Superconducting Accelerating Cavity for KEKB-HER

Jan. 23, 1997

T.Furuya

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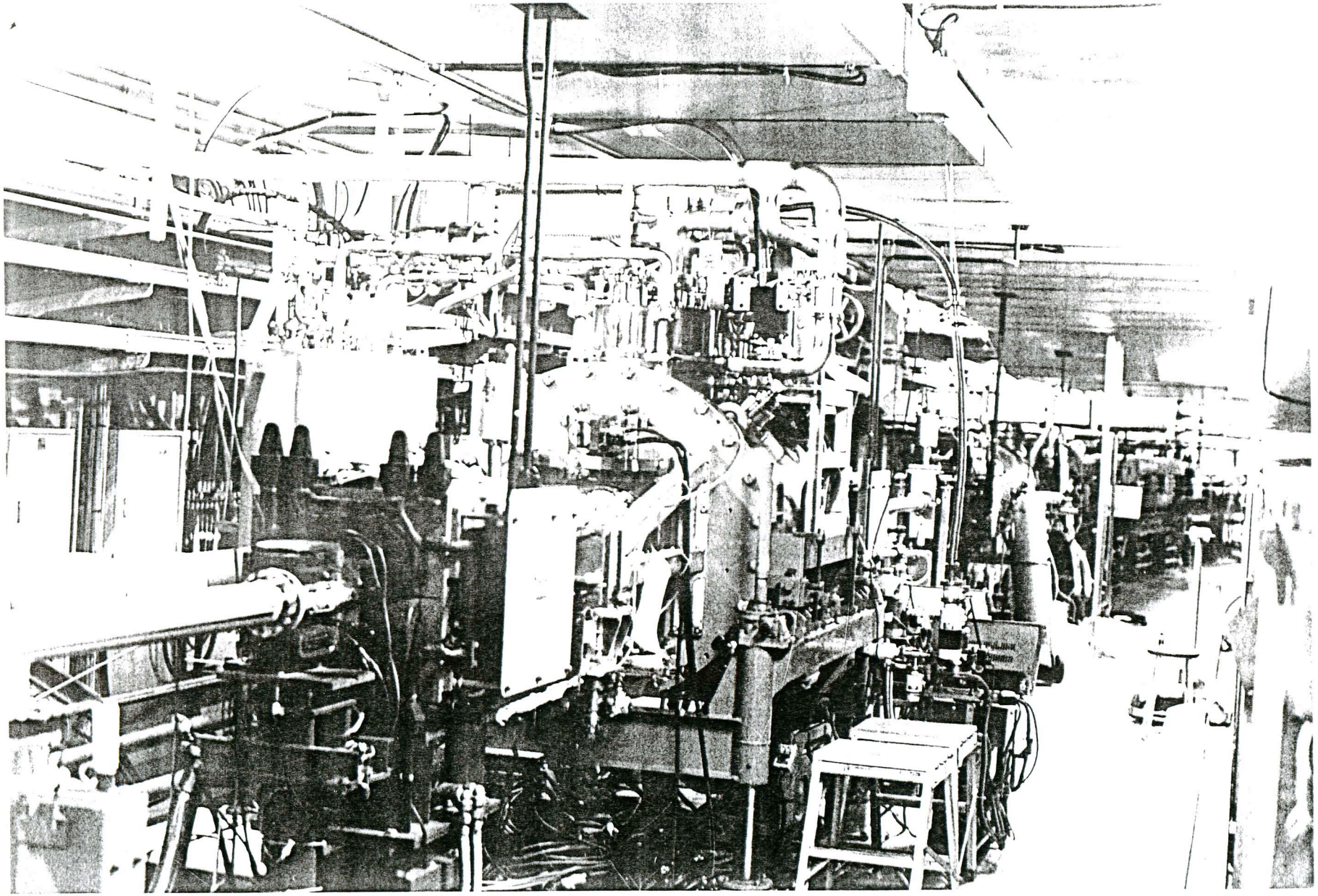


Fig. 1 A test module installed in TRISTAN Accumulation Ring(AR).

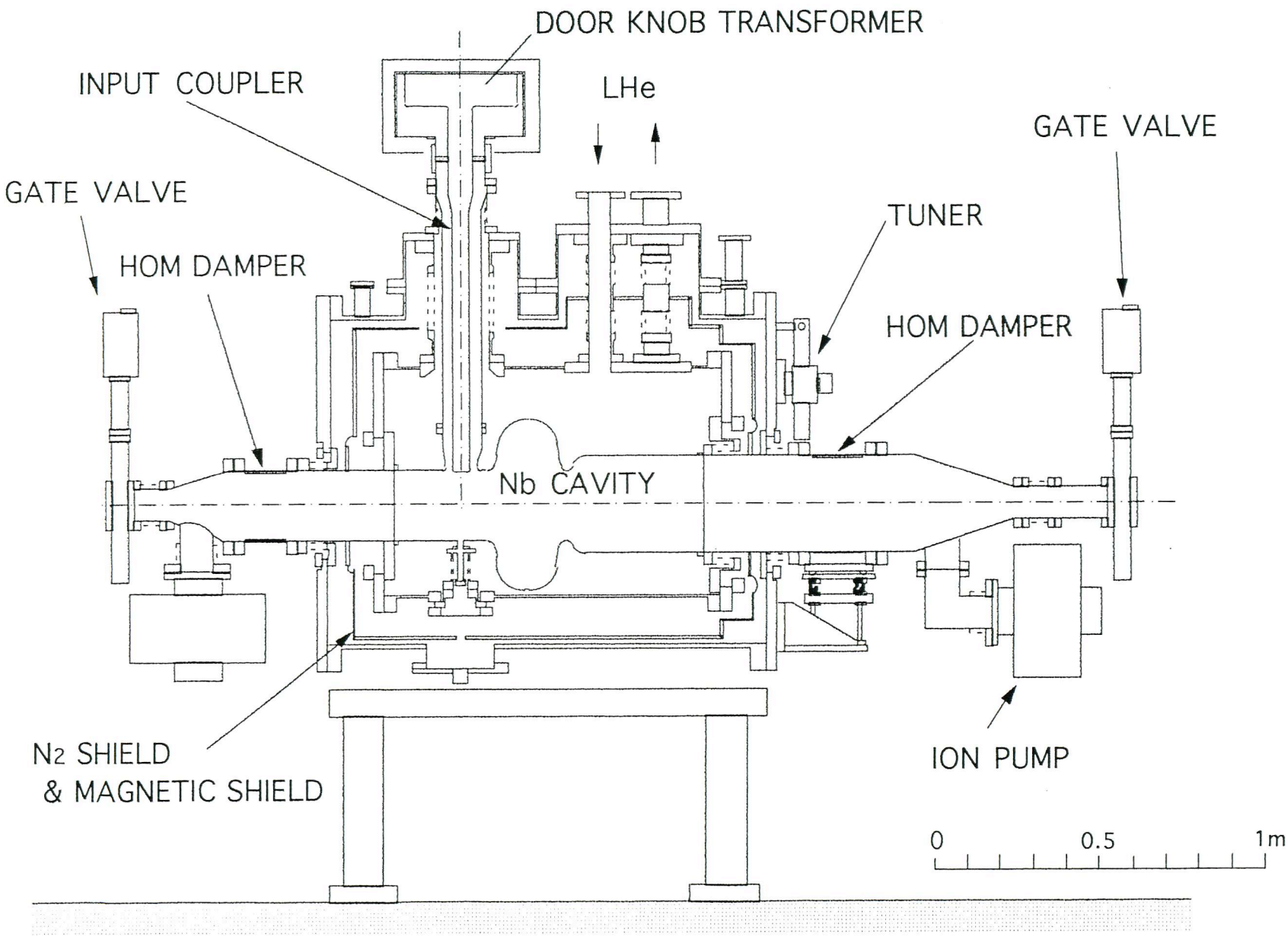


Fig. 2 Cross section of the AR test module.

Standing Wave in the Input Coupler '96 10/23 T.Furuya

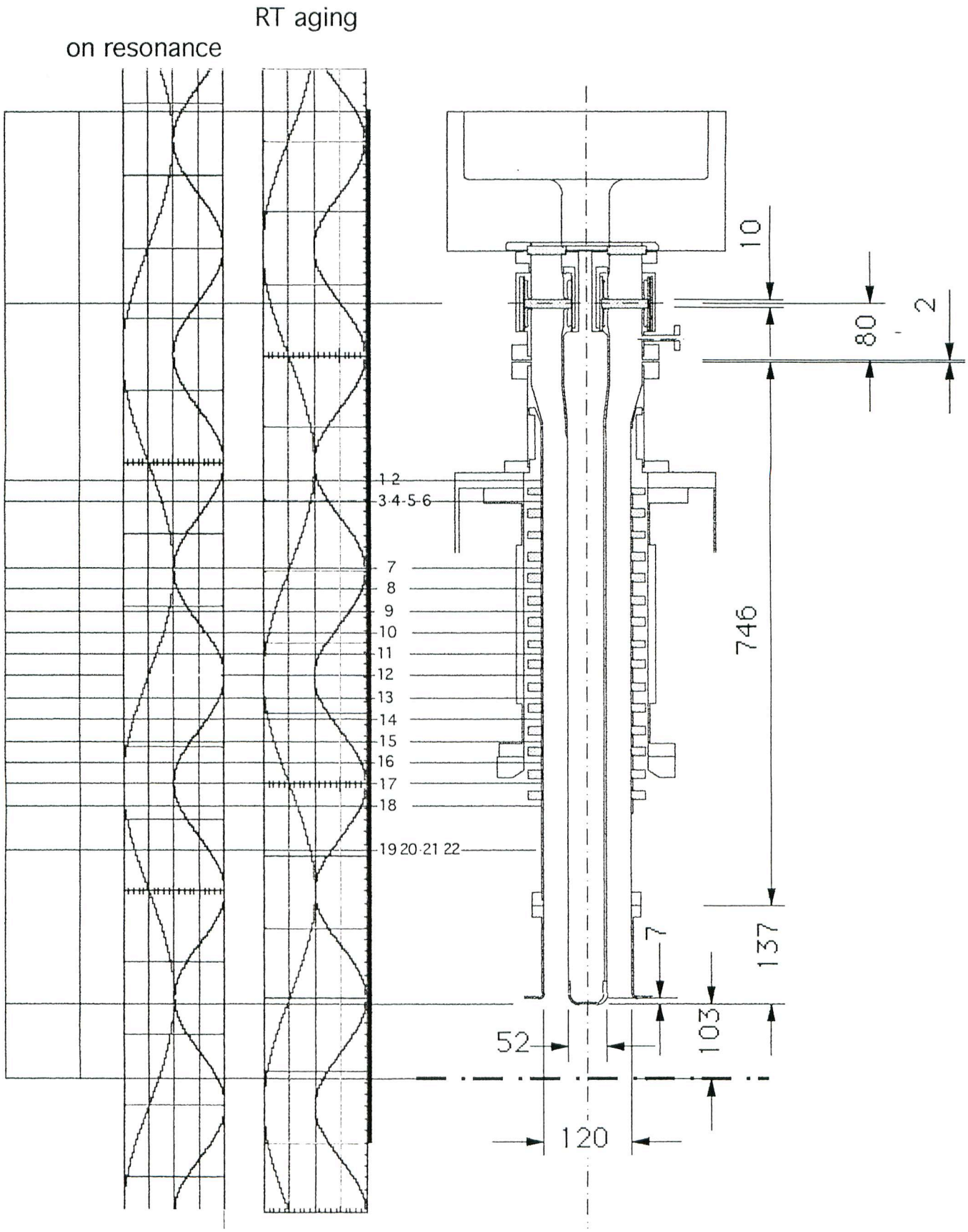


Fig. 2(b) Cross section of the input coupler.
The coupler has three monitoring ports just under the ceramic;
for electron probe, vacuum gauge and photo diode for coupler arc interlock.

1 Beam Test Outlook

1-1 Parameters of the SC Test Module

R/Q of accelerating mode($R=V^2/P$)		93 Ohm/cavity
gap length		0.243 m
Esp/Eacc		1.85
Hsp/Eacc		40.6 Gauss/(MV/m)
Qext of input coupler		8.9×10^4
frequency	coarse tuner(motor)	508.48 - 508.88 MHz
	fine tuner (piezo)	6.7 kHz
cryostat	LHe volume	290 liter
	static heat loss	30 Watts
max. accelerating voltage, Vc		2.9 MV (11.9 MV/m)
diameter of beam pipes		
	Large Beam Pipe(LBP)	300 mm
	Small Beam Pipe(SBP)	220 mm
HOM damper (IB-004 ferrite)		
	for LBP	4t x 300f x 150 mm
	for SBP	4t x 220f x 120 mm
total length (GV-GV)		3158 mm
diameter of beam ducts		100 mm

1-2 Beam Test Outlook

	period	beam total	beam by SC	comments
1st	Mar. 28 - Apl. 2 (6 days)	80hours	30hours	system check single bunch study max. current of 110mA(s=8~9cm) current limitation due to HOMs of the APS cavities Cavity was warned up to 85K (Mar.30 ~ 31)
2nd	Jul. 1 - Jul.22 (22 days)	340hours	200hours	multi bunch study 500mA in 16 bunches limitation: ring vacuum and heating of ring components acceleration to 3.5GeV RF power to the beam was 160kW frequent RF trips due to coupler arc I/L twice of warming up to 85K: Jul. 5 and Jul. 16
3rd	Oct.17 - Nov. 11 (26days for ARES) Nov.11 - Dec. 2 (22 days for SC)	600hours	290hours	improvement of duct vacuum on both sides change a door knob transformer to a bias-type. Before the SC study, the cavity was warmed up to to R.Temp. Limitation of the beam was heating up of ring components. 500mA with 1~2MV/cav (4.1 ~ 8.2MV/m) 350mA with 2.5MV/cav (10.3MV/m) Max. current of 573mA with 1.2MV Max. HOM power absorbed by dampers was 4.2kW.
	total	1020hours	520hours	

2 Summary of Figures

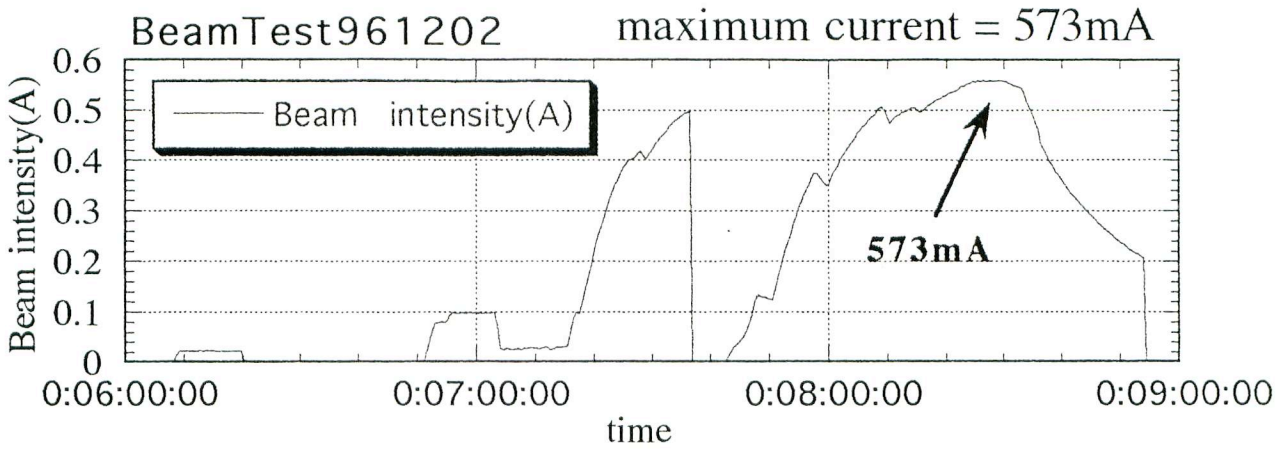
single bunch current	110mA (1.4E-07 C/bunch)	1st beam test, Vc=2MV(8.2MV/m) Bunch charge is 64 times higher than that of HER(2.1E-09).
total beam current	max. 573mA (4.5E-08 C/bunch)	3rd beam test, Vc=1.2MV, 16 bunches limitation: radiation alarm
HOM power	max. 4.2kW	3rd beam test, Vc=2MV, 490mA in 16 bunches, σ=4.2cm average power of 2~3kW during the high current study
Acc. field no beam with beam	2.9MV(12MV/m) 2.5MV(10.3MV/m) 1~2MV	limitation: coupler arc, Pcav of > 250W 350mA in 16 bunches 500mA limitation: heating of ring components
input coupler aging with beam	 Pin = 280kW Pin = 270kW Pbeam = 160kW	Qext = 8.9E+04 under perfect reflection 3.5GeV, 240mA, Vc=2.3MV 3.5GeV, 280mA, Vc=1.6MV Pin = 217kW

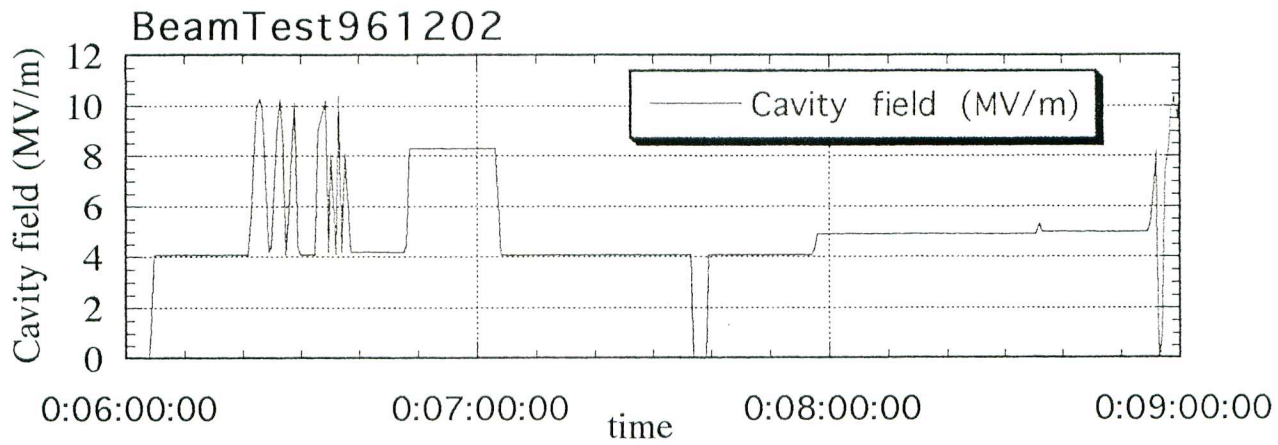
* HOM search

frequency search: The resonant frequency of the cavity was swept from 508.48 to 508.88MHz.

orbit search: The beam orbit was bumped by ±10mm in horizontal and ±4mm in vertical.

Nothing happend to both cavity and beam.





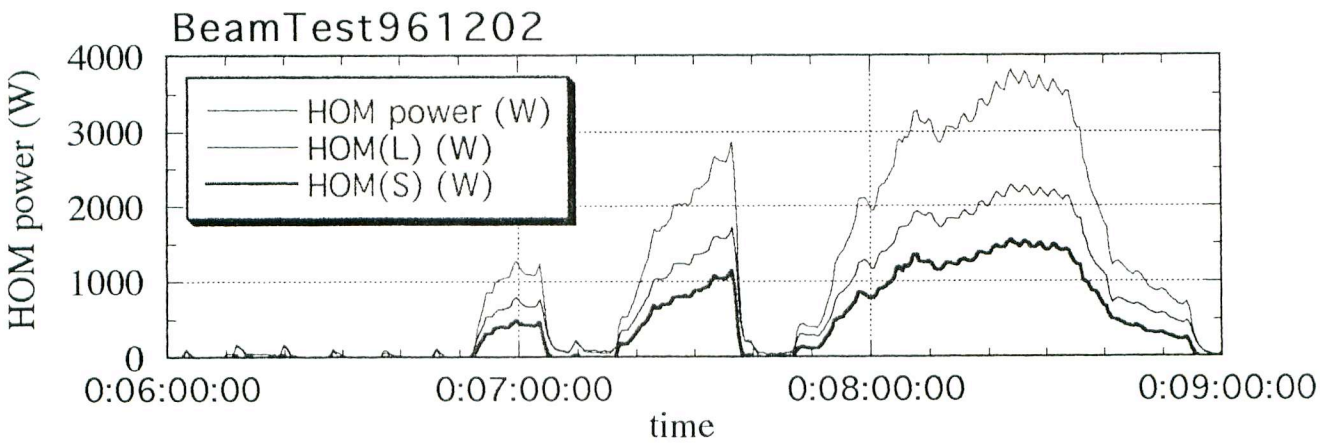
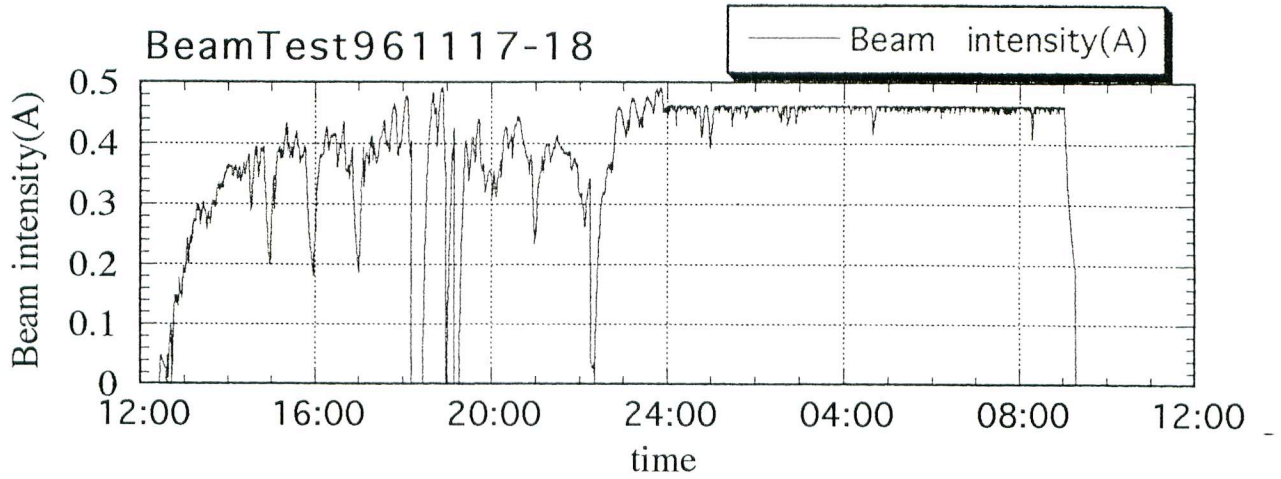
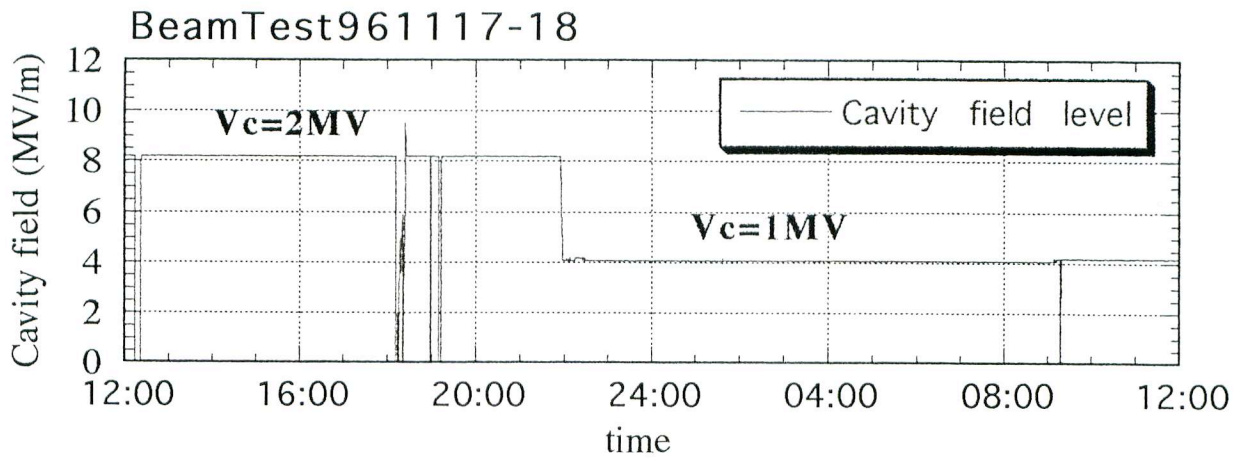


Fig. 3 Data of a maximum current of 573mA .





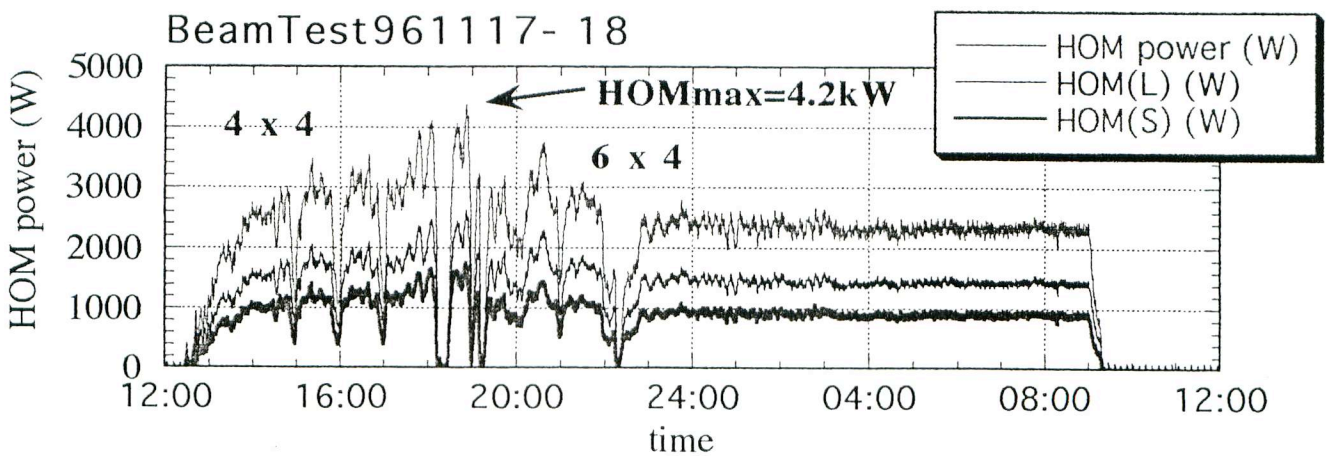


Fig. 4 Data of a maximum HOM power.

3 Other Results

3-1 cavity loss

* Cavity loss was obtained from a LHe consumption rate.
  Fig. 5 Q_0 without a beam obtained at various stages.
  Fig. 6 Power loss obtained from a LHe consumption rate.
* Additional loss related to a beam intensity was observed(Fig. 7).
* Study
  1) acceleration to 3.5GeV (related to synchrotron light(SL)?)
  2) change the number of bunches(8, 16, 24) (to HOM?)
  3) deflection of photo electrons using small coils (to SL and its electrons coming into the cavity?)
  4) supply a DC bias voltage to the input coupler (heating due to the multipacting in the coupler?)
  5) cavity detuning (increase input power from 116kW to 208kW)

  These tests showed no difference of additional loss.

* The mechanism of this loss is still not clear, but it seems not to be a serious problem for 1.1A of HER.

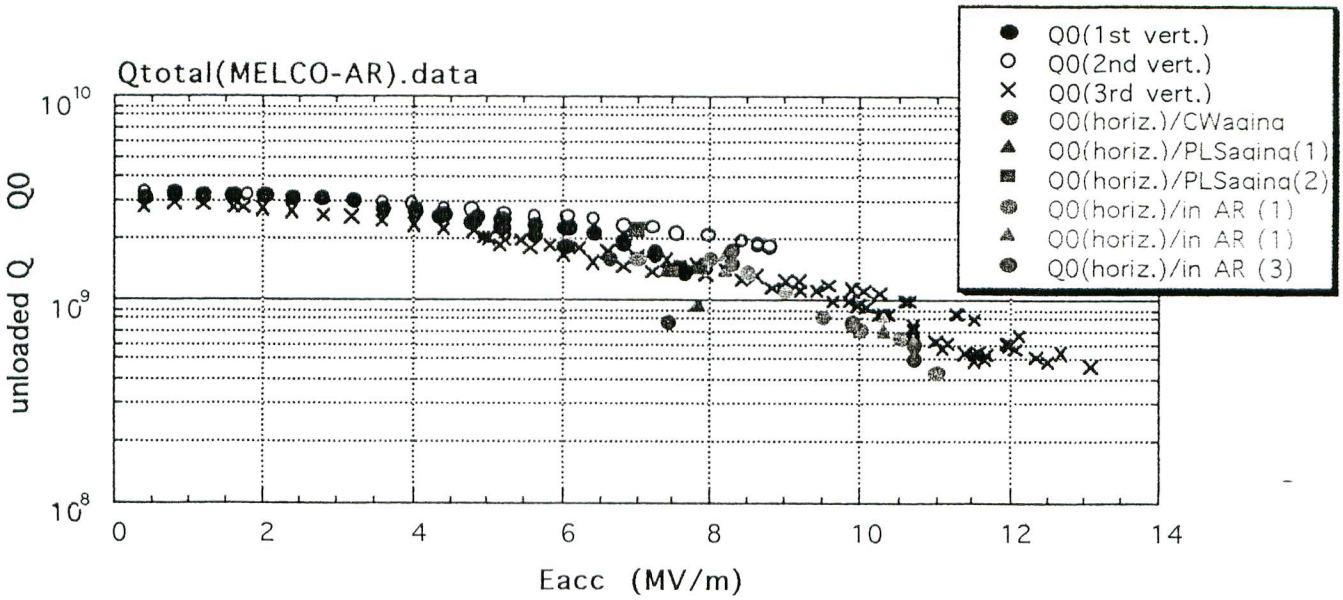


Fig.5 Unloaded Q measured at verious stages.

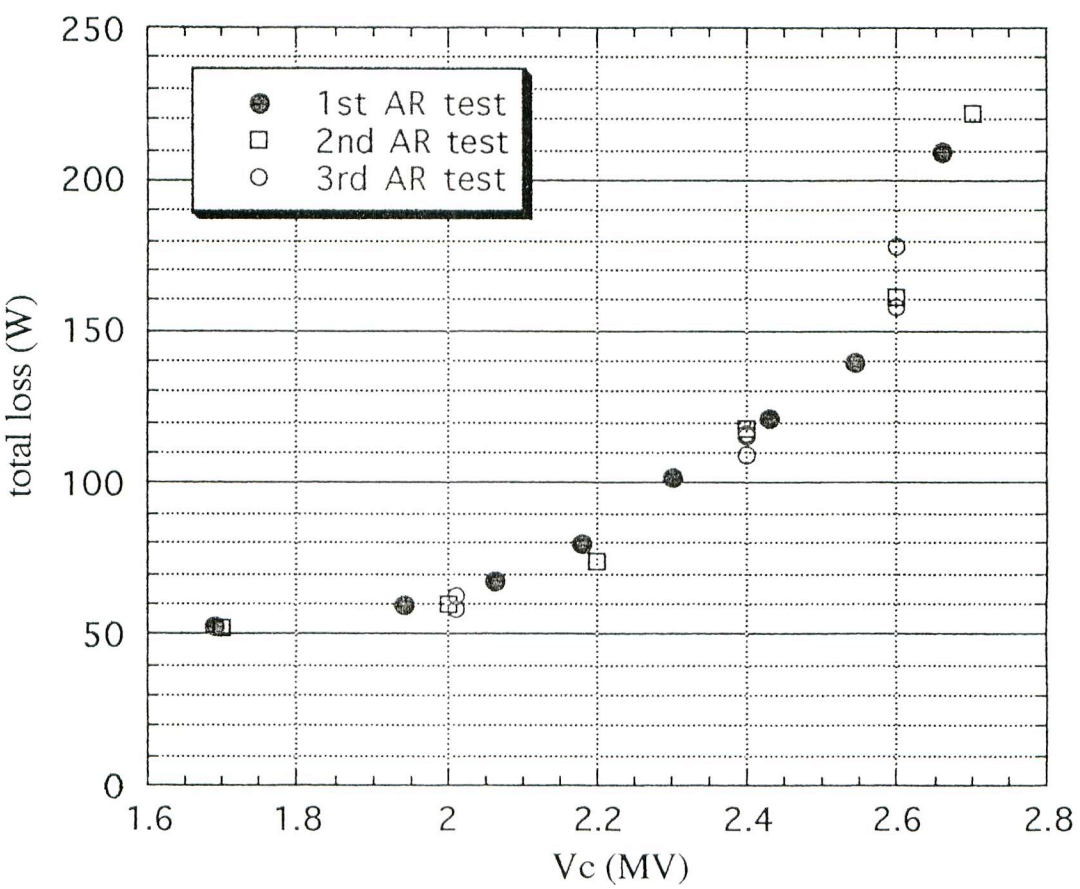


Fig.6 Total power loss obtained from a LHe consumption rate.

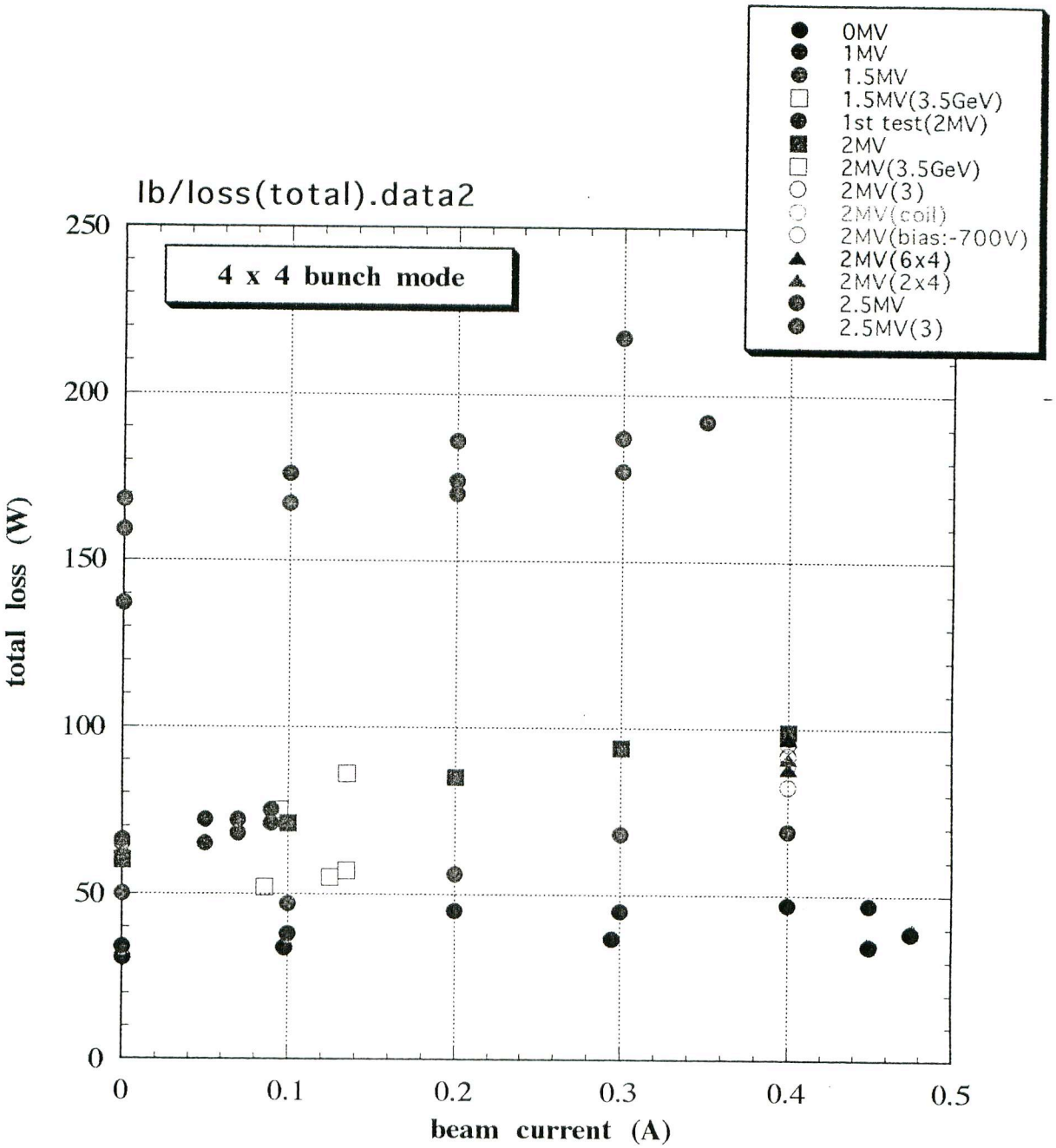


Fig. 7 Additional loss related to the beam intensity.

3-2 RF trip

* During the 1st and 2nd beam test, we were suffered from frequent RF trips due to the coupler arc I/L.
* To continue the test, warming up or frequent aging processes had to be given to the cavity and coupler.
* A large amount of gas came out from the cavity by warming up.
  The trip was suppressed by increasing a flow rate of the cooling gas of the outer conductor.
  Tuning angle of the cavity seemed to have some effect to the trip rate.

  These results suggested that the coupler arc was caused by the discharging due to the condensed gas around the coupler.

* Before the 3rd beam test,
  a) improvement of a vacuum pressure of the neighboring beam ducts.
     increase the number of pumping units from 2 to 6,
     surface polishing and rinsing (O_3) of ducts,
     baking of the ducts,
  b) changing a door knob transformer to a bias-type one to give a DC voltage between conductors for suppressing the multipacting in the input coupler.
* Results

1) The trip rate reduced drastically.
   Several times of trips happened at the begining of the 3rd test.
   After that, no trip happened except for the trips caused by beam off.
   As a result, the effect of the new door knob transformer was not verified.
2) Improvement of a vacuum pressure of the beam ducts
   Fig.9 vacuum pressure at 2nd test.
   Fig.10 vacuum pressure at 3rd test.
3) Effect of a DC bias voltage
   Fig.11 DC biasvoltage suppressed the trip?

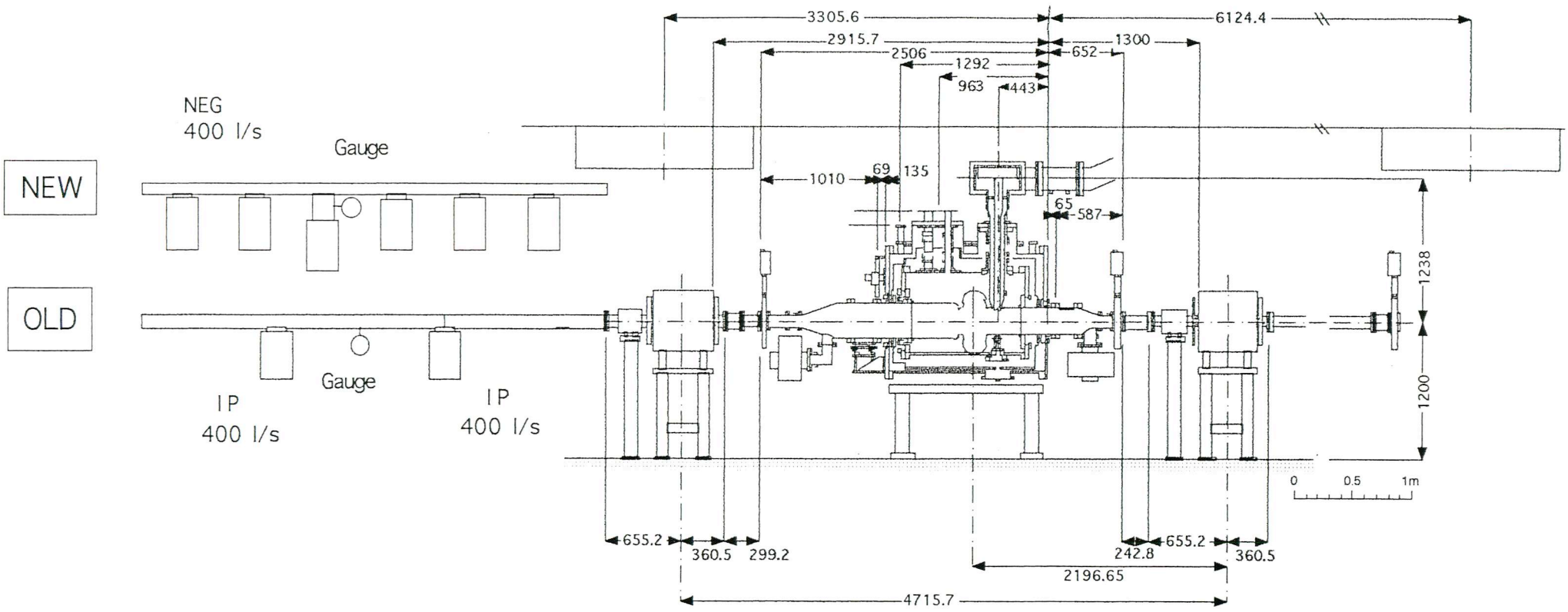


Fig. 8 Improvement of pumping system for the neighboring sections.

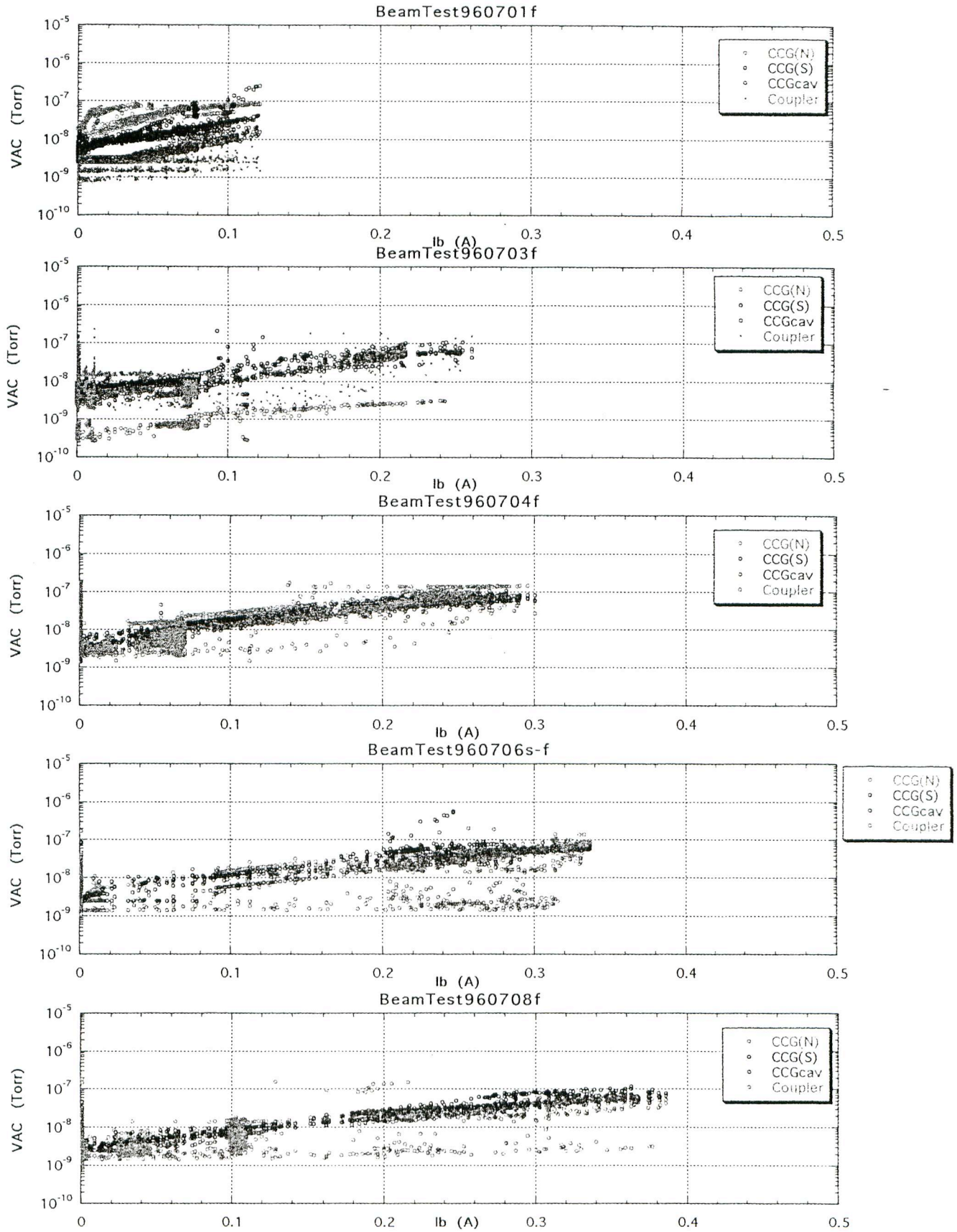


Fig. 9 Vacuum pressure vs beam intensity at 2nd test.

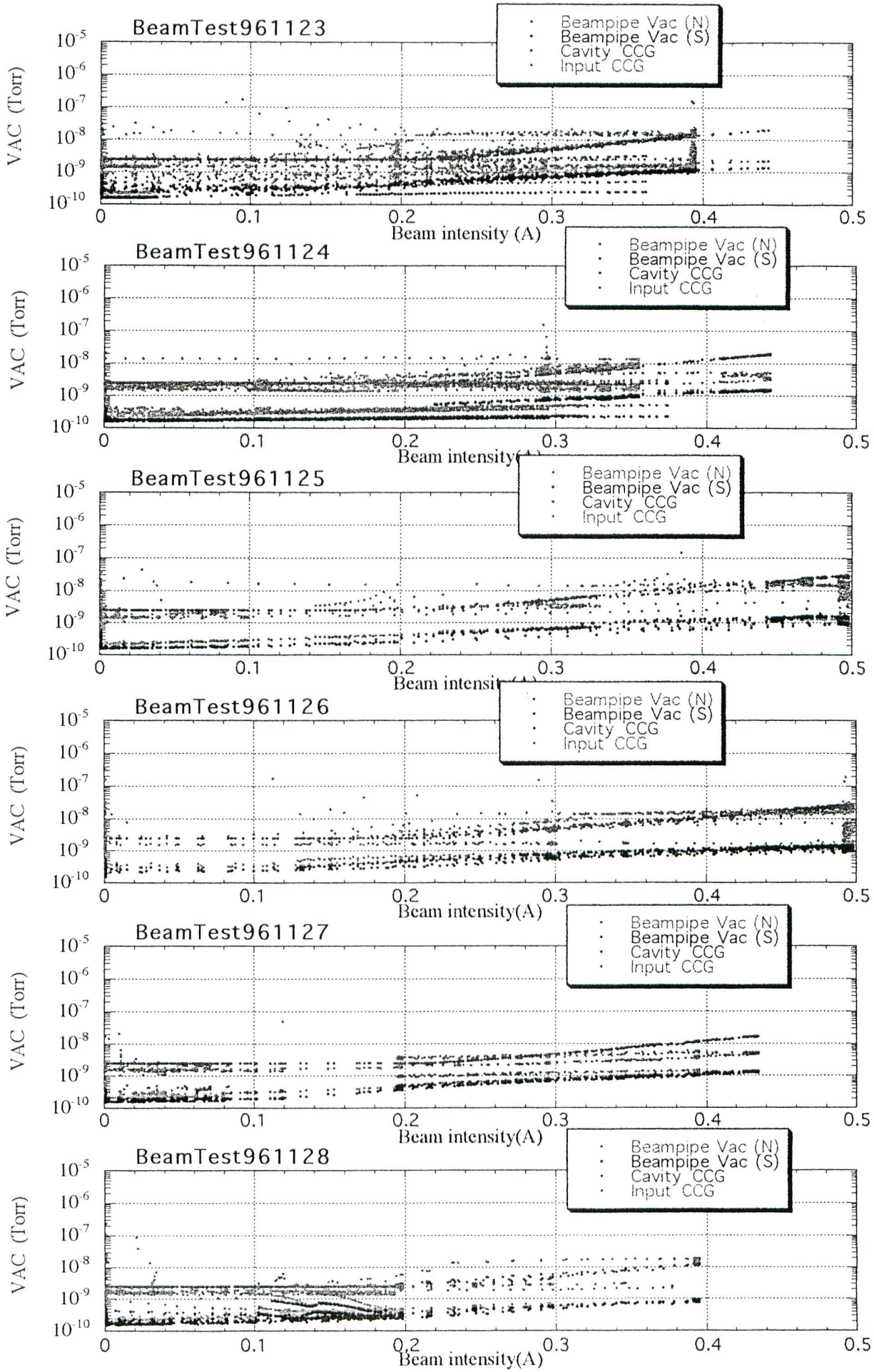
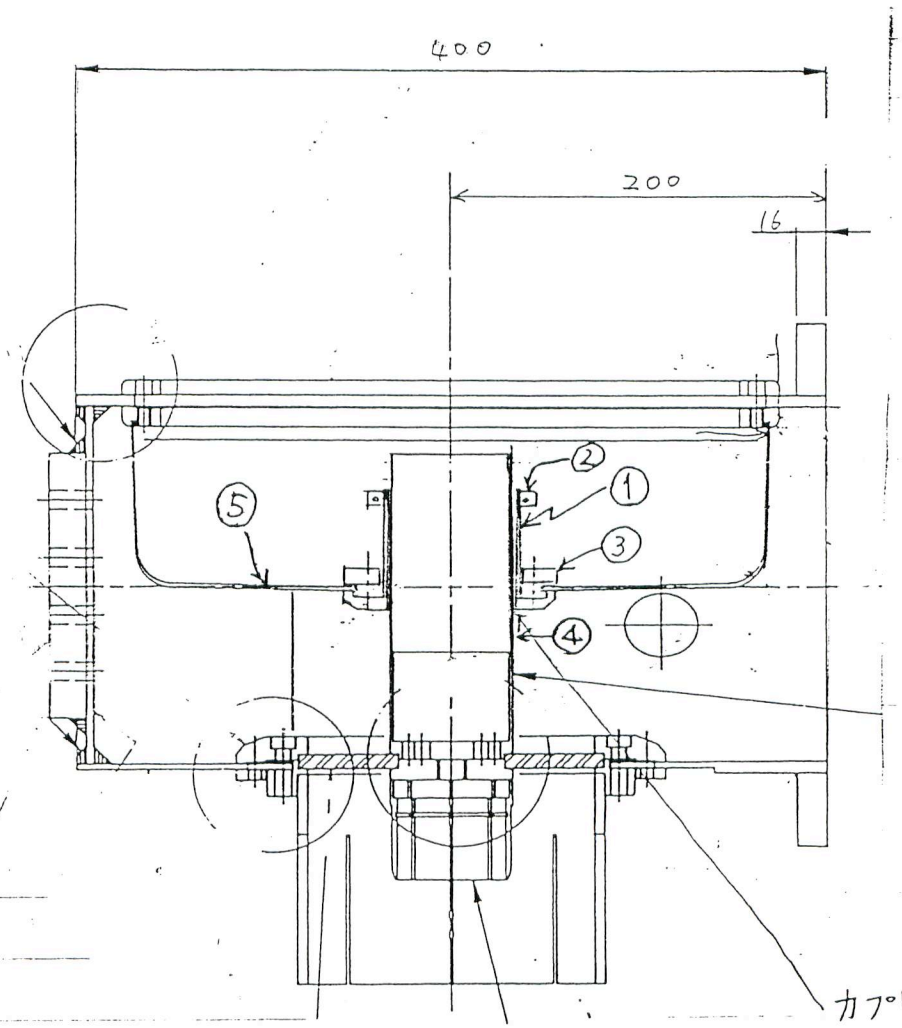


Fig. 10 Vacuum pressure vs beam intensity at 3rd test.

超伝導空洞入力結合器　バイアス電極



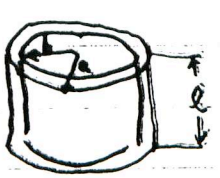
円筒コンデンサー

$$C = 2\pi\varepsilon \cdot \ell \Big/ \ln\frac{a}{b}$$

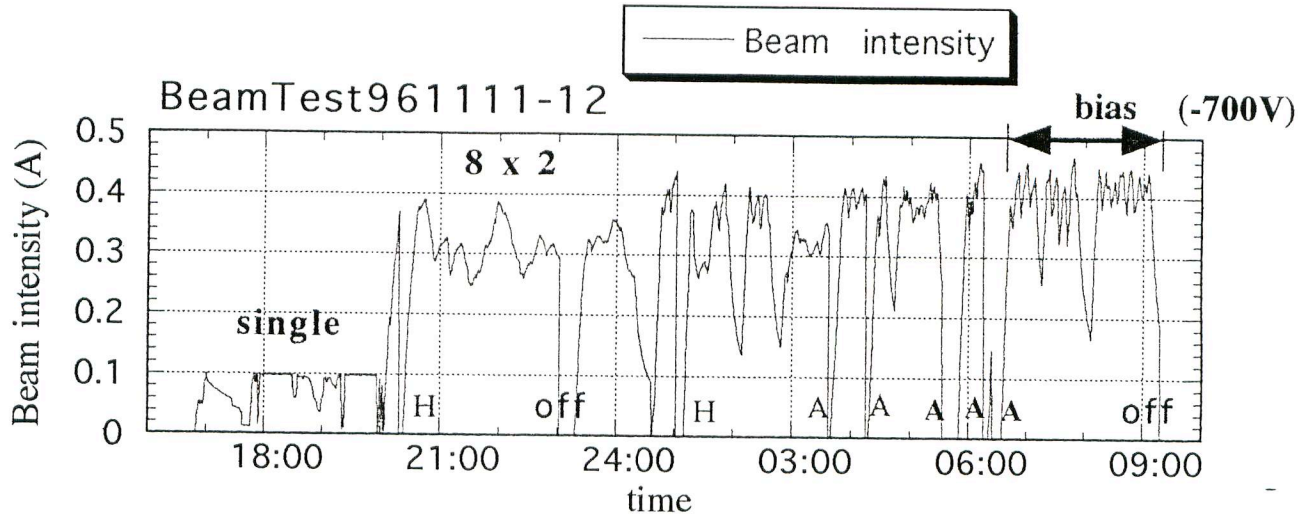
ε : カプトン　3.45

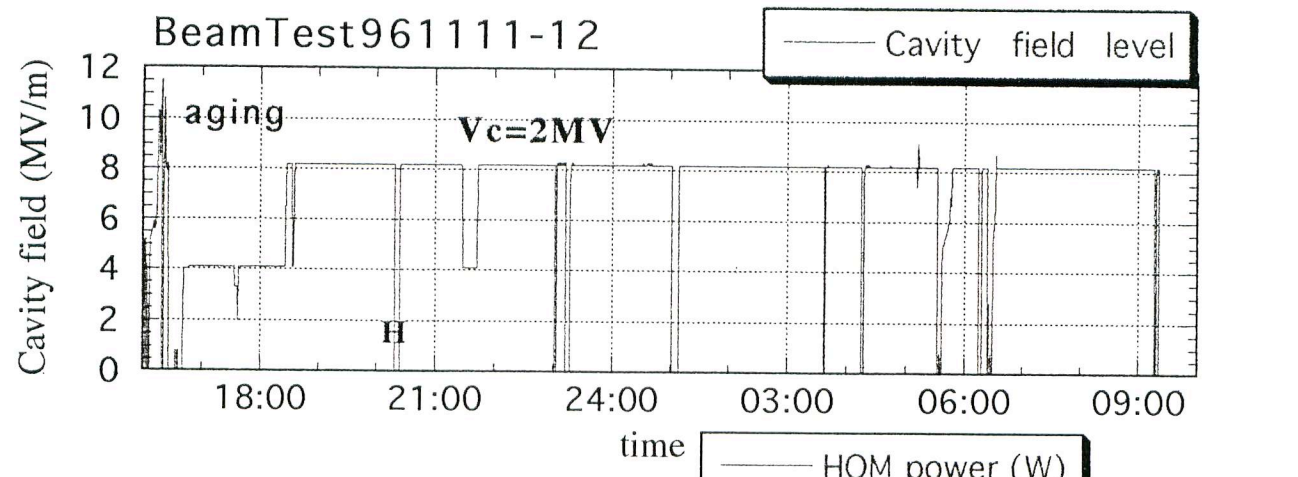
$\ell = 60\,mm$

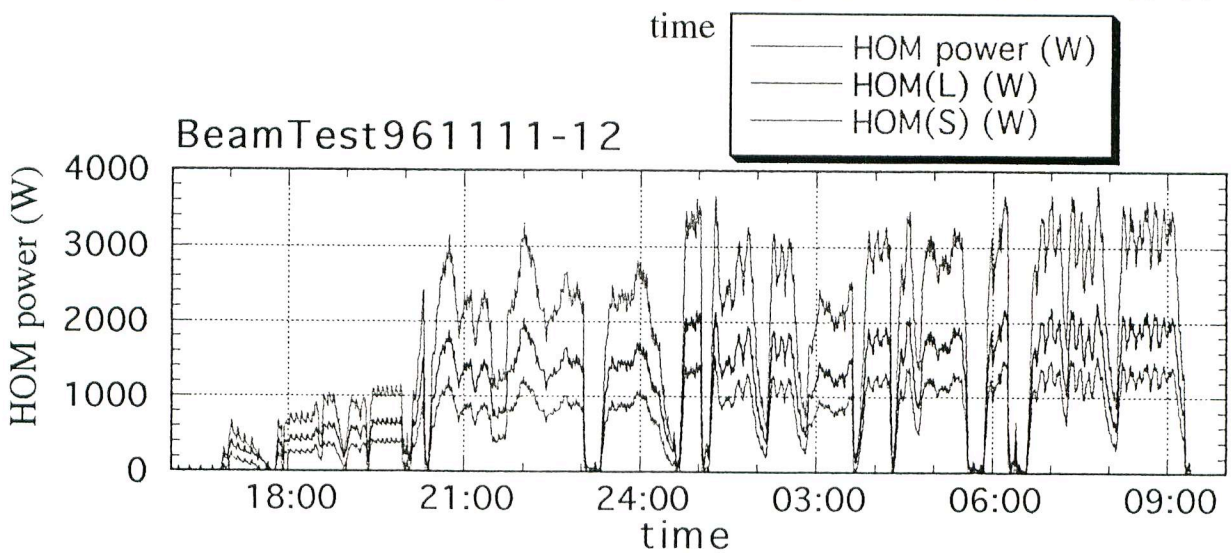
$C = 1.52 \times 10^{-9}\ (F)$



$a = 66.5$, $b = 66$


Beam intensity
BeamTest961111-12
bias (-700V)
Beam intensity (A)
0.5
0.4
0.3
0.2
0.1
0
8 x 2
single
H
off
H
A
A
A
A
A
off
18:00
21:00
24:00
03:00
06:00
09:00
time


BeamTest961111-12
Cavity field level
Cavity field (MV/m)
12
10
8
6
4
2
0
aging
Vc=2MV
H
18:00
21:00
24:00
03:00
06:00
09:00
time


HOM power (W)
HOM(L) (W)
HOM(S) (W)
BeamTest961111-12
HOM power (W)
4000
3000
2000
1000
0
18:00
21:00
24:00
03:00
06:00
09:00
time

4 Conclusion

4-1 Cavity

* Stable operation of the cavity voltage up to 2MV with 500mA, and 2.5MV with 350mA without any problem.
  These currents were limited by heating up of other ring components.
  The desired voltage for HER is 0.9 - 1.6MV/cavity in the full SC version.
  The maximum stored current of 573mA is just the half of our goal for HER.
* No change of cavity performance.
* Frequent RF trips happened at 1st and 2nd test.
  This trip was caused by a large amount of condensed gas from the ring.
  The trip can be suppressed by the improvement of vacuum pressure of the neighboring sections(~1 x 10^{9} Torr).

* The vacuum circumstance around the SC cavities is the most impotant factor for the stable operation of SC cavities.

4-2 HOM damper

* HOM modes were damped sufficiently.
  No beam instability caused by the SC cavity was obserbed.
* No degradation or change of damping characteristic was observed.
* The HOM power absorbed by a pair of ferrite dampers reached to 4.2kW.
  (Vc=2MV, 490mA in 16 bunches, s=4.2cm, k=0.22V/pC)
  The absorbed power was obtained using the temperature and flow rate of cooling water.
  The temperature of the ferrite surface is estimated as about 50°C for the tested flow rate of 2l/min.
  For the designed flow rate of 5l/min, this temperature rise corresponds to the total power of 8kW.
  (Each dampers had been tested to 15kW of TM01 at a test stand.)
* HOM power in HER
  Loss factor was measured for the bunch length of >1.5cm.
  Measured loss factor was as expected or below(Fig.12).
  This module has a loss factor of 2.9V/pC for a bunch of 4mm.
  2.9V/pC=2.3(ABCI) + 0.6(ferrite)
  This loss factor can be reduced to 1.8V/pC in HER(Fig.14);
  by using longer tapers
  larger diameter of beam ducts at RF sections(150mm)
  The HOM power due to the loss factor is 4.4kW.

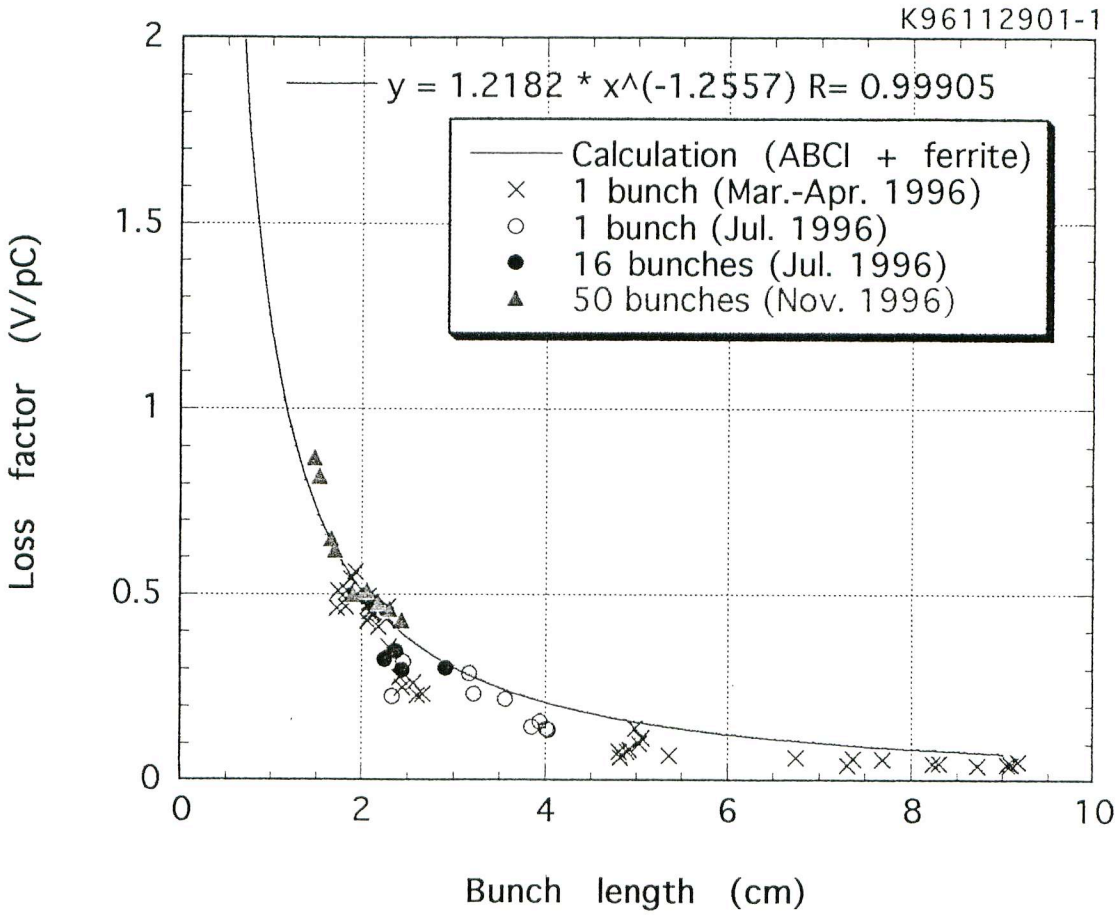


Fig. 12 Loss factor of the AR test module.

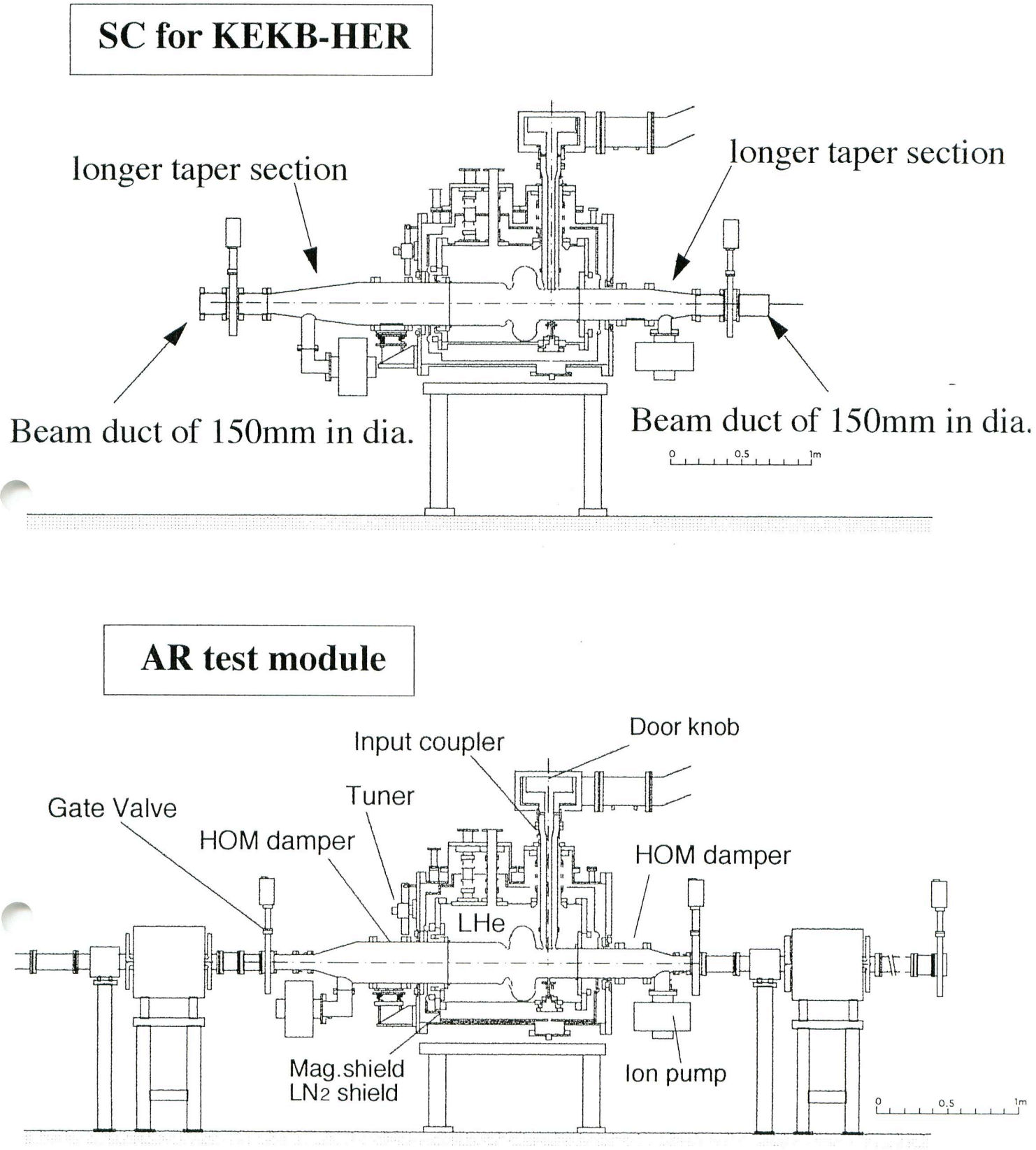


Fig. 13 A sketch of a module for HER.
The module has the same dimensions as the AR test module, except for the length of tapers and a diameter of beam ducts.

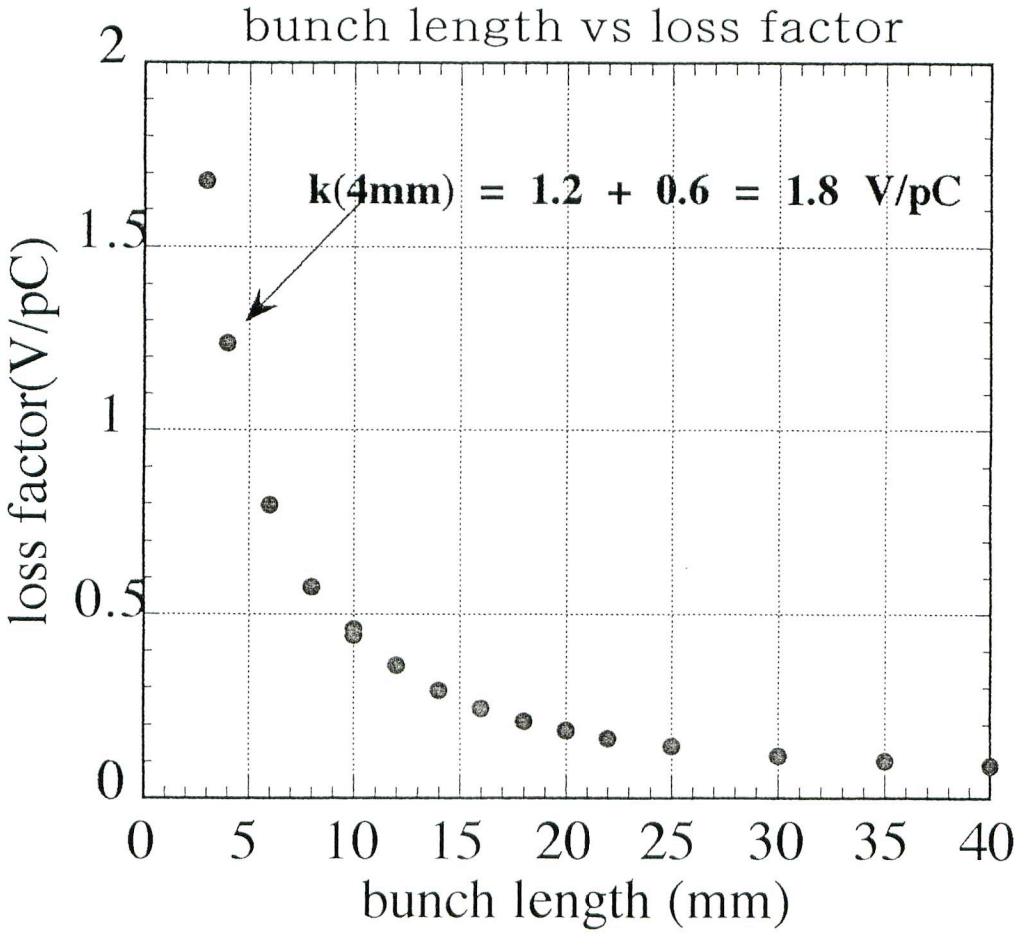


Fig. 14 Loss factor of a HER module.

4-3 Input coupler

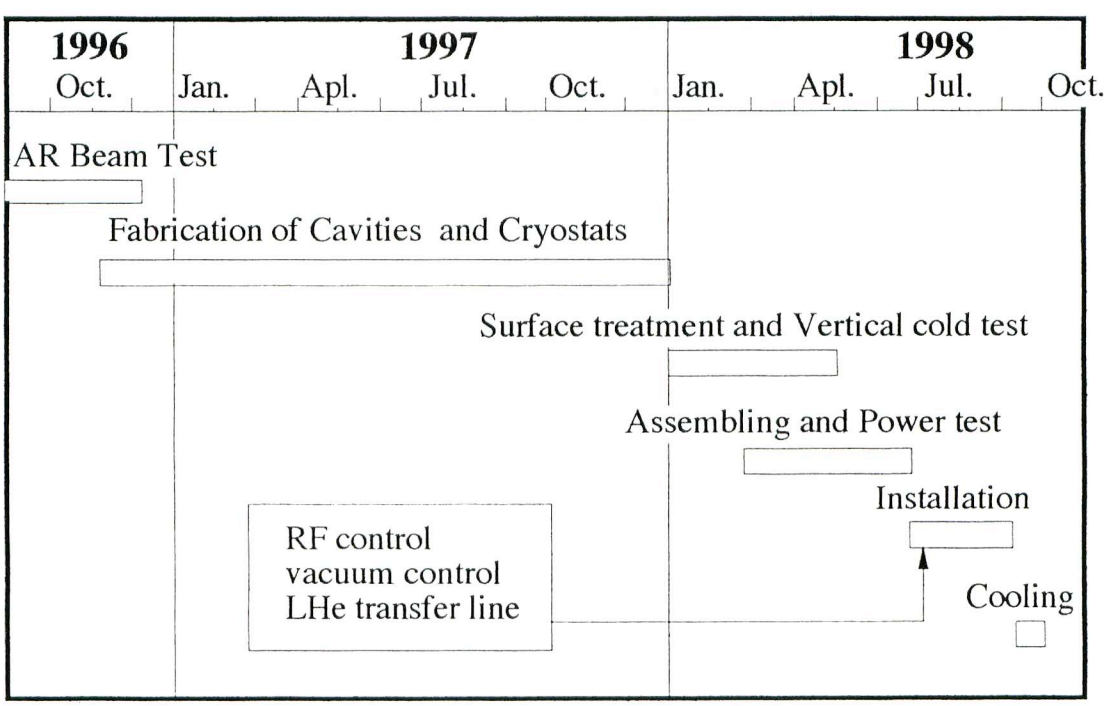
* Maximum RF power supplied to the input coupler;
  a) 280kW at the cavity aging process under perfect reflection.
  b) 270kW with beam.
* The required handling power is 500 - 600kW in HER.
  Almost half of the required power was achieved at this beam test.
  But we have to give more R&D to the coupler and a door knob transformer.

4-4 Low level control system

* The system used for the test was the same as that for TRISTAN cavities.
* The system could change the cavity voltage and the phase smoothly.
* Detail will be reported in the later session.

4-5 For commissioning

* Fabrication of 4 module has started for commissioning.
* These modules will be installed in the summer of 1998.
* The design of whole system is underway.

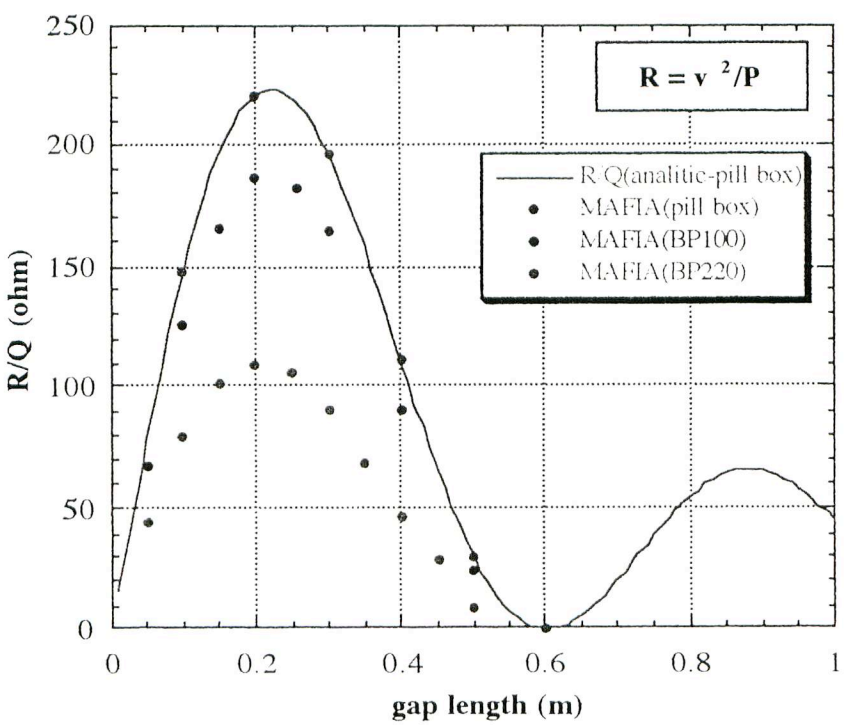


Low R/Q cavity with a narrow gap length

* A question on a low R/Q cavity with a narrow gap length was given at the last MAC.
* A shape with the R/Q of below 50ohm is required in LER to obtain a sufficient growth time of ν=-1 mode.
* Calculations of R/Q for TM010 (500MHz) ;
  1) R/Q of pill box cavity without beam pipes (a=cell radius, l=gap length)

$$\frac{R}{Q} = \frac{4}{\pi \varepsilon_0 p_{01}^2 c \cdot J_1^2(p_{01})} \cdot \frac{2a}{p_{01} \cdot l} \cdot \sin^2\left(\frac{p_{01} \cdot l}{2a}\right)$$

  2) R/Q of pill box cavity with beam pipes (by MAFIA)
* Conclusion
  1) For the R/Q of below 50ohm, the gap length must be below 5cm.
     This shape will have a new problem of a multipacting between end plates.
  2) The shape with a long gap length(> 40cm) has the R/Q of 50ohm.
     The frequencies of HOM modes shift toward the lower side.
     These frequency shifts require the beam pipes of a larger diameter.



R/Q of a PILL BOX with beam pipes (500MHz)