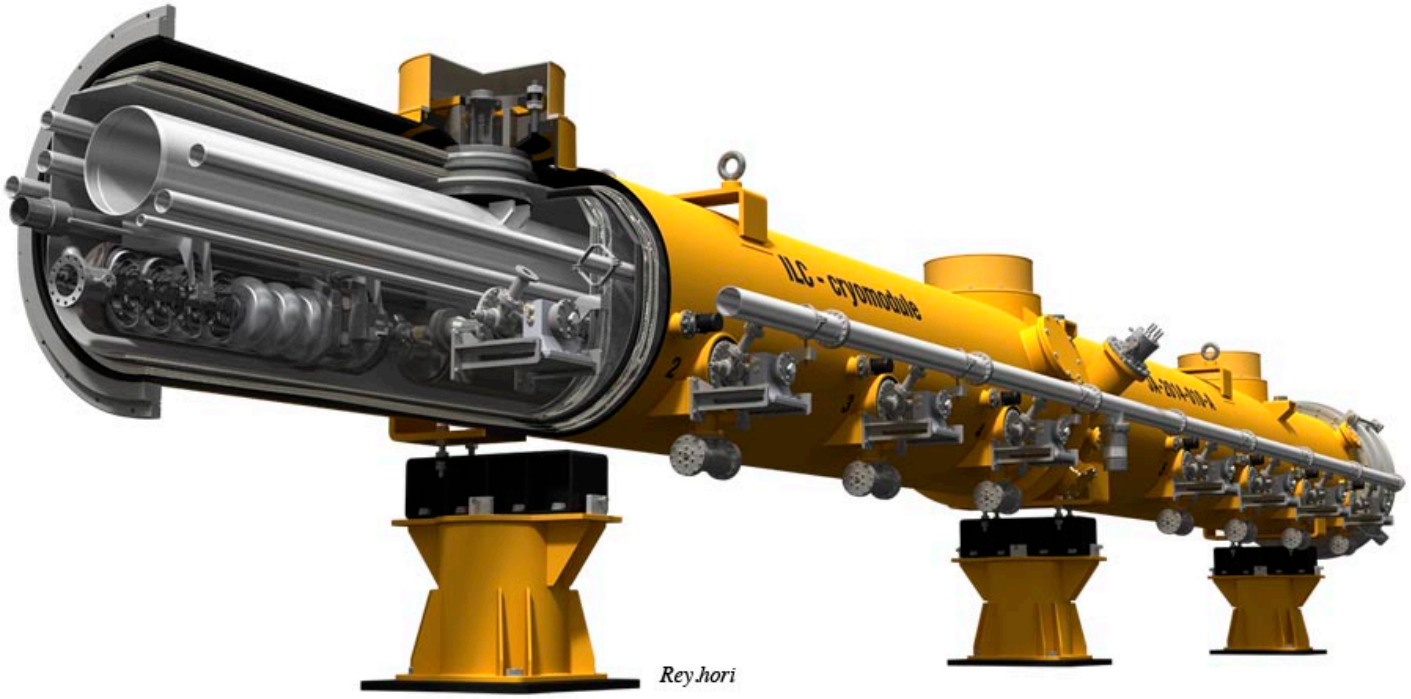
SRF Technology : status and plan



H. Hayano (KEK)

SC RF activities Highlights

from TTC at DESY (Jan. '08) and recent new results

Asia;

KEK STF 0.5; TESLA-type cavity cooled down,
LL cavity is under cool-down experiment.
STF EP is under commissioning.
Kyoto camera provides more data of 3 DESY cavities.

EU;

XFEL is in detailed planning, under industrialization, call for tender process.
cavity package & module 3* is under pressure test. (later by Lutz)
INFN & DESY: blade tuner test results. (later by Lutz)
Saclay: Ar baking on Ichiro single cell results.
XFEL: horizontal MBK was delivered and tested.

NA;

CM 1 (module 9) is ready to test.
Ichiro#5 is under test in Jlab.
24 cavities will be delivered in 2008.
Re-plan of cryomodule development.

Status of Asia

STF development plan update

Phase 1 (2005 -2007),

for quick startup of ILC SCRF, infra-structure development
subdivided to

Phase 0.5 TESLA-shape: 1 cavity in short cryostat
(cool-down was in Oct-Nov. 2007)

Phase 0.5 LL-shape: 1 cavity in short cryostat
(cool-down will be in Feb-Mar. 2008)

Phase 1.0 : 4 cavities in each short cryostat
(cool-down schedule is under discussion)

Phase 2 (2008 - 2010),

New plan of "S1 global" is under discussion

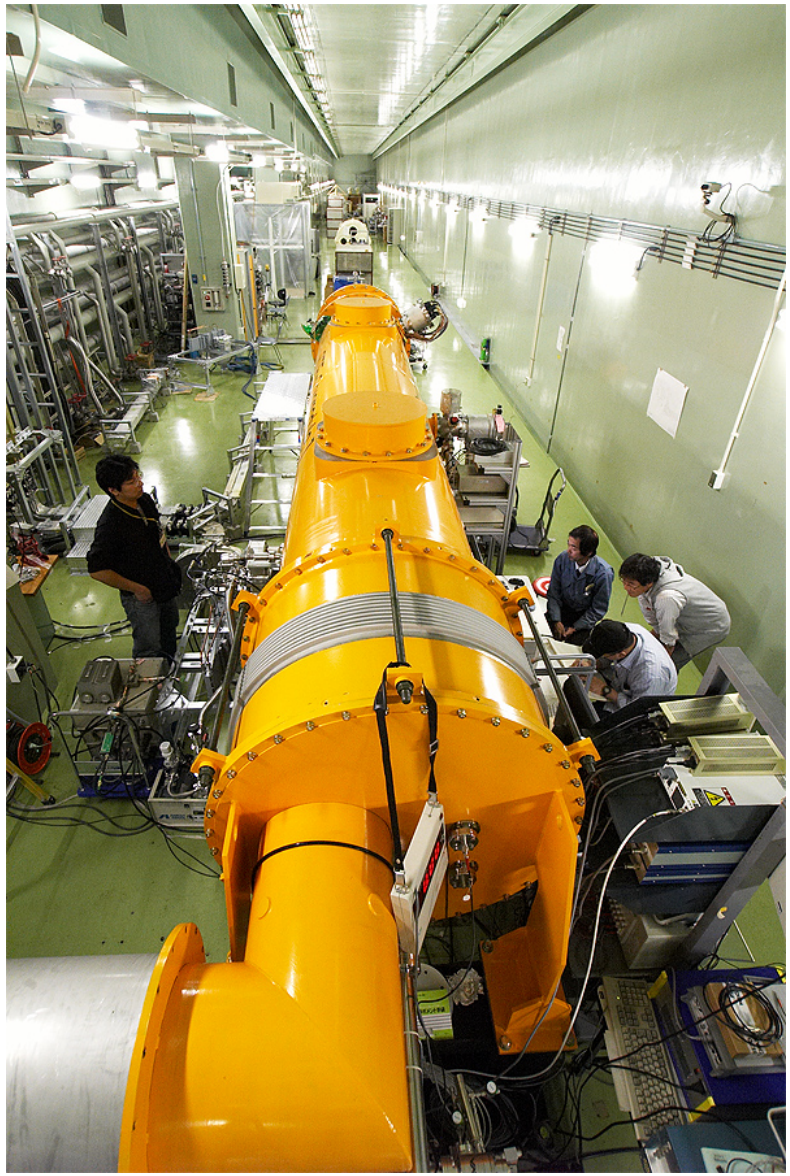
develop ILC Main Linac RF unit
start design Apr. 2008; fabrication in 2009 and 2010
completion end of 2010 (cool-down 2011)

GDE S0 task (2006 - 2009)

Phase 3 plan will be requested

develop ILC performance cavity (>35MV/m at vertical test)

TESLA-shape cavity cool-down test



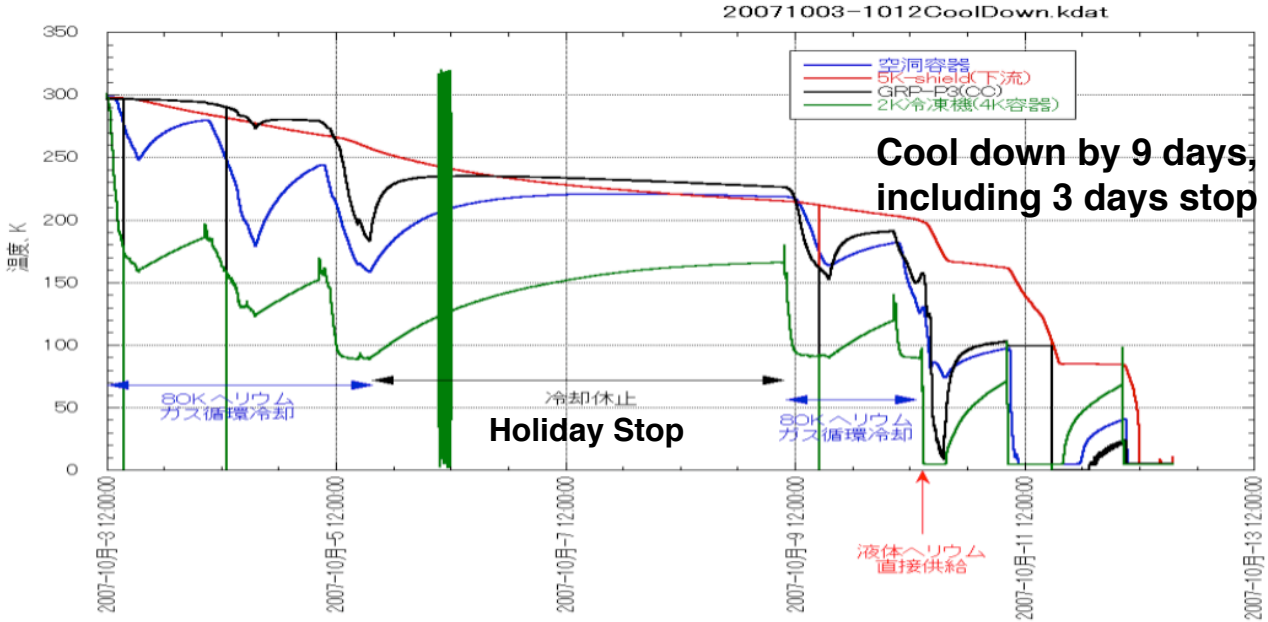
Program:

Oct. 03-12: cool down test,
suspended by SRF workshop
Oct. 22 -26: re-cool down
Oct.29 - Nov. 02 : 4K Test (1 week)
Nov.05 - Nov. 09 : 2K Test(1 week)
Nov.12 - Nov 22 : 2K with HLRF on
(2 weeks)

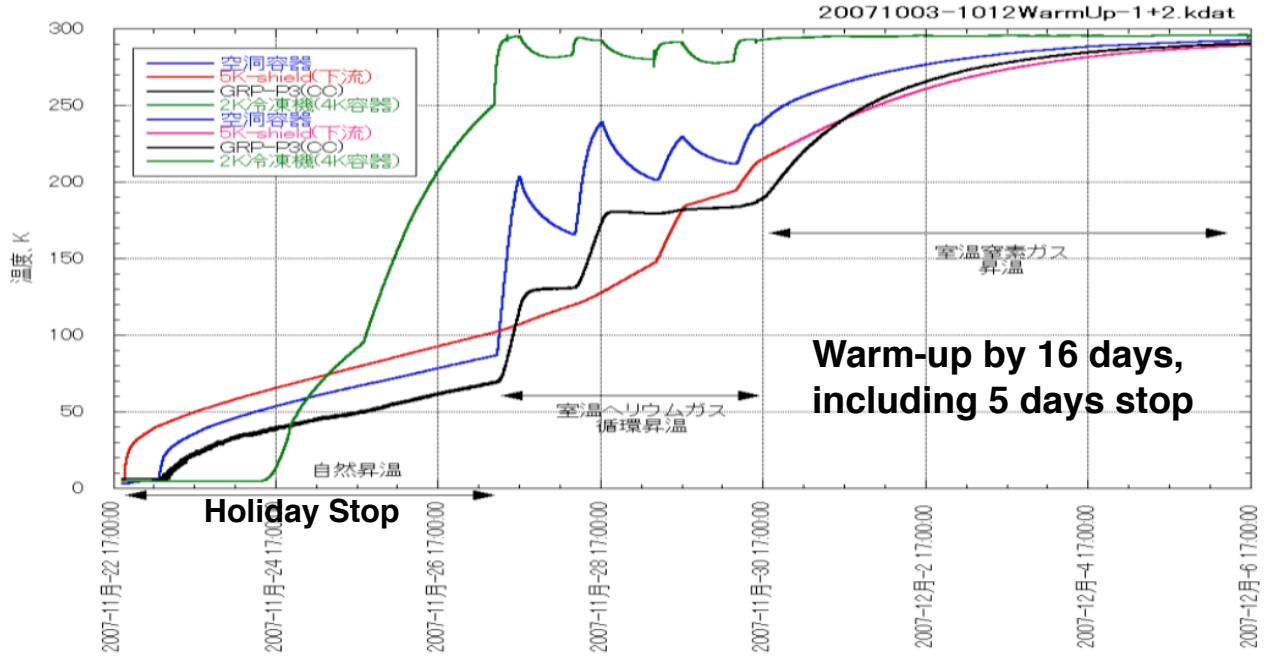
Study Item:

Cool down control
Heat load measurements
Cavity fundamentals(Q,Eacc,f0..)
Lorentz detuning
Piezo compensation
Mechanical vibration
GRP distortion by WPM
etc.

Cryomodule Thermal Performance



Cool down by 9 days,
including 3 days stop

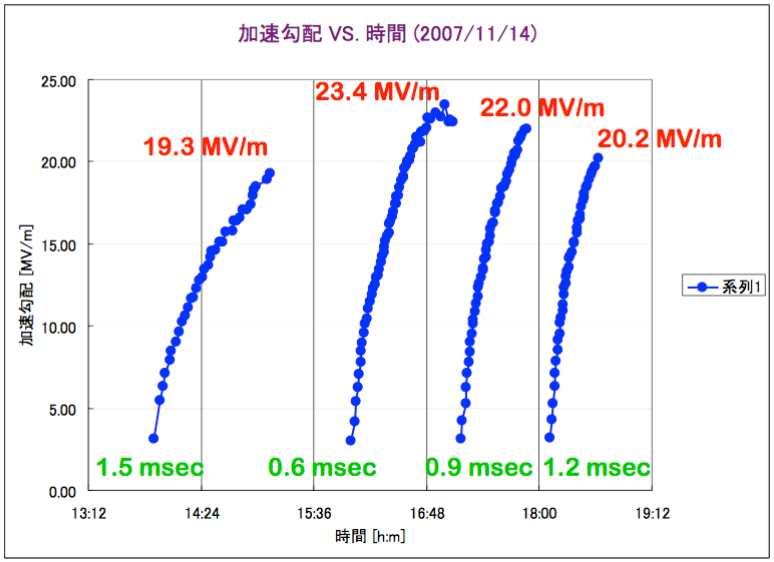


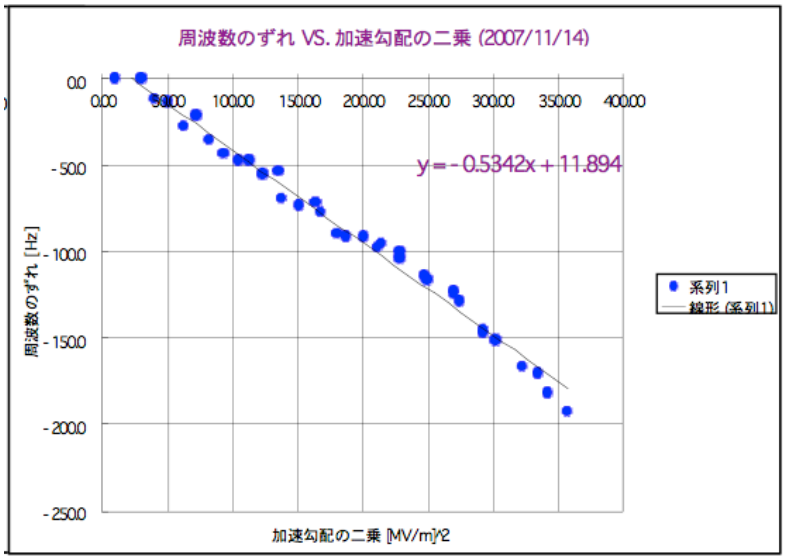
Warm-up by 16 days,
including 5 days stop

Steady state Heat Load to 2K system: 5.6W

Cavity Tests

Achieved Eacc,max



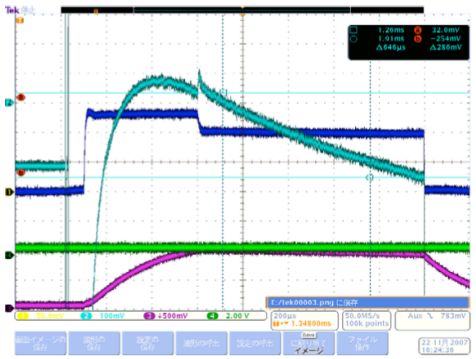


K = - 0.5 Hz/(MV/m)²

Flat-top Lorentz detuning

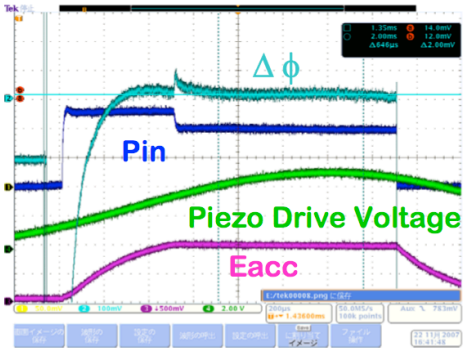
Compensation by Piezo (1) ; higher Tension

Eacc = 18. MV/m
Piezo / OFF



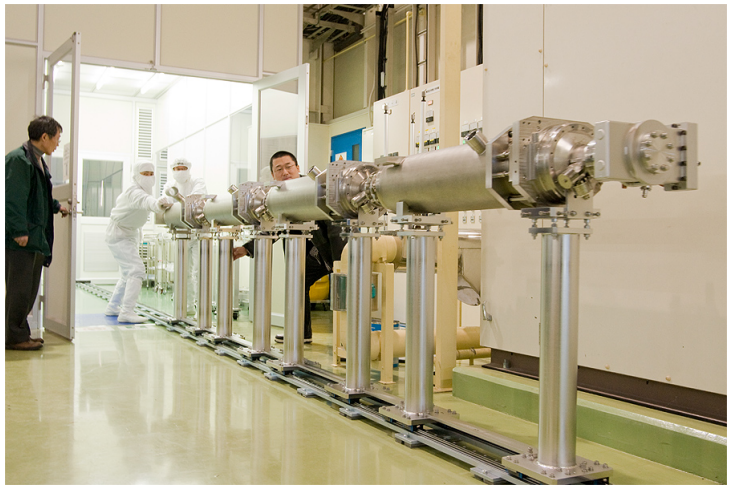
$\Delta\phi$ = - 15 °

Eacc = 18. MV/m
Piezo / ON
300 Hz, 500 V, - 700 μsec

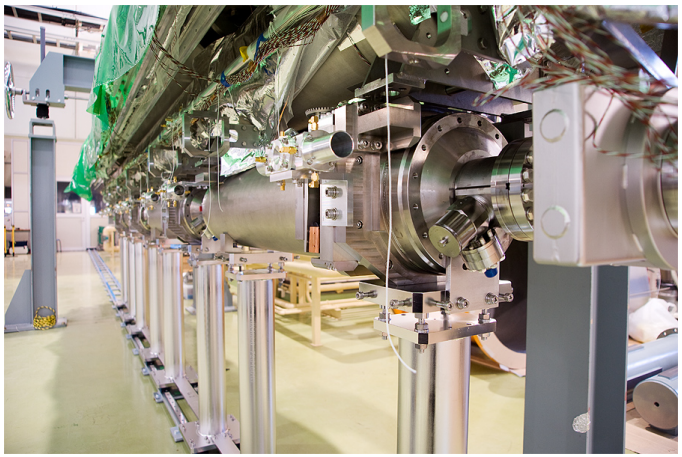


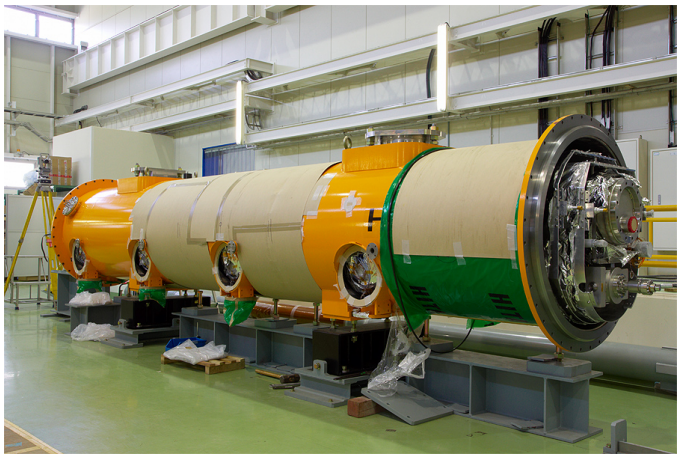
$\Delta\phi$ = ~ 0 °

4 TESLA cavities are ready for STF 1 experiment



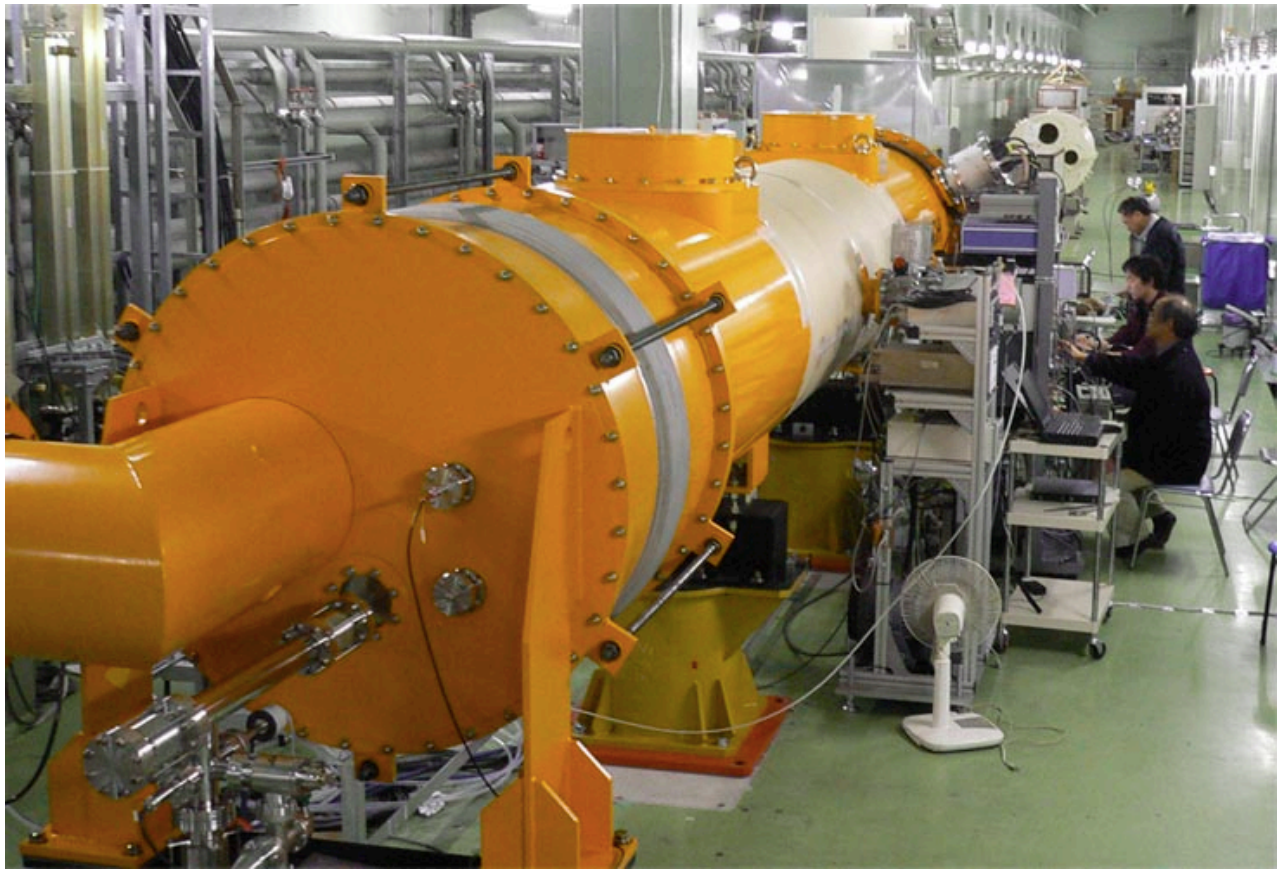
TESLA-style cavities were assembled in clean room, hung on the cold mass, and inserted into the vessel, on Feb. 29, 2008.





LL ICHIRO cavity in STF0.5 experiment

Ichiro #1 cool down test in cryomodule: Feb. 13 to Mar. 28, 2008

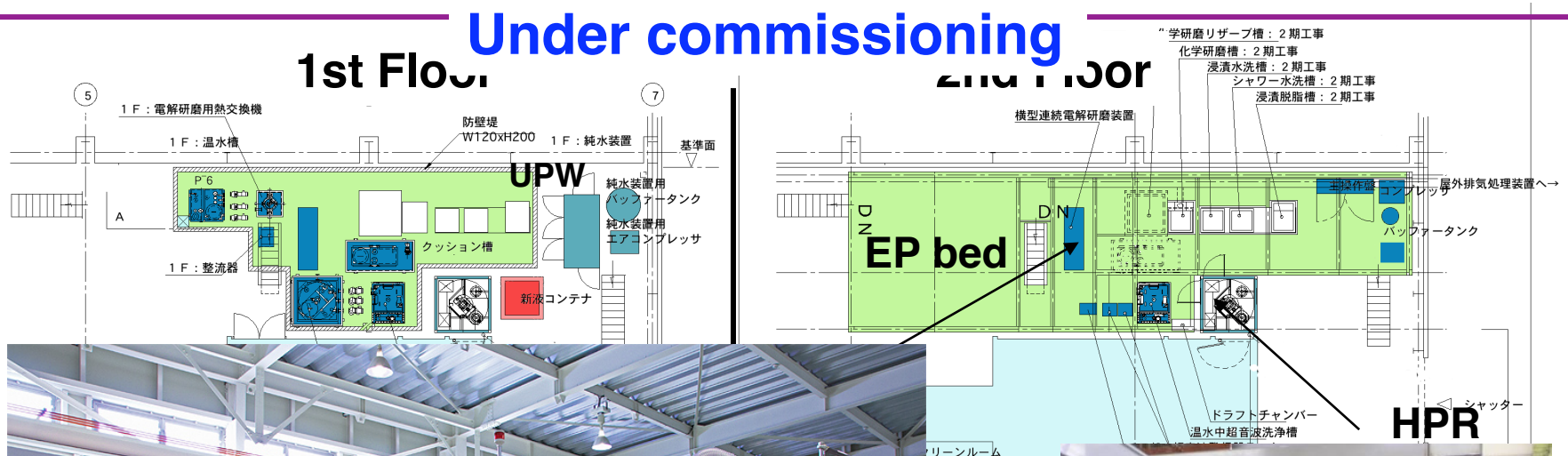


Now under test!

Heat load measurement,
Ball-screw tuner test,
coupler performance test,
cavity performance test (19.5MV/m in VT),
etc.

STF Cavity Surface Process Facility

Under commissioning

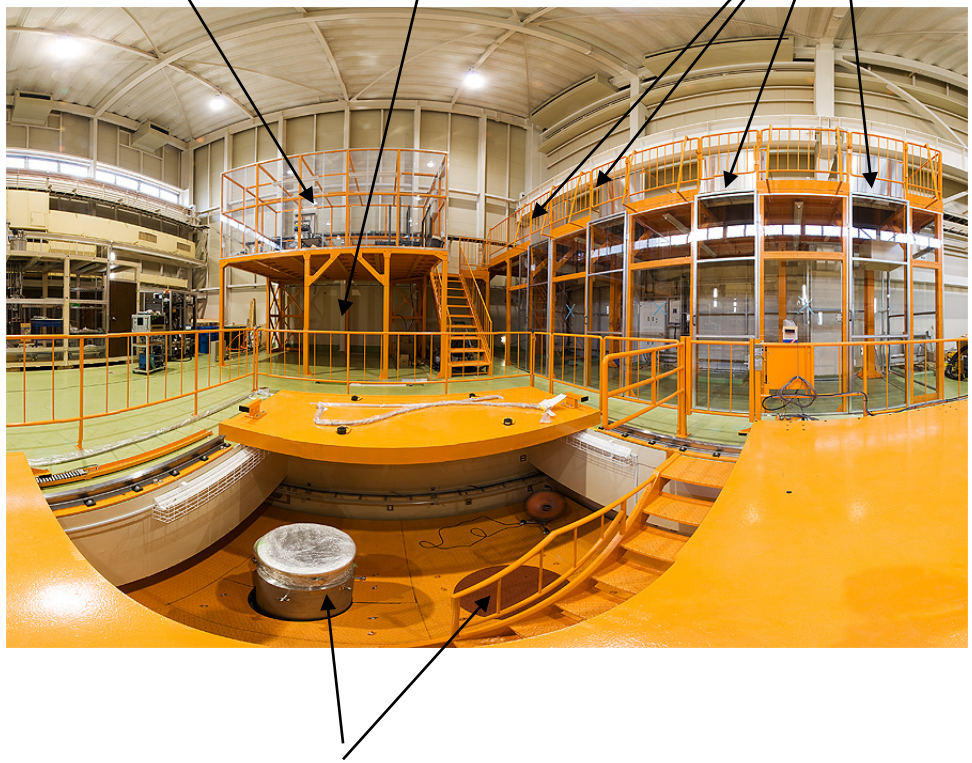


STF – EP system commissioning using old MHI cavity
Picture shows acid draining by holding cavity up.
3 times EP cycle (40+60+60μm removal) were done.

Cavity on the turntable, moveable into rinse position.

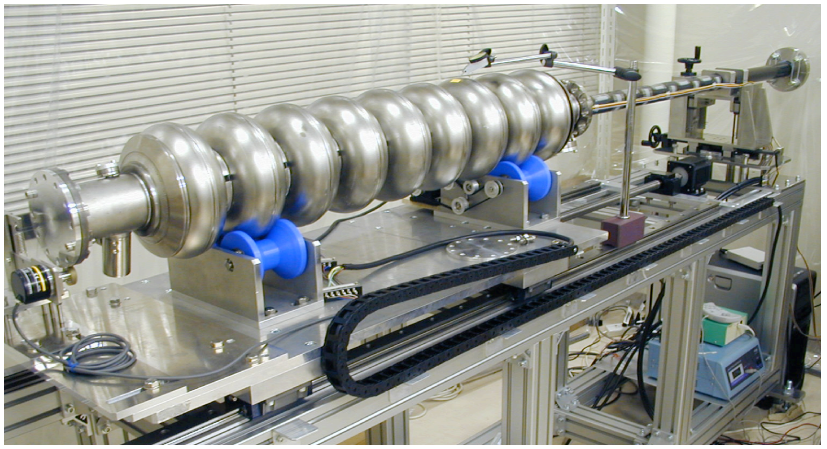
STF Vertical Stand

Under final Installation, almost ready to commission



Kyoto/KEK High Resolution Camera

For visual inspection of cavity inner surface.

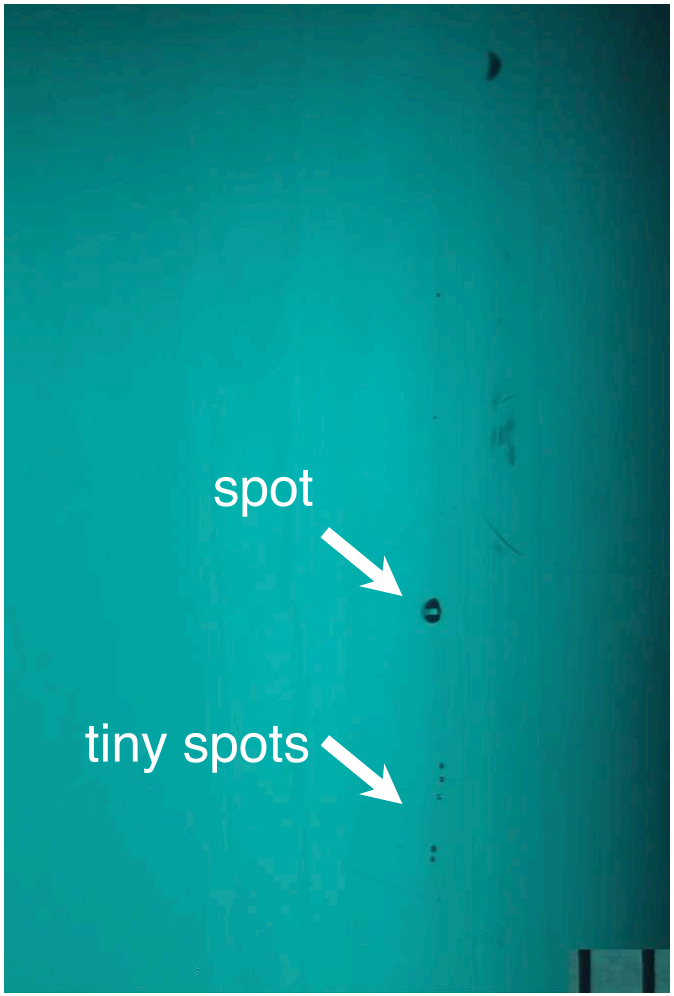


Camera system (7μm/pix) in 50mm diameter pipe.

perpendicular illumination by LED & half mirror

tilted sheet illumination by Electro-Luminescence

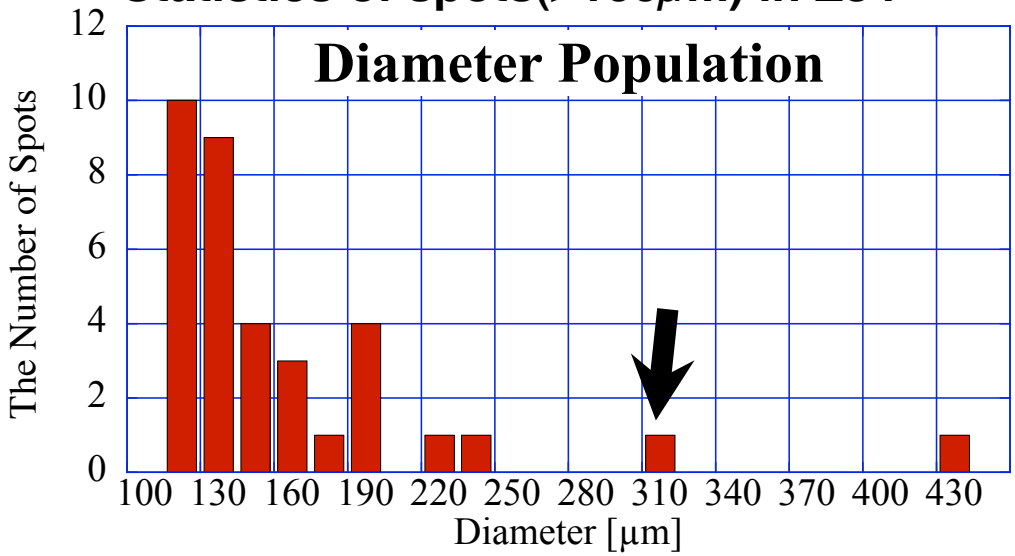
results of Z84 (DESY)



Z84: 27 – 22 MV/m, Q-disease,
530μm total removal at the last test.

→ many tiny spots found in equator

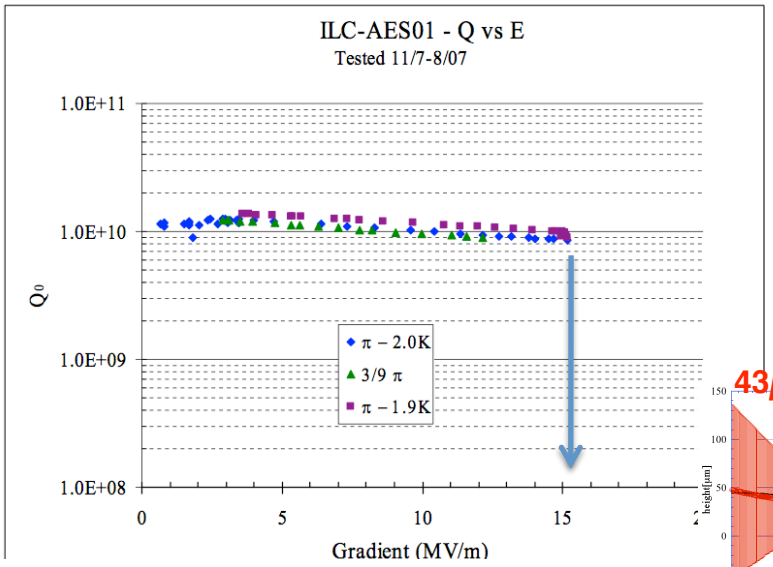
Statistics of spots(>100μm) in Z84



• **28 spots like cat's-eye were found at the equators of the cells. (only the spots with diameters larger than 100μm are counted.)**

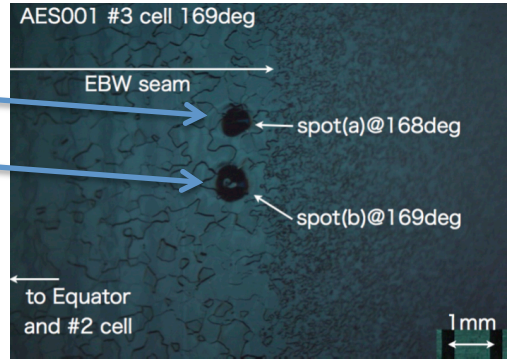
Results of AES01 (FNAL)

3rd Test Results



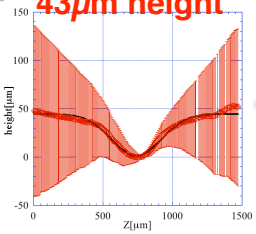
84μm height

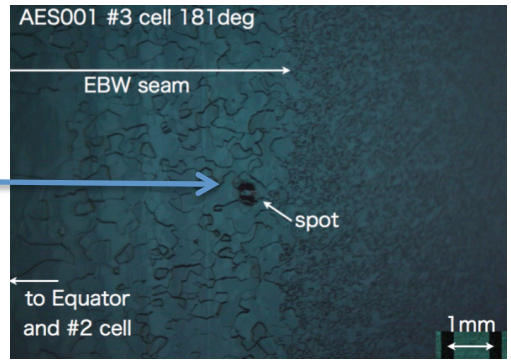
60μm height



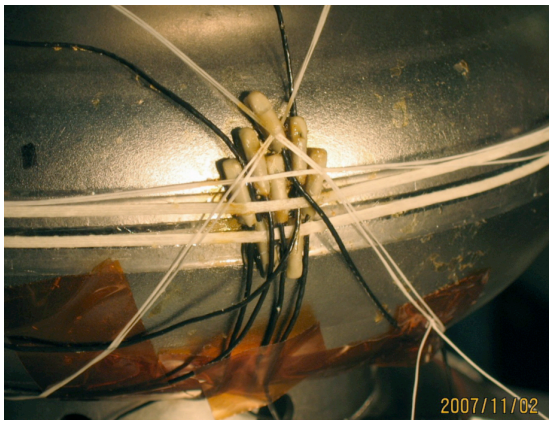
~21mm

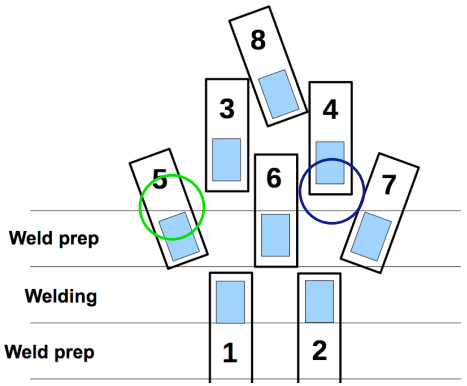
43μm height

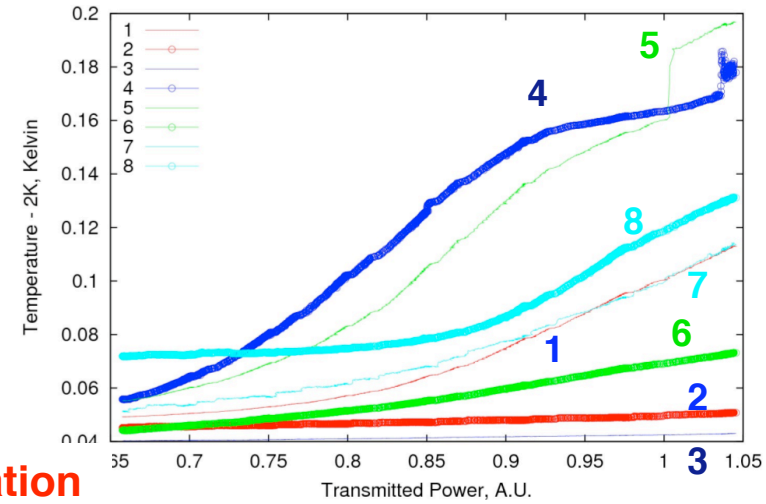




AES01 has hard quench at 15MV/m,
its location was identified by Cernox at FNAL.







Kyoto-camera found 3 spots in their exact location

Results of AC71,AC74,AC80(DESY)

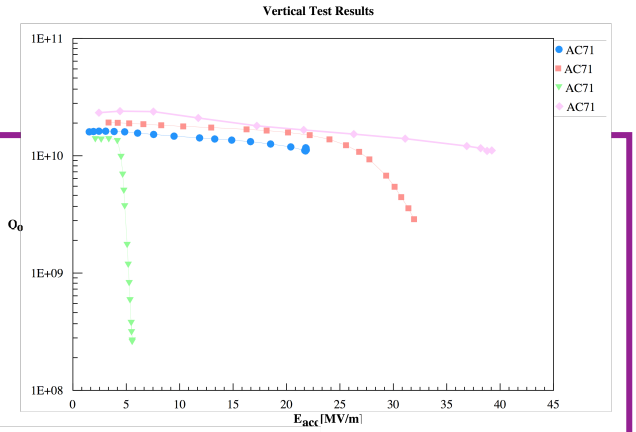
Summary of Vertical Test

cavity	# of meas.	# of T-map data	Exp # with T-map
AC71	17	0	
AC74	8	2	#2 & #3
AC80	6	1	#4

Summary of T-map

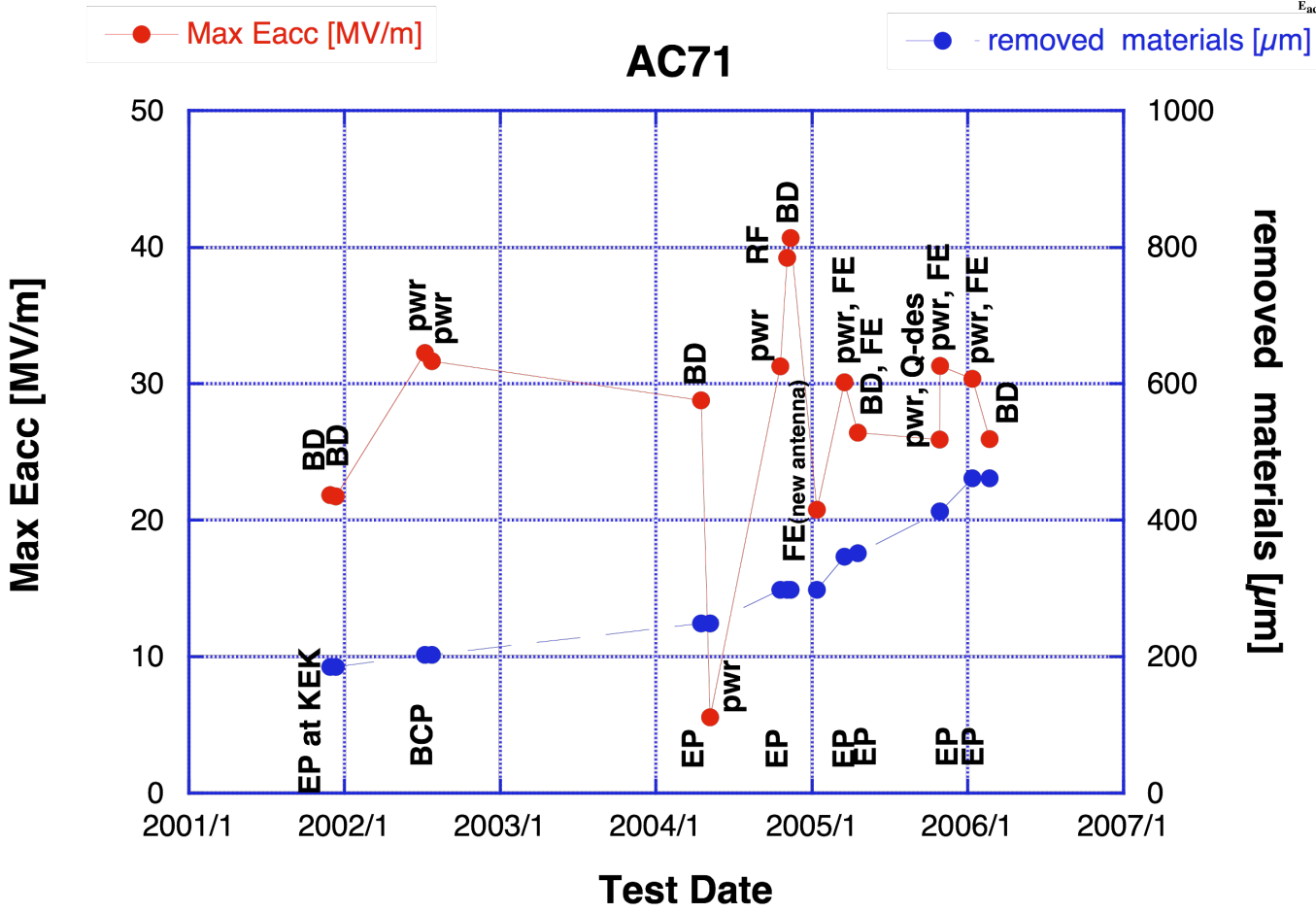
cavity	Exp. #	date	# of data	comment	results
AC74	2	2002/02/15	6	T-map at 18.0MV/m	Hot spot at #2cell 35°
AC74	3	2002/02/22	4	T-map at 17.6MV/m	Hot spot at #2cell 60°
AC80	4	2004/09/03	3	T-map at 27.7MV/m self-pulsing	Hot spot at #5cell 90°

AC71



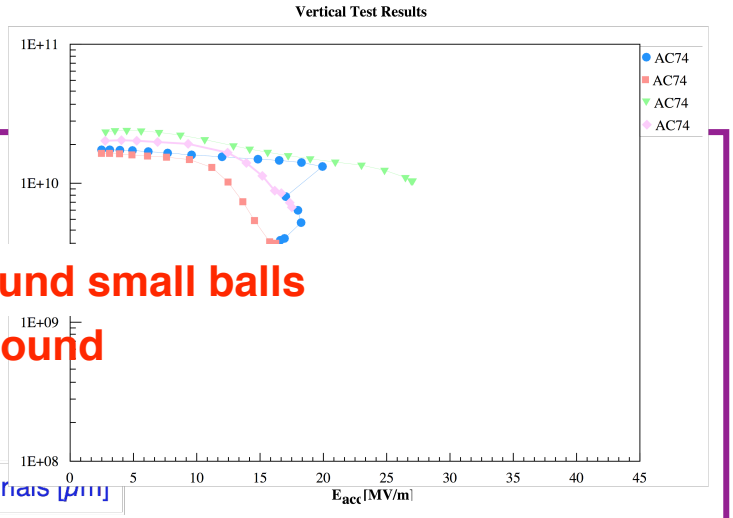
RF trouble, FE etc. after 40MV/m

no significant mark in the cavity!



AC74

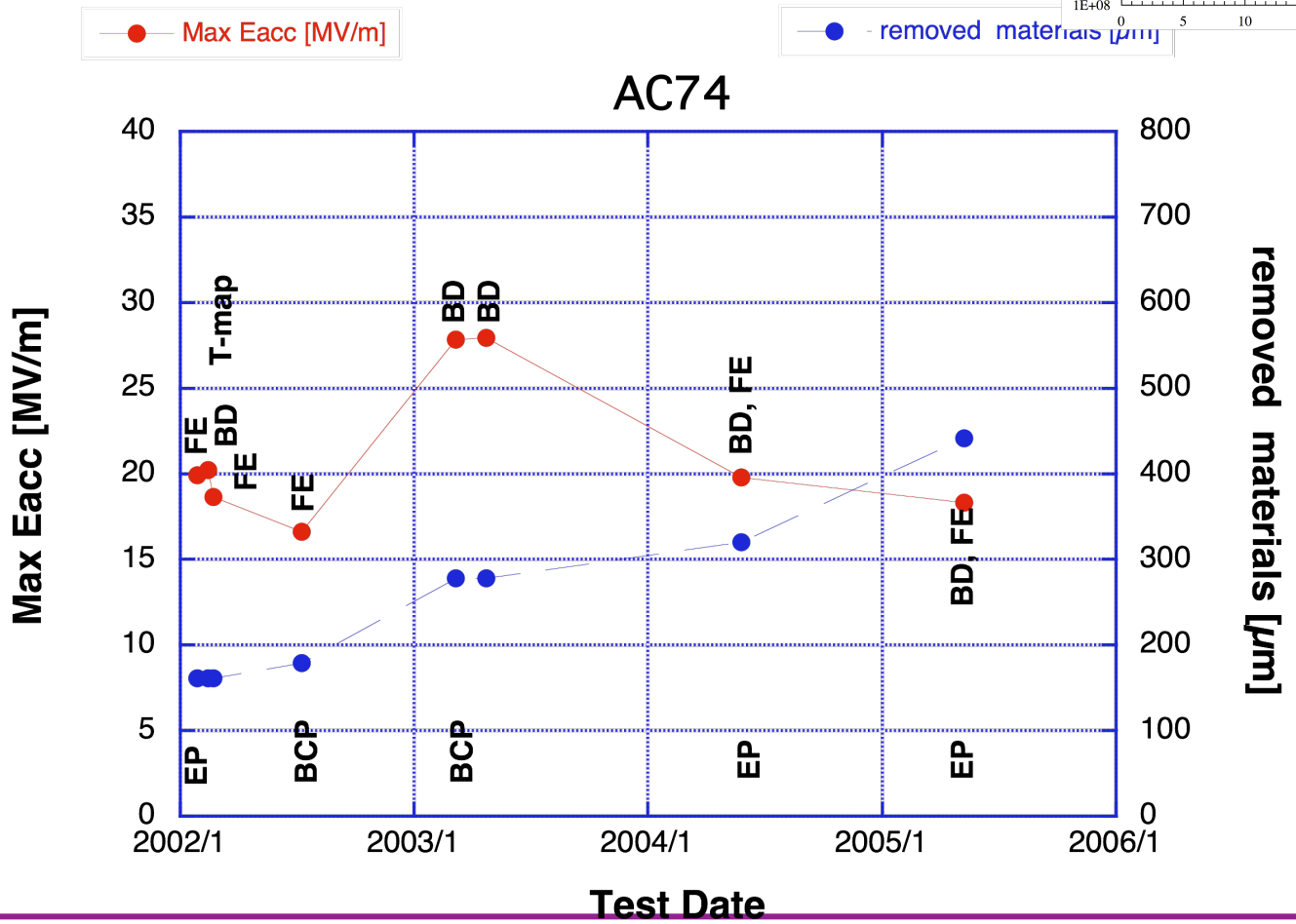
Field Emission, and Break Down



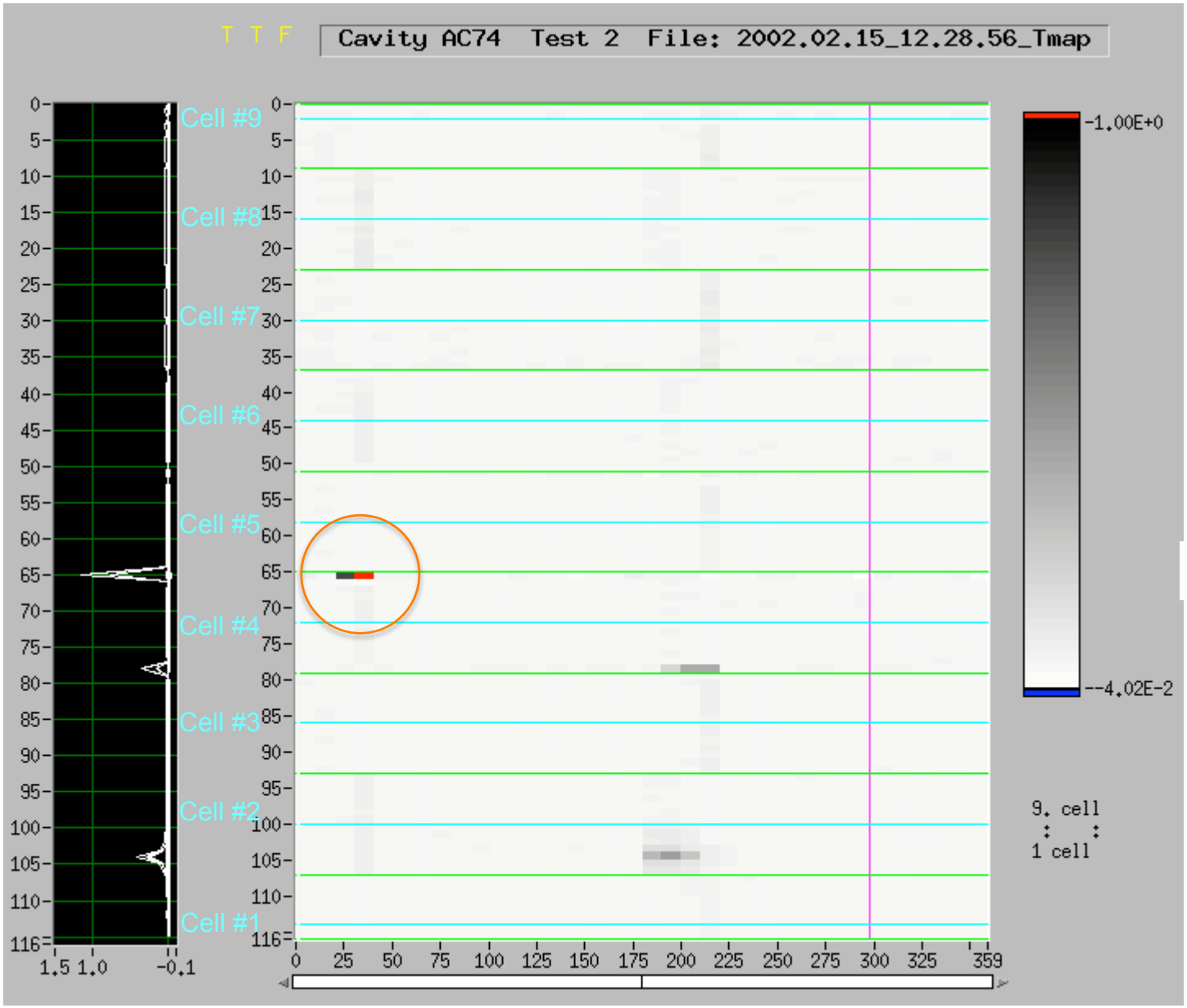
T-map indicate; hot spot at cell#4 near Iris, → **Found small balls**

at cell #2 between Iris & Equator → **Nothing Found**

Found many small pits on many Iris

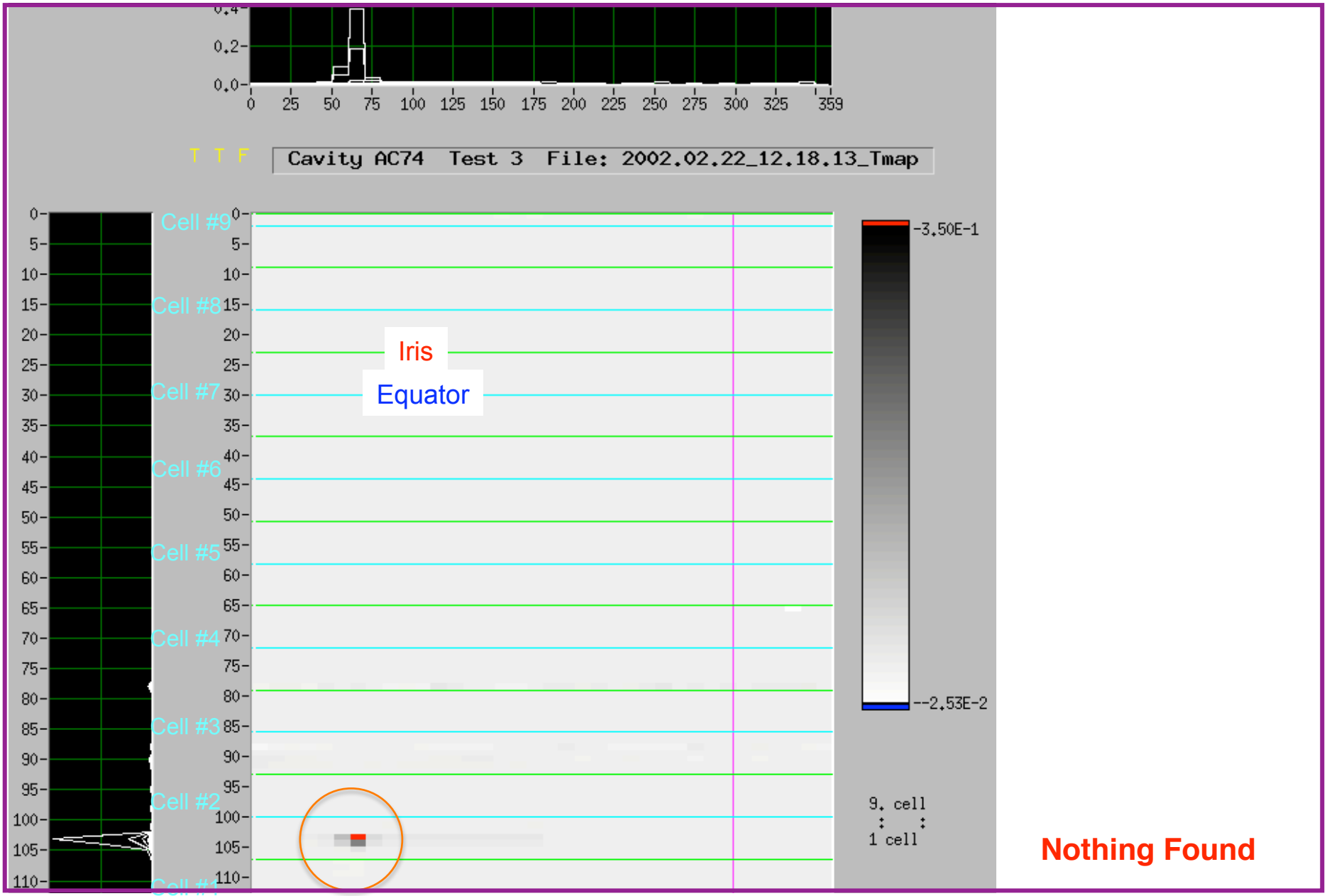


AC74 Test #2 ①



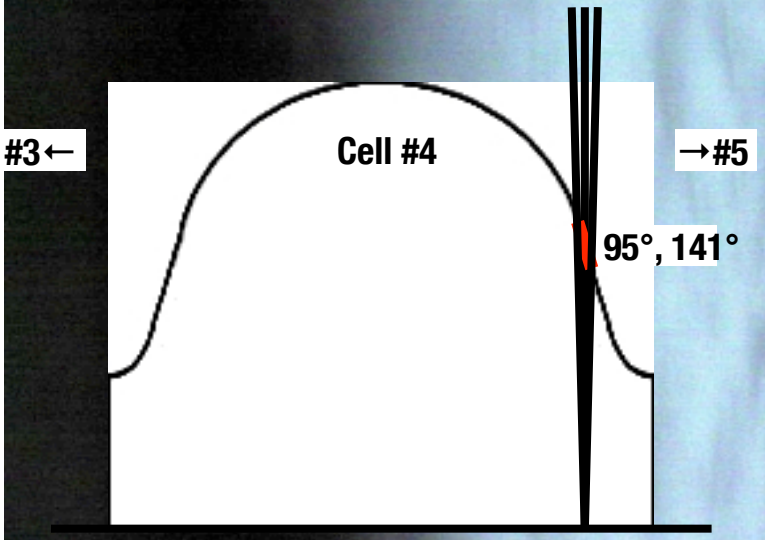
Found small balls

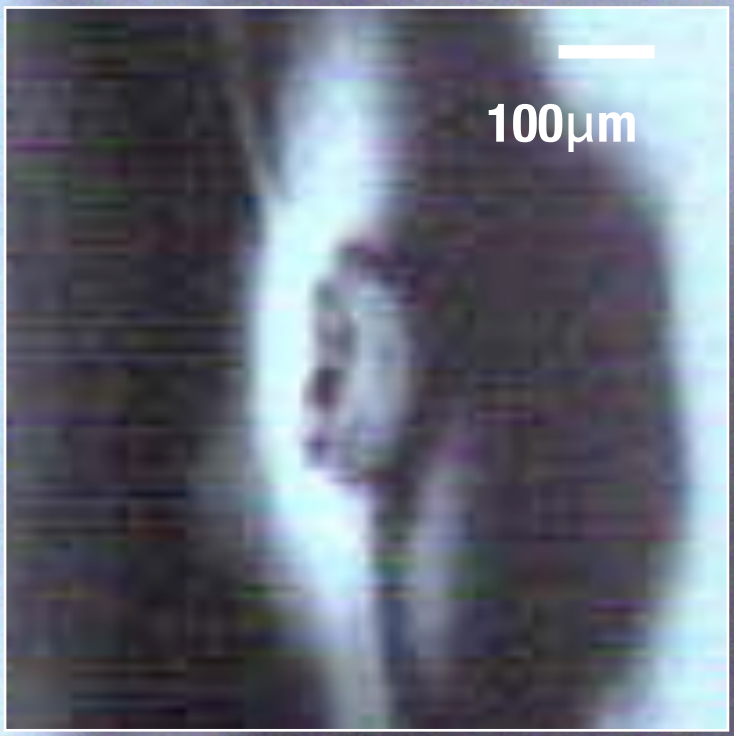
AC74 Test #3 ①



Nothing Found

AC74: hot spot1 95°

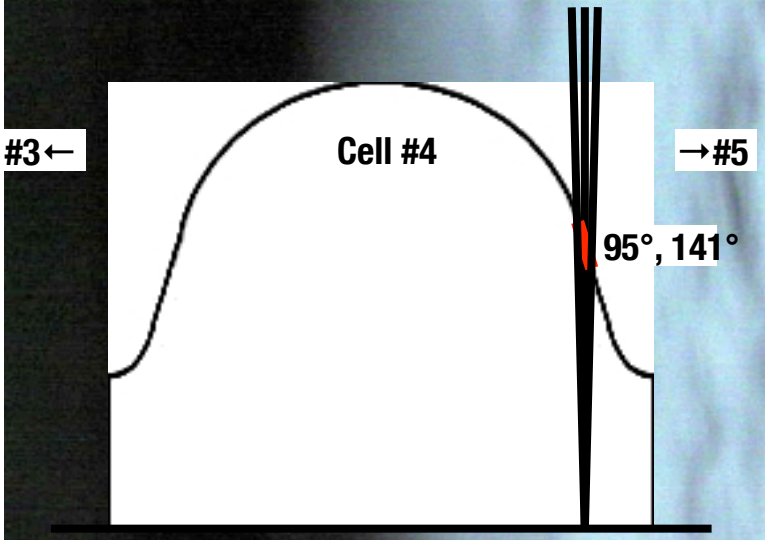


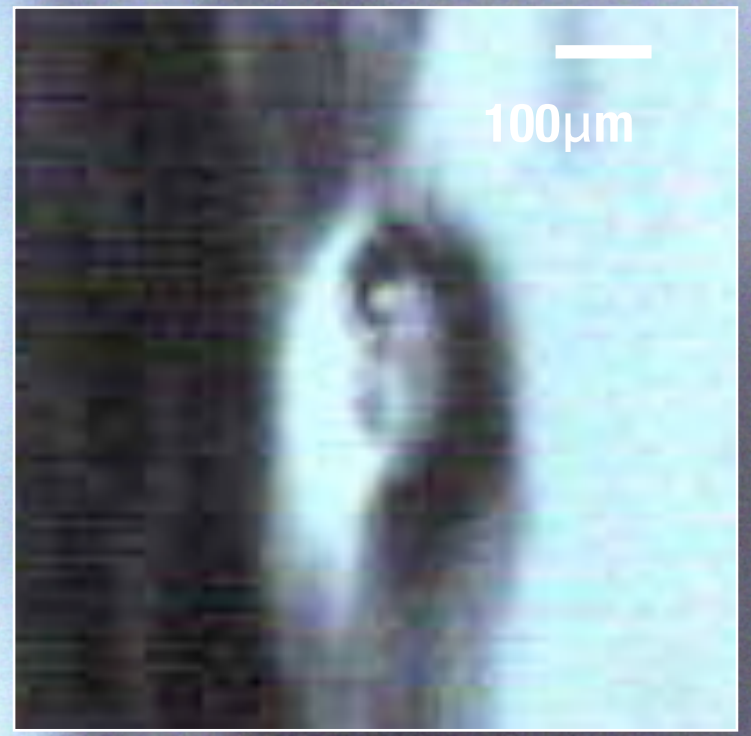


Cell #4

1mm

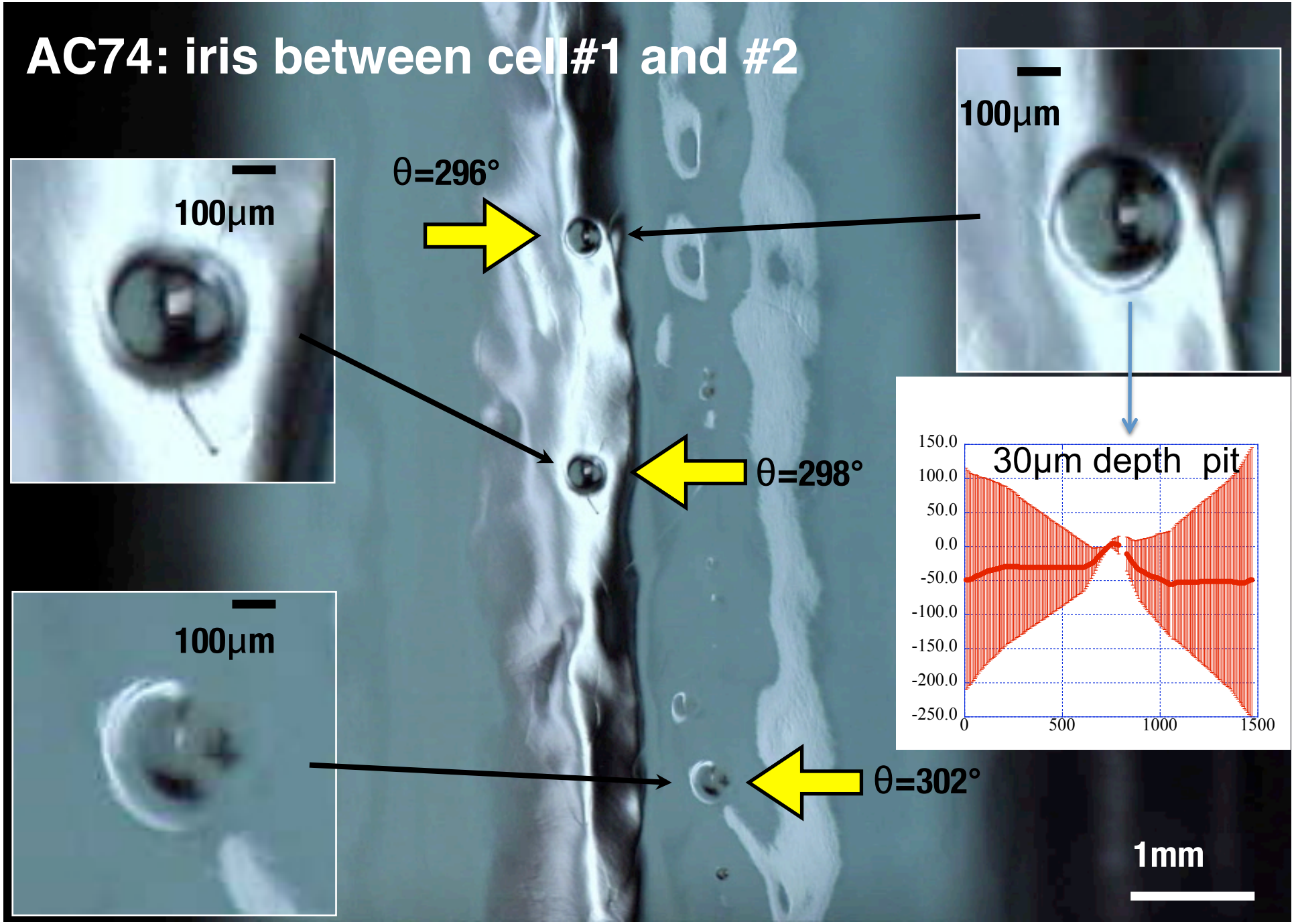
AC74: hot spot2 141°





Cell #4

1mm

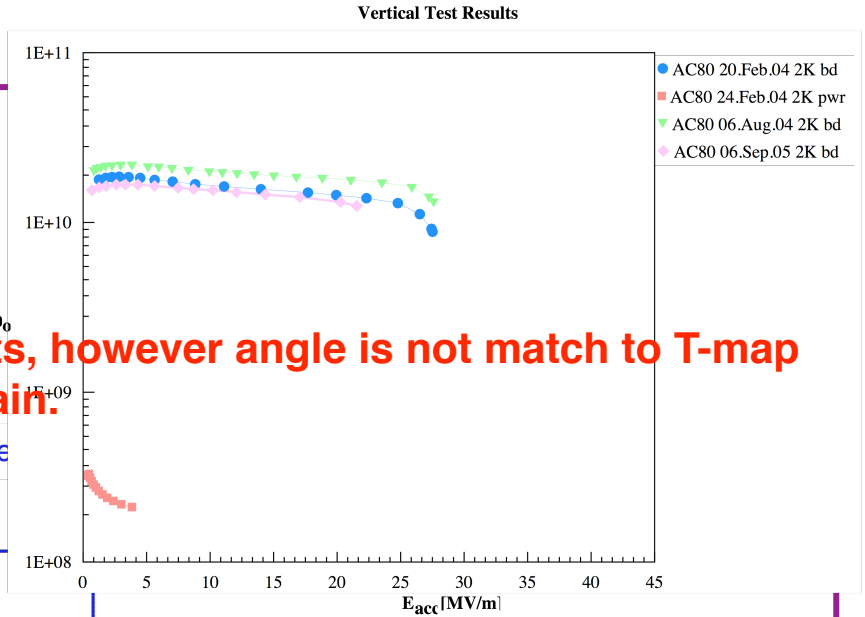

AC74: iris between cell#1 and #2
100µm
θ=296°
100µm
θ=298°
100µm
θ=302°
30µm depth pit
150.0
100.0
50.0
0.0
-50.0
-100.0
-150.0
-200.0
-250.0
0
500
1000
1500
1mm

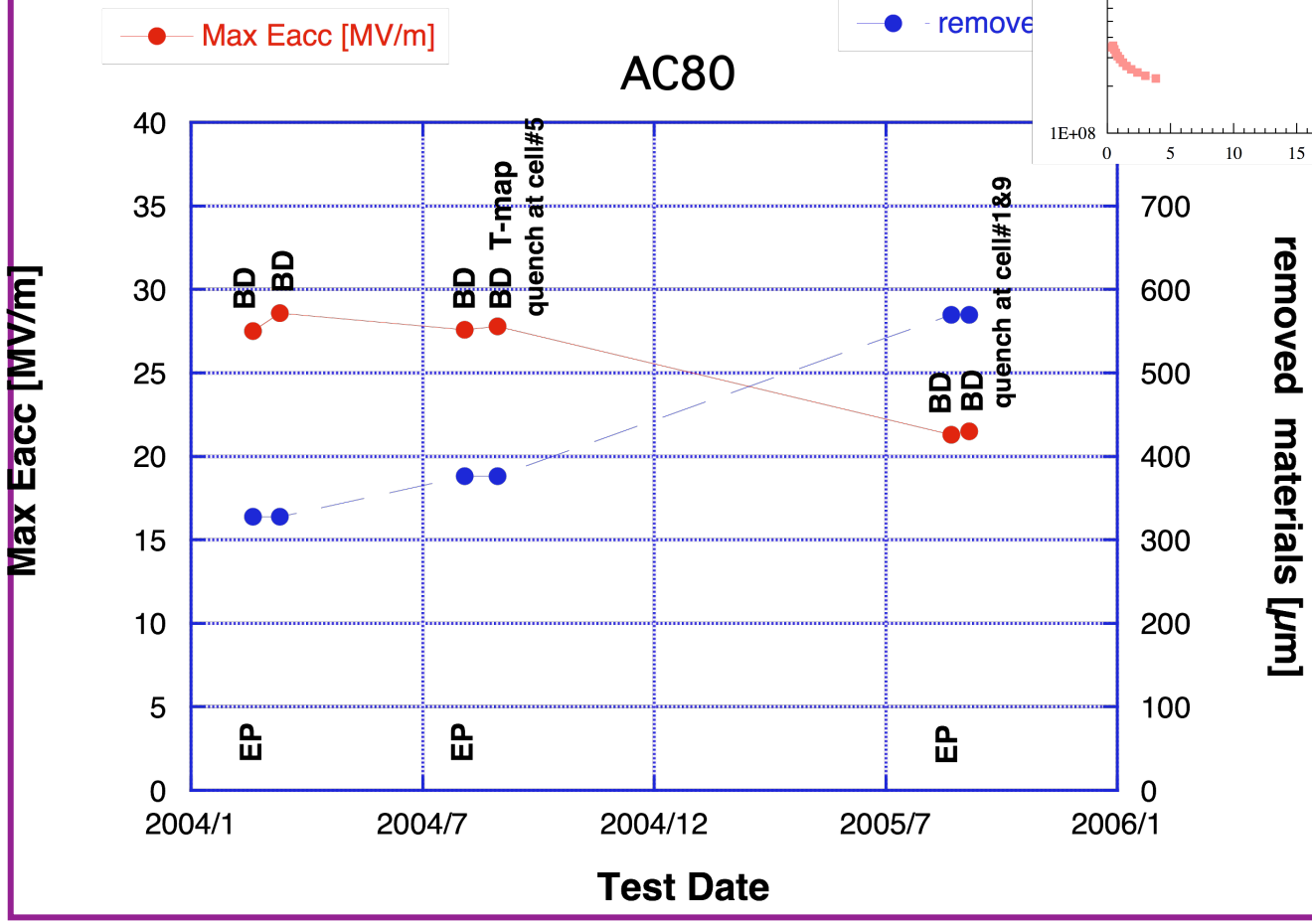
AC80

Quench at cell #5,cell #1 or9

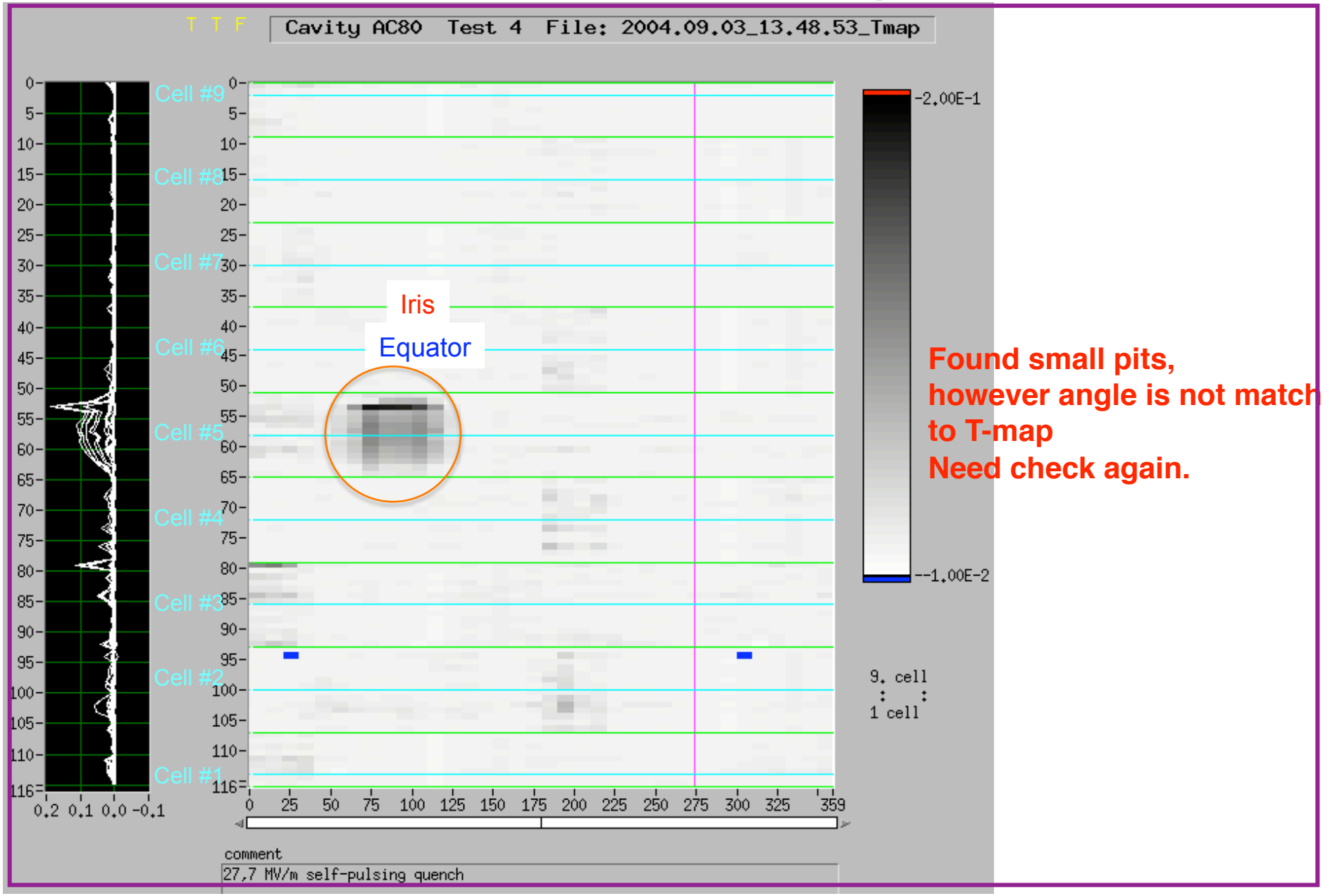
T-map indicate;
hot spot at cell#5 equator

Found small pits, however angle is not match to T-map
Need check again.



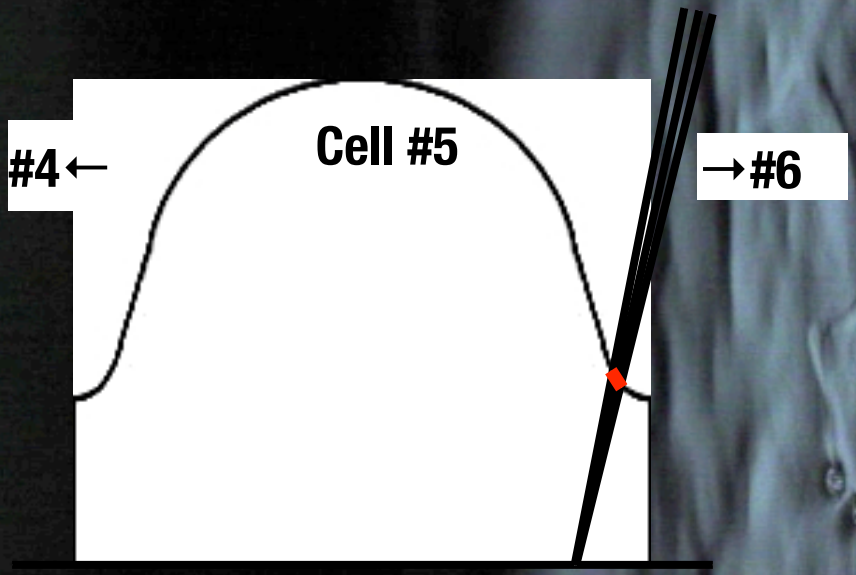


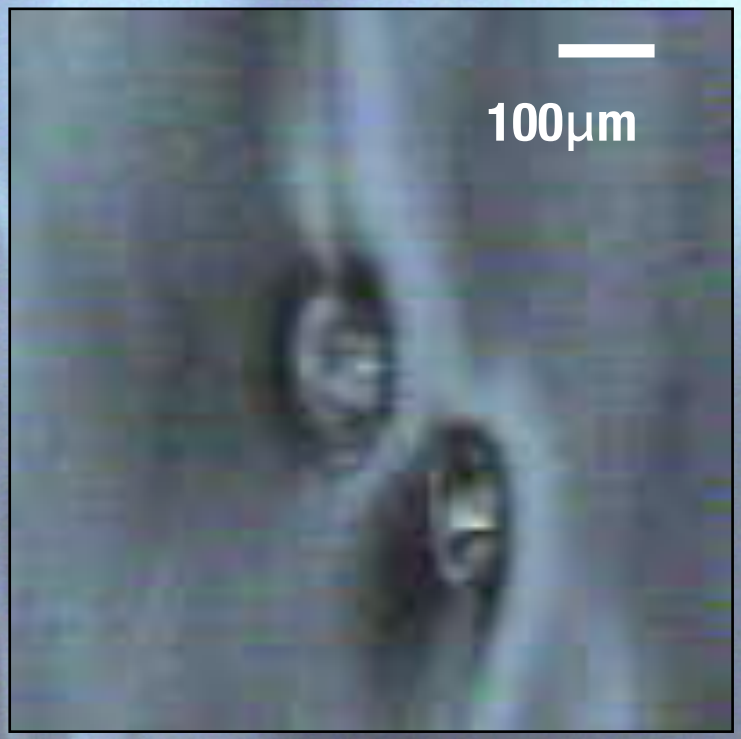
AC80 Test #4 ①



Found small pits,
however angle is not match
to T-map
Need check again.

AC80: hot spot1

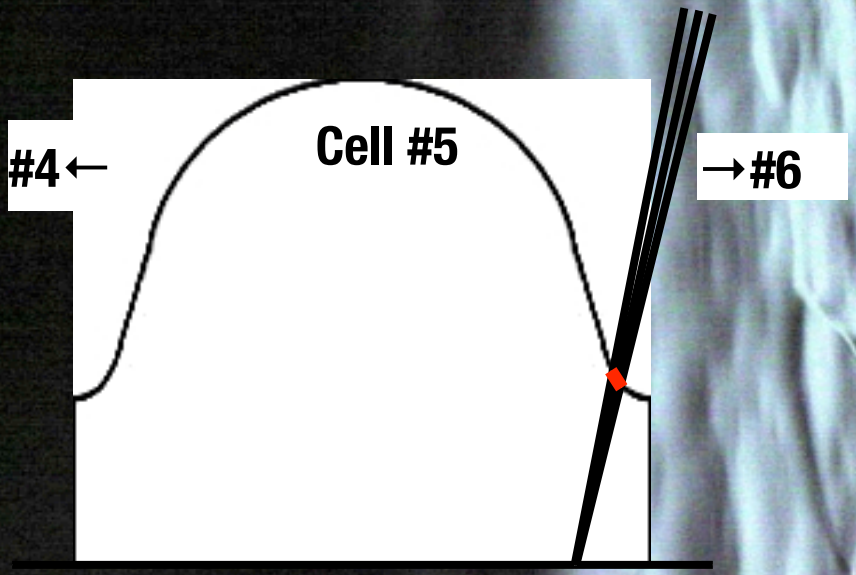


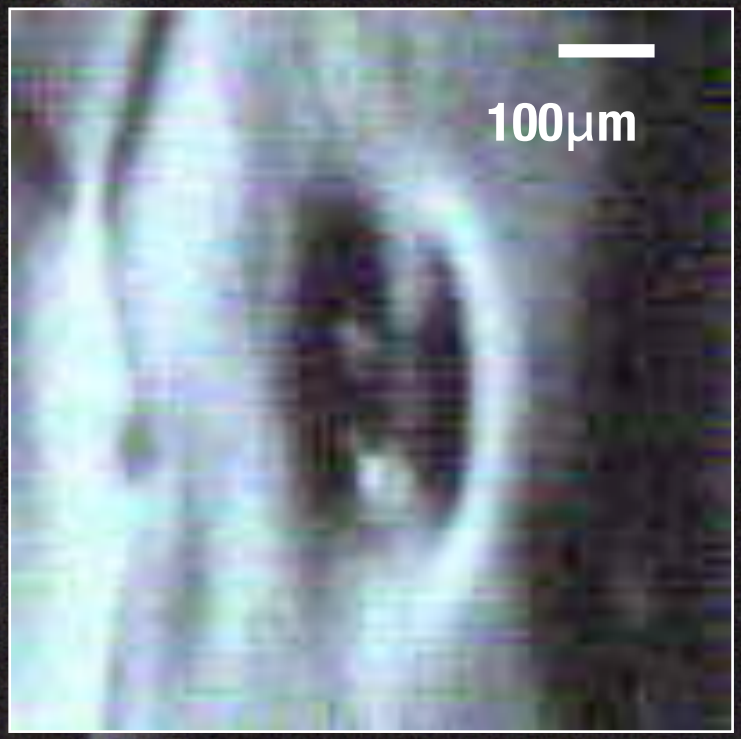


Cell #5.

1mm

AC80: hot spot2

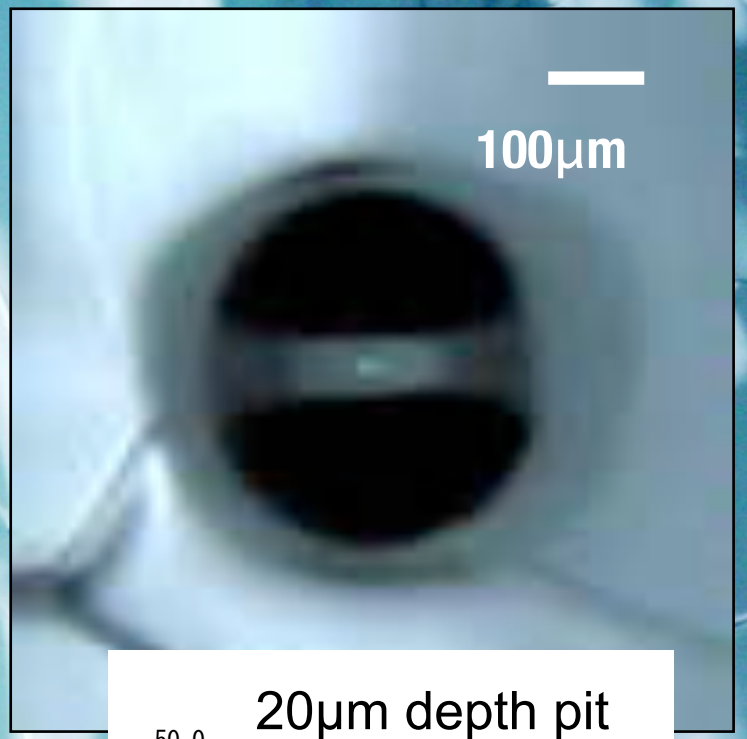


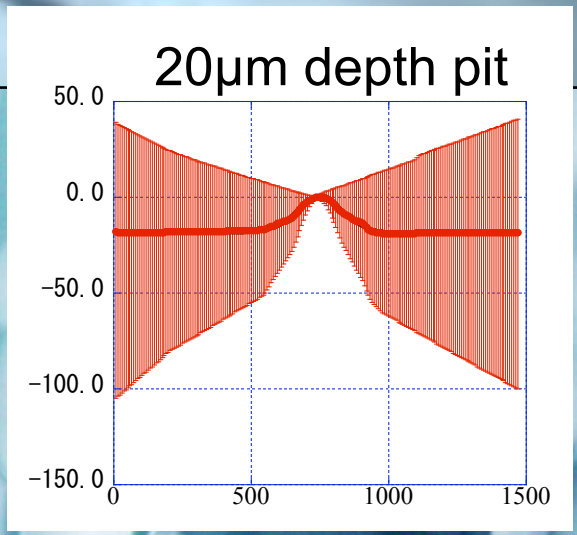


Cell #5.

1mm

AC80: cat's eye @cell#5_equator





This does not match to T-map hot spot. Need to check again.

1mm

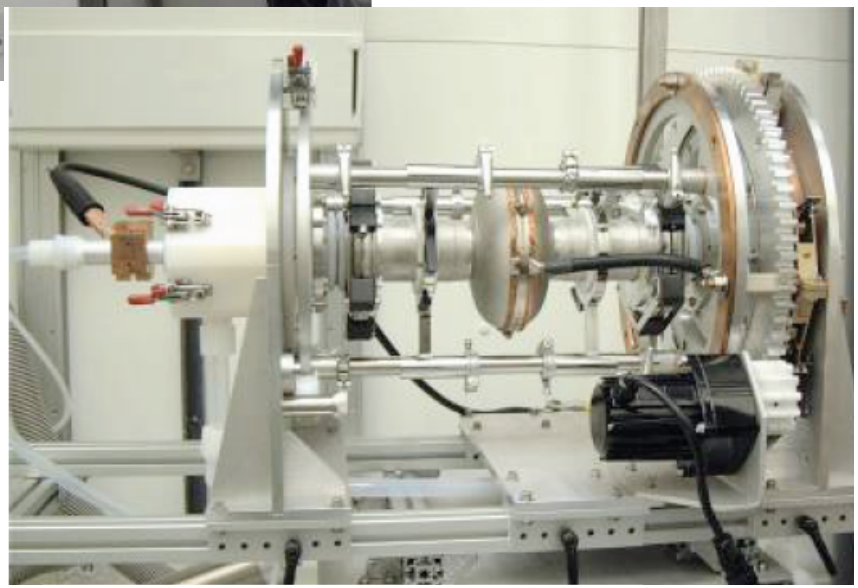
Status of NA

NA Outline

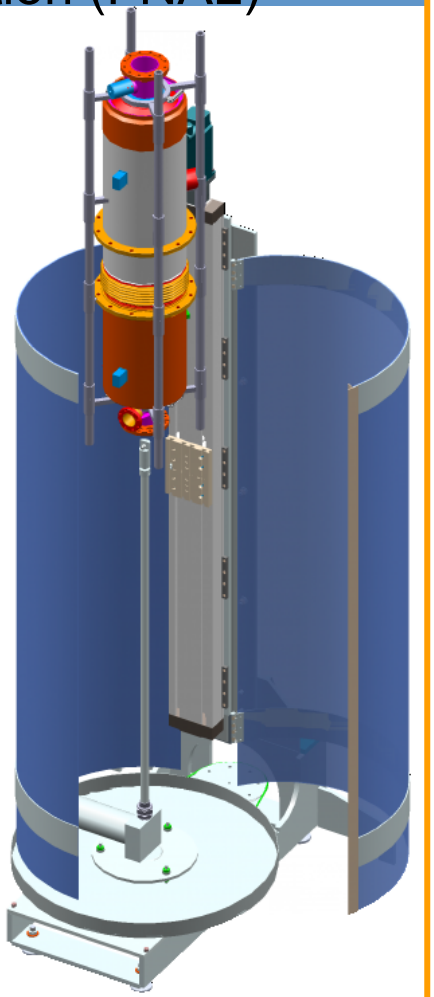
- **Status of infrastructure installations (FNAL, ANL)**
- **SRF R&D for ILC - S0/S1 (Jlab, Cornell)**
  + New vendor qualification
- **Large Grain 9-cell first results (Jlab)**
- **Newcomer TRIUMF**

* From presentation in TTC at DESY

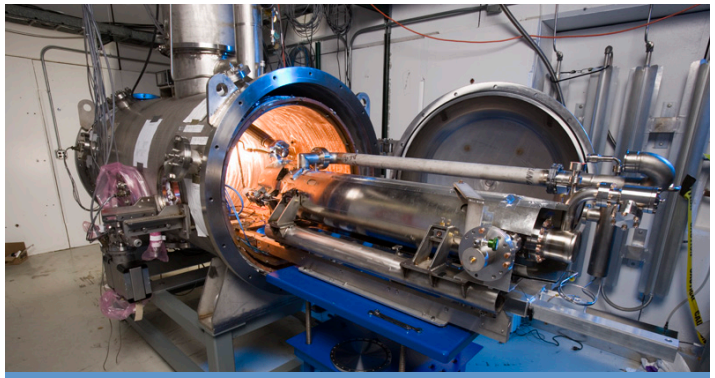
Argonne EP Commissioned with One-Cell



Cornell HPR System Designed and Under Construction (FNAL)



FNAL CM Assembly



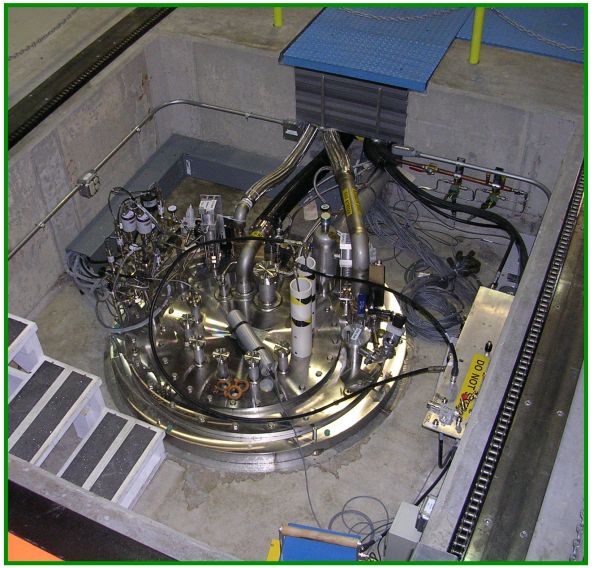
Horizontal Test
Cryomodule, C22 tested

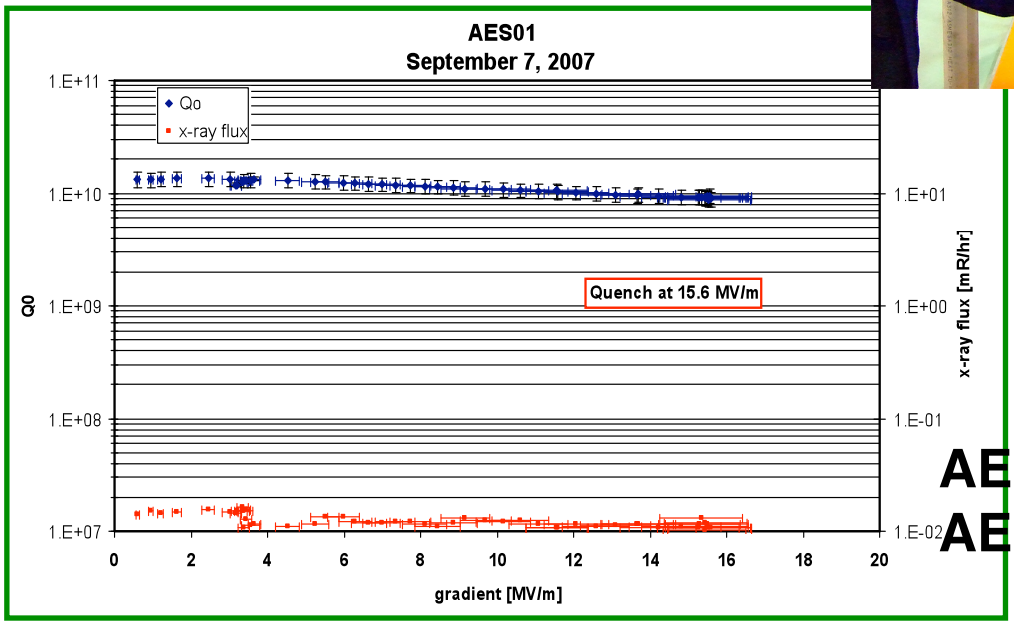
String Assembly with DESY Cavities

Cryomodule Assembly with DESY Assistance

First CM Ready for Test Facility

FNAL: Vertical Test Set Up Complete
AES 9-cell Cavities under Test





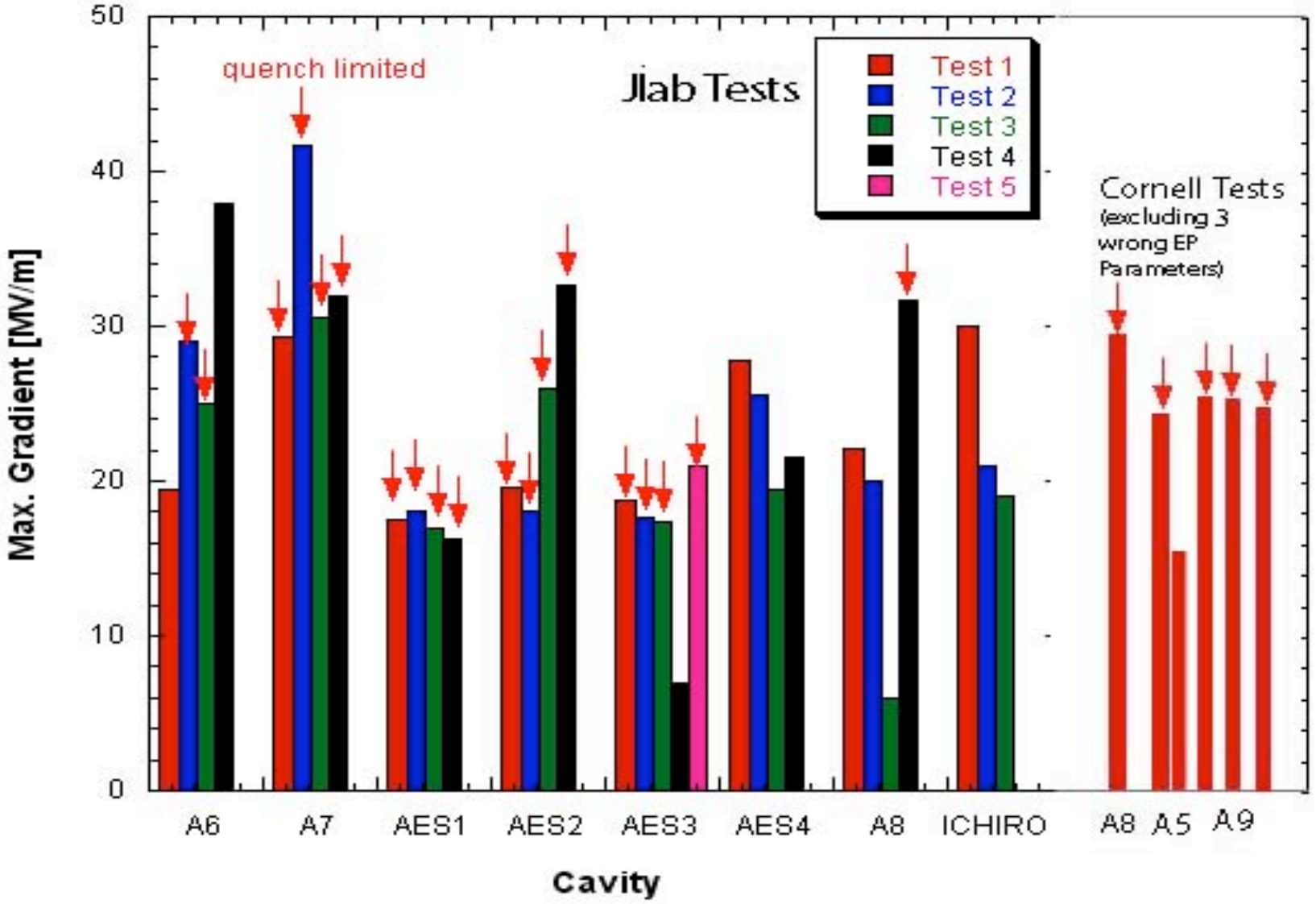
AES01 Tested,
AES03 under test

9-cell EP and Vertical Tests

- Jlab
  - Achieved 30 cycles of EP/VT per year.
  - Post-EP ultrasonic cleaning with “soap” always used.
  - A6 and A7 processed 4 cycles for ILC S0/S1.
  - A8 started on S0 tight loop
  - KEK ICHIRO 5 cavity testing started
  - New vendor cavities evaluation AES 1 – 4
- Cornell
  - One cycle per month
  - Post-EP ultrasonic cleaning with “soap” always used.
  - A8 and A9 qualified for quench ≥ 25 MV/m
  - A8 sent to Jlab for tight S0 tight loop
  - A9 started micro-EP (5 microns) to study effect on quench
  - 9-cell re-entrant cavity work started
  - New vendor AES (new beam welder) 1-cell cavity rapid qualification

9-cell Test Results

Mostly Jlab and Some Cornell

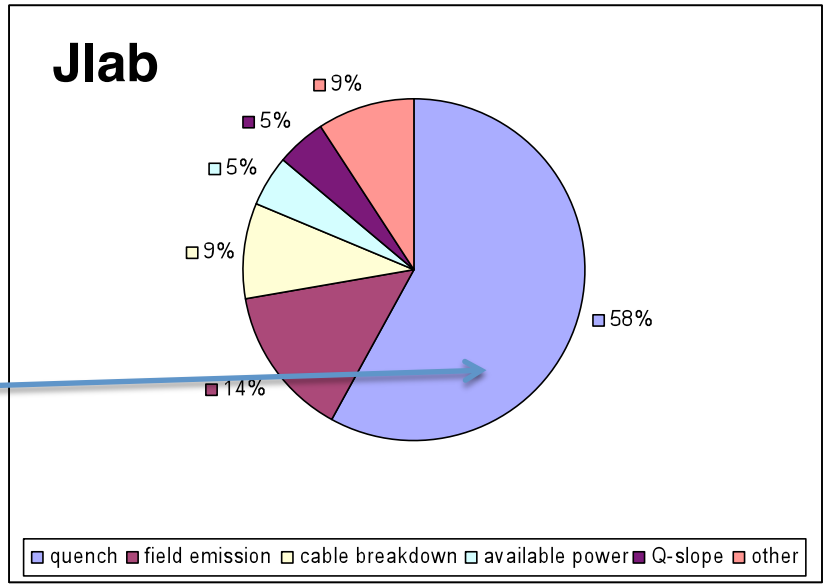


Best 9-cell cavity gradient results

- 4 cavities (A6, A7, A8, AES2) best gradients of 31-42 MV/m. Quench limit sensitive to re-processing.
- 2 cavities (AES4, ICHIRO5) reached gradient of 28-36 MV/m. Field emission limit.
- 2 cavities (AES1, AES3) reached gradient of 19-21 MV/m. Quench limit insensitive to re-processing
- Pass-band & Thermometry to locate defect.
- AES 3 defect is in cell 6
  - Near, but outside equator weld
- AES 1 sent to FNAL to qualify VTS, Quench located in cell #3
  - AES 1 sent to KEK for optical microscopy

Total 43 vertical tests

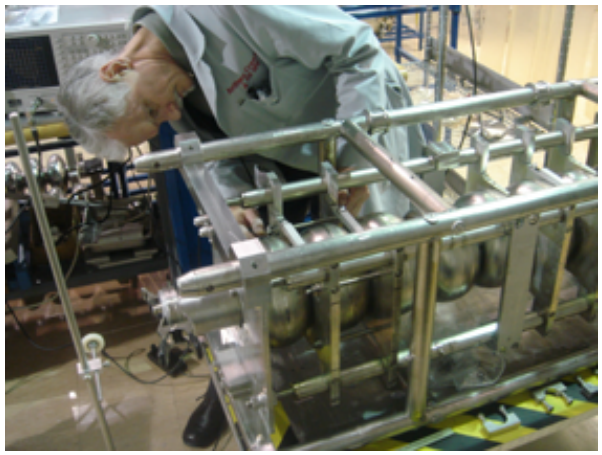
Quench limited 58%



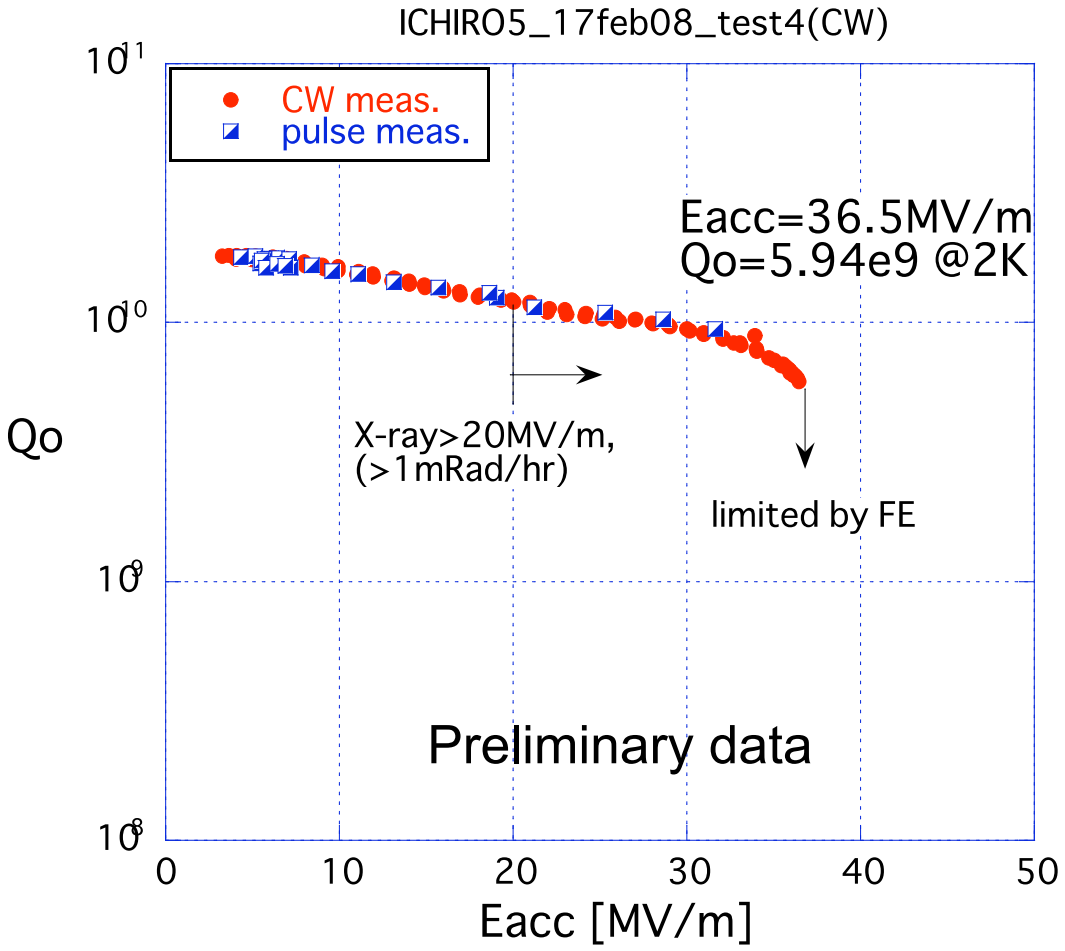
LL ICHIRO test at Jlab

New Ichiro #5(KEK), #6(PAL)

New Ichiro #5(KEK) was sent to Jlab for S0 work.



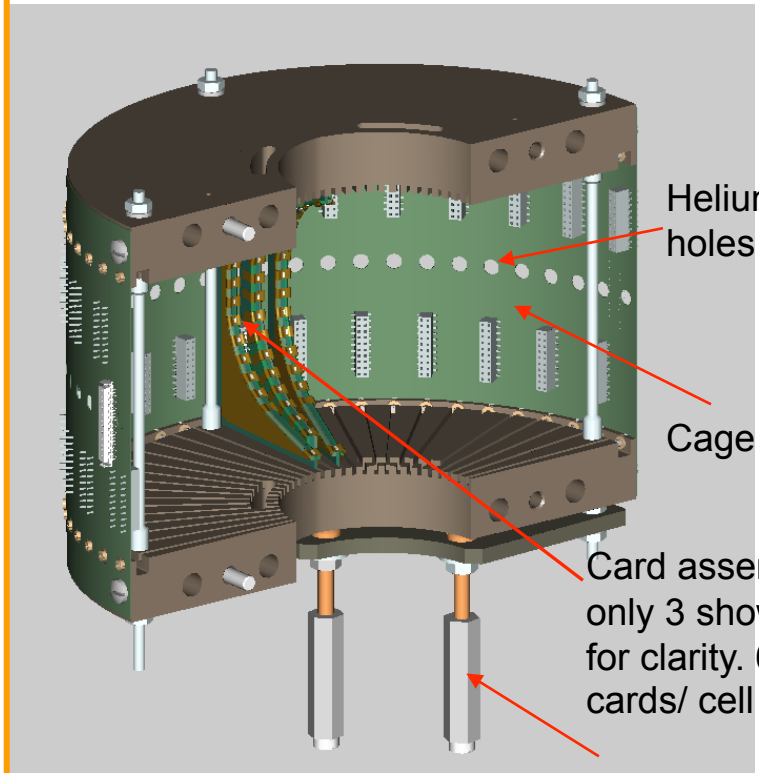
Pre-tuning (96% flatness) at Jlab, total 30μm removal at Jlab at 4-th vertical measurement



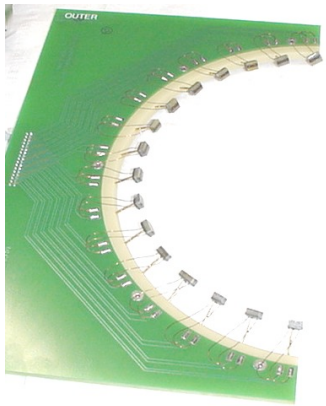
T-map development

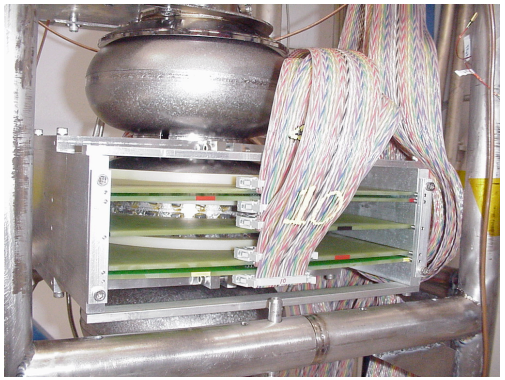
FNAL

Model of half cage assembly

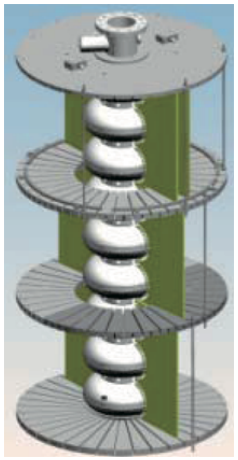


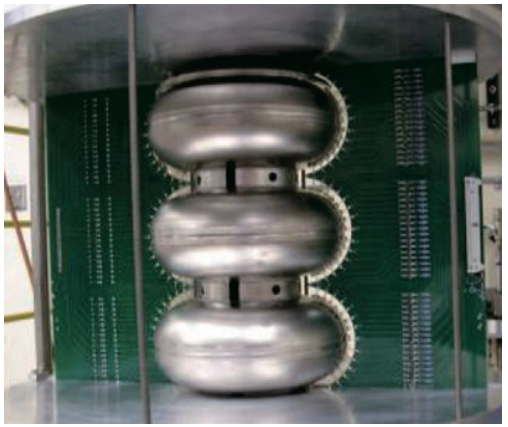
1-cell prototype was made and the fixture was cold tested (shock) successfully





Jlab One Cell Thermometry Assembly





LANL 9-cell T-map development

New Vendor Development Continued
AES New Beam Welder

Rapid Qualification : 5 Single Cells, 110 μm BCP, HPR 2 hrs

- Cornell/FNAL collaboration
- BCP and Tests carried out at Cornell
- 4 of 5 cavities reached 25 MV/m without quench
  - limited by high field Q-slope
- 1 of 5 cavities reached 17 MV/m limited by field emission
- AES new beam welder is qualified

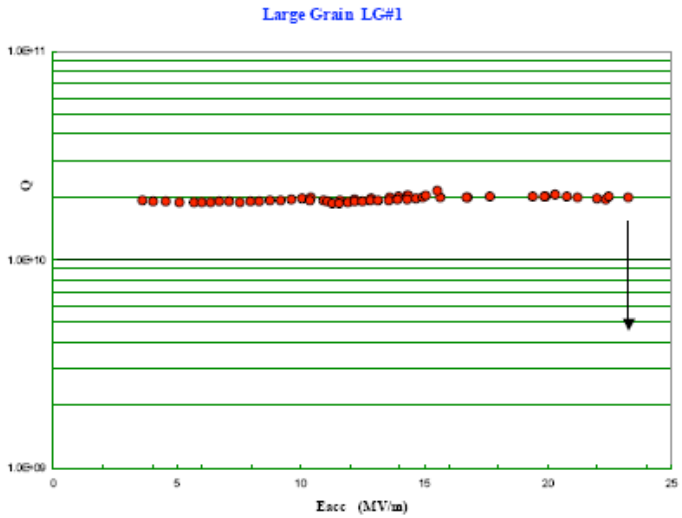
FNAL : delivery of 9 cell cavities

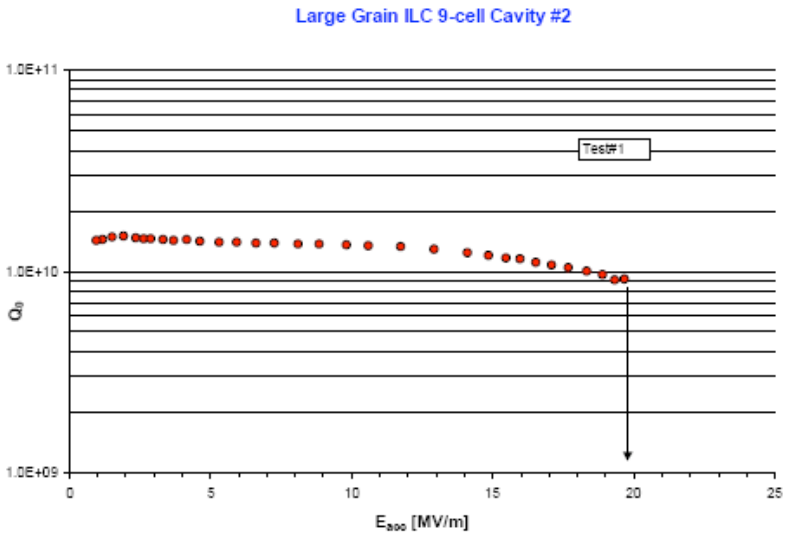
- 8 ACCEL : in next few weeks
- 6 AES : Summer 2008
- 10 ACCEL : Fall 2008

9-cell Cavity performance(Jlab)

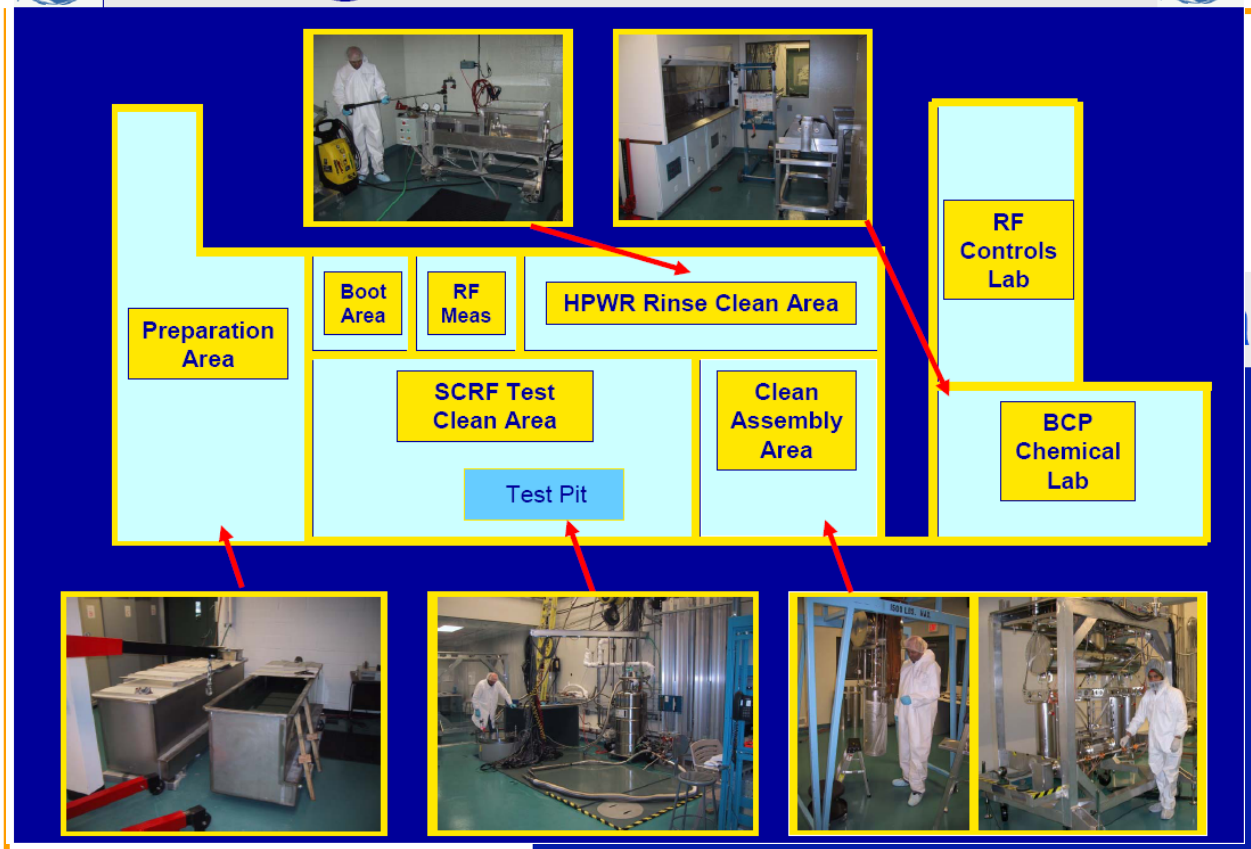
Large Grain

- 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





SRF@TRIUMF : Infrastructure



TRIUMF

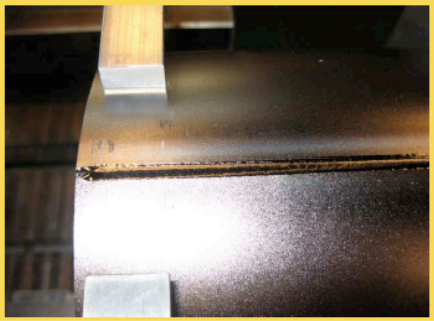
PAVAC

l Fabricator

PAVAC

Forming and Machining

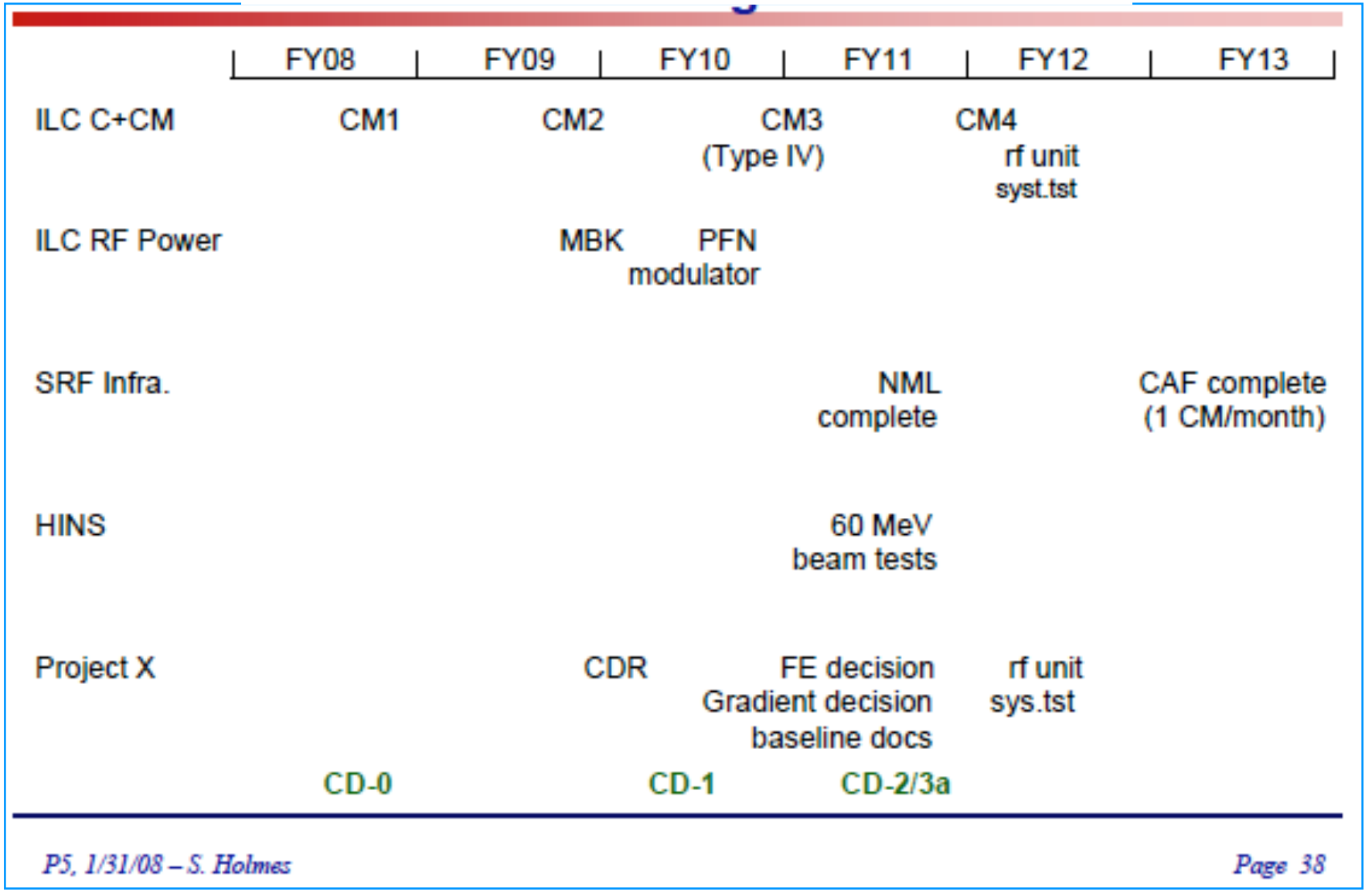
EB Welding



Pre-weld Etching - TRIUMF

SCRF R&D Plan at Fermilab

from P5 talk by S. Holmes

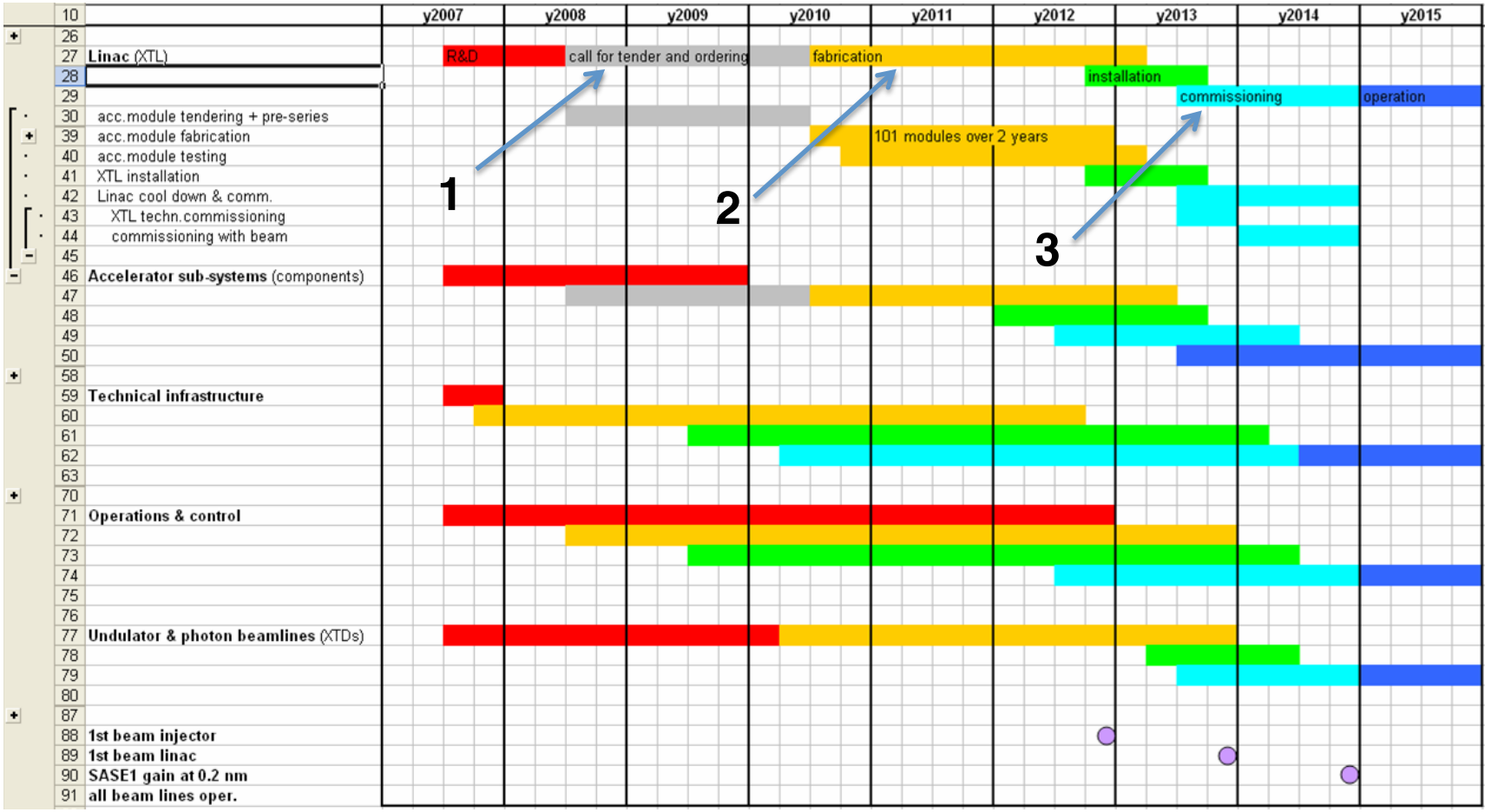


Status of EU

* XFEL project

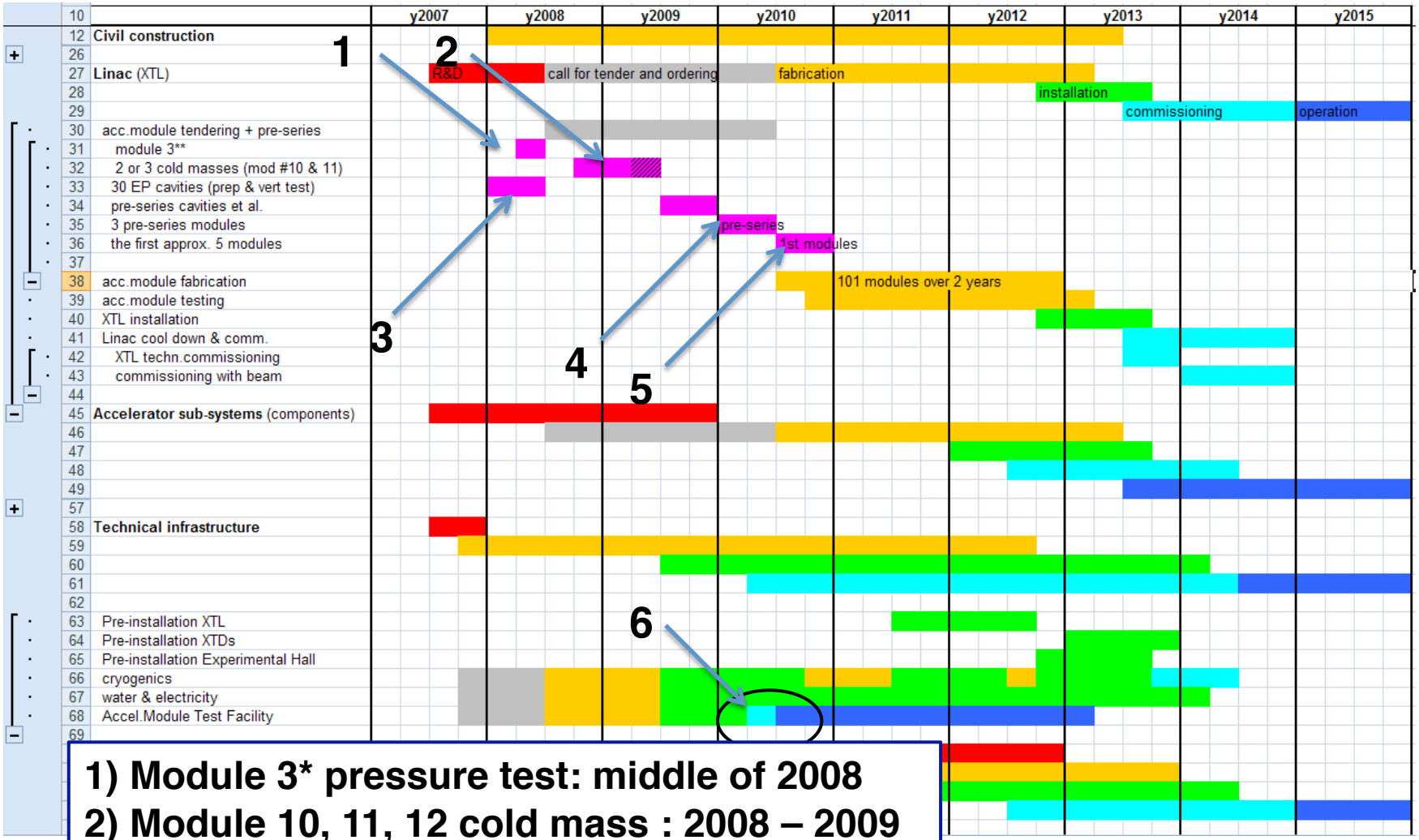
* From presentation in TTC at DESY

XFEL Overall Schedule as the Basis



1) Call for tender & ordering : middle of 2008 – middle of 2010
2) 101 modules production : middle of 2010 – end of 2012
3) Commissioning start in 2013

XFEL Overall Schedule - First Details



1) Module 3* pressure test: middle of 2008
2) Module 10, 11, 12 cold mass : 2008 – 2009
3) 30 EP cavities (prep & VT) : 2008
4) 3 pre-series modules : 2010 first half
5) First 5 modules : 2010 latter half
6) Module Test Facility commissioning : 2010

XFEL Overall Schedule - Comments

Module #3* will be 'destructively' tested at the CMTB; therefore it needs to be repaired; additional assembly training possible (old module type!)

Module #8 is going to be tested in Q1/2008; and needed for installation in FLASH in Q1/2009; it will be extensively tested at CMTB, and then be used for a first transportation test of assembled modules; we 'bought' a Return Ticket to Saclay.

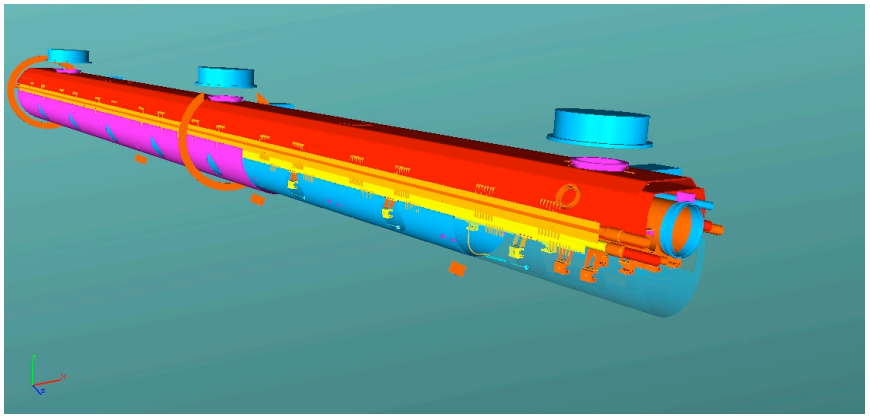
We are going to receive the **cold mass for modules #10 to #11 (or #12?)** beginning of Q4/2008; these XFEL type modules offer assembly checks / training (remark: the final 101 module call for tender will not wait for the module assembly!!!)

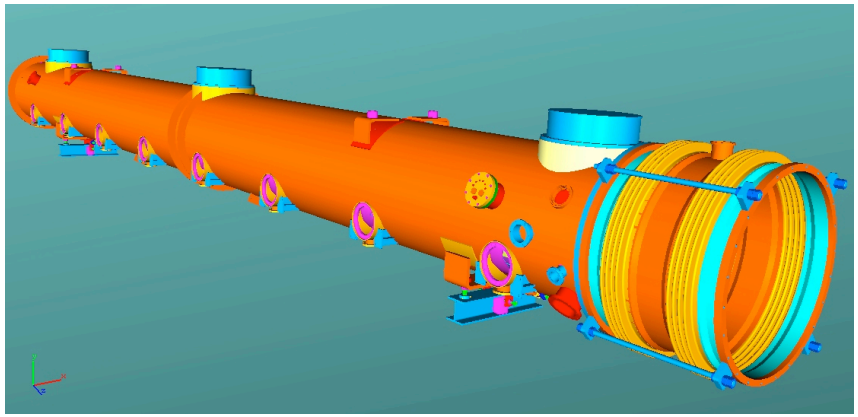
Three **pre-series XFEL modules** need to be assembled approx. Q4/2009 – Q1/2010; a first check on CMTB should follow, then they are to be used for AMTF commissioning (Q2/2010); all sub-components have to be available.

We expect to see **the first few (≤ 5) assembled modules** at AMTF until end of 2010; after this we have two years time for the remaining 101 – 5 = 96 modules; module tunnel installation starts in Q4/2012

WP – 3 Accelerator Modules

Invest	FTE
60% CEA 19% INFN 21% DESY	43% CEA 29% INFN 29% DESY





- Fabrication of cold masses (incl. outer vessel)
- module assembly w/o frequency tuner & power coupler; start with assembled string and finish with module installation
- weld connections
- alignment inside modules
- transportation of assembled accelerator modules

- material specifications, safety issues
- define processes for integration / assembly
- magnetic shielding / demagnetization
- sensors inside the accelerator modules
- pre-alignment of cavities and coupler position

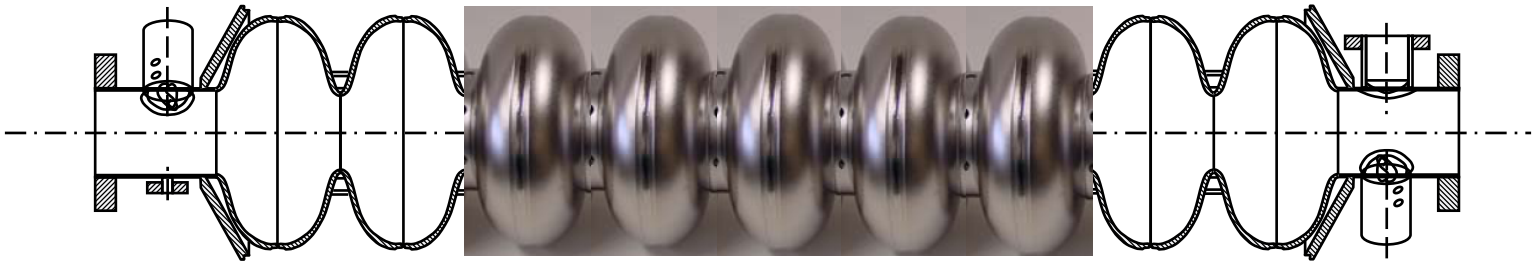
WP – 4 Supercond. Cavities

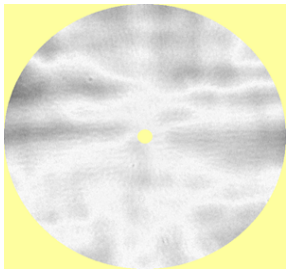
50% INFN
50% DESY

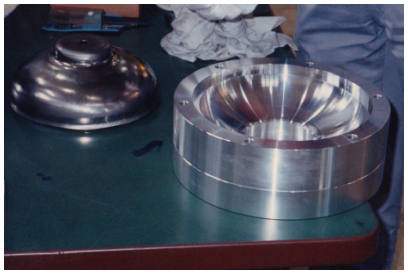
Invest

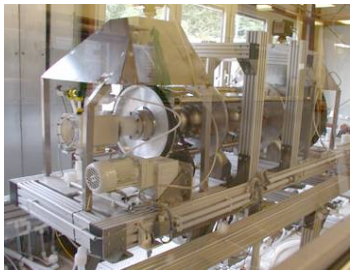
FTE

34% INFN
66% DESY









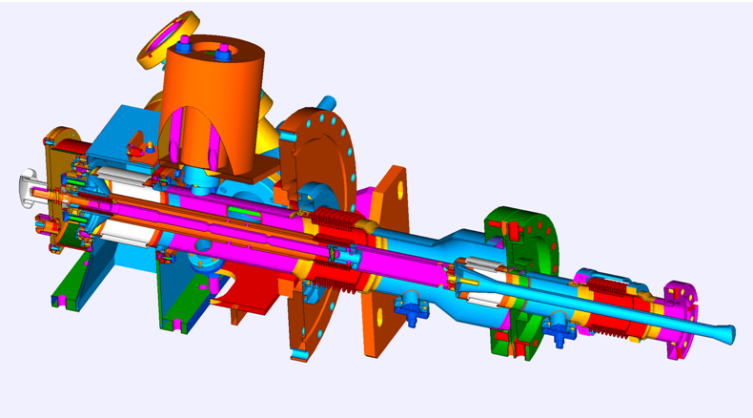
- Procurement of all niobium
- Scanning of NB sheets
- Complete mechanical fabrication of all cavities
- Surface treatment
- Consultant at start up of infrastructure and at full running production

- Data base setup and database running
- EDMS
- Helium vessel incl. Titanium parts (taken over from WP-9)

WP – 5 Power Coupler

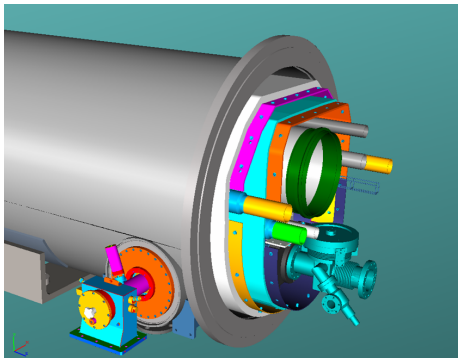
Invest	
73% LAL 27% DESY	

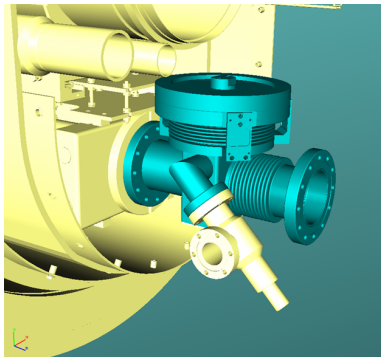
FTE	
52% LAL 48% DESY	

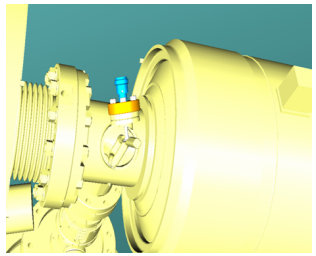


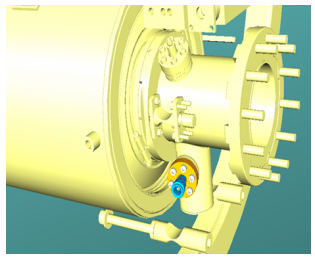
- Coupler production incl. project and industries follow-up
- Coupler conditioning
- Infrastructure required for coupler assembly and conditioning, i.e. clean room and modulator / klystron
- Technical interlock
- Tunnel installation / cabling of technical interlock
- Motor electronics

WP – 6 HOM Coupler / Pick-up









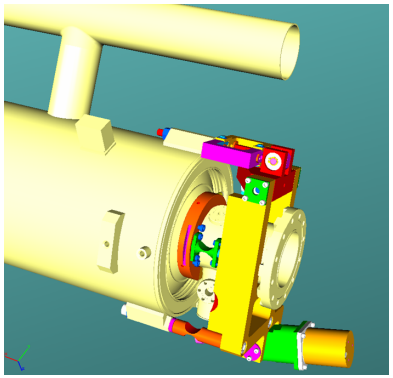
Invest	
100% Swierk	

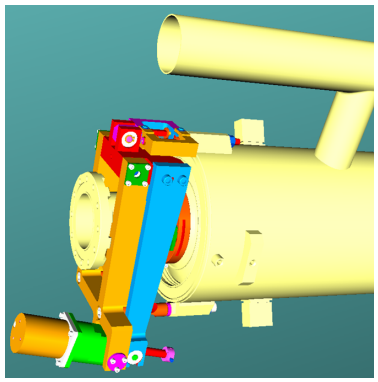
FTE	
100% Swierk	

- Fabrication of HOM beam pipe absorbers
- HOM Pick-ups and cables

WP – 7 Frequency Tuners

Invest	FTE
100% DESY	100% DESY

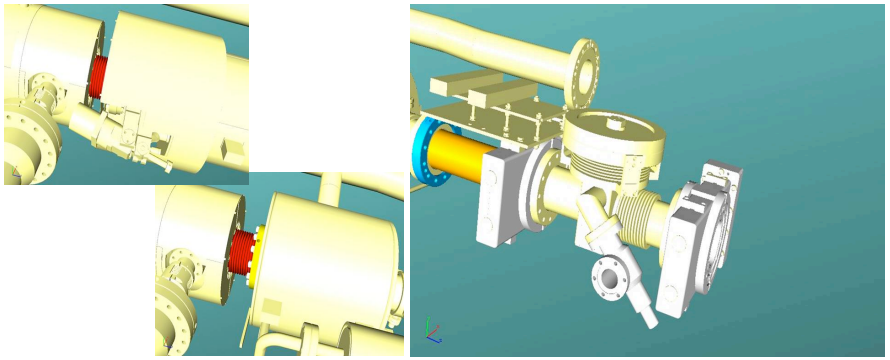




- procurement of motors, gear box, piezo actuators
- fabrication of mechanical tuner parts
- fabrication of drive unit (motor and piezo) electronics
- cabling
- survey of production

WP – 8 Cold Vacuum

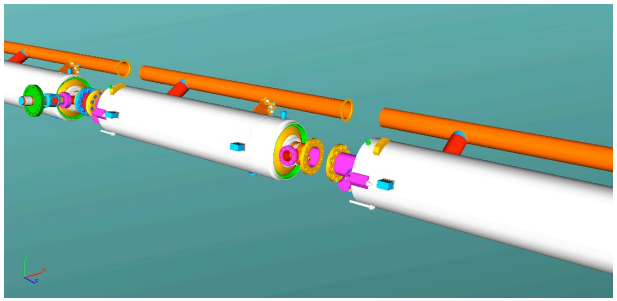
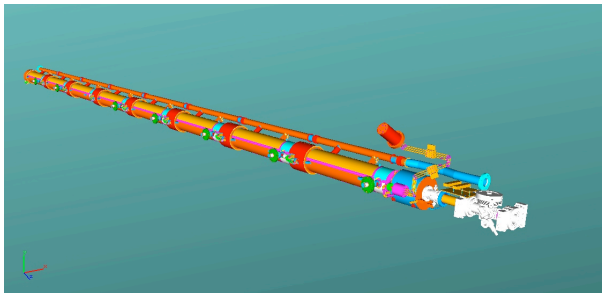
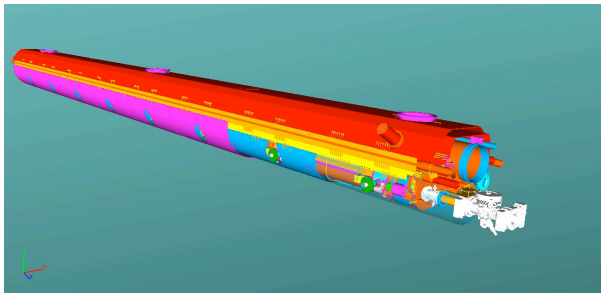
Invest	FTE
100% DESY	100% DESY



- procur of all vac components within the cold linac, i.e.
  - bellows between cavities
  - cold manual valves at both ends of cavity strings
  - valves in the module connection
  - isolation vac valves
  - ion and TSP pumps incl. power supplies/controllers
  - all vac components part of the cryogenic connection boxes and of the cold-warm transitions
- vacuum components in the injector as well as bunch compressor sections (to be transferred to WP – 19)

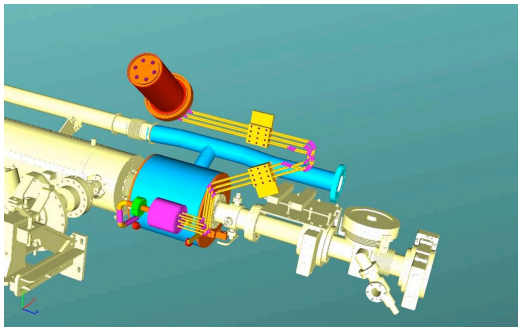
WP – 9 Cavity String Assembly / Clean Room Quality Assurance

	Invest	FTE
90% CEA 10% DESY		51% CEA 49% DESY

- Helium vessel fabrication
- Titanium Tube and 2-phase line
- String assembly
- Knowledge transfer / consultant / training
- Database set-up and running / QC of infrastructure
- EDMS

WP – 11 Cold Magnets



	Invest	FTE
56% CIEMAT 44% DESY		10% CIEMAT 90% DESY

- fabrication of 2K quadrupole package
- test of quadrupole package

XFEL Components (the “scrf ones…”)

XFEL needs

808 cavities for
101 accelerator modules, i.e.
808 frequency tuners,
808 RF main input couplers,
1616 HOM pick-ups,
101 HOM absorbers
etc.

Due to the long lead time, all components need to be specified in 2008,

- **the call for tender process to be started before end of 2008,**
- **orders be placed not later than beginning of 2009.**

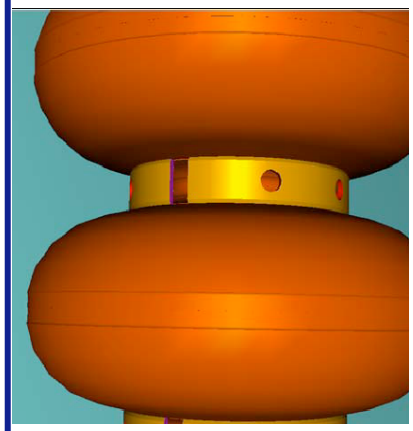
WP 4: Cavities
Items not finished in the XFEL preparation phase

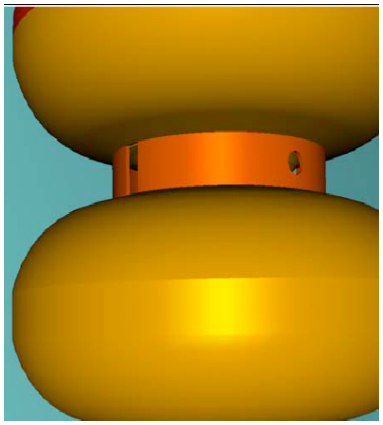
- **Fabrication of 30 cav.** for industrial EP
  ACCEL delivered 15 cav.;
  ZANON delivered 5 cav., rest till end of the year
- Qualifying of **new Nb vendors** on 9 cell cavities
  1 cav. of PLANSEE niobium is in fabrication at ACCEL,
  3 cav. of NINGXIA niobium are in fabrication at ACCEL
- **Industrial study of EP**

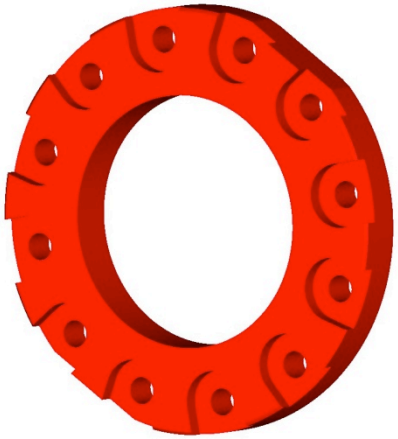
  set up of prototype EP and carry out the first step EP (rough EP) of 30 cav.

  Fa. ACCEL: EP treatment of first cavities till end of 2007
  Fa. Henkel is also going to start EP treatment now

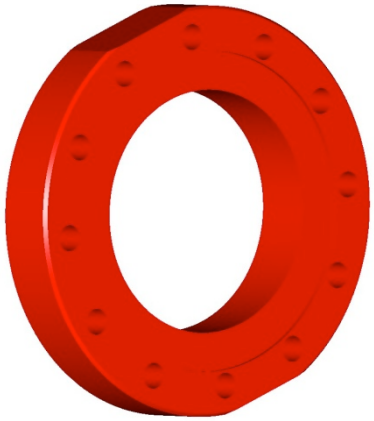
WP 4: Cavities - Small design changes to reduce cost and simplify fabrication







Short side
(machined step
under discussion)



Long side

Removal of coupler port stiffener

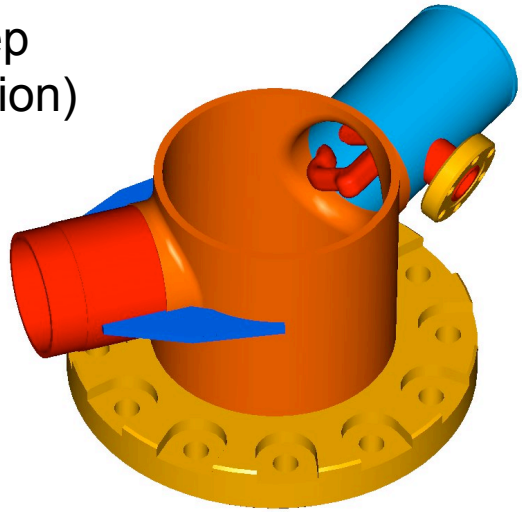
Reducing of flange machining short side

Removal of outside recess (equator area)

Less holes and thinner the stiffener ring

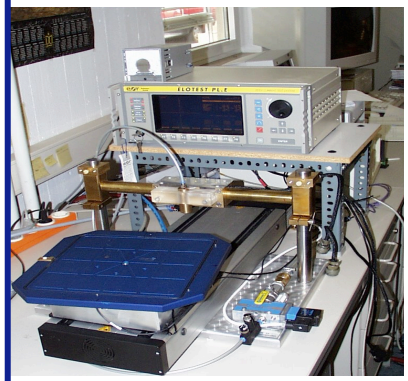
Review tolerances

No rib

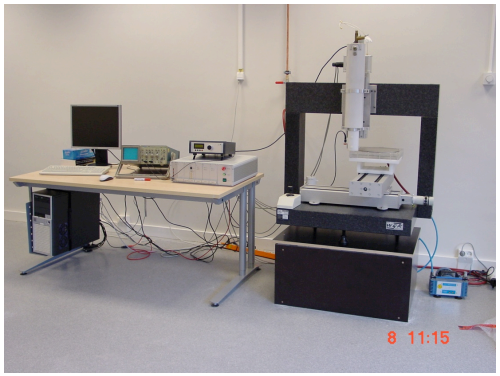


WP 4: DESY will supply companies with following material / equipment and carry out the training

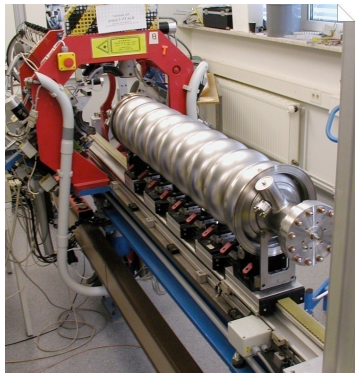
- Niobium for 50 cavities
- Apparatus for scanning of niobium
- Equipments for RF measurement of half cells, dumb bells and end groups
- Equipment for warm tuning (tuning machine)



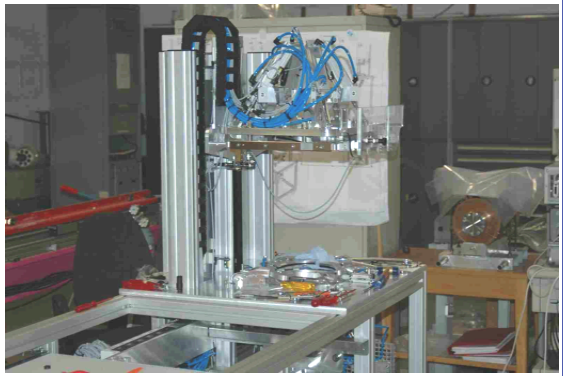
DESY Eddy current apparatus



DESY SQUID apparatus



Equipment for warm tuning (tuning machine)



RF measurement device Equipments for RF measurement of half cells, dumb bells and end groups

WP 4: Pending Decisions

- Vertical RF test of cavities with He tank or not
- Treatment procedure is not finally defined.

  Fine Grain:

  Final EP (with or without ethanol) or BCP-Flash?

  Large Grain:

  BCP only

  or rough EP with final EP (with or without ethanol)

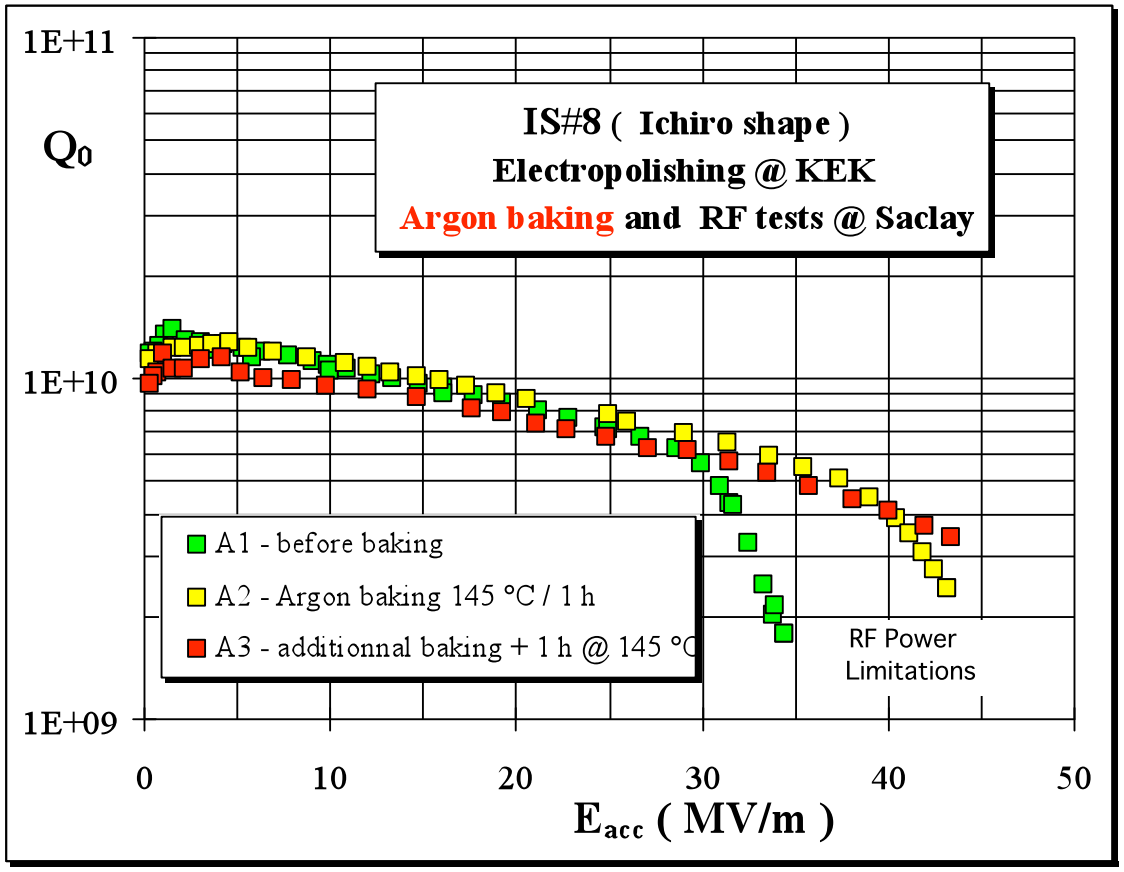
  or rough EP with BCP-Flash?
- Material scanning: Eddy Current or SQUID
- Niobium for 50 cavities

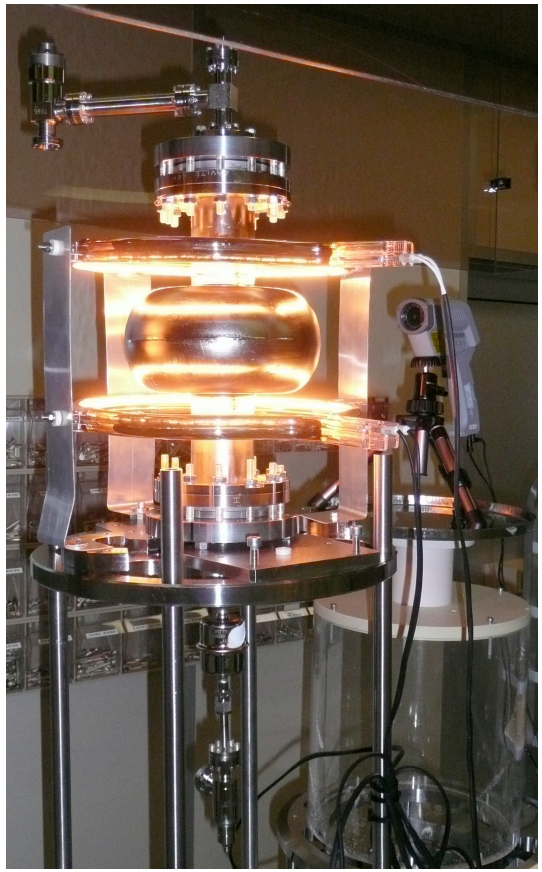
  (as ingot material, discs or fine grain sheets??)

Argon Baking @ 145 °C vs. time

Electropolishing at KEK

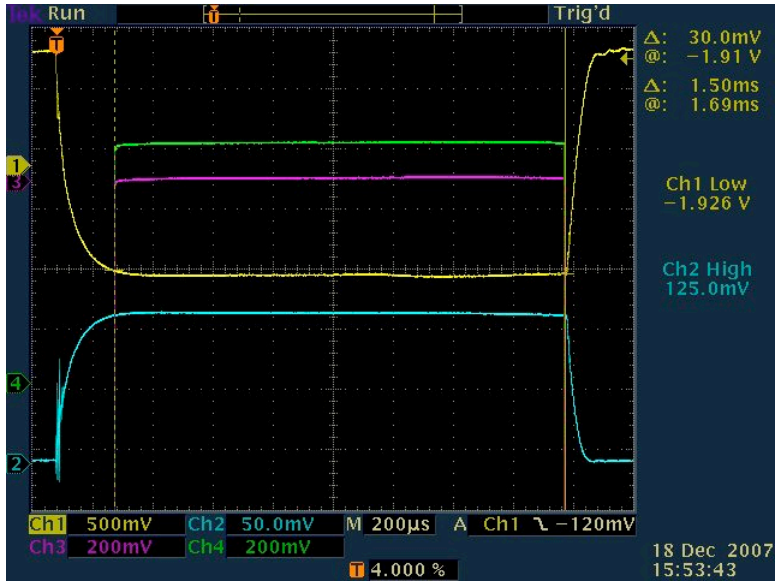
Argon baking and RF tests at Saclay



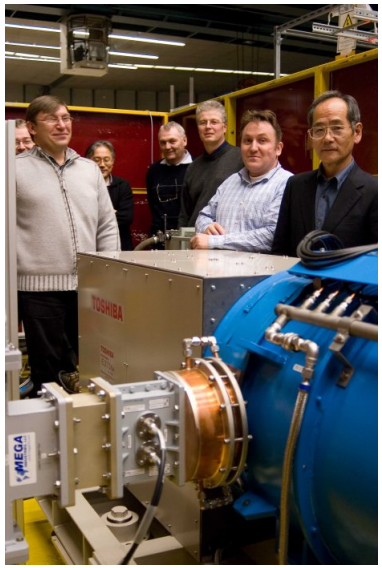


ICHIRO IS#8

Horizontal Multi-beam Klystron test at DESY



10MW 1.5ms
67% efficiency



Scope picture of the klystron test. The lines show the klystron voltage (116 kV) in yellow, the current (128 A) in blue and RF output (5 MW each) in magenta and green.

Toshiba E3736H

http://www.linearcollider.org/newsline/readmore_20080117_atw.html

Plans of cryomodules

cryomodule plans