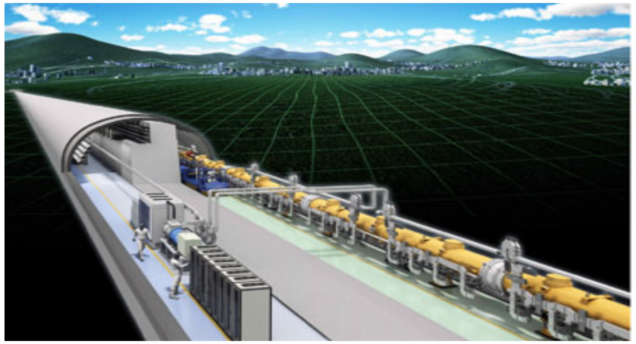


ILC TDR Overview
ILC 技術設計書･概要

Akira Yamamoto (KEK)
山本　明 (KEK ILC 準備室)

the 1st ILC TDR Verification Working Group
第一回　ILC 技術設計書･ 検証作業部会
30 June, 2014

Outline

- Introduction
- Accelerator R&D: 加速器研究開発
- Accelerator Baseline Design：加速器基本設計
- Detectors ：測定器
- Energy Staging：エネルギー･アップグレード
- Schedule：スケジュール
- Summary

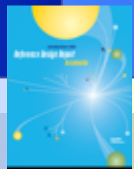
ILC Technical Design Phase

ILC 技術設計段階・期間

1980’ ~ Basic Study

2005 2006 2007 2008 2009 2010 2011 2012 2013 2014

2004



ILC-GDE

LCC

Ref. Design (RDR)

Tech. Design : TDP1

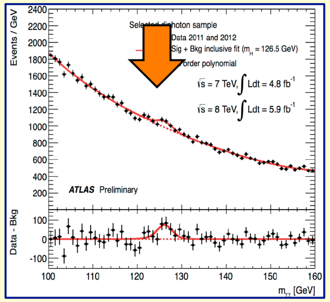
TDP 2

LHC

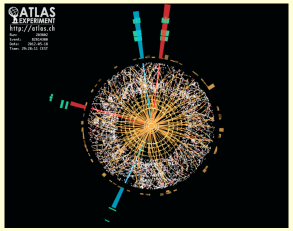
TDR completion

Selection of SC Technology

126 GeV



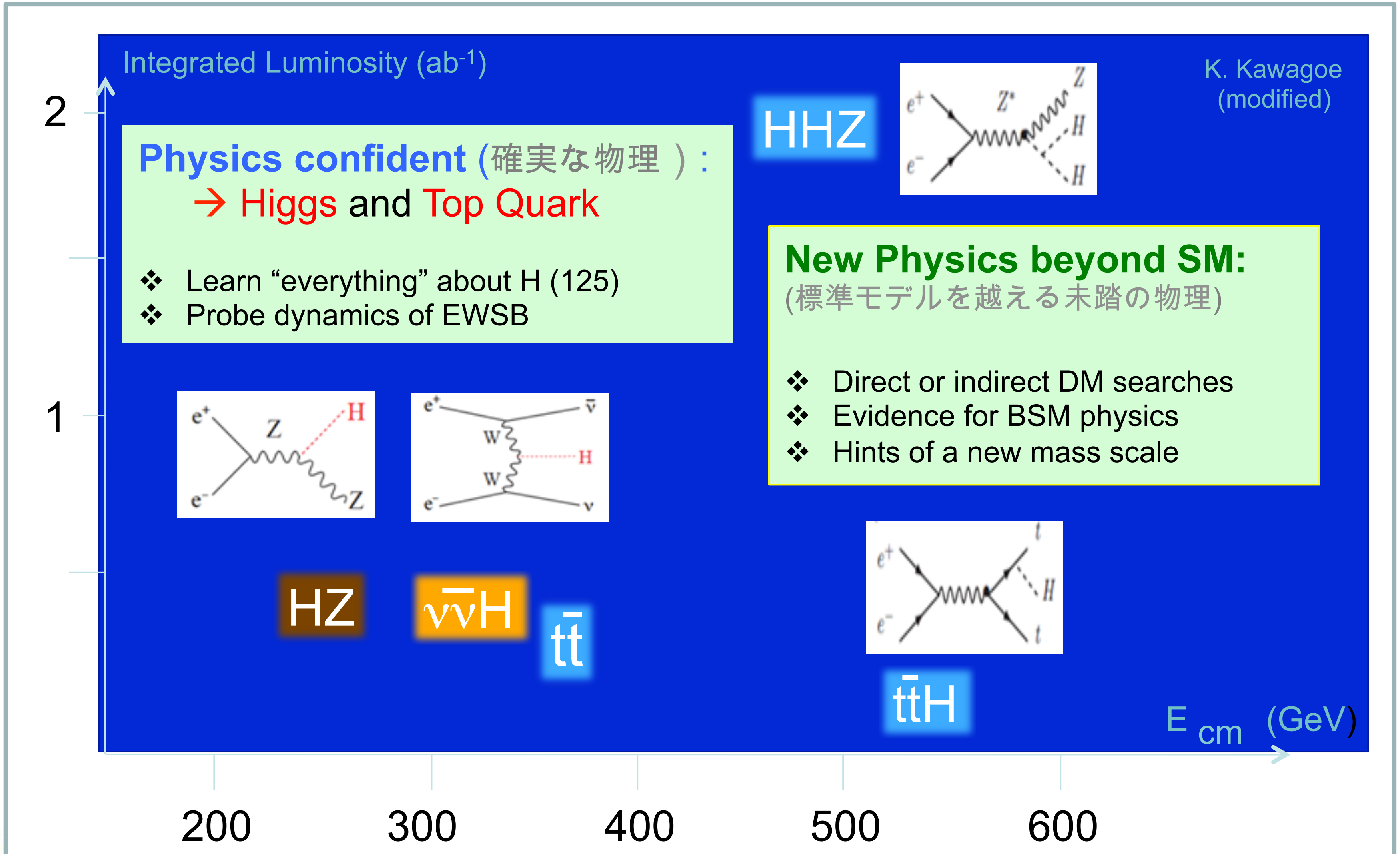
Higgs discovered



Important Energies in ILC

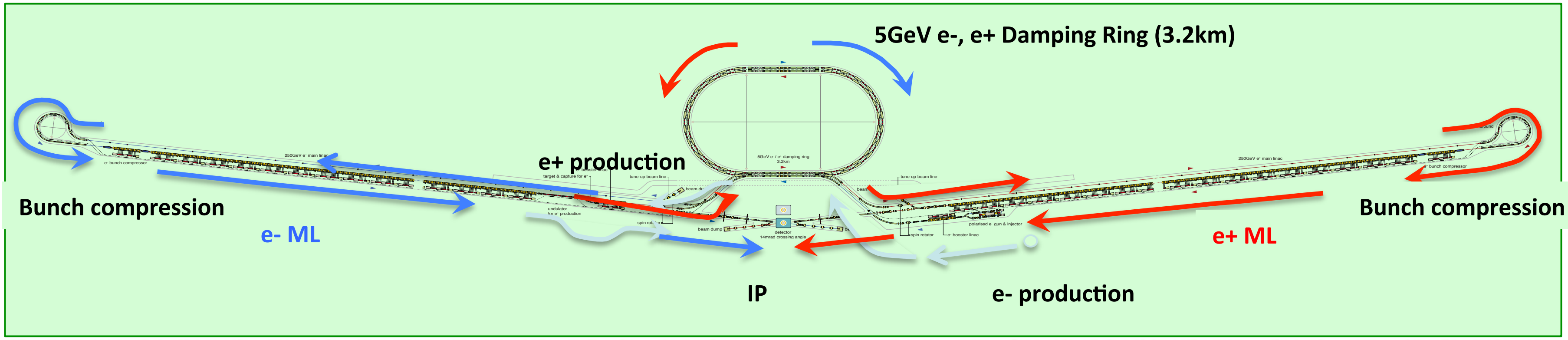
ILCにおける重要な衝突エネルギー

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

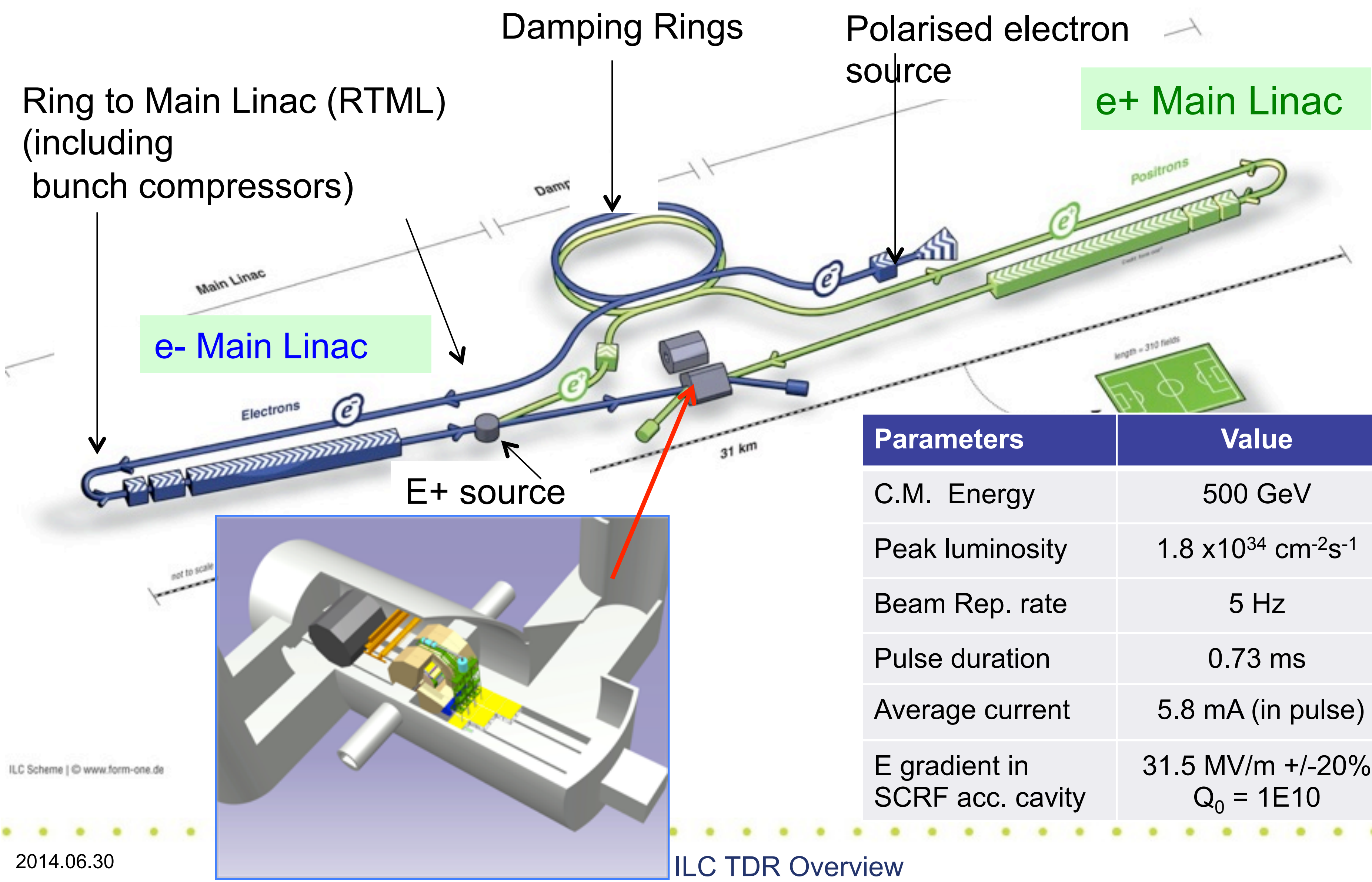


Requirements from Physics
物理実験からの要求

- **Basic requirements （基本要求）：**
  - Luminosity ： $\int L dt$ = 500 fb^{-1} in 4 years
  - E_{cm} : **200 – 500 GeV, and the ability to scan**
  - E stability and precision: < 0.1%
  - Electron polarization: > 80%
- **Extend-ability（エネルギー拡張性）：**
  - Energy upgrade: **500 → 1,000 GeV**



ILC TDR Layout

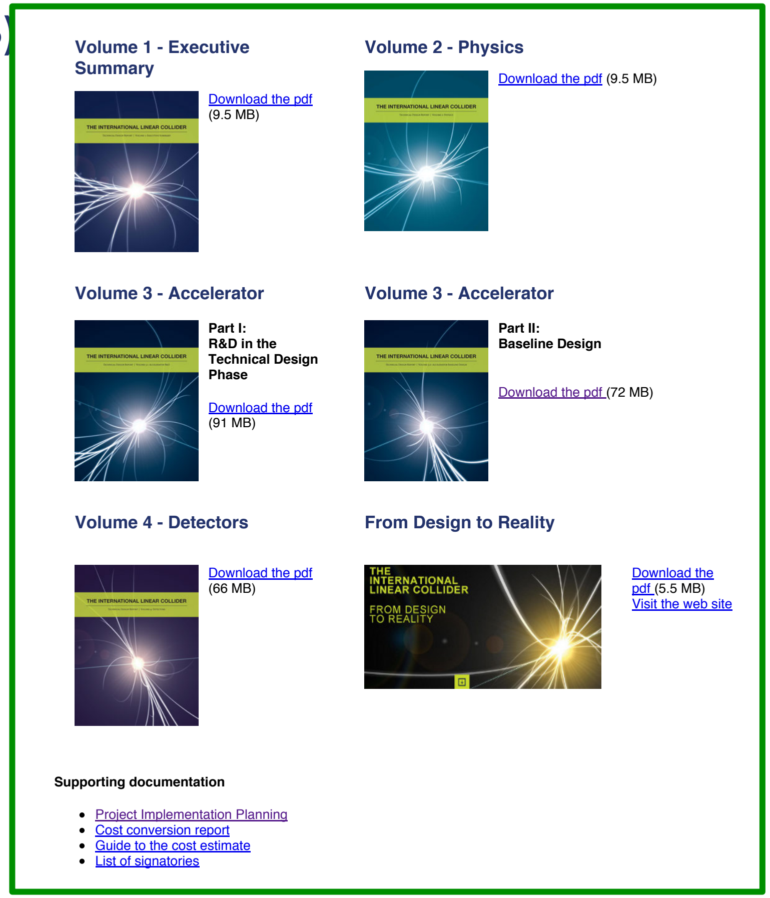


Parameters	Value
C.M. Energy	500 GeV
Peak luminosity	1.8 x10^{34} $cm^{-2}s^{-1}$
Beam Rep. rate	5 Hz
Pulse duration	0.73 ms
Average current	5.8 mA (in pulse)
E gradient in SCRF acc. cavity	31.5 MV/m +/-20% Q_0 = 1E10

Preface: ILC TDR Configuration

TDR の構成

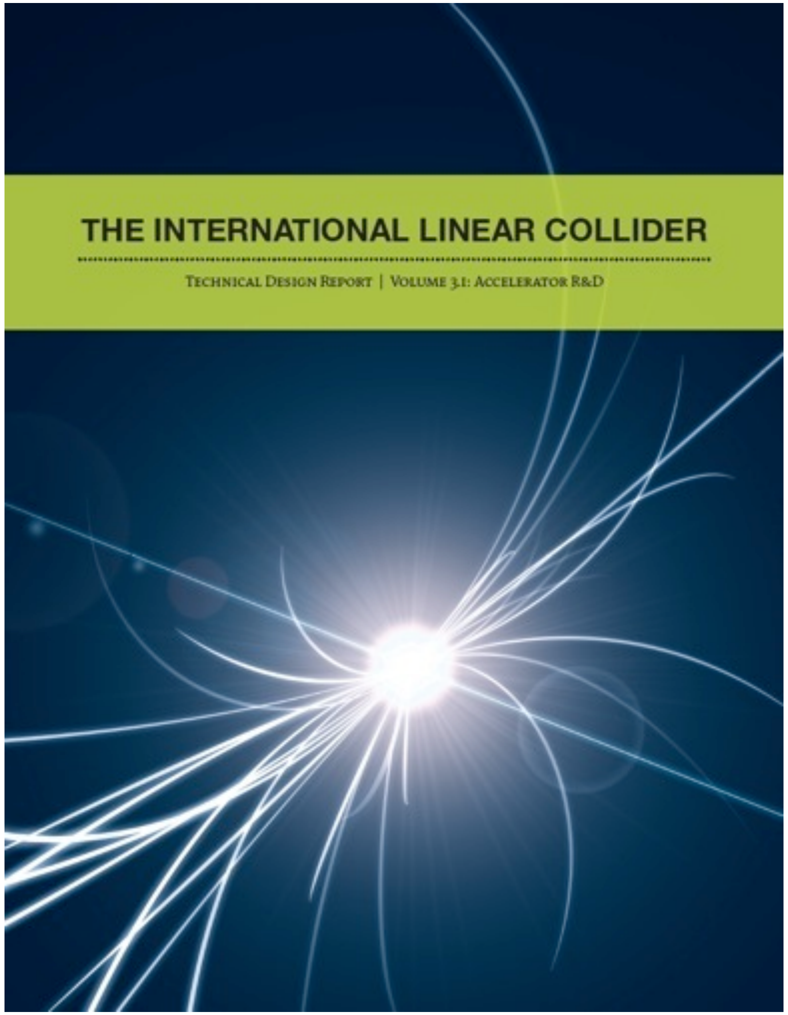
- **ILC Technical Design Report (Published, June, 2013)**
  https://www.linearcollider.org/ILC/Publications/Technical-Design-Report
  – Vol. 1. Executive Summary
  – Vol. 2. Physics
  – **Vol. 3, P1. Accelerator: R&D in the TD Phase**
  – **Vol. 3, P2. Accelerator: Baseline Design**
  – **Vol. 4. Detectors**
  – (+) From Design to Reality
- **TDR Supporting Documents**
  https://www.linearcollider.org/ILC/Publications/Technical-Design-Report
  – Project Implementation Planning
  – Cost Conversion Report
  – Guide to the Cost Estimate
  – List of signatures



- ILC TDR Value Estimate and Schedule (confidential documents)
  – V. 6.0, April 13, 2013.
- Further details in ILC EDMS (confidential documents),

ILC-TDR Vol. 3-I Accelerator R&D

Vol. 3−I, ILC 加速器技術開発



1. Introduction
2. Superconducting RF (SCRF) technology
    1. **Cavity field gradient**
    2. **Cavity system test: S1 Global**
    3. **Industrialization E-XFEL**
    4. **…**
    5. **…**

    } focused
3. Beam Test Facilities
    1. **SCRF, Beam Acceleration: FLASH, STF,**
    2. **Nano-beam handling : ATF**

    } focused

    3. **E- cloud mitigation: CESR-TA**
    4. **…**
    5. **…**
4. Accelerator Systems R&D
5. Conventional Facilities and Siting Studies
6. Post-TDR R&D (to be briefly reported)
    1. **SCRF, ATF, …**

Global Cooperation for Test Facilities

国際協力による加速器試験施設

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

STF (KEK) operation/construction
ILC-like Cryomodule test : S1-Gloabal
SRF beam acceleration : QB, STF2

CesrTA (Cornell)
electron cloud
low emittance

DESY

INFN Frascati

KEK, Japan

FNAL

Cornell

DAΦNE (INFN Frascati)
kicker development
electron cloud

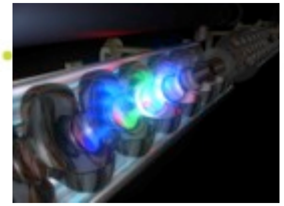
ATF & ATF2 (KEK)
ultra-low emittance
Final Focus optics, nano-beam
KEKB electron-cloud

NML/ASTA facility
ILC RF unit test
Full-CM Test,
SRF beam acceleration, soon

Technical Highlight in TD Phase
技術設計段階での技術開発・ハイライト

- **SCRF Technology（超伝導・ビーム加速技術）**
  - Cavity: High Gradient R&D:
    - 35 MV/m with 50% yield by 2010 , and 90% by 2012 (TDR)
    - Manufacturing with cost effective design
  - Cryomodule performance including HLRF, and LLRF
  - Beam Acceleration
    - 9 mA: FLASH
    - 1 ms: STF2 - Quantum Beam
- **Nano-beam handling （ナノビーム技術）**
  - ILC-like beam acceleration
    - Ultra-low beam emittance: Cesr-TA, ATF
    - Ultra-small beam size at Final Focusing: ATF2

Advantage of Superconducting RF
超伝導RF の特色･利点



- 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

  (高い高周波電力効率)
- Long beam pulses (~1 ms)

  → intra-pulse feedback

  (パルス中でのフィードバック制御、可)
- Larger aperture / smaller beam loss

  → better beam quality with larger aperture - lower wake-fields

  (大口径→少ビームロス)
- Work necessary on engineering for:
  - Cryomodule (thermal insultation)
  - Cryogenics

    (冷却)
  - Gradient to be further improved

Luminosity:

RF efficiency — RF power / beam current — Vertical emittance (tiny beams)

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

- Luminosity proportional to RF efficiency ILC
  - (ルミノシティはRF効率に比例):
  - for given total power (electricity bill !),
  - ~160MW @ 500GeV
- Capable of efficiently accelerating high beam currents (大電流)
- Low impedance aids preservation of high beam quality (low emittance) (良質ビーム)

→ Ideal for Linear Collider

Global Plan for SCRF R&D

超伝導空洞技術開発タイムライン

Year	07	2008	2009	2010	2011	2012
Phase	TDP-1			TDP-2		
Cavity Gradient （電界） test to reach 35 MV/m	→ Yield 50%			→ Yield 90%		
Cavity-string to reach 31.5 MV/m, with one-cryomodule (システム)		Global effort for string assembly and test (DESY, FNAL, INFN, KEK)				
System Test with beam acceleration (ビーム)		FLASH (DESY) , NML/ASTA (FNAL) QB, STF2 (KEK)				
Preparation for Industrialization (工業化)			Production Technology R&D			
Communication with industry （企業との検討:	1^{st} Visit Vendors (2009), Organize Workshop (2010) 2^{nd} visit and communication, Organize 2^{nd} workshop (2011) 3^{rd} communication and study contracted with selected vendors (2011-2012)					

Progress in 1.3 GHz Cavity Production

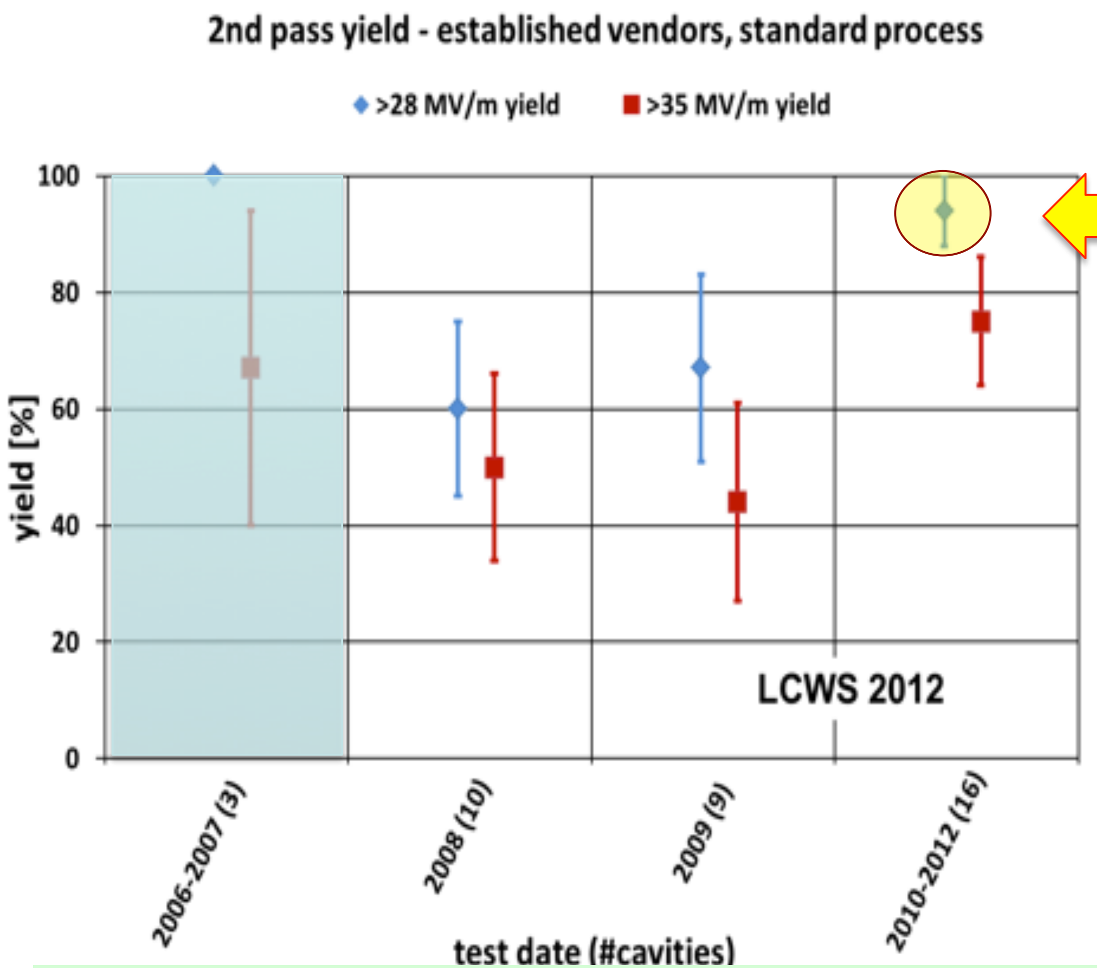
1.3 GHz 超伝導加速空洞製造実績の進展

year	# 9-cell cavities qualified	Capable Lab.	Capable Industry
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**

- One Lab (2 vendor) in 2006, and 5 Lab (5 vendor) in 2012 may handle to fabricate 35 MV/m at Q= 8E9
- 6年間で、技術を保有する研究所、（製造会社）が1,(2) → 5 機関に、.

Progress in SCRF Cavity Gradient

空洞製造･成功率の向上



Production yield:
94 % at > 35+/-20%
（目標の> 90 % を達成）,

Average gradient:
37.1 MV/m

reached (2012)

電界性能幅+/-20 %→成功率（歩留まり）~10% 向上

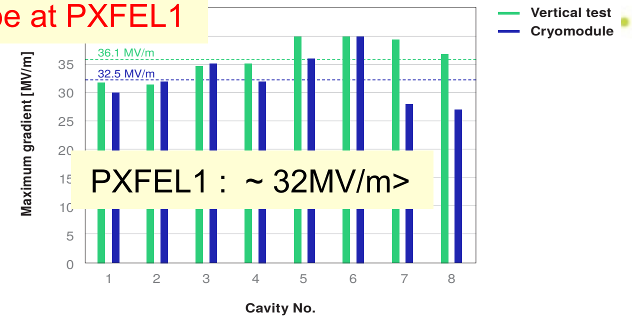
Cryomodule System Test

超伝導加速空洞･CMおよびビーム加速実証試験

DESY: FLASH

- ❖ 1.25 GeV linac (TESLA-Like tech.)
- ❖ ILC-like bunch trains:
- ❖ 600 ms, 9 mA beam (2009); ← ILC ビーム電流の実証
  800 ms 4.5 mA (2012)
- ❖ RF-cryomodule string with beam → PXFEL1 operational at FLASH

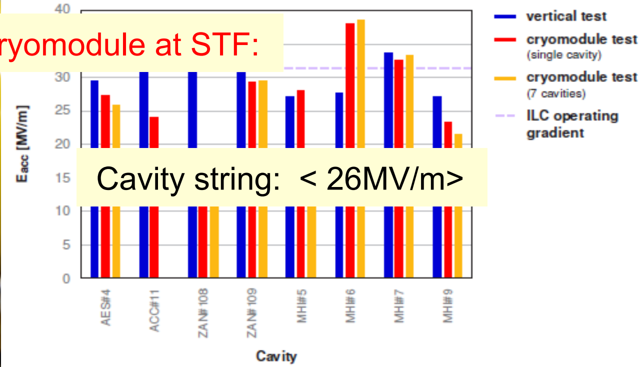
XFEL Prototype at PXFEL1



KEK: SRF Test Facility (STF/STF2)

- ❖ S1-Global: completed (2010)
- ❖ Quantum Beam Accelerator (Inverse Laser Compton): 6.7 mA, 1 ms ← ILC ビームパルス長の実証
- ❖ CM1 test with beam (2014 ~2015)
- ❖ STF-COI: Facility to demonstrate CM assembly/test in near future

S1 Global Cryomodule at STF:

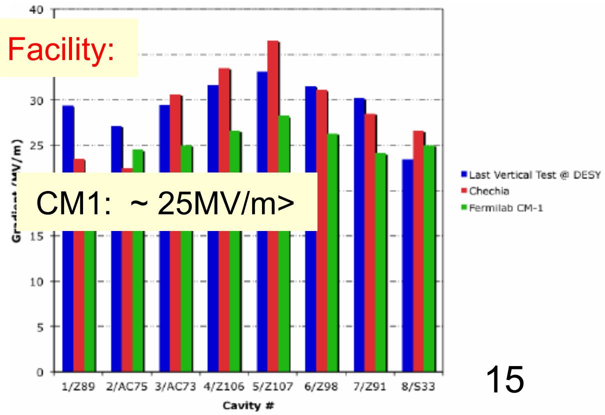


FNAL: NML (New Muon Lab) / ASTA

(Advanced Superconducting Test Accelerator)

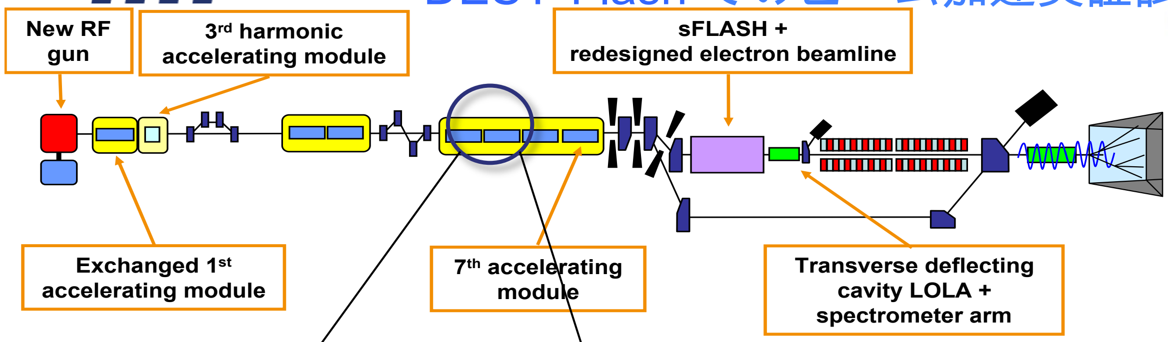
- ❖ CM1 test complete
- ❖ CM2 operation (2013)
- ❖ CM2 with beam (soon)

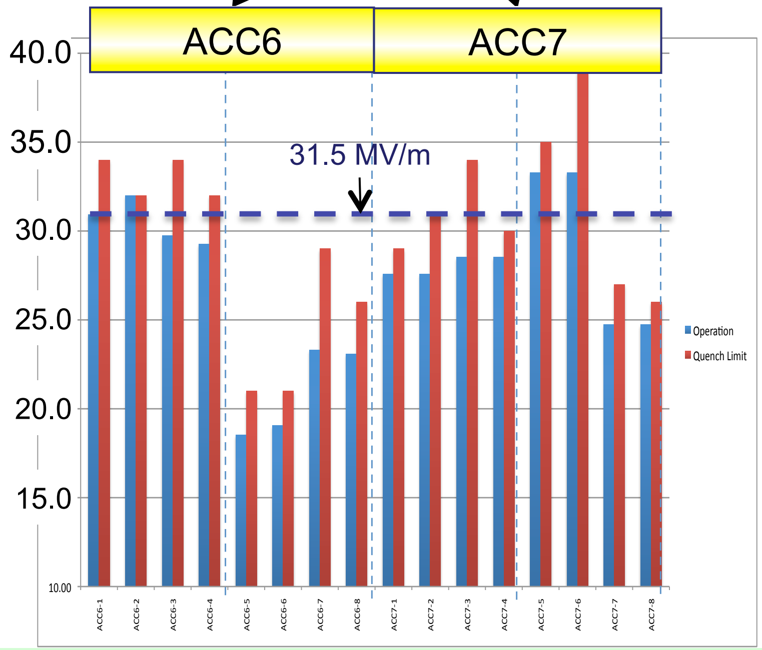
CM1 at NML Facility:



DESY-FLASH Beam Test

DESY-Flash でのビーム加速実証試験





← ILC ビーム電流実証

- ✓ 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
  - ✓ Auto
- ✓ Controls c
- ✓ Klystron c
- ✓ General c
  - ✓ Fast
  - ✓ Deal (prot

Parameters	Value
C.M. Energy	500 GeV
Peak luminosity	1.8×10^{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

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

IPAC14: Courtesy: H. Weise

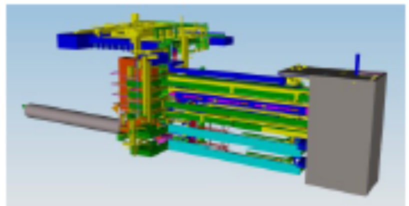
European XFEL

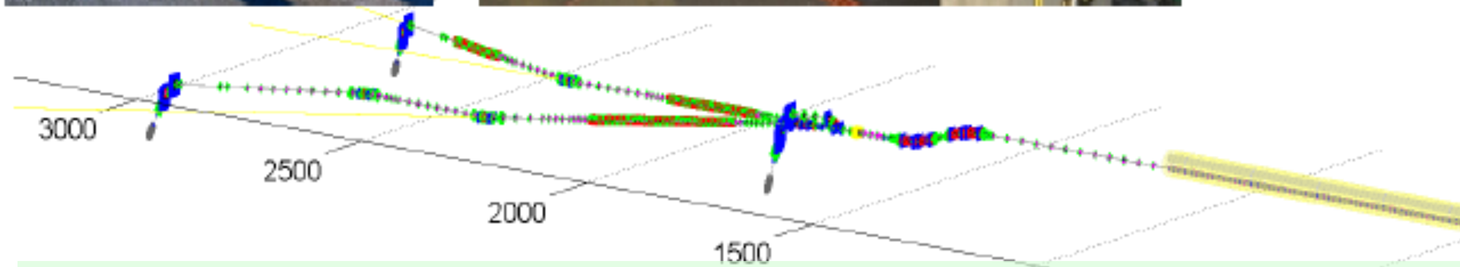
An Accelerator Complex for 17.5 GeV

100 accelerator modules

800 accelerating cavities
1.3 GHz / 23.6 MV/m

25 RF stations
5.2 MW each





E-XFEL: 欧州・ X線自由電子レーザー・ 光科学施設・ 建設中 ：2016年稼働予定
800台の超伝導加速空洞をRI, Zanon 社で工業生産、CEA-Saclay, DESY で組み立て・ 試験

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

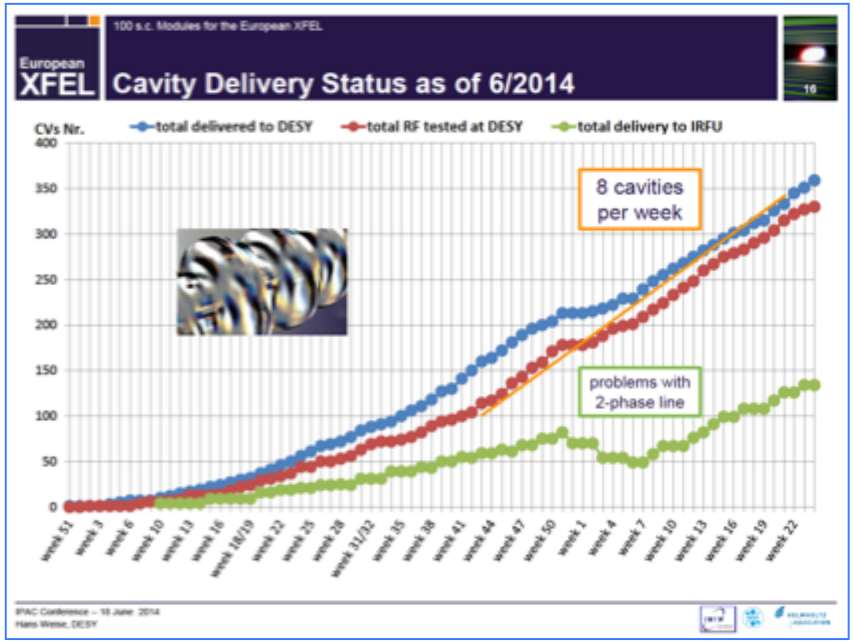
25 RF stations
5.2 MW each

EXFEL: 1/20 Scale Project on going, Industrialization being verified !!
EXFEL: 1/20 スケール実計画、進行中→工業化技術を実証中

IPAC14: Courtesy: H. Weise

SCRF Cavity Production

超伝導加速空洞・製造(RI, ZAON)と試験実績 (DESY)



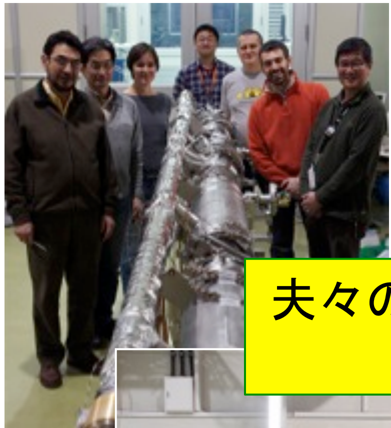
- **Gradients** in average above specification (almost 300 cavities tested)
  - Average usable gradient after delivery (26.8 ± 7.1) MV/m
  - 2/3 of cavities can be used w/o further treatment
  - 1/3 is getting additional treatm. -> usable grad. increased to (29.6 ± 5.1) MV/m

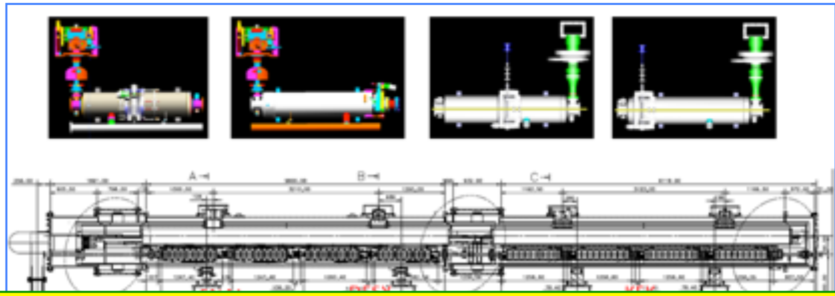
2014.6現在：空洞製造・試験 ＞300 台。 使用可能電界、~＜30＞MV/m

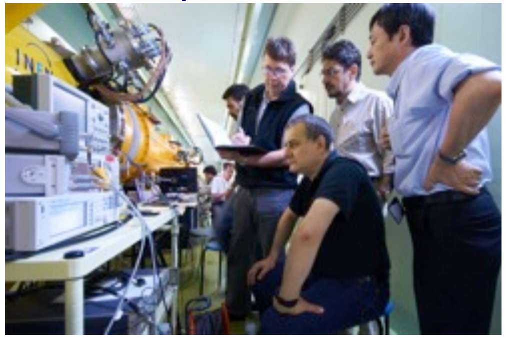
S1-Global hosted at KEK:
国際協力による共同作業、空洞相互整合性、評価試験

DESY, FNAL, Jan., 2010

DESY, Sept. 2010







FNAL & INFN, July, 2010

夫々の設計による空洞を持ち寄り、お互いに評価
協調した運転に成功

INFN
and
FNAL
Feb.
2010

March, 2010

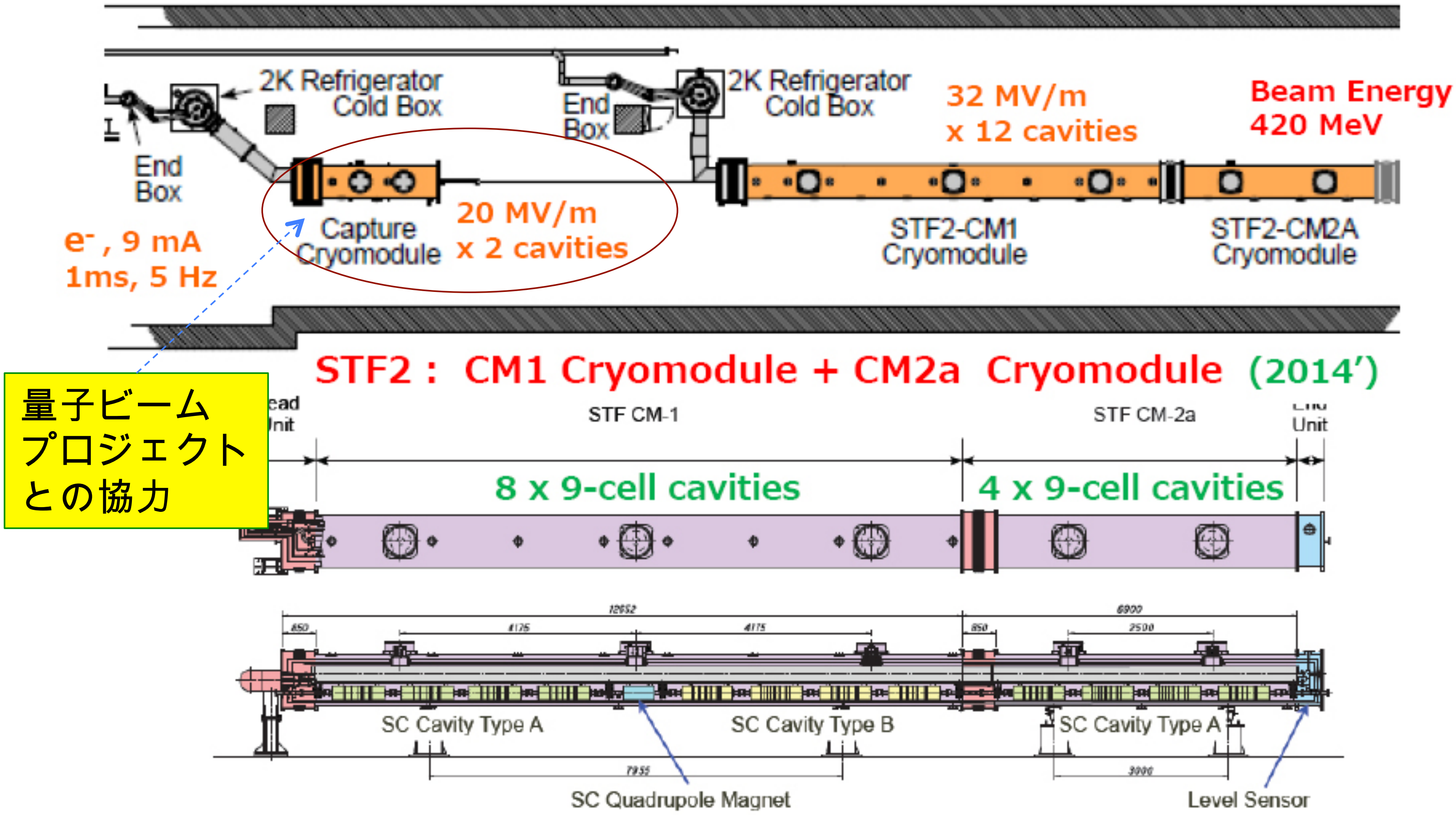
DESY, May, 2010

June, 2010 ~

E. Kako, Dec. 2013

10 year Evolution of STF at KEK

KEK-STF: 10年をかけた超伝導RF 試験加速器の進展



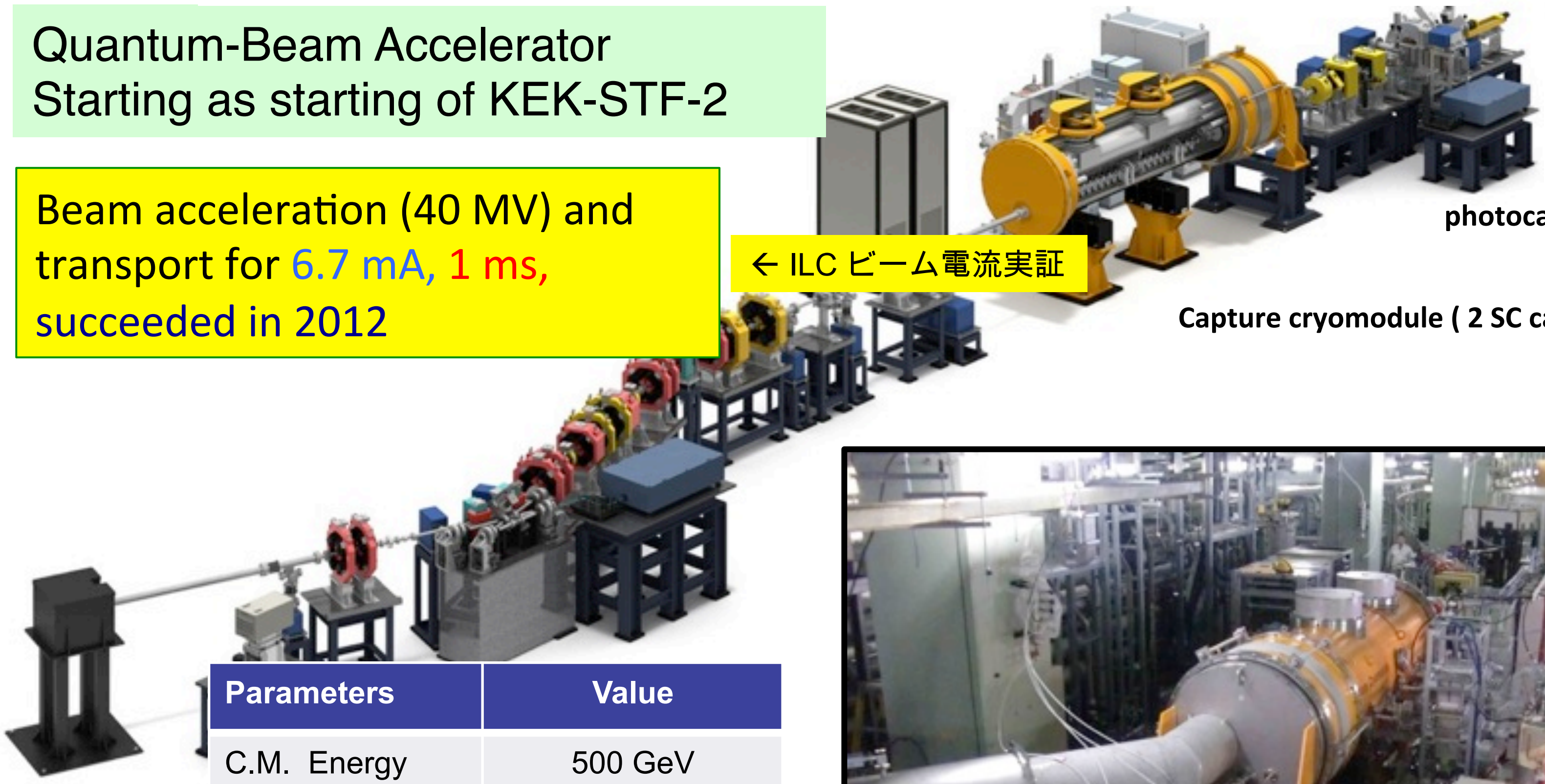
up to ~ 420MeV

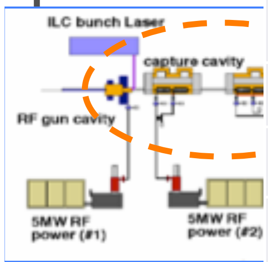
ILC beam Acceleration at KEK STF

KEK-STF でのビーム加速実証試験

Quantum-Beam Accelerator
Starting as starting of KEK-STF-2

Beam acceleration (40 MV) and transport for 6.7 mA, 1 ms, succeeded in 2012





Parameters	Value
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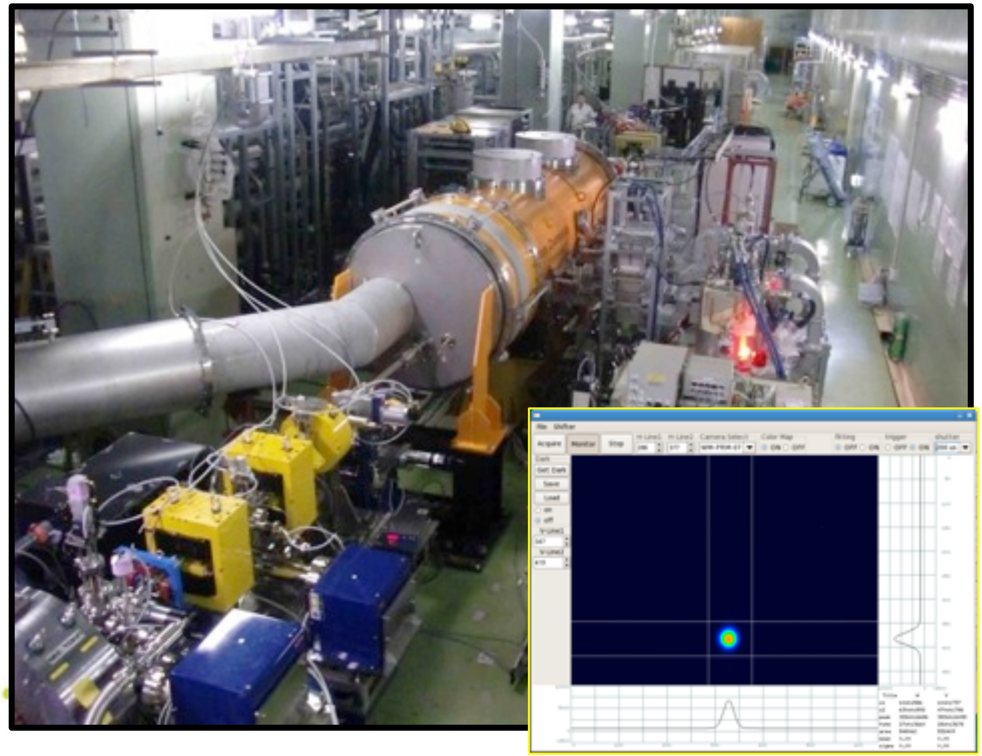
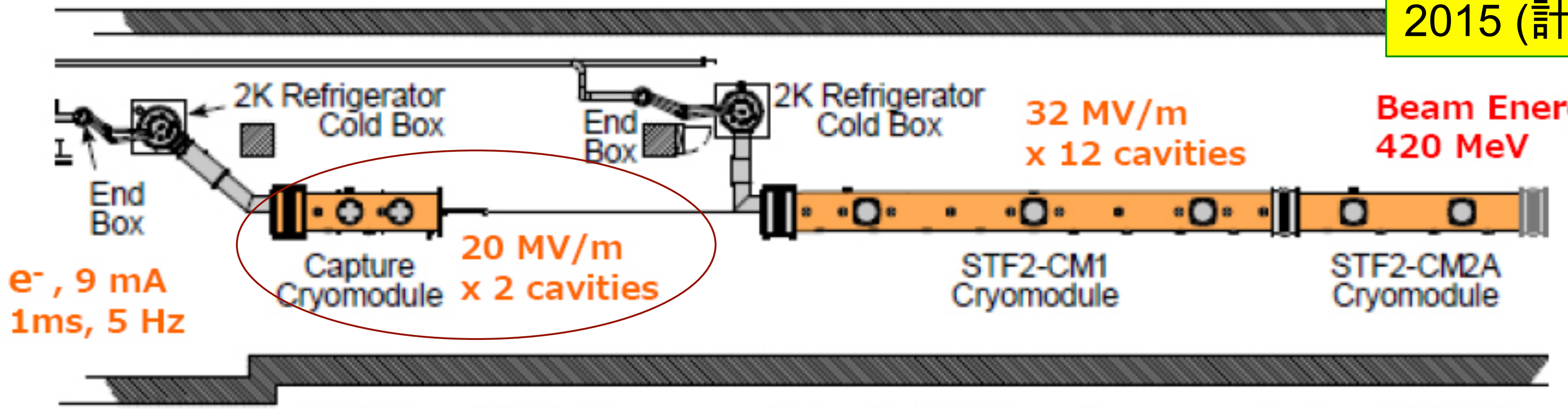
Beam Rep. rate	5 Hz
Pulse duration	0.73 ms
Average current	5.8 mA (in pulse)
E gradient in SCRF acc. cavity	31.5 MV/m +/-20% Q_0 = 1E10



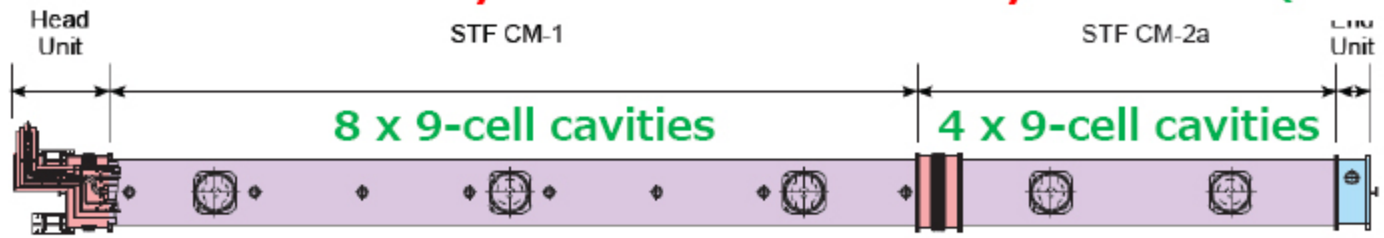
10 year Evolution of STF at KEK

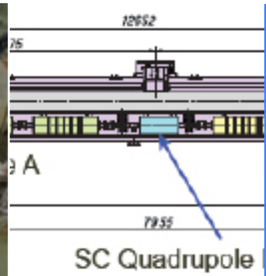
KEK-STFでの10年をかけた進展

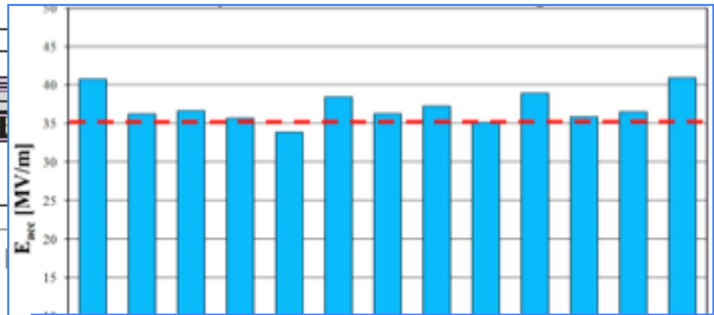
ビーム加速
2015 (計画)



STF2 : CM1 Cryomodule + CM2a Cryomodule (2014')



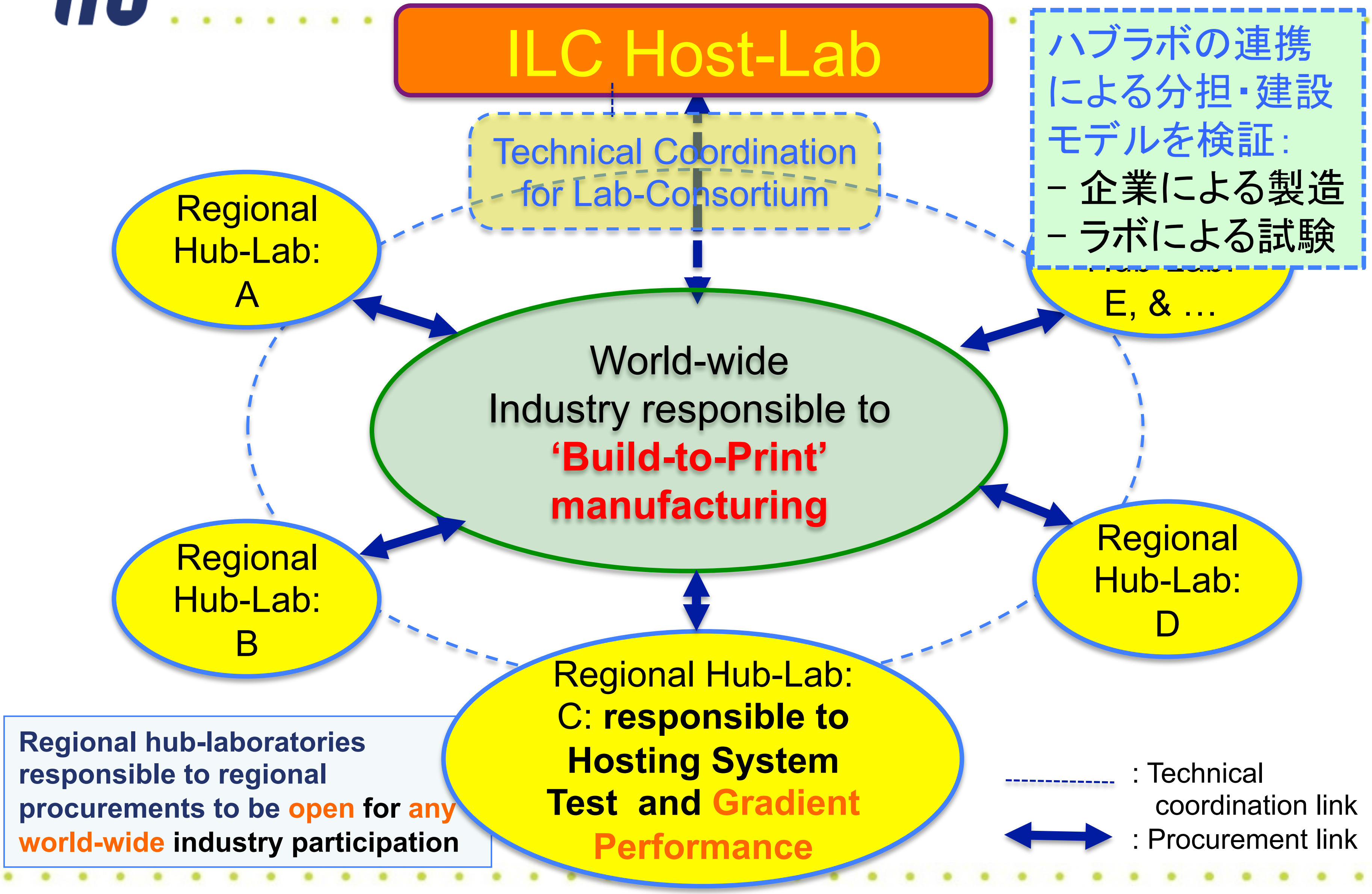




up to ~ 420Me

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

Cooperation of ILC host- and hub-laboratories with worldwide industry (proposed)



Technical Goals in TD Phase

技術設計段階での技術開発・ハイライト

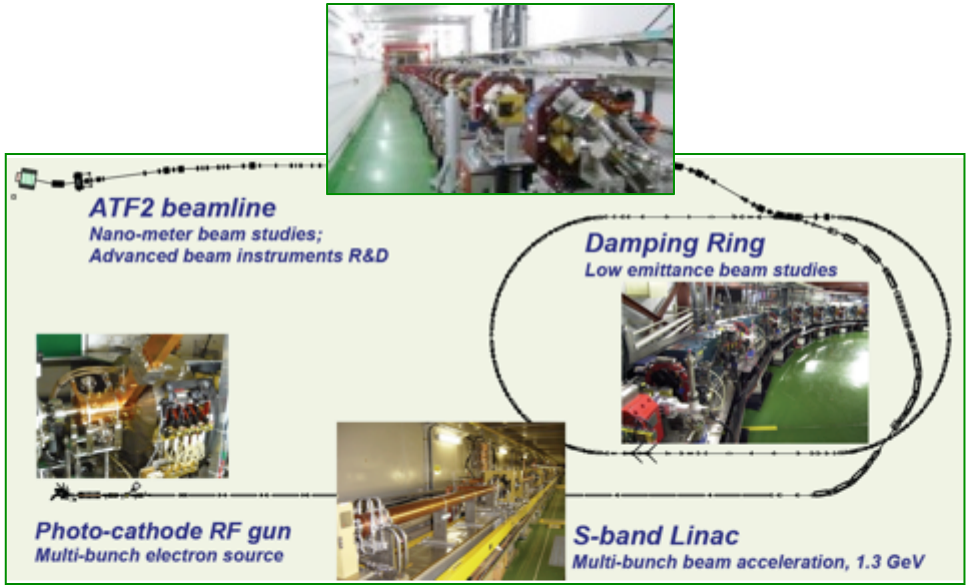
- **SCRF Technology (超伝導・ ビーム加速技術)**
  - Cavity: High Gradient R&D:
    - 35 MV/m with 50% yield by 2010 , and 90% by 2012 (TDR)
    - Manufacturing with cost effective design
  - Cryomodule performance including HLRF, and LLRF
  - Beam Acceleration
    - 9 mA: FLASH
    - 1 ms: STF2 - Quantum Beam
- **Nano-beam handling （ナノビーム技術）**
  - ILC-like beam acceleration
    - Ultra-low beam emittance: Cesr-TA, ATF
    - Ultra-small beam size at Final Focusing: ATF2

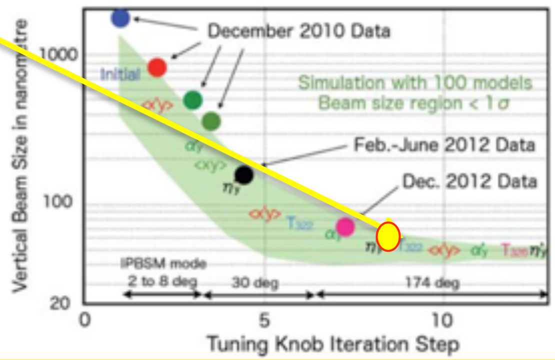
ATF2 Progress by 2013
2013年までの進展

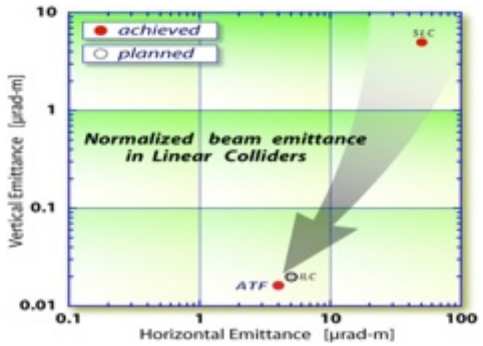
Ultra-small beam

- Low emittance : KEK-ATF
  - **4 pm achieved**
  - **(ILC target value, in 2004).**
- Small vertical beam size : KEK ATF2
  - **Goal = 37 nm,**
    - 160 nm (spring, 2012)
    - 65 nm (April, 2013) at low beam current

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







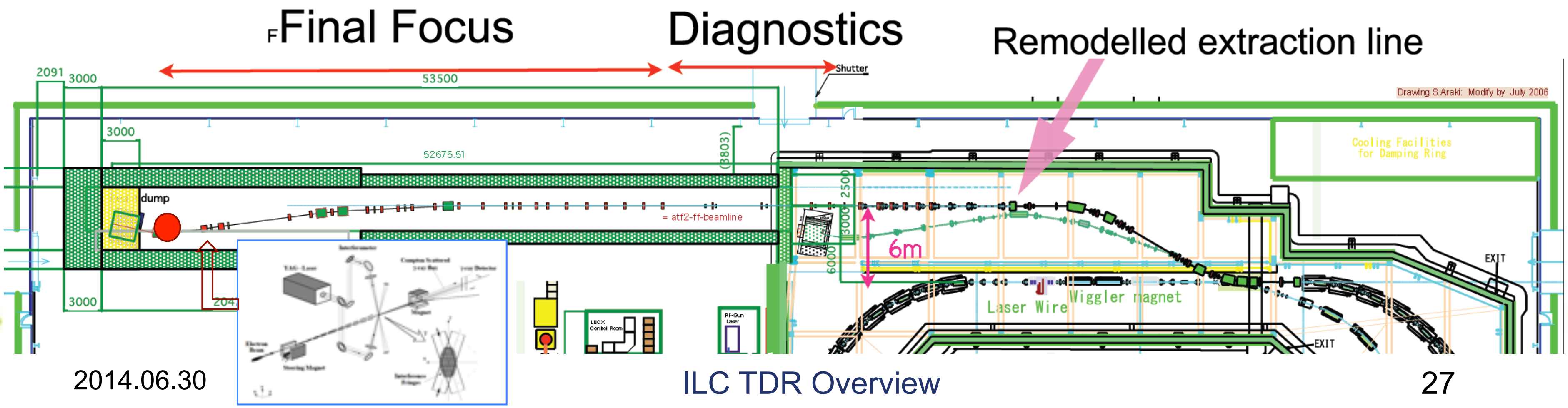
ナノビームによるルミノシティ向上：KEK-ATFが国際協力の中心的役割

KEK-ATF2: BDS Test Facility for ILC

ILC 最終収束モデル化・ナノビーム技術検証

- **Modeling of ILC BDS**
  - Same Optics: ILCと同じ光学
  - Int'l Collab. (国際協力）
- **~25 Lab. , > 100 Collaborators**

- **Goal:**
  FF Beam Size: 37 nm
  - (ILC で5.9 nm に相当）



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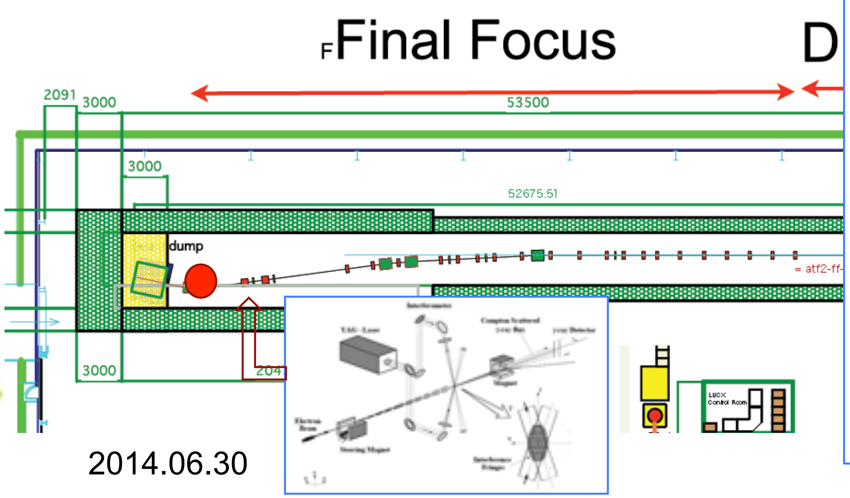
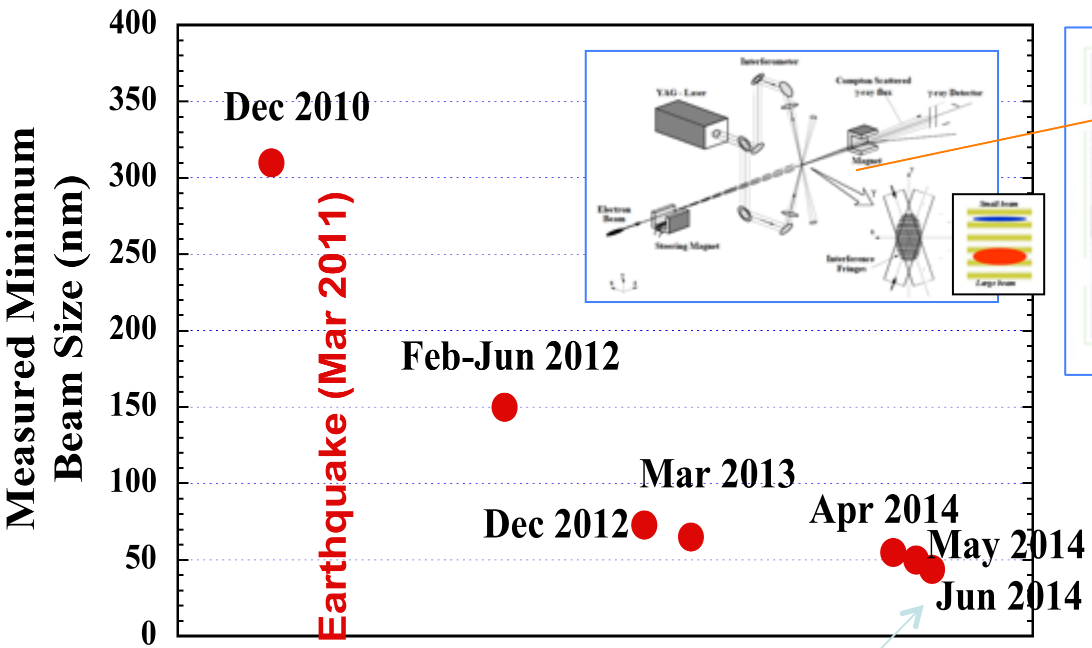


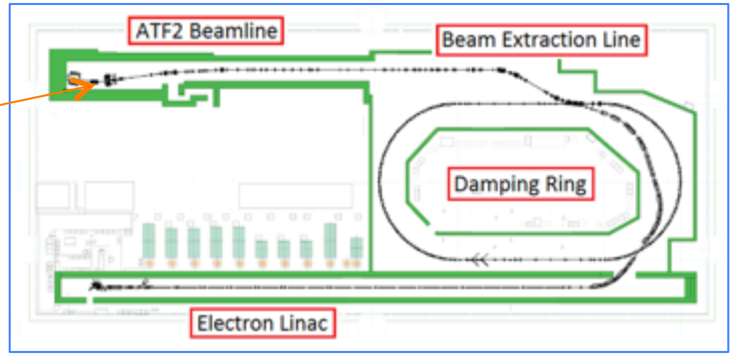
Parameter	ILC	ATF2
Beam Energy [GeV]	250	1.3
Energy Spread (e^+/e^-) [%]	0.07/0.12	0.06~0.08
Final quad – IP distance (L^*) (SiD/ILD detector) [m]	3.5/4.5	1.0
Vertical beta function at IP (β^*_y) [mm]	0.48	0.1
Vertical emittance [pm]	0.07	12
Vertical beam size at IP (s^*_y) [nm]	5.9	37
L^*/β^*_y (~natural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

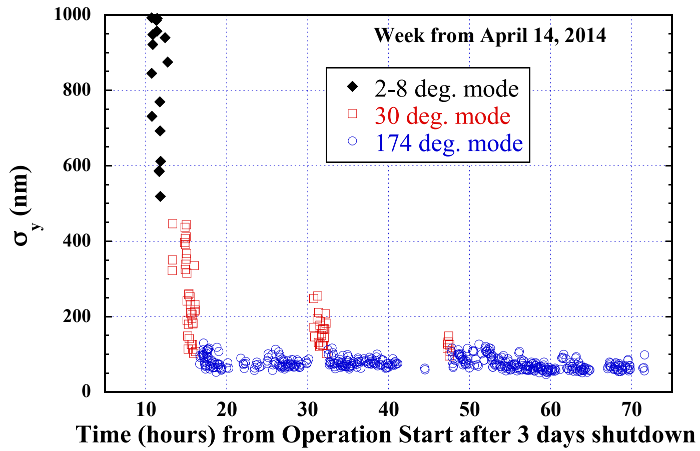
IPAC2014, K. Kubo

Progress in measured min. beam size at ATF2

2014年の進展（目標達成まで、あと一歩！）

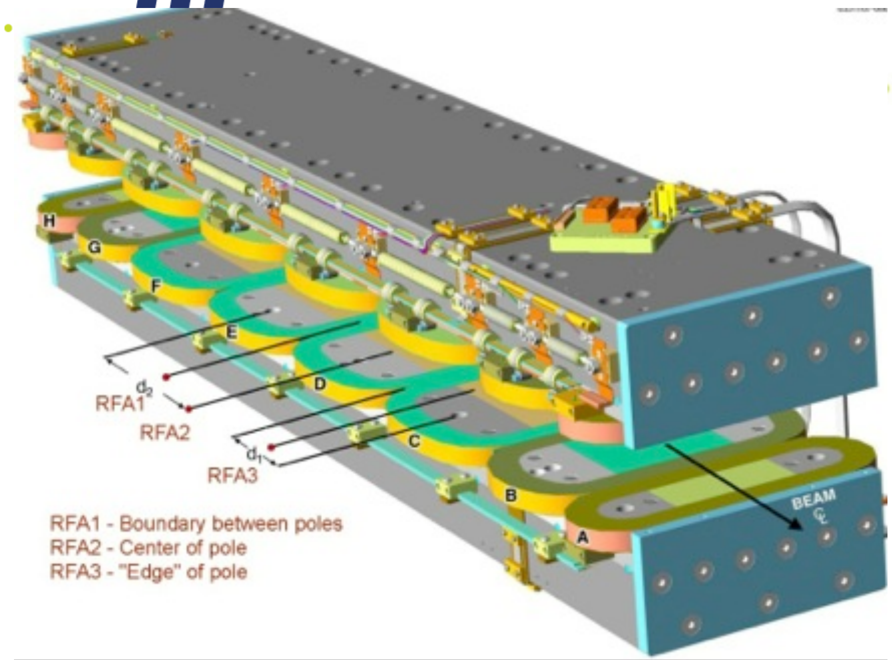


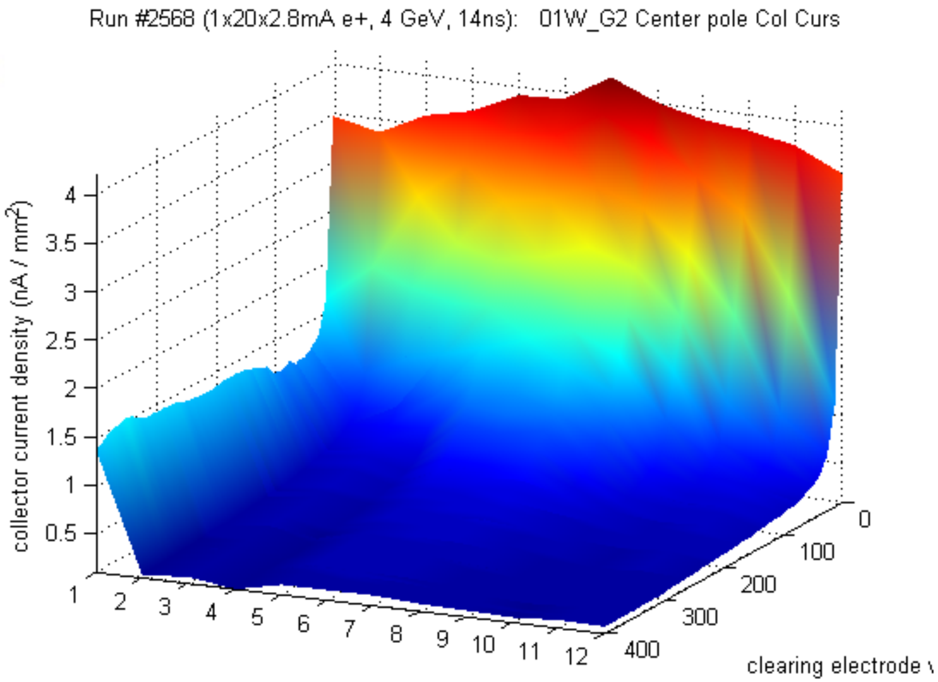


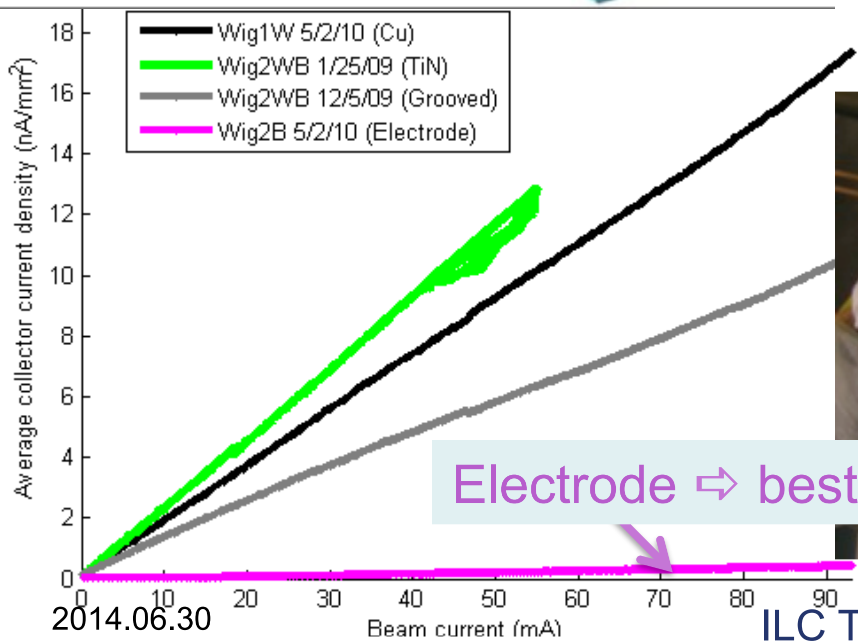


Beam Size 44 nm observed,
(Goal : 37 nm)

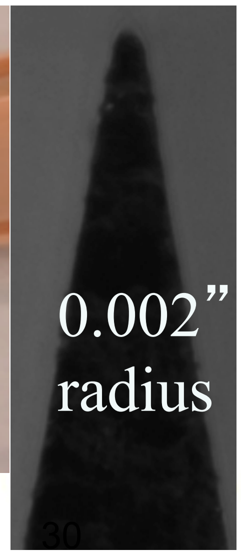
CesrTA - Wiggler Observations







Electrode ⇨ best performance



Baseline Mitigation Plan

EC Working Group Baseline Mitigation Recommendation				
	Drift*	Dipole	Wiggler	Quadrupole*
Baseline Mitigation I	**TiN Coating**	**Grooves with TiN coating**	**Clearing Electrodes**	**TiN Coating**
Baseline Mitigation II	**Solenoid Windings**	**Antechamber**	**Antechamber**	
Alternate Mitigation	**NEG Coating**	**TiN Coating**	**Grooves with TiN Coating**	**Clearing Electrodes or Grooves**

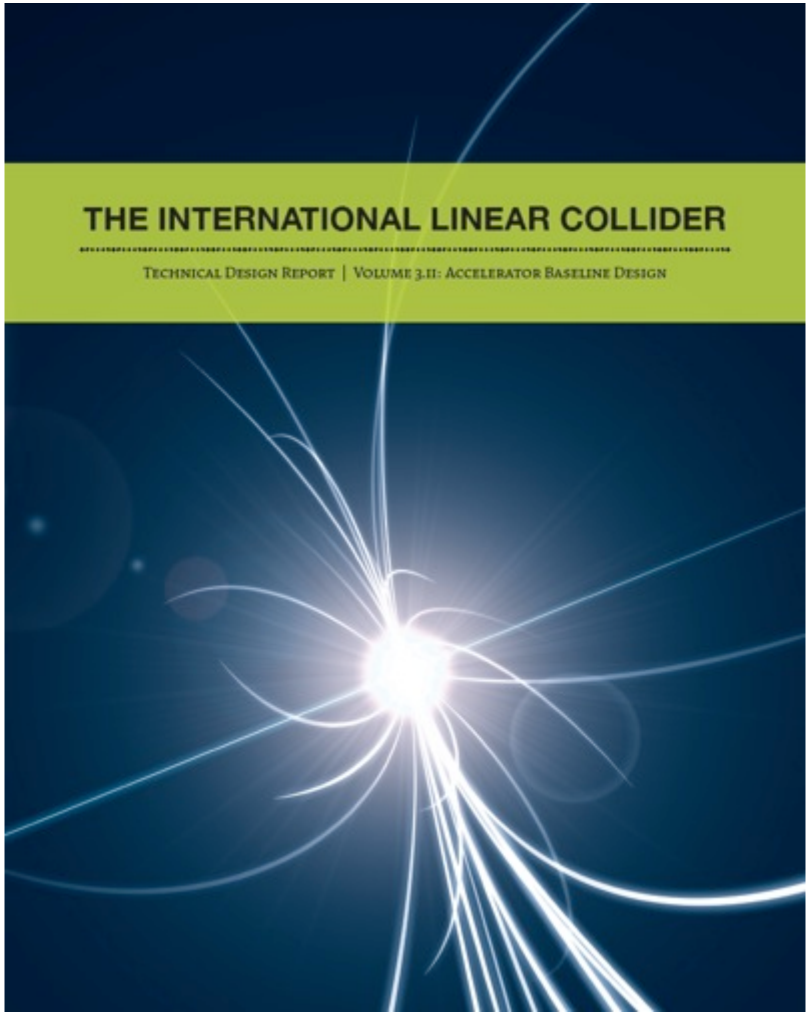
*Drift and Quadrupole chambers in arc and wiggler regions will incorporate antechambers

- Preliminary CESRTA results and simulations suggest the presence of *sub-threshold emittance growth*
  - Further investigation required
  - May require reduction in acceptable cloud density ⇨ reduction in safety margin
- An aggressive mitigation plan is required to obtain optimum performance from the 3.2km positron damping ring and to pursue the high current option

Outline

- Introduction
- Accelerator R&D
- Accelerator Baseline Design,
- Detectors
- Energy Staging
- Schedule
- Summary

ILC TDR: Vol. 3-II Acc. Baseline Design
Vol. 3–II. 加速器基本設計



1. Introduction
2. General Parameters, Layout, System Overview → (山本)
3. Main Linac and SCRF Technology → (早野、道園)
4. Electron Source
5. Positron Source
6. Damping Rings (DR)
7. Ring to Main Linac (RTML)
8. Beam Delivery Sys. (BDS) & Machine Detect. Int. (MDI)

(4.–8.) → (横谷)

9. Global Accelerator Control Systems
10. Availability, Commisssioning, and Operations
11. Conventional Facilities and Siting (CFS) → (榎本、宮原)
12. Possible upgrade and staging options
13. Project Implementation Planing
14. Construction schedule

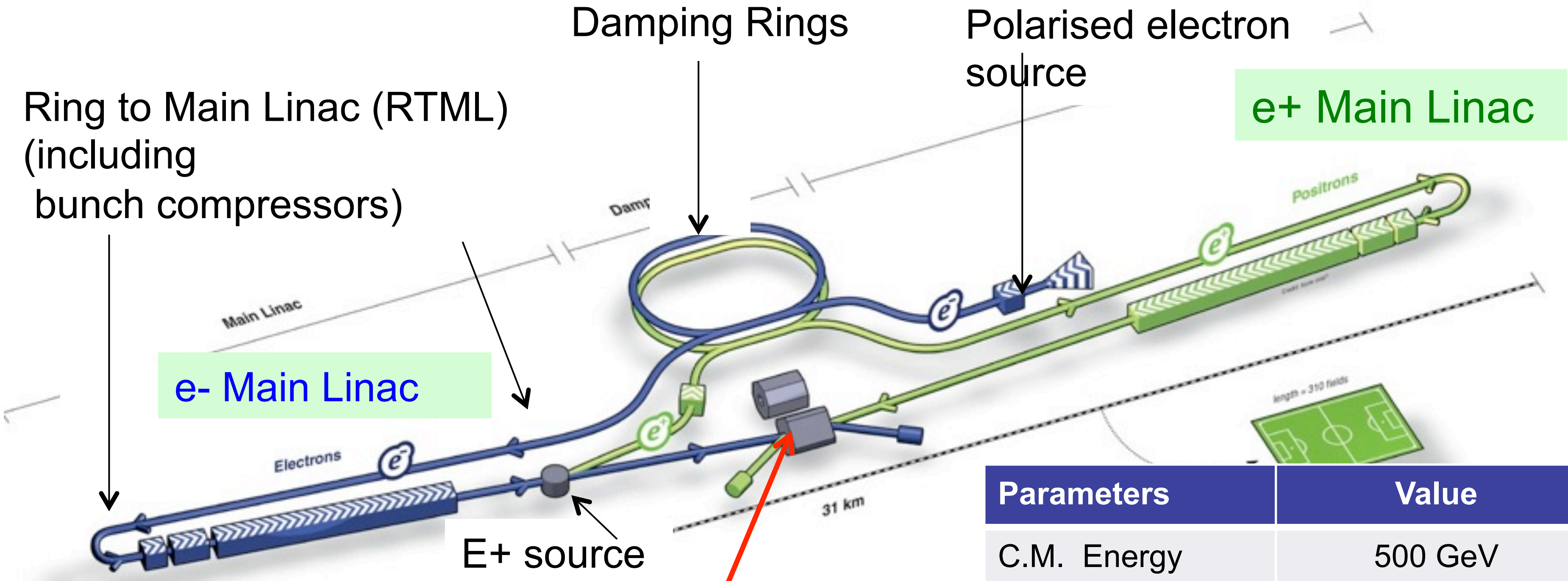
(12.–14.) → (山本)

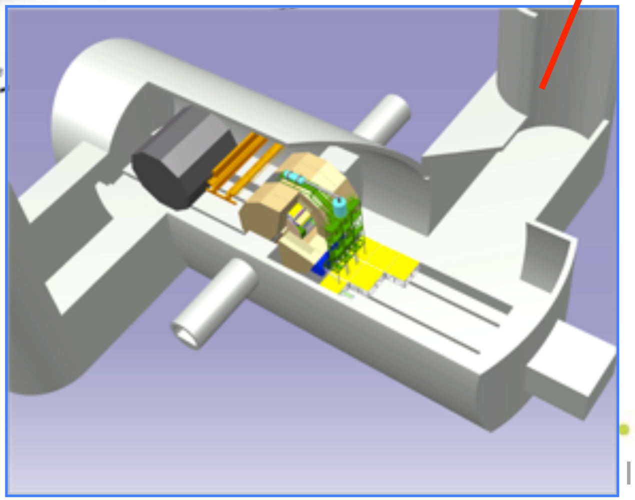
15. ILC TDR Value Estimate → (設楽)

A. Evolution of the ILC design in the TD Phase

- Detectors: → (藤井)

ILC TDR Layout





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 Published Parameters

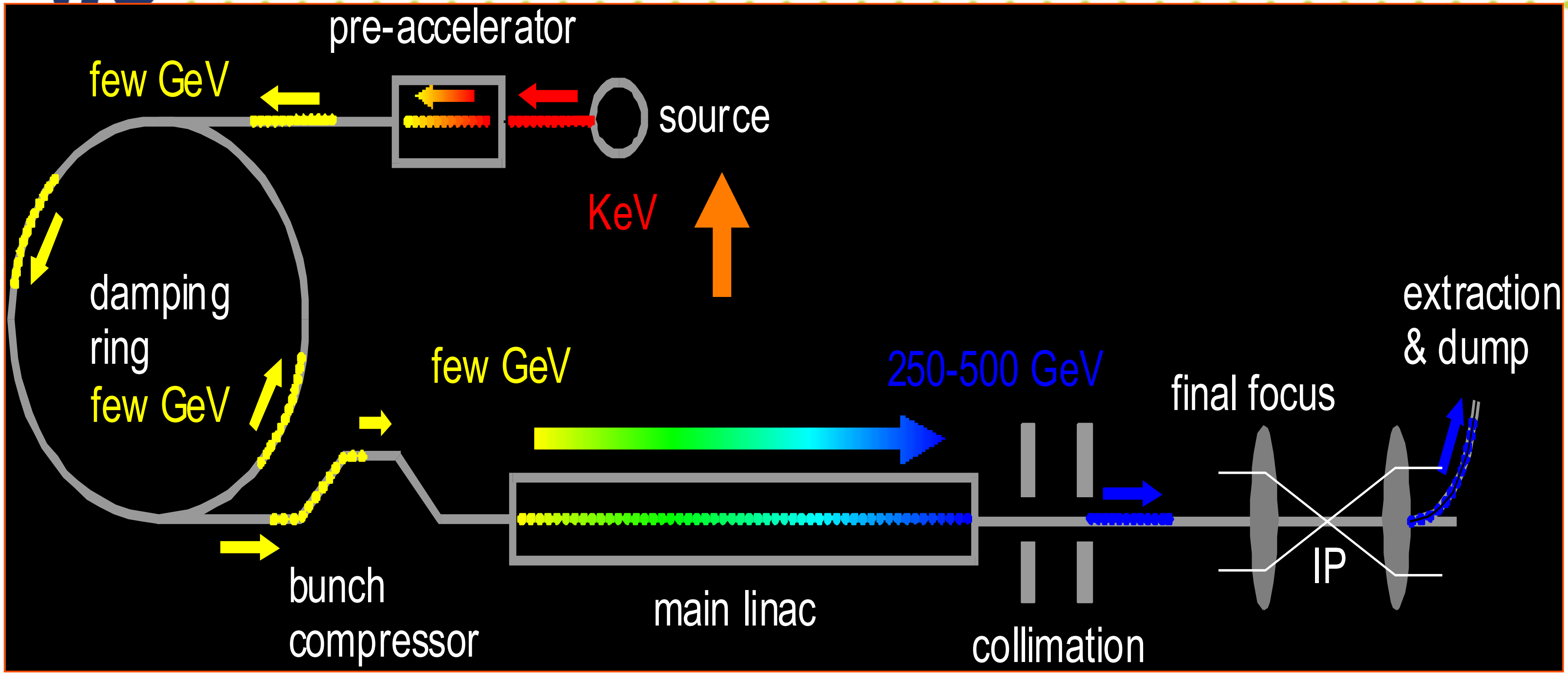
Centre-of-mass dependent:

Focus of design (and cost!) effort

Centre-of-mass energy	GeV	200	230	250	350	500
Electron RMS energy spread	%	0.21	0.19	0.19	0.16	0.12
Positron RMS energy spread	%	0.19	0.16	0.15	0.10	0.07
IP horizontal beta function	mm	16	16	12	15	11
IP vertical beta function	mm	0.48	0.48	0.48	0.48	0.48
IP RMS horizontal beam size	nm	904	843	700	662	474
IP RMS veritcal beam size	nm	9.3	8.6	8.3	7.0	5.9
Vertical disruption parameter		20.4	20.4	23.5	21.1	24.6
Enhancement factor		1.83	1.83	1.91	1.84	1.95
Geometric luminosity	$\times 10^{34}$ $cm^{-2}s^{-1}$	0.25	0.29	0.36	0.45	0.75
Luminosity	**$\times 10^{34}$ $cm^{-2}s^{-1}$**	**0.50**	**0.59**	**0.75**	**0.93**	**1.8**
% luminosity in top 1% ΔE/E		92%	90%	84%	79%	63%
Average energy loss		1%	1%	1%	2%	4%
Pairs / BX	$\times 10^{3}$	41	50	70	89	139
Total pair energy / BX	TeV	24	34	51	108	344

http://ilc-edmsdirect.desy.de/ilc-edmsdirect/item.jsp?edmsid=D00000000925325

ILC Accelerator: Sub-Systems



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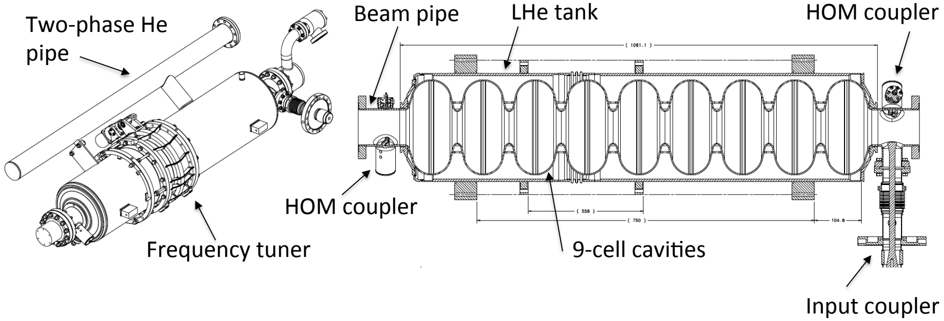
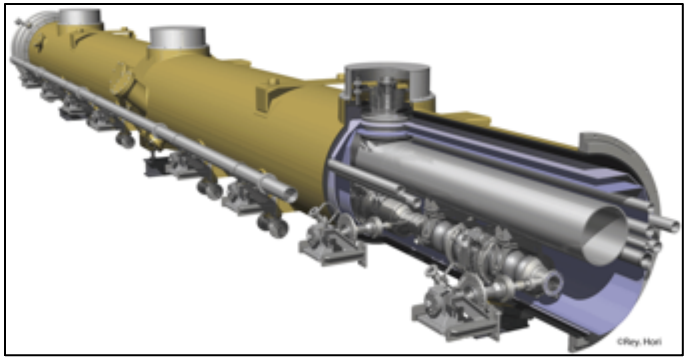
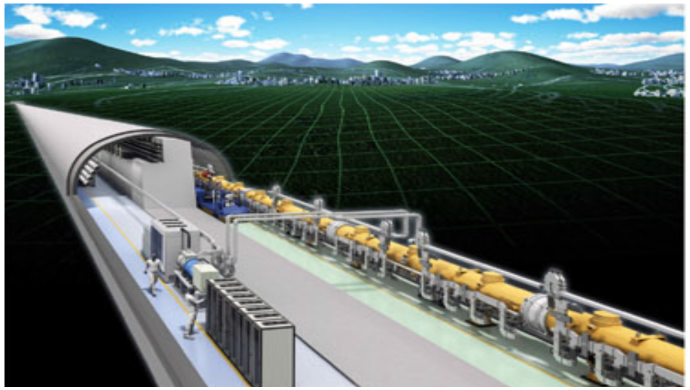
SCRF Linac Technology
超伝導・線形加速器技術







1.3 GHz Nb 9-cellCavities	16,024
Cryomodules	1,855
SC quadrupole pkg	673
10 MW MB Klystrons & modulators	436 /(471 *)

* site dependent

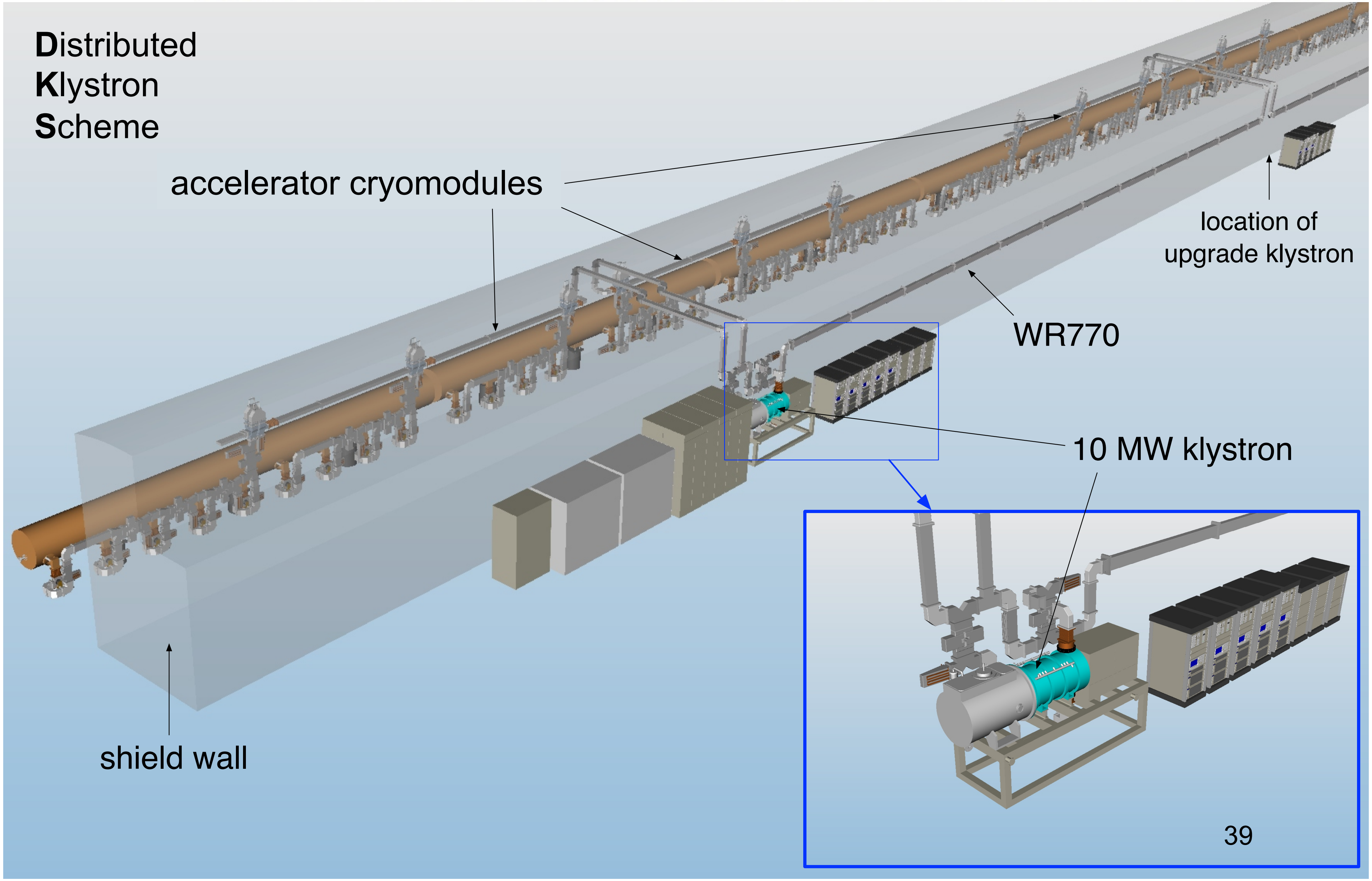
Approximately 20 years of R&D worldwide
→ Mature technology

SCRF Main Linac Parameters (500 GeV)

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		
Charge per bunch	3.2	nC	
Bunch spacing	554	ns	
Beam pulse length	730	μs	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	
Peak beam power per cavity	190*	kW	* at 31.5 MV/m

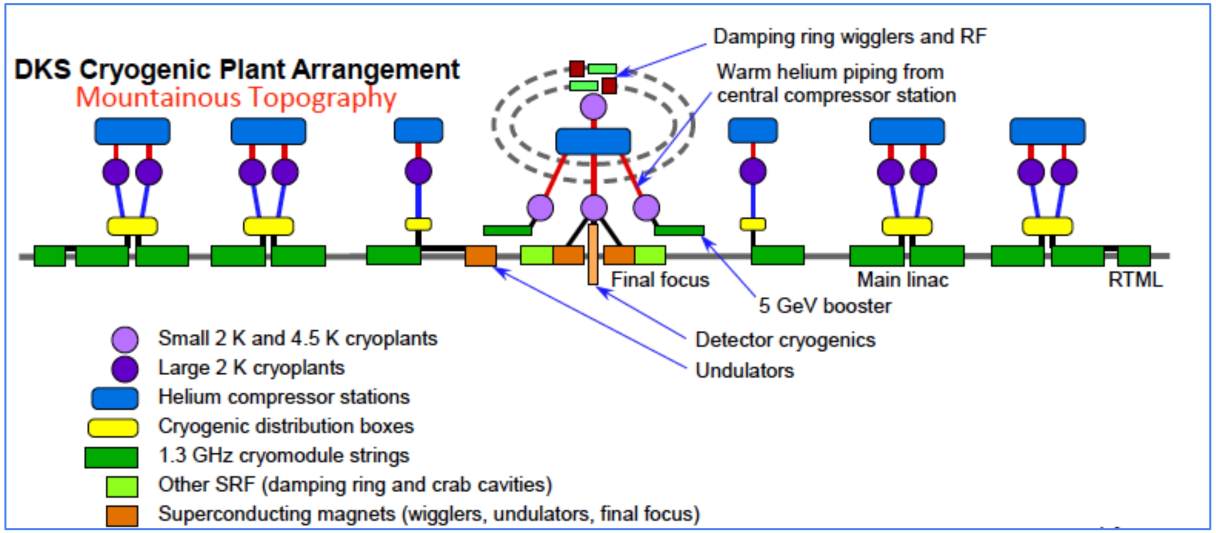
→ To be reported by S. Michizono

Site Specific Design in RF Power



ILC Cryogenic (TDR)

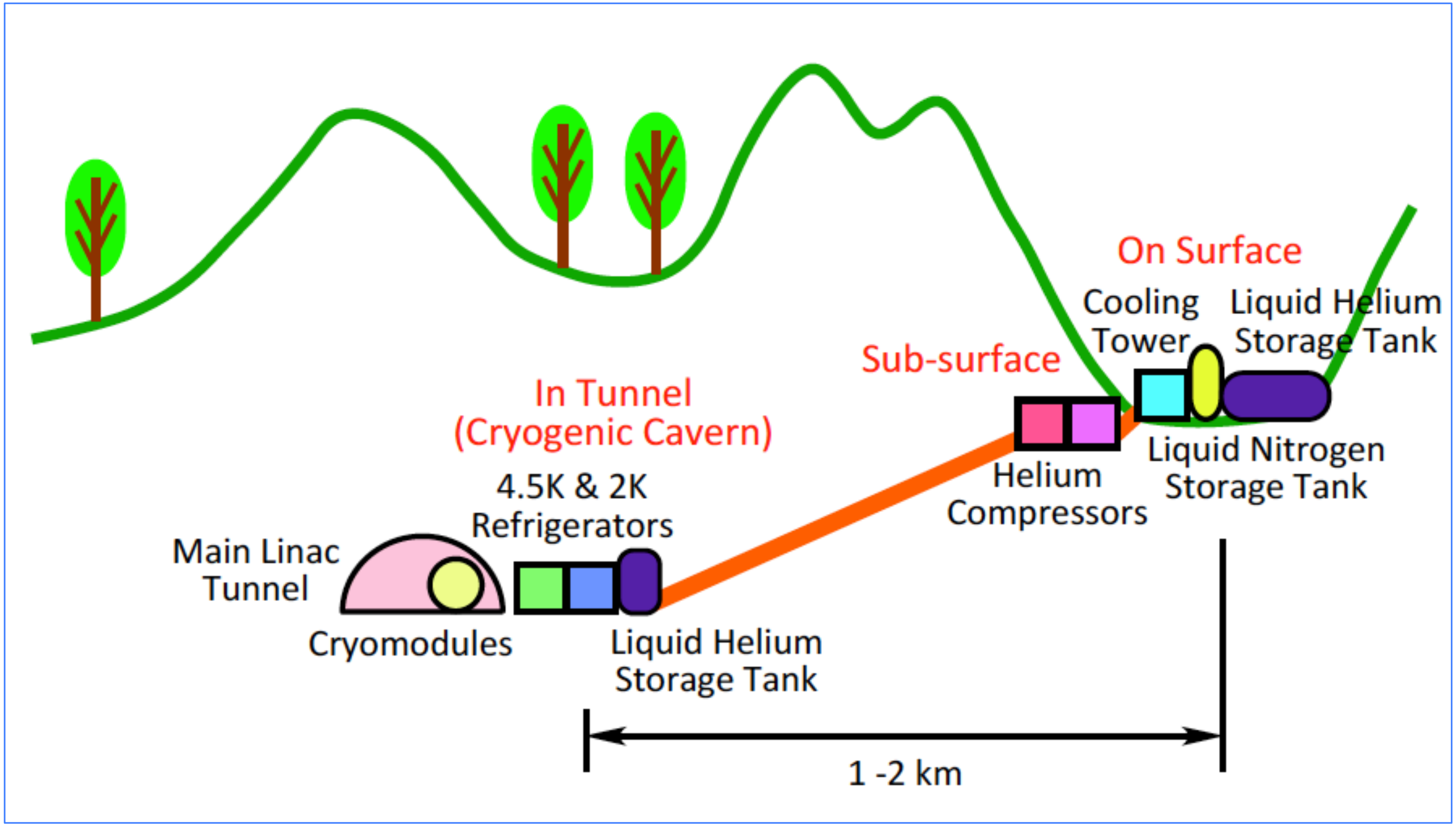
ILC 冷却システム



		40–80 K	5–8 K	2 K
Predicted module static heat load	(W/module)	75.04	10.82	1.32
Predicted module dynamic heat load	(W/module)	58.80	5.05	9.79
Number of cryomodules per cryogenic unit		156 / 189	156 / 189	156 / 189
Non-module heat load per cryo unit	(kW)	0.7 / 1.1	0.14 / 0.22	0.14 / 0.22
Total predicted heat per cryogenic unit	(kW)	21.58 / 26.40	2.61 / 3.22	1.87 / 2.32
Efficiency (fraction Carnot)		0.28	0.24	0.22
Efficiency in Watts/Watt	(W/W)	16.45	197.94	702.98
Overall net cryogenic capacity multiplier		1.54	1.54	1.54
Heat load per cryogenic unit including multiplier	(kW)	33.23 / 40.65	4.03 / 4.96	2.88 / 3.57
Installed power	(kW)	547/669	797/981	2028 / 2511
Installed 4.5 K equiv	(kW)	2.50 / 3.05	3.64 / 4.48	9.26 / 11.47
Percent of total power at each level		0.16	0.24	0.60
Total operating power for one cryo unit based on predicted heat (MW)			2.63 / 3.24	
Total installed power for one cryo unit (MW)			3.37 / 4.16	
Total installed 4.5 K equivalent power for one cryo unit (kW)			15.40 / 19.01	

flat / mountain topographies

ILC Cryogenics Layout (After TDR)

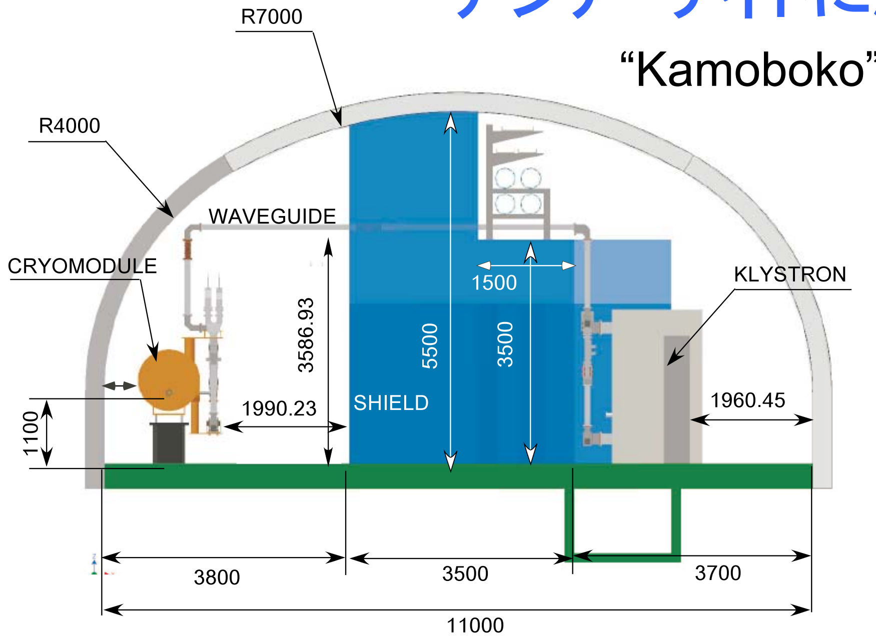


→ To be reported by A. Emonoto, M. Miyahara

Site Specific Design in CFS

アジア・サイトに沿った土木・建築設計

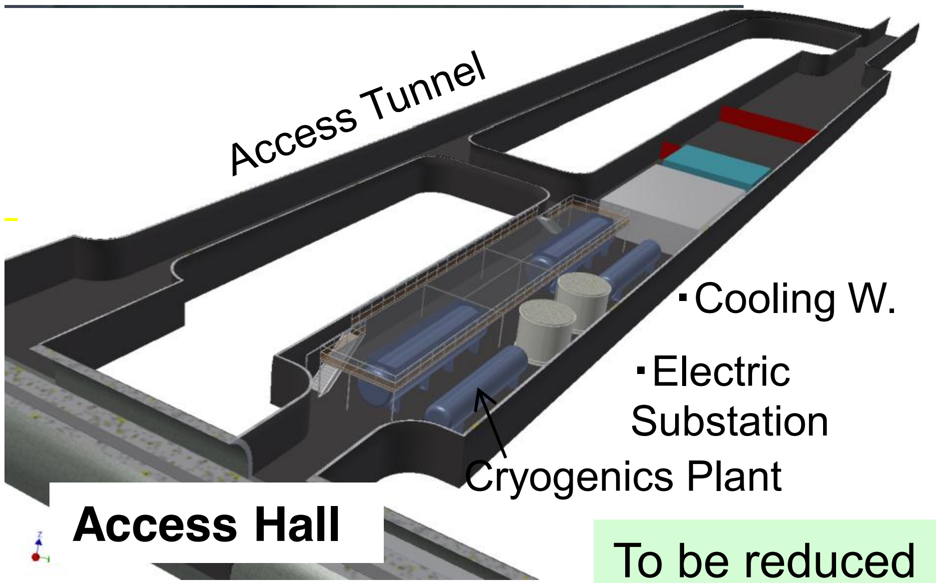
“Kamoboko” tunnel



Reduced surface presence.

Horizontal access

Most infrastructure underground.



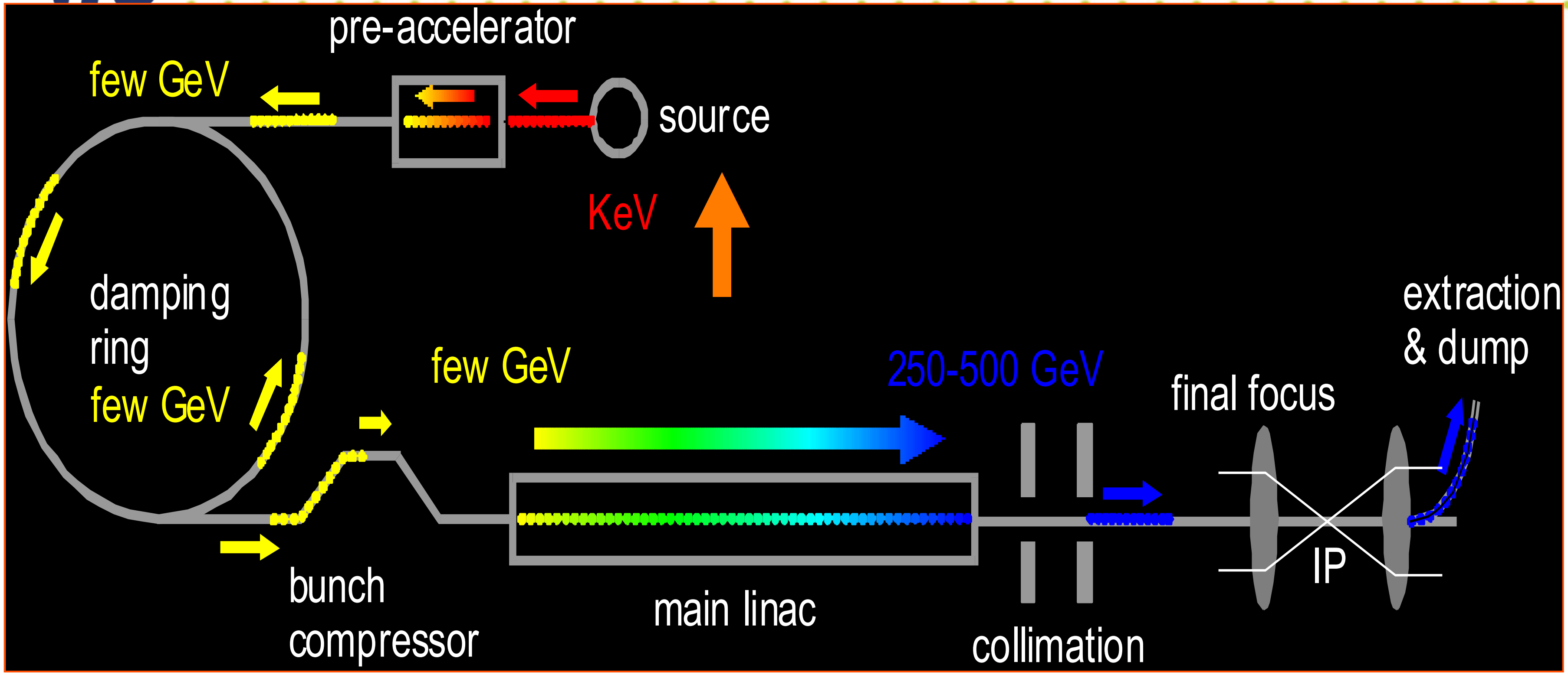
To be reduced

“Mountainous” Topography site-dependent design

→ To be reported by A. Enomoto, M. Miyahara

→ To be reported by K. Yokoya

ILC Accelerator: Sub-Systems



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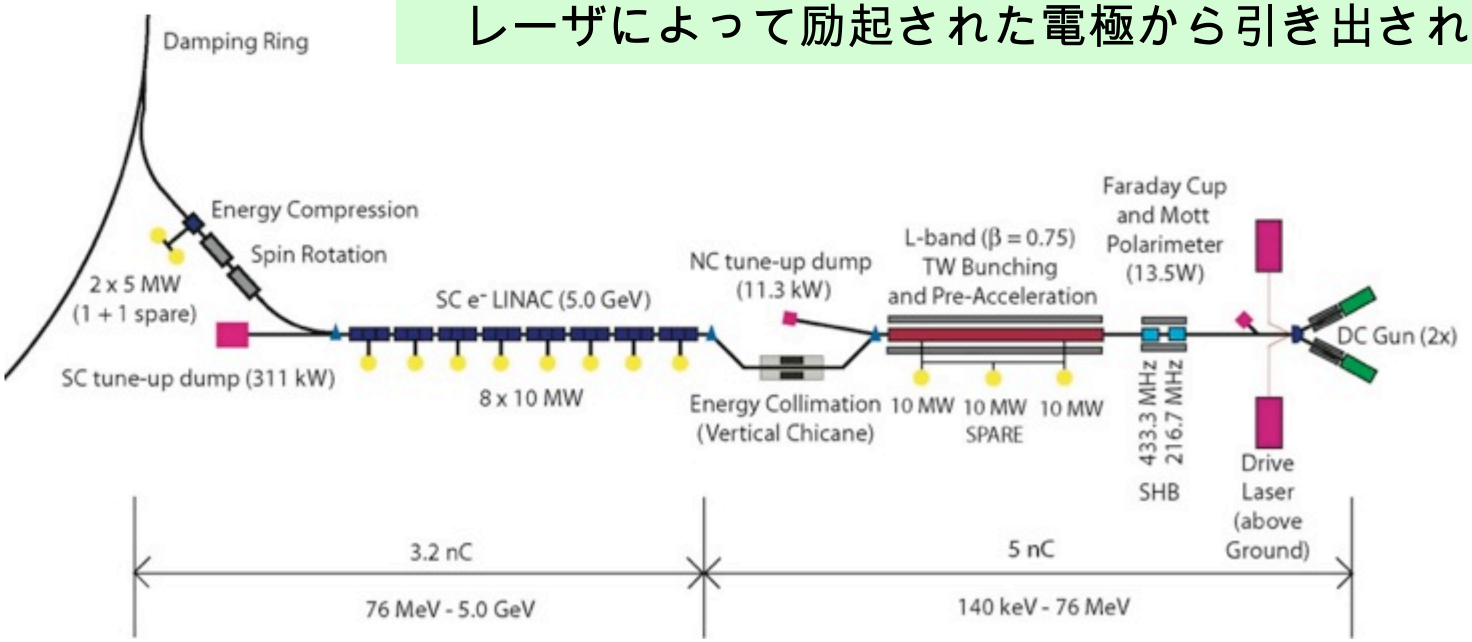
- Beam Delivery System（BDS ）：ビーム伝達・ 最終収束システム)

Polarised e- Source
偏極電子源

- **Laser-driven photo cathode (GaAs)**
- **DC gun**
- **Integrated into common tunnel with positron BDS**

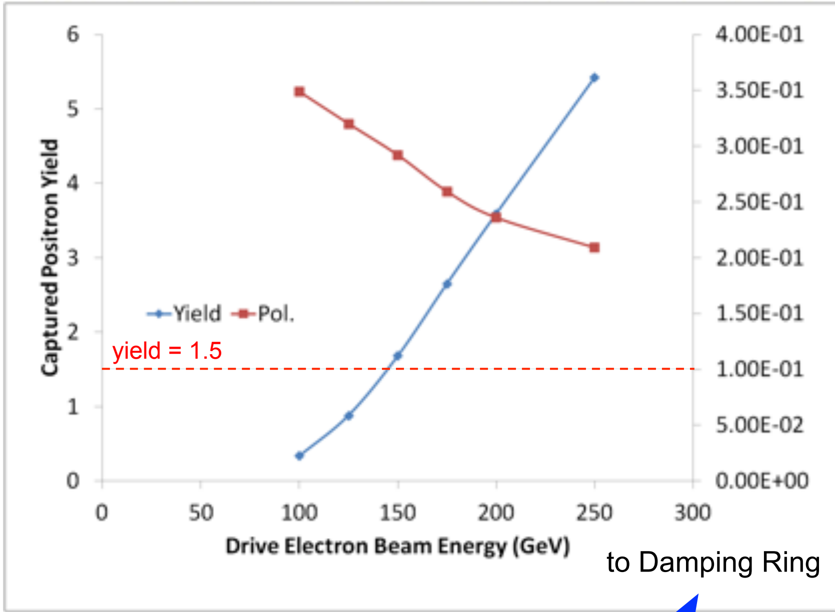
レーザによって励起された電極から引き出される電子

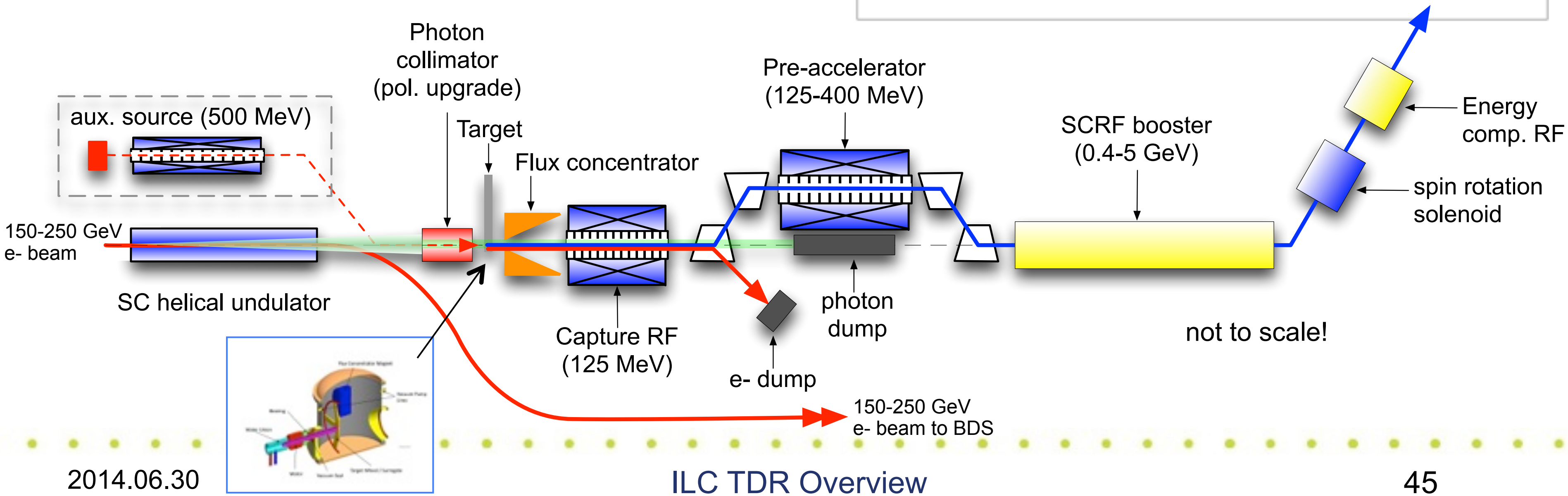


→ To be reported by K. Yokoya

Positron Source
陽電子源

- **located at exit of electron Main Linac**
- **147m (~230m) SC helical undulator**
  - ヘリカルアンジュレーターによる円偏向ガンマ線
- **driven by primary e- beam (150-250 GeV)**
- **produces ~30 MeV photons**
- **converted in thin target into e+e- pairs**
  - → 偏極陽電子の発生





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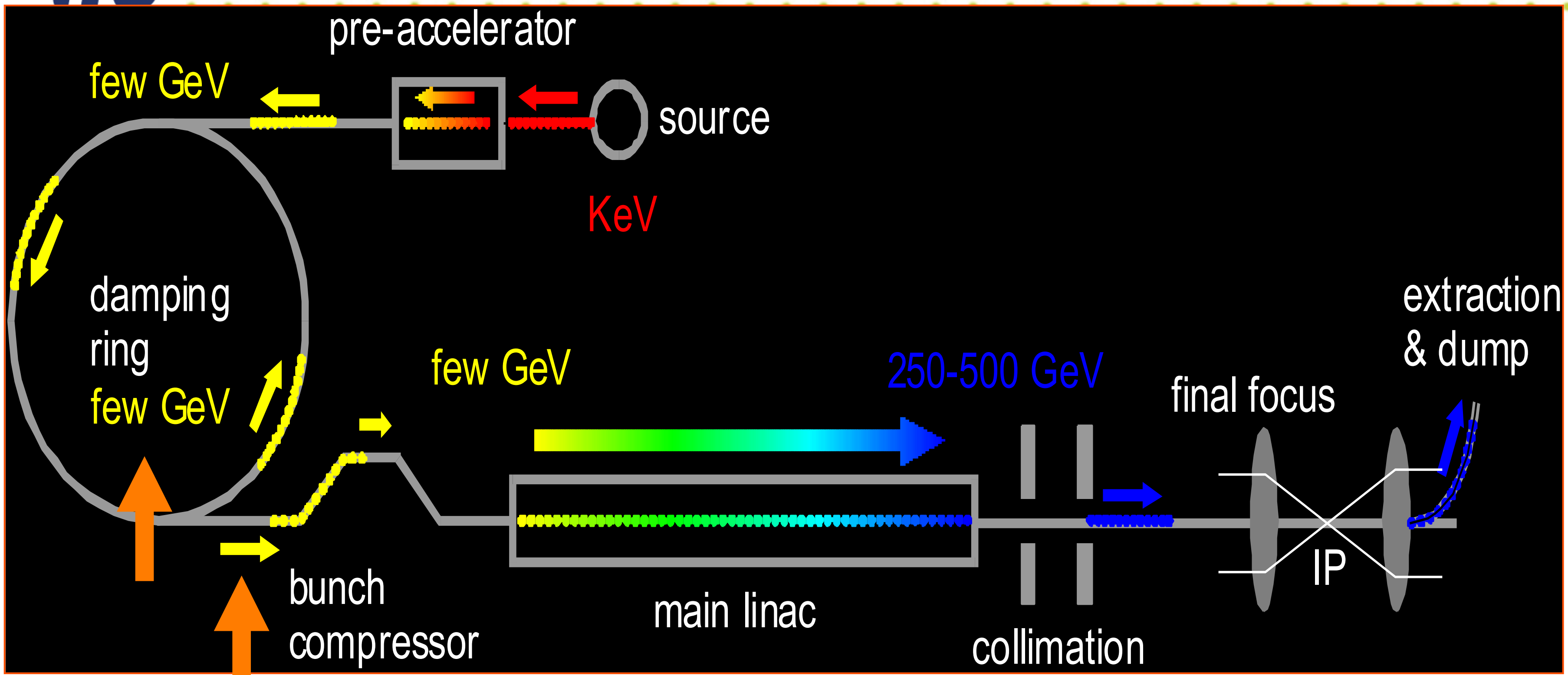

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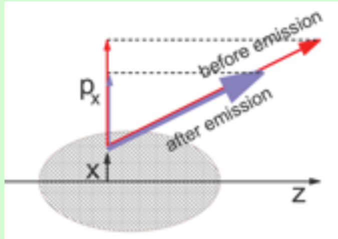
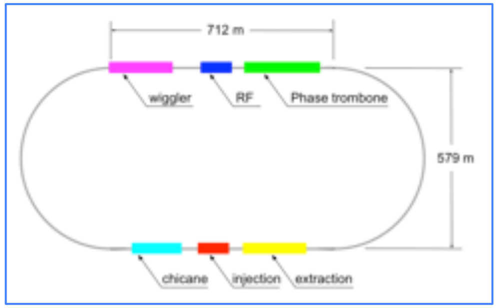
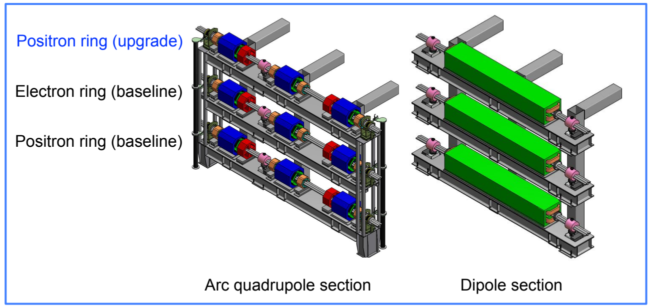
Damping Rings
減衰リング

- Concept
  - **Reduce eimittance with SR** (輻射によりエミッタンスを減少)
  - **Further reduction in short time, by using Wiggler** （Wiggler磁石を用いることで、さらに短時間で減少）
  - **All bunch in the DR, same time,** (一旦全てのバンチを収納）
- Requirements
  - **$\gamma\varepsilon_x$ = 5.5 μm, $\gamma\varepsilon_y$ = 20nm**
  - **Time for damping 200 (100) ms**
  - **1st step 1312 bunches, (2625) bunches**
  - **bunch-by-bunch injection/extraction**







Circumference		3.2	km
Energy		5	GeV
RF frequency		650	MHz
Beam current		390	mA
Store time		200 (100)	ms
Trans. damping time		24 (13)	ms
Extracted emittance	x	5.5	μm
(normalized)	y	20	nm
No. cavities		10 (12)	
Total voltage		14 (22)	MV
RF power / coupler		176 (272)	kW
No.wiggler magnets		54	
Total length wiggler		113	m
Wiggler field		1.5 (2.2)	T
Beam power		1.76 (2.38)	MW

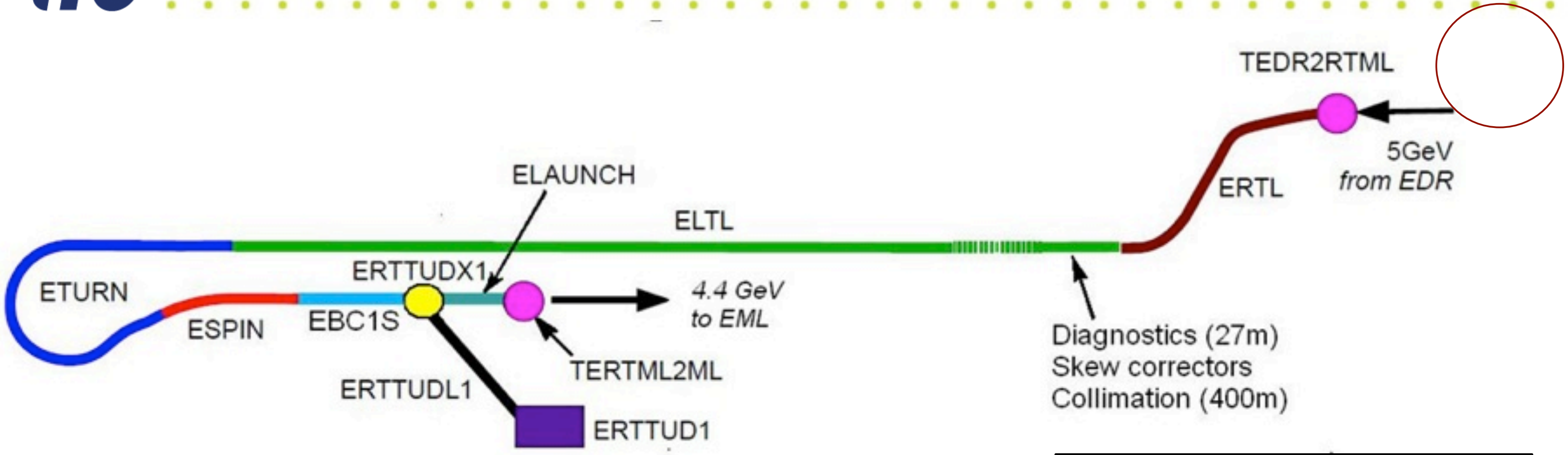
Values in () are for 10-Hz mode

Many similarities to modern 3rd-generation light sources

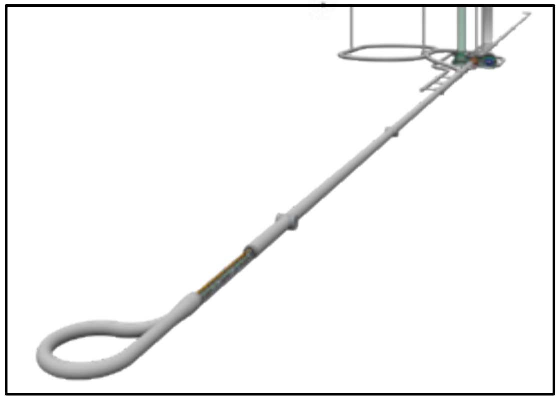
→ To be presented by K. Yokoya

RTML (Ring To Main Linac)

DR からML へのビーム輸送



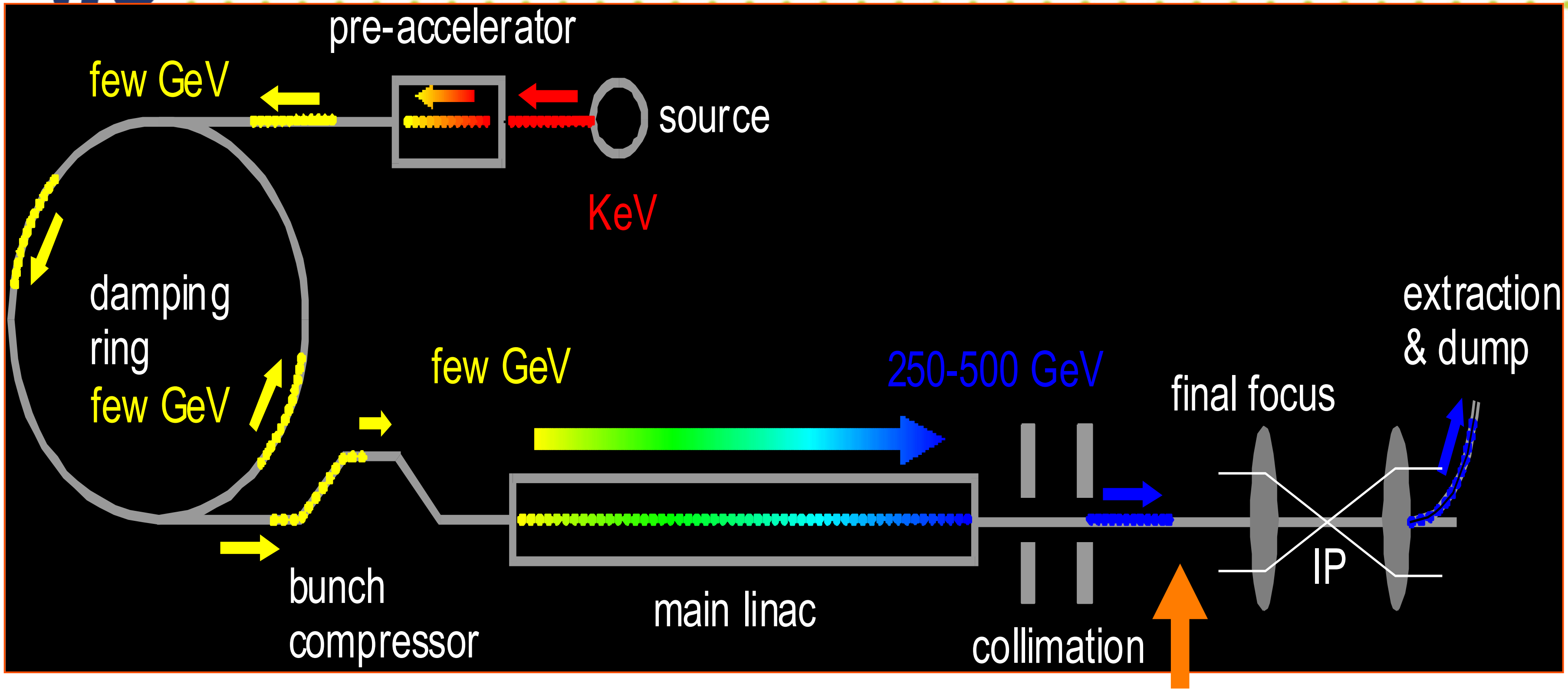
- **RTML:** DRからMLへのビームの輸送
- **Spin Rotation:** スピンの回転
- **Bunch compression:** バンチ長の圧縮
- **Interim Beam Dump :** ビームの中途ダンプ



10 km を越えるとても長いビームライン。地磁気の影響も考える必要がある。

→ To be reported by K. Yokoya

ILC Accelerator: Sub-Systems



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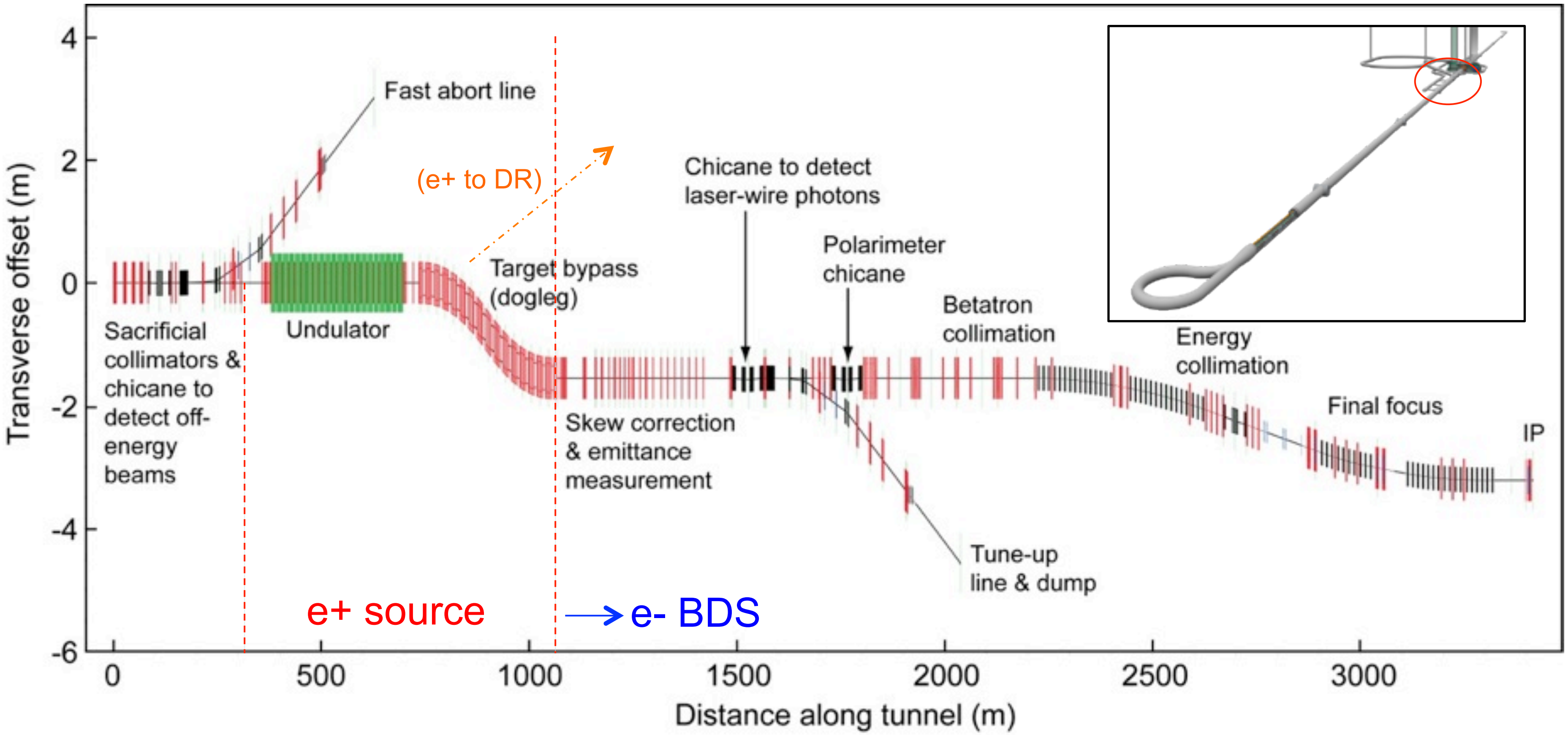
BDS and MDI

(Beam Delivery System and Machine-Detector Interface)

ビーム伝達システム、加速器・ 測定器・ 接続



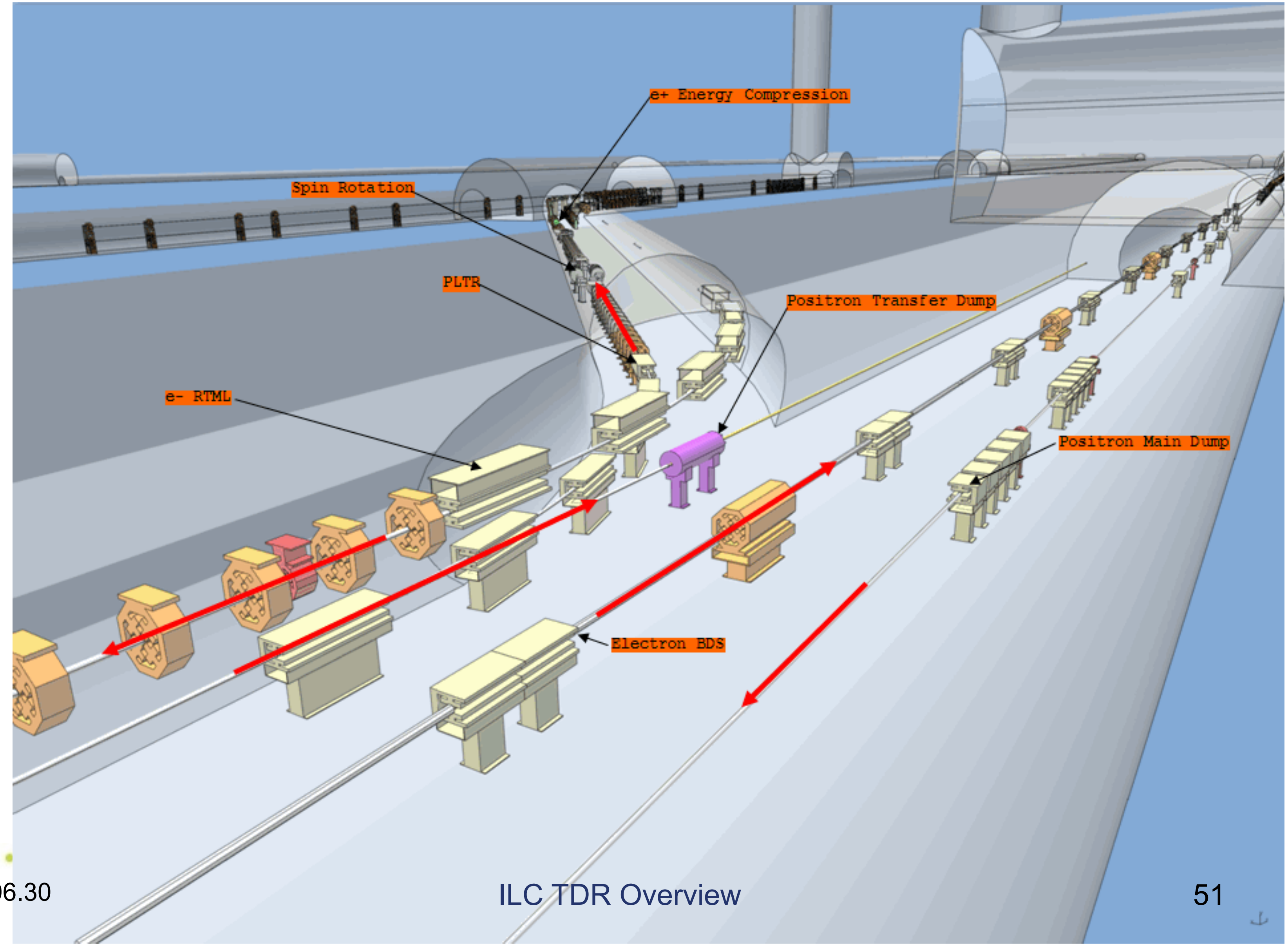
e- Beam Delivery System

→ To be reported by K. Yokoya

→ To be reported by A. Emonoto, M. Miyahara

3D View of Target Region

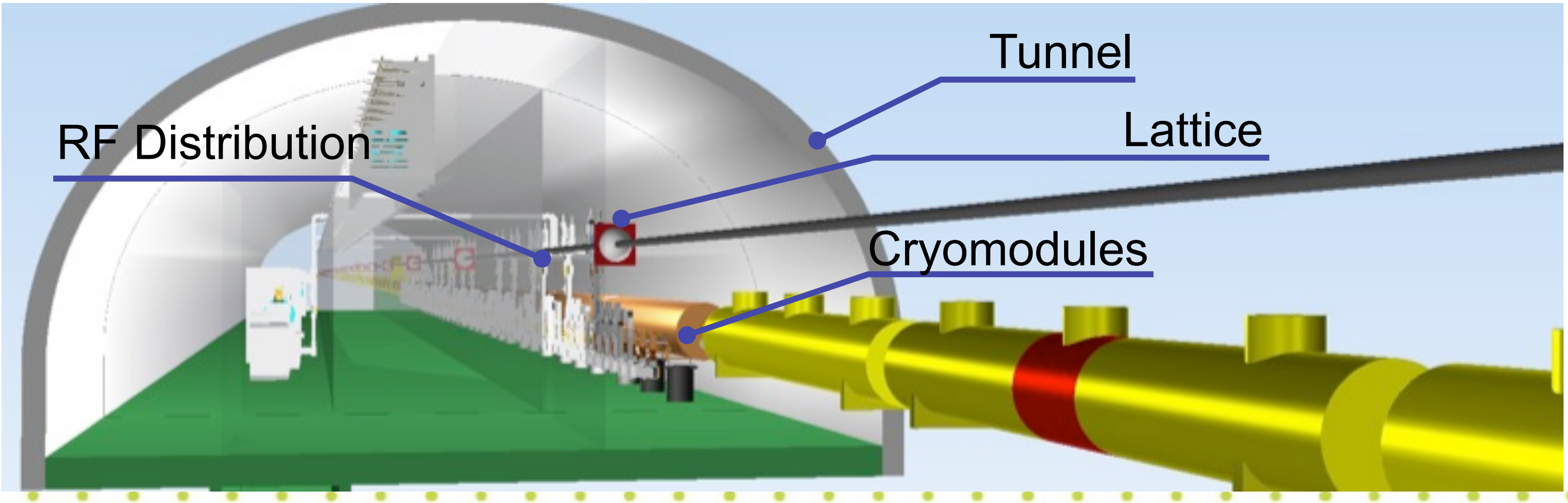
陽電子源･BDS、中央領域



→ To be reported by A. Emonoto, M. Miyahara

Engineering Data Management (EDMS)

- Collaborative engineering:
  - Design integration, visualisation, traceability, configuration management
- Design integration:
  - Geology, Civil engineering, accelerator design, experimental groups
- Different user groups in remote:
  - ILC Community, Planning team, local team, sub-contractors
- Standardization:
  - Names, procedures, formats, conventions, design rules

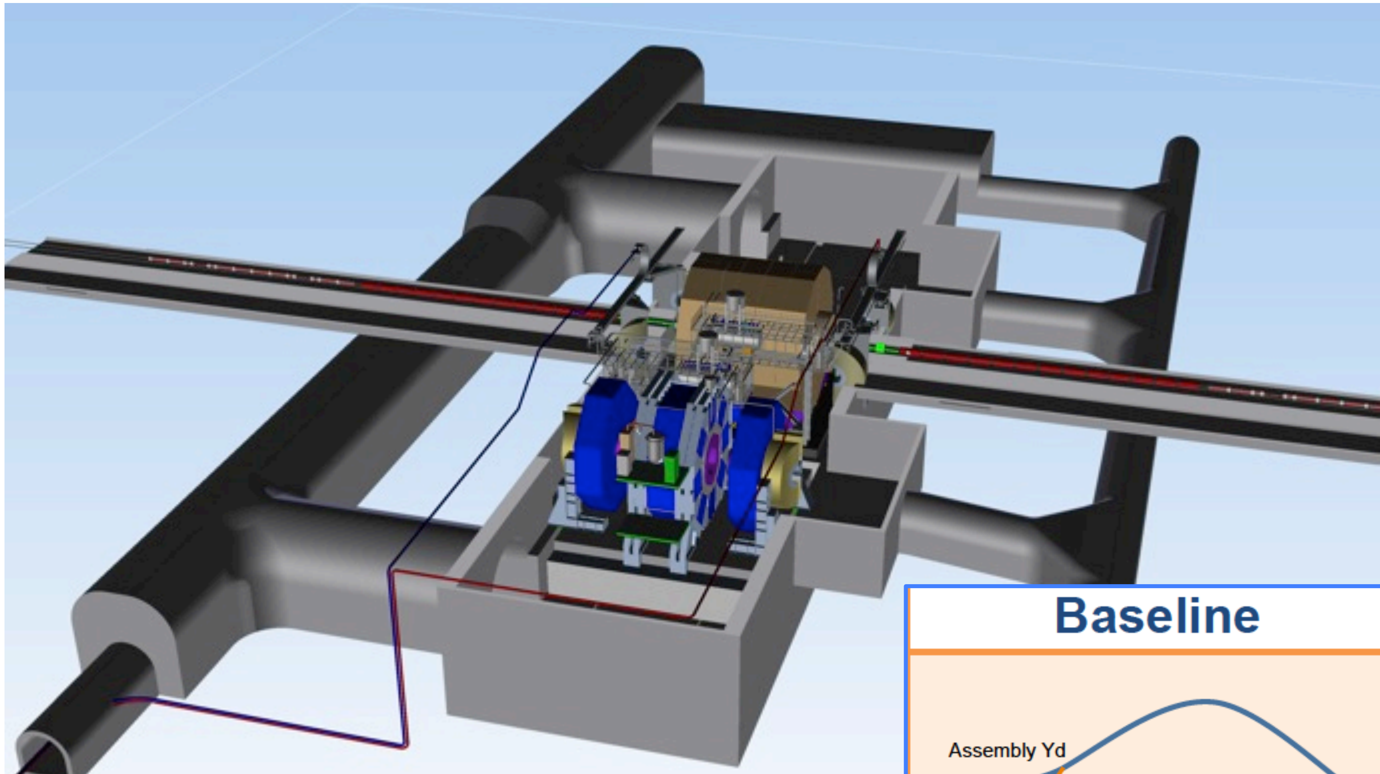


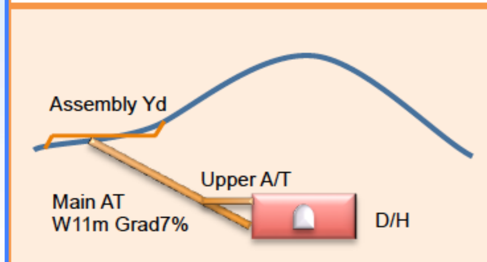
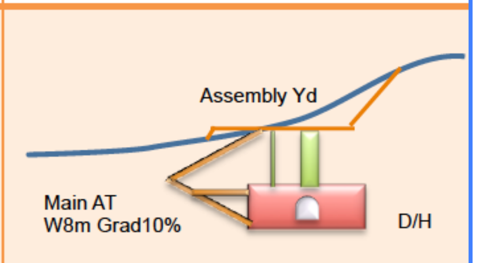
Outline

- Introduction
- Accelerator R&D
- Accelerator Baseline Design,
- Detectors
- Energy Staging
- Schedule
- Summary

→ To be reported by A. Enomoto and M. Miyahara

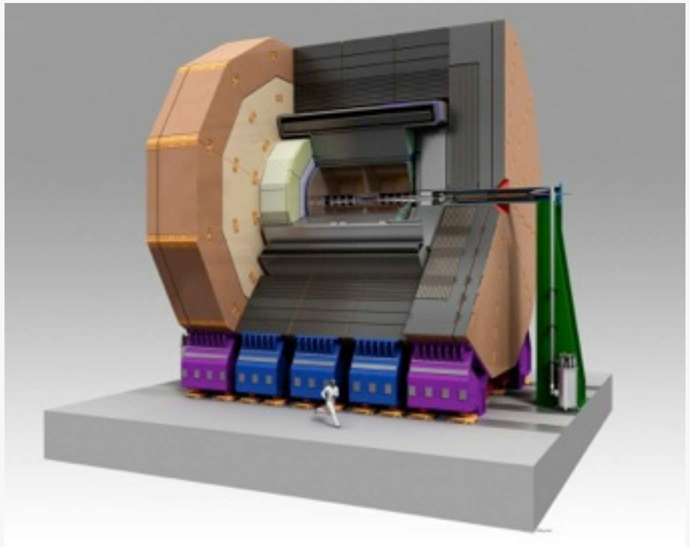
MDI (Detector Hall)
検出器ホール



<table>
<tr><th>Baseline</th><th>Hybrid-A</th></tr>
<tr><td>
</td><td>
</td></tr>
<tr><td>• 1 HT (11x11m 7%grad)
• Detector assembling is inside of DH</td><td>• 1 HT (8.0x7.5m 10%gradl)
• 2 VS (D18m, D10m)
• Detectors assembling is on-ground.</td></tr>
</table>

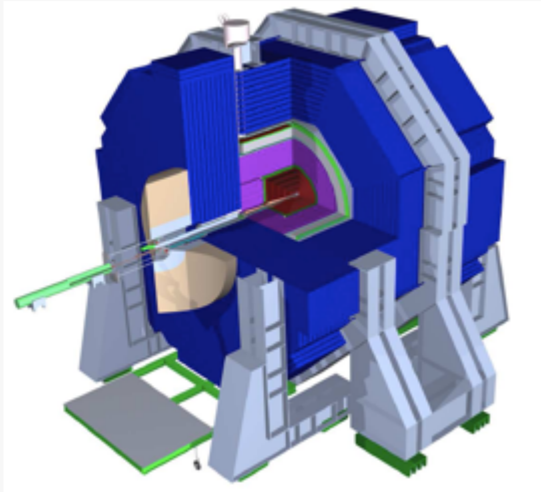
2 Detector Concepts:
Detailed Baseline Design

ILD



- Large R with TPC tracker
  - 32 countries, 151 institutions, ~700 members
  - Most members from Asia and Europe
  - B=3.5T, TPC + Si trackers
  - ECal: R=1.8m

SiD

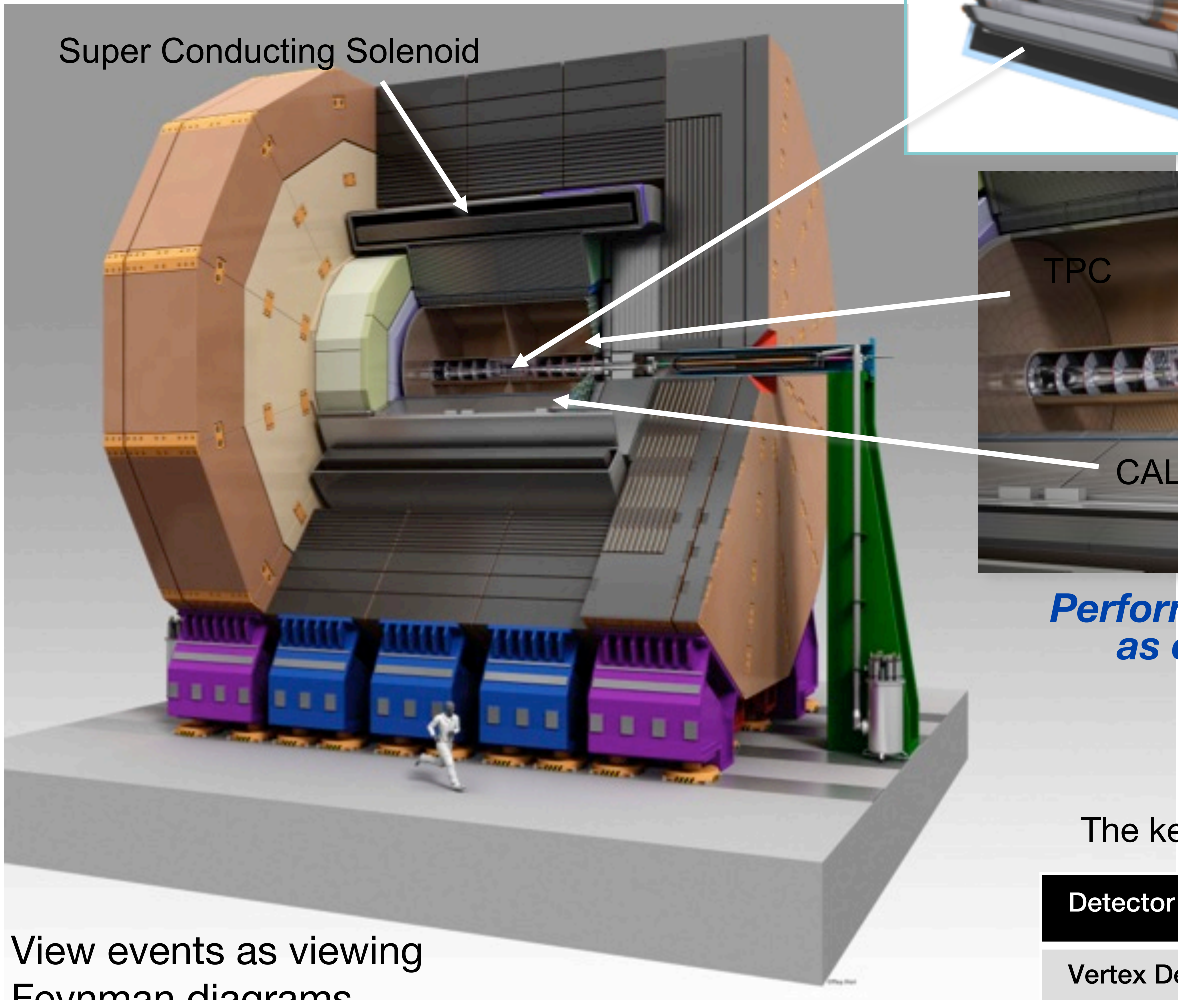


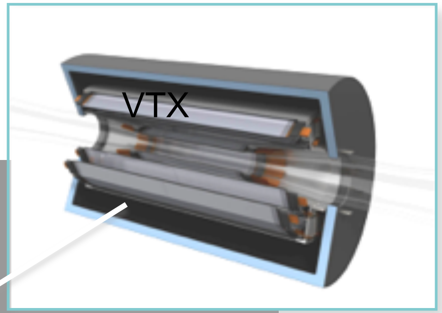
- High B with Si strip tracker
  - 18 countries, 77 institutions, ~240 members
  - Mostly American
  - B=5T, Si only tracker
  - ECal : R=1.27m

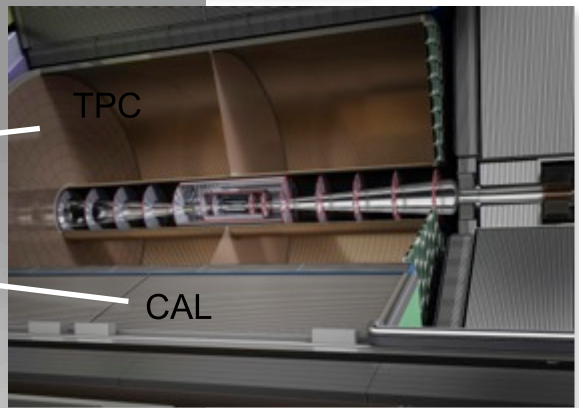
Both detector concepts are optimized for

Particle Flow Analysis

International Large Detector







Vertex Detector

detects production and decay points of unstable particles and identifies b- and c-quarks.

Time Projection Chamber

measures momenta of charged particles

Calorimeter

measures energies of neutral particles

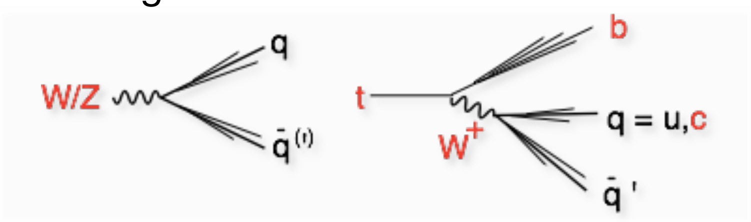
Performance Goal as compared to LHC detectors

Vertex resolution	2-7 times better
Momentum resolution	10 times better
Jet energy resolution	2 times better

The key is ultra high granularity!

Detector	ILD	ATLAS	Granularity
Vertex Det.	5×5μm²	400×50μm²	x 800
Tracker	1×6mm²	13mm²	x 2.2
EM Calorimeter	Silicon: 5×5mm² Scintillator: 5×45mm²	39×39mm²	x 61 x 7

View events as viewing Feynman diagrams



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Known Physics and Possible Staging
物理課題とエネルギー·ステージング

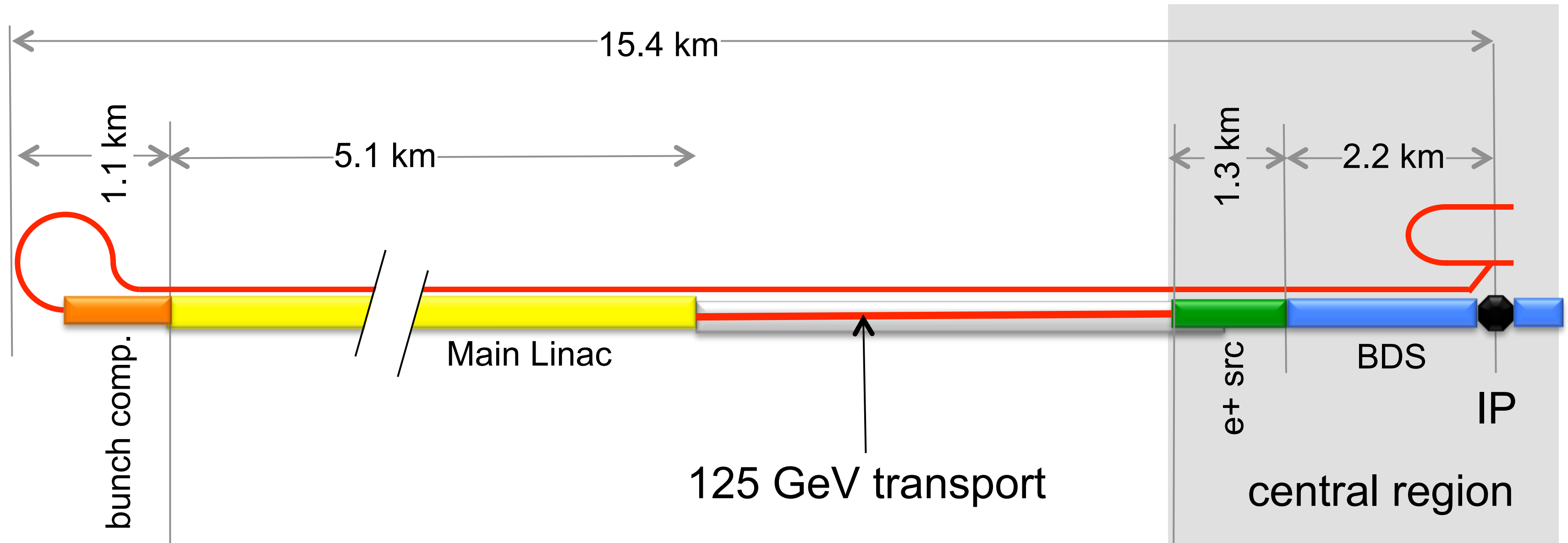
- **~125 GeV 'Higgs boson'**
  - 125+91=216 GeV cm → 250 GeV
- **173 GeV 'Top quark'**
  - 2x173=346 GeV cm → 350 GeV and higher
- **Higgs self coupling (ZHH)**
  - σ (ZHH) : maximum → ~ 500 GeV
- **Top Yukawa coupling ($t\bar{t}H$)**
  - 2x173+125 = 471 GeV → 500 GeV and higher
- **Beyond**
  - ~ TeV or higher

Staging / Upgrading

250 GeV staged

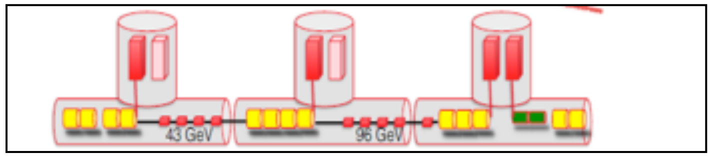
250 GeV からのスタート

quasi-adiabatic energy upgrade?



- Half the linac
- Full-length BDS tunnel & vacuum (TeV)
- ½ BDS magnets (instrumentation, CF etc)
- 1 RTML LTL
- 5km 125 GeV transport line

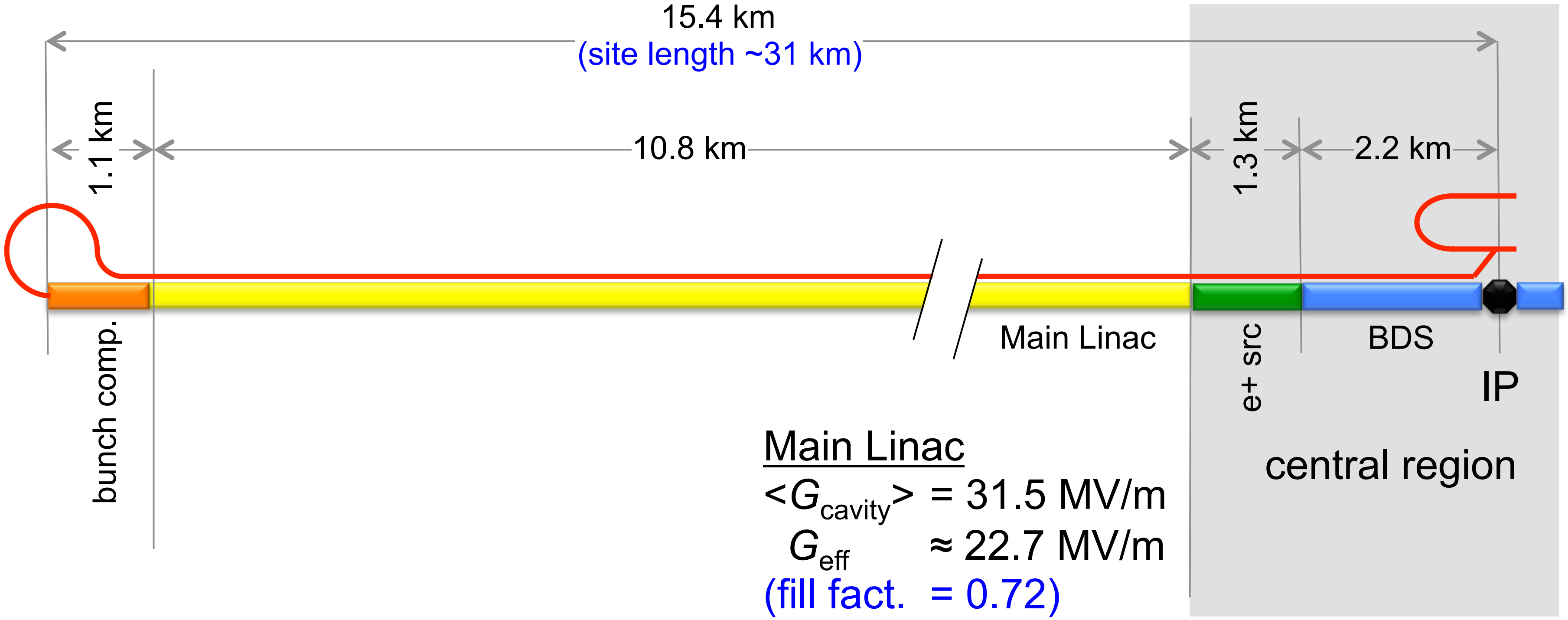
Extended tunnel/CFS already 500 GeV stage
10Hz mode e- linac



an Alternate configuration

TDR 500 GeV Baseline

500 GeV: TDR 基本計画



Main Linac

$\langle G_{cavity} \rangle$ = 31.5 MV/m

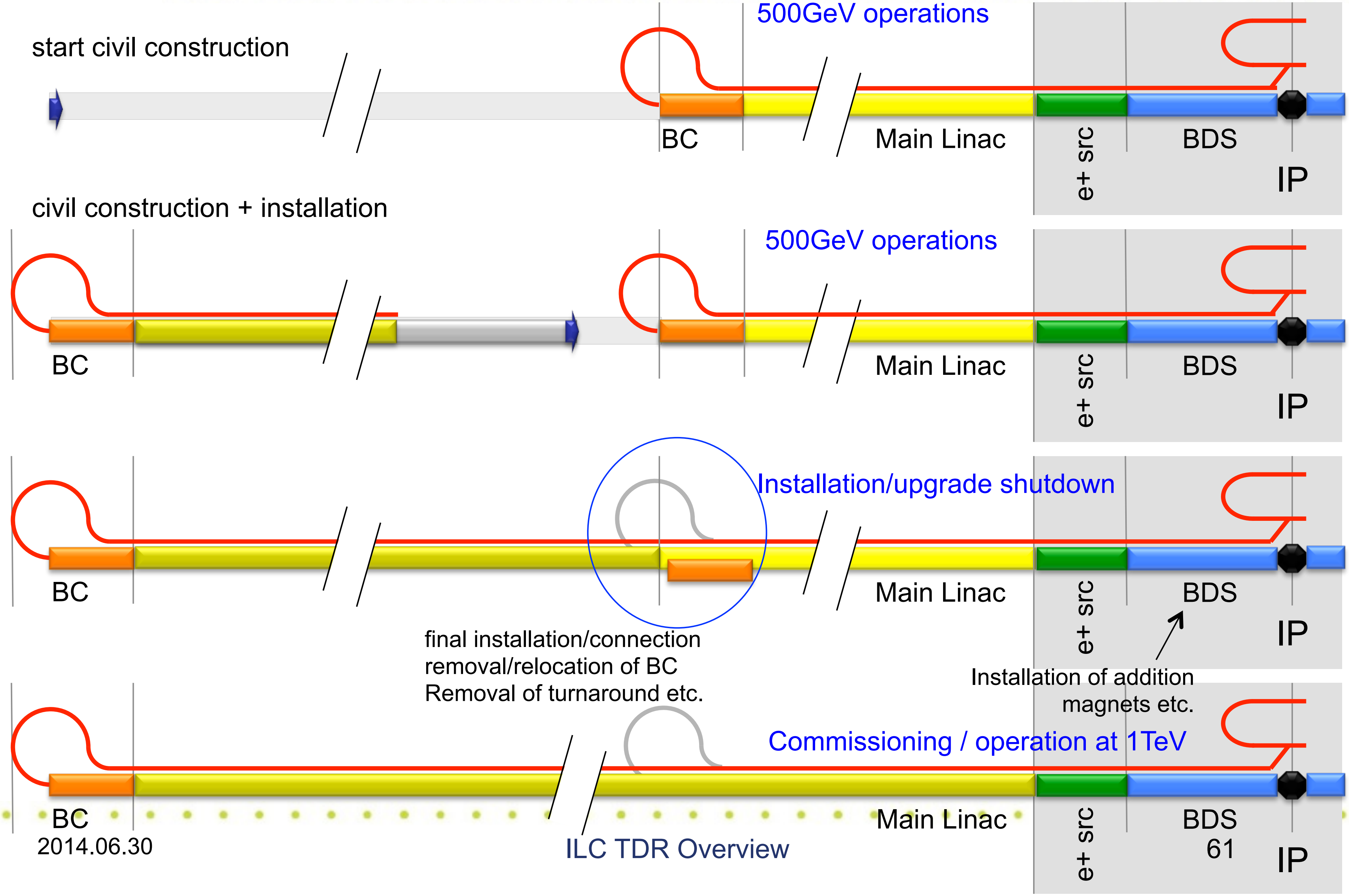
G_{eff} ≈ 22.7 MV/m

(fill fact. = 0.72)

P_{AC}: 161 MW

TeV upgrade: Construction Scenario

TeV アップグレードへの方策・シナリオ



ILC Construction Schedule

ILC建設期間（予測）

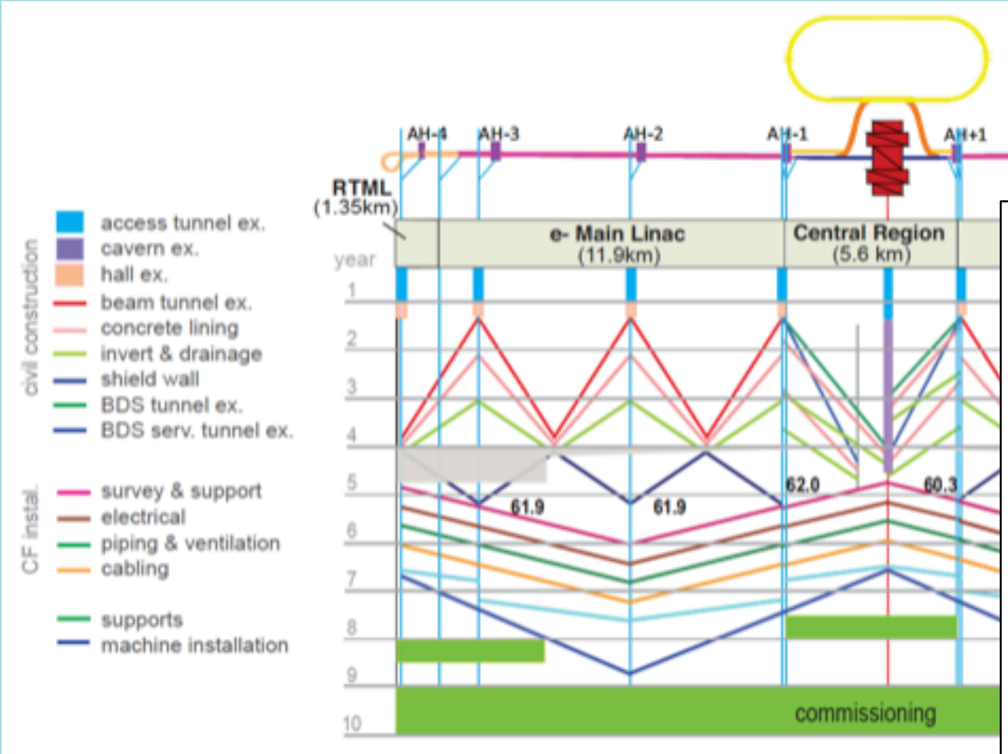
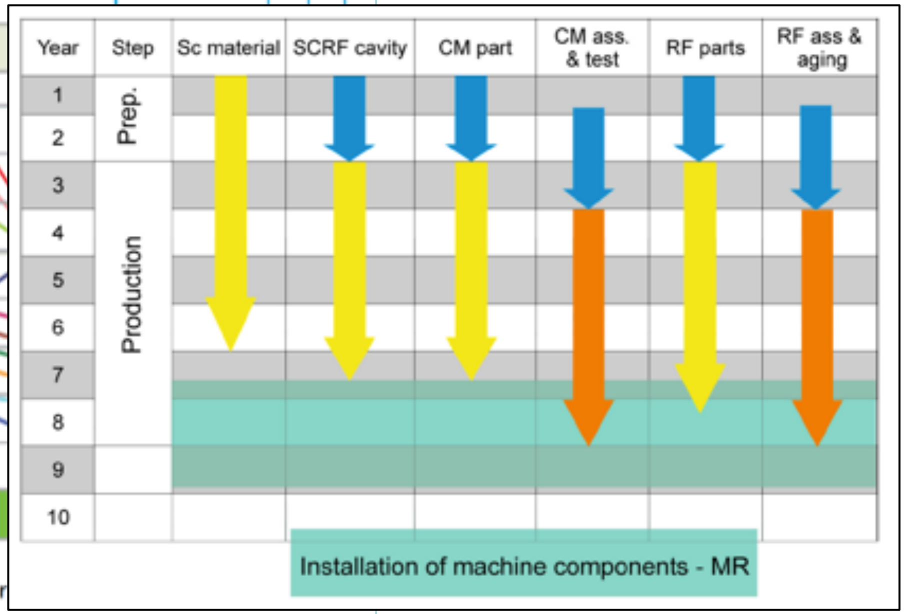


Figure 14.3. The construction and commissioning schedule for the mountain topogr
Fig. 14.2 caption for details.



施設関連建設期間、　　SCRF関連建設期間
建設：9年、コミッショニング、1年　（直接500 GeV 加速器を建設した場合）

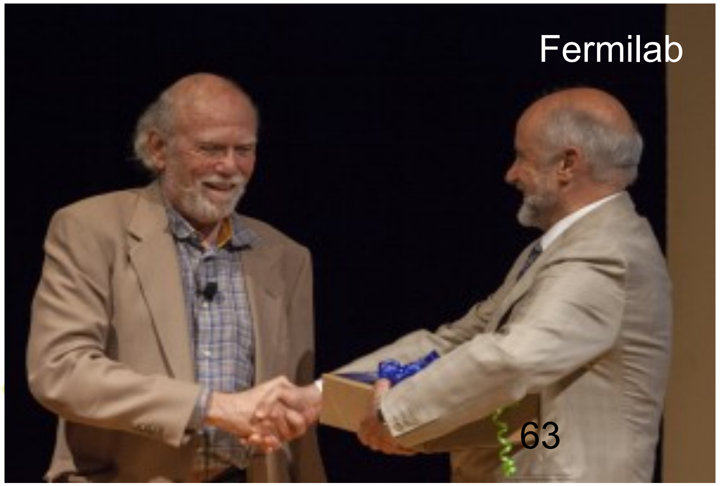
Official Completion of ILC TDR

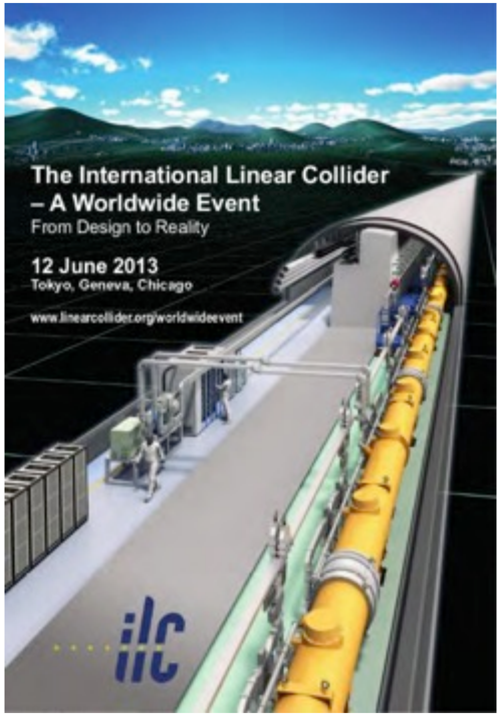
"A World-Wide Event – From Design to Reality"

TDR設計書の公開とGDE→ LCC への伝達

June 12, 2013:

TDR handed to LCC Director Lyn Evans





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

"THE ILC IS "READY TO GO AHEAD" !
ILC: 『設計から実現へ』

Summary:

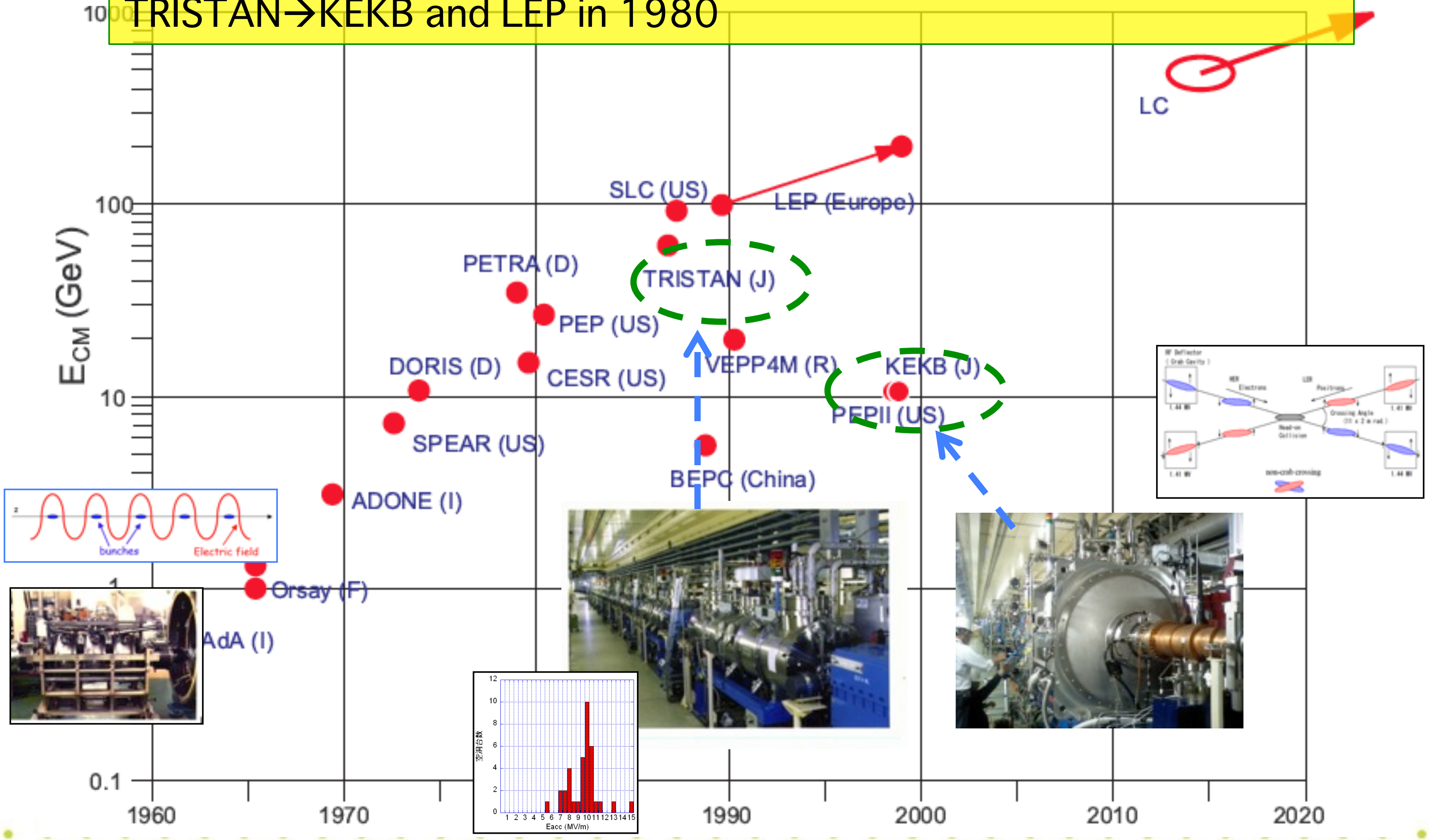
まとめ

- **ILC TD Phase R&D** : TD Phase (前後を含む)における技術開発
  - Demonstration of SCRF Technology: 超伝導加速空洞技術・実証
    - 加速電界(> 35. MV.m) 、加速ビーム電流 (9 mA) 、加速ビームRF パルス長 (1 ms)、RF制御技術が向上し、ILCが求める性能
  - Nano Beam Technology: ナノビーム技術・実証
    - DR Emittance: ダンピングリングでの超低エミッタンス (4 pm @ 1.3 GeV))
    - FF Beam size: 最終フォーカスポイントの極小ビームサイズ 44 nm@ 1.3 GeV)
- **ILC TDR Publication:** 技術設計書を発行
  - TDR Completion: 技術実証実験に裏付けされた、技術設計書が完成。
  - Design to Reality: 『設計から実現』にむけた活動段階を迎える。
- Next: Cost Overview Report: 次の報告で、コスト見積もり概要、
- Further Detail 次回WG 以降、サブシステム詳細を、順次報告する。

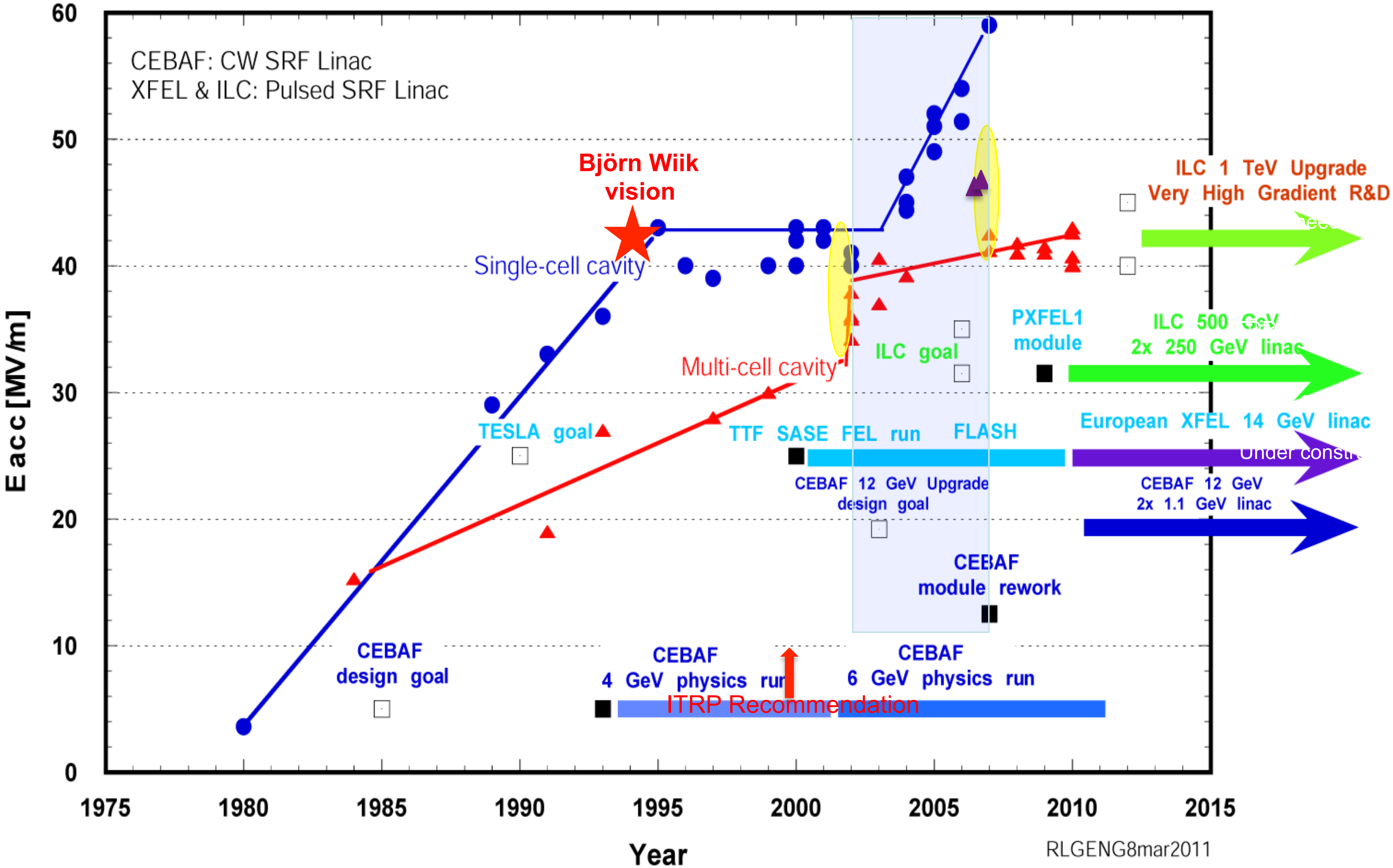
予備

Development of e-/e+ Colliders

KEK and CERN, pioneering for SCRF beam acceleration
TRISTAN→KEKB and LEP in 1980



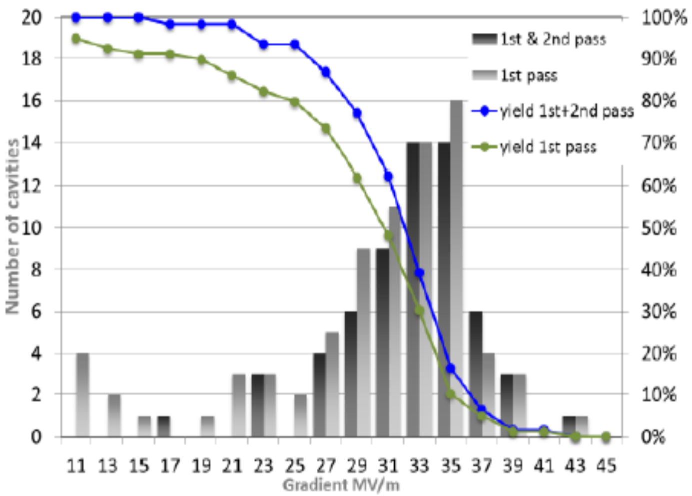
超伝導加速空洞の加速勾配の進展

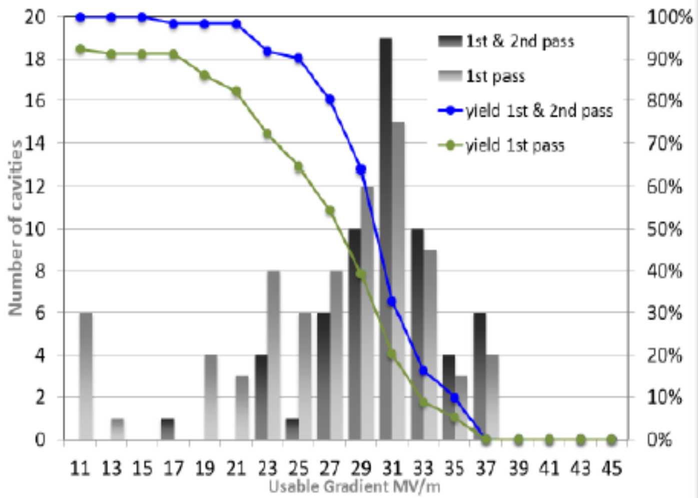


Industrial Mass Production of SRF Cavities for EU - XFEL

- 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)





Status of May 2014:

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

D. Reschke, SRF 2013 TTC 2014

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:

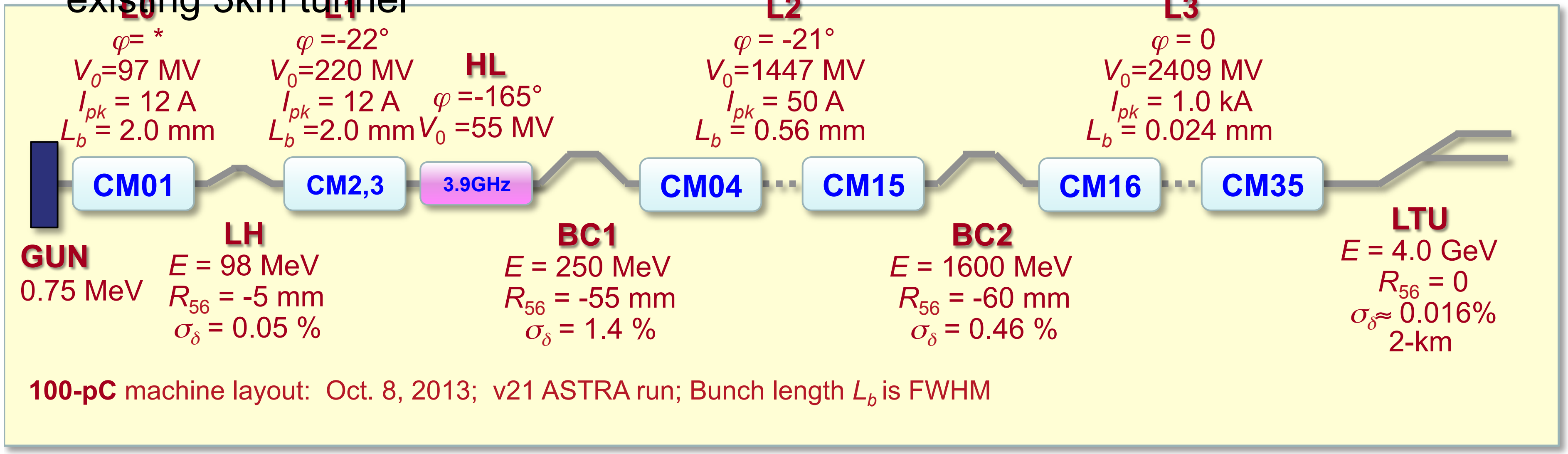
Average **usable** gradient:
(29.0 ± 3.9) MV/m
EZ: (28.4 ± 4.0) MV/m
RI: (30.6 ± 3.1) MV/m

- 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

US – LCLS II

4 GeV CW SRF Linac based FEL based on ILC cavities at SLAC

- 35 cryomodules – 280 cavities
- Gradient 16 MV/m; Q0 2e10 at 1.8
- Beam power 1.2 MW max
- Cryogenic power 5.5 MW
- Located in the upstream end of the existing 3km tunnel



Linac and compressor layout

M.Harrison, LCWS13

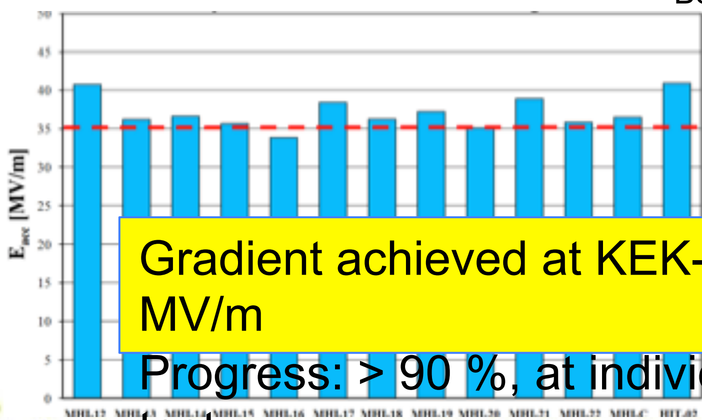
STF2; SCRF ACCELERATOR PLAN AT KEK

■ Objective
- High Gradient (31.5 MV/m)
  ＝＞Demonstration of full cryomodule
- ・Pulse and CW operation (for effectuve
- Training for next generation s

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

Electron Gun **Full Cryomodules** **Undulators** **Detector**

Beam Acceleration to be in 2015

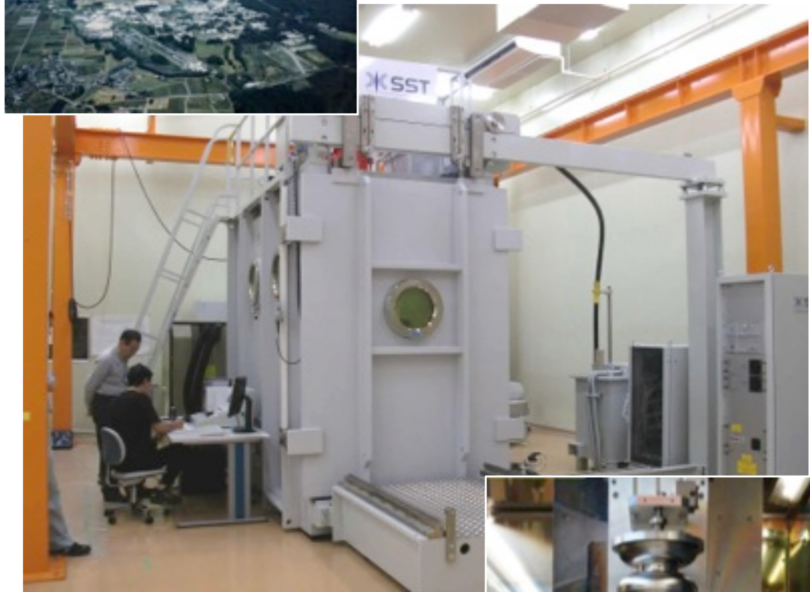


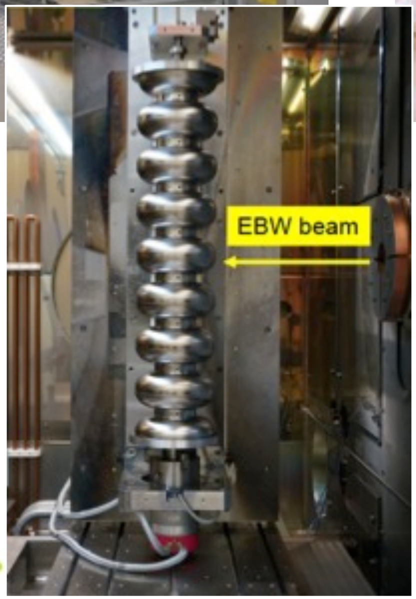
Gradient achieved at KEK-STF: > ~ 35 MV/m

Progress: > 90 %, at individual vertical test

Effort to lead industrialization technology at KEK

EBW





SST EBOCAM KS-110 – G150KM
Chamber (Stainless Steel chamber)

Press

AMADA digital-survo-press
SDE1522
150t, 50stroke/min,
225mmstroke

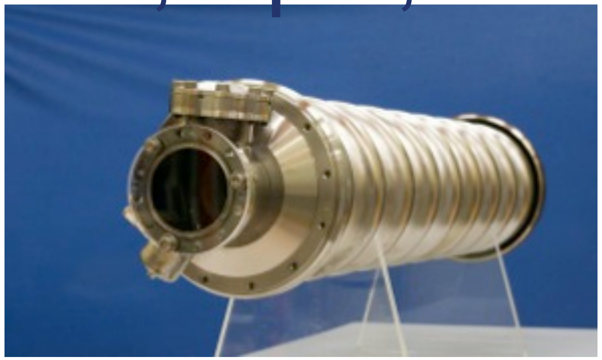
Trim

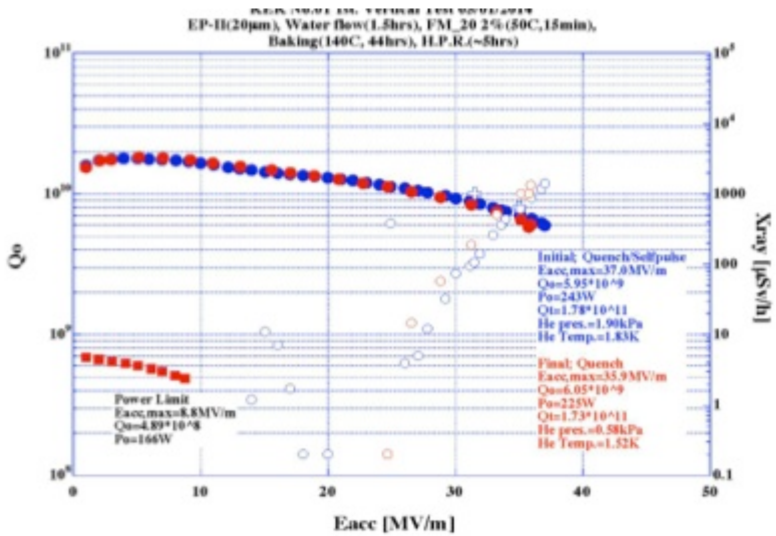
MORI VKL-253
Vertical CNC lathe

Chemical process

More discuss w/
Y. Yamamoto,
T. Saeki,
H. Hayano

KEK (in-house) 9-Cell Cavity (KEK-01) completed, and tested, April, 2014





ILC Published Parameters

Centre-of-mass independent:

Luminosity Upgrade

Collision rate	Hz	5	
Number of bunches		1312	2625
Bunch population	$\times 10^{10}$	2	
Bunch separation	ns	554	366
Pulse current	mA	5.8	8.8
Beam pulse length	μs	730	960
RMS bunch length	mm	0.3	
Horizontal emittance	μm	10	
Vertical emittance	nm	35	
Electron polarisation	%	80	
Positron polarisation	%	30	

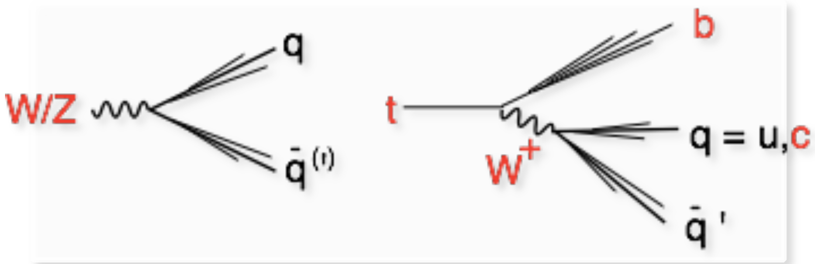
Advantage of SCRF technology: long pulses

http://ilc-edmsdirect.desy.de/ilc-edmsdirect/item.jsp?edmsid=D00000000925325

New Paradigm :

View events as viewing a Feynman diagram

Reconstruct final states in terms of fundamental particles (quarks, leptons, gauge bosons, and Higgs bosons)



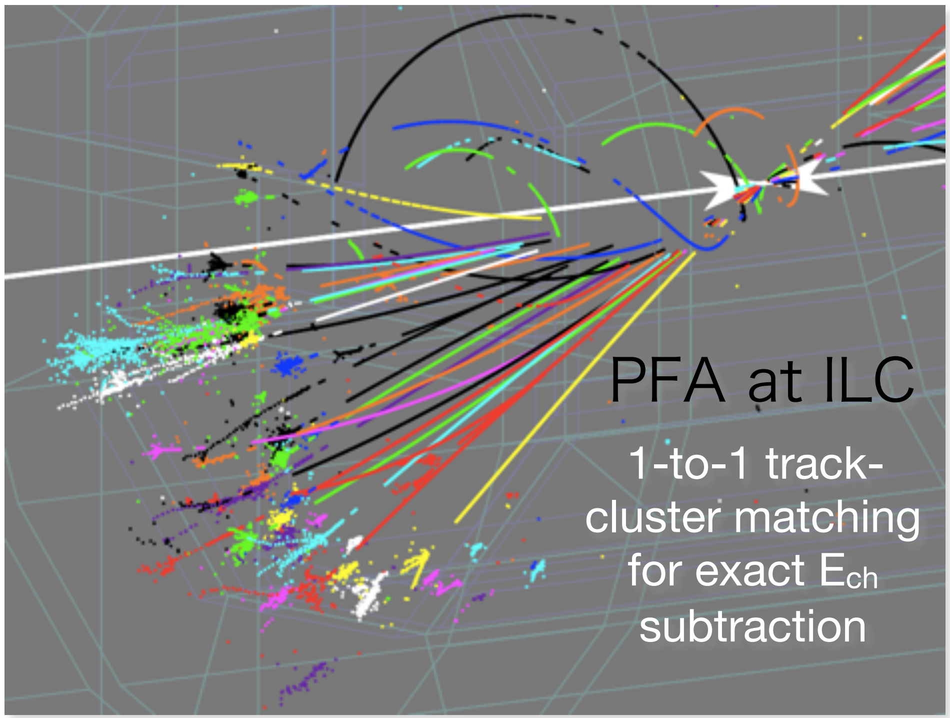
Identify W/Z/top/Higgs with their jet invariant mass: M_{jets}

Particle Flow Analysis

PFA is the key to achieve excellent jet invariant mass resolution comparable to the natural width of the weak boson:

$$\sigma_{M_{jets}} \simeq \Gamma_Z$$

Use tracker for charged particles, use CAL only for neutral particles, removing energy deposits by charged particles (E_{ch}) in CAL by 1-to-1 track to CAL cluster matching

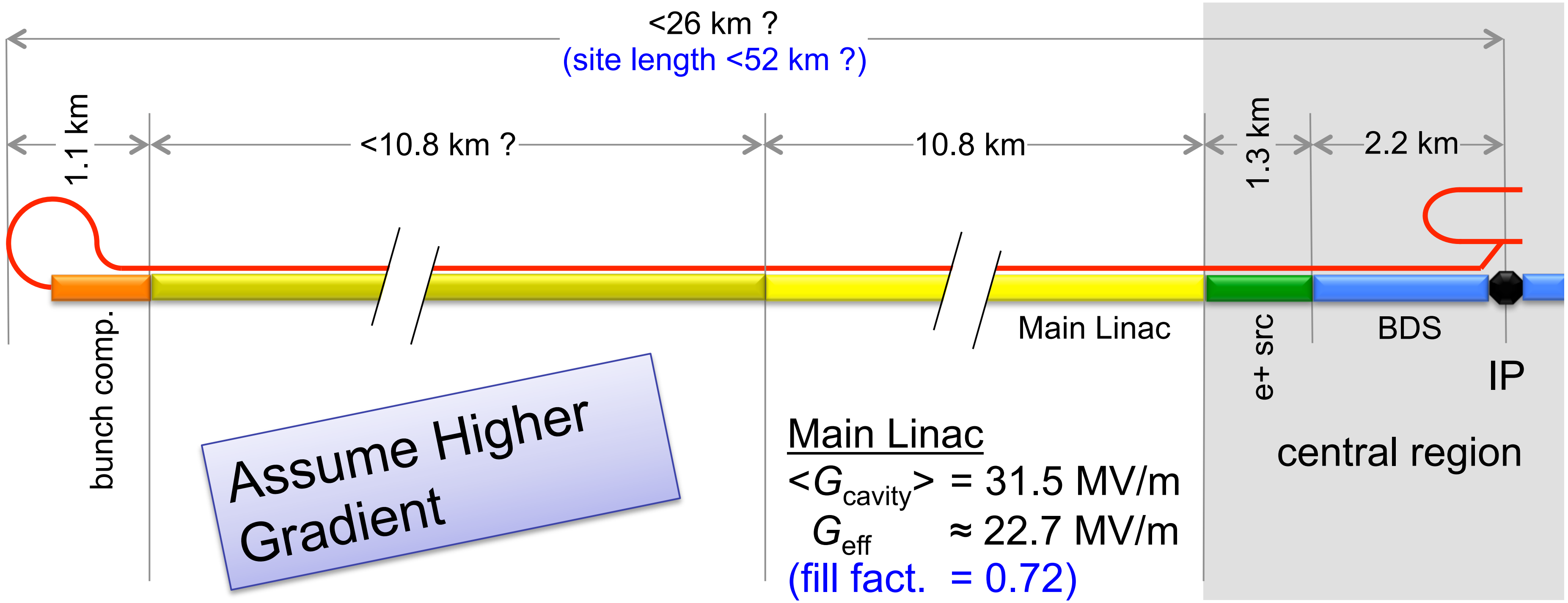


1-to-1 matching requires

High resolution tracking

High granularity calorimetry

TeV Upgrade



Main Linac

$\langle G_{cavity} \rangle$ = 31.5 MV/m

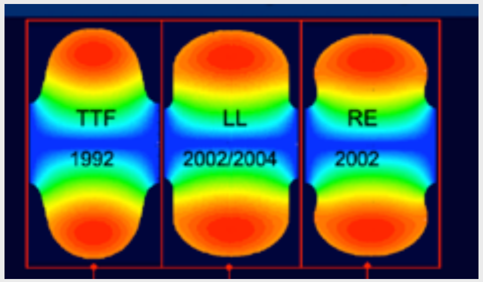
G_{eff} ≈ 22.7 MV/m

(fill fact. = 0.72)

Snowmass 2005 baseline recommendation for TeV upgrade:

G_{cavity} = 36 MV/m ⇒ 9.6 km

(VT ≥ 40 MV/m)



Based on use of low-loss or re-entrant cavity shapes

ILC Time Line: Progress and Prospect