CONSTRUCTION OF THE TRISTAN MAIN RING

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INTRODUCTION

TRISTAN, which stands for Transposable Ring Intersecting Storage Accelerator in Nippon, is a KEK high energy physics facility for aiming at electron-positron colliding beam experiments at 50 $\sim$ 60 GeV in the center-of-mass energies. The TRISTAN beam collider complex consists of three accelerator stages. First, electrons and positrons are accelerated to 2.5 $\sim$ 3 GeV by the KEK Photon Factory electron linac[1]. Positrons will be produced with a separate 200 MeV electron linac which is under construction for the completion at the end of the fiscal year 1984[2]. Then, electrons and positrons are injected into the accumulation ring, AR[3]. AR is a storage accelerator of 377 m in circumference and accelerates electrons and positrons to 6 $\sim$ 8 GeV prior to injection into the main electron-positron colliding beam ring, MR, of 3 km in circumference. MR has a four-fold symmetry. Four arcs of 347 m in average radius are joined by four long straight sections of 194 m in length. Two electron and two positron bunches circulating in the opposite direction will make collisions each other at the middle of the four straight sections, where colliding beam detectors are located. A site layout of the TRISTAN accelerator complex is shown in Fig. 1. The four experimental halls of MR are named Fuji, Nikko, Tsukuba and Oho corresponding to those locations at the south-west, north-west, north-east and south-east of the ring, respectively.

Responding to the official approval of the TRISTAN project as a five-year program, we started the construction of AR in April 1981 and that of MR and the positron source linac in April 1982. The project is proceeding following the time schedule shown in Fig. 2.

In this paper, we give a brief description of the MR general design and present the status of construction works of the accelerator elements.

GENERAL DESIGN

TRISTAN-MR was designed so that its beam energy can be made as high as possible with a ring which fits the area available on the KEK site. As is well-known, the attainable beam energy and intensity in the high energy electron storage ring are ultimately limited by an available accelerating rf power to overcome a high rate of synchrotron radiation loss. This necessarily leads the MR structure to that shown in Fig. 1, which has extraordinarily long straight sections to install rf cavities in comparison with the overall accelerator circumference.

The MR magnet lattice has a four-fold super periodicity[4]. A quadrant extends from one colliding point to the next, and is further divided into two mirror symmetrical octants, both ends of which are the colliding point and the center of the arc, the symmetry point of the quadrant. Each octant consists of a wiggler section starting from a symmetry point, normal cells, dispersion suppressor cells, rf cells and an experimental insertion. Such a configuration was adopted to fulfill a requirement that the dispersion function and its derivative should be zero both in the rf cells and experimental insertion. Figure 3 illustrates an evolution of the horizontal and vertical betatron function, (β_x, β_y), and the dispersion function, (η_x), in the octant lattice. Also shown is the arrangement of the main dipole and quadrupole magnets. As depicted in Fig. 4, the normal cell has a periodic FODO structure. The cell parameters are determined so as to make the betatron tune rather high in due consideration of emittance increase in the possible operation at energies higher than the design value. The rf cell length is shorter by about 15 % than that of the normal cell.

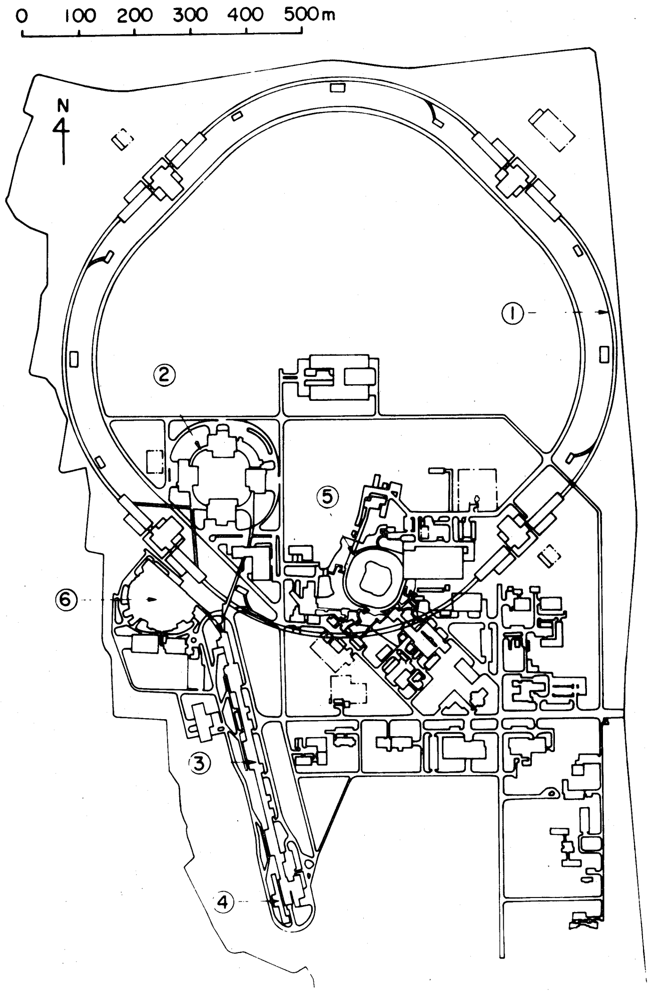

Fig. 1 Site layout of the TRISTAN accelerator complex. 1. TRISTAN-MR. 2. TRISTAN-AR. 3. 2.5 GeV Electron Linac. 4. Positron Source Linac. 5. 12 GeV PS. 6. PF Electron Storage Ring.

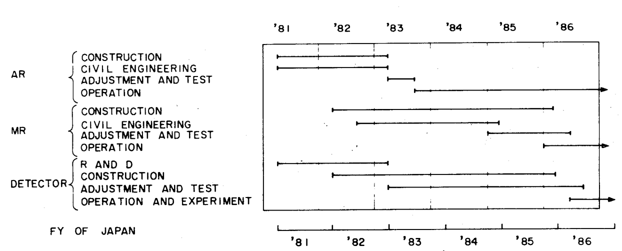

Fig. 2 Time schedule of the TRISTAN project.

This makes the average betatron function in the rf cell smaller by about 30 % than that in the normal cell, and is expected to be helpful to increase the beam current limited by an instability arising from beam-cavity interactions. A threshold current of such an instability is predicted to be inversely proportional to the betatron function at the rf cavity. The design of the experimental insertion is mainly governed by requirements for betatron functions at the colliding point,

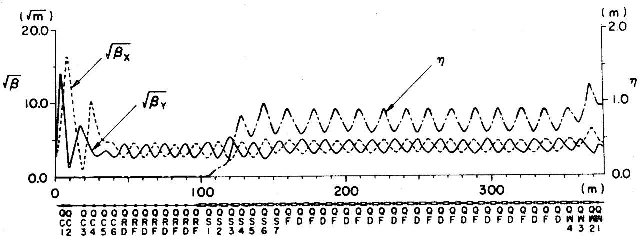

Fig. 3 Betatron functions, β_x and β_y, and dispersion function, η, in an octant of TRISTAN-MR.

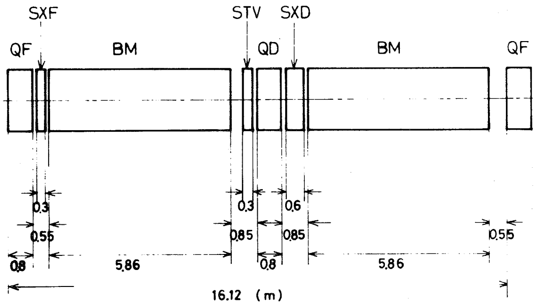

Fig. 4 Normal cell structure of the TRISTAN-MR magnet lattice. B, Q, SX, and ST are be nding, quadrupole, sextupole and steering magnet, respectively.

which should be as low as possible for the highest luminosity, and restrictions imposed by the chromaticity correction which is largely affected by such a low-beta insertion structure. To lower the betatron functions at the colliding point while keeping chromaticities in a tolerable amount, quadrupole magnets for the low-beta should be located as close as possible to the colliding point. In the present scheme, the horizontal and vertical betatron function at the colliding point, (β^*_x, β^*_y), are calculated to be (1.6 m, 0.1 m) for the case of locating conventional iron core quadrupole magnets 4.5 m away from the colliding point, and can be reduced to (0.8 m, 0.05 m) by inserting superconducting air core quadrupole magnets at a distance of 1.7 m from the colliding point. General design parameters of TRISTAN-MR are listed in Table 1.

Table 1

General Design Parameters of TRISTAN-MR

Beam energy	25 ∿ 30	GeV
Injection energy	6 ∿ 8	GeV
Circumference	3018	m
Average radius of curved section	346.7	m
Long straight sections	4 × 194.4	m
Wiggler straigth section	4 × 15.6	m
Bending radius	246.5	m
Number of bending magnets	272	
Number of quadrupole magnets	392	
Magnet free spaces allocated for rf cavities (Fuji + Nikko + Tsukuba + Oho)	(12 + 20 + 20 + 20) × 6.07	m
Revolution frequency	99.3	kHz
Accelerating rf frequency	508.6	MHz
Parameters at 30 GeV		
Radiation loss per turn	290	MeV
Natural energy spread (σ_E/E)	1.64×10^{-3}	
Natural hor. beam emittance	1.8×10^{-7}	m·rad
Over voltage ratio for 24 hrs beam life	1.314	
Peak rf voltage	383	MV
Synch. oscillation frequency	9.98	KHz
Natural bunch length (σ_z)	1.17	cm
Minimum design value of beta-functions at colliding point (β^*_x/β^*_y)	0.8 m/0.05 m	
Design luminosity	$1 \sim 2 \times 10^{31}$	$cm^{-2} \cdot s$

CONSTRUCTION WORKS

The MR lattice is composed of 272 dipole and 392 quadrupole magnets. Production of the magnets was started in April 1982 as a three-year program. Most of the magnets have been fabricated and delivered to KEK. After being submitted to the magnetic field measurement, the magnets are stocked in an assembly hall as shown in Fig. 5. To show useful field apertures of the magnets, the effective magnet lengths measured are plotted as a function of radial positions in Fig. 6. Figure 7 illustrates geometrical apertures of the magnets together with cross sections of the vacuum tubes. The present dipole magnet system is designed to be operative at beam energies as high as 40 GeV. While the working energy of the quadrupole magnet system will be limited at about 35 GeV. To go beyond this, it might be needed to replace some of the quadrupole magnets with superconducting ones. Installation of the magnets in the MR tunnel, Fig. 8, is scheduled to start in September 1984[5].

As mentioned above, the highest attainable beam energy of MR is determined by an available accelerating rf voltage. For instance, a peak rf voltage of about 383 MV will be required at 30 GeV. In the case of the conventional room temperature cavity, the cavity wall loss is a significant part of the rf power consumption. Then, a cavity of higher shunt impedance is desirable for generating larger accelerating voltage within a limited power. However, it should be noted that a large impedance also implies a strong coupling between the beam and cavity, and may cause a serious beam instability. After extensive development works, we have decided to adopt the alternating periodic structure, APS, for the MR accelerating cavity[6]. APS is a

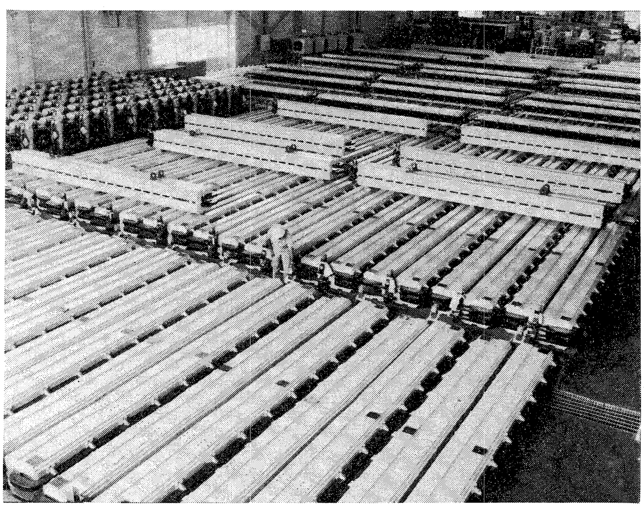

Fig. 5 TRISTAN-MR main magnets which are ready for installation in the tunnel.

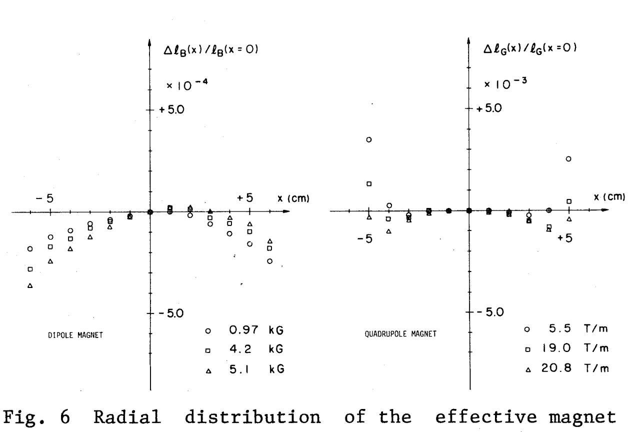

Fig. 6 Radial distribution of the effective magnet length of the TRISTAN-MR bending and quadrupole magnet.

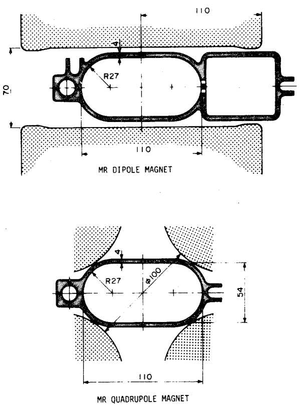

Fig. 7 Geometrical apertures of the TRISTAN-MR bending and quadrupole magnet. Also shown are cross-sections of the vacuum tubes.

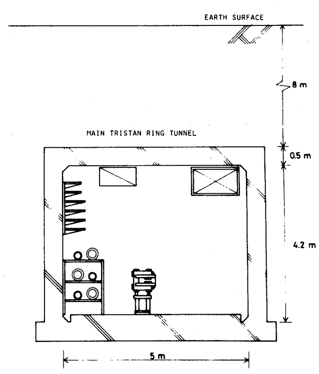

Fig. 8 Cross-section of the TRISTAN-MR tunnel in the arc.

confluent type, in which the TM_{01} mode has a finite group velocity at the accelerating frequency, and has wide mode separations compared with ordinary slot-coupled cavities. One of the most desirable of the present APS is that it has a perfect axial symmetric structure and is expected to behave in accordance with computer calculations. A unit of the MR rf cavity is a 9-cell APS, the cell unit of which has dimensions as shown in Fig. 9. The shunt impedance of the cavity thus designed is calculated to be 28.2 MΩ/m with use of the computer code SUPERFISH, and that of the practical one is expected to be not less than 80 % of this figure. The cavity body will be made of a low carbon steel. A copper layer of about 0.2 mm thick is electroplated on the inner surface in a pyrophosphrous acid bath. Figure 10 shows a picture of the 9-cell APS test cavity under fabrication.

In parallel with the conventional room temperature cavity, extensive works are going on to develop a 500 MHz superconducting cavity for practical use in TRISTAN[7]. Recently a three cell cavity has been fabricated and successfully tested with a beam in TRISTAN-AR. The cavity stably accelerated the beam giving the accelerating field as high as 4.3 MV/m. The results of this experiment has strongly encouraged a possible extension of the MR beam energy to considerably higher values than the originally designed.

In building the MR rf system, we have decided to proceed on the following plan. As the first stage, we will fill three long rf sections, Fuji, Oho, and Tsukuba side, with 104 units of the room temperature 9-cell APS cavities, and the remaining one, Nikko side, with 40 units of the 5-cell superconducting cavities.

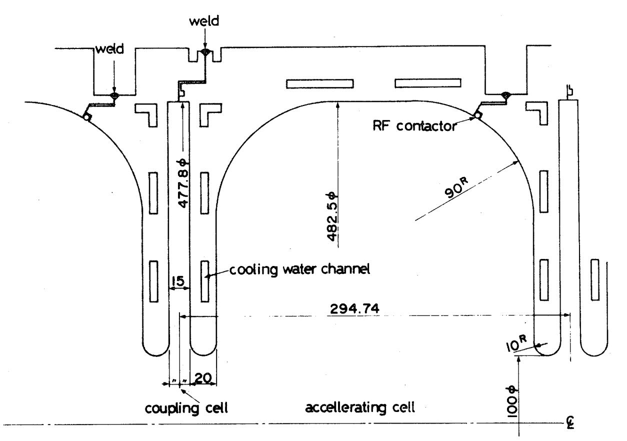

Fig. 9 Unit cell structure of the TRISTAN APS type rf cavity.

The construction of the room temperature cavity system is scheduled to take about two and a half years, and it will take at least one more year to complete the superconducting cavity system. The highest MR beam energy attainable with this first stage rf system is estimated to be about 33 GeV, provided that the 9-cell APS cavity unit is operated at the largest available input rf power of 150 kW, corresponding to a field strength of 1.1 MV/m, and the 5-cell superconducting cavity unit produces a field strength of 4.3 MV/m at the highest. To reach higher beam energies, we intend to replace the room temperature cavities with the superconducting ones successively in the later stage.

As shown in Fig. 11, a room temperature cavity composed of two 9-cell APS cavity units is installed in an rf straight section between the lattice quadrupole magnets. An output of a 1 MV klystron will be delivered to four 9-cell APS cavity units, after being fed through a circulator and equally divided into four by magic tees.

Based on the very successful results in AR, the construction of the vacuum[8], beam transport[9], beam monitor[10], and control system[11] of MR is duly in progress with adding necessary improvements to those for AR.

REFERENCES

Detailed descriptions of the items referenced in this paper will be given in the following papers also collected in the present Proceedings.
1: B-2. 2: D-5, D-7. 3: B-3. 4: I-18.
5: G-10, G-11. 6: E-6. 7: E-9, E-10.
8: H-6 ∿ H-12. 9: I-17. 10: F-9. 11: J-2 ∿ J-10.

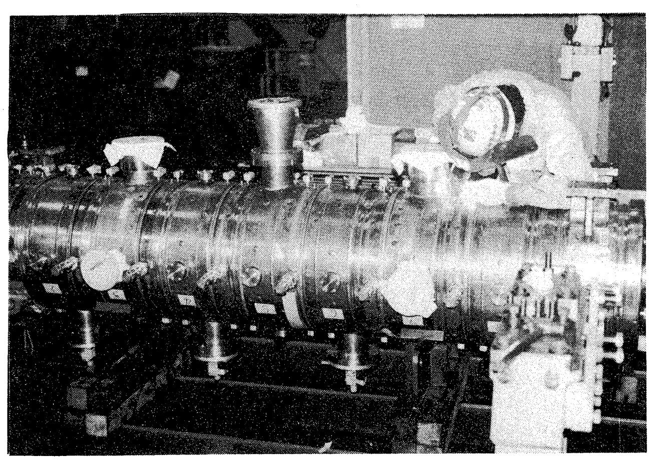

Fig. 10 A 9-cell APS test cavity under fabrication.

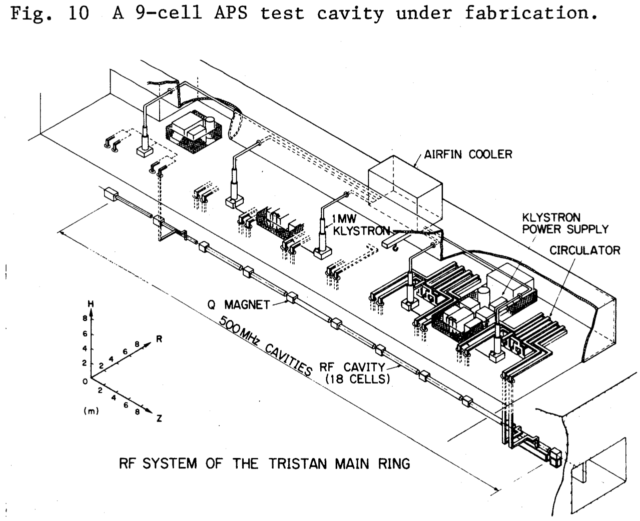

Fig. 11 Setup of the TRISTAN-MR rf system for the APS cavities.