

ERL主加速部超伝導空洞の 開発状況の報告

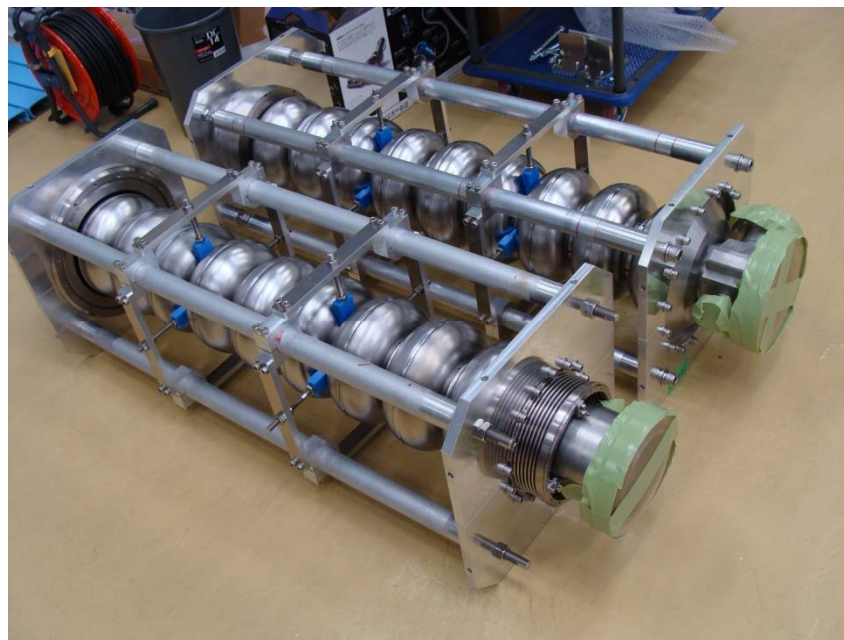
2011/11/2

ERL検討会

ERL-SCグループ 梅森健成、阪井寛志、
佐藤昌史、沢村勝、篠江憲治、古屋貴章、
Enrico Cenni

ERL 9-cell #3 & #4 cavity

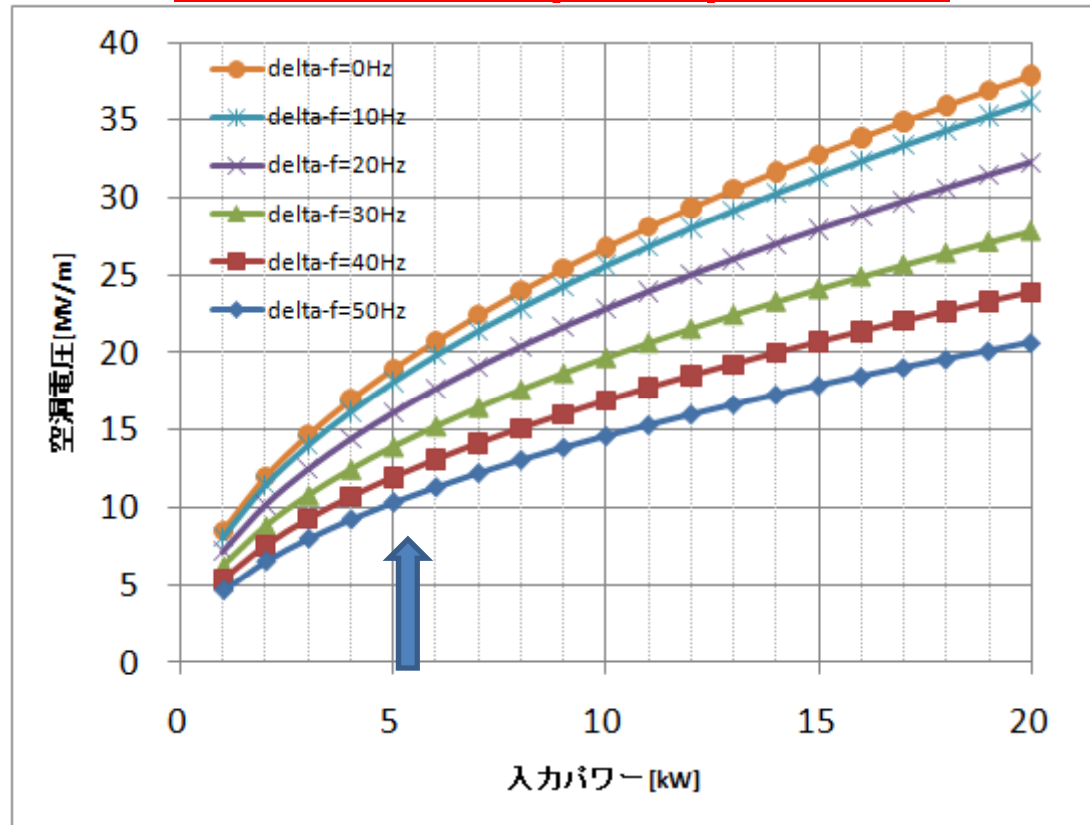
- #3 & #4 cavity will be installed into cERL cryomodule and applied for beam operation.
- Procedure of high pressure gas regulation has been applied.
- Now, under surface treatment and vertical testing



Specification for cERL main linac cavity

- Eacc
 - Required Eacc is 30 MV for two cavities
 - But, operated with vector sum mode at first stage
 - Assuming 2×10^7 coupling and maximum detuning of 50 Hz
 - Required maximum Eacc is $\sim 20 \text{ MV/m}$ for a cavity
- Q_0 value
 - Larger Q_0 value is desirable for He refrigerator
 - Target is 1×10^{10} at 15 MV/m
- Frequency
 - Frequency must be within mechanical tuner range (3mm = 900 kHz) at 2K, i.e. 1299.1~1300.0MHz
 - With good field flatness of $> 98\%$

Eacc vs Input power



Assuming one cavity has $\Delta f=0\text{Hz}$ and another has $\Delta f=50\text{Hz}$.
In order to accelerate the beam with 30MV.

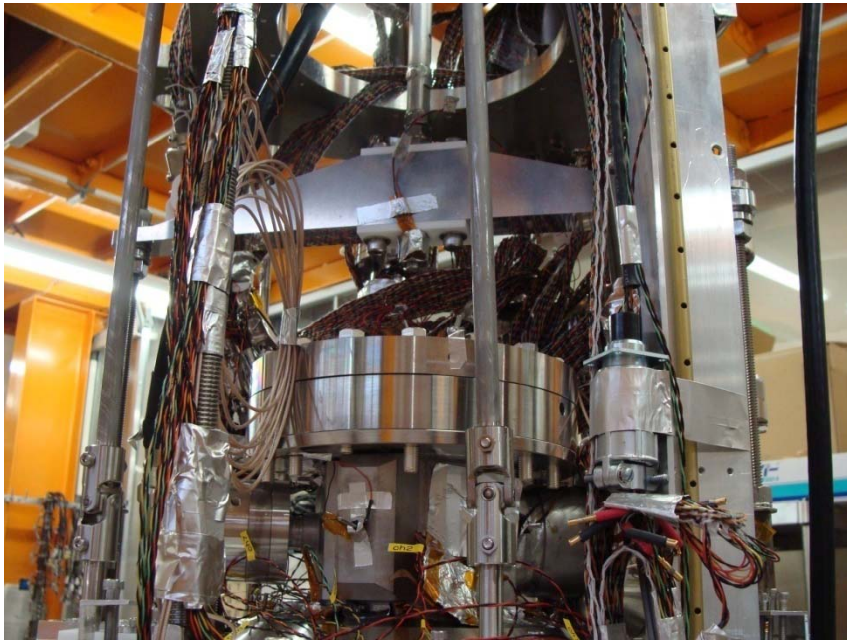
19.5MV($\Delta f=0\text{Hz}$) + 10.6MV/m($\Delta f=50\text{Hz}$) (@5.3kW + 5.3 kW)

20MV/m should be cleared, for vector sum operate of 15MV/m + 15MV/m

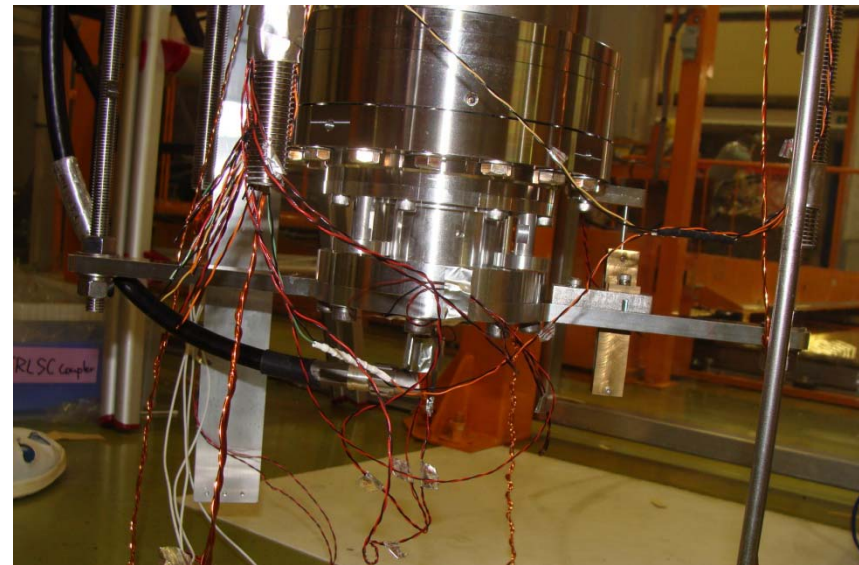
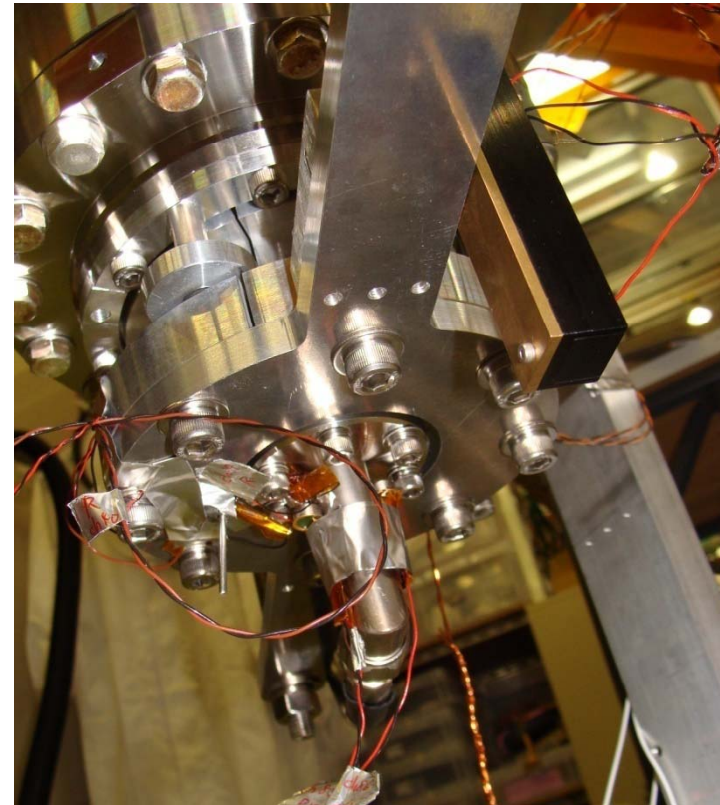
History for ERL 9-cell #3/#4 cavities (for cERL)

	#3 cavity (1st)	#3 cavity (2nd)	#4 cavity
Pre-EP and EP-1	5 um + 120 um		5 um + 120 um
Annealing	750 degree x 4hours		750 degree x 4hours
Pre-tuning	> 98% flatness	> 99 % flatness	> 98% flatness
EP-2	50 um	20 um	50 um
HPR	5hours + 5hours	7.5 hours + 5 hours	6hours + 5.5 hours
Assembly			
Baking	> 110 degree, 48 hours	> 110 degree, 48 hours	> 110 degree, 48 hours
Vertical test	(Done)	(Done)	(Done)

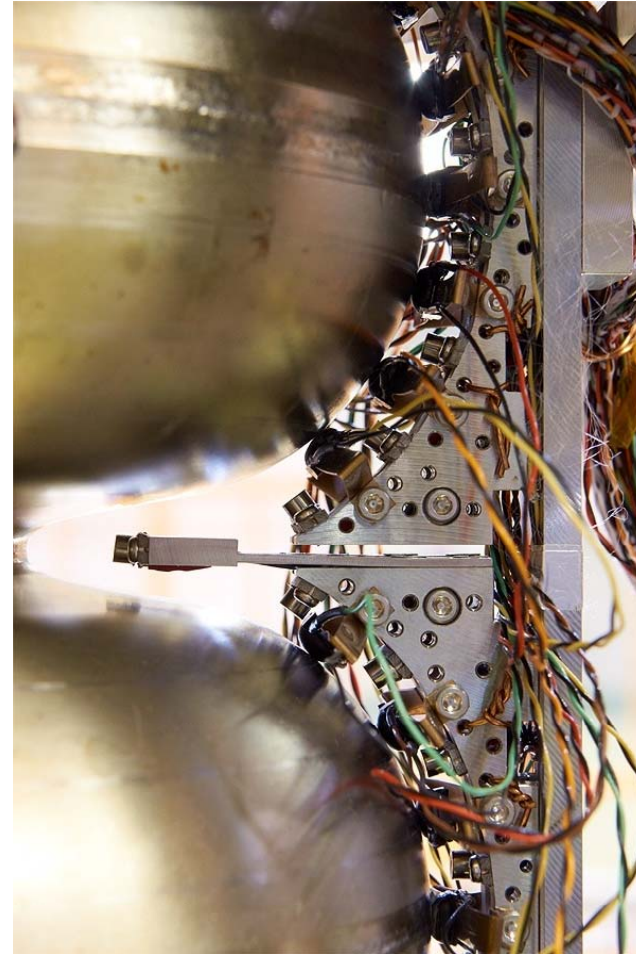
Vertical test setup



Variable input coupler was moved to bottom side, to avoid dust contamination from bellows

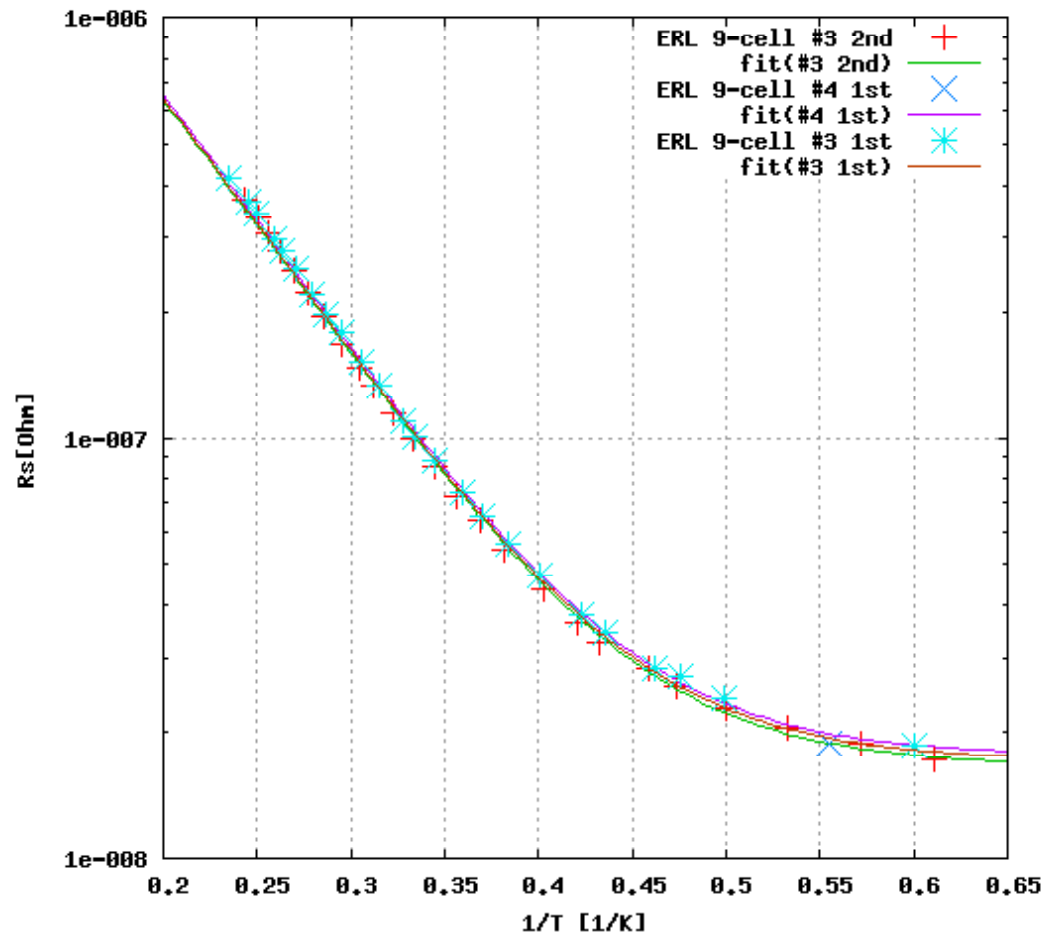


Cavity diagnostics



- Array of **Si diode** for X-ray detection and **carbon resistor** for temperature measurement
- They will rotate around cavity by using pulse motor

Q-T curve for ERL 9-cell #3, #4 cavities



#3 cavity (1st VT)

1299.647 MHz(@2K)

17.5 nΩ

#3 cavity (2nd VT)

1299.603 MHz(@2K)

16.6 nΩ

#4 cavity

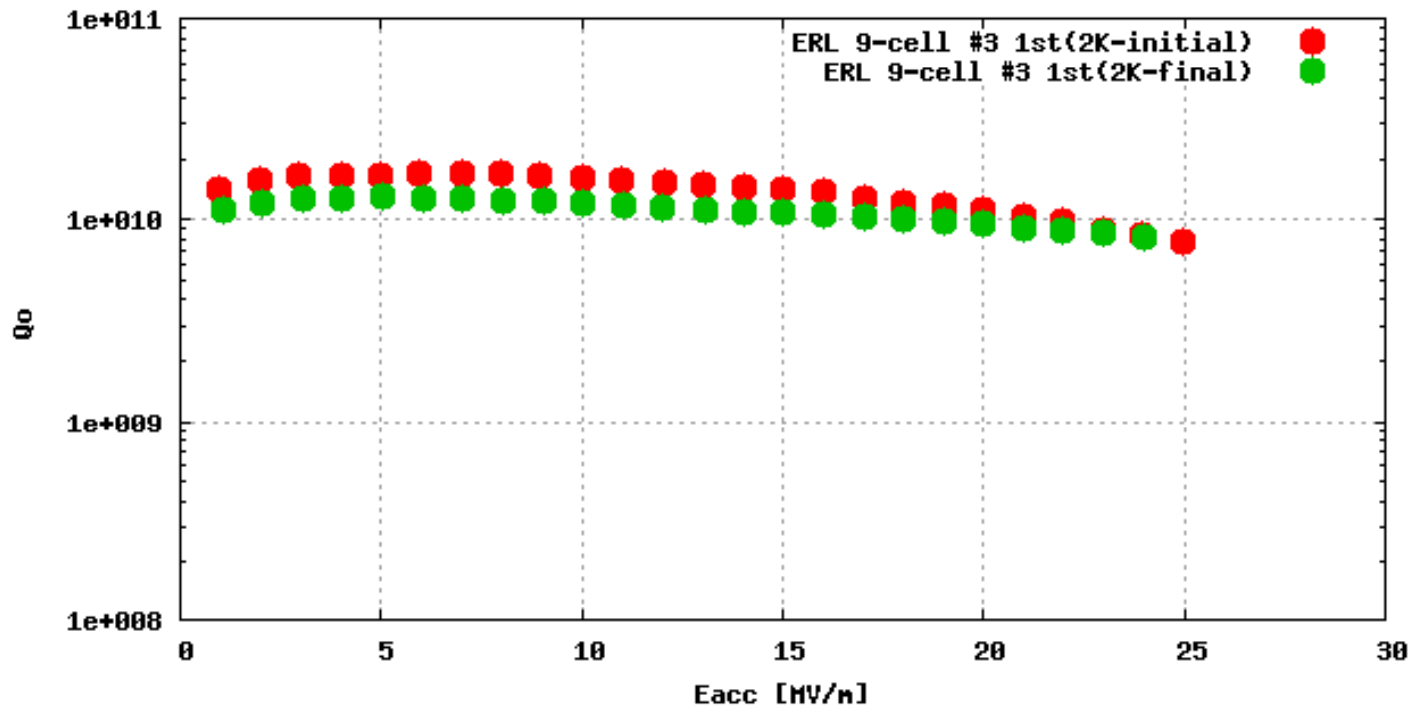
1299.717 MHz(@2K)

17.0 nΩ

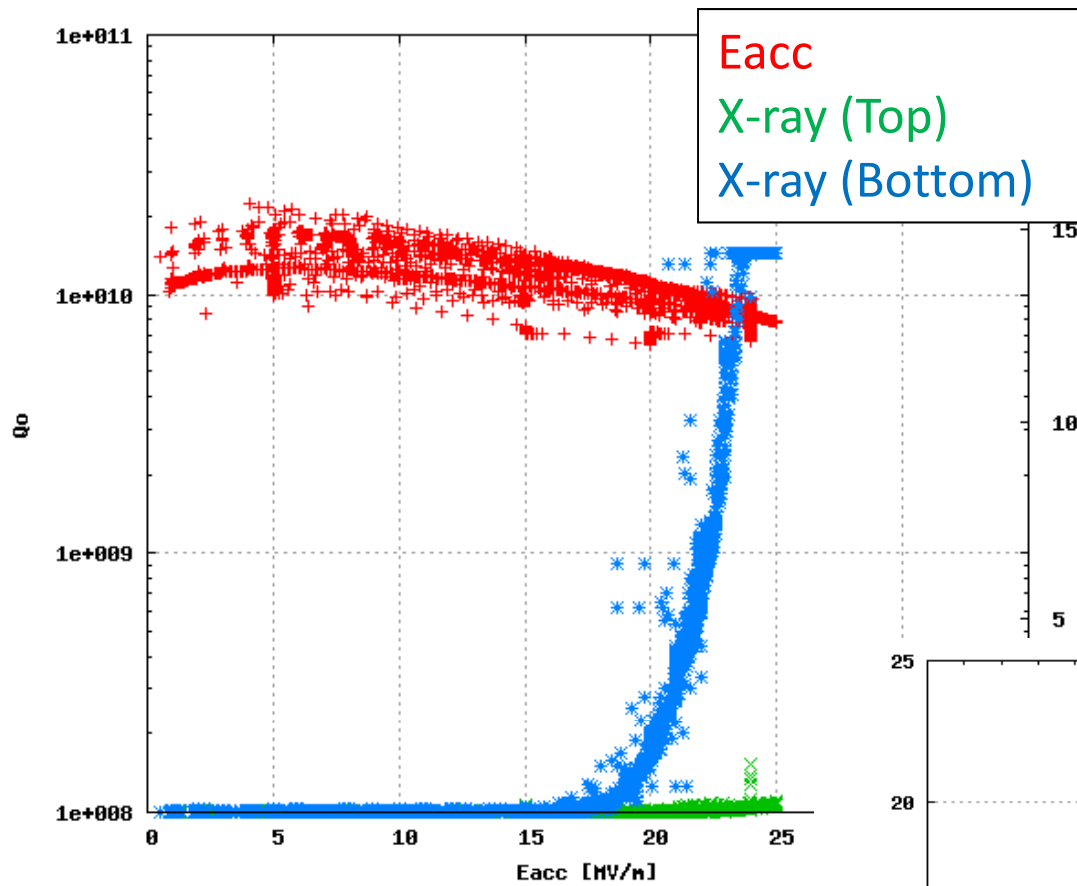
Residual resistance
Includes loss at SUS
flanges

ERL 9-cell #3 cavity
1st vertical test

Eacc curve for pi-mode

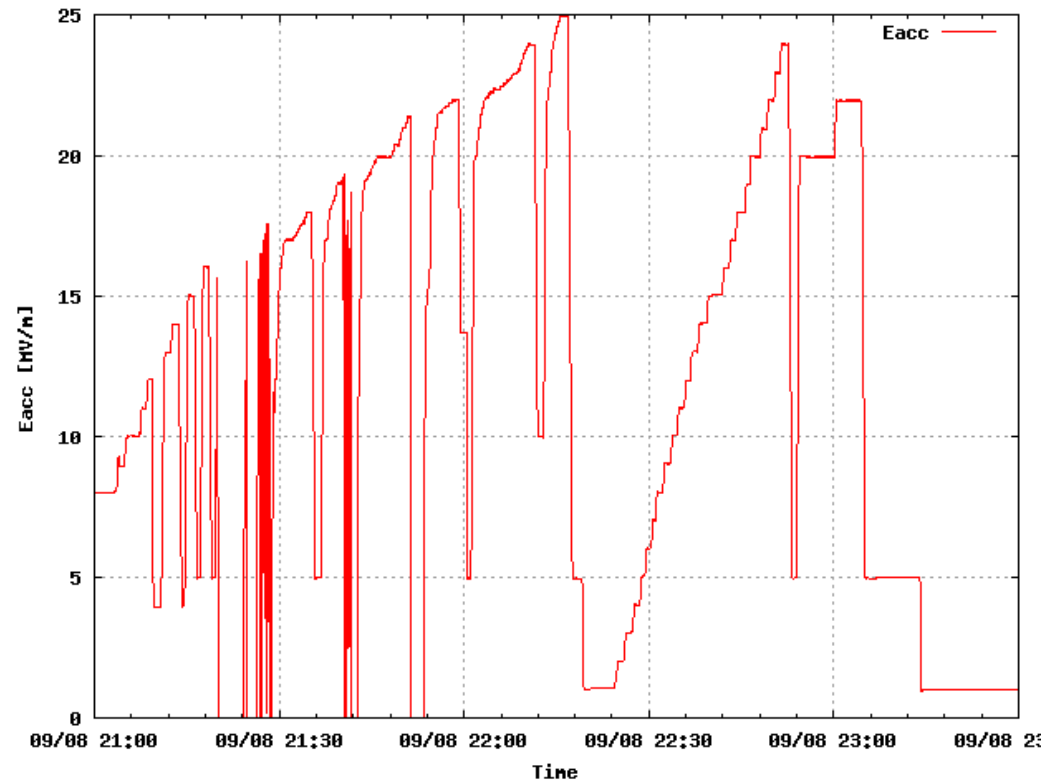


- Initial (1.5-2.0K), No passband meas, Final (1.9-2.0K)
- Reached to 25 MV/m. Satisfied ERL spec.
- 1.08×10^{10} (@15MV/m), 9.5×10^9 (@20MV/m)
- No limitation up to 25MV/m

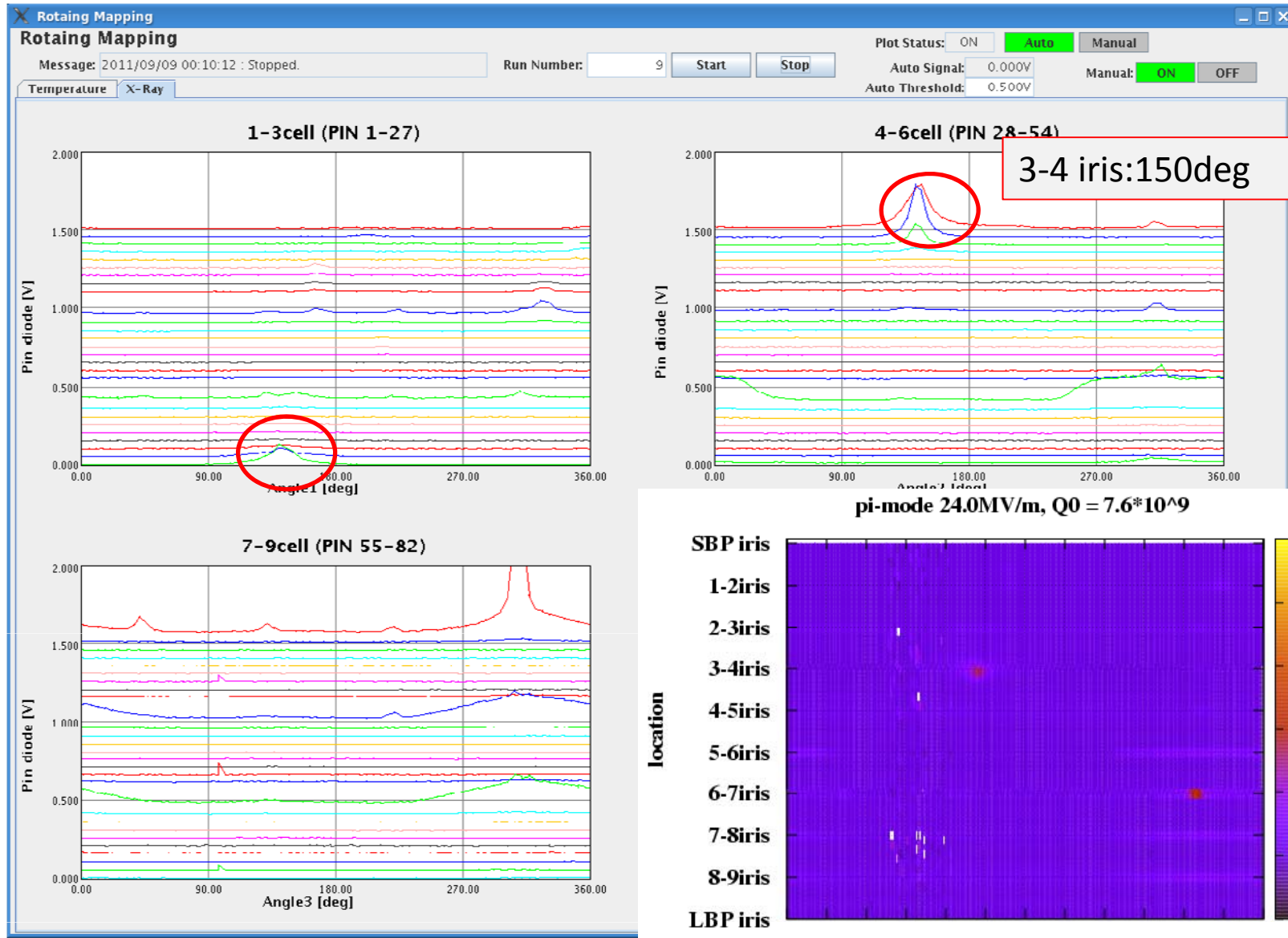


X-ray onset around 15 MV/m

Processed multipacting from 16 to 22 MV/m. Temperature rises were observed at 1-cell and 9-cell equators.



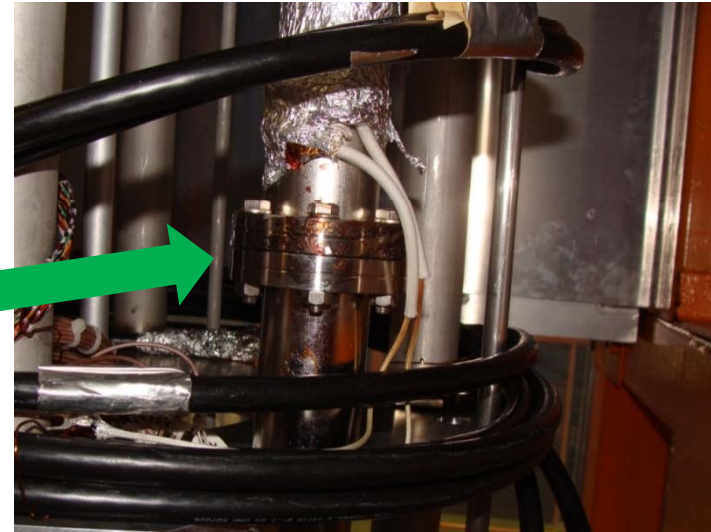
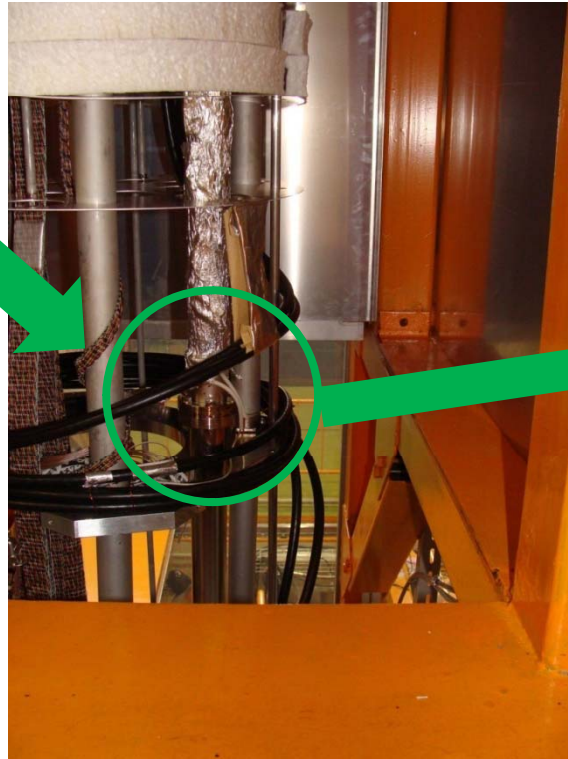
24MV/m X-ray mapping



sharp peak near 3-4 iris: 150deg

5-6,6-7,7-8,8-9 iris : broad signal were observed : peaks are 330deg

Vacuum leak after vertical test



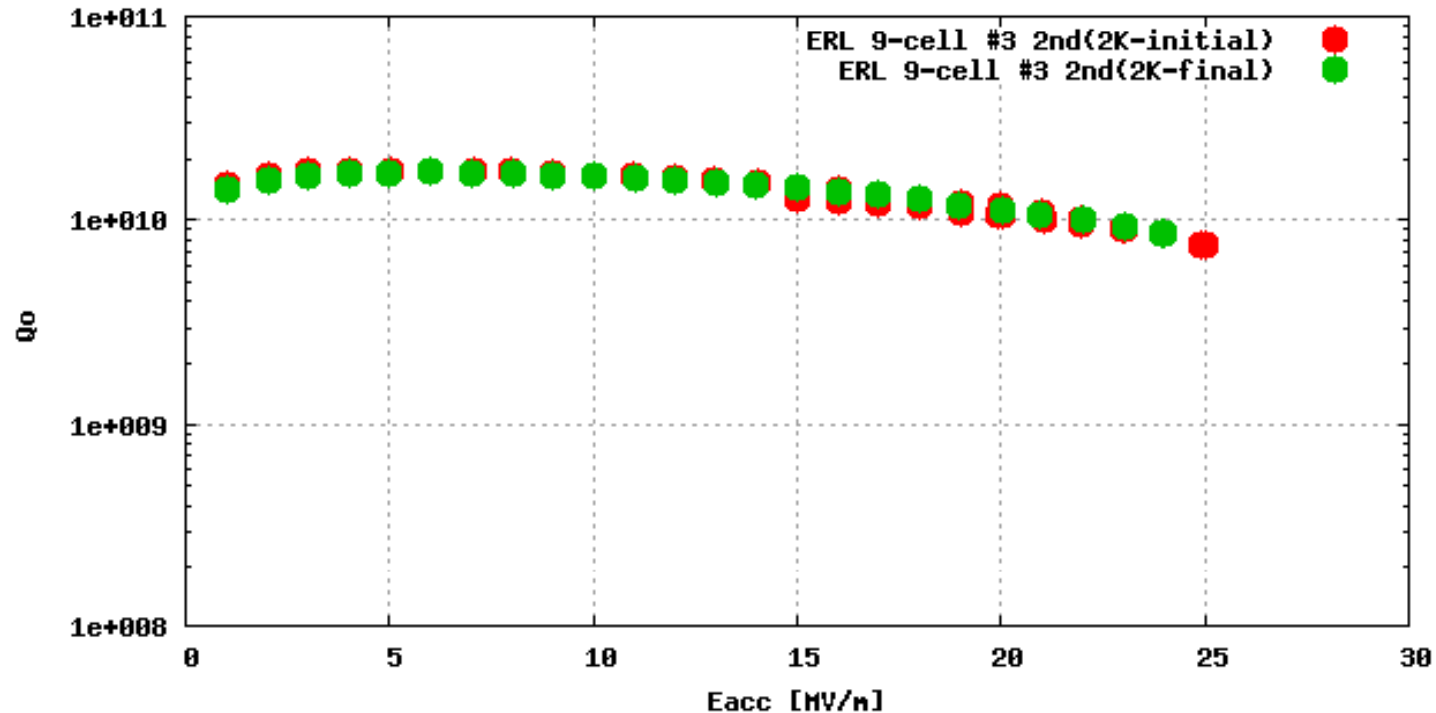
Forgot one bolt to remove, when cavity brought from cryostat

→ Cavity was tilted and vacuum pipe got some stress

→ Try another EP and vertical test

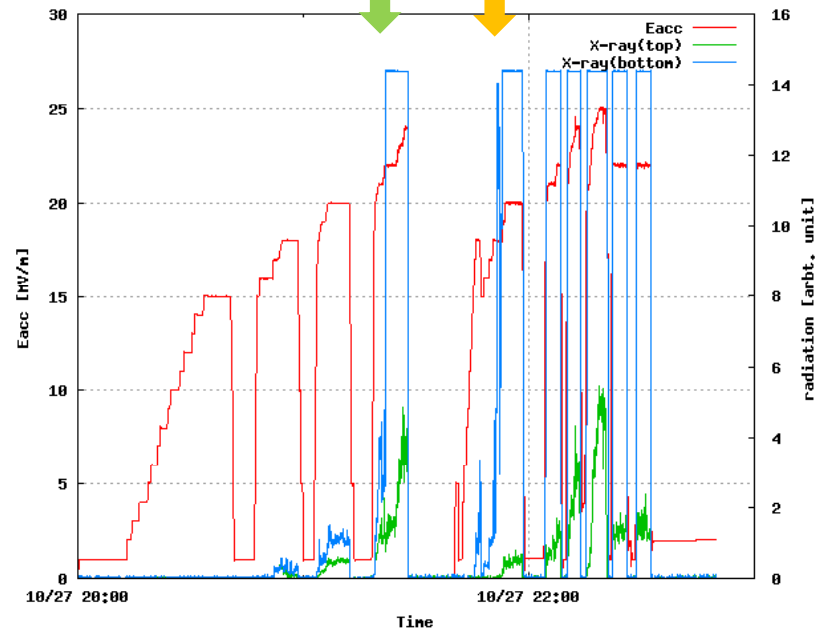
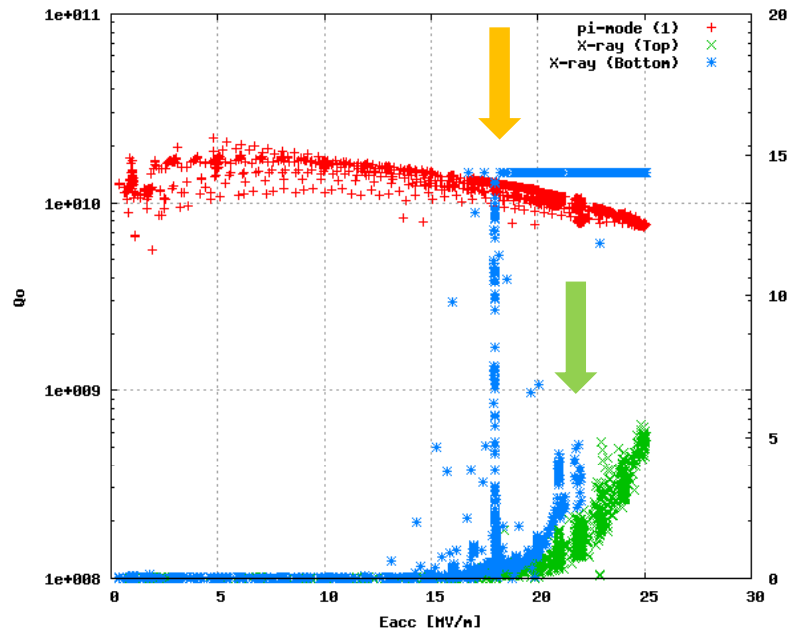
ERL 9-cell #3 cavity
2nd vertical test

2K π -mode measurement



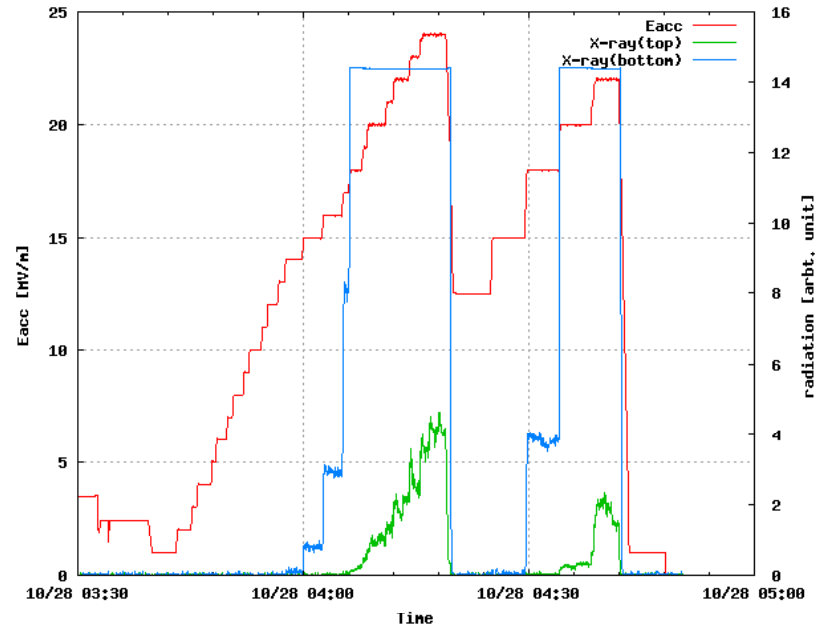
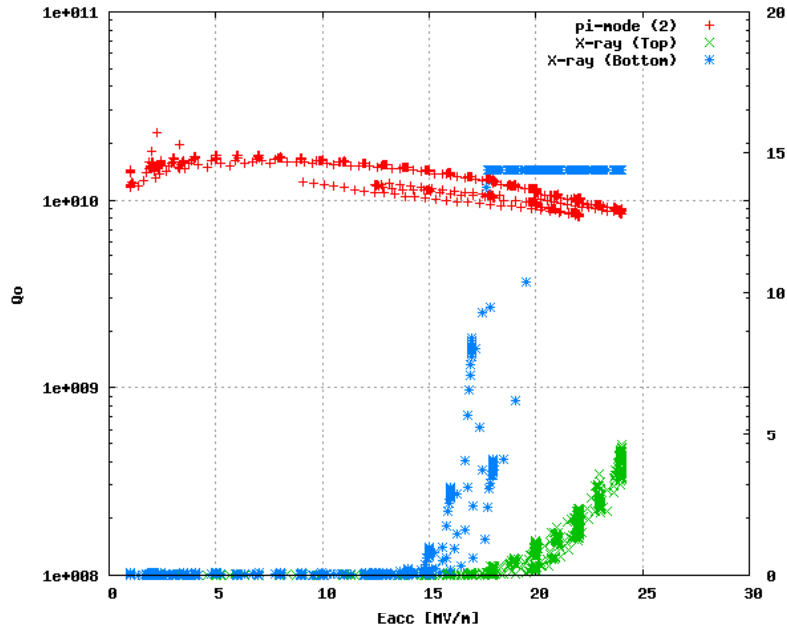
- Initial (1.5-2.0K), Passband(3, 4, 7, 8pi), Final (1.6-1.9K)
- Reached to 25 MV/m. Satisfied ERL spec.
- 1.4×10^{10} (@15MV/m), 1.1×10^{10} (@20MV/m)
- No limitation up to 25MV/m

2K π -mode (initial)



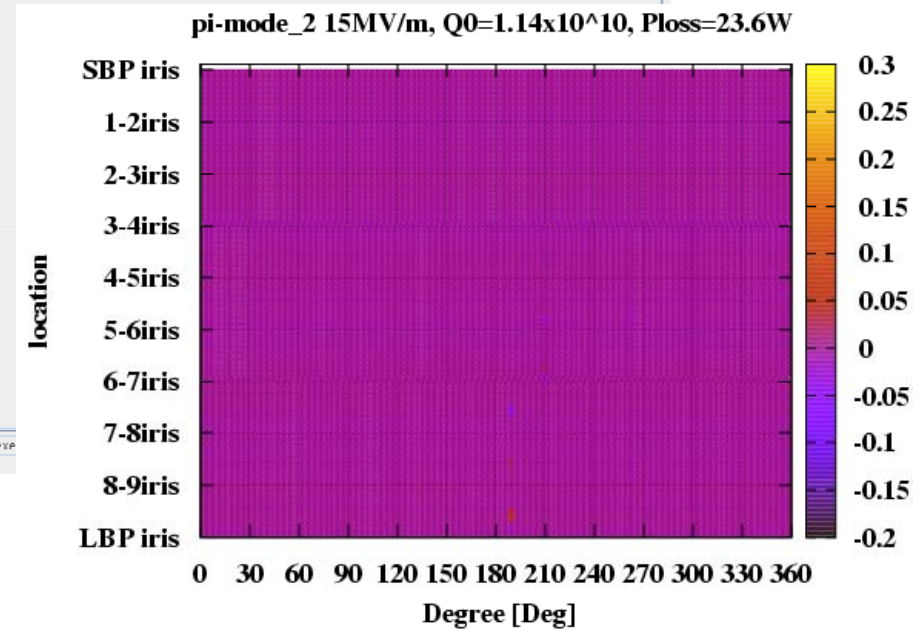
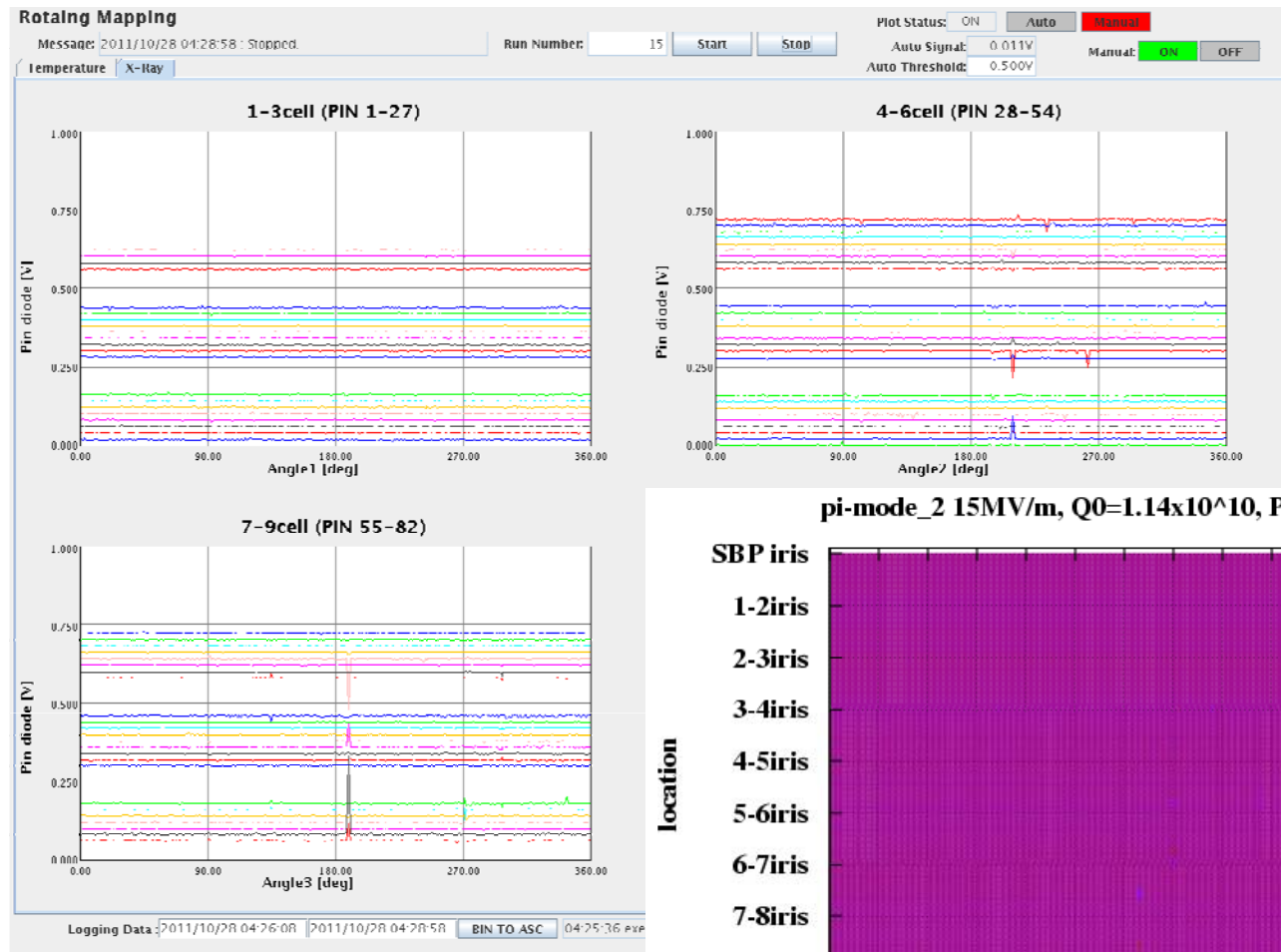
- Field reached to 25 MV/m. No limitation up to 25 MV/m
- One quench occurred around 24 MV/m
- No quenches caused by multipacting were observed
- Strong field emission at bottom side occurred during power rise
- Suddenly X-ray increased at 22MV/m and 18 MV/m

2K π -mode (final)



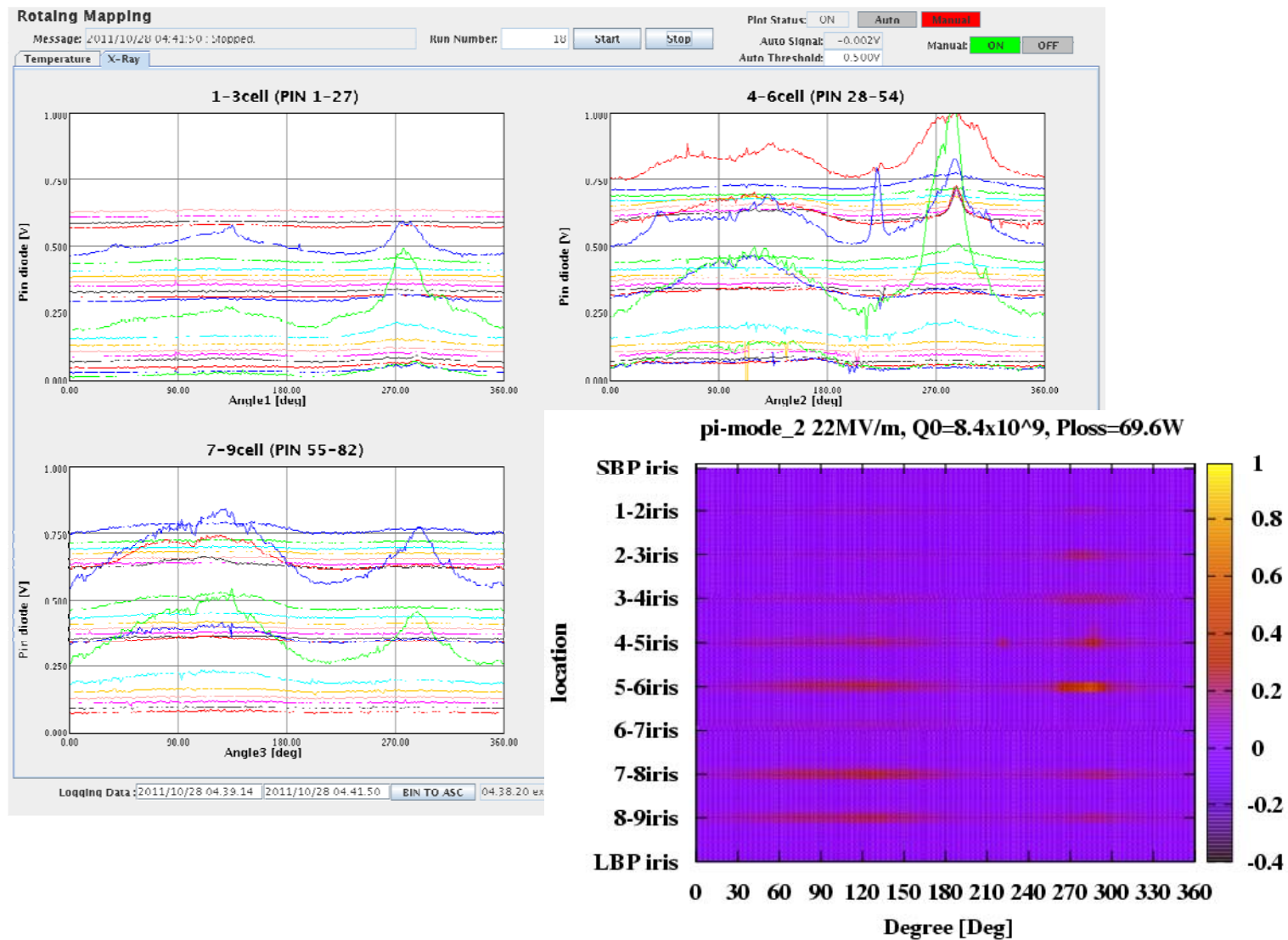
- Field reached to 25 MV/m. No limitation up to 25 MV/m
- Strong field emission at bottom side
- X-ray onset around 14 MV/m

π -mode(final) 15 MV/m



No X-rays were observed

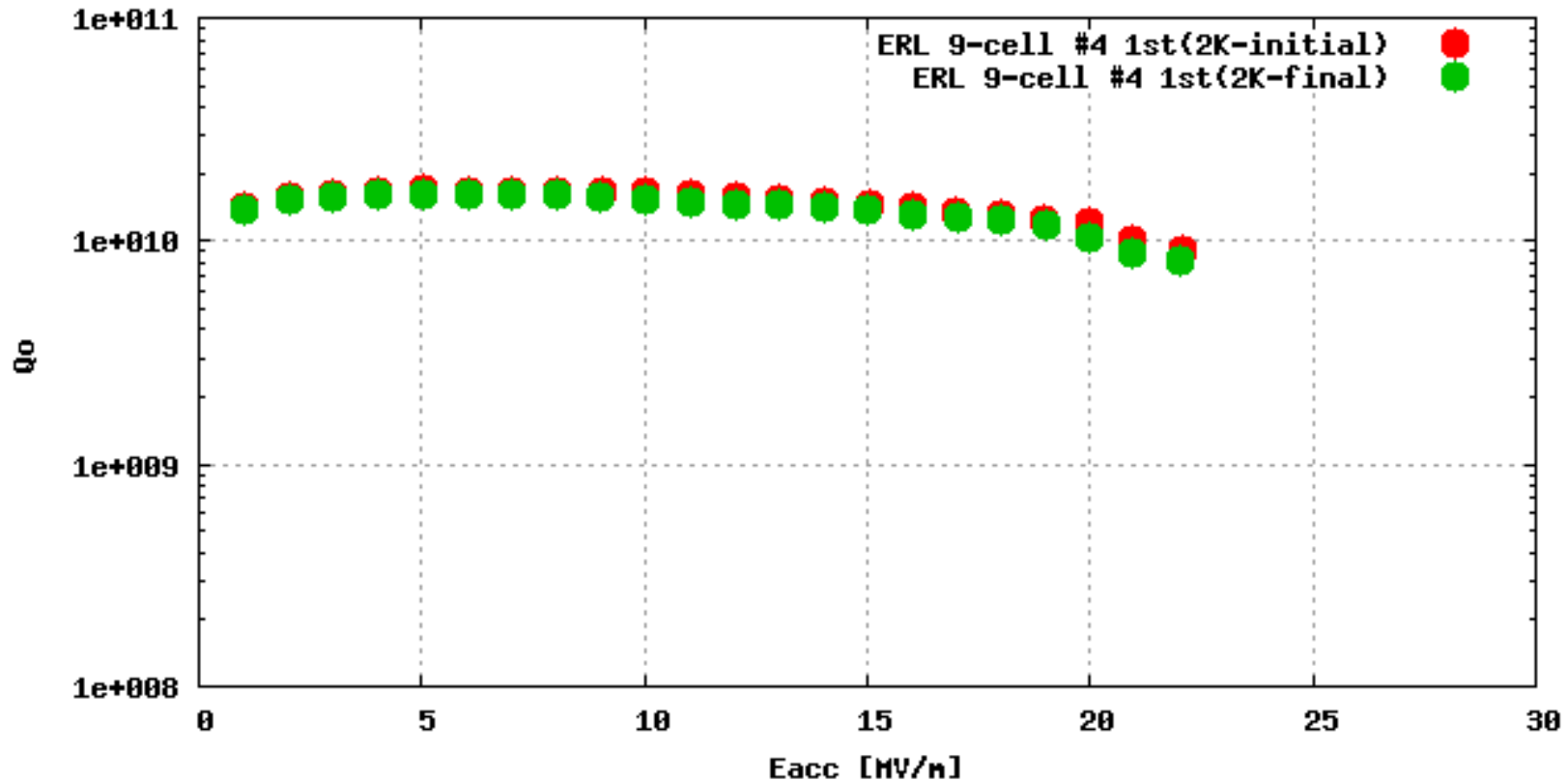
π -mode(final) 22 MV/m



X-rays observed at ~ 100 and ~ 280 degree
Emitter locations seem to be 4-5 iris and 1-2 iris??

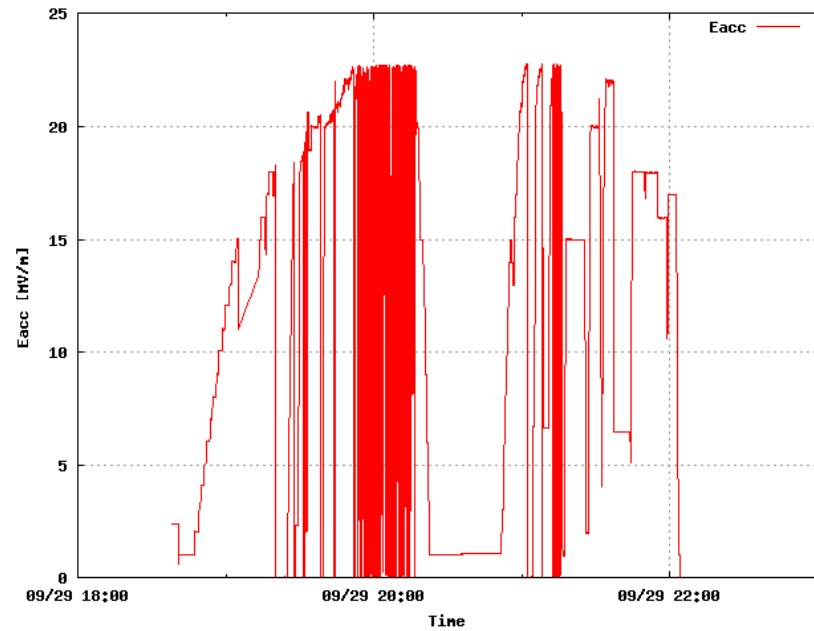
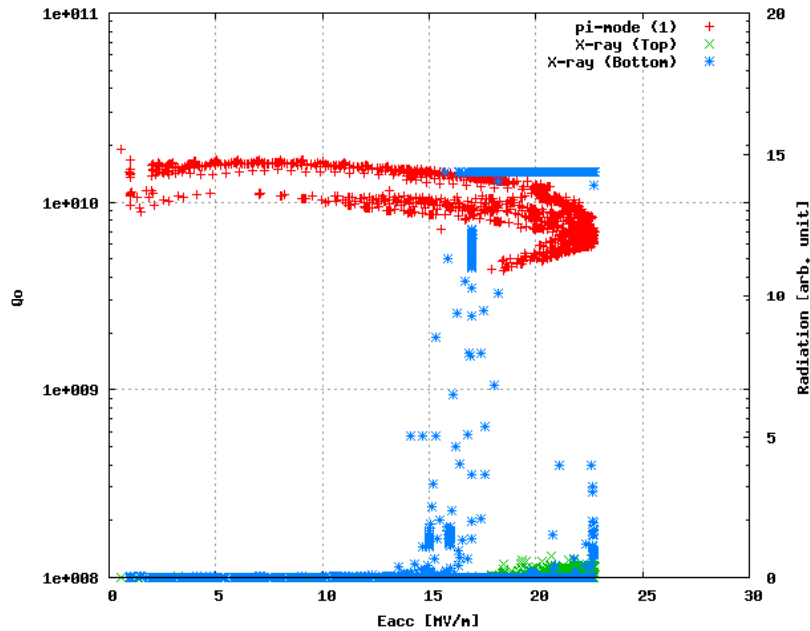
ERL 9-cell #4 cavity
1st vertical test

2K π -mode measurement



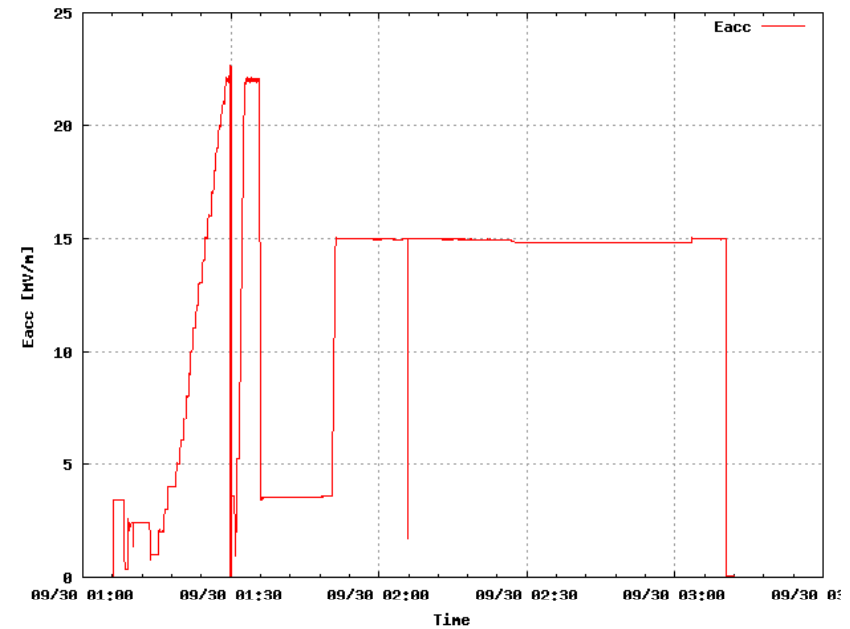
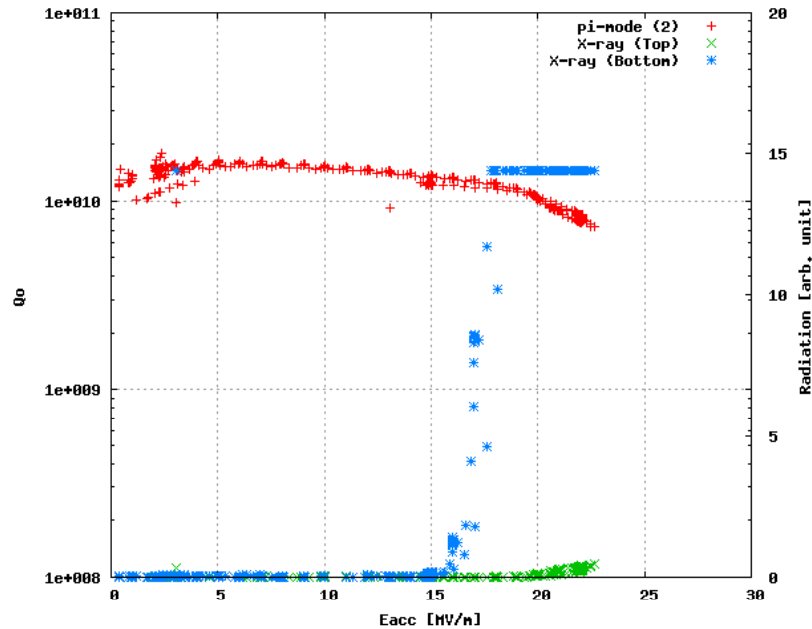
- Initial (1.6-1.8K), Passband(8pi), Final (1.7-1.8K)
- Max. Field 22.7 MV/m, quench at 1 cell equator
- $Q=1.4 \times 10^{10}$ (@15MV/m), 1.0×10^{10} (@20MV/m)
- X-ray on set: (initial) 18MV/m \rightarrow (final) 15MV/m
- X-ray at 20 MV/m: (initial) 3.7uSv/h \rightarrow (final) 644 uSv/h

2K π -mode (initial)



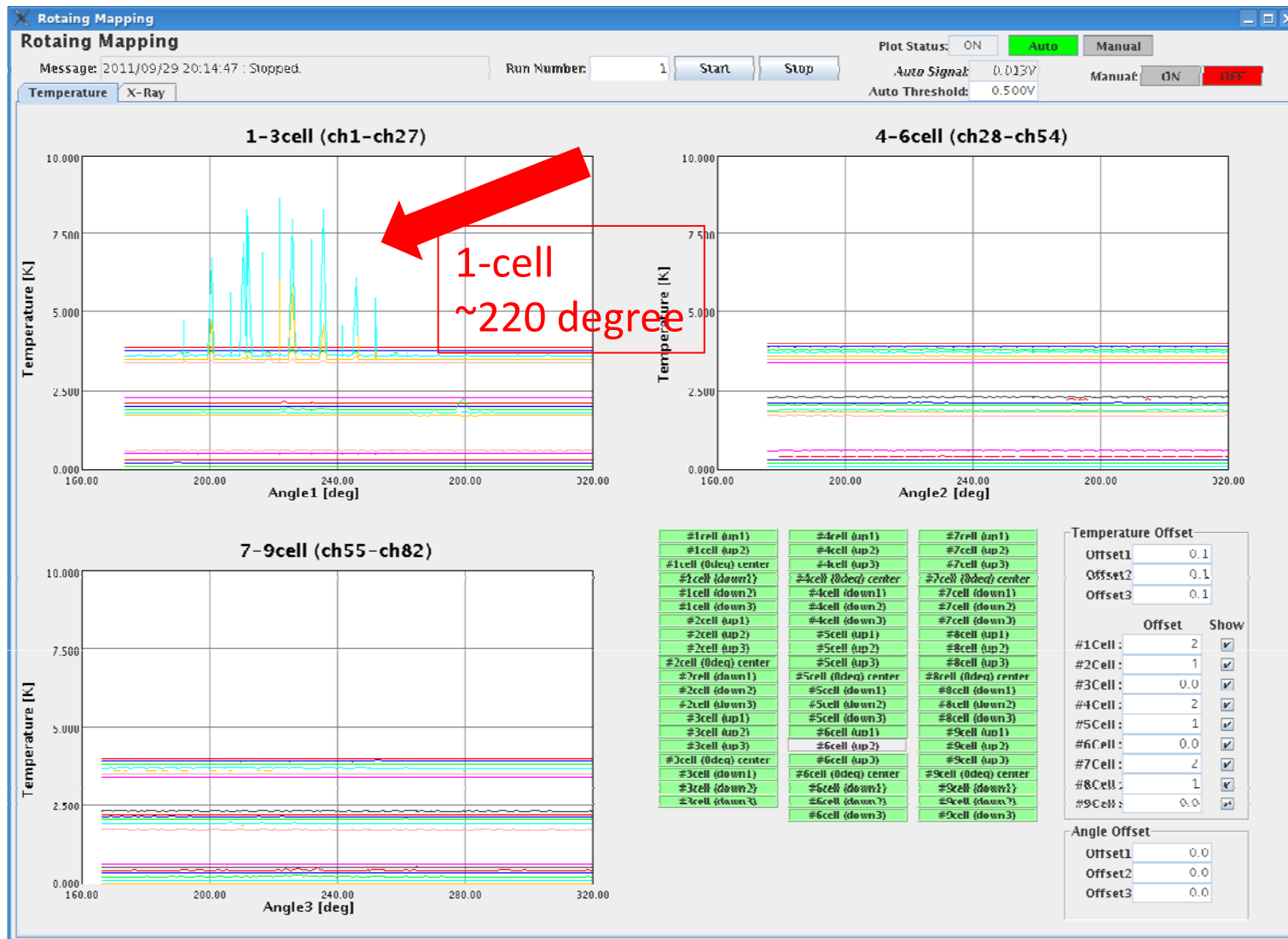
- Quench around 20 MV/m due to multipacting.
- Field was limited at 22.7 MV/m, by quenches observed at 1-cell equator
- Strong field emission at bottom side

2K π -mode (final)



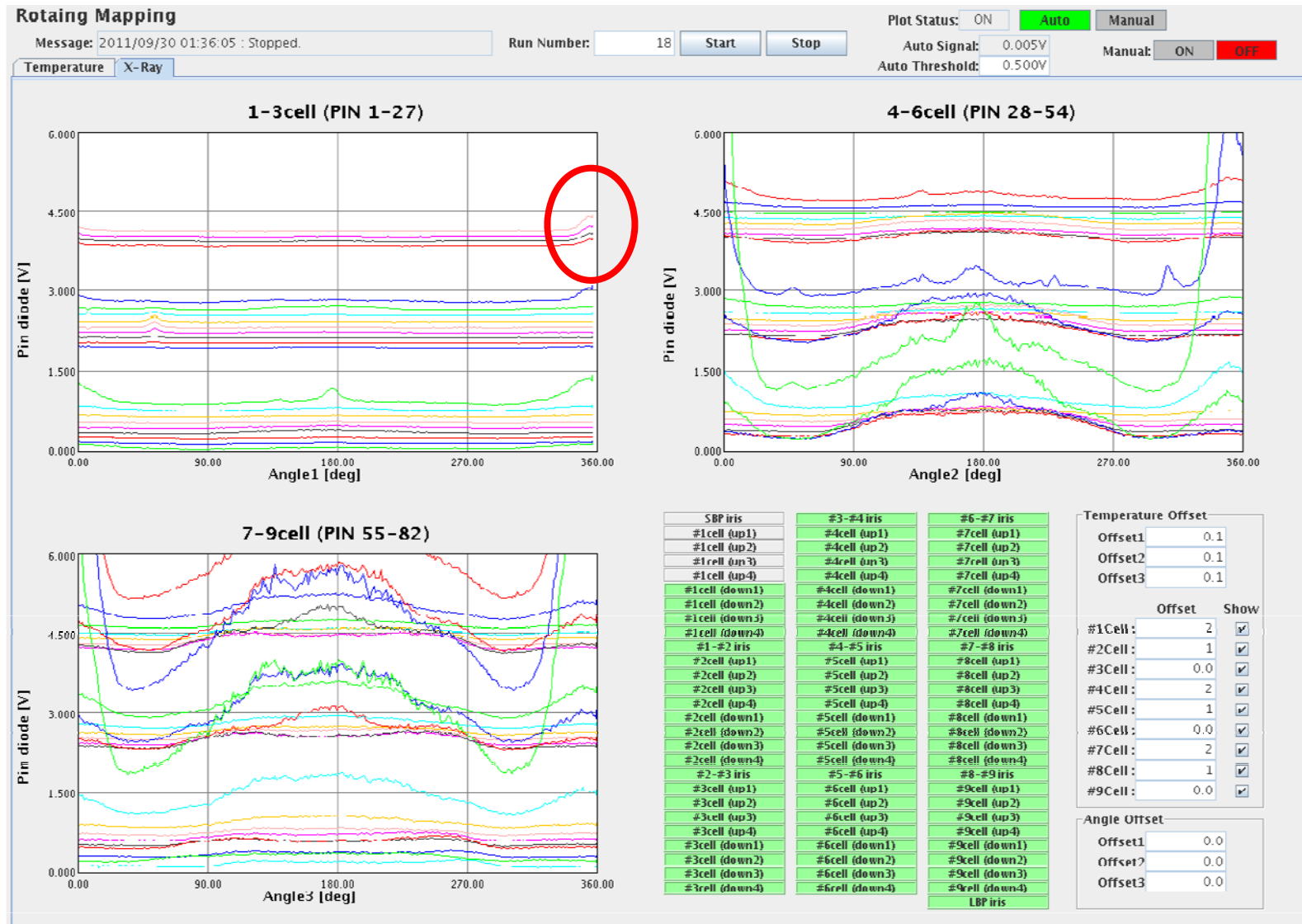
- Field was limited at 22.7 MV/m, by quenches observed at 1-cell equator (\rightarrow surface inspection at this week)
- Strong field emission at bottom side

π -mode: Quench @ 22.7MV/m



Temperature rise was observed during self-pulsing at 1-cell equator ~220 degree.

X-ray: π -mode(2) @ 22 MV/m



Source point seems to be ~ 360 degree of SBP-1cell iris or 1-2 cell iris

Summary

- ERL 9-cell #3 and #4 cavities go forward, to installed into cERL cryomodule.
- #3 cavity:
 - First vertical test: Field reached to $> 25\text{MV/m}$, $Q_0 = 1.1 \times 10^{10}$ (@ 15MV/m , 1.9K), satisfy ERL spec, but vacuum leak happened by mistake.
 - Second vertical test: Field reached to $> 25\text{MV/m}$, $Q_0 = 1.4 \times 10^{10}$ (@ 15MV/m , 1.6K), satisfy ERL spec
 - Go for He jacket welding
- #4 cavity:
 - First vertical test, Field reached to 22.7MV/m (limited by quench), $Q_0 = 1.4 \times 10^{10}$ (@ 15MV/m , 1.7K), satisfy ERL spec
 - Will another EP and vertical test, hope to reach better performance.

Plan

- Vertical test
 - #3 cavity : finished
 - #4 cavity: next trial at end of November
- Jacket welding
 - From January to March, done at MHI
- Module assembly
 - Scheduled at next summer