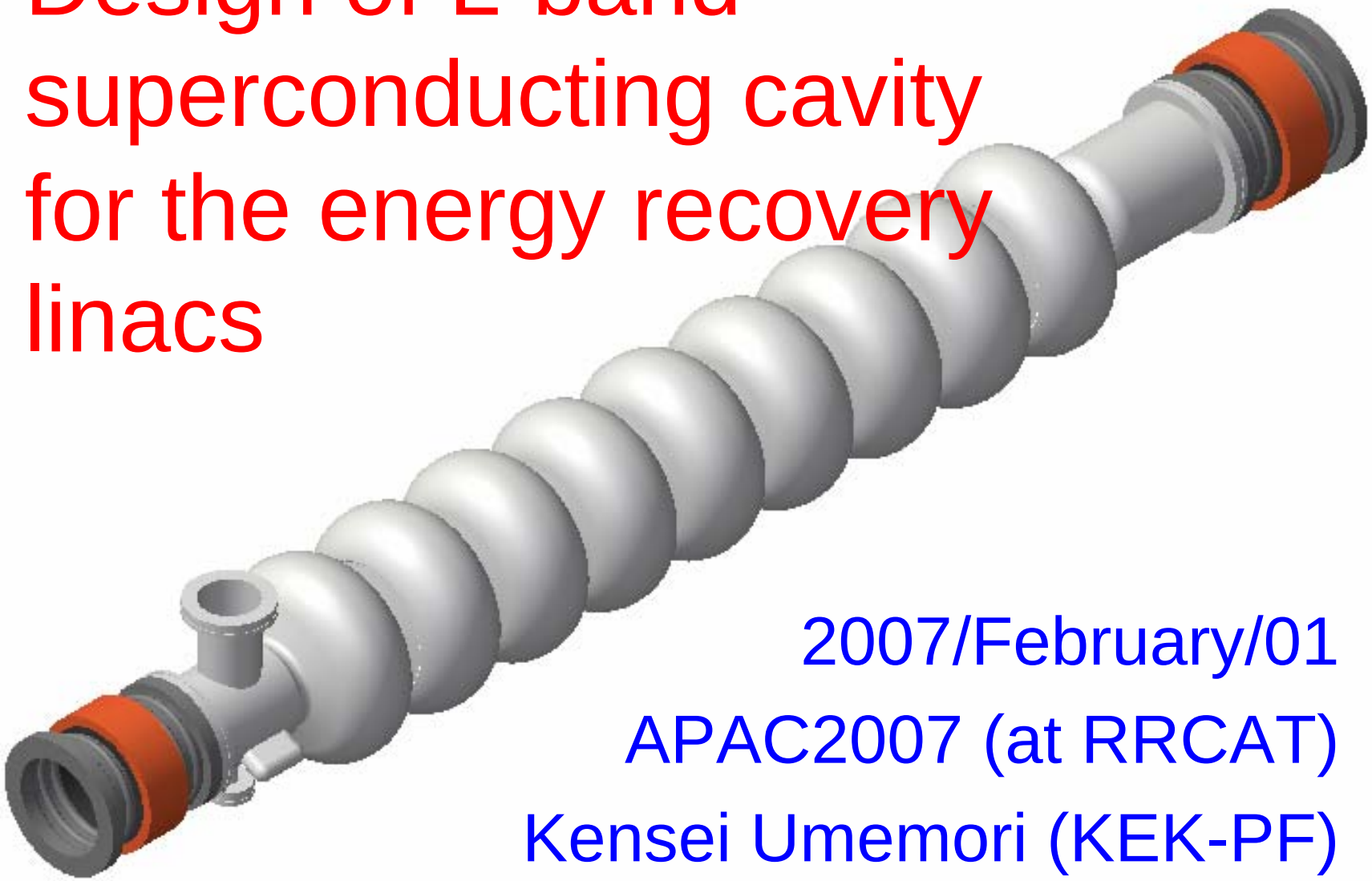
Design of L-band superconducting cavity for the energy recovery linacs



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Introduction

- KEK, JAEA, Univ. of Tokyo and other Japanese institutes started ERL project to construct 100-200MeV ERL test facility. [T. Kasuga et al, TUPMA046]
- Development of the 1.3 GHz superconducting cavity, which is a key component of ERLs, has been started.
- Requirement for cavity (for main linac)
  - Frequency 1.3GHz
  - Eacc 15~20MV/m
  - Beam current 100mA CW → Strong HOM damping
- ERL-SC group (for main linac)
  - KEK: T.Furuya, T.Suwada, S.Sakanaka, T.Takahashi, K.Umemori
  - JAEA: M.Sawamura
  - Univ. of Tokyo: H.Sakai, K.Shinoe

HOM requirement

[M.Liepe, Proc. of the 11th workshop on Superconductivity (SRF2003)]

- Monopole mode (Heat load)
  - 100W heat load at resonant condition

$$\left(\frac{R}{Q}\right)Q < 2500\,[\Omega]$$

  - HOM frequencies should be apart from multiples of 2.6 GHz(=1.3GHzx2)

- Dipole mode (Beam-breakup(BBU) instabilities)
  - HOM requirement for 100mA beam current

$$\left(\frac{R}{Q}\right)\frac{Q}{f} < 1.4\times 10^{5}\left[\frac{\Omega}{cm^{2}GHz}\right]$$

- Quadrupole mode (Quadrupole BBU instabilities)
  - HOM requirement for 100mA beam current

$$\left(\frac{R}{Q}\right)\frac{Q}{f} < 4\times 10^{6}\left[\frac{\Omega}{cm^{4}GHz}\right]$$

Strategy of cavity design for ERL

HOW about the TESLA cavity …

- HOM damping is not enough for ERL operations
- Loop-type HOM coupler has heating problem for the CW operation

TESLA cavity is not adequate for ERL operations

Need L-band superconducting cavity optimized for ERL

Policy of KEK-ERL cavity design

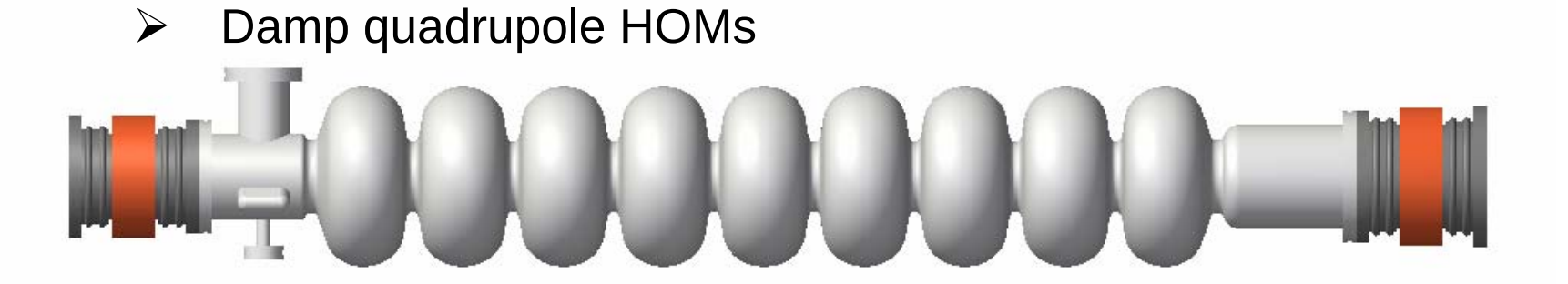
- Suppress dipole modes as strong as possible
- No monopole modes around multiples of 2.6 GHz
- Damp quadrupole modes
- Keep Rsh of accelerating mode as high as possible

KEK-ERL model-2 cavity

1) Cavity cell shape
   - Iris diameter 80mm, elliptical shape at equator
   - Cavity diameter 206.6mm

2) Large beampipe with microwave absorbers
   - Beampipe diameter 120mm & 100mm

3) Eccentric fluted beampipe
   - Damp quadrupole HOMs



Parameters for accelerating mode

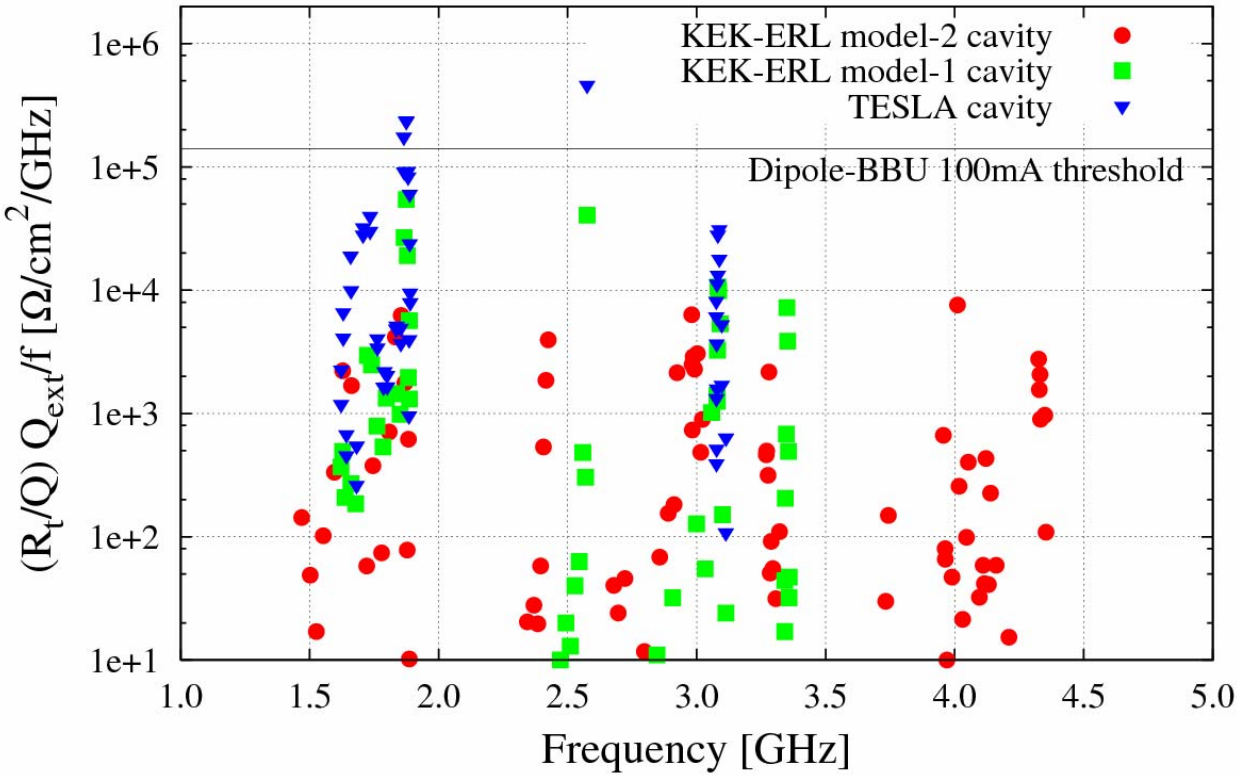
Frequency	1300 MHz	Coupling	3.8 %
Rsh/Q	897 Ω	Qo x Rs	289 Ω
Ep/Eacc	3.0	Hp/Eacc	42.5 Oe/(MV/m)

KEK-ERL model-2 cavity	New 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

Dipole mode

KEK-ERL cavity
Impedances are calculated by MAFIA

TESLA cavity
Impedances are from TESLA and TTF design report



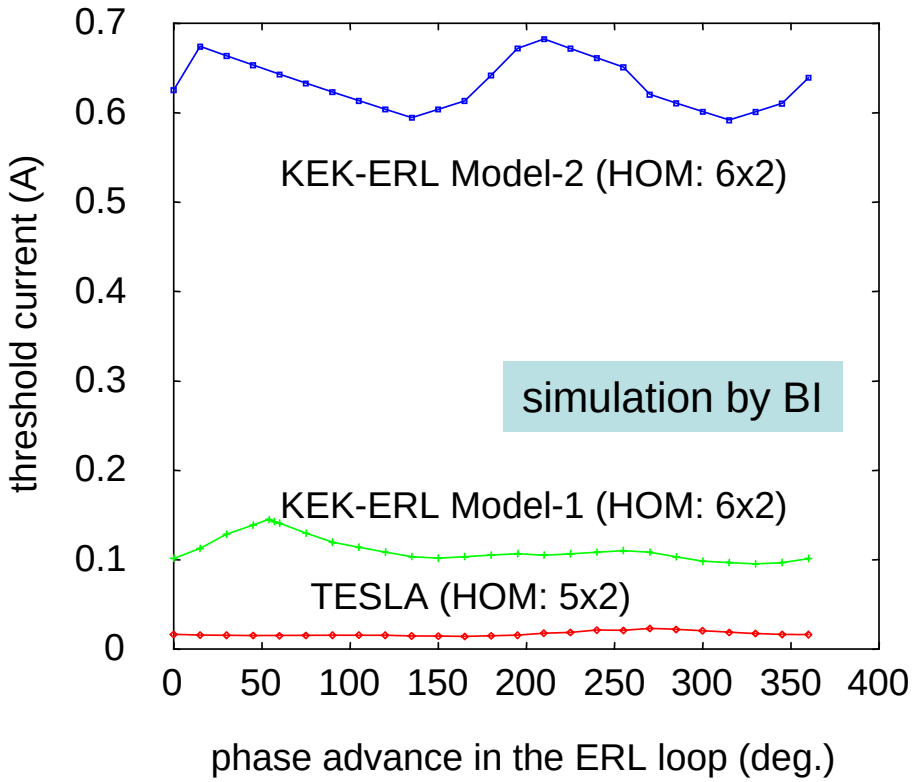
- New cavity cell shape and large beampipe damper is effective for HOM damping
- HOM impedances are one order smaller than BBU 100 mA threshold for KEK-ERL model-2 cavity

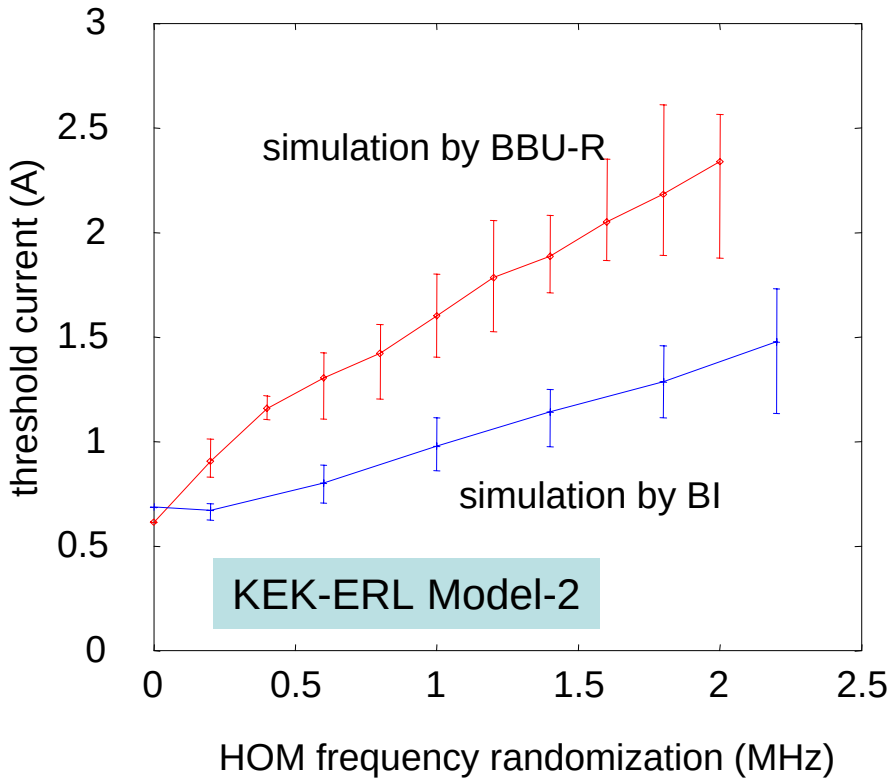
HOM-BBU threshold current

(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

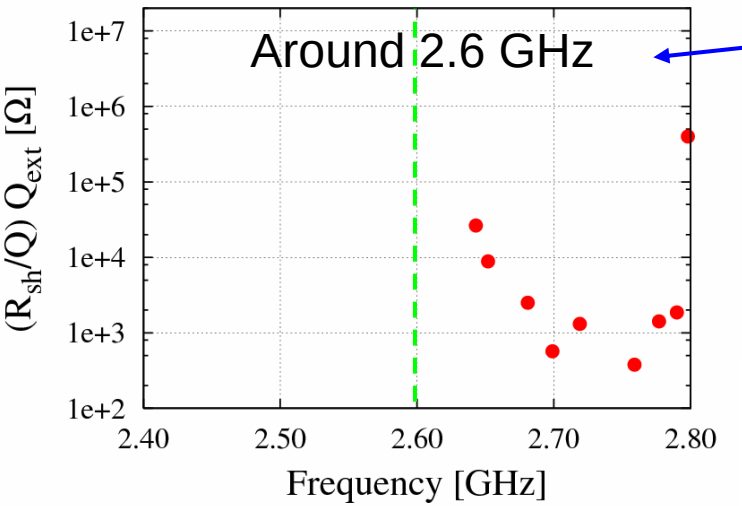


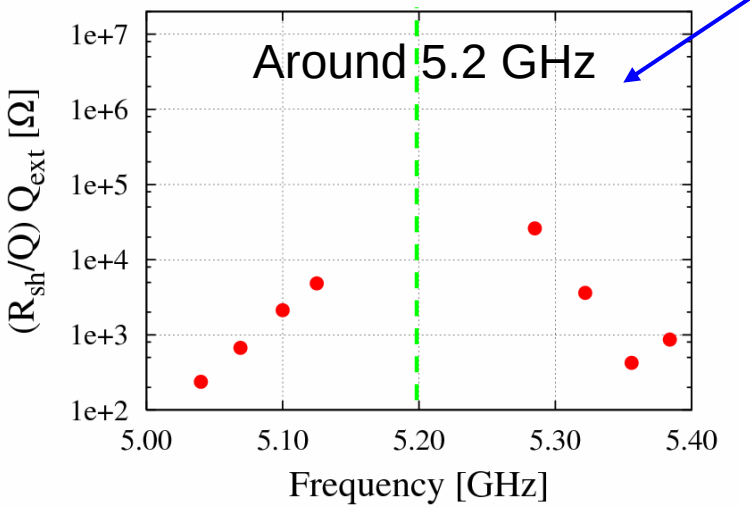


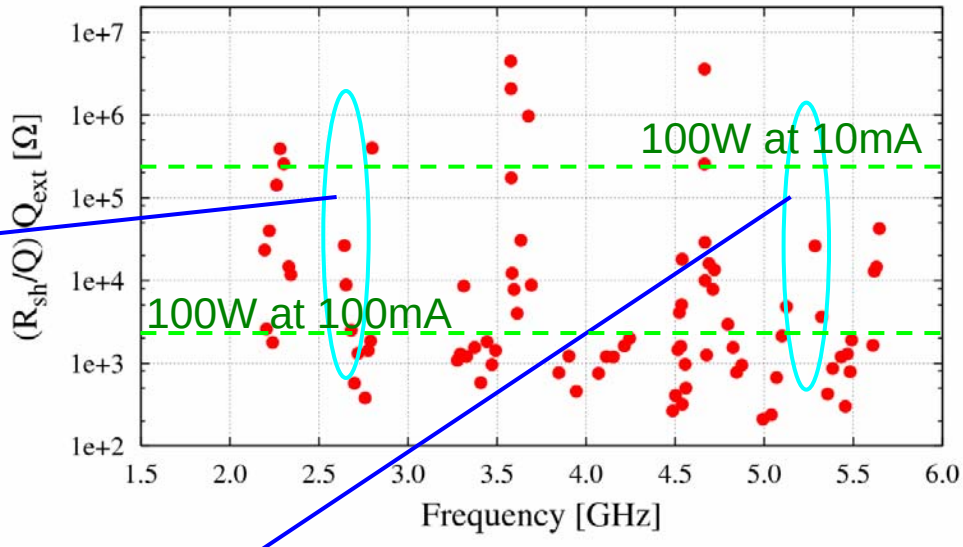
BBU threshold are significantly improved
More than 600mA is possible for KEK-ERL model-2 cavity

Monopole mode

KEK-ERL model-2 cavity





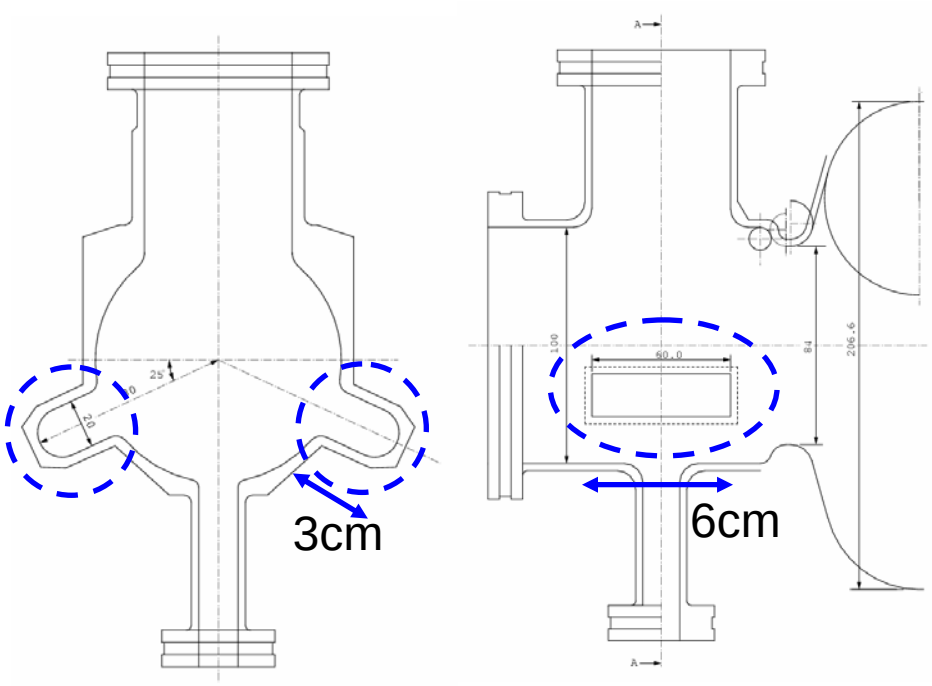


No monopole modes around 2.6GHz and 5.2GHz, within +/- 40MHz

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

Eccentric-fluted beampipe

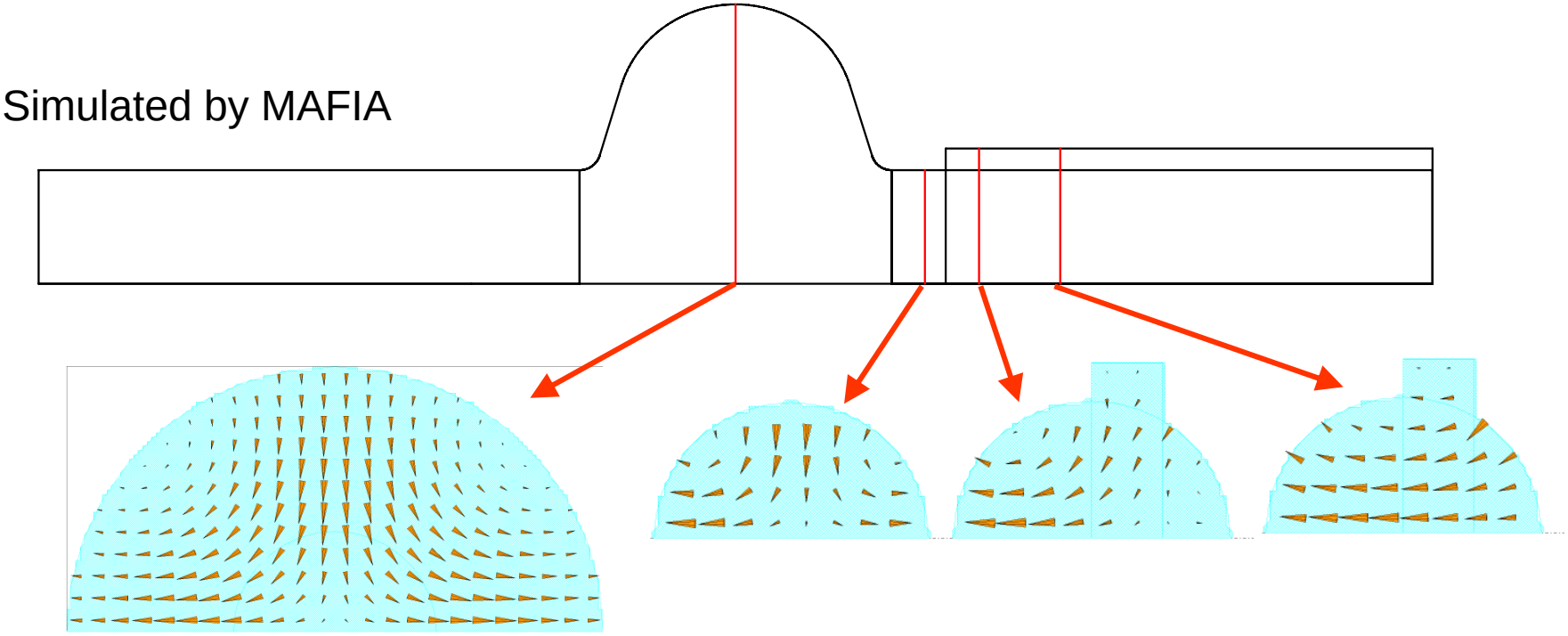
~Against quadrupole mode~



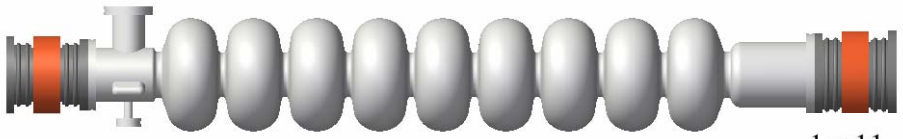
- Act as a mode transformer from quadrupole mode into dipole mode due to its asymmetric shape
- Then, can propagate through the beampipe and be damped with RF absorbers mounted on beampipe.
- Couple with both polarizations
- Effect to acceleration mode is negligible.

Mode transformation by eccentric-fluted beampipe

Simulated by MAFIA

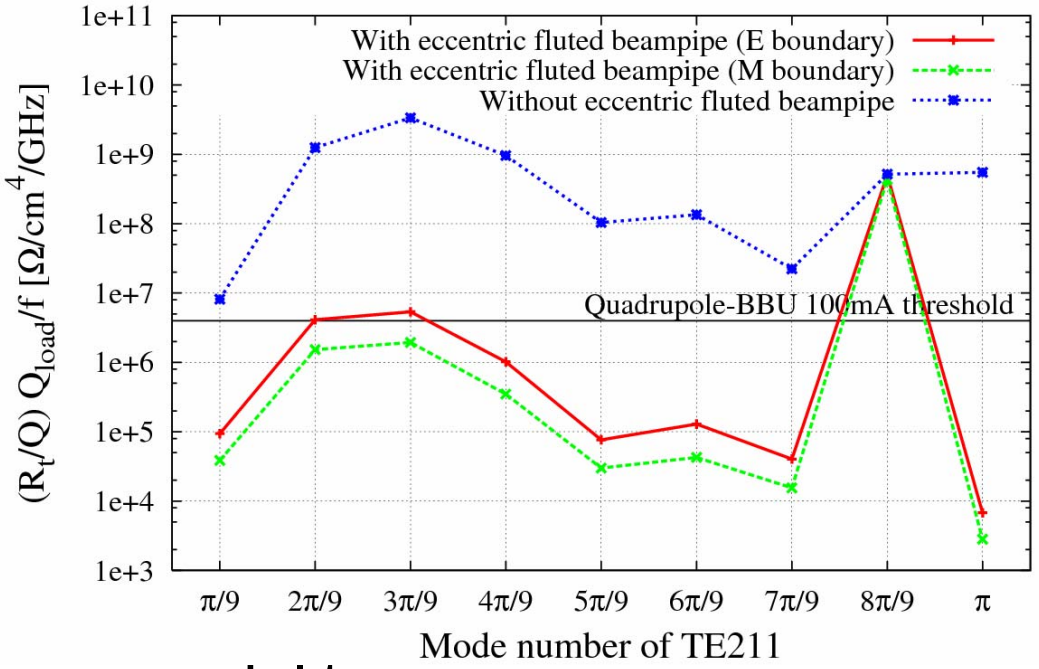


Fields of quadrupole mode can be transformed to that of dipole mode



Quadrupole mode

KEK-ERL model-2 cavity



- Shows promising damping ability
- 8pi/9 mode: field is excited at opposite side of eccentric fluted beampipe
- At present, not optimized for KEK-ERL model-2 cavity

100mA quadrupole BBU condition is expected to be satisfied after design optimization

Summary

- We have designed the 1.3GHz superconducting cavity, which is optimized for ERL operations.
- New cavity shape and large beampipe damper can strongly damp the HOMs.
- There is enough margin against 100mA dipole-BBU threshold.
- Frequency of monopole modes are apart from multiples of 2.6 GHz.
- Eccentric-fluted beampipe has been investigated. It shows promising damping ability of quadrupole modes.
- Single and nine-cell Nb KEK-ERL model-2 cavities are now in production. Thier performance will be evaluated in the near future.
- We also proceed the developments of components such as, HOM damper, input coupler, frequency tuner and so on.

Thank you very much
for your attention!