Kobayashi-Maskawa Institute
for the Origin of Particles and the Universe
Nagoya University

Annual Report

April 2022 – December 2022

Foreword

I (Junji Hisano) was reappointed to the second term as director of KMI in April 2022. During the first term, the KMI activities were subject to various restrictions due to the spread of the new type of coronavirus infection. Although the spread of coronavirus infection has not yet subsided, we have regained the activities we had before the coronavirus infection spread. We are costumed to be with coronavirus. In 2022, we dispatched many people overseas. In addition to it, the 4th KMI International School, " Statistical Data Analysis and Anomalies in Particle Physics and Astrophysics" was held face-to-face in December 2022. The core-to-core program "DMNet" held an international symposium at the Max Planck Institute for Nuclear Physics in Heidelberg, Germany, in September 2022. We also held workshops in hybrid ways. Research activities using Internet technology, which did not exist before the spread of coronavirus infection, are expanding.

At the end of 2022, we received good news. Nagoya University has Tau-lepton Physics Research Center under the Graduate School of Science, and the deadline for its establishment will come in March 2023. In conjunction with this, the International Research Center for Flavor Physics will be established under the KMI in April 2023. This will help to revitalize international research and education in flavor physics. For this establishment, we have submitted a budget request to the Ministry of Education, Culture, Sports, Science and Technology (MEXT), which was approved. This will enable KMI to grow its activities in the future.

In this report, the experimental and theoretical highlights at KMI are reported in Sect. 3, where other activities spanning through all scientific missions at KMI are also summarized. Research-related activities, such as regular seminars and colloquia, conferences and meetings, are summarized in Sect.4. Publications and presentations through these activities are listed in Sect. 5.

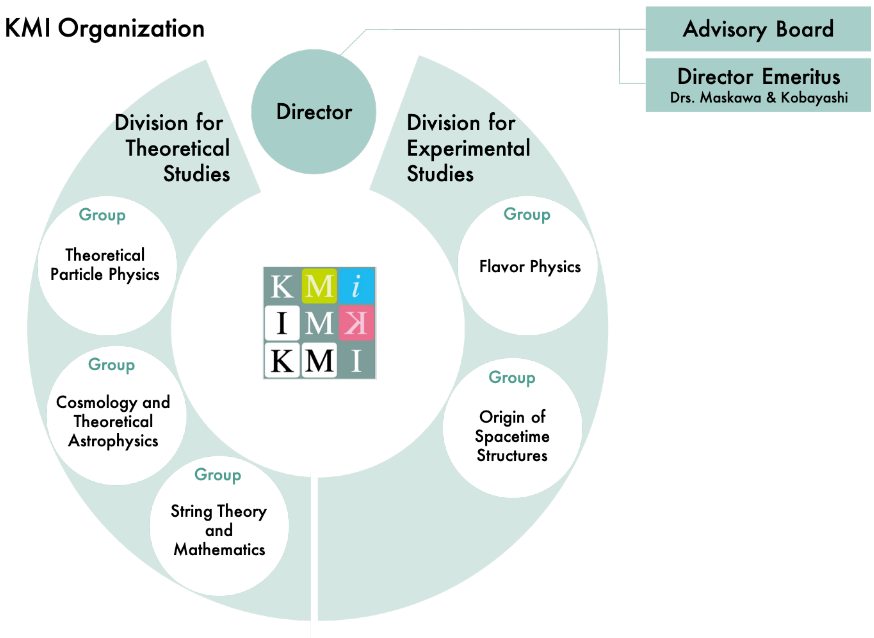
Junji Hisano

Contents

Chapter 1

Organization

1.1 Organization



1.2 Staff List

Director : HISANO Junji

Director Emeritus: MASKAWA Toshihide, KOBAYASHI Makoto

Division of Theoretical Studies (Chair, NOJIRI Shin'ichi)

Theoretical Particle Physics Group

TANABASHI Masaharu (Professor)
HISANO Junji (Professor)
TOBE Kazuhiro (Associate Professor)
MAEKAWA Nobuhiro (Associate Professor)
KANEKO Takashi* (Lecturer)
KITAHARA Teppei (Assistant Professor)
YAMANAKA Nodoka (Assistant Professor)

String Theory and Mathematics Group

KANNO Hiroaki (Professor)
SHIROMIZU Tetsuya (Professor)
SAKAI Tadakatsu (Associate Professor)
IZUMI Keisuke (Lecturer)

Cosmology and Theoretical Astrophysics Group

NOJIRI Shin'ichi (Chair, Professor)
ICHIKI Kiyotomo (Associate Professor)
MIYATAKE Hironao (Associate Professor)
YOKOYAMA Shuichiro (Assistant Professor)
KOBAYASHI Takeshi (Assistant Professor)
SUNAYAMA Tomomi (JSPS Research Fellow)
ARAI Shun (Researcher)
KOBAYASHI Takeshi (Visiting Scientist)
NISHIZAWA Atsushi J.*

Computational Theoretical Physics Laboratory (Chief, ICHIKI Kiyotomo)

TANABASHI Masaharu (Professor)
ICHIKI Kiyotomo (Chief, Associate Professor)
AOYAMA Tatsumi (Visiting Scientist)
NONAKA Chiho (Visiting Scientist)

Division of Experimental Studies (Chair, ITOW Yoshitaka)

Flavor Physics Group

Tau-Lepton Physics

IIJIMA Toru (Professor)
KRIZAN Peter (Professor)
TOMOTO Makoto (Professor)
HORII Yasuyuki (Associate Professor)
YOSHIHARA Keisuke (Associate Professor)
SUZUKI Kazuhito (Lecturer)
ZHOU Qidong (Assistant Professor)
GAZ Alessandro (Visiting Scientist)
KATO Yuji (Visiting Scientist)
MATSUOKA Kodai (Visiting Scientist)
NAKAHAMA Yu (Visiting Scientist)

Fundamental Astroparticle Physics

ITOW Yoshitaka (Chair, Professor)
NAKAMURA Mitsuhiro (Professor)
KITAGUCHI Masaaki (Associate Professor)
OKUMURA Akira (Junior Associate Professor)
NAKANO Toshiyuki (Lecturer)
KAZAMA Shingo (Assistant Professor)
NAKA Tatsuhiro (Visiting Scientist)

Origin of Spacetime Structures Group

Observational Astrophysics

NAKAZAWA Kazuhiro (Associate Professor)

Theoretical Spacetime Analysis

NAMBU Yasusada (Associate Professor)

Instrument Development Laboratory

NAKAMURA Mitsuhiro (Chief, Professor)

NAKAZAWA Kazuhiro (Associate Professor)

Tau-Lepton Data Analysis Laboratory

IIJIMA Toru (Chief, Professor)

TOMOTO Makoto (Professor)

KATO Yuji (Visiting Scientist)

Public Relations Office

MIYATAKE Hironao (Chief, Associate Professor)

KAZAMA Shingo (Associate Professor)

TAKAHASHI Shota* (Assistant Professor)

MINAMIZAKI Azusa (Researcher)

MIZUTANI Mayu (Secretary)

Associate Members

SUGIYAMA Naoshi

HARADA Masayasu

KAWAMURA Seiji

SHIMIZU Hirohiko

TAJIMA Hiroyasu

SATO Osamu

ROKUJO Hiroki

FUKUDA Tsutomu

(New members are indicated with * .)

Chapter 2

Management System

- Steering Committees
  - Steering Committee of KMI
    In this Committee, the following agenda items are discussed:
    1. Selection of Director General in KMI,
    2. Future plans and evaluation on the plans in KMI,
    3. Basic policies of managements and administrations in KMI,
    4. Personnel affairs in KMI,
    5. Budgets and facilities in KMI,
    6. Collaborations with the Division of Theoretical Studies and the Division of Experimental Studies,
    7. Anything else related with managements and administrations in KMI.
  - Steering Committee for each Laboratory in the following list is placed, where its managements and administrations are discussed:
    * Computational Theoretical Physics Laboratory
    * Instrument Development Laboratory
    * Tau-Lepton Data Analysis Laboratory

- Advisory Board

  By following the foundation of KMI, an international advisory board has started.

  The members of the advisory board are the followings (in alphabetical order):

  · ELLIS John (Professor at King's College London)

  · KAJITA Takaaki (Director, Institute for Cosmic Ray Research, The University of Tokyo)

  · ISO Satoshi (Professor, KEK)

  · MURAYAMA Hitoshi (Professor, University of California, Berkeley)

  · SASAKI Misao (Professor, Kavli Institute for the Physics and Mathematics of the Universe, The University of Tokyo)

  · SILK Joseph (Professor, Institut d'astrophysique de Paris)

  · YAMAUCHI Masanori (Director General of High Energy Accelerator Research Organization)

Chapter 3

Progress in Research

3.1 Division of Theoretical Studies

3.1.1 Theoretical Particle Physics Group

This year I investigate the following topics: Study of the effects of U(1) axial anomaly introduced in a hadronic effective model to properties of neutron stars, construction of an effective model of octet baryons based on the parity doublet structure, Study of mass spectra and decay widths of singly heavy baryons based on an effective model respecting the chiral symmetry and the heavy-qurak symmetry. (Masayasu Harada)

When the QCD axion is absent in full theory, the strong CP problem has to be explained by an additional mechanism, e.g., the left-right symmetry. Even though tree-level QCD $\bar{\theta}$ parameter is restricted by the mechanism, radiative corrections to $\bar{\theta}$ are mostly generated, which leads to a dangerous neutron electric dipole moment (EDM). The ordinary method for calculating the radiative $\bar{\theta}$ utilizes an equation $\bar{\theta} = \arg\det m_q^{\rm loop}$ based on the chiral rotations of complex quark masses. We point out that when full theory includes extra heavy quarks, the ordinary method is unsettled for the extra quark contributions and does not contain its full radiative corrections. We formulate a novel method to calculate the radiative corrections to $\bar{\theta}$ through a direct loop-diagrammatic approach, which should be more robust than the ordinary one. As an application, we investigate the radiative $\bar{\theta}$ in the minimal left-right symmetric model. We first confirm a seminal result that two-loop level radiative $\bar{\theta}$ completely vanishes (corresponding to one-loop corrections to the quark mass matrices). Furthermore, we estimate the size of a non-vanishing radiative $\bar{\theta}$ at three-loop level. It is found that the resultant induced neutron EDM is comparable to the current experimental bound, and the expected size is restricted by the perturbative unitarity bound in the minimal left-right model.(Junji Hisano, Teppei Kitahara)

We study B meson semileptonic decays in lattice QCD. The Möbius domain-wall quark action is employed for all relevant quark flavors in order to control discretization errors and renormalization of the weak current on the lattice. For the $B \to \pi\ell\nu$ decay, we calculate the vector and scalar form factors. By a simultaneous fit to our lattice and experimental data by Belle and BaBar, we obtain $|V_{ub}|$ with a 10 % accuracy. For the $B \to D^*\ell\nu$ decay, we determine all four form factors as a function of the recoil parameter. These data in particular near zero recoil significantly stabilize the determination of $|V_{cb}|$ and, hence would be useful input to the future determination of $|V_{cb}|$. (Takashi Kaneko)

The rare flavor changing top quark decay $t \to cZ$ is a clear sign of new physics and experimentally very interesting due to the huge number of top quarks produced at the LHC. However, there are few viable models which can generate a sizable branching ratio for $t \to cZ$. In fact, vector-like quark models seem to be the only realistic option. We investigate all three representations (under the

Standard Model gauge group) of vector-like quarks that can generate a sizable branching ratio for $t \to cZ$ without violating bounds from B physics. Importantly, these are exactly the three vector-like quarks which can lead to a sizable positive shift in the prediction for W mass, via the couplings to the top quark also needed for a sizable $\mathrm{Br}(t \to cZ)$. Calculating and using the one-loop matching of vector-like quarks on the Standard Model Effective Field Theory (SMEFT), we find that $\mathrm{Br}(t \to cZ)$ can be of the order of 10^{-4}–10^{-6} depending on the vector-like quark representations and that the large W mass measurement can be accommodated. (Teppei Kitahara)

Recently, the CMS collaboration has reported a di-tau excess with a local significance of 2.6–3.1σ where the invariant mass is $m_{\tau\tau} = 95$–$100\,\mathrm{GeV}$. This excess can be interpreted as a light scalar boson that couples to the third generation fermions, particularly top and τ. Based on the simplest model that can account for the CMS di-tau excess, we evaluate experimental sensitivities to the additional light resonance, using the results reported by the ATLAS collaboration. We see that a search for the top-quark associated production of the SM Higgs boson that decays into $\tau^+\tau^-$ sets a strong model-independent limit. We also find that the CP-even scalar interpretation of the light resonance is excluded by the ATLAS results, while the CP-odd interpretation is not. (Teppei Kitahara)

The magnetic monopole is an important theoretical construct which probes non-perturbative properties or global structures of quantum field theories. It is known that a massless fermion scattering off a Dirac monopole provides a peculiar final state. For example, when the flavor number of the massless Dirac fermion is 1, a non-trivial fermion helicity flip occurs in the scattering. We propose a four-dimensional interpretation of the outgoing state of the scattering of a massless fermion off a Dirac monopole. It has been known that such a state has fractional fermion numbers and is necessarily outside the Fock space on top of ordinary perturbative vacuum, when more than two flavors of charged Dirac fermions are considered. We point out that the Fock space of the fermions depends on the rotor degree of freedom of the monopole and changes by a monopole-fermion s-wave scattering. By uplifting the fermion-rotor system introduced by Polchinski, from two to four dimensions, we argue that the outgoing state can be understood as a state in a different Fock space. (Teppei Kitahara)

The natural SO(10) grand unified theory (GUT) with spontaneous SUSY breaking, which we proposed recently, is a simple SUSY GUT model mainly because it has no hidden sector. The model predicts a long-lived charged lepton, which may be observed in LHC. Unfortunately, it predicts also high scale SUSY in which SUSY breaking scale is around 100-1000 TeV. This is consistent with no SUSY signal at LHC, but unfortunately this destabilizes the weak scale. We have studied a possibility in which the SUSY breaking scale bocomes lower by introducing extra dimension. Interestingly, the extra dimension can avoid very large anomalous U(1) charge which requires some complexity in the model. (Nobuhiro Maekawa).

The discussion of the stability of non-topological strings in $SU(2)\times U(1) -> U(1)$, which was done in the previous year, was extended to the breaking $SU(N)\times U(1) -> SU(N-1)\times U(1)$. This allows us to discuss the stability of non-topological strings generated in more symmetry breaking.(Nobuhiro Maekawa)

Natural grand unified theories have the following problems: 1, it is difficult to reconcile the unification of gauge coupling constants and neutrino masses, and 2, in a scenario in which supersymmetry is spontaneously broken, the sfermion masses become too large to stabilize the electroweak scale. We explored the possibility of solving these problems by not imposing the key assumption of the natural grand unified theory that all terms allowed by the symmetry are introduced with O(1) coefficients, and found a solution that solves the problem 1 and further improves the problem 2. The solution is such that it can be understood naturally by imposing an approximate symmetry. (Nobuhiro Maekawa)

We formulate an extension of Higgs effective field theory which contains arbitrary number of scalar and fermion fields with arbitrary electric and chromoelectric charges. The BSM Higgs sector is described by using the non-linear sigma model in a manner consistent with the spontaneous electroweak symmetry breaking. The chiral order counting rule is arranged consistently with the loop expansion. The leading order Lagrangian is organized in accord with the chiral order counting rule. We use a geometrical language to describe the particle interactions. The parametrization redundancy in the effective Lagrangian is resolved by describing the on-shell scattering amplitudes only with the covariant quantities in the scalar/fermion field space. We introduce a useful coordinate (normal coordinate), which simplifies the computations of the on-shell amplitudes significantly. We show the high energy behaviors of the scattering amplitudes determine the "curvature tensors" in the scalar/fermion field space. The massive spinor-wavefunction formalism is shown to be useful in the computations of on-shell helicity amplitudes. (Masaharu Tanabashi)

A discrepancy between the standard model (SM) prediction and the measured value in the muon anomalous magnetic moment (muon g-2) has been reported. If it is due to the new physics, this could be an important hint for new physics. Since Some of new physics particles such as leptoquarks and extra vector-like leptons can enhance the contribution to the muon g-2, these particles can explain the anomaly of the muon g-2, and hence the studies of these particles in other processes would be important. Since the enhancement on the muon g-2 for these new particles can affect the quantum corrections to the muon mass and the muon Yukawa coupling, we have investigated how large effects on the Higgs decay to muon and anti-muon pair are possible and whether they are visible in the future experiments. (Kazuhiro Tobe)

I worked with Nikolaos Kidonakis to investigate soft gluon corrections to single top quark production processes at LHC. We showed that this approximate evaluation of higher order QCD contributions are important and also quantifiable. I also worked with Enrico Trotti to investigate the interglueball force in the effective field theory of glueball. I also worked with Makoto Oka to investigate the contribution of the CP-odd gluonic Weinberg operator to the CP-odd nuclear force. It is found that this contribution is small compared to the nucleon electric dipole moment generated by the Weinberg operator. I also found that the topological charge of nonabelian gauge theory is unphysical. (Nodoka Yamanaka)

3.1.2 String Theory and Mathematics Group

We investigated the non-stationary difference equation for the conformal block of the deformed Virasoro algebra. The difference eqution, which involves an infinite product, was proposed in 2021 by looking at the Nekrasov partition function with a surface defect. We have shown that this equation can be regarded as a quantization of the discrete Painlevé VI equation, where the Hamiltonian is identified with a translation element in the extended affine Weyl group. We also rewrite the original difference equation as a coupled system for a pair of functions and conjecture that the five dimensinal instanton partition function coming from the affine Laumon space provides solutions to the coupled sysytem. (H. Kanno)

we have investigated the higher dimensional gravitational wave in the setup of AdS/BCFT correspondence. Then, we confirmed that the natural boundary condition for the BCFT is imposed. We also reexamined the area bound for the black holes in inflationary universe. As a consequence, we could have the refined inequality plugged by the contributions from gravitational waves, angular momentum and matters. (T. Shiromizu)

Based on the results obtained last year, we have tried to complete the ongoing projects about higher-group structures in two QFT models, axion-Maxwell system in higher-dimensions and low-energy effective theories of mesons in QCD-like theories. We have succeeded in finding out some new results that have been unknown so far and furthermore giving a clear physical meaning about them. These results have been summarized into two papers, and submitted to JHEP. (T. Sakai)

Surface area in gravitational system is expected to be one of the keys to understand quantum nature of gravity. The upper bound of minimal surfaces was proven to exist, which is called Riemannian Penrose inequality. In 2020, We succeeded in generalizing this area inequality applicable to surfaces existing in weak gravity region in four dimensional spacetimes. This year, we gave a proof for our generalized theorem in the higher dimensional cases. (K. Izumi)

3.1.3 Cosmology and Theoretical Astrophysics Group

In the framework of the Einstein–Gauss-Bonnet gravity coupled with a scalar field, I clarified how we can construct the compact star and gave systematic formalism with G. G. L. Nashed. With him, I also found a problem in the constraint that appeared in the mimetic gravity when we consider the black hole space-time and gave a formalism to avoid this problem. Following the previous years, I also considered the black hole solutions with G. G. L. Nashed in the $F(R)$ gravity with electric and magnetic charges, the ghost-free $F(R, \mathcal{G})$ gravity model which we constructed in the previous year, the Chern-Simons gravity, By using the generalized entropies proposed by us in the previous year, I considered holographic cosmology with S. D. Odintsov and T. Paul. With them, we also considered the cosmology coming from the holographic energy corresponding to the entropies of the apparent horizon. For the generalized entropies, I discussed the consistencies in the black hole solutions with S. D. Odintsov and V. Faraoni. With S. D. Odintsov and V. K. Oikonomou, I investigated how we can solve the problem of the Hubble tension in the framework of the $F(R)$ gravity. With S. D. Odintsov, by investigating the $F(R)$ gravity in two dimensions and we showed the equivalence with the Jackiw-Teitelboim gravity and discussed $\mathrm{AdS}_2/\mathrm{CFT}_1$ correspondence. With S. D. Odintsov, we also considered the anisotropic inflation in the framework of modified gravity. (Nojiri)

We need to remove the foreground radiation from the Milky Way in order to extract information about inflationary gravitational waves from the B-mode patterns of cosmic microwave polarisation anisotropy. In our previous delta-map method for foreground removal, it was difficult to improve sensitivity by increasing the number of observation bands, since the number of observation bands is limited by the number of parameters of the assumed foreground model. In this paper, we extend the previous method in such a way that it can be adapted to an arbitrary number of observation bands. We show that our method can increase the sensitivity to the tensor-to-scalar ratio r without introducing significant bias, using parametric likelihood and realistic foreground and CMB simulations. (Ichiki)

Weak gravitational lensing (WL) is one of the powerful probes of cosmology because of its capability of measuring the matter distributions (including dark matter that makes up more than $\sim 80\%$ of the matte in the Universe) directly. Through WL, we can measure the time evolution of large-scale structure (LSS), which enables us to investigate the nature of cosmic acceleration. Therefore a number of galaxy imaging surveys, such as Suabaru Hyper Suprime-Cam (HSC), Euclid satellite mission, Vera C. Rubin Observatory's LSST, Roman Space telescope, are ongoing and planned. This year, our paper on the first-year cosmology analysis of HSC was published. Specifically, we placed cosmological constraint on σ_8-Ω_m plane (and their combination $S_8 \equiv \sigma_8\sqrt{\Omega_\mathrm{m}/0.3}$) using galaxy-galaxy clustering and lensing, in which we used the BOSS spectroscopic galaxies for clustering and lens objects and HSC photometric galaxies for the sources in the lensing measurements. The results were consistent with the Planck analysis, although other cosmological constraints by cosmic shear prefers smaller values of S_8. Thus we need more statistics to conclude if S_8 measured from LSS is smaller than that from Planck. The results are currently on arXiv, and currently in the process of revision papers according to referee comments. We are now currently focusing on HSC-Y3 cosmology analyses based on the data taken until the semester 2019A (Li et al, 2022). We plan to get these results out this spring. We also published a paper about the first detection of dark matter distributions at $z \sim 4$ galaxies in Physical Review Letters, which is selected to be Editors' Suggestion. This measurement used the HSC data for selecting lens objects and CMB as sources. We issued a press release with University of Tokyo, National Astronomical Observatory of Japan, and Princeton University. Since this measurement of dark matter distributions was around most distant galaxies ever, this study attracted the public, which resulted in appearing more than 15 news papers. (Miyatake)

We have developed a method to measure the photometric redshift of galaxies taken by the imaging observations, based on the machine-learning. It outperforms the traditional template fitting method and can be applied for cosmological analysis. We find that the galaxy redshift distribution infered from our method is well consistent with what estimated by other independent method, a cross-correlation with spec-z (known redshift) sample (Rau et al. submitted). With the great help of the post-doc at Nagoya, we also explore the effect of *blending* of multiple galaxies on the photometric redshift, which will be of great importance in coming deep imaging surveys such as Rubin-LSST, Roman, or Euclid. The methodology will be naturally extended by the image-based analysis in coming years. (A. J. Nishizawa)

We have proposed a three-field inflationary model which is consistent with the current CMB observations by Planck and BICEP/Keck collaborations (Morishita, Takahashi, Yokoyama, 2022). We have developed the phenomenological model in the context of the sneutrinos scenario, and carefully investigated the possibility of successful leptogenesis/baryogenesis with taking active neutrinos masses into account. We found that the tensor-to-scalar ratio is required to be larger than 10^{-4} for the successful model (Takahashi, Yamada, Yokoyama, 2022). As another collaborative work, we have carefully investigated the inspiral spin parameter of the binary black hole system in the case where the binary system consists of the primordial black hole. We found that the typical amplitude of the inspiral spin is in order of 10^{-3} and the correlations between the spin parameter, chirp mass, and mass ratio are not significant (Koga et al., 2022) (Yokoyama).

We presented new bounds on the cosmic abundance of magnetic monopoles based on the survival of primordial magnetic fields in the early universe. The new bounds can be stronger than the conventional Parker bound from galactic magnetic fields, as well as bounds from direct searches. We also applied our bounds to monopoles produced by the primordial magnetic fields themselves through the Schwinger effect, and obtained additional conditions for the survival of the primordial fields. (Kobayashi)

My collaborators and I found that optical clusters are anisotropically distributed, which alters the mass-richness relation as well as boost the lensing signals of the clusters on large scales. Ignoring this effect can bias the cosmological measurements using optical clusters. Therefore, we modeled this anisotorpy of the optical clusters and applied it to the redMaPPer cluster catalog from Sloan Digital Sky Survey (Park et al., 2022). In addition, I developed a method to quantify the boost on the large-scale lensing signals using spectroscopic galaxies (Sunayama 2023). This method enables to give a tight prior on the boost parameters used in cosmological analysis and will potentially improve the constraining power on cosmological parameters. In the fall, I was invited to the Institute of Advanced Study in Princeton to give a talk about my recent work (Sunayama).

We have done the two distinct research works. In the former one, we compute the propagation of gravitational waves in Horndeski theory at which geometrical optics holds. Distinguished from the previous works, we choose the coordinate so that the scalar mode of gravitational waves propagates on its sound cone. This choice allows us to physically understand that the number density of the scalar graviton conserves as long as the scalar field behaves as a perfect fluid. We make it easier to confirm that the conservation of the number density of the scalar graviton breaks if the imperfect fluid part of the scalar-field interactions emerges c.f. Pujolas, Sawicki, and Vikman 2011. In the case of the generalised Brans-Dicke theory, where the scalar field behaves as the perfect fluid in the Einstein frame, we find an effective metric that characterises the sound cone of the scalar mode.

In the latter one, we present a review paper that comprehensively describes cosmological probes of gravity theories ahead the forthcoming observations. The paper consists of the latest knowledge of theoretical studies of modified gravity : the Horndeski and DHOST family, massive gravity/bigravity, metric-affine gravity, and cuscuton/minimally-modified gravity and major observables of CMB and LSS. We provide an outlook of modified gravity at latest in terms of physical motivations, validity, appealing features, the level of maturity, and calculability. We conclude in the outlook that the Horndeski theory is one of the most well-developed theory to be tested. Related to this review paper, we have held a symposium in the autumn JPS meeting on testing gravity on cosmological scales (Arai).

3.1.4 Computational Theoretical Physics Laboratory

Hydrodynamic simulation: The hydrodynamic model is the most successful model for description of quark-gluon plasma (QGP) in the relativistic heavy-ion collisions. The viscous property of QGP is one of the key aspects of the strongly interacting QGP (sQGP). In 2020, we apply our hydrodynamics codes to analyses of small systems as well as large systems at RHIC and the LHC. Also, we investigate possibility of existence of the QCD critical point which is the end point of the QCD phase boundary, analyzing the Beam Energy Scan experiment at RHIC. Furthermore, we analyze mixed harmonic cumulants in heavy-ion collisions at the LHC. We find that the observables have sensitivity to temperature dependence of shear and bulk viscosities of QGP.

Cold and Dense QCD: Understanding of the QCD phase diagram is one of the most important subjects in hadron and nuclear physics. In particular, investigation of possible phases in low temperature and high density region is the center of attention, after success of detailed measurement of radius and mass of neutron stars. Here we approach the issues from point of view of QCD effective theories which are not exact QCD but contain feature of QCD: one is the Gross Neveu Model and the other one is two color QCD. Also, we investigate the magnetic effect on color superconductivity phase, using the NJL model. (Chiho Nonaka)

Cosmological Simulation: The tomography of the polarized Sunyaev-Zeldvich effect due to free electrons of galaxy clusters can be used to constrain the nature of dark energy because CMB quadrupoles at different redshifts as the polarization source are sensitive to the integrated Sachs-Wolfe effect. Here we show that the low multipoles of the temperature and E-mode polarization anisotropies from the all-sky CMB can improve the constraint further through the correlation between them and the CMB quadrupoles viewed from the galaxy clusters. Using a Monte-Carlo simulation made possible by KMI's cluster computer, we find that low multipoles of the temperature and E-mode polarization anisotropies potentially improve the constraint on the equation of state of dark energy parameter by ~ 17 percent. (Kiyotomo Ichiki)

3.2 Division of Experimental Studies

3.2.1 Flavor Physics Group

• B and tau physics at Belle and Belle II

The SuperKEKB/Belle II experiment has started physics data taking with all sub-detector components installed since March 2019. Within this fiscal year, the SuperKEKB accelerator achieved the world highest peak luminosity, 4.7×10^{34} cm^{-2}s^{-1}, about two times higher than the KEKB peak luminosity record. The SuperKEKB/Belle II experiment is entering the Long Shutdown 1 (LS1) period from June of 2022. Belle II experiment has accumulated 424 fb^{-1} data until LS1, which is comparable with the full data size of BaBar experiment. We are working on several analyses by using these data.

One of the biggest challenge in the Tau-Lepton Physics Group is to find evidence of New Physics beyond the Standard Model (SM). There is a hint in existing data collected by the B-factory experiments Belle and BaBar, and also by the LHCb experiment at CERN. These three experiments have reported a deviation from SM prediction on $R(D^{(*)})$, which is the ratio of branching fraction of the semileptonic decay of the B meson into the final state with the τ lepton, $B \to D^{(*)}\tau\nu$, over to those with the muon or the electron, $B \to D^{(*)}\ell\nu(\ell = e, \mu)$. While the weak interaction in the SM does not distinguish the three leptons, this "lepton flavor universality" may be violated in NP models, such as the charged Higgs and the lepto-quark model. Members from Flavor Physics Group at Nagoya University have contributed to the $R(D^{(*)})$ measurements at Belle experiment in the past years. We also started the first $R(D^{(*)})$ measurement with 189 fb^{-1} at Belle II experiment, the result plan to be released by the end of spring 2023. Although the error will still be large and dominated by the statistical uncertainty, the result could provide a fully independent cross check of the $R(D^{(*)})$ anomaly by a new experiment. In addition to the measurement of $R(D^{(*)})$, we also try to measure the branching fraction of tauonic B decay as $B \to \tau\nu$ with the data recorded until LS1. This decay model is considered to have a strong correlation with the new physics involved in $R(D^{(*)})$ anomaly.

The SupperKEKB/Belle II experiment provides unique opportunities for critical test of SM and search for New Physics with variety of channels in B and τ decays. In the Flavor Physics Group at Nagoya University, we are working not only the $B \to D^{*}\tau\nu$ decays, but also the measurement of time-dependent CP violation in rare B decay of $B^{\pm} \to \rho^{\pm}\rho^{0}$. As a intermediate milestone for this measurement, we have measured the branching fraction of $B^{\pm} \to \rho^{\pm}\rho^{0}$ with 189 fb^{-1} data. We are now extending this analysis to measure time-dependent CP violation, $\phi_2(\beta)$ of Unitary Triangle.

We are also working on the measurement of the $e^+e^- \to \pi^+\pi^-\pi^0\gamma$ cross section using initial state radiation. The precise result of the e^+e^- cross section will be crucial input to estimate the hadron vacuum polarization effects, and thus to improve the SM prediction of the anomalous magnetic moment of the muon, so called muon "g-2". In particular, the result recently reported by the Fermilab g-2 experiment has confirmed the deviation reported earlier by the Brookhaven experiment, and the combined result has about 4.2σ deviation from the SM value. On the other hand, some discrepancy exist between the results of the e^+e^- cross section measurements in the past by the BaBar and KLOE experiments. Therefore, the result from the Belle II experiment will provide very important input for verification.

We are also performing several analyses at Belle experiment. Charged-lepton-flavor-violation is predicted in several new physics scenarios. We update the analysis of τ lepton decays into a light charged lepton ($\ell = e, \mu$) and a vector meson ($V^0 = \rho^0, \phi, \omega, K^{*0} or \bar{K}^{*0}$), $\tau \to \ell V^0$ using 980 fb^{-1}. Figure 3.2.1 shows signal and background after box open of signal region. No significant excess of such signal events is observed, and thus 90% credibility level upper limits are set on the $\tau \to \ell V^0$ branching fractions. It improved by 30% on average from the previous results.

We also did a analysis to measure the Electric Dipole Moment (EDM) of τ lepton (d_τ) using 833

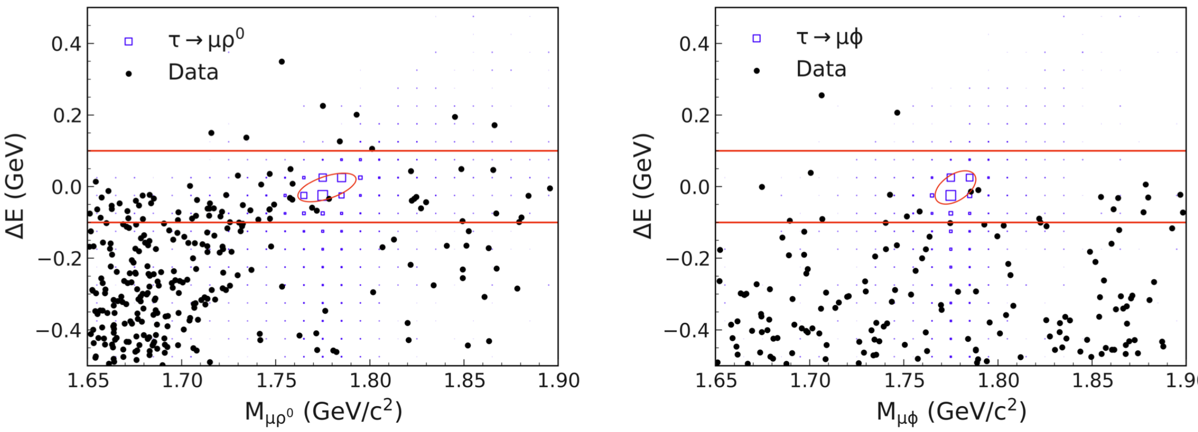


Figure 3.1: Observed event distributions of M_{lV^0} vs. ΔE after $\tau \to \mu V^0$ event selection. Black points are the data, blue squares show the signal MC distribution with an arbitrary normalization. The red ellipse line is the signal region. The estimation of the number of background events is done using the data between the red horizontal lines except the blind region.

fb^{-1} Belle data. The EDM of τ lepton is a fundational parameter that parameterizes time-reversal or charge-conjugation-parity violation at the $\gamma\tau\tau$ vertex. Base on the predication of SM the EDM of τ lepton is an unobservably small value (order of 10^{-37} $e$cm), hence, observation of a nonzero τ-lepton EDM would be a clear sign of new physics. The measurement obtain the real and imaginary parts of d_τ as Re(d_τ) = (-0.62 ± 0.63) × 10^{-17} $e$cm and Im(d_τ) = (-0.40 ± 0.32) × 10^{-17} $e$cm, published at JHEP04(2022)110. The result shows consistent with null τ-lepton EDM at the present level of experimental sensitivity and improve the sensitivity by about a factor of three.

Apart from the New Physics search, heavy flavor hadron physics is also the area we are intensively working. B-factory experiments have observed a large number of charmonium-like states in the B meson decay and opened a new era in the field of hadron spectroscopy. In particular, we measured the properties of candidate of exotic states of $c\bar{c}$-meson spectrum, so called $X(3872)$. It has been discovered in the decay of $B \to J/\psi\pi^+\pi^-$ at Belle experiment. The lineshape was studied by using Breit-Wigner model. It is possible that $X(3872)$ include DD^* component. To understand the nature of $X(3872)$, we measrued total width of $X(3872)$ as well as the lineshape in the $X(3872) \to DD^*$ decays by using Belle data. We improved the measurement of mass and width of Breit-Wigner lineshape, and also determine parameters of Flatte lineshape as that with multiple decay channels. The result is now going to submit to the journal.

- **ATLAS**

KMI achievements in 2022 at the energy-frontier LHC-ATLAS experiment

Our scientific goals are (a) to reveal the structure of vacuum and the origin of the mass of particles through the measurements of the Higgs-boson properties and (b) to discover new phenomena arising from physics beyond the Standard Model (SM) such as supersymmetry (SUSY). In 2022, several analyses based on the full Run 2 (2015–2018) data samples were completed: measurements of the Higgs coupling to gauge bosons and fermions, search for Higgs-pair (di-Higgs) production, and search for long-lived particles (LLP) included in R-parity-violating SUSY models. The dataset includes 140 fb^{-1} of proton-proton collisions at a centre-of-mass energy of $\sqrt{s}$ = 13 TeV. The Higgs coupling measurements are consistent with the SM, indicating that the particle masses arise from the Higgs mechanism.

No significant signals were found in the searches, and stringent limits were set on the cross sections. On 5th July, we successfully started next run, called Run 3, with a higher centre-of-mass energy of $\sqrt{s}$ = 13.6 TeV. We operated the muon trigger system with high efficiency, and accumulated data sample of 38 fb^{-1} by the end of the year. In parallel, we have been developing advanced technologies for the muon trigger system to be used at the High-Luminosity LHC (HL-LHC) planned to be started in 2029. The system determines which physics events are retained for offline data analyses, and is of fundamental importance to the ATLAS physics program.

Physics achievements

(1) Measurements of Higgs coupling to gauge bosons and fermions

Since the Higgs boson discovery in 2012, more than 30 times as many Higgs bosons have been recorded by the ATLAS experiment, enabling much more precise measurements and new tests of the SM. The Higgs coupling to gauge bosons and fermions were extracted from the measurements of the cross section times the branching ratio for various Higgs boson production and decay modes based on the Run 2 full dataset (Figure 3.2(a)). We took a leading role in the search for the Higgs boson decay to two muons. The result constituted an essential ingredient in the Higgs coupling measurements. The measured Higgs coupling to muons relative to the SM prediction is $\kappa_\mu = 1.06^{+0.25}_{-0.30}$. The consistency between the measured κ_μ and the unity indicates that the muon mass arises from the Higgs field as predicted in the SM. The results were presented at a symposium of tenth anniversary for the Higgs boson discovery, and published in Nature 607, 52–59, in Jul. 2022.

(2) Search for di-Higgs production

Based on the method of our search for resonant di-Higgs production in the $b\bar{b}b\bar{b}$ final state, published in Phys. Rev. D 105, 092002, May 2022, we established a new search on nonresonant di-Higgs production, which is sensitive to the self-coupling of the Higgs boson. The analysis utilises the full Run 2 dataset and targets both the gluon–gluon fusion and vector-boson fusion (VBF) production modes. No evidence of the signal is found and the observed (expected) upper limit on the cross-section for nonresonant di-Higgs production is determined to be 5.4 (8.1) times the SM prediction at 95% confidence level. Constraints are placed on modifiers to the HHH and $HHVV$ couplings. The observed (expected) 2σ constraints on the HHH coupling modifier, κ_λ, are determined to be $[-3.5,\ 11.3]$ ($[-5.4,\ 11.4]$) (Figure 3.2(b)), while the corresponding constraints for the $HHVV$ coupling modifier, κ_{2V}, are $[-0.0,\ 2.1]$ ($[-0.1,\ 2.1]$). In addition, constraints on relevant coefficients are derived in the context of the effective field theory (EFT). We submitted a paper draft to Phys. Rev. D in Jan. 2023 (arXiv:2301.03212).

(3) Search for LLP production

No new physics phenomena were observed yet with focus on prompt decays, and new weakly-interacting particles can have long lifetimes. We searched for LLP decaying into hadrons using events that contain multiple energetic jets and a displaced vertex in the full Run 2 dataset. The search employs dedicated reconstruction techniques that significantly increase the sensitivity to LLP decaying in the ATLAS inner detector. We established a data-driven method of background estimation for SM processes and instrumental effects. The observed event yields are compatible with those expected from background processes. The results are used to set limits at 95% confidence level on model-independent cross sections for processes beyond the SM, and on scenarios with pair production of SUSY particles with long-lived electroweakinos that decay via a small R-parity-violating coupling (Figure 3.2(c)). We submitted a paper draft to JHEP in Feb. 2023 (arXiv:2301.13866).

(4) Uncertainty estimation for top-quark mass measurement using J/ψ

The Nagoya group has been focusing on top-quark physics historically since the LHC start and made various results with Run 1 dataset. A precise measurement of the top-quark mass has been becoming important with even higher statistics, in order to understand the stability of vacuum. We are working on the top-mass measurement using a J/ψ meson. This channel can suppress the large uncertainty from jet energy measurement, which has been one of the largest uncertainties in some high-statistics channels. We confirmed that the uncertainty due to jet energy measurement is less than 0.1 GeV, which will be presented in Japanese Physical Society meeting in Mar. 2023. Dominant systematic uncertainty arises from the modeling of final state radiation, and we are working on an improved analysis method to suppress the uncertainty.

(5) Background separation for STXS measurement of the VBF Higgs production

Simplified Template Cross Sections (STXS) have been adopted by the LHC experiments as a common framework for Higgs measurements. Their purpose is to reduce the theoretical uncertainties that are directly folded into the measurements as much as possible, while at the same time allowing for the combination of the measurements between different decay channels as well as between experiments. In 2022, we launched a new analysis on the STXS for the VBF Higgs production. We reconstruct Higgs boson candidates using the Higgs boson decay to tau leptons. The main background is the Z boson decay to tau leptons, and we are currently optimising the method of the separation using the Boosted Decision Tree. We aim to test the SM and EFT using the results on STXS.

Trigger achievements

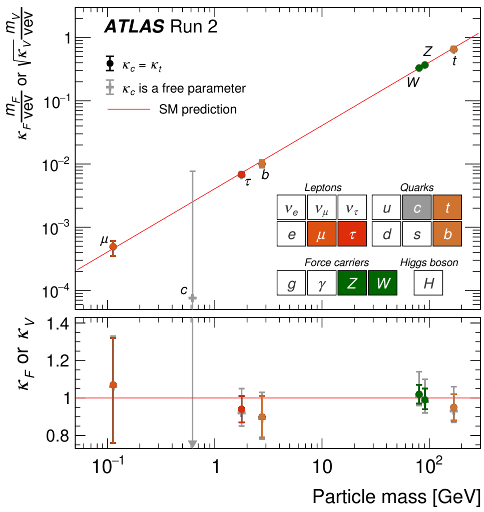
(1) Operation

KMI keeps playing a main role in the operation and the maintenance of the muon trigger system with the thin gap chambers (TGC), which cover the pseudorapidity range $1.05 < |\eta| < 2.4$. Nagoya PhD students played an important role for highly efficient and continuous operation of TGC by taking 24-hour TGC oncall shifts about 50 days in 2022. We also continue our efforts at the calibration and the alignment of TGC, which are essential for the collection of high quality data using muon trigger. This year, we analysed early Run 3 data and measured the TGC position relative to monitored drift tube chambers used for precision muon tracking. We found no significant TGC position difference from Run 2.

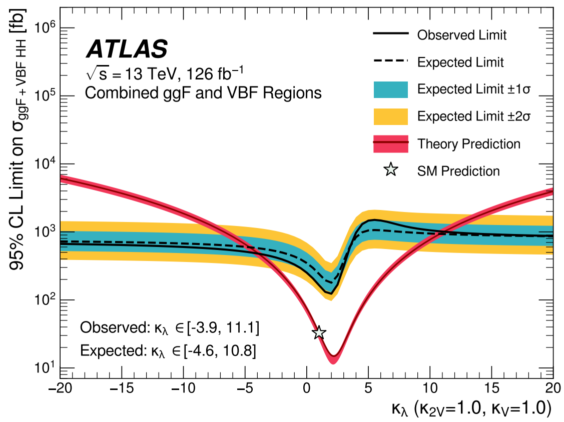
(2) Phase-II upgrade

HL-LHC starting from 2029 is planned to increase the luminosity by a factor of about 10 compared to the current LHC for more precise measurements of the Higgs boson properties and more sensitive searches for the physics beyond the SM. The trigger and data acquisition system of the ATLAS experiment is being upgraded to cope with the higher radiation levels, the higher detector occupancy, and the higher data rate at HL-LHC (called Phase-II upgrade). This year, we promoted gamma and neutron irradiation tests for the electronics chips to be used for the TGC frontend boards, and confirmed that they have sufficient tolerance. Thanks to the confirmation of the radiation tolerance, we could start the mass production of the TGC frontend boards. The first three boards were delivered in late 2022 (Figure 3.2(d)) and the quality was fine. In total ~ 1600 boards will be produced, and we are preparing an automatic system of the quality check for the produced boards.

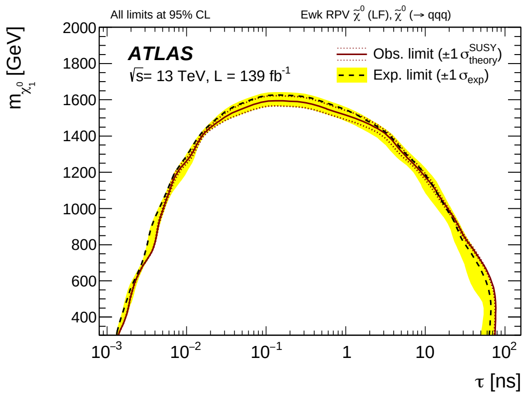
The backend board shall implement huge amount of optical links (around 200) and high-end FPGA (XCVU13P), and the design requires significant efforts. We received the first prototype board in late 2021, and intensively tested the performance. We found only minor problems for the power up/down sequencing and clock distribution, which will be fixed for the second prototype to be produced in 2023. We developed the track reconstruction and selection firmware, and confirmed that it works on high-pileup dataset provided by an overlay of the events taken with unbiased trigger.



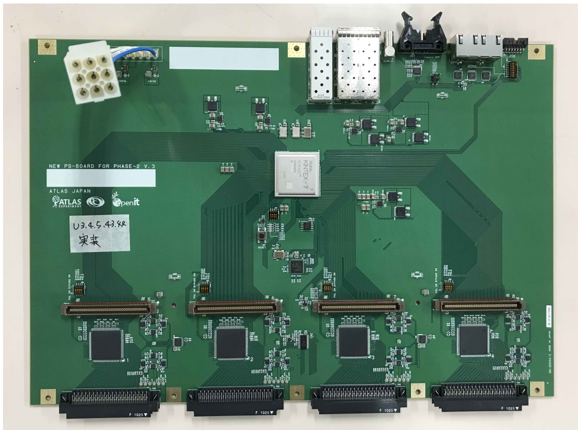
(a)



(b)



(c)



(d)

Figure 3.2: (a) Reduced Higgs boson coupling strength modifiers and their uncertainties. They are defined as $\kappa_F m_F$ over the vacuum expectation value for fermions ($F = t,\ b,\ \tau,\ \mu$) and $\sqrt{\kappa_V} m_V$ over the vacuum expectation value for vector bosons ($V = W,\ Z$), where κ_F and κ_V are the Higgs coupling with respect to the SM prediction and m_F and m_V are the masses of the fermions and vector bosons. (b) Observed and expected 95% confidence level upper limits on the production cross-section for nonresonant di-Higgs production as a function of the coupling modifier κ_λ. (c) Exclusion limits at 95% confidence level on the lifetime and mass of the $\tilde{\chi}^0_1$ in electroweakino pair production models. The area below the solid line is the excluded parameter space. (d) The TGC frontend board from mass production for the HL-LHC.

• Fundamental Astroparticle Physics

T-violation in resonance reactions, neutron lifetime, medium range interactions

The enhancement of the violation of time-reversal symmetry is predicted in the neutron capture reaction for some nuclei. The enhancement depends on the resonance parameters and spin states of the nuclei. We successfully estimated the enhancement factor for ^{139}La as a target candidate at the order of 10^6 by measuring angular correlation terms of (n, γ) reaction. We are continuing to take the data for ^{115}In, ^{117}Sn, ^{131}Xe, and so on, by using germanium detectors in ANNRI neutron beam line in Material and Life Science Experimental Facility (MLF) at J-PARC. The enhancement of the symmetry violation is related to the treatment of compound nuclei. The detailed analysis of compound states can be discussed by using polarized neutrons. We measured the angular correlation terms of ($\vec{n}$, γ) reaction by using high-performance ^{3}He neutron spin filter on the beamline. We have also install the polarimeter of γ ray into the beamline to measure the other correlation terms. In addition, we tried to measure the correlation between the polarized neutron and the polarized nuclei. The brute-force nuclear polarization technique was applied to the metal lanthanum to measure the asymmetry of the capture reaction between neutron spin directions. This was a demonstration of whole setup of the T-violation search experiment.

For the T-violation search experiment, the polarized nuclear target has to be prepared. A $LaAlO_3$ single crystal, which has the perovskite structure, is a candidate for the polarized target. The collaborative study started to fabricate the large scale of the crystal with Tohoku University. Dynamical nuclear polarization (DNP) system are developing with Hiroshima University, Osaka University and Yamagata University. The enhanced polarization of ^{139}La nuclei was demonstrated by the DNP method with the $LaAlO_3$ single crystal fabricated by ourselves.

These results showed the feasibility of the T-violation search experiment with high sensitivity, which is comparable to that of neutron EDM and which has different systematics. We are continuing detailed design of the T-violation search experiment in the international collaboration 'NOPTREX'.

The recent values of neutron lifetime deviate far beyond the systematic errors claimed in the past and sometimes can be a trigger of discussion of new physics. We published the first result of neutron lifetime measurement by using pulsed neutron beam at NOP beamline in J-PARC. The time projection chamber (TPC) detects both of the electrons from neutron beta decay and the nuclear reaction by ^{3}He in order to estimate the flux simultaneously. The measured value was 898^{+18}_{-20} s, which still has a large uncertainties. To improve the statistics the upstream beam optics has been upgraded. By using high flux neutron beam, large amounts of data are being accumulated. We have also taken various data to survey the origin of the systematic uncertainties by using the improved statistics.

The cold-neutron interferometer with pulsed neutrons was constructed on NOP beamline. The interferometer system is being maintained for stable operation. Nuclear emulsion as a neutron detector with high position resolution were developed with the emulsion group in Nagoya University. It will be applied to various experiments including a study of gravity. Neutron small angle scattering with nanoparticles can be used for search for unknown interactions in the medium range.

Understanding Cosmic-Ray Air Shower using Accelerator

The Large Hadron Collider forward (LHCf) experiment measures neutral particles emitted in the very forward angle region of hadron-hadron collisions at LHC. A similar version of the experiment RHICf has been done at RHIC with polarized proton-proton collisions at 510 GeV. Knowledge of the forward particle production is expected to improve the hadronic interaction models used in the interpretation of cosmic-ray air shower observations. In September 2022 LHCf have performed an operation with $\sqrt{s}$ = 13.6 TeV proton-proton collisions. The main target of this operation is to increase the statistics of rare events like high energy π^0s and η. Thanks to the upgraded data-taking system, 300 millions events was obtained in total, which was factor 5 more than the data obtained in 2015. A joint operation with ATLAS was performed in the operation as well as the past operations. It was a first time to have joint data taking with ATLAS ZDC and RPs detectors, which can allow us to extend the physics cases like diffractive event measurements and the one-pion-exchange measurement. The number of common events with ATLAS was dramatically improved to approximately 300 M from 6 M in 2015 operation. In October, a beam test at CERN-SPS was performed also to make a precise energy calibration of the detectors.

Dark Matter and Neutrino Experiments at Kamioka Mine

Super-Kamiokande (SK) is the 50-kton water Cherenkov detector underground of the Kamioka Observatory dedicated to the observation of neutrinos and possible proton decay. SK has prepared for the observation of supernova relic neutrinos emitted by all of the supernova explosions by adding gadolinium (Gd) to the pure water in the detector. Despite the difficult COVID-19 situation, followed by the first 0.01 % Gadolinium loading in 2020 summer, an additional 0.02 % Gadolinium was successfully introduced in the summer of 2022. Again no major impact on detector performance has been observed. A new Honda neutrino flux model has been developed with hadron production models tuned with the existing accelerator data. We have successfully produced the initial results, which were compared with the new Bartol neutrino flux model. It was discussed in the dedicated annual workshop for atmospheric neutrino productions, WANP2023. Construction of Hyper-Kamiokande (HK) is on going successfully. construction. In 2022, the access tunnel to the main cavern has been completed, and excavation of the main cavity has started. The Nagoya group intensively contribute to the study of the performance of 136 new 20" B&L PMTs installed in the Super-K tank since 2018. This is the first massive long-term test in the water. We confirmed the new Hyper-K PMTs successfully work as we expected from the study done in the air past. We concluded the final data analysis of XMASS experiment for a WIMP search with a full data set of 1590.9 days. We also published on searching for neutrinoless quadruple beta decays. At the end of 2022, the collaboration completed its activity.

Dark Matter and Neutrino Experiments at Laboratori Nazionali del Gran Sasso (LNGS)

The XENONnT experiment, the latest detector of the XENON dark matter program, was constructed to look for elusive dark matter particles. The detector holds almost 6 tonnes of ultrapure liquid xenon as a target medium. The XENON experiment aims at detecting tiny amount of charge and light produced after the interaction of a dark matter particle with a xenon nucleus. The detector is installed inside a water Cherenkov active muon and neutron veto. Despite the pandemic situation, XENONnT was successfully constructed and commissioned from spring 2020 to spring 2021. Afterwards, the XENONnT experiment took the first science data over 97.1 days, from July 6 to November 10, 2021.

In 2020, the XENON collaboration announced the observation of an excess of electronic recoil events in the XENON1T experiment, which is consistent with solar axions, neutrinos with an anomalous magnetic moment, axion-like particles, or hypothetical dark sector particles might induce so-called "electronic recoil" signals. We have analyzed the obtained science data, and then released the first results from its new and more sensitive experiment, XENONnT, with ~ 20 % of the electronic recoil background of its predecessor, XENON1T. The absence of an excess in the new data suggests that the origin of the XENON1T excess was most likely due to trace amounts of tritium in the liquid xenon, radioisotope of hydrogen and one of the hypotheses considered at the time. In consequence, this leads to very strong limits on new physics scenarios originally invoked to explain an excess. The data will be further analyzed to search for weakly interacting massive particles (WIMPs) and also low-energy interaction of solar pp neutrino.

We are also conducting various R&D works for the future DARWIN project, an experiment with 40-ton double-phase xenon Time Projection Chamber (TPC). With its great sensitivity to rare WIMP-nucleus interaction, the DARWIN experiment has to improve background rates achieved by the currently leading experiments such as XENONnT. One of the important background especially for low mass dark matter searches is ionization-only (so-called S2-only) background. One of the origins of such S2-only backgrounds is due to the photoelectric effect of scintillation light on electrode materials. We have built a dedicated setup to measure quantum efficiency (QE) of electrode materials in liquid xenon using a dedicated VUV light system. We found that additional thin layer such MgF2 will help to reduce QE of electrode materials by a factor of ~ 10.

Search for dark matter and research on the origin of cosmic rays with gamma-ray observations

Cosmic gamma rays are produced through interactions of dark matter, CRs, and the interstellar medium. Therefore, gamma rays are useful probes to search for dark matter and investigate the properties and distribution of CRs and the interstellar medium.

We are developing a next-generation gamma-ray observatory, CTA, to observe cosmic gamma rays in an energy range from well below 100 GeV to above 100 TeV. We oversee the development, procurement, and calibration of silicon photomultipliers (SiPMs) for small-sized telescopes (SSTs) in CTA. In the design finalization stage of the SST camera, we selected 50 μm cell size over 75 μm mainly due to lower power consumption. Although 75 μm cell provides 10% better photon detection efficiency, it also has higher gain (thus, higher current, power, and optical crosstalk) by a factor of two. The heat produced in SiPMs is conducted by the heatsink attached to the backside of the SiPM module by heat-conductive adhesive. We selected a heat-conductive ($\sim$1 W/m/K) substrate for the SiPM module. After finalizing the SST camera design, we initiated procurement of components for the engineering camera which is considered to be the first camera of 42 cameras planned for CTA. (The first camera is planned to be assembled in 2023.) The nominal lead time for the SiPM module production is 6 to 8 months. However, due to the tight supply of the heat-conductive substrate, the lead time was extended to 15 months. In the meantime, we prepared a test setup and procedure to measure infant mortality rate and lifetime. In this test, we perform accelerated tests with high current under high temperature and high humidity conditions.

Directional Dark Matter Search

Direction sensitive search is a new promising methodology for direct dark matter detection and its identification. However, expected nuclear recoils scattered by WIMPs like dark matter and target nuclei recoils in the detector being low-energy of 10-100 keV scale because of lowness of the dark matter velocity. The expected track length in the solid (or liquid) detector is less than 1 μm, therefore development of technologies to obtain tracking information in such a short distance is the unique key of the project.

NEWSdm (Nuclear Emulsion WIMPs Search directional measurement) experiment has been operated by the international collaboration consisting of 12 institutes, 5 countries. Current main experimental site is the National Laboratory of Gran Sasso (LNGS), Italy, and R&D and data analysis sites are KMI, Nagoya University, Toho University and Napoli university. This project utilize originally developed the Nano Imaging Tracker (NIT) which is super-high resolution tracking device based on nuclear emulsion with 10 nm scale resolution and also, new readout systems to obtain nano-scale direction information continue to develop in KMI and Italian group, those systems are very unique in this experiment. NIT has a good signal noise ratio, especially electron background rejection power

(10^{-3} or even better).

The scanning speed increases year by year and 60g/year/machine in spring and with effort for change to wide field camera, currently achieved 440g/year/machine by autumn 2022, The effort of scanning speed up will be continued to the target value around several kg/year/machine. NEWSdm facility in LNGS, underground site, Hall-F have been constructed. In the site , a new emulsion gel production machine which was installed at the end of 2018, started production of NIT devices under clean condition at deep underground from 2019. Pouring NIT emulsion films and development of them were also at the underground site. So all processes other than film scanning and analysis are performed underground where background caused by cosmic rays is significantly less than on the surface lab.

We started demonstrations for data analysis and scanning data using 1 g scale target mass in 2019. This year, a series of test runs with 2 NIT plates (target NIT mass$\sim$ 4g) changing exposure time as 0.2-0.3 day, 2 weeks, 4 weeks to see signal increase by exposure time. At the exposure time, the NIT devices were at the condition of -30 degree temperature and surrounded by thick polyethylene bloke shields. By doing several runs with the same condition at 0.2-0.3 days of exposure, the detected number of signal-like candidates fluctuated and the amount was larger than expected. Now we are investigating to understand this issue. One simple problem which we already supposed is the need to reduce storing the background gamma or neutrons during NIT film development or NIT setting up time into a shield at the exposure site. The shield during development or detector construction will be set after fixing the design of shield and test experiment in near future. In 2021, a measurement of environmental neutrons at the LNGS surface lab was performed with 28 days exposure time. The analysis was summarized and we reported the status at the JPS meeting in March 2022, and the preliminary result in September 2022.

Nuclear Emulsion Technologies

Nagoya University is almost the only university/public research institute capable of research, development and manufacturing of nuclear emulsions. In recent years, the use of emulsion films has expanded beyond elementary particle physics to include various imaging fields, and the demand for them is growing on the order of 1000m^2. Currently, a large gel production machine is in operation, 20kg of emulsion gel can be produced a day. This corresponds to approximately 10 m^2 emulsion films. An upgrade of the emulsion gel/film facility operating at Nagoya University is underway to promote further research activities. For example, in order to achieve both film production capacity and gel production capacity, we have developed a roll-to-roll automatic coating machine. This machine can pull the base film directly from the roll, pour the emulsion gel on the surface, dry it continuously, and finally wind the film onto another roll. Automation has made it possible to produce films of sufficient thickness and uniformity in a short period of time. This machine was used to produce films for the FASER and GRAINE projects.

Also our emulsion scannig facility is assuming role of the center of nuclear emulsion analysis for particle physics ,muon radiography and other applications. The HTS1 is working for these applications and is the world fastest emulsion scanning system. The 2nd generation system, HTS2, is under commisioning and the new nuclear emulsion has been developing. The new gel has lager AgBr crystals and optimized for HTS2 optics. In order to get the further scannig throughput and covinience for other institutes and groups, also the third generation of scanning system has been developping.

The developement of PTS, which is focused to read-out for fine graine emulsion "NIT", is on going for the directional dark matter search, NEWSdm. In last year, we reported that a novel ellipse analysis with the 2nd order moment method has been implemented, thereby causing carbon ion tracks down to kinetic energy of 30 keV to be detected. The recent upgrade of PTS has been achieved 4 times of throughtput as last year version. That is corresponding over 400g per year of the capability of analysis speed. A new new objective and imager was equipped which had 8 time field of view, and develope new method of correcting aberration of optics. At present, the further tuning of algorithm is ongonging. The next upgrade will increase the effective frame rate by equipping multiple image sensors, enabling kg-scale experiments with a few number of PTS systems.

Balloon Experiment for Gamma-rays Astronomy using Nuclear Emulsion Technology

Observation of cosmic gamma rays is important in understanding high-energy phenomena in the universe. Since 2008, the Fermi Gamma-ray Space Telescope has surveyed the sub-GeV/GeV gamma-ray sky and provided a large amount of data. However, observation remains difficult owing to the lack of angular resolution, and new issues have arisen.

We started up a precise gamma-ray observation project, Gamma-Ray Astro-Imager with Nuclear Emulsion (GRAINE), using balloon-borne emulsion gamma-ray telescopes to enable high angular resolution, polarization-sensitive, and large-aperture observations in the 0.01–100 GeV energy region. In the last balloon experiment (GRAINE 2018), which was performed in April 2018, we succeeded in the first detection of a celestial gamma-ray object, Vela pulsar, via the balloon-borne emulsion telescope. The expanse of the gamma-ray image in the 100-MeV region is $\sim 0.4^\circ$, which is the expected performance of our telescope, and the world's highest angular resolution was demonstrated.

We start the scientific observation phase by enlarging the aperture area, extending the flight duration, and repeating balloon flights. The next balloon experiment (GRAINE 2023) is approved by JAXA and scheduled in March 2023 (The original schedule was in 2021, but postponed due to covid 19). The experiment aims at the observation of Vela pulsar, Geminga pulsar, the galactic center, etc. in the GeV energy region, and the survey of transient phenomena by the largest aperture area telescope.

Since June 2022, we conducted nuclear emulsion production using new facilities in Nagoya University at full-capacity operation for the first time, and completed 600 m^2 of Nagoya-made emulsion films for the next experiment. We have also developed a 6-m long large pressurized vessel gondola, which mounts 2.5-m^2-aperture-area emulsion telescopes (6.6 times larger than that of GRAINE 2018) and attitude monitors, via various performance and environmental tests. All equipment and films were shipped to Alice Springs, Australia at the end of 2022 and the beginning of 2023. The GRAINE team will start final preparations for the experiment at the launching site in February 2023.

Study for Neutrino Physics using Nuclear Emulsion

Tau neutrino is the one of the least known standard model particles. It is due to large uncertainty of its production and difficulties in detection and identification. So far tau neutrino-nucleon interaction cross section has a large error of several tens % and we, **DsTau, SHiP**, are aiming to measure it within10% accuracy. And we also study tau neutrino production at the forward direction from the LHC collision point by **FASER**ν.

DsTau experiment aims to study the tau neutrino production with CERN SPS 400 GeV proton on tungsten and molybdenum target. DsTau will provide accurate tau neutrino flux information for future experiments like SHiP measuring tau neutrino cross section with high statistics by performing a detailed analysis of the differential production cross-section of $Ds \to \tau + \nu_\tau$ and the $\tau \to X + \nu_\tau$. Nuclear emulsion trackers used in DsTau can identify $Ds \to \tau + \nu_\tau$ cascade decay, thanks to the sub-micrometric position resolution of emulsion, average 7 mrad angle difference between Ds and tau in few mm distance can be detected. The uncertainty of tau neutrino production flux will be reduced below 10% using 1000 detected such a cascade decays from 2.4×10^8 proton -tungsten interaction. After the success of 2018 pilot run data taking and analysing status, the DsTau is formally approved as **CERN NA65**. The physics run started from 2021 and 17 (12 tungsten, 5 molybdenum) Emulsion Cloud Chamber (ECC) modules were exposed to 10^5 protons/cm^2 beams. The 2021 run developed emulsion films are under scanning and analysing. Together with the 2021 run data analysis, we produced a total surface of 110 m^2 emulsion films and sent them to CERN for the 2022 run. In the middle of

October 2022 we performed the 2022 run, again 17 (9 tungsten and 8 molybdenum) ECC modules were exposed to proton beams with the same track density as the 2021 run. The developed 2022 run films have just arrived at Nagoya University for the analysis.

SHiP experiment is planning to expose tau neutrinos from 2031 or later. Currently we are polishing the design of the beam dump facility and detector components to get the approball. We are doing performance tests for tau decay daughter track's change and momentum measurements. Thanks to sub-micrometric resolution of nuclear emulsion, a compact spectrometer length of 3 cm can determine charged track's charge for momentum $\leq$ 7 GeV/c. The compact emulsion spectrometer (CES) has emulsion films as a tracking device with low density 1.5cm spacers. The CES performance tests have been conducted with several base materials. As a result the glass base or solid thicker base (COP) make the distortion of emulsion plates smaller and then produce better performance on momentum resolution.

FASERν is a new project taking data in 2021-2024 and later aiming to study high energy neutrinos from the ATLAS collision point at 480m away in forward direction. 1.1 tons of neutrino ECC detector using 1mm thick tungsten plates as neutrino interacting target interleaved with nuclear emulsion films will be mounted in the TI12 tunnel. By analysing a sub-sample (target mass of 11kg, luminosity of 12.2fb^{-}1) of 2018 pilot run data by two small 15kg ECCs, the first observation of neutrinos from LHC were reported in **Phys.Rev.D 104, L091101(2021)** . A total of about 140 m^2 emulsion films produced at Nagoya university were sent to CERN by 3 bunches of shipment and constructed 3 neutrino detectors. We installed them one by one in front of the FASER detector. Films of all 3 modules are developed and sent back to Nagoya university and currently we are analyzing 1st and 2nd modules and will scan the films of 3rd module soon.

The NINJA experiment at J-PARC and related activities

Currently study of Sub-Multi GeV neutrinos is one of most important subject in the field of particle physics because almost long baseline neutrino oscillation experiments which search for the CP violation in the lepton sector use neutrinos in this energy region and the main systematic error in current and future neutrino oscillation analysis is caused from the uncertainty of neutrino-nucleus interactions in this energy region. Furthermore, the MiniBooNE experiment at Fermilab reported an anomaly of 4.7 sigma excess of electron like neutrino events in Sub GeV energy region which indicates the existence of a sterile neutrino. Sterile neutrino search is also a big topics in this field because it is not predicted by the Standard Model and a candidate of right-handed neutrino, dark matter or dark radiation. However, the MiniBooNE signal has been not concluded as evidence of sterile neutrino because there is still a possibility that it comes from an unknown systematic error, for instance, the uncertainty of neutrino-nucleus interactions. So more precision measurement of short baseline neutrino oscillation like MiniBooNE condition is needed. In summary, the study of Sub-Multi GeV neutrinos is a key to open physics beyond the Standard Model.

The NINJA experiment aims to measure Sub-Multi GeV neutrino-nucleus interactions precisely and search for sterile neutrino at the same physics condition in the MiniBooNE with different detector and accelerator at J-PARC. Thanks to the excellent position resolution of the emulsion detector which is the main detector in NINJA, we can measure not only leptons but also hadrons from neutrino interactions at low energy threshold. This allows us to reconstruct neutrino interactions without ambiguities. Actually, we clearly demonstrated to detect below 500 MeV/c protons from neutrino interactions in iron and water target which could not be detected so far. Then we found the disagreement between the measured data and the simulated prediction in backward pion production at anti neutrino-iron interactions. This indicates the understanding of neutrino-nucleus interactions are not enough and our measurements is effective to modify the current neutrino interaction models or the current neutrino interaction generators.Currently, we have anlyzed neutrino-water interactions with a

250 kg large mass detector (iron:130 kg, water:75 kg, emulsion:30 kg, CH:15 kg) which implemented neutrino beam exposure from Nov. 2019 to Feb. 2020 as our 1st Physics Run.

The activities of the NINJA experiment have been documented at Snowmass2021 as one of the leading precise neutrino-nucleus interaction measurement experiments. Furthermore, NINJA-type water target emulsion detector was adopted as one of the near detectors for ESSnuSB project, a future ultra-large long-baseline neutrino oscillation experiment.

3.2.2 Origin of Spacetime Structures Group

Progress on the X-ray observatory XRISM (X-Ray Imaging and Spectroscopy Mission)

XRISM is a JAXA-lead X-ray astronomy satellite, to be launched in JFY 2023. Based on the heritage of the Hitomi X-ray observatory, XRISM focuses on its soft X-ray super high resolution spectroscopy with an energy resolution of $\sim$ 5 eV using a calorimeter array, 30 times better than existing X-ray CCD detectors. Because it does not use dispersion optics, the energy resolution is not affected by the spatial structure of the target and therefore is a powerful tool to observe diffuse objects, such as clusters of galaxies and super-nova remnants.

The XRISM the satellite is assembled and environmental testing were underway. It will be shipped to the launch site at Spring 2023. The ground support systems and science analysis software are also ready. Target selection of Performance Verification Phase has been defined. Uxg member is contributing in developing the information sharing system, as a member of the science operations preparation team (SOPT).

The Imaging X-ray Polarimetimetry Explorer (IXPE) mission

IXPE is a SMEX mission lead by MSFC/NASA, launched in 9 December 2021, into a 600 km circular orbit at approximately 0° inclination. The mission provides the first imaging-polarimetry observation in the 2–8 keV X-ray bands. It has already revealed the EM-effect of extremely high magnetic field of a Magnetor (highly magnet1zed neutron-star) 4U 0142+6's surface, geometric limitation of X-ray emitter in AGNs, as well as apparently turbulent magnetic field of SNR shock waves. Nagoya University provided the thermal-shield for the X-ray mirror optics, based on the experience on those of the Suzaku and Hitomi satellites.

The COMPTON Spectrometer and Imager (COSI) mission

COSI is the newest SMEX mission selected by NASA, to be launched into equatorial low-earth orbit on 2027. COSI is a MeV all-sky survey mission, which was last performed in 1990-2000 by the CGRO/COMPTEL mission. The main detector is made of Ge double-sided strip detectors and operated as a semiconductor Compton telescope. With its good energy resolution, COSI is good at line detection in 0.2-3 MeV, which includes 511 keV annihilation-line, $56Co$, $44Ti$, ^{60}Fe, ^{26}Al and others. Nagoya University supports the MeV science analysis study and sub-detectors "BTO" dedicated for transient monitoring and supporting background estimation.

X-ray optics and detector development activities

In view of the future X-ray observatory, we are developing new optics. One is a new mirror using domestic electroforming technology, and aiming at a few arcsec level of angular resolution. The technology is adopted as one of the optics for FORXSI-4 sounding rocket mission to be launched in 2023. It is dedicated for Solar flare observations, and now the flight models are in fabrication and calibration.

The FORCE mission, a wide-band fine imaging probe in 1-80 keV, is proposed for launch around early-2030s. The main science aim is to probe the hidden black-holes in the universe, and measure the non-thermal components in SNRs and cluster of galaxies and other objects. While the optics

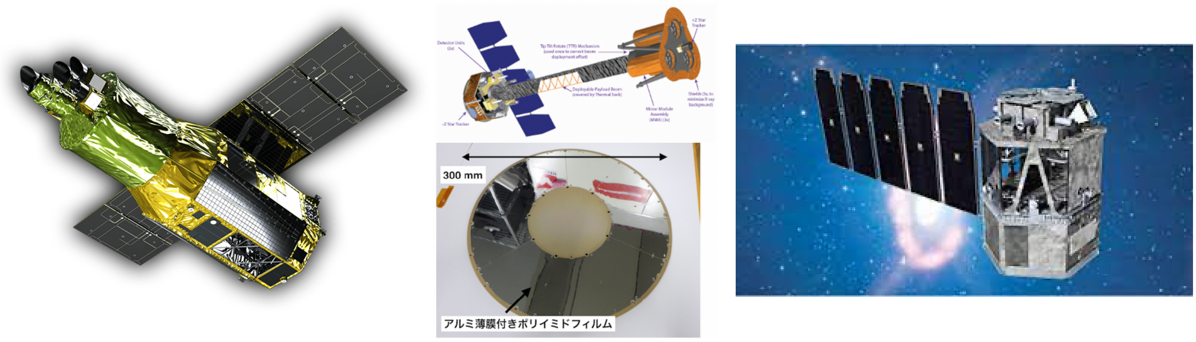


Figure 3.3: (left) The XRISM mission image. (middle) The IXPE mission and its thermal shield. (right) Image of the COSI mission.

development is ongoing in NASA/GSFC, detector components and satellite system design work is ongoing in Japan. Nagoya University is one of the leading member in satellite systems and detector sub-systems design. Another mission based on FORCE's study is also under consideration in ISAS, and Nagoya University is also one of the leading members in satellite systems and detector sub-systems design.

We are also developing "miniSGD" scientific ballooning trial experiment. It uses similar detector technologies to be adopted by FORCE, but using the Double-sided Si Strip Detectors (DSSDs) and CdTe double-sided Strip Detector combined as yet another semiconductor Compton telescope. Original plan was to sky this mission concept verification system on April-May 2023 and the 40 cm large 60 kg compact system has been developed and tested. Unfortunately the flight was canceled because of issued unrelated to miniSGD. The technology development and performance verification activity will continue, both for the future MeV ballooning flight, and as a test-model for the FORCE imager technology.

X-ray data analysis: merging cluster of galaxies

Cluster of galaxies are the node of the large-scale-structure, and is the largest self-gravitating system in the Universe. We are analyzing a early-phase merging cluster using X-ray data of Suzaku and XMM-Newton. In the bridge region connecting the two clusters, we found two zones with high-pressure. We performed detailed 3D analysis of an early-phase merging cluster, and revealed its 3D structure for the first time.

Thundercloud gamma-ray observation

Thunderclouds are known to emit gamma rays with energy as high as 30 MeV. As one of the applications of space-borne compact X-ray/gamma-ray detector technology, we are performing gamma-ray observations of winter thunderclouds around the seashore of Japan Sea. In late 2021, we observed five gamma-ray flashes within $\sim$5 ms which is associated with peculiar radio signals. At the time, majority of the discharge activities were happening $\sim$3 km north, but a few ms after the gamma-ray flashes, the discharge activities have moved near the gamma-ray detectors. We are now analyzing the relation between the gamma-ray flashes and the discharge activities. In 2022 winter, we deployed two-types of new gamma-ray detectora to observe these gamma-ray flashes, in addition to the two gamma-ray glow orientation monitors. The observation champaign is continuing.

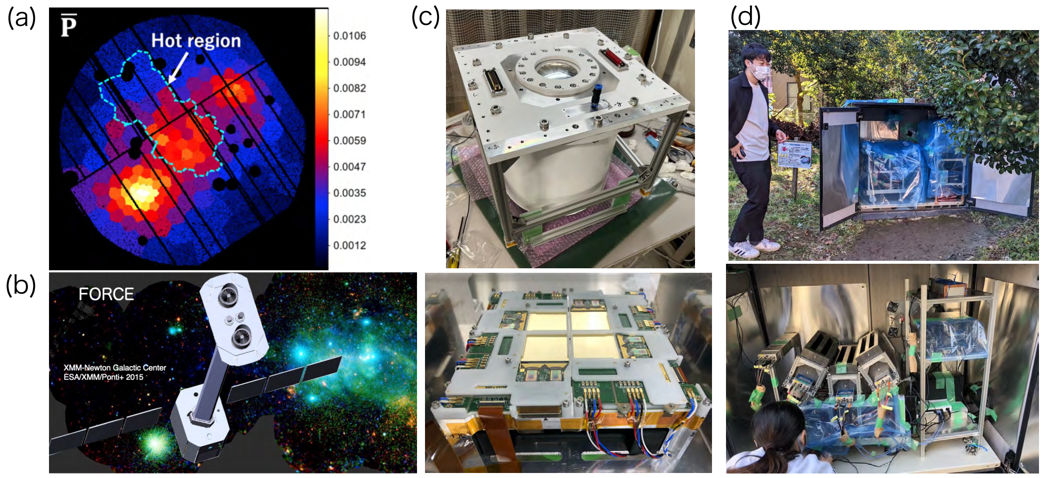


Figure 3.4: (a) Plasma pressure distribution of a merging cluster CIZA J1358.9-4750. (b) The FORCE mission. (c) miniSGD system and its CdTe-DSD imager. (d) Thunder cloud gamma-ray observation champaign of FY2021.

3.2.3 Instrument Development Laboratory

Operation of the TOP counter in the Belle II experiment

We have operated the TOP counter, which is the Cherenkov ring imaging detector for the particle identification in the Belle II spectrometer. It measures the Cherenkov photon's arrival time and position on the photodetector, MCP-PMT, attached on the end of accurately polished quartz radiator.

The Belle II operation was continued by the end of June 2022. The integrated luminosity is about 400 fb^{-1}. Then, we have started the long shutdown 1 (LS1) period, for about one year. During the LS1, we perform the upgrade of the vertex detector, many update of other sub-detectors and accelerator components. For the TOP counter, we will replace the MCP-PMTs, which shows some deterioration of the photo-cathode efficiency, and the malfunctioned frontend electronics.

We evaluated the PMT performance variation using the di-muon samples accumulated by the summer 2022. The gain change is within the expectation, then we corrected it by tuning the supplied high voltage. The photo-cathode efficiency shows faster deterioration than the expectation using lifetime test samples. We checked the effect of the event selection, correction of gain-efficiency relation, etc., but not found other cause of efficiency drop.

To confirm the photo-cathode deterioration, we opened the detector and unmounted the 32 PMTs in one TOP module. The quantum efficiency (QE) was measured using the test bench at Nagoya. The result (Fig. 3.5) shows good correlation with the efficiency change in the detector.

We have investigated the reason of faster QE deterioration in situ. One of the difference is the temperature in situ. The temperature at around the PMT region in the TOP module is about 40 deg-C, because of the electronics heating, which is a bit higher than the lifetime test environment. We set up the lifetime test bench inside the oven and tested with the temperature of 40 deg-C and room temperature. The result indicates faster QE drop in the high temperature condition than room temperature, while we need further study using different samples to conclude the effect.

PID performance have been improved by introducing the following feature to the reconstruction software (Fig. 3.6); 1) Improved PDF modeling; numerical derivatives with more precise forward ray tracing, contribution from quartz surface roughness, 2) Multiple tracks in a module; others treated as contributing to background, iterative procedure to determine most probable PDF's, 3) Bunch finder

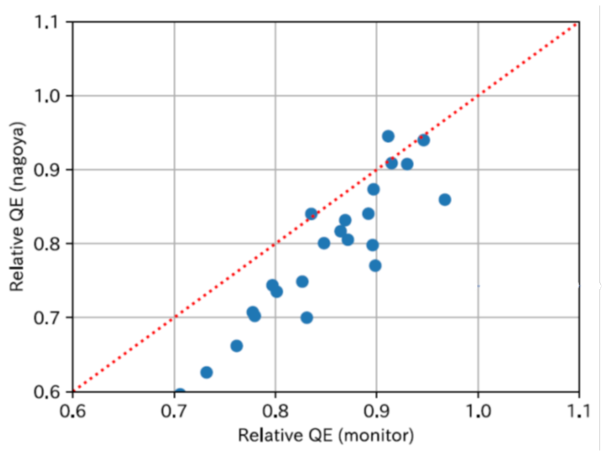


Figure 3.5: Correlation of relative QE measured in the detector (horizontal axis) and the test bench at Nagoya (vertical axis). Red line indicates the linear correlation. The displacement from the red line is due to the difference of reference point of relative value.

efficiency enhancement; seeding with other subdetector's event timing and use of fill pattern.

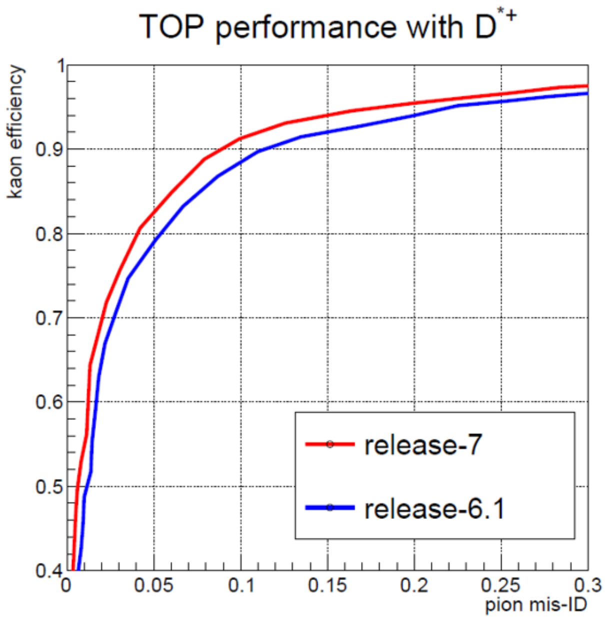


Figure 3.6: Kaon efficiency as a function of pion mis-identification rate for TOP detector evaluated by D^{*+} decay. Red and blue curves show the performance using the reconstruction software version-7 and version-6.1, respectively.

3.2.4 Tau-lepton Data Analysis Laboratory

In the Belle II experiment, the required computing resource is O(10^5) CPU cores and O(100 PB) storages. In order to accumulate such a huge resource, we adopted the distributed computing technique, which connect the computing resources all over the world and utilize it as a single big computer. The Belle II experiment started the data taking with all the detector installed since Apr, 2019. In 2020

FY, SuperKEKB achieved world highest luminosity, and distributed computing is playing important role.

The important task in the distributed computing side is to uploaded the raw data in the grid world and make one copy in the Brookhaven National Laboratory (BNL) in USA as soon as data is taken. Last year, we developed a system to make the copy in the automatic way. With increase of the luminosity, higher throughput for to make the copy. We made various improvement in both hardware, software, and monitoring system to increase the throughput and make the operation smooth. Thanks to those efforts, we handled more than 1 PB of data in this year, as shown in Fig. 3.2.4.

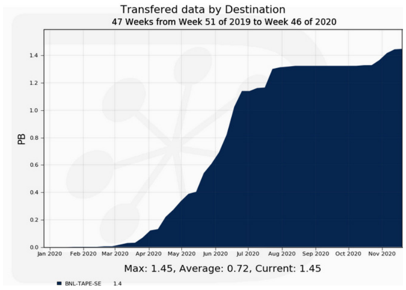


Figure 3.7: Size of Belle II raw data copied to BNL tape system.

As data is accumulated, the importance of the end-user analysis is rapidly growing. Figure 3.2.4 shows the number of end user jobs concurrently running. As you can see, some fraction of jobs are failed with various reasons. It is important to make sure that user jobs can be successfully finished before submitting massive number of jobs to use the computing resource efficiently. In order to realize it, we developed two frameworks. One is Python syntax checker, which check the syntax of the analysis code before the submission, and stop it when an issue in the code is found. The other one is the framework called "scout job". In this framework, when a user submit a massive number of jobs, tiny fraction of jobs which execute small number of events are submitted first. Only when those test jobs are successfully finished, remaining jobs are submitted. These machineries have been successfully implemented in Belle II distributed computing system just now. We expect number of failed jobs to be decreased drastically in the future.

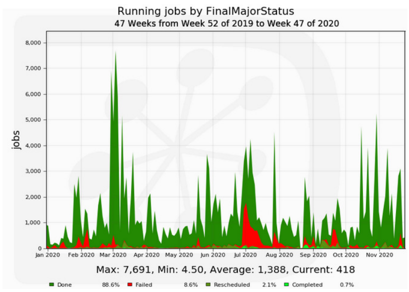


Figure 3.8: Number of user analysis jobs concurrently running.

Chapter 4

Research Related Activities

4.1 Conferences and meetings held by KMI

[1] 26th Meeting on Physics at B Factories Date: 19 Jul, 2022
Place: KMI, Nagoya Univ.+ Online (zoom)
Style: International
Number of participants (foreign): 66 (7)
Sponsorship: KMI
Web site: `https://kds.kek.jp/event/42653/`

[2] IBS and KMI Joint Workshop 2022 Date: 3-5 Aug, 2022
Place: Online (Zoom)
Style: International
Number of participants (foreign): 109 (71)
Sponsorship: KMI (Core-to-Core program),IBS
Web site: `https://www.kmi.nagoya-u.ac.jp/jsps-core-to-core-program/seminar/321-2`

[3] The 2nd DMNet International Symposium “Direct and Indirect Detection of Dark Matter”
Date: 13-15 Sep, 2022
Place: The Max Planck Institute for Nuclear Physics in Heidelberg, Germany + online (Zoom)
Style: International
Number of participants (foreign): about 50 (20)
Sponsorship: KMI (Core-to-Core program),The Max Planck Institute for Nuclear Physics in Heidelberg
Web site: `https://www.kmi.nagoya-u.ac.jp/jsps-core-to-core-program/seminar/252-2`

[4] The 26th International Summer Institute on Phenomenology of Elementary Particles and Cosmology Date: 18-22 Sep, 2022
Place: Fuji Seminar House ”Fuji Calm”, Fuji-Ypshida, Japan + online (Zoom)
Style: International
Number of participants (foreign): 55(12) in face, 32(12) by ZOOM
Sponsorship: KMI, Kakenhi of LOC members
Web site: `http://phys.sc.niigata-u.ac.jp/~asaka/si22/index.html`

[5] Workshop on General Relativity, Cosmology, and Black Hole Information Paradox Date: 21-23 Sep, 2022
Place: Nagoya University + online (zoom)
Style: Domestic
Number of participants: about 160
Sponsorship: 学術変革領域研究（A）「極限宇宙の物理法則を創る－量子情報で拓く時空と物質の新しいパラダイム」 C03班「量子情報を用いた量子宇宙の数理とその応用, KMI
Web site: https://sites.google.com/view/workshop-2209/

[6] 3rd Workshop for Atmospheric Neutrino Production in the MeV to PeV range (WANP2022)
Date: 16-17 Nov. 2022
Place: KMI, Nagoya Univ.+ Online (zoom)
Style: International
Number of participants: 81
Sponsorship: KMI
Web site: https://www-kam2.icrr.u-tokyo.ac.jp/event/14/

[7] Machine Learning in Astrophysics Workshop Date: 21-22 Nov, 2022
Place: KMI, Nagoya Univ. + online (zoom)
Style: International
Number of participants (foreign): about 35 (about 15)
Sponsorship: KMI
Web site: https://www.kmi.nagoya-u.ac.jp/eng/events/2683/

[8] The 4th KMI School: Statistical Data Analysis and Anomalies in Particle Physics and Astrophysics
Date: 14-17 Dec, 2022
Place: KMI, Nagoya Univ.
Style: International
Number of participants (foreign): 76 (20)
Sponsorship: KMI
Web site: https://www.kmi.nagoya-u.ac.jp/workshop/kmi-school-2022/

[9] Cross-disciplinary Seminar Series (分野横断セミナー): Asymptotic Structure of Spacetimes, Infrared divergence, Gravitational waves (時空の漸近構造、赤外発散、重力波) Date: 18 Dec, 2022
Place: KMI, Nagoya Univ.
Style: Domestic
Number of participants: about 80
Sponsorship: KMI
Web site: https://www.math.nagoya-u.ac.jp/~shiromizu/bms/

[10] The 5th KMI International Symposium: Quest for the Origin of Particles and the Universe
Date: 20-21 Feb, 2021
Place: ES Hall, Nagoya Univ.
Style: International

Number of participants (foreign): ()
Sponsorship: KMI
Web site: https://www.kmi.nagoya-u.ac.jp/workshop/KMI2023/

[11] KMI workshop "Searches for Electric Dipole Moments: From Theory to Experiment" Date: 2-4 Mar, 2023
Place: KMI, Nagoya Univ.
Style: International
Number of participants (foreign): ()
Sponsorship: KMI
Web site: https://www.kmiedmws.com

4.2 Seminars and Collquia

[1] 2022/04/13 17:00- KMI Colloquium (Zoom)
"Neutrino oscillations and CP Violation with the European Spallation Source neutrino Super Beam project"
Prof. Marcos A. Dracos (IPHC-IN2P3/CNRS, University of Strasbourg)

[2] 2022/04/27 17:00- KMI Topics (ES635 + Zoom)
"B meson semileptonic decays on the lattice"
Dr. Takashi Kaneko (KEK and KMI)

[3] 2022/05/25 17:00- KMI Colloquium (Zoom)
"Multi-Messenger Signals from Unjetted Active Supermassive Black Holes"
Dr. Yoshiyuki Inoue (Assoc. Prof. of Osaka-U)

[4] 2022/06/08 17:00- KMI Colloquium (Zoom)
"Nuclear Physics from Lattice QCD"
Dr. Takumi DOI (RIKEN)

[5] 2022/06/15 17:00- KMI Topics (Zoom)
"Exotic hadrons in the hybrid model of hadronic molecules and compact states"
Dr. Yasuhiro Yamaguchi (H-lab, Nagoya University)

[6] 2022/06/28 15:45- KMI Theory Seminar (Zoom)
"Probing the Origin of Gravitational Wave Sources"
Dr. Johan Samsing (Niels Bohr International Academy, Univ. of Copenhagen)

[7] 2022/07/06 17:00- KMI Theory Seminar (ES635)
"A fierce new challenge: unveil the connection between the first galaxies and reionization"
Dr. Enrico Garaldi (Max-Planck-Institut fuer Astrophysik)

[8] 2022/07/13 17:00- KMI Colloquium (ES635 ; Zoom)
"Astrophysics of compact binary mergers"
Dr. Kenta Hotokezaka (RESCEU, University of Tokyo)

[9] 2022/07/22 17:00- DMnet Seminar (ES635 ; Zoom)
"Search for New Physics in Electronic Recoil Data from XENONnT"
Dr. Shingo Kazama (KMI, Nagoya University)

[10] 2022/08/04/ 16:00- KMI Theory Seminar (ES635 + Zoom)
"Decoding Galaxy Formation Physics with the UniverseMachine"
Dr. Peter Behroozi (University of Arizona / National Astronomical Observatory of Japan)

[11] 2022/09/21 17:30- KMI Topics (ES635 + Zoom)
"Probing Gravity using Quantum Information"
Dr. Masamichi Miyaji (E-lab, Nagoya University)

[12] 2022/09/28 17:00- KMI Colloquium (ES635 + Zoom)
"Quest for the small-scale dark matter distribution"
Dr. Masamune Oguri (Chiba University)

[13] 2022/10/26 17:00- KMI Colloquium (Zoom)
"Pushing the Frontiers at ATLAS"
Dr. Zachary Marshall (Lawrence Berkeley National Laboratory)

[14] 2022/11/16 18:00- KMI Topics (ES635 + Zoom)
"Rapid formation of Gas Giant Planets via Collisional Coagulation from Dust Grains to Planetary Cores"
Dr. Hiroshi Kobayashi (Ta-lab, Nagoya University)

[15] 2022/11/29 11:00- KMI Theory Seminar (ES635 + Zoom)
"The Vera C. Rubin Observatory and the Legacy Survey of Space and Time"
Dr. Andrés Plazas Malagón (SLAC National Accelerator Laboratory)

[16] 2023/01/18 17:30- KMI Topics (Zoom)
"Singularity Theorem and Non-Singular Universe"
Dr. Daisuke Yoshida (Department of Math, Nagoya University)

4.3 Awards

No awards this year.

Chapter 5

Publications and Presentations

5.1 Published papers

5.1.1 Division of Theoretical Studies

Refereed papers

[1] B. Gao, T. Minamikawa, T. Kojo and M. Harada, "Impacts of the U(1)A anomaly on nuclear and neutron star equation of state based on a parity doublet model", Phys. Rev. C 106, no.6, 065205 (2022).

[2] Y. Aoki *et al.* (Flavour Lattice Averaging Group), "FLAG Review 2021", Eur. Phys. J. C **82**, 869 (2022) doi:10.1140/epjc/s10052-019-7354-7 [arXiv:1902.08191 [hep-lat]].

[3] B. Colquhoun, S. Hashimoto, T. Kaneko and J. Koponen, "Form factors of $B \to \pi\ell\nu$ and a determination of $|V_{ub}|$ with Möbius domain-wall fermions", Phys. Rev. D **106**, 054502 (2022) doi:10.1103/PhysRevD.106.054502 [arXiv:2203.04938 [hep-lat]].

[4] Y. Hamada, T. Kitahara and Y. Sato, "Monopole-fermion scattering and varying Fock space," JHEP **11** (2022), 116 doi:10.1007/JHEP11(2022)116 [arXiv:2208.01052 [hep-th]].

[5] S. Iguro, T. Kitahara and Y. Omura, "Scrutinizing the 95–100 GeV di-tau excess in the top associated process," Eur. Phys. J. C **82** (2022) no.11, 1053 doi:10.1140/epjc/s10052-022-11028-y [arXiv:2205.03187 [hep-ph]].

[6] A. Crivellin, M. Kirk, T. Kitahara and F. Mescia, "Large t→cZ as a sign of vectorlike quarks in light of the W mass," Phys. Rev. D **106** (2022) no.3, L031704 doi:10.1103/PhysRevD.106.L031704 [arXiv:2204.05962 [hep-ph]].

[7] Y. Kanda and N. Maekawa, "Stability of non-topological string in supersymmetric $SU(2)\times U(1)$ gauge theory", to appear in International Journal of Modern Physics A, arXiv:2205.12638[hep-ph].

[8] ParticleDataGroup:2022pth R. L. Workman *et al.* [Particle Data Group], PTEP **2022** (2022), 083C01 doi:10.1093/ptep/ptac097

[9] N. Yamanaka and M. Oka, "Weinberg operator contribution to the CP-odd nuclear force in the quark model," Phys. Rev. D **106** (2022) no.7, 075021

[10] N. Kidonakis and N. Yamanaka, "QCD corrections in $tq\gamma$ production at hadron colliders," Eur. Phys. J. C **82** (2022) no.8, 670

[11] N. Osamura, P. Gubler and N. Yamanaka, "Contribution of the Weinberg-type operator to atomic and nuclear electric dipole moments," JHEP **06** (2022), 072

[12] K. Izumi, T. Shiromizu, K. Suzuki, T. Takayanagi and N. Tanahashi, "Brane dynamics of holographic BCFTs," JHEP **10** (2022), 050 doi:10.1007/JHEP10(2022)050

[13] K. Lee, T. Shiromizu, K. Izumi, H. Yoshino and Y. Tomikawa, "Four types of attractive gravity probe surfaces," Phys. Rev. D **106** (2022) no.6, 064028 doi:10.1103/PhysRevD.106.064028

[14] T. Shiromizu, K. Izumi, K. Lee and D. Soligon, "Maximum size of black holes in our accelerating Universe," Phys. Rev. D **106** (2022) no.8, 084014 doi:10.1103/PhysRevD.106.084014

[15] M. Amo, K. Izumi, Y. Tomikawa, H. Yoshino and T. Shiromizu, "Asymptotic behavior of null geodesics near future null infinity. III. Photons towards inward directions," Phys. Rev. D **106** (2022) no.8, 084007 doi:10.1103/PhysRevD.106.084007

[16] T. Shiromizu and D. Soligon, "The positive mass theorem in Kaluza–Klein picture, Eur. Phys. J. Plus **137**, no.9, 1037 (2022) doi:10.1140/epjp/s13360-022-03245-x

[17] G. G. L. Nashed and S. Nojiri, "Black holes with Lagrange multiplier and potential in mimetic-like gravitational theory: multi-horizon black holes," JCAP **05** (2022) no.05, 011, doi:10.1088/1475-7516/2022/05/011

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[19] G. G. L. Nashed and S. Nojiri, "Isotropic compact stars in 4-dimensional Einstein-Gauss-Bonnet gravity coupled with scalar field – Reconstruction of model," to appear in EPJC

[20] S. Nojiri, S. D. Odintsov and V. Faraoni, "From nonextensive statistics and black hole entropy to the holographic dark universe," Phys. Rev. D **105** (2022) no.4, 044042, doi:10.1103/PhysRevD.105.044042

[21] S. Nojiri, S. D. Odintsov and T. Paul, "Towards a smooth unification from an ekpyrotic bounce to the dark energy era," Phys. Dark Univ. **35** (2022), 100984, doi:10.1016/j.dark.2022.100984

[22] S. Nojiri and G. G. L. Nashed, "Consistency between black hole and mimetic gravity – Case of (2+1)-dimensional gravity," Phys. Lett. B **830** (2022), 137140, doi:10.1016/j.physletb.2022.137140

[23] S. Nojiri, S. D. Odintsov and T. Paul,

[24] S. Nojiri, S. D. Odintsov and V. K. Oikonomou, "Integral F(R) gravity and saddle point condition as a remedy for the H0-tension," Nucl. Phys. B **980** (2022), 115850, doi:10.1016/j.nuclphysb.2022.115850

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5.1.2 Division of Experimental Studies

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5.2 Presentations at International Conferences

(I: Invited, O: Oral, P: Poster)

5.2.1 Division of Theoretical Studies

Name of Conference	Place	Date	I	O	P
RCNP workshop on Hadron Physics at the LEPS2 photon beamline (SPring-8, Hyogo, Japan)	Japan, Korea, USA	March 6-7, 2023	1	0	0
Third International Workshop on the Extension Project for the J-PARC Hadron Experimental Facility (3rd J-PARC HEF-ex WS)	Japan, Italy, USA, etc.	March 14-16, 2023	1	0	0
The 2nd DMNet International Symposium "Direct and Indirect Detection of Dark Matter"	Germany	13-15 Sep 2022	3	0	0
IBS and KMI Joint Workshop	online	3-5 Aug 2022	2	0	0
Challenges in Semileptonic B Decays	Italy	19-23 Apr 2022	1	0	0
The 39th International Symposium on Lattice Field Theory (Lattice 2022)	Germany	8-13 Aug 2022	1	0	0
International Conference on Kaon Physics 2022 (KAON2022)	Japan	13-16 Sep 2022	1	1	0
The 4th KMI school -Statistical Data Analysis and Anomalies in Particle Physics and Astrophysics-	Nagoya University	15-17 Dec 2022	1	0	0
IBS and KMI Joint Workshop 2022	online	3-5 Aug 2022	1	0	0
TDLI-PKU BSM workshop 2022: Electroweak lights the way	Tsung-Dao Lee Institute (online)	1-3 Aug 2022	1	0	0
26th meeting on physics at B factories	Nagoya University	19 Jul 2022	1	0	0
Physics in LHC and Beyond	Matsue	12-15 May 2022	0	1	0
10th international conference on Hard and Electromagnetic Probes of High-Energy Nuclear Collisions	online	1-6 Jun 2020	0	1	0
18th International Conference of Computational Methods in Sciences and Engineering (ICCMSE 2022)	online	26-29 Oct 2022	1	1	0
IBS and KMI Joint Workshop 2022	online	3-5 Aug 2022	0	1	0
NCTS Workshop "The Future is Illuminating"	online	28-30, Jun 2022	0	1	0
SUSTech-Nagoya workshop on Quantum Science 2022	Online	1 June 2022	1	0	0
Fundamental aspects of gravity	UK	8-12 August 2022	1	0	0
Quantum extreme universe from quantum information	Japan (hybrid)	26-30 September 2022	1	0	0
The 31st Workshop on General Relativity and Gravitation in Japan (JGRG31)	Japan (hybrid)	24-28 October 2022	0	0	1
V Institute of Space Sciences Summer School	Spain	4-15 July 2022	1	1	0
2022 MIAPbP Program "Advances in Cosmology"	Germany	16-27 May 2022	1	1	0
Astrophysics Seminar at Institute of Advanced Study	United States	13 October 2022	1	1	0
OUTAP Colloquium	Japan	15 June 2022	1	0	0
Key Challenges in Galaxy and CMB Lensing	UK	5-8 July 2022	1	0	0
Intriguing Inconsistencies in the Growth of Structure over Cosmic Time	Italy	25-29 July 2022	1	0	0
International Astronomical Union (IAU) General Assembly	Korea	2-11 August 2022	1	0	0

The 10th KIAS Workshop on Cosmology and Structure Formation	Korea	24-28 October 2022	1	0	0
Kashiwa Dark Matter Symposium 2022	Japan	November 29 - 2 December 2022	1	0	0
New Frontiers in Cosmology with the Intrinsic Alignments of Galaxies	Japan	5-9 December 2022	1	0	0
Subaru User's meeting 2022	Japan	31 January - 2 Februrary 2023	0	1	1
theory total			28	10	2

5.2.2 Division of Experimental Studies

Name of Conference	Place	Date	I	O	P
ISVHECRI 2022	India	23-27 May 2022	1	0	0
ICHEP 2022	Italy	6-14 Jul. 2022	0	1	0
ICNFP 2022	Greece	30 Aug. - 11 Sep. 2022	0	1	0
FPUA 2022	Japan	24-25 Nov. 2022	0	1	0
JpGU-AGU joint meeting 2022	Japan	22 May - 3 June 2022	0	0	1
IAU GA 2022	Korea	2-11 August 2022	0	0	1
SPIE Astronomical Telescopes + Instrumentation 2022	Canada	17 - 22 July 2022	0	0	1
The international workshop of "Physics in LHC and Beyond	Matsue	5 May 2022	0	1	0
Gravitational Wave Advanced Detector Workshop	online	24 May 2022	0	1	0
The 2nd DMNet International Symposium	Heidelberg (Germany)	Sep. 2022	0	1	0
LIDINE2022,	Warsaw (Poland)	Sep. 2022	0	1	0
9th Conference on New Developments in Photodetection	Troyes (France)	July 2022	0	1	0
International Conference on Neutrino Physics and Astrophysics	Online	30 May-4 June 2022	0	1	1
The 21st International Symposium on Very High Energy Cosmic Ray Interactions	Online	23-27 May 2022	0	1	0
experiment total			1	10	4

5.3 Presentations at Domestic Conferences

5.3.1 Division of Theoretical Studies

Name of Conference	Place	Date	I	O	P
次世代エネルギーフロンティア実験の検討会	湯河原	18-20 Aug 2022	0	1	0
7th meeting of hadron, nucleon, molecular meeting, "Clustering as a window on the hierarchical structure of quantum systems"	online	2 Sep 2020	1	0	0
MIE Meeting of Quantum Science 2022 (MM-QS 2022)	三重大学	8-9, Dec 2022	1	1	0
RCNP workshop " Fundamental Physics Using Neutrons and Atoms"	online	12-13, Aug 2022	1	1	0
J-PARC Workshop	online	28, Sep 2022	0	1	0

Colloquium at Department of Mathematics, Tohoku University	Online	6 June, 2022	1	0	0
日本物理学会2022年秋季大会	岡山理科大学+online	6-10, 12-15 September 2022	0	7	0
第5回ブラックホール研究会	日本大学	11 November 2022	1	0	0
新学術領域「ニュートリノで拓く素粒子と宇宙」研究会	京都大学	1-3 Nov, 2022	0	1	0
T-GEx 研究成果エキシビション	名古屋大学	7 Nov, 2022	0	0	1
第35回理論懇シンポジウム	福島大学	21-23 December 2022	1	0	0
theory total			6	12	1

5.3.2 Division of Experimental Studies

Name of Conference	Place	Date	I	O	P
耐放射線エレキ研究会2022	KEK	10 Aug. 2022	1	0	0
第1回ML@HEPワークショップ	東京大学	8-9 Jul. 2022	1	0	0
GROWTH meeting 2020	online	23 April 2020	1	1	0
日本天文学会2022年秋季年会	新潟大学	13-15 Sep. 2022	0	3	0
1st DECIGO workshop	online	17 Dec. 2022	0	1	0
日本物理学会2022年秋季大会	岡山理科大学+online	6-10 Sep. 2022	0	5	0
日本物理学会2023年春季大会	online	22-25 Mar. 2023	0	1	0
experiment total			3	10	0

5.4 Tutorial and Reviews Articles

[1] A. Hebecker and J. Hisano, “Grand Unified Theories” in Review of Particle Physics, published in PTEP 2022 (2022) 083C01

[2] Junji Hisano,”Proton Decay in SUSY GUTs”, PTEP, (2022) 12, 12B104

[3] 遠藤基, 北原鉄平, 柳生慶, 「電弱対称性の破れの破れ? Wボソン質量アノマリー」高エネルギーニュース **41-2**, 62-70 (2022)

[4] H. Kanno, Intensive Lecture at Department of Mathematics, Tohoku University, “Quantum Toroidal Algebra and Quantum Knizhnik-Zamolodchikov Equation （量子トロイダル代数と量子 Knizhnik-Zamolodchikov 方程式）”, 7-10 June 2022

[5] T. Shiromizu, Intensive Lecture at Department of Physics, Osaka Metropolitan University, ”Mathematical Relativity”, 17-19 Oct. 2022

[6] K. Suzuki, Organizer of “The 1st muon g-2/EDM mini school”, Nagoya University, 11-12 Nov. 2022

[7] M. Kitaguchi, “Neutron Physics”, The 6th Neutron and Muon School, Tokai, Japan, Dec. 2022.

[8] Yoshitaka Itow, Experimental Neutrino physics, Korea, Feb. 2023

Chapter 6

International Relations

6.1 International Collaborations

Collaboration Name	the other parties
MWA	CSIRO, Curtin University, University of Western Australia (Australia), Kumamoto University, Nagoya University (Japan), Shanghai Astronomical Observatory (China), and others
LiteBIRD	KEK, IMPU, Berkeley, MPA and others (26 organizations)
Subaru Hyper Suprime-Cam	NAOJ, Kavli IMPU, Princton, ASIAA, Nagoya, others (all institues in Japan and Taiwan)
Roman Space Telescope	NASA, STScI, Caltech, Kavli IMPU, Nagoya, and others
ATLAS	CERN, High Energy Accelerator Research Organization (KEK), and others (178 organizations)
Belle	High Energy Accelerator Research Organization (KEK), Tohoku University, Niigata University, University of Tokyo, Osaka University, Nara Women's University, National Taiwan University (Taiwan), University of Hawaii (USA), Budker Institute of Nuclear Physics (Russia), Institute for Theoretical and Experimental Physics (Russia), University of Ljubljana (Slovenia), Max Planck Institut fur Physik Muenchen (Germany), Karlsruhe Institute of Technology (Germany), and others
Belle II	High Energy Accelerator Research Organization (KEK), Tohoku University, Niigata University, University of Tokyo, Osaka University, Nara Women's University, National Taiwan University (Taiwan), University of Hawaii (USA), Budker Institute of Nuclear Physics (Russia), Institute for Theoretical and Experimental Physics (Russia), University of Ljubljana (Slovenia), Max Planck Institut fur Physik Muenchen (Germany), Karlsruhe Institute of Technology (Germany), and others

Muon $g-2$/EDM	Ibaraki University, High Energy Accelerator Research Organization (KEK), Japan Atomic Energy Agency (JAEA), J-PARC center, The graduate university for advanced studies (Soken-dai), Tokyo Institute of Technology, The University of Tokyo, Kyushu University, Nagoya University, Niigata University, Osaka University, International University for Health and Welfare, RCNP. Osaka University, Research Center for Electron-Photon Science, Tohoku University, RIKEN, Toyama College, TRIUMF (Canada), University of Victoria (Canada), University of British Columbia (Canada), Charles University, Faculty of Mathematics and Physics, Prague (Czech Republic), CNRS/IN2P3/UPMC/LPNHE (France), LPNHE Paris (France), LPNHE Paris Sorbonne Universite (France), Central University of Karnataka (India), Indian Institute of Technology Hyderabad (India), Manipal Academy of Higher Education (India), Budker Institute of Nuclear Physics (Russia), Korea University (Republic of Korea), Sungkyunkwan University (Republic of Korea), Center for Axion and Precision Physics Research (CAPP), Institute for Basic Science (IBS) (Republic of Korea), KAIST (Republic of Korea), Seoul National University (Republic of Korea)
XRISM	JAXA, NASA (US), Kanto Gakuin University, Kwansei Gakuin University, Kyoto University, Nagoya University, Nara University of Education, Nara Women's University, Nihon Fukushi University, Osaka University, RIKEN, Rikkyo University, Saitama University, Shibaura Institute of Technology, Shizuoka University, Tohoku Gakuin University, Tokyo Metropolitan University, Tokyo University of Science, University of Miyazaki, University of Tokyo, Waseda University, Canadian Light Source Inc. (Canada), University of Chicago (US), Harvard-Smithsonian Center for Astrophysics (US), Lawrence Livermore National Laboratory (US), Massachusetts Institute of Technology (US), Saint Mary's University (Canada), University of Maryland (US), University of Michigan (US), University of Waterloo (US), University of Wisconsin (US), Yale University (US), ESA (European Space Agency), European Sauther Observatory (Germany), SRON (Netherland), University of Amsterdam (Neitherland), University of Durham (UK), University of Geneva (Switzerland) and others
Athena X-ray observatory	European Space Agency, ISAS/JAXA, NASA (USA) and others
FORCE X-ray observatory	ISAS/JAXA, Kyoto University, Osaka University, Miyazaki University, NASA(USA), and others
The Compton Spectrometer and Imager (COSI)	SSL University of California Berkeley, CASS UC San Diego, U.S. Naval Research Laboratory, NASA Goddard Space Flight Center, IRAP Toulouse, Clemson University, Louisiana State University, Los Alamos National Laboratory, Istituto Nazionale di Astrofisica, IoA Insitute of Astronomy, National Tsing Hua University, Kavli IPMU, The University of Tokyo, KMI Nagoya University, Universität Würzburg
TUCAN	KEK, RCNP Osaka Univ., TRIUMF, The University of Winnipeg and others (12 organizations)
Cherenkov Telescope Array (CTA)	Max-Planck-Institut für Kernphysik, and others (216 organizations)
Fermi Gamma-ray Space Telescope	NASA Goddard Space Flight Center, and others (57 organizations)
LHCf	INFN University of Florence (Italy), University of Catania (Italy), Ecole Polytechnique (France), LBNL Berkeley (USA), Waseda University, Kanagawa University, Tokushima University, Shibaura Institute of Technology, University of Tokyo

RHICf	INFN University of Florence (Italy), University of Catania (Italy), Tokushima University, Shibaura Institute of Technology, Waseda University, University of Tokyo, RIKEN, Japan Atomic Energy Agency, Korea University (Korea), Seoul National University (Korea)
Super-Kamiokande	Kamioka Observatory, Institute of Cosmic Ray Research (ICRR), University of Tokyo, and others (40 organizations)
Hyper-Kamiokande	Kamioka Observatory, Institute of Cosmic Ray Research (ICRR), University of Tokyo, and others (76 organizations)
XENON	Istituto Nazionale di Fisica Nucleare, Laboratori Nazionale del Gran Sasso (INFN-LNGS), and others (28 organizations)
DARWIN	University of Zurich, University of Freiburg and others (33 organizations)
XMASS	Kamioka Observatory, Institute of Cosmic Ray Research (ICRR), University of Tokyo, and others (14 organizations)
OPERA	INR Institute for Nuclear Research (Russia), University of Napoli (Italy), University of Bari (Italy), Lomonosov Moscow State University (Russia), Kobe University (Japan), Univer-sity of Bern (Switzerland), Nagoya University (Japan), METU Middle East Technical University (Turkey), Univer-sity of Padova (Italy), Universite de Savoie (France), Ham-burg University (Germany), JINR-Joint Institute for Nuclear Research (Russia), INFN-Laboratori Nazionali del Gran Sasso (Italy), University of Bologna(Italy), Universite de Strasbourg (France) , Toho Univeristy (Japan), University of Roma (Italy), Gyeongsang National University (Korea), In-stitute for Theoretical and Experimental Physics (Russia), Universite Libre de Bruxelles (Belgium) and others
NEWSdm	INR Institute for Nuclear Research (Russia), University of Napoli (Italy), University of Bari (Italy), Lomonosov Moscow State University (Russia), METU Middle East Technical University (Turkey), JINR-Joint Institute for Nuclear Re-search (Russia), INFN-Laboratori Nazionali del Gran Sasso (Italy), University of Roma (Italy), Institute for Theoretical and Experimental Physics (Russia)
DsTau	University of Bern (Switzerland), JINR-Joint Institute for Nuclear Research(Russia), METU Middle East Technical University (Turkey), Institute of Space Science (Romania)

SHiP	University of Sofia (Bulgaria), UTFSM (Universidad Técnica Federico Santa Maria) (Chile), NBI (Niels Bohr Institute), Copenhagen University (Denmark), LAL, Univ. Paris-Sud, CNRS/IN2P3 (France), LPNHE Univ. Paris 6 et 7 (France), Humboldt University of Berlin (Germany), University of Bonn, (Germany), University of Hamburg (Germany), Forschungszentrum Jülich (Germany), University of Mainz, (Germany), University and INFN of Bari (Italy),University and INFN of Bologna (Italy),Istituto Nazionale di Fisica Nucleare (INFN), Sezione di Cagliari (Italy), Università Federico II and INFN of Naples (Italy), University La Sapienza and INFN of Rome (Italy), Lab. Naz. Frascati (Italy), Lab. Naz. Gran Sasso, (Italy), Aichi University of Education (Japan), Kobe University, (Japan), Nagoya University (Japan), Nihon University (Japan), Toho University (Japan), Gyeongsang National University (Korea), KODEL, Korea University (Korea), University of Leiden,(The Netherlands), Laboratory of Instrumentation and high-energy Particle physics (LIP) (Portugal), Joint Institute of Nuclear Research (JINR) (Russia), Institute for Theoretical and Experimental Physics (ITEP) (Russia), Institute for Nuclear Research (INR) (Russia), P.N. Lebedev Physical Institute of the Russian Academy of Sciences (LPI) (Russia), National University of Science and Technology "MISIS" (Russia), National Research Centre (NRC) "Kurchatov Institute" (Russia), Institute for High Energy Physics (Russia), Petersburg Nuclear Physics Institute (PNPI) (Russia), Moscow Engineering Physics Institute (MEPhI) (Russia), Skobeltsyn Institute of Nuclear Physics of Moscow State University (Russia) ,Yandex School of Data Analysis (Russia), Institute of Physics, University of Belgrade, (Serbia), Stockholm University (Sweden), Uppsala University, (Sweden), CERN, University of Geneva (Switzerland), Ecole Polytechnique Federale de Lausanne (EPFL) (Switzerland), University of Zurich (Switzerland), Middle East Technical University (METU) (Turkey), Ankara University (Turkey), Imperial College London (UK), University College London (UK), Rutherford Appleton Laboratory (RAL) (United Kingdom), Bristol University (UK), Warwick University (UK), Taras Shevchenko National University of Kyiv (Ukraine), Florida University (USA)

6.2 Visitors

Name	Affiliation	Period	Host
K. Kadota	IBS	Jul to Oct. 2022	J. Hisano
Kiwoon Choi	IBS	1-4 March 2023	J. Hisano
E. Trotti	University Jan Kochanowski	30th June - 26th July, 2022	N. Yamanaka
J. Samsing	Niels Bohr International Academy, University of Copenhagen	27 Jun. - 1 Jul., 2022	H. Miyatake
P. Behroozi	University of Arizona / NAOJ	4-5 Aug., 2022	H. Miyatake
S. More	UInter-University Centre for Astronomy and Astrophysics (IUCAA)	10-21 Oct., 2022	H. Miyatake
A. More	UInter-University Centre for Astronomy and Astrophysics (IUCAA)	10-21 Oct., 2022	H. Miyatake
D. Rana	UInter-University Centre for Astronomy and Astrophysics (IUCAA)	16-24 Oct., 2022	H. Miyatake
A. Plazas Malagón	SLAC National Accelerator Laboratory	19 Nov.- 13 Dec., 2022	H. Miyatake
J. Park	Yonsei University	27 Jun. - 29 Jul. 2022	T. Iijima
Y. Kwon	Yonsei University	27 Jun. - 9 Jul. 2022	T. Iijima
Y. Kwon	Yonsei University	18 Jul. - 29 Jul. 2022	T. Iijima
A. Soffer	Tel Aviv University	13 Jun. - 21 Jun. 2022	T. Iijima

Chapter 7

Public Relations

7.1 Media Relations

[1] Press release「AIとスーパーコンピュータで広大な銀河地図を解読 - 宇宙の成り立ちを決める物理量を精密に測定」
Date: 21 July, 2022
Related KMI member: Hironao Miyatake
News link: https://www.nagoya-u.ac.jp/researchinfo/result/2022/07/ai--.html
Joint press release: Kavli Institute for Mathematics and Physics for the Universe, University of Tokyo (Kavli IPMU), Kyoto University, National Astronomical Observatory of Japan (NAOJ)

[2] Press release「120億年前の銀河周辺のダークマターの存在を初検出！宇宙は予想外になめらかだった？～多波長観測が描いた遠方宇宙の姿～ (Scientists reveal distribution of dark matter around galaxies 12 billion years ago–further back in time than ever before)」
Date: 2 August, 2022
Related KMI member: Hironao Miyatake, Atsushi J. Nishizawa
News link: https://www.kmi.nagoya-u.ac.jp/eng/blog/2022/08/02/scientists-reveal-distribution-of-dar
Related link: https://www.nagoya-u.ac.jp/researchinfo/result-en/2022/08/20220802-01.html
Joint press release: KMI, Institute for Cosmic Ray Research, The University of Tokyo (ICRR), National Astronomical Observatory of Japan (NAOJ), Princeton University

[3] Press release「暗黒物質探索実験XENONnTによる最初の新物理探索の成果：電子反跳事象に関する最新観測結果 (First results from a Search for New Physics in Electronic Recoils from XENONnT)」
Date: 22 July, 2022
Related KMI member: Yoshitaka Itow, Shingo Kazama
News link: https://www.kmi.nagoya-u.ac.jp/eng/blog/2022/07/22/xenonnt_first_results/
Related link: http://www.xenon1t.org (Press release by XENON collaboration)

7.2 Newspaper Articles

Date	Media	Title	KMI Members
2022/06/20	中日新聞	＜Ｍｅｅｔ　ＳＴＥＡＭ＞ 研究成果を発信する「科学広報」　名古屋大素粒子宇宙起源研究所　広報室研究員 南崎梓さん	南崎梓研究員
2022/08/02	マイナビニュース	約120億年前の遠方銀河周辺に存在するダークマター、名大などが検出に成功	宮武広直准教授
2022/08/03	AstroArts	宇宙背景放射を使って遠方銀河周辺のダークマターを検出	宮武広直准教授
2022/08/06	共同通信	最も遠い暗黒物質検出 約120億光年、名古屋大など	宮武広直准教授
2022/08/06	毎日新聞	120億光年離れた暗黒物質検出　最も遠い例に　名古屋大など	宮武広直准教授
2022/08/07	北海道新聞	最も遠い暗黒物質検出	宮武広直准教授
2022/08/07	岩手日報	最も遠い暗黒物質検出	宮武広直准教授
2022/08/07	茨城新聞	最も遠い暗黒物質検出	宮武広直准教授
2022/08/07	信濃毎日新聞	最も遠い暗黒物質検出	宮武広直准教授
2022/08/07	岐阜新聞	最も遠い暗黒物質検出	宮武広直准教授
2022/08/07	北日本新聞	最も遠い暗黒物質検出	宮武広直准教授
2022/08/07	福井新聞	最も遠い暗黒物質検出	宮武広直准教授
2022/08/07	山陽新聞	最も遠い暗黒物質検出	宮武広直准教授
2022/08/07	高知新聞	最も遠い暗黒物質検出	宮武広直准教授
2022/08/07	西日本新聞	最も遠い暗黒物質検出	宮武広直准教授
2022/08/07	大分合同新聞	最も遠い暗黒物質検出	宮武広直准教授
2022/08/07	宮崎日日新聞	最も遠い暗黒物質検出	宮武広直准教授
2022/11/17	しんぶん赤旗	初期銀河とり巻く "宇宙進化の黒幕"	宮武広直准教授

7.3 Outreach Events held by KMI

[1] 第二回 KMI OBOGトーク：BelleII実験で探る素粒子物理の最前線
Date: 15 October 2020
Place: KMI + online (Zoom)
Lecturer: Keiji Hayasaka(Niigata University)
Number of Participants: 24
Co-host: ITbM and KMI

7.4 Outreach Events held by KMI members

[1] T.Shiromizu「ブラックホールの謎は解けるか？」数理科学2022年7月号

[2] T.Shiromizu協力, ニュートン別冊「ゼロからわかる宇宙論改訂第二版」2022年9月

[3] D.Yoshida, T.Shiromizu訳,「A. アルムヘリ　事象地平をまたぐ「アイランド仮説」」日経サイエンス 2022年12月号

[4] M.Amo, T.Shiromizu訳、「E. シャグーリアン　２つの地平の物語」日経サイエンス　2022年12月号

[5] H. Miyatake, 謎の物質ダークマター, NHK コズミックフロントΩ, 13 September 2022

[6] K. Nakazawa, シチズンサイエンス・ワークショップ「雷から文化を創造する」, シチズンサイエンス雷雲プロジェクト, 9 July 2022

[7] K. Nakazawa, わくわく天文講座「ブラックホールの周囲はX線で輝く」, 小牧中部公民館プラネタリウム, 5 June 2022

[8] Seiji Kawamura, "Space Gravitational Wave Antenna DECIGO and B-DECIGO", Seminar, Cardiff University, Cardiff, UK, online (2022.4.21)

[9] Seiji Kawamura, "Gravitational wave astronomy", Lecture on the Universe, NHK, Nagoya (2022.6.18)

[10] Seiji Kawamura, "Beginning of the Universe investigated by gravitational waves", Lecture, Chunichi culture center, (2022.6.26)

[11] Seiji Kawamura, "Melody of gravitational waves played by Einstein", Lecture, Tenpaku high school (2022.10.13)

[12] Seiji Kawamura, "Repel light pressure noise! Solve the mystery of the birth of the universe with gravitational waves!", Lecture, The Physical Society of Japan, Osaka branch, online (2022.12.24)

[13] H. Tajima, 東海どまんなか (NHK), 13 January 2023

7.5 Public Lectures by KMI members

Name	Date	Location	Event Title	Lecture title	Approx. # of participants
J. Hisano	2022/04/24	中日文化センター	宇宙の始まりに迫る	素粒子のスープから始まる宇宙	50
J. Hisano,	2023/01/21	半田高校	スーパーサイエンスコミュニュ ケーション	謎の粒子、ニュートリノ	30
Hironao Miyatake	2022/10/02	名古屋市立菊里高等学校	出前講義	大規模観測で迫る宇宙の暗黒成分の謎	120
Masaaki Kitaguchi	2022/10/25	私立南山高校男子部	出前講義	素粒子物理を楽しもう	40
Masaaki Kitaguchi	2022/10/27	三重県立伊勢高校	出前講義	素粒子物理を楽しもう	60

7.6 KMI Science Communication Team

KMI supports outreach activities by a student group called KMI Science Communication Team (KMISCT; `https://teamkmisc.wixsite.com/home`). Here is the list of activities and products from KMISCT.

- Dark Candy: Detailed explanations of topics related to particle physics and cosmology (link).
- Podcast "The Particle Physics Roundtable": Invites a guest from KMI and ask the frontline of their research area (link).
  Here is the list of guest in FY2022.
  - Shingo Kazama and Akira Okumura
  - Shin'ichi Nojiri
  - Kazuhiro Nakazawa
  - Kiyotomo Ichiki
  - Takashi Kaneko

7.7 Other Contributions by KMI members

Name	Activity
Junji Hisano	Editor of Physics Letters B

Chapter 8

External Funding related with KMI

Grant-in-Aid for Scientific Research (KAKENHI)

(All items are for PI (Principal Investigator) if not specified. Co-I stands for Co-Investigator.)

Name	Research Funds	ID	Amount [JPY] (Direct Expense)
FUKUDA, Tsutomu	Grants-in-Aid for Scientific Research (B)	21H01108	7,750,000
FUKUDA, Tsutomu	Grant-in-Aid for Challenging Exploratory Research	21K18627	2,329,195
FUKUDA, Tsutomu	Grant-in-Aid for Scientific Research on Innovative Areas [Co-I]	18H05537	8,500,000
HARADA, Masayasu	Scientific Research (C)	20K03927	1,000,000
HISANO, Junji	Scientific Research (C)	21K03572	1,170,000
HISANO, Junji	Scientific Research (B) [Co-I]	20H01895	500,000
HORII, Yasuyuki	Transformative Research Areas (B)	21H05085	10,100,000
HORII, Yasuyuki	Scientific Research (S) [Co-I]	22H04944	11,850,000
ICHIKI, Kiyotomo	Scientific Research (C)	18K03616	700,000
ICHIKI, Kiyotomo	Scientific Research (A) [Co-I]	21H04467	600,000
IIJIMA, Toru	Promotion of Joint International Research (International Leading Research)	22K21347	34,100,000
IIJIMA, Toru	Scientific Research (S)	18H05226	21,900,000
IIJIMA, Toru	Specially Promoted Research [Co-I]	20H05625	4,500,000
ITOW, Yoshitaka	Scientific Research (A)	21H0446	13,130,000
ITOW, Yoshitaka	Transformative Research Areas (A) [Co-I]	18H05538	12,194,000
ITOW, Yoshitaka	Scientific Research (A) [Co-I]	19H00675	650,000
ITOW, Yoshitaka	Scientific Research (B) [Co-I]	20H01917	130,000
IZUMI, Keisuke	Bilateral Joint Research (JSPS-DST)	JPJSBP 120227705	950,000
IZUMI, Keisuke	Scientific Research (B)[Co-I]	20H01902	100,000
IZUMI, Keisuke	Transformative Research Areas (A)[Co-I]	21H05189	700,000
IZUMI, Keisuke	Transformative Research Areas (A)[Co-I]	21H05182	100,000
KANEKO, Takashi	Scientific Research (B)	21H01085	3,300,000
KANNO, Hiroaki	Scientific Research (C)	18K03274	800,000
KAWAMURA, Seiji	Scientific Research (B)	22H01247	4,800,000
KAWAMURA, Seiji	Challenging Research (Exploratory)	21K18626	2,400,000
KAZAMA, Shingo	Scientific Research (B)	20H01931	4,700,000
KAZAMA, Shingo	Transformative Research Areas (A)	21H05455	2,000,000
KAZAMA, Shingo	Scientific Research (A) [Co-I]	21H04471	500,000
KAZAMA, Shingo	Scientific Research (A) [Co-I]	21H04466	300,000

KAZAMA, Shingo	Grant-in-Aid for Scientific Research on Innovative Areas (Research in a proposed research area) [Co-I]	19H05805	2,400,000
KAZAMA, Shingo	Scientific Research (A) [Co-I]	22H00127	200,000
KITAGUCHI, Masaaki	Scientific Research (B)	21H01092	2,400,000
KITAGUCHI, Masaaki	Scientific Research (A) [Co-I]	21H04475	500,000
KITAGUCHI, Masaaki	Scientific Research (A) [Co-I]	22H00140	500,000
KITAGUCHI, Masaaki	Scientific Research (B) [Co-I]	22H01231	200,000
KITAGUCHI, Masaaki	Scientific Research (B) [Co-I]	22H01236	200,000
KITAHARA, Teppei	Early-Career Scientists	19K14706	600,000
KOBAYASHI, Takeshi	Scientific Research (C)	22K03595	700,000
MAEKAWA, Nobuhiro	Scientific Research (C)	19K03823	800,000
MIYATAKE, Hironao	Promotion of Joint International Research (International Leading Research) [Co-I]	22K21349	860,000
MIYATAKE, Hironao	Grant-in-Aid for Scientific Research on Innovative Areas (Research in a proposed research area)	21H00070	1,800,000
MIYATAKE, Hironao	Transformative Research Areas (A)	21H05456	1,900,000
MIYATAKE, Hironao	Scientific Research (B)	20H01932	2,600,000
MIYATAKE, Hironao	Scientific Research (A) [Co-I]	19H00677	100,000
NAKAMURA, Mitsuhiro	Grant-in-Aid for Specially promoted Research	18H05210	48,900,000
NAKANO, Toshiyuki	Grant-in-Aid for Specially promoted Research [Co-I]	18H05210	2,000,000
NAKANO, Toshiyuki	Grants-in-Aid for Scientific Research (A) [Co-I]	21H04472	2,500,00
NAKANO, Toshiyuki	Grants-in-Aid for Scientific Research (B) [Co-I]	22H01233	800,000
NAKAZAWA, Kazuhiro	Scientific Research (A)	20H00157	5,100,000
NAKAZAWA, Kazuhiro	Scientific Research (A) [Co-I]	22H00145	1,050,000
NAKAZAWA, Kazuhiro	Scientific Research on Innovative Areas (A)	21H00166	2,600,000
OKUMURA, Akira	Scientific Research (B)	20H01916	6,100,000
TAJIMA, Hiroyasu	Scientific Research (A)	21H04468	6,100,000
ROKUJO, Hiroki	Grants-in-Aid for Scientific Research (B)	20H01915	1,700,000
ROKUJO, Hiroki	Grants-in-Aid for Scientific Research (B) [Co-I]	20H01233	500,000
SATO, Osamu	Grants-in-Aid for Scientific Research (B) [Co-I]	21H01108	50,000
SATO, Osamu	Grant-in-Aid for Specially promoted Research [Co-I]	18H05210	2,000,000
SATO, Osamu	Grant-in-Aid for Scientific Research on Innovative Areas [Co-I]	18H05535	50,000
SATO, Osamu	Grant-in-Aid for Scientific Research on Innovative Areas	18H05541	14,200,000
SHIMIZU, Hirohiko	Challenging Research (Exploratory)	22K18996	2,200,000
SHIMIZU, Hirohiko	Scientific Research (S) [Co-I]	20H05646	2,000,000
SHIROMIZU, Tetsuya	Scientific Research (C)	21K03551	500,000
SHIROMIZU, Tetsuya	Scientific Research (A)[Co-I]	17H01091	217,620
SHIROMIZU, Tetsuya	Transformative Research Areas (A)	21H05189	12,300,000
SHIROMIZU, Tetsuya	Transformative Research Areas (A)[Co-I]	21H05182	100,000
SUNAYAMA, Tomomi	Transformative Research Areas (A)	20H05855	300,000
SUZUKI, Kazuhito	Scientific Research (A) [Co-I]	22H00141	150,000
TOBE, Kazuhiro	Scientific Research (C)	20K03947	500,000
YOKOYAMA, Shuichiro	Scientific Research (C)	20K03968	1,000,000
YOSHIHARA, Keisuke	Scientific Research (B)	22H03867	7,100,000
ZHOU, Qidong	Early-Career Scientists	22K14056	1,400,000
ZHOU, Qidong	Scientific Research (A) [Co-I]	22H00144	800,000

Other Research Funds

Name	Research Funds	ID	Amount [JPY] (Direct Expense)
HISANO, Junji	JSPS Core-to-core program		13,074,300
ICHIKI, Kiyotomo	JST FOREST	JPMJFR20352935	7,900,000
ICHIKI, Kiyotomo	AIP Acceleration Research	JP20317829	9,700,000
KAWAMURA, Seiji	Murata Science Foundation		3,000,000
KAZAMA, Shingo	JST FOREST	JPMJFR212Q	7,100,000
MINAMIZAKI, Azusa	Daiko Foundation		950,000
MIYATAKE, Hironao	JST FOREST	JPMJFR2137	6,400,000
MIYATAKE, Hironao	T-GEx tailor-made grant		3,000,000
NAKAZAWA, Kazuhiro	JAXA/ISAS Strategic development [Co-I]		2,400,000
NAKAZAWA, Kazuhiro	JAXA/ISAS Basic development for onboard equipment		2,000,000