ILC S0 Strategy

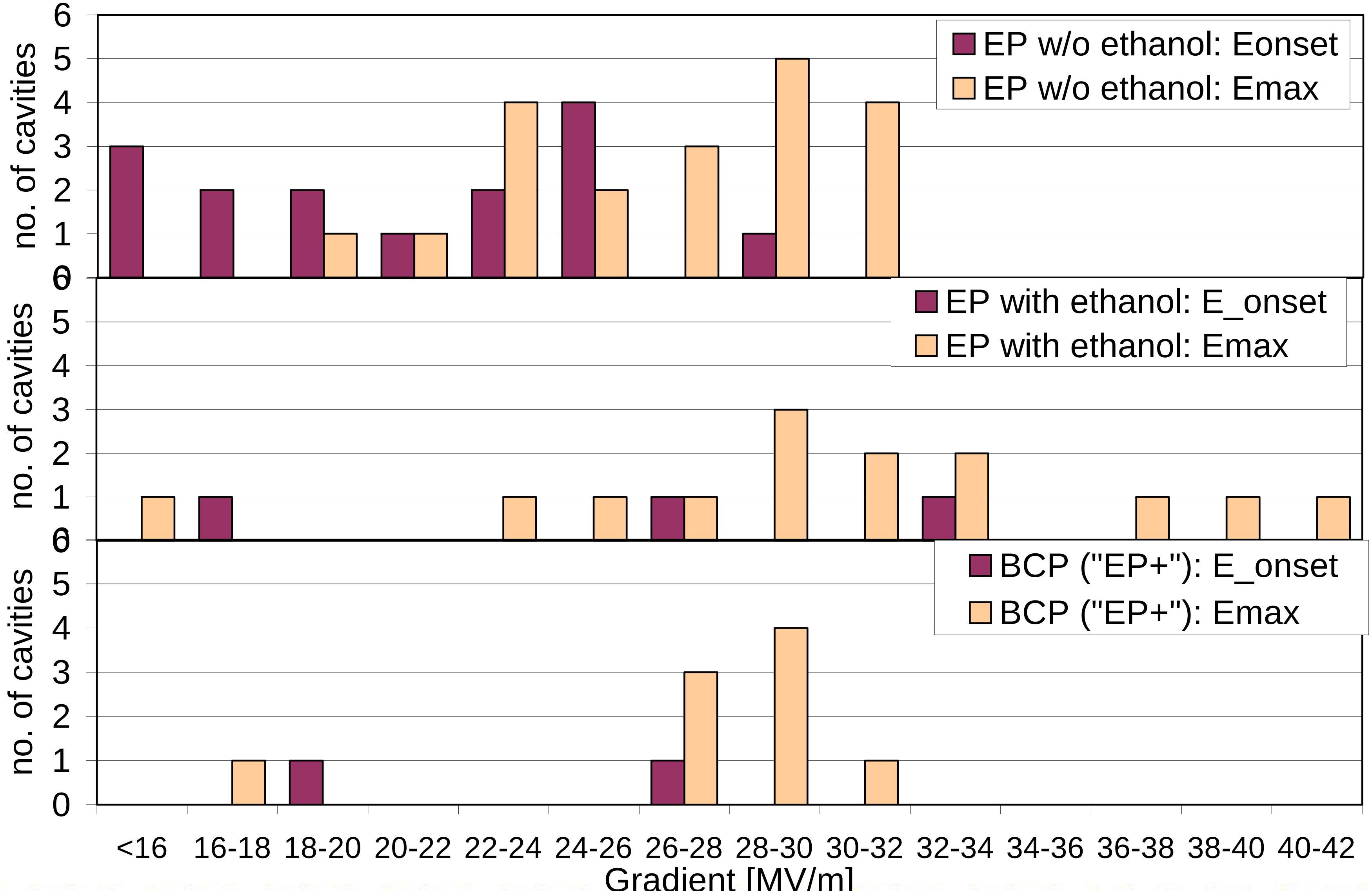
Proposal

FNAL 24.4.2008

S0 Status: High Gradients

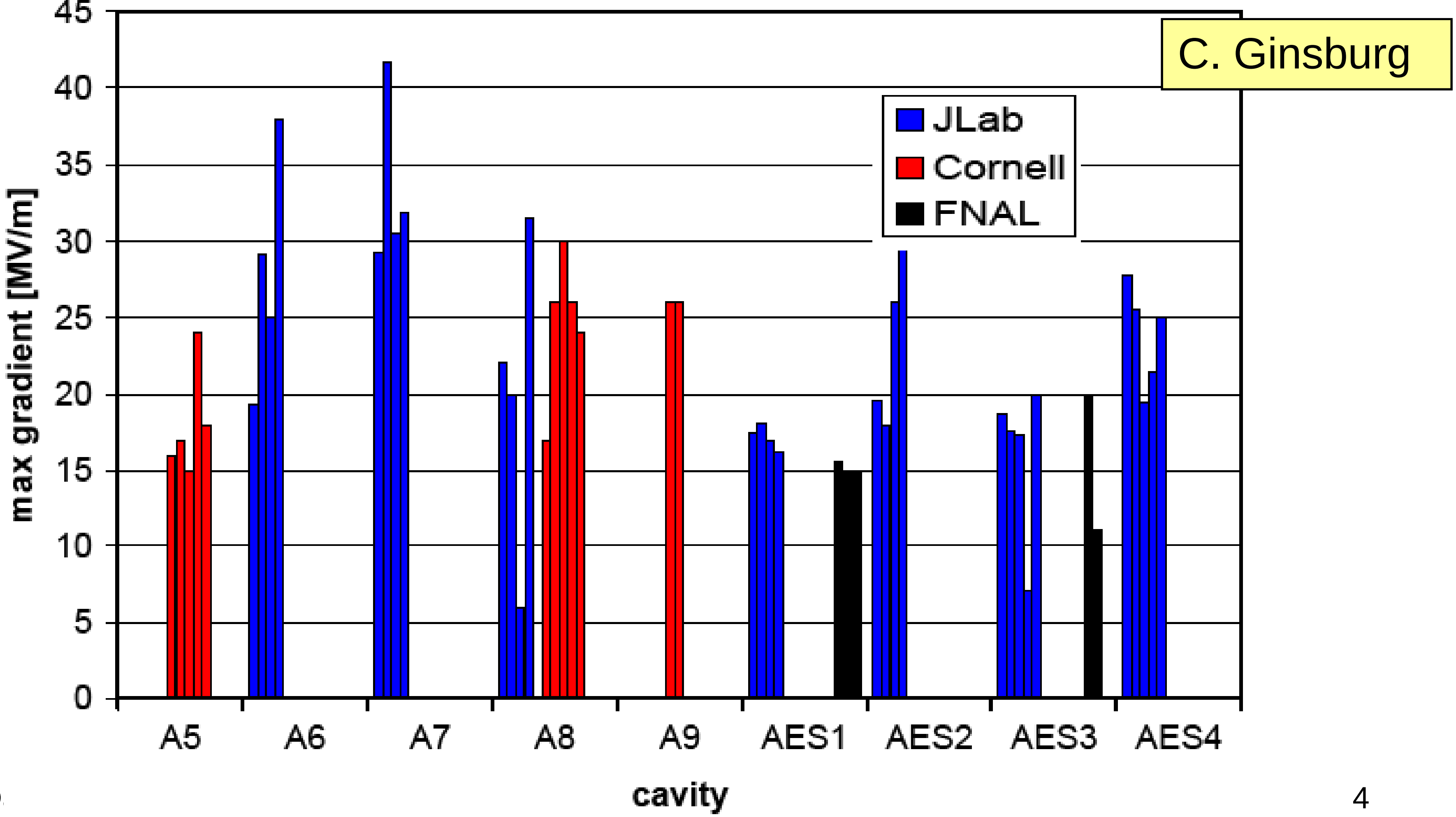
- Field emission has been reduced
  - **This is good news**
  - **Monitoring the three approaches (Ethanol, Ultrasound or Fresh EP) needed**
    - Is there a significant advantage of one over the other?
    - Data set for Fresh EP on multi-cells small
- Still rather large gradient differences are observed due to thermal breakdowns
  - **Needs improved understanding of the nature of these breakdowns**
    - E.g. some of the very low gradient breakdowns have been tracked to the equator region
    - At higher gradients this is not yet obvious
    - Need improved diagnostics
      - High-resolution temperature maps and high resolution optical inspection
  - **There is a broad consensus on this in the SCRF community**
    - See recent TTC Meeting at DESY
- In the following a program to attack this problem is proposed

DESY 4th: Field Emission Analysis



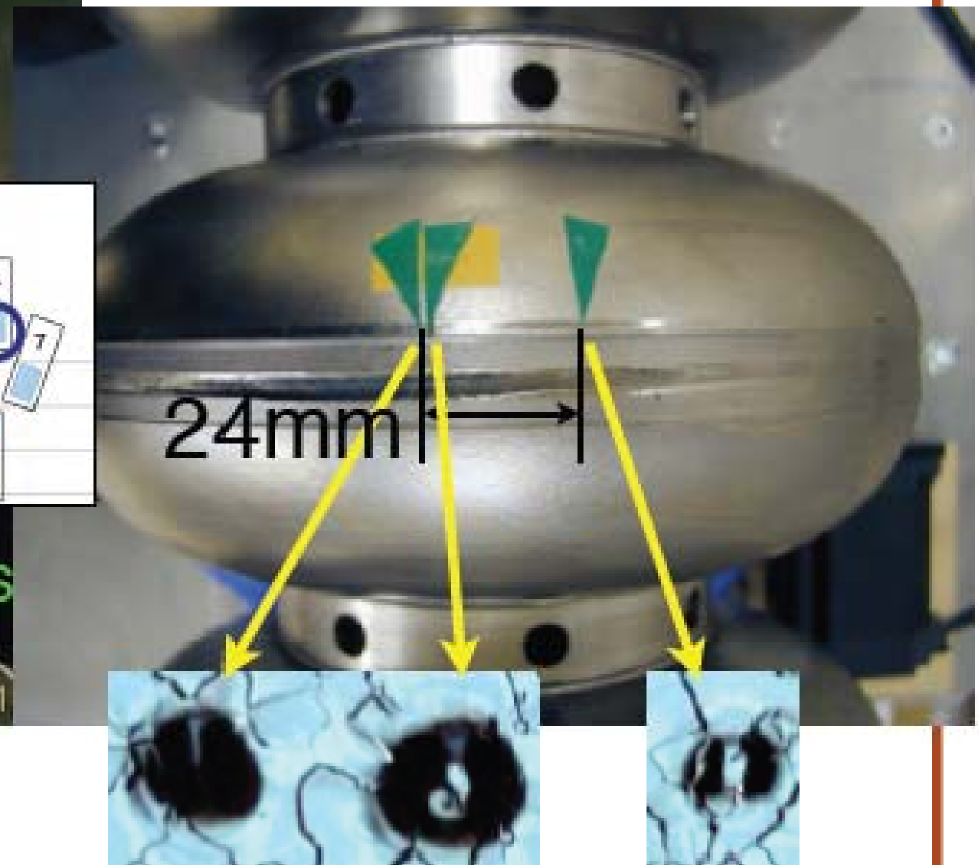
Summary of 9-cell (Tesla-style) Test Results

- >45 tests at JLab, Cornell and Fermilab
- Highest gradient in a test was 42 MV/m - A7, 2nd test of 4
- Four of the eight cavities made 31.5 MV/m at least once



Correlation with Thermometry

Dmitri A. Sergatskov: Thermometry on AES01 cavity at Fermilab
@webex20071204



Two hot spots@FNAL/JLAB

Three spots found@Kyoto

High Gradient R&D

H. Hayano

- step 1: research to find cause of low gradient

  for quench: high resolution camera

  for field emission: confirm what is the residuals on the surface (SEM, XPS)

  for Q-disease: confirm what is the diffused into the surface (XPS)

- step 2: develop countermeasure

  for quench: (remove beads & pits, material impurities & defect scan, …)

  for field emission: (ethanol rinse, degreaser rinse, sponge wipe, Ultra-sonic, HPR,...)

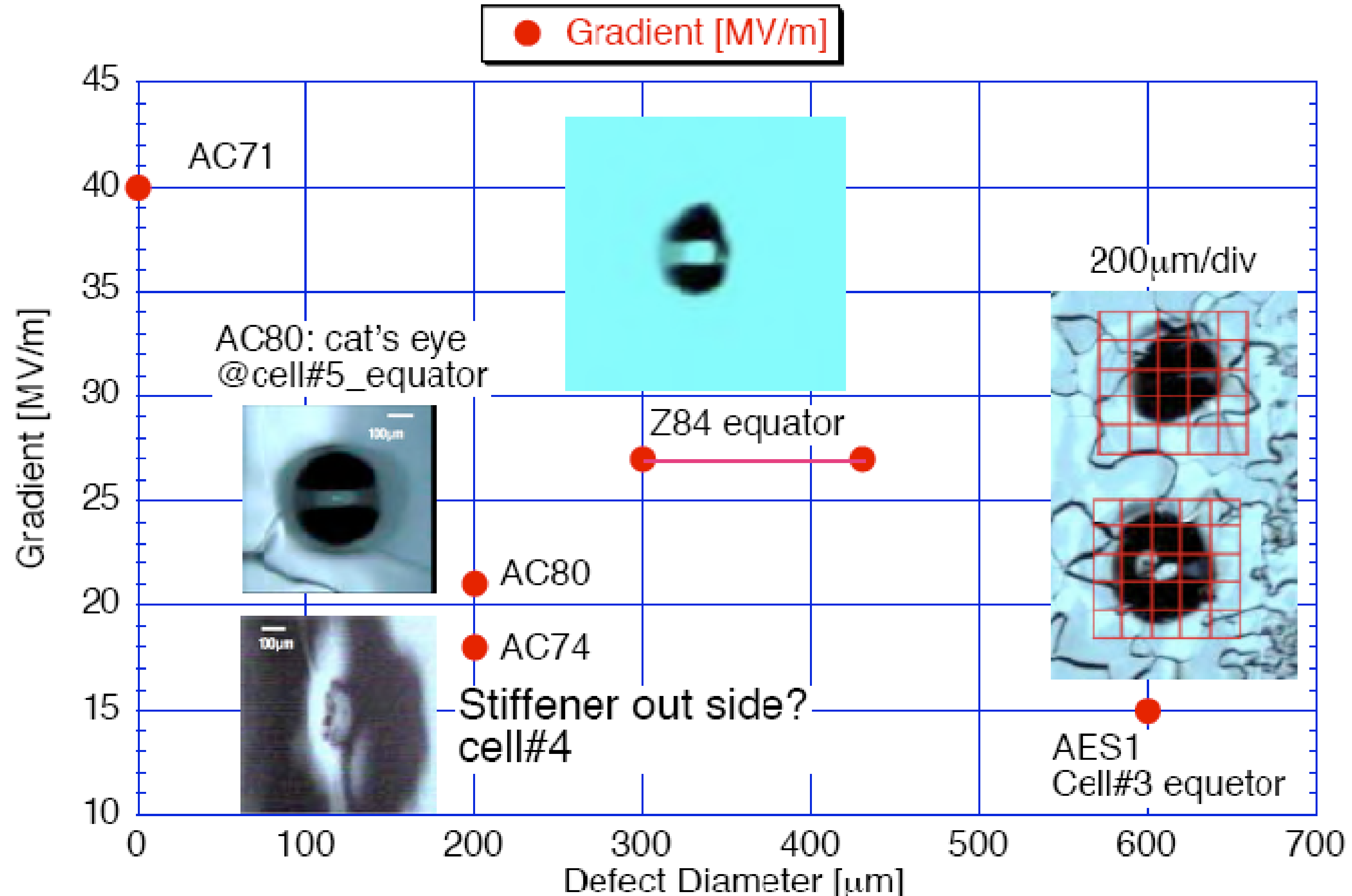
  for Q-disease: (baking, Argon baking, …)

- step 3: apply & verify countermeasure

  exchange problem cavities and apply the countermeasure

- step 4: evaluate statistics for the countermeasure

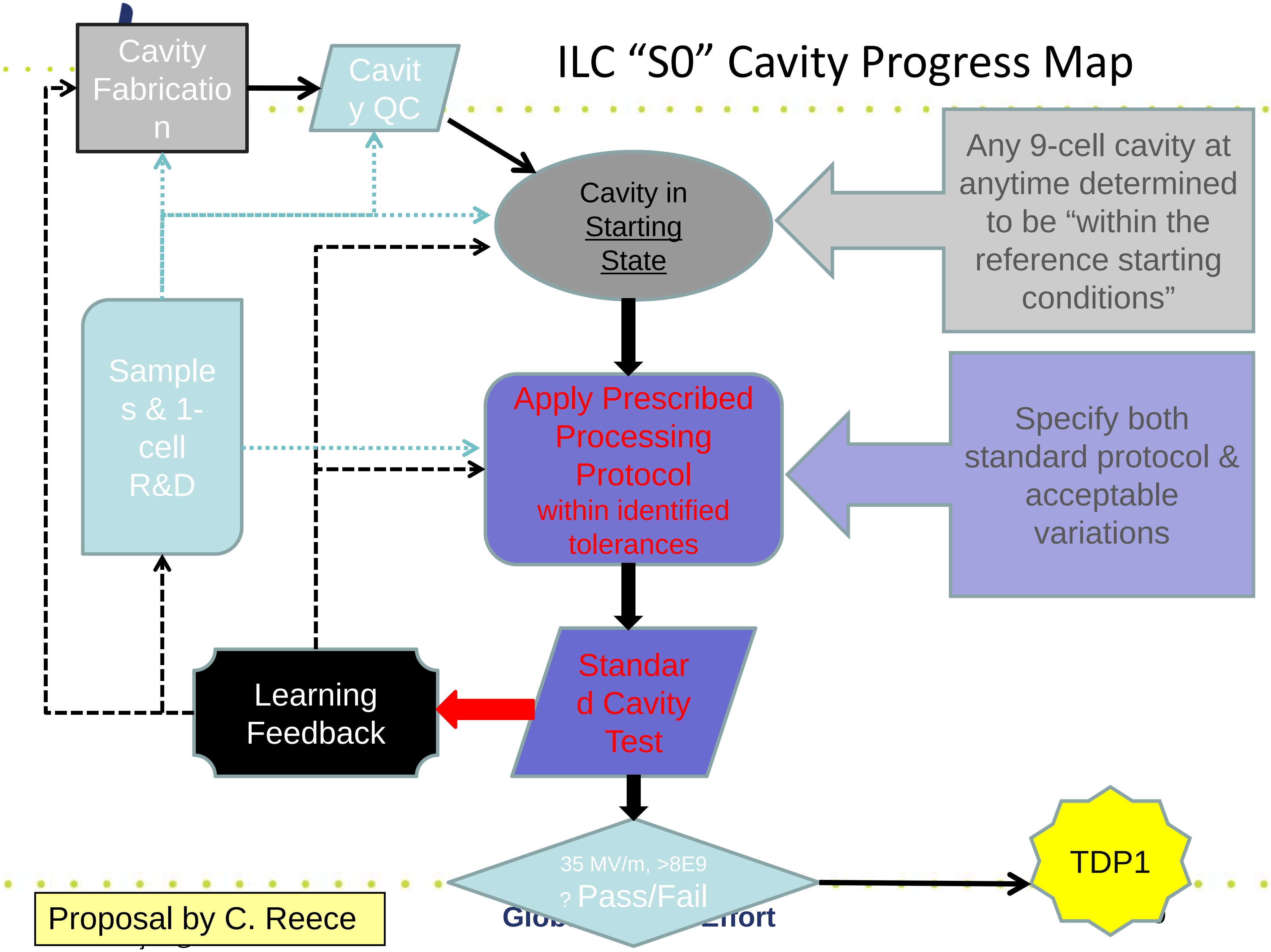
  install the countermeasure world-wide, get statistics world-wide.


Gradient [MV/m]
45
40
35
30
25
20
15
10
0
100
200
300
400
500
600
700
Defect Diameter [µm]
Gradient [MV/m]
AC71
AC80: cat's eye
@cell#5_equator
100µm
Z84 equator
200µm/div
AC80
AC74
Stiffener out side?
cell#4
AES1
Cell#3 equetor

S0 Program: Rationale

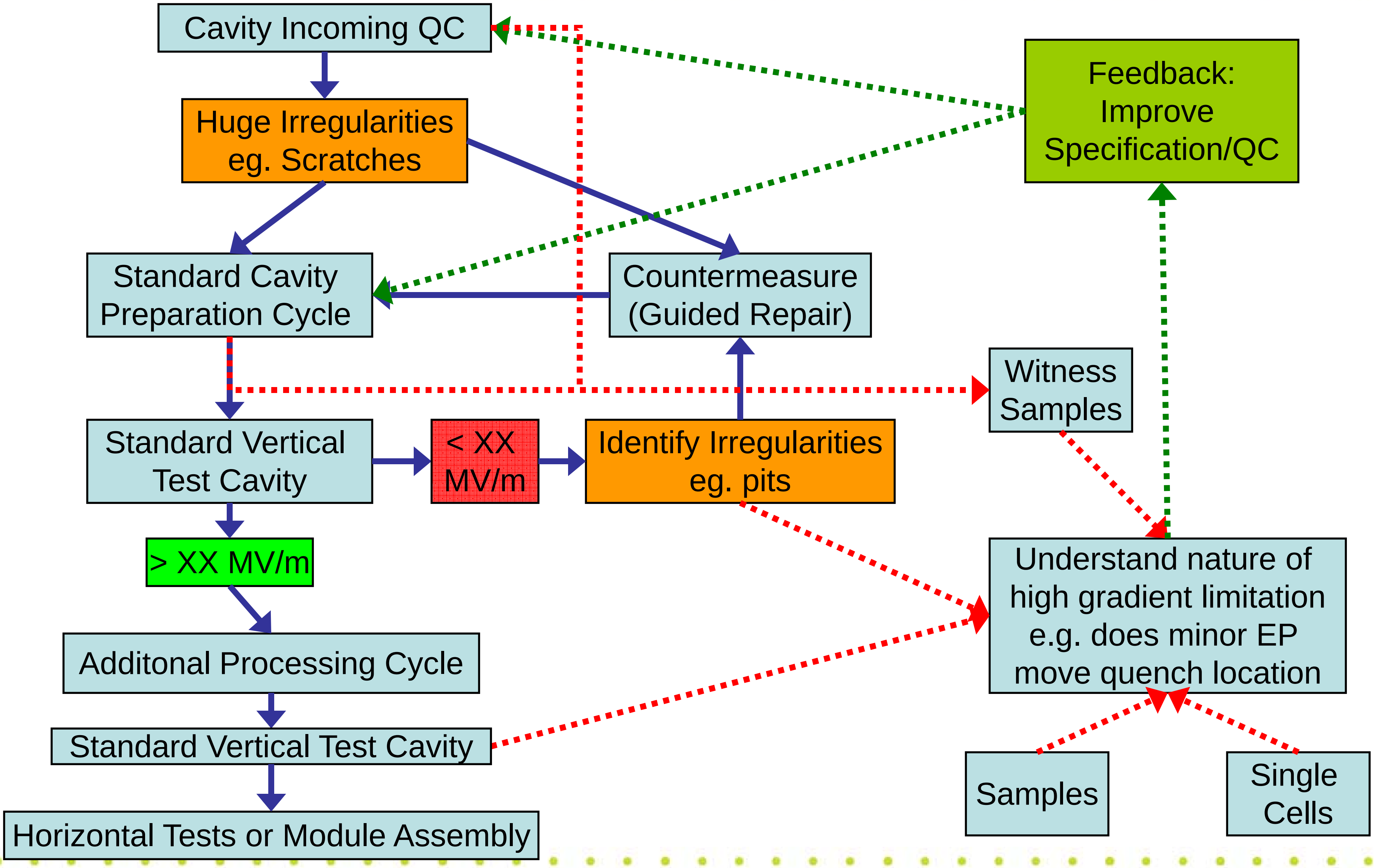
- Take a sample of cavities e.g. DESY 4th production
  - **May depend on manufacturer**
- Assume cavities below a threshold (<XX MV/m) have well identifiable defects (>50 um)
  - **This is substantiated by the initial results on AES cavities**
- Decision Point at threshold
  - **<XX MV/m**
    - Identify and remove defect
    - Retest
      - Demonstrate effectiveness of guided repair
    - 20 % of cavities go this way if estimate from DESY 4th production
  - **>XX MV/m**
    - need understand causes of cavity performance variability at high-gradient limit
    - Possible Hypotheses
      - Visible defects (with high-res optical inpsection), but smaller
      - contaminants from solvent/detergent rinse
    - ‘Process-test-reprocess-retest’ is required using thermometry
      - This was done e.g. with Ichiro 5

ILC "S0" Cavity Progress Map



Proposal by C. Reece

ILC S0 Feedback Loop



Definition of the Cavity Processing Cycle

- **Incoming cavity QC: Niobium material and cavity fabrication**
  - Optical inspection of as-received cavity.
  - Decision: Continue or Repair
- **Standard Processing Recipe**
  - Bulk electro-polishing of ~150 um.
  - Ultrasonic degreasing.
  - High-pressure rinsing.
  - QC : Optical inspection
  - Hydrogen degassing at 600 deg C.
  - Field-flatness tuning.
  - QC : Optical inspection
  - 20 um electro-polishing.
  - Ultrasonic degreasing.
  - High-pressure rinsing.
  - Assembly and vacuum leak testing.
  - 120 deg C bake.
- **Vertical dewar test.**
  - Decision: Optical inspection or send to module?
  - QC: Optical inspection

Definition of Standard Test

- Hold at ~100 K during cool down to check for Q disease.
- Q vs. T measurement during cool down.
- Q vs. E measurement on π mode. RF process as needed.
- Q vs. E measurement on all other modes. RF process as needed.
- Final Q vs. E measurement on π mode.
- Notes:
- All Q vs. E measurements to include radiation data logging.
- Utilize nine-cell temperature-mapping system if available.

- Diagnostic Techniques
  - Determine limiting cells based on mode measurements.
  - If nine-cell temperature-mapping was not employed, apply thermometry to limiting cells and retest.
  - Perform optical inspection of limiting cells.

Definition of Countermeasures

- Defect is identified, size is known
- Possible Countermeasures
  - **Local**
    - Grinding and/or etch
      - guided repair e.g. diamond proposed by Hayano
    - Re-weld
      - needs to be validated on samples first
  - **Full cavity**
    - Tumbling
      - better for defects in equator region
    - Full EP with sufficient removal
      - especially effective in iris region
    - Titanisation
      - very time consuming treatment
      - should be the last resort

Definition of a Single-Cell Program for S0

- Use a set of single-cells cavities to 'calibrate' the systems mentioned i.e. optical inspection and thermometry
- A detailed analysis of the results is needed
  - **Need to determine**
    - the distribution of defects (size, location, type) with optical inspection
    - the distribution of hotspots below maximum field
    - the quench location
    - final step could be the dissection of the cavity
- Check for correlation with the
  - **weld affected region e.g. overlap**
  - **grain boundary**
  - **grain size**
- Re-treatment of several cavities is needed to verify whether the breakdown locations are changing or are locally invariant
- Sample cavities to included
  - **Fine grain, welded**
  - **Large-grain (or single crystal), welded**
    - Compare EP and BCP
  - **Fine-grain seamless**
- Acknowledgdement:
  - **Some work has already started e.g on effects of grain boundaries**
  - **This should be encouraged and intensified**

Requirements for a Sample Program for S0

- The sample program should investigate
  - **Quality of the weld region**
    - check for voids
    - use as witness samples in fabrication
      - simulate procedures at companies
    - (RRR distribution: See DESY results W. Singer et al.)
  - **Improvements of weld quality**
    - EP of weld regions before EBW
  - **Sample holder cavity**
    - Witness samples from preparation process
- Use all available surface inspection methods...
- Acknowledgdement:
  - **Some work has already started e.g on residues from preparation processes**
  - **This should be encouraged and intensified**

Choice of the Threshold Gradient XX MV/m

- Repair and testing cycles are likely resource limited
  - **Some repair methods not yet available**
  - **Overall resource issues**
- Proposal:
  - **Test of a set of cavities**
  - **Subset of ~20% low-performing cavities will be repaired**
    - Demonstrate the effectiveness
    - Gradient should at least reach the average of the 80% of the cavitiy set
- The threshold should therefore increase over time and is measure of the success of the program

Cavity and Test Options for 2008/2009

- DESY
  - **Cavities**
    - 10 (+8) with pure EP cycle
      - Only partially with T-maps, tank-welded
    - 8 LG cavities
  - **Tests: According to the number of cavities**
- US
  - **Cavities**
    - 20 ACCEL
    - 6 AES
    - 2 JLab
  - **Tests: 54 test cycles total (FY09)**
- KEK
  - **Cavities**
    - 2 Cavities TESLA-like ready for preparation now
    - 3-5 Cavities TESLA-like ready for preparation end march 09
    - 4 LL-Caviities ready for preparation now
      - 2 w/o HOM
      - 2 with HOM
  - **Tests: ~24 test cycles**

M. Champion

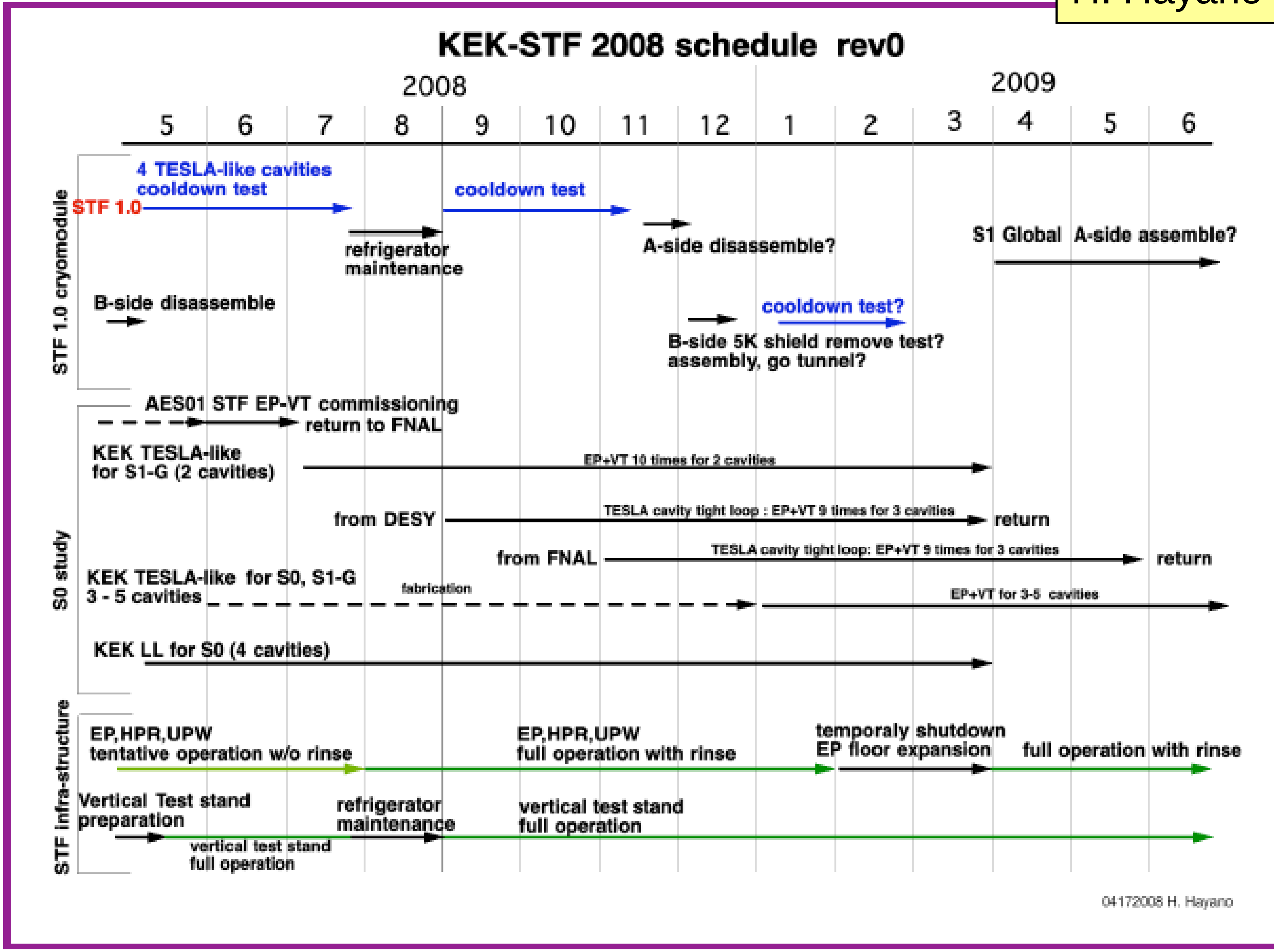
ILC Cavity Inventory

Fermilab

Cavity Inventory

	A	B	C	D
1	**ILC Tesla-shape nine-cell cavities**			
2	**Description**	**No. Cavities**	**Status**	**Location**
3	AES 1-4	4	tested	AES1 at KEK; AES3 at FNAL; AES2,4 at Jlab
4	AES 5-10	6	due May 2008	
5	Accel 5-9	5	tested	Acc7 at ANL; Acc6,8 at Jlab; Acc5,9 at Cornell
6	Accel 10-17	8	received Mar 2008	at FNAL
7	Accel 18-29	12	due Sep 2008	
8	Jlab fine-grain prototype	1	tested	at Jlab
9	Jlab large-grain 1-2	2	tested	at Jlab
10	Jlab fine-grain 1-2	2	fabrication incomplete	at Jlab
11	TBD - 10 cavity FY09 order	10	will order in FY09	
12				
13	Total	50		
14	Already Received	20		
15				
16				
17				
18				
19	**ILC Tesla-shape single-cell cavities**			
20	**Description**	**No. Cavities**	**Status**	**Location**
21	AES 1-6	6	tested at Cornell	one at Jlab, two at FNAL, three at Cornell
22	Accel 1-5	6	due Sep 2008	
23	Roark 1-3	3	due Apr 2008	
24	Niowave 1-3	3	due Apr 2008	
25				
26	Total	18		
27	Already Received	6		

H. Hayano



KEK-STF 2008 schedule rev0
2008
2009
5 6 7 8 9 10 11 12 1 2 3 4 5 6
STF 1.0 cryomodule
STF 1.0
4 TESLA-like cavities
cooldown test
cooldown test
refrigerator
maintenance
A-side disassemble?
S1 Global A-side assemble?
B-side disassemble
cooldown test?
B-side 5K shield remove test?
assembly, go tunnel?
S0 study
AES01 STF EP-VT commissioning
return to FNAL
KEK TESLA-like
for S1-G (2 cavities)
EP+VT 10 times for 2 cavities
from DESY
TESLA cavity tight loop : EP+VT 9 times for 3 cavities
return
from FNAL
TESLA cavity tight loop: EP+VT 9 times for 3 cavities
return
KEK TESLA-like for S0, S1-G
3 - 5 cavities
fabrication
EP+VT for 3-5 cavities
KEK LL for S0 (4 cavities)
STF infra-structure
EP,HPR,UPW
tentative operation w/o rinse
EP,HPR,UPW
full operation with rinse
temporaly shutdown
EP floor expansion
full operation with rinse
Vertical Test stand
preparation
vertical test stand
full operation
refrigerator
maintenance
vertical test stand
full operation
04172008 H. Hayano

Cavity Programs beyond S0

- Programs with great importance which need to be funded are
  - **Large-grain material**
  - **Vendor qualification**
- Both Programs are extending beyond the initial scope of S0
  - **too limited capacity/funding to incorporate in S0 funding**
- Tax on standard program for near term and long term R&D items
  - **10 % near-term**
    - large-grain and vendor qualification
  - **5 % long-term**

Conclusion

- After reduction of field emission additional diagnostics methods need to be applied systematically
  - **High-resolution optical inspection and temperature-mapping have shown very encouraging results**
- A plan has been developed to implement a feedback loop into the cavity production cycle
  - **Loop is designed to generate understanding of nature of defects**
    - E.g. origin and relevance of defects by optical inspection
    - Need more data to substantiate results from Kyoto
  - **Supporting single-cell and sample program**
  - **Standard test definition will allow to compare data across labs**

BACKUP

Definition of a data set for TDP1

- Proposals from Discussion
  - **Take all cavities**
  - **Take only selected vendor**
  - **After successful optical inspection counting of cavities does start**
  - **Remove accidents, leaks etc. from data set**
- In all cases allow 20 % retreatment of cavities
    - What does re-treatment mean?
    - Is repair allowed?
- How many cavities will be left?

Basic understanding

- Tools
  - **Samples**
      - Do we see the defects similar to those in cavity on samples?
      - Do we see the chemical contaminations similar to those in cavity on samples?
    - Dummy or ‚button‘ cavity with demountable samples
    - polish samples in main coupler port
      - QC of nine-cells
  - **Single-cells**
  - **(Other fabrication techniques)**
  - **Understanding nature of defects by anodisation**
    - e.g Foreign material inclusions
  - **Guided repair to demonstrate understanding**
    - see talk be H. Hayano
    - crosscheck applicability of methods with soft niobium
- Method
  - **variation of fabrication and preparation parameters**
    - on purpose or by chance
    - e.g. single-crystal cavities compared to fine-grain
      - find quench location is there a distinction

Training of companies

- Necessity in all regions
  - **Fabrication**
    - Is this a quality control issue? At least partially
    - Need to understand whether the defects (balls or pits are related to EBW process)
  - **Preparation**
    - XFEL goes first
    - ILC has probably more time with this part

- Certainly one source of variability
  - **e.g. DESY 4th production**

- Plays a role in the selection of the data set for the TDP 1+2 data sets

- Check vendor qualification criteria
  - **Well enough defined?**

- Is this a generic SRF issue?

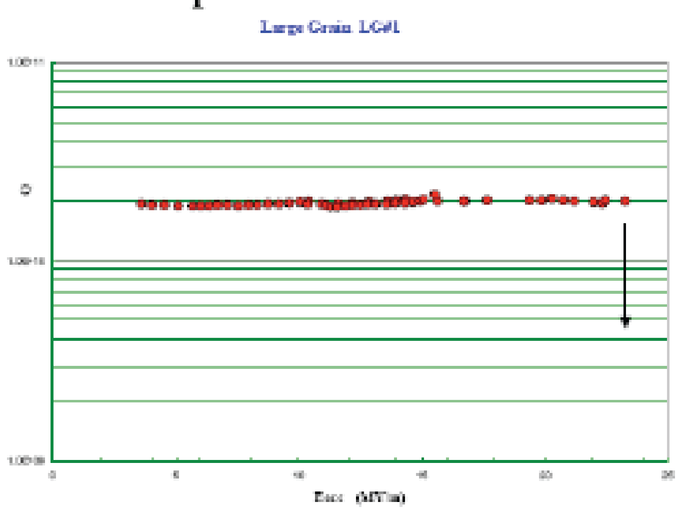
Handling of alternatives

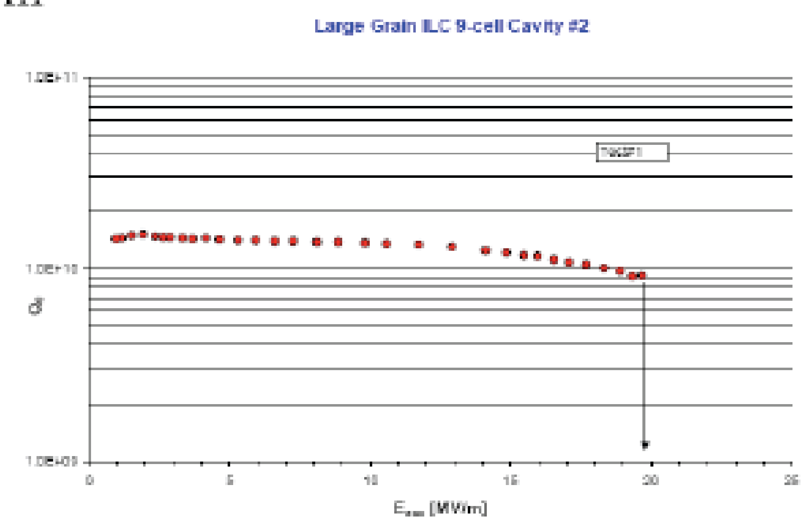
- Some proposals
  - **are advanced R&D where it is unclear whether they pay off**
  - **are beyond of the high-gradient scope e.g. cost reduction**
- These should be supported from the generic SRF fund!
- If funding is limited to High-Gradient work a priorization needed
  - **Suggested criteria**
    - Near-term, Long-term
    - Integration in international context

9-cell Cavity performance(Jlab)

Large Grain

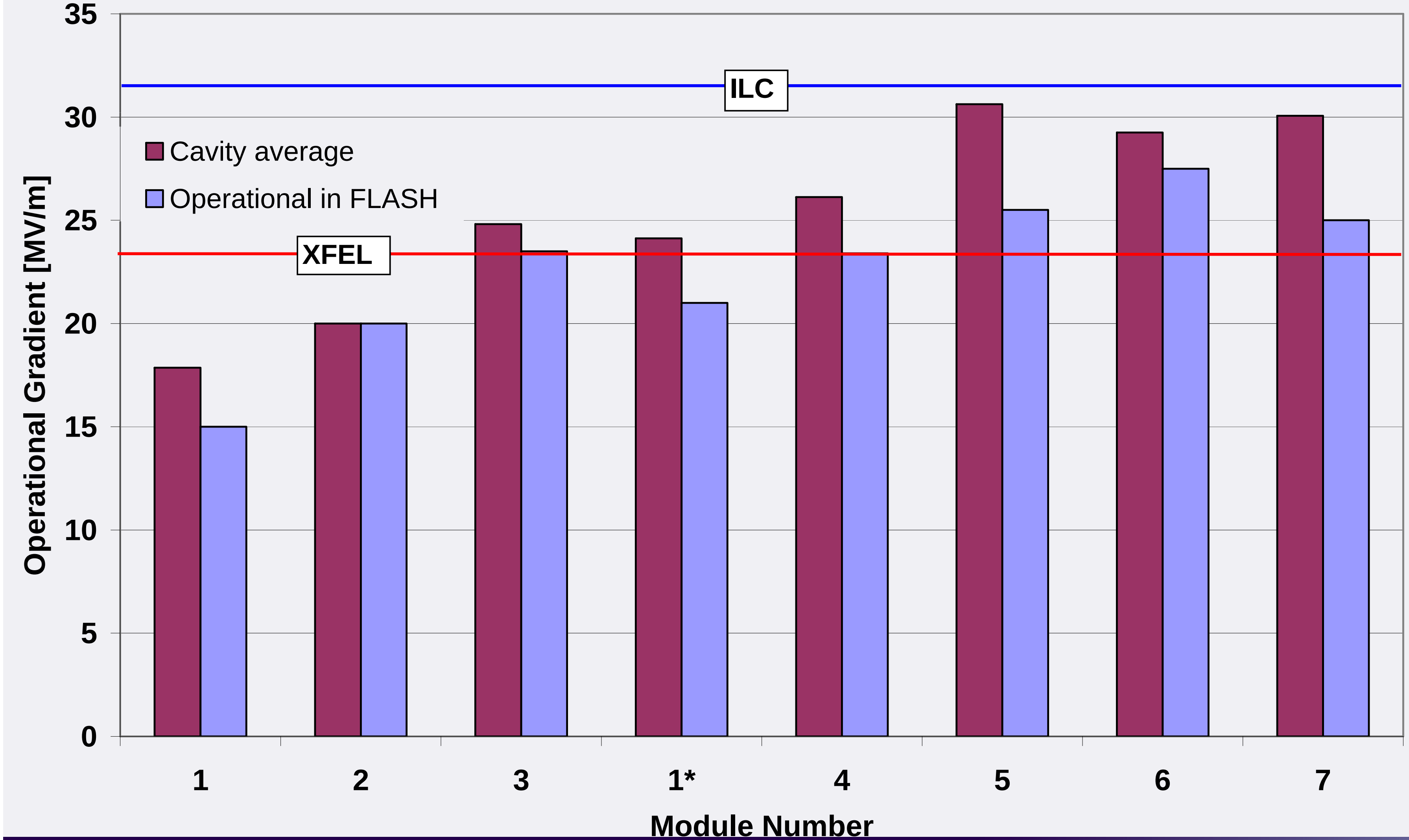
- Two 9-cell cavities (LG#1,LG#2) were fabricated at Jlab from large grain CBMM niobium (ingot"D"); several holes during EBW in both cavities
- Standard processing:pre-tuning, 100 micron bcp,hydrogen degassing at 600C for 10 hrs,final tuning, final bcp
- LG #1 received only ~ 40 micron, LG#2 ~ 57 micron bcp in final bcp
- LG#1: quench at Eacc = 23 MV/m,
- LG#2: quench at Eacc = 20 MV/m



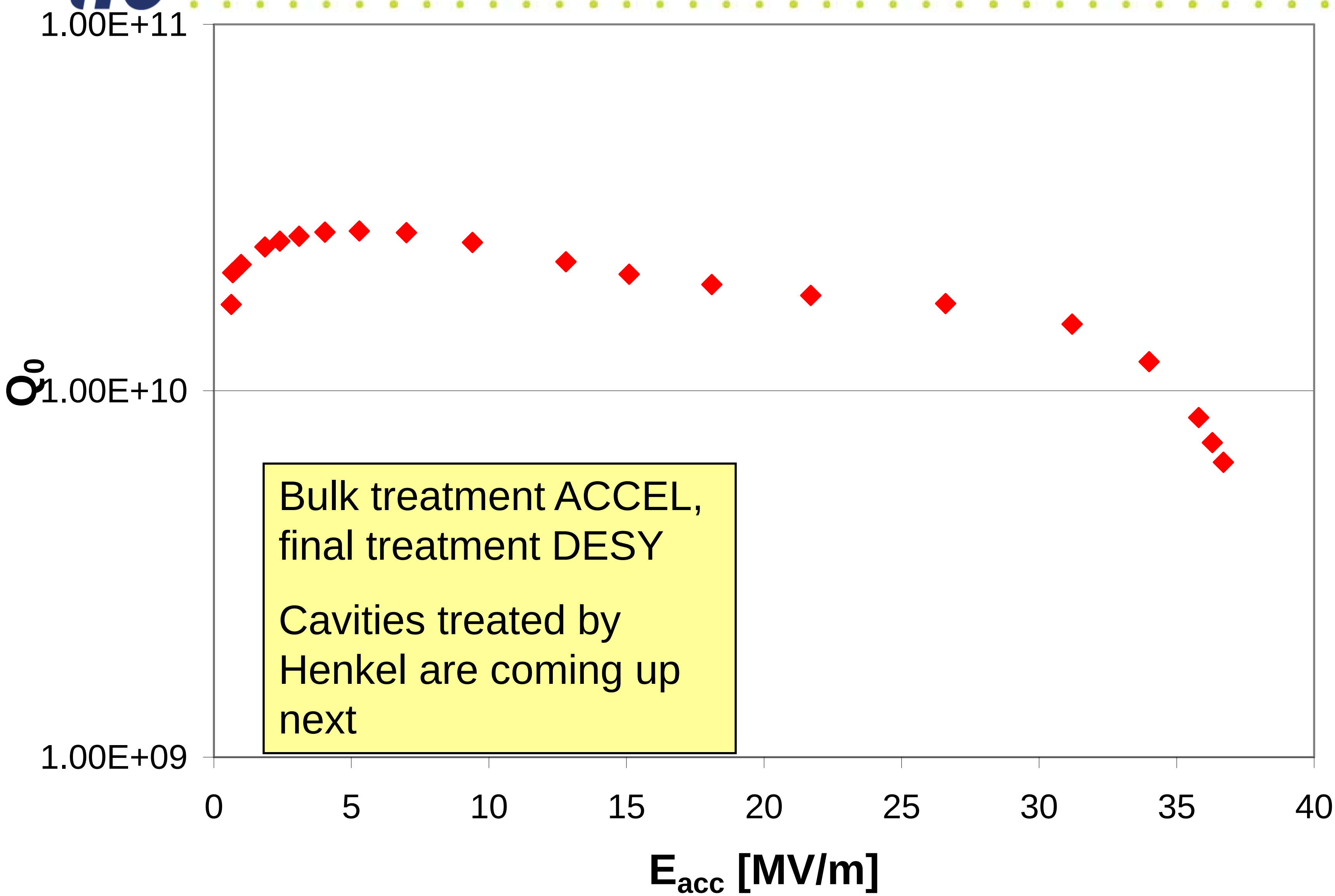


October 15-19, 2007 SRF 2007 40

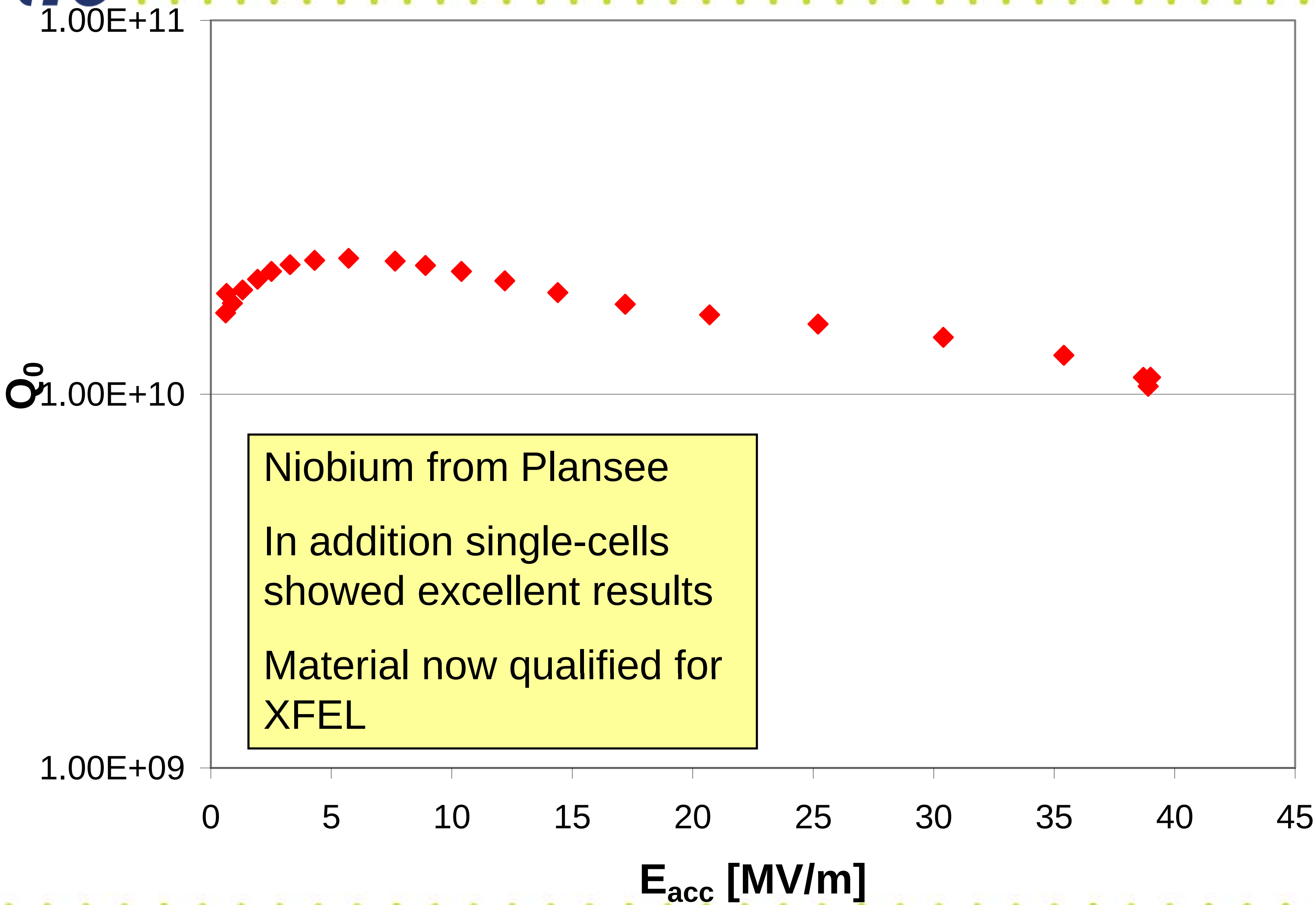
XFEL: Accelerator Module Performance



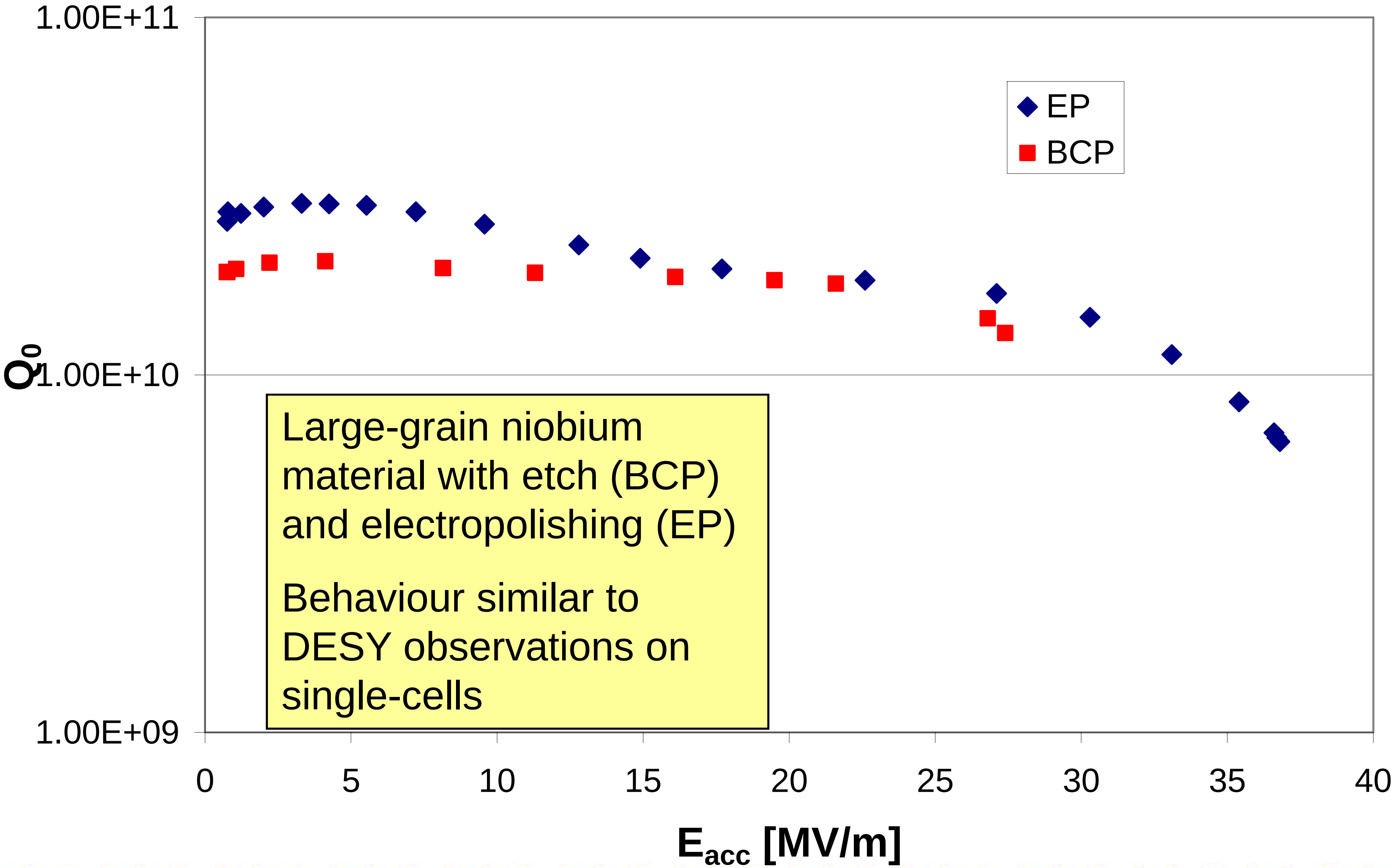
XFEL Industry EP on Multi-cells



XFEL Qualification of Niobium Vendors: Nine-cell of Plansee Material



XFEL: Large Grain Multi-cell with EP



Large-grain niobium material with etch (BCP) and electropolishing (EP)

Behaviour similar to DESY observations on single-cells

Status of Re-Planning

- Address variability in gradients with improving on diagnostics
  - **Add temperature mapping capacity to labs who have no capabilities yet**
  - **Add high-resolution inspection**
  - **Monitor on-going effort with best preparation methods**
- Less resources, stretch timeline to 2012
- International 'proof-of-principle' module
- Next:
  - **FNAL Meeting 21-25th of April**

Replan of ILC-SCRF R&D

updated, March 4, 2008

- **TDP1 by 2010:**
  - **S0:** achieve 35 MV/m with 9-cell cavities at the yield 50 % under well defined processing-base,
  - **S1-Global:** achieve <31.5 MV/m> with cryomodule-assembly
    - with global cooperation (for example, 4-AS, 2-US, 2-EU).
    - Note: the S1 achievable also, if 3 Tesla-type cavities added to the existing 5 cavities in CM2 at Fermilab.
  - **Cryomodule design:** establish "plug-compatible interface and design
- **TDP2-by 2012:**
  - **S0:** achieve 35 MV/m with 9-cell cavities at the yield 90 % under well defined processing-base.
  - **S1:** achieve <31.5 MV/m> with full cavity-assembly (similarly processed) in single cryomodule, CM3 or CM4 (at Fermilab, US)
  - **S2:** achieved <31.5 MV/m> with 3 cryomodule assembly to be powered by 1 RF unit, and with beam acceleration, in STF-2 at KEK.
  - **Industrialization:** Learn from XFEL, & Cooperation with Project-X

Global Plan proposed

		CY08		CY10		CY12
EDR	TDP1				TDP-II	
S0: Cavity Gradient (MV/m)	30					35 (>90%)
KEK-STF-0.5a: 1 Tesla-like						
KEK-STF-0.5b: 1 LL						
KEK-STF1: 4 cavities						
S1-Global (AS-US-EU) 1 CM (4+2+2 cavities)			CM ($4_{AS}+2_{US}+2_{EU}$) <31.5 MV/m>			
S2 & STF2: One RF unit & 3 CM with beam		design	Fabrication in industries		Assembled and test at STF	
S1-Fermilab/US ILC-CM-3 or -4		CM1	CM2	CM3(Type-IV)	CM4	

Cryomodule Design
with plug-compatible components

	Cost fraction
• **CM with modular sub-assemblies**	Cost fraction
– Cavity unit (cavity + helium vessel + tuner)	64%
– Coupler	12%
– Quad package (quad + corrector)	4%
– BPM	2%
– Cold-mass (cold-piping)	x/19%
– Vacuum vessel	y/19%

- **Plug-compatible, Interface specifications (IS)**
  - To be generally agreed at Fermilab meeting, in April, 2008

- **Plug-compatible IS** enables parallel development, afterwards, during the TDP phases,