HELSINKI INSTITUTE OF PHYSICS

Long-term Strategy of the Helsinki Institute of Physics

Maximizing effectiveness by collaboration

In the world of increasing change and challenge, the Helsinki Institute of Physics (HIP) advances Finland's level of science, technological leadership, and promotes the societal impact of research.

HIP is a physics research institute that is operated jointly by the University of Helsinki (UH), Aalto University (AU), the University of Jyväskylä (JYU), the Lappeenranta-Lahti University of Technology (LUT), and Tampere University (TAU). The Radiation and Nuclear Safety Authority (STUK) is an interim member of HIP.

The goal of HIP is to achieve internationally excellent results in experimental subatomic physics, in theoretical physics, in applied research in physics and in technological development related to accelerator centers, as well as in joint university projects in particle physics. HIP creates cohesion and effectively focuses the best resources in experimental research connected to the accelerator centers in Finland. This increases Finland's scientific, technological and societal impact.

HIP research extends over the borders of the Universities. HIP coordinates research with international accelerator centers CERN (European Organization for Nuclear Research, in Geneva) and FAIR (Facility for Antiproton and Ion Research, in Darmstadt). This collaboration provides a robust foundation for all activities of HIP partner universities with these centers.

HIP aims to maximize the benefit to the Finnish partner universities and society in general that derives from Finland's membership in the CERN and FAIR infrastructures, especially by educating the next generation of students and researchers, as well as nurturing scientific thinking in the society. HIP facilitates links to industry and annually hosts nearly 400 high-school students with teachers at CERN.

The HIP member universities have extensive and complementary expertise and know-how of research topics related to accelerator centers:

- UH concentrates on particle physics, including the development of equipment, scientific computation, the ESA's EUCLID mission, and climate change research at CERN with CLOUD experiment.
- JYU concentrates on the borderline between particle physics and nuclear physics also utilizing its accelerator laboratory.
- AU, LUT and TAU contribute to the instrumentation and technological innovation and application, material science, ICT, and synergies in the field of theoretical physics.
- The interim membership of STUK adds opportunities to apply research to nuclear safety, security and safeguards and development of radiation detectors and instrumentation, as well as medical applications.

The distribution of HIP research activities is based on the strengths and focus areas of member universities. Thus, the HIP long-term strategy builds on and interacts with the research strategies of the member universities. HIP's research focus is in line with the 2020 Update of the European strategy for particle physics, the NuPECC Long Range Plan (2017), the European Astroparticle Physics Strategy 2017-2026, as well as the National CERN strategy (2002) and the CERN Medium Term Plan 2021-2025.

Mission

HIP effectively maximizes the creation of scientific, technological and societal impact of Finnish accelerator-related research by collaborative leading national research activities that cover an extensive range of subjects in theoretical physics and experimental subatomic physics. The institute carries out and facilitates research in basic and applied physics as well as in physics research and technology development at international accelerator laboratories. The institute is responsible for the Finnish research collaboration with CERN. Also, the institute coordinates the Finnish contribution to the FAIR laboratory currently under construction in Darmstadt, Germany.

Summary

In order to achieve its goals:

- HIP coordinates Finland's research at CERN, especially contributions to the CMS programme. HIP is also responsible for Finland's participation in the construction of FAIR and research in Darmstadt. HIP will closely follow future developments of experimental particle and nuclear physics in Europe and participate in leading experiments.
- HIP supports a relatively broad theory program at an internationally high level.
- HIP supports participation in missions and experiments in related fields such as cosmology.
- HIP participates in technological development related to accelerator laboratories, including knowledge transfer.
- HIP supports higher education in particle physics and its instrumentation.
- HIP's societal impact remains strong. Using accelerator centers in high school student education and extending the use of open data from experiments will be focus areas.
- HIP has a good working environment for staff and students promoting an inclusive, gender-neutral working environment.
- HIP is operated by five Finnish universities. HIP will actively study needs to expand to include membership of other institutions.

1. LHC experiments

Main focus of HIP in the coming decade will be to fully exploit the participation in the LHC experiments. To this end the WLCG resources and detector R&D are essential.

Currently the main research focus is on three of the LHC experiments: ALICE, CMS and TOTEM, in which Finnish scientists are making significant contributions to ultra-relativistic heavy ion physics, new physics searches, standard model measurements and forward physics. Currently, the full physics exploitation of these, including their preparations for the high luminosity LHC (HL-LHC), constitute the highest priority of the Finnish high-energy physics community.

Computing and data access are an integral part of this physics exploitation. HIP participates in the Worldwide LHC Computing Grid (WLCG) through the Nordic Tier-1 (NGDF) and the HIP Tier-2 (T2_FI_HIP) centers. Securing and developing further the WLCG resources will be essential if we are to take full advantage of the LHC data. The Finnish Grid and Cloud Infrastructure (FCCI) collaboration is crucial for developing and maintaining the necessary national grid infrastructure. Collaboration with CSC is important in being able to satisfy the needs of the data intensive LHC computing.

The HL-LHC upgrades of the experiments, requiring continued detector R&D, are also key elements for successful exploitation. HIP contributes to the construction and upgrades of the ALICE Fast Interaction Trigger (FIT), the CMS Tracker pixel detector, the endcap layer of the CMS Minimum ionizing particle Timing Detector (MTD) and the CMS Proton Precision Spectrometer (PPS). Common focused European and/or global efforts on semiconductor and gas detector development for the LHC detector upgrades, and also at future collider experiments, are crucial. It is essential that the HIP Detector Laboratory is maintained and developed to support the detector R&D and the experimental upgrades. Finland supports the continuation of heavy ion collisions at the LHC beyond 2029.

2. **FAIR operations**

HIP strongly supports timely completion of the construction of FAIR, with priority in the NUSTAR experiment.

FAIR is an international facility that has been chosen by NuPECC to be a top priority for the European Nuclear Physics Community. The outstanding level of the science program of FAIR was confirmed in 2019 by an international evaluation. FAIR will provide unique experimental opportunities with antiproton and relativistic heavy ion beams as well as secondary radioactive ion beams for a broad range of studies in atomic and plasma physics, hadron and nuclear physics and in astrophysics. At the moment Finnish priority is the NUSTAR experiment. The main contribution of Finland is therefore Superconducting Fragment Separator (Super-FRS) beamline components and NUSTAR-related spectrometers, but Finland also supports the development of the facility by providing the expertise in developing materials that are tolerant to high-intensity irradiation fluxes of high-energy charged particles. The Phase-0 experiments utilizing the upgraded GSI accelerators and storage rings will start in 2020. The Finnish community fully supports early realization of Super-FRS which could allow early start of the Day-1 experiments prior to full-scale completion of FAIR in 2025.

3. Future high-energy frontier

HIP intends to participate in future leading high-energy frontier experiments, based on physics-driven decision.

The high-energy frontier relies on the development of new more powerful accelerators exceeding the existing LHC and its planned upgrades either in energy or precision. Two independent and conceptually different designs of the next generation particle collider which meet these requirements, the compact linear electron-positron collider (CLIC) and high-energy future circular collider (FCC), are currently under development at CERN. HIP is contributing to the CLIC and FCC R&D programs.

These activities are multidisciplinary and inter-sectorial, and include material physics, superconductivity and engineering aspects, as well as collaboration with the industry. The development and preparation of the CLIC and FCC options as the next high-energy frontier facility should continue in parallel until a physics-driven decision based on the LHC results can be taken. To ensure the steady progress of these developments, many truly global efforts are needed. We emphasize that CERN, as the European Particle Physics Laboratory, should play the key role in any international post-LHC high-energy facility.

HIP actively also follows particle physics programs in other international laboratories, like the Electron-Ion Collider (EIC) in the United States and the European Spallation Source (ESS) in Sweden.

4. Theoretical physics

HIP supports a broad theory program at an internationally high level.

Research in the HIP theory program focuses on high energy physics, cosmology and related areas of theoretical physics. The close connection between high energy physics and cosmology is particularly well reflected in theoretical research. The links between theory and particle physics experiments are closest in particle physics phenomenology. Here research at HIP includes both beyond the Standard Model (BSM) physics and QCD theory. The research in QCD focuses on collider phenomenology and deconfined QCD matter properties. Thus, there is close synergy with experiments, especially in high energy nuclear collisions. BSM phenomenology is connected to collider experiments at the LHC or at future colliders, and to facilities and observatories not based on colliders. This research has important implications for cosmology, including inflation, structure formation and primordial gravitational waves.

The HIP theory program welcomes proposals for new theory initiatives that have synergy with HIP activities.

5. Other experimental activities at CERN

HIP is also involved in other experimental activities at CERN, such as ISOLDE and CLOUD, and actively considers other experiments that can utilize HIP's strengths.

ISOLDE is the flagship ISOL-technique-based facility and can provide by far the broadest selection of post-accelerated radioactive ion beams for diverse research program. ISOLDE has ambitious development plans to match high beam time demands better by the continuously growing user community and it is a key player in the EURISOL-DF project that aims to pave the way for a construction of the EURISOL facility. Finland will continue the fruitful long-term collaboration with ISOLDE that from the physics perspective, has been devoted in particular to in-beam spectroscopy experiments and investigations of ground-state properties of atomic nuclei.

CLOUD is the world's first—and, so far, unique—laboratory experiment to reach the demanding technical performance required to measure nucleation and growth of aerosol particles under well-controlled atmospheric conditions. The general purpose of the CLOUD detector is to conduct experiments concerning aerosol and cloud formation using an advanced detector that can reproduce conditions anywhere in the troposphere or lower stratosphere. The research group in Helsinki is worldwide recognized on the subject of nucleation and growth and CLOUD is an ideal laboratory for this purpose. The group develops and provides state-of-the-art detectors used at CLOUD as well as in the field. The group has a key role in the CLOUD 10-year scientific strategy plan for CERN (2019-2029).

6. Cosmology and astroparticle research

HIP supports research in related fields, including cosmology (ESA's EUCLID mission), research on gravitational waves (LISA mission), and astroparticle physics (Dark Matter experiments).

The accelerated expansion of the universe requires an explanation beyond the standard model of particle physics. Finland participates in the ESA Euclid satellite mission. For the next decade, this will be the most important relevant cosmology mission for studying large scale structure, dark energy and modified gravity. Finland contributes one of the nine Euclid data centers, funded as an Academy of Finland Roadmap Research Infrastructure. Euclid will be launched in 2022, and will survey the extragalactic sky for six years, covering over one-third of the sky (15 000 square degrees) and the last three-quarters of the 14-billion-year history of the universe. Analysis of Euclid data will continue until at least 2030.

HIP supports participation in investigating how gravitational waves can be used to directly observe physical processes in the very early universe. Gravitational waves in the relevant frequency range can be observed with the ESA's LISA (Laser Interferometer Space Antenna) gravitational wave satellite mission, scheduled for launch in 2034. The University of Helsinki is a member of the LISA consortium and an active participant in the LISA Cosmology Working Group.

HIP is a member of APPEC, which coordinates astroparticle physics research in Europe.

7. Technological connections and knowledge transfer

The HIP Technology Programme promotes research, development, innovation, technology transfer and pre-commercialization activities with links to the CERN experiments. Synergies with other international big science initiatives are actively sought. HIP collaborates closely with Business Finland, the Finnish agency for supporting and funding innovations with the aim of enabling companies to grow through specific actions focused on CERN-related new business ideas.

The knowledge gained within the CLIC and FCC R&D is vigorously being used for other applications. For example, the high-gradient linear accelerator technology developed for CLIC is considered for the Light Dark Matter eXperiment, LDMX, as well as for future Free Electron Laser facilities under study and planning. HIP is already participating and contributing in these two fields in the form of the eSPS project at CERN as well the European CompactLight project.

Finland is actively participating in fusion R&D within the large international collaboration project ITER. HIP supports this activity, transferring the knowledge gained within the CERN-related projects for particle accelerators to address the problems in fusion reactors. These studies have synergies with both fission and fusion technologies, and may be beneficial in developing new technologies for energy production. Further synergies are being sought with ESA in relation to the challenge of operating in harsh radiation environments.

Technological aspects of radiation safety are developed in close collaboration with STUK.

8. Detector laboratory

Instrumentation of particle physics means designing, constructing and testing scientific instruments needed for measuring and recording physical properties of particles created in high energy physics experiments.

Participation in instrumentation is a prerequisite in experimental particle physics for accessing scientific data and for producing new physics. Thus, the Detector Laboratory infrastructure at HIP is maintained and developed for high-quality instrumentation with appropriate laboratory premises, cutting-edge equipment, skillful teams and wide national and international networks.

9. Outreach

These measures foster collaboration between scientific domains and bring much-needed expertise in machine learning and artificial intelligence, for example, from which particle physics can greatly benefit. Furthermore, open data in a simplified format has been used in secondary education with great success, increasing interest in particle physics, data analysis, computing and the STEM fields in general through tangible access to authentic data.

Similarly, the Detector Laboratory provides and develops hands-on education by pedagogically competent teachers who are specialists both in instrumentation and in particle physics. Actions of this kind and other outreach activities are an integral part of research work. The continuation and development of outreach is important in order to encourage children and youth from all backgrounds to pursue careers in particle physics and its instrumentation. Special attention is paid to encouraging girls, especially by bringing forward positive role models.

10. Open science

Finland is committed to promoting and implementing open science and has been active in the field of high energy physics through important contributions to data preservation and open access in the CMS experiment. Support from the highest level for these activities is a key success factor and stable long-term support is needed to keep LHC legacy data available and in widest possible use in different domains, also in the distant future.

11. Wellbeing and diversity

HIP works actively to promote an excellent work environment for staff and students promoting inclusiveness and gender-neutrality.

Special attention is paid to preventing discrimination and harassment, encouraging diversity and equality, recognizing implicit biases, reducing work-related stress, and implementing Codes of Conduct, such as the Kumpula Campus Code of Conduct and the CERN Code of Conduct.

HIP encourages its personnel to participate in wellbeing groups of member institutions. At the Kumpula Campus, HIP has representatives in the physics wellbeing group that has several activities to increase and monitor work wellbeing and is a point of first contact for any difficult situations an employee might have.

Special care is taken of internal communication. This is one of the focal points of internal operations: the communication group is working on different means of spreading information and personnel are active in the wellbeing groups.

To further promote wellbeing and diversity, HIP takes advantage of the experiences and good practices of national and international communities, e.g. the Diversity in Physics Finland Working Group of the Finnish Physical Society (FinDiP), the Nordic Network for Diversity in Physics (NORNDIP) and the Gender Equality Network in the European Research Area (GENERA).

12. Sustainability and responsibility

Ecological, economic and social sustainability and responsibility are integrated in all HIP functions

HIP's research has great potential in finding sustainable solutions for the society, such as in energy production technologies (see part 7). The CLOUD experiment is increasing understanding of atmospheric processes and mechanisms of climate change (see part 5). Open science is a sustainable approach to research data and results (see part 10). Sustainability topics are included in HIP's teaching, as in the yearly CERN Bootcamp that is organized in cooperation with universities of applied sciences.

The cultural change of activities towards sustainability include virtual mobility both from and towards Finland, as well as remote participation in HIP seminars and other functions, whenever feasible. Opportunities for teleworking are being increased.

HIP is managed in an economically sustainable and responsible manner. This means the responsible use of funds and other resources, as well as aiming to secure adequate and stable funding in the long run.

HIP's personnel policy enhances wellbeing, diversity and inclusivity and reduces inequalities (see part 11). HIP promotes responsible leadership that focuses on equal and just treatment of personnel, responsible decision-making, interactive leadership and personnel development. HIP's social sustainability is based on communality, interaction and individual's integration to the research community.

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Update expected 2024

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Appendix: Relationships between the HIP strategy to the recommendations in the 2020 Update of the European Strategy for Particle Physics, the NuPECC Long Range Plan (2017), and the European Astroparticle Physics Strategy 2017-2026, sorted by the points in HIP strategy:

1. **LHC experiments**

The 2020 Update of the European Strategy for Particle Physics, recommendation 1A: The successful completion of the high-luminosity upgrade of the machine and detectors should remain the focal point of European particle physics, together with continued innovation in experimental techniques. The full physics potential of the LHC and the HL-LHC, including the study of flavour physics and the quark-gluon plasma, should be exploited.

NuPECC Long Range Plan 2017, third recommendation: Support for ALICE and the heavy-ion programme at the LHC with the planned experimental upgrades.

2. **FAIR-operations**

NuPECC Long Range Plan 2017, first recommendation: Complete urgently the construction of the ESFRI flagship FAIR and develop and bring into operation the experimental programme of its four scientific pillars APPA, CBM, NUSTAR and PANDA.

3. **Future high-energy frontier**

The 2020 Update of the European Strategy for Particle Physics, recommendation 3A:
-the particle physics community should ramp up its R&D effort focused on advanced accelerator technologies, in particular that for high-field superconducting magnets, including high-temperature superconductors;
-Europe, together with its international partners, should investigate the technical and financial feasibility of a future hadron collider at CERN with a centre-of-mass energy of at least 100 TeV and with an electron-positron Higgs and electroweak factory as a possible first stage. Such a feasibility study of the colliders and related infrastructure should be established as a global endeavour and be completed on the timescale of the next Strategy update.

The 2020 Update of the European Strategy for Particle Physics, recommendation 5A: In the global context, a new electron-ion collider, EIC, is foreseen in the United States to study the partonic structure of the proton and nuclei, in which there is interest among European researchers. Europe should maintain its capability to perform innovative experiments at the boundary between particle and nuclear physics, and CERN should continue to coordinate with NuPECC on topics of mutual interest.

4. **Theoretical physics**

The 2020 Update of the European Strategy for Particle Physics, recommendation 4B: Europe should continue to vigorously support a broad programme of theoretical research covering the full spectrum of particle physics from abstract to phenomenological topics. The pursuit of new research directions should be encouraged and links with fields such as cosmology, astroparticle physics, and nuclear physics fostered. Both exploratory research and theoretical research with direct impact on experiments should be supported, including recognition for the activity of providing and developing computational tools.

European Astroparticle Physics Strategy 2017-2026:
In recommendation 10: APPEC supports an ambitious theory programme in the field of astroparticle physics, with special attention focused on adjacent disciplines such as particle physics, astronomy and cosmology.

5. **Other experimental activities at CERN**

The NuPECC Long Range Plan 2017, second recommendation: Support for construction, augmentation and exploitation of world leading ISOL facilities in Europe.

6. **Cosmology and astroparticle research**

The 2020 Update of the European Strategy for Particle Physics:
Recommendation 4A: The quest for dark matter and the exploration of flavour and fundamental symmetries are crucial components of the search for new physics. … Experiments in such diverse areas that offer potential high-impact particle physics programmes at laboratories in Europe should be supported, as well as participation in such experiments in other regions of the world.
Recommendation 5B: Astroparticle physics, coordinated by APPEC in Europe, also addresses questions about the fundamental physics of particles and their interactions. The ground-breaking discovery of gravitational waves has occurred since the last Strategy update, and this has contributed to burgeoning multi-messenger observations of the universe. Synergies between particle and astroparticle physics should be strengthened through scientific exchanges and technological cooperation in areas of common interest and mutual benefit.

European Astroparticle Physics Strategy 2017-2026:
In recommendation 4: In the field of space-based interferometry, APPEC strongly supports the European LISA proposal.
In recommendation 5: APPEC encourages the continuation of a diverse and vibrant programme (including experiments as well as detector R&D) searching for WIMPs and non-WIMP Dark Matter.
In recommendation 9: APPEC supports the forthcoming ESA Euclid satellite mission, which will establish clear European leadership in space-based Dark Energy research.

7. **Technological connections and knowledge transfer**

The 2020 Update of the European Strategy for Particle Physics, recommendation 3B: The European particle physics community must intensify accelerator R&D and sustain it with adequate resources. A roadmap should prioritise the technology, taking into account synergies with international partners and other communities such as photon and neutron sources, fusion energy and industry.

Deliverables for this decade should be defined in a timely fashion and coordinated among CERN and national laboratories and institutes.

8. Detector laboratory

The 2020 Update of the European Strategy for Particle Physics, recommendation 4C: Detector R&D programmes and associated infrastructures should be supported at CERN, national institutes, laboratories and universities.

9. Outreach

The 2020 Update of the European strategy of particle physics, recommendation 6D: Public engagement, education and communication in particle physics should continue to be recognised as important components of the scientific activity and receive adequate support. Particle physicists should work with the broad community of scientists to intensify engagement between scientific disciplines. The particle physics community should work with educators and relevant authorities to explore the adoption of basic knowledge of elementary particles and their interactions in the regular school curriculum.

10. Open science

The 2020 Update of the European Strategy for Particle Physics:
Recommendation 4D: Further development of internal policies on open data and data preservation should be encouraged, and an adequate level of resources invested in their implementation. Recommendation 6C: The particle physics community should work with the relevant authorities to help shape the emerging consensus on Open Science to be adopted for publicly-funded research, and should then implement a policy of Open Science for the field.