ILC Progress Report
- Updates of the Design & Development after TDR -

LCC Collaboration and

KEK Planning Office of the ILC

10 July, 2015

Outline

Contents:

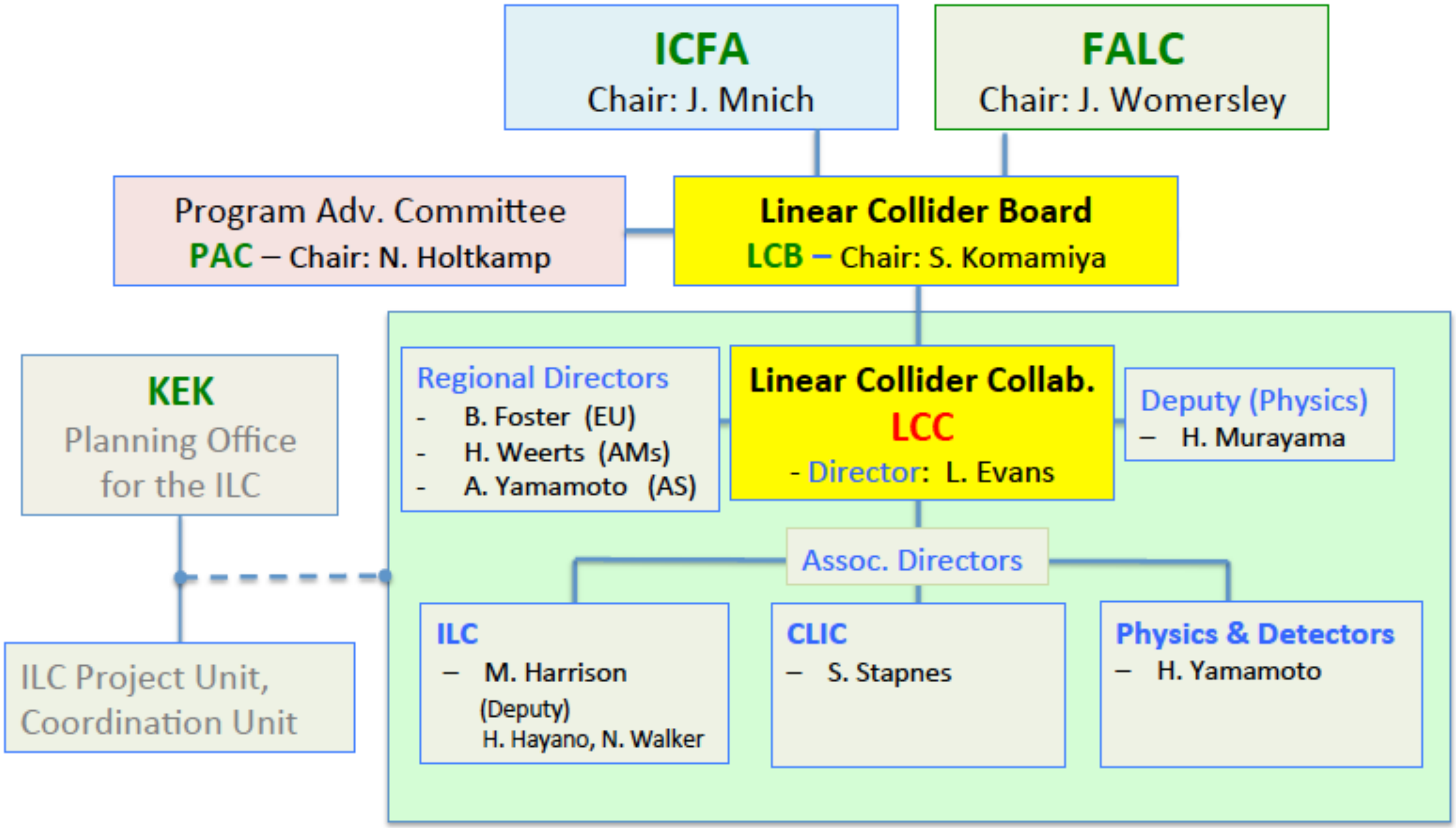
References:

- URL/online available for most references

Appendix:

- Table: Summary of the progress
- Figures: Highlighted design improvements (in progress)

LCC Global Structure



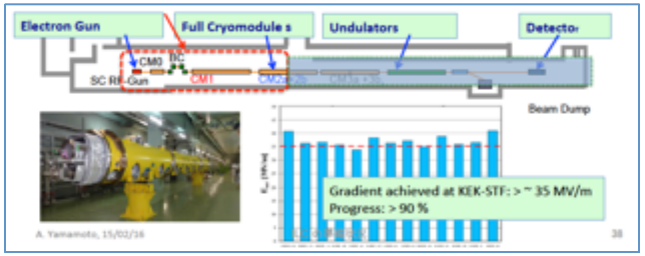
2. ILC, Post-Organization and Activities

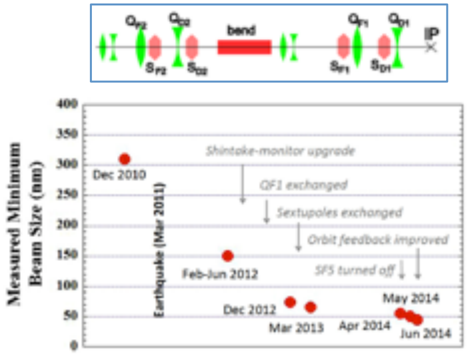
LCC Associate Director responsible for ILC Accelerator: M. Harrison (BNL)
- Deputies: H. Hayano (KEK) and N. Walker (DESY)

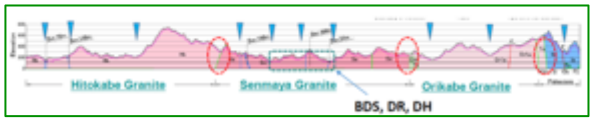
Sub-System	*Global Leader* *- Deputy Leader*	*Sub-System*	*Global Leader* *- Deputy Leader*
ADI	N. Walker (DESY) - K. Yokoya (KEK)	**SRF**	H. Hayano (KEK) - C. Ginsburg (Fermilab) - E. Montesinos (CERN)
e-/e+ Sources	W. Gai (ANL) - M. Kuriki (Hiroshima)	**RF Power & Cntl**	S. Michizono (KEK) - TBD - TBD
Damping Ring	D. Rubin (Cornell) - N. Terunuma (KEK)	**Cryogenics**	H. Nakai (KEK) - D. Delikaris (CERN) - T. Peterson (Fermilab)
RTML	S. Kuroda (KEK) - A. Latina (CERN)	**CFS**	V. Kuchler (Fermilab) - J. Osborne (CERN) - M. Miyahara (KEK)
Main Linac	N. Solyak (Fermilab) - K. Kubo (KEK)	**Radiation Safety**	T. Sanami (KEK) - S. Roesler (CERN) - TBD
BDS	G. White (SLAC) - R. Tomas (CERN) - T. Okugi (KEK)		

Issues to prepare for ILC Realization

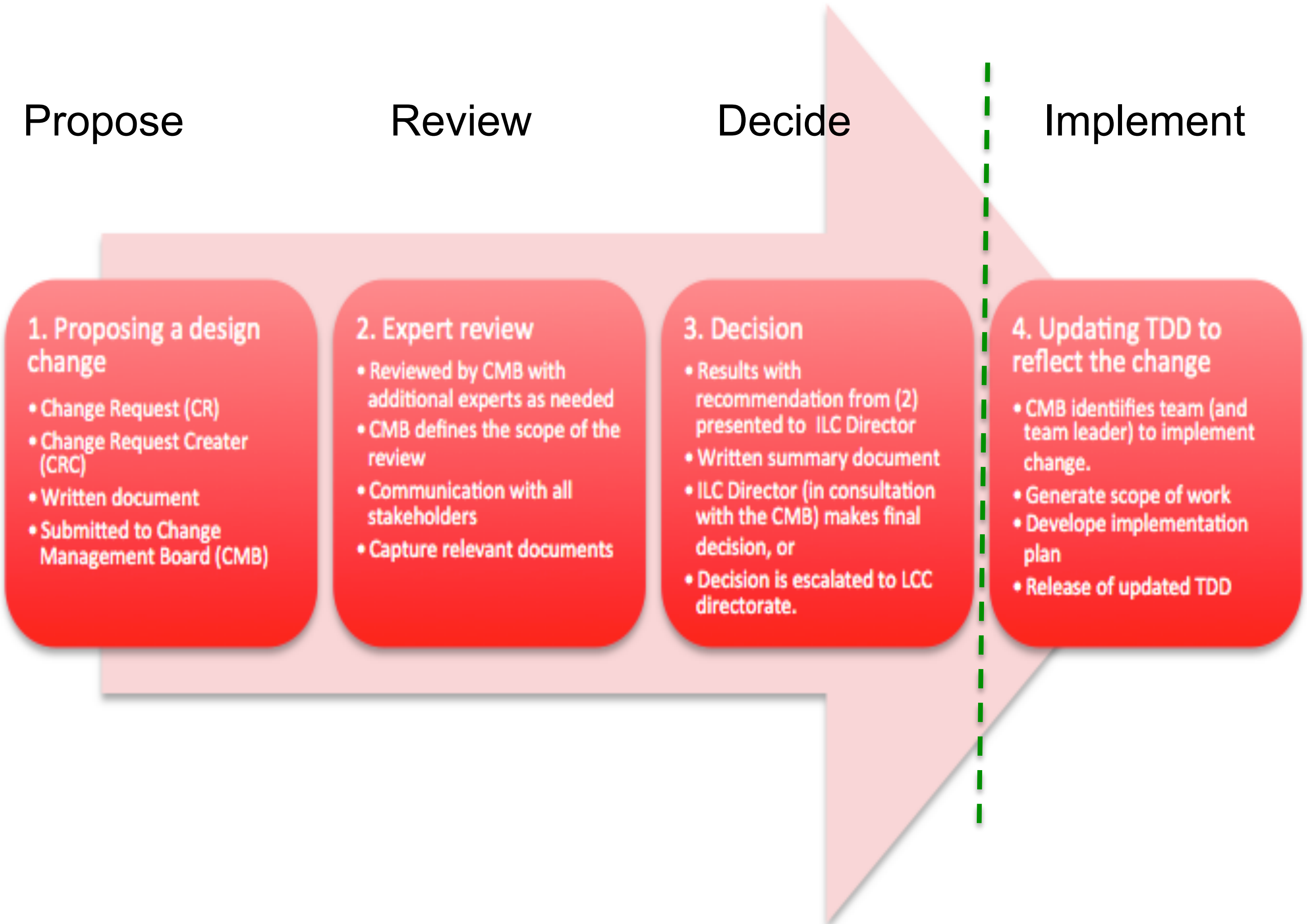
Themes	Issues/Subjects	Global Cooperation/work-sharing
ADI	<u>Acc.</u> **Parameter** optimization & eng. Design Change Management (CM)	**LCC-ILC-ADI** to take a central role with global cooperation
SRF	Mass-production & Testing technology → **Hub-lab functioning** to be balanced Stabilization of the performance	**TTC Collab.**, as a worldwide community - KEK-STF: Hub-Lab function - EXFEL: mass production and testing - LCLS : mass production and testing
Nano-beam	Ultra low emittance, <u>**Nano-beam, and the stability**</u>	**ATF Collab.**, as a worldwide community - KEK-ATF to be maximized in use, as a globalyl unique
CFS	<u>**Site-specific** CFS design</u>, env. assess. General plan, eng. Design, drawings	**JP-CFS** to serve a central role in cooperation with global experts.
Management	Preparation for the int'l <u>ILC laboratory</u>	A main Issue for the ILC to be prepared







Change Management: The Basic Path



ILC Accelerator Design: Post-TDR Updates

- **Objectives: :**
  - Further optimize the ILC accelerator design parameters, assuming a site model in Japan, and to seek for the best cost-effective construction,

- **Process for the Change Management:**
  - Changes

		Propose (Creator)	Review	Decide	Implement
CR-001	Add return "Dogleg" to target by-pass	2014/08/27 (K.Yokoya)	done	**Rejected**	
CR-002	Adapt equal L* for both detectors	2014/09/02 (G. White)	done	Differed to Review Panel	L* to be settled to ~ 4 m
CR-003	Detector hall with vertical shaft access	2014/09/16 (K. Buesser)	done	**Accepted**	In progress
CR-004	Extension of the e-e+ ML tunnels by about 1.5 km	2014/12/18 (N. Walker)	In progress		
CR-005	…				

3. The Preferred Site

- Process to reach the preferred site

  1999: more than 10 candidates in Japan

  2010: two candidates,Kitakami and Sefuri, remain

  2013; Kitakami as "the preferred site"

  - The selection reached by the high-energy physics community, and approved by the international expert committee and by the LCC collaboration.
  - No formal discussion/decision made yet by the Japanese government

4. Geological Survey and Civil-engineering Studies

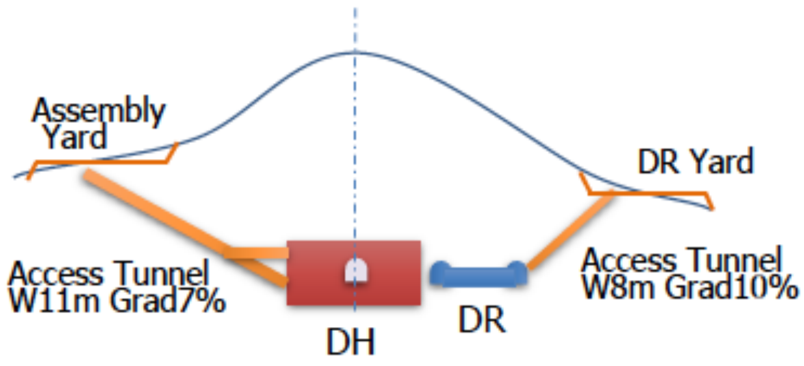
- Design changes and further studies according to the preferred site assumed as a working model.
  - CR-0003:
    - Detector hall with vertical shaft access
  - CR-0004:
    - Extension of the e- and e+ main linac tunnels approximately 1.5 km
  - Under study:
    - Shielding wall in ML tunnel to be thinner, with assuming no human access to the ML utility are during beam operation

- Development of a software for tunnel layout optimization

Change Request: CR-0003

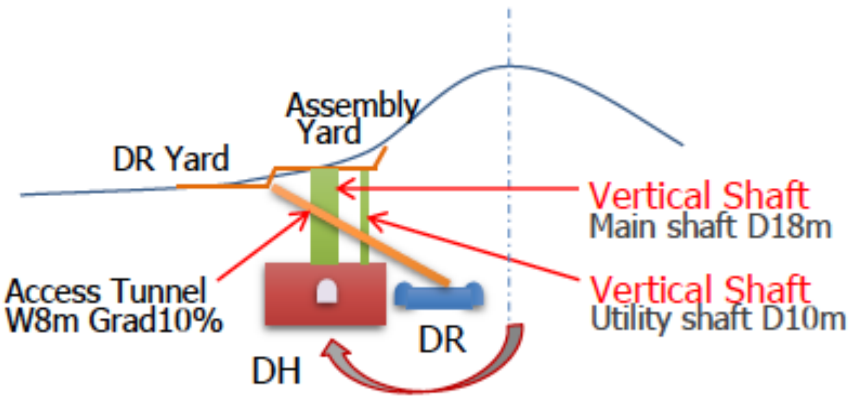
TDR Baseline

- Assembly Place: Surface Building/AH
- Access way to DHl underground
  - only Inclined Access Tunnel (AT)
  - Transport. by special long trailer



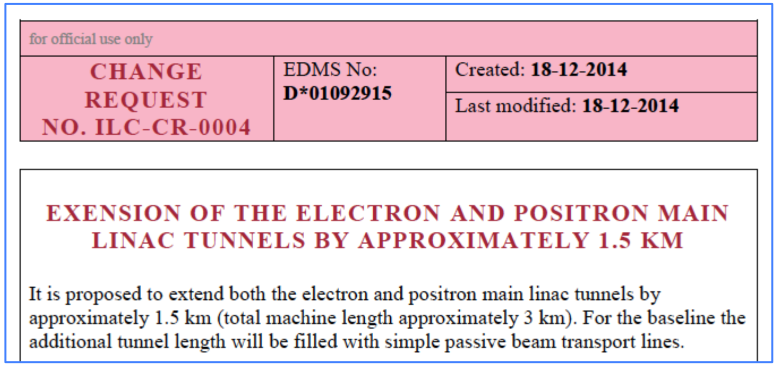
New Baseline

- Assembly Place: Underground/DH
- Access way to DH underground
  - mainly Vertical Shaft (VS)
  - Transport. by Gantry Crane



CR-004: Timing Issue

K. Yokoya-141204



for official use only		
CHANGE REQUEST NO. ILC-CR-0004	EDMS No: **D*01092915**	Created: **18-12-2014**
		Last modified: **18-12-2014**

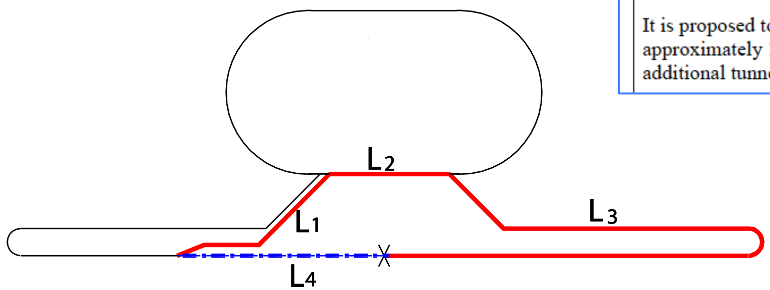
EXENSION OF THE ELECTRON AND POSITRON MAIN LINAC TUNNELS BY APPROXIMATELY 1.5 KM

It is proposed to extend both the electron and positron main linac tunnels by approximately 1.5 km (total machine length approximately 3 km). For the baseline the additional tunnel length will be filled with simple passive beam transport lines.

Machine Footprint

- Timing constraints

  $(L_1 + L_2 + L_3) - L_4 = n \times C_{DR}$

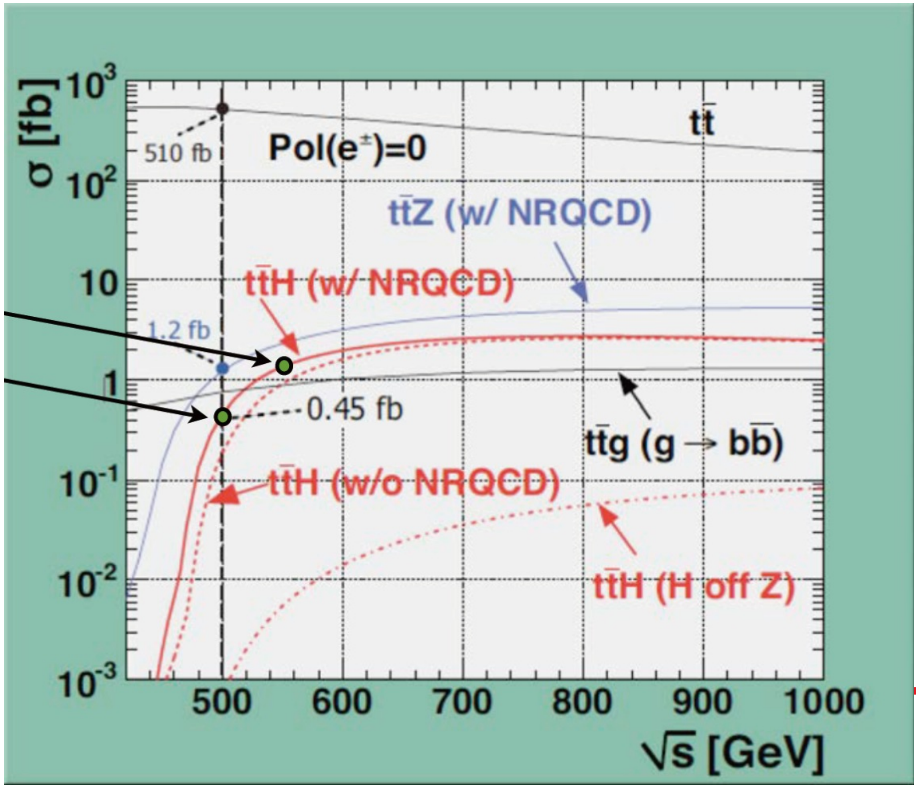


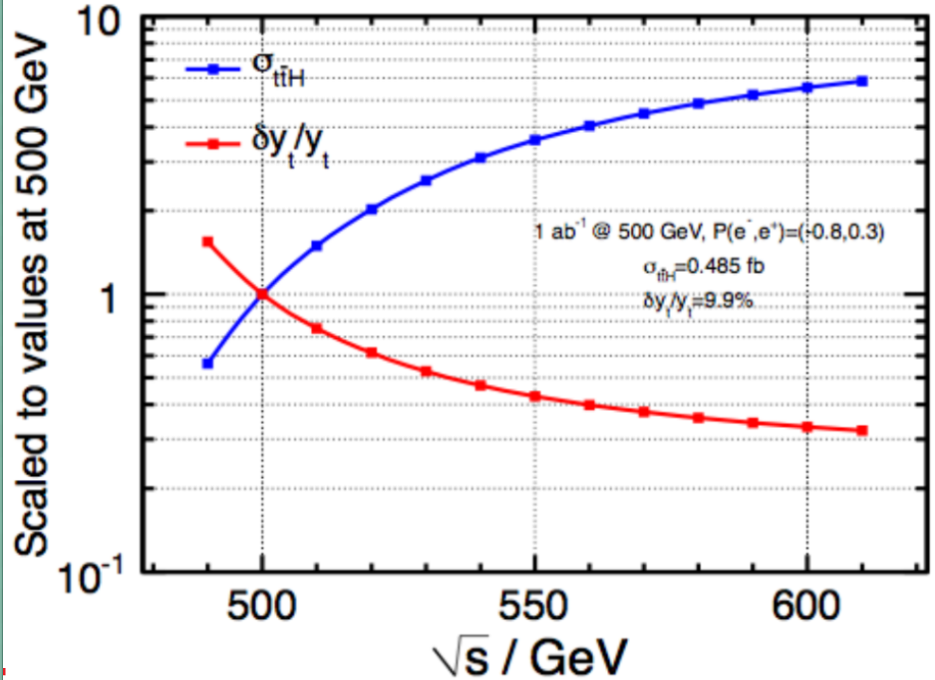
- TDR values give

  $(L_1 + L_2 + L_3) - L_4 = 9 \times C_{DR} + 294\text{m}$
- It is possible to adjust the value either by
  - Shortening the BDS by ~150m, or by
  - Expanding the DR circumference by ~30m
- This will nearly keep the TDR layout
- But no margin for 500GeV, no way to reach 550GeV

Physics Issue

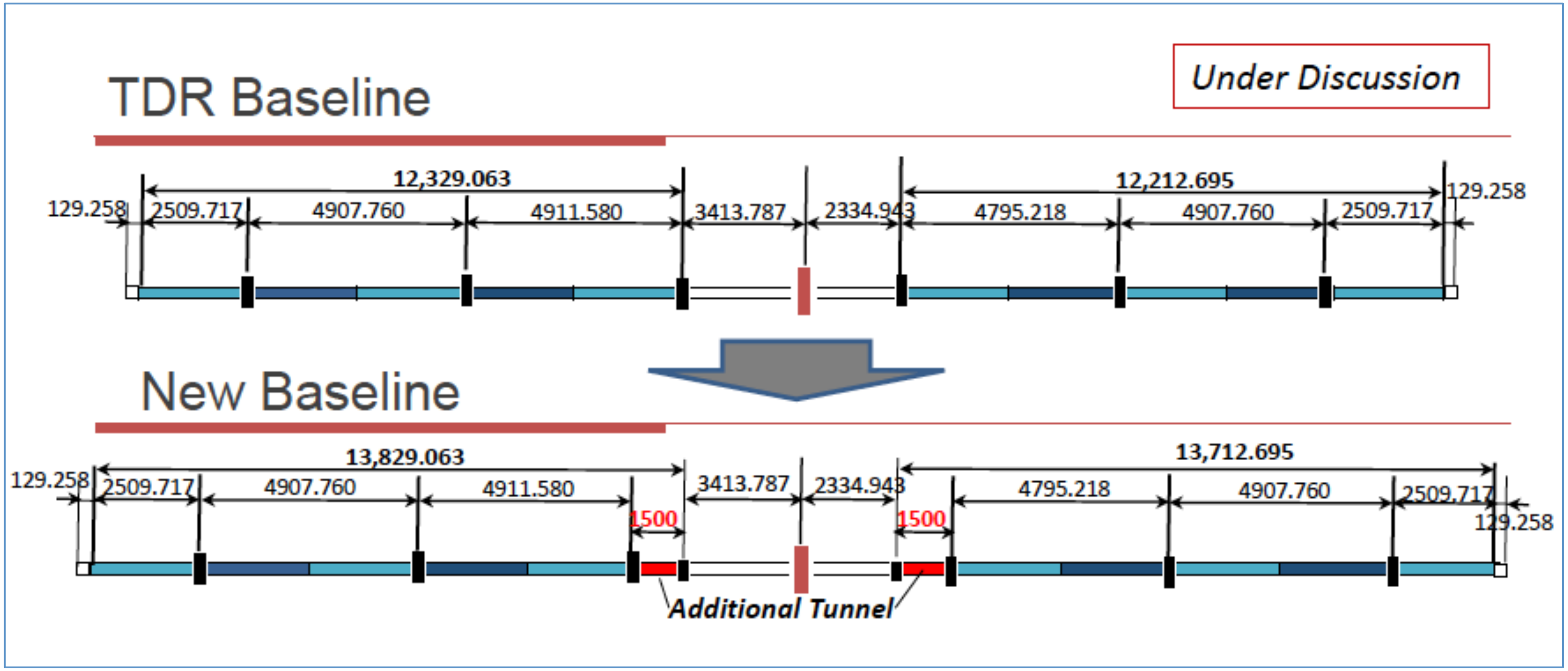
- TDR Design : Maximum energy E_{CM}=500GeV
  - ✓ Decided before the discovery of Higgs at ~125GeV
- 500GeV is close to the threshold of e+ e- → t t H at E_{CM}=475GeV
- E_{CM}~550GeV is preferable for measuring top-Yukawa coupling
  - The cross-section at 550GeV is factor ~4 larger than at 500GeV



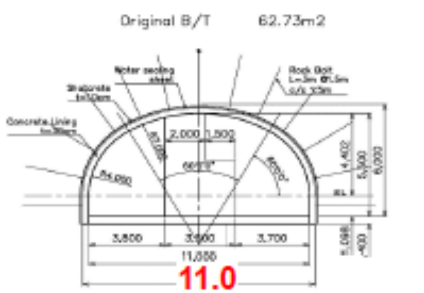
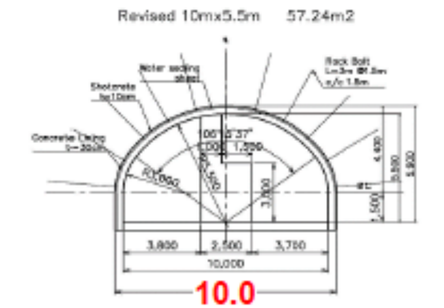
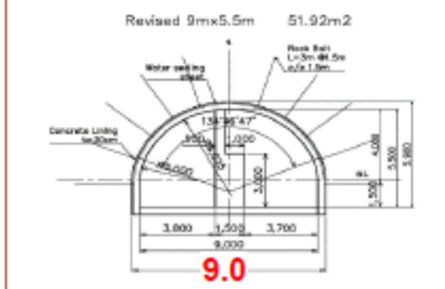


Parameter Group report (Oct.2014)

Change Request: CR-0004



Change Request: in preparation

	Baseline SW3.5m	Option-1 SW2.5m	Option-2 SW1.5m
Cross Section			
Cross Section	W11m x H5.5m 62.7 m2	W10m x H5.5m 57.2 m2	W9m x H5.5m 51.9 m2

5. Accelerator Hardware Design and Development, Updates

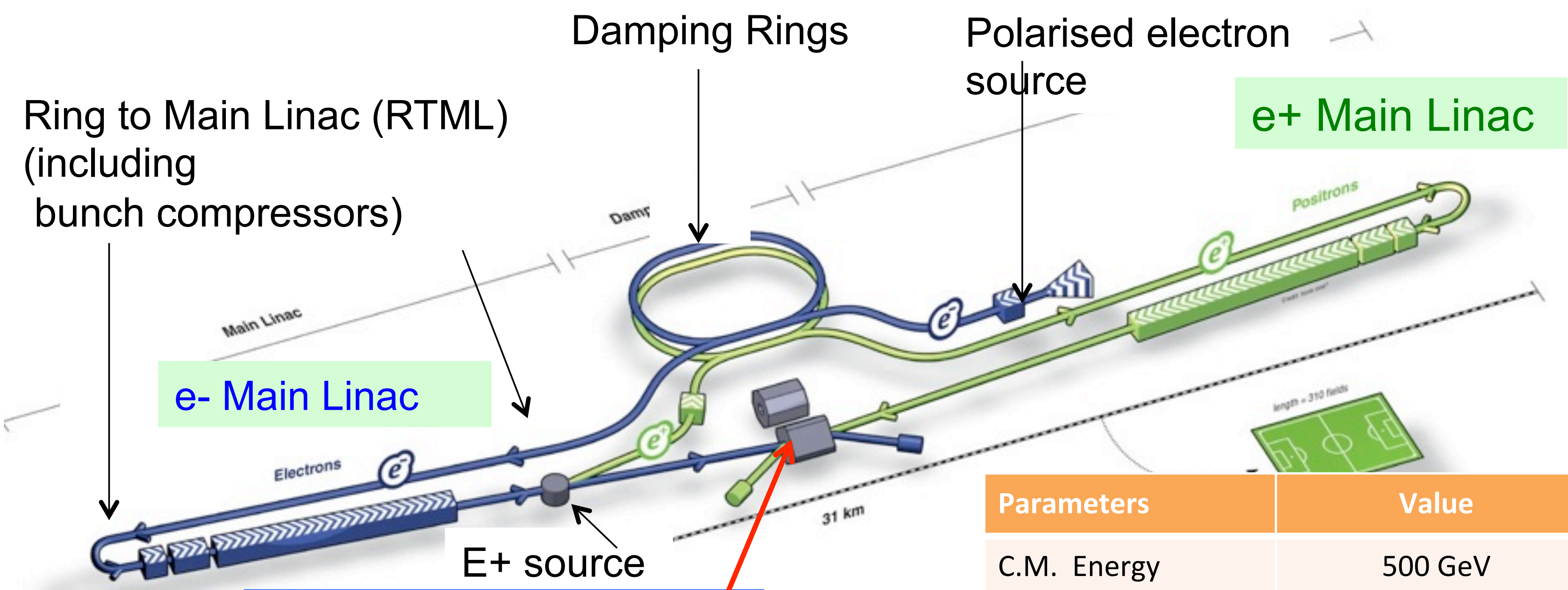
- “Value engineering”, where the different systems are optimized to reduce cost.
  - SRF cavity/cryomodule design and integration most attentioned.

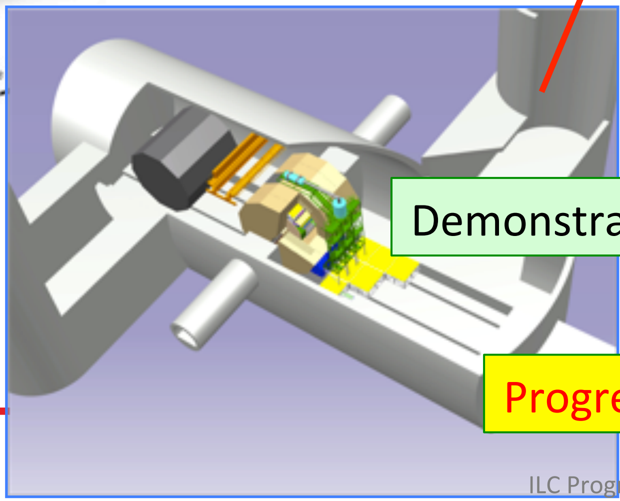
5.1 SRF cavity/cryomodule design and integration

- Superconducting material, cavity, and magnetic shield
- Cavity integration with power couplers and tuners

5.2 Power system, industrialization of K. Modulators

ILC Accelerator in TDR



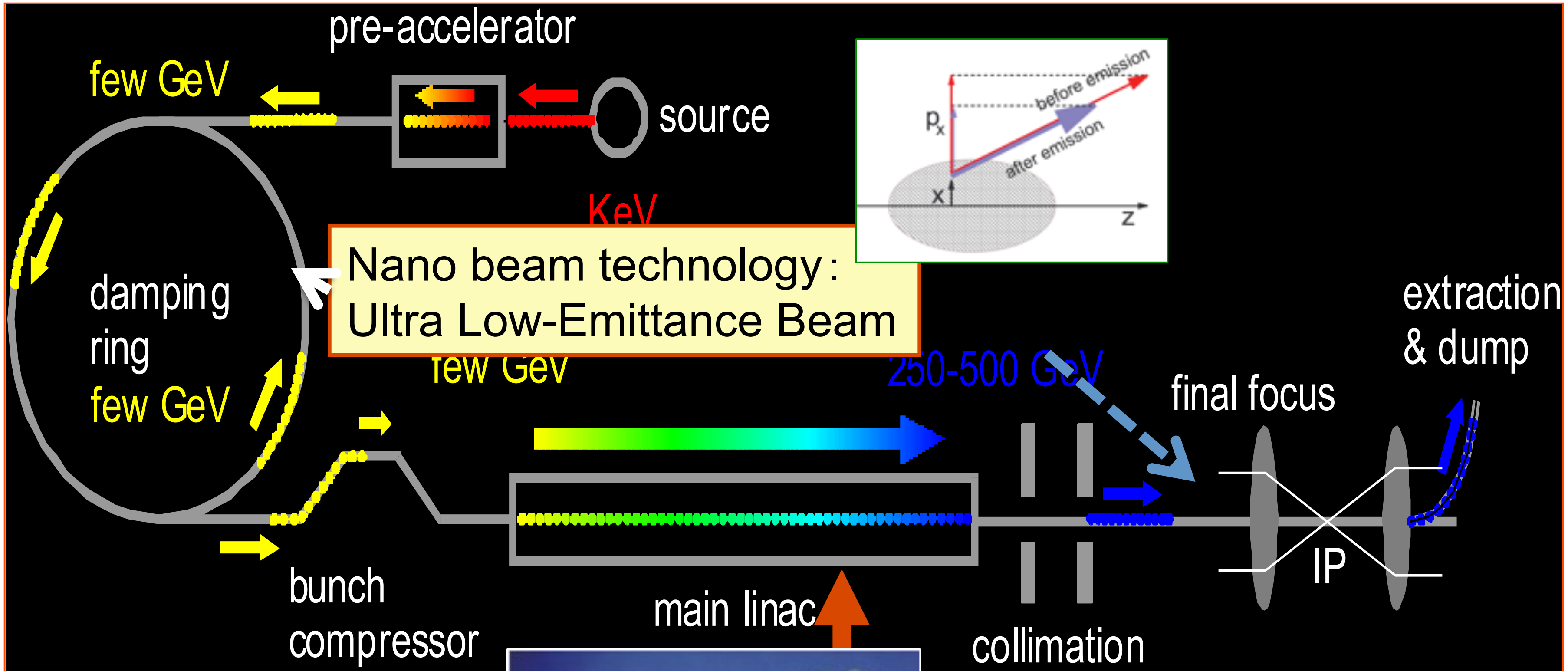


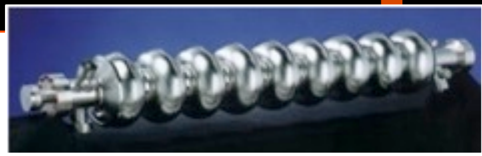
Parameters	Value
C.M. Energy	500 GeV
Peak luminosity	1.8 x10^{34} $cm^{-2}s^{-1}$
Beam Rep. rate	5 Hz
Pulse duration	0.73 ms
Average current	5.8 mA (in pulse)
FF beam size (y)	**5.9** nm
E gradient in SCRF acc. cavity	**31.5** MV/m +/-20% Q_0 = 1E10

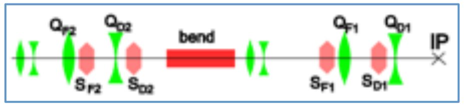
Demonstrated in TDR

Progress in 2014

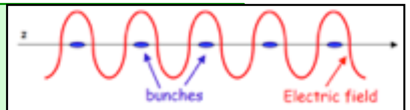
Key Technologies to realize ILC







- Sources (e-, e+) :
- Damping Ring (DR):
- Beam Transport to ML (RTML) :
- Main Linace (ML) : SCRF Technology
- Beam Delivery System (BDS)



SRF Technology :
High G and Power saving

SRF Main Linac Parameters, Demonstrated

Characteristics	Parameter	Unit	Demonstrated
Average accelerating gradient	31.5 (±20%)	MV/m	DESY, FNAL, JLab, Cornell, KEK,
Cavity Q_0	10^{10}		
(Cavity qualification gradient	35 (±20%)	MV/m)	
Beam current	5.8	mA	DESY-FLASH, KEK-STF
Number of bunches per pulse	1312		DESY
Charge per bunch	3.2	nC	
Bunch spacing	554	ns	
Beam pulse length	730	ms	DESY-FLASH, KEK-STF
RF pulse length (incl. fill time)	1.65	ms	DESY-FLASH, KEK-STF, FNAL-ASTA
Efficiency (RF→beam)	0.44		
Pulse repetition rate	5	Hz	DESY, KEK
FF beam size (y)	5.9	nm	Closing at KEK-ATF
Peak beam power per cavity at 31.5 MV/m	190	kW	

Technical Highlights in 2014

- **Nano-beam**
  - **ATF2**: reached 44 nm at the final focus, closing the primary goal of 37 nm
    - Corresponding to 7 nm at the ILC energy (250 GeV/beam) with the goal of 6 nm
- **SRF**
  - **EXFEL**: exceeded 75 % (400/800) cavity production, and > 40 % (40/100) cryomodule assembly and test
  - **Fermilab**-ASTA: reached the ILC specification gradient
  - **SLAC**-LCLS: started the project in consortium with the US SRF laboratories
  - **KEK**-STF2: completed CM1+CM2a installation into the beam line
- **Accelerator Design and Integration (ADI)**
  - **LCC:** processed Post-TDR design update with a model-site assumption
    - Common L* for both detectors of ILD and SiD
    - Vertical access at Detector Hall at IR points
    - Extension of ML tunnel for optimizing e+e- collision timing and for redundancy of ML SRF cavity gradient integration
  - **LCC**: is continuing to seek for potential cost saving in balance to necessary increase

IPAC14: Courtesy: H. Weise

European XFEL

An Accelerator Complex for 17.5 GeV

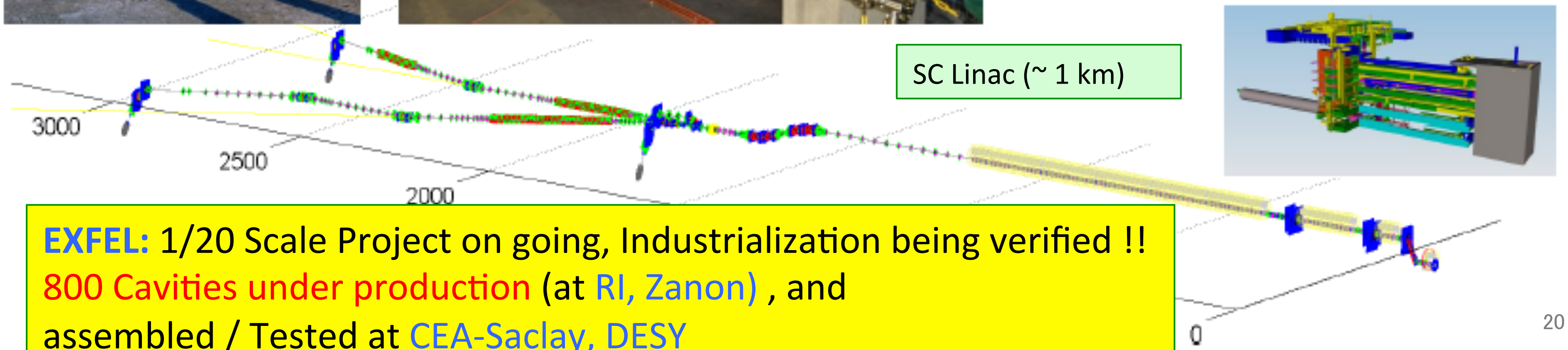
100 accelerator modules

Some specifications

- Photon energy 0.3 - 24 keV
- Pulse duration ~ 10 - 100 fs
- Pulse energy few mJ
- Superconducting linac. 17.5 GeV
- 10 Hz (27 000 b/s)

800 accelerating cavities
1.3 GHz / 23.6 MV/m

25 RF stations
5.2 MW each

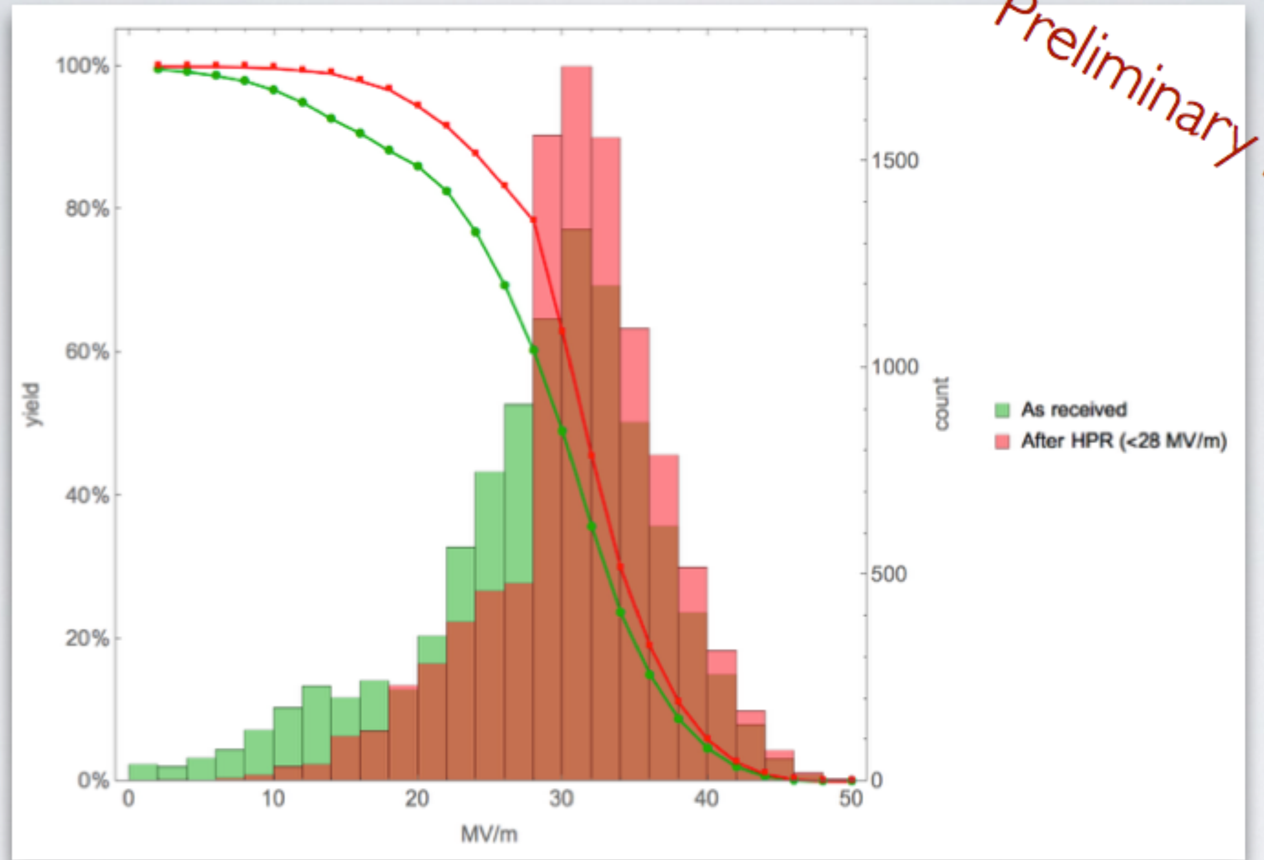


SC Linac (~ 1 km)

EXFEL: 1/20 Scale Project on going, Industrialization being verified !!
800 Cavities under production (at RI, Zanon) , and
assembled / Tested at CEA-Saclay, DESY

LCWS14, Belgrade

ILC MODEL - RESULT



	Tests	Average	rms	Yield@28	Yield@31.5	Yield@35
As received	10 000	28.4	8.3	61%	40%	19%
Second Pass	10 000	30.9	6.4	77%	49%	24%

XFEL cavities

XFEL Vertical Test Results and extrapolation to ILC, N. Walker(DESY)

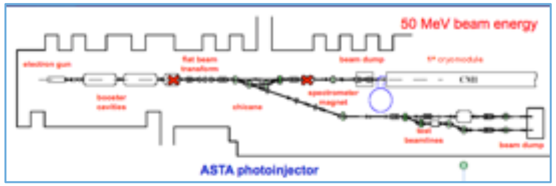
CM2 reached <31.5 MV/m > at Fermilab in 2014

CERN Courier **December 2014**

ACCELERATORS

ILC-type cryomodule makes the grade

For the first time, the gradient specification of the International Linear Collider (ILC) design study of 31.5 MV/m has been achieved on average across an entire ILC-type cryomodule made of ILC-grade cavities. A team at Fermilab reached the milestone in early October. The cryomodule, called CM2, was developed to advance superconducting radio-frequency technology and infrastructure at laboratories in the Americas region, and was assembled and installed at Fermilab after initial vertical testing of the cavities at Jefferson Lab. The milestone – an achievement for scientists at Fermilab, Jefferson Lab, and their domestic and international partners in superconducting radio-frequency (SRF) technologies – has been nearly a decade in the making, from

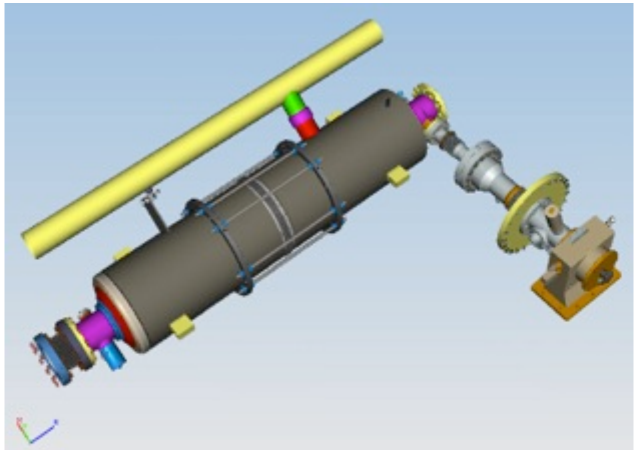


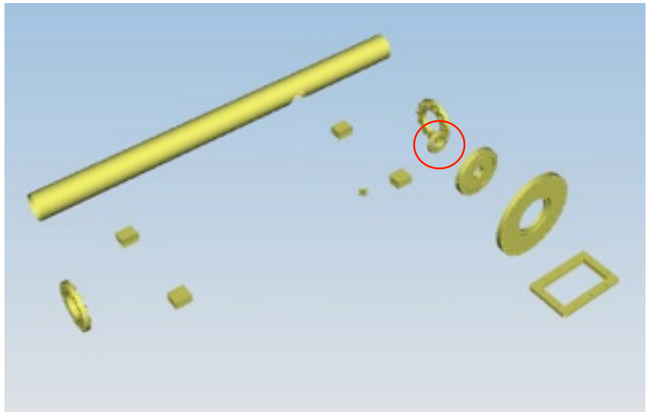
CM2 in its home at Fermilab's NML building, as part of the future Advanced Superconducting Test Accelerator. (Image credit: Fermilab.)

Cavity	Gradient (MV/m)
1	31.9
2	30.8
3	31.8
4	31.7
5	31.5
6	31.3
7	31.6
8	31.4

Cryomodule test at Fermilab reached < 3.15 > MV/m, exceeding ILC specification

Plug-compatible Conditions





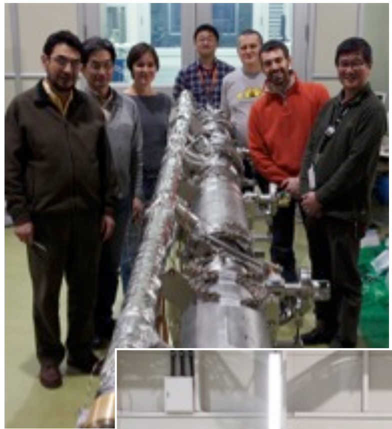
Item	Varieties	Baseline
Cavity shape	TESLA / LL	TESLA
Length		Fixed
Beam pipe flange		Fixed
Suspension pitch		Fixed
Tuner	Blade/ Slide-Jack	Blade
Coupler flange (cold end)	40 or 60	40 mm
Coupler pitch		Fixed
He –in-line joint		Fixed

Plug-compatible interface established

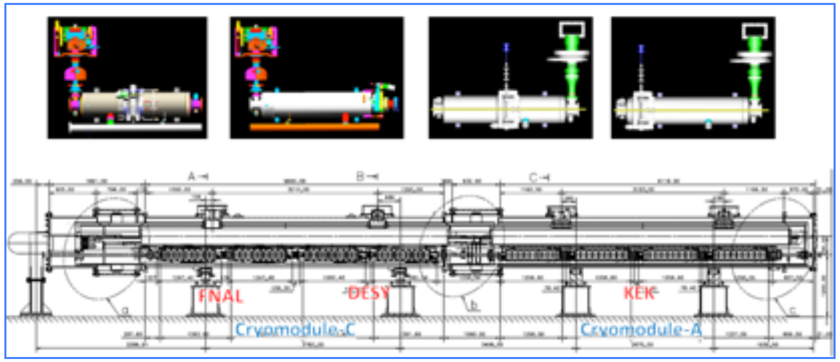
S1-Global hosted at KEK:
Global cooperation to demonstrate SCRF system

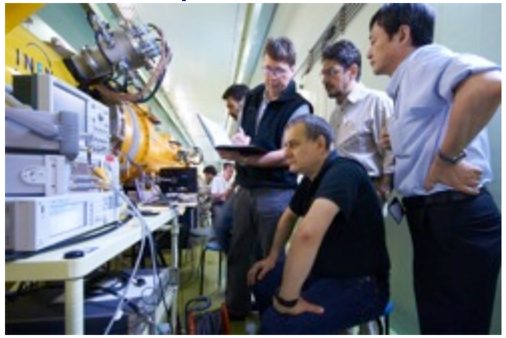
DESY, FNAL, Jan., 2010

DESY, Sept. 2010



INFN and FNAL Feb. 2010





FNAL & INFN, July, 2010

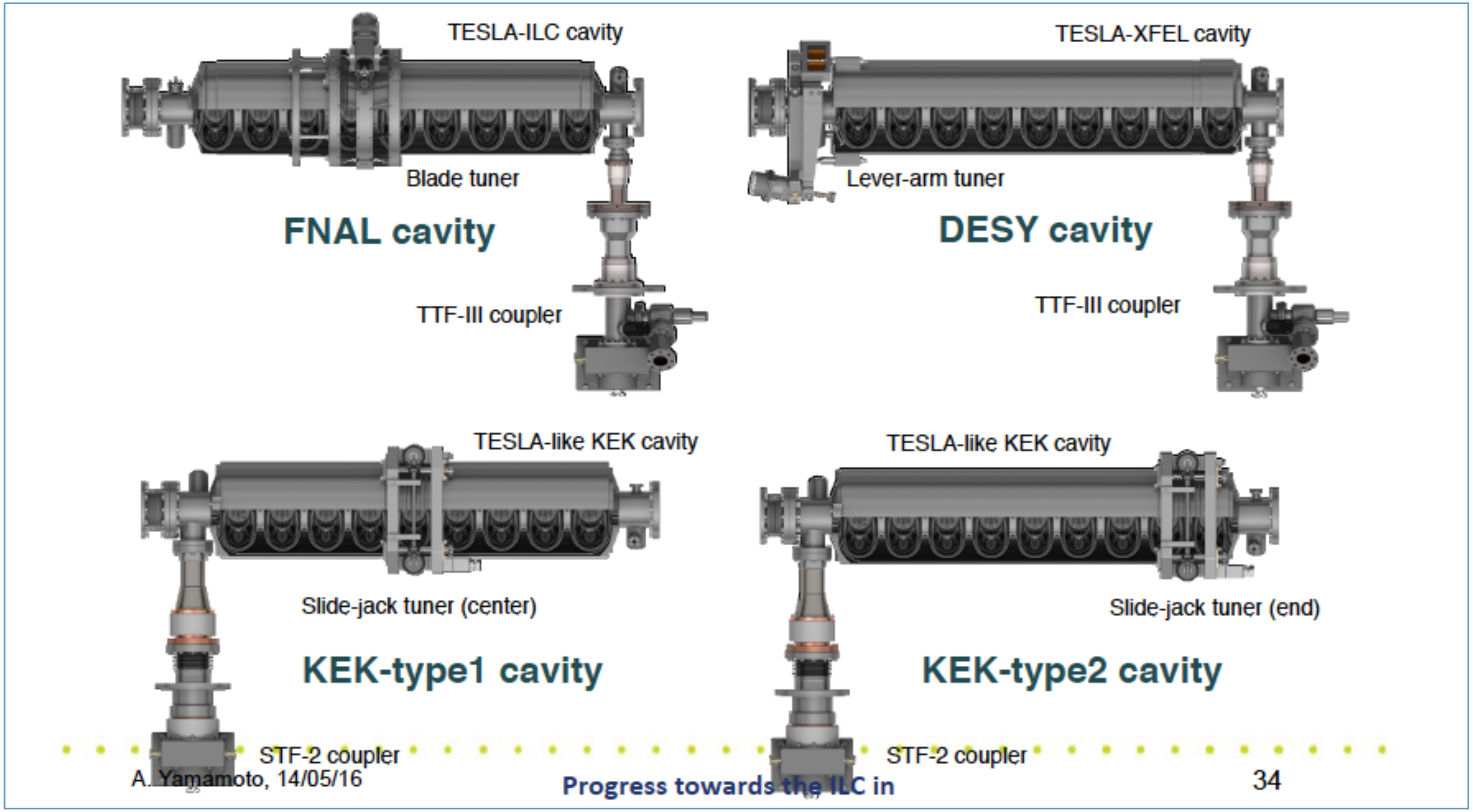
March, 2010

DESY, May, 2010

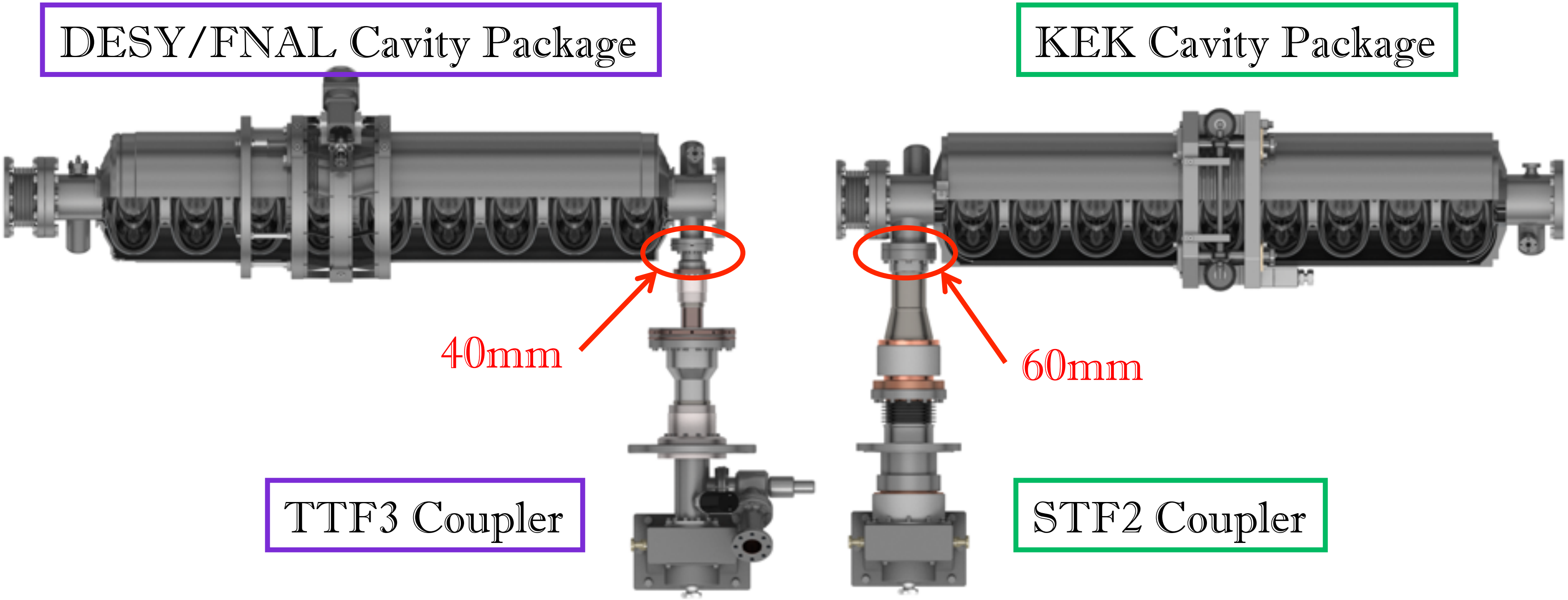
June, 2010 ~

Value Engineering of SRF

S1-Global, demonstration of various cavity integration



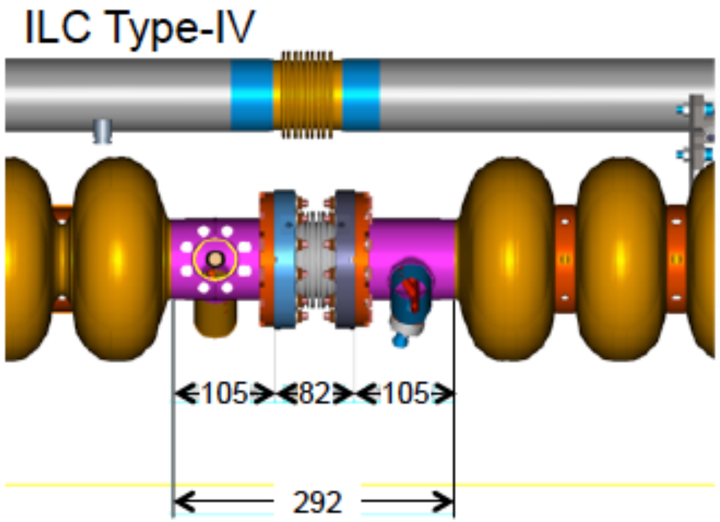
Motivation

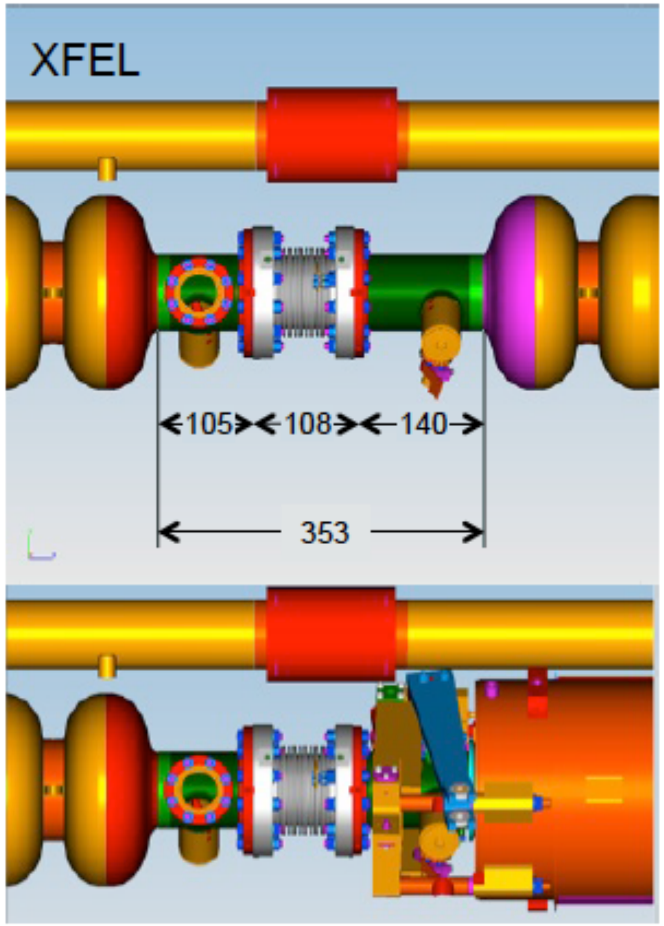


In view of "Plug compatibility", the use of STF2 coupler should be evaluated for 40mm diameter.

What is the most simple way for this change?

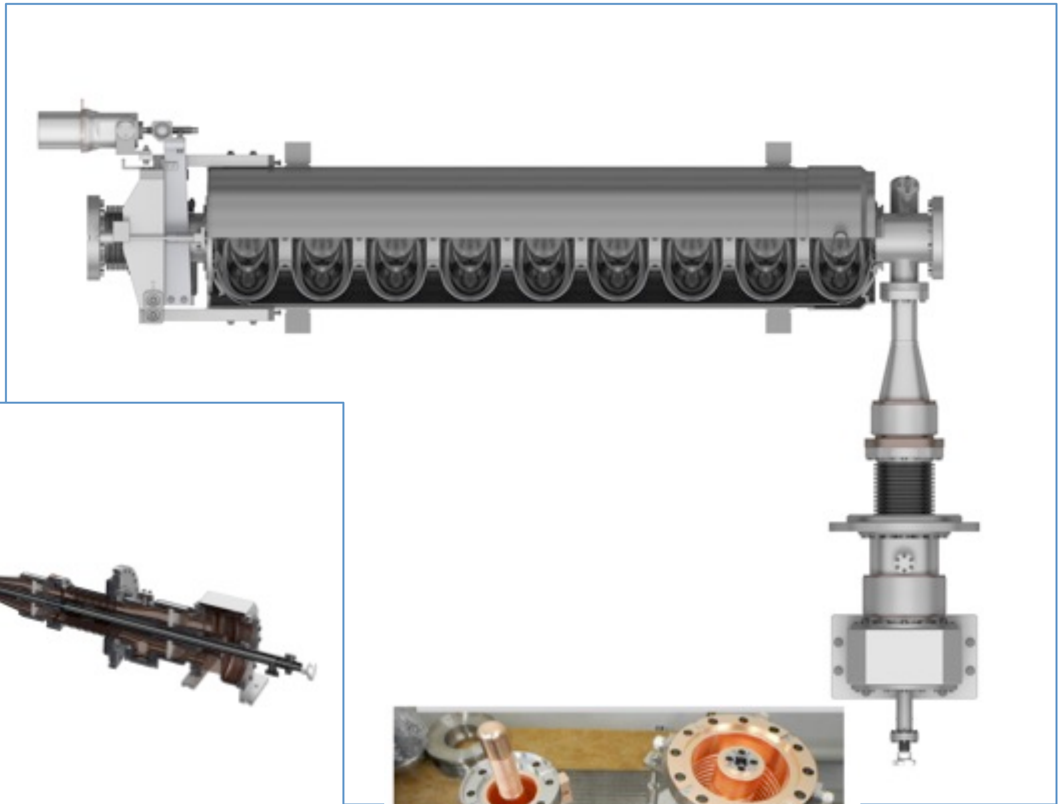
Longitudinal Configuration Difference of Cavity Integration in ILC and EXFEL

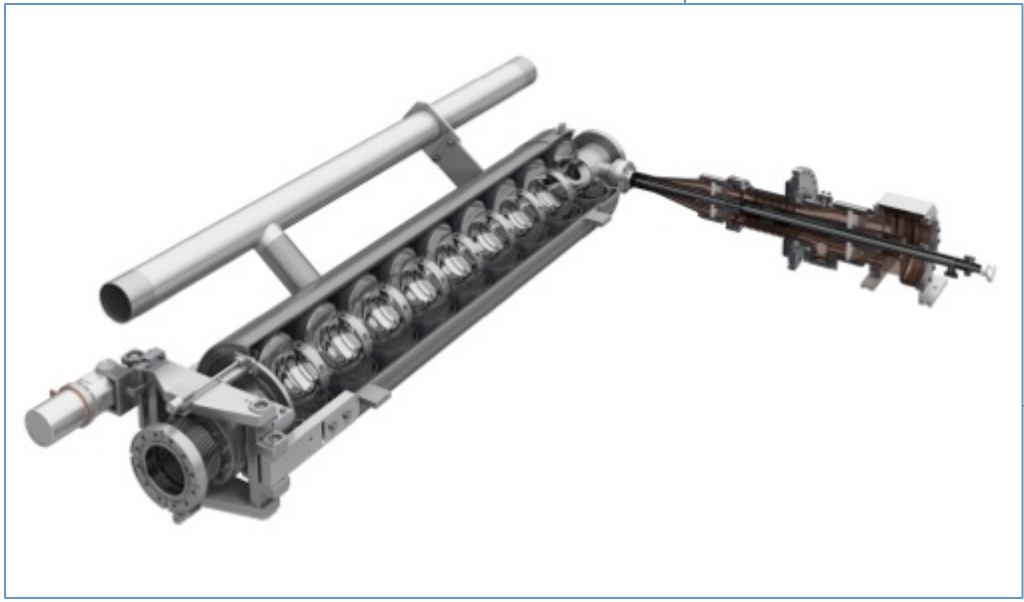




Reduction in inter-cavity spacing		**= 61 mm**
Bellows:	= 108→82	= 26 mm
"Long" cavity end	= 140→105	= 35 mm

A Possible Cavity Integration optimization for the ILC





6. Layout updates for accelerator/ associated systems

6.1 Final focus layout

- CR-0002:
  - Baseline optics to provide for a single FFS L* (QD0 exit-IP distance) optics configuration

6.2 Positron production

- Under study:
  - A conventional (electron driven) positron source
  - A change request in preparation for the “beam delivery system tunnel layout”

6.3 Cryogenics System

- Under study:
  - A change request in preparation for the “Cryogenics layout update”.

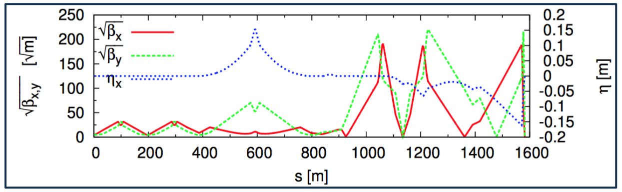
T. Okugi

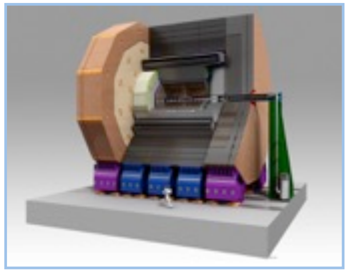
CR-002: Equalize L* for both Detectors

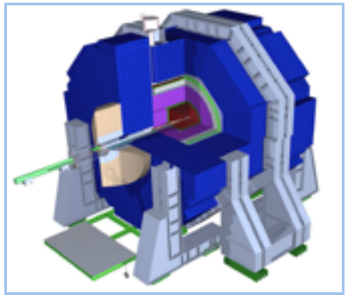
CHANGE REQUEST NO. ILC-CR-0002	EDMS No: **D*01082495**	Created: **02-09-2014** Last modified: **09-09-2014**

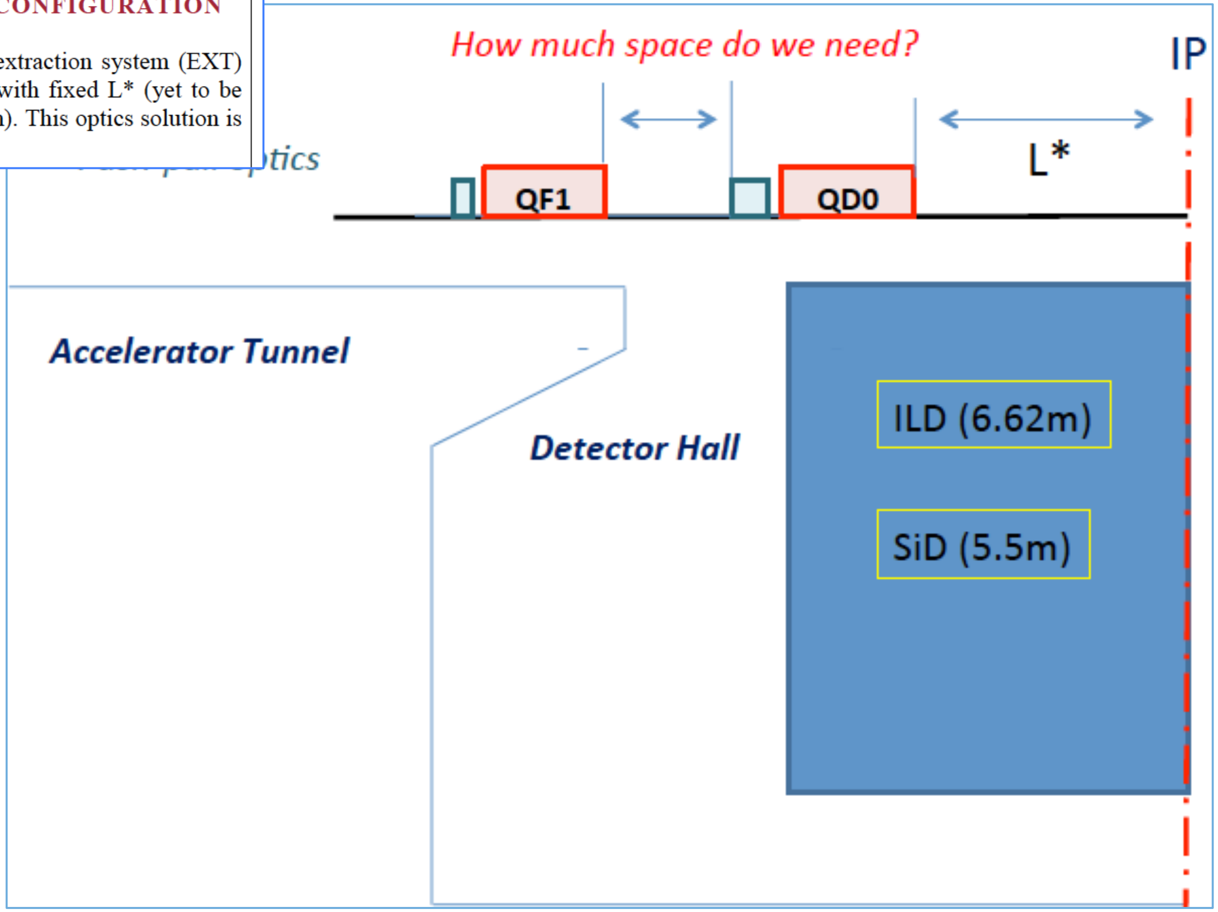
BASELINE OPTICS TO PROVIDE FOR A SINGLE FFS L* (QD0 EXIT – IP DISTANCE) OPTICS CONFIGURATION

The final focus system (FFS) and beam dump extraction system (EXT) baseline design is to provide a standard optics with fixed L* (yet to be determined, but provisionally assumed to be ≤4m). This optics solution is to be common to both detectors.



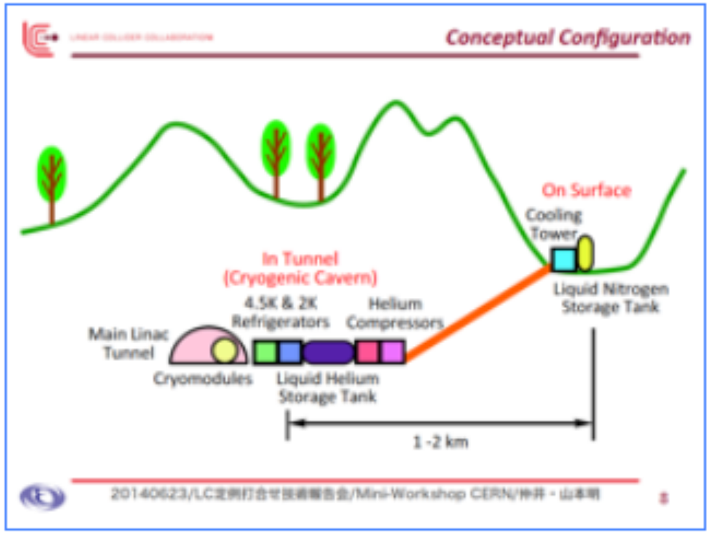




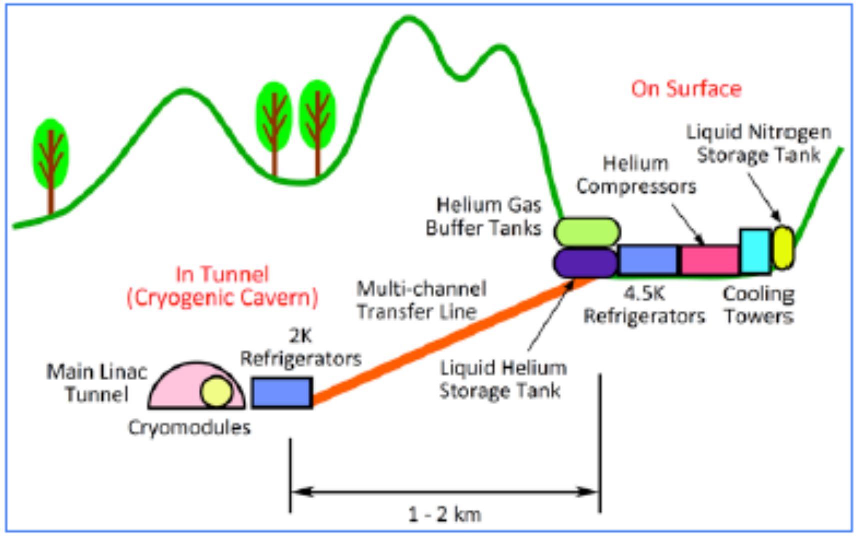


Change Request: in preparation

ILC-TDR Baseline



New Baseline to be proposed to CMB



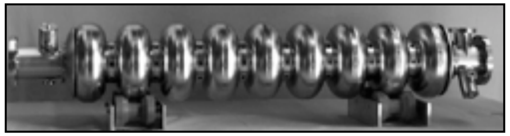
7. Integration and Test Facilities

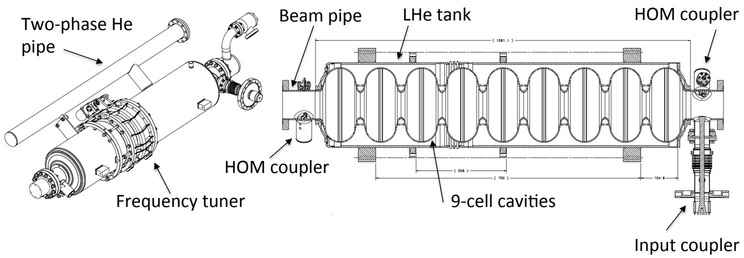
- SLAC, Fermilab, and JLab (US)

- DESY (Germany)
- CEA-IRFU and CNRS-LAL (France)

- IHEP and Peking University (China)
- RRCAT and IUAC (India)
- KEK (Japan)

空洞・CMの製造および性能試験・プロセス



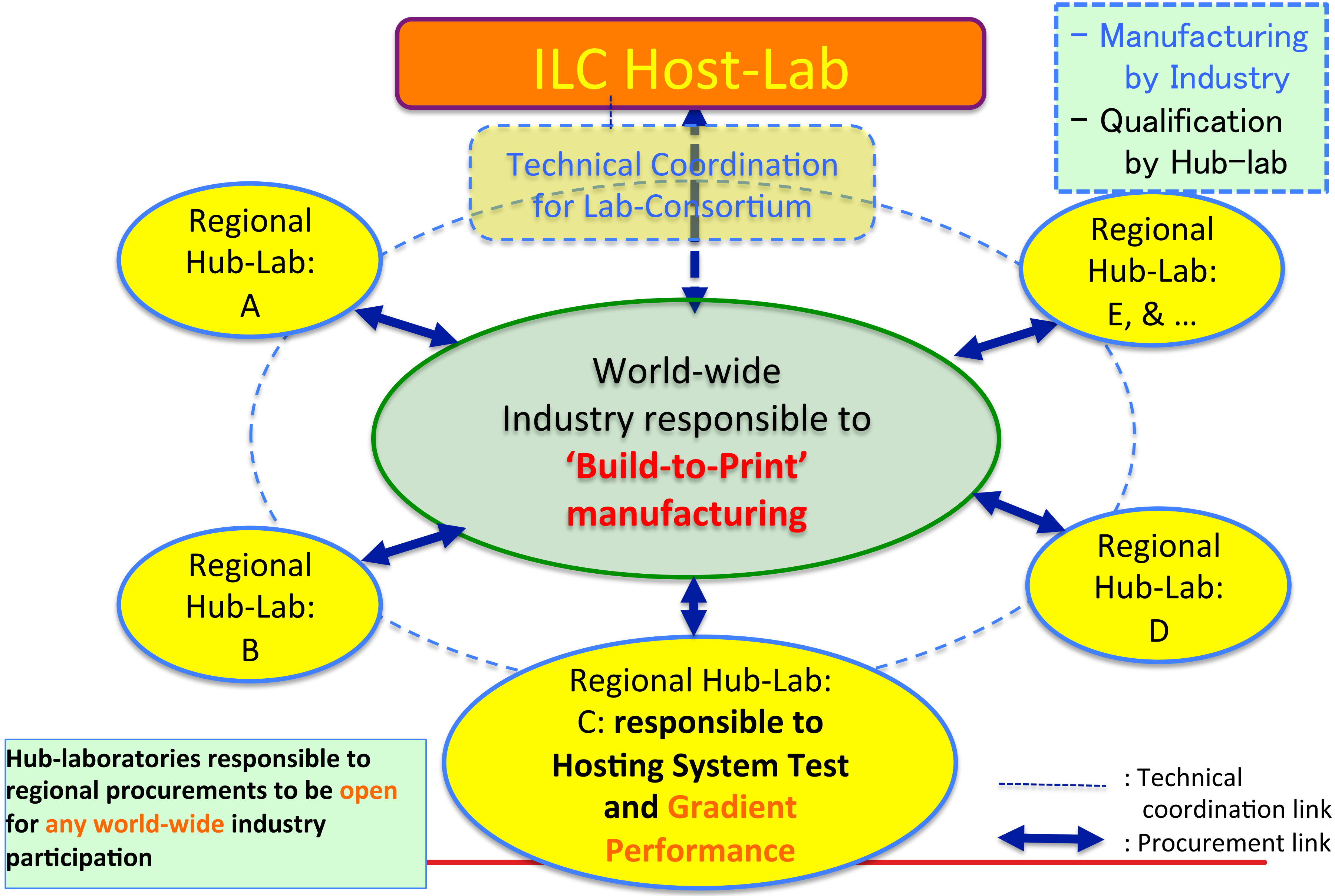


16,024 台 x 1.1

1,855 台

- Purchasing Material/Sub-component
- Manufacturing Cavity：機械加工
- Processing Surface：表面処理
- Assembling LHe-Tank ：組み立て
- Qualifying Cavity, 100 %：性能評価
- Cavity String Assembly：多連空洞組立
- Cryomodule Assembly:: CM 組立
- Qualifying CMs, 33 + 5 %：CM性能評価

Cooperation of Hub-Labo and industry



SRF Facilities anticipated for Hub/Consortium

AMTF @DESY/E-XFEL, CM

STF-CFF @ KEK

ASTA @ FNAL, TEDF @ JLab

8. The Scale of a Hub-laboratory for SRF Cavity/CM Production

The responsibilities are:

- reception and QA of Niobium raw material and dispatch to cavity manufacturers;
- follow-up of cavity manufacturing;
- cold tests of all cavities;
- follow-up of coupler fabrication;
- conditioning of couplers and delivery to cryomodule assembly firm;
- follow-up of cryomodule assembly;
- testing of complete cryomodules - the TDR assumes that 38% (5 % for the pre-series, and 33 % of the series production) will be tested cold;
- maintain a data baseand documentation of the whole production;
- packing and delivery of complete cryomodules ready for installation to the ILC site.

Comparison of E-XFEL production with that of ILC production

	E-XFEL	ILC
Number of hubs	1	3
Production duration (weeks)	125	325
Cavities/hub-lab	800	6000
Cryomodules/hub-lab	100	617
Cryomodule production/week	0.8	1.9
Cavity tests/week	6.4	18.5
Cryomodule tests/week	0.8	0.72*

- Assuming 38% tested cold.

Experiences from EXFEL and Extrapolation to ILC

EXFEL experiences:

- Cavity production and testing of cavities and CMs at DESY requires 56 FTE/year (av.),
  - and in-kind contribution from Poland (IFJ-PAN) about 26 persons [82].
- CM assembly follow-up at CEA-Saclay requires about 12 FTE/year, and
  - and industrial subcontractor of 34 persons [83], and
  - It should be noted that the averaged CM production/assembly rate has been reaching 1.25 module/week (one cryomodule / 4 days, since Jan. 2015, after many months of efforts.
  - It would support the ILC cryomodule assembly rate to be sufficiently reliable.
- Coupler follow-up and conditioning requires about 6 people [84].

Extrapolation to ILC (hub-laboratories)

- Rhe increased weekly rate would require more people, notably for cavity testing.
- It is estimated that 200 ~ 250 FTE/year will be required
  - including administrative staff (~20%), for SRF cavity and cryomodule preparation and qualification work, at a hub laboratory, before delivery to the ILC host laboratory.

9. Project Implementation Plan

- A new and comprehensive report dealing with issues such as governance, funding models, host responsibilities etc. is currently being reviewed by LCB.

- A preliminary copy of this report is available on request; the final version is expected by the summer of 2015 [85].

10. Further Preparatory Work (1)

10.1 General

- It is anticipated that preparation (w/ appropriate funding) will take about 4 years

10.2 SRF technology

- Nb material, cutting sheet from Ingot w/ control grain size
- Tuner in cooperation w/ LCLS-II
- Coupler value engineering w/ simplified structure and new ceramic w. optimized process of CM assembly.
- Long term effort for further gradient to scope 1 TeV upgrade,
  - Hydro-forming w/ seamless Nb cylilnder, or Cu cylinder followed by surface coating w/ Nb.
  - High-Q realization w. new surface treatment or doping technology
- Mitigation of degradation during the process of the CM assembly

10.3 Modulator industrialization for SRF

- Demonstration of the industrial manufacturing and long-term reliability

10. Further Preparatory Work (2)

10.4 Test/Qualification infrastructure at KEK

- Full prototype cryomodules under high power in which a beam can be accelerated must be completed with the highest priority.
- An assembly and cryogenic-test hall at KEK must be equipped with the entire infrastructure necessary for integrating full CMs and for testing, to demonstrate the capability of series production rate.

10.5 Nano-beam technology

- The effort at the accelerator test facility (ATF) at KEK must be continued to achieve the technical goals of both the beam size and the stability at the final focus, providing sufficient operational margin.

10.6 Positron production

- The positron source is challenging. Further effort must be put into the undulator-based design including the convertor target. In parallel an alternative design using conventional means (which will exclude polarised positrons) must be pursued as a backup solution.

11. Summary

- The ILC technical design is now being adapted to the preferred candidate site. Changes in layout are being managed by a rigorous change-control procedure.

- Series production of cavities for the European XFEL has shown that cavities can be mass-produced in industry with a performance well above XFEL requirements and close to that needed for the ILC.

- A number of technical developments are under way with a view to further reducing the ILC cost. This work must continue through the preparatory stage for ILC construction once resources become available.

- A summary of the design updates and of the further preparatory work needed is shown in tabular form in the Appendix.