Cavity design for KEK-ERL main linac

2013/6/12

TTC topical meeting on CW SRF

KEK ERL main linac group

K. Umemori, K. Enami, T. Furuya, H. Sakai, M. Sato, K. Shinoe (KEK),

M. Sawamura (JAEA-ERL), E. Cenni (Sokendai)

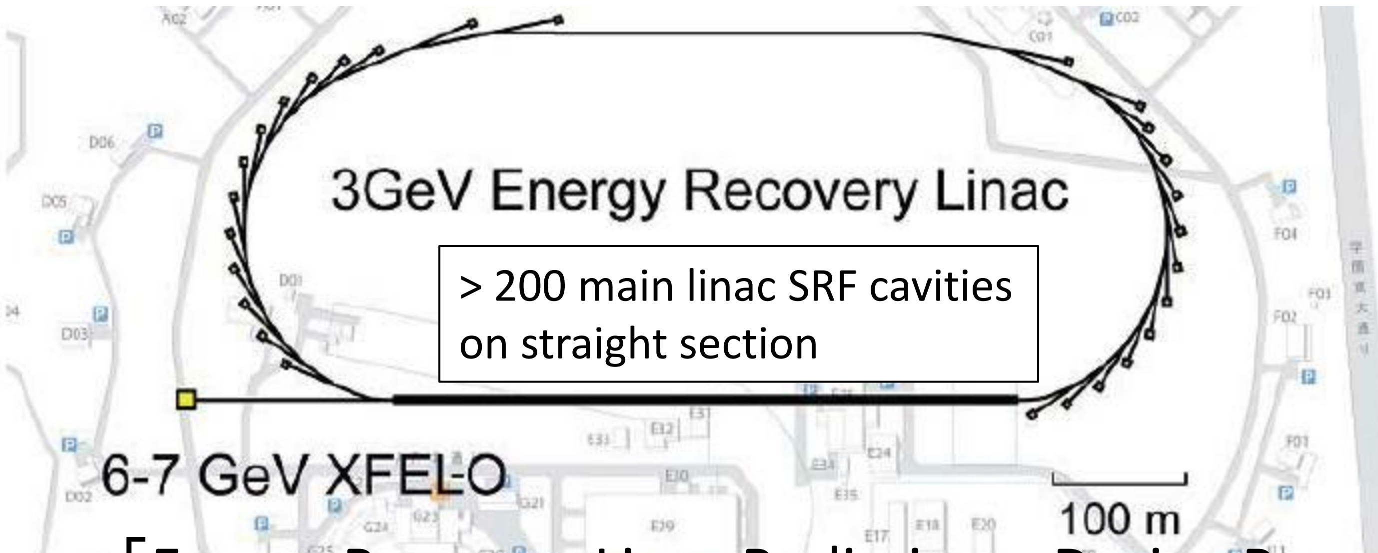
Contents

- Requirement for ERL main linac cavity
- HOM damping
- Surface electric field
  - Cavity performance and Field emission

Requirement for ERL main linac cavity

- Maximum Eacc = 15 ~ 20 MV/m
  - Operation: 12～15MV/m
- $Q_0 > 1x10^{10}$ at 15 MV/m
  - Lower cryogenic loss is desirable
- **CW operation**
  - **HOM damping** → high current operation
  - Suppression of **field emission**

Cavity design is focused on HOM suppression (designed at 2006)

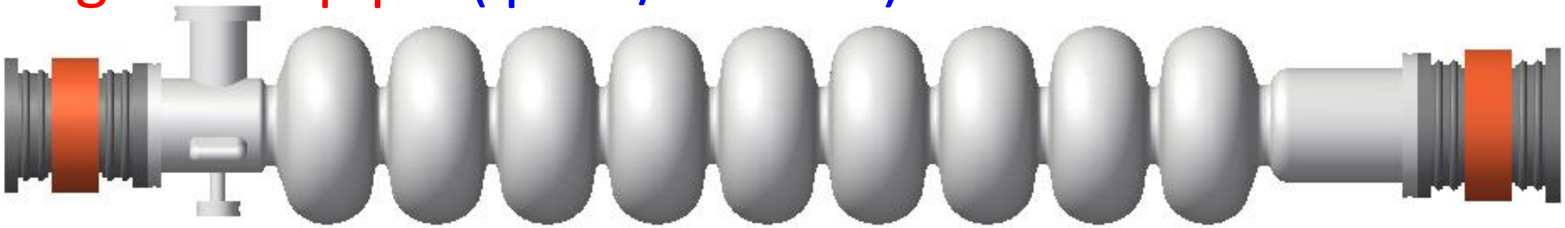


From「Energy Recovery Linac Preliminary Design Report」

HOM Strategy and cavity design

- Dipole mode: Lower impedance of (R/Q)Qext/f
- Monopole mode: Avoid frequency around 2.6GHz, 5.2GHz …
- Quadrupole mode: Eccentric fluted beampipe
- Packing factor: Select 9cell structure

1) Iris diameter 80mm, elliptical shape at equator
2) Large beampipes(ϕ100/123mm) mounted with RF absorber



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)

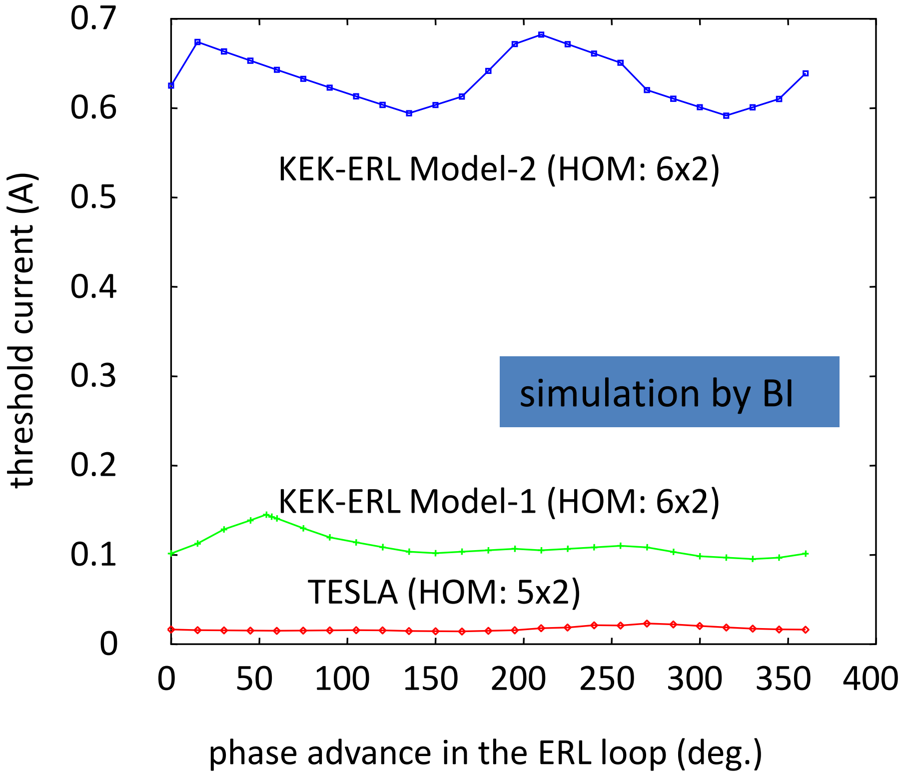
KEK-ERL model-2 cavity	ERL model-2 cavity shape + Large beampipe damper
KEK-ERL model-1 cavity	TESLA cavity shape + Large beampipe damper
TESLA cavity	TESLA cavity shape + Loop-type HOM coupler

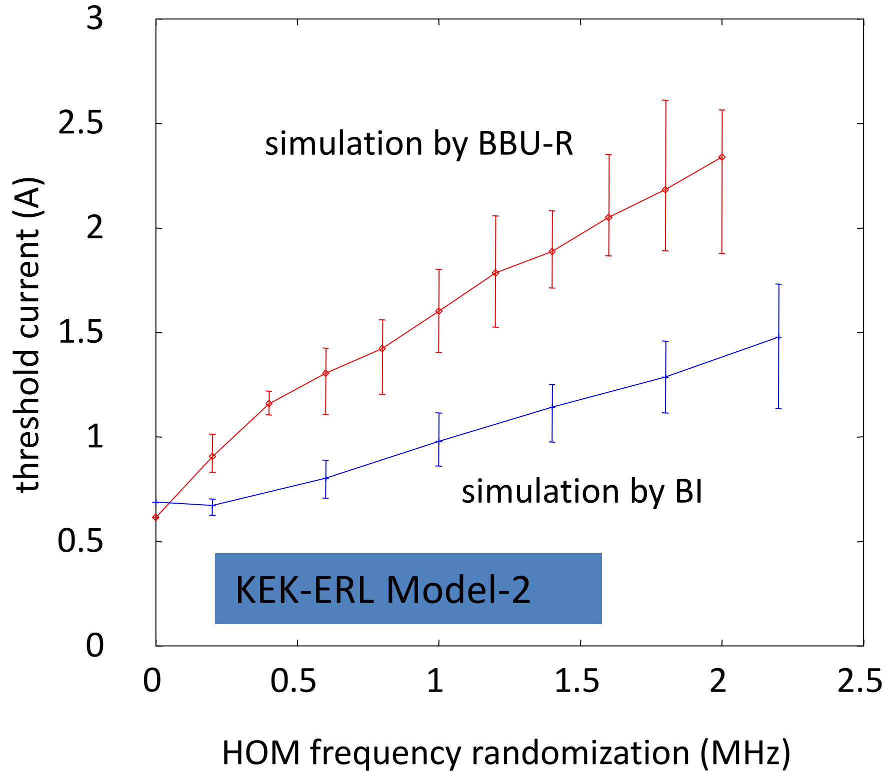
HOM-BBU threshold current

(Calculation performed by R. Hajima, JAEA)

E_{inj} = 10 MeV, E_{loop} = 5 GeV, E_{acc} = 20 MV/m

BI : developed at Cornell
BBU-R : developed at JAEA

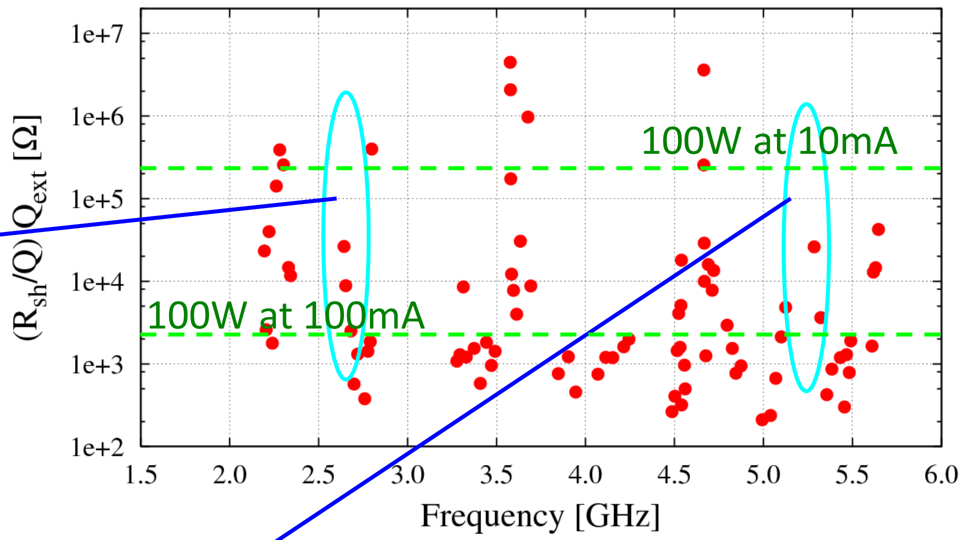


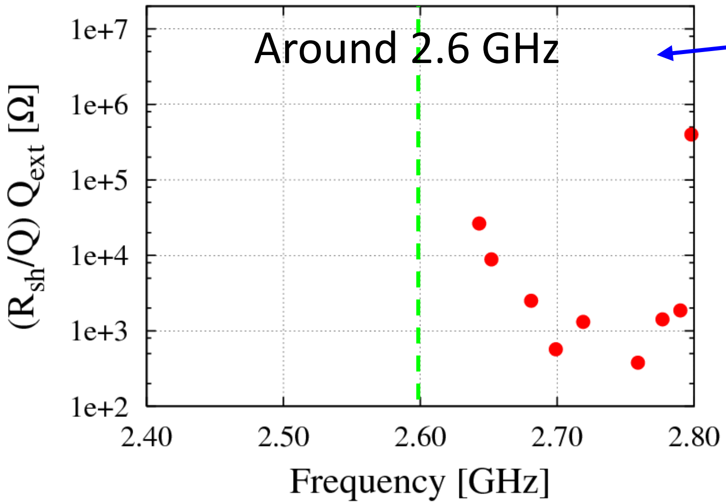


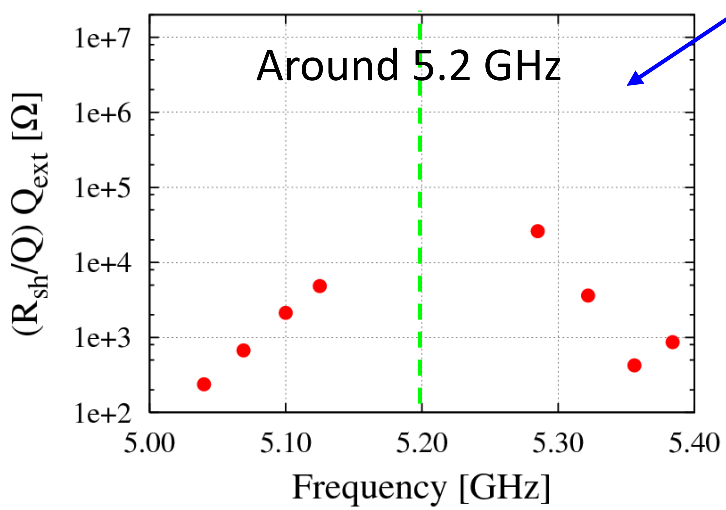
BBU threshold are significantly improved
More than 600mA is possible for KEK-ERL model-2 cavity

Monopole mode

KEK-ERL model-2 cavity







No monopole modes around 2.6GHz and 5.2GHz, within +/-40MHz

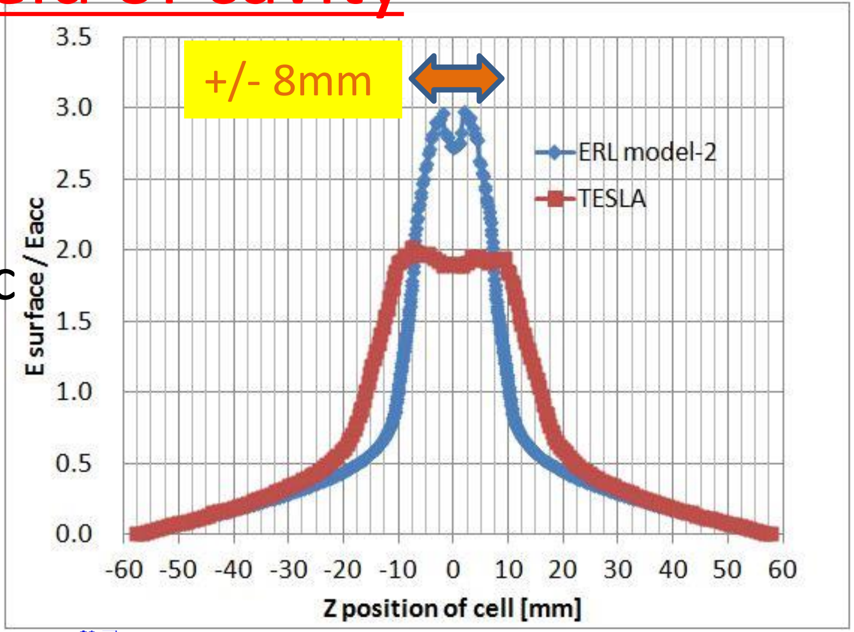
Need to avoid resonant excitation for the case of lower frequency ERL operations.

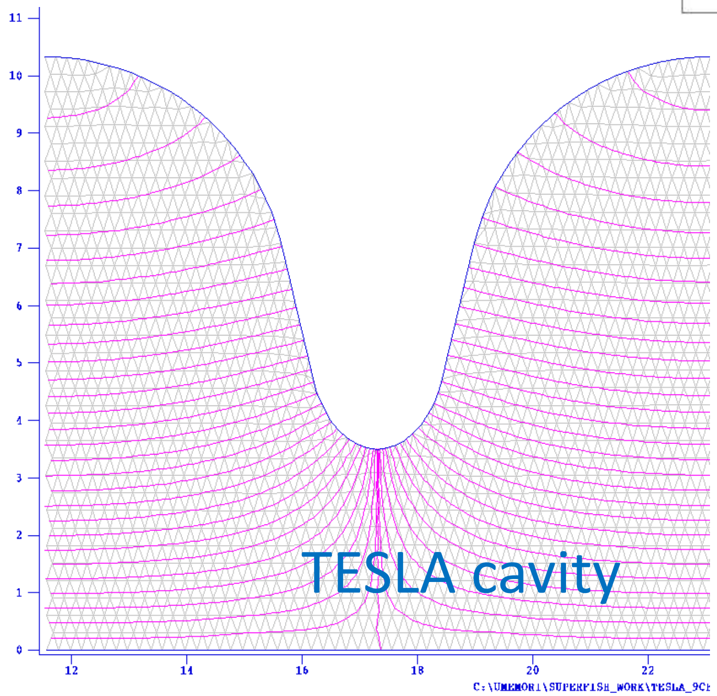
Cavity performance and Field emission

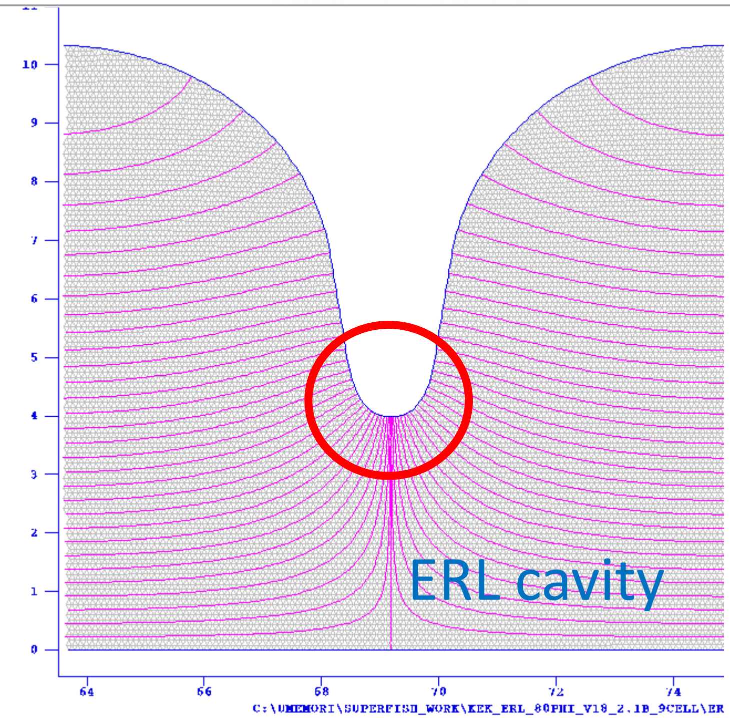
Surface electric field of cavity

Effect of large iris diameter
HOM suppression ⇔ Large Epeak

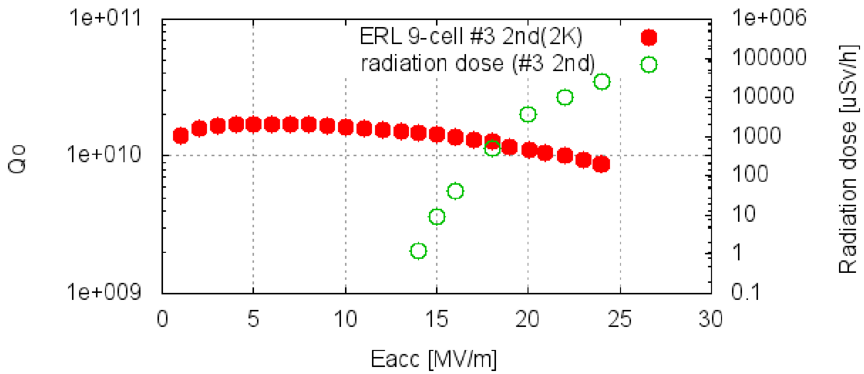
- Field emission becomes the cryogenic losses and radiation, which could be problem under CW operation.
- So, it is important to suppress field emission for ERL operation

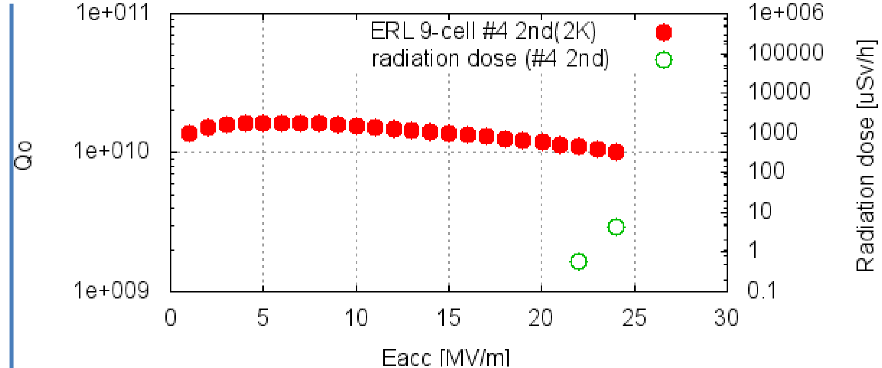




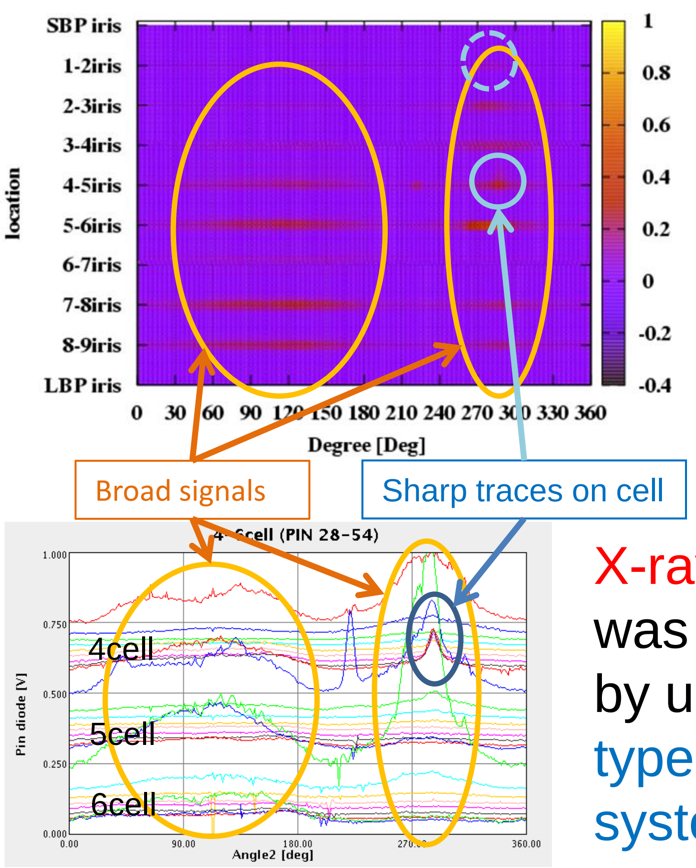


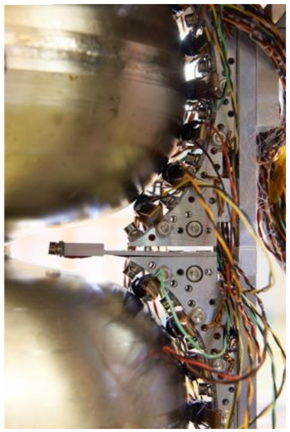
Vertical test results for #3 and #4 cavities



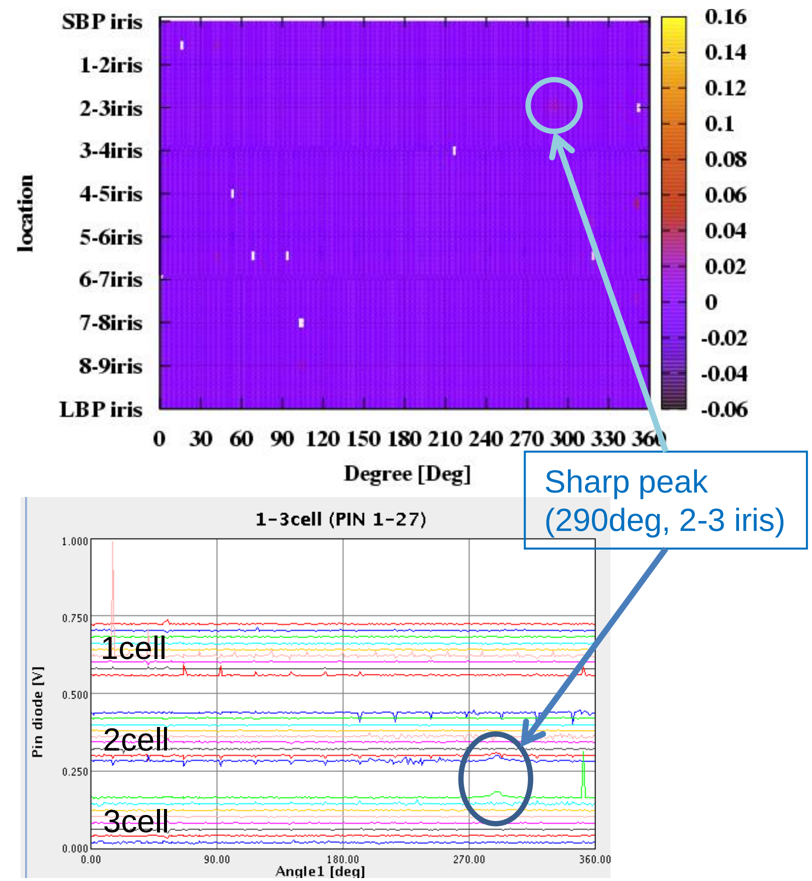


#3 cav., 2nd VT, Eacc=22MV/m



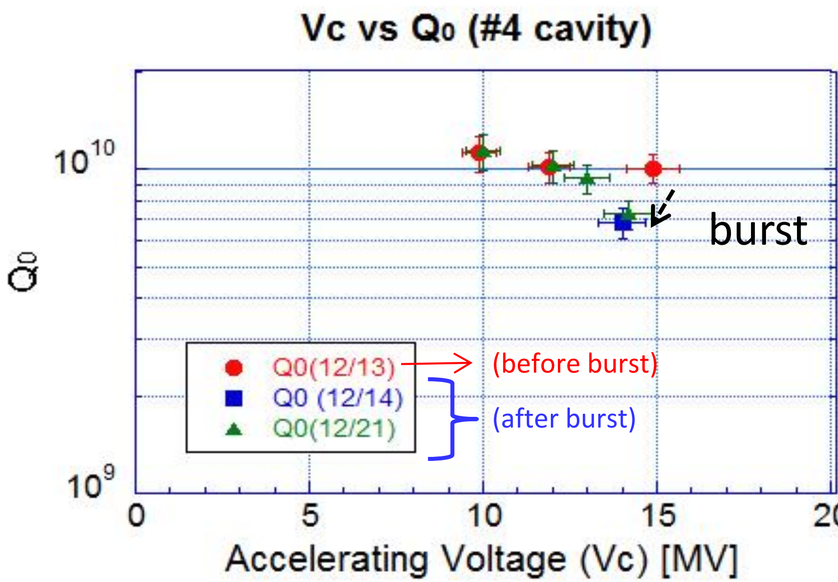


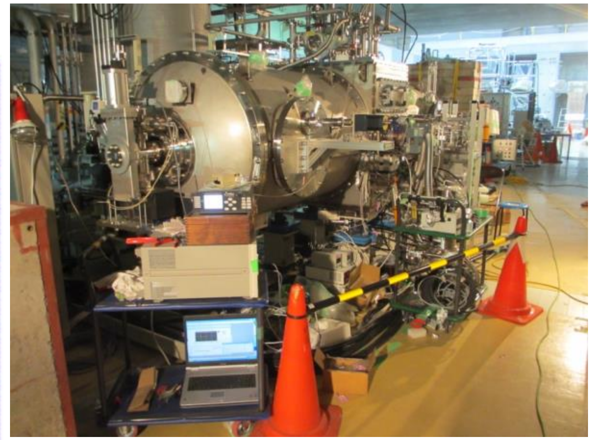
#4 cav., 2nd VT, Eacc=24MV/m

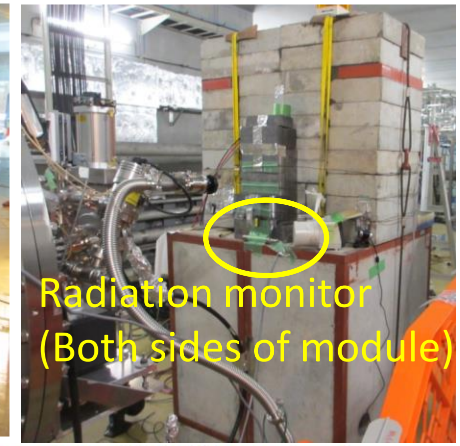


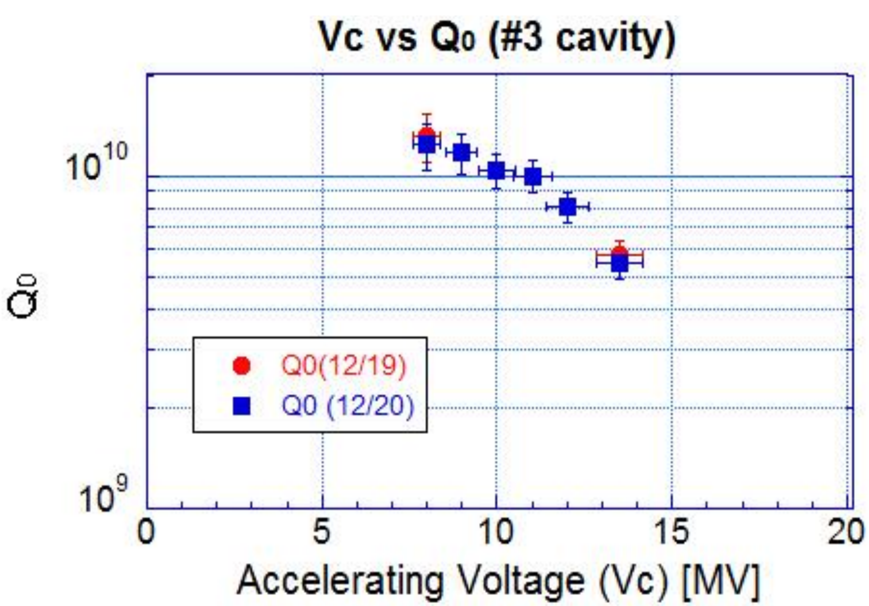
X-ray mapping was observed by using rotating type mapping system

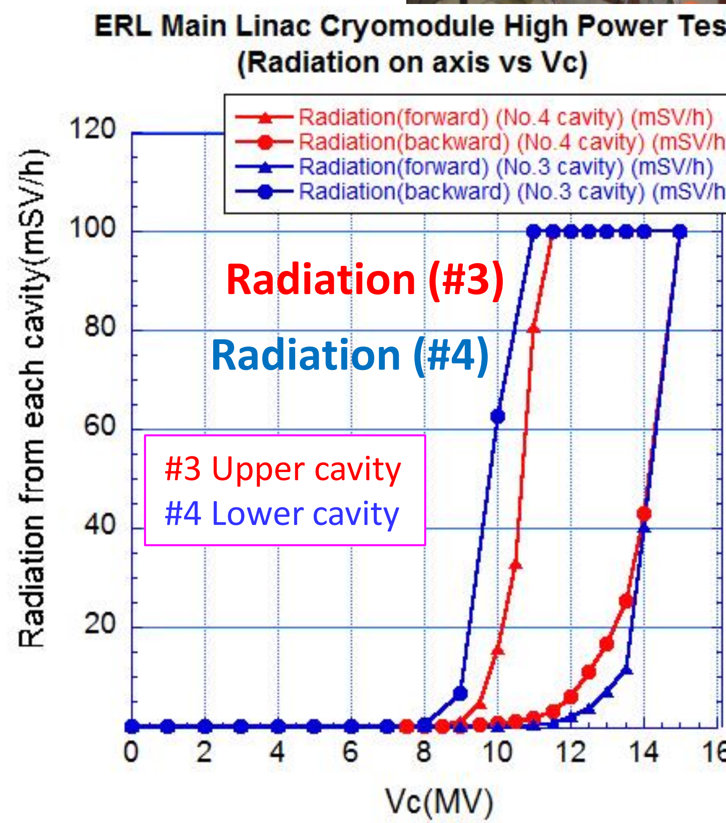
High power cryomodule test





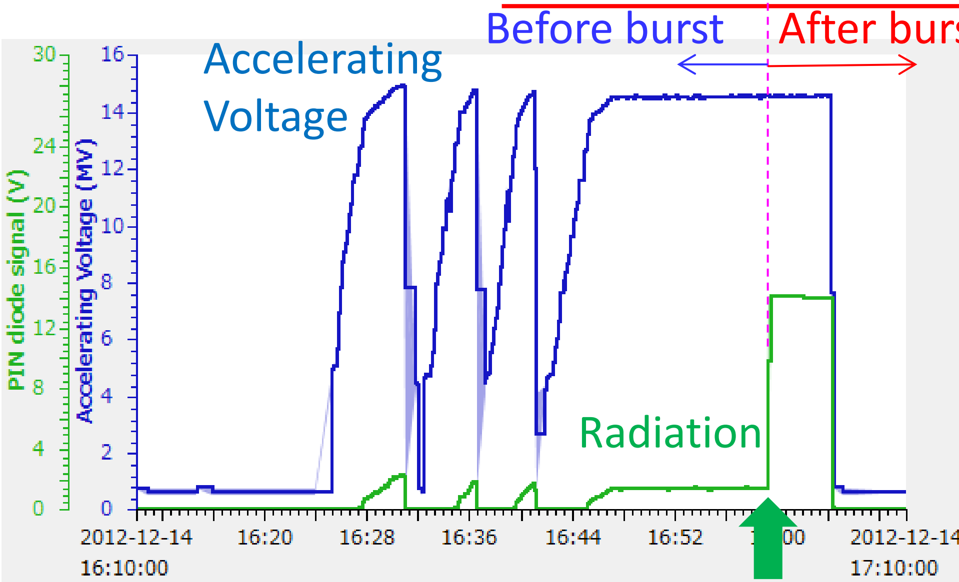




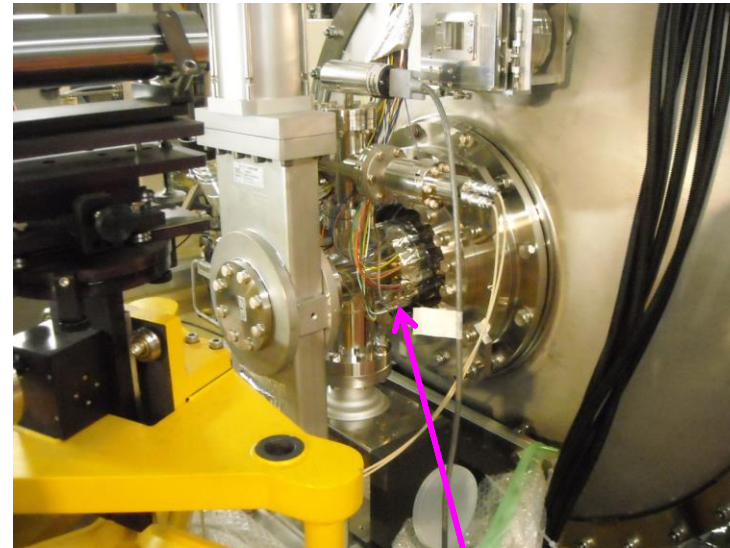


Q values are dropped due to field emission.

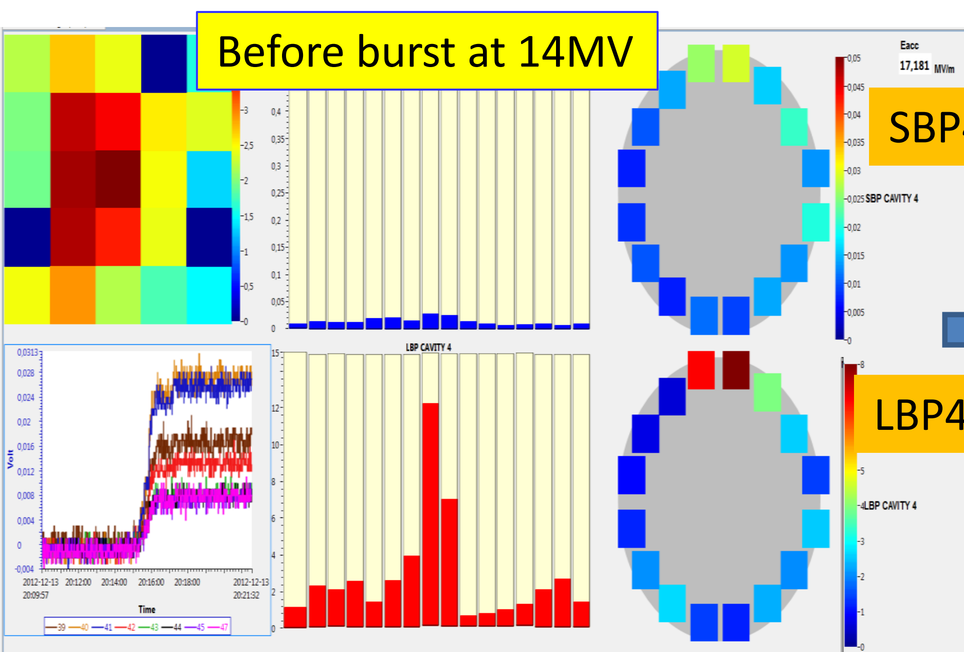
Radiation measurement

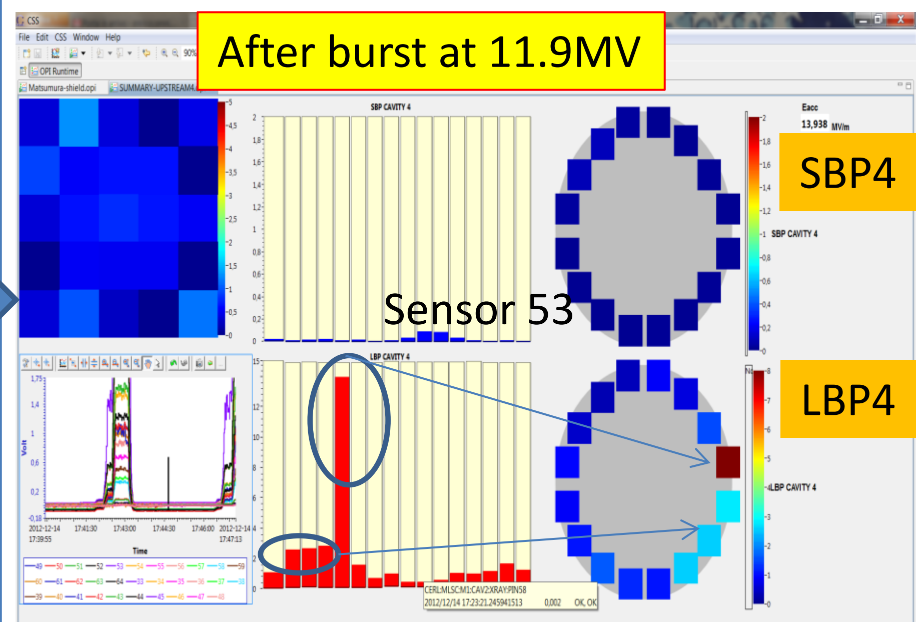


During conditioning X-ray burst happened.



Si PIN diode around beam axis





Summary and future

- KEK-ERL main linac cavity was designed mainly focused on HOM damping
- At present, field emission is problem
  - Cavity design?
  - Module assembly technique?

- Future direction
  - Improvement of module assembly technique is essential.
  - New cavity design with lower surface E field, but still keeping HOM damping as strong as possible, is desirable.

Discussion

- HOM
  - How high frequencies should we calculate/measure HOMs, in order to confirm BBU threshold and HOM heating?
    - ~ps beam → beam spectrum ~1THz
    - Before construct hundreds of cavities(multi GeV ERL), we want to confirm cavity performance.
- Field emission
  - How field emission is severe/ or not severe for ERL operation?
    - Radiation safety
    - Cryogenic loss
    - Really run inside cavities up to ~GeV?
  - How is the situation of field emissions for running CW SRF facilities?
  - During operation, what's happen?
    - Gradually degraded?
    - Processed?

Backup slide

Dependence of number of cells

- Study for TESLA + large beampipe
  - Impedance becomes half for 7-cell cavity

		9 cell			7 cell		
		Rsh/Q	Q	Rsh	Rsh/Q	Q	Rsh
TM011	π/9	159	1730	2.8×10^{5}	156	868	1.3×10^{5}
TM012	8π/9	46	118000	5.4×10^{6}	33	44500	1.5×10^{6}
		Rt/Q	Q	Rt	Rt/Q	Q	Rt
TM110	5π/9	9	10700	9.4×10^{4}	7	8000	5.8×10^{4}
TE-iris		23	4256	9.6×10^{4}	17	2100	3.6×10^{4}

Study on iris diameter

	TM010	TE-iris			TM110		
	Rsh/Q	Rt/Q	Qext	Rt/Q*Q/f	Rt/Q	Qext	Rt/Q*Q/f
70phi	1010	22	9500	80000	9	10000	49000
80phi	890	11	4000	18000	6	7600	24000
90phi	780	5	4600	13000	4	7000	13000
100phi	690	3	1000	1000	4	9700	24000

- Condition of study
  - Equator shape is same with TESLA cavity
  - Large beampipe of ϕ118 is used.
  - Both end cells are symmetric.
- Generally, dipole modes are efficiently damped.

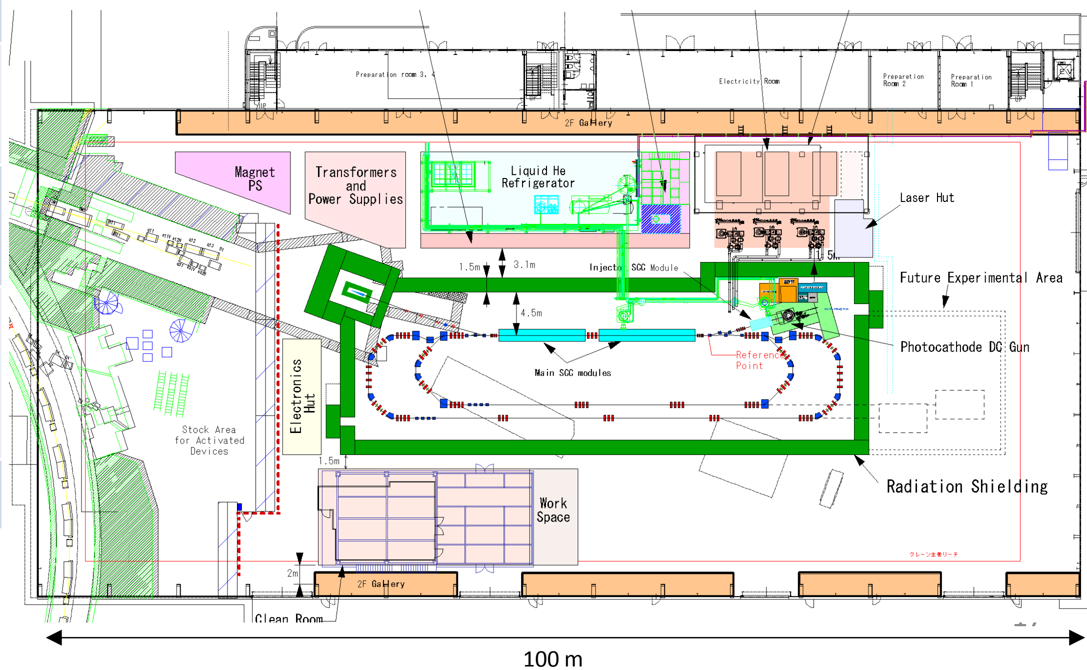
Compact ERL(cERL) project

Demonstrate the technologies needed for future multi-GeV class ERL, and show its beam performances

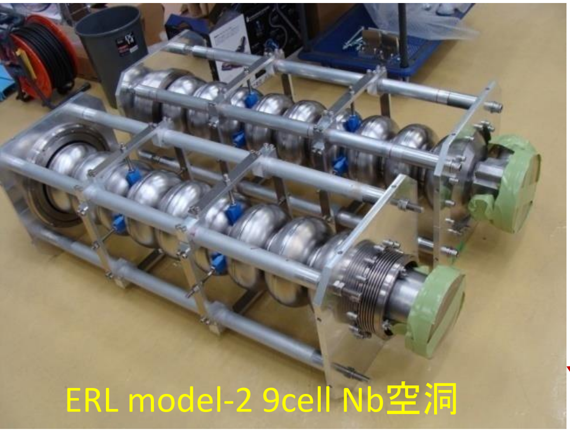
Parameters of the Compact ERL

	Parameters
Beam energy	35 - 200 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

※ red numbers are parameters for initial stage

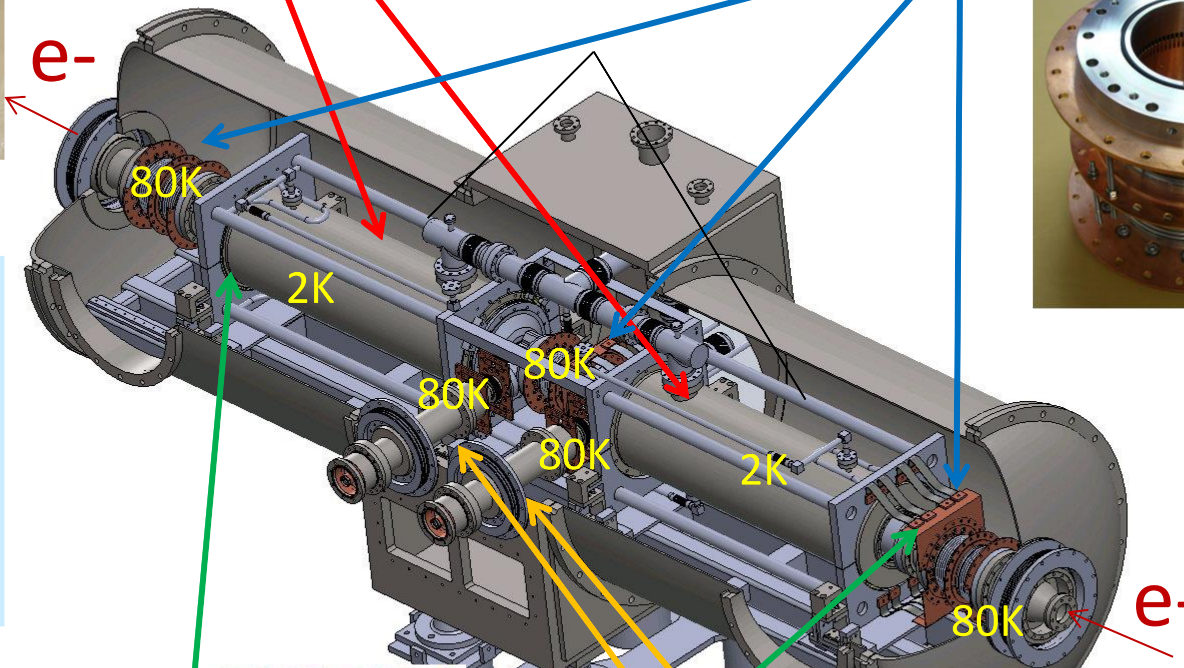


cERL main linac cryomodule



9-cell SRF cavity
HOM damped cavity
Eacc = 15-20 MV/m
Q0 > 1*10^10 @15MV/m

HOM damper
- HIP ferrite on Cu beampipe
- Operation at 80K
- 150W HOM power handling



Requirement

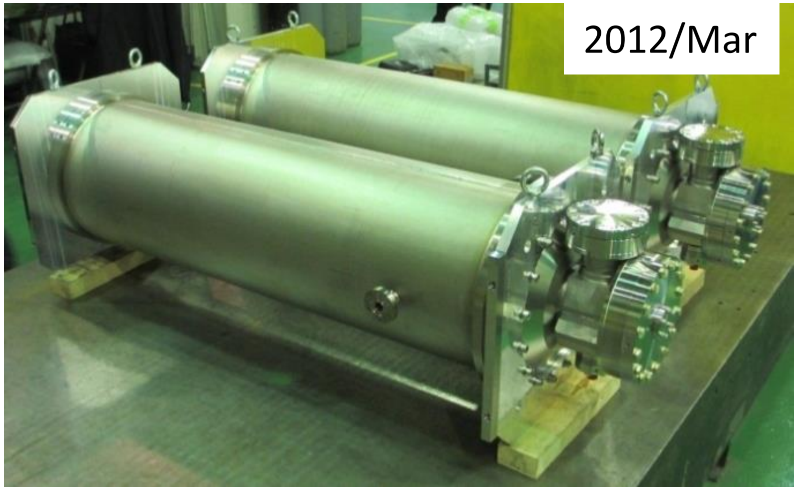
Frequency : 1.3 GHz
Input power : 20kW CW (SW)
Gradient: 15-20MV/m
Q0: >1*10^10
Beam current : max 100mA
(HOM-BBU対策を施した空洞設計)

2-cavity cryomodule had been developed for cERL main linac

Frequency Tuner
Slide jack tuner
piezo tuner

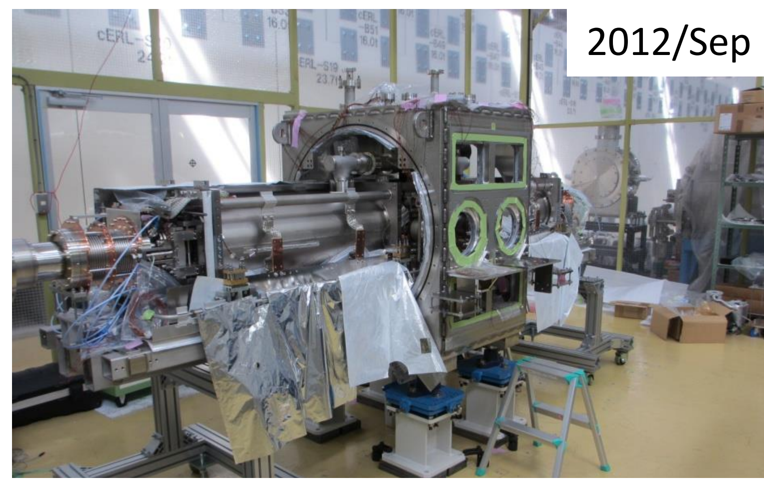
Input coupler
- 20kW CW(total reflection)
- Cold and warm window
- HA997 ceramic is used
- QL=(1-4)*10^7(variable)

Module assembly

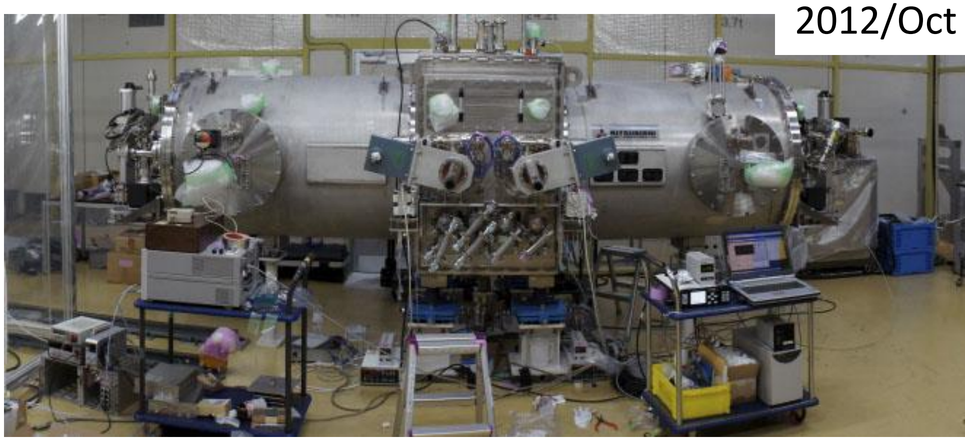


He jackets were welded on cavities

Cavities, HOM dampers and input couplers were assembled.

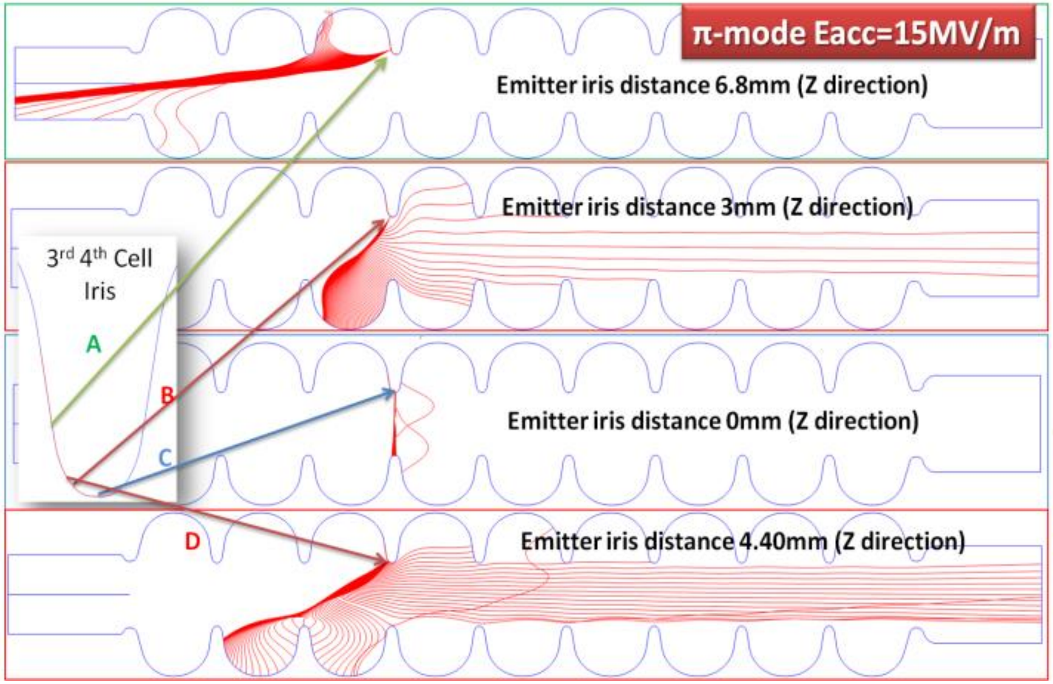


Assemble He line, magnetic shield, sensors and so on

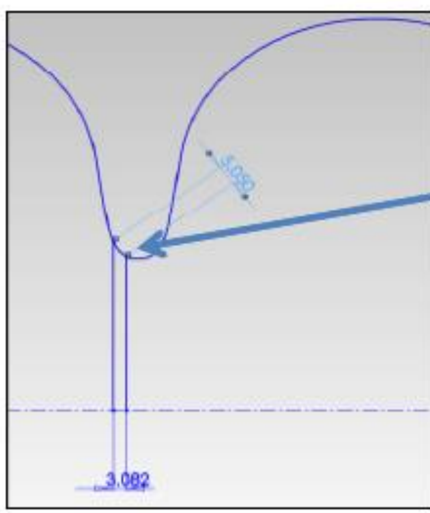


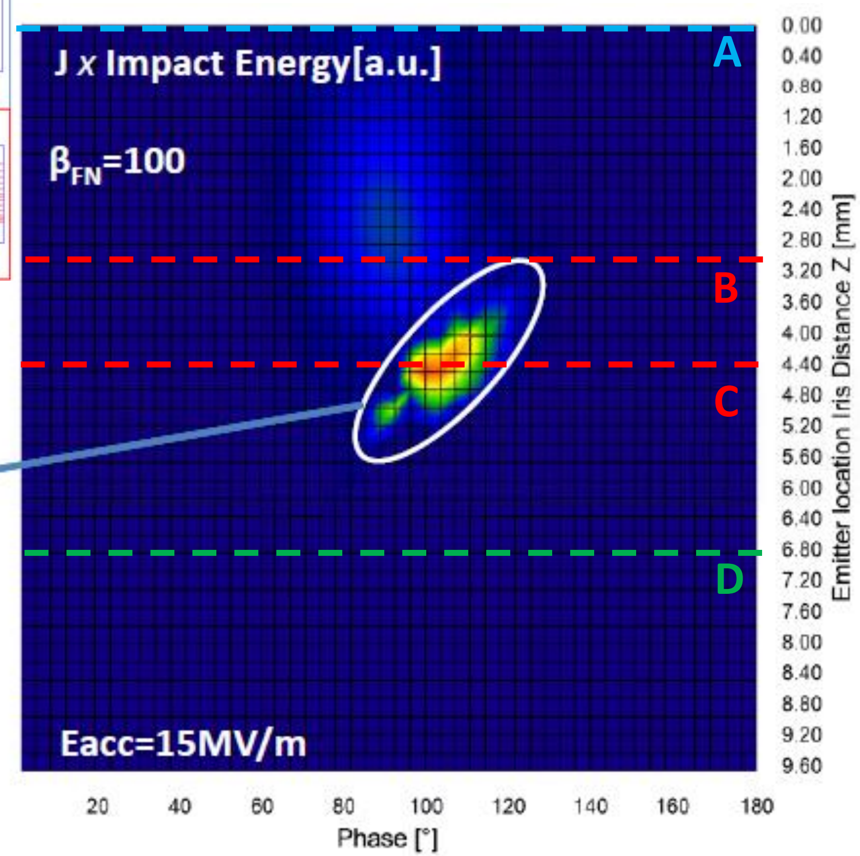
Installed into cryomodule. Gate valves were mounted on both sides.

Field emission calculation

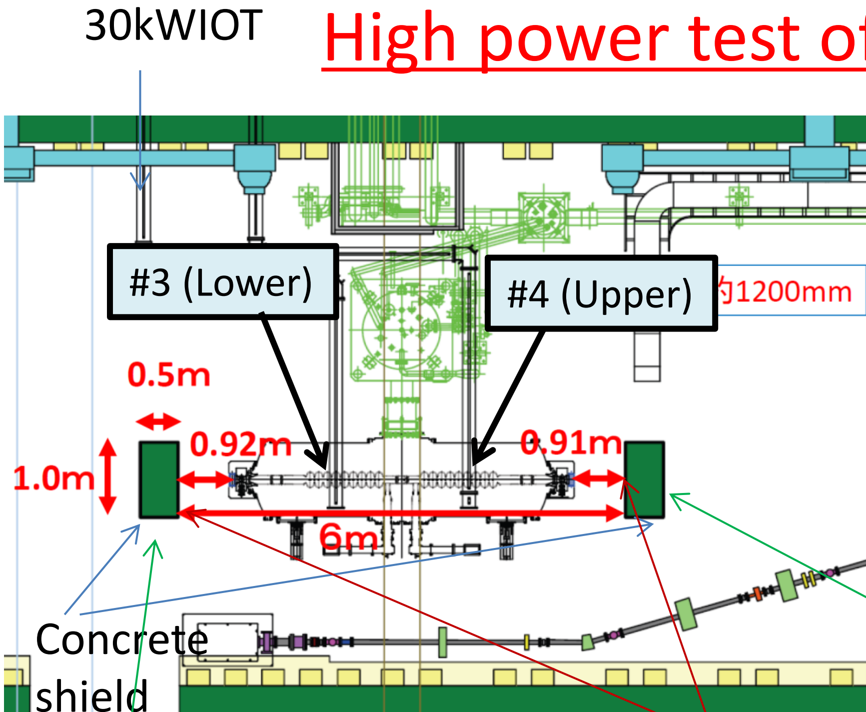


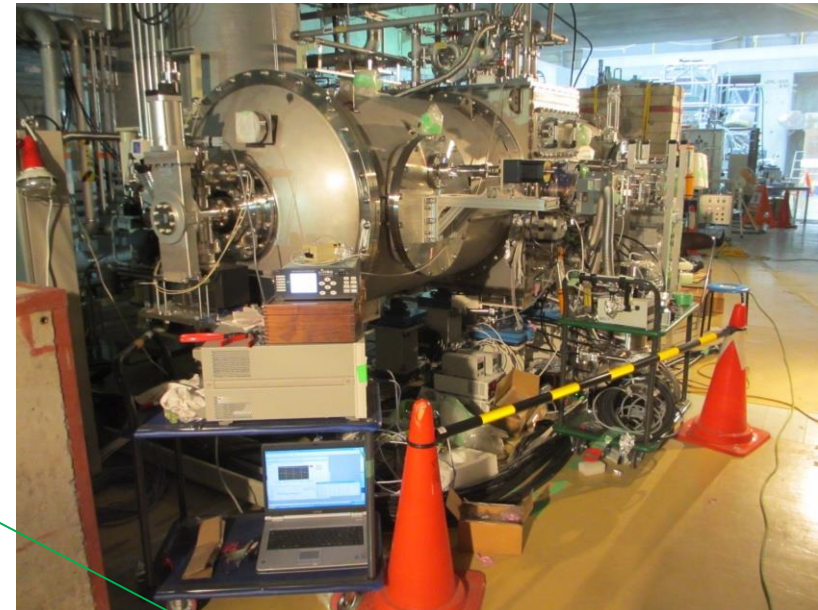
Trying to understand field emission by using simulation code, Fishpact etc.





High power test of cERL main linac cryomodule

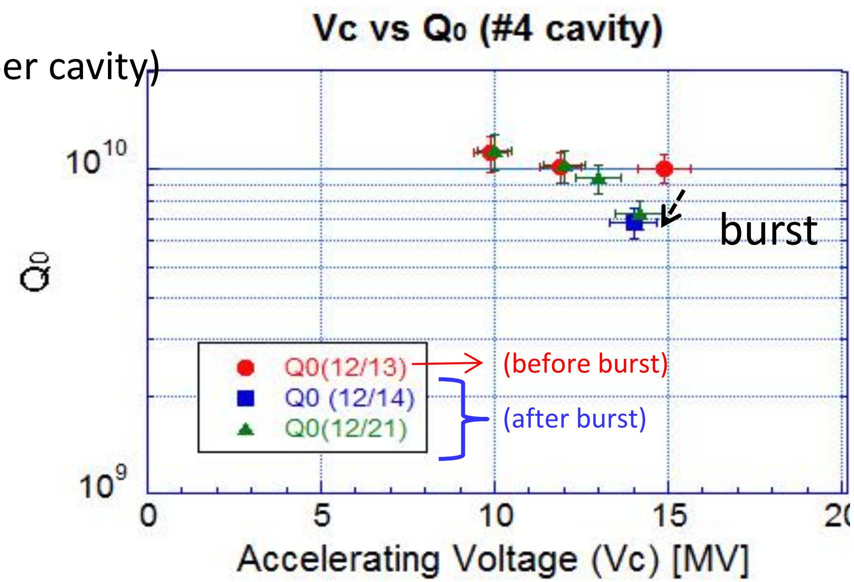


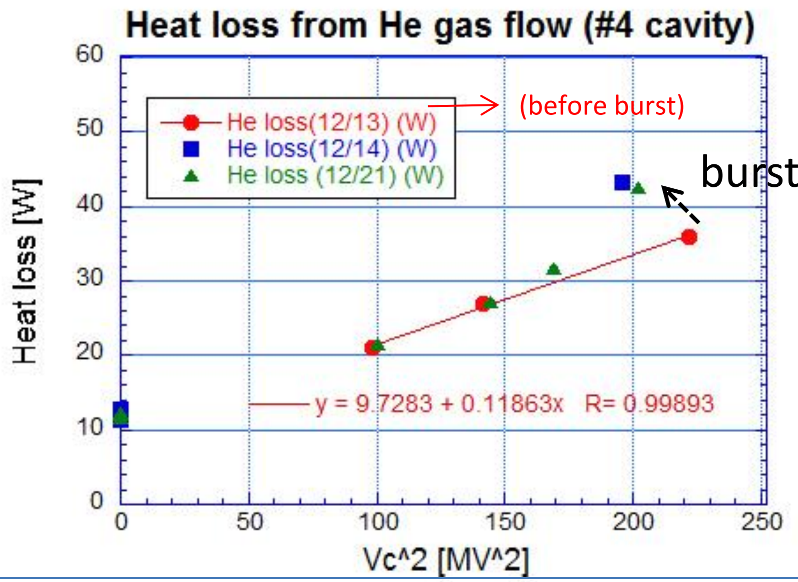


Radiation monitors

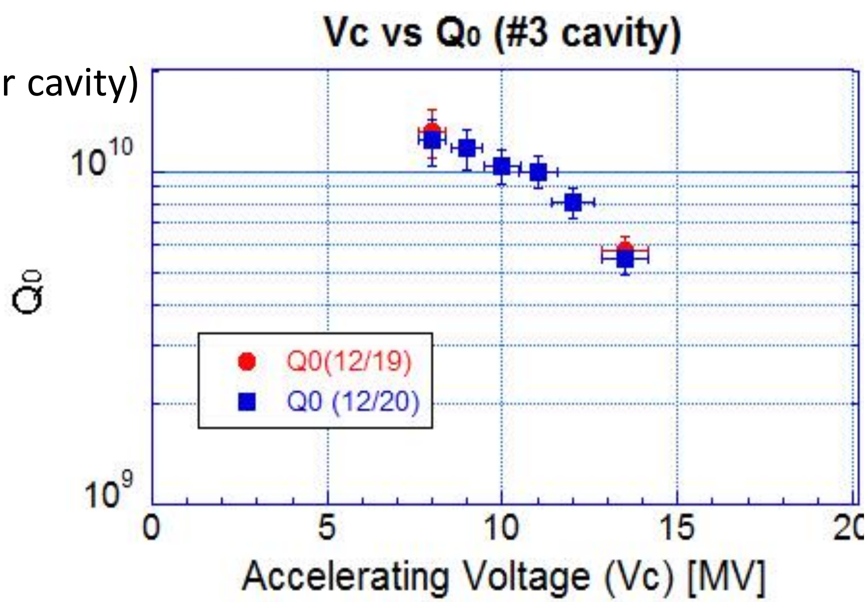
Dynamic loss measurement

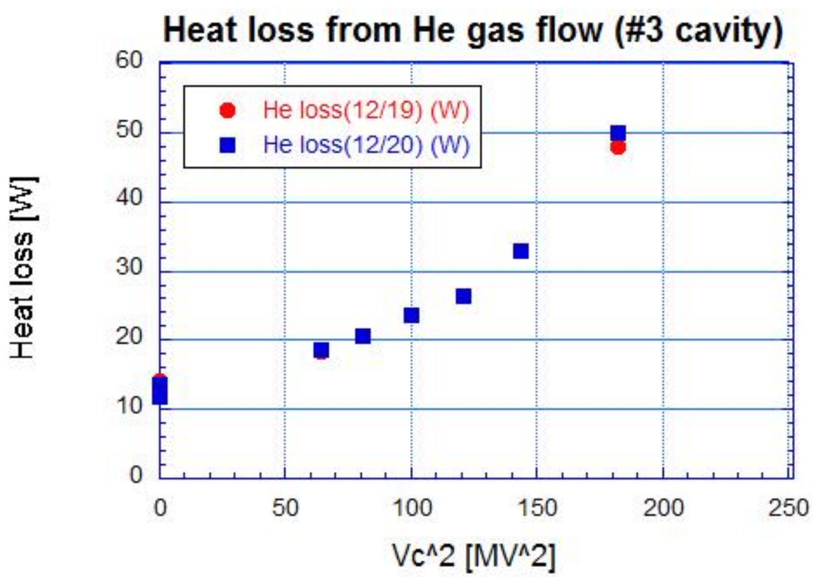
#4
(Upper cavity)





#3
(Lower cavity)





Q values are dropped due to field emission. Cryogenic loss also increase.