th>
<th>Basic Planning</th>
<th>Schematic Design</th>
<th>Detailed Design</th>
</tr>
</thead>
<tbody>
<tr>
<td>Borehole Survey</td>
<td>- 1 p DH area</td>
<td>- 5 p DH/DR area</td>
<td>- 10 p along the BL</td>
</tr>
<tr>
<td>Seismic Exploration</td>
<td>- 1 area /1,000m</td>
<td>- 5 area /5,000m</td>
<td>0 (Additional)</td>
</tr>
</tbody>
</table>
“Kitakami” Landscape, ILC Acc., and CM Models

EDMS work, in cooperation w/ DESY & Fermilab EDMS Team

A. Yamamoto, 2014/05/12

B. List and H. Lars

AWLC14
Radiation Shield Optimization

• Central Radiation Shield
  – Wall thickness is being optimized with worldwide discussion
  – CERN’s expert advice is being given
Summary

• ILC published Technical Design Report in 2013, and is getting into the “preparation phase”.

• The new organization has been established with merging the ILC and the CLIC project under the Director-ship by Dr. L. Evans.

• It includes significant CERN’s participations in the world-wide organization, specially for DR, BDS, SRF, Cryogenics, CFS, and Radiation Safety, and further close cooperation is being realized.

• We would thank CERN’s cooperation and special support for maximizing the ATF operation in the critical stage approaching a design goal of the R&D in final focusing.
backup
# ILC Project Overview

<table>
<thead>
<tr>
<th>Years</th>
<th>TDR baseline Scenario</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 - 2</td>
<td>Pre-preparation for 2yrs (for technical effort continuity) 前段階・先端技術開発の継続(2年)</td>
</tr>
<tr>
<td>3 - 6</td>
<td>Preparation (4 yrs) ILC 建設への準備段階(4年)</td>
</tr>
<tr>
<td>7 - 15</td>
<td>Construction (9 yrs) 建設(9年)</td>
</tr>
<tr>
<td>(12 -)</td>
<td>(start installation) 組み込みの開始</td>
</tr>
<tr>
<td>(13 -)</td>
<td>(start preparation for Commissioning and operation (to be studied) 運転経費（加速器要素・試験設備運転等）の段階的立ち上げ (検討要)</td>
</tr>
<tr>
<td>16 -</td>
<td>Beam Commissioning start ビームコミッションングのスタート</td>
</tr>
<tr>
<td>17 -</td>
<td>Operation at 250 ~ 500 GeV (550 GeV) 物理実験 @ 250 ~ 500 GeV (550 GeV)</td>
</tr>
<tr>
<td>TBD</td>
<td>Toward 500 GeV HL upgrade ルミノシティーアップグレード(500 GeV)</td>
</tr>
<tr>
<td>TBD</td>
<td>Toward 1 TeV upgrade エネルギーアップグレード (1 TeV)</td>
</tr>
</tbody>
</table>
Management of Cryogenic Fluids

- Total **HELIUM** inventory at CERN: 170’000 kg
- LHC (accelerator & detectors) helium full inventory: 136’000 kg
- Additional strategic permanent storage during operation: 15’000 kg

- In situ helium liquefaction for central services (up to 350’000 liter per year) and distribution by means of mobile containers ranging from 100 to 2’000 liter (users without dedicated cryogenic plant)