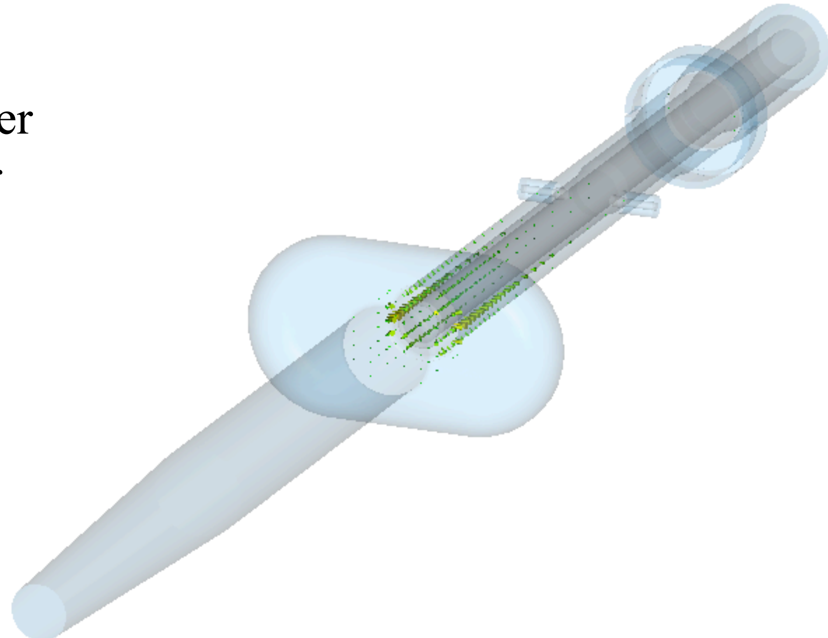
RF Design of Crab Cavity

Parasitic modes in the coaxial coupler
Modifications of the coaxial coupler
Stop band of the notch filter
Rotation of the notch filter
HOM measurement
HOM power estimation

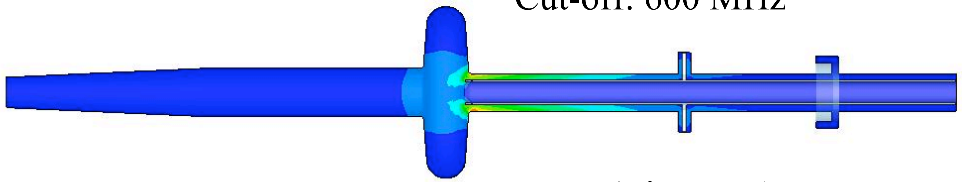


Yoshiyuki Morita
Mar. 19, 2007
Accelerator Review Committee

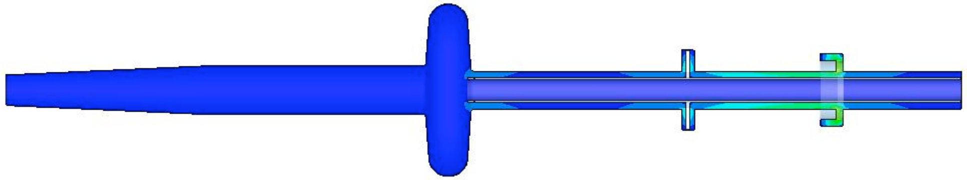
Parasitic modes in the coaxial coupler

-Straight coaxial coupler design-

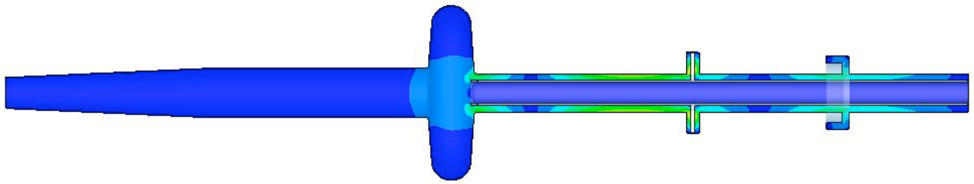
Coaxial coupler
Cut-off: 600 MHz



1/4λ mode



3/4λ mode

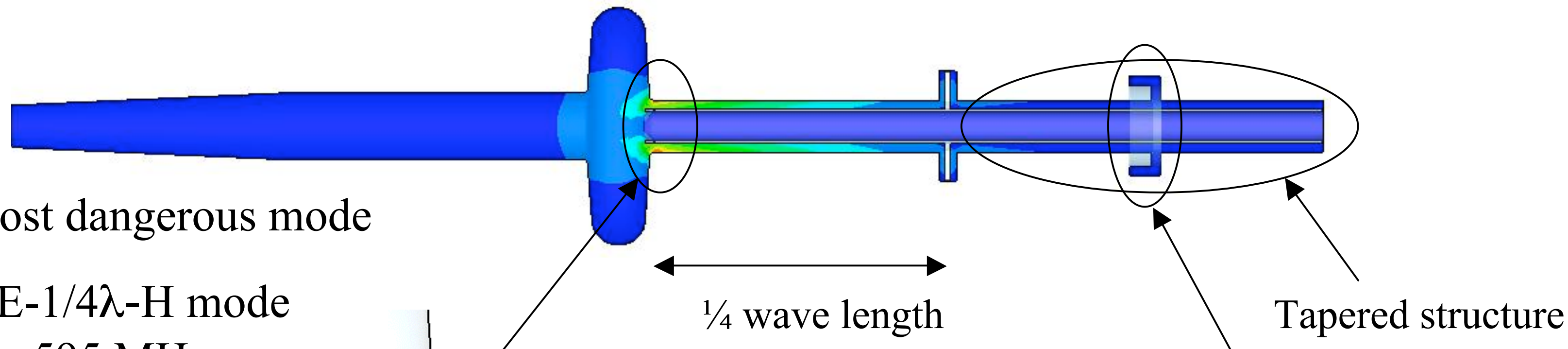


5/4λ mode

Mode	Freq.(MHz)	R/Q	Q
1/4λ	595	5.7	10^6
3/4λ	602	0.17	9000
5/4λ	616	1.24	3000

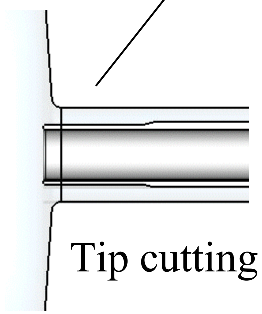
- Coaxial coupler has parasitic modes like a quarter wave resonator.
- These parasitic modes are very dangerous because of its high Q values.
- The most dangerous mode is the horizontally polarized TE-λ/4 mode.

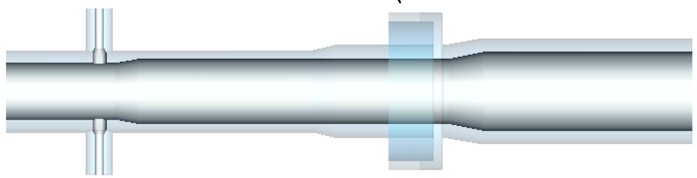
Modifications of the coaxial coupler



The most dangerous mode

TE-1/4λ-H mode
f = 595 MHz
R/Q = 5.3 Ω
Q = 10^6

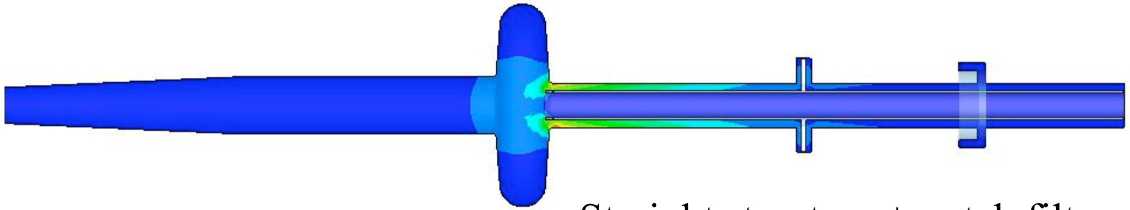




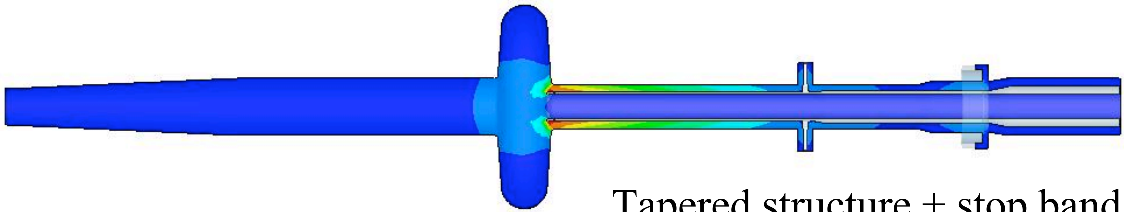
Three modifications were applied to damp this mode.

1. Tapered coupler design for lower cut-off.
2. TE stop band splitting of notch filter.
3. Tip cutting design to raise freq. of TE-1/4λ-H mode

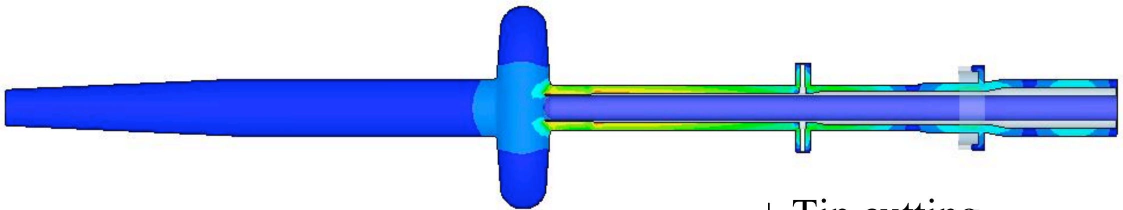
Comparison of TE-1/4λ-H mode damping



Straight structure + notch filter



Tapered structure + stop band splitting notch filter

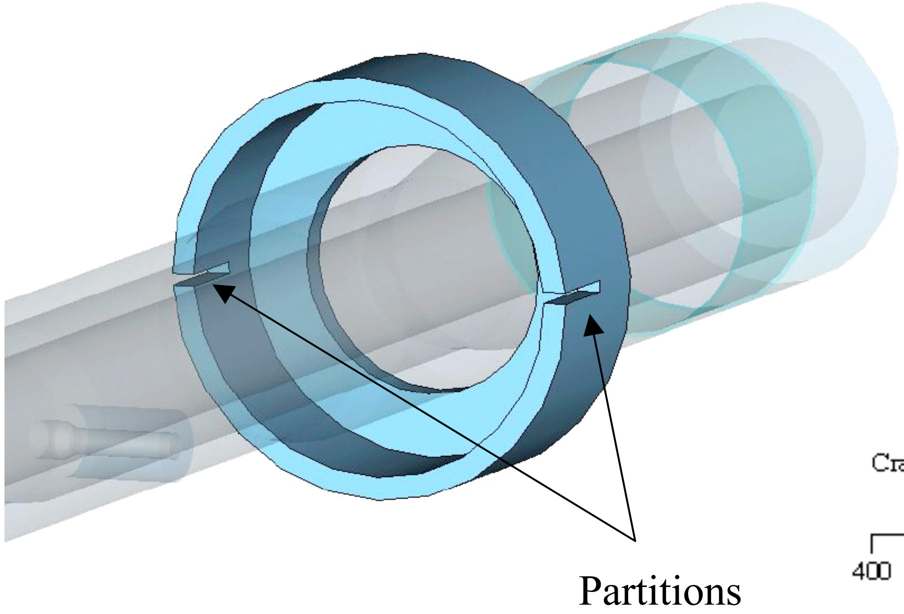


+ Tip cutting

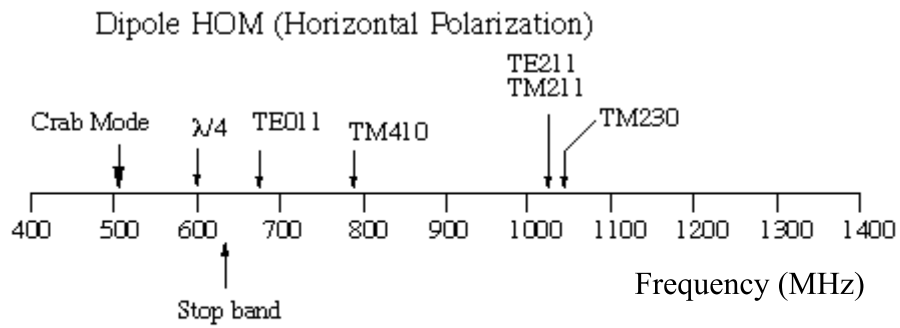
Type	f	R/Q(MWS)	Q(HFSS)
Straight	595 MHz	5.7 Ω	10^6
Tapered	602 MHz	5.2 Ω	5800
Tapered + tip cutting	607 MHz	2.1 Ω	2700

Stop band splitting design of the notch filter

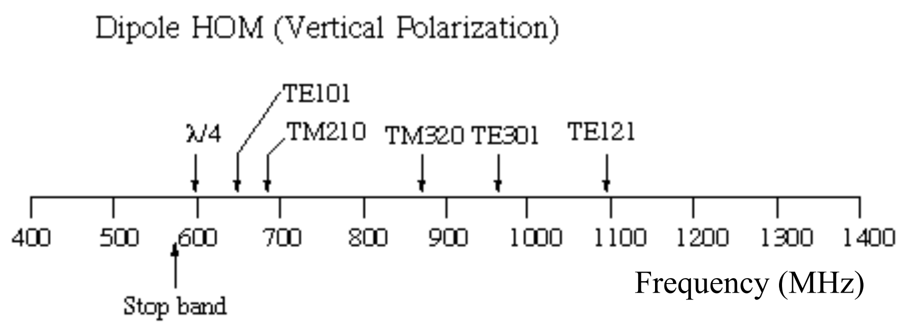
Notch filter: reject TEM-coupled crab mode



Notch filter has stop band for TE mode.
An axially-symmetric design has a stop band around 630 MHz. This stop band is close to the TE-1/4λ-H mode.
A stop band splitting notch filter has partitions in mid-plane to separate stop bands.

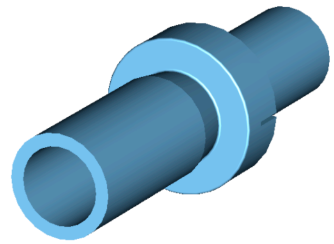


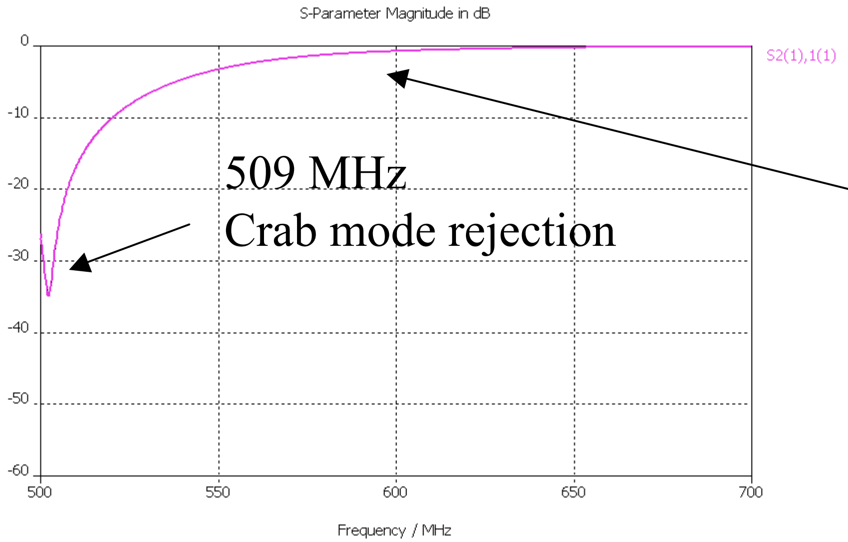
Stop band (H-V splitting)	
TEM	509 MHz
TE(H)	650 MHz
TE(V)	570 MHz

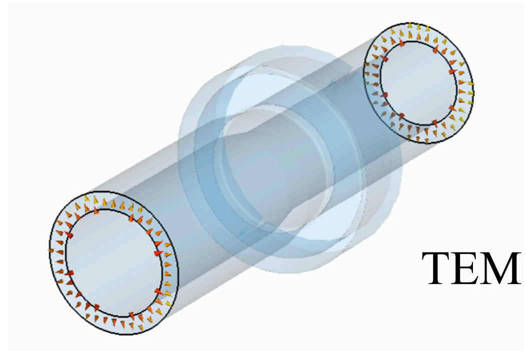


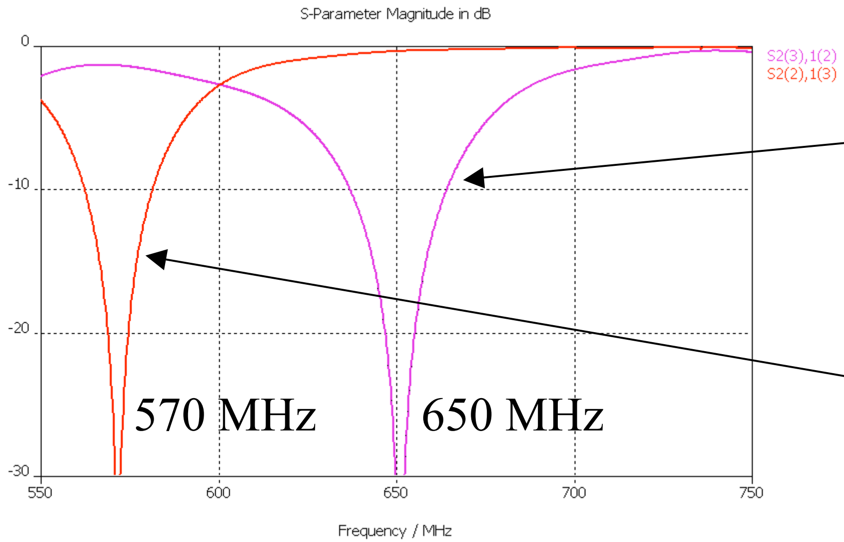
Transmission property

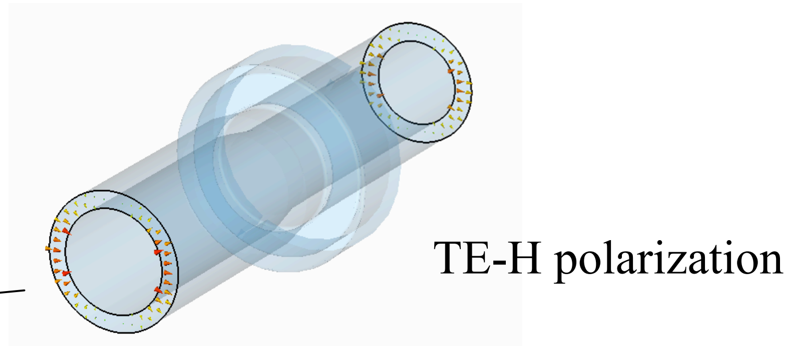
-Stop band splitting notch filter-

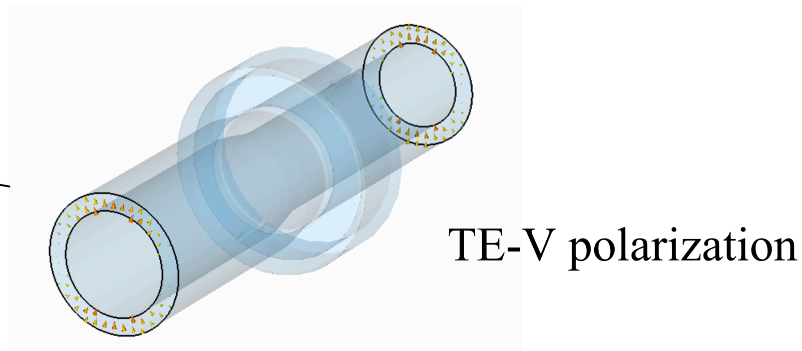






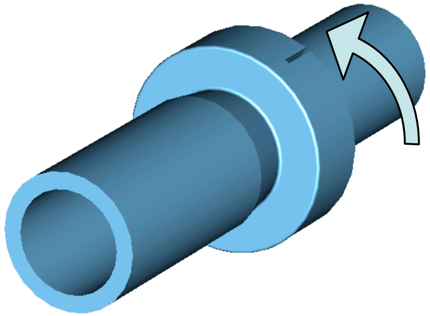


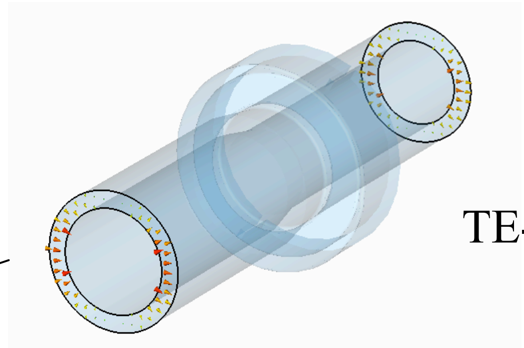




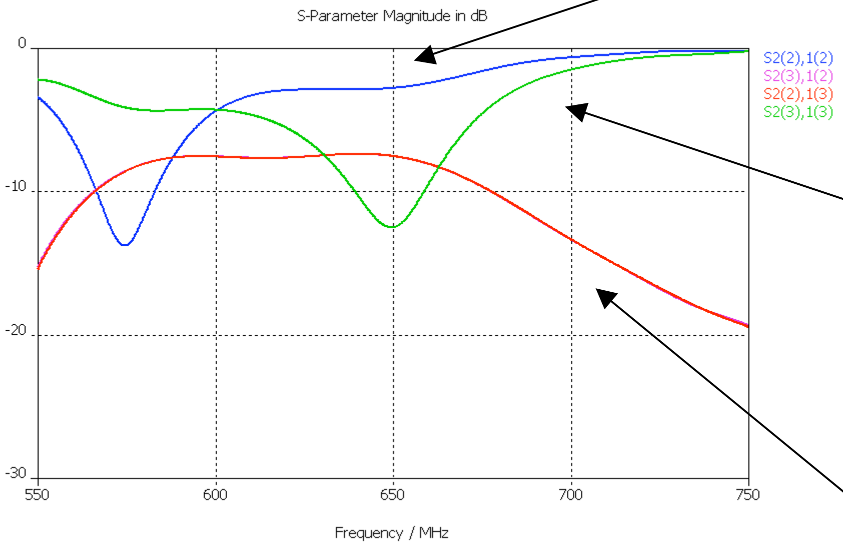
New idea: Rotated notch filter

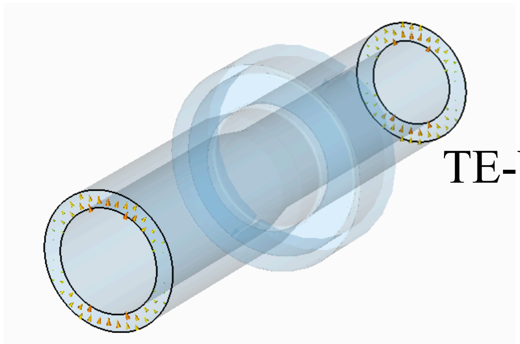
What will happen when the notch filter rotates ?
Mixing of TE modes occurs.



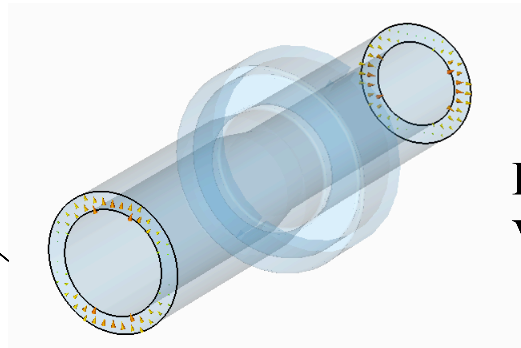


TE-H pol.





TE-V pol.

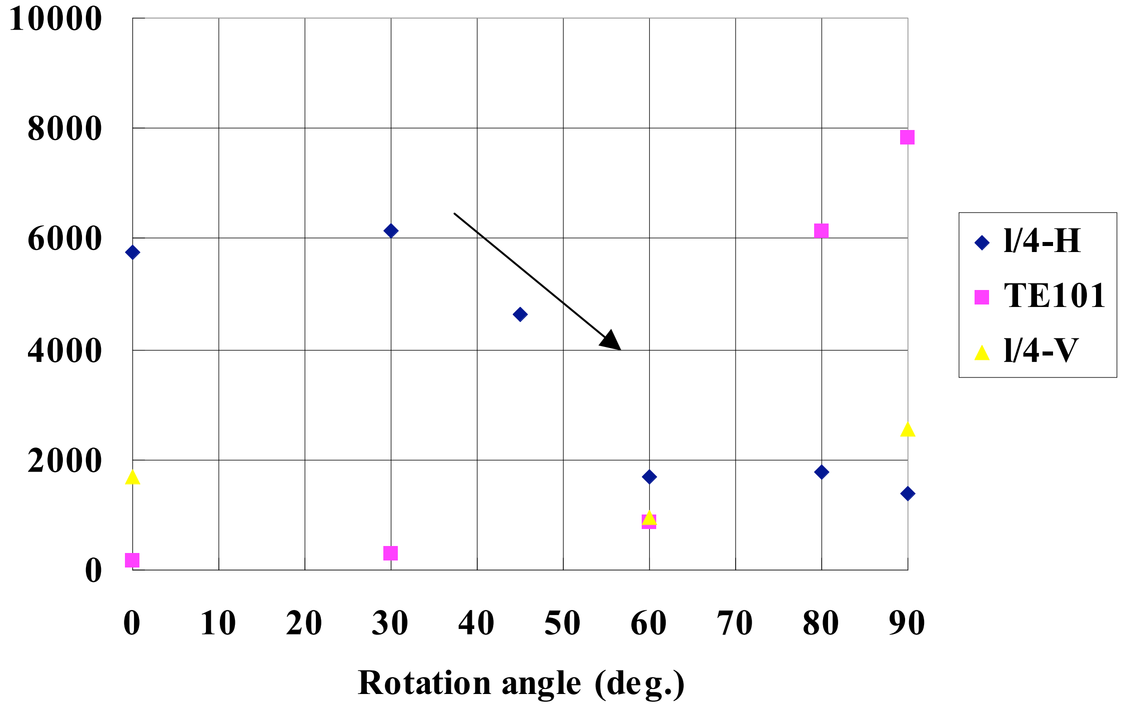


H to V
V to H

Rotation angle: 60°

Q and R/Q of λ/4-H, λ/4-V and TE101 modes

Q



Q value of the λ/4-H mode significantly decreases as rotating the notch filter.

R/Q

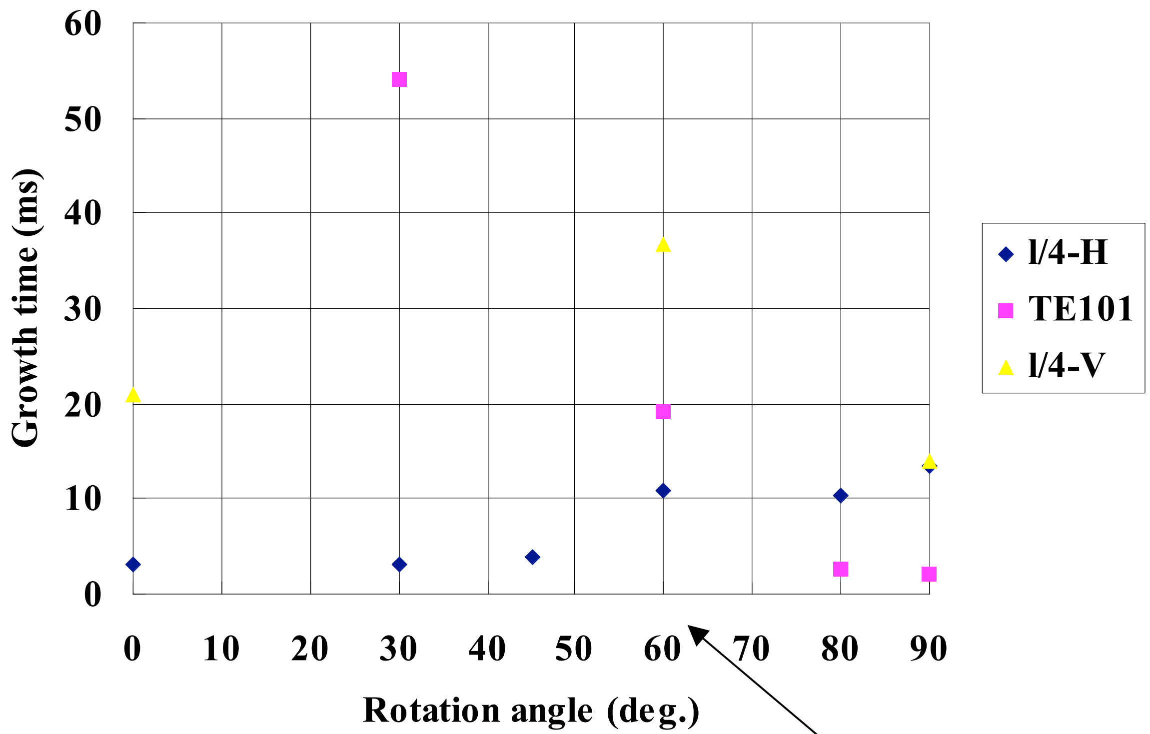
Mode	0 deg.	45 deg.	90 deg.
l/4-H	5.24	5.32	5.36
l/4-V	4.98	5.30	5.17
TE101	10.3	10.1	10.8

R/Q: no change

We applied 60° rotation angle

Tip cutting design
Q of λ/4-H = 2700
R/Q of λ/4-H = 2.1

Growth time



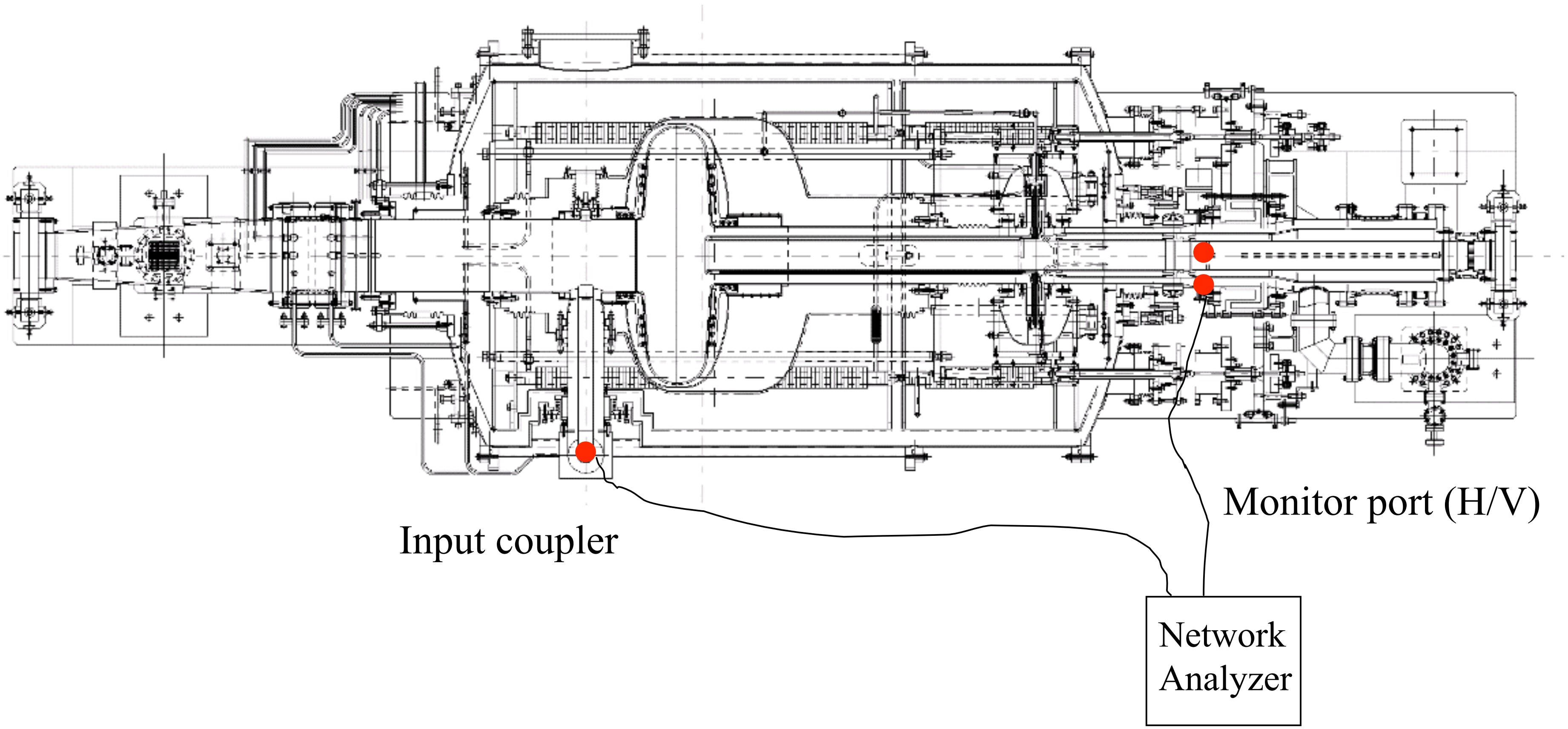
Present crab cavity

λ/4-H : HER, Horizontal
λ/4-V, TE101: LER, Vertical

Machine parameters

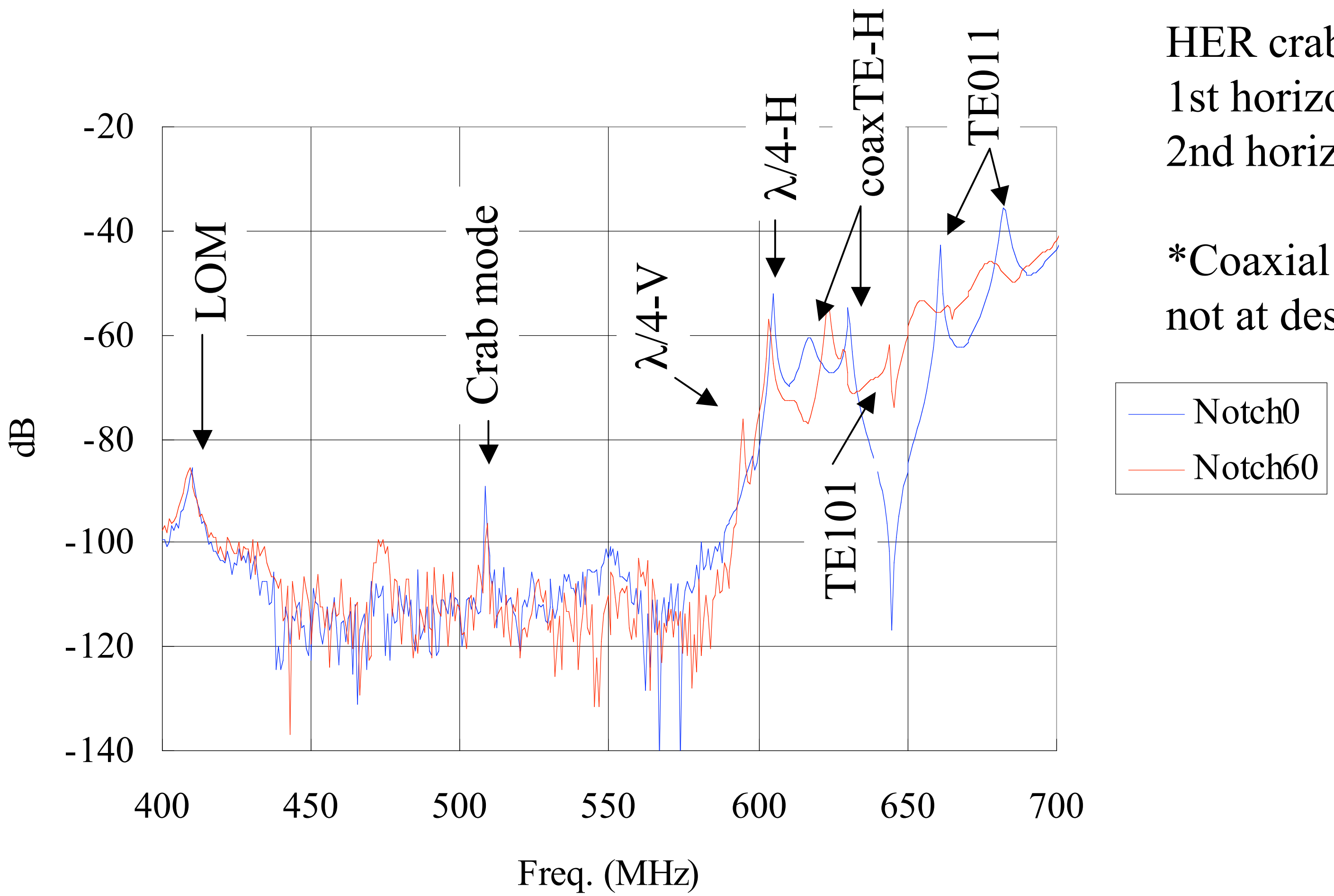
	HER	LER
Energy (GeV)	8	3.5
Current (A)	1.3	1.6
Beta-x (m)	200	40
Beta-y (m)	13.5	38.5

HOM/LOM measurement



HER crab cavity

Measurement Result (HER at RT)



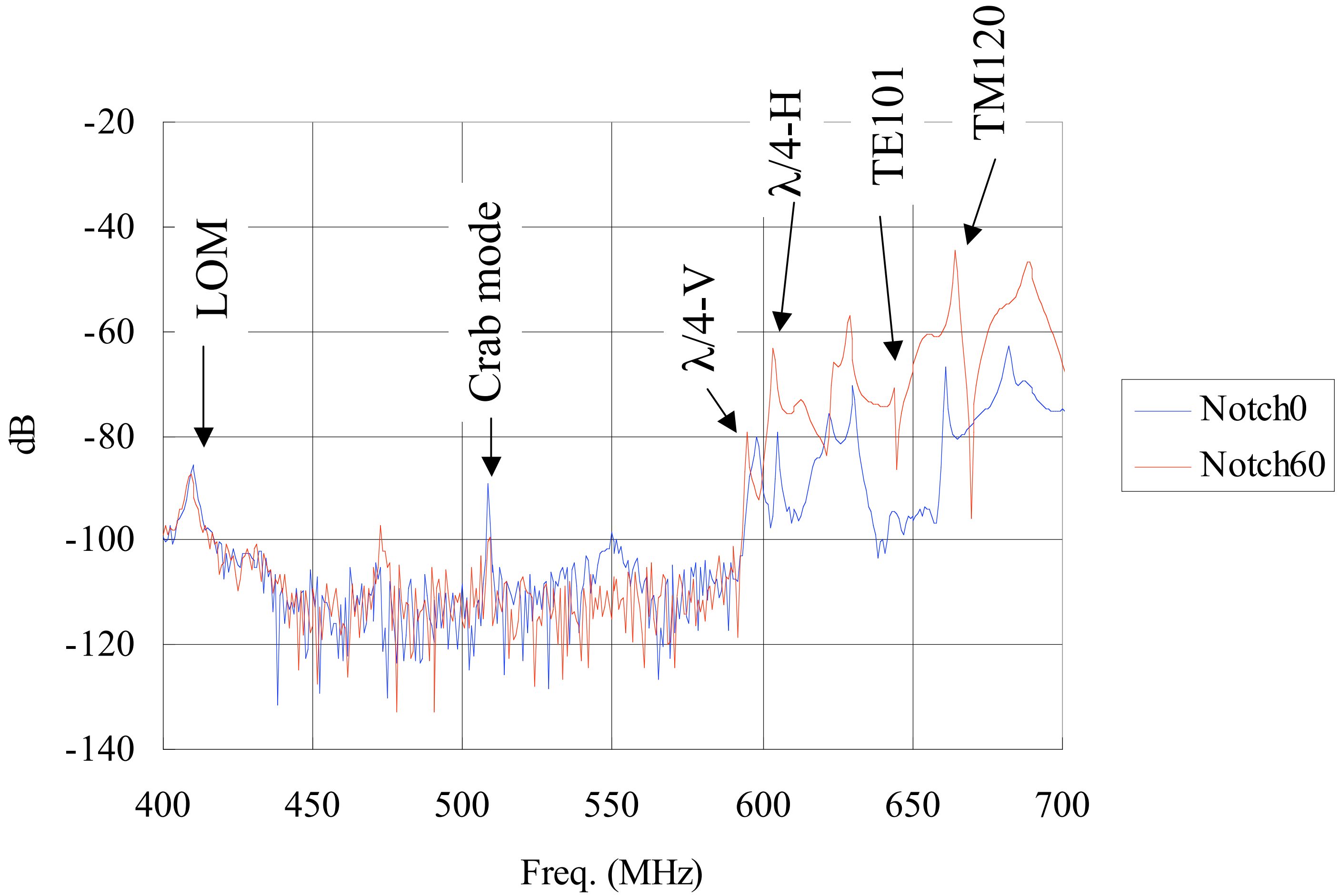
H-port

HER crab cavity
1st horizontal test*: 0°
2nd horizontal test: 60°

*Coaxial coupler:
not at designed position

Measurement Result (HER at RT)

V-port



Summary of measurement

-HER crab cavity at RT-

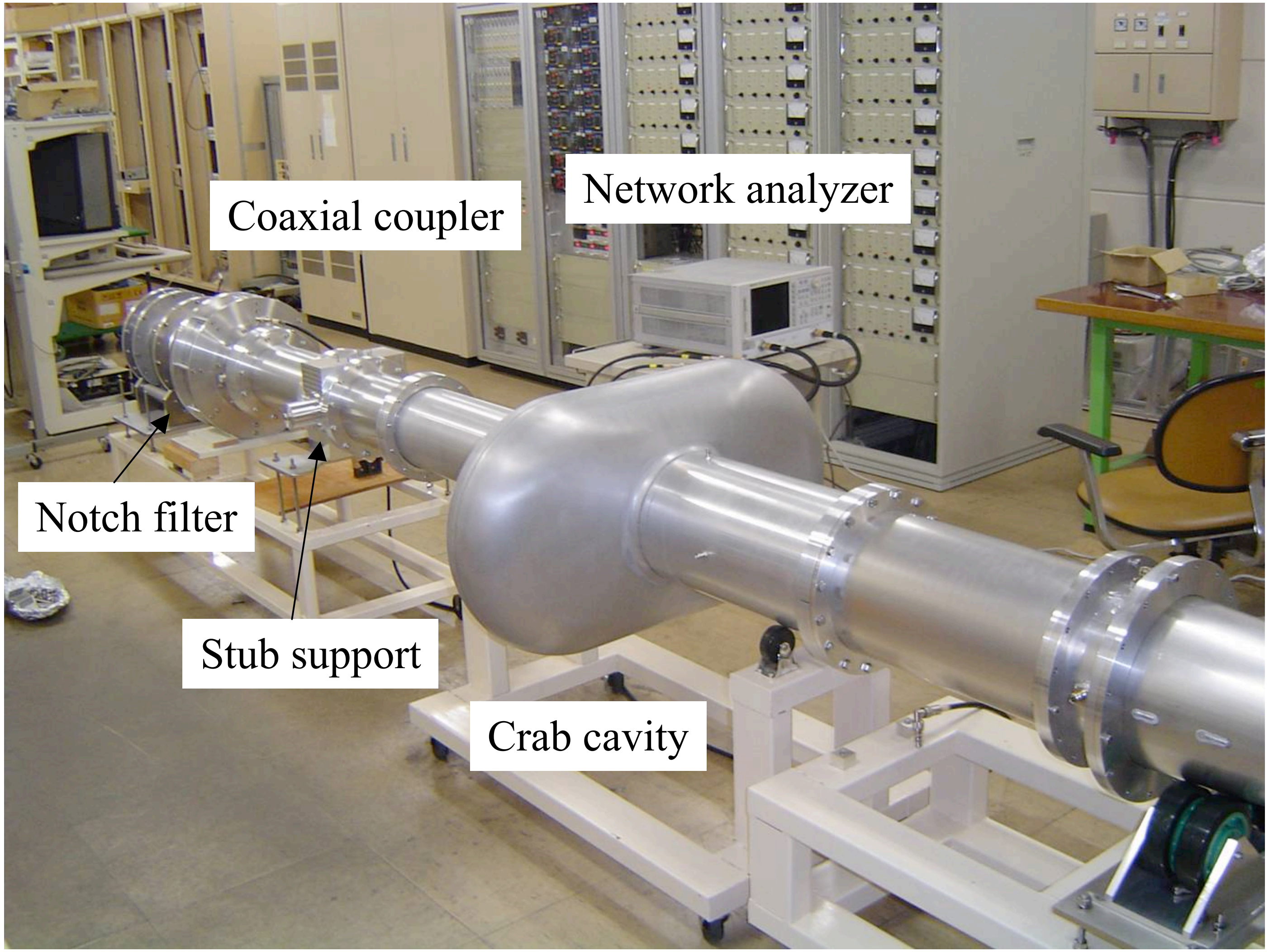
mode	R/Q	f and Q at 0^{o} *	f and Q at 60^{o}
LOM	80.1	409 / 164	409 / 142
λ/4-H	5.24	604 / 1257	603 / 893
λ/4-V	4.98	597 / 394	594 / 1329
TE101	10.33	642 / 327	643 / 721

*coaxial coupler: not at designed position

Acceptable for KEKB

Model cavity

Recently a model coupler was made to check the mode damping scheme.



Summary of measurement

-Comparison with calculation and model measurement-

Rotation angle: 0^o

mode	f and Q (calc.)	f and Q (HER)*	f and Q (model)
LOM	406 / 48	409 / 164	407 / 131
λ/4-H	602 / 5774	604 / 1257	602 / 1775
λ/4-V	597 / 1681	579 / 394	601 / 486
TE101	641 / 181	642 / 327	646 / 305

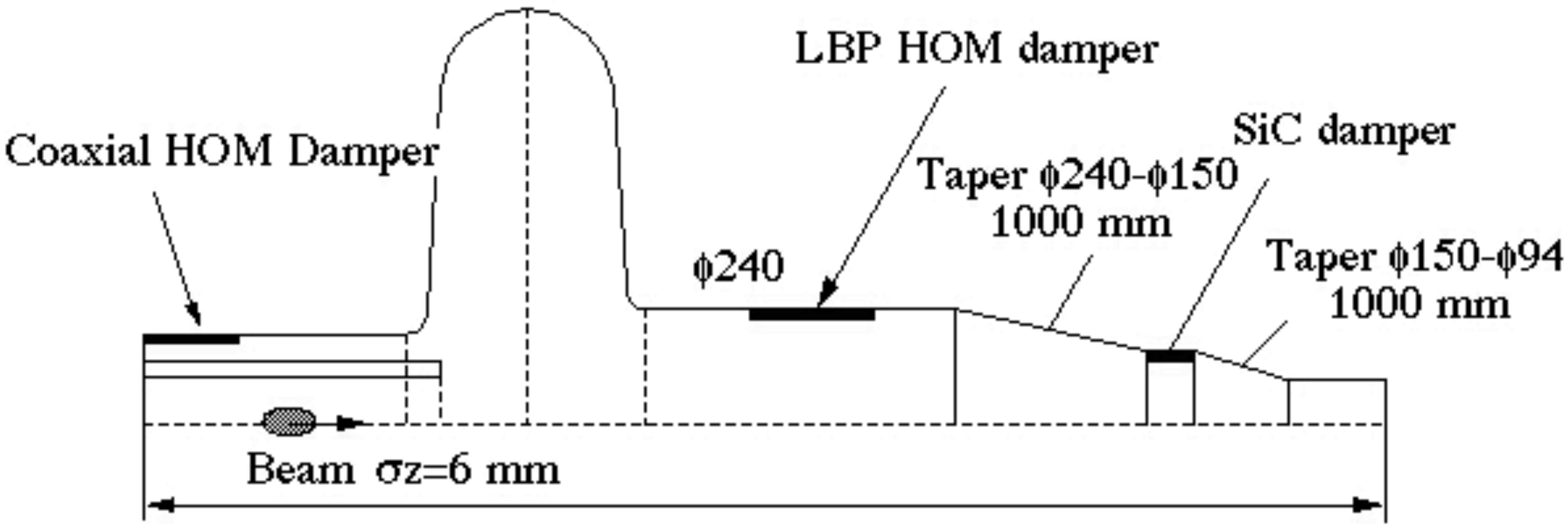
*coaxial coupler: not at designed position

Rotation angle: 60^o

mode	f and Q (calc.)	f and Q (HER)	f and Q (model)
LOM		409 / 142	407 / 133
λ/4-H	603 / 1687	603 / 893	602 / 886
λ/4-V	596 / 958	594 / 1329	600 / 653
TE101	642 / 850	643 / 721	647 / 889

Further investigation with model cavity

HOM Power

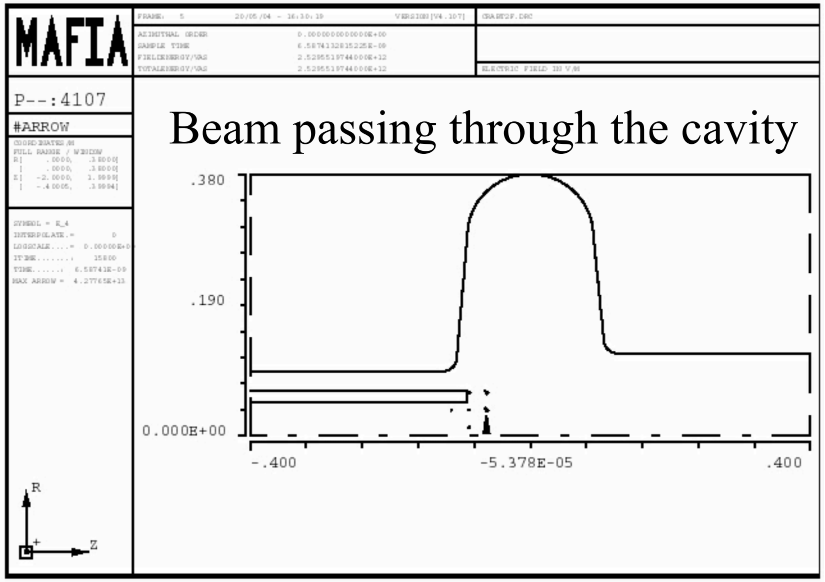


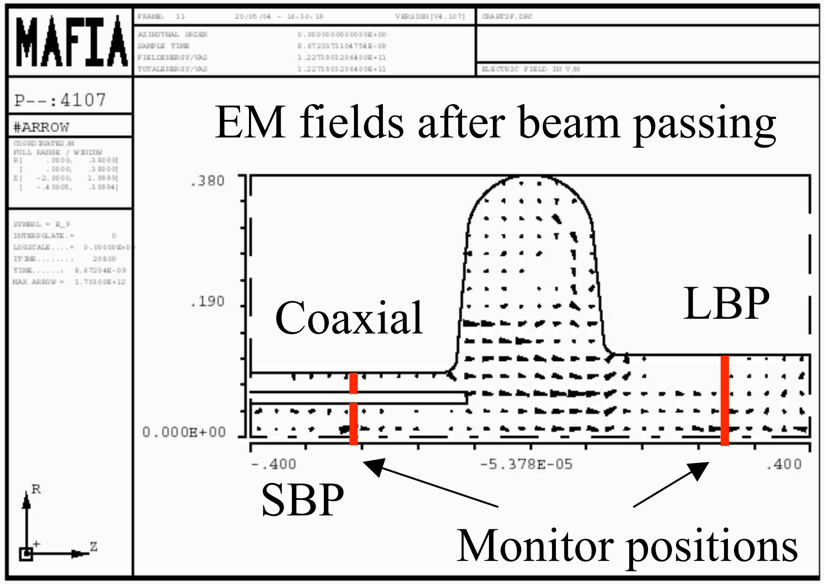
Loss factor: 0.85 V/pC (ABCI)

Coax: 0.2 V/pC
LBP: 0.65 + 0.25 = 0.9 V/pC

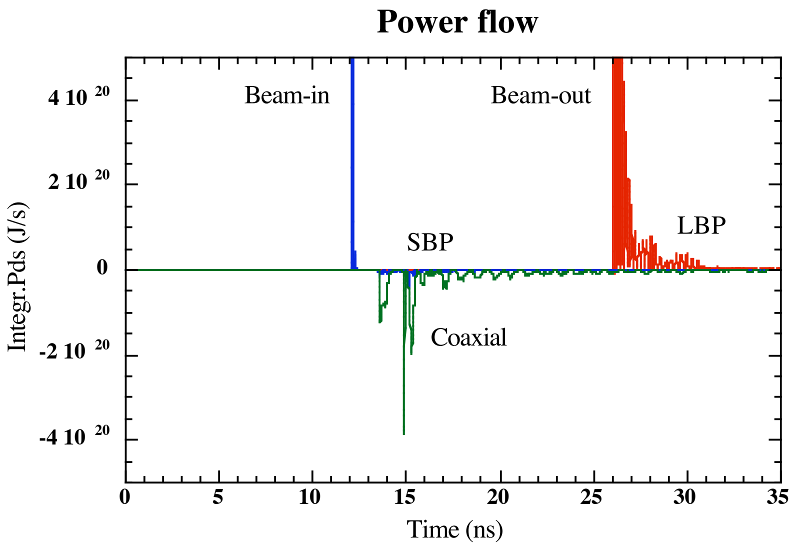
Damper loss

Power Flow Estimation

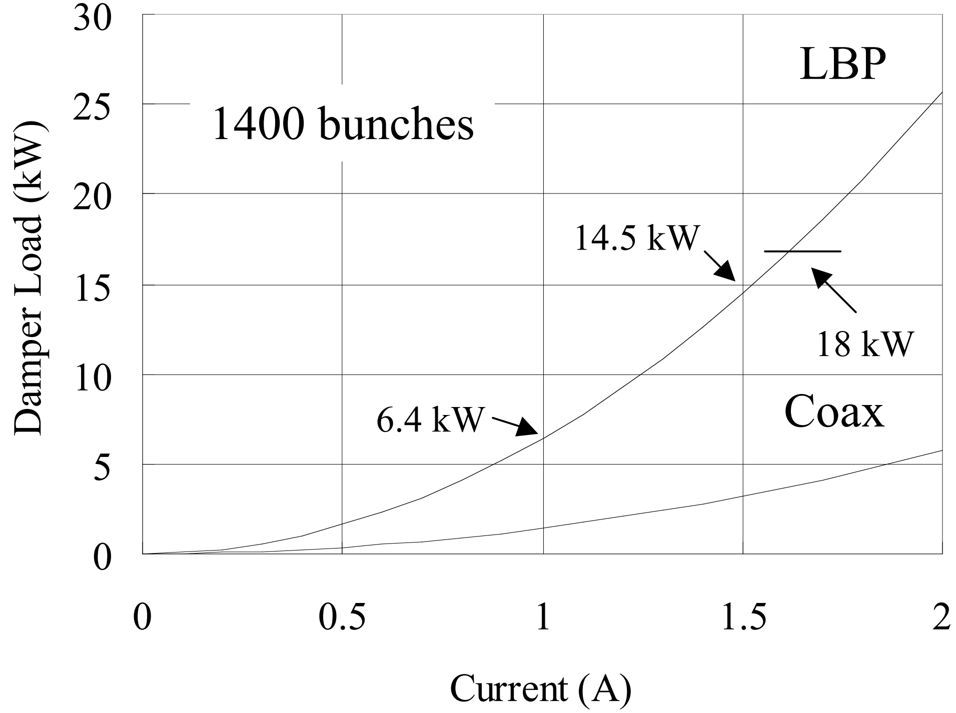




- Monitor E and B fields during beam passing
- Calculate the Poynting vector
- Integrate the Poynting vector on the monitoring surface



Expected HOM Load



HOM dampers for crab cavity
High power tested up to 10 kW
Capability up to 18 kW (Mitsunobu et al)

Summary

- Parasitic mode damping of the coaxial coupler
  - Rotation of the notch filter improves mode damping
  - Optimum rotation angle found
  - No need for tip cutting design ?
- HOM/LOM measurement
  - LOM: Q=142, larger than calculated Q value
  - $\lambda/4$ mode at 60^o: consistent with calculation
  - $\lambda/4$ mode at 0^o: significant discrepancy with calculation
  - Further investigation with a model cavity
- HOM power estimation
  - LBP: 6.4 kW, coax: 1.4 kW (1A, 1400 bunches)