BBU Simulation using HOM Randomization for Application of TESLA-like Cavity to KEK-ERL

Outline

- Motivation
- Cavity Comparison
- BBU Simulation code
- HOM Randomization
- Result
- Summary

This work was completed by Hajima-san's cooperation.

Motivation

Application of STF Baseline (TESLA-like) Cavity to KEK-ERL
as ILC-ERL Collaboration in KEK

Merit

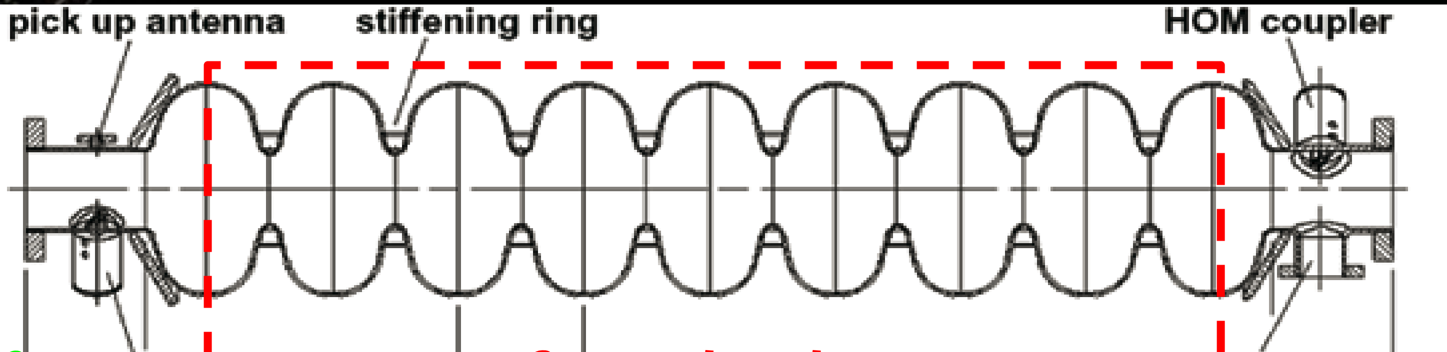
- Cost saving
- Manpower limitation

Demerit

- Lower beam current
- HOM coupler heating for CW
- Unexpected matter

3 Types of Cavities for ILC, FEL & ERL

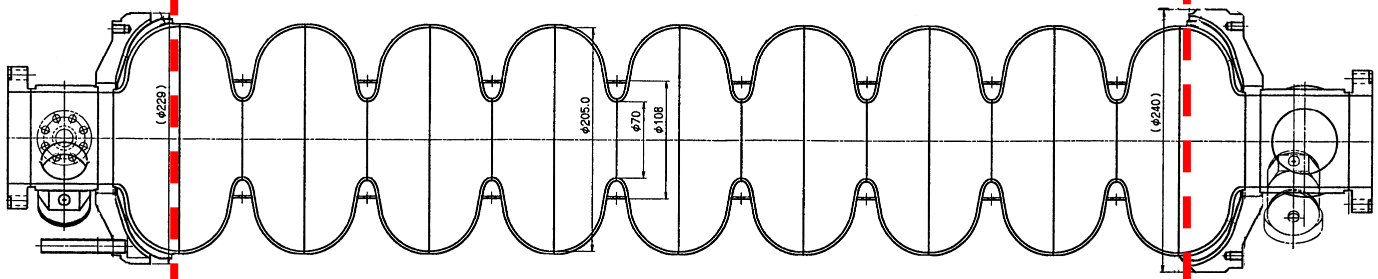
TESLA



Two HOM couplers

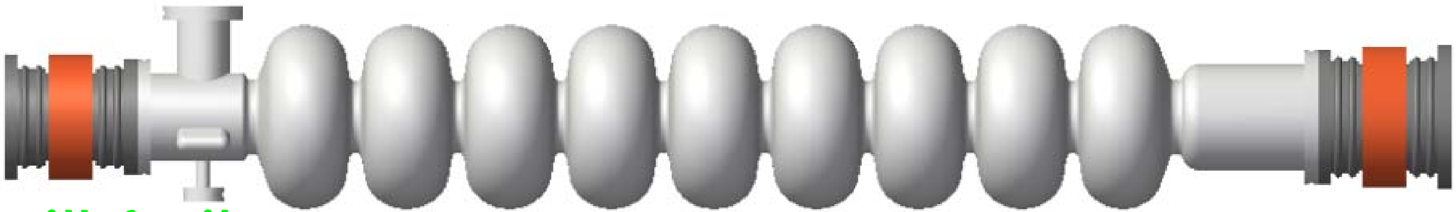
Same structure

TESLA-like



Stiffer structure
for reduction of effect of LFD

KEK-ERL (ML)



Two HOM dampers with ferrite
Larger beam pipe with groove

Much better HOM damping than above two cavities

BBU simulation codes

- ## BBU simulation codes in the world

Nuclear Instruments and Methods in Physics Research A 557 (2006) 176-188

- BBU-R (JAERI)
- TDBBU (J-lab)
- New Code (J-Lab)
- bi (Cornell Univ.)
  - Used for this work
- MATBBU (J-Lab)

	BBU-R	TDBBU	New Code	bi	MATBBU
Developer	JAERI	J-Lab	J-Lab	Cornell	J-Lab
Solve	Tracking	Tracking	Tracking	Tracking	Eigenvalue
Dimension	1D	2D	1D/2D	2D	1D
Programming language	C	Fortran/C	C++	C++	Fortran/C

bi (Beam Instability Code)

- Developed by Dr. Ivan Bazarov at Cornell Univ.
- http://www.lepp.cornell.edu/~ib38/bbu/
- How to use
  - Parameter file
    - beam energy, beam current…
  - Lattice file (Optics)
    - 6x6 transfer matrix
  - HOM data file (changed at this work)
    - R/Q, Q, f, polarization (0° or 90°)

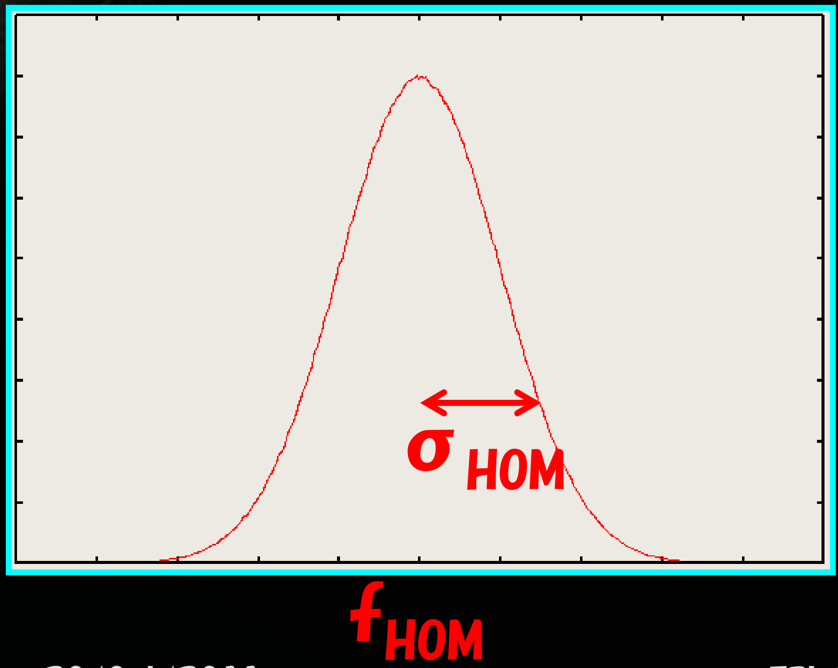
⇒ After fixing these parameters, we can run "bi".
And, we can find out the beam threshold current (b_{th}) for BBU.

For KEK-ERL cavity, Hajima-san at JAEA already calculated BBU threshold current.

What's HOM Randomization?

It is possible to increase the beam threshold current by applying HOM randomization.

Each HOM (f_{HOM}) is distributed by Gaussian (assumption).
The error (σ_{HOM}) may be caused by fabrication process.



In BBU calculation,
HOM frequency is changed slightly following Gaussian with σ_{HOM}.

The statistics of iteration is 10 for Gaussian with each σ_{HOM}.

Changing HOM parameters from KEK-ERL to TESLA-like

courtesy of Umemori-san

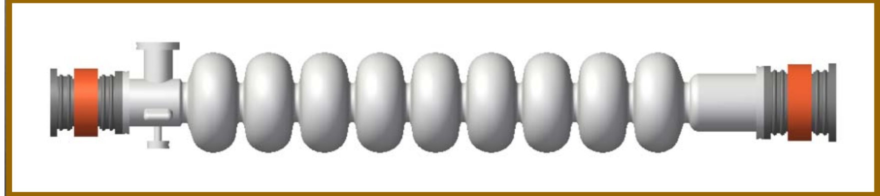
f_{HOM} [GHz]	R/Q [Ω]	Q
4.011	4.542	1.141×10^4
1.856	48.32	1.698×10^3
2.428	26.26	1.689×10^3
4.330	0.02186	6.068×10^5
3.002	0.8210	2.999×10^4
1.835	54.68	1.101×10^3

TE-iris mode

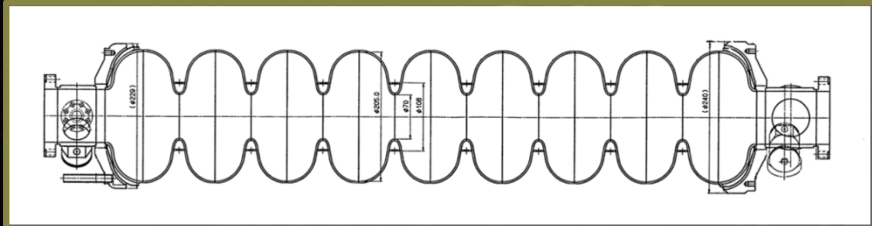
courtesy of Kako-san & Watanabe-san

f_{HOM} [GHz]	R/Q [Ω]	Q
1.719	42.00	4.370×10^3
1.878	25.40	1.050×10^5
1.604	0.448	3.840×10^5
1.688	10.98	1.450×10^4
1.887	7.880	2.150×10^5
1.895	0.400	4.720×10^5

w/ TE-iris mode for TESLA cavity



Two HOM dampers with ferrite
Larger beam pipe with groove

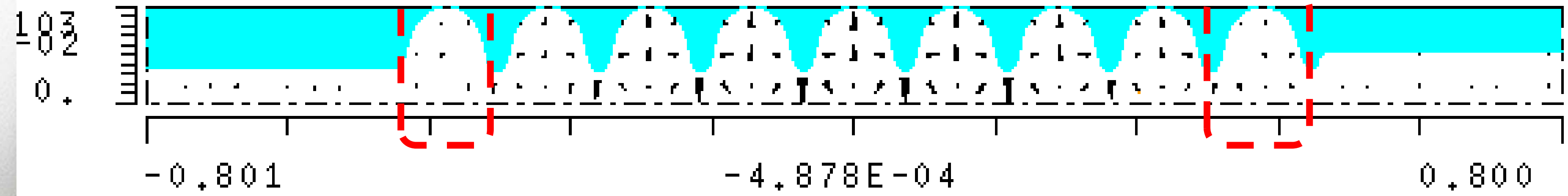


Two HOM couplers

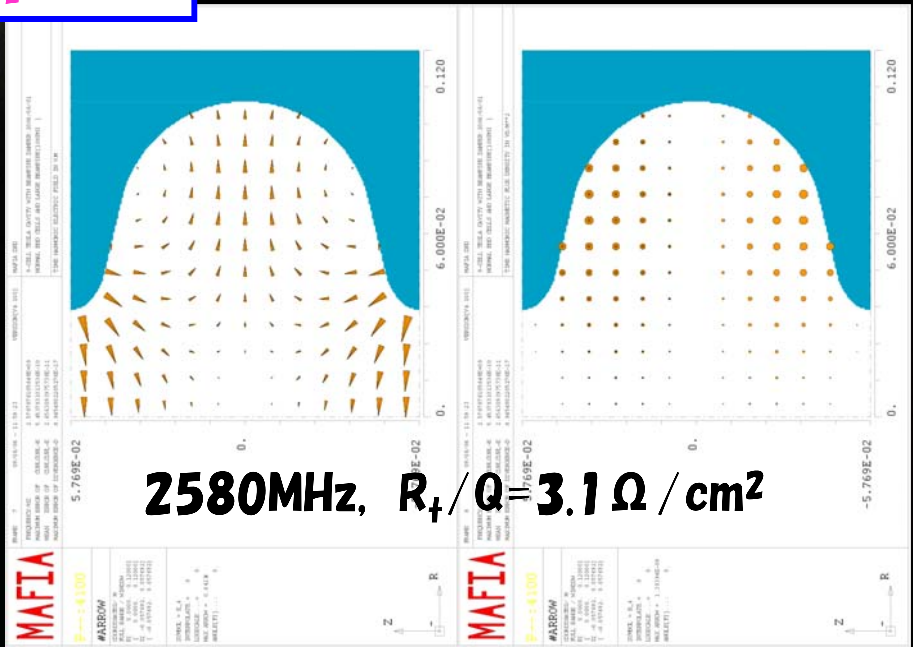
TE-iris mode (most dangerous mode)

9-cell

Cell shape of TESLA



1-cell



2580MHz, $R_t/Q=3.1\,\Omega/cm^2$

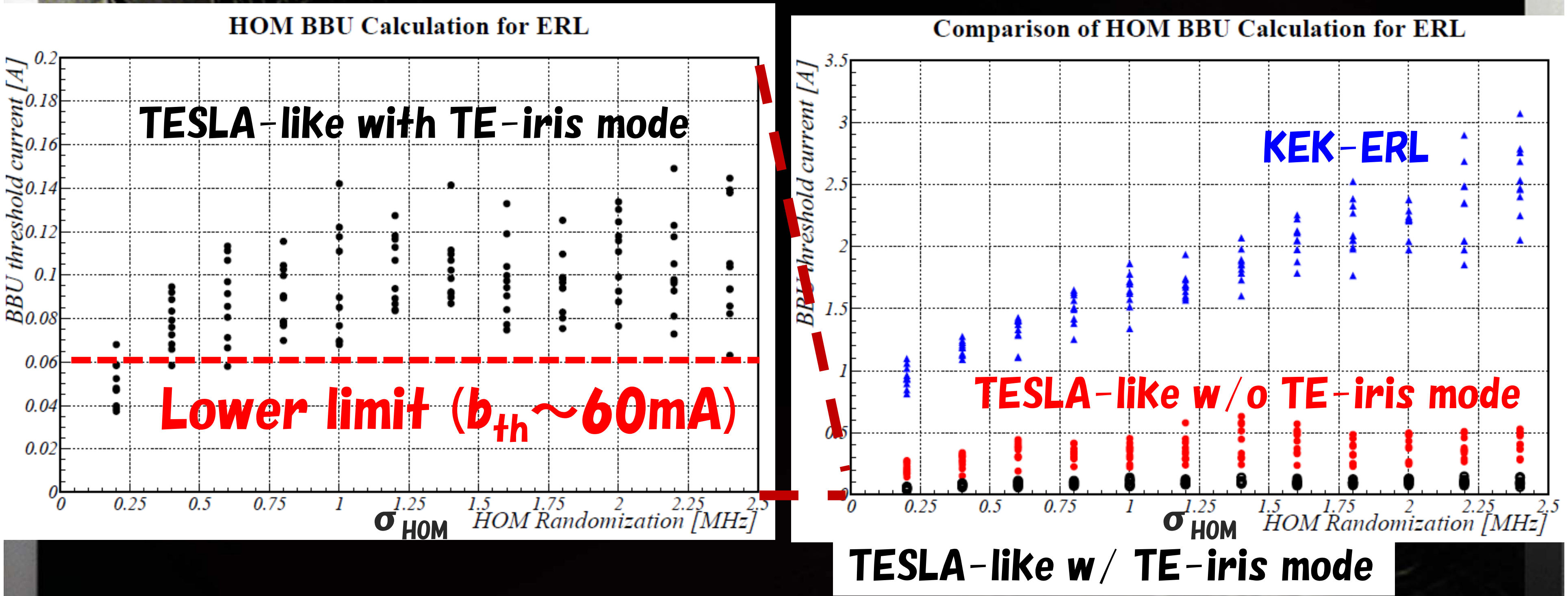
This mode is not calculated for TESLA-like cavity.

But, this is more problematic for TESLA-like cavity than TESLA, because of symmetric shape of end cells.

courtesy of Umemori-san

Result ①

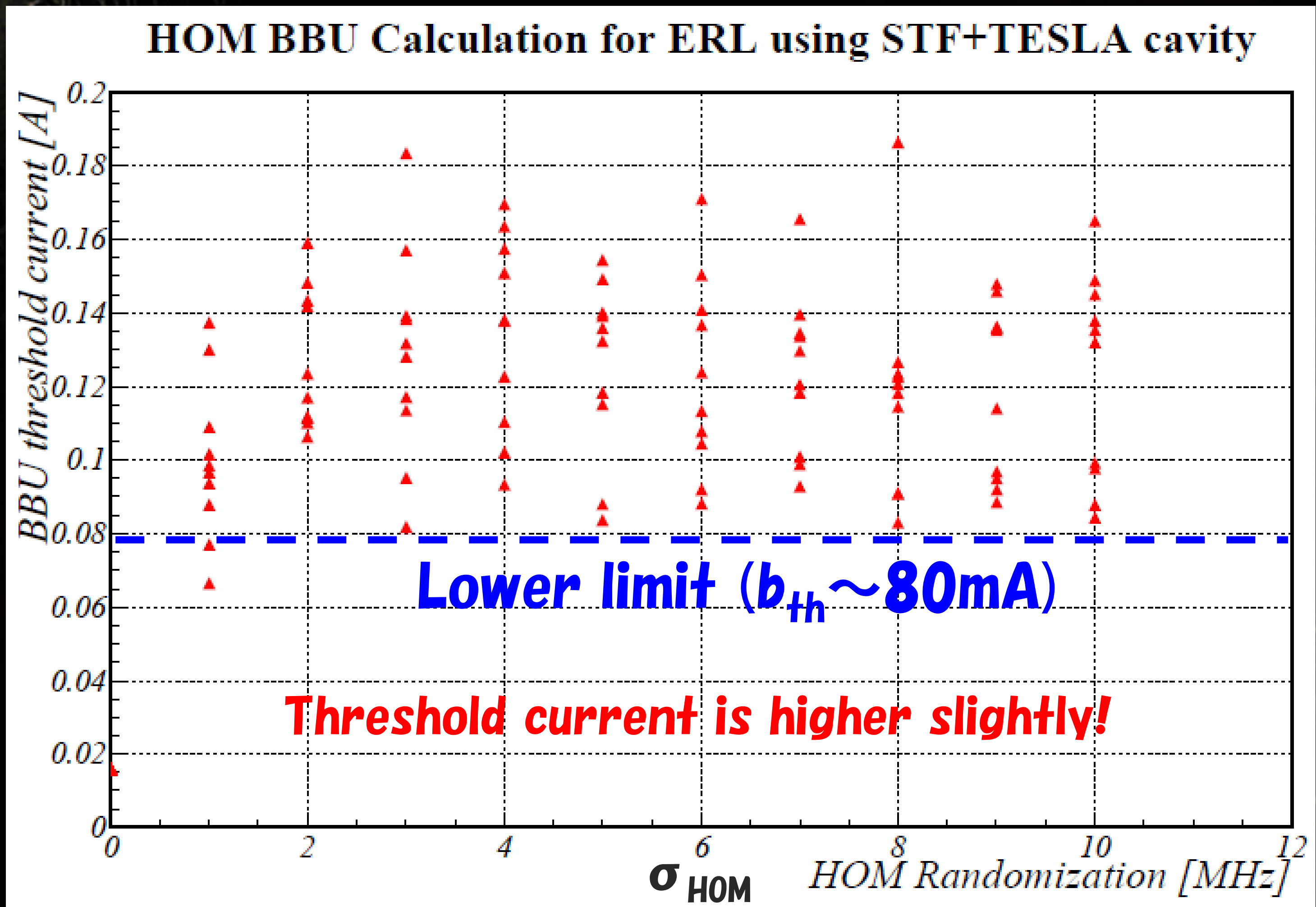
At each Gaussian of σ_{HOM}, the calculation was iterated 10 times.



If there is no TE-iris mode for TESLA-like cavity,
BBU threshold current would achieve above 200mA!

Result ②

BBU calculation was also done for wider range of σ_{HOM}.



Simple Evaluation Method

It is possible to evaluate simply the effect of BBU for each HOM by calculating $(R_t/Q)*Q_{ext}/f_{HOM}$.

$$(R_t/Q\ [\Omega/m^2] = (R/Q)*k^2)$$

This method was introduced by Dr. M. Liepe at Cornell Univ.

TESLA-like

f_{HOM} [GHz]	R/Q [Ω]	Q_{ext}	R_t/Q [Ω/m^2]	$(R_t/Q)*Q_{ext}/f_{HOM}$ [$\Omega/m^2/Hz$]
1.719	42.00	4.370×10^3	5.457×10^4	0.139
1.878	25.40	1.050×10^5	3.938×10^4	2.202
1.604	0.448	3.840×10^5	5.068×10^2	0.121
1.688	10.98	1.450×10^4	1.376×10^4	0.118
1.887	7.880	2.150×10^5	1.233×10^4	1.405
1.895	0.400	4.720×10^5	6.316×10^2	0.157

This value for TE-iris mode would be larger than TESLA!

Simple Evaluation Method

KEK-ERL

f_{HOM} [GHz]	R/Q [Ω]	Q_{ext}	R_t/Q [Ω/m²]	$(R_t/Q)*Q_{ext}/f_{HOM}$ [Ω/m²/Hz]
4.011	4.542	1.141×10^4	3.210×10^4	0.0913
1.856	48.32	1.698×10^3	7.311×10^4	0.0669
2.428	26.26	1.689×10^3	6.800×10^4	0.0473
4.330	0.02186	6.068×10^5	1.800×10^2	0.0252
3.002	0.8210	2.999×10^4	3.250×10^3	0.0325
1.835	54.68	1.101×10^3	8.087×10^4	0.0485

very small!

TESLA

TE-iris mode

f_{HOM} [GHz]	R/Q [Ω]	Q_{ext}	R_t/Q [Ω/m²]	$(R_t/Q)*Q_{ext}/f_{HOM}$ [Ω/m²/Hz]
2.575	81.72	5.000×10^4	2.380×10^5	**4.621**
1.875	56.99	5.110×10^4	8.800×10^4	2.398
1.865	42.54	5.060×10^4	6.500×10^4	1.764
1.881	11.58	9.510×10^4	1.800×10^4	0.910
1.887	1.28	6.330×10^5	2.000×10^3	0.671

Summary

- In this work, BBU threshold current for TESLA-like cavity was evaluated in KEK-ERL using "bi".
- Using HOM randomization, the beam current of 60mA below 2.5MHz of σ_{HOM} was achieved. And, it was 80mA below 10MHz.
- TE-iris mode is the most dangerous for BBU.

Thank you very much for your attention.

And, special thanks to Hajima-san, Kako-san, Umemori-san and Watanabe-san.