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

Annual Report

April 2021 – March 2022

Foreword

More than a year has passed since the spread of the new coronavirus infection. KMI's research activities, which are based on international collaborative research, are still severely restricted. On the other hand, restrictions on international travel are gradually being eased, and we were able to dispatch long-term overseas researchers in 2021. In addition, it has become more established to hold research meetings and other events online. Although there are still some things that are difficult to do without face-to-face research activities, such as creating new ideas, we are fortunate to be in a situation where we can look forward to conducting research activities.

In 2021, we received very sad news: Professor Toshihide Maskawa passed away on July 23. Professor Maskawa, together with Dr. Makoto Kobayashi, won the Nobel Prize in 2008 for their proposal of the Kobayashi-Maskawa mechanism, which leads to CP violation in the Standard Model of elementary particles. Professor Maskawa was the first director of KMI, which was established in 2010, and he contributed greatly to the establishment and subsequent development of KMI. I will hold Professor Maskawa's many advices in our heart and strive for the development of KMI.

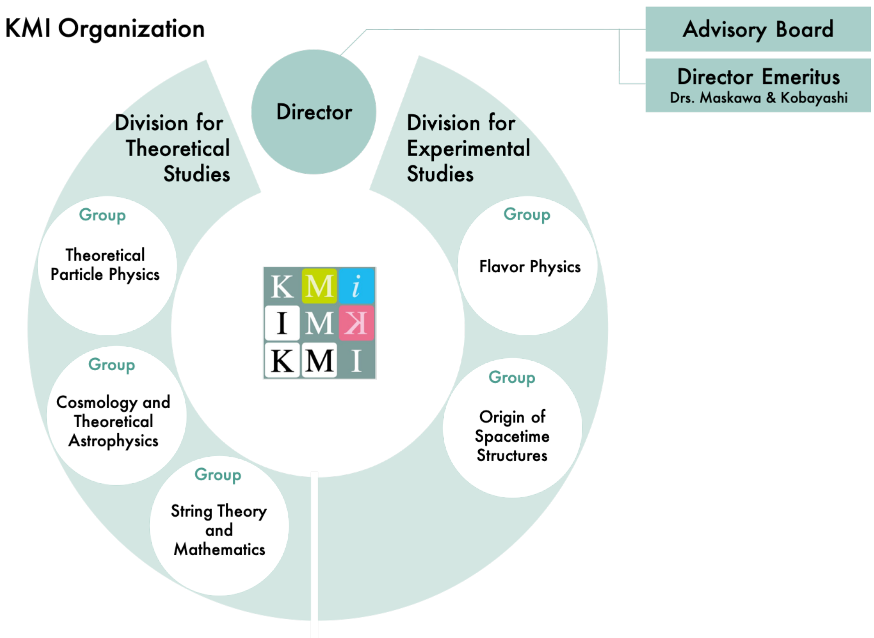
In this report, the experimental and theoretical highlights at KMI are reported in Sect. 3, where other activities spanning through all scientific missions at KMI are also summarized. Research-related activities, such as regular seminars and colloquia, conferences and meetings, are summarized in Sect.4.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

Junji Hisano

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)
NONAKA Chiho (Associate Professor)
MAEKAWA Nobuhiro (Associate Professor)
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

SUGIYAMA Naoshi (Professor)
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)

Computational Theoretical Physics Laboratory (Chief, ICHIKI Kiyotomo)

TANABASHI Masaharu (Professor)
NONAKA Chiho (Associate Professor)
ICHIKI Kiyotomo (Chief, Associate Professor)
AOYAMA Tatsumi (Visiting Scientist)
MIURA Kohtaroh (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)
NAKAHAMA Yu (Associate Professor)
YOSHIHARA Keisuke* (Associate Professor)
SUZUKI Kazuhito* (Lecturer)
KATO Yuji (Assistant Professor)
ZHOU Qidong (Assistant Professor)
GAZ Alessandro (Visiting Scientist)
MATSUOKA Kodai (Visiting Scientist)
HAYASAKA Keiji (Visiting Scientist)

Fundamental Astroparticle Physics

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

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 (Assistant Professor)

Public Relations Office

MIYATAKE Hironao* (Chief, Associate Professor)

NAKAHAMA Yu (Associate Professor)

KAZAMA Singo (Associate Professor)

MINAMIZAKI Azusa (Researcher)

MIZUTANI Mayu (Secretary)

Associate Members

HARADA Masayasu

KAWAMURA Seiji

SHIMIZU Hirohiko

TAJIMA Hiroyasu

SATO Osamu*

ROKUJO Hiro*ki**

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 tetraquarks made from two heavy quarks and two light quarks based on a quark model. Study of the density dependence of the chiral condensate in neutron stars using the haronic model. (Masayasu Harada)

Electric dipole moments (EDMs) of a fermion are sensitive to beyond the standard model. We derive a simplified formula of the EDMs. In the Standard Model, it is well-known that non-trivial cancellations between some rainbow-type diagrams induced by W boson exchanges occur in the calculation of the neutron EDM at the two-loop level due to the gauge symmetry. The fermion self-energy and the vertex correction are related through the Ward-Takahashi identity, and this relation causes the exact cancellation of the EDM. We derive EDM formulas for a more general setup by introducing the form factors for the fermion self-energy and the vertex correction so that the derived formulas can be applicable to a larger class of models. We conclude that the non-zero EDM contributions are induced from rainbow-type diagrams with the chirality flipping effects for internal fermions. We also discuss the other possible generalization of the EDM calculation which is applicable to the other classes of models. (Junji Hisano)

The dark matter may be unknown neutral particle in models beyond the standard model. We study gamma-ray line signatures from electroweakly interacting non-abelian spin-1 dark matter (DM). In this model, Z_2-odd spin-1 particles including a DM candidate have the $\mathrm{SU}(2)_L$ triplet-like features, and the Sommerfeld enhancement is relevant in the annihilation processes. We derive the annihilation cross sections contributing to the photon emission and compare with the $\mathrm{SU}(2)_L$ triplet fermions, such as Wino DM in the supersymmetric Standard Model. The Sommerfeld enhancement factor is approximately the same in both systems, while our spin-1 DM predicts the larger annihilation cross sections into $\gamma\gamma/Z\gamma$ modes than those of the Wino by 389. This is because a spin-1 DM pair forms not only $J = 0$ but also $J = 2$ partial wave states where J denotes the total spin angular momentum. Our spin-1 DM also has a new annihilation mode into Z_2-even extra heavy vector and photon, $Z'\gamma$. For this mode, the photon energy depends on the masses of DM and the heavy vector, and thus we have a chance to probe the mass spectrum. The latest gamma-ray line search in the Galactic Center region gives a strong constraint on our spin-1 DM. We can probe the DM mass for $\gtrsim$25.3 TeV by the Cherenkov Telescope Array experiment even if we assume a conservative DM density profile. (Junji Hisano)

The Fermilab Muon $g-2$ collaboration recently announced the first result of measurement of the muon anomalous magnetic moment $(g-2)$, which confirmed the previous result at the Brookhaven

National Laboratory and thus the discrepancy with its Standard Model prediction. The world average of measured values deviates from their standard-model predictions at 4.2σ level. We revisit low-scale supersymmetric models that are naturally capable to solve the muon $g-2$ anomaly, focusing on two distinct scenarios: chargino-contribution dominated and pure-bino-contribution dominated scenarios. It is shown that the slepton pair-production searches have excluded broad parameter spaces for both two scenarios, but they are not closed yet. For the chargino-dominated scenario, the models with $m_{\tilde{\mu}_L} \gtrsim m_{\tilde{\chi}_1^\pm}$ are still widely allowed. For the bino-dominated scenario, we find that, although slightly non-trivial, the region with low $\tan\beta$ with heavy higgsinos is preferred and the muon $g-2$ anomaly can be explained while satisfying the LHC constraints. We also checked that the stau-bino coannihilation works properly to realize the bino thermal relic dark matter. (Teppei Kitahara)

Spinor-helicity formalism can produce scattering amplitudes directly from symmetry, locality and unitarity, and without relying on Lagrangian. Such a formalism is called the on-shell approach. The on-shell approach is expected to extract some essences in field theory, which are not obvious in the usual Feynman methods. We study the on-shell version of the Higgs mechanism in effective field theories (EFTs) containing particles of different spins, focusing on contact terms as a simple starting point. We derive the massive contact terms and their coefficients from the massless amplitudes of the EFT above the symmetry breaking scale, by covariantizing the massless contact terms under the massive little group. Mass-suppressed contributions to the contact-term coefficients arise from higher-point contact terms with additional soft Higgs legs. We apply this procedure to obtain massive four-point amplitudes featuring scalars, spin 1/2 fermions and vectors, in the standard-model EFT. (Teppei Kitahara)

Motivated by the $R(D^{(*)})$ anomalies, we study non-resonant searches for new physics at the LHC by considering final states with an energetic and hadronically decaying τ lepton, a b-jet and large missing transverse momentum ($pp \to \tau_h \bar{b} + E_{\mathrm{T}}^{\mathrm{miss}}$). Such searches can be useful to probe new physics contributions to $b \to c\tau\bar{\nu}$. They are analyzed not only within the dimension-six EFT but also in explicit leptoquark (LQ) models with the LQ non-decoupled. The former is realized by taking a limit of large LQ mass in the latter. It is clarified that the LHC sensitivity is sensitive to the LQ mass for $\mathcal{O}(1)$ TeV even in the search of $pp \to \tau_h \bar{b} + E_{\mathrm{T}}^{\mathrm{miss}}$. Although the LQ models provide a weaker sensitivity than the EFT limit, it is found that the non-resonant search of $pp \to \tau_h \bar{b} + E_{\mathrm{T}}^{\mathrm{miss}}$ can improve the sensitivity by $\approx 40\%$ versus a conventional mono-τ search in the whole LQ mass region. Consequently, it is expected that most of the parameter regions suggested by the $R(D^{(*)})$ anomalies can be probed at the HL-LHC. We also investigate the angular correlations among b, τ and the missing transverse momentum to discriminate the LQ scenarios. (Teppei Kitahara)

Rare meson decays are among the most sensitive probes of both heavy and light new physics. Among them, new physics searches using kaons benefit from their small total decay widths and the availability of very large datasets. On the other hand, useful complementary information is provided by hyperon decay measurements. We summarize the relevant phenomenological models and the status of the searches in a comprehensive list of kaon and hyperon decay channels. We identify new search strategies for under-explored signatures, and demonstrate that the improved sensitivities from current and next-generation experiments could lead to a qualitative leap in the exploration of light dark sectors. (Teppei Kitahara)

The 2020 report of the NANOGrav experiment, which can be interpreted as gravitational waves of cosmic string origin, suggests that the cosmic string is generated by symmetry breaking on a scale of about 10^{14} GeV. Since the scale at which $SU(2)_R \times U(1)_{B-L} \to U(1)_Y$ breaking occurs in the natural grand unified theory is exactly that scale, we investigated whether the cosmic string generation by such a breaking is possible or not. Since a topological string with guaranteed topological stability does not arise in this breaking, we discussed the stability of a non-topological string. Since this breaking is the same as the breaking of the Standard Model, we extended the discussion of the stability of the electroweak string, which is a non-topological string discussed in that case, to the theory with supersymmetry. As a result, we were able to show that it is the same as the stability argument for electroweak strings with appropriate readings. Unfortunately, in natural grand unified theories, the non-topological strings are found to be unstable. (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, the relatively low new physics scale is suggested. Therefore, the current and near future experiments can probe such a new physics, and hence a study of the new physics interpretation would be very important. It has been suggested that some of leptoquarks can enhance the contribution to the muon g-2 due to the top quark loop contribution, and hence these leptoquarks would be an interesting possibility to explain the muon g-2 anomaly. We have studied the contributions of leptoquarks to other processes such as $B \to D^{(*)} l \bar{\nu}$ and $B \to K^{(*)} l^+ l^-$, whose measured values also deviate from the SM predictions, and we have clarified how large deviations from the SM predictions of these processes are possible in the leptoquark models. (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 Naohiro Osamura and Philipp Gubler to investigate the contribution of the CP-odd gluonic Weinberg operator to the electric dipole moment of atoms. It is found that a non-negligible contribution through the pion-exchange appears. (Nodoka Yamanaka)

3.1.2 String Theory and Mathematics Group

Ding-Iohara-Miki algebra (a.k.a. the quantum toroidal algebra of type $\mathfrak{gl}_1$) is the underlying symmetry of the correspondence between the instanton partition function of supersymmetric gauge theory and the conformal block of two dimensional conformal field theory. We worked out the difference equation (quantum KZ equation) for the correlation functions of the intertwiners of the MacMahon representation of Ding-Iohara-Miki algebra. We also worked out the quantum KZ equation for the elliptic deformation of Ding-Iohara-Miki algebra, where we have to take the trace of the intertwiners. Solutions of our difference equation give building blocks of the partition function of the six dimensional supersymmtric gauge theory compactified on the torus. (H. Kanno)

We have discussed the uniqueness of static black hole solutions for the Einstein-conformal scalar system in the two ways. In the proof based on the divergence inequalities, we could give a systematic way to derive the divergence inequalities. And we also gave the proof of uniqueness of the static solution in higher dimensional version of the Einstein conformal field system. Meanwhile, we could refined the area inequality in the gravitational field taking account of the contribution from angular momentum, gravitational waves and matters. (T. Shiromizu)

We have aimed at a deeper understanding of higher-group structure in quantum field theories, among which a special focus has been on an axion-Maxwell system in higher-dimensional space-time and the low energy effective theories of mesons in QCD-like theories. Finding out the higher-form symmetries manifested in these models is complete. On the basis of these results, we will continue to explore the higher-group structures and their physical meanings in the next year. (T. Sakai)

We have pointed that, in asymptotically flat four-dimensional spacetimes, the behaviors of null geodesics in the asymptotic region cannot be approximated by those in flat spacetime. The time dependence of gravitational potential and/or gravitational wave, whose amplitudes decay in the asymptotic region due to the asymptotic flatness, gives the same-order contribution to null geodesics in the $1/r$ expansion as that by the centrifugal force. With large luminosity, such effects can be balanced with the centrifugal force, and thus a null geodesic can stay on $r =$const. surface temporarily no matter how large r is. (K. Izumi)

3.1.3 Cosmology and Theoretical Astrophysics Group

I studied the dressed asymptotic states in QED and clarified the infrared physics with H. Furugori. In this work, we constructed a divergence-free and unitary S-matrix using dressed states proposed in this paper. We may give a unified and new insight into IR physics, including asymptotic symmetries, memory effects, and unitarity of the state evolution. With M. Terasawa, I proposed statistical systems based on p-adic numbers and we have shown that there appear phase transitions even for the one-dimensional system. In the framework of the $F(R)$ gravity, I investigated the compact star with K. Numajiri and T. Katsuragawa and we have shown that the models are strictly restricted if the space-time outside the compact star is the Schwarzschild space-time. With G. G. L. Nashed, I constructed black hole solutions with/without electric charge or with/without rotation in several kinds of gravity theories like $F(R)$ gravity, and mimetic Euler-Heisenberg theory. In order to solve the problem of the Hubble tension, I considered the equation of state for the early dark energy with S. D. Odintsov, D. Saez-Chillon Gomez, and G.. S. Shanov. I also considered the thermal effects in the propagation of gravitational waves with S. Capozziello and S. D. Odintsov. With S. D. Odintsov and T. Paul, I proposed a wide class of holographic dark energy models and investigated their properties. I also compared several kinds of black entropies with S. D. Odintsov and V. Faraoni. With them, I also generalized known entropies and applied them to black hole physics and cosmological expansion. Because so-called $F(R, \mathcal{G})$ gravity has ghosts in general, I considered the modification of the models to avoid the ghosts with S. D. Odintsov, V. K. Oikonomou, and A. A. Popov. By using this ghost-free $F(R, \mathcal{G})$ gravity model, I proposed a model describing the ekpyrotic bounce in the early universe and the dark energy era in a unified way with S. D. Odintsov and T. Paul. (Nojiri)

Primordial black holes (PBHs) as part of the dark matter (DM) would modify the evolution of large-scale structures and the thermal history of the Universe. Future 21 cm Forest observations, which are sensitive to small scales and the thermal state of the intergalactic medium (IGM), could probe the existence of such PBHs. We show that the shot-noise isocurvature mode on small scales induced by the presence of PBHs can increase the amount of low-mass halos, or minihalos, and thus the number of 21 cm absorption lines. However, if the mass of PBHs is as large as $M_{\mathrm{PBH}} s 10 M_{\odot}$ with a sufficiently abundant fraction of PBHs as DM, $f_{\rm PBH}$, the IGM heating due to accretion on the PBHs counteracts the enhancement due to the isocurvature mode and instead reduces the number of absorption lines. The confluence of both effects imprints a distinctive signature on the number of absorbers, allowing the abundance of PBHs to be constrained. We calculate the prospects for constraining PBHs with future 21 cm Forest observations and find achievable competitive upper bounds on the abundance as low as $f\mathrm{PBH} \sim 10^{-3}$ at $M_{\rm PBH} = 100 M_\odot$, or even lower at larger masses, in regions of parameter space unexplored by current probes. The influence of astrophysical X-ray sources on the IGM temperature, which could potentially weaken the limits, was studied. (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, we have completed the first-year cosmology analysis of HSC. Specifically, we placed cosmological constraint on σ_8-$\Omega_{\rm m}$ plane (and their combination $S_8 \equiv \sigma_8 \sqrt{\Omega_{\rm m}/0.3}$) 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. This study was featured in a YouTube channel called "Cosmology Channel." In addition we published a forecast paper of Roman space telescope, in which Miyatake contributed to forecasting modified gravity constraints (Eifler et al., 2021). This study was featured in the NASA website (Miyatake).

We have investigated the abundance of the primordial black hole with the non-Gaussian primordial fluctuations. In Kitajima et al., 2021, we mainly focused on the exponential-tailed non-Gaussianity which has been extensively discussed in the inflationary model that could realize the enhancement of the primordial fluctuations. We found that the non-Gaussianity strongly enhances the probability of generating primordial black holes. In Escriva et al., 2022, we performed numerical simulations to investigate the formation of the primordial black hole with the negatively-skewed non-Gaussianity and we carefully checked the validity of the conventional formation criteria for such a case. To probe the existence of the primordial black hole indirectly by making use of the future gravitational waves detector, I have started a collaboration with the Uxg group led by Prof. Kawamura (Kawasaki et al., 2022, Wu et al., 2022) (Yokoyama).

We explored a new connection between monopoles and astrophysics by showing that monopole-antimonopole pairs can be produced by cosmological magnetic fields in the early Universe. We demonstrated that monopoles of GUT scale mass can even be produced if primordial magnetic fields exist at sufficiently high redshifts. In addition, we derived new limits on the monopole mass and also on the initial amplitude of primordial magnetic 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 compute the propagation of gravitational waves from binary mergers in inhomogeneous universes at late time. This study aims to capture the large-scale structure (LSS) via gravitational waves, which would provide a new way of probing the Universe. In addition, we are interested in how potential signatures of modified gravity can be observed in realistic situations of wave propagation in the Universe. We numerically produce mock universes by the state-of-the-art N-body simulations. We assume the propagation equation of gravitational waves that is obtained in the WKB approximation in a FRW universe. We then fit the models of inhomogeneous matter distributions e.g. the conventional Dyer - Roeder modulation of the cosmological distances and its extension called the mDR model c.f. Clarkson et al. 2012 with the output of the N-body simulations, quantifying the luminosity distance in the amplitude of the propagating gravitational waves. Besides the previous works, our way of computation is capable of considering the wave propagation in gravitational potentials around galaxy clusters or sparse voids in one of the most realistic ways. We reveal, in practical science cases with Einstein Telescope and Cosmic Explorer, the inhomogeneity of the matter distribution can cause a systematic deviation from the FRW-assumed distance indicator up to 5% level. This implies the systematics may overlap with the signatures of modified gravity. We conclude that serious considerations of inhomogeneity is significant for gravitational-wave cosmology in high precision. In this study, we neglect the effect on phases on gravitational waves for simplicity. In future works, we will employ the propagation equation of gravitational waves in the limit of geometrical optics and weak gravitational fields (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 2021, we apply our hydrodynamics code to analyses of photon production at RHIC and the LHC. Also, we propose the new photon production process, radiative recombination model. The model succeeds the resolution to the photon puzzles found in transverse momentum spectra and elliptic flow as a function of P_T. Furthermore, in 2022, we construct a relativistic resistive magneto-hydrodynamics code. We carry out the test calculation for validation of the code. Then we apply the code to analysis of observables at RHIC. As a result, we find that the charge-dependent anisotropic flow is a good probe to extract the electrical conductivity of the QGP medium from high-energy heavy-ion experiments.

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. (Chiho Nonaka)

Cosmological Simulation: Cosmic microwave background (CMB) scattering in galaxy clusters induces polarization signals corresponding to the quadrupole anisotropy in the photon distribution at the cluster location. This "remote quadrupole", derived from measurements of the induced polarization, provides an opportunity to reconstruct primordial fluctuations on large scales. We discuss how comparing the local CMB quadrupoles predicted by these reconstructed primordial fluctuations, and direct measurements from CMB satellites may allow us to test dark energy beyond cosmic variance limits. (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, 3.8×10^{34} cm^{-2}s^{-1}, while the KEKB peak luminosity record is 2.1×10^{34} cm^{-2}s^{-1}. Belle II experiment has accumulated 230 fb^{-1} data, 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 at Belle II experiment. 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 Belle II data. 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 plan to measure the branching fraction of $B^\pm \to \rho^\pm\rho^0$ with 189 fb^{-1} data.

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} data. A machine learning selection method was developed, It improved by about 30% efficiency compare to the previous cut-based selection.

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 try to determine parameters of Flatte lineshape as that with multiple decay channels.

• **ATLAS**

KMI achievements in 2021 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). The Run 2 period (2015–2018) of the LHC-ATLAS experiment at CERN finished successfully, collecting 140 fb^{-1} of proton-proton collision data at a centre-of-mass energy of $\sqrt{s} = 13$ TeV. This data allowed us to measure the SM processes including the Higgs-boson properties more precisely and also to explore heavier new particles with significantly improved sensitivities. Three complex analyses are in progress: search for Higgs-boson pair (di-Higgs) production, search for long-lived particles (LLP), and measurement of top-quark mass using J/ψ in the final state of top-quark-pair production. In parallel, we have been developing advanced technologies for the muon trigger system. This system determines which physics events will be retained for offline data analyses, and is of fundamental importance to the ATLAS physics program.

Physics achievements

(1) Search for di-Higgs production

We searched for resonant di-Higgs production in the $b\bar{b}b\bar{b}$ final state using the full Run 2 dataset collected with the ATLAS detector. The analysis is divided into two channels, targeting Higgs boson decays which are reconstructed as pairs of small-radius jets or as individual large-radius jets. Spin-0 and spin-2 benchmark signal models are considered, both of which correspond to resonant di-Higgs production via gluon-gluon fusion. The Nagoya group took a leading role in the estimations of the trigger uncertainty and the contamination of the single Higgs boson production. The data are consistent with SM predictions. Upper limits are set on the production cross section times branching ratio (Figure 3.1(a)). Paper draft was submitted in Feb. 2022, and published in May 2022 (Phys. Rev. D 105, 092002).

(2) 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. The Nagoya group started a new activity in 2020 to search for LLP decaying into hadrons using events that contain multiple energetic jets and a displaced vertex. The search employs dedicated reconstruction techniques that significantly increase the sensitivity to LLP decaying in the ATLAS inner detector. The Nagoya group is responsible for data-driven background estimation for SM processes and instrumental effects. We plan to obtain the search result in 2022.

(3) Measurement of the top-quark mass using $J\psi$

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 started a new activity with the focus of the top-mass measurement using a J/ψ meson. This channel can suppress the large uncertainty from physics modelling on jet hadronization, which has been one of the largest uncertainties in high-statistics channels. We established the method of top-quark mass fit using the distribution of the invariant mass of J/ψ in the bottom quark jet and charged lepton from the W boson decay. We found that the statistical uncertainty for the full Run 2 dataset is about 1 GeV, which can be reduced with larger dataset expected in the near future.

Trigger achievements

Operation and maintenance

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 $1.05 < |\eta| < 2.4$. High voltage could not be applied to about 40 TGC chambers in late Run 2. Eleven chambers were replaced by spare chambers in 2021. Nagoya PhD student staying in CERN with the supports from KMI took a leading role in the cabling required for the chamber replacements (Figure 3.1(b)). In addition to the chamber replacements, we completed the installation of new backend boards (Figure 3.1(c)), which can receive signals from New Small Wheel (NSW). The inclusion of NSW signals in the muon trigger system is crucial for the reduction of fake muon trigger due to low momentum particles from secondary interactions of the proton beam, and is a major upgrade of the ATLAS trigger system during Long Shutdown 2 (2019–2021).

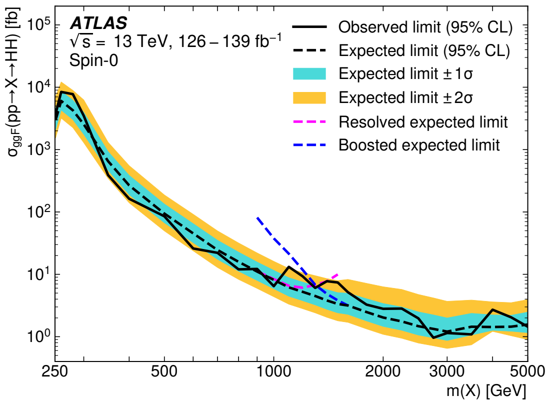
Phase-II upgrade High-luminosity LHC (HL-LHC) starting from 2029 is planned to increase the luminosity by a factor of about 10 compared to the current LHC for more precise measurements of Higgs-boson properties and more sensitive searches for the physics beyond the SM. The trigger and data acquisition 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 worked on prototyping of frontend and backend boards of the TGC in the phase-II upgrade program. The second prototype of the frontend board was produced and a thorough test on the functions was performed. No problems were found and the design for mass production was fixed. The backend board shall implement huge amount of optical links (around 200) and high-end FPGA (XCVU13P), and the design requires significant efforts. We produced the first prototype and confirmed that basic functions such as FPGA configuration work as expected (Figure 3.1(d)). The track reconstruction firmware was established for full coverage of TGC, and the performance was confirmed with Vivado simulation using detector inputs provided from Monte-Carlo samples.

- **Fundamental Astroparticle Physics**

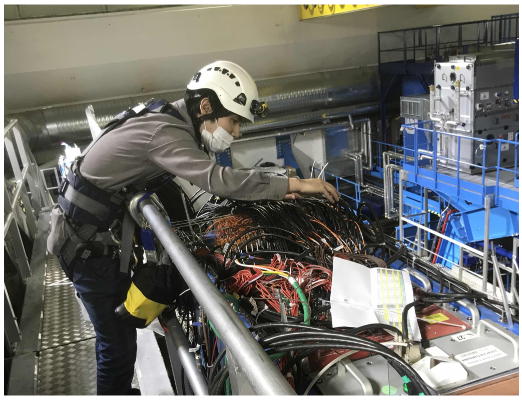
T-violation in resonance reactions, neutron lifetime, medium range interactions

The enhancement of the violation of time-reversal symmetry is predicted in the neutron capture reaction for some nuclei. We estimated the enhancement factor for ^{139}La as a target candidate at the order of 10^6. The enhancement depends on the resonance parameters and spin states of the nuclei, which can be discussed with the angular correlation terms of the (n, γ) reaction. The neutron-spin dependence of the angular correlation terms ($\vec{n}$, γ) provide powerful information to confirm the enhancement mechanism. We measured the various correlation terms by surrounding germanium detectors in ANNRI neutron beam line in Material and Life Science Experimental Facility (MLF) at J-PARC. A high-performance ^{3}He neutron spin filter is installed on the beamline to polarize the incident neutrons. We have also measured the reactions of ^{117}Sn, ^{131}Xe to estimate each enhancement factors. We discuss the compound states with the global analysis of the whole data with the theory group.

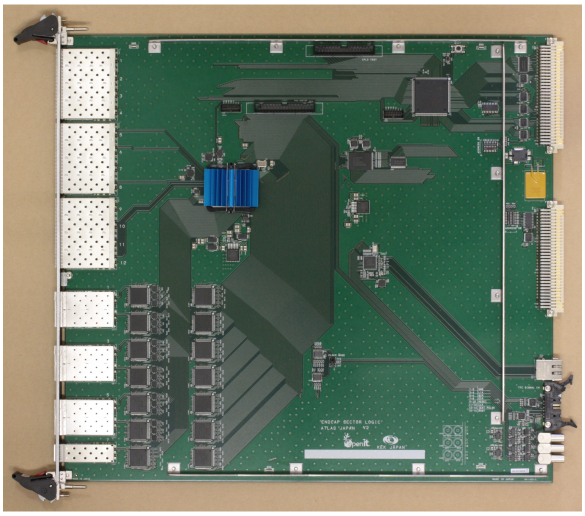
For the T-violation search experiment, the polarized nuclear target has to be prepared. A $LaAlO_3$ single crystal, which has the perovskite structure, is a candidate for the polarized target. The collaborative study started to fabricate the large scale of the crystal with Tohoku University. Dynamical



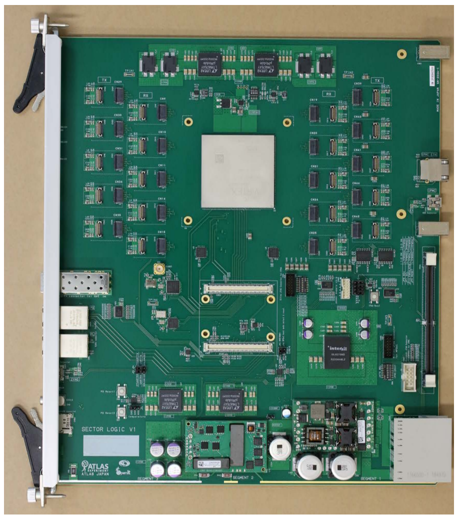
(a)



(b)



(c)



(d)

Figure 3.1: (a) Expected (dashed black lines) and observed (solid black lines) 95% confidence level upper limits on the cross section of resonant di-Higgs production in the spin-0 signal models. The 1σ and 2σ uncertainty ranges for the expected limits (colored bands) are shown. Expected limits using each of the resolved and boosted channels individually (dashed colored lines) are shown. (b) Nagoya PhD student working on cabling for the TGC electronics after chamber replacements. (c) Muon trigger board installed during Long Shutdown 2 for the inclusion of NSW signals in the muon trigger system. (d) First prototype of the muon trigger board for the HL-LHC. A high-end FPGA, XCVU13P, is mounted at around the center of the board.

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 have started the detailed design of the T-violation search experiment. International collaboration 'NOPTREX' is established with US and Chinese group.

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. The spin flip chopper (SFC) produced the well-defined bunches, which have short length enough to fit in the fiducial volume of the TPC. The SFC consists of neutron spin flippers and spin-selecting mirrors, which control the beam trajectory with the spin-flip, however, the size of the devices is limited the beam cross section. We installed new spin flippers and mirrors with large beam-acceptance to improve the statistics of the measurement. The origin of the systematic uncertainties is also studied by using the improved statistics.

Dynamical diffraction in the perfect crystal provides the detail information about interactions in the crystal, for example, the movement of nuclei, the charge radius of neutron, and the fifth force. We have successfully provided the limit of the existence of the Yukawa-type fifth force between the atom and neutron by using Pendellösung interference fringes. A cold-neutron interferometer with artificial multilayer mirrors was demonstrated by using pulsed neutrons. We tried to apply the interferometer to precise measurement the nuclear scattering length, which can be used for test for models of nuclear physics. It also can be utilized for search for unknown force, for example, chameleon field. 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 2021 we accelerated the preparation for an operation with $\sqrt{s} = 13.6$ TeV proton-proton collisions scheduled in 2022. The goal of the operation is to increase the number of events for precise measurement of high energy π^0, and rare particle measurements like η and K^0_s. The read-out system of the LHCf-Arm2 detector was upgraded to improve the data-taking speed. In September we performed a beam test at CERN-SPS and electron and proton beams were injected to the detectors. Even a minimum number of persons could join the beam test due to travel restrictions related to COVID-19, we could check the basic performance of the detectors and confirmed the improvement of Arm2 read-out speed. In the beam test, a joint operation with ATLAS-ZDC detector was performed also. The improvement of energy resolution for hadronic showers was confirmed by combining the measured energy deposit in the LHCf and ZDC detectors, which was an important milestone for a joint operation with ATLAS in 2022.

Dark Matter and Neutrino Experiments at Kamioka Mine

Super-Kamiokande (SK) is the 50-kton water Cherenkov detector underground of the Kamioka Observatory dedicated for observation of neutrinos and possible proton decay. In 2021, the performance of a new 50cm photomultiplier tube with a Box&Line type dynode was studied for the construction of the Hyper-Kamiokande. As well as the signal test work of the delivered PMT at the Kamioka site, a test bench has been set up in the laboratory to evaluate the signal stability. We have also developed a new atmospheric neutrino simulation based on the Honda code utilizing existing hadron production data by accelerator expriments. We continued data analysis of the XMASS experiment to finalize dark matter search by using the full data set.

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.

The XENONnT experiment requires the lowest possible levels of natural radioactivity, both from sources intrinsically present in the liquid xenon target and from detector materials and the environment surrounding the detector. The former is dominated by radon, and its elimination affects the discovery potential of dark matter. The XENON experiment has successfully managed to reduce such radon BG to an unprecedentedly low-level, thanks to extensive material screening and the successful operation of an online cryogenic distillation column that actively removes radon from the xenon.

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. These are dominated by radon constantly emanated from detector surfaces. The idea of a hermetic quartz chamber in a dual-phase xenon TPC has the potential to improve the detector sensitivity because it can isolate the TPC’ s sensitive volume from external interference and is thus expected to prevent contamination caused by radioactive and electronegative impurities, which originate from the outer detector materials. We have built a dedicated small TPC, and are currently testing its performance with gaseous xenon in a room temperature.

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 in CTA. One advantage of the SiPM is its ability to operate under moonlight, which can increase the observation time by a factor of two. We studied the behavior of the SiPM under intense background light. Under intense background light, the SiPM current increases, the voltage drops across the series resistor of the bias circuit, and the drift of the breakdown voltage due to the temperature rise are expected to reduce the pulse amplitude. In addition, the pulse amplitude of the SiPM output signal can be reduced if the SiPM detects photons while recovering from detecting previous photons owing to the background light. When the series resistor is at a minimum, the pulse amplitude drop is measured to be approximately 7%, with a background light intensity equivalent to that of the full moon. We found that the temperature increase had the largest effect on the pulse amplitude at 4%, whereas the effect of the voltage drop across the series resistor was 1.5%. These two effects accounted for 5.5% and 7% of the measured amplitude reduction, respectively. The simulation of pulse overlap during the recovery time indicates that this effect can fully explain the remaining 1.5%.

The CTA is now considering employing the SiPM for the large-sized telescope to take advantage of the higher photon detection efficiency, smaller pixel size, and ability to operate under moonlight. However, the SiPM suffers from higher background light owing to better photon detection efficiencies in the red region, where the background light is bright. We proposed the application of a red filter on the surface of a light concentrator to reduce background light. We developed a prototype light concentrator and verified its characteristics. We also performed simulation studies on the gamma-ray detection efficiencies and found that the red filter improved the efficiency by more than 20% at a gamma-ray energy of 20 GeV. By reducing the pixel size by half, the improvement can be as much as 30%.

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 2022. 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 team is concentrating developing and testing the mission systems, the satellite, the ground support systems and science analysis software. Also, target selection of Performance Verification Phase is on going. 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, to be launched in October 2021. It aims at the first imaging-polarimetry observation in the 2–8 keV X-ray bands. Polarization reflects the geometry of the emission region, such as the magnetic field orientation and/or scattering material distribution. Nagoya University is providing the thermal-shield for the X-ray mirror optics, based on the experience on those of the Suzaku and Hitomi satellites. Because of the higher temperature requirement, the material of the thermal shield is changed from PET to polyimide film, and production parameters are newly developed. In 2020 summer, final set of calibration activities using material os the same lot of the flight models was performed. The output will provide vital information to evaluate the detector response.

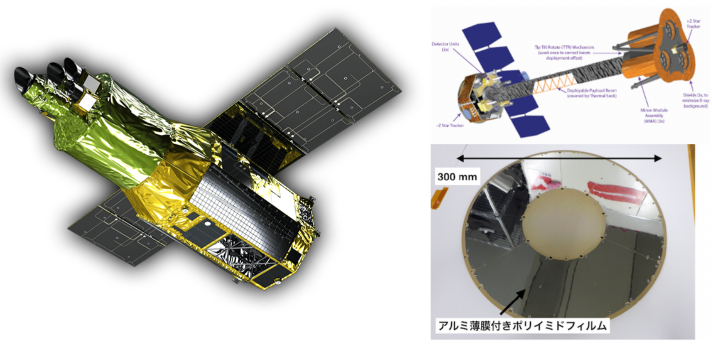


Figure 3.2: (left) The XRISM mission image. (right) The IXPE mission and its thermal shield.

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. As the first year trial, we succeeded in developing a miniature mirror, and demonstrated the technology. Designing of mirror holding structure, improvement of the mirror itself is going on.

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 other objects. While the optics development is ongoing in NASA/GSFC, detector components and satellite system design work is ongoing. In 2020, imager subsystem design work has started. Also be sharing technologies with MeV gamma-ray measurement detector development activities in our group, one of the key FORCE detector elements, CdTe double-sided Strip Detector development has started.

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, separated by an apparent "channel" with pressure deficit in between. Very hot plasma, or enhanced high-energy particle and magnetic field, which all cannot be easily observed in existing X-ray observatories can reside in the channel.

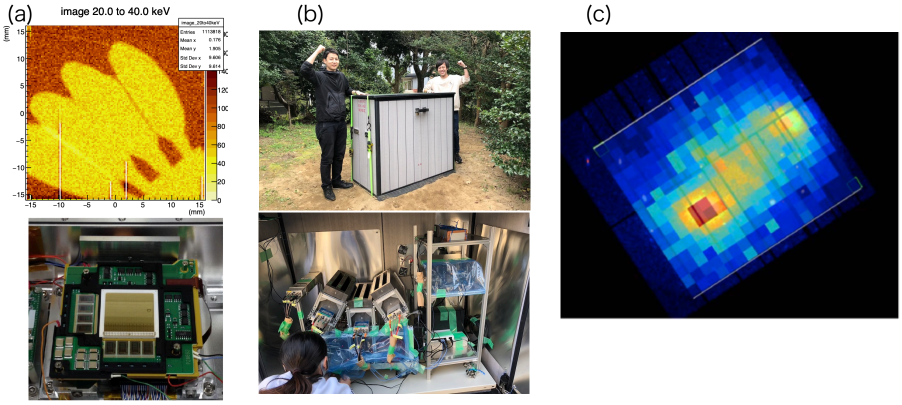


Figure 3.3: (a) Test result of the newly developed CdTe-DSD imager. (b) Thunder cloud gamma-ray observation champaign of FY2020. (c) Plasma pressure distribution of a merging cluster CIZA J1358.9-4750.

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 early 2019, we observed a series of gamma-ray glows, a minute-lasting gamma-ray emission originating from the cloud itself, within $\sim$ 6 minutes. The phenomena can be understood as two or three rapidly growing electron acceleration regions coming out of one thundercloud. We are continuing the observation activity by adding two "collimated" detectors aiming at measuring the accelerator altitude.

3.2.3 Instrument Development Laboratory

Operation of the TOP counter in the Belle II experiment

The TOP (Time-Of-Propagation) counter is a ring imaging Cherenkov detector for particle identification (PID) in Belle II. It utilizes the time of propagation of Cherenkov photons and position to reconstruct the Cherenkov ring image. Each TOP module consists of a 2.7-m long highly-polished quartz radiator bar, an array of 32 Micro-Channel-Plate photomultiplier tubes (MCP-PMTs) at the end of the bar, and readout electronics with a high-speed waveform sampling ASIC.

The Belle II experiment gradually increased the luminosity with keeping the beam background level in 2021. The operation of the TOP counter was rather stable, while we improved the operation system. We introduced alert system to notify the frequently happened trouble and to shorten the dead time of data taking.

The deterioration of the quantum-efficiency (QE) of MCP-PMT is the main issue to keep the PID performance. The deterioration is happened due to the ion and neutral gas generated from the MCP surface by hitting the multiplied electrons. Because of the high beam background rate, we expected that the QE lifetime will reach by 2022, therefore we need to replace about 220 MCP-PMTs during the long shutdown 1 (LS1) in 2022-2023.

We have developed the PMT monitoring system, which evaluate the variation of the hit rate, gain and QE of each PMTs and check the lifetime. By the monitoring result during 2021 run, we found the larger QE drop than expected in some of PMTs. To check the phenomena in the laboratory bench, we started to perform the lifetime test with high temperature environment.

Toward the PMT replacement, we have performed the studies to improve the known issues. 1) The current PMT modules were assembled with 4 MCP-PMTs and fixed limited position of silicone potting and silicone glue to the optical filter. Since the magnetic field in the Belle II detector applies the rotation force to PMTs, some MCP-PMTs were peeled off from the optical filter, which cause the photon loss. To prevent the peeling off, we will install silicone shim under MCP-PMT. For selecting the right thickness, we need to know the PMT thickness (or gap size). We have developed the thickness measurement system using a movable stage and a laser displacement sensors, and successfully measured the thickness with $< 10\mu$m precision and determined the appropriate shim thickness. 2) To make the PMT replacement work easy, fast and safely, we developed HV module carrier and special hex wrench. The PMT replacement work will be carried out inside the detector with up-side-down position in some TOP module. We need to remove and set the screws in the blind region. We prepared the HV module carrier with the screw fall prevention and special wrench to tighten the hex screws in the blind region.

We have an upgrade option of the TOP counter with replacing the PMTs with silicon photomultipliers (SiPMs). We have studied the feasibility of using SiPMs for the TOP counter with a Monte Carlo simulation. Though SiPMs have a worse time resolution and a much higher rate of dark noise than the MCP-PMT, the PID performance of the TOP counter with SiPMs is comparable with the current system, owing to the higher photodetection efficiency. We have confirmed the timing resolution of SiPM under the high hit rate environment. By using the waveform digitizer and performing the constant-fraction-discriminator timing determination, the timing resolution is stable up to 2MHz hit rate (Fig. 3.4).

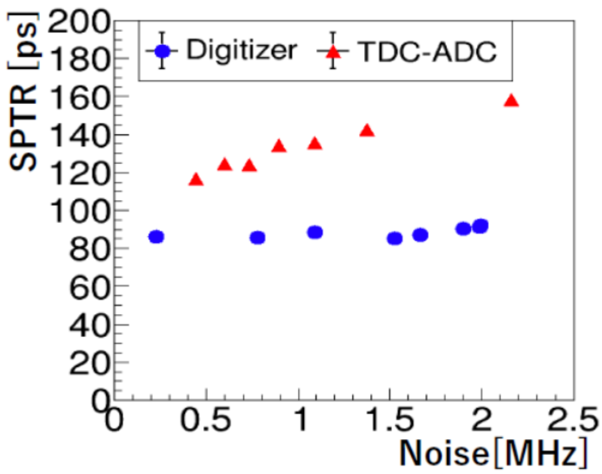


Figure 3.4: Single-photon timing resolution of Hamamatsu SiPM (MPPC) as a function of the noise rate. Red triangles show the result measured by threshold-type discriminator, TDC and ADC. Blue points are for the result by digitizer with constant-fraction-discriminator algorithm.

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.

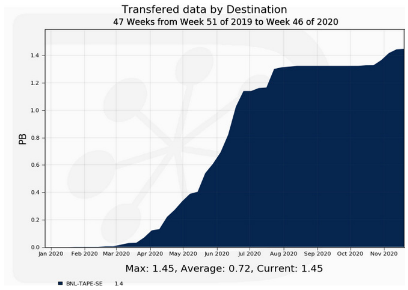


Figure 3.5: Size of Belle II raw data copied to BNL tape system.

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.

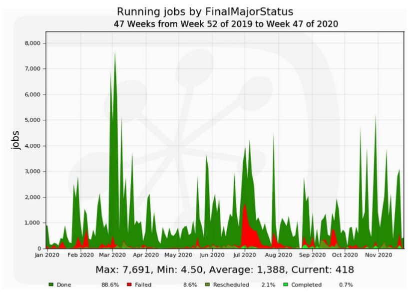


Figure 3.6: Number of user analysis jobs concurrently running.

Chapter 4

Research Related Activities

4.1 Conferences and meetings held by KMI

[1] 1st KMI Flash
Date: 28 Jul. 2021
Place: KMI, Nagoya Univ.+ Online (zoom)
Style: Domestic
Number of participants: 68
Sponsorship: KMI
Web site: `https://www.kmi.nagoya-u.ac.jp/events/3869/`

[2] 素粒子論のこの50年、そして未来　— 益川さんを偲んで
Date: 12-13 Mar, 2022
Place: Yukawa Institute for Theoretical Physics, Kyoto University
Style: Domestic
Number of participants: registered participants 177, in-person attendance about 50
Sponsorship: Yukawa Institute for Theoretical Physics, Kyoto University; Division of Physics and Astronomy, Graduate School of Science, Kyoto University; KMI, Nagoya University
Web site: `https://www2.yukawa.kyoto-u.ac.jp/~tm2022/index.php`

[3] KMI Interdisciplinary Seminar ”Dark matter and new physics searches with a polarized xenon detector”
Date: 05 Jan, 2022
Place: KMI, Nagoya Univ.+ Online (zoom)
Style: Domestic
Number of participants: 7
Sponsorship: KMI

4.2 Seminars and Collquia

[1] 2021/04/08 10:30- KMI Colloquium (Zoom)
“Quest for Unification”
Prof. Qaisar SHAFI (Bartol Research Institute, Univ. of Delaware)

[2] 2021/05/19 17:30- KMI Topics (Zoom)
“Weak Lensing Cosmology from the Subaru Hyper Suprime-Cam Survey First Year Data”

Dr. Hironao Miyatake (KMI, Nagoya University)

[3] 2021/06/09 17:00- KMI Colloquium (Zoom)
"X-ray Probing of Death of a Massive Star"
Dr. Toshiki Sato (Rikkyo University)

[4] 2021/06/23 17:30- KMI Topics (Zoom)
"Muon source development for the J-PARC muon g-2/EDM experiment"
Dr. Kazuhito Suzuki (KMI, Nagoya University)

[5] 2021/06/24 17:00- KMI Theory Seminar (Zoom)
"On the 4-dimensional Einstein-Gauss-Bonnet theory"
Dr. Chunshan Lin (Jagiellonian University)

[6] 2021/07/14 17:30- KMI Topics (Zoom)
"Status and prospect for SuperKEKB/Belle II Experiment"
Dr. Keisuke Yoshihara (KMI, Nagoya University)

[7] 2021/07/28 17:00- KMI Colloquium (Zoom)
"Research and development of xenon bubble chamber detector for underground experiments"
Dr. Yoshihito Gando (Tohoku University)

[8] 2021/09/22 17:30- KMI Topics (Zoom)
"Glueball dark matter in SU(N) lattice gauge theory"
Dr. Nodoka Yamanaka (KMI, Nagoya University)

[9] 2021/09/29 16:30- KMI Colloquium (Zoom)
"Fate of quarkonia in the quark-gluon plasma"
Prof. Yukinao Akamatsu (Osaka Univ.)

[10] 2021/10/13 17:00- KMI Colloquium (Zoom)
"Recent developments in JT gravity"
Prof. Kazumi Okuyama (Shinshu U.)

[11] 2021/11/25 14:00- KMI Colloquium (ES635 + Zoom)
"The pursuit of the most general gravity theory"
Prof. Masahide Yamaguchi (Tokyo Tech)

[12] 2021/12/08 17:30- KMI Colloquium (ES635 + Zoom)
"The search for primordial gravitational waves from cosmic inflation with CMB experiments in the Atacama desert and space"
Dr. Yuji Chinone (Univ. of Tokyo)

[13] 2022/01/19 17:30- KMI Topics (Zoom)
"A brief review on primordial black hole formation and recent related topics"
Dr. Chulmoon Yoo (Nagoya University)

[14] 2022/01/26 17:30- KMI Colloquium (Zoom)
"A new dawn of spectroscopy"
Dr. Franz Muheim (Edinburgh University)

[15] 2022/03/9 17:00- KMI Colloquium (Zoom)
"Origin of neutrino masses — Implications to particle physics and cosmology"
Prof. Takehiko Asaka（Niigata Univ.）

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] T. Minamikawa, T. Kojo and M. Harada, "Quark-hadron crossover equations of state for neutron stars: constraining the chiral invariant mass in a parity doublet model", Phys. Rev. C 103, 045205 (2021).

[2] S. Kono, D. Jido, Y. Kuroda and M. Harada, "The role of the $U_A(1)$ breaking term in dynamical chiral symmetry breaking of chiral effective theories," PTEP **2021**, no.9, 093 (2021)

[3] Q. Meng, M. Harada, E. Hiyama, A. Hosaka and M. Oka,"Doubly heavy tetraquark resonant states", Phys. Lett. B 824, 136800 (2022).

[4] T. Minamikawa, T. Kojo and M. Harada, "Chiral condensates for neutron stars in hadron-quark crossover: From a parity doublet nucleon model to a Nambu-Jona-Lasinio quark model", Phys. Rev. C 104, no.6, 065201 (2021).

[5] Motoko Fujiwara, Junji Hisano, and Takeshi Toma, "Vanishing or non-vanishing rainbow? Reduction formulas of electric dipole moment", JHEP 10 (2021) 237 [arXiv:2106.03384 [hep-ph]]

[6] Tomohiro Abe, Motoko Fujiwara, Junji Hisano, and Kohei Matsushita, "Gamma-ray line from electroweakly interacting non-abelian spin-1 dark matter", JHEP 10 (2021) 163 [arXiv: 2107.10029 [hep-ph]]

[7] E. Goudzovski, D. Redigolo, K. Tobioka, J. Zupan, G. Alonso-Álvarez, D. S. M. Alves, S. Bansal, M. Bauer, J. Brod and V. Chobanova, *et al.* "New physics searches at kaon and hyperon factories," Rept. Prog. Phys. **86** (2023) no.1, 016201 doi:10.1088/1361-6633/ac9cee [arXiv:2201.07805 [hep-ph]].

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M. Gatti, E. Gaztanaga, R. A. Gruendl, J. Gschwend, W. G. Hartley, D. L. Hollowood, K. Honscheid, B. Jain, D. J. James, M. Jarvis, B. Joachimi, A. Kannawadi, A. G. Kim, E. Krause, K. Kuehn, K. Kuijken, N. Kuropatkin, M. Lima, N. MacCrann, M. A. G. Maia, M. Makler, M. March, J. L. Marshall, P. Melchior, F. Menanteau, R. Miquel, H. Miyatake, J. J. Mohr, B. Moraes, S. More, M. Surhud, R. Morgan, J. Myles, R. L. C. Ogando, A. Palmese, F. Paz-Chinchón, A. A. P. Malagón, J. Prat, M. M. Rau, J. Rhodes, M. Rodriguez-Monroy, A. Roodman, A. J. Ross, S. Samuroff, C. Sánchez, E. Sanchez, V. Scarpine, D. J. Schlegel, M. Schubnell, S. Serrano, I. Sevilla-Noarbe, C. Sifón, M. Smith, J. S. Speagle, E. Suchyta, G. Tarle, D. Thomas, J. Tinker, C. To, M. A. Troxel, L. Van Waerbeke, P. Vielzeuf, and A. H. Wright, "Lensing without borders - I. A blind comparison of the amplitude of galaxy-galaxy lensing between independent imaging surveys," MNRAS, 510(4):6150–6189 (2022), doi:10.1093/mnras/stab3586

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5.1.3 Papers in Science Communication

Refereed papers

[1] Yuko Ikkatai, Atsushi Inoue, Azusa Minamizaki, Kei Kano, Euan McKay and Hiromi M. Yokoyama, ‘Effect of providing gender equality information on students’ motivations to choose STEM.’ PLOS ONE, 16(6): e0252710 (2021)

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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
Reimei Workshop "Hadrons in dense matter at J-PARC" (KEK Tokai, Japan and On-line 2022	Japan, Korea	February 21-23, 2022	1	0	0
KASHIWA DARK MATTER SYMPOSIUM 2021	online	29 Nob-2 Dec 2021	1	0	0
Workshop "Quarkonia meet Dark Matter"	online	29 15-18 Jun 2021	1	0	0
Second International Workshop on the Extension Project for the J-PARC Hadron Experimental Facility	online	16-18 Feb 2022	1	0	0
The 75th General Meeting of ILC Physics Subgroup	online	15 Dec 2021	1	0	0
International Joint Workshop on the SM and Beyond	National Taiwan University (online)	12-15 Oct 2021	1	0	0
Strings and Fields 2021	online	23-27 Aug 2021	1	0	0
The 22th muon $g-2$/EDM Collaboration Meeting	KEK Tokai (online)	1-4 June 2021	1	0	0
Mini-Workshop on Colour Allowed Non-Leptonic Tree-Level Decays	Universität Siegen (online)	25 Mar, 1 Apr 2021	1	0	0
ATHIC 2021	online	5-9 Nov 2021	0	1	0
Quark Matter 2022	online	4-10 April 2022	0	1	0
The 24th International Spin Symposium	online	18-22, Oct 2021	0	1	0
12th International Workshop on Multiple Partonic Interactions at the LHC (MPI@LHC 2021)	online	11-15, Oct 2021	0	1	0
Strings and Fields 2021	Online	23-27 August 2021	0	1	0
LeCosPA 4th International Symposium Unity of Physics – From Plasma Wakefields to Black Holes	National Taiwan University (hybrid)	29 November - 3 December 2021	1	0	0
Recent Advances in Theoretical Cosmology and Astrophysics	Greek	16 Dec. 2021	1	1	0
Symmetry 2021 - The 3rd International Conference on Symmetry	Israel	8 Aug. 2021	1	1	0
Debating the potential of machine learning in astronomical surveys & IAP	Paris, France and online	18-22 Oct. 2021	0	1	0
Cambridge cosmology seminar	Cambridge, UK and online	6 Dec. 2021	1	0	0
Subaru Users Meeting	online	January 11-13	0	1	0
Mini-Workshop on "Non-Gaussianities as Probe of BSM," Majorana-Raychaudhuri Seminars	India, Italy, online	18 Jun. 2021	1	1	0
IBS-ICTP Workshop on Axion-Like Particles	IBS, Korea	29 Oct. 2021	1	1	0
theory total			15	11	0

5.2.2 Division of Experimental Studies

Name of Conference	Place	Date	I	O	P
FPCP 2021	Shanghai, China	7-11 Jun. 2021	0	1	0
Muon g-2 theory initiative workshop in memorial Simon Eidelman	Online	28 Jun. - 3 Jul. 2021	0	1	0
HQL 2021	University of Warwick, UK	13-17 Sep. 2021	1	0	0
NUCLEUS 2021	Online	20-25 Sep. 2021	0	1	0
TAU 2021	Indiana University, USA	27 Sep. - 1 Oct. 2021	1	0	0
JpGU-AGU joint meeting 2020	Japan	12-16 July 2021	0	1	2
16th Marcel Grossmann Meeting	online	7 July 2021	0	1	0
Gravitational wave detection at the Moon Workshop	Firenze, Italy	14 Oct. 2021	0	1	0
The 24th International Spin Symposium (SPIN2021)	Japan and online	18-22 October	1	0	0
Low-x 2021	Elba, Italy	Setember 26	0	1	0
ICRC 2021	Online	July 15−− 22	0	1	0
37th International Cosmic Ray Conference	Online	12-13 July 2021	0	0	1
The 22nd International Workshop on neutrinos from accelerators	Online	23-27 Sep 2021	0	1	0
International Conference on Materials and Systems for Sustainability 2021	Online	6 Nov. 2021	0	3	0
experiment total			3	12	3

5.3 Presentations at Domestic Conferences

5.3.1 Division of Theoretical Studies

Name of Conference	Place	Date	I	O	P
ILC Summer Camp 2021	online	21-24 Sep 2021	1	0	0
日本物理学会2021年秋季大会	online	14-17 Sep 2021	1	0	0
EFT勉強会	網張温泉休暇村	30 Jun - 2 Jul 2021	1	0	0
テラスケール研究会	online	22 May 2021	1	0	0
高エネルギー将来計画委員会:第9回勉強会	online	22 Apr 2021	1	0	0
熱場の量子論とその応用	online	30 Aug - 1 Sep 2021	0	1	0
熱場の量子論とその応用	online	20-21 Sep 2022	0	1	0
The Physical Society of Japan 2021 Autumn meeting	online	14-17, Sep 2021	0	2	0
The Physical Society of Japan 2022 Spring meeting	online	15-19, Mar 2022	0	2	0
YITP Workshop	online	7-10, Dec 2021	0	1	0
天文観測におけるビッグデータ解析と宇宙論パラメータの推定	online	27 Sep. 2021	1	0	0
第10回観測的宇宙論ワークショップ	online	17-19 Nov. 2021	0	1	0
第３４回　理論懇シンポジウム	online	22-24 Dec. 2021	0	1	0
新学術領域「ニュートリノで拓く素粒子と宇宙」研究会	千葉+online	7-8 Mar, 2022	0	1	0
theory total			6	10	0

5.3.2 Division of Experimental Studies

Name of Conference	Place	Date	I	O	P
The Physical Society of Japan 2021 Autumn meeting	online	14-17, Sep 2021	0	5	0
The Physical Society of Japan 2022 Spring meeting	online	15-19, Mar 2022	0	6	0
KEK Photosensor/Scintillator Workshop	Tohoku University (+zoom)	Dec. 2021	0	2	0
KEK Detector Technology Project Workshop	KEK (+zoom)	Sep. 2021	0	1	0
experiment total			0	14	0

5.3.3 PR office

Name of Conference	Place	Date	I	O	P
名古屋大学教養教育院物理学小部会FD物理学講義分科会	online	2 Apr. 2021	1	0	0

5.4 Tutorial and Reviews Articles

[1] 遠藤基, 岩本祥, 北原鉄平, 「此のたびのミューオン異常磁気能率」高エネルギーニュース **40-2**, 56-65 (2021)

[2] M. Kitaguchi, "Neutron Physics", The 5th Neutron and Muon School, Tokai, Japan, Dec. 2021.

[3] Yoshitaka Itow, Neutrino physics in Super-K/Hyper-K, Neutrino physics in Super-K/Hyper-K, China (online), Jul. 2021

[4] 井上敦, 一方井祐子, 南崎梓, 加納圭, マッカイユアン, 横山広美, "高校生のジェンダーステレオタイプと理系への進路希望", 科学技術社会論学会誌, 19 巻 p. 64-78 (2021)

[5] 一方井祐子, 井上敦, 南崎梓, 加納圭, マッカイユアン, 横山広美, "STEM分野に必要とされる能力のジェンダーイメージ日本とイギリスの比較研究", 科学技術社会論学会誌, 19 巻 p. 79-95 (2021)

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, Kaveli, 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
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

No visitor this year.

Chapter 7

Public Relations

7.1 Media Relations

[1] Press release「世界最高エネルギーの衝突型加速器 LHC にてニュートリノ反応候補を初めて観測– ニュートリノ実験の新しい視点– (First observation of neutrino interaction candidates at the LHC – A new perspective on neutrino experiments –)」
Date: 29 Nov., 2022
Related KMI member: Toshiyuki Nakano, Mitsuhiro Nakamura, Hiroki Rokujo, Osamu Sato
News link: `https://www.kmi.nagoya-u.ac.jp/eng/blog/2021/11/29/first-observation-of-neutrino-interac`
Related link: `https://journals.aps.org/prd/abstract/10.1103/PhysRevD.104.L091101`
Joint press release: FASER collaboration

7.2 Newspaper Articles

Date	Media	Title	KMI Members
2021/11/10	NASA Website (link)	NASA's Roman Mission Will Help Empower a New Era of Cosmological Discovery	Prof. H. Miyatake

7.3 Outreach Events held by KMI

[1] KMI x ITbM MIX CAFE
Date: 19 May 2021
Place: Online (Zoom)
Lecturers: Keisuke Yoshihara (KMI), Hidenori Takeuchi (Institute for Advanced Ressearch, ITbM)
Number of Participants: 18
Co-host: Institute of Transformative Bio-Molecules (ITbM), Nagoya University and KMI

[2] KMI x ITbM MIX CAFE「重力波 x 光る分子」
Date: 26 June 2021
Place: Online (Zoom)
Lecturers: Seiji Kawamura (Graduate School of Science, KMI), Shigehiro Yamaguchi (Graduate School of Science, ITbM)
Number of Participants: 77
Co-host: ITbM and KMI

[3] 捉える・つくる〜多角的に迫る宇宙の起源〜
Date: 3 Oct 2021
Place: Online (Zoom)
Lecturers: Keisuke Yoshihara (KMI), Shigeru Yoshida (Chiba University)
Number of Participants: 108
Co-host: International Center for Hadron Astrophysics (ICEHAP), Chiba Uniberisty and KMI

[4] 第一回 KMI OBOGトーク：スパコンによる素粒子物理の最前線
Date: 16 Oct 2021
Place: Online (Zoom)
Lecturer: Yasumichi Aoki (Riken)
Number of Participants: 37
Host: KMI

[5] 好き！で飛び込む私の世界〜物理の道を選んだ２人の女性研究者のキャリアパス
Date: 11 Feb 2022
Place: Online (Zoom)
Lecturers: Anno Ishihara (Chiba University), Yu Nakahama (KEK, KMI)
Number of Participants: 45
Co-host: ICEHAP, KMI

[6] 小林・益川理論50周年　益川さんを偲んで
Date: 14 January, 2022
Place: Sakata-Hirata Hall, Nagoya University + online
Lecturers: Makoto Kobayashi (KMI, KEK), Seiji Tanabashi (Gradualte School of Science, KMI), Toru Iijima (KMI), Junji Hisano (KMI), Taichi Kugo (Kyoto University), Mitsuhiro Nakamura (Institute of Materials and Systems for Sustainability Advanced Measurement Technology Cente, Nagoya University), Shinsaku Kitakado (Nagoya University)
Number of Participants: in-person 51, online about 140
Host: KMI

7.4 Outreach Events held by KMI members

[1] M. Nozawa, T.Shiromizu訳, ”ギデイングス　ブラックホールの情報パラドクス　解決への新たな糸口”日経サイエンス2021年6月号

[2] K.Tanabe, T.Shiromizu訳, ”ホッセンフェルダ　思考実験物理学者の心の旅”別冊日経サイエンス247 2021年10月

[3] K.Kashiyama,T.Shiromizu, ”バルセロなど　相対論と量子論をつなぐブラックスター”別冊日経サイエンス247 2021年10月

[4] H. Miyatake, HSC's latest constraints on Ω_m and σ_8!, Cosmology Talks (YouTube Channel) [link], Nov. 5, 2021

[5] H. Miyatake, 寝ても覚めてもブツリがスキ！ 宮武広直さん | 研究者ご紹介, 名大フロントライン [link], Feb. 9, 2022

7.5 Public Lectures by KMI members

Name	Date	Location	Event Title	Lecture title	Approx. # of participants
Keisuke Izumi	2021/11/18	愛知県立豊田西高等学校	豊西総合大学（出前授業）	時空の幾何学	40
Masaaki Kitaguchi	2021/11/04	三重県立伊勢高校	出前講義	素粒子物理学 — 精密測定で宇宙を見る —	60
Yoshitaka Itow	2021/06/05	名古屋市科学館サイエンスホール	第41回古河為三郎サイエンス講演会	地下から探る宇宙の始まりの謎	100
Yoshitaka Itow	2021/08/02	愛知県立岡崎高等学校(online)	総合学習	ニュートリノ	32

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.

- Welcome to Nagoya University!: Special contents to encourage freshmen who entered the University during COVID-19 (link).
- Physics in your pocket: Sticky notes from which one can learn physics trivia, e.g., how many muons go through this sticky per second (link)?
- Lunch meeting: Invite a guest to learn tips for outreach.
  - How to make effective slides? (Issei Takahashi; ITbM)
  - What is an effective approach in a hands-on science museum during COVID-19? (Hideki Miura; vice-director of Science World)
  - Science communication via YouTube (Shunsaku Kitagawa; Kyoto University)
- Dark Candy: Detailed explanations of topics related to particle physics and cosmology (link).
- Received President's Award 2021

7.7 Other Contributions by KMI members

Name	Activity
Junji Hisano	Editor of Physics Letters B
Takeshi Kobayashi	Review Editor on the Editorial Board of Cosmology, Frontiers in Physics

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	3,650,000
FUKUDA, Tsutomu	Grant-in-Aid for Challenging Exploratory Research	21K18627	2,400,000
FUKUDA, Tsutomu	Grant-in-Aid for Scientific Research on Innovative Areas [Co-I]	18H05537	5,000,000
HARADA, Masayasu	Scientific Research (C)	20K03927	1,000,000
HISANO, Junji	Scientific Research (C)	21K03572	1,430,000
HISANO, Junji	Scientific Research (B) [Co-I]	20H01895	500,000
HORII, Yasuyuki	Transformative Research Areas (B)	21H05085	10,200,000
ICHIKI, Kiyotomo	Scientific Research (C)	18K03616	700,000
ICHIKI, Kiyotomo	Scientific Research (A) [Co-I]	21H04467	100,000
IIJIMA, Toru	Scientific Research (S)	18H05226	19,000,000
IIJIMA, Toru	Specially Promoted Research [Co-I]	20H05625	4,500,000
ITOW, Yoshitaka	Scientific Research (A)	21H0446	13,130,000
ITOW, Yoshitaka	Grant-in-Aid for Challenging Exploratory Research (A)	20K20919	4,810,000
ITOW, Yoshitaka	Transformative Research Areas (A) [Co-I]	18H05538	12,194,000
ITOW, Yoshitaka	Scientific Research (A) [Co-I]	19H00675	390,000
ITOW, Yoshitaka	Scientific Research (B) [Co-I]	20H01917	130,000
IZUMI, Keisuke	Scientific Research (B)[Co-I]	20H01902	300,000
IZUMI, Keisuke	Scientific Research (A)[Co-I]	17H01091	200,000
IZUMI, Keisuke	Transformative Research Areas (A)[Co-I]	21H05189	300,000
IZUMI, Keisuke	Transformative Research Areas (A)[Co-I]	21H05182	100,000
KANNO, Hiroaki	Scientific Research (C)	18K03274	500,000
KAWAMURA, Seiji	Scientific Research (B)	19H01924	3,400,000
KAWAMURA, Seiji	Challenging Research (Exploratory)	21K18626	2,500,000
KAZAMA, Shingo	Scientific Research (B)	20H01931	4,380,000
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	2,700,000
KITAGUCHI, Masaaki	Scientific Research (B)	21H01092	2,800,000

KITAGUCHI, Masaaki	Scientific Research (A) [Co-I]	19H00690	100,000
KITAGUCHI, Masaaki	Scientific Research (B) [Co-I]	19H01927	200,000
KITAGUCHI, Masaaki	Scientific Research (A) [Co-I]	21H04475	700,000
KITAHARA, Teppei	Early-Career Scientists	19K14706	600,000
MAEKAWA, Nobuhiro	Scientific Research (C)	19K03823	800,000
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	2,000,000
MIYATAKE, Hironao	Scientific Research (B)	20H01932	3,700,000
MIYATAKE, Hironao	Scientific Research (A) [Co-I]	19H00677	500,000
NAKAHAMA, Yu	Scientific Research (C)	21K03598	1,600,000
NAKAMURA, Mitsuhiro	Grant-in-Aid for Specially promoted Research	18H05210	39,800,000
NAKANO, Toshiyuki	Grant-in-Aid for Specially promoted Research [Co-I]	18H05210	2,500,000
NAKANO, Toshiyuki	Grants-in-Aid for Scientific Research (S) [Co-I]	17H06132	3,000,000
NAKANO, Toshiyuki	Grants-in-Aid for Scientific Research (A) [Co-I]	21H04472	3,000,000
NAKANO, Toshiyuki	Grants-in-Aid for Scientific Research (B) [Co-I]	19H01909	200,000
NAKANO, Toshiyuki	Grants-in-Aid for Scientific Research (B) [Co-I]	19H01988	320,000
NAKAZAWA, Kazuhiro	Scientific Research (A)	20H00157	14,800,000
NAKAZAWA, Kazuhiro	Scientific Research on Innovative Areas (A)	21H00166	2,500,000
NOJIRI, Shin'ichi	Scientific Research (C)	18K03615	4,420,000
OKUMURA, Akira	Scientific Research (B)	20H01916	2,600,000
ROKUJO, Hiroki	Grants-in-Aid for Scientific Research (B)	20H01915	2,100,000
SATO, Osamu	Grants-in-Aid for Scientific Research (B) [Co-I]	21H01108	50,000
SATO, Osamu	Grants-in-Aid for Scientific Research (A) [Co-I]	18H03699	2,590,000
SATO, Osamu	Grant-in-Aid for Specially promoted Research [Co-I]	18H05210	2,500,000
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	8,600,000
SATO, Osamu	Fostering Joint International Research (B) [Co-I]	18KK0085	1,500,000
SATO, Osamu	Grants-in-Aid for Scientific Research (B) [Co-I]	19H01909	200,000
SHIMIZU, Hirohiko	Scientific Research (S) [Co-I]	20H05646	3,000,000
SHIROMIZU, Tetsuya	Scientific Research (C)	21K03551	100,000
SHIROMIZU, Tetsuya	Scientific Research (A)[Co-I]	17H01091	300,000
SHIROMIZU, Tetsuya	Transformative Research Areas (A)	21H05189	2,900,000
SHIROMIZU, Tetsuya	Transformative Research Areas (A)[Co-I]	21H05182	100,000
SUNAYAMA, Tomomi	Transformative Research Areas (A)	20H05855	1,000,000
TAJIMA, Hiroyasu	Scientific Research (A)	21H04468	5,700,000
TOBE, Kazuhiro	Scientific Research (C)	20K03947	600,000
YOKOYAMA, Shuichiro	Scientific Research (C)	20K03968	900,000

Other Research Funds

Name	Research Funds	ID	Amount [JPY] (Direct Expense)
HISANO, Junji	JSPS Core-to-core program		12,984,750
ICHIKI, Kiyotomo	JST FOREST	JPMJFR20352935	7,000,000
ICHIKI, Kiyotomo	AIP Acceleration Research	JP20317829	11,300,000
KAZAMA, Shingo	Ozawa-Yoshikawa Memorial Electronics Research Grant Fund		2,000,000
MINAMIZAKI, Azusa	Daiko Foundation		950,000

MIYATAKE, Hironao	T-GEx startup grant		500,000
MIYATAKE, Hironao	T-GEx tailor-made grant		1,500,000
NAKAZAWA, Kazuhiro	JAXA/ISAS Basic development for onboard equipment		1,400,000