Development of main linac cavity for cERL project

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Contents

- cERL project
- Design and requirement for main linac cavity
- Surface treatment
- Results for vertical tests
- Conclusion and plan

The Compact ERL(cERL) for demonstrating ERL technologies

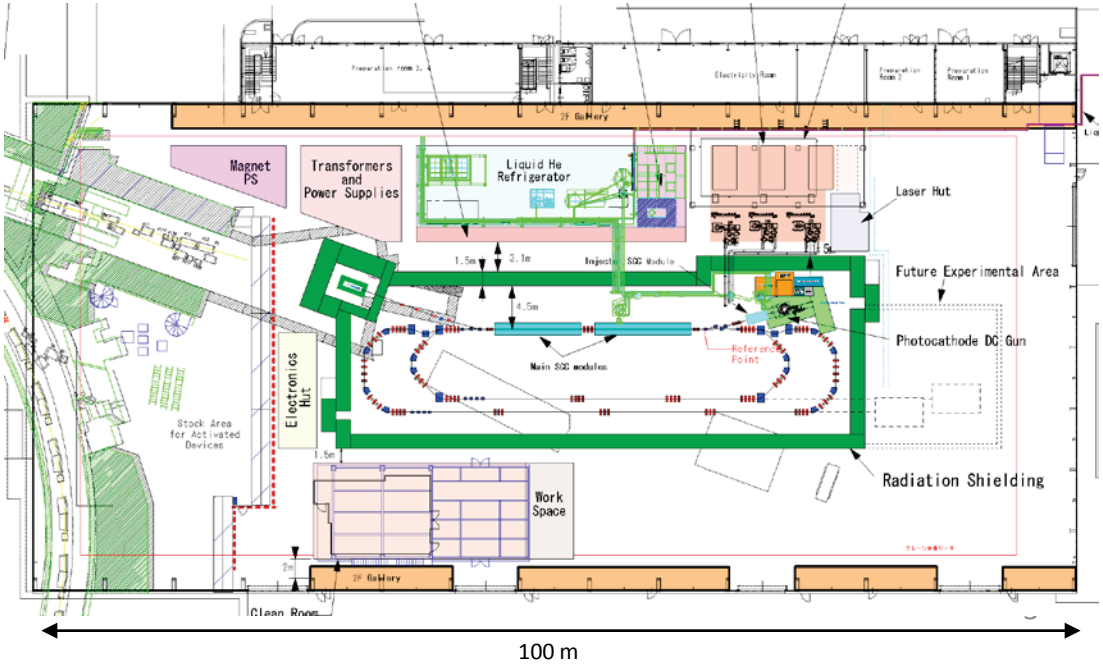
Before constructing large-scale ERL facility, we need to demonstrate the generation of ultra-low emittance beams using key devices.

➡ Compact ERL

Parameters of the Compact ERL

	Parameters
Beam energy	35 - 245 MeV
Injection energy	5 MeV
Average current	10 - 100 mA
Acc. gradient (main linac)	15 MV/m
Normalized emittance	0.1 - 1 mm·mrad
Bunch length (rms)	1 - 3 ps (usual) ~ 100 fs (with B.C.)
RF frequency	1.3 GHz

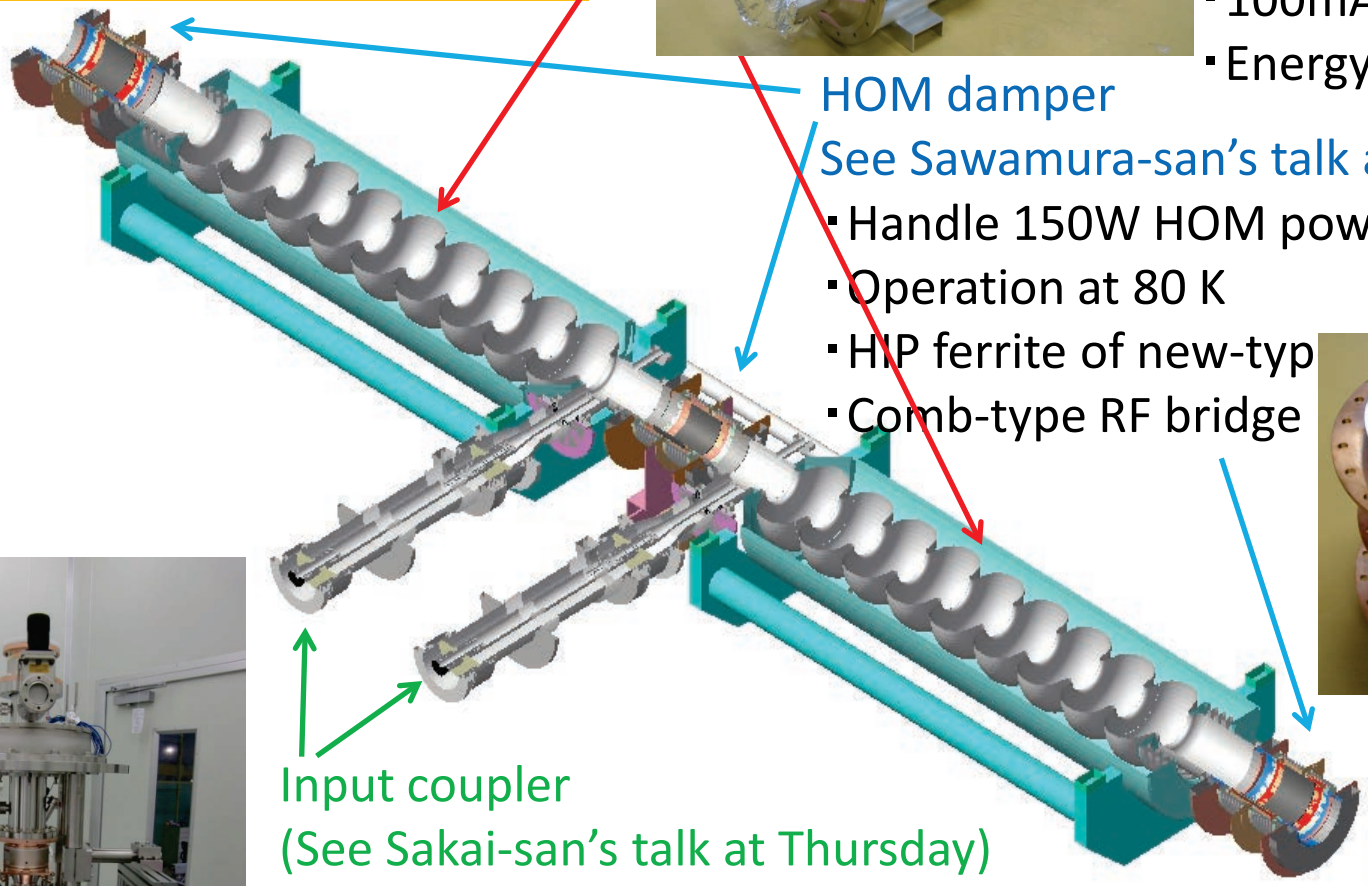
※ blue numbers are parameters for initial stage



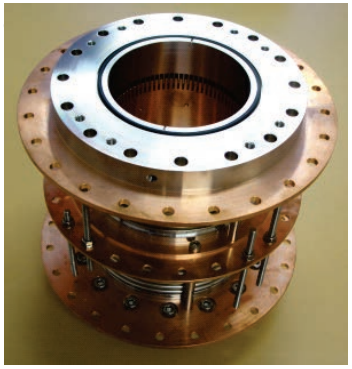
ERL main linac

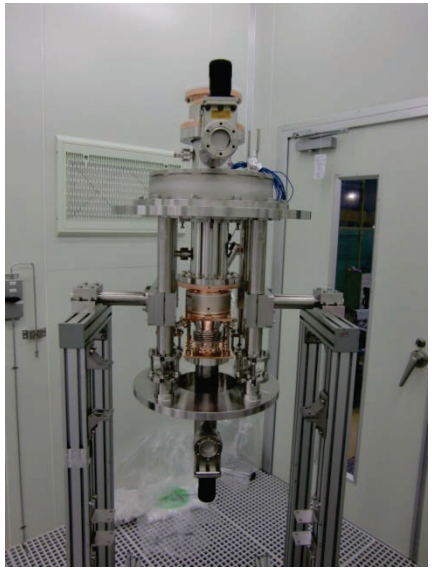
Construct first module with two cavities for cERL project

9-cell cavity
See Enrico's talk today
- HOM damped shape
- Eacc=15-20MV/m
- 100mA CW
- Energy recovery



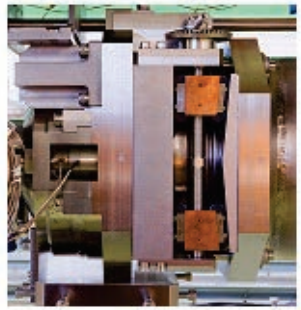
HOM damper
See Sawamura-san's talk at Thursday
- Handle 150W HOM power
- Operation at 80 K
- HIP ferrite of new-typ
- Comb-type RF bridge





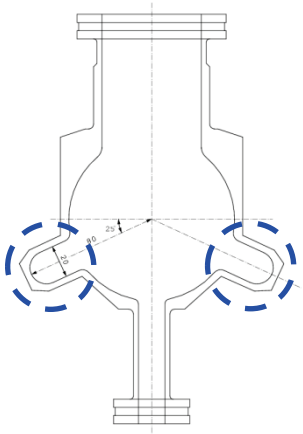
Input coupler
(See Sakai-san's talk at Thursday)
- 20kW CW (total reflection)
- Cold and warm window
- HA997 ceramic is used

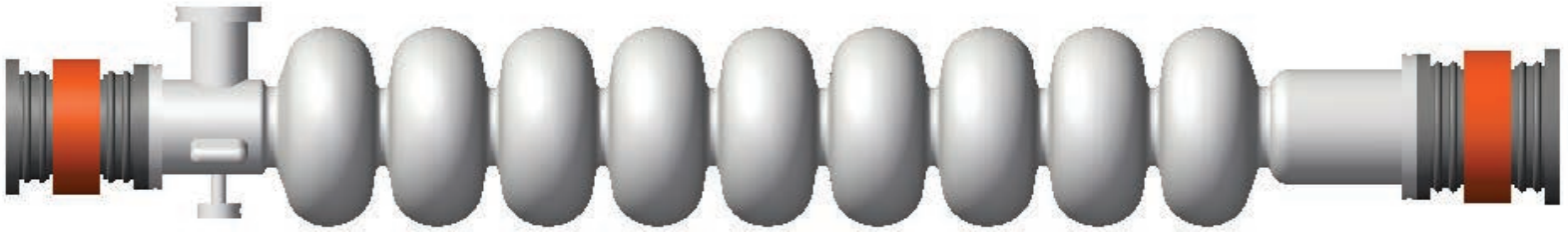
Tuners
See Enami-san's
Talk at Thursday
- Slide-jack tuner



KEK-ERL model-2 Cavity

1) Cell shape is optimized to reduce HOM impedances
   - ➢Iris diameter 80mm, elliptical shape at equator
   - ➢Cell diameter 206.6mm
2) Eccentric-fluted beampipe
   - ➢Suppress Quadrupole HOMs
3) Large beampipes mounted with RF absorber
   - ➢Bempipe diameter 100mm and 120mm



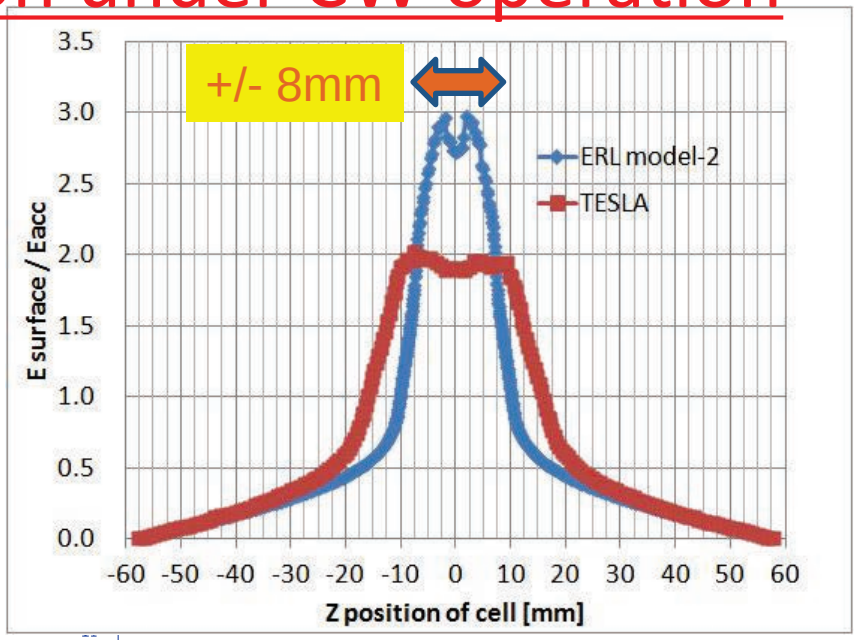


Main parameters for the acceleration mode

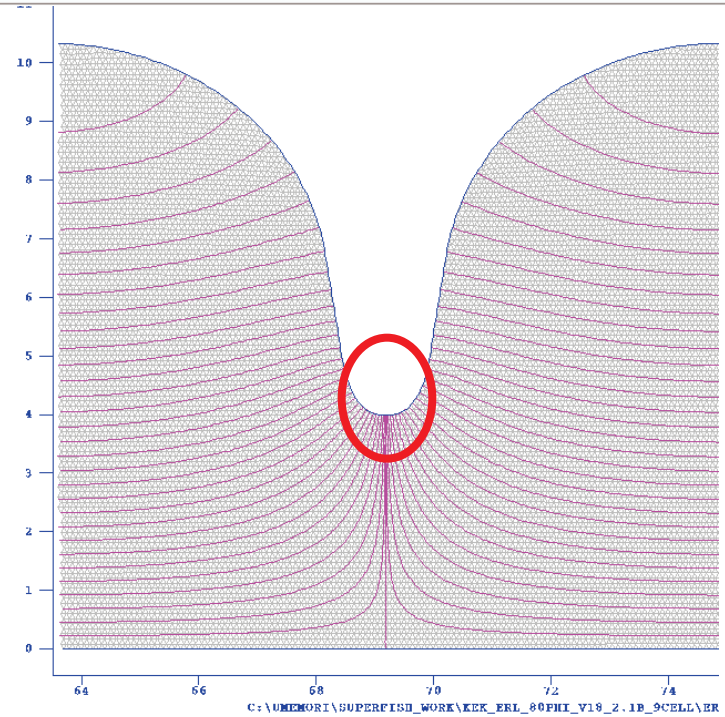
Frequency	1300 MHz	Coupling	3.8 %
Rsh/Q	897 Ω	Qo x Rs	289 Ω
Ep/Eacc	3.0	Hp/Eacc	42.5 Oe/(MV/m)

Epeak/Eacc and field emission under CW operation

- Field emission becomes the cryogenic losses and radiation, which could be problem under CW operation.
- So, it is important to suppress field emission for ERL operation



- But our cavity have large Epeak value…
- It is challenging, but essential to suppress emission.

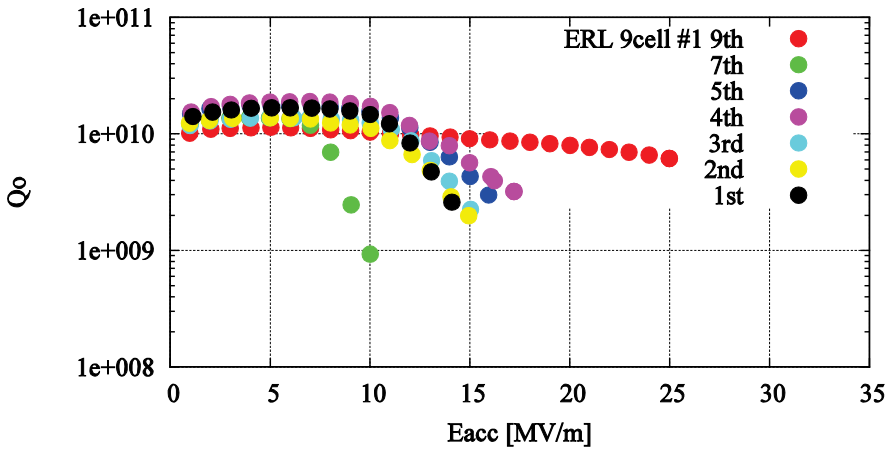


Specification for cERL main linac cavity

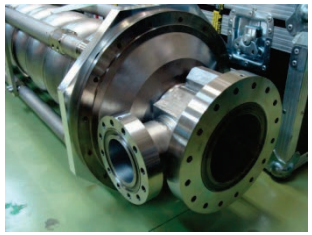
- Eacc
  - Required Eacc is 30 MV for two cavities
  - But, operated with vector sum mode at first stage
  - Assuming 2×10^7coupling and maximum detuning of 50 Hz
  - Required maximum Eacc is ～20MV/m for a cavity
- Q_0 value
  - Larger Q_0 value is desirable for He refrigerator
  - Target is 1×10^{10} 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%

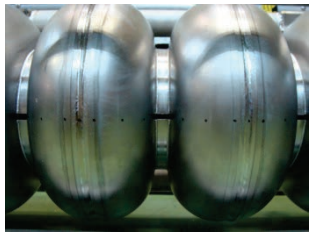
Results of vertical tests for #1, #2 cavities(prototypes)

#1 ERL 9-cell cavity

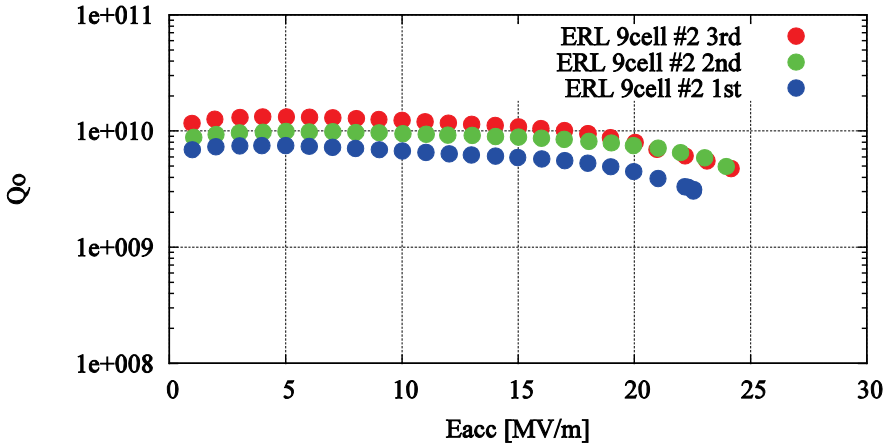


- Severe field emissions were observed
- Maximum Eacc was limited to 15 ~ 17 MV/m, until 8th measurements.
- At last, we got nice results, > 20 MV/m at 9th measurements.





#2 ERL 9-cell cavity (With Ti endplate, stiffener ring, NbTi flanges)



- Can reach to > 20 MV/m for both tests
- Field emissions were not so large

low Q value is due to SUS flanges, used after 5th measurement of #1 cavity
low Q value #2 cavity 2nd VT was recovered at 3rd VT, by just warming-up

History for #3/#4 cavities (for cERL)

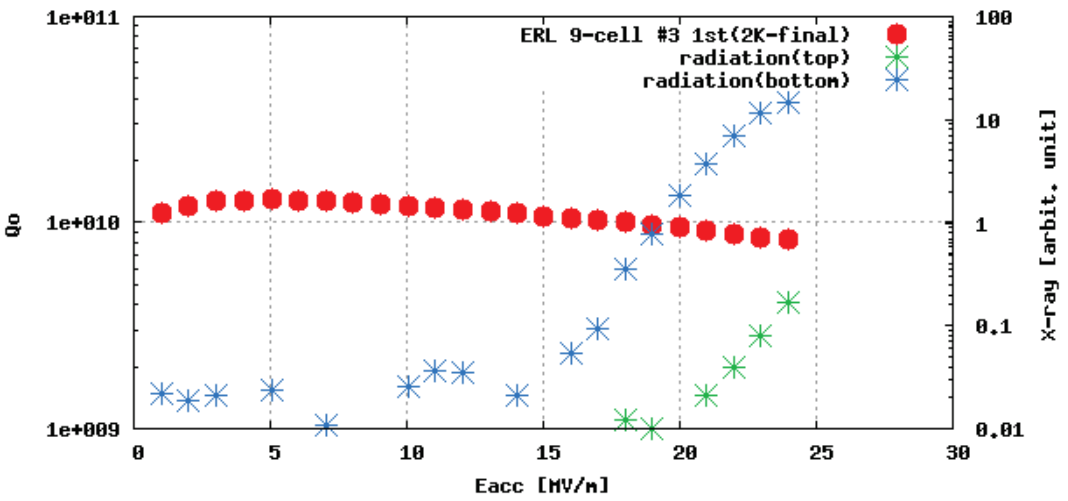
	#3 cavity (1st)	#3 cavity (2nd)	#4 cavity
Pre-EP and EP-1	5 um + 120 um		5 um + 120 um
Annealing	750 degree x 4hours		750 degree x 4hours
Pre-tuning	> 98% flatness	> 99 % flatness	> 98% flatness
EP-2	50 um	20 um	50 um
HPR	5hours + 5hours	7.5 hours + 5 hours	6hours + 5.5 hours
Assembly			
Baking	> 110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

Trial for suppressing field emissions…

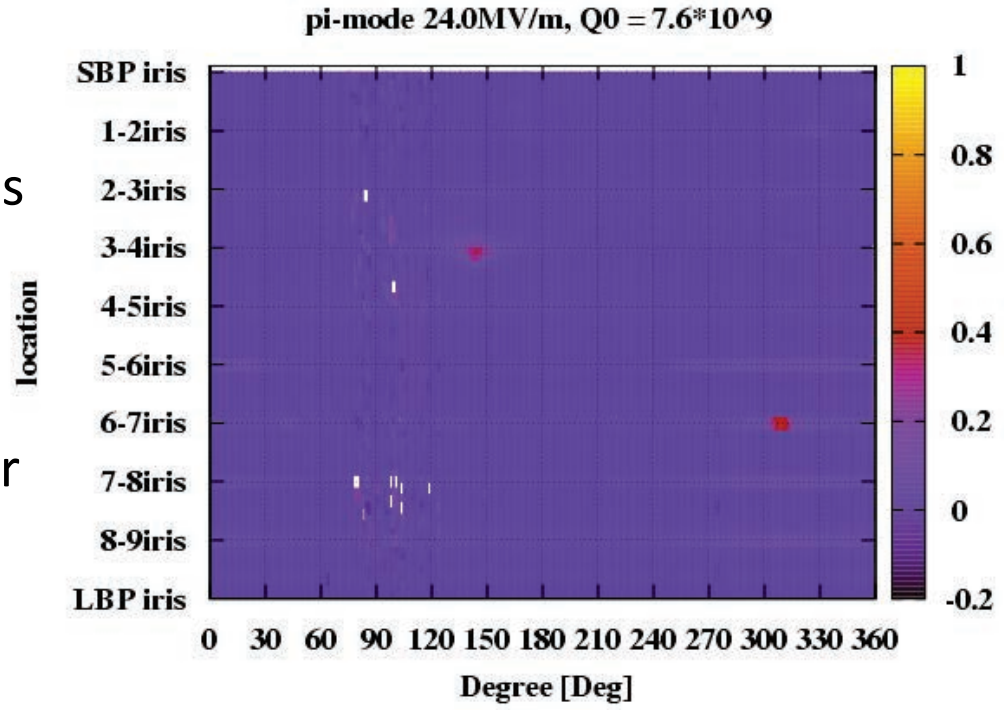
- Lower current EP(32mA/cm^2) and optimized washing
- Careful assembly using ionized gun and particle counter
- Trying to keep cleaner circumference

Results of vertical test for #3 cavity

- Field reached to 25 MV/m
- No limitation up to 25 MV/m
- Q > 1e10@15MV/m
- 1299.65 MHz@2K
- Satisfied cERL specification

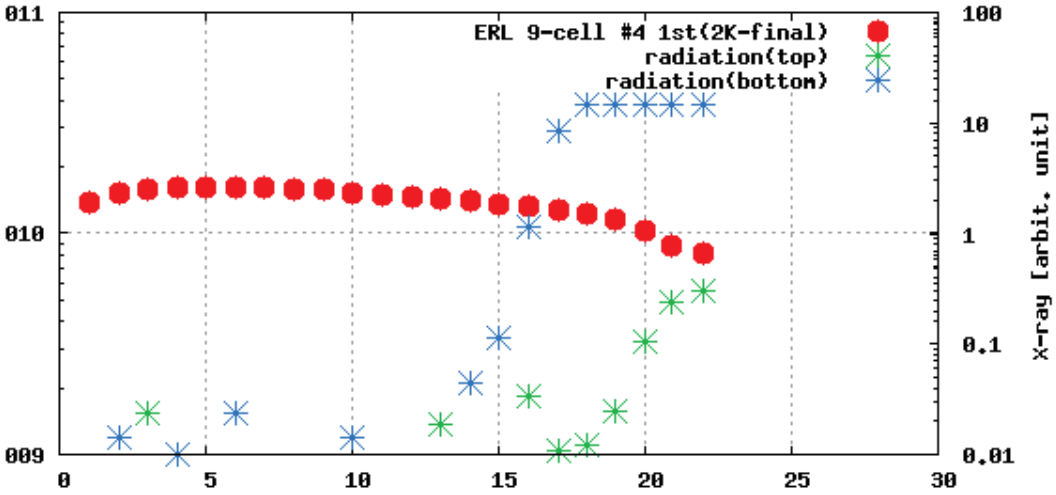


- X-ray on-set around 15 MV/m
- Emission source seems to be on iris between 3-4 cells, 130 or 310 degree



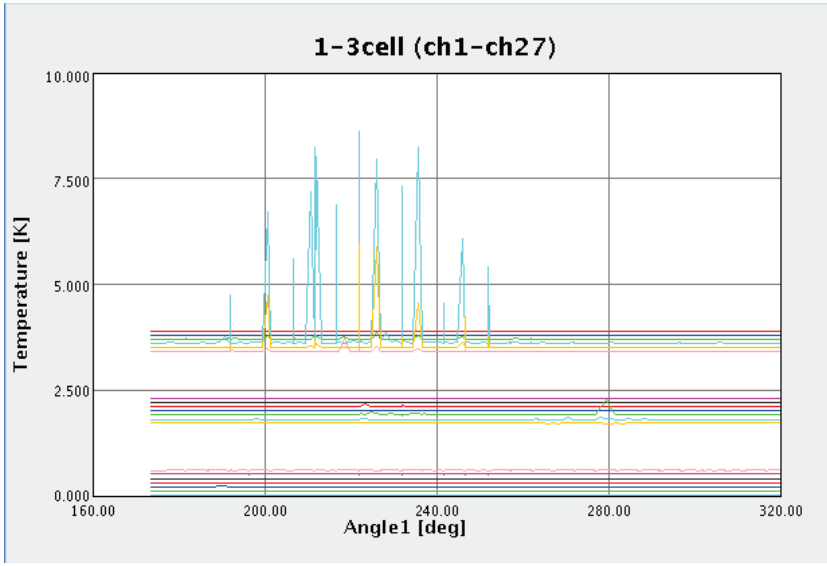
- But vacuum trouble happened after vertical test
- We will do another vertical test at next week

Results of vertical test for #4 cavity



- Field reached to 22 MV/m
- Limit by quenches around 1-cell equator.
- Q > 1e10@15MV/m
- 1299.72 MHz@2K
- Satisfied cERL specification

- X-ray on-set was initially around 18 MV/m
- But after processing, X-ray on-set went down to 15 MV/m
- Emission source seems to be on irises between 1-2 cells or 1-cell/SBP. (See next Enrico's talk)



Thermal response around 1-cell equator, 220 degree, during self-pulsing

Conclusion and plan

- cERL project is on going at KEK.
- A cryomodule with two 9-cell cavities are under construction.
- Surface treatments have been applied for #3 and #4 cavities, and vertical tests have been performed.
- Cavities reach Eacc > 20 MV/m and Q > 1e10(@15MV/m), satisfying cERL specification.

[Plan]

- Vertical tests will be finished within a few month.
- Then, He jacket will be welded.
- Module assembly will be held around summer.
- Cooling test, high power test and beam operation will follow.