Americas

S0 Plan in USA

Shekhar Mishra

Fermilab/GDE

US Main Linac Cavity and Cryomodule WBS

Cavity and Cryomodule R&D Priorities

- Determine cavity processing parameters for a reproducible cavity gradient of 35 MV/m
- Test one ILC rf unit at ILC beam parameters, high gradient, and full pulse rep rate
  - Assemble 1st Cryomodule using DESY Kit
  - Build 1st US produced Cryomodule
  - Build 2-4 ILC Cryomodule
- Design, produce and test the ILC-specific cryomodule.
- Participate in the global Cavity and Cryomodule R&D.

Cavity Gradient R&D: S0 Scope Details

- Plan (S0 Task Force Report) has two main parts
  - S0.1: Tight loop to improve “final preparation” yield
    - 3 Cavities from each region (9 best cavities globally)
      - x 3 tests each, cross calibrate regions
    - Parallel/coupled R&D to improve yield (1-Cell Program, Study of failed cavity, Material R&D, etc.)
    - Repeat 3 cycles on 9 cavities with improved process

    (Total of 6-12 US Cavities)
  - S0.2; Production-like activities to determine overall yield for cavity materials, fabrication and full cavity processing
    - First batch of about 36 cavities globally (12 US Cavities)
    - Second batch of about 150 cavities globally (50 US Cavities)

Americas

Number of Cavities in US

We have the following cavities in hand or will be shortly.

- 4 from ACCEL: AC6 (Jlab), AC7 (Jlab), AC8 (Cornell) and AC9 (Cornell)
- 1 from AES (Jlab) AE1, AES plans to deliver next 3 cavities in 6 weeks.
- 4 cavities (2 Fine Grain, 2 Large Grain) are being fabricated by Jlab.

These cavities are needed for 1st US Build Cryomodule

- 6 (AES) +8 (ACCEL) Cavities are on order.
- Plan to buy 12-24 additional cavities in FY07.

A Total of 38-50 Cavities for S0.

US will provide some of these cavities to KEK for processing and testing.

S0: Short Term Cavity Plan

S01. Goals. : Process a cavity till it reach 35 MV/m. Once at 35 MV/m process 3 times to get the distribution in processing. This is "Tight Loop"

- AC7: This cavity has been processed 3 times to get to ~41 MV/m.
  - This will be processed 2 more times (10 um EP) to get the distribution.
- AC6: This cavity has been processed 2 times to get to ~29 MV/m. This will be processed 1 more time to see if its gradient improves.
  - After that we should process it 2 more times (10 um) to get the distribution.
  - We will send this cavity to KEK for Tight Loop (10 um, 3 times) processing after the commissioning of the KEK EP.
- AE1: This cavity needs to be processed to determine the quality of US fabricated cavity production.
  - Depending on the result of this cavity we will send this cavity to KEK for Tight Loop (10 um, 3 times) processing.

Americas

S0: Short Term Cavity Plan…

- AC8: This cavity has gone through BCP at Cornell and achieve ~26MV/m. This will be used to develop Vertical EP at Cornell.
  - This is our second choice of sending 2nd cavity to KEK for "Tight Loop".
- AC9: This cavity has been tuned by Cornell. It is available for processing at Jlab when ever the pipeline there is free. This could be used by Cornell in Vertical EP if Jlab receives the next 3 cavities from AES by end of Feb 07 as projected.
- AE2-4: Will go to Jlab for processing.
- Provide ANL the trial cavity from DESY and 1-cell cavity to Debug EP system.

Plan for US Cavities

Americas

	FY07			FY07									
	FY07	11	12	1	2	3	4	5	6	7	8	9	10
Available cavities													
Cavities at Jlab – EP													
Accel B1-01 (Jlab) A7			2	3	Dress at Jlab for High Power Test at Fermilab								
Accel B1-02 (Jlab) A6			1	2,3		Send to KEK for S0							
Accel B1-03 (Jlab) A?				0,1,2		3	Send to KEK for S0						
AES B1-1 (Jlab)					0,1	2,3	Kit 2-cavity 1						
AES B1-2 (Jlab)						0	1,2		3	kit 2-cavity 2			
AES B1-3 (Jlab)								0	1,2	3	kit 2 – cavity3		
AES B1-4 (Jlab)									0,1	2,3	kit 2-cavity4		
Jlab B1-1 (small grain)											0	1,2	3
Jlab B2-2 (small grain)												0,1	2,3
Jlab B1-1 (large grain)							BCP		0,1		2		
Jlab B1-2 (large grain)								BCP	0,1		2		
Vertical tests Jlab		**0**	**2**	**3**	**2**	**2**	**2**	**2**	**3**	**2**	**4**	**3**	**3**
Cavities at Cornell – Vertical EP													
Accel B1-04	0,1		0	3	kit 2-cavity5								
Accel B2-3 ILC			0,1		2	3	Kit 2-cavity6						
Accel B2-4 ILC						0,1		2	3	kit 2 – cavity7			
Accel B2-5 ILC									0,1		2	3	kit 2 – cavi
Vertical Tests Cornell		**1**	**1**	**2**	**1**	**1**	**1**	**1**	**2**	**1**	**1**		
Cavities Qualified for Strings		**2**	**2**	**2**	**2**	**2**	**2**	**4**	**3**	**4**	**3**	**3**	**3**
Vertical Tests		1	3	5	3	3	3	3	5	3	5	3	3

Cryomodule fabrication — CM1 DESY Kit1 Type3

Cavity Tests Completed

Feed back on new vendor's performance

Cryomodule assembly activities

Americas

Yield Improvement: 35 MV/m

- The yield improvements would come in a few stages
  - Input from R&D activities becomes incorporated into the 9-cell preparation
  - Testing batches for each stage.
- Improvement in yield and spread will require coupled R&D programs in parallel to large scale testing of 9-cell cavities.
  - Basic R&D on the preparation recipes
  - Materials R&D
  - Diagnostics on EP, HPR, VTS systems
  - Multi-cell tests with full diagnostics
  - Single cells preparation/tests
- Present Limiting Factors:
  - Field emission
  - Quench
  - Hydrogen initiated Q-disease.
- Existing Procedure needs optimization and we need to explore any promising procedures that reduces these effects. Some examples are:
  - Improved methods of final rinsing
  - New final rinsing agents
  - Stringent control of cleanliness during assembly
  - Processing field emission with high pulsed power RF.

Present: US SRF Infrastructure Strength

- Limited cavity fabrication capability in US industry
  - One US company (AES) fabricating SRF cavity
  - Two new companies (Niowave and Roark) being developed
  - European Industry much advanced in ILC cavity fabrication
- Cavity Processing and Vertical Testing R&D Facility
  - Jlab (30 FY07, 40 FY08, 50 FY09) cycles/yr
  - ANL/FNAL (50 FY08, 60 FY09) cycles/yr
  - Cornell 12 cycles/yr
  - VTS @FNAL 70 cycles/yr (FY07)
  - Significant capacity will be used by supporting R&D Program
    - Process development
    - Single cell Processing
- Horizontal Test Stand
  - FNAL 24 cavities/yr
- Cavity Dressing and Cryomodule Assembly
  - FNAL 12/yr (FY07)

Proposed: US Laboratory Capacity

Fermilab

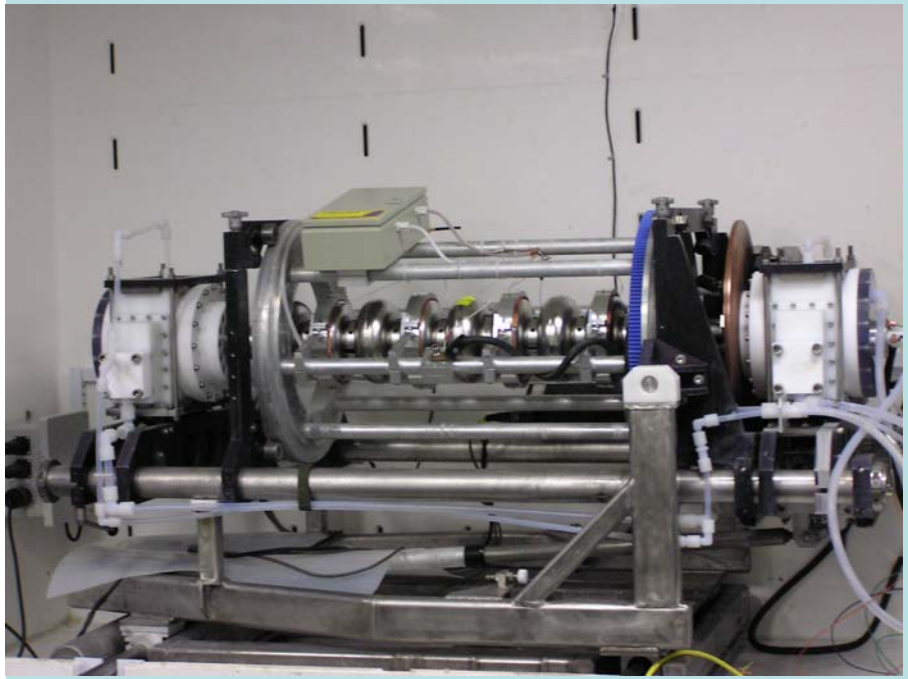
Program	FY07	FY08	FY09	FY10	Capacity Needed/yr by FY10
Cavity Processing (EP, HPR, Bake)	Jlab-30 Cornell-10	Jlab-40 Cornell-10 ANL-40	Jlab-40 Cornell-10 ANL-40 Fermilab-20	Jlab-40 Cornell-10 ANL-40 Fermilab-100	200
Vertical Testing	Jlab-30 Cornell-10 Fermilab-20	Jlab-40 Cornell-10 Fermilab-75	Jlab-40 Cornell-10 Fermilab-75	Jlab-40 Cornell-10 Fermilab-200	200
Horizontal Testing	Fermilab-6	Fermilab-24	Fermilab-24	Fermilab-72	72
Cryomodule Assembly	Fermilab-1	Fermilab-4	Fermilab-12	Fermilab-12	12
Cryomodule Test	Fermilab: ILCTA_NML	Fermilab: ILCTA_NML	Fermilab: ILCTA_NML	Fermilab: ILCTA_NML CMTS	12

Americas

Jlab R&D Program

- R&D Program
  - Processing and Vertical Testing of 9 Cell Cavity for S0 program
  - Single Cell R&D to improve the Processing
  - Field Emission studies for tracking the contamination
  - ACD: LL Shape Cavities, Large Grain and Single Crystal
- Jlab Infrastructure Upgrade
  - Jlab has already commissioned a electro-polishing and vertical testing for ILC cavities
  - Development of Field emission studies
  - Incremental upgrade and maintenance of the facility

Jlab: Electro-polish Development Status



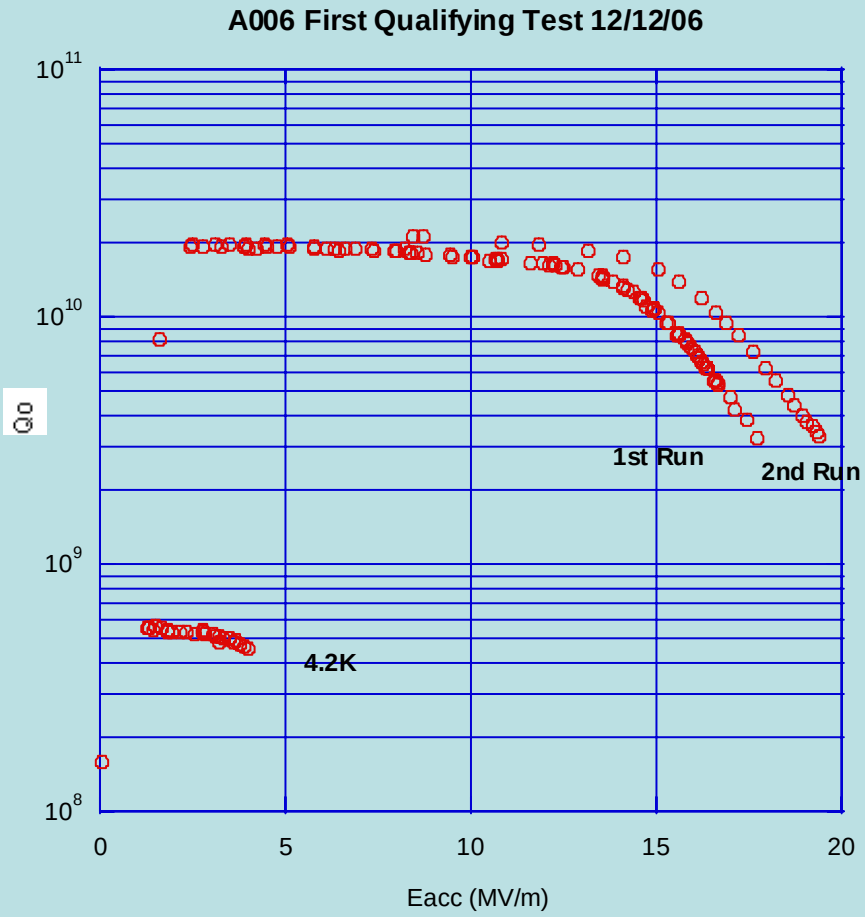
- **Process cabinet working fine**
- **All tooling and test hardware for two cavities in use**
  - Improved cavity cage hardware working perfectly
  - Two vertical stands in use
- **Assembly procedures established**
  - Almost no field emission last 8 tests consecutively
  - Videotaped assemblies, fogging tests investigations completed
  - Material removal uniform across cavities ±20um
  - Improved tooling reduced assembly errors (more to come)
  - Started witness sample measurements, single cell cavity next
- **Most activities performed on shift to minimize conflicts**

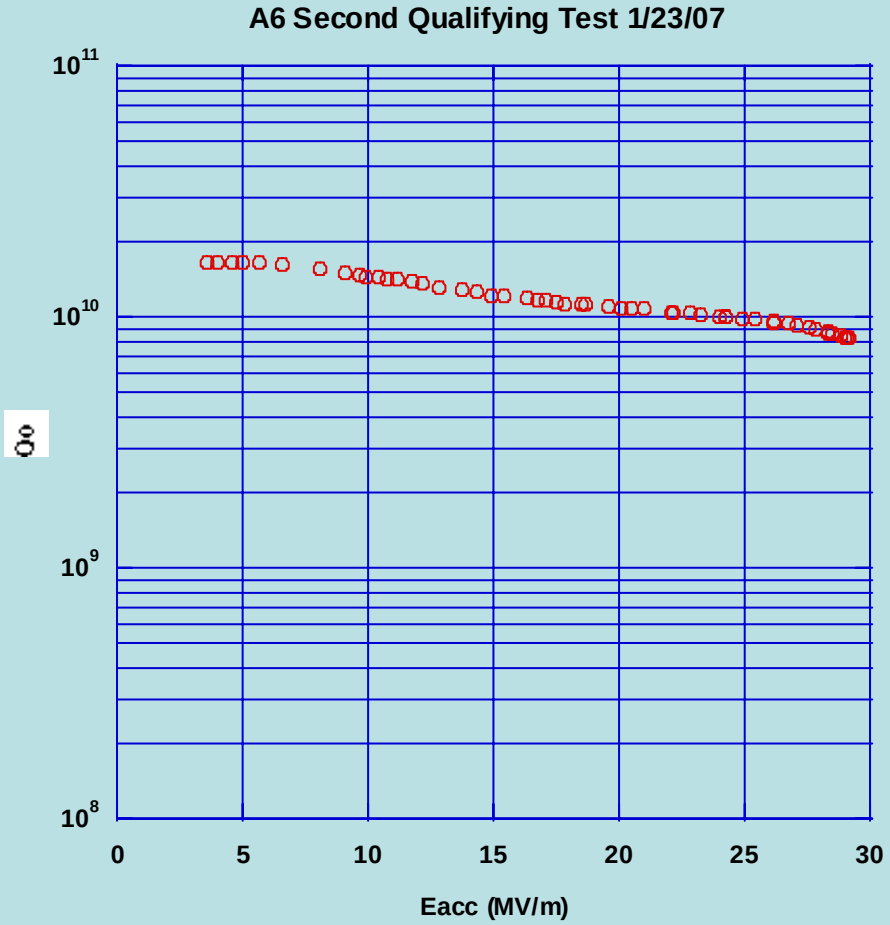
Americas

Summary of Recent Vertical Test Data

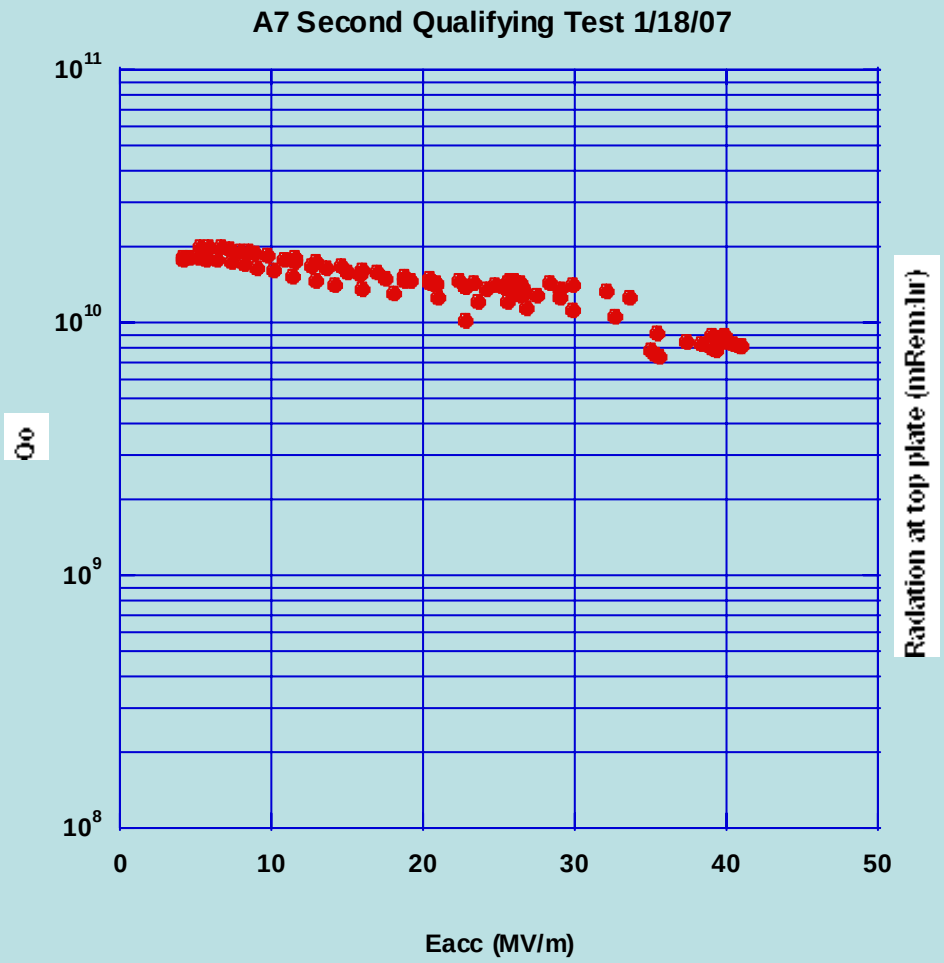
Qualification Runs				Qualification								
Test Date	**Cavity #**	**Purpose of test**	**Processing Performed**	**Low Field Qo 5MV/m**	**Max Gradient (MV/m)**	**Q at Max**	**Rad onset**	**Max Rad (mRem/hr)**	**Limit**	**Q-disease**	**Mode Excited**	**Grad_excited**
12/12/2006	A6	First qualifying test	EP20um,Degrease,HPR,Bake 120,100K soak 3days	2.00E+10	19.4	3.22E+09	17.3	0.3	Cable	No	not checked	
1/10/2007	A7	Second qualifying test	EP20um,Degrease,HPR,Bake 120	1.92	39.5	8.90E+09	28.3	100	unknown	NA	not checked	
			Soak at 100K 8 hours							yes	not checked	
			Warmup to 300K, cooldown	1.92E+10	41.25	8.00E+09	25.3	298	Quench	No	7/9th	24
1/23/2007	A6	Second qualifying test	EP20um,Degrease,HPR,Bake 120	1.66E+10	29.14	8.20E+09	none	none	Quench	NA	none	

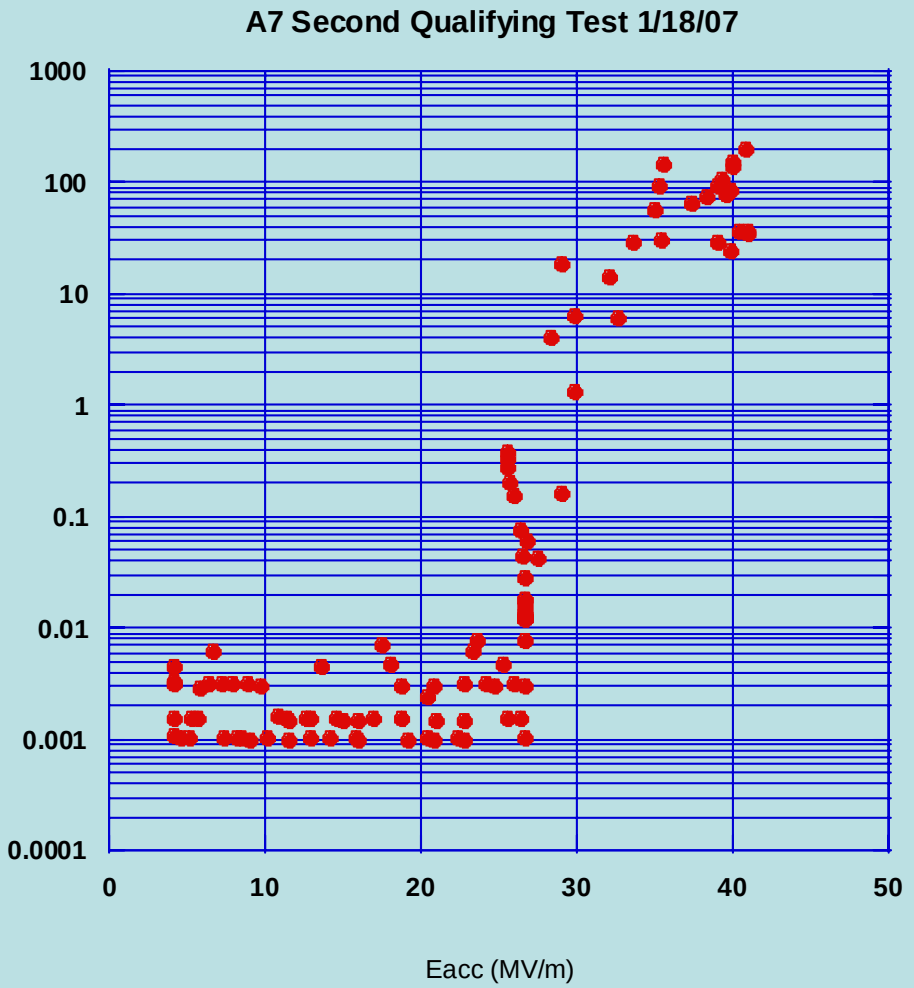
Results of Cavity: AC6



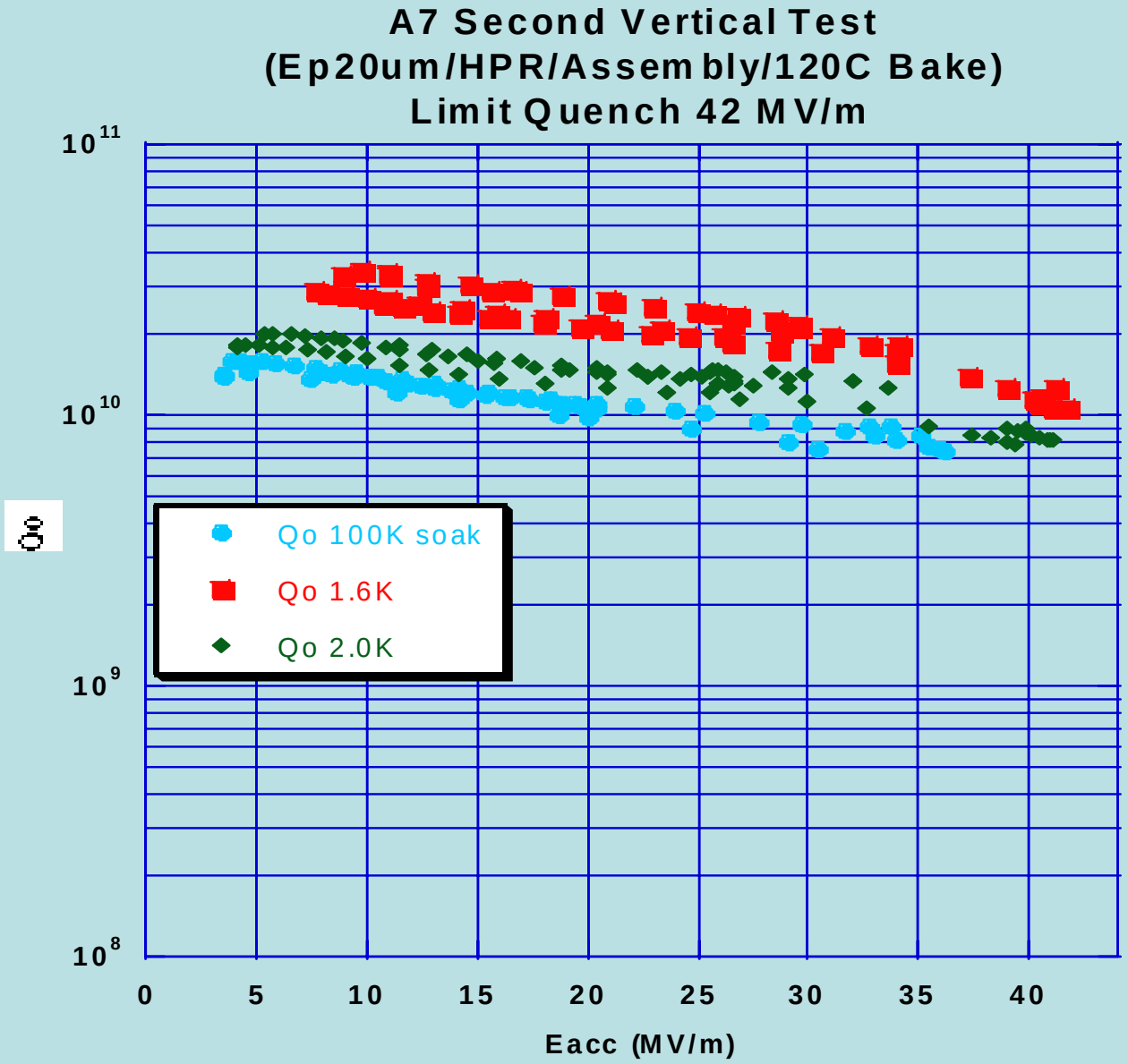


Results of Cavity: AC7





Jlab: Results of Cavity: AC7



Americas

Cornell R&D Program

- R&D Program
  - Electro-polishing and testing of 9-cell cavities (S0)
  - Explore basic parameters for HPP with 9-cell ILC Cavity
  - Process and test two 9-cell re-entrant cavities (0.5 FTE)
    - Fine grain with EP, large-grain with BCP
- Cornell SRF Infrastructure Upgrade
  - Vertical EP
  - RF power source 300 – 400 Watt
  - Smaller diameter vertical test dewar

Americas

Cornell: ILC Cavity R&D

- Upgrade Facilities for BCP, HPR, and testing for 9-cell ILC cavities
  - Complete
- One 9-cell : BCP/ HPR/ Test complete: Eacc = 26 MV/m
- Develop a provisional method to tune 9-cells
  - Complete
- Develop Vertical EP for 9-cell ILC cavities
  - In progress
- Basic R&D for EP contamination
  - In progress
- New shape (re-entrant) 9-cell cavity for ACD complete

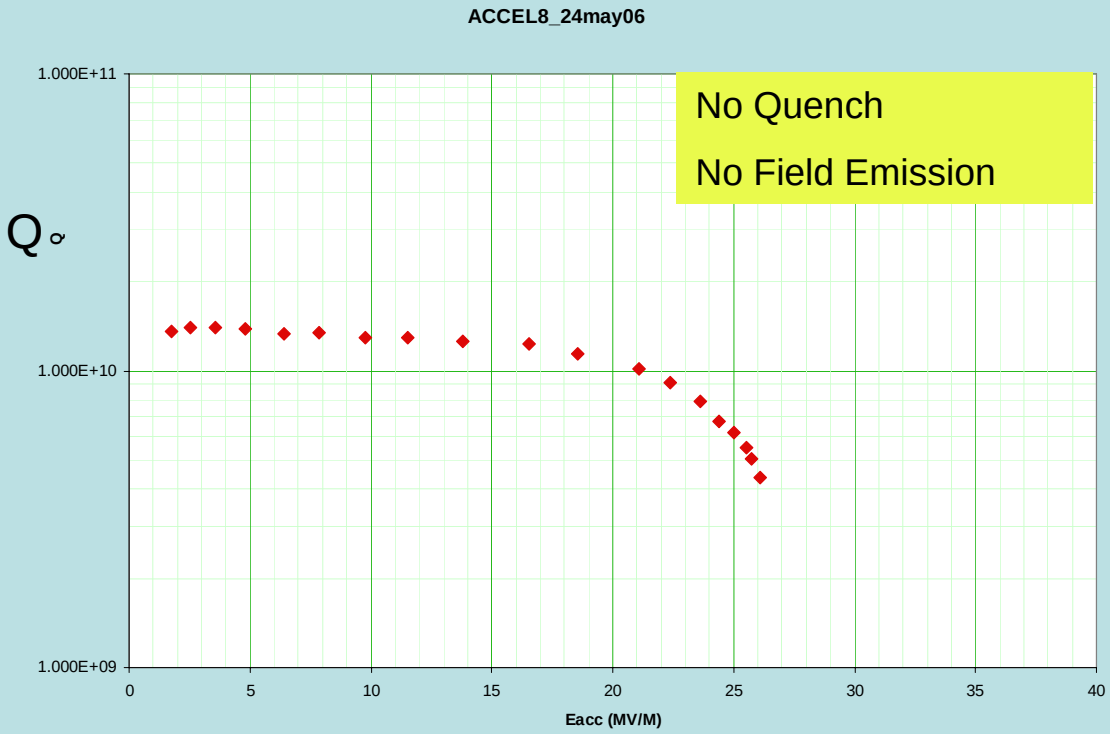
Cornell: BCP and Vertical Test of ACCEL Cavity

50 + 60 μm BCP + 50 μm at ACCEL + HPR No Heat treatment at 800 Deg C

Maximum field = 26 MV/m (high field Q-slope)

Two cycles to reach best field for classical BCP

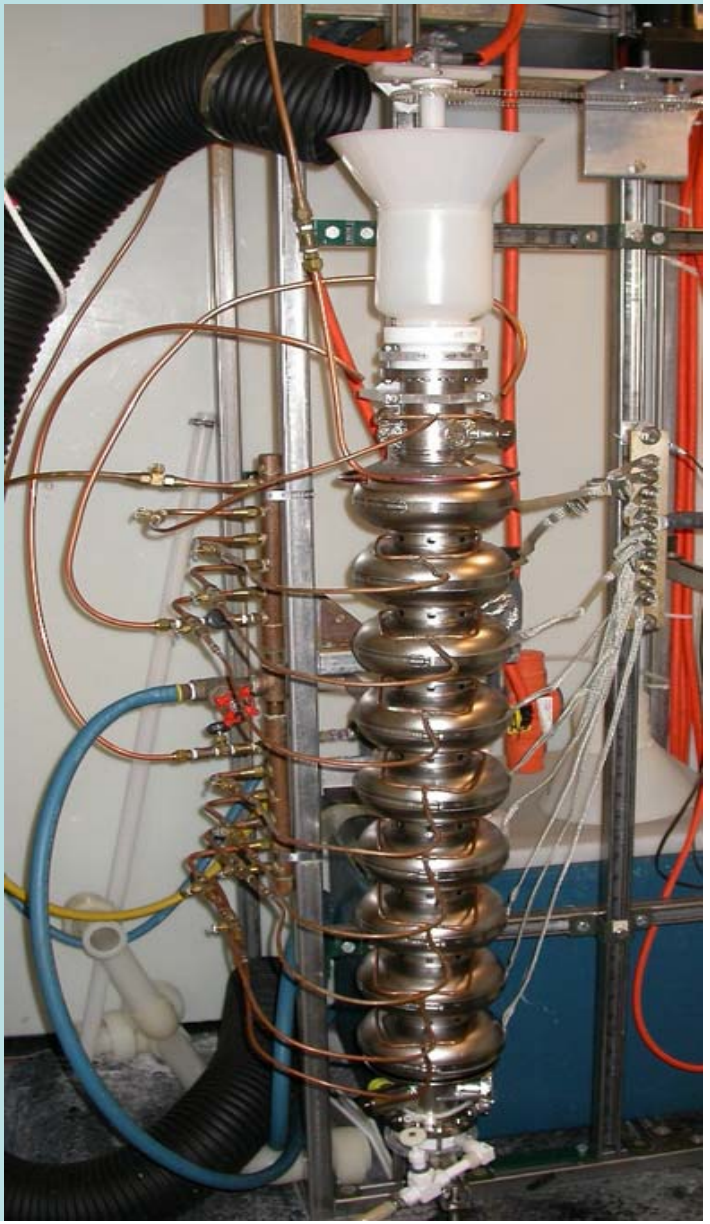
BCP (Etching)



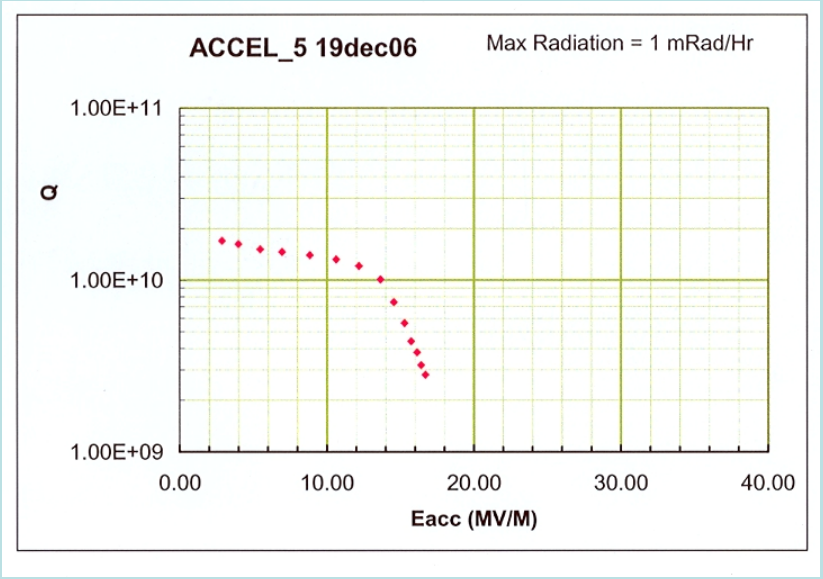
E_{acc} (Mv/m)

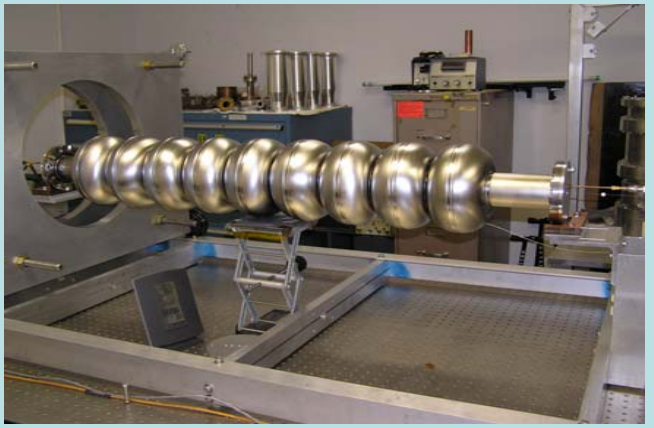
Cornell: 9-cell Vertical EP Development

- Single Cell vertical EP successful
  - E^{acc} = 47 MV/m achieved in re-entrant cavity
- 9-Cell Cavity, 120 micron EP
- 600 C, 12 hour bake @ Jlab to remove H
- Flash BCP (< 10 microns) + HPR & VT
- E_{acc} = 17 MV/m (max)
- Result (next slide) suggests more material removal necessary for this cavity
- No field emission



Results from 1st Vertical EP





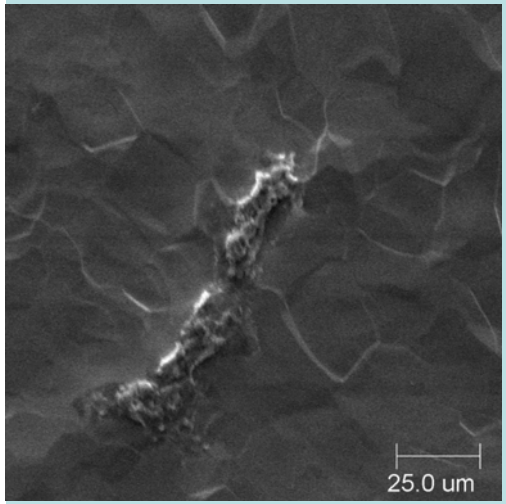
AES 9-Cell Reentrant

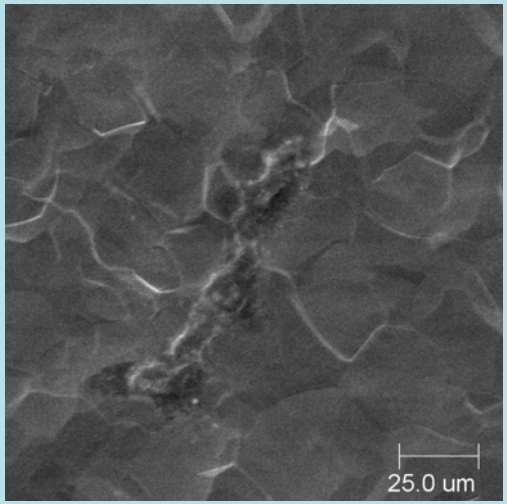
- Two main types of particles captured during EP,
  - S and niobium-oxide (most likely pentoxide)

- Traces of Al also found with Auger, as expected due to Al cathode

- S particles dissolve in ethanol rinse but leave an imprint

- Oxide particles dissolve in HF rinse





ANL R&D Program

- ANL R&D Program
  - Electro-polish ILC cavities for S0
  - Develop and improve processing parameters
  - Optimize existing EP hardware/Interface with U.S. EP vendors/develop and optimize hardware suitable for large-scale EP
- ANL SRF Infrastructure Upgrade:
  - Finish and commission the new EP system
  - Install new HPR system
  - Installation of a PLC-based control system for EP

Americas

EP Facility at ANL

- Tailor the system to the dimensions of the 1.3 GHz geometry
- Design for ease of assembly and disassembly
- Ensure tanks, pumps, acid lines are accessible and cleanable – no sulfur buildup
- Use a pure aluminum heat exchanger for much improved heat transfer to the acid
- Empty the cavity of acid and fill with water rapidly at the end of the procedure (keep the cavity wet before HPR)
- Include a provision for separating the acid flow rate from the need to maintain constant temperature
- *Provide timely direct hands-on experience for FNAL/ANL personnel*

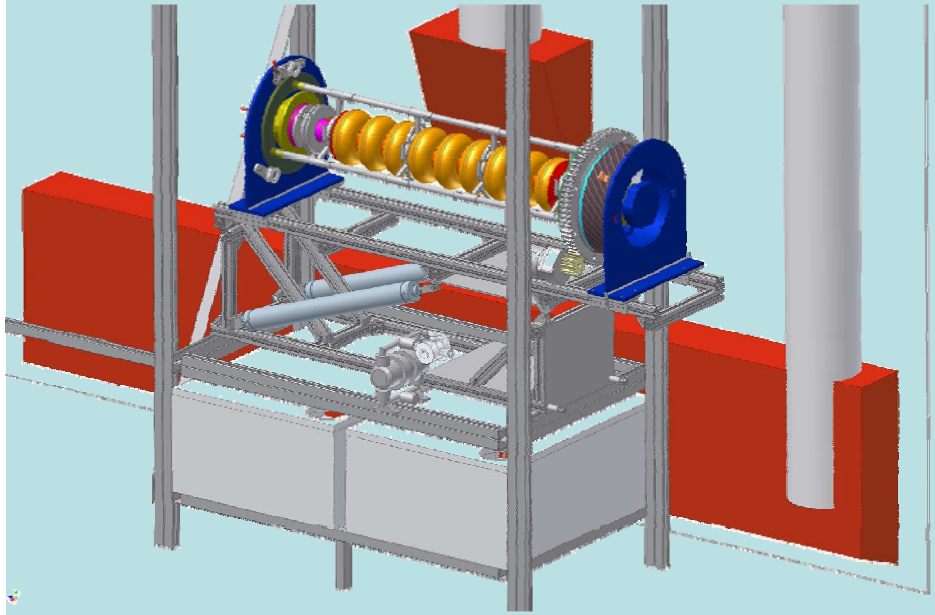
Americas

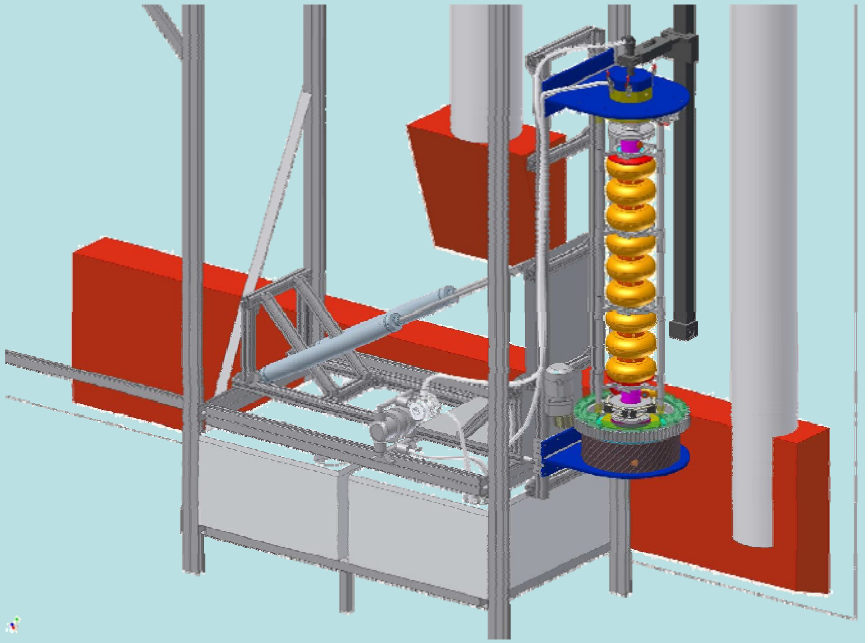
SCSPF: ANL EP Room

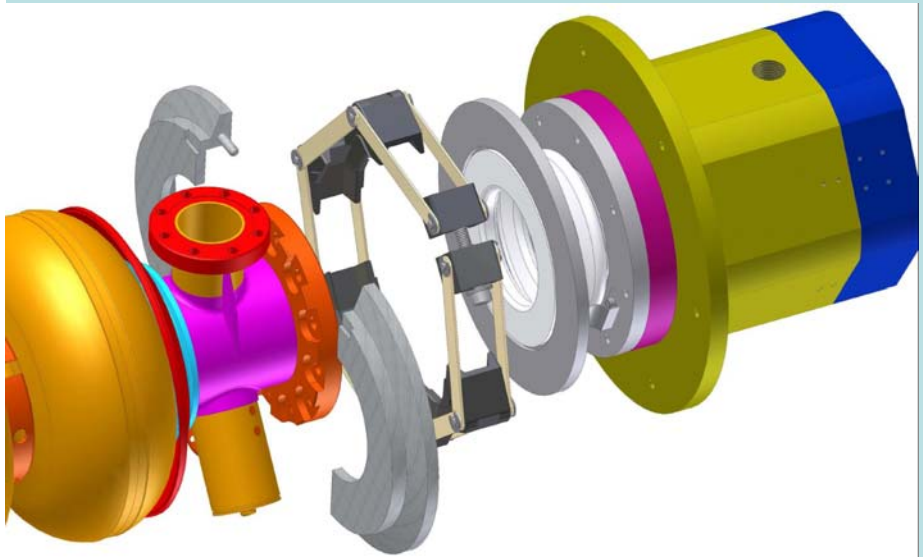
Americas

SCSPF: Class 1000 Anteroom

Technical Design in Progress







This facility is scheduled to be commissioned in the last quarter of FY07.

Americas

MSU and LANL R&D Program

- MSU R&D Program:
  - Cavity Autopsy (Yield Improvement)
  - Single Cell Cavity (R&D)
  - Advanced Cavity and Material Science studies (R&D)
- MSU SRF Infrastructure Upgrade:
  - Upgrade ultra-pure water and high pressure rinse
  - Nine-cell structure vertical test dewar
- LANL R&D Program:
  - Cavity Autopsy (Yield Improvement)
- LANL SRF Infrastructure Upgrade:
  - Re establish cavity testing at LANL
  - 1.3 GHz Power Amplifier
  - Thermometry (provided by Fermilab)

Fermilab Program

- Order Cavity and Cryomodule parts
  - Material QC and R&D (S0-2)
- Vertical test processed cavities at collaborating laboratories (S0-2).
- Dress cavities with Power Coupler, Tuner etc.
- High Power test of dressed cavities
- Assemble and test cryomodule

Fermilab New Infrastructure Development

- Design and Build one Cryomodule Test Stand
- Design and build one Cavity Processing Facility
- Upgrade to VTS and HTS

Americas

Summary: S0 Plan

- S0-1 work has started at Jlab with excellent initial results.
  - We plan to continue a systematic study of EP
- Cornell Vertical EP is being commissioned
- ANL EP facility is under construction
- Fermilab Vertical Test Facility is under construction
- MSU and LANL infrastructures will be used for yield improvement study.