International Linear Collider (ILC) Technical Status and Prospect

Akira Yamamoto (KEK)
for the
Linear Collider Collaboration (LCC)

To be presented at IAS Conference, Hong Kong, 20 January, 2016

Outline

- **Introduction**
  - Features and Key Technologies
- **Technical Status**
  - Progress in Global Design Effort & beyond TDR
  - Further Effort to prepare for the ILC
- **Prospect**
  - Actions progressed in Japan
  - KEK-ILC Action Plan
- **Summary**

ILC GDE to LCC

1980' ~ Basic Study

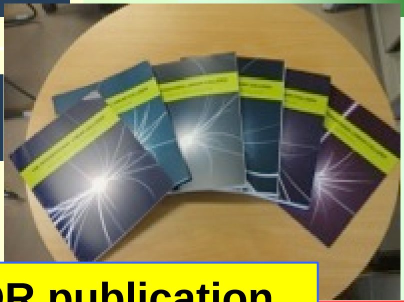
2004 | 2006 | '07 | '08 | '09 | '10 | '11 | '12 | '13 | '14 | '15 | '16

ILC-GDE

LCC

Ref. Design (RDR)

Technical Design Phase

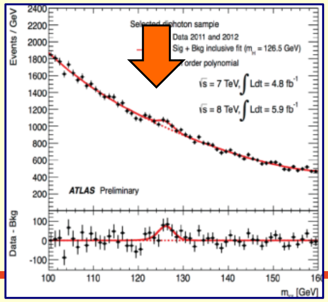


TDR publication

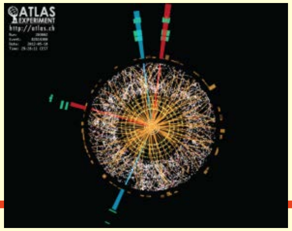
Selection of SC Technology

LHC

126 GeV



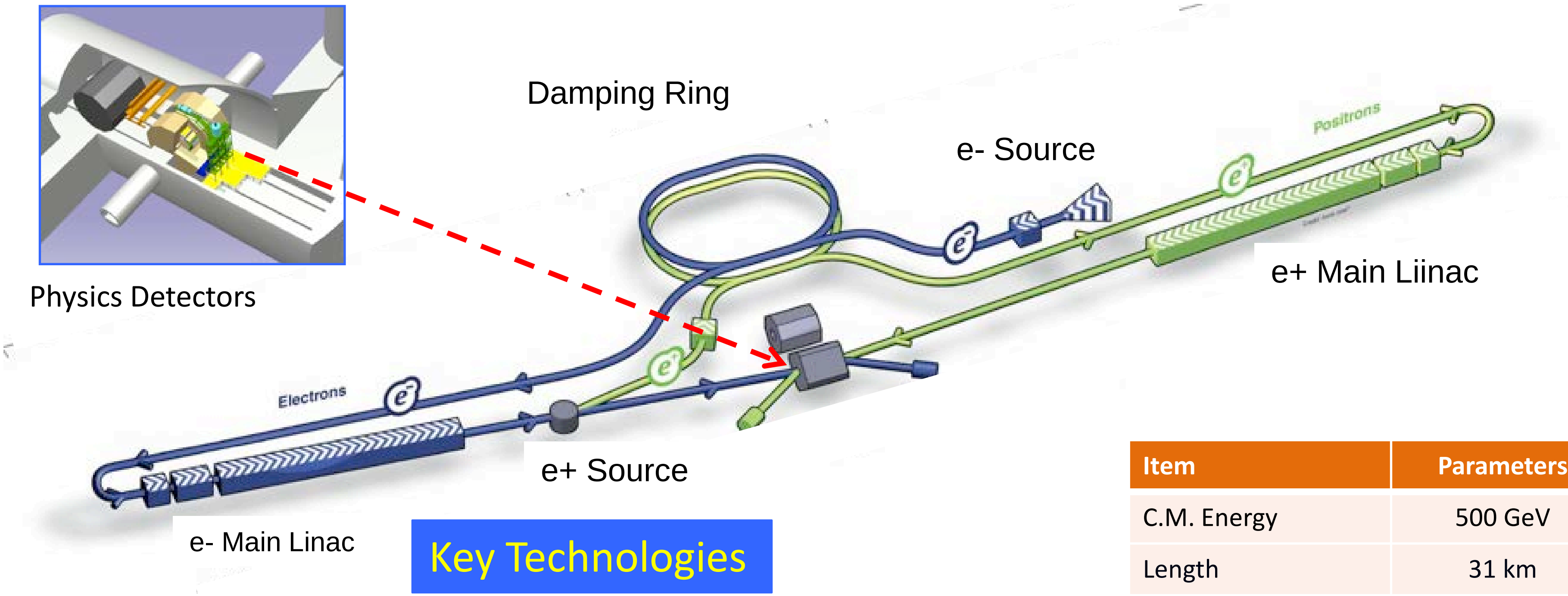
Higgs discovered



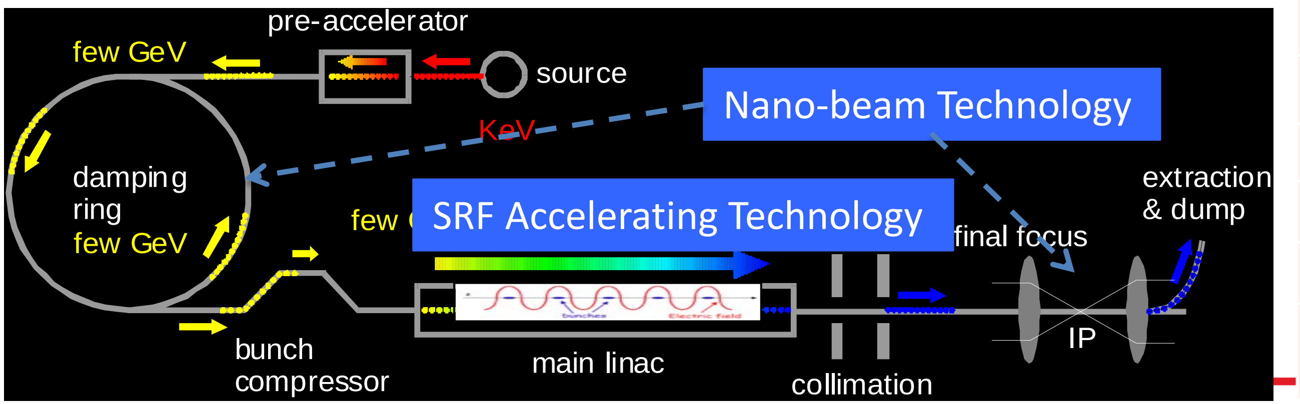
2012.12.15

2013.6.12

ILC Acc. Design Overview (in TDR)



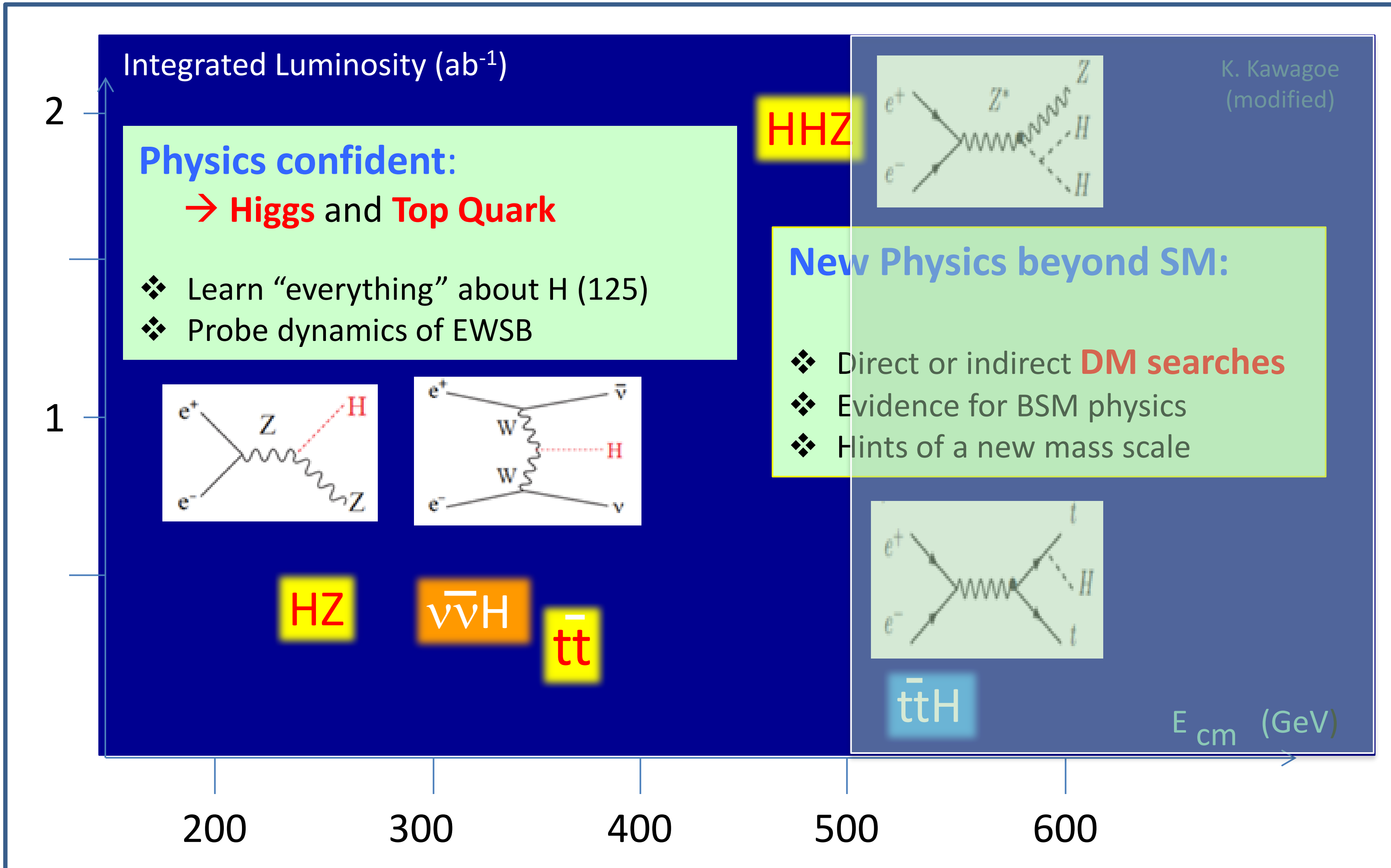
Key Technologies



Item	Parameters
C.M. Energy	500 GeV
Length	31 km
Luminosity	1.8 x10^{34} $cm^{-2}s^{-1}$
Repetition	5 Hz
Beam Pulse Period	0.73 ms
Beam Current	5.8 mA (in pulse)
Beam size (y) at FF	**5.9** nm
SRF Cavity G. Q_0	**31.5** MV/m Q_0 = 1x10^{10}

Important Energies in ILC

❖ 125 GeV Higgs discovery reinforcing the ILC importance



ILC ML Parameters, demonstrated in TDR

Characteristics	Parameter	Unit	Demonstrated
SRF:			
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, KEK**
RF pulse length (incl. fill time)	1.65	ms	**DESY, KEK, FNAL**
Efficiency (RF→beam)	0.44		
Pulse repetition rate	5	Hz	**DESY, KEK**
Nano-bam:			
ILC-FF beam size (y) KEK-ATF-FF equiv. beam size (y)	5.9 37 (44 reached)	nm nm	**KEK-ATF**

Technical Highlights after TDR

- **SRF** (→Report from H. Hayano)
  - **E-XFEL**: exceeded 90 % of 800 cavity production, and 65 % of 100 cryomodule assembly and testa, Excellent !! (→ Report from O. Napoli)
  - **Fermilab**-ASTA: reached the ILC specification gradient of ≥31.5 MV/m
  - **KEK**-STF2: CM1+2a (12 cavity string) under cold test, First 4 reaching> 35 MV/m
- **Nano-beam**
  - **ATF2 Collab.**: reached 44 nm at the FF, closing to the primary goal of 37 nm
- **CFS**
  - Geological Survey & boring at a candidate IP region in progress in Tohoku
  - Tunnel Optimization Tool (TOT) being developed by CERN/KEK-ARUP cooperation
- **Accelerator Design and Integration (ADI)**
  - Post-TDR design update (→ see The ILC Progress Report 2015)
    - **Common L*** for both detectors of ILD and SiD
    - **Vertical access** at Detector Hall at IR points
    - **Extension of ML tunnel length** for optimizing e+e- collision timing and redundancy of ML SRF

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Technical Status

– Progress in Global Design Effort & beyond TDR

– Further Effort to prepare for the ILC

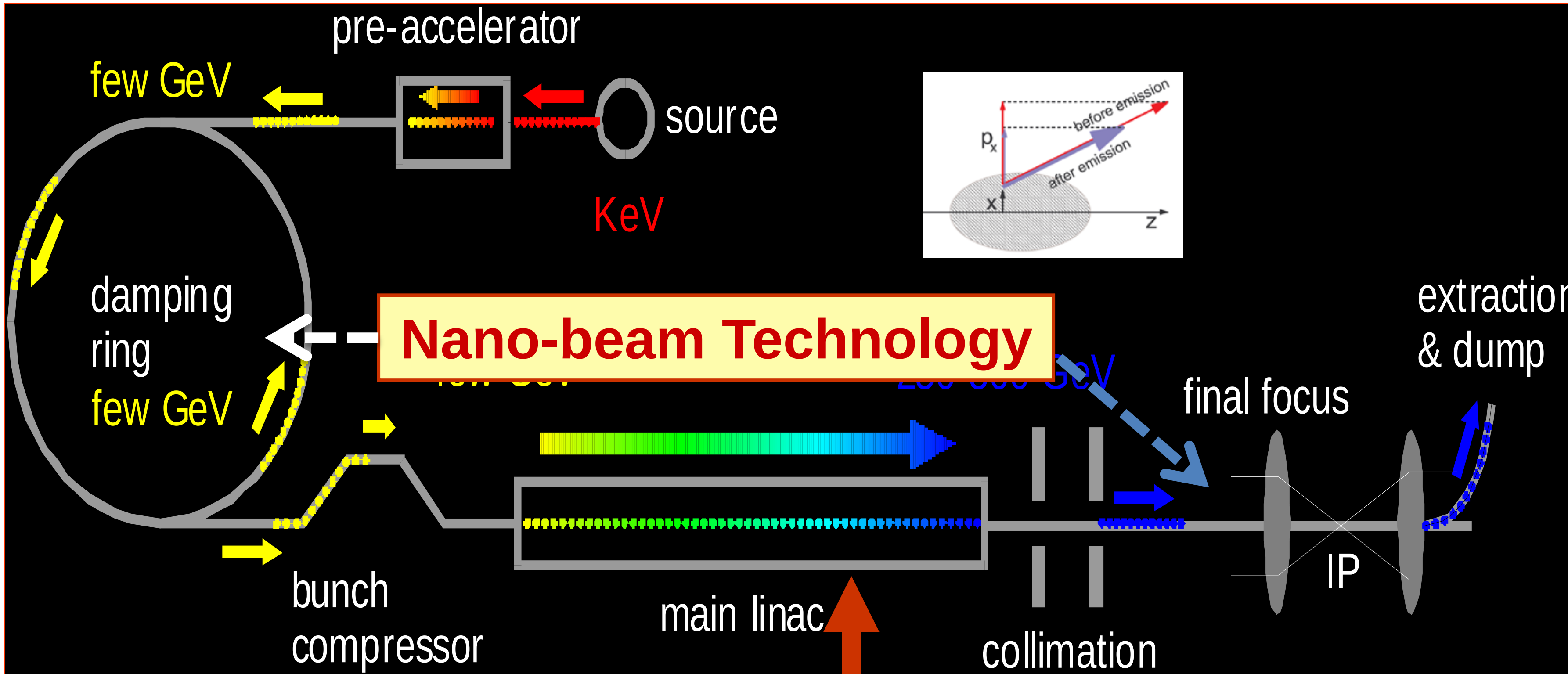
Prospect

– Actions progressed in Japan

– KEK-ILC Action Plan

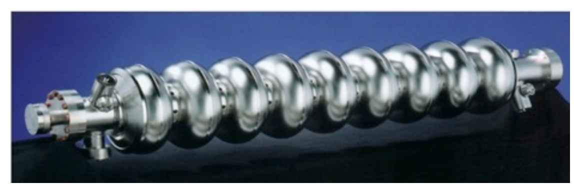
Summary

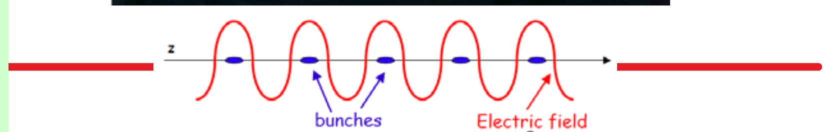
ILC Accelerator Concept



SRF Technology

- Electron and Positron Sources (e-, e+) :
- Damping Ring (DR):
- Ring to ML beam transport (RTML) :
- Main Linac (ML) : SCRF Technology
- Beam Delivery System (BDS)





Advantage of Superconducting RF

- Ultra-high ($Q_0 = 10^{10}$):
  - small surface resistance → nearly zero power (heat) in cavity walls
- Long beam pulses (~1 ms)
  - → intra-pulse feedback
- Larger aperture
- → better beam quality w/ larger aperture - lower wake-fields
- Work necessary on engineering for:
  - Cryomodule (thermal insulation)
  - Cryogenics

Luminosity:

RF efficiency

RF power / beam current

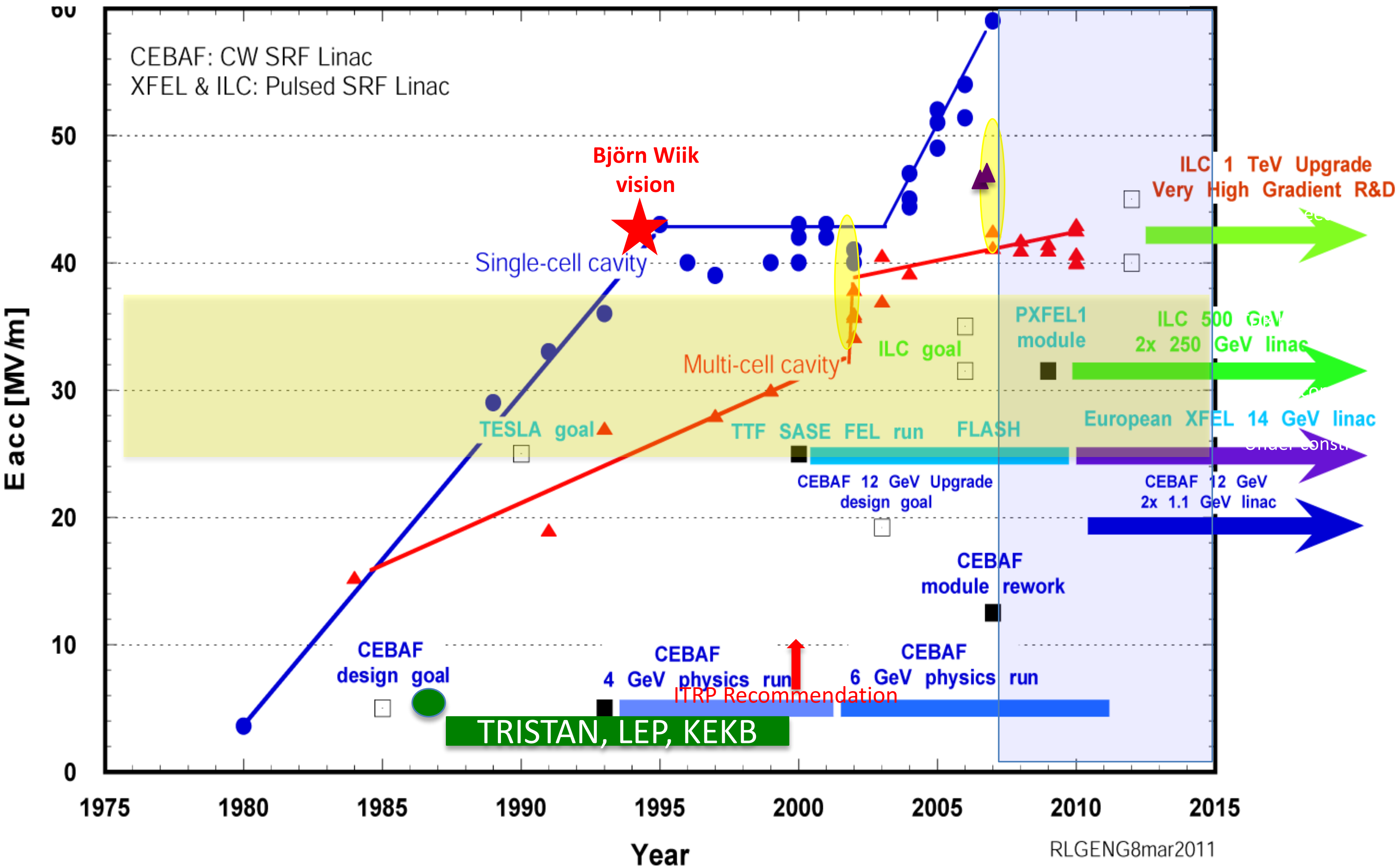
$$L \propto \frac{\eta P_{RF}}{E_{CM}} \sqrt{\frac{\delta_{BS}}{\varepsilon_y}}$$

Vertical emittance (tiny beams)

- Luminosity proportional to RF efficiency ILC
  - ~160MW @ 500GeV (only)
- Capable of efficiently accelerating high beam currents
- Low impedance aids preservation of high beam quality (low emittance)

Progress/Prospect in SRF Cavity Gradient
for Frontier Particle Accelerators

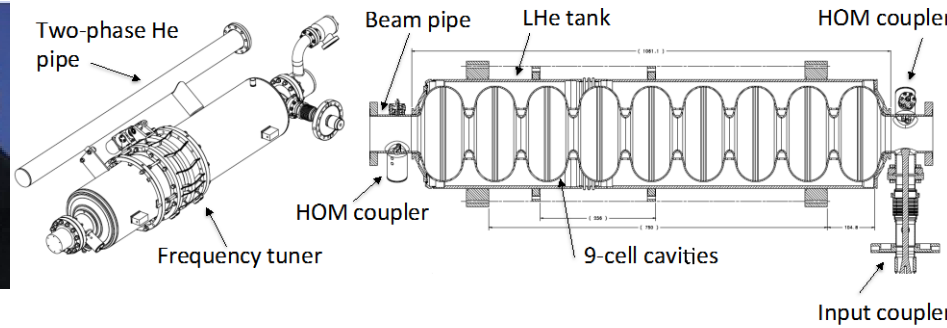
R. Geng



Major Accelerators Under Construction
2010 ~

Project	Notes	# cavities
CEBAF-JLAB (US)	Upgrade 6.5 GeV => 12 GeV electrons	80
XFEL-Hamburg (EU)	18 GeV electrons – for Xray Free Electron Laser – Pulsed)	840
LCLS-II – SLAC (US)	4 GeV electrons –CW XFEL (Xray Free Electron Laser)	300
SPIRAL-II (France)	30 MeV, 5 mA protons -> Heavy Ion	28
FRIB – MSU 8US)	500 kW, heavy ion beams for nuclear astrophys	340
ESS (Sweden)	1 – 2 GeV, 5 MW Neutron Source ESS - pulsed	150
PIP-II–Fermilab (US)	High Intensity Proton Linac for Neutrino Beams	115
ADS- (China, India)	R&D for accelerator drive system	> 200
Globally Int. Effort		> 2000

SCRF Linac Technology

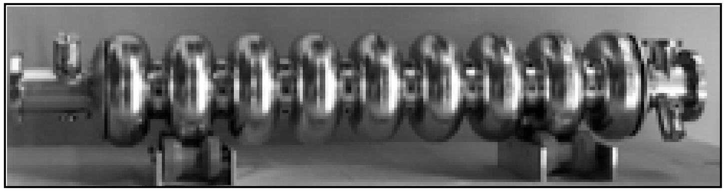


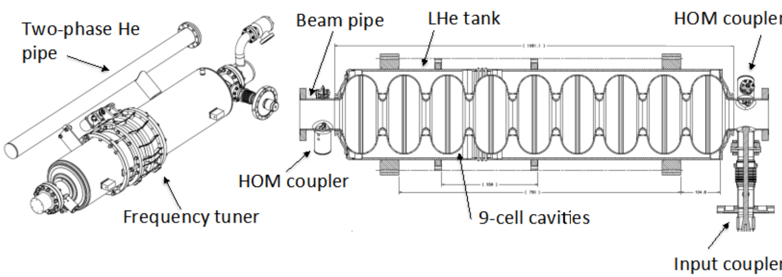
1.3 GHz Nb 9-cellCavities	16,024
Cryomodules	1,855
SC quadrupole pkg	673
10 MW MB Klystrons & modulators	436 *

* site dependent

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

Cavity/Cryomodule Fabrication



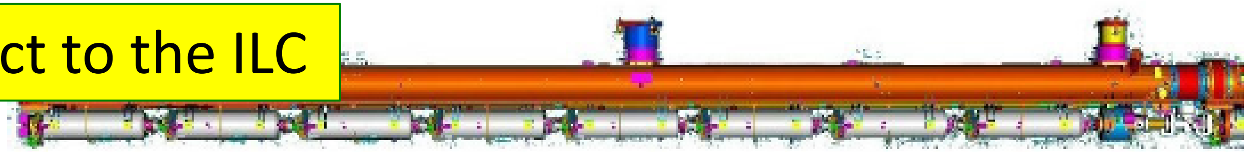


- Purchasing Material/Sub-component
- Manufacturing Cavity :
- Processing Surface
- Assembling LHe-Tank :
- Qualifying Cavity :
- Cavity String Assembly :
- Cryomodule Assembly:
- Qualifying CMs :

IPAC14: Courtesy: H. Weise

An Accelerator Complex for 17.5 GeV

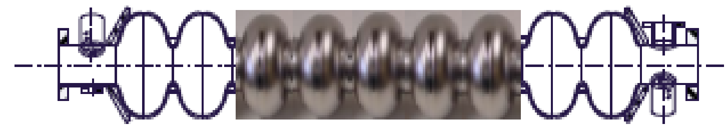
EXFEL: 1/20 Scale Project to the ILC



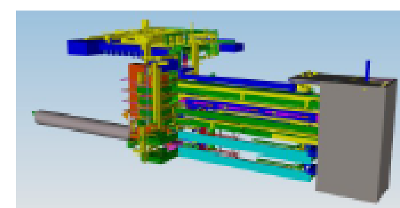
Some specifications

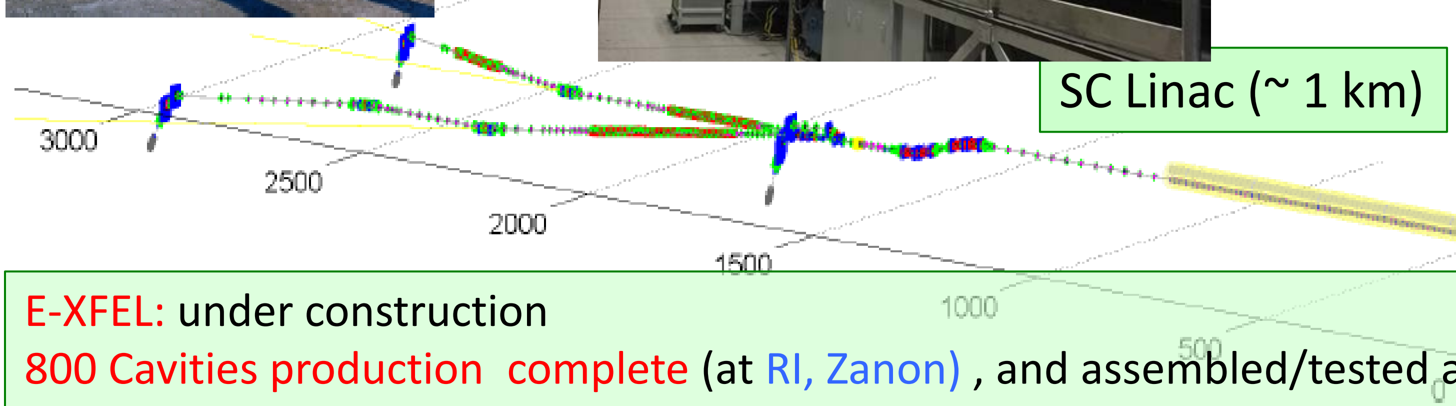
- Photon energy 0.3 - 24 keV
- Pulse duration ~ 10 - 100 fs
- Pulse energy few mJ
- Superconducting linac. 17.5 GeV
- 10 Hz (27 000 b/s)

800 accelerating cavities
1.3 GHz / 23.6 MV/m



25 RF stations
5.2 MW each

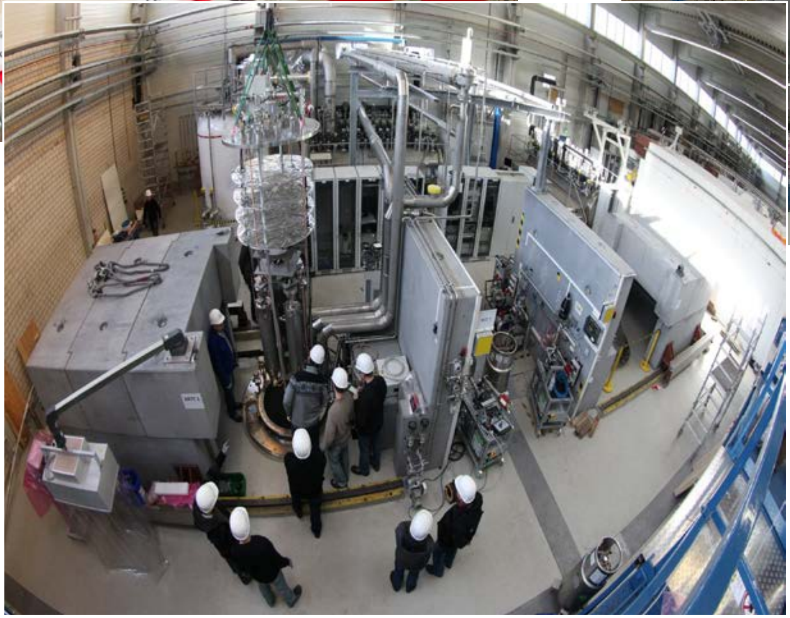




SC Linac (~ 1 km)

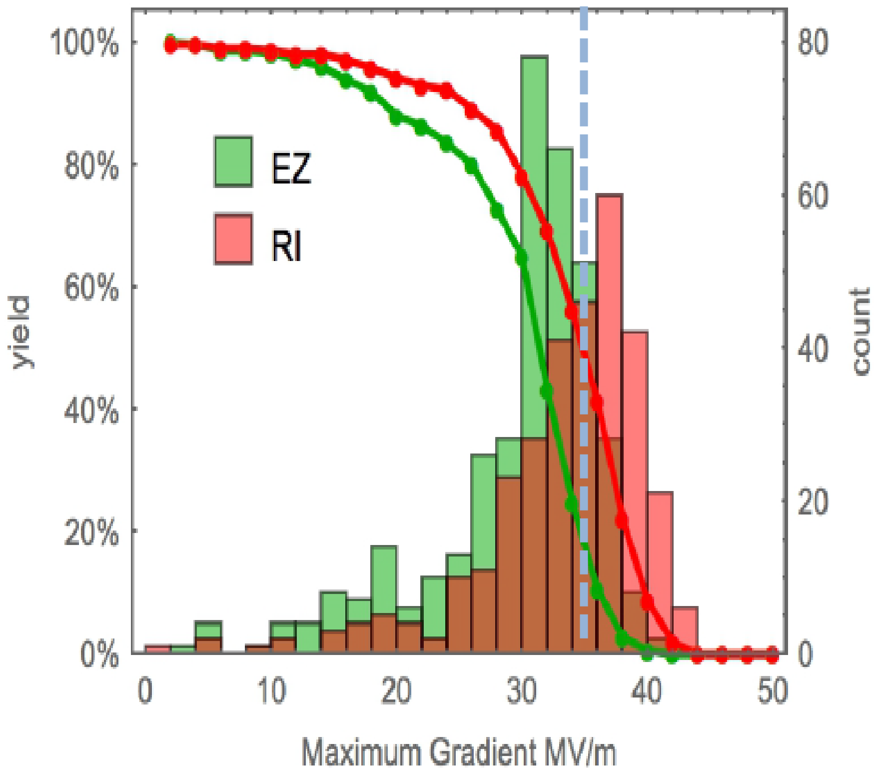
E-XFEL: under construction
800 Cavities production complete (at RI, Zanon) , and assembled/tested at CEA-Saclay, DESY

XFEL: Mass Production Perfomance Tests of 840 Cavities



D. Reschke/SRF2015

E-XFEL: Gradient Yield after First Treatment

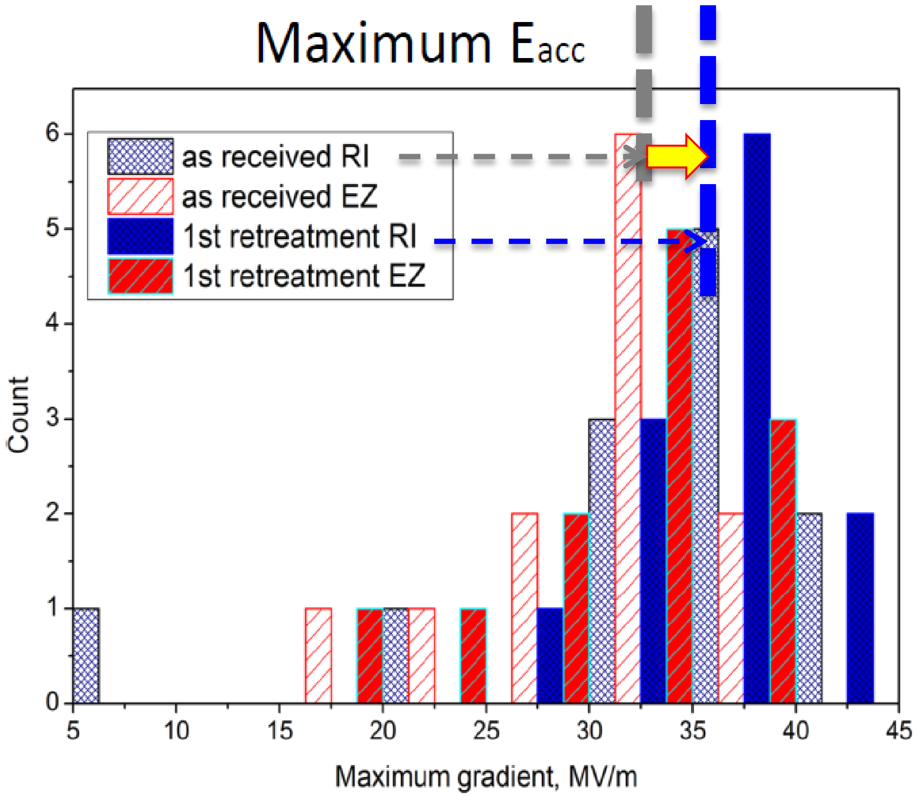


- **738** Cavities (as of 2015/9)
  - from two vendors, RI and EZ (1/2 each)
- RI: w/ Bulk EP & Final EP (as for ILC)
- EZ: w/ Bulk EP & Final BCP
  - Final EP gives 3~4 MV/m higher performance
  - Lesson for highest gradients: → Don't use BCP

	G-max (E-XFEL)			G-usable (E-XFEL)			(ILC-req.)
	RI	EZ	C	RI	EZ	C	---
<G> MV/m	**33**	29.6	31.4	**29.4**	26.3	27.7	(35)
Yield at 28MV/m	**86%**	73%	79%	**66%**	44%	54%	(90)

Effect of Re-treatment

on “High Gradient Cavities” --- for Special R&D

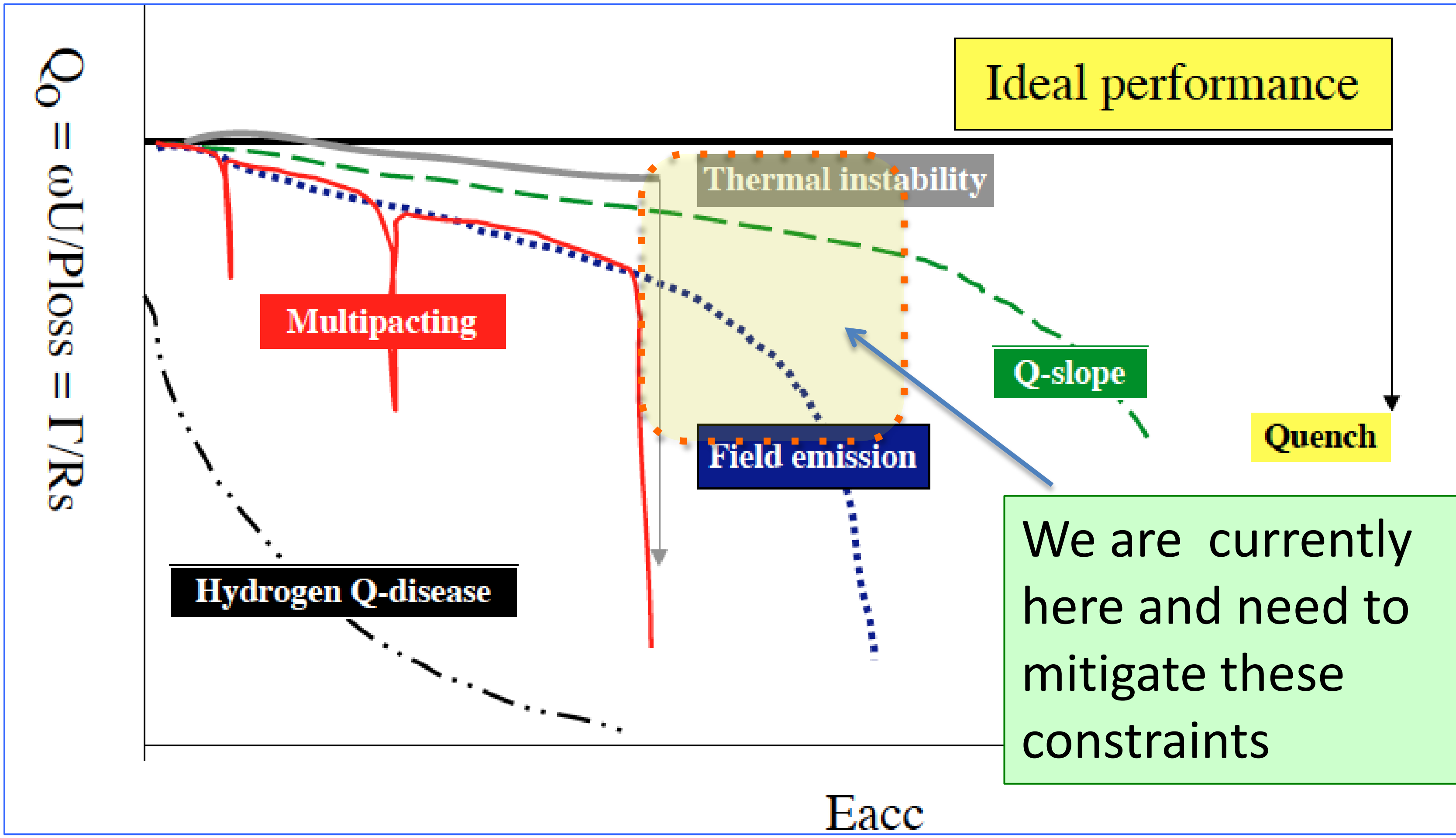


Maximum Eacc (RI as received): 32.1±10.2 MV/m
Maximum Eacc (RI after retreatment): 35.5±4.7 MV/m

- 12 cavities each from RI and EZ for High Gradient R&D
- Av. Max-gradient for RI cavities rises by about 3 MV/m after re-treatment
- Ave Max 35.5 ± 4.7 MV/m
- Average yield at 28 MV/m rises by 10%

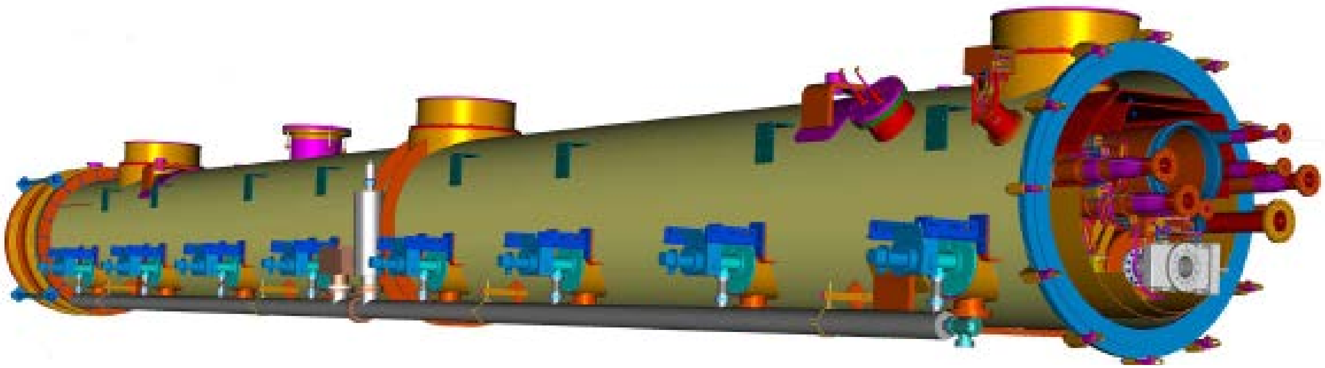
D. Reschke, N. Walker /SRF2015
H. Padamsee / ILCWS2015

Real SRF Cavity Performance and necessary mitigation

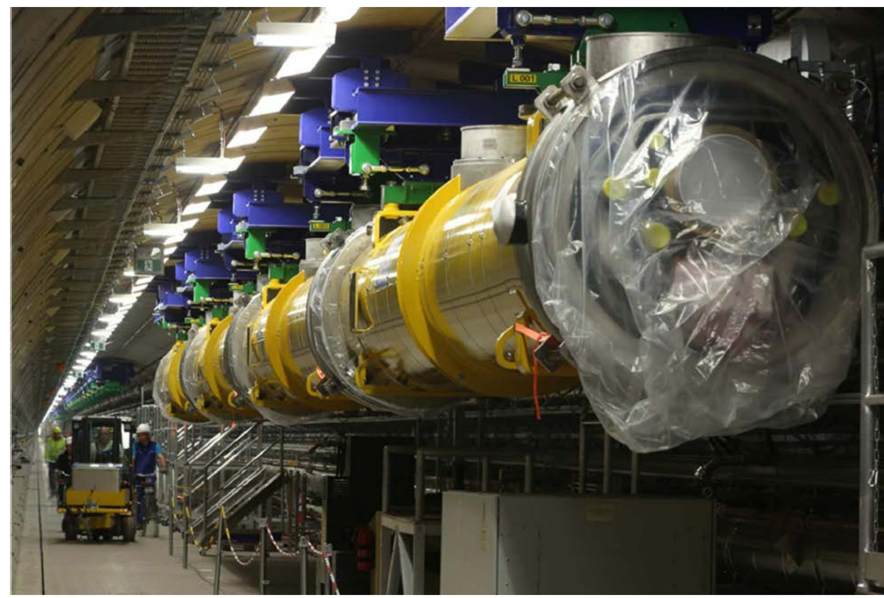


We are currently here and need to mitigate these constraints

Module performance in E-XFEL cryomodule mass-production

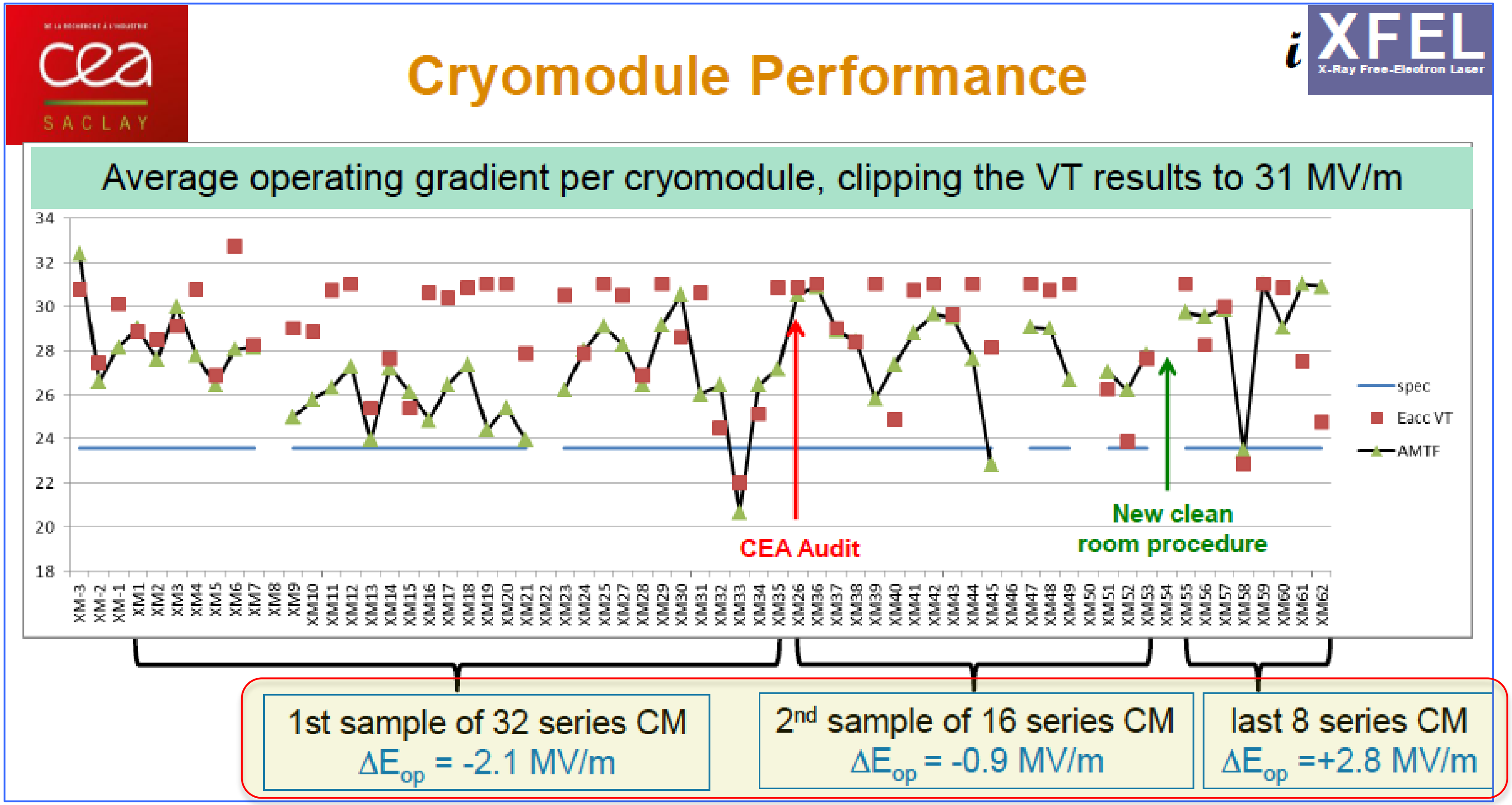


1. Cryomodule production at CEA-Saclay (*from the assembly standpoint)*



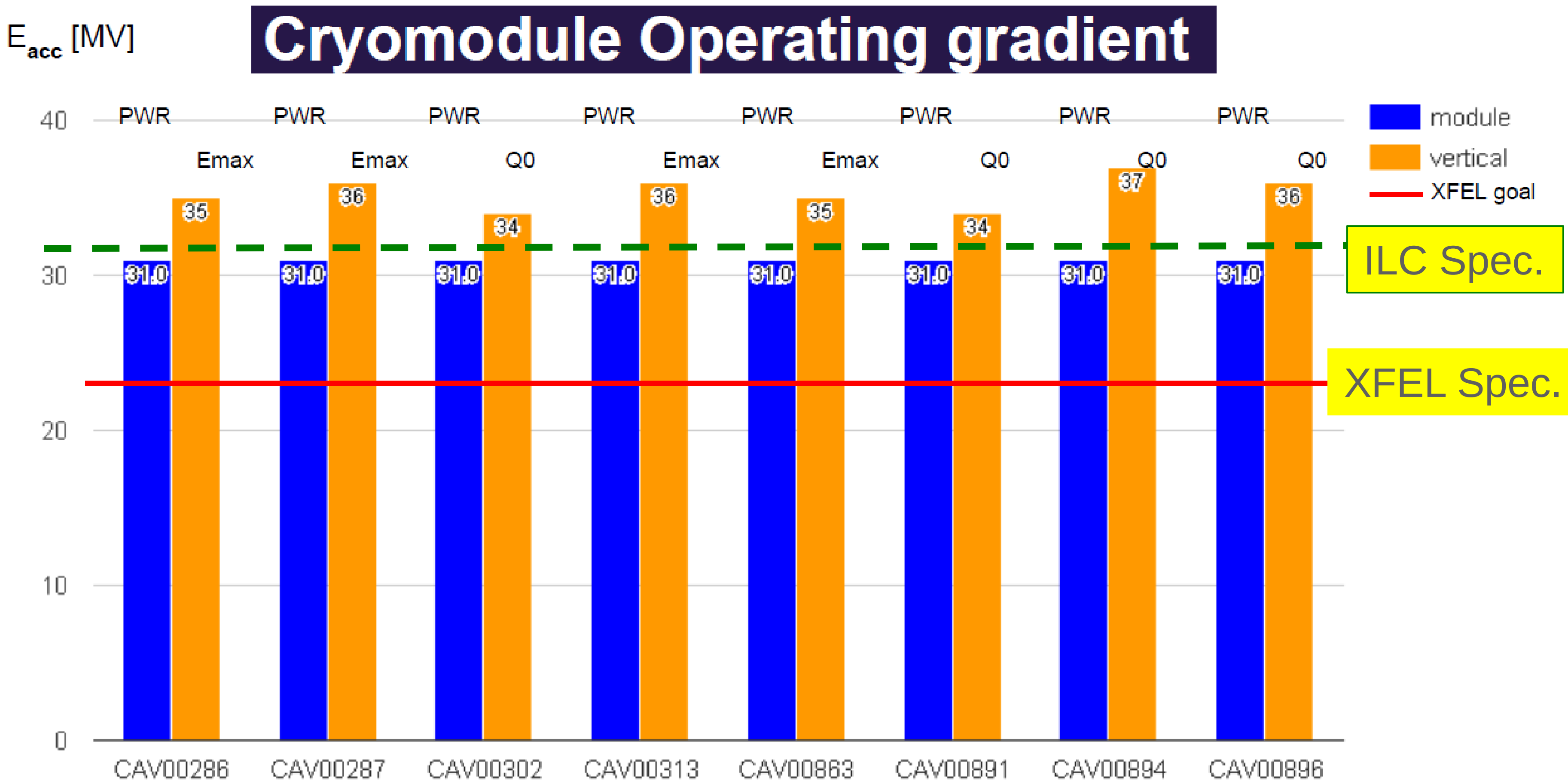
2. Cryomodule performances *(measured at DESY/AMTF)*

E-XFEL CM Performance compared w/ Cavity Tests



Degradation being overcome !! →

Cryomodule Performance : XM59



$\langle E_{acc} \rangle = 31$ MV/m

XM59 is an excellent module, assembled after the change of CR procedure.

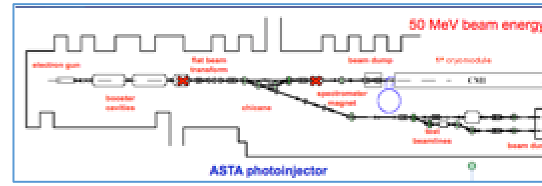
Fermilab : CM2 reached <31.5 MV/m >

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

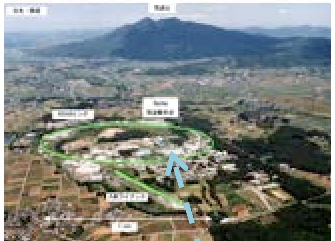


CM2 in its home at Fermilab's NML building, as part of the future Advanced Superconducting Test Accelerator. (Image credit: Fermilab.)

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

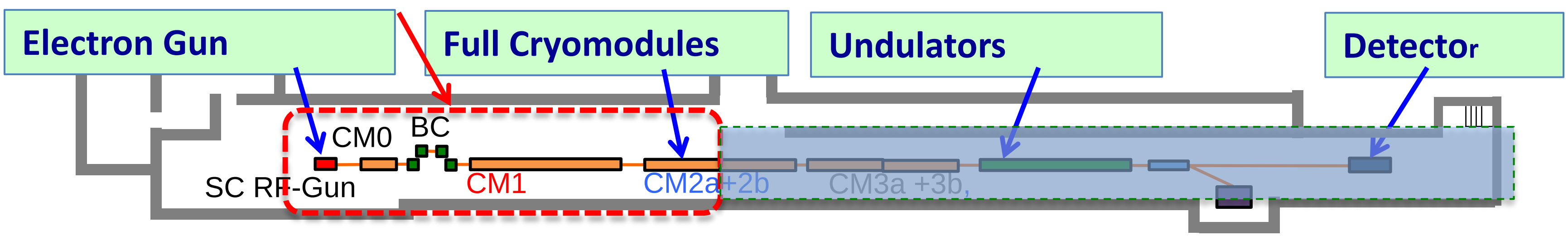
Cryomodule test at Fermilab reached < **31.5** > MV/m, exceeding ILC specification

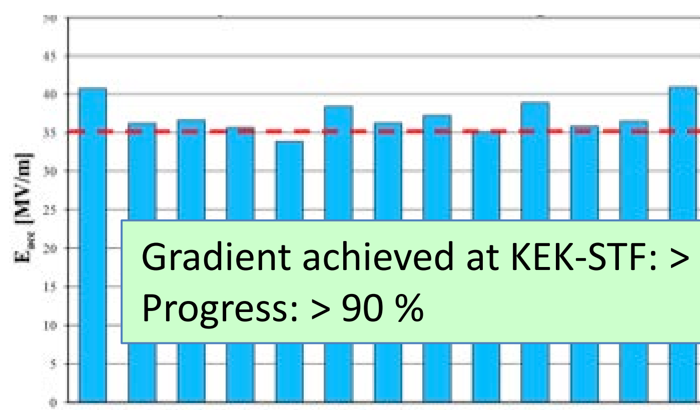
KEK STF2, SRF-CM BEAM ACCELERATION



<u>Objective</u>

- High Gradient (31.5 MV/m)
  - → Demonstration of full cryomodule
- SCRF electron gun
- Training for next generation





Gradient achieved at KEK-STF: > ~ 35 MV/m
Progress: > 90 %

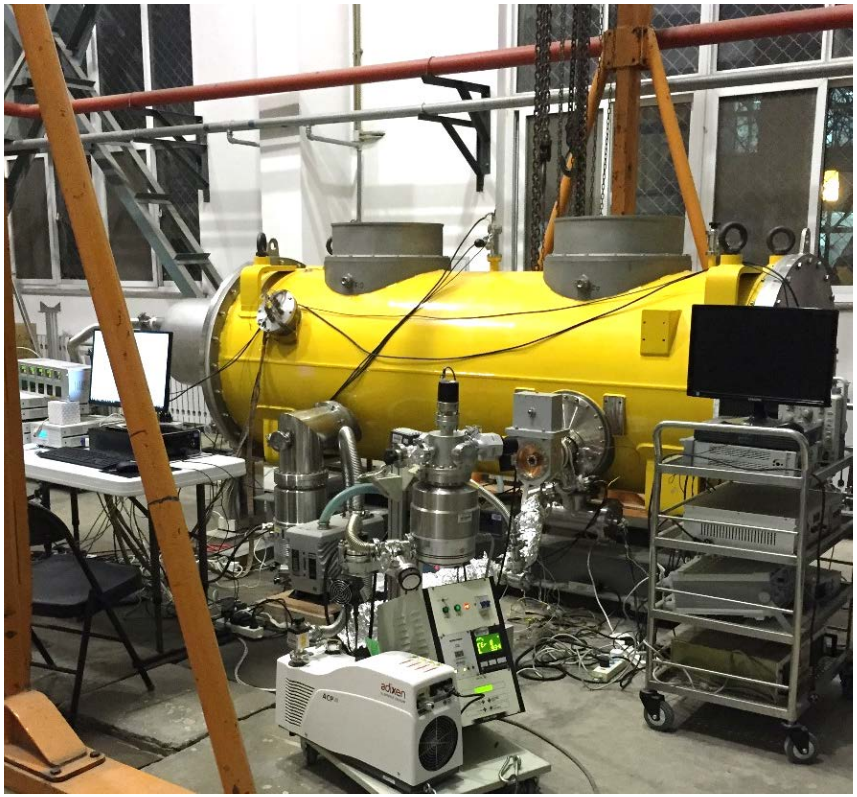
KEK-STF2: Cavity RF performance in CM1/CM2a and Beam Acceleration Preparation

Module	CM1a				CM1b				CM2a			
Cavity #	1	2	3	4	5	6	7	8	9	10	11	12
Cavity name	MHI-14	MHI-15	MHI-17	MHI-18	MHI-19	MHI-20	MHI-21	MHI-22	MHI-24	MHI-23	MHI-25	MHI-26
E_{acc} @V.T. [MV/m]	36.6 (power limit)	35.7 (Cell#1 Quench)	38.4 (power limit)	36.2 (power limit)	37.2 (Cell#1 Quench)	35.1 (power limit)	38.9 (power limit)	35.8 (power limit)	12.0 (heavy F.E.)	35.9 (Cell#3 Quench)	32.3 (Cell#1 Quench)	31.6 (Cell#1 Quench)
E_{acc} @C.T. (full pulse) [MV/m]	39	37	35	36	26	16	26	32	18	34	33	32
	Gradient kept				G. degraded systematically				Gradient kept			

* Gradient red colored : used for beam acc.

Preparation for the SRF beam acc., by using CM1 and CM2a
JFY-2014: Assembly and installation of cavity string
JFY-2015: Individual cavity process and RF test in CM
RF power system preparation,
JFY-2016: Eight cavity string to be full-RF tested
e- acceleration up to ~ 250 MeV

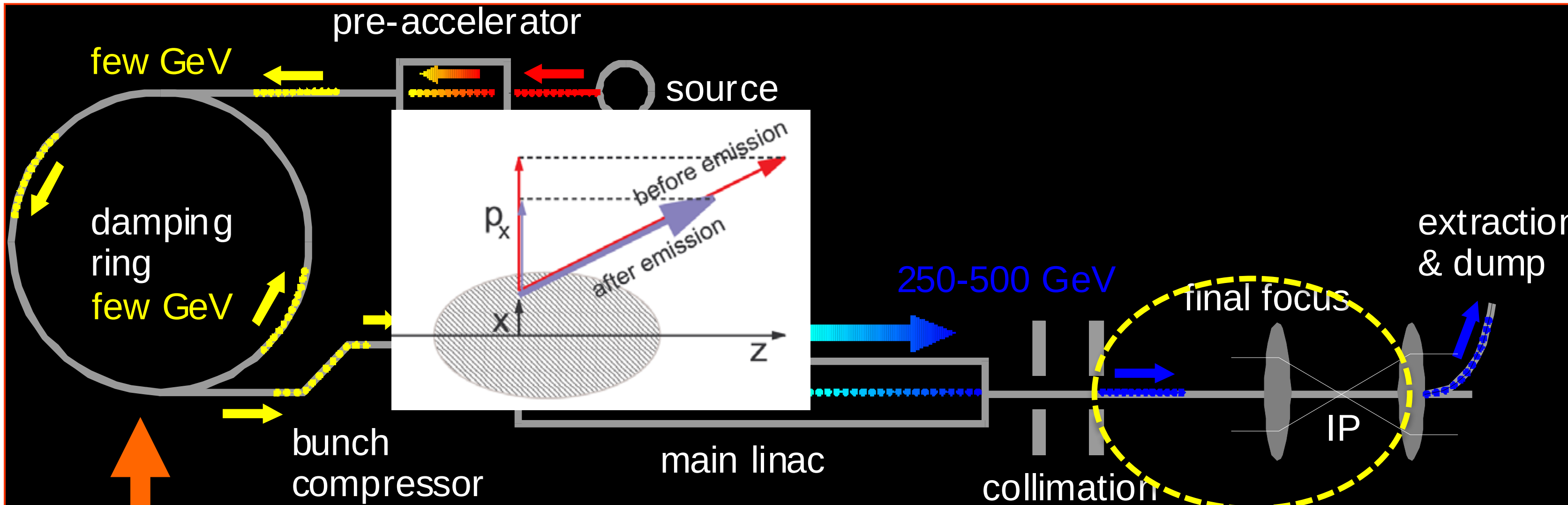
SRF Technology Development at IHEP



IHEP03 TESLA-lie 9-cell cavity
Fabricated at IHEP and
processed/tested at KEK

The development in progress with fabrication of 1.3 GHz cavity and cryomodule in cooperation with ADS society in China, and with HE Phys. Lab. in JP and US.

Nano-beam Technology

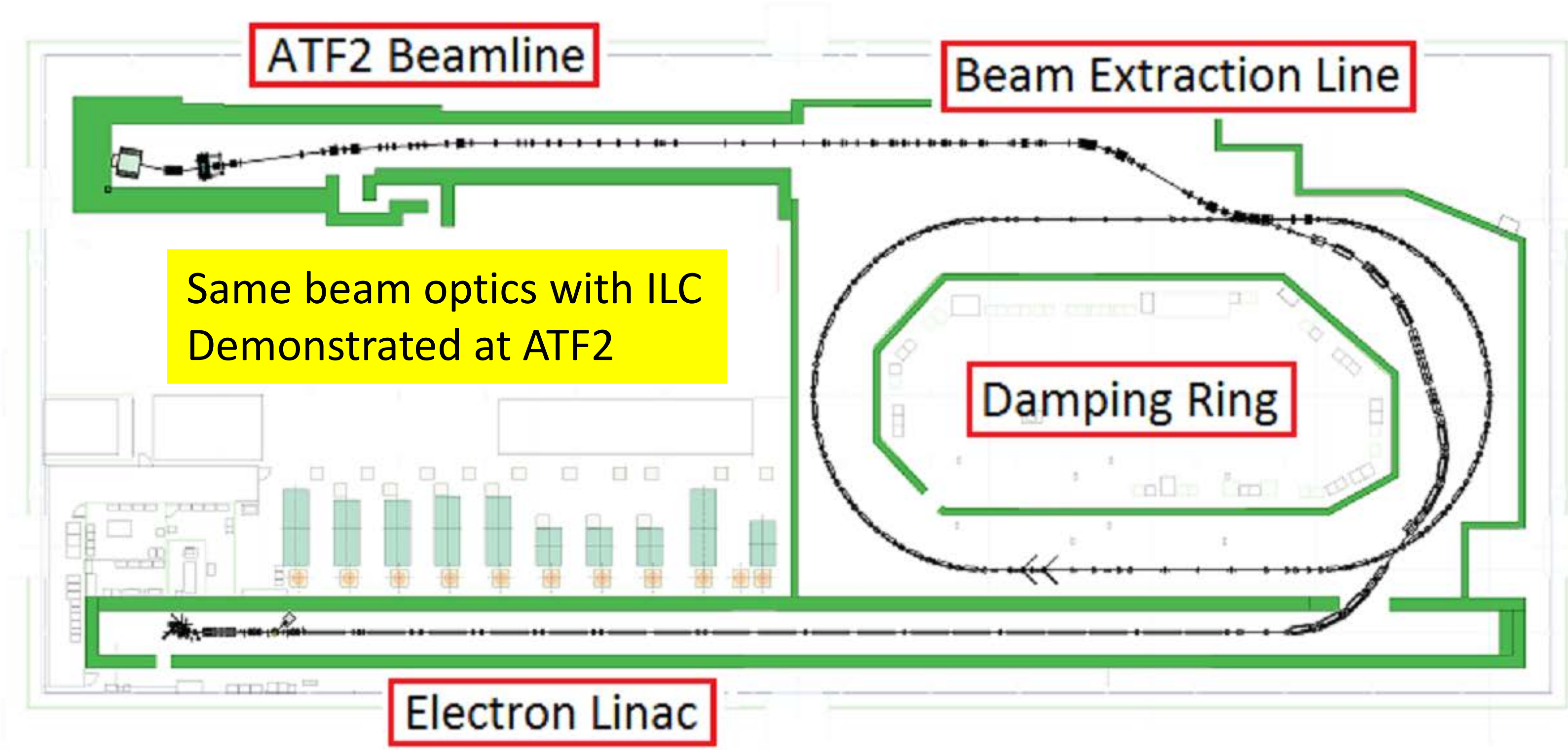


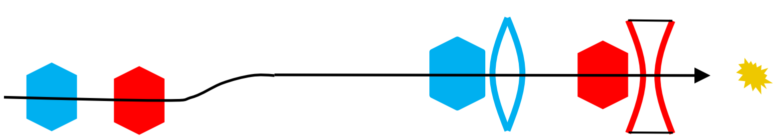
- Electron and Positron Sources (e-, e+) :
- Damping Ring (DR):
- Ring to ML beam transport (RTML) :
- Main Linac (ML) : SCRF Technology
- Beam Delivery System (BDS)

$$\mathcal{L} = f_{rep} \frac{n_b N^2}{4\pi\sigma_x^*\sigma_y^*} \times H_D$$

The nano-beam technology progressed with a global effort
Hosted at KEK (→ ATF Collaboration)

Will it work ? System Tests: ATF 2 @ KEK





Local chromatic corrections

Goal 1:
- demonstrate optics, tunability

Goal 2:
- beam stabiization through feedback

From Kubo at al

KEK-ATF2: BDS, FF Test Facility for ILC

Modeling of ILC BDS

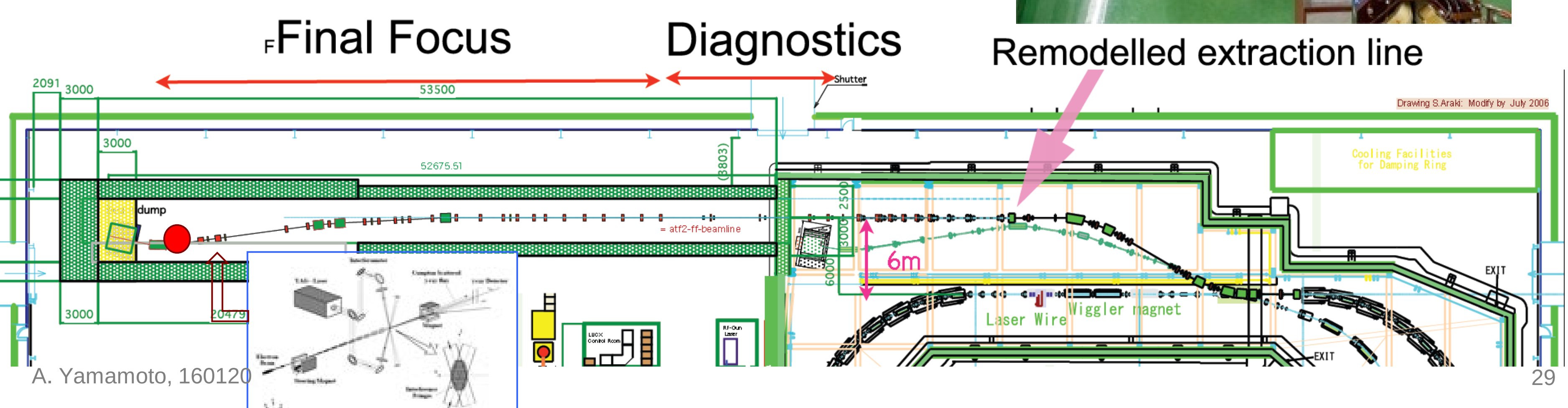
- Same Optics:
- Int'l Collab.

~25 Lab. , > 100 Collaborators

Goal:

FF Beam Size: 37 nm

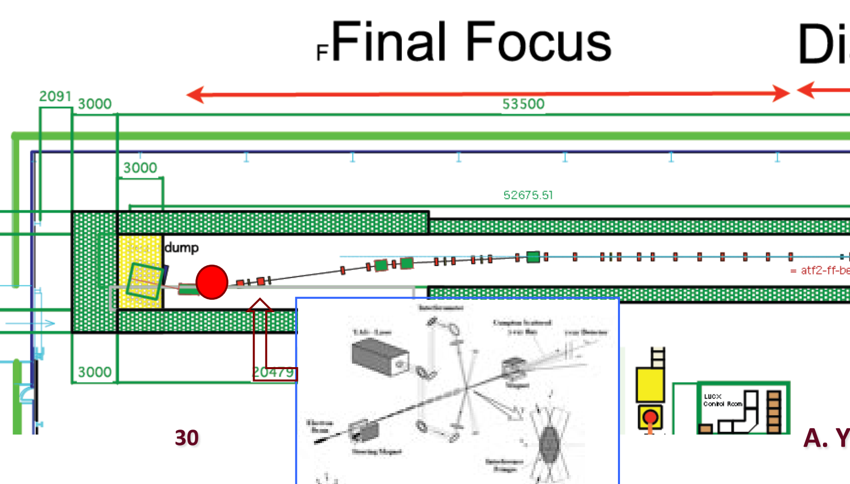
- (corresponding to 5.9 nm



KEK-ATF2: BDS, FF Test Facility for ILC

- **Modeling of ILC - BDS**
  - Same Optics:
  - Int'l Collab.
- **~25 Lab. , > 100 Collaborators**

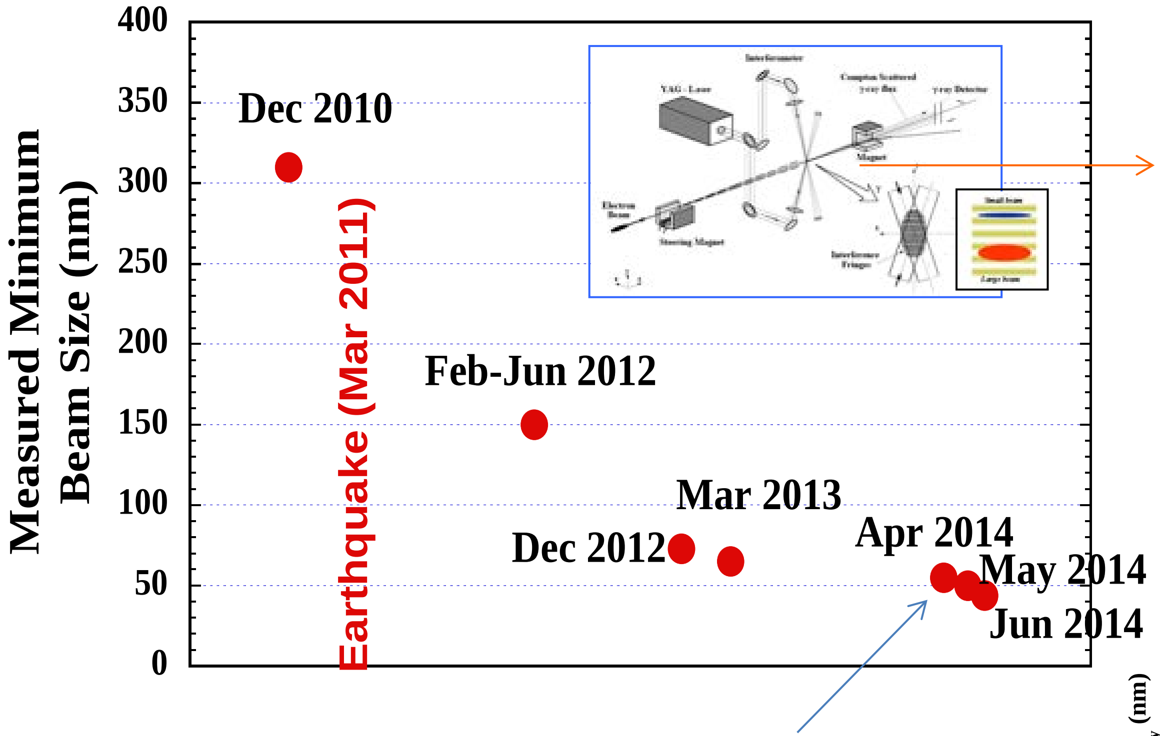
- **Goal:**
  FF Beam Size: 37 nm
  - (corresponding to 5.9 nm at ILC

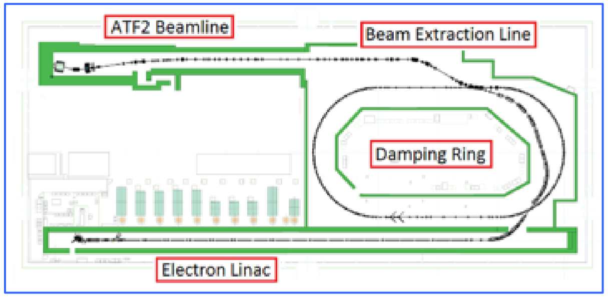


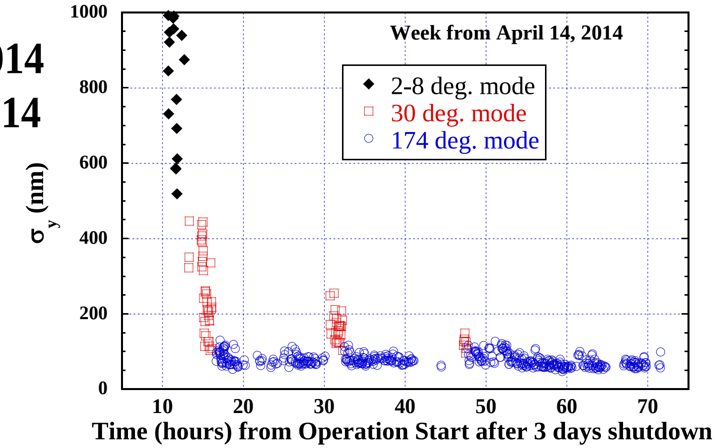
Parameter	ILC	ATF2
Beam Energy [GeV]	250	1.3
Energy Spread (e^+/e^-) [%]	0.07/0.12	0.06~0.08
Final quad – IP distance (L^*) (SiD/ILD detector) [m]	3.5/4.5	1.0
Vertical beta function at IP (β^*_y) [mm]	0.48	0.1
Vertical emittance [pm]	0.07	12
Vertical beam size at IP (s^*_y) [nm]	5.9	37
L^*/β^*_y (~natural vertical chromaticity, SiD/ILD detector)	7300/9400	10000

IPAC2014, K. Kubo
ICHEp2014, S. Kuroda

Progress in Beam Size at ATF2

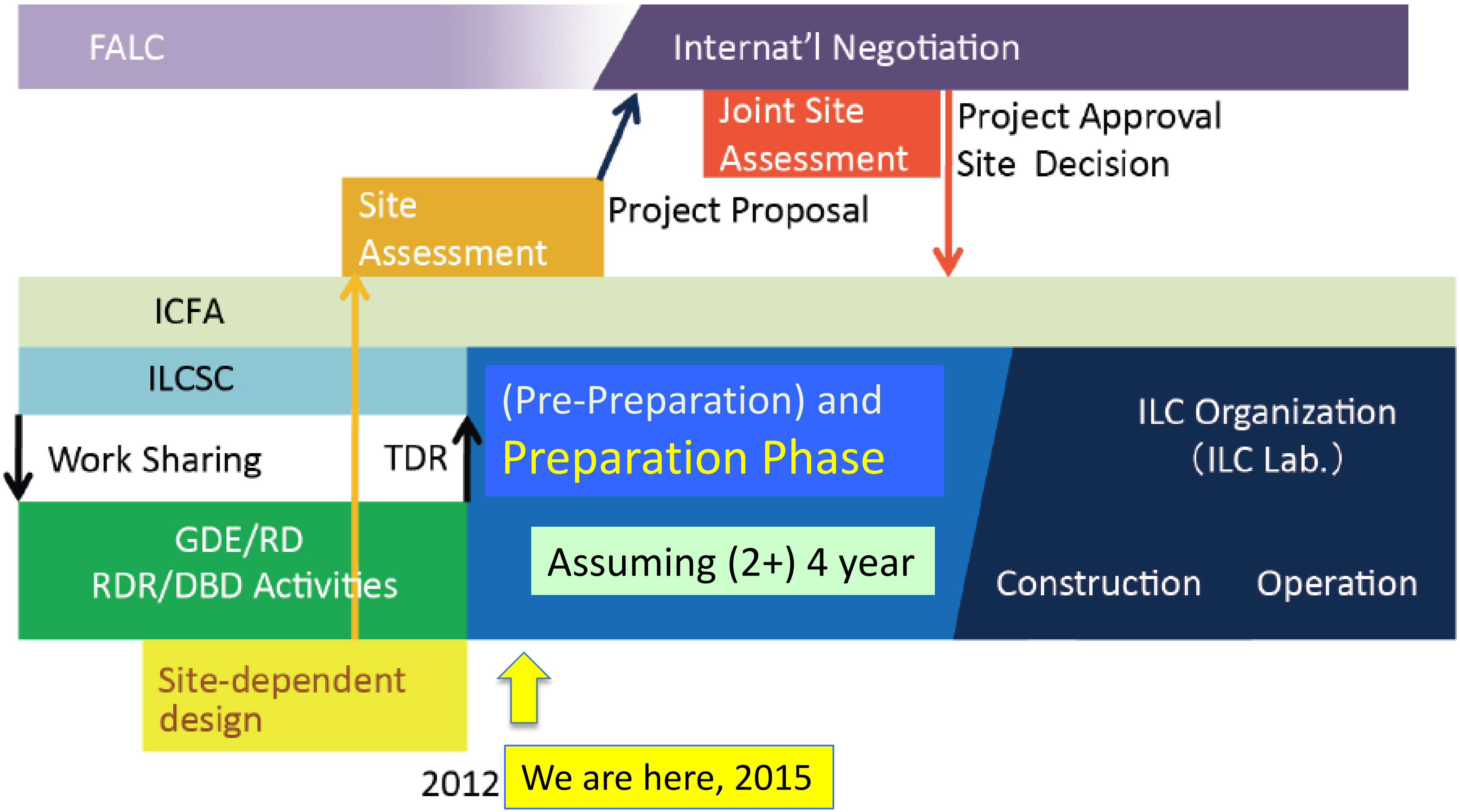






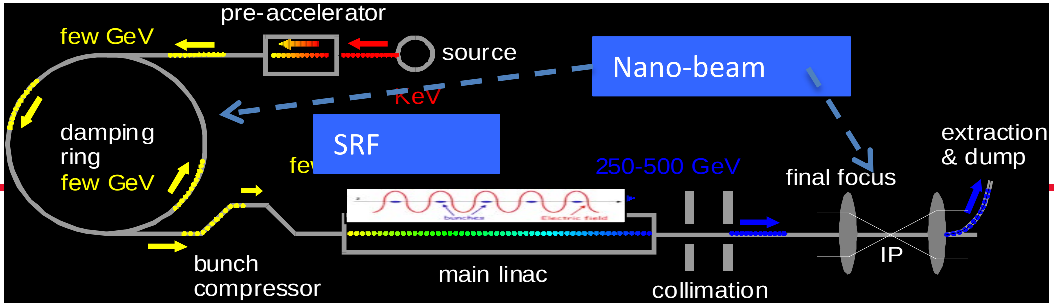
Beam Size 44 nm observed,
(Goal : **37** nm
corresponding to **6** nm at ILC)

ILC Time Line: Progress and Prospect



Further Technical Issues to prepare for the ILC

The. Field	Subject	Global Cooperation
ADI	**Optimize Acc. Design and Integration**	**LCC-ILC-ADI Global Team**
SRF	Improve Gradient and Stability Establish three regional contribution - Industrialization - Hub-lab functioning	**TTC: TESLA Tech. Collaboration:** **Three regional effort and experience** - EU : European XFEL - AMs: LCLS-II - AS : KEK-STF as Asian Hub.
Nano-beam	Realize ultra-low emittance (in DR), and nano-beam size and stability at FF	**ATF: Acc. Test Facility Collab:** - Global collaboration with KEK-centered
E+ Source	Demonstrate thermal balance with rotational target in vacuum	**PosiPol** Collaboration: - Global collaboration
CFS	Establish a site-specific engineering Geological survey and assessment,	LCC-CFS Collaboration - Japan-centered
Management	Establish ILC Pre-Lab Prepare for the ILC Lab.	**>> ICFA leading** **>> Inter-Government Agreement ineviable**



Design Update Realized

	Title	Contents	Decision
CR-001	Add return dogleg to target by-pass	Add additional lattice to bring BDS beamline on axis with main linac, to accommodate future >1 TeV beam energies.	No
CR-002	Adopt equal L* for both detectors	Find solution for single L* value for BDS and both detectors	Yes
CR-003	Detector hall with vertical shaft access	Consolidated solution for IR hall / layout which supports surface construction of the detectors.	Yes
CR-004	Extension of the electron and positron Main Linac tunnels by ~ 1.5km	Lengthen Main Linac tunnels by about 1.5km, to (i) fulfill the Global Timing constraint and (ii) add margin for total beam energy of 500GeV CME, w/ very reliable reach	Yes
CR-005	Update top-level parameters	Correct errors in reported luminosity for 500 GeV baseline and 1 TeV (b) parameters.	Yes
CR-006	Add BPM downstream of QD0	Add a BPMs immediately downstream of the QD0s to facilitate beam capture and construction of a "virtual IP BPM".	Yes
CR-007	Adoption of the Asian design as sole baseline	Only the Asian version of the TDR designs will be the basis for further development; the baseline HLRF distribution scheme will be DKS, the CFS planning will be based on the mountainous topography design.	Yes
CR-008	Formal release TDR-2015a lattice	Complete set of matched lattices reflecting TDR design	Yes

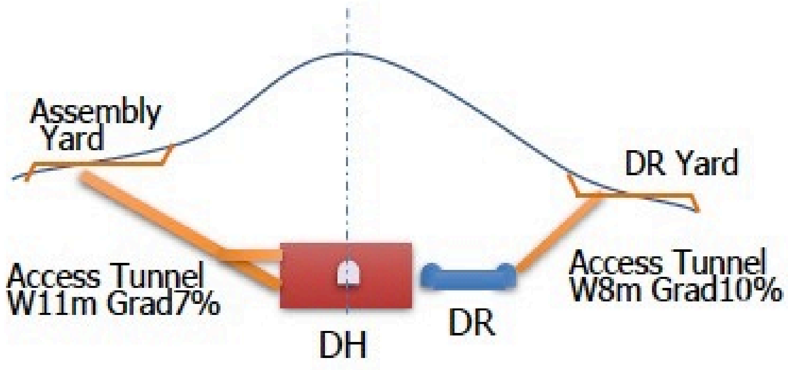
CR 3: Vertical shaft access to the detector hall at IP

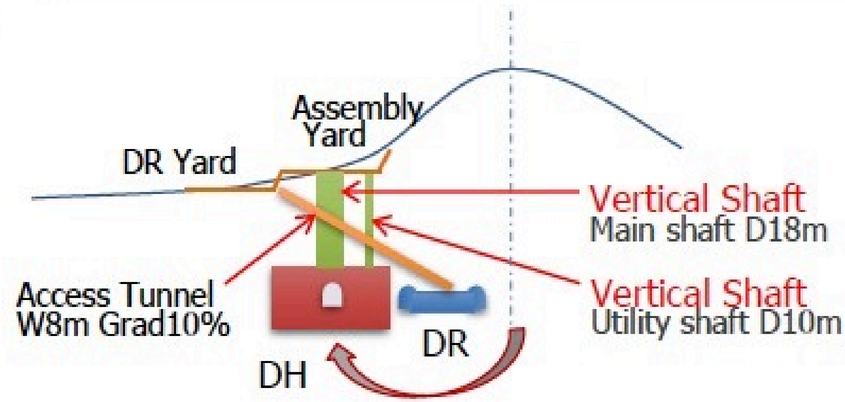
TDR Baseline

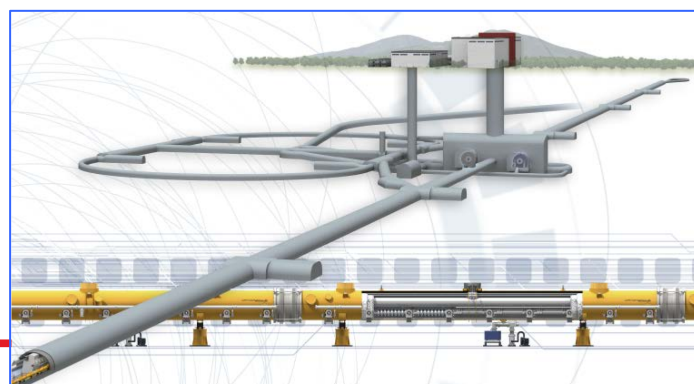
- Assembly Place: Surface Building/AH
- Access way to DHl underground
  - only Inclined Access Tunnel (AT)
  - Transport. by special long trailer

New Baseline

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

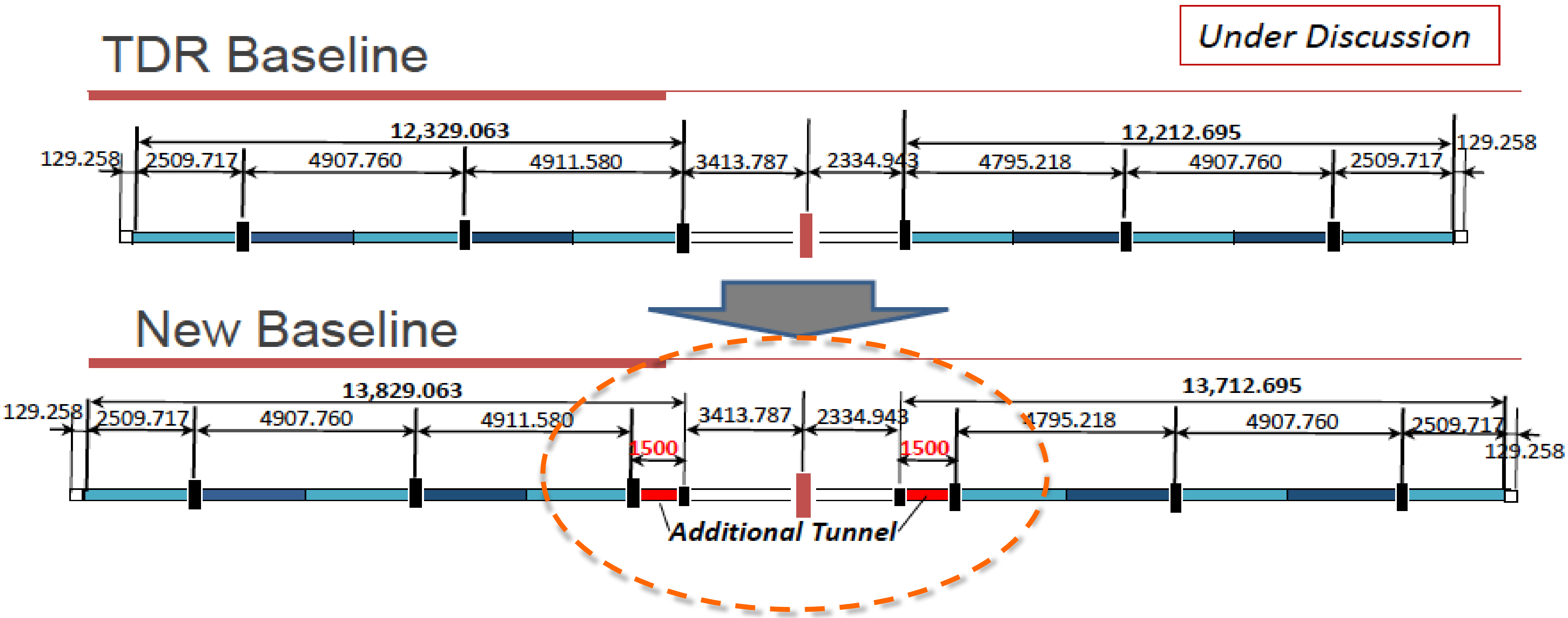






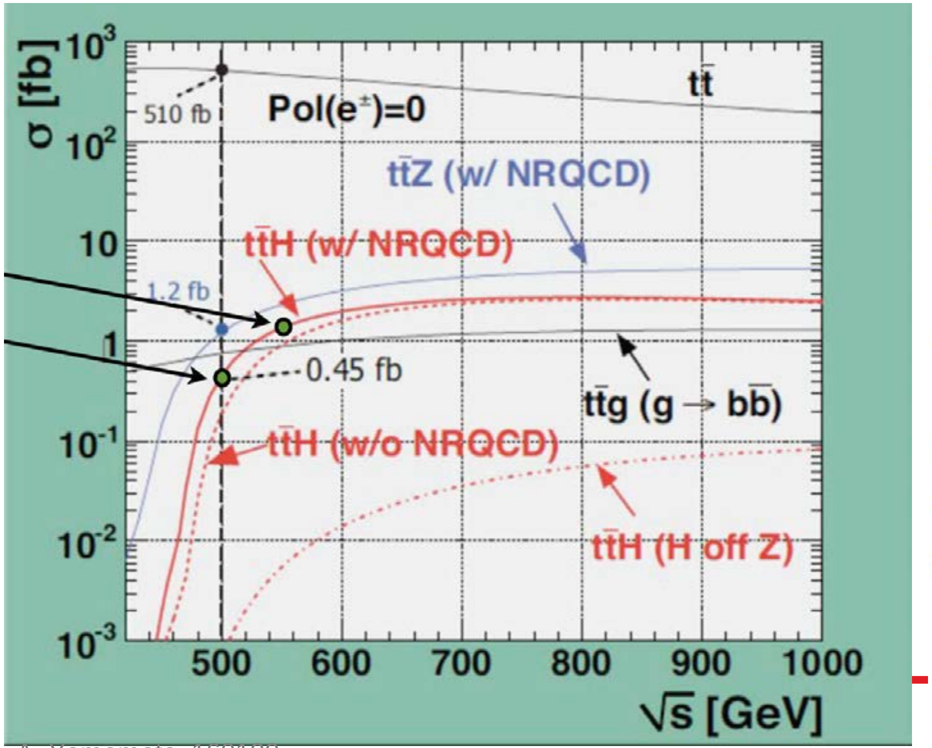
CR 4: Adding ML tunnel lengths

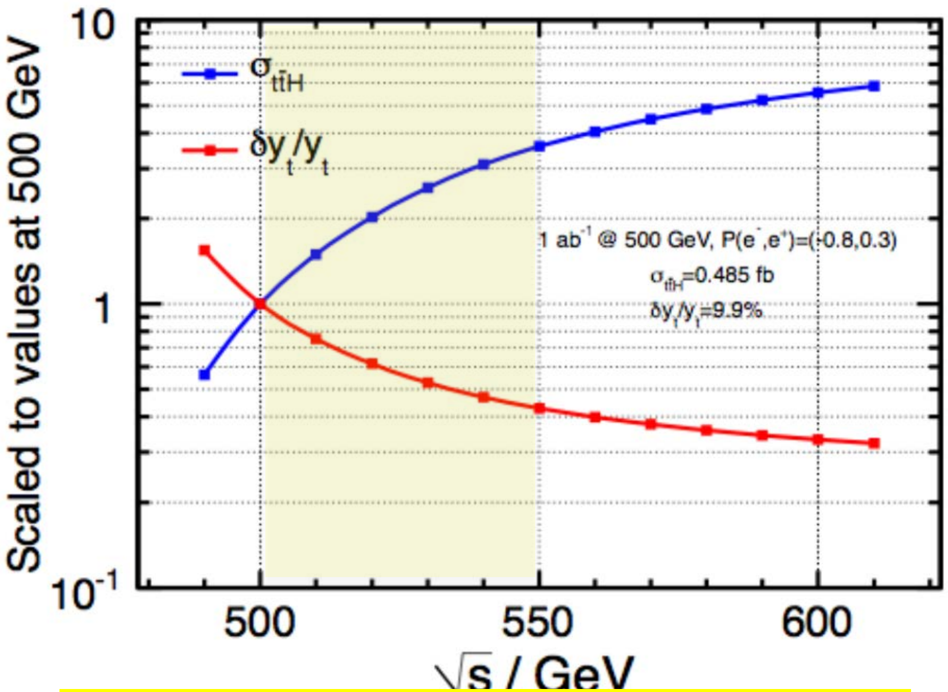
for both e+e- timing and more reliable reaching 500 GeV



Physics Issue

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

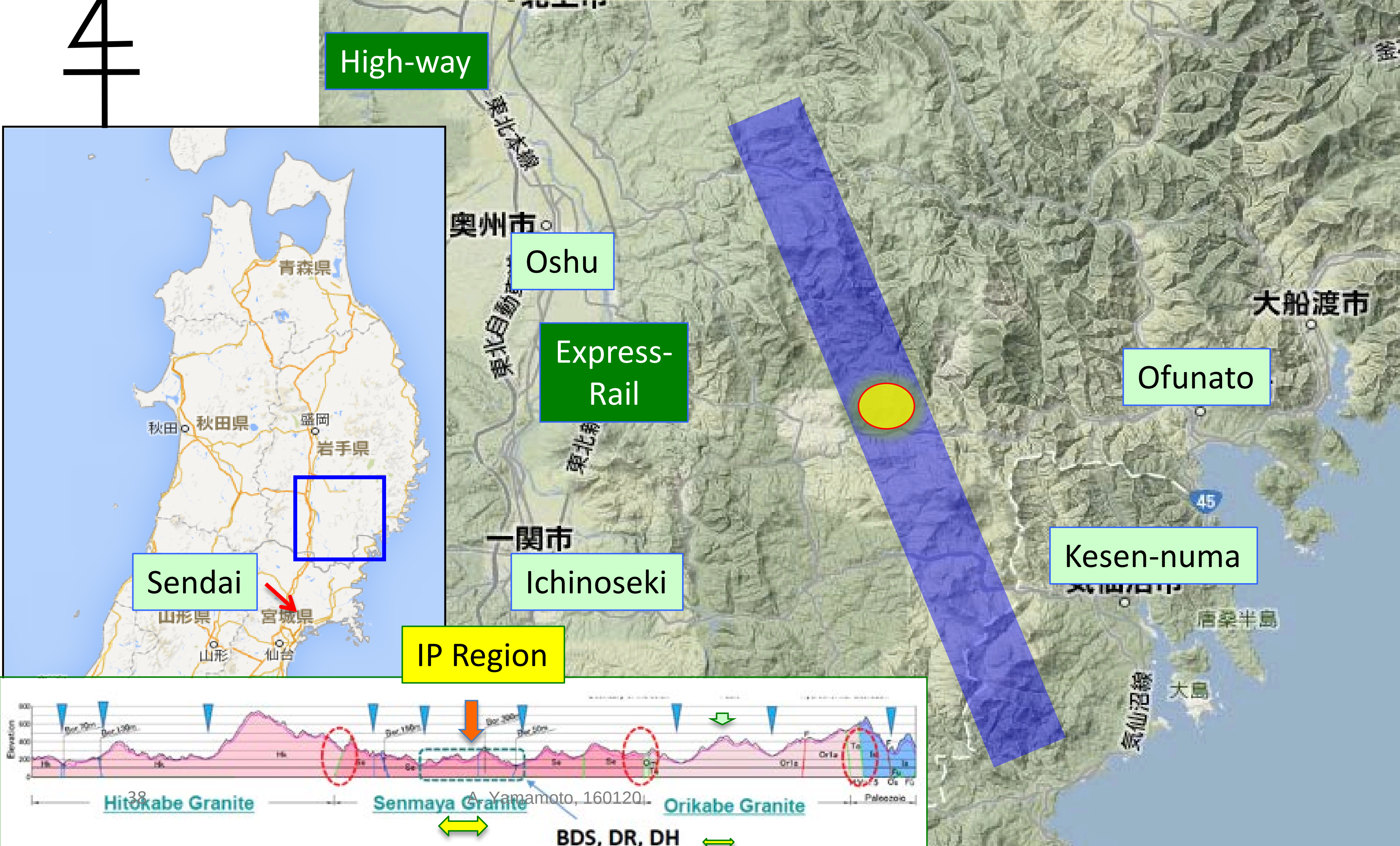




ILC Parameter Group report (Oct.2014)

ILC Site Candidate Location in Japan: Kitakami

- Preferred site selected by JHEP community,
- Endorsed by LCC, in 2013



A. Yamamoto, 160120

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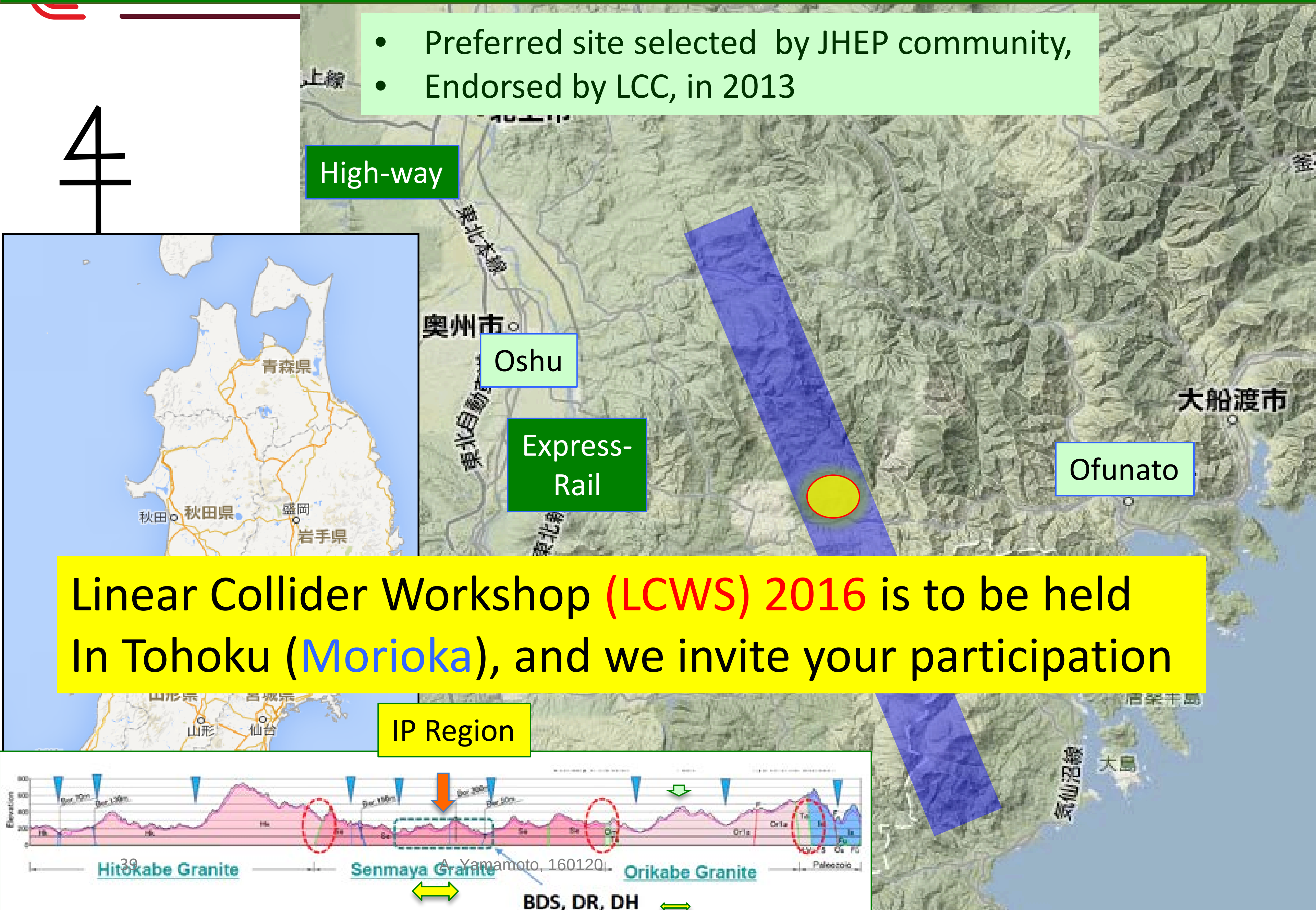


Linear Collider Workshop (LCWS) 2016 is to be held
In Tohoku (Morioka), and we invite your participation

Outline

Introduction

– Features and Key Technologies

Technical Status

– Progress in Global Design Effort & beyond TDR

– Further Effort to prepare for the ILC

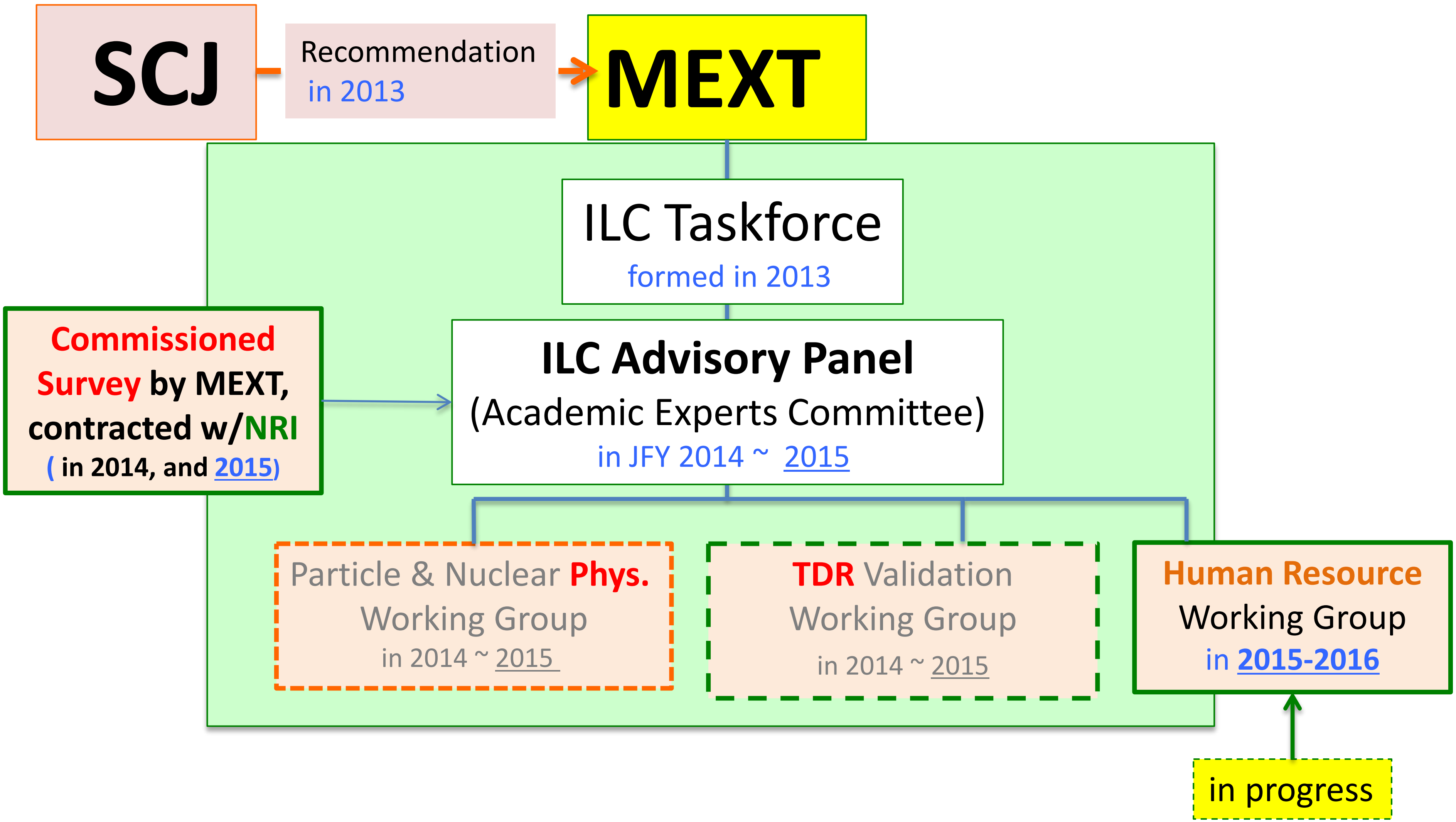
Prospect

– Actions progressed in Japan

– KEK-ILC Action Plan

Summary

Official Actions progressed in Japan



KEK-ILC Action Plan Issued

6 Jan., 2016

Go to KEK URL: “TOPICS”

https://www.kek.jp/en/

KEK-ILC Action Plan announced, Jan. 6, 2016

https://www.kek.jp/en/NewsRoom/Release/20160106140000/

- KEK issued an KEK-ILC action plan for how KEK should start its preparation toward the International Linear Collider when the Ministry of Education, Culture, Sports, Science and Technology (MEXT), decides to initiate negotiations with foreign countries. ,,,

- The study provides the basic information required to plan the technical actions, organization, human resources, and training to realize formal approval of the ILC project, and to ensure a smooth start of the construction phase through the preparation phase from the current status.

KEK-ILC Action Plan

- It assumes that work sharing with foreign institutions will be available based on an international agreement and that this phase will be four-year long to be started in 2016, 2017, or 2018.

- If we may start:
  - the main preparation phase in 2016 (2018),
  - ILC construction phase can begin in 2020 (2022), and
  - Physics experiments would start in 2029 (2031).

KEK-ILC-Action Plan

Table 1. ILC accelerator preparation tasks, international collaborations, and human resource sharing

Area	Tasks	International collaborations	Sharing JP : Abr.**
ADI	Design parameter optimization	LCC-ILC centered	~1 : 2
SRF	Mass-production and quality control Hub-lab functioning System performance stabilization (CM assembly and transportation)	Tesla Technology Collaboration (TTC) - KEK-STF (JP) - E-XFEL construction (EU) - LCLS-II construction (US)	~ 2 : 1
Nanobeam	Minimizing the beam size and demonstrating stability Beam handling (DR, RTML, BDS, BD)*	ATF Collaboration	~1 : 1
Positron source	Undulator-driven polarized positron source Electron beam–driven positron source (backup) Thermal balance, cooling and safety	Complementary cooperation between US and Japan	~1 : 1
CFS	Basic Plan by assuming a model site, engineering design, drawings, survey, assessment	JP-CFS centered Collaboration w/ local organizations	JP centered
Common technical support	Safety (radiation, high-pressure gas, etc.) Communication and network	International standard and harmonization Global networking	JP centered
Administration	General affairs, finace, int. relations, public relations Administrative support for ILC pre-lab	Share and cooperation between ILC pre-lab and participating institutions	JP centered

SCRF Procurement/Manufacturing Model

ILC Host-Lab

Technical Coordination
for Lab-Consortium

Regional
Hub-Lab:
A

Regional
Hub-Lab:
E, & …

World-wide
Industry responsible to
'Build-to-Print'
manufacturing

Regional
Hub-Lab:
B

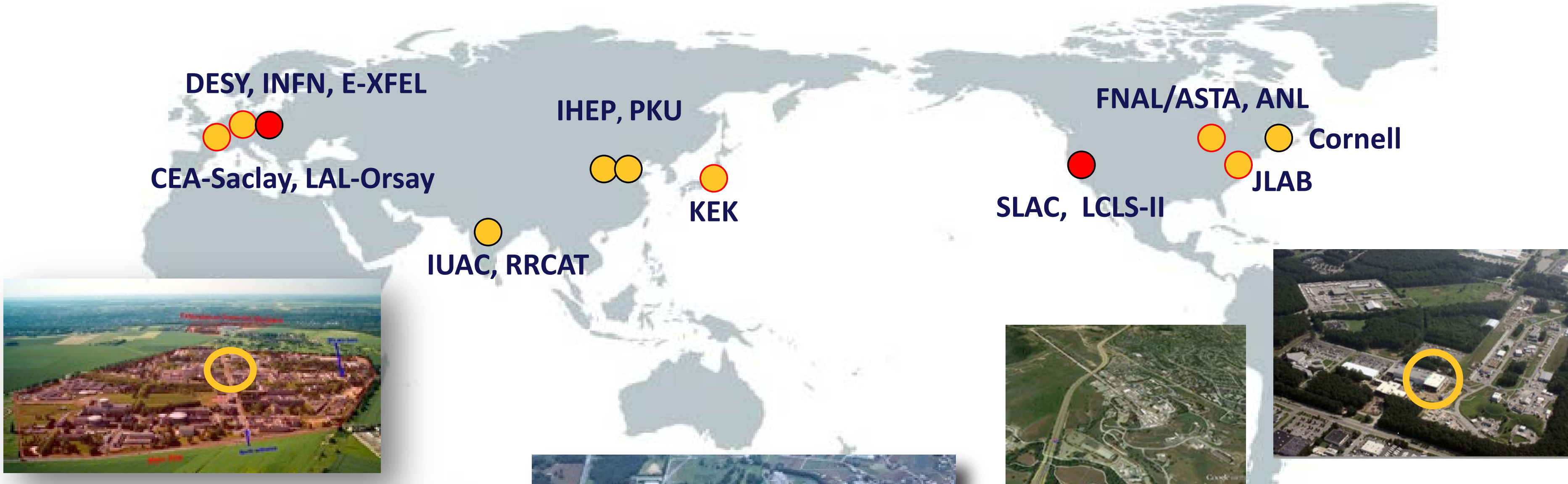
Regional
Hub-Lab:
D

Regional Hub-Lab:
C: **responsible to**
Hosting System Test
and Gradient
Performance

Regional hub-laboratories responsible to regional procurements to be open for any world-wide industry participation

: Technical coordination link
: Procurement link

SRF Facilities anticipated for Hub/Consortium



AMTF @DESY/E-XFEL, CEA,

STF-CFF @ KEK

ASTA @ FNAL, TEDF @ JLab

KEK-ILC Action Plan in Preparation Period

	Pre-preparation Phase	Main Preparation Phase			
	Present	P1	P2	P3	P4
ADI	Establish main parameters	Verify parameters w/ simulations			
SRF	Accelerate beam with SRF cavity string and cryomodule	Demonstrate mass-production technology and stability Demonstrate Hub-lab functioning and global sharing			
Nanobeam	Achieve the ILC beam-size goal	Demonstrate the nanobeam size and stabilize the beam position			
Positron source	Demonstrate technological feasibility	Demonstrate both the undulator and e-driven e+ sources			
CFS	Pre-survey and basic design	Geology survey, engineering design, specification, and drawings			
Common technical support	Support engineering and safety	Common engineering supports (network, radiation safety, etc.)			
Administration	Project planning and promotion Preparation for the ILC pre-lab	General affairs, finance, international relations, public relations Establishing the ILC pre-lab and managing the ILC preparation			

	Pre-P.[2]	Main Preparation[3]				Construction[4]		Notes
	(present)	P1	P2	P3	P4	C1	C2	
Acc: JP	42	54	74	98	122	172	530	JP: needs to mature SRF mass-prod. technology[5]
: abroad	≥ 20	28	41	65	89			EU/US: already has experience[6]
CFS: JP	3	11	11	13	17	52	53	JP: is primarily responsible, w/ outsourcing
: abroad	1	3	5	5	5			abroad: professional contribution
Comm: JP	2	7	10	13	14	109	109	JP: is primarily responsible
: abroad	1	3	4	6	7			abroad: professional contribution[7]
Admin: JP	5	8	10	14	18	77	230	JP: is primarily responsible
: abroad	3	4	6	8	10			abroad: professional and regional contribution[8]
Sum	≥ 77	118	161	222	282	410	922	

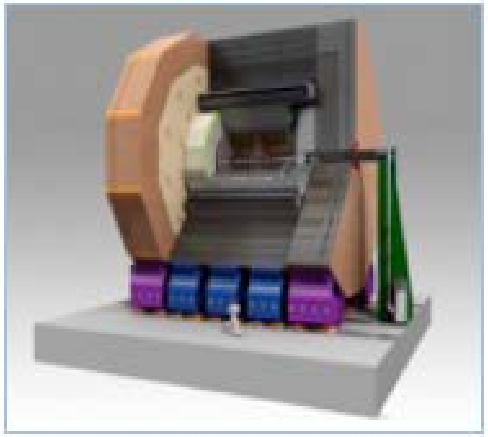
Summary

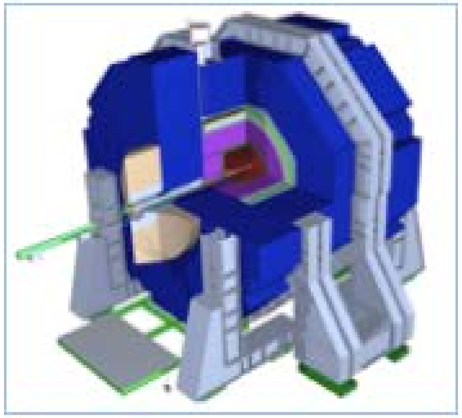
- International Linear Collider (ILC) is a unique energy frontier e+e- colliding accelerator with an (COM) energy of 500 GeV efficiently and extendable to 1 TeV (and further if the SRF technology much advanced), having critically important features complementary to the LHC.

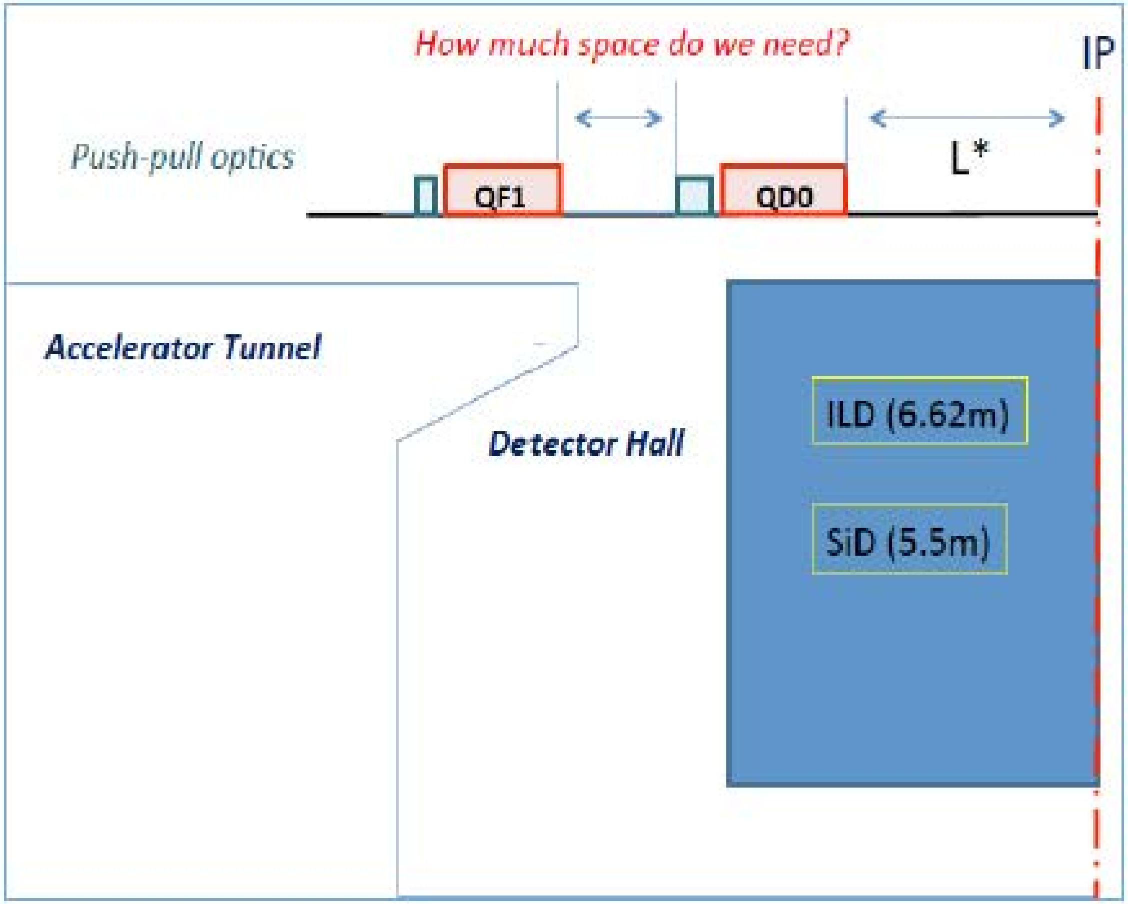
- Two key technologies of SRF and Nano-Beam have been demonstrated by European XFEL and ATF programs, functioning prototype works, with global cooperation.

- The KEK-ILC action plan awaits the project "**Green Light**". The global teams are enthusiastically preparing for this development

CR 2: Equalization of L* for ILC and SID detectors





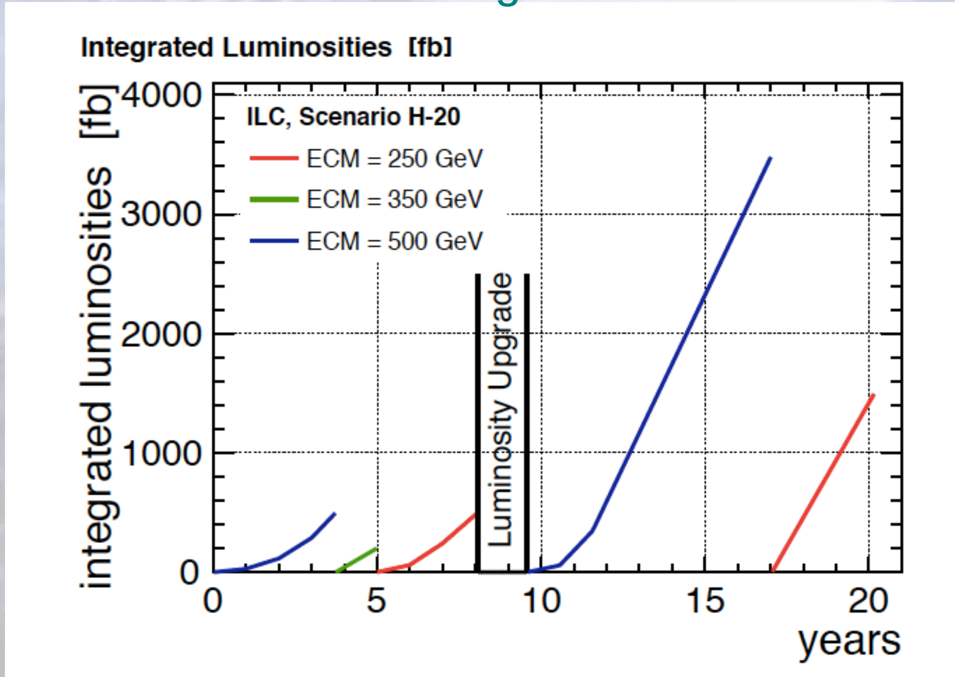


LINEAR COLLIDER COLLABORATION

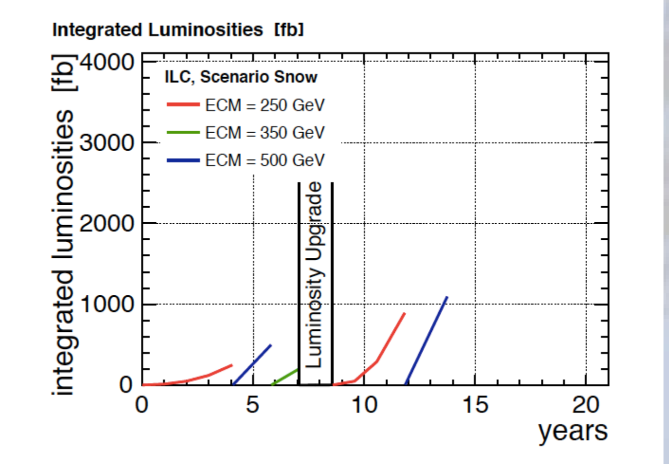
Standard ILC Running Scenario

	Stage	500			500 LumiUP		
Scenario	$\sqrt{s}$ [GeV]	500	350	250	500	350	250
G-20	$\int \mathscr{L} dt$ [fb^{-1}]	1000	200	500	4000	-	-
	time [years]	5.5	1.3	3.1	8.3	-	-
H-20	$\int \mathscr{L} dt$ [fb^{-1}]	500	200	500	3500	-	1500
	time [years]	3.7	1.3	3.1	7.5	-	3.1

‘H20’: Standard Running Scenario



Reference: Snowmass study scenario Fits within 15 years



Measurement precisions are somewhat improved wrt the Snowmass numbers