ACTIVITIES OF RF SUPERCONDUCTIVITY AT KEK

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1. INTRODUCTION

Five years have passed since the 508MHz superconducting(SC) RF system was installed in TRISTAN electron/positron collider[1]. The system has been operated successfully without any serious trouble except for heating of RF connectors of HOM couplers[2,3], and the total operating time amounts to 24000 hours.

The system is composed of sixteen cryo-modules(thirty-two 5-cell cavities) in the ring and other two modules at a test bed as spare modules. In 1989, the energy of TRISTAN was raised up to 32GeV adding the accelerating gradient of 200MV generated by the SC system. Since 1990, the energy has been lowered to 29GeV for the high luminosity operation, and the average gradient of the SC cavities has also been lowered from 4.4-4.7 MV/m to around 3.5 MV/m. Nowadays, the beam current has been improved to 13mA, which is limited by a beam instability at injection and partly by RF-trips of the SC cavities[4]. The history of operation is listed in Table 1.

In parallel with the operation and the maintenance of the TRISTAN SC system, R & D of 508MHz and 1.3GHz SC cavities has been continued for the future plans, namely, KEK B-Factory (TRISTAN II) and TESLA. This report gives the recent operation status of the TRISTAN SC cavities and outlines of these R & D results.

Table 1: Operation summary of the TRISTAN SC system[5]

	Period	Energy [GeV]	Ibeam [mA]	No. of Cav.	Vc of SC [MV]	ave.Eacc [MV/m]
1988	summer	(Installation of 16 cavities)				
	Nov.-Dec.	30.0	10	16	105-109	4.4-4.6
1989	Jan.-May	30.0	9	14	82-88	4.0-4.2
	May -Jul.	30.7	10	16	87-105	4.2-4.5
	summer	(Installation of 16 cavities)				
	Oct.-Dec.	32.0	12	28-29	190-200	4.6-4.7
1990	Feb.-Jul.	29.0	12-13	25-31	130-160	3.5-3.6
	summer -autumn	(Changing all HOM connectors) (Installation of SC Q-magnets for mini-beta)				
1991	Jan.-Jul.	29.0	9	29-30	140-145	3.3
	Oct.-Dec.	29.0	13	26	140	3.6
1992	Feb.-Jun.	29.0	12-13	23-25	125-140	3.6-3.8
	Oct.-Dec.	28.8-29.9	13	25-31	150-170	3.3-4.1
	Nov.	(Installation of a movable SR-mask)				
1993	Feb.-Jun.	29.0	13	28-32	145	3.2

Ibeam = 2 bunches(e-) x 2 bunches(e+)

2. THE TRISTAN 508MHZ CAVITIES

2-1. Cavity Performance

In the summer of 1988 the first 8 cryo-modules(16 cavities) were installed in TRISTAN, and the installation of the next 8 modules was made in the following summer. Two more modules were prepared in 1991 as spare ones[6]. Since the first installation, the performances of the cavities, Eacc,max and Q value, have been measured under no beam at the beginning and the end of every operation period. In Fig. 1, the distribution of Eacc,max measured in the summer of 1993 is compared with that obtained in 1989. In general the cavities seem to keep their initial field gradients and Q values, although some of them were opened and re-assembled due to troubles described later.

In our system, the cavities are cooled keeping the cooling rate of about 6K/hour and it takes about 50 hours from room temperature to 4.4K. However Q-degradation has never been observed. This is due to the annealing of 700°C[7].

2-2. Troubles

Up to now 14 cryo-modules had to be taken out from the ring and be replaced with spare or repaired modules. The causes of these replacements are summarized in Table 2. The cavities of underlined modules were re-treated. Others were simply re-assembled with no additional surface treatment.

Table 2: Replaced modules; modules underlined are re-treated.

troubles	'89		'90	'91		'92		'93
input coupler leak	C-6		C-11		C-2	C-10 C-11		
cryostat leak	C-7							
cavity leak		C-12			C-3 C-15 C-17	C-7 C-13		
degradation								C-6
HOM heating								C-7

(input coupler)[8]

Six times of vacuum leak at a ceramic window and three times of cooling water leak happened on input couplers. Vacuum leaks were due to discharging or burning down of the polyethylene back up disk. An arc detection system using photo diodes has been added for the protection of ceramics since 1991. This protection is effective and no more trouble has happened since the summer of 1991.

In 1991 and 1992, the leakage of cooling water occurred on three modules. Six cavities were contaminated with a large amount of water containing Cu and Mo, and had to be electropolished again[9]. The erosion-corrosion was found only around the outer conductor wall(Fig. 2) and the cooling water for outer conductors has been stopped.

(cavity leak)

Vacuum leak at indium seal flanges happened on six modules. Four of them were in warm up or cool down processes. These cavities were simply re-assembled and reproduced the initial performance except for one module(C-3). This cavity pair was re-electroplished because they had shown the low gradients of 4 MV/m and 5 MV/m since the first installation. Poor strength of SUS flanges and the inadequate position of indium wires on the flanges were looked on as a cause and required the replacement to thicker flanges. This replacement has been completed on eight modules.

Another trial has been given since the summer of 1992, where the frequency tuners are set free during warm up to reduce the additional force against the flanges. Since then no leak trouble has happened.

(tuner)

A fine tuner using piezo ceramics has been used together with a motor drive tuner to cancel the frequency oscillation within 20Hz in the range of 6kHz. Seven piezo elements were broken by the radiation damage of the plastic stacking bolts and twenty-nine elements were due to the problem of the elements themselves that was caused by the abnormal heat condition for sintering. Recently the trouble of elements has been reduced by using new elements covered with lead shield and the electrical filter system to suppress the spike noise.

(degradation)

The change of Eacc during a long term operation is within 1 MV/m[10]. A couple of cavities of which fields were degraded and limited by the input coupler arc due to gas absorption could be recovered by warm up. A cavity that had a low Eacc,max(3.0 MV/m) at a horizontal test was installed and detuned for three and a half years in the ring. This cavity was recovered by RF processing in a vertical cryostat without any surface treatment[9].

2-4. RF-trip

Since the early stage of operation, we have suffered from RF-trips[11]. In most cases these trips can be recovered easily, but sometimes cause the shorter life time of the stored beam or beam loss when the trips happen on several cavities at the same time. The trips are caused by the protection of cavity vacuum, arc detection of input coupler, Eacc limit or cavity breakdown. These signals suggest us that most of these trips are due to the discharging in cavities, input couplers or HOM couplers.

Several trials have been made to understand the mechanism of this discharging but it is still not confirmed [5,8,12]. Fig. 3 shows the recent trip rate per fill of 32 cavities. Although the rate changes day by day, the distribution does not change by replacing the modules to others. This means that the trip does not relate to the cavity performance but to the location of the cavity. Some of them are obviously due to the radiation from bending or focusing magnets. Realignment of fixed masks which are equipped on the bending magnet side of every cryostat(Fig. 4), the installation of superconducting quadrupole magnets for low beta optics and realignment of the quadrupole magnets around the SC cavities change the rate of some modules drastically. However, the frequent trips of the end modules have not been suppressed yet.

In 1992 a movable mask was added on the bending magnet side of the end module to shield the fixed mask against the radiation from bending magnets in order to reduce the reflecting radiation from the fixed mask. The improvements of the monitoring and correction system of the beam position were also made for the study of the trip. The radiation around the end module(Fig. 5,6) could be reduced by a factor of ten, the trip rate however did not decreased. The orbit study was made on both electron and positron beams separately, but no trip happened, in spite of the orbit change of several millimeters around the SC cavities and the considerable change of the radiation distribution detected by the PIN arrays on the beam duct adjoining the end module. We should study the relation between the trips and the situation of the beam, as well as the rapid phenomena of the trips.

3. R & D ACTIVITIES FOR FUTURE PLANS

3-1. KEK B-Factory

Nowadays KEK B-Factory, named TRISTAN II, is under planning, which will be constructed on the basis of existing TRISTAN[13]. Two rings with the energy of 3.5GeV(LER) and 8GeV(HER) for positron and electron respectively, will be installed in the existing TRISTAN tunnel. Commissioning of the 1st stage, in which the beam currents of 0.5A(LER) and 0.2A(HER) are accelerated with normal conducting cavities and four SC cavities, is scheduled in 1998. In the final stage, intensity of the beam will be upgraded to 2.6A(e+) and 1.1A(e-) respectively to achieve the luminosity of 10^{34}. Before the 1st stage operation, a beam accumulation test of 0.5A is also scheduled in 1995, where a single-cell SC damped cavity will be installed in TRISTAN Accumulation Ring(AR) together with normal conducting damped cavities.

Because of a heavy beam loading, a single cell cavity with large cylindrical beam pipes has been designed to propagate out and damp the HOM modes by the ferrite fixed on the beam pipes(Fig. 7). The parameters of the HOM damper such as thickness, length and position have been studied on IB-004 ferrite by SEAFISH program that was transferred from Cornell University. The design of the damper was also confirmed using an Al model cavity(Fig.8).

A prototype cavity was tested in a vertical cryostat and Eacc of 11.7 MV/m was obtained with Q of 8 x 10^8(Fig. 9,10). A new diagnostic tool with the rotating 25 carbon resisters and 19

PIN diodes were developed for the maps of temperature and radiation, which showed the growth of the electron traces as the cavity field and three traces at the maximum field clearly(Fig. 11). The limitation of the field was due to the electron emission[14,15].

Three bonding methods have been tested to fix the ferrite on the beam pipes; ultrasonic soldering, brazing and HIP(Hot Isostatic Press)[16]. Now we are considering the HIP as the most promising way, where sintering and bonding process can be given to the ferrite powder at the same time and that makes it possible to form a cylindrical ferrite absorber.

3-2. TESLA Activity

Up to now two nine-cell structures and five single cell cavities have been fabricated under the collaboration with CEBAF[17,18]. These cavities were devoted to the study for obtaining the field gradient of more than 25 MV/m as well as for the cost down problem. Many trials such as forming, chemical and electropolishing, high pressure rinsing, heat treatment and so on has been continued energetically. Recent results on the nine-cell and the single cavities are shown in Fig. 12. Details of these studies will be given in this workshop[19].

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REFERENCES

[1] Y. Kojima et. al., Proc. of the 1989 Particle Accelerator Conference, Chicago, 1989, pp.1789-1791.

[2] Y. Kojima et. al., Proc. of the 2nd European Particle Accelerator conference, Nice, 1990, pp.1082-1084.

[3] S. Mitsunobu et.al., Proc. of the 5th Workshop on RF Superconductivity, DESY, 1991, pp.84-94.

[4] H. Fukuma et. al., Proc. of the 9th Symposium on Accelerator Science and Technology, KEK, 1993, pp.32-33.

[5] S. Noguchi et. al., Proc. of the 1993 Particle Accelerator Conference, Washington, 1993.

[6] T. Tajima et. al., Proc. of the 5th Workshop on RF Superconductivity, DESY, 1991, pp.766-781.

[7] T. Furuya et. al., Proc. of the 5th Workshop on RF Superconductivity, DESY, 1991, pp.684-693.

[8] T. Shishido et. al., Proc. of the 3rd European Particle Accelerator Conference, Germany, 1992, pp.57-52.

[9] K. Asano et. al., this workshop.

[10] K. Kubo et. al., Proc. of the 15th Int. Conf. on High Energy Accelerators, Hamburg, 1992, pp.691-693.

[11] K. Kubo et. al., Proc. of the 2nd European Particle Acceleraror Conference, Nice, 1990, pp.1085-1087.

[12] K. Akai et. al., Proc. of the 1991 Particle Accelerator Conference, San Fracsisco, 1991, pp.2405-2407.

[13] S. Kurokawa et. al., Proc. of Int. Workshop on B-Factorys: Accelerators and Experiments, KEK, 1993, pp.19-30.

[14] T. Takahashi et.al., Proc. of the 9th Symposium on Accelera tor Science and Technology, KEK, 1993, pp.327-329.

[15] S. Mitsunobu et. al., this workshop.

[16] T. Tajima et.al., this workshop.

[17] E. Kako et. al., Proc. of the 9th Symposium on Accelerator Science and Technology, KEK, 1993, pp.443-445.

[18] K.Saito et. al. Proc. of the 1993 Particle Accelerator Conference, Washington, 1993.

[19] E. Kako et. al., this workshop.

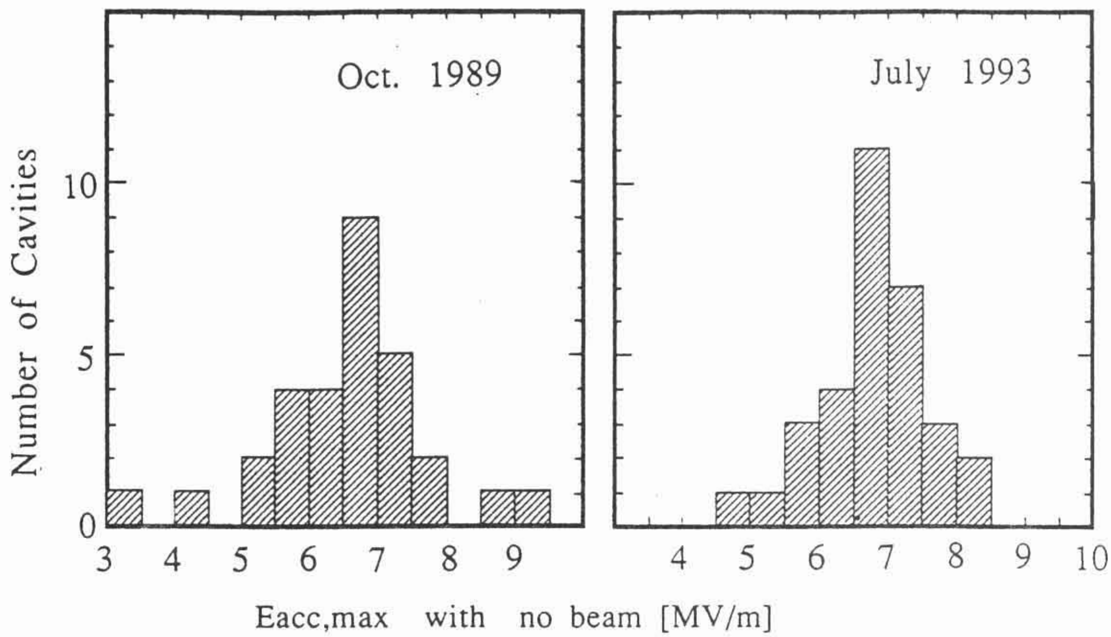

Fig.1 Distribution of Eacc,max of TRISTAN cavities.

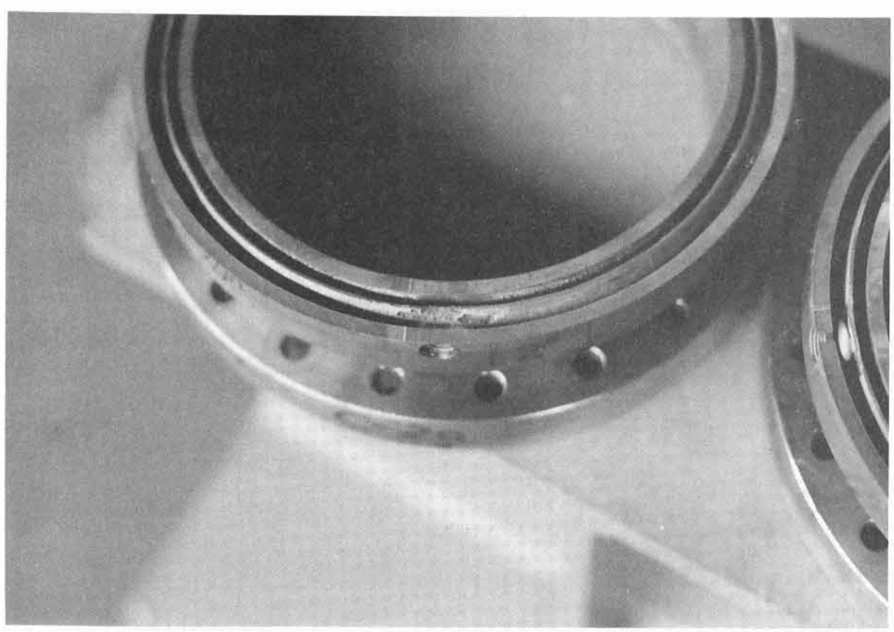

Fig.2 Corrosion of a water jacket for input coupler ceramic. Local corrosion pits were observed on 1mm thick Cu wall.

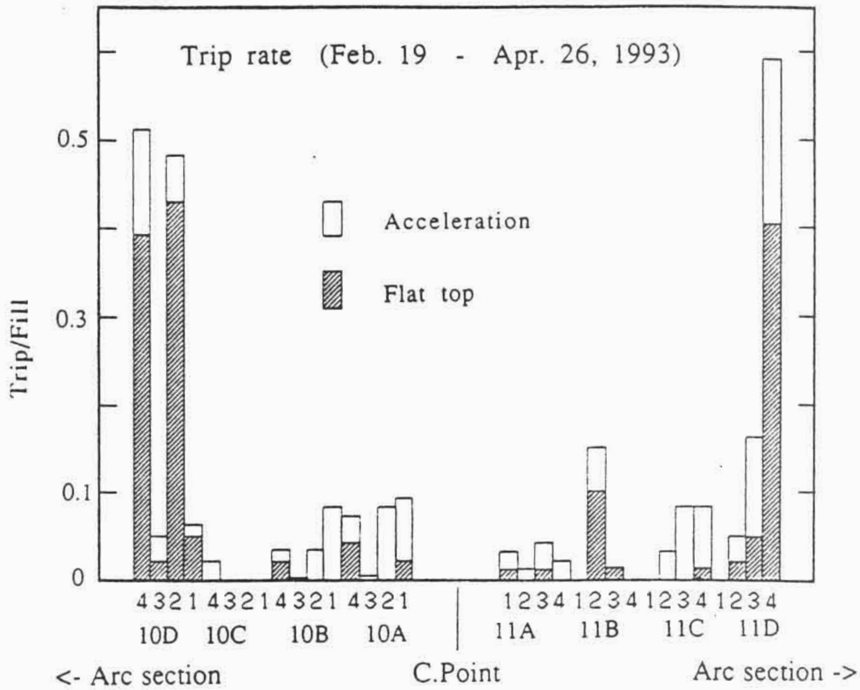

Fig.3 Recent RF-trip rate of TRISTAN cavities

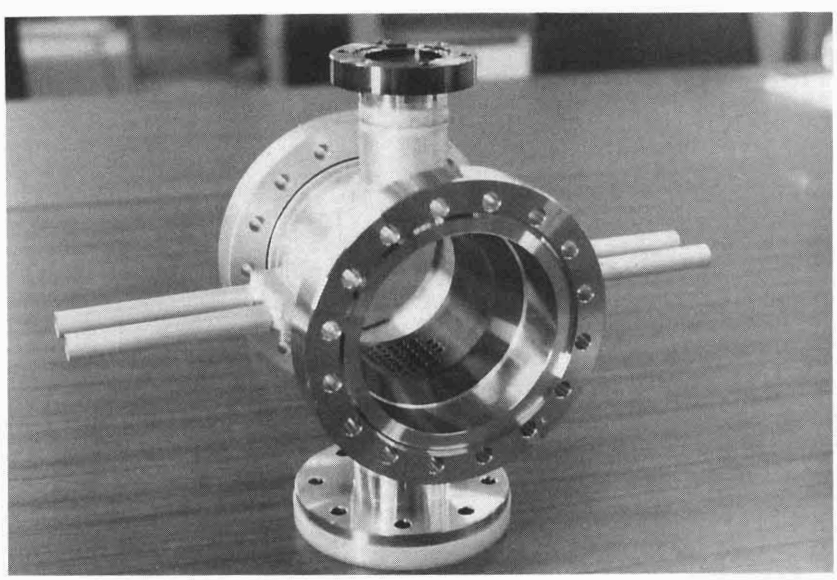

Fig.4 Photograph of a fixed radiation shield mask. Each cryostat has a fixed Cu-mask (50mm thick) on the arc-section side.

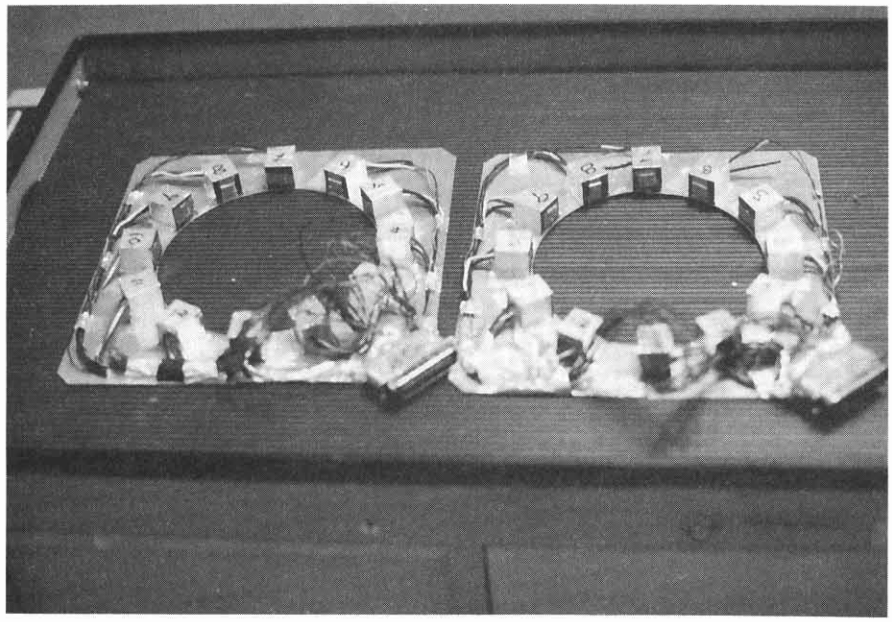

Fig.5 Array of PIN diodes for the radiation measurement. They were set on the beam duct adjoing the end module.

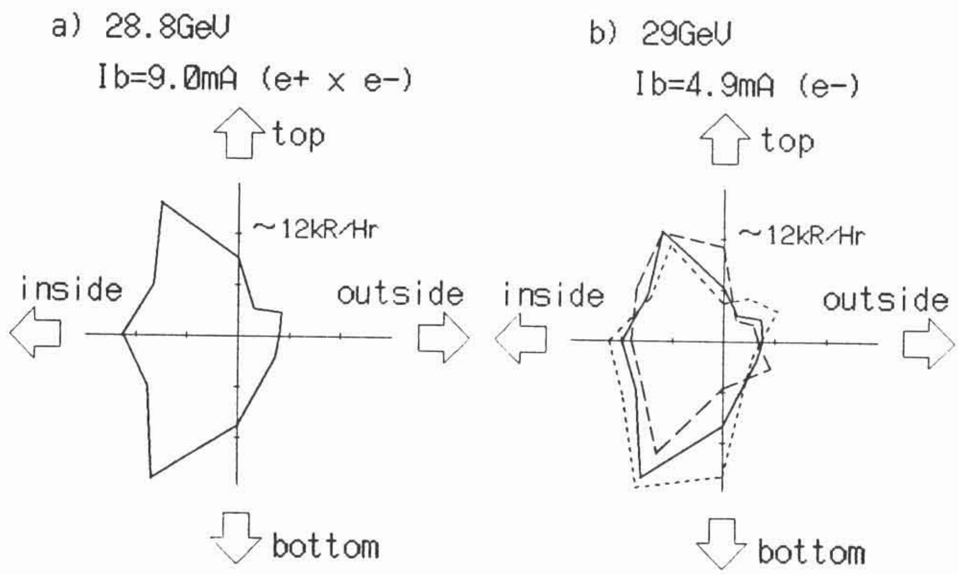

Fig.6 Radiation distribution at the end module. The radiation of the outside was shielded by a fixed mask(a), and the inside could be reduced by a factor of ten by an additional moving mask. (b) shows the distribution change during the beam orbit study.

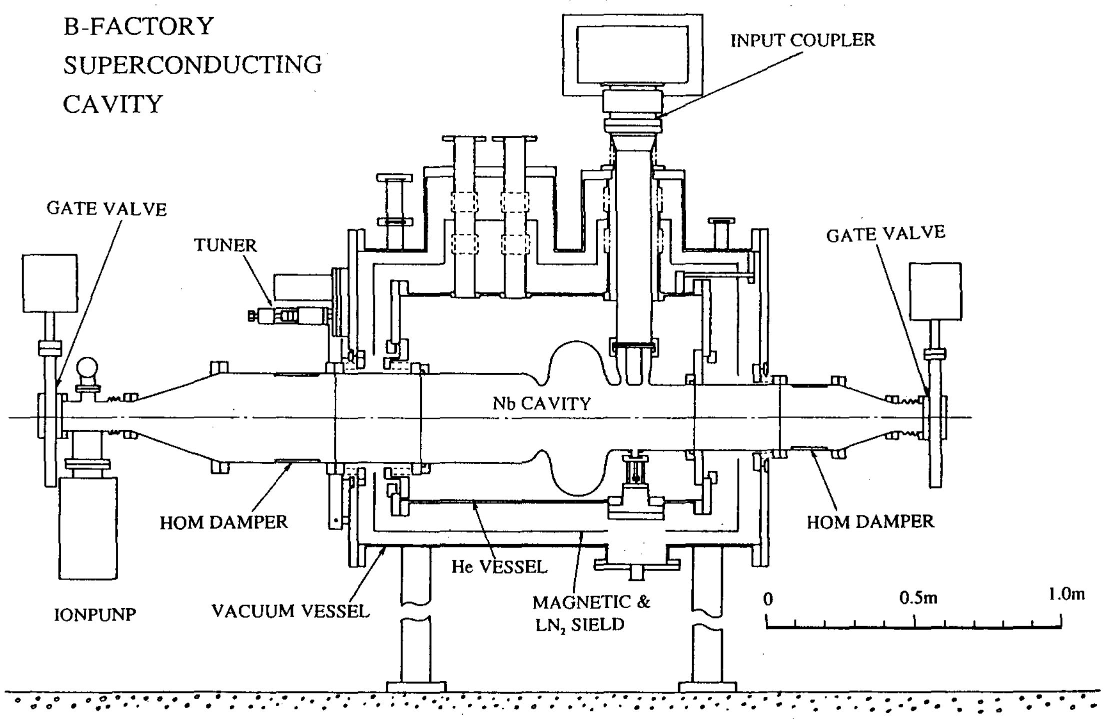

Fig.7 AR beam test module with the optimized ferrite dampers.

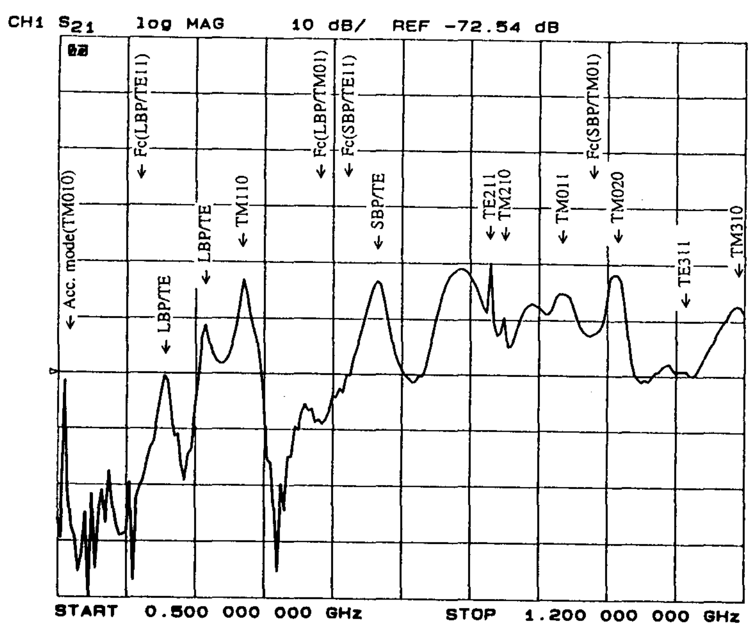

Fig.8 HOM modes of the Al- cavity with the cylindrical dampers.

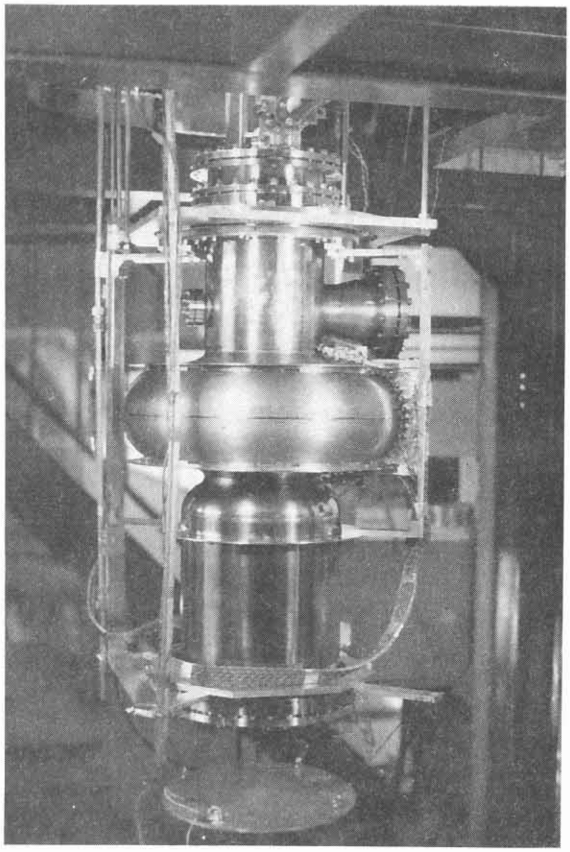

Fig.9 508MHz damped SC cavity with a mapping system of 25 carbon re-sisters and 19 PIN diodes.

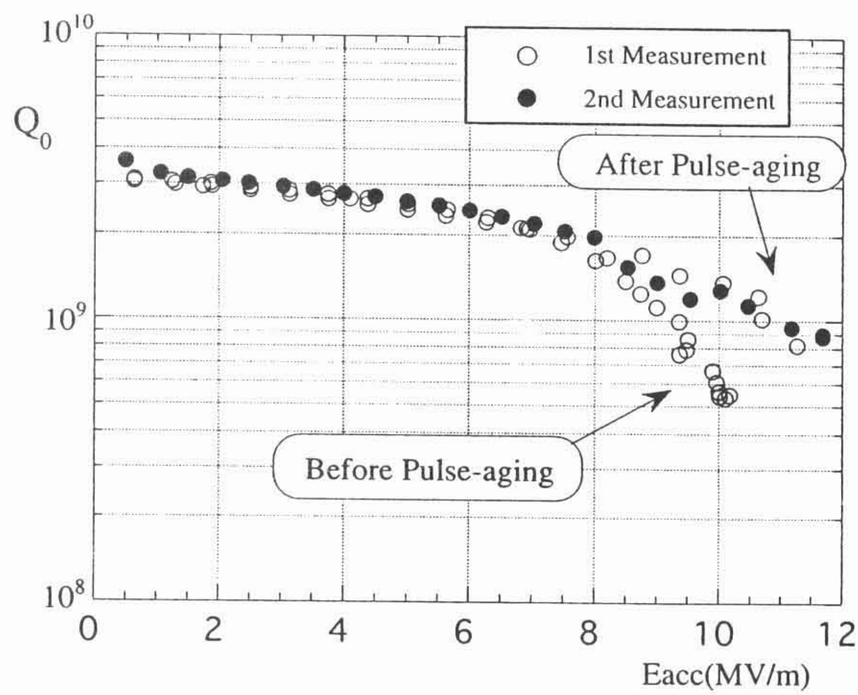

Fig.10 Q-E of a vertical test of the damped cavity.

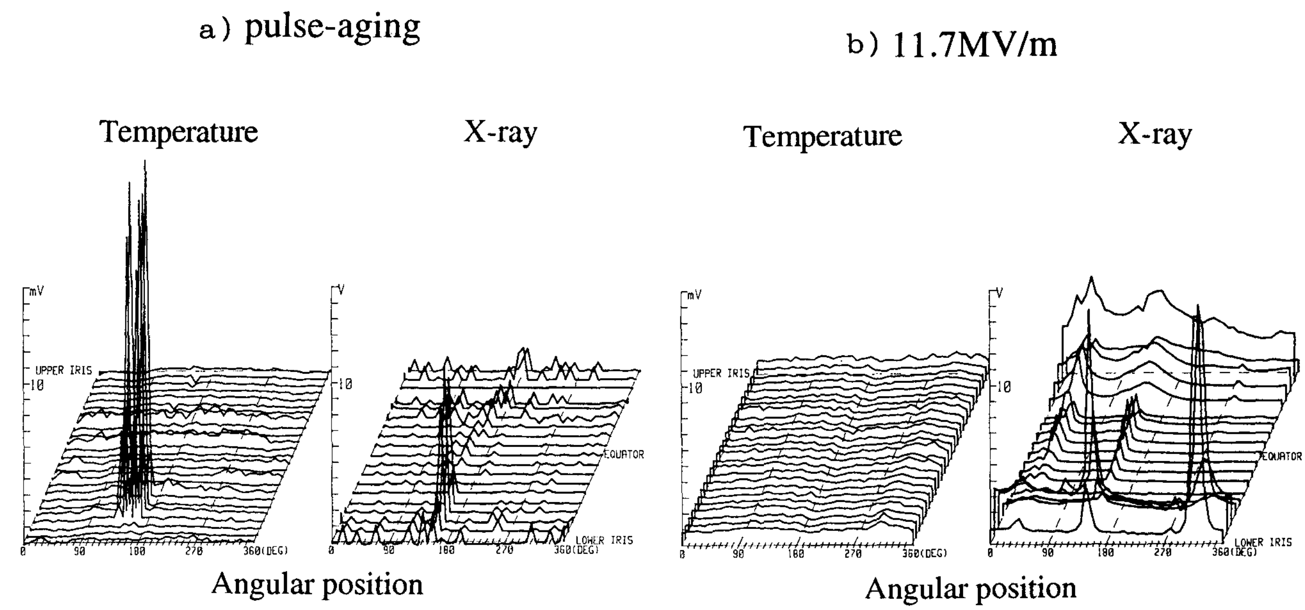

Fig.11 Temperature and radiation mapping of the damped cavity;
a) in pulse aging, b) at 11.7 MV/m.

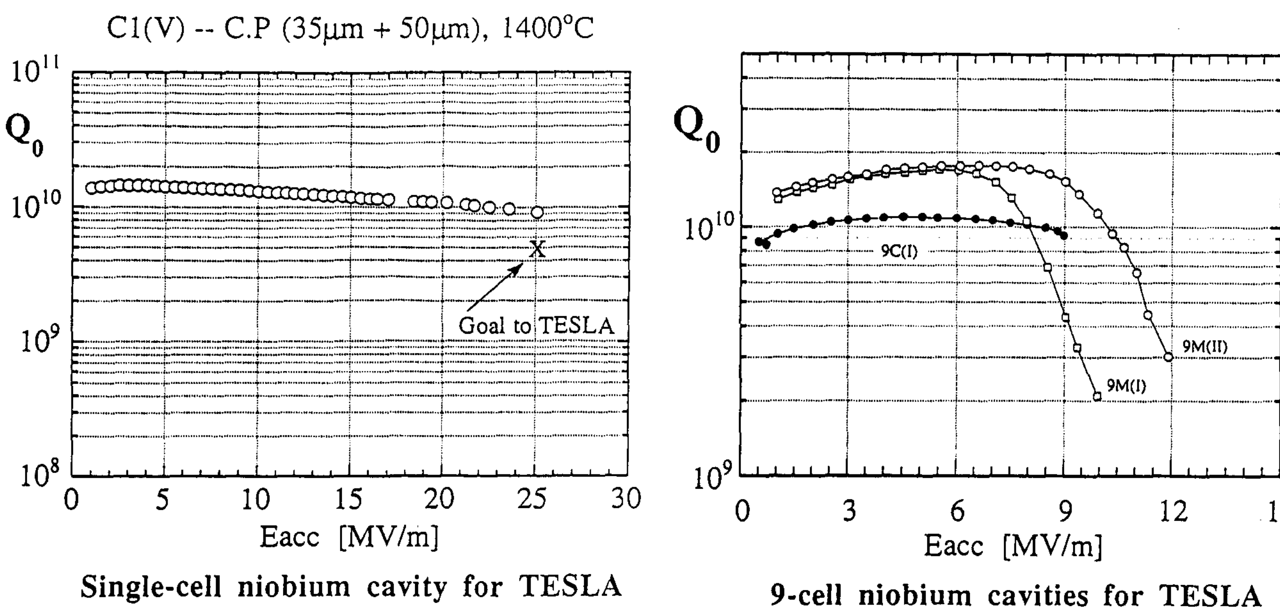

Fig.12 Typical Q-E of 1.3 GHz nine-cell and single cell cavities.