Coordinated

Global R&D Effort for the ILC SC Linac Technology

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KEK

and

ILC-GDE, PM for SCRF

To be presented in EPAC-08, Genoa, June 23, 2008

First of all

- I would thank the **EPAC** program committee for providing me (us) me (us) the opportunity to present this talk.

- This talk has been **prepared with "global effort"** for ILC-GDE GDE **SCRF** in participation and cooperation of

  - ***DESY, INFN, CEA-Saclay, LAL, CERN, Industries, in Europe,***
  - ***FNAL/ANL, SLAC, J-LAB, Cornell, (LLN), Industries in Americas,***
  - ***KEK, Kyoto, IUAC, RRCAT/BARC, TTIF, VECC, IHEP, Beijing, Ningxia, Ningxia, PAL, KNU, PNU, Industries, in Asia***

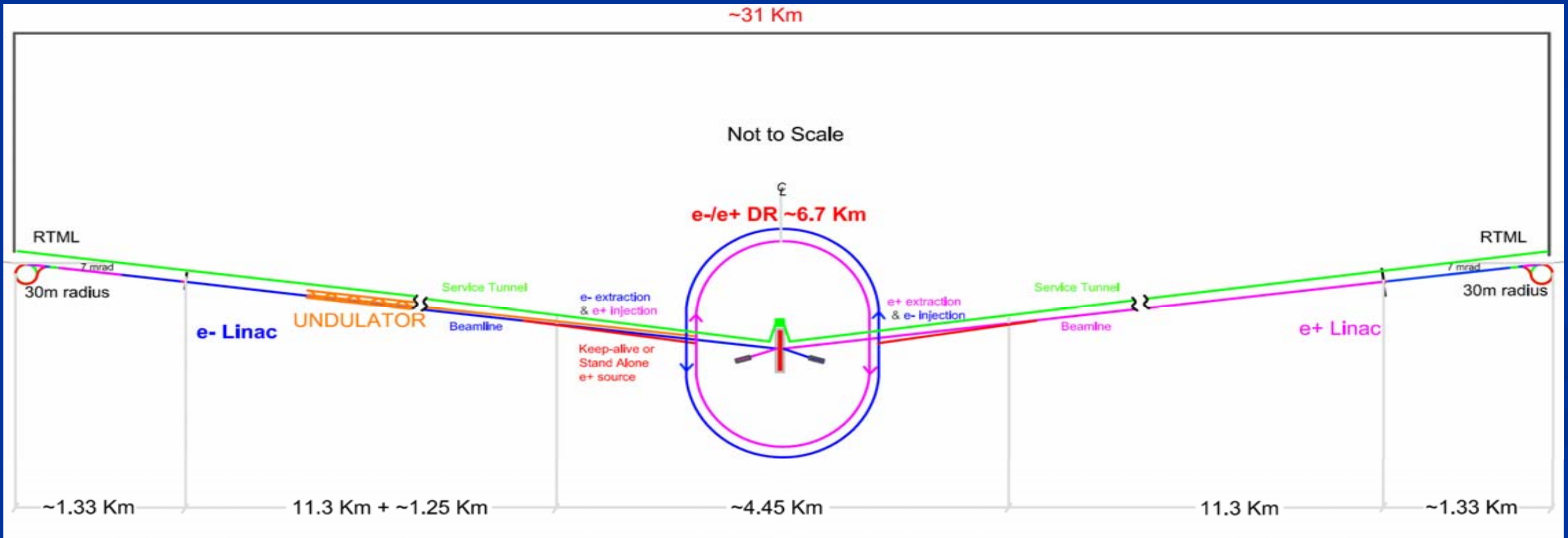
I sincerely thank their kindest **cooperation** and various advices. advices.

Outline

- **Introduction**
- **R&D Status**
  - Progress from Europe, Americas, and Asia
- **Plan for Technical Design Phase**
  - Cavity Gradient,
  - Plug-compatible Engineering
- **Global Effort**
- **Summary**

Reference Design Report published, 2007

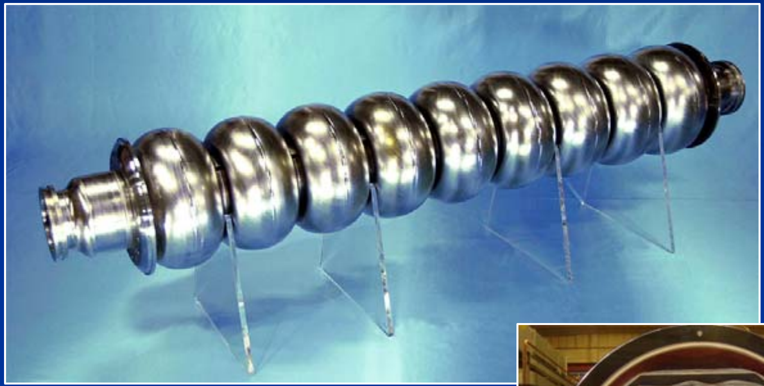
- **SC linacs (11 km) operating at 31.5 MV/m for 500 GeV**
- **Injector centralized**
  - Circular damping rings for e- and e+, and Undulator-based e+ source
- **Single IR with 14 mrad crossing angle**



Schematic Layout of the 500 GeV Machine

Why Superconducting?

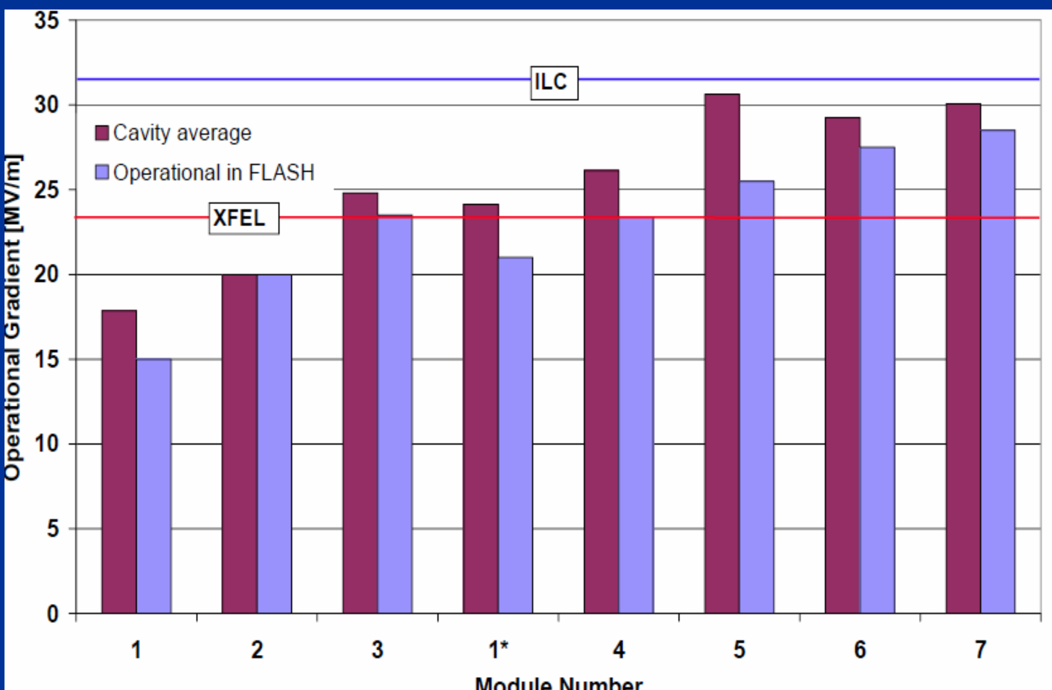
- **Advantages:**
  - Small RF surface resistance
  - Large Q
  - Low frequency
  - Large aperture and
  - Small beam loss
- **Further work required includes:**
  - Cryomodule (thermal insultation)
  - Cryogenics,
  - “E” Gradient to be improved



8 or 9 cavities in a cryomodule

“E” in Progress at TTF toward XFEL at DESY

- Progress of averaged field gradient in cryomodule at TTF, DESY,



- **ILC operation :**
  - **<31.5> MV/m**
- **R&D Status :**
  - **<~ 30> MV/m**
  - meeting XFEL requirement

Toward Technical Design Report

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

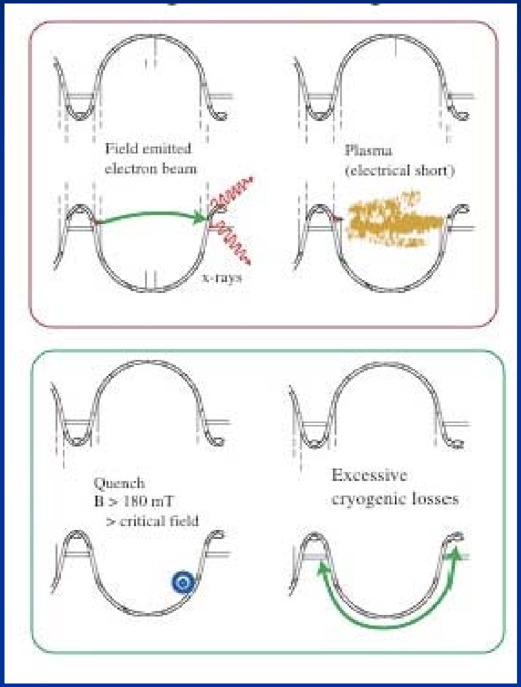
Reference Design, 2007 >> Technical Design Phase, 2008-2012

Goals of ILC-SCRF R&D

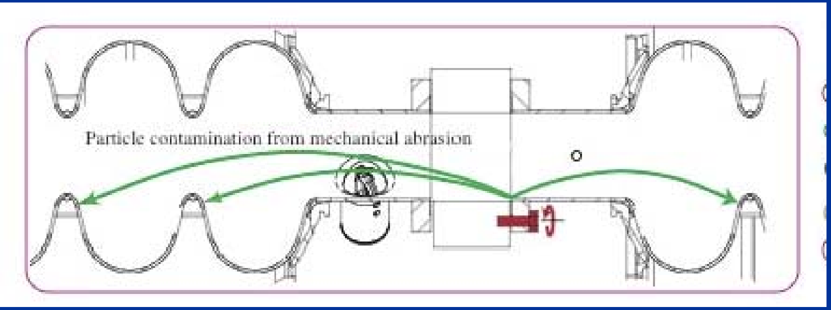
- **Field Gradient**
  - **35 MV/m** for cavity performance
  - **31.5 MV/m** (10 % lower) for operational gradient
    - to build two x 11 km SCRF main linacs
- **Cavity & Cryomodule Integration with**
  - **Plug-compatible concept to:**
    - Allow variety in component design
    - Encourage to extend innovative/creative work in R&D phase
    - Motivate practical ‘Project Implementation’ in “global effort”
- **System Engineering/Tests**
  - **Beam Acceleration**
    - with an accelerator unit of one RF-unit cotaining 3 crymodule
    - to demonstrate that the whole complex functions

Why Field Gradient Limited in SC Cavity ?

In fabrication



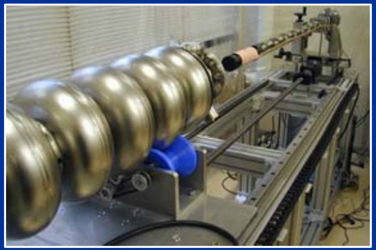
In integration

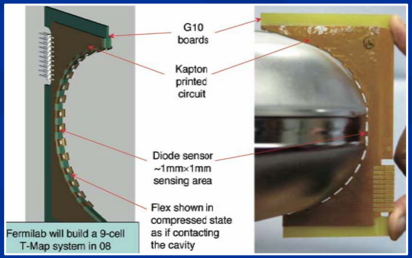


- **Field Emission**
  - due to high field
    - around "Iris"
- **Quench**
  - caused by surface heating from dark current or magnetic field penetration.
    - around "Equator"
- **Contamination**
  - during assembly

Cavity R&D Efforts Required

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

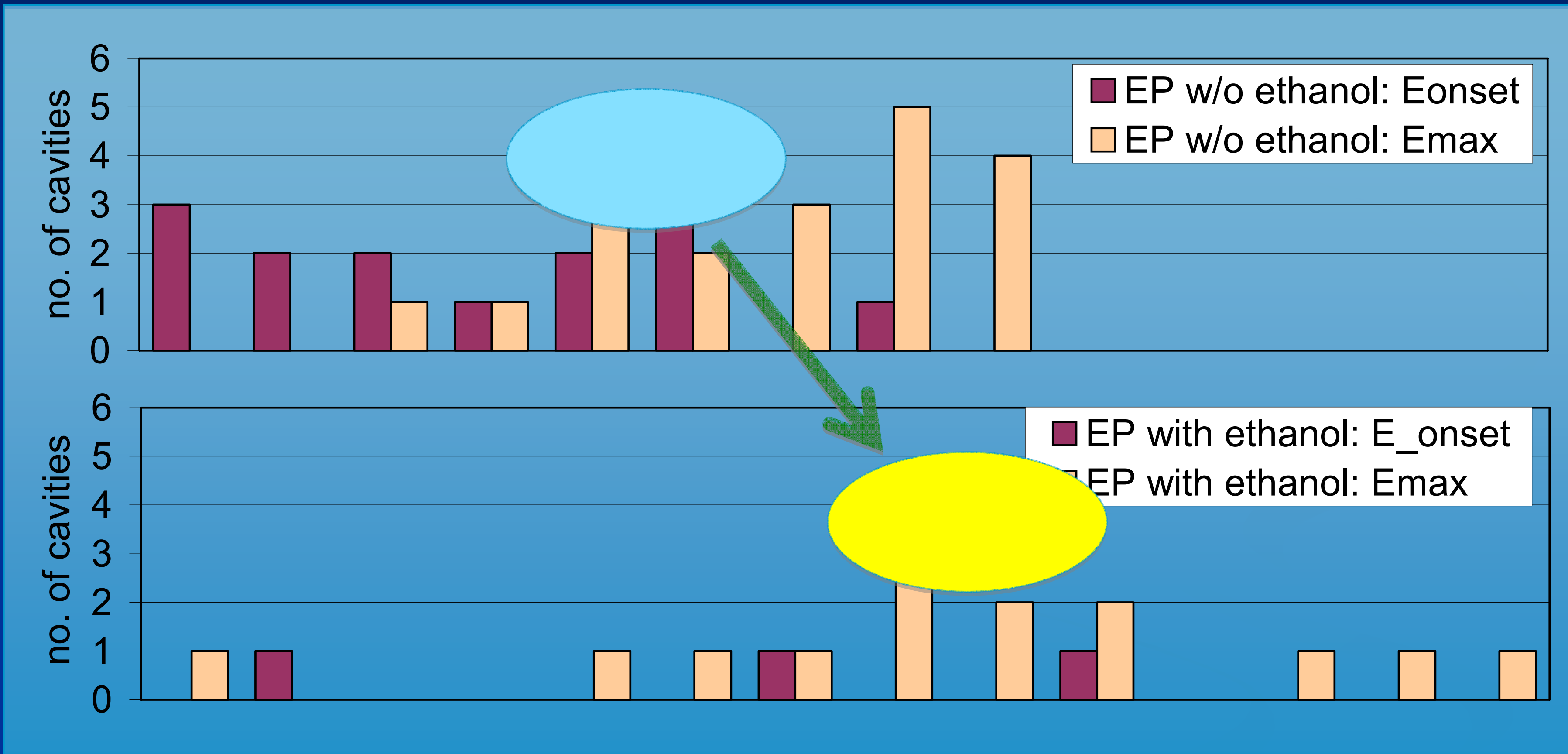




Progress in Cavity Basic R&D
2007-2008

- **Europe**
  - "Gradient" improved (<31.5> **MV/m**) with Ethanol rinse (DESY):
  - Large-grain cavity (DESY)
  - Surface process with baking in Ar-gas (Saclay)
  - Industrial (bulk) EP demonstrated **(<36> MV/m)** (DESY)
- **Americas**
  - Basic research and surface process (> <30> **MV/m**) (Americas)
  - Large-grain cavity **(<36> MV/m)** (J-lab)
  - Surface process facility (Fermilab/ANL)
  - Vertical (cold) test facility with thermometry (Fermilab)
- **Asia**
  - **Optical inspection** much improved (KEK)
  - Fabrication R&D (India/Fermilab), (China, Korea/KEK)
  - Surface-process R&D (India/KEK)

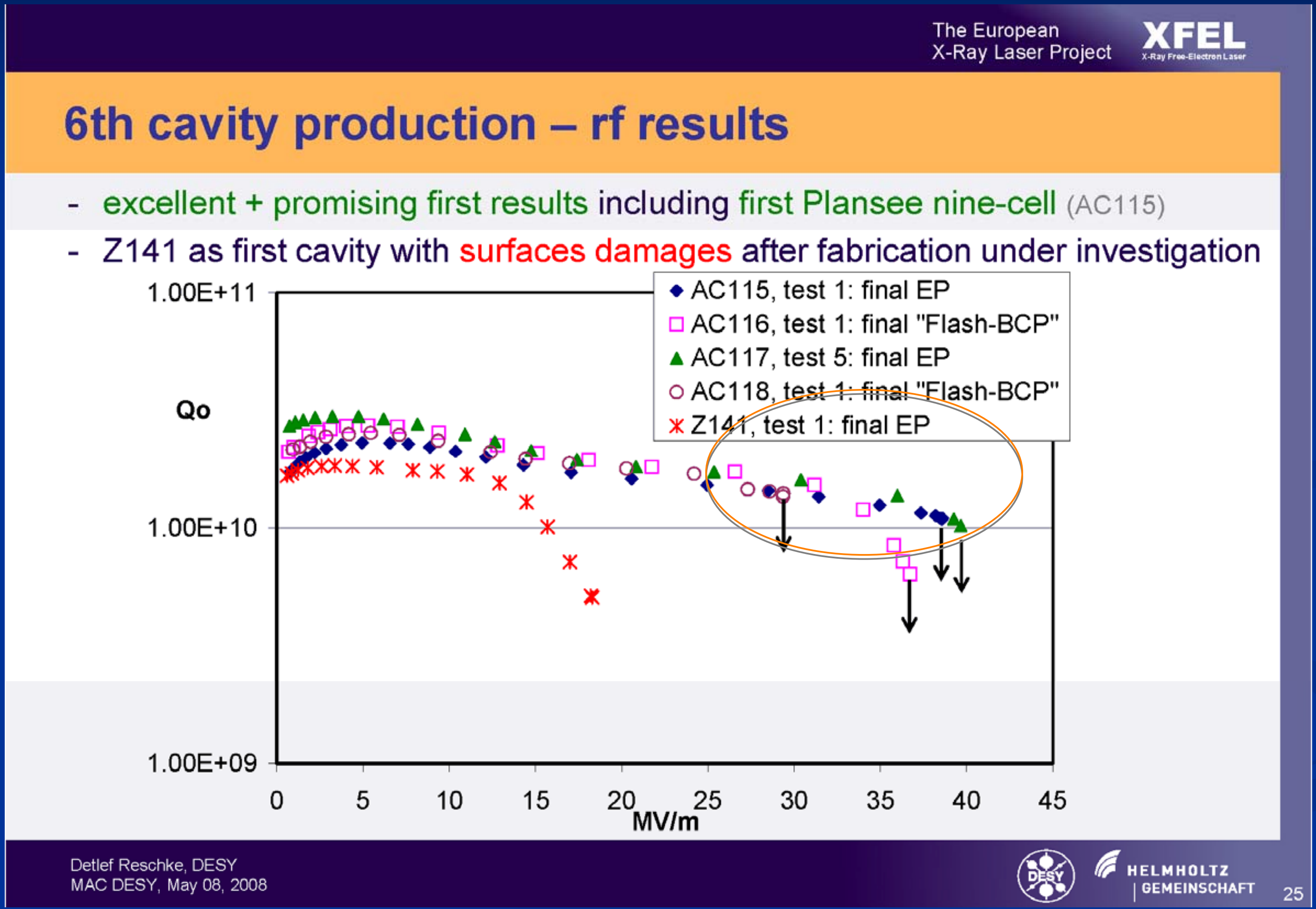
DESY 4th: Field Emission Analysis



20 MV/m 30 40

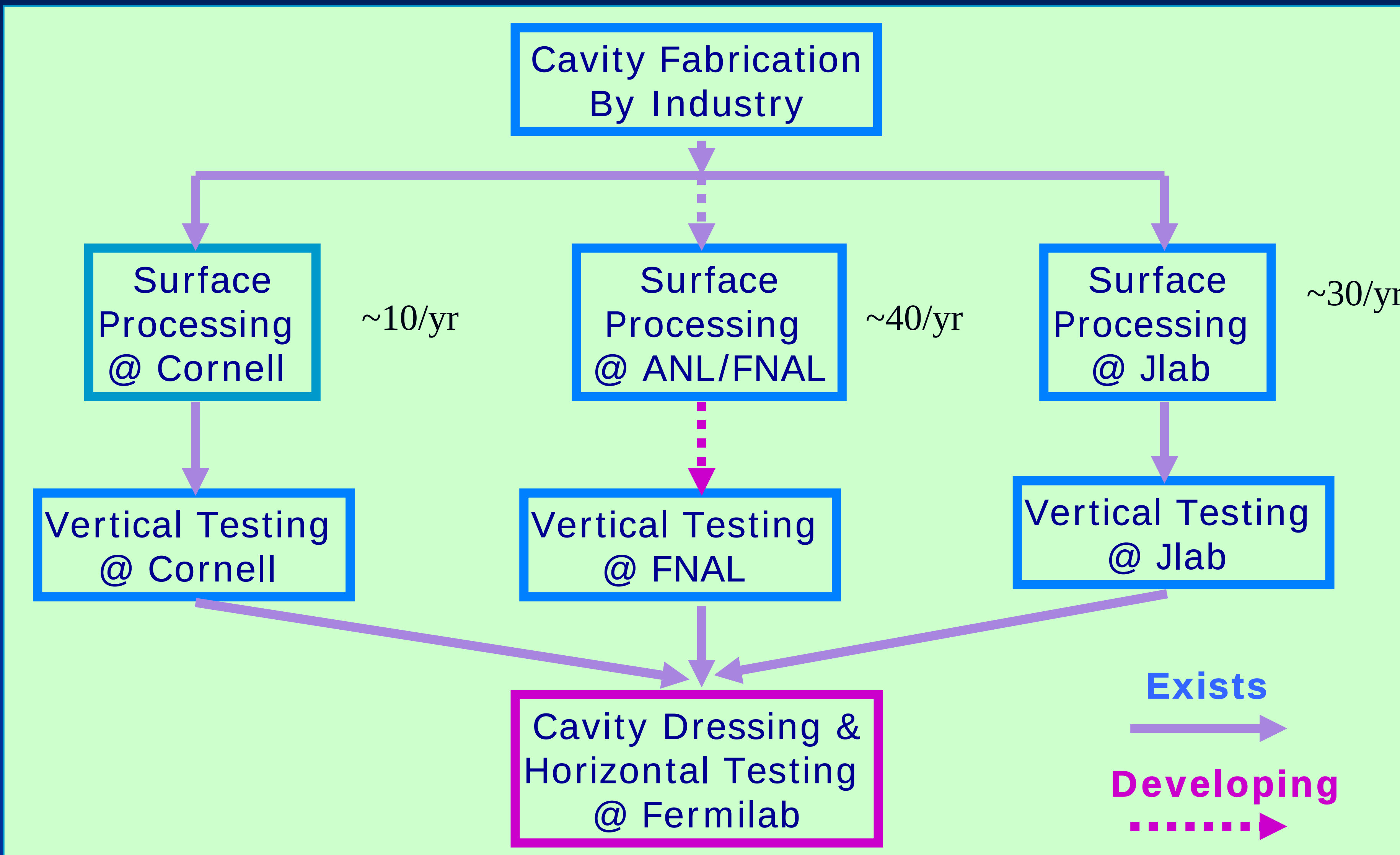
Cavity gradient shifted to High Gradient by ‘ethanol rinse’, excepting for “lowest two” due to different reason

Industrial EP at DESY/Plansee



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

Americas' Cooperation on Cavity Processing & Test

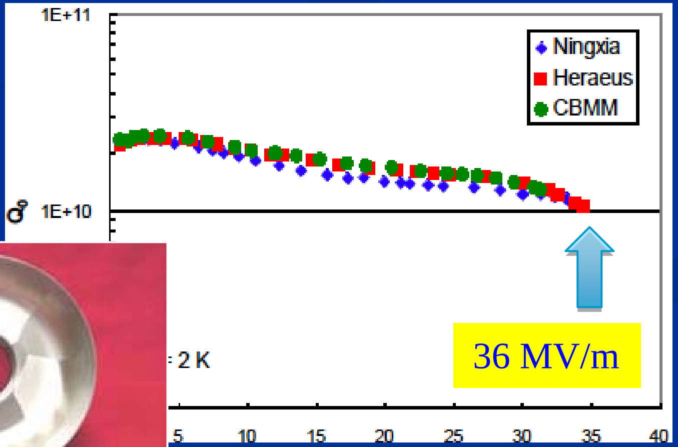


Basic Research at J-Lab and Cornell

- **J-Lab** (2006-2008)
  - Nine 9-cell cavities process and tested
    - six of them reached **>> 30 MV/m**
  - Large-grain cavity
    - Pionner work

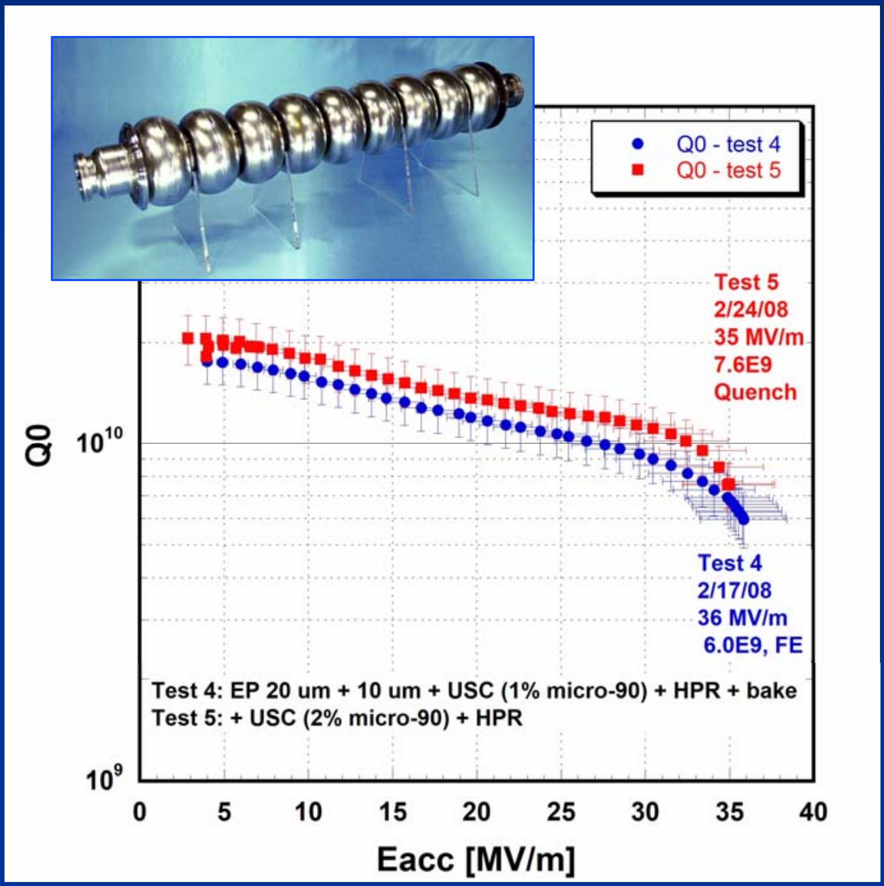
No.	Co-work	Cavity Name	No. Tests	E-max (MV/m)
1	Fnal/Accel	Accel-6	Test-4	38
2	Fnal/Accel	Accel-7	Test-2	42
3	Fnal/AES	AES-2	Tes-t4	32
4	Fnal/Accel	Accel-8	Test-3	31
5	KEK/MHI	Ichiro-5	Test-4	36
6	Fnal/Accel	Accel-11	Test-1	30

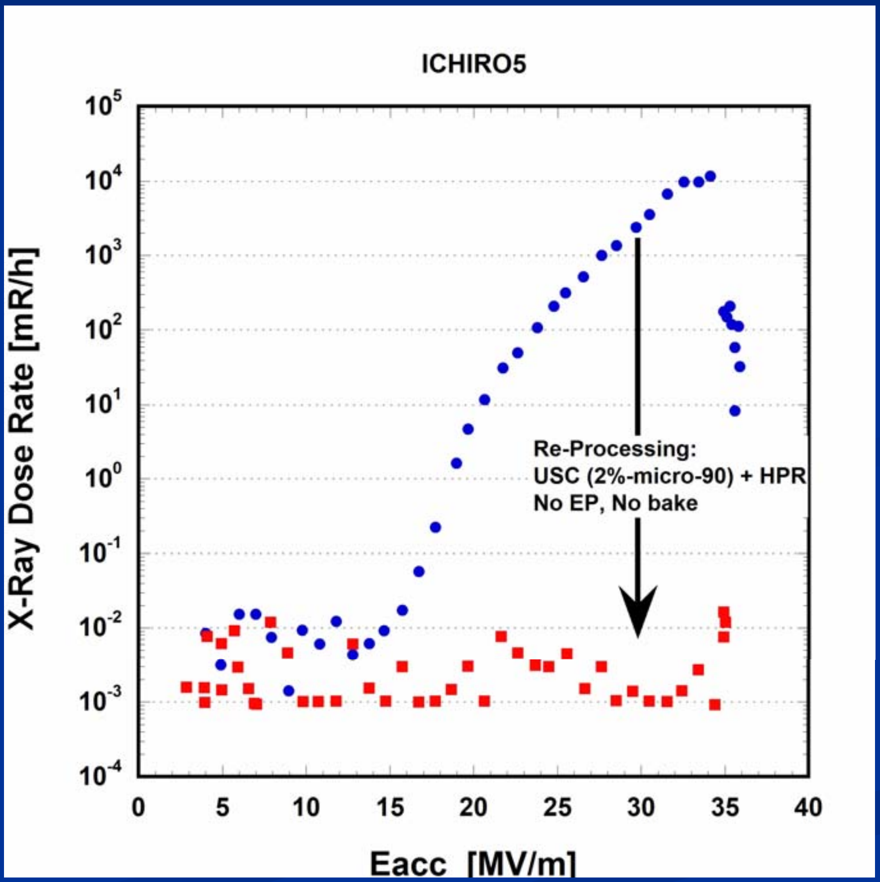
- **Cornell**
  - Re-entrant cavity
    - Single-cell study for best shape
  - Basic research
    - Highly systematic study



Surface Process Study on Low-loss Type Cavity

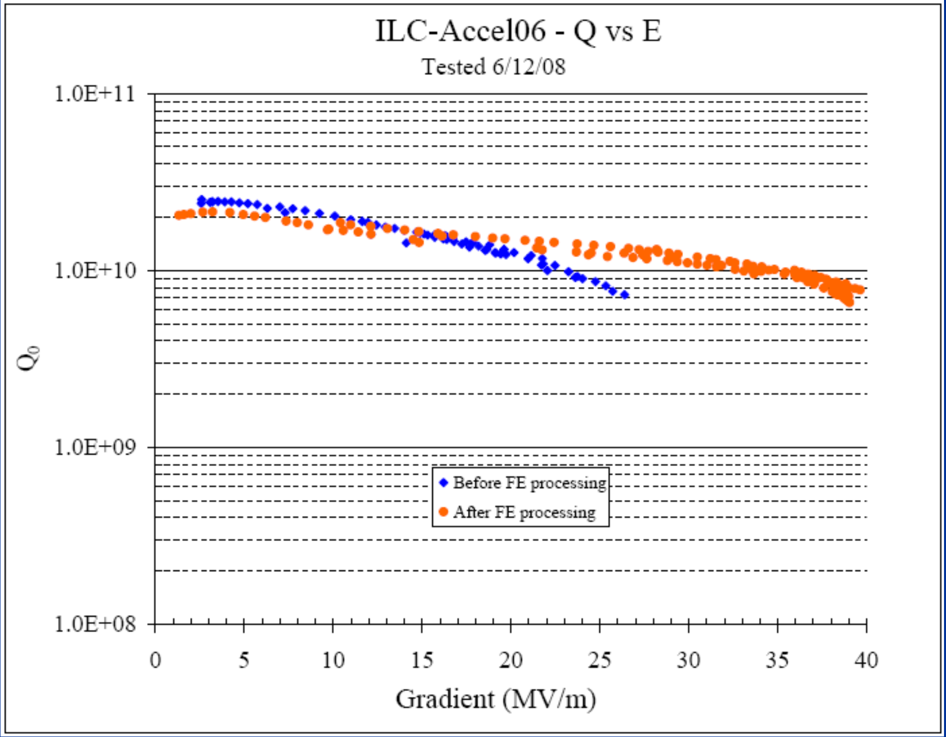
JLab - KEK





Ultrasonic Cleaning with degreaser very effective method to to reduce field emission

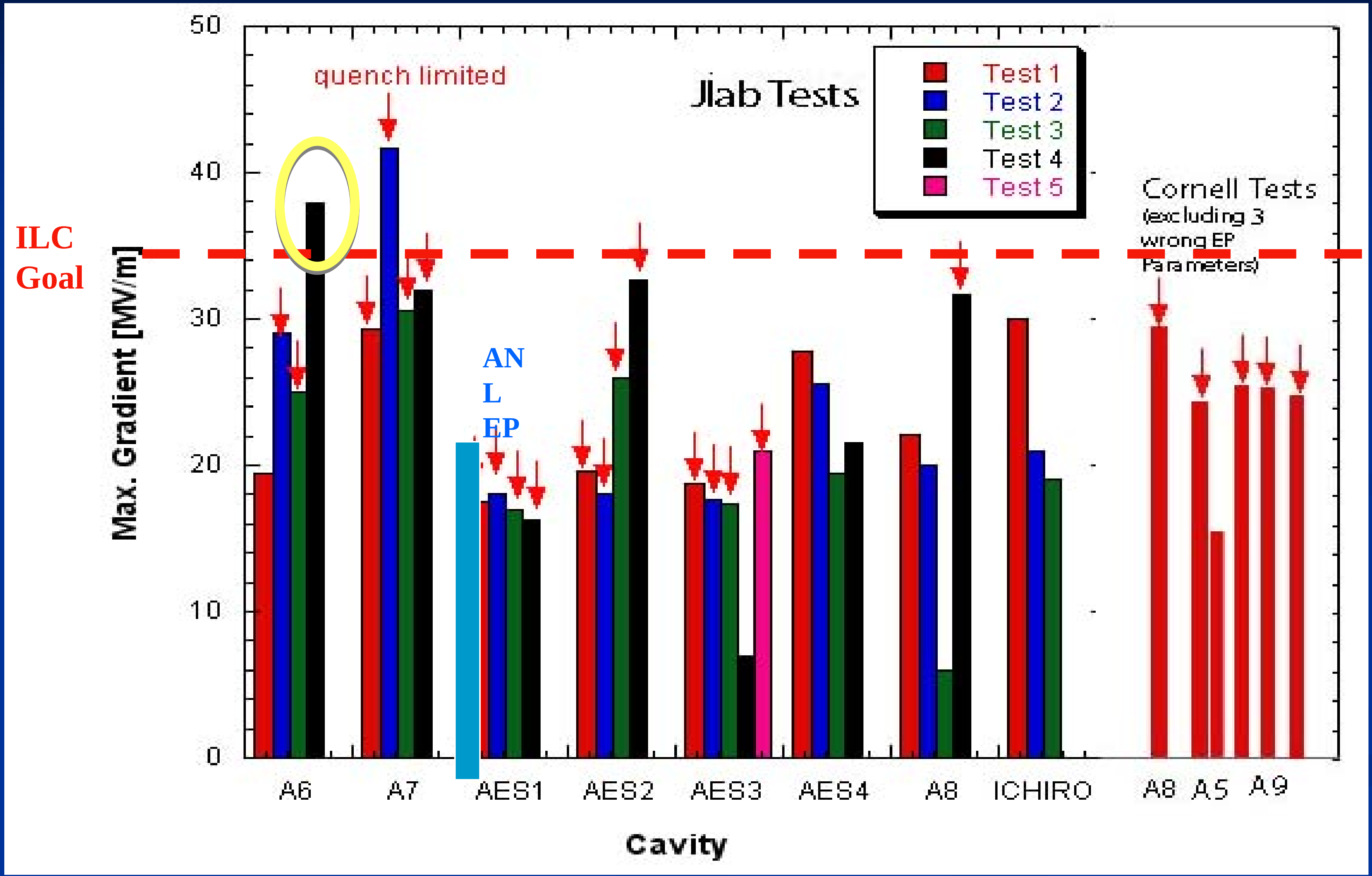
A result from Accel – JLab-FNAL Co-Effort
Accel-6: Q_o vs Gradient



We learn:

- **Accel:** fabrication quality
- **JLab:** processing quality
- **FNAL:** evaluation and coordination
- **Evidence:** long-distance cavity transport is possible possible without loss of performance, if the cavity is is evacuated and sealed.

9-cell Test Results in the Americas Region



Average A6-8, AES2,4 = 32 MV/m

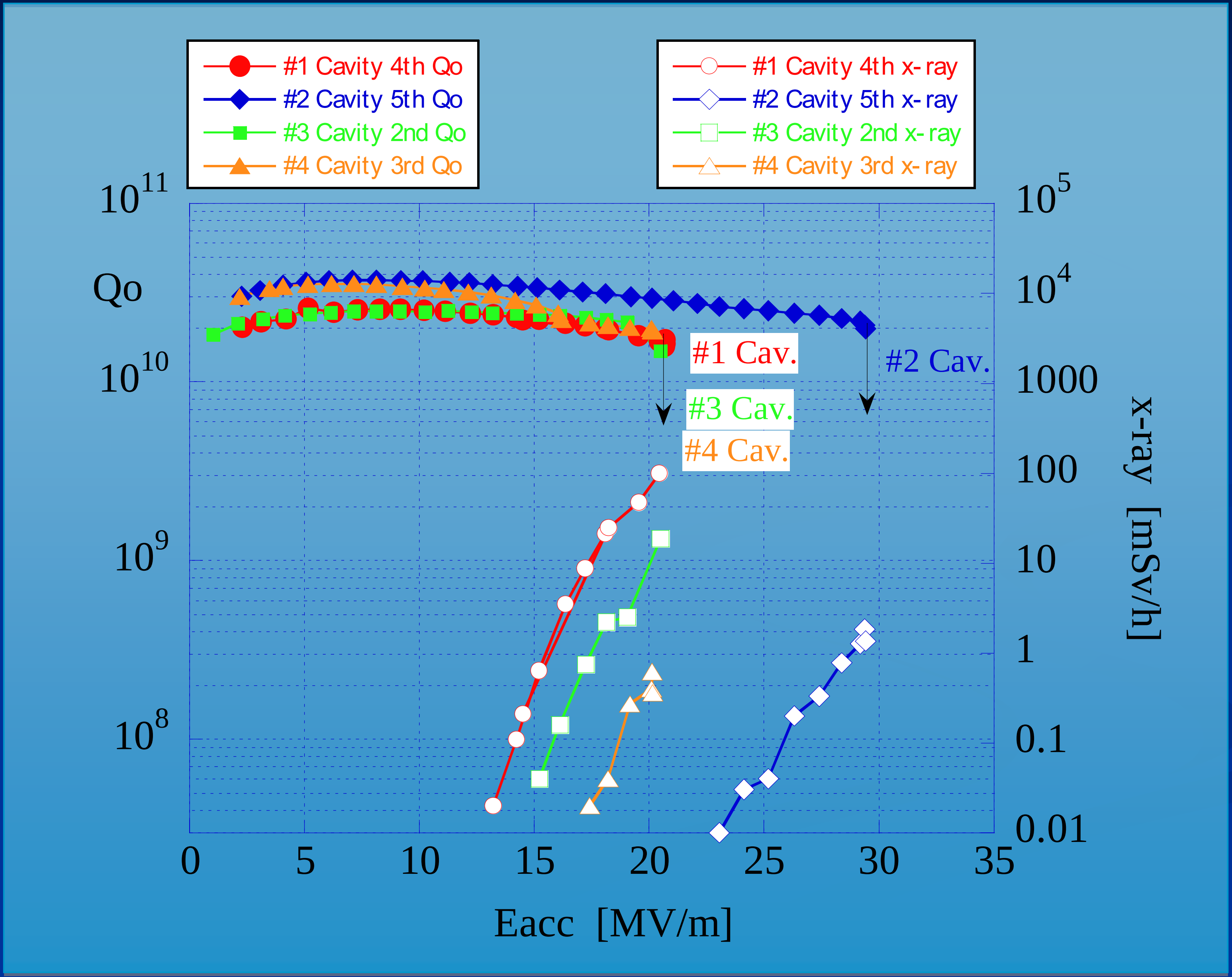
A9 reprocess at Jlab

First 9-cell electro-polishing performed at ANL, May 2008, (FNAL/ANL/JLab cooperation)

- Accel cavity A7 electro-polished; <removal> ~27 microns at ANL.
- Upon completion of low-pressure rinsing, cavity was filled with ultra-pure water and shipped **to JLab**.
- Ultrasonic cleaning, high-pressure rinsing, and assembly complete at J-Lab.
- Testing scheduled at **FNAL**, in June

Photos courtesy of Mike Kelly

STF TESLA-style 9cell cavity performance at KEK



SCRF Activities in China, Korea, India

- Participation in STF at KEK
  - Cryomodule and coupler design (IHEP)
  - 9-cell cavity fabrication (PAL)
  - LL single cell (IHEP)
  - Cold BPM development (PNU)
  - Cavity design/processing (PNU/KNU)
  - Joining STF operation (RRCAT)
- China
  - Cavity fabrication test (Deep drawing, EBW, CBP, etc) (IHEP, Beijing U.)
  - Large grain cavity (Ningxia)
  - Works other than SCRF (DR design, etc)
- Korea
  - Works other than SCRF (RTML design, cavity BPM, DR)
- India
  - Nb material investigation
  - Cavity fabricationR&D in cooperation with FNAL
  - Cavity process R&D in cooperation with KEK

Further High Gradient R&D Plan

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

for quench: **high resolution camera**

for field emission: confirm what are the residuals on the surface (SEM, XPS)

for Q-disease: confirm what is diffused into the surface (XPS)

2: **develop countermeasure**

for quench: (**remove beads & pits**, material impurities & defect scan, …)

for field emission: (ethanol **rinse,** degreaser rinse, sponge wipe, Ultra-sonic, HPR,...)

for Q-disease: (baking, Argon baking, …)

3: **verify** countermeasure

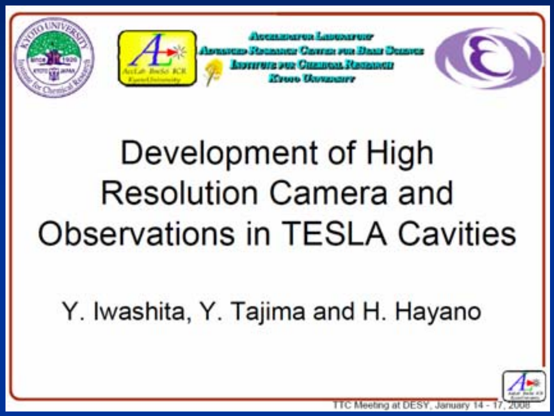
exchange problem/information of cavities and apply the countermeasure

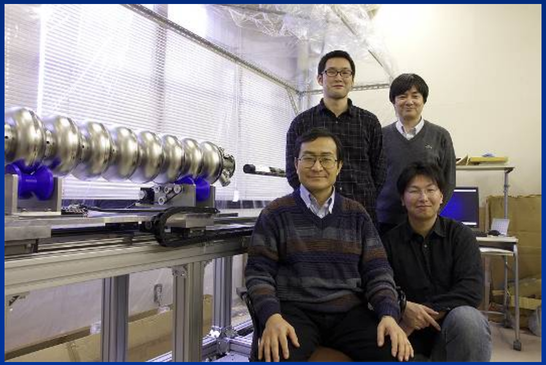
4: **Integrate statics** for the countermeasure

install the countermeasure world-wide, get **statistics**

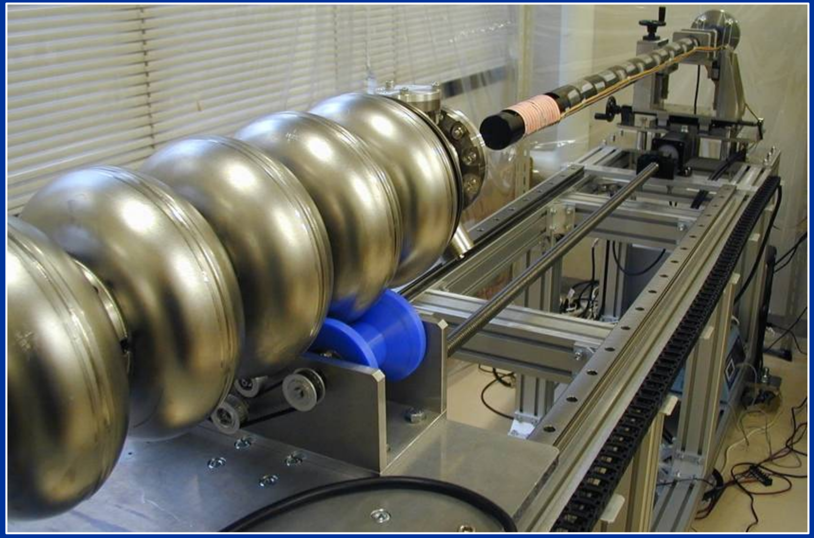
A Technology Developed at Kyoto/KEK collaboration

Visual Cavity Surface Inspection

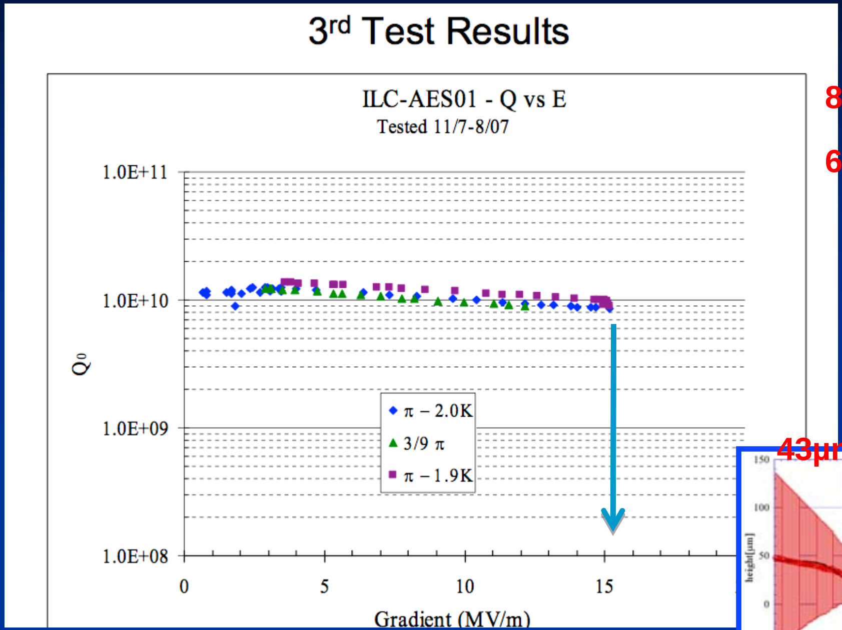




AES001 #3 cell 169°
Edge of heat-affected zone



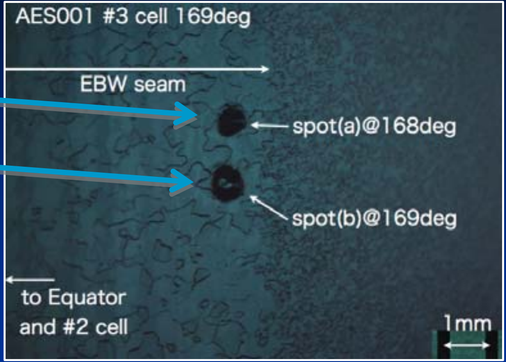
Very consistent with Thermal Measurement



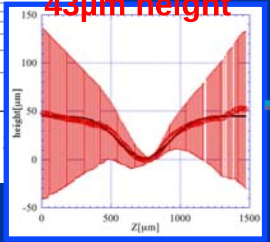
84μm height

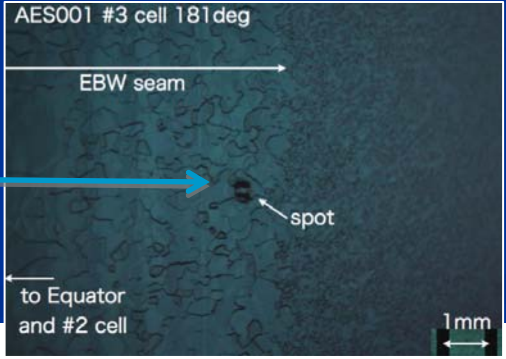
60μm height

~21mm

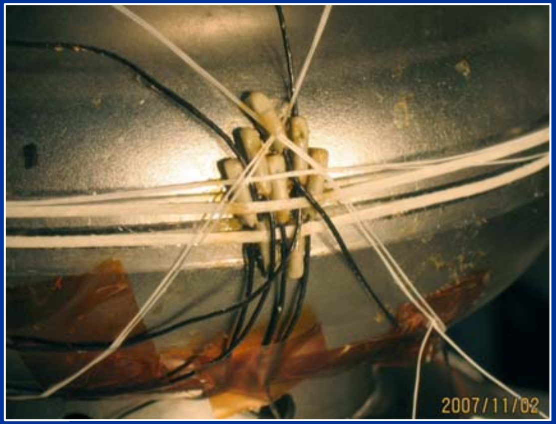


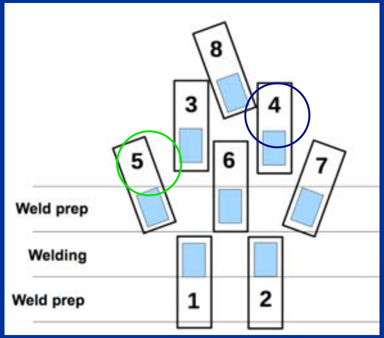
43μm height

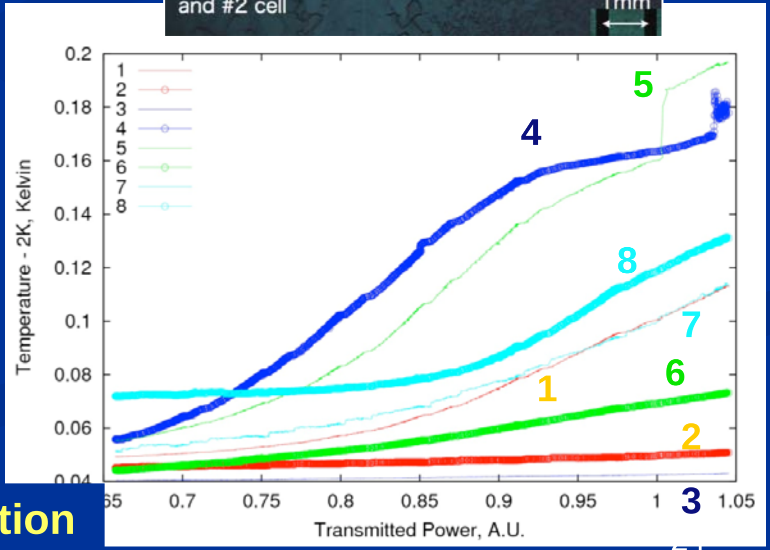




AES01 has hard quench at 15MV/m,
its location was identified by Cernox at FNAL.







Kyoto-camera found 3 spots in their exact location

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		**Optical inspection**
		(Tumbling)	(Optical Inspection)
Process	EP-1 (Bulk: ~150um)		
	Ultrasonic degreasing (detergent) or ethanol rinse		
	High-pressure pure-water rinsing		
	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 specificatio **Optical inspection**

w/o optical inspection

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		**Optical inspection**
		(Tumbling)	(Optical Inspection)
Process	EP-1 (Bulk: ~150um)		
	Ultrasonic degreasing (detergent) or ethanol rinse		
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	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**

w/ optical inspect.

Improve yield.

Progress in Cavity & Cryomdule Integration and Engineering (2007-2008)

- **Europe (EU)**
  - Input-coupler industrial assessment (for XFEL, LAL-Orsay)
- **Americas (Ams)**
  - Cryomodule engineering design (FNAL)
  - Cryogenics engineering (FNAL in cooperation with CERN)
  - SCRF Test Facility (New Meson Lab: NML) (FNAL)
- **Asia (AS)**
  - Cryomodule engineering design (KEK/IHEP)
  - Superconducting test facility (STF) (KEK)
- **A global effort (plan agreed)**
  - Plug-compatible integration and test in cryomodule:
  - Contribution : 2 cavities from **EU (DESY)**, 2 from **Ams (FNAL)**, 4 from **AS AS (KEK)**, and with cryomodule cooperation **(KEK, INFN)**

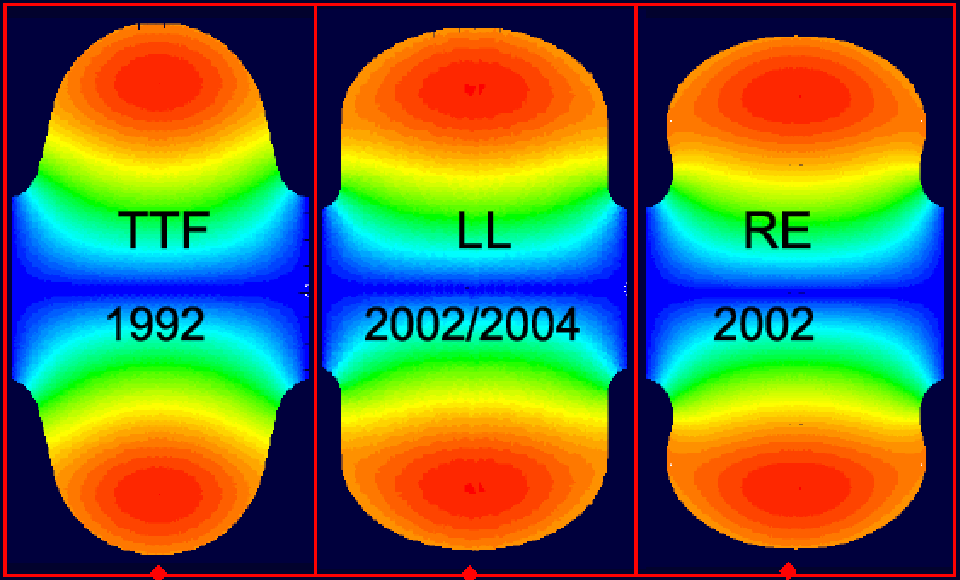
Why Plug compatible Integration and Engineering ?

- **Plug-compatible design**
  - To allow variety of component design with features, constraints in each each region/institution
  - To encourage continuous R&D effort specially to improve the field gradient and the yield
    - Cavity Type: Tesla, Low-loss (Ichiro), Re-entrant
    - Fine-grain or large grain
    - Fixed or tunable coupler ,
- **The concept to be examined,**
  - Cavity-Integration and test in **one Cryomodule with** global cooperation cooperation to reach 31.5 MV/m in the middle of TD phase (2010)

Cavity Design

from J.Sekutowicz lectuer Note

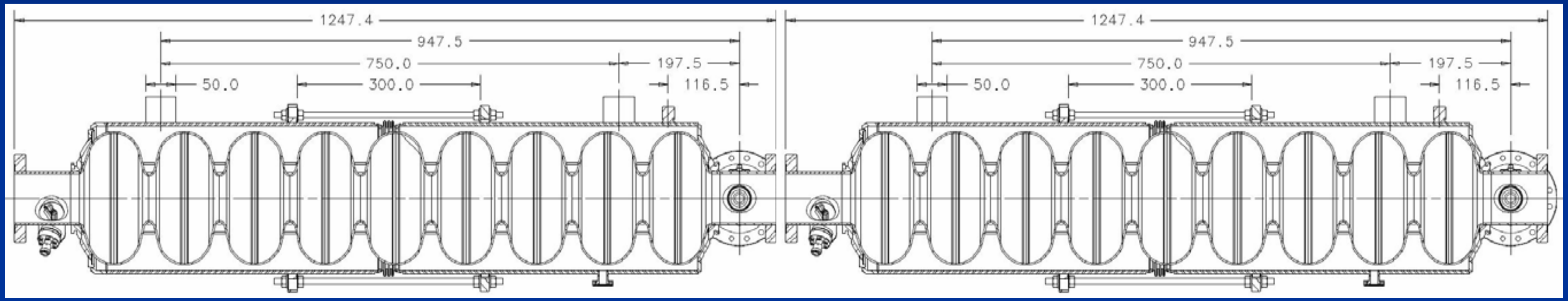
Example: 1.3 GHz inner cells for TESLA and ILC

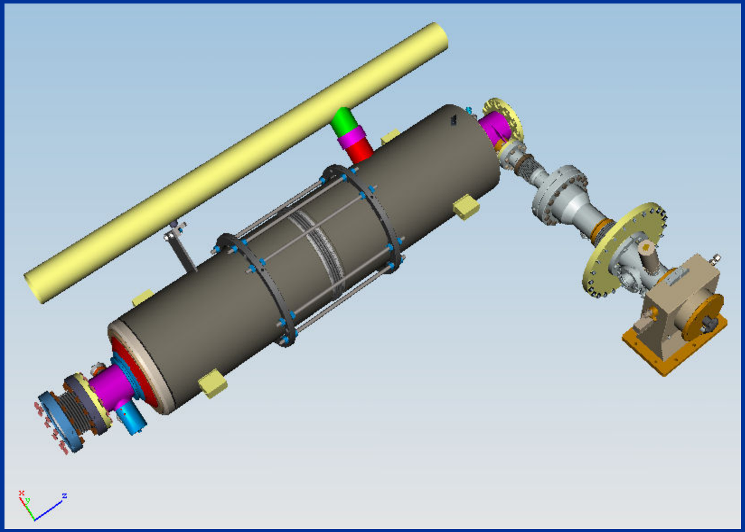


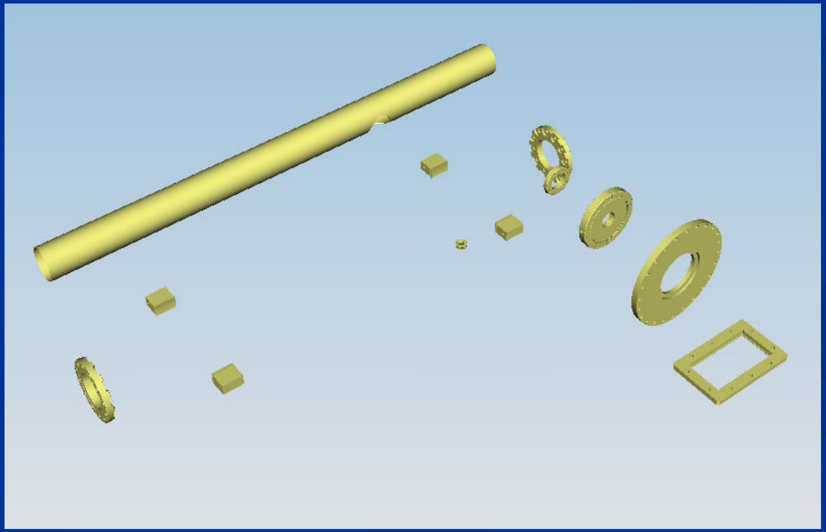
		TTF	LL	RE	
r_{irisb}	[mm]	35	30	33	
k_{cc}	[%]	1.9	1.52	1.8	field flatness
E_{peak}/E_{acc}	-	1.98	2.36	2.21	max gradient (E limit)
B_{peak}/E_{acc}	[mT/(MV/m)]	4.15	3.61	3.76	max gradient (B limit)
R/Q	[Ω]	113.8	133.7	126.8	stored energy
G	[Ω]	271	284	277	dissipation
R/Q*G	[Ω*Ω]	30840	37970	35123	dissipation (Cryo limit)

Plug-compatibly of Cavities

Important for Global Cooperation



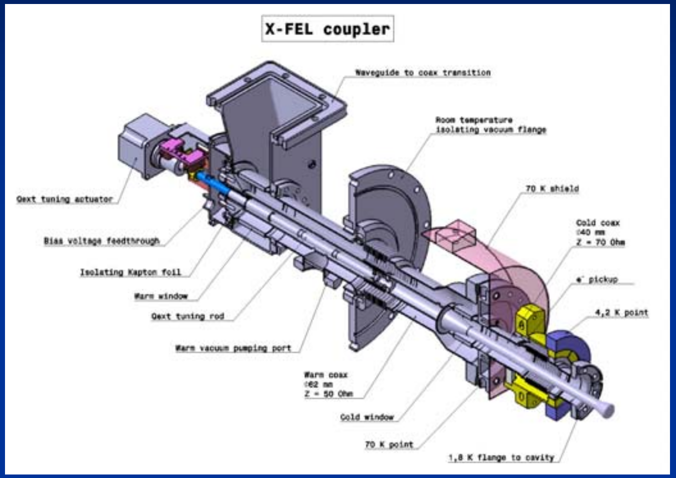




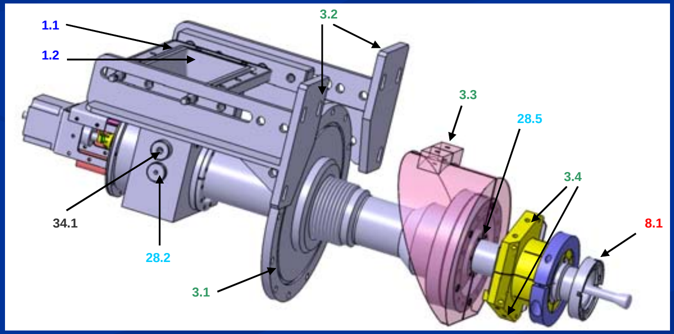
Input Coupler R&D at LAL-Orsay

1. Industrialization studies

- Optimize design for functionality
- Decrease number of parts and junctions
- Define precisely manufacturing processes
- Cost reduction



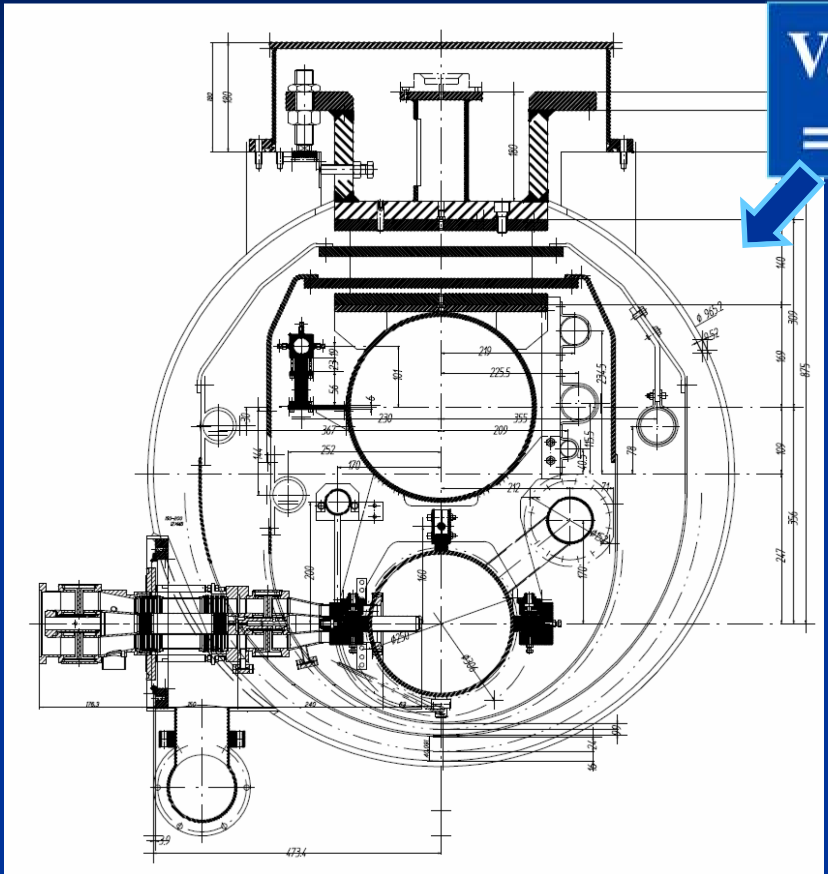
2- Define interfaces for plug-compatibility

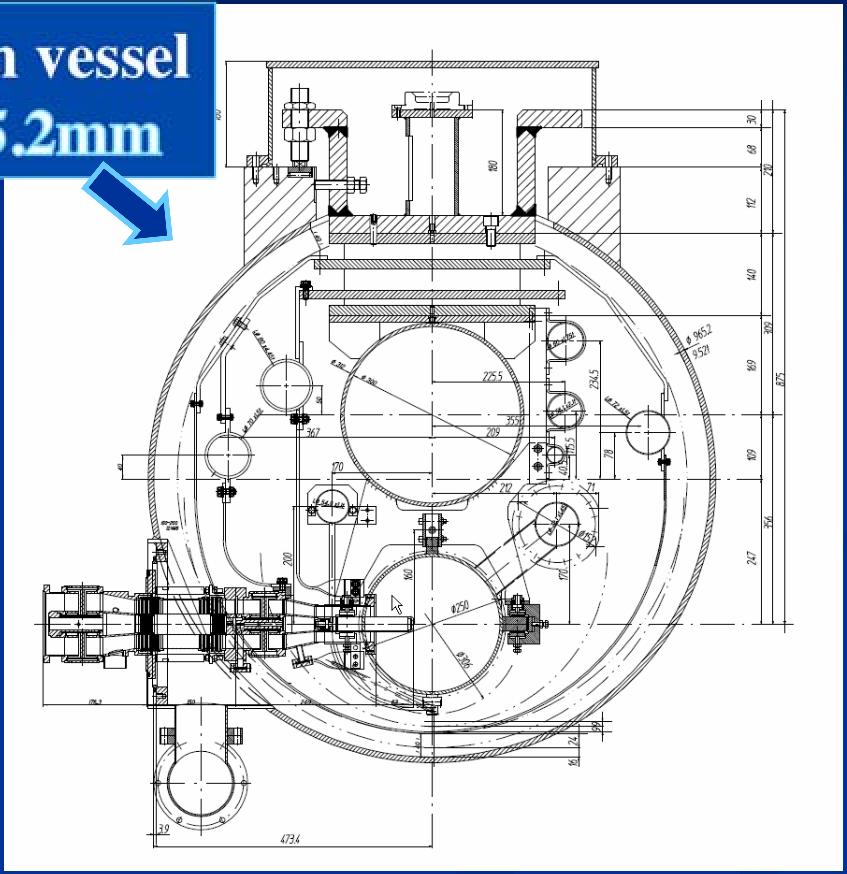


3- Develop new couplers:

TW 60

Study of the cryomodule cross-section





Vacuum vessel = ϕ 965.2mm

Two shields model based on TTF-III

One shield model

Cryomodule Assembly Facility at FNAL

- Goal: Assemble R&D Cryomodules
- Where:
  - **MP9**: 2500 ft^2 clean room, Class 10/100
  - Cavity dressing and string assembly
  - **ICB**: final cryomodule assembly
- Infrastructure:
  - Clean Rooms, Assembly Fixtures
  - Clean Vacuum, gas, water & Leak Check
- DESY Cryomodule "kit" assembled

ICB clean: Final Assembly fixtures installed

MP9 Clean Room

String Assembly

Cavity string for 1st CM

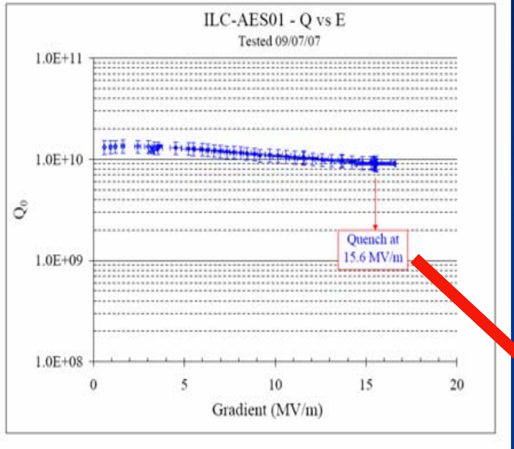
ILC SCRF R&D
Major Test Facilities

Facility	Host Lab	Operation start
TTF FLASH	DESY	1997
STF	KEK	2007~2008
ILCTA-ML	FNAL	2008~2009

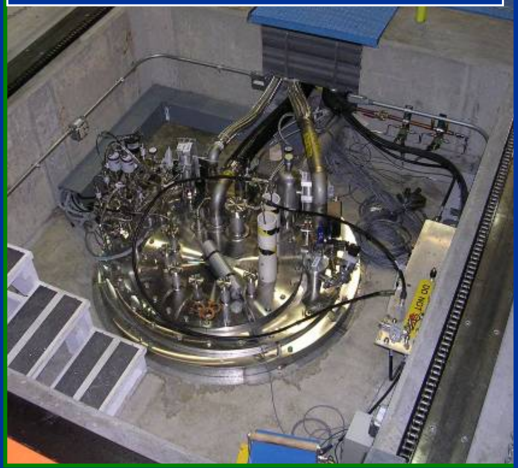
New Vertical Test @ FNAL

- Recently commissioned (IB1)
  - Existing 125W@ 1.8 K Cryogenic plant
  - RF system in collaboration with Jlab
  - Capable of testing ~50 Cavities/yr
  - Evolutionary upgrades:
    - Thermometry for 9-cells, 2 cavities at a time, 2 top plates, Cryo upgrades
    - Plan for two additional VTS cryostats
  - Ultimate capacity ~ 264 cavity tests/yr

Nine-cell Tesla-style cavity

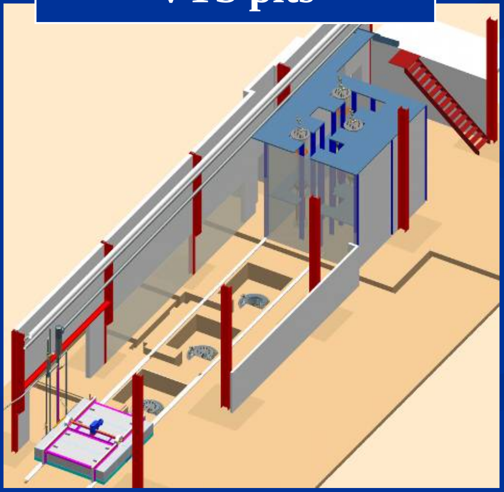


VTS Cryostat:IB1



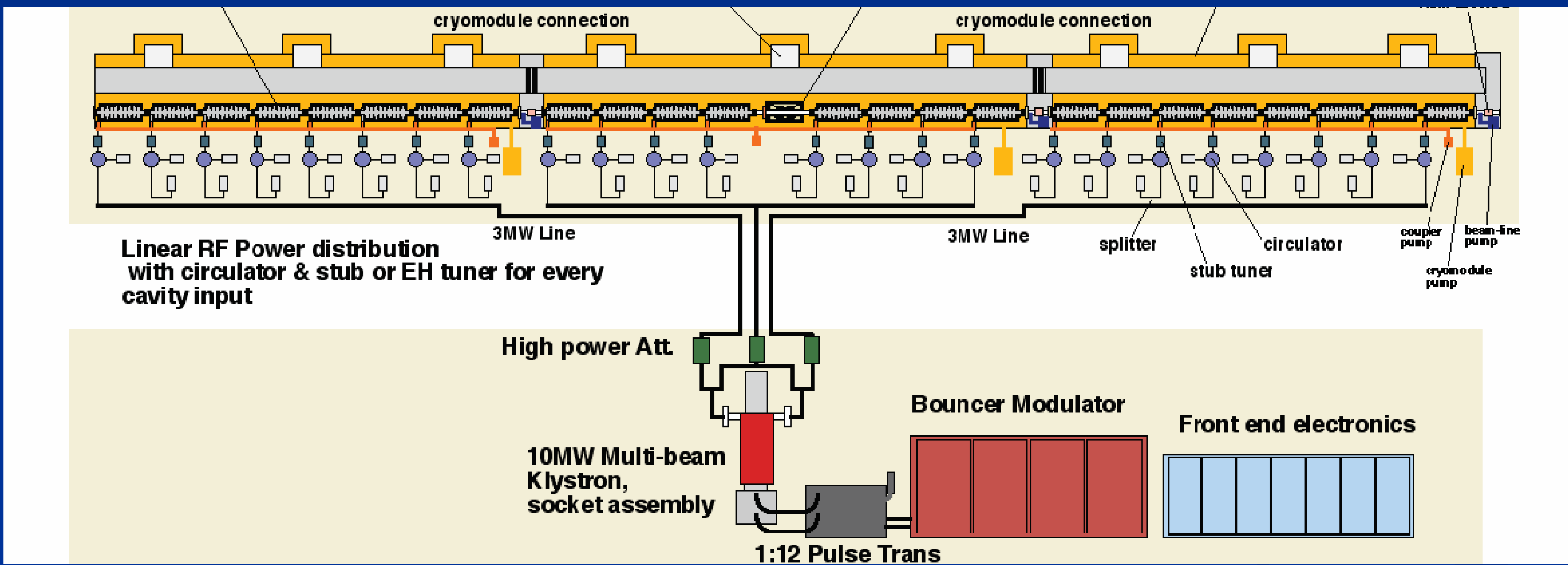
New RF & Control Room

Plan for 2 more VTS pits



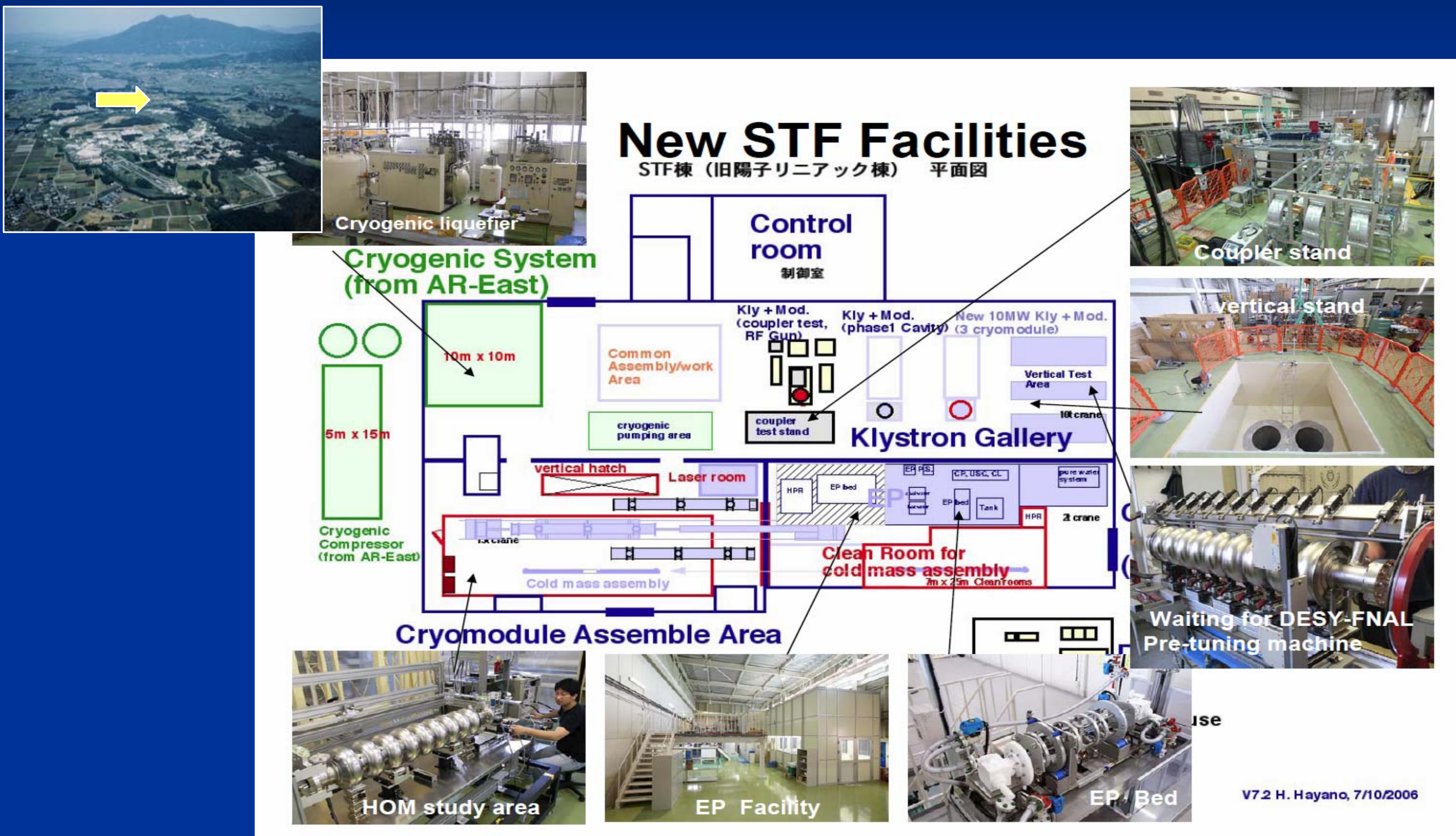
ML basic building block

ILC RF Unit: 3 CM, klystron, modulator, LLRF



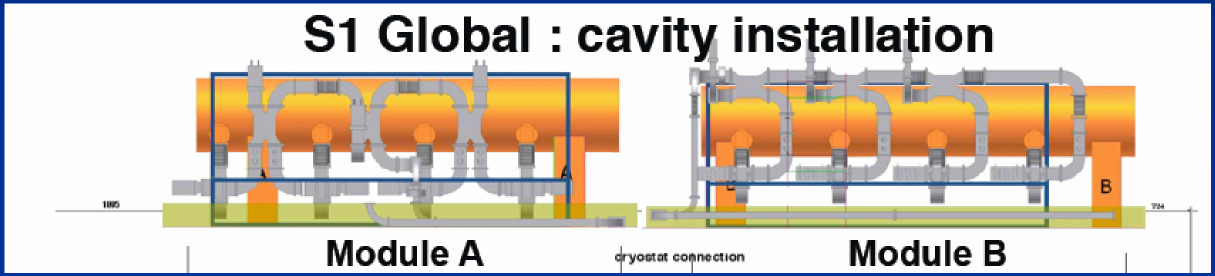
Baseline design now has 2 CM with 9 cavities, 1 CM with 8 cavities + quad

KEK: SCRF Test Facility (STF)

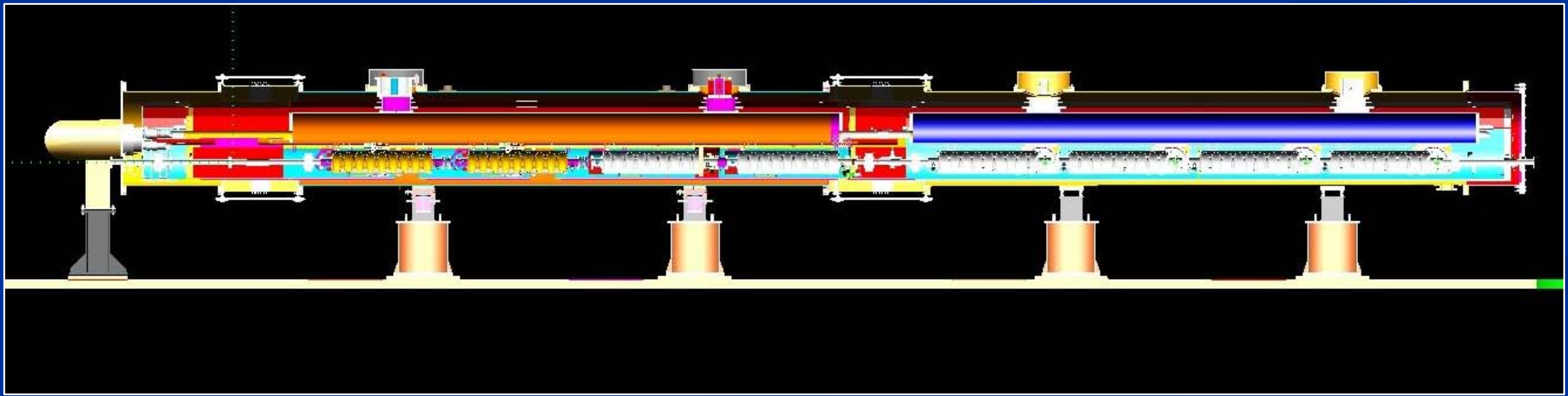


Cavity and Cryomodule Performance Test to demonstrate <31.5 MV> with Global Effort

String Test with:
- 2 cavities: DESY
- 2 cavities: Fermilab
- 4 cavities: KEK



Plug compatible integrattion to be demonstrated



Cryoomodule cooperation between KEK and INFN

STF-2: Beam Acceleration with One RF unit (3 cryomodule)

ILC RF unit test, in the existing STF tunnel,

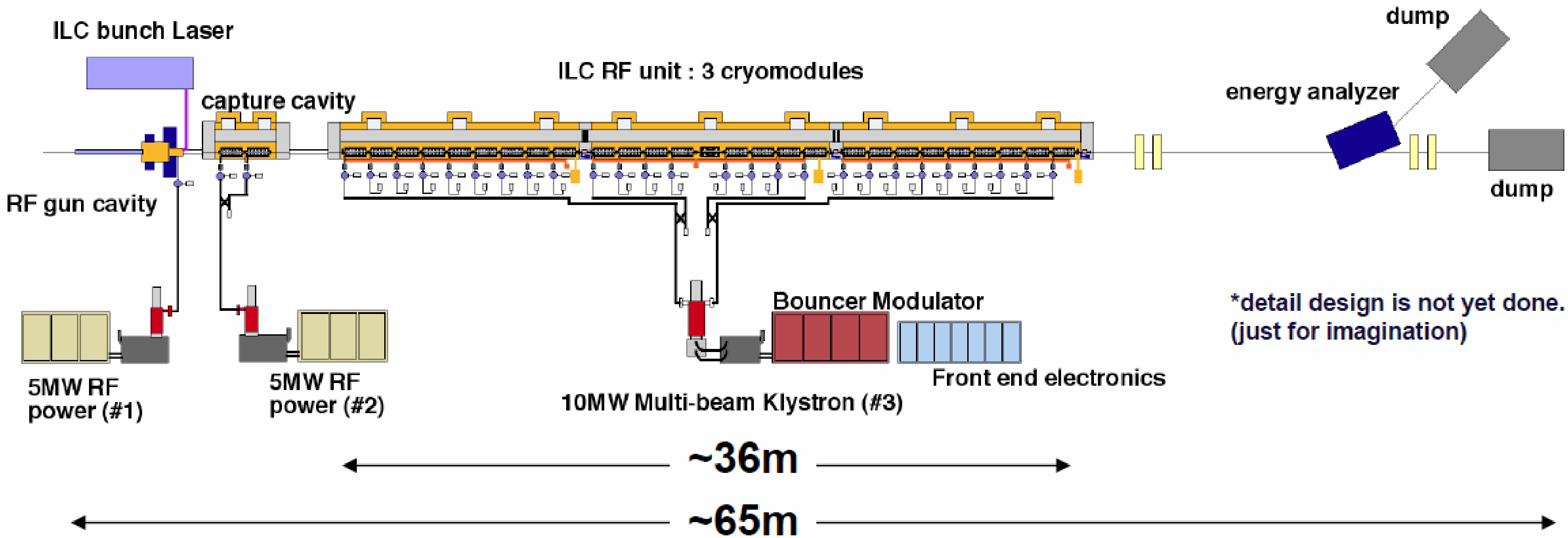
With ILC beam by L-band RF-gun.

design and preparation of vessel code : 2008

fabrication : 2009 - 2010

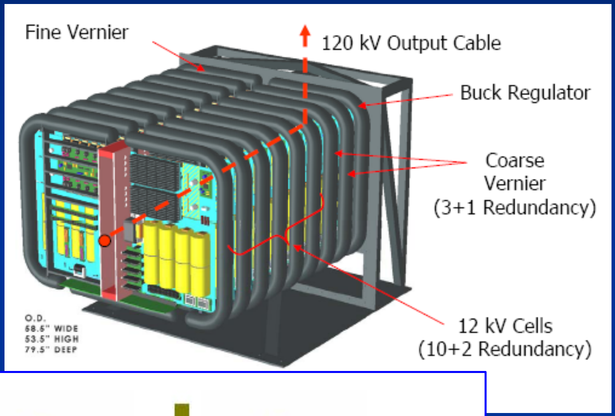
operation : 2011

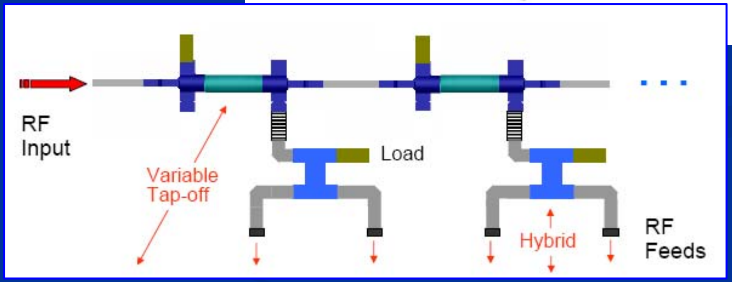
STF Phase 2 Plan

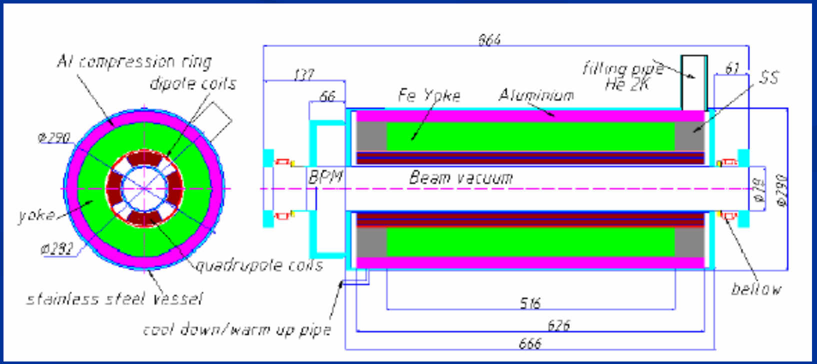


High Level RF and MLI R&D at SLAC

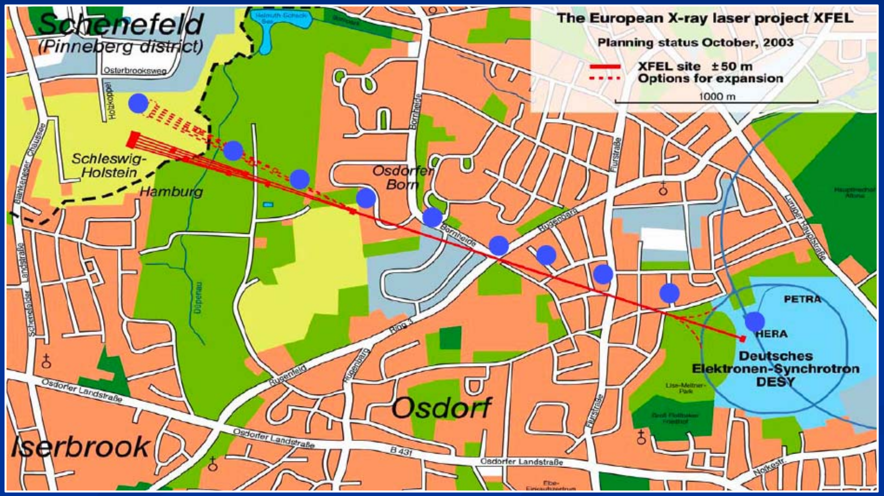
- **RF Power System**
  - be cost-effective
    - Advanced Klystron,
    - Marx Generators,
  - Distribution system
    - be efficient, tunable
- **Integration**
  - Beam handling
  - alignment
    - Control level < 100 nm





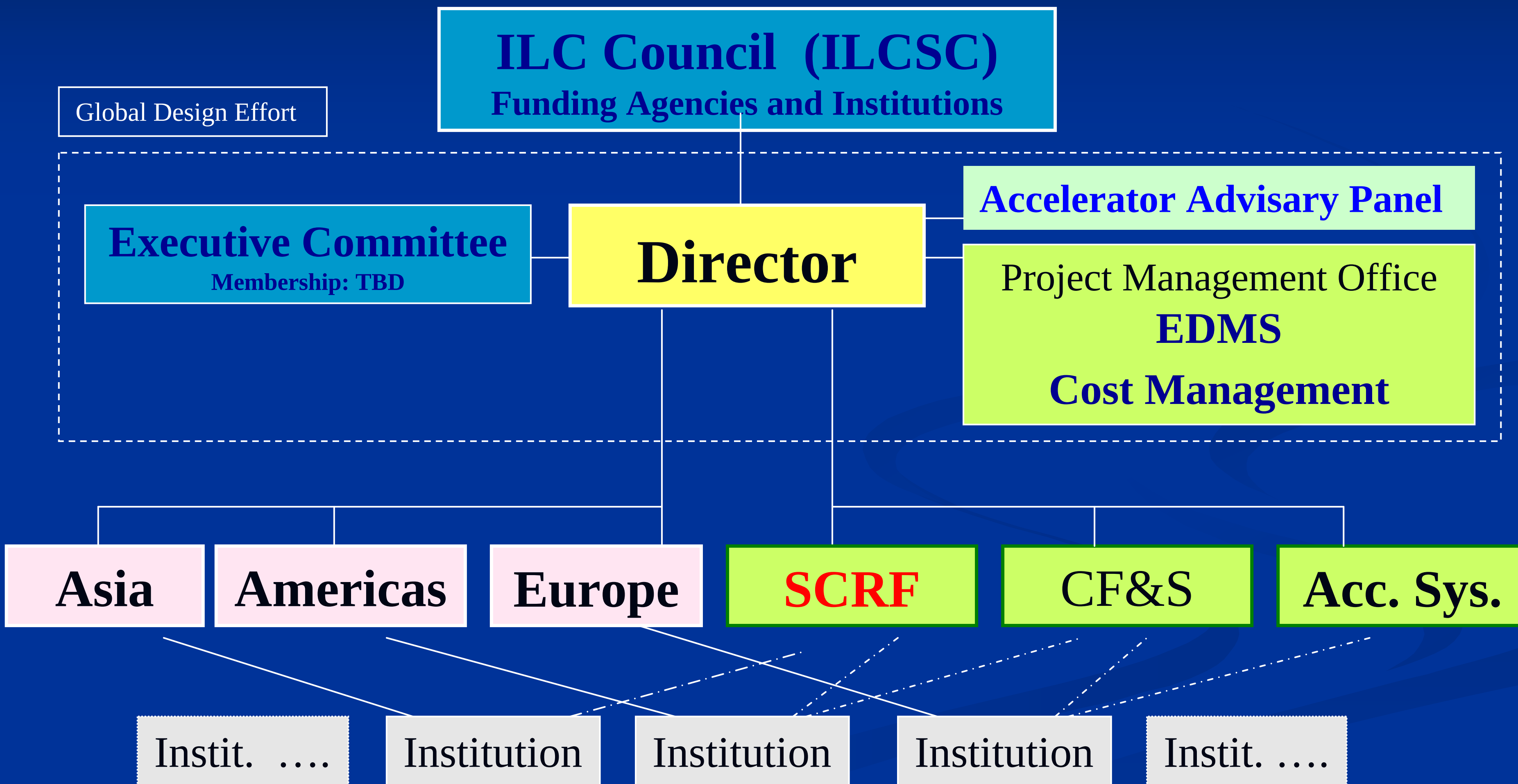


Important: Cooperation with XFEL



- SRF design gradient： 25 MV/m
- ~ 100 SCRF cryomodule, based on the experience at TTF, DESY,
- Leading SCRF industrialization (scale: **1/20 of ILC**, in coming 5 years)
- Very important to keep close cooperation with XFEL, on-going project.

ILC-GDE Project Management in TDP



How We Work Together?

- **Project Managers responsible for:**
  - Facilitating the world-wide technical development effort, effort,
  - Setting technical direction and executing the project for for realization of the ILC.

- **Regional Directors and Inst. Leaders responsible responsible for:**
  - Promoting, funding and authorizing the cooperation program.

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		Surface Process Yield > 50%			Production Yield >90%	
Cavity Integration: with 1 cryomodule			**Global effort** **<31.5 MV/m>**			
System Test with beam 1 RF-unit (3-modulce)		FLASH (DESY)			STF2 (KEK) NML (FNAL)	

R&D and technical design phased extended for two years, and **to be completed in 2012.**

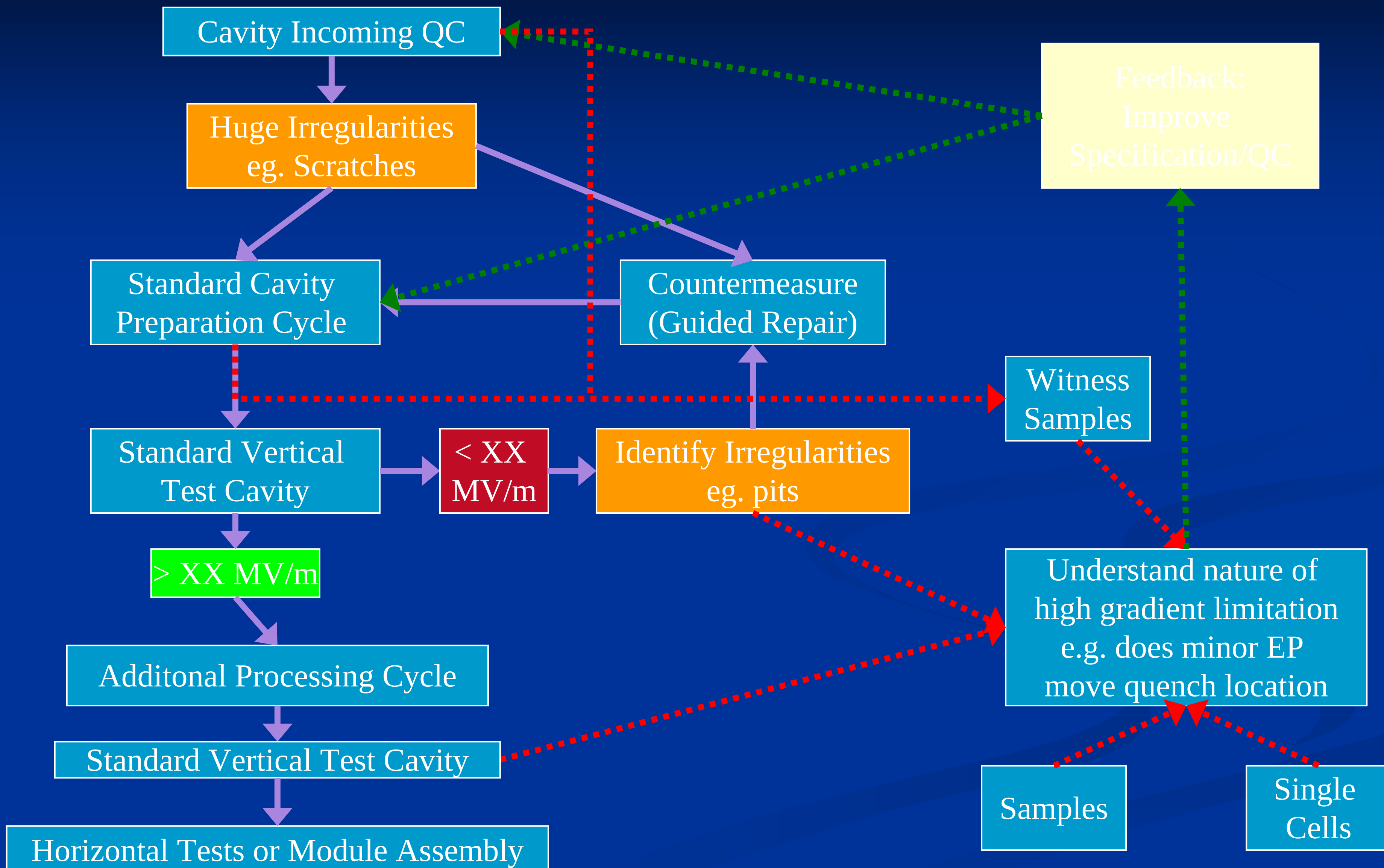
Summary

- ILC **Technical Design Phase is** starting with the goals of:
  - Phase-1: for SCRF technical feasibility to be verified,
    - **35 MV/m** with yield **50 %** for 9-cell cavity gradient and
    < 31.5 MV/m> with the cavity-string in a cryomodule
    - **Plug-compatible cavity/crymodule** to be examined with global effort
  - **Phase-2: for the technical reality** to be demonstrated
    - **35 MV/m** with the yield **90 %** **for** 9-cell cavity field gradient of
      - To be ready for industrialization with cost-effective fabrication
    - **System engineering including beam acceleration with one RF unit and** 3 **and** 3 cryomodules with the field gradient <31.5> MV/m.

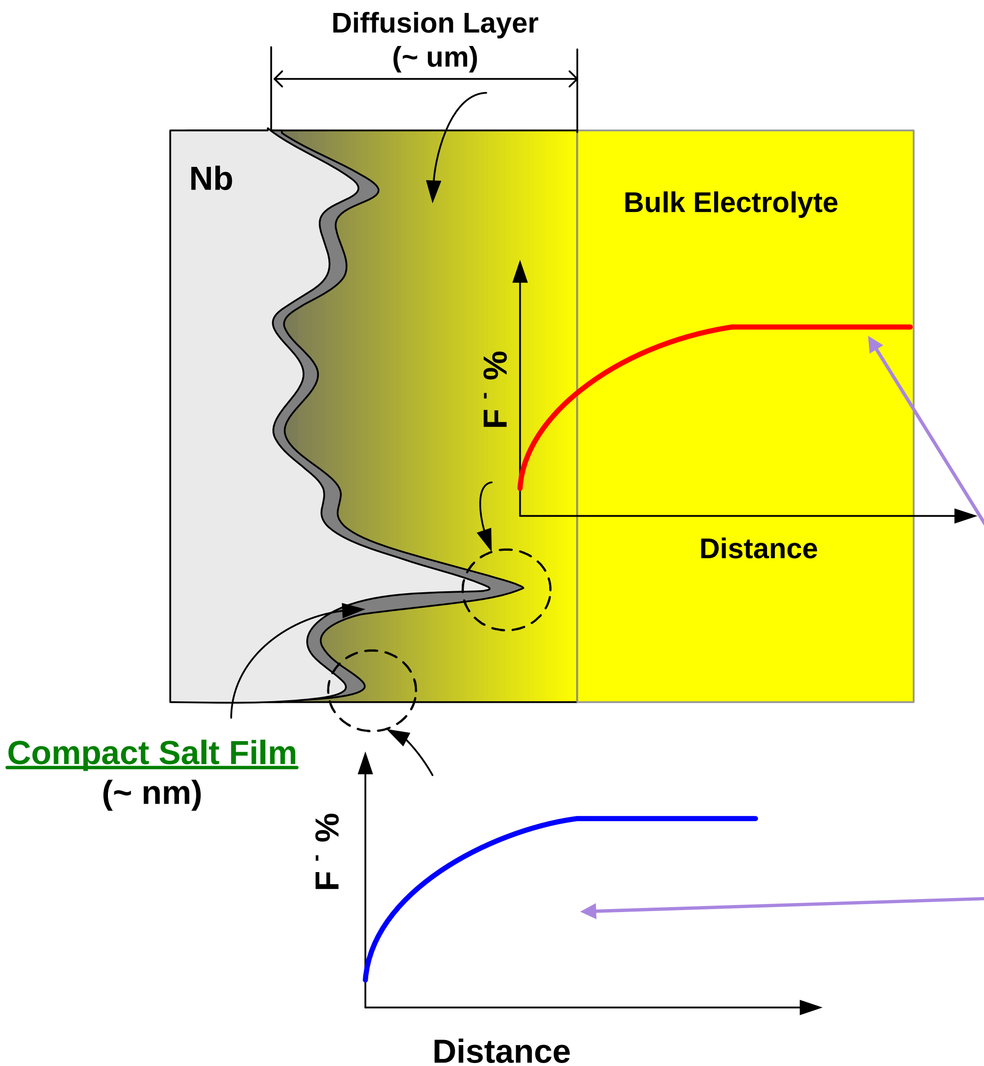
- We aim at the best effective **global cooperation** with **plug-plug-compatible approach** in technical design and R&D
  - in close cooperation with XFEL and other SCRF projects

backup

ILC S0 Feedback Loop



The Diffusion-Limited Access of F^- To the Salt Film Produces Best Polishing



Local temperature, flow & electrolyte composition affect the local F^- gradient

A New High Resolution, Optical Inspection System in TDP

For visual inspection of cavity inner surface.