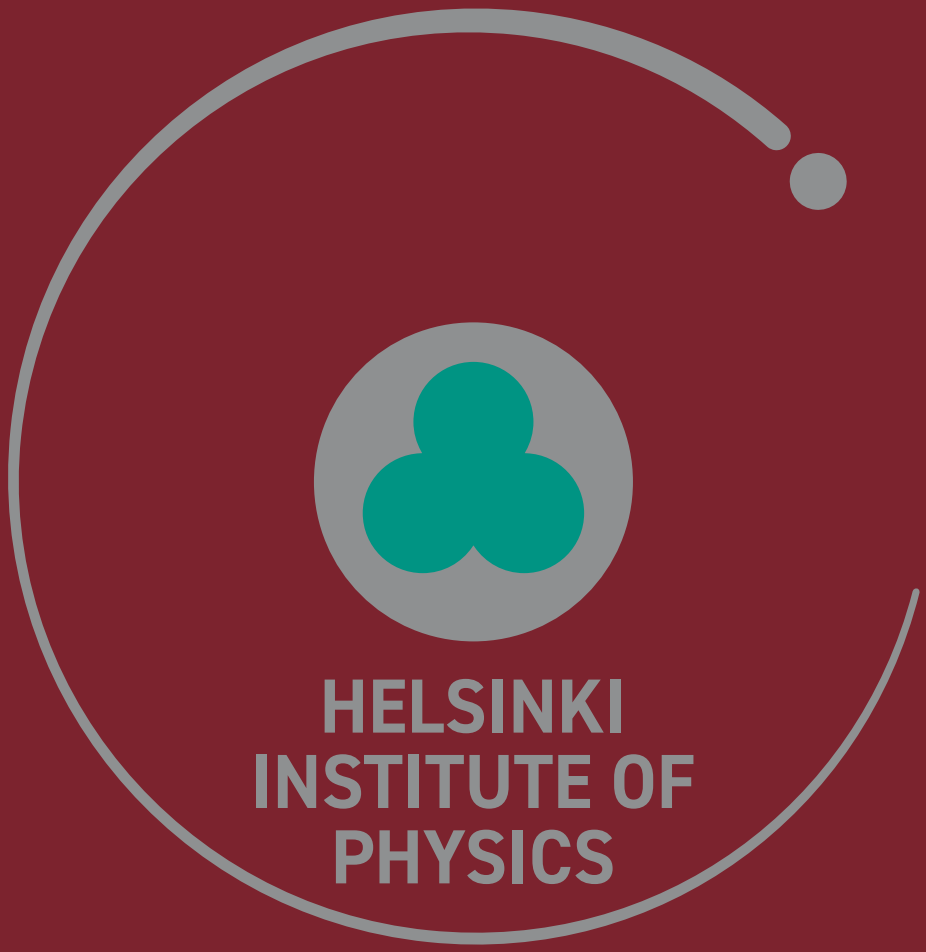
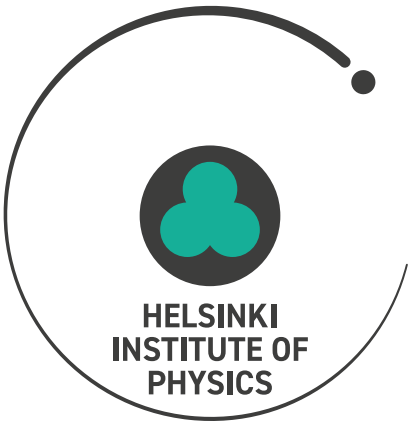


Annual Report 2022



Annual Report 2022

Celebrating Mikko Voutilainen's ERC Grant on 29 March. © *J. Aaltonen, HIP.*

The HIP Board met in hybrid form during 2022. © *J. Aaltonen, HIP.*

HIP 25 Years Silver Jubilee on 20 May. © *J. Aaltonen, HIP.*

HIP Summer Trip to Porvoo on 15 June. © *J. Aaltonen, HIP.*

Two quarters of the new TOTEM T2 assembled and tested at CERN. © *F. Garcia.*

The Scientific Advisory Board for 2020–2024 met in person for the first time in Helsinki on 30–31 August. © *J. Aaltonen, HIP.*

Visit of Finnish industry representatives at CERN IdeaSquare on 29 November. © *IdeaSquare.*

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 2022, the research activities of HIP consisted of four research programmes: 1) the Theory Programme; 2) the CMS Programme including the CMS and TOTEM experiments; 3) the Nuclear Matter Programme including involvements in the ALICE and ISOLDE experiments, and the FAIR facility; and 4) the Technology Programme, with five 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 future ESA LISA mission and with the dark matter COSINUS experiment, which is under construction in the Gran Sasso Laboratory.

The year started with remote working due to the COVID-19 pandemic. When offices started to be more in use again, Russia invaded Ukraine on 24 February, and the atrocious war put a heavy stamp on the whole year. Both CERN and FAIR have had big involvement from Russia, and Russia's invasion of Ukraine is then naturally reflected also in HIP's experimental activities. One example of this disruption relates to the authorship of articles from the LHC collaborations, which remained unsolved in 2022.

Good things also happened during the year. The HIP 25 Years Silver Jubilee took place on 20 May. HIP turned 25 years already on 1 September 2021, but the festivities were postponed until the celebration could be in person. At the same time, we celebrated the 30 years anniversary of Finland joining CERN, and 10 years since discovering the Higgs boson, which remains the only discovered particle of its kind. The three-month summer trainee programme at CERN and at ESRF was revived, as well as the one-week BootCamp at CERN IdeaSquare, organised with three Universities of Applied Sciences. In December the high-school student science camps at CERN also started again.

The Scientific Advisory Board (SAB) visited Kumpula at the end of August. This was the present SAB's first meeting in person. They were very satisfied with the presentations that they heard and gave useful advice for future operations to the

HIP Board, which started its new term in April. A long-term recommendation of the SAB was fulfilled when Business Finland nominated an Industrial Liaison Officer for CERN and FAIR.

In the Theory Programme, the hugely successful projects 'High Energy Phenomenology in the LHC Era' and 'QCD and Strongly Interacting Gauge Theory' ended. Leaders of both projects, Aleksi Vuorinen and Tuomas Lappi, respectively, became professors while the projects lasted, and both received an ERC grant. Since January 1, 2022, Tuomas Lappi leads the Quark Matter Centre of Excellence of the Academy of Finland. The two other projects were evaluated with recommendation to continue the 'Theoretical Cosmology' and the 'Designer Topological Matter' projects for another three-year period. Also, two new projects were selected to start in 2023, namely 'Fundamental Particle Interactions Beyond the Standard Model' and 'Phases of Strongly Interacting Matter'.

Run 3 of the LHC started with an increased energy of 13.6 TeV. Run 3 is scheduled to last until the end of 2025, after which the upgrades under construction for CMS and ALICE for the high luminosity LHC will be installed. Disk space for LHC-computing Tier-2 operations was purchased with FIRI funding. Mikko Voutilainen received an ERC grant for CMS analysis work. The SMARTHEP ITN programme is ongoing. From the ALICE project, the project leader Sami Räsänen, as well as DongJo Kim belong to the Quark Matter Centre of Excellence.

In the Technology Programme, three research projects connected to the activities with STUK were evaluated positively, and the SAB recommended to merge them into one larger project. The 'Accelerator Technology: Materials' project participates in the Future Circular Collider feasibility study which is going on at CERN. Peter Dendooven will continue as a visiting Professor until the end of 2025.

The Detector Laboratory supports the work for the CMS, ALICE, and TOTEM experiments and FAIR, but also has the Business Finland R2B project DeNuSa, which was presented at SLUSH. Further activities include the MoEDAL experiment at the LHC and the Finnish Quantum Institute, as well as the dark matter experiment COSINUS.

HIP scientists have been recognised in receiving several prizes: Aleksi Vuorinen received the Magnus Ehrnrooth Foundation's Science Award, Kaapo Seppänen the 2021 Finnish Physical Society's Master's Thesis Prize, and Markus Kortelainen, who was a HIP project leader three years ago, received the Scientific Breakthrough Prize from the University of Jyväskylä.

Several people connected to HIP research have been appointed to a position in member universities: Anu Kankainen from the ISOLDE and FAIR projects was promoted to a Professor position at JYU, Erik Brücken from the CMS Upgrade project started as a University Lecturer at UH, Teemu Siiskonen started as a Professor of Practise at UH, Mikko Voutilainen was promoted to a Professor position at UH, and Dr Risto Paatelainen became an Academy Research Fellow at HIP.

HIGHLIGHTS OF RESEARCH RESULTS

Theory Programme

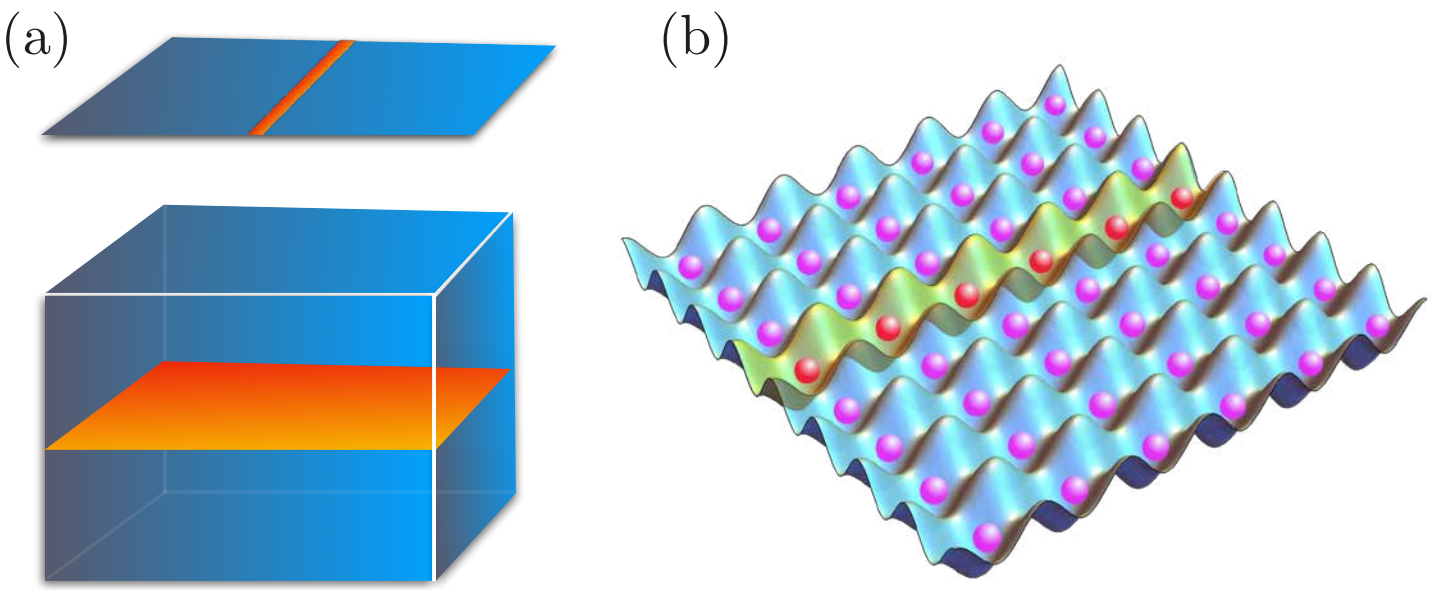
In 2022, the Theory Programme consisted of four research projects, spanning scales from elementary particles up to the whole universe: High Energy Phenomenology in the LHC Era, QCD and Strongly Interacting Gauge Theory, Theoretical Cosmology, and Designer Topological Matter. For the first two projects mentioned above, 2022 was the last year of operation, and these are replaced by two new projects in 2023.

One of the significant achievements in the High Energy Phenomenology project was to obtain the state-of-the-art equation of state of dense QCD matter using theoretical input from perturbative QCD, lattice field theory, and constraints from recent neutron star observations. The results strengthen the evidence for the existence of quark matter at the core of neutron stars.

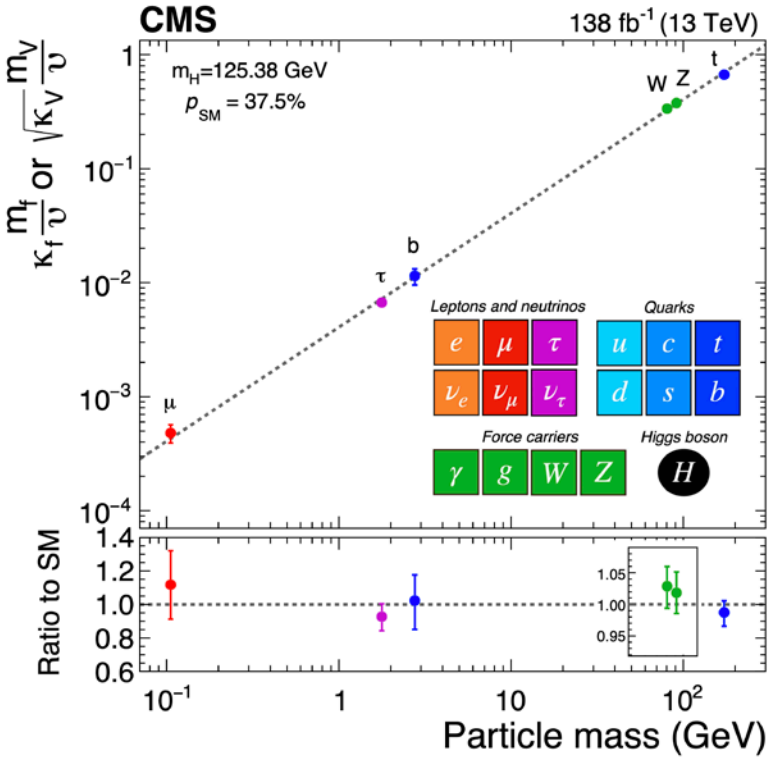
The highlight of the QCD and Strongly Interacting Gauge Theory project was the calculation of the virtual photon to quark-antiquark light cone wave function with massive quarks to one loop, as a Jyväskylä-Helsinki-Warsaw collaboration. This is a rare case of a one-loop elementary field theory calculation that had not yet been done. As an application it led to new and successful predictions for the charm quark deep inelastic scattering total cross section at small x in the dipole model.

A broad research programme on phase transitions in the early universe was among the highlights of the Theoretical Cosmology research project. Research included turbulence generation, vorticity, and formation of so-called 'hot droplets' of matter. These features affect the generation of gravitational waves in the early universe, which can potentially be measured in future gravitational wave detectors.

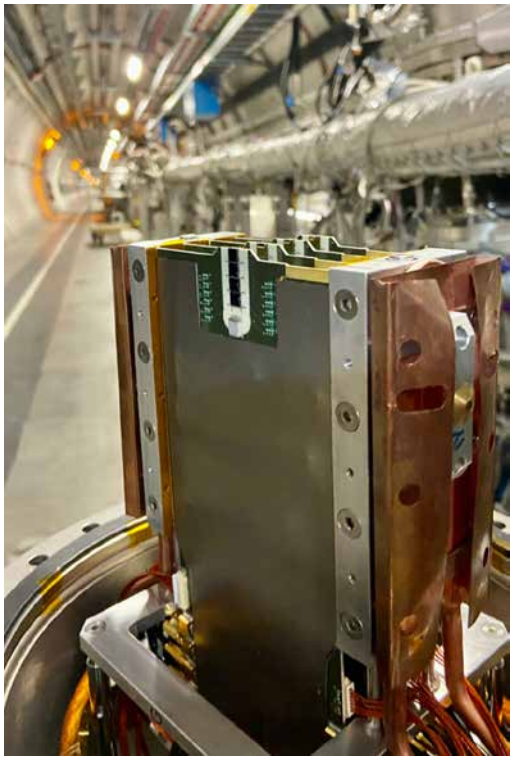
In the Designer Topological Matter project one of the main research themes was quantum entanglement in many-body systems. In a high-profile work, published in *PRX Quantum*, the group members showed how the entanglement in these systems can mimic features of finite temperature.



[A. G. Moghaddam, K. Pöyhönen, and T. Ojanen, PRX Quantum 3 (2022) 030335].



© Nature.



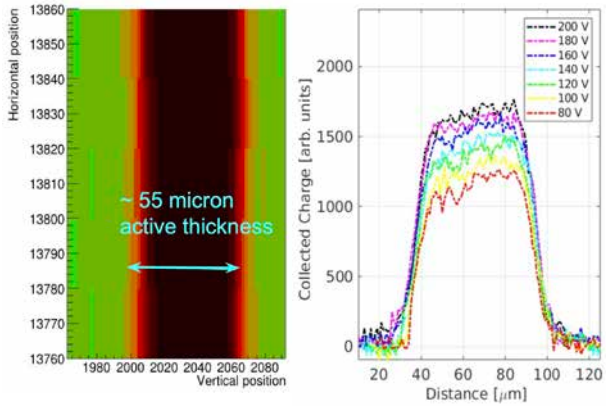
Credit: N. Turini.

CMS Programme

CMS is a general-purpose experiment at the Large Hadron Collider (LHC). The overall CMS highlights were celebrations of the Higgs boson discovery turning 10 years and the CMS experiment 30 years, as well as presenting the first Run 3 measurement (top quark pair cross section).

HIP contributed to *new physics searches* (Higgs bosons and supersymmetry), *precision physics with jets* (top quark mass m_t and strong coupling constant), and *vector boson scattering*. In 2022, the focus was on quickly validating the first Run 3 data. *CERN Courier* highlighted the precise m_t measurement and jet energy corrections, both with strong HIP connections. M. Voutilainen became Jets and Missing Energy and H. Kirschenmann Top Mass and Properties convener. M. Voutilainen got an ERC Consolidator Grant for Jet Energy Correction at High-Luminosity LHC (JEC4HL-LHC).

The upgraded CMS pixel detector, for which HIP made the quality assurance of all bare modules for the new innermost layer, provided high quality data during the 2022 LHC run. The focus has turned to the planning of the Phase-2 pixel tracker upgrade. The Minimum Ionizing Particle Timing Detector Endcap Timing Layer (MTD-ETL) construction is in a market survey phase of the sensor procurement. The Business Finland-funded spin-off project Detector for nuclear safety, decommissioning and diagnostic applications (DeNuSa) is ongoing.



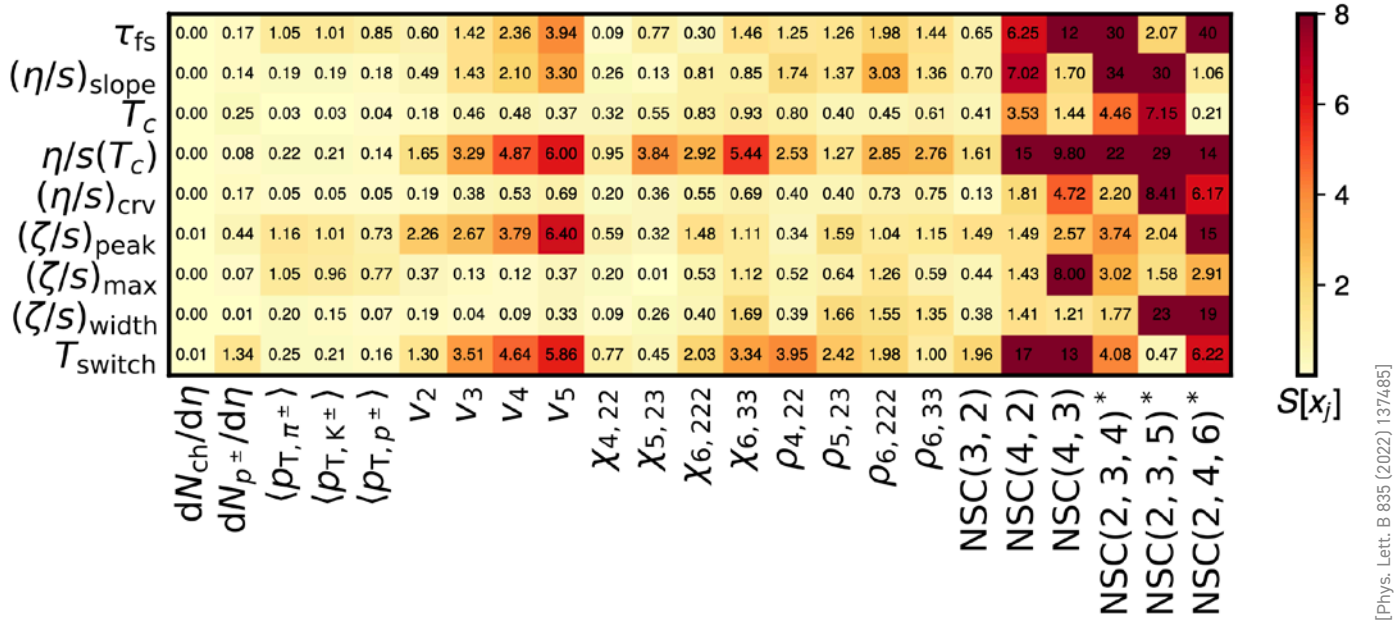
Credit: E. Brücken.

TOTEM is a forward physics experiment at the LHC. In 2022, the tiles for the four new TOTEM T2 detector quarters were produced and tested at CERN SPS showing excellent performance. The first part of the CMS Proton Precision Spectrometer time-of-flight detector was installed for the 2022 LHC run and the diamonds to complete the second part have been prepared and tested in view of an installation for the 2023 run.

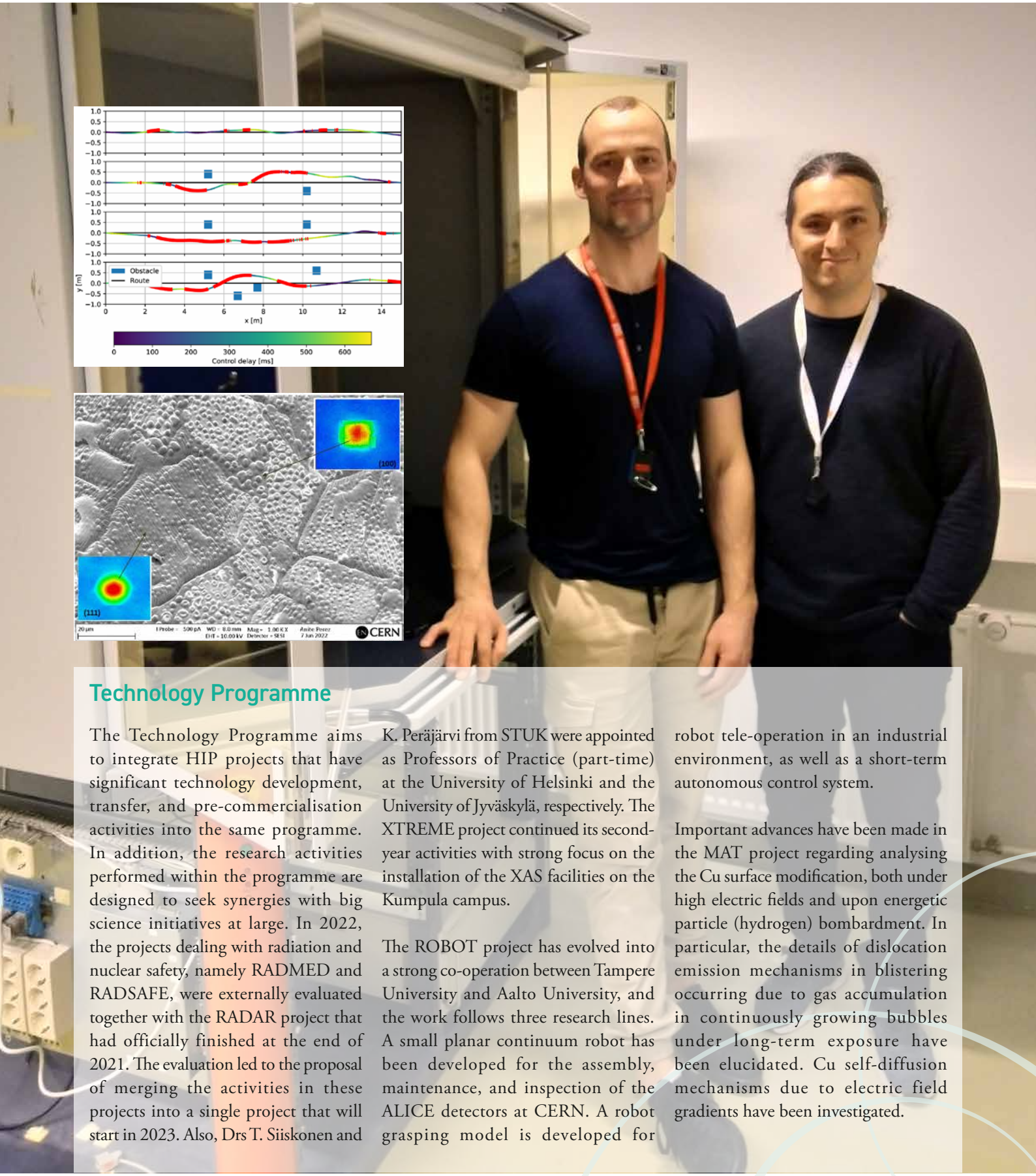
Nuclear Matter Programme

In 2022, the Jyväskylä ALICE group continued to improve our understanding of the QCD matter properties with a new flow measurement [*Phys. Lett. B 834 (2022) 137393*] as well as a Bayesian analysis [*Phys. Lett. B 835 (2022) 137485*] which utilises experimental measurements. These new flow observables quantifying the correlations between mean transverse momentum and anisotropic flow coefficients will provide new insight into the initial conditions. The Bayesian analysis confirmed that flow measurements are crucial to reduce uncertainties of extracted matter properties.

A precision laser spectroscopy experiment was performed at ISOLDE to probe the behaviour of nuclear moments of neutron-rich indium isotopes, which are textbook examples of where the nuclear properties are dominated by effects arising from the behaviour of a single unpaired proton hole. Abrupt changes in the electric quadrupole and magnetic dipole moments were found at the magic neutron number 82. The inclusion of time-symmetry-breaking mean fields is needed to reproduce the observed results in a combination of two extensive and complementary nuclear many-body calculations. The results were published in *Nature* with W. Gins and R. de Groote as co-authors [*Nature 607 (2022) 260*].



[Phys. Lett. B 835 (2022) 137485]



Technology Programme

The Technology Programme aims to integrate HIP projects that have 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. In 2022, the projects dealing with radiation and nuclear safety, namely RADMED and RADSAFE, were externally evaluated together with the RADAR project that had officially finished at the end of 2021. The evaluation led to the proposal of merging the activities in these projects into a single project that will start in 2023. Also, Drs T. Siiskonen and K. Peräjärvi from STUK were appointed as Professors of Practice (part-time) at the University of Helsinki and the University of Jyväskylä, respectively. The XTREME project continued its second-year activities with strong focus on the installation of the XAS facilities on the Kumpula campus.

The ROBOT project has evolved into a strong co-operation between Tampere University and Aalto University, and the work follows three research lines. A small planar continuum robot has been developed for the assembly, maintenance, and inspection of the ALICE detectors at CERN. A robot grasping model is developed for robot tele-operation in an industrial environment, as well as a short-term autonomous control system.

Important advances have been made in the MAT project regarding analysing the Cu surface modification, both under high electric fields and upon energetic particle (hydrogen) bombardment. In particular, the details of dislocation emission mechanisms in blistering occurring due to gas accumulation in continuously growing bubbles under long-term exposure have been elucidated. Cu self-diffusion mechanisms due to electric field gradients have been investigated.

THEORY PROGRAMME

In 2022, the Theory Programme consisted of four research projects, spanning scales from elementary particles up to the whole universe: High Energy Phenomenology in the LHC Era, QCD and Strongly Interacting Gauge Theory, Theoretical Cosmology, and Designer Topological Matter. For the first two projects mentioned above, 2022 was the last year of operation, and these are replaced by two new projects in 2023.

KARI RUMMUKAINEN
Theory Programme director

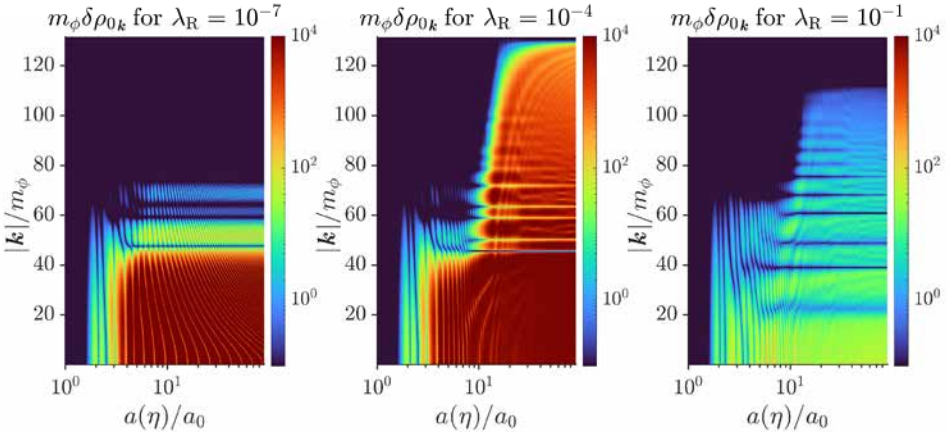
Theoretical Cosmology

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 explored microscopical models for inflation based on gauge theories and non-minimal gravitational sectors. We made new progress in understanding important out-of-equilibrium systems during inflation and the subsequent reheating process. In particular, we applied novel quantum transport machinery to study weakly coupled scalars in reheating and found new non-perturbative phenomena which can have important effects on the dark matter component in the universe. We also developed new 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 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, studied holographical models for phase transitions, and investigated connections between cosmological phase transitions and the superfluid He3 AB transition. We work broadly on supermassive black holes in galactic centres that are an important GW source from later times in the history of the universe. This year, we have been applying the locally developed KETJU code to run accurate simulations of supermassive black holes and black hole binaries together with the global galaxy dynamics, and also constrained simulations of local structures.



Evolution of the momentum space structure of the two-point function of a non-minimally coupled spectator scalar during reheating. *[K. Kainulainen, O. Koskivaara, and S. Nurmi, arXiv:2209.10945].*

High Energy Phenomenology in the LHC Era

The primary objective of the High Energy Phenomenology (HEP) project, active in 2014–2022, has been to perform cutting-edge theoretical research on high-energy physics topics that are timely and relevant due to a close connection to one or several ongoing experimental efforts. The nine year project has indeed achieved a number of milestone observational results, but unlike originally anticipated, the majority of them did not originate from the Large Hadron Collider but rather from gravitational and strong-interaction physics. Indeed, spearheaded by the first detections of gravitational waves from the mergers of two black holes in 2015 and two neutron stars in 2017, this era has been defined by the opening of an entirely new window into extreme astrophysical systems. This fact has been clearly reflected in the activities of the project that have gradually shifted towards the study of extreme matter and gravity via neutron stars and black holes.

To provide a more detailed look into our activities during 2022 – where this shift is clearly visible – let us next describe two highlight results that have emerged from the project during the past year.

In a study published in *Physical Review X* in March 2022, *E. Annala, A. Vuorinen*, and their collaborators studied the impact of recent neutron-star observations on the equation of state (EoS) of cold and dense strongly interacting matter. The new measurements added to their model-agnostic EoS inference setup included a 2021 radius measurement of a massive pulsar by the NICER Collaboration and information on the likely formation of a black hole in the famous GW170817 neutron-star merger. These novel constraints were seen to dramatically reduce the current uncertainty in the behaviour of ultradense Quantum Chromodynamics matter and to significantly strengthen earlier evidence for the presence of deconfined quark matter in the inner cores of the most massive stable neutron stars.

In another article published in *Physical Review D* in September 2022, project members *N. Jokela, K. Kajantie, and M. Sarkkinen* analysed the gravitational wave memory effect in a Friedmann-Robertson-Walker universe containing both matter and a non-zero cosmological constant. The main finding of this work was the identification of a previously undiscovered component in the stochastic gravitational wave background of the universe, which arises from the so-called 'tail part' of the memory effect. This non-linear effect was identified by studying induced gravitational radiation produced by first-order gravitational radiation propagating over cosmological distances. The potential implications of this discovery are currently unclear and will be further explored in future research.

ALEKSI VUORINEN
High Energy Phenomenology in the LHC Era project leader

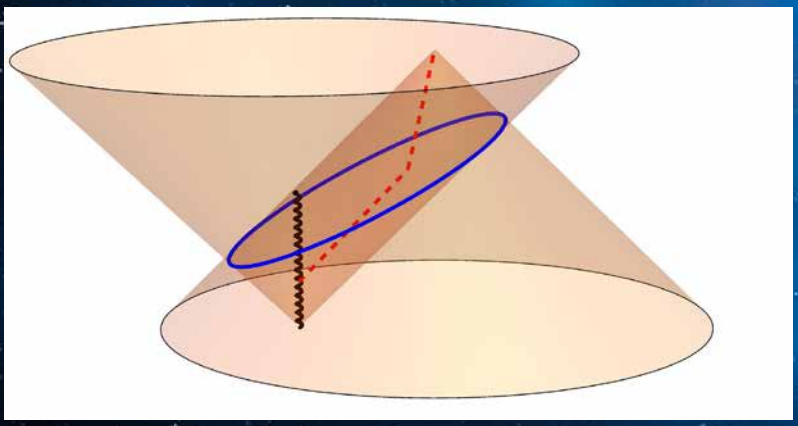


Illustration of the generation of gravitational waves (GWs) from a black hole binary coalescence (black wiggly line), with the direction of time pointing upwards. The red dashed line represents the main GW signal first emitted from the binary and propagating at the speed of light, which sources a subluminal tail GW that travels to the detectors at the tip of the cone. The observation discovered in this work shows that two free-falling detectors will continue drifting apart (tail memory effect) even after the main GW has passed. *[N. Jokela, K. Kajantie, and M. Sarkkinen, Phys. Rev. D 106 (2022) 064022].*

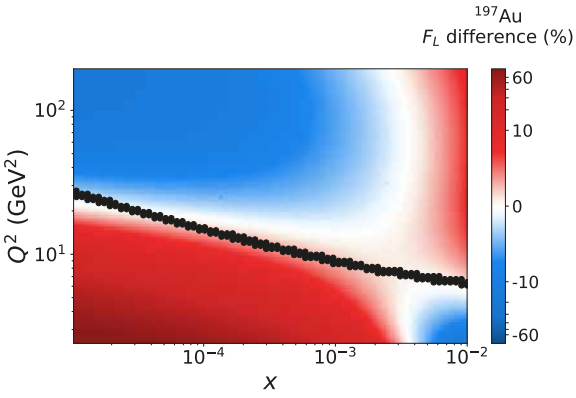
TUOMAS LAPPI
QCD and Strongly Interacting Gauge Theory project leader

QCD and Strongly Interacting Gauge Theory

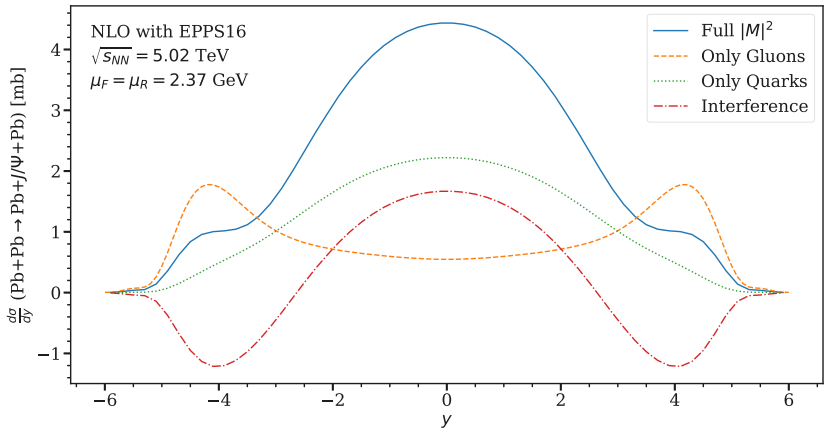
Our work revolves around different aspects of QCD at high energy and density. In addition to the phenomenology of high-energy nuclear collisions at the LHC and RHIC, we are involved in physics studies for planned colliders such as the EIC and FCC. We use weak coupling QCD renormalization group equations to study the partonic structure of hadrons and nuclei. We then use this information to understand the formation of a thermalized quark gluon plasma in heavy ion collisions and model its subsequent evolution using relativistic hydrodynamics.

The DGLAP equations describe the scale dependence of parton distributions (PDFs) in protons and, as our particular expertise, nuclei. The year 2022 marked the publication of our new nuclear PDFs set EPPS21. The BK evolution equation, in turn, describes the energy dependence of QCD cross sections at high energy. In 2022, we published our result for the virtual photon to quark-antiquark light cone wavefunction at one loop with massive quarks and used the result to obtain a good description of HERA heavy quark cross section data. We also quantified the power of future EIC measurements of inclusive cross sections to distinguish between BK and DGLAP evolution scenarios. We study exclusive vector meson production in photon-mediated collisions using several different approaches. In the high energy BK formulation, we were the first to calculate this process at NLO accuracy. In collinear factorisation we published the first NLO calculations of J/Psi photoproduction in LHC heavy ion collisions, quantifying the scale and PDF uncertainties, as well as the gluon and quark contributions. A new complete physics manual for PYTHIA, the leading general-purpose Monte Carlo event generator for particle physics, was published in 2022, with major contributions from our group.

To describe the formation of quark gluon plasma, we use two complementary QCD approaches. In the Colour Glass Condensate picture in terms of a strong classical gluon field, we studied how the hot spot structure of the field can be constrained by deep inelastic scattering data. We also model the initial stages of heavy ion collisions starting from perturbative quark and gluon scattering complemented with a saturation conjecture. These initial conditions are then used in our event-by-event hydrodynamical studies of heavy ion collisions, where in 2022, we focussed on developing methods for multicomponent fluids and a better dynamical treatment of the freezeout to non-interacting particles. We also launched studies of describing collective phenomena with machine learning.



Relative difference between the nuclear longitudinal structure function from the BK gluon saturation and DGLAP linear evolution approaches, in the deep inelastic scattering kinematical plane.



Contributions of quarks, gluons, and the interference between them to the exclusive J/Psi meson photoproduction cross section at LHC energies.

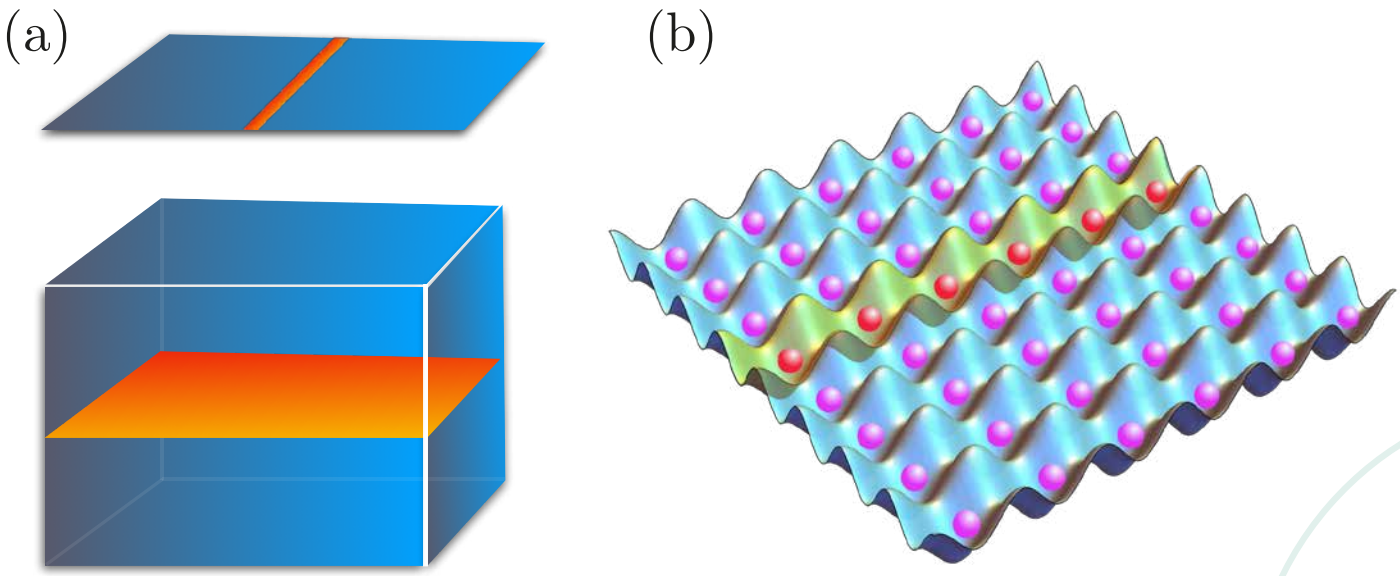
Designer Topological Matter

TEEMU OJANEN
Designer Topological Matter project leader

We study many-body systems, such as topological materials and quantum devices, which exhibit rich collective quantum behaviour. Recently, our focus has shifted towards the universal quantum information processes underlying the many-body systems. Quantum information and entanglement have emerged as the unifying concepts in contemporary research to understand a large variety of different systems from quantum computers to black holes. Our aim is to gain better fundamental understanding of complex quantum systems, as well as explore their potential for applications.

The main research themes initiated in 2022 revolved around quantum entanglement in many-body systems and its consequences on various observable properties. We established the generic link between fluctuations of conserved quantities and the entanglement entropy scaling laws. In the ongoing work, we are exploring further consequences of this link to probe various aspects of entanglement through fluctuations.

In the high-profile work published in *PRX Quantum,* we showed how quantum entanglement in many-body systems can mimic the properties of finite temperature. It is known that in certain circumstances, such as in the vicinity of a black hole, vacuum fluctuations give rise to an effective temperature. In our work, we show that in the ground state of gapped Dirac fermion systems, the density matrix of lower-dimensional subsystems effectively takes a Gibbs form with finite temperature. We propose that the phenomenon could be directly observed in ultracold atomic gases and explain how the lower-dimensional thermal subsystems are intimately connected to the dimensional hierarchy of topological insulators. Our work sheds new light on many-body entanglement and fundamentals of statistical physics.



Entanglement-induced thermal subsystems embedded in a *D*-dimensional Dirac fermion system at zero temperature. (a) Examples of lower-dimensional thermal subsystems embedded in 2D and 3D parent states. When the full system is in the ground state of the total system Hamiltonian, the reduced density matrix of the subsystem has a thermal form. (b) Thermal state emerging from vacuum entanglement could be observed in cold-atom quantum simulators by probing particle fluctuations in the one-dimensional subsystem.
[A. G. Moghaddam, K. Pöyhönen, and T. Ojanen, PRX Quantum 3 (2022) 030335].

CMS PROGRAMME

KENNETH ÖSTERBERG
CMS Programme director

The HIP CMS Programme co-ordinates the Finnish participation in the CMS and TOTEM experiments at the Large Hadron Collider (LHC). The Compact Muon Solenoid (CMS) is a general-purpose detector 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, located at the same LHC interaction point as CMS, is devoted to forward physics, focussing on elastic scattering, total cross section, diffractive and exclusive processes. The programme has four projects: 1) the CMS Experiment project for physics analysis and operation; 2) the CMS Upgrade project for detector upgrades; 3) the Tier-2 Operations project for LHC computing; and 4) the TOTEM project for CMS and TOTEM forward physics. The Finnish groups in CMS are: HIP (currently 17 authors); the Department of Physics at the University of Helsinki (3 authors); and Lappeenranta-Lahti University of Technology (3 authors). TOTEM presently has 8 HIP authors, of which 6 are also affiliated with the Department of Physics at the University of Helsinki.

MIKKO VOUTILAINEN
CMS Experiment project leader

CMS Experiment

Introduction and Highlights

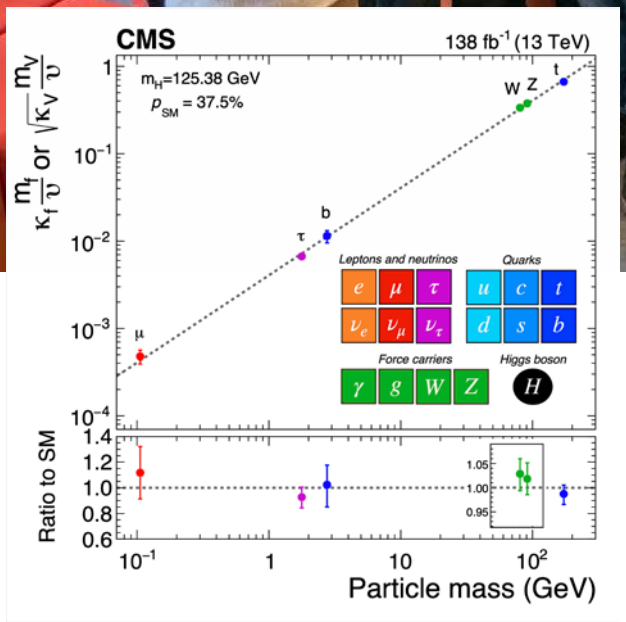
The LHC is in a unique position to explore electroweak symmetry breaking and the origins of the universe. The CMS Experiment project is focussed on analysis of the LHC data, particularly of new physics searches (charged Higgs bosons, supersymmetry), precision measurements with jets (top quark mass m_t,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

The focus of 2022 was on quickly validating the first data from Run 3, which commenced in April. In parallel, precision analyses continued on Run 2 Legacy data. We received an ERC Consolidator Grant for Jet Energy Correction at High-Luminosity LHC (JEC4HL-LHC) and the SMARTHEP International Training Network started in October, with a new PhD student P. Inkaew recruited from Stanford. M. Lotti (now at SimCorp) and H. Siikonen (now at Planmeca) successfully defended their theses on searching for charged Higgs bosons and a very precise m_t measurement, respectively.

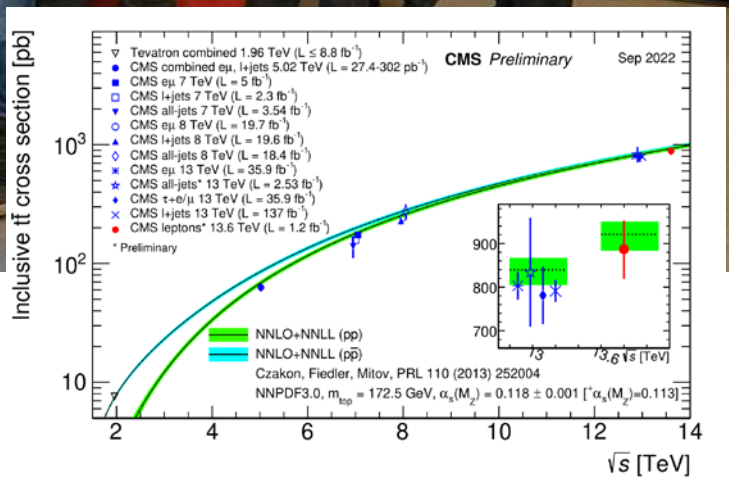
HIP maintained its strong scientific leadership at CERN: T. Lampén continued as PCL manager and M. Kim (also at GWNU in South Korea) as Jet Energy Resolutions and Corrections convener, while M. Voutilainen became Jets and Missing Energy and H. Kirschenmann Top Mass and Properties convener.

Overall, the CMS highlights of the year were the celebrations of the Higgs boson discovery turning 10 years and the CMS experiment 30 years as well as a first direct search of the Higgs decaying to charm quarks. The JEC and m_t were both highlighted in *CERN Courier*, and the first Run 3 measurement (top quark pair cross section) was made public.

The HIP CMS Experiment team celebrating the awarding of the ERC Consolidator Grant for Jet Energy Corrections at High-Luminosity LHC in March 2022. *Credit: J. Aaltonen.*

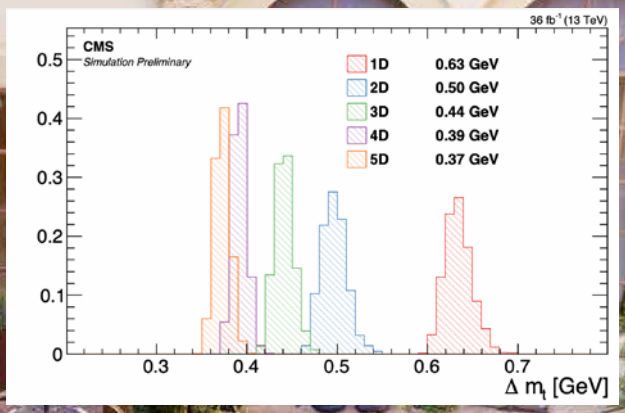


Summary of the Higgs boson coupling to the masses of the elementary particles, 10 years after the Higgs discovery. © *Nature.*



The top quark cross section measurement at 13.6 TeV (first Run 3 measurement). © *CMS Collaboration, CERN.*

CMS 30 Years Symposium social event in building 40 at CERN in December 2022. © *CMS Collaboration, CERN.*



The improvement of the precision of the top quark mass from the 2016 data when applying a new profile likelihood method and adding more observables to the measurement. *© CMS Collaboration, CERN.*

Detector Operations

The PCL group re-commissioned the PCL for Run 3 and the JEC group provided the first set of calibrations for Run 3 prompt data, migrating to Pileup Per Particle ID (PUPPI) as the central reconstruction algorithm. The new AlCaRaw stream was also set up for trigger-level JEC. The JetMET Algorithms and Reconstruction group derived the first quark-gluon discrimination scale factors for the Run 2 Legacy data, while 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.

Precision Measurements

Measurements of m_t (M. Myllymäki, H. Siikonen), the inclusive jet cross section (L. Martikainen), and gluon jet production continued on the full Run 2 data set, aiming at constraining m_t and α_s in exploration of Standard Model (SM) vacuum stability. The new most precise measurement of the top quark mass at 171.77 ± 0.38 GeV using 2016 data was made public [*CMS-PAS-TOP-20-008*], and H. Siikonen defended his thesis demonstrating a path to a 0.19 GeV m_t precision using 2017 and 2018 data.

New Physics Searches

M. Lotti defended his PhD thesis on the search of charged Higgs bosons in the WH final state, while the search continued on the full Run 2 data in the $\tau\nu$ channel (S. Lehti). Search for doubly-charged Higgs bosons in a same-sign double-τ final state started as a MSc thesis of R. Öhrnberg with the HIP Theory group, and the SUSY search for a gluino pair to $t\bar{t}t\bar{t}$ (K. Kallonen) was published. These channels allow exploration of electroweak symmetry breaking in the search for physics beyond the Standard Model and candidates for dark matter.

Vector Boson Scattering

The HIP team applied for a VBS-related COST action and was involved in both the first analysis of VBS in the all-hadronic final state using Run 2 data that is currently in CMS-internal review, and in preparations for the Run 3 measurement. ●

CMS Upgrade

PANJA-RIINA LUUKKA
CMS Upgrade project leader

Introduction

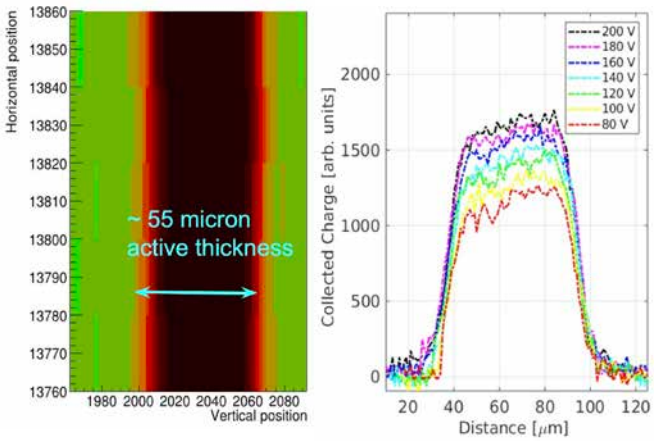
The Large Hadron Collider (LHC) is the world's largest and most powerful particle collider. It will be upgraded to the High-Luminosity LHC (HL-LHC) to extend its potential to test the validity of the Standard Model and to search for new physics at the energy frontier. The objective is to increase its luminosity by a factor of 5 to 7 beyond the design value, and consequently the LHC experiments must be upgraded to meet the requirements for detector performance.

Pixel Detector Upgrade

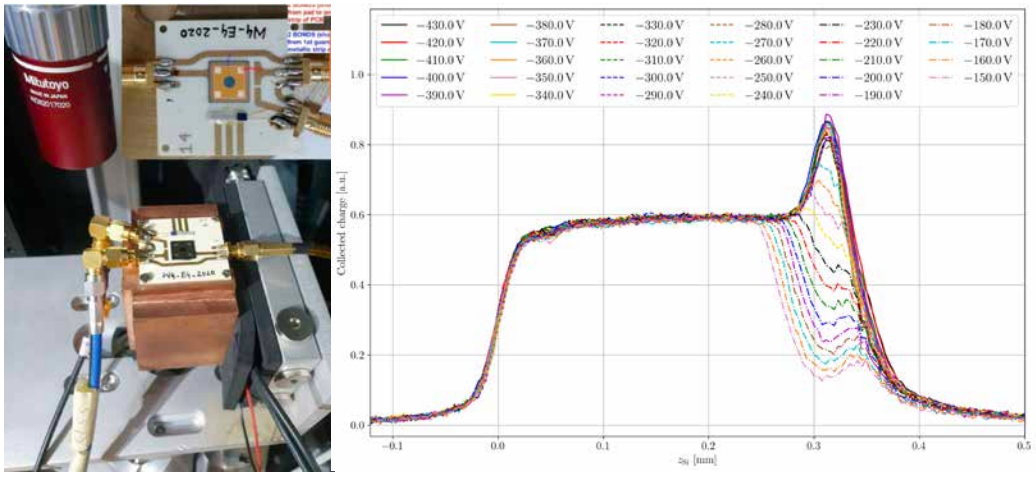
Finland has been strongly involved in the intermediate upgrades of the innermost pixel detector in past years. The innermost layer of the pixel detector was replaced in the latest upgrade during 2019–2021. The commissioning of the upgraded detector started in October 2020 and was successfully finished in summer 2021. The first data with the refurbished pixel detector was obtained from the LHC pilot run in 2021. In 2022, when the LHC Run 3 finally started, the pixel detector has been a fundamental part in obtaining high quality data. Currently the HIP CMS Upgrade and LUT Particle Physics Instrumentation teams have actively started to plan for the Phase-2 upgrade of the pixel detector. In this upgrade, Finland will participate in the testing, building, and calibration of the Inner Tracker TEPX pixel detector together with the Paul Scherrer (Switzerland) and Ruđer Bošković (Croatia) Institutes.

Minimum Ionizing Particle Timing Detector Endcap Timing Layer (MTD-ETL)

In the MTD-ETL construction project, our group has significantly contributed to the qualification of the pre-production runs of the Low Gain Avalanche Detectors (LGAD), which is the chosen technology for the MTD-ETL. LGADs were tested locally at the HIP Detector Laboratory using various methods that helped in optimising the detector design. This was followed by the ongoing market survey, which is expected to conclude in early 2023. During 2023, the tendering process for the manufacturing of the final sensors for the detector production is expected to start.



An edge-Transient Current Technique scan of a 55-micrometer thick LGAD detector using an infrared laser done for the MTD-ETL market survey: spatial homogeneity (left) and charge collection profile (right). *Credit: E. Brücken.*



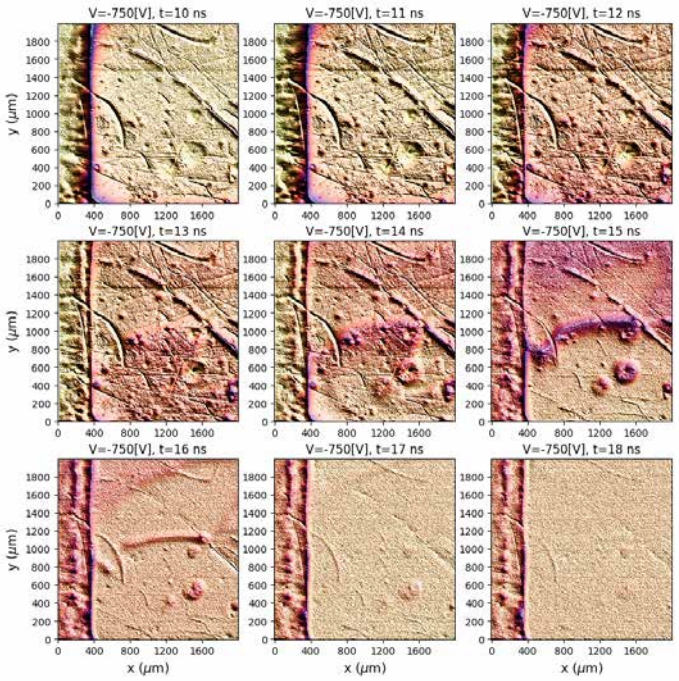
A two-photon absorption Transient Current Technique measurement of a Micronova-fabricated silicon detector at CERN using a setup of the RD50 Collaboration: measurement setup (left) and charge collection profile (right). *Credit: S. Bharthuar.*

← CMS Jet and Missing Energy Workshop in Florence in April 2022, which was the first CMS in-person meeting after the COVID-19 pandemic with strong HIP participation. *Credit: M. Voutilainen.*

Detector R&D and Spin-Off Projects

One of the largest collaborative spin-off projects, Multispectral Photon-Counting for Medical Imaging and Beam Characterization (MPMIB), was concluded at the end of 2021. The last publications from this project were finished during 2022. Even after the project was completed, a strong collaboration between the participants continues.

Another, currently ongoing, project that is based on the detector R&D of the CMS Upgrade group is 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. This project started in July 2021 and is continuing until the end of March 2023. M. Golovleva successfully defended her PhD on simulations of defects in semiconductor detectors.



The time evolution of transient currents on the surface of a Ti/CdTe detector. *Credit: M. Bezak.*

TOMAS LINDÉN
Tier-2 Operations project leader

Tier-2 Operations

The HIP WLCG resources are run in collaboration between HIP, 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 2022 with excellent availability. The CMS Site Readiness Status average value was 91% (65% in 2021). T. Lindén represented HIP in the NeIC Nordic LHC Computing Grid (NLCG) steering committee as chairman. M. Myllymäki worked 10% in the Tier-2 project. There were 12 Global Grid User Support tickets (38 in 2021) concerning HIP.

The CMS jobs were run on the Linux cluster Kale (672 dedicated cores from 2015). The usage of local disk solved the 2021 ZFS/NFS performance problem. The problem with unrealistic high CPU efficiency was fixed. The OpenHPC image was optimised by moving the CVMFS area from RAM to disk to increase the usable RAM for jobs. The dCache services at CSC were stable. The performance of the dCache Postgres was optimised, which increased the CPU efficiency of jobs.

The NLCG LUMI task force worked on a pilot setup to achieve a technical plan to enable WLCG computing on the LUMI supercomputer. The storage servers and a switch for the new dCache system purchased with Academy of Finland FIRI funding were delivered by DELL at the end of the year.

In 2022, 1018 TB of data was transferred to HIP and 780 TB from HIP to elsewhere (948 TB to HIP and 348 TB from HIP in 2021). A total of 0.13 million CMS grid jobs (0.17 million in 2021) using 49 MHS06 CPU hours (37 MHS06 in 2021) were run with an average CPU efficiency of 57% (89% in 2021).

TOTEM

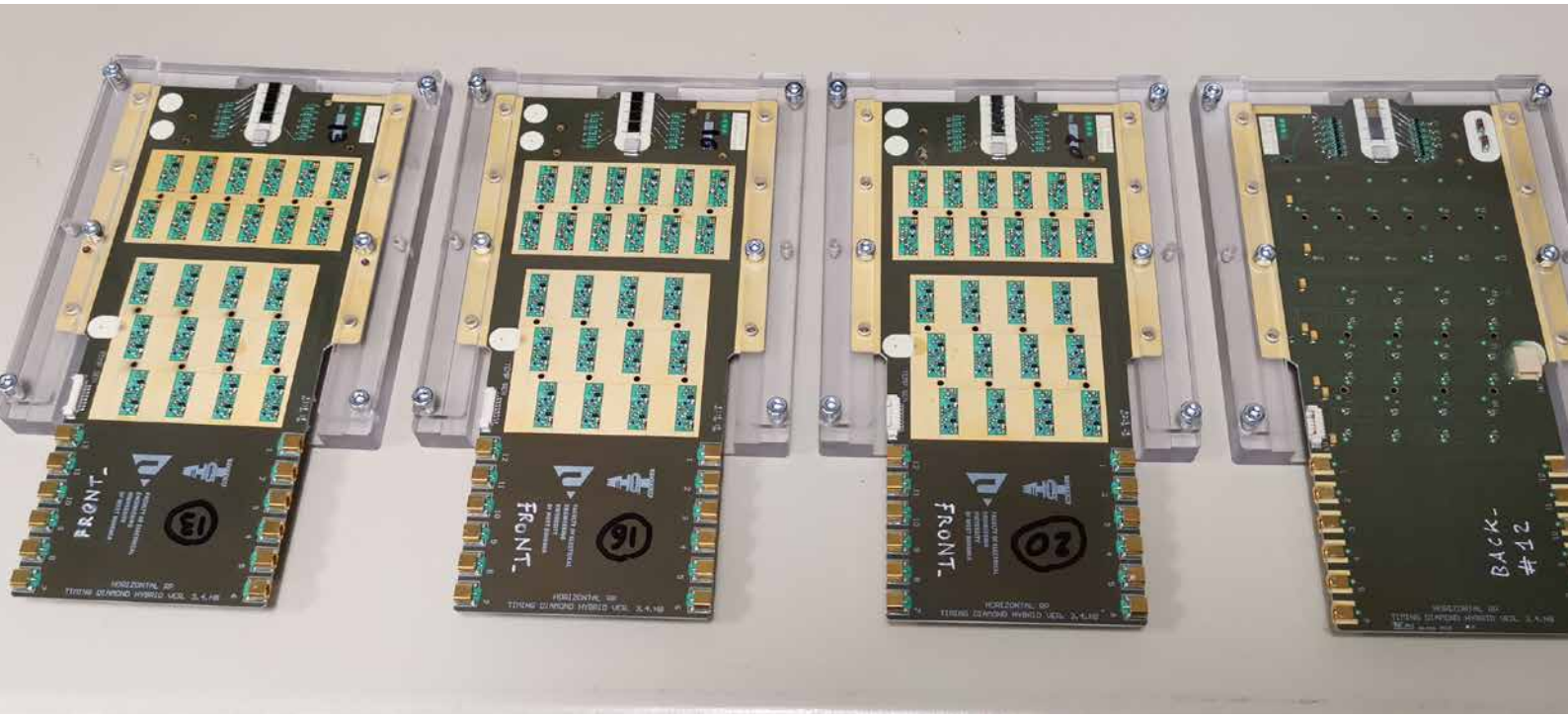
KENNETH ÖSTERBERG
TOTEM
project leader

Introduction

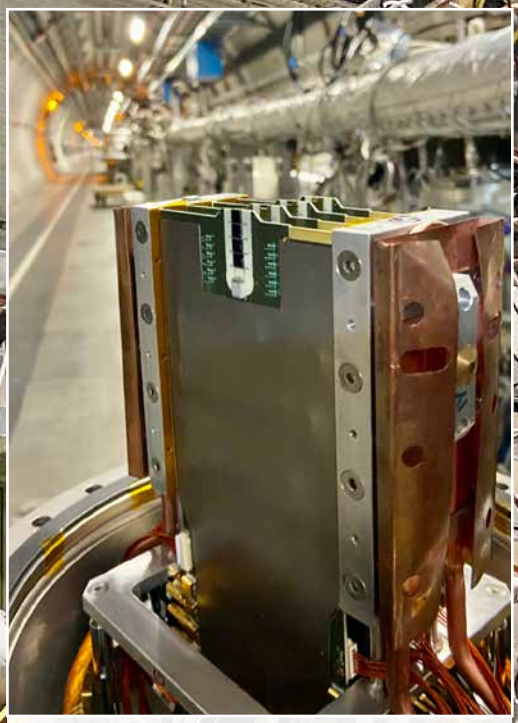
The TOTEM project is responsible for the Finnish TOTEM and CMS forward physics contributions. In 2022, the group consisted of Professor K. Österberg, Professor Emeritus H. Saarikko, senior scientist F. Garcia, post-doc F. Oljemark, and PhD student M.-M. Rantanen. The focus in 2022 was on Run 3 detector upgrades, as well as physics analysis and publications of Run 2 data. K. Österberg continued co-ordinating the TOTEM physics and F. Garcia the CMS Proton Precision Spectrometer (PPS) test beam activities.

Detector Upgrades

For the Run 3 PPS time-of-flight (TOF) detector, HIP plays a key role for the diamond sensor purchase, metallization, and quality assurance (M.-M. Rantanen, P. Koponen, K. Österberg, F. Garcia). Applied Diamond, Inc. produces diamond metallization of good quality allowing for an installation of three additional TOF planes per arm in the LHC tunnel during winter 2023 in addition to the four planes per arm already installed in spring 2022. Due to problems with the PPS tracking detectors, the PPS data taken in 2022 is not good enough for physics analysis. HIP is responsible for producing and testing the scintillator tiles (F. Garcia, R. Turpeinen, M.-M. Rantanen) as well as developing the software (F. Oljemark) for the TOTEM new T2 (nT2) detector. In 2022, the remaining tiles to complete the four nT2 quarters were produced and tested at CERN SPS showing excellent performance. The nT2 will be used for a 13.6 TeV total cross section measurement in an upcoming dedicated special run postponed to 2023. In view of the longer-term future, HIP is also involved in the preparations of an HL-LHC PPS upgrade.



CMS PPS time-of-flight detector planes prior to the module assembly inside a Roman Pot. *Credit: F. Garcia.*

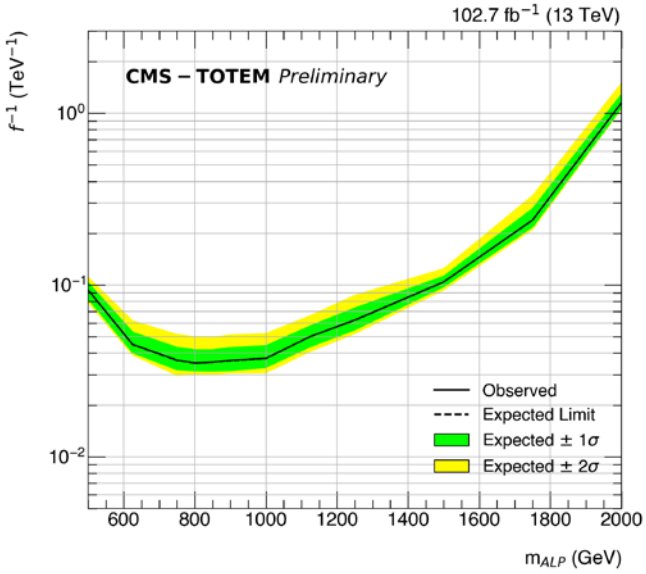


A CMS PPS time-of-flight detector module in the LHC tunnel before installation in one of the PPS Roman Pots. *Credit: N. Turini.*

A CMS PPS time-of-flight detector module mounted inside a Roman Pot under test in the CERN SPS H8 test area prior to the LHC tunnel installation. *Credit: F. Garcia.*

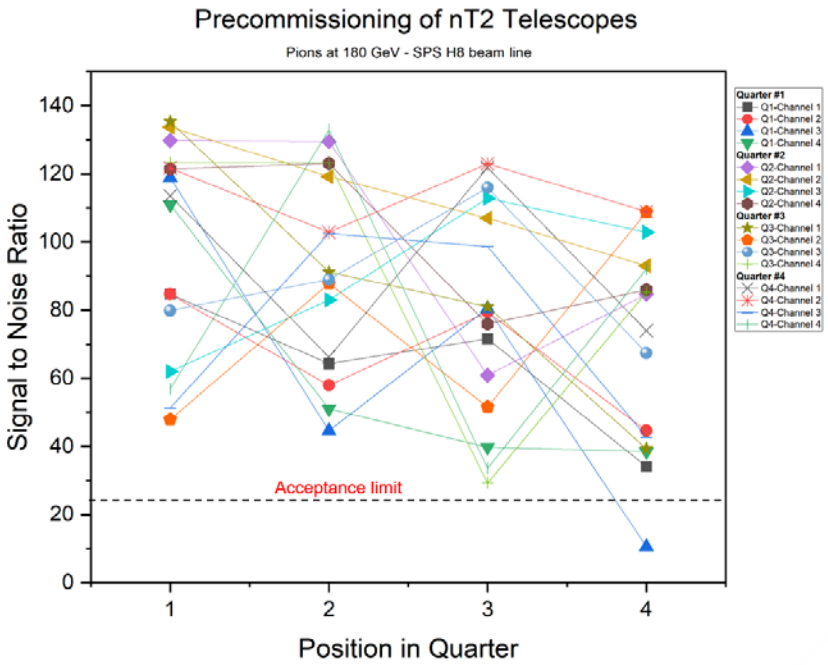
Physics

In 2022, the group continued studying glueball candidates in low mass exclusive meson production and effects of Odderon exchange in elastic scattering. TOTEM published the observation of the diffractive minimum and secondary maximum in 8 TeV elastic proton-proton collisions. Regarding PPS physics, CMS and TOTEM published the first limits on anomalous four-photon couplings from a search for exclusive diphoton events at high mass with measured protons using 2016 data. During 2022, CMS and TOTEM also made public results on searches for exclusive photon, W and Z pair production at high mass using the whole Run 2 PPS data set as well as searches for exclusive top quark pair and Z/photon + X production using 2017 PPS data. In the latter, the mass of X is reconstructed from the kinematics of the boson and the two protons.



Limits on the mass of an axion-like particle as a function of its coupling to the photon derived from a search for high mass exclusive diphoton production. *© CMS and TOTEM Collaborations, CERN.*

Two quarters of the new TOTEM T2 assembled and tested at CERN. *Credit: F. Garcia.*



The signal to noise ratio of each new TOTEM T2 scintillator tile as measured with minimum ionizing particles at the CERN SPS. *Credit: F. Garcia.*

NUCLEAR MATTER PROGRAMME

ARI JOKINEN
Nuclear Matter Programme director

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.

SAMI RÄSÄNEN
ALICE project leader

ALICE

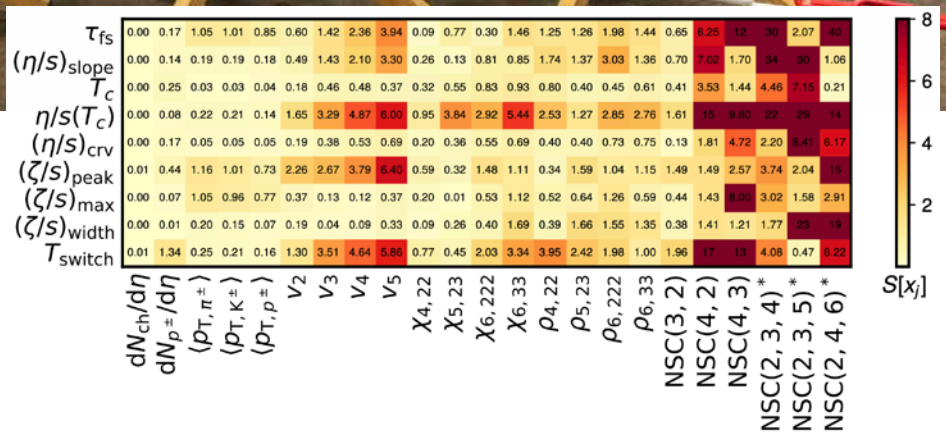
ALICE (A Large Ion Collider Experiment) is one of the four big CERN experiments studying hadron collisions using the Large Hadron Collider (LHC). The 3rd LHC running period, Run 3, started on 5 July 2022, after a three-year-long upgrade period. The improved ALICE setup is now capable of triggerless operation, beneficial for example for studying thermal electromagnetic radiation or heavy-flavoured hadrons at low momenta. In addition, the modified ALICE setup will accept 50 times higher interaction rates and record all minimum bias (MB) Pb-Pb collisions. As a result, in 2022, ALICE collected over 300 times more MB pp-data than during Run 1 and Run 2 combined!

Due to the energy crisis resulting from the Russian invasion of Ukraine, the eagerly awaited 2022 Pb-Pb run was cancelled. Fortunately, the running plan for the coming years was adjusted such that the expected Pb-Pb luminosity should not be seriously compromised.

One of the significant improvements in the upgraded ALICE setup is the new Fast Interaction Trigger (FIT). In addition to delivering fast triggers, FIT also provides online luminosity monitoring, determination of the collision time, and an unbiased sample of the forward multiplicity needed to extract the centrality and the reaction plane of the colliding heavy ions. The Finnish team leads the FIT Collaboration of 19 institutions from 9 countries. In 2022, two members of our group were stationed at CERN full-time, working on the maintenance and operation of the FIT detector, taking expert shifts, co-ordinating software development, and participating in ALICE data-taking and analysis.

The Centre of Excellence (CoE) in Quark Matter funded two new post-doctoral researchers. We continued analysis of collective phenomena in small and large systems to infer QGP matter properties, like shear and bulk viscosities. For example, we completed the first and novel measurements of asymmetric flow correlations. In hard probes, we reached preliminary results for di-jet mass distributions in pp and p-Pb collisions. In the future, this analysis in Pb-Pb collisions will provide constraints for the jet transport coefficient in QGP. We participated in all 2022 test beam campaigns for the new ALICE forward calorimeter (FoCal). FoCal is heading towards the technical design report in which we shall provide performance studies for neutral pions, neutral pion correlations, and jet measurements.

ALICE members celebrating successful heavy ion pilot run in 2022. *Credit: W. H. Trzaska.*



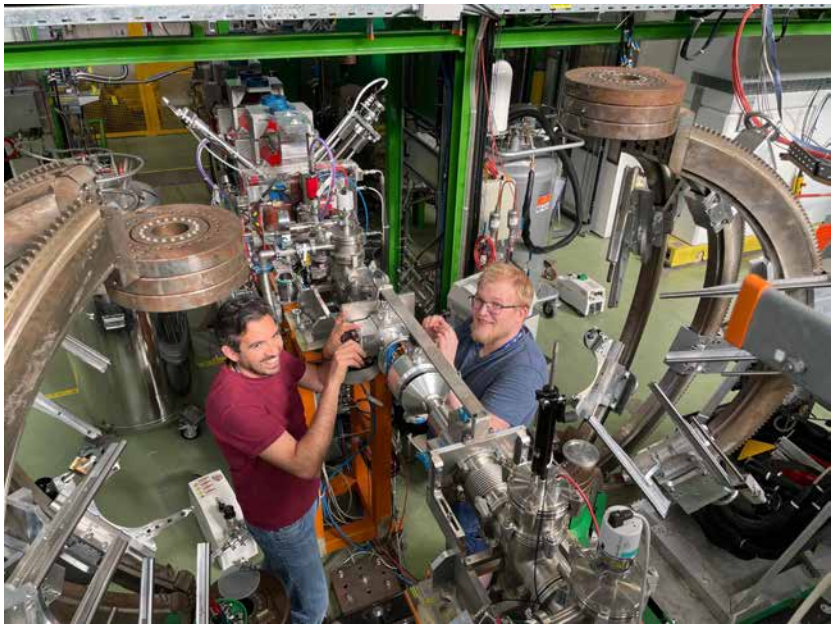
Sensitivity of different flow measurements to QGP matter properties. *[Phys. Lett. B 835 (2022) 137485].*

JANNE PAKARINEN
ISOLDE
project leader

ISOLDE

The ISOLDE facility was in full swing in 2022 after two COVID-19 hampered years. While some measures were still in place, most of the operations were conducted as normal and the HIP contribution to ISOLDE activities was very strong. HIP-affiliated researchers participated in 12 different experiments and J. Pakarinen was granted 8 months of Scientific Associateship at ISOLDE.

The publication highlight of the year was a measurement published in *Nature* by *A. R. Vernon et al.* HIP-affiliated researchers W. Gins and R. de Groote were part of the research team that performed precision laser spectroscopy measurements to probe the behaviour of nuclear moments of neutron-rich indium isotopes. These isotopes have been considered textbook examples where the nuclear properties are dominated by effects arising from behaviour of a single unpaired proton hole. At the magic neutron number 82, they found abrupt changes in the electric quadrupole and magnetic dipole moments. In combination with two extensive and complementary nuclear many-body calculations, they showed that the inclusion of time-symmetry-breaking mean fields is needed to reproduce the observed results.



Former HIP-affiliated researchers P. Papadakis (STFC Daresbury, UK) and J. Ojala (University of Liverpool, UK) setting up the SPEDE spectrometer in the Miniball beam line.

An important milestone was reached at the end of the HIE-ISOLDE campaign when the SPEDE spectrometer was employed, for the first time, in a radioactive beam experiment. This represented years of R&D work conducted in Jyväskylä in close collaboration with the University of Liverpool, UK. SPEDE introduces a novel concept that allows for direct measurement of conversion electrons from radioactive nuclei without the use of transportation magnets. It was designed to work in conjunction with the Miniball germanium detector array for simultaneous observation of electrons and gamma rays. The *successful commissioning in real experimental conditions can be considered as a new opening for future campaigns* and is likely to attract more experiment proposals.

Future Plans

The ISOLDE users community has been steadily growing in the last 15 years and the demand for beam time exceeds current production capabilities. Thus, the ISOLDE Collaboration has initiated the EPIC project (Exploiting the Potential of ISOLDE at CERN) to take full advantage of the recent upgrades at CERN, driven by the LHC Injectors Upgrade. Ambitious plans to expand the ISOLDE facility have been presented in two ISOLDE - EPIC workshops. These plans include a new building for the low-energy branch of ISOLDE with several new target stations and front-ends.

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

TUOMAS GRAHN
FAIR
project leader

FAIR is a new international accelerator laboratory for research with antiparticle and particle beams. It is under construction in Darmstadt, Germany and is a joint effort of an international community of nations and scientists. The mission of FAIR is to shed new light on the scientific questions of great current interest and develop new technologies to advance basic and applied research. The key scientific focus is on understanding the structure and dynamics of subatomic constituents of matter in the universe and how such building blocks came into being.

FAIR will provide high-energy particle and antiparticle beams up to 99% of the speed of light in parallel operation mode. The beams will serve four experiments (science pillars), NUSTAR, CBM, PANDA, and APPA, that have been designed to study multidisciplinary science cases spanning from elementary particles through nuclear physics to material physics and medical applications.

APPA is an umbrella for several collaborations working on Atomic Physics, Plasma and Applied (APPA) sciences that share installations and scientific techniques. The goal of the Compressed Baryonic Matter (CBM) experiment is to explore the QCD phase diagram in the region of high baryon densities using high-energy nucleus-nucleus collisions. The research interest of Nuclear Structure, Astrophysics and Reactions (NUSTAR) is focussed on use of secondary beams for studies of highly unstable atomic nuclei that will be produced by in-flight fragmentation of primary beams and, for the most exotic nuclei, by secondary fragmentation with the Super-FRS separator-spectrometer. The fourth pillar, the PANDA experiment, will carry out research on various topics around the weak and strong forces, exotic states of matter and the structure of hadrons by gathering information from antiproton-proton collisions.

The first experimental programme, FAIR Phase-0, is currently ongoing. It utilises existing accelerators that have been upgraded to FAIR standards. Finland is one of the six FAIR partners that support the Phase-0 experimental programme that will precede the full FAIR operation. Therefore, HIP researchers have been active in participating and steering the experiments at FAIR Phase-0. For instance, Finnish researchers participated in several new experiments (with one as a co-spokesperson) that were selected in the programme advisory committee meeting in 2022.

Notable milestones were achieved in FAIR construction in 2022. The civil construction of the experimental areas is nearing completion for the CBM and NUSTAR experiments. Finland will deliver components and instrumentation for the Super-FRS separator-spectrometer and the NUSTAR experiment. For instance, the conceptual design was completed for the beamline detector components of Super-FRS.

Credit: T. Grahn.

TECHNOLOGY PROGRAMME

FILIP TUOMISTO
Technology Programme director

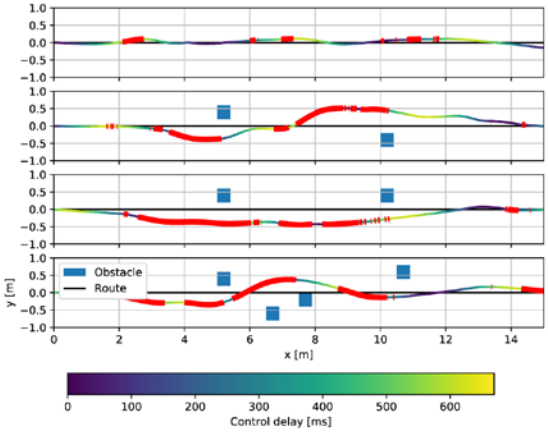
The Technology Programme aims to integrate HIP projects that have significant technology development, transfer, and pre-commercialisation activities into the same programme. In addition, the research activities performed within the programme are designed to seek synergies with big science initiatives at large. The programme consists of 2 larger CERN-focussed projects dealing, on one hand, with robotics for monitoring and intervention purposes in accelerator tunnel conditions and, on the other hand, with materials technology challenges in existing and new large accelerators. In addition, the programme hosts 3 smaller projects that focus on radiation safety and radiation detection technologies in strong co-operation either with STUK or 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.

The robot prototype used in the control delay and object detection experiments.



The trajectories are recorded during an experiment, where connection delay compromises the tele-operation. Red indicates the sections where the robot controlled itself when the tele-operation was compromised.

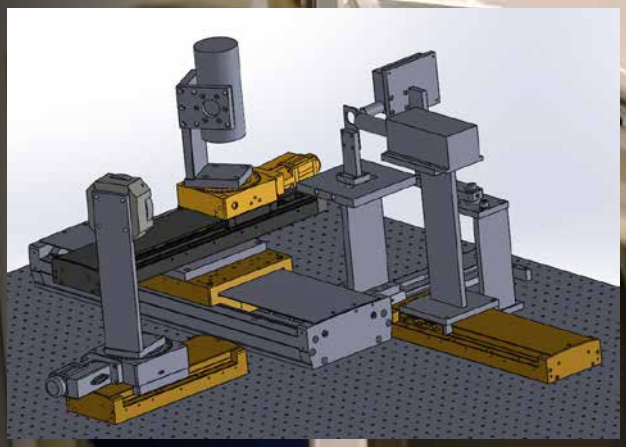
1. *Continuum robot.* Assembly, maintenance, and inspection of the ALICE detector can benefit from robot-assisted tools for better views or for assisted assembly. A small planar continuum robot (35 × 62 × 940 mm) has been developed and improvements to the design are in continuous integration. This work is part of D. Mohamadi's PhD studies and in collaboration with CERN's Experimental Physics Department.

2. *Vision-based grasp pose estimation.* Towards robot tele-operation, a robot grasping model has been developed that can handle novel industrial parts typical in (robotic) maintenance interventions. Data generation for training of a grasping model utilises only simulation and is completely automated. Grasping is evaluated with a 6DOF collaborative robot. This work is part of K. Samarawickrama's PhD studies.

3. *Aiding mobile robot tele-operator with short-term autonomous control system.* Tele-operating is challenging when there is delay fluctuation in the control signal and under sensor noise. A short-term autonomous control system has been developed for a maintenance robot for aiding the tele-operator. Moreover, control strategies, which utilise this system, have been developed and tested. This work is part of A. Seppänen's doctoral thesis.

From left to right, PhD candidate S. Orlat and his supervisor R. Bes in front of the radiation safety enclosure box where the new X-ray absorption spectrometer 'HotXAS' is built.

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



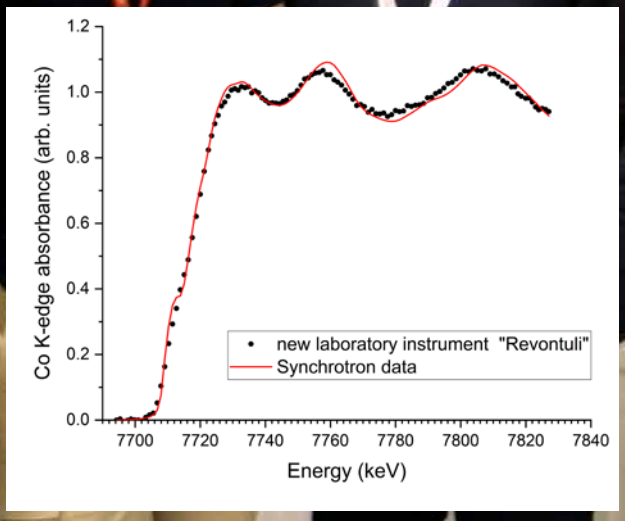
3D-design of the 'HotXAS' instrument as made by PhD candidate S. Orlat.

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

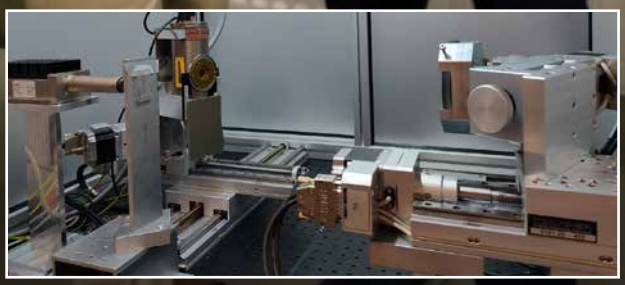
X-ray absorption (XAS) and emission spectroscopies (XES) are non-destructive methods allowing the direct characterization of a given element in any kind of sample: liquid, solid, gas, crystalline or amorphous. XAS is nowadays an essential approach for the study of materials submitted to extreme conditions 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 preclude 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), could solve this issue for routine XAS experiments. For chemically complex samples, however, replacing the usual detectors by an X-ray emission spectrometer remains mandatory for XAS reliable results. Not yet available at the laboratory, the XTREME project aims to implement such an emission spectrometer adapted to a laboratory scale XAS apparatus.

In addition to XAS, XES very recently became a promising complementary technique but remains in its infancy at synchrotron facilities and laboratory scale apparatus can play a leading role in its development. XTREME is thus also aiming to pioneer the XES alternative by leading an overview of XES sensitivity towards degree of oxidation and local environment for materials in extreme conditions.



First ever XAS spectrum (Co K-edge of a 5 µm Co metal foil) measured with the 'Revontuli' instrument (now in commissioning phase) and its comparison to synchrotron data.



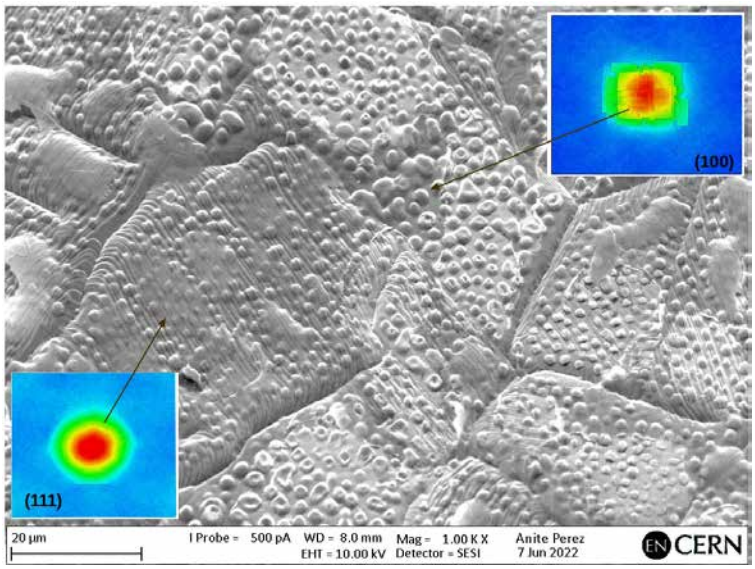
The heart of the 'Revontuli' instrumentation where one can see from left to right the detector, the X-ray tube, and the analyser crystal, all sitting on top of their motorised movement system.

FLYURA DJURABEKOVA
Accelerator Technology: Materials (MAT) project leader

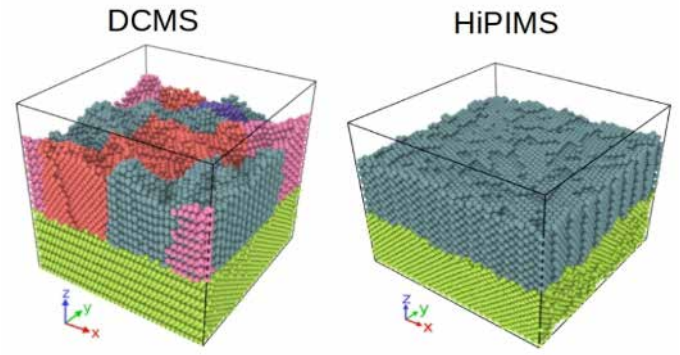
Accelerator Technology: Materials (MAT)

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 of withstanding extreme conditions of electromagnetic fields and particle irradiation. We also address the detrimental effect of proton beams on surfaces of the radio-frequency quadrupole (RFQ) structures of the Large Hadron Collider (LHC) proton injector. Blisters grown upon irradiation on RFQ surfaces are found to correlate with breakdowns that cause erosion and necessity of frequent expensive replacements. We previously identified the atom-level mechanism of prismatic loop punching under internal pressure in bubbles and now we found a strong correlation of the shape of blisters with surface orientation. 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).

Moreover, we have joined the study of effects of heavy ions on materials such as high-entropy alloys, as potential beam window materials within CERN's Innovation Fostering in Accelerator Science and Technology work package 4 (I-FAST). The study aims to find materials that can withstand large radiation doses from ions with a wide range of energies. These new activities will open new horizons in the MAT project for Accelerator Technologies at CERN. ●



SEM images of the Cu surface irradiated by H^- ions up to the fluence of ~ 1.3 × 10^{19} H^-/cm^2. Insets are the top views of atomistic models of the hydrogen blisters that start growing on surfaces with {100} (top right) and {111} (bottom left) orientations into the shapes that compare very closely with those found on experimental surfaces of the same orientation.



Atomistic models of Nb films grown on Cu substrate under direct current magnetron sputtering (DCMS, left image) and high-power impulse magnetron sputtering (HiPIMS, right image) showing highly granular structure of the film near the interface. Elevated temperature of HiPIMS deposition (~ 450 K) results in smoother Nb films with flat interface.

Radiation Safety and STUK

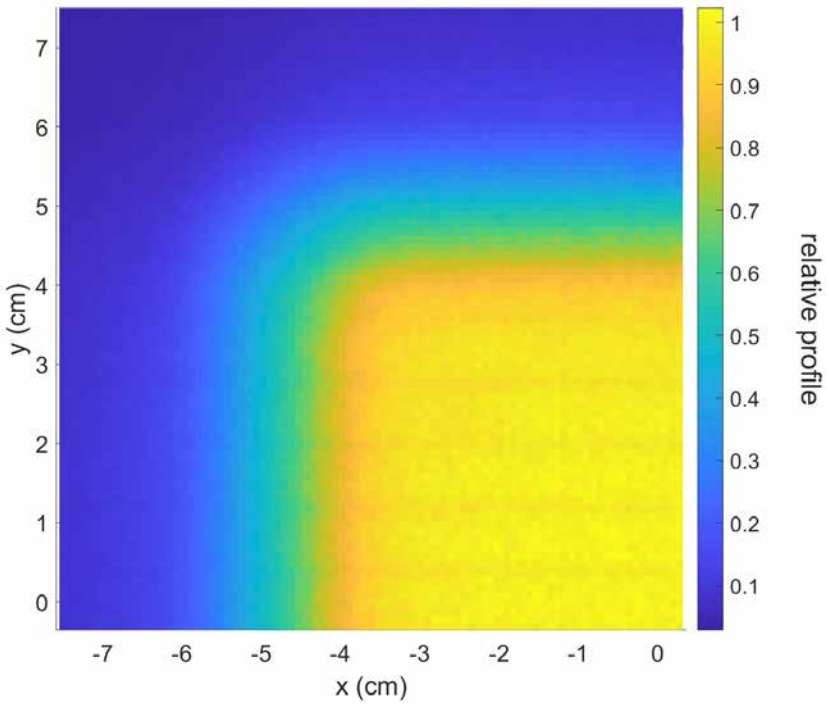
TEEMU SIISKONEN
Radiation Metrology for Medical Applications (RADMED) project leader

Radiation Metrology for Medical Applications (RADMED)

The RADMED project develops radiation detection methods and accurate dosimetry for medical applications of ionising radiation. Different external beam radiotherapy (RT) techniques and computed tomography (CT) are both of particular interest, as both have indisputable benefits for patients, but also present significant risks at individual (RT) or population (CT) level if practices are not properly optimised. To help in ensuring optimal patient protection and treatment or diagnostic outcome, detectors are developed for radiation beam quality control, to achieve better diagnostic information at lower dose level, and to accurately determine patient exposure.

The Multispectral Photon-Counting for Medical Imaging and Beam Characterization (MPMIB) project develops a next-generation position sensitive imaging system. A real-time detection system is used, which is based on single photon counting with silicon and cadmium telluride semiconductor pixel sensors, using readout electronics developed for high-energy physics experiments. The pixelised detectors enable a very good position resolution, which is important for beam characterization. The detection of the energy spectrum of the impinging radiation provides further information on the beam properties. The detectors were successfully tested at the national radiation metrology laboratory at STUK. Future work will concentrate on testing the detectors in hadron beams (protons and neutrons in particular) that are used in cancer treatments.

The MPMIB project received funding from the Academy of Finland (RADDESS programme). Collaborators are the Helsinki Institute of Physics, Aalto University, Lappeenranta-Lahti University of Technology, the University of Jyväskylä, Danish Centre for Particle Therapy, and the Finnish Radiation and Nuclear Safety Authority STUK.



A corner of the Co-60 irradiator beam profile at the Finnish Radiation and Nuclear Safety Authority STUK measured with a silicon pixel detector. *Credit: J. Tikkanen.*

PAUL GREENLEES
Radiation Detection for Safety, Security and Safeguards (RADSAFE) project leader

Radiation Detection for Safety, Security and Safeguards (RADSAFE)

In 2022, the RADSAFE project continued with several research lines aiming to bring state-of-the-art radiation detection technologies developed in fundamental research to routine use in safety, security, and safeguards (3S) applications, improving the sensitivity and reliability of radiation measurements. The project is carried out in close collaboration with STUK and the University of Jyväskylä. Following the end of the RADICAL project which ran during 2018–2021, and which was funded internally by STUK, the resources available to the RADSAFE project were somewhat reduced.

Work to develop an application-specific detector for full-body counting progressed further in 2022. Using the extensive GEANT4 simulation package developed in 2020 [*H. Jutila et al.*, submitted to *Physica Medica*], numerous different detector configurations have been investigated and a quantitative analysis of the improvement in detection sensitivity has been made. It is hoped that measurements to benchmark the simulated results can be made with appropriate detectors in 2023. A publication related to this work has been drafted and will soon be sent for review [*H. Jutila et al.*, manuscript in preparation].

The first steps to develop a position-sensitive contamination meter capable of nuclide identification were also completed in 2022. The possibility to discriminate between beta and alpha radiation and locate sources within a position resolution of approximately 1 cm^2 was demonstrated. The results formed the basis of an MSc thesis at the University of Jyväskylä [*O. Celik, 'Prototype surface contamination monitor with positional sensitivity'*, MSc thesis, University of Jyväskylä, 2022].

Research into 3S applications at the University of Jyväskylä was further boosted by the appointment of K. Peräjärvi as a Professor of Practice.

OTHER PROJECTS

CLOUD

MARKKU KULMALA
CLOUD
project leader

Background and Aims

Indirect observations and theoretical studies have suggested that galactic cosmic rays (GCR) may have influenced the Earth's cloud cover and climate, possibly by affecting the properties of aerosol particles. These tiny particles, floating in the atmosphere, 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 CLOUD (Cosmics Leaving OUtdoor Droplets) experiment at CERN is one of the most advanced laboratory setups to study these processes. The experiment aims to find the possible pathways of these phenomena and to evaluate 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.

Highlights of 2022

1) *Recommissioning the improved CLOUD facility.* In 2020 and 2021 the East Hall building at CERN, where the CLOUD chamber is located, went through a major renovation. The CLOUD facility was also upgraded in tandem, by extending the experimental area, renewing the control room, building a chemical laboratory, and including a flow tube FLOTUS. The new CLOUD facility was tested and commissioned in a 4-week test campaign (CLOUD15T) in spring 2022. The first major 8-week physics run (CLOUD15) after the renovation and pandemic was conducted in autumn 2022.

2) *Scientific results and education.* A new MSCA Doctoral network CLOUD-DOC started in autumn 2022. Twelve PhD students, one of them in Helsinki, will be educated within this project. This year eight peer-reviewed papers were published by the Collaboration (3 led by UH). *Wang et al.* [*2022, Nature*] found that a synergistic mechanism including HNO_3, H_2SO_4, and NH_3 can rapidly form particles in cold temperatures, which could explain new particle formation in the upper troposphere. *Shen et al.* [*2022, ES&T*] explored the gas-phase mechanism of dimethyl sulfide oxidation and found high production of methane sulfonic acid at low temperatures relevant for Arctic marine conditions. *Finkenzeller et al.* [*E-pub ahead of print 2022, Nature Chemistry*] discovered the chemical mechanism underpinning the formation of iodic acid in the atmosphere; iodic acid was earlier found to be a strong aerosol source, especially in polar and marine atmospheres [*He et al. 2021, Science*]. Several other important papers are currently in review or in preparation.

The CLOUD experiment in the renovated East Area. © *2022–2023 CERN, M. Brice.*

HANNU KURKI-SUONIO
Euclid project leader

Euclid

Euclid is a cosmology mission of the European Space Agency. Euclid will study the 'Dark Energy Question' – why is the expansion of the universe accelerating, and what is the nature of the dark energy causing this? To achieve this goal, Euclid will survey over one 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 Euclid Consortium will use the observations 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 the dark energy equation of state. Euclid will be launched in the third quarter of 2023 and will make observations for 6 years.

The analysis of Euclid data is divided among nine Euclid Science Data Centers (SDC). We operate one of them, SDC-FI, at the national CSC Kajaani Data Center. In 2022 we participated in preparations for the first Performance Verification Phase Rehearsal (PVPR1). This was a test of the readiness of the Euclid computing infrastructure to support the real Performance Verification Phase. One of the main tasks of this phase will be the calibration of the Euclid instruments. With the upcoming launch, the beginning of 2023 will be busy with test campaigns on the SDC infrastructure. The last few months of 2022 were dedicated to preparing for these tests. We continued to contribute to the development and validation of the code to produce simulated NISP data, and in the production of the simulated VIS data. Participation in the integration of data from external, ground-based, surveys into the Euclid data archive also continued in 2022. In this effort, Finland has the main responsibility for the integration of the Northern Surveys (PanSTARRS, CFIS, WISHES, WHIGS, and JEDIS).

The Euclid space telescope. In this image the solar panel is still missing. It was attached in May. *Credit: ESA – S. Corvaja.*

Together with an international team we are developing the 2PCF code, which is used to estimate one of the main cosmology products of Euclid, the 2-point correlation function of the distribution of galaxies. The formal code development proceeds as a series of maturity levels. We aim to reach the final level in January 2023. We have the main responsibility for validating the 2PCF code, using simulated galaxy catalogues. In 2022 we published a paper about a new method for estimating the covariance matrix of the 2-point correlation function. The new method uses significantly less computational resources than the current standard method.

In the Euclid Theory Working Group we prepared non-linear modelling and forecasts for the constraining power of Euclid on beyond standard early universe models.

Education and Open Data

KATRI LASSILA-PERINI
Education and Open Data project leader

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

Two high-school group visits to CERN from Finland took place in December 2022, the first ones after the pandemic. The visit schedule has been prepared for 2023 and it should be back to normal with 19 groups expected. A list of resources for teachers to prepare for future visits or organise CERN activities in schools is available at https://cern-tiedeopiskelu.github.io/intro.html. A teacher training programme for Finnish high-school teachers was organised in June 2022.

CMS Data Preservation and Open Data Releases

The CMS Data Preservation and Open Access group manages the actions needed for data and knowledge preservation of the experiment. Data is regularly released for public use, and an important milestone was reached in December 2022 when the release of all proton-proton data from the LHC Run 1 was completed. The CMS Open Data are increasingly in use, for scientific studies and in education. The third CMS Open Data Workshop (https://cms-opendata-workshop.github.io/2022-08-01-cms-open-data-workshop/) to ease getting started with CMS Open Data was organised at CERN in August and was a success with over 40 active participants.

Open Data Training

The project organises courses for using open data in schools with 'Jupyter notebooks' and common Python libraries. These can be 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's website https://opendata-education.github.io/ in Finnish, Swedish, and English.

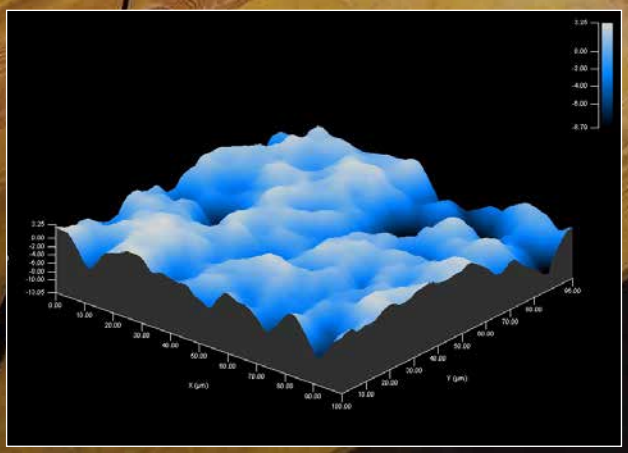
Single-day teacher trainings were held on five occasions over the year in Espoo, Hämeenlinna, and Tampere, both on their own and as a part of some wider teacher networks' events (LUKEMA climate education days etc.). Multi-lesson workshops were held on voluntary high school science courses in Espoo and Hämeenlinna as well as on a health science course in Vaasa. Other notable individual events include a climate data workshop in Hyvinkää, a podcast visit (https://www.spreaker.com/show/ekoaavistuksia episode 2), a guest talk for an IT education group at the University of South-Eastern Norway and participating in the GIREP22 Conference in Slovenia. Except for the health course in Vaasa, conducted by L. Hammarström, the events mentioned above were carried out by project members MSc P. Veteli and V. Juntunen. This work is made possible by a subvention for innovative learning environments in high school by the Finnish National Agency for Education and a grant from the Magnus Ehrnrooth Foundation.

P. Veteli conducting an Open Data workshop at the Kauriala high school in Hämeenlinna.

DETECTOR LABORATORY

R. Turpeinen installing a FluxGate-magnetometer for COSINUS at Grand Sasso. *Credit: M. Kallikoski.*

Optical scanning of MoEDAL foils using UV-light and photoluminescence. *Credit: M. Kallikoski.*



Profilometer scan of a MoEDAL CR39 foil irradiated with oxygen ions at the LHC. *Credit: J. Heino.*

EIJA TUOMINEN
Detector Laboratory chief engineer

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 semiconductor, gas-filled, and scintillator detector technologies.

The Detector Laboratory provides instruments for several **big science physics experiments**. In 2022, we participated in the instrumentation of the CMS Upgrade and CMS Forward experiments at CERN, and the NUSTAR experiment at FAIR. In the MoEDAL-MAPP experiment at CERN, we took part in developing new simulation models, and in calibration of our optical scanning system with Nuclear Track Detector foils. The research was highlighted in a paper that was published in *Nature*. For the COSINUS experiment we made measurements in Gran Sasso and determined the intensity and variations in the Earth's magnetic field inside and around the experiment for passive and active shields development. In InstituteQ we took part in various activities, such as seminars and workshops and supported the development of the Finnish Quantum Agenda.

In 2022, the Laboratory hosted the **externally funded** HIP-LUT project 'Detector for nuclear safety, decommissioning and diagnostics applications (DeNuSa)', funded by the Business Finland Research to Business instrument. There, we developed a portable and scalable semiconductor detector concept based on small size and on simultaneous and precise measurement of several kinds of radiation.

The Detector Laboratory has a wide **network**. The Laboratory works closely with the CERN RD50 and RD51 Collaborations for developing semiconductor and gas-filled detectors, respectively. The collaboration is also very tight especially with the laboratories of the UH Faculty of Science, the Aalto University Nanofabrication Centre, the University of Jyväskylä Accelerator Laboratory, and the LUT University Department of Physics. In addition, the Laboratory collaborates with Finnish industry, especially with small- and medium-size companies.

Laboratory personnel participate in providing **research-based education**. In 2022, the Laboratory hosted a course on semiconductor detectors and a laboratory course on instrumentation in the framework of the Master's Programme for Particle Physics and Astrophysical Sciences (PARAS). Doctoral and master students are supervised in their thesis works, especially in the Doctoral Programme in Particle Physics and Universe Sciences (PAPU).

Special effort was devoted to **societal interaction** to ignite interest in physics especially among children and youth. In 2022, the Laboratory participated in the EU Researchers' Night by producing online videos. In addition, the Laboratory provided two one-week internships for secondary school students.

M. Väänänen, A. Karjalainen, and M. Arenius with the DeNuSa detector at the SLUSH start-up event. *Credit: S. Fabritius.*

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. At the end of 2022, the membership agreement was continued for five years, 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 flavour and challenges.

Russia invaded Ukraine in February 2022. The invasion has most of all been a humanitarian disaster for the Ukrainians, but it has been a defining event in Europe with wide impact, also on HIP. The prices in Europe rose considerably during 2022, and the sanctions against Russia caused by its actions hindered scientific co-operation. Many experimental collaborations at CERN have significant Russian participation. Russia is also the second largest shareholder of FAIR.

The COVID-19 pandemic finally eased its grip in Europe due to vaccinations and the evolution of the virus during 2022. The postponed HIP 25 Years celebration event finally took place in May 2022. HIP also invested in community building and work wellbeing, for example by starting monthly HIP Happy Hours in Helsinki, to remedy the ills caused by the reduced social interaction. At the same time, HIP continued to utilise remote means in making the seminars and meetings more accessible and, thus, reducing travelling and the Institute's carbon footprint.

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 to a very high degree open. The number of publications, however, was smaller than usual. This is mainly due to the reduced amount of CERN collaboration publications and the situation will, fortunately, improve.

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 2018–2022, 50 doctoral degrees and 60 Master's degrees have been earned in connection to HIP research projects. The CERN BootCamp was organised after a two year break, and the HIP summer student programme at CERN and ESRF continued on-site in 2022.

A new term of the HIP Board with new elected representatives of the personnel started in April 2022.

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 also 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 societal problems, often related to sustainability. The University of Helsinki, the host organization of HIP, offers students sustainability courses, both general and discipline specific. The aim is to provide students with academic knowledge and skills related to sustainability.

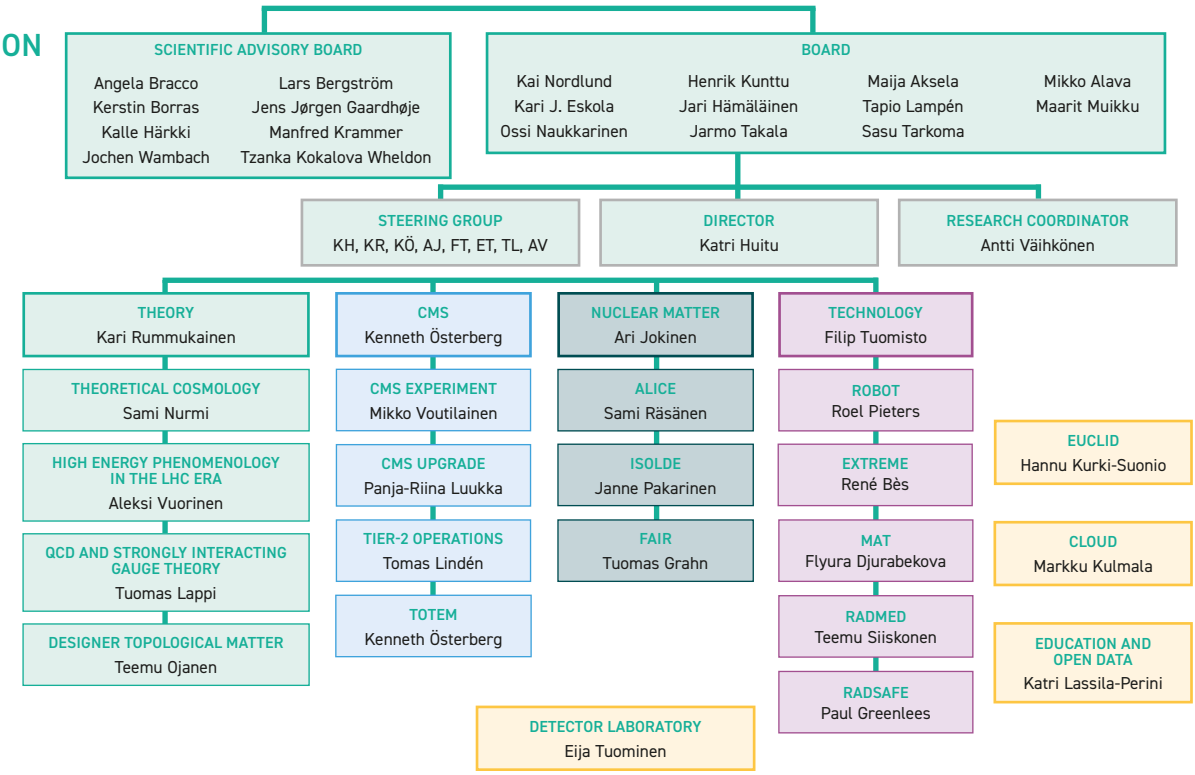
Open access to research results is an important part of the responsibility and sustainability of scientific work. About 95% of HIP publications are open access each year. Researchers at HIP participate in opening data from the LHC experiments and making tools for utilising it. One important objective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

In 2022, 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 streaming and hybrid meeting capabilities of the HIP seminar and meeting rooms were in good use and worked well. The ease of use of the seminar room equipment was also improved further in 2022. These measures make remote participation in the HIP seminars and meetings easy to set up and use, and increase accessibility. 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 2022, HIP continued organising the HIP Leaderships' Afternoon workshop for the HIP programme directors and project leaders. The aim of these recurring events is to discuss leadership issues with varying themes. HIP has a joint wellbeing group of peers together with the University of Helsinki Physics Department. The composition of the group was renewed in 2022.

ORGANIZATION AND PERSONNEL

ORGANIZATION



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CMS Experiment

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J. Ojala, adj. doctoral researcher

FAIR

T. Grahn, ass. prof., proj. leader
J. Äystö, prof., director emeritus, adj. senior scientist
A. Kankainen, prof., senior scientist
A. Jokinen, prof., adj. senior scientist
I. Moore, prof., adj. senior scientist
E. Tuominen, chief engineer
T. Eronen, adj. senior scientist
H. Penttilä, adj. senior scientist
S. Rinta-Antila, 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.
M. Aicheler, senior scientist
T. Salmi, senior scientist
S. Ihantola, scientist (at STUK)
M. Laassiri, scientist
P. Kauttu, doctoral researcher
R. Virta, doctoral research

Robotics and AI for Monitoring and Intervention (ROBOT)

R. Pieters, ass. prof., proj. leader
E. Rahtu, ass. prof., adj. scientist
D. Mohamadi, adj. scientist
K. Samarawickrama, adj. scientist
K. Tammi, adj. scientist
J. Vepsäläinen, adj. scientist
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
T. Ahlgren, adj. senior scientist
A. Kyritsakis, scientist
A. Leino, adj. scientist
A. Lopez Cazalilla, adj. scientist
I. Makkonen, adj. scientist
V. Zadin, adj. scientist
J. Byggmästar, doctoral researcher
M. Ghaemikermani, doctoral researcher
J. Kimari, doctoral researcher

Radiation Safety and STUK

Radiation Metrology for Medical Applications (RADMED)
T. Siiskonen, prof. of practice (UH), proj. leader (at STUK)
M. Kortesniemi, adj. senior scientist
S. Särkkä, adj. senior scientist
R. Hostettler, adj. scientist
J. Ojala, adj. scientist
H. Petrow, adj. scientist
Z. Purisha, adj. scientist
M. Golovleva, doctoral researcher
S. Kirschenmann, doctoral researcher
J. Tikkanen, doctoral researcher

Radiation Detection for Safety, Security and Safeguards (RADSAFE)
P. Greenlees, prof., proj. leader
K. Peräjärvi, prof. of practice (JyU), scientist (at STUK)
T. Hildén, senior scientist
P. Rahkila, adj. senior scientist
H. Badran, scientist (at STUK)
M. Muikku, scientist (at STUK)
R. Pöllänen, scientist (at STUK)
J. Turunen, scientist (at STUK)
V. Bogdanoff, doctoral researcher
H. Jutila, doctoral researcher

Other projects

CLOUD

M. Kulmala, prof., Academician, proj. leader
K. Lehtipalo, ass. prof.
J. Duplissy, senior scientist
R. Baalbaki, doctoral researcher
X. He, doctoral researcher

Euclid

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

E. Tuominen, chief engineer
A. Karadzhinova-Ferrer, senior scientist
I. Kassamakov, docent, lab. engineer
M. Kalliokoski, staff scientist
F. García, lab. engineer
J. Heino, lab. engineer
P. Koponen, lab. engineer
R. Turpeinen, 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
H. Kinnunen, controller
S. Sadesalo, controller
T. Hardén, service coordinator
M. Toivonen, HR coordinator
E. Veranen, HR coordinator
T. Heikkilä, secretary
T. Karppinen, secretary (at CERN)
T. Onnela, secretary (at CERN)

HIP SEMINARS

8 March P. Hoyer (Helsinki)
Bound states in perturbative quantum field theory

29 March L. Bartolini (Henan)
Neutron stars and phase diagram in hard-wall holography

31 March V. Vaskonen (IFAE Barcelona)
Bubble dynamics in (non-)interacting plasma

5 April J. Kost (Sussex)
Massless preheating and electroweak vacuum metastability

12 April P. Navarrete Noriega (Bio Bio U, Chillan, Chile)
Tackling the infamous g^6 term of the hot QCD pressure

26 April W. Trzaska (HIP and Jyväskylä)
Dark matter searches in Finland: a glimmer of light at the end of the tunnel?

10 May C. Hoyos (Oviedo)
Effective theories and scattering in holographic models

24 May M. Sarkkinen (Helsinki)
Gravitational wave memory and its tail in cosmology

2 June E. Keski-Vakkuri (Helsinki)
Sequences of entanglement monotones and Landauer inequalities

7 June O. Henriksson (Helsinki)
Bubbles at strong coupling from holographic effective actions

14 June J. Heisig (Université Catholique de Louvain)
Bound state effects on dark matter coannihilation - pushing the boundaries beyond the WIMP paradigm

21 June J. G. Subils (NORDITA)
Boost-invariant superfluid flows

23 August J. Penttala (Jyväskylä)
Exclusive vector meson production at next-to-leading order in the color glass condensate framework

6 September T. Ward (Santa Fe)
Dark matter, dark energy in radiation gauge extended standard model

4 October A. Pimikov (JINR, Dubna)
Nonlocal condensates in OPE of vacuum correlators

11 October J. Correia (Helsinki)
On multi-tension string networks

18 October J. Holden (Southampton)
Partial deconfinement

25 October H. Siikonen (Helsinki)
Profile likelihood methods in top quark mass measurements at the CMS

15 November S. Bharthuar (Helsinki)
Prototype evaluation and radiation hardness studies of position-sensitive and timing detectors for the future CMS detector

22 November A. Drew (Cambridge)
Massless and massive radiation from global cosmic strings with adaptive mesh refinement

13 December T. Lindén (Helsinki)
Privately funded fusion research

14 December D. Panizo (Uppsala)
Blowing bubbles from string theory

VISITORS

Theory Programme

Theoretical Cosmology

K. Zhang (UK/Finland) 1.1.-12.12.
J. Kost (UK) 14.3.-10.4., 27.11.-6.12.
J. Kume (Japan) 1.4.-10.6.
J. Heisig (Belgium) 13.-14.6.
K. Kainulainen (Finland) 3.-10.8.
A. Cable (UK) 12.-14.9.
T. Toma (Japan) 17.-23.9.
S. Khan (Germany) 17.-21.10.
S. Portegies Zwart (Netherlands) 20.-22.10.
C. Gowling (UK) 13.-20.11.
N. Venkatesan (Finland) 18.11.
A. Drew (UK) 21.-25.11.
O. Iarygina (Sweden) 22.-24.11.
A. Gow (UK) 28.11.-2.12.
I. Rybak (Portugal) 29.11.-2.12.
J. Hou (USA) 14.12.

High Energy Phenomenology in the LHC Era

C. Hoyos (Spain) 9.-16.5.
J. G. Subils (Sweden) 19.-23.6.
S. Kawai (South Korea) 27.6.-31.7.
H. Mäntysaari (Finland) 23.8., 21.11.
J. Penttala (Finland) 23.8.
J. Holden (UK) 17.-18.10.
S. Säppi (Italy) 24.-29.10.
T. Gorda (Germany) 24.10.-3.11.
S. G. Coca (Mexico) 7.-15.12.
D. Panizo (Sweden) 12.-15.12.

QCD and Strongly Interactiong Gauge Theory

J. Fotakis (Germany) 1.-16.11.
O. Evdokimov (USA) 7.-10.12.
M. Strickland (USA) 7.-10.12.

Detector Laboratory

A. Upreti (USA) 23.5.-3.6.
A. Maulik (Italy) 14.-18.11.
A. Upreti (USA) 28.11.-2.12.

CONFERENCE PARTICIPATION, TALKS AND VISITS BY PERSONNEL

Theory Programme

Theoretical Cosmology

Nordita Winter School 2022 – Waves in Astrophysics,
10–14 January, Stockholm, Sweden (online) (A. Kormu)

EuCAPT Virtual Colloquium,
11 January (online) (invited colloquium by D. Weir)

University of Bielefeld,
15 February, Bielefed, Germany (online)
(invited seminar by D. Weir)

MPA Cosmology Seminar,
22 February (online) (invited talk by D. Hooper)

TIFR State of the Universe Seminar,
25 February (online) (invited talk by D. Hooper)

Astronomy Colloquium,
3 March, Leiden, the Netherlands
(invited talk by P. Johansson)

University of Groningen,
10 March, Groningen, the Netherlands (online)
(invited seminar by D. Weir)

ETH Zurich CosmoClub,
14 March (online) (invited talk by D. Hooper)

UCL Cosmo/ExGal Seminar,
14 March (online) (invited talk by D. Hooper)

Institute of Astrophysics and Space Science,
28 March, Lisbon, Portugal (online)
(invited seminar by S. Nurmi)

2022 Ringberg Workshop on Computational Galaxy Formation,
3–8 April, Kreuth, Germany (invited talk by P. Johansson)

CERN Theory Colloquium,
20 April (online) (invited talk by M. Hindmarsh)

Neutrino Cosmology Day,
6 May, Munich, Germany (invited talk by D. Hooper)

Wave Physics and Imaging Applications,
22 May, Institute of Seismology, Helsinki, Finland
(invited talk by D. Weir)

Second EuCAPT Annual Symposium,
23–25 May (online) (D. Hooper, A. Kormu)

Prisma+ Institute,
24–26 May, Mainz, Germany
(invited talk by M. Hindmarsh)

Iberian Gravitational Waves Workshop,
6–8 June, Braga, Portugal (invited talk by D. Weir)

University of Aveiro,
9–10 June, Aveiro, Portugal (D. Weir)

Physics of the Early Universe,
13–17 June (online) (invited talk by K. Kainulainen,
invited talk by S. Räsänen)

California Institute of Technology,
14–16 June, Pasadena, CA, USA (seminar by D. Weir)

International HPC Summer School 2022,
19–25 June, Athens, Greece (A. Kormu)

Metric-affine Frameworks for Gravity Conference,
27 June – 1 July, Tartu, Estonia (J. Annala, A. Hassan)

Cosmology from Home 2022,
4–15 July (online) (D. Hooper)

Queen Mary University of London,
5–6 July, London, UK (seminar by D. Weir)

Loops 22 Summer School,
7–14 July, Marseille, France (A. Hassan)

YETI 2022: Phenomenology in the Sky,
11–14 July, Durham, UK (invited lecture by D. Weir)

14th International Conference on Identification of Dark Matter,
18–22 July, Vienna, Austria (talk by D. Hooper)

Intriguing Inconsistencies in the Growth of Structure over Cosmic Time,
24–29 July, Sesto, Italy (invited talk by D. Hooper)

LISA Symposium,
25–29 July (online) (talk by M. Hindmarsh)

Cargese International Summer School: Rethinking beyond the Standard Model,
25 July – 7 August, Cargese, France (talk by A. Kormu)

Palestinian Conference on Modern Trends in Mathematics and Physics VII,
30 July – 1 August, Birzeit, Palestine (talk by S. Räsänen)

Low Temperature 29,
18–24 August, Sapporo, Japan (talk by M. Hindmarsh)

Nordic Lattice Meeting,
22–24 August, Helsinki, Finland (talk by J. Annala,
A. Kormu, talk by D. Weir)

Ultra-Low Temperature 2022,
25–31 August, Otaru, Japan (talk by M. Hindmarsh)

What's the Matter? Workshop,
29 August – 2 September, MITP, Mainz, Germany
(D. Weir)

Baryon and Lepton Violation 2022 (BLV-2022),
5–9 September, Brussels, Belgium
(invited talk by K. Kainulainen)

Gravity@Prague 2022,
19–23 September, Prague, Czech Republic (A. Hassan)

GW Probes beyond the Standard Model 2,
21–25 November (online) (invited talk by M. Hindmarsh)

London-Oldenburg Relativity Seminar,
14 December (online) (invited talk by D. Hooper)

High Energy Phenomenology in the LHC Era

Ecole Polytechnique Seminar,
10 February, Paris, France (online) (talk by N. Jokela)

Holotube Seminar,
1 March, Holotube seminar series (online)
(talk by N. Jokela)

Iberian Strings 2022,
23–25 March, Oviedo, Spain (talk by J. Penín)

Southampton University Colloquium,
24 March, Southampton, UK (online) (talk by N. Jokela)

Mini Workshop: Phase Transitions in Particle Physics,
28 March – 1 April, Galileo Galilei Institute, Florence, Italy
(talk by P. Schicho)

Eurostrings 2022,
25–29 April, Lyon, France (O. Henriksson, W.-H. Tam)

Quark Matter 2022,
4–10 May, Cracow, Poland (talk by P. Schicho)

SUBATECH Seminar,
15–17 June, Nantes, France (talk by P. Schicho)

Strong and Electroweak Matter 2022,
20–24 June, Paris, France (talk by P. Schicho, plenary talk by A. Vuorinen)

23rd International Conference on General Relativity and Gravitation,
3–8 July, Beijing, China (talk by M. Sarkkinen)

18th International Conference on QCD in Extreme Conditions,
27–29 July, Trondheim, Norway (plenary talk by A. Vuorinen)

XVth Quark Confinement and the Hadron Spectrum Conference,
1–6 August, Stavanger, Norway (talks by N. Jokela and K. Seppänen)

NCU Fundamental Theory Group Seminar,
14 September, Taoyuan City, Taiwan (online)
(talk by M. Sarkkinen)

Gravity@Prague 2022,
19–23 September, Prague, Czech Republic
(M. Sarkkinen, W.-H. Tam)

Modern Equations of State and Spectroscopy in Neutron-Star Matter Workshop,
21–23 September, Alcalá de Henares, Spain
(talk by N. Jokela)

Physics Department Colloquium,
7 October, University of Helsinki, Helsinki, Finland
(talk by A. Vuorinen)

Holography for Astrophysics and Cosmology Workshop,
19–21 October, NORDITA, Stockholm, Sweden
(O. Henriksson, member of the organising committee, talks by J. Penín and A. Vuorinen)

From Holography to Machine Learning Workshop,
24–26 October, Helsinki, Finland (talks by O. Henriksson and K. Seppänen, N. Jokela, J. Penín, A. Piispa, and A. Vuorinen, members of the organising committee)

QCD and Gauge/Gravity Duality: APCTP Focus Program,
6–11 November, Pohang, South Korea
(talk by O. Henriksson, N. Jokela, member of the organising committee)

T. D. Lee Institute Seminar,
14 November, Shanghai, China (online)
(talk by A. Vuorinen)

FPS Particle Physics Day 2022,
24 November, Helsinki, Finland (talk by N. Jokela)

QCD and Strongly Interacting Gauge Theory

Quark Matter 2022,
4–11 January, Cracow, Poland (S. Demirci, K. J. Eskola, H. Hirvonen, H. Hänninen, T. Lappi, talk by T. Löytäinen, talk by H. Mäntysaari, invited talk by P. Paakkinen, J. Penttala, talk by P. Singh, M. Tevio)

Quarkonia As Tools 2022,
9–15 January, Aussois, France (C. Flett, H. Mäntysaari, talk by J. Penttala)

DIS2022,
2–6 May, Santiago de Compostela, Spain (talk by C. Flett, invited talk by I. Helenius, H. Hänninen, talk by T. Lappi, talk by H. Mäntysaari, talk by P. Paakkinen, H. Paukkunen, talk by J. Penttala, talk by M. Tevio)

LHCP 2022,
16–10 May, Taipei, Taiwan (invited talk by P. Paakkinen)

HERA4EIC Workshop,
8–10 June, Stony Brook, NY, USA (online)
(talk by H. Mäntysaari)

58. Karpacz Winter School of Theoretical Physics,
19–25 June, Karpacz, Poland (H. Hirvonen, lectures by H. Niemi)

Synergies between the EIC and LHC Workshop,
20–21 June, CERN, Geneva, Switzerland
(talk by H. Mäntysaari)

Workshop: Exploration of Small-x Structure of Nuclei and Signals of Saturation in Forward Measurements at the LHC,
22 June, CERN, Geneva, Switzerland
(talk by H. Mäntysaari)

Saturation and Diffraction at the LHC and the EIC Workhop,
27 June – 1 July, Trento, Italy (talk by T. Lappi, talk by J. Penttala)

Electron-Ion Collider User Group Meeting 2022,
26–29 July, Stony Brook, NY, USA
(invited talk by H. Mäntysaari)

ISMD 2022,
31 July – 5 August, Pitlochry, Scotland, UK
(talk by C. Flett, talk by M. Utheim)

XVth Quark Confinement and the Hadron Spectrum Conference,
1–6 August, Stavanger, Norway (S. Demirci)

Deciphering Nuclear Phenomenology across Energy Scales Workshop,
20–23 September, Saclay, France
(invited talk by P. Paakkinen)

Diffraction and Low-x 2022,
24–30 September, Corigliano Calabro, Italy
(invited talk by T. Lappi, invited talk by J. Penttala)

From Initial Gluons to Hydrodynamics: Gluons inside Hadrons and their Thermalization,
24–25 October, Saclay, France
(invited talk by H. Mäntysaari)

QCD@LHC2022,
24–25 October, Orsay, France (invited talk by P. Paakkinen)

LHC Forward Physics Meeting,
24–25 October, CERN, Geneva, Switzerland (online)
(talk by J. Penttala)

Resummation, Evolution, Factorization 2022,
31 October – 4 November, Podgorica, Montenegro (online)
(talk by Y. Tawabutr)

PHENOmenal Workshop,
10–11 November, CERN, Geneva, Switzerland
(talk by Y. Kanakubo)

QCD with Electron Ion Collider,
18–20 December, Delhi, India (talk by M. Utheim)

Designer Topological Matter

Stockholm University,
1–3 June, Stockholm, Sweden (T. Ojanen)

Correlations in Topological Quantum Matter Workshop,
7 September, Lammi, Finland (talk by T. Ojanen)

University of St Andrews,
13–15 October, St Andrews, Scotland, UK (T. Ojanen)

CMS Programme

CMS Experiment

January CMS Week,
24–28 January, CERN, Geneva, Switzerland (online)
(H. Kirschenmann, M. Voutilainen)

SMP-HAD Workshop,
24–25 February (online) (talk by L. Martikainen)

Moriond Electroweak 2022,
12–19 March, La Thuile, Italy (H. Kirschenmann)

April CMS Week,
4–8 April, CERN, Geneva, Switzerland (online)
(plenary talk by M. Voutilainen)

JetMET Workshop in Florence,
11–13 April, Florence, Italy (talk by K. Kallonen, M. Kim, talk by H. Kirschenmann, talk by L. Martikainen, talk by M. Myllymäki, talk by J. Pekkanen, talk by M. Voutilainen)

23rd IPPOG Meeting,
11–13 May, Podgorica, Montenegro (online) (S. Lehti)

June CMS Week,
27 June – 1 July, CERN, Geneva, Switzerland
(H. Kirschenmann, M. Voutilainen, meeting chair)

110th Plenary ECFA Meeting,
21–22 July, CERN, Geneva, Switzerland
(talk by H. Kirschenmann)

BOOST 2022,
15–19 August, Hamburg, Germany (H. Kirschenmann)

The 15th International Workshop on Top Quark Physics,
4–9 September, Durham, UK (M. Myllymäki)

September CMS Week,
19–23 September, CERN, Geneva, Switzerland
(H. Kirschenmann, M. Voutilainen, meeting chair)

24th IPPOG Meeting,
26–28 October, CERN, Geneva, Switzerland (online)
(S. Lehti)

SMARTHEP Kick-Off at the University of Manchester,
21–25 November, Manchester, UK
(P. Inkaew, H. Kirschenmann)

FPS Particle Physics Day 2022,
24 November, Helsinki, Finland (talk by H. Kirschenmann, chair, M. Voutilainen, chair)

CMS PPD Workshop Nov-Dec 2022,
30 November – 2 December, CERN, Geneva, Switzerland ((online) P. Inkaew, talk by T. Lampén)

December CMS Week,
6–9 December, CERN, Geneva, Switzerland (P. Inkaew, (online) T. Lampén, S. Lehti, M. Voutilainen, meeting chair)

CMS TOP Workshop 2022,
13–15 December, CERN, Geneva, Switzerland
(talk by H. Kirschenmann, talk by M. Myllymäki)

Physics Department Colloquium,
16 December, Jyväskylä, Finland (talk by M. Voutilainen)

CMS Upgrade

January CMS Week,
24–28 January, CERN, Geneva, Switzerland (P. Luukka)

Vienna Conference on Instrumentation 2022,
21–25 February, Vienna (online) (talk by S. Kirschenmann)

Frontier Research in Astrophysics and Particle Physics Seminar,
24–25 February, Santander, Spain (talk by P. Luukka)

FPS Physics Days 2022,
28 February – 4 March, Espoo, Finland (online)
(E. Brücken, S. Kirschenmann)

CMS Tracker Fortnight,
28 February – 11 March, CERN, Geneva, Switzerland
(P. Luukka)

April CMS Week,
4–8 April, CERN, Geneva, Switzerland (P. Luukka)

CMS Tracker Week,
2–6 May, CERN, Geneva, Switzerland (P. Luukka)

9th Conference on PET/MR and SPECT/MR & Total-Body PET Workshop,
28 May – 1 June, Isola d'Elba, Italy (S. Kirschenmann)

RADDESS Academy Programme Closing Seminar,
22 June, Helsinki, Finland (talk by E. Brücken, A. Gädda, S. Kirschenmann, N. Kramarenko, P. Luukka, A. Winkler)

FACET Collaboration Meeting,
24–25 June, CERN, Geneva, Switzerland
(talk by E. Brücken)

23rd International Workshop on Radiation Imaging Detectors,
26–30 June, Riva del Garda, Italy (M. Bezak, S. Bharthuar, E. Brücken)

National Monte Carlo User Meeting (FinMoCa 2022),
26 August, Tampere, Finland (E. Brücken, T. Hildén)

September CMS Week,
19–23 September, CERN, Geneva, Switzerland
(T. Hildén, P. Luukka)

Paul Scherrer Institute,
12–14 October, Villigen, Switzerland (E. Brücken, T. Hildén, P. Luukka)

CMS Tracker Week,
31 October – 4 November, CERN, Geneva, Switzerland
(E. Brücken, T. Hildén, P. Luukka)

SLUSH Startup Event,
17–18 November, Helsinki, Finland (A. Karjalainen, M. Väänänen)

FPS Particle Physics Day,
24 November, Helsinki, Finland (E. Brücken).

RD50 Workshop,
29 November – 2 December (online) (E. Brücken, P. Luukka)

December CMS Week,
5–9 December, CERN, Geneva, Switzerland (P. Luukka)

MATRENA Fall Seminar,
14 December, Helsinki, Finland (S. Kirschenmann)

Tier-2 Operations

FPS Physics Days 2022,
2–4 March, Espoo, Finland (online) (T. Lindén)

HEPiX Spring 2022,
25–29 April (online) (T. Lindén)

Nuclear Energy Ecosystems – Open Business Day 2022,
3–4 May, Helsinki, Finland (T. Lindén)

ARC 7 Technical Workshop,
4–5 May, Lund, Sweden (online) (T. Lindén)

FUNET Technical Days,
18–19 May, Espoo, Finland (online) (T. Lindén)

NeIC Conference 2022,
30 May – 1 June, Oslo, Norway (T. Lindén)

Mind and Matter 2022,
16–18 June, Helsinki, Finland (T. Lindén)

CernVM Users Workshop,
12–13 September, Nikhef, Amsterdam, the Netherlands (online) (T. Lindén)

NORDUnet 2022,
13–15 September, Reykjavik, Iceland (T. Lindén)

Nuclear Science and Technology Symposium 2022,
1–2 November, Helsinki, Finland (talk by T. Lindén)

De Finlandssvenska Fysik- och Kemidagarna 2022,
18–20 November, Helsinki-Stockholm-Helsinki ferry
(T. Lindén)

FPS Particle Physics Day 2022,
24 November, Helsinki, Finland (T. Lindén)

Fusion Power Associates 43rd Annual Meeting,
7–8 December, Washington, DC, USA (online) (T. Lindén)

TOTEM

CERN,
7–21 February, 7–21 March, 10–28 May, 18 July – 5 August, 17 August – 2 September, 12–30 September, 12–21 December, Geneva, Switzerland (F. García)

FPS Physics Days 2022,
2–4 March, Espoo, Finland (online)
(F. Oljemark, talk by M.-M. Rantanen)

LHCC Referees Meeting,
8 March (online) (talk by K. Österberg)

TOTEM Collaboration Meeting,
27–28 April (online) (F. García, talk by F. Oljemark, talk by K. Österberg, chair)

CERN,
10–20 May, 22 July – 3 August, 24–31 August, 21–28 September, Geneva, Switzerland (M.-M. Rantanen)

LHCP 2022,
16–20 May (online) (talk by F. García)

LHCC Referees Meeting,
31 May (online) (talk by K. Österberg)

CERN,
21–24 June, Geneva, Switzerland (K. Österberg)

HIP Scientific Advisory Board Meeting,
30–31 August, Helsinki, Finland (talk by K. Österberg)

Diffraction and Low-x 2022,
24–30 September, Corigliano Calabro, Italy
(talk by K. Österberg, chair)

LHC Forward Physics Workshop,
24–25 October, Geneva, Switzerland (talk by K. Österberg)

LHC RRB,
24–27 October, Geneva, Switzerland (K. Österberg)

FPS Particle Physics Day,
24 November, Helsinki, Finland (talk by F. García, F. Oljemark, K. Österberg)

LHCC Referees Meeting,
29 November (online) (talk by K. Österberg)

Nuclear Matter Programme

ISOLDE

Scientific Associateship,
1 December 2021 – 31 July 2022, CERN, Geneva, Switzerland (J. Pakarinen)

93rd ISCC Meeting,
4 February, CERN, Geneva, Switzerland (J. Pakarinen)

69th INTC Meeting,
9–10 February (online) (A. Kankainen)

CERN,
7–11 April, 20–24 April (online), 13–20 May, 25–29 May, 27 June – 6 July, 15–22 August, 1–4 November, 21–27 November, Geneva, Switzerland (A. Illana Sison)

CERN,
13–17 April, 1–5 May, Geneva, Switzerland (S. Kujanpää)

CERN,
13–16 May, 25–29 May, 27 June – 6 July, 15–22 August, Geneva, Switzerland (M. Stryjczyk)

CERN,
13–20 May, 25–29 May, 1–4 November, 21–27 November, Geneva, Switzerland (J. Pakarinen)

CERN,
17–24 May, Geneva, Switzerland (W. Gins)

94th ISCC Meeting,
21 June, CERN, Geneva, Switzerland (J. Pakarinen)

70th INTC Meeting,
22–23 June, CERN, Geneva, Switzerland (A. Kankainen)

CERN,
15–22 August, 21–27 November, Geneva, Switzerland (A. Montes-Plaza)

JYFL-ACCLAB IAB Meeting,
23 August, Jyväskylä, Finland (talk by J. Pakarinen)

HIP Scientific Advisory Board Meeting,
30 August (online) (talk by J. Pakarinen)

Miniball Stable Beam-time,
12–15 September, CERN, Geneva, Switzerland (J. Pakarinen)

71st INTC Meeting,
8–9 November, CERN, Geneva, Switzerland (A. Kankainen)

95th ISCC Meeting,
9 November, CERN, Geneva, Switzerland (J. Pakarinen)

CERN,
21–27 November, Geneva, Switzerland (A. Briscoe, P. Rahkila)

ISOLDE Workshop and Users Meeting 2022,
30 November – 2 December (online)
(A. Illana Sison, J. Pakarinen, M. Stryjczyk)

IDS Collaboration Meeting,
2 December (online) (A. Illana Sison)

Key Reactions in Nuclear Astrophysics,
12–16 December, ECT*,Trento, Italy (talk by M. Mougeot)

FAIR

International Particle Accelerator Conference 2022,
12–17 June, Bangkok, Thailand (M. Luoma)

International Nuclear Physics Conference 2022,
12–16 September, Cape Town, South Africa
(talk by T. Grahn)

Argonne National Laboratory,
27 September – 5 October, Lemont, IL, USA
(talk by T. Grahn)

Super-FRS Experiment Collaboration Meeting,
15–16 December, Darmstadt, Germany (T. Grahn, A. Jokinen, J. Äystö)

Technology Programme

44th ESARDA Annual Meeting,
2–5 May, Luxemburg, Luxemburg (online) (P. Dendooven)

Nordic Nuclear Safety Seminar,
24–25 May, Stockholm, Sweden (P. Dendooven)

National Monte Carlo User Meeting (FinMoCa 2022),
26 August, Tampere, Finland (M. Laassiri)

IAEA Safeguards Symposium,
31 October – 4 November, Vienna, Austria
(talk by R. Virta)

IEEE Nuclear Science Symposium, Medical Imaging Conference and Room Temperature Semiconductor Detector Conference,
5–12 November, Milan, Italy (talk by P. Dendooven)

7th Biennial African School of Fundamental Physics and Applications (ASP),
28 November – 9 December, Port Elizabeth, South Africa
(talk by M. Laassiri)

Accelerator Technology: Materials (MAT)

2022 MRS Spring Meeting & Exhibit,
8–13 May, Honolulu, HI, USA (talk by F. Djurabekova, symposium organiser)

The 15th Conference of COmputer Simulation of IRradiation Effects in Solids,
22–26 May, Porquerolles, France (talk by F. Djurabekova)

TUMIEE Training School 'Electronic Effects in far-from Equilibrium Atom Dynamics (E3AD)',
13–17 June, Helsinki, Finland (F. Djurabekova, A. Leino)

The 29th International Conference on Atomic Collisions in Solids and the 11th International Symposium on Swift Heavy Ions in Matter,
19–24 June, Helsinki, Finland
(F. Djurabekova, chairperson, main organiser)

Collaborative Meeting at CMAM,
4–5 July, Madrid, Spain (F. Djurabekova)

22nd International Conference on Ion Beam Modification of Materials,
10–15 July, Lisbon, Portugal
(invited talk by F. Djurabekova)

TUMIEE COST Action Meeting,
17–18 July, Heraklion, Crete, Greece (F. Djurabekova)

2nd Baltic School of High-Energy Physics and Accelerator Technologies 2022,
8–12 August, Saaremaa, Estonia (invited talk by F. Djurabekova, M. Ghaemikermani, A. Lopez Cazalilla)

29th in the Series of General Conferences of the Condensed Matter Division of the European Physical Society,
21–26 August (hybrid) (invited talk by F. Djurabekova)

European Conference on Surface Science - ECOSS35,
29 August – 2 September, Luxembourg, Luxembourg
(invited talk by F. Djurabekova)

10th International Workshop on the Mechanisms of Vacuum Arcs (Hybrid MeVArc 2022),
18–22 September, Chania, Crete, Greece
(F. Djurabekova, International Committee member, (online) M. Ghaemikermani, talk by J. Kimari, talk by A. Lopez Cazalilla)

EU Project Collaborative Meeting,
22–24 September, HZDR, Dresden, Germany
(F. Djurabekova)

The 10th International Conference on Multiscale Materials Modeling,
2–7 October, Baltimore, MD, USA (talk by J. Kimari)

26th International Conference on the Application of Accelerators in Research & Industry and 53rd Symposium of Northeastern Accelerator Personnel,
30 October – 3 November, Denton, TX, USA (invited talk by F. Djurabekova)

'Nanoscale Phase Transitions in Amorphous Materials Under Swift Heavy Ion Irradiation' at MRS Fall Meeting,
27 November – 2 December, Boston, MA, USA (invited talk F. Djurabekova)

'Materials Simulations from First Principles and Molecular Dynamics with Application in the Fusion R&D', Fusion HPC Workshop – 3rd Edition (2022),
15–16 December (online) (keynote talk by F. Djurabekova)

Radiation Safety and STUK

Radiation Metrology for Medical Applications (RADMED)

Vienna Conference on Instrumentation 2022,
21–25 February, Vienna, Austria (online)
(talk by S. Kirschenmann)

RADDESS Academy Programme Closing Seminar,
22 June, Helsinki, Finland (S. Kirschenmann)

Other projects

CLOUD

University of York Seminar Series,
18 May, University of York, York, UK
(invited talk by K. Lehtipalo)

Gordon Research Conference – Molecular and Ionic Clusters,
6–11 August, Castelvecchio Pascoli, Italy
(invited talk by X. He)

International Aerosol Conference 2022,
4–9 September, Athens, Greece
(talk by X. He, K. Lehtipalo)

CLOUD Collaboration Meeting,
11–14 October, CERN, Geneva, Switzerland
(talk by R. Baalbaki, talk by X. He)

Euclid

Euclid Consortium Meeting,
26–29 April, Oslo, Norway (hybrid)
(E. Keihänen, H. Kurki-Suonio, A. Viitanen, J. Väliviita)

INAF-OAS,
9–20 May, Bologna, Italy (A. Viitanen)

Galaxies & AGN with the First Euclid Data and Beyond (Euclid SWG-GAE),
14–16 September, Naples, Italy (talk by A. Viitanen)

INAF-OAC,
19–22 September, Naples, Italy (A. Viitanen)

Euclid Theory Working Group Meeting,
10–11 October, Bologna, Italy (hybrid) (J. Väliviita)

Exploring the Hot and Energetic Universe: the Third Scientific Conference dedicated to the Athena X-ray Observatory,
7–10 November, Barcelona, Spain (hybrid) (A. Viitanen)

Education and Open Data

FAIR for AI Workshop,
6–7 June, Argonne National Laboratory, Lemont, IL, USA
(remote talk by K. Lassila-Perini)

GIREP2022,
4–8 July, Ljubljana, Slovenia (P. Veteli)

CMS Open Data Workshop,
1–4 August, CERN, Geneva, Switzerland
(talk by K. Lassila-Perini)

Belle II Data Preservation Workshop,
1 October, Rome, Italy (talk by K. Lassila-Perini)

Detector Laboratory

FPS Physics Days 2022,
2–4 March, Espoo, Finland (online) (M. Kalliokoski)

Nuclear Energy Ecosystems – Open Business Day 2022,
3–4 May, Helsinki, Finland
(M. Arenius, A. Karadzhinova-Ferrer)

Business Finland Science Start-Up Day 2022,
4 May (online) (M. Arenius, A. Karadzhinova-Ferrer)

Research Spinout Showcase,
12 May, Helsinki, Finland (M. Arenius)

10th Euratom Conference on Reactor Safety & 10th Euratom Conference on Radioactive Waste Management, FISA 2022 & EURADWASTE '22,
30 May – 3 June, Lyon, France (M. Arenius)

European Physical Society Forum 2022,
2–4 June, Paris, France (talk by E. Tuominen)

Nordic Nuclear Forum 2022,
7 June, Helsinki, Finland (M. Arenius)

Artic15 Start-Up Conference,
8 June, Helsinki, Finland (M. Arenius)

17th MoEDAL Collaboration Meeting,
13–14 June, 20 June (online) (talk by M. Kalliokoski)

GENERA (Gender Equality Network in Physics in the European Research Area) General Assembly,
21 June, Lund, Sweden (talk by E. Tuominen)

GeDiMIRT (Gender Dimension in Physics and Math-Intensive Research and Teaching) Conference,
22–23 June, Lund, Sweden (E. Tuominen)

23rd International Workshop on Radiation Imaging Detectors,
26–30 June, Riva del Garda, Italy (J. Heino, M. Kalliokoski, R. Turpeinen)

4th Conference of the Nordic Network for Diversity in Physics,
18–19 August, Reykjavik, Iceland (talk by E. Tuominen)

National Monte Carlo User Meeting (FinMoCa 2022),
26 August, Tampere, Finland (M. Kalliokoski)

8th COSINUS Collaboration Meeting,
21–23 September, Ringberg, Germany
(talk by M. Kalliokoski, R. Turpeinen)

Nordic Deep Tech Business Summit,
11–12 October, Espoo, Finland (M. Arenius)

Nuclear District Heating / Energia 2022,
25 October, Tampere, Finland (M. Arenius)

Nuclear Science and Technology Symposium 2022,
1–2 November, Helsinki, Finland
(M. Arenius, M. Kalliokoski)

Working visit to COSINUS Project,
9–12 November, Gran Sasso, Italy
(M. Kalliokoski, R. Turpeinen)

Workshop of the EU UniSAFE Project,
10 November, Madrid, Spain (invited talk by E. Tuominen)

SLUSH Startup Event,
17–18 November, Helsinki, Finland (M. Arenius)

FPS Particle Physics Day 2022,
24 November, Helsinki, Finland
(M. Kalliokoski, talk by E. Tuominen)

18th MoEDAL Collaboration Meeting,
5–7 December, CERN, Geneva, Switzerland
(talk by M. Kalliokoski)

PUBLICATIONS

Theory Programme

Theoretical Cosmology

D. C. Hooper in E. Abdalla et al.,
Cosmology intertwined: A review of the particle physics, astrophysics, and cosmology associated with the cosmological tensions and anomalies,
J. High Energy Astrophys. 34 (2022) 49

M. Al Ajmi and M. Hindmarsh,
Thermal suppression of bubble nucleation at first-order phase transitions in the early Universe,
Phys. Rev. D 106 (2022) 023505

D. J. Weir in P. Amaro Seoane et al.,
The effect of mission duration on LISA science objectives,
Gen. Relativ. Gravit. 54 (2022) 3

D. Cutting, M. Hindmarsh, K. Rummukainen, and D. J. Weir in P. Auclair et al.,
Generation of gravitational waves from freely decaying turbulence,
J. Cosmol. Astropart. Phys. 09 (2022) 029

D. J. Weir in J.-B. Bayle et al.,
Workshop on gravitational-wave astrophysics for early career scientists,
Nat. Astron. 6 (2022) 304

R. Beneduci, E. Frion, and J.-P. Gazeau,
Quantum description of angles in the plane,
Acta Polytech. 62 (2022) 8

E. Frion in R. Beneduci et al.,
Quantum formalism on the plane: POVM-Toeplitz quantization, Naimark theorem and linear polarization of the light,
Ann. Phys. 447 (2022) 169134

D. Bettoni, A. Lopez-Eiguren, and J. Rubio,
Hubble-induced phase transitions on the lattice with applications to Ricci reheating,
J. Cosmol. Astropart. Phys. 01 (2022) 002

D. J. Weir in R. Caldwell et al.,
Detection of early-universe gravitational-wave signatures and fundamental physics,
Gen. Relativ. Gravit. 54 (2022) 156

G. Choi and E. D. Schiappacasse,
PBH assisted search for QCD axion dark matter,
J. Cosmol. Astropart. Phys. 09 (2022) 072

D. Cutting in S. Craven et al.,
Machine learning a manifold,
Phys. Rev. D 105 (2022) 096030

D. Cutting, E. Vilhonen, and D. J. Weir,
Droplet collapse during strongly supercooled transitions,
Phys. Rev. D 106 (2022) 103524

J. Dahl, M. Hindmarsh, K. Rummukainen, and D. J. Weir,
Decay of acoustic turbulence in two dimensions and implications for cosmological gravitational waves,
Phys. Rev. D 106 (2022) 063511

D. C. Hooper in Q. Decant et al.,
Lyman-α constraints on freeze-in and superWIMPs,
J. Cosmol. Astropart. Phys. 03 (2022) 041

D. G. Figueroa, S. Raatikainen, S. Räsänen, and E. Tomberg,
Implications of stochastic effects for primordial black hole production in ultra-slow-roll inflation,
J. Cosmol. Astropart. Phys. 05 (2022) 027

P. Gallagher, T. Koivisto, and L. Marzola,
Pregeometric first order Yang-Mills theory,
Phys. Rev. D 105 (2022) 125010

O. Gould, S. Güyer, and K. Rummukainen,
First-order electroweak phase transitions: A nonperturbative update,
Phys. Rev. D 106 (2022) 114507

D. C. Hooper and M. Lucca,
Hints of dark matter-neutrino interactions in Lyman-α data,
Phys. Rev. D 105 (2022) 103504

D. C. Hooper et al.,
One likelihood to bind them all: Lyman-α constraints on non-standard dark matter,
J. Cosmol. Astropart. Phys. 10 (2022) 032

A. Ito, W. Khater, and S. Räsänen,
Tree-level unitarity in Higgs inflation in the metric and the Palatini formulation,
J. High Energy Phys. 06 (2022) 164

S. M. Koksbang and S. Räsänen,
The effect of dark matter discreteness on light propagation,
J. Cosmol. Astropart. Phys. 04 (2022) 030

A. Mantziris, T. Markkanen, and A. Rajantie,
The effective Higgs potential and vacuum decay in Starobinsky inflation,
J. Cosmol. Astropart. Phys. 10 (2022) 073

High Energy Phenomenology in the LHC Era

K. Ala-Mattinen, M. Heikinheimo, K. Kainulainen, and K. Tuominen,
Momentum distributions of cosmic relics: Improved analysis,
Phys. Rev. D 105 (2022) 123005

M. Heikinheimo, K. Huitu, and A. Stendahl in G. Angloher et al.,
Simulation-based design study for the passive shielding of the COSINUS dark matter experiment,
Eur. Phys. J. C 82 (2022) 248

E. Annala and A. Vuorinen in E. Annala et al.,
Multimessenger constraints for ultradense matter,
Phys. Rev. X 12 (2022) 011058

F. R. Ares, O. Henriksson, M. Hindmarsh, C. Hoyos, and N. Jokela,
Effective actions and bubble nucleation from holography,
Phys. Rev. D 105 (2022) 066020

F. R. Ares, O. Henriksson, M. Hindmarsh, C. Hoyos, and N. Jokela,
Gravitational waves at strong coupling from an effective action,
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S. Ashanujjaman, K. Ghosh, and K. Huitu,
Type II seesaw model: Searching for the LHC-elusive low-mass triplet Higgs bosons at e^-e^+ colliders,
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Evolutions in first-order viscous hydrodynamics,
J. High Energy Phys. 08 (2022) 298

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Domain collisions,
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Holographic bubbles with Jecco: expanding, collapsing and critical,
J. High Energy Phys. 09 (2022) 008

S. Biondini, P. Schicho, and T. V. I. Tenkanen,
Strong electroweak phase transition in *t*-channel simplified dark matter models,
J. Cosmol. Astropart. Phys. 10 (2022) 044

N. Jokela and J. M. Penín in A. Garbayo et al.,
Flavored anisotropic black holes,
J. High Energy Phys. 10 (2022) 061

J. Ghiglieri, G. D. Moore, P. Schicho, and N. Schlusser,
The force-force-correlator in hot QCD perturbatively and from the lattice,
J. High Energy Phys. 02 (2022) 058

T. Gorda, J. Österman, and S. Säppi,
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M. Heikinheimo, S. Sassi, K. Nordlund, K. Tuominen, and N. Mirabolfathi,
Identification of the low-energy excess in dark matter searches with crystal defects,
Phys. Rev. D 106 (2022) 083009

O. Henriksson,
Black brane evaporation through D-brane bubble nucleation,
Phys. Rev. D 105 (2022) L041901

J. Hirvonen and P. Schicho in J. Hirvonen et al.,
Computing the gauge-invariant bubble nucleation rate in finite temperature effective field theory,
J. High Energy Phys. 07 (2022) 135

N. Jokela, J. Tarrío, and A. Vuorinen in C. Hoyos et al.,
Holographic approach to transport in dense QCD matter,
Phys. Rev. D 105 (2022) 066014

C. Hoyos, N. Jokela, and A. Vuorinen,
Holographic approach to compact stars and their binary mergers,
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Multiphase critical Higgs boson at colliders,
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Shape of the hot topological charge density spectral function,
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On gravitational preheating,
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Massive holographic QFTs in de Sitter,
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T. Rindlisbacher, K. Rummukainen, A. Salami, and K. Tuominen,
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P. Schicho et al.,
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QCD and Strongly Interacting Gauge Theory

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N. Armesto, T. Lappi, H. Mäntysaari, H. Paukkunen, and M. Tevio,
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G. Beuf, H. Hänninen, T. Lappi, Y. Mulian, and H. Mäntysaari,
Diffractive deep inelastic scattering at NLO in the dipole picture: The $q\bar{q}g$ contribution,
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G. Beuf, T. Lappi, and R. Paatelainen,
Massive quarks in NLO dipole factorization for DIS: Transverse photon,
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K. Boguslavski, T. Lappi, M. Mace, and S. Schlichting,
Spectral function of fermions in a highly occupied non-Abelian plasma,
Phys. Lett. B 827 (2022) 136963

S. Demirci, T. Lappi, and S. Schlichting,
Proton hot spots and exclusive vector meson production,
Phys. Rev. D 106 (2022) 074025

A. Dumitru, H. Mäntysaari, and R. Paatelainen,
Cubic color charge correlator in a proton made of three quarks and a gluon,
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K. J. Eskola, C. A. Flett, V. Guzey, T. Löytäinen, and H. Paukkunen,
Exclusive J/ψ photoproduction in ultraperipheral Pb+Pb collisions at the CERN Large Hadron Collider calculated at next-to-leading order perturbative QCD,
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EPPS21: a global QCD analysis of nuclear PDFs,
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C. A. Flett et al.,
Predictions of exclusive Υ photoproduction at the LHC and future colliders,
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Exclusive J/ψ and Υ production in high-energy pp and p-Pb collisions,
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Multicomponent relativistic dissipative fluid dynamics from the Boltzmann equation,
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NNLO nuclear parton distribution functions with electroweak-boson production data from the LHC,
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npj Quantum Mater. 7 (2022) 23

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CMS Programme

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