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

Nagoya University

Annual Report

April 2019 — March 2020

Foreword

I am Makoto Kobayashi, the former director of KMI (until March 2020). I suggested that my successor as director of KMI should be an active researcher, and Professor Junji Hisano accepted the appointment to this important position. He will manage KMI under his leadership on the front lines of cosmology and particle physics research. He will shoulder all of the responsibilities that will be laid upon him.

In this fiscal year, there were many changes besides my success as the director. By the reorganization of the University, KMI has become a part of Institutes for Advanced Research Excellence (IARE) and keeps contributing to further developments of Nagoya University as a flagship basic-research institute. In company with this reorganization, two centers, that is, the Center of Theoretical Studies and the Center of Experimental Studies, have become the Division of Theoretical Studies and the Division of Experimental Studies, respectively.

The last three months were terrible even for KMI. Due to COVID-19, all the visits of foreign researchers and the overseas dispatching of young researchers and graduate students in this term were canceled and the 3rd KMI School was postponed although it was successfully held online in the autumn of 2020. In this situation, KMI continues to make progress in researches in diverse fields, striving to innovate physics and to cast light onto a deeper understanding of the origin of physical matter and the universe, under the present mission of the KMI is to investigate the dark universe; that is, the dark matter, the dark energy and vanishing antimatter. I expect people in KMI to succeed the mission even under the situation.

In this report, the experimental and theoretical highlights at KMI are reported in Sect. 4, where other activities spanning through all scientific missions at KMI are also summarized. Publications and presentations through these activities are listed in Sect. 6. In order to promote further international collaboration, KMI concluded an agreement of academic and research cooperation with The University of Naples, Federico II, Department of Physics “Ettore Pancini”, Italy. Within this fiscal year, three international workshops, as well as a number of regular seminars and colloquia, were held, although one workshop was canceled due to COVID-19. For such workshops, we invited not only by domestic speakers but also by scholars from overseas. In addition, in spite of COVID-19, we welcomed eleven visitors from foreign institutes as listed in Sect. 7, which signifies the worldwide and compelling activities of KMI.

We also let you notice that KMI’s proposal “International research network to reveal dark matter in the universe by multidisciplinary approach in particle and astrophysics” was selected by the Japan Society for the Promotion of Science (JSPS) as one of the Core-to-Core programs. The KMI’s project starts in FY 2020 and continues until FY 2024 in collaboration with four countries: Japan, Germany, Italy, UK, and Korea. Professor Junji Hisano, the new director of KMI, joins the project as the coordinator of Japan. Through the project, KMI will improve the study of the dark universe.

Makoto Kobayashi

Contents

Chapter 1

Introduction

As in Annual Report in last year, we like to start with a short review of the history of the achievements at Nagoya University, especially in particle physics. At Nagoya University, the foundation of innovative research in particle physics was first established by Dr. Sakata and his colleagues in the early days of the university. Ever since then, at Nagoya University, there were many outstanding achievements in this field, such as two-meson theory, the Sakata model, and Maki-Nakagawa-Sakata theory. Such achievements have led to the establishment of Kobayashi-Maskawa theory, for which Drs. Kobayashi and Maskawa were awarded the Nobel Prize in Physics in 2008. In addition to these theoretical efforts, various experimental research projects, conducted from the early stages, have been producing first class results, including the discovery of the charm quark and the tau neutrino, as well as confirmation of Kobayashi-Maskawa theory by the B-factory experiments. They are key experiments in establishing the Standard Model.

In 2010, the Kobayashi-Maskawa Institute for the Origin of Particles and the Universe (KMI) has been established with the objective of further inherit this brilliant tradition of Nagoya University, and to explore new frontiers of modern physics beyond the Standard Model. This is being achieved by integrating the wisdom of researchers in various fields of physics such as theoretical and experimental particle physics, theoretical and observational astrophysics, mathematical physics, and cosmic ray physics, who are affiliated with the Graduate School of Science, the Graduate School of Mathematics, and the Institute for Space-Earth Environmental Research (ISEE) at Nagoya University, as well as by incorporating techniques of computational physics into theoretical particle physics.

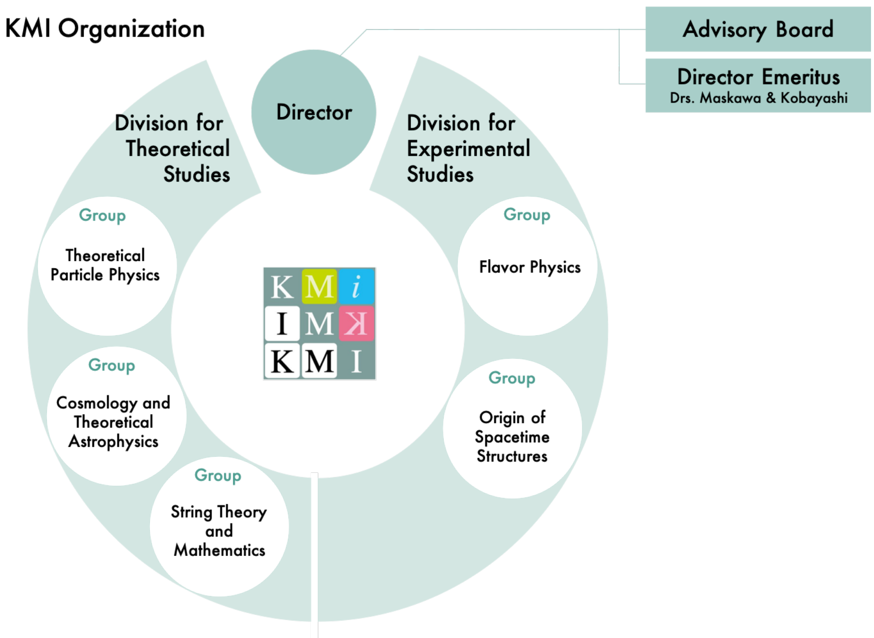
In particular, new discoveries in particle physics, which would be evidence of physics beyond the Standard Model, are expected to be made in the coming years, resulting in a revolution in particle physics which will allow us to elucidate the origin of elementary particles. These discoveries will also shed light on dark matter and dark energy, which have been the subject of intense study in astrophysics and cosmic ray research for many years. These discoveries will also shed light on the origin of the universe and space-time, resulting in enormous impacts in these fields.

Researchers in KMI are key researchers leading front-line experiments such as the LHC experiment at CERN, and the Super B-factory experiment at KEK, Super Kamiokande experiment. In addition to experimental work, particle physics theorists at KMI are playing a leading role in constructing and investigating new physics models beyond the Standard Model, as well as in exploring the dynamics of the Standard Model and string theory. Combining superior minds and skills of researchers from theoretical, experimental and observational studies, KMI aims to expand our knowledge horizon beyond the Standard Model.

Chapter 2

Organization

2.1 Organization



2.2 Staff List

Director : KOBAYASHI Makoto

Director Emeritus: MASKAWA Toshihide

Dupty Director : HISANO Junji

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)
TAKEUCHI Michihisa* (Associate Professor)
ABE Tomohiro (Assistant Professor)

KITAHARA Teppei (Assistant Professor)
SHOJI Yutaro (Assistant Professor)

String Theory and Mathematics Group

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

Cosmology and Theoretical Astrophysics Group

SUGIYAMA Naoshi (Professor)
NOJIRI Shin'ichi (Chair, Professor)
ICHIKI Kiyotomo (Associate Professor)
YOKOYAMA Shuichiro (Assistant Professor)
NISHIZAWA Atsushi (Assistant Professor)
KOBAYASHI Takeshi* (Assistant Professor)

Computational Theoretical Physics Laboratory (Chief, ICHIKI Kiyotomo)

TANABASHI Masaharu (Professor)
NONAKA Chiho (Associate Professor)
ICHIKI Kiyotomo (Chief, Associate Professor)

Division of Experimental Studies (Chair, ITOW Yoshitaka)

Flavor Physics Group

Tau-Lepton Physics

IIJIMA Toru (Professor)
KRIZAN Peter (Professor)
TOMOTO Makoto (Associate Professor)
GAZ Alessandro (Associate Professor)
NAKAHAMA Yu (Associate Professor)
MATSUOKA Kodai (Associate Professor)
MAEDA Yosuke (Researcher)

Fundamental Astroparticle Physics

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

Origin of Spacetime Structures Group

Observational Astrophysics

NAKAZAWA Kazuhiro (Associate Professor)

Theoretical Spacetime Analysis

NAMBU Yasusada (Associate Professor)

Instrument Development Laboratory

NAKAMURA Mitsuhiro (Chief, Professor)

NAKAZAWA Kazuhiro (Associate Professor)

Tau-Lepton Data Analysis Laboratory

IIJIMA Toru (Chief, Professor)

TOMOTO Makoto (Associate Professor)

KATO Yuji (Assistant Professor)

Public Relations Office

TAKEUCHI Michihisa* (Chief, Associate Professor)

NAKAHAMA Yu (Associate Professor)

MINAMIZAKI Azusa (Researcher)

Visiting Scientists

MIURA Kohtaroh

AOYAMA Tatsumi

NAKA Tatsuhiro

(New members are indicated with * .)

Chapter 3

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:

  · KOBAYASHI Makoto (Chairperson)

  Professor Emeritus at High Energy Accelerator Research Organization;

  Director of Research Center for Science Systems, Japan Society for the Promotion of Science;

  University Professor at Nagoya University

  (below in alphabetical order)

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

  · 'T HOOFT Gerardus (Professor at Utrecht University)

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

  · KUGO Taichiro (Emeritus, Kyoto University)

  · SATO Katsuhiko (President of National Institutes of Natural Sciences)

· SILK Joseph (Professor, University of Oxford)

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

Chapter 4

Progress in Research

4.1 Division of Theoretical Studies

4.1.1 Theoretical Particle Physics Group

There are many extensions of the standard model that predict the existence of electroweakly interacting massive particles (EWIMPs), in particular in the context of the dark matter. In the paper (Abe-Chigusa-Ema-Moroi), we provide a way for indirectly studying EWIMPs through the precise study of the pair production processes of charged leptons or that of a charged lepton and a neutrino at future 100 TeV collider experiments. It is revealed that this search method is suitable in particular for Higgsino, providing us the $5\,\sigma$ discovery reach of Higgsino in supersymmetric model with mass up to 850 GeV. We also discuss how accurately one can extract the mass, gauge charge, and spin of EWIMPs in our method. (Tomohiro Abe)

In the work (Abe-Fujiwara-Hisano-Shoji), we investigate the maximum value of the spin-independent cross section ($\sigma_{\rm SI}$) in a dark matter (DM) model called the two-Higgs doublet model + a (THDM+a). This model can explain the measured value of the DM energy density by the freeze-out mechanism. Also, $\sigma_{\rm SI}$ is suppressed by the momentum transfer at the tree level, and loop diagrams give the leading contribution to it. The model prediction of $\sigma_{\rm SI}$ highly depends on values of c_1 and c_2 that are the quartic couplings between the gauge singlet CP-odd state (a_0) and Higgs doublet fields (H_1 and H_2), $c_1 a_0^2 H_1^\dagger H_1$ and $c_2 a_0^2 H_2^\dagger H_2$. We discuss the upper and lower bounds on c_1 and c_2 by studying the stability of the electroweak vacuum, the condition for the potential bounded from the below, and the perturbative unitarity. We find that the condition for the stability of the electroweak vacuum gives upper bounds on c_1 and c_2. The condition for the potential to be bounded from below gives lower bounds on c_1 and c_2. It also constrains the mixing angle between the two CP-odd states. The perturbative unitarity bound gives the upper bound on the Yukawa coupling between the dark matter and a0 and the quartic coupling of a_0. Under these theoretical constraints, we find that the maximum value of the $\sigma_{\rm SI}$ is 5×10^{-47} cm^2 for m_A= 600 GeV, and the LZ and XENONnT experiments can see the DM signal predicted in this model near future. (Tomohiro Abe, Junji Hisano, Yutaro Shoji)

This year I investigated the following topics: constraint to the chiral invariant mass from the neutron star property, the property of heavy baryons based on the chiral partner structure, the heavy-quark spin multiplet structure of heavy pentaquarks, effect of $\mathrm{U}(1)_A$ anomaly on the mass hierarchy of light scalar mesons, and construction of a diquark effective model based on the chiral partner structure. (Masayasu Harada)

The KOTO experiment recently reported four candidate events in the signal region of $K_L \to \pi^0 \nu\bar{\nu}$ search, where the standard model only expects 0.10 ± 0.02 events. If confirmed, this requires physics beyond the standard model to enhance the signal. We examined various new physics interpretations of the result including these: (1) heavy new physics boosting the standard model signal, (2) reinterpretation of "$\nu\bar{\nu}$" as a new light long-lived particle, or (3) reinterpretation of the whole signal as the production of a new light long-lived particle at the fixed target. We studied the above explanations in the context of a generalized new physics Grossman-Nir bound coming from the $K^+ \to \pi^+\nu\bar{\nu}$ decay, bounded by data from the E949 and the NA62 experiments. (Teppei Kitahara)

The combined analysis of the BaBar, Belle, and LHCb data on $B \to D\tau\nu$, $B \to D^*\tau\nu$ and $B_c \to J/\Psi\tau\nu$ decay observables shows a $\sim 3\sigma$ discrepancy compared to these SM predictions. We investigated new physics predictions of the polarization observables which will be probed precisely at Belle II experiment. We put special emphasis on the model-discriminating power of $F_L(D^*)$ and of the τ polarizations, and especially on the constraint from the branching fraction $\mathrm{BR}(B_c \to \tau\nu)$. We had shown that the Belle II experiment can check their correlations, and discriminate among the new physics models. We also found a sum rule for the branching ratios of $B \to D\tau\nu$, $B \to D^*\tau\nu$ and $\Lambda_b \to \Lambda_c\tau\nu$ which holds for any new physics contribution to the Wilson coefficients. (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 applied on-shell methods to the bottom-up construction of electroweak amplitudes, allowing for both renormalizable and non-renormalizable interactions. We derived the most general massive three-point amplitudes and studied them in detail, as the primary building blocks for the construction of scattering amplitudes. This bottom-up analysis remarkably reproduced many low-energy relations implied by electroweak symmetry through the standard-model Higgs mechanism and beyond it. (Teppei Kitahara)

The (1,3) component of the Kobayashi-Maskawa matrix, V_{ub}, is measured as $O(\lambda^4)$, which is smaller than the expected value $O(\lambda^3)$. It is known that this can be explained in an E_6 GUT with family and CP symmetries. But we have found that this is rather generically obtained in $SO(10)$ GUT with three **16** and one (or several) **10** matter fields. (Nobuhiro Maekawa)

The relaxion mechanism is a new concept for solving the hierarchy problem. The Higgs mass term is promoted to the vacuum expectation value of a field called the relaxion and the desired electroweak scale is realized dynamically. We investigated the possibility that the relaxion has a large kinetic energy before it fixes the electroweak scale. It solves a problem of too long relaxation time without any extension of the particle contents of the original relaxion model. We found a viable parameter space, which is now around the corner of discovery. (Yutaro Shoji)

The bounce is the most important configuration in the calculation of the decay rate of a false vacuum. Since it is a saddle point of an Euclidean action, it cannot be calculated by a naive gradient flow method, which is often used for searching a minimum or a maximum. We proposed a modified gradient flow equation that converges to the bounce configuration. It is easy to implement and is also applicable to generic problems to search for a saddle point with one unstable direction in configuration space. (Yutaro Shoji)

The gauge-Higgs unification is a promising candidate of the solution to the hierarchy problem. It is defined on a higher-dimensional gauge theory and thus the theory is not renormalizable. It, however, has been argued that the Higgs potential may be free from divergences and remains finite. In fact, the Higgs potential has been shown to be finite at the one-loop level for generic models and at the two-loop level for an Abelian gauge theory. We executed the two-loop calculation of the Higgs potential for non-Abelian gauge theories and showed that it is finite at the two-loop level. We also investigated the finiteness at the three-loop level with increasing the spacetime dimension and found that a divergence coming from that of a sub-diagram. (Junji Hisano and Yutaro Shoji)

We discussed the possibility that the two Higgs doublet model remains valid up to the Planck scale.

We assume the classical scale invariance at the Planck scale and the electroweak scale is realized by technically natural small parameters. We investigated the constraints from vacuum stability, perturbativity, oblique parameters, flavor and collider searches. We find that the parameter space is small and the scenario has a good predictability. In the analysis, we utilized the state-of-art method for the calculation of vacuum decay rates at the one-loop level with the extension for multi-field scalars. (Yutaro Shoji)

We propose a simple model of radiative neutrino mass, which includes a Dirac dark matter candidate. We introduce two Dirac neutrinos and two inert doublets that are charged under a Z3 symmetry. We investigate the constraints from neutrino oscillation data, lepton flavor violations, dark matter relic abundance and direct detection of dark matter. We execute a parameter scan and find a large allowed parameter region. We also propose its extension to modular A4 symmetry. (Yutaro Shoji)

We formulate a generalization of Higgs effective field theory (HEFT) including ar bitrary number of extra neutral and charged Higgs bosons (generalized HEFT, GHEFT) to describe non-minimal electroweak symmetry breaking models. Using the geometrical form of the GHEFT Lagrangian, which can be regarded as a nonlinear sigma model on a scalar manifold, it is shown that the scalar boson scattering amplitudes are described in terms of the Riemann curvature tensor (geometry) of the scalar manifold and the covariant deri vatives of the potential. The coefficients of the one-loop divergent terms in the oblique correction parameters S and U can also be written in terms of the Killing vectors (symmetry) and the Riemann curvature tensor (geometry). It is found that perturbative unitarity of the scattering amplitudes involving the Higgs bosons and the longitudinal gauge bosons demands the flatness of the scalar manifold. The relationship between the finiteness of the electroweak oblique corrections and perturbative unitarity of the scattering amplitudes is also clari fied in this language: we verify that once the tree-level unitarity is ensured, then the one-loop finiteness of the oblique correction parameters S and U is automatically guaranteed. (Masaharu Tanabashi)

Interesting anomalies have been reported in B-meson decays, $B \to D^{(*)} l\bar{\nu}$ and $B \to K^{(*)} l^+ l^-$. They would be a good hint for new physics beyond the standard model of elementary particles, if they are real. It has been pointed out that some of vector leptoquark models may explain these anomalies in the B-meson decays. In these models, we have been studying the effect on the muon anomalous magnetic moment, where another anomaly has been reported, as well as other relevant processes, and trying to find a possibility to explain all these anomalies. (Kazuhiro Tobe)

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 2019, we apply our hydrodynamics codes to analyses of small systems as well as large systems at RHIC and the LHC. Also, we investigate possibility of existence of the QCD critical point which is the end point of the QCD phase boundary, analyzing the Beam Energy Scan experiment at RHIC. (Chiho Nonaka)

4.1.2 String Theory and Mathematics Group

Invertible transformation of fields gives an equivalent theory to the original, but gives a different description. If a transformation involves derivatives, invertibility is not satisfied generically, but in some special cases it holds. We have formulated explicitly the necessary and sufficient conditions for the local invertibility of a field transformation involving derivative terms. Our approach is to apply the method of characteristics of differential equations. (K. Izumi)

Recently it has been revealed that the fundamental symmetry of the instanton partition function of supersymmetric gauge theories is the quantum toroidal algebra. We investigated the representation theory of the quantum toroidal algebra of $\mathfrak{gl}_1$ type and succeeded in constructing the intertwining operator for the MacMahon representation whose basis is labeled by plane partitions. We compute the R-matrix from the commutation relation of the intertwining operators with a hope that we may obtain some generalization of the Macdonald symmetric functions. We also investigated an application to the theory of homological invariants (hyperpolynomials) of the Hopf link, which are realized as four point function of the intertwining operators. (H. Kanno)

Tadakatsu Sakai has worked on a holographic dual of QCD to investigate excited baryons states. So far, the holographic model captures only the lowlying baryon states with the same spin and isospins. I extend this result by studying a system that is composed of open strings and a single D-brane. The mass formula for the general baryon states is obtained by using several approximations. (T. Sakai)

Motivated by “direct observation” of a black hole, we proposed the dynamically transversely trapping surfaces(DTTS) which specify an observable strong gravity region. Then, we investigated the features of DTTS and had some demonstrations for certain examples. (T. Shiromizu)

4.1.3 Cosmology and Theoretical Astrophysics Group

The ultralight scalar fields can arise ubiquitously, for instance, as a result of the spontaneous breaking of an approximate symmetry such as the axion and, more generally, the axionlike particles and they are a natural candidate for dark matter. We propose to use the 21 cm forest observations to probe the nature of such dark matter. We explored the range of the ultralight dark matter mass m_u and f_u, the fraction of ultralight dark matter with respect to the total matter, which can be probed by the 21 cm forest. We found that 21 cm forest can potentially put the dark matter mass lower bound $m_u s 10^{-18}$ eV for $f_u = 1$, which is a three orders of magnitude bigger mass scale than those probed by the current Lyman-α forest observations. (Kiyotomo Ichiki).

Axion(-like) particles are a viable candidate for dark matter. We have proposed a new production mechanism for axion dark matter. In particular, we showed that a kinetic mixing between the axion and the inflaton can induce axion dark matter production even if the inflationary Hubble scale is smaller than the axion mass. In this framework, different combinations of the axion and inflaton fields play various cosmological roles, including generating the cosmological perturbations, reheating the universe, and serving as dark matter. The proposed mechanism tames axions that would otherwise overdominate the universe, and thus opens up new windows in the axion parameter space, including decay constants at the GUT scale and higher. (Kobayashi)

We have studied several models of the modified gravity, dark energy, and inflation. In order to clarify what kind of model could be realistic, we have investigated the propagation of the gravitational waves in several models. In one of these works, we clarified the affect of the viscosity of the cosmic fluid. In other works, we investigated the models where the scalar field coupled with the gravitational Chern-Simons term in the frameworks of the Einstein gravity and F(R) gravity and we find the difference between the right-handed mode and the left-handed mode of the gravitational wave. As a model of the dark energy, the holographic model has been investigated by several researchers and we applied the holographic model to the inflation. We also proposed and investigated a model of the dark energy where the cosmic fluid obeys the Tsallis statistics. Furthermore we have proposed several models and invesitigated their realities. (Shin’ichi Nojiri)

We investigate the effects of primordial non-Gaussianity on the formation of the primordial black holes (PBHs). We find that the abundance of PBHs can be enhanced/reduced by positive/negative non-linearity parameter. In addition, we show that PBH clustering could never be induced for the Gaussian primordial curvature perturbations, while it can be enhanced by the so-called local-type primordial trispectrum. We obtain a new observational constraint on the abundance of the PBHs with planetary mass, and propose a new multi-phase inflationary model which can simultaneously explain dark matter and LIGO BHs by PBHs. We investigate the effect of the modified theory of gravity in large scale structure. We derive a new limit on the non-Gaussian feature of primordial magnetic fields by closely investigating the diffusion of the primordial magnetic fields in the early Universe (Yokoyama).

4.1.4 Computational Theoretical Physics Lagoratory

Numerical calculations are also essential to theoretical research. The supercomputer "Phi," introduced at KMI in 2012, was used for large-scale numerical calculations in particle physics throughout Japan. After its shutdown in 2015, a cluster system in KMI was used as backup, and even at present, research results based on these data are published. We plan to investigate the properties of quarks and gluons under conditions of high temperature and density and mechanism of phase transition in quantum chromodynamics (QCD) using PC clusters. High-precision experimental data of high-energy heavy-ion collisions, development of theory, and advancement in the performance of computers enable us to quantitatively understand various aspects of QCD.

4.2 Division of Experimental Studies

4.2.1 Flavor Physics Group

• B and tau physics at Belle and Belle II

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 excess 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 universality" may be violated in NP models, such as the charged Higgs and the lepto-quark model. Members from Nagoya have contributed to the Belle analyses in the past years, in particular on the measurements with semileptonic tags, and also with hadronic tags and the hadronic τ decay modes ($\tau \to \pi\nu, \rho\nu$), where the latter (PRD97, 012004) enabled to measure the ratio of the branching fraction;

$$R(D^*) \equiv \frac{\mathcal{B}(B \to D^*\tau\nu)}{\mathcal{B}(B \to D^*\ell\nu)} = 0.270 \pm 0.035(\text{stat.})^{+0.028}_{-0.025}(\text{syst.}) \tag{4.1}$$

and also the τ lepton polarization $P_\tau(D^*)$ for the first time;

$$P_\tau(D^*) = -0.38 \pm 0.51(\text{stat.})^{+0.21}_{-0.16}(\text{syst.}). \tag{4.2}$$

Although the error is still large, our work demonstrates feasibility of such measurements at the forthcoming SuperKEKB/Belle II experiment.

The SupperKEKB/Belle II experiment provides unqiue opportuities for critical test of SM and search for New Physics with variety of channles in B and τ decays. At Nagoya, we are working not only the $B \to D^*\tau\nu$) decays, but also the measurement of CP violation in penguin decays such as $B \to \phi K_S$, and the Lepton-Flavor-Violating τ decays.

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. Such hadron spectroscopy is also our target at the Belle II experiment. In particular, we are studying possibility to measure;

- Absolute branching fractions of $X(3872)$ production from the B decay: $\mathcal{B}(B \to XK^+)$

- Absolute branching fraction of $X(3872)$ decays to particular decay modes: $\mathcal{B}(X \to f)$
- Total width of $X(3872)$ as well as the lineshape in the $X(3872) \to DD^*$ decays

We are also working on the measurement of the e^+e^- cross section using initial state radiation. The precise results of the e+e- cross section will be crucial inputs to estimate the hadron vacuum polarization effects, and thus to improve the SM prediction of the anomalous magnetic moment of the muon, which presently has about 3.5σ deviation from the SM value.

The SuperKEKB/Belle II experiment has stated physics data taking with all subdetector components installed since March 2019. Now we are studying feasibility of the above measurements at Belle II based on Monte Carlo simulation. We are also working on analyses of the real data collected by summer 2020, and have obtained some highlight results including rediscoveries of $B \to \phi K^{(*)}$, as shown in Figure 4.2.1.

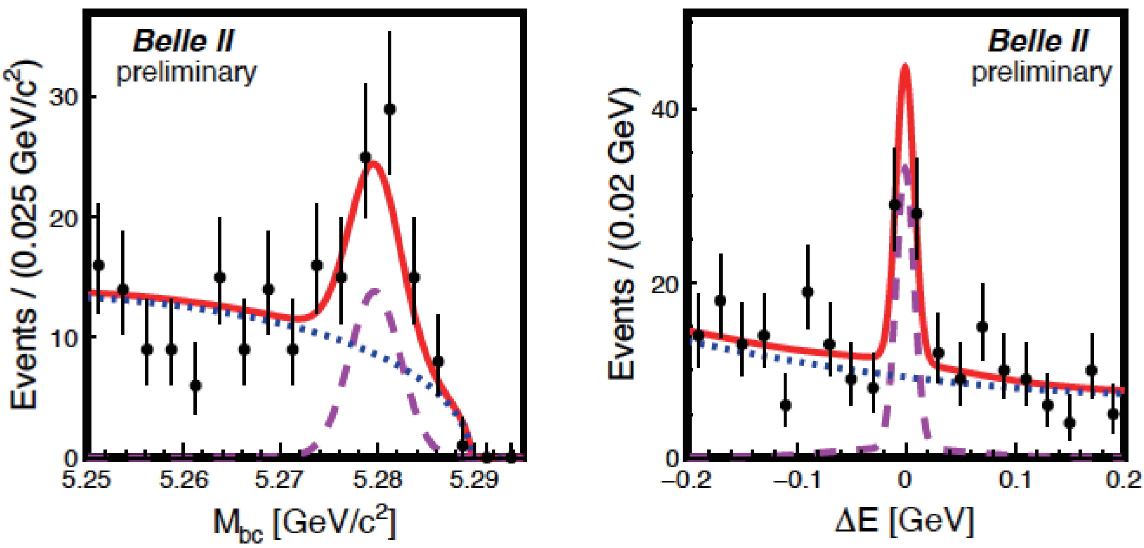


Figure 4.1: The signal of the $B \to \phi K^{(*)}$ decay obtained from the Belle II physics data, collected by summer 2020.

- **ATLAS**

KMI achievements in 2019 at the energy-frontier LHC-ATLAS experiment

Our aim in the LHC-ATLAS experiment is to understand the origin of mass through the measurements of the Higgs boson, and to detect new particles arising from physics beyond the Standard Model such as supersymmetry and other exotic signatures. The LHC-ATLAS "Run-2" period in 2015-2018 finished successfully, collecting 140 fb^{-1} of proton-proton collision data at a centre-of-mass energy to $\sqrt{s} = 13$ TeV. This world-highest-energy allowed us to explore heavier new particles with significantly improved sensitivities and also to measure the Standard Model (SM) processes including the Higgs-boson properties more precisely using even higher-statistics data samples than ever. In 2019, the KMI ATLAS group released three flagship physics results with the full Run-2 dataset, on direct searches for super-symmetric SUSY particles, on new Higgs-boson beyond the SM, and on the Higgs coupling measurements. We lead the technical developments in trigger software and hardware for data taking.

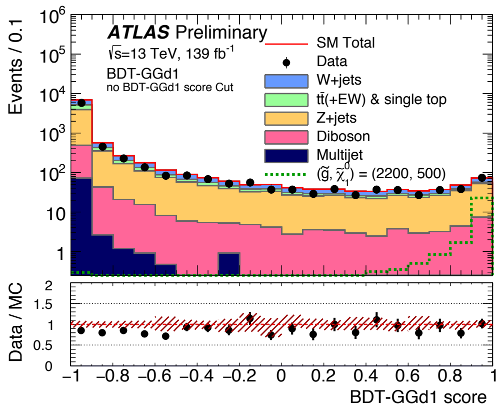
Physics achievements

(1) SUSY searches
Since the start of Run-2, we primarily focus on inclusive gluino search in all-hadronic final states as an analysis coordinator, since the gluino mass is indicated to be light enough (in the framework of "Naturalness" theory) to be discovered using the Run-2 dataset and also this analysis has been considered as one of the flagship analyses in tens of the LHC SUSY analyses. To conclude on this search using high-statistics 140 fb^{-1} pp collisions, we have developed two kinds of state-of-the-art analysis methods (the one based on Machine-Learning as demonstrated in Figure 4.2(a), and the other on some proper statistical fits). These allow us to separate signals and backgrounds effectively and extend sensitivities to any signal masses in target. We released this result in 2019 August. No significant differences were found between the number of observed events and the Standard Model predictions in the signal-enriched regions. An exclusion limit at the 95% CL on the mass of the gluino is set at 2.35 TeV for a simplified model considering only a gluino and the lightest neutralino, assuming the lightest neutralino is massless. For a simplified model involving the strong production of mass-degenerate first- and second-generation squarks, squark masses below 1.94 TeV are excluded if the lightest neutralino is massless. These limits substantially extend the region of supersymmetric parameter space previously excluded by the similar previous ATLAS results.

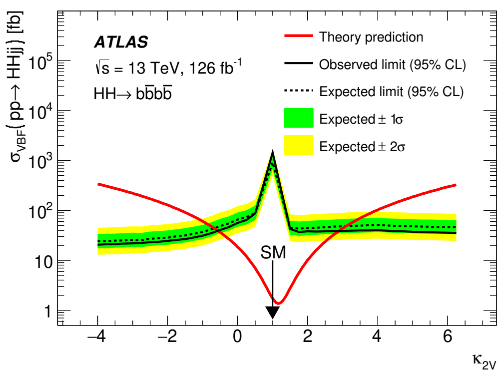
(2) Di-Higgs production searches
Search for additional Higgs bosons beyond the Standard Model is another promising way of New Physics search using the energy-frontier LHC. In 2017, KMI has started new activity on such searches for Higgs pair production (in the 4 b-jet final state, as a an analysis coordinator), initially for heavy neutral Higgs search beyond the SM using the Run-2 dataset and later for the Higgs self-coupling measurement (and the shape of the Higgs potential) using huge amount of dataset in the HL-LHC era from 2026. In the SM, the event rate is too small to be observed but with New Physics contribution the rates can visible. With a Nagoya PhD student, we have developed completely new analysis focusing on the Vector-Boson Fusion (VBF) process, which has different sensitivity to the existing analysis on the gluon-gluon fusion production and a unique access to the coupling of two vector-bosons and two Higgs bosons (a parameter called $\kappa 2V$). We released new result in 2019 July. No hints of deviations from the Standard Model or new particles were observed, but the new ATLAS result probes a yet-untested property of the Higgs boson's interaction with weak bosons. It provides the first constraints on the $\kappa 2v$ coupling to be between –0.56 and 2.89 times the value predicted by the Standard Model, as demonstrated in Figure 4.2(b). With a new Nagoya PhD student, we started a new analysis dedicated to the ultimate understanding of the Higgs self-coupling in the gluon-gluon fusion process, aiming for the result releases in late 2020 and 2021.

(3) Higgs coupling measurements
Complete understanding of the Higgs couplings and searches for any possible deviations from the SM predictions is also one of the extremely important topics in the Run-2 period after several years since the Higgs discovery. We have contributed to the observation on direct interaction of the Higgs boson with top quark in 2018 July, as well as the succeeding observation of the Higgs boson decaying to two b-quarks. All these coupling measurements of the Higgs boson to fermions well match with the SM predictions as a function of fermion mass. In 2018, we started a new activity with a Nagoya PhD student to provide new Higgs-coupling measurement with muon as the second-generation fermion. We made a number of analysis improvements, for instance, increasing signal efficiency and improving the reconstructed Higgs mass-resolution with saving the final-state-radiation events, as demonstrated in Figure 4.2(c). We released a new result in 2019 August. No significant excess of events above the measured background was observed in the signal region around the Higgs boson mass of 125 GeV.

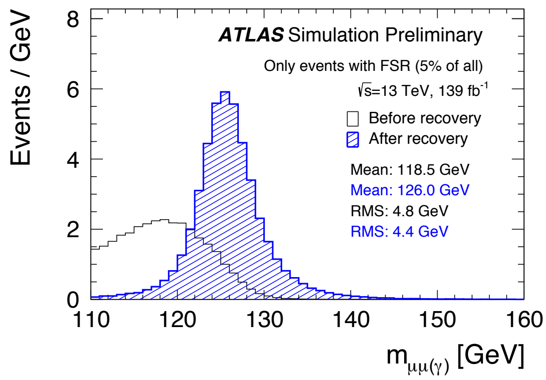
The observed signal significance is 0.8 standard deviations for 1.5 standard deviations expected from the Standard Model. An upper limit on the Higgs boson production cross section times branching fraction to muons was set at 1.7 times the Standard Model prediction at 95 % CL. This new result represents an improvement of about 50 % with respect to the previous ATLAS results.



(a)



(b)



(c)

Figure 4.2: (a) Observed BDT score distributions for the signal region dedicated to a heavy-mass gluino search obtained after applying the selection criteria except for the BDT score requirement. (b) Observed and expected 95% CL upper limits on the production cross-section for non-resonant HH production via VBF as a function of the coupling parameter of two vector-bosons and two Higgs bosons, $\kappa 2V$. (c) Invariant mass of $\mu\mu(\gamma)$ final states for signal simulated events with a reconstructed FSR photon candidate. The black and blue histograms represent the distributions before and after the FSR recovery, respectively.

Trigger achievements

(1) Hardware

KMI keeps playing a main role in the operation and maintenance of the muon trigger system with the thin gap chambers (TGC), which covers the pseudo-rapidity range 1.05< $|\eta|$ <2.4. We continue our efforts at the calibration and the alignment of the TGC chamber, which are essential to provide good quality physics data collected with the muon trigger.

High-luminosity LHC (HL-LHC) starting from 2027 is planned to increase the luminosity by a factor of about 10 comparing with the current LHC in order to provide more precise measurements of Higgs boson properties and more sensitive searches for new physics beyond the SM. ATLAS detector, trigger and data acquisition (DAQ) systems are being upgraded to cope with the higher radiation, the higher detector occupancies, and the higher data-taking rate for the HL-LHC (called phase-II upgrade). In this year, we contributed to design, produce and test the front-end board and the digital-end trigger board of the TGC for phase-II upgrade. The quality assurance and quality control system for 26,000 real Patch-Panel ASIC chips which are mounted on the front-end board of TGC. From the gamma-ray and neutron irradiation tests of optical transceiver modules, which were performed at the Cobalt 60 gamma-ray irradiation facility in Nagoya University and the Tandem electrostatic accelerator in Kobe University respectively, we decided to start the design of the real front-end board. We also developed new firmware of the readout system of the TGC data and the TGC trigger algorithm based on track finding, using the evaluation kit with Xilinx Virtex UltraScale+ FPGA. The performance of these firmwares was shown to be comparable to what was expected by simulation study. The design of the digital-end trigger board of the TGC is on going.

(2) Software and Menu (trigger selections)
KMI has been leading the software-based muon trigger development as a coordinator. We have been upgrading the current muon-trigger software from a single- to a state-of-the-art multi- threading technique for Run-3 (starting in 2021), in the context of a big-data software-development campaign in ATLAS (considered as the biggest software change during next decade). We successfully finished the code migration and validation. We demonstrated the performance of this framework update for the coming commissioning. For the coming Run-3 period with even higher luminosities, in the current Long-Shutdown period 2019-2021, we are improving the muon trigger system by utilizing new hardware components in the ATLAS detector (on more sophisticated tracking and muon information at trigger levels) and improving the trigger selections for the continuous success of the ATLAS physics program.

• Fundamental Astroparticle Physics

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

The enhancement of the violation of time-reversal symmetry is predicted in the neutron capture reaction for some nuclei. The enhancement depends on the resonance parameters and spin states of the nuclei. We successfully estimated the enhancement factor for ^{139}La as a target candidate at the order of 10^6 by measuring angular correlation terms of (n, γ) reaction. We are continuing to take the data for ^{115}In, ^{117}Sn, ^{131}Xe, and so on, by using germanium detectors in ANNRI neutron beam line in Material and Life Science Experimental Facility (MLF) at J-PARC. A new ^{3}He neutron spin filter and the magnetic field are installed into the beam line to extract the polarized epithermal neutrons and to keep the polarization to the sample position. The neutron polarization was about 25% at 0.75 eV. The neutron helicity dependence of the absorption cross section of ^{139}La, which is known as the enhanced parity violation, was reconfirmed with high energy resolution. We also started to measure the other angular correlation terms with the polarized neutrons. They can provide the detailed information about the compound resonance reactions. These results showed the feasibility of the T-violation search experiment with high sensitivity, which can be reach to that of neutron EDM and which has different systematics. Theoretical description of the phenomena is started to discuss with theory groups. Now we can discuss the detailed design of the T-violation search experiment by using nuclear resonance reactions. For the T-violation search experiment, the polarized nuclear target must be prepared. A $LaAlO_3$ single crystal, which has the perovskite structure, is a candidate for polarized target. The collaboration study started to fabricate the large scale of the crystal with

Tohoku University. Dynamical nuclear polarization system are developing with Osaka University. International collaboration is also expanding.

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. Neutron lifetime measurement with pulsed beam is continuing at NOP beam line. The well-defined bunches is injected into time projection chamber (TPC). The TPC detects both of the electrons from neutron beta decay and the nuclear reaction by ^{3}He in order to estimate the flux at the same time. The improvement of the upstream beam optics is required for the accuracy of the order of 0.1% . The beam transport devices were developed and tested at J-PARC and Kyoto University Research Reactor. They will be installed into the NOP beamline in near future.

New types of experiment with neutrons are also discussed. 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 scattering cross section ratio of noble gases were measured by using neutron small angle neutron scattering technique. Dynamical diffraction in perfect crystals were studied for both of a search for neutron electric dipole moment and a search for unknown force.

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 2019 we finalized the result for spin asymmetry measurement of forward neutral pion production at RHICf. The surprising large transverse asymmetry discovered in the forward neutral pions at the low transverse momentum region less than a few hundred MeV seems to connect smoothly to the region with larger transverse momentum larger than GeV. This observation would suggest that a one-pion exchange process accounts for the very forward particle productions, which also accounts for the transverse asymmetry of larger transverse momentum region where a parton model is believed to describe the asymmetry. The result is going to be published. We also proceeded the analyses of data taken with $\sqrt{s}$=13 TeV p-p collisions and the combined analysis with ATLAS which covers the central rapidity regions.

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

- Super-Kamiokande (SK) is the 50-kton water Cherenkov detector underground of the Kamioka Observatory, Gifu dedicated for observation of neutrinos and possible proton decay. SK is preparing for the observation of supernova relic neutrinos emitted by all of the supernova explosions by adding gadolinium (Gd) to the pure water in the detector. In 2019 preparation of Gd-water system has been completed and the detector is ready for Gd-loading operation, which is so far suspended due to the COVID-19 situation. An analysis effort for neutrino/anti-neutrino separation technique using decay-electrons or tagged neutron information have been carried out. A new analysis on non-standard neutrino interaction through atmospheric neutrino oscillation is also undergoing. We have also started real-time analysis with gravitational wave alerts to look for possible coincidence of neutrino events in SK. Besides the efforts, we have started intensive efforts to develop a new atmospheric neutrino flux modeling code to refurbish the Honda-model to cope with the newest hadronic interaction models

- Hyper-Kamiokande (HK) is to the next generation of large-scale 260-kt water Cherenkov detectors with nearly 8 times larger fiducial volume. We have been making continuous effort to contribute staring and promote the project by giving intensive seminars in overseas institutions (4 Taiwanese institutions in April and 4 Australian institutions in May). Since the beginning of 2020, the project has been officially approved by the government and proceeded to a big milestone for the construction phase.

- The XMASS experiment is a direct dark matter search using a single-phase liquid xenon detector. In February 2019, the experiment had completed data taking. Analysis works is going on to finalize the final results on dark matter searches by using a few years of continuous operations.

- The XENON experiment at LNGS in Italy aims at detecting the tiny amount of charge and light that is emitted after the interaction of a dark matter particle with a xenon nucleus. The third phase of the XENON experiment, XENON1T, was the largest LXe time projection chamber (TPC) ever built with ∼3 tons of xenon, of which ∼2 tons are in the active volume of the detector, allowed the sensitivity to be improved to the levels never explored, becoming the most sensitive detector in the world for the direct dark matter detection. In 2019, we performed a dedicated search for low-mass dark matter with masses down to about 85 MeV by looking for electronic recoils induced by the Migdal effect and Bremsstrahlung. This analysis significantly enhances the sensitivity of XENON1T to light dark matter previously beyond its reach. XENON1T detector was decommissioned in 2019 to begin the construction phase of its successor, XENONnT. The XENONnT foresees an upgrade of the current detector with the aim of extending the sensitivity of the experiment by a factor of 10. Such a performance can be realized by increasing the size of the target medium (to ∼8.4 tons of xenon) and a stronger reduction of the background. We are contributing to the construction of a purification system for liquid xenon, veto systems of the neutron background and analysis of acquired data. For future direct dark matter experiments with 50 tons of LXe, we are also developing several key technologies such as a new SiPM with less dark-noises, hermetic quartz chamber, and transparent resistive thin-film.

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

Cosmic gamma rays are expected to be produced through interactions of dark matter, CRs, and the interstellar medium. It makes gamma rays good probes to search for dark matter and to investigate the properties and distributions of CRs and the interstellar medium. We are developing the next-generation gamma-ray observatory, the Cherenkov Telescope Array (CTA), to observe cosmic gamma rays in the energy range from well below 100 GeV to above 100 TeV. We are in charge of the development of silicon photomultipliers (SiPMs) for the Gamma-ray Cherenkov Telescope (GCT), which is one of three telescope designs for small-sized telescope (SST) in the CTA. The GCT camera was down-selected for a camera of the SST and we are now in charge of the SiPM procurement and calibrations. Meanwhile, we studied detailed properties of the origin of the optical crosstalk of the SiPM where the optical crosstalk produces additional signal to the incident photon signal. We found that we have relatively high rate of the delayed crosstalk which requires further careful studies of its effects. We also studied the feasibility of replacing the photomultipliers (PMTs) with SiPMs for the medium-sized telescopes (MSTs) of the CTA. Originally, the PMT was selected as it was less expensive for covering the area required for the MST camera. Since the SiPM cost became comparable to the PMT cost, the SiPM became an attractive alternative because it can operate under the moonlight, which can double the observation time of the MST. The simulation studies combined with experimental verification at several wavelength found that the SiPM can collect 62 % more signal photons while collecting 6.53

times more background photons compared with PMT. Since the signal tends to be blue while the background tends to be red, the simulation found signal and background photons for the SiPM can be similar to the PMT with proper color filtering. These results confirmed that we can use the SiPM for the MST.

Directional Dark Matter Search

Direction sensitive search is new promising methodology for direct dark matter detection and its identification. However, expected nuclear recoils due 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 consist of 12 institutes, 5 countries. Current main experimental site is the National Laboratory of Gran Sasso (LNGS), Italy, and R&D and data analysis site 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 in KMI. And also, new readout systems to obtain nano-scale direction information continue to develop in KMI and Italian group, and those systems are also very unique one in this experiment. In this year, we start demonstration for data analysis and scanning data using 1 g scale target mass. Current scanning speed achieved 3 g/month, and electron background rejection power was better than 1E-3 or more. This system will be utilized in first dark matter experiment in underground. NEWSdm facility in LNGS have been mostly constructed, but ventilation system and around infrastructure are under constructing yet. In end of 2018, new self-device production machine have been installed in the LNGS underground site, Hall-F.

In 2019, first device self-production and its quality checks have been started. We succeeded to produce NIT emulsion gels and usable for experiments. While the random noise level of the first batches of produced emulsion are not yet satisfactory compared with the one in produced at Nagoya University and de-bugging the problem is on going. So far, detection performace of short recoil tracks were demonstrated with tracks by nuclear ions injected from surface of nuclear emulsion and the tracks exist only the surface region. This year monochromatic energy neutron beam exposure at Advanced Industrial Science and Technology (AIST) are conducted to demonstrate the track detection with more realistic nuclear recoils by dark matter, thanks to neutron's penetrating feature recoils inside nuclear emulsion layer can be investigated. The results with analysing proton recoils (length longer than 2 um) are summarized in a Master thesis (Todoroki) in 2019 together with surface neutron background measurement. The analysis of C,N,O recoils (length bellow several 100 nm) by neutron beams have been started and currently background from gamma rays subtraction is under study. A realistic optical simulation tools on track made by developed silver grains were developed and we got good parametrization values to re-produce recoil track data taken by optical microscope. After getting efficiency by AIST neutron data, we are planning to apply the efficiency for dark matter search on ground / under ground exposed NIT samples.

Nuclear Emulsion Technologies

Nagoya university is one of the most powerful institute with nuclear emulsion development and research with in the world. In recent years, the applications of emulsion films have expanded more and more not only in particle physics but also in various imaging fields, and the demand is growing as order of 1000 m^2/year. The upgrade of emulsion gel/film facility operating at Nagoya University is in progress to promote further research activities. In 2019, a large-scale gel production machine has been newly installed. The system has the capacity to produce 20-kg emulsion gel, which corresponds to approximately 10-m^2 emulsion film, in one-day operation. Currently, various construction works (cabling, tubing, calibration of instrument, waste liquid equipment, etc.) for practical operation are in progress. In addition, in order to achieve the capacity of the film production that is compatible with that of the gel production, the automated coating machine applying the roll-to-roll system has been installed. The system enables to pull film from a roll, continuously coat emulsion gel on the surface, dry online, and wind the film onto another reel at the end. In 2019, we started to introduce devices to the laboratory in order, and completed the installation by March 2020. These new facilities are scheduled to complete maintenance and adjustment in June–July 2020, and to start operation in mass production from July–August 2020.

Also our emulsion scannig facility is assuming role of the center of nuclear emulsion analysis for particle physics ,muon radiography and other applications. The HTS-1 is the world fastest emulsion scanning system, however, the 2nd generation system, HTS-2, is under developpment. The almost component (e.g., optics, new mechanics, imager system and so on) has been validating. The commissioning of the HTS-2 will be started in 2020.

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. The recent upgrade of PTS has been achieved 5 times of throughtput as last year version. A new illuminator has 4.3 times light intensity and a narrow spectrum, which make possible enlarge field of view and accept faster frame rate of CMOS image sensor. Another progress is 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 next upgrade is planed that a much higher frame rate image sensor and image processing, which will make possible kg-scale experiment with a few 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 mount of data. However, observation remains difficult owing to the lack of the 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 2019, we proceeded the flight data analysis of the last balloon experiment (GRAINE 2018), which was performed in April 2018. Event selection, energy reconstruction, timestamp, and arrival-direction determination were completed using 98 % of accumulated data. As a result, we succeeded in the first detection of a celestial gamma-ray object, Vela pulsar, via the balloon-borne emulsion telescope. The expanse of gamma-ray image in the 100-MeV region is $\sim 1^\circ$, which is the expected performance of our telescope, and the world's highest angular resolution was demonstrated.

The next balloon experiment (GRAINE 2021) is approved by JAXA and scheduled in April 2021. The aperture area of the telescope is enlarged to 2.5 m^2 (as 6.6 times large as that of GRAINE 2018) and two telescopes will launch from Alice Springs, Australia. The experiment aims at observation of Vela pulsar, Geminga pulsar, the galactic center, etc. in GeV energy region, and survey of transient phenomena by a largest aperture area telescope. Now, we are newly constructing a large-scale emulsion gel production system and a film coating system at the laboratory. In 2020, for GRAINE 2021, we will manufacture 500 m^2 of emulsion plates using these facilities, and develop a large pressure vessel gondola that can mount a 2.5-m^2 telescope.

Study for Neutrino Physics using Nuclear Emulsion

1) Experiments related to tau neutreino physics, **DsTau, SHiP, FASERν**

Tau neutrino is the one of the least known standard model particle. It is due to large uncertainty of its production and difficulties on detection and identification. So far tau neutrino-nucleon interaction cross section has large error of several tens % and we, DsTau, SHiP, are aiming to measure it within10% accuracy.

DsTau experiment aims to study the tau neutrino production with CERN SPS 400 GeV proton on tungsten 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 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 bellow 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 **NA65 for data taking with CERN SPS in 2021-2022.** The emulsion film scanning of 2018 pilot run have been finished at Nagoya University F-lab and proton interactions and decay vertices reconstructions are on going. Several hundreds of charm pair associating proton tungsten interactions are collected from the reconstructed events data. In 2021 the emulsion detector production at Nagoya University is scheduled for the physics run in 2021.

SHiP experiment is planning to expose tau neutrino from 2028 and currently 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) have emulsion films as tracking device with low density spacer 1.5 cm. The CES performance tests have been conducted with changing several base materials. As the result the glass base or solid thicker base make the distortion of emulsion plates smaller and then better performance on momentum resolution. The large scale performance tests are planed for 2021- .

FASERν is a new project data taking in 2021-2024 and later aiming to study high energy neutrinos from the ATLAS collision point at 480m away in forward direction. 1.2tons of neutrino Emulsion Cloud Camber (ECC) detector using tungsten plates as neutrino interacting target interleaved with nuclear emulsion will be mounted in the TI12 tunnel. Currently analysing a pilot run data with two small ECCs total mass of 15kg, the emulsion film scanning have been finished, and search and analysis on neutrino interaction vertices is under finalizing. In 2020 the emulsion detector production at Nagoya University and construction is scheduled.

The NINJA experiment at J-PARC

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 sub-multi GeV energy region. Furthermore recently 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 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 or dark matter or dark radiation. But MiniBooNE signal is not concluded as an evidence of sterile neutrino because there is possibility that it comes from 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, study of sub-multi GeV neutrinos is a key to open physics beyond the Standard Model.

The NINJA experiment aims to measure neutrino-nucleus interactions precisely and search for sterile neutrino at same physics condition in MiniBooNE with different detector and accelerator at J-PARC. Thanks to excellent position resolution of the emulsion detector which is main detector in NINJA, we can measure 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 because of too low energy in 2019. These results were reported at several international conferences and near future the papers will be submitted. Then we successfully implemented neutrino beam exposure with a 250 kg large mass detector (iron:130 kg, water:75 kg, emulsion:30 kg, CH:15 kg) from Nov. 2019 to Feb. 2020 as our 1st Physics Run. Currently the emulsion scanning has been started and the expected number of neutrino events is more than 10,000 events. We will analyze these neutrino events to understand sub-multi GeV neutrino interactions and feedback to make a more concrete plan for the next step, sterile neutrino run.

Finally T. Fukuda (Nagoya Univ.), the spokesperson of NINJA Collaboration, was invited to give a talk for the status and prospects of NINJA in the ESSnuSB annual meeting held at Zagreb in Oct. 2019. ESSnuSB project is one of largest long baseline neutrino oscillation experiments to determine the value of neutrino CP phase after Hyper-Kamiokande project in Europe and the discussion about the research cooperation with precise data of neutrino-water interactions taken in NINJA and consideration to install a large NINJA detector as near detector of ESSnuSB has been started.

4.2.2 Origin of Spacetime Structures Group

Progress on the X-ray observatory XRISM

XRISM (X-Ray Imaging and Spectroscopy Mission, Fig.4.3 left) is a JAXA-lead X-ray astronomy satellite, to be launched in JFY 2021. Based on the heritage of the “Hitomi” X-ray observatory launched on 2016, XRISM focuses on its soft X-ray super high resolution spectroscopy with an energy resolution of ∼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.

Preparing for FY2021 launch, now XRISM is in the process of the flight model (FM) production and integration. Its first observation program in the performance verification (PV) phase is now under the process of selection. Uxg members are contributing in defining the operation system and user support organization, as a member of science operations preparation team.

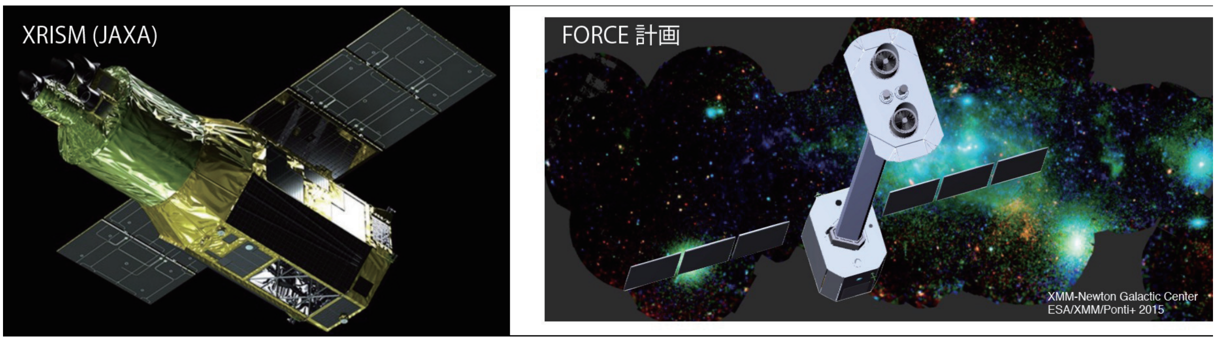


Figure 4.3: (left) Artistic impression image of the XRISM mission. (right) That of the future FORCE mission.

Future wide-band X-ray observatory plan, FORCE

The FORCE (Focusing On Relativistic universe and Cosmic Evolution, Fig.4.3 right) mission is a wide-band fine imaging probe in 1-80 keV, proposed for launch around late-2020s. The main science aim is to probe the hidden black-holes in the universe, and measure the non-thermal components in SNRs, clusters of galaxies and other objects. It is planned to use the pored-Si-based optics with hard X-ray super mirror coating, and combine it with the flight-proven low-background hard X-ray imaging spectroscopy detectors onboard Hitomi, modified to improve lower energy band coverage. The super mirror coating originates from Nagoya University, and the configuration desing of the satettelite and detector are lead by Nakazawa.

In JFY2019, further refining of the mission design with industry, and detector technology development were performed. We also held a work-shop dedicated for SNR and other science cases with FORCE. Another small science meeting was held with the team member of US and Japan-side FORCE group. In February 2020, the FORCE team submitted a proposal for small science satellite mission to JAXA/ISAS.

Data analysis of observations performed via existing X-ray observatories

Within the Uxg group, science data analysis activity on X-ray observations of clusters of galaxies and star-originated X-rays were performed. An example of them is an X-ray data analysis of a merging cluster CIZA J1358.9−4750. The cluster is in the early phase of its merging and a hot region of its intra-cluster medium (ICM) in between is just being developed. Kato and Nakazawa et al. (2015) has identified a narrow "post shock region candidate" using the data obtained by the *Suzaku* satellite. By using the high statistics XMM-*Newton* data, we identified the second "shock or discontinuity" candidate to the north of the already discovered region. This new finding suggests that the merger-affected ICM region is more wider and contains a bit complicated structures. These structures will give us rich information to understand the exact situation of the early phase of cluster merger.

Thundercloud gamma-ray observations

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. The collaboration is named GROWTH, and includes scientists from Kyoto University, the University of Tokyo, JAEA, and us.

In early 2018 at Kanazawa city, we observed a gamma-ray glow, a minute-lasting gamma-ray emission originating from the cloud itself, eventually terminated later. Our gamma-ray detectors also detected a downward TGF (Terrestrial Gamma-ray Flash), a < 1 ms flash of MeV gamma-rays, and Low-Frequency (LF) sensors of our collaboration identified lightning discharges related to the TGF, the moment when the long burst was terminated. The gamma-ray glow showed steep rise of its countrate a few seconds before the termination, which is a behavior first observed. Possible multiplication mechanism of electron acceleration in thunder cloud is discussed. Another important achievement in JFY2019 is identifying the total dose distribution of a downward TGF observed in Kashiwazaki-Kariwa power plant at Nov. 2017. By using Geant4 simulation compared with ionization-chambers' data, we concluded that the dose reaches 1.4 μGy, which is as strong as a half of a chest X-ray photo. This also means the downward TGFs we observed has a comparable flux to the TGFs observed from orbit.

In addition to these data analysis, we continued observation work from Nov. 2019 to March/April 2020 in both Kanazawa city and Kashiwazaki-Kariwa plant. Among them, we developed a new collimated gamma-ray detector system to locate the altitude of the accelerator. The system includes new housing structure to endure harsh environment of winter there. Data analysis of JFY2019 campaign is ongoing.

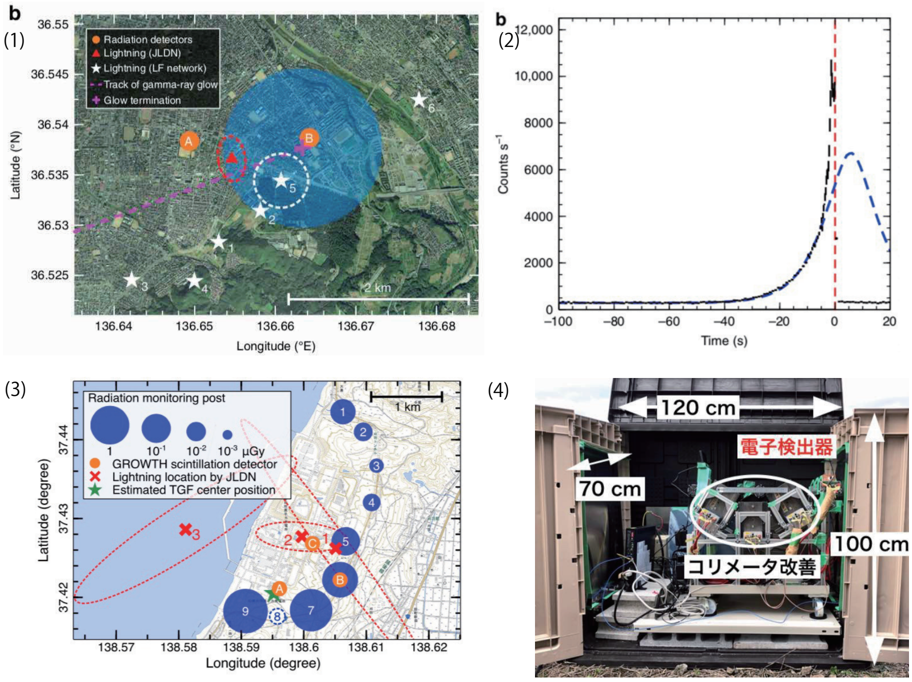


Figure 4.4: (1 and 2) Event in Jan. 2018, at Kanazawa city. Map and orientation of our gamma-ray detectors (A and B) and locations of lightning discharges (1-5). (from Wada et al. Communication Physics 2019) (3) Event in Nov. 2017 at Kashiwazaki-Kariwa power plant. Radiation dose distribution observed by the monitoring posts of the plant are shown in blue circles. (from Wada, Enoto, Nakazawa et al. PRL 2019) (4) New collimated gamma-ray detector deployed to Kanazawa city in Nov. 2019.

Development of new technologies to detect primordial gravitational waves

Space gravitational wave antenna DECIGO is the future Japanese mission aiming mainly at the detection of primordial gravitational waves. DECIGO consists of three spacecraft, whose distances are measured by Fabry-Perot interferometers. Since the target sensitivity of DECIGO is limited by quantum noise, the further reduction of it is essential to ensure the detection of the primordial gravitational waves. We have been developing the quantum locking technique to pursue this aim. The quantum locking employs two sub-cavities, which control the DECIGO main cavity to reduce the quantum noise. In 2019 we developed a new method to optimize the quantum noise of the interferometer with the quantum locking using the square completing method. We also built a Fabry-Perot cavity for the preparation of the experiment to demonstrate the effectiveness of the quantum locking technique.

Another technique we have been developing is the displacement-noise-free neutron interferometer. We invented the displacement-noise-free laser interferometer previously. It cancels all the displacement noise of the mirrors in a laser interferometer with gravitational wave signals remaining. However, this method is only effective above a frequency determined by the size of the laser interferometer, because the light is too fast. Therefore, we have been developing the displacement-noise-free neutron interferometer, because the speed of the neutron is much slower than light. In 2019 we theoretically demonstrated that this method is truly effective at lower frequencies. We have also been designing an experiment to demonstrate the effectiveness of the displacement-noise-free neutron interferometer.

4.2.3 Instrument Development Laboratory

Operation of the TOP counter in the Belle II experiment

The TOP (Time-Of-Propagation) counter is a novel ring imaging Cherenkov de-tector for particle identification (PID) in Belle II. It reconstructs Cherenkov "ring" image by measuring the time of propagation of Cherenkov photons. Sixteen modules of the TOP counter are located in the barrel region of the Belle II detector. Each module mainly 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 started the physics data taking with the full detector components in March 2019. We took initiative of the operation of the TOP counter, in particular in terms of the MCP-PMT. We prepared monitors of the gain, hit rate, accumulated output charge, and relative quantum efficiency (QE) of the 512 MCP-PMTs for the sake of stable operation. The accumulated output charge and relative QE are important for longevity of the MCP-PMTs because the photocathode is deteriorated by outgassing from the MCPs caused in the electron multiplication process. The hit rate is dominated by the beam background, which is attributed mostly to Touschek and Coulomb scattering processes at this moment. It is required to be less than 1.0 MHz/PMT to suppress the QE degradation within an acceptable level until we accumulate the goal of 50 ab^{-1}. However, the actual hit rate is already close to the limit. The beam background level for the TOP counter is higher by one or two orders of magnitude than expected by a Monte Carlo simulation. Therefore, it is a big challenge to increase the peak luminosity while keeping the beam background below the limit.

We had dedicated beam background studies, which revealed that the dominant component of the beam background for the TOP counter was the Coulomb scattering in the positron ring. Further vacuum scrubbing of the ring, studies of the beam collimators, and the accelerator optics tuning are necessary to reduce it.

The 224 conventional MCP-PMTs installed in the seven TOP modules have to be replaced with the life-extended ALD MCP-PMTs in the summer of 2022. That is because they have a short lifetime and the QE will drop significantly in this sever beam background. For the replacement, we produced 176 life-extended ALD MCP-PMTs. The performance of all the MCP-PMTs was inspected in test benches at Nagoya. The one in 1.5 T was also checked for about 50 MCP-PMTs using a dipole magnet at KEK. We sampled several MCP-PMTs from different batches and measured their lifetime. It was found that about 70 MCP-PMTs produced in the first batches seem to have a shorter lifetime than we expect. That is probably due to a trouble in the MCP-PMT production line. Those 70 MCP-PMTs will be replaced by additional procurement.

As an upgrade option of the TOP counter, we consider replacing the MCP-PMTs with silicon photomultipliers (SiPMs) in collaboration with INFN padova and other groups. We submitted our proposal to AIDA2020++ research funding and have been selected as a core Expression of Interest. A SiPM has an advantages of much lower price than the MCP-PMT while the performance could be adequate for the TOP counter. We 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 does not degrade significantly owing to the higher photodetection efficiency. A drawback of SiPMs is the radiation intolerance in the Belle II environment. It must be mitigated by cooling the SiPM to $-30°$C or below and by thermally annealing it time to time.

The PID performance of the TOP counter was evaluated with a large dataset taken in 2019. It is still worse than the Monte Carlo simulation. We found that PID with a probability density function (PDF) generated by the Monte Carlo simulation is better than one with the default analytic PDF. That indicates the worse performance could be attributed to some mismodeling of the PDF. We also tried improving the PID performance by means of a machine learning techniques.

4.2.4 Tau-lepton Data Analysis Laboratory

In the Belle II experiment, the required computing resource is huge and 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. 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. In order to do it smoothly, we developed a software to perform it in a automatic way, which perform registration of file into the logical file catalog and upload into the grid strage, and make copy to the BNL in the secuential way. Figure 4.5 shows the volume of raw data transferred to BNL in this fiscal year. The copy of raw data is done without big issue.

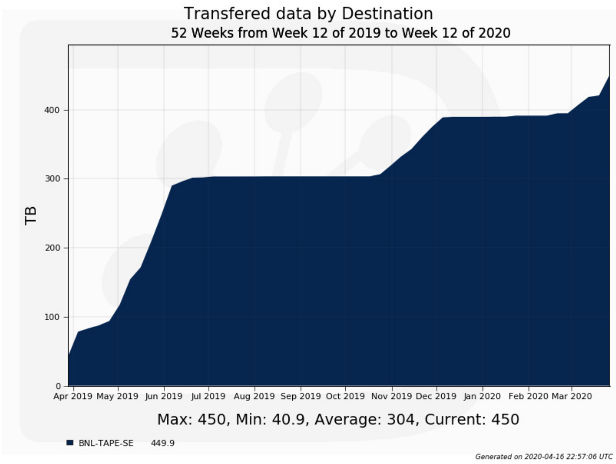


Figure 4.5: Data volume transferred to BNL tape storage.

There are various CPU usage in the Belle II activity, such as processing of raw data, production of Monte-Carlo simulation jobs, extracting events which are interesting for further analysis (skimming). It is very tedious for human to taking care all of such activities. We developed a system called Production System, which enable to handle huge number of jobs in a automatic way just by submitting single json format file where the description of jobs are written. Figure 4.6 shows the number of running jobs in this fiscal year. We can see more than 30k concurrent jobs are running with various purposes. We confirmed our distributed system works after the data taking.

KMI is providing more than 500 CPU cores and 300 TB disk storage. In particuler, the KMI disk is used as "Primary Storage", where the final output of the files are collected.

Operation is the another important task, as various trougles are happening daily as huge amount of computing resources are used. We have 7 days 24 hours computing expert shift to solve the issue in a timely manner. In order to increase number of expert, we prepared the training course so that any collaborator can be an expert. Thanks to this, the number of people taking the expert shift is increasing.

In summary the Belle II distributed computing system is working well in overall and ready to perform physics analysis with massive data coming now.

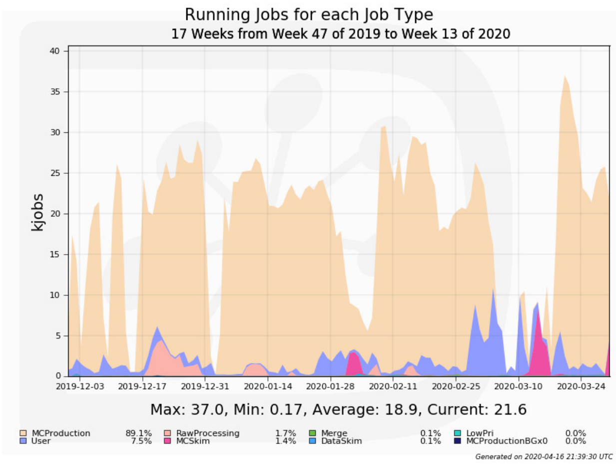


Figure 4.6: Number of running jobs in this fiscal year. Different colors indicate different job types.

Chapter 5

Research Related Activities

5.1 Conferenes and meetings held by KMI

[1] KMI workshop: "Future Perspective in Cosmology and Gravity"
Date: 2-4 April, 2019
Place: KMI, Nagoya University
Number of participants (foreign): 45 (15)
Sponsorship: KMI and Leung Center for Cosmology and Particle Astrophysics (LeCosPA)
Web site: http://www.kmi.nagoya-u.ac.jp/workshop/fpcg2019/

[2] KMI Interdisciplinary Seminar: "Recent developments in SYK model and wormholes"
Date: 22 July, 2019
Place: KMI, Nagoya University

[3] IARE Symposium: "Celebration for the establishment of the Institutes for Advanced Research Excellence (IARE)"
Date: 15 Nov, 2019
Place: Sakata Hirata Hall, Nagoya University
Style: Domestic
Number of participants (foreign): - (-)
Sponsorship: KMI, ITbM, IAR
Web site: http://www.itbm.nagoya-u.ac.jp/naias/

[4] 6th Korea-Japan workshop on dark energy at KMI
Date: 3-5 Dec, 2019
Place: KMI, Nagoya University ES635
Style: International
Number of participants (foreign): 51 (21)
Sponsorship: KMI
Web site: http://www.c.phys.nagoya-u.ac.jp/DE2019/

[5] Machine Learning at LHC
Date: 4-7 Feb, 2020
Place: KMI, Nagoya University
Style: International
Number of participants (foreign): 45 (11)
Sponsorship: KMI
https://agenda.hepl.phys.nagoya-u.ac.jp/indico/conferenceDisplay.py?confId=1336

[6] The 16th Annual meeting of the Science Communication Society of Japan
Date: 29 February 2020
Place: Nagoya University, Aichi, Japan
Style: Online conference due to COVID-19
Number of participants (foreign): 36 (1)
Organizer: Science Communication Society of Japan
Sponsorship: DAIKO FOUNDATION
Supporters: KMI, Nagoya University Museum, ITbM
Web site: http://www.scicomsociety.jp/?page_id=1562

[7] [***cancelled**] Quark Gluon Plasma Phenomenology and Experiments at RHIC and LHC
Date: 10-12 March 2020 [***cancelled**]
Web site: http://www.kmi.nagoya-u.ac.jp/workshop/QGP/

5.2 Seminars and Colloquia

[1] 2019/04/01 17:00- KMI Theory Seminar
"Tabletop Analog Black Holes to Investigate Information Loss Paradox"
Pisin Chen (LeCosPA, National Taiwan University)

[2] 2019/04/09 13:00- KMI Theory Seminar
"Addressing theoretical uncertainties in dark matter direct detection experiments"
Alejandro Ibarra (Munich, Tech. U.)

[3] 2019/04/09 13:30- KMI Theory Seminar
"Delineating the properties of matter in cold, dense QCD"
Toru Kojo (Central China Normal University)

[4] 2019/04/10 17:30- KMI Topics
"Dr. PR Officer or: how I learned to communicate science"
Azusa Minamizaki (KMI, Nagoya University)

[5] 2019/04/15 15:30- KMI Theory Seminar
"The universe evolution and modified gravity: an overview"
S.D. Odintsov (ICREA and ICE, CSIC, Barcelona)

[6] 2019/04/24 17:00- KMI Colloquium
"Primordial Black Hole Cosmology"
Kazunori Kohri (KEK/Sokendai)

[7] 2019/05/08 17:30- KMI Topics
"Search for PeVatrons in Milky-way Galaxy by Cosmic Gamma-ray Observations"
Hiroyasu Tajima (Nagoya University)

[8] 2019/05/13 14:30- KMI Theory Seminar
"First Images of a Black Hole"
Kazunori Akiyama (MIT)

[9] 2019/05/15 17:00- KMI Colloquium
"Axion Seach Experiment, Past and Future"
Atsushi Tokiyasu

[10] 2019/06/12 17:30- KMI Topics
"New physics searches at the LHC"
Michihisa Takeuchi (KMI, Nagoya University)

[11] 2019/07/10 17:30- KMI Topics
"Dark Matter and Modified Gravity"
Shin'ichi Nojiri (KMI, Nagoya University)

[12] 2019/07/22 13:00- KMI Interdisciplinary Seminar
Recent developments in SYK model and wormholes
"A Brief Introduction to Traversable Wormholes"
Tomohiro Harada (Rikkyo University)

[13] 2019/07/22 14:15- KMI Interdisciplinary Seminar
Recent developments in SYK model and wormholes
"The Sachdev-Ye-Kitaev model, random matrices and quantum chaos"
Masaki Tezuka (Kyoto University)

[14] 2019/07/22 15:30- KMI Interdisciplinary Seminar
Recent developments in SYK model and wormholes
"Traversable wormhole and chaotic/integrable transition"
Tomoki Nosaka (KIAS, Korea)

[15] 2019/08/02 17:00- KMI Colloquium
"Unraveling mysteries of neutrinos by flying human-made neutrinos through the earth"
Takashi Kobayashi (KEK)

[16] 2019/09/10 14:00- KMI Theory Seminar
"Determination of QGP parameters from a global Bayesian analysis"
Steffen A. Bass (Duke Univ.)

[17] 2019/09/11 17:30- KMI Topics
"How to study SUSY standard model(s) at O(100) TeV"
Junji Hisano (Nagoya University)

[18] 2019/10/01 17:00- KMI Experiment Seminar
"Project of the Charm-Tau factory in Novosibirsk"
B.Shwartz, (Budker Institute of Nuclear Physics and Novosibirsk State University)

[19] 2019/10/10 17:00- KMI Experiment Seminar
"The FASER experiment at LHC"
Hidetoshi Otono (Kyushu Univ.)

[20] 2019/10/16 16:30- KMI Experiment Seminar
"Searches for long-lived heavy neutrinos at colliders"
Abner Soffer (Tel Aviv University)

[21] 2019/10/30 17:00- KMI Colloquium
"Fundamental Plane and Scaling relations of Galaxy Clusters"
Yutaka Fujita (Osaka University)

[22] 2019/11/13 17:30- KMI Topics
"First Physics Results at the Belle II Experiment"
Alessandro Gaz (KMI, Nagoya University)

[23] 2019/11/28 17:00- KMI Theory Seminar
"Discovering New Physics with Flavour"
Prof. Andreas Crivellin (Paul Scherrer Institut (PSI))

[24] 2019/12/11 17:30- KMI Topics
"Probing BSM Physics with Cosmological Magnetic Fields"
Takeshi Kobayashi (KMI, Nagoya University)

[25] 2019/12/18 17:00- KMI Colloquium
"Instantons in Chiral Magnets"
Norisuke Sakai (Keio University)

[26] 2020/01/08 17:30- KMI Topics
"GRAINE Project: First Detection of Gamma-ray Object by Balloon-borne Emulsion Telescope and Prospects"
Hiroki Rokujo (Nagoya University)

[27] 2020/01/20 17:00- KMI Theory Seminar
"Supersymmetric Solitons: Exact results in super-Yang-Mills"
Prof. M. Shifman (University of Minnesota)

[28] 2020/01/22 16:00- KMI Experiment Seminar
"$B^0K^*\mu\mu$ at CMS: status and perspective"
Stefano Lacaprara (INFN Padova)

[29] 2020/01/28 14:00- KMI Colloquium
"Gravitational wave astronomy and cosmology — the dawn has arrived! —"
Misao Sasaki (Kavli IPMU)

[30] 2020/01/30 17:00- KMI Theory Seminar
"Perturbations of bounce scenario from f(T) modified gravity revisited"
Prof. Taotao Qiu (Central China Normal University)

[31] 2020/02/12 13:00- KMI Theory Seminar
"Axions and low scale inflation"
Lorenzo Ubaldi (SISSA)

[32] 2020/03/10 15:00- KMI Theory Seminar (canceled)
"A phenomenological approach to interacting vacuum in cosmology:a progress report"
Marco Bruni (University of Portsmouth)

5.3 Awards

[1] Top leader among female researchers in Nagoya University. (Nonaka)

[2] Selected as an APS Outstanding Referee. (Nojiri)

Chapter 6

Publications and Presentations

6.1 Published papers

6.1.1 Theoretical papers

Refereed papers

[1] "Maximum value of the spin-independent cross section in the THDM+a" Tomohiro Abe, Motoko Fujiwara, Junji Hisano, Yutaro Shoji. Published in JHEP01(2020)114 e-Print: arXiv:1910.09771 [hep-ph]

[2] "Indirect Studies of Electroweakly Interacting Particles at 100 TeV Hadron Colliders" Tomohiro Abe, So Chigusa, Yohei Ema, Takeo Moroi. Published in Phys.Rev.D100 (2019) 055018 e-Print: arXiv:1904.11162 [hep-ph]

[3] M. Harada, Y. R. Liu, M. Oka and K. Suzuki, Phys. Rev. D 101, no.5, 054038 (2020).

[4] Y. Kuroda, M. Harada, S. Matsuzaki and D. Jido, arXiv:1910.09146, to appear in PTEP.

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[10] Gauthier Durieux, Teppei Kitahara, Yael Shadmi, Yaniv Weiss "The electroweak effective field theory from on-shell amplitudes", JHEP 01 (2020) 119, arXiv:1909.10551 [hep-ph].

[11] Monika Blanke, Andreas Crivellin, Teppei Kitahara, Marta Moscati, Ulrich Nierste, Ivan Nisandzic "Addendum to 'Impact of polarization observables and $B_c \to \tau\nu$ on new physics explanations of the $b \to c\tau\nu$ anomaly' ", Phys.Rev.D 100 (2019) 3, 035035 (addendum), arXiv:1905.08253 [hep-ph].

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[14] Antonio Augusto Alves Junior, et al. (Teppei Kitahara), "Prospects for Measurements with Strange Hadrons at LHCb", JHEP 05 (2019) 048, arXiv:1808.03477 [hep-ex].

[15] Teppei Kitahara "Direct CP Violation in $K \to \mu^+\mu^-$", Springer Proc.Phys. 234 (2019) 211-216.

[16] Alessandro Cerri, et al. (Teppei Kitahara), "Report from Working Group 4 : Opportunities in Flavour Physics at the HL-LHC and HE-LHC", CERN Yellow Rep.Monogr. 7 (2019) 867-1158, arXiv:1812.07638 [hep-ph].

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6.1.3 Papers in Science Communication

Refereed papers

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6.2 Presentations at International Conferences

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

6.2.1 Division of Theoretical Studies

Name of Conference	Place	Date	I	O	P
KEK Theory Meeting on Particle Physics Phenomenology (KEK-PH2020)	Tsukuba (Japan)	19 Feb 2020	0	1	0
27th Regular Meeting of the New Higgs Working Group	Osaka (Japan)	14 Dec 2019	0	1	0
International Joint Workshop on the Standard Model and beyond	Beijing (China)	14 Oct 2019	1	1	0
COSMO19	Aachen (Gernamy)	2 Sep 2019	0	1	0
SI2019	Gangneung (Korea)	22 Aug 2019	0	1	0
SUSY2019	Corpus Christi (USA)	17 May 2019	1	1	0
SUSY2019	Corpus Christi (USA)	16 May 2019	0	1	0
Pheno 2019	University of Pittsburgh	6 May 2019	0	1	0
Physics of heavy-quark and exotic hadrons	Japan	28-29 Jan 2019	1	1	0
Quarks and Compact Stars 2019	Korea	September 27	0	1	0
HADRON2019	China	August 18	1	1	0
The 29th International Symposium on Lepton Photon Interactions at High Energies	Canada	5-10 Aug 2019	1	1	0
ICCMSE 2019	Greece	1-5 May 2019	1	1	0
Workshop in "Flavour Changing and Conserving Processes" 2019 (FCCP2019)	Italy	29-31 Aug 2019	1	1	0
The 3rd International Conference on Charged Lepton Flavor Violation	Japan	17-19 June 2019	1	1	0
2019 NPKI workshop	Korea	12-17 May 2019	1	1	0
GDR-InF workshop: QED corrections to (semi)leptonic B decays	France	8-9 Jul 2019	1	1	0
ANOMALIES 2019	India	18-20 Jul 2019	1	1	0
Heavy-Quark Physics and Fundamental Symmetries: Interplay between theory and experiment	USA	19-23 Aug 2019	0	1	0
2nd Workshop on Hadronic Contributions to New Physics Searches (HC2NP2019)	Spain	23-28 Sep 2019	1	1	0
18th International Conference on B-Physics at Frontier Machines (BEAUTY2019)	Slovenia	30 Sep-4 Oct 2019	1	1	0
27th Regular Meeting of New Higgs Working Group	Japan	13-14 Dec 2019	1	1	0
COST Workshop: Probing BSM physics at different scales	Germany	29-31 Jan 2020	1	1	0
SUSY 19	USA(Corpus Christy)	20-24 May 2019	0	1	0
Koichiro Nishikawa memorial symposium	KEK	27 Sep. 2019	1	1	0
14th Asia-Pacific Physics Conference	Malaysia	17-22 Nov 2019	1	1	0
New physics beyond the standard model	Korea	2-3 Dec 2019	0	1	0
The 1st Asian-European-Institutes Workshop for BSM and the 9th KIAS workshop on Particle Physics and Cosmology	Korea	4-8 Nov 2019	0	1	0

The 22nd International Conference from the Planck Scale to the Electroweak Scale	Spain	3-7 Jun 2019	0	1	0
SUSY2019	Texas (USA)	24 May 2019	1	1	0
J-Park symposium 2019	Tsukuba (Japan)	25 September 2019	1	1	0
1st Asia-European-Institute conference	Jeju (Korea)	6 November 2019	1	1	0
New Physcs beyond the SM	Pohang (Korea)	2 December 2019	1	1	0
1-day Workshop on Quantum Gravity	Japan	4 July 2019	1	1	0
Mini-workshop "Black holes and neutron stars – imagination and reality"	Vietnam	19 Sep. 2019	1	1	0
the APCTP workshop of Gravity, Strings and QM Matter	Korea	18-20 Nov. 2019	1	1	0
Gravitation and Mathematical Relativity	China	11 Dec. 2019	1	1	0
Miyazaki Workshop on Particle Physics and Cosmology 2020	Japan	27-30 Jan. 2020	1	1	0
Topological Field Theories, String theory and Matrix Models - 2019	Russia	26-31 Aug 2019	1	1	0
Workshop on "General relativity and partial differential equation"	Japan	24 May 2019	1	1	0
3rd Korea-Japan bilateral workshop on string axion cosmology	Japan	13-16 Oct. 2019	2	3	0
the Rencontres du Vietnam	Vietnam	12-16 Aug 2018	1	1	0
6th Korea-Japan workshop on dark energy at KMI	Japan	3-5 Dec 2019	0	1	0
Symmetry 2019 - The 2nd International Conference on Symmetry	Spain	1-7 Sept 2019	2	2	0
Modified Gravity and Cosmology	Spain	8-10 May 2019	2	2	0
2019 CCNU-USTC Junior Cosmology Symposium	China	26-29 April 2019	2	2	0
The third NRF-JSPS workshop in particle physics, cosmology, and gravitation	Ishigaki, Japan	15-19 Jun 2019	1	1	0
The fourth NRF-JSPS workshop in particle physics, cosmology, and gravitation	High-One, Korea	2-8 Feb 2020	1	1	0
Cosmic Acceleration	Kashiwa, Japan	17-19 Feb 2020	0	1	0
theory total			39	54	0

6.2.2 Division of Experimental Studies

Name of Conference	Place	Date	I	O	P
Tsukuba Conference 2019	Japan	Oct. 2019	1	1	
Intensity Frontier in Particle Physics: Flavor, CP Violation and Dark Physics	Taiwan	Oct. 3, 2019	1	1	
DIRC2019: International Workshop on Fast Cherenkov Detectors	Germany	Sep. 11, 2019	1	1	
INT Workshop INT-19-74W Hadronic contributions to $(g-2)_\mu$	USA	Sep. 9, 2019	1	1	
Indo-US workshop on Anomalies	India	Jul. 18, 2019	1	1	
European Physical Society Conference on High Energy Physics 2019	Belgium	Jul. 13, 2019		1	
The 15th International Conference on Meson-Nucleon Physics and the Structure of the Nucleon (MENU-2019)	USA	Jun. 2, 2019	1	1	
The XXVII International Workshop on Deep Inelastic Scattering and Related Subjects	Italy	Apr. 9, 2019		1	

JpGU 2019	Japan	26-30 May 2019	1	1	0
22nd edition of the International Conference on General Relativity and Gravitation	Spain	7-12 July 2019	0	1	0
UCANS-VII	France	8-10 July 2019	1	1	0
36th International Cosmic Ray Conference	University of Wisconsin Madison	2019.7/24-8/1	1	1	0
The 40th Anniversary Symposium of the US-Japan Science and Technology Cooperation Program in High Energy Physics	Univeristy of Hawaii	2019 4/15-16	1	1	0
43rd Johns Hopkins Workshop	University of Tokyo	2019 6/4	1	1	0
16th International Conference on Topics in Astroparticle and Underground Physics (TAUP2019)	Toyama International Conference Center	2019 9/9-13	1	1	0
ICMASS2019 (International Conference on Materials and Systems for Sustainability 2019)	Japan	1-3 November 2019	0	1	0
Rencontres du Vietnam 2019: 3 Neutrinos and Beyond	Vietnam	2019/08/04-10	1	1	0
The 21st International Workshop on Neutrinos from Accelerators (NuFact 2019)	Korea	2019/8/26-31	1	1	0
ESSnuSB/EuroNuNET annual meeting	Croatia	2019/10/21-24	1	1	0
experiment total			15	19	0

6.3 Presentations at Domestic Conferences

6.3.1 Division of Theoretical Studies

Name of Conference	Place	Date	I	O	P
JPS 2019 Autumn Meeting	Yamagata (Japan)	19 September 2019	0	1	0
26th regular meeting of the New Higgs Working Group	Osaka	8 August 2019	0	1	0
PPP2019	Kyoto	31 July 2019	0	1	0
Progress of research of exotic hadrons and QCD from the view of quark model	RIKEN	6 Jul. 2019	0	1	0
Flavor Physics Workshop 2019	Osaka Tondabayashi	19-22 Nov 2019	1	1	0
JPS 2020 Annual (75th) Meeting	Nagoya University	16-19 Mar 2020	1	1	0
Heavy Ion Cafe	Sophia Univ.	22-23 June 2019	1	1	0
JPS meeting	Yamagata Univ.	17-20 Sep 2019	0	1	0
Miyazaki Workshop on Particle Physics and Cosmology 2020	Miyazaki	27-30 Jan 2020	0	1	0
The 27th regular meeting of the New Higgs Working Group	Osaka Univ.	13-14 Dec 2019	0	1	0
Summer camp on ILC accelerator and physics / detectors 2019	Ibaraki	3-6 Sep 2019	0	1	0
Progress in Particle Physics 2019	YITP	29 Jul - 2 Aug 2019	0	1	0
New Tera-scale workshop at Univ. Tokyo	Tokyo	Jun. 8, 2019	1	1	0
PPP2019	Kyoto	31 July 2019	1	1	0
Particle physics and math-physics – 40 years from the discovery of the Eguchi-Hanson solution –	YITP, Kyoto Univ.	19-20 Oct 2019	1	1	0

The 66th Geometry Symposium	Nagoya Univ.	26-29 August 2019	1	1	0
workshop on first stars and galaxies	Nagoya Univ.	11-13, Nov 2019	1	1	0
SKA-Japan Symposium 2019	NAOJ	2-6, Sep 2019	0	1	0
theory total			8	18	0

6.3.2 Division of Experimental Studies

Name of Conference	Place	Date	I	O	P
JPS 75th Annual meeting	Japan	2020 March	0	1	0
“Exploration of Particle Physics and Cosmology with Neutrinos” workshop 2019	Japan	Jun 2019	0	1	0
日本物理学会第75回年次大会	日本	2020年3月		1	
新学術領域「ニュートリノで拓く素粒子と宇宙」研究会2019	日本	2019年6月		1	
Workshop on Physics of heavy-quark and exotic hadrons	日本	2020年1月	1	1	
第二回クラスター階層領域研究会	日本	2020年1月		1	
Astronomical Society Japan, 2019 Autumn assembly	Kumamoto Univ.	11-13 Sep 2019	0	1	0
Physical Society Japan, 2019 Autumn assembly	Kumamoto Univ.	11-13 Sep 2019	0	1	0
Physical Society Japan, 2020 Spring assembly	Nagoya Univ. (online)	N/A	0	4	0
The 2nd MeV astronomy conference 2019	Univ. Tokyo	26-27 Sep. 2019	0	1	1
HEAPA future planning Town Meeting	TITEC	26 Dec. 2019	0	1	0
The 18th ECIGO Workshop	Kyoto Univ.	10 Nov. 2019	0	1	0
The First Star and First Galaxy Workshop 2019	Nagoya Univ.	13 Nov. 2019	0	1	0
FY2019 CRC future plan town meeting	GranCube Oksa	31 Dec. 2019	0	1	0
MeV Astrophysics Workshop	University of Tokyo	26-27 Sep 2019	1	1	0
CRC town meeting	Osaka International Convention Center	20-21 Dec 2019	2	2	0
KEK Photosensor/Scintillator Workshop	University of Tokyo	23-24 Dec 2019	1	1	0
JPS meeting	Yamagata University	17-20 Sep 2019	3	3	0
JPS meeting	Nagoya University	16-19 Mar 2020	3	3	0
Exploration of Particle Physics and Cosmology with Neutrinos	Hill Hotel Iga	12-14 Jun 2019	1	1	0
experiment total			12	27	1

6.3.3 PR office

Name of Conference	Place	Date	I	O	P
日本物理学会第75回年次大会（2020年）	Japan	2020 Mar 19	0	1	0

6.4 Tutorial Articles and Reviews

[1] Akira Okumura, ROOT tutorial 2019, young meeting for Cosmology and Particle Physics, 2019 Apr-Jun.

Chapter 7

International Relations

7.1 International Collaborations

Collaboration Name	the other parties
MWA	CSIRO, Curtin University, University of Western Australia (Austral- ia), Kumamoto University, Nagoya University (Japan), Shanghai As- tronomical Observatory (China), and others
LiteBIRD	KEK, IMPU, Berkeley, MPA and others (26 organizations)
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
XRISM	JAXA, NASA (US), Kanto Gakuin University, Kwansei Gakuin University, Kyoto University, Nagoya University, Nara University of Education, Nara Women's University, Nihon Fukushi Univer-sity, Osaka University, RIKEN, Rikkyo University, Saitama Uni-versity, Shibaura Institute of Technology, Shizuoka University, Tohoku Gakuin University, Tokyo Metropolitan University, To-kyo University of Science, University of Miyazaki, University of Tokyo, Waseda University, Canadian Light Source Inc. (Canada), University of Chicago (US), Harvard-Smithsonian Center for As-trophysics (US), Lawrence Livermore National Laboratory (US), Massachusetts Institute of Technology (US), Saint Mary's Uni-versity (Canada), University of Maryland (US), University of Michigan (US), University of Waterloo (US), University of Wis-consin (US), Yale University (US), ESA (European Space Agen-cy), European Sauther Observatory (Germany), SRON (Nether-land), University of Amsterdam (Neitherland), University of Durham (UK), University of Geneva (Switzerland)
Athena	European Space Agency, ISAS/JAXA, NASA (USA) and others

FORCE	Miyazaki University, Kyoto University, Nagoya University, Osaka University, Tohoku Gakuin University, Saitama University, The University of Tokyo, Tokyo Metropolitan University, Tokyo Institute of Technology, Tokyo University of Science, Kanto Gakuin University, JAXA/ISAS, Waseda University, Nara Women's University, Nara University of Education, Kobe University, Hiroshima University, Ehime University, NASA GSFC, UC Berkeley, University of Utah, and others
Cherenkov Telescope Array (CTA)	Max-Planck-Institut f"ur 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
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)
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)

7.2 Visitors

Name	Affiliation	Period	Host
T. Kojo	Central China Normal Univ.	2019/4/8 - 2019/4/26	M. Harada
Y. Kim	RISP, IBS	2020/1/7 - 2020/1/18	M. Harada
A. Ibara	Munich Univ.	2019/4/1 - 2019/4/16	J. Hisano
M. Shifman	Univ. of Minnesota	2020/1/19 - 2020/1/22	J. Hisano
Steffen A. Bass	Duke Univ.	2019/9/2 - 2019/9/13	C.Nonaka
Pisin Chen	National Taiwan U.	2019/3/31 - 2019/4/6	K. Izumi
Yen Chin Ong	Yanzhou U.	2019/4/1 - 2019/4/6	K. Izumi
Jiwoo Nam	National Taiwan U.	2019/4/1 - 2019/4/6	K. Izumi
Shih-Yuin Lin	National Changhua U. of Education	2019/4/1 - 2019/4/5	K. Izumi
A. Shafieloo	KASI	2019/2/16 - 2019/2/29	N. Sugiyama
L. Ubaldi	SISSA	2020/2/11 - 2020/2/29 (cancelled due to storm Sabine and COVID-19)	T. Kobayashi
Ezio Torassa	INFN, Padova	2019/11/14 - 2019/11/26	K. Matsuoka
Stefano Lacaprara	INFN, Padova	2020/1/19 - 2020/2/8	K. Matsuoka
D.Ramírez García	University of Freiburg	2019/6/24 - 2010/9/21	S. Kazama

Chapter 8

Public Relations

8.1 Mdeia Relations

[1] Press Release「金沢市の高校で捉えた放射線バーストで雷発生の瞬間に迫る」
Date: 26 June, 2019
Related KMI member: Kazuhiro Nakazawa
Article link:
http://www.nagoya-u.ac.jp/about-nu/public-relations/researchinfo/upload_images/20190626_kmi.pdf
Joint press release: The University of Tokyo (leading institute), Kyoto University, Nagoya University, Hokkaido University, Kanazawa University, Kindai University, University of Toyama
Web release: Riken, University of Shizuoka, Tokyo Metropolitan University, Kobe City College of Technology

[2] Press Release「女子生徒の進学を阻む要因は？～保護者の男女平等度や性役割態度、理系分野に対するイメージ分析から見えるもの～」
Date: 21 October, 2019
Related KMI member: Azusa Minamizaki
Article link:
http://www.nagoya-u.ac.jp/about-nu/public-relations/researchinfo/upload_images/20191021_kmi1.pdf
Joint press release: Kavli IPMU (leading institute), JST, Shiga University, Nagoya University

[3] Regular Social gathering for Press held by Nagoya University
Date: 27 November, 2019
Speaker: Toru Iijima (KMI)
Title: 「小林-益川理論を超える新しい素粒子の探索」
Article Link:
http://www.nagoya-u.ac.jp/about-nu/public-relations/social-gathering/upload_images/20191127.pdf

8.2 Outreach Events held by KMI

[1] Special planetarium night event,「夜空に潜むダークマター」
Date: 18 February 2020
Place: Nagoya City Science Museum
Lecturer: Makoto Tomoto (KMI)
Co-host: Nagoya City Science Museum and KMI

[2] (*Cancelled due to COVID19) Physical Society of Japan, the 75th Annual Meeting Public Lecture
日本物理学会第75回年次大会(2020年) 市民科学講演会【名古屋】素粒子でひもとく宇宙のなりたち
Date: 20 March 2020
Place: Toyota auditorium, Nagoya University
Lecturer: Makoto Kobayashi (KMI), Koji Hashimoto (Osaka)
Moderator: Naoshi Sugiyama (KMI, Nagoya University)

Sponsorship: Physical Society of Japan (JPS), JPS-Nagoya branch, KMI, and Nagoya University
Organizer: JPS the 75th Annual meeting committee
Supporters: Aichi Prefectural Board of Education, Gifu Prefectural Board of Education, Mie Prefectural Board of Education, City of Nagoya Board of Education

8.3 Public Lectures by KMI members

Name	Date	Location	Event Title	Lecture title	Approx. # of participants
Keisuke Izumi	2020/1/22	国立都城工業高等専門学校	物理特別講演会 (外部講師講話)	宇宙の歴史を探る ～ 宇宙論という学問 ～	80
Tetsuya Shiromizu	2019/8/1	愛知県立明和高校	SSH「数学夏の学校」	ブラックホールの数理	80
Tetsuya Shiromizu	2019/8/9	名古屋大学	名古屋大学オープンキャンパス　理学部研究紹介	時空幾何学～高次元旅行～	400
Kiyotomo ICHIKI	2019/4/17	NHK文化センター	NHK講座2019「最新宇宙学：名古屋大学発」	観測的宇宙論最前線	100
Shin'ichi Nojiri	2019/10/5	阪急西宮ガーデンズ	『秋の星空案内』	宇宙を支配する闇（やみ）の力　～素粒子で宇宙を解き明かす～	100
Shin'ichi Nojiri	2019/12/13	兵庫県立西宮北高校	ふるさと活性化事業講演会	宇宙を支配する闇（やみ）の力 – 素粒子で宇宙を解き明かす –	10
Seiji Kawamura	2019/5/11	Karatsu	The 137th Karatsu Juku	Einstein's GW melody	-
Seiji Kawamura	2019/5/15	NHK Nagoya	Astronomy Course 2019	GW astronomy	-
Seiji Kawamura	2019/6/15	Nagoya Univ.	MIRAI-GSC	Einstein's GW melody	-
Seiji Kawamura	2019/11/7	Tenpaku H.S.	Trial Lecture	Einstein's GW melody	-
Seiji Kawamura	2019/11/15	Nagoya Univ.	Studium Generale	Let's listen to a melody from the universe !	-
Mitsuhiro Nakamura	2019/11/16-17	中京大学放送大学センター	放送大学面接授業	実験で学ぶ物理学	20
Mitsuhiro Nakamura	2019/9/21	名古屋大学物理会議室	先進科学塾	素粒子研究の紹介ならびに霧箱実験	40
Mitsuhiro Nakamura	2019/8/6	名古屋大学物理会議室	先進科学塾	霧箱実験	15

8.4 Other Contrinbutions by KMI members

Name	Activity
久野純治(Junji Hisano)	Editor of Physics Letters B
監修　白水徹也	「ホッセンフェルダー、マッガウ　暗黒物質は幻か？ 修正重力理論の新たな展開」日経サイエンス　2019年5月号
Kazuhiro Nakazawa	Press-release "During a lightning storm over a Japanese city, a gamma-ray glow from thunderclouds preceded a gamma-ray flash and lightning bolt"
Azusa Minamizaki	KMI introductory leaflet "KMI Unfolded Issue 1 / 2020" Editorial team: Masaaki Kitaguchi, Azusa Minamizaki, Masaharu Tanabashi, Shuichiro Yokoyama (KMI) Writers: Kiyotomo Ichiki, Yoshitaka Itow, Yuji Kato, Shingo Kazama, Tatsuhiro Naka, Kazuhiro Nakazawa, Yasusada Nambu, Akira Okumura, Tetsuya Shiromizu, Makoto Tomoto (KMI) Design: opportune design Inc.
Azusa Minamizaki	President of the meeting "The Science Communication Society of Japan"

Chapter 9

External Funding related with KMI

Grant-in-Aid for Scientific Research (KAKENHI)

Name	Research Funds	ID	Amount [JPY] (Direct Expense)
ABE, Tomohiro	Young Scientists (B)	16K17715	500,000
ABE, Tomohiro	Scientific Research on Innovative Areas	19H04615	1,800,000
HARADA, Masayasu	Scientific Research (C)	16K05345	800,000
HISANO, Junji	Scientific Research on Innovative Areas	16H06492	19,900,000
HISANO, Junji	Scientific Research on Innovative Areas Project	16H06492	1,450,000
ICHIKI, Kiyotomo	Scientific Research (A) [CI]	17H01110	90,000
ICHIKI, Kiyotomo	Scientific Research (C)	18K03616	700,000
ICHIKI, Kiyotomo	Scientific Research on Innovative Areas Project [CI]	15H05890	400,000
IIJIMA, Toru	Scientific Research (S)	18H05226	28,300,000
ITOW, Yoshitaka	Scientific Research (A) [CI]	19H00675	500,000
ITOW, Yoshitaka	Scientific Research (A) [CI]	18H03697	800,000
ITOW, Yoshitaka	Promotion of Joint International Research [CI]	18KK0082	500,000
ITOW, Yoshitaka	Scientific Research on Innovative Areas [CI]	18H05535	50,000
ITOW, Yoshitaka	Scientific Research on Innovative Areas [CI]	18H05538	7,600,000
ITOW, Yoshitaka	Scientific Research (B)	18H01227	670,000
ITOW, Yoshitaka	Scientific Research (B)	18H01227	4,000,000
IZUMI, Keisuke	Young Scientists (B)	17K14281	1,000,000
IZUMI, Keisuke	Scientific Research (A) [CI]	17H01091	300,000
KANNO, Hiroaki	Scientific Research (C)	18K03274	800,000
KANNO, Hiroaki	Scientific Research (S) [CI]	15H05738	100,000
KATO, Yuji	Scientific Research on Innovative Areas	19H05148	2,400,000
KAWAMURA, Seiji	Scientific Research (B)	19H01924	4,900,000
KAWAMURA, Seiji	Challenging Research (Exploratory)	19K21875	2,900,000
KAZAMA, Shingo	Fostering Joint International Research (B) [CI]	—	1,500,000
KAZAMA, Shingo	Scientific Research on Innovative Areas Project [CI]	19H05805	1,670,000
KITAGUCHI, Masaaki	Scientific Research (B)	17H02889	2,100,000
KITAGUCHI, Masaaki	Scientific Research (A) [CI]	19H00690	2,500,000
KITAGUCHI, Masaaki	Scientific Research (B) [CI]	19H01927	470,000
KITAHARA, Teppei	Young Scientists	19K14706	1,200,000
MAEKAWA, Nobuhiro	Scientific Research (C)	19K03823	1,000,000
MATSUOKA, Kodai	Scientific Research on Innovative Areas	19H05099	2,600,000
NAKAMURA, Mitsuhiro	Specially Promoted Research	18H05210	140,700,000
NAKANO, Toshiyuki	Scientific Research (B) [CI]	19H01909	100,000
NAKANO, Toshiyuki	Scientific Research (B) [CI]	19H01988	310,000
NAKANO, Toshiyuki	Scientific Research (S) [CI]	17H06132	7,000,000

NAKANO, Toshiyuki	Scientific Research (S) [CI]	17H06132	3,000,000
NAKAZAWA, Tomohiro	Challenging Research (Exploratory)	19K21899	2,100,000
NAKAZAWA, Tomohiro	Scientific Research (B) [CI]	18H01236	2,900,000
NAMBU, Yasusada	Scientific Research (C)	19K03866	1,000,000
NISHIZAWA, Atsushi	Scientific Research on Innovative Areas Project [CI]	15H05890	400,000
NOJIRI, Shin’ichi	Scientific Research (C)	18K03615	1,000,000
NOJIRI, Shin’ichi	Scientific Research on Innovative Areas Project [CI]	15H05890	300,000
NONAKA, Chiho	Scientific Research (C)	17K05438	700,000
OKUMURA, Akira	Young Scientists (A)	17H04838	3,000,000
SHIMIZU, Hirohiko	Challenging Research (Exploratory)	19K21876	2,400,000
SHIROMIZU, Tetsuya	Scientific Research (A) [CI]	17H01091	400,000
SHIROMIZU, Tetsuya	Scientific Research (C)	16K05344	300,000
SUGIYAMA, Naoshi	Scientific Research (A)	17H01110	9,540,000
SUGIYAMA, Naoshi	Scientific Research on Innovative Areas Project	15H05890	5,100,000
SUGIYAMA, Naoshi	Promotion of Joint International Research [CI]	15K21733	2,000,000
TAKEUCHI, Michihisa	Scientific Research (C)	18K03611	1,460,348
TAKEUCHI, Michihisa	Scientific Research on Innovative Areas	19H04613	1,900,000
TAKEUCHI, Michihisa	Scientific Research (A) [CI]	16H02176	100,000
TAKEUCHI, Michihisa	Scientific Research (B) [CI]	16H03991	400,000
TANABASHI, Masaharu	Scientific Research (C)	19K03846	1,000,000
TOMOTO, Makoto	Scientific Research (C)	18K03675	1,400,000
TOMOTO, Makoto	Scientific Research on Innovative Areas	16H06493	22,500,000
TOMOTO, Makoto	University cooperation support project	—	770,000
YOKOYAMA, Shuichiro	Scientific Research on Innovative Areas	18H04356	1,000,000

Other Research Funds

Name	Research Funds	ID	Amount [JPY] (Direct Expense)
KAZAMA, Shingo	Donation		1,500,000
NAKAHAMA, Yu	Donation		120,000
NAKAMURA, Mitsuhiro	Contract research expenses		114,690,000
NAKAMURA, Mitsuhiro	Contract research expenses		2,502,500
SHIMIZU, Hirohiko	Contract research expenses	AS272I006c	3,000,000
SHIMIZU, Hirohiko	Contract research expenses	P216	1,153,847