Global R&D Effort of Superconducting RF Technology for the International Linear Collider

Akira Yamamoto, Marc Ross, and Nick Walker
ILC-GDE Project Managers
and
Kaoru Yokoya
ILC-GDE Asian Resgional Director

Visiting Institutions in Beijing, China, December 9-10, 2008

First of all

- **We would thank** for the opportunity to visit to
  - **Beijing University (北京大学）,**
  - **Tsinghua University （清華大学）,**
  - **IHEP （高能研）**

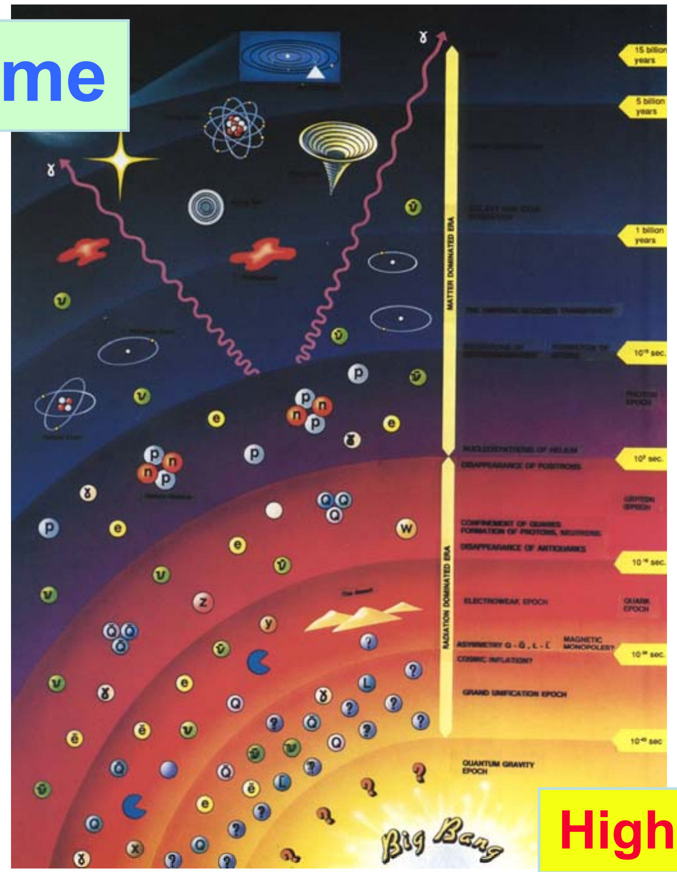
  today, representing ILC-DGE with
  - **Kaoru Yokoya （横谷馨; KEK）: Asian Reg. Director**
    - Leading KEK LC Office and Programs
  - **Marc Ross (Fermilab): Project Manager**
    - Global system and Conventional Facility,
  - **Akira Yamamoto（山本明：KEK）: Project Manager**
    - Superconducting RF and Main Linac Technology,

Outline

- Introduction
- R&D Status
- Plan for Technical Design Phase
- Global Plan and Project Management
- Summary

Particle Physics to study Early Universe

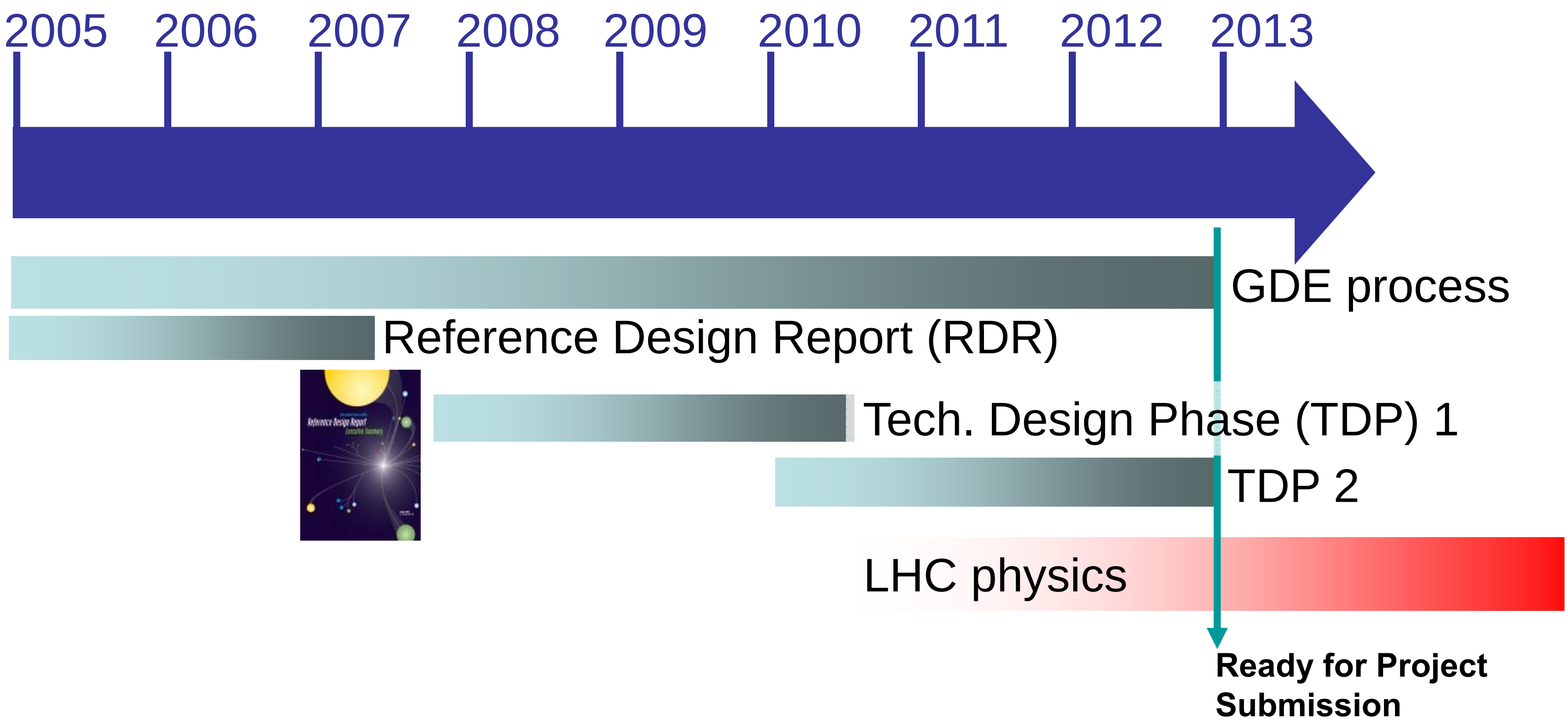
Time



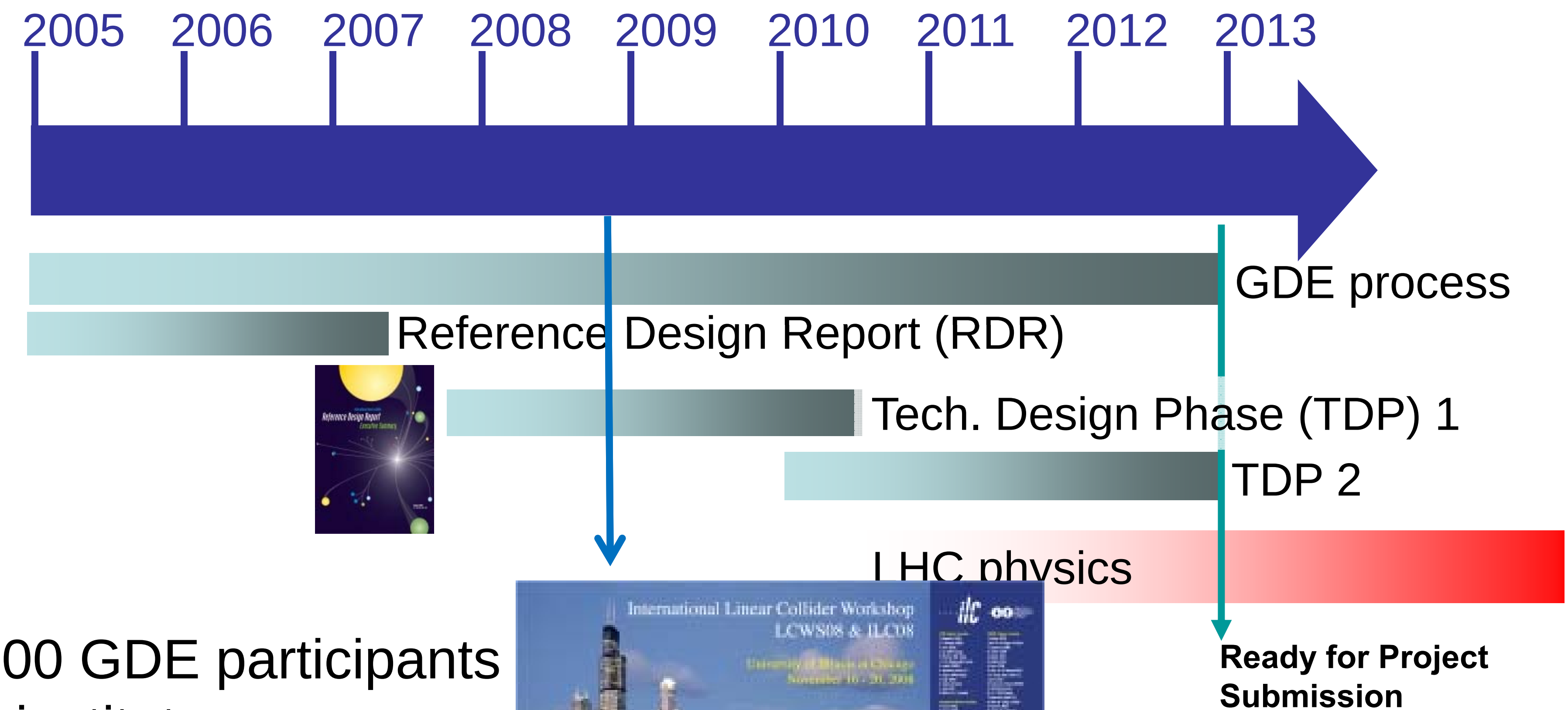
High Energy

- Particle Physics
  - Study history of early Universe
- Particle Accelerators
  - A tool to investigate high-energy particle interactions in early Universe

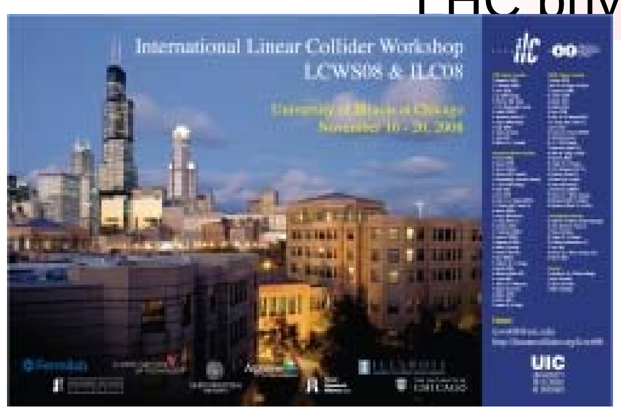
GDE ILC Timeline



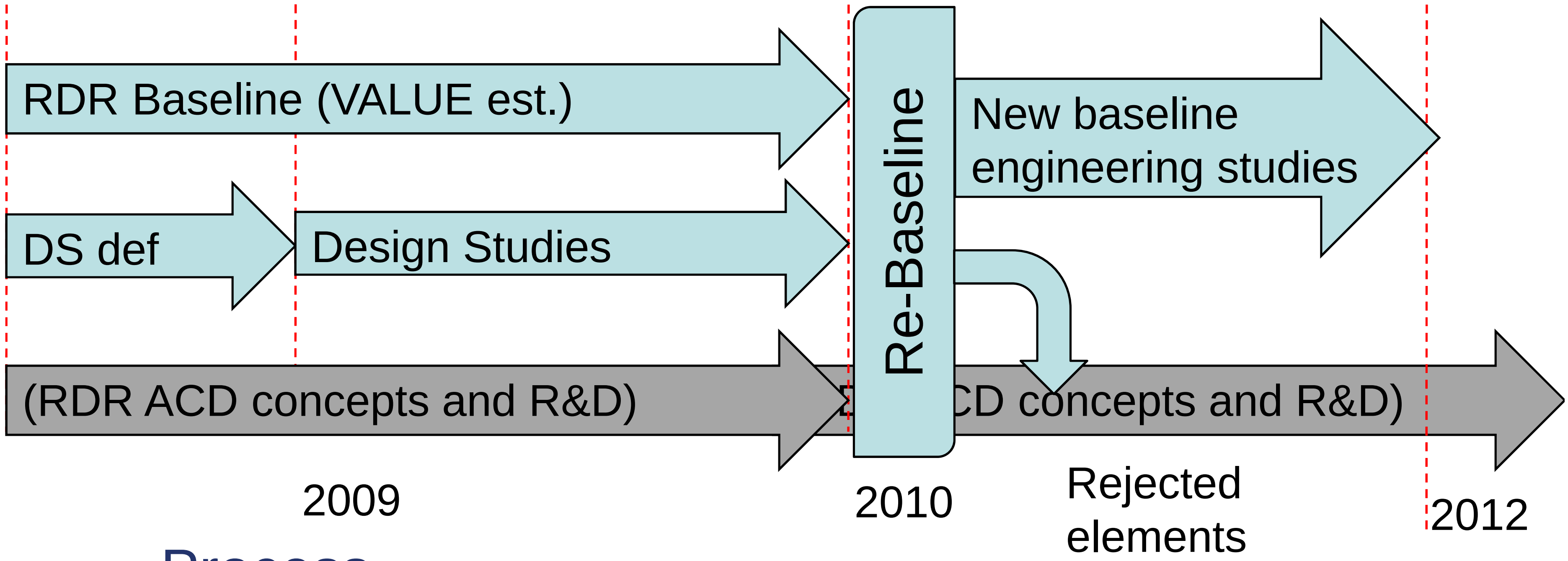
GDE ILC Timeline



~100 GDE participants
55 institutes
12 countries
3 regions



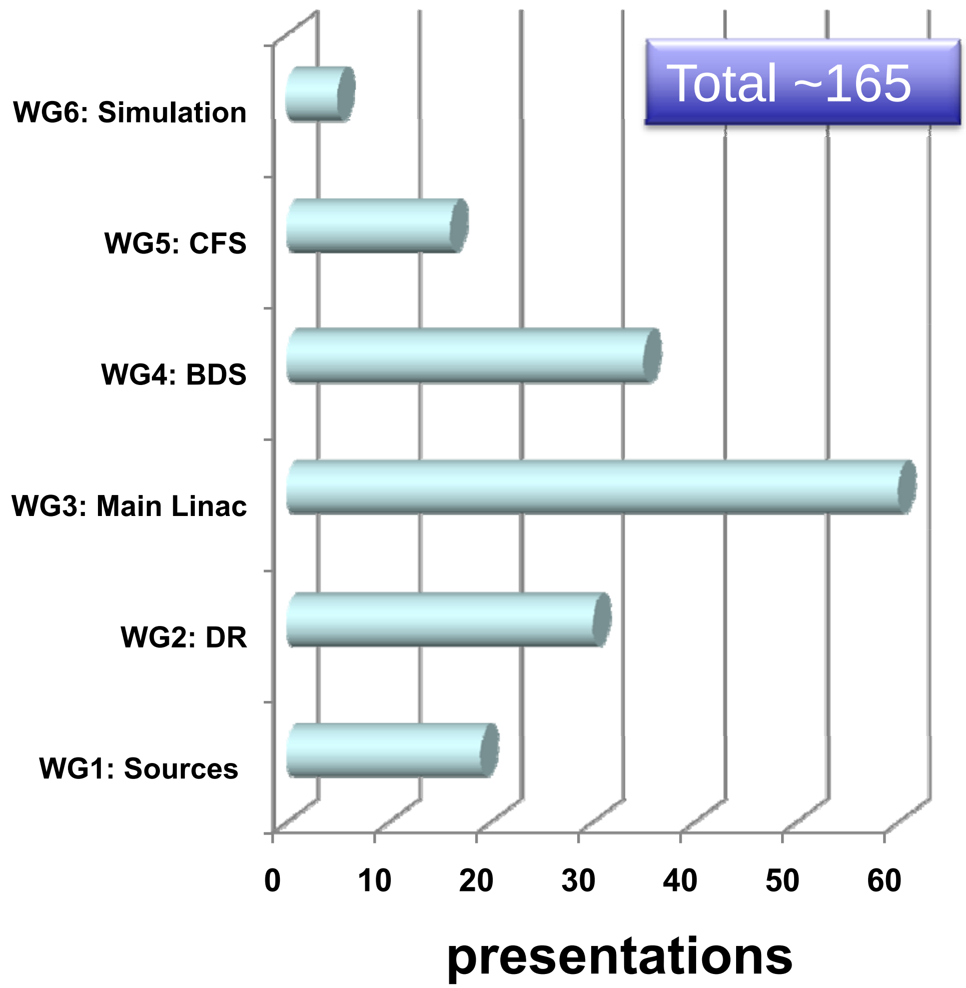
Towards a Re-Baselining in 2010



- Process
  - **RDR baseline & VALUE element are maintained**
    - Formal baseline
  - **Formal review and re-baseline process beginning of 2010**
    - Exact process needs definition
    - Community sign-off mandatory

ILC08 Working Groups

1. Sources
   - Axel Brachmann (SLAC)
   - Jim Clarke (STFC DL)
2. Damping Rings
   - Mark Palmer (Cornell)
   - Andrzej Wolski (CI/UL)
   - Junji Urakawa (KEK)
3. Main Linac
   - Chris Adolphsen (SLAC)
   - Hitoshi Hayano (KEK)
4. BDS/MDI
   - Deepa Angal-Kalinin (CI DL)
   - Andrei Seryi (SLAC)
   - Hitoshi Yamamoto (Tohoku U.)
5. CFS
   - Vic Kuchler (FNAL)
   - John Andrew Osborne (CERN)
   - Atsushi Enomoto (KEK)
6. Simulations
   - Kiyoshi Kubo (KEK)
   - Daniel Schulte (CERN)
   - Nikolay Solyak (FNAL)



Fields and the Roles of Superconductivity in Particle Accelerators

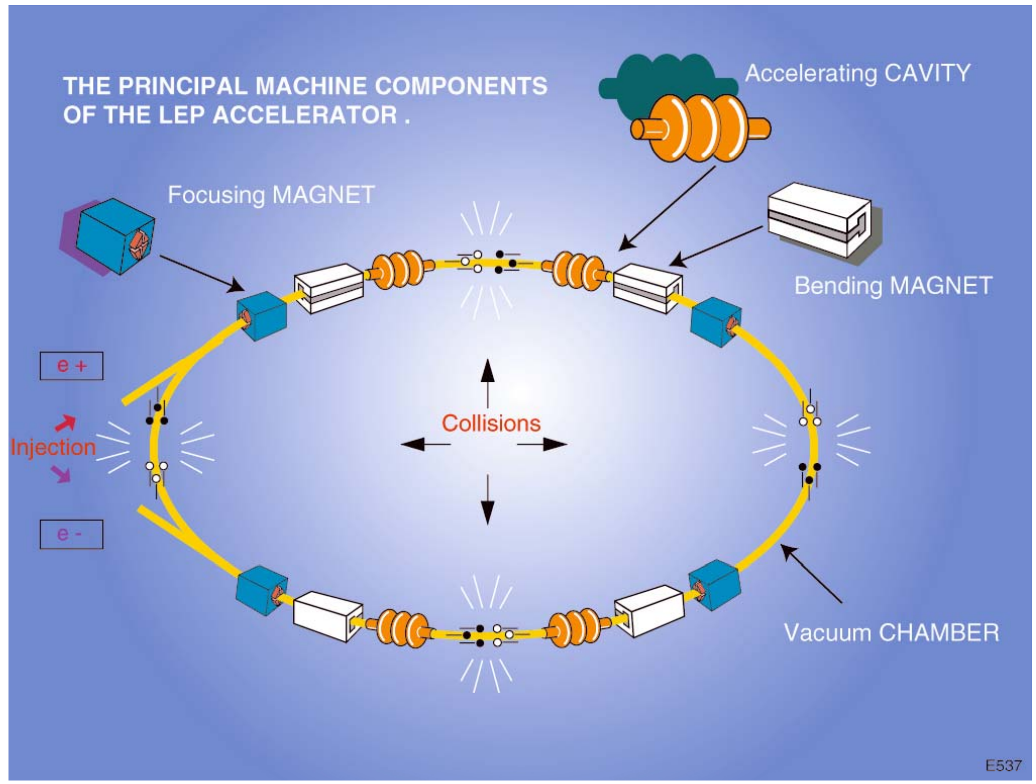
Acceleration

- **Electric Field: E**
  - **Static,**
  - **RF**

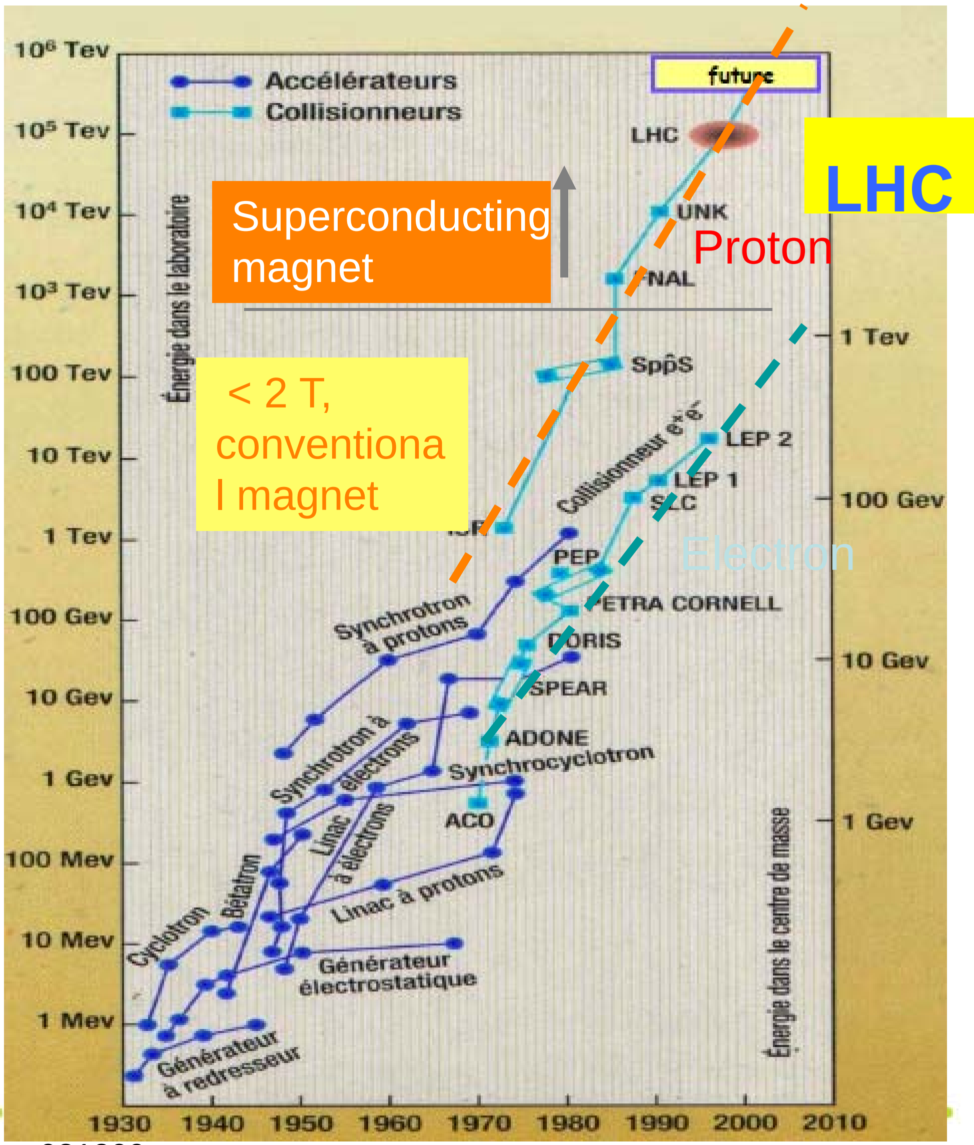
Beam Handling

- **Magnetic Field : B**
  - **Bending**
    (Dipole Magnet)
  - **Focusing**
    (Quadrupole Magnet)

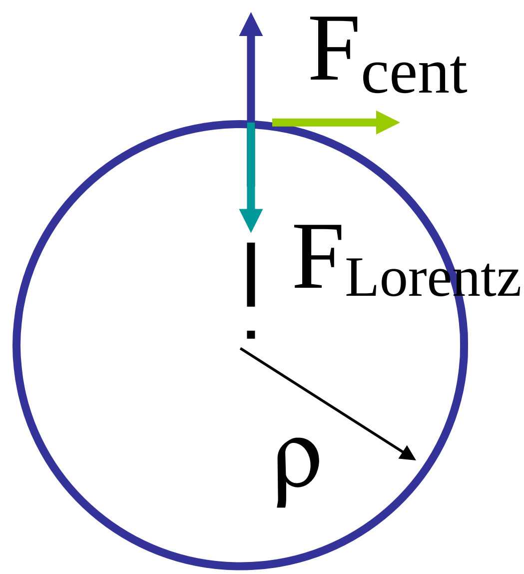
Superconductivity takes an essential role



Development of H.E. Accelerators



- With high magnetic field required



$$p = q \cdot \rho \cdot B$$

P [TeV/c] = 0.3 • ρ [km] • B[Tesla]

Progress in H.E. Proton Accelerators with Superconducting Magnets

Accelerator	Tevatron	SSC	HERA	RHIC	LHC
Lab.	FNAL	SSC	DESY	US	CERN
Energy [TeV]	0.9	20	0.82	0.1/anm	7
Radius [km]	1	14	1	0.5	4.5
Ring	1 (p+p-)	2 (p+p)	1 (e+p)	2 (p+p) &	p+p-
B-dipole [T]	4.4	6.6	4.7	3.5	**8.36**
G-quad [T/m]	76	205	91	72	220
R-coil [mm]	38	25	37.5	40	28
#Dipoles	774	7986 (676)	422	288	2x1232
Temperature [K]	4.5	4.4	4.5	4.5	**1.9**
Complete year	1985	Canceled	1990	2000	(2007)
Note	First SC large Accelerator	Few training quench	First industrial contribution	Economical	Highest field SF-He

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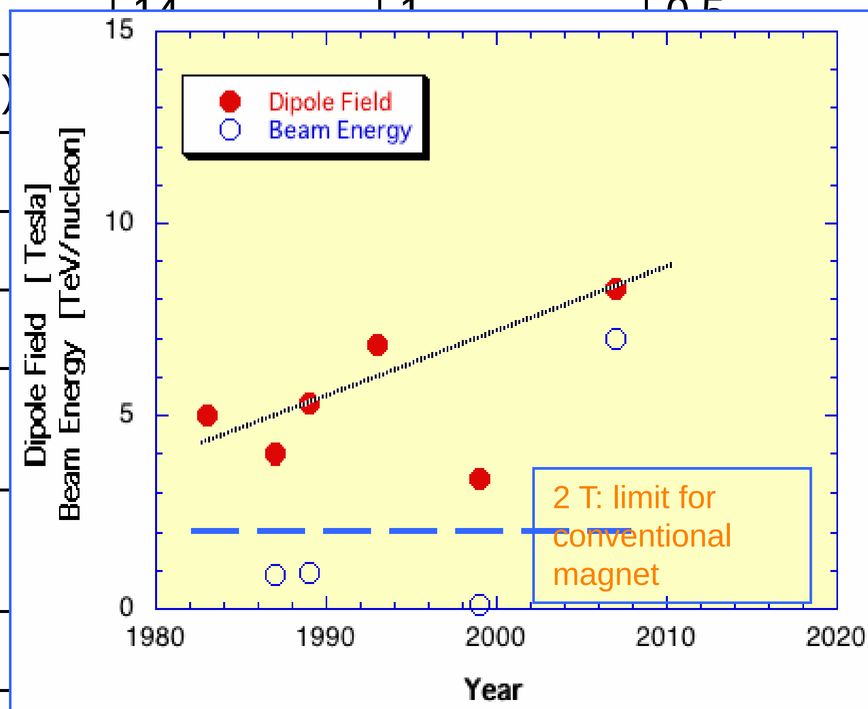
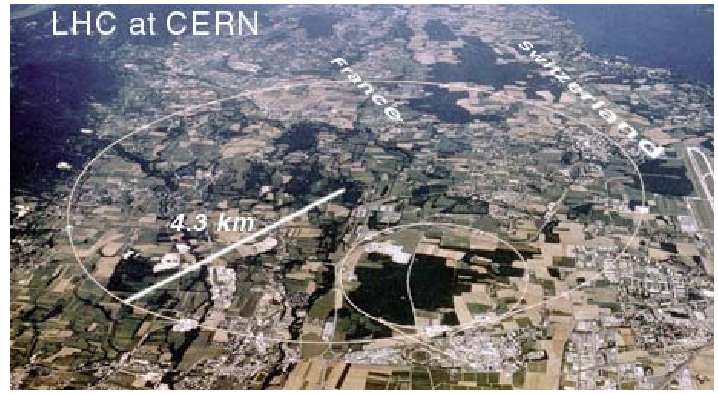
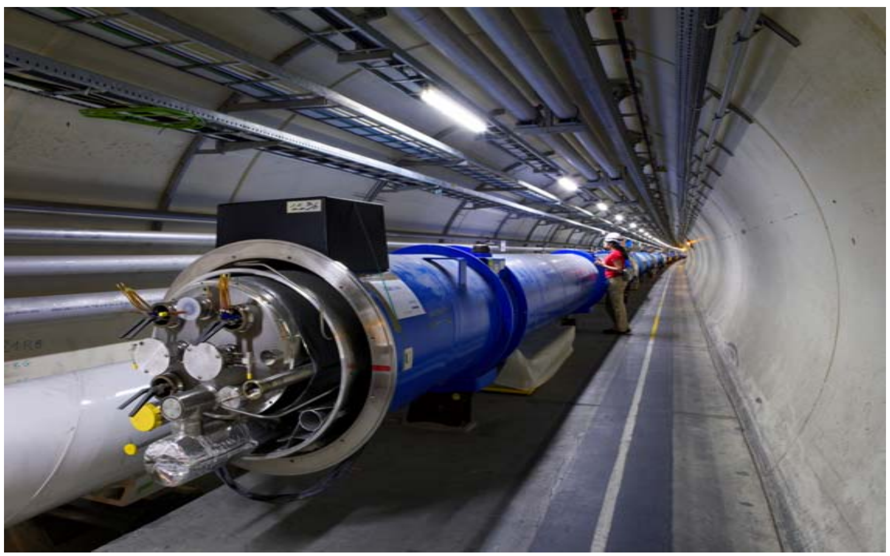
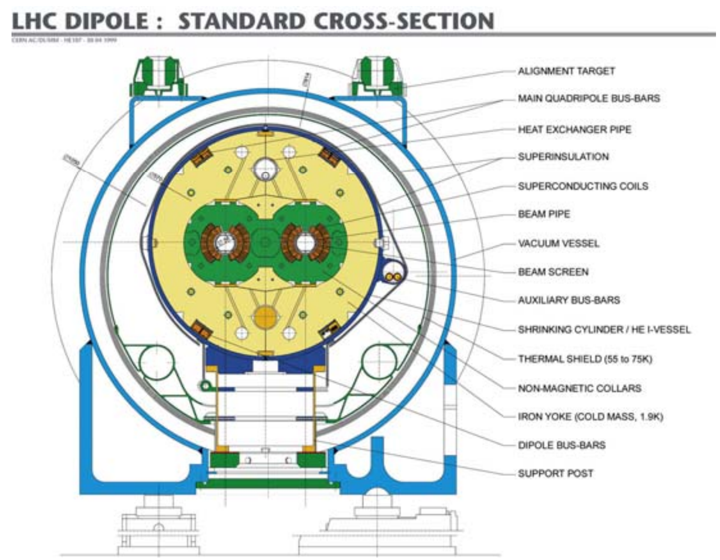


LHC Superconducting Magnets

- Diameter: 27 km
- Energy 2 x 7 TeV
- SC Magnets
- Dipole field 8.4 T,

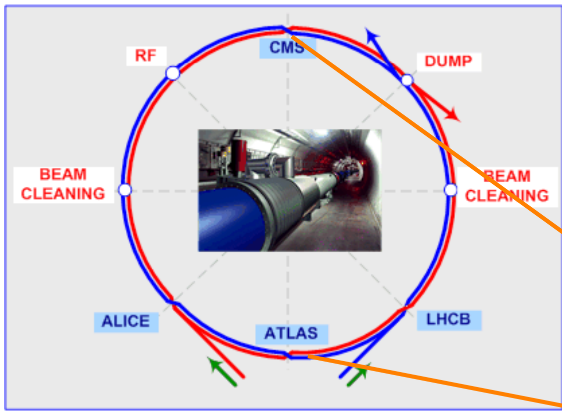


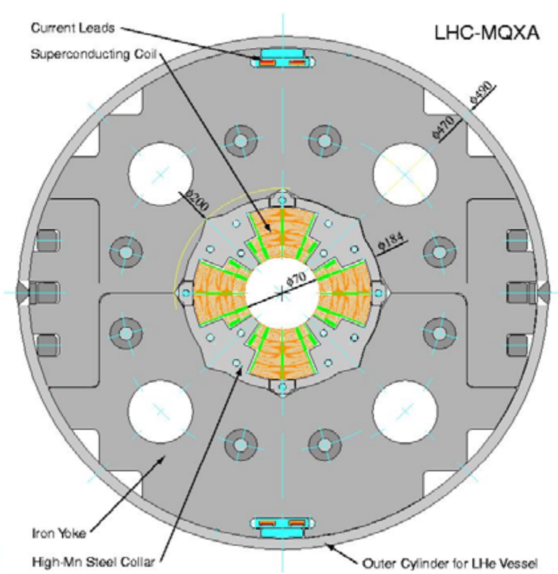




Successful international collaboration including Asia

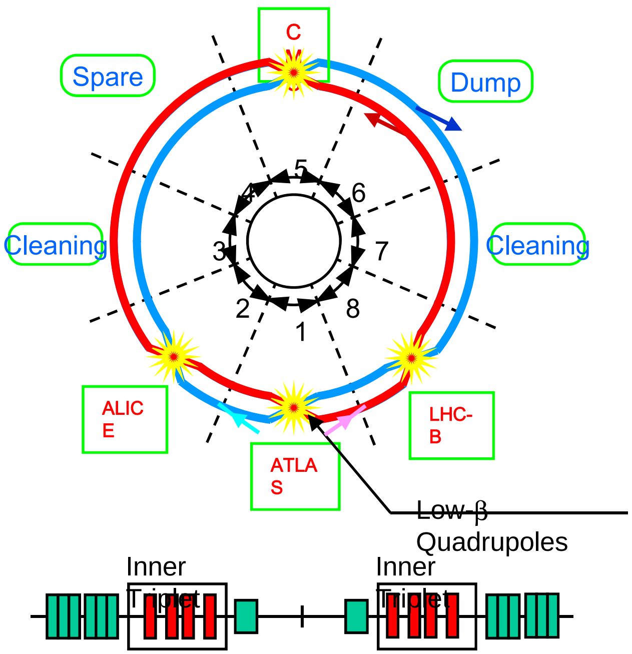
CERN-LHC Interaction Region Focusing Magnets

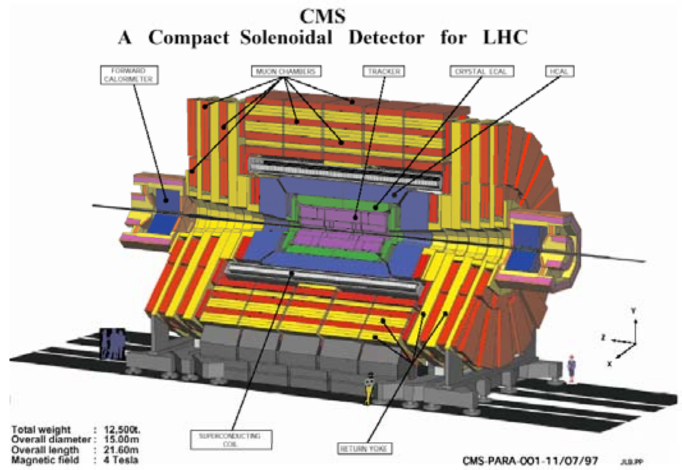




CERN KEK-Fermilab Coollaboration

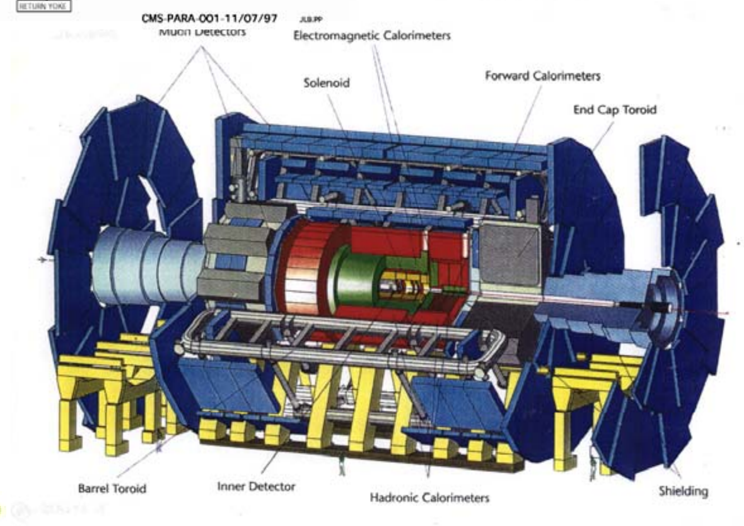
Superconducting Magnets for for CERN-LHC Experiments





CMS

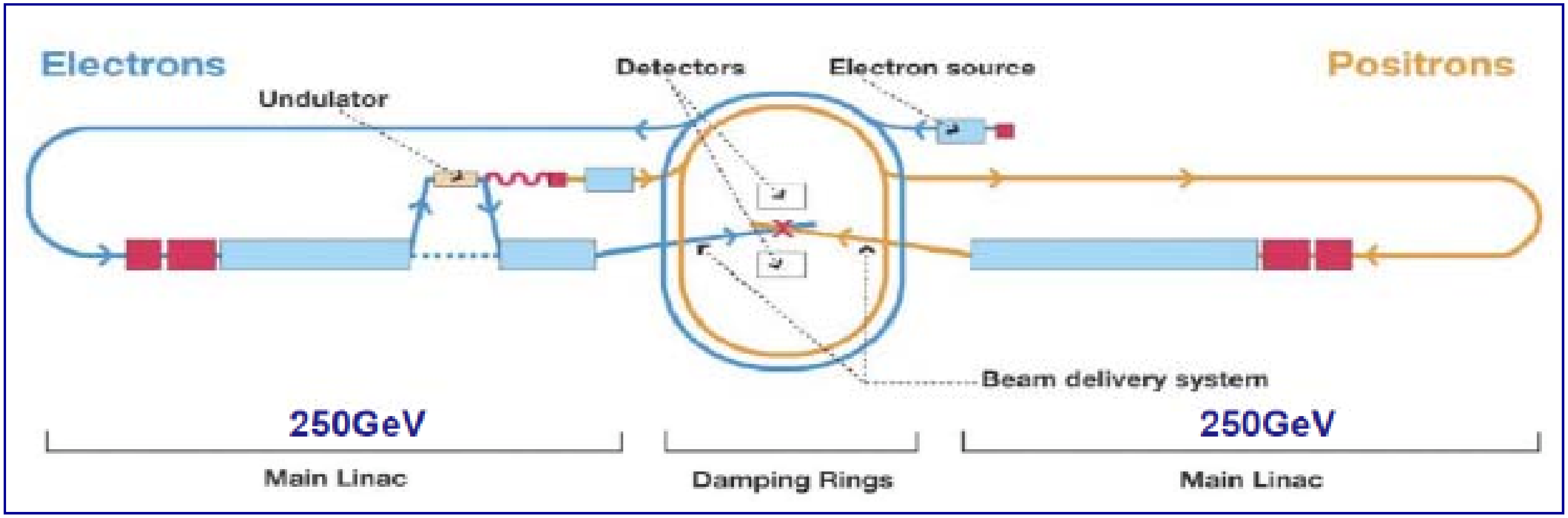
ATLAS



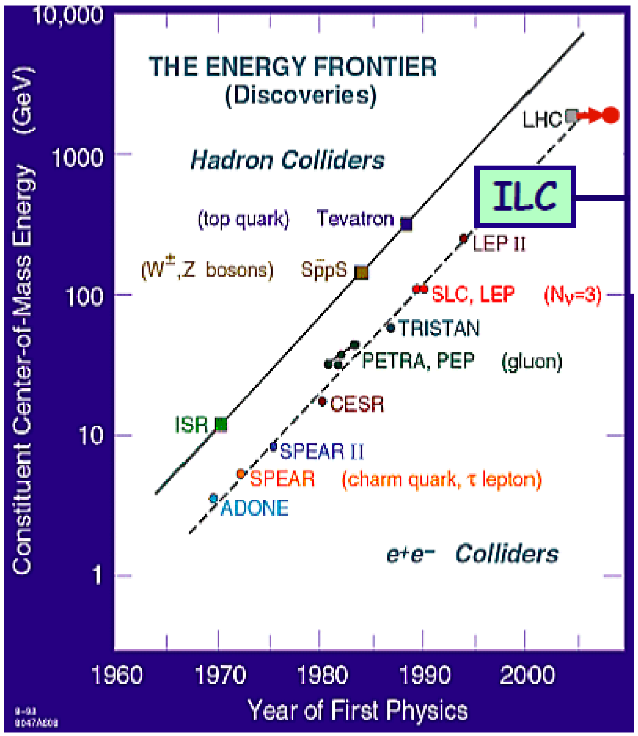
Al-stabilized NbTi SC Magnets

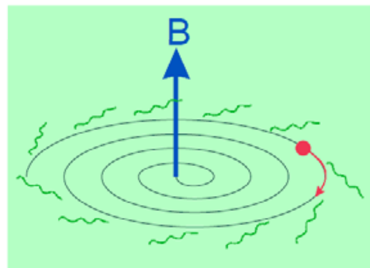
A Next Step

- **International Linear Collider (ILC)**



Particle Accelerators
beyond limit of circular accelerators





Energy loss must be replaced by RF system
cost scaling $ $\propto E_{cm}^2$

Electron machine

Ring accelerator

>> Linear Accelerator

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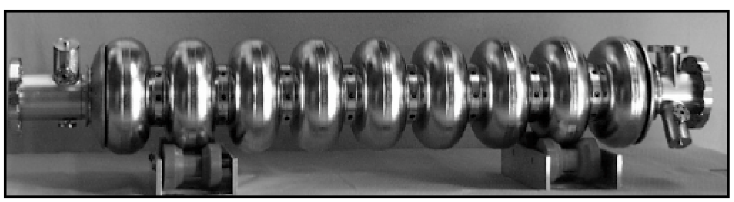
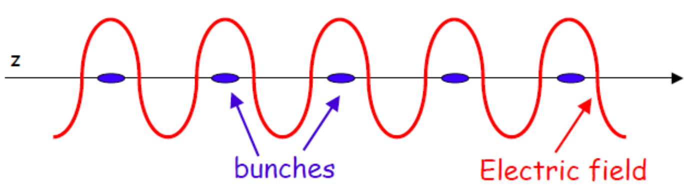
Reference Design

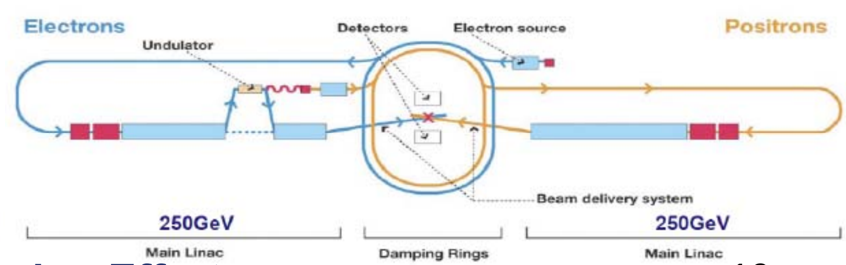
Released in Beijing, Feb. 2007

- **SC linacs: 2x11 km**
  - **for 2x250 GeV**
- **Injector centralized**
  - **Circular damping rings**
- **IR with 14 mrad crossing angle**



Parameter	**Value**
C.M. Energy	500 GeV
Peak luminosity	2×10^{34} $cm^{-2}s^{-1}$
Beam Rep. rate	5 Hz
Pulse time duration	1 ms
Average beam current	9 mA (in pulse)
Average field gradient	**31.5 MV/m**
# 9-cell cavity	14,560
# cryomodule	1,680
# RF units	560





Technical Design Report
to be completed by 2012


ILC Research and Development Plan for the Technical Design Phase

Release 2

June 2008

ILC Global Design Effort

Director: Barry Barish

Prepared by the Technical Design Phase Project Management

Project Managers: Marc Ross, Nick Walker, Akira Yamamoto

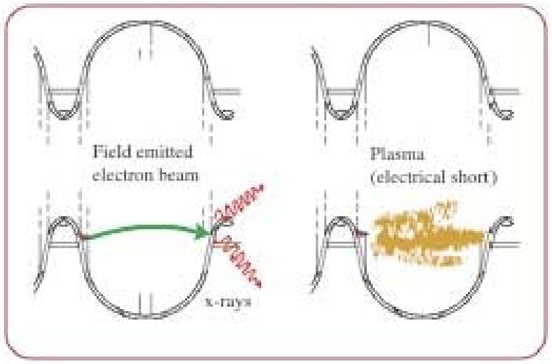
Reference Design, 2007 >> Technical Design Phase, 2008-2012
We are now at the stage of progressing from the RD to TD

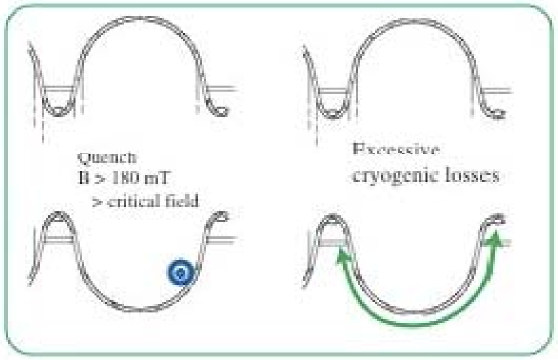
TDP Goals of ILC-SCRF R&D

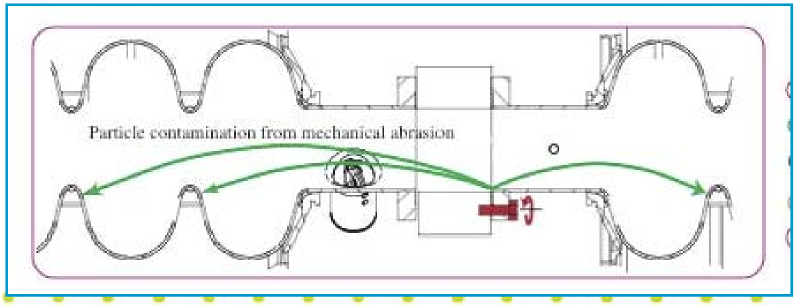
- **Field Gradient**
  - 35 MV/m for cavity performance in vertical test (S0)
  - 31.5 MV/m for operational gradient in cryomodule
    - to build two x 11 km SCRF main linacs
- **Cavity Integration with Cryomodule**
  - **“Plug-compatible” development to:**
    - Encourage “improvement” and creative work in R&D phase
    - Motivate practical ‘Project Implementation’ with sharing intellectual work in global effort
- **Accelerator System Engineering and Tests**
  - Cavity-string test in one cryomodule (S1, S1-global)
  - Cryomodule-string test with Beam Acceleration (S2)
    - With one RF-unit containing 3 crymodule

Why Field Gradient Limited in SC Cavity ? Current major reasons

- **Field Emission**
  - **due to high electric field**
    - around “Iris”
- **Quench**
  - **caused by surface heating from dark current, or**
  - **magnetic field penetration.**
    - around “Equator”
- **Contamination**
  - **during assembly**

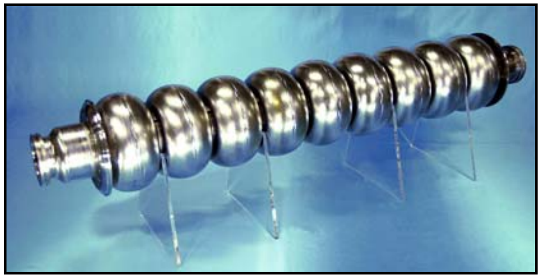


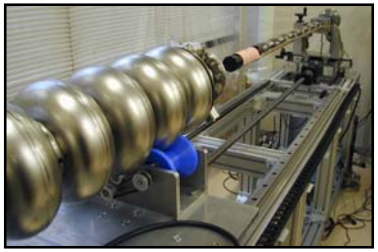


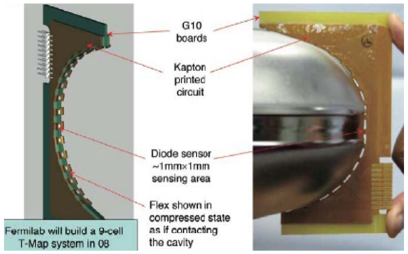


R&D Efforts Required

- **Fabrication:**
  - **Forming and welding (EBW)**
- **Surface Process:**
  - **Chemical etching**
    - Electro-polishing
  - **Cleaning**
    - Ethanol, Detergent, Micro-EP
    - High pressure water rinsing
- **Inspection/Tests:**
  - **Optical Inspection (warm)**
  - **Thermometry (cold)**



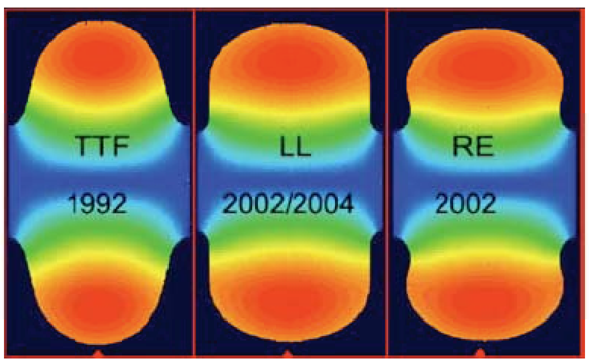


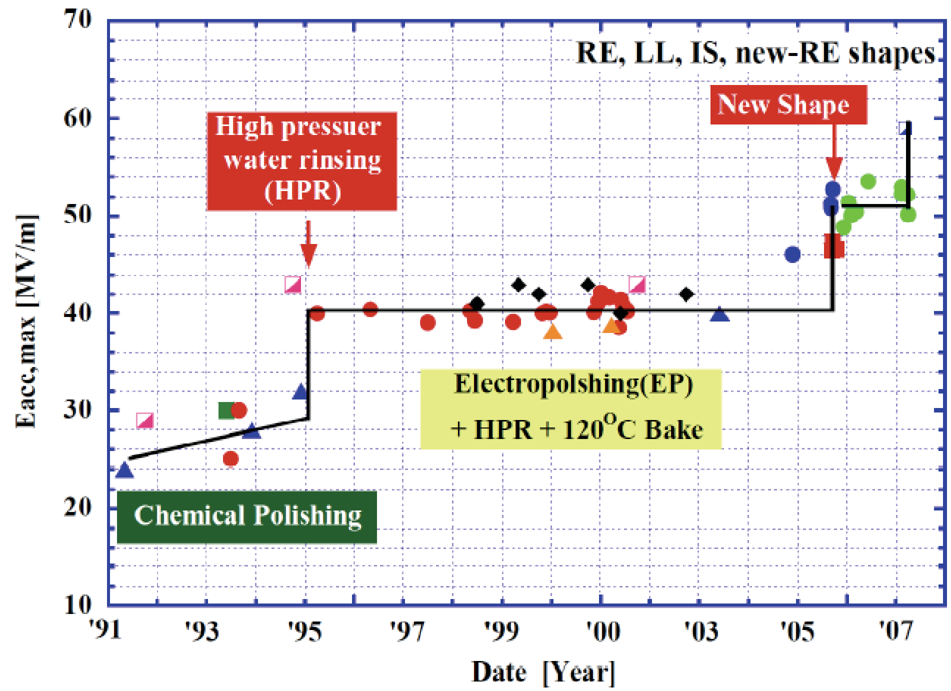


Progress in Single Cell Cavity

TABLE II. Cavity Shapes Studied for the ILC.

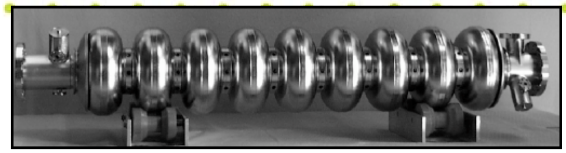
Parameter	TESLA	LL/IS	RE
Iris aperture (mm)	70	60/61	66
E_{peak}/E_{acc}	1.98	2.36/2.02	2.21
B_{peak}/E_{acc} (mT/(MV/m))	4.15	3.61/3.56	3.76
Char. shunt impedance: R/Q (Ω)	114	134/138	127
Geometric factor: G (Ω)	271	284/285	277
$G \times R/Q$ ($\Omega \times \Omega \times 10^5$)	3.08	3.80/3.93	3.51





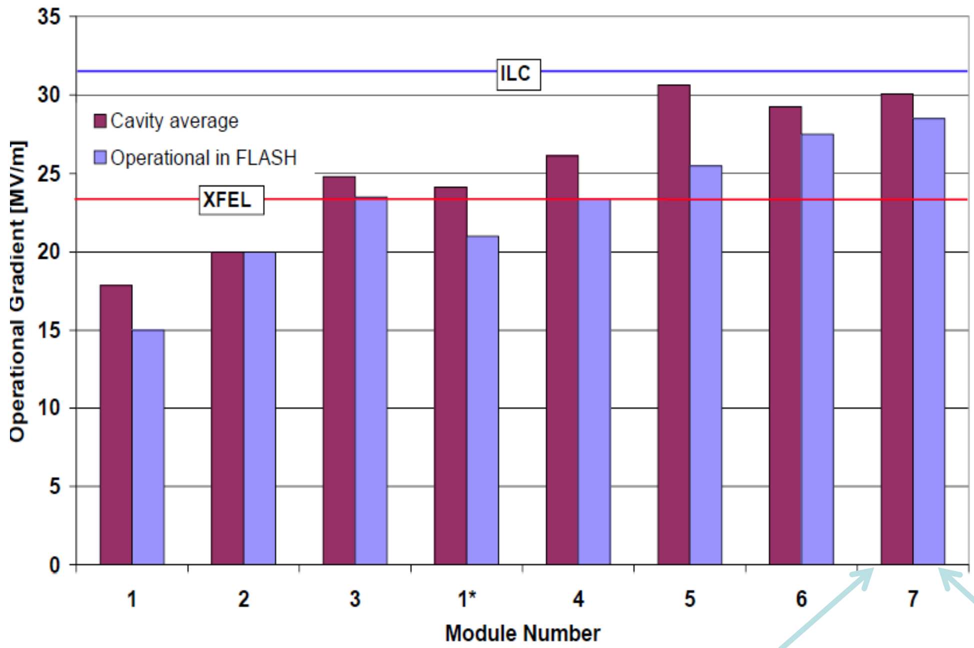
- Record of **59 MV/m** achieved with the RE cavity with EP, BCP and pure-water rinsing with collaboration of Cornell and KEK

Status of 9-Cell Cavity



- **Europe**
  - "Gradient" (<31.5> MV/m) with Ethanol rinse (DESY):
  - Industrial (bulk) EP demonstrated (<36> MV/m) (DESY)
  - Large-grain cavity (DESY)
  - Surface process with baking in Ar-gas (Saclay)
- **America(s)**
  - Gradient distributed (20 – 40 MV/m) with various surface process (Cornell, JLab, Fermilab)
  - Field emission reduced with Ultrasonic Degreasing using Detergent, and "Gradient" improved (JLab)
- **Asia**
  - "Gradient", 36MV/m (LL, KEK-JLab), 32 MV/m (TESLA-like, KEK)
  - Effort in Chinese laboratories in cooperation with KEK, Fermilab, Jlab, and DESY
  - Effort in Indian laboratories in cooperation with Fermilab, KEK

Field Gradient progressed at TESLA

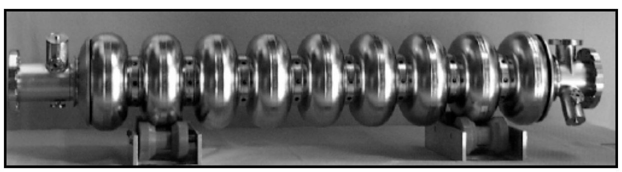


ILC operation :

- <31.5> MV/m

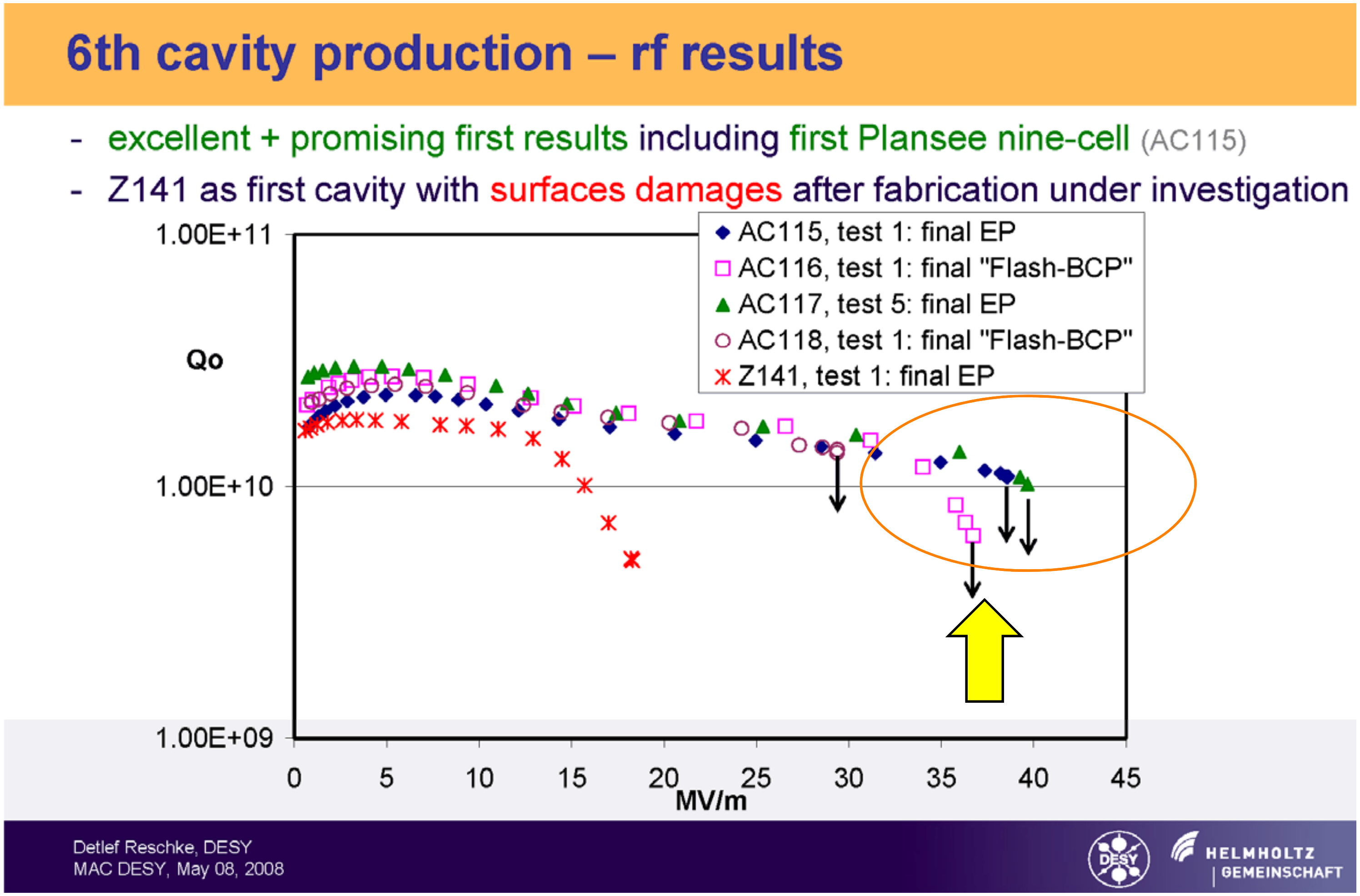
R&D Status :

- ~ 30 MV/m to meet XFEL requirement



•20 % improvement required for ILC

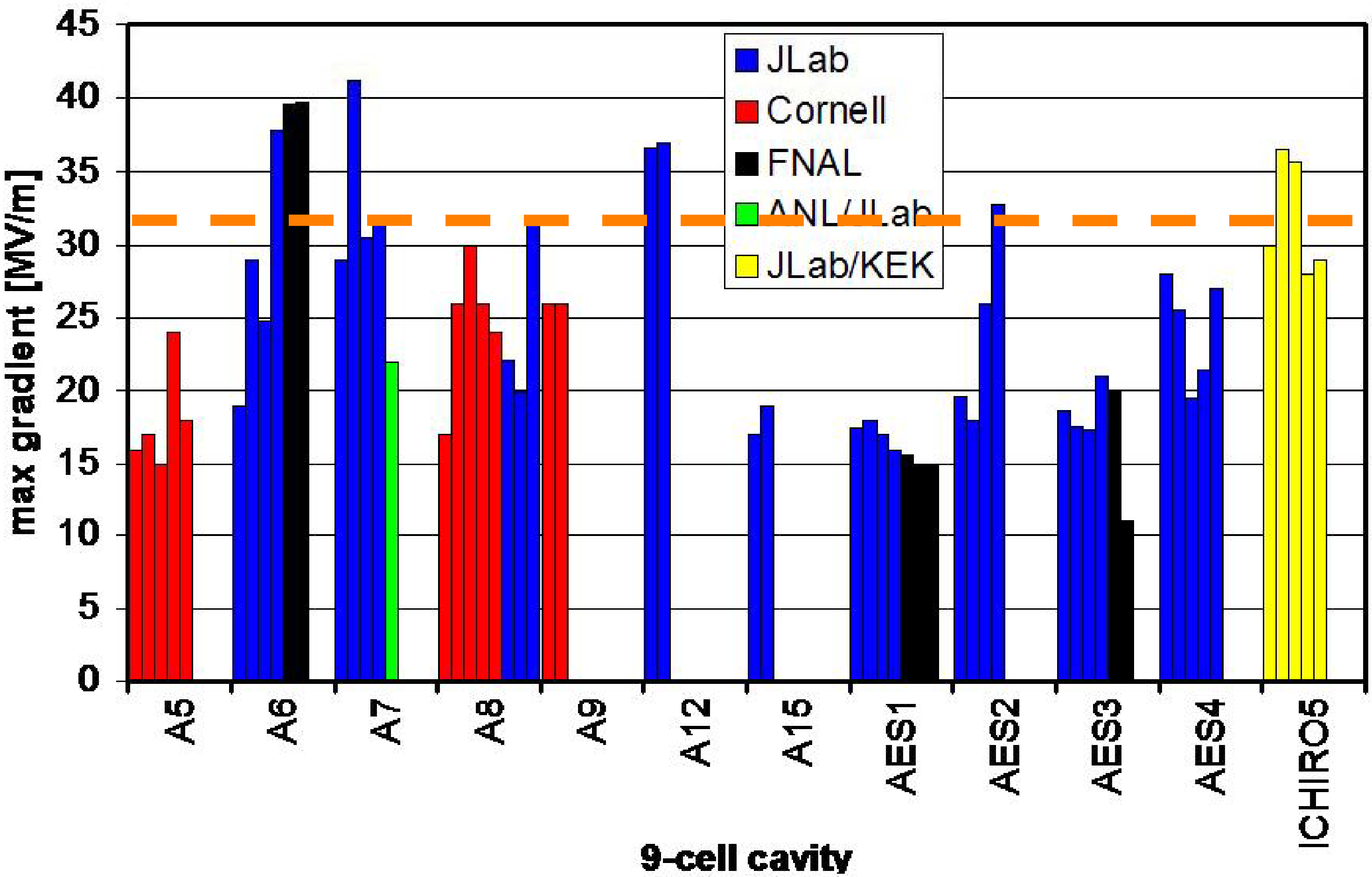
Industrial EP at DESY/Plansee



- The average gradient, **36 MV/m, achieved** with AC115-118

Progress in American Laboratories

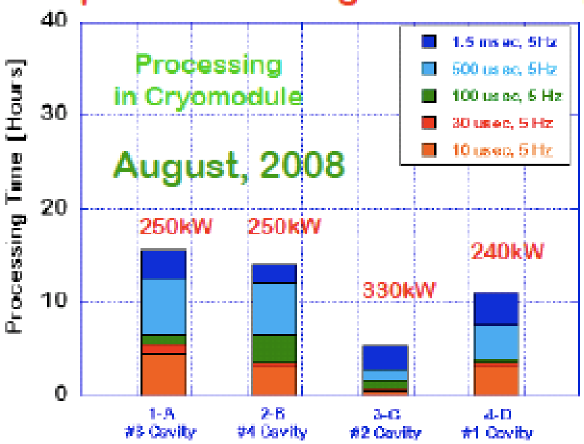
with Japanese contribution for ICHIRO-5



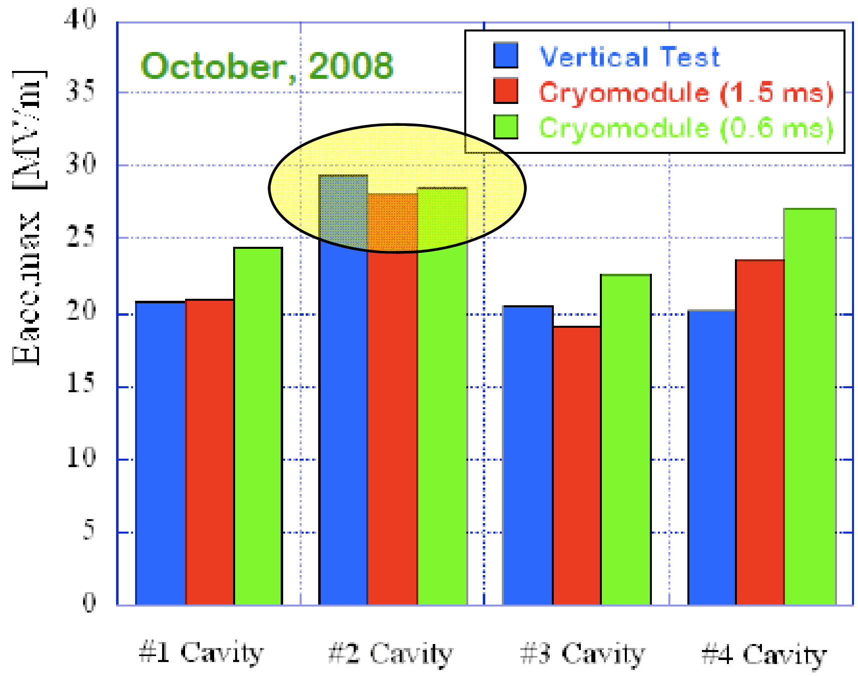
A (Accell), AES: TESLA shape, ICHITO: LL shape

Progress at KEK

Coupler Processing at room temp.



Comparison of achieved Eacc,max
Vertical tests and Cryomodule tests



Ave. Eacc,max (V.T) = 22.7 MV/m

Ave. Eacc,max (Cryo.) = 23.0 MV/m

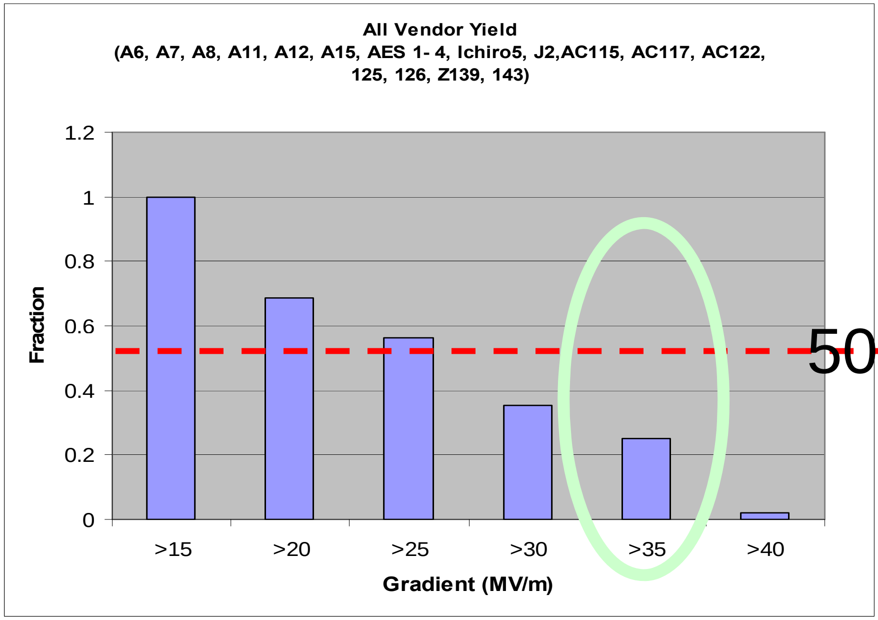
SCRF Activities in Asia

- **Participation in STF at KEK**
  - Cryomodule and coupler design (IHEP)
  - 9-cell cavity fabrication (PAL)
  - LL single cell (IHEP)
  - Cavity design/processing (PNU/KNU)
  - Joining STF operation (RRCAT)
- **China**
  - Cavity fabrication (Deep drawing, EBW, CB) (IHEP,PKU.)
  - Large grain cavity (Ningxia, PKU)
- **Korea**
  - Works other than SCRF (RTML design, cavity BPM, DR)
- **India**
  - Nb material investigation
  - Cavity fabrication in cooperation **with FNAL**
  - Cavity process in cooperation **with KEK**

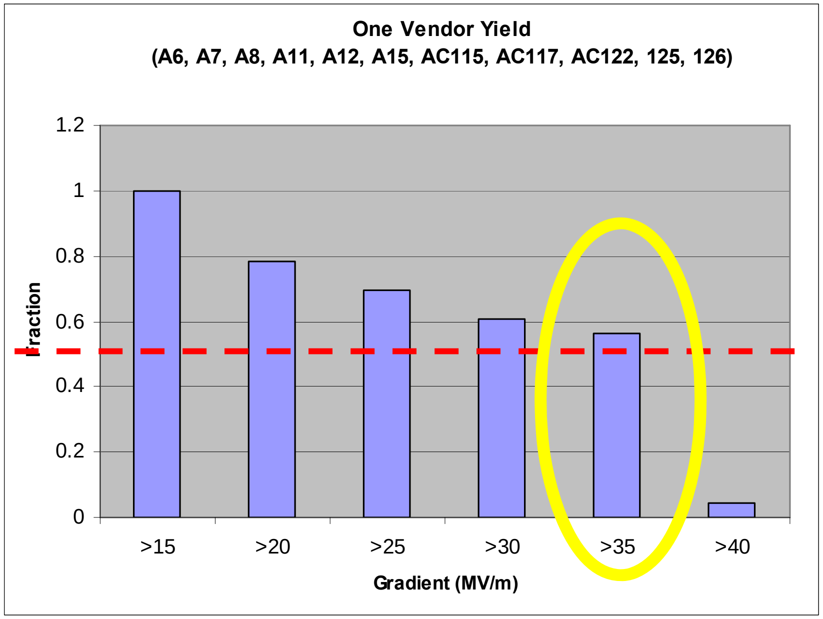
Combined Yield of Jlab and DESY Tests Reported at TTC (Delhi, Oct. 2008),

summarized by H. Padamsee

48 Tests, 19 cavities	23 tests, 11 cavities
ACCEL, AES, Zanon, Ichiro, Jlab	One Vender



50%



Yield 50 % at 35 MV/m being achieved by cavities with a qualified vender !!

We would thank Technical Guidance given by TTC

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Plan for High Gradient R&D

1: **Research**/**find cause** of gradient limit

high resolution camera

surface analysis

2: **develop countermeasures**

remove beads & pits,

establish surface process

3: **verify and integrate** countermeasures

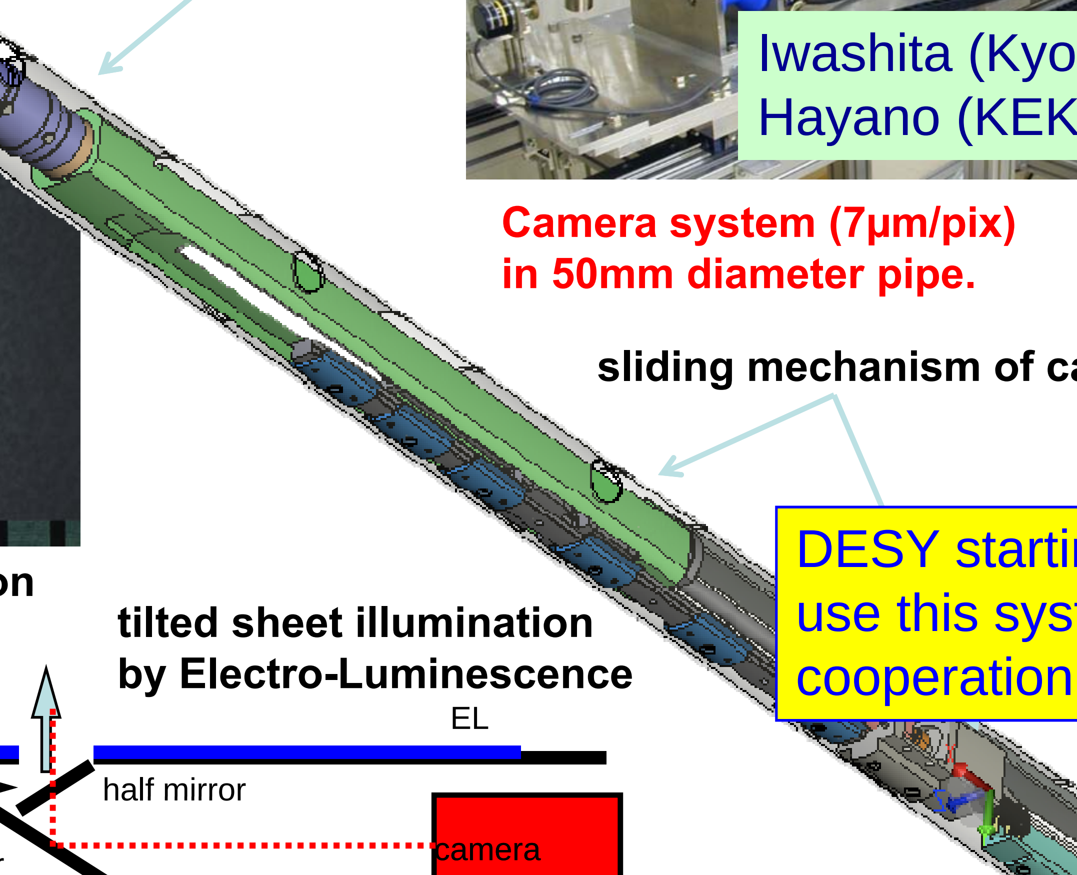
get **statistics**

A New High Resolution, Optical Inspection

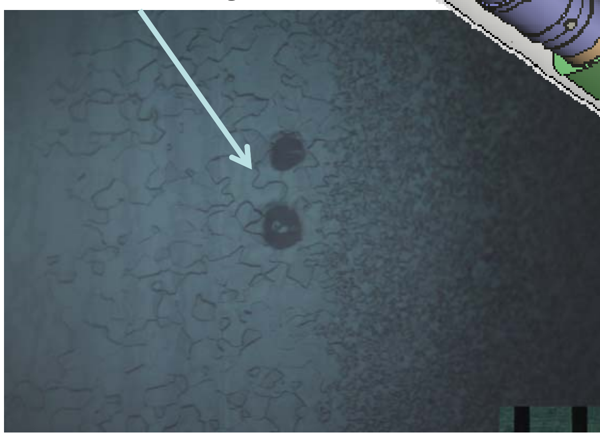
For visual inspection of cavity inner surface.

motor & gear for mirror

camera & lens



~600μm beads on Nb cavity



Iwashita (Kyoto) and Hayano (KEK) et al.

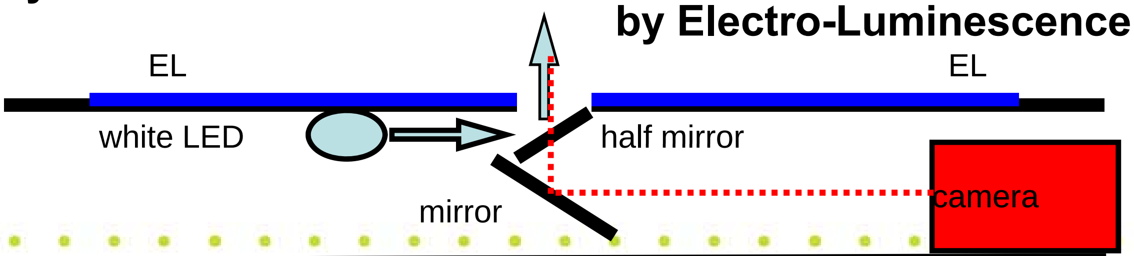
Camera system (7μm/pix) in 50mm diameter pipe.

sliding mechanism of camera

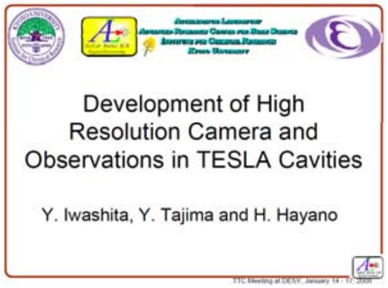
DESY starting to use this system in cooperation with KEK

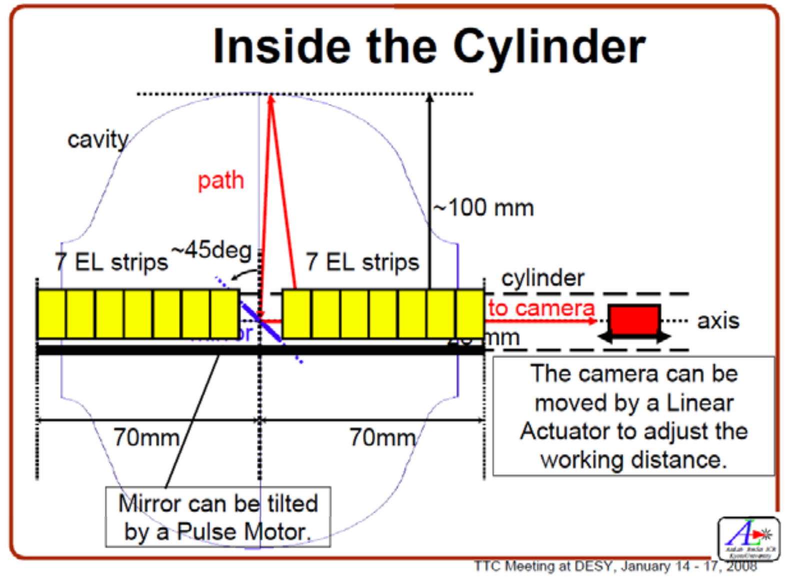
perpendicular illumination by LED & half mirror

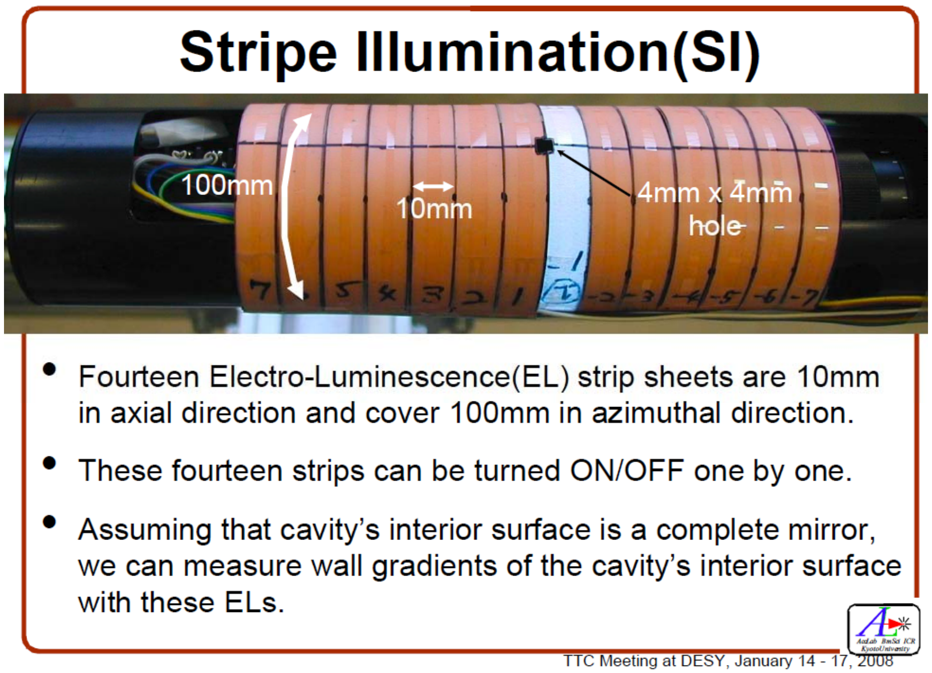
tilted sheet illumination by Electro-Luminescence

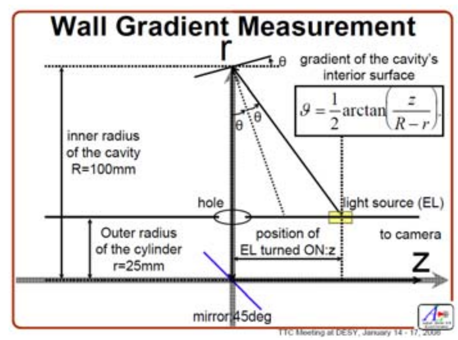


Progress in Profile Measurement

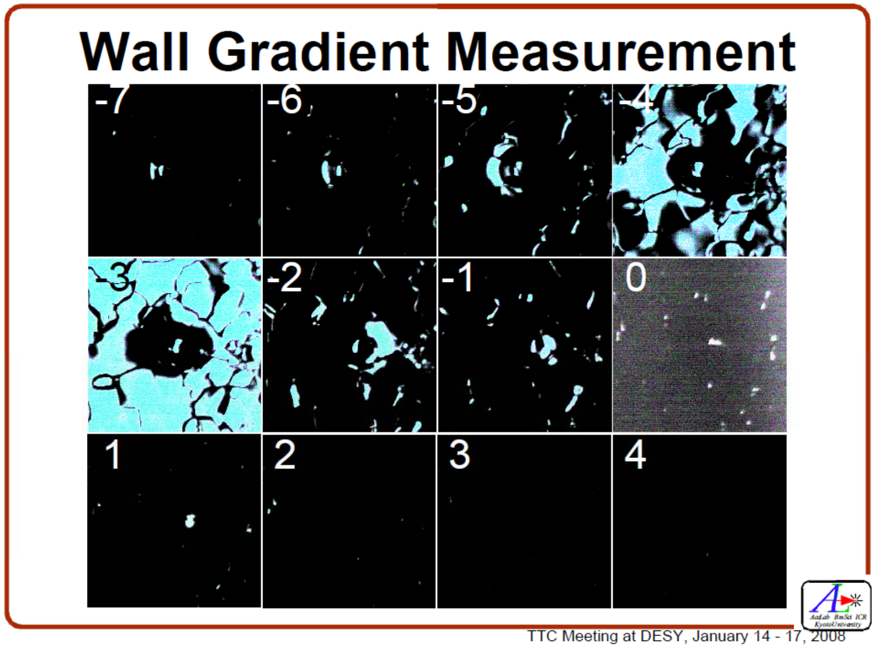




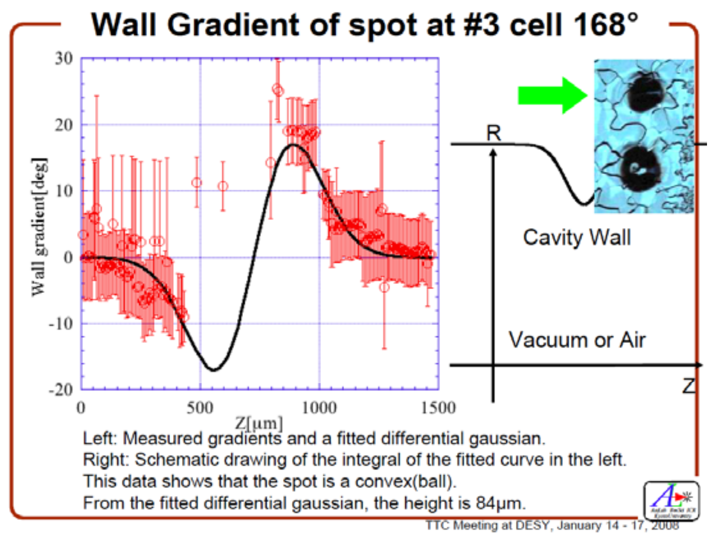




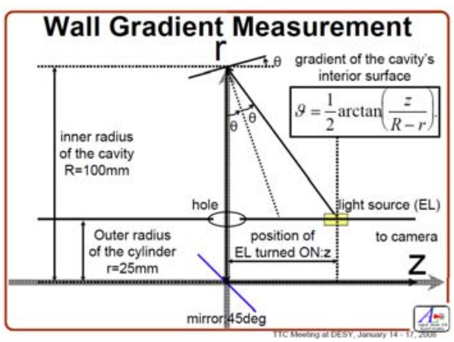
Examples



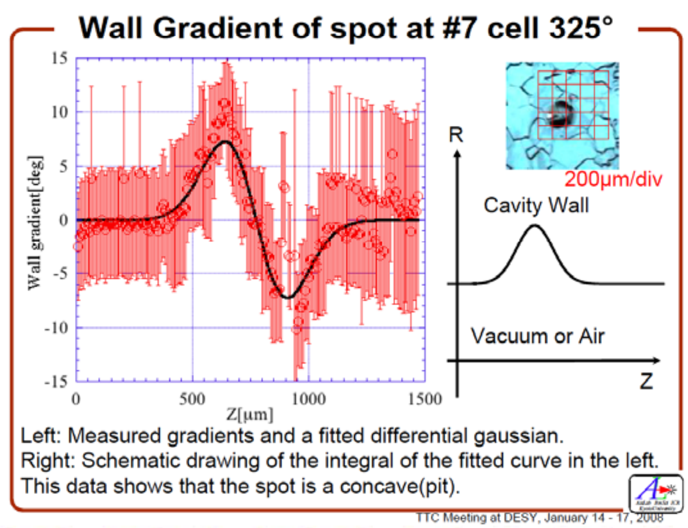
Wall Gradient Measurement
-7
-6
-5
-4
-3
-2
-1
0
1
2
3
4
TTC Meeting at DESY, January 14 - 17, 2008



Wall Gradient of spot at #3 cell 168°
Wall gradient[deg]
Z[μm]
R
Cavity Wall
Vacuum or Air
Z
Left: Measured gradients and a fitted differential gaussian.
Right: Schematic drawing of the integral of the fitted curve in the left.
This data shows that the spot is a convex(ball).
From the fitted differential gaussian, the height is 84μm.
TTC Meeting at DESY, January 14 - 17, 2008



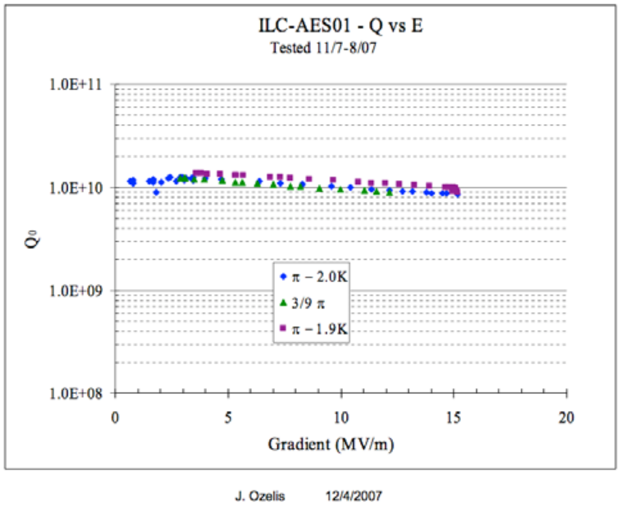
Wall Gradient Measurement
r
gradient of the cavity's interior surface
$\vartheta = \frac{1}{2}\arctan\left(\frac{z}{R-r}\right)$
inner radius of the cavity R=100mm
hole
light source (EL)
Outer radius of the cylinder r=25mm
position of EL turned ON:z
to camera
Z
mirror 45deg

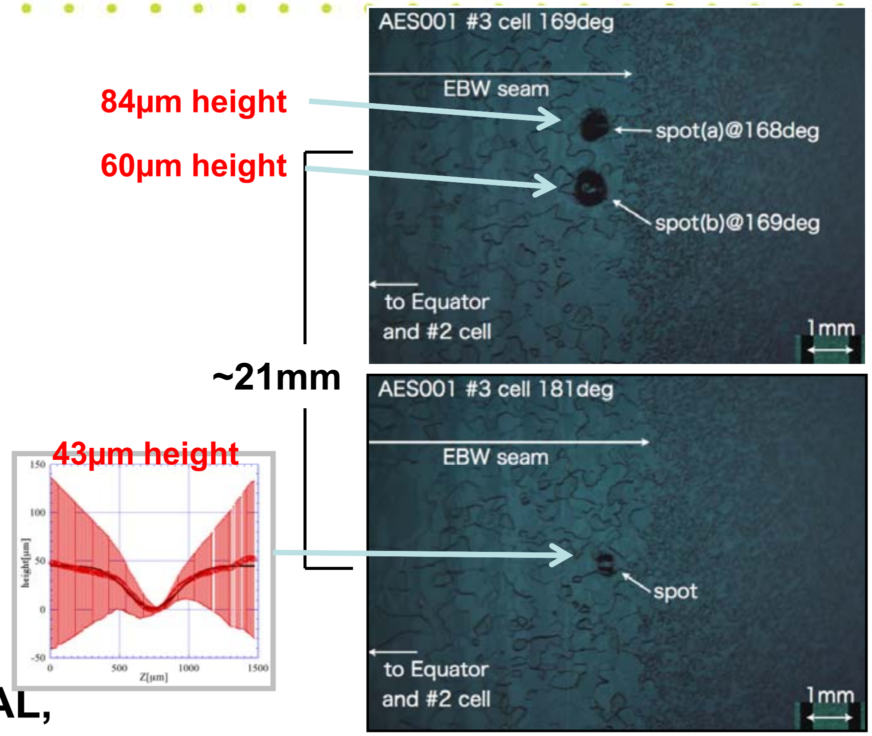


Wall Gradient of spot at #7 cell 325°
Wall gradient[deg]
Z[μm]
R
200μm/div
Cavity Wall
Vacuum or Air
Z
Left: Measured gradients and a fitted differential gaussian.
Right: Schematic drawing of the integral of the fitted curve in the left.
This data shows that the spot is a concave(pit).
TTC Meeting at DESY, January 14 - 17, 2008

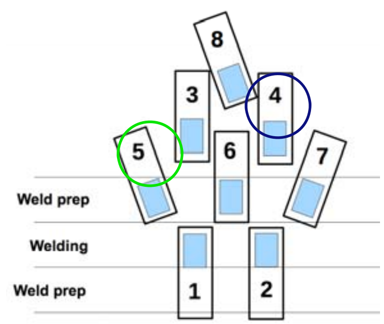
Consistent with Thermal Measurement at FNAL

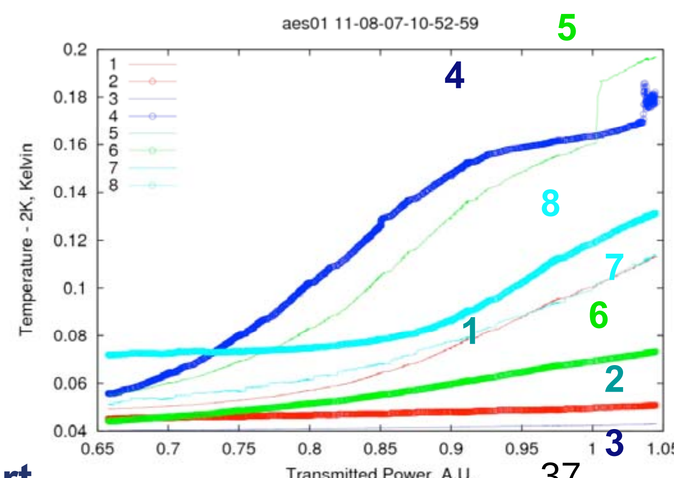
3rd Test Results





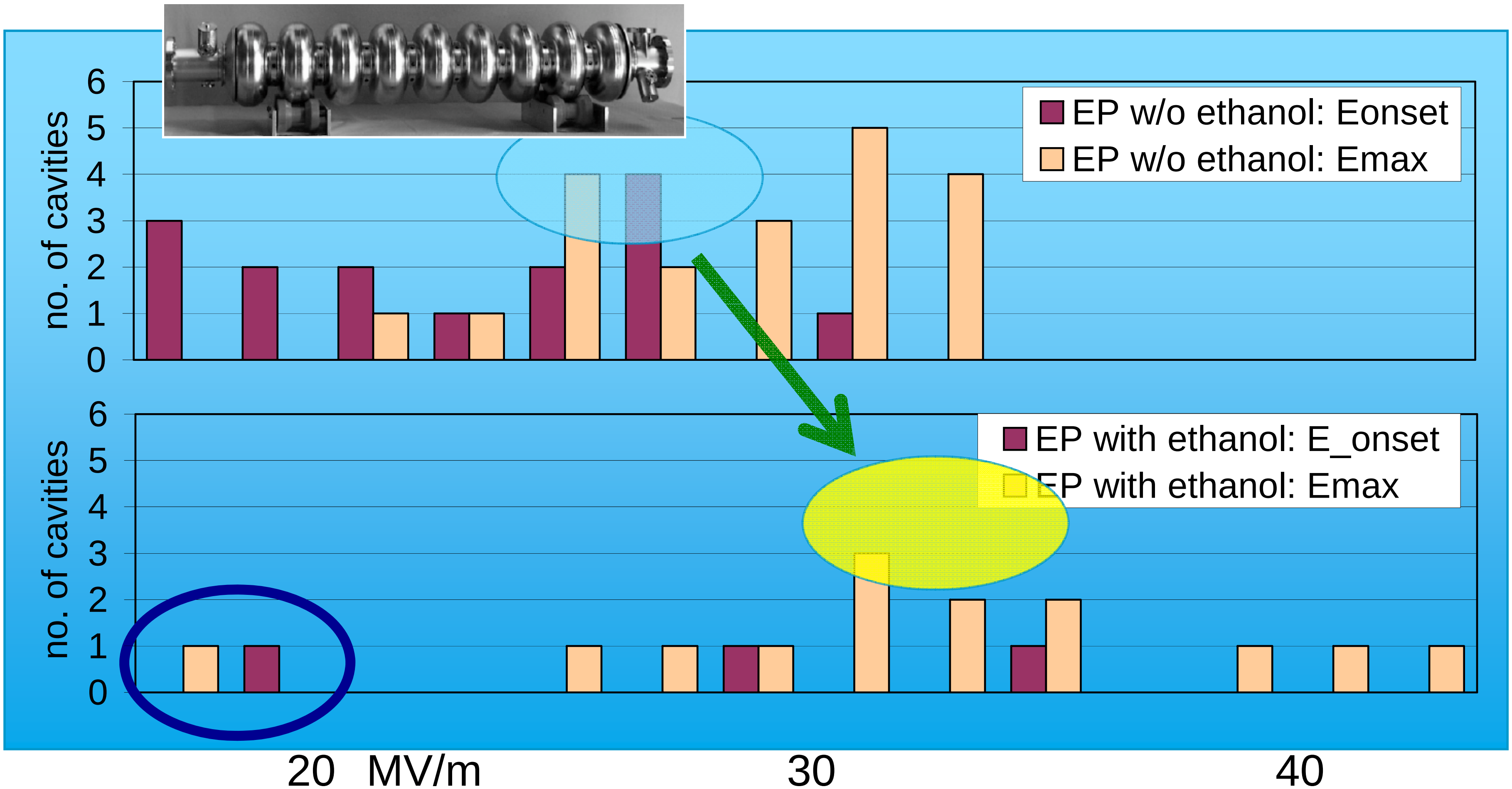
AES01 has hard quench at 15MV/m,
its location was identified by Cernox at FNAL,
(M. Champion et al., This conference)





Kyoto camera found 3 spots in their exact location

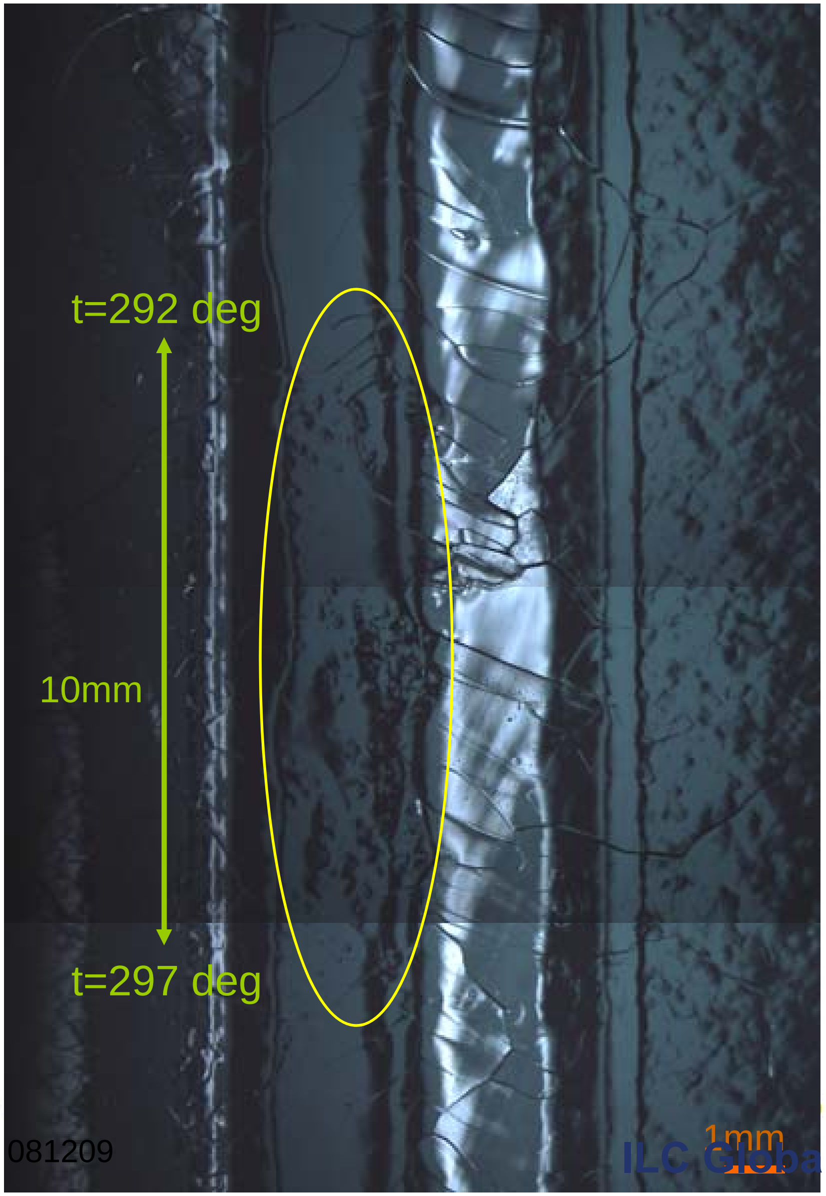
DESY: Field Emission Analysis



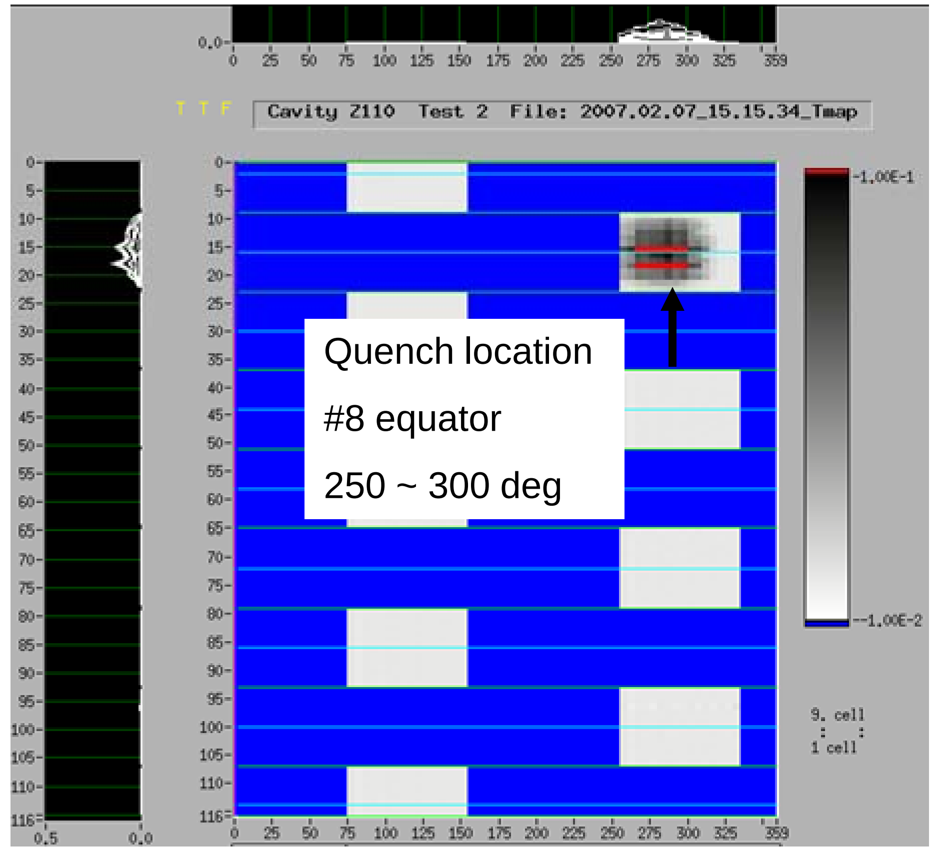
Cavity gradient shifted to High Gradient by ‘ethanol rinse’, except for “lowest two” (due to different reasons)

TESLA cavity Z110: #8 cell equator

#8 equator, t=288 ~ 299 deg



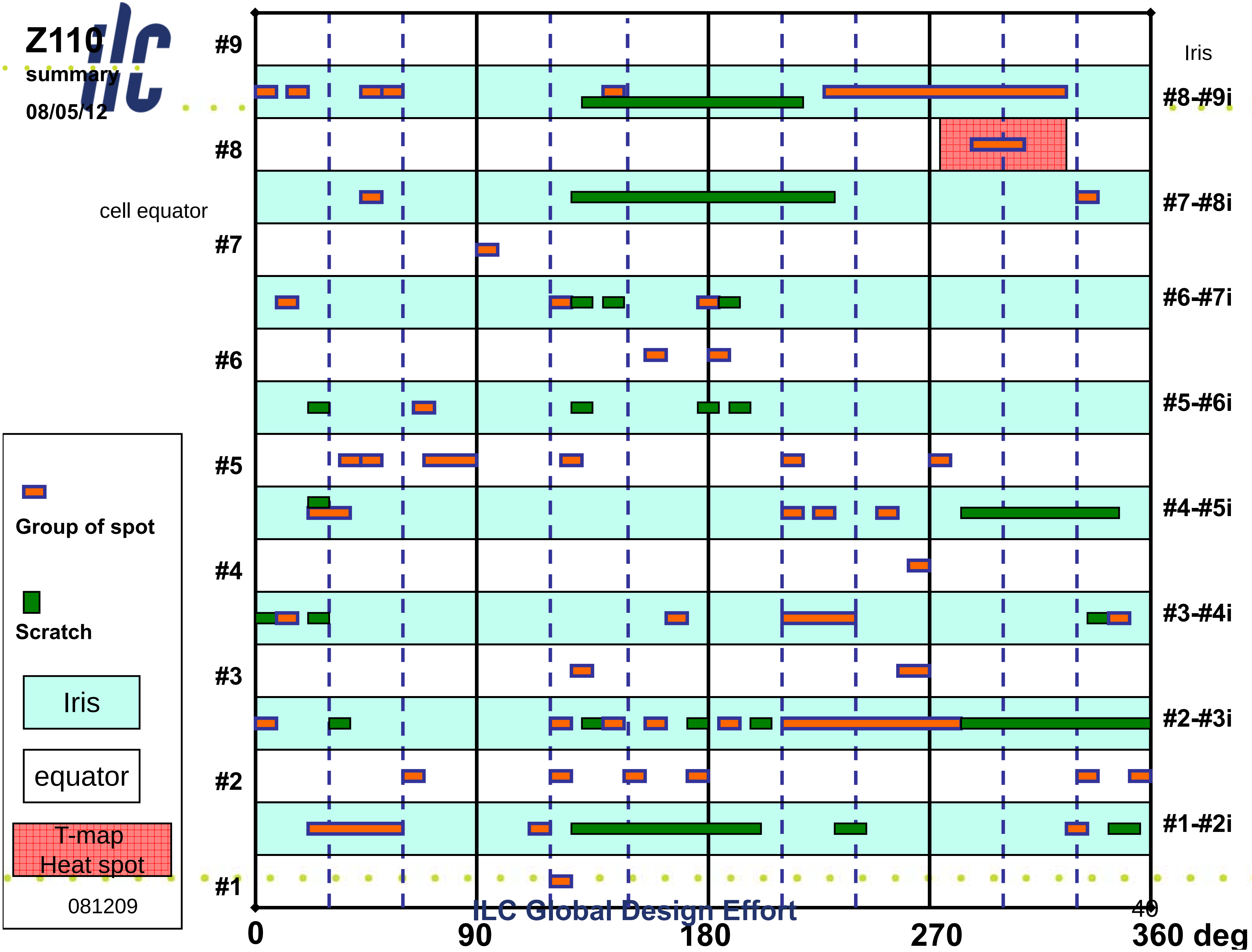
T-map data in test 2, 14.2 MV/m



group of beads(?) with 10mm wide were observed.
Similar beads group were also observed in several places. see following slides.

Z110 summary

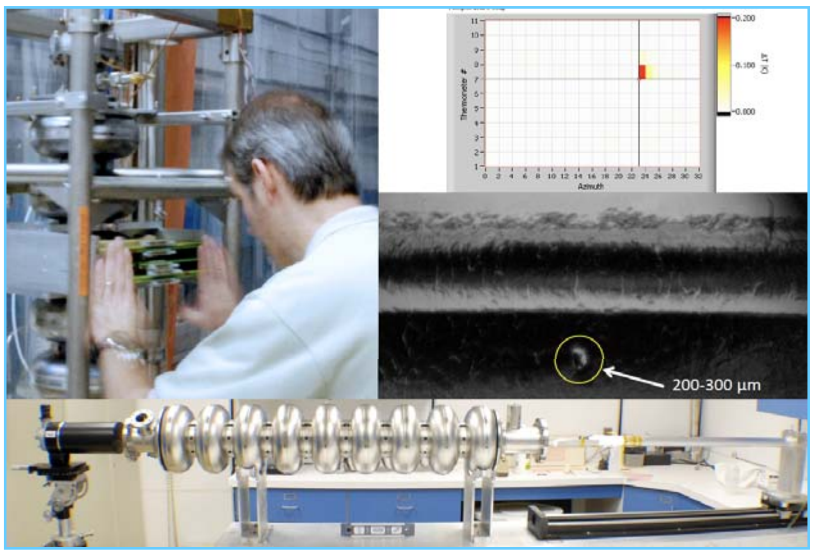
08/05/12

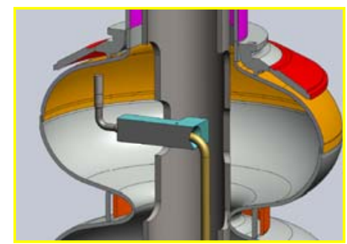


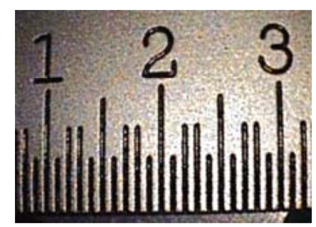
Efforts at JLab and LANL

- Jlab
  - **Thermometry and tele-scope**

- LANL
  - Thermometry and videoscope





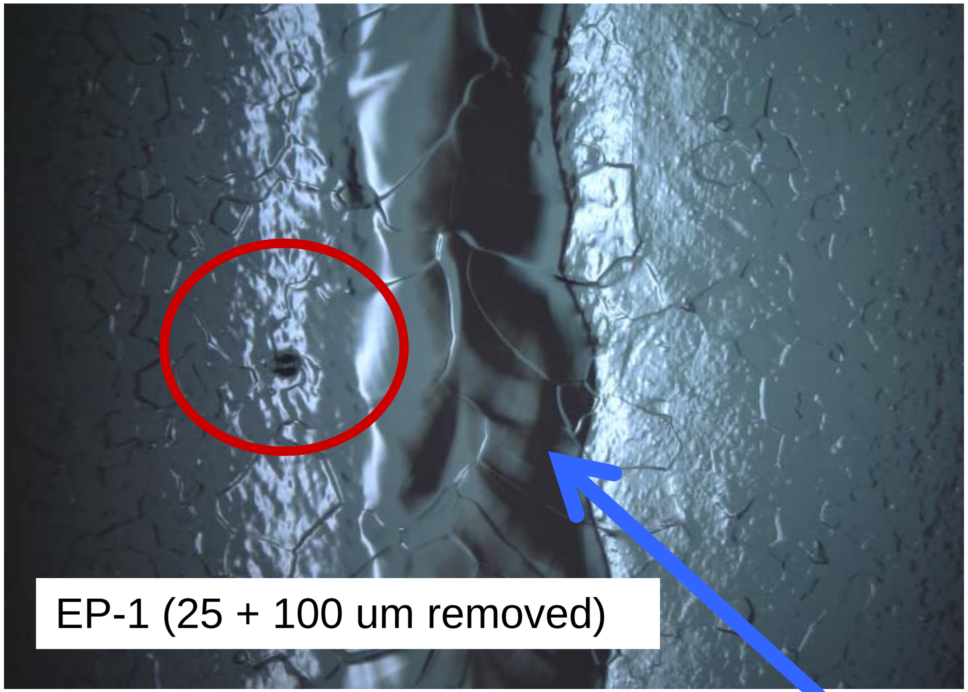


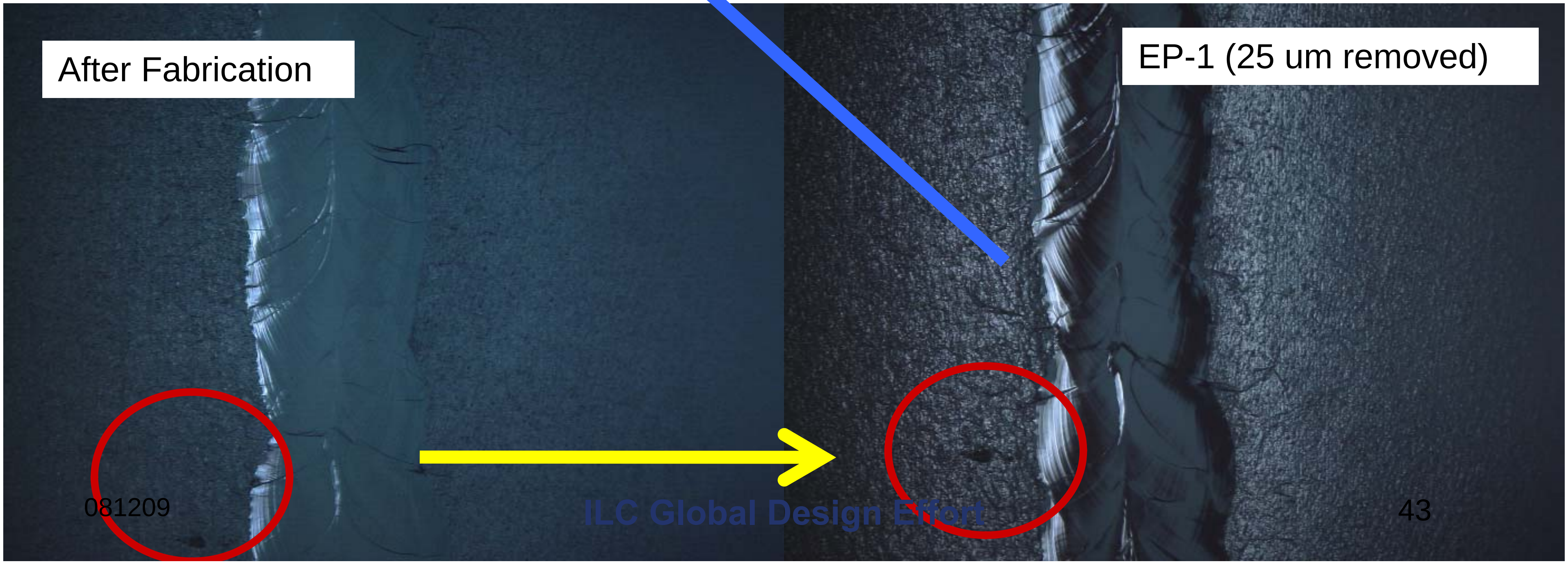
Scale seen by the videoscope

Guideline: Standard Procedure and Feedback Loop

	Standard Fabrication/Process	(Optional action)	Acceptance Test/Inspection
Fabrication	Nb-sheet purchasing		Chemical component analysis
	Component (Shape) Fabrication		Optical inspect., Eddy current
	Cavity assembly with EBW	(tumbling	Optical inspection
Process	EP-1 (Bulk: ~150um)		
	Ultrasonic degreasing (detergent) or ethanol rinse		
	High-pressure pure-water rinsing		Optical inspection
	Hydrogen degassing at 600 C (?)	750 C	
	Field flatness tuning		
	EP-2 (~20um)		
	Ultrasonic degreasing or ethanol	(Flash/Fresh EP) (~5um))	
	High-pressure pure-water rinsing		
	General assembly		
	Baking at 120 C		
Cold Test (vertical test)	Performance Test with temperature and mode measurement	Temp. mapping	If cavity not meet specification Optical inspection

Comparison with each treatment

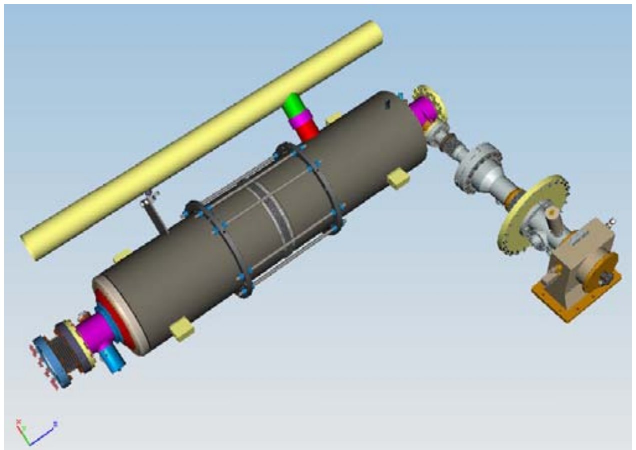


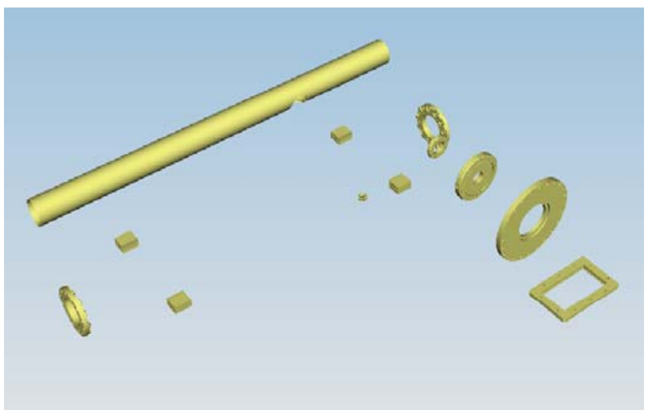


Cavity Integration and Tests

- **Europe (EU)**
  - **Cryomodule assembly plan for XFEL (DESY/INFN/CEA-Saclay)□□□**
  - **Input-coupler industrial assessment for XFEL (LAL-Orsay)**
  - **Cryomodule design for S1-global (INFN/KEK)**
  - **TTF- 9 mA Test**
- **America(s) (AMs)**
  - **Cryomodule design**
  - **Cryogenic engineering (FNAL in cooperation with CERN)**
  - **SCRF Test Facility (FNAL)**
- **Asia (AS)**
  - **Cryomodule engineering design (KEK/INFN, KEK/IHEP)**
  - **Superconducting test facility (KEK)**
- **Global effort for Cavity/Cryomodule Assembly**
  - **Plug-compatible integration and test :**

Plug-compatible Conditions



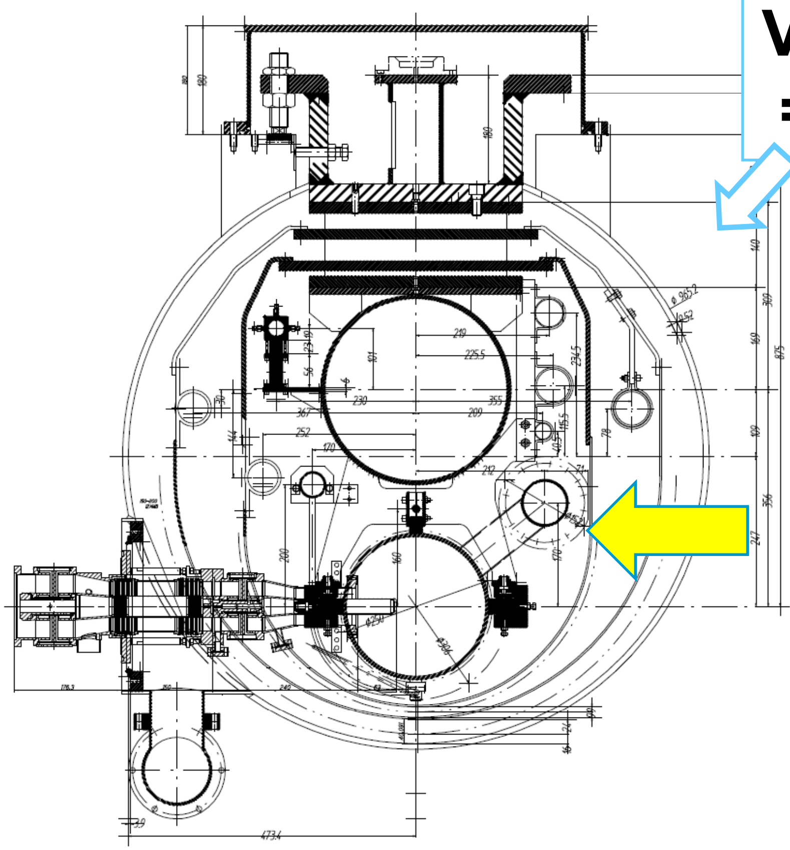


Item	Can be flexible	Plug-comp.
Cavity shape	TeSLA/LL/ RE	
Length		Fixed
Beam pipe flange		Fixed
Suspension pitch		Fixed
Tuner	Blade/Jack	
Coupler flange (warm end)		Fixed
Coupler pitch		fixed
He –in-line joint		TBD

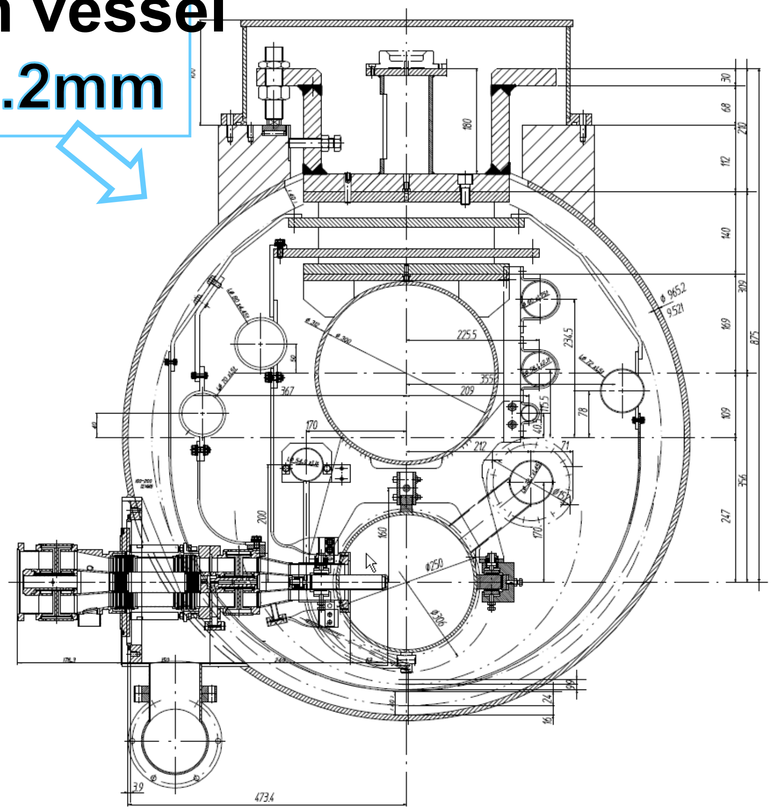
Plug-compatible interface nearly established

Study of the “plug-compatible” cryomodule cross-section

Vacuum vessel = ϕ 965.2mm



Two shields model based on TTF-III

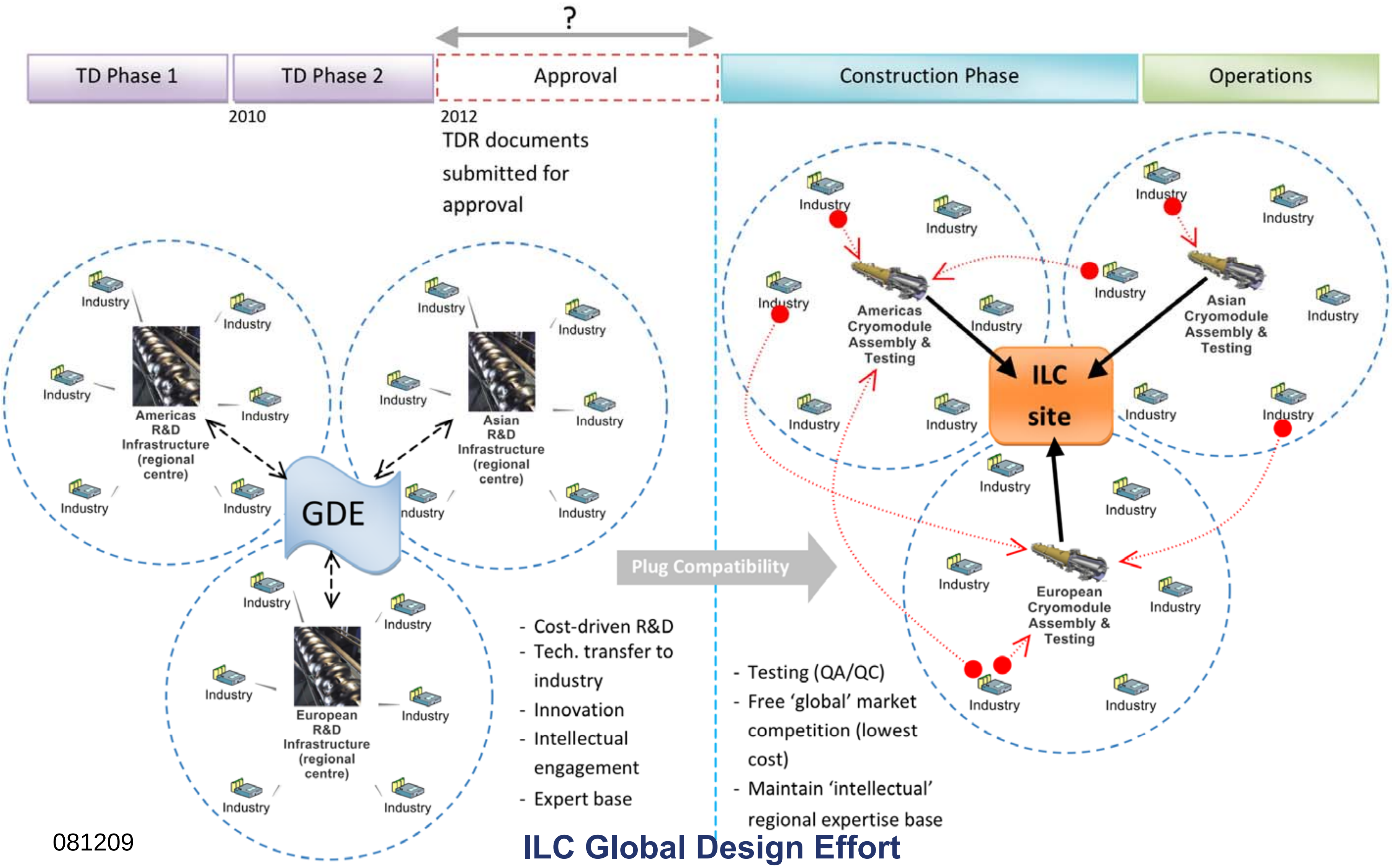


One shield model to save fabrication cost

Why and How Plug-compatibility ?

- **Cavity**
  - Necessary "extended research" to improve field gradient,
  - Keep "room" to improve field gradient,
  - Establish common interface conditions,
- **Cryomodule**
  - Nearly ready for "system engineering"
  - Establish unified interface conditions,
  - Intend nearly unified engineering design
  - Need to adapt to each regional feature and industrial constraint

Global Cooperation with Plug-compatible Design and R&Ds

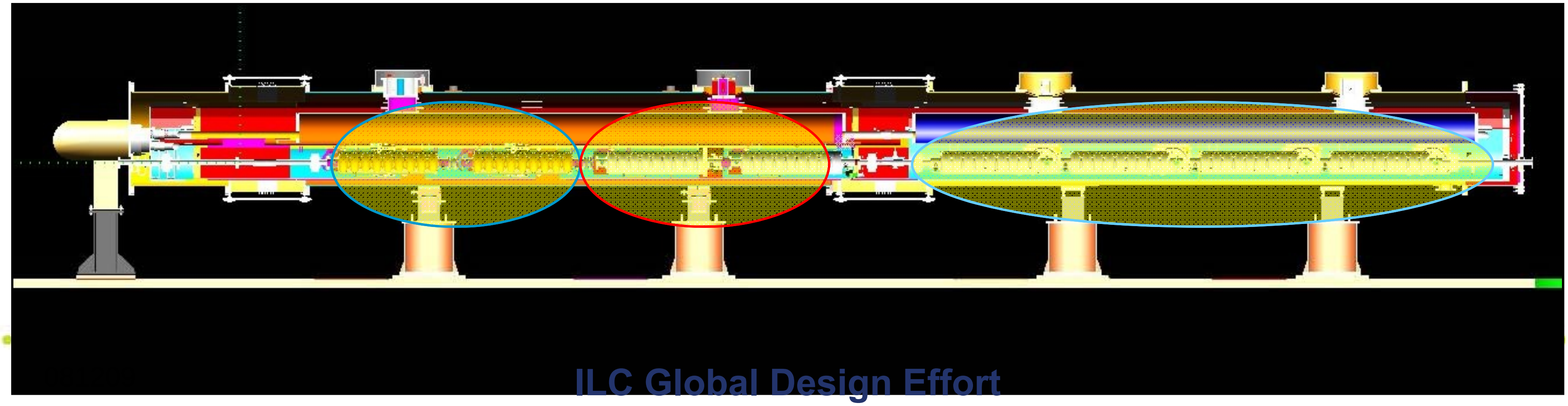


Plug-compatibility in
R&D and Construction Phases

- **R&D Phase**
  - Creative work for further improvement with keeping replaceable condition,
  - Global cooperation and share for intellectual engagement
- **Construction Phase**
  - Keep competition with free market/multiple-suppliers, and effort for const-reduction, (with insurance)
  - Maintain “intellectual” regional expertise base
  - Encourage regional centers for fabrication/test facilities with accepting regional features/constraints

Cavity and Cryomodule Test with Plug Compatibility

- Cavity integration and the String Test to be organized with:
  - 2 cavities from EU (DESY) and AMs (Fermilab)
  - 4 cavities from AS (KEK (and IHEP))
  - Each half-cryomodule from INFN and KEK



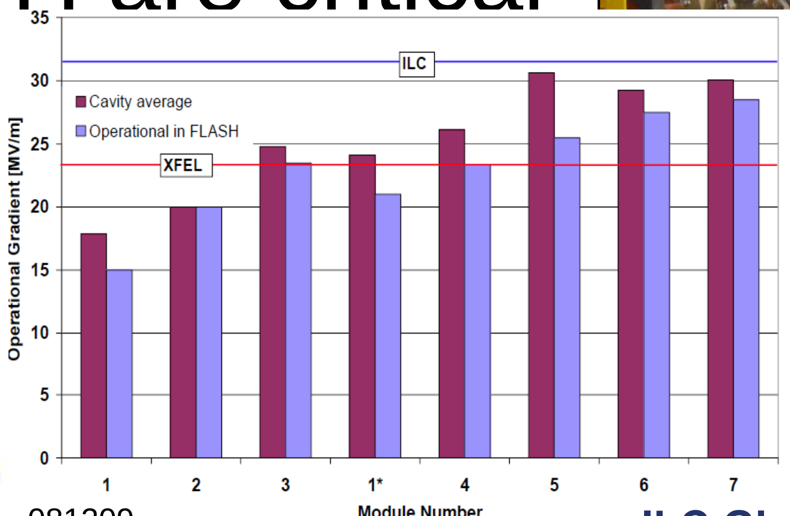
Major Fabrication*/Test Facilities

Regional central facilities to be very important and encouraged:

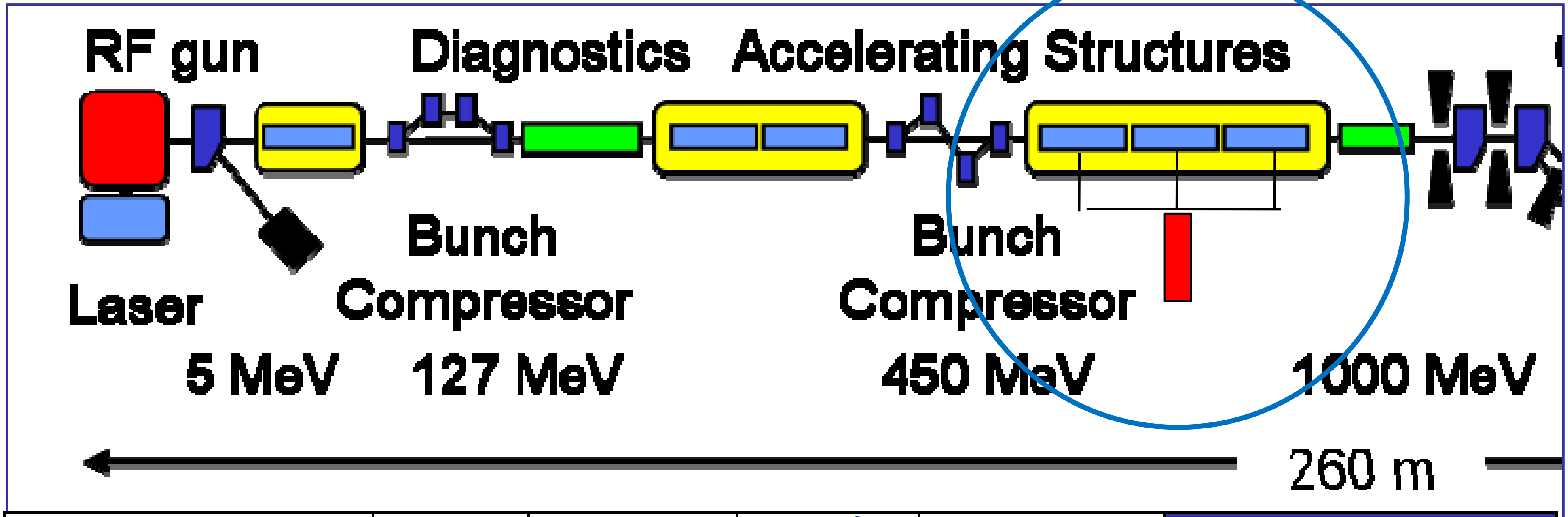
Facilities	Host Lab	Operation start
TTF/FLASH Cryom. Ass.*	DESY CEA/Saclay	1997~, (9mA, 2008~) 2010~
STF	KEK	2007~2008
ILCTA-ML	FNAL	2008~2009

TESLA/FLASH at DESY

Experiences being gained from TELA/FLASH are critical

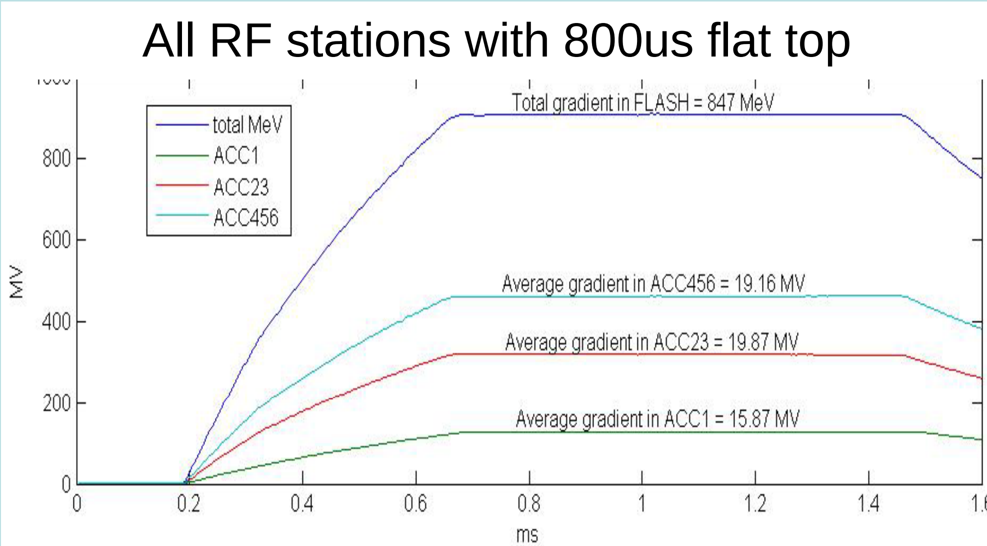


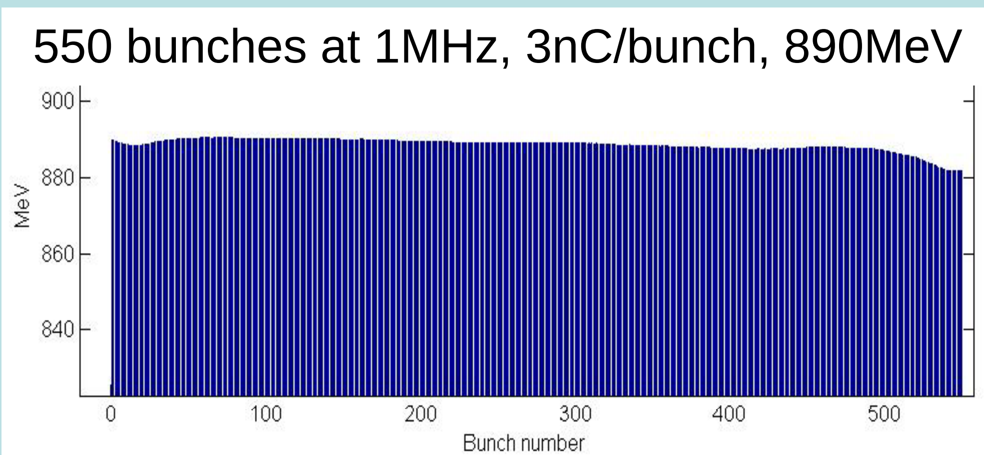
9mA Experiments in TTF/FLASH



		XFEL X-Ray Free-Electron Laser	ILC	FLASH design	FLASH experiment
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

Preliminary Results (2008)





FLASH operations records

- Long bunch trains with 3nC per bunch:
  - **550 bunches at 1MHz**
  - **300 bunches at 500KHz**
  - **890MeV linac energy**
- All modules running with 800us flat-top and 1GeV total gradient

- Limited to 1MHz (3mA) during first (preparatory) experiments
- 6 kW achieved
- 2009 goal: 36 kW (9mA)

First nine-cell electro-polishing performed at ANL, May, 2008

Fermilab/ANL Collaboration

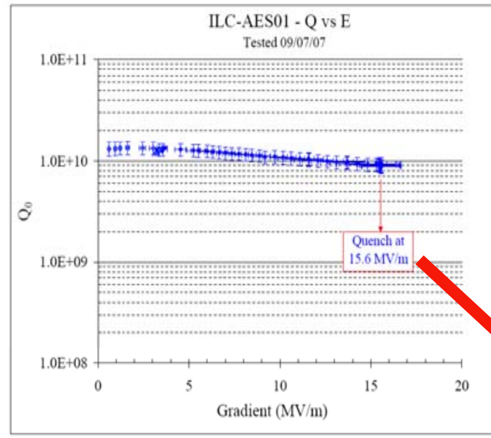
- ACCEL cavity A7 electro-polished at ANL, and
- Further process and tested at Jlab.


Photos courtesy of Mike Kelly

New Vertical Test @ FNAL

- **Recently commissioned (IB1)**
  - **Existing 125W@ 1.8 K Cryogenic plant**
  - **RF system in collaboration with JLab**
  - **Evolutionary upgrades:**
    - **Thermometry for 9-cells**
    - **Plan for two additional VTS cryostat**

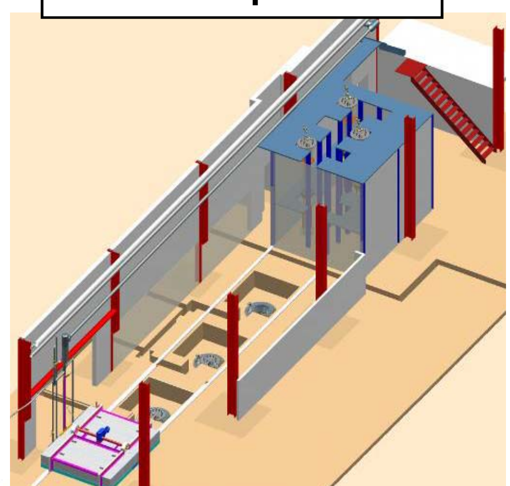
Nine-cell Tesla-style cavity



VTS Cryostat:IB1

New RF & Control Room

Plan for 2 more VTS pits



Assembly Facility at FNAL

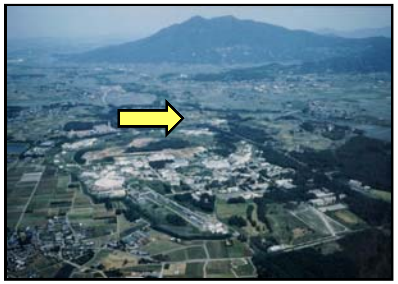
ICB clean: Final Assembly fixtures installed

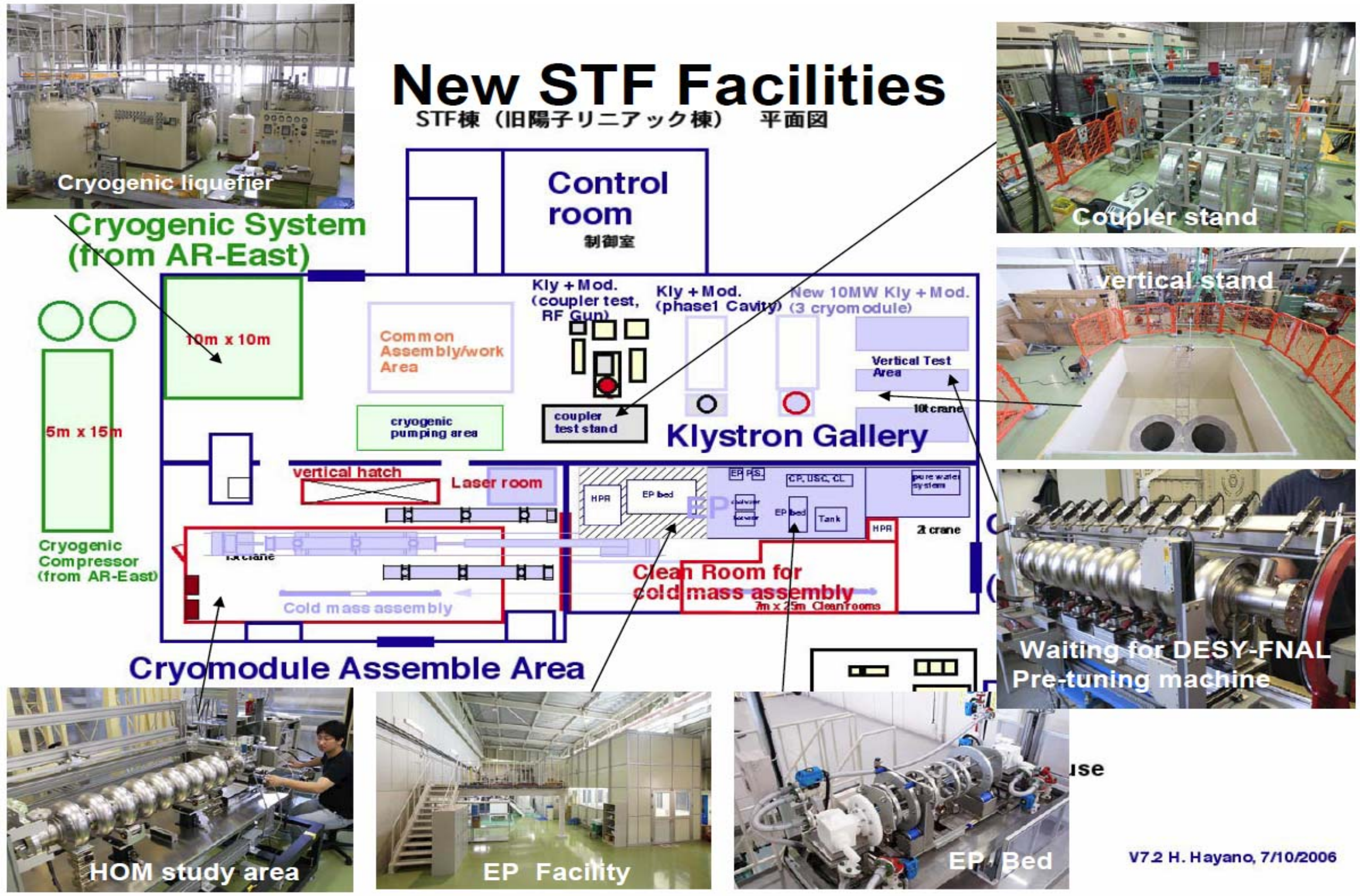
MP9 Clean Room

String Assembly

Cavity string for 1st CM

SC Test Facility (STF) at KEK





Process at STF

Flange-CP

EP

→

H_2O_2
Hot bath
(Alcohol)
(Degreasing)

Rinsing

HPR

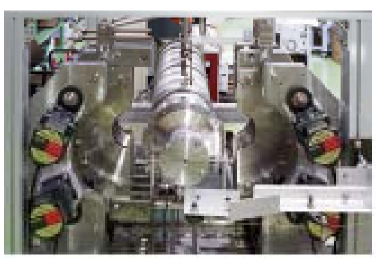
Assembly
(Class 10)

↓

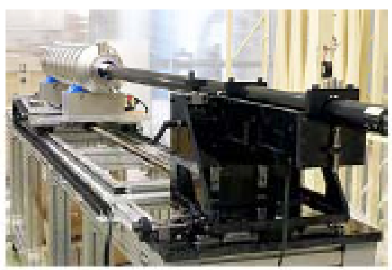
Infrastructure in STF Hall

System check with AES cavity, now.

↑



Pre-tuning
fo adjustment



Inspection of
Inner Surface

Vertical Test

←

Hanging
Stand

Baking
(Class 1000)

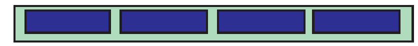
Cavity Sting Assembly with Cryomodule at KEK/STF

String assembly of four cavities and cryomodule assembly were carried out in January ~ March, 2008.

General Plan for SCRF at KEK

STF1

May-Dec. 2008 Cryomodule-A with for 4 base-line cavities: 2K cold test is now continuing.



Jan-Dec. 2009 Cryomodule-B without cavities: Thermal measurement at 2K

S1-Global

May 2008 – Dec.2010 Cryomodule with 8 cavities (FNAL, DESY and KEK cavities, INFN cryostat and STF cryostat)

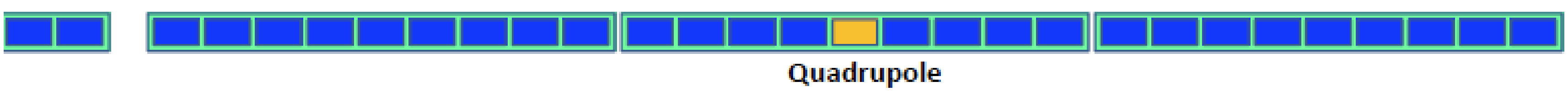
STF-Module A + Module-C

Operation: June-Dec. 2010
Target:31.5MV/m

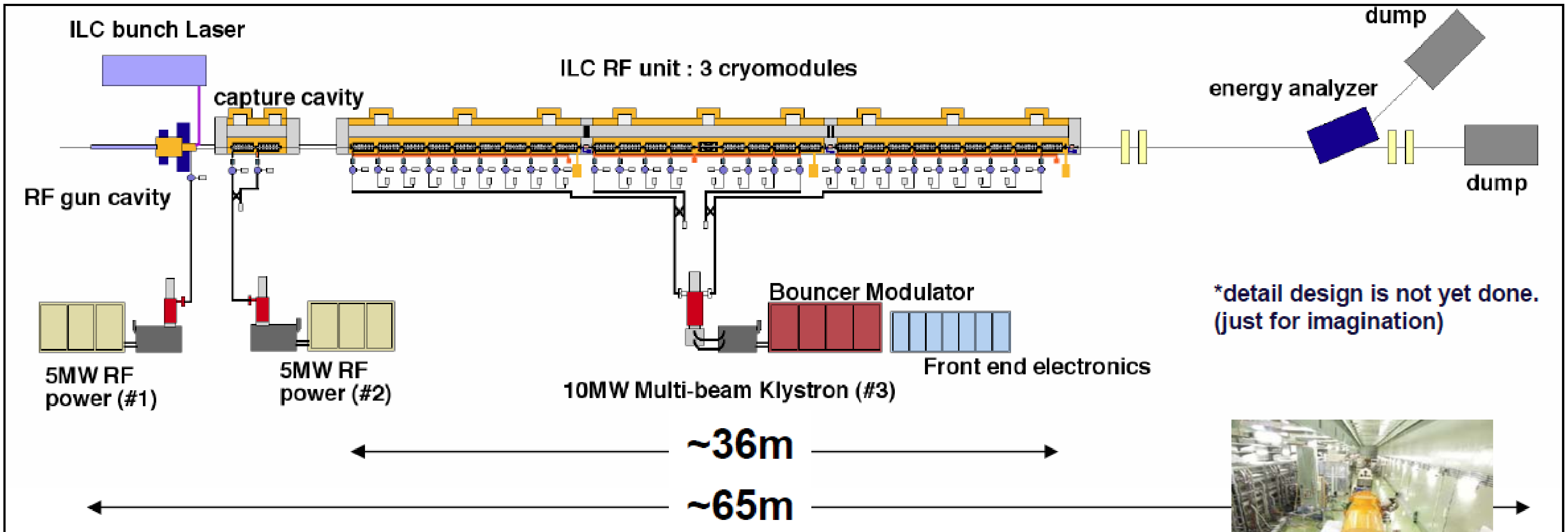
STF2 (ILC 1 RF unit + 1 capture module)

2009-2010 Design work (SC cavity, Cryomodule, Cryogenic system, RF system, etc)

2010- Construction of the components and infrastructure



Beam Acceleration Test Plan with RF unit at KEK

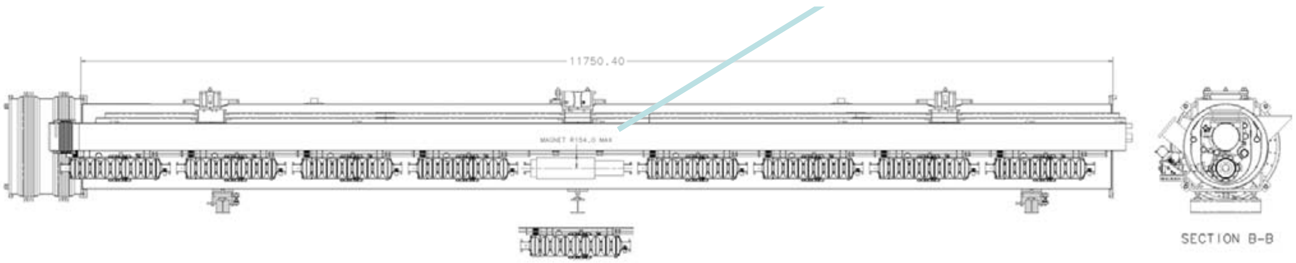


Superconducting Magnets for Beam Focusing and Transport

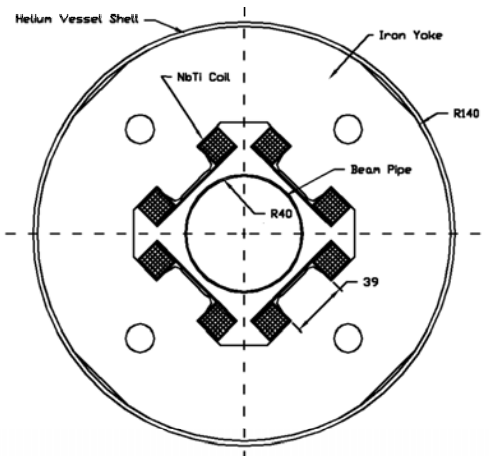
- Components in Cryomodule
  - G-integral : 36 T
    Aperture: 78 mm
  - Alignment: < 100 nm

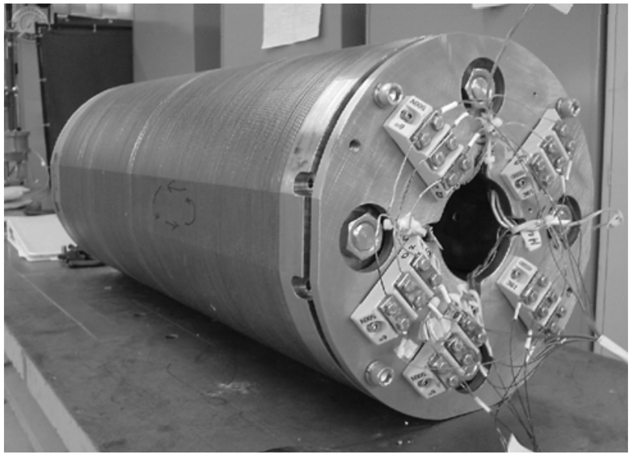
TABLE IV QUADRUPOLE SPECIFICATION.

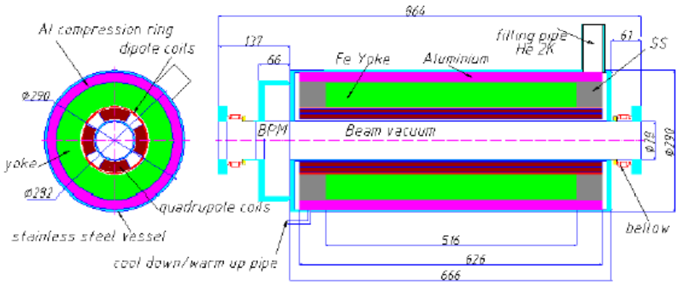
Parameter	Value
Integrated peak gradient	36 T
Aperture	78 mm
Effective length	660 mm
Peak gradient	54 T/m
Field non-linearity at 5 mm radius	0.05 %
Dipole trim coils integrated strength	0.075 T-m
Magnetic center stability	5 μm
Vertical/azimuthal offset in cryomodule	0.3 mm/0.3 mrad
Quantity required	560



Quadrupole R&D Work at Fermilab and SLAC/CIEMAT



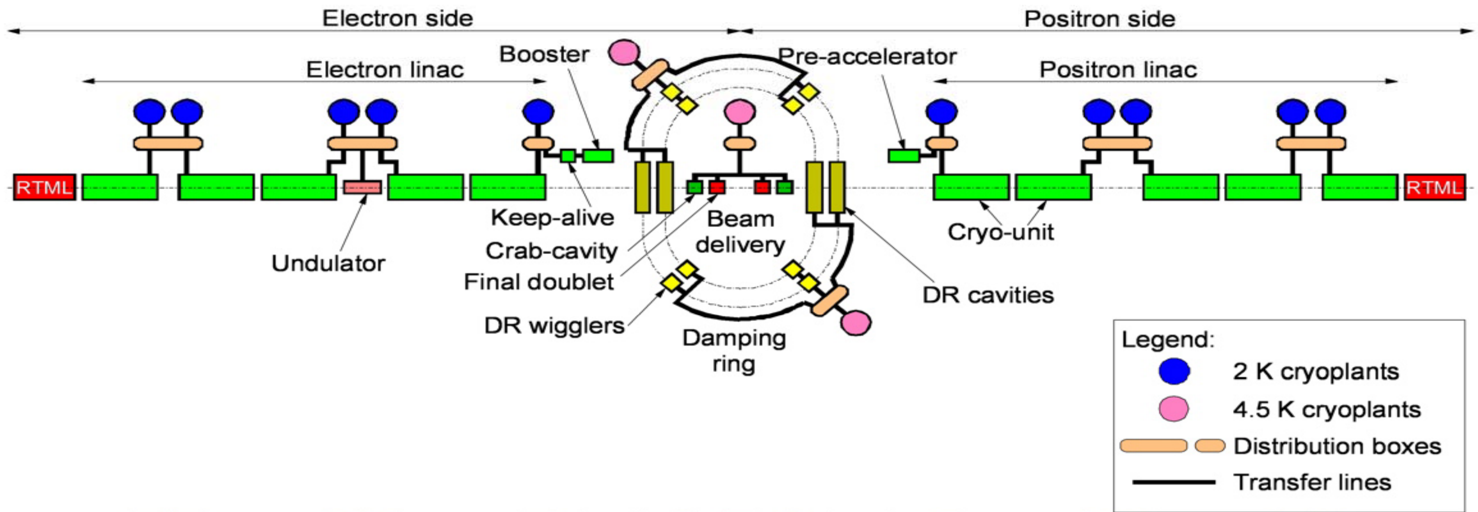




- Fermilab: V. Kashikhin et al.,
  - Test results of superconducting quadrupole model for linear colliders
  - This conference, 4LPA01,
- SLAC/CIEMAT: C. Adolphsen et al

2K Cryogenics Engineering

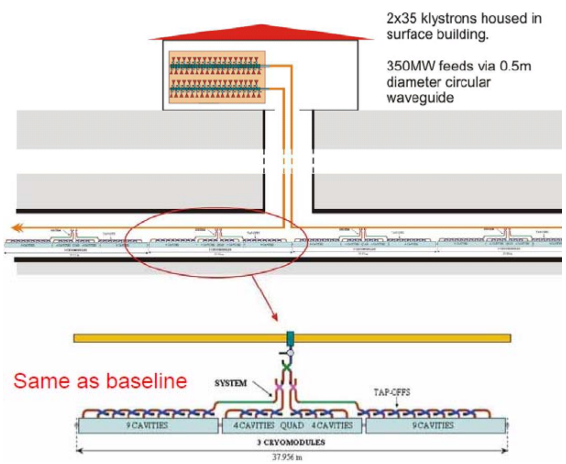
Scale is equivalent to the LHC cryogenics!!



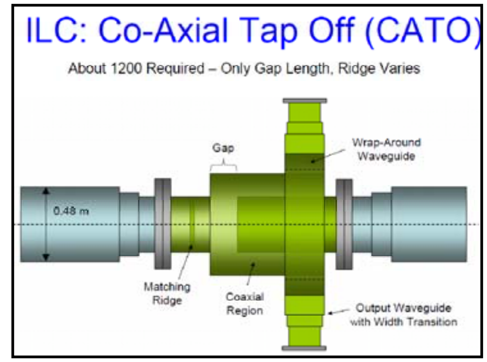
Volumes	Numbers	Liq. He (liter) equivalent	Tevatron eq.	LHC Eq.
One module		346.1		
String	12 modules	4,153	0.1	
Cryo. unit	14-16 strings	62,992	1.0	0.1
ILC ML	2 x 5 cryo. units	630,261	10.5	0.8

Klystron Cluster RF Distribution Scheme

Chris Adolphsen
Chris Nantista



- RF power "piped" into accelerator tunnel every 2.5 km
- Service tunnel eliminated
- Electrical and cooling systems simplified
- Concerns: power handling, LLRF control coarseness



Summary

Surface klystron clusters can save ~ 300 M$ (~ 200 M$ from eliminating service tunnel and ~100 M$ from simpler power and cooling systems).

The GDE Executive Committee encourages R&D to pursue this idea.

The proposed CATO tap in/off design is likely to be robust breakdown-wise. Have a plan to demonstrate its performance, although with only 1/5 of the worst case ILC stored energy after shutoff.

Need to better study:

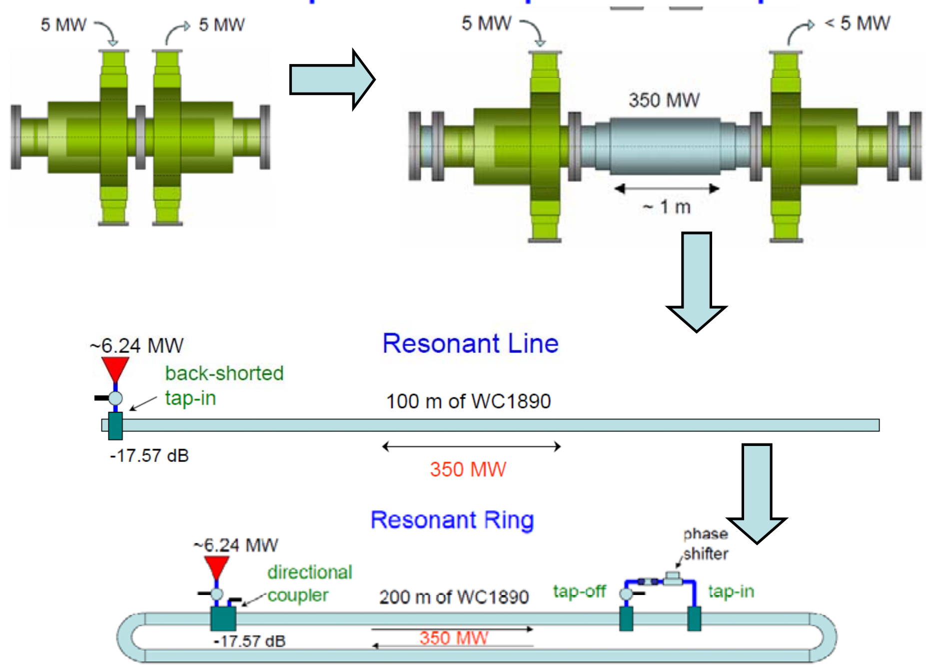
Waveguide fabrication and tolerances – too large to be drawn, but don't want seams (KEK working with industry on this).

Bend design – mode preserving; low-loss; support 350 MW, 1.6 ms; compact enough for tunnel

Impact on LLRF control, energy spread minimization, & efficiency.

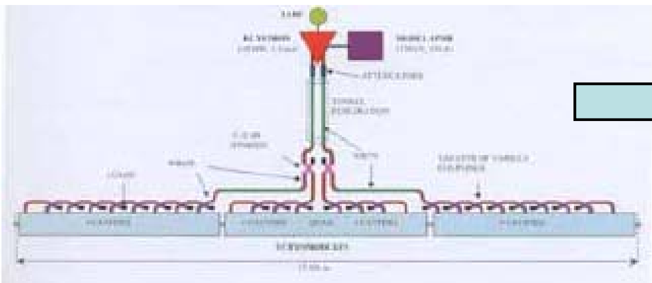
Modifications to accelerator tunnel to accommodate waveguide plus other systems from tunnel systems.

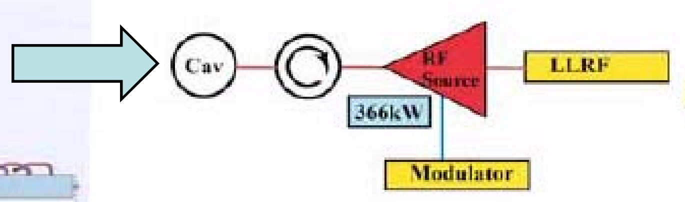
Concept Development Steps



Proposal of Distributed RF-source Scheme (DRFS)

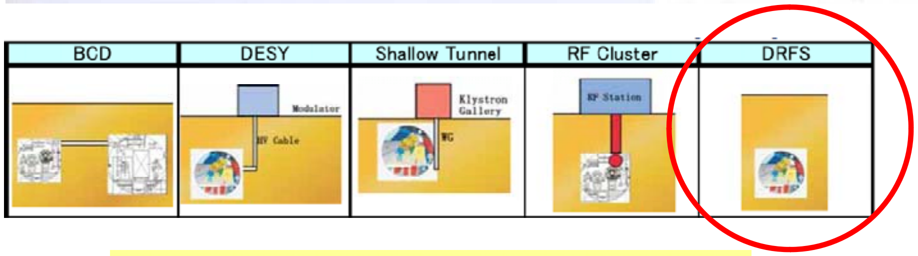
One Klystron feeds power t

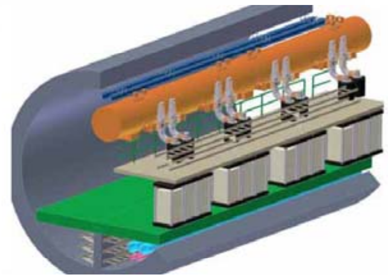


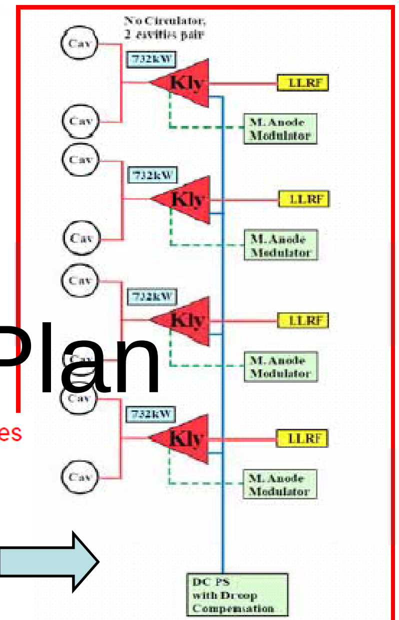


Total amount

X 26 X 650
=16900







There are several merits in DRFS.

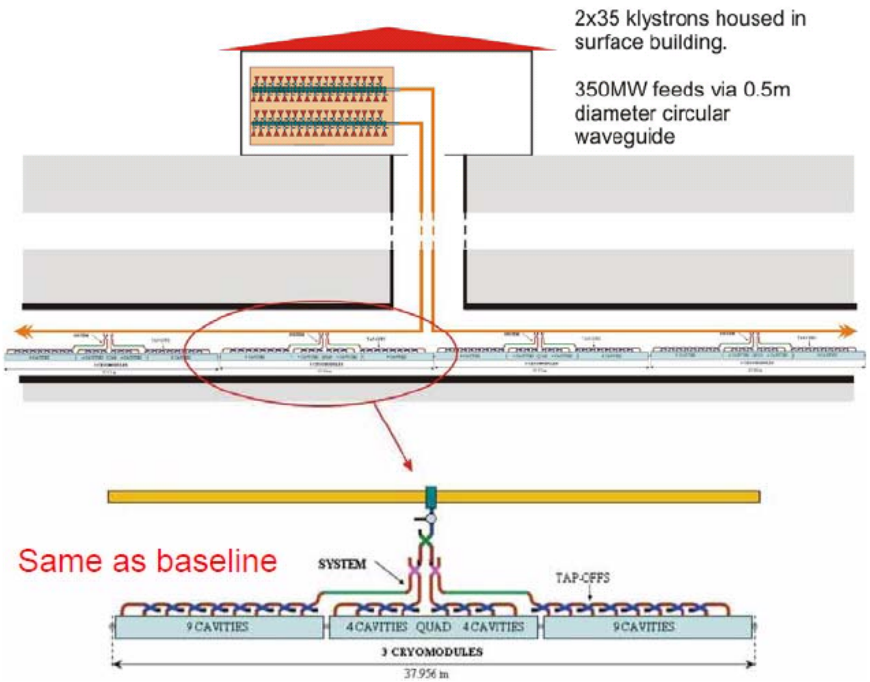
- **Complete single tunnel scheme and simple configuration. (Cost benefit is expected)**
- **Klystron failure doesn't give a serious effect to beam operation since failures are scattered. (cf. BCD, RF Cluster)**
- **Adoption of MAK leads to the cheap HLRF system and introduction of power handling is possible for klystron.**
- **Direct connecting of about 60kV to klystron eliminates pulse transformer and use of huge insulation oil.**
- **LLRF control is easy and vector sum of 2 cavities are better than BCD plan.**
- **By coupling two cavities with same performance, circulators are possibly eliminated.**
- **There are lots of advantages for the operation and control.**

Likely Plan

- Circulator elimination by power feeding to 2 cavities from one klystron. Output power is 732kW.
- Modulated Anode Klystron (MAK) is adopted.
- Anode modulation pulser does not need the high power and cost efficient pulser is manufactured.
- DC Power Supply is common for 26 cavities and voltage drop during the pulse is compensated with appropriate circuits at the level that LLRF can feed back.

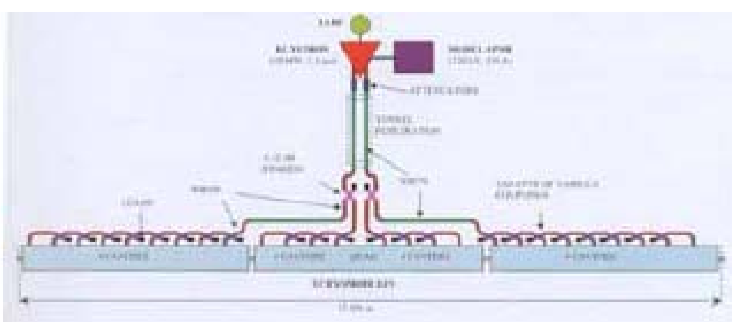
- Cost estimates Under going

Cost Reduced RF Concepts

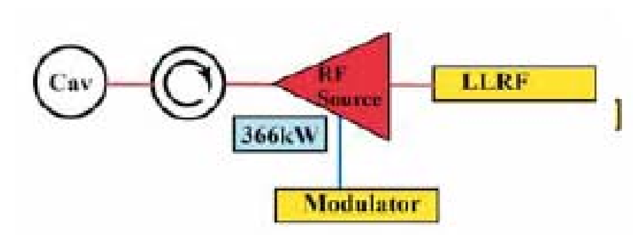


Surface Klystron Cluster (Adolphsen, Nantista, SLAC)

Both options aimed at single-tunnel solutions



Distributed RF Source Concept (Fukuda, KEK)



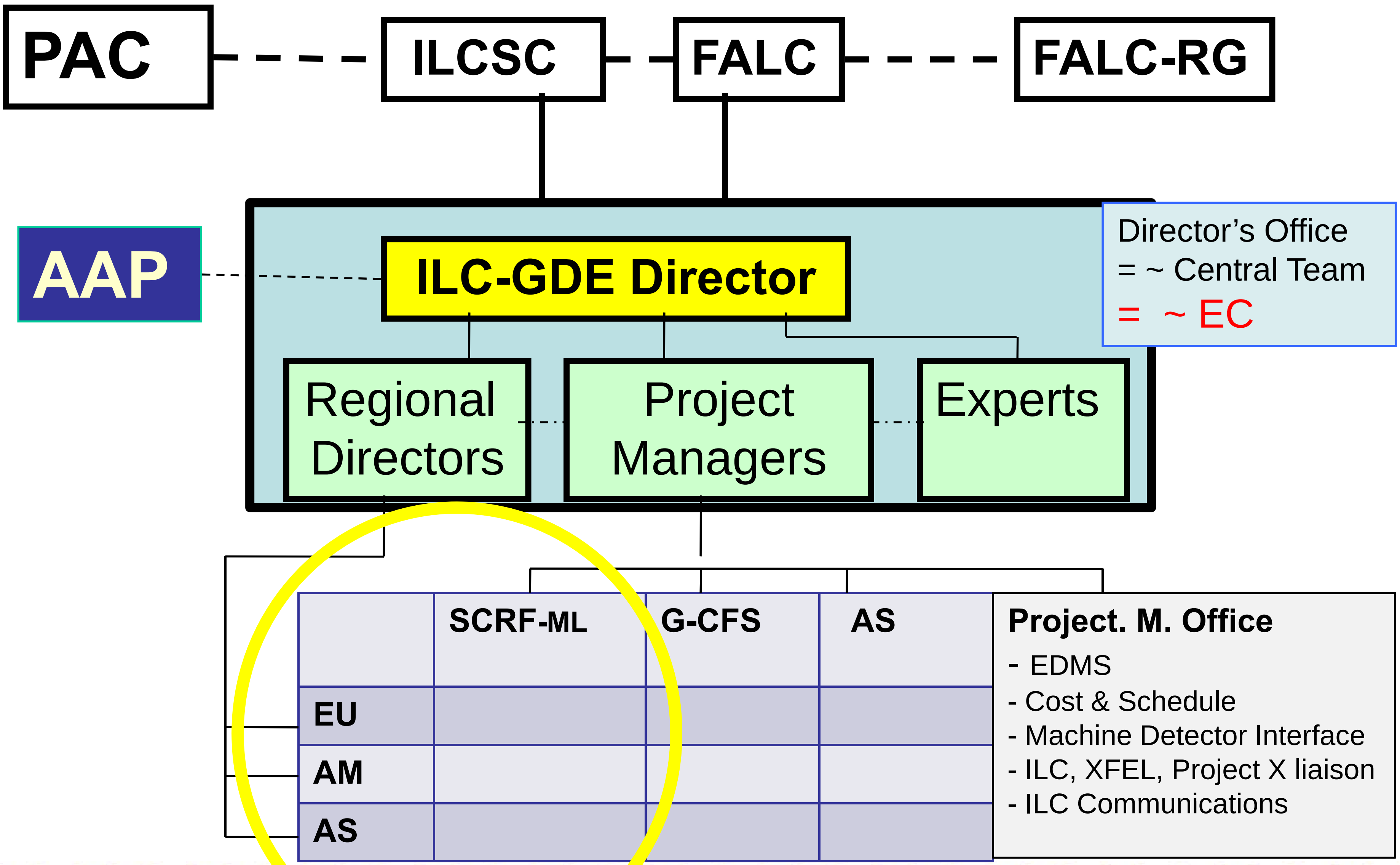
Total amount

X 26 X 650 =16900

Outline

- Introduction
- R&D Status
- Plan for Technical Design Phase
- Global Plan and Project Management
- Summary

ILC-GDE Organization Chart



SCRF Area Organization in TDP

as of Sept., 2008

Regional Effort: Harrison, Foster, Yokoya			**SCRF Technical Effort:** Yamamoto, Shidara, and Kerby					
	Institute	**Institute Leaders**	**Cavity: Process** Lilje	**Cavity: Integ.** Hayano	**Cryomodule** Ohuchii/Carter	**Cryogenics** Peterson	**HLRF (LLRF)** Fukuda	**M LI** Adolphsen
AMs	Cornell Fermilab SLAC ANL J-lab	Padamsee Kephart Raubenheimer Gerig Rimmer	Padamsee Champion Kelly Reece/	Champion Adolphsen	Champion	Peterson	Adolphsen	Adolphsen
EU	DESY CERN Saclay Olsay INFN CIEMAT	Brinkmann Delahaye Dael Wormser Pagani	Lilje	L. Lilje Prat Pagani	Parma Pierini	Tavian		
AS	KEK Korea IHEP RRCAT/BARC IUAC VECC	Yokoya Gao Sahni (Sahni) Roy Bhandari	Hayano Gao	Hayano	Tsuchiya/Ohuchi	Hosoyama / Nakai	Fukuda	Hayano

Technical Area Group Leaders

Akira Yamamoto
Project Manager
SCRF Tech.

- Tetsuo Shidara (KEK)
- Jim Kerby (FNAL)
- Lutz Lilje (DESY) – Cavity Processing
- Hitoshi Hayano (KEK) – Cavity Production & Integration
- Norihito Ohuchi (KEK) Leader, Harry Carter (FNAL) Co-Leader – Cryomodule
- Shigeki Fukuda (KEK) – HLRF
- Tom Peterson (FNAL) – Cryogenics
- Chris Adolphsen (SLAC) – Main Linac Integration

Marc Ross
Project Manager (chair)
CFS & Global

- Wilhelm Bialowons (DESY)
- John Carwardine (ANL)
- John Osborne (CERN) – Civil Engineering
- Vic Kuchler (FNAL) – Conventional Facilities
- Margaret Votava (FNAL) – Controls

Nick Walker
Project Manager
Accelerator Systems

- Frank Lehner (DESY)
- Junji Urakawa (KEK)
- Axel Brachmann (SLAC) – Electron Source
- Jim Clarke (STFC) – Positron Source
- Andy Wolski (Cockcroft Institute) – Damping Ring
- Nikolay Solyak (FNAL) – RTML
- Andre Seryi (SLAC) – BDS
- Kiyoshi Kubo (KEK) – Simulation

- Engineering and Scientific Management
- 25 (16 below PM)
  - **7 Asia**
  - **7 EU**
  - **11 Americas**

How Cooperate/Work Together?

- **Project Managers are responsible for:**
  - Coordinate/lead the world-wide technical development effort,
  - Setting technical direction and executing the project,
  - Day-by-day technical coordination/execution,
- **Regional Directors and Institutional Leaders are responsible for:**
  - Promoting, funding and authorizing the cooperation program.
  - Periodical reviewing of progress,

Project Management in 2007-2008

- Technical Coordination and Leadship (by PMs)
  - **Encourage "extended R&D for cavity gradient (S0)" and integration with establishing "Plug-compatibility"**
  - **Propose "Cavity-string test with global effort (S1-Global) "**
  - **We are developing practical plan for cryomodule string test with accelerator beam (S2)**

  - **Start to prepare for AAP review in spring, 2009,**
  - **We are establishing good communication by visiting world-wide SCRF/RF laboratories**
    - DESY, CEA/Saclay, LAL/Orsay, CERN, (INFN, CIEMAT)
    - Fermilab,SLAC, Jlab, Cornell, LANL (TRIUMF)
    - KEK, IHEP, Beijing U., Tsinghua U, IUAC, RRCAT, TIFR, VECC BARC, KNU, PAL,

Project Management Plan in 2008-2010

Actions Required:

- Field gradient (S0)
  - **To be re-optimized, based on the R&D progress (2010),**
- Plug-compatibility
  - **Common interface conditions to be agreed in LCWS-08 (2008) ,**
  - **Overview document in preparation**
- System engineering/test plan, (S1, S2)
  - **Work sharing in cavity string in global effort (S1-Global)**
  - **Accelerator system test with beam**
    - Necessary detailed study and re-coordination under limited resources, including schedule
- Effort for "minimum machine" in view of SCRF (by N. Walker),
  - **RF power sources and distribution,**
- Prepare for AAP Review in April, 2009
- Global Communication and cooperation with Laboratories & Industries

TD Phase 1 Schedule

Published in:
ILC Research and Development Plan for the Technical Design Phase

Release 2, June 2008
(next release 6 months)

Near term effort on these activities

Value engineering

Value engineering

Global Project Plan

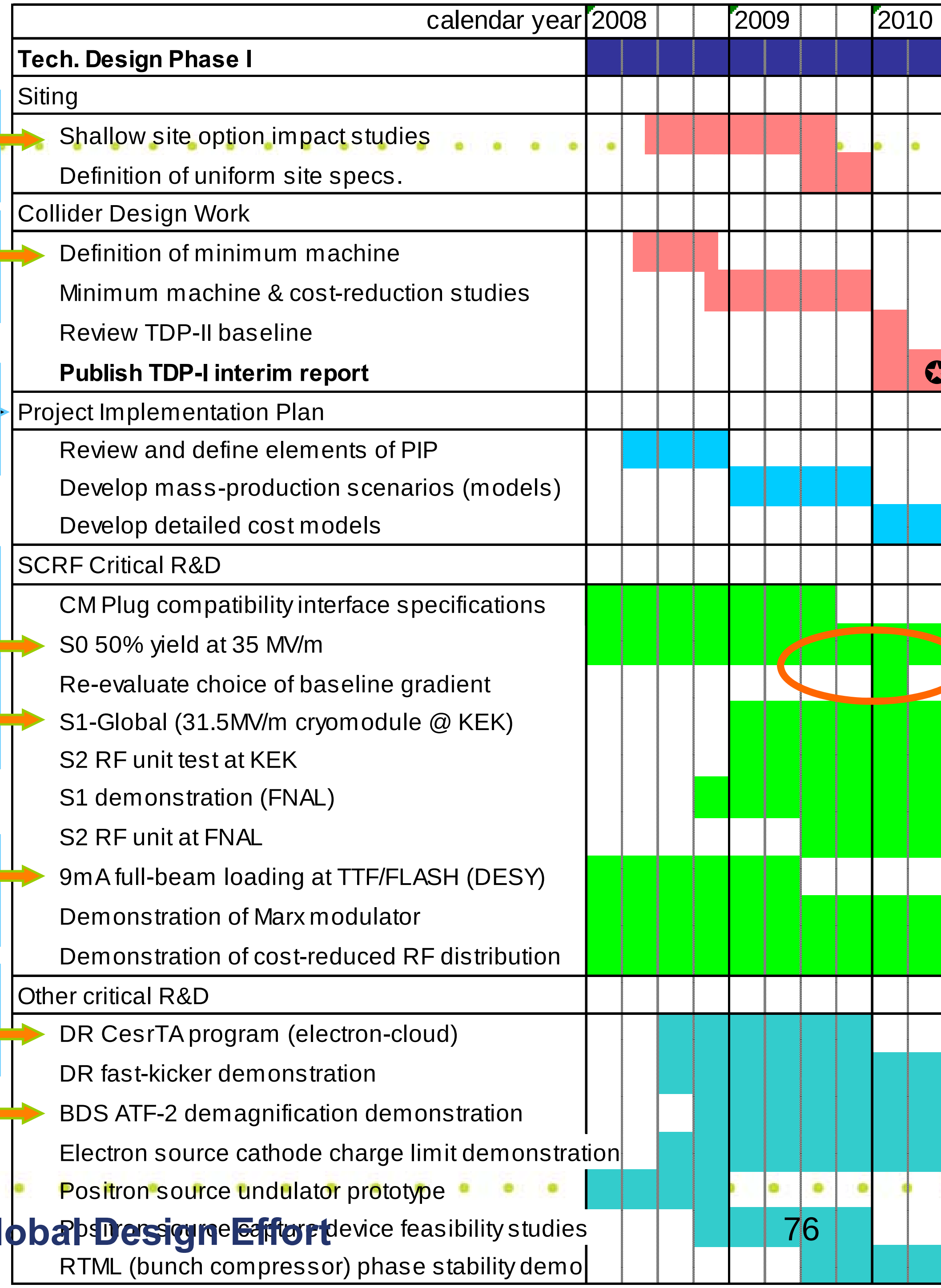
High Gradient

Cryomodule test

Systems Test

Electron Cloud

Precision beam control



Plug-Compatibility Document

Draft: Sept. 4, 2008
revision: October 12, 2008
updated by AY, Oct. 13, 2008

Plug-compatibility in the ILC Technical Design Phase ~~(SCRF)~~

ILC-GDE Project Managers
Marc Ross, Nicholas Walker, and Akira Yamamoto

Purpose of this document
This document is an attempt (draft) to describe how we would 'more explicitly' define plug-compatibility for the R & D Phase. We are planning to include it in the next release of the R & D Plan. Advice and comments are appreciated.

The document has the following sections:
1. Introduction
2. Goals and Guidelines for Plug-compatibility in the Technical Design Phase (TDP)
3. Scenarios outlining the impact Plug-compatibility has on project phases following the TDP
4. SRF Technical Group example – the ILC cryomodule

SCRF Major Goals

High-gradient cavity performance at 35 MV/m according to the specified chemical process with a yield of 50% in TDP1, and with a production yield of 90% in TDP2	2010 2012
Nominal Cryomodule design to be optimized: - plug-compatible design including tune-ability and maintainability - thermal balance and cryogenics operation - beam dynamics (addressing issues such as orientation and alignment)	2009
Cavity-string performance in one cryomodule with the average gradient 31.5 MV based on a global effort (S1 and S1-global)	2010
An ILC accelerator unit, consisting of three cryomodules powered by one RF unit, with achieving the average gradient 31.5 MV/m (S2)	2012

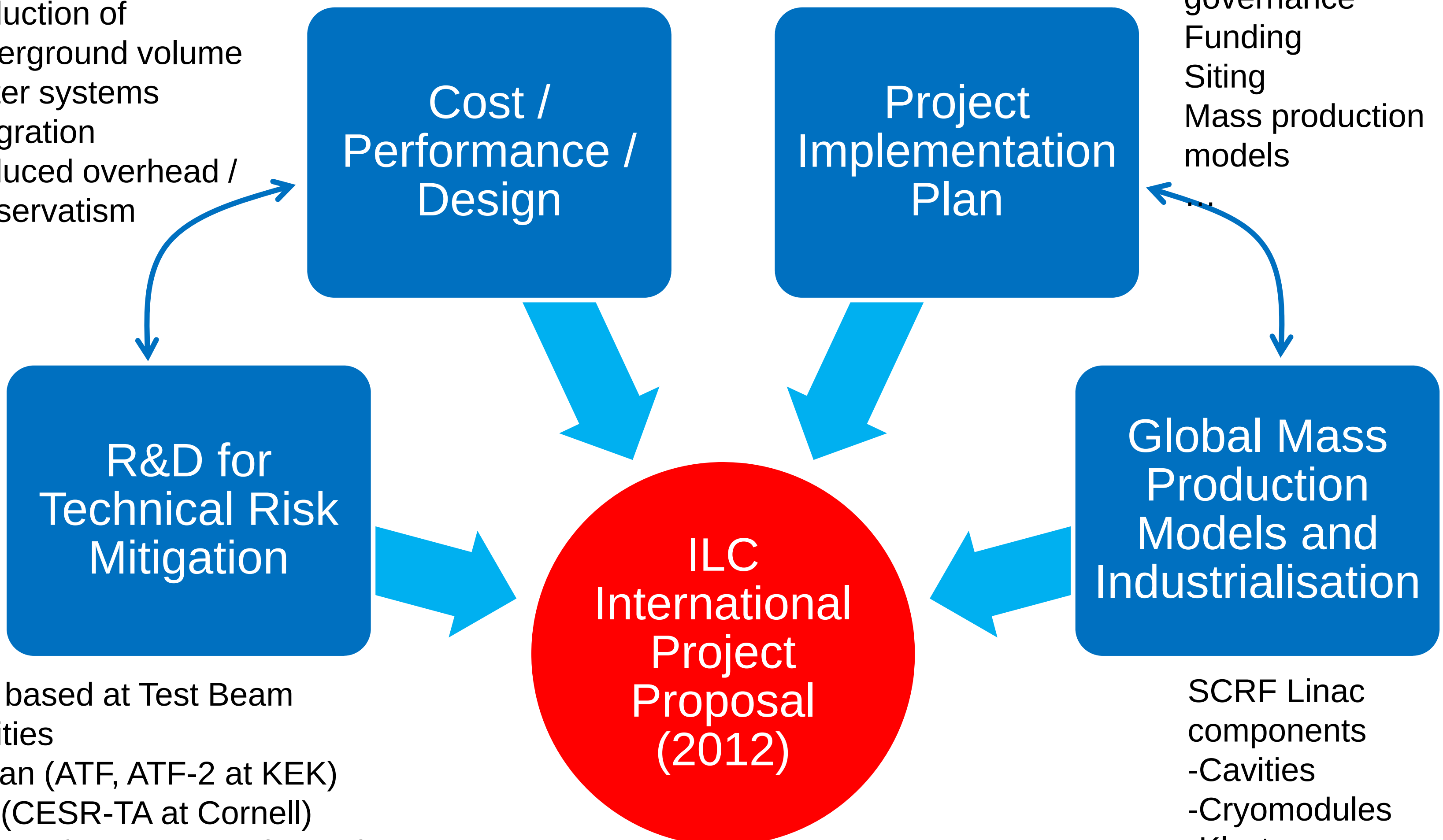
Global Plan for SCRF R&D

Calender Year	2007	2008	2009	2010	2011	2012
Technical Design Phase	TDP-1			TDP-2		
Cavity Gradient R&D to reach 35 MV/m		Process Yield > 50%		Production Yield >90%		
Cavity-string test: with 1 cryomodule		Global collab. For <31.5 MV/m>				
System Test with beam 1 RF-unit (3-modulce)		FLASH (DESY)			STF2 (KEK) NML (FNAL)	

TD Phase Priorities – A Summary

SCRF gradient R&D
Reduction of underground volume
Better systems integration
Reduced overhead / conservatism
…

International governance
Funding
Siting
Mass production models
…



R&D based at Test Beam Facilities
- Japan (ATF, ATF-2 at KEK)
- US (CESR-TA at Cornell)
- EU TTF/FLASH 9mA (DESY)
- EU DAPHNE (INFN)

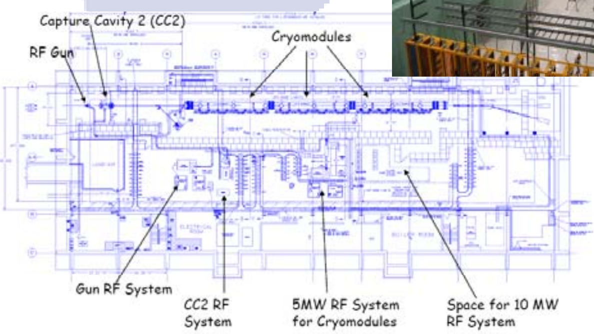
SCRF Linac components
-Cavities
-Cryomodules
-Klystrons
-…

TD Phase 1 Stated Priorities (R&D Plan)

Risk Mitigating R&D	• SCRF Technology (e.g. gradient) • Damping ring electron cloud • …
Beam Test Facilities	• ATF / ATF 2 (KEK) • CesrTA (Cornell) • TTF/FLASH (DESY)
Machine Design / Cost	• CFS / Value Engineering • “Minimum Machine” concept

SRF Test Facilities

FNAL

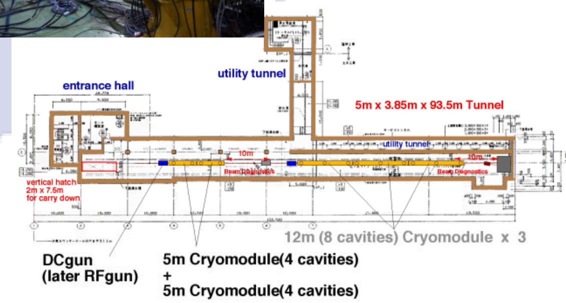


NML facility
Under construction
first beam 2010
ILC RF unit test

DESY

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

KEK, Japan



STF (phase I & II)
Under construction
first beam 2011
ILC RF unit test

Cooperation with EuroXFEL and Other Projects

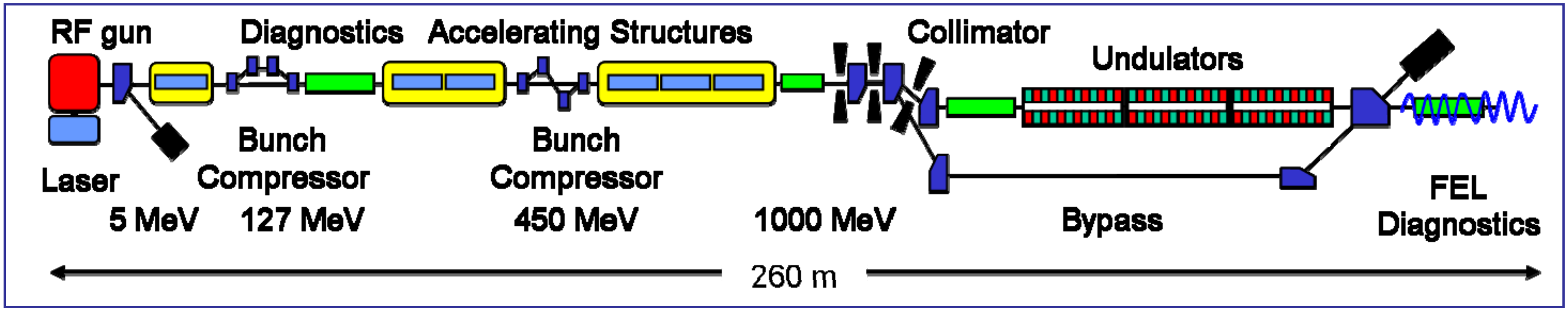
European X-ray Free Electron Laser Facility

- EuroXFEL SRF design gradient : 23.6 MV/m
- Machine designed: 28 MV/m
- ~ 100 SCRF cryomodule, based on the experience at TTF,DESY,
- Leading SCRF industrialization (scale: 1/20 of ILC, in coming 5 years)
- Keep close cooperation with XFEL, on-going project.

Further SCRF Accelerator Project Plans investigated:

- Project X at Fermilab, SC Proton Linac at CERN, and ERL at KEK
- Best effort for common design and cost-effective design

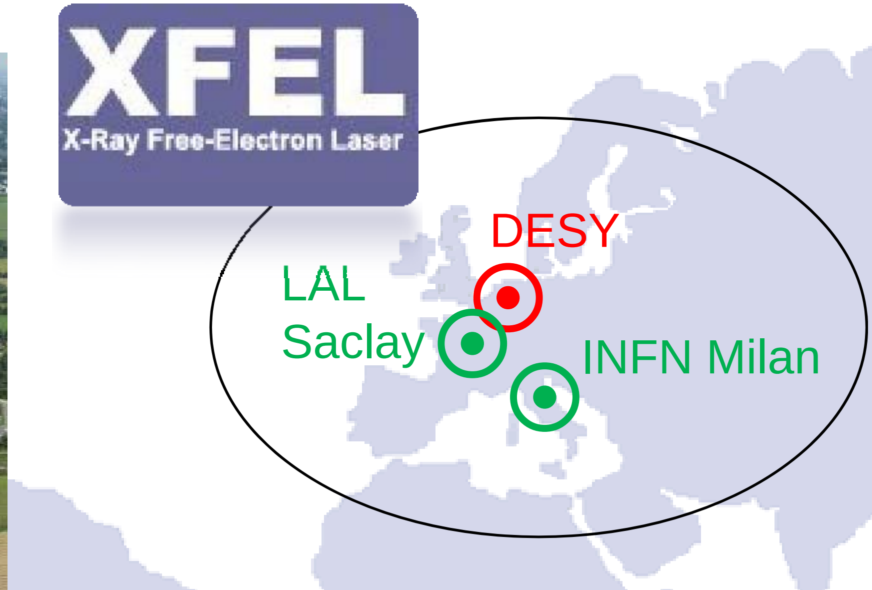
TTF/FLASH at DESY

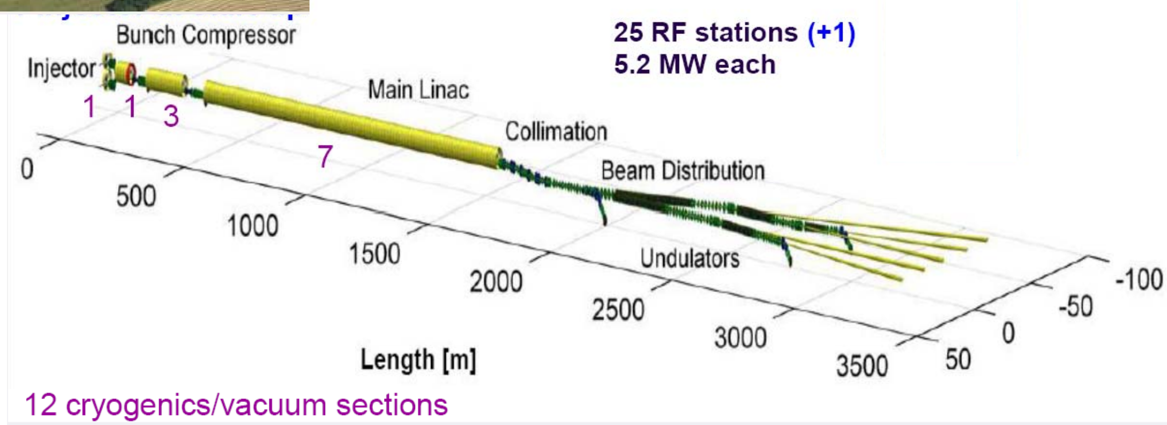


TTF/FLASH: currently a unique facility world-wide

		XFEL X-Ray Free-Electron Laser	ilc	FLASH design	FLASH 9mA experiment
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

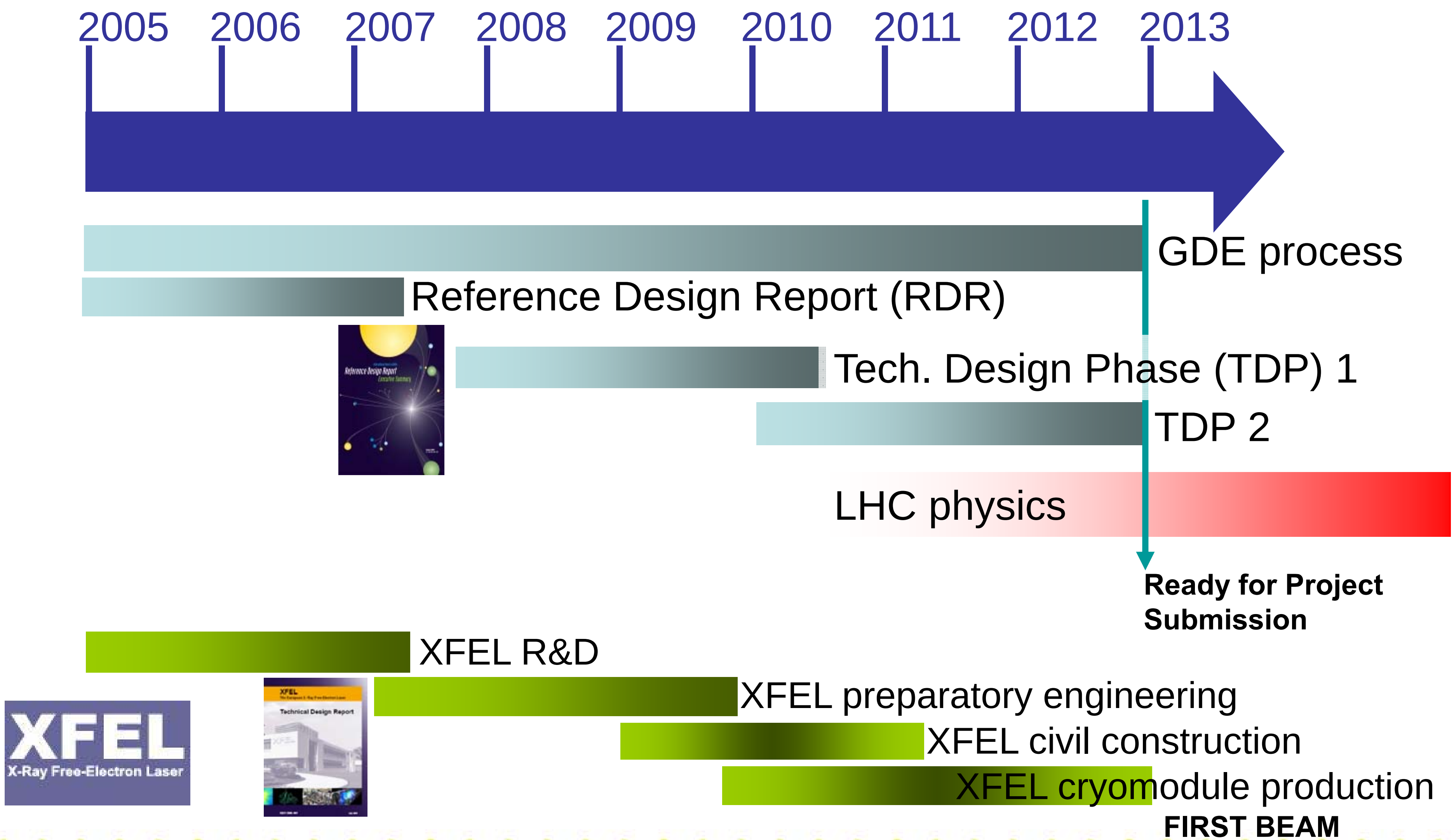
European XFEL





- 101 Cryomodules
- 808 cavities
  - **plus auxiliaries**
- Gradient:
  - **23.5 MV/m**
  - **(28 MV/m)**
- Industrialisation & mass production
  - **1 CM / week**
- "In-kind" international model
- Major Chinese contribution

GDE & XFEL Timelines



2009 – 2010

Proposed meetings and reviews:

- TDP1 Interim Review, Tsukuba – April 17-21, 2009 (Accelerator Advisory Panel, AAP)
- ALCPG Autumn 2009
- ILC Baseline update – January 2010
- TDP1 Final Review, April 2010 (AAP)
- ECFA Workshop, CERN – April 2010 (TBC)
- TDP1 presentation, ICHEP Paris - July 2010

Summary

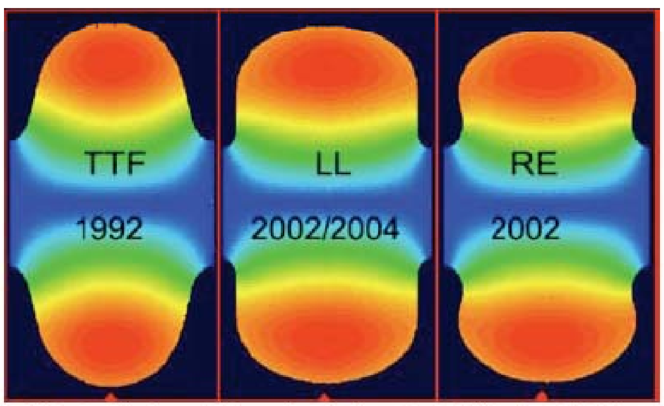
- Technical Design **Phase in progress**:
  - **Phase-1: Technical reality to be examined,**
    - 35 MV/m with yield 50 % in surface process and
    - < 31.5 MV/m> with the cavity-string in a cryomodule
      - Plug-compatible crymodule to be examined with global effort.
  - **Phase-2: Technical credibility to be verified**
    - 35 MV/m with the yield 90 % for 9-cell including fabrication
    - System engineering and beam acceleration with the field gradient <31.5> MV/m.
- **We aim for**
  - Global cooperation with having plug-compatibility, and with a smooth transition to the construction/production phase.
  - Cooperation with world-wide Institutions cricially important

Backup

Cavity Shape Design Investigated

TABLE II. CAVITY SHAPES STUDIED FOR THE ILC.

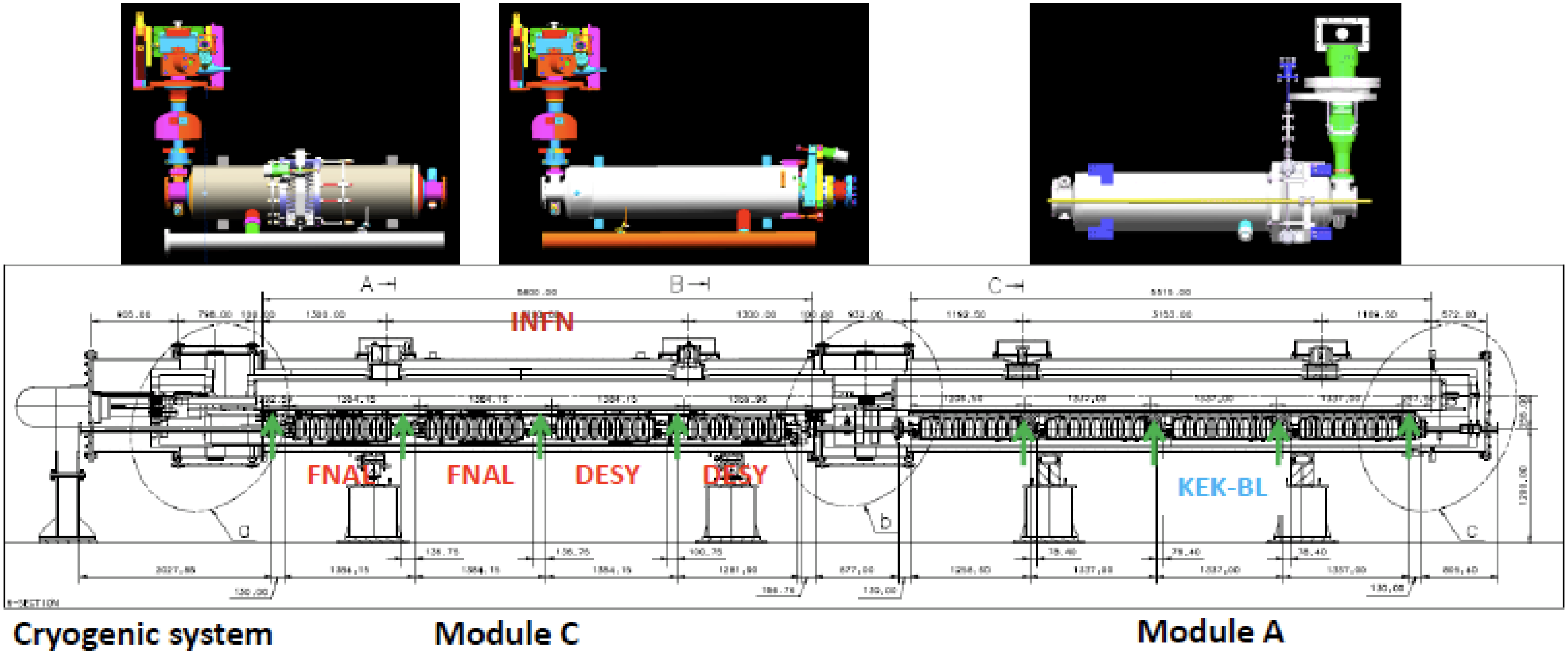
Parameter	TESLA	LL/IS	RE
Iris aperture (mm)	70	60/61	66
E_{peak}/E_{acc}	1.98	2.36/2.02	2.21
B_{peak}/E_{acc} (mT/(MV/m))	4.15	3.61/3.56	3.76
Char. shunt impedance: R/Q (Ω)	114	134/138	127
Geometric factor: G (Ω)	271	284/285	277
G × R/Q (Ω × Ω × 10^5)	3.08	3.80/3.93	3.51



- TESLA
  - **Lower E-peak**
  - **Lower risk of field emission**
- LL/IS, RE
  - **Lower B-peak**
  - **Potential to reach higher gradient**

LL: low-loss, IS: Ichiro-shape, RE: re-entrant

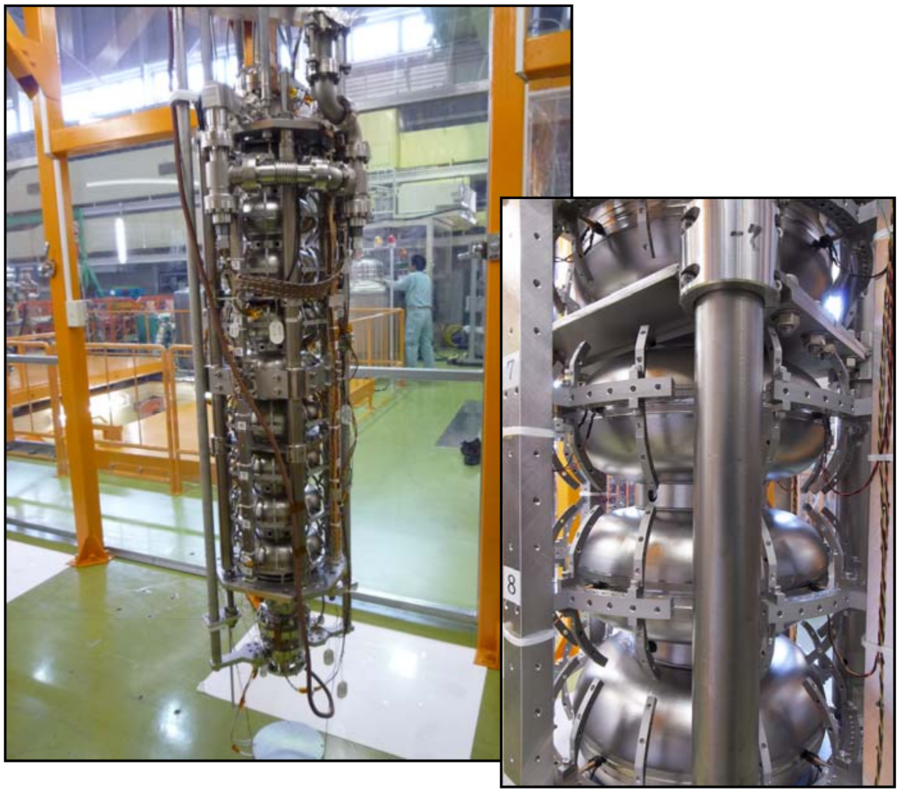
S1-Global: Cryomodule Assembly



Plug-compatibility to be examined

Vertical Test Commissioning at KEK

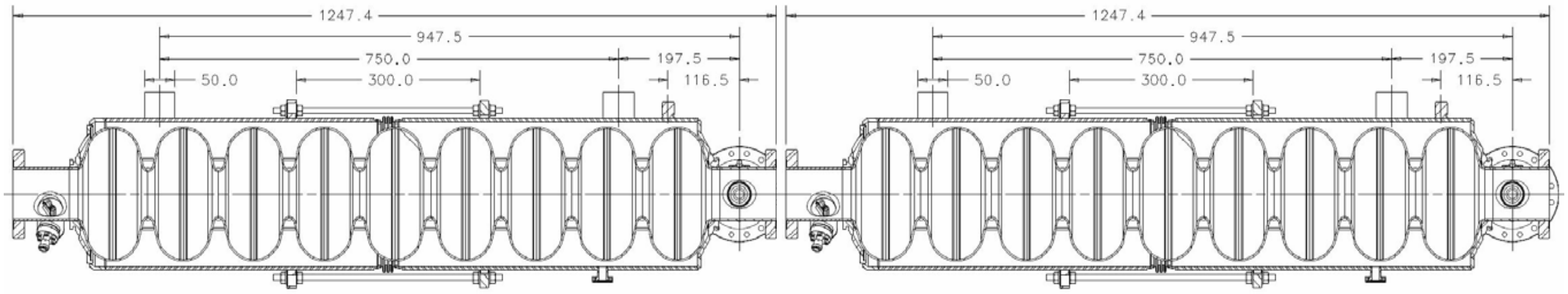
- cool-down test of cryostat was done July 3 – 5, using AES01 cavity.
- EP at STF-EP facility, vertical test again in September.

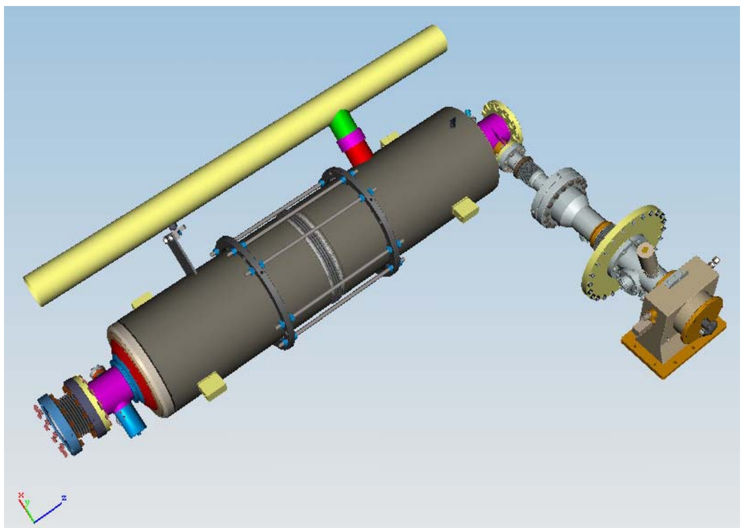


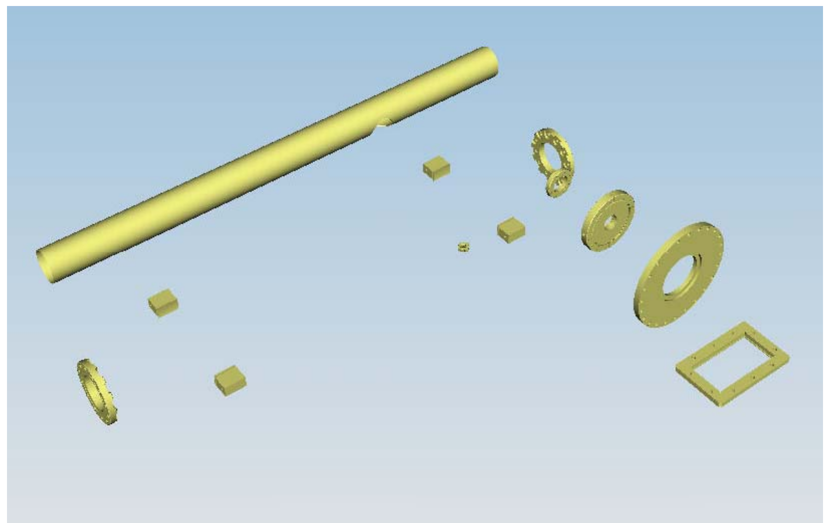
AES01 cavity with T-map

Installation into vertical cryostat

Plug-compatible Development

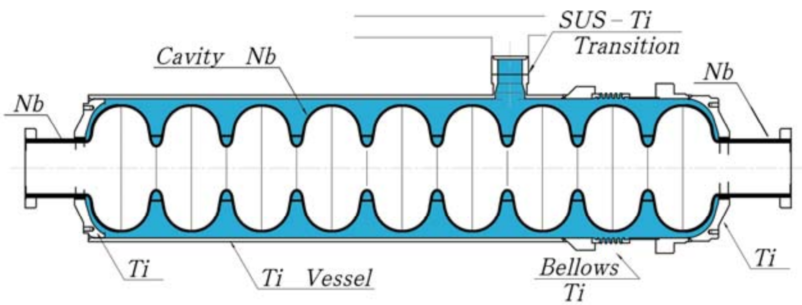


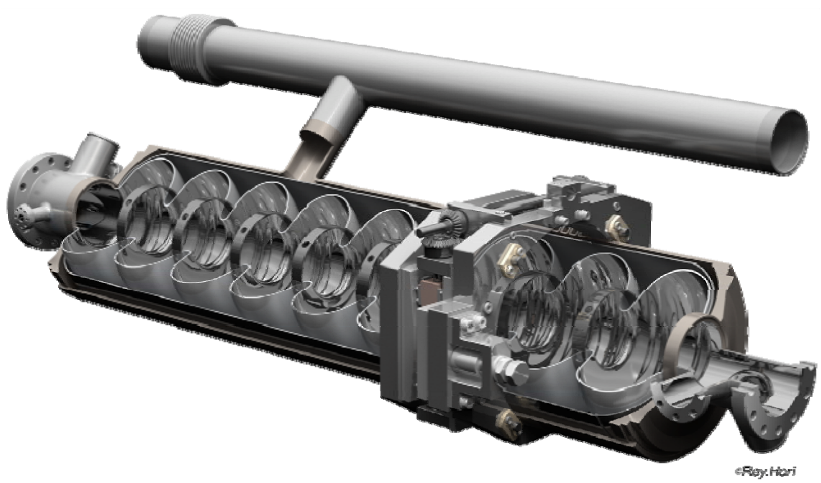




Plug-compatible interface to be established

Plug compatible conditions at Cavity package (in progress)



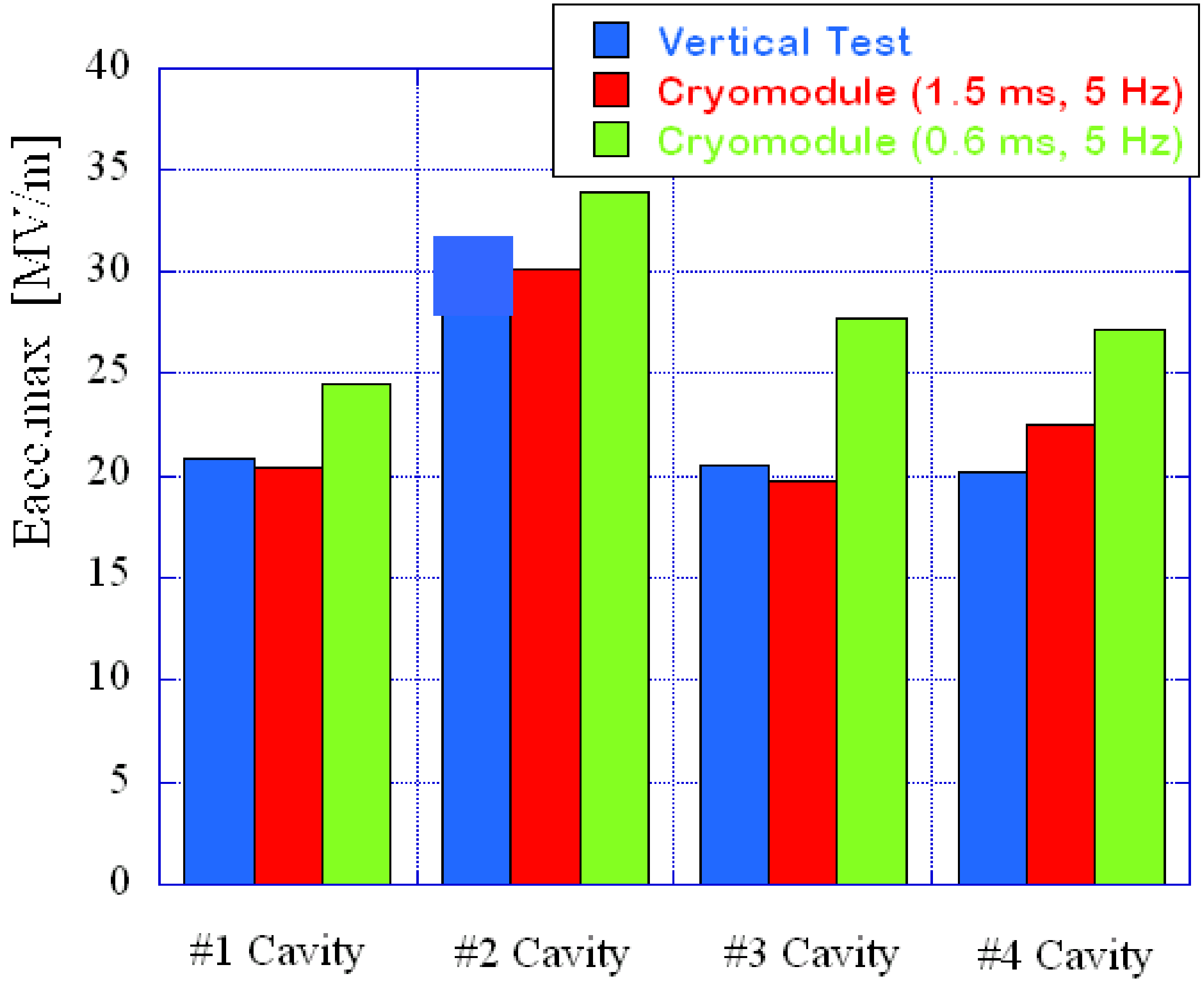


Item	Can be flexible	Plug-compatible
Cavity shape	TeSLA/LL/RE	
Length		Required
Beam pipe dia		Reuuired
Flange		Required
Tuner	0	
Coupler flange		Required
He –in-line joint		Required
Input coupler	TBD	TBD

Eacc,max, and average, in Cryomodule

KEK, Nov., 2008

RF FB / ON



Eacc,max (Cryo.)
= 32 MV/m (max)
> 23 MV/m (average)

What's in a Name?

- "Minimum" a bad choice of word!
  - **historical – now part of the language!**
  - **does <u>not</u> convey what we are attempting to achieve**

- Need a better word!
  - **we are really discussing conceptual studies for specific alternative designs**

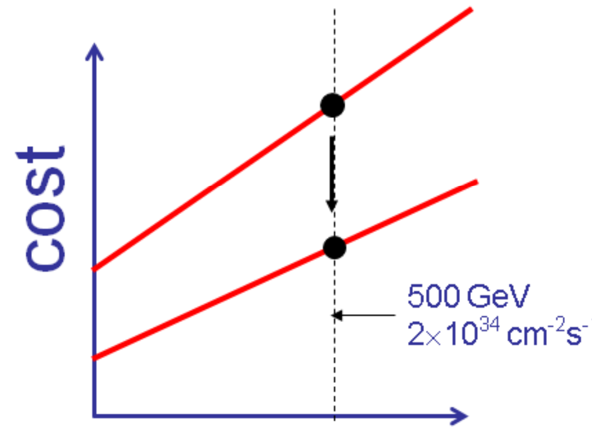
- Will change it soon – but for now…
  - **110 hits on Google!!**

- **最も効果的な加速器**

"?????? Machine" Philosophy

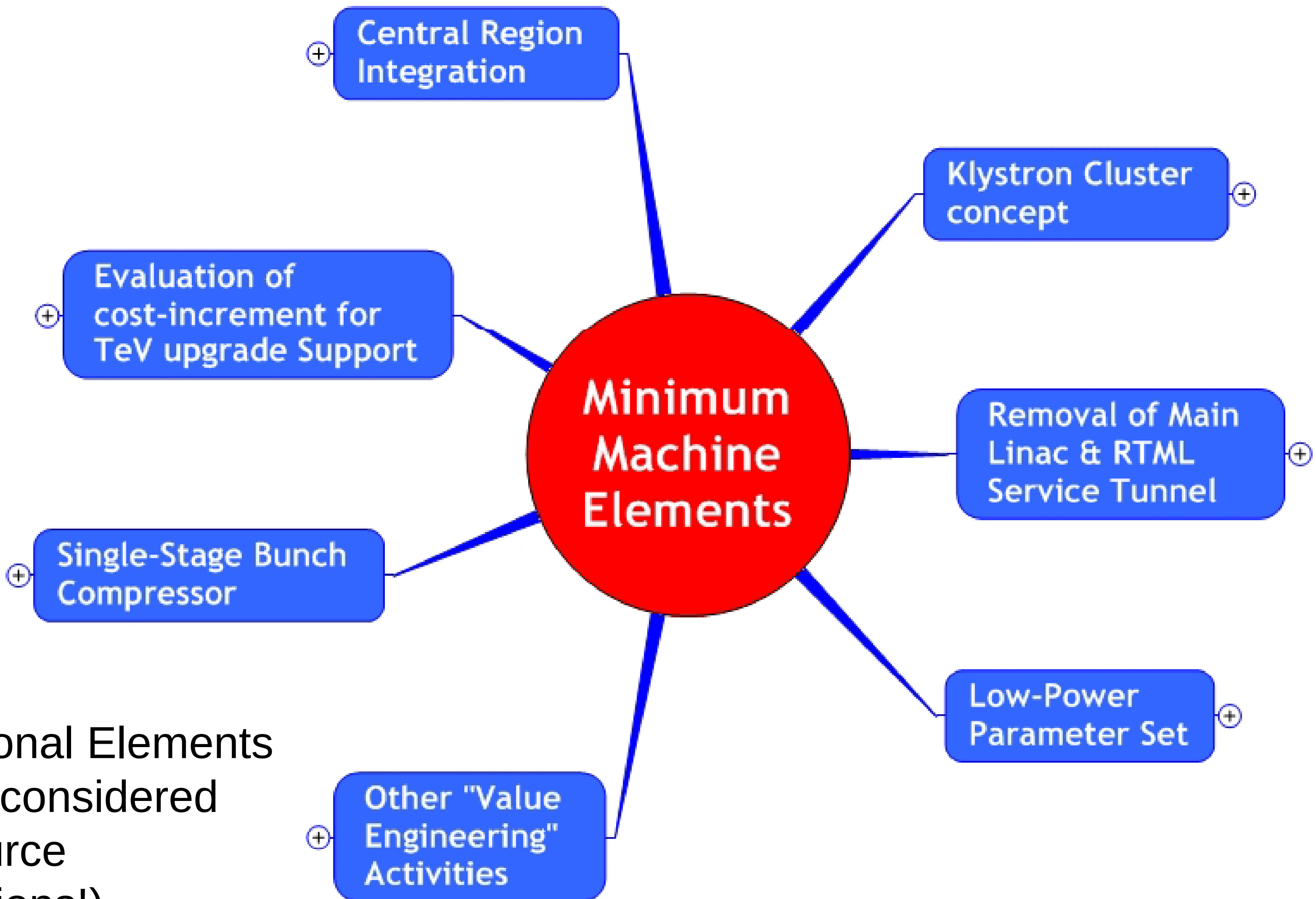
- *Direct* performance
  - **considered a ph... re of merit'**
    - centre ...
    - ...
  - **... s of the**
  p...
- *Indirec*... nce
  - **into w... ch we place mar... redundancy, *etc*.**
  - **tend to impact operation...**
  - **performance risk**
    - potentially affecting integra... within a given time frame
- Concentrate on Indirect
  - **Do not change basic physics parameters**

Global Value Engineering



"Minimum Machine" refers to a set of identified options (elements) which may simplify the design and be cost-effective

Identified Design Study Elements



Additional Elements being considered (resource limitations!)

Minimum Machine Document in Preparation

The ILC Minimum Machine Definition

Release 1

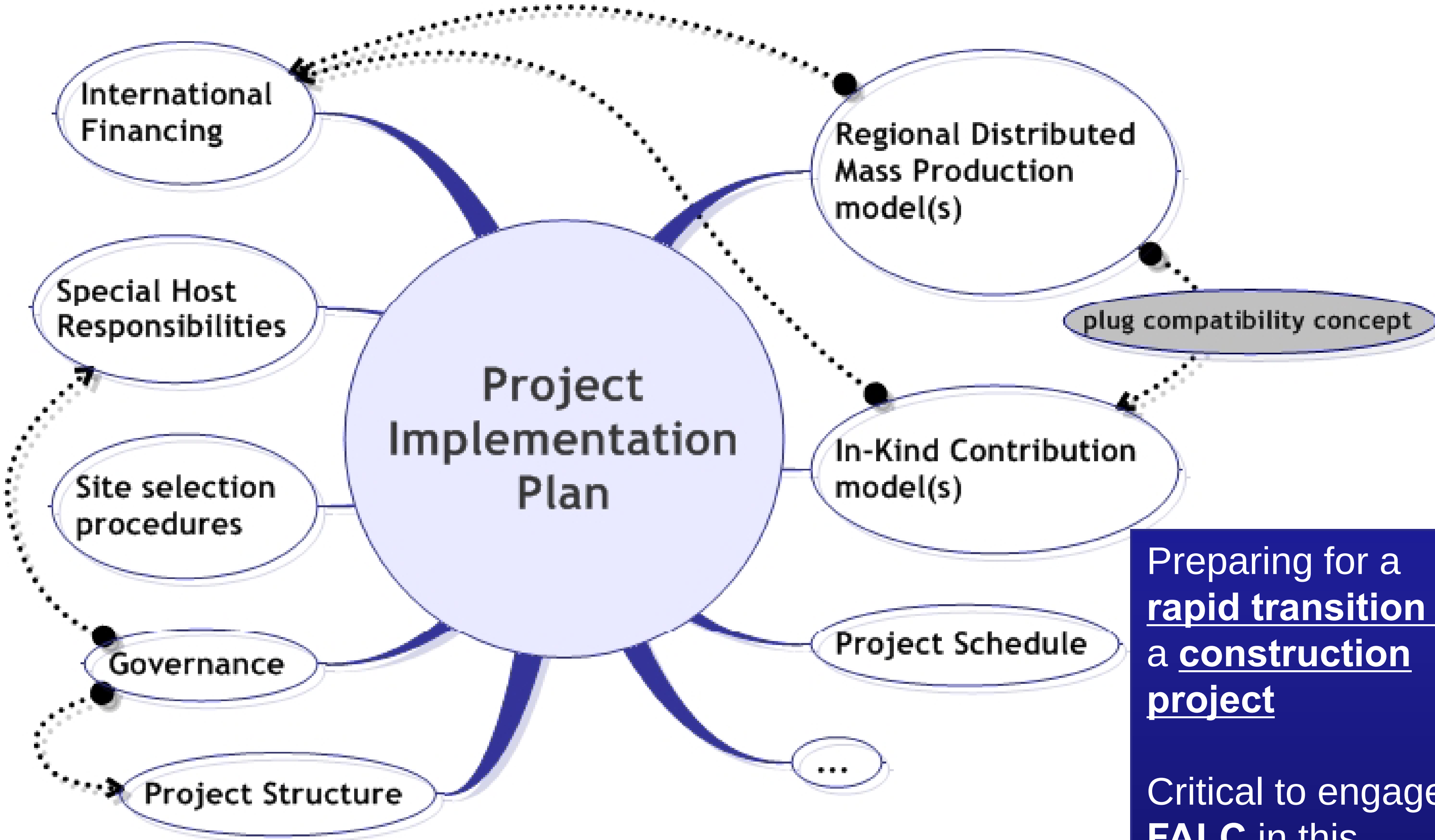
November 2008

Prepared by the Technical Design Phase Project Management

To communicate our ideas to the broader community and form a blue-print for studies in 09

- Draft document is preparation
- (One) Focus of ILC08 workshop
  - **Study planning**
  - **Resources**
- Final publication end of year

Project Implementation Plan



Preparing for a **rapid transition** to a **construction project**

Critical to engage **FALC** in this process

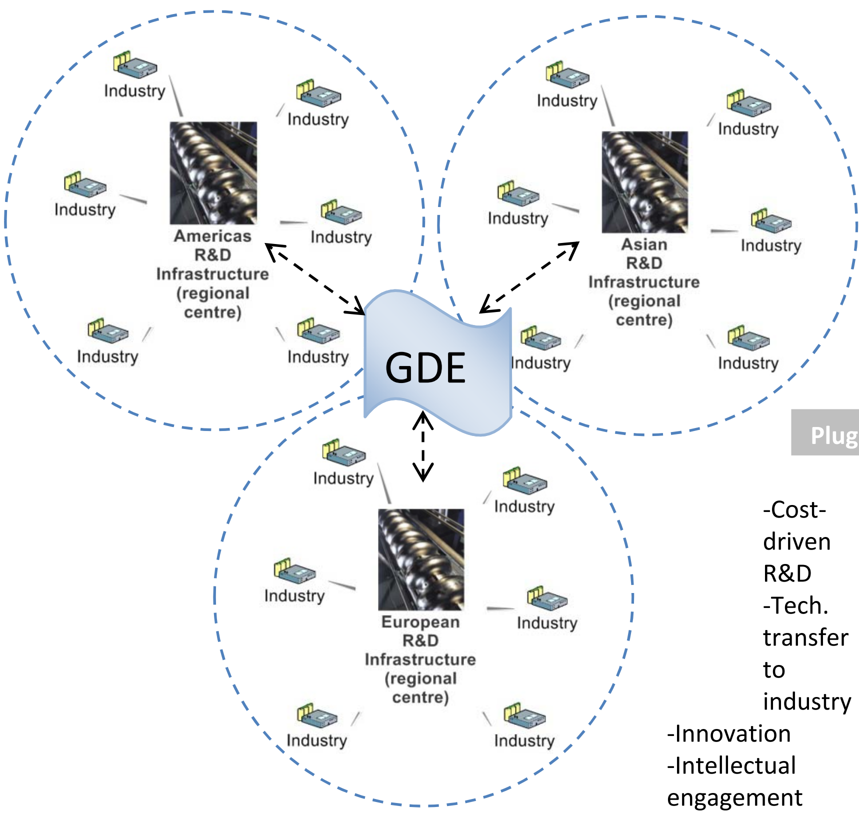
Transition to Construction Project

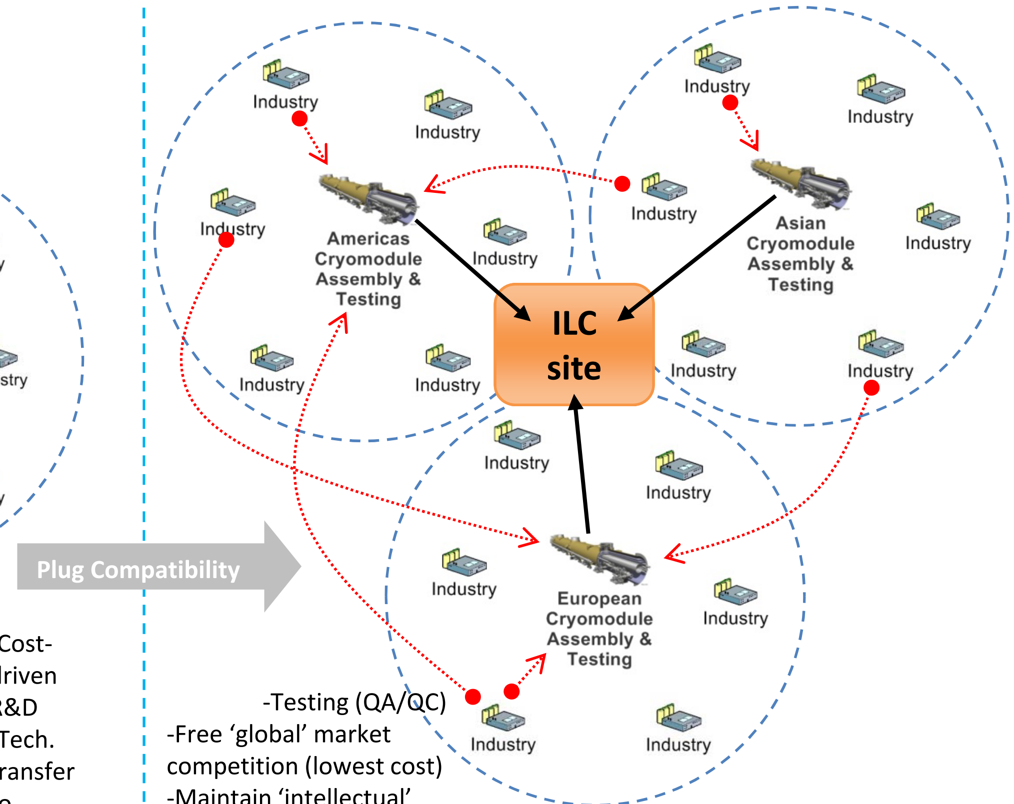
?

TD Phase 1	TD Phase 2	Approval	Construction Phase	Operations

2010

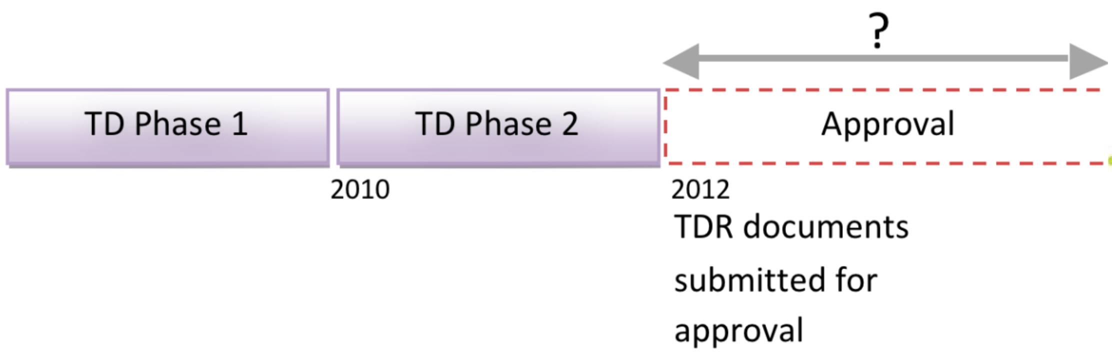
2012
TDR documents submitted for approval



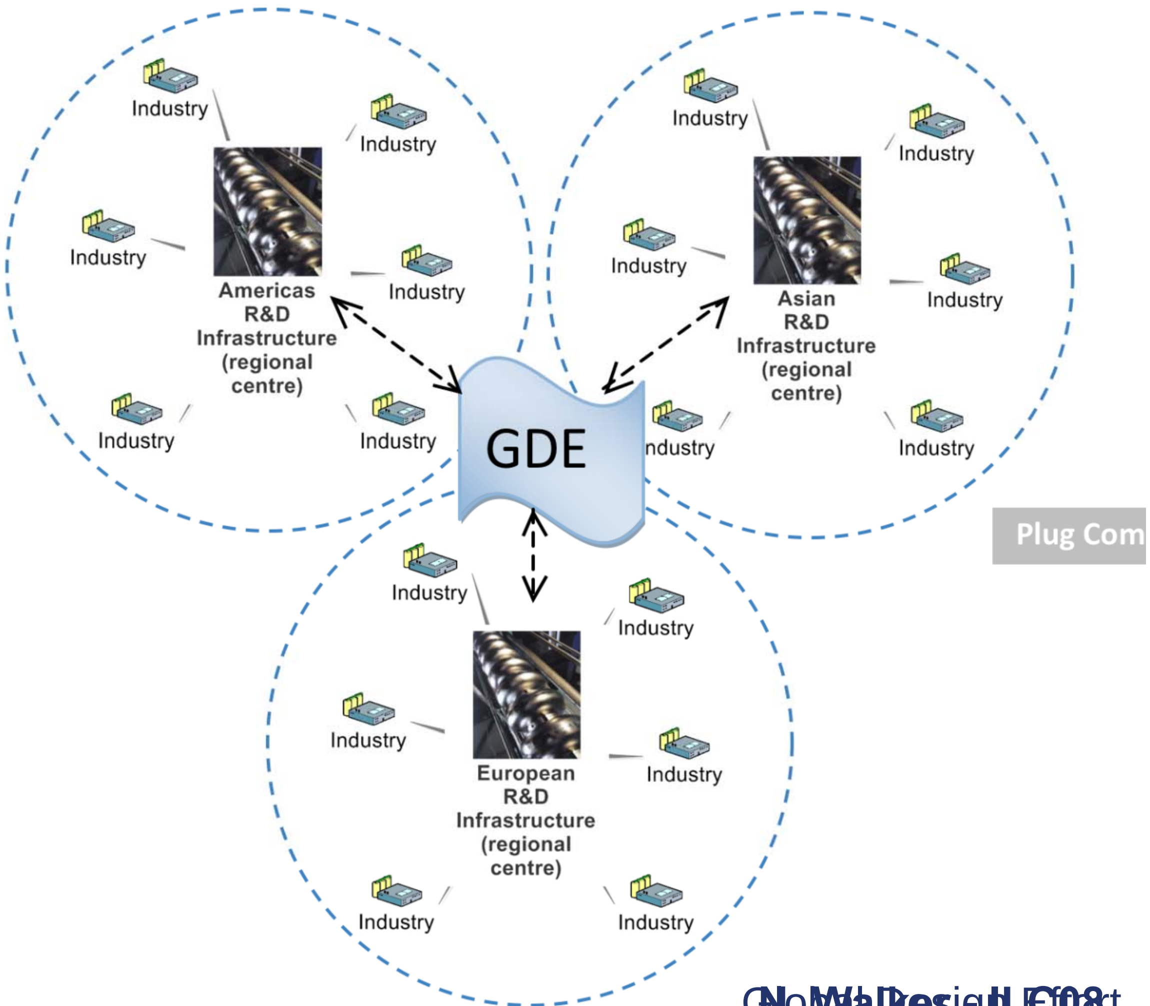


-Cost-driven R&D
-Tech. transfer to industry
-Innovation
-Intellectual engagement
-Expert base

-Testing (QA/QC)
-Free 'global' market competition (lowest cost)
-Maintain 'intellectual' regional expertise base



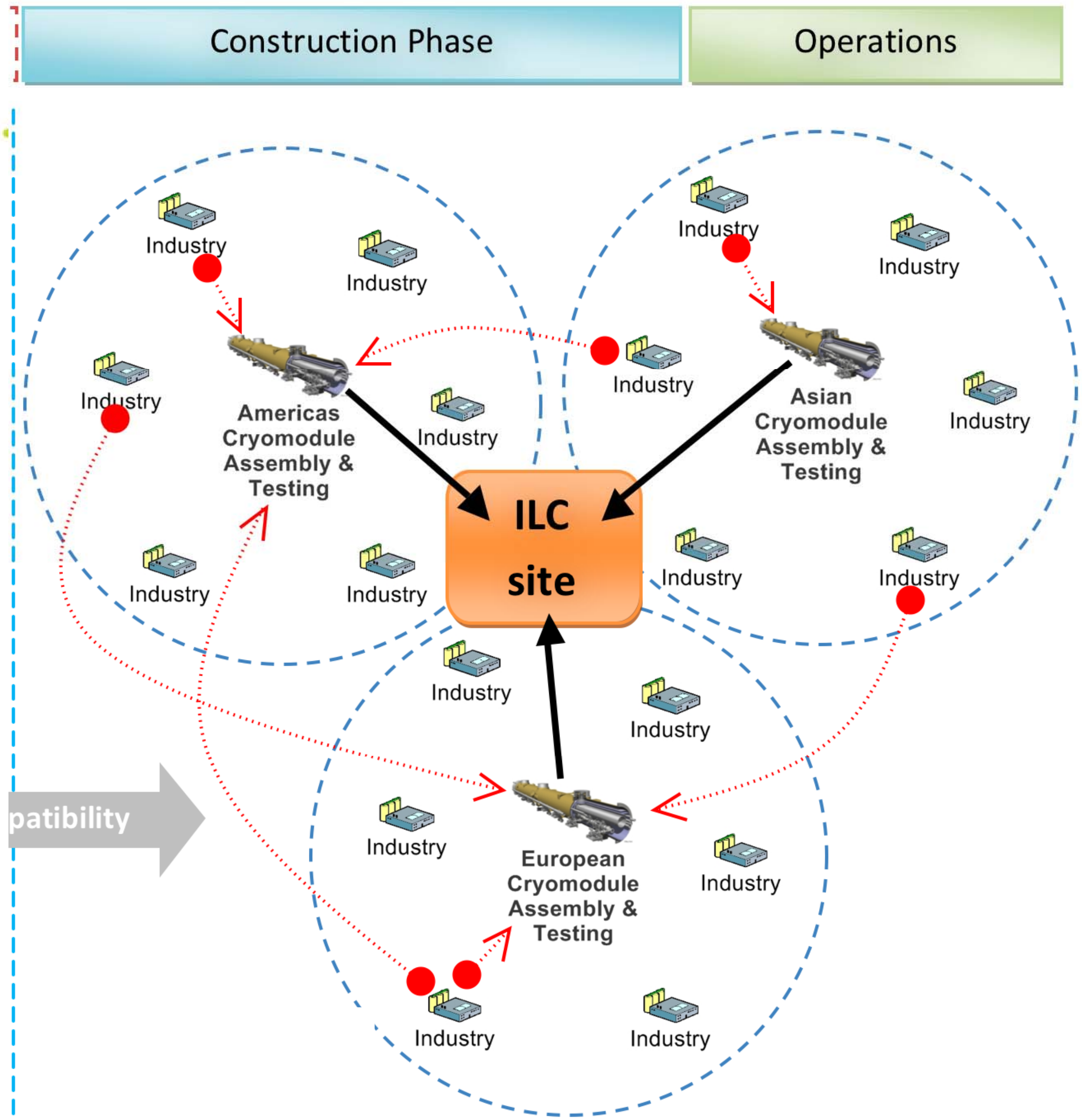
Global Cooperation: Plug-compatible Design and R&D



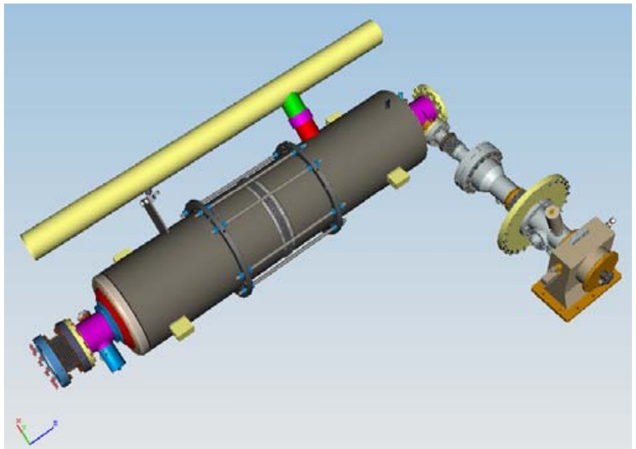
- Cost driven R & D process
- Technology transfer to Industry
- Innovation
- Intellectual engagement
- Expert base

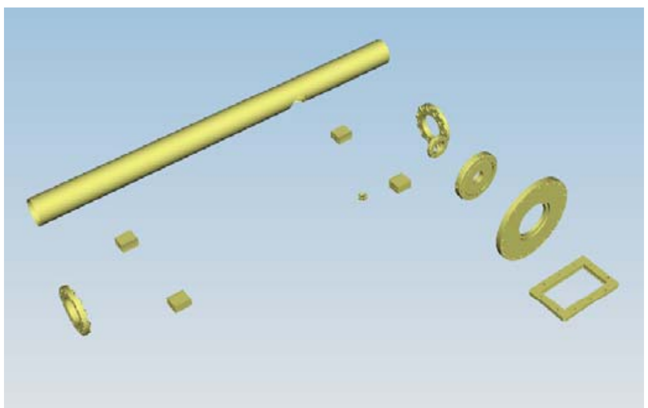
Global Production: Plug-Compatible Production

- Testing (QA/QC)
- Free 'global' market competition (lowest cost)
- Maintain intellectual regional expertise base



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