ILC Cavity Gradient Strategy, A Proposal

Akira Yamamoto

ILC-GDE Project Manager / KEK

To be presented at ILC-10, Beijing, March 28, 2010

TDP Goals of ILC-SCRF R&D

as of March 2010, in TPD-1

- **Cavity Field Gradient (S0)**
  - 35 MV/m in vertical test
- **Cavity-string Assembly in Cryomodule (S1)**
  - <31.5 MV/m> in cavity string test in cryomodule
    - To be re-evaluated in preparation for SB-2009 proposal.
  - Efficient R&D with "Plug-compatibility" for
    - improvement and 'creative work' in R&D (TDP) phase
- **Accelerator System with SCRF (S2)**
  - Beam Acceleration with SCRF Accelerator Unit
    - Need to discuss an reliable, operational field gradient including adequate HLRF/LLRF control margin for stable operation
- **Industrial Production R&D**
  - Preparing for production, quality control, cost saving
    - "Plug compatibility" for global sharing in production phase

Global Plan for SCRF R&D

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

What we need to Discuss?

- **Fundamental Research** to improve 'Gradient'
  - **R&D status and understanding of limit**
  - **Strategy for improvement**
- **Preparation** for 'Industrialization'
  - **Cost effective production and quality control**
    - 90 % (9-cell cavity) corresponding to ~ 99 % (1-cell cavity)
  - **Balance between R&D and ILC operation parameters with beam,**
- **System Design and Engineering**
  - **Integration (compatibility, alignment, accuracy)**
  - **Optimization with other components,**
    - CFS, HLRF/LLRF, Beam handling, and others,
    - Best Operation Gradient to be determined

ILC Gradient Goals

500 GeV: Gradient and Q

Based on BCD cavity shape (TESLA cavity)

- BCD: Linac operating performance
  Eacc = 31,5 MV/m; Q = 1×10^{10}
- BCD: Installed performance
  Eacc ≥ 35 MV/m; Q ≥ 0.8×10^{10}
  - Required R&D
    - Reduction of field emission and multipacting
    - Reduction of scatter of cavity performance

H.Edwards, D.Proch, K.Saito,
ILC snowmass 05, Wg5

Parameter	Value
Type of accelerating structure	Standing Wave
Accelerating Mode	TM_{010}, π mode
Fundamental Frequency	1.300 GHz
Average installed gradient	31.5 MV/m
Qualification gradient	35.0 MV/m
Installed quality factor	$\geq 1 \times 10^{10}$
Quality factor during qualification	$\geq 0.8 \times 10^{10}$
Active length	1.038 m
Number of cells	9
Cell to cell coupling	1.87%
Iris diameter	70 mm
R/Q	1036 Ω
Geometry factor	270 Ω
E_{peak}/E_{acc}	2.0
B_{peak}/E_{acc}	4.26 mT $MV^{-1}m^{-1}$
Tuning range	±300 kHz
$\Delta f/\Delta L$	315 kHz/mm
Number of HOM couplers	2

2005 Snowmass BCD proposal → 2007 RDR → SB2009

4.1.2 Issues of Main Linac System Design

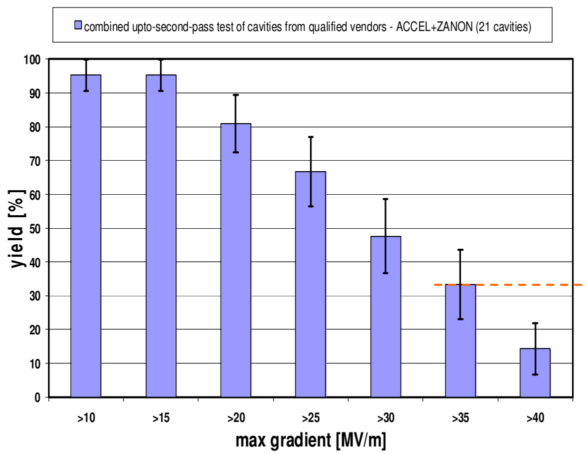
In conjunction with the (GDE and AAP) review process in 2010, based on the current R&D results we propose to keep the cavity gradient goals at 35MV/m in vertical test,S0, and 31.5MV/m in operation in an installed cryomodule, S1. We note that as the R&D progresses, including horizontal testing of

Standard Process Selected in Cavity Production and the Yield

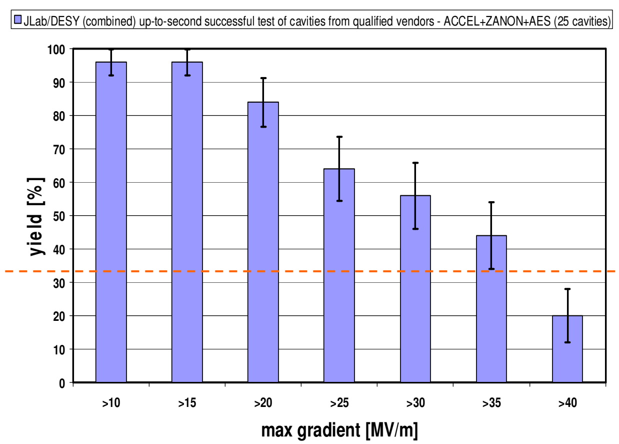
	Standard Cavity Recipe
Fabrication	Nb-sheet (Fine Grain)
	Component preparation
	Cavity assembly w/ EBW (w/ experienced venders)
Process	1st Electro-polishing (~150um)
	Ultrasonic degreasing with detergent, or ethanol rinse
	High-pressure pure-water rinsing
	Hydrogen degassing at > 600 C
	Field flatness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

Historical Progression of Up-to-second-pass yield w/ qualified vendors

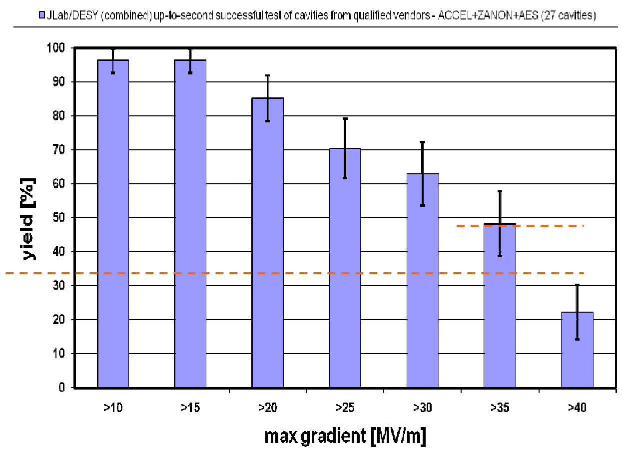
GDE: 1.Oct.2009



AAP: 6-7Jan.2010



ILC-10: 28 March, 2010



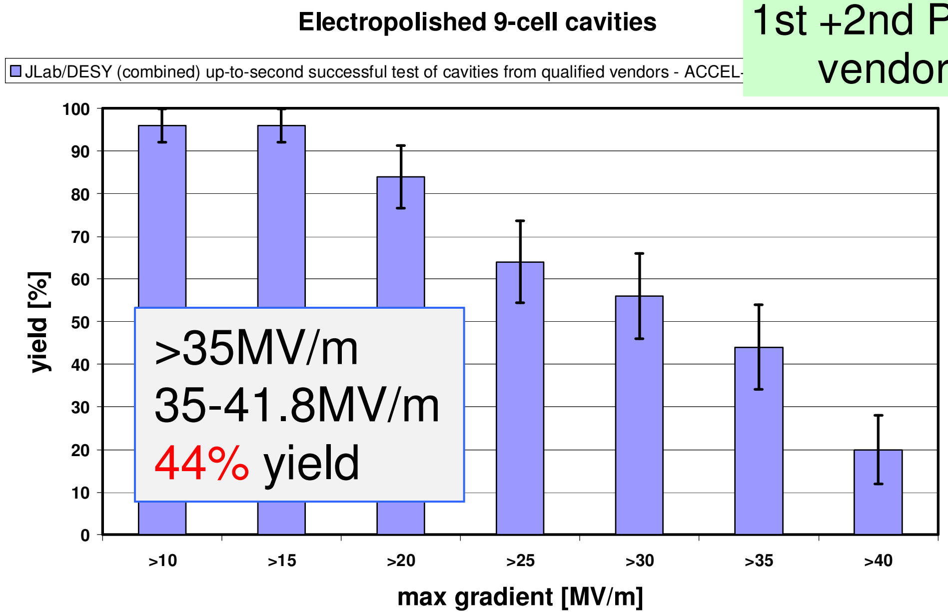
<u>Camille Ginsburg & DB Team:</u>

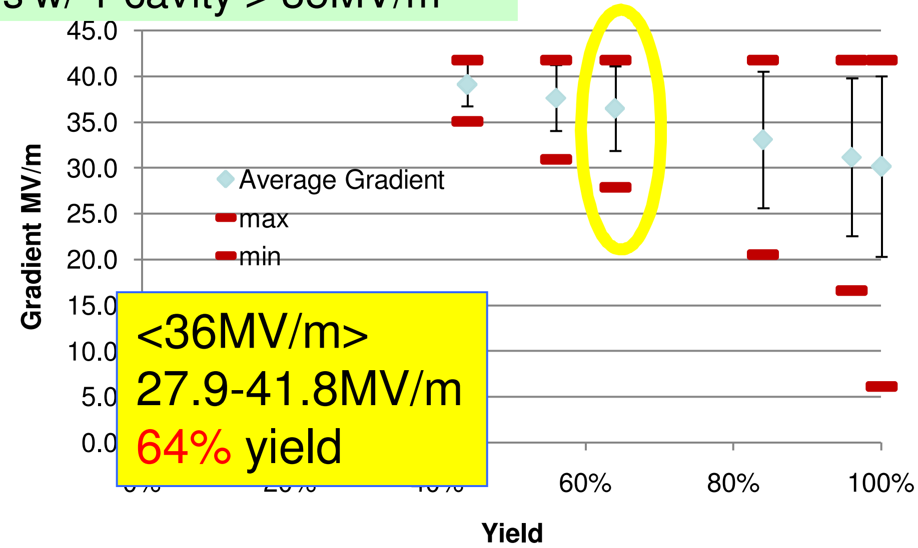
Yield and statistical uncertainties:	>25 MV/m		>35 MV/m	
Reported, March 27, 2010:	1st pass	2nd pass	1st pass	2nd pass
ALCPG-Albuquerque 1.Oct.2009	63+-10	67+-10	23+-9	33+-10
AAP-Oxford 6.Jan.2010	63+-9	64+-10	27+-8	44+-10
ILC-10-Beijing 28.Mar.2010	66+-8	70+-9	28+-8	48+-10

Alternative Yield Plot Analysis

originated by N. Walker and updated by J. Kerby

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





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

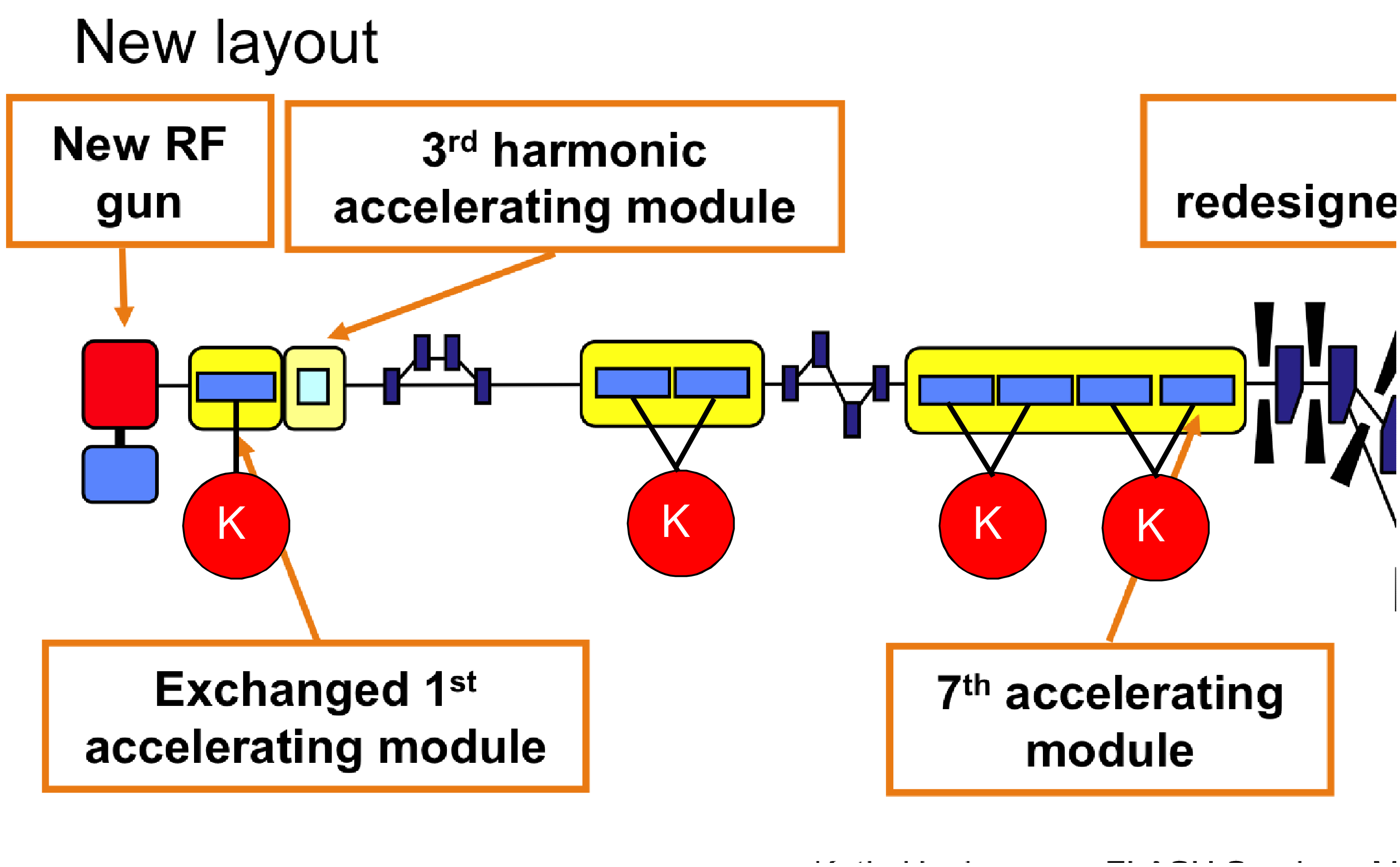
To Establish ILC Operational Gradient

- The RDR has a gradient goal of 35MV/m such that a machine performance based on 31.5MV/m (-10%) may be achieved, and S1 and S2 goals have been set at 31.5MV/m

- This 10% reduction was assumed (in Snowmass, 2005)
  - **to include limitations due to both 'final assembly problems' and required 'machine operational overhead associated with HLRF/LLRF and beam-loading'**

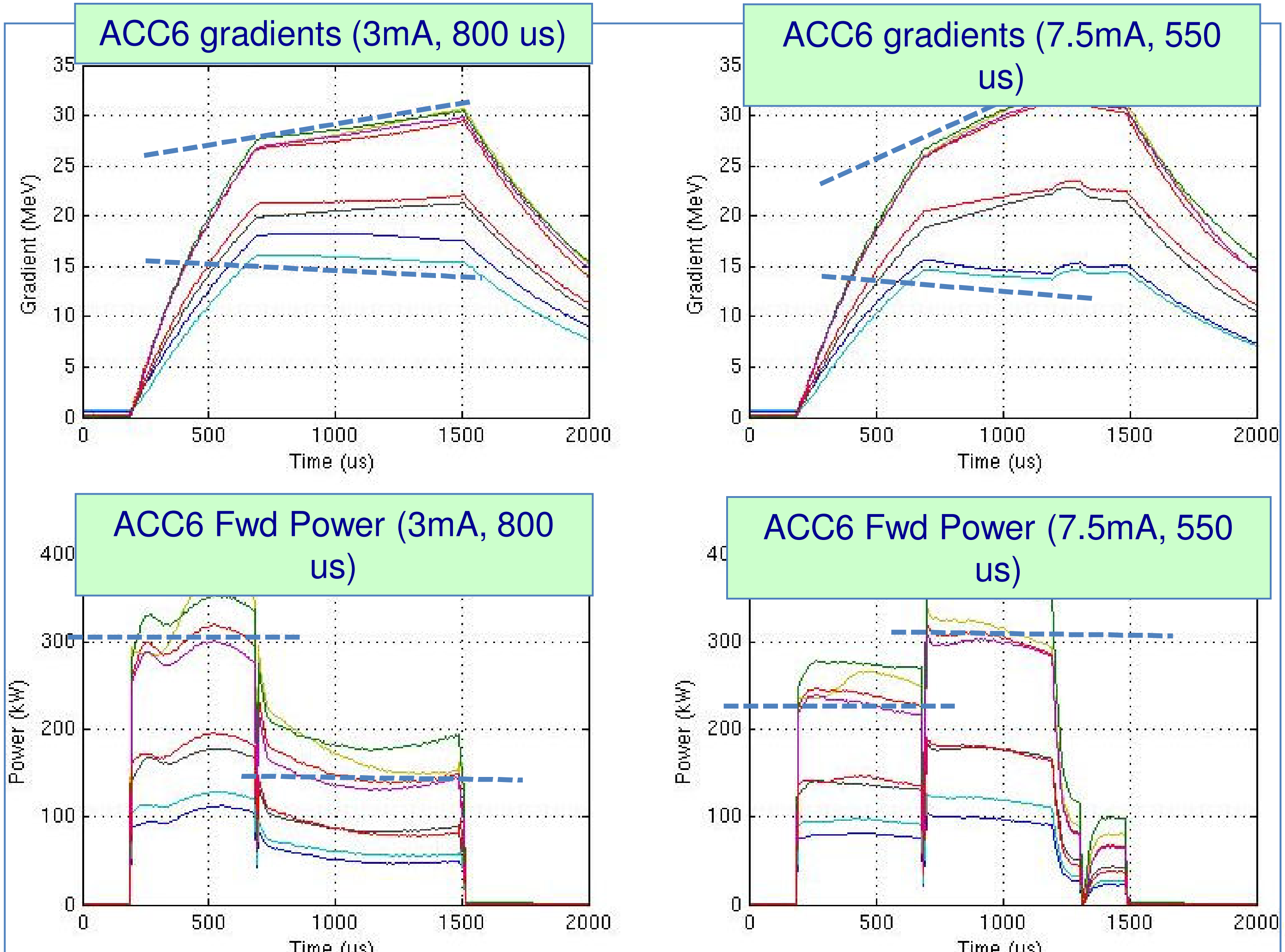
- Further efforts on cavity performance, TDP-2 gives several opportunities to further investigate and quantify the actual required value, and thus the machine design
  - **FLASH at DESY**
  - **NML at FNAL**
  - **STF2 at KEK**

FLASH layout (now)



From Nick's talk at FLASH workshop at DESY, on Feb. 22:

Cavity tilts with long bunch trains and heavy beam loading (3mA and 7.5mA, long bunch trains)



Gradient tilts are a consequence of using a single RF source to power cavities running at different gradients

At 7.5mA, ACC6 cavities #1 and #2 approached their quench limits at the end of the pulse

The RF power during flat-top is higher than the fill power for the 7.5mA case

S1 Goal: Achieved at DESY/XFEL

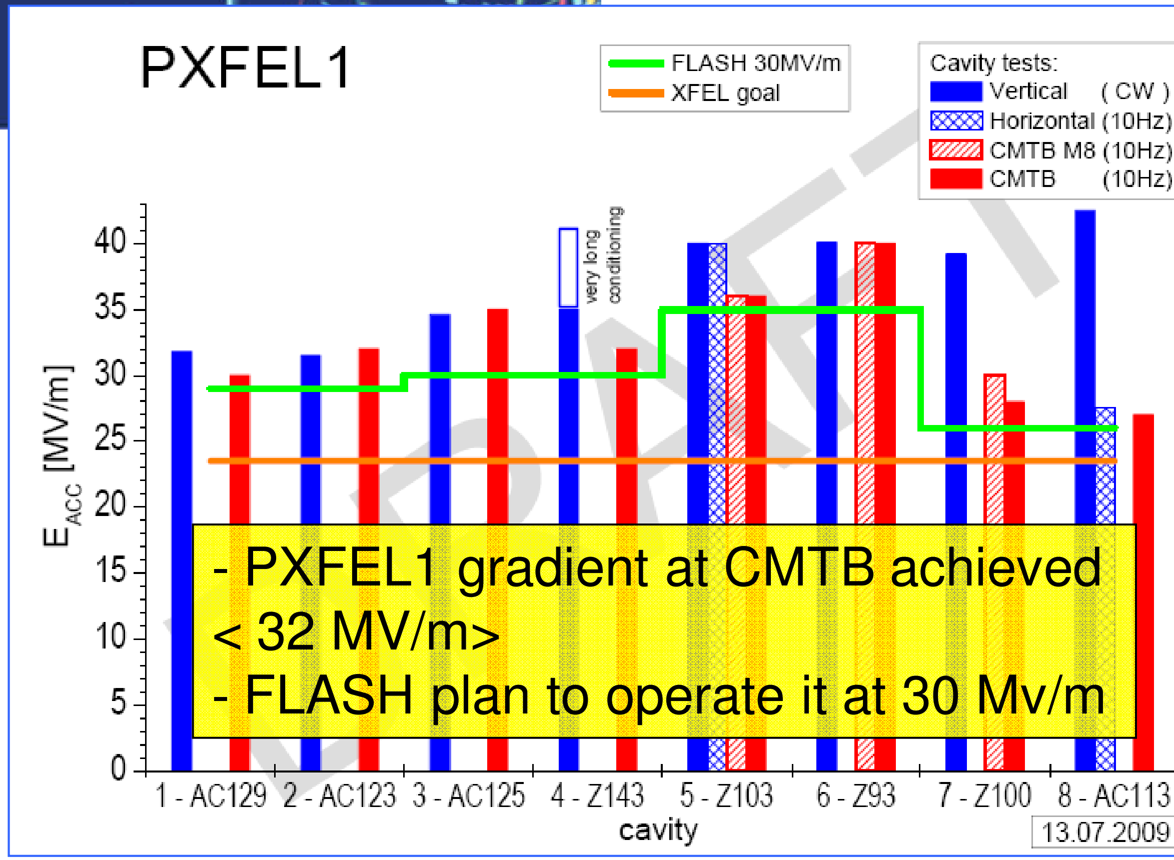

NewsLine

Around the World

Cryomodule surpasses ILC gradient test

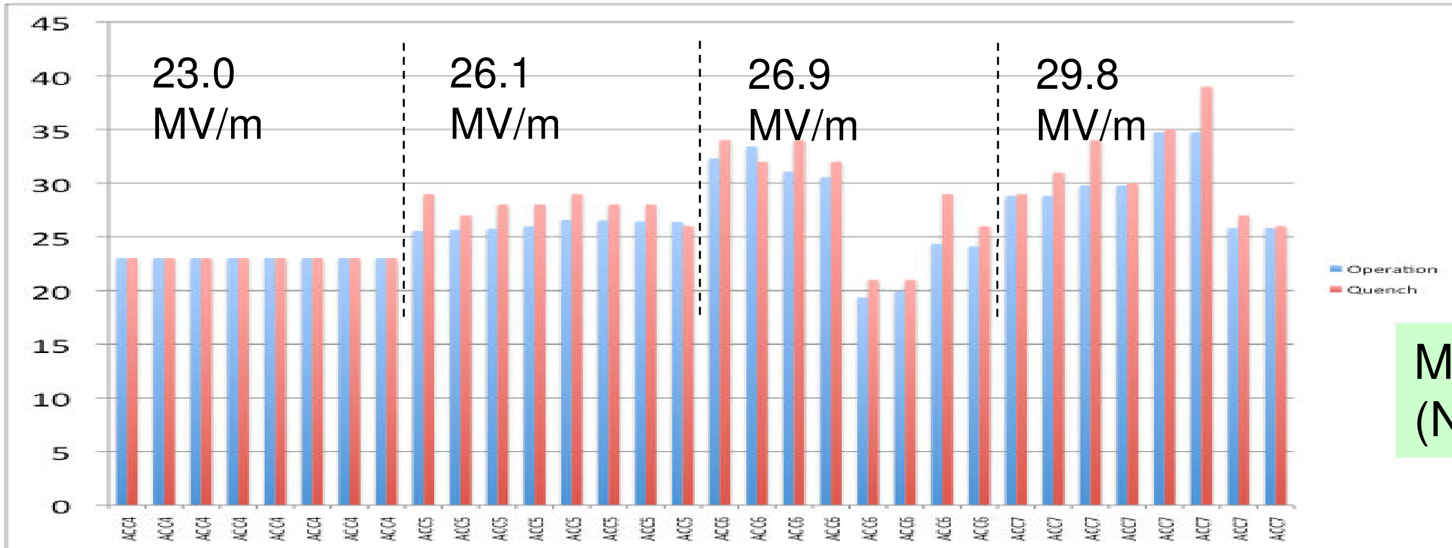
European-XFEL cryomodule using SCRF technology sets new record

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

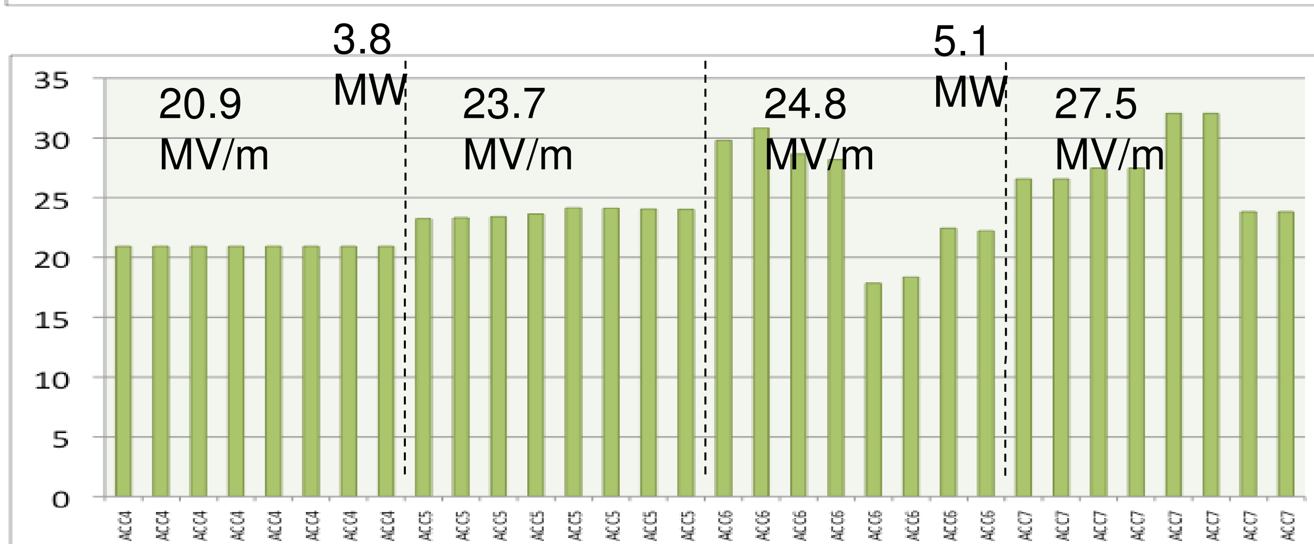


First XFEL prototype module **exceeds 31.5 MV/m average**
- Module will see beam in FLASH in 2010 (av. of 30MV/m)
- Cryostat (cryomodule cold-mass) contributed by IHEP, in cooperation with INFN

FLASH
Cryomodule Layout and Field Gradient



Max. operation (Now)



Nominal foreseen for 1.3 GeV beam energy

What we need to study in TDP-2

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

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

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

A Proposal for Cavity Gradient

- Appropriate balance should be re-considered b/w
  - **R&D stage and Project stage**
  - **Components and Accelerator System Operation**

- A new guideline toward TDP-2 and TDR
  - **R&D Goal for Cavity Gradient (unchanged) : 35 MV/m (@ 90 % yield)**
  - **Guideline for System Engineering to be updated:**

  - **G_{Cavity} > $G_{Cryomodule}$ > $G_{ILC\text{-}operation}$**
  - **<35 MV/m> : <33 MV/m> : <31.5 MV/m>**

- Our homework
  - **How much gradient spread to be allowed?**
    - To be optimized within 10 – 20 % in balance of RF distribution efficiency
  - **Can we justfy the above operational margins?**
    - ~ 5 % in Cavity (itself) operational margin in cryomodule operation
      - To prevent excessive field/field-emission/cryogenics-load and quench
    - ~ 5 % in LLRF/HLRF and beam tune-ability and operational margin or overhead
      - We shall learn FLASH/NML/STF progress in TDP-2

Summary

- In SB2009, ILC operational field gradient left unchanged
  - CF&S study enables to stay at 31 km in ML tunnel length
- R&D Goal for SCRF cavity gradient
  - Keep: 35 MV/m (at Q0 = 8E9) with the production yield of 90 %,
  - Allow: Spread of cavity gradient effective to be taken into account
    - to seek for the best cost effective cavity production and use,
- System Design to establish ILC operational gradient
  - Necessary adequate balance/redundancy between the 'R&D gradient-milestone' and the 'ILC operational gradient
    - G_{Cavity} > $G_{Cryomodule}$ > $G_{ILC\text{-}operation}$
    - <35 MV/m> : <33 MV/m> : <31.5 MV/m>
- Industrialization to be prepared
  - Lab's collaboration and effort with regional varieties/features,
  - Industrialization model to be discussed and studied
    - A satellite meeting for the 'ILC cavity Industrialization at IPAC, May 23, 2010.