AAP Review on SCRF to be prepared

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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 to be reviewed?

- 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 = **$1x10^{10}$**
- BCD: Installed performance
  Eacc ≥ **35** MV/m; Q ≥ **$0.8x10^{10}$**
  - 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	$\geq 1\times10^{10}$
Quality factor during qualification	$\geq 0.8\times10^{10}$
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

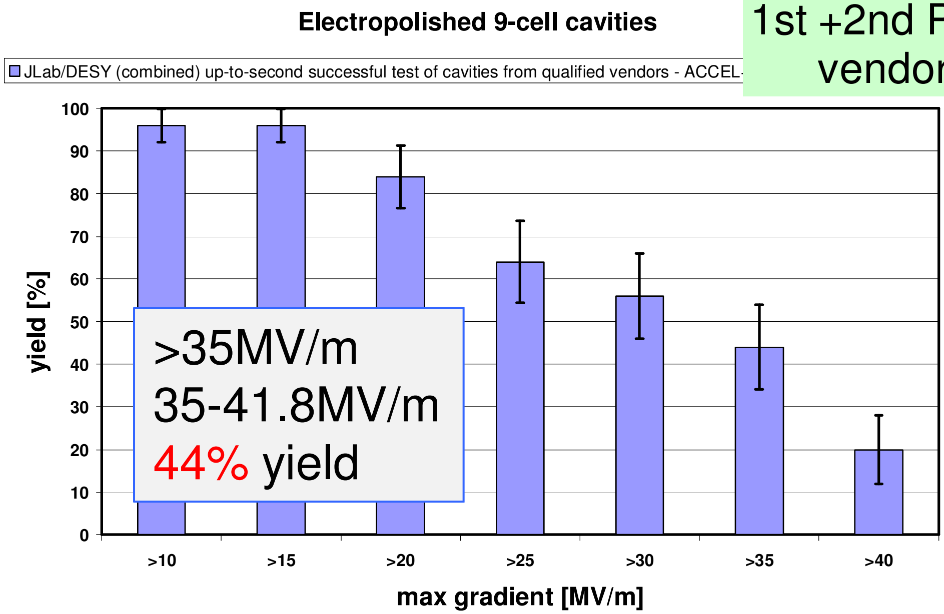
4.1.2 Issues of Main Linac System Design

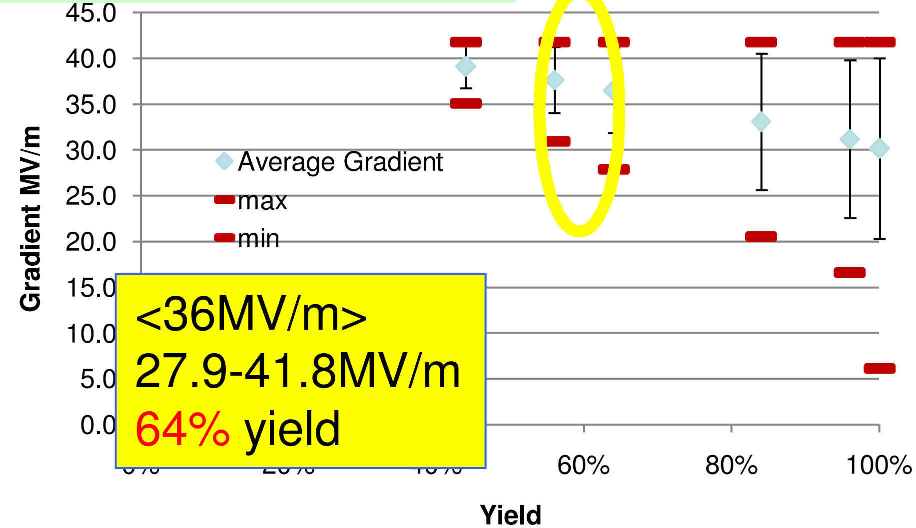
In conjunction with the (GDE and AAP) review process in 2010, based on the current R&D results we propose to keep the cavity gradient goals at 35MV/m in vertical test,S0, and 31.5MV/m in operation in an installed cryomodule, S1. We note that as the R&D progresses, including horizontal testing of

Alternative Yield Plot Analysis

originated by N. Walker and updated by J. Kerby

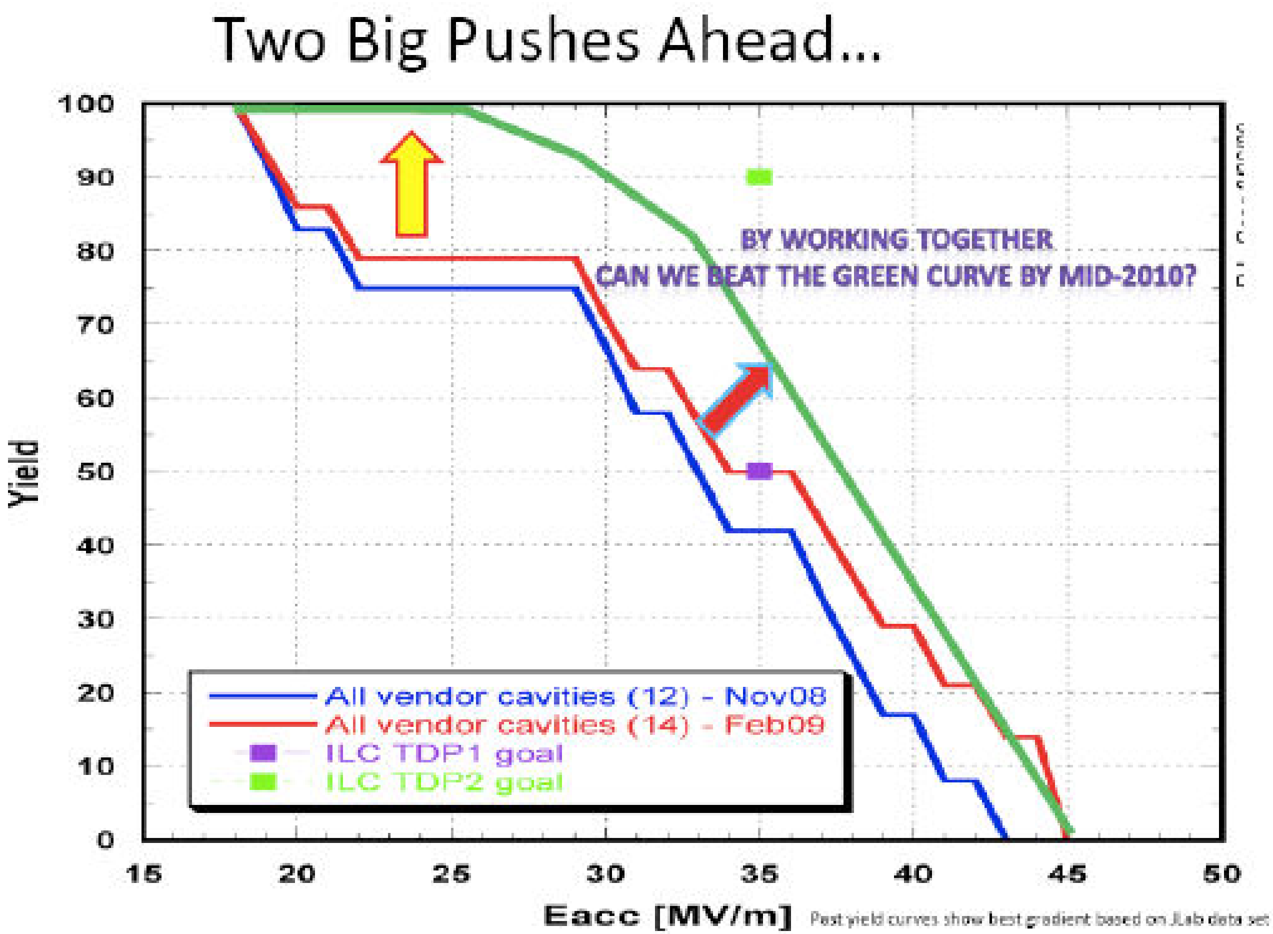
Dec 2009 Data:
1st +2nd Pass, 1st pass cut 35MV/m, vendors w/ 1 cavity > 35MV/m





-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.

Improvement of Cavity Gradient in two ways

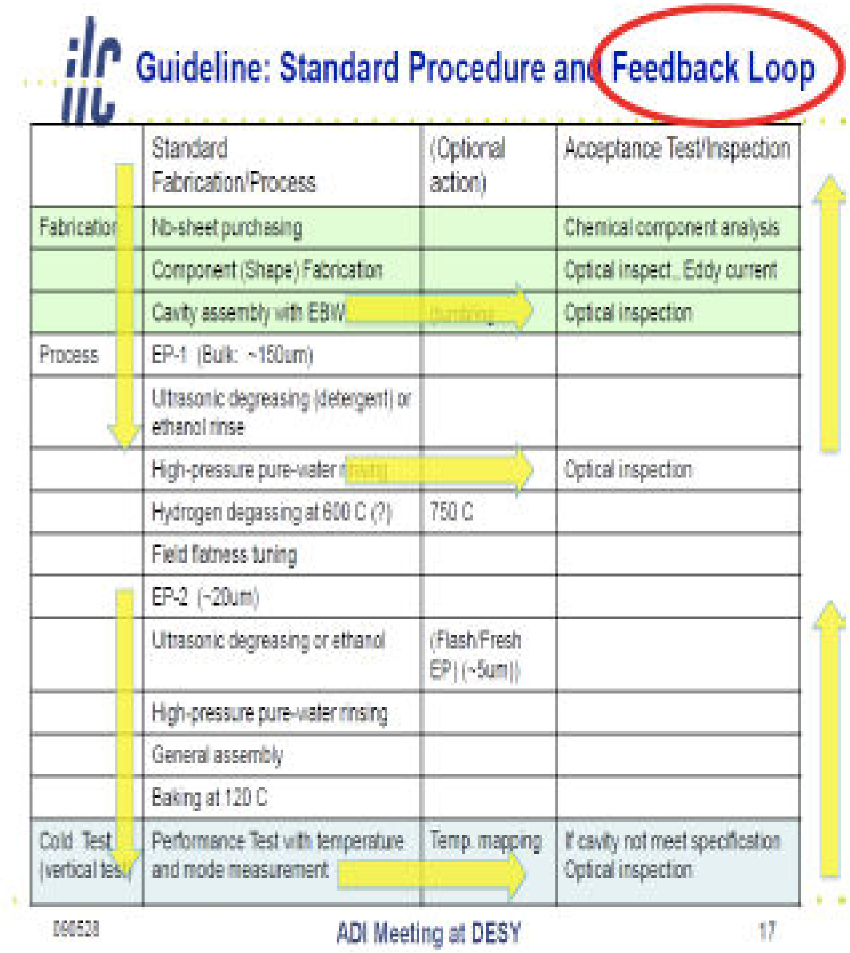


First presented at cavity vendor meeting at FNAL, March 6, 2009

- More discussed by R. Geng in parallel session

How we may improve Gradient ?

- Yield drop at 15-20 MV/m is a major issue
  - **Shared issue with XFEL and CEBAF upgrade cavities**
- Solution requires actions in cavity fabrication
  - **EBW QA/QC**
  - **Finished weld inspection**
  - **Early correction**
- Feedback enables change and then progress expected
  - **Experienced vendors**
  - **New vendors**


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

090528 ADI Meeting at DESY 17

- More discussed in parallel session

SCRF Gradient in 'R&D' and 'Project'

- R&D Goals set in RDR
  - 9-cell cavity: to reach 35 MV/m at Q0 = 8E-9 at the vertical test, with the production yield at > 90 %
  - Cryomodule: to reach <31.5 MV/m> at Q0 = 1 E10,
- Project Goal/Parameter set in RDR
  - ILC operational gradient set at < 31.5 MV/m> including cavity operational margin to the quench/field-emission limit and also accelerator control/operational margin for HLRF/LLRF

- Seek for reasonable balance between 'R&D goals' and the 'Project Parameters' in TDP
  - Understanding the status with the global data base
  - Re-optimization of the parameters in system design

S1 Goal: Achieved at DESY/XFEL

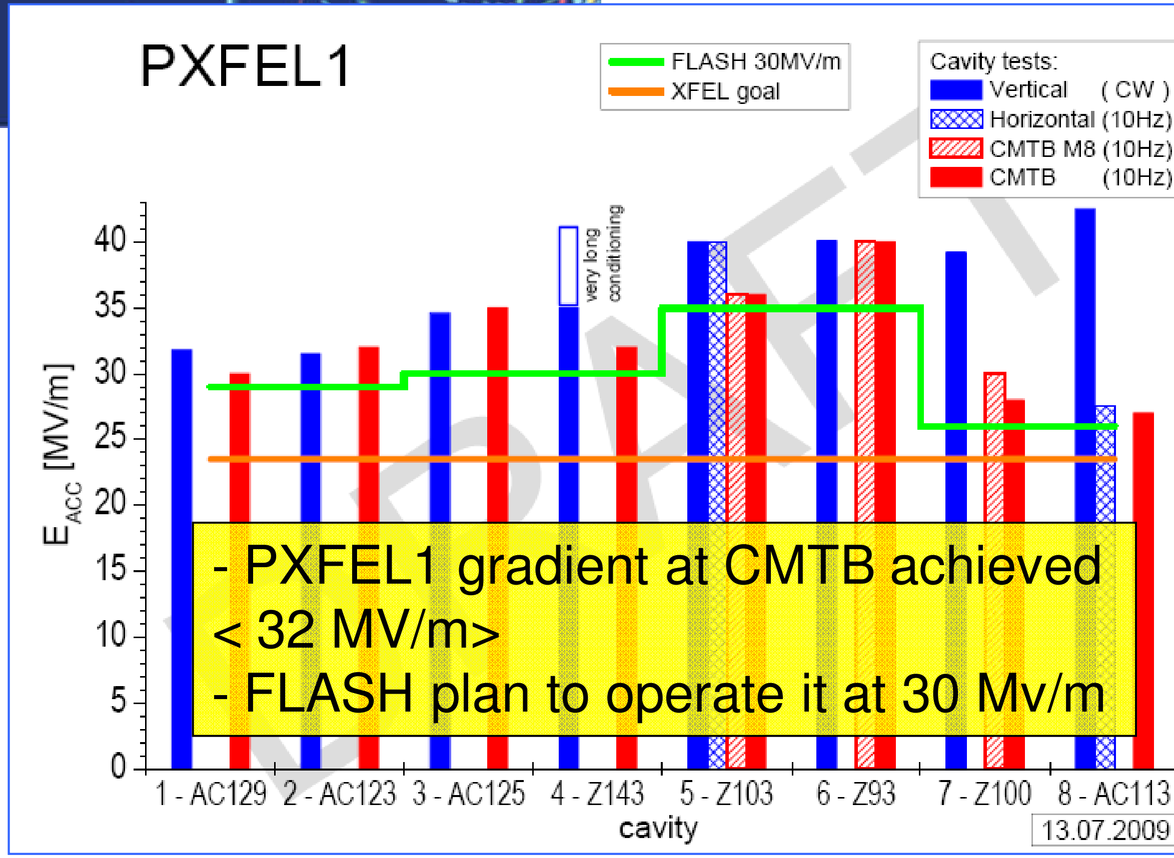
NewsLine

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

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

What to be reviewed?
As Summary

- **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

backup

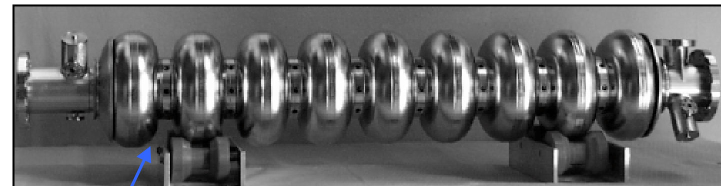
- TBD

Summary

- In SB2009, ILC operational field gradient left unchanged
  - CF&S study enables to stay at 31 km in ML tunnel length
- SCRF cavity gradient R&D Goal
  - Being kept: 35 MV/m (at Q0 = 8E9) with the production yield of 90 %,
  - Spread of cavity gradient effective to be taken into account
    - to seek for the best cost effective cavity production and use,
- Re-optimization to establish ILC operational gradient
  - Necessary adequate balance/redundancy between the ‘R&D gradient-milestone’ and the ‘ILC operational gradient’ including sufficiently high ‘availability’ with risk mitigation.
  - Necessary engineering and cost balance b/w Cavity and HLRF/LLRF
- Further optimization for design parameters & construction.
  - Cryomodule/cryogenics, Quadrupoles, plug-compatibility, and industrialization

SCRF Technology Required

Parameter	Value
C.M. Energy	500 GeV
Peak luminosity	$2\text{x}10^{34}\ \text{cm}^{-2}\text{s}^{-1}$
Beam Rep. rate	5 Hz
Pulse time duration	1 ms
Average beam current	9 (or 4.8) mA (in pulse)
Av. field gradient	**31.5 MV/m**
# 9-cell cavity	**14,560**
# cryomodule	**1,680**



TDP Goals of ILC-SCRF R&D

- **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

Standard Process Selected in Cavity Production and the Yield

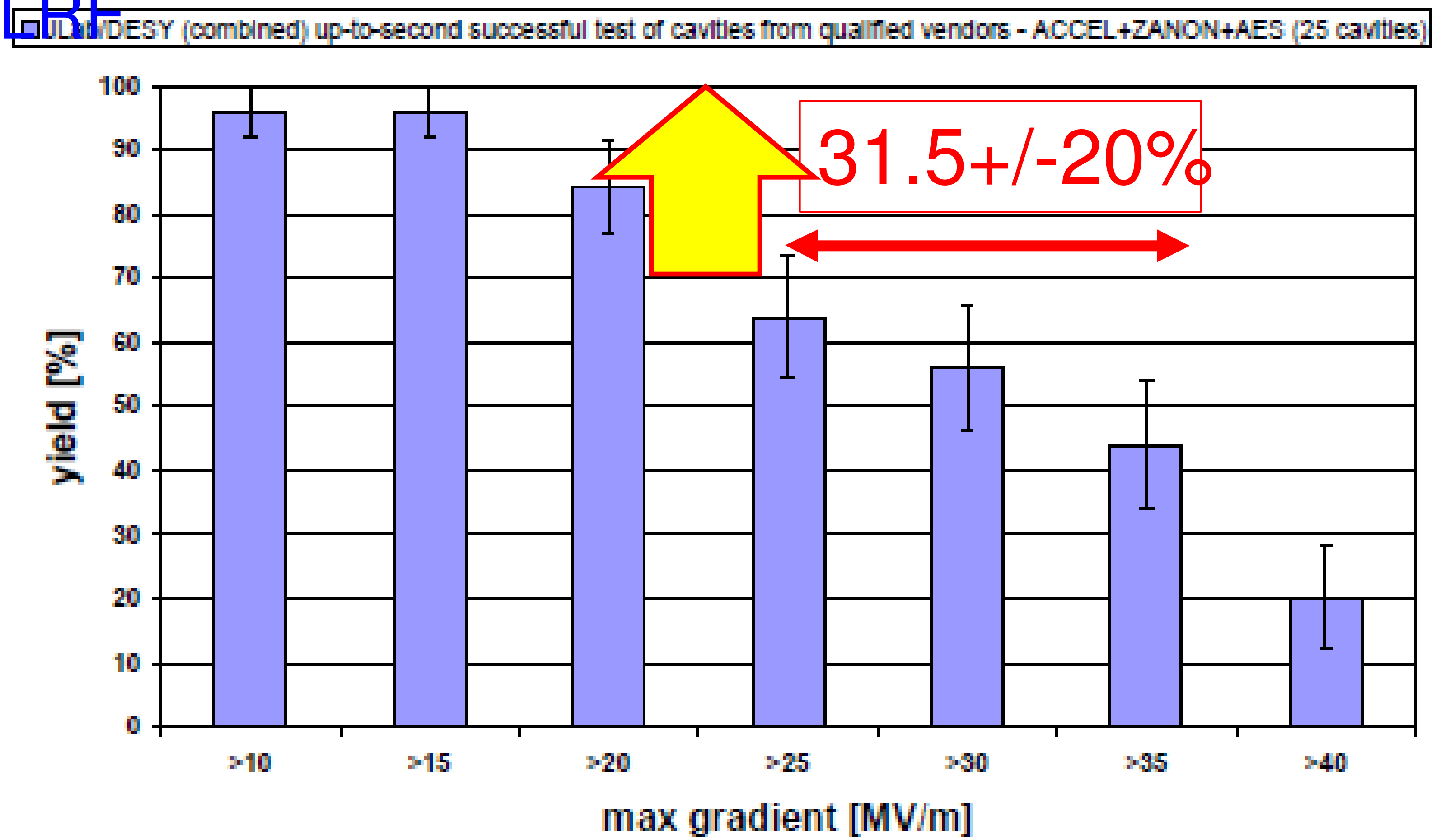
	Standard Cavity Recipe
Fabrication	Nb-sheet (Fine Grain)
	Component preparation
	Cavity assembly w/ EBW (w/ experienced venders)
Process	1st Electro-polishing (~150um)
	Ultrasonic degreasing with detergent, or ethanol rinse
	High-pressure pure-water rinsing
	Hydrogen degassing at > 600 C
	Field flatness 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)

Improved Understanding in Quench Limit

- Routine 9-cell T-mapping and optical inspection
  - **New insights from pre-cursor heating studies at JLab**
  - **First predictive defect study at DESY**
  - **Cornell 2nd sound sensors will be available for labs**
  - **Many labs use "Kyoto camera" (JLab just received a loan unit)**
- New finding: many 9-cell is quench limited at 20-25 MV/m by only one defect in one cell with other superior cells already reaching 30-40 MV/m
  - **There may or may not be observable flaw in quench site**
  - **This seems to suggest we need to address material aspect besides processing and fabrication in TDP-2**
  - **This also suggests some local repairing is needed for efficient raise of 2nd pass gradient yield**

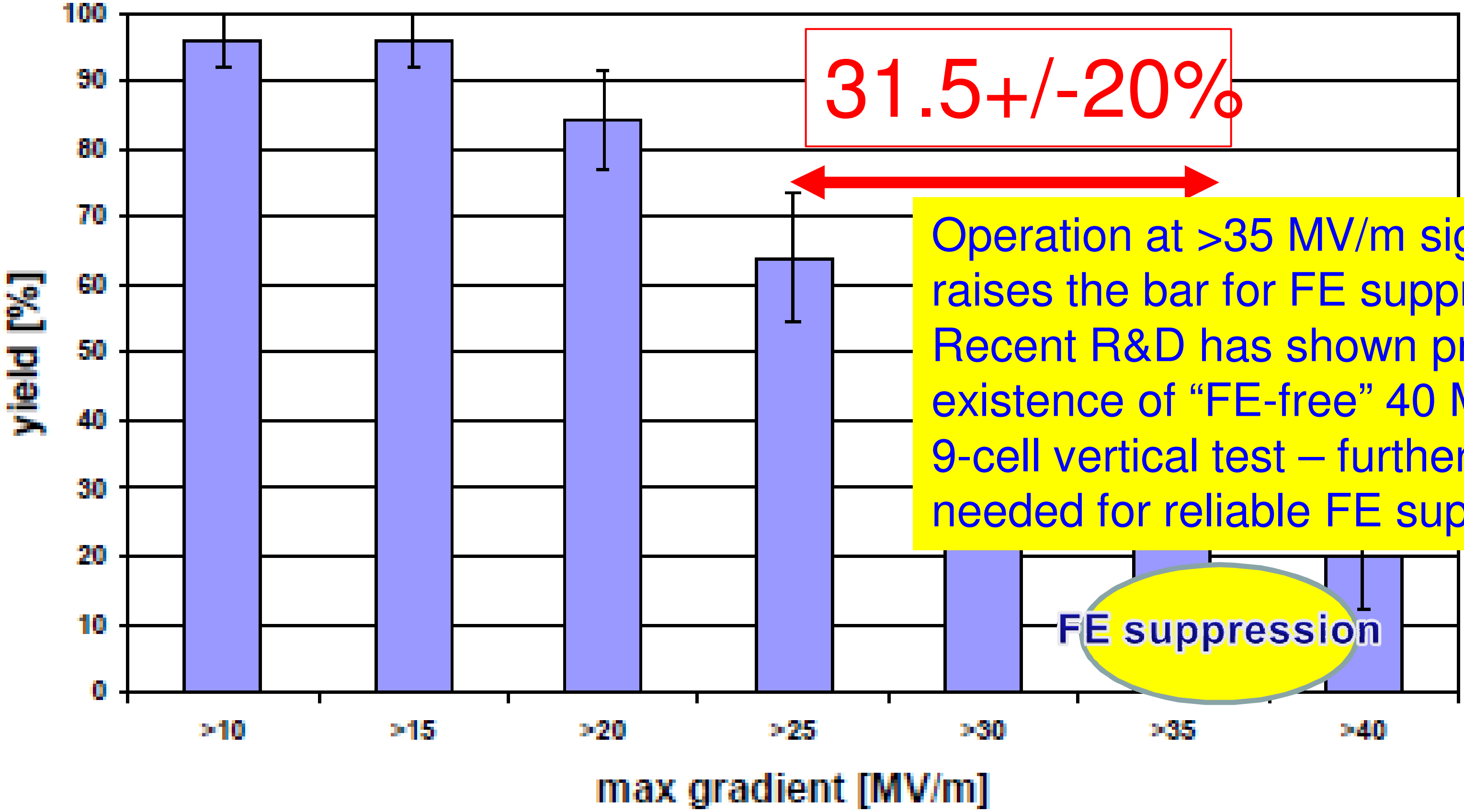
A Major Next Battle: Eliminate Yield Drop near 20 MV/m

Despite increased acceptance thanks to more flexible HLRF



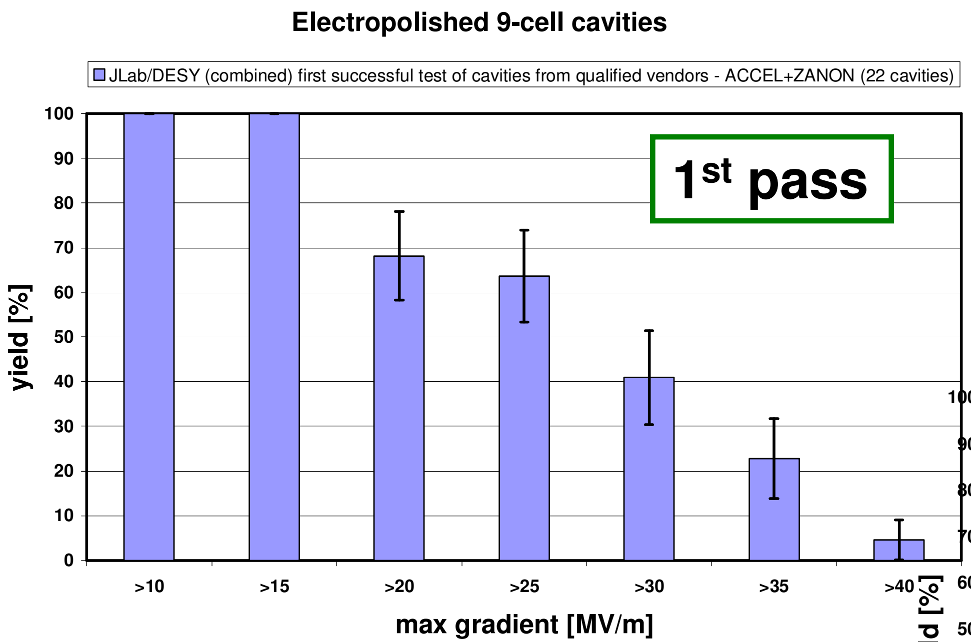
Another Next Battle: Further Reduce Field Emission up to 40 MV/m

Flexible HLRF opens up possibility of some individual cavity operates up to 38 MV/m

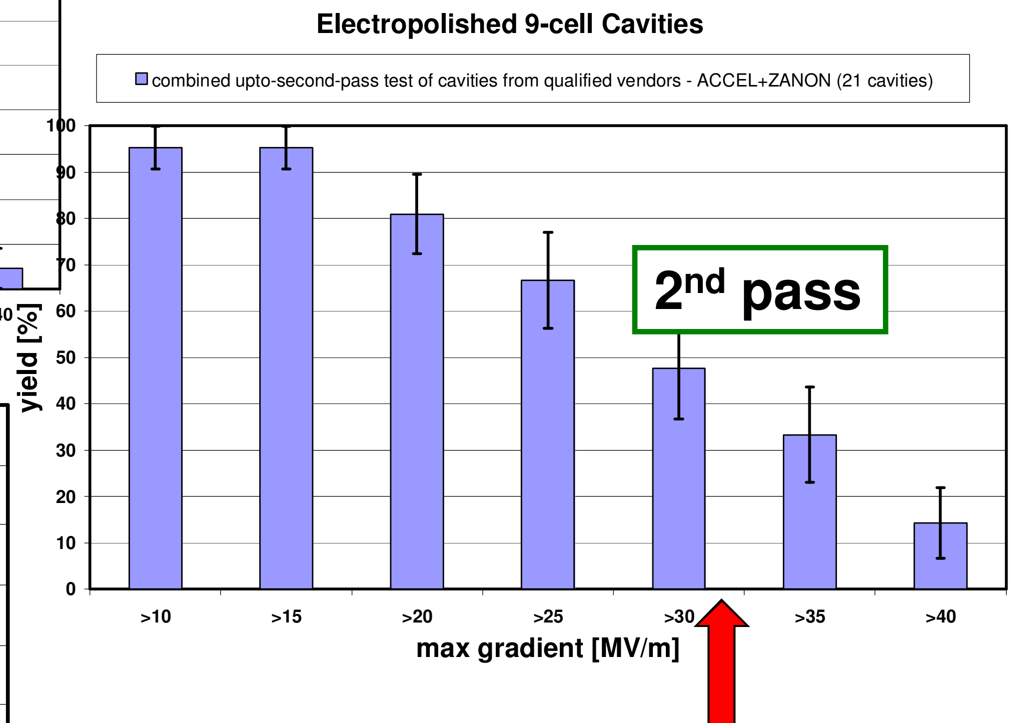


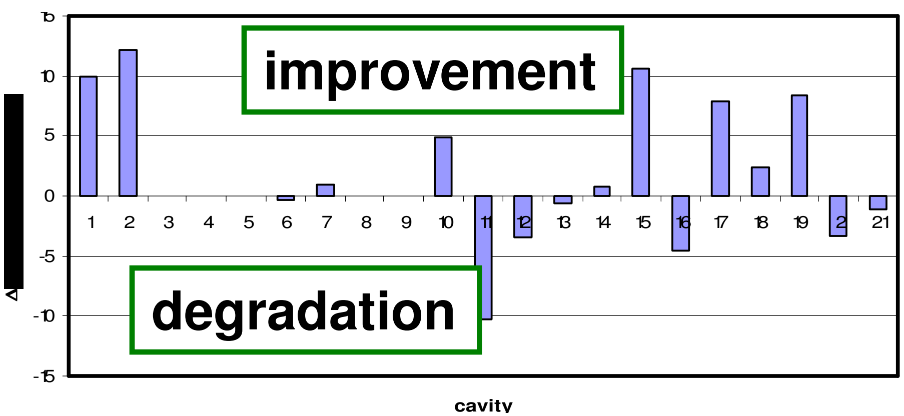
Operation at >35 MV/m significantly raises the bar for FE suppression. Recent R&D has shown proof of existence of "FE-free" 40 MV/m in 9-cell vertical test – further R&D is needed for reliable FE suppression

New Production Yield after 1st and 2nd Pass (RF) Test



Yield at 35 MV/m:
22 % at 1st pass
33 % at up to 2nd pass





ILC Operation at <31.5 MV/m>
Yield reaching ~ 40 %

Reported by C. Ginsburg and GDB team

Progress and Prospect of Cavity Gradient Yield Statistics

	PAC-09 Last/Best 2009-05	FALC 1st Pass 2009-07	ALCPG 2nd Pass 2009-10	To be added (2009-11)	Coming Prod. Y. (2010-06)	Research cavities
DESY	9 (AC) 16 (ZA)	8 (AC) 7 (ZA)	14 (AC/ZA)	4 (Prod-4)	5	8 (large G.)
JLAB FNAL/ANL/Cornell	8 (AC) 4 (AE) 1 (KE-LL5) 1 (JL-2)	7 (AC)	7 (AC)	5 (AE)	12 (AC) 6 (AE) 2 (AC)	6 (NW) (including large-G)
KEK/IHEP				0 (MH)	2 (MH)	~5 (LL) 1 (IHEP)
Sum	39	22	21	10	25	**~ 20**
G-Sum				31	57	

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