KEK News

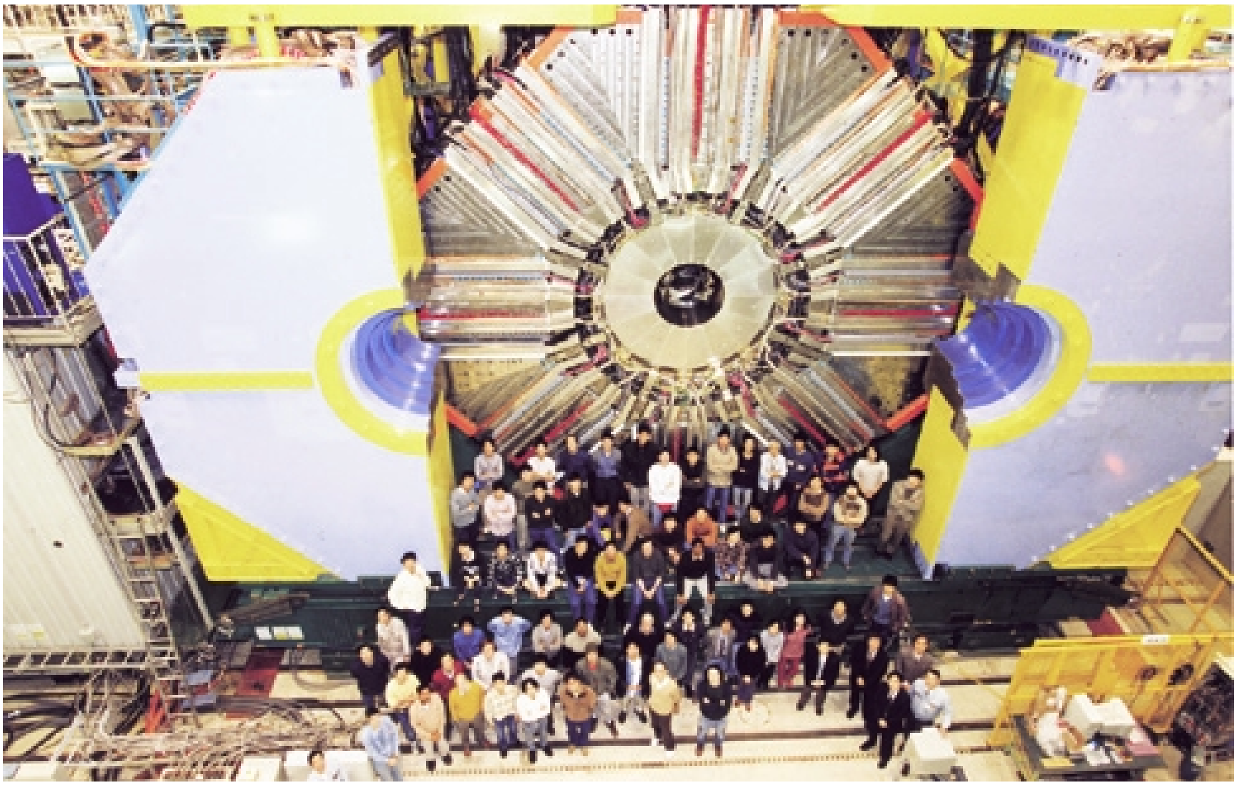
Vol.2 No.3

KEK B-Factory soon to start
Life in Tsukuba

High Energy Accelerator Research Organization

The BELLE experiment

What is the aim of the BELLE experiment and why are we taking the challenge



BELLE detector ready for roll-in

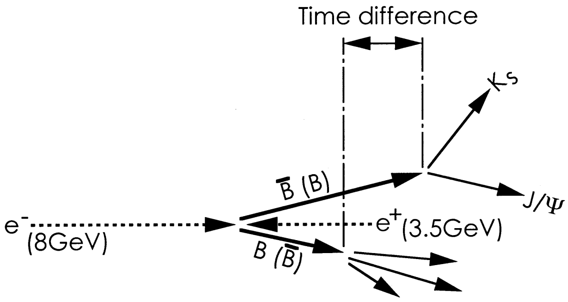
One of the most fundamental nature of the universe is that corresponding anti-matter can, in principle, exist for any matter in universe. It is also widely known that a physics law that can be applied to a matter can also be applied to a corresponding anti-matter. This symmetry is called "CP invariance". (C stands for (electric) charge, P stands for one of the parameters to describe a state of elementary particles, called "parity"). Hence the simple, symmetrical world had been considered to be the fundamental character of the nature. However, in 1964, it was discovered that this symmetry was slightly "broken" in a specific decay of neutral K particle. Now such beauty is gone and serious efforts to find other examples of this "CP violation" started.

The CP violation attracts attention because it may be relevant to the "baryon asymmetry of the universe", i.e., this universe consists almost only of matters and the existing amount of anti-matter is very little in comparison. Many theories have been proposed to explain this phenomenon, and Kobayashi-Maskawa model is believed to be the most convincing theory to explain the CP violation. Experimentally, on the other hand, no other evidence for CP violation has been observed yet.

The purposes of the KEKB project are to get a new evidence of CP violation in B meson (one of the elementary particles) system and to confirm the Kobayashi-Maskawa model, and to search for new physics in rare B decays.

It is now known that some special decay modes of B mesons show order of 10% level CP violation effect, while the known CP violation in K system is of the order of 0.1% level. To measure these effect to required precision, we have to examine huge number of decay events, requiring a production of huge number of B mesons. To achieve this, a high luminosity (=means lots of particles are in a tiny volume colliding each other so that chances of collision is quite high), asymmetric electron-positron collider would be the most desirable for such experiments.

In the KEKB collider, electrons of 8 GeV and positrons of 3.5 GeV collide at luminosity of $L=10^{34}/cm^2 \cdot sec$, which produces Y(4s) meson moving along the electron (e^-) direction at beta=0.4, and then, right away decays into a B/anti-B pair. Here is the advantage of having two different energies between the colliding particles. If they both have the same energy, they will go into a halt right after the collision and, thus, there would be no chance to distinguish B and anti-B when they decay. If one decays into J/Ψ Ks and another decays into a final state that can be identified as B, for example, the distance between the first and the second decay points (=of the order of 100μm) can be measured using a high resolution silicon vertex detector.



It has been predicted that the distribution of this distance is different between B tagged events and anti-B tagged events as a result of quantum mechanical interference. Observing this difference is an immediate evidence of the indirect CP violation in B system. To carry out this measurement, more than 10^7 B meson events have to be examined. This measurement will also result in a measurement of a complex phase which appears in the Kobayashi-Maskawa's quark mixing matrix with little theoretical uncertainty. The result would then either tell that the model is the only reason for CP violation below order of 100 GeV energy scale, or imply that unknown new physics is relevant to B decays. Such phase studies of B decays are also included in the physics scenario of the KEKB, which will take at least a few years of KEKB experiment. As one can see, B physics is one of the hottest topics in elementary particle physics. Three other similar projects are on going : HERAB project at DESY, PEP-II program at SLAC and an upgrade of CDF facility at FNAL. These four, including KEKB, have similar commissioning schedule and very active competition among them is expected.

The author of this section is
Masanori Yamauchi, who is one of the leaders in the BELLE experiment.

The BELLE Detector system

After the five years of intensive construction effort by the BELLE collaboration, the detector was completed by December 18,1998. The 1.5 Tesla super conducting solenoid was turned on on Jan. 19 and the detector will be rolled into the KEKB beam line in April. The experiment will start in May.

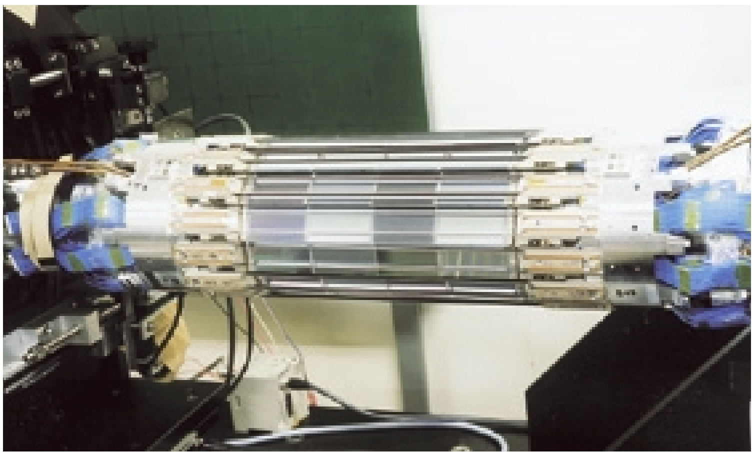
The BELLE detector is operated by the collaboration of about 300 physicists from many countries such as Korea, China, U.S.A., Australia, India, Russia, Poland, Philippines and Taiwan in addition to Japan. The detector itself is about 7 meters in length, containing about 1,400 tons of iron and over 100,000 individual detector elements. The electron and positron beams collide and annihilate at the center of the detector, producing new, sometimes exotic and unfamiliar, matter—particularly b quarks.

To observe the CP violation in the B meson system most efficiently, the following requirements must be met. The detector must be able to (1) locate the decay points (vertices) of the B mesons with high precision, to (2) identify the types of the charged particles flying out of the decay points, to (3) detect gamma-rays with high resolution and with high detection efficiency, to (4) detect K-mesons and π-mesons with high efficiencies, and to (5) collect data at a very high rate.

It is not possible for a single detection device to satisfy these hard-to-clear requirements. Therefore the detector consists of many components (sub-detectors) that are specialized to meet each of the above requirements.

The Silicon Vertex Detector

The inner-most sub-detector placed around the collision point is the silicon vertex detector (SVD) utilizing the technique developed for producing very-large-integrated circuit chips used in most electronics of today.



The SVD detector

This detector is an array of 104 silicon wafers attached on cylindrical frames. Each wafer has 640 etched thin strips on both sides of the wafer at ~50 μm pitch. When a charged particle passes through a 300 μm thick wafer, pairs of electrons and holes are created. The electrons then pulled towards one side of the wafer by the electric field inside, and holes towards the opposite side. They are then collected by the strips on the surface of the wafer and become electric pulses which are then amplified, digitized and recorded by its data acquisition system described below. The SVD is capable of locating the path of the charged particles with better than 20 µm precision in two dimensions. Using these measurements, the location of the decay vertices of the B mesons are extrapolated to 50 - 80 µm accuracy in three dimensions.

Central drift chamber (CDC)

The central drift chamber (CDC) is placed outside of the SVD, inside of very strong magnetic field (1.5 Tesla) of a solenoid. The drift chamber is specialized in measuring the momentum of the charged particle. In magnetic field, the trajectory of a charged particle is bent with a radius proportional to the momentum of the particle.

There are 52 cylindrical active readout layers which allow a precision measurement of the three dimensional trajectory of the charged particle to get the momentum of the particle. At the same time, the CDC can measure the ionization charge produced by each charged particle in the chamber gas, which enables us to identify the particle species.

The CDC

Two sub-detectors specialized in measuring the traveling speed of charged particles are located outside of the CDC, the aerogel Cerenkov counters (ACC) and the time-of-flight counters (TOF). This combination is capable of covering wide momentum range. Both detectors make use of the fact that different species have different masses. For particles that have the same momentum, traveling velocities are different if their masses are different. The aerogel Cerenkov counter emits light in a particular way according to the velocity of a passing particle if its velocity is higher than a specific threshold value. For the particle with lower velocities, the ACC is not appropriate to tell the velocity of the particle. Then the TOF counter measures the time for the charged particle to travel from the decay point to the time of flight counter. Since we know the distance of travel, the velocity of the charged particle can be calculated.

With the measured velocity and the momentum measured by the CDC, one can tell the mass of the charged particle which will indicate what kind of particle it was. Roughly speaking, the TOF identifies the particle with momentum less than 1.2 GeV/c and the ACC, greater than 1.2 GeV/c.

The Endcap ACC

The Electromagnetic calorimeter

The Electromagnetic Calorimeter

The main purpose of the electromagnetic calorimeter is to tell the energy of each particle from the B meson decays with high efficiency and with good resolution. The system contains 8816 Cesium Iodide (Thallium doped) crystals and weighs 43 tons. The real challenge in the construction is to support this large mass with very thin material not to affect the particles entering the crystals. We accomplished this hard task using thin aluminum plates in a multi-fin structure.

The crystals were produced in Russia, China and France. As incident positrons, electrons and photons enter in the crystal, electromagnetic showers are created and the Scintillation lights from them are detected by two light-sensitive silicon diodes attached to each crystal. The diode signal size tells the energy of the incident particles.

K-long-and-muon detector (KLM)

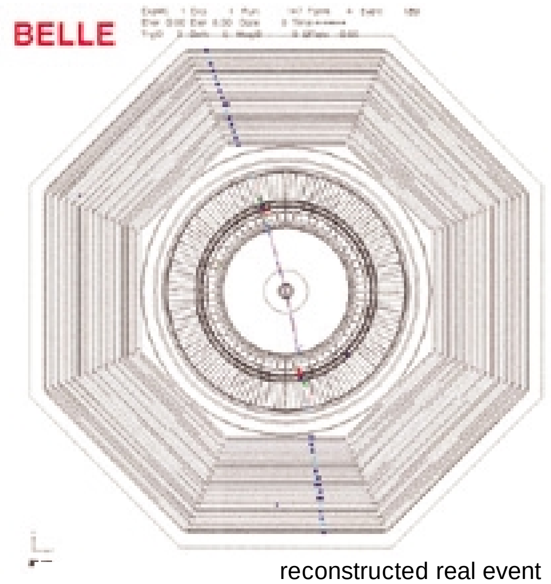
The sub-detectors described above will detect and measure all particles from B meson decays except for neutrinos, K-longs and muons. The neutrinos have very small probability of interaction with matter and thus pass through the BELLE detector undetected. However the K-longs and muons are detected by the outer K-long-and-muon detector (KLM) which consists of a sandwich of fourteen iron plates (5cm thick each) and fifteen layers of resistive plate counters.

Since the detector is located outermost of the BELLE system, the physical dimension and number of elements of KLM are very large. We, therefore, applied a very simple technique to fabricate the KLM system, which basically is composed of a pair of wide glass plates spaced by 2mm. As high as 10 kV is applied between the glass plates and an electrical signal is produced when a charged particle passes through this gap.

As discussed earlier, the event rate is very high, although the really interesting events will occur much less frequently. More than 100,000 channels of electronic signals from the sub-detectors need to be read out, digitized and recorded on magnetic tapes at the speed of up to 15 MB/s. Approximately 50 TB data will be accumulated per year.

To handle such large data samples, seven 28-CPU UNIX servers equipped with three robotic tape libraries are used.

In all, the BELLE detector is ready for the upcoming data taking and 300 hundred physicists from nine countries and a region are waiting for the start of the experiment in May. If everything goes well, the first BELLE result on the CP violation of the B meson system is expected to be observed sometime next year.



reconstructed real event

The authors of this section are ***Nobuhiko Katayama*** (left) and ***Junji Haba*** (right) who are in charge of the construction of BELLE detector complex in both hardware and software aspect.

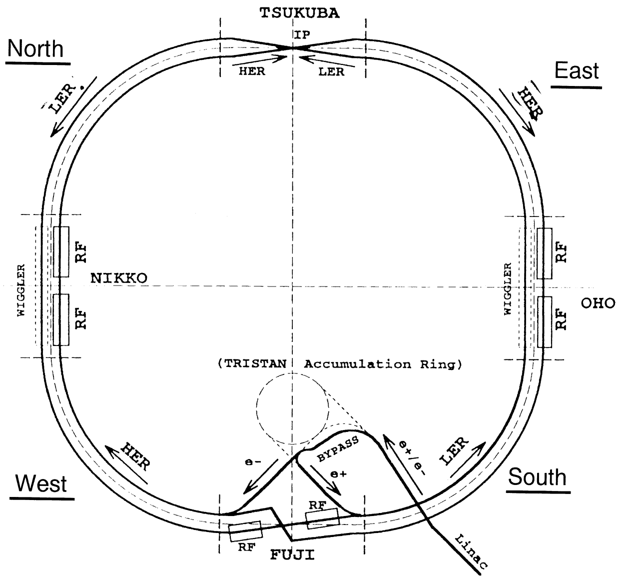
KEKB Accelerator Complex

The KEKB accelerator complex is the rejuvenation of TRISTAN. It consists of two intercepting rings, one for electrons (high-energy ring:HER) and the other for positrons (low-energy ring:LER), in which electrons and positrons circulate in the opposite direction and collide at one point (called interaction point : IP), where BELLE detector is placed.

Since the energy of electrons (8GeV) is different from that of positrons (3.5GeV), KEKB is called an asymmetric-energy collider.

The two rings are installed in the TRISTAN tunnel side-by-side (see picture on the right) and change their inner and outer position at two points: one at the IP and the other at a different-height crossing point, just half of the circumference apart from the IP.


KEKB ring



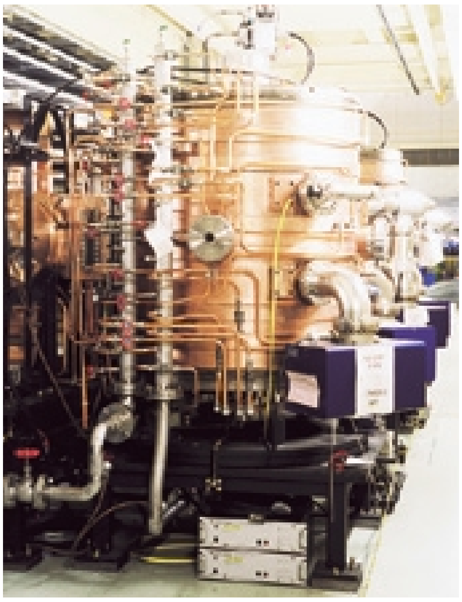
conceptual view of the two rings

Two rings are necessary not only to make the asymmetric energy collision possible (since beams of different energies cannot be circulated in a single accelerator ring even in the opposite direction) but also to get a high luminosity. At KEKB, the stored electric current in the rings amount to 1.1 A in HER and 2.6 A in LER.

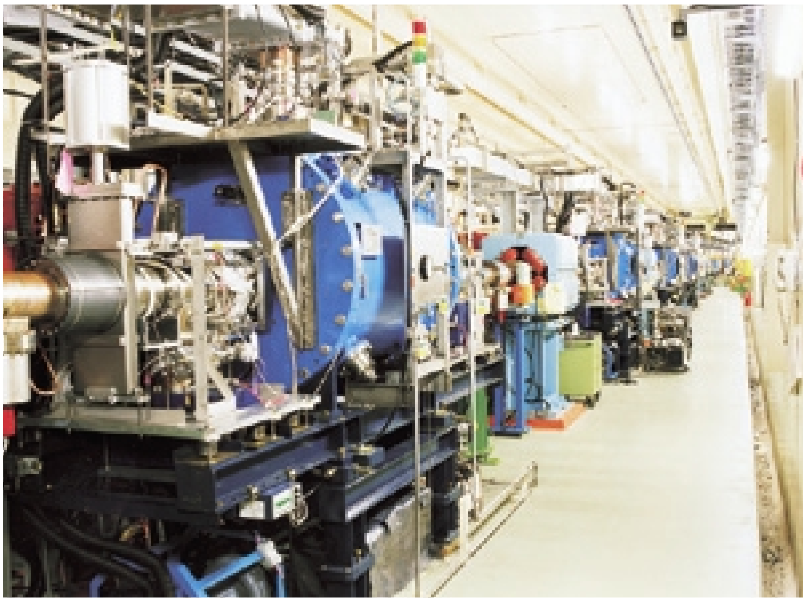
These are at remarkably high current level for circular electron accelerators. They are more than 100 times larger than that of former TRISATAN ring. They are subdivided into 5000 bunches (bunch : group of traveling elementary particles such as electrons or positrons) distributed over the circumference of KEKB rings. Electron and positron bunches circulate in separate rings and collide only at the IP, where the two rings meet. By having separate rings, we can avoid collisions at other places than IP which would disturb the beam circulation.

A pair of superconducting final-focus quadrupole magnets at the IP strongly focus the bunches to increase the chance of the collision.

High beam current stored in the rings interacts with accelerating cavities and produce strong RF (radio frequency) electromagnetic fields in the cavities, which in turn excites oscillation of bunches and cause strong instabilities. KEKB, therefore, adopts two types of special cavities where harmful RF fields are not produced by the beam: one is a normal-conducting, three-cell, single-mode cavity called ARES and the other is a superconducting, single-cell, single-mode cavity SCC.



ARES has a large energy-storage cell to make itself stable against high current



Four SCCs are installed in the tunnel. It can supply 2MV(mega-volts) per cavity

The KEKB accelerator system had been completed by the end of November 1998 and the commissioning started on December 1, which is 56 months after the start of the construction and only 35 months after the termination of the TRISTAN.

On December 11,1998, we observed a circulation of electron beam in HER. Synchrotron light from the beam was also observed.

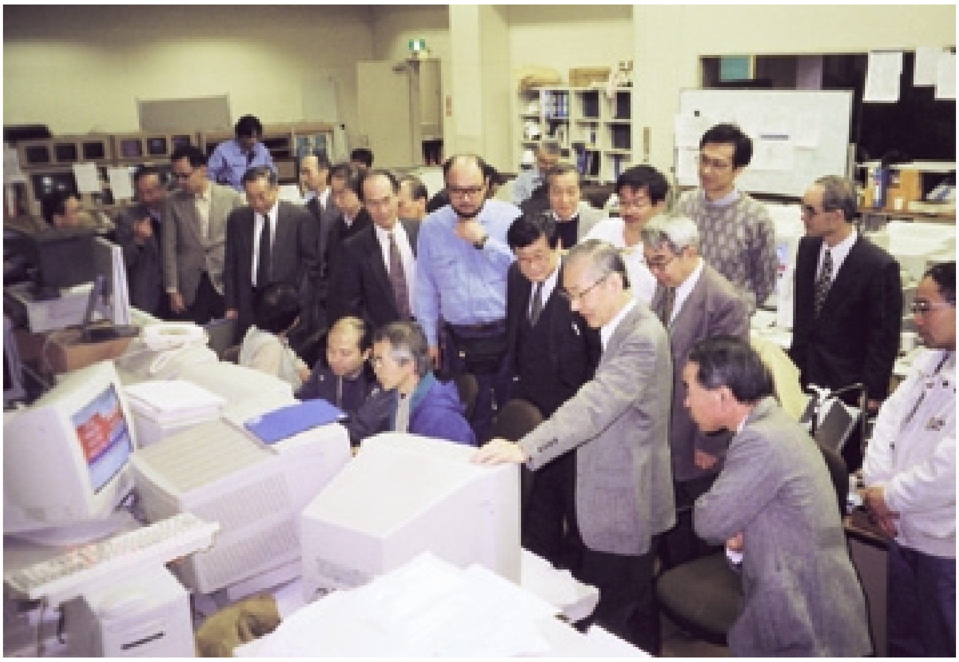
On December 13, storage of the beam in HER was confirmed. Just before the new-year-holiday shutdown, in the morning of December 27, we transported the 3.5GeV positron beam to the end of the transport line close to LER.

KEKB operation resumed on January 8, 1999 after the shutdown and then we began the commissioning of LER. In the evening of January 13, we observed circulation of positron beam in LER, and by next morning, positrons were stored in LER.

In the morning of February 5, we could make one bunch of electrons (contains 1.2×10^{10} electrons in it) and one bunch of positrons (contains 30×10^{10} positrons in it) collide at the IP.

Collision between electron and positron bunches was confirmed by detecting bean-beam deflection. By continuous tuning of the rings, the stored currents reached 243 mA in HER and 370 mA in LER by March 15.

We have further confirmed thus far that both HER and LER work as designed. The next steps are to increase stored currents in the rings and to establish good collision parameters. This operation will continue until mid-April, when we have a 5-week shutdown for the roll-in of the BELLE detector to the IP. The operation of the rings with BELLE detector will start late May.



KEKB control room on Dec. 12, one day after the first circulation of electrons in HER.

Shin-ichi Kurokawa is the head of the KEKB Accelerator

(James Hester working at Australian National Beam Line (ANBF) of KEK Photon Factory wrote up this article to give you some idea on life in Tsukuba.)

The ANBF Lonely Wombat Guide to Tsukuba

Being long-term residents of Tsukuba, ANBF staff members Garry and James know a good deal about life in this unusual city, from where to rent a windsurfer to the best spot for black-market rice. Here is a distillation of some of their wisdom.

Night owls

Fifteen years ago, Tsukuba was little more than a university, research institutes and rows of government apartment blocks. Perhaps not coincidentally, at about the same time that the ANBF appeared, the after-work scene changed substantially. There are several vibrant nightlife districts with an enticing selection of restaurants, karaoke bars and drinking spots. The Lonely Wombat has, on the readers' behalf, pioneered two evening magical mystery adventures:

(a) The 'Japan? Where?' tour, for homesick foreign visitors: 'the restaurant with the flames at the front', followed by the 'Gold Rush' foreigner's hangout bar and dancing the night away at the 'Hot Staff' upstairs.

(b) The 'Real Japan' tour: the sushi restaurant by the rocket, followed by a walk across the road for a warble at the 'Big Echo' karaoke barn, winding down with a quiet tipple at 'The Love Bar'.
This is not to deny the charms of the other Asian, European, South American, and even African (Egyptian, actually, with belly dancers) restaurants within a half hour drive from KEK.

Outdoor types

Nature lovers and sports fans have a field day in Tsukuba. The city has many parks and wide, tree-lined avenues that become very beautiful in spring (cherry blossom time) and autumn. A 10km walking / bicycle track runs north / south through the centre of town, and in the centre is elevated above the road with easy access to shops, restaurants and the blood donation centre. Alternatively, a 10 minute bike-ride from the centre will land you in the middle of acres of rice fields or a tiny farming community which might have existed unchanged for centuries.

Just about everywhere you look in Tsukuba there are tennis courts, although the Lonely Wombat is perfectly satisfied with KEK, which has 5 courts with night lights. There are gyms, year-round swimming pools, bicycle paths, baseball pitches, football grounds and golf clubs in and around Tsukuba. ANBF visitors have also been known to head for the Pacific ocean, a 50km (1.5 hour) drive to the east.

City Types

Apart from a couple of big shopping centres, Tsukuba also has its very own 'Electric Town'. If the hunger for flashing neon signs and really big shops is too overwhelming, Tokyo is only a 1.5 hour bus ride away. However, the Lonely Wombat has found that a half hour drive around neighbouring downtown Tsuchiura is often enough to alleviate the worst symptoms.

Culture Vultures

Tsukuba's cultural scene is reasonably active, with a number of local orchestras who welcome new members, a once yearly music festival usually featuring some big name orchestras and musicians, and excellent facilities for music and drama. ANBF staff have been known to take to the stage in the past to broad acclaim.

down town Tsukuba

The author of this article,
the ***Lonely Wombat,*** or ***James Hester*** is a member of the ANBL (Australian National Beam Line) Facility of KEK Photon Factory. See their special article in the previous issue of KEK News (vol.2, No.2)

November 2-6, 1998

A music concert on Nov. 2 initiated the annual KEK Art Festival week.

December 14-17,1998

International Symposium on “Physics of Hadrons and Nuclei” was held at Tanashi campus. 150 participants including 40 from abroad (USA, Germany, Spain, Australia, Israel, Russia, China, Korea, Holland, France, Hungary and India) attended.

January 17, 1999

BELLE solenoid excitation reached 1.5 Tesla and full detector test started.

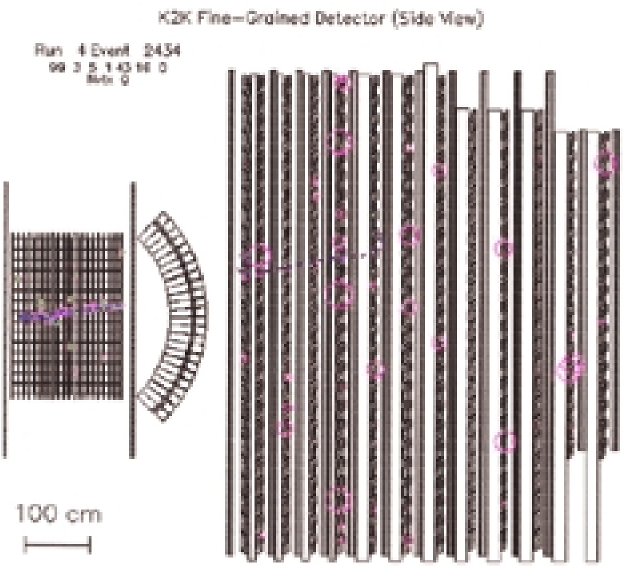
Full track reconstruction from real events had proven that all the detector elements were working properly. (see figure on page 6)

February. 11-12, 1999

26 prominent members participated the ICFA meeting held at KEK discussing on future accelerators. (We heard the sad news of the loss of beloved ICFA chairman, Prof. Bjoern Wiik. He will be remembered.)

March 3, 1999

As neutrino beam commissioning started on March 3, “K2K”, the long-baseline neutrino experiment started taking data and neutrino-induced events are already observed by the on-site neutrino detector system.



March 3, 1999

Meeting of councillors took place in Tokyo.

March 12,13, 1999

The 4th KEK-IHEP(of Beijing, China) Collaboration meeting was held at KEK with 5 IHEP delegates attending.

Professor Hironobu Ikeda passed away

Professor Hironobu IKEDA, an eminent Solid State Physicist and the director of the KEK Neutron Science Laboratory (KENS) died from subarachnoid bleeding on the 1st of November,1998. He was 54 years old. We all miss him very much.

For his doctor of science degree, Hironobu Ikeda employed neutron scattering techniques to study critical phenomena in low-dimensional magnetic systems, a field in which he was to remain preeminent throughout his career. He moved to KEK in 1990 and became the director of the Booster Synchrotron Utilization Facilitity in 1995 and then the head of the KENS in 1997. He was widely respected as one of the leaders in both the Japanese and world neutron scattering communities.

His work on studying the phase transitions in magnetic systems contains many highlights. In his early works, he showed that the spin correlation in the two dimensional antiferromagnet K_2CoF_4 provided a real world example of Onsager's exact solution of the two dimensional Ising model. He inverstigated the effects of random fields on the ordering kinetics of dilute antiferromagnets between the disordered and orderd states. He demonstrated, by inelastic neutron scattering from the dilute antiferromagnet $RbMn_xMg_{1-x}F_3$, the existence of "magnetic fractons", which are the elementary excitations on a fractal lattice. Recentry he was working on measurements of anomalous spin diffusion on fractal lattice and was developing a method for measuring the self-correlation function by magnetic neutron scattering. He was responsible for the Japan-UK collaboration on neutron scattering which has resulted in the development of the MARI and MAPS instruments at the ISIS Facility of Rutherford Appleton Laboratory, UK and provided the opportunity for many scientists to carry out intense pulsed neutron scattering experiments. He was also responsible for the project to construct the high power neutron facility at the JHF and was always looking for new possibilities for the use of neutrons in the study of solid state physics and materials science.

Picture on front cover: While there should be no necessity to explain why picture of honeybees is on the front cover, editor would like to thank the Head of Laboratory of Apiculture, Dr. Kazuhiro Amano, (National Institute of Animal Industry under the Ministry of Agriculture, Forest and Fisheries) for his kind help in taking the picture.

Picture on back cover: Japanese knew about entropy many many hundred years ago. It was expressed as "The higher the level of perfection, the faster it deteriorates". Picture on the back cover is the entrance gate "Yomeimon" of Toshogu Shrine (built 1617) in Nikko. It has 12 wooden pillars covered with beautiful curvings, of which one of the pillars was installed upside-down to make sure that it is NOT perfect therefore the deterioration will go slow.

This obviously worked and the gate is in excellent condition after some 380 years. The symmetry breaking in the gate structure should be a nice company to the B-physics article in this issue.

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