Recent 1.3 GHz 9-cell Cavity Results

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AES Site Visit

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  - Worldwide summary
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- Summary

1.3 GHz 9-cell Cavity Production

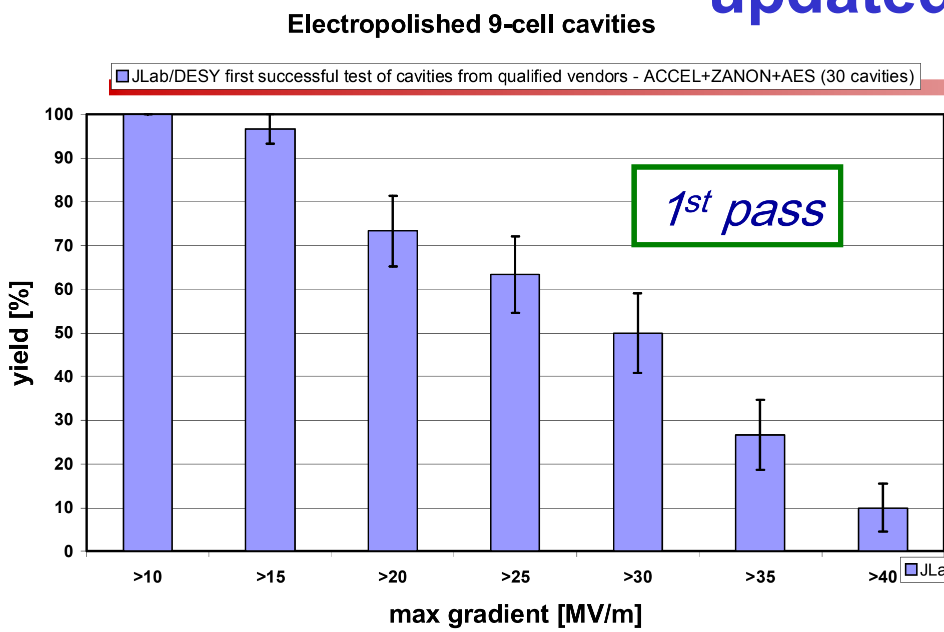
- XFEL, and now ILC (including ARRA funds), are the major drivers for 9 cell development worldwide
- Results from past 3 years have been collected in worldwide database, as a means to further track progress and provide input to ILC machine design
  - Focuses on first 2 test cycles, 'production yield'
  - Data from all three regions, from the last few years
    - KEK [5 cavities]: (MHI)
    - JLab, Cornell, Fermilab [22 cavities]: (Accel/RI, AES, JLab)
    - DESY [53 cavities]: (Accel, Zanon)
- Majority of tests in near term in Americas Region
  - ARRA cavities will add important statistics

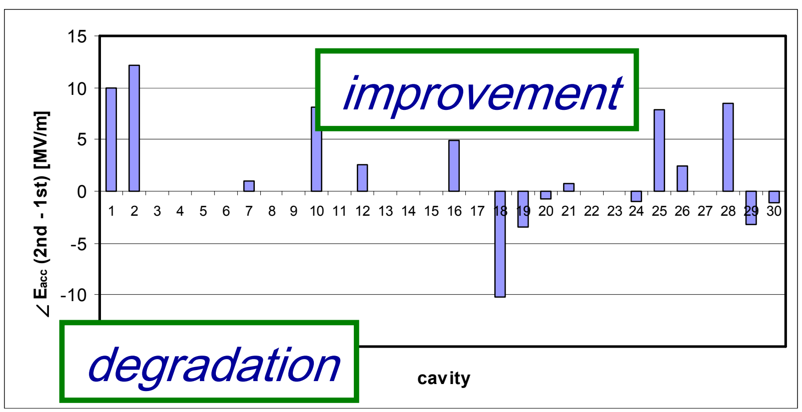
"Up-to-second-pass" ILC Production Yield Plot - Method

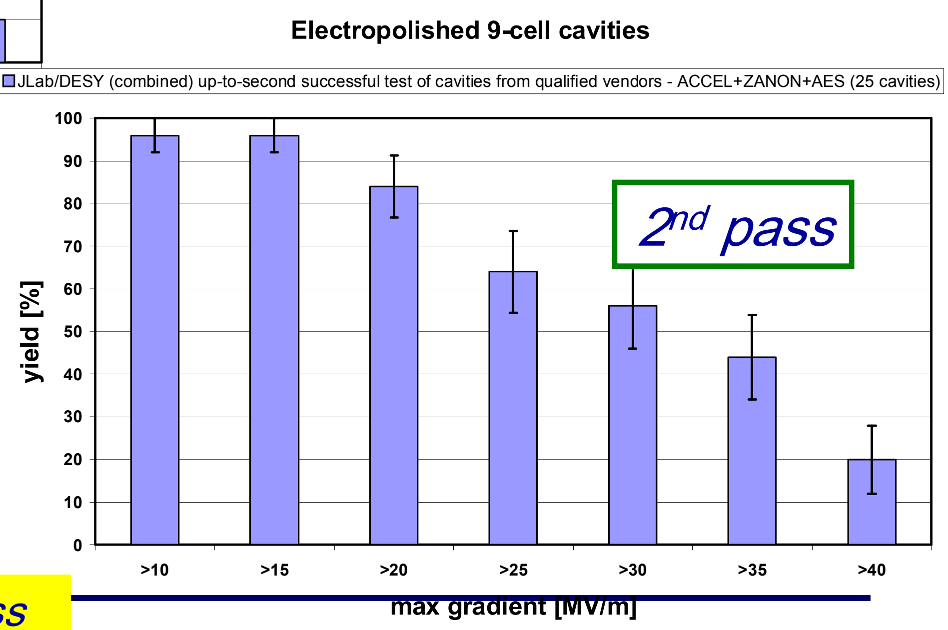
- Cavity from vendors who have manufactured a cavity that has surpassed 35MV/m in vertical test:
  - ACCEL or ZANON or (AES SN>=5)
- Fine-grain cavity
- Use the first successful (= no system problem) test
- Standard EP processing: no BCP, no experimental processes
- (Ignore test limitation)
- Second pass
  - if (Eacc(1st successful test)<35 MV/m) then
    - if (2nd successful test exists) then
      - plot 2nd test gradient
    - else
      - plot nothing [assume 2nd test didn't happen yet]
    - endif
  - else
    - plot 1st successful test gradient
  - endif

Compare 1st and 2nd pass yields

updated, Dec. 2009





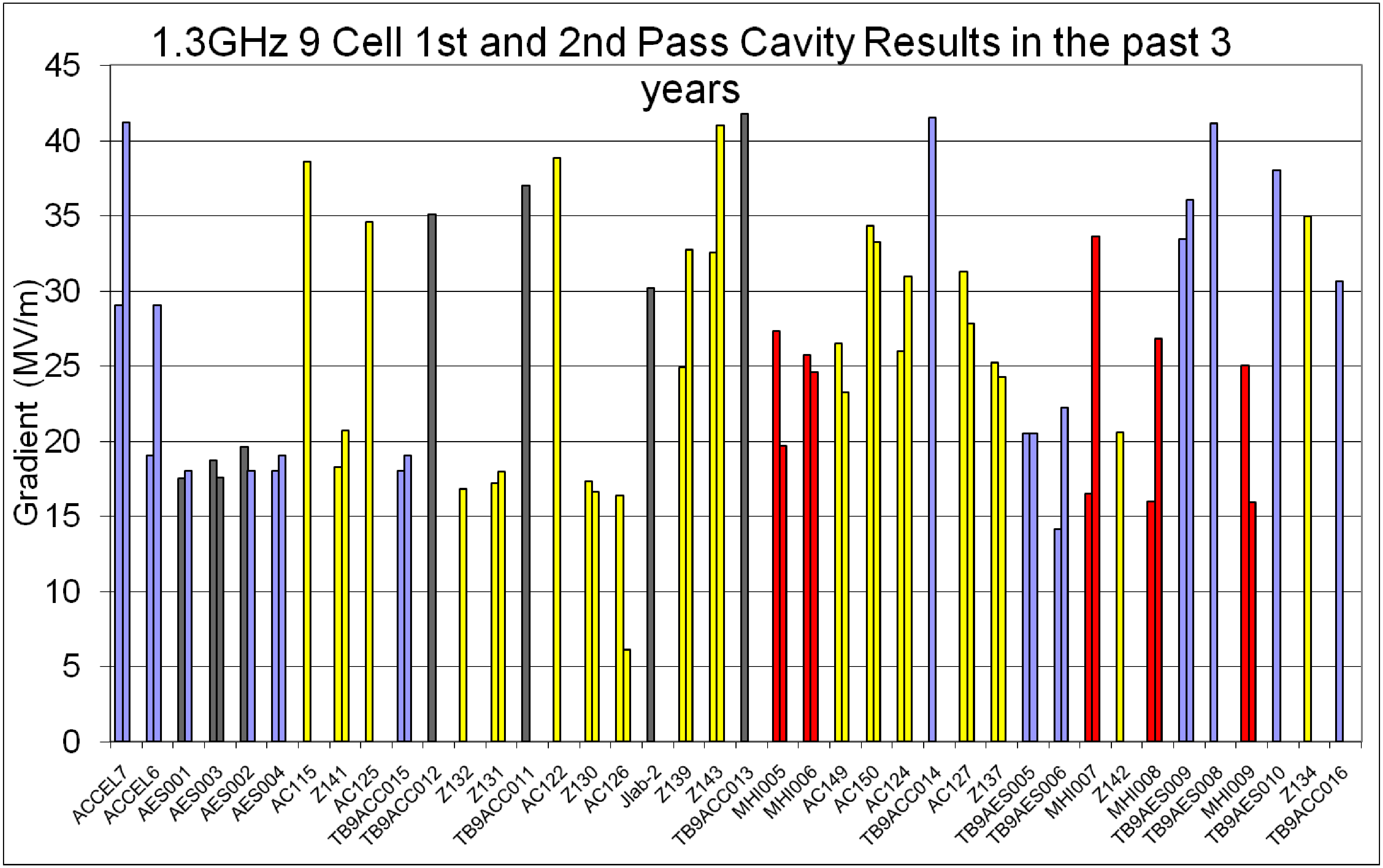


Performance typically improves after 2nd pass

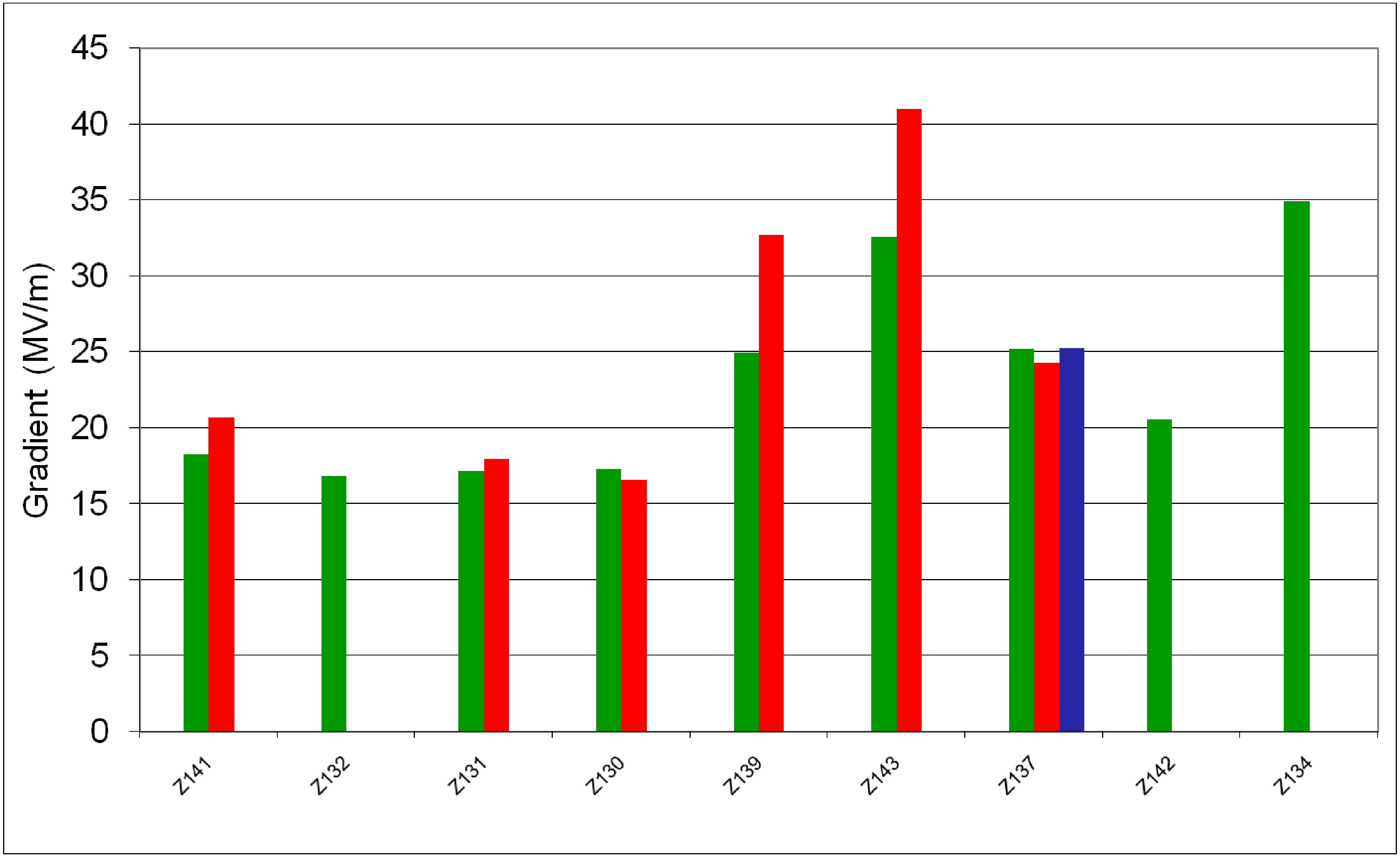
Summary of ILC Cavity Gradient Status

- Global Database has been created
  - Consistent, reproducible plots incorporating worldwide data
- Production, 2nd pass yield of 44% for vendors with a cavity >35MV/m in vertical test
  - Q0 goals met by all cavities >35MV/m--efforts will continue on this aspect as well
- Considerable number of cavity tests coming in 2010
  - Cavity deliveries and orders keep the system loaded
  - Processing and Test Infrastructure up to speed
    - Fermilab completed 6 VTS test cycles in December
  - Better diagnostic equipment in place

Worldwide Vendor Gradient Summary

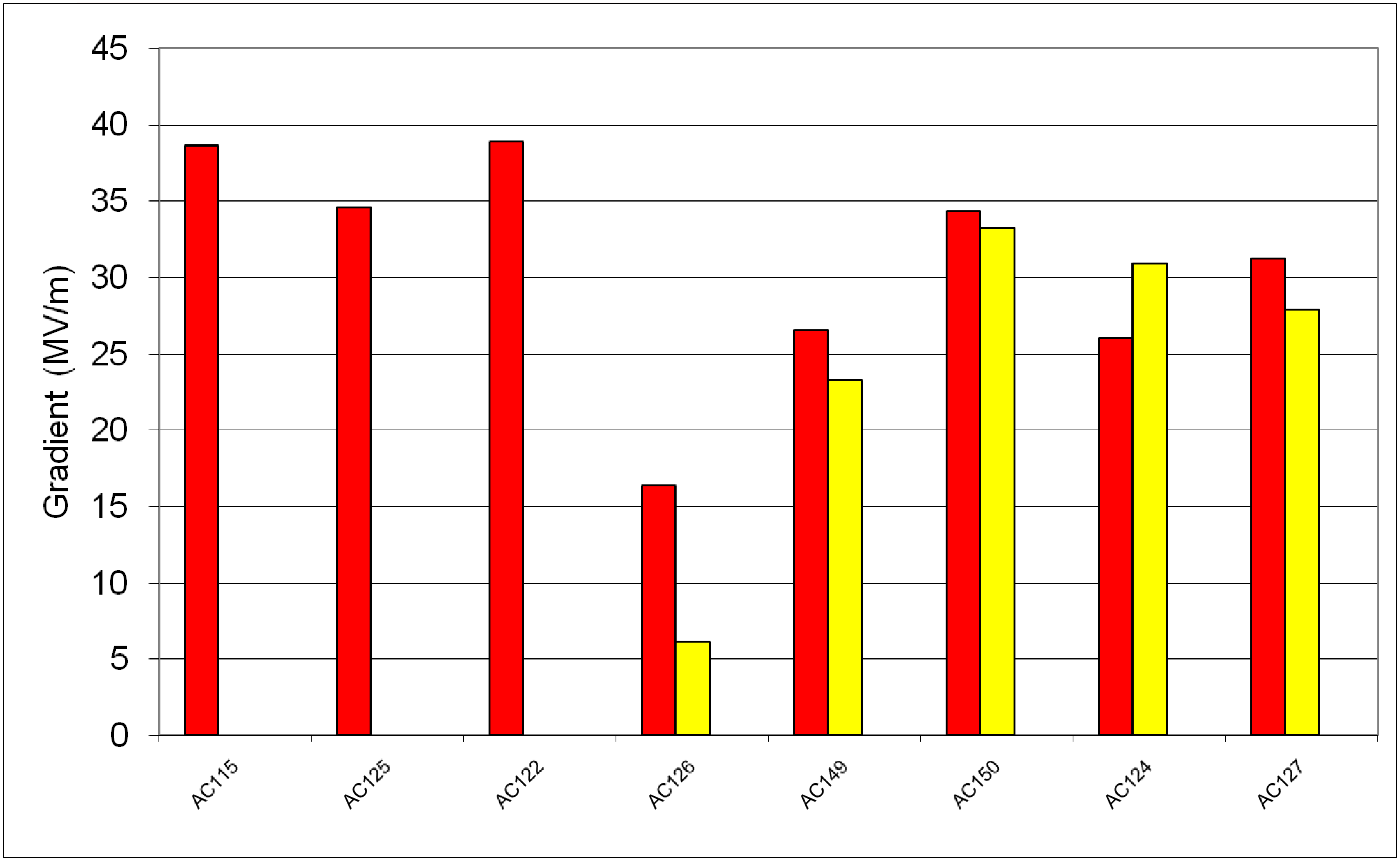


Zanon (XFEL)



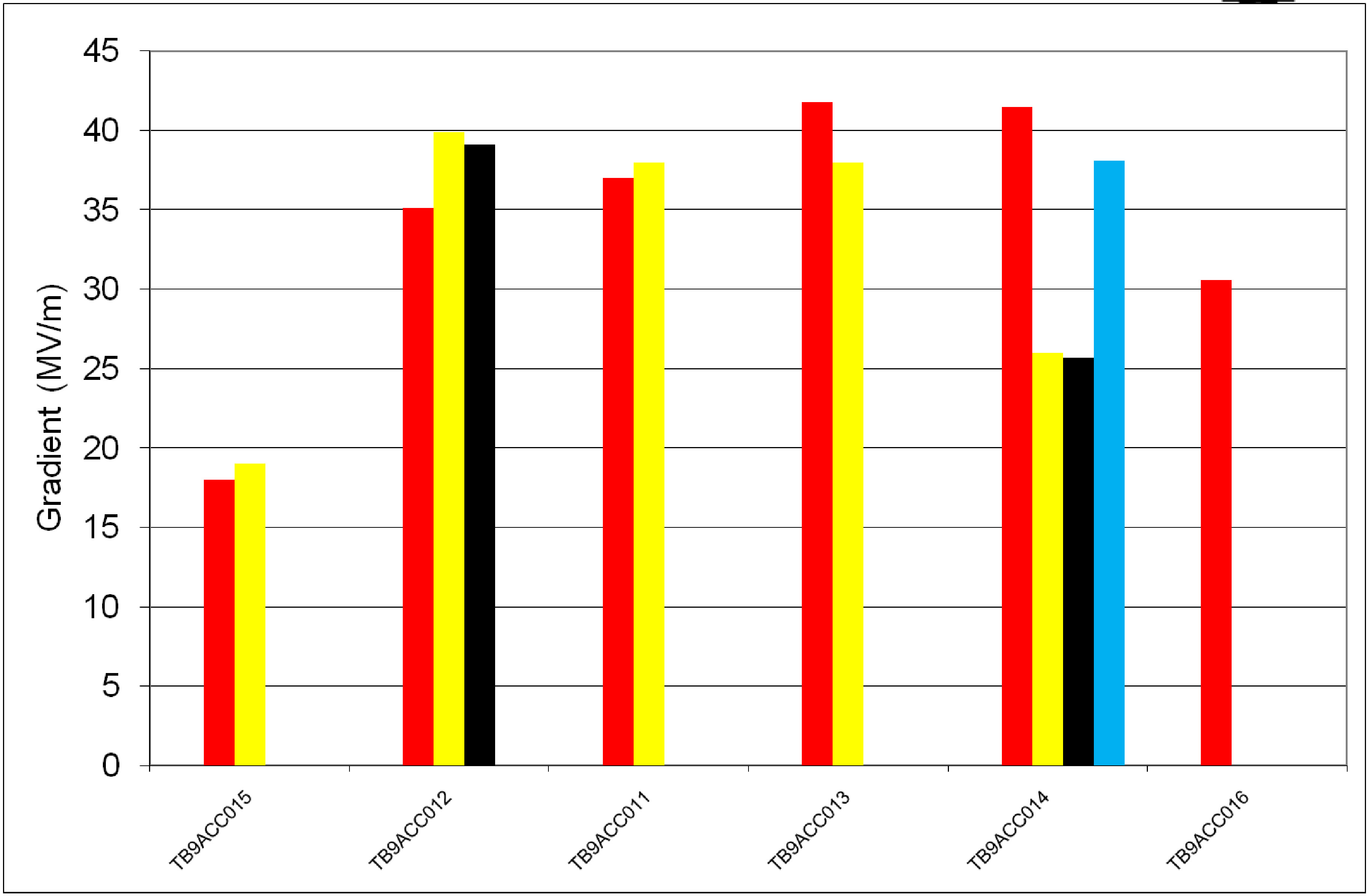
Gradient (MV/m)
45
40
35
30
25
20
15
10
5
0
Z141
Z132
Z131
Z130
Z139
Z143
Z137
Z142
Z134

Accel (XFEL)

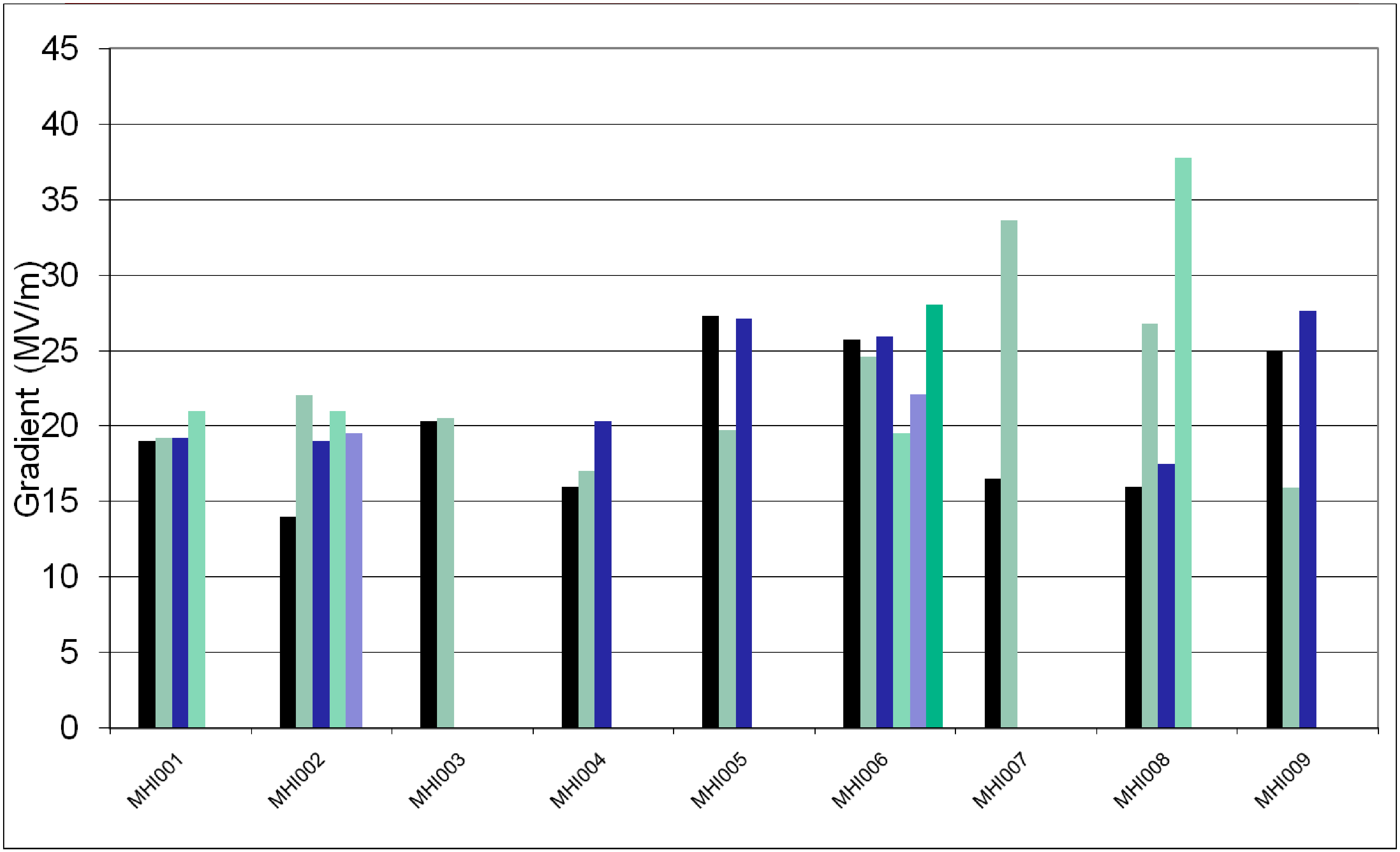


45
40
35
30
25
20
15
10
5
0
Gradient (MV/m)
AC115
AC125
AC122
AC126
AC149
AC150
AC124
AC127

Accel (Americas)

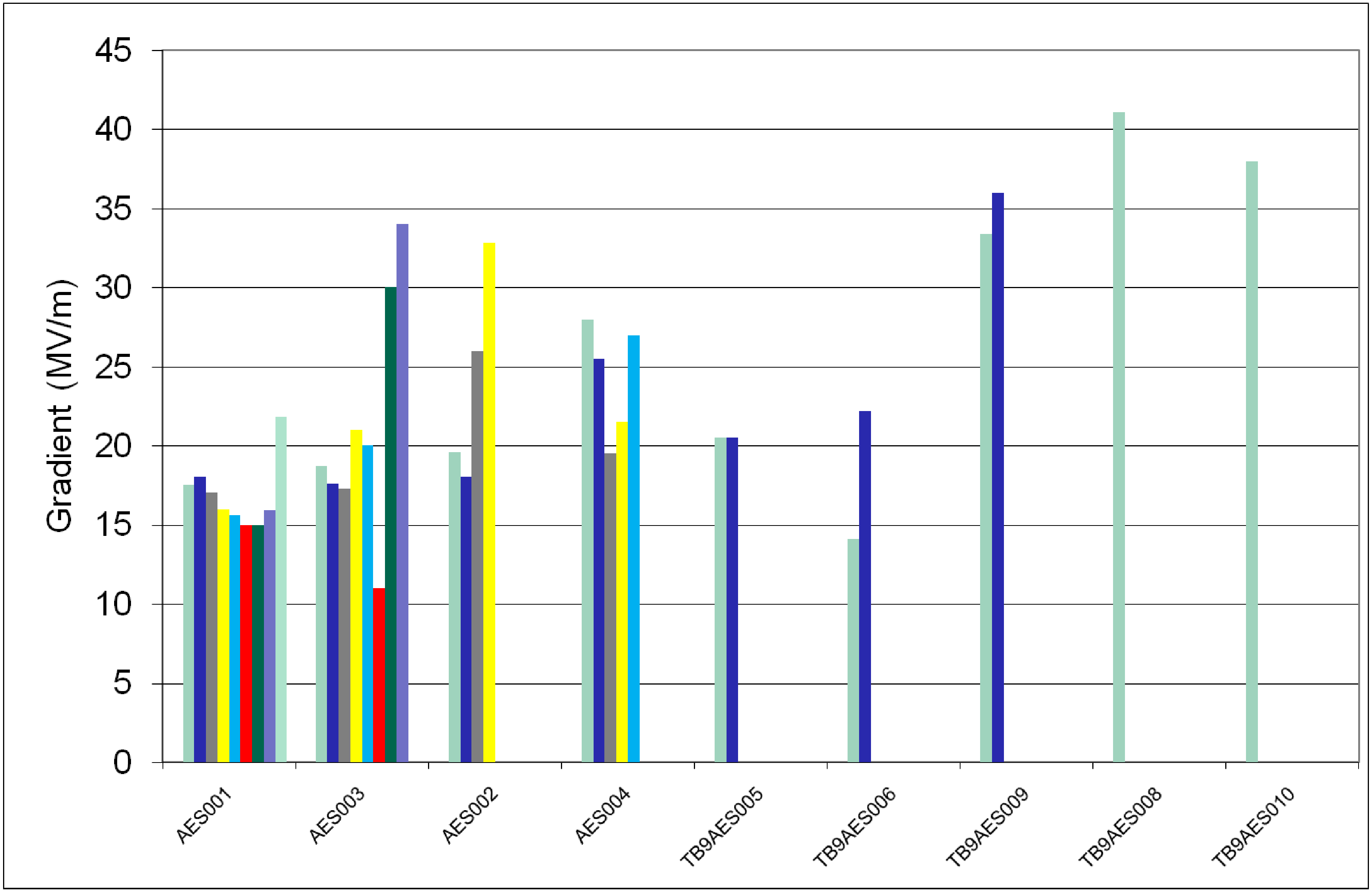


MHI



Gradient (MV/m)
45
40
35
30
25
20
15
10
5
0
MHI001
MHI002
MHI003
MHI004
MHI005
MHI006
MHI007
MHI008
MHI009

AES



45
40
35
30
25
20
15
10
5
0
Gradient (MV/m)
AES001
AES003
AES002
AES004
TB9AES005
TB9AES006
TB9AES009
TB9AES008
TB9AES010

Gradient Summary

- Good Progress Worldwide in Cavity Production, Processing, and Test
- Progress is a partnership between industry and laboratories, results are dependent on both performing well
  - Scars, pits, stains, dirt and residue introduced at different steps
  - Early defects are not typically overcome by the standard processing steps
- The typical learning curve at each company requires a ‘few’ cavities
  - constant vigilance required afterwards to stay there
- Yield statistics to the ILC specification show improvement in the past year
  - Utility of XFEL test data for ILC will be limited by XFEL requirements
- Efforts to exceed ILC gradient spec will continue
  - Field emission prevention at all gradients remains important
- Laboratory Processing and Test facilities are coming up to speed, recent throughput at Fermilab for instance is very good

Status of the AES 9-cell Cavities

Data from JLab, KEK, LANL, FNAL

AES cavity processing @JLab

Processing Recipe
J. Mammosser (JLab), TTC Mtg@Fermilab, April 2007

Cumulative Material Removal (microns)
R. Geng (JLab), AES Mtg @JLab, Aug 2007

Processing recipe

- Degrease
- Electropolishing (20 μm)
- Degrease
- First HPR+dry
- First cleanroom assembly
- Second HPR+dry
- Final cleanroom assembly
- Evacuation and leak check
- Low temperature (110 C) bake

	1st test	2nd test	3rd test	4th test
AES001	213	236	252	269
AES002	164	190		
AES003	177	200		
AES004	221	257	277	

Note: updates since August 2007 are not shown

Most of the AES001-4 cavity processing work was done 2006-2007

Note: all cavities get 150 um bulk EP

AES001 Summary

- JLab: 4 process/tests Mar.-May 2007
  - Quench field repeatedly ~17 MV/m; no x-rays measured
  - Pass-band mode measurements implicate cell #3 and #7 ; confirmed with FNAL fast thermometry to be cell 3 (counting from input coupler)
- Visited PAC07 for LANL show-and-tell
- FNAL: 3 tests Sep.-Dec.2007
  - Only HPR (at JLab) before first test
  - Quench field repeatedly ~16 MV/m; no x-rays measured
  - passband mode measurements and FNAL fast thermometry found hot spot(s) in heat-affected zone
- KEK/Kyoto: Assorted development/commissioning Dec.2007-Dec.2008
  - First demonstration of Kyoto/KEK camera system: double-spot found corresponding to quench location; additional spot found
  - mode measurements imply max gradient anywhere ~lower 20's MV/m; some field emission seen at higher gradients
  - used for STF commissioning, including light EP
  - gradient improved to 22 MV/m; mode measurements imply 6 cells limited to ~lower 20's MV/m, 3 cells could get up to 40 MV/m
- First cavity welded at FNAL into He vessel; some welds not full penetration; used for warm HTS commissioning; do not expect HTS cryogenic test; currently in storage

AES002 Summary

- All surface processing work was done at JLab
- Always quench limited at JLab
  - 19.6,18.0, 26.0, 32.8 MV/m
- Was until recently the best performer of the first AES production batch; had been stored at JLab un-sealed when tapped for dressing
- Fifth Fermilab-dressed cavity initially intended for S1-Global cryomodule
- Vertically tested (dressed) twice at Fermilab with HPR in between; performance degradation to 19 MV/m with FE onset 12 MV/m
  - decision to replace with AES004 in S1-Global
- Currently in storage at Fermilab; good candidate for dressed cavity R&D, e.g., dressed BCP or dressed EP

AES003 Summary

- JLab: 4 process/tests Jun.-Aug. 2007
  - Quench field repeatedly ~18 MV/m; no x-rays measured
  - Pass-band mode measurements implicate cell #4 and #6 ; confirmed with FNAL fast thermometry to be cell 4 (counting from input coupler)
  - mode measurements imply max gradient anywhere ~lower 20's MV/m; some field emission seen at higher gradients
- FNAL: 2 tests Jan.-Apr. 2008
  - hot(-test) spot found more precisely, mode measurements, first test of variable coupler
- LANL:
  - test stand commissioning and instrumentation development
  - bunch of spots found correlated with thermometry
  - Has been scratched on the iris (see picture next slide)

AES003 scratch

T. Tajima (LANL), TTC 2008, Oct 2008

Office of Science

Cell 7 iris to cell 6, approx. 70°. This might have been caused by a screw head of the inspection system.

AES003 Repair

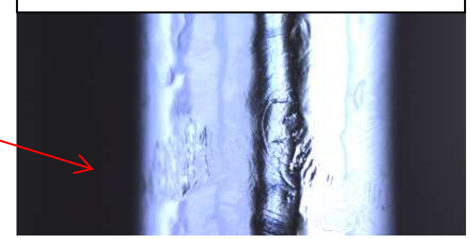
- Sent to KEK for optical inspection (Kyoto/KEK system) , local grinding of equator and iris defects, and EP

Cell 4 defect - before grinding

Cell 4 defect - after grinding and EP 50um

#1-#2iris - before grinding

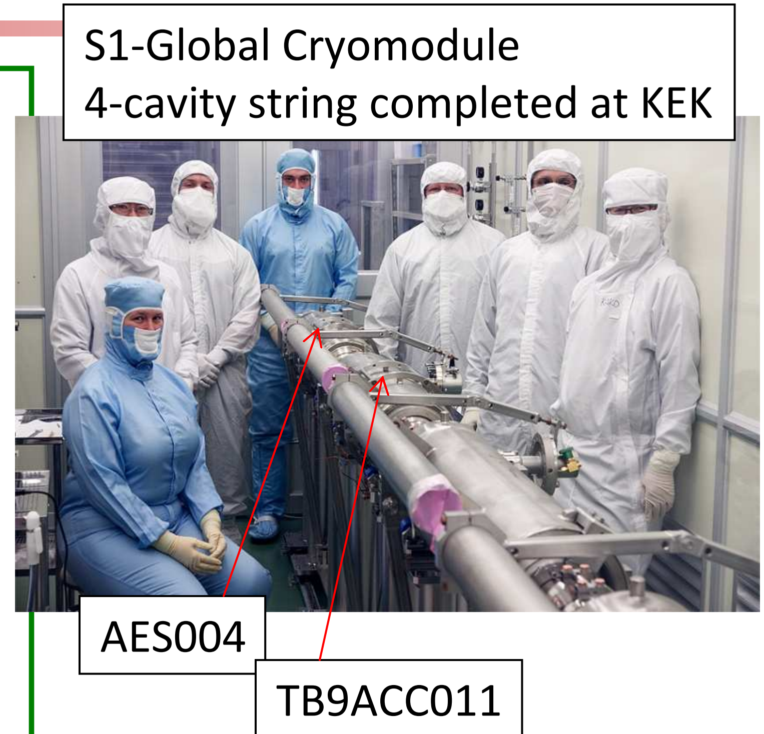
#1-#2iris - after grinding + EP-50um



- FNAL/ANL first test after partial HPR 30 MV/m; field-emission limited; no heating at previous quench site
- FNAL/ANL full HPR cycle, cavity performance improved to 34 MV/m; currently field-emission limited; additional improvement anticipated

AES004 Summary

- All surface processing work was done at JLab
- Always field-emission limited
  - 28.0, 25.5,19.5, 21.5, 27.0 MV/m
  - Iris defect found with optical inspection (see next slide)
- Used for HPR commissioning at FNAL/ANL facility
- 2nd dressed cavity at FNAL
- Horizontally tested (first cold RF test at HTS) at FNAL
  - Maximum gradient 25-31 MV/m (calibration needed work), quench limitation, field emission observed
- Currently at KEK for S1-Global cryomodule

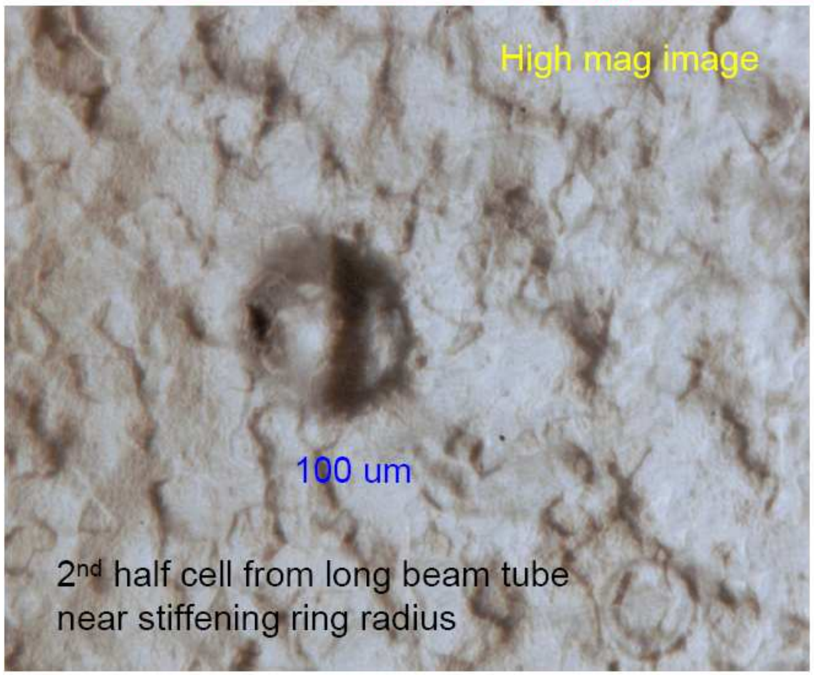


AES004 defect

R. Rimmer (JLab), LCWS 2008, Nov 2008

AES4 High E Field Region

Cavity FE limited even after repeated EP
pass-band measurements suggest field emitters in end cells



TB9AES005, 6

- FNAL incoming inspection waived for expedience
- TB9AES005
  - Two RF tests with light EP in between
    - 20.5 MV/m both times
    - defects observed in optical inspection
  - At Cornell for tumbling and VEP
- TB9AES006
  - Two RF tests at JLab with light EP in between
    - 14.1 MV/m, 22.2 MV/m
    - defects observed in optical inspection
  - Currently in storage at JLab; candidate for tumbling or other remediation

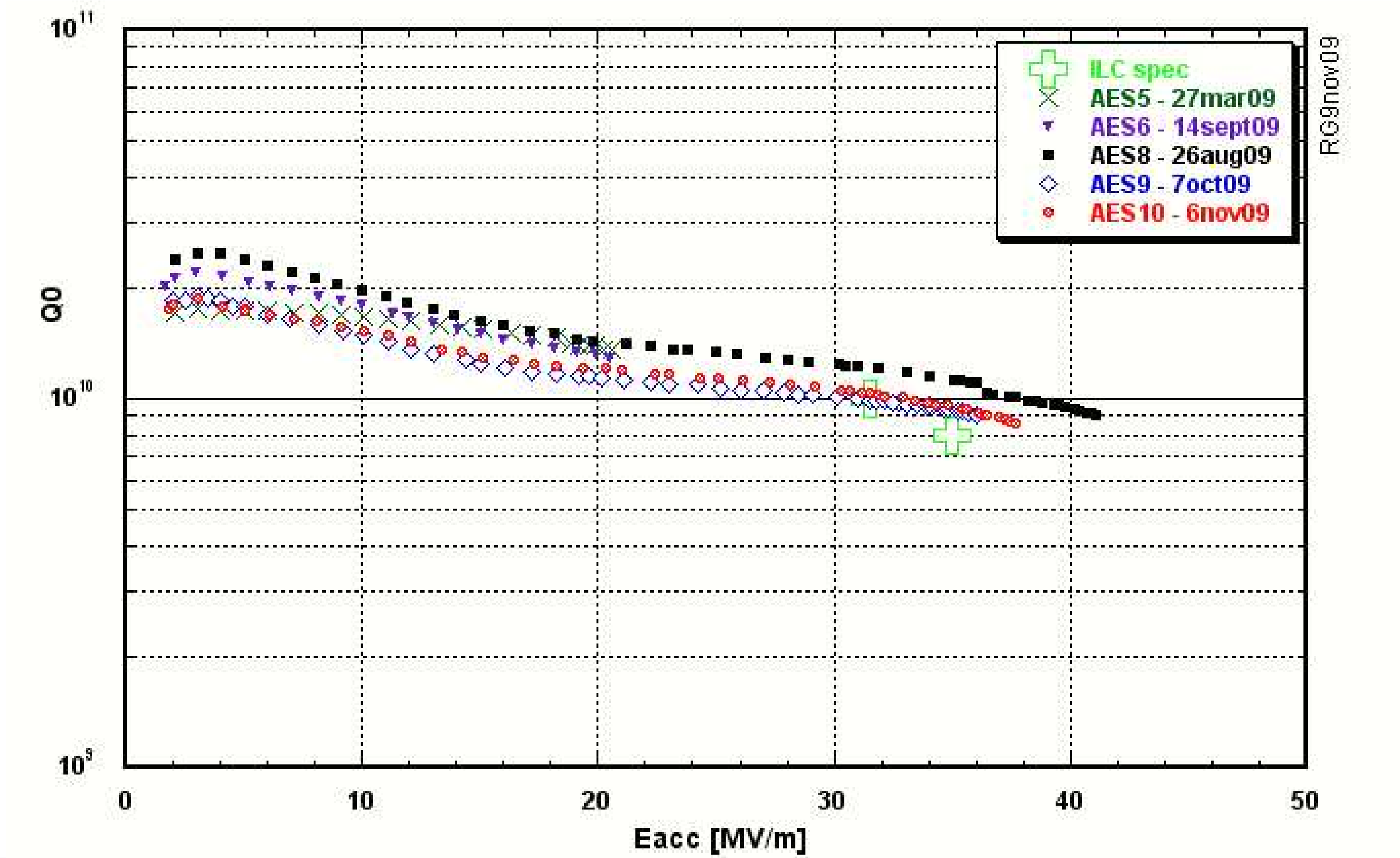
TB9AES007

- FNAL incoming inspection showed void in HOM weld (see photo)
  - No remediation – wait and see
- To get final surface process this week at JLab and cold vertical test soon thereafter

TB9AES008,9,10

- All surface processing done at JLab
- TB9AES008
  - Had end group replaced because of assembly error in which end groups were 180 degrees out of alignment; field probe end group was cut off and replaced with spare unit
  - One cold vertical test at JLab
  - 41 MV/m (best ever, and might have gone higher – administrative limit)
  - is welded with Ti trans rings and at MP9 now for welding into its helium vessel
- TB9AES009
  - Two vertical tests at JLab: 30.0 MV/m (FE), 36.0 MV/m (quench)
  - Dressed at FNAL
  - Ready for horizontal test; next test cycle in early March
- TB9AES010
  - One cold vertical test at JLab
  - 38.0 MV/m (quench)
  - is welded with Ti rings and at MP9 now (in queue for welding into its helium vessel after TB9AES008)

Performance Summary of AES 2nd production



3 of the 5 exceeded ILC S0 specification

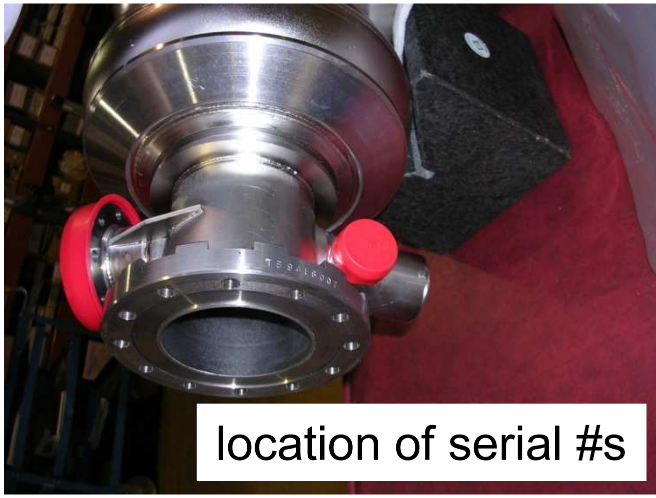
Incoming Inspection

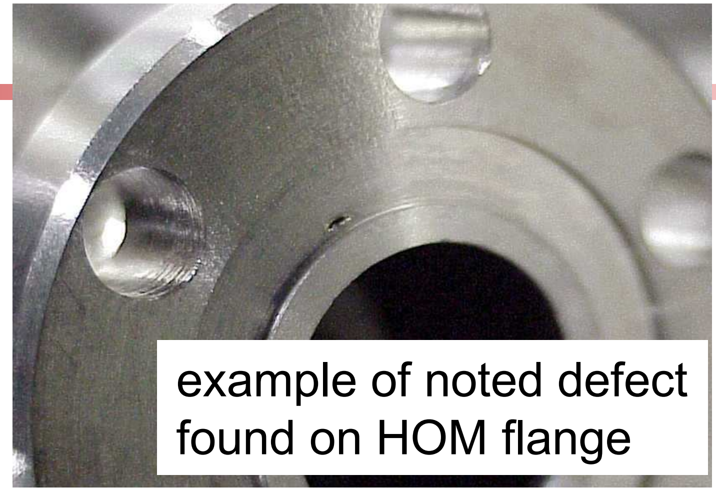
inspection performed by QA specialist;
signed off by engineer/physicist

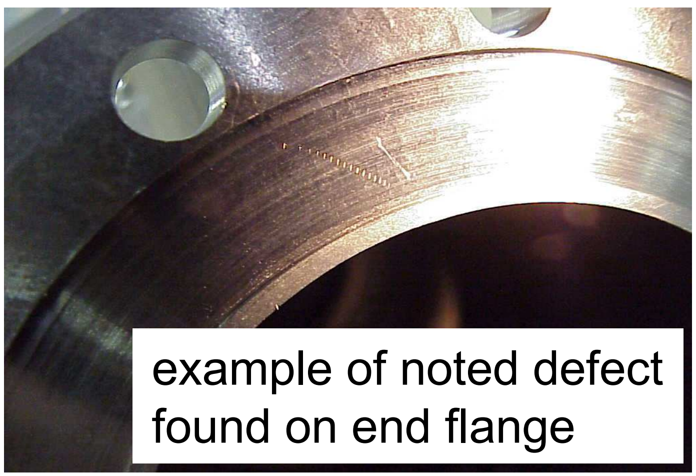
- Visual inspection
  - adequate packaging, flange sealing surface quality, overall external integrity (no dents or scratches), Nb sheet serial #'s, cavity serial #'s
- Leak check
  - oil-free leak detection system with sensitivity 2 E-10 atm-cc/sec or better.
  - No grease or o-rings on the cavity sealing surface; Al hex seals only
  - sealing surfaces may be cleaned with lint-free wipes and alcohol (IPA)
  - no detectable helium leak at room temperature
- CMM
  - cavity: straightness, length, bolt clocking, etc.
  - transition rings: parallelism, ring diameter, etc.
- Incoming room-temperature field flatness

- cavity is cut out of bag at start and left out of bag at end to reduce handling
- cavity is only touched with nitrile (or equivalent) gloves
- whole process takes about 5 days

Inspection Data Examples


location of serial #s


example of noted defect found on HOM flange


example of noted defect found on end flange

Summary

- Progress is a partnership between industry and laboratories, results are dependent on both performing well
- The number of vendors making quality cavities has increased in the past couple of years
- Diagnostic and remediation tools have improved dramatically in the past couple of years
- Americas Region will process and test the majority of 9-cell 1.3 GHz cavities in the next year

Backup Slides

Cavity Processing Steps-Details

Fermilab

Allan Rowe presentation 12 Feb 2010

- Cavity Inspection
  - Visual Inspection
    - Sealing surface integrity
      - Free of radial scratches
      - Machining/finishing marks all circumferential
    - Cavity cleanliness
      - Free of oils, finger prints, dirt, and grime
      - No undue discoloration
      - Vapor film from Ebeam welding deposited on exterior of cavity should be removed where possible
    - HOM cans intact
    - No denting, scratches, scrapes, or other marks
    - Cavity labeled clearly and correctly
  - Mechanical Inspection
    - CMM measurements to verify fabrication tolerances
    - Vacuum leak check

Cavity Processing Steps-Details

Fermilab

- **Cavity Inspection cont…**
  - Optical Inspection (Kyoto camera system)*
    - Inner surface scanned for abnormalities
  - RF Inspection
    - Field-flatness measurements (Bead-pull)
    - Frequency measurements
    - Preliminary RF tuning

Allan Rowe presentation 12 Feb 2010

*AES internal optical inspection technique TBD

Kyoto optical inspection system

RF tuning machine

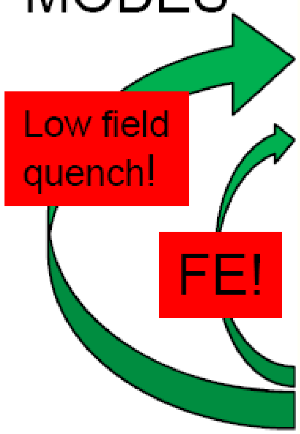
Cavity Processing –Vert. Test

Fermilab

Allan Rowe presentation 12 Feb 2010

Process Step	Required Tool
Clean & Degrease	Ultrasonic Tank + UPW
Outside BCP (20um)	BCP Tool
Bulk Electropolish (120 um)	EP Tool
Ultrasonically Clean	Ultrasonic Tank + UPW
Hydrogen Degasification	Vacuum Oven (800C)
RF Tuning	Tuning Machine
US Clean + Light EP (20 um)	EP Tool + US Tank + UPW
Alcohol Rinse + US Clean	Ultrasonic Tank + UPW
High Pressure Rinse	HPR Tool + UPW
Clean Assem. & Evacuation	Vacuum Skid + Class 10
Low Temperature Bake	Vacuum Oven (120C)
Vertical Test	

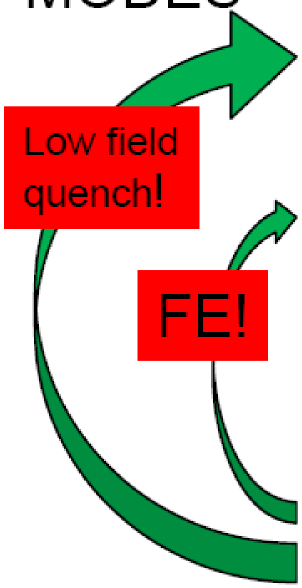
FAILURE MODES



Processing Cycle – Horiz. Test

Allan Rowe
presentation
12 Feb 2010

FAILURE MODES



Process Step	Required Tool
Helium Vessel Welding	EB/TIG Welder
Ultrasonically Clean	Ultrasonic Tank + UPW
*Light BCP or EP (20um)	BCP or EP Tool
Alcohol Rinse + US Clean	Ultrasonic Tank + UPW
High Pressure Rinse	HPR Tool + UPW
Clean Assem. & Evacuation	Vacuum Skid + Class 10 cleanroom
Horizontal Test or String Assembly	

*Step eliminated with success for S1 Global Program.
Capability still desired for reprocessing poor performing cavities.

Backup Slides

- Progress is a partnership between industry and laboratories, results are dependent on both performing well
- Hand off between company and laboratory is dependent on capabilities and expertise developed at company, but quality always has to be verified at the handoff point
- Qualification / Verification of new processes / steps in a process requires careful planning