Superconducting Cavity for ERL Main Linac

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Mini-Workshop for ERL under the collaboration meeting between CLASSE and KEK

outline

- Introduction
- Designed Cavity
  - Dipole (incl. BBU simulation)
  - Monopole
  - Quadrupole (eccentric flute)
- Measurement of Eccentric flute
- Conclusion

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

HOM requirement

[I.V.Bazarov et al., EPAC04 p2197,
M.Liepe, Proc. of the 11th workshop on Superconductivity (SRF2003)]

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

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

- Monopole Mode (Heat load)
  - 100W heat load

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

- Quadrupole Mode (Quad. BBU)
  - HOM requirement for 100mA beam current

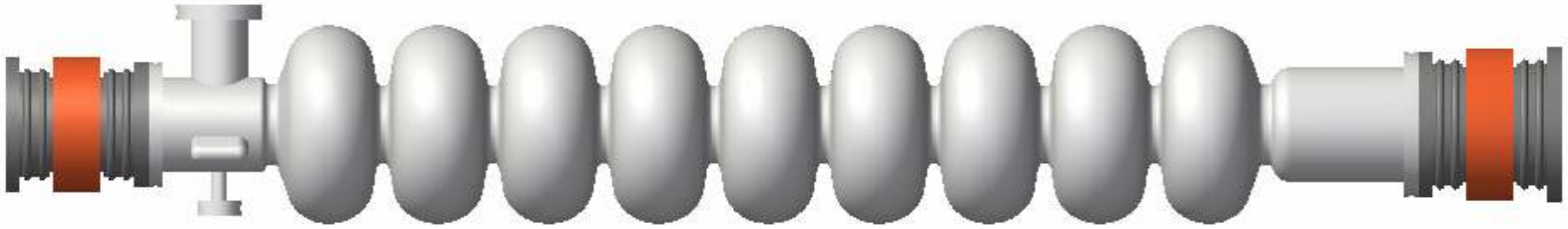
$$\left(\frac{R}{Q}\right)\frac{Q}{f} < 4\times 10^{6}\left[\frac{\Omega}{cm^{4}GHz}\right]$$

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

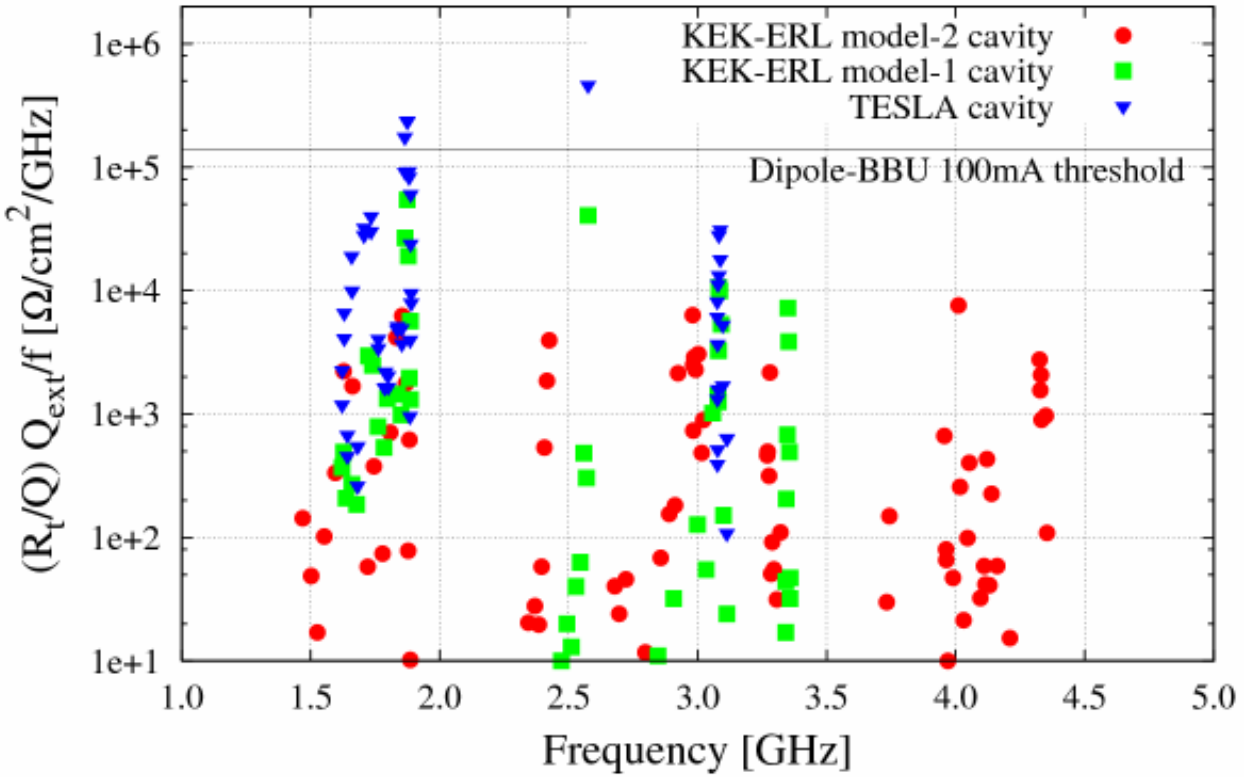
Frequency	1300 MHz	Coupling	3.8 %
Rsh/Q	897 Ω	Qo x Rs	289 Ω
Ep/Eacc	3.0	Hp/Eacc	42.5 Oe/(MV/m)

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

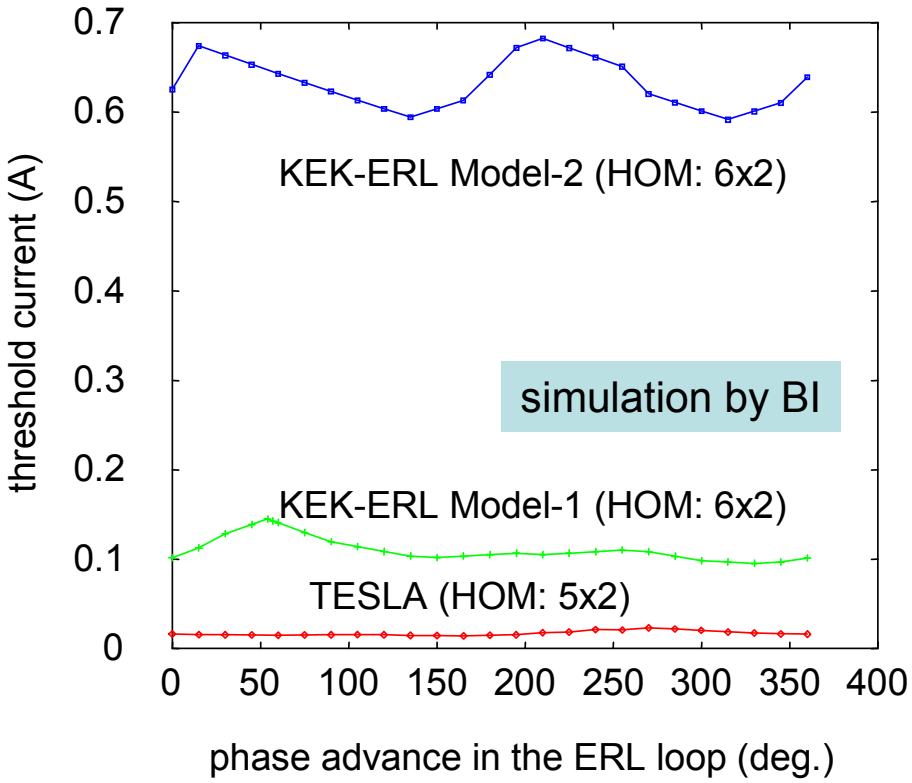


- New cavity cell shape and large beampipe damper is effective for HOM damping
- HOM impedances are one order smaller than BBU 100 mA threshold for KEK-ERL model-2 cavity

HOM-BBU threshold current

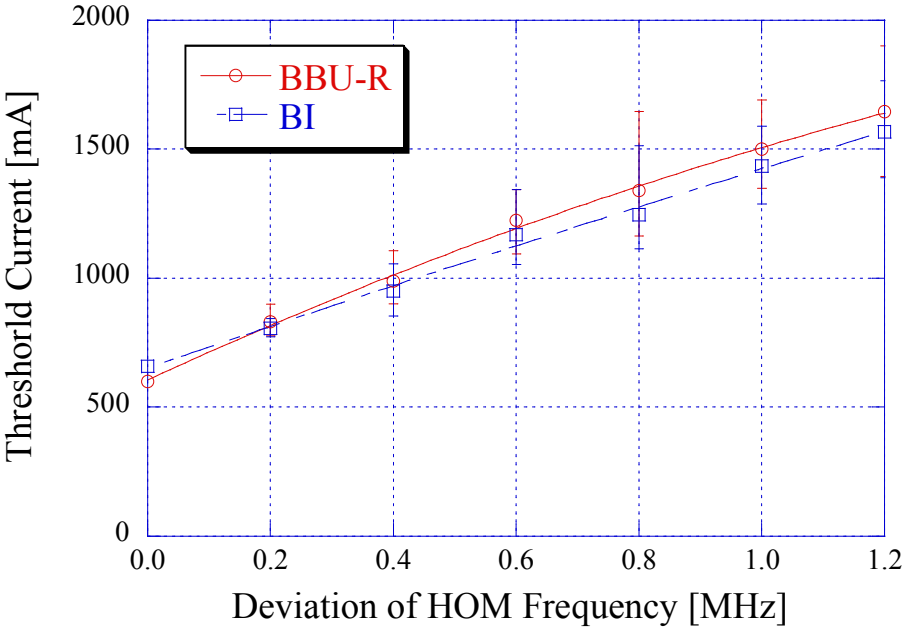
(Calculation performed by R. Hajima and R.Nagai, JAEA)

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



BI : developed at Cornell

BBU-R : developed at JAEA

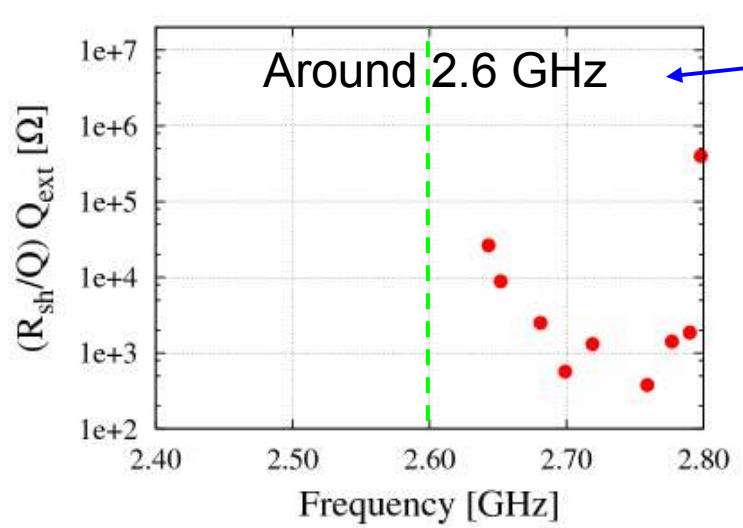


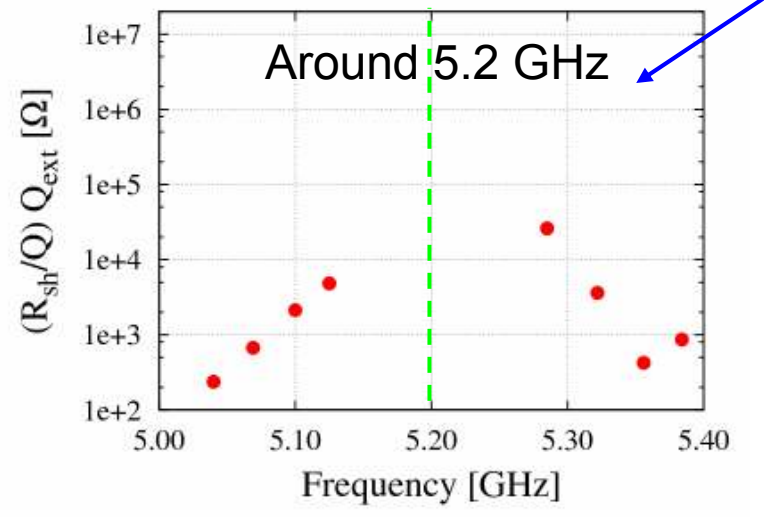
BBU threshold are significantly improved

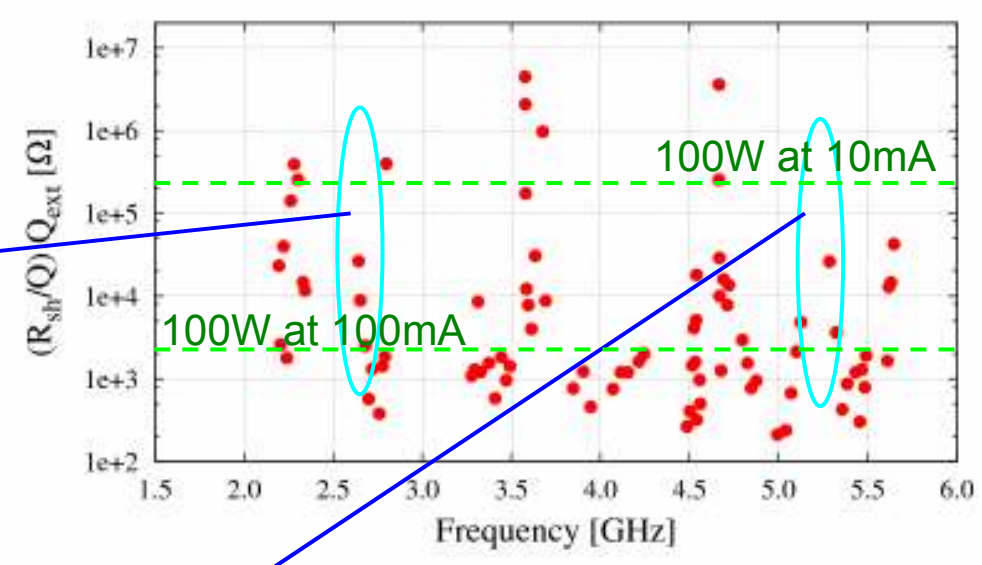
More than 600mA is possible for KEK-ERL model-2 cavity

Monopole mode

KEK-ERL model-2 cavity



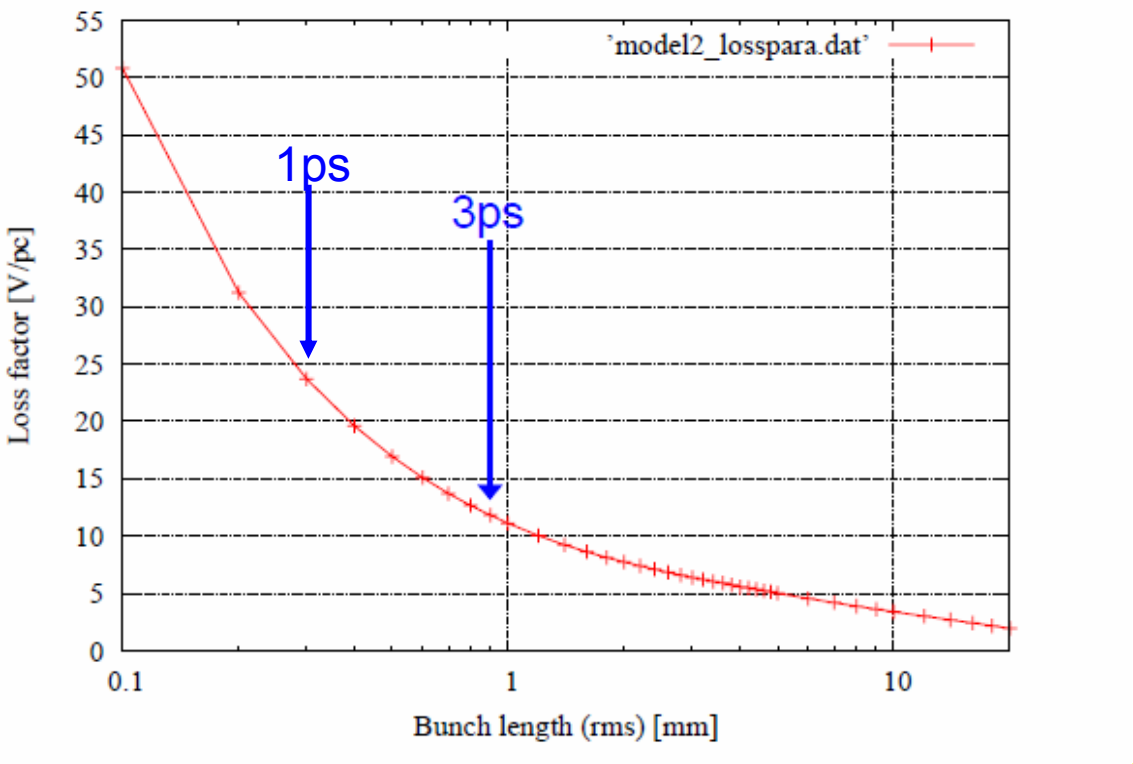




No monopole modes around 2.6GHz and 5.2GHz, within +/- 40MHz

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

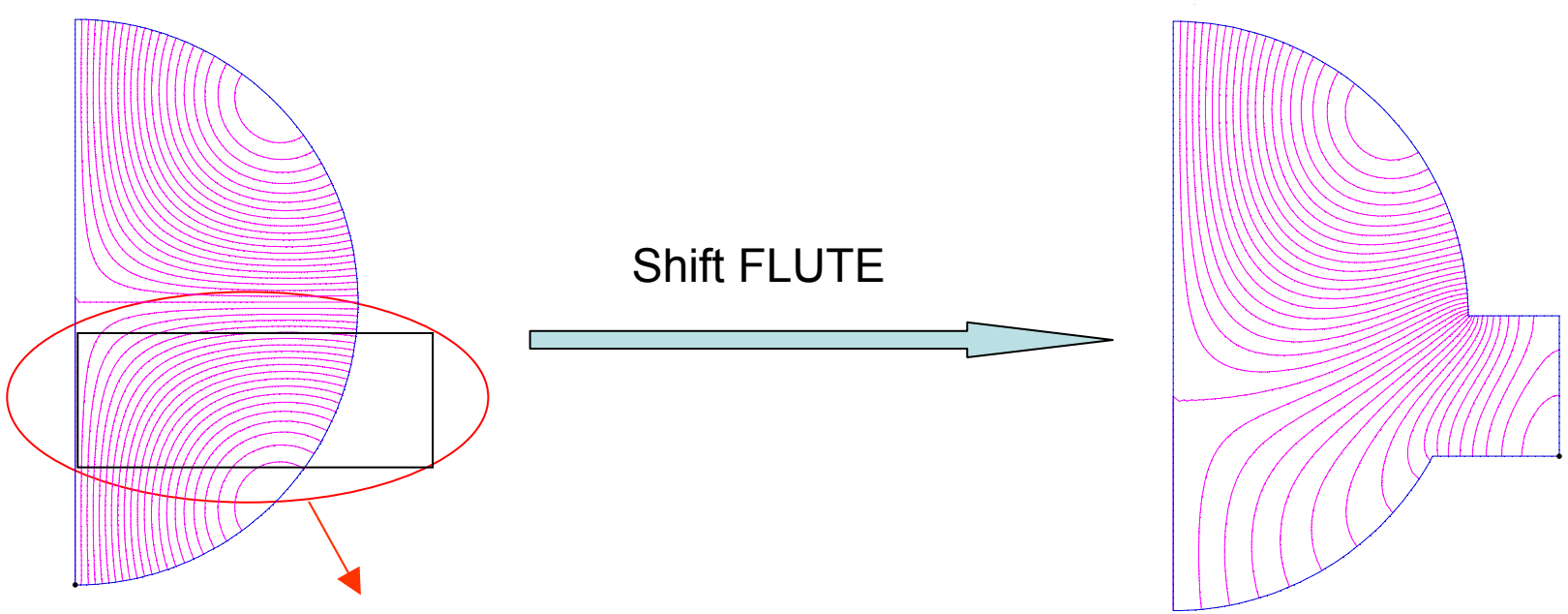
Loss Factor



- Including loss factor for accelerating mode (2V/pC)
- Calculated from only cavity shape, not including RF absorber
- For 3ps bunch length, loss factor of HOM is 12-2=10V/pC. Power is 10V/pC × 77pC × 0.2A=154W.

Eccentric-flute Basic Idea for Quadrupole damping

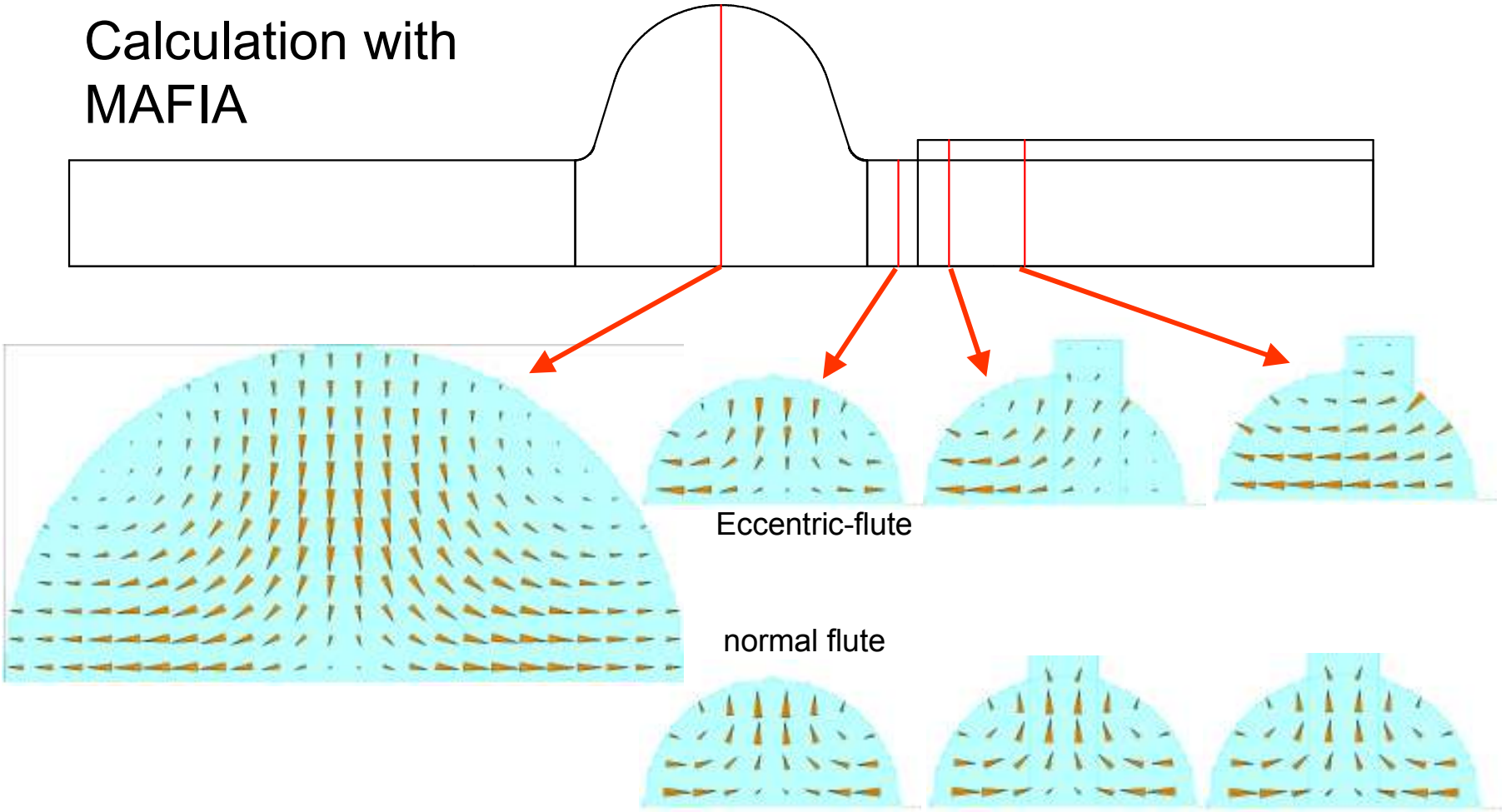
- Quadrupole in Beam Pipe



Dipole-like

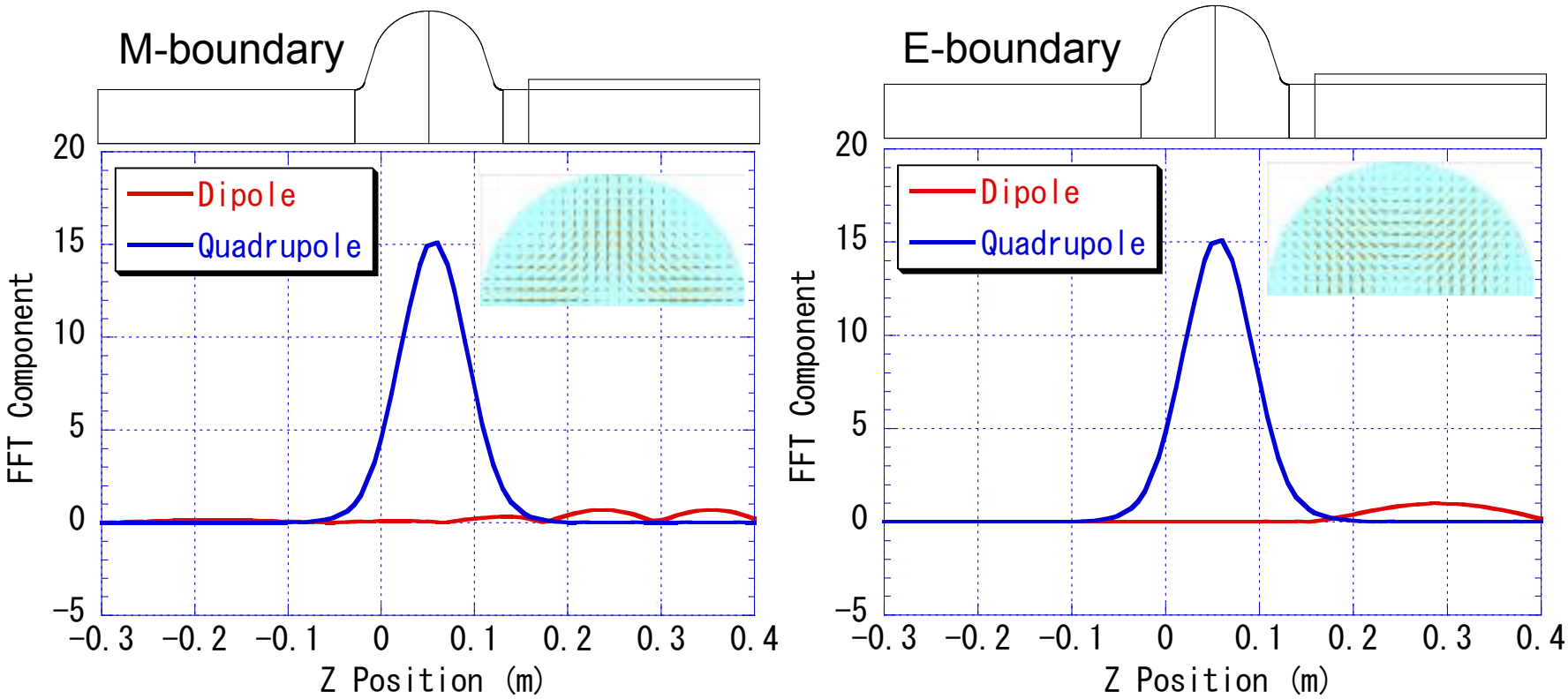
TE21 can transmit as TE11?

Cross-section of Electric field



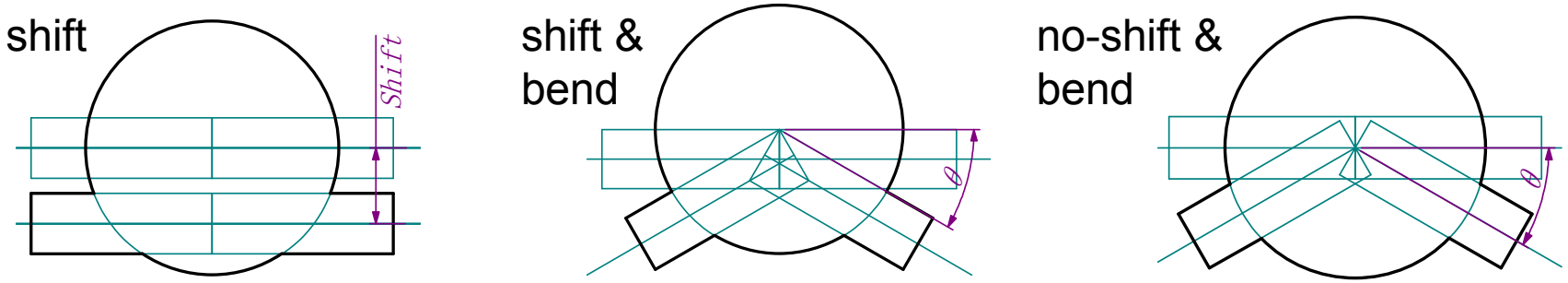
- Quadrupole is transformed to Dipole with eccentric-flute

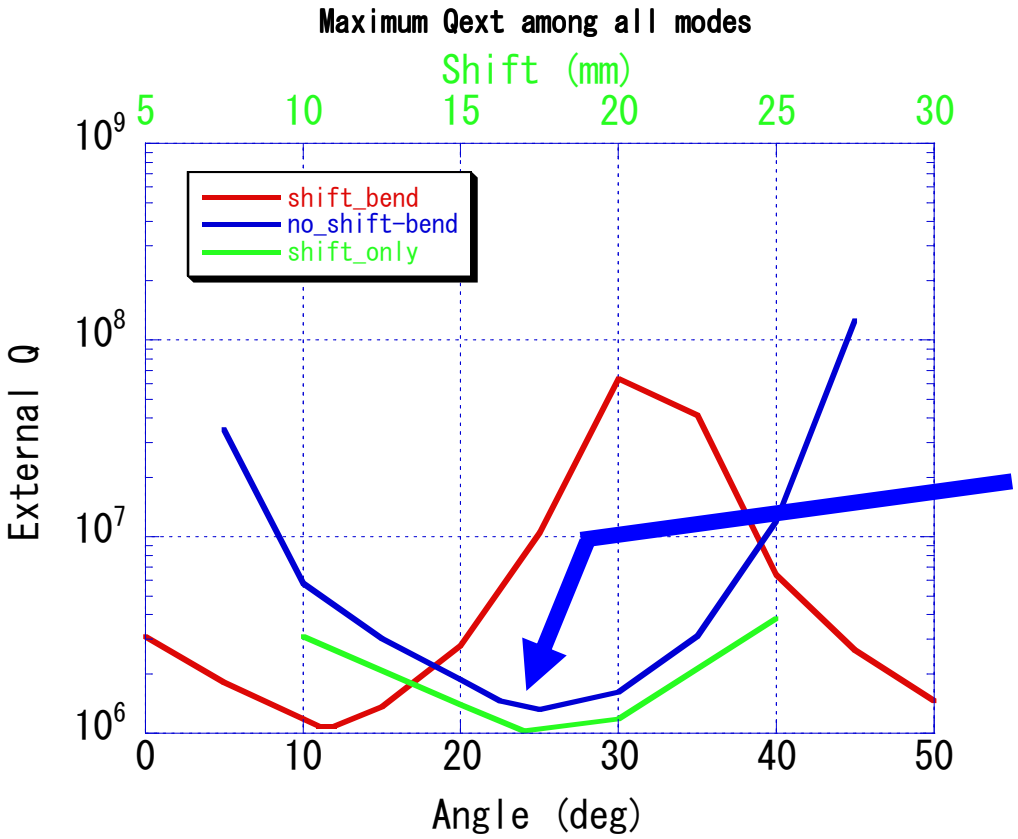
Fourier Component of Electric Field



- Both modes（M-,E-boundary）are transformed to Dipole modes.
- After transformation to Dipole, flute is not necessary？

Comparison of 3 types of eccentric flute

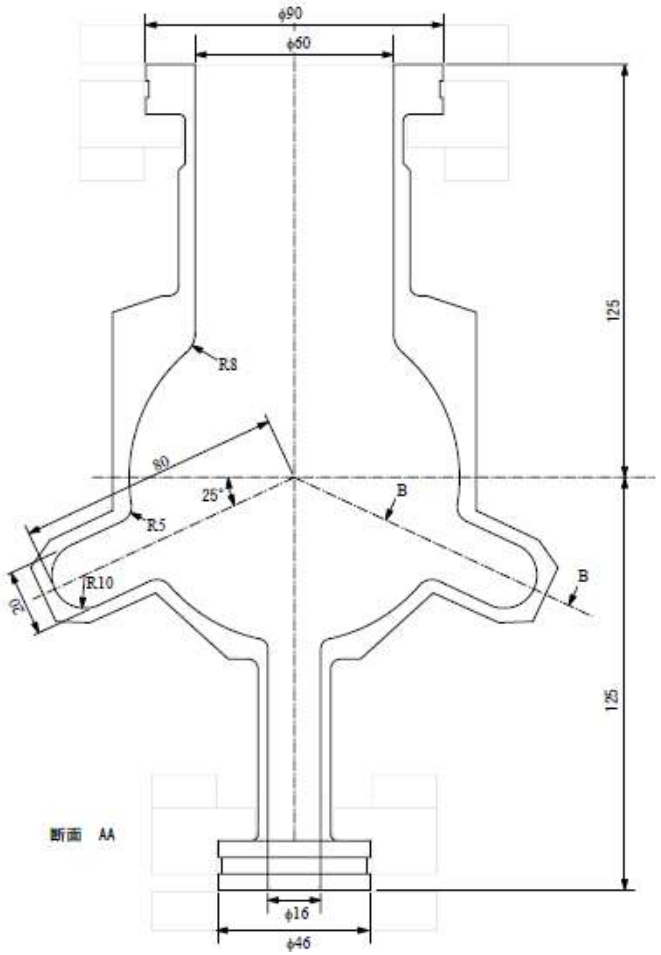


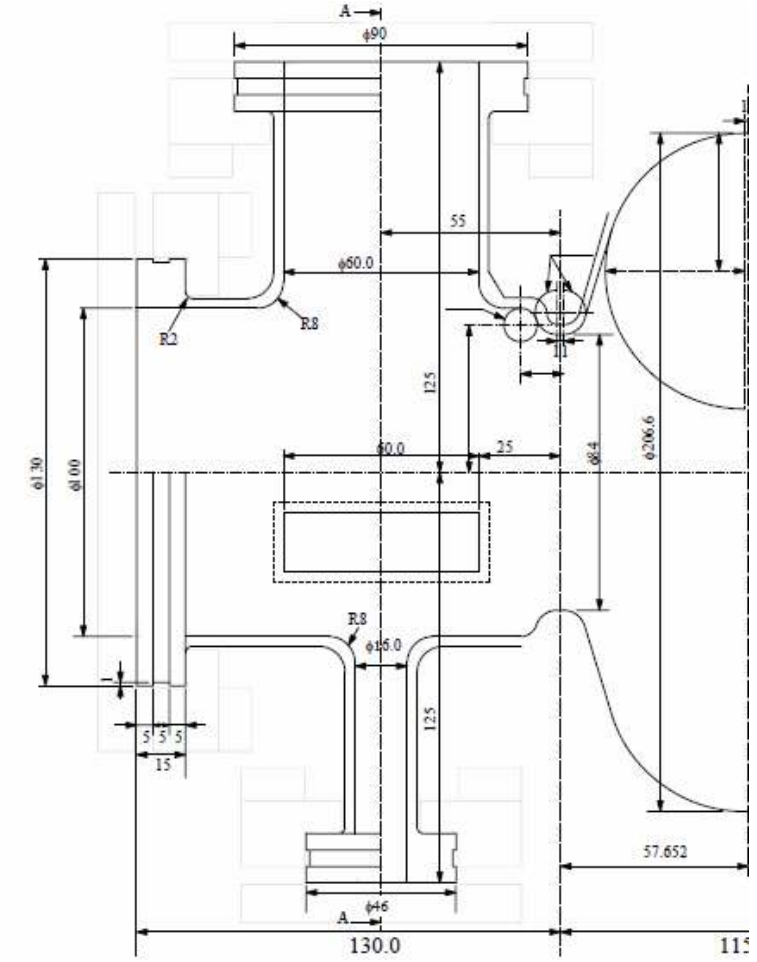


- A little difference among 3 types
- Considering fabrication

We adopt
type of no shift & bend
bending angle of 25°

Beam pipe view on the FLUTE side



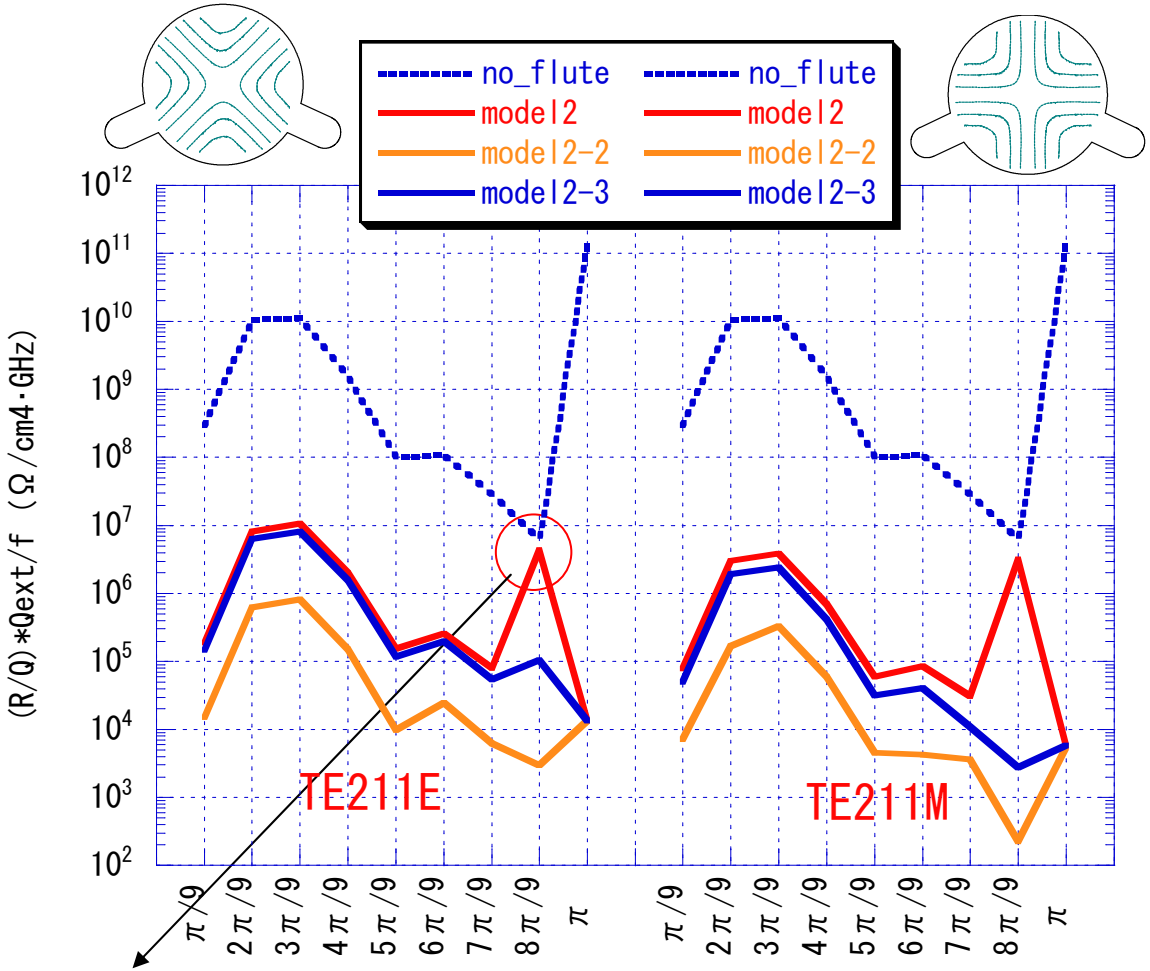


Check: Multipacting

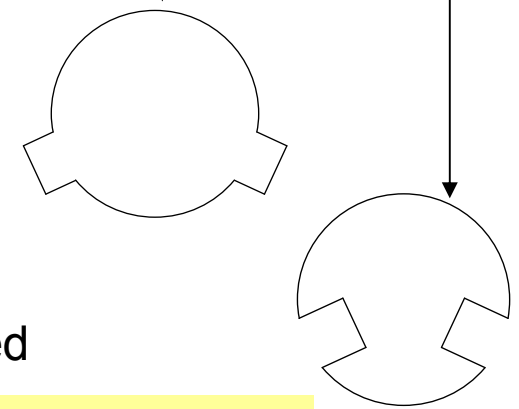
Surface treatment

Affect into other modes (fundamental, dipole)

Quadrupole of Model2



	SBP	LBP
Model 2	Eccentric flute	Non
Model 2-2		Reverse Eccentric flute
Model 2-3		Eccentric flute

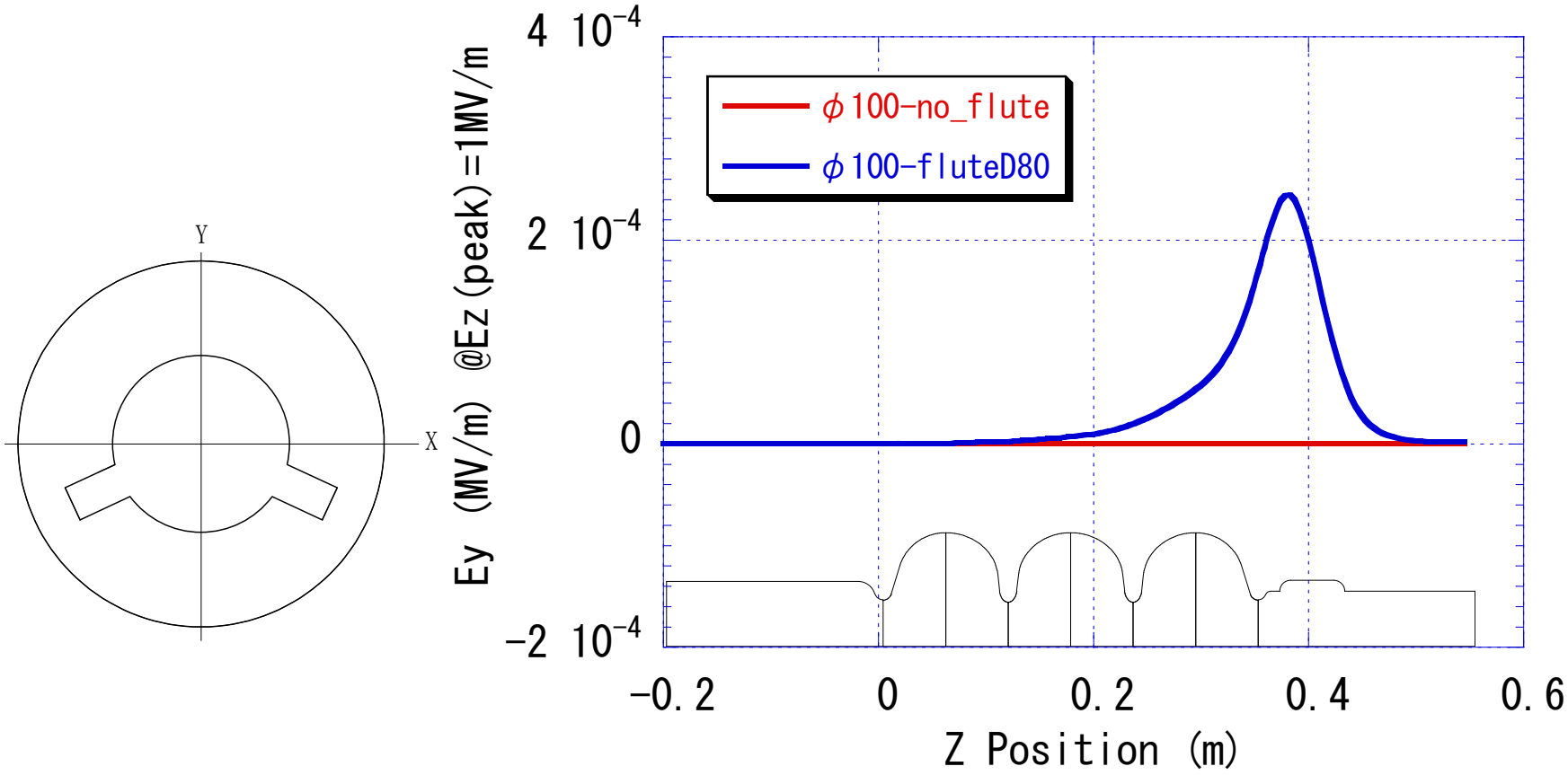


8π/9 → field in end cell opposite eccentric flute is excited

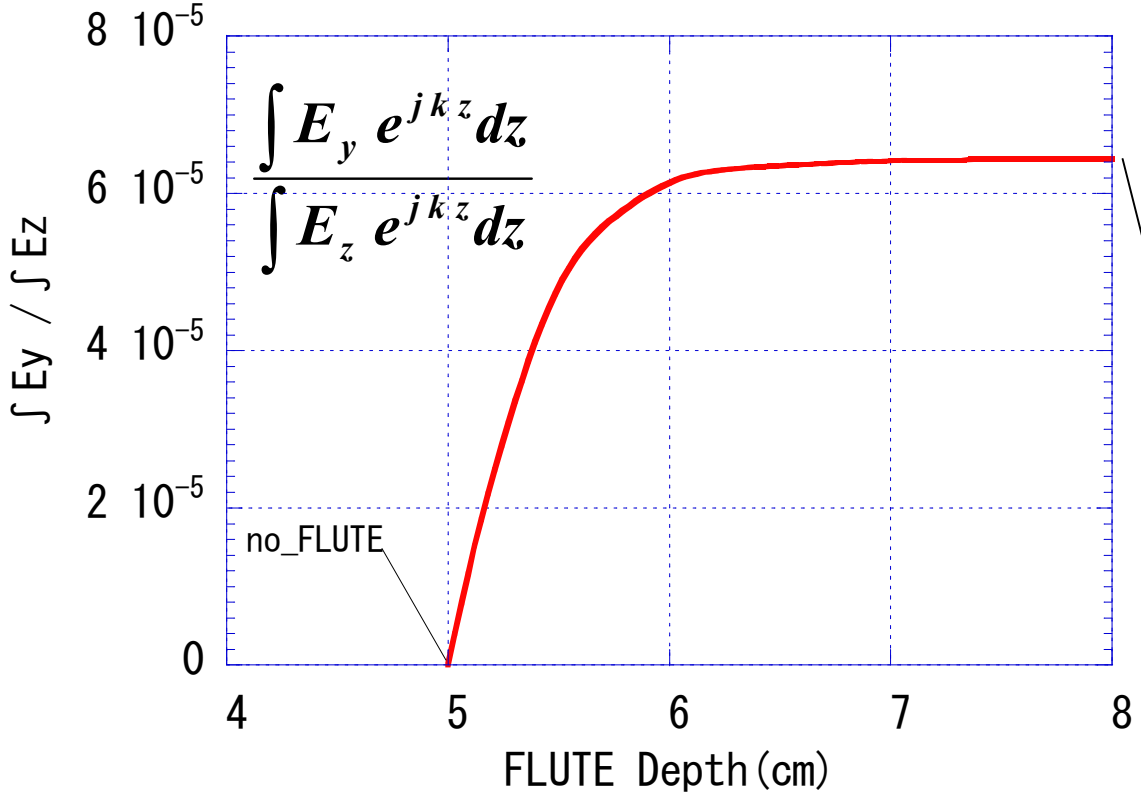
Qext would be lowered by optimization of eccentric flute parameters or adoption of eccentric flutes on both sides.

Transverse field due to FLUTE

- Does eccentric flute affect fundamental field?



Ration of transverse/longitudinal forces



3cell 6.4×10^{-5}

9cell 2.1×10^{-5}

Transverse kick is small due to flute.

Measurement of low power model with eccentric flute

TESLA type cavity

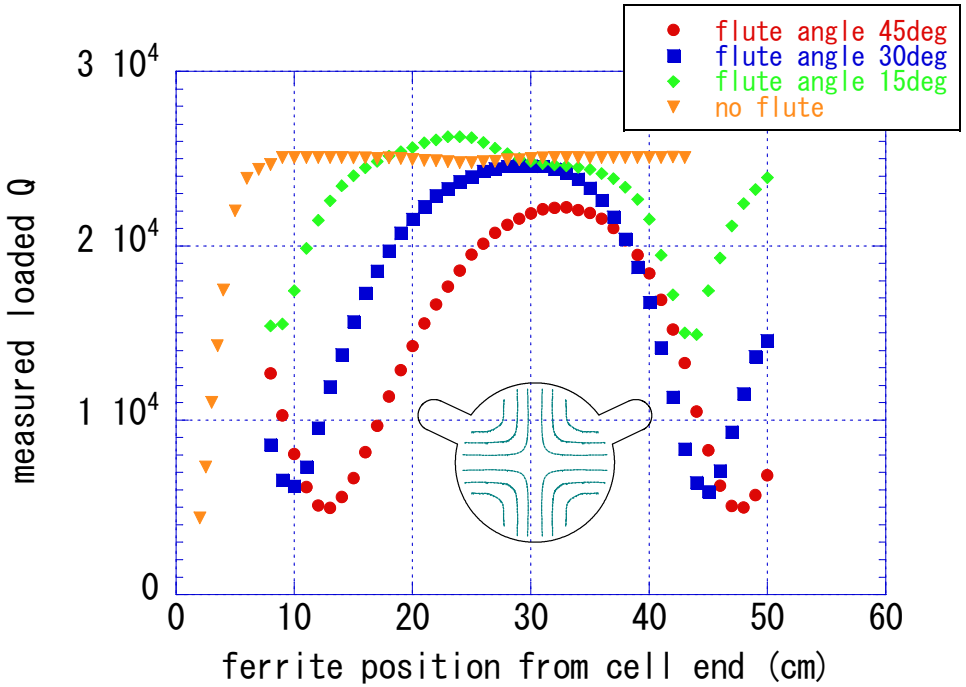
Eccentric flute

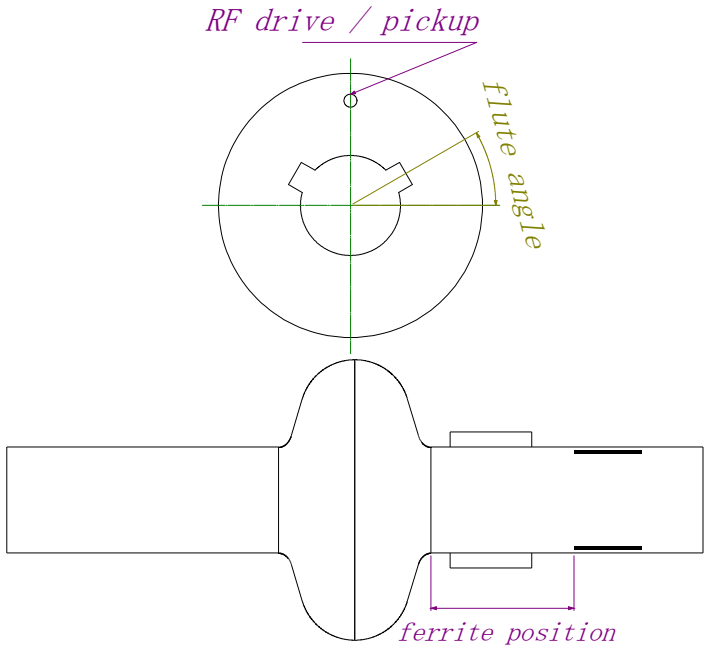
Eccentric flute consists of 7 pieces.

The flute angle can be changed from 0 to 45 degree by 5-degree step.

The flute length and depth are also variable.

Loaded Q with eccentric flute





Without eccentric flute, no field inside the beam pipe far from the cell.

With eccentric flute, field transmits through the beam pipe.

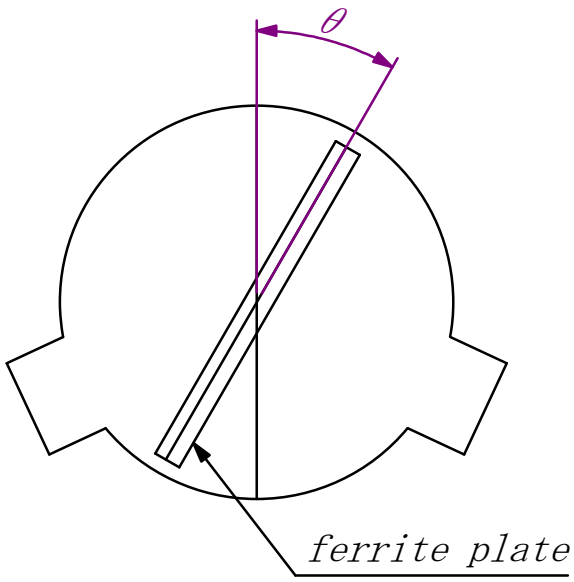
Loaded Q varies with ferrite position

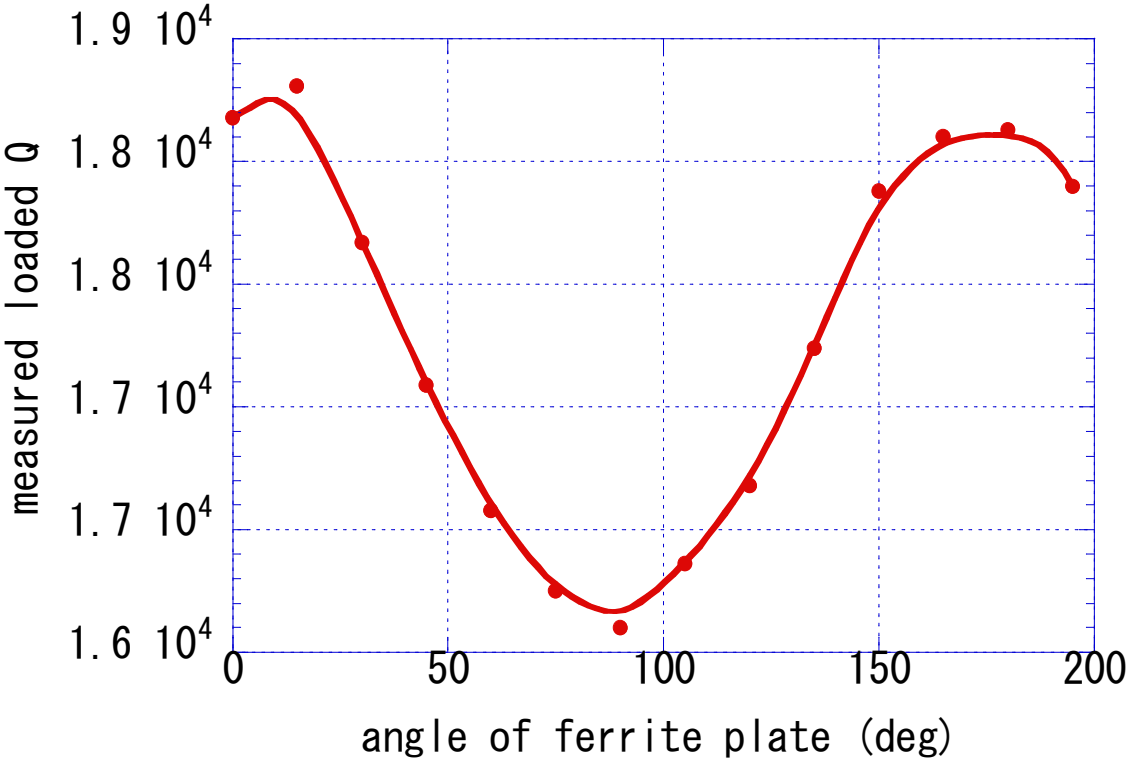
⇒ Ferrite sheet(15cm long, 2mm thick) might be unsuitable for absorber.

(μ_r'=5.10, μ_r''=6.29 @2GHz)

[ref. KEKB μr'=0.964, μr''=5.93 @2GHz]

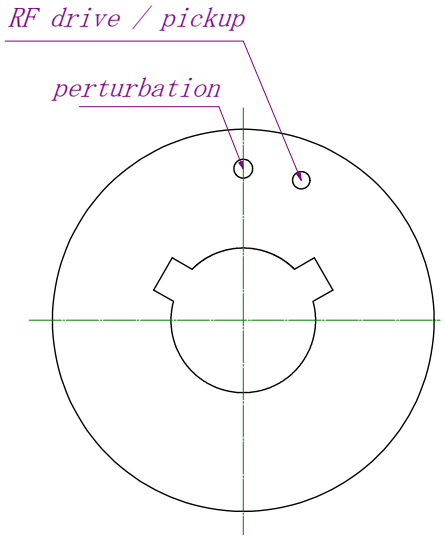
Field Polarization in Beam Pipe



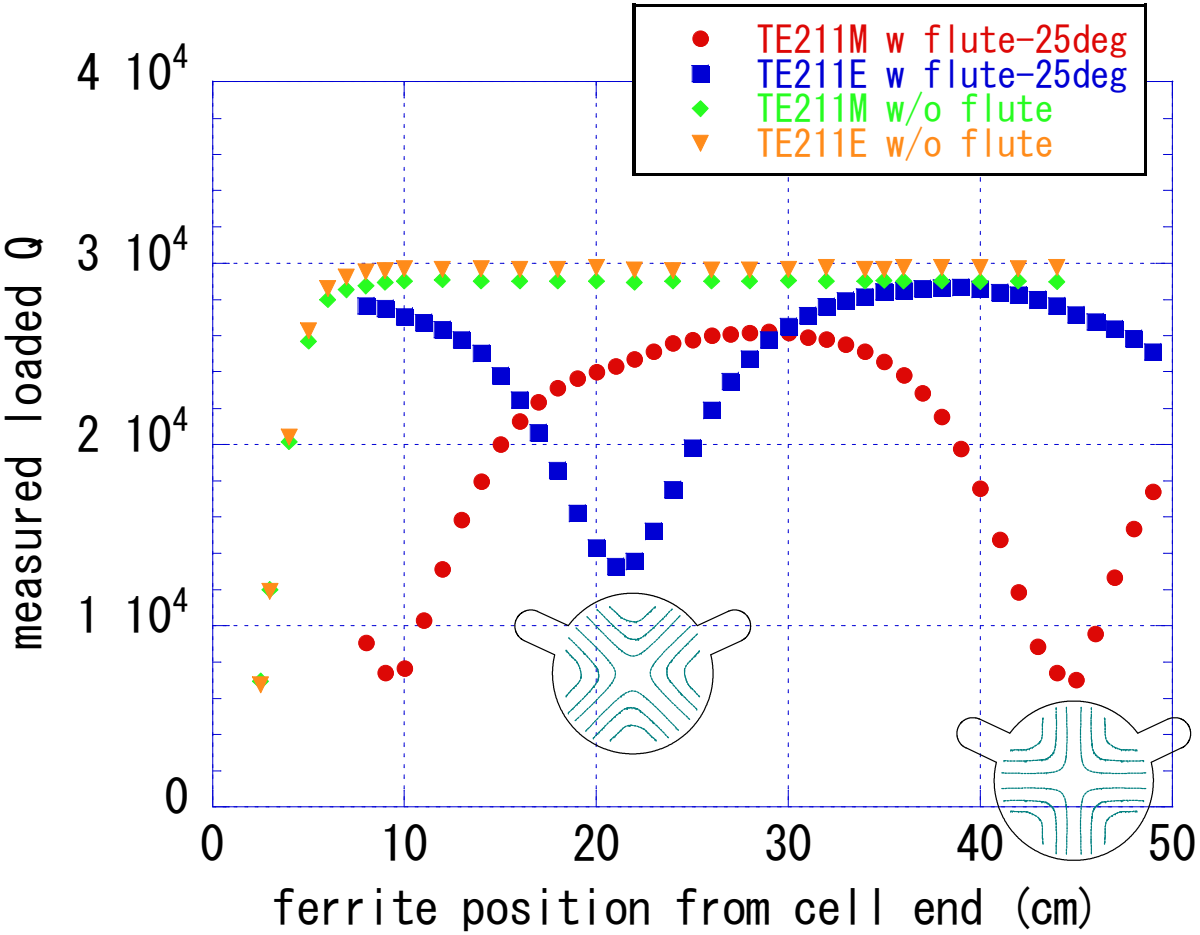


Field inside the beam pipe is DIPOLE mode.

Loaded Q for two degenerated modes



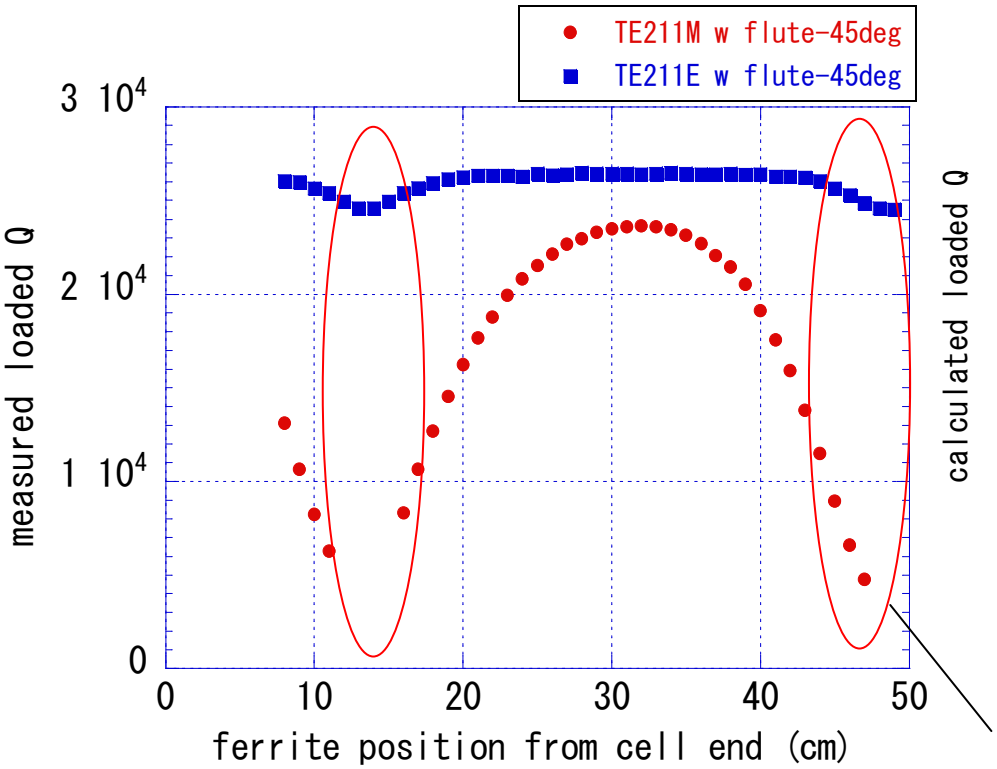
Flute angle = 25 deg

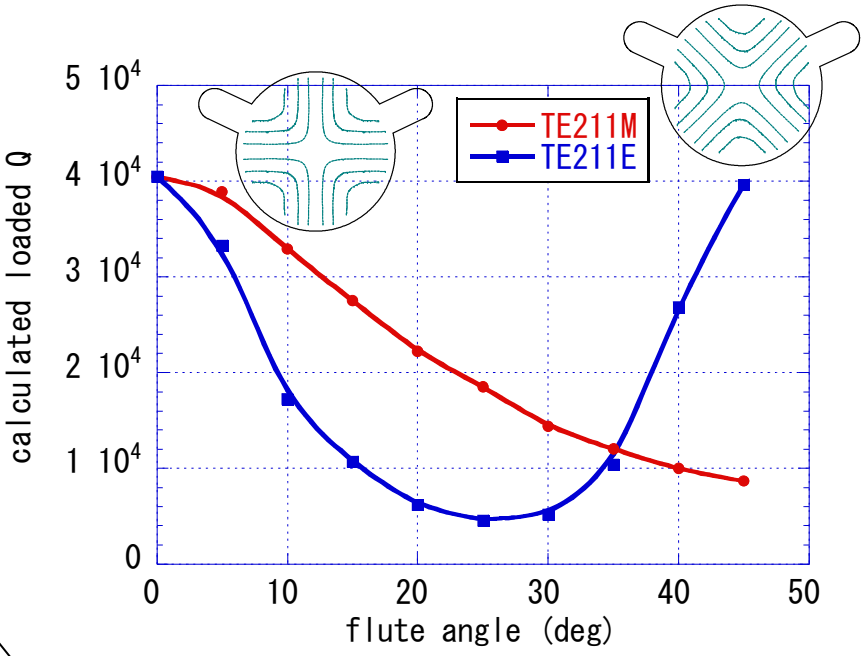


Perturbation can separate TE211 mode into 2 modes.

⇒ Eccentric flute is effective for both modes.

Loaded Q for two degenerated modes (cont.)

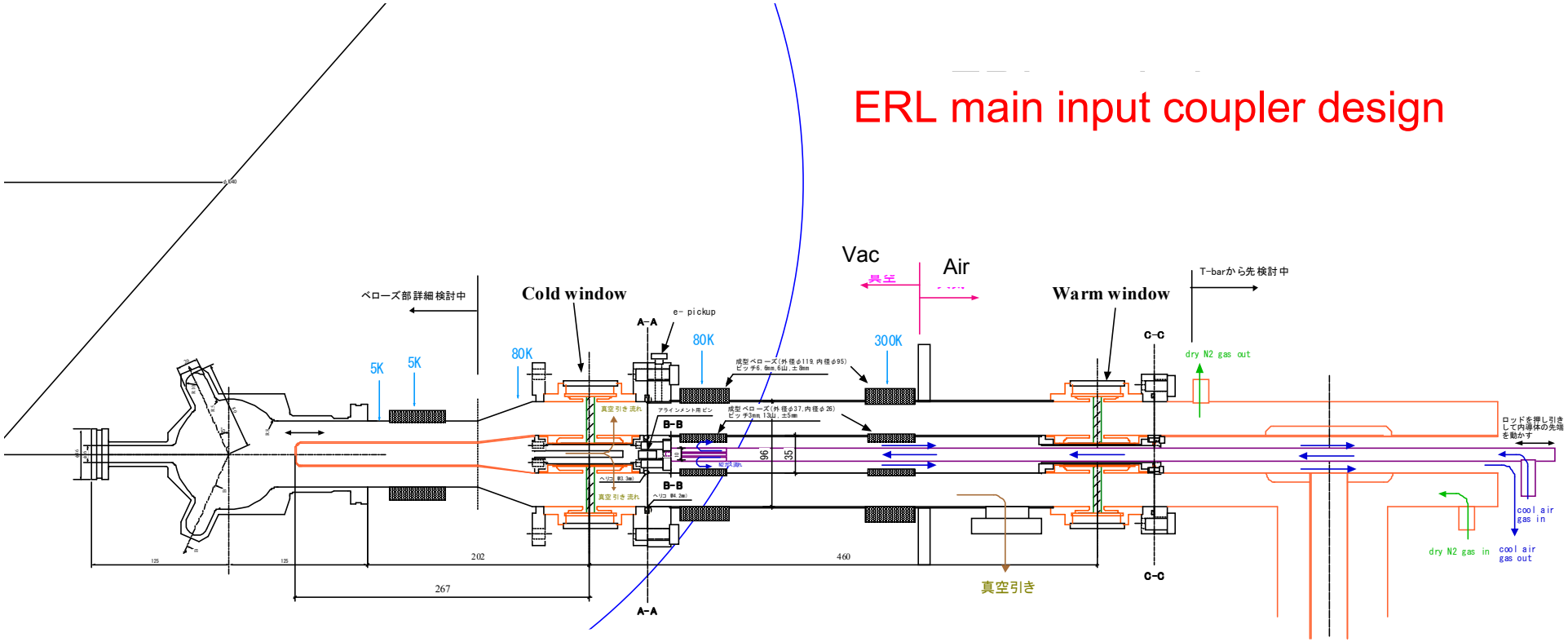




Q value of TE211M is so low that two modes overlap.

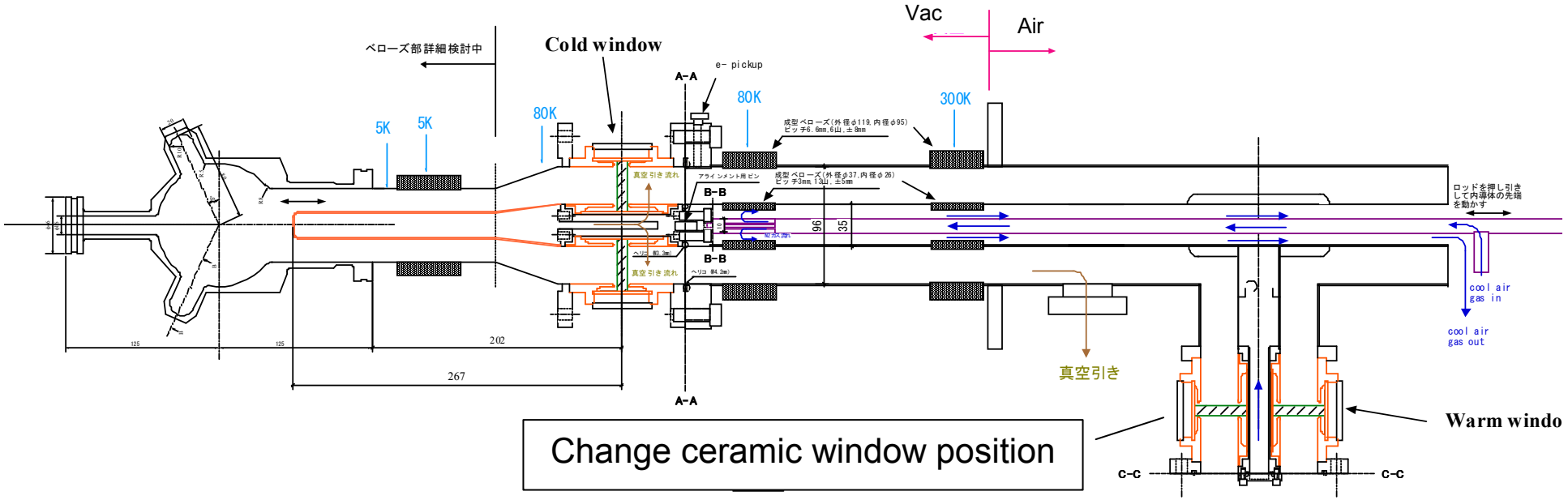
- For 45-deg flute angle
  ⇒ TE211E mode hardly couple with eccentric flute.
  ⇒ This corresponds to calculation.

ERL main input coupler design



- 20kW CW input power
- variable coupling
- gas cooling
- double ceramic of same size
- disk type ceramic window (HA997)
- 60Ω impedance

Alternative design of ERL main input coupler



Change ceramic window position

- Easy assembly
- No dry N2 for suppressing condensation of the inner conductor
- Compact input coupler

Ceramics are under fabrication and component tests will be done this summer.

Conclusion

- Model2 cavity satisfies HOM damping criteria of monopole and dipole modes for 100mA.
- Eccentric flute is effective for damping quadrupole modes, but needs more investigation.
- Nb single-cell model of mid-cell shape only, and that of end-cell shape with coupler ports and eccentric flute, and 9-cell model are in production.
- RF Characteristics of HOM absorber will have to be investigated later on.