

T-mapping Result at KEK-STF

- I. Improvement for fabrication of MHI #5 & #6 cavity
- II. Result of V.T.s including T-mapping at STF
 - I. AES#001
 - II. MHI#5
 - III. MHI#6
- III. Other topics
- IV. Summary & Future plan



MITSUBISHI
HEAVY INDUSTRIES, LTD.

Improvement for fabrication of MHI #5 & #6 cavities

- Thinning of equator thickness for EBW
- CP before EBW in each step
- Optimum EBW parameters for stable smooth surface
- Clean environment around EBW device
- Clean booth for assembly of EBW jigs
- Check of EBW seam by Kyoto camera

Done at MHI!

- We didn't apply the barrel polish to these two cavities!

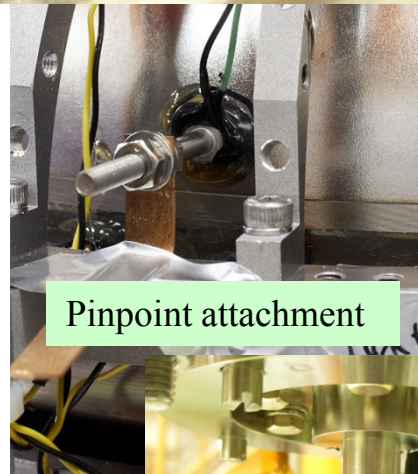
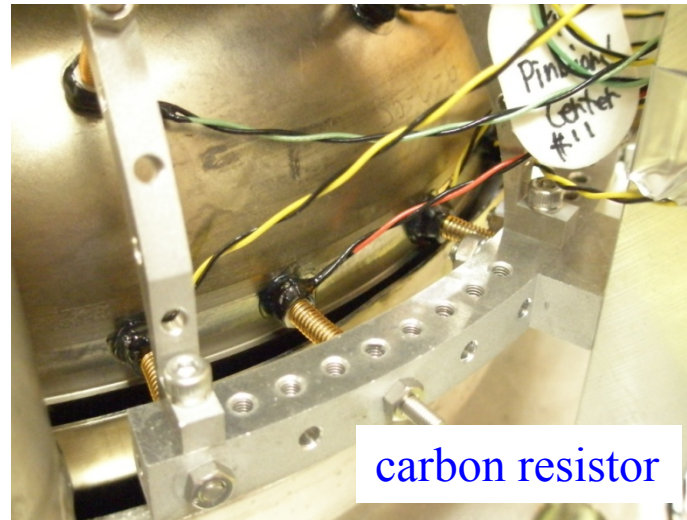
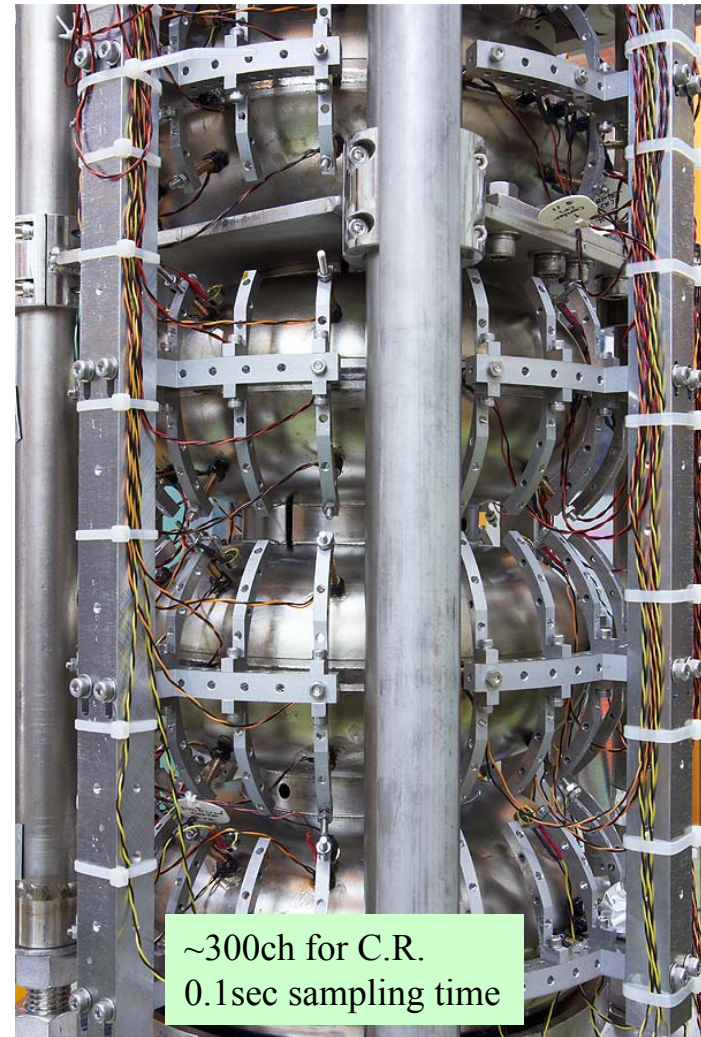
Causes of Field Limit

- Thermal quenching due to abnormal heating
 - Defect or contamination
 - Good correlation between the result of T-mapping and pass-band measurement
 - Not almost found suspicious spot at heating location
- Field emission
 - Source of anxiety
 - Heating by electron bombardment, not defect or contamination
 - No correlation between the result of T-mapping and pass-band measurement
- Multipacting(?)
 - Generally, multipacting location is not fixed
 - In our case, the cavity field gradually increases during multipacting and the barrier almost easily is overcome.
 - Unclear if it limits the cavity field or not
 - We think it is possible to overcome it for long RF conditioning

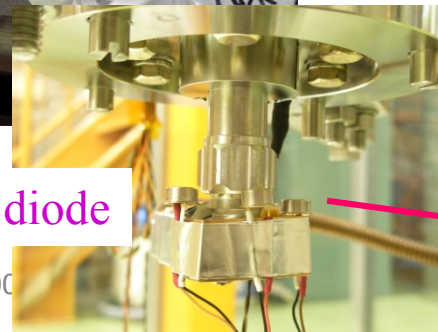
Cavity diagnostic system

It is composed of the carbon resistors and PIN diodes.

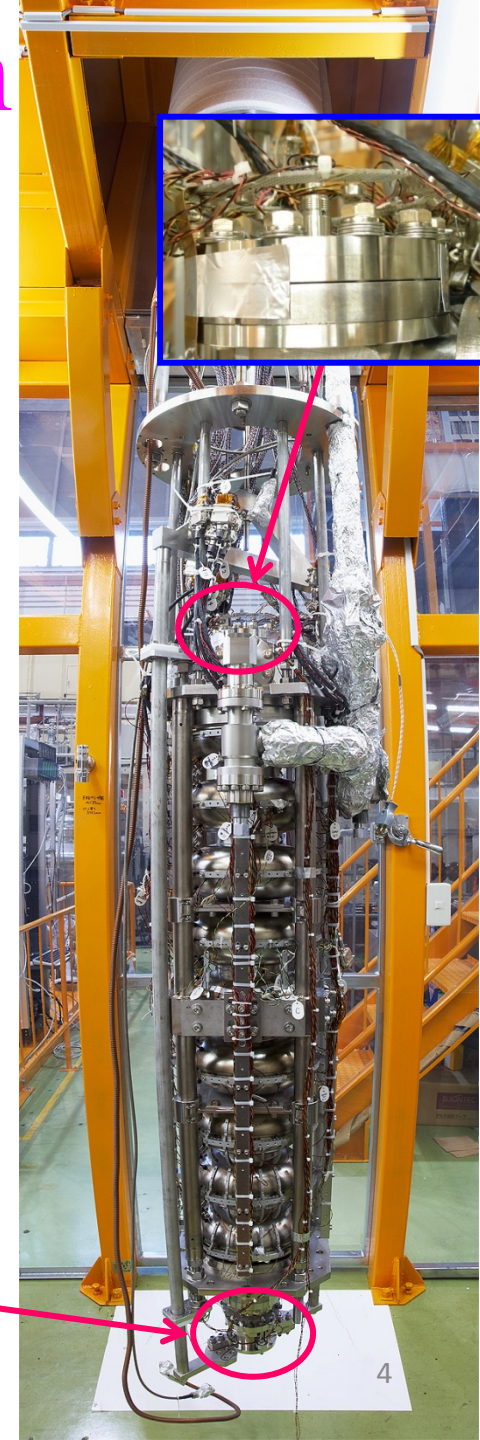
Fish-bone structure



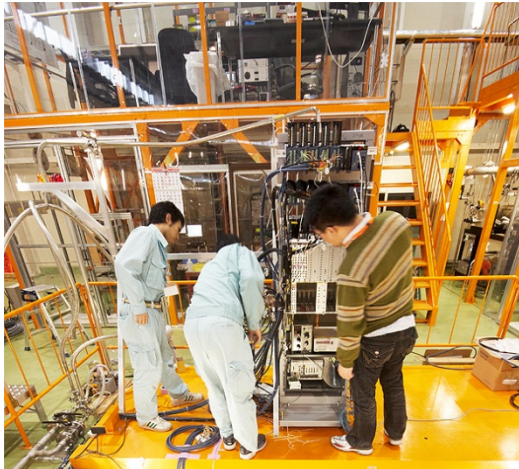
PIN diode



TILC09 @200

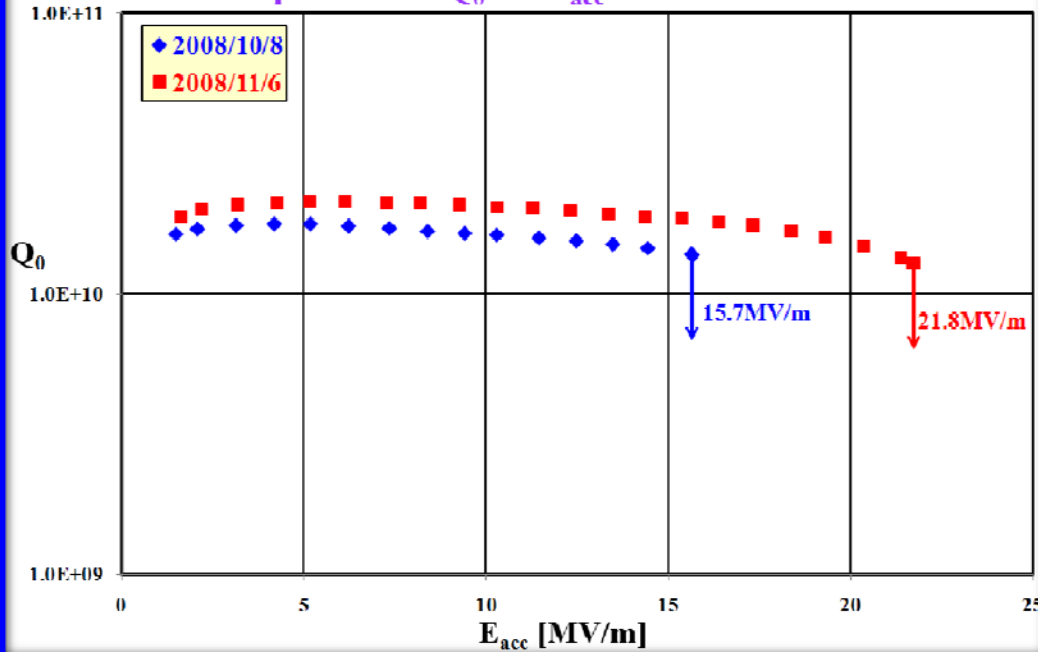


Vertical Test Stand at STF



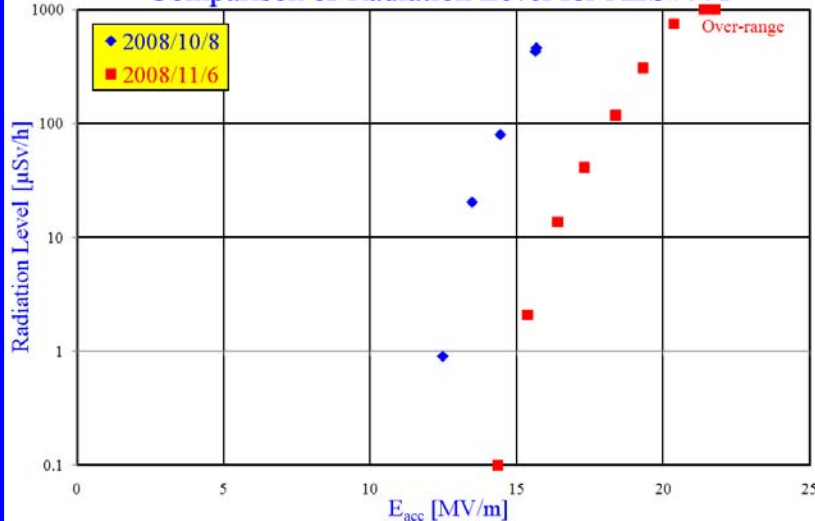
Case of AES #001 Cavity

Comparison of Q_0 vs. E_{acc} curve for AES#001



- Totally 3 times V.T.s
 - 1st : 11.2MV/m at π mode
 - Only HPR
 - 2nd : 15.7MV/m at π mode
 - Only HPR
 - 3rd : 21.8MV/m at π mode
 - EP(20 μ m) + HPR
- Heating cells at π mode
 - #3(2nd V.T.), #3(3rd V.T.)
- Suspicious spots
 - Two spots were found at #3 cell

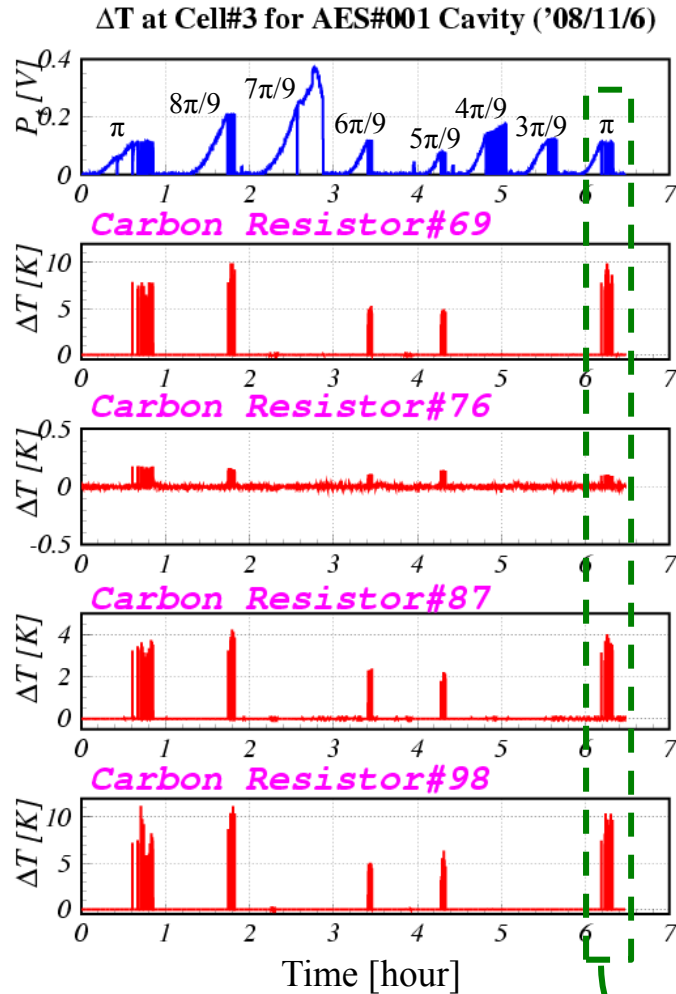
Comparison of Radiation Level for AES#001



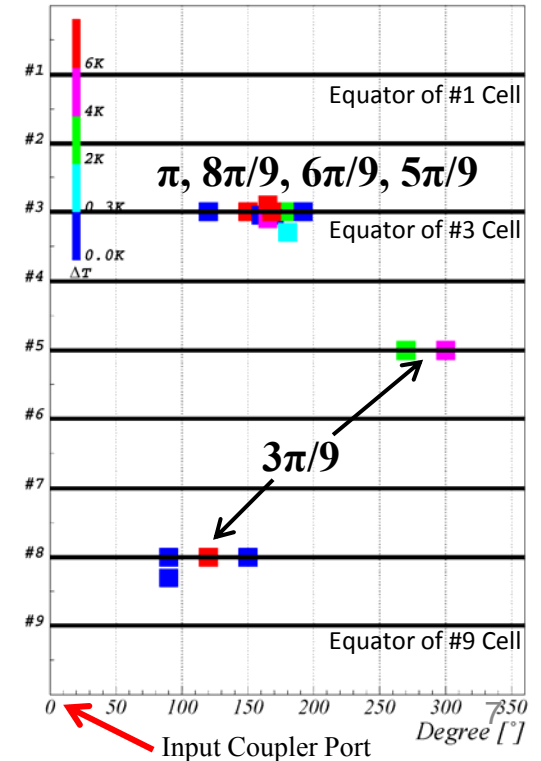
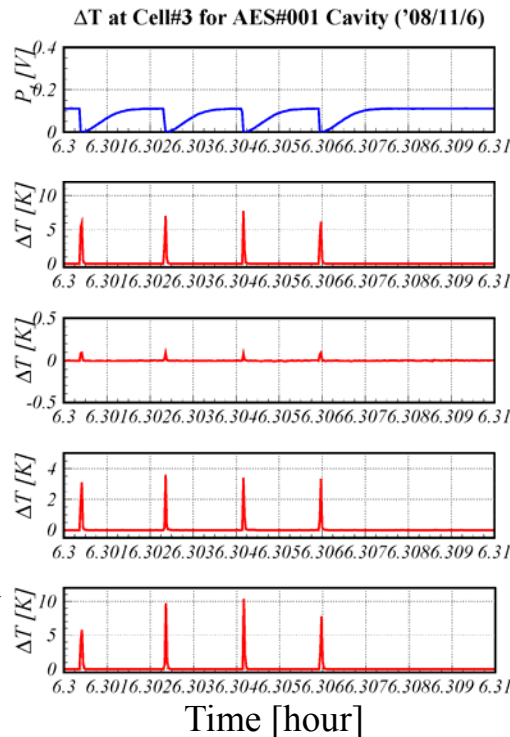
This is a very clear result.

Thank you very much for FNAL's people!

Result of T-mapping at 3rd V.T. for AES#001 Cavity



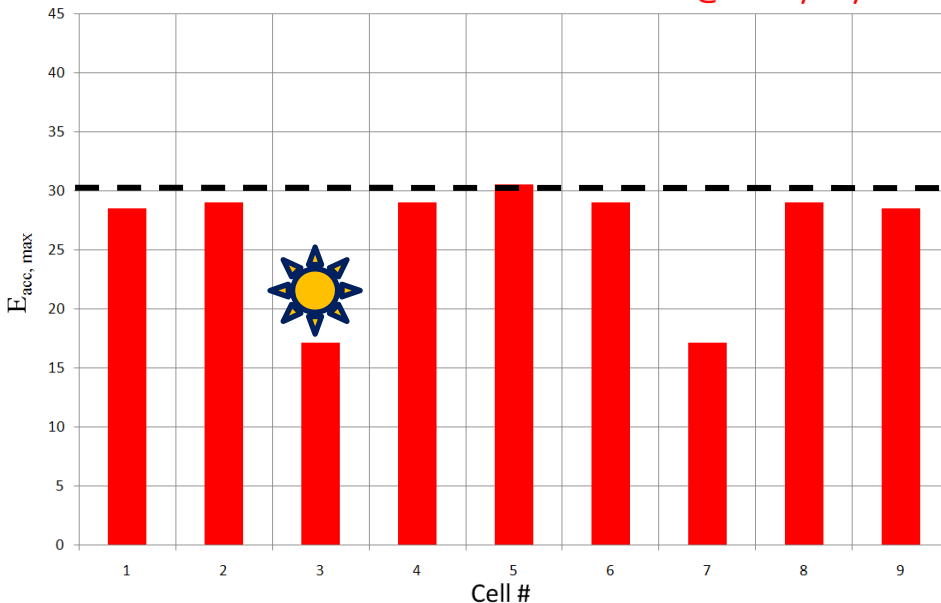
cell	π	$8\pi/9$	$7\pi/9$	$6\pi/9$	$5\pi/9$	$4\pi/9$	$3\pi/9$
1 & 9	21.8	33.9	34.3	21.8	17.9	23.9	20.0
2 & 8	21.8	30.2	18.2	0.0	12.2	31.3	40.0
3 & 7	21.8	22.4	6.9	21.8	21.1	13.6	20.0
4 & 6	21.8	12.5	26.4	0.0	3.6	34.7	20.0
5	21.8	0.0	36.7	21.8	22.7	0.0	40.0
limiting cause	Cell #3	Cell #3	Power Limit	Cell #3	Cell #3	Stopping	Cell #5 & #8



Comparison of $E_{acc, max}$ for Each Cell

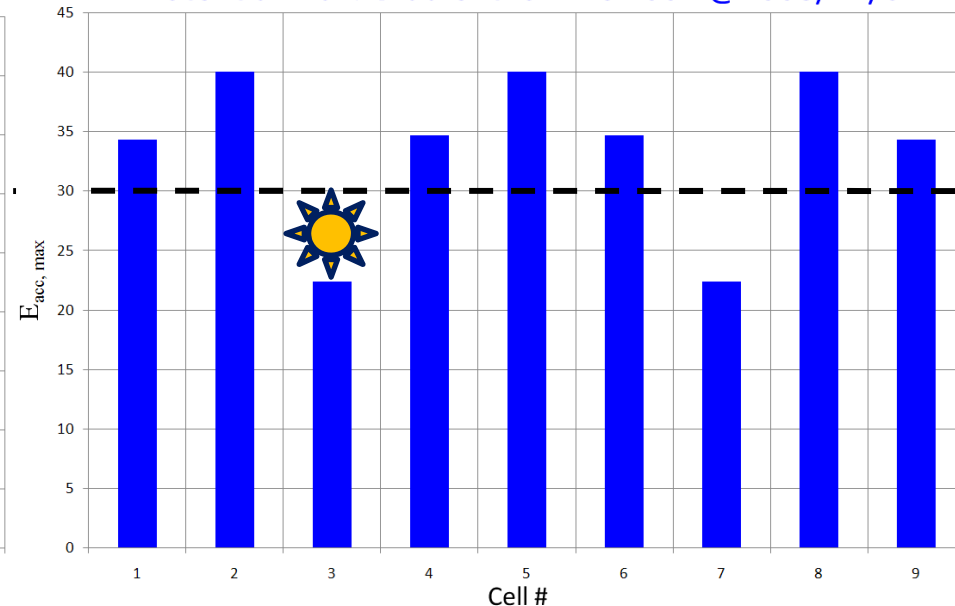
Second Test

Potential Max. Gradient for AES #001 @2008/10/8



Third Test

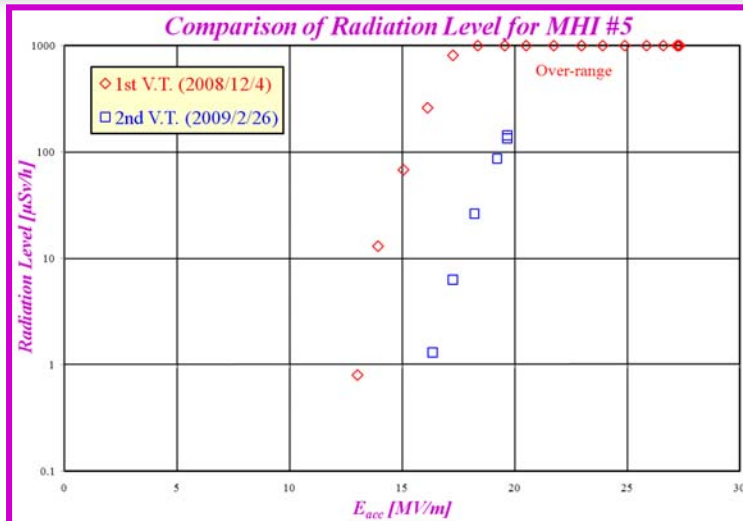
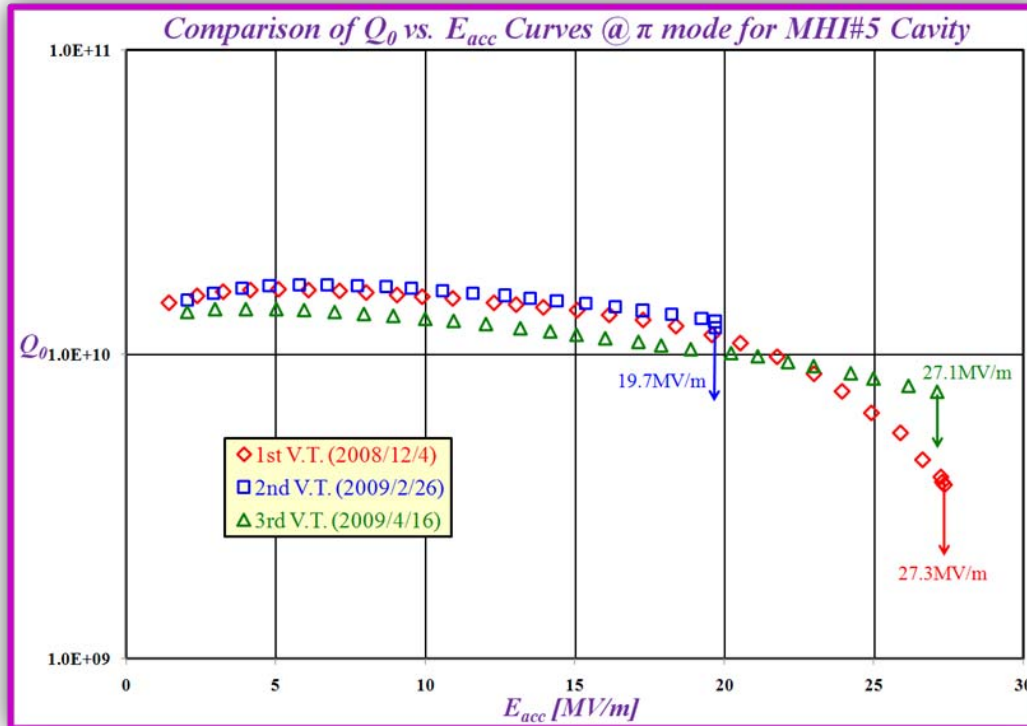
Potential Max. Gradient for AES #001 @2008/11/6



The heating cell was not changed, although the gradient for each cell was increased. The EP(20 μ m) was not sufficient and more polish may be necessary.

In the third test, other cells excluding #3 and #7 cell achieved above 30MV/m.

Case of MHI #5 Cavity

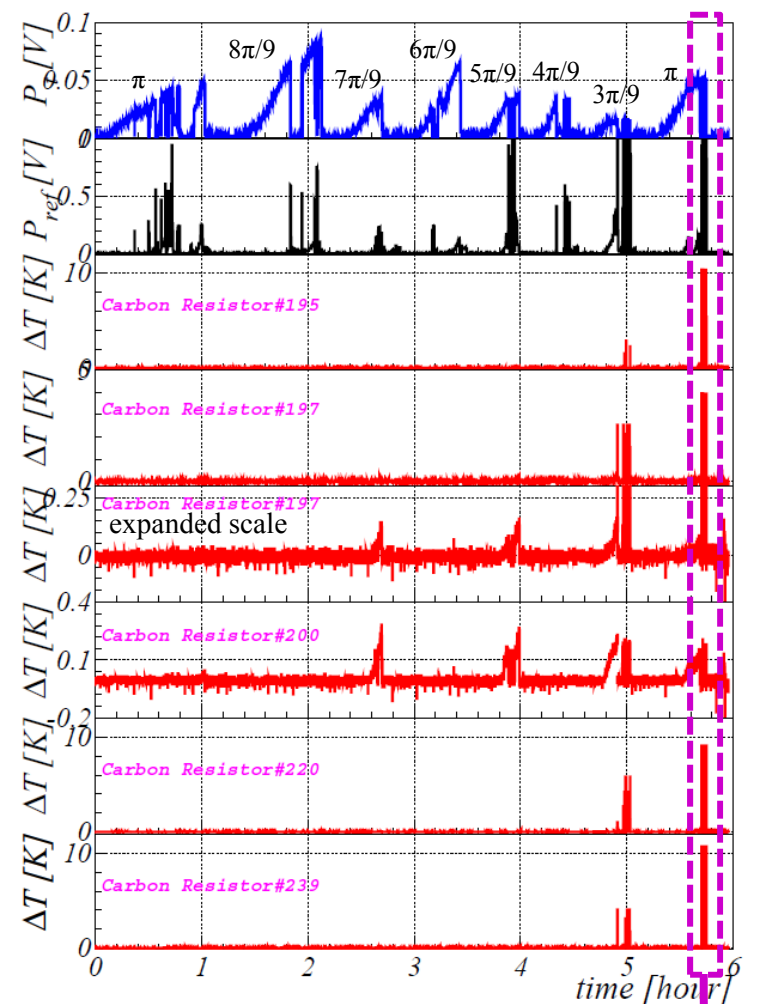


- Totally 3 times V.T.s
 - 1st : 27.3MV/m at π mode
 - EP(50 μ m) + H₂O₂rinsing+HPR
 - Field flatness : 98.4%
 - 2nd : 19.7MV/m at π mode
 - EP(50 μ m) + H₂O₂rinsing+HPR
 - Field flatness : 97.1%
 - 3rd : 27.1MV/m at π mode
 - EP(20 μ m) +ethanol rinsing+ HPR
 - Field flatness : 96.9%
- Heating cells at π mode
 - #5(1st V.T.), #8(2nd V.T.), #5(3rd V.T.)
- Suspicious spots
 - Not found
(later presented by K. Watanabe)

@2009/4/18 (Sat)

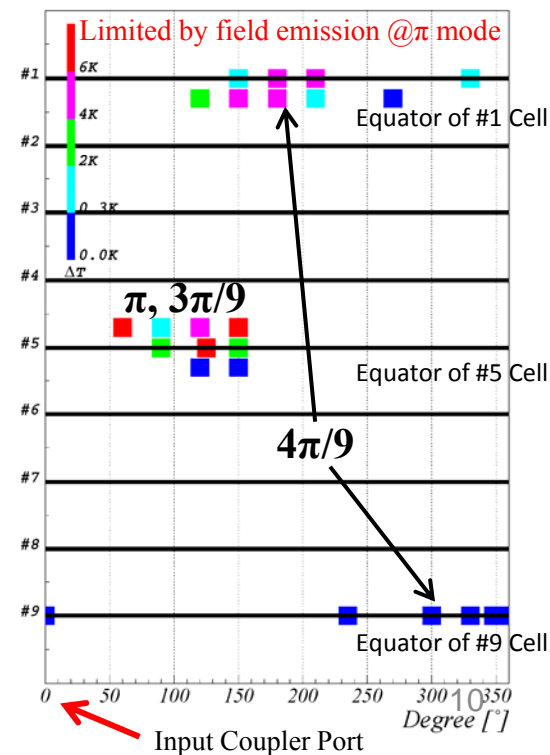
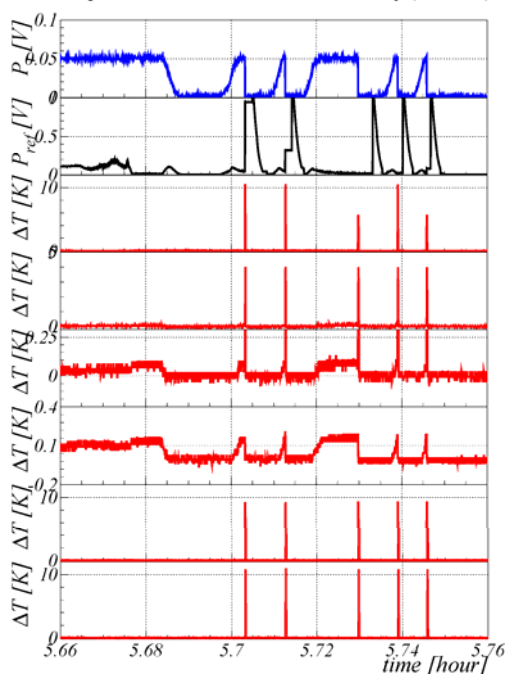
Result of T-mapping at 1st V.T. for MHI#5 Cavity

ΔT plot at Cell#5 for STF B.L.#5 Cavity ('08/12/4)



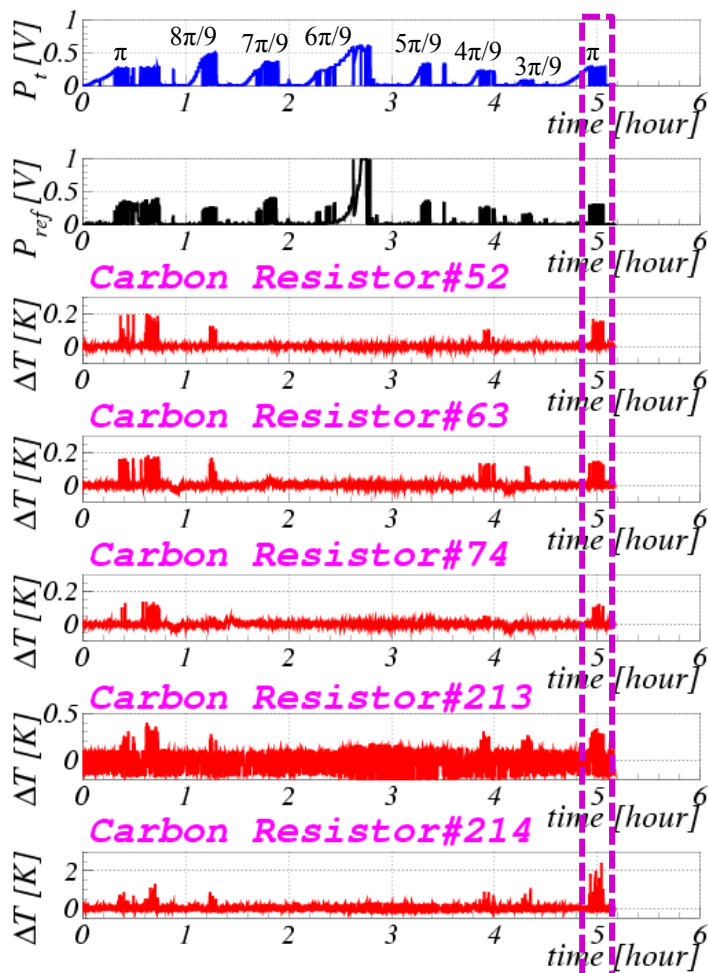
cell	π	$8\pi/9$	$7\pi/9$	$6\pi/9$	$5\pi/9$	$4\pi/9$	$3\pi/9$
1 & 9	27.3	36.1	27.3	34.2	23.0	20.4	15.4
2 & 8	27.3	32.1	14.5	0.0	15.6	26.7	30.8
3 & 7	27.3	23.8	5.5	34.2	27.1	11.6	15.4
4 & 6	27.3	13.3	21.1	34.2	4.6	29.5	15.4
5	27.3	0.0	29.3	0.0	29.2	0.0	30.8
limiting cause	Cell #5	Power stop	Power stop	Power stop	Power stop	Cell #1 & #9	Cell #5

ΔT plot at Cell#5 for STF B.L.#5 Cavity ('08/12/4)

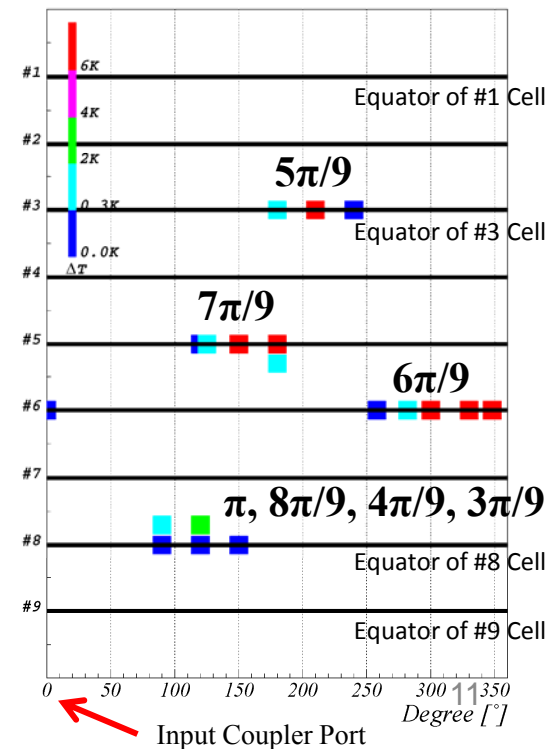
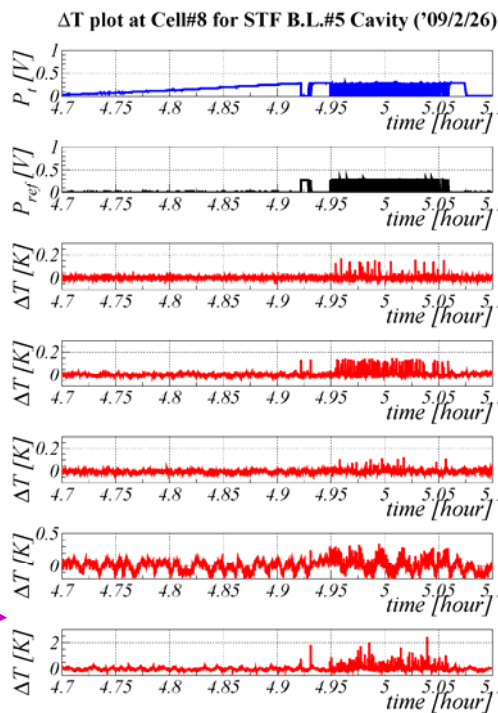


Result of T-mapping at 2nd V.T. for MHI#5 Cavity

ΔT plot at Cell#8 for STF B.L.#5 Cavity ('09/2/26)



cell	π	$8\pi/9$	$7\pi/9$	$6\pi/9$	$5\pi/9$	$4\pi/9$	$3\pi/9$
1 & 9	19.7	25.6	27.3	32.9	21.7	16.2	10.9
2 & 8	19.7	22.8	14.5	0.0	14.7	21.3	21.7
3 & 7	19.7	16.9	5.5	32.9	25.6	9.3	10.9
4 & 6	19.7	9.5	21.0	32.9	4.3	23.5	10.9
5	19.7	0.0	29.2	0.0	27.5	0.0	21.7
limiting cause	Cell #8	Cell #8	Cell #5	Cell #6	Cell #3	Cell #8	Cell #8



Result of Pass-band at 3rd V.T. for MHI#5 Cavity

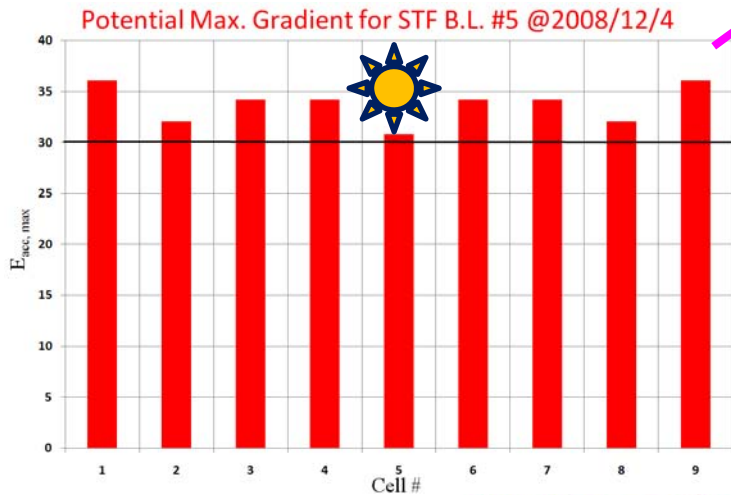
Preliminary!

↖ another excitation

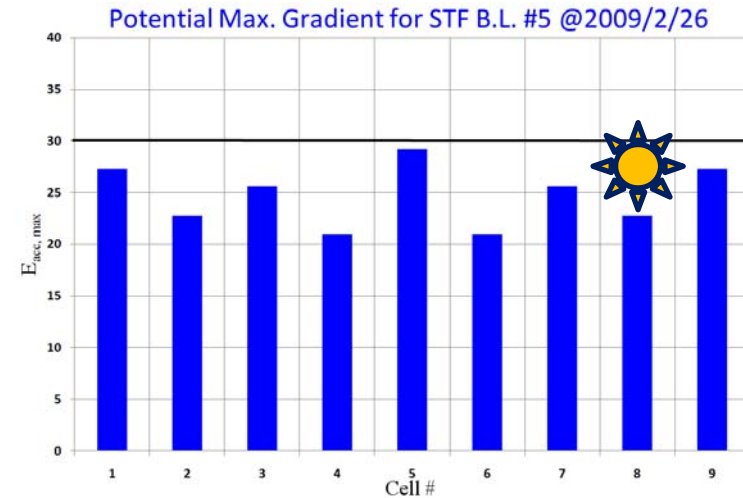
cell	π	$8\pi/9$	$7\pi/9$	$6\pi/9$	$5\pi/9$	$4\pi/9$	$3\pi/9$
1 & 9	27.1	34.9	26.0	31.2	21.5	20.9	14.1
2 & 8	27.1	31.0	13.8	0.0	14.7	27.3	28.1
3 & 7	27.1	23.0	5.2	31.2	25.4	11.9	14.1
4 & 6	27.1	12.9	20.0	31.2	4.3	30.2	14.1
5	27.1	0.0	27.8	0.0	27.4	0.0	28.1
limiting cause	Cell #5	?	Cell #5	Cell #6	Cell #5	Cell #6	Cell #5

Comparison of $E_{acc, max}$ for Each Cell

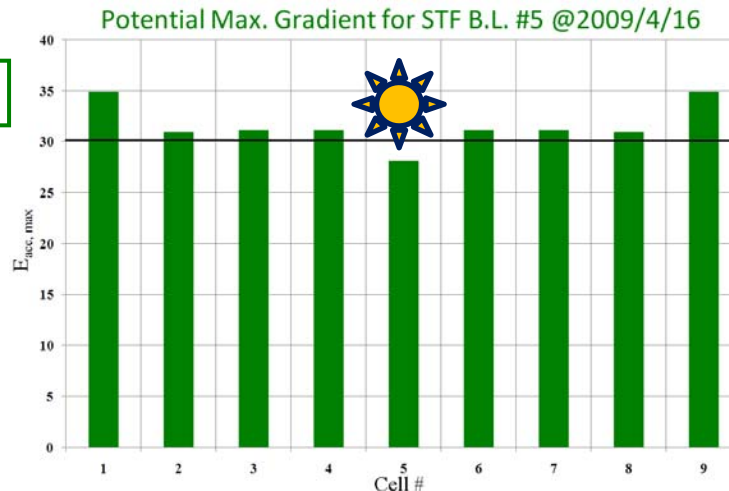
First Test



Second Test



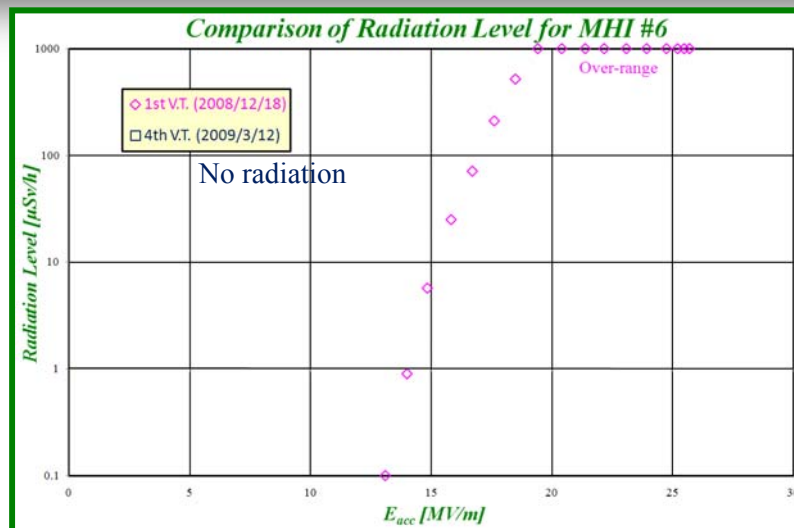
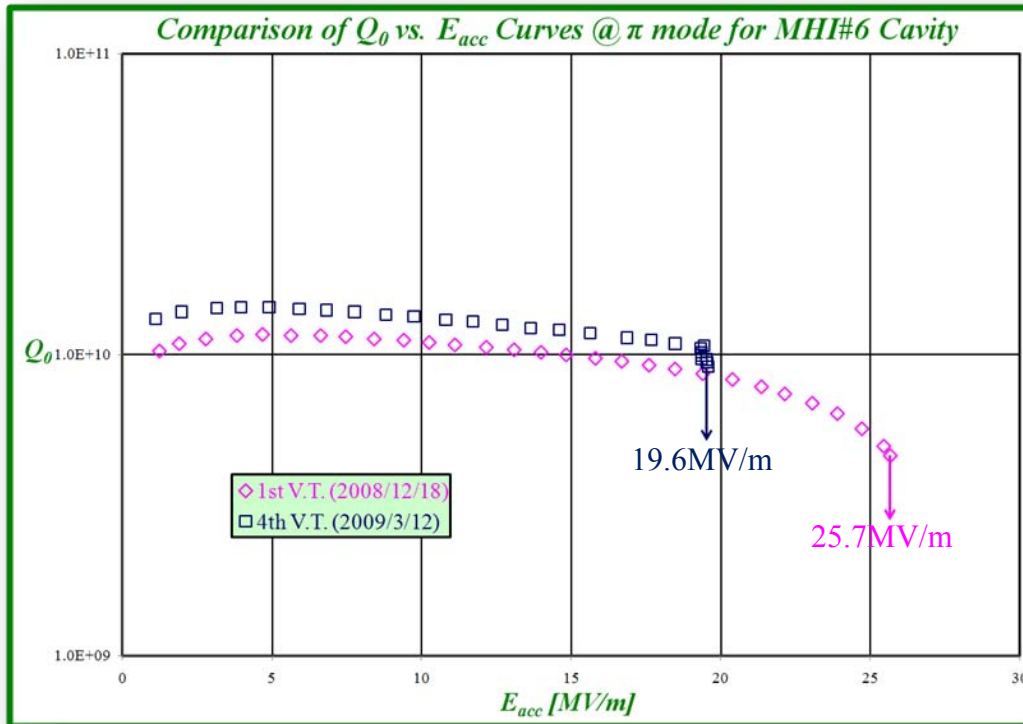
Third Test



The heating cell was changed from Cell #5 to #8 and to #5 again among these tests, but the limiting causes are different. 1st V.T. was limited by the field emission, and 2nd and 3rd V.T.s by the thermal quenching due to defect or contamination. We don't understand the reason of the significant field degradation at 2nd V.T.

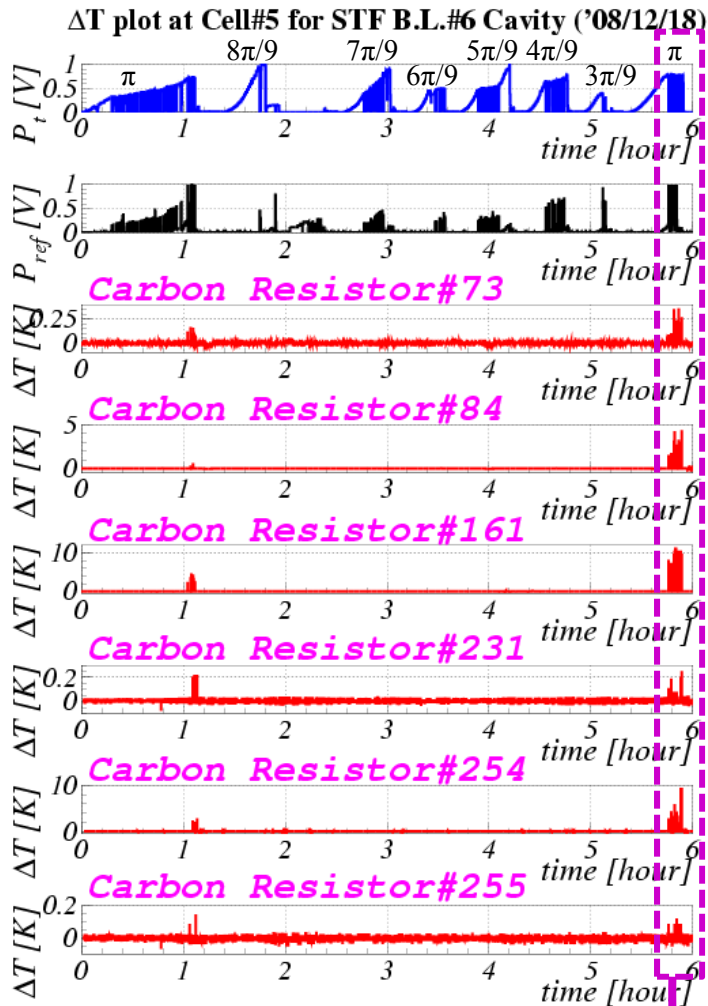
Although each cell achieved above 30MV/m at 1st V.T., the field was limited 27.3MV/m due to the field emission in only π mode!

Case of MHI #6 Cavity

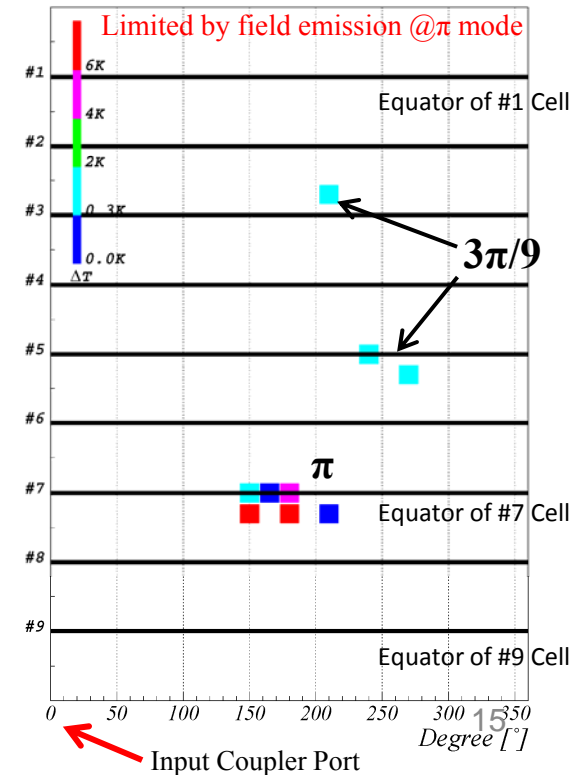
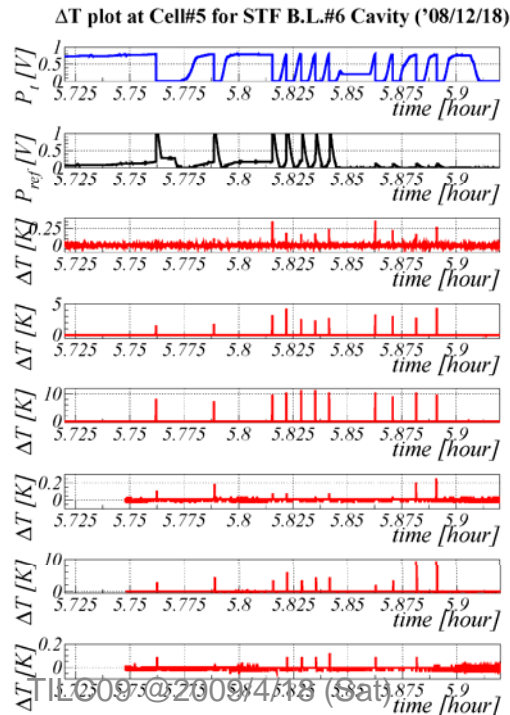


- Totally 4 times V.T.s
 - 1st : 25.7 MV/m at π mode
 - EP(50 μ m) + H₂O₂ rinsing + HPR
 - Field flatness : 97.8%
 - 2nd : 24.6 MV/m at π mode
 - Magnetic shield study
 - No surface process
 - No T-mapping
 - 3rd : 25.9 MV/m at π mode
 - Magnetic shield study
 - No surface process
 - No T-mapping
 - 4th : 19.6 MV/m at π mode
 - EP(50 μ m) + H₂O₂ rinsing + HPR
 - Field flatness : 97.5%
- Heating cells at π mode
 - #7(1st V.T.), #9(4th V.T.)
- Suspicious spots
 - Not found
 - (later presented by K. Watanabe)

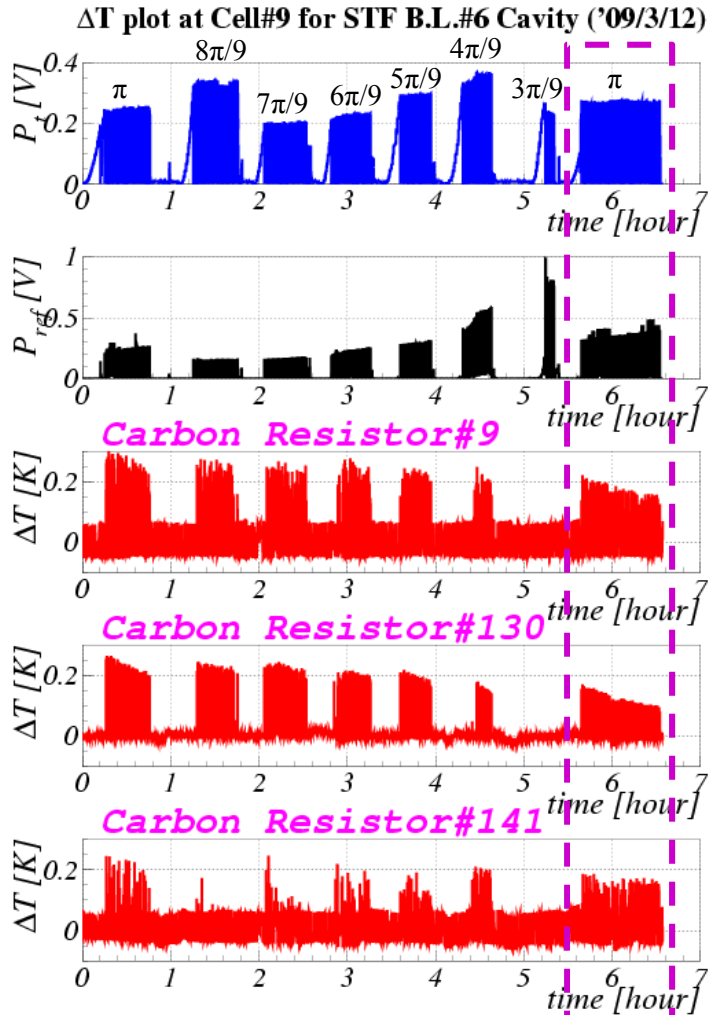
Result of T-mapping at 1st V.T. for MHI#6 Cavity



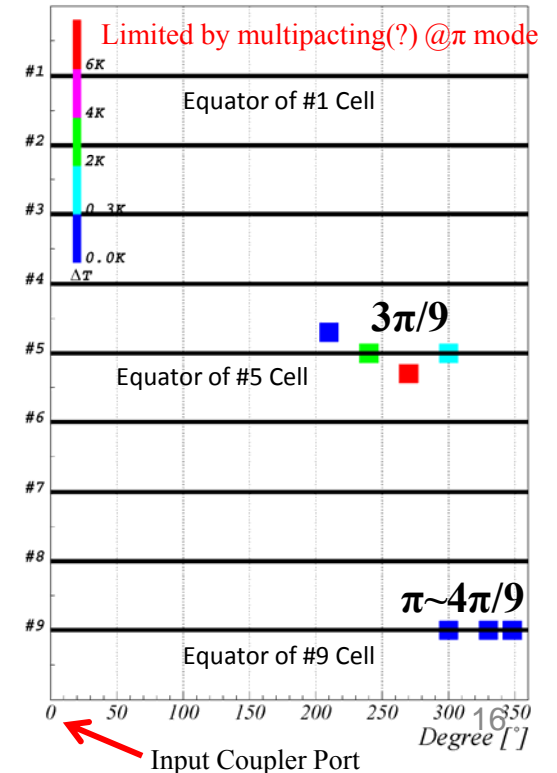
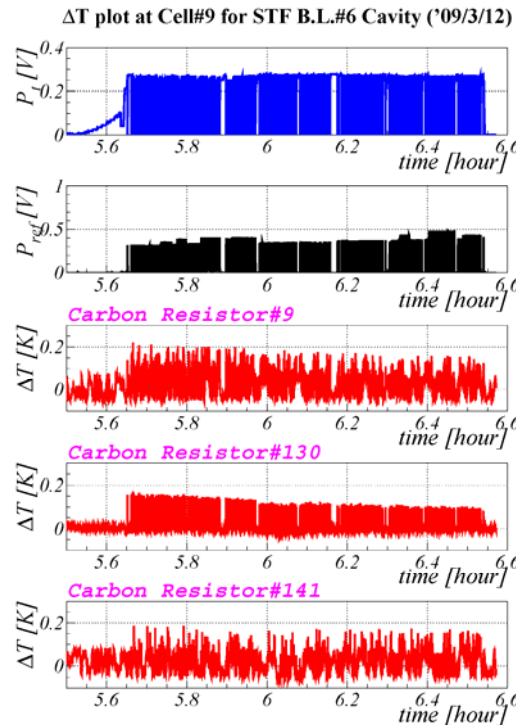
cell	π	$8\pi/9$	$7\pi/9$	$6\pi/9$	$5\pi/9$	$4\pi/9$	$3\pi/9$
1 & 9	25.7	35.7	30.3	(20.6)	27.6	22.6	17.7
2 & 8	25.7	31.8	16.1	0.0	18.8	29.6	35.4
3 & 7	25.7	23.6	6.1	(20.6)	32.6	12.9	17.7
4 & 6	25.7	13.2	23.4	(20.6)	5.5	32.7	17.7
5	25.7	0.0	32.4	0.0	35.1	0.0	35.4
limiting cause	Cell #7	Power stop	Power stop	Another excitation	Power stop	Power stop	Cell #3



Result of T-mapping at 4th V.T. for MHI#6 Cavity



cell	π	$8\pi/9$	$7\pi/9$	$6\pi/9$	$5\pi/9$	$4\pi/9$	$3\pi/9$
1 & 9	19.6	20.9	21.1	21.5	21.1	21.3	19.9
2 & 8	19.6	18.6	11.2	0.0	14.3	27.9	39.9
3 & 7	19.6	13.8	4.2	21.5	24.9	12.1	19.9
4 & 6	19.6	7.7	16.2	21.5	4.2	30.9	19.9
5	19.6	0.0	22.6	0.0	26.8	0.0	39.9
limiting cause	Cell #9	Cell #9	Cell #9	Cell #9	Cell #9	Cell #9	Cell #5



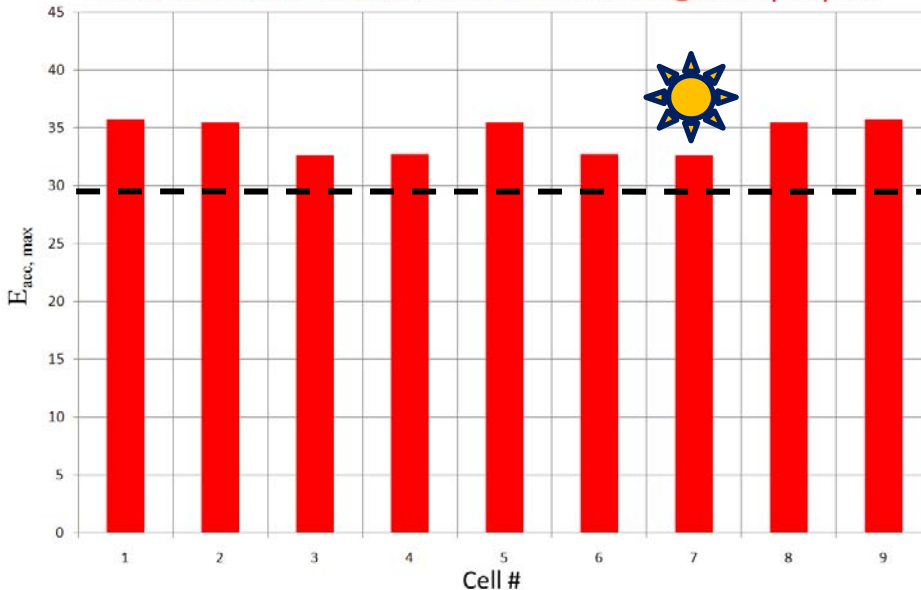
It seems that the heating is gradually decreasing.
We may overcome it,
if we continue the test one more day.

Comparison of $E_{acc, max}$ for Each Cell

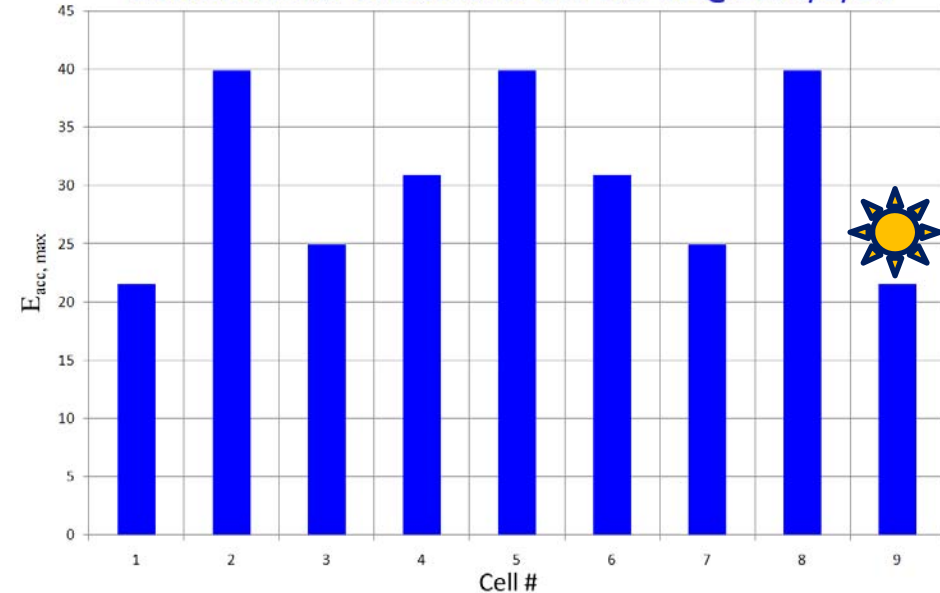
First Test

Fourth Test

Potential Max. Gradient for STF B.L. #6 @2008/12/18



Potential Max. Gradient for STF B.L. #6 @2009/3/12



The heating cell was changed from Cell #7 to #9, but the limiting cause was different.
1st V.T. was limited by the field emission and 2nd V.T. by the multipacting.
We don't understand the reason of the significant field degradation.

Although each cell achieved above 30MV/m in 1st V.T., the field was limited 25.7MV/m due to the field emission in only π mode!

Summary of T-mapping result at STF

cavity	# of V.T.	$E_{\text{acc, max}}$ [MV/m]	heating cell @ π mode	cause of limitation for π mode	heating cell @other pass-band modes	radiation level @ $E_{\text{acc, max}}$ [$\mu\text{Sv/h}$]
AES#001	2 nd	15.7	#3	defect	#3@5, 6, $8\pi/9$	464
AES#001	3 rd	21.8	#3	defect	#5 & #8@ $3\pi/9$ #3@5, 6, $8\pi/9$	>1000
MHI#5	1 st	27.3	#5	field emission	#5@ $3\pi/9$ #1 & #9@ $4\pi/9$	>1000
MHI#5	2 nd	19.7	#8	defect or contamination	#8@3, 4, $8\pi/9$ #3@ $5\pi/9$ #1 & #6@ $6\pi/9$ #5@ $7\pi/9$	143
MHI#5	3 rd	27.1	#5	defect or contamination	#5@3, 5, $7\pi/9$ #6@4, $6\pi/9$	303
MHI#6	1 st	25.7	#7	field emission	#5@ $3\pi/9$	>1000
MHI#6	4 th	19.6	#9	multipacting (?)	#5@ $3\pi/9$ #9@ $4\sim 8\pi/9$	0

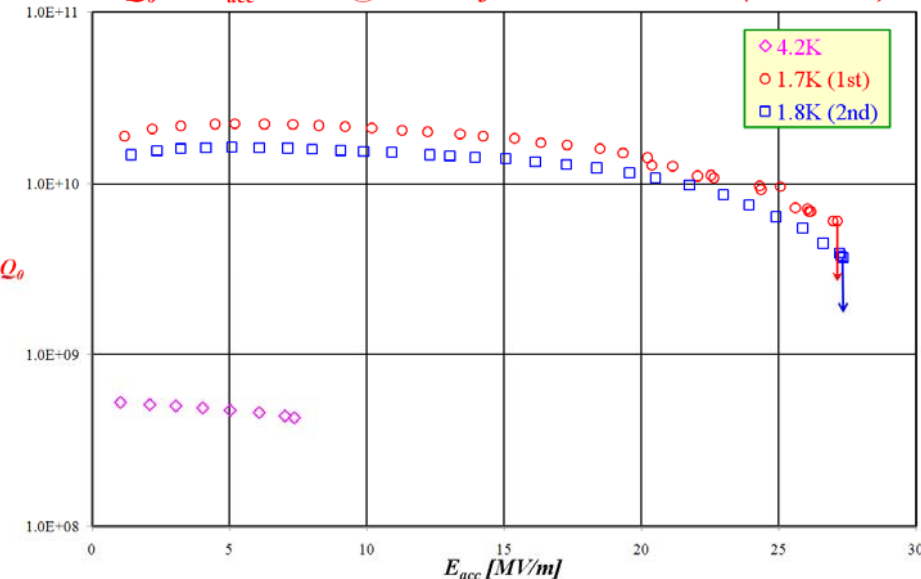
T-mapping system at STF detected the heating cell for **every** V.T.s!

Other topics ①

(Q_0 & Q_t degradation)

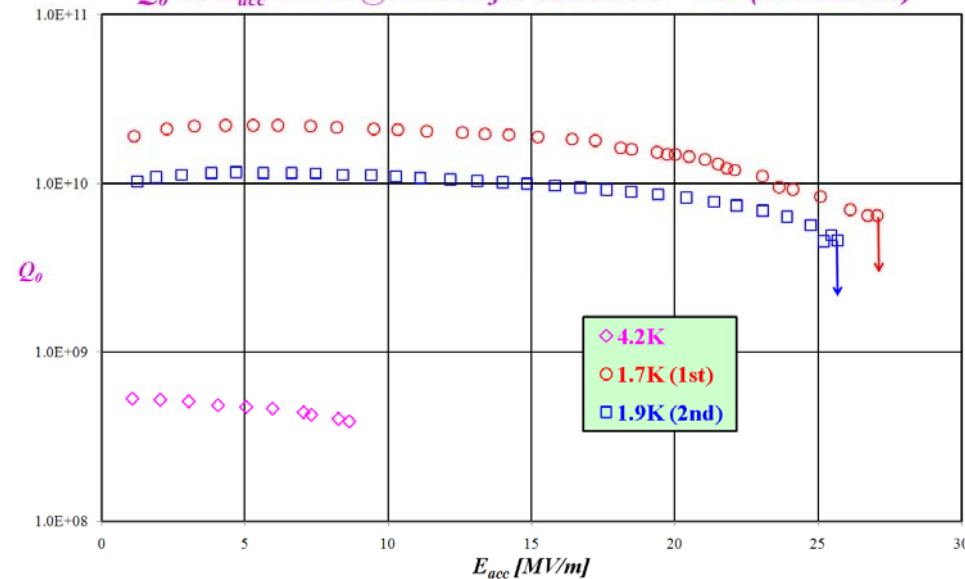
Q_0 was degraded by 36% from 1st and 2nd π mode measurement.
 Q_t was degraded by 7% from 1st and 2nd π mode measurement.

Q_0 vs. E_{acc} Curve @ π mode for MHI #5 1st V.T. (2008/12/4)



Q_0 was degraded by 50% from 1st and 2nd π mode measurement.
 Q_t was degraded by 20% from 1st and 2nd π mode measurement.

Q_0 vs. E_{acc} Curve @ π mode for MHI #6 1st V.T. (2008/12/18)



In every V.T.s at STF, two strange phenomena are observed.

One is Q_0 degradation. The other is Q_t degradation.

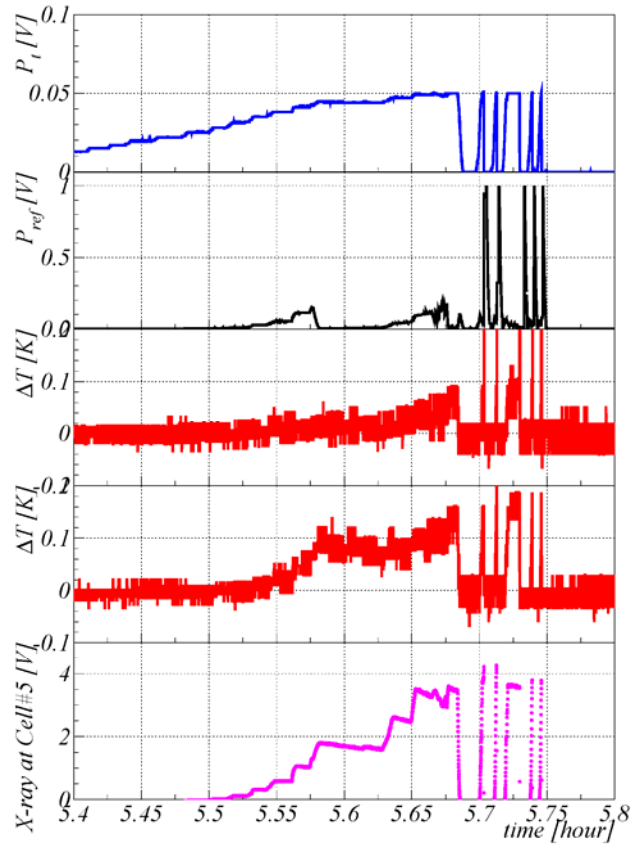
After many thermal quenching, both parameters are degraded.

For Q_0 degradation, it is considered that it is related to the magnetic field trapping at the quenching. The cable correction was no problem.

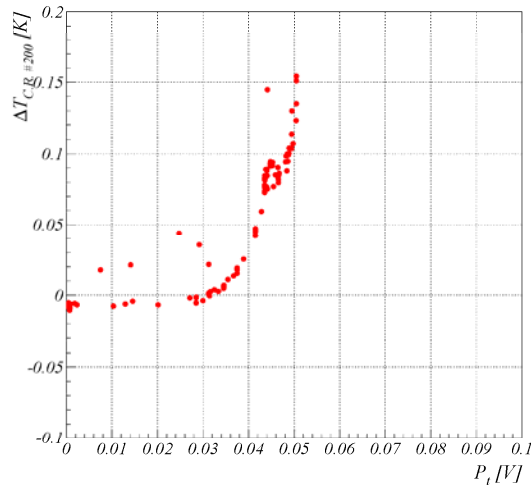
Other topics ②

(a little heating before quenching)

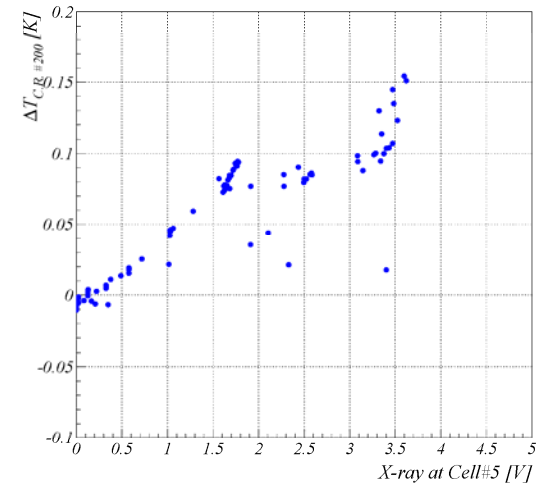
ΔT vs. X-ray at Cell#5 for STF B.L.#5 Cavity ('08/12/4)



ΔT vs. X-ray at Cell#5 for STF B.L.#5 Cavity ('08/12/4)



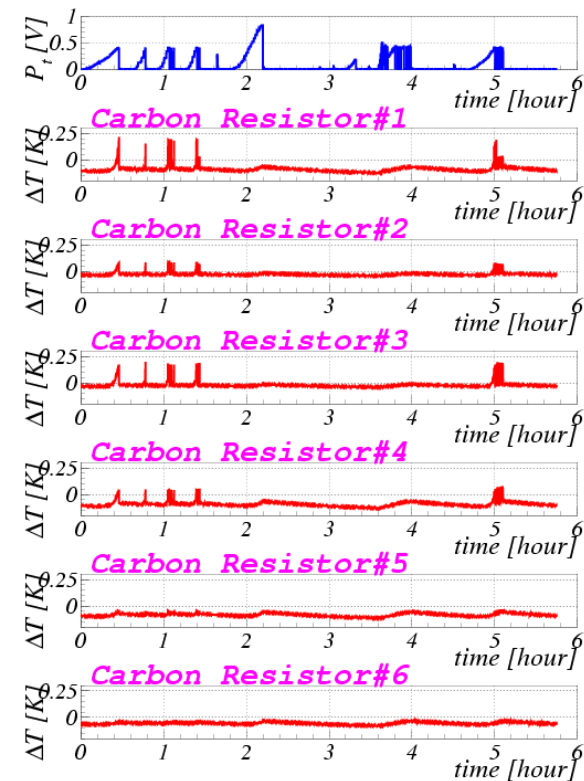
ΔT vs. X-ray at Cell#5 for STF B.L.#5 Cavity ('08/12/4)



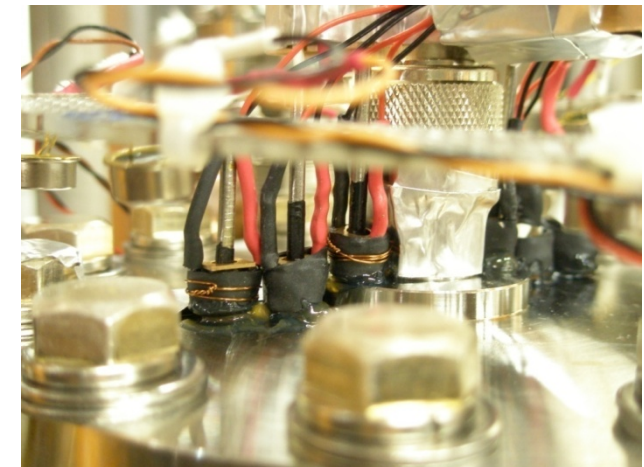
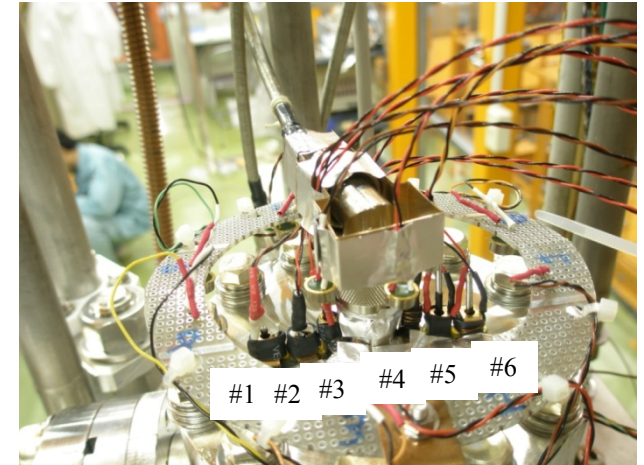
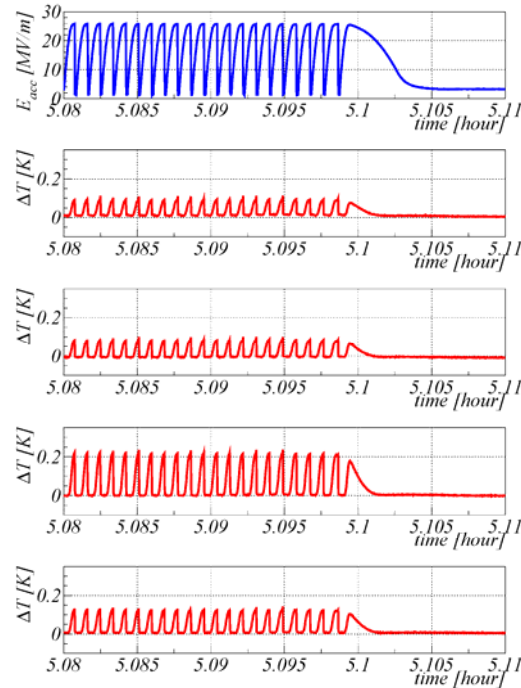
Other topics ③

(heating by electron bombardment at Top flange)

ΔT plot (Module #1) for STF B.L.#6 Cavity ('09/2/5)



ΔT plot at Top Flange for STF B.L.#6 Cavity ('09/2/5)



Summary & Future Plan

- T-mapping system at STF is very useful and excellent, because **it detected the heating location for every vertical test.**
- More R&D including the surface treatment is needed for the higher gradient at STF.
- MHI #7, #8 and #9 cavities will be also tested at STF soon.
- 4 cavities above 30MV/m will be prepared for S-1 Global project at STF by **November.**

Acknowledgement

- *For providing AES#001 Cavity*
 - *Dr. S. Mishra, Dr. B. Kephart, Dr. M. Champion and Dr. C. Ginsburg*
- *For Carbon Resistors*
 - *Dr. H. Padamsee*
 - *Dr. W. Moeller*
 - *Dr. Y. Morita*
- *For the assembly working of T-mapping*
 - *Mr. T. Okada and Mr. M. Iitake(K-Vac Co.)*

Thank you for your attention!

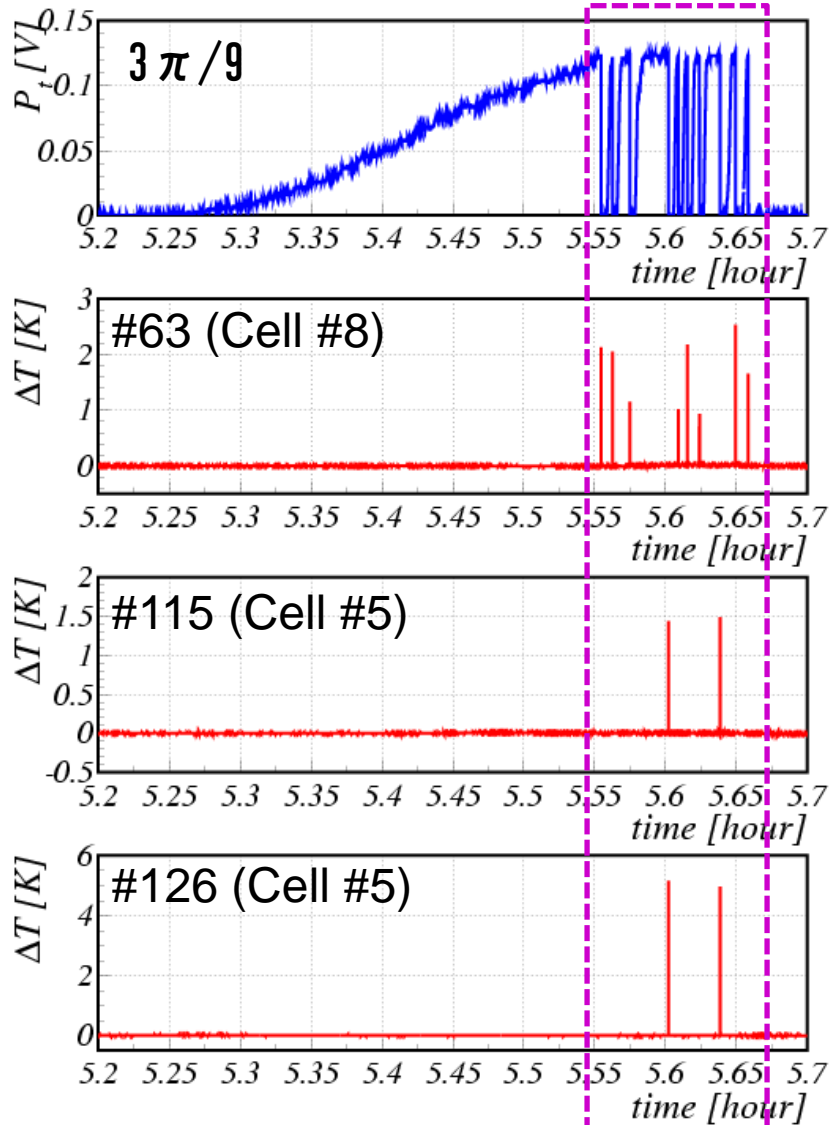
*H. Hayano, E. Kako, Y. Kikuchi, S. Noguchi, M. Sato, T. Shishido,
K. Umemori, K. Watanabe, Y. Yamamoto(KEK),
H. Sakai(ISSP, Univ. of Tokyo)*

We will present these results in detail at PAC09!

Back-up slides

Result of T-mapping at 3rd V.T. for AES#001 Cavity

ΔT at Cell#5&8 for AES#001 Cavity ('08/11/6)



ΔT at Cell#5&8 for AES#001 Cavity ('08/11/6)

