Missions

of the HUN-REN Wigner Research Centre for Physics

Research. Innovation. Impact.

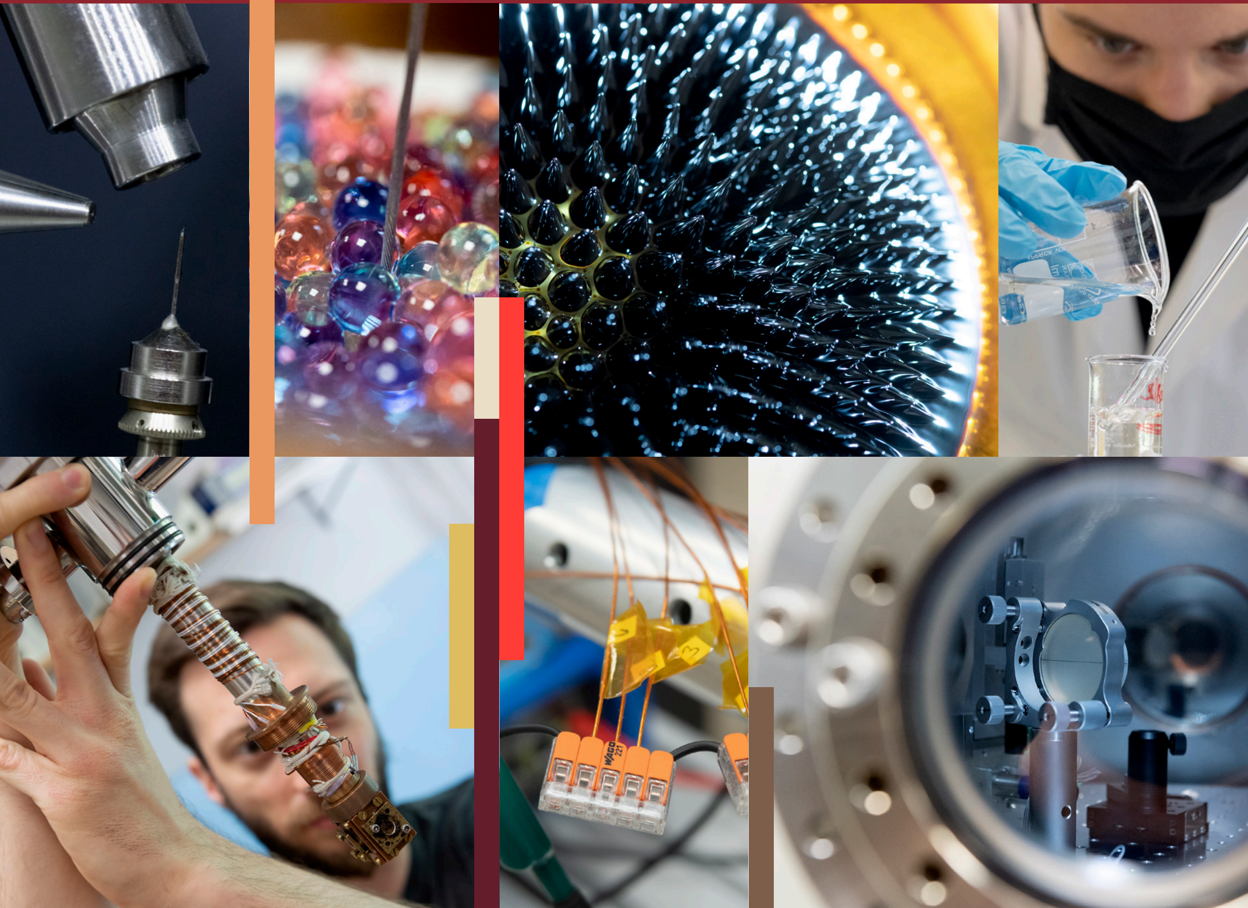


Table of Contents

Introduction

The challenges of our modern world, such as environmental protection, the rapid development of computers and their inevitable presence in the daily life of everyone, the extraordinary advancement of artificial intelligence in many fields, or even new medical procedures, require support at the highest level from natural sciences based on cutting-edge results, and the most precise and validated analysis from social sciences. The researchers of the HUN-REN Wigner Research Centre for Physics (HUN-REN Wigner RCP) possess excellent scientific competencies, internationally respected professional experiences, and wide networking activity in many related fields. Furthermore, the institute offers a modern research infrastructure to meet these challenges. Thanks to these, the HUN-REN Wigner RCP is deeply integrated in the European Research Areas, participating successfully in numerous cross-border and often interdisciplinary scientific collaborations, and coordinates the Hungarian participation in numerous large-scale projects.

The HUN-REN Wigner RCP, which looks back on a 70-year history through its predecessor institutions, was formed on January 1, 2012, by the merger of the former MTA KFKI Particle and Nuclear Physics Research Institute (MTA KFKI RMKI) and the former MTA Solid State Physics and Optics Research Institute (MTA SZFKI). **The resulted modern scientific research centre is built on traditions, including high-quality theoretical research, as well as exploratory and applied experimental physics, chemistry, computer science. The concentrated knowledge base of the Centre is a source of synergies among our research areas resulting in an infinite source of multidisciplinary ideas. A key goal is to achieve and maintain the international leading-edge standards in Hungary.** The present laboratories have the potential for establishing pioneering research activities and accomodating several future technologies, supporting technology and knowledge transfer to the domestic R&D sector.

The HUN-REN Wigner RCP is currently the largest research centre in the field of physics of the Hungarian Research Network (HUN-REN), integrating the activity of 374 employees including 263 researchers at the end of 2023. The internationally recognized scientific activity of the Centre is acknowledged recently by the title of „Centre of Excellence of the Hungarian Academy of Sciences".

Board of Directors

Dr. Péter József Lévai
Director General

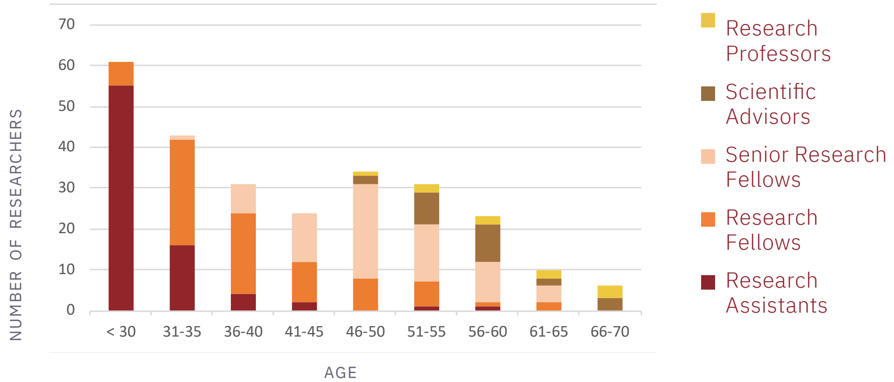
Klára Vámos-Szigeti
Financial Director

Dr. Péter Domokos
Scientific Director of the Institute for Solid State Physics and Optics

Dr. Péter Ván
Scientific Director of the Institute for Particle and Nuclear Physics

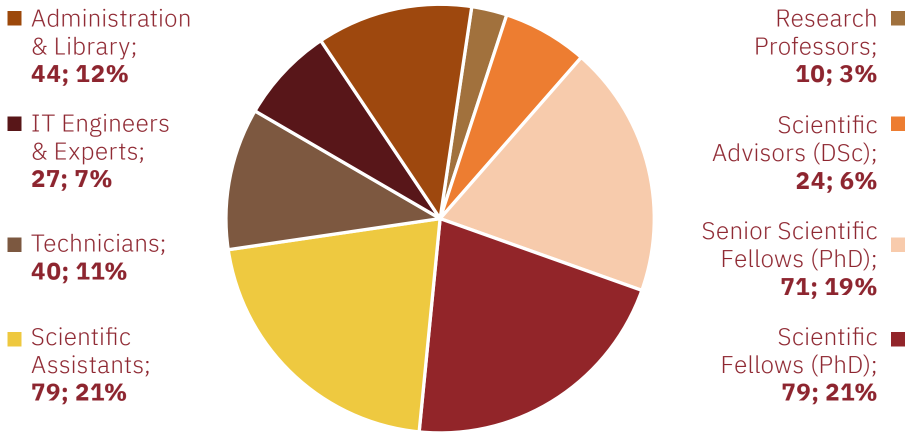
Human Resources

Age distribution of 263 researchers



31/12/2023

Position distribution of 374 employees



31/12/2023

Our Competencies

- Quantum Technology
- High Energy Particle and Nuclear Physics
- Computational Sciences
- Gravitational Physics
- Photonics
- Materials Science
- Space Research

Our Competencies

Quantum Technology

One of the scientific breakthroughs of the 21st century is quantum technology, which brings about significant changes in communication, computing, and information technologies. Its impact extends to metrology and medical diagnostics as well. This new technology fundamentally surpasses the limitations of traditional methods in terms of security, efficiency, accuracy, and sensitivity. For our research centre, it is vitally important to participate in quantum technology research, development, and innovation projects to contribute to national and European efforts.

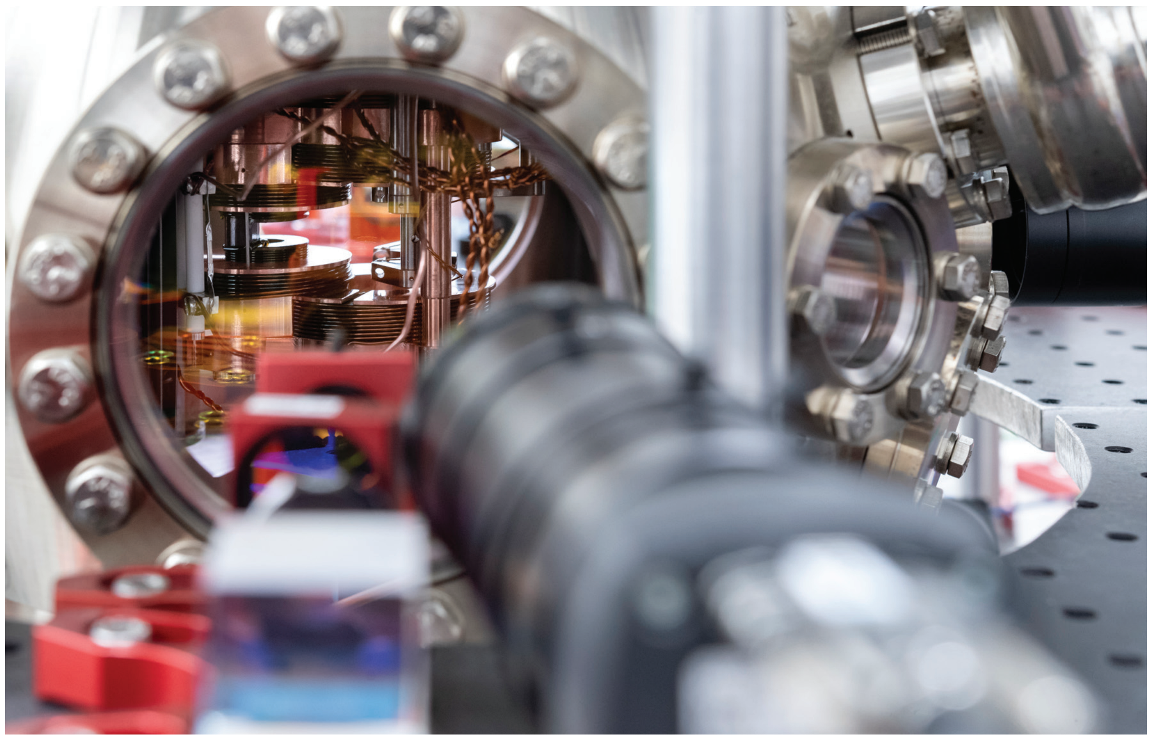
At the Department of Quantum Optics and Quantum Information of the HUN-REN Wigner RCP, theoretical and experimental research is conducted to exploit high-precision coherent quantum mechanical manipulation of individual atoms and photons, as well as ultracold quantum gases, for implementing quantum information operations. They are developing a universal atom-photon interface, gaining cutting-edge knowledge and experimental know-how in the field of atomic and laser physics. There is also intensive research in the field of quantum information and quantum communication at the department. The fact that they are currently working with remotely available quantum computers and are building up a quantum communication network with commercial quantum key distribution (QKD) devices shows that the field of quantum information has outgrown the traditional boundaries of fundamental research. There is an ever increasing interest in their protocols developed for benchmarking quantum computers.

The Wigner Admil Laboratory contributes to quantum physics research with artificial atoms in diamond and silicon carbide that behave as quantum bits. These quantum bit states are read out and operated on by using a combination of optical and electron spin resonance methods.

The Quantum Computing and Informatics Research Group deals with the most radical aspect of quantum technology: quantum computers and their potential applicability. Due to the central role of quantum computing, many quantum computer simulators are being developed worldwide, but almost all of them focus on qubit-based architectures. The group thus considers, possibly involving industrial partners, the realization of an effective photonic qumode-based quantum computer simulator which could even be accessed as a cloud service.

The HUN-REN Wigner RCP coordinates the Quantum Information National Laboratory which is the primary national initiative to coordinate the R&D activity in the field of quantum technology. Our colleagues are involved in 15 Horizon Europe quantum technology collaborations, for example, in the OpenSuperQPlus project which aims to build a 100-qubit European superconducting quantum computer by 2026 and a 1,000-qubit one by 2030. We are also a key participant in the QCI Hungary collaboration, aiming to create the foundations of a national quantum communication infrastructure, which could later be part of a pan-European infrastructure.

Quantum materials are artificial nanostructures with exotic physical properties that represent a great potential for future technological applications. The design of new superconductors, systems with reduced dimensions, topological materials, Weyl semimetals, or quantum spin liquids often relies on the most advanced numerical simulation techniques. Recognizing this, we focus on describing the electrical and magnetic properties of quantum materials with strong entanglement and exotic topological properties. Research based on advanced numerical models and parameter-free material simulations has always been a strong asset of the Theoretical Solid State Physics Department, no wonder that our researchers are still deeply embedded in both the Hungarian and the international theoretical and experimental scientific community.



Our Competencies

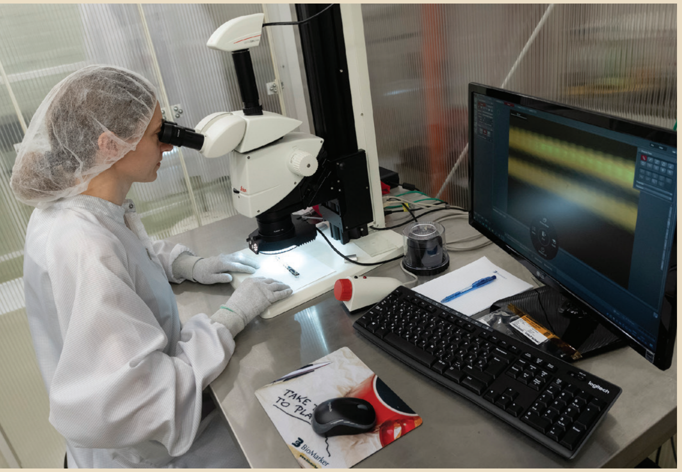
High Energy Particle and Nuclear Physics

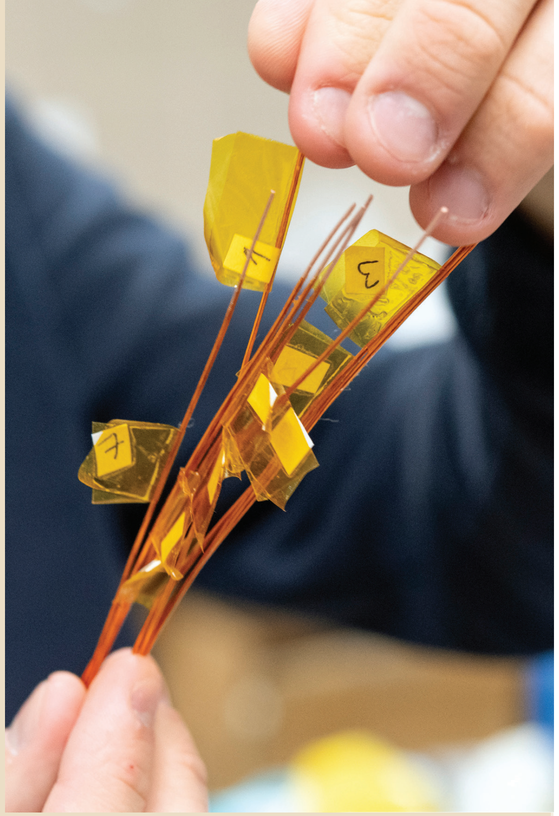
High-energy particle and nuclear physics has been an important research area at the KFKI Campus for decades. The professional experience gained over many years and the continuously developed modern research infrastructure provide a stable background for many theoretical and applied projects. **The well-equipped clean laboratories of HUN-REN Wigner RCP enable significant developments that can be used in many areas, from volcano research to cancer therapy.** Our colleagues use their knowledge in leading domestic and international collaborations such as the experiments of the Geneva-based CERN.

The Innovative Gaseous Detector Development “Lendület” Research Group carries out research and development activities, within the framework of designing and building new types of gas-filled detectors. Their activities include, for example, gas-electron multipliers suitable for Cherenkov detection, three-dimensional trackers for the CERN NA61 experiment, large and cost-efficient multi-wire proportional chambers (MWPC) suitable for detection of cosmic muons for geological tomographic research. The group is involved in the upgrade of the ALICE TPC (Time Projection Chamber) and the development of neutron detectors in collaboration with the European centre for neutron research, the European Spallation Source (ESS).

The Standard Model and New Physics Research Group is pursuing the development and prototyping of magnetic elements for new types of particle accelerators – such as the Future Circular Collider (FCC) accelerator –, and participating in the design and construction of semiconductor particle-tracking detectors to be used in the experiments of high-energy particle and nuclear physics. The goal of the group is to discover new types of particles and interactions using the data collected by the CMS experiment at CERN. Both former and present members of the group have played leading roles in the construction, operation, and calibration of three generations of the CMS tracking detectors. They are experts of both reconstruction softwares and data analysis of proton-proton collisions recorded by the CMS detector.

The Hadron Physics Research Group in cooperation with the Heavy Ion Research Group aims to gain a better understanding of the strong interaction, one of Nature’s fundamental forces. The two groups investigate the matter under extreme conditions a few microseconds after the

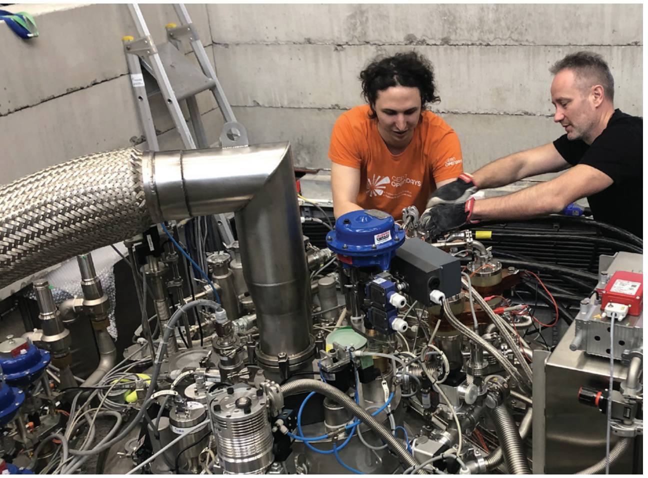


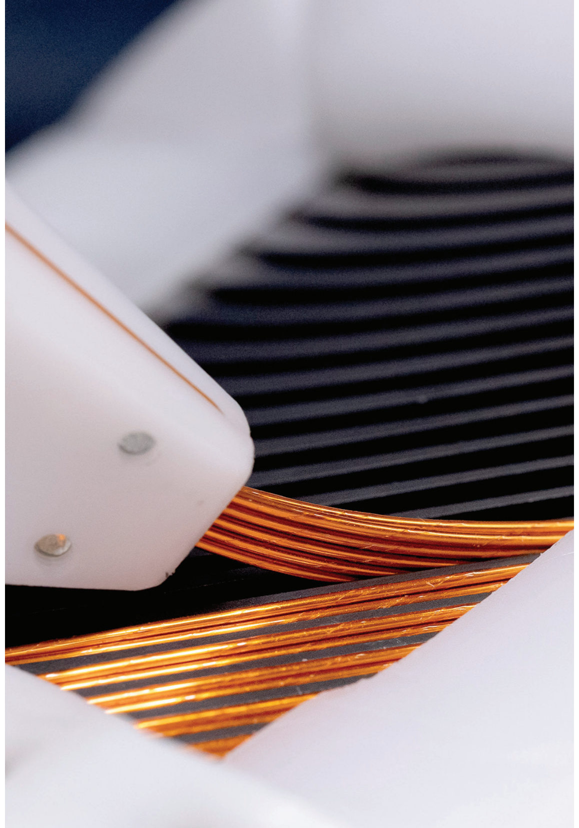


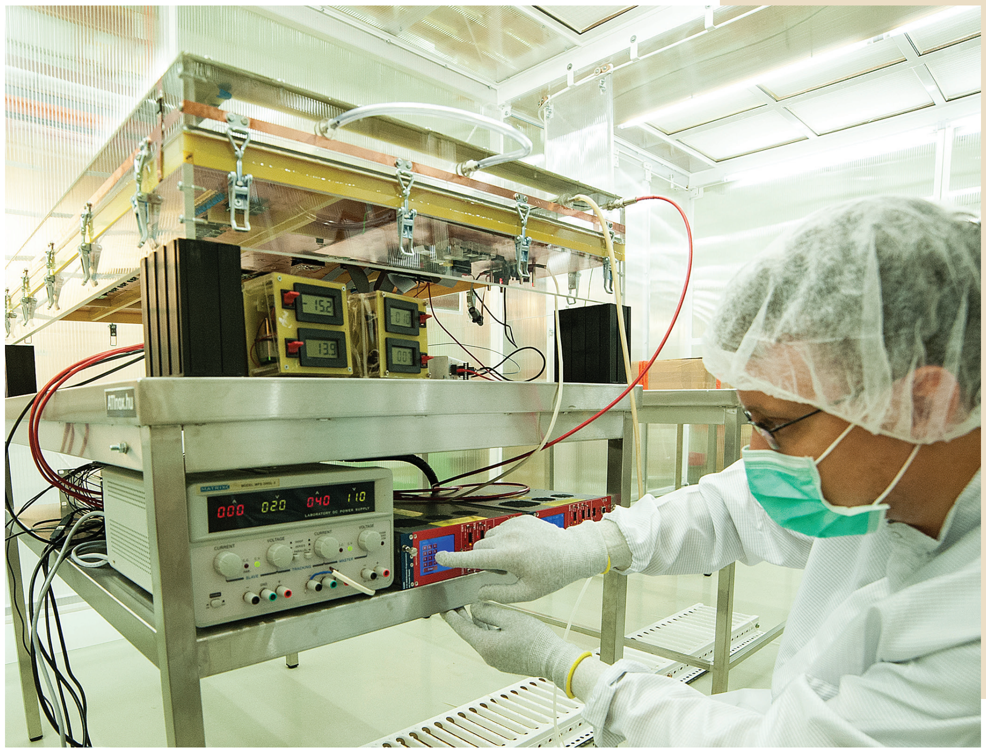
Big Bang. This matter, the quark-gluon plasma can be characterised by properties under intensive study. Group members are participating in the CERN LHC ALICE and CMS experiments, and in the projects executed by the German GSI and the USA-based BNL RHIC accelerators to this end. **They play leading roles in heavy-flavour measurements in high-energy nuclear reactions, as well as in the exploration of gluonic states in proton-proton collisions (glueballs).** Phenomenological description of the smallest droplets of the quark-gluon plasma is studied, as well as the construction of ALICE-3, the future detector complex at LHC. Wigner Scientific Computing Laboratory provides the necessary computing background for data analysis, in particular high-performance parallelized GPU and FPGA clusters, and quantum computer emulators. This Laboratory operates the WLCG Grid Units and the Wigner Analysis Facility for high-throughput big data challenge of ALICE Collaboration.

The Laser Particle Accelerator Technology Research Group uses a modern pulsed laser device to investigate what processes take place when extremely short duration, so-called ultrashort laser pulses interact with matter. In this case, the light that breaks atoms into pieces creates an electromagnetic plasma, and this plasma can act as a compact, small-size particle accelerator.

The High-Energy Geophysics Research Group started its activities in January 2024. Its members have multiple expertise and relevant experience in the research and development of instruments in the field of particle physics, earth sciences and engineering sciences. The group will focus on the development of the muographic technologies for various applications. **The targeted areas are primarily in earth sciences, including the evaluation of volcanic and atmospheric hazards; mine exploration for sustainable, efficient and safe mining; passive and non-destructive assessment of the structure of built infrastructures; as well as for the navigation and security application of positioning based on muon tracing.**







Our Competencies

Computational Sciences

The Department of Computational Sciences is a uniquely multidisciplinary research hub within the HUN-REN Wigner RCP characterized by the application and development of highly complex modern computational methods in various scientific fields. This includes neuroscience, sociology, physics, economics, data mining, quantum informatics, robotics, analysis of stock market processes, game theory, as well as the scientific computation-supported rehabilitation of individuals with spinal cord injuries or paralysis.

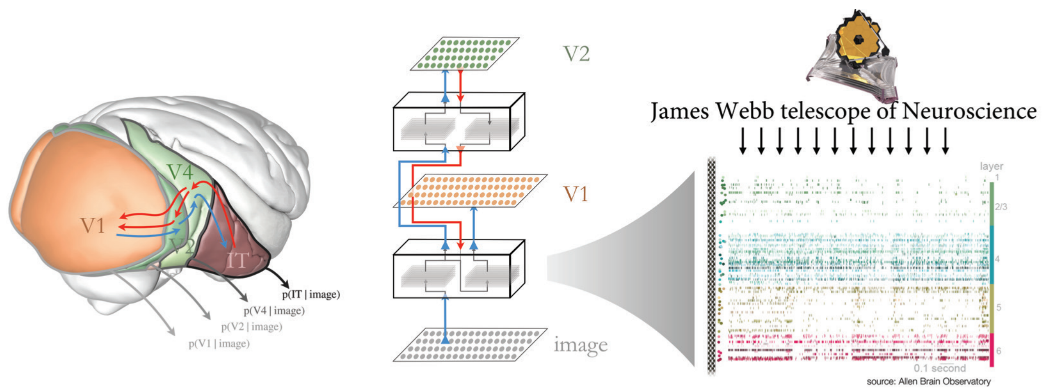
Members of the department possess a diverse research portfolio and actively engage in computational neuroscience, cognitive neuroscience, neuro-rehabilitation, computational social science, mathematics, and theoretical physics. In line with the interdisciplinary approach of the Department, researchers in this department have backgrounds in physics, mathematics, and biology.

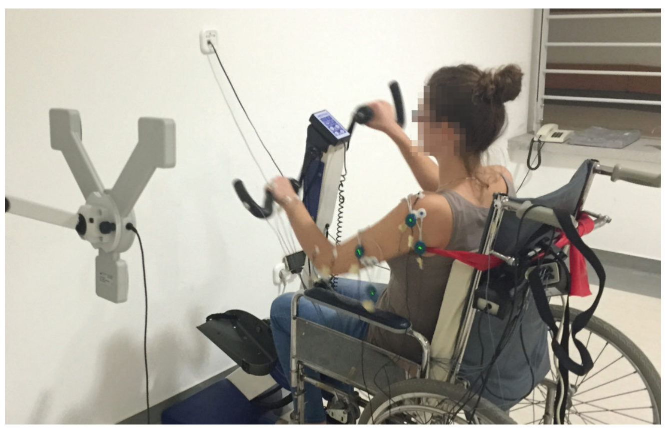
The research of the System Level Neuroscience Research Group focuses on understanding the functioning of the nervous system, aiming to uncover the computations performed by the brain. To this end, they use high-level computational models to understand how people represent elements of the external world during perception and learning. On the other hand, their research targeting low-level computations aims to understand how the network of neurons solves the problems posed by the extremely rich stimuli they encounter.

The fundamental mission of the Theoretical Neuroscience and Complex Systems Research Group is to use mathematical tools to aid in the understanding and exploration of complex systems, primarily focusing on the functioning of the nervous system. **To fulfill this mission, they develop new data analysis methods and create mathematical models to deepen the understanding of phenomena behind measured observations.** While the majority of their work revolves around scientific problems related to the functioning and disorders of the nervous system, the application of the analysis methods and models developed by the group extends beyond the nervous system. They have investigated numerous complex systems, ranging from the citation structures of patents and budget fluctuations to time series characterizing power consumption. Their research extends to the analysis of functional brain connectivity, utilizing network theory methods and causality analysis. They conduct electrophysiological measurements, develop and optimize methods, and design new data analysis procedures for the analysis of their measurement results. They actively participate with their partners in clinical research and development projects in the field of translational medicine.

The Neurorehabilitation and Motor Control Research Group is dedicated to the study of human movement. Researchers of the Group investigate healthy movement patterns to address various motor control issues using mathematical models and algorithms. **Their research findings are primarily applied in the rehabilitation of individuals with spinal cord injuries, and they actively participate in the execution of rehabilitation therapies.**

The Data- and Computation-Intensive Sciences Research Group is responsible for overseeing a laboratory that spans across departments and research groups. The Group is responsible for providing up-to-date hardware for researchers specializing in GPU programming within the institute. Moreover, it offers professional support to accelerate research work and provides opportunities for researchers less experienced with technology to address massively parallelizable problems.





Our Competencies

Gravitational Physics

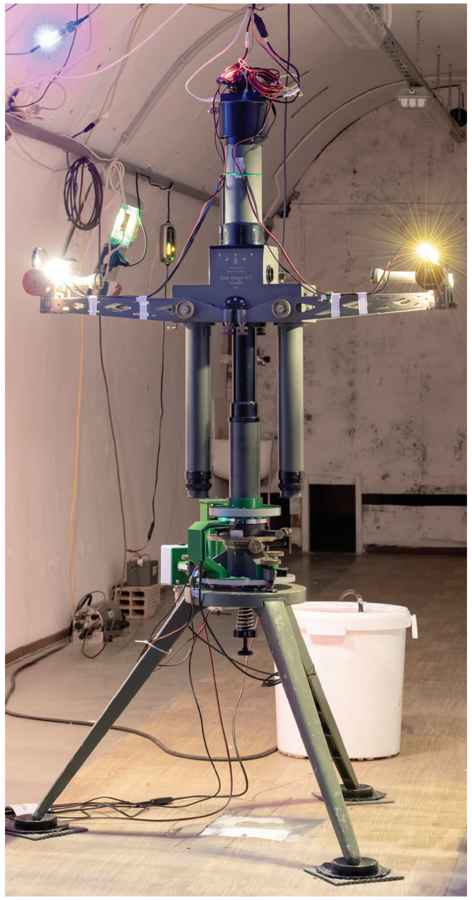
In the HUN-REN Wigner RCP, research on gravitational physics addresses the underlying physical problems of Einstein's theory of general relativity and beyond. In addition to research on the mathematical aspects of general relativity, the home activity includes analytical, numerical, and post-Newtonian tools for describing black hole binaries as the primary sources of gravitational waves, and the determination of the properties of the waves produced by these sources.

Gravitational studies go far beyond the scope of the research conducted in our Research Centre and require a substantial international collaboration. **The Gravitational Physics Research Group is a member of the Virgo Collaboration, the European scientific community that operates the Virgo gravitational-wave detector and participates in utilizing data analysis tools developed for the LIGO-Virgo detectors.** In this context, data analysis algorithms are developed by the group. Our colleagues also have expertise in developing efficient numerical algorithms for modelling compact stars and templates of gravitational waves, as well as algorithms running on computing grids, on GPU clusters and on multi-processor clusters. In collaboration with the Wigner Scientific Computing Laboratory, high-performance, massively parallel computations can be carried out, while providing resources for the LIGO-Virgo collaborations. They also contribute their experience and extensive theoretical skills to the team paving the way for the construction of the Einstein Telescope, enabling the next generation of researchers to participate in a truly challenging and stimulating international scientific project. The newly formed Einstein Telescope Collaboration was established in Budapest.

The research on gravity is far from being limited to the theoretical aspects at the HUN-REN Wigner RCP. Some experiments are carried out in underground facilities, allowing low-background measurements to be performed inside the Jánossy Underground Research Laboratory as part of the Vesztergombi High Energy Physics Laboratory. These measurements contribute, among other aspects, to the site selection and the design of the infrastructure to be constructed and to be dealing with specific synchronisation issues. This entails tests on rock mechanics, as well as the accurate modelling and filtering of Newtonian-noise effects to be eliminated in third generation detectors. **The underground laboratory is also equipped with a high-sensitivity Eötvös pendulum. Its latest observations suggest that it might not only be suitable**

for taking gravimetric measurements, but also for forecasting earthquakes. These all can fit into the new approaches to the directions of modified gravitational theories, dark matter searches, and novel cosmological aspects.

We have also gained useful insights from a recently completed project at the Mátra Gravitational and Geophysical Laboratory, which was established in a former ore mine and provided us with valuable data taken from measurements carried out in an undisturbed underground environment.



Our Competencies

Photonics

Optics and photonics have always been in the focus at the HUN-REN Wigner RCP ranging from solid-state and fiber laser technology through the development of chirped mirrors (playing a crucial role in the Nobel-prized work of Ferenc Krausz) to state-of-the-art integrated optics and ultrafast spectroscopy for applications. In addition to internationally leading fundamental *tabletop* research, there are ongoing R&D activities in different laser applications. This has enabled the development of cutting-edge nano-optical and spectroscopy areas that have been supported by various research grants (Lendület, Élvonal, VEKOP, NKP, TKP), bringing in a total of 2.5 billion HUF in research funding over the past 6-7 years. The effectiveness of HUN-REN Wigner RCP's photonics research has been evidenced by several high-impact publications in recent years. The research groups are actively collaborating with the ELI-ALPS in Szeged.

The Ultrafast Nanooptics Group makes ultrafast electron processes visible in plasmonic and nano-optical systems. Developments related to ultrafast transient metallization have allowed the creation of an optical chip capable of detecting current generated by femtosecond laser pulses, that could also lay the foundation for petahertz optical switches.

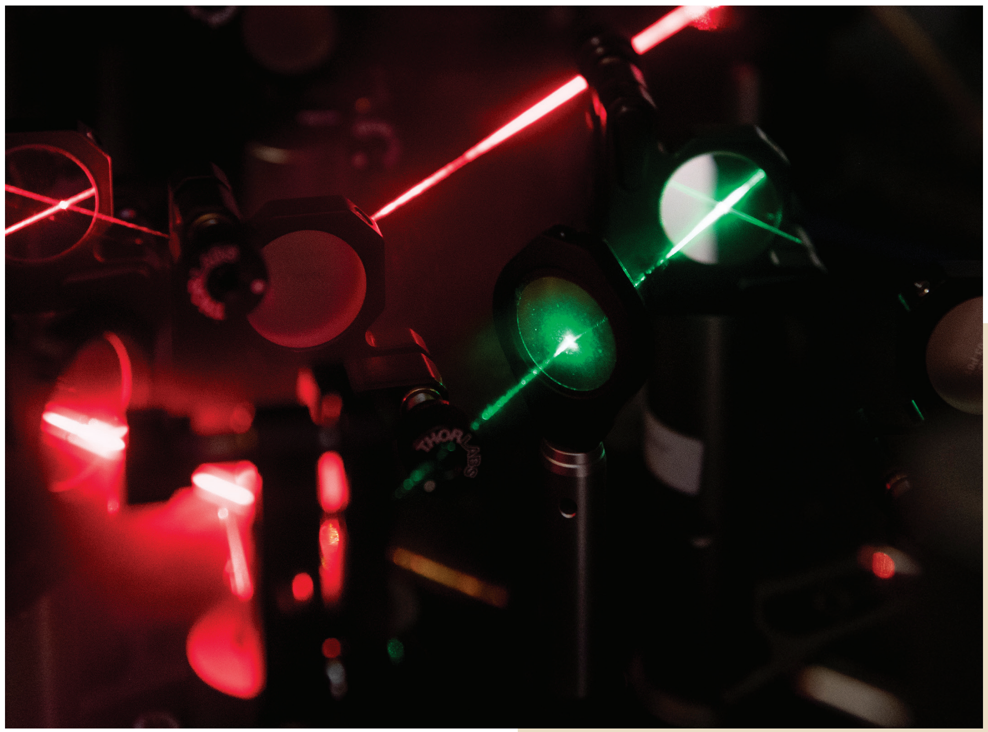
The Femtosecond Lasers in Nonlinear

Microscopy Research Group aims to develop femtosecond laser systems for microscopy imaging in medical diagnostics and basic research, that can investigate cell-level metabolic processes and facilitate the diagnosis of certain cancerous diseases. Several Hungarian life science teams have used these devices resulting in publications in Nature and Science.

The Laser Applications and Optical Measurement Techniques Research Group is actively involved in monitoring the health and environmental effects of aerosols generated in various industrial processes, including 3D metal printing. They participated in COVID research focusing on the spread of the virus in hospital environments.

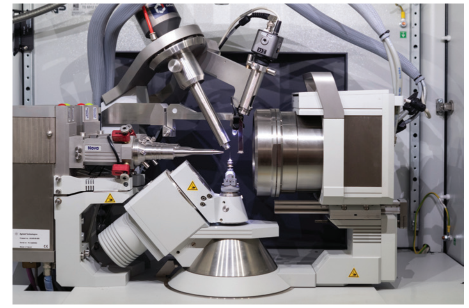
The Crystal Physics Research Group is working on the growth and characterization of crystals for non-linear optics, including lithium niobate used for terahertz photon pulses and second harmonic generation with high-energy lasers. They also use rare-earth doping of crystals for laser spectroscopy measurements and quantum-optical experiments.

The Nanostructures and Applied Spectroscopy Research Group is developing technologies for the fabrication of nanocrystalline diamond structures containing color centres, that can be used as single-photon sources, nano-magnetometers and biomarkers. They also patented vibrational spectroscopy based methods for medical diagnostics of genetic diseases, viruses and bacteria.



Our Competencies

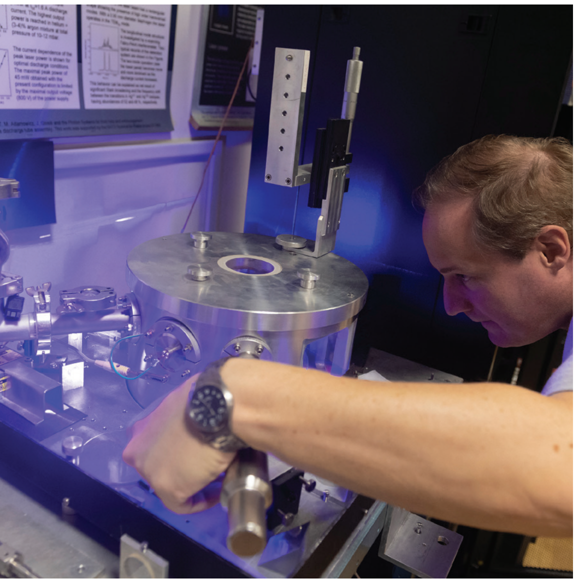
Materials Science

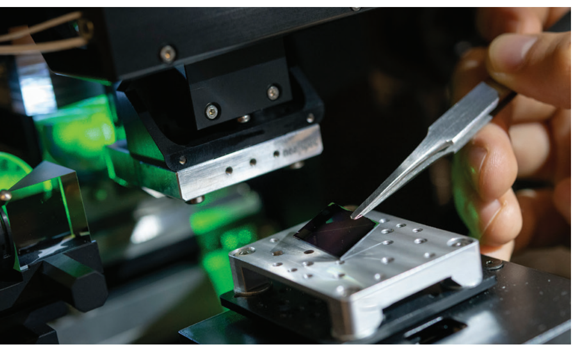


Modern materials science research is just as essential for the development of modern industry and technology as it is for medical or environmental protection. **The development of new materials and test methods, precise measurements and original test solutions require serious expertise and research infrastructure.** In the field of materials science, the coordinated work of physicists, chemists and engineers in several groups of the HUN-REN Wigner RCP offers solutions to numerous research and industrial issues.

The Department of Experimental Solid State Physics focuses on the production and the characterization of the structural, spectroscopic and magnetic properties of advanced materials with unique and interesting physical properties. Not only the necessary experimental methods are being developed, but also the theoretical background and evaluation methods. The groups of the Department of Materials Science by Nuclear Methods carry out basic experimental materials science research using nuclear physics and spectroscopic methods within the framework of the Functional Materials Laboratory that was selected to the TOP50 research infrastructures in Hungary.

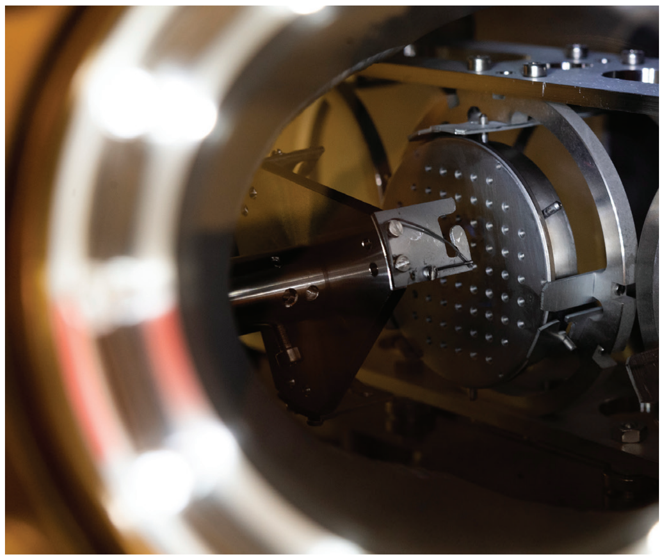
Novel research directions include exploration of ultrafast processes of light-activated functional molecules; instruments based on such systems span a wide range from molecular switches to solar energy utilization and can reflect on many social and economic challenges. **The experimental tests carried out in the home-made laser and X-ray laboratories, or quantum chemical and dynamic modelling provide a good basis for their research at international infrastructures (ELI, European-XFEL, ESRF).**





A spectacular and important equipment of our Research Centre is the Van de Graaff accelerator of the ion-beam laboratory of several storeys height, as well as the also very impressive heavy-ion cascade generator. The research that is performed out here includes the examination of biological, environmental, materials science, archaeology and cultural heritage samples.

Electric gas discharge plasmas are one of the important areas, the results of which are utilized in numerous fields from medical sterilization to micro-, and nanotechnological processes. Applied spectroscopy can have a similar variety of uses. In the last few years, members of the Nanostructures and Applied Spectroscopy Research Group have been working with thin films of amorphous carbon and mainly with films showing diamond-like properties. Their results can be used in the fields of electronics, energetics and medicine.

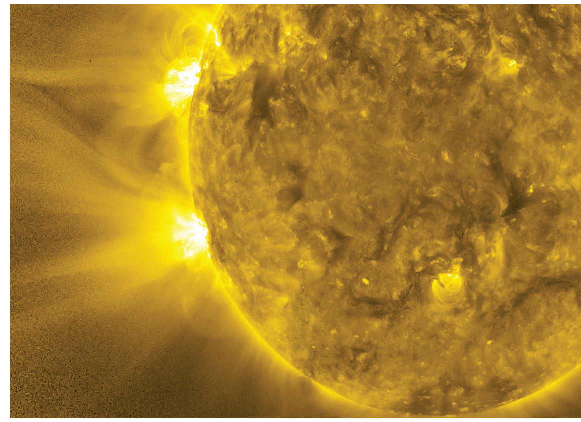


Our Competencies

Space Research

Space holds huge dangers and untold opportunities. **A significant portion of drastic climate change and extinction events in Earth's history have been caused by cosmic effects; at the same time, without growing space economy, national defence, communications, broadcasting, navigation and many other industries would be nonexistent.** In addition, through the study of space phenomena, we can learn about fundamental physical processes that cannot be investigated in terrestrial laboratories. Given the threats from space and the huge potential of space economy, the study of the interaction between the matter filling the solar system and the celestial bodies (the so-called space weather) is of prime importance. However, it is not enough to study near-Earth effects to predict and mitigate damage, we also need to know the triggering processes near the Sun; how these effects propagate through space and the principal drivers behind them. In addition to global propagation models, a better understanding of the interaction between solar wind effects and magnetospheres is essential. This interaction shows its different faces at the various celestial bodies of the Solar System, and the study of their differences and similarities provides important information about the processes taking place in the Terrestrial environment, in addition to their fundamental scientific importance.

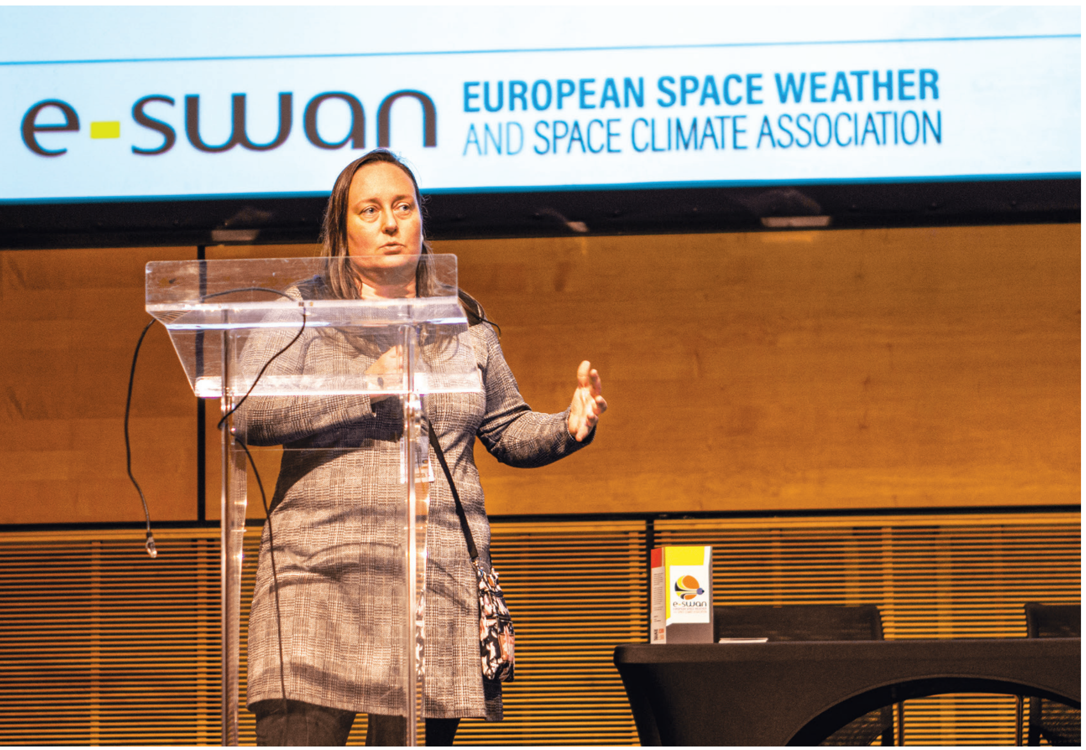
The Department of Space Physics and Space Technology is dedicated to the study of the Solar System, with the aim of understanding how it works. The flow of charged particles together with the fields they carry in interplanetary space link the Sun, planets and other celestial bodies, and our researchers focus on the details of this complex plasma interaction.

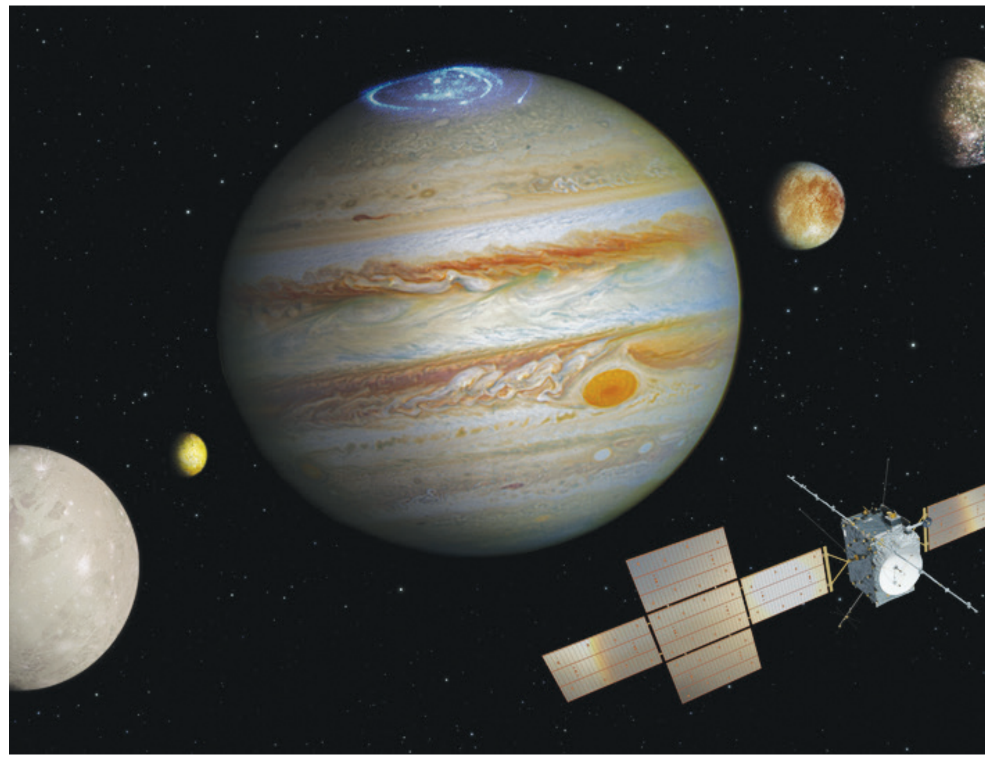


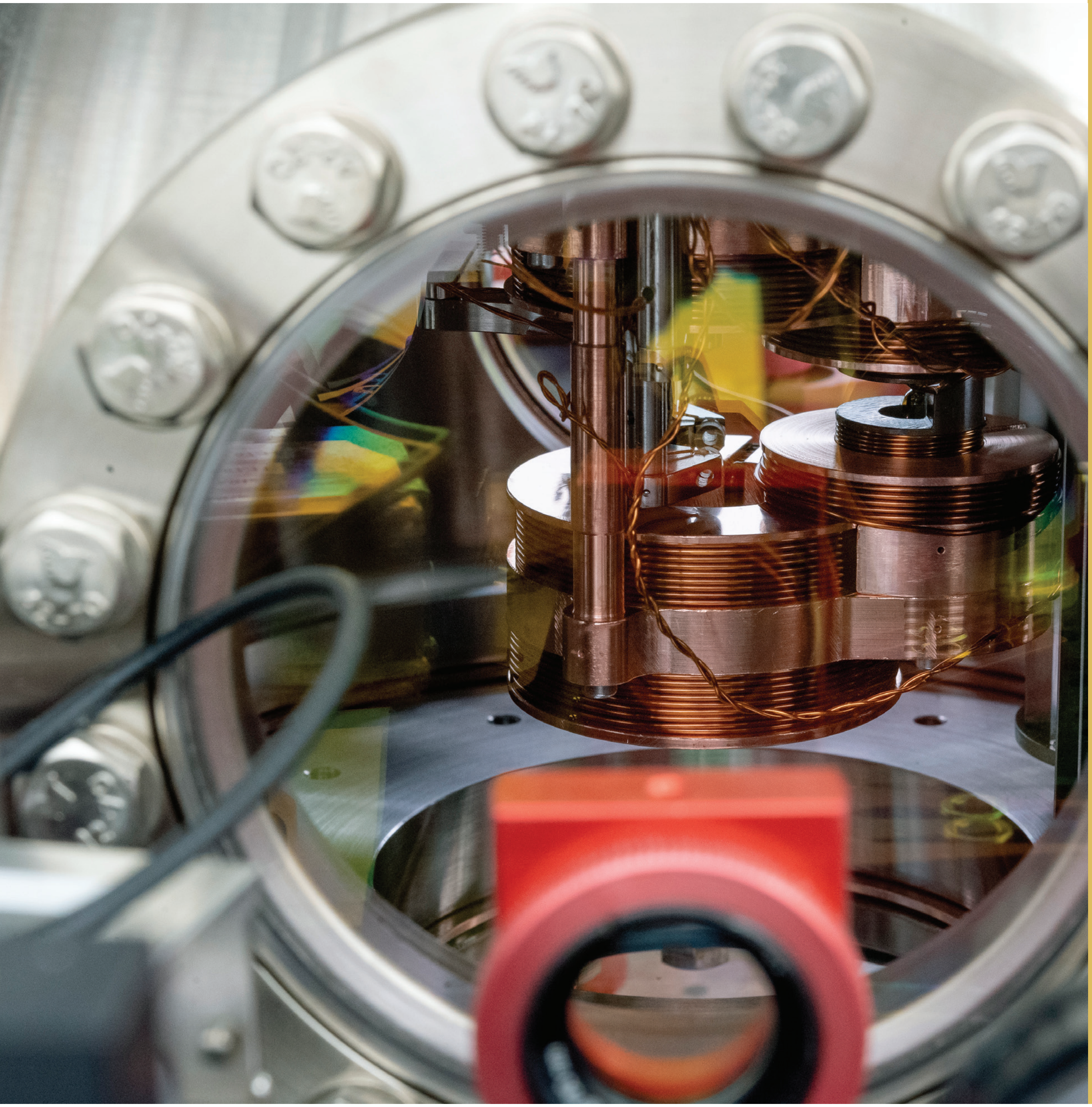
The research method is to observe the interactions and physical processes between the Sun and the bodies and other entities of the solar system (planets, moons, asteroids, comets, dust and the solar wind plasma), as well as the space environment of the planets, using space-based instruments (space probes), and to process and evaluate the resulting data using theoretical and numerical tools. This requires participation in the preparation and implementation of international space missions.

The key to the success of space research, beyond the excellence of the researchers, is primarily the international embeddedness of the participating research teams. For decades, the researchers of HUN-REN Wigner RCP have been successfully participating in several space missions, investigating planetary and cometary environments, as well as interplanetary space probes and spacecraft carrying out in situ measurements near the Sun. **In the last decade, the focus has been on the Cassini, Rosetta, BepiComombo, Solar Orbiter, Parker Solar Probe missions, and the preparation of the JUICE and Comet Interceptor missions has also been an important task.**

Our researchers have built the network, methods and techniques to ensure our successful participation in international space missions in the future as well.

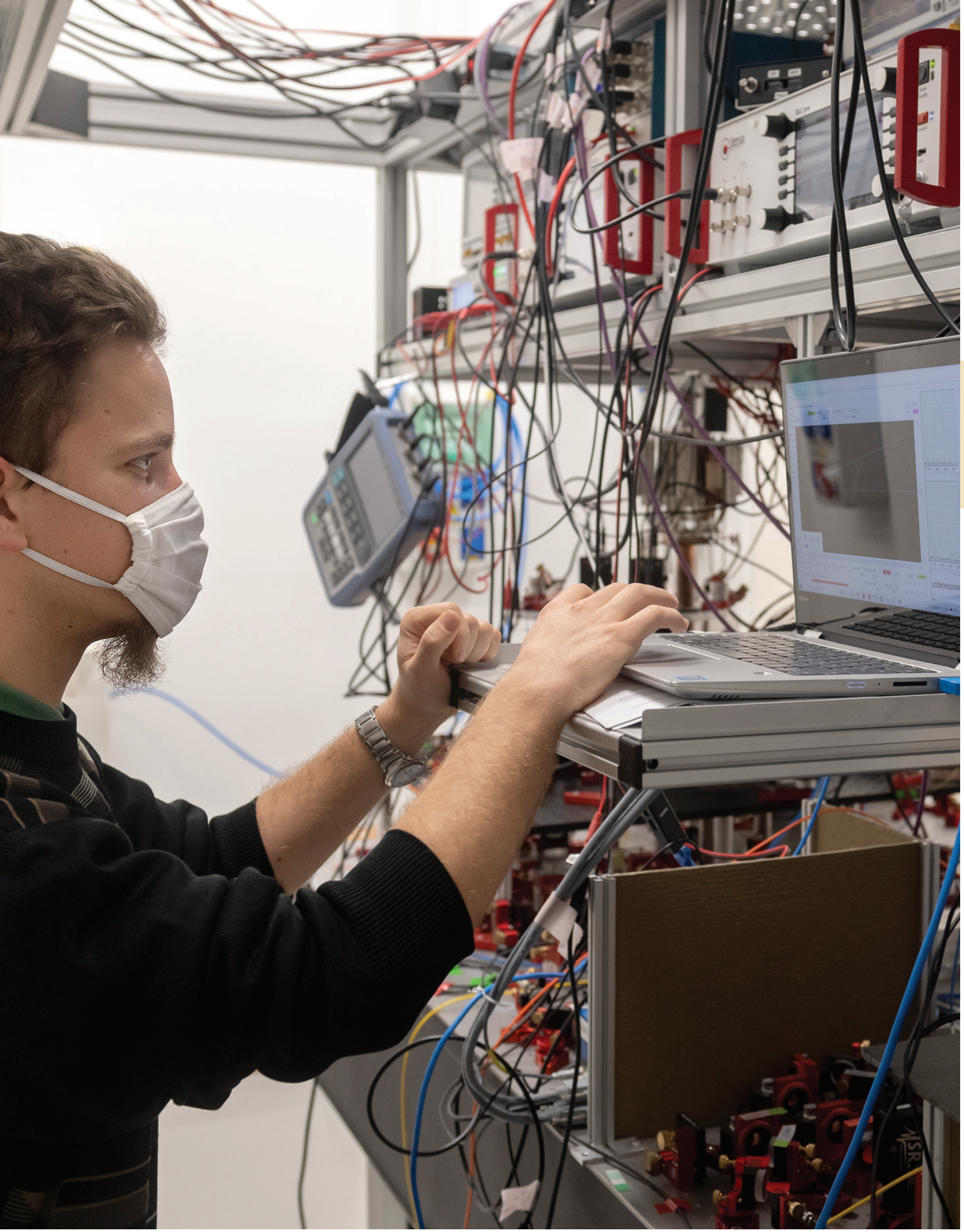






National Laboratories

- Quantum Information National Laboratory (QNL)
- Nanoplasmonic Laser Initiated Fusion Experiment National Research Laboratory (NAPLIFE)



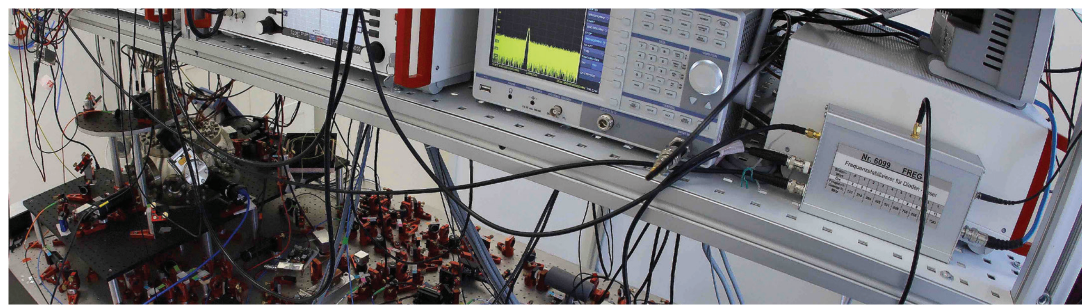
National Laboratories

Quantum Information National Laboratory (QNL)

The aim of the Quantum Information National Laboratory is to maximize our country's role and significance in the now unfolding broad horizon of quantum informatics through thoughtful and coordinated development.

The collaboration, coordinated by the HUN-REN Wigner RCP, brings together groups from the Budapest University of Technology and Economics (BME), Eötvös Loránd University (ELTE), and the HUN-REN Wigner RCP specializing in quantum physics and quantum informatics. In these institutions, a significant number of (15-20) internationally highly-rated research groups work on quantum informatics topics. The effective coordination of these groups, focusing on physics, computer science, engineering, and mathematics, enhances our country's competitiveness on the international playground of the second quantum revolution. Successful participation in European priority projects is backed by substantial professional and infrastructure support.

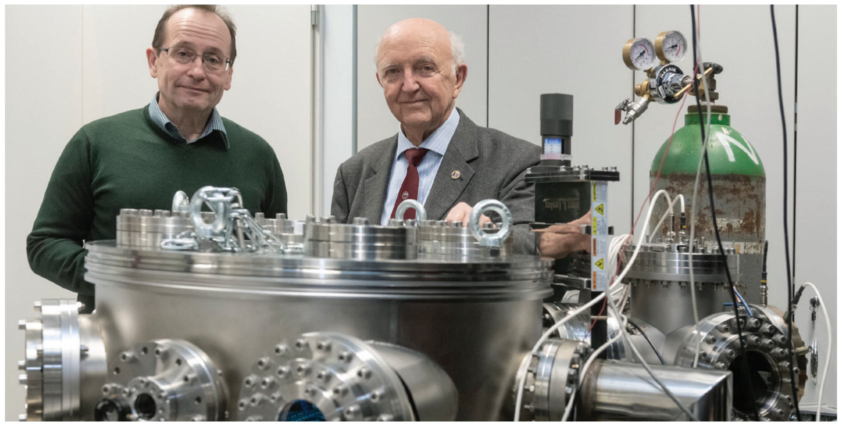
Key research fields in the Quantum Information National Laboratory include the study of the elementary building blocks of quantum informatics, the simulation of quantum computing and quantum systems, and the implementation of quantum communication networks.



For more information: [*https://qi.nemzetilabor.hu/*](https://qi.nemzetilabor.hu/)

National Laboratories

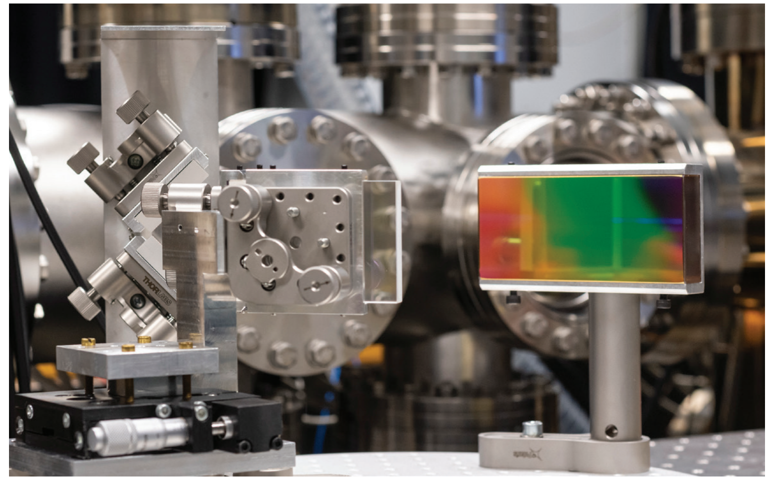
Nanoplasmonic Laser Initiated Fusion Experiment National Research Laboratory (NAPLIFE)



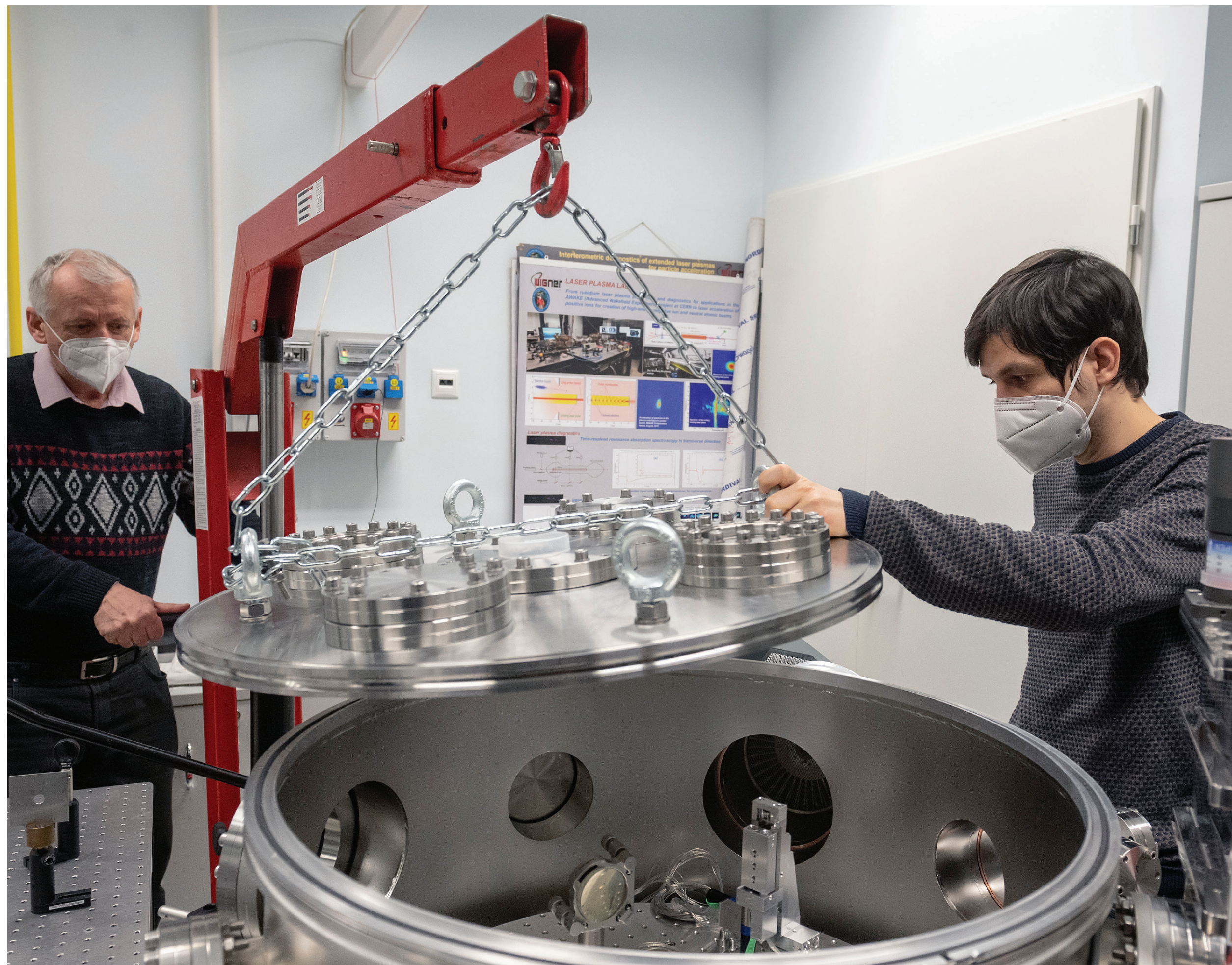
Fusion power generation is more concentrated, uses less raw material than other current production methods, including nuclear fission power plants. 20 tons of coal is equivalent to about 1 kilogram of fissile material (e.g., uranium), and the same amount of energy can be extracted from 1 gram (sic!) of fusion fuel.

The simplest fusion fuel, hydrogen and to a small extent deuterium, is present in natural water. Only nuclear fusion reactions can be designed so that they do not have difficult-to-stop end products with long decay times and destructive energies. The energy released from nuclear fusion is several times greater than even the fission-based reactions currently in operation.

Applied research is underway worldwide to achieve this goal. Given that even the most advanced projects are decades away from operational industrial reactors, the race is not yet decided.



Our laboratory has set itself the goal of developing a way of realising “nanofusion”, i.e., nanoplasmonic laser fusion, based on the ideas of two Hungarians: Norbert Kroó and László Csernai.



Highlighted Scientific Publications 2023

- Institute for Particle and Nuclear Physics
- Institute for Solid State Physics and Optics

Institute for Particle and Nuclear Physics

- Kovács R., *Heat equations beyond Fourier: From heat waves to thermal metamaterials,* **PHYSICS REPORTS-REVIEW SECTION OF PHYSICS LETTERS 1048, 1-75 (2024); IF: 30**

- Miller, A.; Zimborás, Z.; Knecht, S.; Maniscalco, S.; García-Pérez, G., *Bonsai Algorithm: Grow Your Own Fermion-to-Qubit Mappings,* **PRX QUANTUM 4, 030314 (2023); IF: 9.7**

- Szabados L.B., *An odd feature of the "most classical" states of SU (2) invariant quantum mechanical systems,* **JOURNAL OF MATHEMATICAL PHYSICS 64, 032104 (2023); IF: 1.3**

- Hanczár, G.; Stippinger, M.; Hanák, D.; Kurbucz, M. T.; Törteli, O. M.; Chripkó, Á.; Somogyvári, Z., *Feature space reduction method for ultrahigh-dimensional, multiclass data: Random forest-based multiround screening (RFMS),* **MACHINE LEARNING: SCIENCE AND TECHNOLOGY 4, 045012 (2023); IF: 6.8**

- Merkel, D.G.; Sajti, S.; Deák, L.; Hegedűs, G.; Horváth, Z.E.; Lengyel, A., *Iron self-diffusion in B2-FeRh thin film,* **VACUUM 218, 112617 (2023); IF: 4**

- Acharya, S.; [...] Barnaföldi, G.G.; [...] Bencedi, G.; [...] Biro, G.; [...] Boldizsár, L.; [...] Frajna, E.; [...] Gyulai, L.; [...] Lévai, P.; [...] Mishra, A.N.; [...] Varga, D.; Varga, Z.; [...] Vértesi, R.; [...] Zurlo, N. ALICE Collaboration, *Azimuthal correlations of heavy-flavor hadron decay electrons with charged particles in pp and p–Pb collisions at $\sqrt{s_{NN}} = 5.02$ TeV,* **EUROPEAN PHYSICAL JOURNAL C 83, 741 (2023); IF: 5**

- Tanaka Hiroyuki, K. M.; [...] Varga, D., *The Muography,* **NATURE REVIEWS METHODS PRIMERS 3, 88 (2023); IF: 20.89**

- Demeter, G.; Moody, J.T.; Kedves, M.Á.; Batsch, F.; Bergamaschi, M.; Fedosseev, V.; Granados, E.; Muggli, P.; Panuganti, H.; Zevi Della Porta, G., *Generation of 10-m-lengthscale plasma columns by resonant and off-resonant laser pulses,* **OPTICS AND LASER TECHNOLOGY 168, 109921 (2024); IF: 5**

- Nemeth, Z., *Closed field line vortices in planetary magnetospheres,* **MONTHLY NOTICES OF THE ROYAL ASTRONOMICAL SOCIETY 519, 5536-5542 (2023); IF: 4.8**

- Pápai, M.; Rozgonyi, T.; Vankó, Gy., *Ultrafast 3MLCT quenching and vibrational coherence: excited-state dynamics of the first-discovered Fe(II)-carbene sensitiser resolved,* **JOURNAL OF MATERIALS CHEMISTRY A 11, 25955-25962 (2023); IF: 11.9**

Institute for Solid State Physics and Optics

- Mikac, L.; Rigó, I.; Himics, L.; Tolić, A.; Ivanda, M.; Veres, M., *Surface-enhanced Raman spectroscopy for the detection of microplastics,* **APPLIED SURFACE SCIENCE 608, 155239 (2023); IF:6.7**

- Hanus, V.; Fehér, B; Csajbók, V.; Sándor, P.; Pápa, Zs.; Budai, J.; Zilong, W.; Pallabi, P.; Szeghalmi, A.; Dombi, P., *Carrier-envelope phase on-chip scanner and control of laser beams,* **NATURE COMMUNICATIONS 14, 5068 (2023); IF: 17.69**

- Benedek, Z.; Babar, R.; Ganyecz, Á.; Szilvási, T.; Legeza, Ö.; Barcza, G.; Ivády, V., *Symmetric carbon tetramers forming spin qubits in hexagonal boron nitride,* **NPJ COMPUTATIONAL MATERIALS 9, 187 (2023); IF: 9.7**

- Cambria, M.C.; Norambuena, A.; Dinani, H.T.; Thiering, G.; Gardill, A.; Kemeny, I.; Li, Y.; Lordi, V.; Gali, Á.; Maze, J.R.; Kolkowitz, S., *Temperature-Dependent Spin-Lattice Relaxation of the Nitrogen-Vacancy Spin Triplet in Diamond,* **PHYSICAL REVIEW LETTERS 130, 256903 (2023); IF: 8.185**

- Deák, P.; Udvarhelyi, P.; Thiering, G.; Gali, A., *The kinetics of carbon pair formation in silicon prohibits reaching thermal equilibrium,* **NATURE COMMUNICATIONS 14, 361 (2023); IF: 17.694**

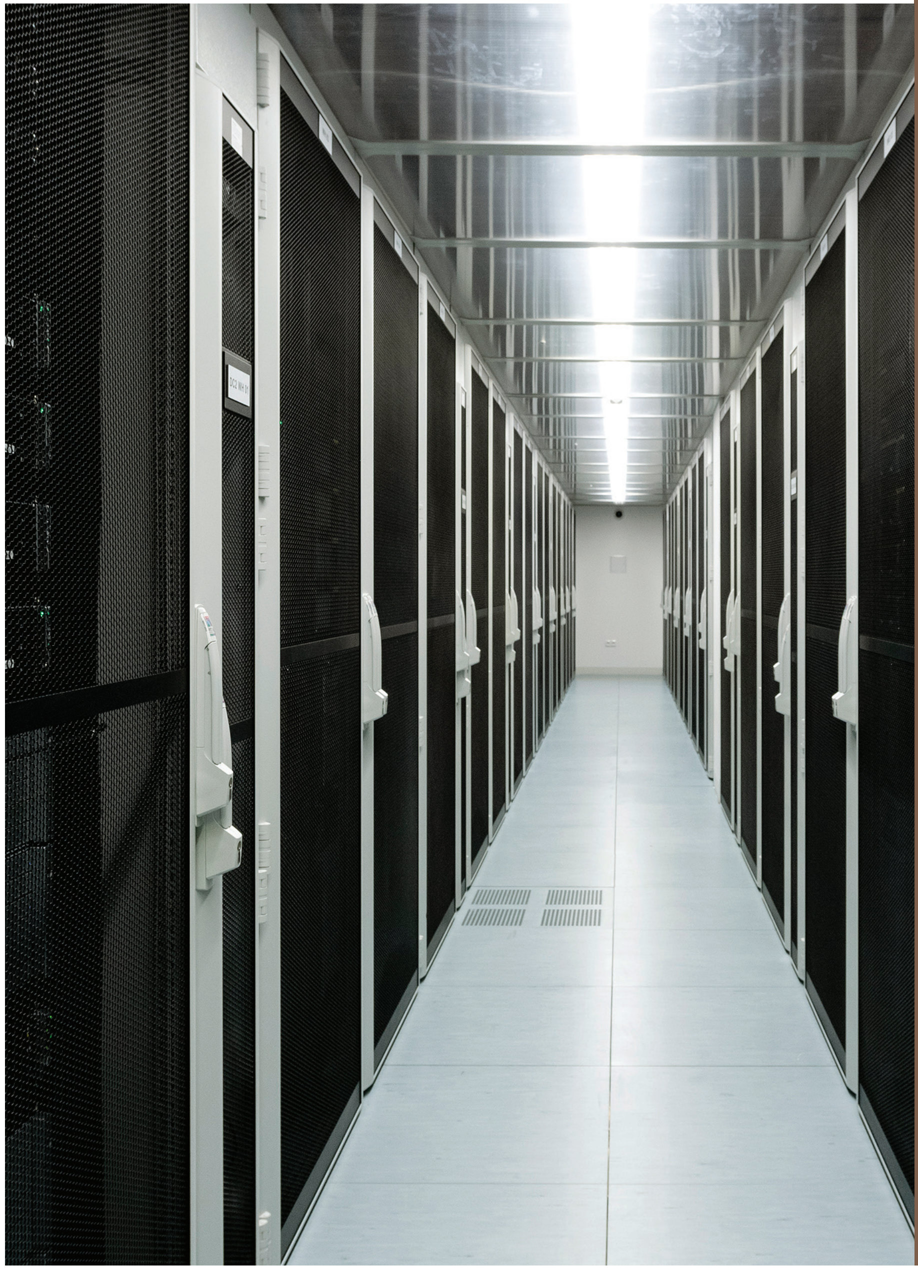
- Schulte, S.; Néel, N.; Rózsa, L.; Palotás, K.; Kröger, J., *Changing the Interaction of a Single-Molecule Magnetic Moment with a Superconductor,* **NANO LETTERS 23, 1622-1628 (2023); IF: 10.8**

- Máthé, M. T.; Farkas, B.; Péter, L.; Buka, Á.; Jákli, A.; Salamon P., *Electric field-induced interfacial instability in a ferroelectric nematic liquid crystal,* **SCIENTIFIC REPORTS 13, 6981 (2023); IF: 4.6**

- Gránásy, L.; Rátkai, L.; Zlotnikov, I.; Pusztai, T., *Physical Phenomena Governing Mineral Morphogenesis in Molluscan Nacre,* **SMALL, 2304183 (2023); IF: 13.3**

- Czene, Sz.; Jegenyes, N.; Krafcsik, O.; Lenk, S.; Czigány, Zs.; Bortel, G.; Kamarás K.; Rohonczy, J.; Beke, D.; Gali A., *Amino-Termination of Silicon Carbide Nanoparticles,* **NANOMATERIALS 13, 1953 (2023); IF: 5.7**

- Gábor, B.; Nagy, D.; Dombi, A.; Clark, T. W.; Williams, F. I. B.; Adwaith, K. V.; Vukics, A.; Domokos, P., *Ground-state bistability of cold atoms in a cavity,* **PHYSICAL REVIEW A 107, 023713 (2023), IF: 2.9**



Highlighted Infrastructures

- Wigner Data Centre
- Magnetically Shielded Laboratory
- TOP 50 Research Infrastructures at the HUN-REN Wigner RCP
- Functional Materials Laboratory
- Vesztergombi High Energy Physics Laboratory
- Wigner Scientific Computing Laboratory
- Wigner Laser and Spectroscopy Centre

Highlighted Infrastructures

Wigner Data Centre

The success of modern science and the execution of computation-intensive research necessitate the creation of increasingly large IT bases, which can satisfy the needs of various scientific fields. Additionally, the long-term storage and preservation of data under secure conditions are becoming increasingly important. The Wigner Data Centre is a server infrastructure of the highest modern technological standards, which supports the dynamically changing needs of research and innovation in an exceptionally energy-efficient and environmentally friendly way. Since 2013, the world-class Wigner Data Centre has housed CERN's remote Tier-0 infrastructure, thus playing a key role in processing the data from the Large Hadron Collider (LHC). The Wigner Data Centre continuously capitalizes on the substantial professional experience gained in this project at an elevated security level, ensuring high availability in data centre infrastructure services, in the development, and operation of the HUN-REN Cloud service, and in the implementation and operation of the HUN-REN Data Repository project on the HUN-REN Wigner RCP side. Following the completion of the CERN project, the reconstruction of hardware elements and redesign of software components led to the establishment of WSCLAB (Wigner Scientific Computing Laboratory), which houses the GPULAB servers, the Virgo research project, the Tier-2 cluster operated for CERN's ALICE and CMS detectors, and last but not least, the infrastructure of the Wigner ALICE Analysis Facility. Our goal is to pass on the acquired knowledge to the research community through various channels of knowledge transfer.

For more information: https://wignerdc.wigner.hu

Magnetically Shielded Laboratory

The opening of a magnetically shielded laboratory, established by the consortium of the HUN-REN Institute of Earth Physics and Space Science and the HUN-REN Wigner RCP in Fertőboz, offers the opportunity to conduct geophysical, space research, petrological, metallurgical, biological, and medical research and applications that were previously unattainable in our country. This project, funded with over 400 million HUF in grant support, has created a world-class research infrastructure for Hungarian researchers. The primary goal of the laboratory is to conduct geophysical measurements, simulate magnetic conditions in space, investigate the magnetic purity of space instruments, and develop space research instruments. In addition to the primary objectives mentioned above, the laboratory is open to all scientific and technological developments that require a low-noise, magnetically clean environment.

TOP 50 Research Infrastructures at the HUN-REN Wigner RCP

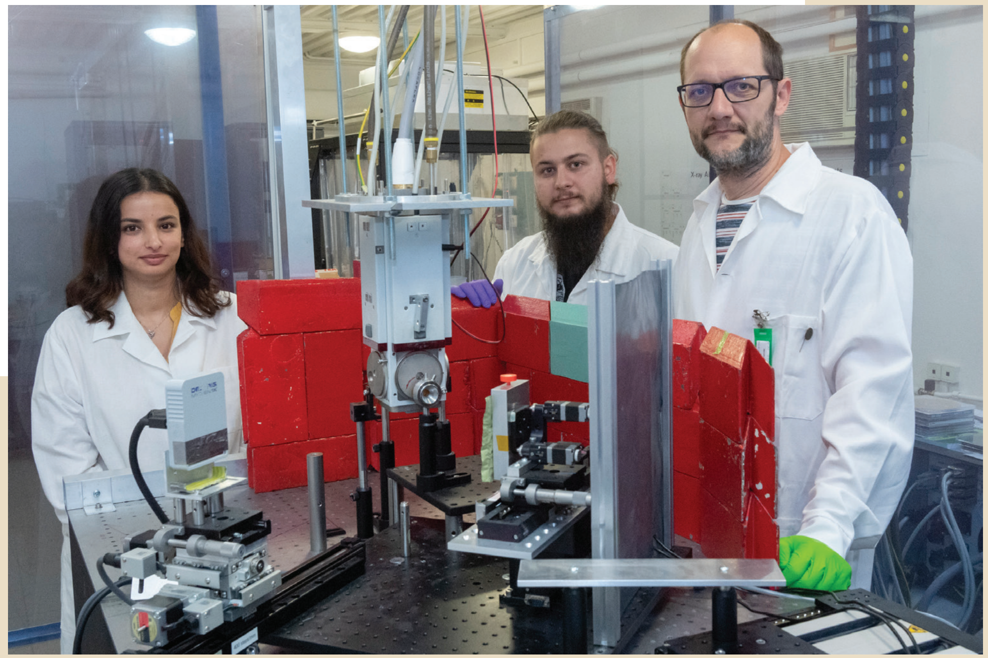
EXCELLENT RESEARCH INFRASTRUCTURE HUNGARY

On December 16, 2021, for the first time, Hungary's most outstanding research infrastructures were recognized at the initiative of the National Research, Development and Innovation Office (NKFI Office), with four laboratories from HUN-REN Wigner RCP being among them.

Functional Materials Laboratory

Functional Materials Laboratory (FunMatLab), supporting modern materials science measurements, is an open-access research infrastructure (RI) that is available worldwide to all researchers, developers and students. The research topics of the projects currently using the laboratory include the study of ultrafast transitions in functional molecules activated by light and the use of X-ray spectroscopy as a probe aiming to develop smart materials with appropriate structure and function. The professional history of FunMatLab dates back to the 1960s, when material analysis and measurements with γ-photons, X-rays, neutrons and accelerated ions started at the Central Research Institute for Physics in Budapest.

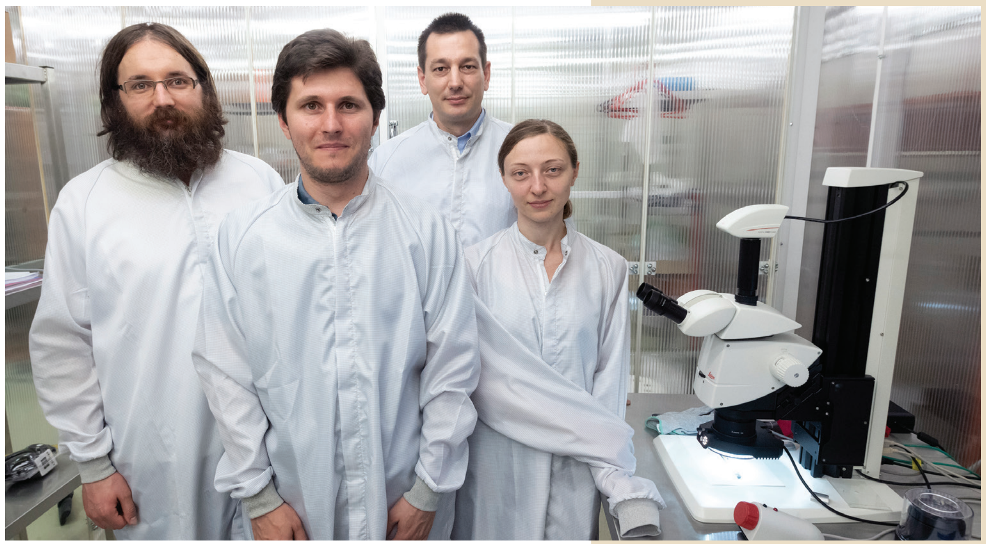
More information: ***https://wigner.hu/nao/en/facilities***



Vesztergombi High Energy Physics Laboratory

The Vesztergombi High Energy Physics Laboratory (VLAB) was created by the need for competitive experimental participation in domestic and international particle and nuclear physics research. It was named after György Vesztergombi (1943-2016), a particle physicist and the founder of Hungarian experimental research connected to CERN. The purpose of the laboratory is to provide an opportunity for the development of instruments, the implementation of innovation steps, and the construction of specific detector elements. VLAB was established in 2017 by merging the Innovative Detector Development "Lendület" research group and the semiconductor, tracking, and superconducting magnet development laboratories at the HUN-REN Wigner RCP. An ESD-protected microelectronic laboratory for data acquisition system R&D is also available (Wigner DAQ Laboratory). The laboratory cooperates with several research groups and provides the development background for H2020 projects. Its subunits are: development of silicon-based and tracking devices (clean room, ISO 6), development related to data reading, superconducting magnet laboratory, and the Jánossy Underground Research Laboratory (JURLAB) for low radiation background and low infranoise and seismic measurements down to a 30 m depth. The VLAB is an Open Laboratory and holds the title "TOP50 National Infrastructure of the NRDIO".

More information: https://vlab.wigner.hu



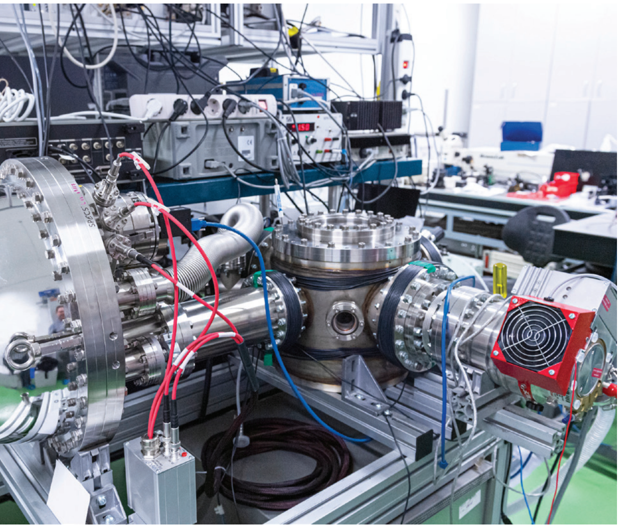
Wigner Scientific Computing Laboratory

The Wigner Scientific Computing Laboratory (WSCLAB) was created via the merger of the GPU Laboratory, which has been operating since 2009, and other computing facilities established during the last decade. These facilities were dedicated to the solution of specific physical tasks using multiprocessors in massively parallel ways: CPUs, GPUs and FPGAs. The Laboratory is located in one of the computing halls of the Wigner Data Centre (1 MW IT capacity, 100 racks) and it is connected to the outside world at a speed of 100 Gb/s. The Laboratory provides various computing capacities to researchers on various platforms. It also acts as a knowledge centre, and provides annual training on the creation and application of computer clusters. Excellent examples are the GPU Day workshop, which has been held regularly for almost 15 years, and the "Academy-Industry Matching Event on IT-solutions" (AIME), which has also been held for a decade, with the main purpose to promote the cooperation of industrial and academic professionals.

WSCLAB is constantly monitoring new trends. The development and application of Field Programmable Gate Arrays (FPGA) based systems emulating the operation of quantum computers is underway, paving the way for the acceptance of machine learning and real quantum computers, and their routine use. Moreover, it provides continuous service for large-scale international collaborations (such as ALICE, CMS, EUPRAXIA, VIRGO/LIGO), national laboratories (NAPLIFE) and Horizon 2020 or Horizon Europe projects (QINLAB, QCI Hungary). The WSCLAB is an Open Laboratory and holds the title "TOP50 National Infrastructure of the NRDIO".

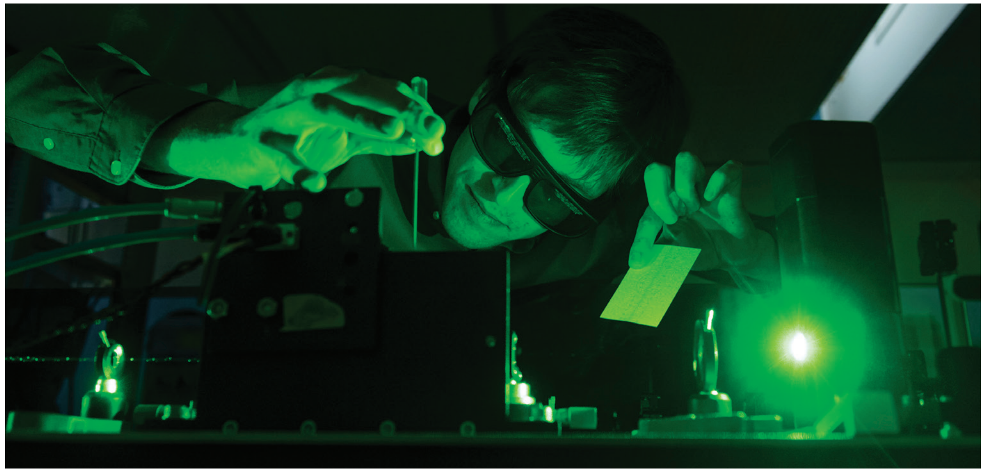
More information: https://wigner.hu/en/wsclab

Wigner Laser and Spectroscopy Centre



The Wigner Laser and Spectroscopy Centre was awarded the title of being one of the TOP50 research infrastructures in Hungary. Since 2021 when this happened, laser laboratories at our institute have been living up to the high expectations demanded by such a distinction. The Centre provides external partners with state-of-the-art femtosecond laser, ultrafast science and spectroscopy equipment in Budapest. These partners include international academic research institutes, European industrial actors such as LAYERTEC GmbH and several Hungarian universities as well. With several infrastructural developments realized in these laboratories since 2012, we offer a unique combination of equipment for photonics („the science of light") and its broad applications in physics, chemistry and biology. More detailed description of the areas of life and physical sciences covered can be found in the Photonics section of this document.

More information: https://wigner.hu/lasercenter/



Scientific Cooperations and Industrial Relations

- Large-scale International Cooperations
- Supporting the Scientific Community Data Repository Platform
- Industrial Collaboration

Eugene P. Wigner predicted ahead of his time - recognizing the rapid growth of scientific knowledge – that researchers from various fields should come together to form research groups and even larger collaborations for performing efficient research activity. In many cases this collective effort is necessary for achieving outstanding scientific results. These days it is widely recognized that providing high-level research support is manageable only if research infrastructures go beyond the capabilities of individual institutes and cutting-edge infrastructures are established with wide-scale international collaboration of member states. The HUN-REN Wigner RCP strives to participate in this international endeavour and contributes its experience and expertise to such large-scale projects with long-term commitments. Very often our Centre coordinates the Hungarian efforts of research institutes and universities in international cooperations.

Large-scale International Cooperations

Extreme Light Infrastructure (ELI):

Joint research with the ELI-ALPS facility – HUN-REN Wigner RCP was the initiator of the Hungarian pillar of the ELI project in its preparatory phase between 2008-2011. Joint research projects have been taking place ever since. HUN-REN Wigner RCP has built up 5 user groups in various fields who actively take part in the development of the ELI-ALPS facility and in recent years they also have acted as user groups with several successful proposals. Joint research topics include research in ultrafast nanooptics and plasmonics, coordinated by Péter Dombi. Development of novel time-resolved spectroscopic methods such as femtosecond stimulated Raman spectroscopy (FSRS) is pursued by Miklós Veres with several user experiments at ELI-ALPS. György Vankó and his group performs innovative transient spectroscopy experiments on various functional molecules (light-harvesting molecules and switchable molecular complexes) both with the ELI-ALPS facility in Szeged and the ELI-Beamlines facility in the Czech Republic. The particle acceleration group has been using the ELI-ALPS facility for their positive ion and neutral particle acceleration experiments with high-intensity lasers. Last but not least, the Nanoplasmonic Laser Fusion Laboratory is performing fusion experiments as a user group at the ELI-ALPS facility using its SYLOS laser with higher intensity and shorter pulses than the Hydra laser available for this purpose at HUN-REN Wigner RCP.

European Organization for Nuclear Research (CERN):

Hungary joined CERN more than 30 years ago, 1 July 1992, and since then our physicists and engineers have been able to take an active role in the creation of countless results as a key partner of this Europe-based international institute. From Hungary, in addition to the HUN-REN Wigner RCP, the Eötvös Loránd University, the University of Debrecen, HUN-REN Institute for Nuclear Research, Hungarian University of Agriculture and Life Sciences, University of Szeged and the University of Miskolc participate in the cooperation with CERN. Beside the state-of-the-art experimental collaborations, they are also involved in the technical development of new accelerators. In addition, our local Grid Unit is an important member of the CERN Worldwide LHC Computing Grid. This membership is the guarantee for secure data processing in the local computing infrastructure. At HUN-REN Wigner RCP, our colleagues participate in several CERN experiments, ALICE, CMS, TOTEM, FCC, RD51, NA61, and AWAKE in particular as well as in various related international projects.

European Spallation Source (ESS):

The HUN-REN Wigner RCP represents the domestic neutron-based materials research user community in the European Spallation Source (ESS). ESS stands as the most potent neutron source, spanning various domains such as materials science, biology, and other related fields. Guided by the leadership of ESS, a comprehensive roadmap and implementation strategy for the future capabilities of neutrons were meticulously developed. This significant effort has been published under the title "Neutron Science in Europe: Strengthening World-class Research and Innovation, Delivering Economic and Societal Impact."

European X-Ray Free-Electron Laser Facility (XFEL):

Scientists of the HUN-REN Wigner RCP have long played a leading role in the Hungarian community for X-ray research and applications. They were among the first users at the European X-ray Free Electron Laser (Eu-XFEL), which generates extremely intense and short X-ray flashes and it is open for scientific projects since 2022. Hungary is a full member of the Eu-XFEL, which facility is enabling cutting-edge experiments in various scientific disciplines, including physics, chemistry, biology, and materials science. Gyula Faigel and György Vankó have served the Eu-XFEL in several advisory roles (SAC, Council, Proposal Review Panels) and their groups have performed several experiments to investigate the structure and dynamics of matter at the atomic and molecular level, capturing snapshots of molecules and their ultrafast transformations.

Supporting the Scientific Community

Data Repository Platform

Long-term, secure data management and data storage are becoming increasingly important in modern scientific research. Recognizing this, the Data Repository Platform project was initiated with the support of the ELKH (now HUN-REN) Secretariat. The goal of this project is to establish the foundations of a new repository infrastructure service that can support continuous and long-term secure research data management within the research network. In addition to the HUN-REN Wigner RCP, three research institutions of the Hungarian Research Network, including the HUN-REN Institute for Computer Science and Control (HUN-REN SZTAKI) and the HUN-REN Centre for Social Sciences, are also involved in the implementation of the data repository.

The project's objective extends to knowledge transfer regarding data repository and the management of scientific data, as well as supporting the research network in achieving FAIR (Findable, Accessible, Interoperable, Reusable) data management practices.

For more information: https://science-research-data.hu/en

HUN-REN Cloud

The HUN-REN Cloud's Wigner RCP branch operates in the Wigner Data Centre, established jointly with HUN-REN SZTAKI and supported by the Hungarian Research Network Secretariat. This scientific research cloud offers exceptionally secure services not only to the research network, but also to every Hungarian researcher who requires substantial computational and storage capacity. The new cloud-based infrastructure is much more efficient and cost-effective than the traditional model of maintaining server farms at each institution, making this upgraded institutional infrastructure an important step in the scientific world's paradigm shift. The project's goal is to keep pace with the security and data protection rules of various scientific projects, providing international standard services to the domestic research community. The cloud operating in the Data Centre boasts nearly 6000 vCPUs of computational capacity, 24 TB of memory, 1 PB of redundant data storage cluster, and 32 Nvidia A100 GPU cards, with fast communication between components ensured by 100 Gbit/s network links.

For more information: *https://science-cloud.hu/en/hun-ren-cloud*

QCI Hungary

The goal of the collaboration among the Governmental Agency for IT Development (KIFÜ), HUN-REN Wigner RCP, Budapest University of Technology and Economics (BME), and Eötvös Loránd University (ELTE) in this project is to establish the foundations of a national quantum communication infrastructure, which could later become a part of a pan-European infrastructure.

In addition to quantum key distribution over a terrestrial optical network, the project also aims to prepare for the installation of a ground station that enables testing of satellite quantum key distribution. Besides the technical implementation of quantum communication, the project involves software development and the establishment of an appropriate knowledge base for the possible future users of quantum communication through workshops and various training materials.

More information: *https://qcihungary.hu/en/home/*

Industrial Collaboration

LynXes Innovation Ltd.

HUN-REN Wigner RCP and LynXes Innovation Ltd. are collaborating to combine academic excellence with entrepreneurial innovation in the field of X-ray spectroscopy. The aim is to create a synergy between scientific research and commercialization. In this collaboration, HUN-REN Wigner RCP is providing technical assistance to LynXes to further develop state-of-the-art technologies. The collaboration benefits both the Centre's scientific research programme and its finances. LynXes is leading the current commercialization efforts for this innovative technology, which has the potential to significantly impact the market of laboratory-sized materials analysis. The partnership is well-positioned to take advantage of a starting Accelerator grant of the European Innovation Council (EIC), which is a crucial factor in moving our innovative X-ray spectrometer from concept to a tangible, market-ready product. The collaboration between HUN-REN Wigner RCP and LynXes highlights the integration of academic expertise and private-sector dynamism, which is currently propelling transformative technologies to the forefront of scientific and commercial landscapes.

R&D Ultrafast Lasers Ltd.

R&D Ultrafast Lasers Ltd. is a spin-off company of HUN-REN Wigner RCP, which was founded by Róbert Szipőcs, the co-inventor of chirped mirrors and mirror-dispersion controlled, ultrashort pulse Ti-sapphire laser oscillators that were patented by him and by one of the 2023 year Nobel prize winners in Physics, Ferenc Krausz. This patent was filed in Hungary by the Institute of Solid State Physics and Optics (SZFKI) in 1993 and in the USA in 1994 by the inventors. All costs related to the U.S. Patent No. 5,734,503 had been covered by R&D Ultrafast Lasers Ltd. As a project coordinator, the company collaborated in several national projects (e.g., National Technology Programs) with HUN-REN Wigner RCP on development of ultrashort pulse lasers Ti-sapphire, Yb-fiber lasers and OPO-s, or on development and biomedical imaging applications of nonlinear microscope systems. Those include a handheld nonlinar microscope system for skin diagnostics and a CARS imaging system for stain-free, real time histology of human tissues, which devices might have important applications in skin or brain surgery in the near future. Currently, HUN-REN Wigner RCP and R&D Ultrafast Lasers Ltd collaborate on development of a „Next generation quantum microscope" system together with a German industrial partner Qutools GmbH and Ulm University in the framework of the three-year EUREKA project No. 2020-1.2.3-EUREKA-2022-00022 since Sept 1, 2023.

Nippon Electric Corporation (Japan) and Muon Solutions Oy (Finland)

Cosmic muon imaging (Muography) is one of the most successful innovative outcome of the research activity in the field of high-energy particle physics at HUN-REN Wigner RCP. During the last decade, a new generation of multi-wire chambers have been developed and they could be utilized in various fields outside fundamental science, including industrial applications. Two companies, Nippon Electric Corporation (Japan) and Muon Solutions Oy (Finland) have established strategic partnership with our Centre, including joint projects (funded by Horizon Europe and several other agencies), purchasing tracking detectors, and licensing technologies patented by HUN-REN Wigner RCP (Muographic Observation Instrument).

Technoorg Linda Ltd.

Technoorg Linda Ltd. (www.technoorg.hu, formerly Technoorg Ltd., a spin-off of SZFKI) was established in 1990 and now operates according to ISO 9001 standards. Its main activity is the development of sample preparation equipment for electron microscopes. In this field, they have a long track record of excellence in developing and manufacturing ion-beam milling equipment, which has been exported to more than 20 countries. More recently, femtosecond lasers have been used for this purpose, whose beam, temporal, and energy parameters have to be tuned and stabilised very precisely to the sample. We are working with the company in this field, from the selection of the lasers to the definition of the necessary parameters. With the managing director of the company - András Szigethy - and his two colleagues - Károly Havancsák and Vencel Borbély – we had a discussion in December 2023 in the HUN-REN Wigner RCP on the possibility of submitting a joint consortium proposal to NRDIO.

Optilab Ltd.

Optilab Ltd. is one of SZFI's spin-off companies engaged in developing and manufacturing special optical thin films. We have a professional contract with the company in several fields, mainly focusing on submicron interferometric measurement of optical quality, planarity or curvature of surfaces (using the ZYGO NewView 7100 profilometer), and development and production of unique optical components and thin films. The above activities are carried out under mutually advantageous conditions within the current R&D cooperation agreement framework, which is valid for several years.

Mirrotron Ltd.

For Mirrotron Ltd. (https://mirrotron.com/en), we developed a laser-interferometric device for parallel alignment of the opposite sides of their neutron guide channels, enabling us to adjust the parallelism of the opposite sides of the neutron guides to sub-micron precision, which is very critical. The successful collaboration was with György Kaszás, the managing director, and the equipment developed was later used for other purposes.

KTI Hungarian Institute for Transport Sciences and Logistics Non Profit Ltd.

For the company, which was formed from the Institute for Transport Science (https://www.kti.hu/), we developed a high-concentration aerosol measurement device for in-situ measurement of combustion engine emission parameters over a wide dynamic range with short sampling times (a few seconds). The equipment was used to investigate and optimise engine combustion processes with different power outputs for diesel and petrol engines. Later on, a measurement laboratory was also set up using this equipment (under the leadership of Mihály Kardos), which was used in several tenders and individual tests.

In the past, we have had several industrial contacts - e.g. with the Small Industrial Production Company, Bioinnokord Biotechnology Ltd. (Budaörs), Isotope Institute Ltd., Toxicological Research Centre Ltd. (Veszprém Szabadságpuszta), etc. - for which we developed and installed aerosol measuring instruments for various fields, as well as fibre-optic visualisation and monitoring equipment in experimental laboratories.

Lasram Engineering Ltd.

Lasram Engineering Ltd. develops and manufactures industrial and surgical lasers and provides laser technology services. The company's founders started working with lasers in 1976 at the TUNGSRAM Research Institute. The company sells its products under its name and private label, contracts with other companies and has delivered over 700 laser systems in the last 30 years. In the last decade, Lasram has also carried out two major projects in collaboration with HUN-REN Wigner RCP: a KFI-16 project "Research into surgical applications of lasers and short-pulse lasers, development of prototype equipment", and a VKE-17 project "Digitalisation of unique manufacturing technology" (in cooperation with Csepel Machine Tool Factory Ltd.). The latter project has resulted in a Robot Automated Additive Manufacturing Production Cell for which we were awarded the Grand Prize of the Industry Days Exhibition 2020.

Collaborations do not end after the completion of a project, and we are constantly looking for new opportunities for applications and further cooperation.

Education and Talent Development

- Wigner Colloquium
- University Education (Lecturing at Universities, Diploma and Doctoral Supervision)
- PhD Student Program
- Wigner Internship Program
- High-School Programs and Talent Development
- Science Outreach

Wigner Colloquium

We emphasize and focus on the continuous reinforcement and improvement of our colleagues' knowledge and professional competence, which can be accomplished successfully by internal seminars and presentations of guest scientists. These occasions also provide an opportunity for colleagues to familiarize themselves with each other's research activity and improve their own presentation skills. Young researchers are able to harvest the most on these seminars.

The most prestigeous event among these seminars is the Wigner Colloquium series, which has been running since 2015. Every year 7-8 times we invite Hungarian and foreign researchers with outstanding scientific carrier to give an introductory talk and present the latest results achieved in their respective fields. This series is a perfect tool to bring the latest scientific advancements within reach of our colleagues, especially the young ones, and provide opportunities for professional consultation and networking. The colloquium also serves as an excellent opportunity to enhance the international recognition of HUN-REN Wigner RCP.

Information about previous years' speakers and video recordings of the presentations can be accessed on the following website:
https://wigner.hu/en/wigner-colloquia

University Education (Lecturing at Universities, MSc and PhD Supervision)

The scientific staff of the HUN-REN Wigner RCP consists of outstanding researchers, many of whom have decades of research experience and possess substantial expertise and several skills necessary for building a successful scientific carrier. They strive to pass on this knowledge firsthand to the next generation. The most effective method for this is the active participation in the education system of the universities. Many staff members serve as mentors for undergraduate (BSc), graduate (MSc), and doctoral (PhD) students, supporting their professional development, building up the cornerstones of a successful scientific career for the members of the next generation. PhD students who have a supervisor at the Wigner FK receive special support from the institute.

We maintain connections with the leading natural sciences and engineering faculties of universities in Hungary. Moreover, collaborations exist in medical, chemical, and geophysical fields as well. Our colleagues teach at institutions such as Eötvös Loránd University, Budapest University of Technology and Economics, Semmelweis University, Óbuda University, Pázmány Péter Catholic University, University of Debrecen, University of Miskolc, University of Pécs, and University of Szeged.

For more detailed information:
University courses: https://wigner.hu/en/university-courses
PhD education: https://wigner.hu/en/phd-education
National Scientific Student Circle (OTDK) results: https://wigner.hu/en/otdk-results

PhD Student Programme

Our highest-level education programme consists of a series of local conferences and workshops like the international Zimányi Winter School or the Spacetime Summer Schools that are organized in collaboration with universities and attract graduate and PhD students toward our Centre and toward our research areas.

Wigner Internship Programme

The Wigner Internship Programme is a flagship initiative at our research centre, designed to support the most talented students who are devoted to join the local research activities. The title of “Wigner Intern” can be earned through a competitive application process by students who excel academically and are enrolled in full-time BSc or MSc programme at Eötvös Loránd University or Budapest University of Technology and Economics.

„Since autumn 2021, I have been a Wigner Intern under the supervision of Dr. Karlo Penc, in a semester break. My first motivation was to write a thesis for the Scientific Student Conference and to join cutting-edge research. My topic was to investigate a two-dimensional spin ice system, first numerically and then analytically. Working with my supervisor was a very positive experience, and I could also get to know the whole research group. The research eventually led to my B.Sc. thesis and a publication in Physical Review Research. I presented my results at a summer school in Dresden and an international conference in India, where I won a poster prize.

I am still a Wigner Intern, working on my M.Sc. thesis on the theory of superconductivity in elementary rhenium. The broad spectrum of the group allows me to broaden my knowledge and learn about new phenomena and methods.”

Márk Kondákor
Wigner Intern 2023-2024
Supervisor: Karlo Penc, Quantum Materials Research Group

„I have been a Wigner Intern since 2021 when I joined the Theoretical Solid State Physics group. Thanks to my supervisor Karlo Penc, I quickly integrated into the group and met many people at the Research Centre. In the inspiring environment, I had the chance to study some of the most recent problems in quantum magnetism. I presented posters at international conferences (HFM 2022 Paris, a conference on emergent gauge fields in Trieste in 2023, and HFM 2024 Chennai). These events allowed me to get to know the community, broaden my knowledge, improve professionally, and, most importantly, make many new contacts and collaborations. These would not have been possible without the financial support of the Wigner Research Centre for Physics, for which I am very grateful."

Péter Kránitz
Wigner Intern 2023-2024
Supervisor: Karlo Penc, Quantum Materials Research Group

For students who do not qualify for the Wigner Internship Programme, there is an opportunity to join our research community as department interns, if their academic interests and achievements make them suitable to be candidates.

For several years now, HUN-REN Wigner RCP has been participating as a host institution in the National Research, Development, and Innovation Fund's Summer Internship programme. The programme is targeting talented Hungarian citizens studying at universities in the United Kingdom, Germany, and Austria and its main aim is to attract and engage these students in research and development activities at companies, universities, and research institutes in Hungary.

"The pandemic, like for many, disrupted my summer plans and made many opportunities inaccessible. Fortunately, I found Wigner Research Centre for Physics, specifically the Computational Neuroscience Group. Despite the complications caused by the pandemic, Gergő Orbán and his team welcomed me with enthusiasm at their weekly lab meetings, involving me in discussions and their daily lives. This allowed me to experience various aspects of a research group's work. In addition, I learned a lot about computational neuroscience. With Gergő Orbán's guidance, I became familiar with the fundamentals of the mathematical background and had the opportunity to practice programming. In the end, I even reached a point where I analyzed data myself. This experience greatly helped me decide which subjects to choose in my university studies and which area to focus on in my third-year project. I am very grateful for the experience and the knowledge I gained here."

Virág Lakner
Summer Intern 2020
Supervisor: Gergő Orbán, System Level Neuroscience Research Group

For more information: https://wigner.hu/en/internship

High-School Programmes and Talent Development

As one of Hungary's leading research centres in physics, we recognize the importance of nurturing the future generation of researchers. We understand that fostering research talents begins well before university, so we seriously consider it our responsibility to engage high-school students into research activities and support the educators who teach them. We have a multi-element portfolio for secondary school students and teachers.

A, Research Student Camp:

During the one to two-week summer Research Student Camp, high-school students (usually six pairs) have the opportunity to work with various research groups. They collaborate with members of their host research teams, who serve as mentors to help the young participants develop a project. At the end of the Camp, the participants present their results at a mini-conference. The goal of the Camp is to provide interested students with insights into the scientific activity and daily life of researchers, and the reality of a result-oriented research activity.

B, Teacher-Researcher Programme:

As a natural science research centre, we understand the crucial role played by motivated and professionally trained educators in nurturing the next generation of researchers. With this programme, we assist dedicated teachers in embarking on a Researcher-Teacher Path and obtaining the necessary PhD degree. We provide opportunities for teachers to engage in research work in our laboratories, under the mentorship of faculty scientists. Several teachers have already earned their doctoral degrees and continue their research work with us under the guidance of our colleagues, bringing their students to the institute for regular work or visits.

C, Research Student Laboratory:

As part of the Teacher-Researcher Programme, students of the high-scool teachers conducting research at our institution also have the opportunity to participate in laboratory projects. This participation demands a longer commitment and more frequent personal appearance, which turns the opportunity into a more serious activity for a 16-17 years old teenager. We are proud to say that several students who participated in this programme have pursued careers in physics, engineering or other natural sciences, enrolling in university education.

D, Research Student Programme:

The Research Student Programme requires an even more significant commitment and effort from both students and mentors. It involves several months or even a full year of continuous research work, with guidance from a specific mentor. At the end of their research period, students present their work to invited colleagues from our Centre, including representatives from the leadership team. Recently we have had the first doctoral students who used to be involved in this Programme.

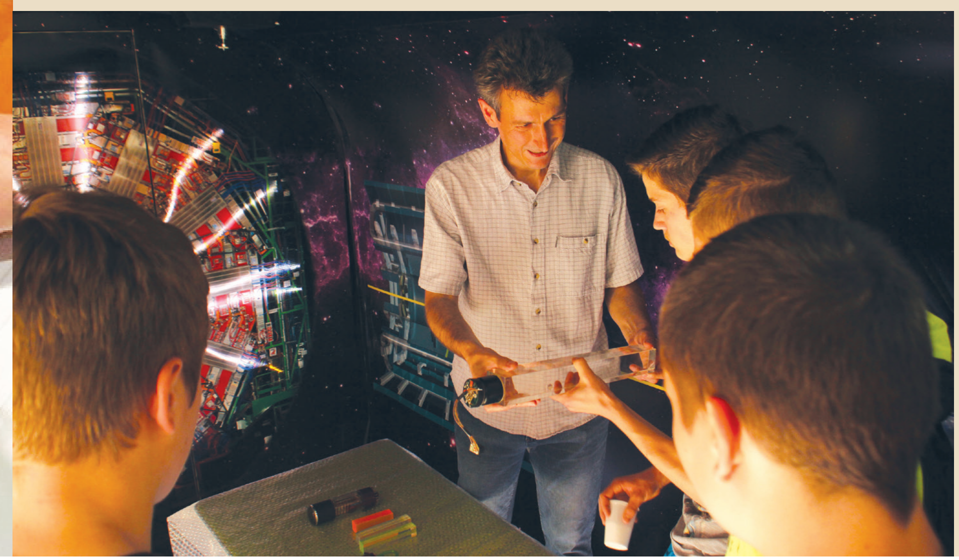
E, CERN Teacher Programme:

For several years now, we have been coordinating and providing professional support for the CERN Teacher Programme organized for high-school teachers from Hungary. The international programme aims to train and support educators in teaching the not-so-simple subject of particle physics to students in an interesting and engaging manner. Within the framework of the Programme, for several years twenty teachers have participated in a one week-long training session combined with practical experience at CERN in Geneva. The CERN Teacher Programme is announced every year, and participants are selected through a competitive application process.

For more information:
https://wigner.hu/en/programs-for-high-school-students-and-teachers

Science Outreach

Our colleagues regularly give lectures at Hungarian high schools, and occasionally at Hungarian institutions beyond the borders as well. Throughout the year, we also organize various science outreach events. In the spring, we have the Particle Physics Student Workshop and Girls' Day, whereas in the fall, we participate in Researchers' Night, which all welcome those interested in science. Staff members and doctoral students have joined the Alumni Programme of the Hungarian Academy of Sciences and give talks in secondary schools, especially in their original alma maters.



Social Responsibility, Research Community

- Physics for Health
- The Legacy of Great Pioneers

Physics for Health

Neurorehabilitation:

Research into motor control and rehabilitation is an interdisciplinary field that requires the collaboration of physicists, engineers, mathematicians, human kinesiologists, and physicians to develop successfully. The Neurorehabilitation and Motor Control Research Group uses mathematical models to address various movement control issues by studying healthy movement. The group works in collaboration with the University of Pécs, Pázmány Péter Catholic University, and the National Institute of Medical Rehabilitation to study human movement and contribute to the development of rehabilitation methods. **As a result of their research, they monitor the improvement of spinal cord injured patients during rehabilitation training, tracking changes in their various physiological and biomechanical parameters.**

For more information see: https://rehab.wigner.hu/en

HUN-REN Wigner RCP in the Fight Against Covid:

When the Covid pandemic broke out, HUN-REN SZTAKI and HUN-REN Wigner RCP offered their own computational clouds integrated with the HUN-REN (then MTA) Cloud, which included thousands of processors and several terabytes of memory of computing capacity, to assist in the research needed to overcome the pandemic. The results of a large-scale study, involving the HUN-REN Centre for Energy Research (EK), the HUN-REN Wigner RCP, Semmelweis University, and the Törökbálint Pulmonology Institute, were also published in Scientific Reports, demonstrating that the SARS-CoV-2 viruses causing pneumonia originate from the upper respiratory tract of patients and cause a severe illness. This finding represented a significant advancement in the prevention of more serious infections.

More information:
https://hun-ren.hu/koronavirus/a-sars-cov-2-virusok-leguti-kiulepedese-es-a-tudogyulladas-kialakulasa-kozotti-osszefuggeseket-tart-fel-az-ek-es-a-wigner-munkatarsait-is-a-tagjai-kozott-tudo-magyar-kutatocsoport-2

Following these findings, we conducted model measurements in hospitals, wards, and treatment rooms to examine the dynamics of pathogen spread. Based on these measurements, we determined which nursing and medical activities pose the highest risks during patient care, the extent to which respiratory function and bronchoscopy examinations carry extra risk for the performing physician, and the distribution of the virus on airborne particles in a hospital room.

Several publications have resulted from these studies:
GeroScience: https://doi.org/10.1007/s11357-021-00512-0
J. Hospital Infection: https://doi.org/10.1016/j.jhin.2021.08.025
Scientific Reports: https://doi.org/10.1038/s41598-023-30702-z

From CERN to cancer therapy:

Cancer is one of the leading diseases with high mortality, and its therapy is a serious burden on the health care sector (especially in Hungary). One of the important tasks of today's science is therefore to discover and develop the most effective treatment methods, to improve the effectivity of the therapy, while minimizing the side effects. Physicists have been important players in cancer therapies from the early times; even today they play key role in the development of the most modern therapies based on head-on particle physics methodology.

In hadron therapy, beams of strongly interacting particles such as protons or carbon ions are used to irradiate tumors. Its big advantages are precise focusing and controlled depth of energy deposition, leading to a much higher contrast of damage between healthy and cancerous tissues than traditional radiotherapy. **The Heavy Ion Physics Research Group as a part of the Bergen Proton CT group, deals with the research and development of a therapeutic method not yet available in Hungary within the framework of an international collaboration.** This project includes not only detector R&D, but also medical-analysis methods and AI-based imaging techology developments.

Another group of our research centre develops superconducting particle accelerator magnets in collaboration with CERN and several other European institutes and companies. **The group has designed and constructed a canted cosine-theta-like magnet magnet in-house as a special prototype for the Future Circular Collider (the future successor of the Large Hadron Collider), and developed an impregnation method using paraffin wax.** The magnet demonstrated excellent performance, reaching its nominal field without training. The group is a major participant in Horizont Europe funded HITRIplus and I.FAST projects with a significant contribution to the development of prototypes of special superconducting magnets. The goals of these projects are fostering innovation in accelerator technology (I.FAST) and the design of a small, compact superconducting synchrotron for hadron therapy using protons and carbon ions, in direct collaboration with the industry.

The Legacy of Great Pioneers

The intellectual legacy of Nobel laureate Eugene P. Wigner, whose name is carried proudly by our centre, is a valuable treasure for us. We strive to keep it in mind in our daily work; the wide scope of intellectual work of Eugene P. Wigner demonstrates the possibility and the necessity of interdisciplinary approach on cutting-edge research fields. On significant anniversaries, we make special efforts to commemorate his contributions. Thus we organized the Wigner-111 Scientific Symposium commemorating the founding of our research centre, coinciding with the 111th anniversary of Eugene P. Wigner's date of birth. Ten years later, we held the Wigner-121 Scientific Symposium. These prestigious international scientific conferences featured talks by both domestic and international researchers who are outstanding in their respective fields. Two plenary speakers of the Wigner-111 Scientific Symposium won Nobel Prize in the forthcoming years. The plenary speaker of Wigner-121, the Hungarian-born Ferenc Krausz became Nobel laureate in the Fall of 2023. These events facilitated high-level professional discourses among the participants with different expertise and evoked the spirit of Eugene P. Wigner, who - ahead of his time - envisioned the future of a modern scientific research institute:

"If science is expected to grow so great, both in the comprehensiveness of its subject and also in depth, that the human mind will not be able to embrace it, that the life span of man will not be long enough to penetrate to its fringes in time to enlarge it, could several people not form a team and accomplish jointly what no single person can accomplish? Instead of returning with Shaw to Methuselah, can we find a new way to enlarge the capacity of human intellect by the juxtaposition of several individual intellects rather than by extending a single one?"

E.P. Wigner: The Limits of Science, 1950

In addition to Eugene P. Wigner, the HUN-REN Wigner RCP is standing on the shoulders of several other great predecessors whose scientific and human legacy we continue to build upon. One such figure is Károly Simonyi, an engineer and physicist whose work has been recognized as part of Hungary's national heritage. His memory is preserved through the annual Simonyi Day event, which is held mostly at the Hungarian Academy of Sciences headquarters. The event aims to present the latest research findings in an understandable way for high-school and university students, as well as the interested general public.

József Zimányi's legacy is upheld by the Zimanyi Winter School, a joint initiative of HUN-REN Wigner RCP and Eötvös Loránd University. The event's purpose is to provide an annual overview of the latest scientific results in heavy-ion physics. The event is named after the late József Zimányi, a Széchenyi laureate physicist, a member of the Hungarian Academy of Sciences, and a pioneer in both national and international heavy-ion physics research. In his honor, the predecessor of our research centre, the KFKI Particle and Nuclear

Physics Research Institute, established the Zimányi Medal in the spring of 2011. This medal is awarded biannually to theoretical physicists under the age of 40 who have achieved significant international recognition and success in theoretical high-energy nuclear physics. The Zimányi Medal is awarded at the Quark Matter Conferences (QM).

The room of the exceptional theoretical physicist, specialist of the strong interaction, Vladimir Gribov is still commemorated by a plaque in the Theoretical Physics Division. His legacy and scientific achievements are commemorated by the Gribov Medal, established by HUN-REN Wigner RCP and the Eötvös Physical Society. This is awarded biannually to the most talented theoretical physicists under the age of 35 who have achieved outstanding results in theoretical high-energy nuclear physics, gaining significant international recognition, and it is awarded at the High Energy Physics Conference of the European Physical Society (EPSHEP).

Inspiring Environment and Community Life

The HUN-REN Wigner RCP is located in a beautiful suburban area, set amidst the forests of the Buda Hills in Csillebérc. The office windows offer stunning views of tall, ancient trees, and the area is frequented by woodland birds and squirrels. The clean air and the serene environment, far away from the hustle and bustle of urban traffic, provide ideal conditions for research and focused work. While the occasional challenges of winter snow and ice may arise, the tranquility and beauty of the landscape compensate for the few uncomfortable days each year.

The scientific campus is adjacent to a sports field, and the surrounding forest trails offer numerous opportunities for sports and relaxation. The nearby Normafa is also an ideal location for team-building activities.

The sport field of the Csillebérc Campus hosts the annual Wigner Octoberfest event, where colleagues and their family members gather for a delicious lunch prepared in cauldrons. Another annual community-building event is Wigner Christmas, which also serves as a year-end review and celebration.

Alumni

Working at the Csillebérc KFKI campus has been a unique experience for the past 70 years, and it remains special today. Our former colleagues, including retired staff members, as well as young researchers having moved to high-tech domestic or international industrial firms, often visit us and strive to maintain a close connection with their former workplace. We facilitated this ongoing relationship by establishing the Wigner Alumni program, which allowed former colleagues to keep contact and to stay informed about news and events related to our Research Centre.

For more information: [*https://wigner.hun-ren.hu/en/alumni/*](https://wigner.hun-ren.hu/en/alumni/)

IMPRINT

Publisher: HUN-REN Wigner Research Centre for Physics

Editors: Csilla DOVICSIN-PÉNTEK and Péter József LÉVAI

Proofreading: András KÁLMÁN, Imre BAKONYI, Dezső HORVÁTH

Graphic designer: Luca GULYÁS-SZABÓ

Photo: Tamás SZIGETI, Márton KOVÁCS, Nikolett BIRÓ, HUN-REN Wigner RCP archive, HUN-REN Centre for Energy Research, ESA, Keyestudio

Printing house: nyomdavonal.hu (Micropress Kft.)

nyomdavonal.hu
egyszerű.kedvező.nyomtatás...

2024

Contact Information

HUN-REN Wigner Research Centre for Physics
1121 Budapest, Konkoly-Thege Miklós út 29-33.

E-mail: wigner@wigner.hun-ren.hu
Website: wigner.hun-ren.hu

You can watch a short film introducing
HUN-REN Wigner Research Centre for Physics here:
https://www.youtube.com/watch?v=wIy92WPwUDk