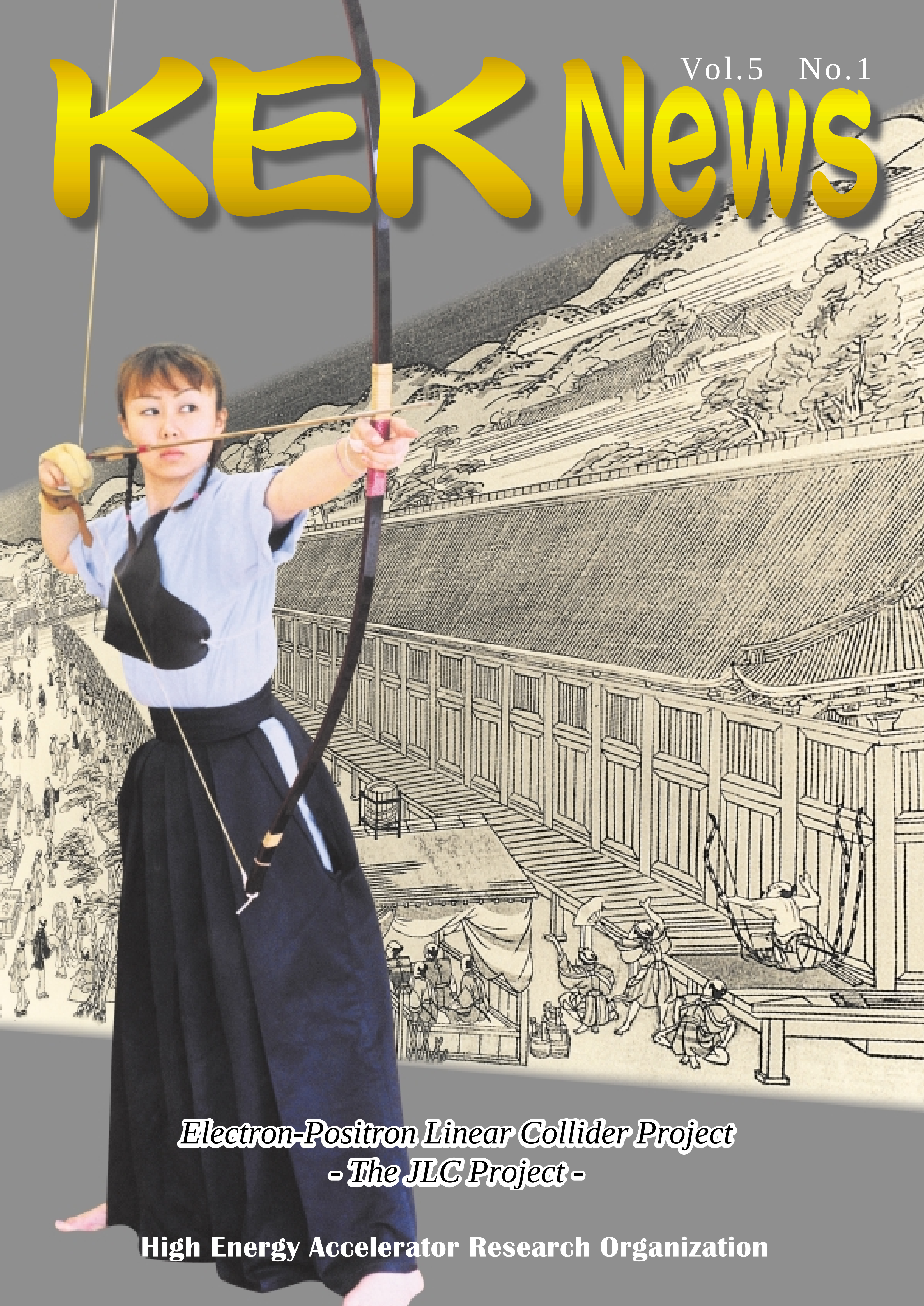
KEK News

Vol.5 No.1



Electron-Positron Linear Collider Project

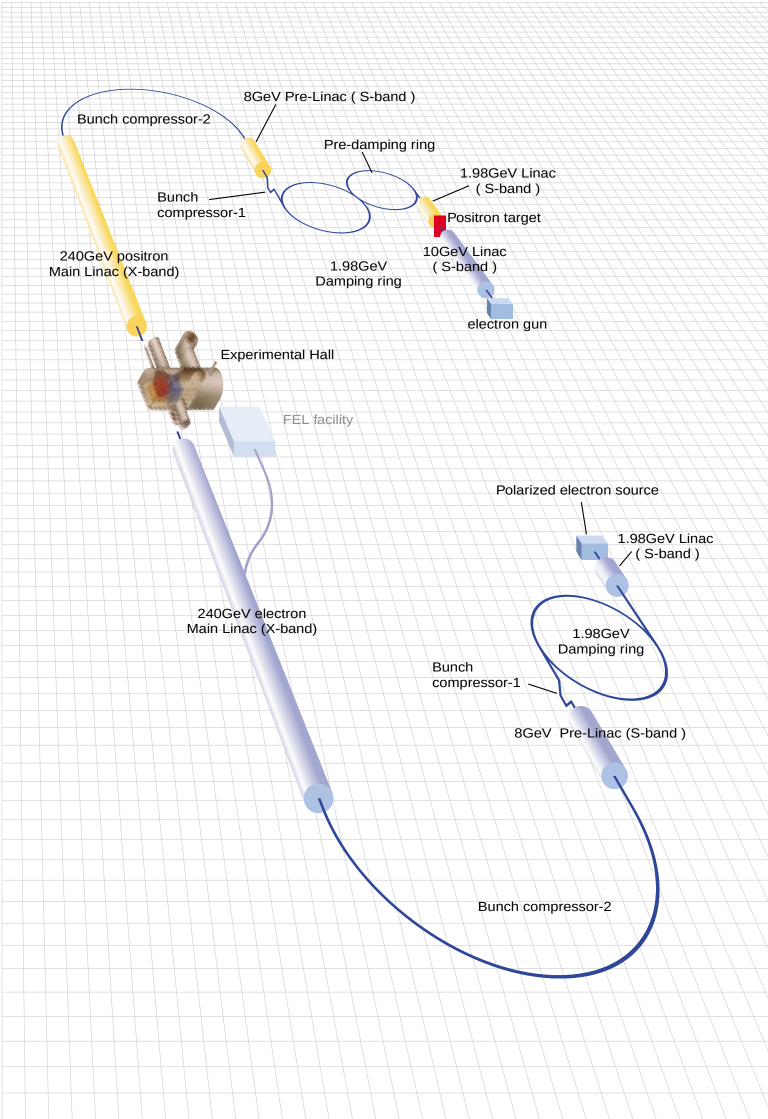
- The JLC Project -

High Energy Accelerator Research Organization

Electron-Positron Linear Collider

- The JLC Project -

The JLC project consists of the construction of an electron-positron linear collider and the experiment therewith, at a start up center of mass energy of around 250 GeV. The accelerator will eventually reach TeV energy region, along with successive machine upgrades. The JLC machine will allow us to study elementary processes that could have happened only in the early very hot universe and will pave a way to uncover the secrets of the creation and evolution of our universe.



Schematic View of the JLC

The JLC project stems from the Japanese High Energy Committee's recommendation made back in 1986 as the post-TRISTAN program for energy-frontier physics. Following the recommendation, we set up a 5-years R&D program to address key issues in basic component technologies and to formulate the project as a whole. The R&D program led us to the first project design in 1992, where we elucidated physics prospects and novel detector concepts matching the opportunities, and outlined the accelerator complex including its application to X-ray laser production.

The principal guideline shown there for the project promotion remains valid and even enforced especially in the necessity for further internationalization of the project. In this respect, the 1997 endorsement of the JLC as one of the major future facilities in the Asia-Pacific region is a remarkable milestone made by the Asian Committee for Future Accelerators (ACFA). This action in ACFA was an important step towards its realization in this region.

The inter-regional cooperation also became more important than ever, which is reflected in recent close cooperation with European and North American regions to promote R&D's for the linear collider.

In the first stage of an entire JLC program, we are planning to cover the center of mass energies of up to about 500 GeV with a luminosity of more than 1.5×10^{34} cm^{-2} sec^{-1}.

A high luminosity e^+e^- collider of that class is capable of producing more than 0.5 million light Higgs bosons and top quarks within 5-6 years. Consequently, the facility naturally serves as a Higgs and top factory. In addition it has a remarkable physics potential as a W and Z factory equipped with highly polarized beams and a two-orders-of-magnitude higher luminosity than those of existing facilities.

Physics

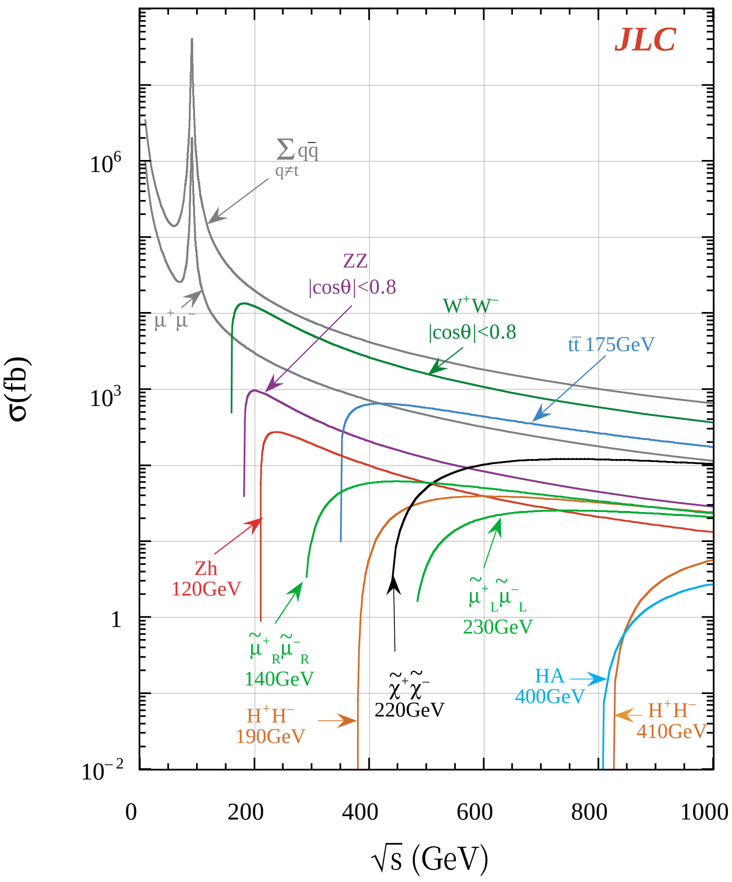
The only missing ingredient of the Standard Model is the Higgs boson that gives masses to all the fundamental particles. Its discovery and detailed studies are the most urgent experimental task in present high energy physics. The recent precision electroweak data put an upper limit on the Higgs boson mass to be about 200 GeV at the 95% confidence level, strongly suggesting the existence of a light Higgs boson.

One of the most exciting possibilities is the discovery of the Higgs boson with a mass of less than 150 GeV. This mass range is particularly interesting from the viewpoint of grand-unified models with the grand-desert hypothesis. It also fits more naturally in Supersymmetric extensions of the Standard Model than in the Standard Model itself.

Once such a light Higgs boson is found, the most important question is whether the observed Higgs boson is of the Standard Model or not. The JLC will answer this question through systematic studies of its decay properties, precision branching ratio measurements in particular. These detailed studies are possible only with a high luminosity and a clean environment of lepton colliders.

Even more exciting is the discovery of supersymmetric particles or some hints of extra dimensions. Their precision studies would open up a completely new era of high energy physics, that might lead us to a unified picture of all the matter and forces, and even space-time as well.

It should be emphasized, however, that even in the absence of any direct indications of new physics, there remain many important measurements to be made regarding W / Z boson properties, QCD, and two-photon physics. It is then of vital importance to further improve the precision of the data from the existing large-scale experiments in the world, so as to find any indirect indications of physics beyond the Standard Model.



Physics Target

Notice also that, although the top quark has already been discovered at Tevatron and studied to some extent, its detailed study at the JLC will shed a totally new light on the heavy quark dynamics. Since QCD effects remain well under control, the study enables us to extract other smaller effects such as the Higgs exchange contribution: the first observation of the top Yukawa coupling.

The experiments at the JLC will thus bring us to a deeper understanding of nature and possibly open up a way to uncover the secrets of the creation and evolution of our universe.

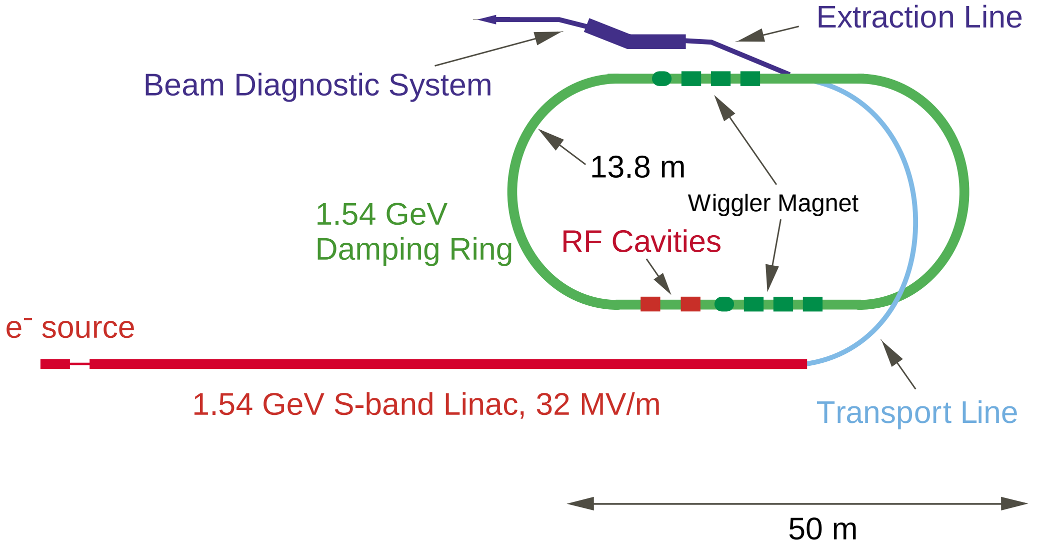
The Accelerator

A high energy electron or positron emits synchrotron light when forced to turn and loses its energy. The center of mass energy of a storage-ring-type e^+e^- collider is practically limited to around 200 GeV, e.g. LEP at CERN, due to this energy loss. Exploration into TeV energy region with e^+e^- collisions thus requires development of a new collider concept, a linear collider and not a ring-type collider.

The major component of the JLC is a pair of very long, powerful linear accelerators called main linacs, one for electron and the other for positron. The accelerated beams of electrons and positrons are then focused into a nanometer-size spot in the interaction region and are brought into collisions at physicists' disposal.

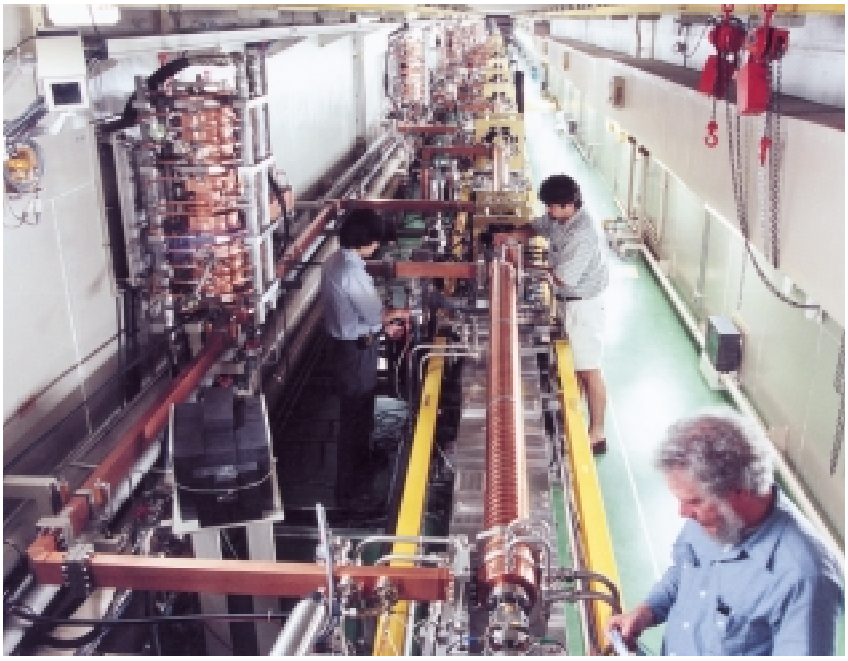
A minimum attainable beam size at the interaction point is determined only by the initial beam emittance which is one of the most important beam parameters that defines the beam quality. Therefore it is essentially important to produce a high quality beam at the initial stage of acceleration. Such a beam can be obtained by storing it in a ring called a damping ring, where the beam emittance is reduced due to the mechanism of synchrotron radiation damping.

To experimentally confirm its feasibility, we have constructed a large scale Accelerator Test Facility (ATF) at KEK. The ATF consists of two major components: an S-band injector linac and a damping ring.



Schematic View of the ATF

The injector linac consists of a conventional thermionic gun, a sub-harmonic buncher, an S-band buncher and eighteen 3m-long S-band accelerating structures with constant acceleration gradient. The overall length of the linac is 75 m. The compressed pulse from a high power RF source, an 80 MW klystron, is divided into two and are fed to two accelerating structures. The average accelerating gradient is designed to be 32 MV / m with beam loading.



ATF Injector Linac

For achieving ultra-low emittance, the arc sections of the damping ring have a special lattice structure of FOBO type in which a focusing quadrapole (F) and a defocusing bend (B) are placed at the minimum point of dispersion.

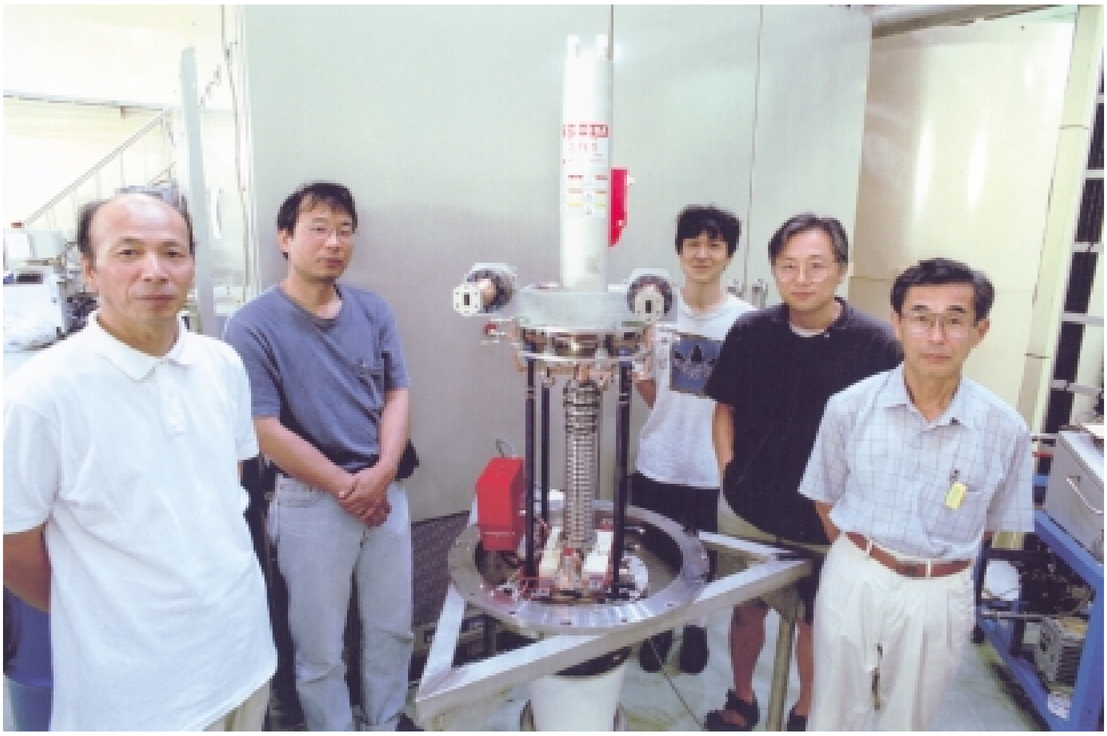
ATF Damping Ring

The commissioning of the ATF began in early 1997. Since then, various improvements have been made to achieve the stable operation of the ATF. In November 1997 the extraction line from the damping ring became available for detailed beam diagnostics. The design goal on the beam emittance has almost been met in a single-bunch mode; the horizontal and vertical emittance are about 2×10^{-9} meter rad and $1\sim2 \times 10^{-11}$ meter rad at 10^{10} electrons/bunch.

It is worth mentioning that the performance of the ATF has also encouraged people working on linear colliders such as CLIC (the Compact LInear Collider at CERN) in which beam-emittance should be even lower.

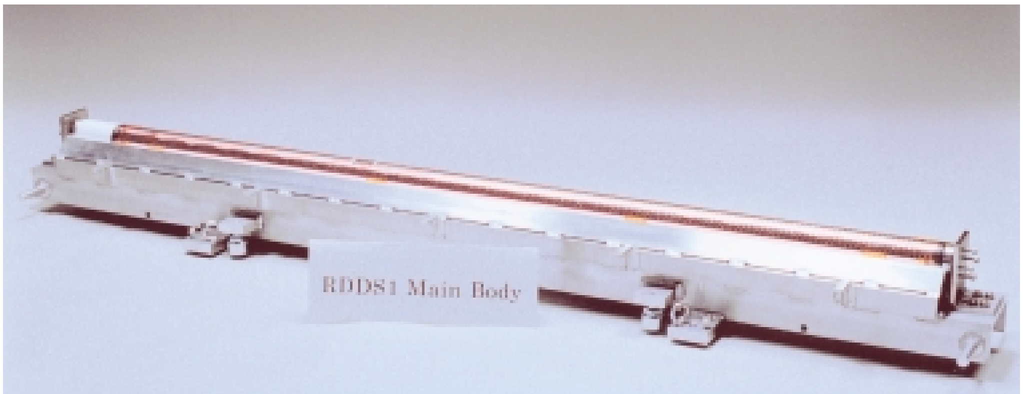
The RF system for the main linacs is one of the most important components to be newly developed for reaching into the TeV energy region. Considering the potentially higher acceleration gradient and efficiency, X-band (11.4GHz) was chosen as the best frequency for the RF system of the JLC, and C-band (5.7GHz) as its backup option. The X-band is four times higher than the S-band which is employed for many existing linacs. This big jump in frequency implies a technological challenge, and necessitates a systematic and time-consuming R&D.

In order to make maximum use of resources available in the world, the X-band R&D has been carried out in close collaboration with Stanford Linear Accelerator Center and the Protvino branch of Budker Institute of Nuclear Physics. The collaboration led us to deeper understanding of the behaviors of the X-band RF system and resulted in the first prototype klystron successfully tested in the FY 2000. The most recent model has been producing 73 MW output power with a 1.4 microsec pulse width, nearly satisfying the JLC specification.



X-band Klystron

Another important element in the RF system is an accelerating structure, which usually consists of a stack of disks. Because of the shorter wavelength of the X-band, the accelerating structure becomes much more compact than that of the S-band system. The hind side of this merit is the mechanical tolerance that is much tighter, thereby calling for a new method to construct a high quality structure with high precision.



X-band Accelerating Structure

The latest design of the structure requires the disks to be machined to 1 micron precision and to be aligned to better than 5 μm precision over the whole length of 1.8 m. The KEK team has established the technology to meet the requirements and the constructed prototype structures have fulfilled the tolerance specifications.

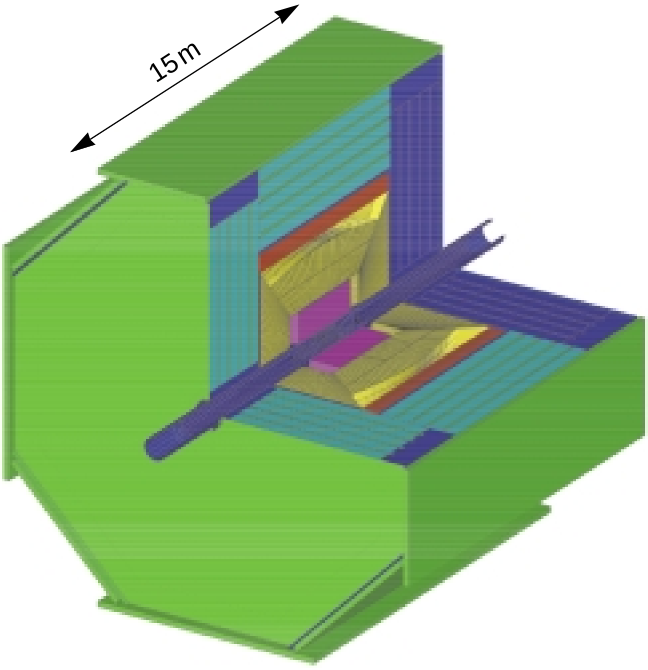
The JLC is a huge accelerator complex and there are many activities for each component R&D far more than listed in here. The R&D on essential components of the whole accelerator system has been nearly completed. We are finalizing the conceptual design of the JLC through the integration of our cumulative R&D efforts and resultant advance in accelerator physics.

The Detector

The e^+e^- annihilation experiments in this energy region have a remarkable advantage. Thanks to its clean experimental conditions, all the fundamental particles such as W, Z, top, and Higgs can be reconstructed through quark-jet invariant mass method.

A high resolution hadron calorimeter is the key for achieving the best energy-flow measurements. Together with a high resolution tracker, it then assures the best quark-jet invariant mass resolution, thereby allowing us to fully exploit this novel feature of the experiments.

Since the most important physics target is the Higgs boson, the detector should be capable of measuring nature of Higgs boson in detail. In the Higgs production process $e^+e^- \rightarrow Zh$ followed by a $Z \rightarrow \ell^+\ell^-$ decay, the Higgs boson mass and Higgs boson width can be determined by measur-



3 Tesla Detector Model

ing the mass recoiling against the Z boson. There is a limitation in the recoil mass resolution, which is determined by the width of the initial beam energy. Hence, we require that the recoil mass resolution should be comparable with the width of the JLC beam energy, 0.1% in our central tracker design. For detailed studies of the Higgs boson, it is essential to have good flavor-tagging efficiencies for both bottom and charm quarks. We thus need a high precision vertex detector. Taking into account these requirements and possible future upgrading, we are now considering a large general-purpose detector. A large 3 Tesla superconducting solenoid magnet is placed outside of the calorimeter in order to keep the hermeticity for the calorimeter system.

The energy resolutions of the calorimeter consisting of lead-scintillator layers with readout fibers are 15% for 1 GeV electrons / photons and 40% for 1 GeV hadrons. We adopt a small-cell jet chamber as the central tracker to achieve spatial resolutions of 100 μm in r-ϕ and 1 mm in z directions, and a two-track resolution of better than 2 mm. At the center of the detector very close to the interaction point, there is a CCD vertex detector, whose innermost radius is 2.5 cm from the beam line. The spatial resolution of the vertex detector is expected to be better than 4 μm.

The proof-of-principle phase of the R&D's for these detector components is almost completed and we are now moving towards the detector design in engineering aspect.

International Cooperation

At various facilities in the Asian region, there have been significant progresses in high energy physics and synchrotron radiation experiments. In addition, many researchers from ACFA member nations are actively participating in large-scale experiments such as those at KEKB / PEP-II, Tevatron, HERA, and LHC. The Asian physics community has grown significantly and has thus set a firm enough foundation for further bigger projects.

The linear collider has a facet which can serve as a new means for materials science. The ultra-low-emittance beam essential for the JLC is also an indispensable element of the next-generation, coherent x-ray source. Therefore it is very important to collaborate with the materials science community in ACFA to efficiently and effectively promote accelerator science.

In response to the ACFA statement of the linear collider project, a study group, Joint Linear Collider Physics and Detector Working Group, has been set up under ACFA. The charge of the working group is to elucidate physics scenario and experimental feasibilities. The working group has been subdivided, according to physics topics and detector components. Now 62 institutions in Asia are participating in various subgroups, expanding their research activities at their home institutes. The subgroup activities in different part of Asia are discussed over Internet and have been summarized annually at series of ACFA workshops.

ACFA Workshop at Korea University

The first workshop was held at Tsinghua University in Beijing (1998), followed by one at Korea University in Seoul (1999), and then one at Taiwan University in Taipei (2000). Thanks to the hospitality and thoughtfulness of the hosts, all of these meetings were very enjoyable and fruitful.

Taking into account the scale of and the worldwide interests in linear collider projects, it is highly desirable that actual studies be carried out in a more global scope in spite of the regional nature of ACFA's initiative. In this respect, it should also be noted that there have always been a few participants from Europe and the U.S.A. in the framework of the inter-regional cooperation. Reciprocally, Asian colleagues have been contributing to the workshops of the other regions. All of these regional activities are reported and discussed at a series of worldwide linear collider workshops.

The JLC is a reasonable next step for the Asian high energy physics community well motivated by our present knowledge of particle physics. KEK has been integrating outcomes from the accelerator, physics, and detector studies to realize the project in Asia through a healthy collaboration with Asian laboratories and universities. The inter-regional cooperation has become more active in time and has helped further promote the project.

KEK, being one of the most active major high energy physics laboratories in the world, is willing to host this challenging large-scale inter-regional facility in the 21st century. The JLC project would provide a good model case for the promotion of accelerator-based science in Asia.

For details please see http://acfahep.kek.jp/

The author of this article, Professor ***Takayuki MATSUI***, is the leader of JLC physics group.

Congratulations to BELLE group members

BELLE Collaboration (See page 14 for detail)

Noh Theatre, a classic alive

The history of Noh Theatre goes back to the 8th century. A quantum jump was achieved by Kan-ami (1333-1384) and his son Ze-ami (1364?-1443) under the patronage of General Yoshimitu ASHIKAGA (1358-1408). Suddenly, the play became a theatrical art for highly sophisticated audiences. Ze-ami wrote a famous Noh textbook, "Kadensho" (1413). Now in the 21st century, the book still stands as an inspiring textbook for theater directors. Many say that Noh has been left unchanged for the last 600 years because it reached such a high level of sophistication in the early years. I think the reason Noh survived through the long history of social (sometimes violent) changes is not only because of this; it is the strong will of the whole society of Noh players, who have been working towards perfection over centuries. Noh society kept it as family business, so that they can work through many generations to improve the art.

A family that takes the role of "Shite-kata" (hero) stays as a "Shitekata" family; a family that takes supporting roles, "Waki-kata", remains as a "Waki-kata" family and a family that plays musical instruments stays as a "Hayashi-kata" family forever.

The picture on the right shows Mr. Nobushige KAWAMURA of one of the major "Shite-kata" families. He started his childhood on the Noh stage and continued playing for almost 40 years. He has been very active in keeping the public recognition on Noh through teaching in a university and many other places in addition to performing Noh himself. His group has been performing in many places in Japan, as well as Paris, New York, Milan and Rome. Most Japanese would consider Noh players to be someone out of reach, mainly due to their highly respected status.

On the contrary, Mr. Kawamura is a very kind and friendly person although he would appear awesome on the Noh stage. It is the people, like Mr. Kawamura, who kept the Noh Theatre alive as one of the modern play style of the time. Noh will never be a play of the past; it is fully alive.

Noh stands out as one of the most impressive theatrical arts in the world.

The costume Noh players wear is of superlative design and quality and the masks they wear bear hundreds of years of history. It is as if the Noh masks have their own will to keep appearing on stage. Some masks are over 600 years old and still used. Although there is no provision to move any parts of it, a Noh mask can express every kind of emotion, thanks to the great talent of Noh players. Enclosed in the costume and the mask, a Noh player can become anything, often a ghost, a spirit or a god.

In almost any play in which a ghost plays a major role, audiences know that in it is a human that is playing the role of a ghost on stage. In Noh, a good player will make you feel that you are really seeing a ghost. Behind the costume and the mask, the sense of a human being inside magically disappears. In well made movies where the directors can use all sorts of modern tricks, audiences can also be lead to believe that the super being exists. But I have never seen this magic happen on theater stages except in Noh plays, where the stage is only 5.4 meters wide and 5.4 meters deep. The first picture shows Mr. KAWAMURA in the "U-kai" play, where musicians and singers are visible behind the players. Neither stage settings (of any significance) nor lighting techniques are employed. Despite this, you will be lead into the scenery as if you were there. It is like a daydream.

Music in Noh is also extraordinary and is just like listening to an excellent performance of jazz. Each player feels the on-going rhythm and improvises the exact timing they should apply. Sprit seconds counts. It is amazing to know that there is no practice session prior to a performance except for some discussion between the performers.

While the music is going on, a Noh player will display an elegant dance called "Mai", while occasionally reciting a poem. It is like listening to a the softest passage of a masterpiece of music, where the music is at the highest spiritual point. The temperate movement of a Noh dance could show awesome solemnity or deep sorrow as well as the aggressive emotion of a flamenco dance. The energy on stage is sometimes so tense, you might hold your breath. Well, will you believe me? I can only say that seeing is believing. I should also mention a comic Kyogen play that often is associated with Noh plays, but I have no space for it here. (T.K.O.)

March 2

Professor Kazuo Moriwaki, the vise director of Sokendai Graduate School, gave a talk titled "Looking at a human from a mouse's point of view". The section of DNA structure common to both human and mouse genes was discussed.

March 26-30

The 18th International High Energy Accelerator Conference was held at the Tsukuba International Congress Center. 170 participants actively talked about high luminosity factories, present and future colliders, muon accelerators, new techniques and novel ideas on future accelerators, etc.

April 6

The 3rd International Hanami Party under Cherry Blossoms was attended by around 40 people.

Lively discussions went on along with Japanese tea and sweets.

April 6

KEK Restaurant and Cafeteria started to serve authentic non-Japanese food roughly once every two weeks with the help from visitors from outside of Japan. Since then, Fish & Chips, Shepherd's Pie, Thai Green Curry, Mushroom Risotto, Pumpkin Gnocchi, Chili con Carne, Indian Chick pea Curry, Moscow style Cutlet have been served and well appreciated.

May 17

Professor Cecilia Jarlskog visited KEK and gave a talk at KEK Colloquium. The auditorium was filled with audiences who enjoyed her presentation very much.

May 24-30

The 3rd international workshop on neutrino factories based on the muon storage ring was held at the Tsukuba International Congress Center.

Participants (91 from overseas and 73 from Japan) extensively discussed physics potential and feasibility of neutrino factories. It was a timely workshop, as KEK/Jaeri joint project (see last issue of the KEK News) was approved by then.

June 1

After the 1997 KEK reorganization, changing the KEK logo was talked about. A new KEK Logo was chosen through a design competition and became official as of June 1. (right)

July 10

K2K Collaboration (See KEK News Vol. 2, No.1) announced new results that represent the first significant data on neutrino oscillations. A total of 44 neutrinos from KEK have been identified in the Super-Kamiokande detector where the expected number of events in the absence of neutrino oscillations would be 64, while conservatively estimated error margins is approximately 10%. Thus the K2K results are statistically inconsistent with the no-oscillation hypothesis at about the 97% confidence level. K2K is expected to continue accumulating data through early 2004.

For details, see:

http://neutrino.kek.jp/news//2001.07.10.News/index-e.html

July 23

The Belle collaboration (see KEK News Vol.2 No.3 1999) reported the observation of large CP violation in the neutral B meson system at the Lepton Photon Conference Symposium in Rome and at the talk in KEK on the same day.

Obtained CP asymmetry parameter established the CP violation with a probability greater than 99.999%. This result confirms the validity of the Kobayashi-Maskawa model for CP violation and is a great step towards further understanding of its mechanism. They will continue taking data for more refinements. Picture on page 10 (bottom) shows members of the Belle collaboration.

For details, see:

http://bsunsrv1.kek.jp/bdocs/sin2phi1_prl2/sin2phi1.html

Front and back covers

The front cover shows an archery contest at the Sanjusangen-do temple in Kyoto. The building is 125 meters long and people competed the number of arrows that successfully passes through the long corridor within 24 hours. Recorded high was 8133 out of 13053 shots by Wasa DAIHACHIRO in 1686. Future linear accelerator will also need similar super human efforts for linear acceleration.

This building houses 1001 Kannon Bodhisattva statues and many Buddhism-related statues inside. (back cover) Many are designated as National Treasures. The number of statues being so large meant to express that the mercy of Buddha fills the world, just like elementary particles fill space. Shown along on the front cover is an archery club member of University of Tsukuba.

We are much grateful to the Rengeohin Sanjusangen-do Temple for their understanding and support and to the Askaen for their advise and to the Archery club for their help.

ISSN 1343-3547

KEK News Vol.5, No.1 July 2001

Published by High Energy Accelerator Research Organization
1-1 Oho, Tsukuba, Ibaraki, 305-0801 Japan
Printing and cover design : Matsueda Printing Inc.
2438 Tenmancho, Mitsukaido, Ibaraki, 303-0034 Japan
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