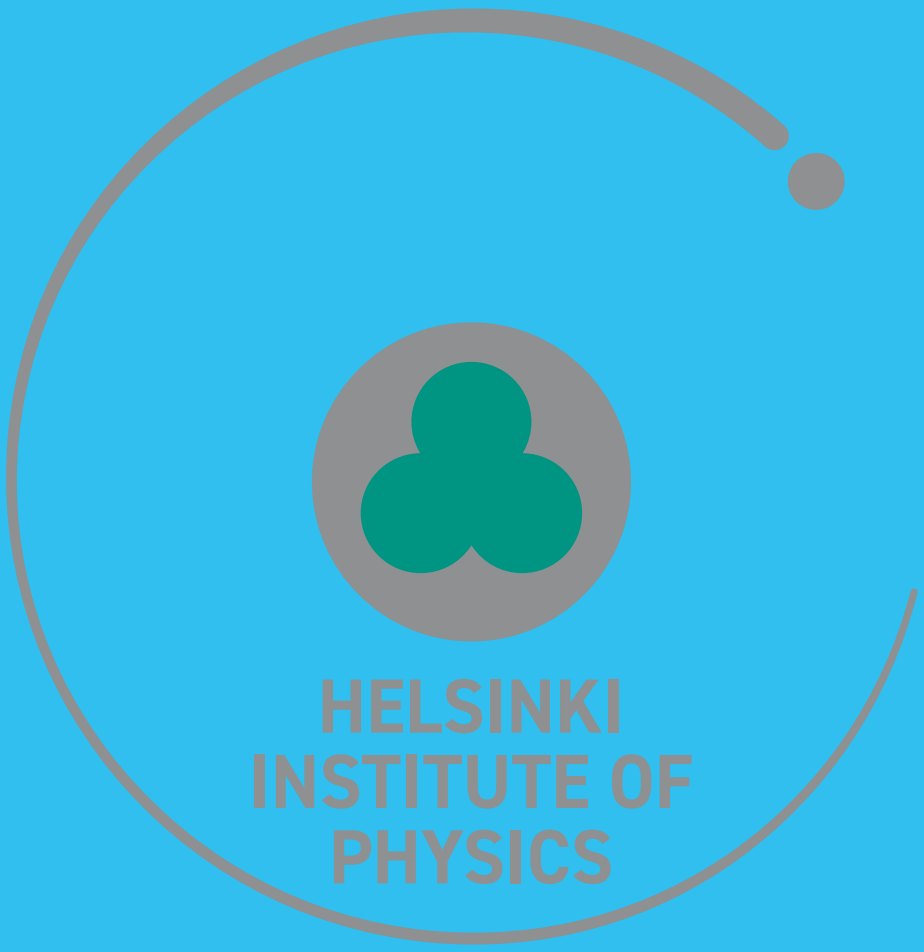

Annual Report 2023

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The HIP Steering Group visiting the Accelerator Laboratory of the University of Jyväskylä on 29 May. © *S. Rinta-Antila.*

Happy organisers of the CERN BootCamp from three Finnish Universities of Applied Sciences and HIP at CERN IdeaSquare on 9 June. © *J. Aaltonen.*

Launch of Euclid from Cape Canaveral, Florida, on a SpaceX Falcon 9 launcher on 1 July. © *ESA – S. Corvaja.*

Finland's delegation led by Ambassador H. Schroderus-Fox at the CERN Gateway Inauguration on 7 October. © *2023–2024 CERN.*

The first doctoral defence on FAIR research in Finland by M. Luoma (centre) on 10 November, with custos T. Grahn, and opponent K. Kolos next to her. © *J. Sarén.*

The HIP Board visiting CERN on 23 November. © *2023–2024 CERN.*

The HIP Board visiting the CMS detector cave on 23 November. © *K. Nordlund.*

CONTENTS

KATRI HUITU
Helsinki Institute of Physics director

PREFACE

The Helsinki Institute of Physics (HIP) is a joint research institute of the Universities of Helsinki, Jyväskylä and Tampere, Aalto University, and Lappeenranta-Lahti University of Technology LUT. The Finnish Radiation and Nuclear Safety Authority (STUK) has been an interim member of HIP since 2018. Hosted by the University of Helsinki, HIP addresses fundamental science questions from quarks to Cosmos, as well as technologies from semiconductors to medical applications and climate research. It serves as a national institute for Finnish physics and related technology research and development at international accelerator laboratories. By mandate of the Finnish Ministry of Education and Culture, HIP is responsible for the Finnish research collaboration with the European Organization for Nuclear Research (CERN) in Geneva and with the Facility for Antiproton and Ion Research (FAIR GmbH), which is under construction in Darmstadt.

In 2023, the research activities of HIP consisted of four research programmes: 1) the Theory Programme; 2) the CMS Programme including the computation for LHC experiments; 3) the Nuclear Matter Programme including involvements in the ALICE and ISOLDE experiments, and the FAIR facility; and 4) the Technology Programme, with four applied research projects. In addition, there were three stand-alone research projects: CLOUD; Education and Open Data; and Euclid. The Detector Laboratory served as a general facility for the Institute. The Theory Programme has strong ties with the ESA Euclid mission and the future LISA mission and with the dark matter COSINUS experiment, which is under construction in the Gran Sasso Laboratory. The Euclid satellite was successfully launched in July, and its mission to better understand dark matter and dark energy has started.

The Russian invasion of Ukraine has continued to be visible at HIP. In December, the CERN Council decided to terminate the International Collaboration Agreements of Russia and Belarus. The authorship of the publications of the LHC experiments was a difficult issue, which finally was solved: Russia or Belarus do not appear in the list of institutes, but instead a collaboration agreement covering them.

The Scientific Advisory Board of HIP, or SAB, visited Kumpula at the very end of August. They were very satisfied with the presentations that they heard. They also received the evaluation reports of the ISOLDE, MAT, and XTREME projects, and strongly recommended the continuation of ISOLDE and MAT. The XTREME project will be substituted by the IDEAL project, which improves the detection for elemental analysis in the laboratory.

As reported by the SAB, research activity has been strong.

In the Theory Programme, the Theoretical Cosmology project and the Designer Topological Matter project started their second 3-year period with active co-operation between HIP member universities. The new Phases of Strongly

Interacting Matter project is tightly connected to the Research Council of Finland's Centre of Excellence, and the leader of the project, H. Mäntysaari, received an ERC Consolidator Grant, so the project has a very strong start. The fourth project, Fundamental Particle Interactions Beyond the Standard Model, relating to research at accelerators, is also new.

The experimental activities with the Large Hadron Collider are very busy for the CMS, the CMS Forward Physics, and the ALICE projects. The analyses with full Run 2 datasets are ongoing, the Run 3 data are coming in, and analyses are being done. The RCF infrastructure committee granted funds for the HL-LHC phase upgrades of CMS and ALICE. The TOTEM experiment took its last data, but the analyses will continue. The purchase of disk space for LHC computing was finalised and is now in use at CSC in Kajaani. In September, H. Kirschenmann started as an Academy Research Fellow in the CMS Experiment project. The ERC funding of M. Voutilainen is also very important for the CMS research, as well as the CoE funding in Jyväskylä for the ALICE research.

The RCF infrastructure committee granted all remaining cash contributions to the FAIR laboratory in 2023. The in-kind contributions are ongoing, and Finnish scientists are taking part in the Phase-0 experiments of FAIR.

In the Technology Programme, in the Accelerator Technology: Materials project the materials research for future accelerators, like HL-LHC, CLIC, FCC, and also for the FAIR laboratory, is being done. The new Radiation and Nuclear Metrology, Safety, Security and Safeguards Applications project combines three previous projects which were closely connected to activities at STUK. Professors of Practise in the field started during 2022 at the Universities of Helsinki and Jyväskylä, and a visiting professor continues at HIP. Thus, the activity has gained momentum, and the SAB was very pleased with the work done.

There were major changes in the Detector Laboratory: M. Kalliokoski began as the new director of the laboratory in May, and long-term laboratory engineer, J. Heino, retired at the beginning of September. The Detector Laboratory supports all the experimental groups at the LHC collider, and one of the LHC experiments, MoEDAL, is a purely Detector Laboratory activity. The laboratory also has activities in the national Quantum Institute and participates in the dark matter COSINUS experiment construction work. The Business Finland Research-to-Business project DeNuSa was finalised.

Several scientists in the HIP projects were recognised by awards: project leader of ISOLDE, J. Pakarinen, received the Tomek Czosnyka Honorary Award; and A. Kankainen from the ISOLDE and FAIR projects received the Väisälä Prize.

HIGHLIGHTS OF RESEARCH RESULTS

Theory Programme

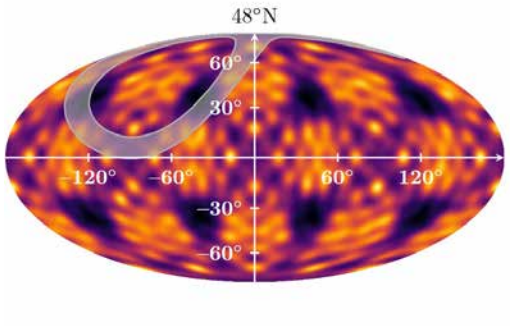
The research in the four HIP Theory projects spans scales from elementary particles up to the whole universe. For the projects 'Fundamental Particle Interactions Beyond the Standard Model' and 'Phases of Strongly Interacting Matter', 2023 was the first year of operations, whereas the projects 'Theoretical Cosmology' and 'Designer Topological Matter' are now in their second three-year period.

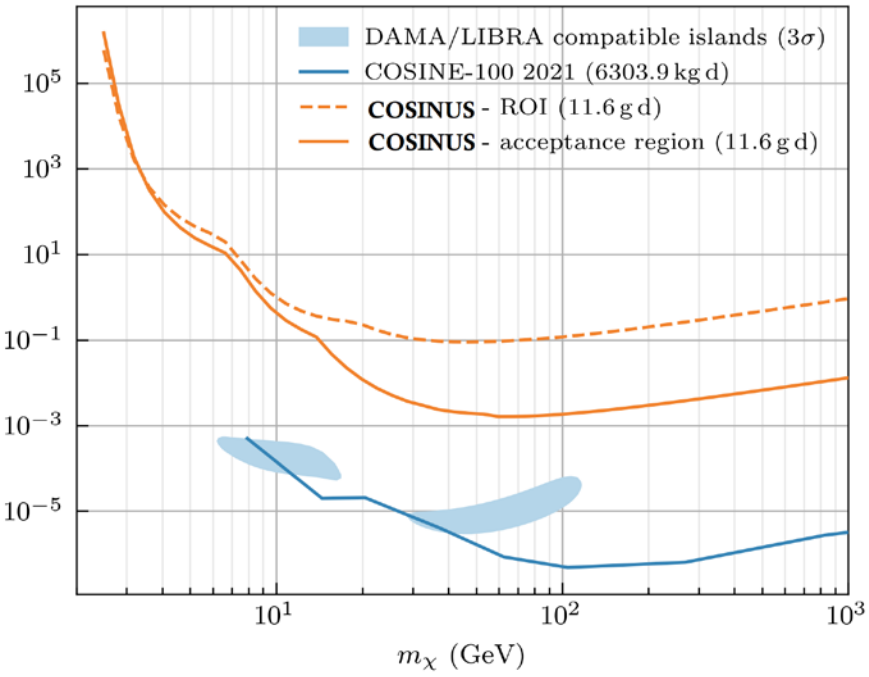
Among the highlights in the Fundamental Particle Interactions Beyond the Standard Model project are studies of the detection possibilities of dark matter candidates. For example, direct detection with solid-state detectors can be used to study the directional variation of the dark matter flux.

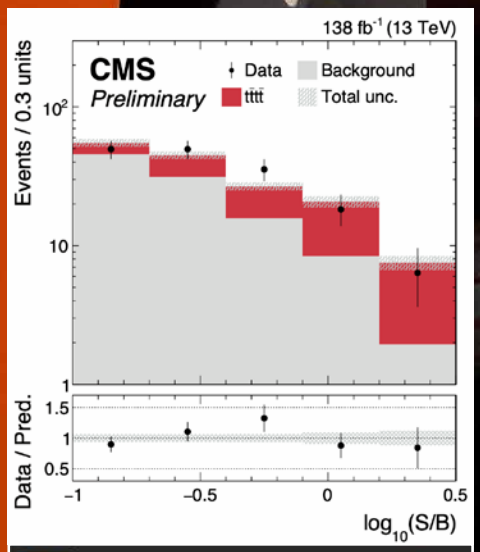
In the Phases of Strongly Interacting Matter project, we developed a novel approach to study fluid dynamics in relativistic heavy-ion collisions based on machine learning. This method can accelerate the measurement of various correlation functions by several orders of magnitude, when compared to the standard hydrodynamic calculation.

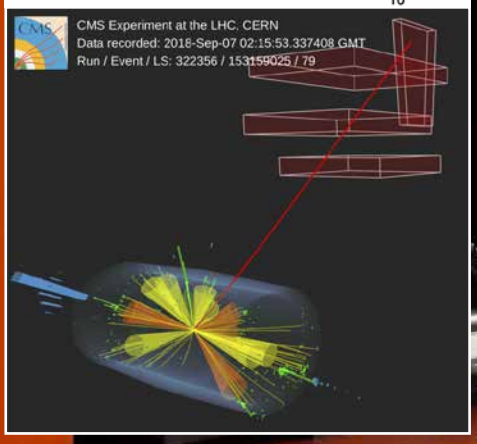
In the Theoretical Cosmology project, the research includes the origin of structures and matter in the early universe. The structures are most likely seeded by inflation, an extremely early period of accelerated expansion. This year we studied various microscopical models of inflation, including setups with non-minimal kinetic terms. We showed that stochastic effects during inflation and fluctuations of spectator fields can efficiently source primordial black holes.

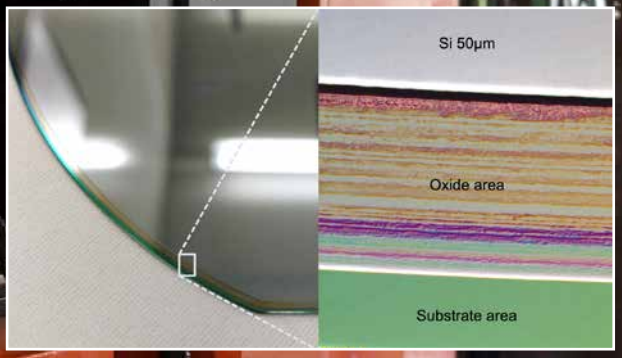
In the Designer Topological Matter project, we showed how entanglement phase transitions between a volume-law and an area-law entangled state can be directly observed through fluctuations of conserved charges. We showed that, in the presence of a conserved charge, the entanglement entropy can be faithfully deduced from the fluctuations of the charge in a subsystem, avoiding the exponential bottleneck.











CMS Programme

CMS is a general-purpose experiment at the Large Hadron Collider (LHC). Overall CMS highlights were the observation of the simultaneous production of four top quarks and the measurements of Higgs bosons decaying to boosted τ leptons and b-quark pairs.

HIP contributed to new physics searches (Higgs bosons), precision measurements with jets (top quark mass and strong coupling constant), and vector boson scattering. In 2023, the focus was on jet calibrations for the 2022–2023 data. S. Laurila was hired as University Researcher at UH. H. Kirschenmann received a Research Council of Finland (RCF) Fellowship and gave an invited EPS-HEP plenary talk. T. Lampén was renewed as PCL manager, while S. Lehti became JETMET trigger and M. Voutilainen PdmV group convener. A new larger disk system was acquired for Finnish LHC computing.

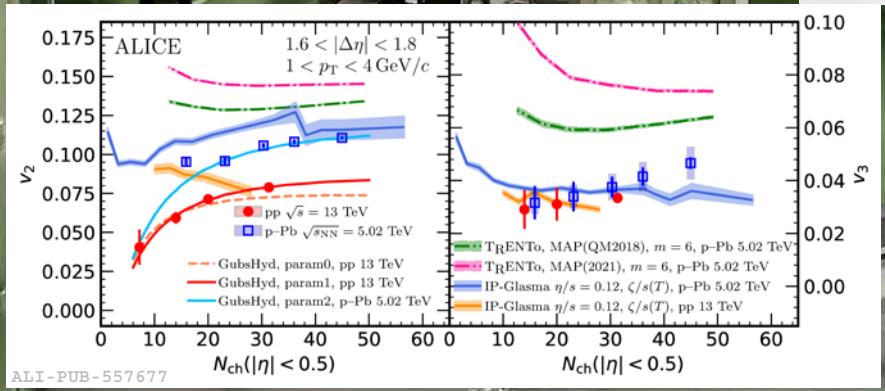
Detector upgrade contributions were focussed on the High Luminosity (HL-LHC) endcap pixel tracker. In 2023, a joint module production centre at CERN with Croatia and Switzerland was finalised. After securing RCF infrastructure funding, the building of a main production centre at HIP began. Detector development for beam monitoring and profiling at the BNCT facilities continued and the development of ultra-thin silicon drift detectors started.

TOTEM is a forward physics experiment at the LHC. In 2023, TOTEM successfully ended its LHC data taking with special runs for the 13.6 TeV total cross section and rho measurements. In the former, a new T2 detector with major HIP contributions exceeded expectations. The CMS Proton Precision Spectrometer time-of-flight detector with crucial HIP involvement was completed and its HL-LHC upgrade approved. CMS and TOTEM also made public a detailed Pomeron exchange study in exclusive pion pair production.

Nuclear Matter Programme

At CERN, both the ALICE and the ISOLDE project had successful running periods. The upgraded ALICE experiment collected 12 billion Pb-Pb events in a five-week long run, gaining 40 times the statistics collected in all previous heavy ion runs between 2010 and 2018. In the physics data analysis, the ALICE group further developed non-flow subtraction methods, which gained visibility in the *CERN Courier* in November.

At ISOLDE, scientists from Jyväskylä led two successful experiments on neutron-deficient mercury isotopes. In the beta decay study of ^{182,184,186}Hg, nearly 400 new transitions were observed and the internal conversion coefficient for 23 transitions were determined. These results confirm the shape coexistence phenomenon in these nuclei and provide complementary data for the analysis of Coulomb excitation experiments. In the same region, the first Coulomb excitation experiment of an odd-even nucleus ^{185}Hg was performed. In this experiment, Miniball was operated in conjunction with the SPEDE spectrometer.

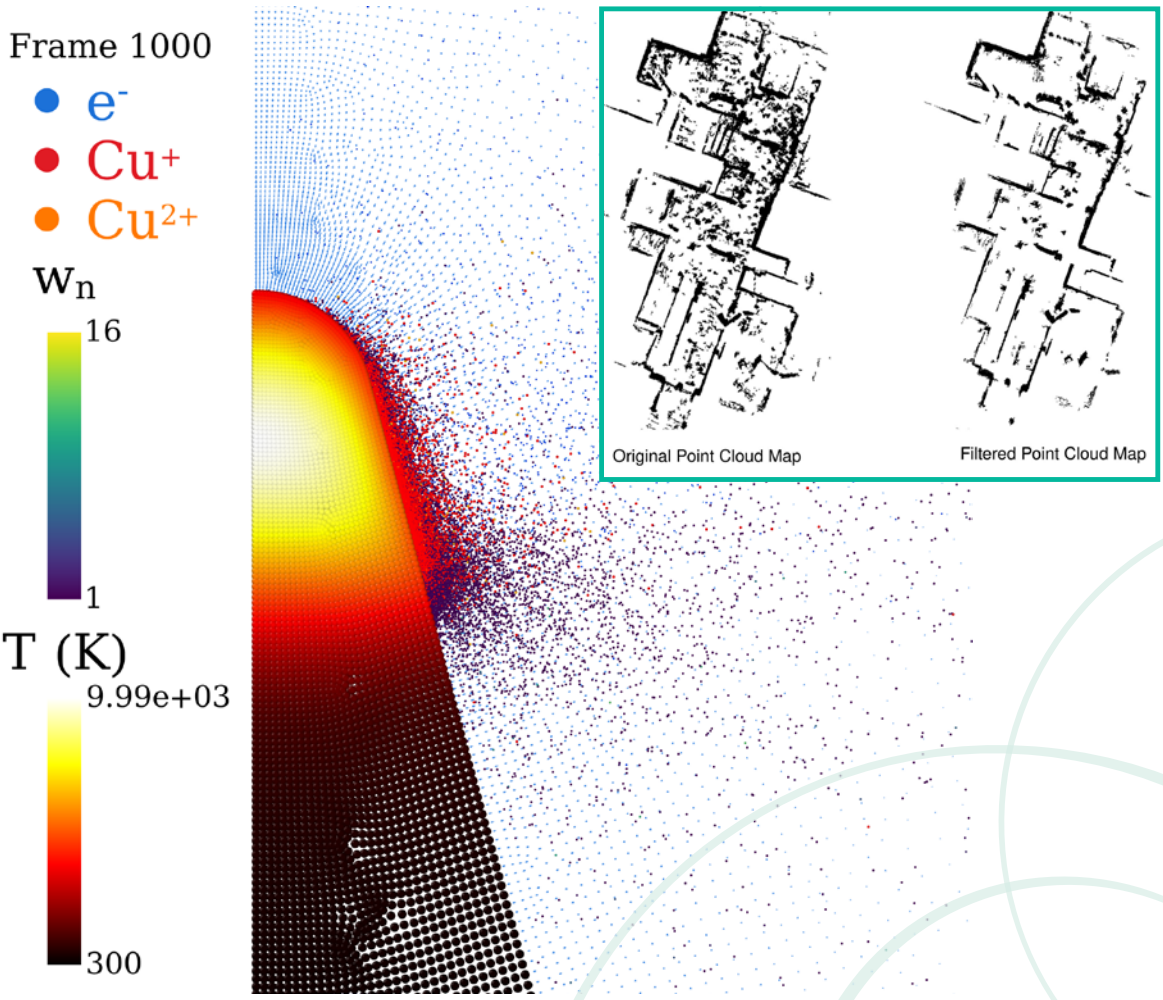


Technology Programme

The Technology Programme aims to integrate HIP projects with significant technology development, transfer, and pre-commercialisation activities into the same programme. In addition, the research activities performed within the programme are designed to seek synergies with big science initiatives at large. The year 2023 saw the start of the RAD3S project that investigates and develops new measurement and analysis methods, produces basic physical data, and uses computational methods to foster radiation and nuclear safety, security, and safeguards. This project includes all the programme research activities related to the partnership with STUK. The XTREME project reached its end with the demonstration of the lab-based X-ray absorption spectroscopy device on the Kumpula campus and the implementation of an X-ray emission spectrometer in the system.

The ROBOT project has evolved into a strong co-operation between Tampere University and Aalto University, and the work follows two research lines. Multi-modal perception approaches for humans interacting with robots are being developed and have been demonstrated on a real industrial assembly task. Novel density-based filtering algorithms have been developed for LIDAR-based mapping and localisation in complex environments.

In the MAT project, important advances have been made in developing the multiscale modelling of vacuum arcing at the surfaces of rf-accelerating structures for CLIC. In particular, inclusion of direct ionization phenomena in the plasma above the surface has been achieved. In addition, research activities have been pursued in relation to the proton beam-induced deterioration of RFQ structures of the LHC, and modelling of thin film growth for superconducting cavities for the FCC.



THEORY PROGRAMME

The research in the four HIP Theory projects spans scales from elementary particles up to the whole universe. For the projects Fundamental Particle Interactions Beyond the Standard Model and Phases of Strongly Interacting Matter, 2023 was the first year of operations, whereas the projects Theoretical Cosmology and Designer Topological Matter are now in their second three-year period.

KARI RUMMUKAINEN
Theory Programme director

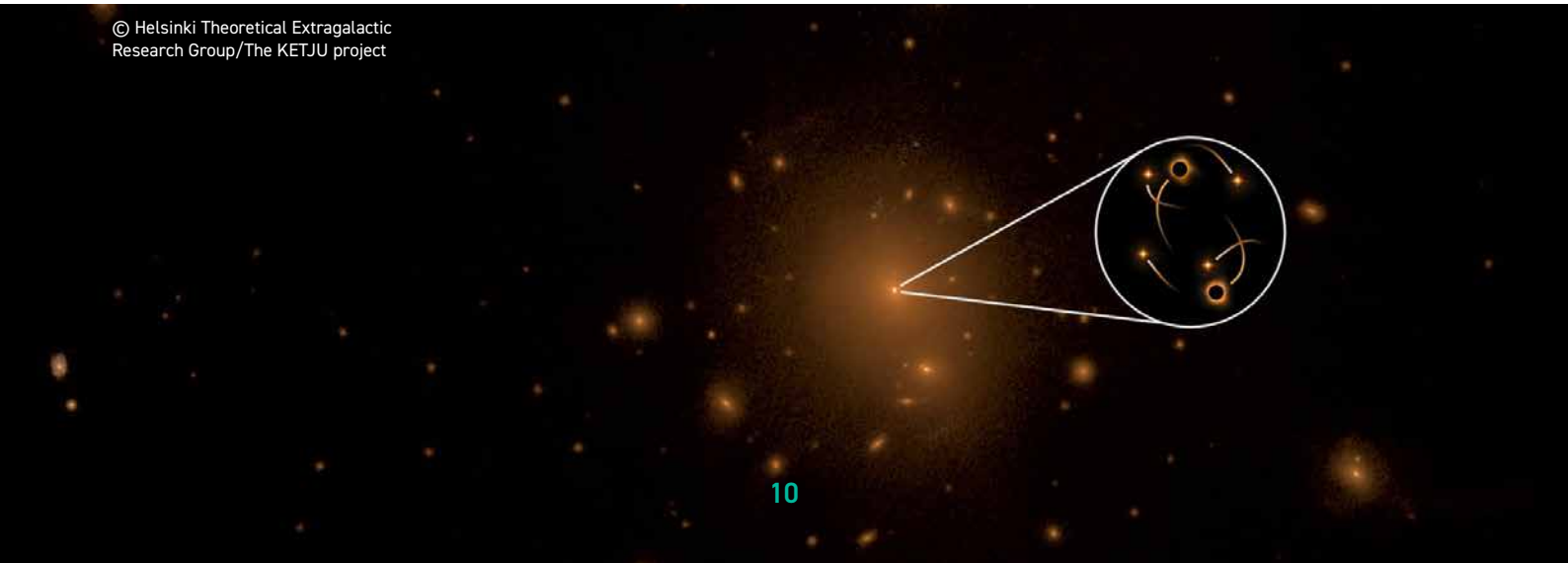
Theoretical Cosmology

SAMI NURMI
Theoretical Cosmology project leader

We study the origin and evolution of the universe, and connections between cosmology and particle physics. Our research topics involve inflation, dark matter, out-of-equilibrium quantum physics, early universe phase transitions, large scale structures of the universe, and gravitational waves. We test microscopical models against the data from cosmological and collider surveys, searching for deeper understanding of the most fundamental properties of matter and gravity. We are part of the LISA Gravitational Wave Survey Consortium, as well as the LISA Astrophysics and Cosmology Working Groups.

We work broadly on the origin of structures and matter in the early universe. The structures are most likely seeded by inflation, an extremely early period of accelerated expansion. This year we studied various microscopical models of inflation, including setups with non-minimal kinetic terms. We showed that stochastic effects during inflation and fluctuations of spectator fields can efficiently source primordial black holes. We also applied quantum transport machinery to study weakly coupled scalars in reheating and developed precision methods for computing the phase space distribution of cosmic relic particles that can be generated in a wide range of theoretical setups.

We explore gravitational wave (GW) signals over the entire history of the universe. This year we showed that the scale invariant GW spectrum predicted by inflation is dominated by a subluminally propagating tail component. We worked broadly on phase transitions in the early universe. We studied shocks, turbulence, and so-called 'hot droplets' which can have important effects on the measurable GW signals. We also developed new methods to speed up the LISA data analysis using template spectra and studied holographical models for phase transitions. Supermassive black holes in galactic centres are very interesting GW sources. Using the locally developed KETJU code, we run precision simulations of supermassive black holes and black hole binaries together with the global galaxy dynamics, and constrained simulations of local structures. We also tested the consistency of the LCDM model with the Local group and the local large-scale structure (two *Nature Astronomy* papers).



© Helsinki Theoretical Extragalactic Research Group/The KETJU project

Fundamental Particle Interactions Beyond the Standard Model

ANCA TUREANU
Fundamental Particle Interactions Beyond the Standard Model project leader

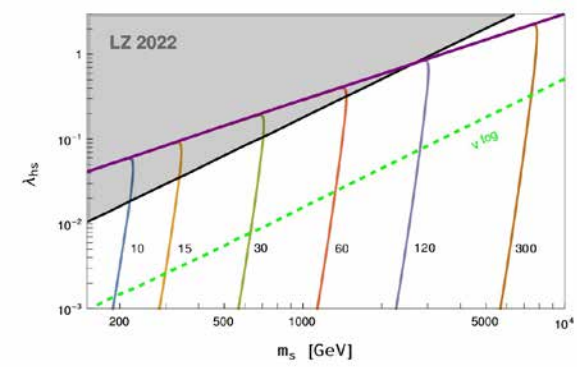
The project has a strong community component, covering the diverse theoretical particle physics research performed at the University of Helsinki. We started in 2023, with a focus on *neutrino theories*, the *problem of dark matter*, *modified gravity*, and *quantum information*.

We have formulated a manifestly coherent mechanism for neutrino oscillations, seamlessly combining quantum field theory with quantum mechanics. The scheme gives a definite identity to the flavour states as asymptotic states in all processes involving neutrinos and simplifies conceptually and technically the description of the only laboratory observed phenomenon beyond the Standard Model.

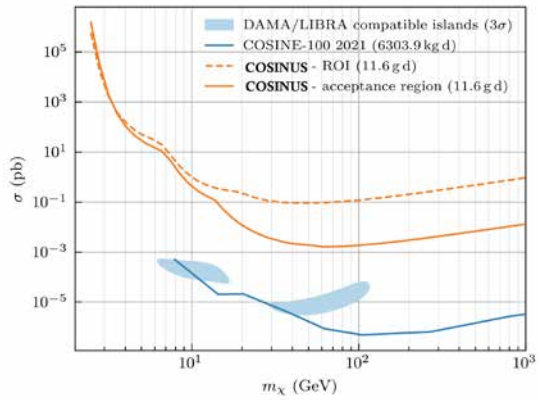
Our group showed that non-thermal dark matter can have a large coupling to normal matter as long as the temperature in the universe has never been too high, above the electroweak energy scale, making possible its direct detection or observation at the LHC. This creates exciting prospects in the race for the first laboratory evidence of the existence of dark matter.

We have continued our research on dark matter direct detection using solid-state targets. Our results show that with an energy resolution of $O(10\ \text{eV})$ it is possible to identify the presence of an anisotropic component consistent with observations for sub-GeV dark matter. The introduction of daily modulation substantially improves the sensitivity albeit in a narrow mass range.

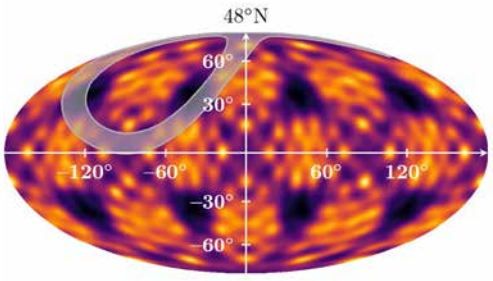
Our group is responsible for the HIP activities in the COSINUS experiment. Its main purpose is to test the DAMA dark matter result, apparently incompatible with other direct detection experiments. We had the leading role in an analysis of the measurements to determine the natrium iodine crystal quenching factor, which is essential for the accurate calibration of the energies of nuclear recoil signals induced by dark matter particles.



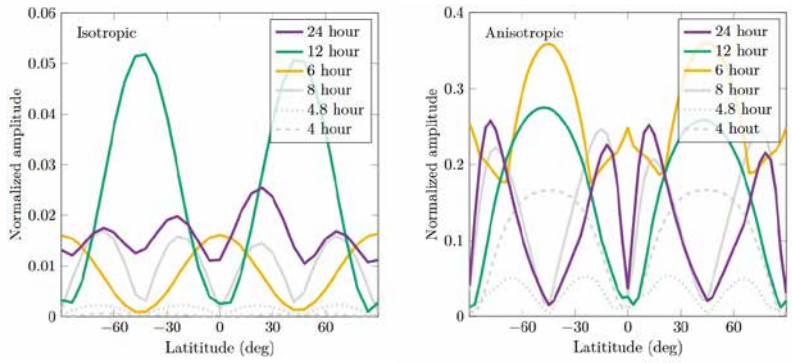
Parameter space of non-thermal dark matter (mass vs coupling to the Higgs field). The coloured curves, marked by the maximal temperature of the universe in GeV, correspond to the observed DM density. The shaded region is excluded by the direct detection experiment LZ 2022, while the white region can be probed in upcoming experiments. *[C. Cosme, F. Costa, and O. Lebedev, arXiv:2306.13061].*



Direct search for dark matter with the COSINUS experiment: a limit on the spin-independent dark-matter nucleon elastic scattering cross section achieving a sensitivity of *O* (pb) with an exposure of only 11.6 g day. For comparison, the contours compatible with the DAMA/LIBRA result are shown, as is the COSINE-100 result from 6303.9 kg day exposure, a factor $\sim 10^5$ higher than the current study. *[The COSINUS Collaboration, arXiv:2307.11139].*



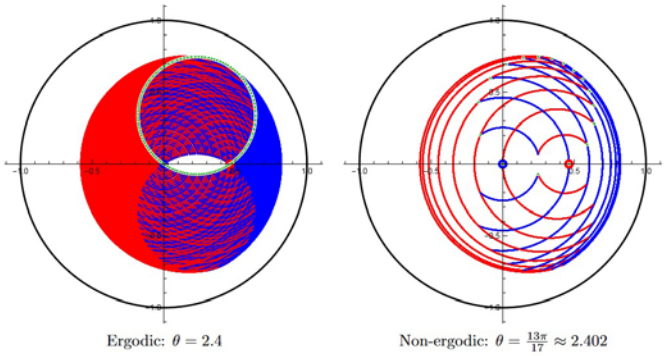
Directions swept by the direction of the dark matter wind throughout the year (shaded band) at latitude 48 degrees north overlaid on the energy threshold surface of a germanium crystal. *[M. Heikinheimo, K. Nordlund, S. Sassi, and K. Tuominen, arXiv:2312.17550].*



Amplitudes of Fourier components for the isotropic and anisotropic contributions to the event rate for spin-independent dark matter scattering operators. The amplitudes have been normalized relative to the amplitude of the zero-frequency component, i.e., the average rate. *[M. Heikinheimo, K. Nordlund, S. Sassi, and K. Tuominen, arXiv:2312.17550].*

Some classes of modified theories of gravity provide an alternative to the dark matter models for explaining the same signature observations. Our group proposed a dynamical modified gravity model, in which the Starobinsky model for inflation can emerge, while the requirement of absence of ghost modes constrains the parameters of this model to fit the observational data.

In the field of quantum information, we constructed a quantum information geometry based on the Bogolyubov-Kubo-Mori metric in conformal field theory (CFT) and used it to identify and visualise different regimes in driven out-of-equilibrium CFT, in particular to identify ergodic and non-ergodic regimes. ●



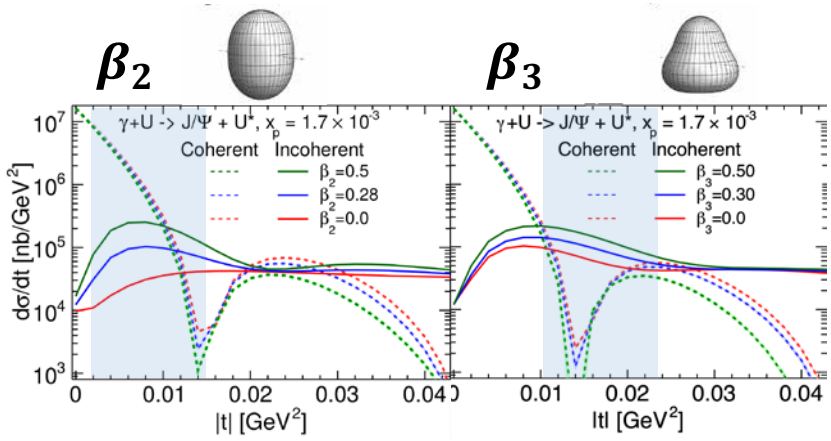
Two-step process in the non-heating phase. The green points correspond to the positions of the process after each period. They lie on the process circle. Ergodicity of the dynamics on this circle, characterised by an angle θ, leads to ergodicity of the process in a region R of a disk. Each step is a rotation of angle T_k around a centre the point u_k representing the Hamiltonian H_k. The red and blue points are u_1 and u_2 corresponding to H_1 and H_2. This picture corresponds to 1000 steps and $\lambda = 1$. *[J. de Boer, V. Godet, J. T. Kastikainen, and E. Keski-Vakkuri, J. High Energy Phys. 09 (2023) 087].*

HEIKKI MÄNTYSAARI
Phases of Strongly Interacting Matter project leader

Phases of Strongly Interacting Matter

Our project focusses on QCD, the quantum field theory describing strong interactions between the quarks and gluons, using different theoretical approaches both in a collider environment and in an astrophysical context. We are also involved in physics studies for planned colliders, such as the EIC and FCC. In 2023, the project leader obtained an ERC Consolidator Grant focussing on QCD in the high-energy limit.

We describe the evolution of the deconfined Quark Gluon Plasma (QGP) produced in heavy ion collisions at high energy using relativistic fluid dynamics. These simulations are computationally demanding, and in 2023 we developed a machine learning based setup that enables us to use a neural network to simulate a very large number of collisions. This development makes it possible to obtain predictions for various correlation observables that require a lot of statistics and are sensitive to the detailed properties of the QGP.

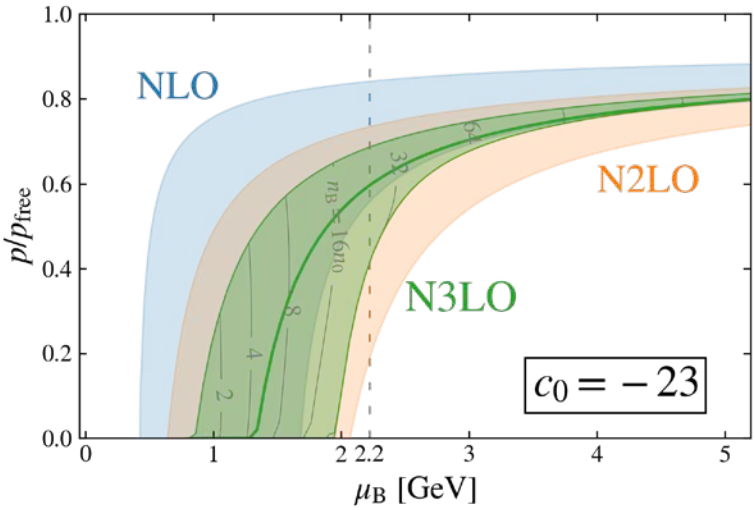


Demonstration that exclusive vector meson photoproduction at the EIC is sensitive to the quadrupole (β_2) and octupole (β_3) deformation of uranium in different squared momentum transfer t regions. Figure based on *Phys. Rev. Lett. 131 (2023) 6, 062301.*

The formation of the QGP is described using two complementary approaches. In the Colour Glass Condensate picture dynamics is described in terms of strong classical gluon fields. In this context, in 2023 we focussed on possibilities to probe non-linear QCD dynamics in inclusive and diffractive scattering processes and identified a possibility to probe nuclear deformations at high energies at the Electron-Ion Collider, bridging the gap between low- and high-energy nuclear physics. In the collinear factorisation-based approach where early time dynamics is calculated from perturbative quark and gluon scatterings complemented with a saturation conjecture, we developed a 3D Monte Carlo version of the widely used EKRT initial condition. We also included non-linear corrections from gluon recombination to the proton parton distribution functions.

QCD dynamics in the non-perturbative domain is described using a holographic approach. To improve the accuracy of the holographic calculations, we constructed a gravity dual to the physical gauge theory by calculating the entanglement entropy and matching that to explicit lattice results. We also collaborated with the HIP Theoretical Cosmology project to show that subluminal signals of primordial fluctuations dominate the gravitational wave background.

In the context of neutron stars, we computed a new state-of-the-art perturbative QCD equation of state for cold quark matter. These calculations are now finally on par with comparable theoretical calculations performed for collider environments at high temperatures. These developments play a crucial role in determining whether deconfined quark matter exists inside neutron stars.



The equation of state for cold quark matter computed to the order $\alpha_s^3 \ln\alpha_s$ (N3LO) level. An estimation for the remaining unknown constant c_0, determined by computing many hard four-loop diagrams, is obtained using Bayesian modelling. Figure based on *Phys. Rev. Lett. 131 (2023) 18, 181902.*

Designer Topological Matter

Modern physics research can be roughly divided into three frontiers: the study of the very small; the study of the very large; and the study of the very complex. Our research deals with topics on the complexity frontier, involving quantum systems and devices that exhibit interesting collective behaviour. Building on our experience in condensed-matter systems, our focus has moved to understanding the entanglement patterns and complexity in many-body systems. While these issues are now predicted to also play an important role in understanding the big questions in the other two research frontiers, understanding complex quantum systems is hoped to lead to breakthroughs in practical quantum information applications in the near future.

In 2023, our research mainly concentrated on studies of entanglement dynamics in monitored quantum circuits and formulating the theory of Fock complexity of many-fermion states. In a paper published in *Physical Review Letters*, we showed how entanglement phase transitions between a volume-law and an area-law entangled state can be directly observed through fluctuations of conserved U(1) charge. A direct measurement of the entanglement entropy requires carrying out an exponentially complex state tomography protocol. In our work we showed that, in the presence of a conserved charge, the entanglement entropy can be faithfully deduced from the fluctuations of the charge in a subsystem, avoiding the exponential bottleneck.

Our long-time efforts in understanding random and amorphous topological materials culminated in the discovery of the quantum Hall effect and effective Landau levels on lattices without long-range spatial order. The Landau levels are typically associated with the translation symmetry of the system as they provide a practical tool to probe the underlying lattice geometry. In our work we showed that the notion of Landau levels, and thus the rich panoply of physical phenomena associated with them, essentially survives without long-range order as long as the magnetic length remains smaller than the geometric correlation length of the lattice.

TEEMU OJANEN
Designer Topological Matter project leader

CMS PROGRAMME

KENNETH ÖSTERBERG
CMS Programme director

The HIP CMS Programme co-ordinates Finnish participation in the CMS and TOTEM collaborations at the Large Hadron Collider (LHC). The Compact Muon Solenoid (CMS) is a general-purpose experiment with a broad physics programme covering precision measurements of particles and interactions, the origin of electroweak symmetry breaking (Higgs bosons), and the search for new physics. TOTEM focussed on elastic scattering, total cross section, diffractive and exclusive processes, and completed its data taking at the LHC in 2023. The programme has four projects: 1) the CMS Experiment project for physics analysis and operations; 2) the CMS Upgrade project for detector upgrades; 3) the Tier-2 Operations project for LHC computing; and 4) the CMS Forward Physics project for forward physics and the TOTEM physics programme completion. The Finnish groups in CMS are: HIP (currently 15 authors); the Department of Physics at the University of Helsinki (3 authors); and Lappeenranta-Lahti University of Technology (2 authors). TOTEM presently has 7 HIP authors, of which 5 are also affiliated with the Department of Physics at the University of Helsinki.

MIKKO VOUTILAINEN
CMS Experiment project leader

CMS Experiment

Introduction and Highlights

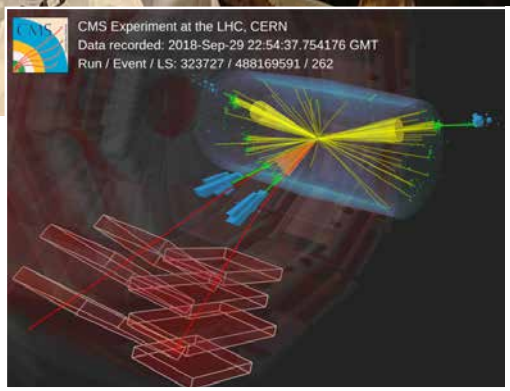
The LHC is in a unique position to explore electroweak symmetry breaking and the origins of the universe. The CMS Experiment project is focussed on analysis of the LHC data, especially on new physics searches (charged Higgs bosons), precision measurements with jets (top quark mass m_t, strong coupling constant α_s), and vector boson scattering (VBS). These are supported by a strong involvement in detector operations on prompt calibration loop (PCL), jet energy corrections (JEC), and machine learning (ML) applications in high energy physics (HEP).

The focus of 2023 was on understanding and calibrating the first half of the Run 3 data collected since 2022, with Run 2 Legacy analyses continuing in parallel. S. Laurila was hired as University Researcher at UH, and H. Kirschenmann received a Research Council of Finland (RCF) Academy Fellowship for the 'ForVVard' project. L. Martikainen defended her thesis on the measurement of the inclusive jet cross section at 13 TeV with the full Run 2 data. Our ERC+RCF call received more than 30 post-doc and 70 PhD applications to 2+4 positions starting in 2024.

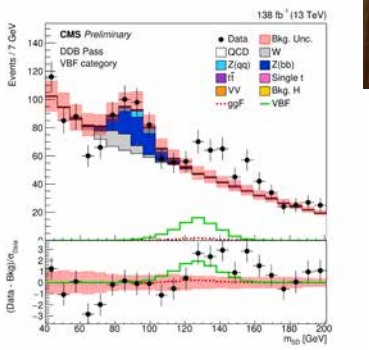
HIP continued its strong scientific leadership at CERN: T. Lampén was renewed as PCL manager, while M. Voutilainen took up convenership in the Physics Data and Monte Carlo Validation (PdmV) group and S. Lehti in the JetMET trigger group. H. Kirschenmann completed his tenure as Top Mass and Properties convener and gave an invited plenary talk on Standard Model (SM) Physics at the EPS-HEP 2023 Conference.

Overall CMS highlights of the year included observation of the simultaneous production of four top quarks, one of the rarest processes ever observed at the LHC, and measurements of Higgs bosons at high momentum through dedicated algorithms to identify strongly collimated τ lepton and b-quark pairs.

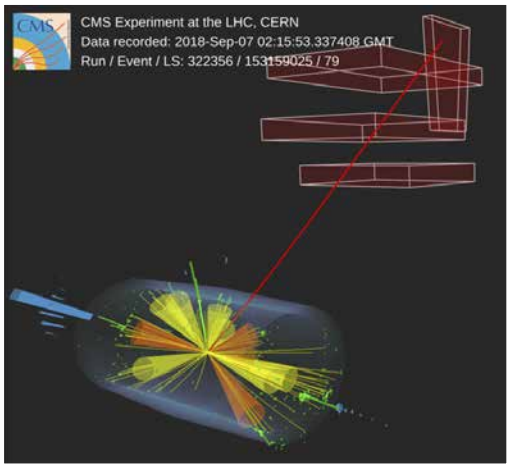
CMS Experiment team members at the karonkka of L. Martikainen's thesis defence. *Credit: M. Voutilainen.*



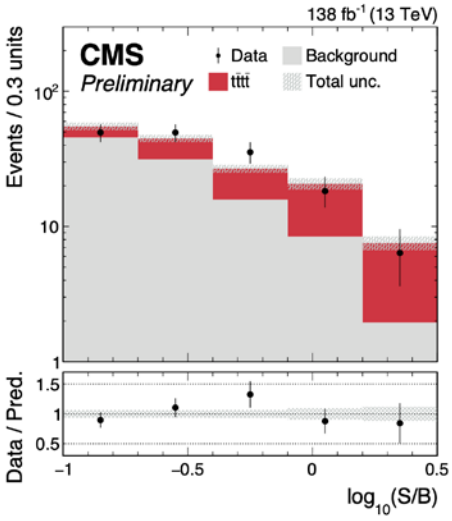
Event display of a Higgs boson candidate produced via a vector boson fusion process and decaying to boosted b-quarks. © *CMS Collaboration, CERN.*



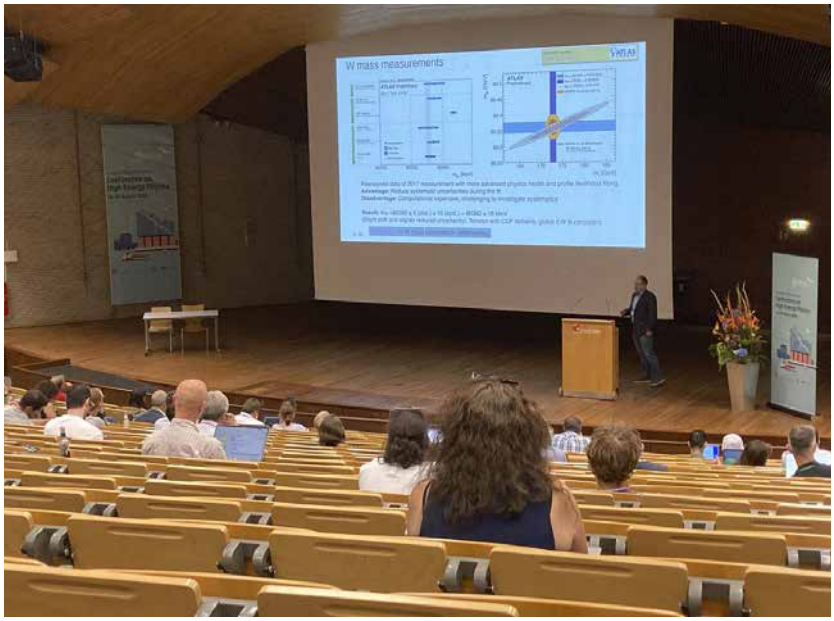
Mass distribution of Higgs boson candidates produced via a vector boson fusion process and decaying to boosted b-quarks. © *CMS Collaboration, CERN.*



Event display of a four top quark candidate. © *CMS Collaboration, CERN.*



Observation of the simultaneous production of four top quarks. © *CMS Collaboration, CERN.*



Invited plenary presentation on Standard Model Physics at the EPS-HEP 2023 Conference by H. Kirschenmann. *Credit: M. Voutilainen.*

Participants in the CMS JetMET Workshop in Brussels in May 2023 with many CMS Experiment team members. *Credit: M. Voutilainen.*

Detector Operations

The PCL group operated and improved further the automatic calibration workflows while developing some new ones; the JEC group provided calibrations for the first half of the Run 3 data, focussing particularly on jet energy corrections and triggering at the very highest energies and their interplay with the new HCAL readout electronics. Work on the Run 2 Legacy JEC paper and the first paper on quark-gluon discrimination continued in parallel. HIP had major contributions in all of these, with new personnel being hired through the ERC project 'JEC4HL-LHC' for 2024.

Precision Measurements

Measurements of m_t (M. Myllymäki), the inclusive jet cross section (L. Martikainen), and gluon jet identification (K. Kallonen, N. Toikka) continued on the Run 2 legacy data, aiming at constraining m_t and the strong coupling constant α_s in exploration of the SM vacuum stability. The m_t measurement with 2016 data was published [*EPJC 83 (2023) 963*], and L. Martikainen's thesis demonstrated the potential of Run 2 legacy data for inclusive jets.

New Physics Searches

The search for charged Higgs bosons in the $\tau\nu$ channel continued on the full Run 2 data (S. Lehti), while the search for doubly-charged Higgs bosons in a same-sign double τ final state continued with R. Öhrnberg's MSc thesis with the HIP Theory group. P. Inkaew got involved in the boosted Higgs bosons search. These channels allow exploration of the electroweak symmetry breaking, in search for physics beyond SM (BSM) and dark matter candidates.

Vector Boson Scattering

H. Kirschenmann started the RCF 'ForVVard' project and participation in the COST action 'COMETA' (CA22130). HIP was also involved in both the first study of VBS in the all-hadronic final state using Run 2 data and in preparations for the Run 3 measurement. ●

CMS Upgrade

The CMS Upgrade project contributes to the CMS hardware upgrades. In the coming years, we will focus on the LHC High Luminosity (HL-LHC) upgrade of the inner tracking detector and the production of the new timing layer to cope with the higher HL-LHC instantaneous luminosity.

CMS Inner Pixel Detector

For the tracking detector upgrade, we concentrate on the production of the Tracker Endcap PiXel layers (TEPX), starting officially in 2024. In 2023, we continued preparing our laboratories for the upcoming production phase. Our share in the production is 250 TEPX modules and their full quality control. First, we focussed on building a production laboratory at CERN, together with the Paul Scherrer and the Ruđer Bošković institutes that is now mostly ready to serve.

After securing important RCF infrastructure funding, we started to build our main production centre in the HIP clean room. Having the production in Helsinki, we benefit from local expertise, availability of students, and collaboration between the Finnish ALICE and CMS groups. Two production sites also minimise the risk of production bottlenecks.

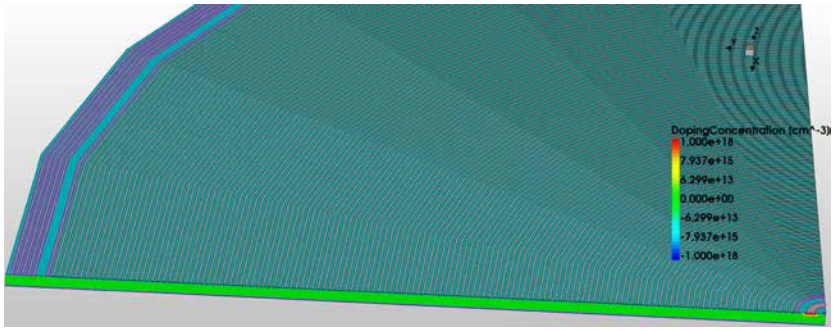
New Timing Layer for CMS

The upcoming Minimum ionizing particle Timing Detector (MTD) enables true 4D tracking with CMS. Low Gain Avalanche Detectors (LGAD) are the chosen technology for the Endcap Timing Layer (ETL), where we are involved. In 2023, we continued our contribution to the R&D by characterizing LGAD sensors from various manufacturers for the market survey. S. Bharthuar, who made major contributions to the ETL R&D, successfully defended his thesis in 2023.

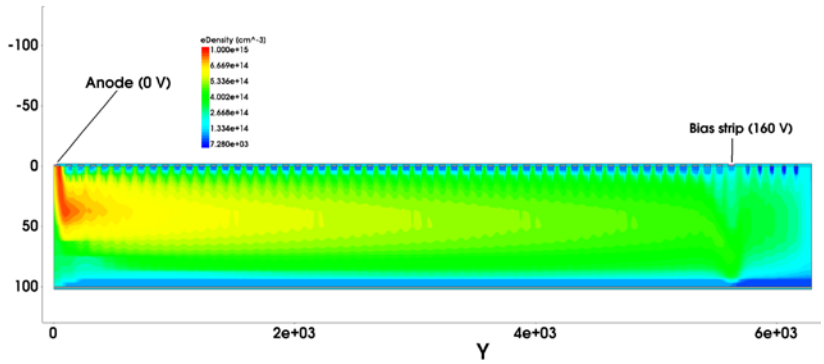
Local Detector R&D

To develop knowledge and expertise, in 2023 we continued the development and manufacturing of ionizing radiation sensors in Micronova at OtaNano, Finland. A wafer scale production of AC-coupled pixel sensors using ALD grown insulation and resistor materials was started, as well as the development of ultra-thin silicon drift detectors in collaboration with Okmetic Oy. We are also involved in the RCF project 'Optimisation of boron neutron capture therapy (BNCT) for cancer treatment at Helsinki University Hospital accelerator-based BNCT facility', where we test detector technologies for beam monitoring and profiling. The aim is to develop suitable detectors for future use at

ERIK BRÜCKEN
CMS Upgrade project leader



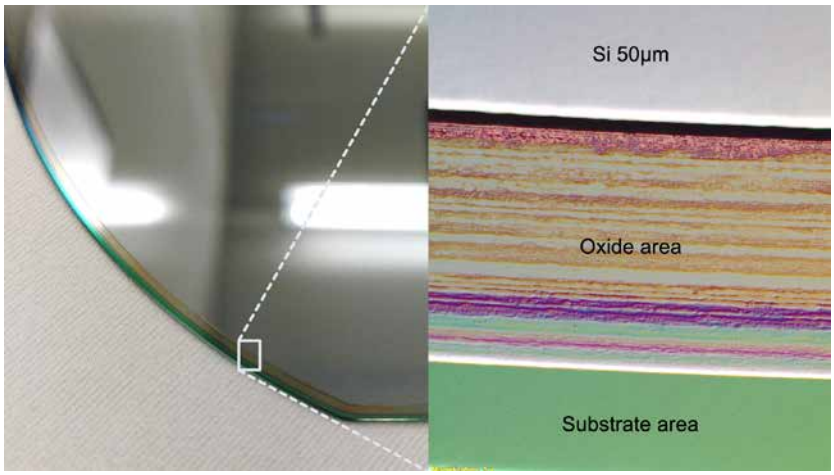
The conceptual design of a thin silicon drift detector.
Credit: S. Saariokari and T. Hildén.



Preliminary result of a TCAD simulation of a thin silicon drift detector design.
Credit: S. Saariokari and T. Hildén.

BNCT facilities. This is a natural continuation of our already completed RCF project, which developed photon counting detectors for medical imaging and beam characterization. S. Kirschenmann successfully defended her thesis on this topic in 2023.

In spring 2023, the Business Finland-funded 'Detector for nuclear safety, decommissioning and diagnostic applications (DeNuSa)' project of the HIP Detector Laboratory and the LUT Particle Physics Instrumentation group concluded successfully. A patent application to protect the IPR obtained in this project was submitted in 2023. ●



Detail of a silicon wafer to be further processed to thin silicon drift detectors. *Credit: A. Gädda, Okmetic Oy.*

TOMAS LINDÉN
Tier-2 Operations project leader

Tier-2 Operations

The HIP WLCG resources are run in collaboration with CSC (IT Center for Science Ltd), and the NeIC Nordic DataGrid Facility. CMS analysis and simulation jobs were run on the HIP Tier-2 site in 2023 with excellent availability. The CMS Site Readiness Status was 84% (91% in 2022). T. Lindén represented HIP in the Nordic LHC Computing Grid committee. S. Lehti and M. Myllymäki worked 10% in the Tier-2 project. There were 12 Global Grid User Support tickets (12 in 2022) concerning HIP.

CMS jobs were run on the 672 core Linux cluster Kale (from 2015). Optimisation improved the cluster usage by increasing available memory for the jobs through better use of local disks. HIP participated in the 2023 Finnish Competence Computing Infrastructure FIRI application for new CPU capacity.

Three projects were started to enable the CSC LUMI supercomputer for HEP usage. The first LUMI CMS jobs were run, but the production setup needs more work to develop a robust CVMFS configuration, the jobs scratch space, and the job submission.

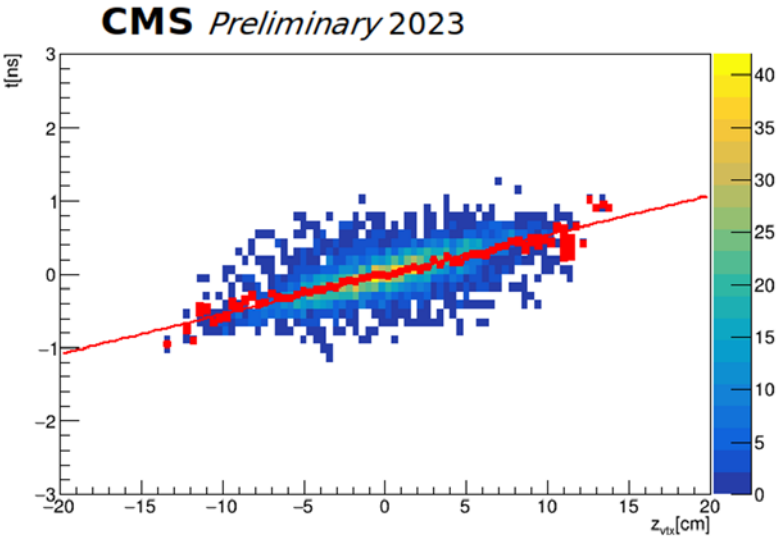
The dCache services run by CSC were stable. The new 6760 TB dCache disk system in Kajaani was a significant upgrade over the old 2176 TB system, which was moved to Kumpula. The network speed increased from 40 Gb/s to 100 Gb/s, and was almost filled at times. The new dCache was presented at the HEPiX Autumn 2023 Workshop.

In 2023, 1860 TB (642 TB in 2022) of data was transferred to HIP and 486 TB (407 TB in 2022) from HIP to elsewhere with FTS. A total of 0.15 million CMS jobs (0.13 million in 2022) using 44.9 MHS06 CPU hours (49.2 MHS06 in 2022) were run with an average CPU efficiency of 52.8% (56.9% in 2022). ●

CMS Forward Physics

The CMS Forward Physics project is responsible for the Finnish contributions to CMS forward physics and the TOTEM experiment. The focus in 2023 was on completing the Run 3 detector upgrades and performing the last TOTEM physics measurements as well as physics analysis and publications of Run 2 data. K. Österberg continues as TOTEM physics co-ordinator and F. Garcia took on the responsibility for the CMS Proton Precision Spectrometer (PPS) time-of-flight (TOF) detector operation.

KENNETH ÖSTERBERG
CMS Forward Physics project leader

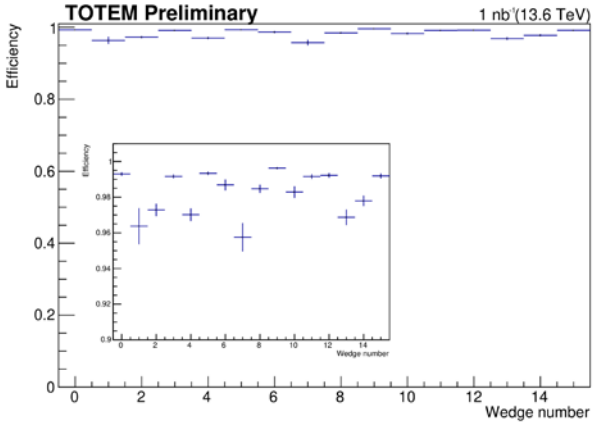


Correlation between the PPS time-of-flight measurements of the protons and the longitudinal position of the reconstructed vertex by the CMS Tracker in 2023 low-pileup data. © *CMS Collaboration, CERN.*

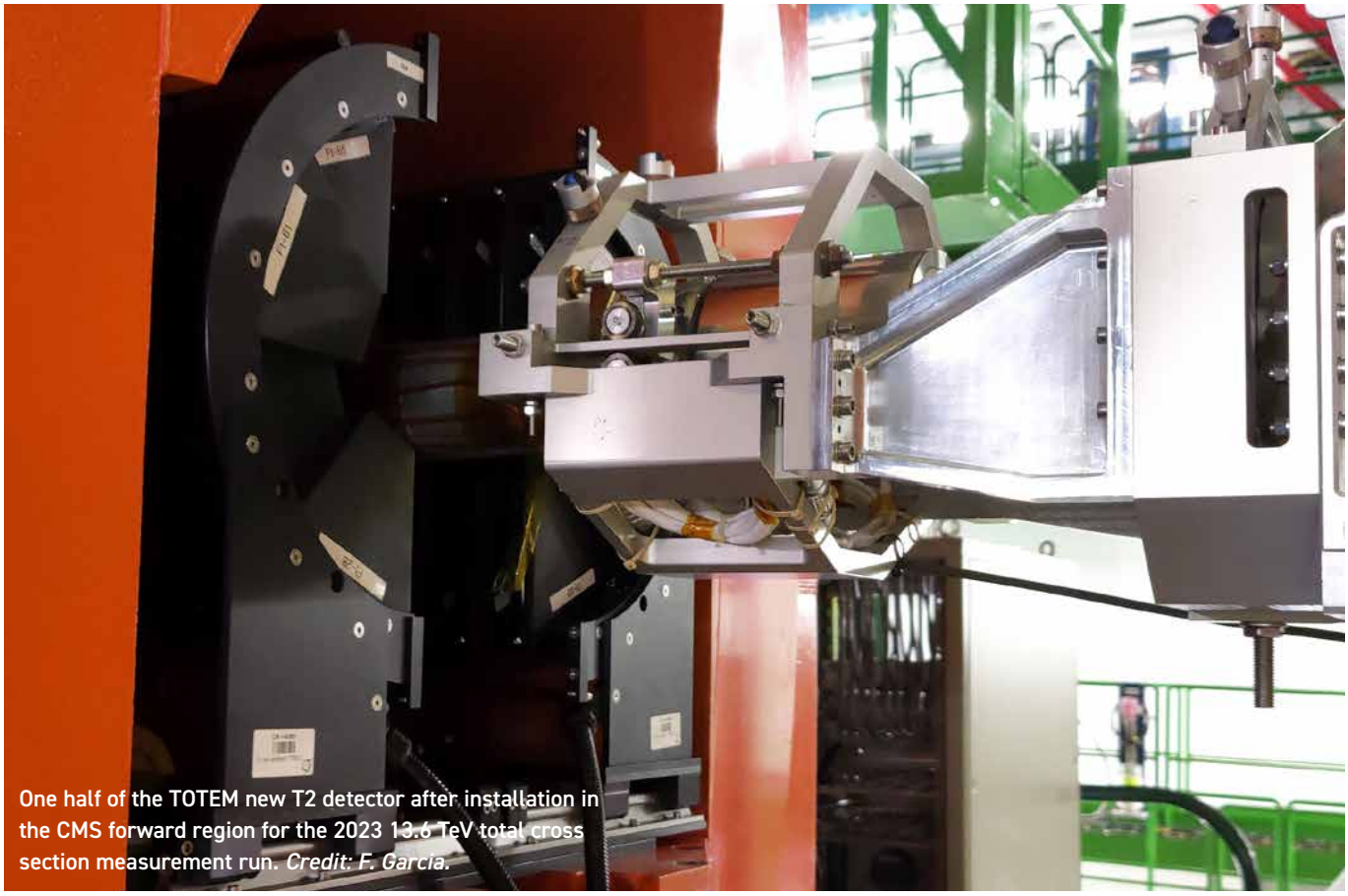
A PPS Roman pot containing a diamond-based time-of-flight detector module in the LHC tunnel for the 2023 high luminosity running. *Credit: F. Garcia.*

Detector Upgrades

For the Run 3 PPS TOF detector, HIP played a key role via the diamond sensor purchase, metallization, and quality assurance (M.-M. Rantanen, P. Koponen, K. Österberg), as well as TOF plane assembly, testing, installation, and commissioning (F. Garcia). The TOF detector was completed for the LHC 2023 run with the installation of three additional TOF planes per arm in addition to the already installed four planes per arm. The shortened 2023 LHC run allowed the extraction of the TOF planes to try to fix an observed efficiency problem. The refurbished TOF planes will be installed for the LHC 2024 run. Regarding the TOTEM new T2 (nT2) detector, HIP was responsible for producing and testing the scintillator tiles (F. Garcia, R. Turpeinen) and developing the software (F. Oljemark). The nT2 was installed for the June 13.6 TeV total cross section measurement run. The first data analysis indicates excellent single-track efficiency with negligible background despite optical fibre problems. Moving forward, HIP is involved in the preparations of the HL-LHC PPS upgrade, PPS2, that was approved by CMS and CERN in 2023.



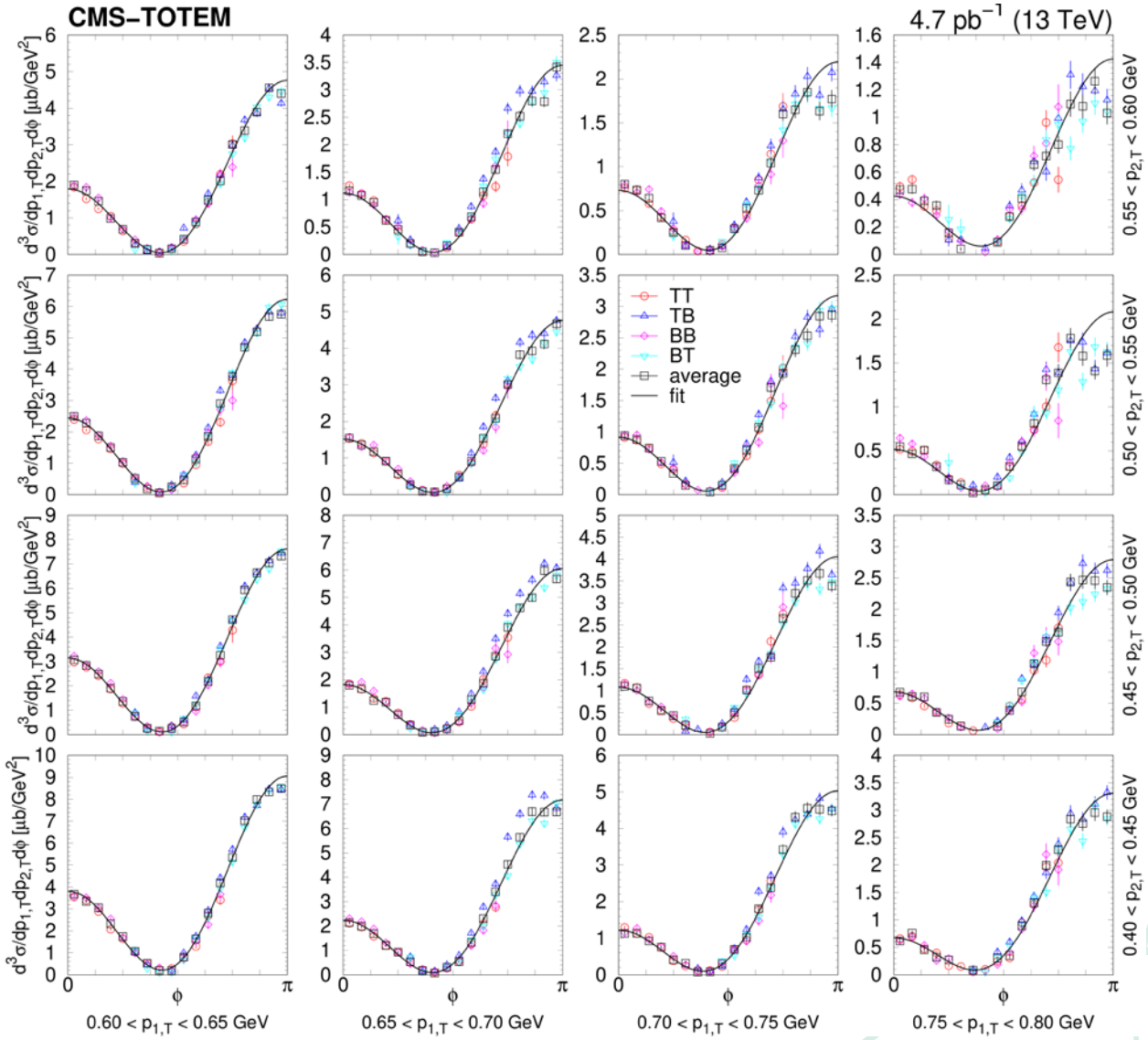
Preliminary particle-track efficiencies for the TOTEM new T2 detector planes based on the 2023 13.6 TeV total cross section measurement run data. © *TOTEM Collaboration, CERN.*



One half of the TOTEM new T2 detector after installation in the CMS forward region for the 2023 13.6 TeV total cross section measurement run. *Credit: F. Garcia.*

Physics

In 2023, the work on updating the analysis of the observation of Odderon exchange in elastic scattering (K. Österberg) and the study of glueball candidates in low mass exclusive meson production (J. Vieros) continued. An analysis was also started for the total cross section measurement at 13.6 TeV (F. Oljemark). Regarding PPS physics, an analysis to search for exclusive pair production of doubly-charged Higgses decaying to same-signed τ leptons (A. Milieva) was started in collaboration with the CMS Experiment project (S. Lehti). In addition to the publications on the PPS proton reconstruction and BSM searches, CMS and TOTEM made public a detailed study of Pomeron exchange in exclusive charged π pair production, where a parabolic minimum in the two-proton azimuthal angle difference was observed for the first time.



The differential cross section for exclusive charged pion pair production as a function of the two-proton azimuthal angular difference for various combinations of transverse momentum bins of the two protons, manifesting a clear parabolic minimum. © *CMS and TOTEM Collaborations, CERN.*

NUCLEAR MATTER PROGRAMME

The Nuclear Matter Programme involves the participation of Finnish teams at CERN in studies of two aspects of nuclear and hadronic matter. These are cold exotic matter with the extreme composition of its proton and neutron numbers on the one hand, and dense matter created in relativistic heavy ion collisions on the other. Exotic nuclei are studied at the ISOLDE facility, while the study of quark gluon plasma and related phenomena takes place at ALICE. The Nuclear Matter Programme has also continued co-ordinating Finnish participation in the planning and construction of the FAIR project in Darmstadt. The Finnish involvement in the FAIR scientific programme concentrates on the NUSTAR Collaboration for nuclear structure, reaction, and astrophysics studies.

ARI JOKINEN
Nuclear Matter Programme director

SAMI RÄSÄNEN
ALICE project leader

ALICE

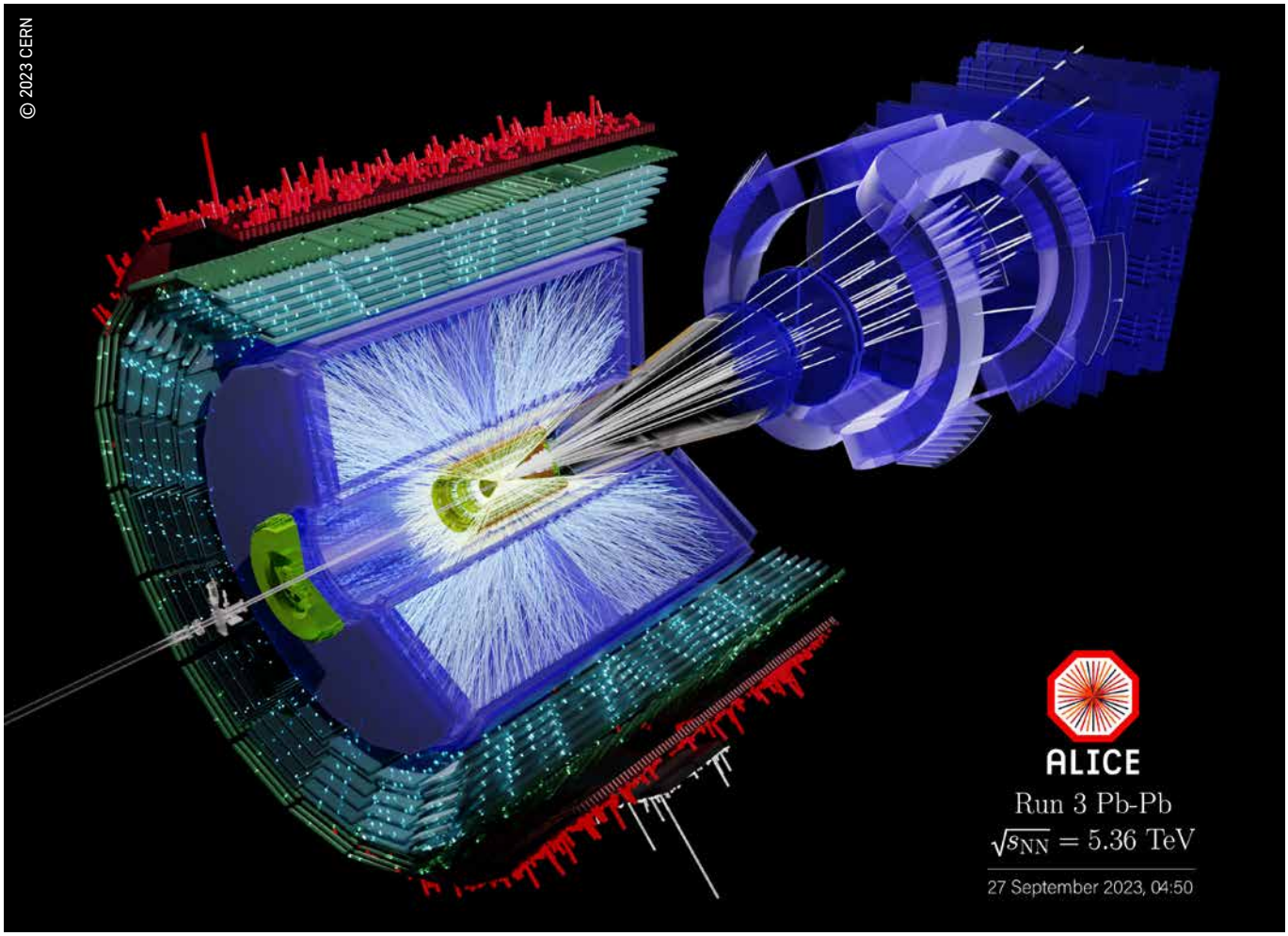
ALICE (A Large Ion Collider Experiment) is the dedicated heavy ion experiment at the Large Hadron Collider (LHC). The primary aim of relativistic heavy ion physics is to study the deconfinement phase transition to quark gluon plasma (QGP). It is the only early universe phase transition that can be reproduced in the laboratory.

In 2023, in addition to a sizeable proton-proton sample, the upgraded ALICE experiment collected 12 billion Pb-Pb events. During this five-week run, we gained 40 times the statistics collected in all previous heavy ion runs between 2010 and 2018. ALICE uses triggerless data collection to study, e.g., thermal electromagnetic radiation or heavy-flavoured hadrons down to low momenta, where QGP medium effects are more pronounced.

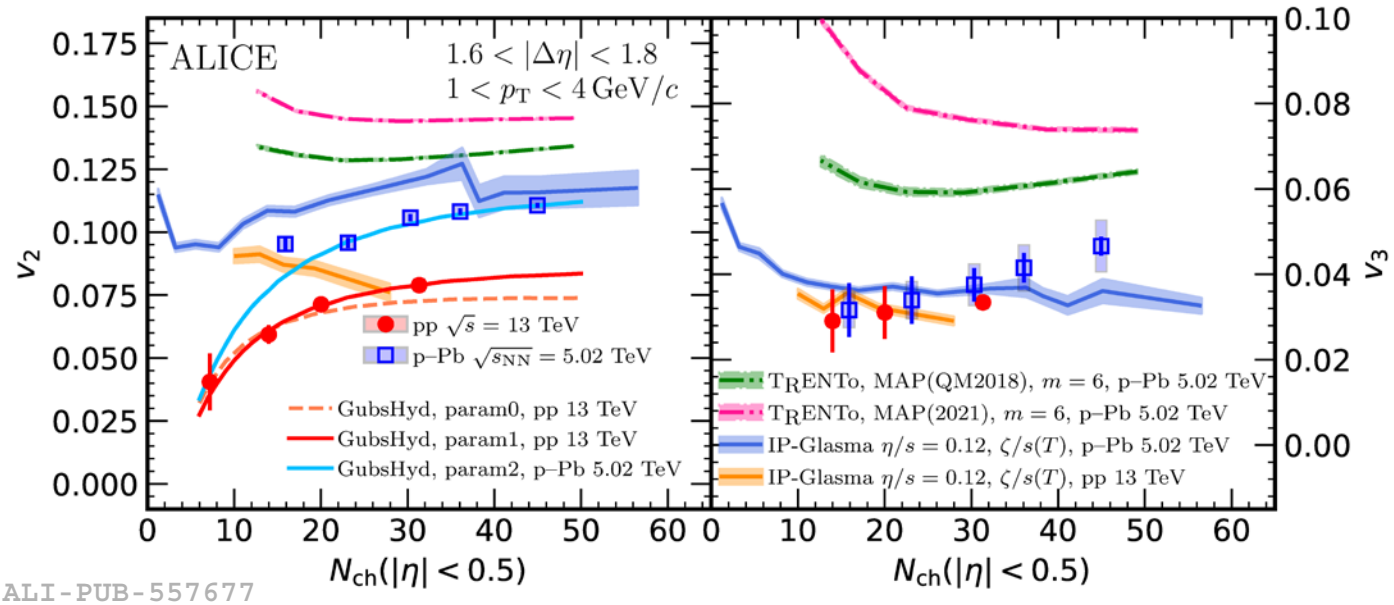
The Fast Interaction Trigger (FIT) detector is pivotal for ALICE operation. FIT delivers triggers for the detectors that need them, provides online luminosity monitoring, a precise collision time, and an unbiased sample of the forward multiplicity needed to extract the centrality and the reaction plane of the colliding heavy ions. Our team co-ordinates the work of scientists representing 17 institutions from 8 countries. We contribute to FIT software development, take expert shifts, and monitor and mitigate detector ageing.

In physics data analysis, we concentrate on collective flow phenomena and jets that constrain the QGP transport properties. In pp and p-Pb lead collisions, signals of collective flow are challenging to extract due to a significant non-flow background. In 2023, we further developed non-flow subtraction methods. Related ALICE results achieved visibility, e.g., in the *CERN Courier* in November. In jet studies, we concentrated on the expected performance of the new ALICE forward calorimeter (FoCal). Measuring forward jets and their angular correlations with FoCal are among the most promising observables searching for experimental evidence for gluon saturation phenomena. In 2024, we will move to study flow and dijet correlations with the new Run 3 heavy ion data.

In December 2023, the Research Council of Finland made a favourable funding decision for the joint CMS-ALICE infrastructure application for the upcoming detector upgrades. The grant enables the acquisition of a new automated bonder for the HIP Detector Laboratory in 2024. We will contribute to the FoCal upgrade by participating in the pixel layer bonding effort, providing expertise in expected radiation tolerance of SiPM's, and designing the laser calibration system of the hadronic calorimeter.



A lead–lead collision event in the ALICE detector.



Elliptic (left) and triangular (right) flow in pp and p-Pb collisions compared to hydrodynamical models. The results shed light on limits of the fluid-like behaviour in these collisions. *[ALICE Collabration, arXiv:2308.16591].*

JANNE PAKARINEN
ISOLDE
project leader

The new ISOLDE decay station frame allows for many degrees of freedom to position detectors around the implantation point.

ISOLDE

In 2023, ISOLDE delivered radioactive beams to experimental setups from 14 April to 20 November. During the campaign, HIP affiliated researchers participated in 6 different experiments. The HIP-ISOLDE project went through an external review that culminated in a one-day workshop at the University of Jyväskylä Department of Physics.

The publication highlight of the year was the β-decay experiment performed by M. Stryjczyk *et al.* at the ISOLDE decay station exploiting the SPEDE spectrometer. Using simultaneous γ-ray and electron spectrometry, nearly 400 new transitions in ^{182,184,186}Hg nuclei were observed. In total, internal conversion coefficients for 23 transitions were determined, including 12 transitions with an *E0* component. It is also noteworthy, that the 0_3^+ state in ^{184}Hg was identified using the electron-electron coincidence condition. These results confirm the shape coexistence phenomenon in these nuclei and provide important complementary data for the analysis of Coulomb excitation experiments performed at Miniball, HIE-ISOLDE.

The Miniball campaign at HIE-ISOLDE included the first Coulomb excitation experiment of an odd-even nucleus in the neutron-deficient Pb region, namely ^{185}Hg. The shape coexistence phenomenon was discovered in the 1970s in laser spectroscopic measurements when isotope shifts in ^{185}Hg and its neighbouring nuclei were studied, rendering this nucleus an ideal starting point for Coulomb excitation experiments of odd-mass nuclei in the region. Yields of converted transitions are the key in the analysis of these data, consequently, Miniball was operated in conjunction with the SPEDE spectrometer. HIP affiliate researchers J. Pakarinen (spokesperson), P. Rahkila, A. Montes Plaza, and U. Grönroos, as a HIP summer trainee from the University of Jyväskylä, participated in the experiment.

Future Prospects

The ISOLDE facility keeps attracting users, best demonstrated by continuous requests for beam time. The collaboration is also strengthening, and new members, such as South Korea and an institute in Brazil (IPEN), are joining in. The future upgrades and ISOLDE consolidation will provide new opportunities not only to participate in fundamental research, but also in related technical developments.

FAIR (Facility for Antiproton and Ion Research in Europe GmbH) Operations

TUOMAS GRAHN
FAIR
project leader

The FAIR accelerator laboratory (https://fair-center.eu/) is projected to begin operations with new accelerators at the end of 2026. Currently, the civil construction of the SIS100 synchrotron is finished and the experimental areas of the NUSTAR and CBM experiments are under construction. The installation of the accelerators will commence in 2025.

After its commission, FAIR will provide high-energy particle and antiparticle beams up to 99% of the speed of light, serving the four experiments (or *pillars*) that are NUSTAR, CBM, PANDA, and APPA. Together they will cover multidisciplinary science cases of nuclear physics and astrophysics, elementary particles, material physics, and medical applications.

Finland is mainly participating in the NUSTAR experiments currently through studies of nuclear physics. The main instrument of NUSTAR, the Super-FRS separator-spectrometer, will be highest priority in FAIR commissioning. Finland will deliver components and instrumentation for the Super-FRS and the NUSTAR experiment and therefore our role in FAIR commissioning is highlighted. The beam particle identification depends largely on the in-kind contributions of Finland.

In 2023, the HIP FAIR operations project was focussed on detector technology R&D. For instance, the conceptual design of the GEM-TPC tracking detectors and its readout electronics were finalised. Such detectors will track the ion beams through the Super-FRS beamline and are used for particle identification. The SEM-grid beam profile detectors were also further developed with a US company and the detector insertion units designed in collaboration with the University of Jyväskylä. The MUSIC energy-loss detector was successfully tested in-beam during the FAIR Phase-0 beam time. Furthermore, HIP researchers continued to be involved in the FAIR Phase-0 experiments. New experiments were proposed in preparation for the 2024 beam time, with HIP researchers in leading positions.

Dr M. Luoma,
Assoc. Prof. T. Grahn,
and opponent Dr K. Kolos.
Credit: J. Sarén.

Dr M. Luoma defended her PhD thesis in November 2023 at the University of Jyväskylä. The thesis was carried out within the HIP FAIR project and dealt with detector development and beta-decay studies of heavy neutron-rich nuclei. The work is part of the larger project that aims to produce and identify new isotopes relevant to the astrophysical nucleosynthesis *r*-process. Indeed, such studies of nucleosynthesis near the neutron number $N = 126$ has been recognised as one of the key physics cases of the NUSTAR experiment.

The Super-FRS target area under construction with T. Grahn (left) and P. Katrik of FAIR. *Credit: T. Grahn.*

TECHNOLOGY PROGRAMME

FILIP TUOMISTO
Technology Programme director

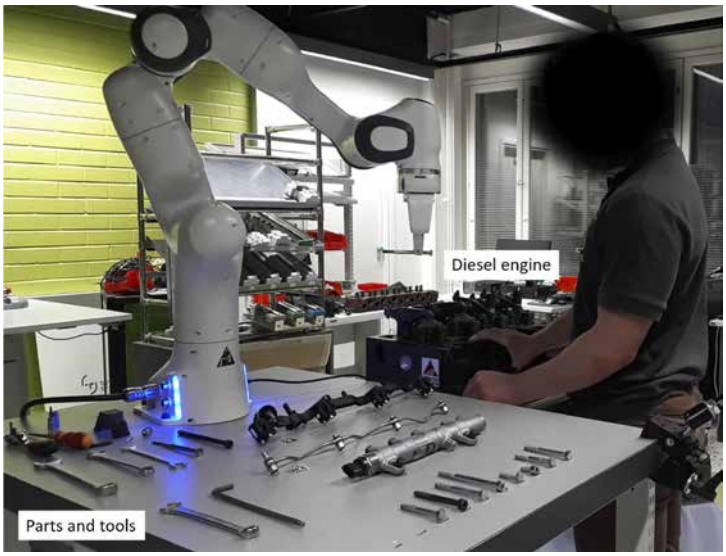
TThe Technology Programme aims to integrate HIP projects with significant technology development, transfer, and pre-commercialisation activities into the same programme. In addition, the research activities performed within the programme are designed to seek synergies with big science initiatives at large. The programme consists of three larger projects dealing with robotics for monitoring and intervention purposes in accelerator tunnel conditions, materials technology challenges in existing and new large accelerators, as well as radiation and nuclear safety, security, and safeguards. These projects have strong connections with CERN and STUK. In addition, the programme hosts one smaller project that focusses on radiation detection technologies in close co-operation with CEA (France). Several projects have been successful in raising external funding for the R&D work, strengthening the impact of the programme.

ROEL PIETERS
Robotics and AI for Monitoring and Intervention (ROBOT) project leader

Robotics and AI for Monitoring and Intervention (ROBOT)

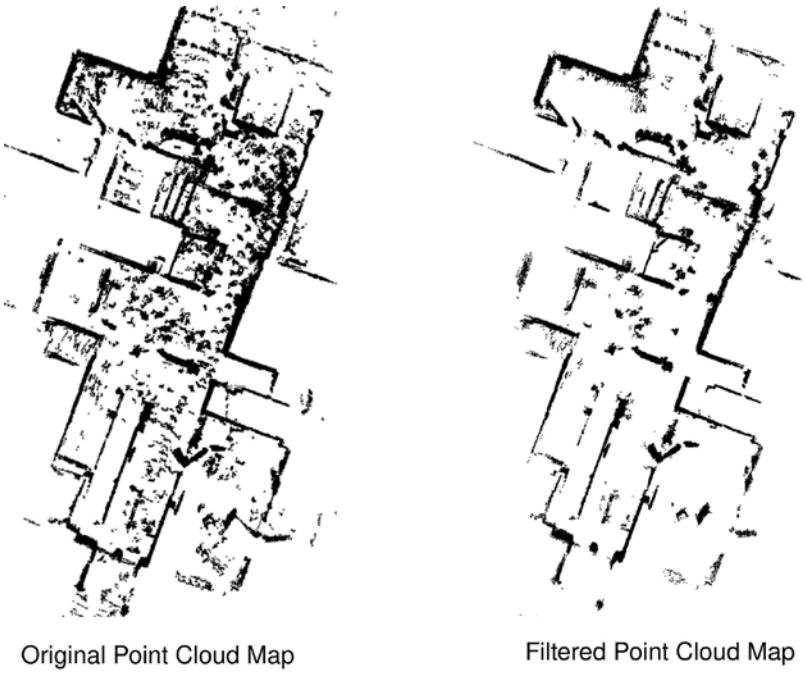
The ROBOT project of HIP's Technology Programme aims to utilise robotics and AI for assistance in monitoring and intervention of CERN's accelerator infrastructure.

1. *Perception for robot manipulation.* Tampere University has been investigating multi-modal perception approaches for humans interacting with robots. This included visual-speech models that utilise images, speech data, and a combination of both for extracting relevant actions that a robot can take in an industrial maintenance environment. In addition, an assembly pose estimation method for robot manipulation and assembly tasks has been developed that utilises semantic segmentation and point cloud registration between target and source point clouds. The approach is evaluated with suitable metrics on two simulated gear assembly datasets, which indicates that point cloud registration is well capable of estimating 6D assembly poses for object assemblies. We also demonstrated the approach on a real industrial assembly task, i.e., Diesel engine assembly, which verified that feasible assembly poses can be estimated for real industrial applications. This work was part of the research work of E. Airaksinen, MSc theses of G. Sharma and W. Rafi, and K. Samarawickrama's doctoral studies.



Experimental setup with a collaborative robot (Franka Emika), Diesel engine and parts for assembly tasks. *[A. Angleraud et al., Robot. Comput.-Integr. Manuf. 86 (2024) 102663].*

2. *Mobile robot mapping and navigation.* Aalto University has been focussing on mobile robots in challenging environments, operating fully autonomously or with partial human remote control. Experiments have been run on Aalto University's delivery bot platform. The research previously delivered methods for improved control strategies for transitioning between remote user and robot. More recent research has analysed LIDAR-based mapping and localisation in environments featuring dynamic objects. Dynamic points within point cloud maps, caused by moving objects during mapping operations, result in noise which undermines the usability and quality of the generated map. Problems in the map hinder localisation and navigation capabilities of mobile robots. To address this challenge, a novel density-based filtering algorithm has been developed which achieved more accurate results than previous state of the art in indoor testing. The described works have been part of A. Seppänen's and P. Habibiroudkenar's doctoral studies. ●



Dynamic objects cause noise in point cloud maps. Our developed algorithm is capable of filtering out dynamic points, as displayed in the figure.

X-Ray Spectroscopy for Materials in Extreme Conditions (XTREME)

X-ray absorption (XAS) and emission spectroscopies (XES) are non-destructive methods allowing the direct characterization of a given element in any kind of sample: liquid, solid, gas, crystalline, or amorphous. XAS is nowadays an essential approach for the study of materials submitted to extreme conditions of temperature, pressure, and irradiation, such as nuclear fuels. Despite the development of beamlines dedicated to radioactive samples at synchrotron radiation facilities, the lack of a credible alternative in the laboratory and the severely time-limited access to synchrotrons precludes a significant number of potentially ground-breaking studies.

The renewal of laboratory instrumentation with performance complementing the synchrotrons, as developed for example during the GAMMA project (2018–2020), allows for potential routine XAS experiments. For chemically complex samples, however, more advanced detection systems are required to compensate the energy resolution limits encountered with the usual detectors. To this aim, the XTREME project explored the possibility to implement an emission spectrometer adapted to a laboratory scale XAS apparatus.

In addition to such new instrumentation, XTREME also evaluated how XES can become an alternative to XAS for complex systems, with an emphasis on actinides for which laboratory scale apparatus can play a leading role for a safer nuclear energy production. ●

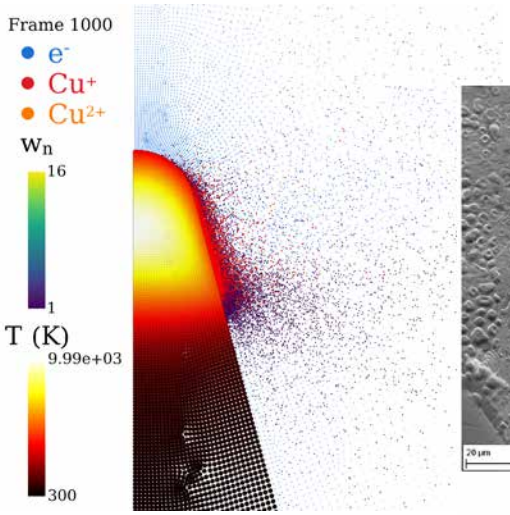
RENÉ BÈS
X-Ray Spectroscopy for Materials in Extreme Conditions (XTREME) project leader

FLYURA DJURABEKOVA
Accelerator Technology: Materials (MAT) project leader

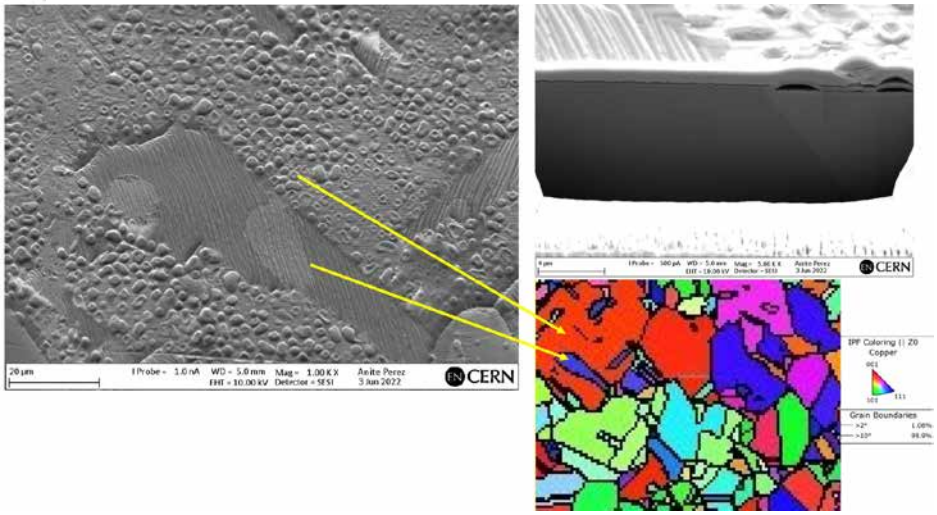
Accelerator Technology: Materials (MAT)

The project Accelerator Technology: Materials (MAT) focusses on materials-related problems faced in particle accelerators. Vacuum arcing as a long-standing problem in rf-accelerating structures for the Compact Linear Collider (CLIC) project at CERN is in the focus of the MAT project. Our multiscale model includes different physical processes that take place at different time and length scales. The exciting high-energy physics relies on materials capable to withstand the extreme condition of electromagnetic fields and particle irradiation. Our latest development of the model allows a realistic development of plasma above the surface to be seen, taking into account not only the ionization of neutral atoms in collisions with electrons, but also the direct ionization. The current static model, where the phase transition within the material is not yet included, already provides deep insights into the preferential contribution of one process over the other. In the next step, when the current particle-in-cell simulations will be fully coupled with molecular dynamics, we will observe the plasma buildup step-by-step. This will revolutionise the understanding of plasma onset in the community of vacuum arcing. The manuscript uploaded to the *arXiv* database was actively downloaded (among 10 of the most frequently downloaded publications in 2023).

We continued the study of the detrimental effect of proton beams on surfaces of the radio-frequency quadrupole (RFQ) structures of the Large Hadron Collider (LHC) proton injector. In close collaboration with the experiments performed at CERN, we were able to unveil the mysterious dependence of blister density on the grain orientation. The agreement with experiment is remarkable. Our research also helps to elucidate detailed mechanisms of thin film growth under different deposition conditions considered by the experimental group at CERN for achieving the best quality of superconducting cavities for the Future Circular Collider (FCC). Surprisingly, the skills and insights gained in this subproject led to a successful EU project related to hydrogen storage in metal matrices.



A visualisation snapshot of the top part of a nanotip, where the applied electric field is enhanced locally to 15 GV/m. In the figure the colour within the tip shows the temperature distribution (mesh points), the small blue arrows in the vacuum indicate the electric field, ionized particles are coloured according to the legend and the neutral superparticles in particle-in-cell simulations (spheres) are coloured according to their weights w_n.



SEM images of the Cu surface irradiated by H^- ions up to the fluence of ~ 1.3×10^{19} H^-/cm^2. The image is taken from a transition zone, where the irradiation fluence is lower. The small, coloured image shows the electron backscattering diffusion map of the same surface to indicate the crystal orientation of the grains. It is clear that at this lower fluence, the blisters grow only on 100 and 111 surfaces, but not on 110, which supports the dislocation mobility the strongest. This result is counter-intuitive, which is successfully addressed in our manuscript submitted to the *Acta Materialia* journal.

TEEMU SIISKONEN
Radiation and Nuclear Metrology, Safety, Security and Safeguards Applications (RAD3S) project leader

Radiation and Nuclear Metrology, Safety, Security and Safeguards Applications (RAD3S)

The RAD3S project investigates and develops new measurement and analysis methods, produces basic physical data, and uses computational methods to foster radiation and nuclear safety, security, and safeguards.

In medical applications, the focus was on the safety of external beam radiotherapy. A position sensitive silicon pixel detector was successfully tested in proton beams with the aim to develop real-time beam monitoring for hadron therapy. Tests will continue with clinically relevant high-energy, high-intensity proton beams. In addition, development of a neutron irradiation station for detector testing and calibrations for hadron and boron neutron capture therapy applications started. Tests for producing quasi-monoenergetic neutrons were done in 2023 at the Kumpula proton cyclotron. Optimisation of patient positioning imaging using cone beam computed tomography was investigated in a project with the European Radiation Dosimetry Group (EURADOS) and the European Alliance for Medical Radiation Protection Research (EURAMED).

The collaboration with STUK on the development of Passive Gamma Emission Tomography (PGET) for nuclear safeguards at the Onkalo geological repository for spent nuclear fuel continued. Measurements in air, instead of water as previously, were performed using neutron-activated cobalt rods at the Atominstitut in Vienna and using real spent fuel at Zwilag in Switzerland. The measurements in Vienna, within their poor statistical quality, showed no difference in PGET performance between measurements in air and in water. PGET measurements at the Olkiluoto and Loviisa nuclear power plants focussed on tomography with fine angular spacing and on fine-tuning the gamma ray energy windows to investigate background subtraction.

The simulations performed in the POSEIDON project (position-sensitive detectors for nuclear fuel imaging, a collaboration with Uppsala University) show quantitatively the large benefit for imaging that can be achieved by using large semiconductor detectors. In addition, experiments with two different position-sensitive germanium detectors provided proof-of-principle evidence.

The main activity in 2023 in radiation detection for safety, security and safeguards was the continuation of research into application-specific detectors for lung counting. Earlier work resulting in the development of a Geant4 simulation package including an ICRP adult reference computational phantom was published *[H. Jutila, P. Greenlees, T. Torvela, M. Muikku, Technical note: Simulation of lung counting applications using Geant4, Physica Medica 108 (2023) 102573*].

Based on the simulations, optimised detection geometries have been suggested and shown to reduce the minimum detectable activity in lung-counting applications. Using a segmented germanium detector and various configurations of passive and active shielding, along with digital electronics and list-mode data, tests were made to benchmark and quantify the improvement in performance with a real detector. Two more manuscripts related to this work are in progress.

OTHER PROJECTS

MARKKU KULMALA
CLOUD
project leader

CLOUD

The Cosmics Leaving OUtdoor Droplets (CLOUD) experiment at CERN is one of the most advanced laboratory setups to study processes related to the formation and growth of aerosol particles and their activation to cloud droplets. Indirect observations and theoretical studies have suggested that galactic cosmic rays (GCR) may influence the Earth's cloud cover and climate, possibly by affecting the properties of aerosol particles. Aerosol particles influence the Earth's climate system via two mechanisms. First, they can directly reflect or absorb solar radiation, and second, they can act as seeds for the formation of cloud droplets or ice crystals and thereby affect the lifetime and albedo of clouds. Measuring the underlying chemical processes and microphysics in controlled laboratory conditions is a key to understanding the dynamical behaviour of aerosol particles and cloud droplets, including their formation and growth processes, cloud droplet activation, and ice nucleation. The experiment aims to find the possible pathways of these phenomena and evaluating their significance in the atmosphere by using the CERN proton synchrotron to vary the levels of GCR. The research is directly connected to both climate and air quality issues. The CLOUD Collaboration comprises 23 institutes, with a strong Finnish contribution.

During 2023, we performed two CLOUD campaigns at CERN. A test campaign was performed in spring to commission the new flow tube (FLOTUS) connected to the chamber. During the autumn CLOUD16 campaign, we investigated aerosol formation in upper tropospheric conditions, as well as in conditions representing the Arctic.

Ten peer-reviewed papers were published by the collaboration. *Kirkby et al.* [*2023, Nat. Geosci.*] provided an overview of the current understanding of aerosol particle formation based on CLOUD experiments. *He et al.* [*2023, Science*] showed that iodic oxoacids can form particles together with sulfuric acid, providing an efficient mechanism to form particles without ammonia. *Dada et al.* [*2023, Sci. Adv.*] demonstrated the potential of sesquiterpenes (a class of organic molecules) to form particles. *Nie et al.* [*2023, Nat. Commun.*] showed that NO can enhance the formation of highly oxygenated molecules that are precursors for particle formation.

Euclid

Euclid is a cosmology mission of the European Space Agency. It studies the 'Dark Energy Question' – why is the expansion of the universe accelerating, and what is the nature of the dark energy causing this? Euclid will survey over a third of the sky, obtaining images of over a billion galaxies and tens of millions of galactic spectra. Euclid is a 1.2-meter wide-field space telescope with two instruments: NISP (Near Infrared Spectrometer and Photometer) and VIS (imager at visible wavelengths). The observations are used to determine the 3-dimensional distribution of galaxies and dark matter in the universe, compare their statistics to cosmological models, and thus constrain the law of gravity and dark energy properties. Euclid was launched successfully on 1 July, 2023, and is now orbiting the second Lagrange point of the Sun-Earth system, 1.5 million km away.

Euclid published the Euclid Early Release Observations on 7 November. These images were taken during commissioning and performance verification of the telescope before the beginning of the main 6-year survey. Five targets were chosen: the Horsehead Nebula (1375 light-years away), globular star cluster NGS 6397 (7800 light-years away), irregular galaxy NGC 6822 (1.6 million light-years away), spiral galaxy IC 342 (11 million light-years away), and the Perseus Cluster of galaxies (240 million light-years away). For Euclid, they are close-by objects, as Euclid will survey the universe up to over 10 billion light-years distance.

The analysis of Euclid data is divided among nine Euclid Science Data Centers (SDC). We operate one of them, SDC-FI. We participated in the Performance Verification Phase Rehearsal 2 (PVPR2) to support the real performance verification in October and November. SDC-FI processed data from space for the first time in early December and this processing will continue until the end of the mission.

We improved the pipeline for simulated NISP data. This prepares it to effectively simulate and address potential unknowns that may arise in real data. Integration of data from external, ground-based, surveys continued in 2023. Finland has the main responsibility for the integration of the Northern Surveys (PanSTARRS, CFIS, WISHES, WHIGS, and JEDIS).

We completed validation tests for the galaxy two-point correlation code of Euclid, which is now ready to be used for the flight data. We are now developing methods for the analysis of wide-angle effects in Euclid data. Our aim is to perform analysis of the galaxy distribution and of the cosmic shear field on the full spherical sky, avoiding the flat-sky approximations involved in the traditional analysis of small sky patches. A pilot version of the code is ready and has been tested on simulated data.

In the Euclid Theory Working Group we finalised forecasts for the constraining power of Euclid on beyond standard early universe models, including the local non-Gaussianity, the nature of primordial perturbations, the running of the scalar spectral index, and alpha attractor inflation models.

HANNU KURKI-SUONIO
Euclid project leader

Launch of Euclid from Cape Canaveral, Florida, on a SpaceX Falcon 9 launcher, on 1 July, 2023. *Credit: ESA – S. Corvaja.*

The Perseus Cluster. The image, taken by Euclid, shows about 1000 galaxies belonging to the Perseus Cluster and about 100 000 more distant galaxies in the background. (This is a downgraded version of the original 600-megapixel Euclid image.) *Credit: ESA and the Euclid Consortium.*

KATRI LASSILA-PERINI
Education and Open Data project leader

Education and Open Data

The Education and Open Data project covers and connects two activities: the Finnish high-school visit programme at CERN, and the preservation of CMS experiment data and preparing open access to them. The project is led by K. Lassila-Perini, who also acts as the Data Preservation and Open Access co-ordinator of the CMS experiment. P. Veteli, a doctoral researcher, leads activities promoting the use of open data in schools.

High School Visits

In 2023, fourteen high-school group visits from Finland were conducted at CERN. While this figure was slightly below the anticipated number, this was primarily due to temporary restrictions during the inauguration of the Science Gateway – the new science exhibition at CERN. Since its opening in October, all groups have been able to include a hands-on laboratory session and an exhibition visit at the Science Gateway to enrich their three-day visit programme at CERN. The highlight of these visits, however, remains the opportunity for students and teachers to engage with and learn from the scientists at CERN.

Climate-related data workshops at the Harppi festival for high-school students (Helsinki 2023).

Open Data in Research

The CMS Data Preservation and Open Access group manages the actions needed for data and knowledge preservation of the experiment. Regular releases of data for public use have become a standard practice, with a noteworthy milestone achieved in September 2023 – the release of heavy-ion collision data from 2013, completing the transition of all data from the LHC Run 1 into the public domain. The success of the fourth CMS Open Data Workshop at Fermilab in July, attended by approximately 30 active participants, underscores the growing interest and engagement in utilising CMS open data.

Open Data in Education

The project promotes using open data in schools with 'Jupyter notebooks' and common Python libraries through teacher trainings, student workshops, or hands-on help with regular school courses. With the loosening of COVID-19 restrictions, multiple face-to-face events were held this year. Materials and guides can be found on the project website https://opendata-education.github.io/ in Finnish, Swedish and English.

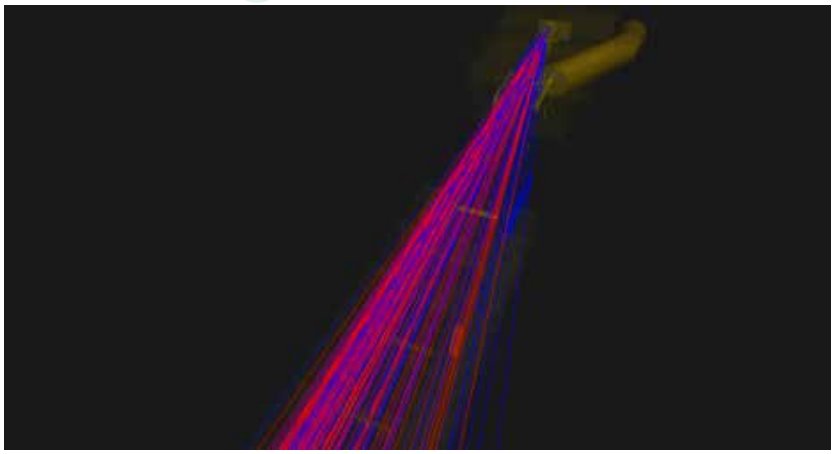
Teacher training sessions for secondary school teachers were held on three separate occasions in the Helsinki area. Student workshops were conducted both as singular and in multiple-session coursework form at the Helsinki Natural Sciences high school, Lauttasaari, Maunula, and Kumpula campus, as well as at events like the Harppi festival. A field trip to the Hyytiälä SMEAR II station was also organised at the end of the year with the University of Helsinki's science teacher education group. Climate themes and co-operation with atmospheric research groups like INAR and ICOS were prominent this year, carrying into 2024. The work has been carried out by MSc P. Veteli, who has now begun his PhD project on the topic and presented the project in various conferences: GIREP 2023 in Slovakia (awarded with a Young Researcher's Excellent Presentation commendation), ESELS23 in Helsinki, ML-days 2023 in Turku, and University of Helsinki Learning Adventure 2023. This work is made possible through a subvention by the Finnish National Agency for Education and a grant from the Magnus Ehrnrooth Foundation.

DETECTOR LABORATORY

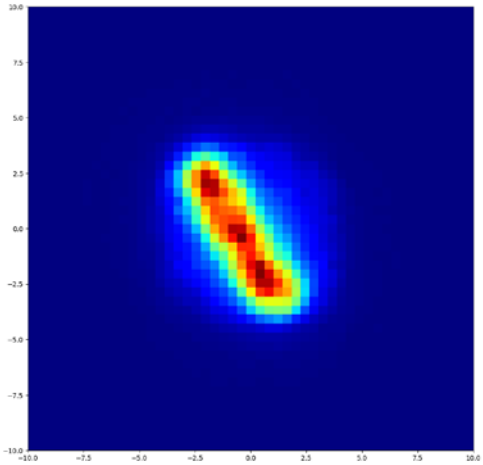
The Helsinki Detector Laboratory is a national permanent infrastructure specialised in the instrumentation of particle and nuclear physics. It is a joint laboratory between HIP and the UH Department of Physics, especially the Division of Particle and Astrophysics (PAP). The Laboratory provides premises, equipment, expertise, and technical support for research projects developing detector technologies for various applications.

For HIP projects, the main activities in the Laboratory were focussed on the CMS Forward experiment and the MoEDAL-MAPP experiment at CERN. We also took part in measurements and consulted the Geant4 simulation development for the POSEIDON project and supported the BNCT study activities of the CMS Upgrade project.

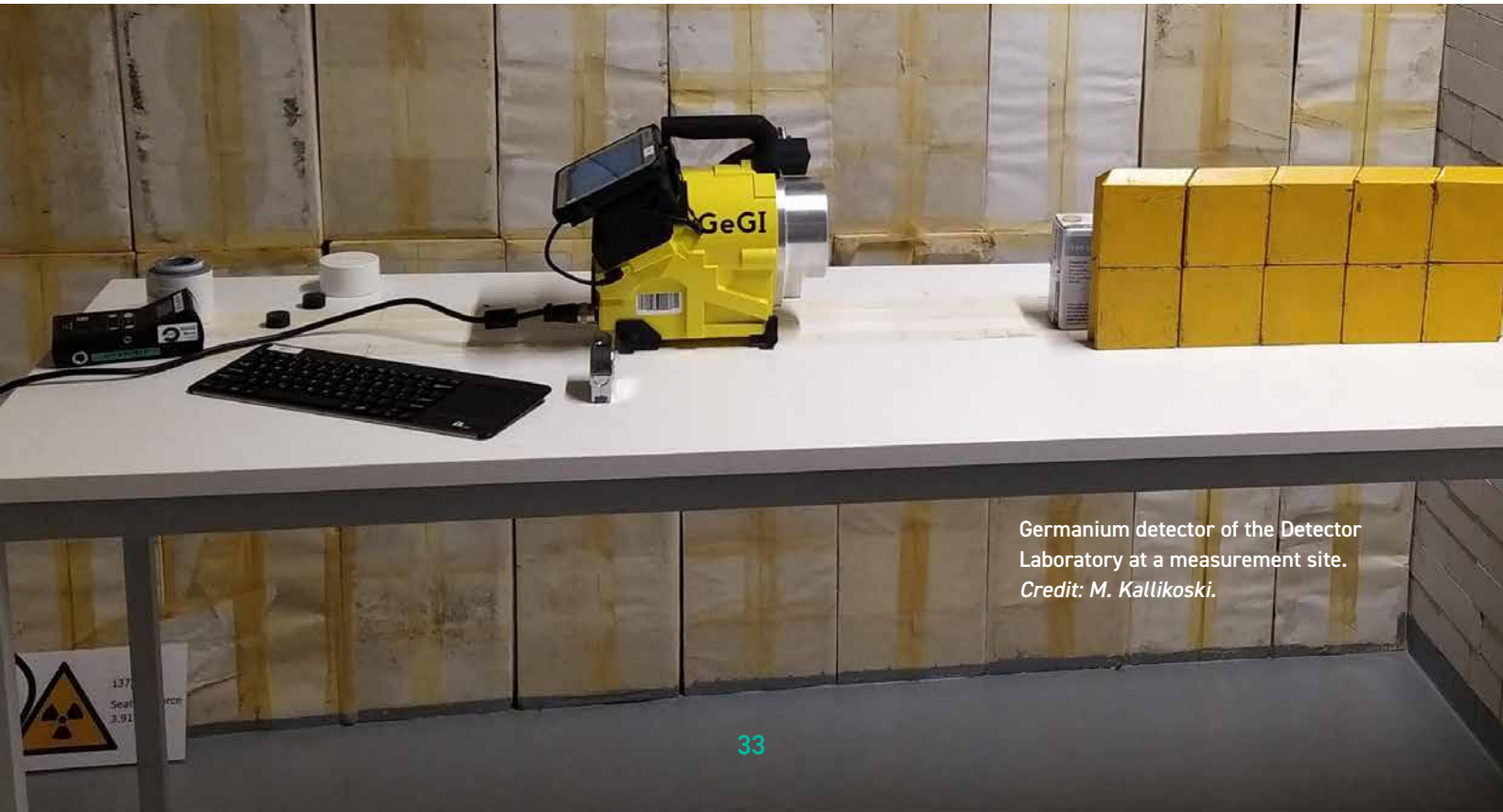
MATTI KALLIOKOSKI
Detector Laboratory director



Geant4 simulation of millicharged particles traversing from Interaction Point 8 of the Large Hadron Collider towards the MoEDAL-MAPP detectors.



Compton-image of a Cesium-source that is placed behind a slit in lead shielding. *Credit: M. Kallikoski.*



Germanium detector of the Detector Laboratory at a measurement site. *Credit: M. Kallikoski.*

The Laboratory has expertise in room-temperature semiconductor detectors. In addition to development and characterization of CdTe and CZT crystals, we have also obtained various instruments for gamma-ray measurements.

The Laboratory was involved in the RD50 Collaboration, which came to an end in 2023. Thus, we actively took part in the formation of new research collaborations, DRD3 and DRD5, that will start their activities in 2024.

The Laboratory supports teaching in the PARAS programme. The main support is for a laboratory course on instrumentation, where students actively work at the Laboratory, but also for the other courses where measurements are needed. In addition, doctoral researchers and master's and bachelor's students work in the Laboratory.

Special effort was devoted to societal interaction to ignite interest in physics, especially among children and youth. In 2023, the Laboratory participated in the EU Researchers' Night at the Observatory building of the Helsinki University Museum Flame.

Analysis of the positron accelerator secondary yield with the GeGI germanium detector of the Detector Laboratory. *Credit: M. Kallikoski.*

In 2023, there were major changes in the Laboratory personnel. Long-term director of the Laboratory, E. Tuominen, moved to VTT as research team leader in Quantum Sensors, and even longer-term employee laboratory engineer J. Heino retired. These changes brought new challenges for the development of the Laboratory which we plan to address in 2024.

Preparations for the Researchers' Night at the Observatory. ***Credit: J. Aaltonen.***

JOINT ACTIVITIES

ANTTI VÄIHKÖNEN
Research coordinator

HIP is a joint institute of five universities with the University of Helsinki as the host, with the Finnish Radiation and Nuclear Safety Authority (STUK) as an interim member since 2018, and the present membership agreement continuing until 2027. Due to its core mission, many of the research activities of HIP take place at CERN and FAIR. The distributed nature of HIP brings its own idiosyncrasies and challenges.

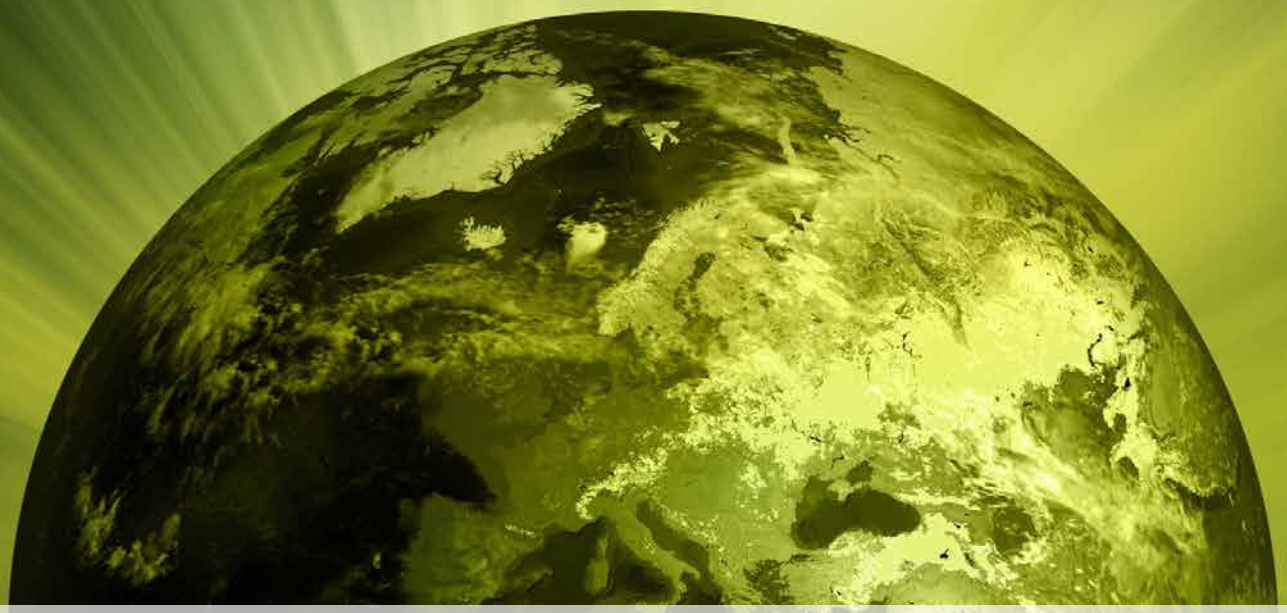
The Russian invasion of Ukraine continued throughout the year. Most of all it inflicted a humanitarian disaster on the Ukrainians, but it was also felt in the scientific activities of HIP. Many experimental collaborations at CERN have significant Russian participation. Russia is also the second largest shareholder of FAIR.

The political landscape was in motion in 2023. A new national RDI funding law came into force at the start of 2023, with the aim of increasing the RDI funding steadily to 4% of GDP by 2030. The details were left open, but this creates opportunities for HIP and its research fields. The HIP directorate was active in policy-maker communications. The CERN Director of International Affairs, Charlotte Warakaulle, visited Finland and two ministries in March. Parliamentary elections took place in Finland in April 2023, and a new government took over a bit later.

The Institute's planning and strategy work continued in 2023. The HIP Steering Group visited the University of Jyväskylä in June, the Scientific Advisory Board visited HIP in August, and the HIP Board visited CERN in November. The Theory and CMS Programmes organised their programme meetings in 2023 with the remaining two expected in early 2024.

The Institute's scientific output continues to be very good and of high quality. HIP publications are mostly in the two highest national JUFO categories and open to a very high degree, more than 95% each year. Doctoral education continues to be one of the main tasks of the Institute. A fair number of undergraduate students have also joined the research groups. Many of them are continuing as doctoral researchers in Institute projects. During the period 2019–2023, 57 doctoral degrees and 70 Master's degrees have been earned in connection to HIP research projects. The CERN BootCamp was organised again, and the HIP summer student programme at CERN and ESRF continued on-site in 2023.

SUSTAINABILITY AND RESPONSIBILITY



HIP conducts research on themes of responsibility and sustainability, including materials research on energy production technologies. We also participate in CERN's CLOUD experiment, which investigates atmospheric processes and mechanisms contributing to climate change.

HIP participates in advancing the understanding and skills related to sustainability. HIP has continued to organise the annual CERN BootCamp in collaboration with three Universities of Applied Sciences, as well as CERN. The intensive course concentrates on resolving current problems related to the UN sustainability goals. The University of Helsinki, the host organization of HIP, offers students sustainability courses. The aim is to provide students with academic knowledge and skills related to sustainability.

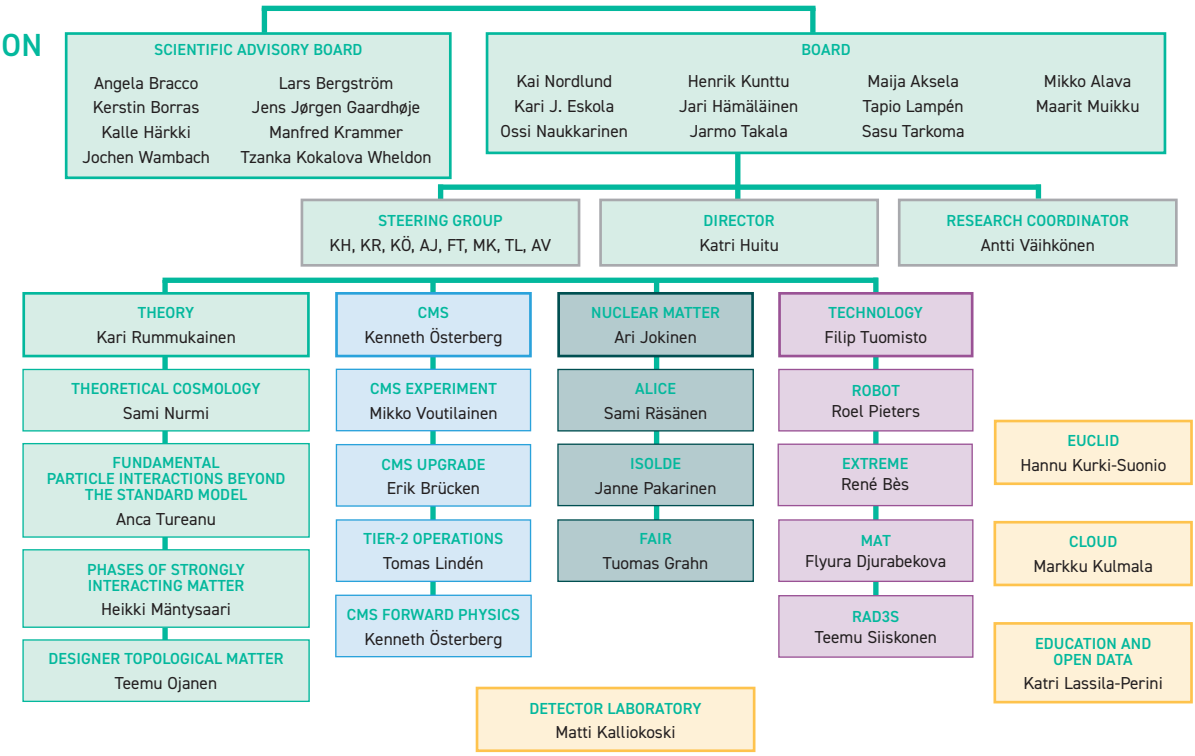
Open access to research results is an important part of the responsibility and sustainability of scientific work. Over 95% of HIP publications are open access each year. Researchers at HIP also participate in opening data from the LHC experiments and making tools for utilising it. One important objective of HIP's Education and Open Data project is to develop discipline-independent open science tools and teach their usage to school pupils and teachers.

In 2023, HIP continued to advance sustainability by using digital tools to facilitate research and to promote a sense of community and inclusivity by enhancing accessibility. The easy-to-use streaming and hybrid meeting capabilities of the HIP seminar and meeting rooms were in good use and worked well. Decreasing the need to travel also reduces HIP's carbon footprint.

Work wellbeing and responsible leadership are important and interlinked parts of workplace sustainability. HIP has fared well in the wellbeing surveys on supervision. In 2023, HIP continued organising the traditional HIP Leaderships' Afternoon workshops. Also, HIP's host organization, the University of Helsinki, continued its methodical supervisor training. In 2023, HIP invited a work physiologist to go through the ergonomics in the offices in Kumpula. A gathering for the summer workers and trainees was organised both before and after the summer in Helsinki, and at the start of the summer at CERN. HIP has a joint wellbeing group of peers together with the University of Helsinki Physics Department.

ORGANIZATION AND PERSONNEL

ORGANIZATION



The HIP Board visiting CERN on 23 November. In the picture from left to right: Tuulikki Laurila, Panja-Riina Luukka**, Lasse Laurson**, Maija Aksela*, Peter Chochula, Maarit Muikku*, Charlotte Warakaulle, Katri Huitu, Kai Nordlund*, Antti Väihkönen, Tiina Väisänen, Ari Jokinen**, Harri Lipsanen**, Markus Nordberg, Sasu Tarkoma*. © *CERN.*
*Board member, **substitute Board member.

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Theoretical Cosmology

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D. Irodotou, adj. scientist
D. Karamitros, adj. scientist
S. Liao, adj. scientist
T. Miranda, adj. scientist
T. Tenkanen, adj. scientist
R. Wright, adj. scientist
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J. Dahl, doctoral researcher
L. Giombi, doctoral researcher
A. Hassan, doctoral researcher
A. Keitaanranta, doctoral researcher
A. Kormu, doctoral researcher
O. Koskivaara, doctoral researcher
L. Laulumaa, doctoral researcher
T. Minkkinen, doctoral researcher
J.-M. Ojanperä, doctoral researcher
H. Parkkinen, doctoral researcher
P. Rahkila, doctoral researcher
A. Rawlings, doctoral researcher
N. Venkatesan, doctoral researcher
O. Väisänen, doctoral researcher

Fundamental Particle Interactions Beyond the Standard Model

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O. Lebedev, prof., adj. senior scientist
K. Tuominen, prof., adj. senior scientist
M. Heikinheimo, adj. senior scientist
E. Keski-Vakkuri, adj. senior scientist
M. Oksanen, adj. senior scientist
W. Trzaska, adj. senior scientist
T. Gupta, scientist
T. Kupiainen, adj. scientist
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T. Sirkiä, doctoral researcher
A. Stendahl, doctoral researcher

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T. Lappi, prof., adj. senior scientist
N. Jokela, senior scientist
R. Paatelainen, senior scientist
J. Auvinen, adj. senior scientist
V. Guzey, adj. senior scientist
I. Helenius, adj. senior scientist
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H. Niemi, adj. senior scientist
H. Paukkunen, adj. senior scientist
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F. Hekhorn, adj. scientist
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J. Peuron, adj. scientist
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I. Soudi, adj. scientist
Y. Tawabutr, adj. scientist
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C. Casuga, doctoral researcher
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A. Hippeläinen, doctoral researcher
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M. Tevio, doctoral researcher
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A. Moghaddam, adj. scientist
K. Pöyhönen, adj. scientist
T. Vanhala, adj. scientist
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M. Mustonen, doctoral researcher
I. Sahlberg, doctoral researcher

CMS Programme

K. Österberg, prof., programme director

CMS Experiment

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T. Lampén, senior scientist
K. Lassila-Perini, senior scientist (at CERN)
S. Lehti, senior scientist
J. Tuominiemi, adj. senior scientist
J. Heikkilä, adj. scientist
M. Kortelainen, adj. scientist
S. Laurila, adj. scientist
J. Pekkanen, adj. scientist
H. Siikonen, adj. scientist
P. Inkaew, doctoral researcher
K. Kallonen, doctoral researcher
L. Martikainen, doctoral researcher
M. Myllymäki, doctoral researcher
N. Toikka, doctoral researcher

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E. Tuominen, adj. senior scientist
A. Karadzhinova-Ferrer, adj. scientist
A. Karjalainen, adj. scientist
M. Bezak, doctoral researcher
S. Bharthuar, doctoral researcher
W. Cao, doctoral researcher
S. Kirschenmann, doctoral researcher
N. Kramarenko, doctoral researcher
L. Martikainen, doctoral researcher
S. Saariokari, doctoral researcher
J. Tikkanen, doctoral researcher
M. Väänänen, doctoral researcher

Tier-2 Operations

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S. Lehti, senior scientist
M. Myllymäki, doctoral researcher

CMS Forward Physics

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H. Saarikko, prof. emer., adj. senior scientist
F. Oljemark, scientist
F. García, lab. engineer
A. Milieva, doctoral researcher
M.-M. Rantanen, doctoral researcher

Nuclear Matter Programme

A. Jokinen, prof., programme director

ALICE

S. Räsänen, Dr., proj. leader
D. J. Kim, adj. senior scientist
W. Trzaska, adj. senior scientist
H. Hassan, scientist
Y. Melikyan, scientist
C. Mordasini, scientist
M. Slupecki, scientist
L. Huhta, doctoral researcher
A. Molander, doctoral researcher
H. Rytkönen, doctoral researcher
O. Saarimäki, doctoral researcher
M. Virta, doctoral researcher
A. Önnerstad, doctoral researcher

ISOLDE

J. Pakarinen, Dr., proj. leader
P. Greenlees, prof., adj. senior scientist
A. Jokinen, prof., adj. senior scientist
A. Kankainen, prof., adj. senior scientist
I. Moore, prof., adj. senior scientist
T. Grahn, ass. prof., adj. senior scientist
P. Rahkila, adj. senior scientist
P. Ruotsalainen, adj. senior scientist
A. Briscoe, adj. scientist
M. Mougeot, adj. scientist
M. Reponen, adj. scientist
M. Stryjczyk, adj. scientist
A. Montes Plaza, doctoral researcher

FAIR

T. Grahn, ass. prof., proj. leader
J. Äystö, prof., director emer., adj. senior scientist
A. Jokinen, prof., adj. senior scientist
A. Kankainen, prof., adj. senior scientist
I. Moore, prof., adj. senior scientist
T. Eronen, adj. senior scientist
H. Penttilä, adj. senior scientist
S. Rinta-Antila, adj. senior scientist
E. Tuominen, adj. senior scientist
D. Nesterenko, adj. scientist
J. Tuunanen, adj. scientist
F. García, lab. engineer
M. Luoma, doctoral researcher
V. Virtanen, doctoral researcher

Technology Programme

F. Tuomisto, prof., programme director
P. Dendooven, visiting prof.
T. Salmi, senior scientist
S. Ihantola, scientist (at STUK)
P. Kauttu, doctoral researcher

Robotics and AI for Monitoring and Intervention (ROBOT)

R. Pieters, ass. prof., proj. leader
K. Tammi, prof., adj. scientist
E. Rahtu, ass. prof., adj. scientist
D. Mohamadi, adj. scientist
K. Samarawickrama, adj. scientist
J. Vepsäläinen, adj. scientist
R. Ojala, doctoral researcher
A. Seppänen, doctoral researcher

X-Ray Spectroscopy for Materials in Extreme Conditions (XTREME)

R. Bès, Dr., proj. leader
S. Huotari, prof., adj. scientist
S. Orlat, doctoral researcher

Accelerator Technology: Materials (MAT)

F. Djurabekova, prof., proj. leader
K. Nordlund, prof., adj. senior scientist
V. Zadin, prof., adj. scientist
A. Kyritsakis, adj. ass. prof.
T. Ahlgren, adj. senior scientist
J. Byggmästar, adj. scientist
A. Leino, adj. scientist
A. Lopez Cazalilla, adj. scientist
I. Makkonen, adj. scientist
M. Ghaemikermani, doctoral researcher
J. Kimari, doctoral researcher
R. Koitermaa, doctoral researcher

Radiation and Nuclear Metrology, Safety, Security and Safeguards Applications (RAD3S)

T. Siiskonen, prof. of practice (UH), proj. leader (at STUK)
P. Dendooven, visiting prof.
P.-R. Luukka, prof.
P. Greenlees, prof., adj. senior scientist
K. Peräjärvi, prof. of practice (JyU), scientist (at STUK)
E. Brücken, senior scientist
M. Kalliokoski, senior scientist
H. Kettunen, adj. senior scientist
M. Kortesniemi, adj. senior scientist
P. Rahkila, adj. senior scientist
M. Muikku, scientist (at STUK)
R. Pöllänen, scientist (at STUK)
J. Turunen, scientist (at STUK)
M. Laassiri, adj. scientist
I. Makkonen, adj. scientist
V. Bogdanoff, doctoral researcher
H. Jutila, doctoral researcher
J. Tikkanen, doctoral researcher
R. Virta, doctoral researcher

Other projects

CLOUD

M. Kulmala, prof., Academician, proj. leader
K. Lehtipalo, prof.
D. Worsnop, prof.
J. Duplissy, senior scientist
C. Williamson, senior scientist
X. He, scientist
R. Baalbaki, doctoral researcher
B. Rörup, doctoral researcher
J. Shen, doctoral researcher
W. Yu, doctoral researcher

Euclid

H. Kurki-Suonio, prof., proj. leader
E. Keihänen, senior scientist
J. Väliviita, adj. senior scientist
V. Lindholm, scientist
K. Kiiveri, doctoral researcher
S. Kivistö, doctoral researcher
S. Tuomisto, doctoral researcher
A. Viitanen, doctoral researcher

Education and Open Data

K. Lassila-Perini, Dr., proj. leader (at CERN)
P. Veteli, doctoral researcher

Detector Laboratory

M. Kalliokoski, doc., laboratory director
I. Kassamakov, doc., lab. engineer
F. García, lab. engineer
J. Heino, lab. engineer
P. Koponen, lab. engineer
R. Turpeinen, senior lab. technician
M. Arenius, expert

Administration and Support

K. Huitu, prof., director
A. Väihkönen, research coordinator
J. Aaltonen, lab. engineer

University Services administration team including:
T. Laurila, admin. manager
S. Sadesalo, controller
T. Hardén, service coordinator
M. Toivonen, HR coordinator
T. Heikkilä, secretary
T. Karppinen, secretary (at CERN)
T. Onnela, secretary (at CERN)

HIP SEMINARS

10 January T. Lappi (Jyväskylä)
EIC – the most powerful microscope on Earth

24 January S. Han (T. D. Lee Institute, Shanghai)
Probing exotic matter in neutron star cores with g-mode oscillations

31 January N. Ramberg (Mainz)
Bubbles from dark confinement with holography

7 February A. Malara (Brussels U., IIHE)
Reconstruction and calibration of jets at the CMS experiment: Run 2 and perspective for Run 3

21 February H. Waltari (Uppsala)
The anatomy of Higgs pair production with light stops

4 April R. Rodgers (NORDITA)
Holographic nodal-antinodal dichotomy from infrared scaling

25 April S. Säppi (Munich)
Updates on finite-density perturbative QCD: pressure with soft gluons, complex analysis and loops, and quark masses

2 May N. Sherrill (Sussex)
Probing ultralight scalar fields with atomic clocks

9 May M. Ornigotti (Tampere)
Gauge fields, topology, and the optical response of 2D materials

10 May C. Fröjdh (Mittuniversitetet, Sundsvall)
Spectral X-ray detection and imaging

16 May J. Österman (Helsinki)
Feynman integrals at finite density and vanishing temperature: complex analysis and Integration-by-Parts relations

23 May V. Leino (Mainz)
Heavy quark momentum diffusion from lattice simulations

30 May K. Kainulainen (Jyväskylä)
The quantum early universe

30 May P. Romatschke (Boulder)
What if ϕ^4 theory in 4 dimensions is non-trivial in the continuum?

6 June D. Litim (Sussex)
Interacting UV fixed points – from quantum field theory to quantum gravity

13 June O. Hannuksela (Hong Kong)
Gravitational-wave astronomy

29 June C. Royon (University of Kansas)
Measuring intact protons at the LHC: from the odderon discovery to the search for axion-like particles

15 August Z. Berezhiani (Aquila, Gran Sasso)
The neutron anomalies: a portal to new physics?

7 September A. Tapadar (IACS Kolkata)
Reconciliation of secluded dark sector and muon (g - 2) in the light of fast expanding universe

19 September P. Schicho (Frankfurt)
Impact of computational diligence on GW signals from phase transitions

25 September Z. Ahmed (Stavanger)
Modified Kerr and black hole ringdowns

26 September M. Gogberashvili
(Andronikashvili Institute of Physics, Tbilisi, Georgia)
LIGO signals from the mirror world

12 October J. Louko (Nottingham)
Thermality of circular motion, in spacetime and in the laboratory

24 October T. Salmi (Amsterdam)
Neutron star atmosphere effects on X-ray pulse profile modeling with NICER

21 November N. Norjoharuddeen (University of Malaya)
New physics searches with dibosons at the LHC: a survey of Run-2 results

28 November G. Endrődi (Bielefeld)
QCD matter in extreme environments: isospin-asymmetry and electromagnetic fields

5 December R. Virta
(STUK, Radiation and Nuclear Safety Authority, HIP)
Verifying spent nuclear fuel with Passive Gamma Emission Tomography (PGET)

VISITORS

Theory Programme

Theoretical Cosmology

D. Blixt (Italy) 11.1.
G. Torrieri (Brazil) 16.–21.1.
T. Konstandin (Germany) 31.1.–2.2.
S. Bahamonde (Japan) 8.2.
H. Lucien (UK) 21.–27.2.
V. De Romeri (Spain) 27.2.–4.3.
M. Taoso (Italy) 27.2.–4.3.
A. Heinesen (France) 12.–18.3.
V. Briaud (France) 22.3.
A. Socha (Poland) 4.–6.4.
A. Goudelis (France) 12.4.
S. Delos (Germany) 19.4.
P. Stengel (Italy) 24.–28.4.
J. Regan (Ireland) 3.–5.5.
C. Cosme (Spain) 8.–14.5.
F. Costa (Germany) 14.–19.5.
A. Guerrero Menkara (South Korea) 24.5.
I. Masina (Italy) 7.6.
S. Ramazanov (Czech Republic) 12.–17.6.
T. Naab (Germany) 14.–16.6.
C. Partmann (Germany) 14.–21.6.
G. Lavaux (France) 9.–18.8., 6.–20.10.
R. Gonzalez Suarez (Sweden) 5.–7.9.
D. A. Nichols (USA) 13.9.
J. van de Vis (Netherlands) 17.–23.9.
T. Koivisto (Estonia) 11.10.
F. Koutroulis (Poland) 15.–22.10.
E. Mottola (USA) 1.11.
N. Koivunen (Estonia) 6.–10.11.
J. Donoghue (USA) 15.11.
J. Baeza Ballesteros (Spain) 22.11.
V. Errasti Díez (Germany) 28.–30.11.
K. Schmitz (Germany, Switzerland) 13.12.

Fundamental Particle Interactions Beyond the Standard Model

H. Waltari (Sweden) 20.–24.2., 1.–17.11.
F. Englert (Belgium) 31.7.–14.8.
Z. Berezhiani (Italy) 1.–20.8.
A. Tapadar (India) 9.–14.9.
M. Gogberashvili (Georgia) 22.9.–5.10.

Phases of Strongly Interacting Matter

C. T. Preuss (Switzerland) 20.–23.3.
R. Rodgers (Sweden) 3.–6.4.
S. Säppi (Germany) 9.–12.4.
F. Hekhorn (Italy) 19.–23.4.
M. Ornigotti (Finland) 9.–10.5.
P. Hoyer (Finland) 1.–3.6.
A. Dumitru (USA) 5.–8.6.
O. Hannuksela (Hong Kong/China) 12.–16.6.
C. Royon (USA) 25.–28.6., 6.–10.8.
S. Kawai (South Korea) 27.7.–25.8.
J. Jalilian-Marian (USA) 1.–26.8.
L. Szymanowski (Poland) 6.–9.8.
A. Watts (Netherlands) 14.–16.9.
J. Louko (UK) 11.–16.10.
P. Schicho (Germany) 19.10.
T. Salmi (Netherlands) 24.10.
T. Dore (Germany) 6.–10.11.
G. Endrődi (Germany) 28.11.
M. Järvinen (South Korea) 20.–21.12.

CMS Programme

A. Malara (Belgium) 6.–10.2.
C. Fröjdh (Sweden) 9.–12.5.
D. Bortoletto (UK) 15.–17.5.
C. Royon (USA) 27.–29.6.
S. Schramm (Switzerland) 22.–23.10.
N. Norjoharuddeen (Malaysia) 14.–23.11.

Nuclear Matter Programme

ALICE

L. Martikainen (Finland) 25.–29.9.

CONFERENCE PARTICIPATION, TALKS AND VISITS BY PERSONNEL

Theory Programme

Theoretical Cosmology

Spåtind 2023 – 27th Nordic Particle Physics Meeting,
3–8 January, Fefor Høifjellshotell, Vinstra, Norway
(talk by D. Weir)

2023 Chung-Ang University Beyond the Standard Model Workshop,
20–24 February, Chung-Ang University, Seoul, South Korea (talk by D. Weir)

Tampere Cosmology Meeting 2023,
11–12 May, Tampere, Finland (talk by J. Annala, talk by A. Hassan, M. Hindmarsh, K. Kainulainen, S. Nurmi, talk by H. Parkkinen, S. Räsänen, talk by N. Venkatesan, talk by O. Väisänen, D. Weir)

XXXIVth Rencontres de Blois,
15–19 May, Gaston d'Orléans, Blois, France
(talk by D. Weir)

University of Helsinki,
31 May, Helsinki, Finland (K. Kainulainen)

Third EuCAPT Annual Symposium,
31 May – 2 June, CERN, Geneva, Switzerland
(J. Annala, D. Hooper, talk by A. Kormu)

10th LISA Cosmology Working Group Workshop,
5–9 June, University of Stavanger, Stavanger, Norway
(talk by L. Giombi, M. Hindmarsh, talk by D. Hooper, A. Kormu, K. Rummukainen, talk by D. Weir)

LISA Consortium Board In-Person Meeting,
6–7 June, SRON, Leiden, Netherlands (D. Weir)

The IIIrd Nordic Lattice Meeting 2023,
6–8 June, University of Stavanger, Stavanger, Norway
(talk by J. Annala, talk by A. Kormu, talk by K. Rummukainen, D. Weir)

Thermal Field Theory Meets Phenomenology Workshop,
12–16 June, Swedish Collegium for Advanced Study (SCAS), Uppsala, Sweden (D. Weir)

Geometric Foundations of Gravity 2023,
19–22 June, University of Tartu, Tartu, Estonia (talk by J. Annala, A. Hassan, talk by S. Räsänen)

MaNiTou Summer School on Gravitational Waves,
3–8 July, Universite Cote d'Azur, Nice, France
(T. Minkkinen)

International Neutrino Summer School,
8–19 August, Fermilab, Batavia, IL, USA (H. Parkkinen)

Gravity Across All Scales at SDU Mini-Course on "Primordial Gravitational Waves",
11–15 September, SDU, Odense, Denmark
(lectures by D. Weir)

LISA Astrophysics Working Group Meeting,
13–15 September, Milan, Italy (talk by P. Johansson)

University of Chicago,
10 October, Chicago, IL, USA (seminar by S. Räsänen)

Colloquium,
11 October, Edinburgh, UK (invited talk by P. Johansson)

Washington University,
13 October, St Louis, MO, USA (seminar by S. Räsänen)

Oskar Klein Centre 15 Year Anniversary Conference,
17–19 October, Stockholm, Sweden (talk by P. Johansson)

First Nordic Cosmology Meeting,
23–25 October, NORDITA, Stockholm, Sweden
(talk by J. Annala, J. Dahl, talk by L. Giombi, M. Hindmarsh, talk by D. Hooper, talk by A. Kormu, talk by S. Räsänen, talk by T. Tenkanen, talk by D. Weir)

Fundamental Particle Interactions Beyond the Standard Model

CEICO Institute,
21–24 March, Prague, Czech Republic (O. Lebedev)

FPS Physics Days 2023,
29–31 March, Tampere, Finland
(invited member in panel discussion K. Tuominen)

COSINUS Collaboration Meeting,
19–21 April, Helsinki, Finland
(talks by M. Heikinheimo, A. Stendahl)

Tampere Cosmology Meeting 2023,
11–12 May, Tampere, Finland (K. Tuominen)

CryoCourse 2023 School and Workshop,
18–26 May, Espoo, Finland (A. Stendahl)

PLANCK 2023 – The 25th International Conference From the Planck Scale to the Electroweak Scale,
20–26 May, Warsaw, Poland (invited talk by O. Lebedev)

FCC Week 2023,
5–9 June, London, UK (K. Huitu)

Entangle This: Randomness, Complexity and Quantum Circuits,
11–17 June, Benasque, Spain (E. Keski-Vakkuri)

ICTP Summer School on Particle Physics 2023,
19–30 June, Trieste, Italy (T. Gupta)

University of Messina,
17–28 July, Messina, Italy (O. Lebedev)

Excess at TAUP 2023 Workshop,
26 August, Vienna, Austria (M. Heikinheimo)

University of Warsaw,
9–15 September, Warsaw, Poland (O. Lebedev)

Scalars 2023,
13–16 September, Warsaw, Poland
(invited talk by O. Lebedev)

Ecole Polytechnique,
28–30 September, Paris, France (O. Lebedev)

Particle Physics Day 2023,
12 October, Jyväskylä, Finland
(A. Al-Adulrazzaq, T. Gupta, M. Heikinheimo, T. Sirkiä, talk by A. Stendahl, K. Tuominen)

Institut Pascal – Université Paris-Saclay,
22–27 October, Paris, France (O. Lebedev)

Astroparticle Symposium,
23 October – 17 November, Paris/Orsay, France
(invited talk by O. Lebedev)

Instituto de Fisica Teorica,
29–31 October, Madrid, Spain (seminar by K. Huitu)

Inauguration of the Quantum Theory Center, University of Southern Denmark,
20–21 November, Odense, Denmark
(invited talk by K. Tuominen)

Phases of Strongly Interacting Matter

University of Cape Town,
8 January – 5 February, Cape Town, South Africa
(lectures by T. Lappi)

University of Helsinki,
9–10 January, Helsinki, Finland (T. Lappi)

Iberian Strings 2023,
11–13 January, Murcia, Spain (talk by J. Penin)

XXIX Cracow Epiphany Conference,
16–19 January, Cracow, Poland (talks by V. Guzey, talk by H. Mäntysaari, talks by Y. Tawabutr)

Intersection of Nuclear Structure and High-Energy Nuclear Collisions, INT Workshop,
23 January – 24 February, Seattle, WA, USA
(invited talk by P. Singh)

Emergent Topics in Relativistic Hydrodynamics, Chirality, Vorticity and Magnetic Field,
2–5 February, Bhubaneswar, India
(invited talk by Y. Kanakubo)

The 8th International Conference on Physics and Astrophysics of Quark Gluon Plasma,
7–10 February, Puri, Odisha, India
(invited talk by Y. Kanakubo)

International Workshop on QCD Challenges from pp to AA Collisions,
13–17 February, Padua, Italy (invited talk by Y. Kanakubo, talk by Paakkinen, convener)

Institute of Physics,
20–24 February, Belgrade, Serbia (J. Auvinen)

FNHP2023 Frontiers in Nuclear and Hadronic Physics,
27 February – 10 March, Florence, Italy (D. Avramescu, C. Casuga, lectures by T. Lappi, J. Peuron, P. Singh)

University of Jyväskylä,
9–11 March, Jyväskylä, Finland (R. Paatelainen)

Physics Alumni Day,
10 March, Jyväskylä, Finland (invited talk by K. J. Eskola, I. Helenius, member of the Organisation Committee, invited talk by H. Hirvonen)

Holographic Perspectives on Chiral Transport,
13–17 March, Trento, Italy (talk by N. Jokela)

Anton Pannekoek Institute for Astronomy,
14–16 March, Amsterdam, Netherlands
(colloquium by A. Vuorinen)

University of Kansas,
21–26 March, Lawrence, KS, USA (seminar by J. Penttala)

The 11th International Conference on Hard and Electromagnetic Probes of High-Energy Nuclear Collisions,
26–31 March, Aschaffenburg, Germany
(talk by D. Avramescu, talk by K. J. Eskola, member of the IAC, invited talk by V. Guzey, talk by J. Peuron)

DIS2023: XXX International Workshop on Deep-Inelastic Scattering and Related Subjects,
27–31 March, East Lansing, MI, USA
(talk by P. Duwentäster, talk by A. D. Le, talk by H. Mäntysaari, talk by J. Penttala, talk by Y. Tawabutr, talk by M. Tevio, talk by M. Utheim)

University of Helsinki,
14 April, Helsinki, Finland (colloquium by T. Lappi)

University of Wrocław,
17–21 April, Wrocław, Poland (lecture series by J. Auvinen)

Phenomenal: ALICE and MC Meeting,
18 April, CERN, Geneva, Switzerland
(invited talk by I. Helenius (online))

The 9th Asian Triangle Heavy-Ion Conference,
24–27 April, Hiroshima, Japan
(invited talk by Y. Kanakubo)

Physics Opportunities at an Electron-Ion Collider 2023,
2–6 May, São Paulo, Brazil (invited talk by P. Paakkinen)

Goethe University,
10–12 May, Frankfurt, Germany
(transport seminar by Y. Kanakubo)

Tampere Cosmology Meeting 2023,
11–12 May, Tampere, Finland
(N. Jokela, talk by M. Sarkkinen)

Heidelberg University,
15–19 May, Heidelberg, Germany
(ISOQUANT special seminar by Y. Kanakubo)

Color Glass Condensate at the Electron-Ion Collider,
15–19 May, ECT*, Trento, Italy (invited talk by T. Lappi, invited talk by A. D. Le, invited talk by R. Paatelainen, invited talk by J. Penttala, invited talk by Y. Tawabutr)

1st International Workshop on a 2nd Detector for the Electron-Ion Collider,
17–19 May, Temple University, Philadelphia, PA, USA
(invited talk by V. Guzey)

Brookhaven National Laboratory,
19 May – 16 June, Upton, NY, USA
(seminar by H. Mäntysaari)

Pythia Week Spring 2023,
22–26 May, Lund, Sweden (I. Helenius, J. Laulainen)

Lund University,
22 May – 16 June, Lund, Sweden (I. Helenius)

Stavanger University,
25–28 May, Stavanger, Norway (A. Vuorinen)

HIP-Preparation Group Meeting,
29 May, Jyväskylä, Finland (invited talk by K. J. Eskola)

Exploring Quark-Gluon Plasma through Soft and Hard Probes,
29–31 May, Belgrade, Serbia (J. Auvinen, convener, invited talk by Y. Kanakubo, invited talk by T. Lappi)

Gravity Sagas Conference,
30 May – 2 June, Reykjavik, Iceland
(talk by O. Henriksson, talk by N. Jokela, W. H. Tam)

Workshop on the Modeling of Photon-Induced Processes,
5–7 June, IPPP, Durham, UK (invited talk by I. Helenius)

QCD Master Class 2023,
5–16 June, Saint-Jacut-de-la-Mer, France (P. Navarrete)

Brookhaven National Laboratory,
7–17 June, Upton, NY, USA (seminar by J. Penttala)

Quantum Connections Session XI Summer School,
11–24 June, Stockholm, Sweden (A. Piispa)

The 7th Edition of the International Conference on the Initial Stages in High-Energy Nuclear Collisions,
19–23 June, Copenhagen, Denmark
(J. Auvinen, talk by D. Avramescu, C. Casuga, invited talk by K. J. Eskola, invited talk by V. Guzey, I. Helenius, talk by H. Hirvonen, talk and inivited talk by Y. Kanakubo, T. Lappi, member of the Organisation Committee, A. D. Le, H. Mäntysaari, H. Niemi, R. Paatelainen, J. Penttala, J. Peuron, talk by P. Singh, Y. Tawabutr)

Hólmganga: CLASH Workshop 2023,
26–30 June, Helsingborg, Sweden
(Y. Kanakubo, convener, T. Lappi, convener, J. Peuron, co-convener, convener, and member of the Organising Committee, P. Singh, co-convener, M. Utheim)

MCnet Summer School 2023,
9–13 July, Durham, UK (J. Laulainen)

Chinese Academy of Sciences,
17 July, Beijing, China (X. Li)

Short-Distance Nuclear Structure and PDFs,
17–21 July, ECT*, Trento, Italy
(invited talk by P. Duwentäster)

Methods of Effective Field Theory and Lattice Field Theory Summer School,
18–20 July, Bad Honnef, Germany
(invited lectures by A. Vuorinen)

19th International Conference on QCD in Extreme Conditions (XQCD 2023),
26–28 July, Coimbra, Portugal
(talk by L. Fernandez, P. Navarrete, K. Seppänen)

University of Jyväskylä,
6–8 August, Jyväskylä, Finland (R. Paatelainen)

HIP Theory Programme Meet,
18 August, Helsinki, Finland (J. Auvinen, D. Avramescu, C. Casuga, P. Duwentäster, K. J. Eskola, P. Gimeno Estivill, invited talk by H. Hirvonen, T. Lappi, invited talk by H. Mäntysaari, H. Niemi, P. Paakkinen, J. Penttala, Y. Tawabutr, invited talk by M. Tevio)

52nd International Symposium on Multiparticle Dynamics (ISMD 2023),
21–26 August, Gyöngyös, Hungary
(invited talk by Y. Tawabutr)

HIP Scientific Advisory Board Meeting 2023,
28–29 August, Helsinki, Finland
(K. J. Eskola, T. Lappi, talk by H. Mäntysaari)

XXXth International Conference on Ultra-Relativistic Nucleus-Nucleus Collisions, Quark Matter 2023,
3–9 September, Houston, TX, USA (K. J. Eskola, member of the IAC, H. Hirvonen, invited talk by Y. Kanakubo, M. Kuha, talk by T. Lappi, invited talk by H. Mäntysaari, talk by P. Paakkinen, talk by J. Peuron, talk by P. Singh)

Hydrodynamics at All Scales,
4–8 September, Stockholm, Sweden (N. Jokela)

63. Cracow School of Theoretical Physics,
19–21 September, Zakopane, Poland
(invited lectures by A. Vuorinen)

Particle Physics Day 2023,
12 October, Jyväskylä, Finland (J. Auvinen, D. Avramescu, invited talk by C. Casuga, K. J. Eskola, P. Gimeno Estivill, V. Guzey, invited talk by F. Hekhorn, I. Helenius, H. Hirvonen, Y. Kanakubo, invited talk by M. Kuha, T. Lappi, organiser, J. Laulainen, A. D. Le, H. Mäntysaari, invited talk by P. Navarrete, H. Niemi, P. Paakkinen, R. Paatelainen, H. Paukkunen, organiser, J. Peuron, invited talk by K. Seppänen, Y. Tawabutr, M. Tevio, X. Tong, M. Utheim)

University of Münster,
16–20 October, Münster, Germany
(P. Duwentäster, V. Guzey)

WE-Heraeus-Seminar: Forward Physics and QCD at the LHC and EIC,
23–27 October, Bad Honnef, Germany (P. Duwentäster, invited talk by V. Guzey, Y. Tawabutr)

2nd Annual Retreat of the Jyväskylä Centre of Excellence in Quark Matter,
2–3 November, Konnevesi research station, Konnevesi, Finland (invited talk by J. Auvinen, D. Avramescu, C. Casuga, P. Duwentäster, invited talk by K. J. Eskola, P. Gimeno Estivill, V. Guzey, F. Hekhorn, I. Helenius, organiser, H. Hirvonen, invited talk by T. Lappi, invited talk by J. Laulainen, invited talk by H. Mäntysaari, organiser, P. Paakkinen, invited talk by H. Paukkunen, J. Peuron, P. Singh, I. Soudi, J. Tawabutr, M. Tevio, organiser, invited talk by X. Tong, M. Utheim, S. Yrjänheikki)

2nd Workshop on Advancing the Understanding of Non-Perturbative QCD Using Energy Flow,
6–9 November, Stony Brook University, New York, NY, USA (invited talk by V. Guzey (online))

Instituto Galego de Fisica de Altas Enerxias (IGFAE),
21–29 November, Santiago de Compostela, Spain
(seminar by D. Avramescu)

CosmoConce y Partículas 2023,
22–24 November, Concepción, Chile (P. Navarrete)

UPC 2023: International Workshop on the Physics of Ultra Peripheral Collisions,
10–15 December, Playa del Carmen, Mexico (invited talk by V. Guzey, co-convener, invited talk by I. Helenius, co-convener, T. Lappi, co-chair, International Programme Committee, H. Mäntysaari, co-convener, invited talk by P. Paakkinen)

Inverse Days 2023,
13 December, Lahti, Finland (M. Sarkkinen)

Designer Topological Matter

DPG Meeting,
1–5 March, Stuttgart, Germany (T. Ojanen)

CMS Programme

CMS Experiment

Spåtind 2023 – 27th Nordic Particle Physics Meeting,
3–8 January, Fefor Høifjellshotell, Vinstra, Norway
(talk by P. Inkaew, talk by S. Laurila, talk M. Myllymäki)

CERN,
15–21 January, Geneva, Switzerland (S. Lehti)

CMS Physics Days: Precision Physics,
18–19 January, CERN, Geneva, Switzerland
(talk by M. Voutilainen)

CMS Week,
16–21 April, St. Malo, France
(M. Voutilainen, session chair)

Automation Framework Hackathon,
26–28 April, CERN, Geneva, Switzerland (T. Lampén)

Stockholm University,
4–6 May, Stockholm, Sweden (S. Lehti)

CMS JetMET Workshop,
15–17 May, Brussels, Belgium (talk by H. Kirschenmann, talk by T. Lampén, talk by M. Myllymäki, talk by N. Toikka, talk by M. Voutilainen)

Large Hadron Collider Physics Conference,
22–26 May, Belgrade, Serbia (talk by H. Kirschenmann)

BootCamp,
5–9 June, CERN, Geneva, Switzerland (T. Lampén)

CERN,
11 June – 1 July, Geneva, Switzerland (S. Lehti)

CMS Week,
12–16 June, CERN, Geneva, Switzerland (S. Lehti, plenary talk by M. Voutilainen)

European Physical Society Conference on High Energy Physics (EPS-HEP),
20–25 August, Hamburg, Germany (plenary talk by H. Kirschenmann, M. Voutilainen, session chair)

HIP Scientific Advisory Board Meeting,
28–29 August, Helsinki, Finland (talk by M. Voutilainen)

The 16th International Workshop on Top Quark Physics,
24–29 September, Traverse City, MI, USA
(plenary talk by M. Myllymäki)

Top Quark Physics at the Precision Frontier,
1–4 October, Lafayette, IN, USA (M. Myllymäki (online))

CMS Physics Object & Data Analysis School,
9–18 October, Hamburg, Germany (N. Toikka)

Particle Physics Day 2023,
12 October, Jyväskylä, Finland
(talk by M. Myllymäki, talk by M. Voutilainen)

Jubilee Symposium "Electroweak Milestones – 50 Years of Neutral Currents, 40 Years of W and Z Bosons",
31 October, CERN, Geneva, Switzerland (J. Tuominiemi)

Integraatiofest,
11 November, Lappeenranta, Finland
(invited talk by H. Kirschenmann)

PPD Workshop,
19–21 November, CERN, Geneva, Switzerland
(M. Voutilainen, session chair)

Automation Framework Hackathon 2.0,
29 November – 1 December, CERN, Geneva, Switzerland
(T. Lampén (online), N. Toikka)

CMS Upgrade

CMS Tracker Week,
20–24 February, CERN, Geneva, Switzerland
(talk by E. Brücken, T. Hildén, P.-R. Luukka)

CMS Week,
16–21 April, St. Malo, France (E. Brücken)

42nd RD50 Workshop,
20–23 June, Tivat, Montenegro (E. Brücken, T. Hildén)

HIP Scientific Advisory Board Meeting,
28–29 August, Helsinki, Finland (talk by E. Brücken)

Paul Scherrer Institute,
12–15 September, Villingen, Switzerland (E. Brücken)

University of Oslo,
25–27 September, Oslo, Norway (E. Brücken)

University of Jyväskylä,
25–29 September, Jyväskylä, Finland (L. Martikainen)

Particle Physics Day 2023,
12 October, Jyväskylä, Finland
(E. Brücken, talk by T. Hildén, S. Saariokari)

CMS Tracker Week,
23–27 October, Santander, Spain (E. Brücken, T. Hildén)

43rd RD50 Workshop,
28 November – 1 December, CERN, Geneva, Switzerland
(M. Bezak, E. Brücken, N. Kramarenko, P.-R. Luukka, S. Saariokari)

RD51 Collaboration Meeting,
4–8 December, CERN, Geneva, Switzerland (E. Brücken)

TEPX Production Center Meeting,
14 December, CERN, Geneva, Switzerland (online)
(talk by E. Brücken, T. Hildén, P.-R. Luukka)

Tier-2 Operations

Science Coffee Seminar,
31 January, Lund, Sweden (talk by T. Lindén)

Physics Colloquium,
3 March, Jyväskylä, Finland (talk by T. Lindén)

FPS Physics Days 2023,
29–31 March, Tampere, Finland (T. Lindén)

WLCG Workshop,
6–7 May, Norfolk, VA, USA (T. Lindén)

26th International Conference on Computing in High Energy & Nuclear Physics,
8–12 May, Norfolk, VA, USA (T. Lindén)

FUNET Technical Days,
25–26 May, Helsinki, Finland (T. Lindén)

Fall 2023 Offline Software and Computing Week,
2–6 October, CERN, Geneva, Switzerland (T. Lindén)

Particle Physics Day 2023,
12 October, Jyväskylä, Finland (T. Lindén)

HEPiX Autumn 2023 Workshop,
16–20 October, Victoria, Canada (talk by T. Lindén)

Canadian Workshop on Fusion Energy Science and Technology (CWFEST) 2023,
24 October (online) (T. Lindén)

CMS Topical Dynamic Resources Meeting – LUMI HPC,
12 December (online) (talk by T. Lindén)

CMS Forward Physics

CERN,
26 January – 9 February, 20 February – 14 March,
10 April – 11 May, 25 May – 6 June, 15–27 June,
14 August – 28 September, 30 October – 13 November,
4–16 December, Geneva, Switzerland (F. Garcia)

PPS@HL-LHC Upgrade Workshop,
22 February, 23–24 October, CERN, Geneva, Switzerland
(talk by F. Garcia, M.-M. Rantanen (online), K. Österberg (online))

LHCC Referees Meeting,
7 March (online) (talk by F. Garcia, talk by K. Österberg)

Hasselt Diamond Workshop 2023,
15–17 March, Hasselt, Belgium (M.-M. Rantanen)

FPS Physics Days 2023,
29–31 March, Tampere, Finland (F. Oljemark)

TOTEM Collaboration Meeting,
4–5 May, CERN, Geneva, Switzerland (talk by F. Garcia, talk by F. Oljemark, talk by K. Österberg, chair)

Stockholm University,
30 May – 2 June, Stockholm, Sweden (K. Österberg)

CMS Data Analysis School @ CERN 2023,
5–10 June, CERN, Geneva, Switzerland (A. Milieva)

LHCC Referees Meeting,
6 June, 12 September, 28 November (online)
(talk by K. Österberg)

CMS Week,
12–16 June, CERN, Geneva, Switzerland (K. Österberg)

ISMD 2023,
21–26 August, Gyöngyös, Hungary
(invited talk by K. Österberg)

HIP Scientific Advisory Board Meeting,
28–29 August, Helsinki, Finland (talk by K. Österberg)

CERN,
4–11 September, Geneva, Switzerland (F. Oljemark)

CMS Collaboration Meeting,
18–22 September, CERN, Geneva, Switzerland
(K. Österberg)

TOTEM Collaboration Meeting,
20–21 September, CERN, Geneva, Switzerland
(talk by F. Oljemark, talk by K. Österberg, chair)

CMS Physics Object & Data Analysis School,
9–18 October, Hamburg, Germany (A. Milieva)

Particle Physics Day 2023,
12 October, Jyväskylä, Finland
(F. Oljemark, M.-M. Rantanen, K. Österberg)

WE-Heraeus-Seminar: Forward Physics and QCD at the LHC and the EIC,
23–27 October, Bad Honnef, Germany
(invited talk by K. Österberg, chair)

Nuclear Matter Programme

ALICE

The 38th Winter Workshop on Nuclear Dynamics,
5–11 February, Puerto Vallarta, Mexico (talk by D. J. Kim)

International Workshop on QCD Challenges from pp to AA Collisions,
13–17 February, Padua, Italy (talk by D. J. Kim)

FPS Physics Days 2023,
29–31 March, Tampere, Finland (talk by L. Huhta, talk by A. Molander, talk by A. Önnerstad)

ALICE Upgrade Week,
11 May, CERN, Geneva, Switzerland (talk by L. Huhta)

LHCP2023,
23 May, Belgrade, Serbia (A. Molander)

Yonsei University,
24–25 May, Seoul, South Korea (seminar by D. J. Kim)

Heavy Ion Meeting,
26–27 May, Yonsei University, Seoul, South Korea (talk by D. J. Kim)

ALICE Physics Week 2023,
12–16 June, Bucharest, Romania (talk by D. J. Kim)

Initial Stages 2023,
19 June, Copenhagen, Denmark (C. Mordasini)

XXXth International Conference on Ultra-Relativistic Nucleus-Nucleus Collisions, Quark Matter 2023,
3–9 September, Houston, TX, USA (D. J. Kim, talk by C. Mordasini)

Inha University,
9–18 October, Incheon, South Korea (H. Hassan)

FAIR

NUSTAR Annual Meeting,
27 February – 3 March, Darmstadt, Germany (T. Grahn, A. Jokinen)

Super-FRS Experiment Collaboration Meeting,
26–28 April, Walldorf, Germany (talk by T. Grahn, A. Jokinen)

NUSTAR Week 2023,
10–13 October, Bucharest, Romania (T. Grahn)

Technology Programme

Accelerator Technology: Materials (MAT)

30th International Symposium on Discharges and Electrical Insulation in Vacuum (ISDEIV2023),
25–30 June, Okinawa, Japan (contributed talk by F. Djurabekova, member of the permanent international scientific committee, invited talk by A. Kyritsakis)

Mechanisms of Vacuum Arcing Mini-Workshop,
14–15 September, CERN, Geneva, Switzerland (F. Djurabekova, M. Ghaemikermani, A. Lopez Cazalilla)

CERN,
21–26 November, Geneva, Switzerland (F. Djurabekova)

Radiation and Nuclear Metrology, Safety, Security and Safeguards Applications (RAD3S)

Workshop on "Research Plans for the Technology Park Annexed to the Italian National Near-Surface Repository for Radioactive Waste",
20–21 January, Rome, Italy (invited talk by P. Dendooven)

American Physical Society March Meeting,
5–10 March, Las Vegas, NV, USA (invited talk by M. Laassiri)

INMM-ESARDA Joint Annual Meeting 2023,
22–26 May, Vienna, Austria (talk by R. Virta)

24th International Workshops on Radiation Imaging Detectors (iWoRiD),
25–29 June, Oslo, Norway (P. Dendooven)

International Congress on Industrial and Applied Mathematics,
21–25 August, Tokyo, Japan (invited talk by R. Virta)

Applied Inverse Problems 2023,
4–8 September, Göttingen, Germany (invited talk by P. Dendooven, invited talk by R. Virta)

3rd African Conference of Fundamental and Applied Physics (ACP2023),
25–29 September, George, South Africa (talk by M. Laassiri)

GammaSkill Seminar,
26–28 September, Vantaa, Finland (talk by R. Virta)

Other projects

Euclid

Euclid Consortium Board Meeting,
21–22 February, Frankfurt, Germany (H. Kurki-Suonio)

Euclid Theory Science Working Group Meeting,
6 March (online) (J. Väliviita)

Tampere Cosmology Meeting 2023,
11–12 May, Tampere, Finland (E. Keihänen, H. Kurki-Suonio, J. Väliviita)

Euclid Consortium Meeting,
19–23 June, Copenhagen, Denmark (E. Keihänen, K. Kiiveri, V. Lindholm, A. Viitanen, J. Väliviita)

Euclid Science Implementation Meeting,
1–3 July, Cocoa Beach, FL, USA (H. Kurki-Suonio)

Euclid Consortium Board Meeting,
4 July, Cocoa Beach, FL, USA (H. Kurki-Suonio)

Euclid Consortium Board Meeting,
20–21 September, Munich, Germany (H. Kurki-Suonio)

Euclid Theory Science Working Group Meeting,
5–6 October, Paris, France (J. Väliviita (online))

First Nordic Cosmology Meeting,
23–25 October, NORDITA, Stockholm, Sweden (E. Keihänen)

Euclid SGS Meeting,
14–17 November, ESAC, Madrid, Spain (H. Kurki-Suonio, V. Lindholm)

Education and Open Data

DK ALM Open Data Workshop,
16–17 January, Venet Gipfelhütte, Tyrol, Austria (talk and exercise sessions by K. Lassila-Perini)

FAIROS-HEP Kick-Off Workshop,
8–10 February, CERN, Geneva, Switzerland (talk by K. Lassila-Perini)

Learning Adventure 2023,
7–8 March, Helsinki, Finland (talk by P. Veteli)

GIREP 2023,
3–7 July, Košice, Slovakia (talk by P. Veteli)

CERN-NASA Open Science Summit,
10–14 July, CERN, Geneva, Switzerland (panel discussion by K. Lassila-Perini)

ESELS 2023,
29 September, Helsinki, Finland (talk by P. Veteli)

ML-days 2023,
2–3 November, Turku, Finland (talk by P. Veteli)

Detector Laboratory

Terrestrial Very-Long-Baseline Atom Interferometry Workshop,
13–14 March, CERN, Geneva, Switzerland
(M. Kalliokoski)

FPS Physics Days 2023,
29–31 March, Tampere, Finland (M. Kalliokoski)

COSINUS Collaboration Meeting,
19–21 April, Helsinki, Finland (talk by M. Kalliokoski)

Computing in High Energy Physics, CHEP 2023,
8–12 May, Norfolk, VA, USA (talk by M. Kalliokoski)

42nd RD50 Workshop,
20–23 June, Tivat, Montenegro (M. Kalliokoski)

19th MoEDAL Collaboration Meeting,
26–28 June, CERN, Geneva, Switzerland
(talk by M. Kalliokoski)

Technology and Instrumentation in Particle Physics, TIPP 2023,
4–8 September, Cape Town, South Africa
(talk by M. Kalliokoski)

HiZPAD Workshop,
20–21 September, Hamburg, Germany (M. Kalliokoski)

DRD5 Preparatory Workshop,
2–4 October, CERN, Geneva, Switzerland (M. Kalliokoski)

European Spallation Source,
5–6 October, Lund, Sweden (talk by M. Kalliokoski)

Particle Physics Day 2023,
12 October, Jyväskylä, Finland (M. Kalliokoski)

2023 IEEE NSS MIC RTSD,
4–11 November, Vancouver, Canada (M. Kalliokoski)

43rd RD50 Workshop,
28 November – 1 December, CERN, Geneva, Switzerland
(M. Kalliokoski)

20th MoEDAL Collaboration Meeting,
11–13 December, CERN, Geneva, Switzerland
(talk by M. Kalliokoski)

TEPX Production Center Meeting,
14 December, CERN, Geneva, Switzerland (online)
(P. Koponen, R. Turpeinen)

PUBLICATIONS

Theory Programme

Theoretical Cosmology

J. Annala and K. Rummukainen,
Electroweak sphaleron in a magnetic field,
Phys. Rev. D 107 (2023) 073006

J. Annala and S. Räsänen,
Stability of non-degenerate Ricci-type Palatini theories,
J. Cosmol. Astropart. Phys. 04 (2023) 014

D. Cutting, M. Hindmarsh, D. C. Hooper, K. Rummukainen, and D. J. Weir in P. Auclair et al. (The LISA Cosmology Working Group),
Cosmology with the Laser Interferometer Space Antenna,
Living Rev. Relativ. 26 (2023) 5

C. Gowling and M. Hindmarsh in G. Boileau et al.,
Prospects for LISA to detect a gravitational-wave background from first order phase transitions,
J. Cosmol. Astropart. Phys. 02 (2023) 056

C. Gowling, M. Hindmarsh, D. C. Hooper, and J. Torrado,
Reconstructing physical parameters from template gravitational wave spectra at LISA: first order phase transitions,
J. Cosmol. Astropart. Phys. 04 (2023) 061

M. Hindmarsh and J. Kume,
Multi-messenger constraints on Abelian-Higgs cosmic string networks,
J. Cosmol. Astropart. Phys. 04 (2023) 045

K. Kainulainen, O. Koskivaara, and S. Nurmi,
Tachyonic production of dark relics: a non-perturbative quantum study,
J. High Energy Phys. 04 (2023) 043

J. T. Mäkinen, K. Zhang, and V. B. Eltsov,
Vortex-bound solitons in topological superfluid ^{3}He,
J. Phys.: Condens. Matter 35 (2023) 214001

L. Niemi, K. Rummukainen, R. Seppä, and D. J. Weir,
Infrared physics of the 3D SU(2) adjoint Higgs model at the crossover transition,
J. High Energy Phys. 02 (2023) 212

S. Räsänen and Y. Verbin,
Palatini formulation for gauge theory: implications for slow-roll inflation,
Open J. of Astrophysics 6 (2023)

M. Shaposhnikov and A. Tokareva,
Anomaly-free scale symmetry and gravity,
Phys. Lett. B 840 (2023) 137898

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Shallow relic gravitational wave spectrum with acoustic peak,
J. Cosmol. Astropart. Phys. 12 (2023) 042

K. Zhang and M. Hindmarsh in Y. Tian et al.,
Supercooling of the A phase of ^{3}He,
Nat. Commun. 14 (2023) 148

Fundamental Particle Interactions Beyond the Standard Model

K. Ala-Mattinen, M. Heikinheimo, K. Tuominen, and K. Kainulainen,
Anatomy of real intermediate state-subtraction scheme,
Phys. Rev. D 108 (2023) 096034

M. Heikinheimo, K. Huitu, and A. Stendahl in G. Angloher et al.,
First measurements of *remoTES* cryogenic calorimeters: Easy-to-fabricate particle detectors for a wide choice of target materials,
Nucl. Instr. Meth. A 1045 (2023) 167532

E. Keski-Vakkuri in R. Arias et al.,
Probing RG flows, symmetry resolution and quench dynamics through the capacity of entanglement,
J. High Energy Phys. 03 (2023) 175

E. Keski-Vakkuri in R. Arias et al.,
Sequences of resource monotones from modular Hamiltonian polynomials,
Phys. Rev. Research 5 (2023) 043082

D. Benisty, M. M. Chaichian, and M. Oksanen,
Mimetic tensor-vector-scalar cosmology: Incorporating dark matter, dark energy and stiff matter,
Phys. Dark Universe 42 (2023) 101280

I. Brevik, A. M. Favitta, and M. Chaichian,
Axionic and nonaxionic electrodynamics in plane and circular geometry,
Phys. Rev. D 107 (2023) 043522

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Propagating quantum microwaves: towards applications in communication and sensing,
Quantum Sci. Technol. 8 (2023) 023001

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Alternative approach to the Starobinsky model for inflation scenarios,
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C. R. Das, K. Huitu, and T. J. Kärkkäinen,
The Higgs trilinear coupling and the scale of new physics for the SM-Axion-Seesaw-Higgs portal inflation (SMASH) model,
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A. M. Favitta, I. H. Brevik, and M. M. Chaichian,
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Vector dark matter in supercooled Higgs portal models,
Phys. Rev. D 108 (2023) 015033

O. Lebedev,
Scalar overproduction in standard cosmology and predictivity of non-thermal dark matter,
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Phases of Strongly Interacting Matter

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Phase transitions in particle physics: results and perspectives from lattice quantum chromo-dynamics,
Prog. Part. Nucl. Phys. 133 (2023) 104070

E. Annala, J. Hirvonen, and A. Vuorinen in E. Annala et al.,
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Phys. Rev. D 107 (2023) 114024

A. Dumitru, H. Mäntysaari, and R. Paatelainen,
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A. Ekstedt, P. Schicho, and T. V. I. Tenkanen,
DRalgo: A package for effective field theory approach for thermal phase transitions,
Comput. Phys. Commun. 288 (2023) 108725

K. J. Eskola, C. A. Flett, V. Guzey, T. Löytäinen, and H. Paukkunen,
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Degenerate fermionic matter at N³LO: Quantum electrodynamics,
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Phys. Rev. Lett. 131 (2023) 181902

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Gravitational wave memory in conformally flat spacetimes,
J. High Energy Phys. 05 (2023) 055

N. Jokela, K. Kajantie, M. Sarkkinen, M. Laine, and S. Nurmi,
Inflationary gravitational wave background as a tail effect,
Phys. Rev. D 108 (2023) L101503

N. Jokela, K. Rummukainen, A. Salami, A. Pönni, and T. Rindlisbacher,
Progress in the lattice evaluation of entanglement entropy of three-dimensional Yang-Mills theories and holographic bulk reconstruction,
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X. Li in S. Lan et al.,
Heating up quadruply quantized vortices: splitting patterns and dynamical transitions,
Phys. Rev. Lett. 131 (2023) 221602

T. Lappi, A. D. Le, and H. Mäntysaari,
Rapidity gap distribution of diffractive small-x_p events at HERA and at the EIC,
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P. Schicho in J. Löfgren et al.,
Nucleation at finite temperature: a gauge-invariant perturbative framework,
Phys. Rev. Lett. 130 (2023) 251801

H. Mäntysaari et al.,
Multiscale imaging of nuclear deformation at the Electron-Ion Collider,
Phys. Rev. Lett. 131 (2023) 062301

J. Rausch, V. Guzey, and M. Klasen,
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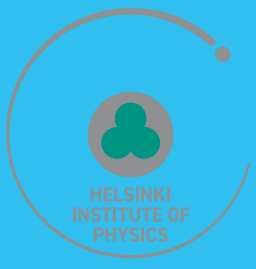

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