Superconducting RF R&D for the ILC

Lutz Lilje

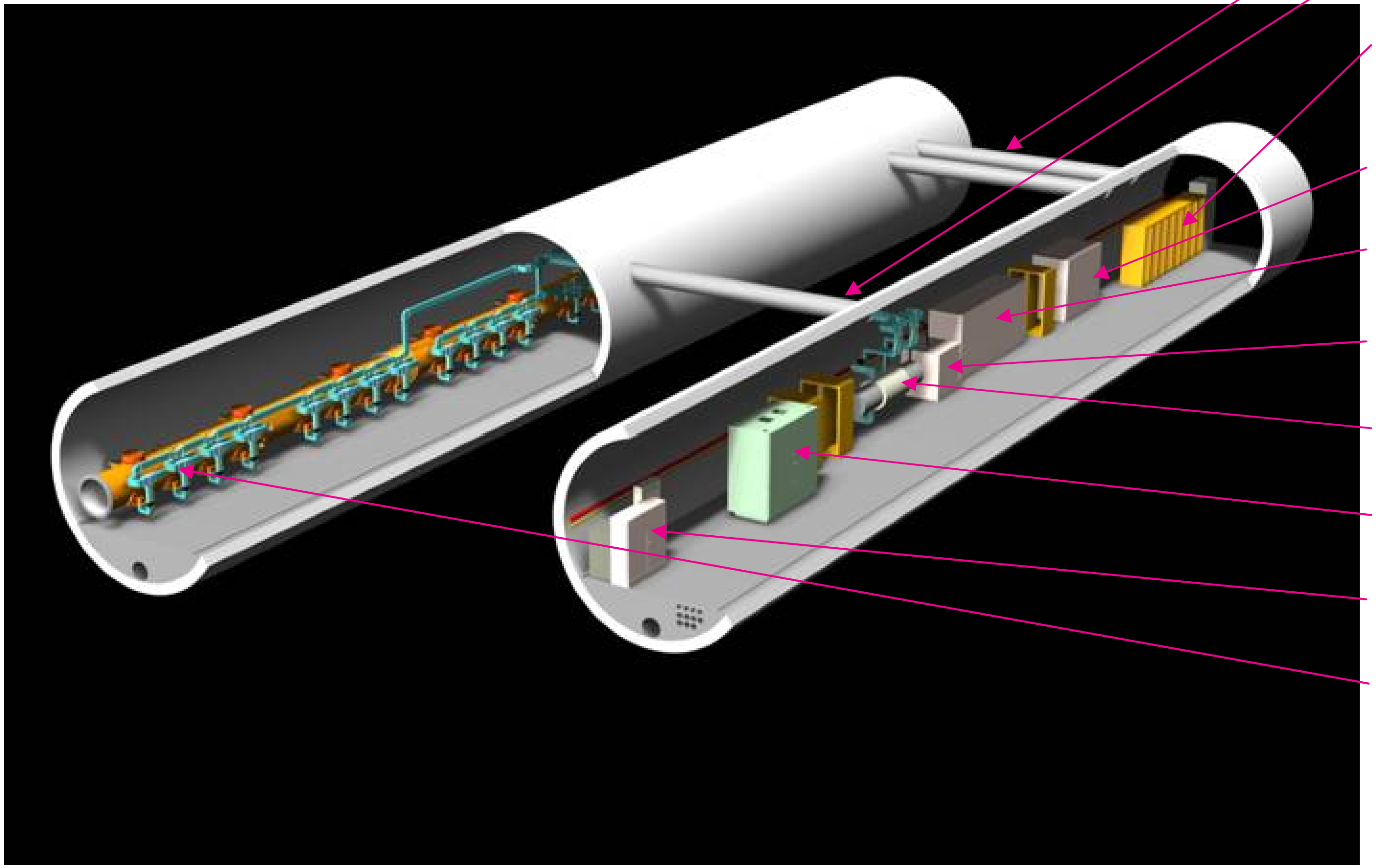
GDE

Outline

- Principal Layout of the SRF system
- R&D for the baseline
  - **Guaranteeing baseline performance and cost**
    - Final surface preparation
    - Qualifying new niobium vendors
    - Continued cavity production
    - Dedicated module testing
    - Industrialization issues
- R&D for alternatives
  - **Major idea is to cut cost further**
  - **New materials**
  - **New cavity designs**
  - **Surface preparation**
    - Vertical bakeout
    - Argon bake
  - **and much more (not covered in this talk, but at the conference!):**
    - e.g. Coaxial couplers WEPMS049 WEPMS061, Superstructure WEPMS062
- Organise ILC R&D beyond the RDR

Main Linac Layout

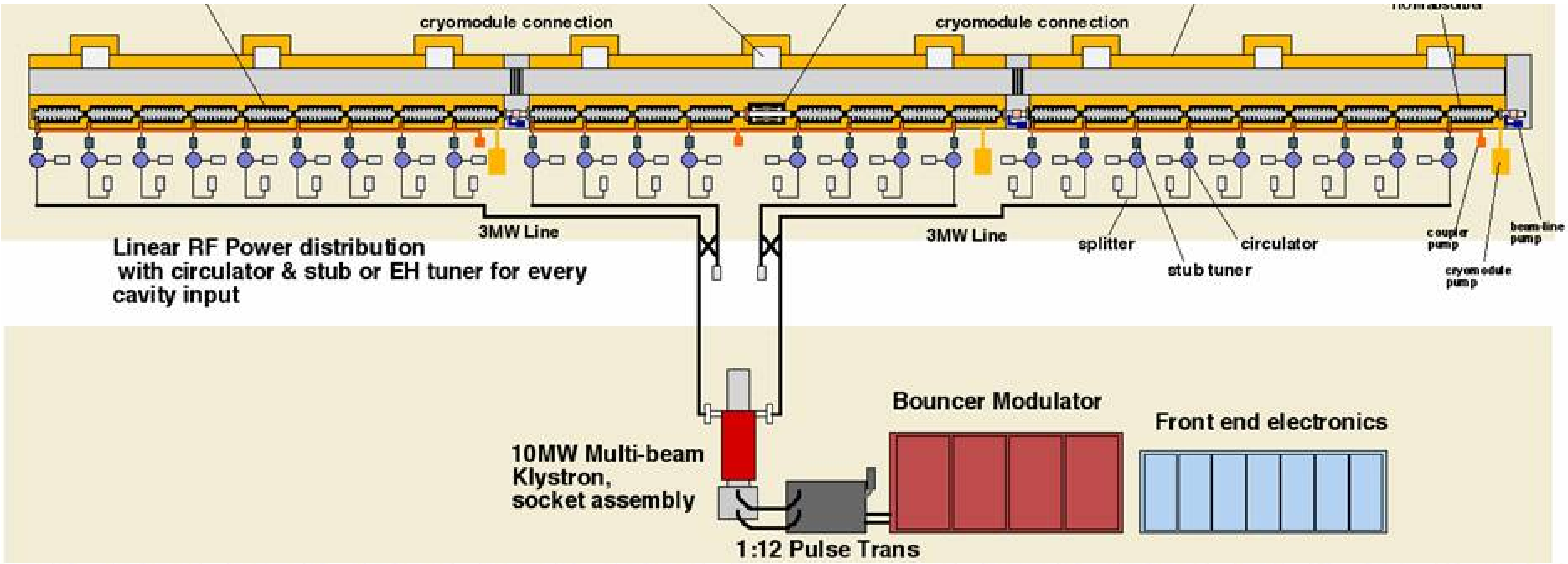
- Length ~11 km x 2
- Average gradient 31.5 MV/m
- 2 tunnels diameter 4.5 m



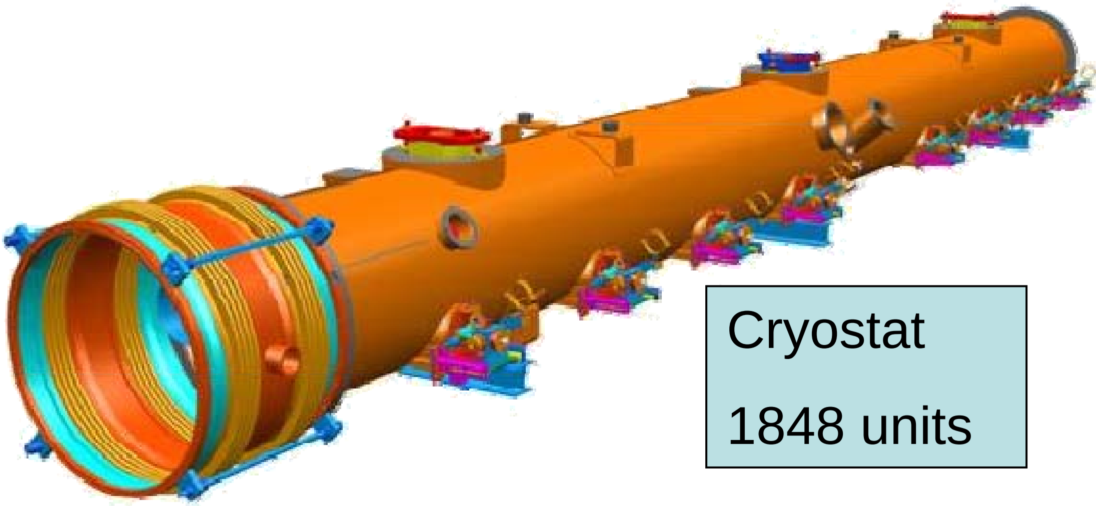
Dwg: J. Liebfritz

Main Linac RF Unit Overview

- Bouncer type modulator
- Multibeam klystron (10 MW, 1.6 ms)
- 3 Cryostats (9+8+9 = 26 cavities)
- 1 Quadrupole at the center

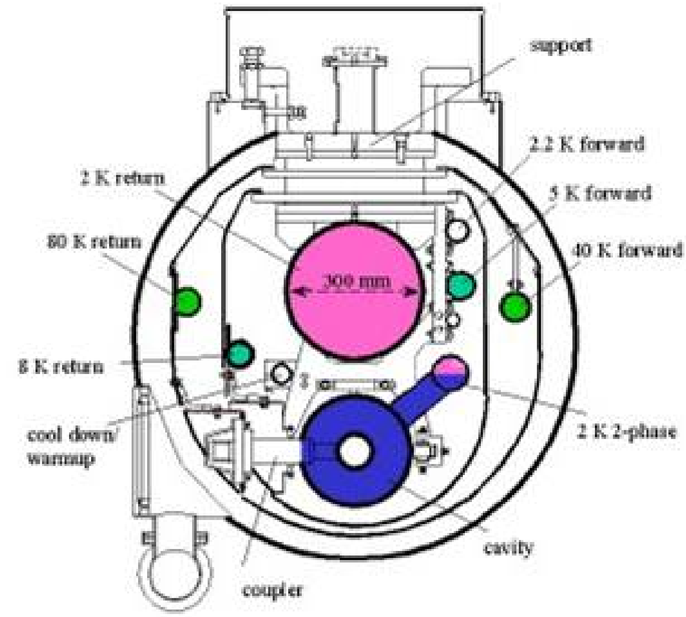


ILC Cryomodules

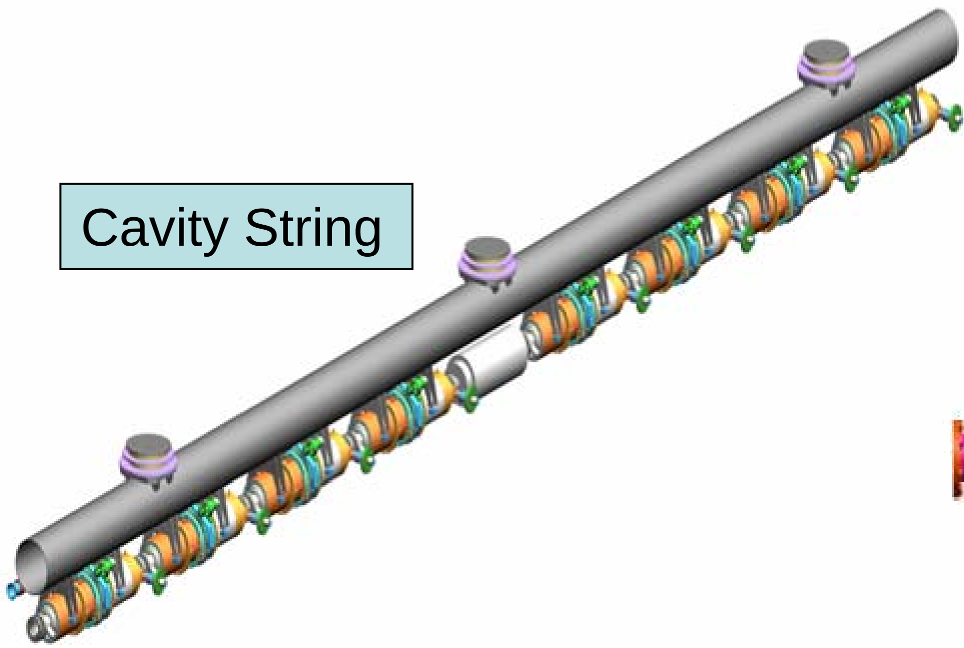


Cryostat

1848 units

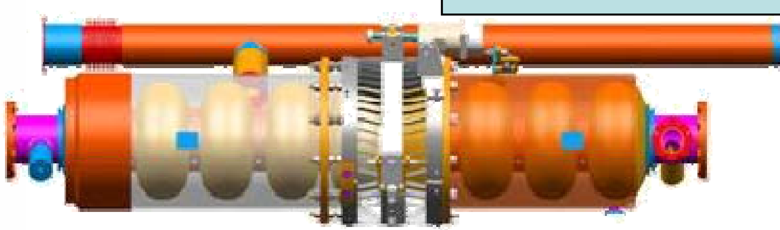


Cavity String



Cavity

16,088 units



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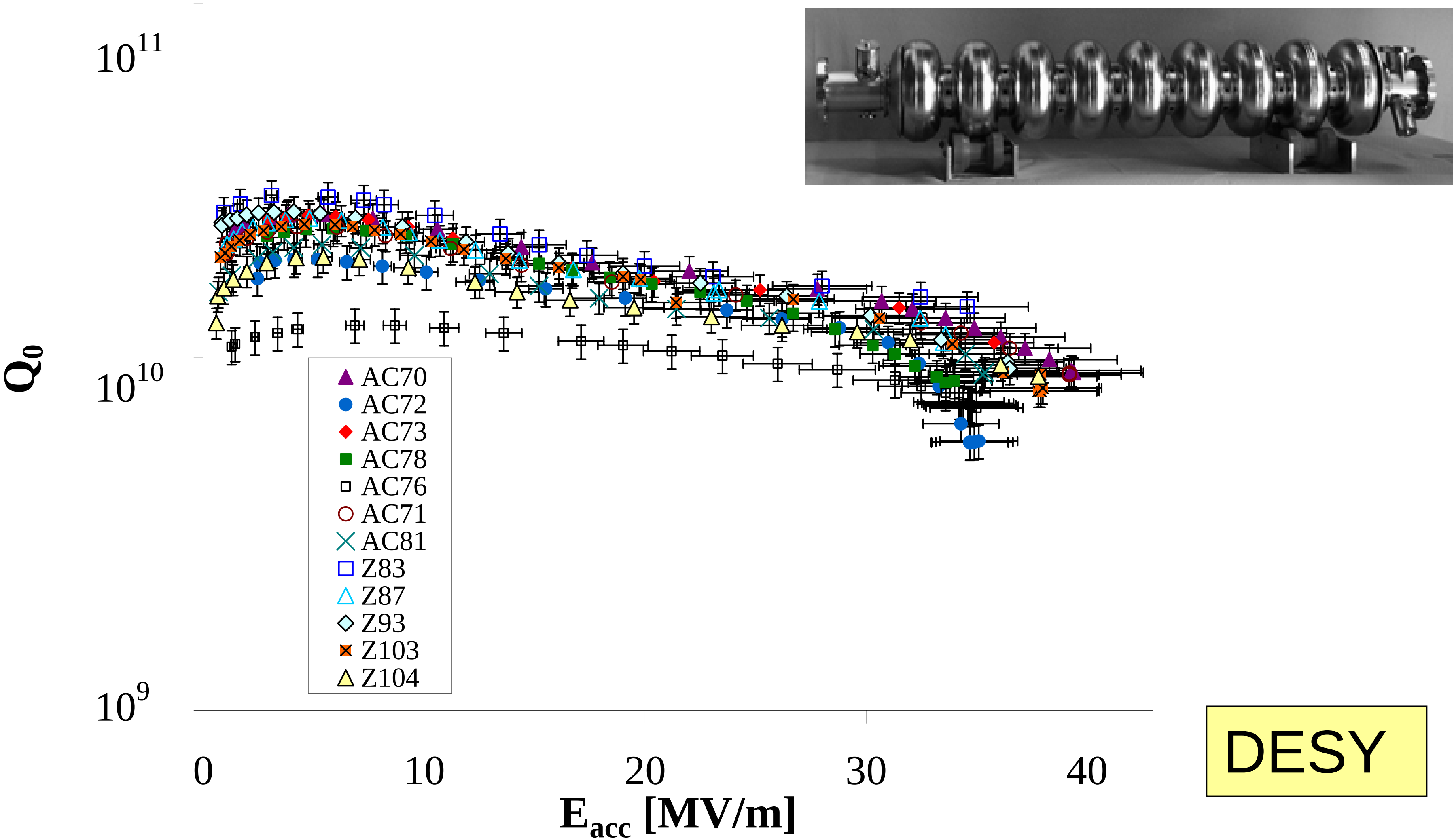
ILC Baseline Cavity Parameters

Parameter	**Value**	**Units**
Type	Standing wave	
Number of cells	9	
Accelerating mode	TM010, π-mode	
Active length	1.038	m
R/Q of fundamental mode	1036	Ω
Iris diameter	70	mm
Cell-to-cell coupling	1.9	%
Operating gradient	31.5	MV/m
Average Q_0	1.0×10^{10}	
Average Q_{ext}	3.5×10^{6}	
Fill time	596	μs
Cavity resonance width	370	Hz
B_{peak}/E_{acc}	4.26	mT/(MV/m)
E_{peak}/E_{acc}	2	

Acceptance Test of Nine-cells Cavities

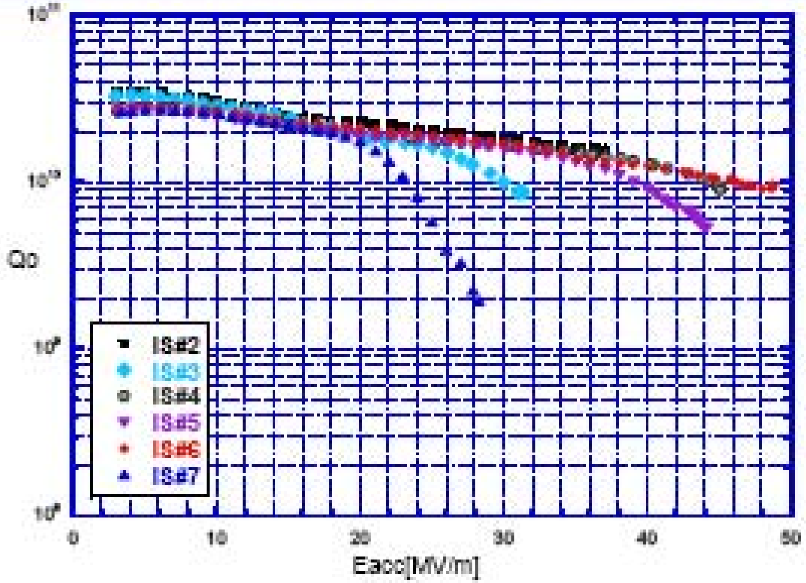


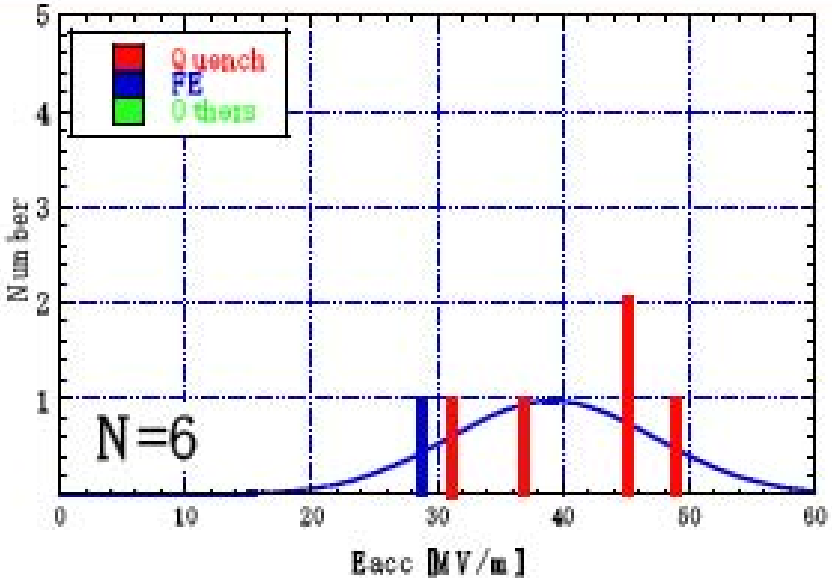
DESY

- Several Nine-cell Cavities have reached the ILC Specifications

(A) CBP+CP+Anneal+EP(80μm) +HPR+Baking(120C*48hrs)

K. Saito et al.





Ave. Eacc=39.1±8.2MV/m

Scattering:20%, Acceptability@40MV/m(ACD):50%

		IS#2	IS#3	IS#4	IS#5	IS#6	IS#7
EP(80)	Eacc	36.90	31.40	45.10	44.20	48.80	28.30
	Qo	1.53e10	8.66e9	9.07e9	5.38e9	9.64e9	1.94e9

Baseline R&D: Cavity Preparation

- The basic recipe for highest gradients is known: Electropolishing, High Pressure Water Rinse and In-situ Bakeout
  - Results are not fully reproducible
  - Field emission is a major problem
  - Some contaminants have been identified
    - e.g. H. Padamsee et al. WEPMS010
- Fine-tuning the surface preparation parameters is needed
  - Need to separate the surface preparation process from the potential fabrication errors by new vendors
- Need to get a statistically meaningful sample for the overall cavity fabrication and preparation
  - Large number of cavities from several regions in a production-like mode eventually
- Set up a dedicated international R&D effort
  - This is dubbed ‘S0’.

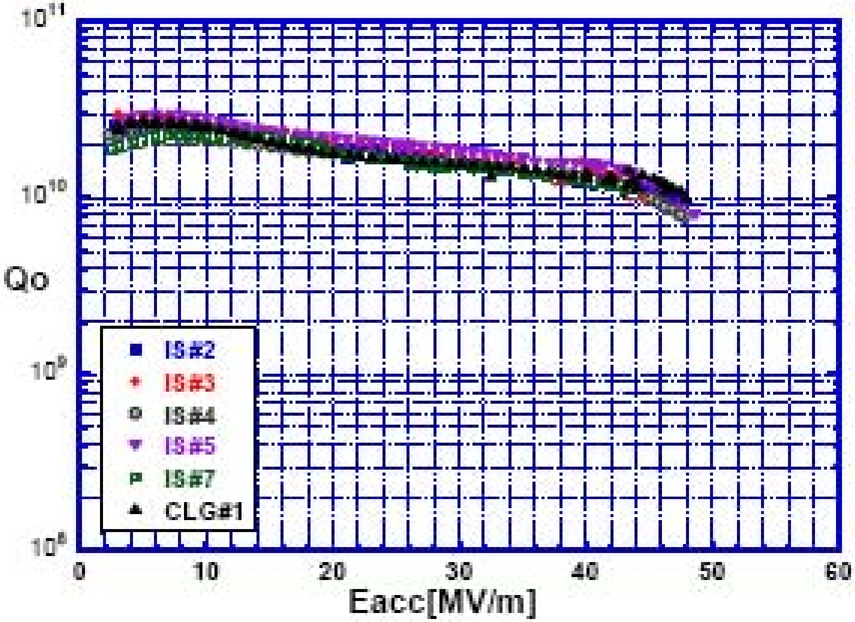
S0-Single cell study @ KEK

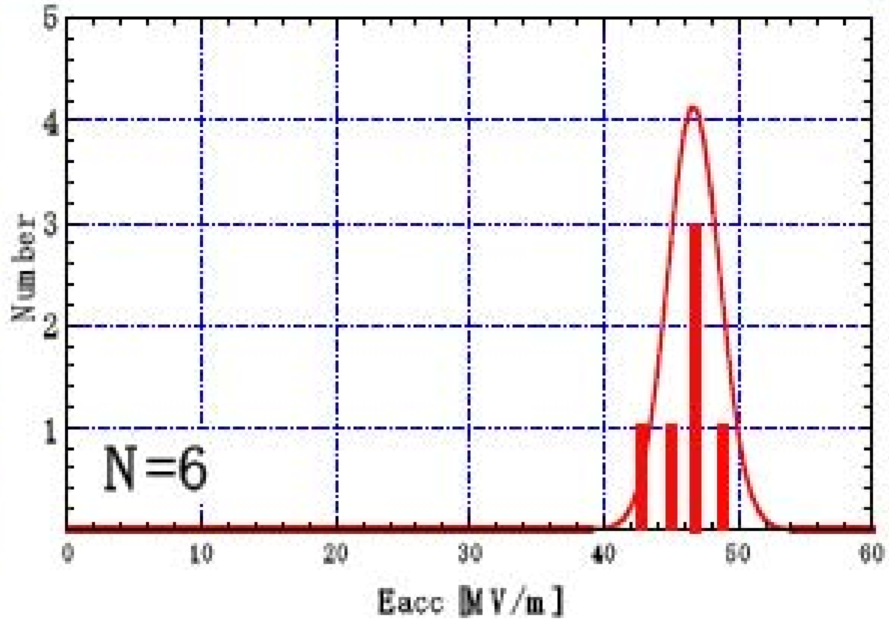
K. Saito et al.

	Eacc, max[MV/m] / Qo@Eacc max								Ave.Eacc
recipe	IS#2	IS#3	IS#4	IS#5	IS#6	IS#7	CLG#1	CLG#2	
(A) CBP+CP+AN +EP(80) +HPR+Bake	36.90	31.40	45.10	44.20	48.80	28.30			39.1±8.2
	1.53e10	8.66e9	9.07e9	5.38e9	9.64e9	1.94e9			
(B) CBP+CP+AN +EP(80+3)+HF +HPR+Bake		42.00	46.10	44.70	34.25	39.30		43.80	41.7±4.4
		9.72e9	9.47e9	1.08e10	8.56e9	1.03e10		3.46e9	
(C) +EP(20) +HPR+Bake	47.24	52.44	52.91	31.10	48.92	46.54			46.5 ±8.0
	5.98e9	1.51e10	5.23e9	5.21e9	7.56e9	9.03e9			
(D) +EP(20+3)+HF* +HPR+Bake	47.07	44.67*	47.82		48.60*	43.93*	47.90*		46.7 ±1.9
	1.06e10	0.98e10	0.78e10		0.80e10	1.17e10	1.0e10		
(E) +EP(20)+H_2O_2 +HPR+Bake	Now on going								
(F) +EP(20)+Degrease +HPR+Bake									

(D) +EP(20μm)+EP(3μm, fresh, closed) +HF* +HPR+Baking (120C*48hrs)

K. Saito et al.



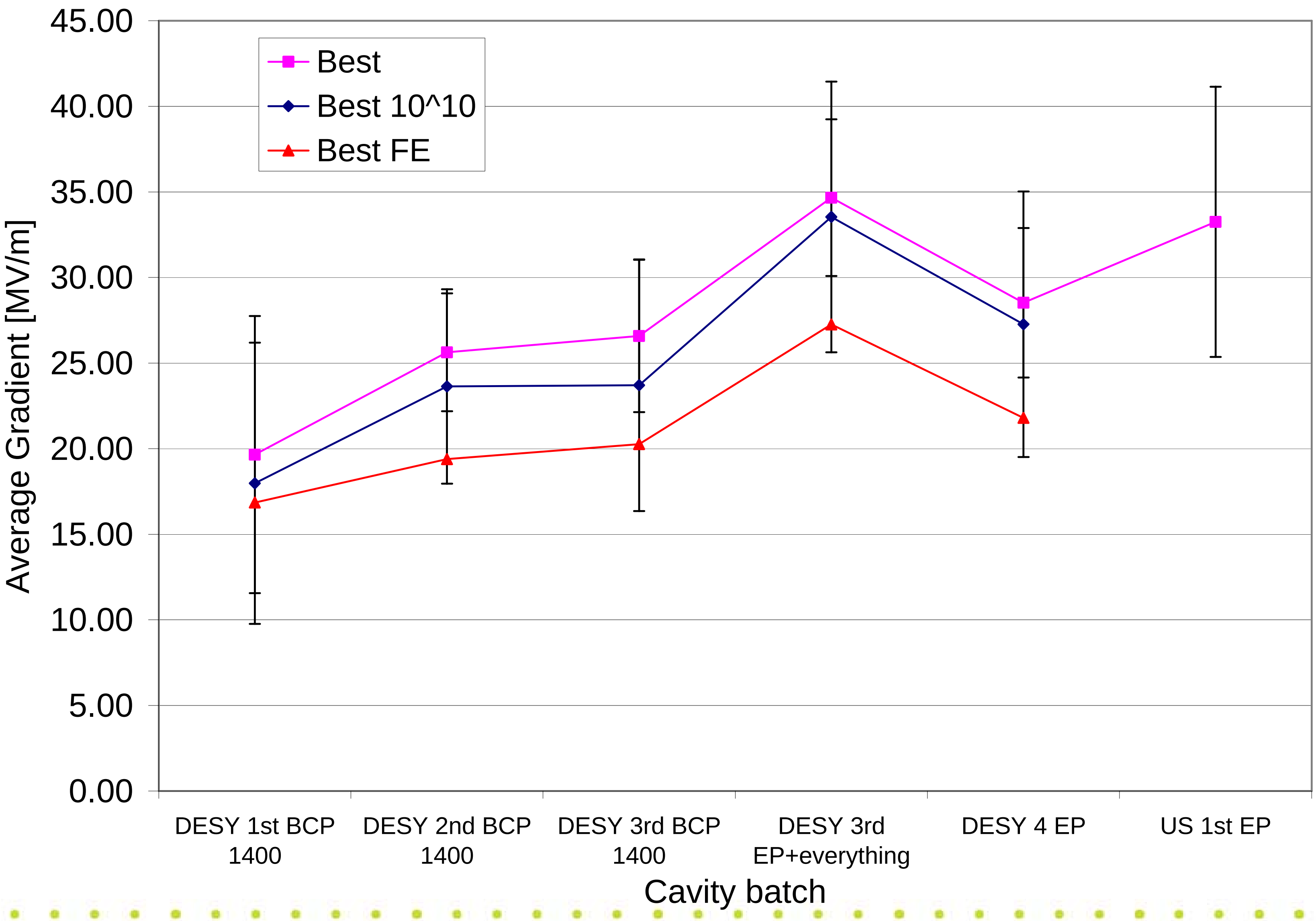


Ave. Eacc=46.7±1.9MV/m

Scattering:4%, Acceptability@40MV/m(ACD):100%

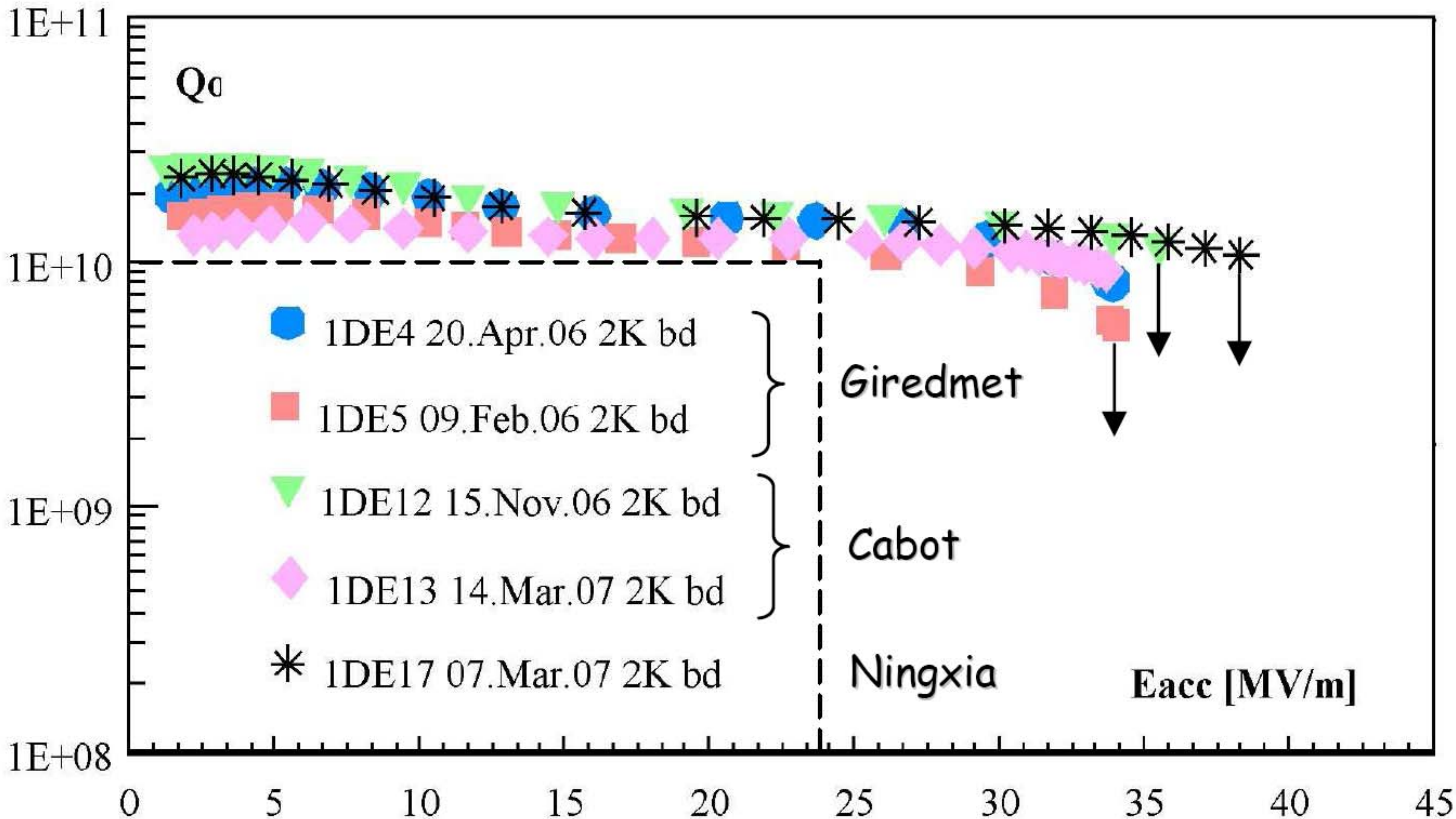
		IS#2	IS#3	IS#4	IS#6	IS#7	CLG#1
+EP(20+3) +HF*	Eacc	47.07	44.67*	47.82	48.60*	43.93*	47.90*
	Qo	1.06e10	0.98e10	0.78e10	0.80e10	1.17e10	1.0e10

'Qualified' Baseline Cavity Vendor Productions: Best Multi-Cell Test Results

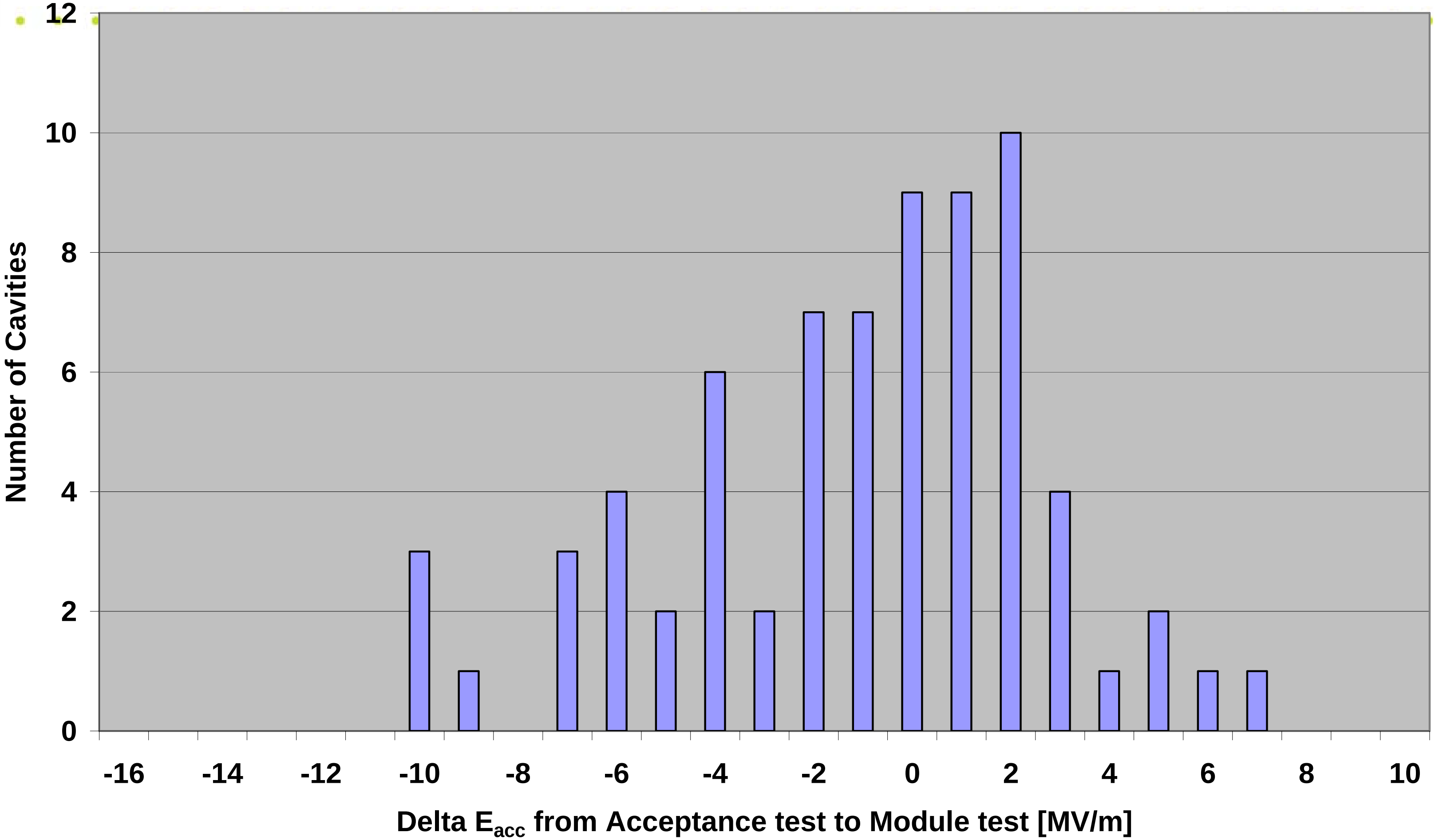


Baseline Material: More Fine-Grain Niobium Vendors

D. Reschke et al.



From Acceptance Test to the Accelerator Module

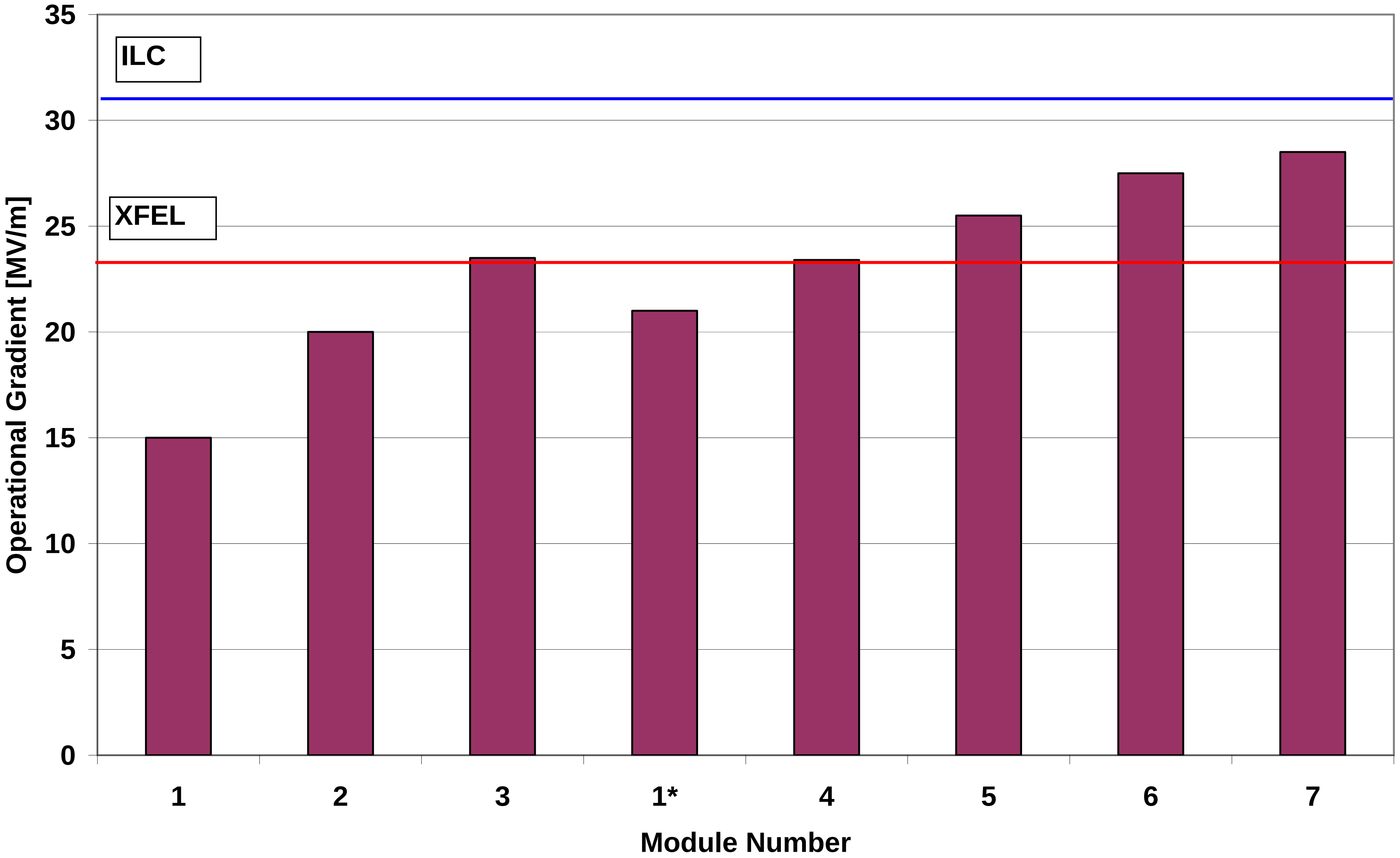


- Performance Change between Acceptance Test and Module Operational Accelerating Gradient
- Improvement on assembly procedures needed
  - **This is being addressed in an international R&D effort (called 'S1')**
  - **Addressed in studies with industry for XFEL also**

Module Test at DESY

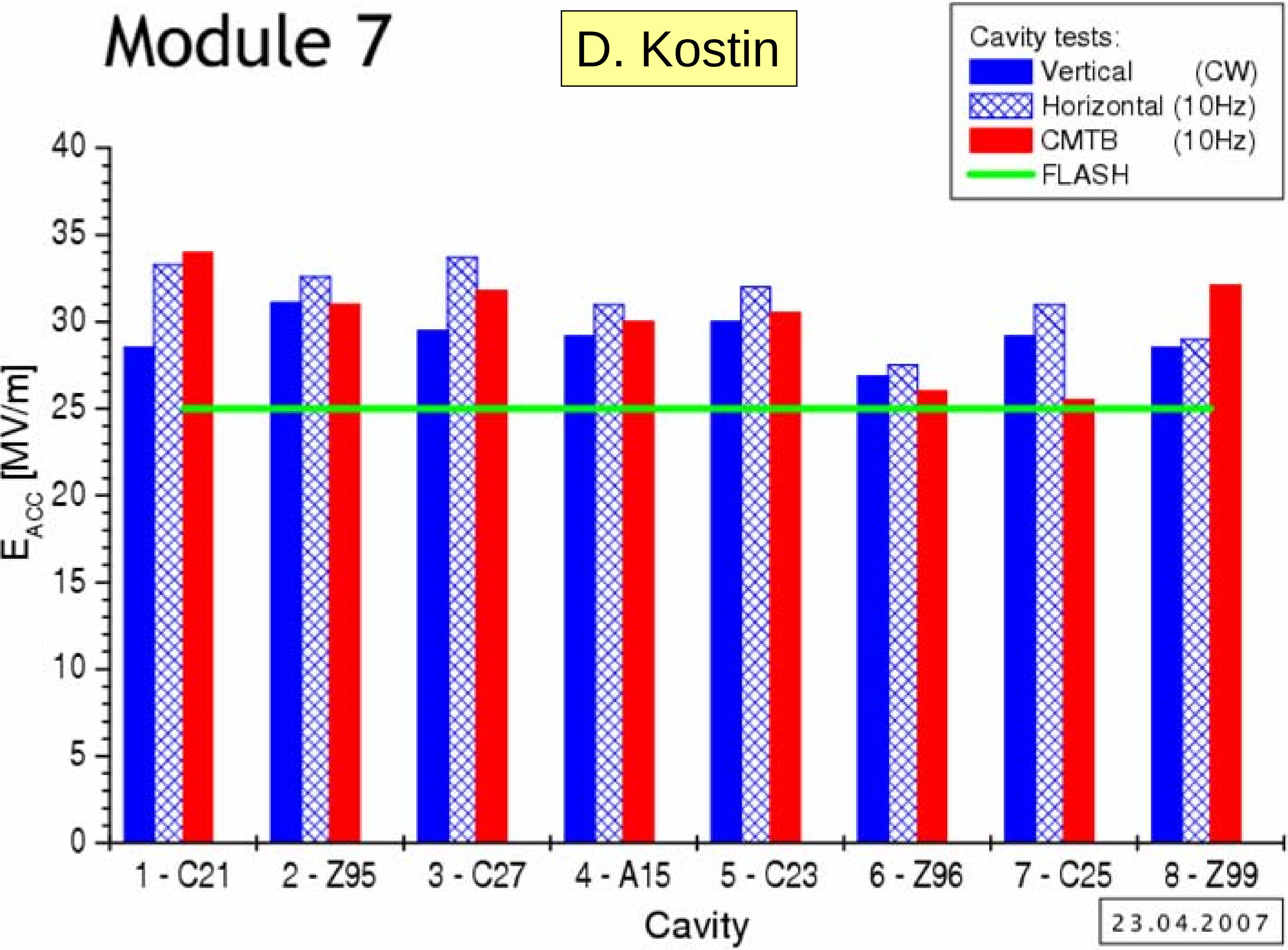
- High gradient modules have been assembled
  - **For installation in FLASH**
- Test in dedicated test stand possible e.g.
  - **Cavity performance**
  - **Thermal cycles**
  - **Heat loads**
  - **Coupler conditioning**
  - **Fast tuner performance**
  - **(LLRF tests)**
- Part of the ongoing preparation work for XFEL

Accelerator Module Operational Gradients



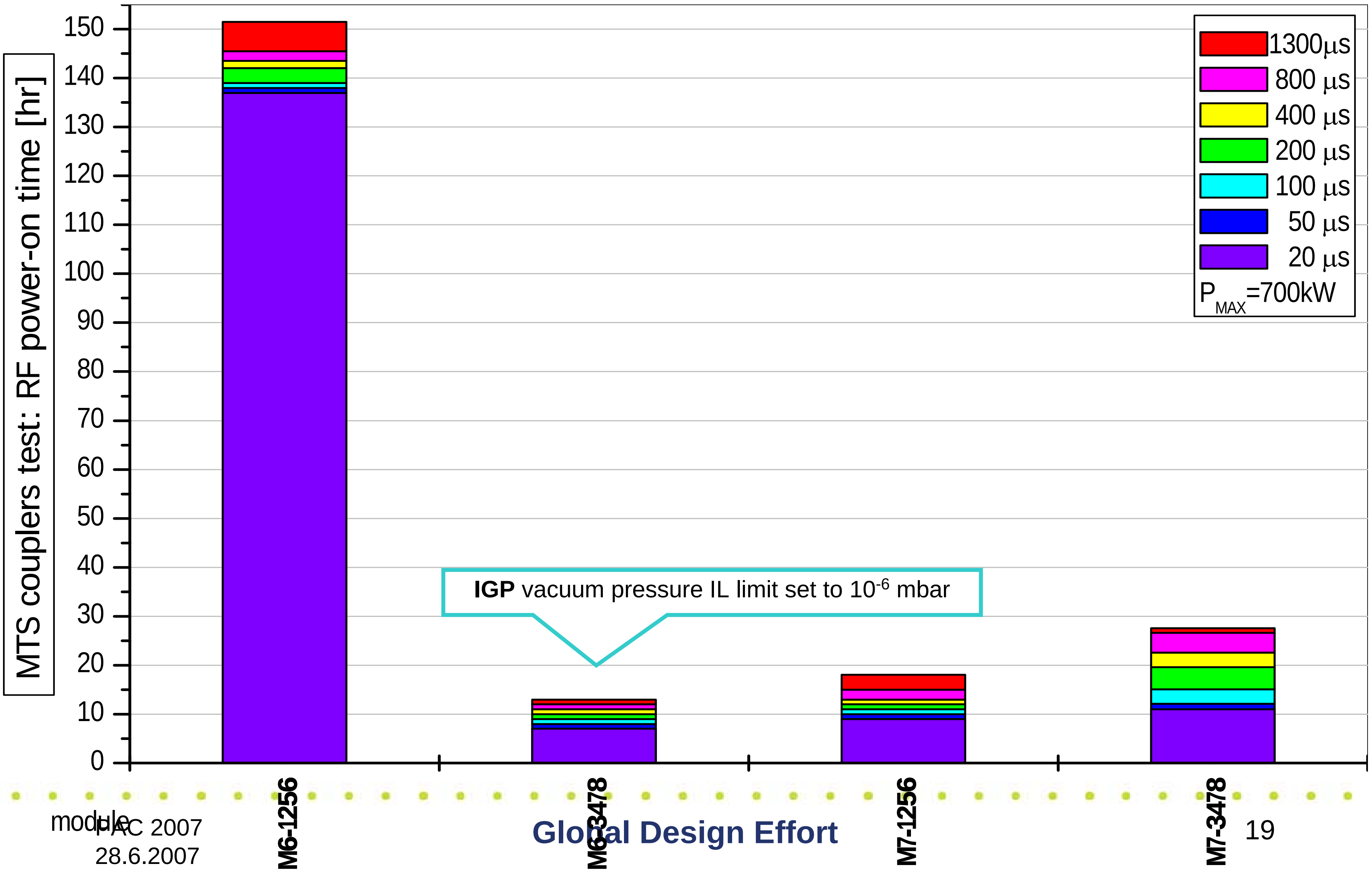
Module 7

D. Kostin



M6 and M7 RF conditioning

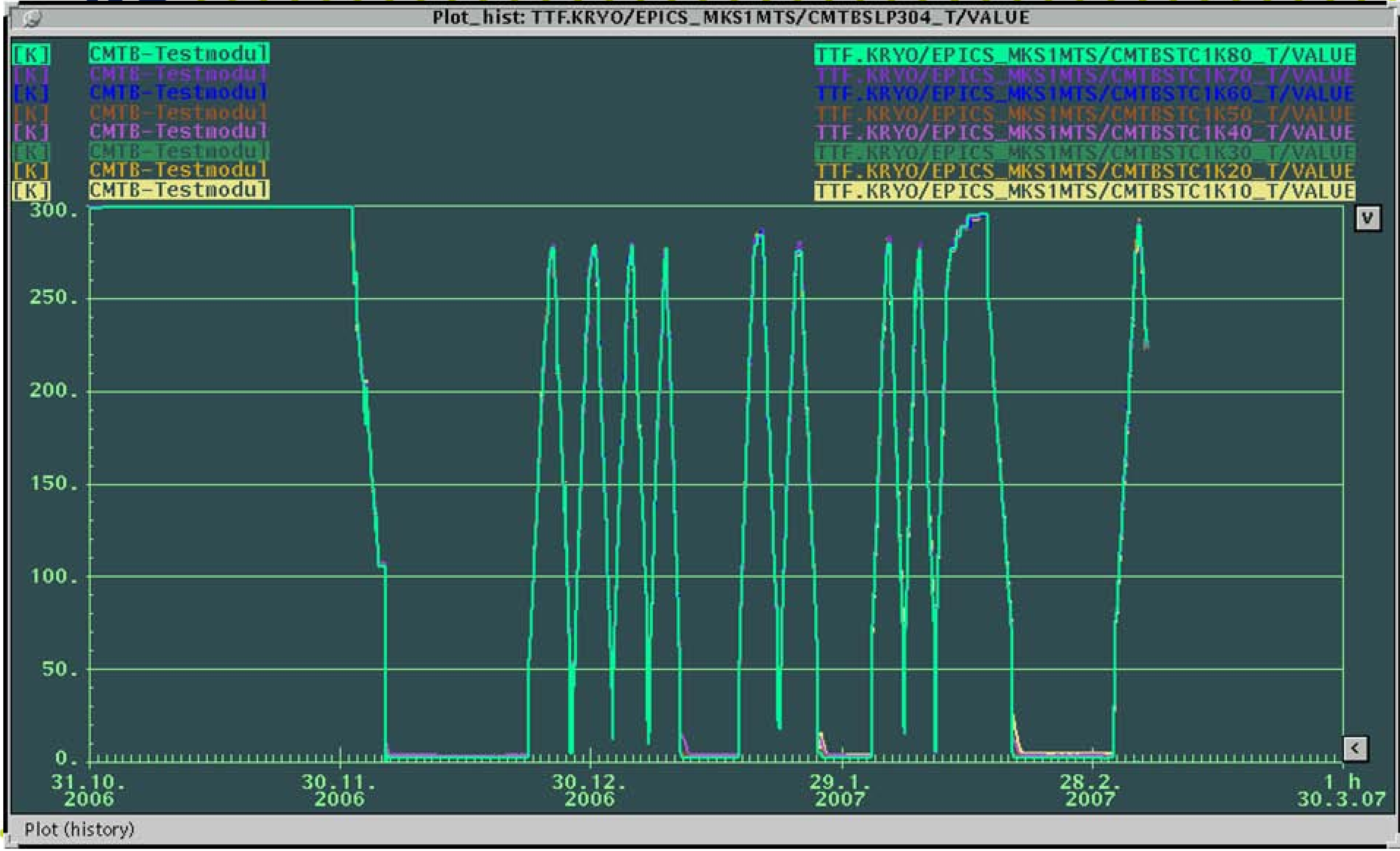
D. Kostin



CMTB Module 6 during 11th cool down

Status:06-March-07

R. Lange



XFEL Assets: E.g. Module Transportation

ACCEL

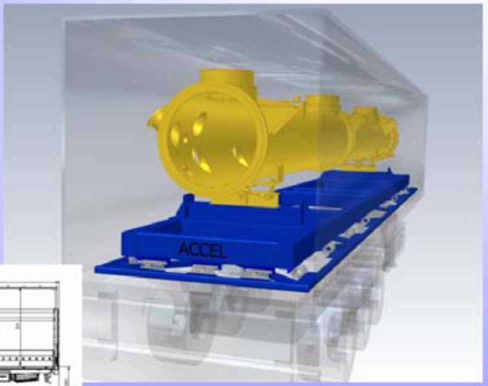
ACCEL Cryomodule Assembly Study I

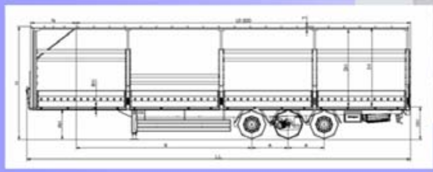
S. Bauer, B. Griep, M. Pekeler, H. Vogel, J. Zeutschel
ACCEL Instruments GmbH
Friedrich-Ebert-Str. 1
51429 Bergisch Gladbach

TTC meeting at FNAL, April 23-26, 2007

possible solution for XFEL module transports ACCEL

- transport frame is mounted on truck
- truck can be loaded with crane from top
- truck travels between assembly site and XFEL site
- available length: 13.6 m
- available width 2.5 m
- available height: 2.5 m
- allowable weight: 12 t





Caution: top loaded road semi trailer hard to find outside EU. In US only hard cover or flat bed

BILFINGER BERGER

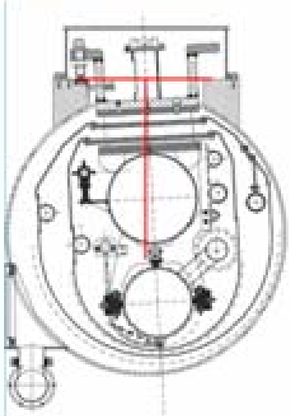
BABCOCK NOELL

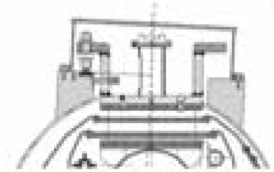
Industry Study on the Series Production of XFEL Cryomodules

C.Boffo, W. Gärtner, S. Sattler, G. Sikler, U.-M. Tai

CM Transport
Critical Components II

BABCOCK NOELL





- A lift-off case has to be avoided.
- Bending of the post is still critical, even though distributed over three posts
- A fixture of the GRT at both ends will (widely) solve both problems (-stiffness of the GRT)

XFEL: An Important Asset for the Baseline R&D

- Continuous production of cavities in line of preparation improvements
  - **Is a significant part of the cavity data set, as you have seen**
- Material issues
  - **Scanning for a large batch of material**
  - **Qualifying more niobium vendors**
  - **Alternatives: Large-grain material is still an option for the XFEL**
- Pre-series will start 2008
  - **EP is becoming industry process from autumn**
- Design for manufacturing for the cavities
  - **Review types of welds and welding procedures**
- Quality assurance
  - **Defining a reasonable and affordable QC procedure**
- Module design and assembly has been reviewed by industry
  - **Report is due soon**
- (Coupler industrialization)

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Large Grain Material (JLab)

CBMM

Ingot "D",800 ppm Ta

Ingot "A", 800 ppm Ta

Ninxia

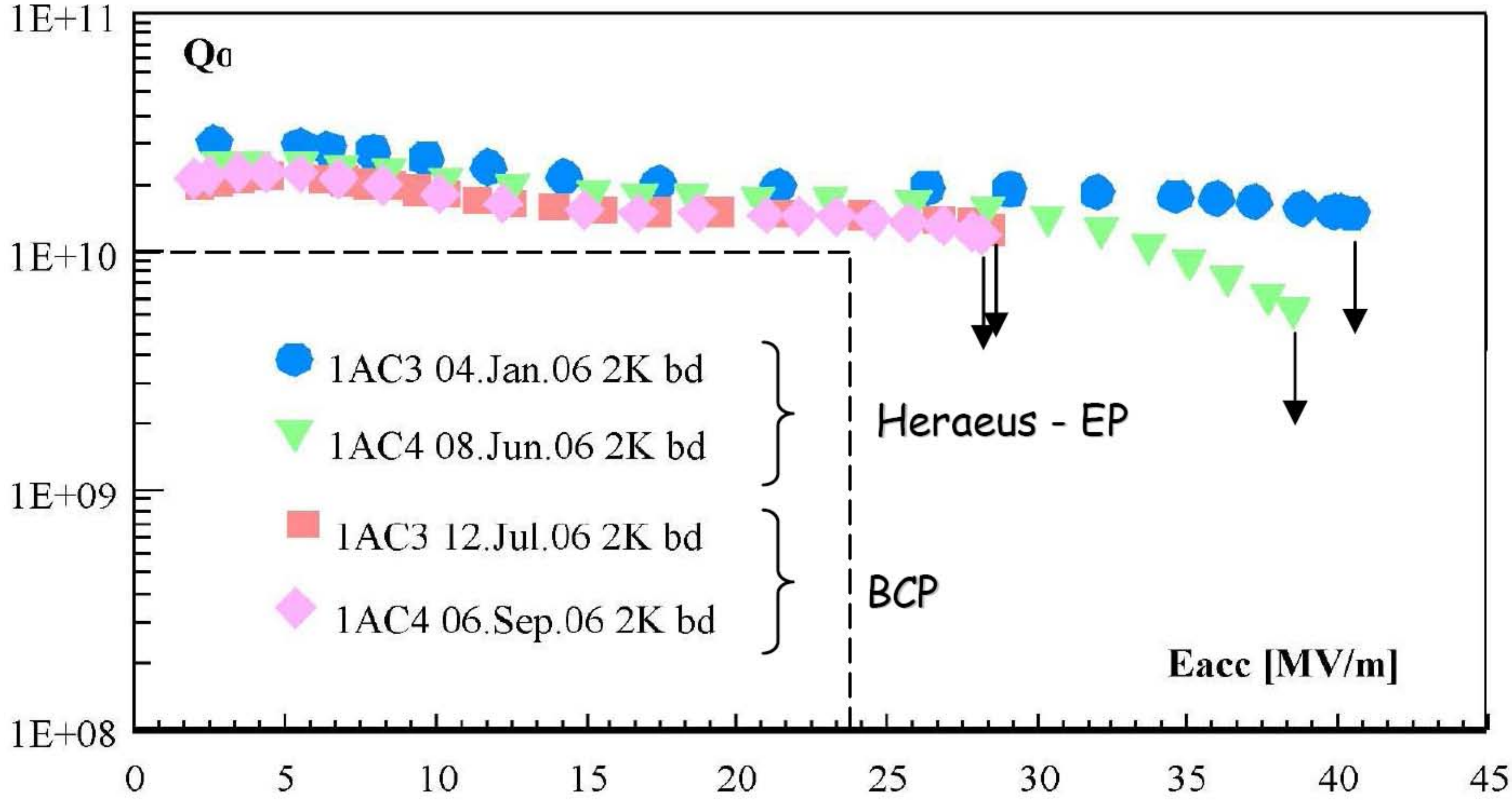
Ingot "C", 1500 ppm Ta

Wah Chang

Heraeus

Talk by W. Singer, THOAKI01

Large Grain Material: EP and BCP

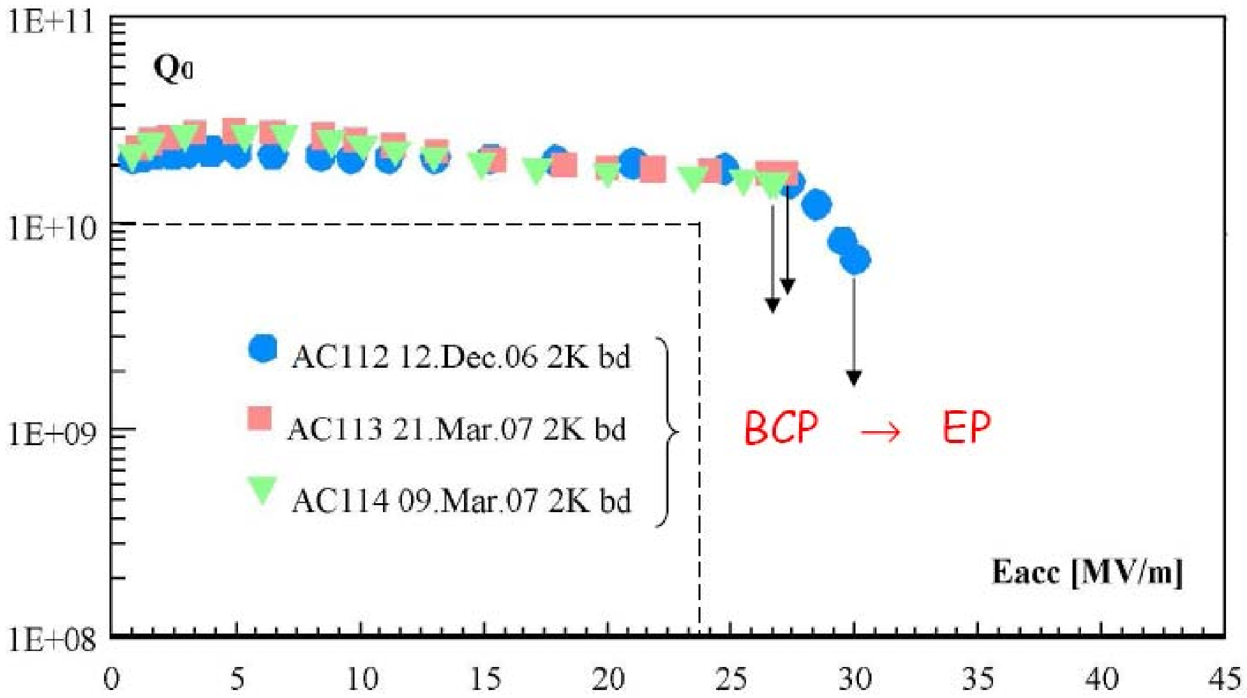


D. Reschke et al.

Large Grain Material: Multi-Cells (XFEL option)

Option : Large Grain cavities / BCP

Heraeus / Accel (three cavities)



Less fabrication steps (lower cost)

no forging-rolling

disk from ingot

(less material pollution)

High RRR ~ 500

(avoid HT to ↗ K)

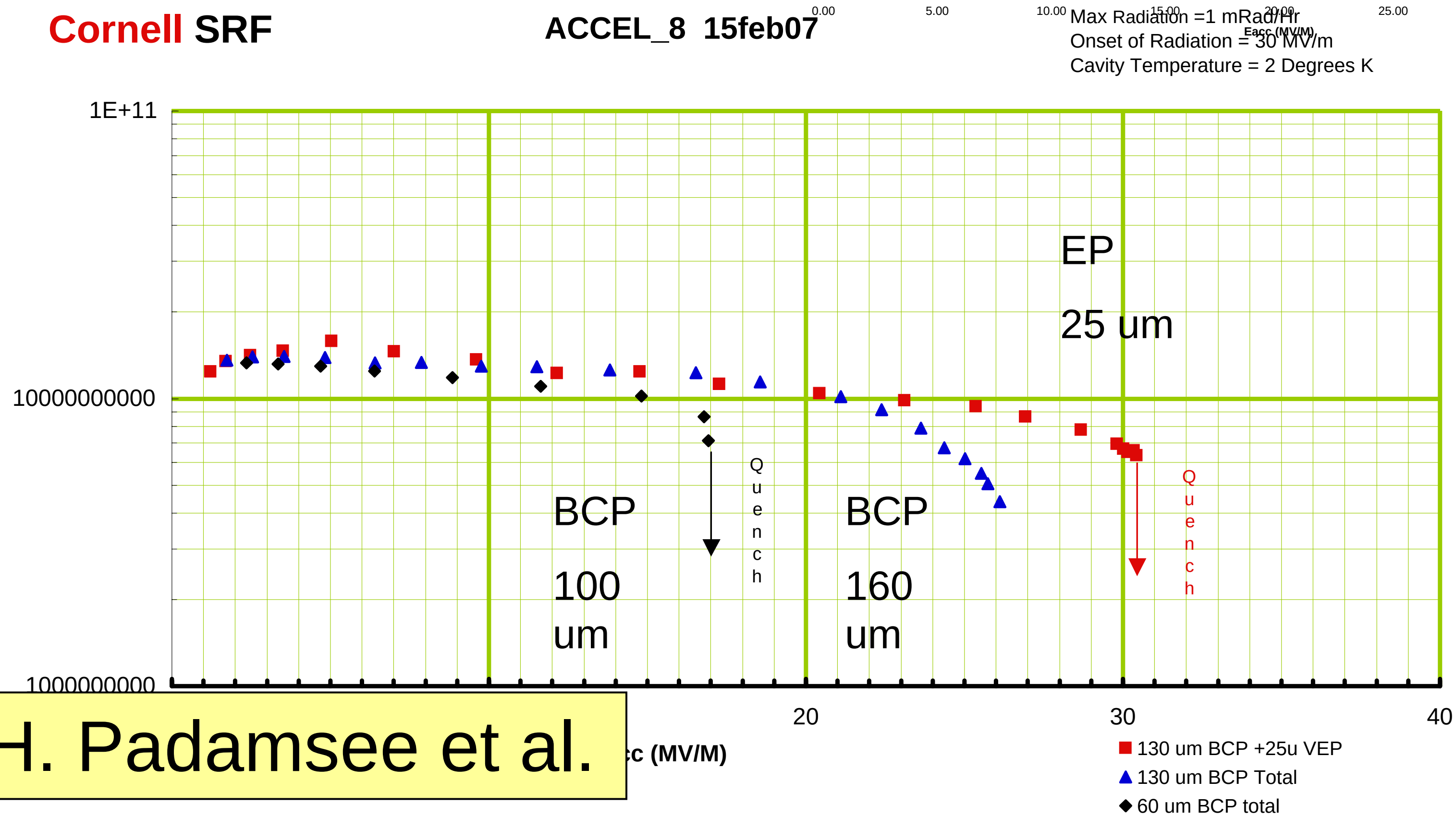
Probably higher gradients after Electropolishing (coming tests)

Vertical Electropolishing Set-up

- Cornell development
- Possible benefits
- Simpler
  - **No large acid barrel, no plumbing, valves, no acid heat exchanger…**
- Less expensive to reproduce many systems
- Possible disadvantage
  - **more exposure to H**
  - **600 - 800 C, H degassing required**

H. Padamsee et al.

Vertical EP Test Results



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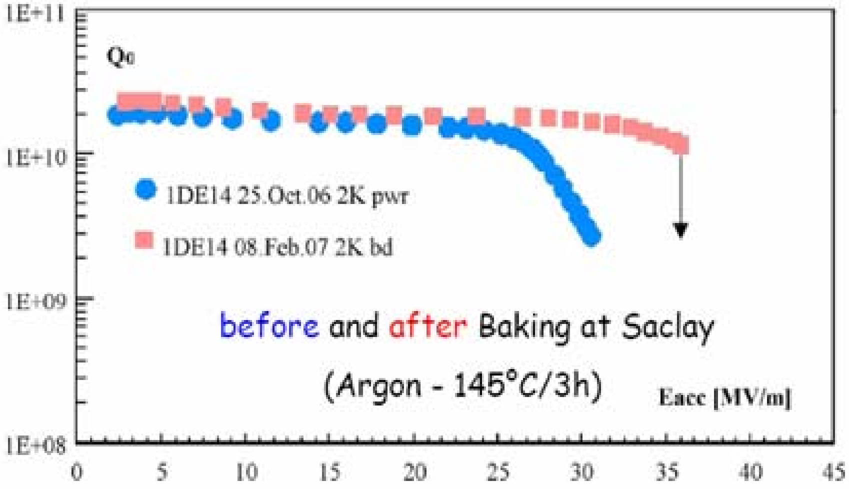
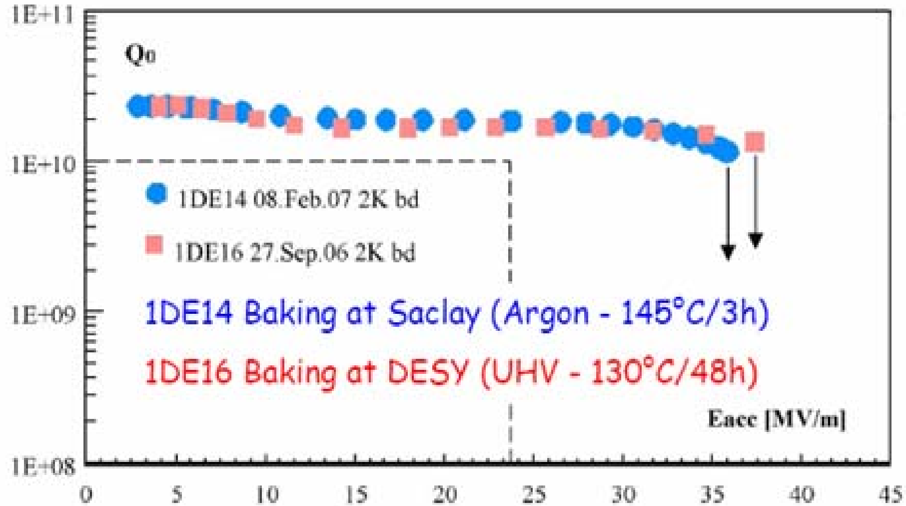
Baking

Best parameters for Baking XFEL

- Standard process : Ultra High Vacuum
  110°C/60h - 120°C/48h - 139°C/12h

- Fast Argon baking : Argon - 145°C / 3 h
  successfully tested on EP cavity



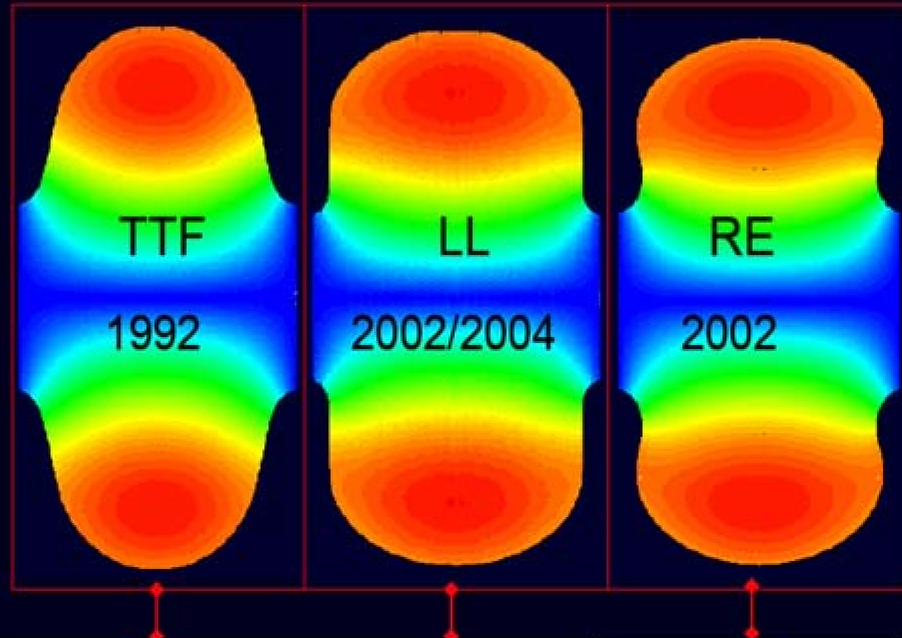


Equivalent Results
Q-drop removal
gradients performances

1DE14 / 1DE16 are in-house DESY twin Cavities
Plansee (Fine Grain Nb) : qualified

Alternative Cavity Shapes

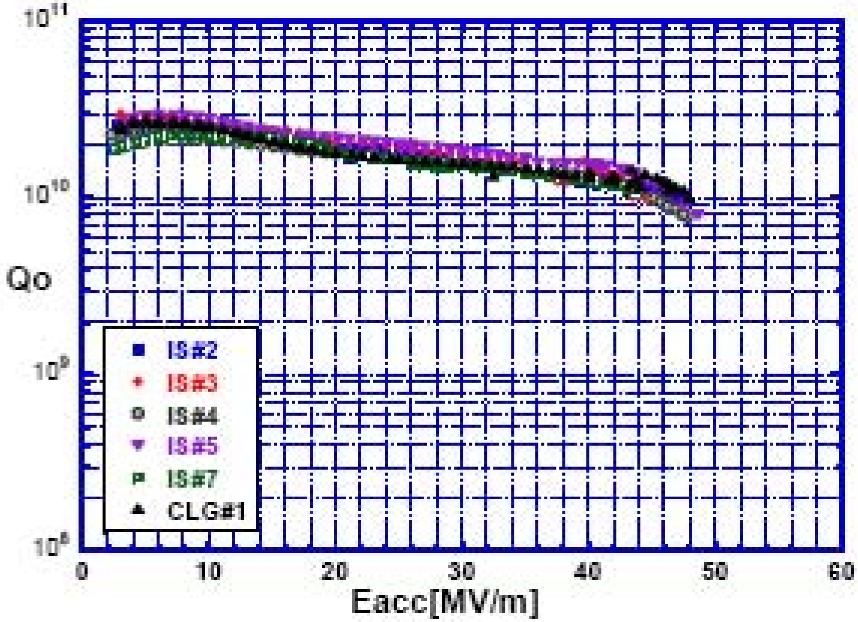
Example: 1.3 GHz inner cells for TESLA and ILC

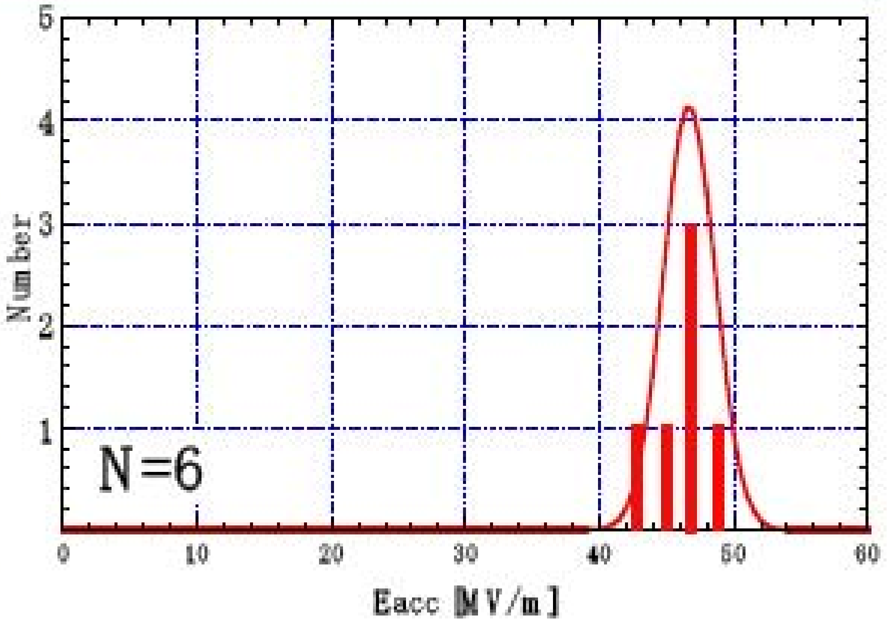


r_{irisb}	[mm]	35	30	33	
k_{cc}	[%]	1.9	1.52	1.8	field flatness
E_{peak}/E_{acc}	-	1.98	2.36	2.21	max gradient (E limit)
B_{peak}/E_{acc}	[mT/(MV/m)]	4.15	3.61	3.76	max gradient (B limit)
R/Q	[Ω]	113.8	133.7	126.8	stored energy
G	[Ω]	271	284	277	dissipation
R/Q*G	[Ω*Ω]	30840	37970	35123	dissipation (Cryo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

K. Saito et al.

(D) +EP(20μm)+EP(3μm, fresh, closed) +HF*
+HPR+Baking (120C*48hrs)





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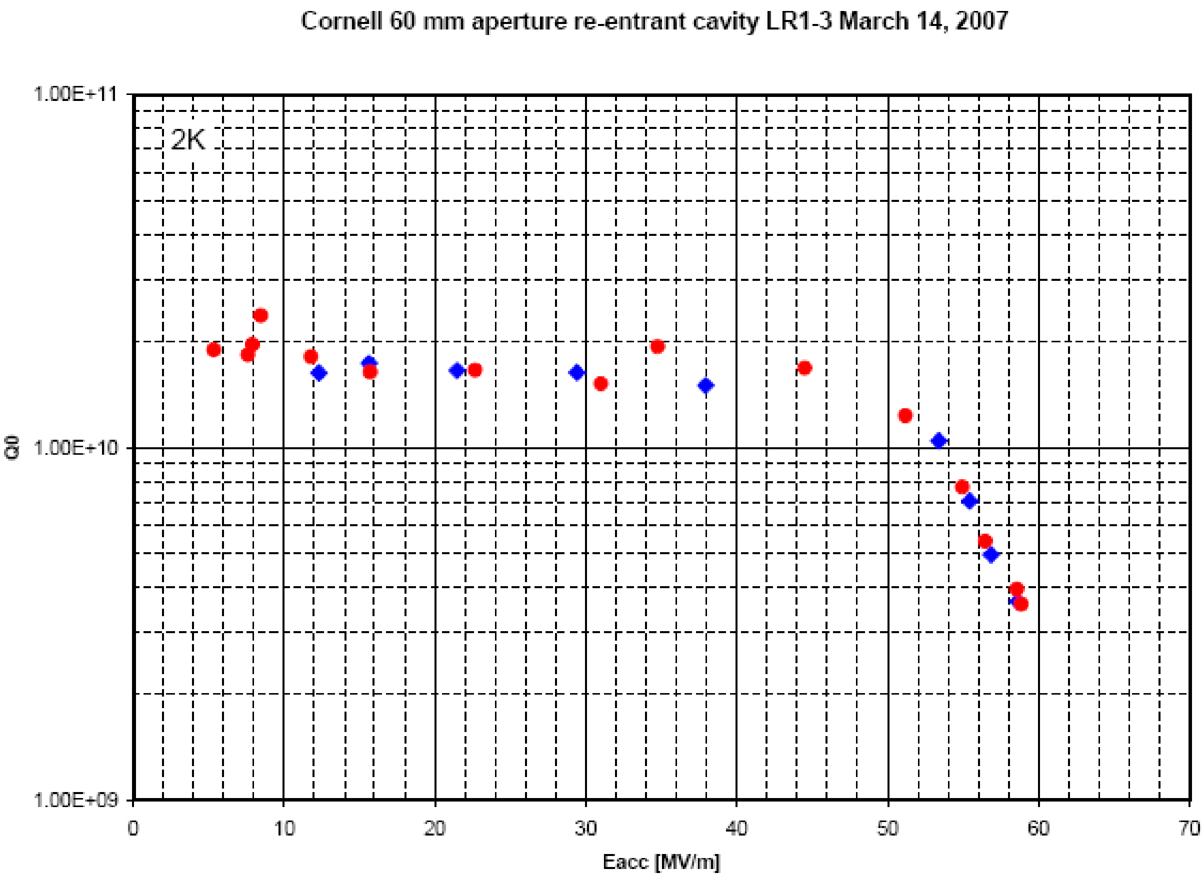
	Qo	1.06e10	0.98e10	0.78e10	0.80e10	1.17e10	1.0e10

60mm-Aperture Re-Entrant Cavity
Best Eacc = 59 MV/m

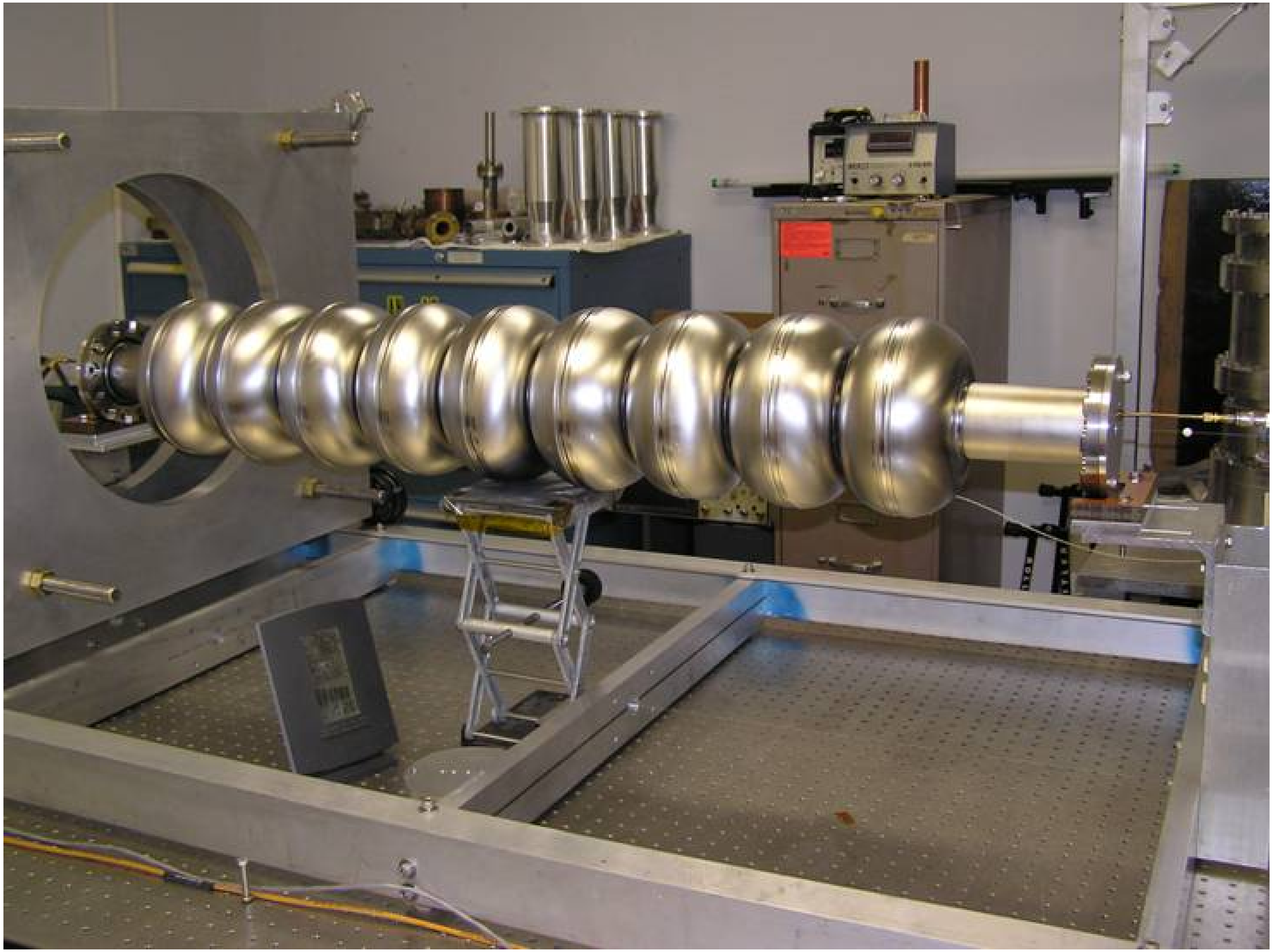
Cornell-KEK Collaboration

H. Padamsee et al.
WEPMS009



RE-LR1-3

ACD: 9-cell Re-Entrant Cavity (70 mm aperture)



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ILC SRF R&D Organisation

- First steps toward an internationally coordinated program have been undertaken
  - **‘S0‘ and ‘S1‘ Task Force**
- ILC Engineering Design Report is the next milestone
  - **Move toward a project-like organisation**
    - See B. Barish‘s talk, MOXKI02
  - **For SRF R&D**
    - Ensuring the baseline performance is high priority
      - Coordination between regions is essential
    - At the same time develop alternatives to a level where the technical choices to replace baseline choices can be made
      - Develop criteria with proponents of alternatives e.g. type of tests needed
      - Timelines and impacts on ILC system design of alternatives need to be understood
  - **This will allow to be flexible enough to integrate alternatives in the design when they are ready**

Conclusion & Outlook

- The R&D for the ILC SRF has a large variety of topics
  - **Ensure baseline performance and reduce cost**
- International coordination of R&D programme has started
  - **Task Force on high-gradient performance**
  - **Results are promising and will be evaluated on multi-cells**
- The ongoing work for the XFEL is a major asset for ILC
  - **e.g. ongoing cavity production, industrialization**
- Several alternatives have shown excellent results
  - **e.g. new material, shapes**
- The move towards a project-like structure has to and will accomodate both baseline and alternatives

- Thanks for your attention!