ILC加速器設計と技術開発の

進捗と展望

1) 国際協力による加速器設計と技術開発の進展:　　山本　明
2) ILC超伝導加速技術と超伝導加速試験施設(STF) :早野　仁司
3) 超低エミッタンスビームの生成と制御(ATF):　　栗木雅夫

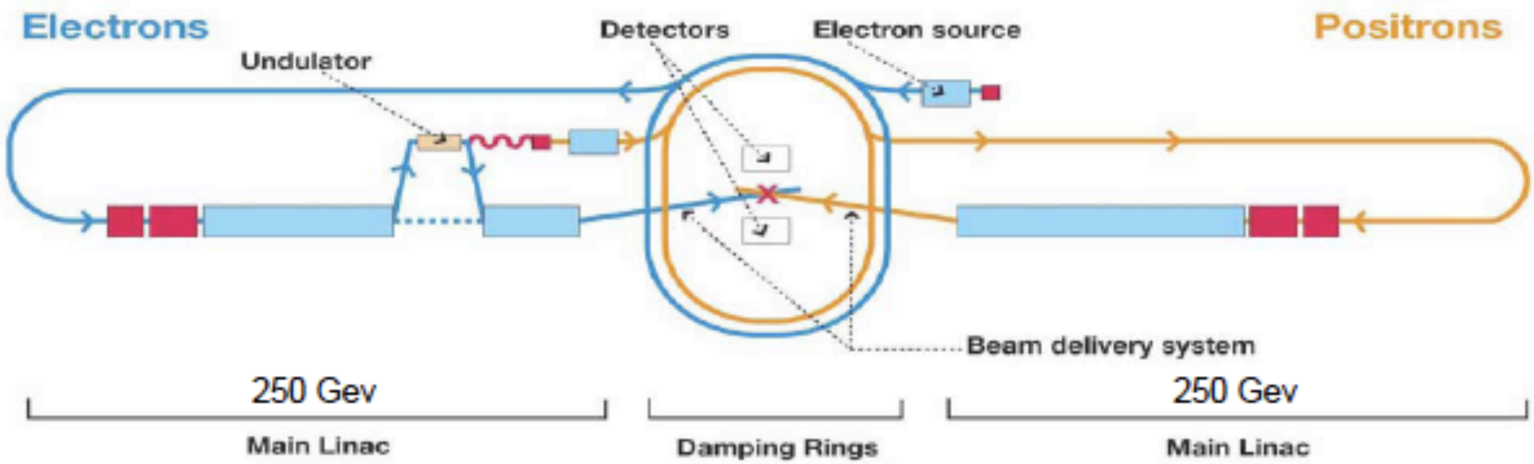
Outline

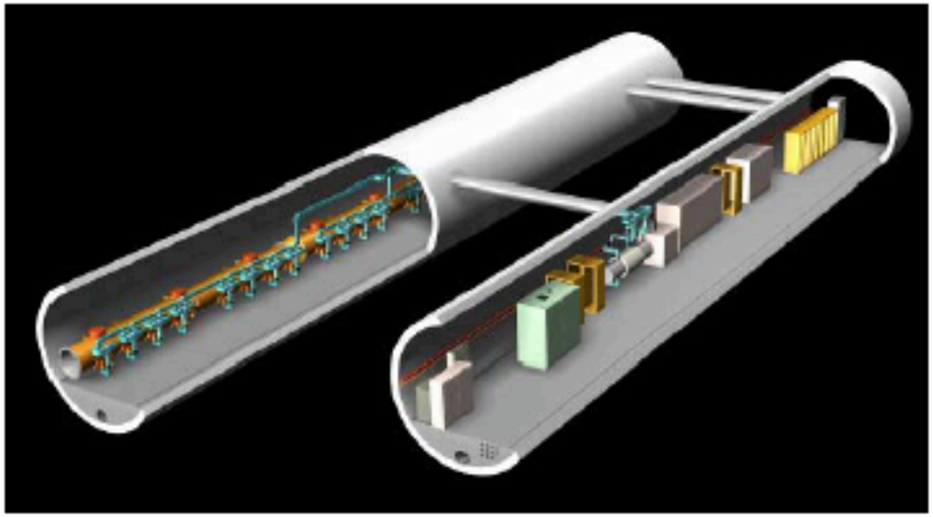
- Introduction
  - **RDR to TDP, and Global Collaboration**

- Technical Development Status
  - **SCRF and ML Technology**
  - **International Relation and Global Effort**
    - XFEL, Project-X, and CLIC (to be included)

- Accelerator Design Update
  - **SB-2009 (Effort for Re-optimization/Re-baseline**
    - Single-tunnel (HLRF), Low-Power, e+ source, (Cent. Integration)
  - **Toward Technical Design Phase 2**

ILC Baseline Design (RDR-2007)



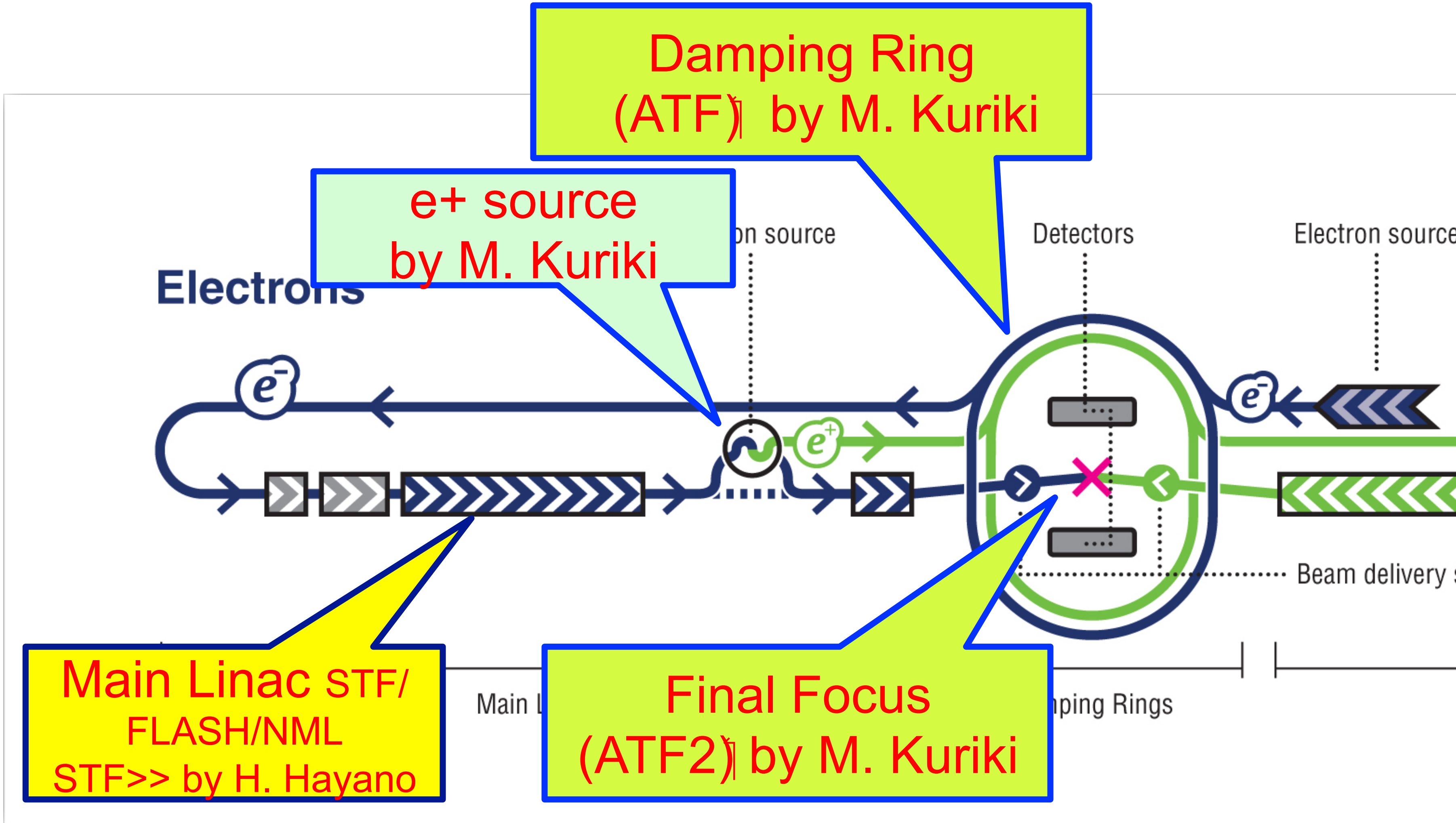


e+ e- Linear Collider

Energy	250 Gev x 250 Gev
Length	11 + 11 km
# of RF units	560
# of cryomodules	1680
# of 9-cell cavities	14560

2 Detectors push-pull
2e34 peak luminosity
5 Hz rep rate, 1000 -> 6000 bunches per cycle
IP spots sizes: σ_x 350 – 620 nm; σ_y 3.5 – 9.0 nm

ILC Layout and Technical Issues



Technical Design Report
to be completed by 2012

ILC Research and Development Plan for the Technical Design Phase

Release 3

February 2009

ILC Global Design Effort

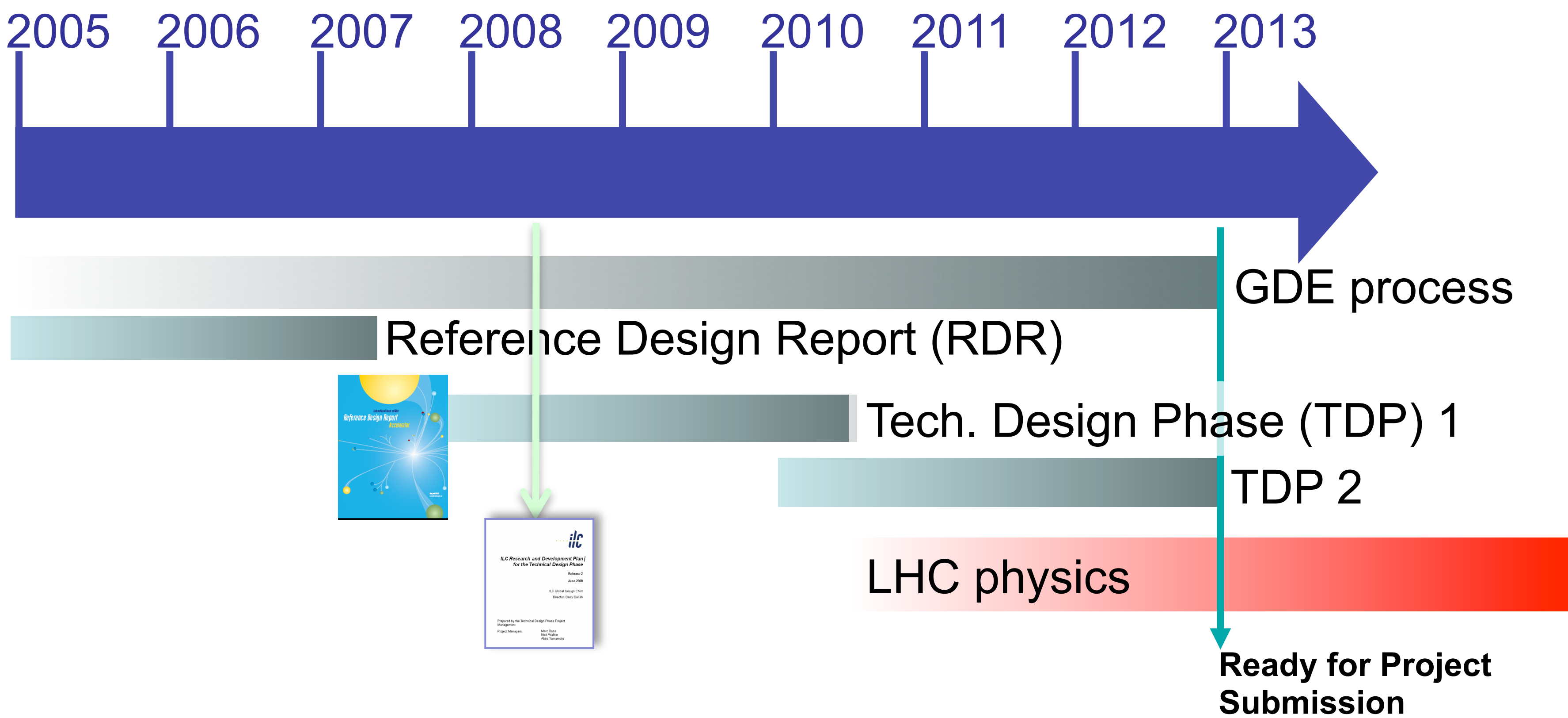
Director: Barry Barish

Prepared by the Technical Design Phase Project Management

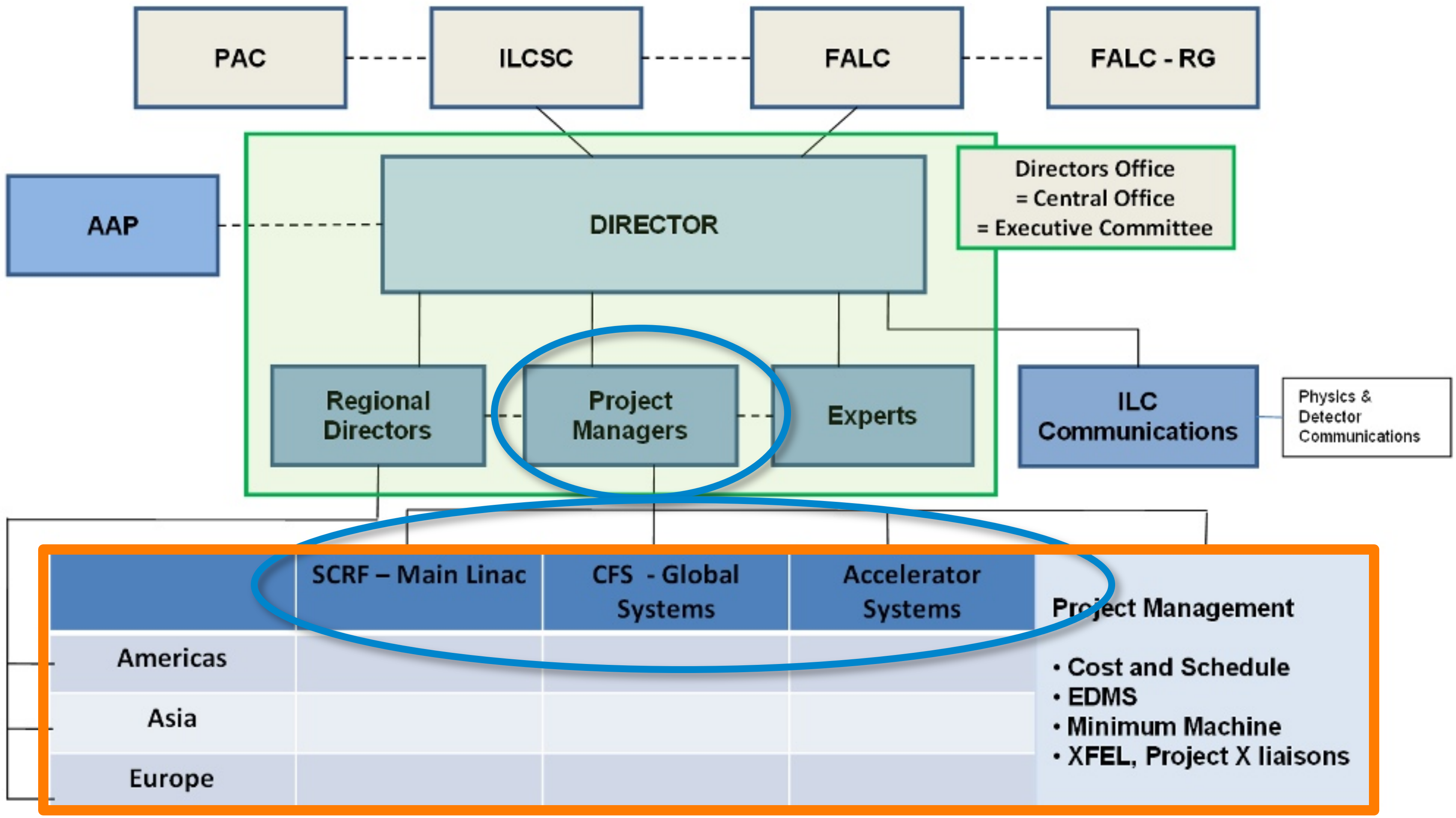
Project Managers: Marc Ross, Nick Walker, Akira Yamamoto

Reference Design, 2007 >> Technical Design Phase, 2008-2012
We are now at the stage of progressing from the RD to TD

GDE: ILC Timeline

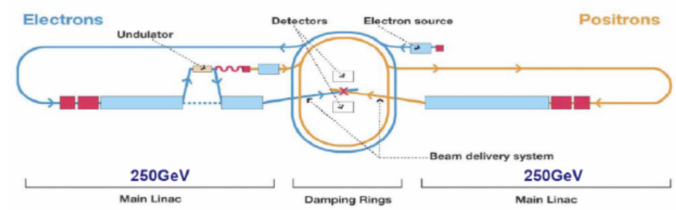


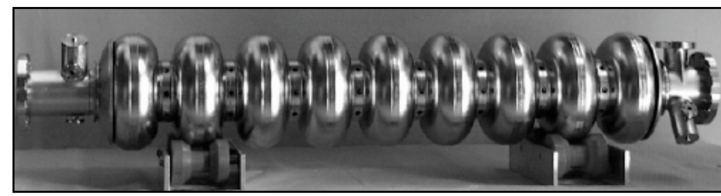
GDE Project Structure



SCRF Technology Required

Parameter	Value
C.M. Energy	500 GeV
Peak luminosity	$2x10^{34}$ $cm^{-2}s^{-1}$
Beam Rep. rate	5 Hz
Pulse time duration	1 ms
Average beam current	9 mA (in pulse)
Av. field gradient	**31.5 MV/m**
# 9-cell cavity	**14,560**
# cryomodule	**1,680**
# RF units	**560**





Global Plan for SCRF R&D

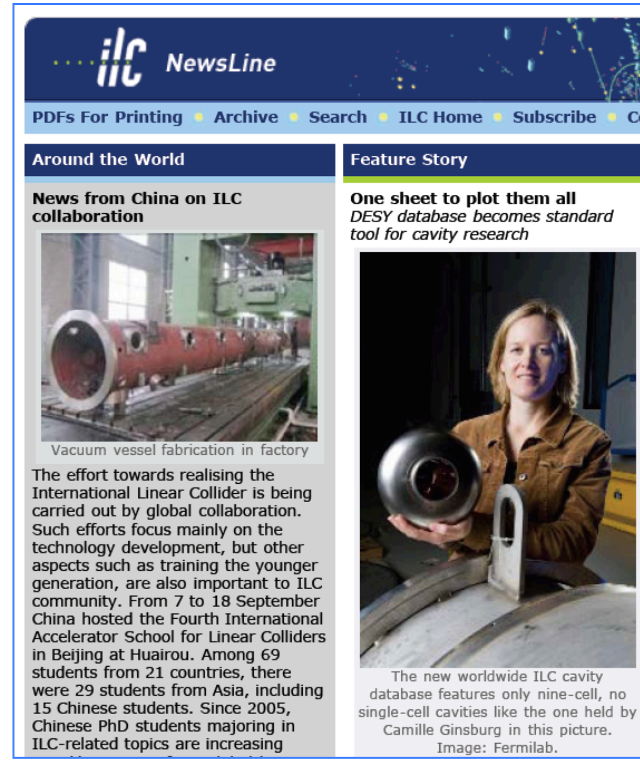
Year	07	2008	2009	2010	2011	2012
Phase	TDP-1			TDP-2		
Cavity Gradient in v. test to reach 35 MV/m	→ Yield 50%			→ Yield 90%		
Cavity-string to reach 31.5 MV/m, with one-cryomodule		Global effort for string assembly and test (DESY, FNAL, INFN, KEK)				
System Test with beam acceleration		FLASH (DESY) , NML (FNAL) STF2 (KEK, extend beyond 2012)				
Preparation for Industrialization			Production Technology R&D			

Standard Process Selected for Further Yield Plot

	Standard Cavity Recipe
Fabrication	Nb-sheet (Fine Grain)
	Component preparation
	Cavity assembly w/ EBW (w/ experienced venders)
Process	1st Electro-polishing (~150um)
	Ultrasonic degreasing with detergent, or ethanol rinse
	High-pressure pure-water rinsing
	Hydrogen degassing at > 600 C
	Field flatness tuning
	2nd Electro-polishing (~20um)
	Ultrasonic degreasing or ethanol
	High-pressure pure-water rinsing
	Antenna Assembly
	Baking at 120 C
Cold Test (vert. test)	Performance Test with temperature and mode measurement (1^{st} / 2^{nd} successful RF Test)

Creation of a Global Database for Better Understanding of "Production Yield" in TDP-2

- Global Data Base Team formed:
  - Camille Ginsburg **(Fermilab)**
    - Team Leader & Data Coordination
  - Rongli Geng **(JLab)**
    - GDE-SCRF Cavity TA Group Leader
  - **Zack Conway (Cornell University)**
  - **Sebastian Aderhold (DESY)**
  - **Yasuchika Yamamoto (KEK)**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Around the World

News from China on ILC collaboration

Vacuum vessel fabrication in factory

The effort towards realising the International Linear Collider is being carried out by global collaboration. Such efforts focus mainly on the technology development, but other aspects such as training the younger generation, are also important to ILC community. From 7 to 18 September China hosted the Fourth International Accelerator School for Linear Colliders in Beijing at Huairou. Among 69 students from 21 countries, there were 29 students from Asia, including 15 Chinese students. Since 2005, Chinese PhD students majoring in ILC-related topics are increasing

Feature Story

One sheet to plot them all

DESY database becomes standard tool for cavity research

The new worldwide ILC cavity database features only nine-cell, no single-cell cavities like the one held by Camille Ginsburg in this picture. Image: Fermilab.

- Activity Plan/Schedule
  - **July 2009:**
    - **- Determine DESY-DB to be viable option,**
  - **Sept., 2009: (ALCPG/GDE)**
    - **- Dataset, web-based, support by FNAL-TD or DESY**
    - **- Some well-checked, easily explainable, and near-final plots, available,**
  - **Nov.- Dec., 2009:**
    - **- Finalize DB tool, web I/F, standard plots, with longer-term plans**

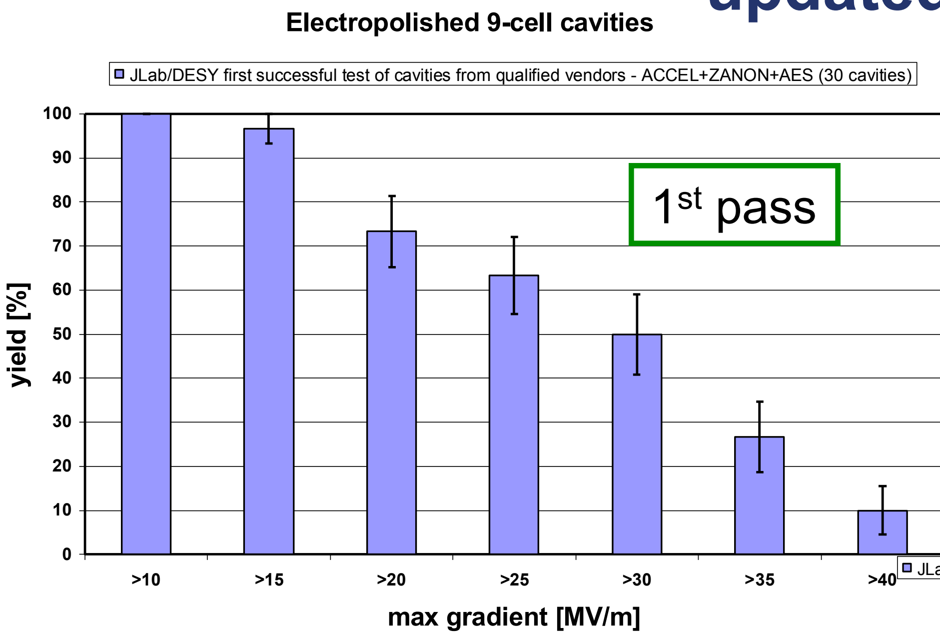
Progress and Prospect of Cavity Gradient Yield Statistics

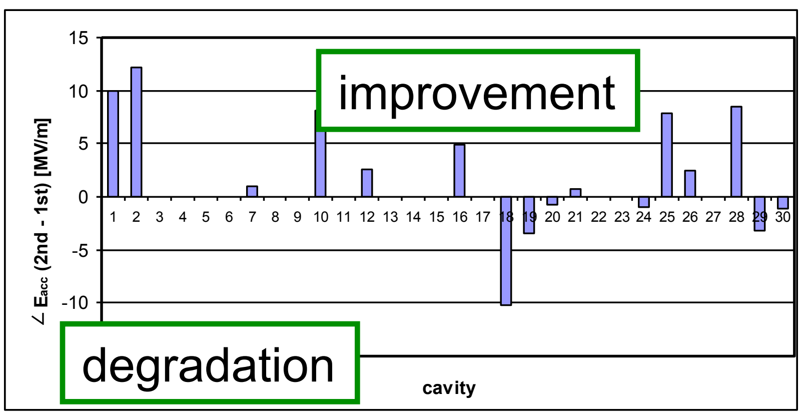
	PAC-09 Last/Best May 2009	FALC 1st Pass Jul 2009	ALCPG 2nd Pass Oct 2009	Current Dec 2009	Coming Prod/Test Jun 2010	Research cavities
DESY	9 (AC) 16 (ZA)	8 (AC) 7 (ZA)	14 (AC/ZA)	10-6 (Prod-4)	5	8 (large grain)
JLAB FNAL/ANL/ Cornell	8 (AC) 4 (AE) 1 (KE-LL5) 1 (JL-2)	7 (AC)	7 (AC)	5 (AE) 1 (AC)	12 (RI) 6 (AE) 2 (AC)	6 (NW) (including large-G)
KEK/ IHEP/PKU			(4 -4:MH)	5 -5 (MH)	2 (MH)	~5 (LL) 1 (IHEP) 2 (PKU)
Sum	39	22	21	21 -11	27	**~ 22**
G-Sum				42-11 = 31	69-11=58	

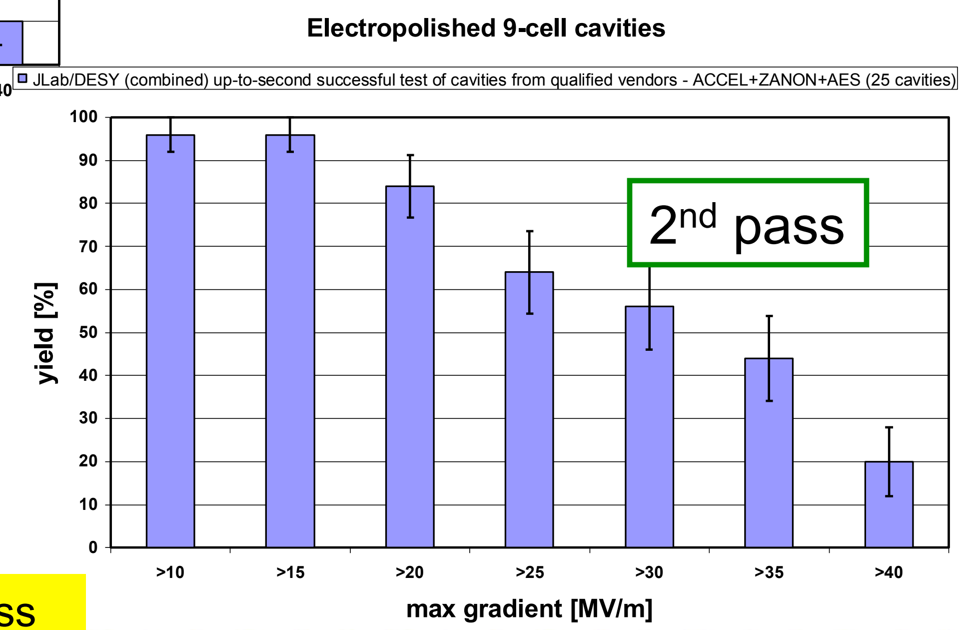
Statistics for Production Yield in Progress to reach ~ 60, within TDP-1.
We may need to have separate statistics for 'production' and for 'research',

Compare 1st and 2nd pass yields

updated, Dec. 2009





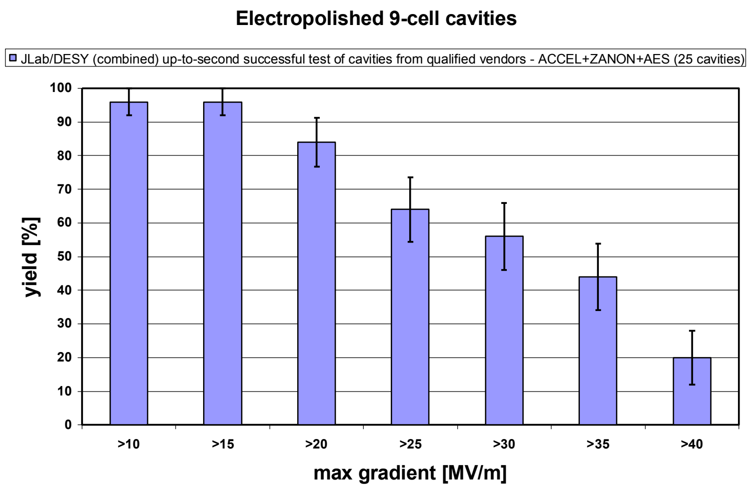


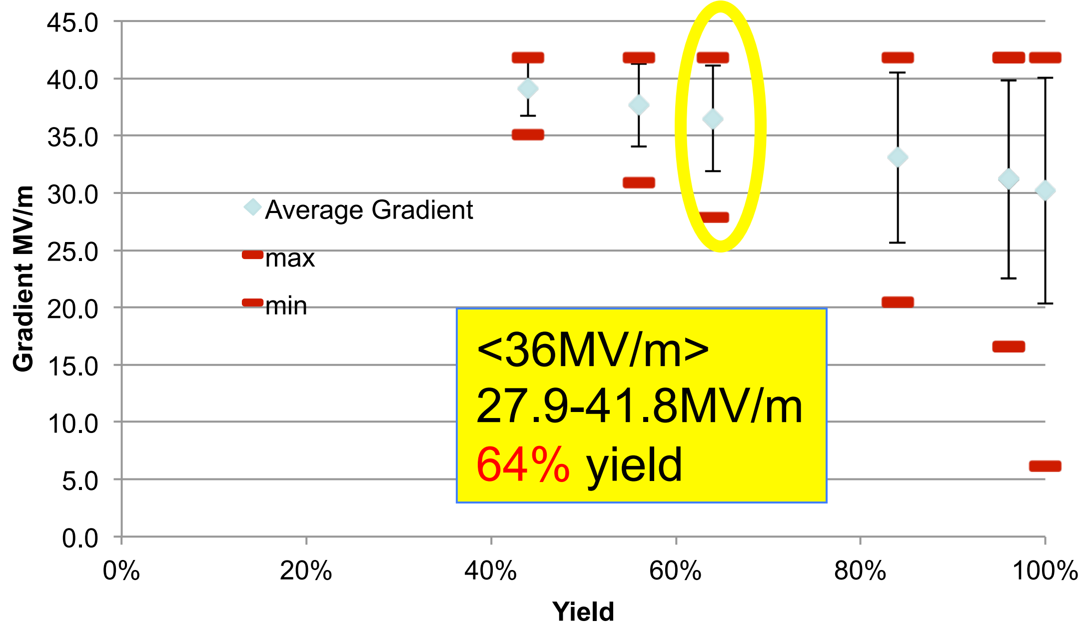
Performance typically improves after 2nd pass

Alternative Yield Plot Analysis

originated by N. Walker

Dec 2009 Data:
1st +2nd Pass, 1st pass cut 35MV/m,
vendors w/ 1 cavity > 35MV/m



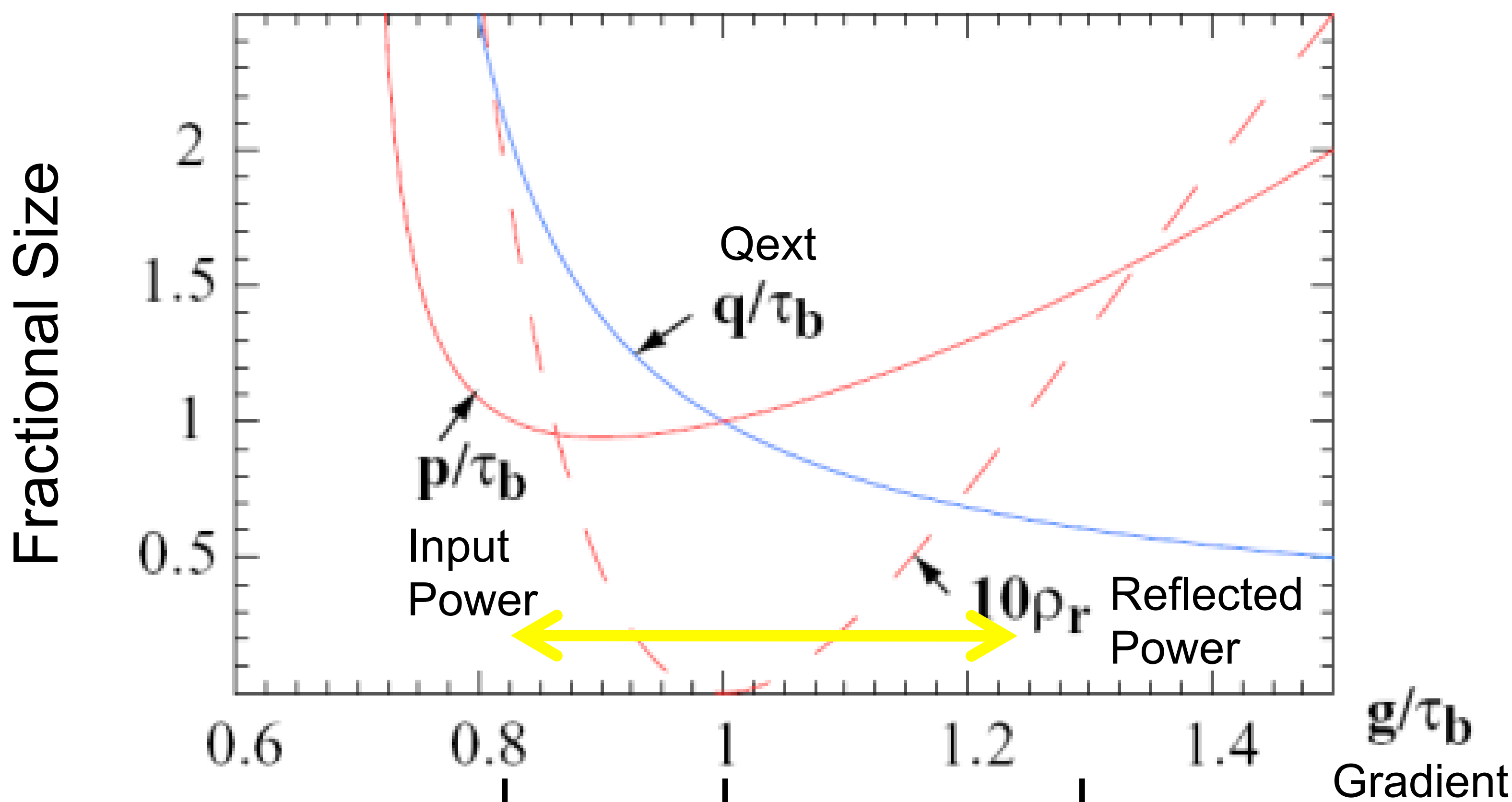


>35MV/m
35-41.8MV/m
44% yield

-Yield: estimated assuming a specific lower cut-off in cavity performance, below which cavities are assumed 'rejected'.
- Error bar: +/- one RMS value (standard deviation of the population) of the remaining (accepted) cavities (gradient above cut-off).
- Additional bars (min, max) indicated the minimum and maximum gradients in the remaining cavities.

Flattop Operation with a Spread of Cavity Gradients

reported by C. Adolphsen



31.5 MV/m Average

24.5 MV/m

29.8 MV/m

38.5 MV/m

Subject to be studied in TDP-2

- Balance between R&D target values and Operational parameters
Will be reviewed after S1 experience
-System design should require reasonable margin for the individual component and the system operation

S1 (~ Component performance) > ILC-Acc. Operational Gradient

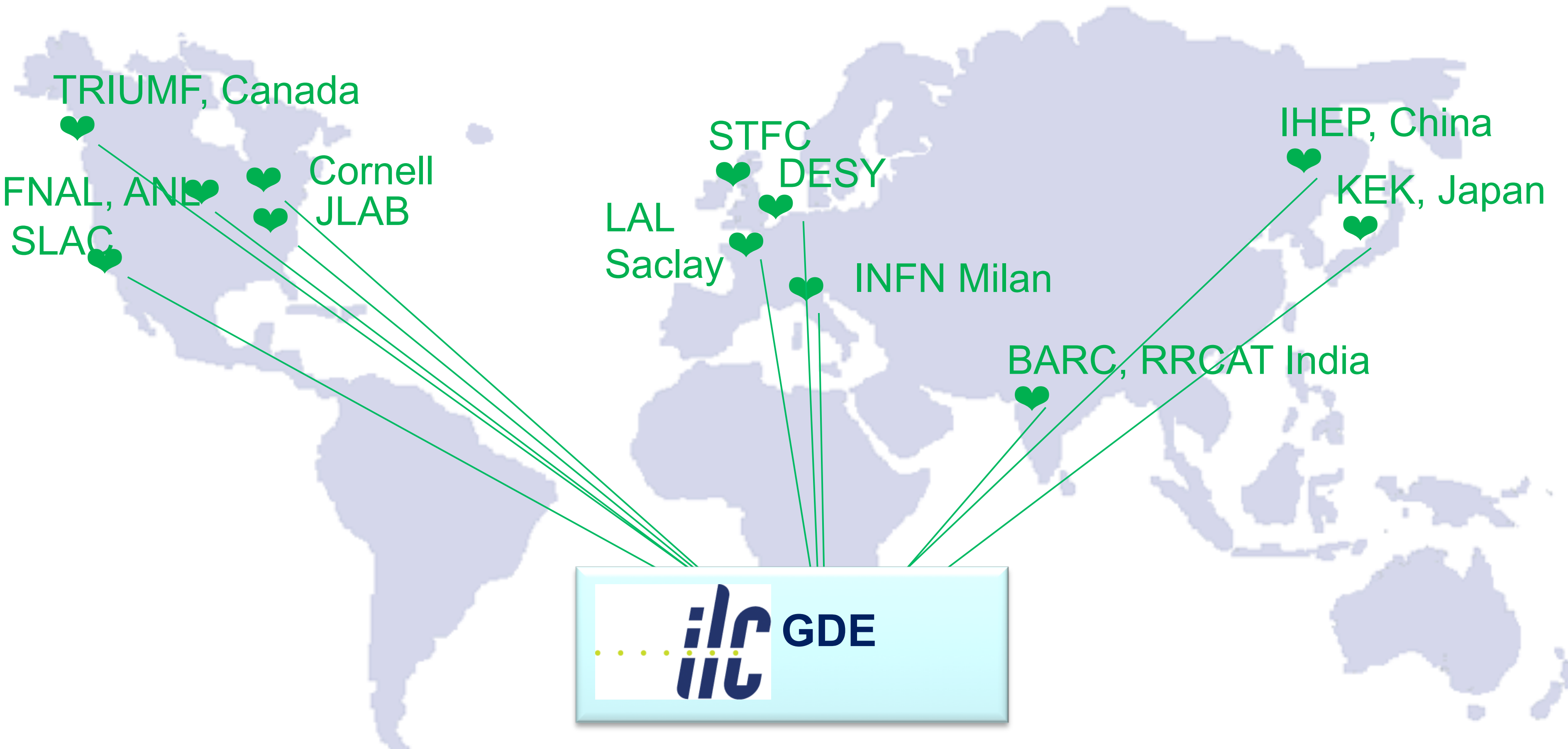
	RDR/SB2009	Re-optimization required with cautious, systematic design	
R&D goal: S0	35 (> 90%)	35 MV/m (> 90 %) *Keep it, and forward looking*	
S1 (w/o beam)	31.5 in av.	*need:* > 31.5 in av., to be further optimized	31.5 in av.
S2 (w/ beam acc.)	31.5 in av.	> 31.5 in av.	31.5 in av.
ILC: operational gradient	31.5 in av.	31.5 in av. (+/- 10 ~ 20 %)	*or:* < 31.5 in av,, to be further optimized

Global Plan for SCRF R&D

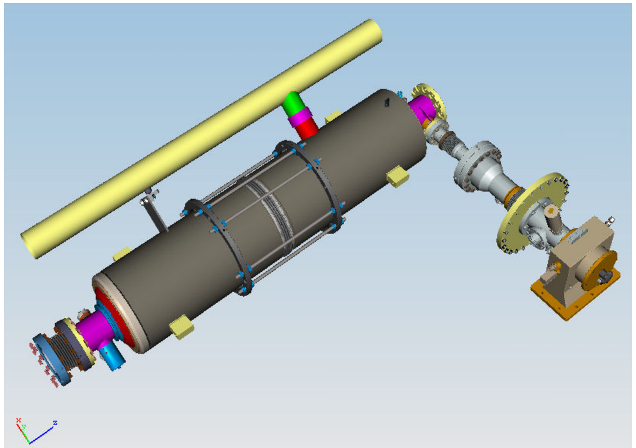
Year	07	2008	2009	2010	2011	2012
Phase	TDP-1			TDP-2		
Cavity Gradient in v. test to reach 35 MV/m	→ Yield 50%			→ Yield 90%		
Cavity-string to reach 31.5 MV/m, with one-cryomodule		Global effort for string assembly and test (DESY, FNAL, INFN, KEK)				
System Test with beam acceleration		FLASH (DESY) , NML (FNAL) STF2 (KEK, extend beyond 2012)				
Preparation for Industrialization			Production Technology R&D			

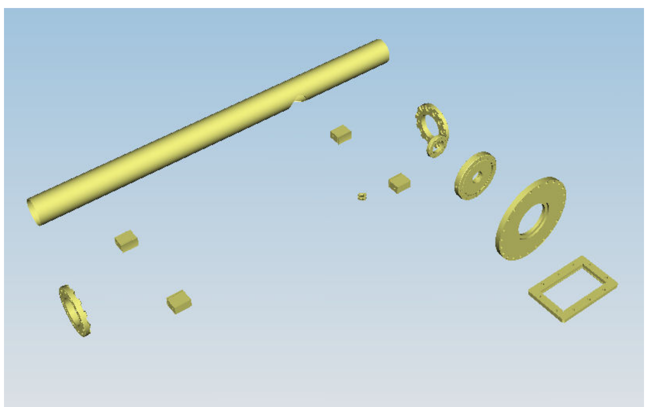
Global Collaboration

focusing on SCRF



Plug-compatible Conditions





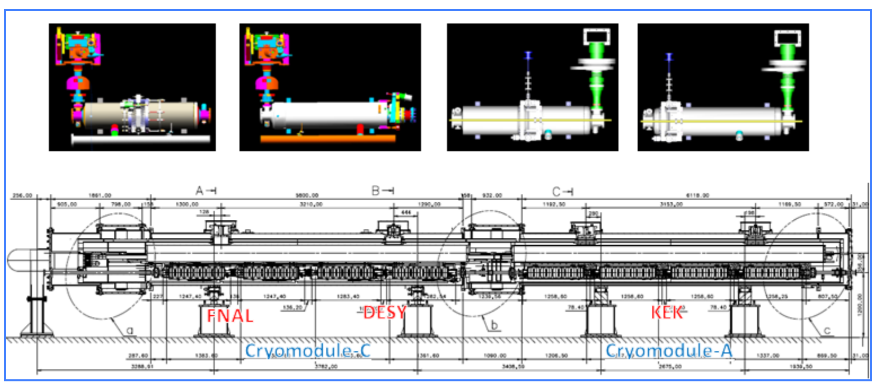
Item	Can be flexible	Plug-comp.
Cavity shape	TeSLA/ LL/RE	
Length		Fixed
Beam pipe flange		Fixed
Suspension pitch		Fixed
Tuner	Blade/Jack	
Coupler flange (warm end)		Fixed
Coupler pitch		fixed
He –in-line joint		TBD

Plug-compatible interface nearly established

Additional Report: S1-Global Progress

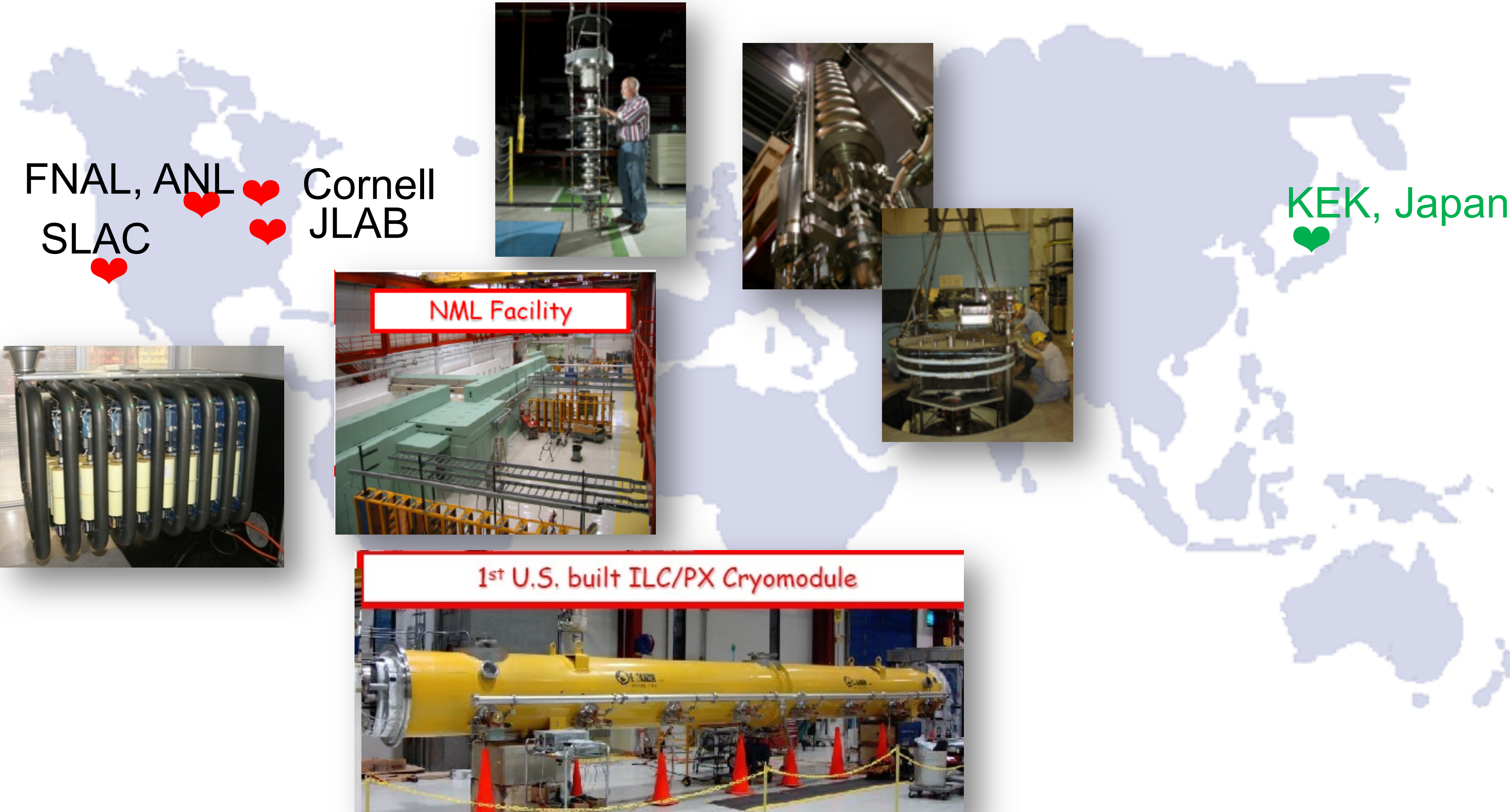
All Components arrive in Japan, Dec. 2009

- Global effort for cryomodule test
  - **INFN: Cryomodule**
  - **DESY: 2 cavities**
  - **FNAL/JLab: 2 cavities**
  - **KEK: 4 cavities, Cryomodule**

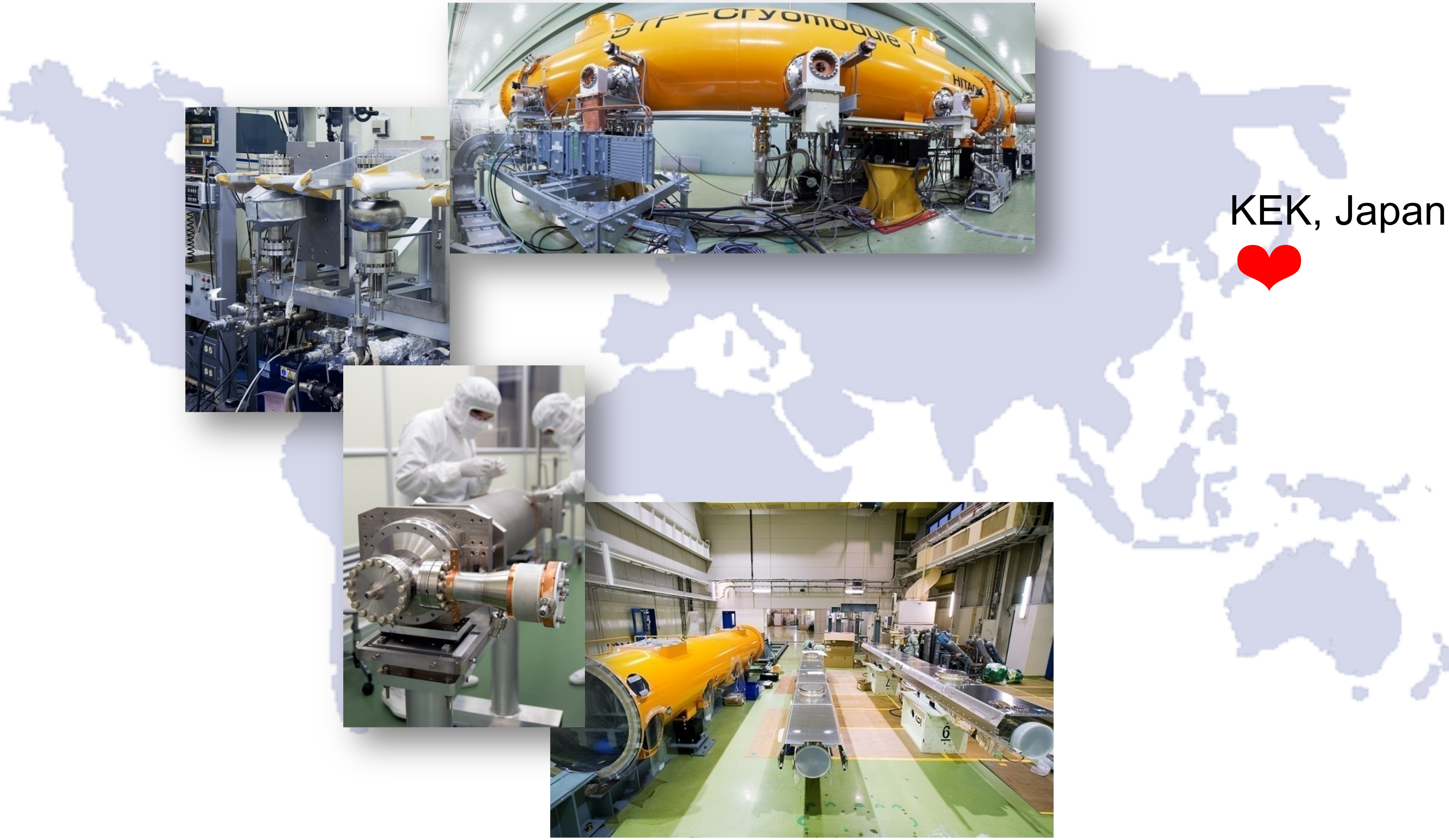


Delivered to KEK on Dec.25, 2009

SCRF : AMERICAS

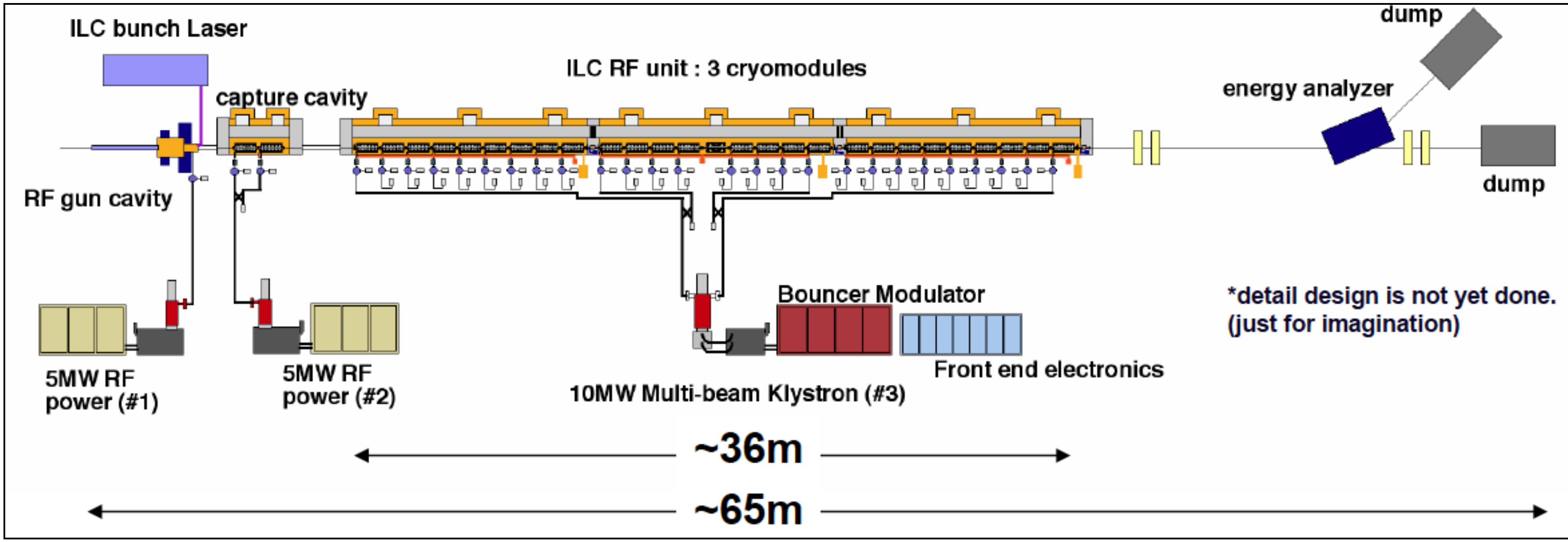


SCRF: ASIA



Beam Acceleration Test Plan

with RF unit at Fermilab and KEK in TDP-2

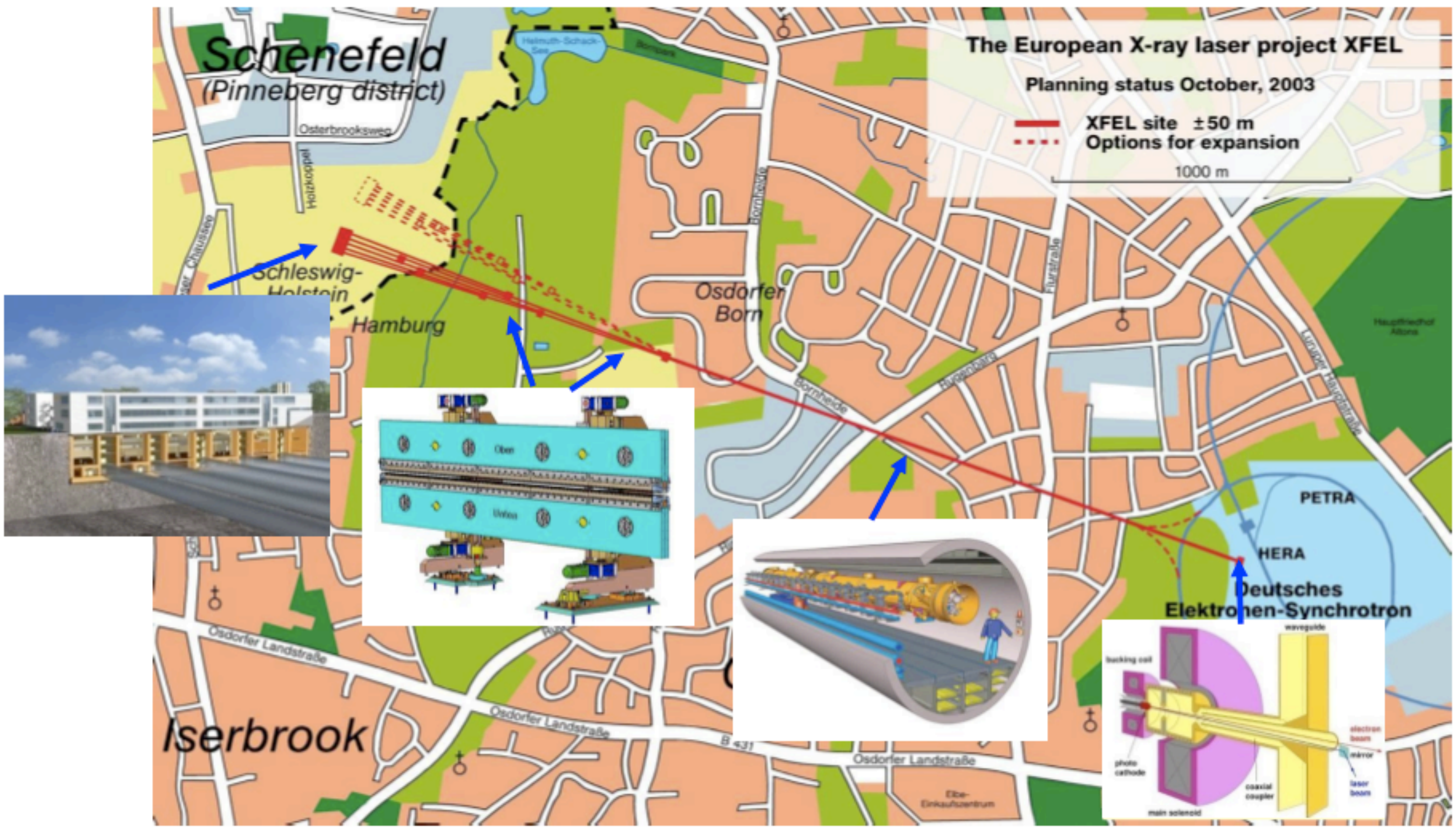


Global SCRF Technology: EUROPE

European XFEL

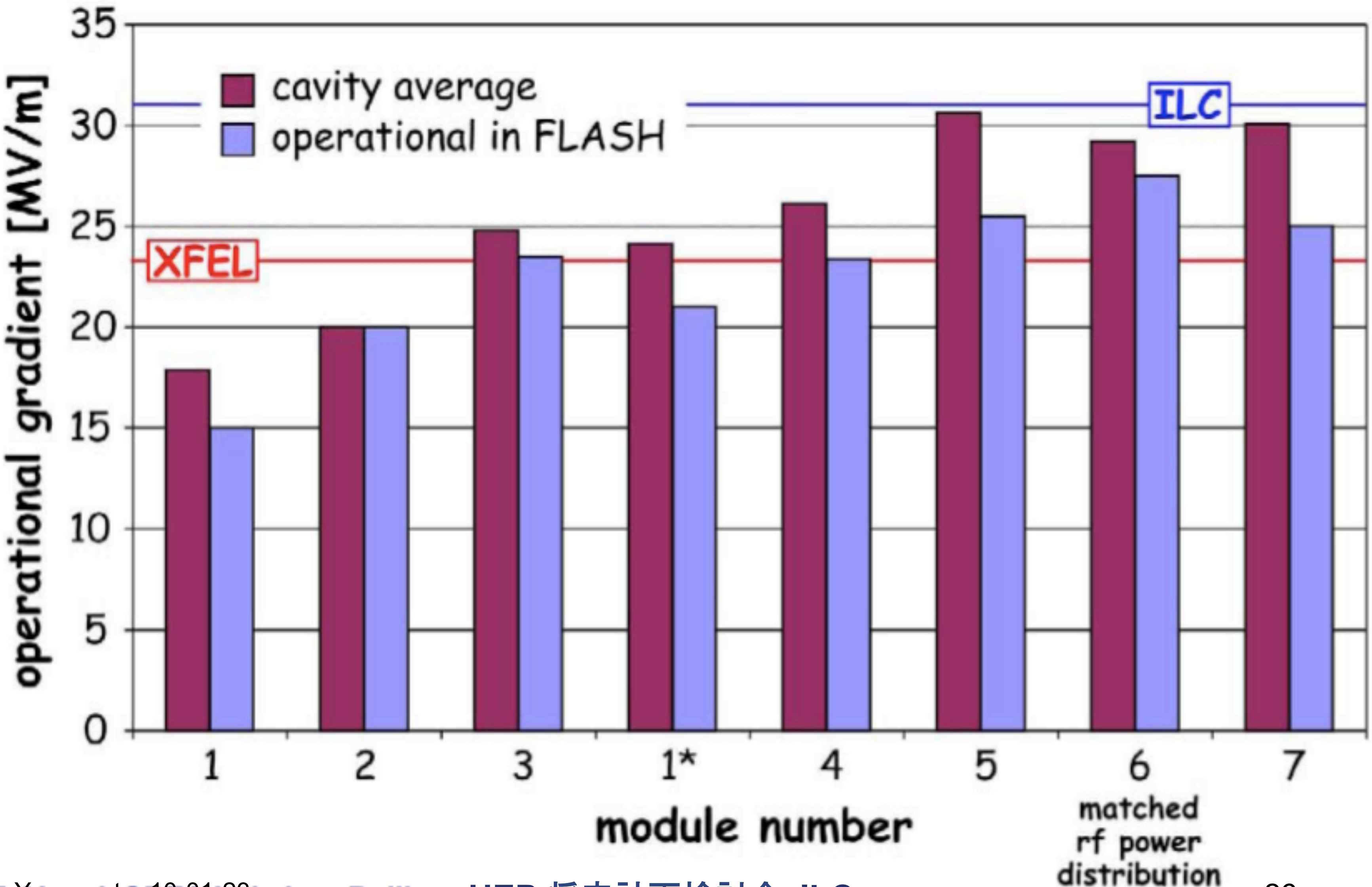
Overall Layout of the European XFEL

3.4km



加速モジュール

TTF/FLASH Modules 運転勾配31.5M



S1 Goal: Achieved at DESY/XFEL

NewsLine

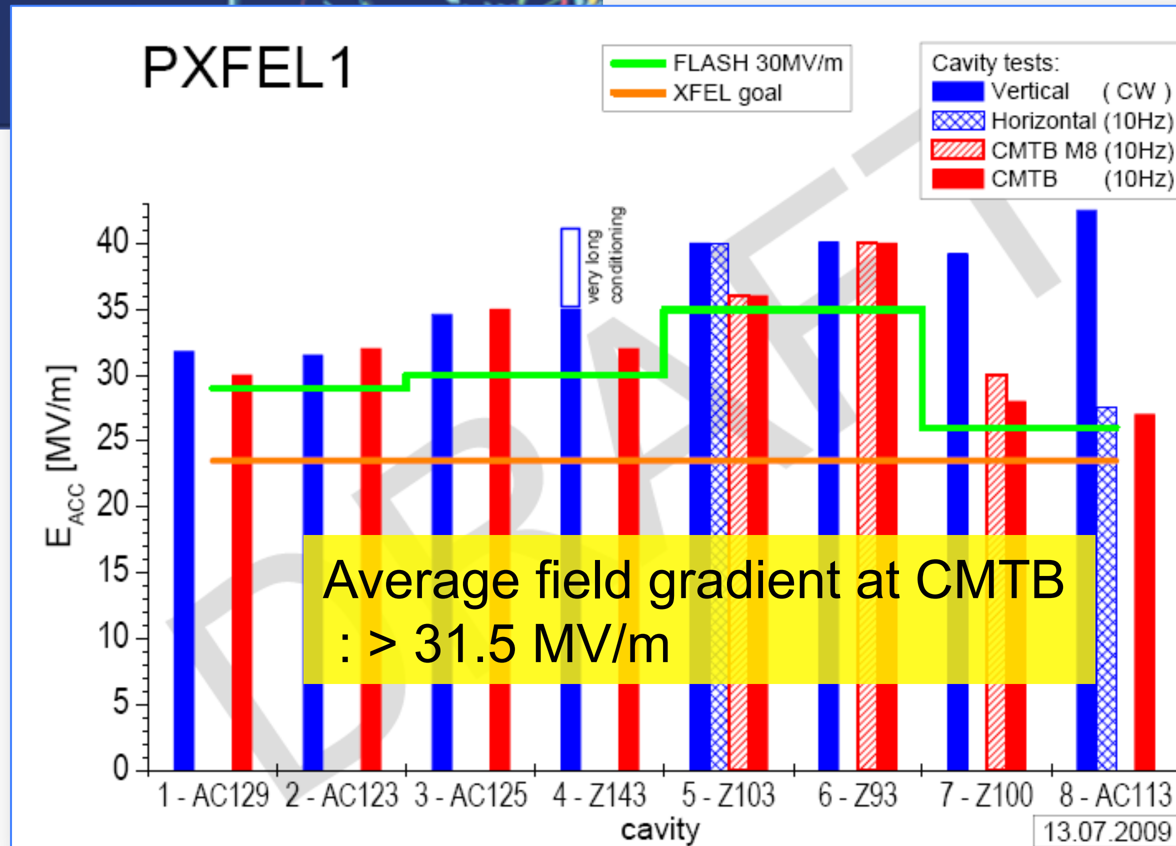
Around the World

Cryomodule surpasses ILC gradient test

European-XFEL cryomodule using SCRF technology sets new record

The cryomodule that set the world gradient record in the testbench at DESY

A cryomodule prototype for the European XFEL has set the world gradient record for cryomodules built with superconducting radiofrequency technology, reaching an average accelerating gradient of more than 32 megavolts per metre (MV/m) in recent

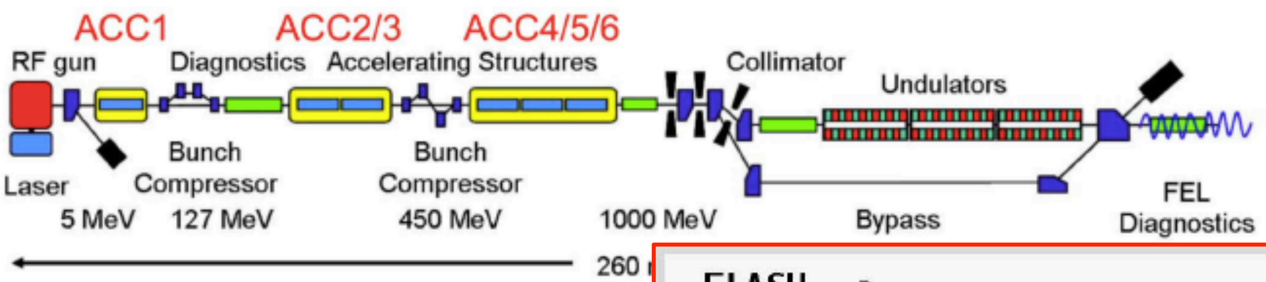


- First XFEL prototype module **exceeds 31.5 MV/m average**
- Module will see beam in FLASH in 2010 (av. of 30MV/m)
- Cryostat (cryomodule cold-mass) contributed by IHEP

S2: TTF/FLASH 9mA Experiment

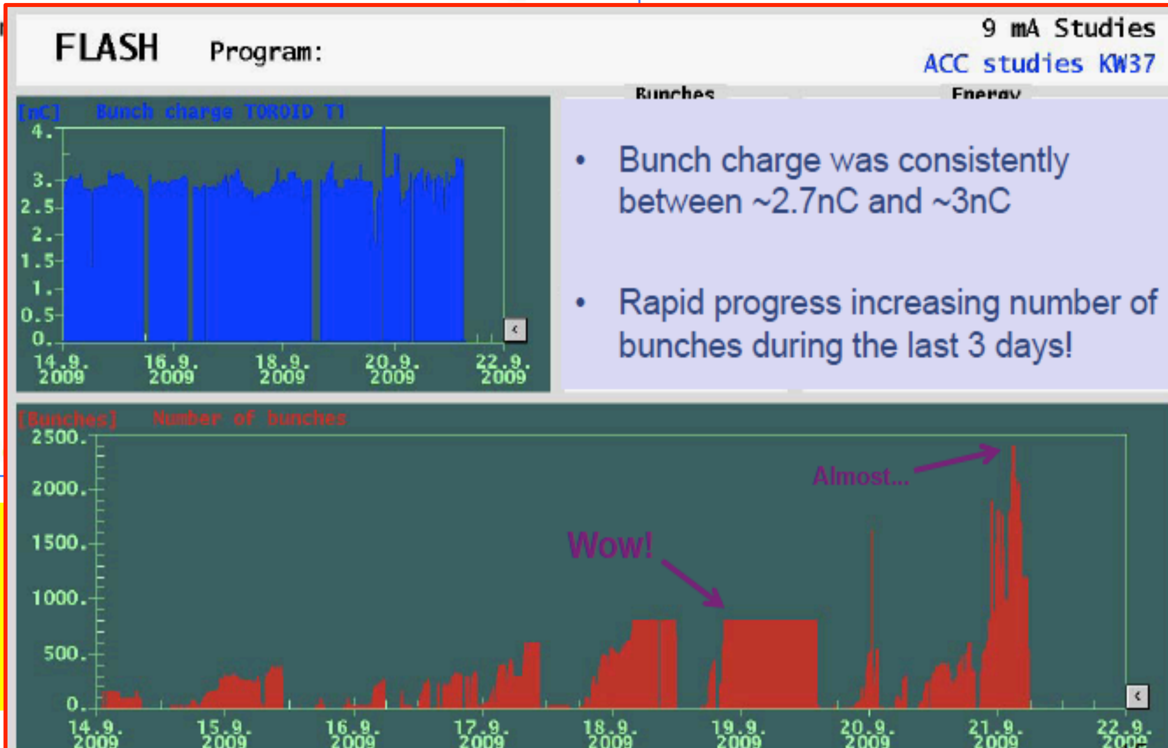
Successfully Progressing

Full beam-loading long pulse operation → "S2"



		XFEL	ILC	FLASH design	9mA studies
Bunch charge	nC	1	3.2	1	3
# bunches		3250	2625	7200'	2400
Pulse length	μs	650	970	800	800
Current	mA	5	9	9	9

- Successful experiment, dedicated two weeks, Sept. 2009.

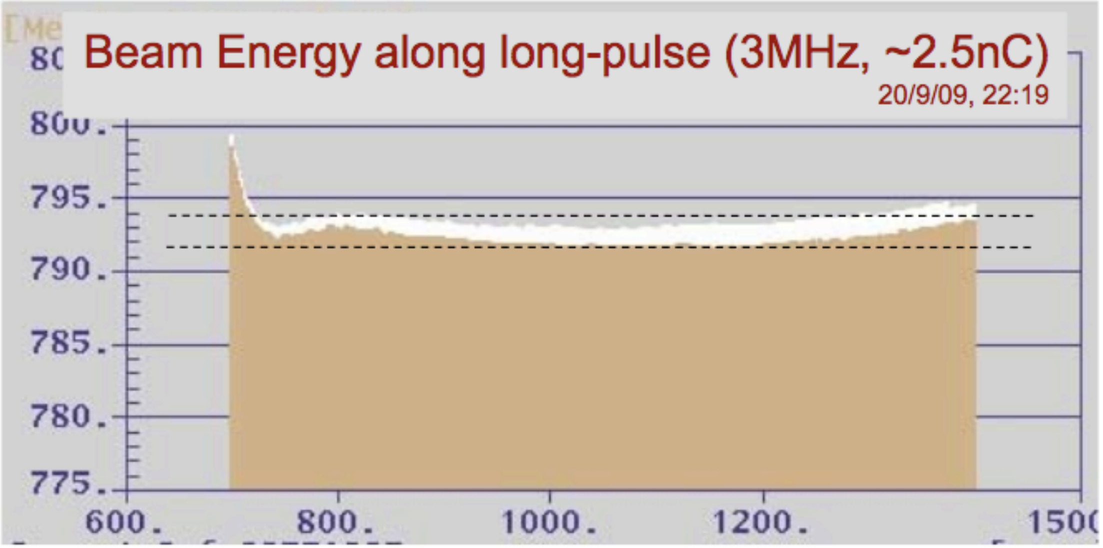


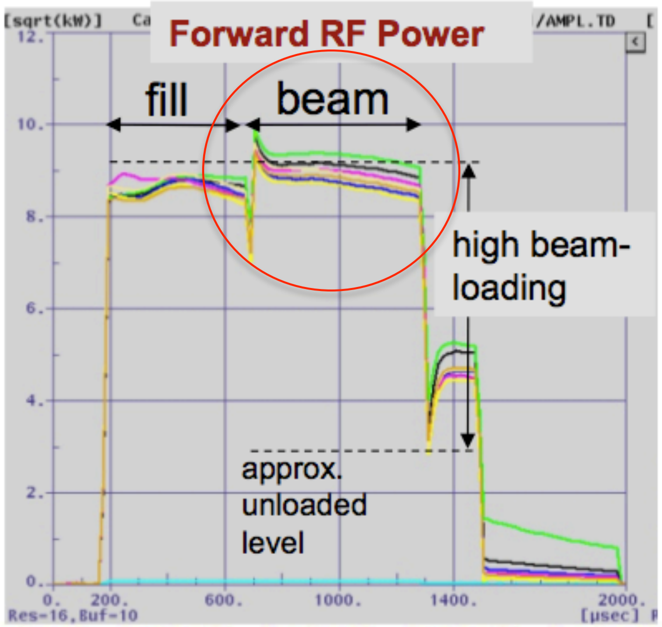
連結モジュールでのビーム加速試

9mA Example Results

Much experience gained running with high beam-loading conditions

Approx. 15 TBytes of data to be analysed (beginning)





Along pulse: 0.1% RMS (0.5% pk-to-pk)
(after initial transient)
Pulse-to-pulse (5Hz): 0.13% RMS

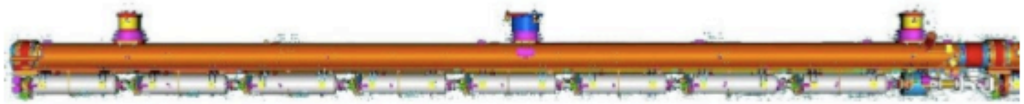
Integrated Systems Test
- Understanding trip and trip recovery (beam loss)
- RF parameter tuning
- RF system calibration

Extrapolation to XFEL/ILC

7

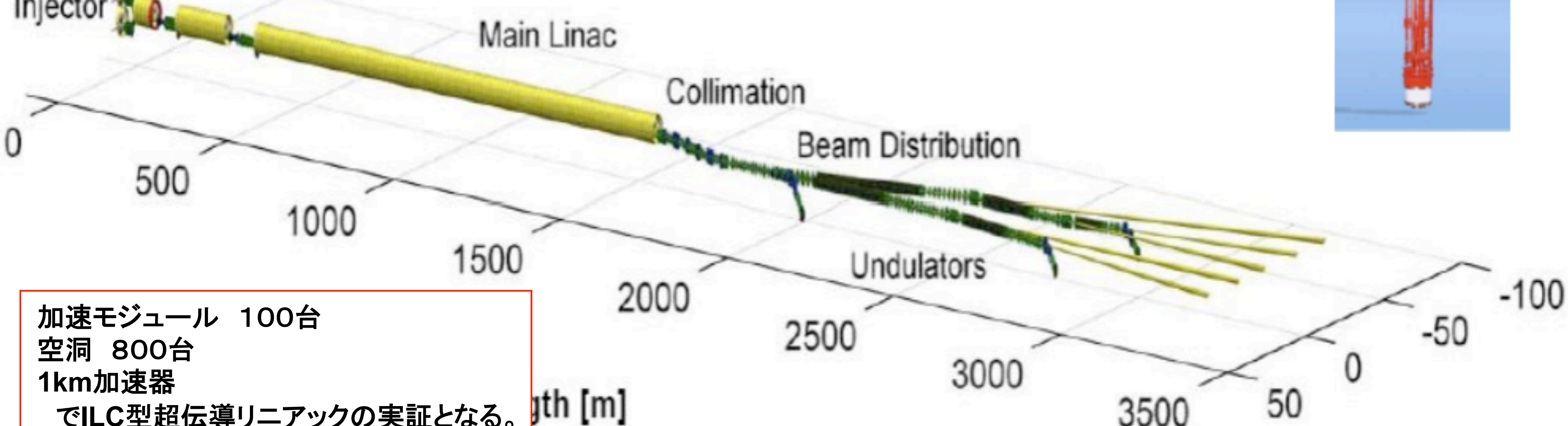
Accelerator Complex

100 accelerator modules



800 accelerating cavities
1.3 GHz / 23.6 MV/m

25 RF stations
5.2 MW each

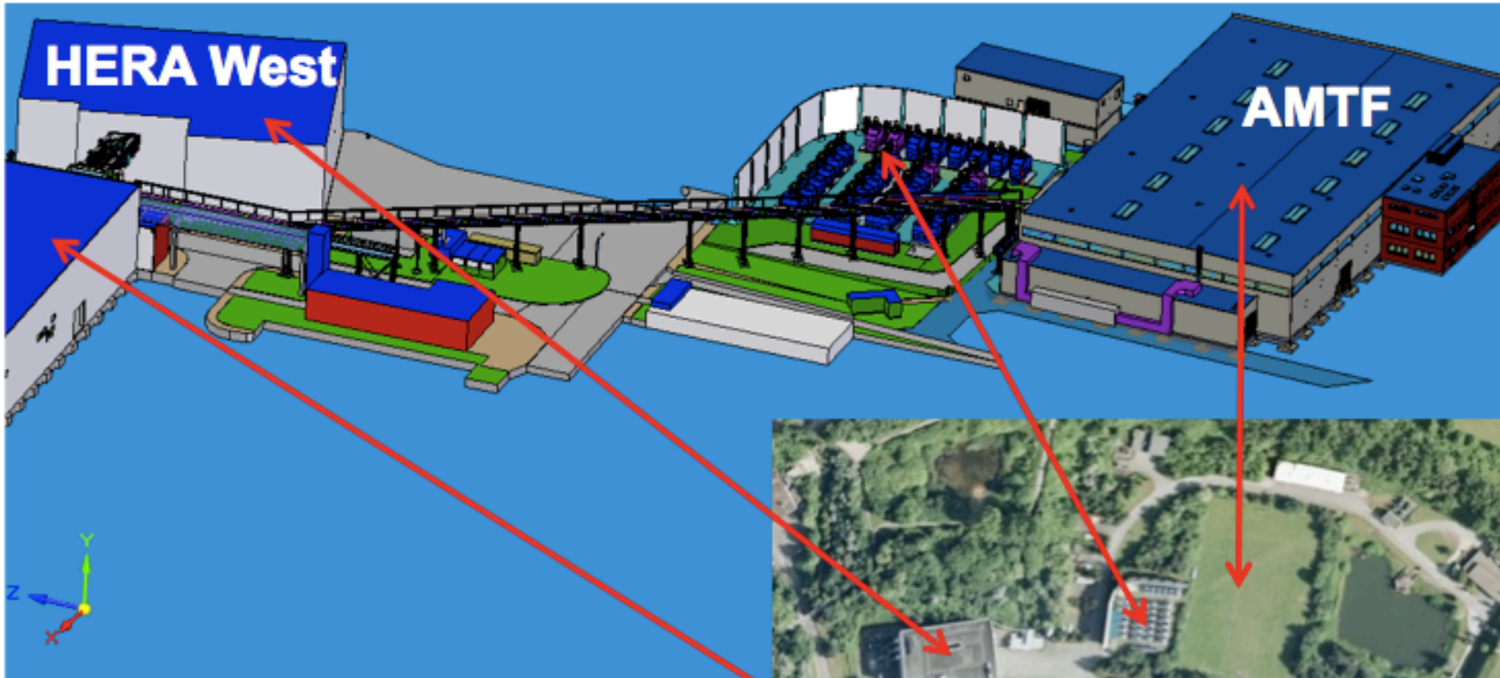


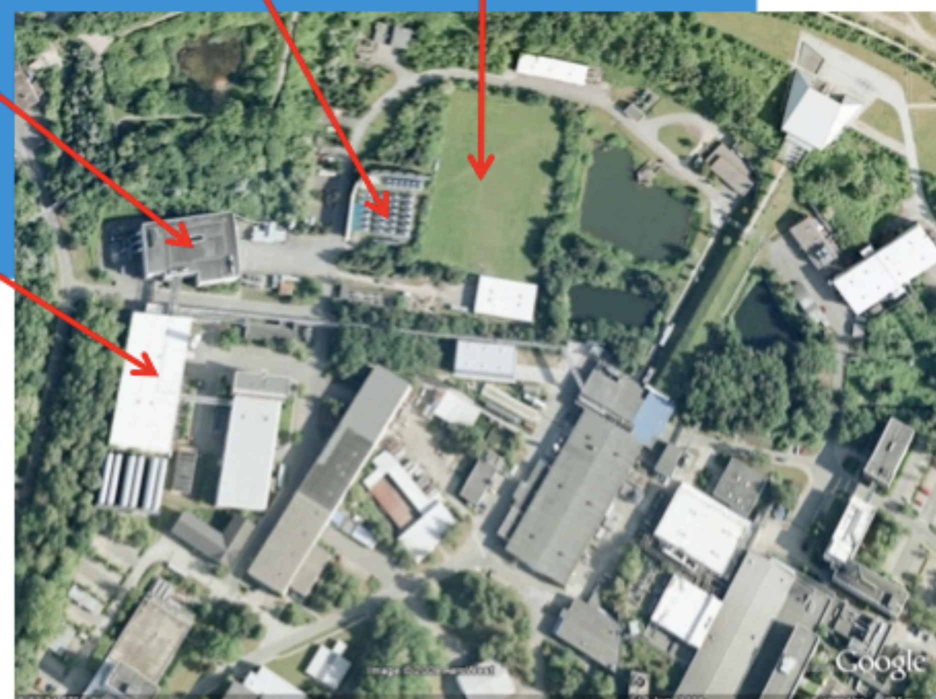
加速モジュール　100台
空洞　800台
1km加速器
でILC型超伝導リニアックの実証となる。
～2012年完成予定

European XFEL

Civil Construction at all XFEL Sites

Accelerator Module Test Facility (AMTF) Including Single Cavity Tests





- First cavity tests required for 1/2011
- Commissioning of module test facility 4/2011
- AMTF ready for infrastructure installation 3/2010

Global Plan for SCRF R&D

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System Test with beam acceleration			FLASH (DESY) , NML (FNAL) STF2 (KEK, extend beyond 2012)			
Preparation for Industrialization				Mass-Production Technology R&D		

Toward Industrialization

- Global status of Industries
  - **Research Instruments (ACCEL) and Zanon in Europe**
  - **AES, Niowave, PAVAC in Americas**
  - **MHI in Asia**

Project Scope			
SNS	~ 110	3years	< ~ 1 cavity / week
Euro XFEL	~800	2 years	~1 cavity / day
Project X	~400	3 years	~2 cavities/ week
ILC	~15,500	4 years	~20 cavities / day
(÷ 3 regions			~7 cavities / day)

- Industrial Capacity: status and scope
  - **No company currently ready for the ILC capacity**
  - **Need to understand what is required (and cost) by 2012**

Visit to Cavity Manufacturers: 2009

Europe:

- RI << ACCEL
- ZANON

Amecas:

- AES
- NIOWAVE
- PAVAC

Asia

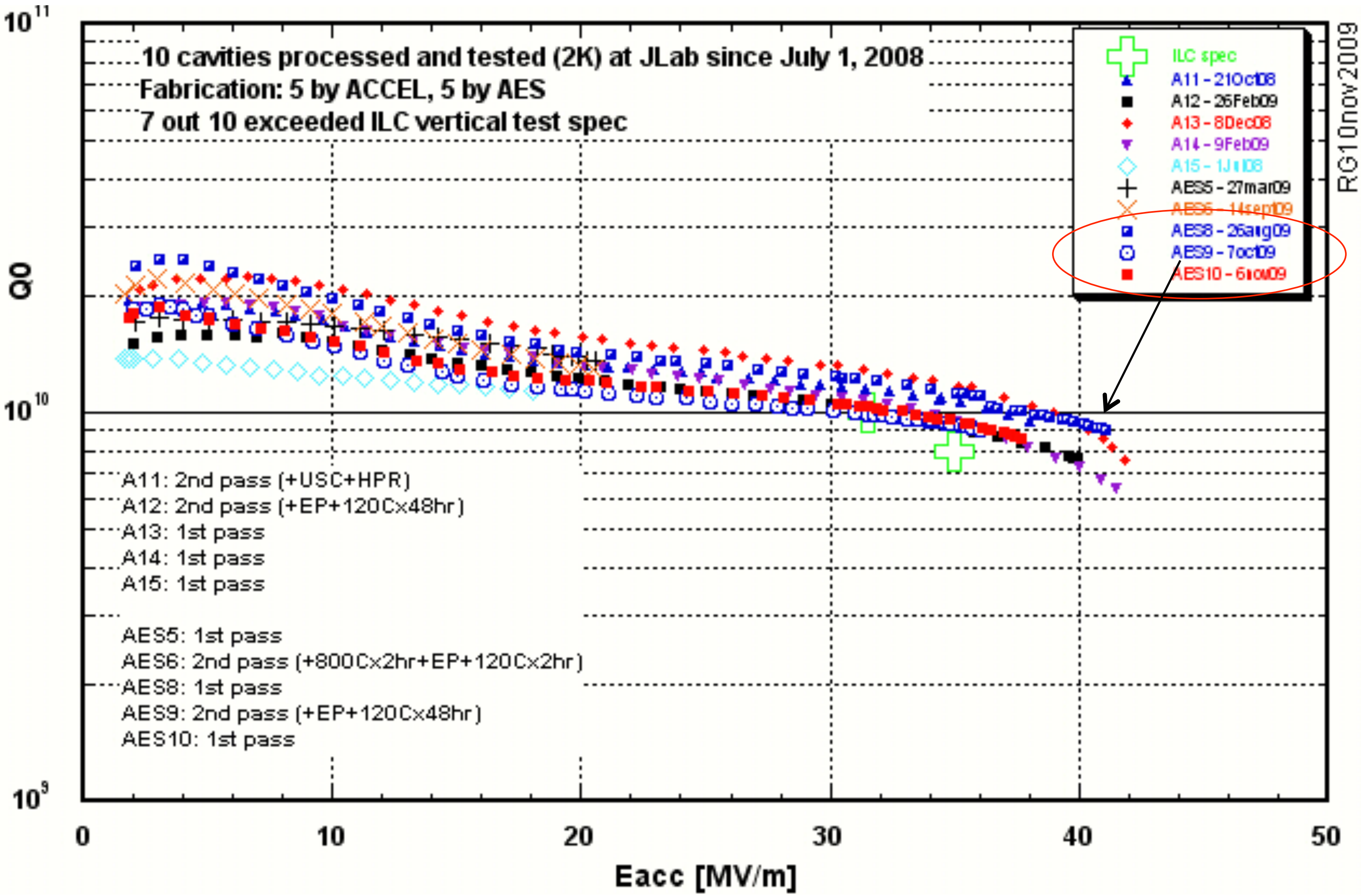
- MHI

Notes:

AES: Advanced Energy Systems
RI: Research Instruments (previously, ACCEL)
MHI: Mitsubishi Heavy Industries

米国

FY09 Results from JLab/FNAL



A Satellite Meeting at IPAC-2010

Industrialization of SCRF Cavities

Date : May 23, 2010, a full-day meeting, prior to IPAC-2010

Place: Int. Conf. Center, Kyoto, Japan

Organized by: ILC-GDE Project Managers,

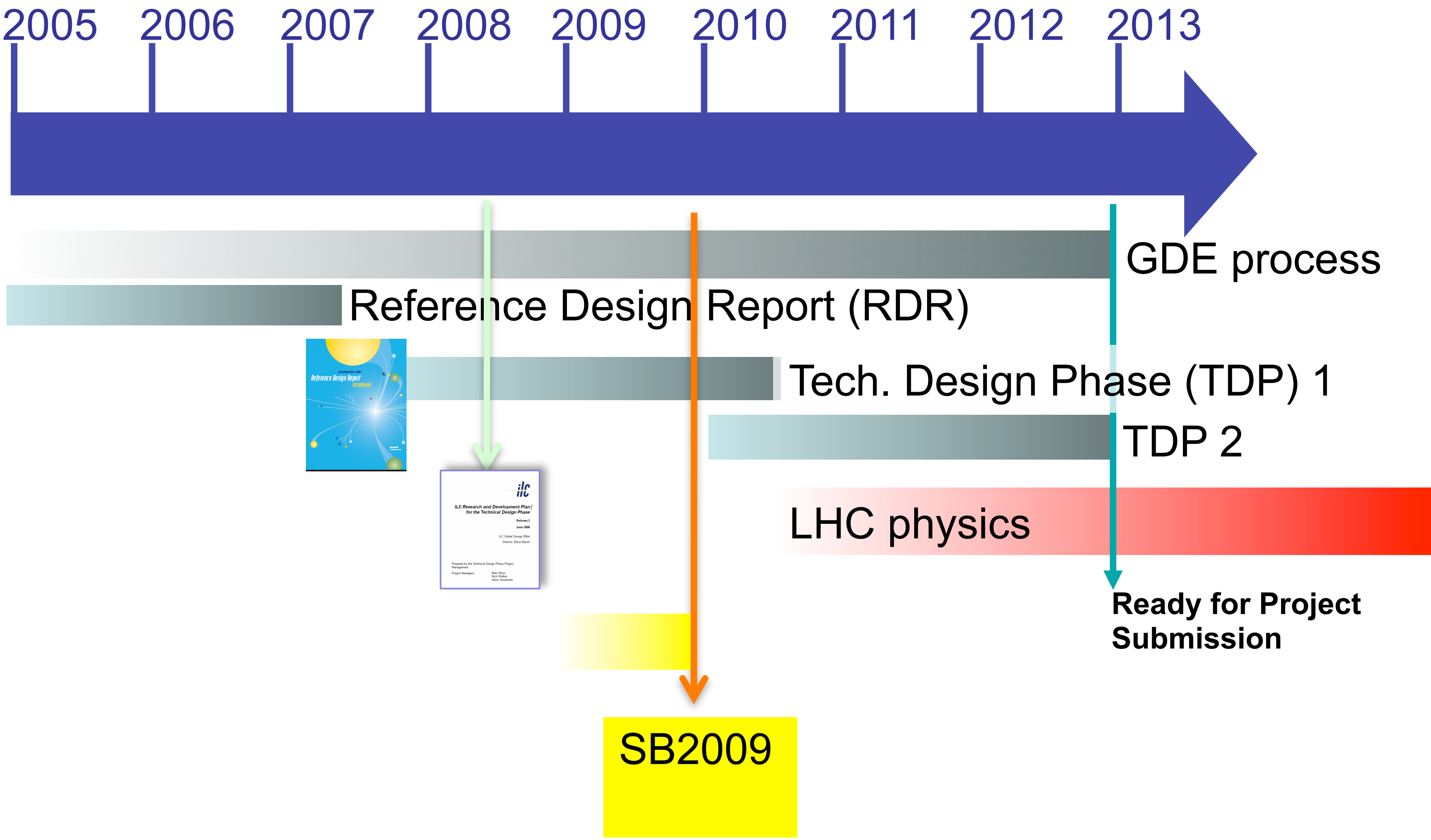
Objectives and Plan:

- To discuss and exchange information on preparation for the 'ILC SCRF Cavity' industrialization between industries and laboratories,
- Industrialization plan to be reported by laboratories, and comments/advices given by industries,

Announcement sent/made to major cavity venders, RI, Zanon, AES, Niowave, PAVAC, MHI, other SCRF industries, and ILC-SCRF institutions,

Strawman Baseline 2009

Proposed by PMs

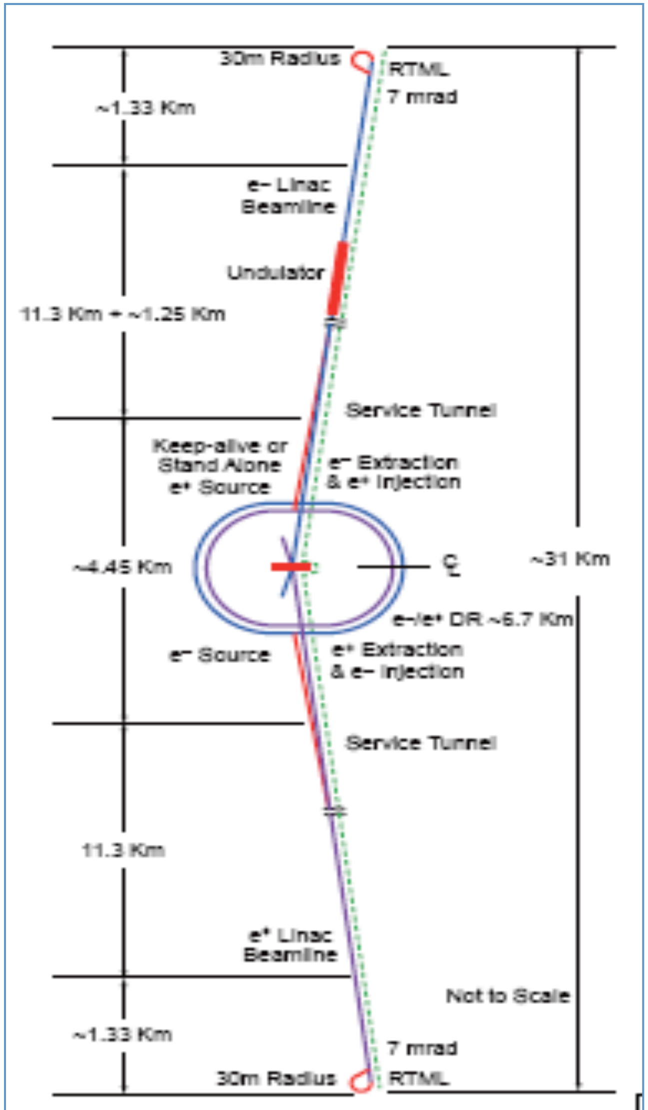


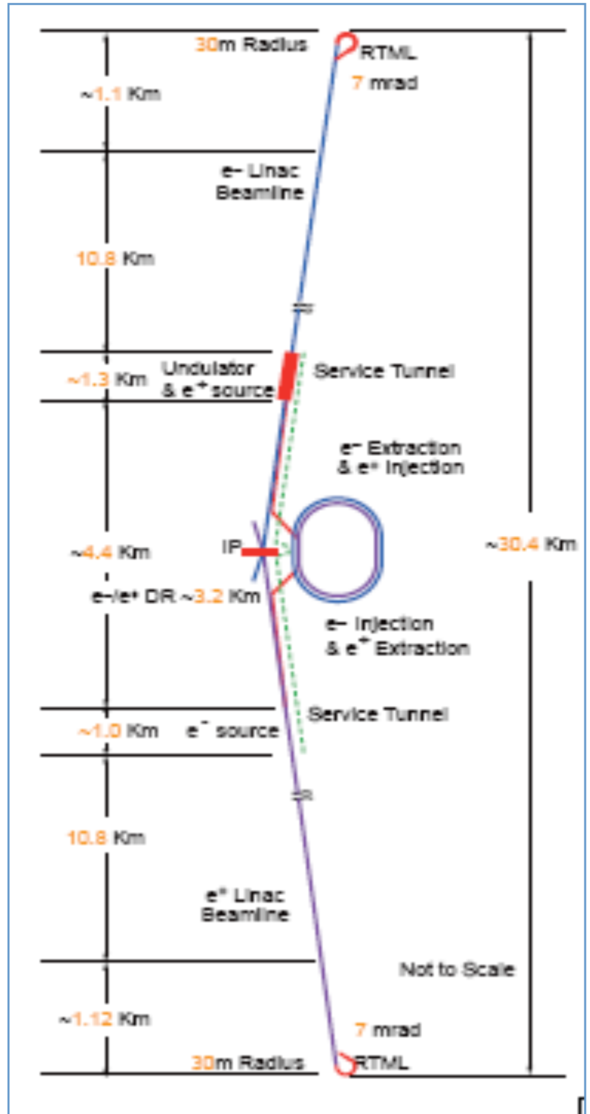
ADI Goals

- Overall cost
  - **Best effort to keep the project cost stable**
- Improved cost balancing
  - **Need to prepare for re-optimizing the cost balance**
- Improved understanding of system functionality

- More complete and robust design
  - **The plan should become ‘practical’ to be ready for starting**
- Re-optimised R&D plans
  - **Prepare for TDP-2**

RDR & SB2009 Layouts

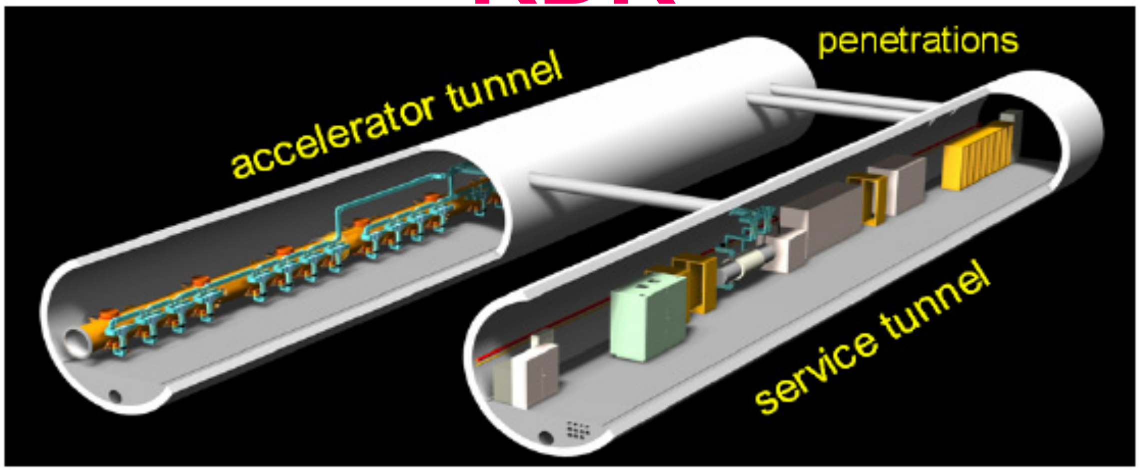




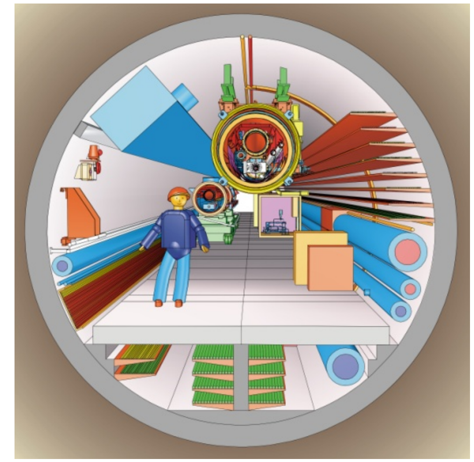
- Single tunnel containing accelerator
- Lower Power DR, ..
- Central Area Integration
- e+ source and the location
- Cavity Gradient To be studied

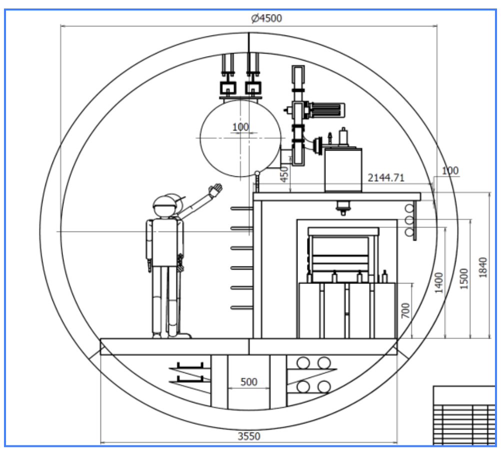
Tunnel Variants

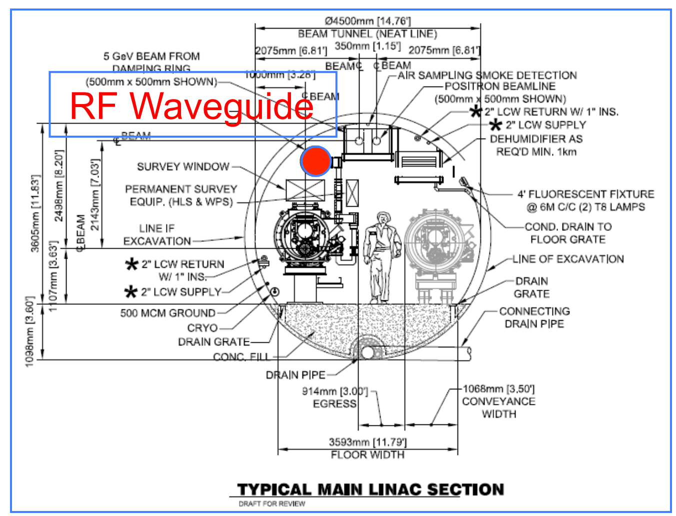
RDR



XFEL







Single Tunnel: Safety

	Asia	Americas	Europe
HLRF scheme examined so far	Primarily DRFS.	Primarily KCS.	Primarily KCS
Isolation of incident location	Firewalls / doors every 500 m along the tunnels, and selective closure of the airflow.	Utilize caverns at the vertical shaft bases for isolating oil-filled equipment.	Firewalls / doors every 500 m along the tunnels
Safe pathways	Rest of the tunnels.	Most of the tunnels.	Rest of the tunnels.

SB2009 Proposal

1. A Main Linac length
   - **consistent with an *average* accelerating gradient of 31.5 MV/m and maximum operational beam energy of 250 GeV**
   - **together with a High-Level RF distribution scheme which optimally supports a spread of individual cavity gradients.**

2. A single-tunnel solution for
   - **the Main Linacs and RTML, with two possible variants for the High-Level RF (HLRF):**
     - Klystron cluster scheme (KCS);
     - Distributed RF Source scheme (DRFS).

SB2009 Proposal

3. Undulator-based e+ source
   - **located at the end of the electron Main Linac (250 GeV), in conjunction with a Quarter-wave transformer as capture device.**

4. A lower beam-power parameter set with
   - **the number of bunches per pulse reduced by a factor of two (n_b = 1312), as compared to the nominal RDR parameter set.**

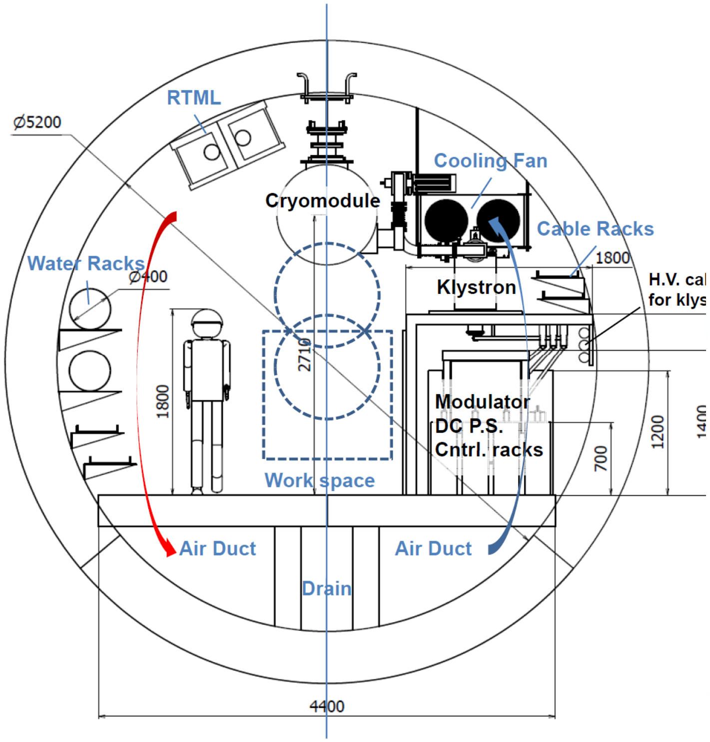
SB2009 Proposal

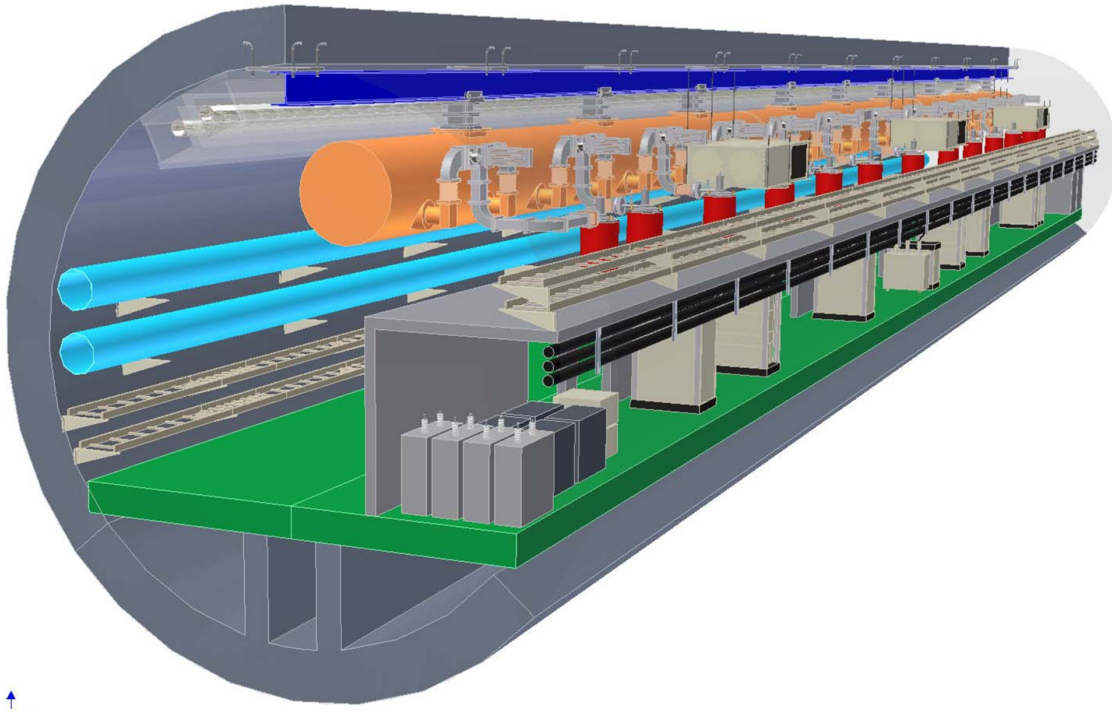
5. Reduced circumference Damping Rings (~3.2km) at 5 GeV with a 6 mm bunch length

6. Single-stage bunch compressor with a compression ratio of 20.

7. Integration of the positron and electron sources
   - **into a common “central region beam tunnel”,**
   - **together with the BDS,**
   - **resulting in an overall simplification of civil construction in the central region.**

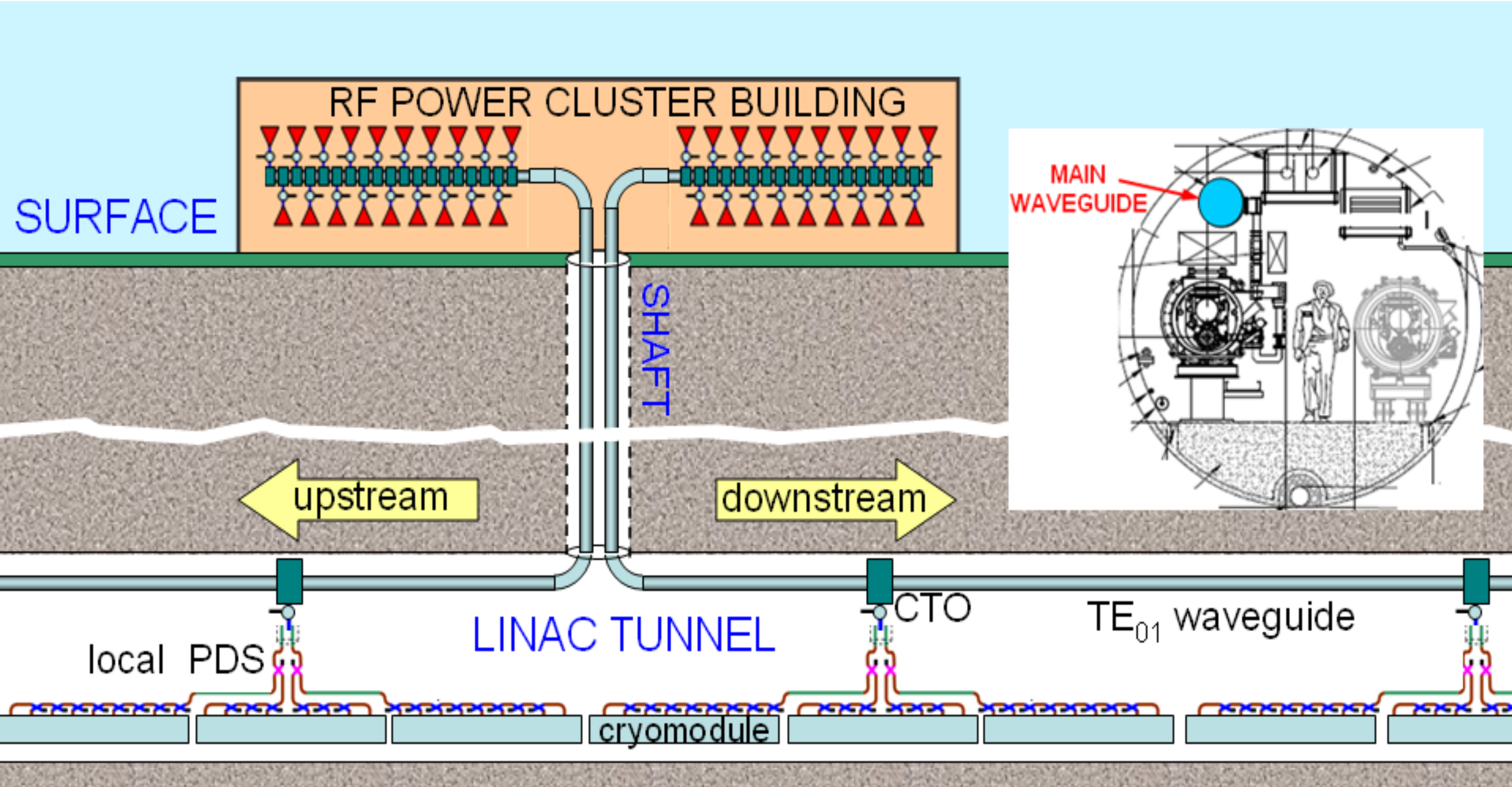
Distributed RF Source





All RF power source components in single tunnel

Klystron Cluster Scheme



All active RF power source components moved to surface buildings

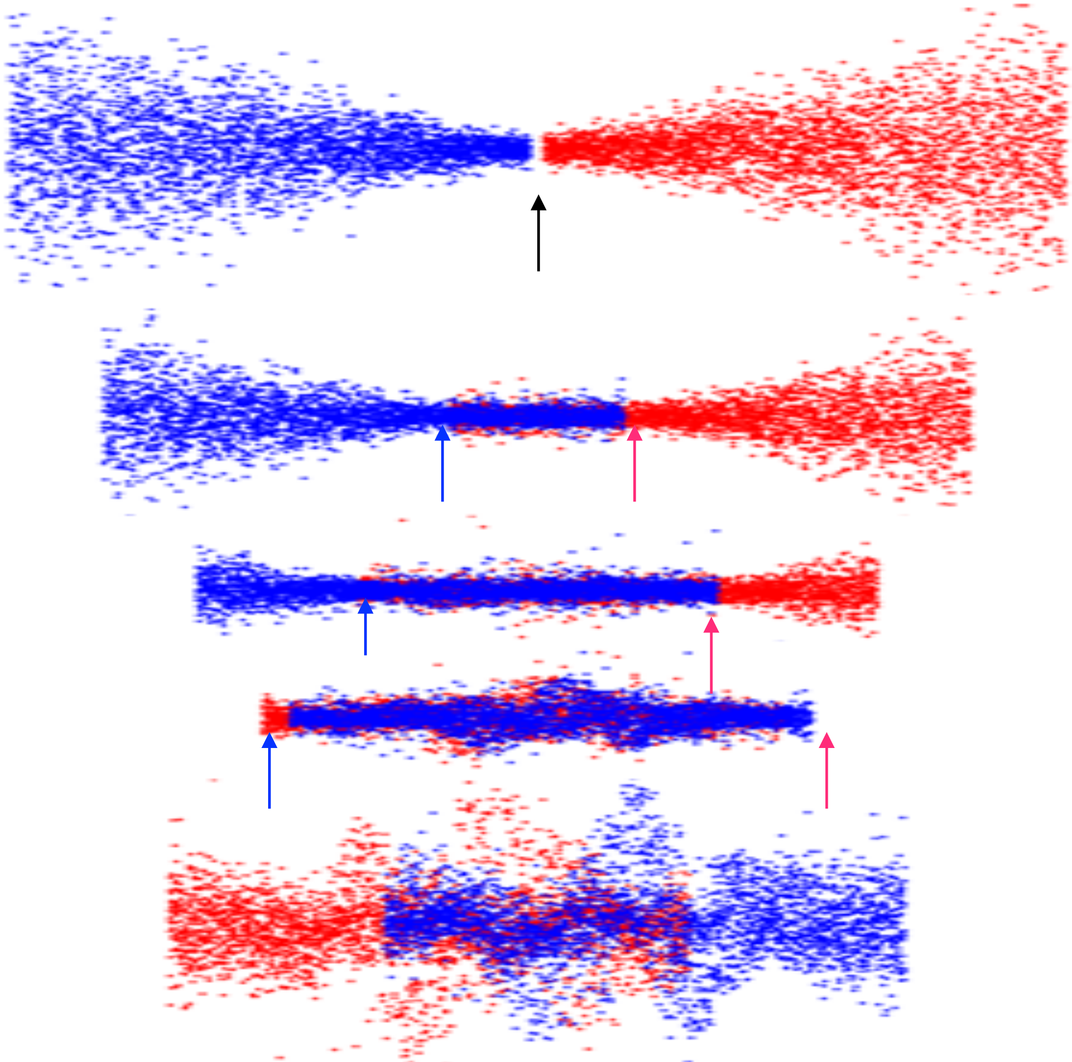
SB2009 Parameters (1/2)

		RDR (nominal)	SB2009
Beam and RF Parameters			
No. of bunches		2625	1312
Bunch spacing	ns	356	670
beam current	mA	9.0	4.8
Avg. beam power (250 GeV)	MW	10.8	5.4
Accelerating gradient	MV/m	31.5	31.5
Pfwd / cavity (matched)	kW	294	156
Qext (matched)		3.5E+06	6.6E+06
Tfill	ms	0.60	1.12
RF pulse length	ms	1.57	2.00
RF to beam efficiency (matched)	%	61	44

SB2009 Parameters (2/2)

IP Parameters				
Norm. horizontal emittance	mm.mrad	10	10	
Norm. vertical emittance	mm.mrad	0.040	0.035	
bunch length	mm	0.3	0.3	
horizontal β*	mm	20	11	
horizontal beam size	nm	640	470	
			no trav. focus	with trav. focus
vertical β*	mm	0.4	0.48	0.2
vertical beam size	nm	5.7	5.8	3.8
Dy		19	25	38
δEBS/E	%	2	4	3.6
Avg. P_{BS}	kW	260	200	194
Luminosity	cm -2 s -1	2.00E+34	1.50E+34	2.00E+34

Travelling Focus $\beta^* < \sigma_z$



Summary on AD & I (SB-2009)

- Initial Accelerator Design & Integration effort has successfully concluded
  - **Approximately 1 year study**
- Publication of proposed baseline modifications (Dec. 2009).

- 7 primary SB2009 Working Assumptions
  - **Wide-ranging impact on accelerator design**
  - **Core technologies remain the same as RDR**
- 3 primary themes ($$$)
  - **Single tunnel for Main Linac (including new HLRF solutions)**
  - **Low-power parameter set**
  - **Central region integration**

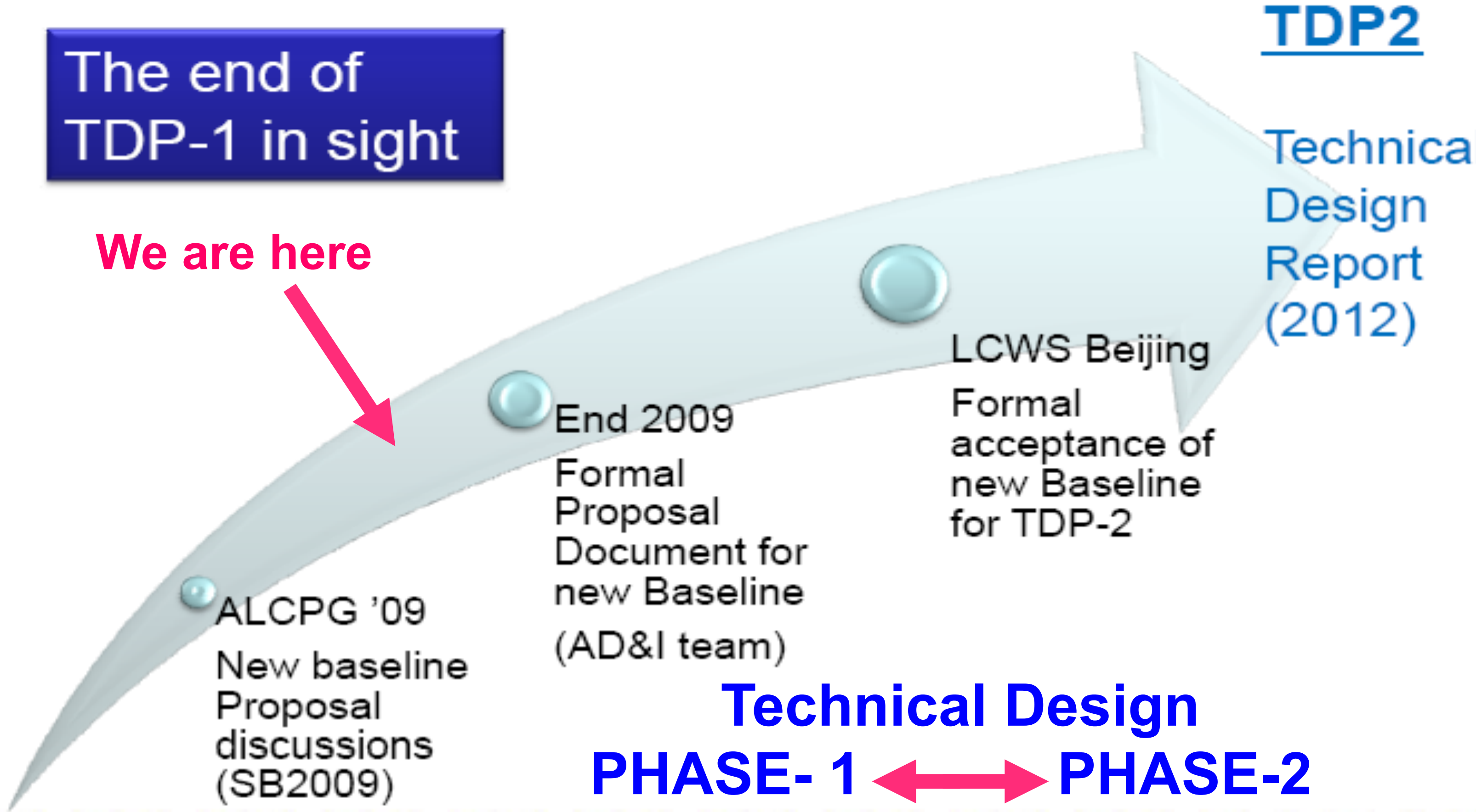
- Initial studies have demonstrated feasibility
  - **But clearly more detailed design work is required in TDP2**
- Impact on luminosity acknowledged and requires further study
- Estimated 13% reduction in RDR value estimate

Comments on SCRF

- In SB2009, ILC operational field gradient left unchanged
  – for CF&S study to enable to stay at 31 km in ML tunnel length and to be consistent with 250 GeV beam energy,
- SCRF cavity gradient R&D Goal
  – Kept to be 35 MV/m (at Q0 = 8E9) with the production yield of 90 %,
  – Global data base appreciated to continue for monitoring the progress,
- Spread of cavity gradient effective to be taken into account
  – to seek for the best cost effective cavity production and use,
  – Final acceptable range requires confirmation from RF effort,
- Re-optimization required, to decide ILC operational gradient
  – to have adequate balance/redundancy between the ‘R&D gradient-milestone’ and the ‘ILC operational gradient’ including ‘cryomodule operation margin’ and ‘HLRF/LLRF adjustability’ for stable and sufficiently high ‘availability’ with risk mitigation.

AD&I and SB2009 Schedule

The end of TDP-1 in sight



Formal start of TDP-2

Summary and Further Actions

- SB2009 has been reviewed by AAP, Jan. 2010,
- Feedback from physics/detector community reflected during the review process

- We are waiting for the review results with written document,

- GDE is to make further actions in response to the PAC/AAP review, and discuss with ILC-GDE community.
- The GDE needs to be responsible to provide Technical Design Report which can scope the ILC to be realized under the given condition in 2012.