AES 9-cell ILC Cavity Processing and Testing at JLAB

What have been learned and proposals for future steps

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Acknowledgements

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- FNAL: Damon Bice, Dmitri Sergatskov
- JLAB: Ralph Afanador (now SNS), John Mammosser (now SNS), Byron Golden, Jeff Saunders, Pete Kushnick, Danny Forehand, Rolland Johnson, Kirk Davis, Christiana Grenoble, Bob Manus, Julian Gordon.

ILC High Gradient R&D

- Goal Eacc=35 MV/m, Q0=1E10, yield 90%.
- S0 "tight-loop" effort: focus on process and procedure – use qualified cavities.
- S0 "production-like" effort: factory manufactured cavities to determine full production yield.
- Single-cell studies and sample studies.

High Gradient Cavity Processing Steps (example recipe at JLAB)

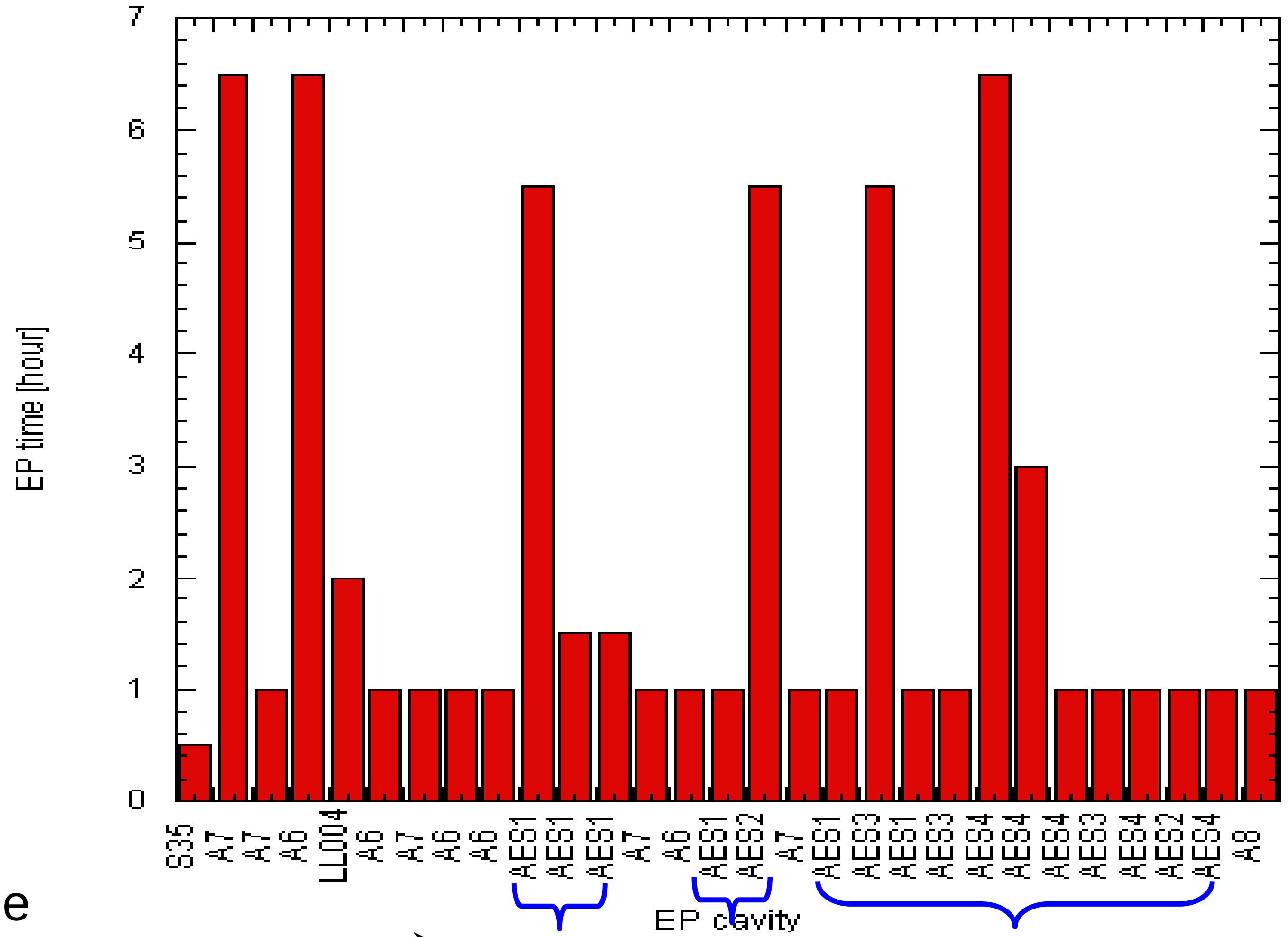
- Electropolishing.
- (Vacuum furnace out-gassing for H removal.)
- Ultrasonic cleaning.
- First high-pressure water rinsing.
- First clean room assembly.
- Second high-pressure water rinsing.
- Clean room drying.
- Final assembly.
- Pump down and leak check.
- Low temperature bake.
- RF test at 2 Kelvin.

Ref: J. Mammosser, TTC meeting, April 6, 2007, FNAL.

JLAB Processes & Tests ILC 9-cell Cavities

- JLAB/FNAL contract – 7 cavities, 30 cycles for FY07.
- 3 (A6,A7,A8)+1(A9) ACCEL-built cavities.
- 4 AES-built cavities (AES#1,#2,#3,#4).
- 1 KEK's ICHIRO cavity (ICHIRO#5).
- 2 JLAB-built cavities.
- 7 new FNAL purchased cavities?
- Expect 11 cavities, 40 EP cycles for FY08.

JLAB accumulated 29 EP cycles since July 2006, total voltage-on time 63 hours



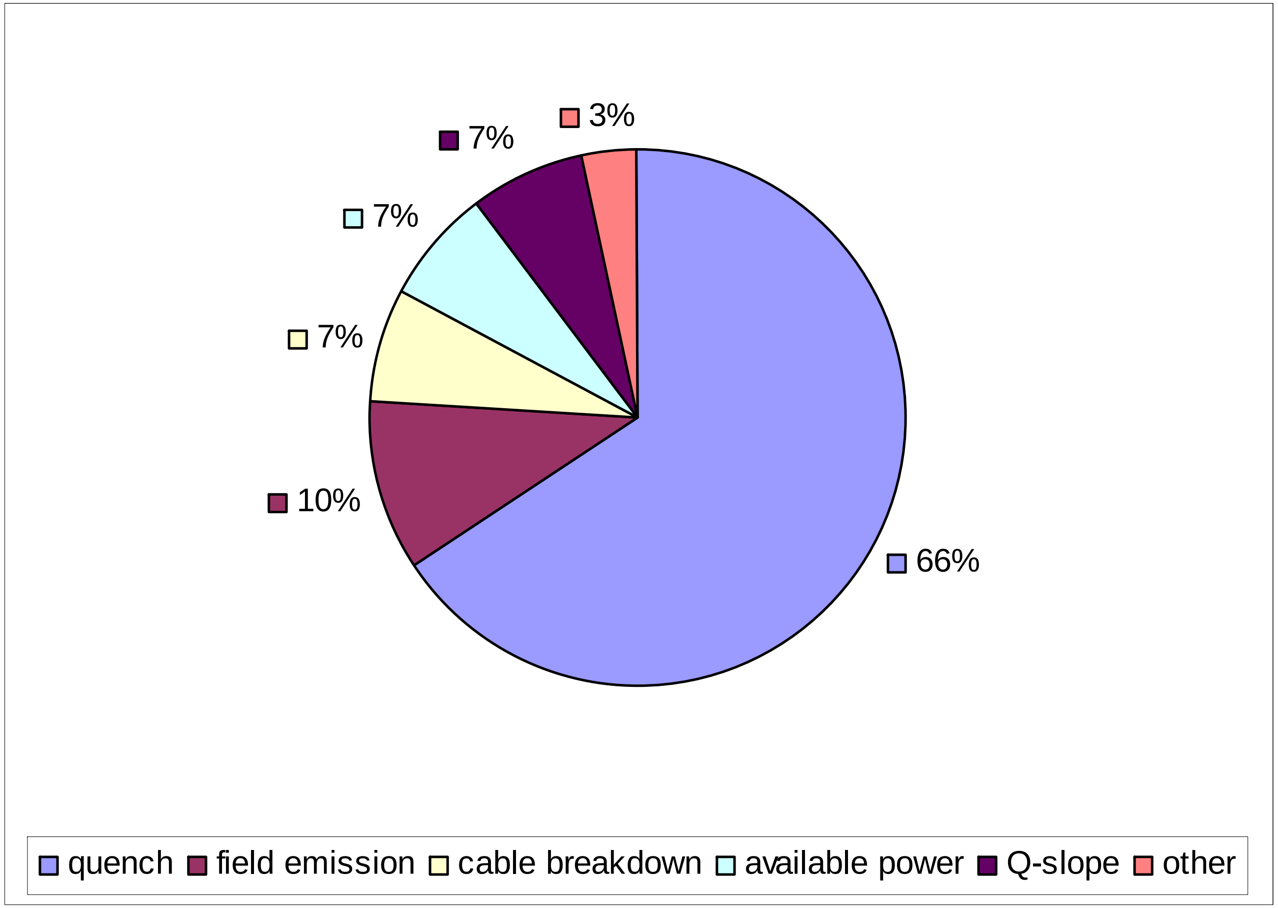
Time

AES

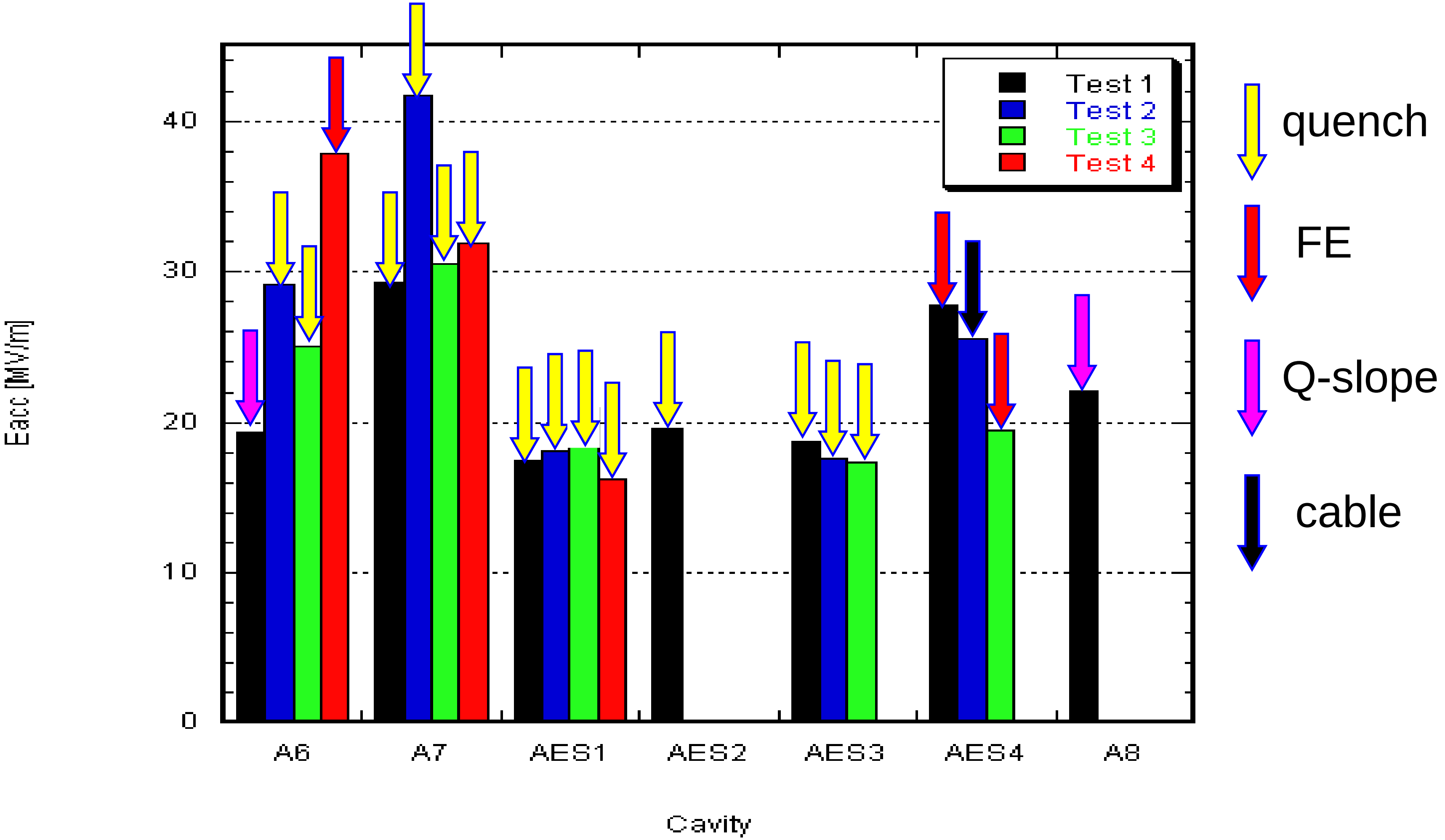
Accumulated Material Removal (in micron)

	1st test	2nd test	3rd test	4th test
A7	172	198	224	251
A6	187	213	239	265
AES1	213	236	252	269
AES2	164	190		
AES3	177	200		
AES4	221	257	277	

9-cell Cavity Gradient Limitations (total 29 RF test since July, 2006)



9-cell Cavity Results at JLAB



AES1 Results

- Serial AES cavity tests started April 16, 2007 at a rate of about 3 tests per month.
- 4 RF tests done, each time following 20 um EP.
- Quench field 17.5, 18.0, 17.0, 16.0 MV/m, no X-ray, insensitive to repeated EP processing.
- Pass-band mode measurements during test 1,2,4 consistently show cell #3 and #7 candidate quenching cells.
- May 30, 2007, first attempt for RF test with 8 thermometers attached to AES1 cell #3 and #7. Test failed due to cable breakdown and thermometers falling off.

AES3 Results

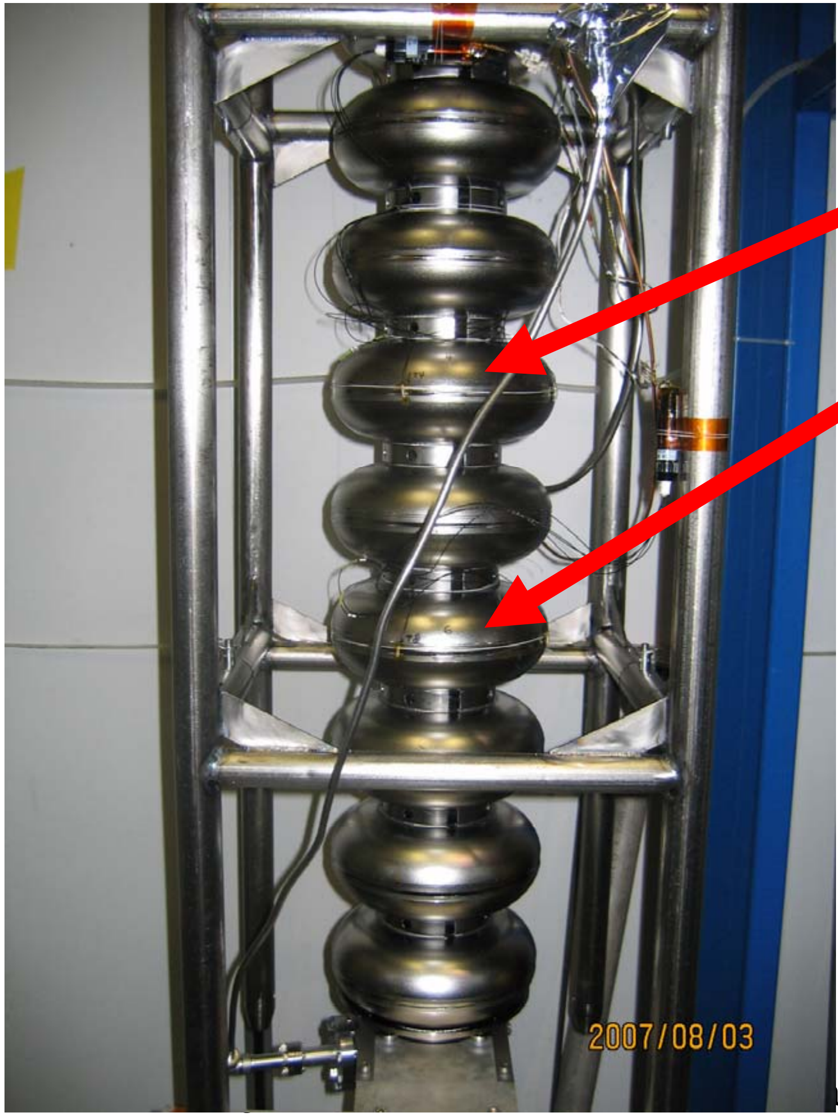
- June 5, 2007, AES3 first RF test, quench limited 18.7 MV/m, no X-ray.
- July 27, 2007, AES3 2^{nd} test, quench limited 17.6 MV/m, some X-ray.
- Pass-band measurements performed in both tests, consistently to show cell #4 and #6 are quenching cell candidates.
- Cell #1 and #9 reached 31.3 MV/m at 8/9-Pi mode
- August 6, 2007, AES3 3^{rd} RF test with 8 thermometers attached to cell #4 and #6. Data show cell #6 (from field probe port) is quenching cell.

AES#3 Pass-Band Result

Pi mode	Cell:1,2,3,4, 5,6,7,8,9	17.6 MV/m	Quench	X-ray 37 mR/h
8/9-Pi	Cell 1,9	21.2 MV/m	No-quench	40 mR/h
4/9-Pi	Cell 4,6	18.5 MV/m	Quench	No x-ray
3/9-Pi	Cell 2,5,8	23.5 MV/m	No-quench	4 mR/h
2/9-Pi	Cell 3,7	22.9 MV/m	Occasional quench	0.3 mR/h

No X-ray when quench occurs in preferentially filled cell 4/6.

AES#3 2.5th test with thermometry First Step Focused on Equators

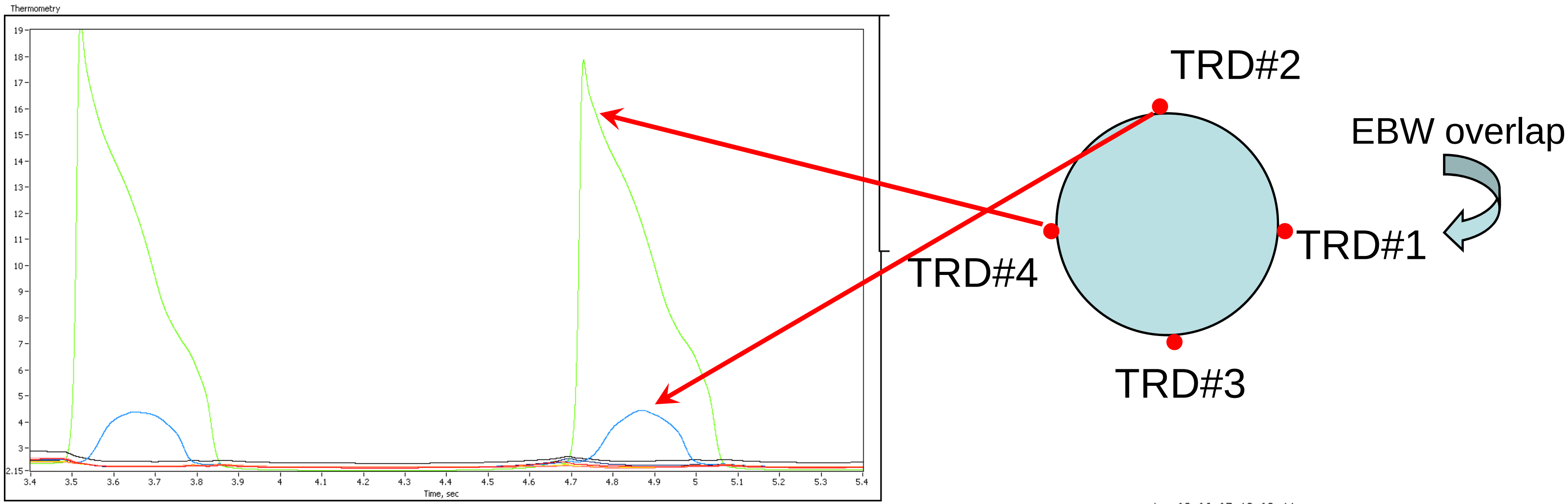


Joint test by JLAB and FNAL with help from many colleagues. Special thanks to Dmitri A. Sergatskov

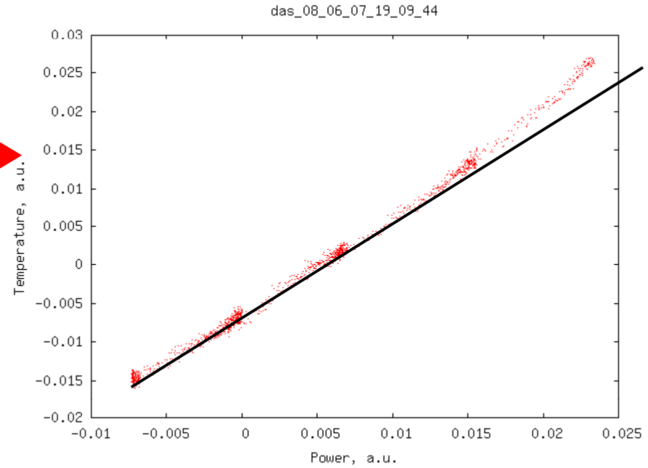
4 TRD on cell #4

4 TRD on cell #6

Cell #6 from field probe port reacted,
2K bath: TRD#4 cyclic spike of 20K in synchronism with cyclic collapsing field
Bath above lamda-point: TRD#4 spike also TRD#2
Cell #4 silent



Power sweeping just below quench:
TRD#4 no-linear temperature rise



- Cell 6 found responsible for quench.
- Quench location in the 1/4 cell within TRD#2 & 4.
- EBW overlap not responsible.
- Next test more thermometers around TRD#4.
- Goal is to resolve defect location within 3 mm.

AES4 Results

- July 12, 2007 1st test, reached 28 MV/m, then spontaneous field emitter activation, finally FE limited at 18 MV/m with strong X-rays.
- August 7, 2nd test reached 25.5 MV/m, limited by cable breakdown.
- August 21, 3rd test reached 19.5 MV/m, limited by FE. Strange processing behavior. Post-test visual inspection revealed cloudy discoloration on cavity inner surface.
- 20 um EP September 3. Next test the week of September 10.

AES2 Results

- Only one test done due to priorities given to AES1,3,4.
- June 22, 2007, 1st test quench limited at 19.6 MV/m. Little X-rays.
- Pass-band measurements show cell #4, 5, 6 and possibly #2 and 8 are candidate quenching cells.
- Pass-band measurements also show cell #1, #9 reached 35.6 MV/m; cell #3, #7 reached 27 MV/m.
- EP 20 um done, 2nd RF test Friday August 31.

What Have Been Learned

- JLAB has a successful cavity processing recipe, pioneered by John Mammosser, for ILC high gradient cavity R&D.
- By using this recipe to A6 and A7, a gradient of 25-42 MV/m is achieved.
- Repeated application of this recipe to A6 and A7 (ILC S0 “tight-loop” effort) show the quench limit varies unpredictably.
- Understanding this variability is needed to reach the ILC cavity performance goal (35 MV/m at Q0 of 1E10 with a yield 90%).
- This issue is the top priority to be addressed at JLAB.

What Have Been Learned (cont.)

- Some AES cavities (AES1 and AES3) are quench limited at 17-18 MV/m, insensitive to repeated EP processing.
- AES1 quench limit is originated in cell #3 and/or #7.
- AES3 quench limit is originated in cell #6. Some cells (cell#1,9) in AES3 have already reached 31 MV/m.
- AES4 has reached 28 MV/m and not limited by quench.
- AES2 has only received one test, quench limit 19.7 MV/m, originated in cell #4,5,6 and possibly #2,8. Other cells reached higher gradient: 27 MV/m in cell#3,7; 35.6 MV/m in cell #1,9.
- More than 40% cells in AES cavities reached 27 MV/m.
- Quench in other 60% cells are caused by defects?

Next Steps (near term plan)

- Answer question whether defect location is EBW, heat affected zone or outside. AES3 next test with more thermometers around suspected region in week of September 3.
- Determine AES4 ultimate gradient. Next test in week of September 10.
- Give AES2 more tests for full evaluation. Next test Friday August 31.

Next Steps (long term proposals)

- 1-cell thermometry for defect localization. AES1 is ideal candidate – only 2 candidate cells.
- Long distance microscope inspection suspected region assisted by anodization for understanding nature of defect (started with AES3 already at JLAB with a borrowed QUESTAR). Past experience with CESR cavity successful in identifying foreign material defect in EBW.
- Explore Ti post-purification for benefit of ultimate production yield. AES2 is ideal candidate – 5 candidate cells. JLAB furnace capability is close to need of optimal recipe.

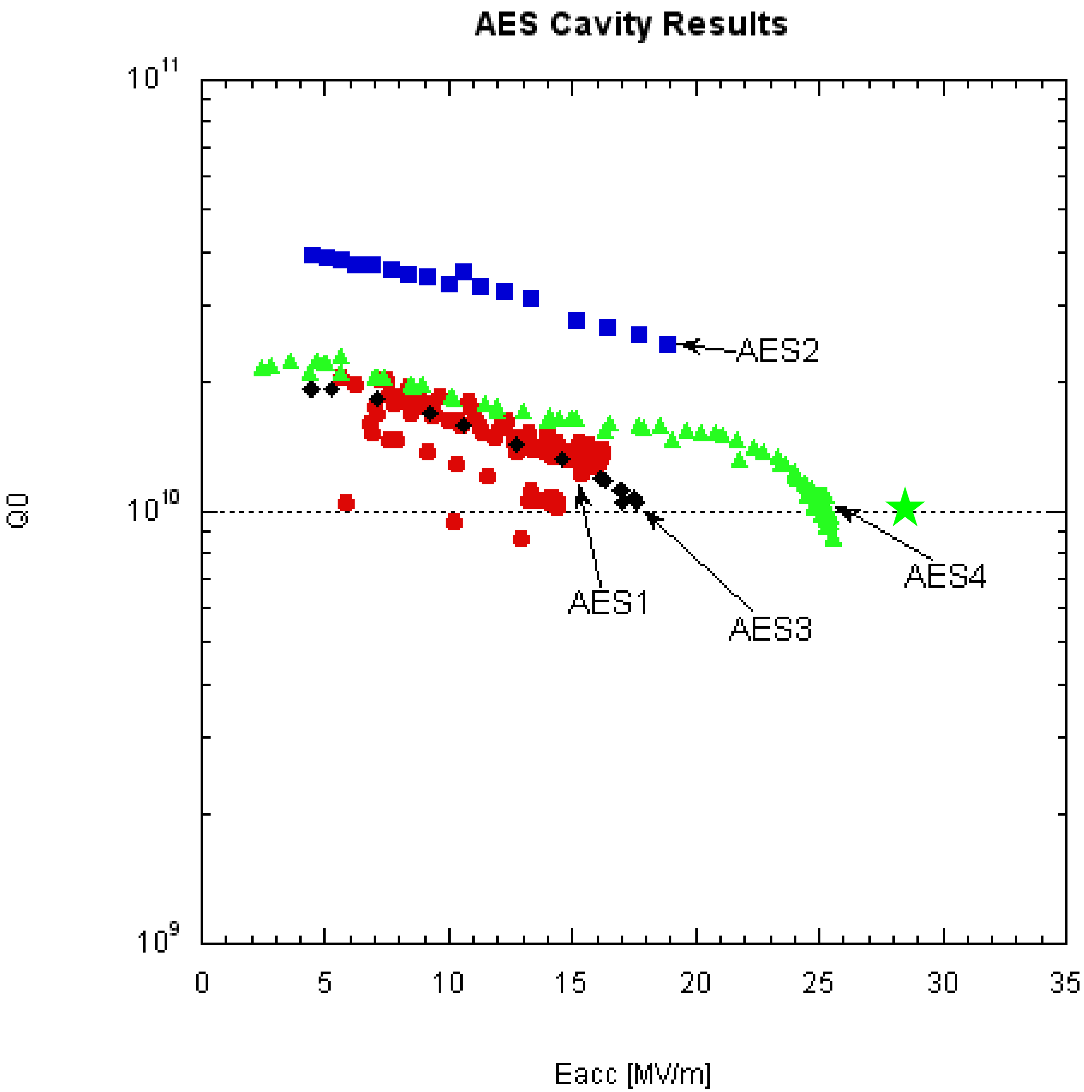
Comments: Pass-Band Measurements

Pass-band measurements useful tool for analyzing cavity behavior.
We are implementing this in cavity test Labview program for routine use.
Algorithm worked out by Haipeng Wang
Software implementation by Christiana Grenoble.
Hardware bandwidth compatibility ckecked by Kirk Davis.

volume integration by SuperFish										
u/U	fraction of total stored energy in each cell integrated E^2 and H^2 by volume between irises in SuperFish									
mode	cell 1	cell 2	cell 3	cell 4	cell 5	cell 6	cell 7	cell 8	cell 9	sum
pi	0.1090	0.1105	0.1116	0.1122	0.1124	0.1123	0.1117	0.1106	0.1098	1.0000
8pi/9	0.2133	0.1673	0.0931	0.0268	0.0000	0.0263	0.0923	0.1665	0.2144	1.0000
7pi/9	0.1963	0.0577	0.0068	0.1285	0.2200	0.1300	0.0073	0.0565	0.1968	1.0000
6pi/9	0.1677	0.0015	0.1638	0.1666	0.0014	0.1649	0.1655	0.0014	0.1672	1.0000
5pi/9	0.1322	0.0546	0.1955	0.0079	0.2198	0.0087	0.1940	0.0565	0.1308	1.0000
4pi/9	0.0940	0.1639	0.0284	0.2129	0.0018	0.2137	0.0269	0.1658	0.0924	1.0000
3pi/9	0.0577	0.2205	0.0551	0.0572	0.2205	0.0555	0.0568	0.2205	0.0563	1.0000
2pi/9	0.0273	0.1670	0.2142	0.0910	0.0008	0.0926	0.2148	0.1658	0.0266	1.0000
pi/9	0.0071	0.0561	0.1307	0.1962	0.2219	0.1957	0.1300	0.0554	0.0069	1.0000

Comments: Selective Thermometry

- As demonstrated, can single out cell from candidate cell pair determined by pass-band.
- Can determine defect location when focused region is desired.
- Spatial resolution and signal strength need trade-off. Variable coupler is necessary to do both in one test (superfluid LHe vs normal fluid LHe or sub-cooled LHe).
- More tests needed to establish credibility.
- Still relevant until a 1-cell thermometry system or 9-cell thermometry system is available.


AES Cavity Results
10^{11}
10^{10}
10^{9}
Q0
0
5
10
15
20
25
30
35
Eacc [MV/m]
AES2
AES1
AES3
AES4

Where to Get More Data

- JLAB test data are routinely (monthly) published at the web site of ILC R&D meeting hosted by Shekhar Mishra.
- Weekly JLAB EP meeting minutes, published at JLAB Docushare web site
  https://jlabdoc.jlab.org/docushare/dsweb/View/Collection-2476
- Raw data are stored in JLAB VTA computer. Given the R&D nature of these cavities, one should use caution when attempting to directly retrieve data from there.
- Way to go is to create and use a data base shared across labs contributing to ILC R&D.