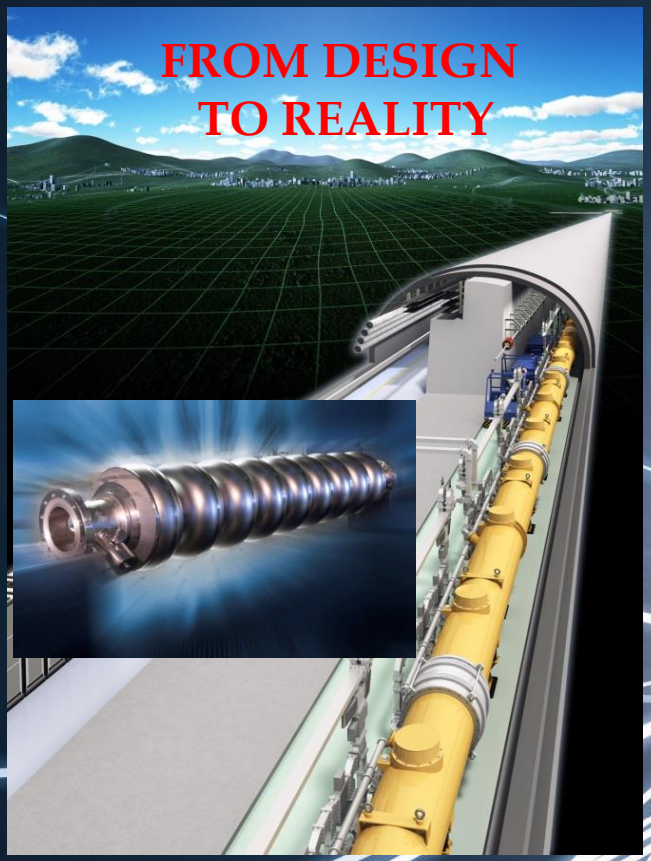
The SRF Technology and the ILC Accelerator Complex



Maxim Titov (CEA Saclay, France)

TIPP 2014 Conference, Amsterdam, June 2-6, 2014

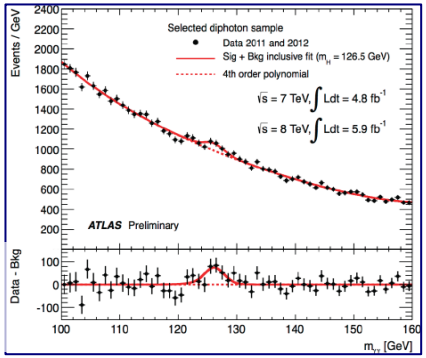
- Acknowledgments to 1000's people for their hard work who advanced the ILC project to the TDR stage

- Special thanks to Akira Yamamoto, Brian Foster, Nick Walker, Eckhard Elsen, Lyn Evans, Mike Harrison, Atsuto Suzuki, Olivier Napoly, Marc Ross, Barry Barish for their help and support during the talk preparation (results or slides are largely from their presentations)

The International Linear Collider (ILC) – From Design to Reality

1980': Basic Study

2012 - Discovery of Higgs Boson: "Revolution in Particle Physics"



Higgs discovered

LHC

2005 2006 2007 2008 2009 2010 2011 2012 2013

2004

ILC - GLOBAL DESIGN EFFORT (GDE)

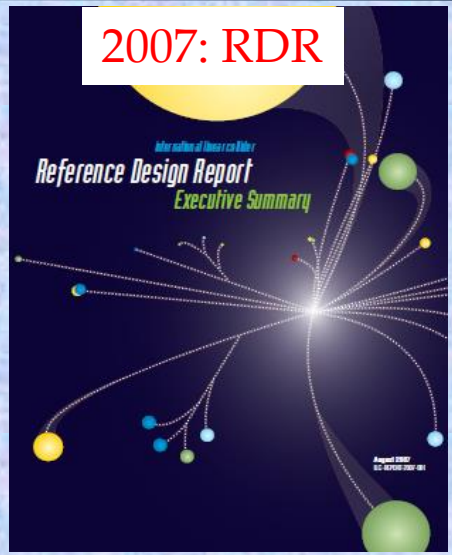
LCC

Linear Collider Collaboration

Selection of SC Technology

Ref. Design Report (RDR)

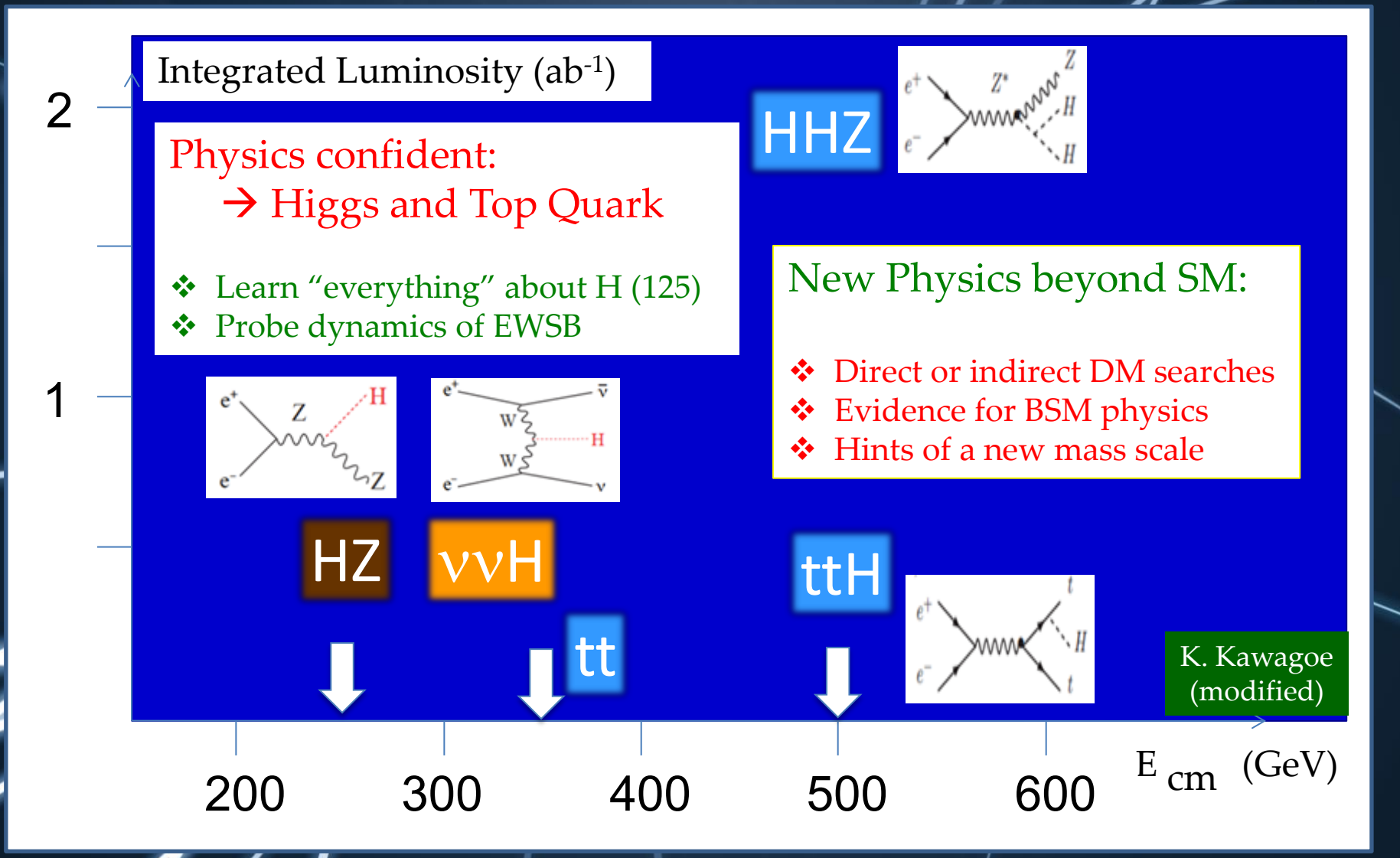
2007: RDR



2013: TDR

The Rising Sun of the Linear Collider → ILC as the "Higgs Factory"

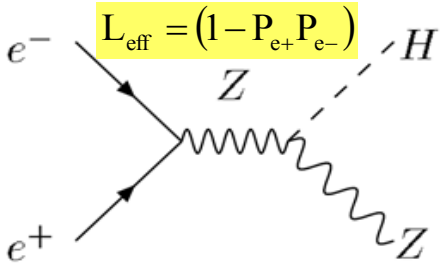
❖ Discovery of a 125 GeV Higgs has reinforced the importance of the ILC



Physics Prospects with ILC: Power of Beam Polarization

Polarized beam(s) provide great diagnostics : e_L and e_R - different particles in gauge interactions

❖ Enhance effective luminosity:



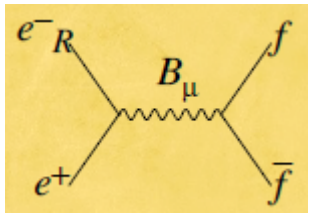
$e^+_R\, e^-_L \rightarrow ZH$
$e^+_L\, e^-_R \rightarrow ZH$

~~$e^+_L\, e^-_L \rightarrow ZH$~~
~~$e^+_R\, e^-_R \rightarrow ZH$~~

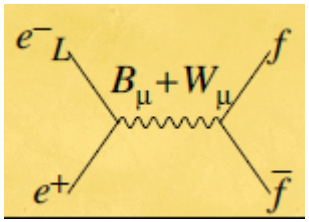
24 % lumi gain for P(e-,e+) = (±80%; ∓30%)

Cross section (in fb) for m_H = 125 GeV							
		250	350	500	1000	1400	3000
ZH	unpolar.	211	134	64.5	16.1	8.5	2.0
	polar.	318	198	95.5	22.3	10.0	2.4
$\nu_e\nu_e$ H	unpolar.	20.8	34.1	71.5	195	278	448
	polar.	36.6	72.5	163	425	496	862
e+e-H	unpolar.	7.7	7.4	8.9	20.1	27.3	48.9
	polar.	11.2	10.4	11.7	24.7	32.9	56.5

❖ Determine quantum #s (if new particle found)

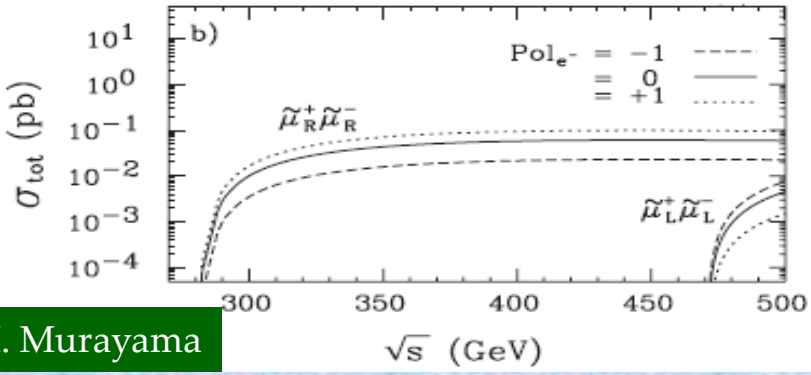


$\propto (g'^2 Y_f)^2$



$\propto (g'^2 Y_f + g^2 I_{3f})^2$

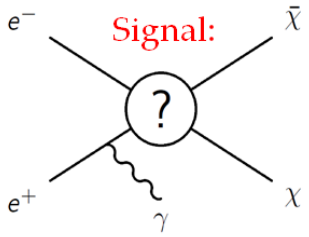
$U(1)_Y$ - gauge boson $B\mu$
$SU(2)_L$ – gauge boson $W^0\mu$
Yf -hypercharge of new particle

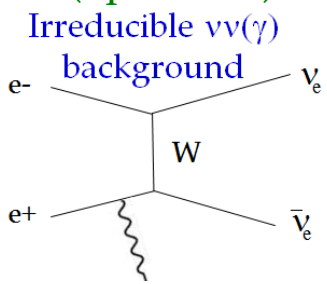


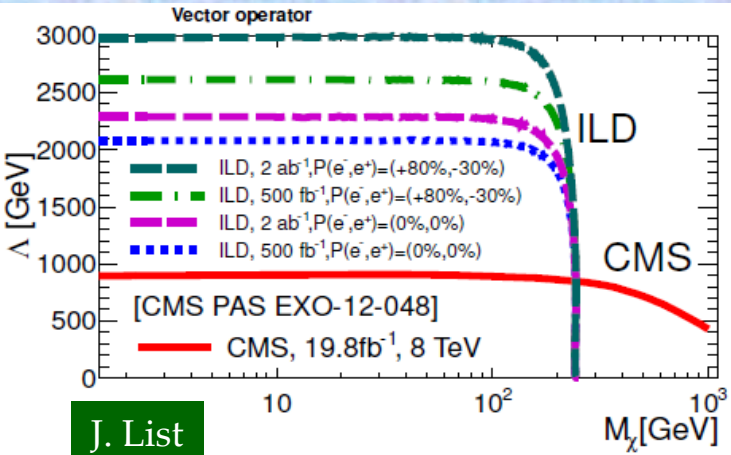
H. Murayama

❖ Increase sensitivity to Dark Matter, WIMP, …

Polarization (e+,e-) is important to:
→ Suppress ee→νν(γ) bkg.
→ Distinguish models (operators)







J. List

LC Detector Challenges: The Higgs is an Important Driving Factor

❖ **VERTEX**: flavour tag, IP resolution (H → bb, cc ττ)
~1/5 $r_{beampipe}$, 1/30 pixel size, ~1/10 resolution (ILC vs LHC)

$$\sigma_{IP} = 5 \oplus \frac{10}{p \sin^{3/2}\theta} (\mu m)$$

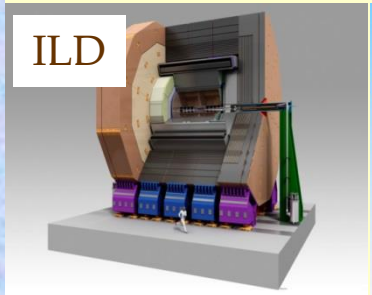
❖ **TRACKING**: recoil mass to Higgs (e+e- → ZH → llX)
~1/6 material, ~1/10 resolution (ILC vs LHC); B = 3.5 – 5T

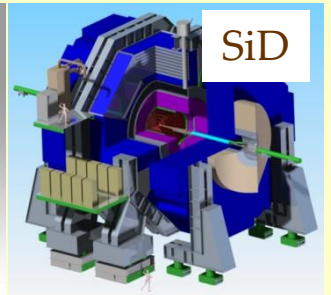
$$\sigma(1/p) = 2 \times 10^{-5} (\mathrm{GeV}^{-1})$$

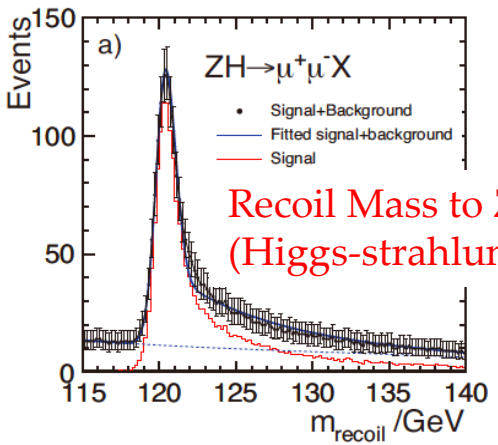
❖ **CALORIMETRY:** particle flow, di-jet mass resolution
1000x granularity, ~1/2 resolution (ILC vs LHC);
detector coverage down to very low angle

$$\sigma_E / E = 0.3 / \sqrt{E(\mathrm{GeV})}$$

❖ "Push-pull Option": two detectors (similar concepts, different realizations)







Recoil Mass to Z (Higgs-strahlung):

ILC TDR: June 2013 - Detailed Baseline Design (DBD) for Detectors
http://www.linearcollider.org/ILC/Publications/Technical-Design-Report

- ❖ Key detector R&D technologies have been demonstrated with prototypes in test beams
- ❖ Physics performance has been studies in full simulations
- ❖ Major engineering R&D efforts and optimization of detector concepts are still needed

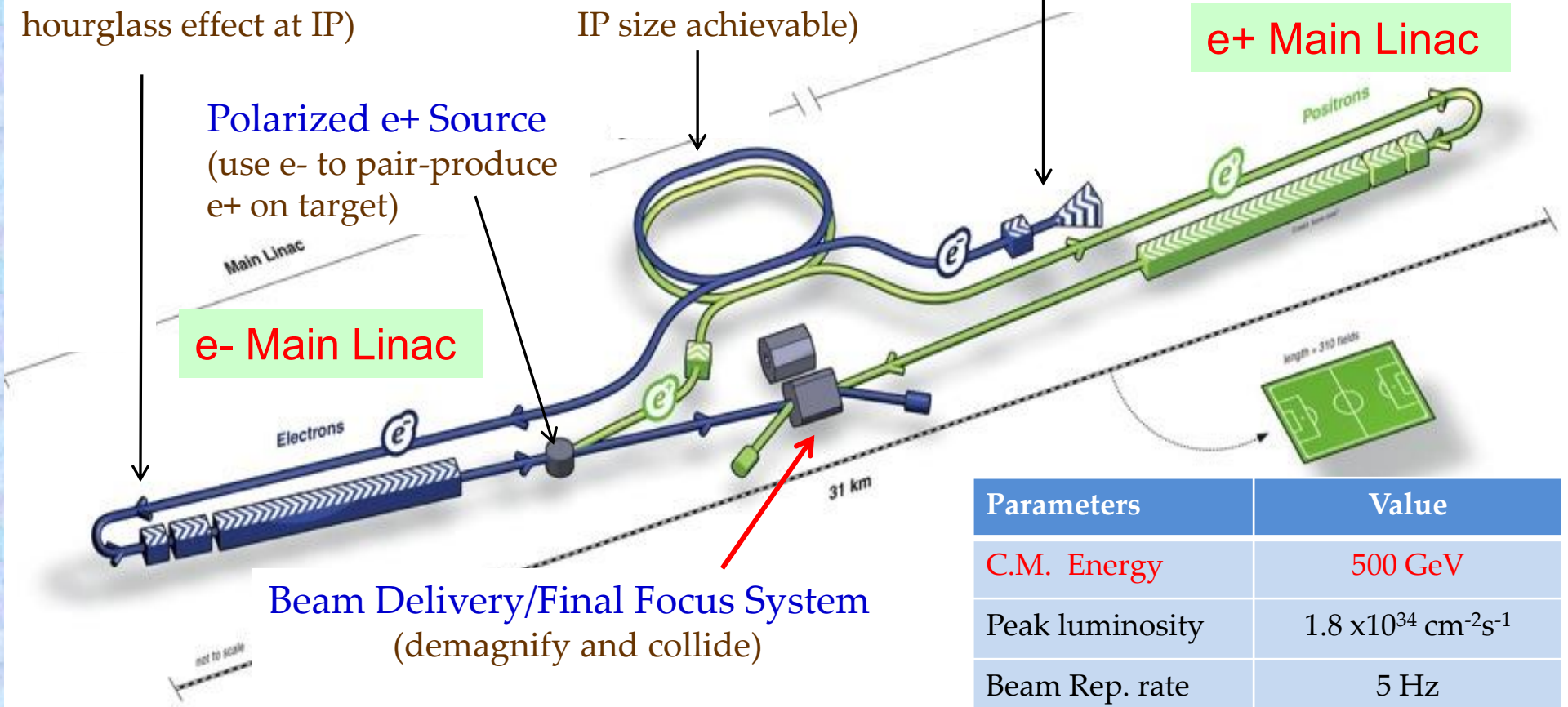
ILC TDR: Accelerator Layout

Ring to Main Linac
(including bunch compressors → reduce σz to eliminate hourglass effect at IP)

Damping Rings
(reduce emittance → smaller transverse IP size achievable)

Polarised Electron Source
(deliver stable beam current)

Polarized e+ Source
(use e- to pair-produce e+ on target)



Beam Delivery/Final Focus System
(demagnify and collide)

Two detectors ("Push-Pull" option)

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)
E gradient in SCRF acc. cavity	31.5 MV/m +/-20% Q_0 = 1E10

ILC TDR: key accelerator technologies in hand after extensive R&D

ILC Scheme | © www.form-one.de

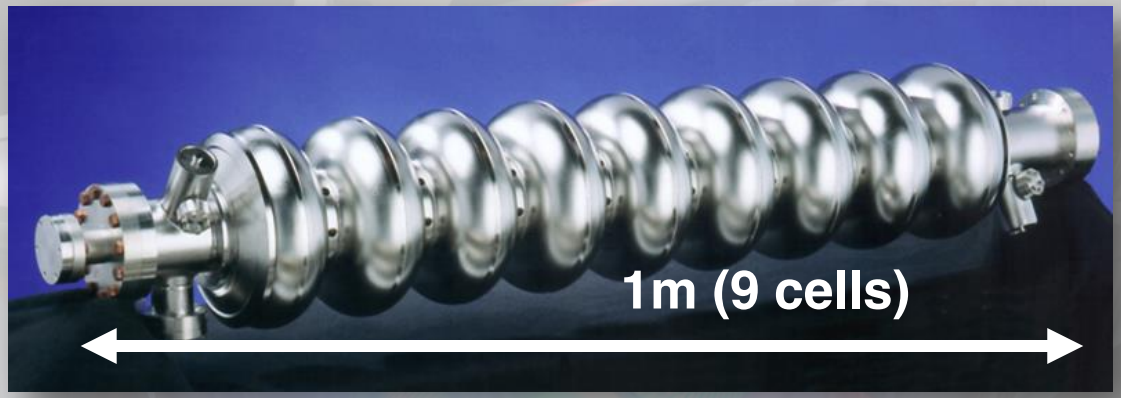
The ILC Accelerator: What is it all about ?

- Why SRF?
  - for an e+e- linear collider
- SRF Technology – the Quest for High Performance – from Nb to Cavities
  - high gradient R&D and performance, demonstration of large- scale production of reproducible high-gradient cavities, industrialization for XFEL
- Worldwide Cryomodule Development and System Tests
  - cryomodule assembly for XFEL, global R&D efforts and integrated system tests (FLASH @ DESY; S1-GLOBAL @ KEK)
- Beyond the SRF Main Linac
  - nanobeam handling and final focus design/performance (ATF2 @ KEK), damping rings, electron and positron sources, electron cloud mitigation (CesrTA @ Cornell)
- ILC costing, Anticipated Timeline and Energy Staging
- Status of the GLOBAL ILC Project in Japan

Superconducting RF Technology for the ILC

The recommendation of the International Technical Recommendation Panel (ITRP) was unanimously endorsed by ICFA on Aug. 20, 2004

- We recommend that the linear collider be based on superconducting RF technology



- This recommendation is made with the understanding that we are recommending a technology, not a design. We expect the final design to be developed by a team drawn from the combined warm and cold linear collider communities, taking full advantage of the experience and expertise of both (from the Executive Summary).

Major R&D Goals for Global Design Efforts (GDE) (2005-2013):

- Achieve high gradient (35MV/m); develop multiple vendors; make cost effective …
- Focus is on high gradient; production yields; cryogenic losses; radiation; system performance

Why is the Trend Towards Super-Conducting RF ?

There are a number of advantages from SRF technology:

- Ultra-high Q_0 (10^{10}):
  - small surface resistance → almost zero power (heat) in cavity walls
  - use relatively low-power microwave source to 'charge up' cavity
- Long beam pulses (~1 ms)
  → intra-pulse feedback
- Larger aperture / smaller beam loss
  → better beam quality with larger aperture - lower wakefields
- Future work will focus on engineering:
  - Cryomodule (thermal insultation)
  - Cryogenics
  - Gradient to be further improved

Luminosity:

RF efficiency — RF power / beam current

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

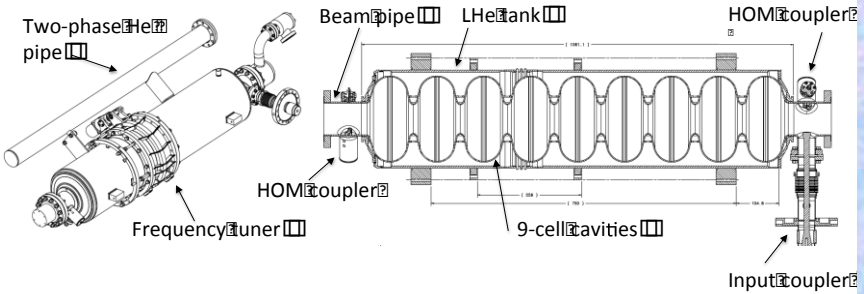
Vertical emittance (tiny beams)

- For given total power (electricity bill !), luminosity proportional to RF efficiency
  ILC: ~160MW @ 500GeV
- Capable of efficiently accelerating high beam currents
- Low impedance aids preservation of high beam quality (low emittance)

→ Ideal for Linear Collider

ILC will extend basic science reach through technology coupled with precision & control

The ILC Superconducting RF Cavity



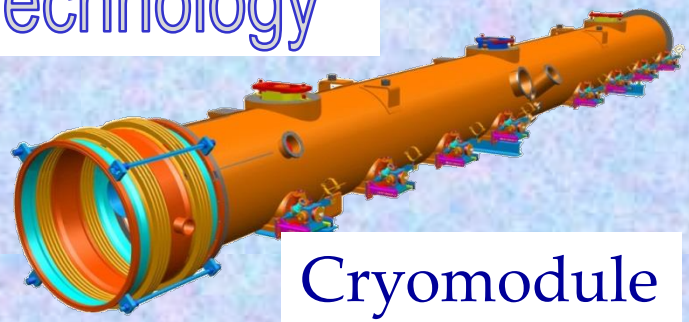
Parameter	Value
Fundamental	1.300 GHz
Average accelerating gradient	31.5 MV/m (±20%)
Quality factor	≥ 1 x 10 10
Active length	1.038 m
Total length	1.247 m
Numbers of cells	9
Cell construction	2.6 mm thick Niobium sheet metal
Niobium material	RRR > 300
Weight	35 kg

1.3 GHz (9-cell Nb) Cavities	16,024
Cryomodules	1,855
10 MW MB Klystrons & modulators	436

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

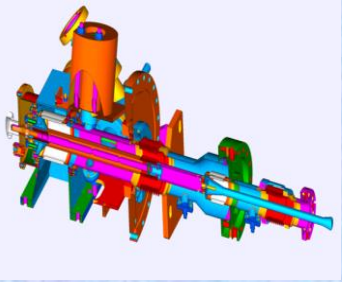
Global Superconducting RF Linac Technology

RF Cavity

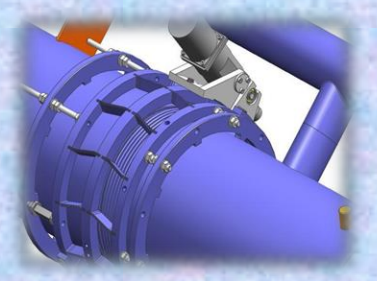


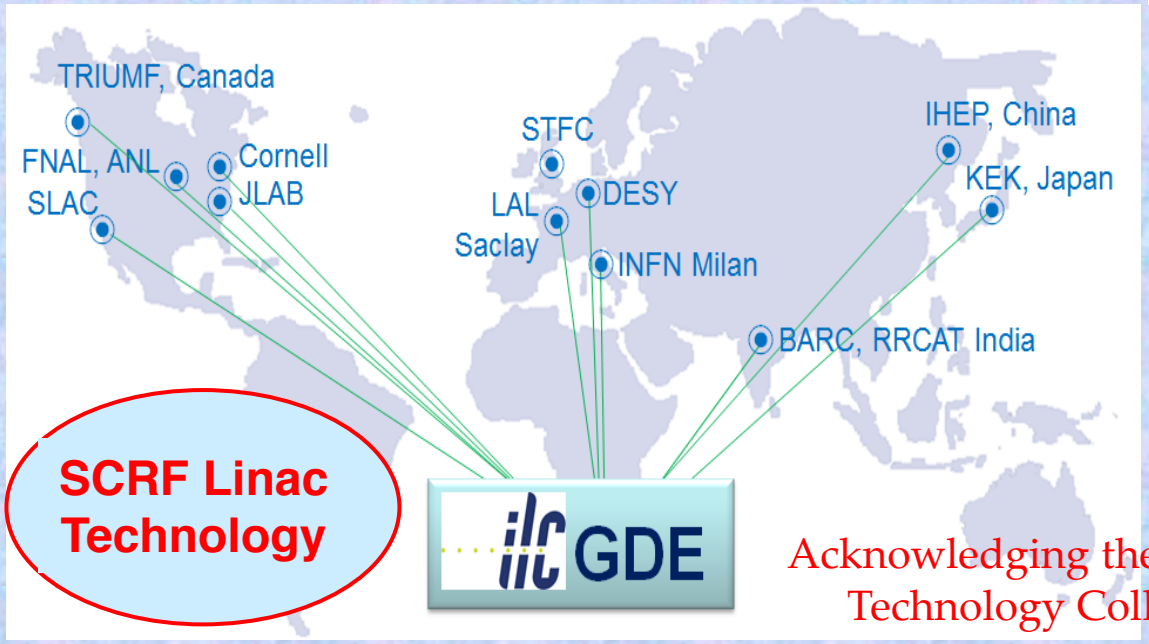
Cryomodule

Power Coupler



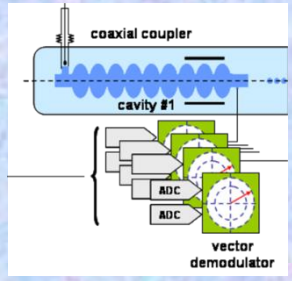
Frequency Tuner





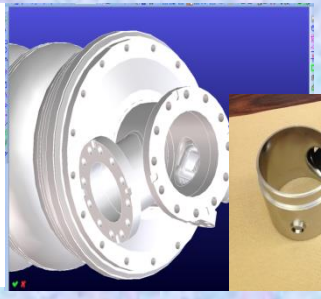
Acknowledging the efforts of the Tesla Technology Collaboration (TTC)

LLRF



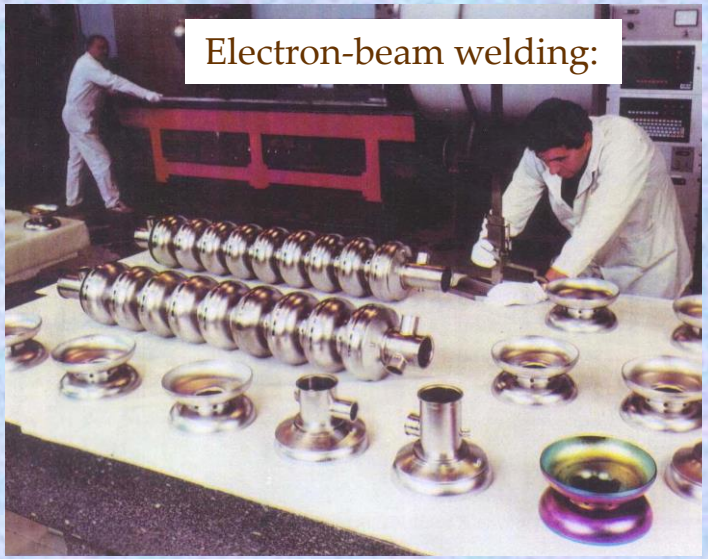
RF power

HOMs (higher order modes) coupler

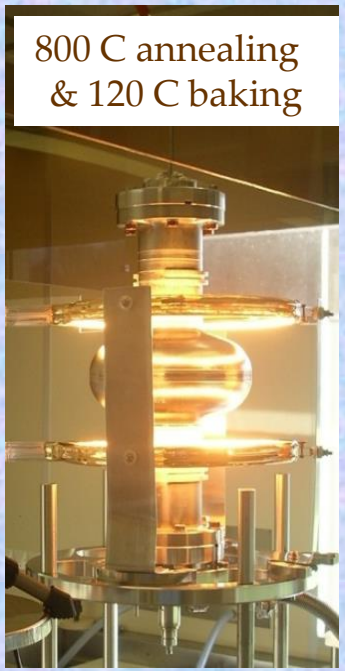


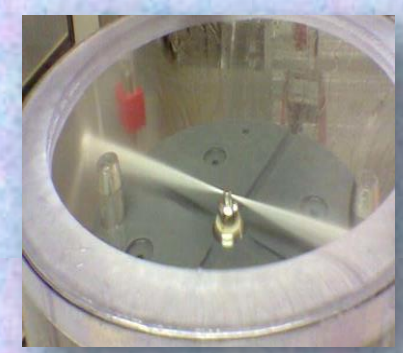
Promote development of 1.3 GHz cavities, expertize and infrastructure in all 3 regions

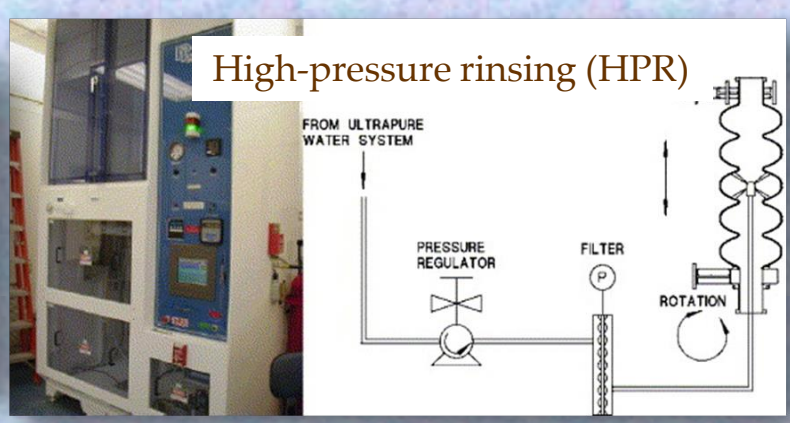
SRF Cavities: The Path to High Performance



- Control of niobium material
- Mechanical construction
  - electron-beam welding (EBW)
- Preparing RF (inner) surface ultra-clean mirror surface
  - electro-polishing (EP)
- Removing hydrogen from the surface layer
  - 800 deg C baking
- Removing surface contamination
  - alcohol and/or detergent rinsing
  - high-pressure rinsing (HPR)







SRF Gradient Performance Worldwide and Industrialization

Goal is to increase the number of qualified vendors in the Americas and Asia regions

Year	#9-cell cavities qualified	Research Laboratories	Qualified Cavity Vendors
2006	10	1 DESY	2 ACCEL, ZANON
2011	41	4 DESY, JLAB, FNAL, KEK	4 RI, ZANON, AES, MHI
2012	(45)	5 DESY, JLAB, FNAL, KEK, Cornell	5 RI, ZANON, AES, MHI, Hitachi

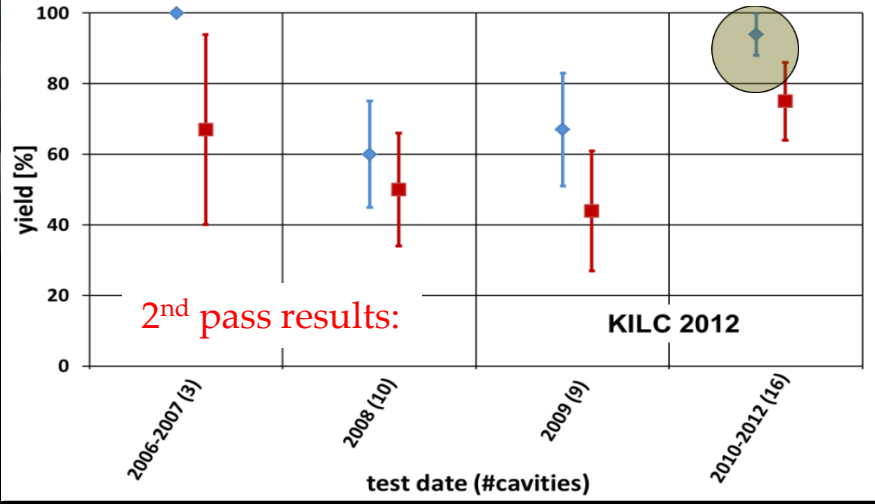
- Production yield: 94 % (±6%) at > 28 MV/m
  → acceptable for ILC mass production
- Average gradient (2nd pass): 37.1 MV/m
  → exceeds 2005 GDE R&D goal
- ILC (linac) gradient spec. : 31.5 MV/m ± 20%

- GDE global database: Asia – KEK;
  Europe – DESY; US – JLab, FNAL, Cornell
- Qualified cavity vendors:
  Asia – 2; Europe – 2; US – 1

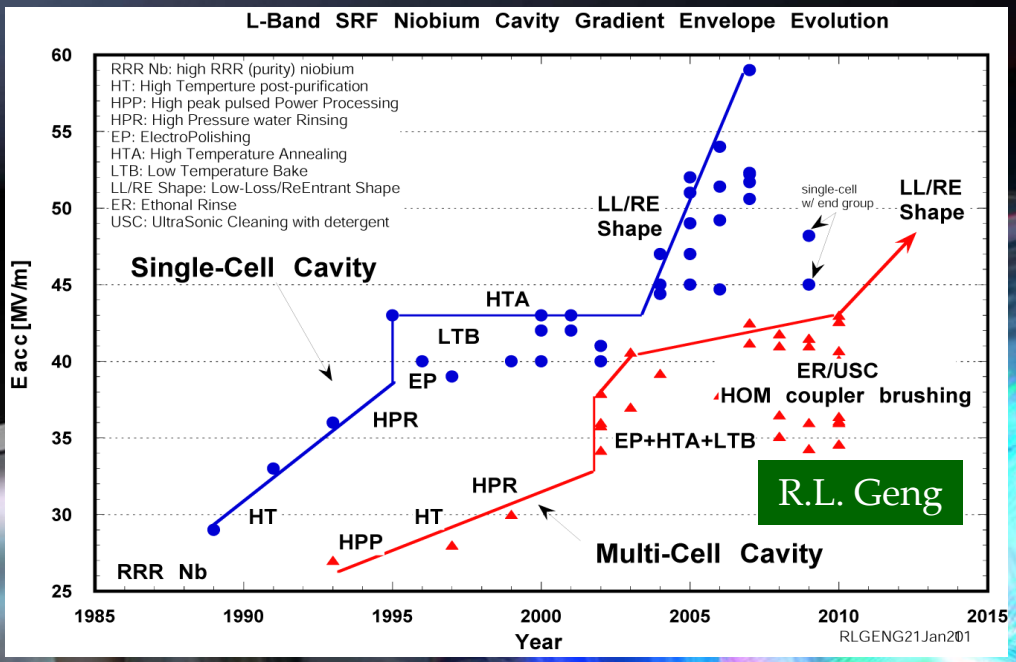
Yearly Progress in Cavity Gradient Yield:

> 28 MV/m yield > 35 MV/m yield

2nd pass: if gradient < 35MV/m and $Q_0 < 8 \times 10^9$



SRF Cavity: Gradient Progress



- Yield for high-gradient cavities is limited by local defects in individual cells:
  → quench of cavity or eventually field emission (excessive X-rays)

E.g.(recipes for post-treatment):

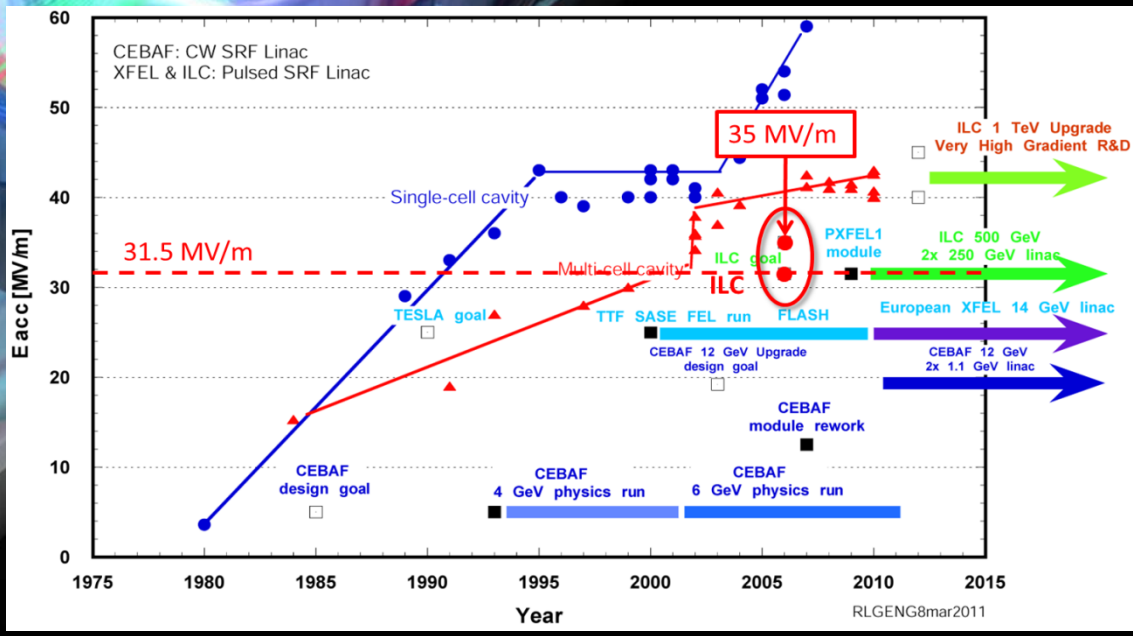
- Geometrical defects limit gradient < 20 MV/m → mechanical polishing

- ILC: < 20% cavities with < 35 MV/m on the first-pass test
  → 2nd pass includes HPR or light EP

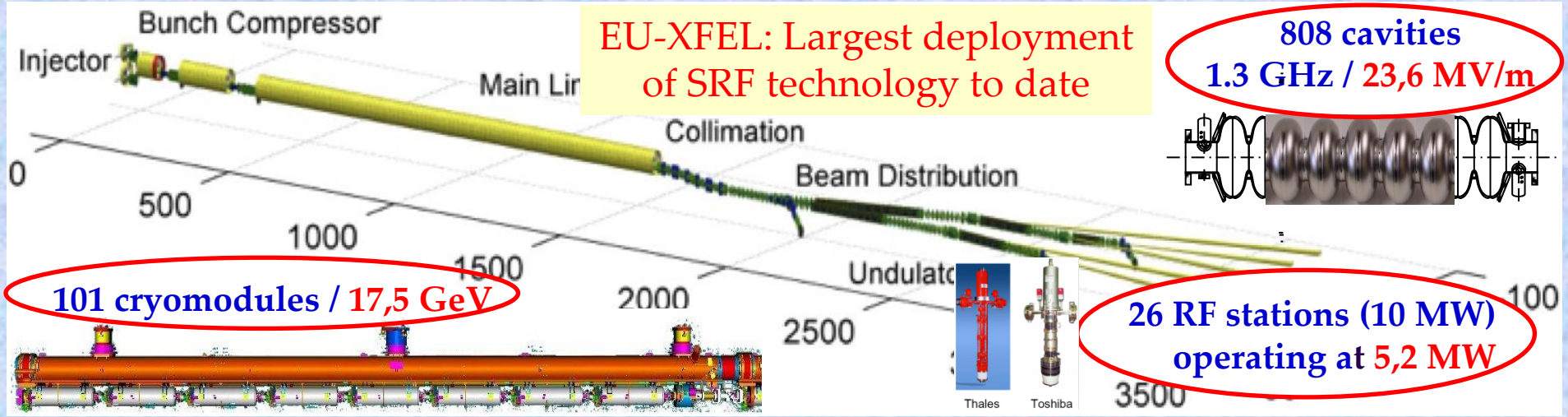
Continued progress in SRF Gradients:

- Breakthrough of 45 MV/m gradient and a record of 60 MV/m achieved in 1-cell (1300 MHz) Nb cavity

- Gradient demonstration of 45-50 MV/m in 9-cell cavity is foreseen in next 5 years.



European XFEL @ DESY



EU-XFEL: Largest deployment of SRF technology to date

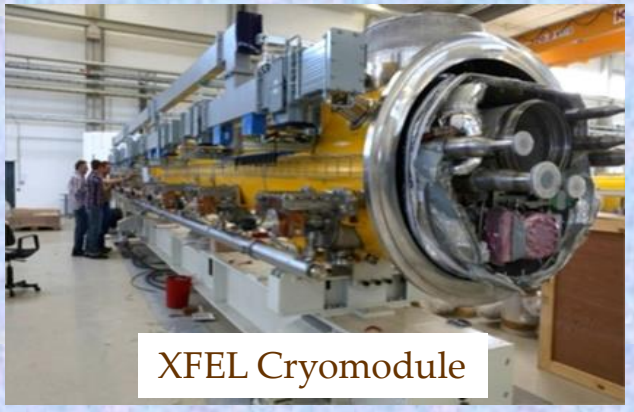
808 cavities
1.3 GHz / 23,6 MV/m

101 cryomodules / 17,5 GeV

26 RF stations (10 MW) operating at 5,2 MW

Vertical Cavity RF Test @ DESY

Cavity String Assembly @ CEA



XFEL Cryomodule

Institute	Component 7 Task
CEA Saclay / IRFU, France	Cavity string and module assembly; cold beam position monitors
CNRS / LAL Orsay, France	RF main input coupler incl. RF conditioning
DESY, Germany	Cavities & cryostats; contributions to string & module assembly; coupler interlock; frequency tuner; cold-vacuum system; integration of superconducting magnets; cold beam-position monitors
INFN Milano, Italy	Cavities & cryostats
Soltan Inst., Poland	Higher-order-mode coupler & absorber
CIEMAT, Spain	Superconducting magnets
IFJ PAN Cracow, Poland	RF cavity and cryomodule testing
BINP, Russia	Cold vacuum components

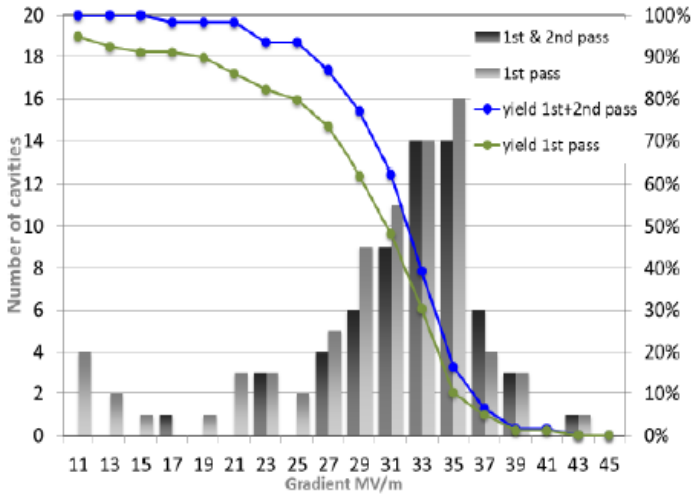
XFEL Linac: the ultimate 'integrated systems test' for ILC

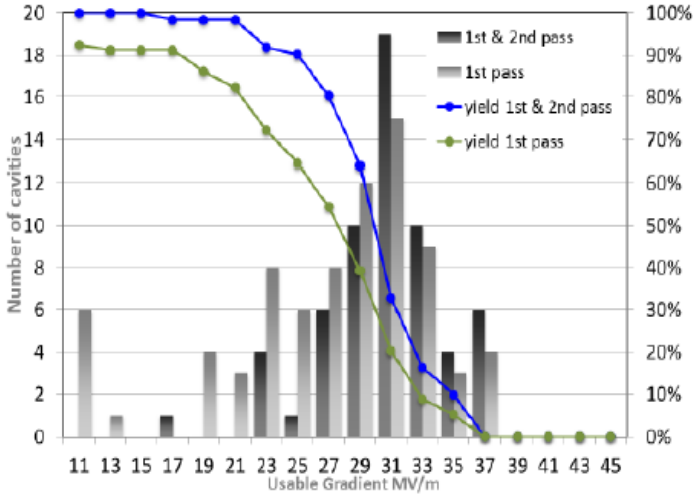
→ Commissioning with beam: beginning of 2016

Industrial Mass Production of SRF Cavities for EU - XFEL

- 800 XFEL SRF cavities for XFEL at DESY (5% of ILC @500 GeV)
  → unique statistical sample to study properties of mass-produced cavities

- Industrial production (RI, ZANON) yields gradients > 23.5 MV/m (XFEL spec)
  Yield of usable maximum gradient of 64 cavities (status as of Sep. 2013)
  → 50 cavities passed in 1st test + 14 cavities after re-treatment (2nd pass)





Average **maximum** gradient:
(30.9 ± 4.4) MV/m
EZ: (30.4 ± 4.5) MV/m
RI: (32.3 ± 4.1) MV/m

ILC Recipe:

Average **usable** gradient:
(29.0 ± 3.9) MV/m
EZ: (28.4 ± 4.0) MV/m
RI: (30.6 ± 3.1) MV/m

Status of May 2014:

~ 300 XFEL cavities were produced by EZ, RI → similar gradient performance

D. Reschke, SRF 2013 TTC 2014

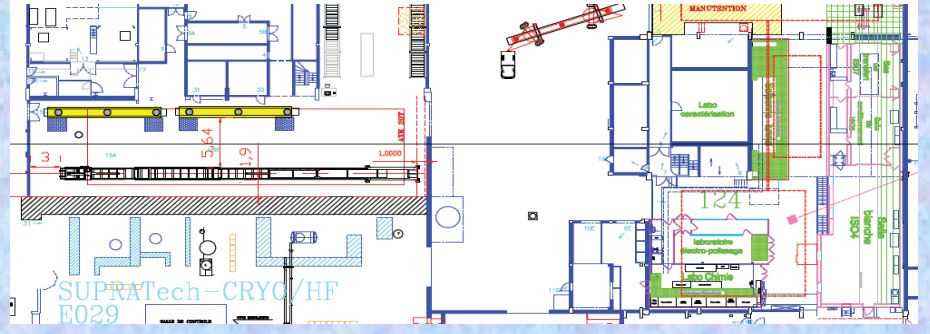
- 24 ILC-HiGrade cavities (http://www.ilc-higrade.eu) added to mass production of XFEL cav.
  → detailed studies of performance limitations (optical inspection of defects, quench localization), development of optimized post- processing methods to improve maximum field

Cryomodule Assembly Line for EU–XFEL at CEA-Saclay

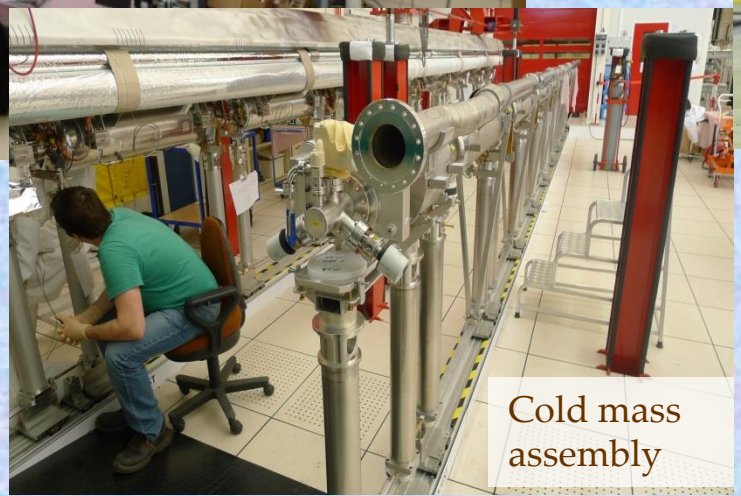
- Assembly of 103 ("ILC-like") cryomodules operated by an industrial contractor using CEA Saclay infrastructure
  → goal to deliver 1 module per week to DESY for RF acceptance

- Status as of May 2014:
  → 6 modules delivered & 3 tested
  → 7 modules in the production line

"XFEL Village":
→ optimized by breaking down the assembly work in 7 successive blocks of one-week procedures

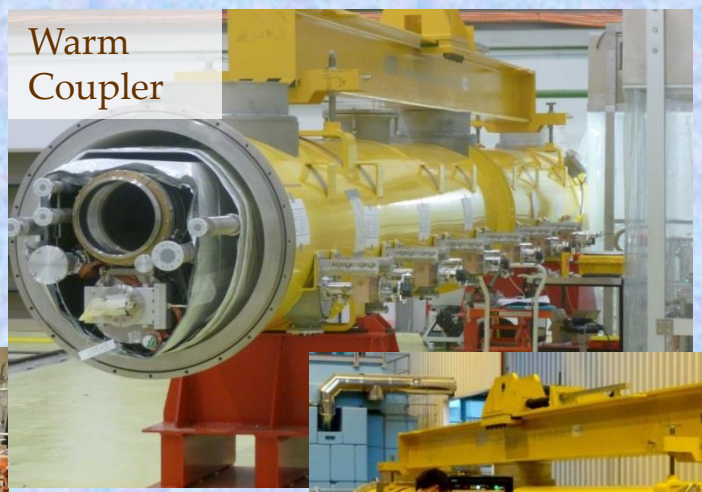


Two strings assembly



Cold mass assembly

Warm Coupler



Shipment

Cryomodule Assembly Line for EU–XFEL at CEA-Saclay

The XFEL cryomodule production is beneficial for ILC

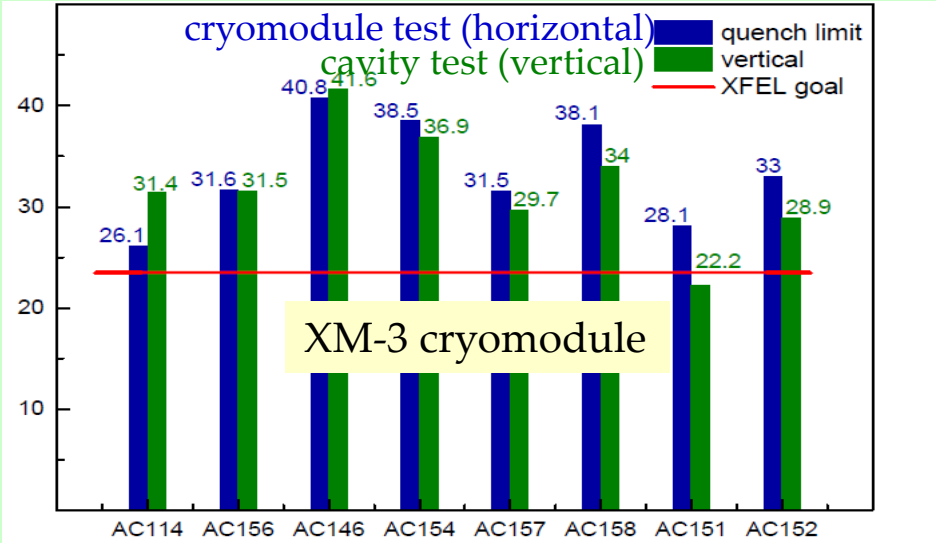
→ building expertize and infrastructure in EU labs, networking EU industries, reliable costing

- Industrialization of production (2008-2016)
- ILC cryomodule demonstration (2013)
- XFEL linac system test (2016 on)
- Infrastructures for 'EU Hub' for ILC cryomodule prod. available in 2016 (used when needed)

- Two figures of merit: quality of cavity (max. operating gradient); quality of assembly (difference in operating gradient between vertical cavity test and after assembly into cryomodule)

XM-3 cryomodule: fulfills "ILC Specifications"

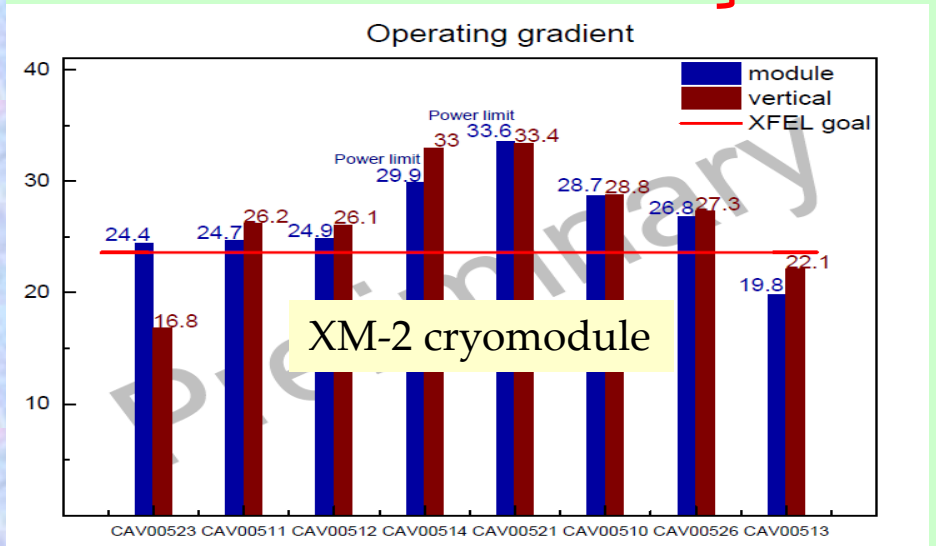
- Aver. gradient: ~32 MV/m (before and after assembly)
- 3 cavities reach gradients above 38 MV/m
- Cryogenics losses are low: Q0 ~ 3e10



XM-2: select cavities with little margin on top of XFEL gradient specifications

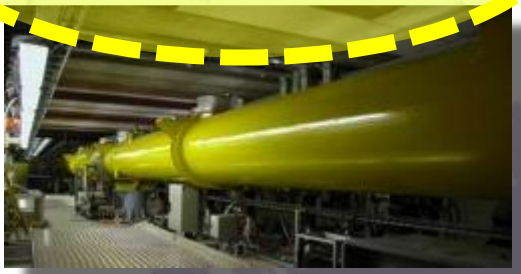
- Vert. cavity test average: 25,8 MV/m
- Cryomodule test average: 24,5 MV/m
- XFEL spec. 23.6 MV/m

XFEL OK



Global Cooperation for ILC Accelerator: Cryomodule Development & System Tests

TTF/FLASH (DESY) ~1 GeV
ILC-like beam
ILC-RF unit (* lower gradient)



STF / STF2 (KEK)
Quantum Beam experiment
ILC Cryomodule Test: S1-Global

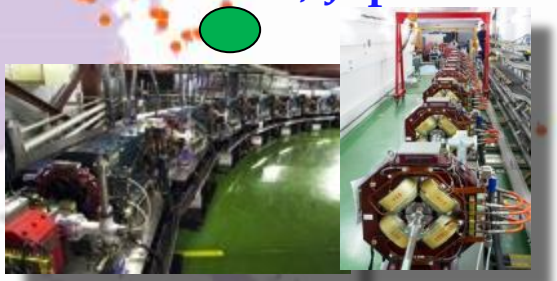
CesrTA (Cornell)
electron cloud
low emittance

DESY

INFN Frascati

DAfNE (INFN Frascati)
kicker development
electron cloud

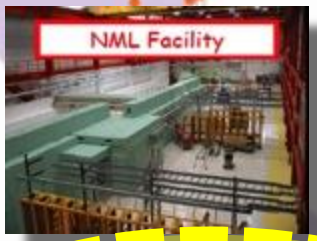
KEK, Japan



ATF & ATF2 (KEK)
ultra-low beam emittance
final focus optics

KEKB electron-cloud

FNAL **Cornell**



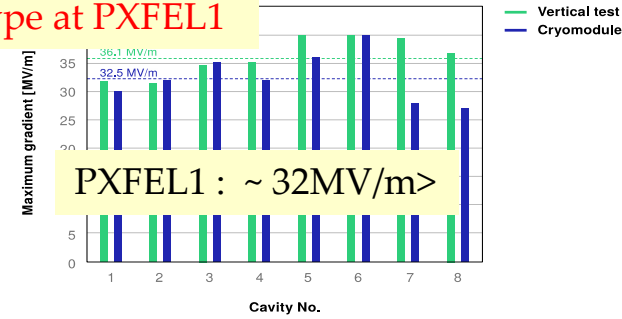
NML /ASTA (FNAL)
ILC RF unit test

Worldwide Cryomodule Development and System Tests

DESY: FLASH

- 1.25 GeV linac (TESLA-Like tech.)
- ILC-like bunch trains:
- 600 μs, 9 mA beam (2009);
  800 μs 4.5 mA (2012)
- RF-cryomodule string with beam
  → PXFEL1 operational at FLASH

XFEL Prototype at PXFEL1

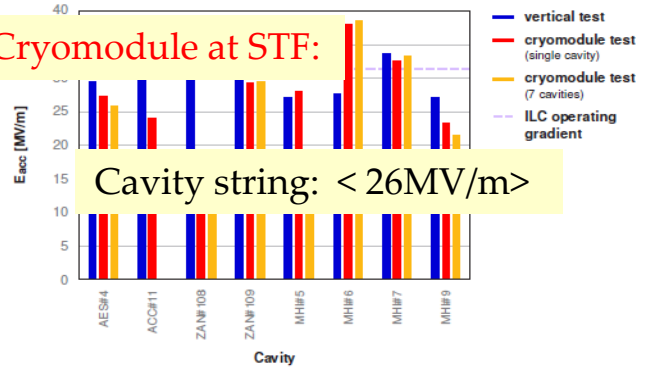


PXFEL1 : ~ 32MV/m>

KEK: SRF Test Facility (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

S1 Global Cryomodule at STF:

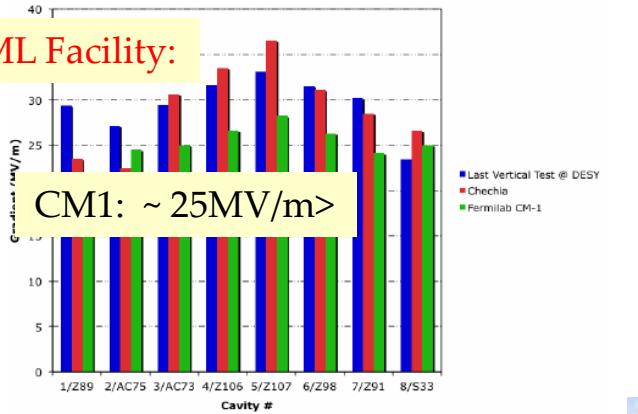


Cavity string: < 26MV/m>

FNAL: NML (New Muon Lab) / ASTA (Advanced Superconducting Test Accelerator)

- CM1 test complete
- CM2 operation (2013)
- CM2 with beam (planned in future)

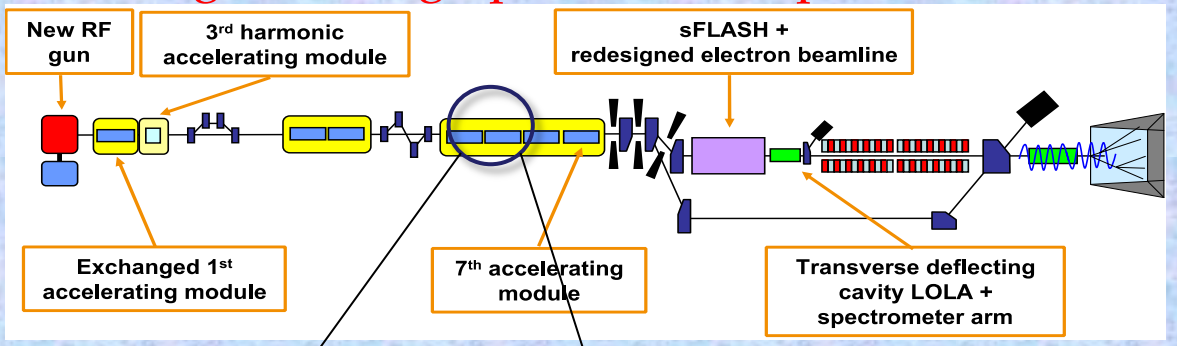
CM1 at NML Facility:

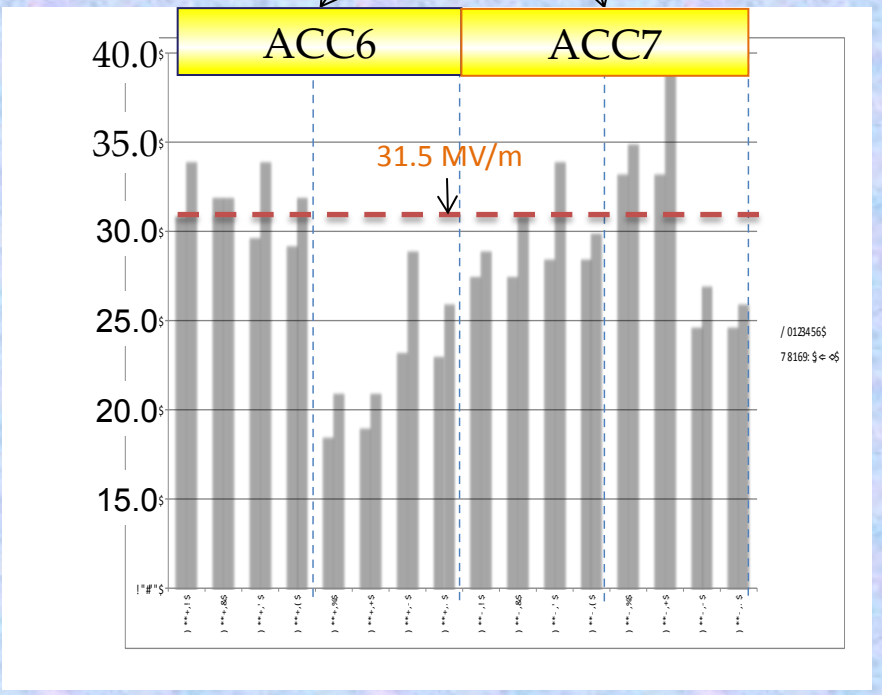


CM1: ~ 25MV/m>

FLASH @ DESY: System Tests for ILC (and XFEL)

Long-standing operational expereince:



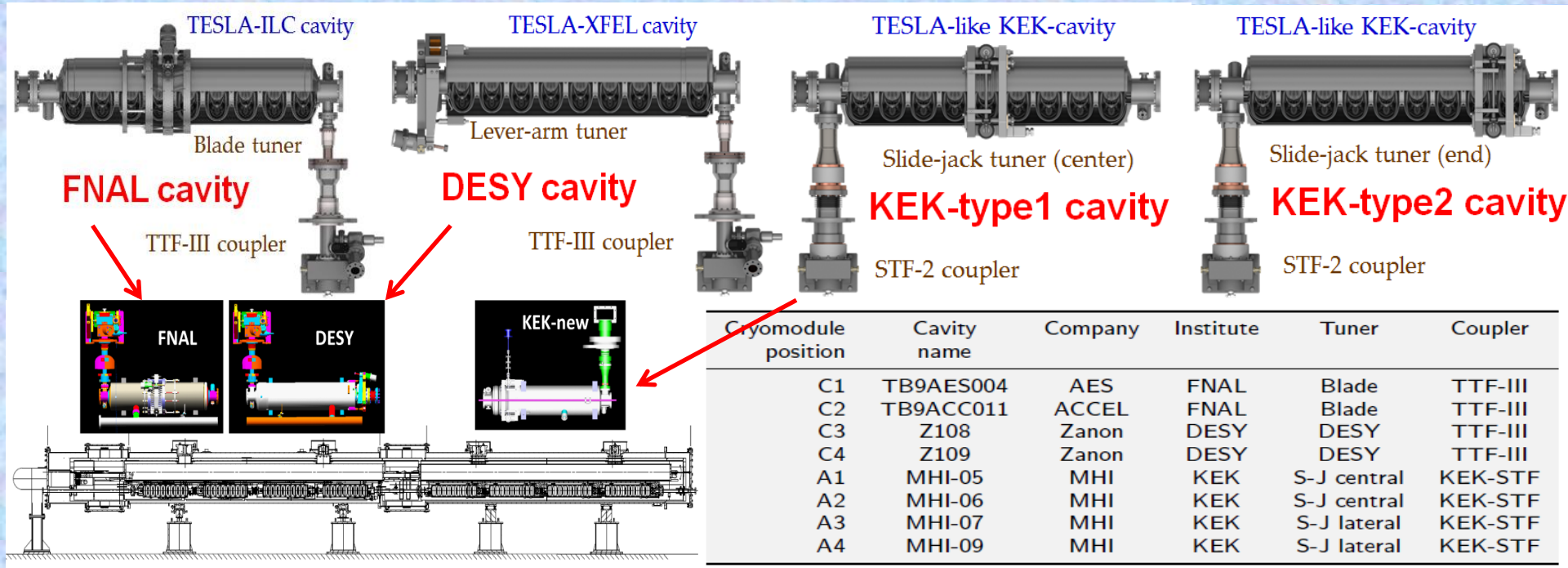


- ✓ ILC-like beam (3, 6 and 9mA)
- ✓ Energy stability (<10^{-3})
- ✓ Control of heavy beam loading
- ✓ Control of cavity Lorentz force detuning
- ✓ Active tuning for large gradient spread operation
- ✓ Operation close to quench limits
  - ✓ Automated quench protection systems
- ✓ Controls development (low-level RF)
- ✓ Klystron control overhead evaluation
- ✓ General operations related:
  - ✓ Fast (automated) trip recovery
  - ✓ Dealing with beam loss (protection systems)

- ➢ Runs 24/7 as VUV SASE user facility
- ➢ Primary SRF systems tests for ILC TDR (dedicated 9mA experiment runs)

S1-G Program at KEK: Global Cooperation to Demonstrate SRF System

- Demonstrate "plug compatibility" concept – integrate cavities and hardware components (i.e. parts which must be compatible but not necessarily identical) delivered by DESY, FNAL, INFN and KEK into a S1-G Cryomodule within a single integrated set-up



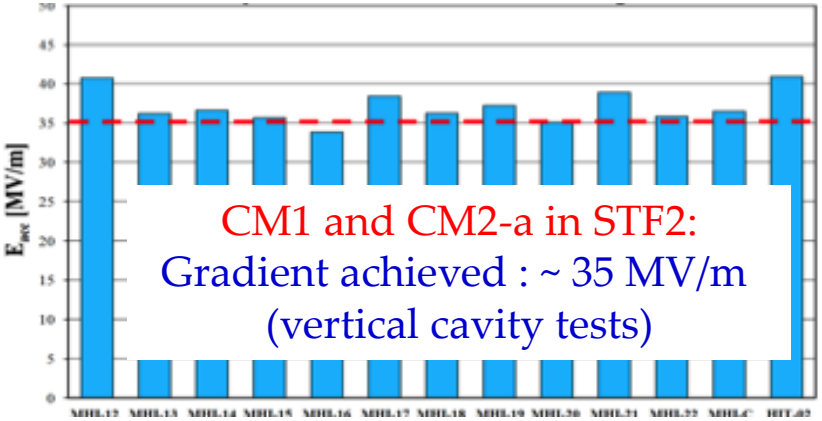
Cryomodule position	Cavity name	Company	Institute	Tuner	Coupler
C1	TB9AES004	AES	FNAL	Blade	TTF-III
C2	TB9ACC011	ACCEL	FNAL	Blade	TTF-III
C3	Z108	Zanon	DESY	DESY	TTF-III
C4	Z109	Zanon	DESY	DESY	TTF-III
A1	MHI-05	MHI	KEK	S-J central	KEK-STF
A2	MHI-06	MHI	KEK	S-J central	KEK-STF
A3	MHI-07	MHI	KEK	S-J lateral	KEK-STF
A4	MHI-09	MHI	KEK	S-J lateral	KEK-STF

Prior to assembly into cryomodules, cavities/tuners/couplers were tested by contributing laboratory

Worldwide Cryomodule Development: a Few Highlights from 2014 ALCW

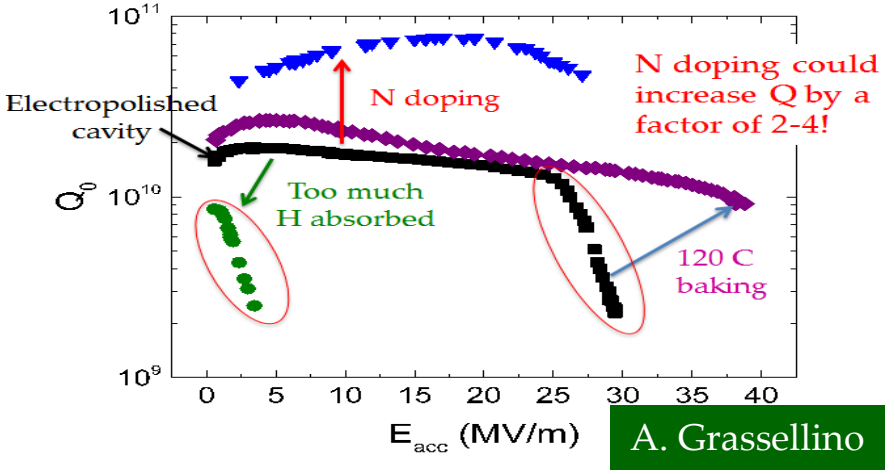
Further System Developments at KEK:

- ❖ STF2 accelerator : Quantum Beam
  → ILC Full-Cryomodule Test
  - ➢ Multiple CM for system study
  - ➢ In-house cavity to be installed in cooperation with industry
  - ➢ Wide range application incl. photon science

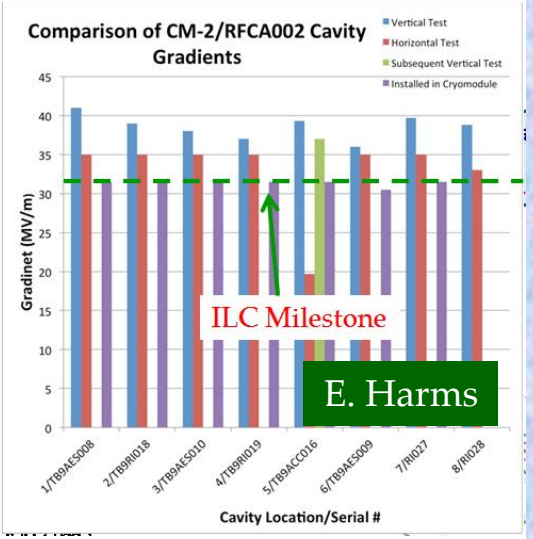


Recent Results at FNAL:

- ❖ Cavity R&D: Nitrogen-doped niobium
  → potential benefit for power consumption

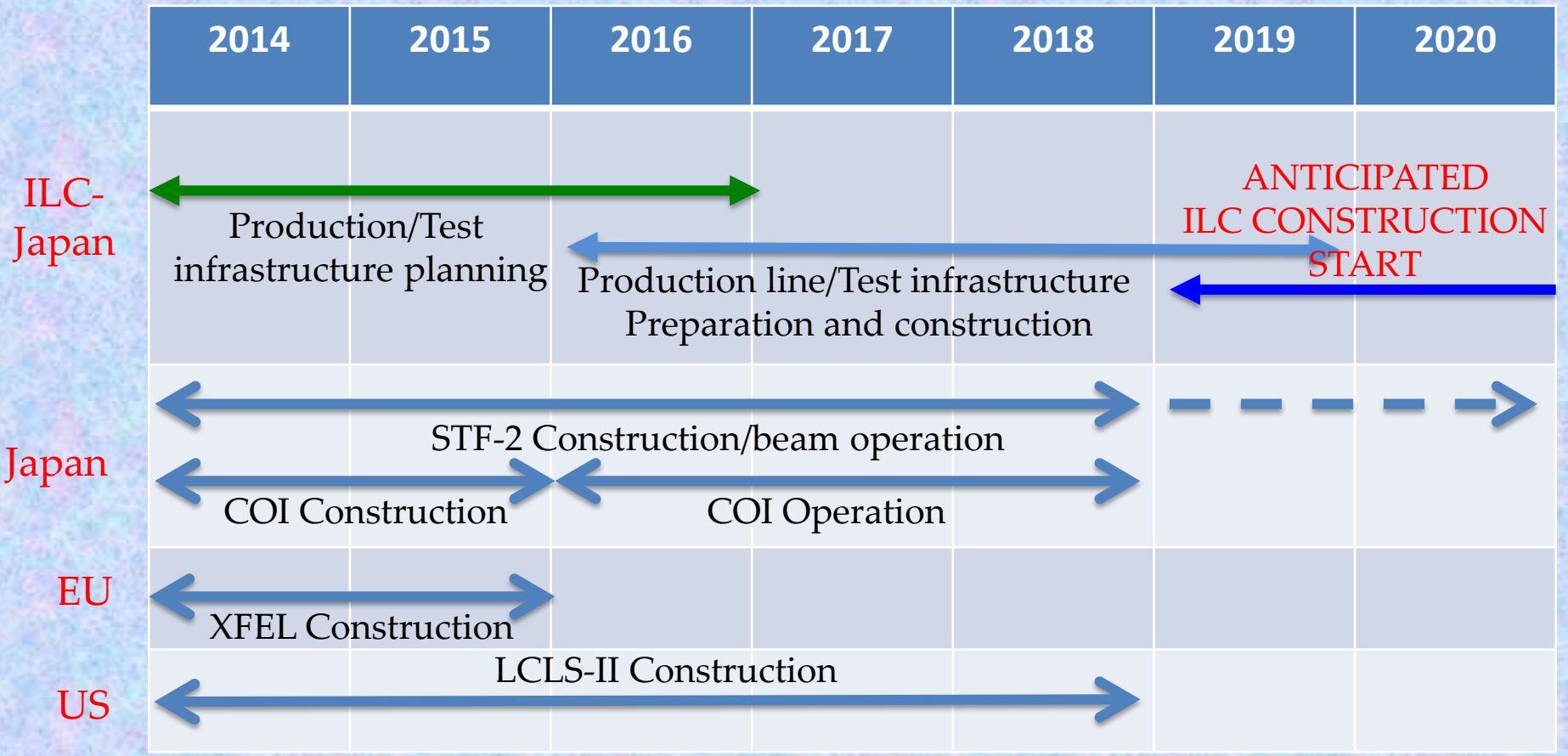


- ❖ CM2: First "ILC-type" cryomodule assembled at FNAL → accelerating device for ASTA



The SRF Technology - Global Cryomodule Development Timeline

Timeline is realistic from a technical point of view



- A solid SRF technological base for the ILC on a global scale is now in place (in cooperation with industry)
  - → EU: XFEL Construction at DESY
  - → US: Future LCLS-II Construction at SLAC
  - → Japan: STF/Center of Innovation (COI); Development of ILC-Hub laboratotry at KEK
- Will bring major worldwide labs in the realm of cryomodule production

Global Cooperation for ILC Accelerator: Beam Demonstration

TTF/FLASH (DESY) ~1 GeV
ILC-like beam
ILC-RF unit (* lower gradient)

DESY

INFN Frascati

DAfNE (INFN Frascati)
kicker development
electron cloud

STF / STF2 (KEK)
Quantum Beam experiment
ILC Cryomodule Test: S1-Global

KEK, Japan

ATF & ATF2 (KEK)
- Ultra-low beam emittance
- Final focus optics

KEKB electron-cloud

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low emittance

FNAL **Cornell**

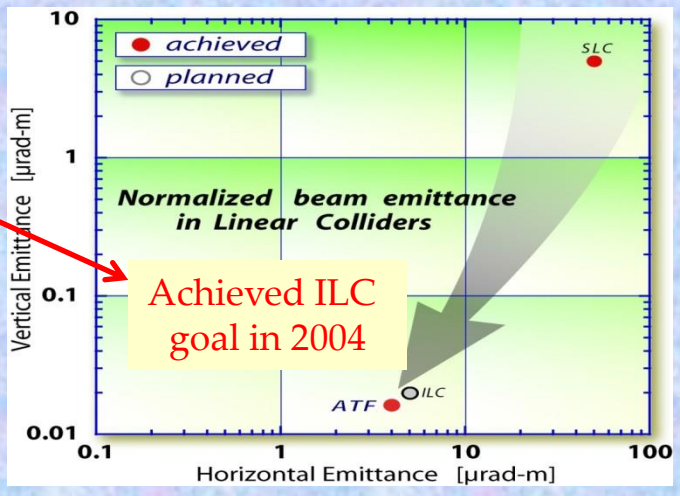
NML /ASTA (FNAL)
ILC RF unit test

Accelerator Test Facility (ATF2 at KEK)

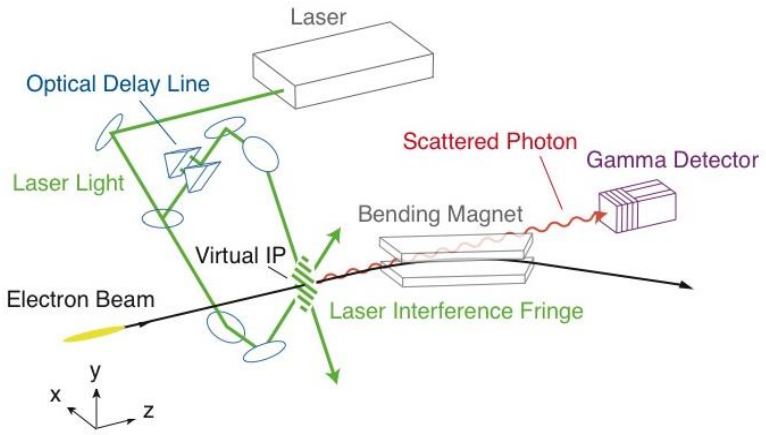
Unique Facility - nanobeam handling technology (stabilization and final beam focus) as a common subject for both ILC and CLIC, through ATF collaboration (http://lcdev.kek.jp/ATF2/)

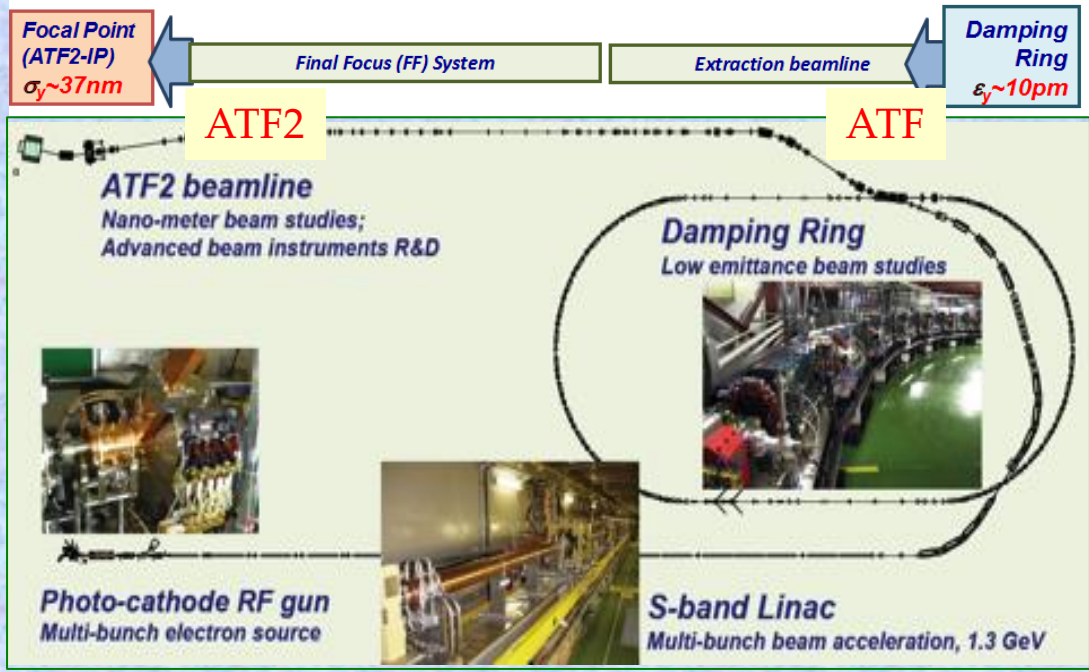
Optics is scaled down version of the ILC design:

- ATF prototype damping ring: create and preserve small emittance beams during acceleration/transport
- ATF2 final focus test-beam line:
  → produce small beam size: achieve 37 nm IP vertical size
  (37 nm at 1.3 GeV(ATF2) corresponds to 5.7 nm at 250 GeV(ILC))
  → demonstrate beam trajectory stabilization at nm scale



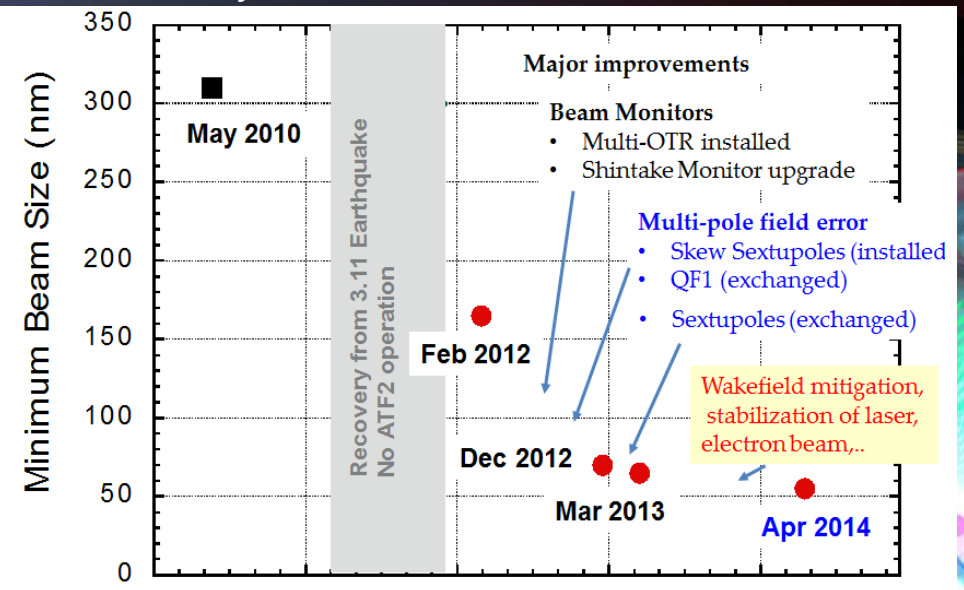
- IP beam position monitor (IPBPM) is based on inverse Compton scattering between the electron beam and a laser interference fringe pattern (Shintake monitor)





ATF2: Final Focus Test Beamline

History of ATF2 minimum beam size:



Further improvement will be reported by the ATF2 collaboration at the IPAC14 N. Terunuma

Beam trajectory stabilization with nm precision:

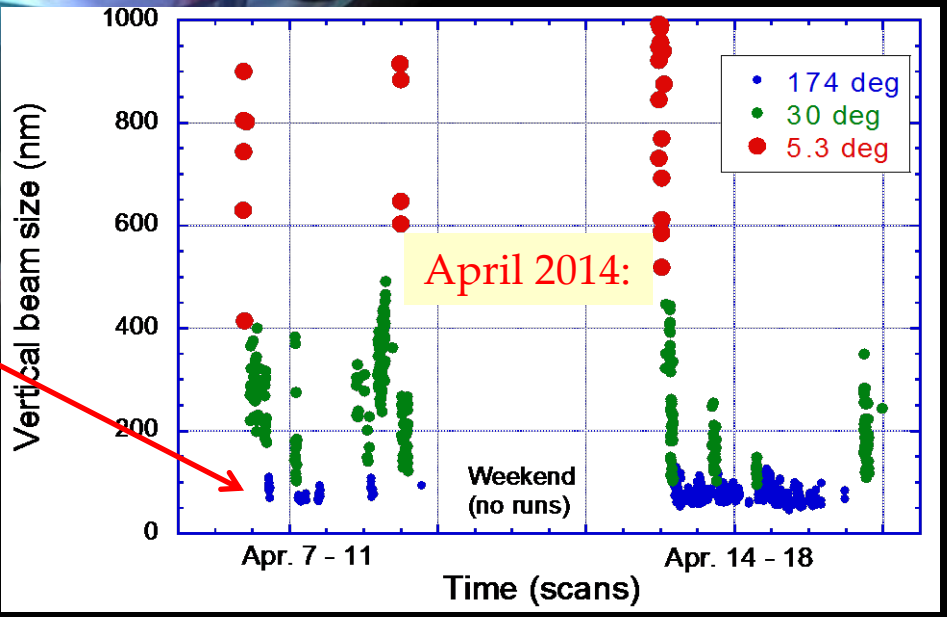
- April 2014: routinely reach < 60 nm vertical beam size (low intensity)
- Future Goals:

→achieve beam size of 37 nm
(beam-size monitor improvement required; optics for final focusing needs to be established)

→achieve beam stability of a few nm and ILC-like intra-train feedback
(instrumentation improvement to reach IPBPM resolution of 2 nm in the 2 ~ 3 years)

Major improvements in beam-size tuning:

- Quick recovery of beam size down to < 60 nm (in less than 1 day)
- Good reproducibility (after machine is off for an extended period of time)

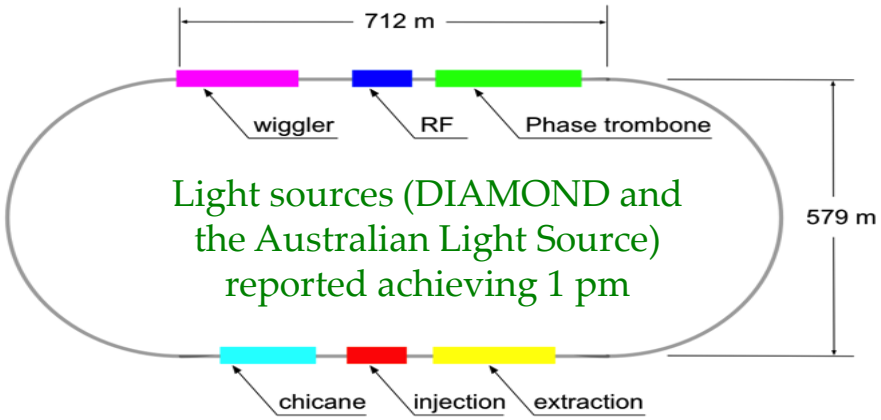


Damping Rings

- "STATE-OF-THE-ART" DAMPING RINGS:
  → Capable of storing a full train (1312 bunches) and reduce emittance by 6 orders of magnitude within the 200 ms (100 ms in the 10 Hz mode)

- Addiabatic emittance damping → physical emittance shrinks as 1/E → beam size as 1/sqrt (E)

Low emittance has been demonstrated by ATF:
(4pm vertical emittance at 5 GeV !)



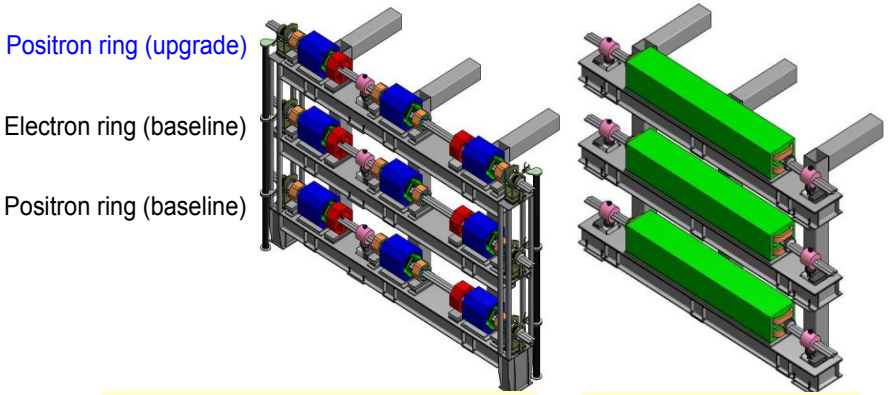
Light sources (DIAMOND and the Australian Light Source) reported achieving 1 pm

Damping Ring parameters for 3 scenarios:
(5 Hz: baseline /High Lumi Upgrade; 10 Hz: baseline)

Parameter	5 Hz Mode		10 Hz Mode	
	Low Power	High Lumi	Positrons	Electrons
Circumference [km]	3.238		3.238	
Number of bunches	1312	2625	1312	
Particles per bunch [$\times 10^{10}$]]	2	2	2	
Maximum beam current [mA]	389	779	389	
Transverse damping time τ_x, τ_y [ms]	23.95		12.86	17.5
Longitudinal damping time τ_z [ms]	12.0		6.4	8.7
Bunch length σ_z [mm]	6.02		6.02	6.01
Energy spread σ_E/E [%]	0.11		0.137	0.12
Momentum compaction factor α_p [$\times 10^{-4}$]	3.3		3.3	
Normalized horizontal emittance $\gamma\epsilon_x$ [μm]	5.7		6.4	5.6
Horizontal chromaticity ξ_x	−51.3		−50.9	−51.3
Vertical chromaticity ξ_y	−43.3		−44.1	−43.3
Wiggler Field [T]	1.51		2.16	1.81
Number of Wigglers	54		54	
Energy loss/turn [MeV]	4.5		8.4	6.19
RF Specifications:				
Frequency [MHz]	650		650	
Number of cavities	10†	12	12	
Total voltage [MV]	14.0		22.0	17.9
Voltage per cavity [MV]	1.40	1.17	1.83	1.49
RF synchronous phase [°]	18.5		21.9	20.3
Power per RF coupler [kW]‡	176	294	272	200

† The baseline RF deployment for positrons is 12 cavities to support 5 and 10 Hz modes.
‡ Power/coupler computed as (Max. Current) × (E loss/turn)/(No. cavities).

High-Lumi: doubling of current (# of bunches) poses a concern for the e+ DR (electron-cloud instability) → possibility to install 2nd positron ring (only if needed - "risk mitigation")



Arc-quadrupole section

Dipole section

Similarities to modern 3rd-generation light sources
→ still remains major "engineering challenge"

Electron and Positron Sources

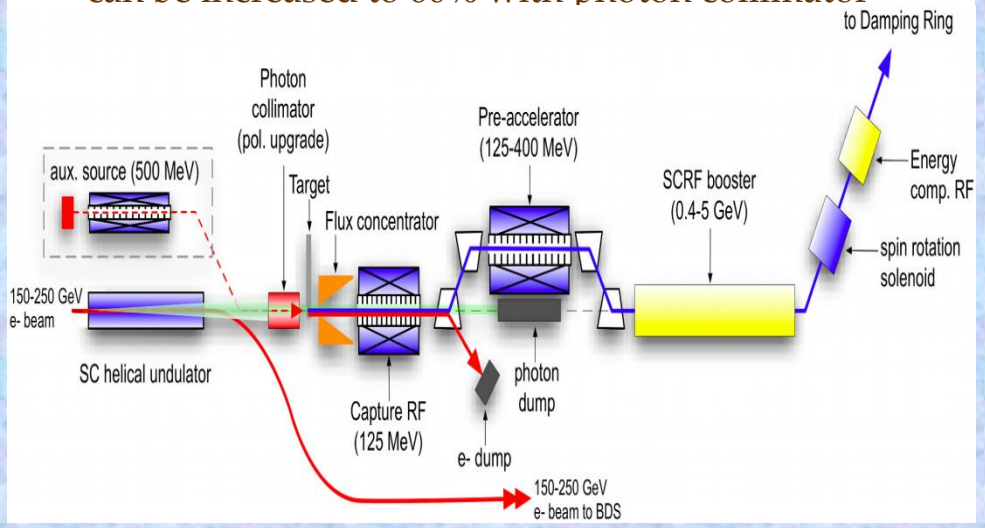
Electron source (Baseline):

- Titanium-sapphire laser emits 2-ns pulses that knock out electrons from NEA GaAs photocathode
- Ready for Detailed Technical Design.

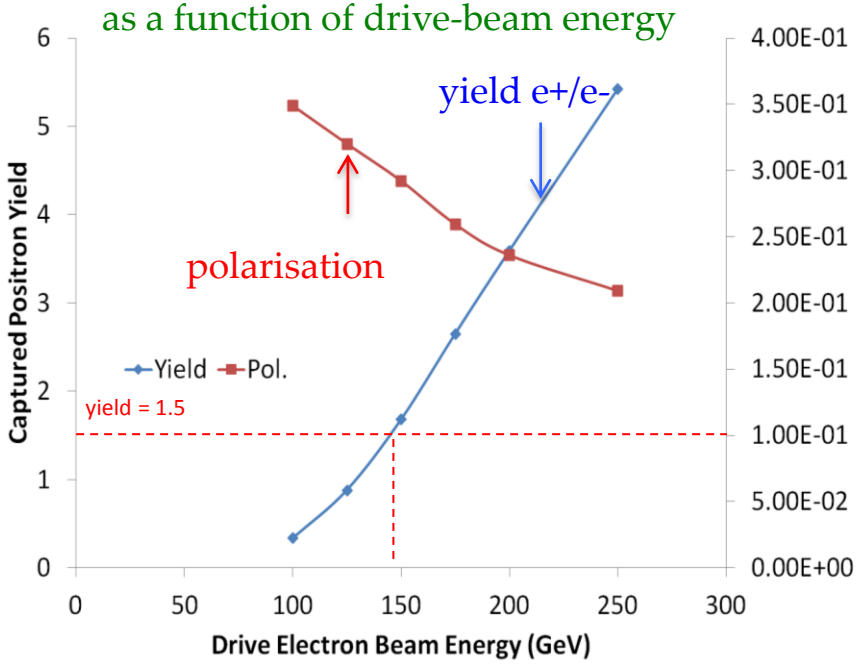
Positron Source (Baseline)

Polarized undulator - driven e+ source

- Electron beam (150 -250 GeV) goes through a ~ 200m helical undulator ring (end of electron main linac) producing ~ 30 MeV photons
- Photon beam strikes a 1.4 cm thick Ti-alloy rotating target to produce e+e- pairs
- Undulator generates circularly polarised photons which create longitudinally (~30%) polarized e+ → can be increased to 60% with photon collimator



Positron source yield and polarisation as a function of drive-beam energy



Positron source (Alternative options): both independent from electron beam used for collisions:

Back-up (conventional): 6 GeV e- beam on W-Re target (non-polarized beam) → under development

Future: Laser-Compton-based polarised Positron source (polarization achieved by inverse-Compton scattering between electrons and a laser) → basic R&D stage

Global Cooperation for ILC Accelerator: Electron Cloud Instability

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ILC-like beam
ILC-RF unit (* lower gradient)

DESY

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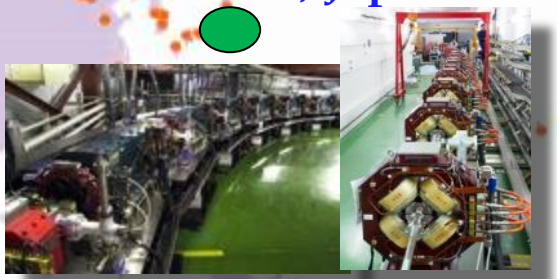
KEK, Japan



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final focus optics

KEKB electron-cloud

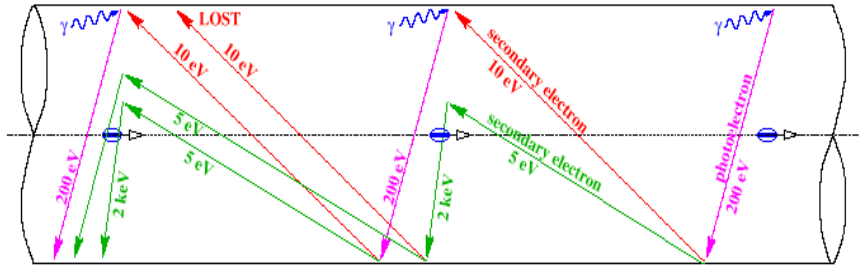
CesrTA (Cornell)
❖ Electron cloud
low emittance

FNAL **Cornell**

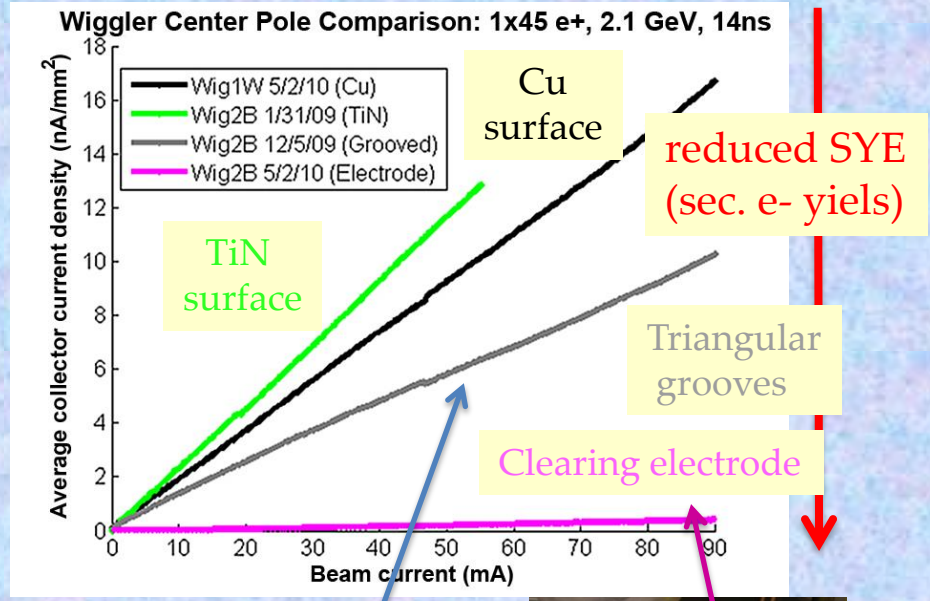
NML /ASTA (FNAL)
ILC RF unit test

Critical R&D: Electron Cloud Instability

CESR, Cornell: wide range of energies (1.8-5.3 GeV, e-/e+), bunch spacings and intensities → systematic studies of primary photoelectron and secondary electron contributions to electron-cloud build-up → instabilities and incoherent emittance growth

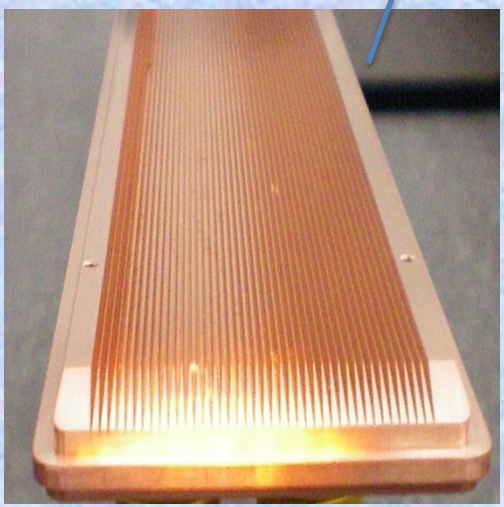


CESR, Cornell: Extensive diagnostics to study the growth and mitigation of the electron cloud in the wiggler vacuum chamber:



Mitigation techniques for ILC positron damping ring (optimum performance & pursue high current option):

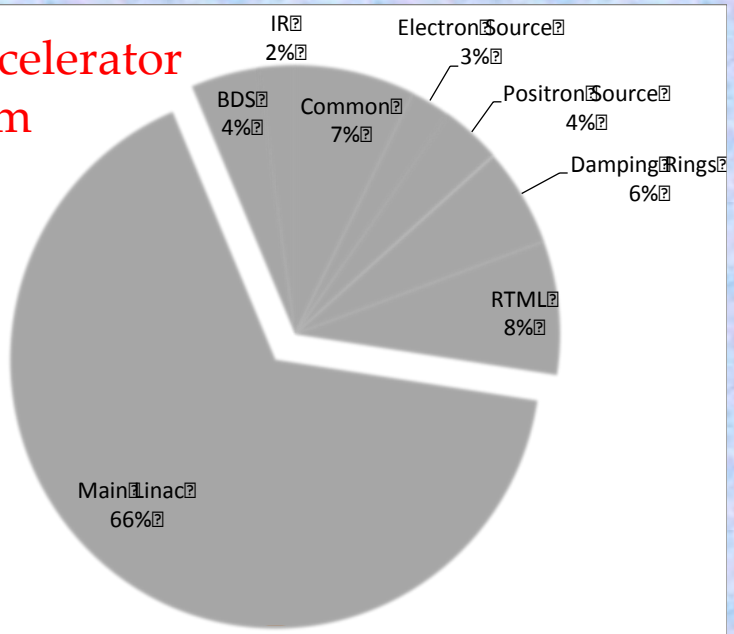
Field Region	Mitigation Recommendation		Alternatives for Further Study
	Primary	*Secondary*	
Drift†	TiN Coating	Solenoid Windings	NEG Coating
Dipole	Triangular Grooves with TiN Coating	Antechambers for synchrotron radiation power loads and photoelectron control	R&D into the use of clearing electrodes
Quad†	TiN Coating		R&D into the use of clearing electrodes or grooves with TiN coating
Wiggler	Clearing Electrode	Antechambers for synchrotron radiation power loads and photoelectron control	Grooves with TiN coating



Electron-Cloud R&D at other laboratories: PEP2/KEKB (different materials/coatings, clearing electrode), INFN Frascati (clearing electrode), CERN SPS (carbon films)

ILC TDR Value Estimate

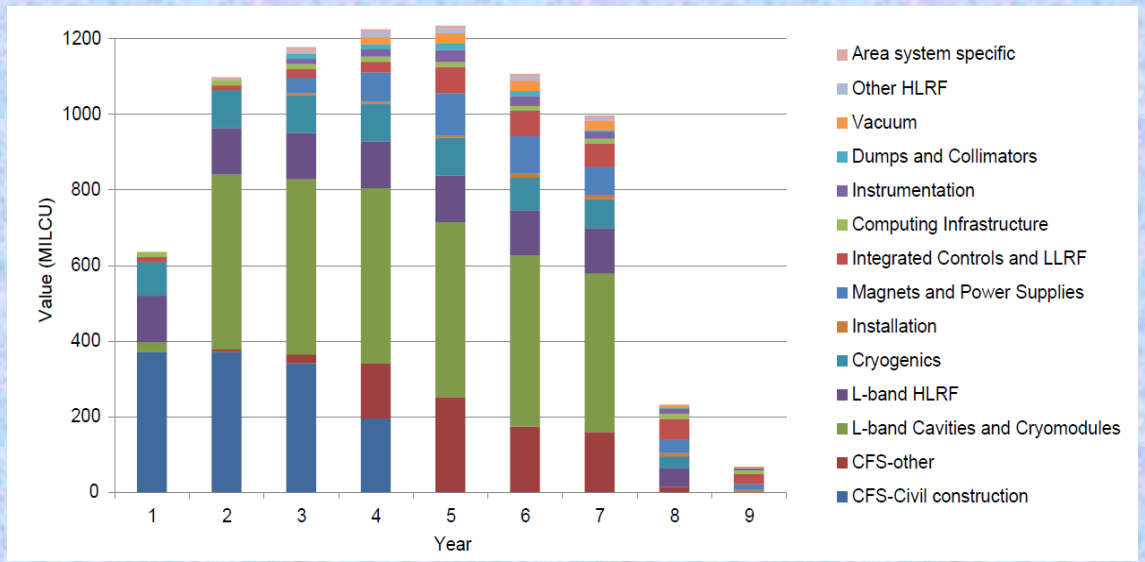
By accelerator system



Average project cost (site-independent):

- 7.8 Billion ILCU
- 22.6 Million person-hours

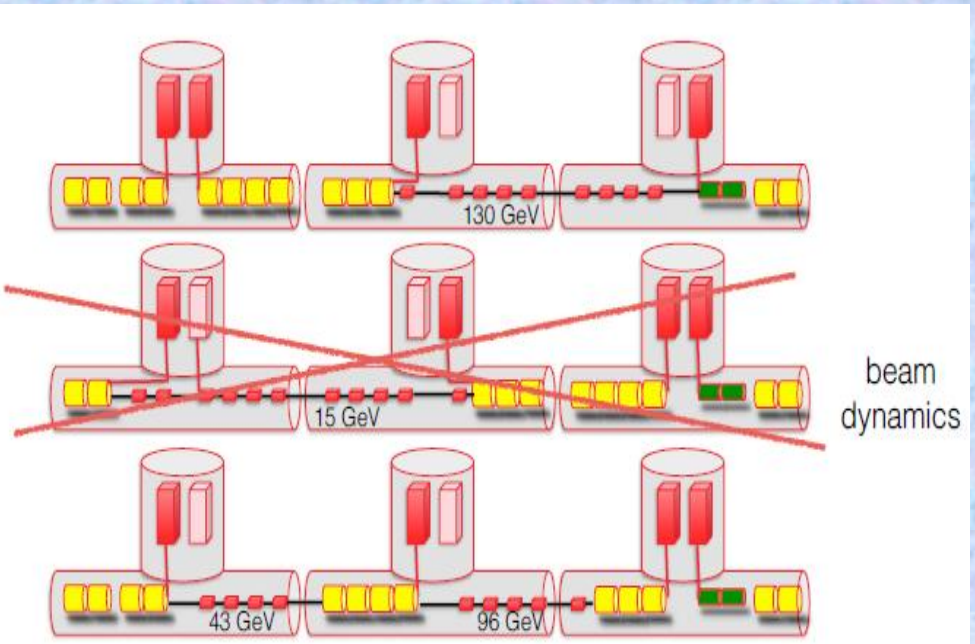
Budget profile vs project year:



- 60% of the cost is in the main linac components

Energy Staging Scenarios and ILC Timeline

Proposed by the JAHEP → being evaluated by the LCC



- Start with a Higgs Boson Factory 250 GeV:
  - → 50% of cryomodules, klystrons, modulators, 60% cryoplants
  - → 100% of sources, damping rings, BDS
- Upgrade up to ~ 500 GeV (TDR baseline)
  - → install remaining linac components
- Technical extendibility of energy staging to ~ 1 TeV has to be secured.

ILC Timeline: →

Progress and Prospect

THE INTERNATIONAL LINEAR COLLIDER
FROM DESIGN TO REALITY

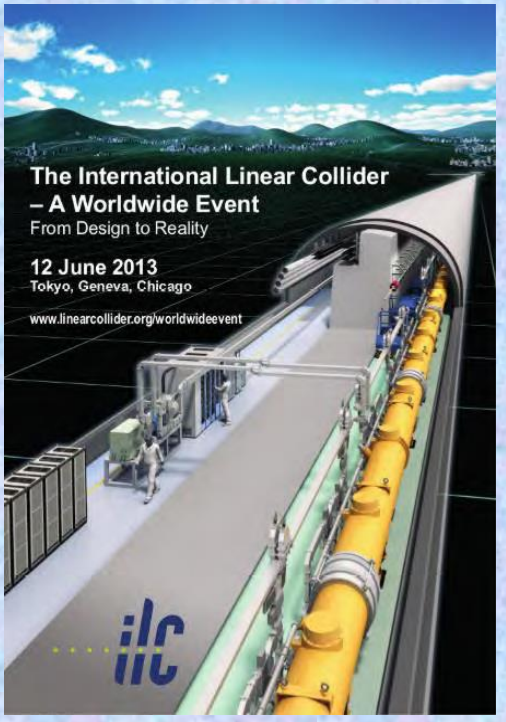
International Linear Collider in Japan,

The First Global HEP Project in Asia

Kitakami promotion videos:
http://www.pref.iwate.jp/seisaku/suishin/ilc/024538.html

June 12, 2013: Official Completion of ILC TDR
"A World-Wide Event – From Design to Reality"

https://agenda.linearcollider.org/conferenceOtherViews.py?view=standard&confId=6004

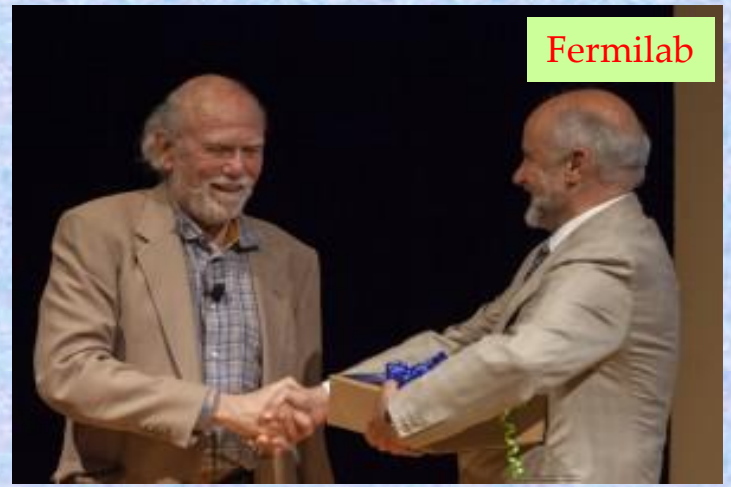


ILC TDR published in a Worldwide Event: Tokyo → Geneva → Chicago

- As compared to other projects of a similar scale (ITER, LHC, ATLAS, CMS, ALMA, XFEL, FAIR, ESS, SSC) the quality of the TDR documentation presented by the GDE team is equal or superior to that utilized to launch into a similar process

→ THE ILC IS "READY TO GO AHEAD" !

TDR handed to LCC Director Lyn Evans



The Way Forward

The ILC is a Global Project, to be designed and constructed by a worldwide cooperation of scientists and engineers

The TDR is the evidence that the ILC can be built now within "carefully estimated envelope" based on the real EU-XFEL@DESY project costs

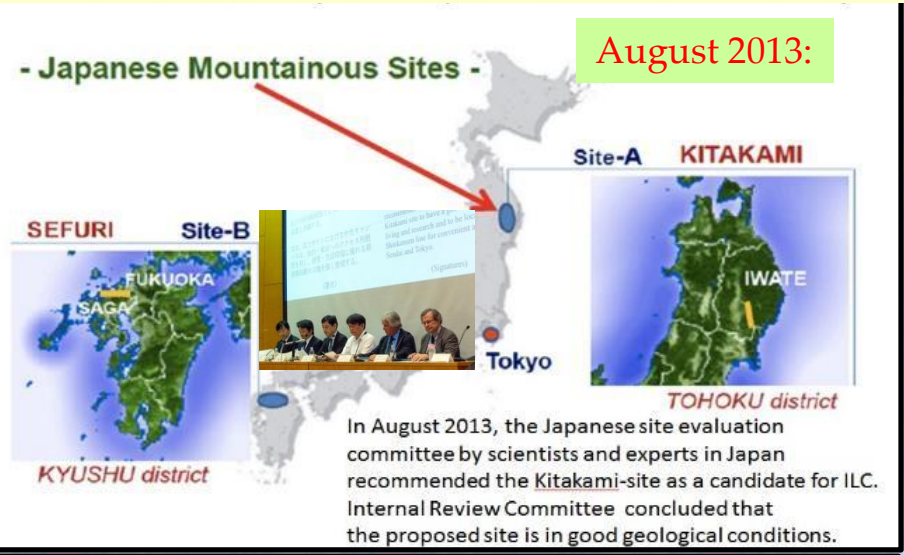
Today, launching the project (= ILC approval by governments) has the highest priority

→ We need to make sure that we can launch the project GLOBALLY

→ We need a VISION, STRATEGY and HARD WORK to materialize our belief

The Way Forward: Recent ILC Progress in Japan

❖ The candidate site is unified by the Japanese HEP



In August 2013, the Japanese site evaluation committee by scientists and experts in Japan recommended the Kitakami-site as a candidate for ILC. Internal Review Committee concluded that the proposed site is in good geological conditions.

❖ Japanese government makes a move

Japan's House of Representatives room.

December 24, 2013:

MEXT (not researchers) requested $0.5M for ILC → approved in Dec. 2013

❖ Japanese government allocates "investigation budget" for the ILC as an official project (for the first time)

❖ KEK sets up Planning Office for the ILC

ILC Project Preparation Office
Director: KEK-DG

Deputy Director

ILC Project Unit
Advanced R&D and Engineering Design

Coordination Unit
Coordination and Integration of Internal / External Efforts

Development anticipated:

KEK Organiation (2014)
→ All-JP Organization
→ Global Org. (2015)

February 6, 2014:

❖ Oversight a broad range of activities required for ILC realization

❖ Expert committee has been setup under MEXT:

Task Force

Academic Experts Committee

Particle・Nuclear Physics WG

TDR Validation WG

Kick-off Meeting: May 8, 2014

❖ Investigate the reliability on hosting the ILC in Japan (report to be completed in FY 2015)

The Way Forward: Japan Started High Level International Discussions

Positive Reference from Japan Prime Minister

April 30,2013: US-Japan Symposium in Washington D.C

100 invited participants from US-Japan (each ~50 persons) from HEP researchers, industry, political and government

US-Japan Advanced Science and Technology Symposium

This symposium gathers US and Japanese leaders from policy makers for the field of science and innovation, academia and industry. [illegible]ission will cover the US-Japan co-operati[illegible]he realization of economic growth as well as methods and policies for the development of scientific and technical human resources.

With the ILC as an example, …

Next meeting – July 2014

MEXT MINISTRY OF EDUCATION, CULTURE, SPORTS, SCIENCE AND TECHNOLOGY-JAPAN

Jan. 2014: MEXT Minister, Japan to Secretary of Energy, USA:

Dr. Ernest Moniz
Secretary of Energy
Department of Energy
1000 Independence Ave. SW
Washington DC 20585
United States of America

February 7, 2014

Dear Secretary Moniz,

It was a great pleasure to talk with you when I visited the United States recently. In our conversation, I explained the current situation regarding the International Linear Collider (ILC) project in Japan, and I would like to reiterate what I said through this letter.

It was a great pleasure to talk with you when I visited the United States recently. In our conversation, I explained the current situation regarding the International Linear Collider (ILC) project in Japan, and I would like to reiterate what I said through this letter.

Researchers in the United States, Europe and Japan have been discussing and continuing their R&D with enthusiasm in the ILC project. Considering the significance and benefit of the ILC project, I believe that discussion from a wider perspective is essential. For this, I recognize that working-level informal exchanges of views among Japan, the United States and / or Europe should be started from the current stage.

However, the priorities for academic and scientific projects and the financial status vary between the countries. Therefore, for making a decision of whether or not to join the ILC project, discussion and sharing of the consensus about the scientific significance and challenges between government and scientists in each country that is interested in the ILC project is indispensable. I understand that the project prioritization process in the field of particle physics in the United States is ongoing. The United States is one of the leading countries in the field of particle physics research in the world, and I hope that substantial

→ Similar letters from MEXT were sent to: CERN DG and European Government

The Way Forward: ILC International Support

Building for Discovery

Strategic Plan for U.S. Particle Physics in the Global Context

DRAFT FOR APPROVAL

US P5 Report Released May 22, 2014:

Rec. #1 ("HEP Global Nature") →

"Pursue the most important opportunities wherever they are …"

Report of the Particle Physics Project Prioritization Panel — May 2014

Project/Activity	Scenario A	Scenario B	Senario C
Large Projects			
Muon program: Mu2e, Muon g-2	Y, Mu2e small reprofile needed	Y	Y
HL-LHC	Y	Y	Y
LBNF + PIP-II	Y, LBNF components delayed relative to Scenario B.	Y	Y, enhanced
ILC	R&D only	R&D, possibly small hardware contributions. See text.	Y
NuSTORM	N	N	N
RADAR	N	N	N

- ❖ Japan is expressing growing interest in hosting the ILC (substantial resources could enter the project)

- ❖ European Strategy for Particle Physics (2013)

- There is a strong scientific case for an electron-positron collider, complementary to the LHC … and whose energy can be upgraded … The European groups are eager to participate.

- ❖ US Particle Physics Prioritization Panel (P5 Report) (May 2014)

- Motivated by the strong scientific importance of the ILC …
… 'Play a world-leading role in the ILC experimental program and provide critical expertise and components to the accelerator, should this exciting scientific opportunity be realized in Japan.'

- Participation by the U.S. in ILC project construction depends on a number of key factors, some of which are beyond the scope of P5
→ This is a reminder that the financial scale of the ILC in Japan is such that high-level political agreements need to be established.

Executive Summary: as the physics case is extremely strong, all budget scenarios include ILC support at some level through a decision point within the next 5 years

ILC Site Candidate Location in Japan: Kitakami Area

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

4

High-way

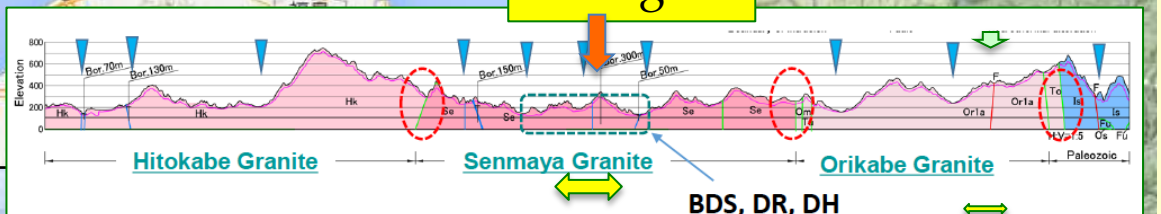
Express-Rail

Sendai

北上市
奥州市
Oshu
一関市
Ichinoseki
Ofunato
大船渡市
陸前高田市
Kesen-numa
気仙沼市
唐桑半島

Proposed by JHEP community
Endorsed by LCC

IP Region



Need to finalize:

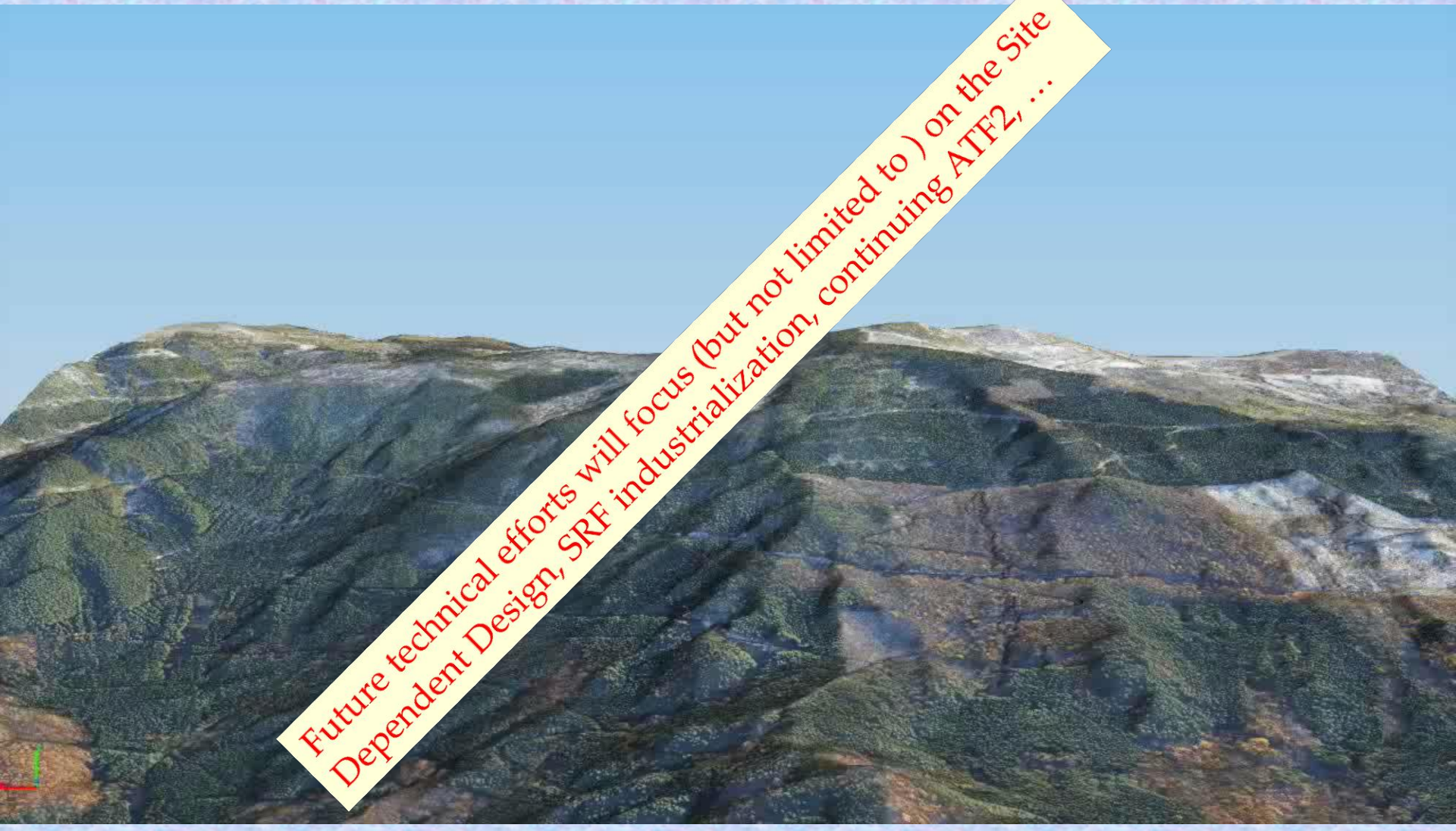
- IP / Linac orientation and length
- Access points and IR infrastructure
- Conventional Facilities and Siting (CFS)
- …

ILC Accelerator Design Integration and 3D Modelling

B. List,
L. Hagge

(Implemented into ILC-EDMS (Engineering Data Management): in cooperation with DESY/FNAL)

EDMS will have a 3D system model of all ILC technical areas in a structured way (design integration, accelerator layout, Kitakami geology, tunnel/cavern requirements, civil engineering …)



Summary and Outlook

HEP Community

Governments

Worldwide Cooperation

GLOBAL ILC PROJECT IN JAPAN:

- Very strong physics case
  - → Model-independent Higgs measurements
  - → DM searches, BSM physics …

- Today, is the only mature technology for the future accelerator at the energy frontier

Concluding Wish:

May all "ILC coming challenges" face ZERO RESISTANCE !!!
(ILC uses "Superconducting Technology")

Photo: Courtesy S. Ganjour (CEA Saclay)