



# International Linear Collider – Technical Design Phase (TDP)

Marc Ross, (Fermilab)

Nick Walker, (DESY)

and Akira Yamamoto (KEK)

*A straightforward path to the Energy Frontier*

ILC Reference Design Talk - 2007 → →

# The Reference Design Report and cost estimate for the International Linear Collider

**Marc Ross, Fermilab  
Jan 31, 2007**

**Reference  
Design:  
*'RDR'***

**First slide  
– 2007...**

- **Research and Development of SRF across a broad front:**
  - **Fundamentals**
  - **Mass production technology**
  - **Accelerator operation**
  - **Cost reduction**
- **There are no entitlements in the accelerator building business**
  - **We have to demonstrate competence**
  - **Our partners are more advanced**
  - **Timing is critical → 50 KW electron beam**
- **Your participation is important**

Last slide  
– 2007...





## Technical Design Phase:

- R & D to demonstrate and support key design parameters
- Updated technical design
- Practical scenarios for global distribution of mass production of high-technology
- Updated cost estimate
- Documented (2012) in the

### **TECHNICAL DESIGN REPORT**



# ILC TDP: Outline

- **SRF R & D**
  - Cavity
  - Cryomodule
  - Linac w/ beam
- **SRF Mass Production and Cost**
- **Beam Test Facilities**
- **Siting the ILC**
- **Path to the Energy Frontier**



## SRF R & D Goals:

Validate RDR Parameter choices

→ *demonstrations at: DESY, US labs, KEK*

Fabrication quality and diagnostics

→ *Electron Beam Welding & hi-res camera*

Surface treatment Recipe

→ *Electro-polish chemical rinse*

System assembly and test

→ *cavity string*

Power/gradient overhead w/beam

→ *1.2 GeV, 7 cryomodule string - DESY (FLASH)*

→ *NML, STF at KEK*



# Global Plan for ILC Gradient 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)			NML CM1 and CM2		
System Test with beam acceleration	FLASH (DESY) , NML (FNAL) STF2 (KEK, test start in 2013)					
Preparation for Industrialization				Production Technology R&D		

## New baseline gradient:

Vertical acceptance: 35 MV/m average, allowing  $\pm 20\%$  spread (28-42 MV/m)

Operational: 31.5 MV/m average, allowing  $\pm 20\%$  spread (25-38 MV/m)



# ILC TDP: (1.1)

- **SRF R & D:**
  - **Cavity** production *yield* @ nominal avg. gradient:
  - Combining / Unifying results:
    - 31 cavities 2<sup>nd</sup> pass (50:40:10% / US:DESY:KEK)
  - Challenge: Taming Field Emission
  - 45 MV/m
- **SRF Mass Production and Cost**
- **Beam Test Facilities**
- **Siting the ILC**
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## SCRF linac – basic building block

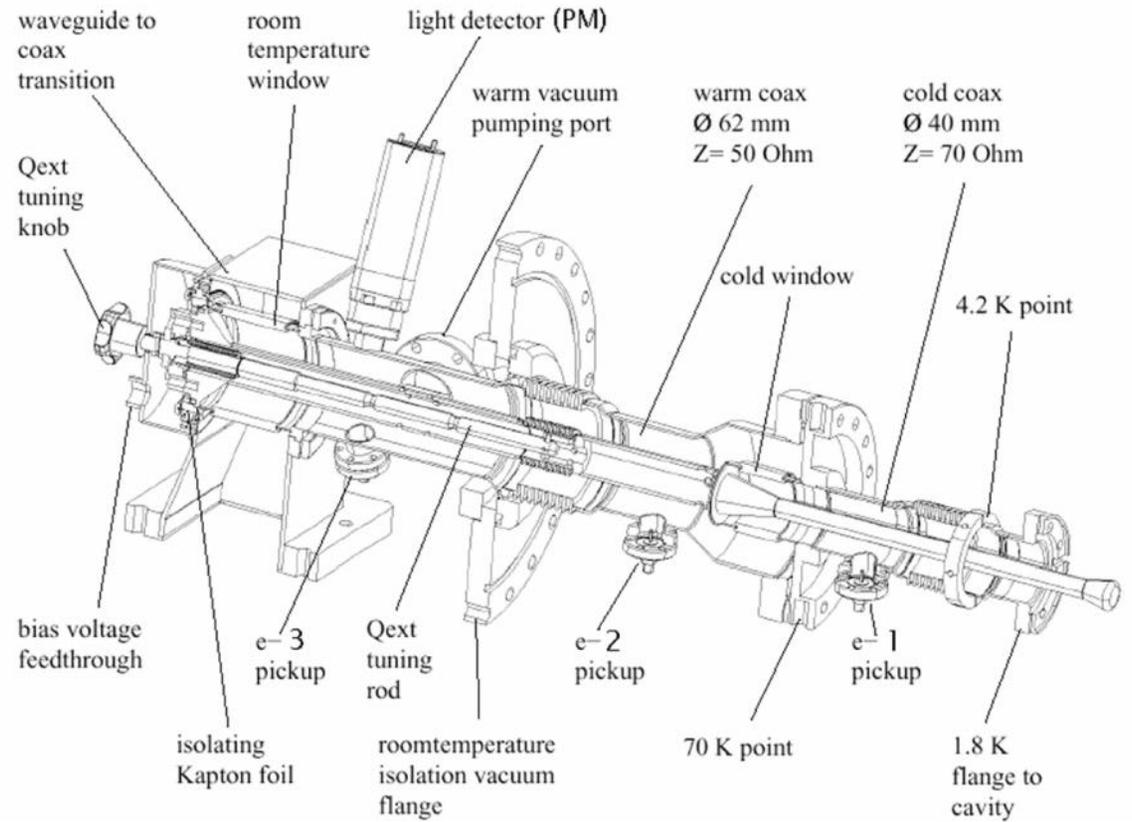
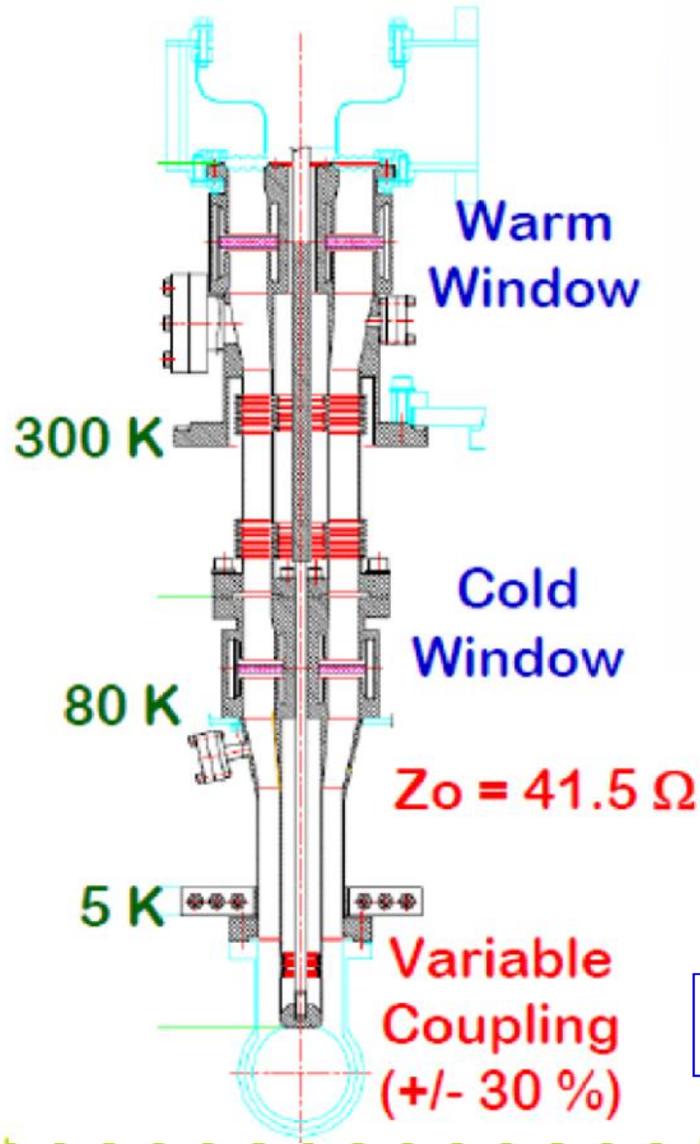


Figure 1.2-1: A TESLA nine-cell 1.3 GHz superconducting niobium cavity.

- ~ 70 parts electron-beam welded at high vacuum
  - ~ 1.25 m<sup>2</sup> x 3mm thick sheet metal
- pure niobium and niobium/titanium alloy
  - niobium cost similar to silver
- weight ~ 70 lbs
- 6 flanges

# Cavity production





## Two Power Coupler Designs

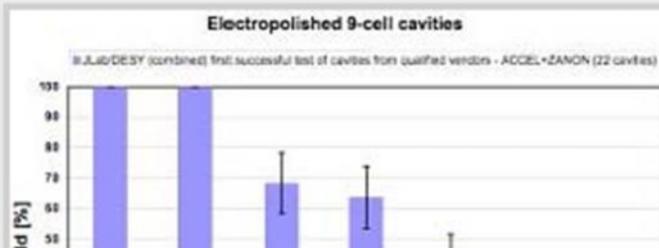
Adjustable; Both tested / compared

# Creation of a Global Database to understand cavity Production Yield



The idea sounds simple enough: collect all the data that exist in the world on cavities – nine-cell TESLA-style cavities, to be precise – including all tests, manufacturers and achieved gradients and merge it into a common format so that all cavity professionals around the world can extract the data they need to compare cavity performance and learn. Anyone who has ever set up a database and tried to merge existing data sets into one knows: it's not that easy. However, the ILC's accelerator experts have just decided that they will all use a database system developed by DESY to set up the world's first global cavity database.

The main driver behind this is a key ILC challenge called 'yield' – an efficient word for a concept that means something like 'the probability that cavities will reach the required gradient'. 'Gradient' in turn means the energy imparted by a cavity to electrons or positrons over the distance of one metre – a challenge at the heart of the ILC, because a high gradient means efficient acceleration, which means short accelerators, which in turn means lower cost. Only good statistics give a good picture of the yield. "That's why we are really after statistics, we need this standardisation to be able to compare data from around the world and provide reliable estimates of expected cavity performance," says Camille Ginsburg from Fermilab, who is in charge of the ILC cavity database project.



The ILC cavity-treating labs (Fermilab, JLab, Cornell, DESY and KEK) agreed in July that they would use the DESY database system (developed by Dieter Gall and Vladimir Gubarev), and data from 76 cavities have been entered so far



The new worldwide ILC cavity database features only nine-cell, no single-cell cavities like the one held by Camille Ginsburg in this picture. Image: Fermilab.

Global Data Base Team formed by:

Camille Ginsburg (Fermilab)

Rongli Geng (JLab)

Zack Conway (Cornell University)

Sebastian Aderhold (DESY)

Yasuchika Yamamoto (KEK)

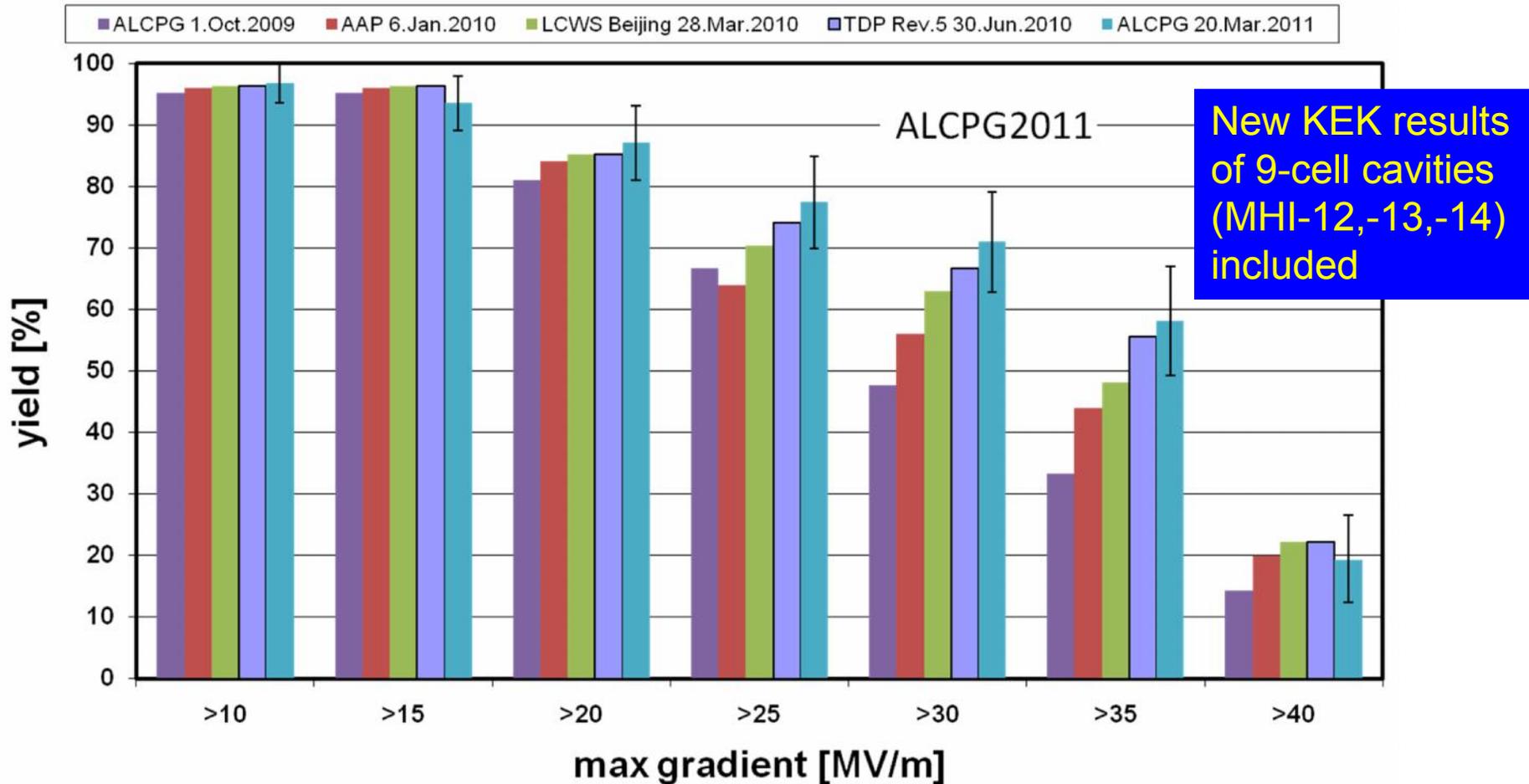


# Global ILC Cavity Gradient Yield

## Updated at ALCPG2011

Plot courtesy  
Camille Ginsburg of FNAL

Electropolished 9-cell cavities  
JLab/DESY (combined) up-to-second successful test of  
cavities from established vendors

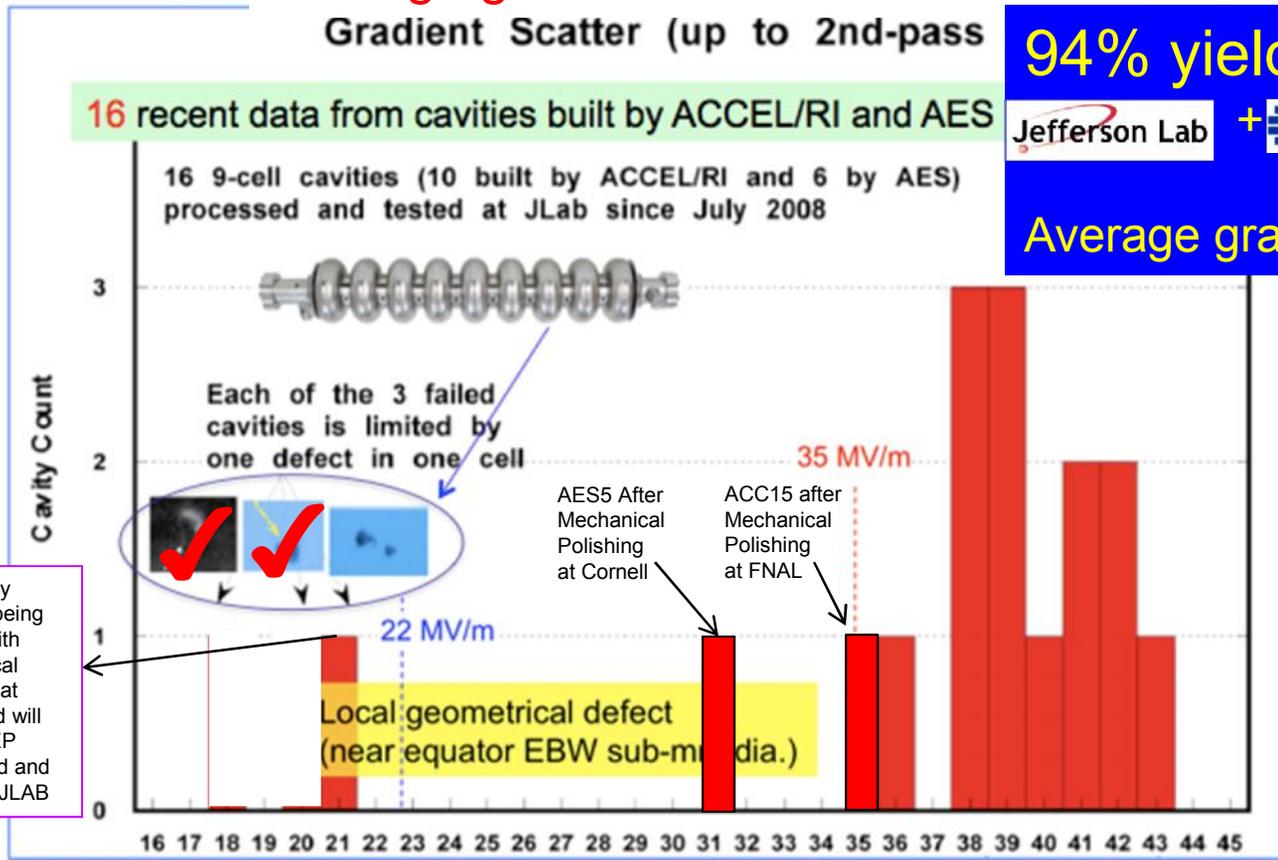




# Impact of Mechanical Polishing

## Today at 6<sup>th</sup> PAC Meeting in Taipei

**88%** Yield at 35 MV/m achieved at JLAB + FNAL  
 Average gradient 39 MV/m



**94% yield at  $\geq 31$  MV/m**

Jefferson Lab + Fermilab + Cornell University

**Average gradient 38.8 MV/m**

This cavity AES6 is being treated with mechanical polishing at FNAL and will be then EP processed and tested at JLAB

A, Yamamoto, 10-11-11

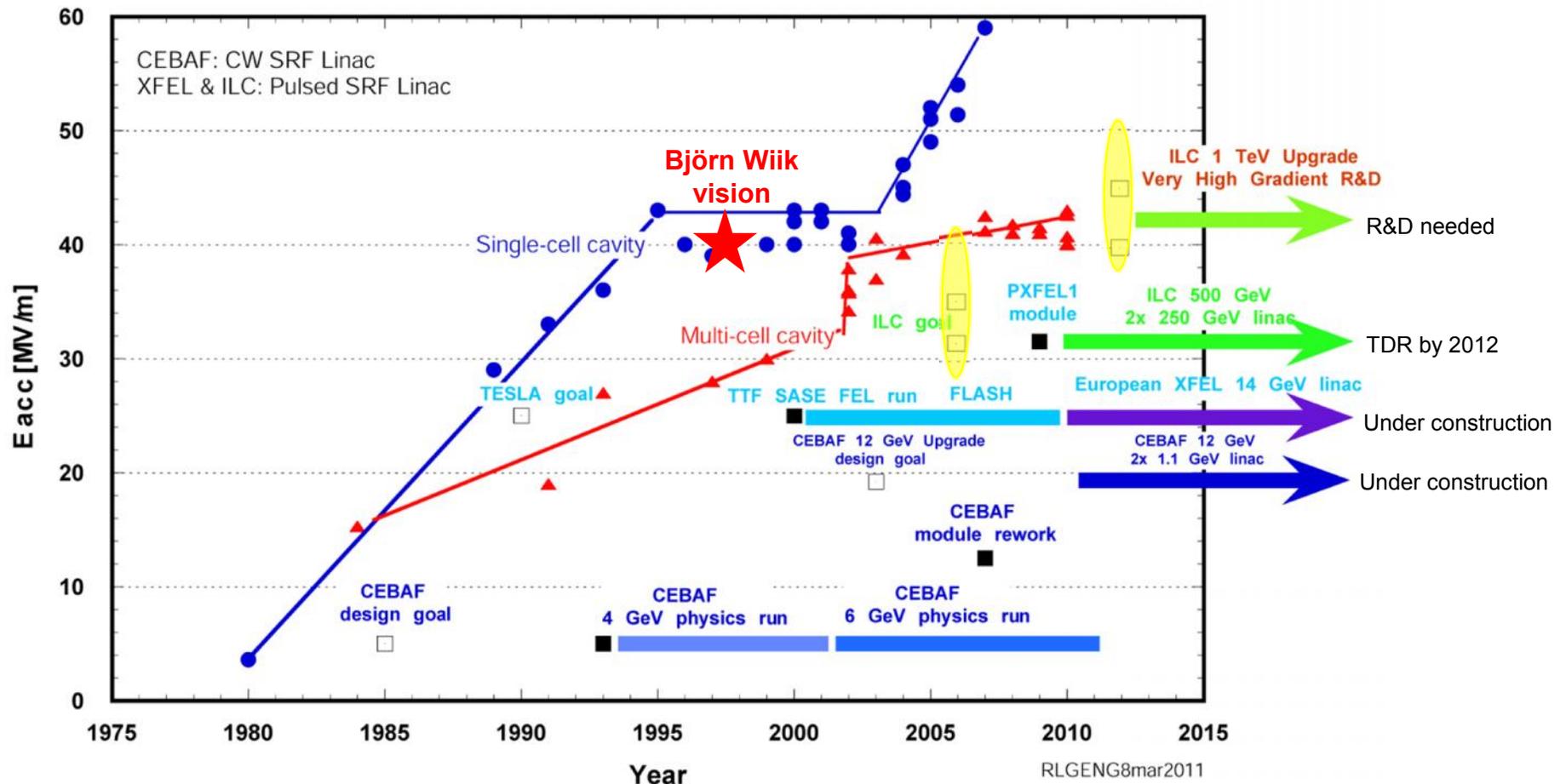
ILC-PAC: SCRF

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# SRF Cavity Gradient Progress

## L-Band SRF Niobium Cavity Gradient Envelope and Gradient R&D Impact to SRF Linacs



Steady progress in SRF cavity gradient makes SRF an enabling technology  
SRF based electron linacs (CW & pulsed) have track record of successful operations



# Main Issues at Very High Gradients (1)

## Field Emission / Dark Current

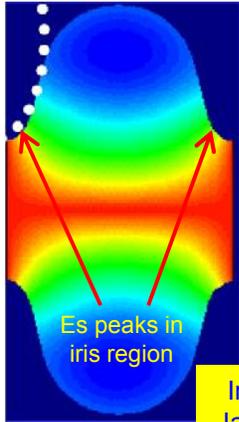


Image courtesy Jacek Sekutowicz

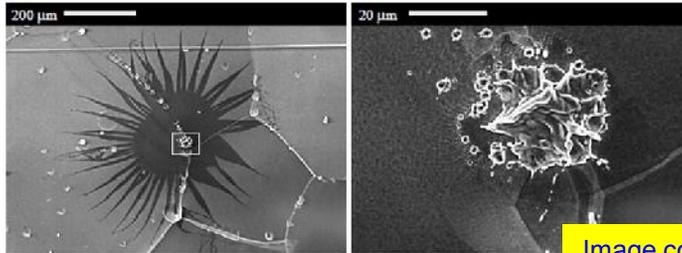
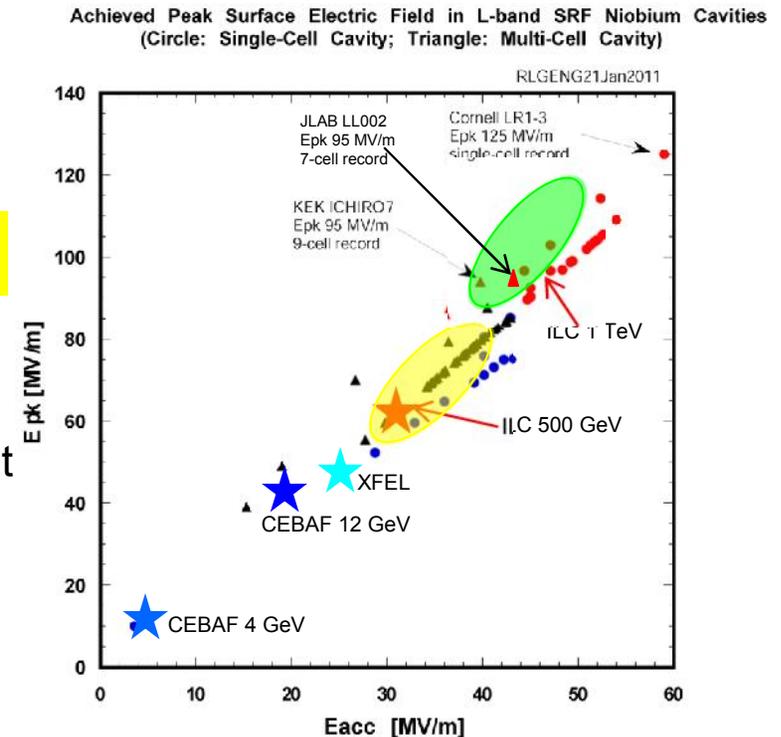
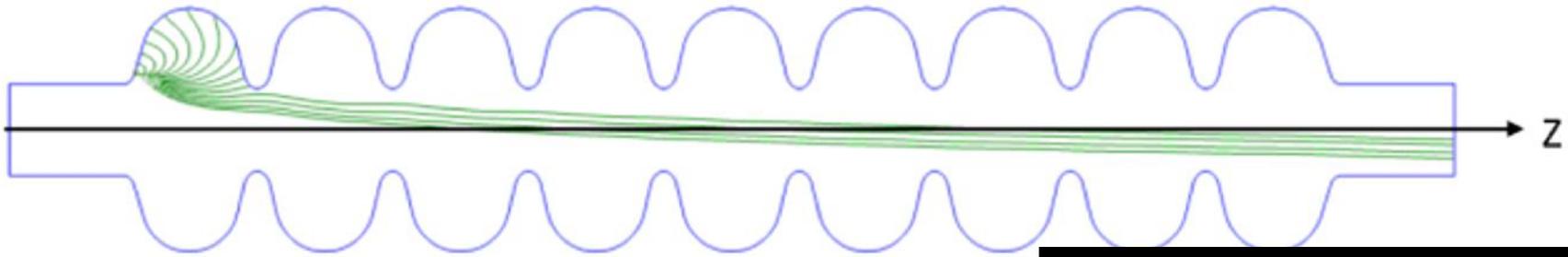


Image courtesy Jens Knobloch

- Peak surface electric field (Epk) a governing parameter
- Physics fairly understood and no known fundamental limit
- Microscopic particles an important family of field emitters
- Epk 100-120 MV/m demonstrated in 1-cell Nb cavities
- Epk 100-120 MV/m needed in multi-cell for ILC 1 TeV
  - Record Epk reached in 9-cell cavity 95 MV/m (KEK ICHIRO7)
  - Improved HOM coupler cleaning is necessary



Field emission is a known problem and has not been completely resolved, despite recent progress in post-EP cleaning advancement. Sudden field emitter turn-on in 9-cell cavities has been reported by almost all labs. Pushing E<sub>pk</sub> into 100-120 MV/m regime is necessary for reaching E<sub>acc</sub> 40-45 MV/m. It is most likely new processing technology needs to be applied besides HPR. Promising work has started in this direction such as snow cleaning, plasma cleaning and HOM horn cleaning.



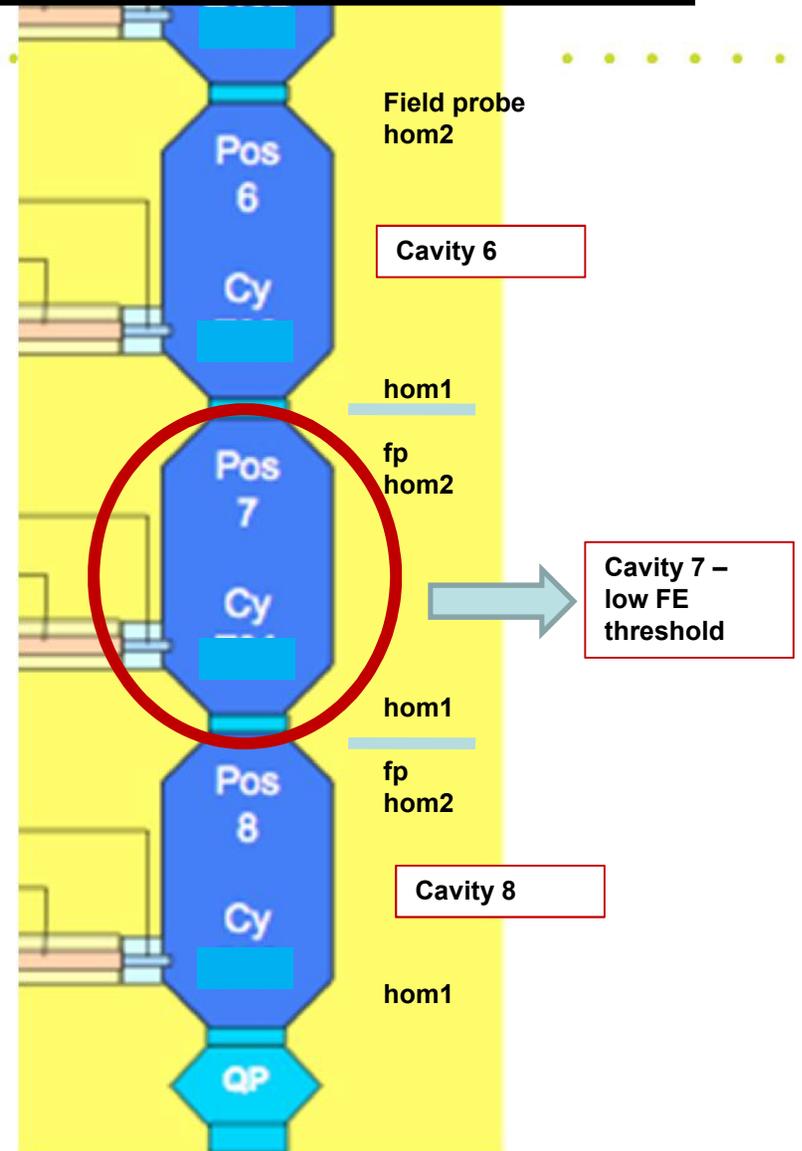
## Field Emission / Dark Current

- 9 cell dark current simulation
  - (Ginsburg – IPAC2010)
- Field emitted current shows non-linear increase as gradient is raised – roughly following ‘Fowler-Nordheim’ scheme.
  - **Clear, repeatable field emission *threshold***
- A field emission point is a ‘diode’ →
  - **dark current is ‘bunched’ w/characteristic time structure**
- Will radiate harmonics of the fundamental 1.3GHz (up to  $\omega \sim 1/\text{bunch length}$ )

## Cryomodule 'PXFEL-3' (DESY CMTB)

### Experiment:

- Look for 2<sup>nd</sup> / 3<sup>rd</sup> harmonics (DESY)
  - cavity 7, PXFEL 3 contaminated
  - 15MV/m threshold
- Check both HOM pickups and field probe
  - → signal easily seen
- compare amplitude of harmonics above & below the threshold





## 2<sup>nd</sup>/3<sup>rd</sup> harmonic change:

- above – below FE threshold:
  - changing klystron output by 20%

Voltage increase	Cav6 HOM1	Cav7 – FP	Cav7 – HOM2	Cav7 – HOM1	Cav8 FP
2.6 GHz	8db (x2.5)	8dB (x2.5)	0dB	3dB (x1.5)	-4dB
3.9GHz	-2dB	2dB	18 dB (x7.5)	-7.5dB	3dB

- Conclusion:
  - a strong signal; seems to respond above/below FE
  - but many questions; esp. klystron harmonics...

- SRF R & D:
  - Cryomodule string assembly / design
  - Compare distinct designs/interfaces: S1 *Global*
  - *Fermilab CM1 @ NML*
  - Lorentz-Force Detuning Compensation
  - Industrial High-Technology: *Tuning Machine*
  - FLASH: 1.2 GeV / 56 cavities → Field emission
- SRF Mass Production and Cost
- Beam Test Facilities
- Siting the ILC
- Path to the Energy Frontier



# S1 Global Cryomodule - KEK

## Goal:

### 1. Integrate cavity efforts

- to understand and / or highlight differences
- 1) Mechanical Stiffness, 2) Tuner, 3) Power Coupler

### 2. Help define plug-compatibility interfaces

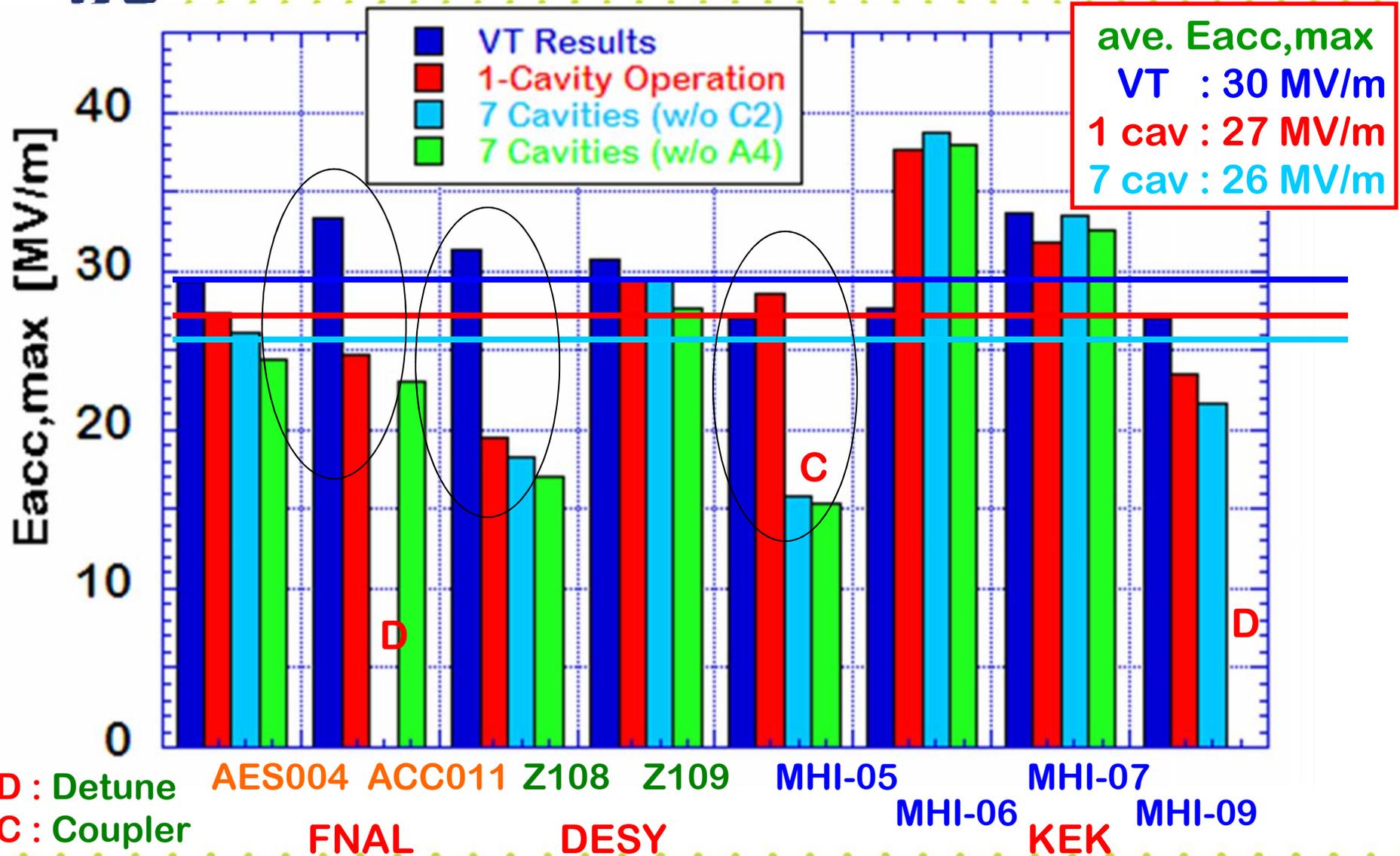
- **RDR 6.1.4:**

- “The European estimate for the cavities and cryomodules is used for the ILC value as it is the most mature, in terms of R&D and industrial studies. Estimates from the other regions provide a crosscheck.”

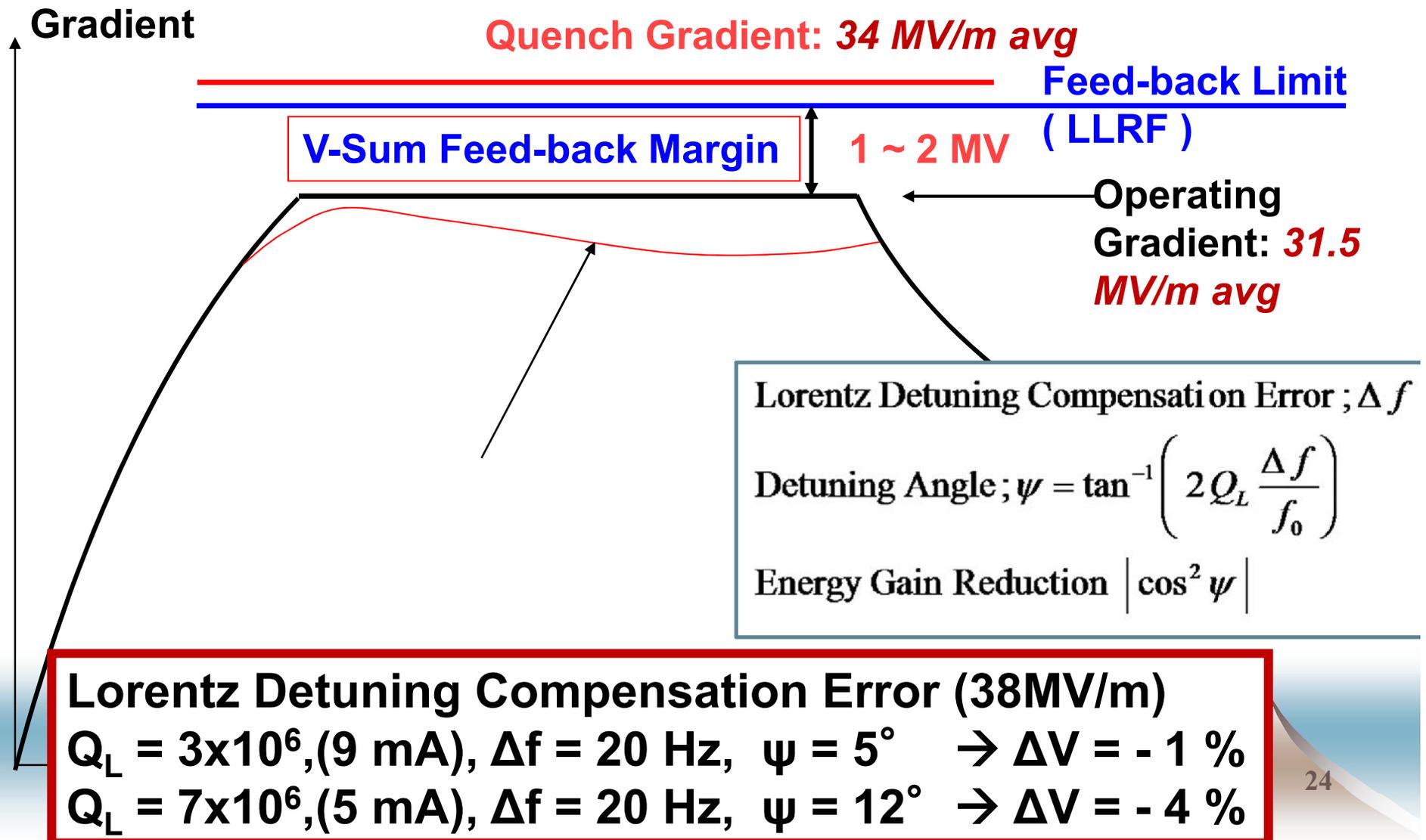
- **TDR cost estimate will have a global basis**



# Comparison of cavity performance



# Highest Gradient Operation



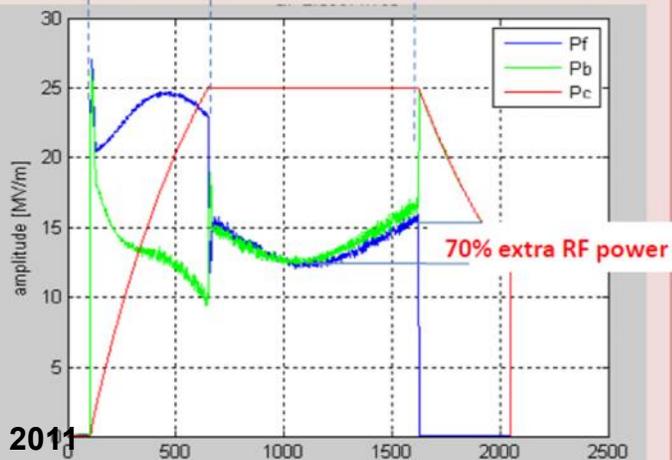
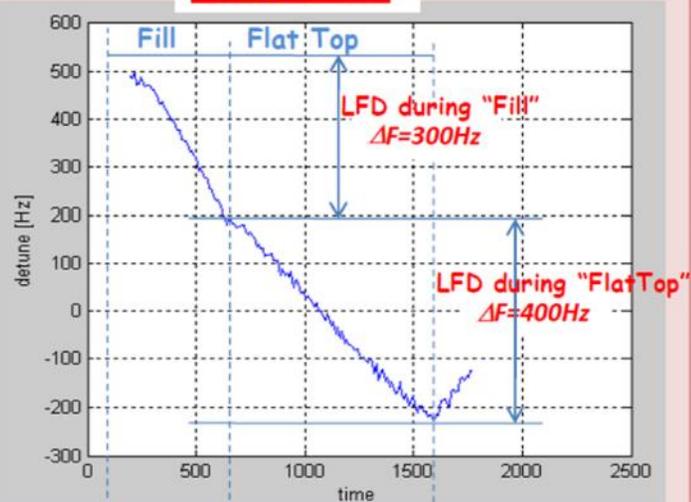


# FNAL Piezo Control System

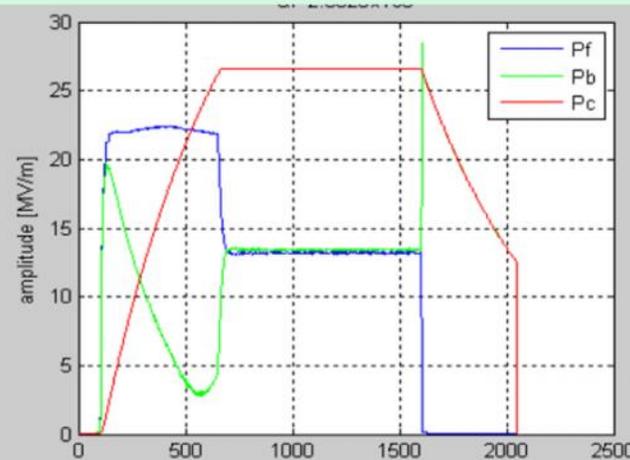
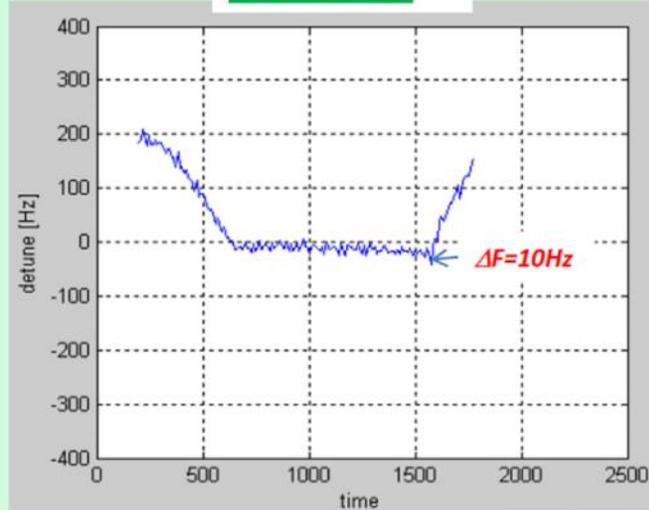
Warren Schappert and Yuriy Pischalnikov (FNAL)

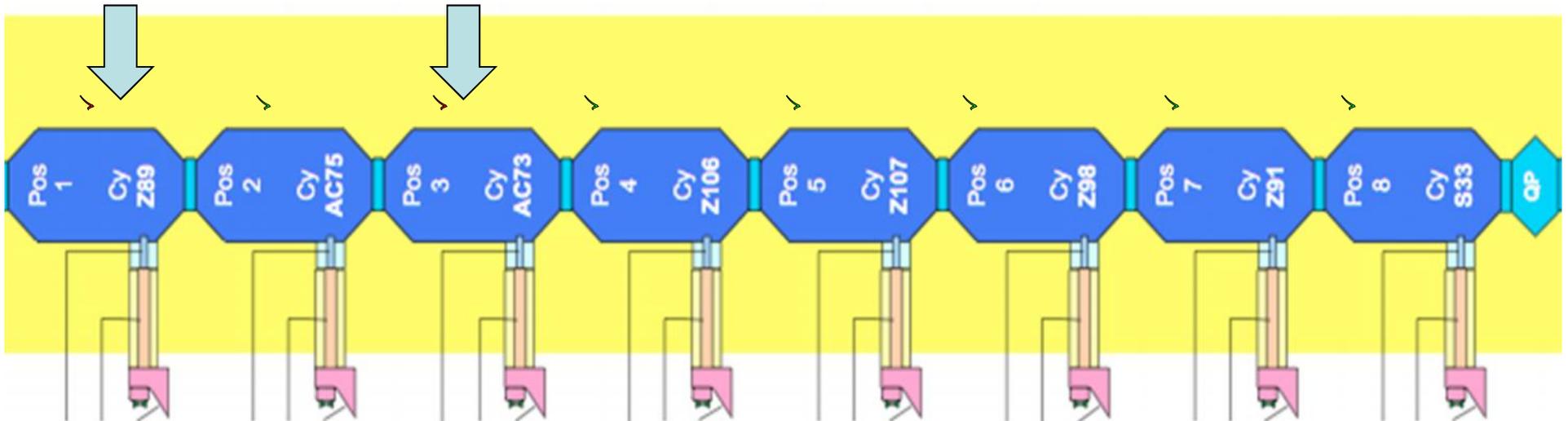
C4-DESY Cavity/Tuner System LFD at  $E_{acc}=25\text{MV/m}$   
RF feedback ON; LFD Compensation "FlatTop" only

**Piezo OFF**



**Piezo ON**

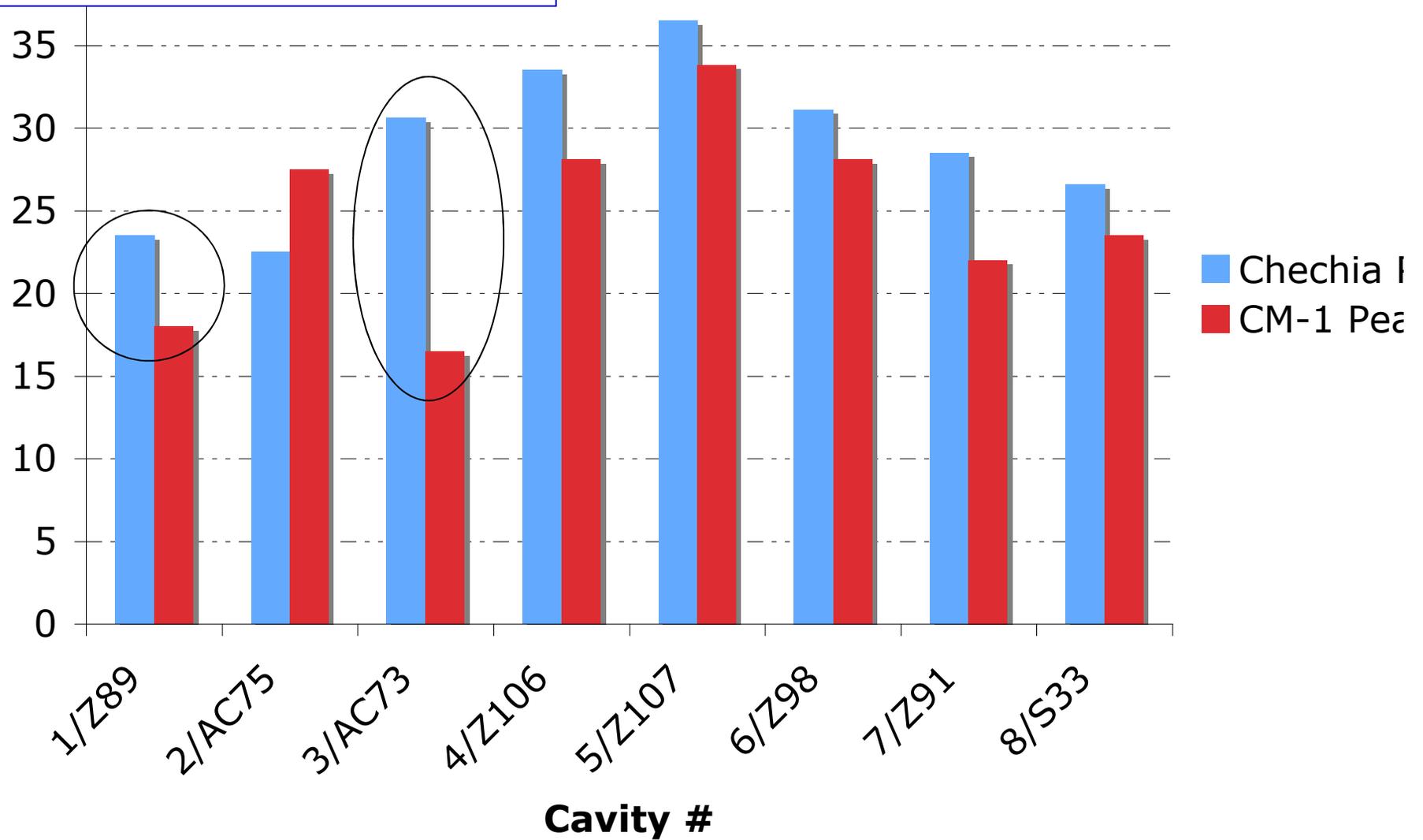




- All cavities individually evaluated (June 2011)
- Elvin Harms, AD
- Cavity 1 and 3 operation may be limited by field emission
- But → expected strong radiation is **not** observed ...
- May be below ~100 KV or well collimated

## Comparison of CM-1 Cavity Gradients

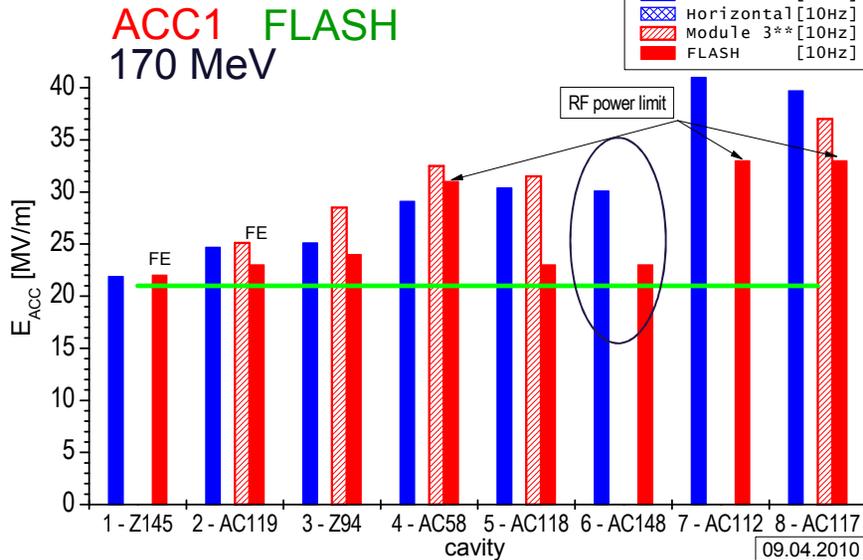
**NML – June 2011**



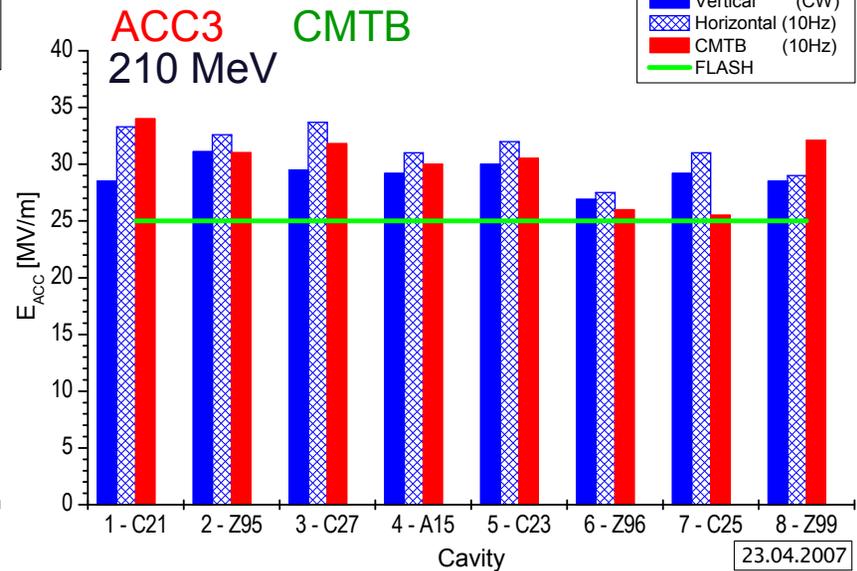
# Modules @ FLASH LINAC (1)



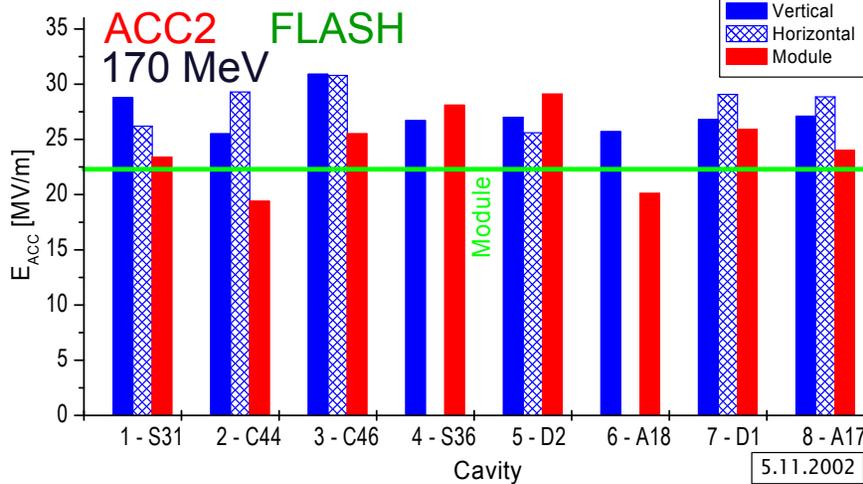
module 3\*\*\*



Module 7

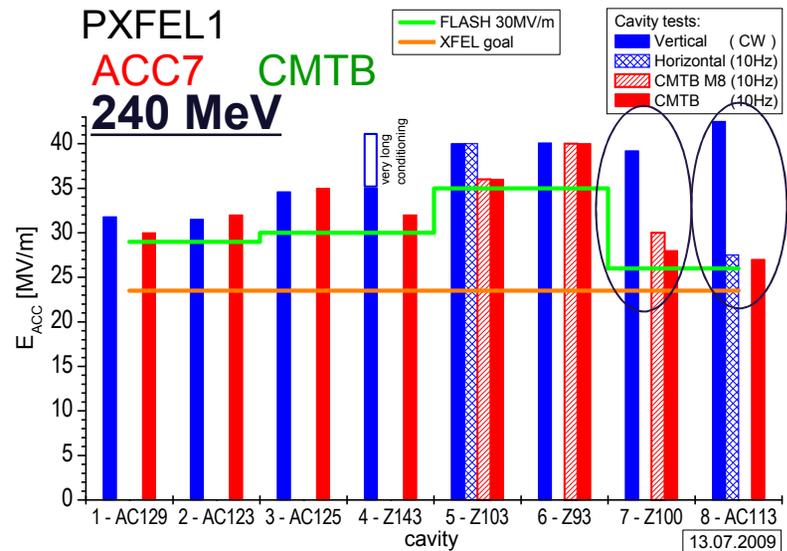
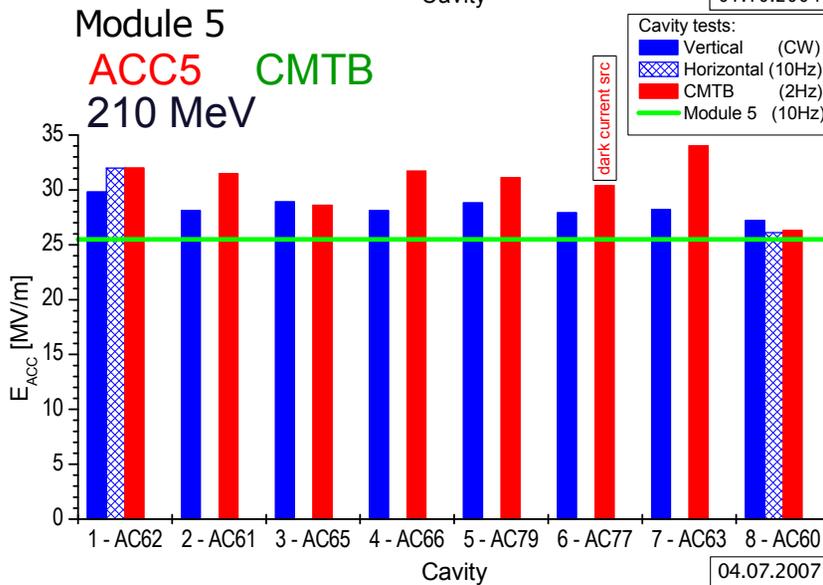
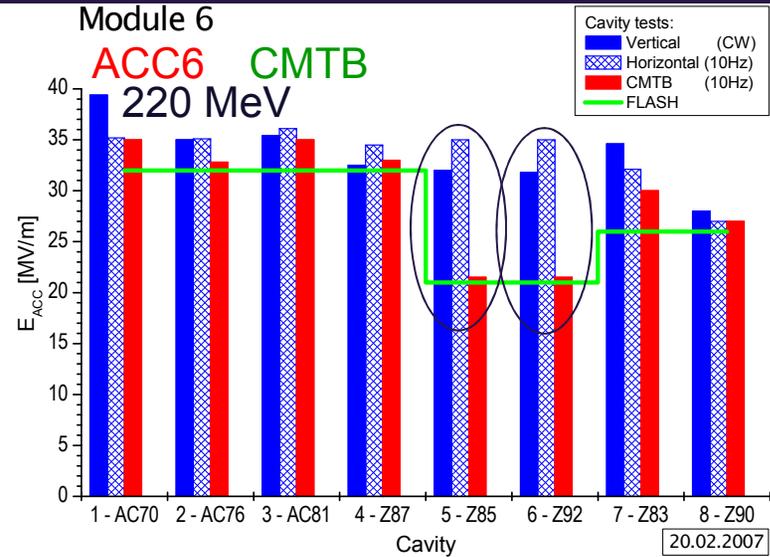
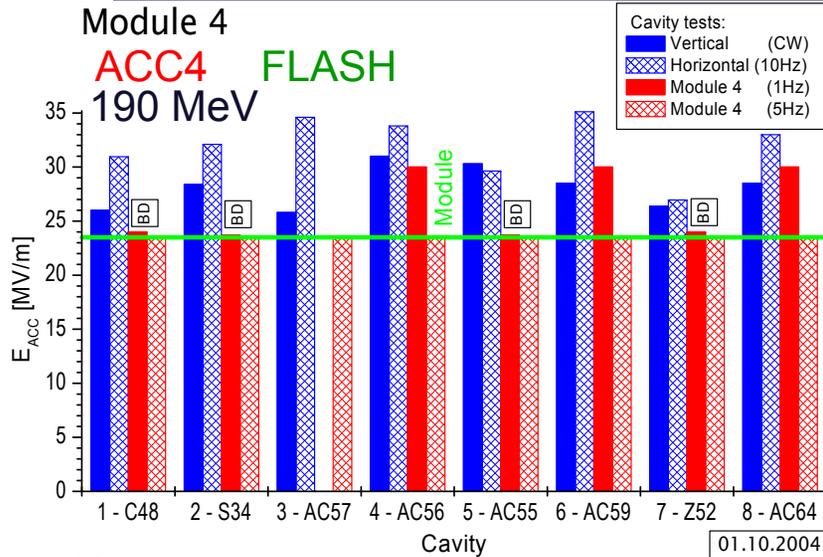


Module 1\*

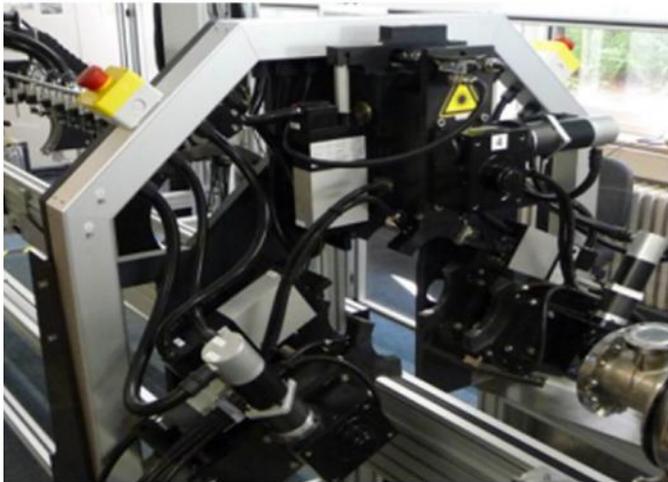
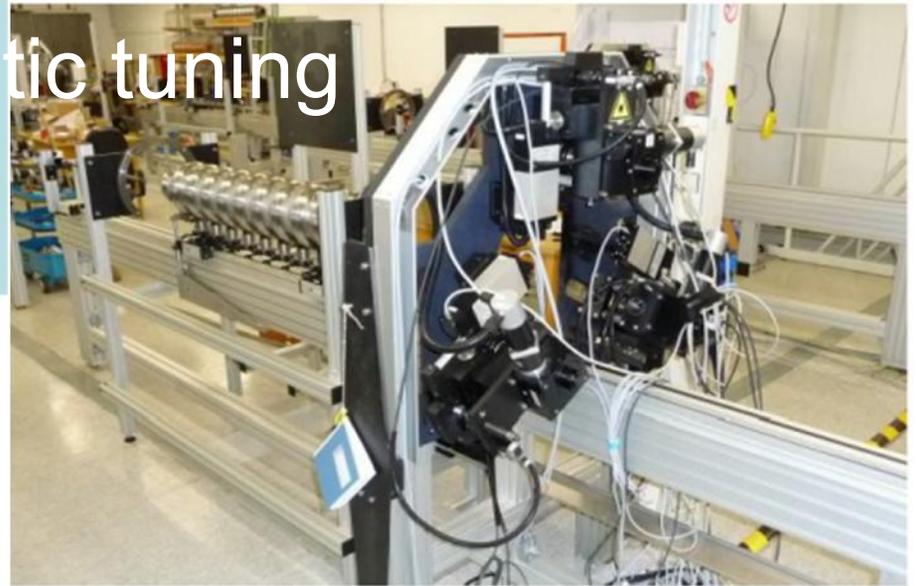


7 Modules are used now at FLASH LINAC at DESY. 3 modules were tested at FLASH and 4 modules were tested at CMTB facility.

## Modules @ FLASH LINAC (2)



# Fermilab/DESY Automatic tuning machine





## ILC TDP: (1.3)

- **SRF R & D:**
  - SC Linac w/Beam: FLASH (DESY)
  - Feedback and Overhead:
    - mid-2010 performance jump (3.9 / beam-based feedback)
  - High current modeling and optimization
  - Post 2012
- **SRF Mass Production and Cost**
- **Beam Test Facilities**
- **Siting the ILC**
- **Path to the Energy Frontier**

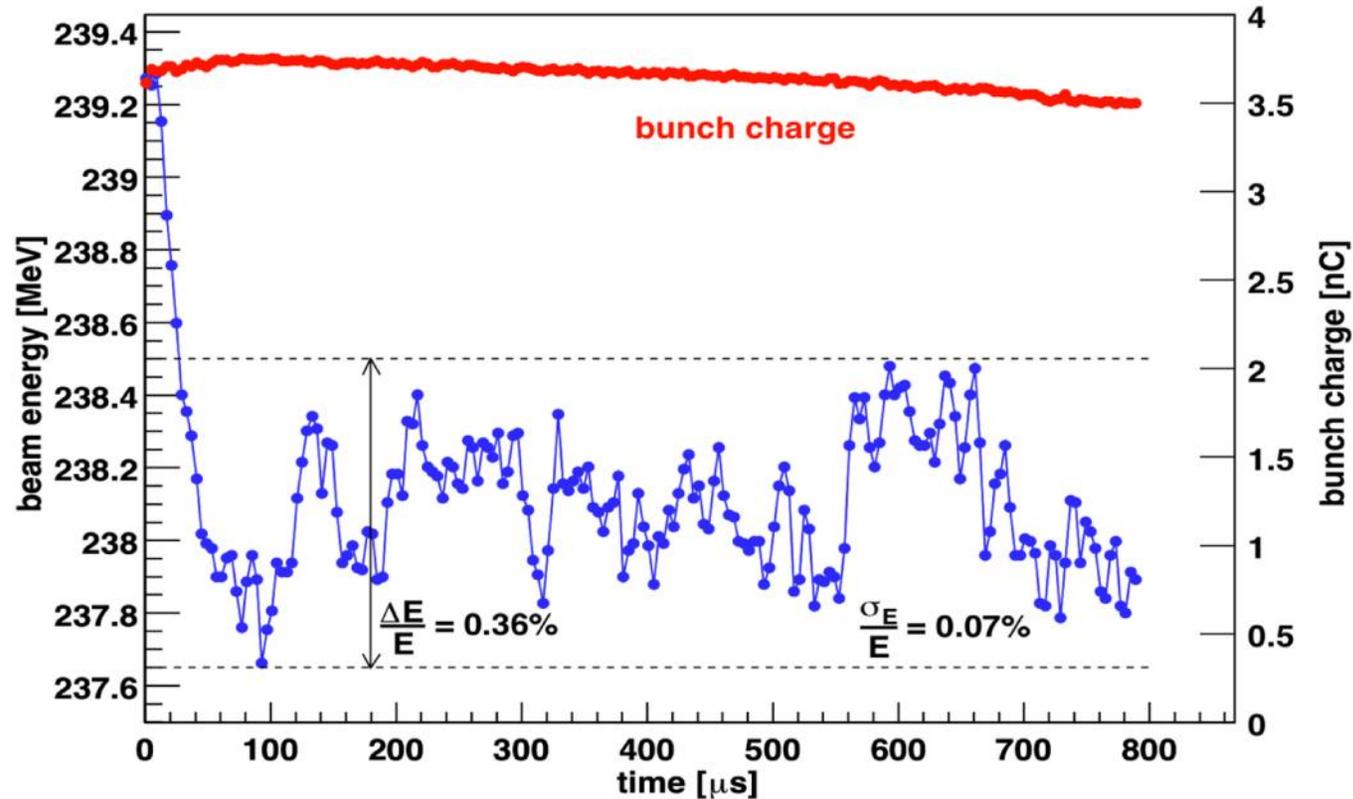


# SRF test linac objectives

- **Demonstration of:**
  - accelerating gradient
- **With specified:**
  - Beam phase and energy stability at full current; with gradient spread
  - Gradient and RF power overhead
- **to establish technology for:**
  - controlling beam loading effects
  - Lorentz – Force detuning compensation
  - *in both static and dynamic conditions*

# Feasibility demonstration at TTF (8mA, 800us)

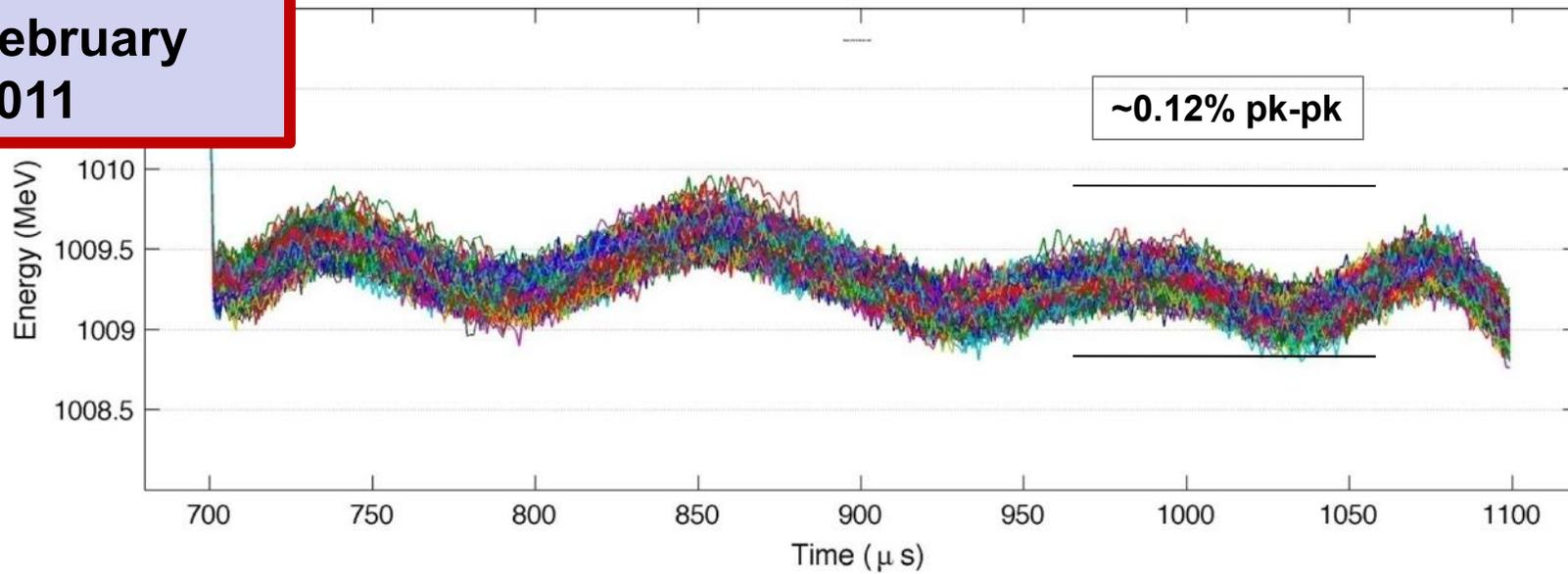
*From ICFA Beam Dynamics Newsletter #24, April 2001*



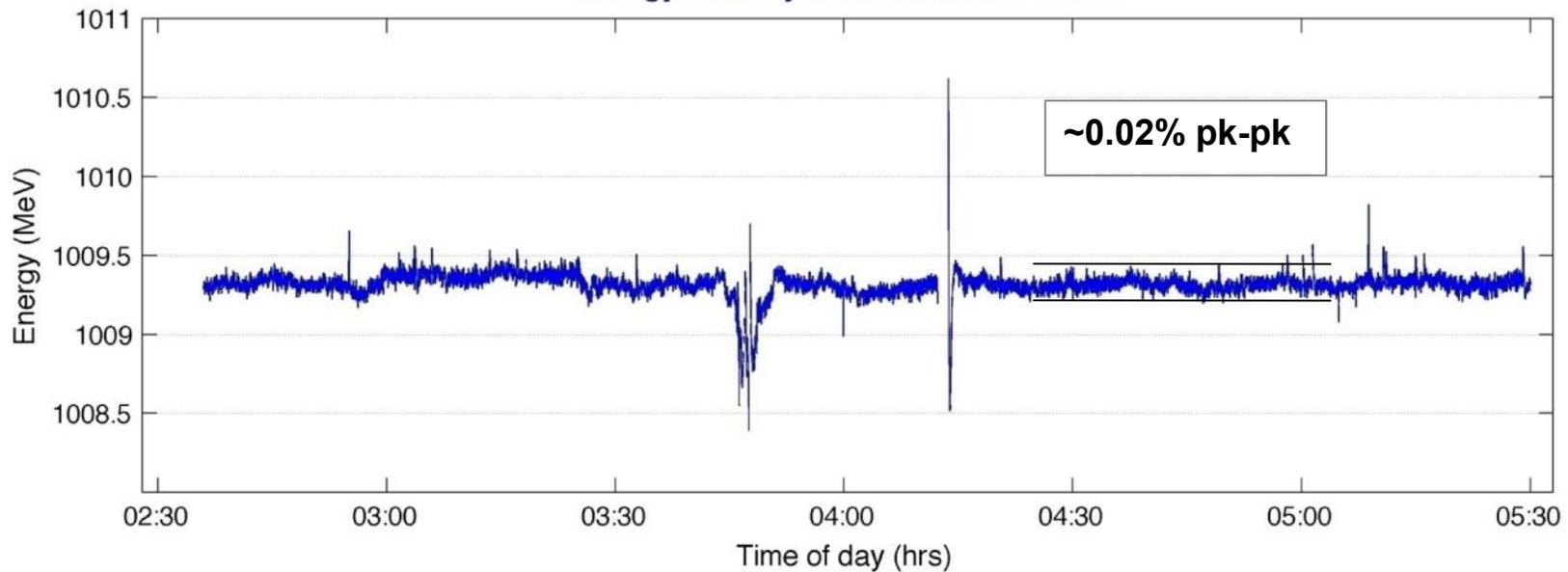
- 2 cryomodules, 8+8 cavities, single klystron
- 238MeV final beam energy
- 3.5nC/bunch 1800 bunches @ 2.25MHz

**FLASH:  
February  
2011**

Energy stability over a 400 $\mu$ s bunch-train with 4.5mA



Energy stability over 3hrs with 4.5mA



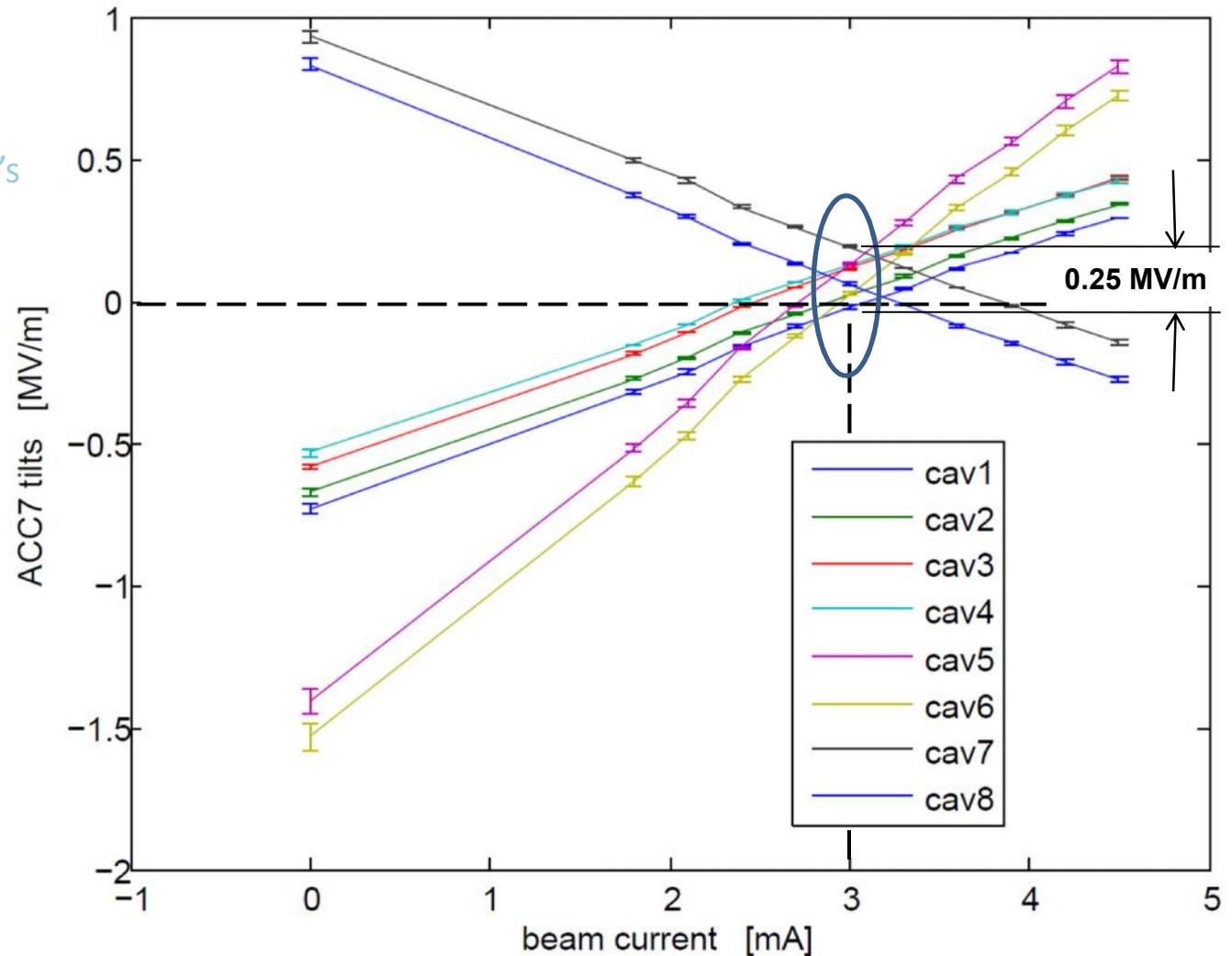
# Assessing the accuracy of the model

- $Q_L$  scan

→ Keep beam current constant but walk  $Q_L$ 's around optimized value

- $I_B$  scan

→ Keep optimized  $Q_L$ 's but ramp beam up/down



(Tilt: gradient change during 400 us beam pulse )



# Achievements: SRF Linac – FLASH (DESY)

## High beam power and long bunch-trains (Sept 2009)

Metric	ILC Goal	Achieved
• Macro-pulse current	9mA	9mA
• Bunches per pulse	2400 x 3nC (3MHz)	1800 x 3nC 2400 x 2nC
• Cavities operating at high gradients, close to quench	31.5MV/m +/-20%	4 cavities > 30MV/m

## Gradient operating margins (Feb 2011)

Metric	ILC Goal	Achieved
• Cavity gradient flatness (all cavities in vector sum)	2% $\Delta V/V$ (800 $\mu$ s, 9mA)	2.5% $\Delta V/V$ (400 $\mu$ s, 4.5mA) "Methodology established"
• Gradient operating margin	All cavities operating within 3% of quench limits	(Focus of early 2012 run)
• Energy Stability	0.1% at 250GeV	<0.15% p-p (0.4ms) <0.02% rms (5Hz)



# ILC TDP: (2.1)

- SRF R & D

- **SRF Mass Production and Cost**

- **Global cavity fabrication** model
  - Tie to ILC Project Governance
- TESLA industrial studies (~10 years old)
- Breakthrough welding costs → '*Pilot Plant*'
- *Commercializing SRF*

- **Beam Test Facilities**

- **Siting the ILC**

- **Path to the Energy Frontier**



# Mass Production of SRF

## 2005:

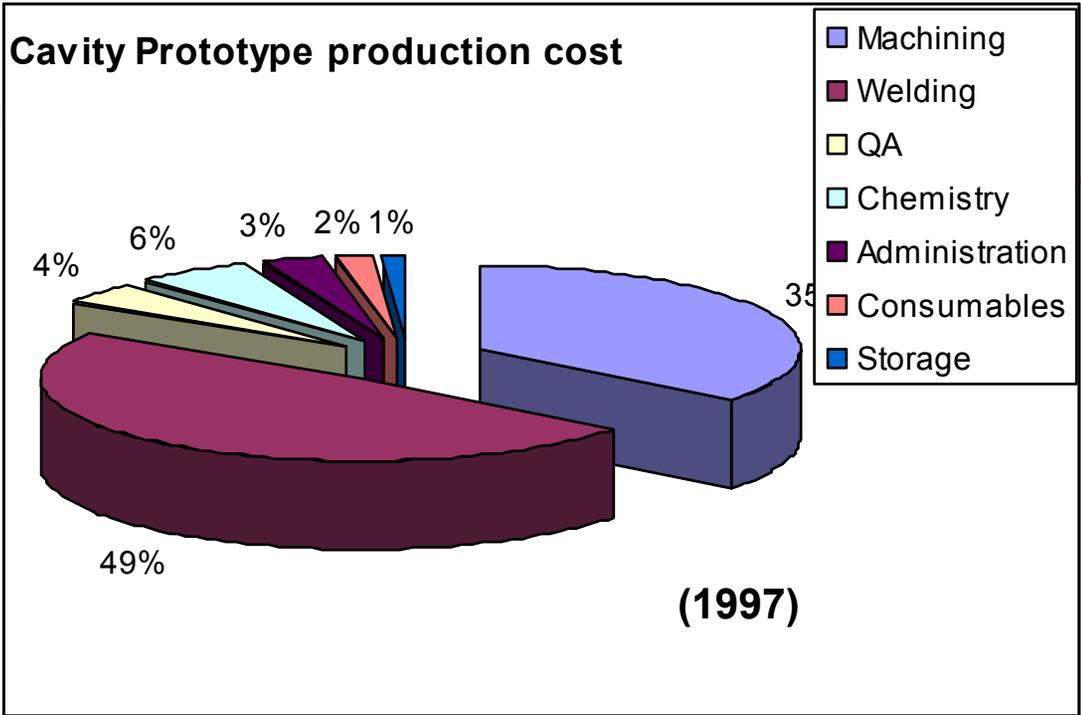
- **RDR cost based on central control**
  - DESY-led industrial studies
  - Modeled after LHC
- **Large process improvements assumed**
  - But - only 1 ½ qualified cavity vendors in 2005

## 2011:

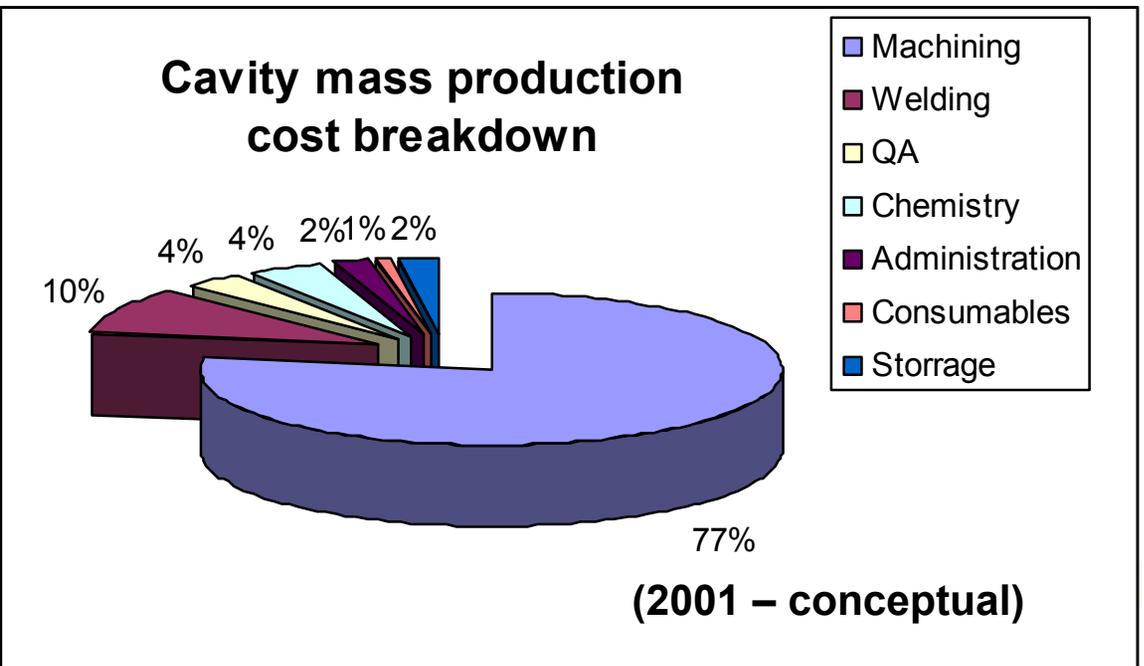
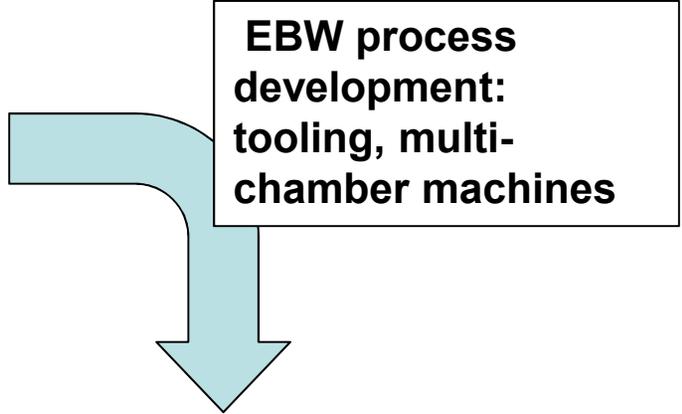
- **Independent markets developing**
  - Expect ~10 qualified cavity vendors ←
- **Joint workshops: 2010, 2011**

# European cost / mass production evaluation by Industrial Studies, cont.

- **Complete planning of new “core tech” factory**
  - Determine costs for buildings, investment, man power, ramp up & production & ramp down, overhead, consumables, QC,...
  - Get bits for outsourced parts
  - Sum up total cost of component fabrication
- **NO** learning curve assumed (e.g. -10% for doubling the production)
- But assumption: stable production after about 50 cavities, couplers, ...
  - **Is verified e.g. by LHC magnet production: assembly time reached stable (and predicted) level after about 40 magnets**
- **This cost model is valid because it was developed by experienced companies. Additional studies would require time, money and competent industry.**



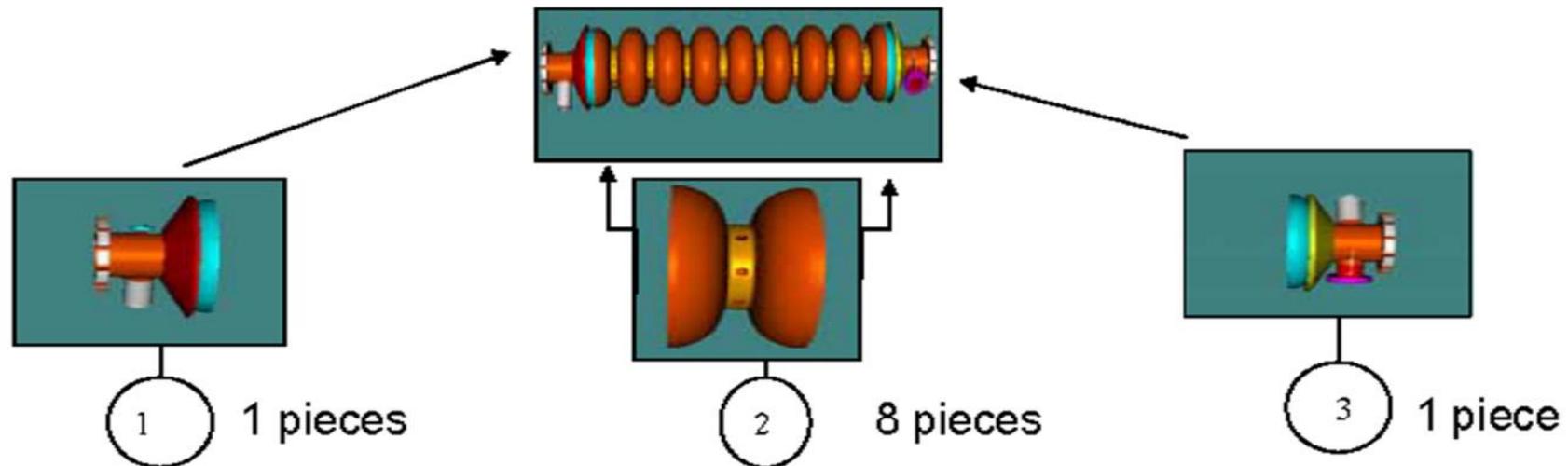
# Cavity fab cost breakdown



**Machining to be outsourced →**

## Cavity welding: the general way

There are differences of welding processes in industry



1. Degreasing and rinsing of parts
2. Drying under clean condition
3. Chemical etching at the welding area ( Equator)
4. Careful and intensive rinsing with ultra pure water
5. Dry under clean conditions
6. Install parts to fixture under clean conditions
7. Install parts into electron beam (eb) welding chamber  
( no contamination on the weld area allowed)
8. Pump down to vacuum in the EBW chamber  $E^{-5}$  mbar
9. Welding and cool down of Nb to  $T < 150^{\circ} C$ , venting
10. Leak check of weld



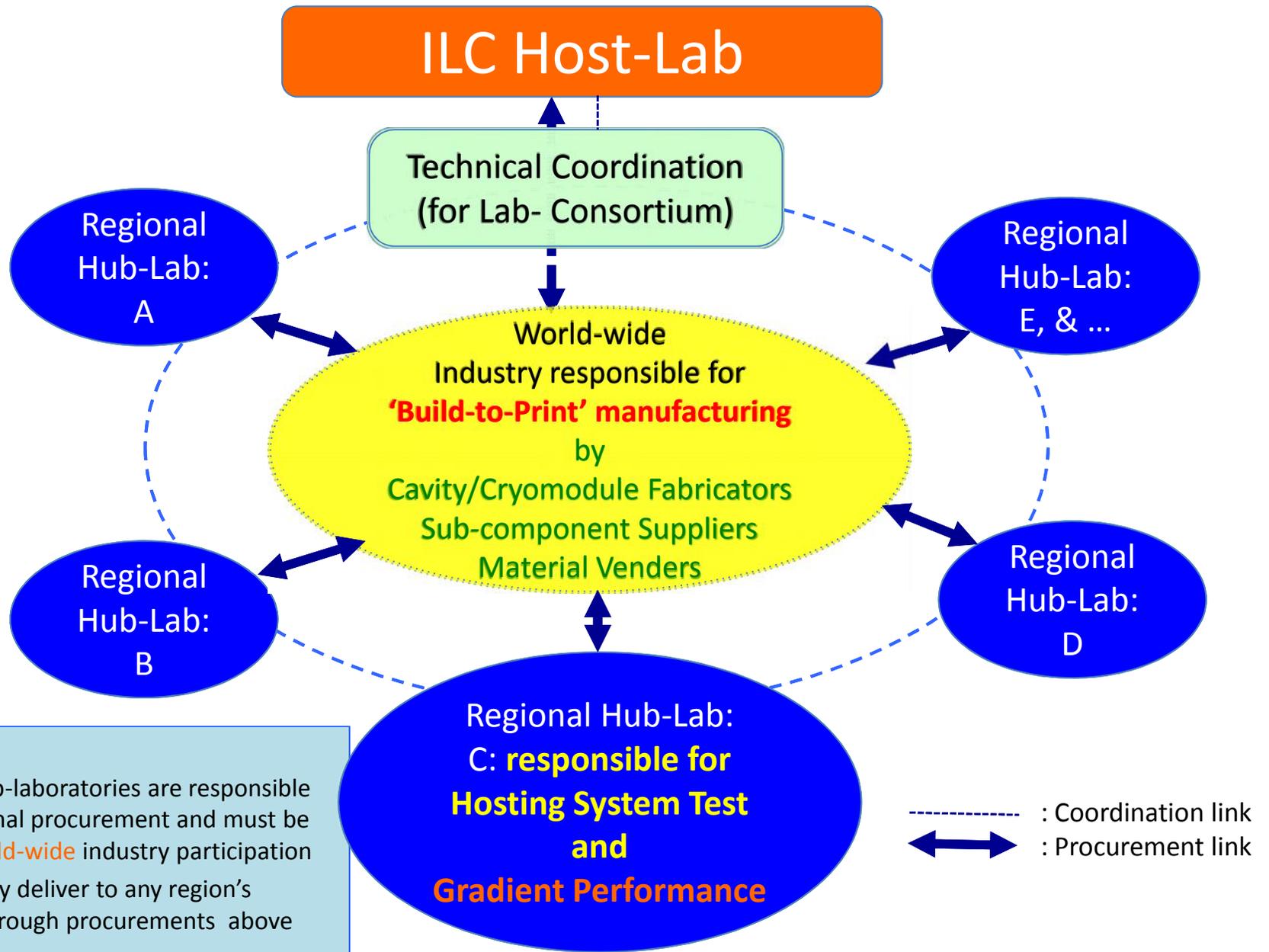
# Conclusion: What can we learn from LHC magnet production for XFEL / ILC planning

- 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

e-beam welder at  
KEK → 'Pilot Plant'



# A Possible ILC-SCRF Industrialization Model



# Niobium Superconducting Cavities

## 1.3 GHz 9-Cell ILC/TESLA

Niobium  
in stock  
for quick  
delivery!



**\$49,999\***

\*Entry level niobium cavity delivered in 3 months (other options available).

Let us help you customize the exact niobium structure you need from 28 MHz to 3.9 GHz and beyond.



**NIOWAVE**  
*Accelerating Your Particles*

[www.niowaveinc.com](http://www.niowaveinc.com)  
[sales@niowaveinc.com](mailto:sales@niowaveinc.com)  
517.999.3475

**Contact us to discuss your needs**



## SRF Technology Cost – 2011:

- **semi-finished material** : fabrication : surface etch & rinse
  - Roughly equal contribution → **1/3:1/3:1/3**

- **ITRP (2004): Superconducting technology:**
  - “The construction of the superconducting *XFEL free electron laser* will provide prototypes and test many aspects of the linac.
  - The *industrialization* of most major components of the linac is underway.
  - .... “



## ILC TDP: (2.2)

- SRF R & D

- **SRF Mass Production and Cost**

- Pure Niobium semi-finished material
- \$ and chemistry
- Capacity and Constraints
- Vendor seminar

- **Beam Test Facilities**

- **Siting the ILC**

- **Path to the Energy Frontier**



# Material – ATR Nb from mine (BR)

- **Is raw niobium a cost driver?**

- 1 {
  - mixed oxides tantalum Ta<sub>2</sub>O<sub>5</sub> and niobium Nb<sub>2</sub>O<sub>5</sub>
  - Ta<sub>2</sub>O<sub>5</sub> + 14 HF → 2 H<sub>2</sub>[TaF<sub>7</sub>] + 5 H<sub>2</sub>O
  - Nb<sub>2</sub>O<sub>5</sub> + 10 HF → 2 H<sub>2</sub>[NbOF<sub>5</sub>] + 3 H<sub>2</sub>O
- 2 {
  - liquid extraction of the fluorides from aqueous solution by organic solvents like cyclohexanone
  - or precipitated with ammonia as the pentoxide
- 3 {
  - process involving the AluminoThermic Reaction (ATR) a mixture of iron oxide and niobium oxide is reacted with aluminium:
  - 3 Nb<sub>2</sub>O<sub>5</sub> + Fe<sub>2</sub>O<sub>3</sub> + 12 Al → 6 Nb + 2 Fe + 6 Al<sub>2</sub>O<sub>3</sub>

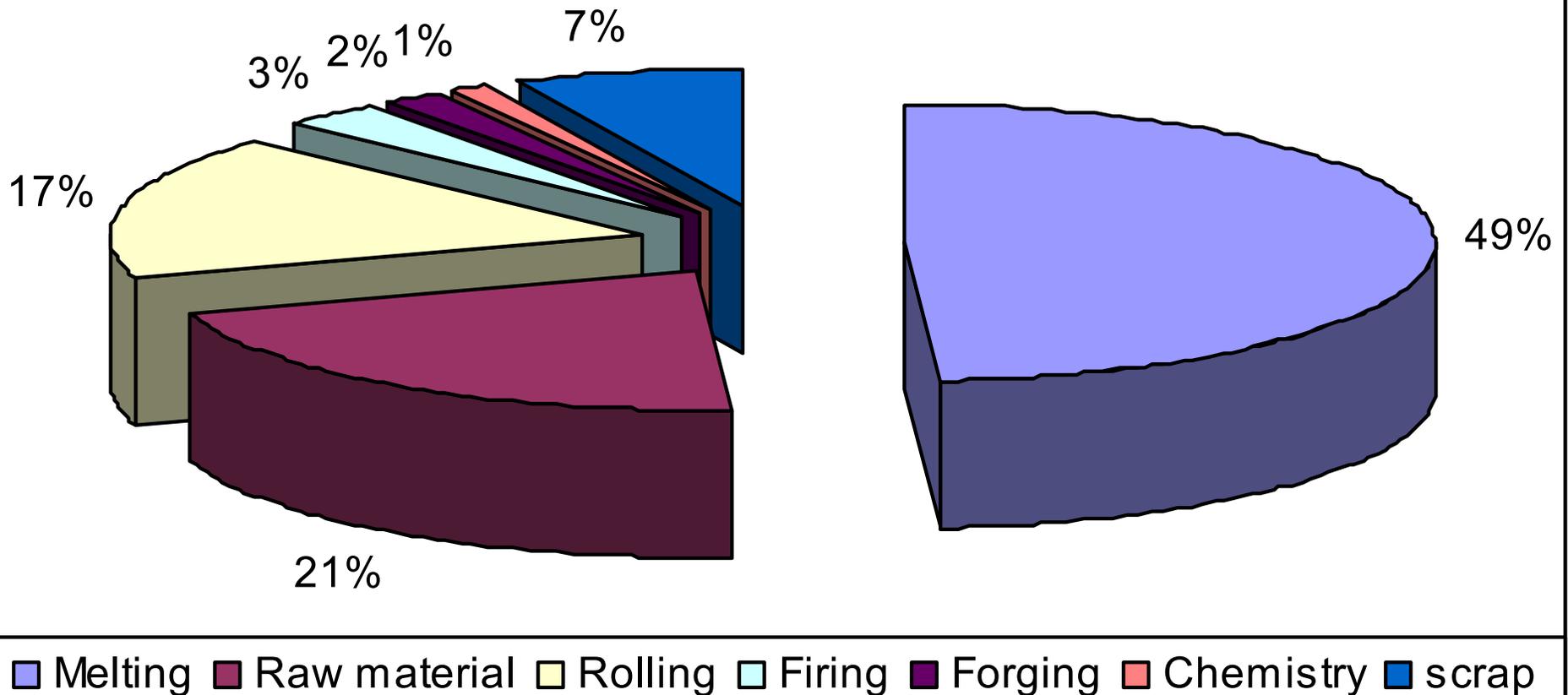
- **(Wikipedia)**



# Comments to mass production / cost evaluation of high purity Niobium

- **Nb Material (high purity, RRR 300)**
  - No shortage of raw Nb material (40.000 tons annual production, ILC needs around 500 tons)
  - But limited number of high purity melting facilities
    - Today (2007) there are 4 qualified companies, but only one is capable of producing full yield for ILC
  - Marginal savings in mass production (from industrial study)
    - Size of melting furnace is limited
    - But some saving can be realized by
      - Disc rather than rectangular sheet (scrap can be recovered)
      - Other material produced ready for fabrication, e.g. flange material
    - **Latest developments in large/single crystal cavities promise cost reductions, needs more experience / studies**

## High purity Niobium production



TESLA 2001-27 Kouptsidis (German)

D.Proch, LCWS 2007

# Niobium Production at CBMM

- Niobium Ore in Araxa mine (open air pit) is pyrochlor with 2.5%  $\text{Nb}_2\text{O}_5$
- The ore is crushed and magnetite is magnetically separated from the pyrochlor.
- By chemical processes the ore is concentrated in Nb contents (50 –60 % of  $\text{Nb}_2\text{O}_5$ )
- A mixture of  $\text{Nb}_2\text{O}_5$  and aluminum powder is being reacted to reduce the oxide to Nb
- This Nb is the feedstock for the EBM processes

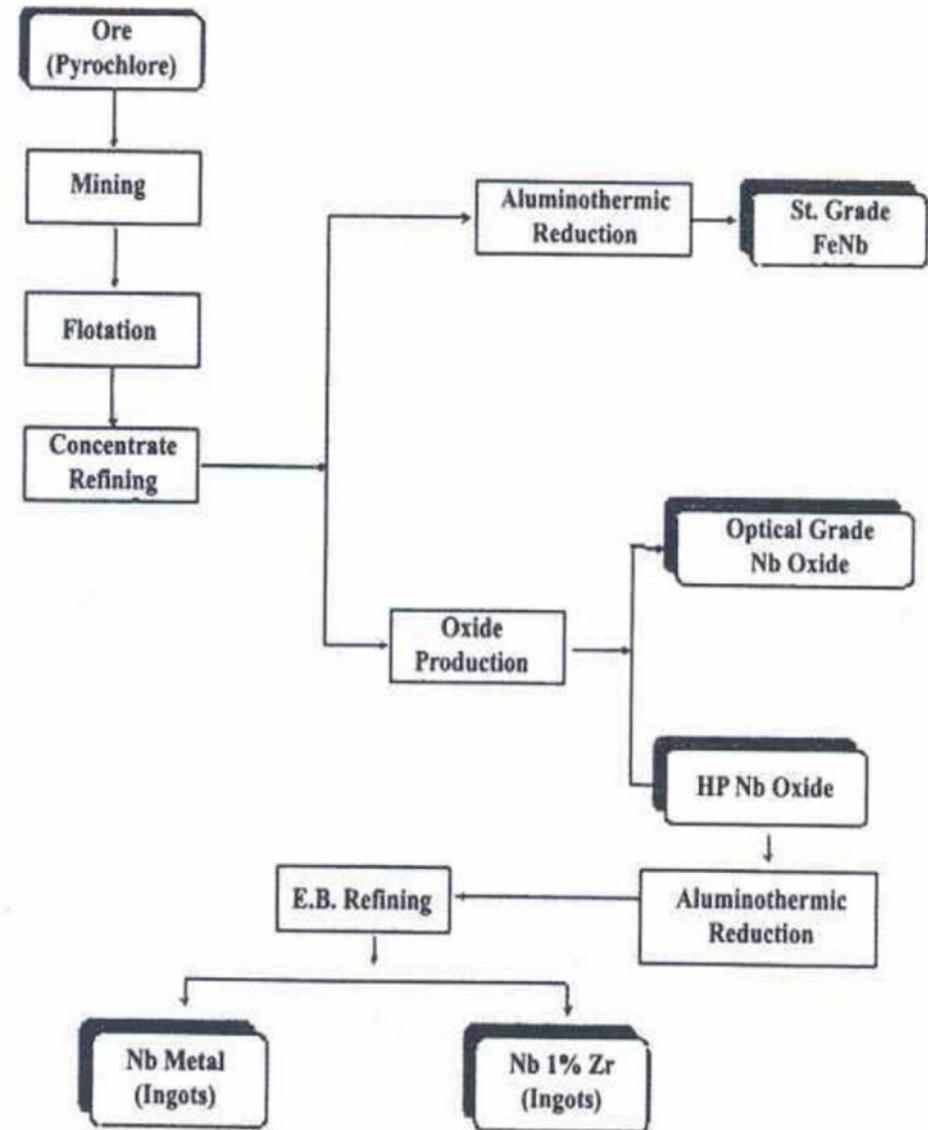
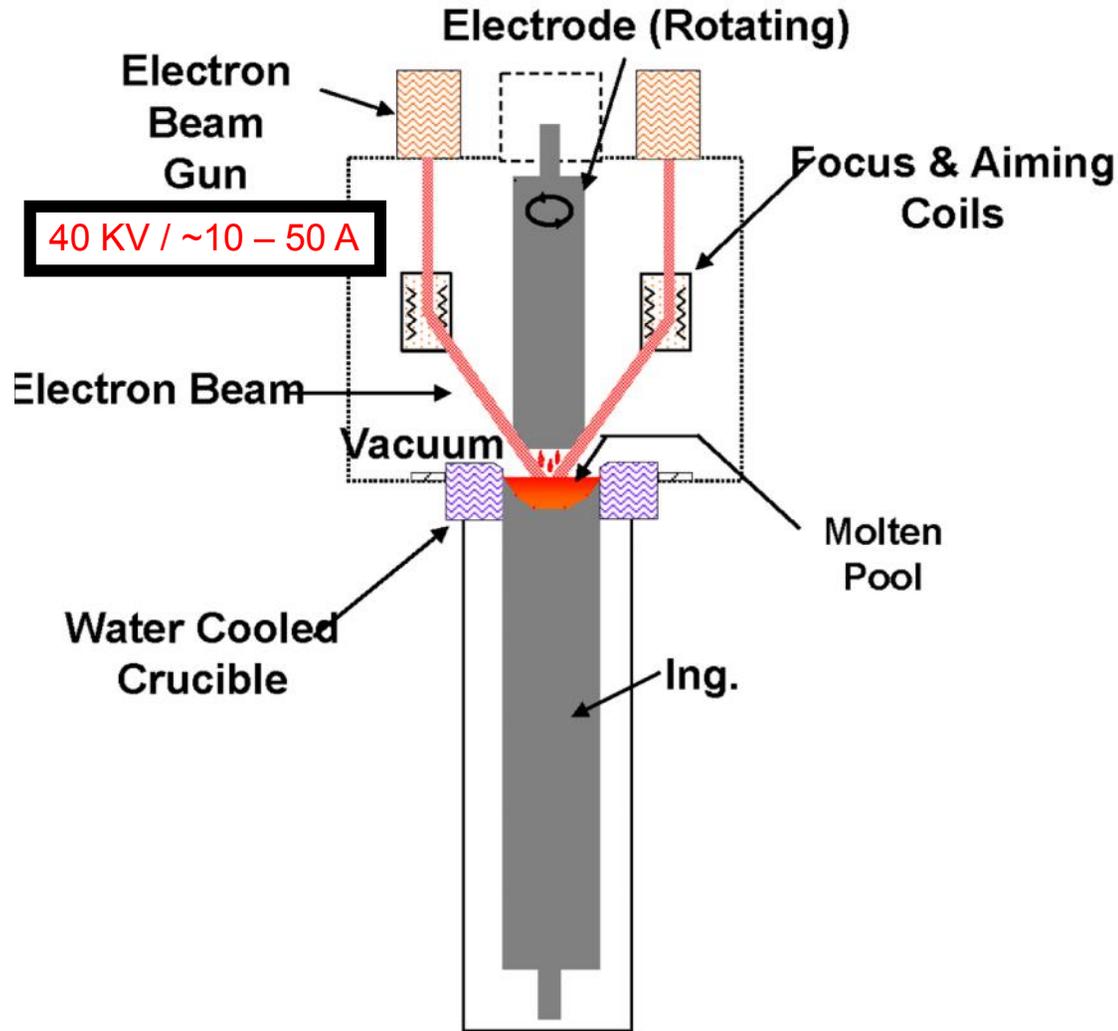


Fig. 3: Production flow chart at CBMM.



**500KW electron beam cold hearth furnace**

# Electron Beam Melting



Electron beam melting of Nb

During of the ingot melts, molten metal **globules** fall into a **pool** on the ingot which is contained in a water cooled copper cylinder (sleeve). Impurities are evaporated and pumped away. Power impact is maintained to keep the pool molten out to within a few mm of the crucible wall. During melting the ingot formed is **continuously withdrawn** through the sleeve. The rate of withdrawal has to be carefully coordinated with the rate of the material to insure complete melting of the feed material and proper outgassing.

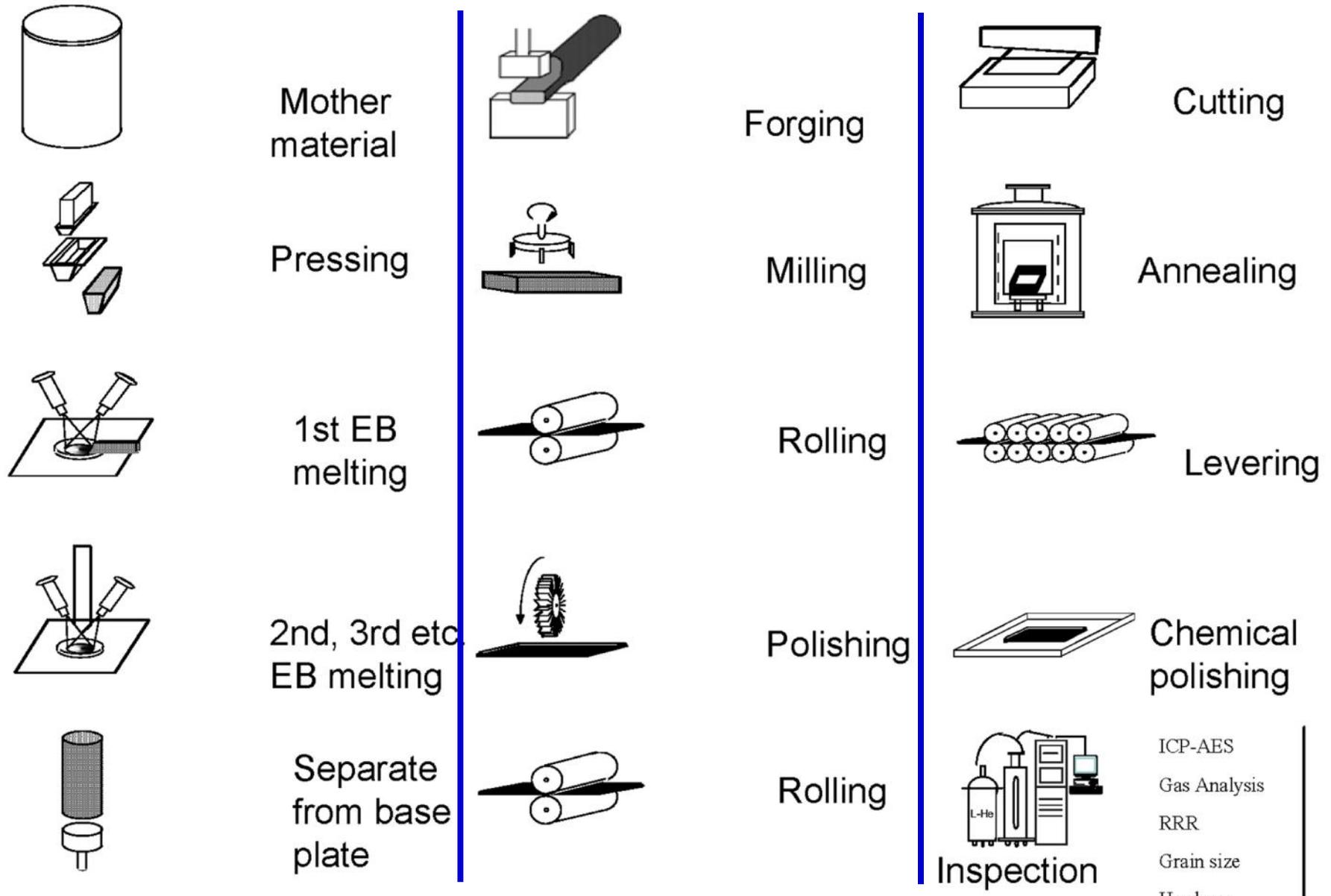
# Electron Beam Melting

As a result of the increasing demand for refractory metals in the last few decades, the electron-beam furnace has been developed to a reliable, efficient apparatus for melting and purification.



# Fabrication of Nb sheets at Tokyo Denkai

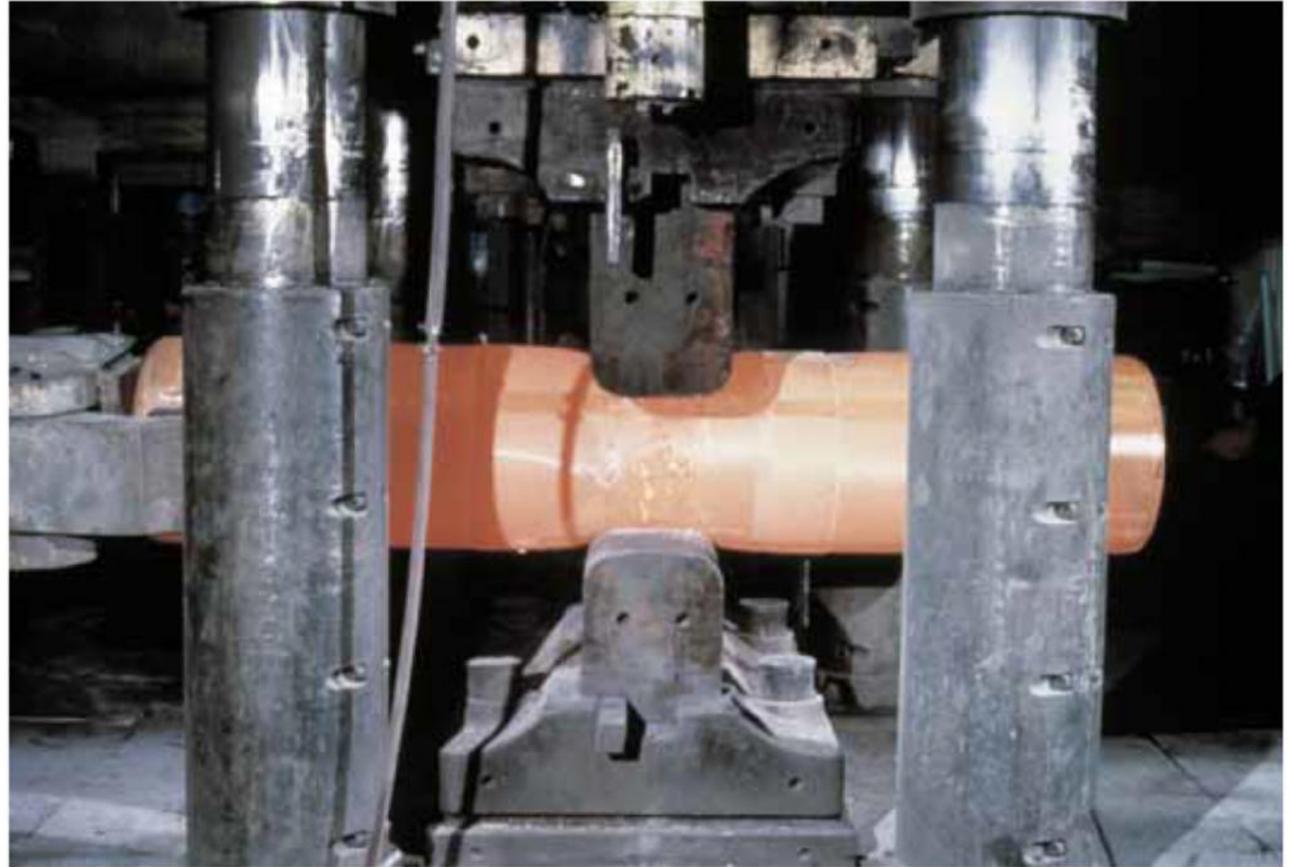
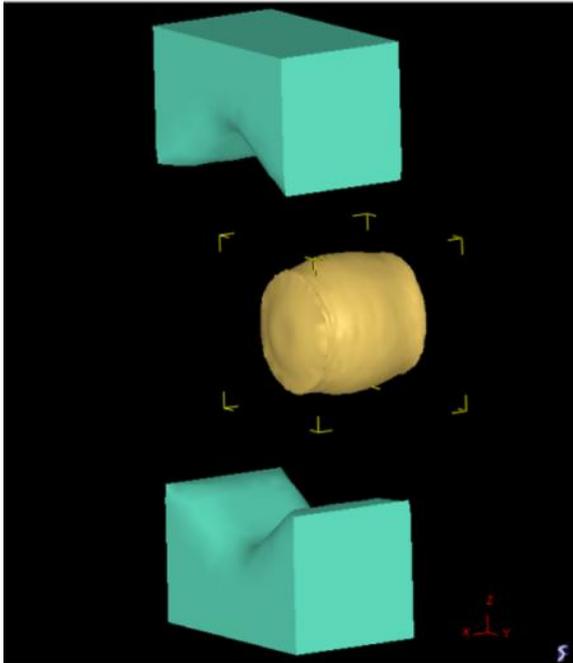
**60% yield?**



- ICP-AES
- Gas Analysis
- RRR
- Grain size
- Hardness
- Tensile tests

In the final sheet the purity of niobium should be not inferior as in the ingot

# Forging



2000 ton open die forge  
(Wah Chang )

# Rolling



700 mm wide cold rolling mill (Wah Chang)



800 mm wide hot rolling mill (Wah Chang)

Hot rolling, used mainly to produce sheet metal is when industrial metal is passed or deformed between a set of work rolls and the temperature of the metal is generally above its recrystallization temperature.

Cold rolling takes place below recrystallization temperature.



## Updated Plan for Visiting Vendor

	Date	Company	Place	Technical subject
1	2/8	Hitachi	Tokyo (JP)	Cavity & Cryomodule
2	2/8	Toshiba	Yokohana (JP)	Cavity & Cryomodule
3	2/9	MHI	Kobe (JP)	Cavity & Cryomodule
4	2/9	Tokyo Denkai	Tokyo (JP)	Nb, NbTi Material
5	2/18	OTIC	NingXia (CN)	Nb, NbTi, Ti Material
6	3/3	Zanon	INFN, Milano (IT)	Cavity & Cryomodule
7	3/4	RI	Koeln (DE)	Cavity & Cryomodule
12	4/27	Plansee	Ruette (AS)	Nb, NB-Ti Material
8	3/14, (4/8)	AES	LI, NY (US)	Cavitu & Cryomodule
9	3/15, (4/7)	Niowave	Lansing, MI (US)	Cavity & Cryomodule
10	4/6	PAVAC	Vancouver (CA)	Cavity & Cryomodule
11	4/25	ATI Wah-Chang	Albany, OR (US)	Nb, Nb-Ti material



# Material

- **Niobium:**
  - Has high melting point – 2500 degC
  - Has strong acid resistance → ‘refractory’
  - Is difficult to machine
  - (pure RRR Nb) is ductile and very difficult to grind
  - Has affinity for oxygen
  - Is a daughter metal to Tantalum
  
- **R & D post 2012**
  - Ta content?



## ILC TDP: (3)

- SRF R & D
- SRF Mass Production and Cost

- **Beam Test Facilities**

- **CesrTA**: Recommendation delivered 2011
- ATF2: *Recovery*
  - Nominal intensity / reasonable starting emittance
  - Alignment ongoing

- **Siting the ILC**

- **Path to the Energy Frontier**



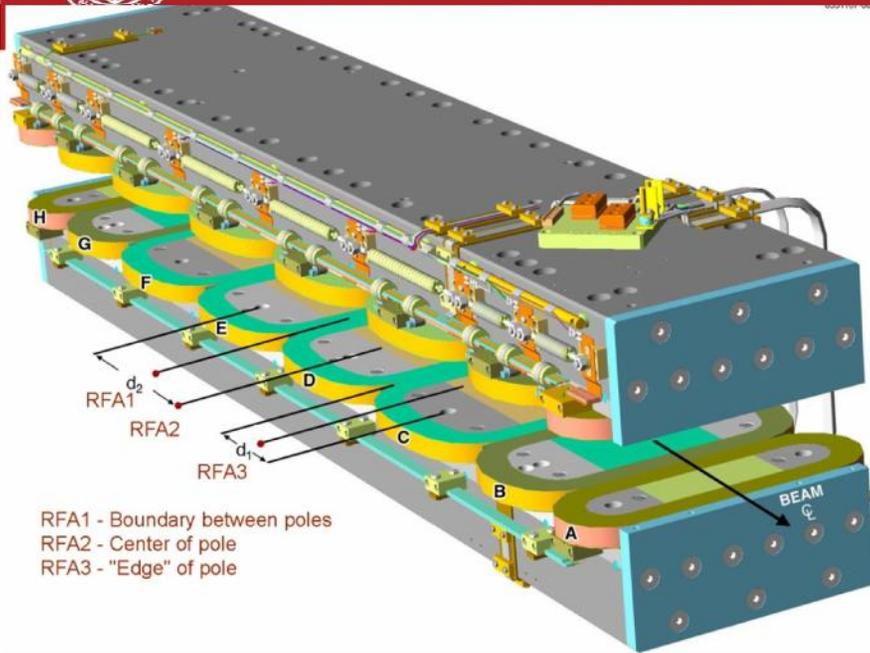
# FC Mitigations

	Drift	Quad	Dipole	Wiggler	VC Fab
Al	✓	✓	✓		CU, SLAC
Cu	✓			✓	CU, KEK, LBNL, SLAC
TiN on Al	✓	✓	✓		CU, SLAC
TiN on Cu	✓			✓, X	CU, KEK, LBNL, SLAC
Amorphous C on Al	✓				CERN, CU
NEG on SS	✓				CU
Diamond-like C on Al	✓				CU, KEK
Solenoid Windings	✓				CU
Fins w/TiN on Al	✓				SLAC
Triangular Grooves on Cu				✓	CU, KEK, LBNL, SLAC
Triangular Grooves w/TiN on Al			✓		CU, SLAC
Triangular Grooves w/TiN on Cu				✓	CU, KEK, LBNL, SLAC
Clearing Electrode				✓	CU, KEK, LBNL, SLAC

✓ = chamber(s) deployed X = deployed in CESR Arc, Jan 2011 = installed Jan 2011

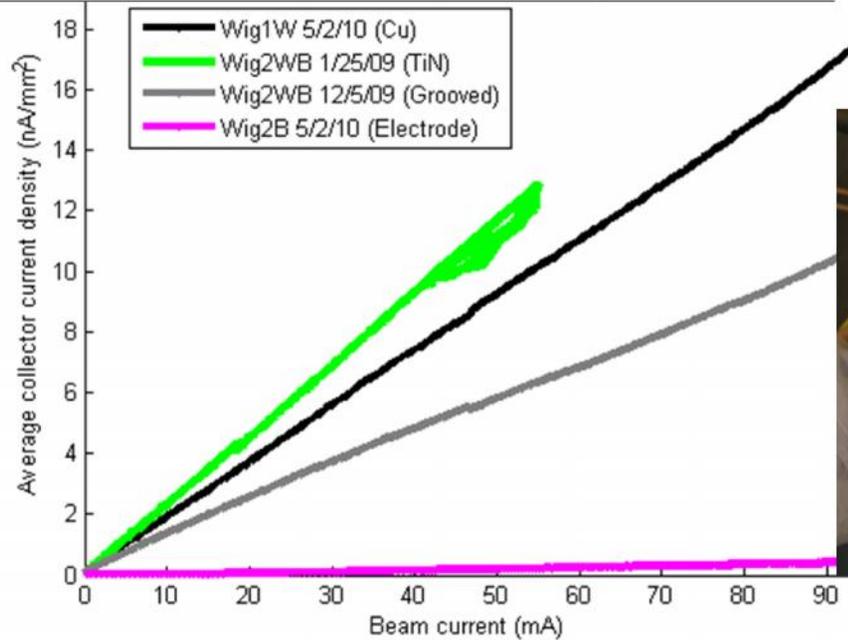
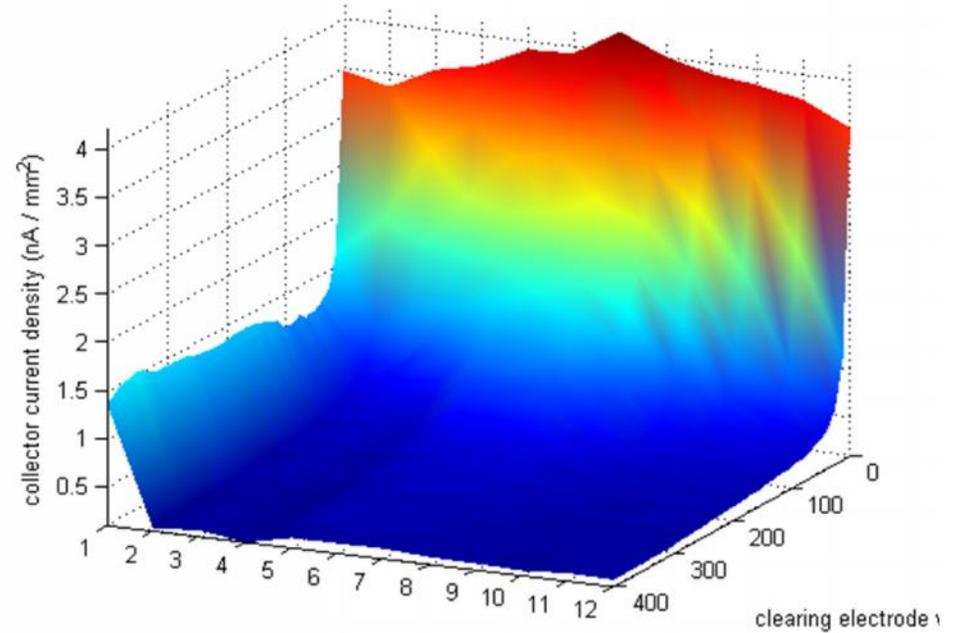


# Wiggler Observations



RFA1 - Boundary between poles  
RFA2 - Center of pole  
RFA3 - "Edge" of pole

Run #2568 (1x20x2.8mA e+, 4 GeV, 14ns): 01W\_G2 Center pole Col Curs





# EC Working Group Baseline Mitigation Plan

Mitigation Evaluation conducted at satellite meeting of ELOUD`10  
(October 13, 2010, Cornell University)

## EC Working Group Baseline Mitigation Recommendation

	Drift*	Dipole	Wiggler	Quadrupole*
<b>Baseline Mitigation I</b>	TiN Coating	Grooves with TiN coating	Clearing Electrodes	TiN Coating
<b>Baseline Mitigation II</b>	Solenoid Windings	Antechamber	Antechamber	
<b>Alternate Mitigation</b>	NEG Coating	TiN Coating	Grooves with TiN Coating	Clearing Electrodes or Grooves

\*Drift and Quadrupole chambers in arc and wiggler regions will incorporate antechambers

- Preliminary CESR-TA results and simulations suggest the presence of *sub-threshold emittance growth*
  - Further investigation required
  - May require reduction in acceptable cloud density  $\Rightarrow$  reduction in safety margin
- An aggressive mitigation plan is required to obtain optimum performance from the 3.2km positron damping ring and to pursue the high current option

S. Guiducci, M. Palmer, M. Pivi, J. Urakawa on behalf of the ILC DR Electron Cloud Working Group

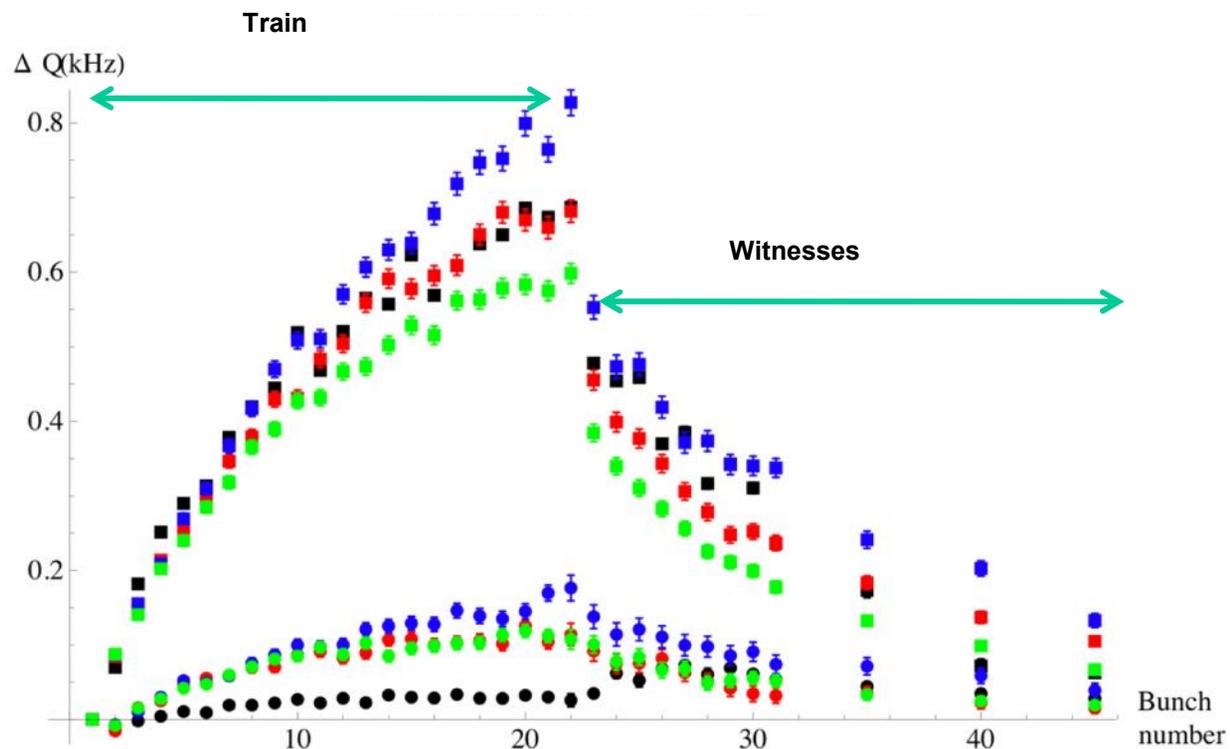


## Peak SEY Scan

## Coherent Tune Shifts (1 kHz ~ 0.0025), vs. Bunch Number

- 21 bunch train, followed by 12 witness bunches
- $0.8 \times 10^{10}$  particles/bunch
- 2 GeV.
- Data (black) compared to POSINST simulations.

- Data: horizontal
- Data: vertical
- SEY=2.0 Simulation 1: horizontal
- SEY=2.0 Simulation 1: vertical
- SEY=2.2 Simulation 2: horizontal
- SEY=2.2 Simulation 2: vertical
- SEY=1.8 Simulation 3: horizontal
- SEY=1.8 Simulation 3: vertical



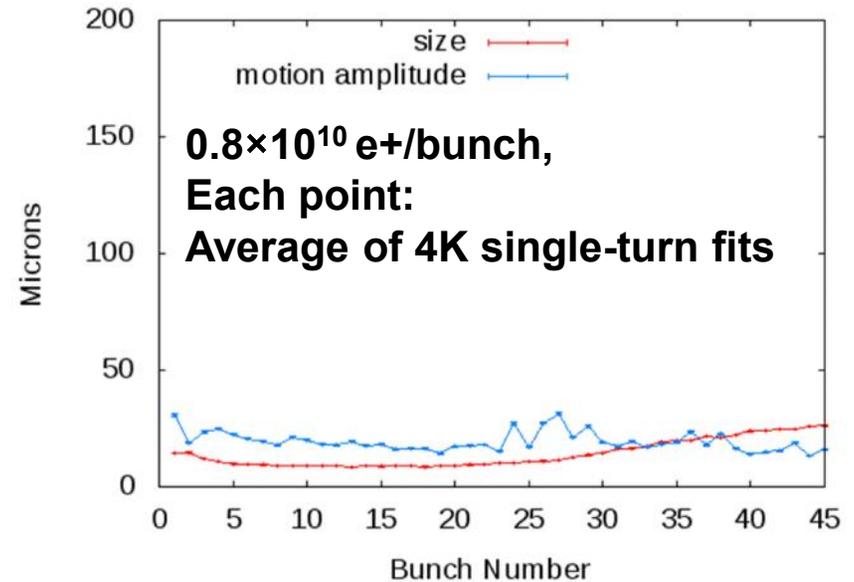


# EC-Induced Emittance Growth

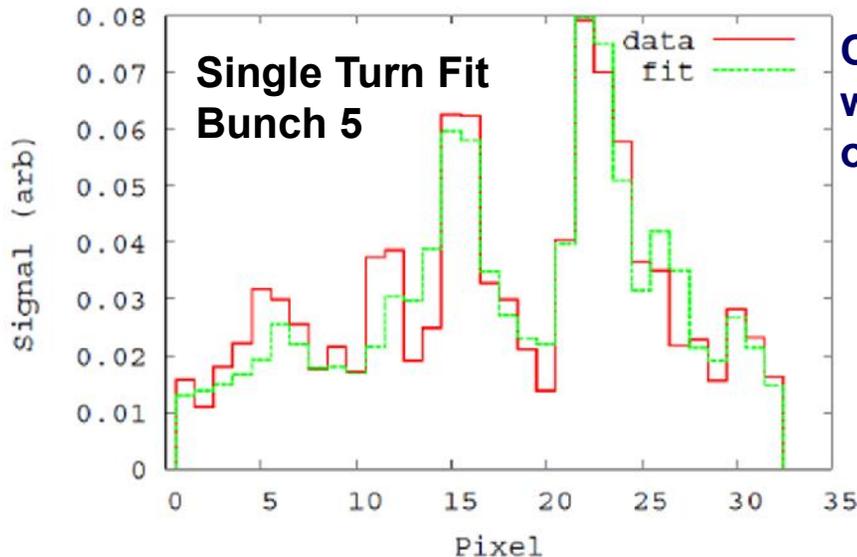
## Measure Bunch by Bunch Beam Size

- Beam size enhanced at head and tail of train  
*Source of blow-up at head appears to be due to a long lifetime component of the cloud.*  
*Bunch lifetime of smallest bunches consistent with observed single bunch lifetimes during LET (Touschek-limited) and with relative bunch sizes.*
- Beam size measured around bunch 5 corresponds to  $\epsilon_y \sim 20\text{pm-rad}$   
[ $\sigma_y = 11.0 \pm 0.2 \mu\text{m}$ ,  $\beta_{\text{source}} = 5.8\text{m}$ ]

1 Train, 45 Bunches, 0.5 mA/bunch



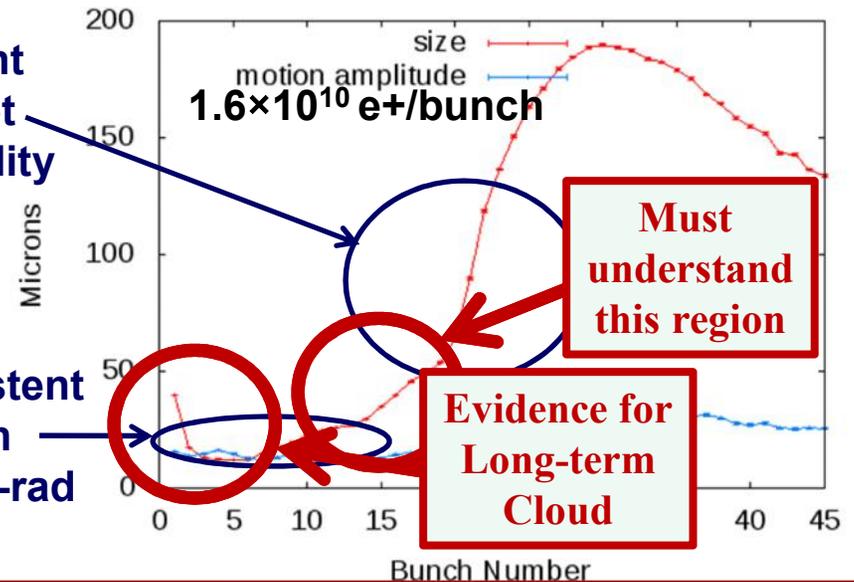
1 Train, 45 Bunches, 1.0 mA/bunch: Bunch 1



Consistent with onset of instability

Consistent with 20 pm-rad

1 Train, 45 Bunches, 1.3 mA/bunch





## ILC TDP (4)

- SRF R & D
- SRF Mass Production and Cost
- Beam Test Facilities
- **Siting the ILC**
  - Jump starting a multi-dimensional process
    - SSC 'Site-Specific' Conceptual Design: 1000 pgs/18 months
  - Technology  $\leftrightarrow$  geology/topography
  - US / Japan studies
    - Tunnel configuration studies  $\rightarrow$
- **Path to the Energy Frontier**



# Linac Configuration Study - US

	A	B	C	D	E
	DEEP		NEAR SURFACE		
	Twin Deep Tunnels	Single Deep Tunnel	Twin Near Surface Tunnels	Near Surface Tunnel, At Surface Gallery	Single Near Surface Tunnel
EXCAVATION	TBM	TBM	TBM	TBM & OPEN CUT	TBM
Nb. of TUNNELS	TWO-TUNNEL	ONE-TUNNEL	TWO-TUNNEL	TWO-TUNNEL	ONE-TUNNEL
SHAFT SOIL	VARIES	VARIES	VARIES	VARIES	Soft/SURRY
TUNNEL SOIL	ROCK	ROCK	COHESIVE SOIL OR ROCK	COHESIVE SOIL - LOW PERMEABILITY	SATURATED SAND & GRAVEL
SERVICE SPACE	SECOND TUNNEL	SURFACE BUILDINGS	SECOND TUNNEL	CONTINUOUS SERVICE GALLERY	AT CAMPUSES
ILC Technology	DISTRIBUTED RF	CLUSTERED RF	DISTRIBUTED RF	DISTRIBUTED RF	CLUSTERED RF
SIMILAIR TO	RDR SAMPLE SITES	RDR & CLIC	RDR	DUBNA ILC	XFEL
ACCESS	VERTICAL SHAFT	VERTICAL SHAFT	VERTICAL SHAFT	VERTICAL SHAFT	VERTICAL SHAFT

T. Lundin /  
T. Lackowski

F	G	H
SURFACE		
Enclosure in Open Cut, Cont. Gallery	Enclosure & Cont. Gallery in Open Cut	Enclosure in Open Cut
OPEN CUT	OPEN CUT	OPEN CUT
ONE-TUNNEL	TWO-TUNNEL	ONE-TUNNEL
NA	NA	NA
SOILS VARIES	SOILS VARIES	SOILS VARIES
CONTINUOUS SERVICE GALLERY	CONTINUOUS SERVICE GALLERY	AT CAMPUSES
DISTRIBUTED RF	DISTRIBUTED RF	CLUSTERED RF
PROJECT X	PROJECT X	
HATCH	HATCH	HATCH

## 2. Case Variations

# Tunnel Configuration Study – KEK/J-Power

<ul style="list-style-type: none"> <li>• HLRF difference           <ul style="list-style-type: none"> <li>– RDR</li> <li>– XFEL</li> <li>– KCS</li> <li>– DRFS</li> </ul> </li> </ul>	<ul style="list-style-type: none"> <li>• Tunneling Method           <ul style="list-style-type: none"> <li>– TBM (circular section)</li> <li>– NATM (horse-shoe section)</li> </ul> </li> </ul>	<ul style="list-style-type: none"> <li>• Tunnel configuration           <ul style="list-style-type: none"> <li>– Double tunnel (RDR)</li> <li>– Single tunnel (TDR)</li> <li>– Japanese-type Single-tunnel Accelerator Configuration</li> </ul> </li> </ul>
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CASE No.	Name	No. of Tunnel	Tunneling	HLRF	備考
CASE_1	D-T-R	2	TBM	RDR	
CASE_2	S-T-R	1	TBM		
CASE_3	JS-T-X	2	TBM	XFEL	Japanese type single-tunnel accelerator configuration
CASE_4	JS-T-K	2	TBM	KCS	
CASE_5	JS-T-D	2	TBM	DRFS	
CASE_6	JS-N-D	2	NATM		
CASE_7	S-N-DR	1	NATM	DRFS/	Thin wall
CASE_8	S-N-DR	1	NATM	RDR	Thick wall

# Site studies in Japan:



“There is an encouraging possibility that Japan will bid to [host the ILC](#). Earlier this month, at the autumn meeting of the Physical Society of Japan held at the Kyushu Institute of Technology, representatives of the Japanese ILC community announced two potential ILC sites. The two locations are at opposite ends of the Japanese archipelago, one in the [Seburi-area, 30 kilometers south of the city of Fukuoka](#) in northwestern Kyushu island, and the other in the [Kitakami-area, 100 kilometers north of the city of Sendai](#) in northern Honshu island”

## Director's Corner

30 September 2010



Marc Ross

**The ILC in a mountainous region – A report on Japanese efforts to develop possible sites**

*Today's issue features a Director's Corner from Marc Ross, Project Manager for the Global Design Effort.*

Roughly six years ago the International Committee for Future Accelerators accepted the recommendation to adopt 'cold', superconducting radiofrequency (RF) technology for the linear collider's main linac. The recommendation came shortly after an extensive review of the designs of the ILC's forerunner projects, TESLA, NLC and JLC. The main linac technology planned for the ILC, now under development in each region, is quite similar to that of the TESLA design.

Of course, the TESLA design included much more than a plan to deploy cold RF technology. In particular, the TESLA *Technical Design Report* included a conventional facilities design and a plan for a site in Germany located along a line stretching towards the northwest from DESY. In contrast to our adoption of cold RF technology, the conventional facilities design for TESLA was not adopted; a quite different design for the ILC has emerged and this has broad implications for several subsystems. The TESLA underground construction scheme was optimised to best suit a site in sandy, flat, water-logged ground with much of the underground construction below the water table, requiring appropriate design techniques.

In the Technical Design Phase, we now face a new challenge, namely how to make sure the ILC design is suitable for a variety of possible sites, including those similar to the DESY site.





Advanced Accelerator Association Promoting Science & Technology

AAA-First Term Activity Report  
Supplemental Volume

# Industry consortium site study (AAA 2010)

## Investigating the Single Tunnel Proposal in a Japanese Mountainous Site

### Tohoku-Oki recovery 11.03.11

ILC Newsline 23. June 2011

みんなと共に  
がんばろう! 東北



*Tohoku recovery logo says: "Let's get together towards  
Tohoku recovery." Image: Ministry of Land, Infrastructure  
and Transport*



*Iwate Prefectural Governor Takuya Tasso. Image: Iwate  
Prefecture*

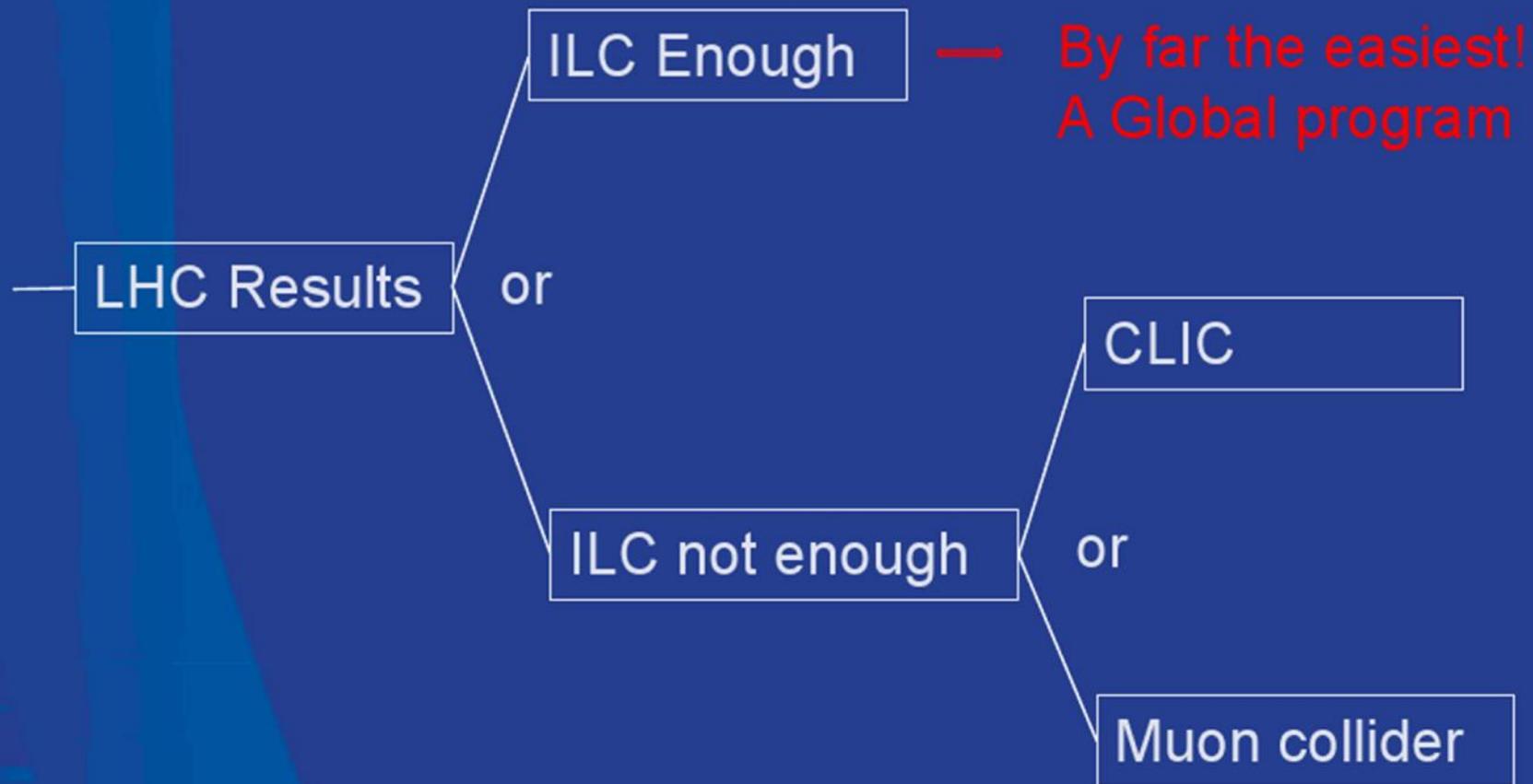
30 June, 2011



## ILC TDP (5)

- SRF R & D:
- SRF Mass Production and Cost
- Beam Test Facilities
- Siting the ILC
- **Path to the Energy Frontier**
  - Position US to *regain the Frontier*...
  - Direction from LHC (2011/2012) – what's next?
  - Normal conducting technology system test
  - Documenting the **Technical Design Phase**

# Biggest decision of the decade !





# 1 TeV: Two Scenarios

- **Scenario 1:**  
**Consider 1 TeV as upgrade to initial 500 GeV machine**
  - current GDE approach for TDR
  - based on original strategy set-out in 2005
- **Scenario 2:**  
**Consider  $>500$  GeV ( $\leq 1$  TeV) as initial machine**
  - consider as gedanken experiment
  - flexibility in light of (emerging) LHC results



# 1 TeV Tentative Parameters

Collision rate	$f_{rep}$	4 Hz
Number of bunches	$n_b$	2625
Bunch population	$N_b$	$2 \times 10^{10}$
Bunch separation	$Dt_b$	356 ns
Pulse current	$I_{beam}$	9.0 mA
RMS bunch length	$S_z$	0.3 mm
RMS energy spread (e-, e+)	$Dp/p$	0.105, 0.038
Polarisation (e-, e+)	$P_{\cdot}$	80, 22 %
Emittance (linac exit)	$\mathcal{G}_{x,y}$	10, 0.035 mm
IP beta function	$b_{x,y}^*$	30, 0.3 mm
IP RMS beam size	$S_{x,y}^*$	554, 3.3 nm
Vertical disruption parameter	$D_y$	19.2
<b>Luminosity</b>	<b><math>L</math></b>	<b><math>2.70 \times 10^{34} \text{ cm}^{-2} \text{ s}^{-1}</math></b>
Fraction of luminosity in top 1%	$L_{0.01}/L$	63.5 %
Average energy loss	$dE_{BS}$	4.9 %
Number of pairs per bunch crossing	$N_{pairs}$	169
Total pair energy per bunch crossing	$E_{pairs}$	1084 TeV

Current “official” parameter set in EDMS\*.

Should still be considered tentative, pending review and further study.

Understanding (and updating) these parameters is our job for the next ~6 months.

**negotiation!**

\* EDMS Doc ID: D\*925325

[http://ilc-edmsdirect.desy.de/ilc-edmsdirect/file.jsp?edmsid=\\*925325&fileClass=ExcelShtX](http://ilc-edmsdirect.desy.de/ilc-edmsdirect/file.jsp?edmsid=*925325&fileClass=ExcelShtX)



# CLIC main parameters

<http://cdsweb.cern.ch/record/1132079?ln=fr> <http://clic-meeting.web.cern.ch/clic-meeting/clictable2007.html>

Center-of-mass energy	CLIC 500 GeV		CLIC 3 TeV	
	Relaxed	Nominal	Relaxed	Nominal
Beam parameters				
Accelerating structure	502		6	
Total (Peak 1%) luminosity	$8.8(5.8) \cdot 10^{33}$	$2.3(1.4) \cdot 10^{33}$	$7.3(3.5) \cdot 10^{33}$	$5.9(2.0) \cdot 10^{34}$
Repetition rate (Hz)	50			
Loaded accel. gradient MV/m	80		100	
Main linac RF frequency GHz	12			
Bunch charge $10^9$	6.8		3.72	
Bunch separation (ns)	0.5			
Beam pulse duration (ns)	177		156	
Beam power/beam MWatts	4.9		14	
Hor./vert. norm. emitt( $10^{-6}/10^{-9}$ )	7.5/40	4.8/25	7.5/40	0.66/20
Hor/Vert FF focusing (mm)	4/0.4	4 / 0.1	4/0.4	4 / 0.1
Hor./vert. IP beam size (nm)	248 / 5.7	202 / 2.3	101/3.3	40 / 1
Hadronic events/crossing at IP	0.07	0.19	0.28	2.7
Coherent pairs at IP	10	100	$2.5 \cdot 10^7$	$3.8 \cdot 10^8$
BDS length (km)	1.87		2.75	
Total site length km	13.0		48.3	
Wall plug to beam transfert eff	7.5%		6.8%	
Total power consumption MW	241		568	



# GDE - Technically-driven post 2012 program

## THEME for post-2012 program

We are discussing possible major themes to guide this R&D development program. Examples including R&D toward a 1TeV, either directly or as an upgrade, emphasizing achieving higher gradient (energy) economically.

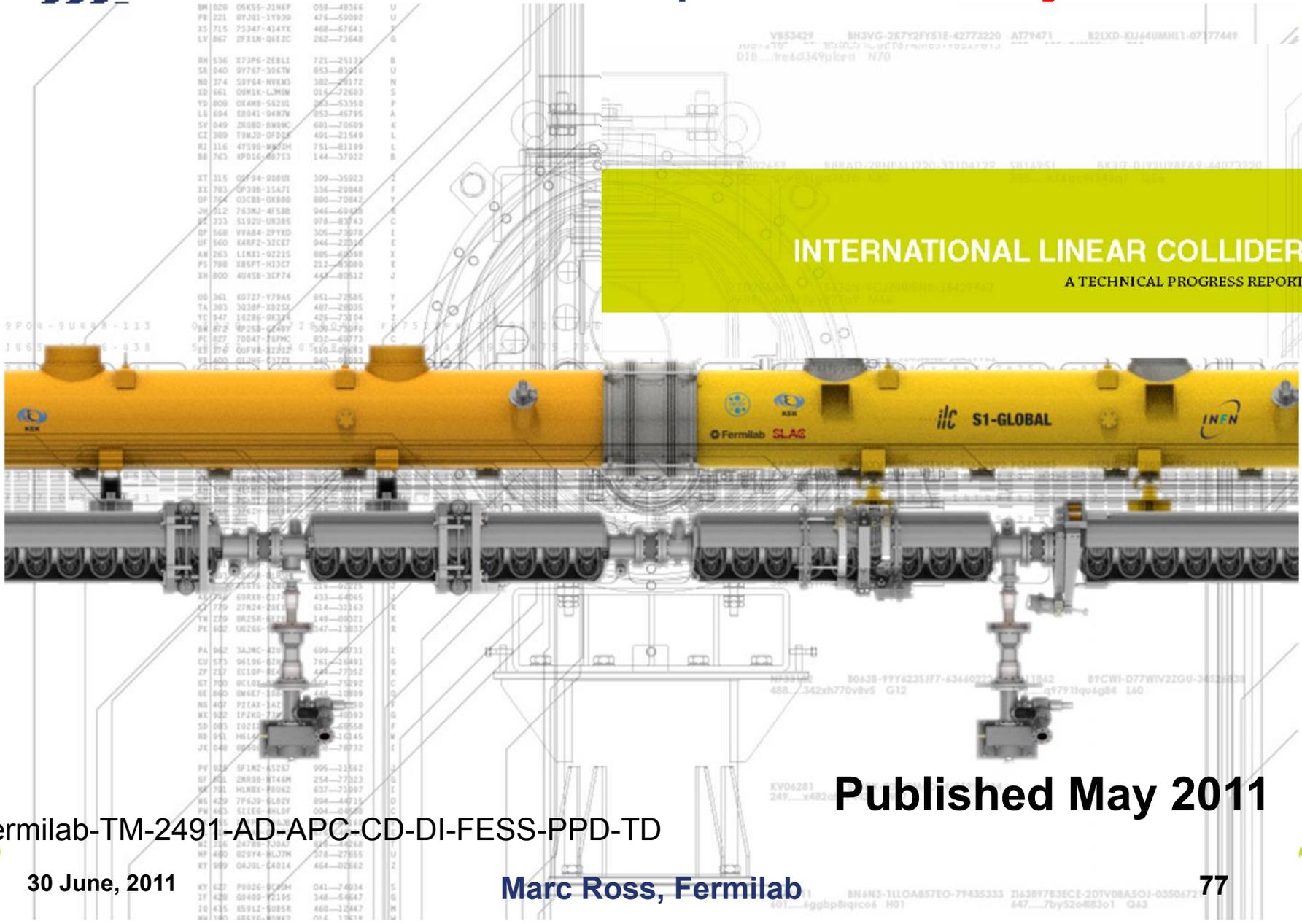
- **SCRF Systems tests; Mass production; Value Engineering, etc.**

- **Design evolution: 1 TeV; Positrons; R&D toward major technical advances**

- **Must preserve GDE-like global decision making and coordination in new pre-project organization**



# TDP Interim Report – 1/2 way done:



**INTERNATIONAL LINEAR COLLIDER**  
A TECHNICAL PROGRESS REPORT

Fermilab-TM-2491-AD-APC-CD-DI-FESS-PPD-TD

30 June, 2011

Marc Ross, Fermilab

**Published May 2011**

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# ILC Technical Design Phase:

- **RDR (2005-2007)**
  - had strong SLAC leadership
- **TDP R & D (2008 – 2012)**
  - Akira Yamamoto,
  - Jim Kerby, Tetsuo Shidara,
  - KEK, INFN, JLab and Fermilab team
- **Accelerator Design (2000 – 2012)**
  - Nick Walker and Accelerator System team
  - CFS: Vic Kuchler, Atsushi Enomoto, John Osborne