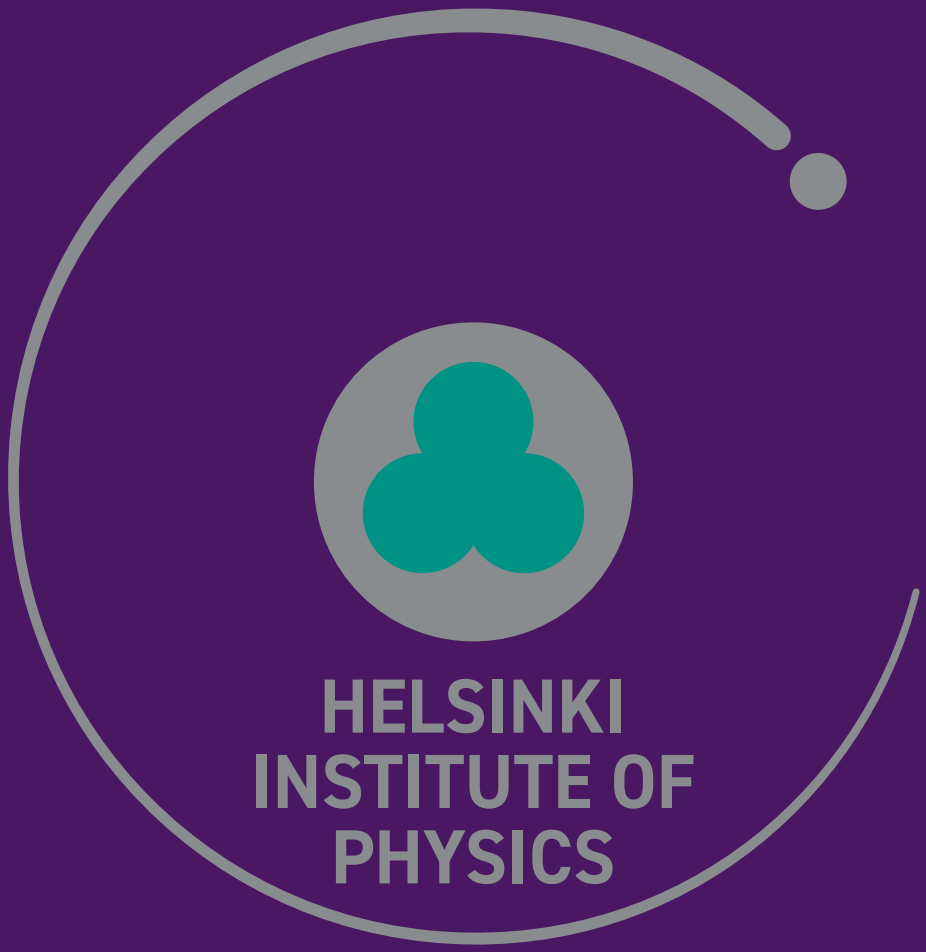
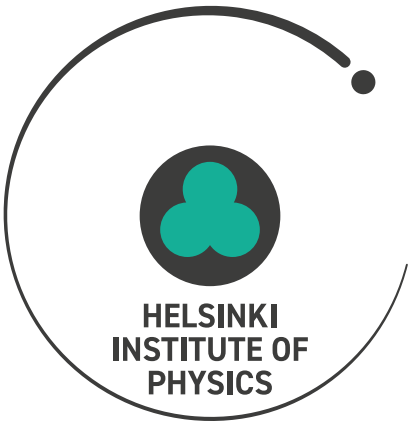
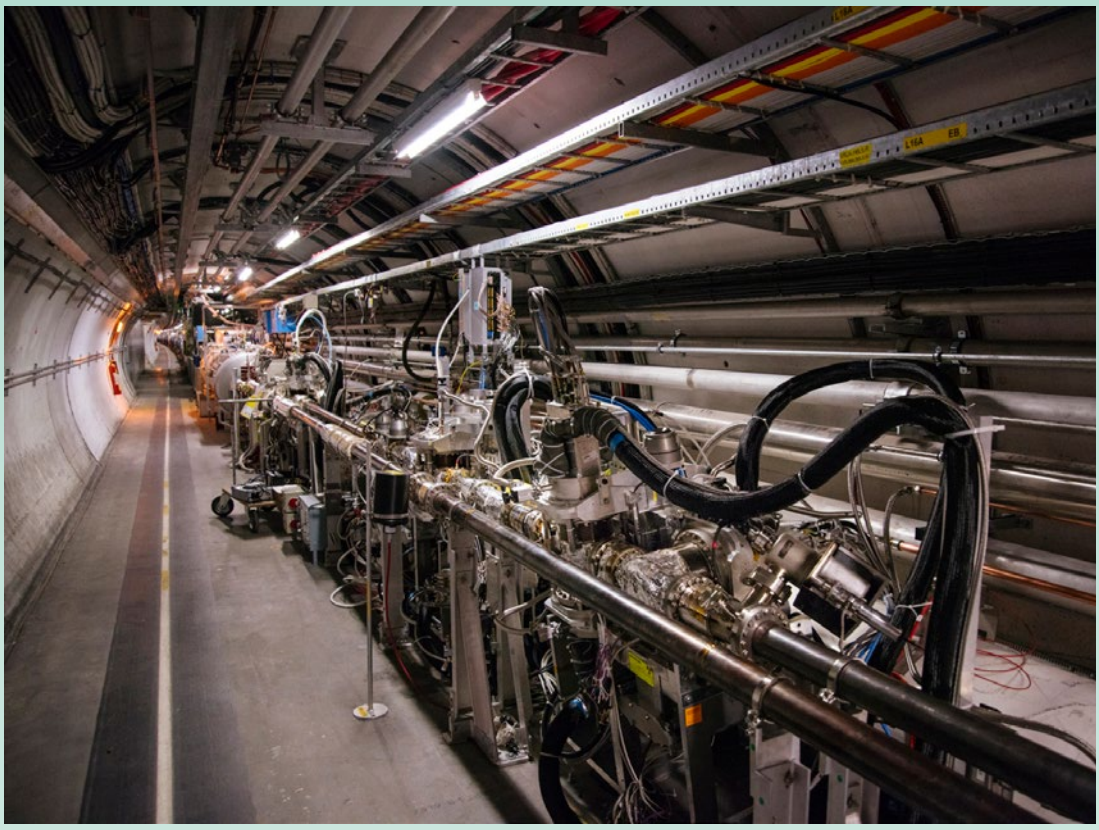


HELSINKI INSTITUTE OF PHYSICS

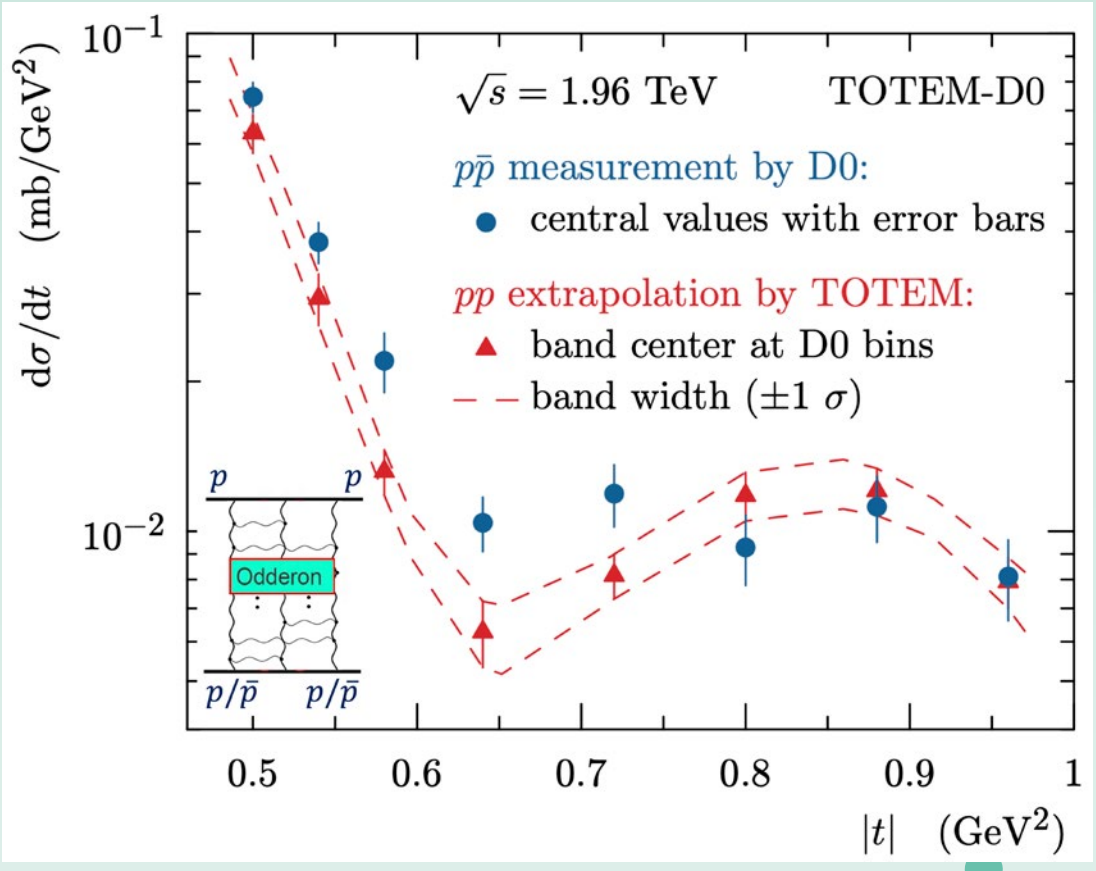
Annual Report 2021



Annual Report 2021



The TOTEM Romans Pots located in the LHC tunnel measured the elastic proton-proton collisions. © *M. Brice, CERN.*



Comparison of the elastic proton-proton and proton-antiproton collision probability showing the expected difference due to Odderon exchange. Inserted: The Odderon exchange diagram drawn with gluons. *Reproduced under Creative Commons 4.0 license from Phys. Rev. Lett. 127 (2021) 062003.*

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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 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 2021, 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 experiment, ISOLDE, and the FAIR facility; and 4) the Technology Programme, with six applied research projects. In addition, there were three independent 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 (Theoretical Cosmology project) and the dark matter COSINUS experiment (High Energy Phenomenology in the LHC Era project), which is under construction in the Gran Sasso Laboratory and which HIP joined in 2021.

During the year 2021, special circumstances due to the COVID-19 pandemic continued for most of the year, and consequently most meetings, conferences and travel, as well as teaching, were conducted by videoconferencing methods. The annual meeting of the Scientific Advisory Board (SAB) at the turn of August and September was also held remotely. The SAB found that the scientific production of HIP continued to be large in size and very high in quality. The SAB also appreciated the excellent performance of HIP in education and outreach. It was noticed that the large reduction in the budget by the Ministry of Education and Culture was compensated by the member universities, and the budget situation seems stable up to 2024. However, the SAB mentioned that the budget situation needs to be monitored, as it is very important to fulfil the various commitments and retain the possibility of enlarging the current scope with new projects.

The Theory Programme had four projects in 2021. The Theoretical Cosmology project has driven strong collaboration between Helsinki and Jyväskylä, and in the Designer Topological Matter project researchers from Tampere and Aalto University collaborate. Two of the projects continue exceptionally for a third term, namely the very successful High Energy Phenomenology in the LHC Era project as well as the QCD and Strongly Interacting Gauge Theory project.

The Large Hadron Collider (LHC) experiments - ALICE, CMS, and TOTEM - have been analysing data from Run 2 and at the same time upgrading their detectors during the Long Shutdown 2, which lasts until 2022. Contrary to many other laboratories in Europe and elsewhere, the Detector Laboratory could help in testing the novel detectors despite COVID-19. The evidence for an Odderon in the TOTEM data was published. Concerning FAIR, the Phase-0 experiments have been active, and several in-kind projects are in progress.

In the Technology Programme, two larger projects were focussed on CERN, one of the projects dealt with robotics and the other with materials technology for accelerators. Four smaller projects were connected with radiation safety, security and safeguards in collaboration with the Finnish Radiation and Nuclear Safety Authority and CEA.

The Detector Laboratory supported all the experimental activities in the Institute, and the activities for the LHC MoEDAL experiment, which HIP joined in 2021, are in the laboratory. In addition, a group from the laboratory joined the National Quantum Institute, InstQ, and an externally funded Research to Business project started in the laboratory.

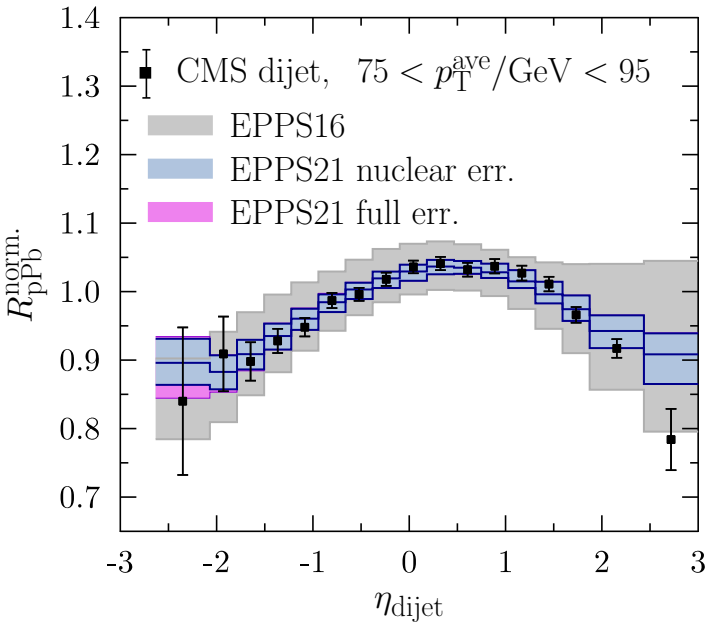
The project leader of the High Energy Phenomenology in the LHC Era project, Aleksi Vuorinen, was promoted to a Professor, as was the project leader of the EUCLID project Hannu Kurki-Suonio, both at the University of Helsinki. Minsuk Kim from the CMS Experiment project moved to a Professorship in GWNU in South Korea. Very sad news was received in December when two valued long-term colleagues passed away. The obituaries of Dr Jaakko Härkönen and Professor Tuure Tuuva appear in connection with the text of the Detector Laboratory and the CMS Upgrade project, respectively.

HIGHLIGHTS OF RESEARCH RESULTS

Theory Programme

The Theory Programme consists of four research projects, spanning scales from elementary particles up to the whole universe: Theoretical Cosmology, High Energy Phenomenology, QCD and Strongly Interacting Gauge Theory, and Designer Topological Matter.

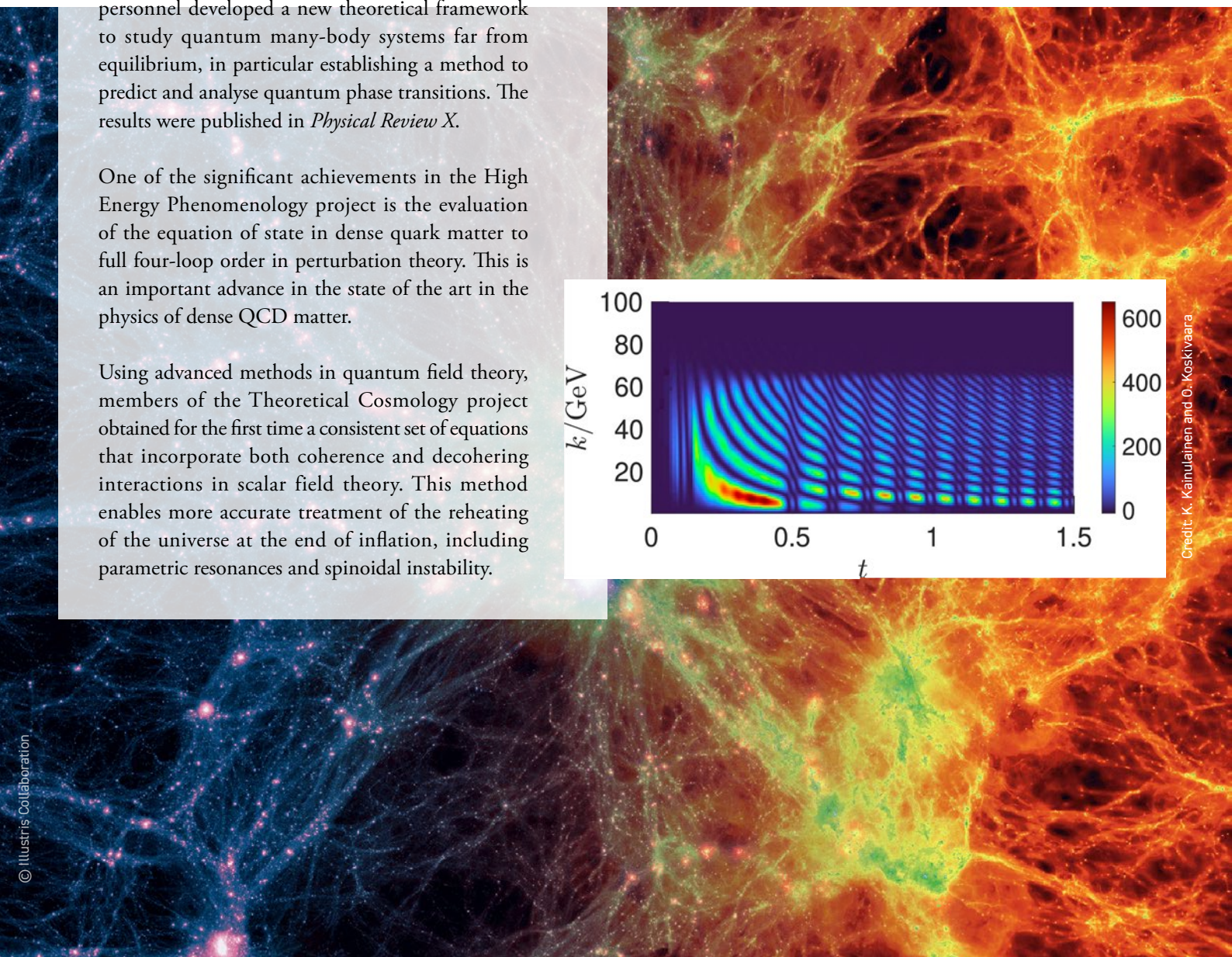
The highlight of the research in the QCD and Strongly Interacting Gauge Theory project is the completion of the new nuclear parton distribution analysis EPPS21, which includes several new constraints from LHC proton-nucleus collision data and fixed target experiments.



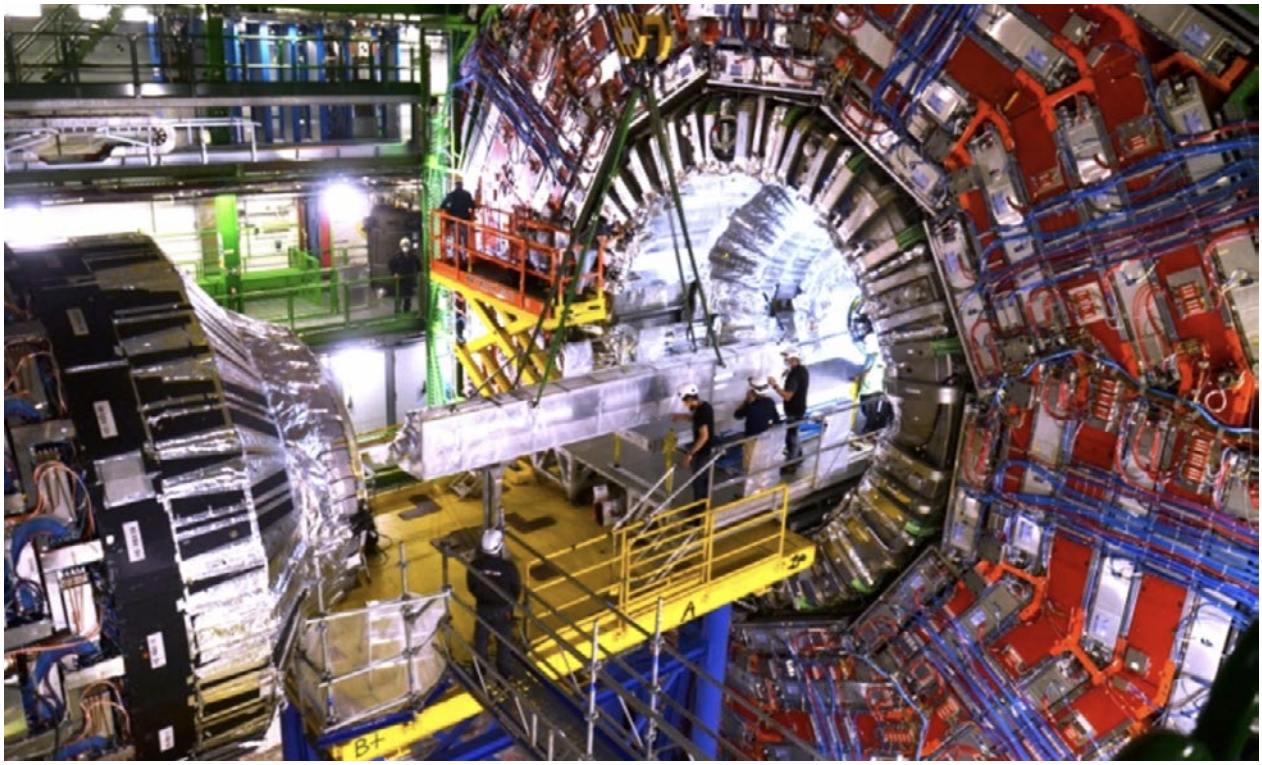
The Designer Topological Matter research project personnel developed a new theoretical framework to study quantum many-body systems far from equilibrium, in particular establishing a method to predict and analyse quantum phase transitions. The results were published in *Physical Review X*.

One of the significant achievements in the High Energy Phenomenology project is the evaluation of the equation of state in dense quark matter to full four-loop order in perturbation theory. This is an important advance in the state of the art in the physics of dense QCD matter.

Using advanced methods in quantum field theory, members of the Theoretical Cosmology project obtained for the first time a consistent set of equations that incorporate both coherence and decohering interactions in scalar field theory. This method enables more accurate treatment of the reheating of the universe at the end of inflation, including parametric resonances and spinoidal instability.



Credit: K. Kainulainen and O. Koskivaara



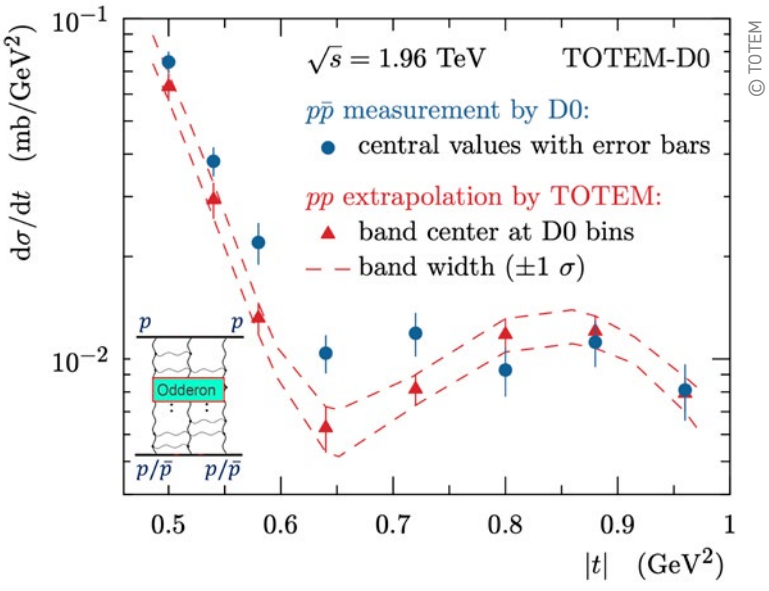
CMS Programme

CMS is a general-purpose experiment at CERN's Large Hadron Collider (LHC). The overall CMS highlights were a precision measurement of the Z invisible width and the first measurement of the Higgs boson width.

HIP contributed to *new physics searches* (Higgs bosons and supersymmetry), *precision physics with jets* (top quark mass and strong coupling constant), and *vector boson scattering*. The focus for 2021 was on preparing for the upcoming Run 3 and improving the calibration of Run 2 Legacy data with a significant HIP contribution to the jet energy corrections. T. Lampén took up a new position as Prompt Calibration Loop (PCL) manager and the SMARTHEP ITN Consortium, which HIP is part of, was successful in securing EU funding.

The upgraded CMS pixel detector, for which HIP made the quality assurance of all pixel detector bare modules for the new innermost layer, was successfully commissioned and it collected data in the LHC pilot run in October 2021. HIP continued its significant role in sensor testing and prototype evaluation for the new Minimum Ionizing Particle Timing Detector Endcap Timing Layer. In addition, a new Business Finland-funded project started - Detector for nuclear safety, decommissioning and diagnostic applications (DeNuSa).

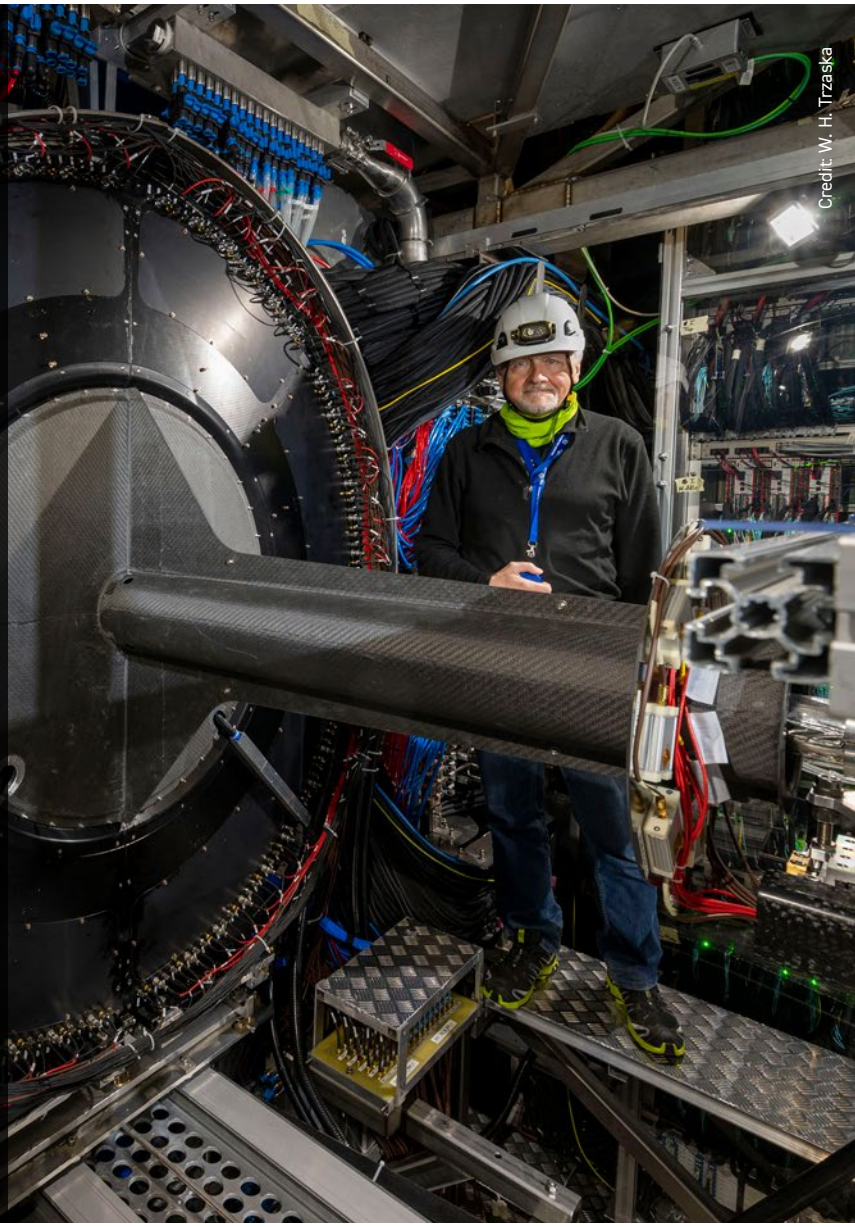
TOTEM is a forward physics experiment at the LHC. The TOTEM highlight was the publication of the *Odderon observation*. Tests of scintillator tile prototypes for the new TOTEM T2 showed excellent performance ensuring the capability of a total cross section measurement at Run 3 maximal collision energy in an upcoming special run. Finally, the metallization quality issues for the diamonds of the CMS Proton Precision Spectrometer time-of-flight detector were solved and the metallization could proceed anticipating installation in spring 2022.



Nuclear Matter Programme

Despite the ongoing pandemic situation, all projects were progressing and delivering new results. At ISOLDE, one of the highlights was the charge radii measurement of exotic potassium isotopes that was published in *Nature Physics* by *Á. Koszorús et al.* (post-doctoral researcher at JYFL). HIP-affiliated researchers M. Kortelainen and R. de Groote were part of the research team that showed that the charge radii of potassium isotopes do not show a signature of a magic shell at $N = 32$, which is in contrast with earlier experimental evidence proposing that $N = 32$ is a new magic neutron number in the calcium region.

As part of the major upgrade of ALICE, a new detector Fast Interaction Trigger (FIT) was installed by the collaboration led by the Finnish team. To ensure timely completion, installation, and commissioning, two ALICE group members stayed full-time at CERN in 2021. The FIT project attracted much attention in CERN media with dedicated articles in the *EP Newsletter*, the *CERN Bulletin*, and *ALICE News*.



Credit: W. H. Trzaska

At FAIR civil construction made remarkable progress, including start of the construction for the NUSTAR and Super-FRS buildings. This is a significant step for the FAIR-HIP project, which presently concentrates on NUSTAR experiments utilising Super-FRS. Despite the pandemic, some of the Phase-0 experiments could be performed, including an investigation of atomic masses of heavy $N = Z$ nuclei with A. Kankainen as a co-spokesperson.

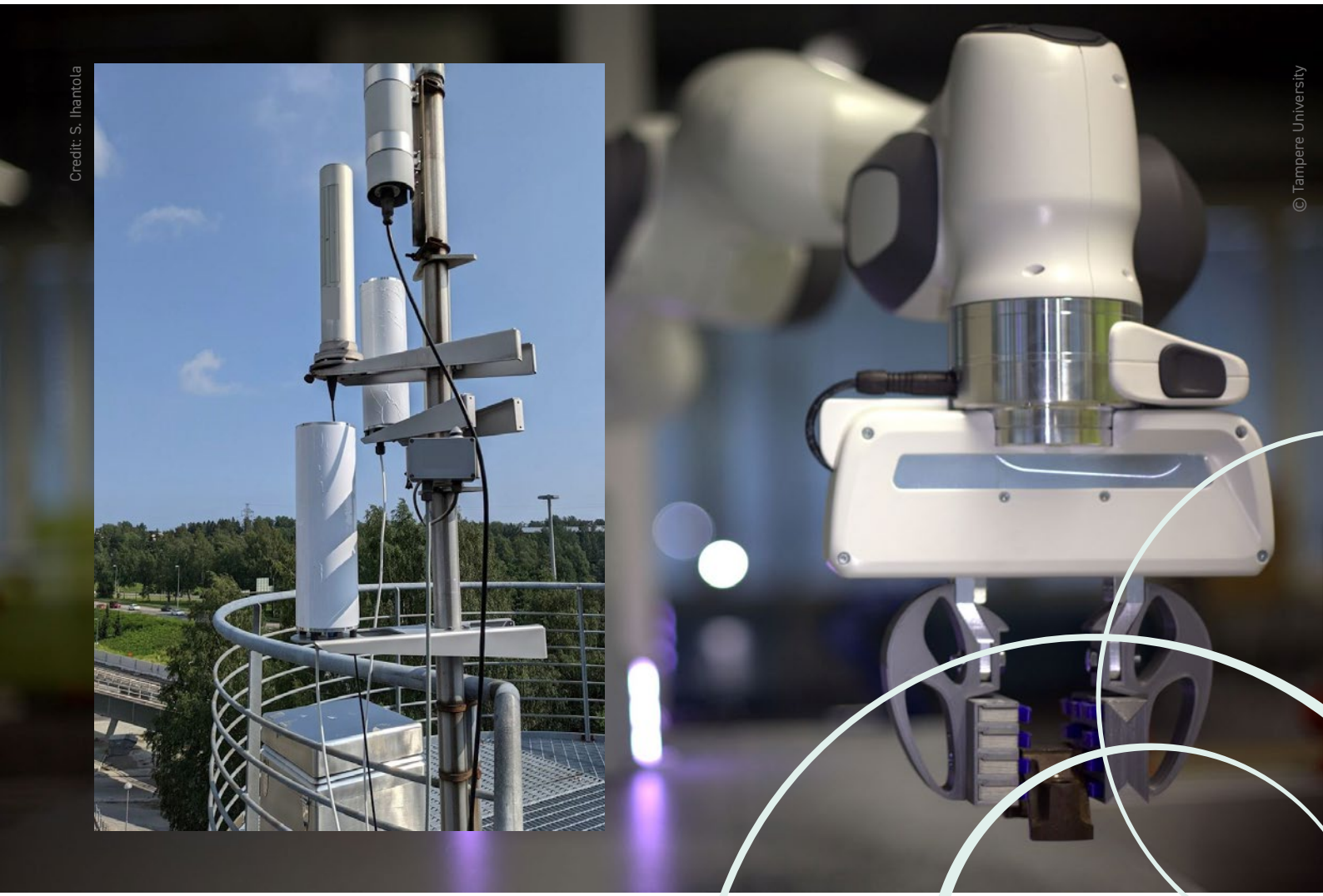
Credit: L. Möller, GSI Helmholtzzentrum für Schwerionenforschung

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 2021, the ROBOT project focussing on the robotics and artificial intelligence for assistance in monitoring and intervention of CERN's accelerator infrastructure was expanded to include activities at both Tampere University and Aalto University. The new MAT project was also expanded to include all the materials science and technology activities related to present and future CERN accelerators from LHC to CLIC and FCC. Another new project, XTREME, was set up to co-ordinate the co-operation with CEA and the research on radioactive materials. The RADAR project ended with its research portfolio transferred to the programme director's activities, in anticipation of the restructuring of the radiation safety research in the coming years.

In RADMED a real-time detection system based on single photon counting with silicon and Cadmium Telluride (CdTe) semiconductor pixel sensors is employed, using readout electronics developed for high-energy physics experiments. Preliminary results indicate that the radiotherapy beam profiles can be measured with good accuracy using the developed silicon pixel detector. CdTe detectors were tested for their applicability in computed tomography and Boron neutron capture therapy.

The XTREME project is proud to announce the arrival of the required hardware from CEA for developing the in-situ X-ray emission spectroscopy apparatus for the examination of chemically complex radioactive materials. In the ROBOT project, a small planar continuum robot has been developed for the inspection of the ALICE detector, as well as novel methods and models for grasping, localisation, and mapping.



Credit: S. Ihantola

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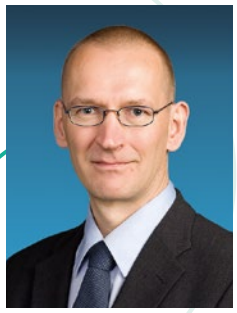
THEORY PROGRAMME

The HIP Theory Programme consists of four fixed-term theory projects: 1) Theoretical Cosmology (leader Sami Nurmi, University of Jyväskylä); 2) High Energy Phenomenology in the LHC Era (leader Aleksi Vuorinen, University of Helsinki); 3) QCD and Strongly Interacting Gauge Theory (leader Tuomas Lappi, University of Jyväskylä); and 4) Designer Topological Matter (leader Teemu Ojanen, Tampere University).



KARI RUMMUKAINEN
Theory Programme director

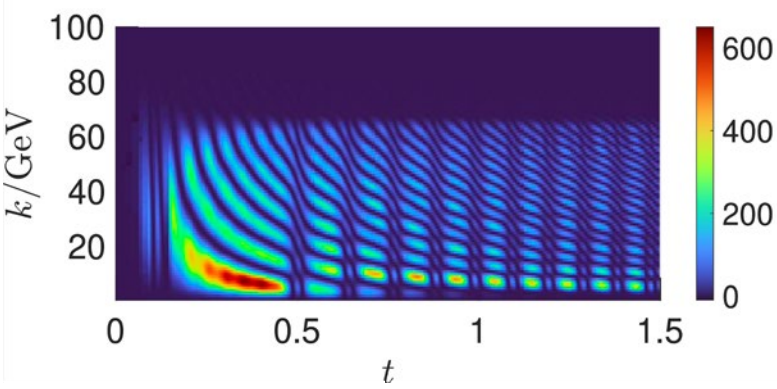
Theoretical Cosmology

SAMI NURMI
Theoretical Cosmology project leader

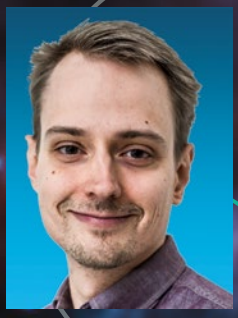
We study the origin and evolution of the universe and connections between cosmology and particle physics. Our research topics involve inflation, dark matter, out-of-equilibrium quantum physics, early universe phase transitions, large scale structures of the universe, and gravitational waves. We test 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 and the LISA Astrophysics and Cosmology Working Groups.

We work broadly on theoretical foundations of inflation in the early universe. This year we enhanced our understanding of the quantum consistency and gravitational couplings in Higgs inflation and more general models and studied novel links between the origin of structures and a non-inflationary Higgs sector. We made progress in understanding several important out-of-equilibrium systems: we performed the most complete simulation of the stochastic inflation that may seed primordial black holes (PBHs) and applied novel quantum transport formalisms to the reheating process at the end of inflation, and also to dark sector electroweak baryogenesis and resonant leptogenesis in the post-inflationary epoch. We studied observationally testable signals associated with PBHs as a dark matter (DM) component, proposing a novel connection with PBHs and the yet unexplained fast radio burst data. We also performed the first quantitative study of light propagation in the high curvature environment due to DM discreteness, proposing a new upper limit on the DM mass.

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. At the microscopic end, we studied two-step transitions non-perturbatively, resolving thermodynamic parameters relevant for the GW signal. On cosmological scales, we investigated GWs from vacuum phase transitions with a combination of three-dimensional and high-resolution two-dimensional simulations. We also made important progress linked to modelling GWs from supermassive black holes: we applied the locally developed KETJU code to run accurate simulations of supermassive black hole dynamics in the centres of massive galaxies, and in addition we also run constrained simulations of local structures. ●



Time evolution of a moment distribution of the scalar field two-point function in reheating *[K. Kainulainen and O. Koskivaara, J. High Energy Phys. 12 (2021) 190].*



ALEKSI VUORINEN
High Energy Phenomenology in the LHC Era project leader

High Energy Phenomenology in the LHC Era

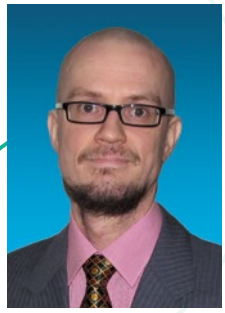
The High Energy Phenomenology (HEP) project carried on its activities in the field of theoretical high-energy physics, with special emphasis on phenomenological topics with direct experimental motivation. On the observational side, the year witnessed a number of interesting developments, including, e.g., hints at lepton non-universality from the LHCb experiment at CERN and accurate new results from neutron-star radius measurements by the NICER Collaboration. These themes were also reflected in the research carried out in the HEP project, with concrete topics ranging from neutron-star physics to dark matter searches, and from early universe thermodynamics to quantum information. Similarly broad research is also envisioned to continue during the last year of the HEP project, 2022.

Three main highlights from 2021 include: the four-loop equation of state (EoS) of cold quark matter, bubble nucleation at high temperatures, and gravitational wave production from a holographic phase transition.

In joint *Physical Review Letters* and *Physical Review D* articles published in the summer of 2021, *R. Paatelainen, A. Vuorinen*, and their international collaborators derived the full four-loop contribution of the soft momentum scale g*mu to the EoS of zero-temperature high-density quark matter. This extremely technical calculation also paves the way towards the completion of the full four-loop EoS, as the authors detailed the calculations needed to obtain the quantity to this order. Their new result was shown to decrease the renormalization scale dependence of the quark-matter EoS and has already found applications in the determination of the neutron-star-matter EoS.

In a *Physical Review D* article from November 2021, *J. Hirvonen and O. Gould* constructed a novel effective field theory approach to the study of bubble nucleation in a high-temperature first order phase transition described through perturbative quantum field theory. They demonstrated that the new approach solves several serious problems encountered in the traditional vacuum bounce formalism and is able to make contact with classical nucleation theory. The new formalism has already been applied to numerical simulations by the authors and their collaborators.

Finally, a future detection of gravitational waves from an early-universe phase transition may teach us interesting lessons about physics beyond the Standard Model. A recent highlight result appeared in the *arXiv* preprint *2110.14442* by *O. Henriksson, M. Hindmarsh, N. Jokela*, and collaborators, who used holographic duality to build a novel and general first-principles method for studying gravitational-wave production at strong coupling. This computationally tractable method opens a path towards a better understanding of bubble nucleation and gravitational-wave production in strongly-coupled theories, thereby enabling a detailed and systematic exploration of vast range of models of beyond-the-Standard-Model physics.



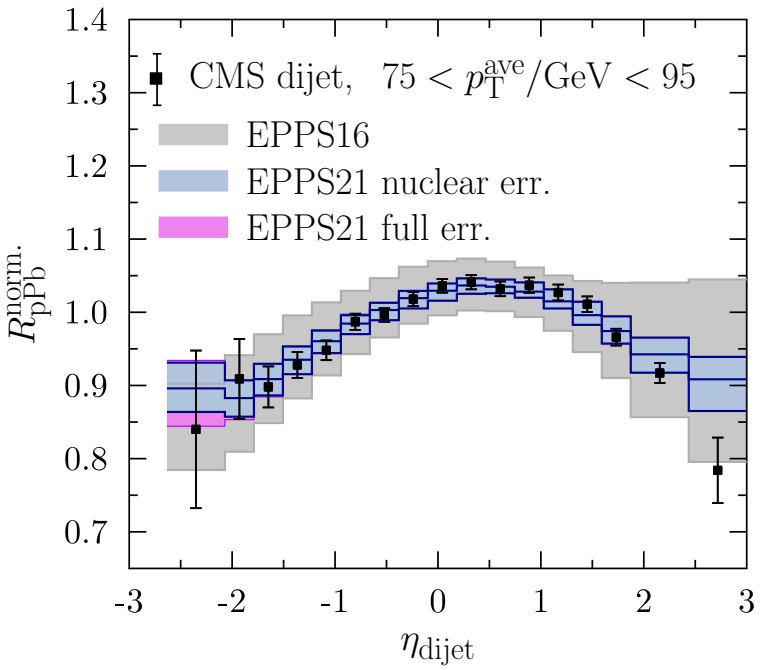
TUOMAS LAPPI
QCD and Strongly Interacting Gauge Theory project leader

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 with physics studies for planned colliders such as the EIC and FCC. We use weak coupling QCD renormalization group equations to understand 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. In 2021, we finalised the analysis for our nuclear PDFs set EPPS21, with new constraints from LHC proton-nucleus data and fixed target experiments. It is expected to become the new standard in the field. We also participated in the TUJU21 analysis where LHC proton-nucleus data is, for the first time, included in a full next-to-next-to-leading order nPDF analysis. The BK evolution equation, in turn, describes the energy dependence of QCD cross sections at high energy. In 2021, we finished a milestone calculation of a new perturbative QCD result, the one-loop photon light cone wavefunction with massive quarks, needed in the BK formalism in deep inelastic scattering. We related the initial conditions of the evolution to a microscopic model of the valence quark structure of the proton. We have studied many aspects of exclusive photon-nucleus processes, such as ultraperipheral collisions at the LHC. We have moved to next-to-leading order accuracy for the first time ever in high energy BK formulation. In collinear factorisation we are finishing the first calculation in nuclei, showing that the process is not as direct a probe of nuclear gluon PDFs as previously claimed, and extended the calculations to electroproduction.

To describe the formation of quark gluon plasma, we use two complementary QCD approaches. In the Colour Glass Condensate picture, it is described in terms of a strong classical gluon field. In the past year, we have focussed particularly on the effects of colour field fluctuations on the eccentricity of small collision systems. 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 2021, we focussed on improving the decoupling description for the end of the evolution.



Dijet data from the CMS Collaboration compared to calculations from our previous and new nuclear parton distribution sets EPPS16 and EPPS21.

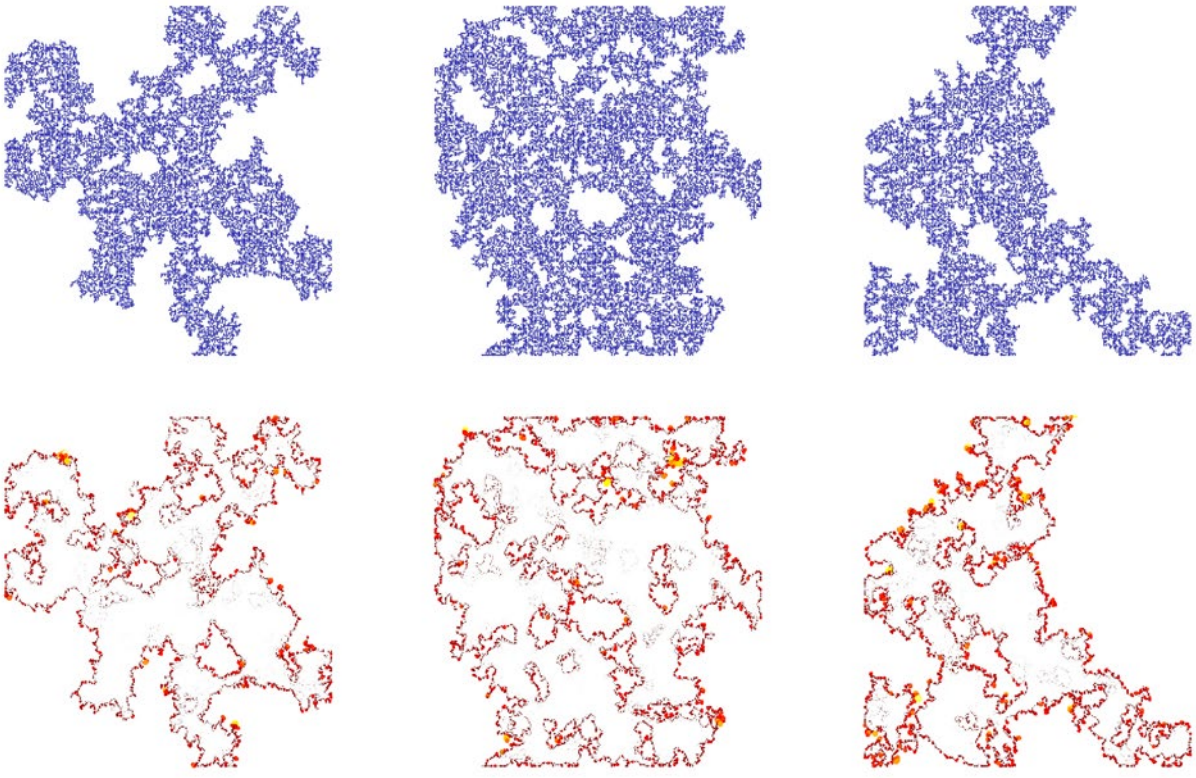
Designer Topological Matter

TEEMU OJANEN
Designer Topological Matter project leader

We study condensed matter and many-body systems with collective quantum behaviour, such as topological materials and quantum devices. Our work ranges from theoretical prediction of novel phases of matter to modelling and proposing experiments and studying complex systems with numerical approaches. In addition to our fundamental interest, we aim to further quantum technologies and quantum information processing.

In breakthrough work published in *Physical Review X*, we collaborated with theorists at Aalto University to develop a new theoretical framework to study quantum many-body systems far from equilibrium. In particular, we established a new method to predict and analyse dynamical quantum phase transitions in strongly correlated systems. The motivation to study dynamical phase transitions originates from the long-standing programme to classify and understand the behaviour of non-equilibrium systems in terms of well-defined phases of matter. Due to their exponentially large Hilbert space dimension and lack of universal physical principles, correlated systems far from equilibrium pose one of the most formidable challenges in contemporary physics. Our work will help in understanding important aspects of these systems better and open new avenues in simulating them with traditional and quantum computers.

Our work on topological states of matter in random lattices recently culminated in the prediction of topological random fractals. We showed that non-integer dimensional random lattices can support well-defined and robust topological states of matter with quantized conductance. This prediction can be seen as continuation of a four-decade long exploration of topological states in increasingly more complex systems.



Random fractal lattices (top) can support robust topological states of matter with quantized conductance.

CMS PROGRAMME

The HIP CMS Programme co-ordinates 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 same LHC interaction point as CMS, is devoted to forward physics, focussing on elastic scattering, total cross section, and diffractive and exclusive processes. The programme is divided into four projects: 1) the CMS Experiment project for physics analysis and operations; 2) the CMS Upgrade project for detector upgrades; 3) the Tier-2 Operations project for LHC computing; and 4) the TOTEM project for CMS and TOTEM forward physics. The Finnish groups in CMS are: HIP (currently 18 authors); the Department of Physics at the University of Helsinki (4 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.

KENNETH ÖSTERBERG
CMS Programme director

MIKKO VOUTILAINEN
CMS Experiment project leader

CMS Experiment

Introduction and Highlights

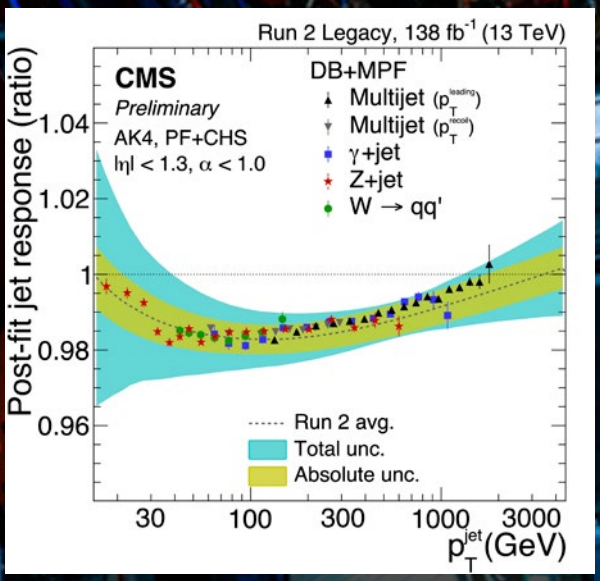
The LHC is in a unique position to explore electroweak symmetry breaking and the origins of the universe. The CMS Experiment project is focussed on analysis of the LHC data, particularly of new physics searches (charged Higgs bosons, SUSY), precision measurements with jets (m_t, α_s) and vector boson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

The focus of 2021 was on improving the calibration of Run 2 Legacy data for precision analyses and preparations for Run 3, which will start in 2022. Both searches and measurements focussed on systematic improvements, with MSc theses on b-jet JEC by A. Pirttikoski (now at U. Geneva), and JEC automation by A. Lintuluoto (now at KIT). J. Havukainen (now at Apple Inc.) defended his PhD thesis on ML applications in HEP, while the SMARTHEP ITN Consortium, which HIP is part of, was successful in securing EU funding. Our ERC-CoG proposal on Jet Energy Corrections for High-Luminosity LHC (HL-LHC) was invited to a second-round interview.

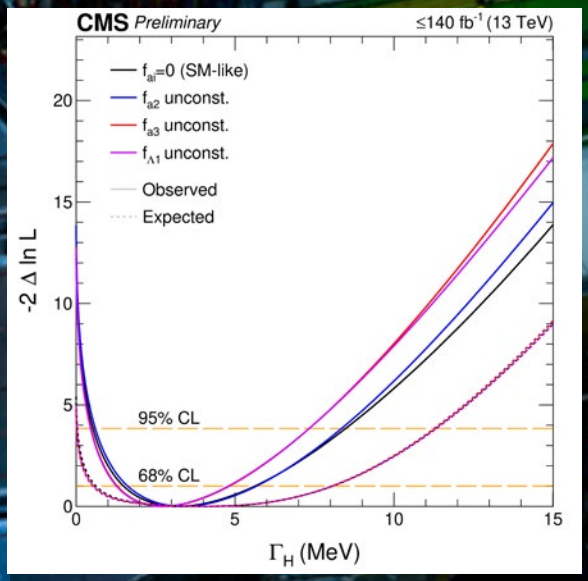
HIP continued its strong scientific leadership at CERN: T. Lampén took up a new position as Prompt Calibration Loop (PCL) manager after convening the Alignment, Calibration and DataBase (AlCaDB) group, while M. Voutilainen, H. Kirschenmann, and M. Kim continued to convene the LHC Electroweak (EW) Working Group Jets & EW Bosons, Jets & Missing Energy and JEC groups, respectively. M. Kim started as Assistant Professor at GWNU in South Korea while maintaining his association with HIP. Overall, the CMS highlights of the year were a precision measurement of the Z invisible width and the first measurement of the Higgs boson width Γ_H = (3.2 + 2.4 - 1.7) MeV.

Detector Operations

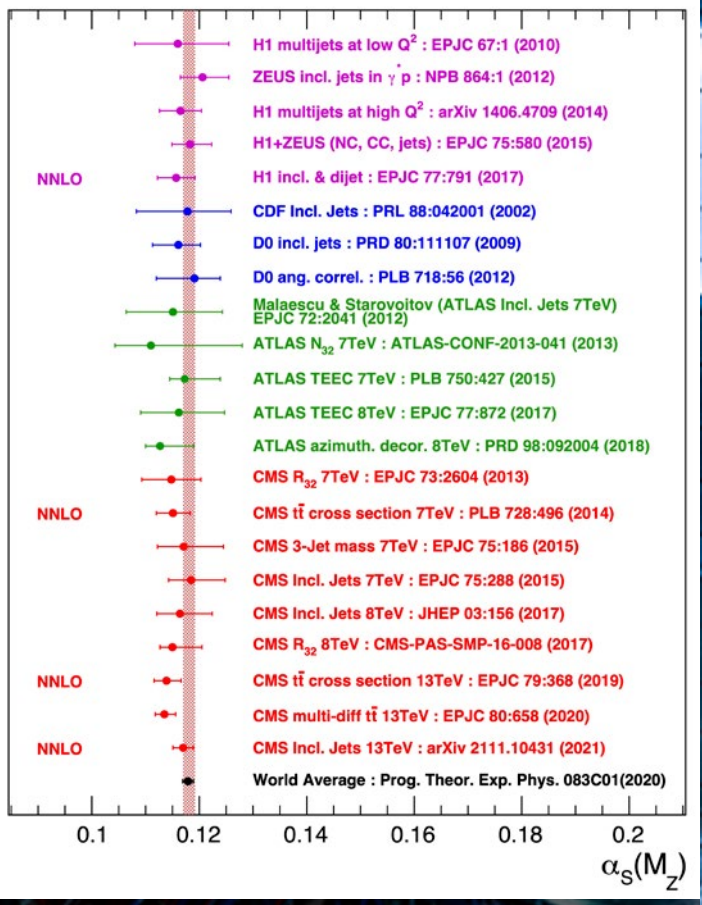
The AlCaDB group focussed on preparations and developments for Run 3, especially concerning the PCL providing up-to-the-minute calibrations for data-taking, while the JEC team with 7 contributors from HIP provided calibrations for Run 2 Legacy data, with a strong focus on further improving systematic uncertainties beyond Run 1. Initial results were released as a detector performance note, with a paper in preparation. The ML team focussed on W boson polarization tagging, quark-gluon discrimination, and ML-based JEC.



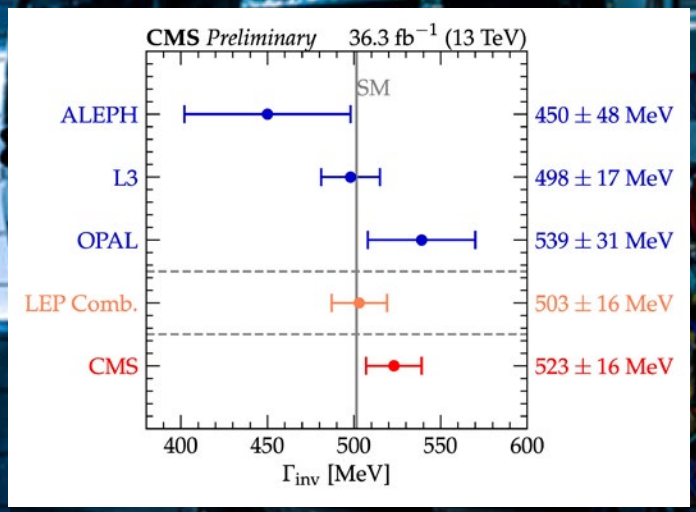
The jet energy corrections for the CMS Run 2 Legacy data set, with all inputs on this plot from the CMS Experiment group. The jet energy uncertainties are similar to those in Run 1, but not yet final. © *CMS Collaboration, CERN.*



The likelihood of the Higgs width Γ_H from off-shell Higgs boson production with and without (f_{ai} = 0) anomalous couplings to vector bosons using the CMS full Run 2 data set. © *CMS Collaboration, CERN.*



Comparison of measurements of the strong coupling constant α_S at hadron colliders. The CMS α_S measurement from inclusive jets using 2016 data and with next-to-next leading order Quantum Chromo Dynamics (QCD) predictions *[arXiv:2111.10431 (2021), J. High Energy Phys. 02 (2022) 142]* is the most precise with a 1.6% relative uncertainty compared to 0.85% for the world average that includes lattice QCD predictions. © *CMS Collaboration, CERN.*



The first measurement of the invisible width of the Z boson at a hadron collider compared to the measurements from the Large Electron Positron (LEP) collider experiments and their combination. © *CMS Collaboration, CERN.*

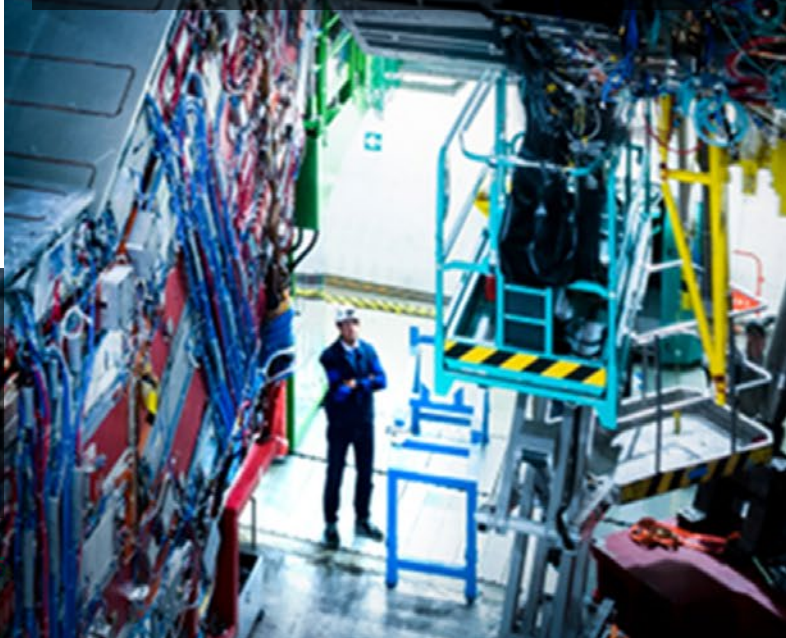


Photo of the CMS Experiment team after J. Havukainen's "karonkka" (PhD thesis defence dinner).
Credit: J. Pekkanen.

Precision Measurements

Measurements of the top quark mass m_t, the inclusive jet cross section, and the gluon jet production continued on full Run 2 data, aiming at constraining m_t and the strong coupling constant α_s in exploration of the Standard Model (SM) vacuum stability and physics up to the Planck scale. The measurement of inclusive jet cross sections on 2016 data was submitted to *JHEP*, providing the most precise single value of α_s at hadron colliders (1.6% uncertainty at next-to-next leading order).

New Physics Searches

Searches for charged Higgs bosons in the full Run 2 data in the $\tau\nu_\tau$ channel continued, while M. Lotti completed his PhD thesis on the WH final state. A new search for doubly-charged Higgs bosons in a same-sign double-τ final state was initiated in collaboration with HIP theoreticians. The SUSY search for a gluino pair decaying to $t\bar{t}t\bar{t}$ was completed on the full Run 2 data and will be published in 2022. These channels explore electroweak symmetry breaking and search for physics beyond the SM and candidates for dark matter.

Vector Boson Scattering

The HIP team participated actively in the VBSCan COST network completion and follow-up and is involved in the first study of VBS in the all-hadronic final state using Run 2 data and preparations for the Run 3 measurement. ●

CMS Upgrade

PANJA-RIINA LUUKKA
CMS Upgrade project leader

Introduction

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

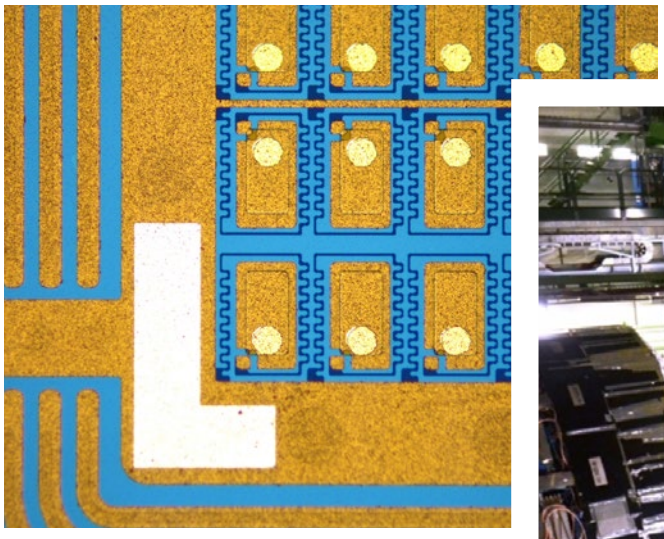
In the CMS Phase-2 upgrade, Finland will participate in the upgrade of the Tracker pixel detector and in the building of the new Minimum Ionizing Particle Timing Detector Endcap Timing Layer (MTD-ETL). J. Ott and A. Gädda successfully defended their PhDs on detector R&D.

Pixel Detector Upgrade

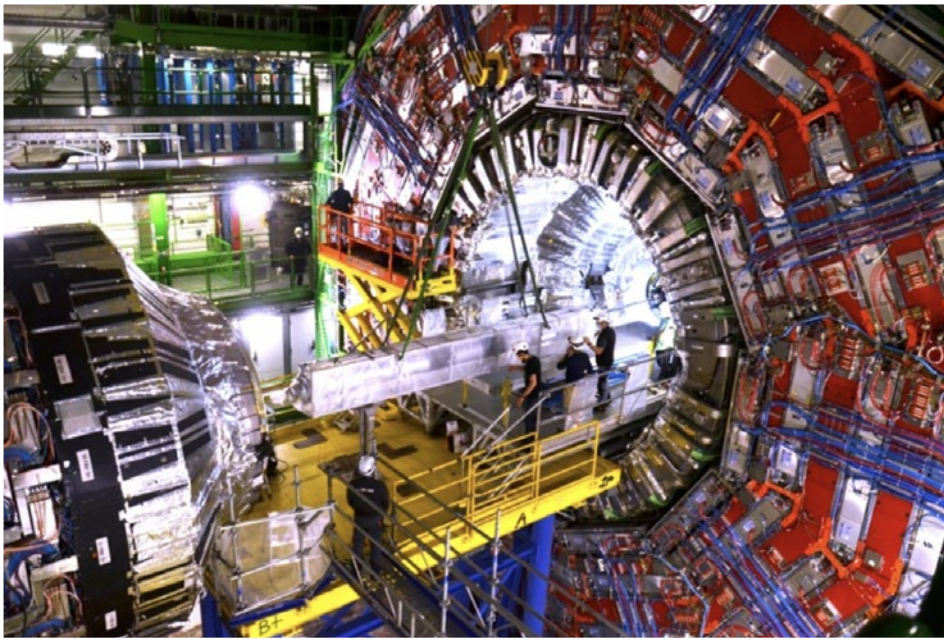
Finland has been strongly involved in the intermediate upgrades of the innermost pixel detector in the past. In 2019-2021, the CMS pixel detector went through an intermediate upgrade, the so-called Pixel Layer 1 refurbishment, to improve its performance for Run 3. In this upgrade, the innermost layer of the pixel detector (L1) was replaced with modules carrying an upgraded readout chip. The CMS Upgrade project was responsible for the quality assurance of all pixel detector bare modules after flip-chip bonding. In October 2020, the full L1 was moved to CERN and the commissioning of the detector began. This project was successfully finished this summer, and the refurbished detector collected data in the LHC pilot run in October 2021.

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

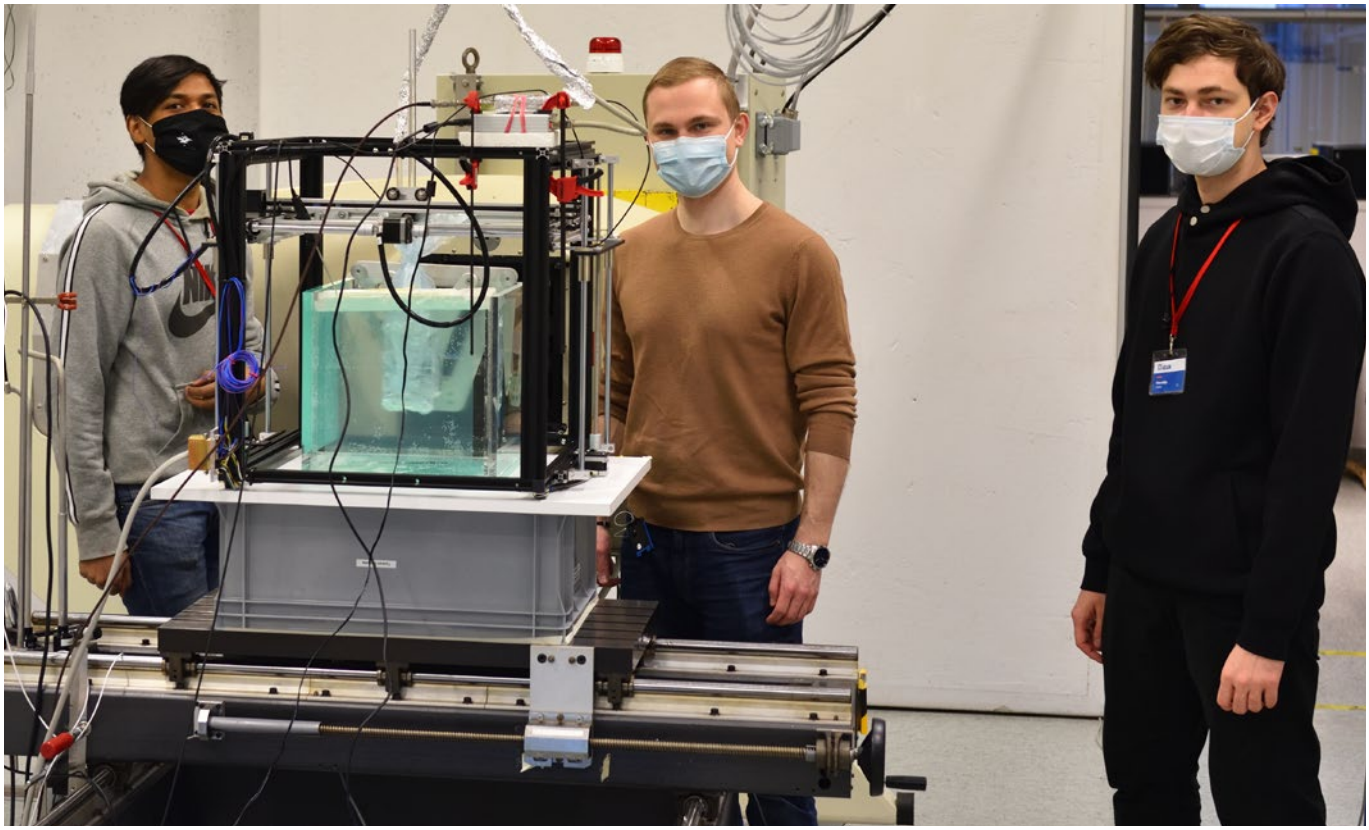
In the CMS MTD-ETL detector construction project, several pre-production runs with different commercial detector producers have been achieved in 2020-2021. The chosen technology for this detector is the Low Gain Avalanche detector (LGAD). The CMS Upgrade project had a significant role in sensor testing and prototype evaluation of the novel LGADs at the Helsinki Detector Laboratory.



Details of an in-house manufactured AC coupled pixel sensor. Pixels with biasing structures and pads coated with gold as under bump metallization are shown. *Credit: A. Gädda.*



Installation of the refurbished CMS pixel tracker. © *CERN.*

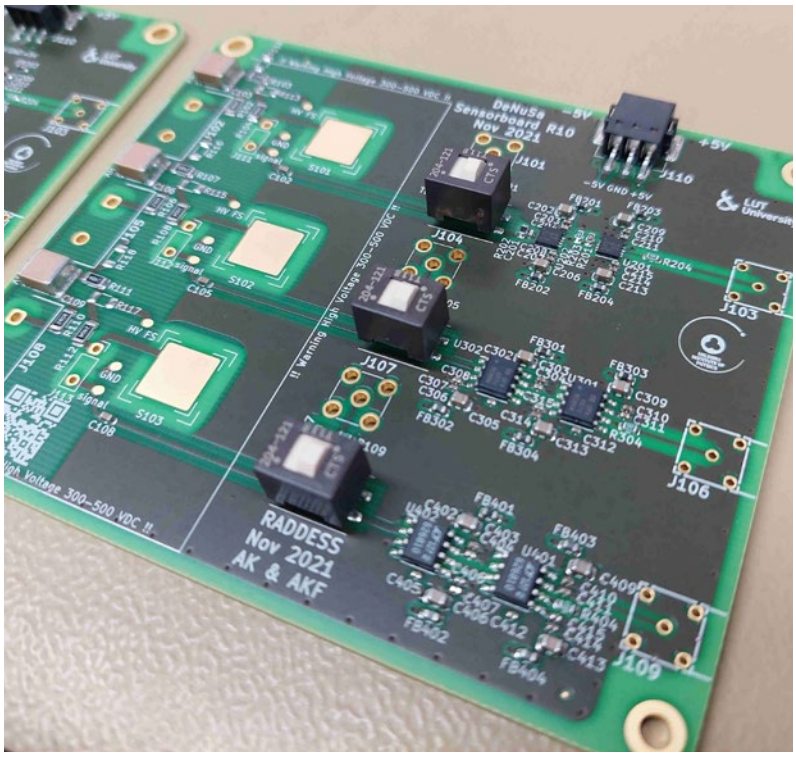


The CMS Upgrade team at the setup to measure the beam dose profile of a gamma-ray beam for medical applications in the facilities of the Finnish Radiation and Nuclear Safety Authority (STUK). *Credit: E. Brücken.*

Detector R&D and Spin-Off Projects

In 2021, the CMS Upgrade project continued collaborating with the Finnish Radiation and Nuclear Safety Authority (STUK), Aalto University, and Lappeenranta-Lahti University of Technology (LUT) in developing multispectral imaging detectors for medical imaging and beam characterization (MPMIB) within the Academy of Finland RADDESS programme. The project ended in 2021 and final results will be reported in scientific journals in spring 2022.

Adjacent to the MPMIB a Business Finland-funded project commenced in July 2021 for Detector for nuclear safety, decommissioning and diagnostic applications (DeNuSa) of the Helsinki Detector Laboratory and the LUT Particle Physics Instrumentation group. This project has achieved its first milestone of building the first detector board prototype. DeNuSa's intention to develop a small and accurate radiation detector was presented at the start-up event SLUSH 2021. ●



DeNuSa ABC -detector ReadOut Input Output (I/O) v1.0 2021 electronics (development and production at LUT).

T. Tuuva in memoriam

Tuure Tuuva (6.3.1957 - 25.12.2021)

On Christmas Day, our dear friend and respected colleague Tuure Tuuva passed away. In our grief we are comforted by knowing that he was able to spend his final days with his most loved ones.

Tuure was a pioneer in studying radiation detectors in Finland, and his endless enthusiasm and interest for new tasks and challenges continued to be powerful and undiminished through decades until the very end. His versatile skills extended from semiconductor and gaseous detectors to readout electronics and data acquisition systems. Already in the 1980s, Tuure was manufacturing semiconductor detectors for the CERN LEP DELPHI Microvertex experiment. Later, at the beginning of the 1990s, he contributed to the design of the central silicon tracker of the CMS experiment. During this millennium, he has been an essential player both in the manufacture of the CMS RPC muon trigger system and in the construction of the CMS GE1/1 station at the CMS forward muon trigger system. He has also participated in several research projects and commercial activities where the detector technologies of particle physics experiments have been expanded to applications in medicine and nuclear safety.

Tuure was always kind, positive, inspiring, and supportive to the people around him. Tuure's skills and enthusiasm expanded from physics to other areas in life. He was a skilful and devoted rock musician, who was able to combine his work and his musical interests in perfecting the sound of electrical guitars by his skills in electronics. He was also often heard playing with a sound and a touch amazingly close to Jimi Hendrix's.

As a Professor and mentor, Tuure devotedly supervised a multitude of new doctors in technology. He was true to his colleagues, many of whom became his friends during the scope of the decades. He loved his family of whom he always spoke very beautifully.

Tuure will always have a special place in our hearts.

Tuure's friends and colleagues from Lappeenranta-Lahti University of Technology and the Helsinki Institute of Physics

TOMAS LINDÉN
Tier-2 Operations project leader

Tier-2 Operations

The HIP Worldwide LHC Computing Grid (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 2021 with acceptable availability. The CMS Site Readiness average fraction was 65% (85% in 2020). T. Lindén represented HIP in the NeIC Nordic LHC Computing Grid steering committee. M. Myllymäki worked 20% in the Tier-2 Operations project. There were 38 Global Grid User Support tickets (18 in 2020) concerning HIP.

From February 2021, all CMS jobs were run on the Linux clusters Kale (5096 cores from 2015) since Alcyone (840 cores from 2011) was taken out of service in January. Issues with the ZFS/NFS file system performance affected the usability of Kale during 2021. The dCache disk storage services at CSC were stable.

A Nordic WLCG resource needs paper was written to prepare for discussions of enabling the CSC Lumi supercomputer resource for WLCG computing. The Finnish Computing Competence Infrastructure (FCCI) infrastructure application was submitted to the Academy of Finland. The acquisition process to renew the HIP Tier-2 disk storage advanced.

In total, 948 TB of data was moved to HIP and 348 TB from HIP to elsewhere in 2021 (1757 TB to HIP and 1691 TB from HIP in 2020). The storage system achieved new peak transfer rates of 3.2 GB/s to HIP and 2.3 GB/s from HIP. A total of 0.17 million CMS grid jobs (0.98 million in 2020) using 37 MHS06 CPU hours (25 MHS06 in 2020) were run with an average CPU efficiency of 89% (48% in 2020).

KENNETH ÖSTERBERG
TOTEM project leader

TOTEM

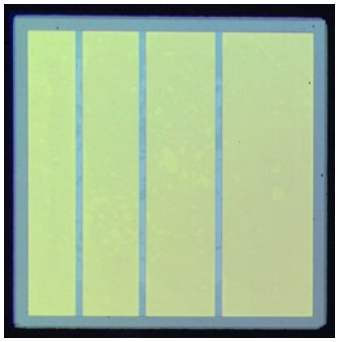
The TOTEM project is responsible for the Finnish TOTEM and CMS forward physics contributions. In 2021, the group consisted of Professor K. Österberg, Professor Emeritus H. Saarikko, scientist F. Garcia, post-docs L. Forthomme and F. Oljemark, PhD student M.-M. Rantanen, and civil service man L. Östman. The focus in 2021 was on Run 3 detector upgrades, as well as physics analysis and publications. K. Österberg continued co-ordinating the TOTEM physics and F. Garcia the CMS Proton Precision Spectrometer (PPS) test beam activities.

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). Long-standing issues with the metallization quality at Princeton were solved and full-scale metallization of the Run 3 diamonds could start both at Princeton and Applied Diamond, Inc. in autumn 2021 in view of an installation of them in the LHC tunnel during spring 2022. HIP is responsible for producing the scintillator tiles (F. Garcia, R. Turpeinen) as well as developing the software

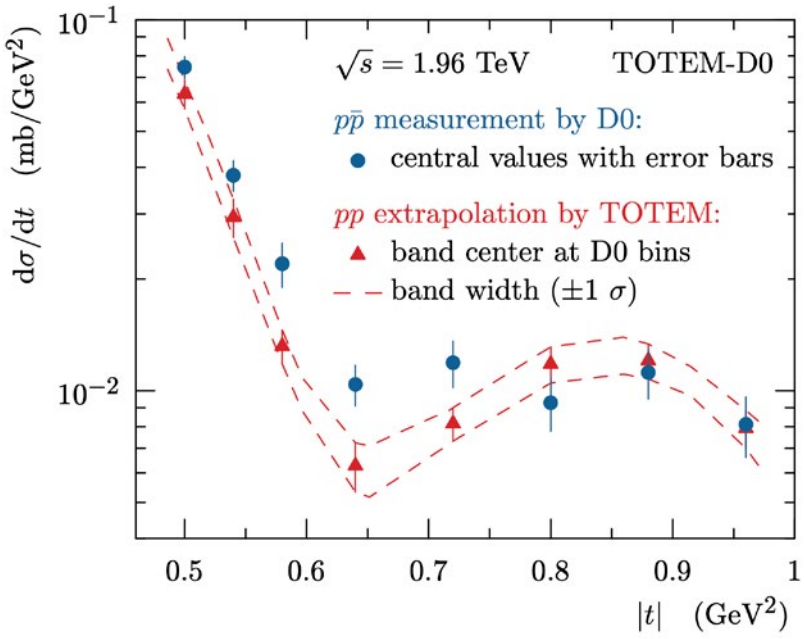
The scintillator tiles for the first TOTEM nT2 quarter manufactured and assembled in Helsinki. *Credit: F. Garcia.*

(F. Oljemark, L. Forthomme) for the TOTEM new T2 (nT2). Tests of nT2 tile prototypes in 2021 at CERN's SPS showed excellent performance. The tiles for the first nT2 quarter have been produced and the preparation of the production of the remaining tiles in Helsinki has been made. The nT2 will be used for a total cross section measurement at Run 3 maximal collision energy (≥ 13.5 TeV) in an upcoming dedicated special run, most likely at the end of 2022. In view of the longer-term future, HIP is also involved in the preparations of a HL-LHC PPS upgrade.

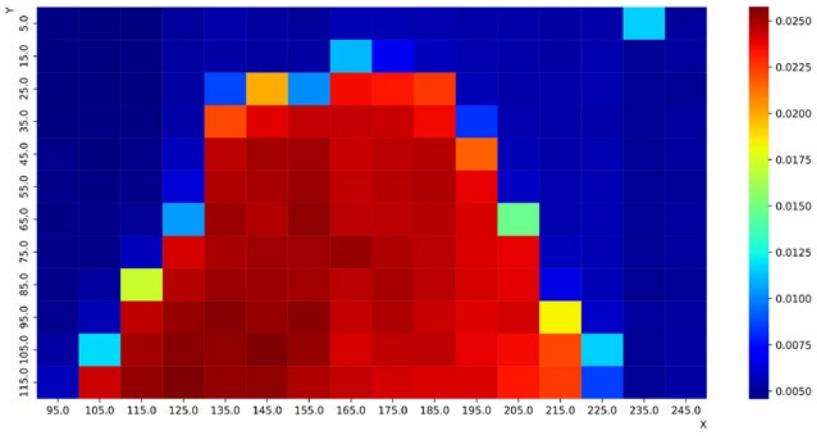
In 2021, the observation of the Odderon, a C-odd colourless gluonic compound, by the TOTEM and D0 experiments was published in *Physical Review Letters (PRL)*. The observation is based on combining a comparison of the 1.96 TeV elastic proton-proton (pp) and proton-antiproton differential cross section in the region of the pp diffractive minimum and secondary maximum with a previously published TOTEM measurement of the decreasing ρ value, the real-to-imaginary hadronic elastic amplitude at momentum transfer squared t = 0, in pp elastic scattering at LHC. Regarding PPS, CMS and TOTEM submitted the first LHC search for exclusive diphoton events at high masses using measured protons based on 2016 data to *PRL* (L. Forthomme). In addition, the feasibility study for a Run 3 low mass SUSY search with PPS tagged protons continued (L. Östman, L. Forthomme). ●



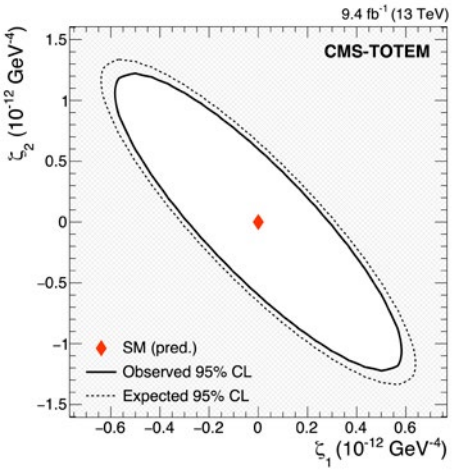
A diamond sensor for the CMS PPS time-of-flight detector metallized at Applied Diamond, Inc. *Credit: P. Koponen.*



Comparison of the elastic proton-proton and proton-antiproton cross section as function of the momentum transfer square $|t|$. The observed difference is due to Odderon exchange. © *Physical Review Letters, American Physical Society.*



Tomography of a TOTEM nT2 scintillator tile prototype with charged pions at CERN's SPS. The mean amplitude (in V) of the pion signal in the nT2 tile is depicted as the coloured scale. © *TOTEM Collaboration, CERN.*



First limits on the anomalous four-photon couplings ζ_1 and ζ_2, derived from the observed upper limit on the high mass exclusive diphoton production cross section. © *CMS and TOTEM Collaborations, CERN.*

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

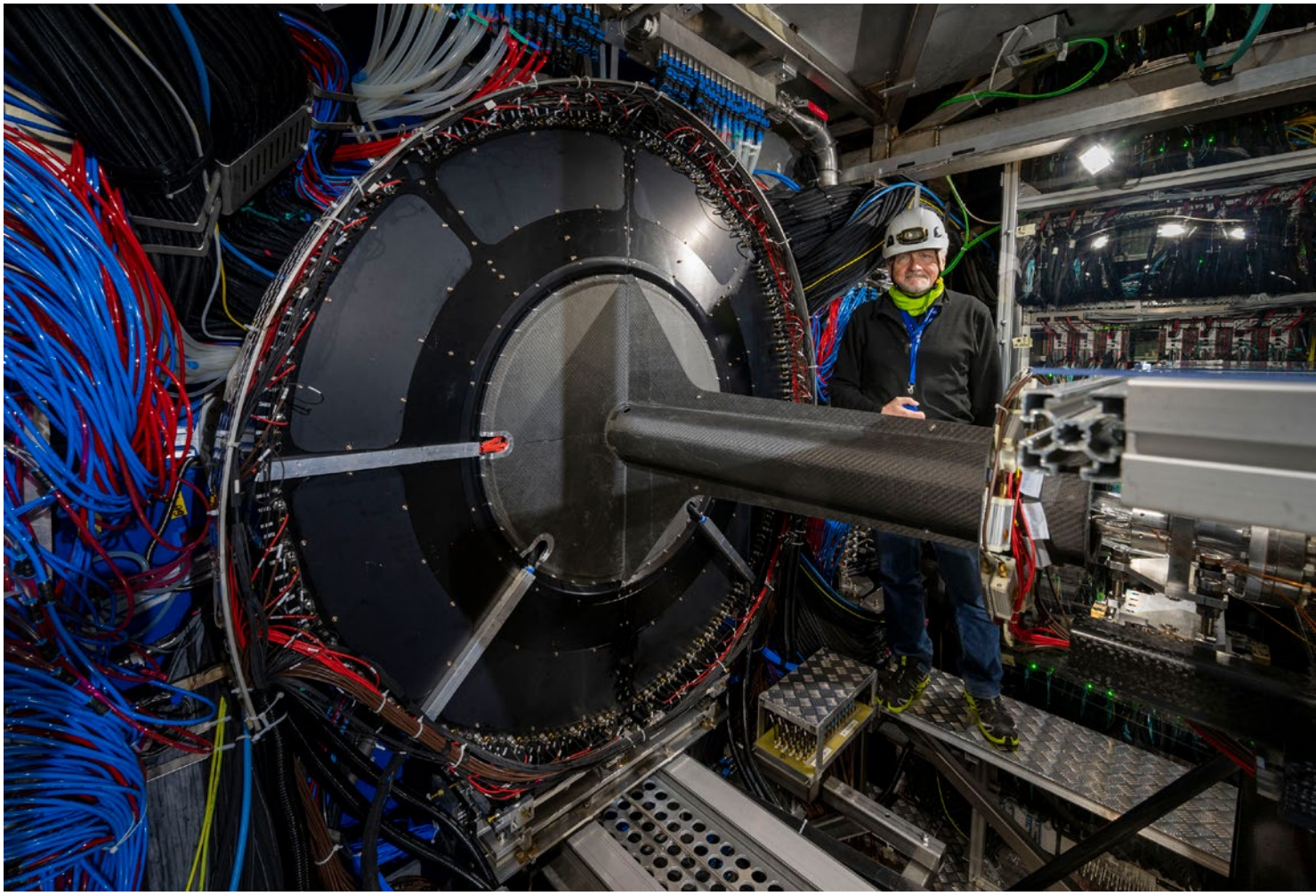
In ultra-relativistic heavy-ion collisions, matter undergoes the deconfined phase transition to quark gluon plasma (QGP), a new state of matter where quarks and gluons no longer form bound states, like protons or neutrons. ALICE (A Large Ion Collider Experiment) is the only dedicated heavy-ion experiment at the CERN Large Hadron Collider (LHC).

In 2021, ALICE completed a significant upgrade preparing for the 2022 start of the LHC Run 3. The expected Pb-Pb instantaneous luminosity will increase by a factor of 6, and the minimum-bias Pb-Pb interaction rate will be ~ 50 times more than the heavy-ion collision rate during Run 2. To cope with such a drastic change and to achieve the proposed physics objectives, ALICE implemented several improvements and installed three new detectors, including the Fast Interaction Trigger (FIT).

FIT is essential for ALICE operation. It was designed to provide input for the new ALICE Central Trigger Processor, monitor luminosity, determine the collision time, and provide an unbiased sample of the forward multiplicity needed to extract the centrality and the reaction plane required in the analysis of heavy-ion collisions. The Finnish team led the collaboration of 19 institutions from 9 countries. To ensure timely completion, installation, and commissioning, two of our group members stayed full-time at CERN in 2021. The schedule was extremely tight, but the detector was ready for the first LHC test collisions in October. The FIT project attracted much attention in CERN media with dedicated articles in the *EP Newsletter*, the *CERN Bulletin*, and *ALICE News*.

In physics data analysis, we continued our studies of the dijet mass distribution in proton-proton and proton-lead collisions. Our team also applied Bayesian analysis of ALICE data to constrain the shear and bulk viscosities of QGP. This novel analysis has been very well received by the community. We have also contributed to the R&D on the new Forward Calorimeter (FoCal) that will be a part of the 2026 upgrade of ALICE. Here we provided a significant portion of the custom simulations supporting the test beam effort and analysed the silicon PAD data.

In 2021, two of our team members were awarded CERN Fellowships. J. Parkkila, who defended his PhD thesis in November 2021, moved to the ALICE CERN team. M. Slupecki, our post-doc, will join the CERN Beam Department in July 2022. In addition, the Academy of Finland awarded the Jyväskylä Theory and ALICE groups with a Centre of Excellence in Quark Matter, thus strengthening our resources for the next eight years.



W. Trzaska next to the FIT-A. *Credit: W. H. Trzaska.*

H. Rytkönen and L. Huhta during the October 2021 FoCal prototype tests with SPS beams. *Credit: W. H. Trzaska.*

Y. Melikyan (JINR) and M. Slupecki assessing rerouting of optical fibres on the ALICE miniframe. *Credit: W. H. Trzaska.*

JANNE PAKARINEN
ISOLDE
project leader

ISOLDE

Due to the COVID-19 pandemic, our ISOLDE operations were mainly focussed on analysis of earlier data obtained at ISOLDE.

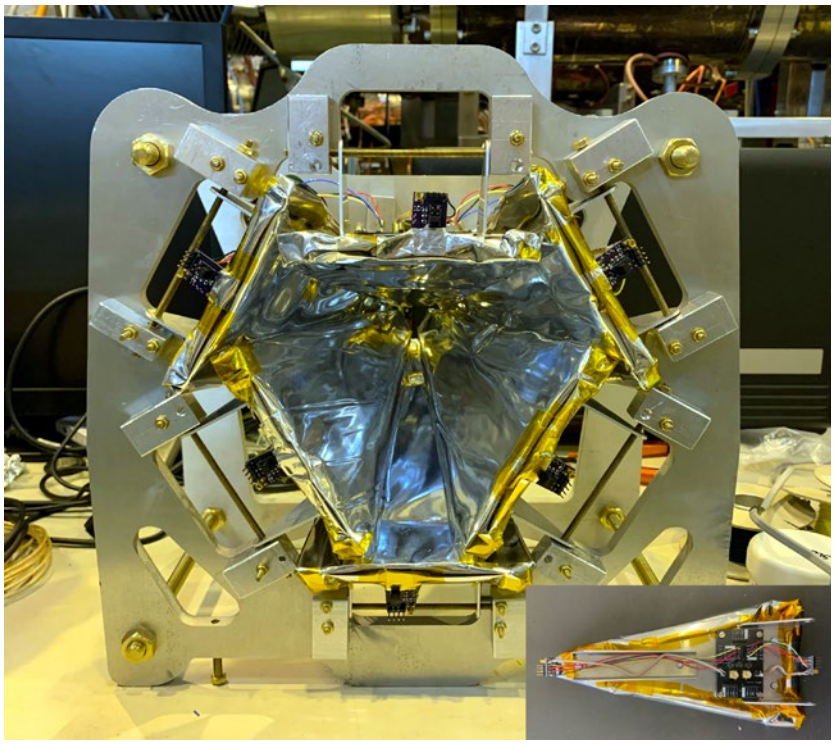
The physics highlight of the year in 2021 was the charge radii measurement of exotic potassium isotopes that was published in *Nature Physics* by *Á Koszorús et al.* The charge radius is a fundamental property of the atomic nucleus that globally scales with the nuclear mass number as $A^{1/3}$, but isotopic variations appear due to complex interactions between protons and neutrons. Charge radii reflect various nuclear structure phenomena such as nuclear halos, shape staggering, and occurrence of so-called nuclear magic numbers that are related to closed nuclear shells. HIP-affiliated researchers, M. Kortelainen and R. de Groote, were part of the research team that showed that the charge radii of potassium isotopes do not show a signature of a magic shell at $N = 32$, which is in contrast with earlier experimental evidence proposing that $N = 32$ is a new magic neutron number in the calcium region.

Another important finding was published in *Physical Review Letters* by *S. M. Udrescu et al.* A recent pioneering work conducted at ISOLDE allowed for measuring the isotope shifts of radioactive $^{223\text{-}226,228}Ra^{19}F$ molecules for different vibrational levels. This technique exhibits a remarkably high sensitivity to changes in the nuclear charge radius of the Ra nucleus and brings added sensitivity to probe electron-nucleon interaction in the proximity of the Ra nuclei.

Despite the COVID-19 pandemic, M. Myllymäki could participate in the HIP-funded summer training at CERN. Her main task was characterization and construction of the detectors used in the β-NMR experiment at the Versatile Ion polarisation Technique Online beamline.

Future Plans

The ISOLDE users community has been steadily growing in the last 15 years and the demand for beam time outnumbers the 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 regarding how the ISOLDE facility could expand in the future have been presented. These plans include a new building for the so-called 'low-energy branch' of ISOLDE with several new target stations and front-ends.



Conical array of six trapezoidal detectors characterised and constructed for the VITO experiment. A trapezoidal detector unit is shown in the bottom right inset.

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

TUOMAS GRAHN
FAIR
project leader

Despite the ongoing pandemic, FAIR civil construction made remarkable progress. The structural work for the SIS100 synchrotron tunnel and ring closure was completed. In addition, civil construction for the NUSTAR and Super-FRS buildings has started, which is a significant step towards the completion of the intermediate objective of FAIR. The facility is on track to start operations in 2025. While the full FAIR is still under construction, a staged approach to science exploitation has been taken. The collaboration's commissioned new spectrometers and Phase-0 experimental programme continued to deliver beams for experiments.

Phase-0 Experimental Programme in 2021

Finland is one of the six FAIR partners that support the Phase-0 experimental programme that will precede the full FAIR operation. In 2021, HIP researchers participated in several experiments utilising the radioactive ion beam from the Fragment Separator (FRS). For instance, nuclear structure in the vicinity of ^{100}Sn was probed using the FATIMA spectrometer and atomic masses of heavy $N = Z$ nuclei were measured (A. Kankainen as a co-spokesperson). Furthermore, fission isomers in heavy radioactive nuclei were studied at the FRS separator.

New instrumentation and methodology to test new radioactive beams in cancer therapy were developed and tested at the FRS separator by the BARB Collaboration. The ultimate goal is to develop a treatment method using β^+-radioactive beams that can be simultaneously used for PET imaging.

FAIR Component Developments

Notable milestones of Finnish component deliveries were achieved as the Conceptual Design Review (CDR) was passed by the SEM-grid detectors for the Super-FRS beam profile detectors. The prototype SEM-grid detectors were successfully tested during the Phase-0 campaign in 2021. The design is carried out in collaboration with a US company who will manufacture the first-of-series detectors. The CDR for the Super-FRS radioactive component safety transport container was also successful. This was done in collaboration with a German industrial partner.

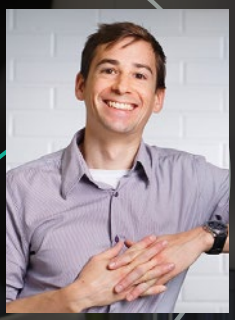
The in-kind contract for the Super-FRS beam tracking detectors was signed. This development will contain 32 units of GEM-TPC detectors which will be the responsibility of the HIP Detector Laboratory. Overall, the HIP FAIR project is responsible for delivering a detector system that will form the backbone of the beam diagnostic and identification system of the Super-FRS, which is needed for the Super-FRS to identify and deliver beams.

The construction site in December 2021. *Credit: L. Möller, GSI Helmholtzzentrum für Schwerionenforschung.*

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 4 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.

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 dozens of industrial parts typical in (robotic) maintenance interventions. The training of the model utilises only simulation and generates training data from CAD models of industrial parts. This work is part of K. Samarawickrama's PhD studies.

3. *Navigation and semantic mapping.* In order to map an environment, both spatial relations and semantic meaning need to be captured and incorporated into a coherent model. Simultaneous localisation and mapping (SLAM) methods have been developed to track the robot pose and reconstruct an environment without pre-existing map (e.g., tunnels). This work was carried out as part of L. Raivio's MSc thesis.

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

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

X-ray Absorption Spectroscopy (XAS) and X-ray Emission Spectroscopy (XES) are non-destructive methods allowing the direct characterization of a given element in any kind of sample. 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 XAS/XES instruments with performance complementing the synchrotrons, as developed for example during the GAMMA project (2018-2020), could solve this issue for routine XAS experiments. However, on chemically complex samples, replacing the usual detectors by an X-ray emission spectrometer is mandatory for XAS reliable results. Not yet available in the laboratory, the XTREME project aims to implement such an emission spectrometer adapted to a laboratory scale XAS apparatus.

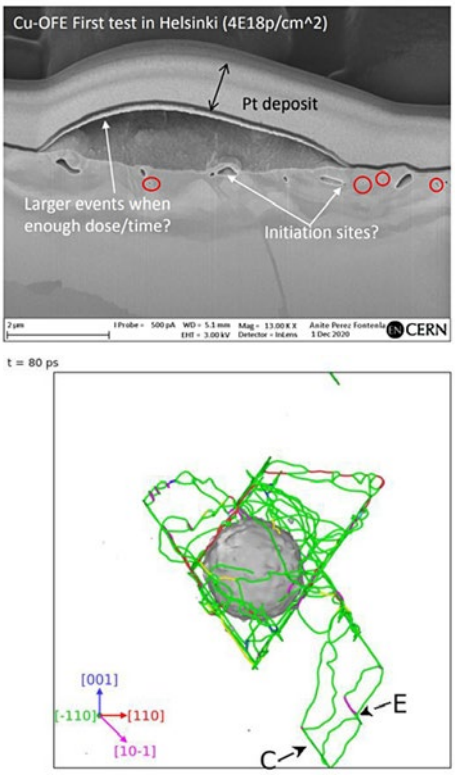
Very recently, XES became a promising complementary technique to XAS but remains in its infancy at synchrotron facilities. Laboratory scale apparatus can play a leading role in its development. XTREME is thus aiming to pioneer the XES alternative by leading an overview of XES sensitivity towards degree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

Accelerator Technology: Materials (MAT)

FLYURA DJURABEKOVA
Accelerator Technology: Materials (MAT) project leader

The project Accelerator Technology: Materials (MAT) focusses on developing a theoretical understanding of vacuum arcing onset with an experimental component in the research. The topic is of strong interest for the Compact Linear Collider (CLIC) project at CERN, where the high-gradient electromagnetic fields are employed to accelerate electrons and positrons to the unprecedented energies in the multi-TeV range. While the CLIC project at CERN has advanced towards the production stage of CLIC components, the results achieved within the MAT project helped to optimise the design of the CLIC accelerating structures. Moreover, it recently became clear that similar problems of vacuum arcing are faced in the radio-frequency quadrupole (RFQ) structures for the LHC proton injector. Surfaces exposed to the high fluence of negative hydrogen ions develop blisters (see SEM experimental image) resulting in frequent breakdowns that are detrimental for the RFQ structures and require frequent replacements of expensive components.

The model has been extended to include the processes developed under high H load conditions. We have shown, for instance, how a bubble can grow in Cu under strong excess of H atoms in the lattice. We have identified the atom-level mechanism of punching of prismatic loops of arbitrary shape under the internal pressure of the accumulated H atoms, see simulation image which shows the moment when a loop is to be detached from a bubble. The project continues its fruitful collaboration with CERN, Tartu University, and Xi'an Jiaotong University. One of the impressive results of this collaboration is the understanding of the effect of power flow in the circuit which allows controlling the breakdown process more precisely.



Top: Experimental scanning electron microscope (SEM) image with the cross-section view of the surface of the OFE-Cu sample irradiated with H^+ ions to fluences 4×10^{18} cm^{-2}.

Bottom: Simulation image of the H bubble in Cu lattice at the moment of detachment of the prismatic loop. The loop takes away atoms along the complete loop allowing for growth of the remaining bubble. The loop is expected to annihilate at the surface of the sample or at a grain boundary.

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

Radiation Safety and STUK

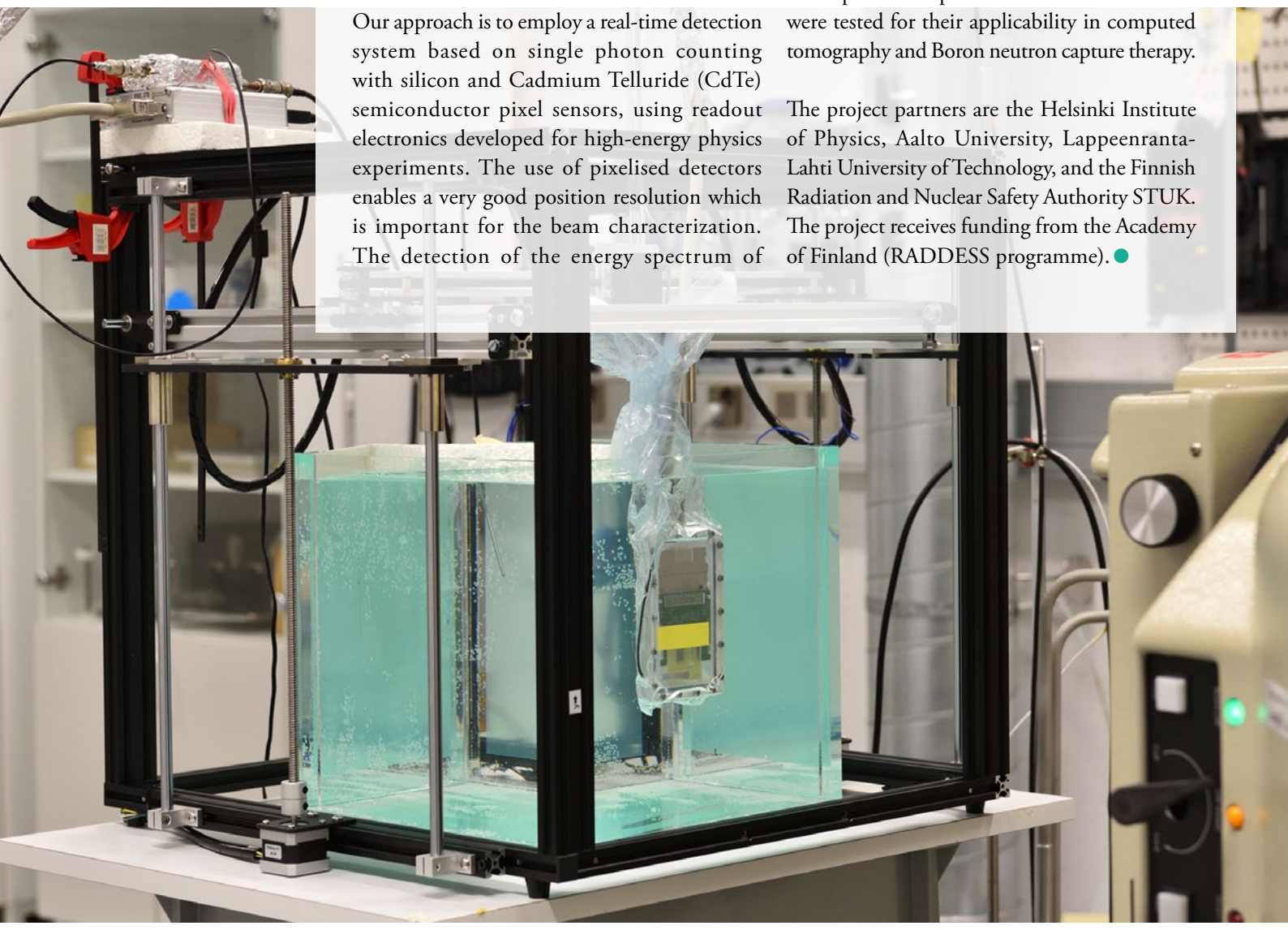
Radiation Metrology for Medical Applications (RADMED)

Modern radiotherapy techniques require a precise determination of therapy beam dimensions and position. Traditionally, these measurements are made with small ionization chambers that are moved step-by-step across the beam to map the dose distribution. To improve the situation, the Multispectral Photon-Counting for Medical Imaging and Beam Characterization (MPMIB) project develops a next-generation position sensitive imaging system. The detectors have applications in computed tomography as well.

Our approach is to employ a real-time detection system based on single photon counting with silicon and Cadmium Telluride (CdTe) semiconductor pixel sensors, using readout electronics developed for high-energy physics experiments. The use of pixelised detectors enables a very good position resolution which is important for the beam characterization. The detection of the energy spectrum of the impinging radiation provides further information on the beam properties.

The developed detectors were thoroughly tested in the standard dosimetry laboratory using X-ray beams and radioactive sources. The suitability of the silicon pixel detector for radiation therapy quality control purposes was studied with a Co-60 therapy source, with the detector immersed in a water tank. A 3d scanner was developed that accurately moves the detector in the water tank for beam scanning purposes. Preliminary results indicate that the radiotherapy beam profiles can be measured with good accuracy using the developed silicon pixel detector. CdTe detectors were tested for their applicability in computed tomography and Boron neutron capture therapy.

The project partners are the Helsinki Institute of Physics, Aalto University, Lappeenranta-Lahti University of Technology, and the Finnish Radiation and Nuclear Safety Authority STUK. The project receives funding from the Academy of Finland (RADDESS programme).



The setup to measure the beam dose profile of a gamma-ray beam for medical applications at the Finnish Radiation and Nuclear Safety Authority (STUK). The pixel detector placed inside the water phantom is visible. *Credit: E. Brücken.*

Radiation Safety Research and Development (RADAR)

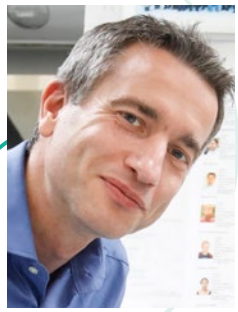
The STUK-HIP joint project DEFACTO (Detector for fallout and air concentration monitoring) that started in 2018 was finished in 2021. The project succeeded in its goal of developing a novel monitoring station for the Finnish radiation early warning network. The unique feature of the developed station is its capability to distinguish airborne radioactivity, fallout components and radioactive contamination of the detector box. In addition, the station enables autonomous radiation monitoring and fast deployment. In 2021, the work focussed on testing the detector robustness both in an environment chamber at the HIP Detector Laboratory and in a real outdoor environment. Two station unit prototypes have been collecting data outdoors successfully since early 2021.

Finland will be the first country in the world to dispose of spent nuclear fuel in an underground repository (www.posiva.fi/en/). In order to verify that no nuclear fuel is missing and to provide a record of the stored material for posterity, safeguards procedures will be implemented before disposal. In the GOSSER II project, the Finnish Radiation and Nuclear Safety Authority (STUK) and HIP are developing and implementing two complementary safeguards methods: Passive Gamma Emission Tomography (PGET) provides information on the distribution of fission products whereas Passive Neutron Albedo Reactivity (PNAR) confirms the presence of fissile material. The PGET performance was improved by fine-tuning the tomographic image acquisition procedure. An axial scan along a fuel assembly showed that PGET can reveal with high precision the axial extent of fuel rods, and that the PNAR result can change significantly with axial position.

PETER DENDOOVEN
Radiation Safety Research & Development (RADAR) project leader

Two DEFACTO station unit prototypes (the white cylinders) installed and operational on the roof of STUK since January 2021. *Credit: S. Ihantola.*

P. Kivimäki



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

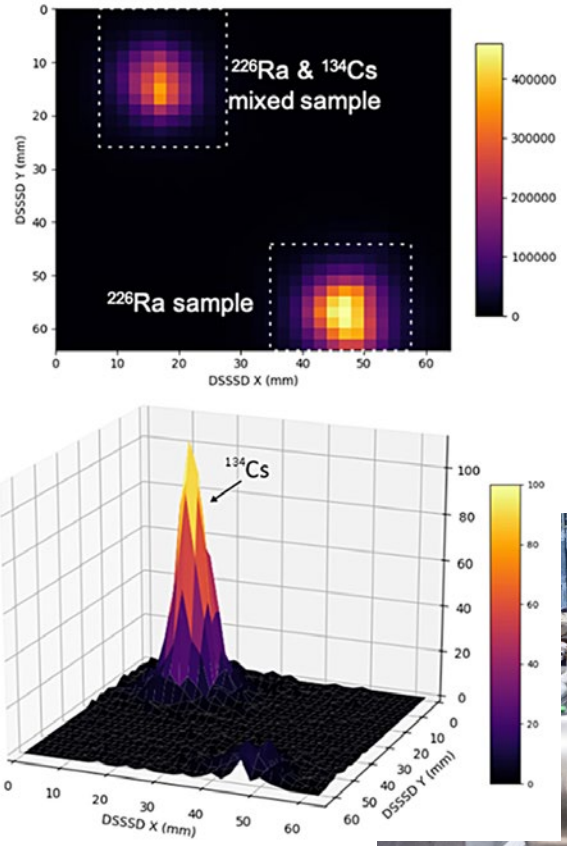
Radiation Detection for Safety, Security and Safeguards (RADSAFE)

The RADSAFE project aims to bring state-of-the-art radiation detection technologies and multi-parameter data-acquisition techniques developed in fundamental research to routine use in safety, security, and safeguards (3S) applications, improving the sensitivity and reliability of radiation measurements. These solutions can ultimately improve the health and security of society as a whole. The project is carried out in close collaboration with STUK and the University of Jyväskylä and the RADSAFE project is partly based on the RADICAL project which ran during 2018-2021 and was funded internally by STUK.

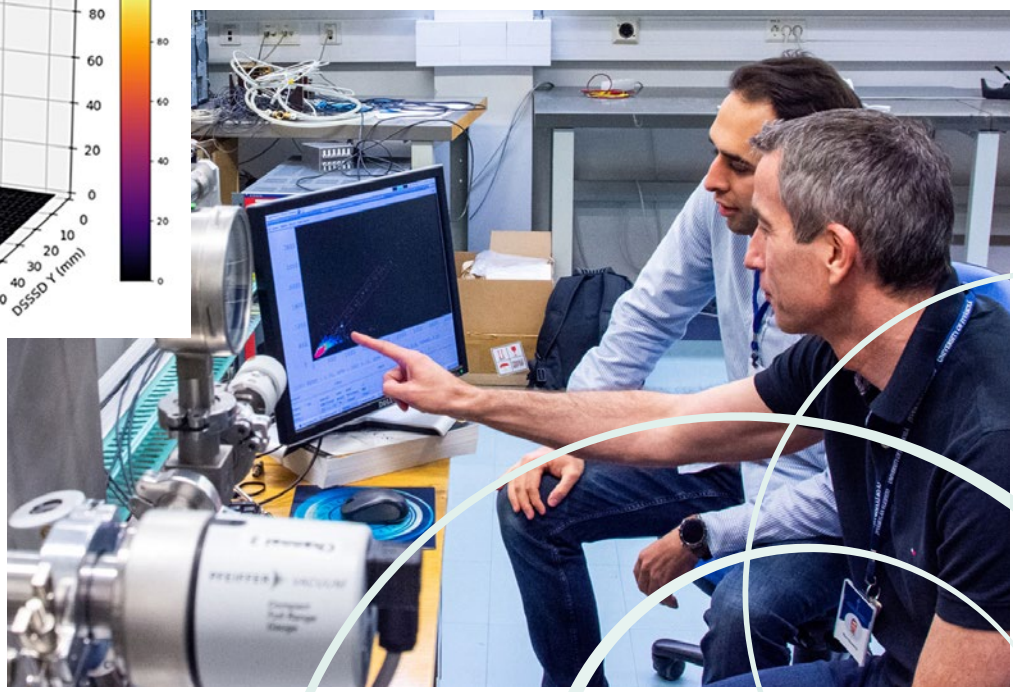
In 2021, the further development of the PANDA (Particles and Non-Destructive Analysis) system used in the analysis of environmental samples was continued. PANDA is now capable of coincident alpha, beta, and gamma-ray spectroscopy. A full GEANT4 simulation package was developed in order to better understand the system response and to aid the design of passive shielding, the addition of which has resulted in higher sensitivity of the device. A publication related to this work is at the submission stage [*H. Badran et al.*, to be submitted to *Nucl. Instr. Meth. A*].

Work to develop an application-specific detector for full-body counting progressed further in 2021. Using the extensive GEANT4 simulation package developed in 2020, a suggested design for a new detector has been validated and negotiations with potential providers begun. It is hoped that the prototype detector will be procured in 2022. A publication related to this work has been submitted and is under review [*H. Jutila et al.*, submitted to *Physica Medica*].

Finally, two new sub-projects were launched in 2021. The first is to develop a position-sensitive contamination meter capable of nuclide identification, the second to develop a new detector for real-time monitoring of radiation levels in foodstuffs, such as milk.



Example position-sensitive sample analysis from the PANDA device. By selecting characteristic radiation, for example gamma rays, it is possible to identify and locate the position of a particular activity in the sample.



P. Greenlees (JYU/HIP) and H. Badram (STUK) working on sample analysis with the PANDA device.

OTHER PROJECTS

MARKKU KULMALA
CLOUD
project leader

CLOUD

Background

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 precipitation of clouds. Measuring the underlying microphysics in controlled laboratory conditions is a key to understanding the dynamical behaviour of aerosol particles and cloud droplets, including the formation and growth processes of aerosols particles, 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 CLOUD Collaboration comprises 21 institutes, with a strong Finnish contribution.

Reconstruction and Improvement of the CLOUD Facility

In 2020 and 2021, the 60-year-old East Hall building, where the CLOUD chamber is located, went through a major renovation. The CLOUD experiment was upgraded by increasing the size of the experimental area, renewing its control and meeting room, and building a chemical laboratory and an aerosol flow tube.

Data Analysis, Education, and Reporting of Results

Two CLOUD students are conducting their PhD at the Doctoral Programme of Atmospheric Sciences at the University of Helsinki. As physical workshops were still difficult to organise due to the COVID-19 pandemic, the CLOUD community held bi-weekly online meetings, where data was presented and discussed. Additionally, the CLOUD-MOTION final conference was organised in online-format during April 2021, where all CLOUD students were presenting their work. Five peer-reviewed papers were published in 2021. Briefly, *He et al. (2021)* demonstrates that for an atmospheric iodic acid system, an ion-induced nucleation mechanism helps to stabilise the cluster against evaporation. Furthermore, a second study by *He et al. (2021, Science)* demonstrates that iodic acid molecules can form new aerosol particles in a much faster way than previously thought. These findings imply that in pristine regions, this rapid process could overtake the previously thought dominant mechanism which includes sulfuric acid molecules. In contrast, in an urban type atmosphere, *Xiao et al. (2021)* demonstrates that NPF is driven by the formation of sulfuric acid-base clusters, which can be stabilised by the presence of amines, high ammonia concentrations and lower temperatures. Finally, *Surdu et al. (2021)* and *Caudillo et al. (2021)* present two new state-of-the-art instruments, an EESI-ToF and a TDMA-CI-ToF, that can measure the chemical composition of particles as small as 20 nm in diameter. Combined with other CLOUD instruments, the condensation processes of various vapour molecules into particle phase can then be studied.

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 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 2021 we participated in the Euclid Science Challenge 8 where the current version of the Euclid data analysis pipeline was tested. Science Challenge 8 represented a major upgrade in the maturity in the Euclid pipeline. We participated in the Operational Rehearsal to demonstrate the ability of the SDC infrastructure to process the continuous data flow from the satellite. We contributed to the development and validation of the code to produce simulated NISP data, and in the production of the simulated VIS data. We participated in the integration of data from external, ground-based, galaxy surveys into the Euclid data archive. Finland has the main responsibility for the integration of the Northern Surveys (PanSTARRS, CFIS, WISHES, and JEDIS).

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 reached the second-to-last level in 2021. We have the main responsibility for validating the 2PCF code, using simulated galaxy catalogues. In 2021 we finished developing and testing a method for estimating the covariance matrix of the 2-point correlation function with significantly less computational resources than what the current standard method requires and prepared a publication on this method that is currently being refereed. In the Euclid Theory Working Group we continued preparing forecasts for the constraining power of Euclid on early universe models.

The VIS (left) and NISP (top) instruments integrated into the Euclid telescope. *Credit: Airbus.*

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. In 2021, she received the Open Science Award of the University of Helsinki for her work to promote open science.

High School Visits

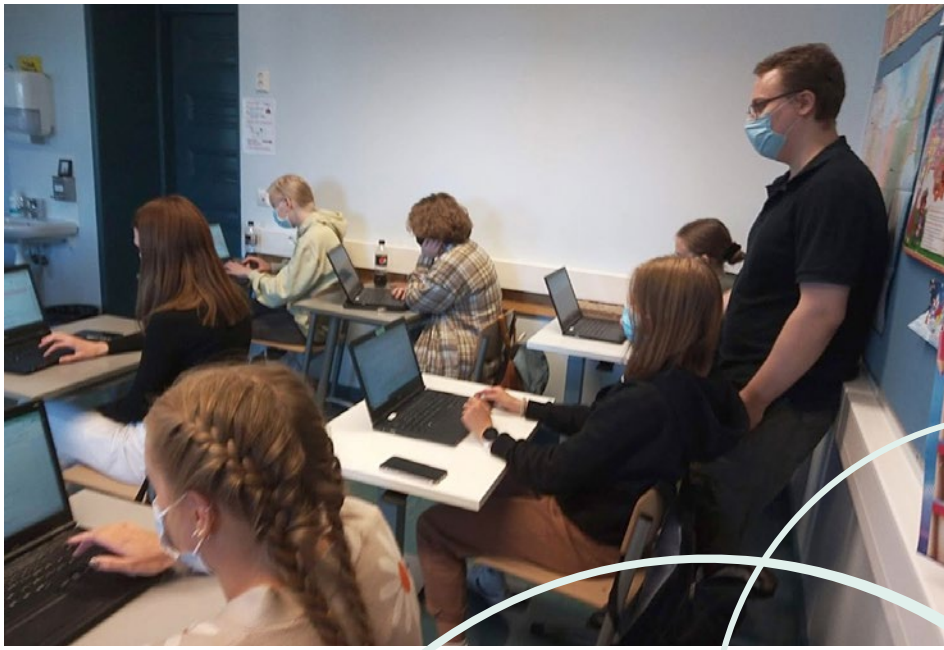
Due to the pandemic, no Finnish high-school group visits to CERN took place in 2021. To compensate, J.-M. Teuho from the Education and Open Data project collected a list of resources for teachers to prepare for future visits or organise CERN activities in schools. The material is available at https://cern-tiedeopiskelu.github.io/intro.html. This work was made possible by a subsidy to promote science studies in high school by the Finnish National Agency for Education.

CMS Data Preservation and Open Data Releases

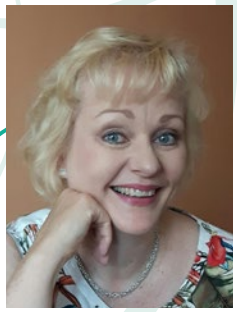
The CMS Data Preservation and Open Access group manages the actions needed for data and knowledge preservation of the experiment. Data is regularly released for public use, and the first batch of research-quality data from the LHC 'Run 2' was brought to the public domain in December 2021. CMS Open Data are increasingly in use, for scientific studies and in education, and the second CMS Open Data workshop was organised in July. HIP summer student A. Kinnunen and CERN summer students under HIP supervision actively contributed to the usage examples, testing and tutorial material for the workshop.

Open Data Training

The project organises courses for teachers for using open data in schools with the help of 'jupyter notebooks' and common python libraries. Three training courses, comprising three sessions each, were organised in 2021 making use of the material developed earlier, and developing it further. Two of the courses were fully remote, in April and in November in Finnish, and hybrid training was organised for the first time in Swedish in October at Korsholm high school. A user guide to ease the use of the material is available at https://opendata-education.github.io/ in Finnish, Swedish, and English. The courses were conducted by project members MSc P. Veteli, J.-M. Teuho, L. Hammarström, and V. Juntunen, and the feedback was excellent. L. Hammarström prepared and conducted a mathematics and a health science course with open data exercises in Korsholm high school and he is preparing a Master's thesis on this topic. Open Data workshops for students were also conducted by P. Veteli in physics teaching in Joensuu high school, a teacher training school for the University of Eastern Finland, and combining biology and weather data in Iisalmi high school. This work is made possible by a subsidy for innovative learning environments in high school by the Finnish National Agency for Education.



DETECTOR LABORATORY



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 large **international physics experiments**. In 2021, despite the limitations imposed by the COVID-19 pandemic, the Laboratory successfully participated in the instrumentation of the CMS, TOTEM, and MoEDAL experiments at CERN, and the NUSTAR experiment at FAIR. Especially, the MoEDAL experiment is under the responsibility of our staff scientist. In 2021, MoEDAL prepared for Run 3 of the LHC. In addition to passive MoEDAL detectors, a new active detector called MAPP was approved to be installed into the UA83 tunnel of the LHC.

In addition, the Laboratory applies for and hosts **externally funded projects**. In 2021, the Laboratory hosted the project 'Multispectral Photon-Counting for Medical Imaging and Beam Characterization', funded by the Academy of Finland RADDESS programme. In addition, the Laboratory launched the HIP-LUT project 'Detector for nuclear safety, decommissioning and diagnostics applications (DeNuSa)', funded by the Business Finland Research to Business instrument.

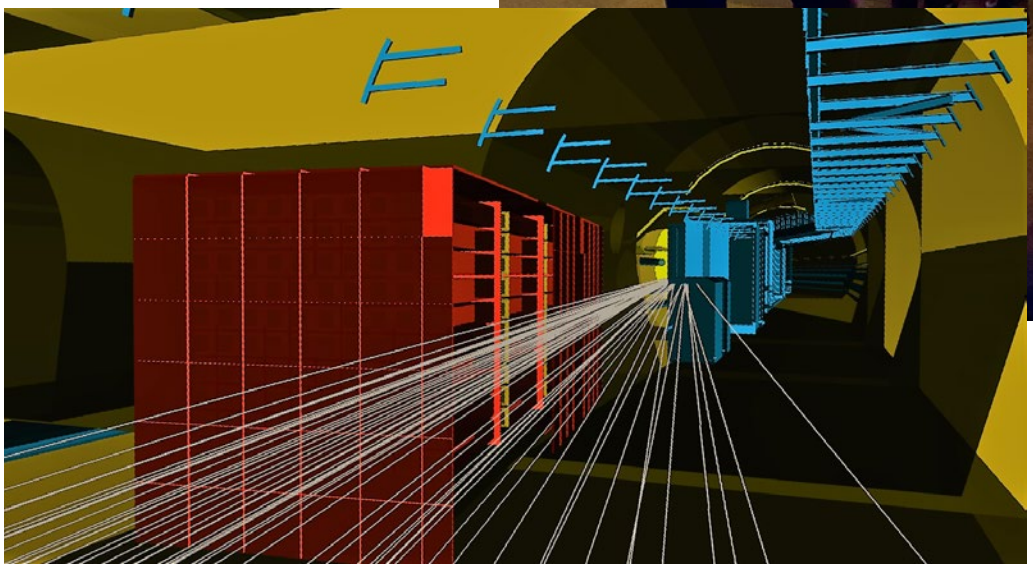
The Detector Laboratory has a wide network of **national collaboration** for sharing expertise, equipment, and infrastructure. In 2021, the Laboratory worked closely with the laboratories of the UH Faculty of Science and with the instrumentation laboratories and physics departments from other Finnish universities, especially the Aalto University Nanofabrication Centre and the Jyväskylä University Accelerator Laboratory. In addition, the Laboratory collaborated with Finnish industry, especially with small- and medium-size companies and start-ups.

UH Board chaired by president Tarja Halonen visited the Detector Laboratory in September. *Credit: T. Väisänen.*

Laboratory personnel participate in guaranteeing the future expertise in physics and its instrumentation by providing **research-based education**. In 2021, the Laboratory hosted a course on gaseous detectors and scintillators and a laboratory course on instrumentation in the framework of the Master's Programme for Particle Physics and Astrophysical Sciences (PARAS). The personnel also supervised doctoral and master students 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 2021, the Laboratory participated in the EU Researchers' Night by producing online videos and virtual visits to the Laboratory. In addition, the Laboratory succeeded in providing a one-week internship for a secondary school student.

Doctoral students M. Bezak and S. Bharthuar promoting the HIP-LUT DeNuSa project at the SLUSH 2021 start-up event. *Credit: M. Arenius.*



Exotic particles hitting the future MAPP extension of the CERN MoEDAL experiment. *Simulation by M. Kalliokoski.*

J. Härkönen in memoriam

Jaakko Härkönen (21.9.1972 - 10.12.2021)

With deep sorrow, we share the news of the unexpected passing away of our beloved and respected colleague Jaakko Härkönen on Friday December 10th, 2021.

Jaakko was a brilliant semiconductor physicist, always bursting with enthusiasm and ideas to develop magnificent radiation detectors for a multitude of applications. Since 2001, Jaakko was an active participant in the CERN CMS community, especially in the instrumentation of the semiconductor Tracker. He was also one of the first members of the CERN RD50 Collaboration for the development of radiation hard semiconductor detectors, always proud of having been the host of the CERN RD50 Workshop in Helsinki in 2005. Already in the 1990s, Jaakko performed pioneering work in Finland with semiconductor solar cells. He was a devoted teacher and mentor, and many generations of engineers and physicists achieved their Master's and doctoral degrees under his skilful and caring supervision. Jaakko was chosen by the European Commission's ERA Chair Project to aid in the establishment of a Particle Detectors Laboratory for Croatia. Under his leadership, the PaRaDeSEC project was successfully completed, and the Detector Laboratory is fully commissioned and operational at the Ruđer Bošković Institute in Zagreb. His legacy lives through his innovative work on detectors for nuclear safety in the ongoing 'Detector for nuclear safety, decommissioning and diagnostics applications (DeNuSa)' project, funded by Business Finland.

Jaakko had a charming personality. With his smart and witty sense of humour, he was always finding the bright side of life. Jaakko was passionate about political history, especially World War II, and was closely following events happening around him. He loved his BMW, his Harley-Davidson, and his big house on the hill in Espoo with its large photovoltaic system on the roof. Jaakko was a faithful and considerate friend whose kindness was valued by all. He was an affectionate and loving father.

We are thankful that we had the privilege to have him in our lives. Jaakko was one of a kind. His all too early and all too sudden departure leaves an empty space in many hearts.

He will be greatly missed by his family, friends, and colleagues.

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) an interim member since 2018. 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.

The year 2021 was the second, and this time a full, year of the COVID-19 pandemic. The extensive remote work and tools were already routine and continued to decrease the significance of geography and to reduce travel. On the other hand, they caused delays and disturbance, and hindered crucial social interaction. The increasing vaccination coverage and the way the virus has evolved provides hope that the situation will improve in 2022.

A new four-year planning, and funding, period started in 2021. The Institute's core funding is expected to be stable during the period since the member universities have committed to compensate the 26% cut of the governmental earmarked funding. On the spending side, however, savings were needed in 2021 as the Institute prepares for upcoming extra costs from experimental collaborations and infrastructure investments.

The publication output of HIP decreased significantly from the previous year to a bit more than 250 peer-reviewed publications in 2021. This is no immediate cause for alarm since the planned long shutdown of the LHC collider at CERN reduces the number of publications from CMS and other collaborations. Moreover, the previous year 2020 had the second highest number ever for HIP. The Institute's scientific output continues to be very good and generally of high quality. HIP publications are mostly in the two highest national JUFO categories and to a very high degree open publications as is traditional in the Institute's core fields.

Doctoral education continues to be one of the main tasks of the Institute. In addition, a fair number of undergraduate students have joined the research groups. Many of them are continuing as doctoral researchers in Institute projects. During the period 2017-2021, 49 doctoral degrees and 55 Master's degrees have been earned in HIP research projects. The CERN BootCamp was cancelled for the second year in a row, but the HIP summer student programme at CERN and ESRF continued also in 2021. Due to COVID-19 restrictions the trainees mostly worked remotely but some could work on-site as well.

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.

The University of Helsinki, the host organization of HIP, has started to offer all students a sustainability course. The aim is to provide students with academic knowledge and skills related to sustainability. HIP also collaborates with three Universities of Applied Sciences in the Helsinki region as well as CERN in organising the annual CERN BootCamp. This offers students the chance to work in groups to resolve current societal problems, often related to sustainability.

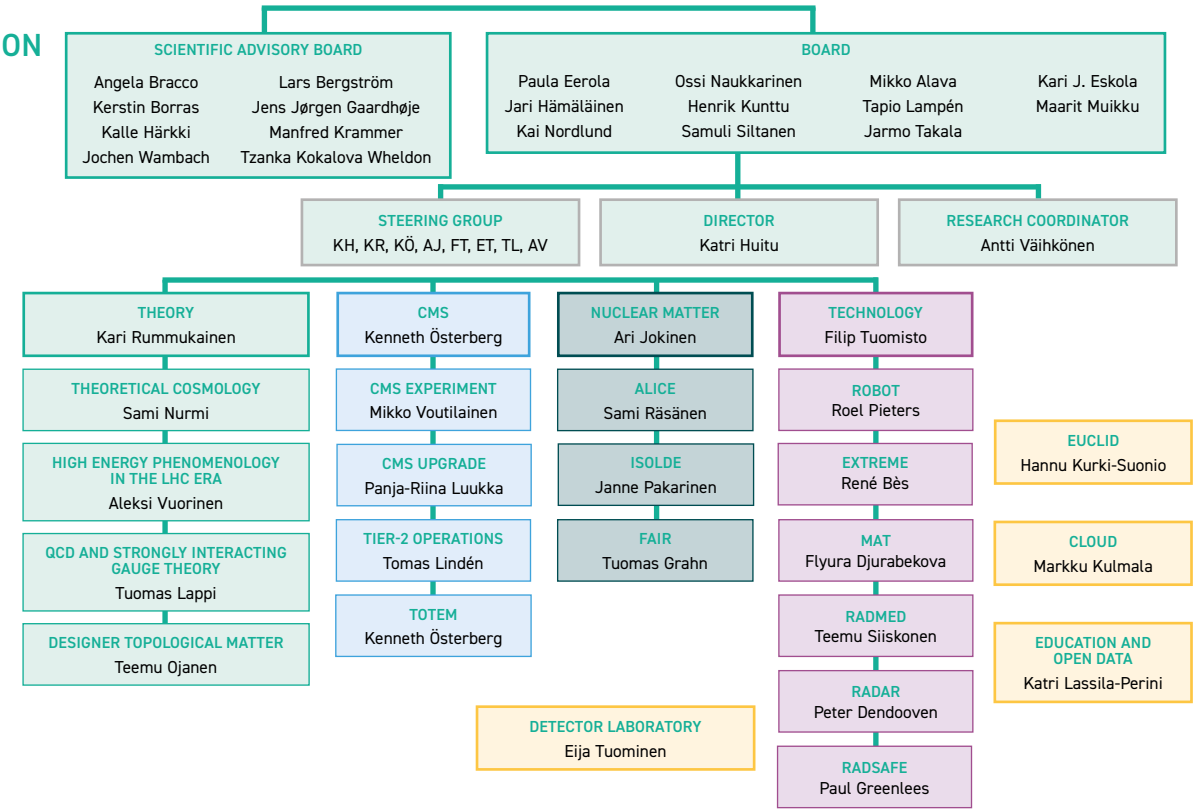
Open access to research results is an important part of the responsibility and sustainability of scientific work. Consistently, about 95% of HIP publications are open access each year. In 2021, the leader of the HIP Education and Open Data project K. Lassila-Perini received the University of Helsinki Open Science Award in recognition of her exceptional work in promoting open science. More specifically, the goal of the award was to highlight the importance of accessible and reusable research data to science and the broader academic community.

One way in which HIP is advancing sustainability is through our increasing use of digital tools to facilitate research and to promote a sense of community and inclusivity. In 2021, the streaming and hybrid meeting capabilities of the HIP seminar and meeting rooms were improved. New but economically conscious equipment was put in place, instructions to users were clarified and acoustic plates were mounted on the walls. These measures make remote participation in the HIP seminars and meetings easy to set up and provide an improved experience for meeting participants. They will also reduce HIP's carbon footprint by eliminating unnecessary travel.

Responsible leadership is an important part of sustainability. In the workplace wellbeing survey conducted by the University of Helsinki in 2021, HIP received very good grades in supervision and with respect to supervisors - higher than the Finnish universities' average grade. In 2021, HIP introduced 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.

ORGANIZATION AND PERSONNEL

ORGANIZATION



The Board: Kari J. Eskola, Kai Nordlund, Tapio Lampén, Mikko Alava, Paula Eerola, Erkki Lähderanta (substitute member), Samuli Siltanen, Maarit Muikku, Ari Jokinen (substitute member).

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PERSONNEL

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Theoretical Cosmology

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P. Johansson, prof., adj. senior scientist
K. Kainulainen, prof., adj. senior scientist
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D. Hooper, scientist
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T. Sawala, Acad. Res. Fellow, adj. scientist
O. Gould, adj. scientist
S. McAlpine, adj. scientist
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A. Kormu, doctoral researcher
O. Koskivaara, doctoral researcher
N. Lahén, doctoral researcher
L. Laulumaa, doctoral researcher
M. Mannerkoski, doctoral researcher
J.-M. Ojanperä, doctoral researcher
S. Raatikainen, doctoral researcher
P. Rahkila, doctoral researcher
N. Venkatesan, doctoral researcher

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K. Kajantie, prof., adj. senior scientist
O. Lebedev, prof., adj. senior scientist
K. Tuominen, prof., adj. senior scientist
N. Jokela, senior scientist
R. Paatelainen, senior scientist
E. Keski-Vakkuri, adj. senior scientist
M. Sainio, adj. senior scientist
M. Heikinheimo, scientist
O. Henriksson, scientist
P. Schicho, scientist
J. Tarrío, scientist
V. Keus, adj. scientist
E. Annala, doctoral researcher
J. Hirvonen, doctoral researcher
T. Nerdi, doctoral researcher
L. Niemi, doctoral researcher
K. Seppänen, doctoral researcher
A. Stendahl, doctoral researcher
J.-H. Yoon, doctoral researcher
J. Österman, doctoral researcher

QCD and Strongly Interacting Gauge Theory

T. Lappi, prof., proj. leader
K. J. Eskola, prof., adj. senior scientist
H. Niemi, adj. senior scientist
H. Paukkunen, adj. senior scientist
C. Flett, scientist
Y. Mulian, scientist
H. Mäntysaari, scientist
F. Cougoulic, adj. scientist
P. Guerrero Rodríguez, adj. scientist
I. Helenius, adj. scientist
M. Li, adj. scientist
T. Rindlisbacher, adj. scientist
P. Singh, adj. scientist
M. Utheim, adj. scientist
S. Demirci, doctoral researcher
H. Hirvonen, doctoral researcher
H. Hänninen, doctoral researcher
M. Kuha, doctoral researcher
T. Löytäinen, doctoral researcher
J. Penttala, doctoral researcher
A. Ramnath, doctoral researcher
M. Tevio, doctoral researcher

Designer Topological Matter

T. Ojanen, prof., proj. leader
J. Keski-Rahkonen, adj. scientist
A. Moghaddam, adj. scientist
L. Yang, adj. scientist
M. Najafi Ivaki, doctoral researcher
I. Sahlberg, doctoral researcher

CMS Programme

K. Österberg, prof., programme director

CMS Experiment

M. Voutilainen, ass. prof., proj. leader
P. Eerola, prof., senior scientist
M. Kim, senior scientist
T. Lampén, senior scientist
K. Lassila-Perini, senior scientist (at CERN)
S. Lehti, senior scientist
J. Tuominiemi, adj. senior scientist
H. Kirschenmann, scientist
M. Kortelainen, scientist
S. Laurila, adj. scientist
J. Pekkanen, adj. scientist
T. Lindén, lab. engineer
J. Heikkilä, doctoral researcher
K. Kallonen, doctoral researcher
M. Lotti, doctoral researcher
L. Martikainen, doctoral researcher
M. Myllymäki, doctoral researcher
H. Siikonen, doctoral researcher

CMS Upgrade

P.-R. Luukka, prof., proj. leader
T. Tuuva, prof., adj. senior scientist
E. Tuominen, chief engineer
E. Brücken, senior scientist
A. Karadzhinova-Ferrer, senior scientist
A. Winkler, adj. scientist
M. Bezak, doctoral researcher
S. Bharthuar, doctoral researcher
M. Golovleva, doctoral researcher
A. Gädda, doctoral researcher
S. Kirschenmann, doctoral researcher
N. Kramarenko, doctoral researcher
L. Martikainen, doctoral researcher
J. Ott, doctoral researcher
H. Petrow, doctoral researcher
J. Tikkanen, doctoral researcher

Tier-2 Operations

T. Lindén, Dr., proj. leader, grid coordinator
M. Myllymäki, doctoral researcher

TOTEM

K. Österberg, prof., proj. leader
H. Saarikko, prof. emeritus, adj. senior scientist
L. Forthomme, scientist
F. Oljemark, scientist
F. García, lab. engineer
M.-M. Rantanen, doctoral researcher
L. Östman, civil service

Nuclear Matter Programme

A. Jokinen, prof., programme director

ALICE

S. Räsänen, Dr., proj. leader
D. J. Kim, adj. senior scientist
W. Trzaska, adj. senior scientist
M. Slupecki, scientist
A. Molander, doctoral researcher
J. Parkkila, doctoral researcher
H. Rytkönen, doctoral researcher
O. Saarimäki, doctoral researcher
A. Önnerstad, doctoral researcher

ISOLDE

J. Pakarinen, Dr., proj. leader
P. Greenlees, prof., adj. senior scientist
A. Jokinen, prof., adj. senior scientist
I. Moore, prof., adj. senior scientist
A. Kankainen, ass. prof., adj. senior scientist
T. Grahn, adj. senior scientist
A. Briscoe, adj. scientist
R. de Groote, adj. scientist
W. Gins, adj. scientist
A. Illana Sison, adj. scientist
P. Rahkila, adj. scientist
M. Reponen, adj. scientist
P. Ruotsalainen, adj. scientist
M. Stryjczyk, adj. scientist
J. Ojala, adj. doctoral researcher
M. Myllymäki, trainee

FAIR

T. Grahn, ass. prof., proj. leader
J. Äystö, prof., director emeritus, adj. senior scientist
P. Greenlees, prof., adj. senior scientist
A. Jokinen, prof., adj. senior scientist
I. Moore, prof., adj. senior scientist
A. Kankainen, ass. prof., 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
M. Aicheler, senior scientist
T. Salmi, senior scientist
P. Kauttu, doctoral researcher
K. Simula, doctoral researcher

Robotics and AI for Monitoring and Intervention (ROBOT)

R. Pieters, ass. prof., proj. leader
E. Rahtu, ass. prof., adj. scientist
V. Kyrki, adj. scientist
D. Mohamadi, adj. scientist
K. Tammi, adj. scientist

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

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

Accelerator Technology: Materials (MAT)

F. Djurabekova, prof., proj. leader
K. Nordlund, prof., adj. senior scientist
T. Ahlgren, adj. senior scientist
P. Jalkanen, adj. senior scientist
A. Kyritsakis, scientist
A. Leino, adj. scientist
A. Lopez, adj. scientist
E. Lu, adj. scientist
I. Makkonen, adj. scientist
V. Zadin, adj. scientist
E. Baibuz, doctoral researcher
J. Byggmästar, doctoral researcher
M. Ghaemikermani, doctoral researcher
V. Jantunen, doctoral researcher
J. Kimari, doctoral researcher
J. Romppainen, doctoral researcher
A. Saressalo, doctoral researcher

Radiation Safety and STUK

Radiation Metrology for Medical Applications (RADMED)
T. Siiskonen, Dr., proj. leader (at STUK)
S. Kirschenmann, doctoral researcher
J. Tikkanen, doctoral researcher

Radiation Safety Research and Development (RADAR)
P. Dendooven, prof., proj. leader
P. Holm, scientist (at STUK)
S. Ihantola, scientist (at STUK)
K. Peräjärvi, scientist (at STUK)
R. Virta, adj. scientist (at STUK)
R. Backholm, doctoral researcher
T. Kerst, doctoral researcher

Radiation Detection for Safety, Security and Safeguards (RADSAFE)
P. Greenlees, prof., proj. leader
H. Badran, scientist (at STUK)
T. Hildén, scientist (at STUK)
M. Muikku, scientist (at STUK)
K. Peräjärvi, scientist (at STUK)
R. Pöllänen, scientist (at STUK)
J. Turunen, scientist (at STUK)
H. Jutila, doctoral researcher
O. Neuvonen, doctoral researcher

Other projects

CLOUD

M. Kulmala, prof., Academician, proj. leader
K. Lehtipalo, ass. prof.
J. Duplissy, senior scientist

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
J. Härkönen, senior scientist
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
T. Hardén, service coordinator
E. Veranen, HR coordinator
T. Heikkilä, secretary
T. Karppinen, secretary (at CERN)
T. Onnela, secretary (at CERN)

HIP SEMINARS

12 January H. Rubira (DESY)
A hybrid simulation of gravitational wave production in first-order phase transitions

2 February U. Gürsoy (Utrecht U.)
Hydrodynamics and holography of spin currents

16 February J. Maalampi (Jyväskylä)
The strange history of Runar Gåsström, a Finnish-American-Soviet physicist

9 March E. Ó Colgáin (CQUEST & Sogang U.)
Comments on H0

16 March W. Sybesma (Iceland)
Evaporation and the price of curiosity

23 March M. Hanada (Surrey)
Color confinement, Bose-Einstein condensation, and emergent geometry in gauge/gravity duality

30 March Y. Bea (Queen Mary)
New insights from real-time dynamics

13 April M. Reichert (Sussex)
Gravitational waves from first-order phase transitions with non-perturbative effective potentials

20 April M. Laine (Bern)
How well do we know the thermal photon rate?

18 May H.-W. Hammer (Darmstadt)
Un-nuclear physics

25 May M. Patel (Imperial College)
B-anomalies at LHCb

8 June K. Österberg (Helsinki)
Observation of odderon exchange from proton-proton and proton-antiproton elastic scattering at TeV scale

28 September T. Kärkkäinen (Budapest)
Super-weakly coupled U(1)_z and GeV neutrinos

2 November M. Sánchez Garitaonandia (Helsinki)
Gravitational waves from first order phase transitions with holography

9 November Y. Bea (Helsinki)
Evolutions in first-order viscous hydrodynamics

12 November H. Waltari (Uppsala)
News from the ILCX workshop

23 November M. Järvinen (Pohang & APCTP)
Strong coupling models for dense and hot QCD

25 November M. Shaposhnikov (Lausanne)
QFT without infinities and hierarchy problem

30 November A. Ekstedt (DESY)
First-order phase transitions: jumping over the barrier

7 December F. Nitti (APC Paris)
Curved holographic RG flows, quantum phase transitions and AdS vacuum decay

14 December J. Kastikainen (Helsinki & APC Paris)
Quantum information geometry of Virasoro states

16 December O. Komoltsev (Stavanger)
How perturbative QCD constrains the equation of state at neutron-star densities

21 December K. Mkrtchyan (Imperial College)
Democratic formulation for non-linear electrodynamics and manifest electric-magnetic duality

VISITORS

Theory Programme

Theoretical Cosmology

M. Laine (Switzerland) 27.9.-16.10., 25.10.-13.11.
J. Hislop (Germany) 11.-22.10.
A. Gopakumar (India) 13.-17.11.

High Energy Phenomenology in the LHC Era

A. Garbayo Peón (Spain) 1.7.-31.10.
T. Tenkanen (Sweden) 1.10.-30.11.
M. Sánchez Garitaonandia (Spain) 2.10.-16.12.
D. Chandrababu Geetha (Norway) 1.-12.11.
M. Järvinen (South Korea) 10.-30.11.
A. Ekstedt (Germany) 29.11.-3.12.
F. Nitti (France) 5.-10.12.
K. Mkrtchyan (UK) 12.-21.12.
O. Komoltsev (Norway) 15.-17.12.

CONFERENCE PARTICIPATION, TALKS AND VISITS BY PERSONNEL

Theory Programme

Theoretical Cosmology

Cosmology 2021, The Rise of Field Theory,
4-8 January, Cambridge, UK / Munich, Germany (online) (T. Miranda)

NORNDiP Virtual Conference 2021,
29 January (online) (S. Räsänen)

Primordial Black Holes Confront GW Data,
8-12 February (online) (S. Räsänen)

Heidelberg Joint Astronomy Colloquium,
9 February, Heidelberg, Germany (online) (P. Johansson)

Seminar Université Libre de Bruxelles,
26 February, Brussels, Belgium (online)
(talk by D. Cutting)

Quantum Gravity, Higher Derivatives and Non-Locality,
8-12 March (online) (talk by A. Tokareva)

Physics Days 2021,
24-26 March, Jyväskylä, Finland (online)
(talk by E. Schiappacasse)

15th Iberian Cosmology Meeting,
29 March - 1 April, Lisbon, Portugal (online)
(talk by E. Schiappacasse)

European Consortium of Astroparticle Theory Annual Symposium,
5-7 May (online) (talk by D. Cutting)

COSMO21,
2-6 June, University of Illinois, Urbana-Champaign, IL, USA (online) (J. Annala, A. Hassan, talk by S. Raatikainen, S. Räsänen)

Lorenz Center Workshop, Computations that Matter 2021,
21-24 June, Leiden, the Netherlands (online)
(D. Cutting, K. Kainulainen)

EAS 2021,
28 June - 2 July (online) (D. Weir)

Sixteenth Marcel Grossmann Meeting - MG16,
5-10 July (online) (A. Tokareva)

Gravitational Wave Probes of Physics Beyond Standard Model,
12-16 July (online) (D. Cutting, talk by D. Weir)

Lattice 2021,
26-30 July, MIT, Cambridge, MA, USA (online) (D. Weir)

EPS-HEP Conference 2021,
26-30 July, DESY, Hamburg, Germany (online)
(A. Tokareva)

Inverno Astrofísico,
12-21 August, Vitória/ES, Brazil (online)
(talk by T. Miranda)

High Energy and Computational Physics Seminar,
6 September, NICPB, Tallinn, Estonia (online)
(talk by D. Weir)

NEB-19 Recent Developments in Gravity,
20-23 September, Athens, Greece (online) (A. Tokareva)

SUSY-2021,
23-28 September (online) (talk by K. Kainulainen)

IAP GReCO Seminar,
4 October, Paris, France (online) (talk by S. Räsänen)

COST CA18108 Second Annual Conference,
6-8 October, Corfu, Greece (online) (A. Tokareva)

Cosmo Principle,
25-28 October, Pohang, South Korea (online) (T. Miranda)

Gravitational Waves Retreat,
25-29 October, Talloires, France
(D. Cutting, M. Hindmarsh, D. Weir)

IAU Symposium 362, The Predictive Power of Computational Astrophysics,
8-12 November (online) (talk by P. Johansson)

Anomalies 2021,
10-12 November, Hyderabad, India (online)
(talk by D. Weir)

FPS Particle Physics Day 2021,
16 November, Jyväskylä, Finland (talk by E. Schiappacasse)

Astro-Obs Journal Club,
22 November, Newcastle, UK (online) (talk by D. Hooper)

Computational Tools for High Energy Physics and Cosmology,
22-26 November, Lyon, France (online) (D. Hooper)

Theoretical Cosmology Seminar ICG,
1 December, Portsmouth, UK (online) (talk by D. Hooper)

Dark Chatter,
3 December, Sydney, Australia (online) (talk by D. Hooper)

Dark Sectors of Astroparticle Physics,
7-10 December, Kavli IPMU, Tokyo, Japan (online)
(talk by E. Schiappacasse)

9th LISA Cosmology Working Group Workshop,
8-9 December (online) (D. Cutting, D. Hooper)

Synergies,
8-11 December, Prague, Czech Republic (online)
(D. Hooper)

NORDITA Gravitation and Cosmology Committee Meeting,
13 December, Stockholm, Sweden (D. Weir)

High Energy Phenomenology in the LHC Era

Institute of Nuclear Theory,
1 March, Seattle, WA, USA
(invited seminar by A. Vuorinen)

IIT Madras,
18 March, Chennai, India (invited seminar by A. Vuorinen)

Fun-QCD Workshop,
29 March, Barcelona, Spain (talk by P. Schicho)

CERN,
12 April, Geneva, Switzerland
(invited seminar by R. Paatelainen)

University of Jyväskylä,
22 April, Jyväskylä, Finland
(invited seminar by R. Paatelainen)

University of Santiago de Compostela,
28 April, Santiago de Compostela, Spain
(invited seminar by R. Paatelainen)

KIAS,
13 May, Seoul, South Korea (invited seminar by P. Schicho)

Asia Pacific Center for Theoretical Physics,
17 June, Pohang, South Korea
(invited seminar by N. Jokela)

Quark Confinement and the Hadron Spectrum,
1-6 August, Stavanger, Norway (online)
(invited talk by N. Jokela)

XIX Mexican School of Particles and Fields,
13 August, Mexico (online) (invited lecture by A. Vuorinen)

QCD Master Class 2021,
7-9 September, Saint-Jacut-de-la-Mer, France
(invited lecture series by A. Vuorinen)

Le laboratoire astroparticule et cosmologie,
12 October, Paris, France (invited seminar by J. Hirvonen)

University of Bern,
19 October, Bern, Switzerland
(invited seminar by P. Schicho)

University of Basel,
28 October, Basel, Switzerland
(invited seminar by P. Schicho)

University of Stavanger,
2 November, Stavanger, Norway
(invited seminar by J. Hirvonen)

University of Nottingham,
29 November, Nottingham, UK
(invited seminar by J. Hirvonen)

Frontiers of Holographic Duality-3,
6-17 December, Steklov Mathematical Institute, Moscow, Russia (online) (invited talk by N. Jokela)

QCD and Strongly Interacting Gauge Theory

The VIth International Conference on the Initial Stages of High-Energy Nuclear Collisions,
10-15 January, Weizmann Institute of Science, Rehovot, Israel (online) (F. Cougoulic, S. Demirci, K. J. Eskola, C. Flett, P. Guerrero Rodríguez, talk by I. Helenius, H. Hirvonen, talk by H. Hänninen, M. Kuha, T. Lappi, member of IAC, M. Li, T. Löytäinen, Y. Mulian, talk by H. Mäntysaari, H. Niemi, talk by H. Paukkunen, talk by J. Penttala, talk by A. Ramnath, M. Tevio)

Opportunities of OO and pO Collisions at the LHC,
4-10 February, CERN, Geneva, Switzerland (online)
(K. J. Eskola, C. Flett, P. Guerrero Rodríguez, M. Kuha, T. Lappi, M. Li, T. Löytäinen, talk by H. Niemi, H. Paukkunen)

Experiment and Theory Intersections: Current Status & Future Planning,
10 February, 3 March, CFNS, Stony Brook, NY, USA (online) (T. Löytäinen)

Virtual Quarkonia As Tools 2021,
22-26 March, Paris, France (online)
(C. Flett, talk by H. Mäntysaari, J. Penttala)

NCBJ,
24 March, Warsaw, Poland (online) (seminar by T. Lappi)

XXVIII International Workshop on Deep-Inelastic Scattering and Related Subjects (DIS2021),
12-16 April, Amsterdam, the Netherlands / Stony Brook, NY, USA (online) (talk by F. Cougoulic, S. Demirci, K. J. Eskola, P. Guerrero Rodríguez, H. Hirvonen, talk by H. Hänninen, M. Kuha, talk by T. Lappi, M. Li, T. Löytäinen, talk by Y. Mulian, talk by H. Mäntysaari, H. Paukkunen, talk by J. Penttala, talk by A. Ramnath, M. Tevio)

Pythia Week 2021,
12-16 April, Jyväskylä, Finland (online) (I. Helenius)

9th Workshop of the APS Topical Group on Hadron Physics,
13-16 April, Sacramento, CA, USA (online)
(talk by H. Mäntysaari)

Workshop: Open Questions in Photon-Induced Interactions - from Relativistic Nuclear Collisions to the Future Electron-Ion Collider,
26-28 April, CFNS, Stony Brook, NY, USA (online)
(talk by H. Mäntysaari, J. Penttala)

Lund University,
20 May, Lund, Sweden (online) (seminar by T. Lappi)

NBI,
28 June, Copenhagen, Denmark (online)
(seminar by T. Lappi)

Saturation and Diffraction at the LHC and the EIC,
29 June - 1 July, ECT*, Trento, Italy (online)
(T. Lappi, talk by Y. Mulian, talk by H. Mäntysaari, talk by J. Penttala)

The 2021 CFNS Summer School on the Physics of the Electron-Ion Collider,
9-20 August, CFNS, Stony Brook, NY, USA (online)
(F. Cougoulic, lecture by T. Lappi, M. Li, Y. Mulian, J. Penttala)

QCD Master Class 2021,
29 August - 11 September, Saint-Jacut-de-la-Mer, France
(J. Penttala, M. Tevio)

MCnet-CTEQ Summer School 2021,
5-16 September, Karlsruhe/Dresden, Germany (online)
(tutorials by I. Helenius)

SUBATECH,
10-15 October, Nantes, France (F. Cougoulic)

12th International Workshop on Multiple Partonic Interactions at the LHC,
11-15 October, Lisbon, Portugal (talk by C. Flett, talk by H. Mäntysaari, talk by M. Utheim)

Technische Universität München,
13 October, Munich, Germany (online)
(seminar by T. Lappi)

NCBJ,
20 October, Warsaw, Poland (online)
(seminar by H. Mäntysaari)

ECFA Higgs Factories: 1st Topical Meeting on Generators,
9-10 November, CERN, Geneva, Switzerland (online)
(talk by I. Helenius)

Resummation, Evolution, Factorization 2021,
15-19 November, DESY, Hamburg, Germany (online)
(F. Cougoulic)

Ecole Polytechnique,
17-20 November, Paris, France (seminar by T. Lappi)

MC4EIC: Monte Carlo Event Simulation for the EIC,
18-19 November (online) (I. Helenius, M. Utheim)

University of Bergen,
23 November, Bergen, Norway (online)
(seminar by T. Lappi)

Paris Saclay,
13 December, Paris, France (online)
(seminar by H. Mäntysaari)

Small-x Physics in the EIC Era,
15-17 December, RBRC, Brookhaven, NY, USA (online)
(talk by I. Helenius, talk by T. Lappi, talk by H. Mäntysaari, J. Penttala, P. Singh, M. Tevio)

Designer Topological Matter

Seminaire Condensee Matiere,
11 March, LPS Orsay/Paris, France (talk by T. Ojanen)

Toposuper2021 Online Conference on Topological Superconductivity,
7-9 June (online) (talk by T. Ojanen)

Nordic Virtual Condensed Matter Seminar,
29 November (online) (talk by T. Ojanen)

CMS Programme

CMS Experiment

Winter 2021 Topical Meeting on VBS: VBS at Snowmass,
25-29 January (online) (H. Kirschenmann)

CERN VM Virtual Workshop 2021,
1-2 February (online) (T. Lindén)

CMS Week,
1-5 February (online) (M. Voutilainen)

SMP-HAD Workshop 2021,
11-12 February (online) (talk by L. Martikainen, M. Voutilainen)

PARTICLEFACE Management Committee Meeting,
24 February (online) (M. Voutilainen)

HEPiX Spring 2021 Online Workshop,
15-19 March (online) (T. Lindén)

CMS PPD Workshop Spring 2021,
22-25 March (online) (H. Kirschenmann, T. Lampén)

Physics Days 2021,
24-26 March (online) (talk by T. Lindén, M. Voutilainen, session chair)

Moriond QCD 2021,
27 March - 3 April (online) (talk by H. Kirschenmann)

Fermilab LPC Physics Forum,
15 April (online) (talk by H. Kirschenmann)

CMS Week,
19-24 April (online)
(talk by H. Kirschenmann, M. Voutilainen)

SMP Workshop,
10-12 May (online) (talks by M. Voutilainen)

vCHEP2021,
17-21 May (online) (T. Lindén)

DPG-PH JetMET,
31 May (online) (S. Lehti)

Thematic CERN School of Computing,
14-18 June (online) (L. Martikainen)

CMS Week,
21-25 June (online) (M. Voutilainen)

EPS-HEP Conference 2021 (+ Plenary ECFA Meeting),
26-30 July (online) (H. Kirschenmann)

Nordic Physics Days 2021,
4-6 August (online) (invited talk by H. Kirschenmann, M. Voutilainen, session committee member)

10th School on LHC Physics,
23-27 August (online) (invited lectures by H. Kirschenmann)

VBSCan Management Committee Meeting,
27 August (online) (H. Kirschenmann, M. Voutilainen)

HIP Scientific Advisory Board Meeting,
31 August - 1 September (online)
(T. Lampén, T. Lindén, talk by M. Voutilainen)

TOP 2021 Conference,
13-17 September (online) (H. Siikonen)

CMS Week,
13-17 September (online) (plenary talk by S. Laurila)

1st CMS AlCaDB Workshop on Run 3 Preparation,
20-22 September (online) (talk by T. Lampén)

Token Transition Workshop,
14-15 October (online) (T. Lindén)

PARTICLEFACE Management Committee Final Meeting,
22 October (online) (M. Voutilainen)

HEPiX Autumn 2021 Online Workshop,
25-29 October (online) (T. Lindén)

CMS TOP Group Workshop 2021,
10-12 November (online) (H. Siikonen)

FPS Particle Physics Day 2021,
16 November, Jyväskylä, Finland (H. Kirschenmann, invited talk by T. Lampén, T. Lindén, L. Martikainen, M. Voutilainen, division meeting chair)

109th Plenary ECFA Meeting,
18-19 November (online) (H. Kirschenmann)

SMARTHEP Consortium Meeting,
24-26 November (online) (H. Kirschenmann, M. Voutilainen)

LHC TOP WG Meeting,
1-3 December (online) (H. Siikonen)

CMS Week,
6-10 December (online) (H. Kirschenmann, M. Voutilainen)

Fusion Power Associates 42nd Annual Meeting,
15-16 December (online) (T. Lindén)

CMS Upgrade

Global Young Scientists Summit,
12-15 January (online) (J. Ott)

CMS Week,
1-5 February (online) (A. Karadzhinova-Ferrer, P. Luukka, chair)

R51 Mini-Week,
15-19 February (online) (E. Brücken)

CMS Tracker Week,
22-26 February (online) (P. Luukka)

Physics Days 2021,
24-26 March (online) (talk by S. Bharthuar, talk by S. Kirchenmann, N. Kramarenko)

FACET Collaboration Meeting,
14 April (online) (talk by E. Brücken)

CMS Week,
19-24 April (online) (A. Karadzhinova-Ferrer, P. Luukka, chair)

LHC RRB,
26-28 April (online) (P. Luukka)

CMS Tracker Week,
3-7 May (online) (P. Luukka)

Searching for Long-Lived Particles at the LHC and Beyond,
25-28 May (online) (E. Brücken)

RD51 Collaboration Meeting,
14-18 June (online) (talk by E. Brücken)

European Congress of Medical Physics (ECMP),
16-19 June (online) (talk by S. Kirchenmann)

RD50 Workshop,
21-23 June (online) (talk by S. Bharthuar, E. Brücken)

CMS Week,
21-25 June (online) (A. Karadzhinova-Ferrer, P. Luukka, chair)

22nd International Workshop on Radiation Imaging Detectors,
27 June - 1 July (online) (E. Brücken, S. Kirchenmann)

International Conference on Women in Physics,
11-15 July (online) (J. Ott)

Hadron Collider Physics School,
18-26 July, Göttingen, Germany (S. Bharthuar)

CMS Tracker Week,
26-30 July (online) (P. Luukka)

CERN - Fermilab HCP Summer School,
23 August - 4 September (online) (S. Bharthuar)

HIP Scientific Advisory Board Meeting,
31 August - 1 September (online) (talk by P. Luukka)

The 12th International Conference on Position Sensitive Detectors,
12-17 September (online) (talk by S. Bharthuar)

CMS Week,
13-17 September (online) (A. Karadzhinova-Ferrer, P. Luukka)

The 30th International Workshop on Vertex Detectors,
27-30 September (online) (S. Bharthuar, E. Brücken)

19th International Congress on Neutron Capture Therapy,
27 September - 1 October (online)
(S. Kirchenmann, talk by A. Winkler)

CMS Tracker Week,
4-8 October (online) (talk by P. Luukka)

LHC RRB,
25-27 October (online) (P. Luukka)

RD51 Collaboration Meeting,
15-19 November (online) (E. Brücken)

FPS Particle Physics Day 2021,
16 November, Jyväskylä, Finland
(invited talk by E. Brücken)

39th RD50 Workshop,
17-19 November, Valencia, Spain and online
(S. Bharthuar, E. Brücken, N. Kramarenko, P. Luukka)

MATRENA Annual Seminar,
23 November (online) (S. Kirchenmann)

CMS Week,
6-10 December (online)
(A. Karadzhinova-Ferrer, P. Luukka)

CMS Tracker Week,
13-17 December (online) (P. Luukka)

TOTEM

CMS PPS General Meeting,
2 February (online) (L. Forthomme, F. García, M.-M. Rantanen, K. Österberg)

TOTEM-PPS Upgrade Workshop,
8-10 February (online) (L. Forthomme, talk by F. García, M.-M. Rantanen, K. Österberg)

RD51 Mini-Week,
15-19 February (online) (talk by F. García)

TOTEM Collaboration and LHCC Referees Meeting,
1-2 March (online) (L. Forthomme, F. García, talk by F. Oljemark, talks by K. Österberg, chair)

Physics Days 2021,
24-26 March (online) (F. Oljemark, talks by M.-M. Rantanen and K. Österberg)

Moriond QCD 2021,
27 March - 3 April (online) (talk by K. Österberg, chair)

DIS 2021,
12-16 April (online) (K. Österberg)

CMS PPS General Meeting,
20 April (online) (L. Forthomme, talk by F. García, M.-M. Rantanen, K. Österberg)

LHC RRB,
26-28 April (online) (K. Österberg)

Snowmass EF06 Topical Meeting: Forward Physics Facility at the LHC,
5 May (online) (K. Österberg)

TOTEM Collaboration and LHCC Referees Meeting,
31 May - 1 June (online) (F. García, F. Oljemark, talks by K. Österberg, chair)

LHCP 2021,
7-12 June (online) (talk by L. Forthomme)

CMS PPS General Meeting,
22 June (online) (talk by F. García, M.-M. Rantanen, K. Österberg)

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

HIP Scientific Advisory Board Meeting,
31 August - 1 September (online) (talk by K. Österberg)

CERN,
13-30 September, Geneva, Switzerland (F. García)

CMS PPS General Meeting,
14 September (online) (talk by F. García, M.-M. Rantanen, K. Österberg)

Super-FRS Experiment Collaboration Meeting,
22-24 September (online) (talk by F. García)

TOTEM Collaboration Meeting,
26-27 September (online) (talk by F. García, F. Oljemark, talk by K. Österberg, chair)

Low-x 2021,
27 September - 1 October (online)
(invited talk by K. Österberg, chair)

CERN,
5-14 October, Geneva, Switzerland (F. García)

Timing Detectors for PPS@HL-LHC,
19 October (online) (F. García, M.-M. Rantanen, K. Österberg)

LHC RRB,
25-27 October (online) (K. Österberg)

CERN,
25 October - 5 November, Geneva, Switzerland (F. García)

CERN,
8-16 November, Geneva, Switzerland (F. García)

RD51 Collaboration Meeting,
15-19 November (online) (talk by F. García)

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

CMS PPS General Meeting,
6 December (online) (M.-M. Rantanen, K. Österberg)

Nuclear Matter Programme

ISOLDE

90th ISCC Meeting,
1 February (online) (J. Pakarinen)

66th INTC Meeting,
3-4 February (online) (I. Moore)

NUSTAR Annual Meeting 2021,
22-26 February (online) (talk by R. de Groote)

EUROLABS Town Meeting,
3-4 May (online) (talk by R. de Groote)

Nuclear Physics Seminar,
21 May, Jyväskylä, Finland (talk by A. Briscoe)

CERN,
7-28 June, Geneva, Switzerland (R. de Groote)

91st ISCC Meeting,
16 June (online) (J. Pakarinen)

Nuclear Physics Seminar,
18 June, Jyväskylä, Finland (talk by M. Stryjczyk)

67th INTC Meeting,
23-24 June (online) (talk by A. Illana Sison, I. Moore)

CERN,
9-20 July, Geneva, Switzerland
(A. Illana Sison, M. Stryjczyk)

FNUC/GEFN Seminars,
30 July (online) (talk by A. Illana Sison)

CERN,
23 August - 2 September, Geneva, Switzerland
(M. Stryjczyk)

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

CERN,
6-9 October, Geneva, Switzerland
(A. Illana Sison, M. Stryjczyk)

92nd ISCC Meeting,
5 November, CERN, Geneva, Switzerland (J. Pakarinen)

68th INTC Meeting,
9-10 November (online) (I. Moore)

CERN,
1-7 December, Geneva, Switzerland (M. Myllymäki)

CERN,
1 December 2021 - 31 July 2022, Geneva, Switzerland
(J. Pakarinen)

IDS Collaboration Meeting,
6 December (online) (J. Pakarinen)

MINIBALL Steering Committee Meeting,
10 December (online) (J. Pakarinen)

ISOLDE Workshop and Users Meeting 2021,
14-16 December (online) (A. Illana Sison,
I. Moore, session chair, talk by J. Pakarinen)

FAIR

NUSTAR Annual Meeting 2021,
22-26 February (online) (T. Eronen, T. Grahn, A. Jokinen,
A. Kankainen, M. Luoma, I. Moore, J. Äystö)

EMMI Workshop: New Avenues for the Low-Energy NUSTAR Program at GSI-FAIR,
16-17 September (online) (T. Eronen, P. Greenlees,
A. Jokinen, A. Kankainen, I. Moore, J. Pakarinen,
H. Penttilä, J. Äystö)

SUPER-FRS Experiment Collaboration Meeting,
22-24 September, Walldorf, Germany (talk by F. García,
T. Grahn, A. Jokinen, A. Kankainen, talk by M. Luoma,
I. Moore, J. Äystö)

NUSTAR Week 2021,
4-8 October (online) (T. Grahn, A. Jokinen, A. Kankainen,
M. Luoma, I. Moore)

Technology Programme

Accelerator Technology: Materials (MAT)

RADIATE Spring School 2021,
28-30 April, Lisbon, Portugal (talk by F. Djurabekova)

IAEA Training Workshop on Ion Beam Driven Materials Engineering: New Roles for Accelerators for Quantum Technologies,
4-7 May (online) (talk by F. Djurabekova)

MEPhI,
5-10 July, Moscow, Russia (talk by F. Djurabekova)

29th International Symposium on Discharges and Electrical Insulation in Vacuum (ISDEIV),
26-30 September, Consorzio RFX, Padua, Italy (online)
(talk by F. Djurabekova)

Technical University of Lisbon,
11 November, Lisbon, Portugal (F. Djurabekova)

29th European Fusion Programme Workshop,
30 November - 2 December, Zagreb, Croatia (online)
(talk by F. Djurabekova)

Radiation Safety and STUK

Radiation Metrology for Medical Applications (RADMED)

Physics Days 2021,
24-26 March, Jyväskylä, Finland (online)
(talk by S. Kirschenmann)

European Congress of Medical Physics (ECMP),
16-19 June (online) (talk by S. Kirschenmann)

22nd International Workshop on Radiation Imaging Detectors,
27 June - 1 July (online) (S. Kirschenmann)

19th International Congress on Neutron Capture Therapy,
27 September - 1 October (online) (S. Kirschenmann)

MATRENA Annual Seminar,
23 November (online) (S. Kirschenmann)

Radiation Safety Research and Development (RADAR)

European Radiation Dosimetry Group (EURADOS) Annual Meeting,
28 January (online) (talk by S. Ihantola (STUK))

Consultancy Meeting on the IAEA Coordinated Research Project on Spent Fuel Characterization,
28 June - 1 July (online) (talk by P. Dendooven)

INMM-ESARDA Joint Annual Meeting,
23 August - 1 September (online)
(talk by R. Virta (STUK), P. Dendooven)

Uppsala University,
11-12 October, Uppsala, Sweden
(seminar by P. Dendooven)

International Conference on the Development of Preparedness for National and International Emergency Response,
11-15 October, IAEA, Vienna, Austria
(talk by S. Ihantola (STUK))

2021 Virtual IEEE Nuclear Science Symposium and Medical Imaging Conference (NSS-MIC),
16-23 October (online) (talk by R. Virta (STUK), P. Dendooven)

GammaRayX 2021 Webinar on Gamma Spectrometry,
20-21 October (online) (talk by R. Virta (STUK))

5th European Radiation Protection Week (ERPW),
22-24 November, Vienna, Austria (online)
(talk by S. Ihantola (STUK))

First Research Coordination Meeting on the IAEA Coordinated Research Project on Spent Fuel Characterization,
6-9 December (online) (talk by P. Dendooven)

Other projects

CLOUD

European Aerosol Conference (EAC 2021),
30 August - 3 September (online) (talk by J. Duplissy)

Euclid

Nordic Optical Telescope,
11 January - 31 December, La Palma, Spain (A. Viitanen)

CODEX SZ Meeting,
27 January (online) (talk by K. Kiiveri)

Euclid IT Architecture Meeting,
27-29 January (online) (H. Kurki-Suonio, V. Lindholm)

Euclid SPV3 Kickoff Meeting,
7 March (online) (H. Kurki-Suonio, V. Lindholm)

Euclid WP9 Meeting,
29-30 March (online) (talk by A. Viitanen)

Euclid SC Meeting,
4-5 May (online) (H. Kurki-Suonio, V. Lindholm)

Euclid Consortium Meeting 2021,
25-28 May (online) (E. Keihänen, K. Kiiveri, A. Viitanen)

Euclid SC8 Closeout Meeting,
8, 29 September (online) (H. Kurki-Suonio, V. Lindholm)

Euclid IT Architecture Meeting,
4-5 November (online) (H. Kurki-Suonio, V. Lindholm)

Detector Laboratory

Physics Days 2021,
24-26 March, Jyväskylä, Finland (online)
(talk by M. Kalliokoski)

GENERA (Gender Equality Network in Physics in the European Research Area) General Assembly Meeting,
12-13 April, Munich, Germany (online)
(talk by E. Tuominen)

15th MoEDAL Collaboration Meeting,
1-4 June (online) (talk by M. Kalliokoski)

38th CERN RD50 Workshop,
21-23 June (online) (E. Tuominen)

GammaRayX 2021 Webinar on Gamma Spectrometry,
20-21 October (online) (talk by M. Kalliokoski)

FPS Particle Physics Day 2021,
16 November, Jyväskylä, Finland (talk by M. Kalliokoski, E. Tuominen)

LHCC 148 Week,
16 November (online) (talk by M. Kalliokoski)

39th CERN RD50 Workshop,
17-19 November, Valencia, Spain (online) (E. Tuominen)

SLUSH Start-Up Event,
1-2 December, Helsinki, Finland (M. Arenius)

16th MoEDAL Collaboration Meeting,
15-17 December (talk by M. Kalliokoski)

Working visits,
CERN, Geneva, Switzerland (R. Turpeinen)

PUBLICATIONS

Theory Programme

Theoretical Cosmology

M. Hindmarsh in N. Aggarwal et al.,
Challenges and opportunities of gravitational-wave searches at MHz to GHz frequencies,
Living Rev. Relativ. 24 (2021) 4

J. Annala and S. Räsänen,
Inflation with $R_{(\alpha\beta)}$ terms in the Palatini formulation,
J. Cosmol. Astropart. Phys. 09 (2021) 032

O. Gould and P. Schicho in D. Croon et al.,
Theoretical uncertainties for cosmological first-order phase transitions,
J. High Energy Phys. 04 (2021) 055

D. Cutting, E. Granados Escartin, M. Hindmarsh, and D. J. Weir,
Gravitational waves from vacuum first-order phase transitions. II. From thin to thick walls,
Phys. Rev. D 103 (2021) 023531

V.-M. Enckell, S. Nurmi, S. Räsänen, and E. Tomberg,
Critical point Higgs inflation in the Palatini formulation,
J. High Energy Phys. 04 (2021) 059

D. G. Figueroa, S. Raatikainen, S. Räsänen, and E. Tomberg,
Non-Gaussian tail of the curvature perturbation in stochastic ultraslow-roll inflation: implications for primordial black hole production,
Phys. Rev. Lett. 127 (2021) 101302

E. D. Schiappacasse in K. Fujikura et al.,
Microlensing constraints on axion stars including finite lens and source size effects,
Phys. Rev. D 104 (2021) 123012

P. Gallagher and T. Koivisto,
The Λ and the CDM as integration constants,
Symmetry 13 (2021) 2076

L. Giani, E. Frion, and O. F. Piattella,
Impact of inhomogeneities on slowly rolling quintessence: implications for the local variations of the fine-structure constant,
Class. Quantum Grav. 38 (2021) 175010

O. Gould,
Real scalar phase transitions: a nonperturbative analysis,
J. High Energy Phys. 04 (2021) 057

O. Gould et al.,
Schwinger pair production of magnetic monopoles: Momentum distribution for heavy-ion collisions,
Phys. Rev. D 104 (2021) 015033

O. Gould and J. Hirvonen,
Effective field theory approach to thermal bubble nucleation,
Phys. Rev. D 104 (2021) 096015

O. Gould, S. Sukuvaara, and D. Weir,
Vacuum bubble collisions: From microphysics to gravitational waves,
Phys. Rev. D 104 (2021) 075039

C. Gowling and M. Hindmarsh,
Observational prospects for phase transitions at LISA: Fisher matrix analysis,
J. Cosmol. Astropart. Phys. 10 (2021) 039

M. Herrero-Valea, R. Santos-Garcia, and A. Tokareva,
Massless positivity in graviton exchange,
Phys. Rev. D 104 (2021) 085022

M. P. Hertzberg, S. Nurmi, E. D. Schiappacasse, and T. T. Yanagida,
Shining primordial black holes,
Phys. Rev. D 103 (2021) 063025

M. Hindmarsh et al.,
Loop decay in Abelian-Higgs string networks,
Phys. Rev. D 104 (2021) 043519

M. Hindmarsh et al.,
Phase transitions in the early universe,
SciPost Phys. Lect. Notes 24 (2021)

M. Hindmarsh and A. Lopez-Eiguren in M. Hindmarsh et al.,
Approach to scaling in axion string networks,
Phys. Rev. D 103 (2021) 103534

H. Jukkala, K. Kainulainen, and P. M. Rahkila,
Flavour mixing transport theory and resonant leptogenesis,
J. High Energy Phys. 09 (2021) 119

K. Kainulainen,
CP-violating transport theory for electroweak baryogenesis with thermal corrections,
J. Cosmol. Astropart. Phys. 11 (2021) 042

K. Kainulainen and O. Koskivaara,
Non-equilibrium dynamics of a scalar field with quantum backreaction,
J. High Energy Phys. 12 (2021) 190

K. Kainulainen, S. Nurmi, E. D. Schiappacasse, and T. T. Yanagida,
Can primordial black holes as all dark matter explain fast radio bursts?,
Phys. Rev. D 104 (2021) 123033

T. Markkanen and S. Nurmi in A. Karam et al.,
Higgs-like spectator field as the origin of structure,
Eur. Phys. J. C 81 (2021) 620

A. S. Koshelev and A. Tokareva,
Unitarity of Minkowski nonlocal theories made explicit,
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Baryogenesis and gravity waves from a UV-completed electroweak phase transition,
Phys. Rev. D 103 (2021) 123529

M. Långvik, J.-M. Ojanperä, S. Raatikainen, and S. Räsänen,
Higgs inflation with the Holst and the Nieh-Yan term,
Phys. Rev. D 103 (2021) 083514

A. Mantziris, T. Markkanen, and A. Rajantie,
Vacuum decay constraints on the Higgs curvature coupling from inflation,
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L. Niemi and D. J. Weir in L. Niemi et al.,
Thermodynamics of a two-step electroweak phase transition,
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Can QCD axion stars explain Subaru HSC microlensing?,
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P. Wu, L. H. Ford, and E. D. Schiappacasse,
Space and time averaged quantum stress tensor fluctuations,
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High Energy Phenomenology in the LHC Era

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Z_3 symmetric inert (2+1)-Higgs-doublet model,
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F. R. Ares, M. Hindmarsh, C. Hoyos, and N. Jokela,
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Quantum hypothesis testing in many-body systems,
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N. Jokela in B. S. DiNunno et al.,
Quantum information probes of charge fractionalization in large-*N* gauge theories,
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Cold quark matter at N^{3}LO: Soft contributions,
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Soft interactions in cold quark matter,
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C. Hoyos, N. Jokela, J. M. Penín, A. V. Ramallo, and J. Tarrío,
Risking your NEC,
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N. Jokela, K. Kajantie, and M. Sarkkinen,
Memory effect in Yang-Mills theory with an axion,
Phys. Rev. D 104 (2021) 074029

N. Jokela and A. Pönni,
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Unified weak and strong coupling framework for nuclear matter and neutron stars,
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Is entanglement a probe of confinement?,
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Non-perturbative determination of collisional broadening and medium induced radiation in QCD plasmas,
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Phys. Rev. D 104 (2021) 114504

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Solar neutrinos and dark matter detection with diurnal modulation,
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P. M. Schicho, T. V. I. Tenkanen, and J. Österman,
Robust approach to thermal resummation: Standard Model meets a singlet,
J. High Energy Phys. 06 (2021) 130

QCD and Strongly Interacting Gauge Theory

G. Beuf, T. Lappi, and R. Paatelainen,
Massive quarks in NLO dipole factorization for DIS: Longitudinal photon,
Phys. Rev. D 104 (2021) 056032

T. Lappi in K. Boguslavski et al.,
Broad excitations in a 2+1D overoccupied gluon plasma,
J. High Energy Phys. 05 (2021) 225

H. Mäntysaari in R. Boussarie et al.,
The importance of kinematic twists and genuine saturation effects in dijet production at the Electron-Ion Collider,
J. High Energy Phys. 09 (2021) 178

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A. Dumitru and R. Paatelainen,
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Impact of dijet and D-meson data from 5.02 TeV p+Pb collisions on nuclear PDFs,
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Exclusive heavy vector meson electroproduction to NLO in collinear factorisation,
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H. Niemi in J. A. Fotakis et al.,
Longitudinal dynamics of multiple conserved charges,
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P. Guerrero-Rodríguez and T. Lappi,
Evolution of initial stage fluctuations in the glasma,
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E. Iancu and Y. Mulian,
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M. Li, T. Lappi, and X. Zhao,
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Nucl. Phys. A 1005 (2021) 121874

H. Mäntysaari et al.,
Gluon imaging using azimuthal correlations in diffractive scattering at the Electron-Ion Collider,
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H. Mäntysaari and J. Penttala,
Exclusive heavy vector meson production at next-to-leading order in the dipole picture,
Phys. Lett. B 823 (2021) 136723

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A first estimate of η/s in Au+Au reactions at E_{lab} = 1.23 *A*GeV,
Phys. Lett. B 817 (2021) 136285

Designer Topological Matter

T. Ojanen in S. Peotta et al.,
Determination of dynamical quantum phase transitions in strongly correlated many-body systems using Loschmidt cumulants,
Phys. Rev. X 11 (2021) 041018

K. Pöyhönen and T. Ojanen,
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Phys. Rev. Research 3 (2021) L042027

Nuclear Structure for Weak and Astrophysical Processes

J. Dobaczewski, M. Kortelainen, and W. Satuła in J. Dobaczewski et al.,
Solution of universal nonrelativistic nuclear DFT equations in the Cartesian deformed harmonic-oscillator basis. (IX) HFODD (v3.06h): a new version of the program,
J. Phys. G: Nucl. Part. Phys. 48 (2021) 102001

J. Dobaczewski in J. A. Sheikh et al.,
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J. Phys. G: Nucl. Part. Phys. 48 (2021) 123001

CMS Programme

CMS Experiment

(P. Eerola, L. Forthomme, H. Kirschenmann, K. Osterberg, M. Voutilainen, E. Brücken, F. Garcia, J. Havukainen, V. Karimäki, M. S. Kim, R. Kinnunen, T. Lampén, K. Lassila-Perini, S. Laurila, S. Lehti, T. Lindén, H. Siikonen, E. Tuominen, and J. Tuominiemi with the CMS Collaboration (V. Khachatryan et al.))

CMS Collaboration,
The very forward CASTOR calorimeter of the CMS experiment,
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(P. Eerola, L. Forthomme, H. Kirschenmann, K. Osterberg, M. Voutilainen, S. Bharthuar, E. Brücken, F. Garcia, J. Havukainen, M. S. Kim, R. Kinnunen, T. Lampén, K. Lassila-Perini, S. Lehti, T. Lindén, M. Lotti, L. Martikainen, M. Myllymäki, J. Ott, H. Siikonen, E. Tuominen, and J. Tuominiemi with the CMS Collaboration (N. Tonon et al.))

CMS Collaboration,
Probing effective field theory operators in the associated production of top quarks with a Z boson in multilepton final states at $\sqrt{s}$ = 13 TeV,
J. High Energy Phys. 12 (2021) 083

(P. Eerola, L. Forthomme, H. Kirschenmann, K. Osterberg, M. Voutilainen, S. Bharthuar, E. Brücken, F. Garcia, J. Havukainen, M. S. Kim, R. Kinnunen, T. Lampén, K. Lassila-Perini, S. Lehti, T. Lindén, M. Lotti, L. Martikainen, M. Myllymäki, J. Ott, H. Siikonen, E. Tuominen, and J. Tuominiemi with the CMS Collaboration (A. M. Sirunyan et al.))

CMS Collaboration,
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