TRISTAN at KEK, Japan

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Abstract

1) The construction of TRISTAN began in the fall of 1981.
2) The present plan aims at obtaining e^+e^- collisions at about 60 GeV in the total energy.
3) With superconducting RF cavities, on which an extensive development work is in progress, the maximum total energy can be substantially increased.
4) The design goal for the luminosity is $1 \times 10^{31} cm^{-2} sec^{-1}$ at 60 GeV. The optimal design luminosity peaks at 27 GeV with a value of $7 \times 10^{31} cm^{-2} sec^{-1}$ and fall off to $2 \times 10^{31} cm^{-2} sec^{-1}$.
5) The construction of the Main Ring is in progress almost on schedule with target date of the first collision in the fall of 1986.
6) The Accumulation Ring has been in operation since November 1983.

The TRISTAN project was presented initially at the International Symposium on High Energy Physics[1] and the US/Japan Seminar on High Energy Accelerator Science[2], both of which were held in 1973. The acronym "TRISTAN" stood for, then, "Tri-Ring Intersecting Storage

Accelerators in Nippon". The original plan called for a construction of a ring tunnel with the circumference 6 to 7 time that of present 12 GeV Proton Synchrotron (approximately 2 km). Two intersecting superconducting rings installed in it could provide protons and/or antiprotons of about 175 GeV in energy. An addition of a room temperature ring could provide electrons of 20 GeV in energy. Taking an advantage of a multi-ring structure, the original TRISTAN proposal would aim at super high energy colliding beam experiments of different configurations, such as pp, ep, e^+e^- and p-bar p. In 1980, the plan was extended to higher energies. At the same time, however, it was also decided to go ahead with the electron ring, leaving the hadron ring as a future possibility.

The current TRISTAN project was approved by the Government of Japan in 1981, and had been under construction since November of the same year at KEK (National Laboratory for High Energy Physics). The laboratory is in the Tsukuba Science City, located about 70 km north of Tokyo, or about 50 km north-west of New Tokyo International Airport. The present objective of the project is to obtain e^+e^- collisions with about 60 GeV in the center-of-mass energy. The circumference of the main electron ring is approximately 3 km, which is the largest possible ring that can be fitted in the laboratory site (about 2km x 1 km).

The lay-out of the TRISTAN e^+e^- collider complex is shown in Figure 1. It consists of four accelerators. First, electrons are accelerated to 2.5 GeV using the electron LINAC, an injector to the KEK Photon Factory which is in operation since 1982. Positrons are produced by a high current electron beam from a separate 200 MeV LINAC under construction. Positrons from the pair-production process are fed to an appropriate stage of the 2.5 GeV LINAC after a pre-acceleration to 200 MeV, and accelerated to 2.5 GeV as are for electron. The electrons (positrons) are injected into the Accumulation Ring where they are stacked to obtain sufficiently high current. After an acceleration to approximately 8 GeV in this ring, bunches of electrons (positrons) are transferred to the Main Ring. Finally, two bunches of positrons and two bunches of electrons, thus transferred to the Main Ring, are accelerated to and held at about 30 GeV for the colliding beam experiments.

The Accumulation Ring is a storage accelerator of 377 m in circumference. The accumulation rate will be about 15 mA/sec for electrons and 0.15 mA/sec for positrons provided that the LINAC delivers an electron and positron beam with the peak current of 0.5 A and 5 mA, respectively.

A short dumping time of this ring at the injection energy ($\sim$ 50 msec) enable us to obtain a high intensity beams. Incidentally, the Accumulation Ring can also run in the storage mode with the maximum energy of 6.5 GeV and can be used for e^+e^- colliding beam experiments at the total energy of 13 GeV and also for a synchrotron radiation research program. An optimum luminosity of approximately 1×10^{31} $cm^{-2}sec^{-1}$.

The Accumulation Ring is complete and the first operation with beams took place in October 1983. Electrons were accelerated to 4.2 GeV, only limited by the RF power available on November 18, on the eve of the two years anniversary from its ground breaking ceremony.

Principal design parameters of the TRISTAN Main Electron Ring are given in Table 1, along with those for the Accumulation Ring. The Main Electron Ring (see Fig. 1) consists of four long straight sections, each with 194 m in length, connected by four arcs of 347 m in average radius of curvature. Two electron bunches and two positron bunches circulating in the opposite direction make collisions with each other at the middle of the four straight sections. The main ring will have 272 dipole magnets and 392 quadrupole magnets. Although the nominal energy of each ring is 30 GeV , the magnets are designed to work at a substantially higher energies.

There will be four experimental mini-beta insertions each with 5 m magnet free section for detectors. In order to obtain as high a luminosity as possible it is highly desirable to make the horizontal and vertical betatron function, (β_x^*, β_y^*) as low as possible. The present design gives the lowest value of (β_x^*, β_y^*) = (1.12 m, 0.07 m), provided that the last quadrupole at the experimental insertion is located as close as 2.5 m from the collision point, leaving only 5 m of space for installation of a colliding beam detector. Here, a plan is being made to deploy a pair of superconducting quadrupole magnets as the last focussing element. The optimal design luminosity peaks at $\sim$ 27 GeV with a value of $\sim 7 \times 10^{31}\mathrm{cm}^{-2}\mathrm{sec}^{-1}$ and falls off to $\sim 2 \times 10^{31}\mathrm{cm}^{-2}\mathrm{sec}^{-1}$ at 30 GeV.

As is well-known, an electron beam in a storage ring looses an energy by synchrotron radiation at a rate of $8.85 \times 10^4\ E(\mathrm{GeV})^4/R$ eV per turn, which becomes enormous at TRISTAN energy. The beam energy and intensity attainable are ultimately limited by the maximum accelerating potential installed or RF power available for the ring. In the design of the Main Electron Ring, an RF power of about 25 MW into the ordinary room temperature cavities of 320 m in total length is planned, yielding an accelerating potential of about 400 MV per turn. This should satisfy the requirement to achieve a design goal of the collision luminosity and energy, of $\sim 1 \times 10^{31}\ \mathrm{cm}^{-2}\mathrm{sec}^{-1}$ at $\sqrt{s} = 60$ GeV, respectively. Two types of RF cavities; the disk and washer (DAW) type and the alternating-periodic structure (APS) type had been investigated for the Main Ring. Those confluent type cavities were chosen since they have a good stability against perturbations in the multi-cell structure. Although we have built and operated a DAW system in the Accumulation Ring, we are opting for an APS structure for the Main Ring due to a lack of a special merit of complex DAW structure. A new high power klystron with a continuous RF power of 1 MW at 500 MHz with an efficiency of about 65% is being developed for the present RF system.

A superconducting RF cavity, on which an extensive development work is in progress at KEK will provide a way to remove the energy limit placed by the RF power. An accelerating field of about 5 MV/m has been obtained with a 3 cell test module in the Accumulation Ring environment. A replacement of on half of the total room temperature RF cavities with superconducting cavities with an accelerating field of about 5 MV/m can upgraded the attainable collision energy to $\sqrt{s} = \sqrt{70}$ GeV , from purely RF power point of view.

To suppress serious beam instabilities which may result from the beam-cavity interactions in such a long RF section of the ring, the beta-functions at the RF cavity section will be kept as small as possible. Option of deploying a powerful higher harmonic RF system is available to control the length of beam bunchs.

Several technical innovations are being introduced in the vacuum system. Vacuum pipes, corrugated bellows and gate valves used in the accelerator are all made of aluminum alloy. The main ion pump is a distributed built-in type of a new structure which works in the field of the ring dipole magnet. By insulating the cathode from the vacuum pipe, we have found that the Penning discharge current can be measured at pressures as low as 10^{-9} Torr. This has ensured that the ion pump itself can be used as a built-in ultra-high vacuum gauge.

The floor of the ring tunnel is placed at 11 m below the grade level, where a layer of hard soil was found. The ring tunnel, therefore, will be build with out piling foundation. The civil construction for the Main Electron Ring is in good progress. One quarter of the tunnel section is almost completed. Incidentally, the cross section of the tunnel measures 4m x 6 m allowing additional devices to be added later. The tunnel in other part are being dug, including the south section which goes under the existing buildings. Sizable fraction of the Main Electron Ring magnets are on-hand now waiting for installation.

There will be four experimental halls on the Main Ring of TRISTAN. Due to the fact that the accelerator beam level is approximately 10 meters below the ground level, floor of the experimental halls is at 15.5 m below the grade and build on an extensive piling foundation. The beam level is approximately 6.5 m high for the detector installation. The construction of the first two halls to house TOPAZ detector and VENUS detector, named " TSUKUBA" and "FUJI" respectively began in 1983 with the target date of completion in late 1984. The construction of the third and forth experimental halls named "NIKKO" and "OHO" began in March 1984. All together, we are proceeding with goal of starting physics research program at TRISTAN in late 1986.

Since the maximum total energy of the TRISTAN e^+e^- collider is below that corresponds to the Z_0 mass, the research activity at this collider will be directed toward the physics below the Z_0 production. This include, of course, a search for the top quark states i.e., toponium states which are yet to be discovered and the investigation of their spectroscopy. Since the mass of the toponium is expected to be heavy, its decay rate to the Higgs scalar through a gamma emission is expected to be high ($\sim$ 1%) and may provide us with the best searching ground for the scalar. The branching ratios for various weak decays of toponium are essential for the determination of Kobayashi-Maskawa mixing. A search for a heavy sequential charged lepton will be another exciting subject of the study, as its discovery may suggest the existence of the forth generation of quarks and leptons.

Further study of jet phenomena at higher energies, leading to a study of QCD, will be of interest. In the TRISTAN energy range, the foward-backward asymmetry of lepton production due to the interference of electromagnetic and weak interactions will become as large as 45%, giving the chance to investigate the effect of Z_0. Since the TRISTAN cover an uncharted new higher energy domain in the e^+e^- collision, a search for a new and unexpected phenomena will certainly be the one of our research goals. All together, the TRISTAN project anticipates a rich field of the research in the elementary particle study.

TRISTAN Program Advisory Committee (TPAC) which includes two eminent physicists from abroad in its members had its third and fourth meeting on March 17-19th and on November 8-10th, 1983, respectively. In these meetings, the committee gave a recommendation to approve three major experimental undertakings, i.e. the proposals submitted by the TOPAZ[*] Collaboration and the VENUS[**] Collaboration, mostly national teams, and the third proposal by the AMY[+] collaboration from US based teams. The decision on the forth experiment including a proposal for HRS[++] collaboration is pending. The decision on the forth experiment was postponed to the future date in order to maintain the flexibility in the TRISTAN physics program for the optimum experimental output.

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[*] Spokesman:Prof. T. Kamae, Faculty of Science, Tokyo Univ.

[**] Spokesman:Prof. Y. Nagashima, Faculty of Science, Osaka Univ.

[+] Spokesman:Prof. S. Olsen, the Univ. of Rochester.

[++] Spokesman:Dr. M. Derrick, Argonne National Laboratory.

References

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2. T. Nishikawa, Proc. U. S.-Japan Seminar on High Energy Accelerator Science, (KEK, 1973), p. 209
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	Main Ring	Accumulation Ring
Circumference (m)	3018	377
Average radius of curved section (m)	346.7	47.7
Bending radius (m)	246.5	23.2
Long straight sections (m)	194.4 (x4)	19.5 (x2)+19.1 (x2)
Total length of RF sections (m)	509.4	38.1
Total length Acc. RF cavities (m)	318	29.6
RF frequency (MHz)	508.6	508.6
Revolution frequency (kHz)	99.3	795
Maximum stored beam energy (GeV)	30	6
RF peak voltage (MV)	400	10
Injection energy (GeV)	6 - 8	2.5 - 3
Experimental insertion (m)	5 (x4)	5 (x2)
Max. design luminosity ($cm^{-2}s^{-1}$)	8×10^{31}	2×10^{31}
Betatron function at colliding point (β_x^*/β_y^*, m)	1.12/0.07	2.0/0.1
Beam size at coll. point (σ_x^*/σ_y^*, mm)	0.434/0.027	0.71/0.036

Table 1: General parameters of TRISTAN Main Electron Ring and Accumulation Ring

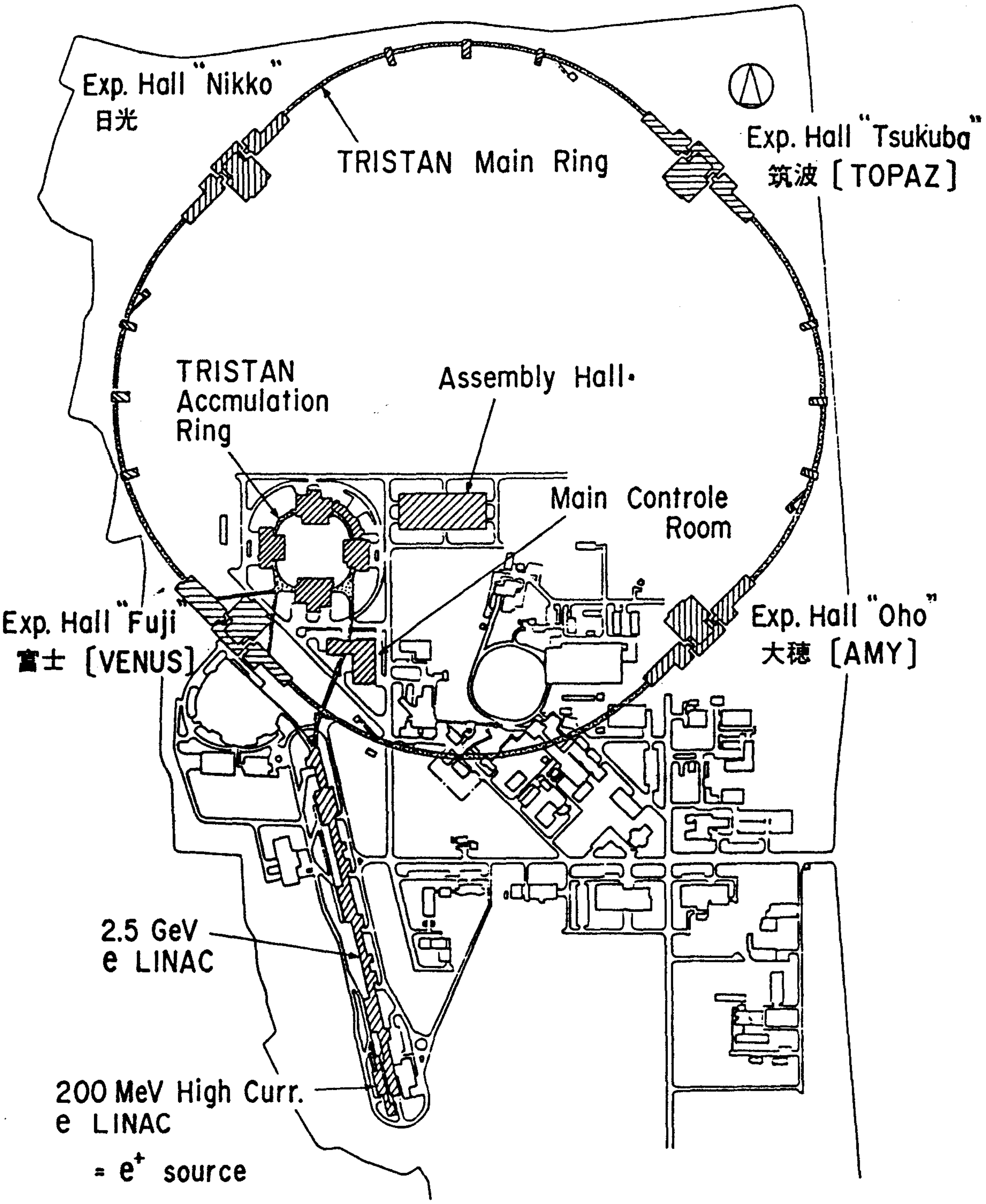

Fig. 1 Lay out of the TRISTAN e^+e^- collider complex.