IEEE Transactions on Nuclear Science, Vol. NS-28, No. 3, June 1981

KEK ACCELERATOR FACILITIES AND TRISTAN PROJECT

T. Kamei and Y. Kimura

KEK, National Laboratory for High Energy Physics
Oho-machi, Tsukuba-gun, Ibaraki-ken, 305, JAPAN

Summary

KEK 12 GeV PS continues stable operation and the maximum beam intensity has reached 4.1×10^{12} ppp, over twice of the design value. Since last June the booster delivers the 500 MeV protons to the Booster Synchrotron Utilization Facility (BSF), and pulsed neutrons and pulsed mesons are successfully produced. The 2.5 GeV electron linac and the storage ring, dedicated for a synchrotron radiation facility, will be completed in one year. The new version of TRISTAN plan has a 25 GeV electron ring and a 300 GeV proton ring. The e^+- e^- ring of 30 GeV will be constructed from FY 1981 as phase I of TRISTAN.

KEK Proton Synchrotron

PS is operating since 1976[1] and the beam intensity at the each accelerator stage has grown by various improvements as shown in Fig. 1. Machine operation is very stable, and over than 70 % of the scheduled operation time is used for particle experiments and the machine down time is less than 5 %.

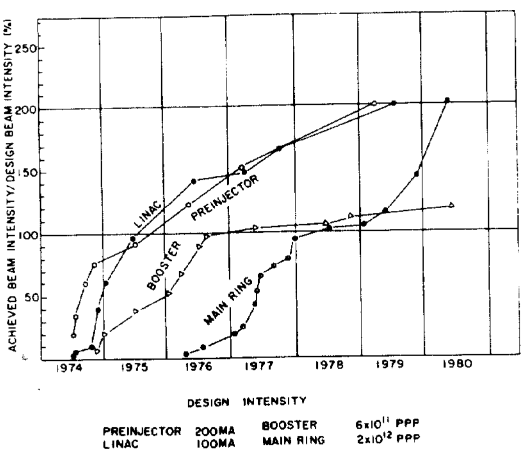

Fig. 1 Growth of the beam intensity.

The high power isolators are developed and installed between the 20 MeV linac cavity and the cavity driving amplifiers.[2] These 20 db isolators can reduce the effect of the reflected power from the cavity and also the coupling between two RF high power amplifiers through the cavity, and then tuning of the power amplifiers is much simplified. In the 750 keV preinjector, proton beam transmission is improved and the beam more than 400 mA can be injected to the cavity,[3] and the 20 MeV linac beam has reached over 200 mA.

Beam pipes of the main ring are replaced by the new one made of SUS 316L stainless steel and low μr ($\sim$ 1.02) of the new pipe material reduces the sextupole field error in the bending magnet to - 0.02 m^{-2}.[4] Then beam transmission at the injection porch, total number of the injected proton beam to the captured proton number ratio, is much improved. Microwave instability due to the negative mass effect is observed near the transition and cause the beam loss. This is improved by the phase shaking of RF and counterphasing between the RF cavities.[5] Improvement of the dynamic filter amplifier can reduce ripples of the bending and quadrupole magnet currents by 26 db[6] and low frequency ripple of the slow extracted beam by 10 db.

Other develepents A polarized proton project has started and a new preinjector for the polarized beam is under construction. We have two problems concerning acceleration of the polarized proton; one is intensity of the beam and the other is depolarization during acceleration. We are developing a new intense polarized H^- ion source, APOLON(Advanced polarized ion source with oriented Na atom).[7] This utilizes the charged exchange reaction between fast proton beam and electron spin oriented sodium atoms. We have obtained about 3 μa H^- ion beam of 30 % polarization, Electron spins of Na atoms are oriented by a multipole magnet method. An optical pumping method to orient electron spin is hopeful to get higher intensity of polarized H^- beam and is being developed. The other difficulty, spin depolarization, is caused by the intrinsic spin resonance and the imperfection spin resonance, and is under systematic study.[8] Preliminary calculations show one strong intrinsic resonance during the booster acceleration could be passed by spin flip. The main ring is now operating at ν_z = 6.25 and ten intrinsic resonances and twenty two imperfection resonances will occur. ν-jump technique and adiabatic slow passage method are expected to minimize depolarization up to 8 GeV. Lower tune operation of the main ring might be desirable to accelerate the polarized proton to higher energy.

Charge exchange injection scheme to the booster might be effective to increase the booster beam and this is essential for multiturn injection of the polarized beam. However, injected beam is low energy of 20 MeV, and may suffer from multiple Coulomb scattering by the carbon foil stripper during multitraverse. As a basic study, the life time of circulating protons through the carbon foil is measured in the booster and more than one hundred turn injection will be possible with the carbon foil of 120 $\mu g/cm^2$. The carbon foil life and emittance blow up will be extensively studied. The linac energy-up is under consideration and the preliminary design study of the proton linac extention to 80 MeV or higher has been performed.[9]

Booster Synchrotron Utilization Facility (BSF)

The 500 MeV booster can accelerate the injected beam to the maximum energy twenty pulses per second. The circumference of the main ring is nine times of the booster and then nine pulses of the booster can fill the main ring. During the main ring cycle of 2.5 sec about forty booster beam pulses can be utilized for spallation neutron and meson productions at BSF. Since last summer pulsed neutrons are generated from the tungsten target and used for neutron scattering experiments. At the meson physics facility, managed by the Univ. of Tokyo, μ mesons are effectively collected by the superconducting solenoid of 5 T (12 cm bore and 6 m long). The pulsed μ mesons have 50 nsec duration and high density of 10^5 particles/pulse, and is suitable for delayed measurements of μSR. The facility for medical and biological applications, managed by Tsukuba Univ., is under construction.

0018-9499/81/0600-2052$00.75©1981 IEEE

Photon Factory

The construction is in progress on schedule. An acceleration unit consititng of four 2 m TW wave guide has been tested up to a level of 30 MW RF power. The linac building was completed last summer and four acceleration units was installed. The storage ring building will be completed this spring and installations of the ring magnet, the RF stations and other equipments will be completed by this **fall.**

TRISTAN

An electron-proton colliding machine plan, TRISTAN, was proposed in 1974 and recently the design has been revised.[10] The final plan is designed so as to have the largest size rings which can be accomodated on the KEK site as shown in Fig. 2. The total circumferences

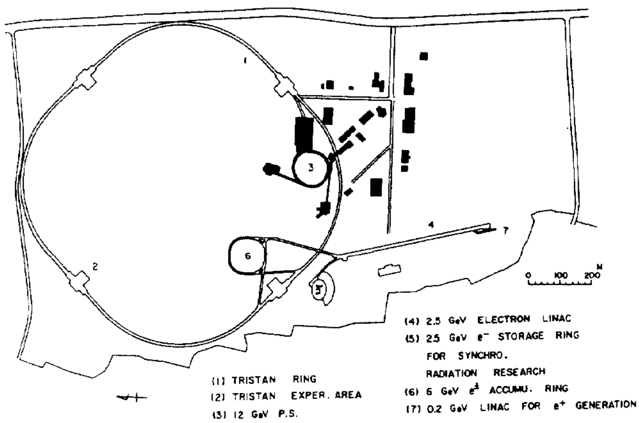

Fig. 2 Plan view of TRISTAN.

of the rings are about 3 km or about nine times of the KEK PS, and we have divided the project into phase I and phase II. In phase I, the electron-positron ring of 25 ∿ 30 GeV with a conventional magnet system will be constructed together with the accelerator enclosure for the whole project. In phase II, the superconducting magnet ring for 300 GeV protons will be installed in the same tunnel. The proton beams are provided by the 12 GeV PS, and electron and positron beams by the 2.5 GeV electron linac of the Photon Factory. Fabrication technology of superconducting magnets will be developed during the construction of the electron ring.

The electron-positron collider enables fruitful particle physics, and experiences about this machine are very useful for proceeding to the more complicated electron-proton collider. During the past year basic design study and technology developments of collider construction have **been performed.** Phase I of TRISTAN has been recently authorized and its construction will start from FY 1981 as a five year project.

Phase I: Electron-Positron Collider The latest design parameters of the TRISTAN electron ring are shown in Table I. The lattice has four-fold symmetry

Table I

General parameters of the TRISTAN electron ring

Circumference		$c = 54\ \mathrm{m} \times 2\pi \times (80/9)$ $= 3015.929$ m
Average machine radius	r =	480.000 m
Length of straight section (including 10 % bends)	L_s =	230.312 m × 4
Average radius of curved section	r' =	$(c - L_s)/2\pi$ = 333.379 m
Bending radius (normal bend)	ρ =	223.371 m
Number of cells in ARC	N_{cell} =	144
in normal ARC		120
in dispersion suppressor		24
Length of a cell	L_{cell} =	14.5464
Number of cells in RF section	$N_{RF\ cell}$ =	32
Length of a cell in RF section	$L_{RF\ cell}$ =	17.9805 m
Revolution time	T_{rev} =	10.060 sec
Revolution frequency	F_{rev} =	99.403 KHz
Typical β-value at colliding point	β_x^* =	2.0 m
	β_y^* =	0.2 m

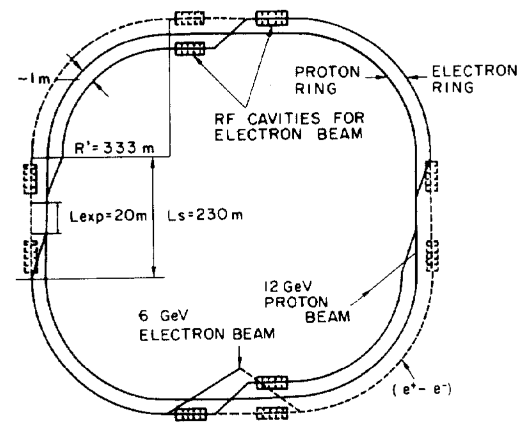

Fig. 3 Layout of the TRISTAN colliding beam system.

and four long straight sections. Fig. 3 shows the colliding beam system, and the electron ring for the electron-positron collider is arranged as the dotted line. The practical maximum electron energy is mainly limited by the available RF power to compensate the energy loss due to synchrotron radiation. The long straight sections of about 400 m can be used for installation of RF cavities. The maximum energy of electron is expected to be 30 GeV with the available RF power and the long RF station, provided that beam instabilities arizing from the higher mode exitation in such a long cavity system are proved to be acceptable. The beam parameters of the TRISTAN electron ring are shown in Table II. The optimum luminosity

Table II

Beam parameters of the TRISTAN electron ring

Energy	E(GeV)	30
Energy loss per turn	U_0(MeV)	319.3
Damping time	τ_x(msec)	1.90
	τ_y(msec)	1.89
	τ_ε(msec)	0.944
Partition number	J_x	0.9973
	J_ε	2.0027
Variation with energy	$\Delta J_x/(\frac{\Delta p}{p})$	− 163.9
	$\Delta J_\varepsilon/(\frac{\Delta p}{p})$	+ 163.9
Natural energy spread	σ_ε/E	1.720×10^{-3}
Transverse emittance (without coupling)	ε_x(mm·mrad)	0.1583
Overvoltage ratio (τ_Q = 24 Hr)		1.277
RF peak voltage	V_{RF}(MV)	407.7
Bucket height	ΔE/E	0.01144
Synchronous phase angle	ϕ_s	128°45
Synch. oscillation per turn	ν_s	0.0925
Synch. oscillation freq.	F_s(KHz)	9.20
Natural bunch length	σ_z(mm)	11.3

expected for the electron-positron collider is shown in Fig. 4.

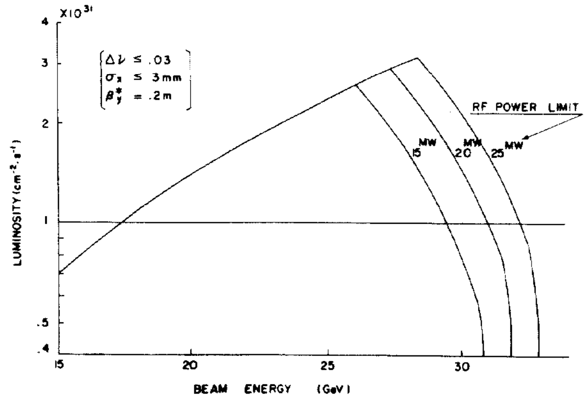

Fig. 4 Luminosity of the TRISTAN e^+-e^- collider.

The electron and positron beam for TRISTAN are provided by the 2.5 GeV electron linac. However, the beam energy of 2.5 GeV is too low for injection into the TRISTAN electron ring. The damping time of 2.5 GeV electron beams in TRISTAN is too long as compared with the repetion time of the linac, 20 msec, and furthermore beam losses due to Toushek effect in TRISTAN have shown that 2.5 GeV beam can not have a life time longer than required for stacking positrons. Then, an intermediate accumulator between the 2.5 GeV linac and TRISTAN is necessary to obtain high electron and positron currents. The energy of the accumulator at the beam transfer to TRISTAN has been determined to be about 8 GeV by taking account of the damping time, Toushek effect, and longitudinal and transverse beam instabilities. The accumulator has four-fold symmetry lattice and a circumference of 377 m and radiation loss at 8 GeV is 15.6 MeV/turn. The detail design of the accumulator has been fixed and its construction will start this April.

Phase II: Electron-Proton Collider The maximum proton energy is about 300 GeV with the superconducting bending magnets of 4.5 T. Collisions of electron beams with bunched proton beam give higher luminosity than collisions with unbunched protons when the same total number of particles circulate in the rings. RF frequency of proton beams is chosen to be 80 MHz to make the proton bunch length as short as 1 m. The electron ring will be arranged as the solid line in fig. 3. The electron energy will be about 25 GeV at the beam current of 70 mA with the 200 m long RF cavity and 18 MW RF power. Fig. 5 shows the luminosity calculated for the optimum parameters as a function of beam energies.

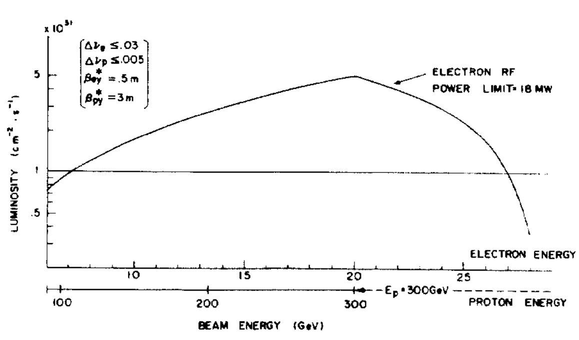

Fig. 5 Luminosity of the TRISTAN e-p collider.

Studies and Technical Developments for TRISTAN
Basic studies are performed about beam instabilities[11] in a storage ring and various technical developments for TRISTAN constructions are being performed.

We are developing the superconducting bending magnet and cryogenic system. The magnet is a warm bore and warm iron type. A model magnet having a bore diameter of 90 mm and a length of 1 m has been built and its maximum field has reached 5.2 T with quenches of ten times.[12]

The maximum energy of the electron ring is mainly limited by the RF power to compensate the energy loss due to synchrotron radiation. The beam parameter of Table II and the luminosity in Fig. 4 is designed with the conventional copper cavities. Higher electron energy will be obtained with superconducting cavities and also RF power could be saved. This is being developed and a 500 MHz spherical cavity has been made from 2.5 mm niobium sheet of 99.6 % purity as **the first** model. Electropolishing and oxipolishing techniques have been applied for surface treatments. The measurements show that Q-value is 3.4×10^9 at 4.2 K and 1.1×10^{10} at 1.9 K, and the maximum accelerating field reaches about 4.1 MV/m without multipactoring.[13]

Another technical research and development for TRISTAN, such as vacuum system of all aluminum alloy, RF accelerating structure of storage ring, computer control system are in progress.[14]

References

1. K. Kikuchi: On the Status of Accelerator Facilities and their porgress in Japan, IEEE Trans NS-26, 3124 (1979).
   T. Kamei and T. Nishikawa: KEK Status and Future Plan, Proc Xth Int. Conf. on High Energy Accelerators, Serpukov, 77 (1977).
2. S. Anami et al: High Power Isolator for the KEK Proton Linac, Proc. 1979 Linear Accel. Conf. Brookhaven, 367 (1979).
3. S. Anami et al: Status of the KEK Injector Linac, ibid, 94.
4. S. Ninomiya et al: Effect of the Non Linear Field on the Slow Extraction, Proc. XIth Int. Conf. on High Energy Accelerators, CERN 341 (1980).
5. Y. Mizumachi and K. Muto: this conference, F-60.
6. H. Baba et al: this conference, I-126.
7. Y. Mori et al: this conference, G-19.
8. S. Hiramatsu and K. Muto: Acceleration of Polarized Protons in KEK PS Proc. of 1980 Int. Symposium on H.E. Physics with Polarized Beams and Polarized Targets, Lausanne, 1980.
9. P. Grand: Options for Increasing the KEK Linac Energy for H^- Injection in Booster, KEK-Report 80-12 (1981).
10. T. Nishikawa: A Preliminary Design of Tri-Ring Intersecting Storage Accelerators in Nippon, Proc. IXth Int. Conf. on High Energy Accelerators, SLAC, 584 (1974).
    Y. Kimura: TRISTAN The Japanese Electron-Proton Colliding Beam Project, Proc. 11th Int. Conf. on High Energy Accelerators, CERN, 144 (1980).
11. T. Suzuki: this conference. F-61.
12. S. Mitsunobu et al: this conference, Q-37.
13. T. Furuya et al: this conference, K-9.
14. H. Ishimaru et al: this conference, K-52.
    H. Ikeda et al: this conference, E-85.
    T. Takata et al: this conference, D- 42.