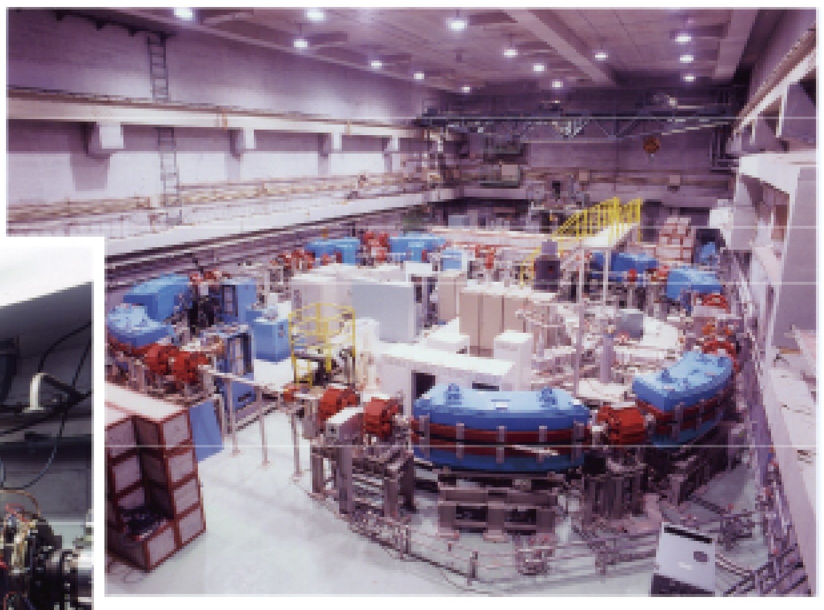
Research Center for Electron Photon Science Tohoku University

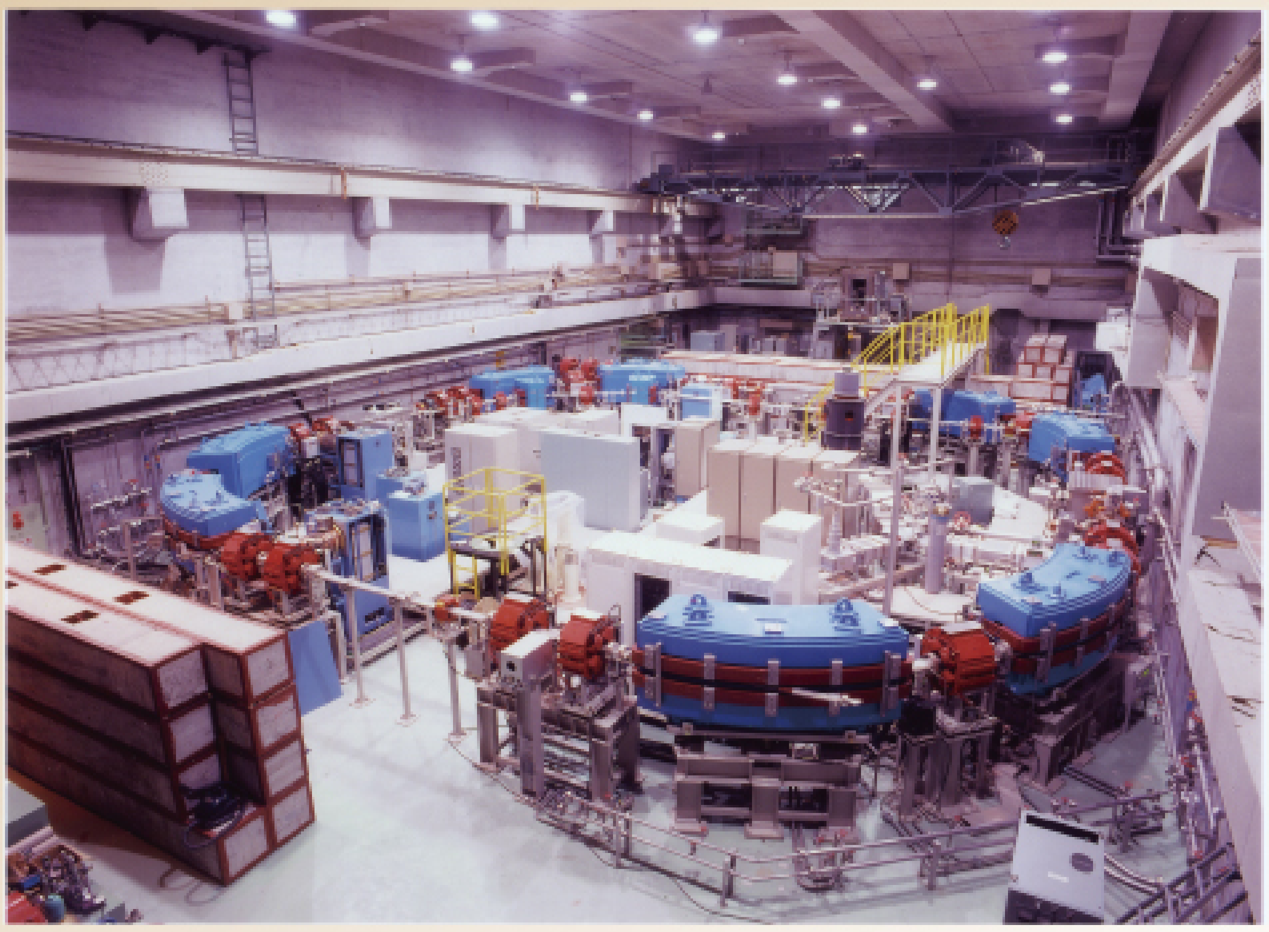
東北大学電子光理学研究センター



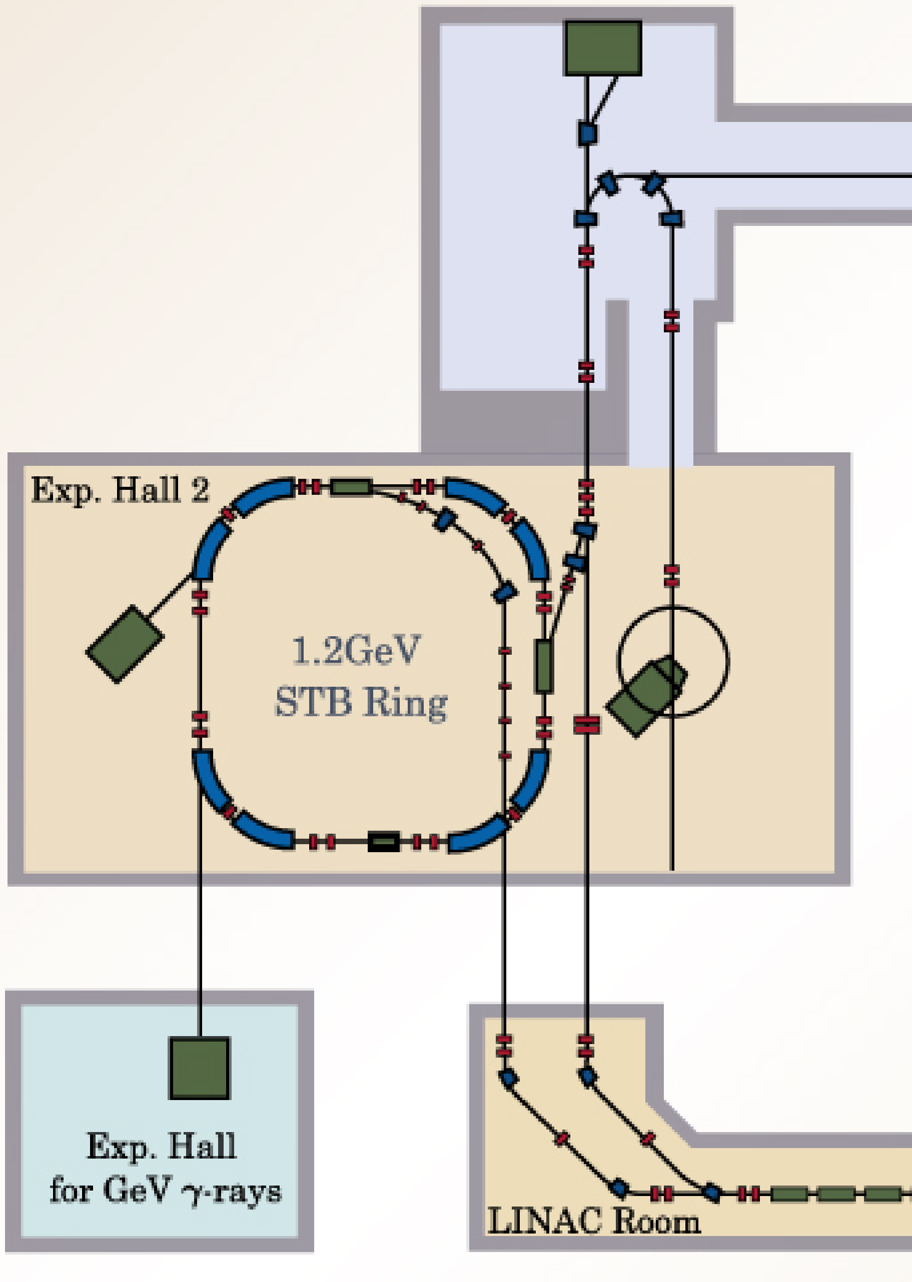
Nuclear Science World viewed with accelerators

Electron accelerators

We use binoculars or a microscope, looking at the structure of matter in detail. The size of the object we can see with an optical microscope is in the order of the wave length of visible light, which corresponds to several hundred nm ≈ 10^{-7} m. It is impossible with the optical microscope, however, to look into the world of atoms being much smaller than that. An electron microscope works for such objects of the atomic size. The "wave length" of electrons used in the electron microscope is of the order of the atomic size, which is about 0.1 nm ≈ 10^{-10} m. In order to pin down the structure of a nucleus smaller than the atom, therefore, the wave length of electrons has to be shorter than the size of the nucleus. A 1 GeV (one billion electron volts) electron beam is necessary to have such a short wave length as the size of the nucleus. (The wave length becomes shorter as the electron energy goes up.) Electron accelerators are machines which provide high energy electron beams for this purpose.



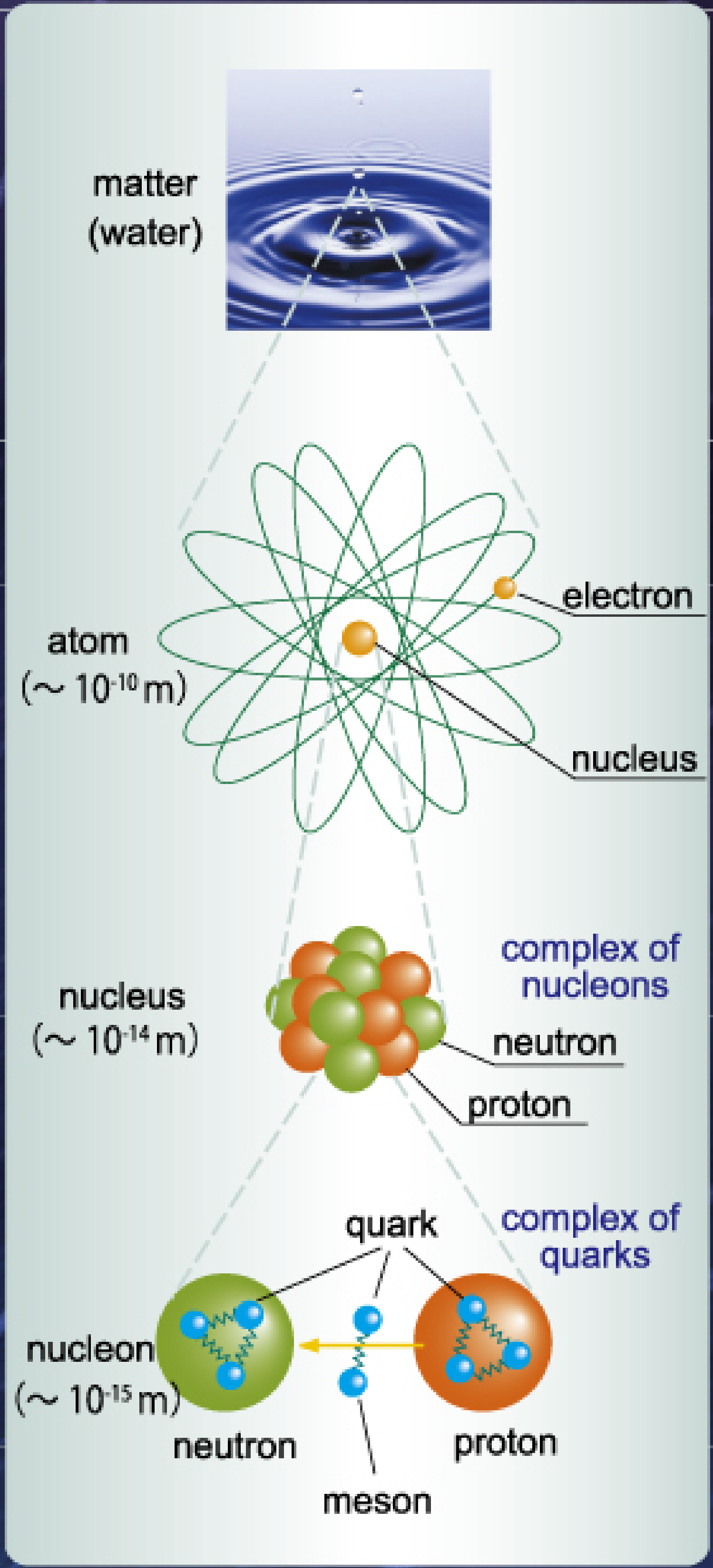
STB ring
There are two functions; pulse stretcher and booster-storage ring. The electron beam can be accelerated up to 1.2 GeV in maximum for the booster-mode.



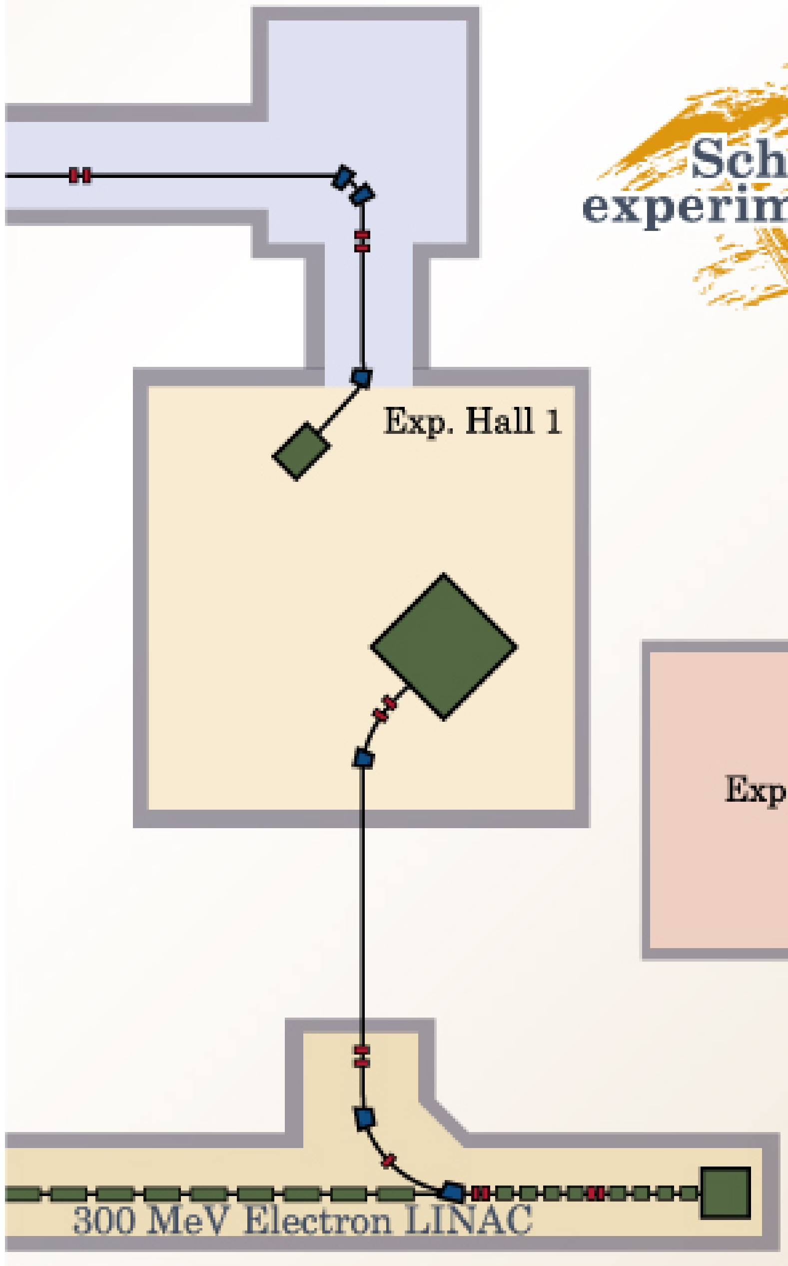
Microscopic structure of matter

Matter is made of atoms which have a nucleus at the center and electrons surrounding it. The nucleus is comprised of protons and neutrons generically called "nucleons", the size of which is about 10^{-14} m. The nucleons are held one another in the nucleus by nuclear forces that are about 10^{39} times stronger than the gravitational force. Mesons are thought to play an important role for nuclear forces. The nucleons and mesons are both categorized into "hadrons", which are about 1/10 times smaller than nuclei. The hadrons are further made of quarks and classified into two types, baryons and mesons. A baryon consists of three quarks and nucleons are included in a group of baryons. A meson is made of a quark and an anti-quark.

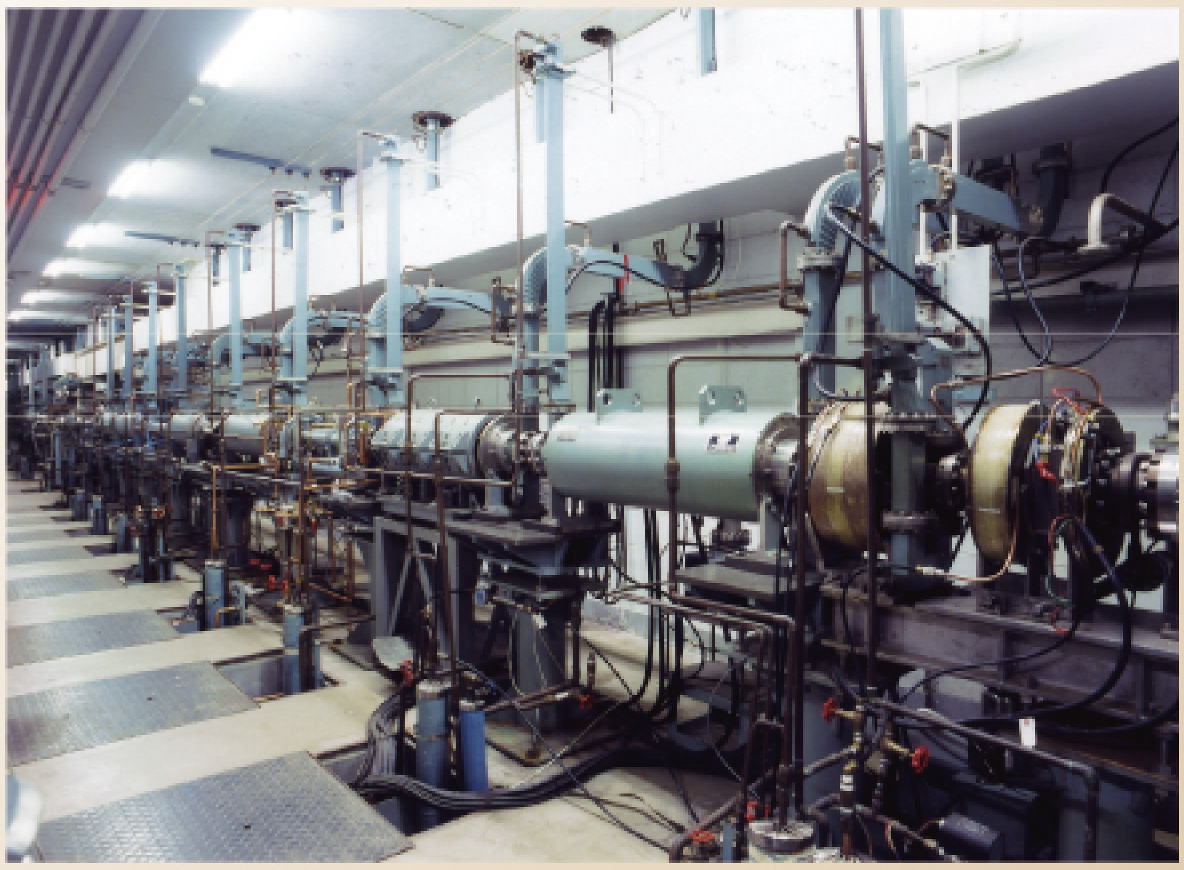
Research Center for Electron Photon Science (ELPH) provides users with an electron beam of the energy up to 1.2 GeV by operating an electron linac and an electron synchrotron for studying the micro-structure and properties of matter with a wide point of view of quarks, hadrons, and nuclei. These researches are supported by continuous development of accelerator science, which is also intensively studied at ELPH to push forward the frontiers of beam physics.



Schematic view of experimental arrangement



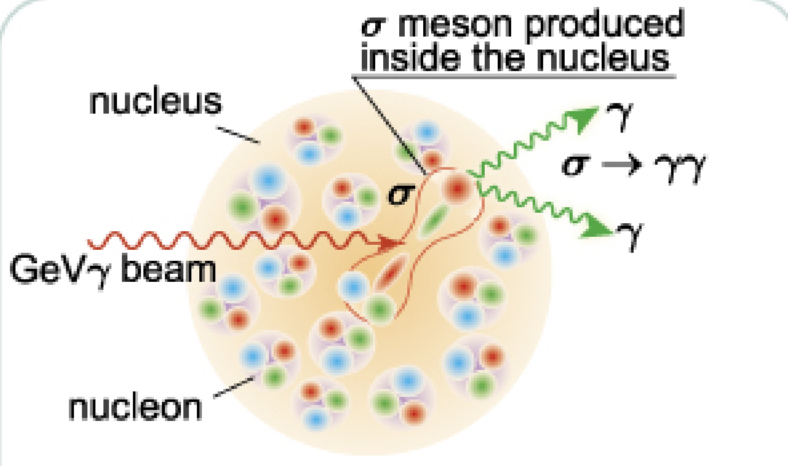
LINAC
Beam energy (in max) : 300 MeV
Repetition rate (in max) : 300 pps
Macro pulse length : 4 μs



Nuclear

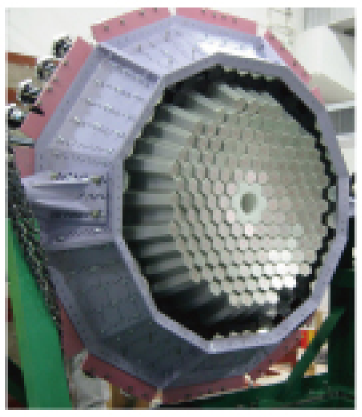
The inside of a nucleus is an ultrahigh density world of about 100 million ton per cubic centimeter, which is equivalent to the density of the universe after a short interval from its beginning. It is conceivable that characters of elementary particles change and their masses go down in such an extreme world. This means that it might be possible to answer the question, " what is the origin of the mass? " if we can observe phenomena taking place inside the nucleus. A GeV γ beam produced with high energy electrons can go into the nucleus and create hadrons in the interaction with nucleons in the nucleus.

Quark Hadron Physics with a GeV γ beam

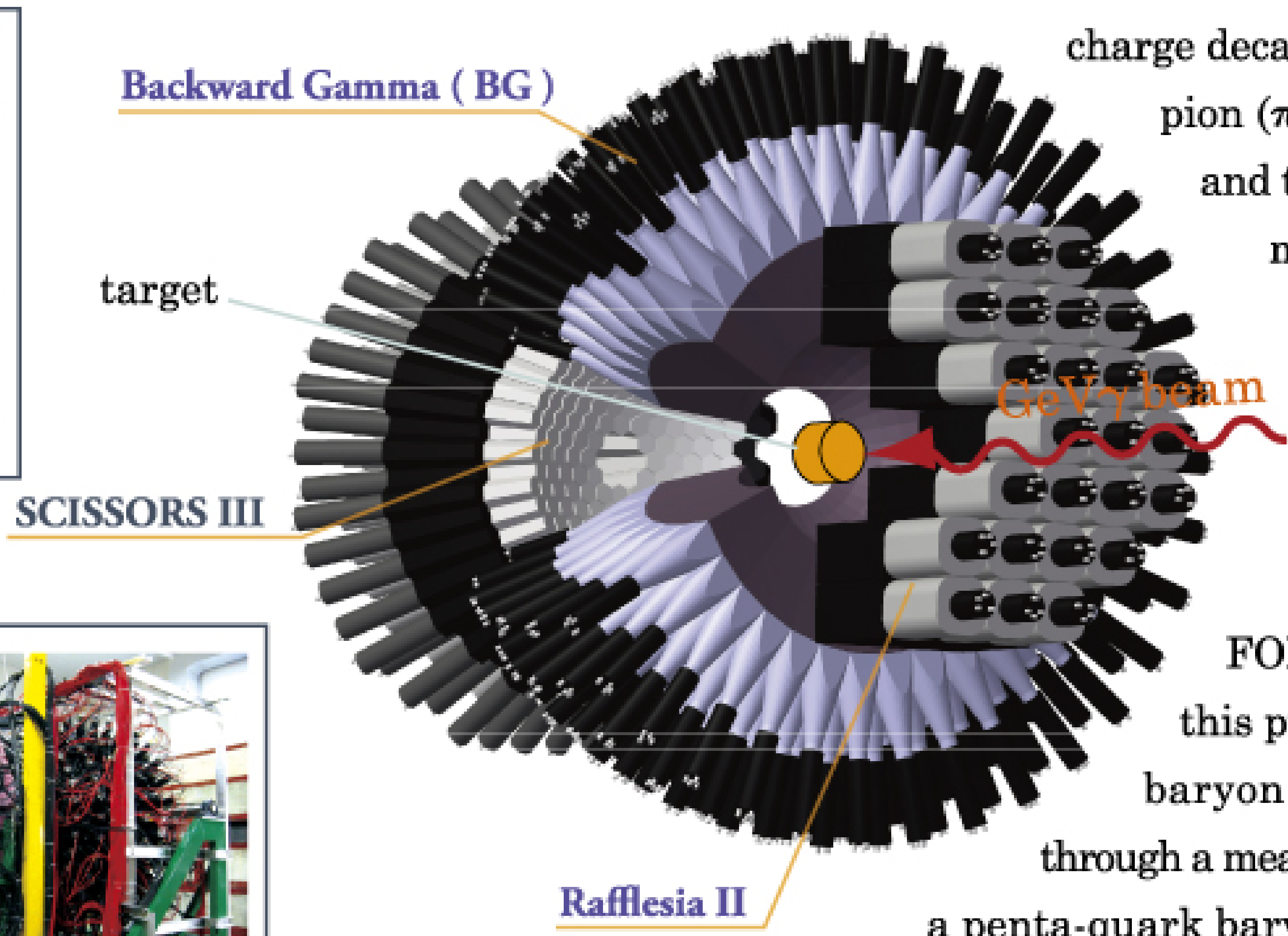


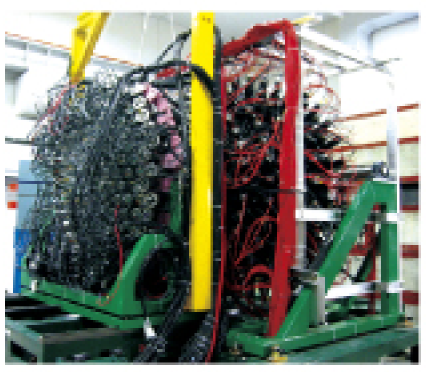
σ meson produced and decaying inside the nucleus

Multi-γ detector assembly : FOREST



SCISSORS III





FOREST after cabling

Some of neutral mesons having no electric charge decay to the 2γ system. The neutral pion (π^0) decays into 2γ almost 100%, and the eta meson (η) and the sigma meson (σ) have a decay mode to the 2γ channel. Therefore γ detectors are necessary to study neutral mesons in quark hadron physics.

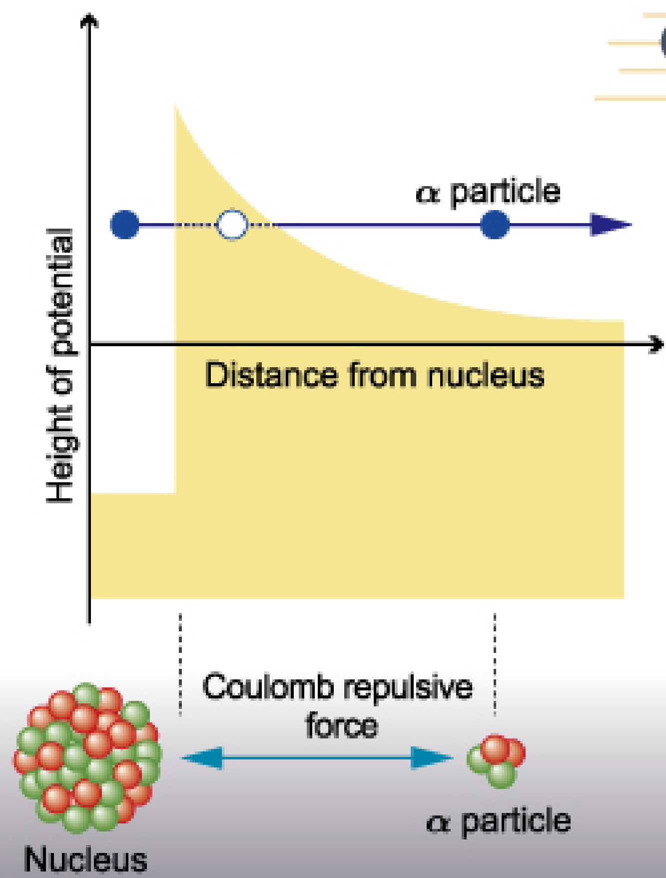
A multi-γ detector assembly, FOREST, has been constructed for this purpose. Recently, a new narrow baryon resonance has been observed through a measurement of η mesons, suggesting a penta-quark baryon with hidden strangeness.

FOREST is an experimental device capable of detecting neutral mesons emitted from baryon resonances or heavier mesons, which are produced in reactions induced by a GeV γ beam. The mass and momentum of a neutral meson are given by measuring the energy and position of each γ ray coming from decay of the meson.

FOREST consists of 3 different type γ detectors, CsI crystals (SCISSORS III), lead scintillating fiber blocks (BG), and lead glasses (Rafflesia II).

FOREST :
Four-pi **O**mnidirectional **R**esponse **E**xtended **S**pectrometer **T**rio

Quantum



Physics

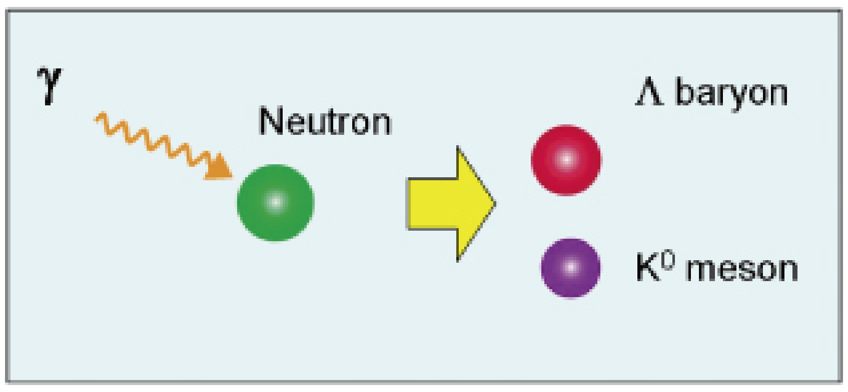
Study for Investigation of Strangeness Production Mechanism

Investigations of strangeness production mechanism have been studied in the world. Those experimental studies, however, had been done using the reaction on gamma + proton going to charged K meson + X, because of ease of the measurement.

We focus the study on $\gamma + n \rightarrow K^0 + \Lambda$, that have not been measured. This reaction is unique and there is no involvement of electrical charge before and after the reaction. The produced particles, K^0 and Λ decay in very short time. Those average lift time and decay channels are:

0.00000000009 sec for $K^0 \rightarrow \pi^+ + \pi^-$ and

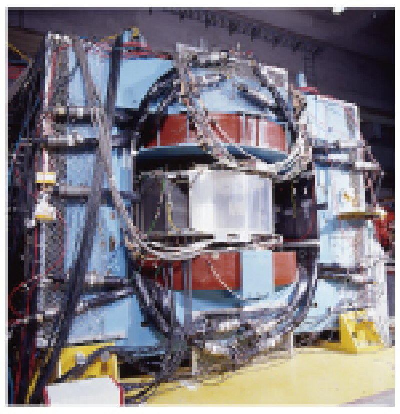
0.00000000026 sec for $\Lambda \rightarrow \pi^- + p$.

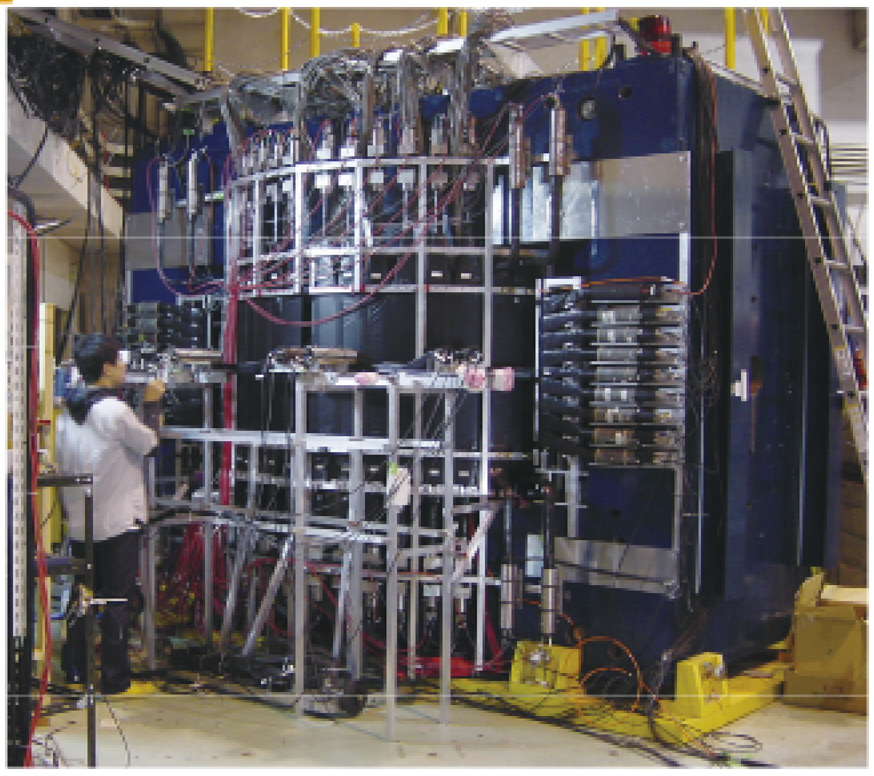


It is difficult to measure those decay particle, therefore the study using those channels have not been done recently. Though we have designed and constructed a large acceptance spectrometer to measure neutral kaon and are studying the strangeness production mechanism.

Neutral Kaon Spectrometer

The first generation



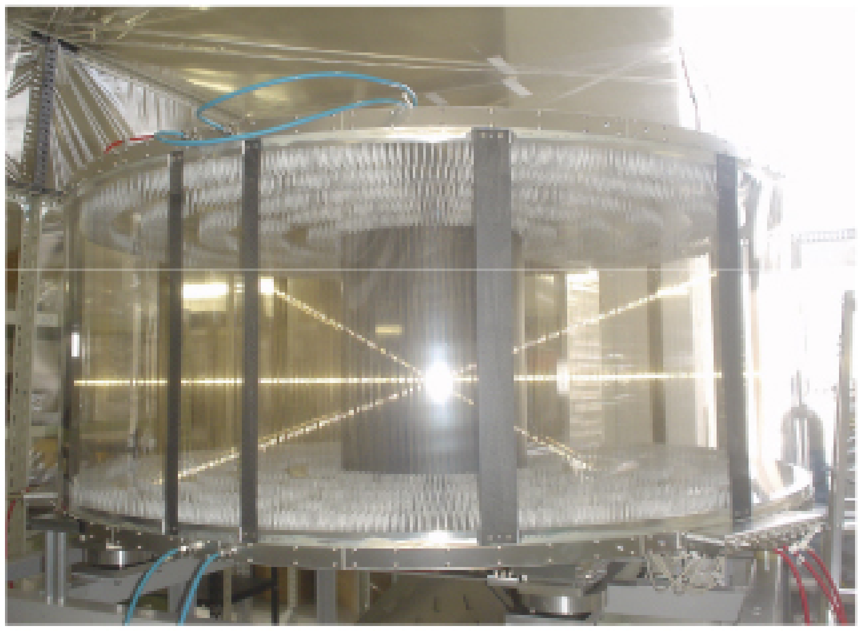


The picture above shows the spectrometer. We have done the first measurement of neutral kaon cross-section via gamma + neutron reaction in the world.

The second generation spectrometer:

All of the detectors and the magnet are designed and constructed from full scratch. It has better performance on momentum resolution and larger acceptance.

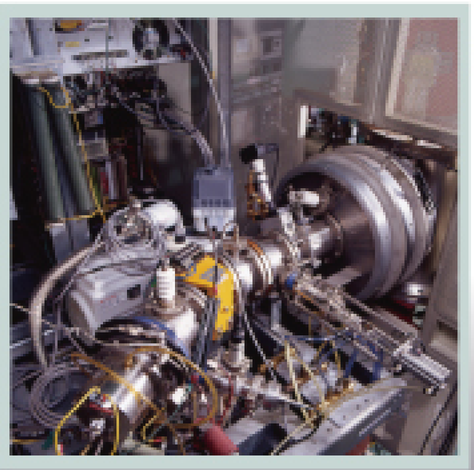
Cylindrical Drift Chamber (CDC)



CDC has large solid angle and important role to measure positive and negative pion decayed from K^0. Its shape is cylinder with 160 cm diameter and 68 cm height. This chamber has three different angle wires. Therefore the trajectory of charged particles can be tracked in three dimension.

tunneling

In the world of quantum mechanics, particles can pass through the potential barrier much larger than their kinetic energy (quantum tunneling).



Low-energy high-intensity beam generator

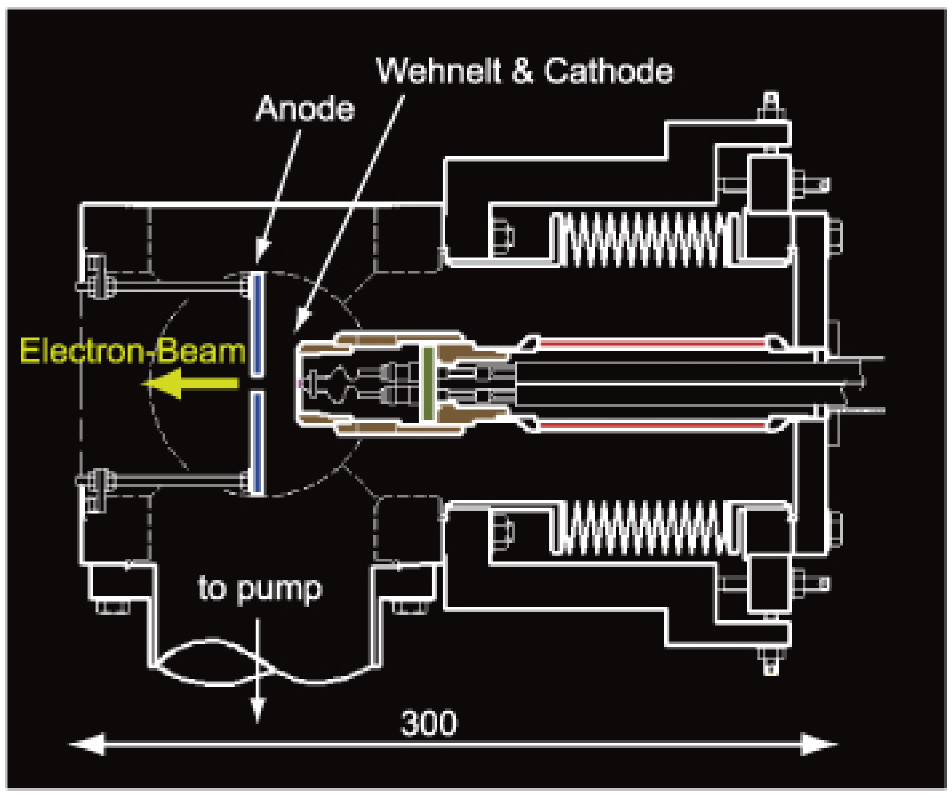
Quantum tunneling is studied in α-decay of nuclei as well as in ultra-low energy nuclear reactions in solids.

Accelerator Science / Beam Physics

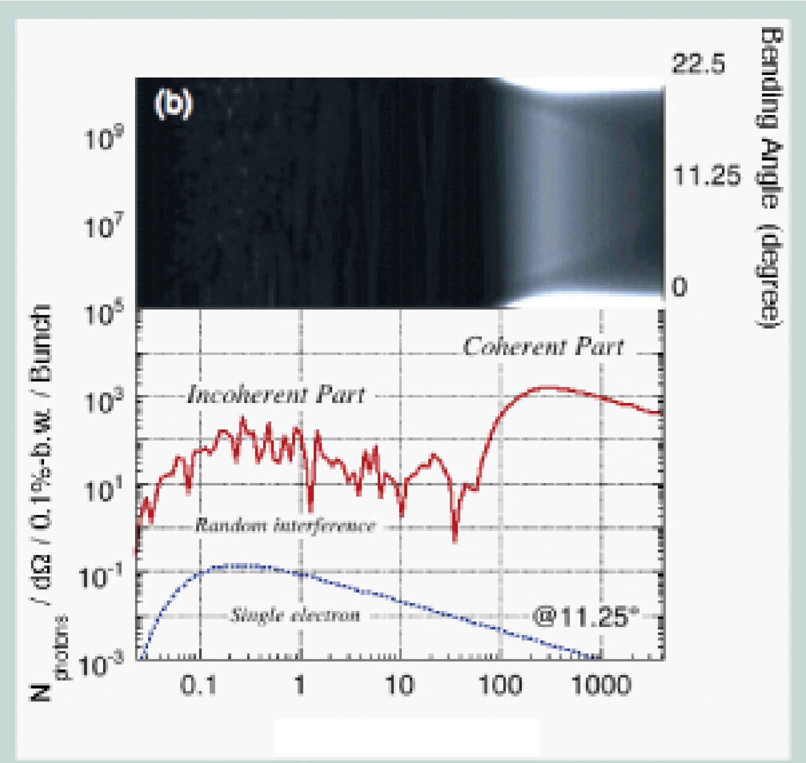
- Beam dynamics in a circular accelerator using STB ring
- Development of high brightness & low emittance DC electron gun
- Coherent terahertz light source R&D

Development of high brightness & low emittance DC electron gun

DC electron gun has been developed to generate high brightness beam, which employs single crystal LaB_6 as the cathode material. The gun is expected to generate the very low emittance beam less than 1 π mm-mrad in spite of very low applied voltage of 50 kV to the cathode. Figure (right) shows the layout of the gun now under the test. Very intense electron beam of 600 mA is extracted from the cathode heated up to about 1800 K.

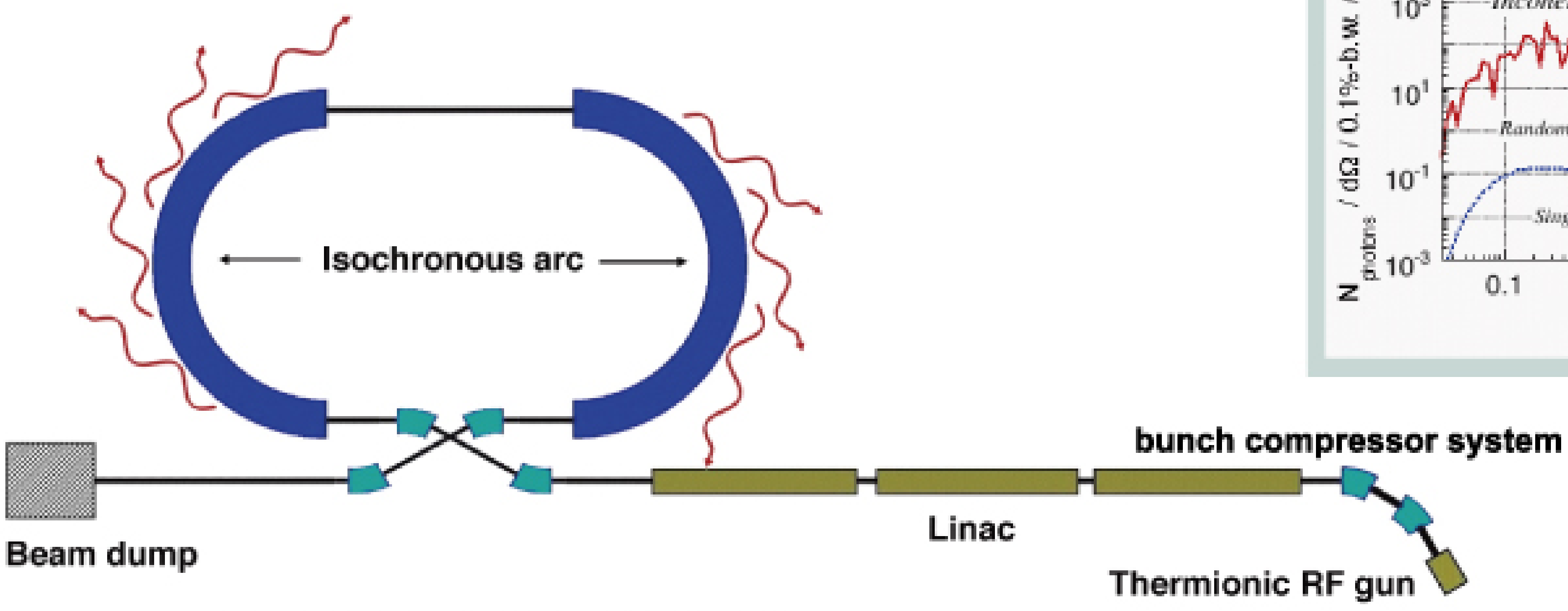


low emittance DC electron gun



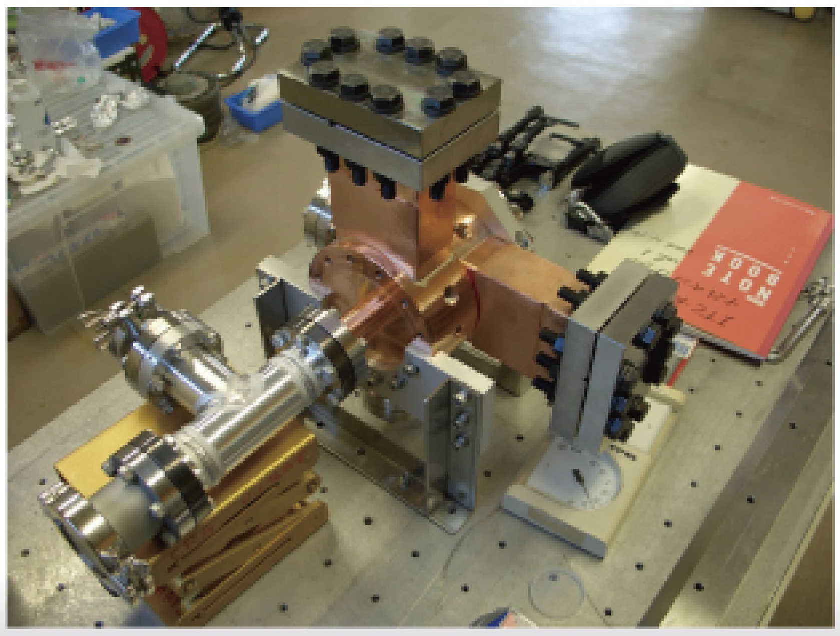
radiation spectrum from the isochronous arc

R&D work for coherent terahertz light source



Schematic view of coherent THz light source

The terahertz light (THz, ~10^{12} hertz) has begun to attract the great attention because of the capabilities to travel in straight lines and also to penetrate non-conducting materials. The development of the powerful THz light source brings new opportunities for scientific research and applications over the immense fields of various disciplines. We have performed R&D work to realize quite unique ring-type light source, which employs quasi-complete isochronous beam optics to conserve ultrashort bunch length less than 100 fs (10^{-13} sec.) generated by specially designed RF gun and a magnetic bunch compressor.

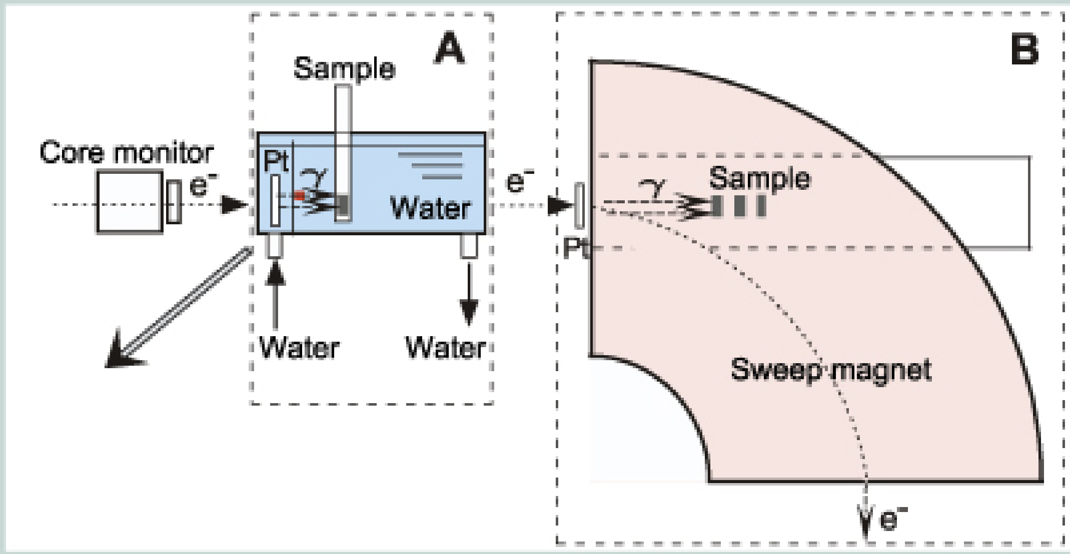


prototype of the RF gun

Materials Science with Radioisotopes

- Study of nuclear phenomena influenced by chemical nature
- Nuclear fission mechanism
- Photon activation analysis for several materials
- Radioisotope production for trace elements
- Radiation chemistry and irradiation effects by electrons
- Radioisotope labeling and its mechanism

Irradiation System

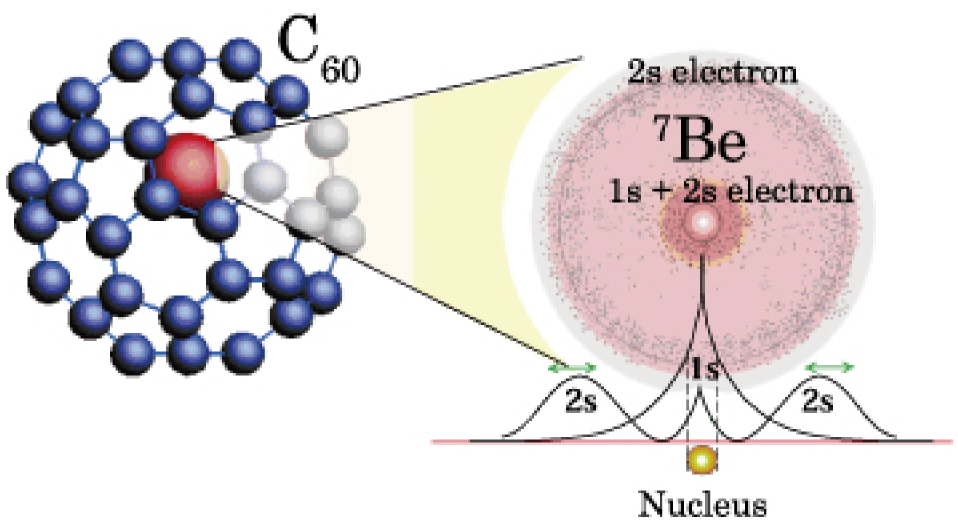


Setup A: an irradiation system of high-intensity bremsstrahlung-photons for production of radioisotopes, activation analysis, etc. Sample is enclosed in quarts tube and irradiated with high-energy photons in water bath.

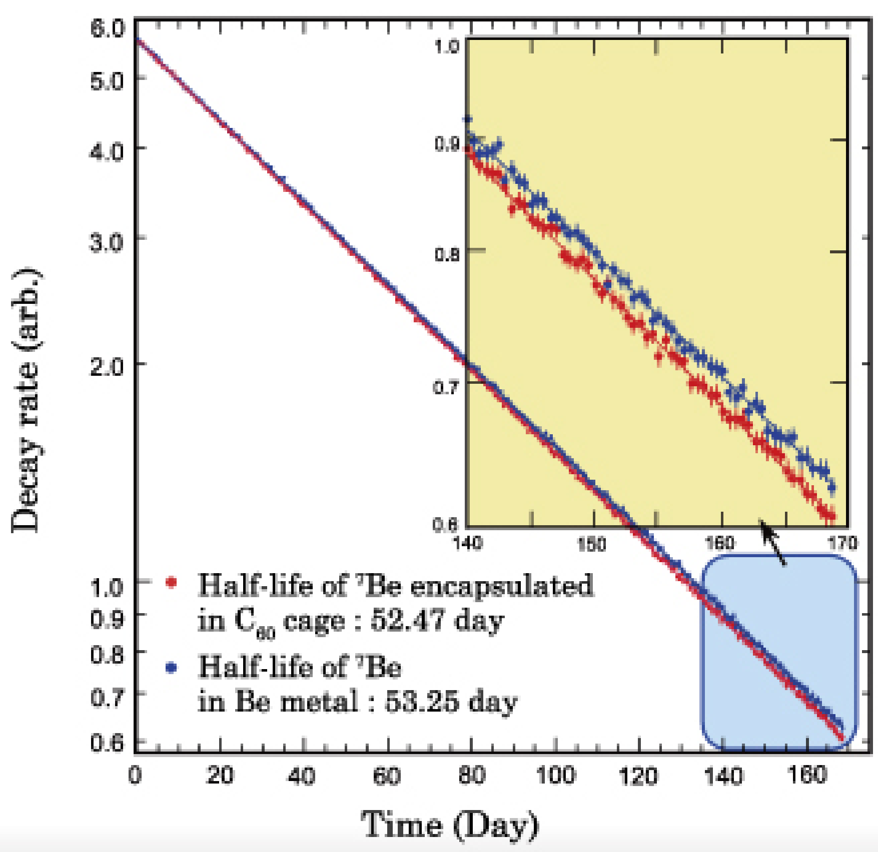
Setup B: an irradiation system of pure bremsstrahlung-photons for hot atom reaction, radiation chemistry etc. Recoil electrons are swept out by a large sweep magnet.

Study on half-live of ^{7}Be under various environment

The decay rate of ^{7}Be electron capture (EC) was measured in C_{60} and Be metal with a reference method. The half-life of ^{7}Be endohedral C_{60} (^{7}Be@C_{60}) and ^{7}Be in Be metal (Be metal(^{7}Be)) was found to be 52.47±0.04 and 53.25±0.04 days, respectively. This amounts to a 1.13% difference in the EC-decay half-life between ^{7}Be@C_{60} and Be metal (^{7}Be). The half-life of ^{7}Be inside C_{60} is shorter than any ^{7}Be half-life reported any environment up to now. The result is a reflection of the different electron wave-functions for ^{7}Be inside C_{60} compared to when ^{7}Be is in a Be metal.



Schematic veiw of electron cloud for 1s and 2s state of Be atom inside C_{60}

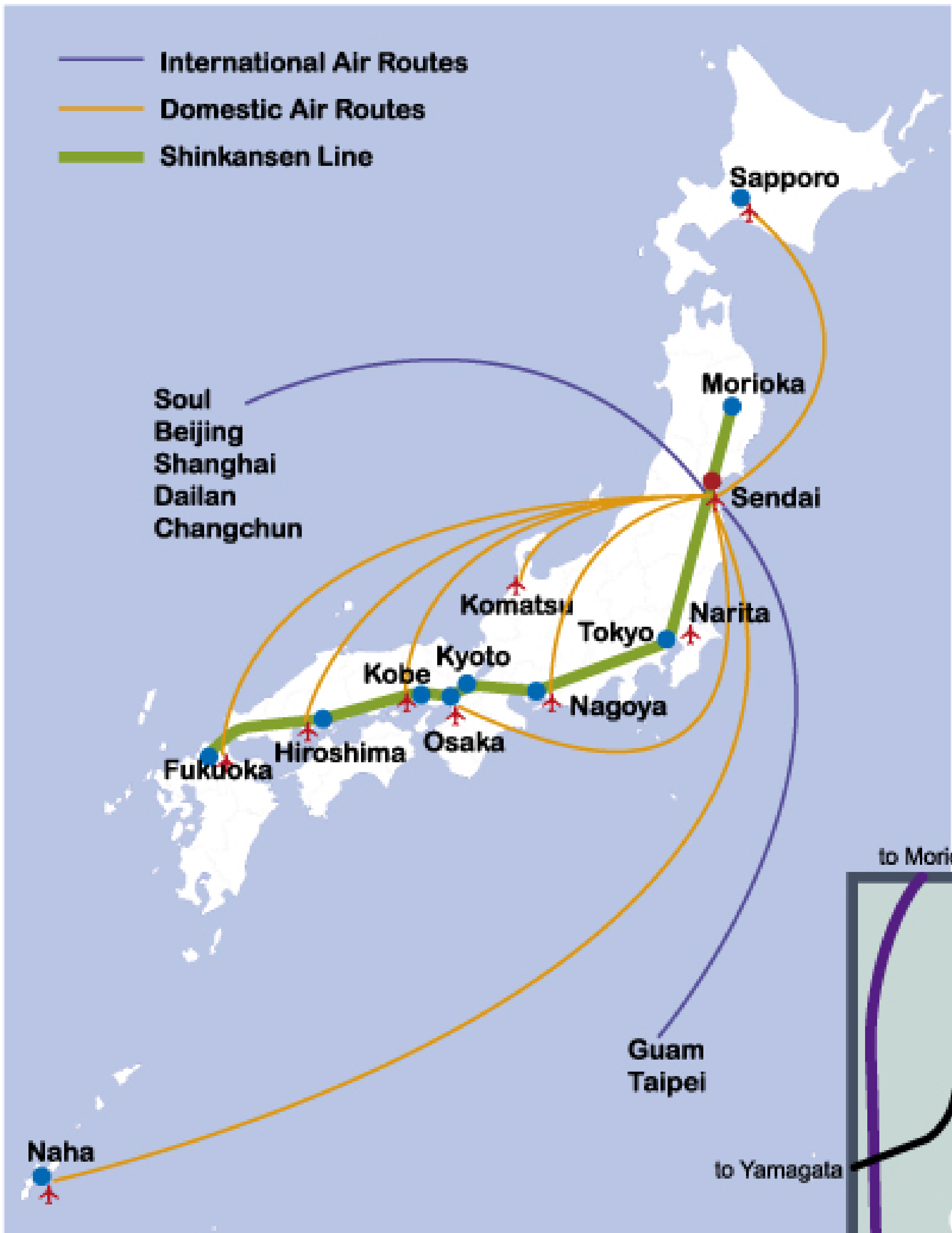


The half-life of ^{7}Be encapsulated in C_{60} and existed in Be metal

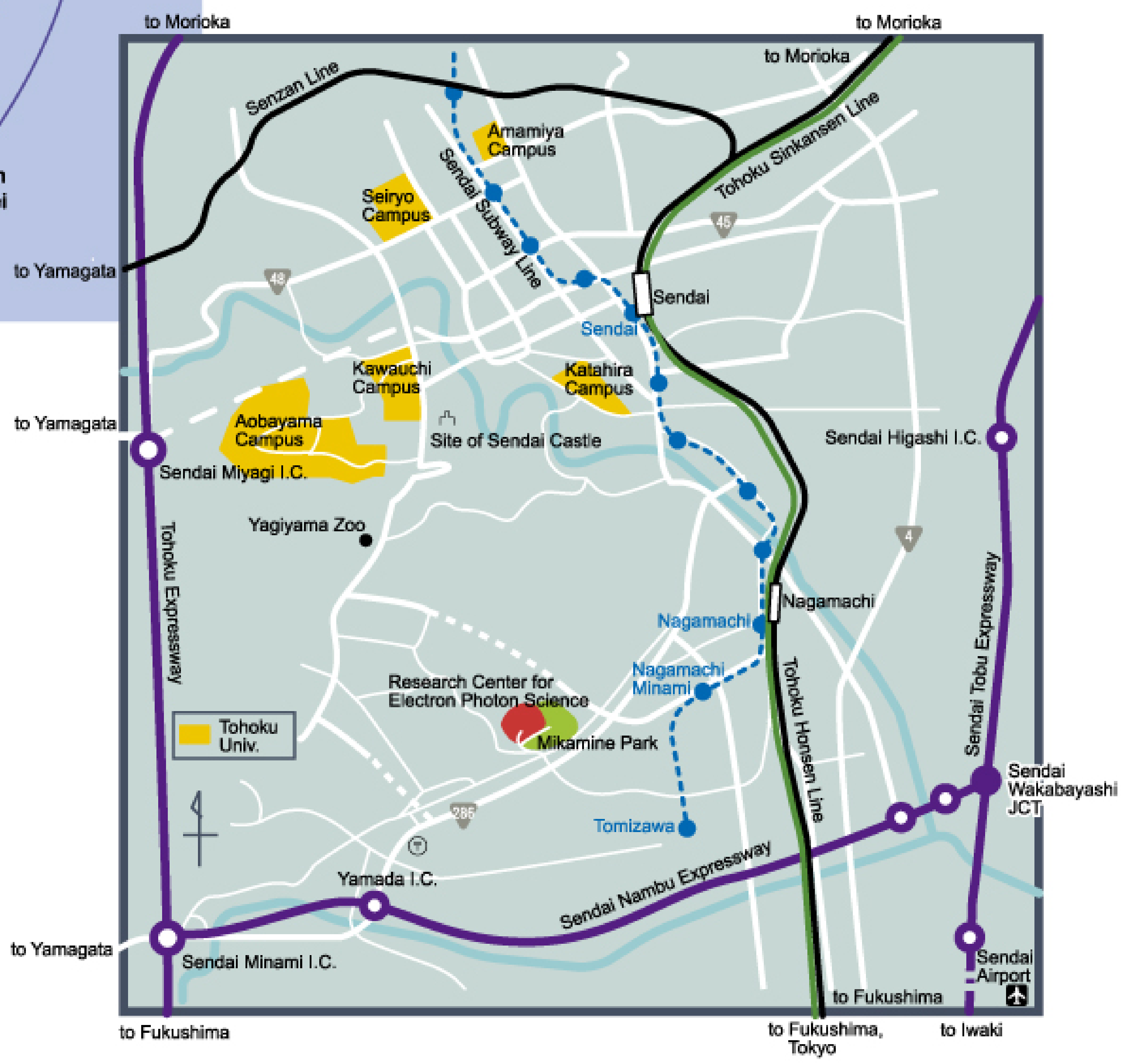
PIN-diode Detection Systems for charged particles

The PIN-diode detectors for the measurements of α-particles, heavy particles and fission fragments. These are installed in the rotating wheel system to detect the charged particles efficiently.

Location of Elphs Lab



photos: Miyagi Prefecture
Sightseeing Section



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