Report for ILC-PAC

SCRF and ML Technology

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for Project Managers
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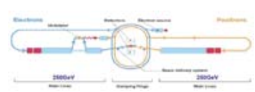
To be presented at ILC-PAC Review, May 9, 2009

Outline

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

SCRF Technology Required

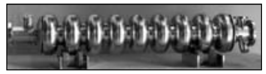
Parameter	Value
C.M. Energy	500 GeV
Peak luminosity	2x10^{34} cm^{-2}s^{-1}
Beam Rep. rate	5 Hz
Pulse time duration	1 ms
Average beam current	9 mA (in pulse)
Av. field gradient	**31.5 MV/m**
# 9-cell cavity	**14,560**
# cryomodule	**1,680**
# RF units	**560**



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

Status of 9-Cell Cavity



- **Europe (DESY, Saclay)**
  - **Gradient: > ~ 40 MV/m (max) ,**
  - **Industrial (bulk) EP demonstrated**
  - **Field emission reduced with ethanol rinsing**
  - **Surface process with baking in Ar-gas**
- **Americas (Jlab, Cornell, FNAL/ANL)**
  - **Gradient: > ~ 40 MV/m (max),**
  - **Field emission reduced by Ultrasonic Degreasing with Detergent**
- **Asia (KEK, IHEP, RRCAT)**
  - **Gradient: 36MV/m (LL, KEK-JLab), 32 MV/m (TESLA-like, KEK)**

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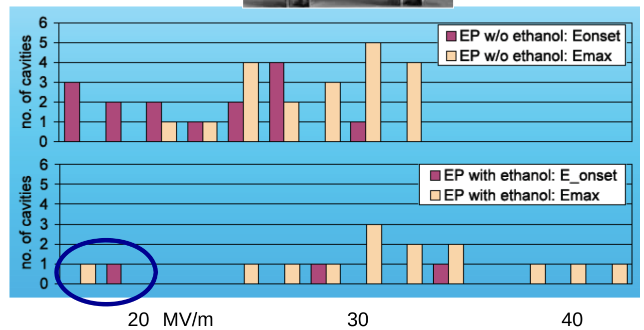
DESY: Ethanol Rinse Effect



Cavity gradient may be improved by 'ethanol rinse', and Field emission significantly reduced.

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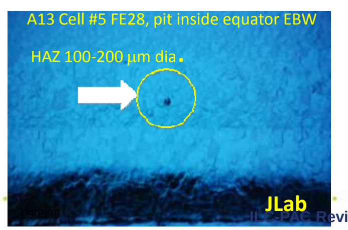
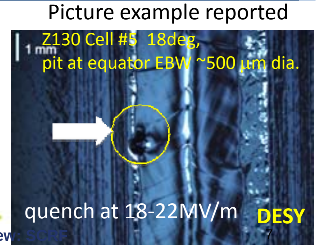
Understanding of Sources for Quench

From TTC-09a Summary (by H. Padamsee)

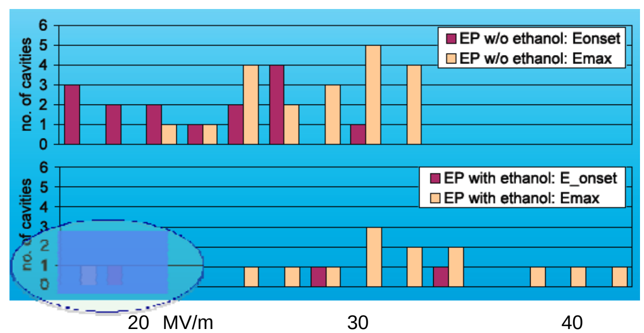
- Sources for quench below 25 MV/m have been identified
- Thermometry first used to locate quench regions followed by optical inspection.
- Quench sites are predominantly bumps and pits on the equator e-beam weld (EBW), or in the heat affected zone.

Picture example reported





After Better Understanding To Exclude Mechanical Defect



Field gradient improved by 'ethanol rinse', and it may be more evident, if the "lowest sample" (limited due to different reasons) may be eliminated.

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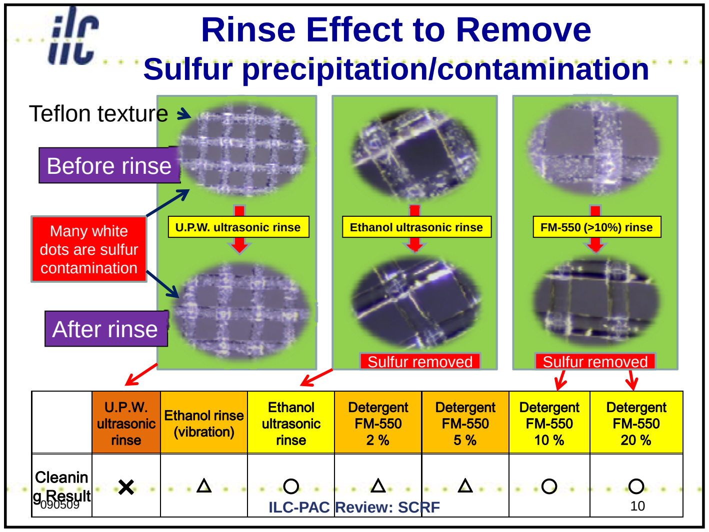
Rinse Effect to Remove
Sulfur precipitation/contamination
Teflon texture
Before rinse
Many white dots are sulfur contamination
After rinse
U.P.W. ultrasonic rinse
Ethanol ultrasonic rinse
FM-550 (>10%) rinse
Sulfur removed
Sulfur removed
U.P.W. ultrasonic rinse
Ethanol rinse (vibration)
Ethanol ultrasonic rinse
Detergent FM-550 2 %
Detergent FM-550 5 %
Detergent FM-550 10 %
Detergent FM-550 20 %
Cleaning Result
×
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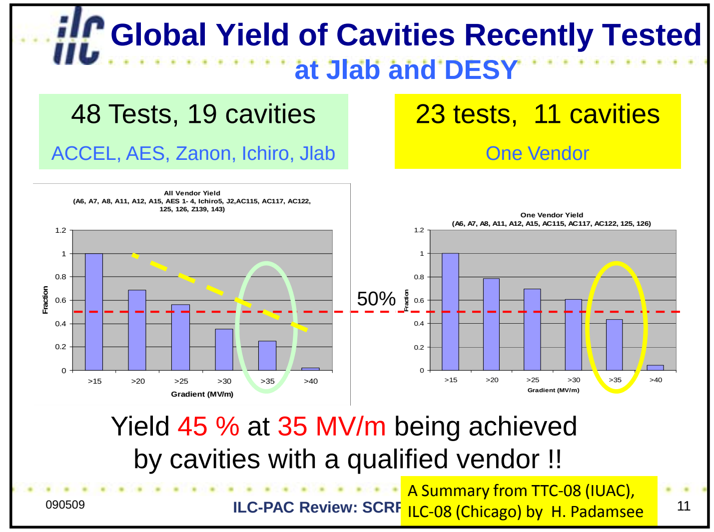
Global Yield of Cavities Recently Tested
at Jlab and DESY
48 Tests, 19 cavities
ACCEL, AES, Zanon, Ichiro, Jlab
23 tests, 11 cavities
One Vendor
50%
Yield 45 % at 35 MV/m being achieved
by cavities with a qualified vendor !!
A Summary from TTC-08 (IUAC), ILC-08 (Chicago) by H. Padamsee
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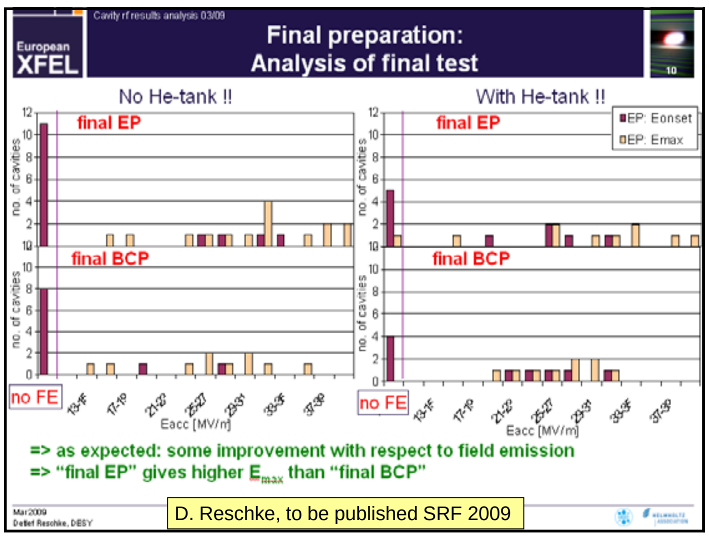
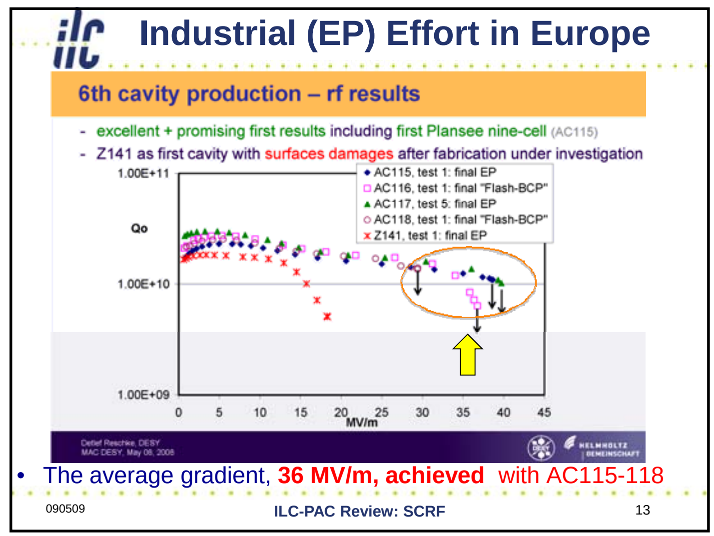

European XFEL
Final preparation:
Analysis of final test
No He-tank !!
With He-tank !!
final EP
final BCP
EP: Eonset
EP: Emax
no FE
Eacc [MV/m]
no. of cavities
=> as expected: some improvement with respect to field emission
=> "final EP" gives higher Emax than "final BCP"
D. Reschke, to be published SRF 2009


Industrial (EP) Effort in Europe
6th cavity production – rf results
- excellent + promising first results including first Plansee nine-cell (AC115)
- Z141 as first cavity with surfaces damages after fabrication under investigation
AC115, test 1: final EP
AC116, test 1: final "Flash-BCP"
AC117, test 5: final EP
AC118, test 1: final "Flash-BCP"
Z141, test 1: final EP
Qo
MV/m
• The average gradient, 36 MV/m, achieved with AC115-118
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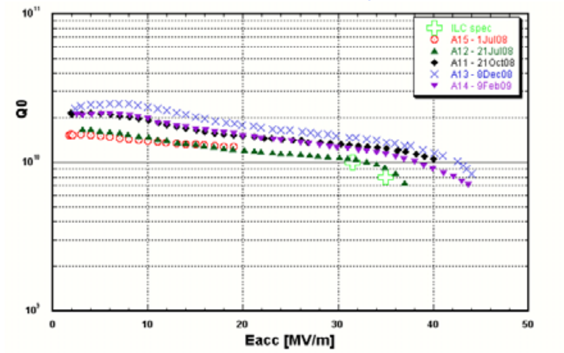
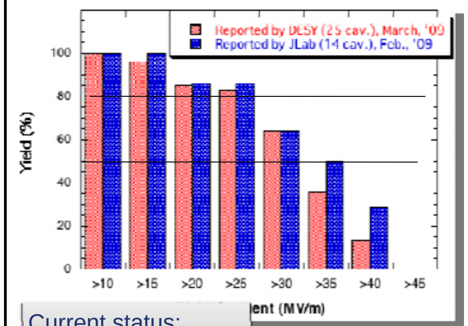
Most Updated Results from Jlab

as of Feb. 18, 2009



- Five 9-cell cavities: built by ACCEL, and processed/tested at Jlab.
- All of them processed with one bulk EP followed by one light EP and by ultrasonic pure-water cleaning with detergent (2%).

Progress Towards High-Gradient Yield



Current status:
50% yield at ~ 33 MV/m;
(80% >25MV/m)

Recent DESY/JLab "production" series.

Total 39 cavities (08/09)

Mostly result of **first cold-test** (few cases second-test)

Field Emission greatly reduced (rinses)
→ identified RDR barrier

Baseline gradient re-evaluation (TDP1) expected to be based on sample of >60 cavities

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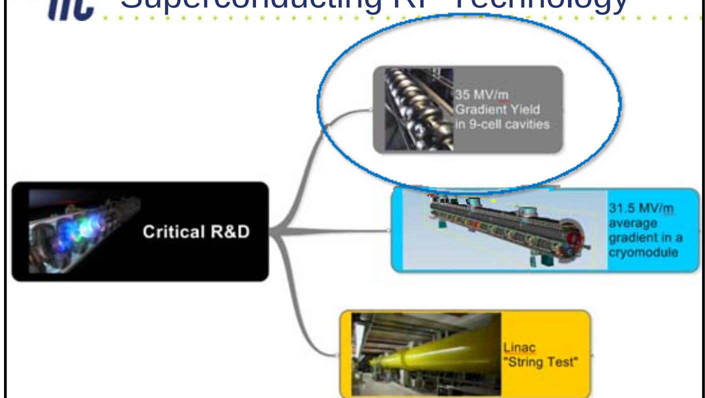
Superconducting RF Technology



Standard Procedure Established

	Standard Fabrication/Process
Fabrication	Nb-sheet purchasing
	Component Fabrication
	Cavity assembly with EBW
Process	EP-1 (~150um)
	Ultrasonic degreasing with detergent, or ethanol rinse
	High-pressure pure-water rinsing
	Hydrogen degassing at > 600 C
	Field flatness tuning
	EP-2 (~20um)
	Ultrasonic degreasing or ethanol (or EP 5 um with fresh acid)
	High-pressure pure-water rinsing
	Antenna Assembly
	Baking at 120 C
Cold Test (vertical test)	Performance Test with temperature and mode measurement

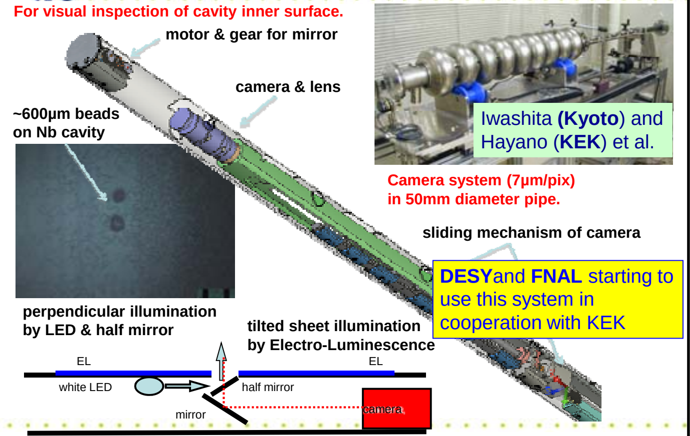
Key Process

Fabrication
- Material
- EBW
- Shape

Process
- Electro-Polishing
- Ethanol Rinsing or
- Ultra sonic. + Detergent Rins.
- High Pr. Pure Water cleaning

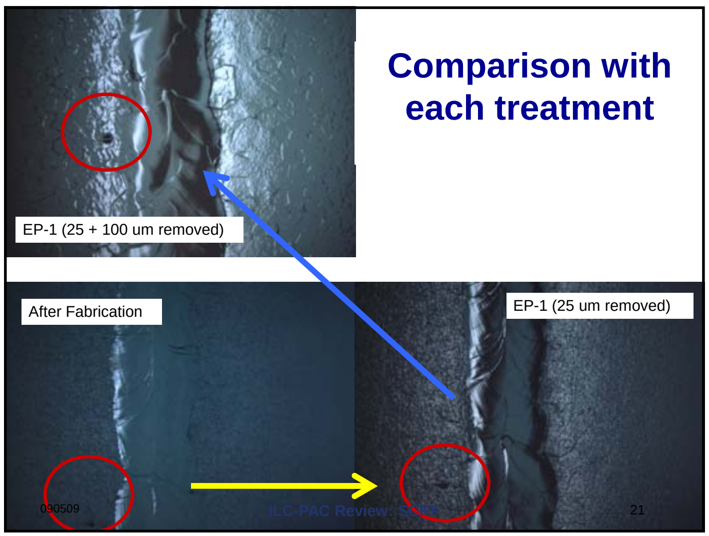
A New High Resolution, Optical Inspection

For visual inspection of cavity inner surface.

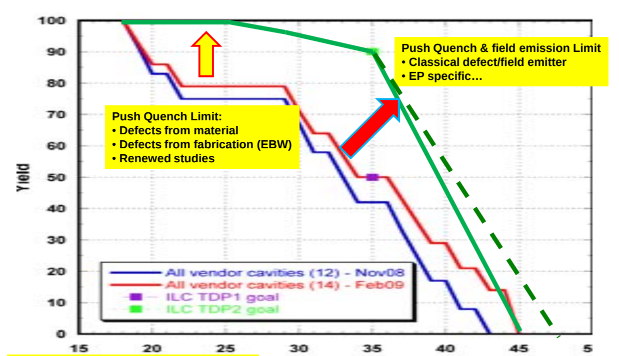


DESY and FNAL starting to use this system in cooperation with KEK

Comparison with each treatment



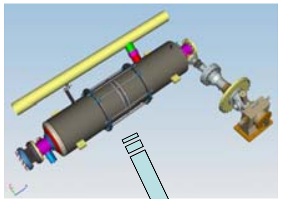
How May We Reach Our Goal?

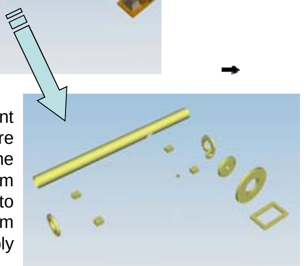


Prepared by R. Geng (Jlab)

Past yield curves show best gradient of JLab data set

Cavity: Plug-compatible Interface



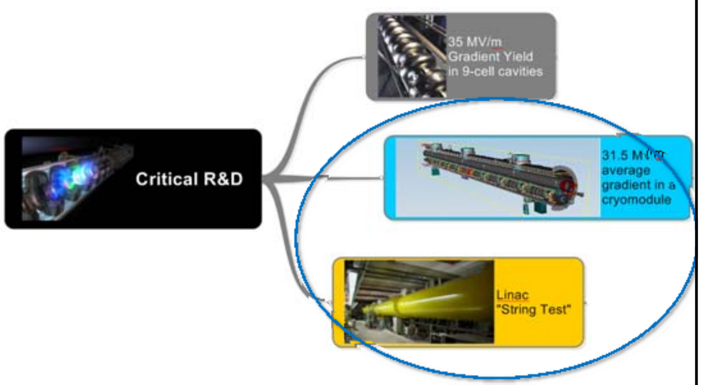


Component interfaces are reduced to the minimum necessary to allow for system assembly

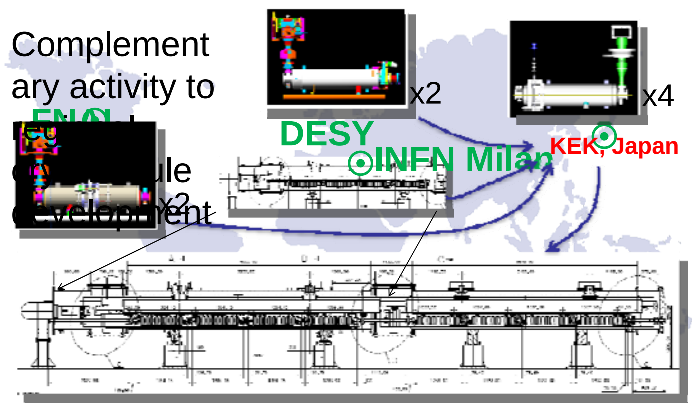
Importance of Plug-compatibility in R&D Stage

- Creative/Innovative work for further improvement with keeping “redundancy” and “replaceable >> plug-compatible” condition
- Seek for Cost-effective Fabrication for “mass production”
- Global cooperation and share for intellectual engagement

Superconducting RF Technology



S1-Global Collaboration



SRF Test Facilities

NML facility
Under construction
first beam 2010
ILC RF unit test

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

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

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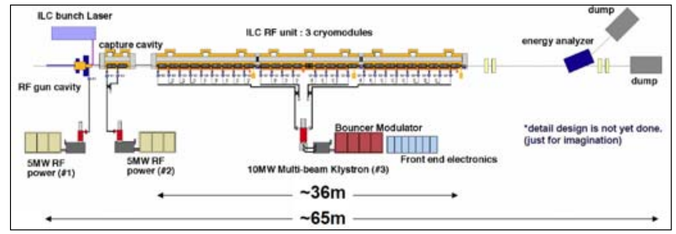
Beam Acceleration Test Plan

with RF unit at Fermilab and KEK in TDP-2



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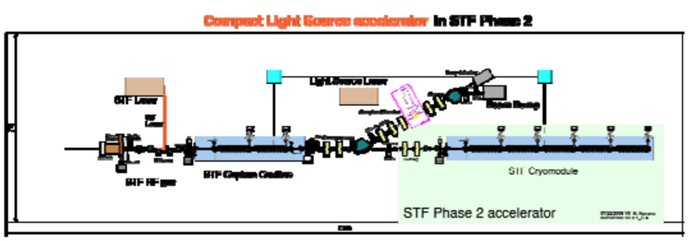
KEK STF-2 Pre-accelerator part

Compact light source accelerator:
- Use of STF RF-gun and capture cavities :
- Granted separately, and to be complete by 2012



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Cavity- and Cryomodule-String Test Program (S1G, S2) at KEK

C. Year	2008	2009	2010	2011	2012	2013	2014
Cavity String (S1-Global)	Cavity	>>	Ins Test				
Cryomodule String Test (S2)	*High Pressure Code Regulation/Stamp to be applied						
Quant. Beam* (Compact L.S.)		Cavity	>>	Inst.	Test		
Cryomodule 1*		Cavity	>>	>>	Ins & T		
Cryomodule 2,3*			Cavity	>>	>>	Ins	Ins & T
	Technical Design Phase					Development to be continued	

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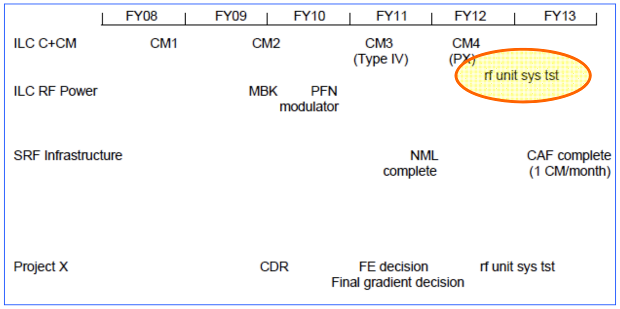
Cavity- and Cryomodule String Test Program at FNAL



- Cryomodule-string/RF-unit Test to start in FY12

A string test in each region

- Complementary testing:
  - Each region must develop industry and must develop 'ownership' of this critical technology
- No one system will exactly represent the baseline reference design RF unit design (before 2012)
  - FNAL: beam format [under review]
  - KEK: number of cryomodules [1 (of 3) by end 2012]
  - DESY: gradient [~27MV/m average over 3 cryomodules]
- Strategy must account for infrastructure limitations and construction schedules at each of the three main linac test facilities under development.

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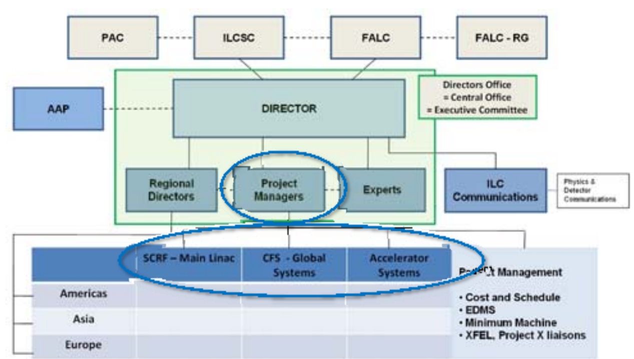
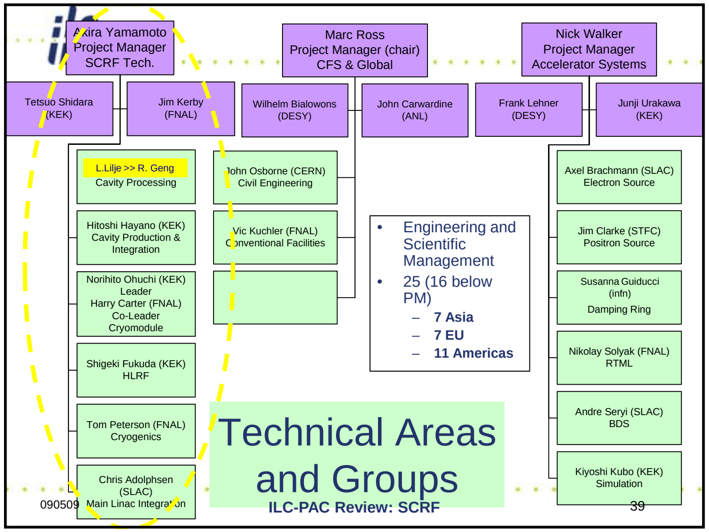
GDE Project Structure





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Project Plan in 2008-2010

- Field gradient (S0)
  - **To be re-optimized, based on the R&D progress (2010),**
- Plug-compatibility
  - **Common interface conditions being fixed ,**
  - **Overview document published**
- 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 "Accelerator Design and Integration" optimization,
  - **Cluster or Distributed RF power sources and distribution,**
- Prepare for AAP Interium Review in April, 2009
- Global Communication and cooperation with Laboratories & Industries
  - **Visit Labs: DESY, INFN, CERN, CEA/Saclay, LAL/Orsay, CIEMAT, FNAL, SLAC, Cornell, Jlab, LANL, TRIUMF, KEK, IHEP, PKU, TU, PAL, KNU, IUAC, RRCAT, BARC, TTIF, VECC,**
  - **Visit Industries: ACCEL, ZANON, AES, Niowave, MHI, PAVAC**

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Visit to Cavity Manufacturers: 2009

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

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Objectives of Visiting

- Learn industrial status and possible future at cavity manufacturers, through visiting the factory, presentations and discussions with factory staff,
- Communicate TD-Phase R&D Plan, and inform necessary boundary conditions, "plug-compatibility", in the word-wide R&D stage,
- Request close collaboration with laboratories to further industrial R&D effort, particularly, to improve "field gradient" and "cost effective production" to prepare for the industrialization (mass production),
- Establish close communication and confident relationship between ILC-GDE and manufacturers.

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Visit to Cavity Manufacturers: 2009

Company	# employees	Features	Date
AES	~26	Experience with RICH magnet production in the previous company, Dedicated for SC/NC RF technology	Feb. 24
NIOWAVE	~40	A New company dedicated for Niobium and microwave technology	Feb. 25
ACCEL/RI	~100	Most experienced company with SCRF, and adaptable for production scale of European XFEL	Mar. 4
ZANON	~200	Much experienced with plumbing work and SCRF cavities, and with HERA cryostat, Adaptable for scale of European XFEL	Mar. 6
MHI	>>1,000	A leading company in heavy-industries in Japan, and experienced with SC/NC RF cavities and accelerator technologies	Mar. 10
PAVAC	~30	A unique features with EBW machine itself and SCRF cavity manufacturing	May 7

Toward Industrialization

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

Project Scope			
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 has required ILC capacity**
  - **Understand what is needed (and cost) by 2012**

Industrialization and cost reduction

- Re-visit previous effort, and update the cost-estimate for production
  - **Review the RDR cost estimate (based on TESLA)**
  - **Include recent R&D experience (industry/lab)**
- Encourage R&D Facilities for industrialization
  - **Develop cost-effective manufacturing, quality control and cost-reduction in cooperation with industry**
- Reflect the R&D progress for cost-reduction
  - **Baseline ⇒ Forming, EBW, assembly work…**

A Plan for R&D facilities and Preparation for Industrialization

- Bench-mark R&D facility (pilot plant) to study cost-effective manufacturing,
  - **Forming and preparation machining,**
  - **Pre-surface treatment and preparation,**
  - **EBW process with efficient automation,**
  - **In-line Inspection during fabrication process for quick-feedback,**
- R&D facilities to be sited at Laboratories
  - **Effort to seek for the most cost-efficient manufacturing with keeping information to be open,**
  - **Development to seek for a bench-mark, manufacturing facilities (design and/or itself can be applicable for the real production.**
  - **It is important for industries to participate to the program since Day-1. for planning.**
- We may discuss a possibility
  - An industrial meeting to be held as a satellite meeting at the 1st IPAC, Kyoto, May, 2010.

Global Plan for SCRF R&D
A Summary

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)	

R&D/prepare for Indusrialization

Summary

- **Technical Design Phase in progress**:
  - **Phase-1: Technical reality to be examined,**
    - 35 MV/m with yield 50 % in surface process
      - ~ 33 MV/m with yield 50 % is being achieved
    - 31.5 MV/m with the cavity-string in a cryomodule
  - **Phase-2: Technical credibility to be demonstrated**
    - 35 MV/m with the yield 90 % for 9-cell in manufacturing
    - Beam acceleration with the field gradient 31.5 MV/m.
- **We aim for**
  - Global R&D efforts toward "High Gradient" keeping "plug-compatibility" concept.
  - Cooperation of world-wide Institutions and Industries crucially important and expected to prepare for industrialization.