Radiation measurement & comparison between VT and CM tests at cERL

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

Contents about radiation measurement

- Radiation measurements at V.T by using T-X rotating mapping system.
- Radiation measurement at cERL cryomodule.
- Comparison between V.T and CM.

Requirements of cERL main linac

Frequency : 1.3 GHz

Gradient: 15MV/m

Q0: >1*10^10

Beam current : max 100mA

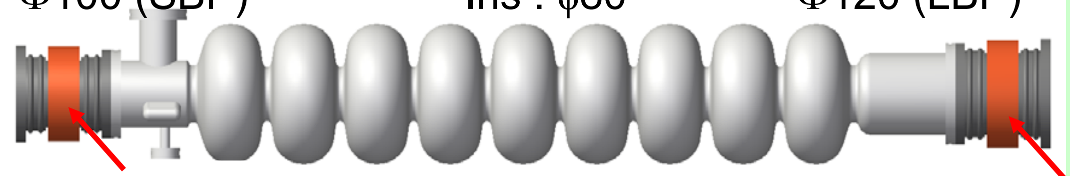
(100mA (in)+ 100mA(out))

Based on TESLA cavity

modified

Compact ERL (cERL) @KEK
Commisoning in 2013

ERL-model-2 cavity: **600mA can be circulated in design (HOM-BBU threshold)**



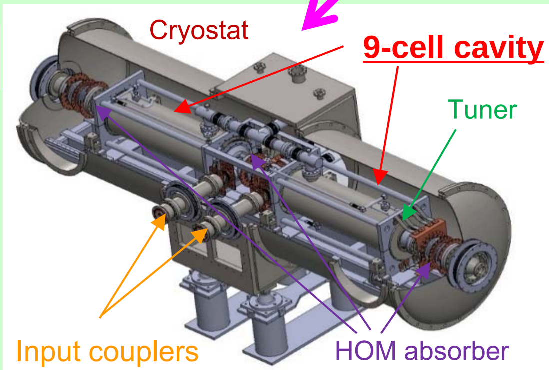
All HOMs damped to both end

H.Sakai et al., Proc. of ERL07 (2007).

Parameters of cERL main linac

():TESLA cavity

Frequency	1300 MHz	Eacc	15-20MV/m
Q0	1e+10	Coupling	3.8 % (1.9%)
R_{sh}/Q	897 Ω (1007Ω)	$Q_o \times R_s$	289 Ω
E_p/E_{acc}	3.0 (2.0)	H_p/E_{acc}	42.5 Oe/(MV/m)

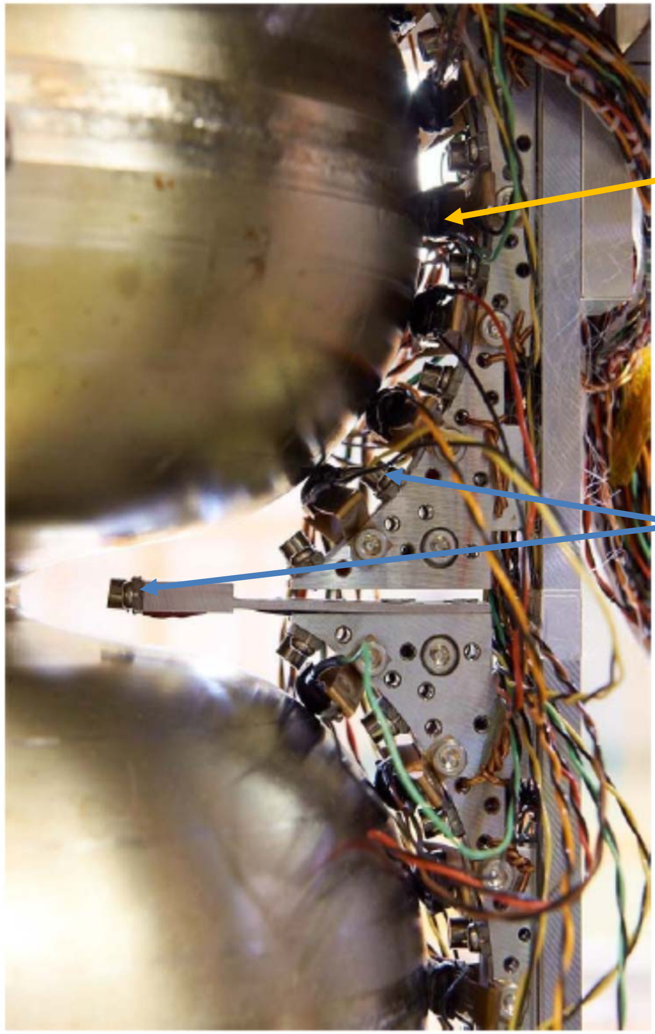


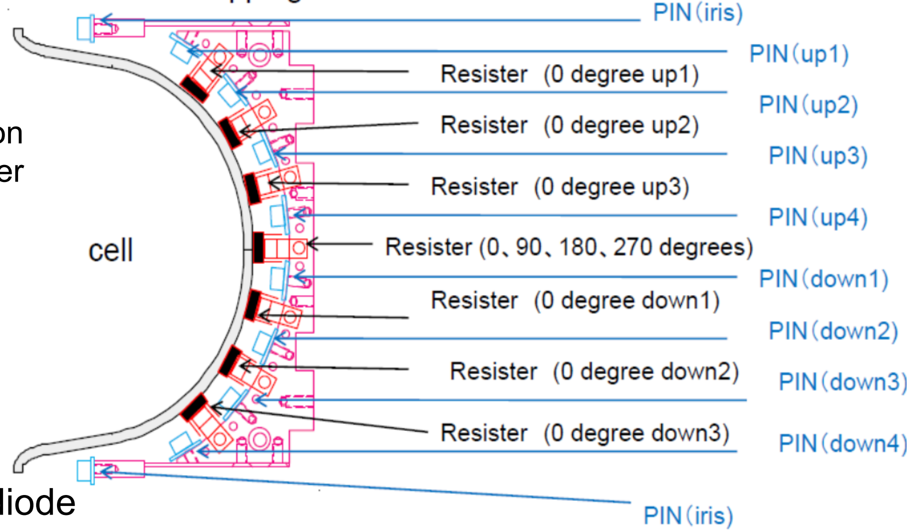
Main-Linac(ML) Cryomodule

We need to see radiation information in detail → motivation for x-ray rotating mapping

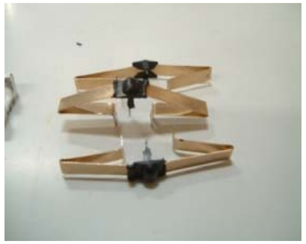
Less than 8 pages *TTC meeting 2014 @DESY. (2014.March.24-March.27) WG8*

X-T Rotating mapping system for radiation measurement at VT



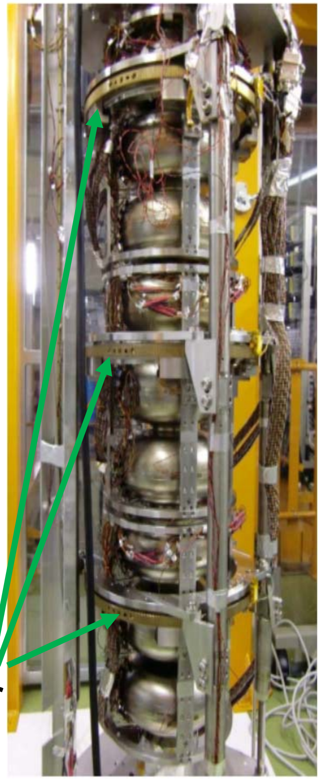


PIN diodes (HAMAMATSU S1231) for X-ray mapping with current Amplifier



Carbon resisters for Temperature map

The sensor array can turn around the cavity surface using stepping motors via gear and data taking every 0.5s by logger



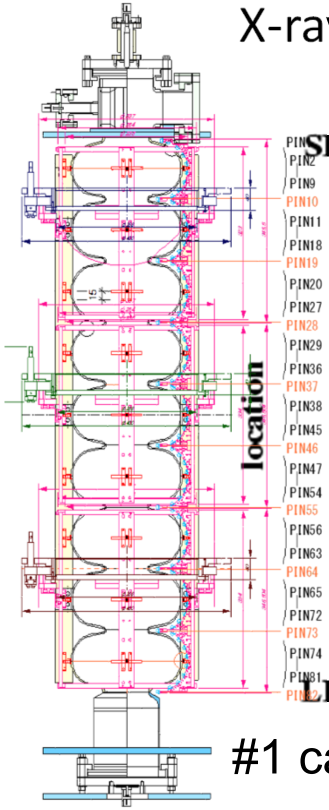
82 PIN diodes and 93 Carbon resistors are mounted on the mapping system along a meridian to detect 9cell radiation and temperature mapping precisely

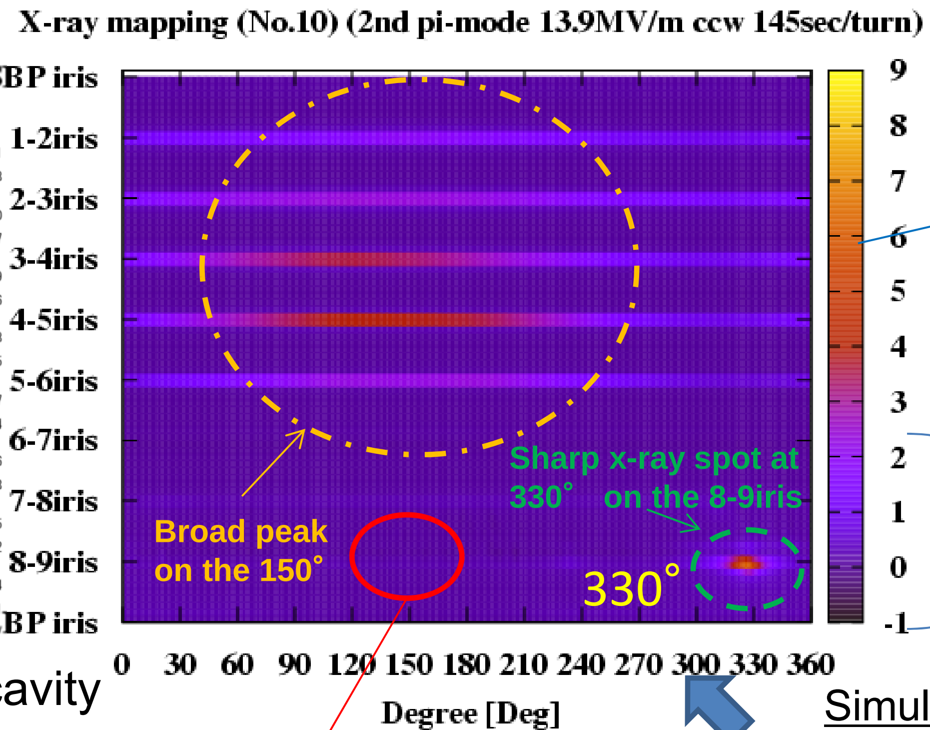
H.Sakai et al., Proc. of IPAC 2010 ,p2950

Figures of merit
(compared with fix mapping)

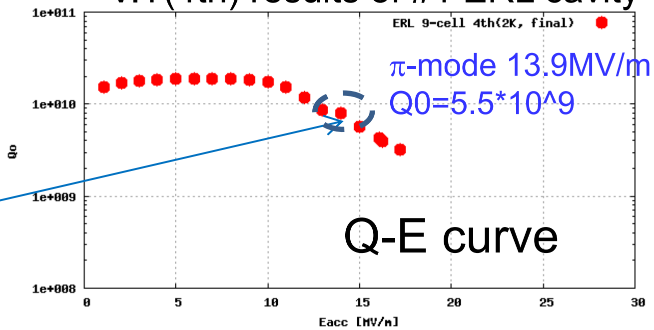
- Resolution 0.5°
- Small number of sensors

X-ray mapping data by rotating mapping system when field emission occurs



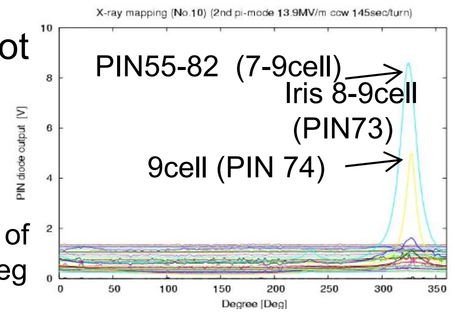


V.T(4th) results of #1 ERL cavity

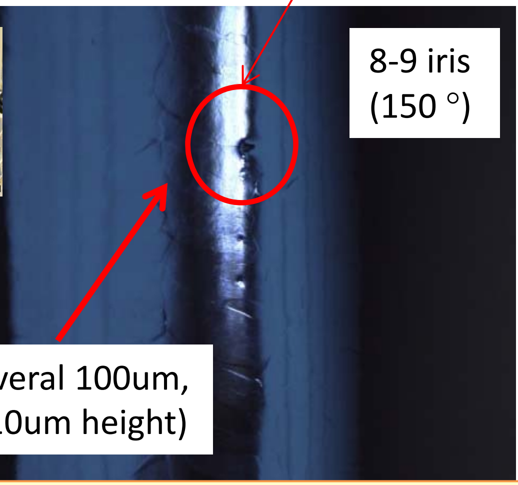


Contor plot of 7-9cell

Sharp peak of FWHM 10deg



Y. Iwashita et al., Phys. Rev. ST Accel. Beams 11, 093501 (2008).

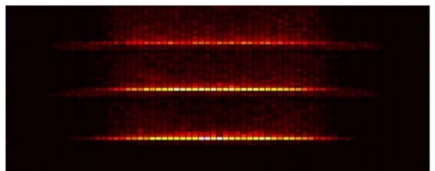


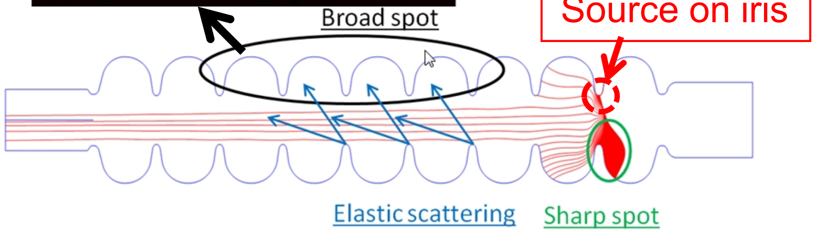
We found clear X-ray profile (broad & sharp) by rotating mapping system. → powerful tool for radiation source search
Tip were observed opposite side of x-ray sharp peak.

Simulation (with Fowler Nordheim eq.)

Field emission Profile on Nb surface simulated with including EGS5 (radiation with materical interaction)

See detail
Enrico Cenni
IPAC12, p295,
and
Doctor thesis



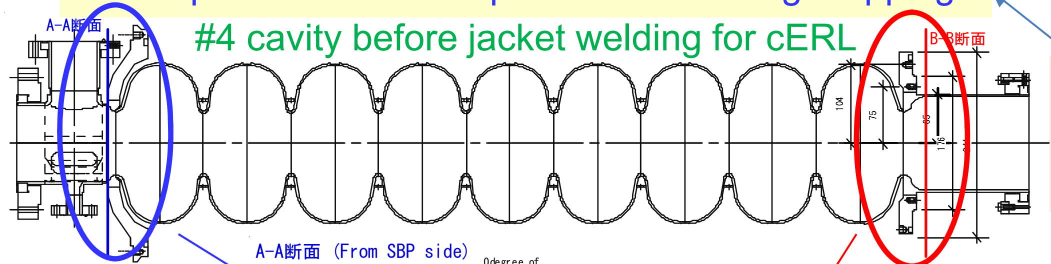


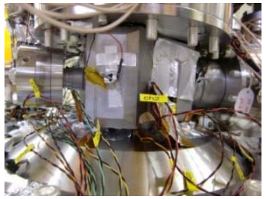
Measured profile were clearly explained by simulation .
We can know the localized source of field emission in V.T

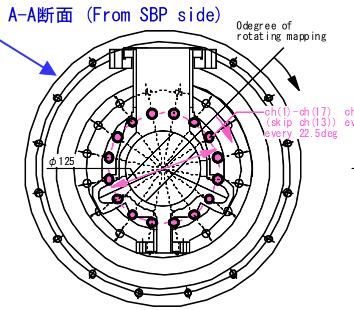
Ring 16 PIN diodes were set on both jacket sides
to compare the radiation profile with rotating mapping

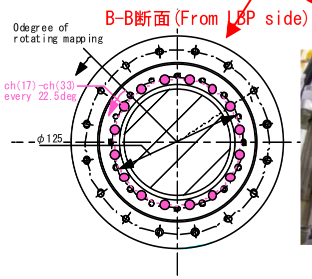
How to know the profile and radiation source on cryomodule test ?

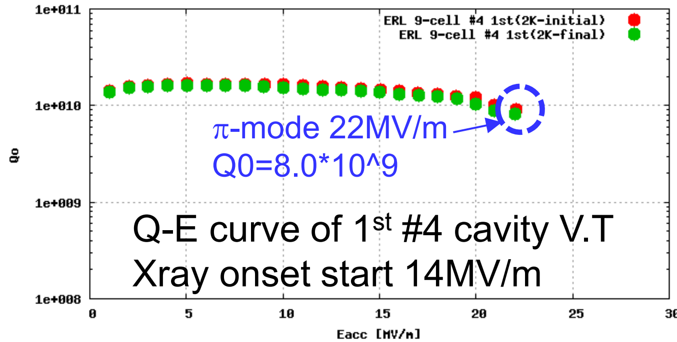
Field emission (F.E) electron run along cavity axis. We think angular distribution of F.E preserved and detected outside of jacket near both end.

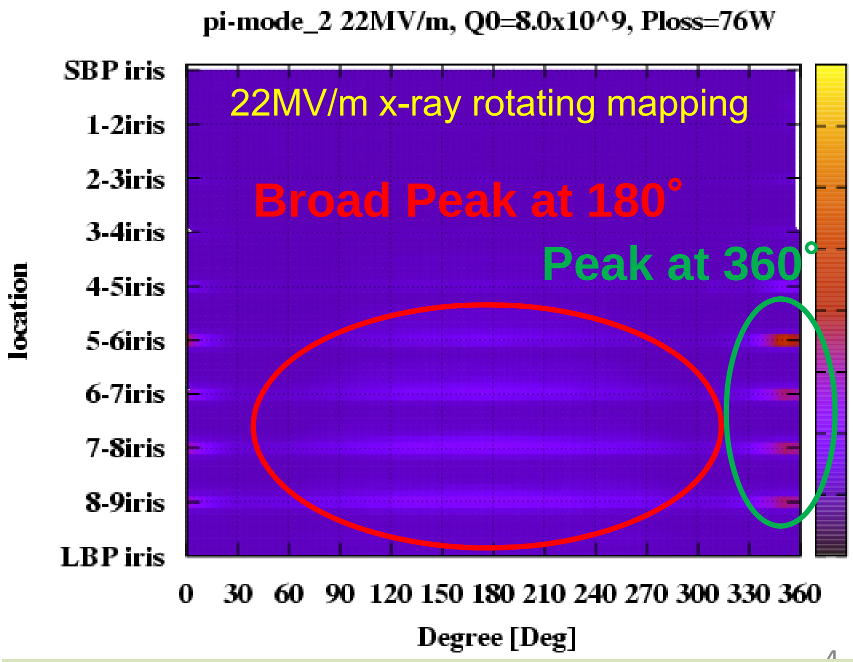


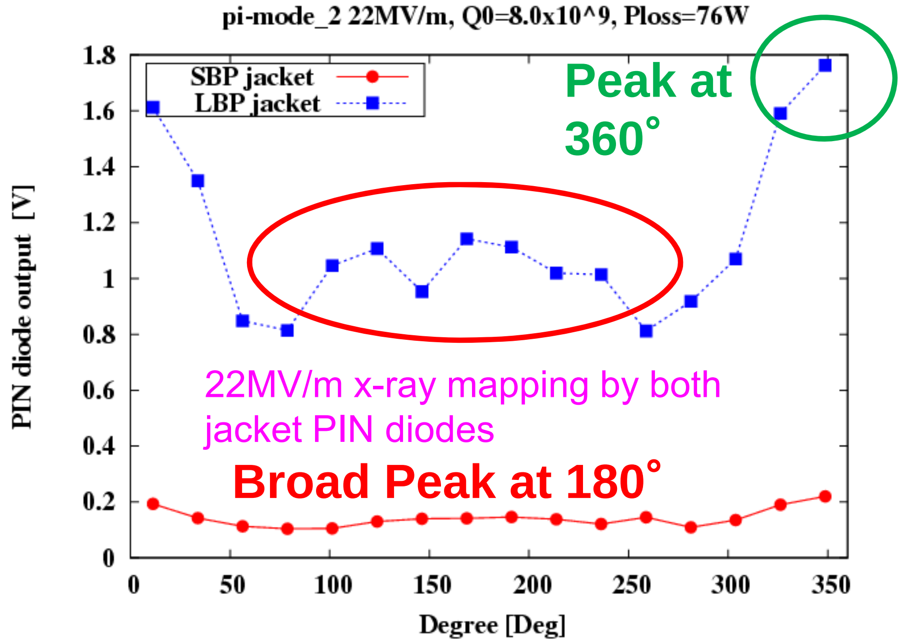










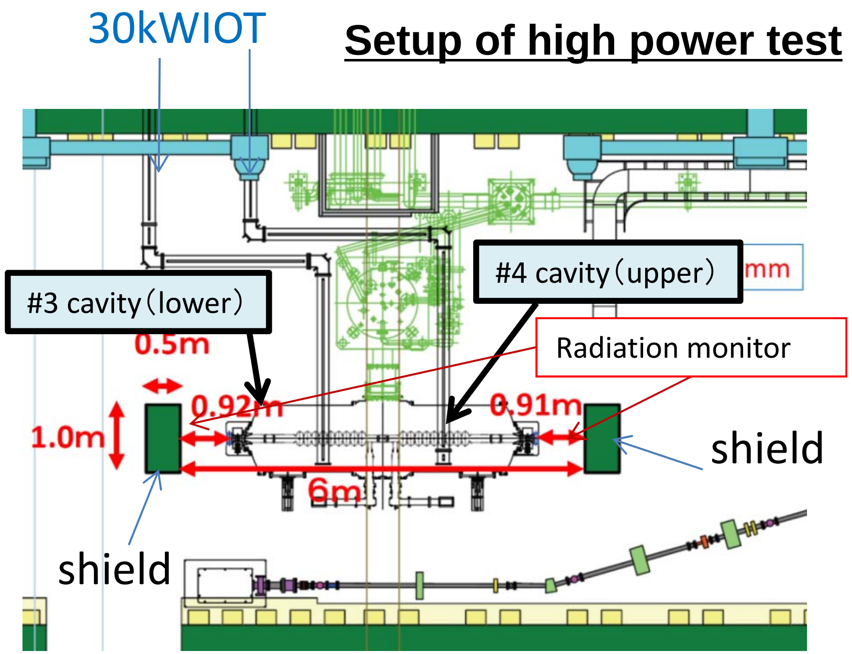


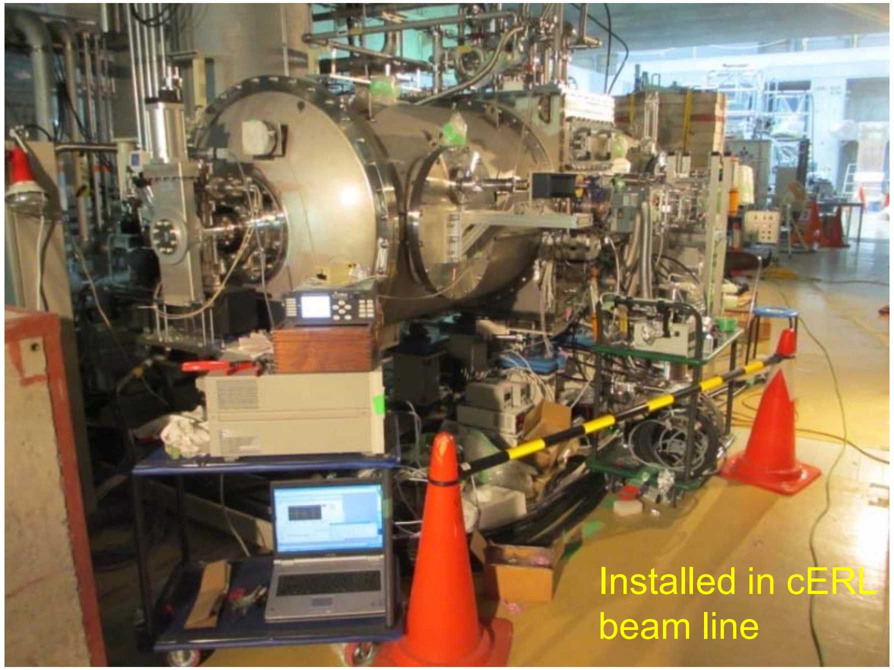
Radiation profile were detected from both direction by a ring of 16 PIN diodes and agree well with x-ray angular distribution of rotating mapping.

16 PIN can detect radiation profile during cryomodule test.

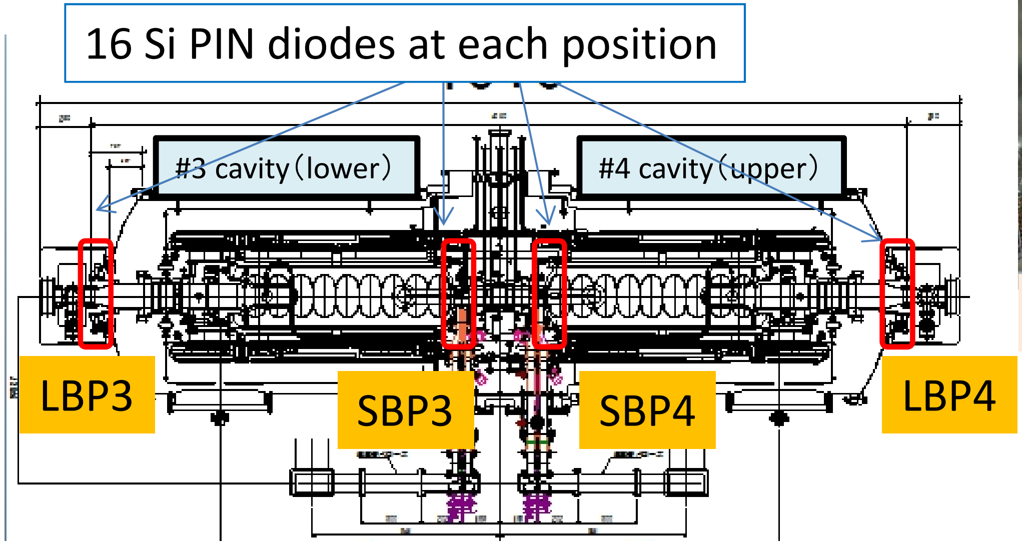
Setup of high power test at cERL-ML cryomodule

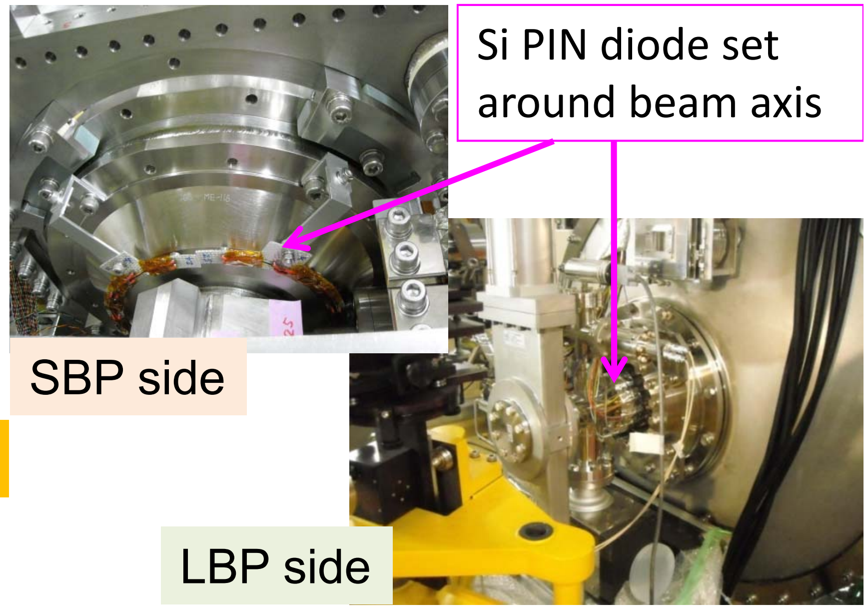
Setup of high power test





PIN radiation profile monitor set around beam axis



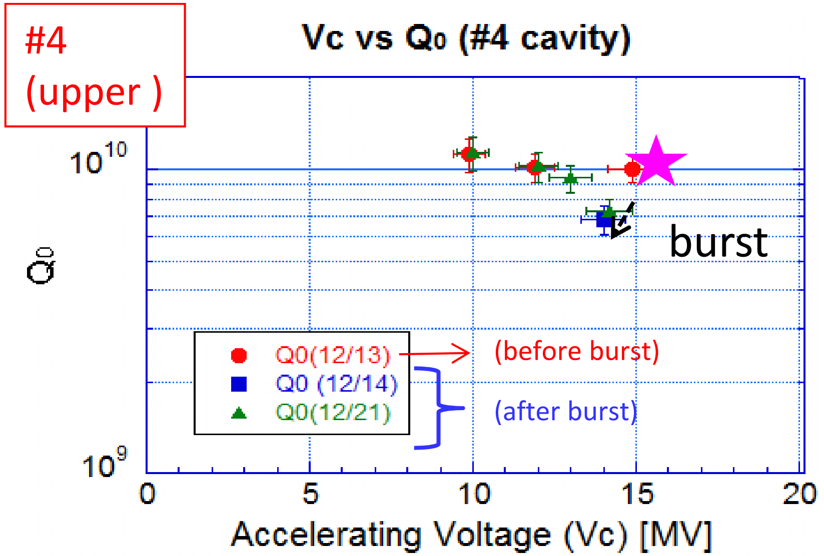


Upper QL : 1.54*10^7
Lower QL : 1.15*10^7

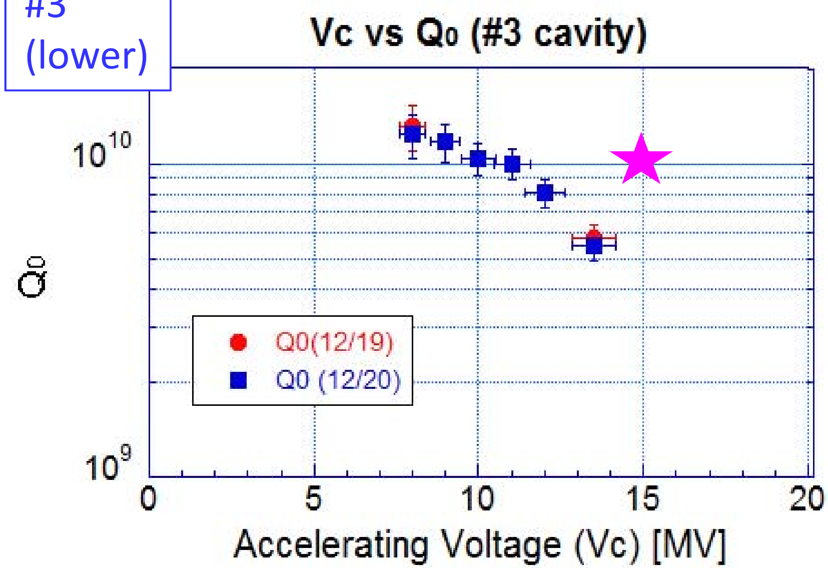
Max input power (Pin) is 5kW during high power test

Results of high power test (Vc vs Q0)

#4 (upper)



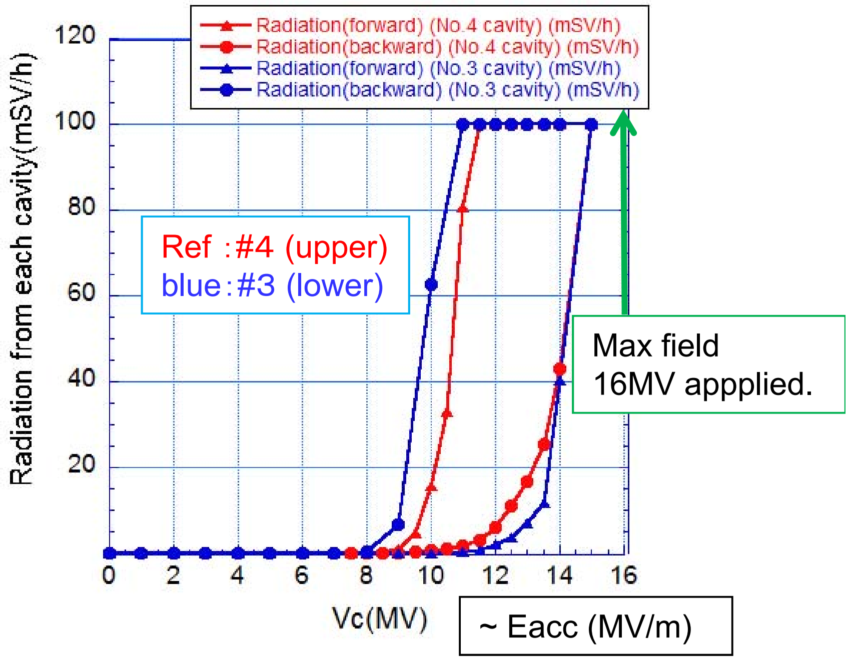
#3 (lower)



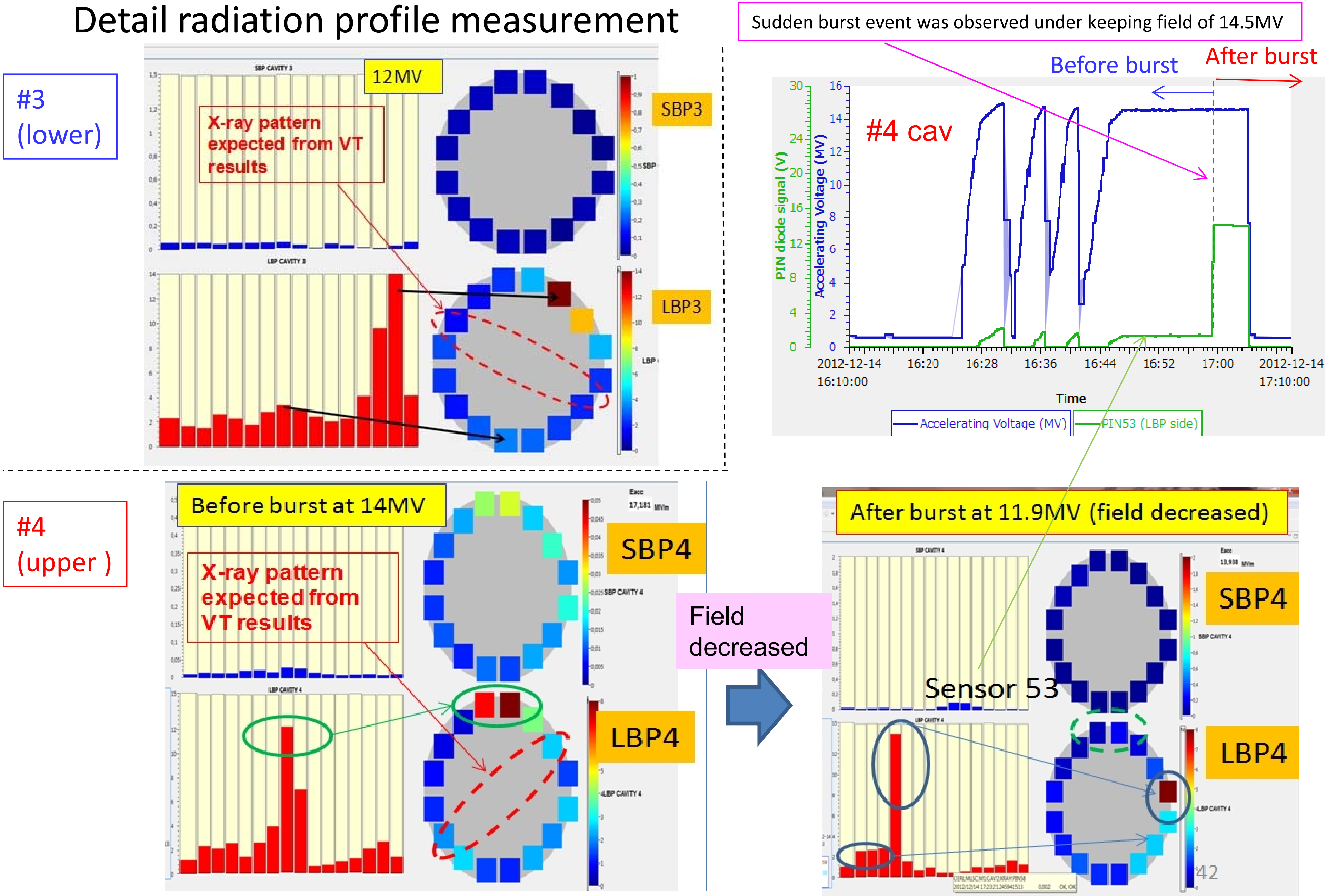
★ : Requirement of cERL

- •High power test was done one by one cavity.
- • Input coupler was processed up to 25kW before high power test.
- • Both cavities reached to Vc = 16MV.
- • Q0 of #4 cavity decreased during processing.
- •Field emission on-set was 8-9 MV for both cavities.

Measured radiation of each cavities at final state



Detail radiation profile measurement



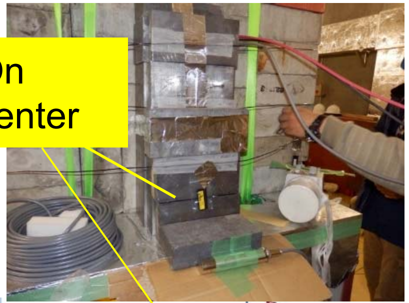
- Radiation pattern was changed from V.T
- Radiation pattern also changed after X-ray burst

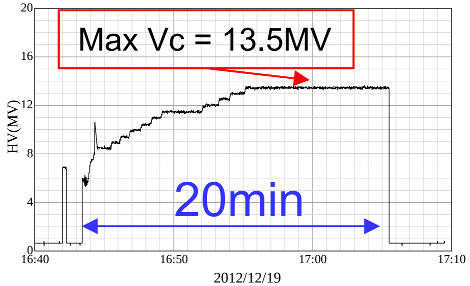
- Another new radiation sources were produced during assembly work and high power test.

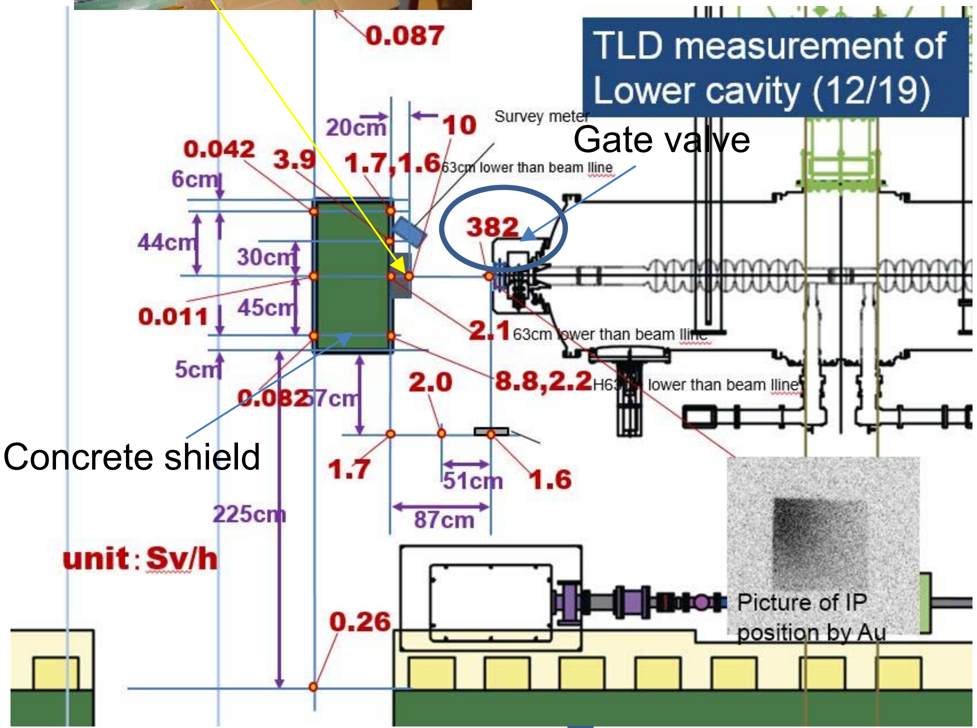
Dose measurement and simulation by MRAS15

Measured dose by TLD on about 20 positions under 13.5MV keeping

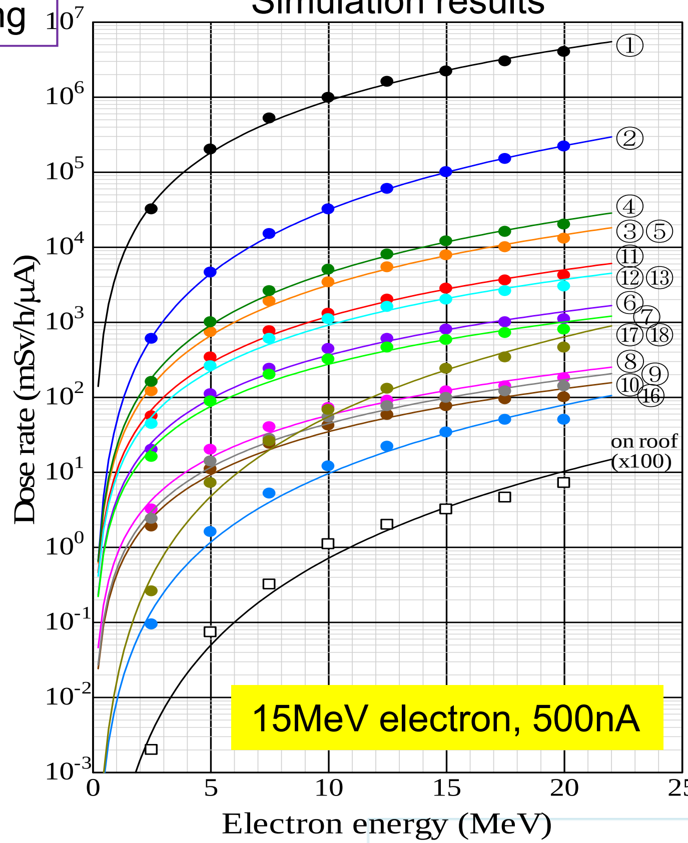
Coatesy by H.Matsumura

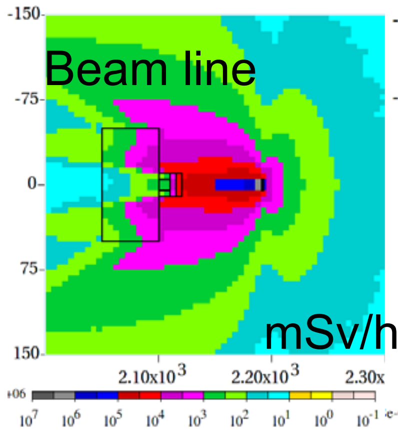


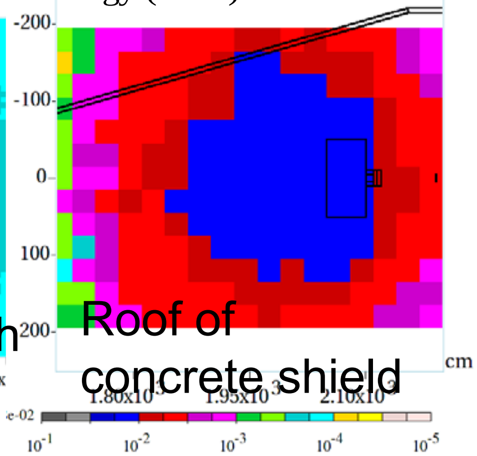




Simulation results







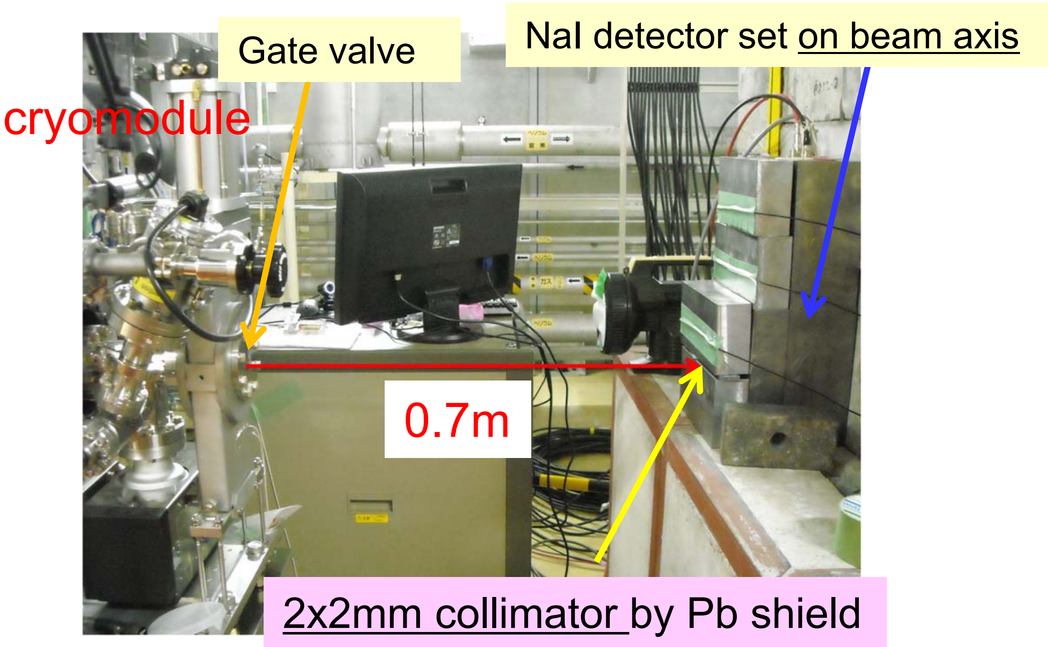
Distributoin are almost consistent with simulation and estimated field emission current by measurement &simulation

= 0.4- 8uA of each position (→ average 3uA)

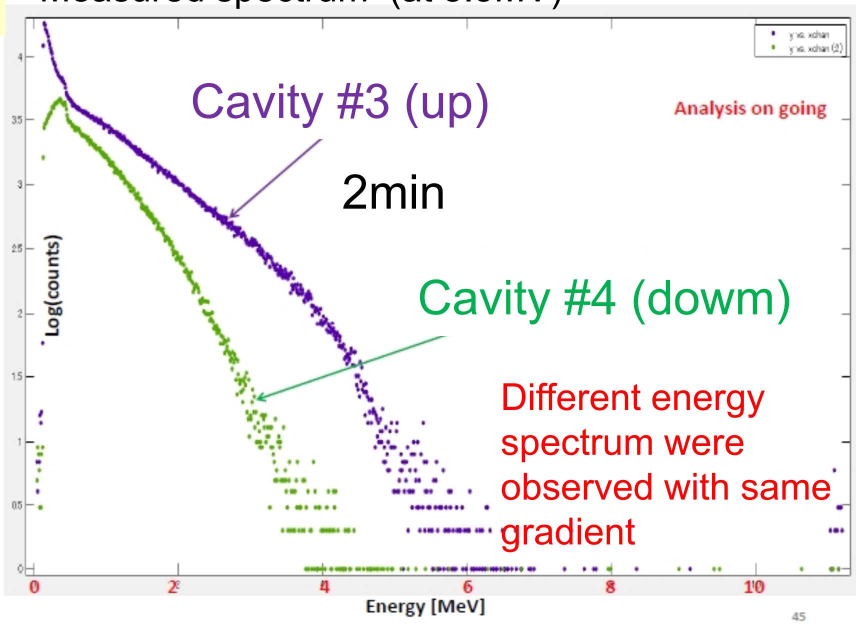
Position of radiation monitor was much sensitive for field emission measurements.

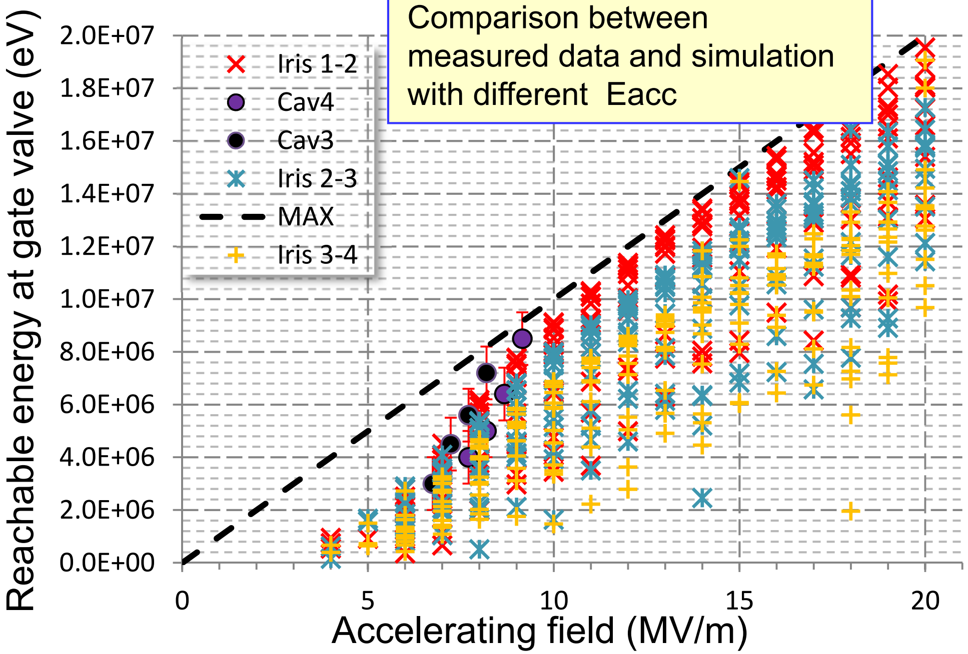
Survey location of field emission source by NaI

Enrico Cenni et al., TUP091 in SRF2013



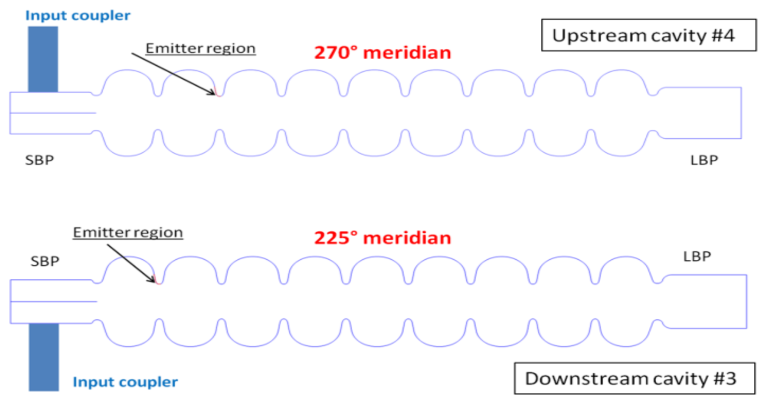
Measured spectrum (at 8.5MV)





Measured error is assumed end point of bremsstrulung effect

Estimated source position

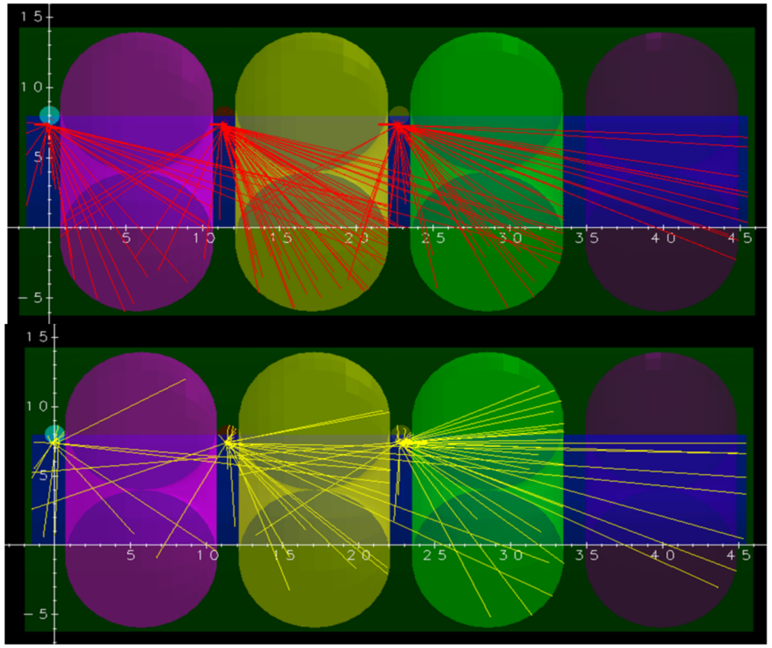


Position near SBP and input port is estimated as a radiation source. String assembly work was poor near SBP side ?? Coupler also caused the burst ??

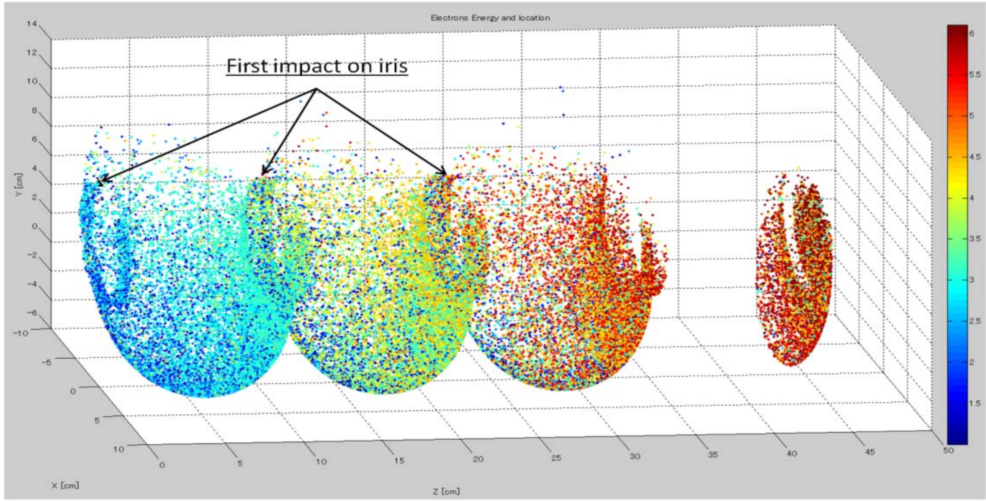
Backup

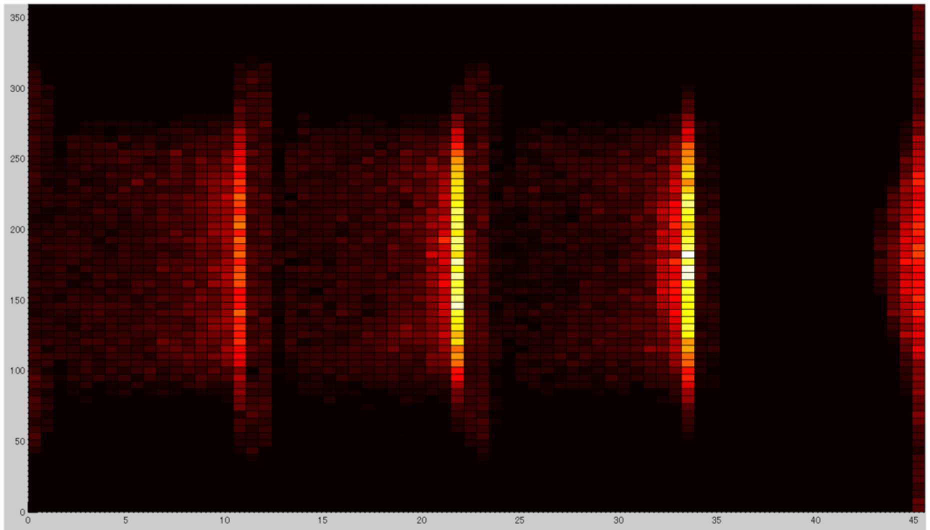
Radiation calculation (EGS5)

electron



photon





Compact ERL(cERL) at KEK

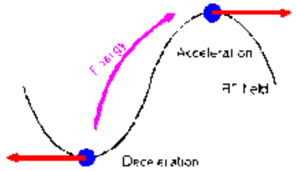
Current : 10-100mA
Emittance : 0.1-1 mm mrad
Bunch length :0.1-3ps

cERL parameters Red: initial case

Requirements of cERL main linac

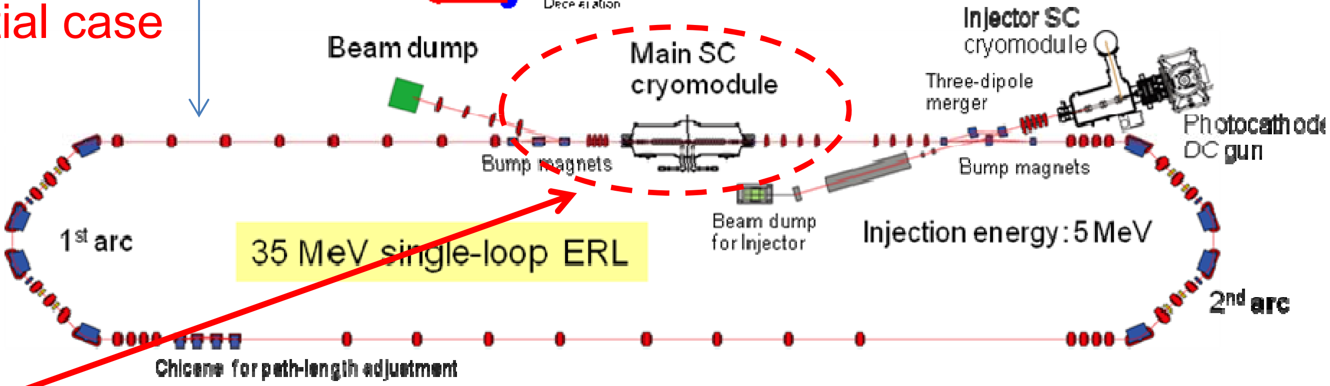
Frequency : 1.3 GHz
Gradient: 15MV/m
Q0: >1*10^10
Beam current : max 100mA
(100mA (in)+ 100mA(out))

Apparatus of cERL



$$P_{loss} = \frac{V_c^2}{(R/Q)Q_0}$$

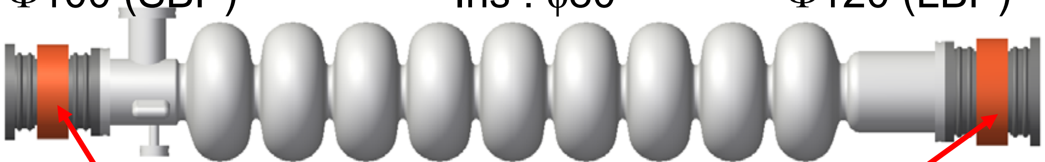
Ploss = 25W/m (15MV/m)

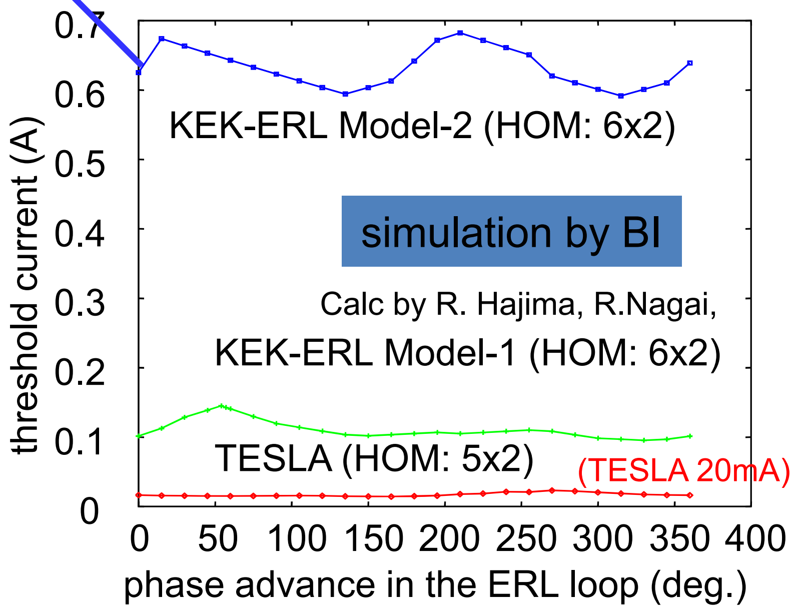


ERL-model-2 cavity : 600mA can be circulated in design

HOM-BBU calculation (w/o HOM randamization)

H.Sakai et al., Proc. of ERL07 (2007). All HOMs damped to both end





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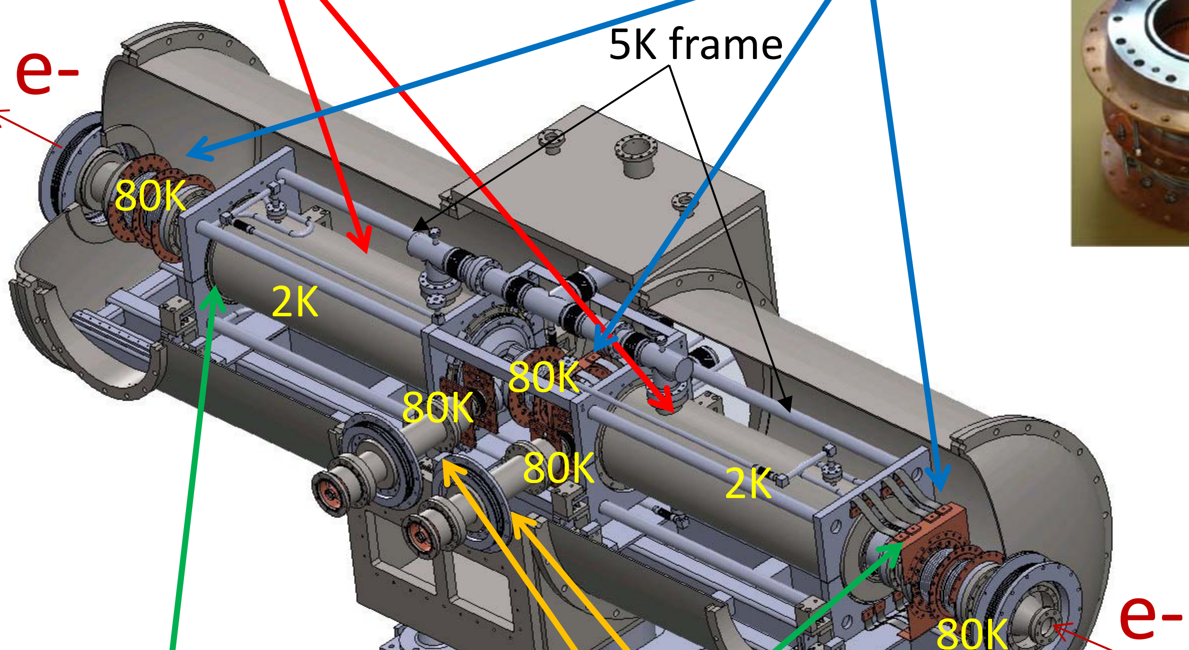
():TESLA cavity

Frequency	1300 MHz	Eacc	15-20MV/m
Q0	1e+10	Coupling	3.8 % (1.9%)
R_{sh}/Q	897 Ω (1007Ω)	$Q_o \times R_s$	289 Ω
E_p/E_{acc}	3.0 (2.0)	H_p/E_{acc}	42.5 Oe/(MV/m)

Compact ERL main linac cryomodule configuration

9cell superconducting cavity
Q0 > 1*10^10 @15MV/m

HOM absorber
- HIP ferrite on Copper beampipe
- Operation at 80K. (expected 150W HOM power)
- Check enough absorption ability of ferrite at 80K



(Compact) ERL target

Frequency : 1.3 GHz
Input power : 20kW CW (SW)
Gradient: 15MV/m
Q0: >1*10^10
Beam current : max 100mA
(against HOM-BBU instability)

2-cavity cryomodule was developed for compact ERL main linac to demonstrate the high current ERL operation at cERL. We have done the high power test by using this cryomodule.

Frequency Tuner
Slide jack tuner (mechanical)
piezo tuner(fine tuning)

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

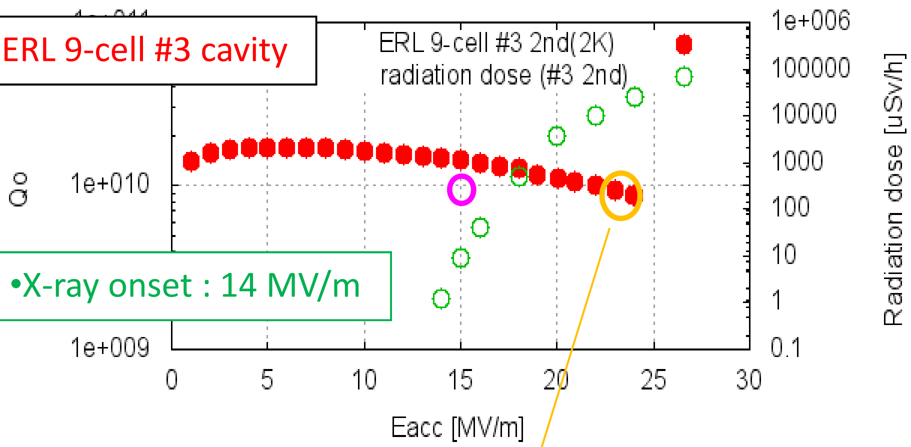
Results of vertical test of cERL Main linac two cavities

Carried out V.T of 2 ERL-model-2 cavities for cERL in 2011.
Achieve 25MV/m (administrative limit) :
Satisfy cERL requirement : Q0>1*10^10@15MV/m

K.Umemori et al., Proc. of IPAC12, p2227

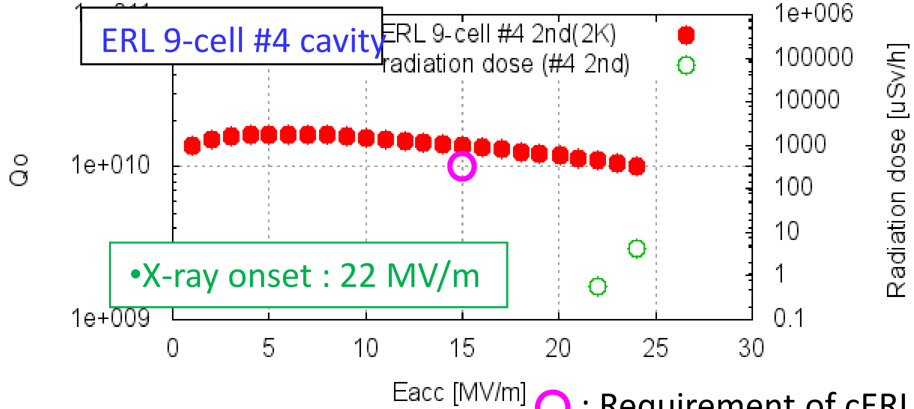
For module assembly

ERL 9-cell #3 cavity



•X-ray onset : 14 MV/m

ERL 9-cell #4 cavity



•X-ray onset : 22 MV/m

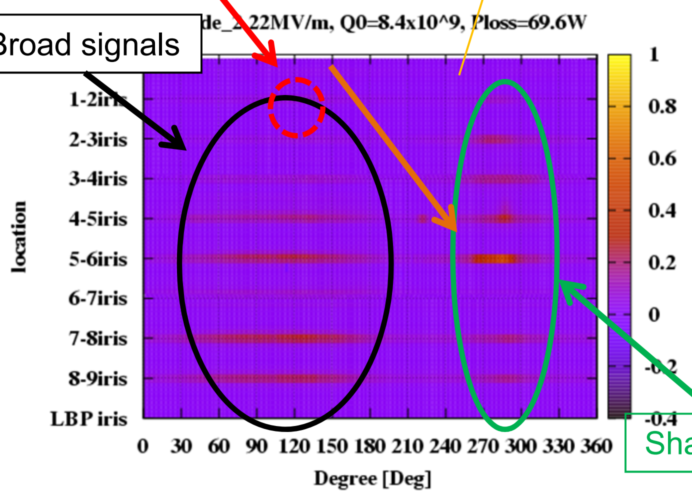
○ : Requirement of cERL

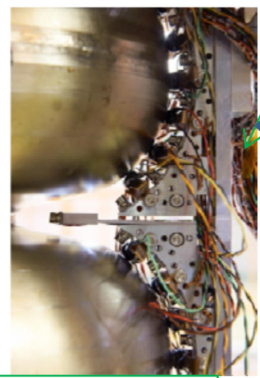
Field emission profile by rotating X-ray mapping

Candidate of source

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

Broad signals





Sharp traces on cell

PIN diode

H.Sakai et al., Proc. of IPAC 2010 ,p2950

Simulation (with Fowler Nordheim eq.)

Field emission Profile on Nb surface simulated with including EGS5 (radiation with materical interaction)

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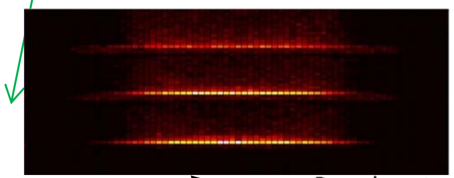

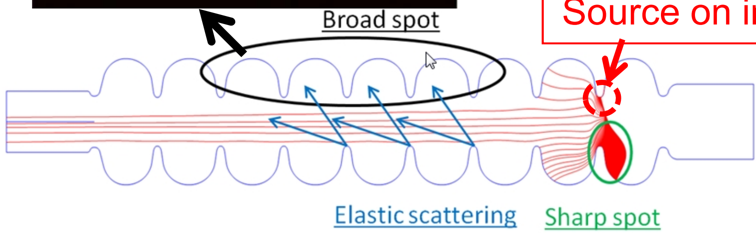

Source on iris

Measured profile were clearly explained by simulation .
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