



# Main Linac Discussion Session

Lutz Lilje for the Working Group



# Contents

- R&D session
  - Thursday morning
- EDR Tasklist discussion I
  - Thursday afternoon
- XFEL Industrialisation
  - Friday morning
- EDR Tasklist discussion II
  - Friday afternoon



# KEK: Single-Cell Comparison

K. Saito et al.

	Eacc,max [MV/m] / Qo @ Eacc,max									E <sub>max</sub> average [MV/m]	Scatt. [%]	MP	Acceptability @ 400 V/m [%]
	IS#2	IS#3	IS#4	IS#5	IS#6	IS#7	IS#8	CLG#1	CLG#2				
CBP+CP+AN+EP(20)+HPR+Bake	36.9	31.4	45.1	44.2	48.8	28.3				39.1 ± 8.2	21	Yes	50
	1.53E10	8.66E9	9.07E9	5.38E9	9.64E9	1.94E9							
CBP+CP+AN+EP(20+3 fresh)+HPR+Bake		42.0	46.1	44.3	34.3	39.3			43.8	41.7 ± 4.4	11	Yes	67
		9.72E9	9.47E9	1.08E10	8.56E9	1.03E10			3.46E9				
CBP+CP+AN+EP(40+3 fresh)+HPR+Bake	43.9						49.2*			46.6 ± 3.7	8	Yes	100
	9.47E9						4.33E9						
+EP(20)+HPR+Bake	47.2	52.2	52.9	31.1	48.9	46.5				46.4 ± 8.0	17	Yes	83
	5.98E9	1.51E10	5.23E9	5.21E9	7.56E9	9.03E9							
+EP(20+3 fresh)+HPR+HF+Bake	47.1	44.7	47.8		48.6	43.9		47.9		46.7 ± 1.9	4	Yes	100
	1.06E10	9.80E9	7.80E9		8.00E9	1.17E10		1.00E10					
+EP(20)+H <sub>2</sub> O <sub>2</sub> +HPR+Bake	52.3			34.1	43.4	40.9				42.7 ± 6.0	18	Light	50
	1.09E10			1.37E10	1.39E10	3.01E9							
+EP(20)+Degreasing (US)+HPR+Bake	50.1	52.2								51.2 ± 1.5	2.9	Light s	100
	7.80E10	7.08E9											
Others Megasonic													



# S0S1 Plan is on the Move

- Dedicated manpower added to task force
- R&D with many results closely linked to this plan are available already
  - **E.g. the XFEL project is an important stepping stone with several important results for the ILC**
- Tight-loop started
  - **Hot candidates for surface preparation:**
    - Fresh acid, H<sub>2</sub>O<sub>2</sub>, Ultrasound degrease
  - **Common data sets are being developed**
- Production-like
  - **Resource-intensive**
  - **Several batches are underway**
  - **Facilities are becoming online (Jlab, STF coming next)**
- Modules
  - **M6 and M7 are important data points**
  - **Resource-intensive and long lead times**
    - Under discussion: Propose to build proof-of-principle across regions
  - **Interface to S2 needs work**
- S0S1 Plan has become much clearer as resources are known better
  - **Scenarios have been developed**
    - Pessimistic case: A lot of data available for an educated decision for the EDR
    - Optimistic case: Even though the final full production-like assessment will be later than the EDR a significantly improved data set available on ILC-specific process
- XFEL
  - **Several points of connection have been discussed and are critical to the success of the ILC R&D program**
- Alternatives are developing rapidly

# Gradient Optimization

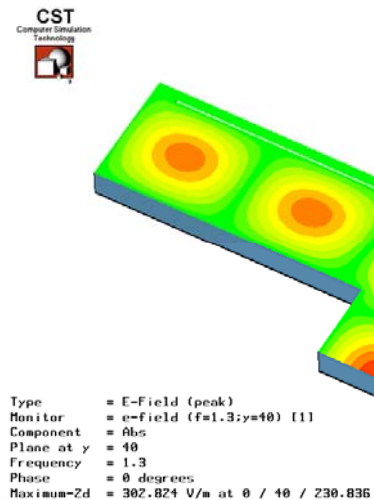
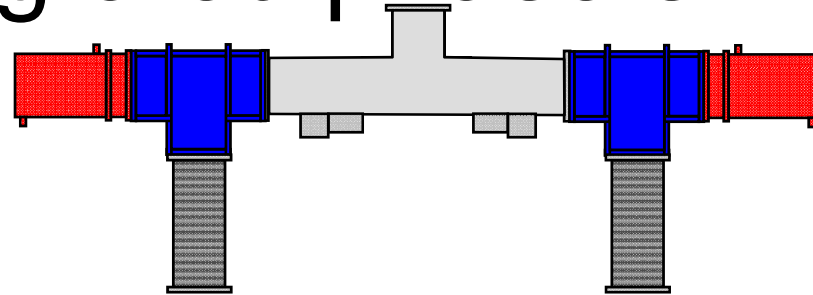
Consider uniform distribution of gradient limits  $(G_{lim})_i$  from 22 to 34 MV/m in a 26 cavity rf unit - adjust cavity Q's and/not cavity power (P) to maximize overall gradient while keeping gradient uniform ( $< 1e-3$  rms) during bunch train

Optimized  $1 - \langle G \rangle / \langle G_{lim} \rangle$ ; results for 100 seeds

Case	Not Sorted [%]	Sorted [%]
Individual P's and Q's (VTO and Circ)	0.0	0.0
1 P, individual Q's (Circ but no VTO)	$2.7 \pm 0.4$	$2.7 \pm 0.4$
P's in pairs, Q's in pairs (VTO but no Circ)	$7.2 \pm 1.4$	$0.8 \pm 0.2$
1 P, Q's in pairs (no VTO, no Circ)	$8.8 \pm 1.3$	$3.3 \pm 0.5$
$G_i$ set to lowest $G_{lim}$ (no VTO, no Circ)	$19.8 \pm 2.0$	$19.8 \pm 2.0$

Date      Event      "Sorted" means cavities are arranged in pairs of nearly equal  $G_{lim}$   
The number after " $\pm$ " is the rms value

# New Binary Cell with shunt tee with integrated phase shifter



Date      Event

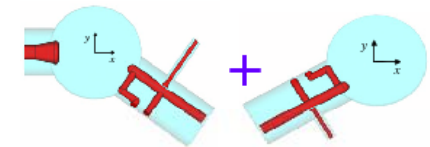
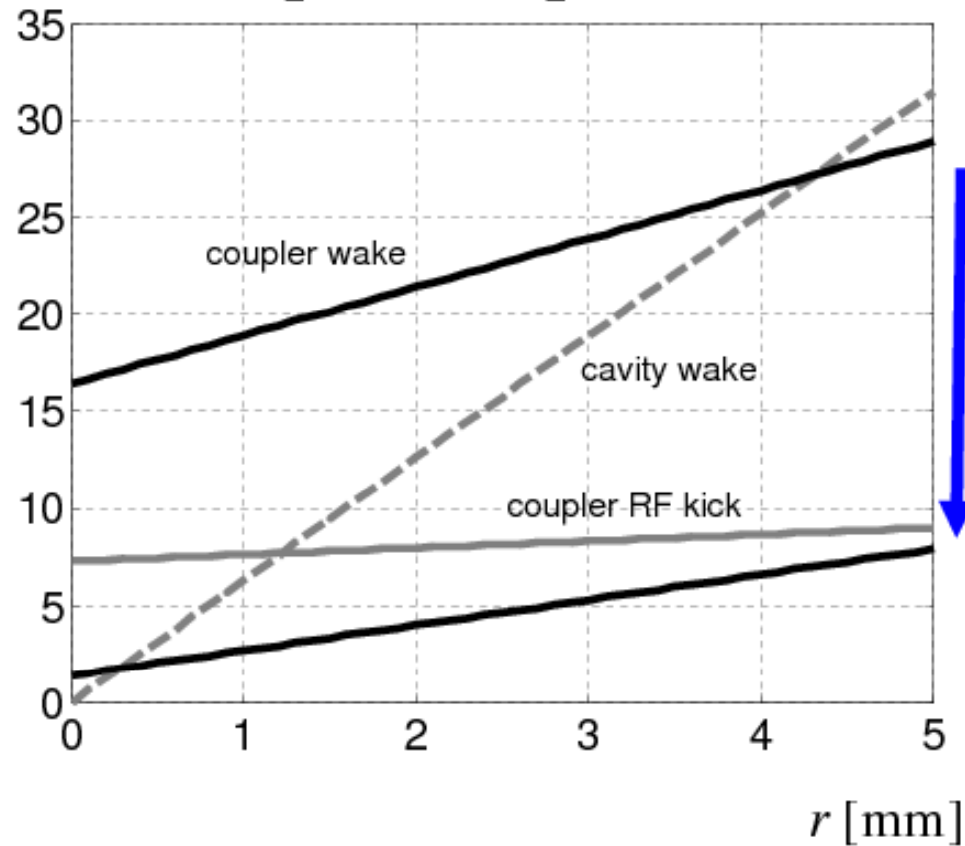
**Stefan Choroba „XFEL High Power RF System Recent Developments“**

## Head-Tail Kick (ILC)

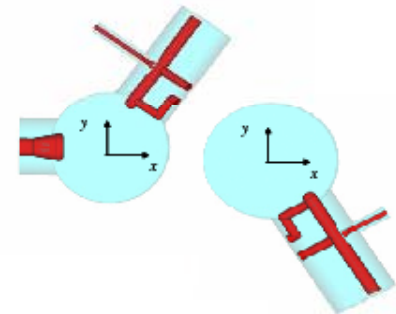
$$\sigma = 300 \mu\text{m}$$

$$k_{\perp}^{rms} \approx k_{\perp}^{0,rms} + k_{\perp}^{1,rms} r$$

$$k_{\perp}^{rms} \left[ \frac{V}{nC * \text{cavity}} \right]$$



Old coupler orientation

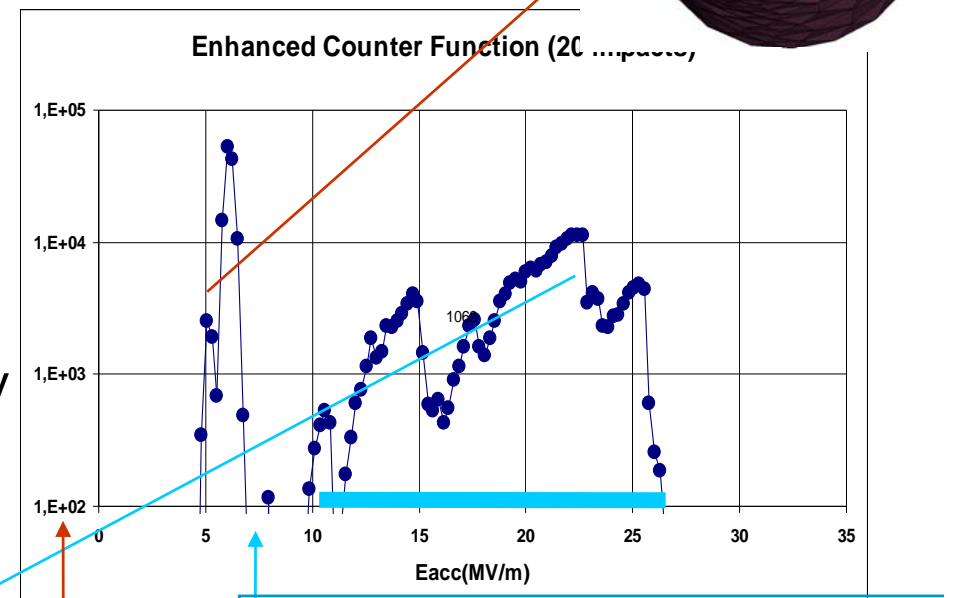
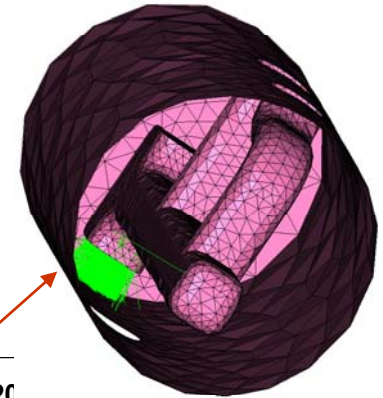
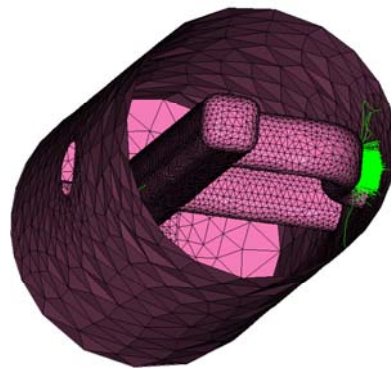


New coupler orientation



# MULTIPACTORING SIMULATIONS IN CAVITIES AND HOM COUPLERS (N.Solyak)

- 3<sup>rd</sup> Harmonic Cavity and couplers
- TESLA cavity and couplers
- LL cavity and HOM
- Re-entrant Cavity
- Ichiro cavity and transition
- HOM coupler in SNS beta 0.81 cavity

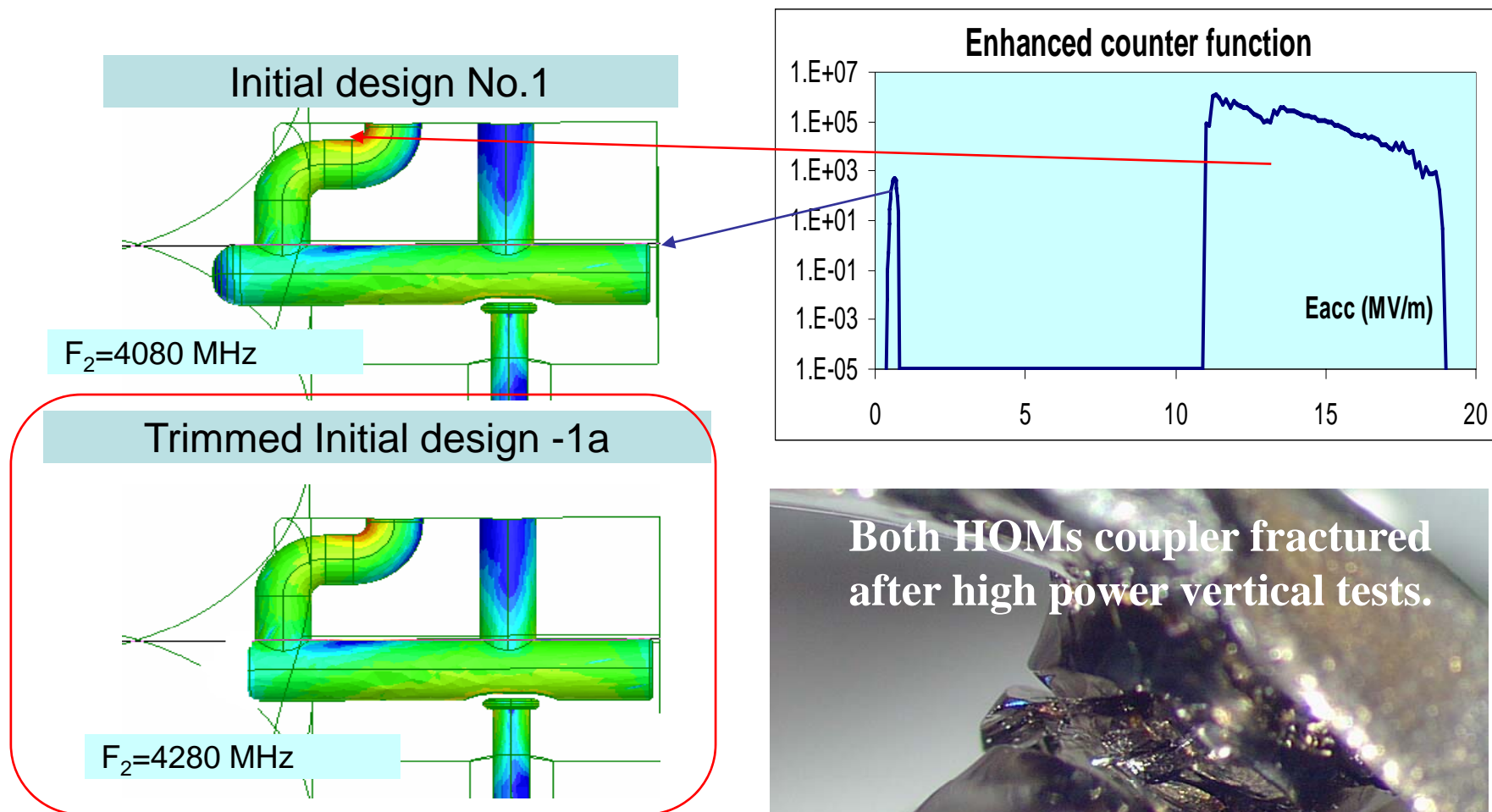


$E_{acc} = (10-26) \text{ MV/m}$  - analytical model

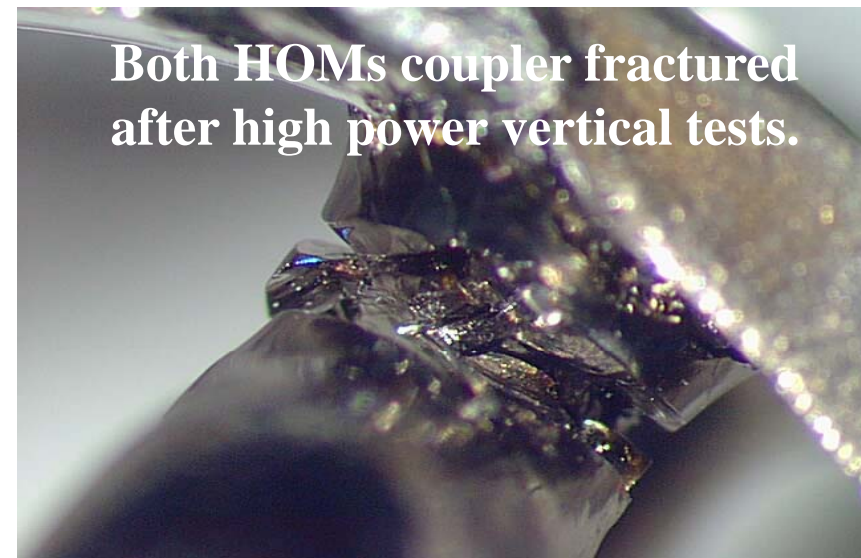
$E_{acc} = 5.1 \text{ MV/m}$  - analytical model



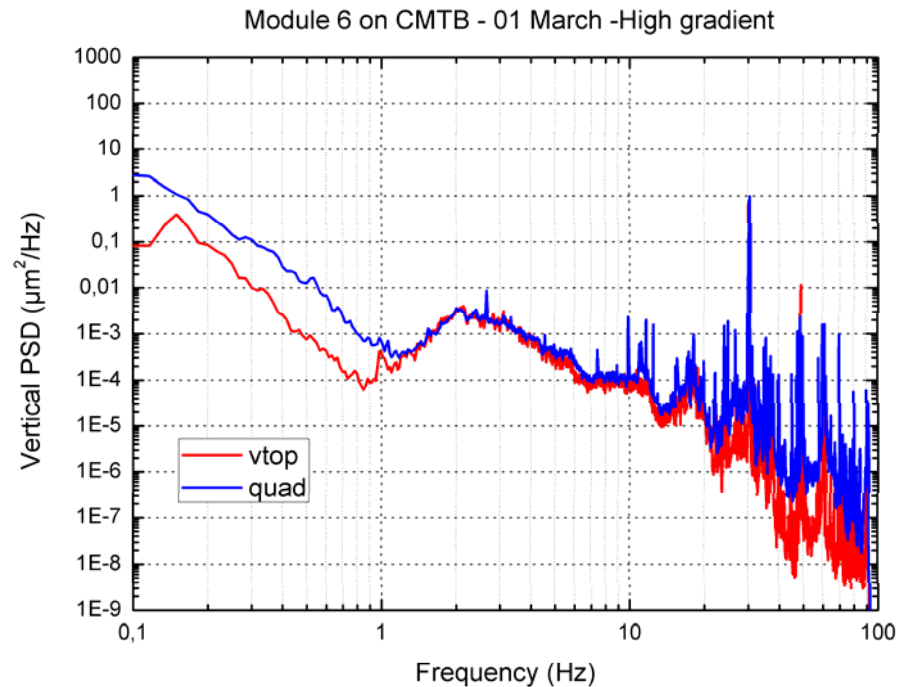
# MP in Old and modified HOM coupler designs



Field reduced by 2.5 times  
No MP up-to 23 MV/m in  
modified design



## Cold quadrupole vibration measurements on Module 6 at CMTB - cold measurement III-



### 01 March High power RF

Quad LHe inlet flow: 5.3 g/sec

Quad LHe inlet valve: 100%

Cavity 2K Inlet valve: 50%

Cavity 2K He flow: 3.8 g/sec

Cavity 2K He reservoir level: 43%

\*1.5 hrs data taken between 6:30 and 8 PM;  
klystron at 10 Hz, ~27 MV/m average gradient

### Comments

Peak frequency ~ 30.6 Hz in this case. The average integrated RMS @1 Hz values are 50 nm (ground), 215 nm (vessel top), 500 nm (quad).

Larger RMS have been measured even with RF off or during LLRF tests. The RF doesn't affect the vibration stability of the module.

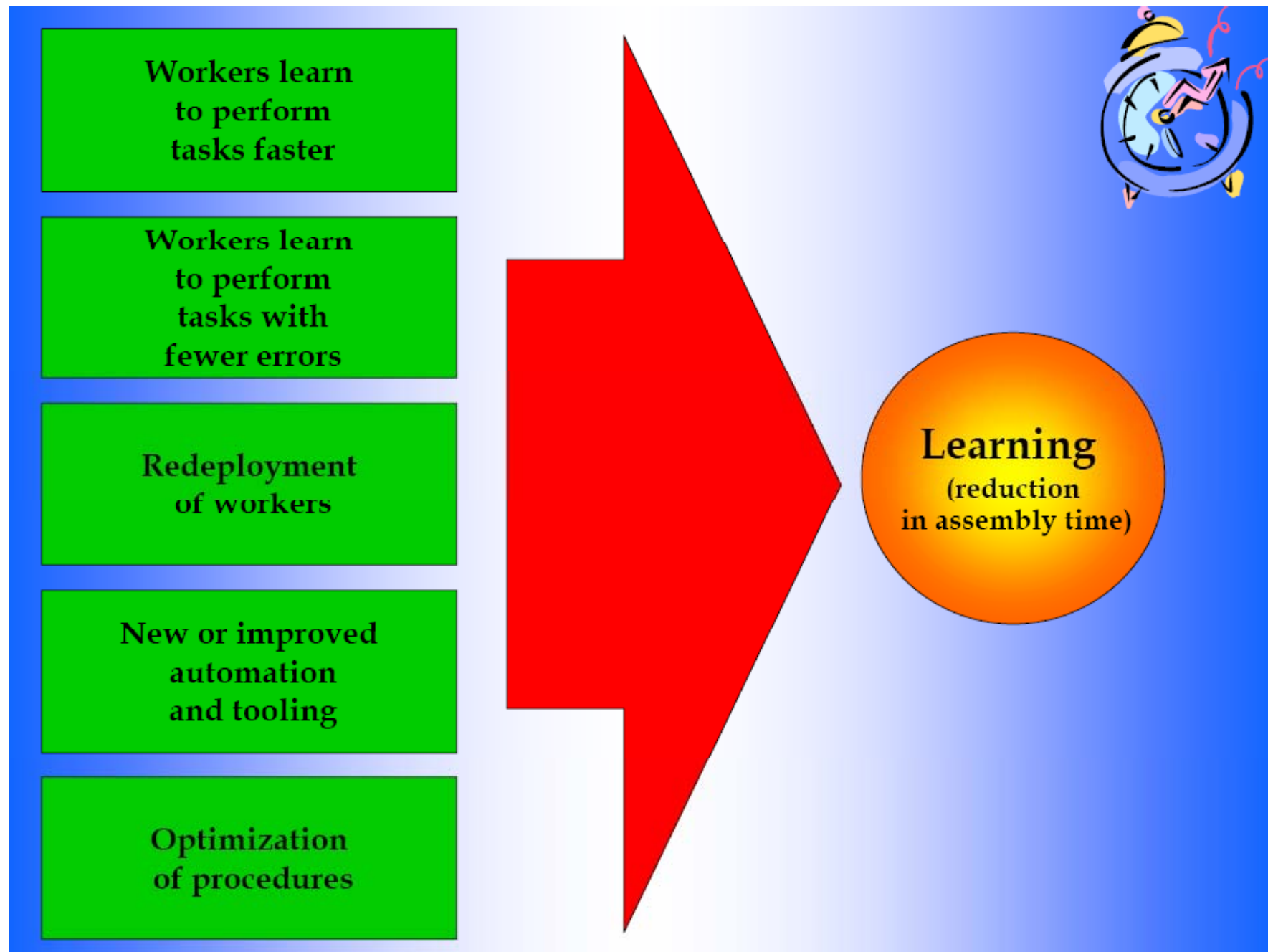
*Vibration studies of a superconducting accelerating module  
at room temperature and at 4.5 K*

R.Amirikas, A.Bertolini, W.Bialowons



# Contents

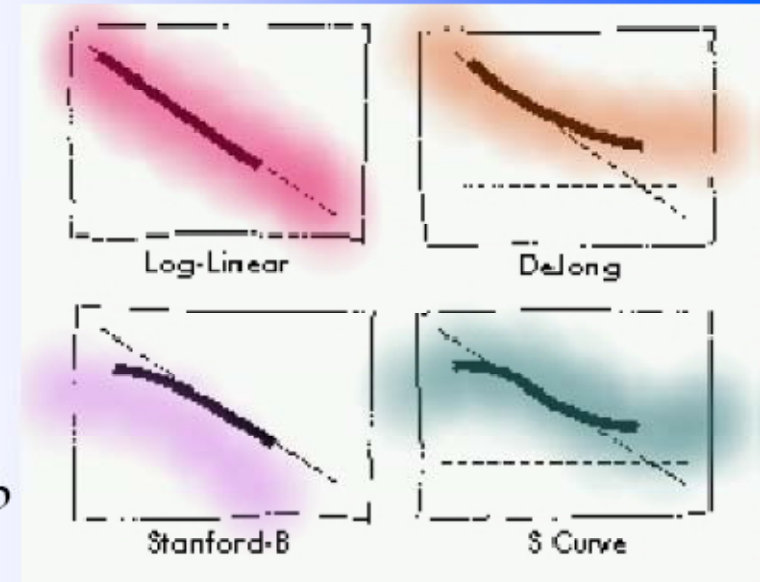
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# 4 models to study effect of learning on production time



- Log-Linear:  $t_n = t_1 n^b$
- Stanford-B:  $t_n = t_1 (n + c_{ex})^b$
- De Jong:  $t_n = c_{in} + t_1 n^b$
- S-Curve:  $t_n = c_{in} + t_1 (n + c_{ex})^b$



$b < 1$

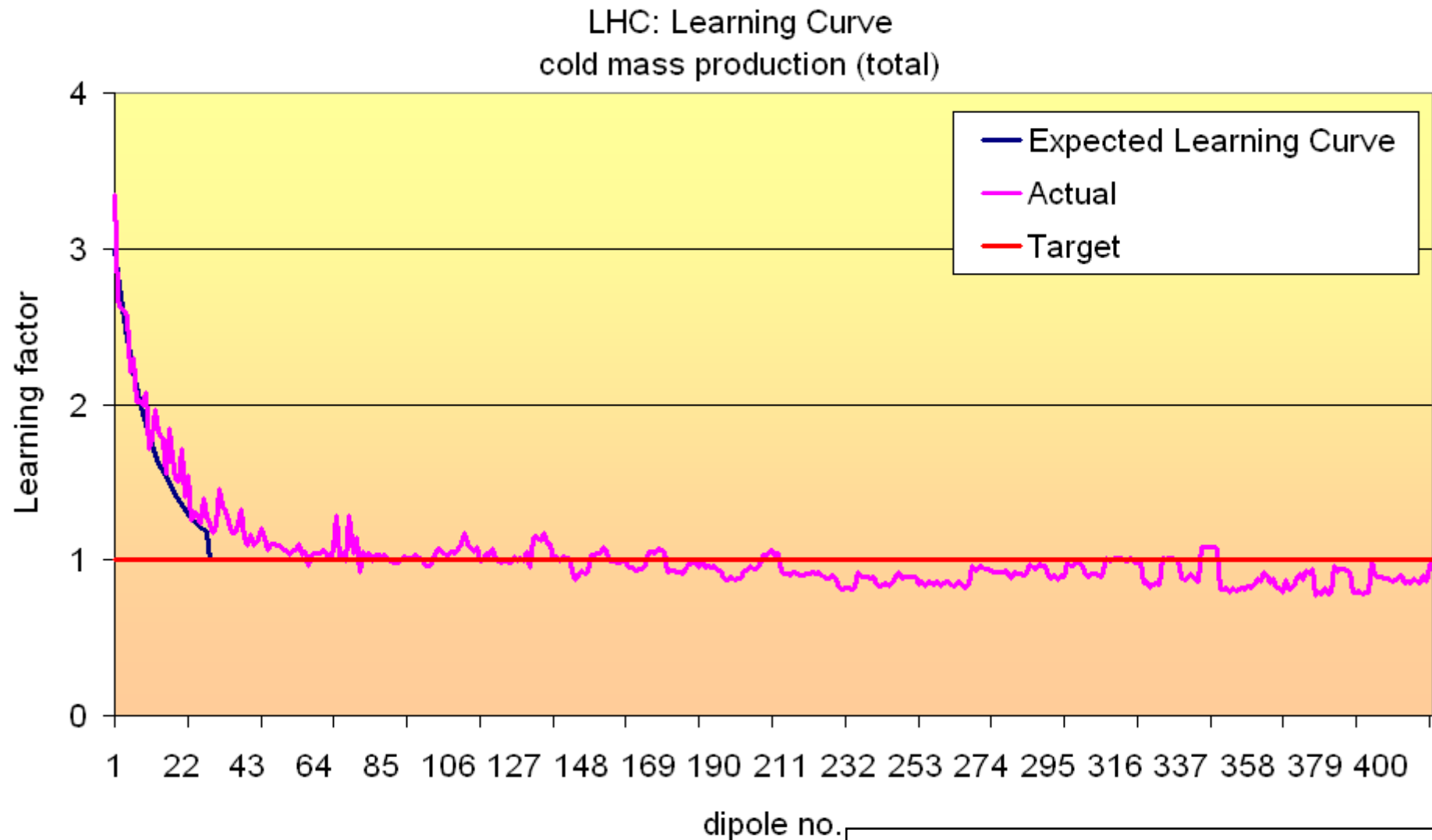
$c_{ex}$  : previous experience

$c_{in}$  : incompressible time (tool limit)

Learning percentage:

$$t_n / t_{2n} = 1/2^b$$

# LHC: Learning Curve collared coil production



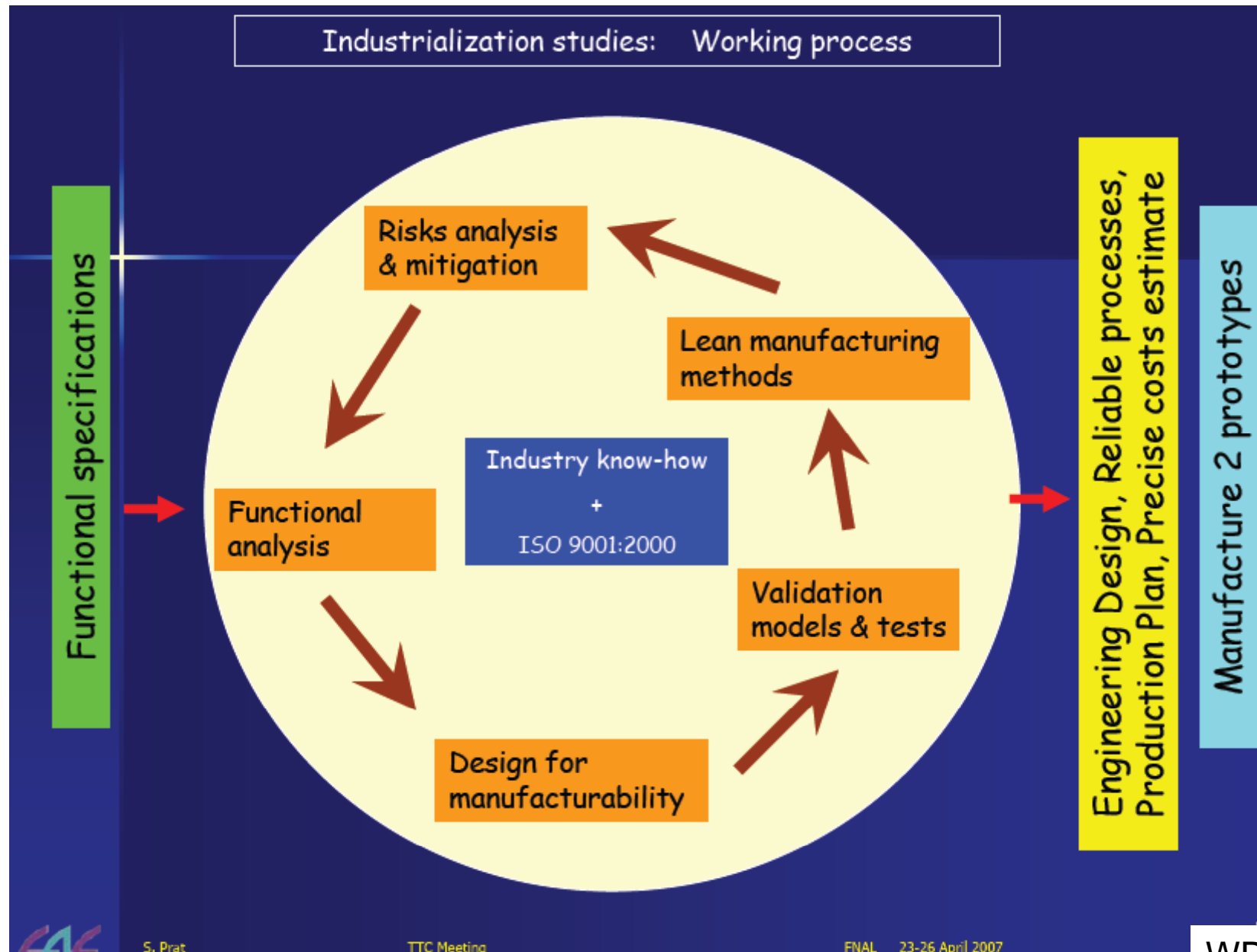
Courtesy of Babcock Noell, Germany

# Conclusion: What can we learn from LHC magnet production for XFEL / ILC planning

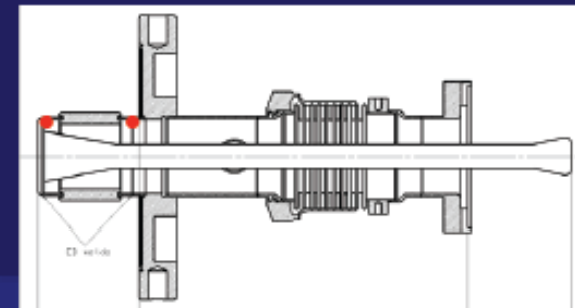
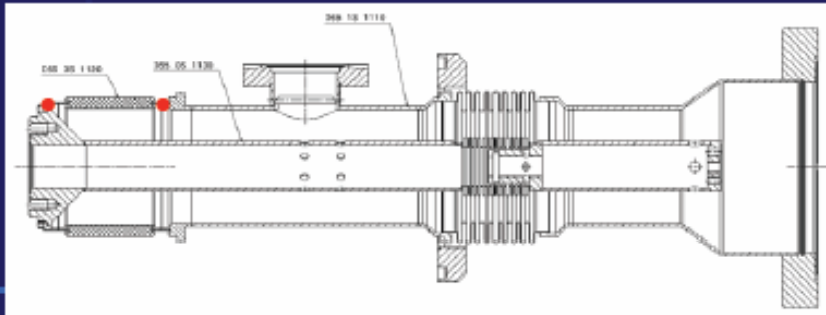
- SC magnet and cavity fabrication is not (yet) of the shelf technology
  - Very tight supervision of companies is recommended
  - XFEL production will improve the situation, but can companies preserve this expertise until ILC construction?
- Cryostat assembly time (=cost) levels around 50 units
- QA on some components for ILC (e.g. Nb sheet scanning) might require automatic chains
- A pre-series production (after proto-typing) will establish the required expertise at companies for realistic bidding without too high risk margin.
  - A cooperative spirit should be established between scientific laboratories and production companies in early time



# Coupler Industrialization



## Joining techniques



### ➤ Proposal 1

- Joining done as for TTF3 couplers baseline:
  - Stainless steel parts: TIG welds
  - Cu to stainless, Cu to ceramics: vacuum brazing
  - Final joints by EB-weld

### ➤ Proposal 2

- Final assembly by TIG welding:
  - Stainless steel parts: TIG welds
  - Cu to stainless, Cu to ceramics: vacuum brazing
  - Final joints by TIG weld

### ➤ Proposal 3

- All metallic joints are brazed under vacuum:
  - Brazing to bellows → problem of annealing bellows
  - Cu to ceramics: vacuum brazing
  - Final joints by brazing → problem of Ti diffusion into ceramic

# Cyromodule Industrialization for XFEL

## Needed

- **Final calculation for diameter 70mm 2 phase tube** (>90mm impacts design!)
- Transit support (solvable, first proposals by NOELL/ACCEL)
- Transportation/installations tests in tunnel mock-up
- New weldings/connections
- M8 assembly (string and cryostat) with active part by industry
- Qualify more than 1 vendor for module cryostats
- Production of prototype cryostats joined by ext. authority TÜV-Nord
- Result M8 on CMTB (results M9 at FNAL?)
- **Destructive test M3\* on CMTB joined by TÜV-Nord**

## Finally

- **Delivery of complete XFEL accelerator modules by industry**

Date

Event

18

R. Lange

# Next Modules 2006-2009

Status:18-Jan-07 R. Lange MKS

## Order at Zanon

2 cryostats  
cold mass/vac-vessel  
Delivery Jan-07

M8

M9

## Order at A, B May-07

2 (x 2) cryostats  
cold mass/vac-vessel  
Delivery May-08

XMP1A

XMP1B

XMP1I

Still time?

XMP2A

XMP2B

more?

## Order at ? (Oct-08)

Preseries-cryostats  
complete modules  
Delivery Jul-09

XMV1

XMV2

XMV3

XMV4

→ Parallel IHEP  
In-kind contrib.

## Goal:

Modify for Type3+  
Must:Compatible with  
Type3(spare TTF)  
Learn specification  
Try EN13445 without ext. author  
M8 assembly joined by industry

## Goal:

Qualify  
2(3) vendors for  
improved design  
XFEL-prototype  
Joined by TÜV  
assembly by industry

## Goal:

Qualify  
2(3) vendors for  
XFEL prototype  
best solution

## Goal:

Production and  
Test of 2(4) complete  
preseries modules  
Delivered by industry

Date Event

19

R. Lange

# Possible Sequence for XFEL-Accelerator Modules

**Industry**                      Cavities, tuners, couplers, HOMs, magnet/bpm, etc

**XFEL(DESY)**                cold test all cavities, magnet/bpm, (tuner? BPM?)

**XFEL(DESY)**  
(partially                      cold test of complete cavities  
                                      (only start up, production control)

**Industry**                      vac-vessel, cold mass, etc.  
**2 lines**                                string assembly  
    module assembly

**XFEL(DESY)**                cold test of modules                                (1 module/week)

**XFEL**                                installation in XFEL tunnel

**XFEL**                                **commissioning XFEL**

Date                      Event



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## Main Linac EDR: Cavity & Cryomodule Discussion

- Some of the discussions at Beijing came back again
  - **Still I did resist to just copy all my slides...**





# Minor recapitulation: Questions on the EDR

- Engineering view
  - What detail is required?
  - What part of the system do we need freeze at which time?
  - Where can I insert changes (to be cheaper, better...) without affecting other components?
  - If there is a influence to some system, what is the impact?
- Topic view:
  - What are the test needed to put forward a change request?
  - What is the mechanism to make the proposal a baseline (or part of the EDR)?
- Project view:
  - Is there a benefit to the project from this change?
  - Is there a way of re-prioritizing efforts?



# Possible Answers

- the working group tried two things
  - **getting answers for the decisions to be made**
    - see Warren Funk's slides
  - **re-starting the process we discussed in Beijing**
    - map out relations between subsystems
      - what are criteria for making a change
      - how is a change affecting the other systems



## Outstanding Technical Issues - 3

- Materials
  - Standard polycrystalline: supplied material variability still not under control; performance variability, even w/o FE, very poorly understood
  - Large grain: qualitative improvement in material uniformity; significant difficulties in fabrication
  - Single crystal: ideal, but needs manufacturing development to become available with required dimensions

- My recommendation:

### Large grain material

- Advantages: Uniformity, Lower  $R_{res}$ , Phonon peak
- Disadvantage: Poor behavior during deep drawing
- This decision should be taken now, to influence next year's R&D funding plans



# At Beijing we had another answer

- “Simple examples: Large-grain niobium material
  - **Description**
    - Use large crystal material for cavities
  - **Justification**
    - Lower cost
  - **Impact on other systems:**
    - none
    - influence on preparation is external to the project (done by companies)
  - **Deadline:**
    - Before cavity order
  - **Effort**
    - reasonable number of cavities (10-30)
    - Test needed:
      - Performance, Feasibility of tank welding (should be a no-brainer)
      - Module test: can be done after EDR”



## Outstanding Technical Issues - 2

- Cell Shape
  - Select to provide additional assurance of achieving 35 MV/m goal!
  - ‘TESLA’ shape only one to have yielded limiting gradient (~42 MV/m) in 9-cell cavity, but provides only modest margin over target
  - ‘Low-Loss’ shapes → cleaning issues, but raise limiting gradient by >10% (increase in margin over target >60%), if field emission eliminated
  - ‘re-entrant’ shapes → very serious processing and cleaning issues; limiting gradient increases of >40% (increase in margin over target >100%) but require substantial process R&D.
  - Limited time & resources mean we must choose among our options and argue strongly for TESLA shape, but resulting project technical risk is high.
- My recommendation: LOW LOSS

This decision should be official by October 1, 2007  
Decision on which low loss shape by January 1, 2008

# At Beijing:

- “Complex example: Cavity shape
  - **Impact on other systems**
    - depends on strategy: Increase linac gradient or increase cavity yield
  - **Estimated deadline:**
    - ???
  - **Effort**
    - several cavities
    - Tests needed:
      - Feasibility: Multi-cell performance
      - Beam test: HOM damping
      - Systems test if full package including coupler and tuner is used”

# Request for Information

- Very complex relations between systems
  - **Therefore formalization required**
- **Repeat:** Request to Technical Groups
  - **Provide information on topic under (re-)design**
    - Description
    - Justification
    - Estimated impact on
      - other components/systems
      - Classification: Severe, significant, minor, none
      - Time needed to re-design
    - Estimated deadline
    - Estimated effort e.g.
      - manpower and investment
      - Test needed
        - » to prove validity e.g. feasibility, lifetime, beam tests, integrated systems test
        - » Test deferrable to the period after project approval
    - Provide deadlines for severe (significant,...) changes required by other systems components
      - in second iteration as a crosscheck
- Request to project management
  - **Advise on developing industrialization models**



# Sample of the Table

Topics	Description	Justification	Impact on other systems (severe, significant, minor, none)	Impact on whom	Time needed for re-design	Expected deadline (proposer)	Expected deadline (affected systems)	Test needed before decision	Test possible after decision	Remark
Gradient choice	Define ILC gradient		severe	CF&s	~1year	end of 2008		S0/S1		Defined by EC
Large-grain	Change niobium for cavities		small	cavity manufacturer		Before cavity order		performance test on multi-cells, make high-power test, build 10 cavities, demonstrate cost benefit	built pre-production	
Cavity Shape	Ichiro as alternative	Two options: Higher yield, shorter linac	Two options: Increase linac gradient or increase yield					Performance demonstration, beam test		
Corrections to shield piping		Optimise design	small	components inside module	3 month	can be post-EDR				

- The information should guide the development of an overall ILC planning
  - need pre-defined categories
  - process of getting the data should provide crosscheck via affected systems/components

# Summary

- Interesting and positive discussion
- Follow-up on Beijing ,table'
  - **Tried to get clearer inter-correlation**
- Work package definition has not happened
  - **some of the ideas were downloaded to tech. groups**
- Request for input from technical systems
  - **we have to start the iterative process NOW!**
  - **the information is needed for the tech reviews coming up**