Plans for Gradient R&D and Cavity Processing and Testing in the Americas Region in FY08-09

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Basis for FY08-09 Planning in the Americas Region

- US FY08 budget signed in December 2007
  - ILC and SRF budgets reduced to 25% of FY08 plan effectively halting S0 work in US
  - The S0 program – funded through Fermilab – was under spent, so work is proceeding with reduced scope (to be described)
  - Meanwhile, US-Japan funds were used to support processing and testing of Ichiro-5 at Jefferson Lab
- US FY09 budget proposal
  - $35M for ILC; $25M for SRF (check this)
  - $3M from the ILC funds budgeted for S0 work
- Guidance from ART Director Mike Harrison
  - $1.825M Jefferson Lab
  - $674k Cornell
  - $500k Argonne/Fermilab
- Charge: create an integrated plan for the remainder of FY08 and for FY09 based on this guidance and the program goals

ILC GDE SRF Program Goals

TDP1: technical feasibility by 2010

- Gradient (S0) to reach 35 MV/m with 50% yield
- One cryomodule (S1) to achieve average gradient of 31.5 MV/m
- Proof-of-Principle and System Engineering
- Cryomodule design with plug-compatible components

TDP2: technical credibility by 2012

- Gradient (S0) to reach 35 MV/m with 90 % yield
- One-RF unit (three cryomodules) operating with beam (S2)

The Americas Region FY08-09 plan supports these goals

  - it is part of a global program and needs to be well-coordinated with respect to the European and Asian work plans

S0 Planning in the Americas

Fermilab

Organization

- **GDE leadership from Lutz Lilje**
- **Americas Region Team Leaders**
  - **Mark Champion – Fermilab**
  - **Mike Harrison – Brookhaven – ART Director**
  - **Mike Kelly – Argonne**
  - **Hasan Padamsee – Cornell**
  - **Bob Rimmer – Jefferson Lab**

FY08 activities are funding limited

- **Approximately $1M remaining as of mid April**

FY09 proposed budget is $3M

FY08 Details

The primary goals for the remainder of FY08 are to:

- Process and test 8 new Accel cavities received in March 2008.
- Complete and commission the Argonne cavity processing facility.
- Acquire Kyoto/KEK-style optical inspection systems at Fermilab and Jefferson Lab (depends on support from US-Japan funds).

Argonne/Fermilab

- Complete and commission the Argonne cavity processing facility.
- Electro-polish Accel-7 to qualify nine-cell EP process.
- Process and test 2-3 new nine-cell cavities.
- Process and test a few single-cell cavities.
- Acquire industrialized Kyoto/KEK optical inspection system.
- Commission the single-cell T-mapping system.

Cornell

- Carry out final EP and test for 2-3 new nine-cell cavities with bulk EP, hydrogen degassing and tuning done at Argonne/Fermilab.

Jefferson Lab

- Test Accel-7 following EP at Argonne.
- Process and test 3-4 new nine-cell cavities.
- Utilize "2 of 9" temperature mapping system and optical inspection system to localize defects.
- Acquire industrialized Kyoto/KEK optical inspection system.
- Complete the fabrication of two nine-cell fine-grain cavities.

FY09 Plan – Cavities and Goals

- At the beginning of FY09, all existing nine-cell cavity orders will be fulfilled
  - 20 new cavities from Accel
    - 8 of the 20 Accel cavities were received in March 2008
  - 6 new cavities from AES
  - 2 new cavities from Jefferson Lab
- The primary goals for FY09 are to:
  - Process and test 20 new Accel, AES and Jefferson Lab cavities.
  - Improve the understanding of gradient limits in nine-cell cavities through the application of temperature-mapping and optical inspection.
  - Improve the understanding of gradient limits via a single-cell R&D program.

ILC Cavity Inventory

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 1-6	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		

Elements of FY09 Plan

- Reduce emphasis on "tight-loop" processing of nine-cell cavities
- Increase emphasis on understanding high-gradient (>25 MV/m) limitations
- Improve understanding of thermal breakdown
  - Utilize temperature (T) mapping and optical inspection
  - Complete nine-cell Fermilab and Cornell T-mapping systems
  - Utilize recently completed "2 of 9" Jefferson Lab T-mapping system
- Improve understanding of the role of sulfur
  - Compare ethanol rinse and ultrasonic rinsing
  - Perform "Flash EP" on nine-cell and single-cell cavities
- Improve understanding of large-grain cavity performance and possible cost advantages
- Investigate advantages of tumbling for bulk removal and/or elimination of defects
  - For example, repair of AES1&3, in collaboration with KEK
- Process and test all new Accel, AES and Jefferson Lab nine-cell cavities
- Procure 10 new nine-cell cavities from industry (funded from SRF, not ILC)

Single-Cell R&D Plans

Reproducibility Studies (degreasing vs. ethanol)

- Select a qualified fine-grain cavity (>25 MV/m with standard BCP processing, >30 MV/m with standard EP processing). If no qualified cavity is available, then cavity qualification becomes part of this experiment.
- Perform bulk EP if not already done.
- Perform 4 cycles of electro-polishing of ~10-20 microns following the standard recipe of processing and testing (ultrasonic degreasing following electro-polish).
- Perform 4 cycles of electro-polishing of ~10-20 microns. Supplement ultrasonic degreasing with ethanol rinsing.
- Compare performance and spread.

Flash-EP Studies (a.k.a. Micro-EP)

- Select a qualified fine-grain cavity (>25 MV/m with standard BCP processing, >30 MV/m with standard EP processing). If no qualified cavity is available, then cavity qualification becomes part of this experiment.
- Perform bulk EP if not already done.
- Perform 4 cycles of Flash-EP followed by either standard degreasing and/or ethanol rinse.
- Compare performance and spread.

Note: utilize temperature mapping in all tests if possible.

Single-Cell R&D Plans

Large-Grain and Single-Crystal Studies

- Fabricate and test large-grain and single-crystal cavities.
- Perform BCP processing and test with temperature mapping.
- Compare performance to fine-grain EP results.

Facility and Diagnostics Commissioning

- Process cavities at Argonne (EP or BCP) followed by testing at Fermilab to qualify facilities. Follow standard recipe.
- Commission Fermilab single-cell temperature-mapping system.
- Commission Fermilab single-cell VTS (A0 facility).

Materials Quality Control Studies

- Fabricate single-cell cavities using niobium sheets deemed "risky" based on eddy-current scanning.
- Process and test these cavities using standard recipe and temperature mapping.
- Study correlation between defects and performance.

Alternative Surface Processing Studies

- Perform studies of the effectiveness of surface processing techniques such as plasma cleaning, dry ice cleaning, oxi-polishing, conformal layers, etc.

FY09 Plan Details

Argonne/Fermilab

- Process and test 5 new nine-cell cavities.
- Perform bulk EP, hydrogen degassing, and tuning on 3 new nine-cell cavities in collaboration with JLab.
- Perform single-cell processing and testing.
- Complete and commission the nine-cell temperature-mapping system.

Cornell

- Process and test 3 new nine-cell cavities (bulk EP, hydrogen degassing and tuning at Argonne/Fermilab).
- Test effect of Flash-EP on gradient spread for 9-cells in collaboration with JLab.
- Design, fabricate and commission 9-cell temperature-mapping system.
- Perform single-cell processing and testing.
- Utilize 2nd-sound and make improvements to system.

Jefferson Lab

- Process and test 12 new nine-cell cavities.
- Test Flash-EP cavities from Cornell and JLab large-grain nine-cell cavities (4+4).
- Perform single-cell processing and testing.
- Perform flat-sample studies.
- Perform cooling upgrade on EP system.
- And a few more items detailed on next slide.

FY09 Budget Details (Request Exceeds Guidance)

Argonne	# cycles	cost/cycle k$	cost k$	Notes
9-cell EP	20.0	15.0	300.0	5 new cavities, 3-4 cycles each
Bulk EP for Cornell	3.0	15.0	45.0	3 new cavities, 1 cycle each
Single-cell EP	10.0	6.0	60.0	
Processing facility maintenance			46.0	
Total			**451.0**	
Fermilab				
9-cell test cycles	15.0	15.0	225.0	5 new cavities, 2-3 cycles each
Single-cell test cycles	10.0	15.0	150.0	
Complete 9-cell T-Map			75.0	
Total			**450.0**	
Cornell				
9-cell process and test cycles (new cavities)	9.0		384.0	3 new cavities, 2-3 cycles each
Single-cell process & test	15.0	6.9	104.0	
Flash-EP cycles (no test)	4.0	10.0	40.0	
Design, Fab & Commission 9-cell T-Map			64.0	
2nd-sound development			32.0	
management & travel			50.0	
Total			**674.0**	
Jefferson Lab				
9-cell process and test cycles				
fine grain EP + maintenance	30.0	30.0	1000.0	12 new cavities, 2-3 cycles each
Cornell Micro-EP & Jlab large-grain tests	8.0		50.0	($6.25k/cycle)
Single-cell process & test	25.0		150.0	($6k/cycle)
EP Cooling upgrade			50.0	
Flat sample studies			250.0	
Fabricate 2 new nine-cell large-grain cavities			125.0	
Cryomodule & component value engineering			50.0	
Integrated cavity processing studies			50.0	
Management & travel			100.0	
Total			**1825.0**	
Grand Total			**3400.0**	**(guidance is $3000k)**

Proposed JLab FY09 high-gradient tasks (Bob Rimmer)

Fermilab

1. Robust 9-cell program with at least 30 standard EP cycles on new batch of cavities with T-mapping (~$1M). Emphasis on maximum learning. Address specific S0 yield goals plus understanding of quench variability. Identify location and nature of limiting quench on all tests. Visual inspection* on all cavities. Provide qualified cavities for S1.
2. Additional 9-cell tests (4 x BCP large grain, 4 x Cornell flash-EP cavities etc.).
3. Single-cell program 25 cycles with T-maps. Bridge between small samples & 9-cells.
   - Q-slope / quench characterization / visual inspection / evaluate guided repair methods / sacrificial surface analysis.
   - Comparison of LG vs fine grain, EP vs BCP (continuation of existing program).
   - Particulate studies related to JLab EP (e.g. cavity exposed to real EP solution, witness samples in active polishing region and full utilization of FE viewer).
   - Alternative material removal methods (e.g. barrel polishing, BEP, VEP).
4. Active cooling upgrade for EP system to address temperature variability.
5. Flat sample R&D *with university and industry partners:* Surface Roughness, contamination control, EP characterization, hydrodynamic modeling, baking studies, material studies, origins of losses, defect identification and characterization, etc.
6. 2 new 9-cell "plug compatible" large grain cavities. [perhaps low-loss shape]
7. Value engineering (e.g.: Superconducting joint, Nb seamless cavities, 1.3 GHz high-power windows).
8. Next generation "advanced integrated cavity processing development" studies (ICP).
9. Management, coordination and travel.

*home built or Kyoto type.

Questions

- Does the FY09 plan address the stated goals?
- Is the work scope and budget distributed appropriately between the participants?
- Are there elements of the work plan that do not fit within the scope of the S0 work?
- Are there missing elements?

Cavity Movements and Status

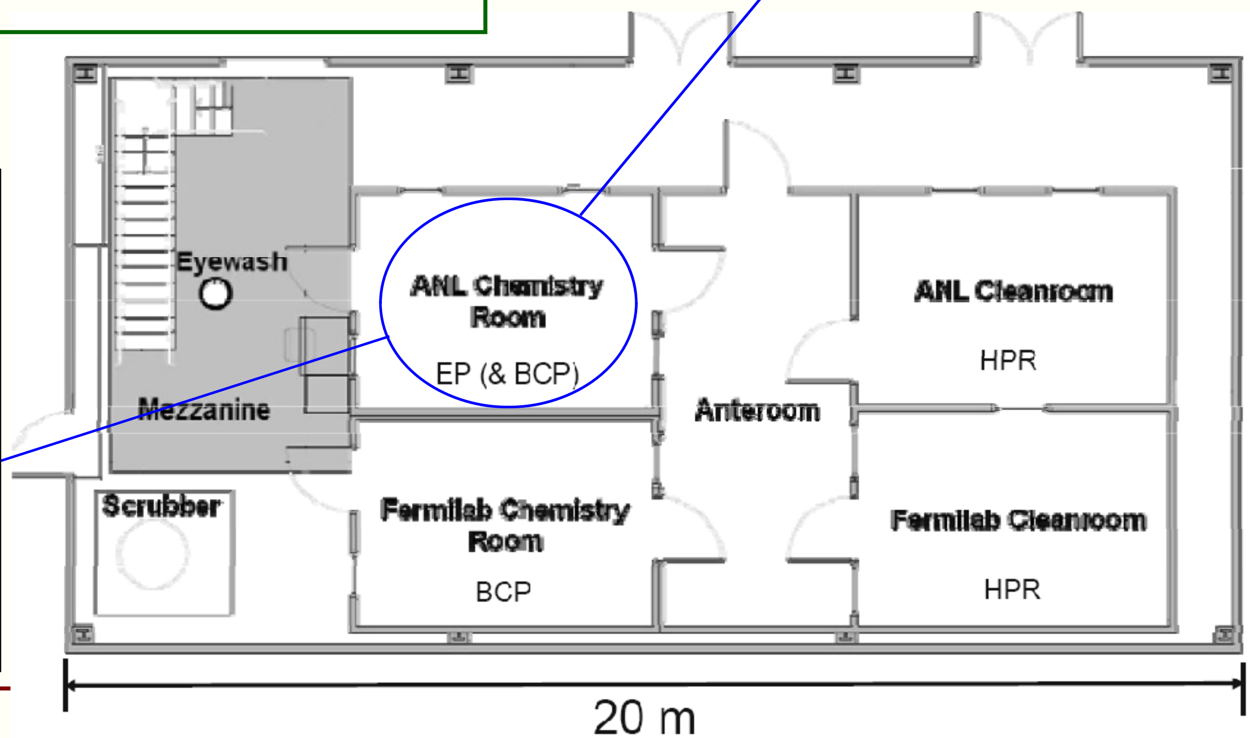
- One of the eight new Accel nine-cell cavities was received at JLab last week; another will follow this week.
- AES3 will be shipped to Los Alamos where Tsuyoshi Tajima will use it for completing and commissioning his nine-cell T-mapping system
  - New funding for national security project will support this work
- A6 will undergo HPR and assembly at JLab and be shipped to Fermilab for vertical tests:
  - Verify performance
  - Test cavity vacuum pumping system (presently being installed)
  - Test fixed- and variable-coupling input couplers
- A7 to qualify Argonne EP facility (ANL → FNAL → JLab)
- Roark / Niowave single-cell cavities expected this month
- Cavities for Cryomodule 2 at Fermilab
  - A6-8, AES2,4 ; others likely to be new Accel cavities
  - AES4 consistently limited by FE, apparently due to geometric defects (similar to Ichiro-5) → must be repaired

Joint ANL-FNAL ILC SRF Activities

- **ANL processing facility capabilities:**
  - **Electro-polishing, including “flash EP”**
  - **Ultrasonic cleaning**
  - **High-pressure rinsing**
  - **Drying**
  - **Assembly and vacuum leak testing**
  - **BCP (for 3.9 GHz and 325 MHz at present)**

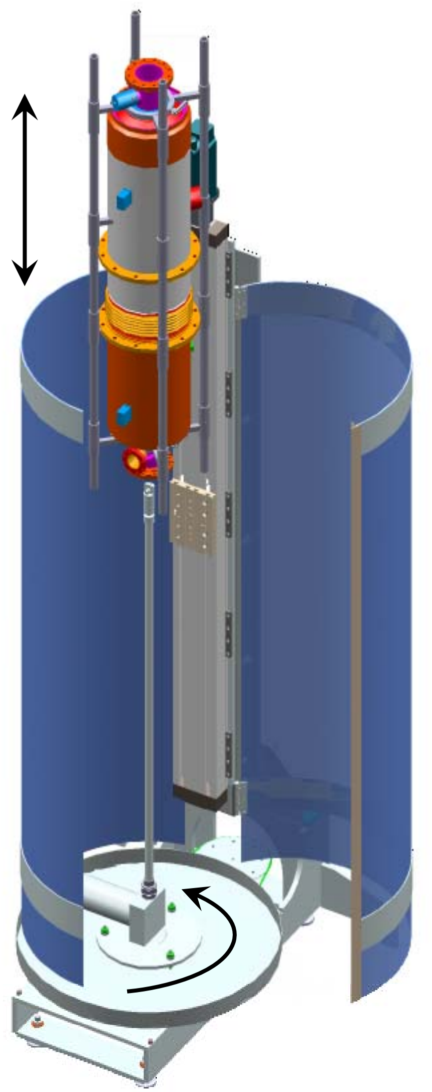
1st EP Aug 20, 2007

20 um removed from cell at 0.5 um/min



Accel 7 is presently at ANL being fitted up for EP

FNAL High Pressure Rinsing System



- Design concept based on Cornell HPR system
- Will be installed and operated at ANL processing facility
- Cavity moves vertically
  - Bosch-Rexroth slide with class 100 certification
- Wand rotates
  - 0.02micron filtration after swivel joint
- 1500psi / 100bar
  - LEWA diaphragm pump
- Status
  - Design complete
  - HPR tool 98% through fabrication
  - High pressure water line 90% procured
- Work has recently resumed
- Plan to perform first complete processing cycle at ANL in Summer 2008

Conclusion

- The Americas Region FY08-09 work plan for the ILC GDE gradient program has been developed and presented.
  - Guidance $3M; Request $3.4M
  - Proposed plan may change somewhat based on input from community, guidance from Harrison and Lilje, and financial constraints
  - Plan calls for processing and testing all new nine-cell cavities
    - 28 cavities from Accel, AES and Jefferson Lab
    - T-mapping and optical inspection to be used extensively
  - Single-Cell R&D program somewhat broadly defined at this time
    - Need to determine who does what in more detail
- Meetings:
  - Presently hold a weekly KEK – Jefferson Lab – Fermilab WebEx meeting
  - What other meetings are necessary?
- Lacking a good mechanism for funding university R&D.
  - Can we establish a fund to support peer-reviewed proposals?
- Comments from the community are welcome.

Back-up Material

Proposed JLab FY09 high-gradient plan (Bob Rimmer)

Fermilab

Concept:

Emphasize maximal scientific understanding and lead process improvement and risk reduction based on knowledge. Design tasks to answer specific technical questions of highest priority to the project. We identify two broad goals that together address the higher level challenge.

Goal 1: Understand the variability of cavity performance at the high gradient limit.

Identify the nature and location of the limiting quench site in every cavity by T-mapping and visual inspection and by sacrificial analysis of single cells.

Quantify the first pass and second pass 9-cell yield using the best effort "standard process" (S0 goal).

Continue the fight to eradicate field emission in 9-cells.

Deliver qualified cavities for S1 cryomodule goal. Exchange cavities between regions.

Based on what is learned above, perform targeted trials to improve the process using flat samples and single-cell cavities.

Goal 2: Pursue alternative concepts to the baseline to address cost and technical risk.

Based on Jlab's unique experience with cryomodule design, assembly and operation and a wide range of structures, contribute to cryomodule and component value engineering studies.

Evaluate alternative materials such as direct from ingot "large grain" Nb, alternative structures such as superstructures and superconducting joints, seamless cavities and alternative cell shapes (low loss, ICHIRO etc.).

Develop improved and "lean" processes based on sound understanding of the fundamental requirements for high gradient and eliminate no-value-added process steps. Aim for scalable industrializable integrated cavity processing system.

Proposed JLab FY09 high-gradient plan (Rimmer)

Fermilab

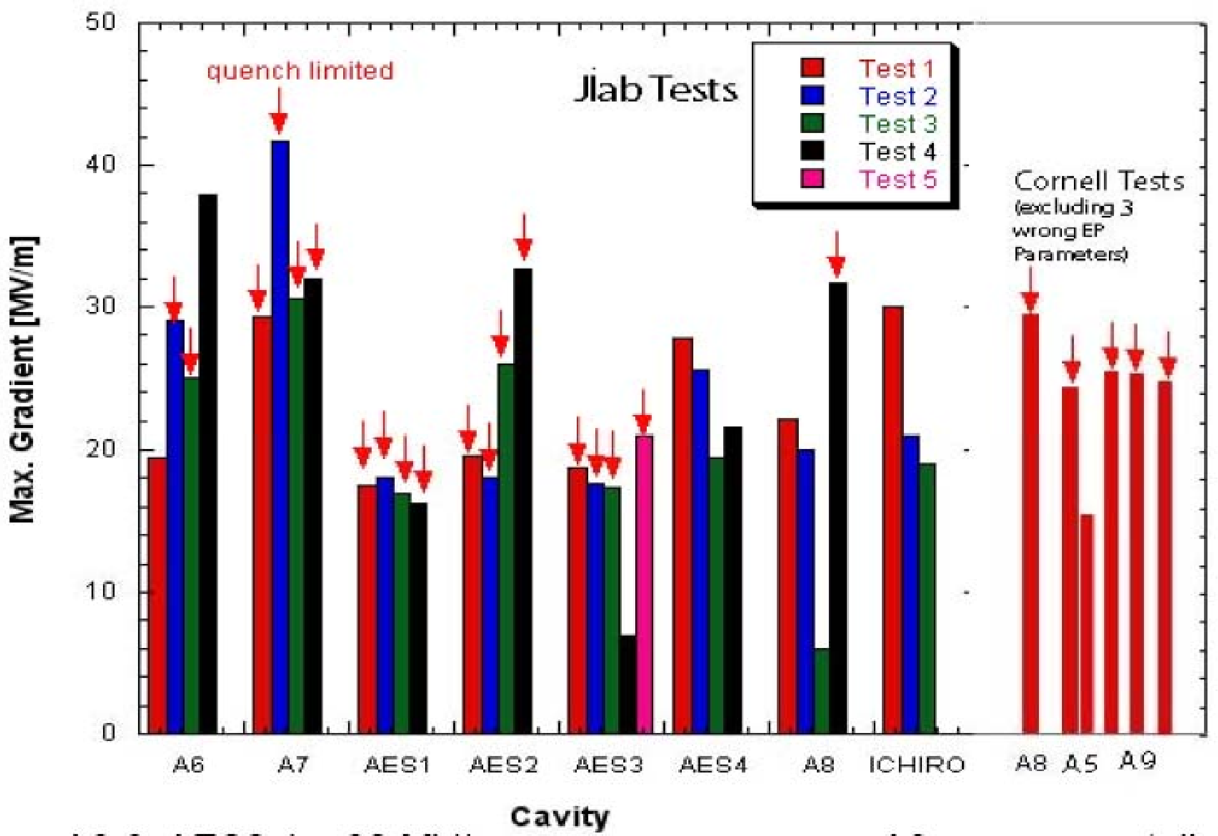
Proposed breakout of JLab FY09 activities (all items include overhead)

goal	item	labor ($k)	M&S ($k)	total ($k)
1	9-cell program 30 cycles + EP maint.	900	100	1000
1	9-cell additional VTA tests (4 LG, 4 Cornell)	40	10	50
1	Single cell program, 25 cycles, 5 new cavities	125	25	150
1	Active cooling upgrade for EP cabinet	30	20	50
1,2	Flat sample studies, university partners, students	200	50	250
2	2 new "plug compatible" 9-cell Large grain cavities*	100	25	125
2	Cryomodule & component value engineering	30	20	50
2	Advanced integrated cavity processing studies	30	20	50
1,2	management, coordination & travel	75	25	100
	totals including overhead:	1530	295	1825
	* material already procured in FY08			

Summary of cavity performance in testing at JLab and Cornell
(data from Geng and Padamsee; presented by Shekhar at Sendai)

Fermilab

9-cell Test Results



Average A6-8, AES2,4 = 32 MV/m

A9 reprocess at Jlab

3/4/2008 US Cavity & Cryomodule 3

Recipes for Processing, Testing, and Diagnosing

Standard Processing Recipe

1. Incoming cavity quality control checks.
2. Optical inspection of as-received cavity.
3. Bulk electro-polishing of ~150 um.
4. Ultrasonic degreasing.
5. High-pressure rinsing.
6. Hydrogen degassing at 600 deg C.
7. Field-flatness tuning.
8. 20 um electro-polishing.
9. Ultrasonic degreasing.
10. Field-flatness verification and retuning if <95%.
11. High-pressure rinsing.
12. Assembly and vacuum leak testing.
13. 120 deg C bake.
14. Vertical dewar test.

Standard Testing Recipe

1. Hold at ~100 K during cool down to check for Q disease.
2. Q vs. T measurement during cool down.
3. Q vs. E measurement on Pi mode. RF process as needed.
4. Q vs. E measurement on all other modes. RF process as needed.
5. Final Q vs. E measurement on Pi mode.

Notes:

All Q vs. E measurements to include radiation data logging.

Utilize nine-cell temperature-mapping system if available.

Diagnostic Techniques

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