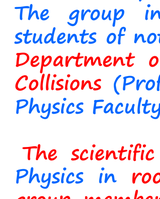
The Department of Theoretical Physics
The ν Neutrino Physics ν program

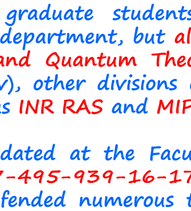
Нобелевская премия 2015 года по физике объявлено Шведской королевской академией наук

Артур Макдональд, Нейтринная обсерватория Садбери (Канада)

Такааки Каджита, Нейтринный телескоп «Супер-Камиоканде» (Япония)



«за открытие осцилляций нейтрино, что доказывает наличие у нейтрино ненулевой массы»



One of the important areas of scientific research and educational process that are implemented at the Department of Theoretical Physics is neutrino physics. The relevance of this section of fundamental science is evidenced by the award of the Nobel prize in 2015 «for the discovery of neutrino oscillations».

1913-1993

The possibility of neutrino oscillations was first predicted in 1957 by the outstanding scientist Bruno Maksimovich Pontecorvo, who worked at the Joint Institute for Nuclear Research (Dubna) and from 1966 to 1988 headed the Department of Elementary Particle Physics at the Faculty of Physics.

On the initiative of the Department of Theoretical Physics and with the support of the Division of Experimental and Theoretical Physics at the Faculty of Physics, the Scientific and Educational Center «Laboratory of Neutrino Physics and Astrophysics named after B.M. Pontecorvo» (Director - Professor A.I. Studenikin) has been operating for many years, continuing the traditions laid down by B.M. Pontecorvo, coordinating educational and research processes.

For almost 25 years, the Group on Neutrino Physics has been actively working at the Department of Theoretical Physics under the leadership of A.I. Studenikin (+7-903-751-74-57).

The group includes employees, graduate students and students of not only the specified department, but also the Department of Nuclear Physics and Quantum Theory of Collisions (Professor K.A. Kouzakov), other divisions of the Physics Faculty and MSU, as well as INR RAS and MIPT.

The scientific group is accommodated at the Faculty of Physics in room 1-51, tel .: +7-495-939-16-17. The group members prepared and defended numerous theses, 10 doctoral and 6 habilitation dissertations. The ongoing research is supported by grants from the RFBR and the Ministry of Education.

Meeting of the members of the Neutrino Physics Group and the performers of the RFBR project «Electromagnetic properties and oscillations of massive neutrinos» (room 1-51, Faculty of Physics, MSU, October 2, 2018)

For undergraduate and graduate students on the program «Physics of Neutrino» lecture courses are given:

- «Introduction to Neutrino Physics» (in English)
- «Interaction of elementary particles in electromagnetic fields»
- «Oscillations and electromagnetic properties of neutrinos: theory and astrophysical applications»
- «Models of neutrino mass generation»
- «Quantum theory of collisions» (read at the Department of Nuclear Physics of Quantum Theory of Collisions)

On the initiative of the Department of Theoretical Physics at the Faculty of Physics, a special master's program «Physics of Neutrino» was opened (supervisors - A.I. Studenikin and K.A. Kouzakov), its description is available on the website of the Faculty of Physics.

An important element of the educational program in neutrino physics is the International Schools of Neutrino Physics held annually at the Faculty of Physics.

Also, for all those interested in this problem, A.I. Studenikin reads an interfaculty course:

- «The invisible elementary particle neutrino».

Diploma theses of the members of the Neutrino Physics Group in recent years:

- K.L. Stankevich, «Effects of Neutrino Oscillations in Supernovae» (2018)
- A.R. Popov, «Spin oscillations of neutrinos in a transversely moving medium» (2017)
- P.G. Pustoshny, «Flavor oscillations of neutrinos in a magnetic field and arbitrarily moving medium» (2017)
- K.L. Stankevich, «Neutrino mixing effects and the density matrix» (2016)
- R. Fabbrikatore, «Neutrinos in strong fields and dense media of astrophysical objects» (2016)
- A.I. Dmitriev, «Energy spectrum and oscillations of neutrinos in a magnetic field» (2015)

PhD theses defended in recent years by members of the Neutrino Physics Group:

- I.V. Tokarev, «Neutrinos in moving magnetized media and new effects in astrophysics» (2014)
- A.V. Lokhov, «Development of methods of statistics and quantum field theory in neutrino physics» (2013)
- I.A. Balantsev, «The motion of neutrinos and electrons in a medium and a magnetic field in the framework of the method of exact solutions» (2012)

Members of the Neutrino Physics Group A.I. Studenikin (right), A.I. Ternov (left) and I.V. Tokarev (center) after successfully defending a Ph.D. thesis at the Faculty of Physics of Moscow State University in 2014

Habilitation dissertations prepared and defended in recent years by members of the Neutrino Physics Group:

- A.I. Ternov, «Massive neutrinos in external fields and dense media» (2015)
- K.A. Kuzakov, «Ionization processes in the interaction of fast particles with matter» (2017)

The main research areas of the Neutrino Physics Group:

- theory of mixing and oscillations of neutrinos under extreme external conditions (strong external electromagnetic fields and dense media)
- study of the electromagnetic properties of neutrinos (electromagnetic form factors of neutrinos, millischarge, magnetic and electric dipole moments, anapole moments)
- theory of neutrino scattering processes
- the search of electromagnetic characteristics of neutrinos when analyzing data from laboratory experiments (GEMMA, etc.)
- consideration of new phenomena in astrophysics, which are based on electromagnetic interactions of neutrinos
- the search of electromagnetic characteristics of neutrinos on the basis of astrophysical observations
- development of a research program for the neutrino mega-projects JUNO and HyperKamiokande
- participation in the creation of the European computer cluster of the JUNO project

Some of the publications by members of the Neutrino Physics Group:

- C.Giunti, A.Studenikin, «Neutrino electromagnetic interactions: A window to new physics», Rev. Mod. Phys. 87 (2015) 531
- K.Kouzakov, A.Studenikin,»Electromagnetic properties of massive neutrinos in low-energy elastic neutrino-electron scattering», Phys. Rev. D 95 (2017) 055013
- P.Kurashvili, K.Kouzakov, L.Chotorlishvili, A.Studenikin, «Spin-flavor oscillations of ultrahigh-energy cosmic neutrinos in interstellar space: The role of neutrino magnetic moments». Phys. Rev. D 96 (2017) 103017
- C.Giunti, K.Kouzakov, Y.-F. Li, A.Lokhov, A.Studenikin, Sh. Zhou, «Electromagnetic neutrinos in laboratory experiments and astrophysics», Ann. Phys. (Berlin) 528 (2016) 198
- I.Balantsev, A.Studenikin, «From electromagnetic neutrinos to new electromagnetic radiation mechanism in neutrino fluxes», Int. J. Mod .Phys. A 30 (2015) 1530044
- I.Tokarev, A.Studenikin, «Millicharged neutrino with anomalous magnetic moment in rotating magnetized matter», Nucl. Phys. B 884 (2014) 396
- A.Studenikin, «New bounds on neutrino electric millicharge from limits on neutrino magnetic moment «, Eur. Phys. Lett. 107 (2014) 21001
- K.Kouzakov, A.Studenikin, «Theory of neutrino-atom collisions: The history, present status, and BSM physics», Adv. High Energy Phys. 2014 (2014) 569409
- A.Grigoriev, A.Lokhov, A.Studenikin, A.Ternov, «The effect of plasmon mass on spin light of neutrino in dense matter», Phys. Lett. B 718 (2012) 512

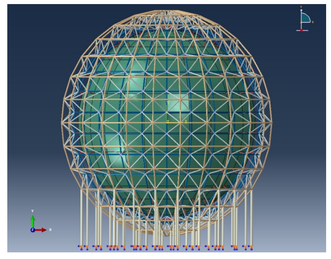
Published by A.I. Studenikin (Eur. Phys. Lett., 2014) upper limit on the magnitude of the neutrino millischarge is included by the Particle Data Group in «The Review of Particle Physics 2016», which contains information on the main characteristics of elementary particles (Particle Data Group, Chinese Physics C 40, 2016, 100001).

Presentation of the report by A.I. Studenikin on the development of research in neutrino physics and the participation of MSU in the neutrino megascience project JUNO at a meeting of the Academic Council of MSU

Participation in international conferences and the world's leading neutrino research projects is an important area of activity of the Neutrino Physics Group. The members of the group have taken part in major world conferences and made presentations in more than 20 countries around the world.

Laureate of the Nobel Prize 2015, awarded for the discovery of neutrino oscillations, Takaaki Kajita and A.I. Studenikin at the International Conference on Neutrino Oscillations NOW-2016 (Italy, September 2016).

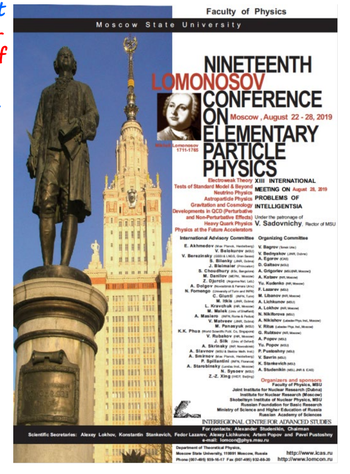
At the initiative of the Neutrino Physics Group with the support of the leadership of MSU and the Faculty of Physics, Moscow University in 2015 became one of the participants in the largest international neutrino megascience project currently being prepared in China, JUNO (A.I. Studenikin leads the group from MSU and represents the university in the governing bodies of the project).



JUNO liquid-accelerated neutrino detector (20 kilotons, R = 40 m, 700 m underground)

The work of the MSU group in the JUNO project is supported by grants from the Russian Foundation for Basic Research and the State Natural Science Foundation of China, including the grant «Electromagnetic Properties and Oscillations of Massive Neutrinos» (supervisor: A.I.Studenikin).

For 25 years an important area of work of the scientific group of A.I. Studenikin has been the organization of Lomonosov Conference on Elemen-tary Particle Physics at MSU, which is among the largest international forums held in Russia.



The Department of Theoretical Physics
The ˅Neutrino Physics˅ program
(addition «2018-2020»)

Workshop of the Neutrino Physics Group (Faculty of Physics, MSU, January 2019)

Diploma theses of the members of the Neutrino Physics Group (2019-2020):

Master 2019

- A. Popov, «Eigenstates and flavor, spin and spin-flavor oscillations of neutrinos in a constant magnetic field» (2019)
- P. Pustoshny, «Spin and spin-flavor oscillations of neutrinos in transverse flows of matter in theories with standard and non-standard interactions» (2019)

Baclelor 2019 and 2020

- F. Lazarev, «Elastic scattering of neutrinos by a nucleus taking into account the electromagnetic form factors of neutrinos» (2019)
- A. Lichkunov, «Oscillations of neutrinos in the case of three flavors in extreme external conditions» (2019)
- V. Shakhov, «Oscillations of neutrinos in arbitrarily directed magnetic fields and currents of matter» (2019)
- U. Abdulaeva, «Majorana neutrino in a moving medium and magnetic field» (2020)
- G. Donchenko, «Scattering of neutrinos by condensed system in the mode of low power transmission» (2020)
- V. Bokov, «Oscillations of neutrinos from supernovae taking into account collective effects» (2020)

МОСКОВСКИЙ ГОСУДАРСТВЕННЫЙ УНИВЕРСИТЕТ ИМЕНИ М.В. ЛОМОНОСОВА
ФИЗИЧЕСКИЙ ФАКУЛЬТЕТ

ДИПЛОМ

III степени

настоящим награждается

Попов
Артем Романович

студент магистратуры 2-го г.о.

призер
конкурса научных студенческих работ
имени Р.В. Хохлова

Декан физического факультета МГУ профессор — Сысоев Н.Н.

Председатель жюри конкурса профессор — Гордиенко В.М.

27 июня 2019 г.

The main results of A. Popov's master's thesis are published in the article:

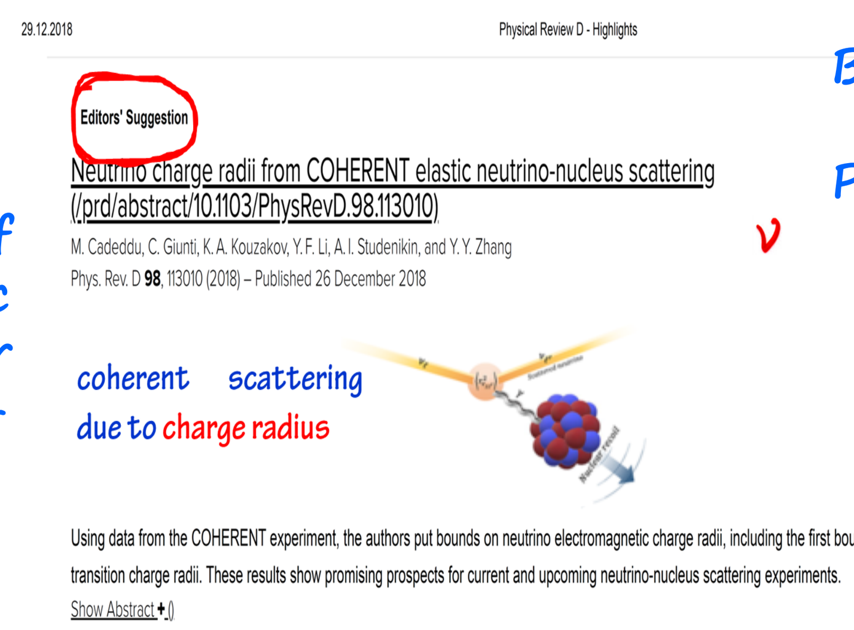
A. Popov and A. Studenikin, «Neutrino eigenstates and flavor, spin and spin-flavor oscillations in a constant magnetic field». Eur. Phys. J. C79 (2019)

According to the results of the competition of scientific student works named after R.V. Khokhlov, A. Popov became one of its winners.

Journal papers of the members of the Neutrino Physics Group from the «Top-25» list (2017-2020):

- K.Stankevich, A.Studenikin, Neutrino quantum decoherence engendered by neutrino radiative decay, Phys.Rev. D 101 (2020) no.5, 056004
- A.Studenikin et al, (IceCube-Gen2 and JUNO Colls.), Combined sensitivity to the neutrino mass ordering with JUNO, the IceCube Upgrade, and PINGU, Phys.Rev. D 101 (2020) no.3, 032006
- M.Cadeddu, F.Dordei, C.Giunti, K.Kouzakov, E.Picciau, A.Studenikin, Potentialities of a low-energy detector based on 4 He evaporation to observe atomic effects in coherent neutrino scattering and physics perspectives, Phys.Rev. D 100 (2019) no.7, 073014
- A.Popov, A.Studenikin. Neutrino eigenstates and flavour, spin and spin-flavour oscillations in a constant magnetic field, Eur. Phys. J. C (2019) 79:144 (7 p.)
- A.Grigoriev, E.Kupcheva, A.Ternov, Neutrino spin oscillations in polarized matter, 134861, Phys. Lett. B 797 (2019)
- P.Pustoshny, A.Studenikin, Neutrino spin and spin-flavour oscillations in transversal matter currents with standard and non-standard interactions, Phys.Rev. D 98 (2018) 113009 (14 p.)
- M.Cadeddu, C.Giunti, K.Kouzakov, Y.F.Li, A.Studenikin, Y.Y.Zhang, Neutrino charge radii from COHERENT elastic neutrino-nucleus scattering, Phys. Rev. D 98 (2018) 113010 (11 p.)
- P.Kurashvili, K.Kouzakov, L.Chotorlishvili, A.Studenikin, Spin-flavor oscillations of ultra-high-energy cosmic neutrinos in the interstellar space: The role of neutrino magnetic moments, Phys. Rev. D 96 (2017) 103017 (8 p.)
- A.Grigoriev, A.Lokhov, A.Studenikin, A.Ternov, Spin light of neutrino in astrophysical environments, J. Cosmol. Astropart. Phys. (2017) 068P_0517 (23 p.)
- K.Kouzakov, A.Studenikin, Electromagnetic properties of massive neutrinos in low-energy elastic neutrino-electron scattering, Phys. Rev. D 95 (2017) 055013 (9 p.)

- Published by K.A. Kouzakov and A.I.Studenikin et al. (Phys. Rev. D 98 (2018) 113010), a new upper bound on the values of off-diagonal charge radii of neutrinos is included by the International Committee on the Properties of Elementary Particles (Particle Data Group) in the review «The Review of Particle Physics 2018» update 2019 containing information on the main characteristics of elementary particles (Physics C 40, 2016, 100001).



29.12.2018 Physical Review D - Highlights

Editors' Suggestion

Neutrino charge radii from COHERENT elastic neutrino-nucleus scattering (/prd/abstract/10.1103/PhysRevD.98.113010)

M. Cadeddu, C. Giunti, K. A. Kouzakov, Y. F. Li, A. I. Studenikin, and Y. Y. Zhang

Phys. Rev. D **98**, 113010 (2018) – Published 26 December 2018

Using data from the COHERENT experiment, the authors put bounds on neutrino electromagnetic charge radii, including the first bounds on the transition charge radii. These results show promising prospects for current and upcoming neutrino-nucleus scattering experiments.

Show Abstract +

By the decision of the editorial board (Editors' Suggestion) Physical Review D journal, this article is selected as the most important achievement of 2018 and is posted In a special section «Highlights 2018» on the journal page https://journals.aps.org/prd/

2017 - 2019 –
over the past three years, the Neutrino Physics Group members made 31 reports, including ones at the leading international conferences:

1) European Physical Society Conference on High Energy Physics, Italy, 2017;
2) 15th International Conference on Topics in Astroparticle and Underground Physics, Canada, 2017;
3) 28th International Conference on Neutrino Physics and Astrophysics, Germany, 2018;
4) 39th International Conference on High Energy Physics, Korea, 2018;
5) 20th International Seminar on High Energy Physics «Quarks-2018». Valday, Russia, 2018;
6) Neutrino Oscillation Workshop, Italy, 2018;
7) 33rd Les Rencontres de Physique de la Vallée d'Aoste on Results and Perspectives in Particle Physics, Italy, 2019;
8) 31st Les Rencontres de Blois on Particle Physics and Cosmology, France, 2019;
9) European Physical Society Conference on High Energy Physics (EPS-HEP2019), Belgium, 2019;
10) 16th International Conference on Topics in Astroparticle and Underground Physics, Japan, September 9-13, 2019.

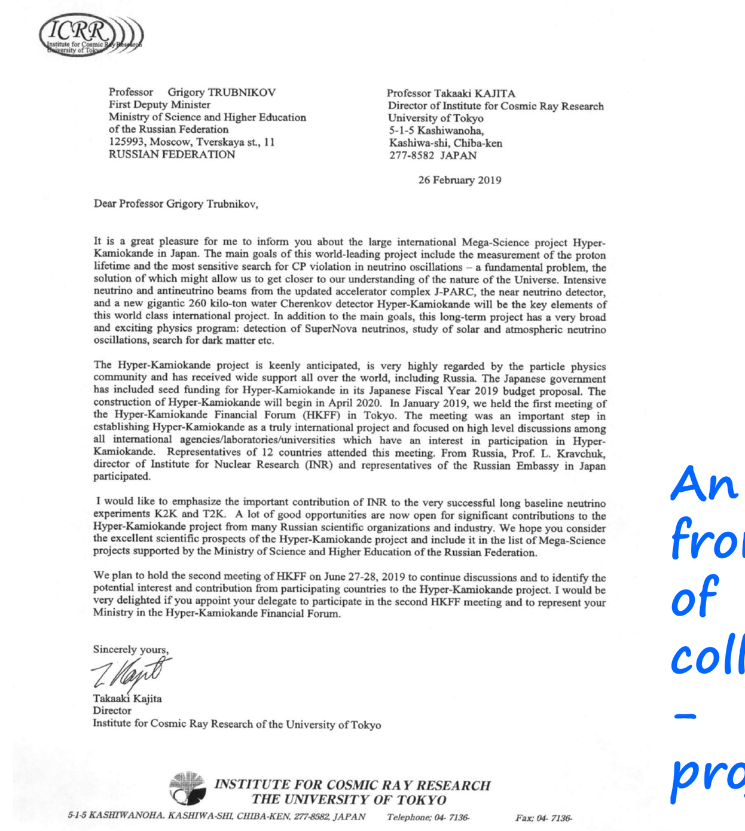
The program of the main International Conference on Elementary Physics Particles of 2020 - 40th International conference on high energy physics (40th International Conference on High Energy Physics, Prague, Check Republic, 30 July - 5 August, 2020) 7 reports of the participants of the Neutrino Physics Group are included:

xxxx – postgraduate
xxxx – students
xxxx – staff

- A.Studenikin, Electromagnetic neutrino properties: new constraints and new effects
- A.Kouzakov, Y.F.Li, K.Stankevich, Yuan, A.Studenikin, Neutrino spin-flavour and collective oscillations in supernovae (Ru-Ch cooperation)
- A.Lichkunov, A.Popov, A.Studenikin, Neutrino oscillations in a magnetic field: The three-flavor case
- V.Shakhov, K.Stankevich, A.Studenikin, Neutrino oscillation accounting for neutrino charge radii
- M.Cadeddu, F.Dordei, K.Giunti, K.Kouzakov, Picciau, A.Studenikin, Revealing new processes with superfluid liquid helium detectors: The coherent elastic neutrino-atom scattering (Ru-It cooperation)
- K.Kouzakov, F.Lazarev, A.Studenikin, Electromagnetic neutrino interactions in elastic neutrino-proton scattering
- K.Stankevich, A.Studenikin, Collective neutrino oscillations accounting for neutrino quantum decoherence

2015 Nobel Prize Laureate Takaaki Kajita and A.I.Studenikin at the International Conference TAUP-2019 (September 2019, Toyama, Japan)

By the decision of the management of MSU, in 2019, the implementation of the program for the participation of MSU in the new international neutrino megascience project Hyper-Kamiokande (Japan) began.



ICRR

Professor Grigory TRUBNIKOV
First Deputy Minister
Ministry of Science and Higher Education of the Russian Federation
125993, Moscow, Tverskaya st., 11
RUSSIAN FEDERATION

Professor Takaaki KAJITA
Director of Institute for Cosmic Ray Research
University of Tokyo
5-1-5 Kashiwanoha, Kashiwa-shi, Chiba-ken
277-8582 JAPAN

26 February 2019

Dear Professor Grigory Trubnikov,

It is a great pleasure for me to inform you about the large international Mega-Science project Hyper-Kamiokande in Japan. The main goals of this world-leading project include the measurement of the proton lifetime and the most sensitive search for CP violation in neutrino oscillations – a fundamental problem, the solution of which might allow us to get closer to our understanding of the nature of the Universe. Intensive neutrino and antineutrino beams from the updated accelerator complex J-PARC, the near neutrino detector, and a new gigantic 260 kilo-ton water Cherenkov detector Hyper-Kamiokande will be the key elements of this world class international project. In addition to the main goals, this long-term project has a very broad and exciting physics program: detection of SuperNova neutrinos, study of solar and atmospheric neutrino oscillations, search for dark matter etc.

The Hyper-Kamiokande project is keenly anticipated, is very highly regarded by the particle physics community and has received wide support all over the world, including Russia. The Japanese government has included seed funding for Hyper-Kamiokande in its Japanese Fiscal Year 2019 budget proposal. The construction of Hyper-Kamiokande will begin in April 2020. In January 2019, we held the first meeting of the Hyper-Kamiokande Financial Forum (HKFF) in Tokyo. The meeting was an important step in establishing Hyper-Kamiokande as a truly international project and focused on high level discussions among all international agencies/laboratories/universities which have an interest in participation in Hyper-Kamiokande. Representatives of 12 countries attended this meeting. From Russia, Prof. L. Kravchuk, director of Institute for Nuclear Research (INR) and representatives of the Russian Embassy in Japan participated.

I would like to emphasize the important contribution of INR to the very successful long baseline neutrino experiments K2K and T2K. A lot of good opportunities are now open for significant contributions to the Hyper-Kamiokande project from many Russian scientific organizations and industry. We hope you consider the excellent scientific prospects of the Hyper-Kamiokande project and include it in the list of Mega-Science projects supported by the Ministry of Science and Higher Education of the Russian Federation.

We plan to hold the second meeting of HKFF on June 27-28, 2019 to continue discussions and to identify the potential interest and contribution from participating countries to the Hyper-Kamiokande project. I would be very delighted if you appoint your delegate to participate in the second HKFF meeting and to represent your Ministry in the Hyper-Kamiokande Financial Forum.

Sincerely yours,

Takaaki Kajita
Director
Institute for Cosmic Ray Research of the University of Tokyo

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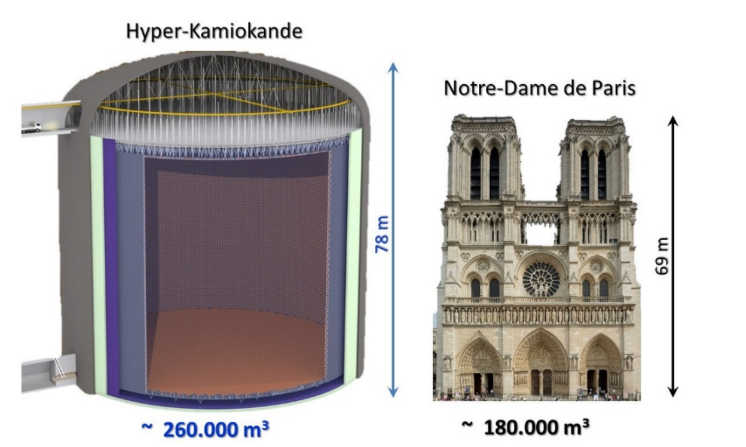

An invitation to the Russian side from Takaaki Kajita - the head of the international neutrino collaboration Hyper-Kamiokande - to join this mega-science project.

By decision of the leadership of MSU, in accordance with the proposal of the leadership of the Faculty of Physics, A.I.Studenikin became a member of the Russian-Japanese group for the coordination of research in neutrino physics and was authorized to represent MSU in the Hyper-Kamiokande collaboration.

МОСКОВСКИЙ ГОСУДАРСТВЕННЫЙ УНИВЕРСИТЕТ имени М.В.ЛОМОНОСОВА (МГУ)
Ленинские горы, Москва, ГСП-1, 119991
Телефон: 939-10-00
Факс: 939-01-26

Первому заместителю министра Министерства науки и высшего образования Российской Федерации
Г.В.ТРУБНИКОВУ

Глубокоуважаемый Григорий Владимирович!

В ответ на Ваше письмо МН-2258/ГТ от 16.10.2019 года Московский государственный университет имени М.В.Ломоносова предлагает кандидатуру в состав Российско-японской группы по координации исследований по физике нейтрино и по проекту ГиперКамиоканде профессора физического факультета А.И.Студеникина.

Профессор физического факультета А.И.Студеникин является известным специалистом по проблемам физики нейтрино, автор многочисленных статей в журналах из списка Топ-25, в том числе большой обзор статьи в журнале Reviews of Modern Physics, руководитель группы по физике нейтрино, член Научного совета РАН «Физика нейтрино и нейтринная астрофизика».

С уважением,

Проректор МГУ профессор — А.А.Федянин

МОСКОВСКИЙ ГОСУДАРСТВЕННЫЙ УНИВЕРСИТЕТ имени М.В. ЛОМОНОСОВА (МГУ)
ФИЗИЧЕСКИЙ ФАКУЛЬТЕТ
Ленинские горы, д. 1, стр. 2, Москва, ГСП-1, 119991
Телефон: 939-3160. Факс: 932-8820

Ректору Московского университета, академику В.А. САДОВНИЧЕМУ

Глубокоуважаемый Виктор Антонович!

Физический факультет предлагает кандидатуру профессора А.И.Студеникина в состав Российско-японской группы по координации исследований по физике нейтрино и по проекту ГиперКамиоканде.

Профессор А.И.Студеникин является известным специалистом по проблемам физики нейтрино, автор многочисленных статей в журналах из списка Топ-25, в том числе большой обзорной статьи в журнале Reviews of Modern Physics, руководитель группы по физике нейтрино, член Научного совета РАН «Физика нейтрино и нейтринная астрофизика».

Декан физического факультета МГУ, профессор — Н.Н. Сысоев

Moscow University was presented with a report at the Hyper-Kamiokande collaboration meeting (February 2020, Tokyo, Japan)