Department of Physics

The Department of Physics at Osaka University offers a world-class education to its undergraduate and graduate students. We have about 50 faculty members, who teach physics to 76 undergraduate students per year in the Physics Department, and over 1000 students in other schools of the university. Our award-winning faculty members perform cutting edge research. As one of the leading universities in Japan, our mission is to serve the people of Japan and the world through education, research, and outreach.

The Department of Physics was established in 1931 when Osaka University was founded. The tradition of originality in research was established by the first president of Osaka University, Hantaro Nagaoka, a prominent physicist who proposed a planetary model for atoms before Rutherford's splitting of the atom. Our former faculty include Hidetsugu Yagi, who invented the Yagi antenna, and Seishi Kikuchi, who demonstrated electron diffraction and also constructed the first cyclotron in Japan. Hideki Yukawa created his meson theory for nuclear forces when he was a lecturer at Osaka University, and later became the first Japanese Nobel laureate. Other prominent professors in recent years include Takeo Nagamiya and Junjiro Kanamori, who established the theory of magnetism, and Ryoyu Uchiyama, who developed gauge theory.

Since then, our department has expanded to cover a wide range of physics, including experimental and theoretical elementary particle and nuclear physics, condensed matter physics, theoretical quantum physics, and interdisciplinary physics. In 2010, the "International Physics Course (IPC)" was created to offer classes in English to students from abroad.

The department also has cooperating groups in five laboratories in the university. Many faculty and students in the department collaborate with other laboratories in Japan and abroad, such as KEK, J-PARC, RIKEN, SPring8, CERN, FNAL, TRIUMF, RAL, and PSI.

Graduate Program

The Department of Physics at Osaka University offers a two-year graduate course in physics leading to a Master of Science in Physics, and a three-year course in Physics leading to a Ph.D. degree.

The **M.S. course** provides advanced study and training in research in physics. A total of 68 students are enrolled each year. The course includes lectures and relevant practical work. Each student joins a research group to pursue a course of supervised research on an approved subject in physics. A Master of Science in Physics is awarded if a submitted thesis and its oral presentation pass the department's criteria.

For the **Ph.D. course** each student joins a research group, and is assigned a research supervisor. Independent original research is central to the Ph.D. and successful graduates require a high degree of self-motivation. The final examination involves the submission of a Ph.D. thesis followed by an oral examination assessed by both internal and external examiners.

Graduates from the M.S. course either advance to the Ph.D. course or go to industry. Many graduates from the Ph.D. course become postdocs or assistant professors and continue their research. Graduates going to industry are highly valued for their understanding of physics, and their problem solving abilities.

Department of Physics

Kobayashi Group

Members Kensuke KOBAYASHI (Professor), Yasuhiro NIIMI (Associate Professor), Tomonori ARAKAWA (Assistant Professor)

[Research Areas]

1) To clarify and control various quantum, many-body, and nonequilibrium effects in solid state devices
2) Quantum Fluctuation Theorem, quantum measurement & quantum feedback control in solid state devices
3) Electron- and nuclear- spin dependent transport
4) Dynamics of electron transport in various materials (topological insulators, magnetic tunneling junctions, etc.)
5) Spin transport measurements in two-dimensional superconductors and in frustrated spin systems
6) Development of measurement techniques to address dynamical aspects of electron transport

Recent progress in nanotechnology enables us to directly address quantum transport of electrons in nano-devices made of metal or semiconductor. For example, the wave nature of electrons can be controlled in electronic interferometers ("Aharonov-Bohm rings"), while their particle nature is accessible in quantum dots ("artificial atoms"). We can even combine these two kinds of devices into one, where the wave-particle duality in quantum mechanics manifests itself.

The advantage of such research field, which is called "mesoscopic physics" or "nanophysics", lies in the controllability and the versatile degrees of freedom in the device design. We aim at controlling charge, spin, coherence and many-body effects in such devices. As an example, the figure shows a micro-meter-sized Aharonov-Bohm ring with a schematic high-sensitive current fluctuation measurement setup, where we performed the first experimental test of "Fluctuation Theorem" in quantum coherent regime. We also work on spin transport measurements in two-dimensional superconductors and in frustrated spin systems where spin structures are complex, and aim to use spin current, flow of spin angular momentum, as a sensitive probe for such complex spin configurations.

We try to understand and control various novel quantum, many-body, and nonequilibrium effects in nano-devices in terms of the dynamical aspects of electron and spin transport.

Department of Physics

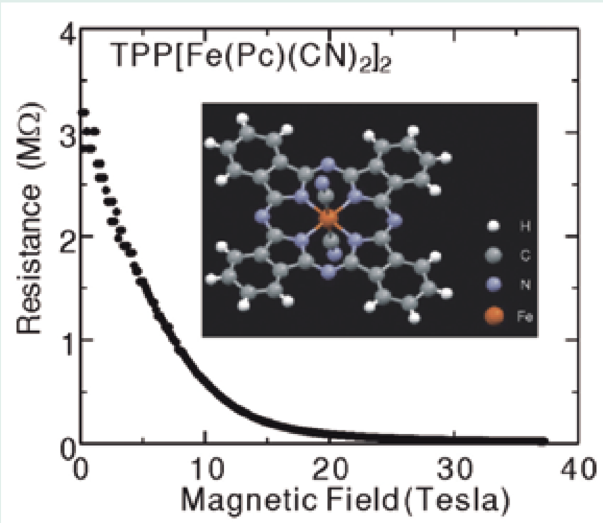
Hanasaki Group

Members Noriaki HANASAKI (Professor), Hideaki SAKAI (Associate Professor), Hiroshi MURAKAWA (Assistant Professor)

[Research Subjects]

Novel magnetotransport phenomena and thermoelectric effect originating from the strong electron correlation in the organic and the inorganic conductors

The strongly correlated electron systems provide a lot of interesting magnetotransport phenomena such as the giant magnetoresistance effect. For the realization of the giant magnetoresistance effect, the correlation between the spin and the charge degrees of the freedom is essential, since the spin configuration, which is controlled by the magnetic field, determines the electron transfer. The phthalocyanine molecules have the strong intramolecular interaction between the conduction electrons and the local moments. In this molecular conductors, we found the giant negative magnetoresistance. The thermoelectric effect is also investigated in the organic and inorganic conductors.



Department of Physics

Tajima Group

Members Setsuko TAJIMA (Professor), Shigeki MIYASAKA (Associate Professor),
Masamichi NAKAJIMA (Assistant Professor)

[Research Area]

Study of superconductivity mechanism, related new phenomena for exotic superconductors including high temperature superconductors, and quantum critical phenomena in strongly correlated electron systems by measuring charge responses such as transport properties, optical spectra and Raman scattering spectra.

When the copper oxide superconductors were discovered about 20 years ago, superconductivity which had been regarded as a phenomenon at ultra-low temperatures (< 10K) came into a higher temperature (>100K) world. Since the physical rules at ultra-low temperatures are different from those in our world at room temperature, the discovery of "high temperature" superconductivity implies the presence of new physics beyond the conventional one, and gave a strong impact to the physicists all over the world. We cannot yet answer the simple question "Why does superconductivity appear at such high temperatures?". Moreover, the intensive studies for this material during these 20 years have revealed many interesting phenomena other than high temperature superconductivity. Self-organization or non-uniform distribution of electrons is one of these new phenomena which would possibly develop into a new physics. We are challenging the elucidation not only of high temperature superconductivity mechanism but also of these new phenomena.

The discovery of high-Tc cuprates has explored new research on the strongly correlated electron systems. The strong electron correlation causes a variety of intriguing physical properties, such as high temperature superconductivity, Mott transition, colossal magnetoresistance and charge/orbital order. In order to find new exotic phenomena, we are investigating the charge dynamics in these systems.

Raman scattering spectrometer with Ar-Kr laser

Department of Physics

Hagiwara Group

(Center for Advanced High Magnetic Field Science)

Members Masayuki HAGIWARA (Professor), Yasuo NARUMI (Associate Professor),
Takanori KIDA (Assistant Professor), Mitsuru AKAKI (Specially Appointed Assistant Professor),
Kiyohiro SUGIYAMA (Adjunct Professor)

[Research Area]

1) Studies on magnetic field-induced quantum phases and phase transitions
2) High magnetic field studies and quantum criticality of strongly correlated electron systems
3) High magnetic field studies of functional materials
4) Development of experimental apparatus utilized under multiplex extreme conditions

Magnetic field is one of the important physical parameters such as pressure and temperature, and is a soft and precisely controllable external parameter. It interacts directly spin degrees of freedom and orbital motions of electrons that characterize the nature of materials.

We are aiming at observing new phenomena in ultrahigh magnetic fields combined with other extreme conditions such as very high pressure and extremely low temperatures, and enlightening their mechanism. In order to conduct such researches, we are developing experimental apparatuses for investigating physical properties of e.g. high-T_C iron pnictide superconductors by utilizing a huge capacitor bank system and a wide-bore pulse magnet as shown in the figures below. We have also developed electron spin resonance apparatuses with a very wide frequency-magnetic field window to study spin dynamics of novel magnets like quantum spin systems and/or frustrated magnets.

Huge capacitor bank system, and cut-view of a wide-bore pulse magnet

Department of Physics

Nozue Group

Members Yasuo NOZUE (Professor), Takehito NAKANO (Assistant Professor), Luu Manh KIEN (Assistant Professor), Isao WATANABE (Guest Professor)

[Research Items]

1) Strongly correlated electron system in nanostructured materials
2) Synthesis of regular nanoclusters arrayed in nanospace of zeolites
3) Magnetic and other electronic properties of arrayed nanoclusters
4) MuSR study of condensed materials

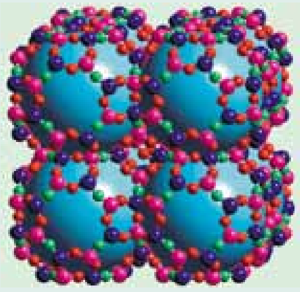


Fig. 1
Schematic illustration of clusters arrayed in zeolite A crystals

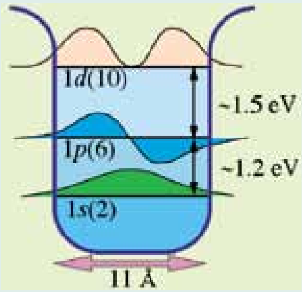


Fig. 2
Quantum states of electrons confined in nanocluster with the inside diameter of 11 Å

[Research Contents]

We are studying arrayed nanoclusters stabilized in porous crystals of zeolites by a wide variety of measurements, such as wide range optical spectroscopy, magnetic measurement, electron spin resonance, MuSR, electric transport, etc. In zeolite crystals, such as A (Fig. 1) and X, nanocages with internal dia meters of 11 and 13 Å are arrayed in simple cubic and diamond structures, respectively. By the loading of guest alkali metal into the nanocages, the *s*-electrons of alkali atoms are made to successively occupy 1*s*, 1*p* and 1*d* quantum electronic states of the clusters (Fig. 2). New electronic states like *superatoms* are formed. Novel electronic properties, such as ferromagnetism of *s*-electrons and metal-insulator transition are observed. These phenomena are explained by the mutual interaction of arrayed clusters, the orbital degeneracy, electron correlation, *etc*. Amazingly, ferromagnetic properties are found in non-magnetic elements introduced into the nanospace of zeolites crystals.

Department of Physics

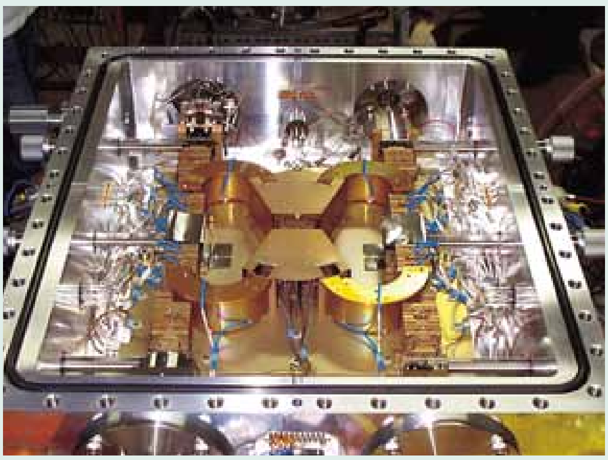
Toyoda Group

Members Michisato TOYODA (Professor), Morio ISHIHARA (Associate Professor), Jun AOKI (Assistant Professor)

[Research Area]

1) Development of a novel mass spectrometer with ultra-high sensitivity and ultra-trace sampling for planetary exploration
2) Development of a high-performance lightweight mass spectrometer for on-site analysis
3) Development of a tandem time-of-flight (TOF) mass spectrometer suitable for proteome analysis
4) Construction of ultra high resolution high speed imaging mass spectrometric technology (MS microscope)

The mass spectrometry is widely used in many fields, e.g., space science, biochemistry, physics and pharmacology. In order to study those fields, we develop high performance mass spectrometers such as multi-turn time-of-flight mass spectrometers.



Department of Physics

Kishimoto Group

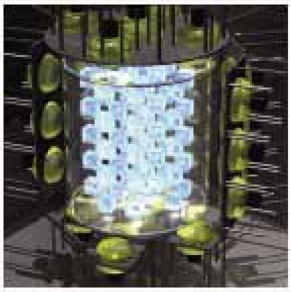
Members Tadafumi KISHIMOTO (Professor), Atsushi SAKAGUCHI (Associate Professor), Sei YOSHIDA (Associate Professor)

[Reearch Area]

1) Study of Majorana mass of neutrino by double beta decay
2) Search for Dark matters of our universe
3) Kaon condensation in neutron stars
4) Nuclear system with strangeness

Recently it has been confirmed that three types of neutrino have different masses by oscillation experiments. However, mass itself has yet to be measured. Observation of double beta decay verifies that neutrino has Majorana mass which violates conservation of lepton number by nature. It thus tells us reason why our universe can be a world with only matters (no antimatters). These research can only be achieved at the low background circumstance for which underground laboratory is best suited. We constructed CANDLES detector at the Kamioka underground laboratory for the study. We also work on a search for dark matters which requires similar low background circumstance.

We are studying nuclear systems with strangeness. Observed mass of neutron stars are in a narrow range. It is considered to be due to the fact that the core of the neutron stars, which is a single giant nucleus, is a nuclear matter with strangeness. In order to have further understanding on the nature of the core, we are studying kaon nucleus interaction. Structure of hypernuclei, which we are intensively studying, gives similar information. Recently we are studying kaon nucleon interaction. It would give a solution to the recent problem on the penta-quark.



Department of Physics

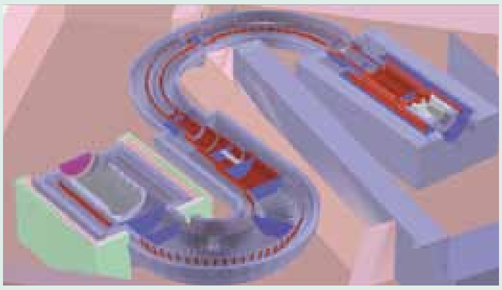
Kuno Group

Members Yoshitaka KUNO (Professor), Masaharu AOKI (Associate Professor), Akira SATO (Assistant Professor), Katsuhiko ISHIDA (Visiting Professor)

[Research Area]

1) Study of lepton flavor violation by searching for muon-to-electron conversion processes in a muonic atom (COMET and DeeMe)
2) Study of lepton universality by precise measurements of the rare pion decay process
3) Development of a next-generation muon source with the highest intensity, the highest luminosity and the highest purity in the world (PRISM)
4) Development of a method of ionization cooling for neutrino factory R&D, where a neutrino factory is a highly intense neutrino source based on decays of muons in a muon storage ring
5) Study of a high intensity muon beam source “MuSIC” at RCNP, Osaka University
6) Study of neutrinos with Super-Kamiokande

To answer fundamental questions such as “What is the origin of the Universe?”, there are two different experimental approaches in particle physics. One is the high-energy frontier approach and the other is the high-intensity frontier approach. The Kuno group adopts the latter, the high-intensity approach, and aims to obtain experimental evidences to reveal new physics scheme beyond the current Standard Model of particle physics. In particular, the Kuno group is looking for the processes that are forbidden in the Standard Model (such process as charged lepton flavor violation, like a muon-to-electron conversion by the COMET and DeeMe experiments at J-PARC) or making precise measurements of the processes that are allowed in the Standard Model (such as the lepton universality, and the matter-antimatter asymmetry in neutrinos). Furthermore, to accomplish such research goals, it is necessary to develop novel and unique experimental methods and detection methods, which are based on advanced technologies. For this purpose, we are, for instance, developing on a next-generation muon source with the highest-intensity, the highest-luminosity and the highest-purity in the world (PRISM). We are also aiming to make applications of these technologies to other interdisciplinary fields (MuSIC), and also technology transfer and spin-off to industry.



Department of Physics

Shimoda Group

Members Tadashi SHIMODA (Professor), Atsuko ODAHARA (Associate Professor), Suguru SHIMIZU (Assistant Professor) , Hideki UENO (Visiting Professor)

[Research Areas]

1) Study of nuclear structure far from the ß-stability line

2) Study of nuclear structure in high-spin states

Nuclei consisting of finite number of two types of particles, proton and neutron, are governed by the nuclear force. This complex system produces a very wide variety of nuclear structures.

Recent experiments with state-of-the-art accelerators, radiation detector systems, lasers to control the quantum atomic states, and so forth, have enabled us to explore the exotic nuclear structures with high sensitivity and high precision under extreme conditions of high spin, high isospin and so on. We are concentrating on the following high-priority subjects by using radio-active beams. (i) We study the nuclear structure of the nuclei with a large excess of proton numbers to those of neutrons, or vice versa. They show very different structures from those of nuclei in or close to the ß-stability line. (ii) We study the nuclear structure in high-spin states, where exotic nuclear shapes are expected to appear.

These nuclei in wide mass region were synthesized in the universe and are products of the Big-Bang nucleosynthesis, of the thermonuclear reactions in stars and supernova explosions, and so on. Study of the nuclear structure is important not only for nuclear physics but also for astrophysics to clearly understand the scenario of element synthesis in the universe.

Department of Physics

Nuclear and Solid State Physics Group [Kishimoto Group]

Members Kensaku MATSUTA (Associate Professor), Mitsunori FUKUDA (Associate Professor), Mototsugu MIHARA (Assistant Professor)

[Research Area]

1) Experimental studies of nuclear structure and nuclear matter through reaction cross sections and nuclear moments
2) Hyperfine interactions of nuclear probes and muons in materials with magnetic resonances detected by beta-ray emission (beta-NMR and muon spin rotation)
3) Symmetries in nature through nuclear beta decays and ultra-cold neutrons (UCN)
4) Dynamics of quarks and mesons in the nucleus

We succeeded to detect quark- and meson-effects in the nucleus. These effects were found to relate strongly to the nuclear matter density. So, we are studying the structure of dilute neutron- and proton-haloes spreading outside of the nucleus, to study the relation more precisely. For the study, we produce various unstable nuclei using the cyclotrons in RIKEN and the synchrotron in National Institute of Radiological Sciences, and measure reaction cross sections and nuclear moments applying beta-NMR technique. We explore the nuclear radii/nucleon density distributions and shell structure through these measurements. Additionally, we study limitation of symmetries in the law of nature, which these phenomena are subject to, through UCN and nuclear beta decays. Further, we can measure magnetic fields and electric field gradients inside crystals by observing the beta-NMR on these unstable nuclear probes implanted directly in various kinds of substances. From these internal fields, we elucidate electron density and its band structure in the crystal. We are collaborating with TRIUMF (Canada) and CIAE (P.R. China) for these studies.

Department of Physics

Yamanaka Group

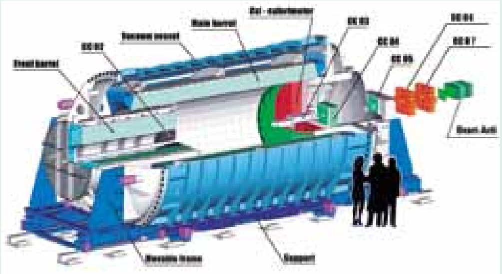
Members Taku YAMANAKA (Professor), Hajime NANJO (Associate Professor)

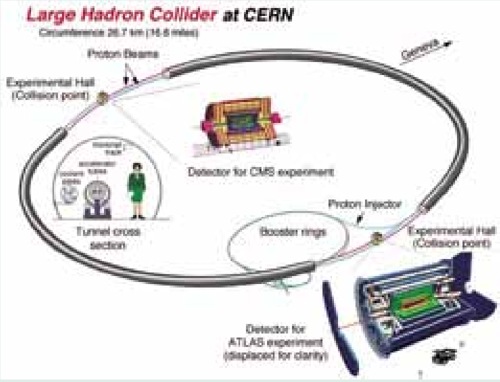
[Research Area]

1) CP violation in K mesons
2) Study of Higgs particle and search for Super Symmetric particles

Right after the Big Bang, the same number of particles and antiparticles were produced, but they annihilated each other into photons as the universe cooled down. However, there are matters (such as stars) left in this universe. This was caused by a small unbalance of $O(10^{-9})$ between the behaviors of particles and antiparticles; so called CP violation. Such CP violation must have been caused by new physics beyond the standard model. At a new high interisity proton accelerator, J-PARC, we are studying a rare CP-violating K_L decay to look for new physics beyond the standard model.

In addition, right after the Big Bang, all the particles were massless. However, they obtained mass due to Higgs particle. Using the highest energy proton-proton collidor at CERN, we are studying the Higgs particle. The same collider will allow us to produce undiscovered particles predicted by Supersymmetry which is the most popular theory beyond the Standard Model. We are also searching for such supersymmetric particles.





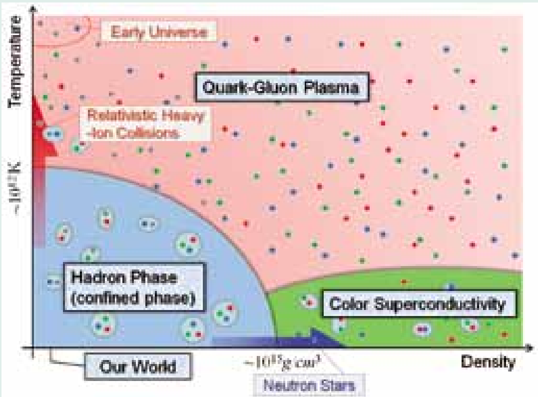
Department of Physics

Nuclear Theory Group

Members Masayuki ASAKAWA (Professor), Toru SATO (Associate Professor), Masakiyo KITAZAWA (Assistant Professor), Yukinao AKAMATSU (Specially Appointed Assistant Professor)

[Research Area]

1) Quark-hadron phase transition at finite temperature and density
2) Theory of high energy nucleus-nucleus collisions
3) Electron and neutrino reactions with nuclei, and hadron resonances
4) Theory of open quantum systems



Hadrons are particles that interact with strong force. Protons and neutrons that constitute nuclei are hadrons. So are Yukawa mesons. These particles were considered as elementary particles, but it is now known that they are composed of quarks and gluons, which are more fundamental particles. Two types of hadrons have been known, mesons and baryons. Mesons are made of two (anti)quarks and baryons are made of three (anti)quarks. Recently, the possibility of other types of hadrons has been considered. Isolated quarks or gluons cannot exist in the world where we live now, but it is believed that quarks and gluons are deconfined and can move freely at high temperature, above approximately 2×10^{12} K. Such high temperature once existed in early universe. We are trying to understand such diverse dynamics in the world of the strong interaction, played by quarks, gluons, and hadrons.

Department of Physics

Particle Physics Theory Group [Kanemura Group]

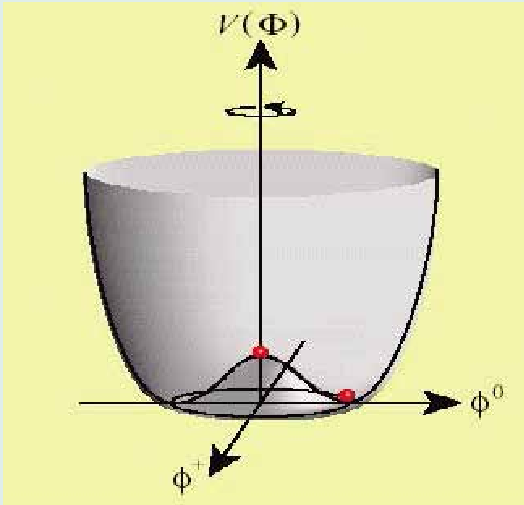
Members Shinya KANEMURA (Professor), Kin-ya ODA (Associate Professor), Kentaro MAWATARI (Designated Assistant Professor)

[Research Area]

1. Structure of vacuum in the early universe and physics of the Higgs sector
2. Solving problems beyond the standard model
3. Particle phenomenology
4. Probing new physics models by using gravitational waves

[Introduction to the research interests]

We are interested in solving problems in current particle physics, and we explore new physics models beyond the standard model which can describe phenomena between the electroweak scale and the Planck scale. By the theoretical speculation with the data from various experiments, we try to understand the Universe in deeper levels. According to the quantum field theory, we try to built new models which can explain various unsolved problems in particle physics such as tiny neutrino mass, dark matter, baryon asymmetry of the Universe and cosmic inflation, and we perform phenomenological studies to test these models using various high energy experiments at the LHC, Super KEKB, the International Linear Collider, etc. Starting from the property of the Higgs boson which was discovered in 2012, we explore the mechanism of electroweak symmetry breaking and new physics behind. Furthermore, we study testability of new physics models by the future space based gravitational wave measurements such as LISA and DECIGO.



Department of Physics

Particle Physics Theory Group [Onogi Group]

Members Tetsuya ONOGI (Professor), Minoru TANAKA (Assistant Professor), Hidenori FUKAYA (Assistant Professor)

[Research Area]

1) Lattice QCD and its application to particle physics and field theory
2) Origin of flavor mixing and CP violation
3) Mechanism for electroweak symmetry breaking and the properties of the Higgs bosons

[Research Contents]

1. Nonperturbative study of field theories from lattice - Dynamics of gauge theories (electroweak phase transition, walking technicolor), electroweak matrix element from lattice QCD.
2. CP violation in B, D, K mesons
3. Higgs Boson and Supersymmetric Model Phenomenology - properties of Higgs bosons, Higgs boson hunting in accelerator experiments

Department of Physics

Particle Physics Theory Group [Hashimoto Group]

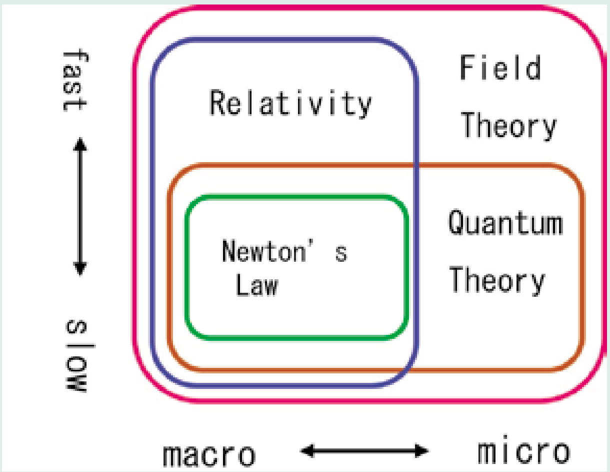
Members Koji HASHIMOTO (Professor), Satoshi YAMAGUCHI (Associate Professor), Norihiro IIZUKA (Assistant Professor)

[Research Interests]

1) Superstring theory
2) Quantum field theory, gauge theory and supersymmetric theory
3) Quantum gravity
4) Mathematical physics

[Introduction to the research interests]

Quantum field theory is the most advanced formulation of physics we have ever reached. Two basic principles of modern physics, relativity and quantum theory, are incorporated in it. The gravity theory of Einstein however is not incorporated in this framework. The most promising candidate is the superstring theory. We are pursuing fundamental problems of particle physics by examining various possibilities of the quantum field theory and the superstring theory. Furthermore, we apply mathematical tools developed in string theory and quantum field theories to various physical phenomena, which would connect different subjects of science via mathematical physics.



Department of Physics

Kuroki Group

Members Kazuhiko KUROKI (Professor), Keith SLEVIN (Associate Professor), Masayuki OCHI (Assistant Professor), Yoshifumi SAKAMOTO (Assistant Professor)

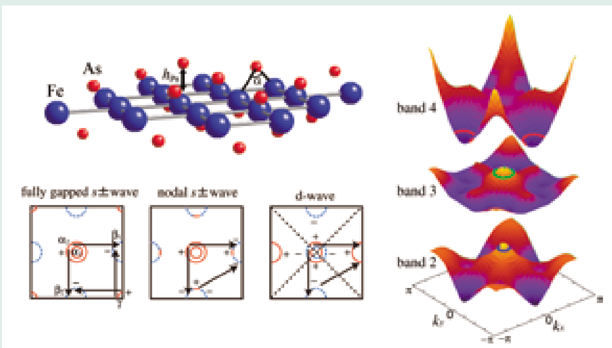
1) Electron correlation effects, unconventional superconductivity
2) Optimization of thermoelectric effects
3) New many-body and/or first principles methods for studying strongly correlated electron systems
4) Quantum transport phenomena in disordered systems, Anderson localization
5) Structure and phase transition on solid surfaces

We theoretically study condensed matter physics, and are particularly interested in the properties of electrons in solids.

In quantum mechanics, electrons behave as waves, and the relation between the wave number and the frequency is described by the electronic band structure of the material, which strongly governs the properties of the material.

Therefore, it is important to correctly understand the band structure from a microscopic viewpoint. In solids, a huge number of electrons interact with one another, and this repulsive interaction induces correlation effects.

The cooperation between the band structure and the electron correlation effects can give rise to various phenomena such as superconductivity and magnetism, but correctly understanding the correlation effect is in general difficult and therefore a challenging issue. In addition to the above, the presence of impurities, defects and randomness in solids can also lead to interesting phenomena such as the Anderson localization. We investigate these issues numerically and/or analytically, and are also interested in developing new theoretical methods to analyze these problems.



Department of Physics

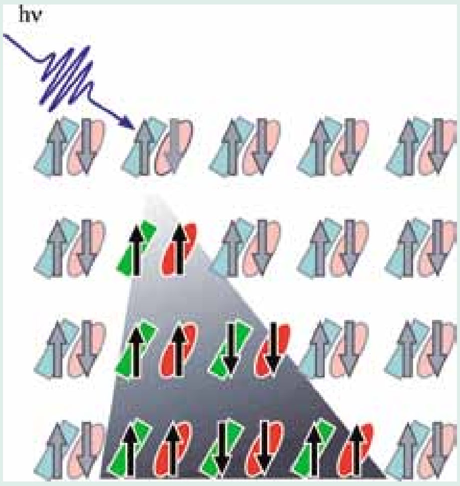
Theoretical Condensed Matter Optics Group

Members Kenichi ASANO (Associate Professor), Takuma OHASHI (Assistant Professor), Yasuhiro AKUTSU (Professor), Tetsuo OGAWA (Executive Vice-President)

[Research Area]

1) Low-dimensional many-body quantum systems
2) Photoinduced quantum phase transitions: the exciton Mott transition
3) Optically-excited states and their dynamical responses
4) Quanmtum theory of lasing in correlated electron-hole systems
5) Control of quantum states of light
6) Development of numerical schemes for computational statistical mechanics

We are interested in solids, which are composed of many microscopic components, e.g., atoms and molecules. Such materials exhibit dramatic and interesting phenomena, phase transitions and/or nonlinear responses, due to interactions among their constituents. There remain many not yet understood phenomena that will require highly-sophisticated theoretical treatments beyond one-body approximations. Our group is trying to explain these exotic phenomena using analytical and computational techniques. We cover many target materials, i.e., "hard" materials: magnetic matters, electronic systems, dielectric materials, solid-state surfaces, and "soft" materials: high polymers, proteins, molecular crystals, and so on.



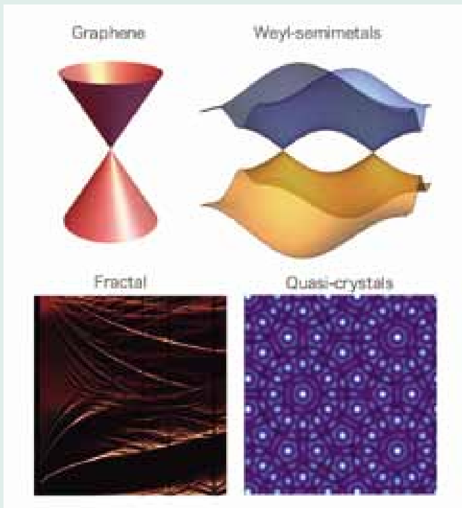
Department of Physics

Koshino Group

Members Mikito KOSHINO (Professor)

[Research Subjects]
Condensed matter theory: the quantum electronic properties in the novel condensed matter systems, including two-dimensional materials, low-dimensional systems, and topological materials.

Two-dimensinoal (2D) materials are atomically-thin crystals less than 1 nm thick. For example, graphene, one of the first 2D materials ever created in history, is a single layer of carbon atoms arranged in a honeycomb lattice. Recently the experimentalist successfully fabricated 2D films of various kind of materials, and the physical properties of these system have been one of the most intensively studied topics in condensed matter physics. Interestingly, many of 2D materials often exhibit completely different physical properties compared to the 3D version's.For example, an electron in single-layer graphene behaves like a massless Dirac electron in the relativistic quantum theory, but it never appears in the 3D graphite (or even bilayer graphene). Likewise, we can make a light-emitting semiconductor by thinning some kind of non-light-emitting 3D semiconductor down to monolayer. Also a single layer of some superconducting material gets the critical temperature 10 times higher than that of 3D bulk. It is also possible to make a hybrid material just by stacking different 2D materials, and realize a bizarre nature never found in the original materials. We are also interested in the topological materials, in which special electronic states emerges on the surface of the system as a consequence of the topological properties in the quantum state. We are searching for the novel and exotic properties by theoretically studying various kind of physical properties in these novel materials.



Department of Physics

Fundamental Nuclear Physics Group

(Research Center for Nuclear Physics · Toyonaka Laboratory)

Members Masaharu NOMACHI (Professor), Yorihito SUGAYA (Assistant Professor)

[Research Area]

1) Neutrino physics (Double beta decay experiment, Sterile Neutrino)
2) Advanced radiation detector development to explore physics frontiers

The origin of matter and the origin of mass is fundamental questions in physics.

One of the keys to understand the problems is the study of the neutrino mass and its origin. We are studying the neutrino mass by the double beta decay experiment. We are developing advanced radiation detectors to explore those physics frontiers.

Department of Physics

Quark Nuclear Physics Theory Group

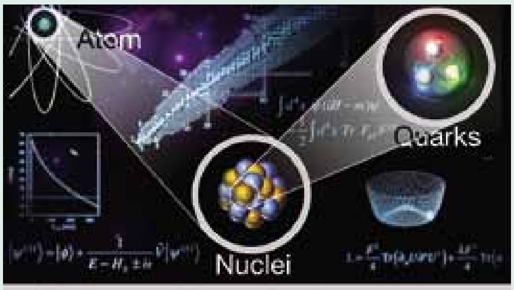
(Research Center for Nuclear Physics)

Members Atsushi HOSAKA (Professor), Kazuyuki OGATA (Associate Professor), Noriyoshi ISHII (Associate Professor), Hideko NAGAHIRO (Specially Appointed Associate Professor), Yoichi IKEDA (Specially Appointed Assistant Professor), Kosho MINOMO (Specially Appointed Assistant Professor), Takayuki MYO (Guest Associate Professor)

[Research Subjects]

Our study covers theoretical hadron and nuclear physics:

1) Structure of hadrons (protons and neutrons) from quarks and gluons
2) Lattice QCD study for hadron structure and interactions
3) High precision reaction study for nuclear structure and synthesis
4) Nuclear physics from QCD



Understand the universe by the law of the subatomic world

Our aim is to understand the divers phenomena of strong interactions from quarks, baryons and nuclei to astrophysics phenomena. Quarks are confined and the vacuum breaks chiral symmetry, but we do not know how quarks form nucleons. Yukawa's interaction by the pion binds the nucleus, but we still cannot solve fully the nuclear-many-body problems. It is rather recent that we can describe nuclear reactions microscopically for the study of history of the universe. We are approaching these problems by using various methods of theoretical physics of quantum mechanics, relativity and field theory. Our method also uses the world top supercomputer Kei. In performing our research, we discuss and collaborate with many physicists from the world. We also discuss with experimentalists who are working at the RCNP cyclotron, SPring-8, KEK, RIKEN and J-PARC.

Department of Physics

Particle and Nuclear Reactions IA Group
(Research Center for Nuclear Physics)

Members Nori AOI (Professor), Atsushi TAMII (Associate Professor), Eiji IDEGUCHI (Associate Professor), Tatsushi SHIMA (Associate Professor), Keiji TAKAHISA (Assistant Professor), Tomokazu SUZUKI (Assistant Professor), Hooi Jin ONG (Specially Appointed Associate Professor), Koichiro SHIMOMURA(Specially Appointed Associate Professor), Dai TOMONO(Specially Appointed Assistant Professor), Nobuyuki KOBAYASHI (Specially Appointed Assistant Professor)

[Research Area]

1) Spin and lsospin responses of nuclei and giant resonance
2) Defomation and vibration of nuclei
3) α-cluster structure and its appearance mechanism
4) Carbon synthesis in the universe
5) Tensor interaction in nuclei originating from Yukawa pion
6) Structure and reaction of unstable nuclei
7) De-coupling of proton and neutron distribution in stable and unstable unclei

A nucleus is a quantum many-body system consisting of protons and neutrons, which are interacting each other with strong force. Nuclear structures have been investigated with many kinds of probes and it has been realized that a nucleus is a quite unique system, where independent particle motions and collective motions coexist. To understand the nature of nuelei, it becomes more important to clarify microscopic structures produced by nucleons near the surface, to search various collective motions with large amplitudes and to investigate modifications of nucleon properties in the nuclear medium.

Nuclear physics is important in interdisciplinary fields such as astrophysics, engineering and medical application. We study nuclear interactions and structures with 0.01-0.4 GeV/nucleon beams obtaind by the RCNP cyclotron. This energy region is most adequate to study nuclear medium and spin isospin responses. The nucleon motions associated with spins and isospins are interesting from several points of view. Spin isospin interactions give rise to spin isopspin giant resonances. The spin isospin responses are associated with pi- and rho-meson exchange interactions. Nuclear spin isospin interactions are relevant to axial-vector weak responses in nuclei. They are crucial for studies of nuclear responses to neutrinos.

With high quality beams and high performance detectors, these physics programs are under way, in collaboration with many physicists from all over the world.

Department of Physics

Particle and Nuclear Reactions IB Group
(Research Center for Nuclear Physics)

Members Takashi NAKANO (Professor), Hiroyuki NOUMI (Professor), Masaru YOSOI (Professor), Shuhei AJIMURA (Associate Professor), Mizuki SUMIHAMA (Specially Appointed Associate Professor), Hideaki KOHRI (Specially Appointed Associate Professor), Tomoaki HOTTA (Assistant Professor), Kotaro SHIROTORI (Assistant Professor)

[Research Theme]

1) Study of the Quark-Nuclear Physics through the meson- and baryon- photoproductions to understand the hadrons in terms of the quarks and their interactions
2) Search for the exotic particles such as penta-quarks
3) Construction and operation of the high-energy polarized photon beam facility by laser-backscattering from the 8 GeV electron beam
4) Development of the detector system for the precise measurement of photo-nuclear reactions with protons and nuclei in the GeV energy region
5) Development of the HD polorized target
6) Spectroscopic study of charmed baryons with a high-momentum pion beam and Quark-Nuclear Physics with K and other hadron beams at J-PARC (Tokai)

Since the wave-length of a few GeV gamma-ray is less than the size of a hadron, typically a proton (~1 fm), it becomes possible to investigate its sub-structure, i.e., the world of quarks and gluons with GeV photons. A polarized GeV-photon beam with good qualities is produced by the backward-Compton scattering of laser photons from high energy electrons. Our group studies the interactions and structures of hadrons in terms of the quarks and their interactions, which is called the Quark-Nuclear Physics. The experiment is performed at SPring-8 which is the synchrotron radiation ring with the highest energy (8 GeV) in the world. Experimental studies of the Quark-Nuclear Physics with high intensity hadron beams at J-PARC are being developed.

Our group has found an evidence for an exotic baryon with an anti-strange quark (penta-quark 'Theta') for the first time. Making sure of its existence and revealing its structure are two of the main goals. The investigations of the quark confinement, quark-pair (diquark) correlations, the partial restoration of the chiral symmetry in the nuclear medium, the freedom of quarks and gluons in the nuclear force, etc. are other objectives. The experimental study is being done with state-of-the-art technologies in order to understand the physical material from the quark-gluon level, also expecting the encounter with unknown phenomena.

Department of Physics

Accelerator Physics Group

(Research Center for Nuclear Physics)

Members Mitsuhiro FUKUDA (Professor), Tetsuhiko YORITA (Associate Professor), Hiroaki KANDA(Associate Professor)

[Research Area]

1) Upgrading of the ring and AVF cyclotrons to provide ultra high-quality beams for precision nuclear physics experiments
2) Ion source developments for production of high-brightness and high-intensity ion beams
3) R&D of a future GeV particle accelerator
4) R&D of next-generation accelerators and their applications utilizing new technologies like high-temperature superconducting (HTS) magnet

A photograph of the ring cyclotron

The RCNP cyclotron facility, consisting of a K400 ring cyclotron and a K140 AVF cyclotron, plays an important role in nuclear physics using intermediate-energy nuclear beams. We study accelerator and beam physics for upgrading the high-performance cyclotrons and ion sources to provide ultra high-quality beams for precision nuclear physics experiments. The R&D of a new particle accelerator to produce ultra-precise GeV beams is in progress for pioneering research fields in particle and nuclear physics. The R&D for applications of state-of-art accelerator technologies to medical, biological, materials sciences and industry is under way; for example, development of high-temperature superconducting magnets for the particle cancer therapy.

Department of Physics

Quantum System Electronics Group

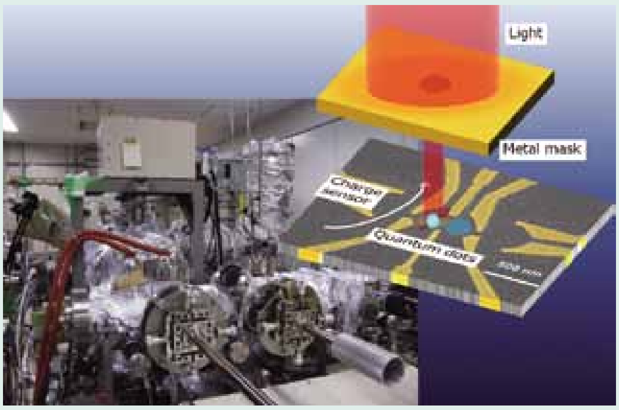
(The Institute of Scientific and Industrial Research)

Members Akira OIWA (Professor), Shigehiko HASEGAWA (Associate Professor), Haruki KIYAMA (Assistant Professor)

[Research Areas]

1) Spin-related quantum transport and nano-level characterization in semiconductor low dimensional systems
2) Quantum interface between single photon and single spin and its application to quantum information processing
3) Novel magnetic semiconductors and their semiconductor spintronics device applications
4) Wide band-gap semiconductor based materials integration and their device applications

Quantum system electronics group studies novel optical, electronic, and spin devices that support the highly-sophisticated information society in the 21st century. Based on semiconductor devices, our research fields are quantum information processing using the quantum mechanical nature of electron spins and photons, and spintronics based on the development and hybridization of optical, electrical and spin materials. We study the growth and characterization of high quality materials and perform precise quantum transport measurements. Aim of our research is the realization of novel phenomena emerging in quantum nano-structures that can control the photon, electron and spin degrees of freedom.



(Left) Molecular beam epitaxy, (Right) Schematic illustration of photon-spin quantum interface using a quantum dot

Department of Physics

Multiferroic and topological properties

Oguchi Group

(The Institute of Scientific and Industrial Research)

Members Tamio OGUCHI (Professor), Koun SHIRAI (Associate Professor), Kunihiko YAMAUCHI (Assistant Professor), Hiroyoshi MOMIDA (Assistant Professor), Mitsuhiro MOTOKAWA (Guest Professor), Takeo JO (Guest Professor), Shigemasa SUGA (Guest Professor)

[Research Area]

1) Novel electronic properties associated with broken symmetry
2) Materials design based on the prediction of phase stability
3) Multiferroic and topological properties
4) Development of first-principles methods and materials in formatics

Various materials such as metals, semiconductors, oxides, and organics can be characterized by their physical and chemical properties, such as electronic conductivity, optical properties, and chemical reactivity, which exhibit variations over wide ranges. In order to utilize those properties in our life, it is desirable to produce materials with preferable properties by modifying their microscopic structures. To this end, it is of crucial importance to clarify the mechanisms underlying their physical and chemical properties. We are developing computational techniques based on quantum mechanics (first-principles methods). The forefront methods are applied to real materials to study their properties, and even to hypothetical structures to design new materials. Based on the obtained knowledge, we extract ideas to design new materials with desired properties. We are collaborating with experimental groups to prove our predictions. Through our researches, we wish to contribute to our society in terms of researches of clean and efficient energy resources, environmental protection, and development of industries.

Department of Physics

Kimura Group

(Graduate School of Frontier Biosciences)

Members Shin-ichi KIMURA (Professor), Junji WATANABE (Associate Professor), Yoshiyuki OHTSUBO (Assistant Professor), Hiroshi WATANABE (Assistant Professor)

[Research Area]

1. Optical and photoelectrical studies on electronic states of functional solids and thin films
2. Development of new spectroscopies using synchrotron radiation and quantum beams
3. Order and pattern formation processes in nonequilibrium systems

Physical properties of solids, such as magnetism and superconducting, and life phenomena, such as redox and photosynthesis, originate from the electronic states in materials and their interactions. To clarify the electronic states provides us not only the information of the origins of the physical properties and life phenomena but also the expectation and creation of novel functionalities. To visualize of the change of the electronic state, we develop new spectroscopic techniques using synchrotron radiation and other quantum beams. The photograph is the symmetry- and momentum-resolved electronic structure analysis instrument (SAMRAI) developed at UVSOR, the high-brilliance low-energy synchrotron radiation facility.

In thermally nonequilibrium systems, various structural and functional orders come out simultaneously. We perform experiments to clarify these phenomena in various systems such as laser oscillation, vibrational reaction, colloidal crystal, domain formation and living systems.

Department of Physics

Interdisciplinary Computational Physics Group

(Cybermedia Center)

Members Macoto KIKUCHI (Professor), Hajime YOSHINO (Associate Professor)

[Research Area]

1) Protein foldings, design and evolution
2) Physics of glass and jamming transitions
3) Traffic flows as nonlinear dynamical systems
4) Mechanism of biomolecular motor
5) Critical phenomena and phase transition
6) New Monte Carlo sampling methods based on extended ensembles

Various interdisciplinary subjects, e.g., biological systems, glassy materials and traffic flows, are studied in the light of statistical mechanics, nonlinear dynamics and computational physics. Although the subjects seem to be quite different from each other, at first glance, they share the same key concepts: their complex behaviors emerged from the complex interactions among large number of relatively simple elements. Researches on new methodologies of scientific computing are also in progress.

Department of Physics

Intense Laser Science Group

(Institute of Laser Engineering)

Members Shinsuke FUJIOKA (Professor), Yasunobu ARIKAWA (Associate Professor), Alessio MORACE (Assistant Professor)

[Research Area]

1) Laser Fusion
2) Radiation Hydrodynamics, High-Density Plasma Physics
3) Precision Diagnostics Development
4) High Intensity EM field science

The ultimate goal of our activity is to realize laser fusion as a next generation energy source by creating plasmas with one thousand times solid density and a temperature of one hundred million degree Kelvin. On the way towards this goal, we study radiation hydrodynamics and high-density plasma physics (Fermi degeneracy and strongly coupled plasma) as physics basis of laser fusion. We also study unexplored physics by using a peta (ten to the fifteenth)-watt laser.

Department of Physics

Theory of High Energy Density Science Group

(Institute of Laser Engineering)

Members Yasuhiko SENTOKU (Professor), Takayoshi SANO (Assistant Professor), Kazunori SHIBATA (Specially Appointed Assistant Professor)

[Research Area]
Theory of High Energy Density Physics
Theory of Ultraintense Laser Matter Interaction
Theory of Astrophysical Plasmas
Plasma Particle Simulations
Radiation Magneto-hydrodynamics Simulations

The Sun gives enormous energy on the Earth. Inside the sun charged particles and photons interact each other and form the complex states of matter. The physics in such extreme states of matter is called the high-energy density physics (HEDP). The HEDP is considerable interest due to their relevance to inertial confinement fusion as well as astrophysical plasmas found in the stellar interiors, the cores of the giant planets, galactic nuclei and x-ray binaries. Due to the recent technological advances, lasers with sub-picosecond duration with petawatt power, which is a few orders of magnitudes higher than the total electric consumption power on the globe, are now available. Such strong laser light is capable of producing solid-state high temperature plasmas, which is equivalent to the states of matter inside the sun. Therefore, the powerful laser allows us study the physics inside the stars on the earth, namely, in laboratory, like our Institute of Laser Engineering, Osaka University.

In our group, we explore the science in HEDP with a help of computational simulations to understand the physics in laser produced plasmas, which are equivalent to the matter in astrophysical objects, particle acceleration, energy transport, radiation physics, plasma instabilities, and high field sciences such as γ-ray emissions & pair creations.