HELSINKI INSTITUTE OF PHYSICS

Annual Report 2014

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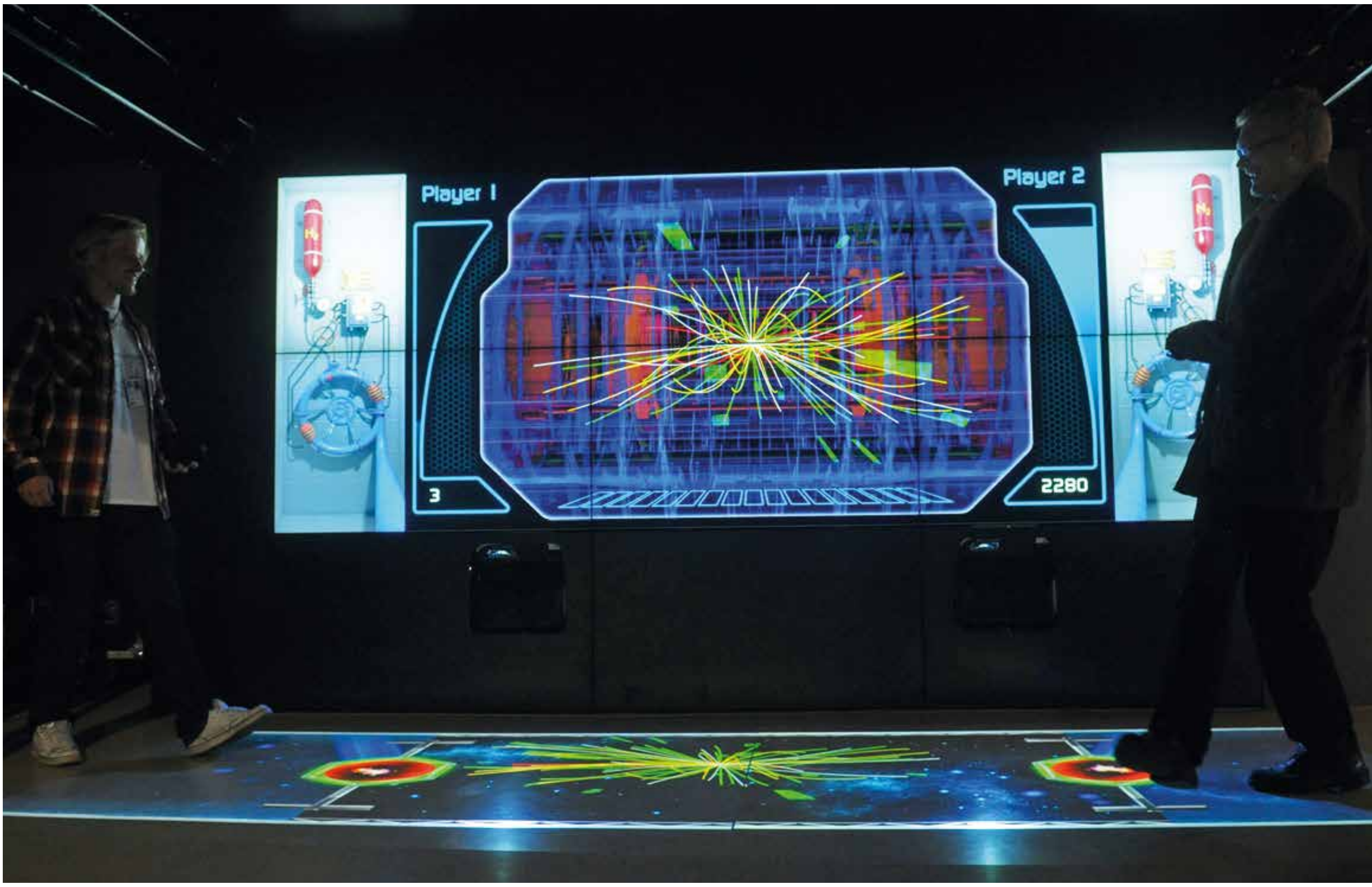


The main attraction of the Higgs weekend in Finnish Science Centre Heureka was the Interactive LHC tunnel, visualising particle physics by, among other things, a proton football game. In the picture Juska Pekkanen and Mikko Voutilainen are kicking protons. *(S. Laurila)*

Annual Report 2014 Helsinki Institute of Physics

Contents

Introduction

Juha Äystö

In its research the Helsinki Institute of Physics (HIP) addresses fundamental science questions from quarks to the Cosmos as well as technologies from semiconductors to medical applications and climate research. Following restructuring, the research activities of HIP in 2014 have consisted of four main research programmes and three independent research projects including a substantial effort on theory. Finland's membership of CERN allows an active participation in front-line particle physics experiments. The HIP groups in the CMS, ALICE and TOTEM detector collaborations participate in the data analysis of the runs of the LHC collider, which will resume operation after a long shutdown in spring 2015. Participation in the research at CERN's ISOLDE continued with active participation starting in July 2014 and aiming further for the upgraded HIE-ISOLDE facility in autumn 2015. The CLOUD experiment at CERN continued data taking with cosmic radiation in 2014. The Facility for Antiproton and Ion Research (FAIR) is another of HIP's responsibilities and will offer substantial subatomic and material science research potential becoming available for experiments in steps to about 2020. Scientific output has been steadily increasing, reaching a level of close to 300 publications in high impact level journals in 2014.

The Helsinki Institute of Physics has since 1997 had a national mandate from the Finnish Ministry of Education and Culture for the co-ordination of the collaboration between CERN and Finland. HIP is also responsible for co-ordination of the Finnish activities at the new international Facility for Antiproton and Ion Research (FAIR) under construction in Darmstadt, Germany. The University of Helsinki, which is the host organization of HIP, and the Swedish Research Council have formed a consortium "FAIRNORD" for joint representation in the Council of FAIR GmbH.

HIP is operated by the University of Helsinki, Aalto University, the University of Jyväskylä and Lappeenranta and Tampere Universities of Technology. Administratively HIP is an independent institute under the Rector of the University of Helsinki. The HIP operations are based on the Finnish CERN strategy, which emphasises, in addition to research and researcher training, the development of technology know-how for Finnish industry and business applications and the exploitation of CERN and FAIR research results in science education and literacy. The success of these outreach efforts is, for example, demonstrated by the great interest in CERN shown by Finnish high schools. In 2014 the Institute was able to host nearly 20 science-study visits to CERN by 372 Finnish high school students and 54 teachers. During 2014, 10 PhD and DSc (Tech) degrees and 11 MSc and MSc (engineering) degrees were awarded by the HIP partner universities on the basis of work conducted within the research projects of the Institute. The summer student programme at CERN represents a key educational effort. During summer 2014, 16 Finnish university students worked at CERN as trainees in HIP research projects.

The research activities of the Helsinki Institute of Physics in 2014 fell into 4 research programmes and 3 special research projects. The research programmes were (1) the Theory Programme, (2) the CMS Programme, (3) the Nuclear Matter Programme and (4) the Technology Programme. The special independent projects in 2014 were the CLOUD experiment project at CERN, which aims at the determination of the role of cosmic radiation in climate warming, the Planck-Euclid project for the analysis of the cosmic background radiation data from the Planck satellite and the Forward Physics project at the LHC. In addition, the Detector Laboratory continued as a common infrastructure operating in collaboration with detector construction and R&D projects of the experimental groups of HIP.

In 2014 after an open competition, five new projects were selected for the Theory Programme. These were: Cosmology of the Early and Late Universe, High Energy Phenomenology in the LHC Era, QCD and Strongly Interacting Gauge Theory, Nuclear Structure for Weak and Astrophysical Processes and Domain Wall Dynamics. Additionally, Professor Mark Hindmarsh (Sussex University) started his five-year part-time Visiting Professor position in Helsinki, shared by HIP and the Department of Physics.

The CMS Programme included the project for physics analysis and operation of the CMS detector and the project for the CMS tracker upgrade. In 2014 the CMS Programme also carried responsibility for the operation of the Finnish Tier-2 Grid computing facility, which is part of the Worldwide LHC Computing Grid WLCG. The CMS Upgrade project received a significant second two-year (2014–2015) upgrade grant from the Academy of Finland, which will ensure the completion of the Finnish contribution to the inner tracker upgrade. The HIP CMS group has been leading the CMS data preservation and open access project. The highlight of the year was the first public release of the CMS data. In 2014 the TOTEM project was included into the CMS Programme following the termination of the High Energy Physics Programme at the end of 2013.

The Nuclear Matter Programme included three projects. The first is a nuclear structure research project at the ISOLDE facility at CERN. The second is a project for physics analysis and instrumentation for the ALICE detector for relativistic heavy ion collisions at the LHC. The ALICE project continued with its major participation in an upgrade project for the ALICE TPC readout based GEM technology with infrastructure funding from the Academy of Finland. In addition the Nuclear Matter Programme contained a project responsible for the Finnish contribution to the FAIR project, which consists of equipment for the accelerator complex and the experiments within the NUSTAR Collaboration. The leader of the ALICE project, Dr. Jan Rak, was appointed to the post of full Professor in the Physics Department at the University of Jyväskylä in January 2014.

The Technology Programme was composed of three research projects. The Green Big Data project focused on optimising energy consumption of scientific computing clusters. The Accelerator Technology project consisted of two activities: the materials properties for accelerator technologies and manufacturing aspects of CLIC accelerating components. The Biomedical Imaging AvanTomography project aims to construct a PET demonstrator for medical imaging and pattern recognition.

In 2014 the total basic budget in euros of the Institute remained constant as compared to the previous year. The project structure for 2015 has been decided with some modifications approved by the Board. The research activities from 2015 on will continue to consist of four main research programmes and two independent research projects. The research programmes will be (1) the Theory Programme consisting of five projects, (2) the CMS Programme including also the TOTEM project, (3) the Nuclear Matter Programme including the ALICE Forward Physics project and (4) the Technology Programme including two new projects, the TEKES-funded FIDIPRO project on detector applications for nuclear safety, security and safeguards and a business incubation activities pilot project with CERN.

During 2014 HIP hosted four international meetings. These were: *Numerical methods for holographic thermalization*, a lecture series by Michal Heller, May 5–9; *Enqfest - 30 years of cosmology*, a workshop to celebrate the occasion of the 60th birthday of Professor Kari Enqvist, May 30–31; *TFT-50 years*, an informal meeting to celebrate 50 years since the beginning of TFT, September 1; the *HIP/FIDIPRO workshop on nuclear isospin properties*, October 16–17.

The Institute is indebted to the outstanding services of Professor Heimo Saarikko who is going to retire in early 2015. His role as the director of the High Energy Physics Programme and continued support to various activities in high energy physics and detector projects has been very important. The 2014 Zimányi Medal was given at the Quark Matter 2014 conference to Tuomas Lappi, project leader in the HIP Theory Programme, for his extraordinary contributions to the field of high energy nuclear physics.

The year 2014 marked the 60th Anniversary Year of the founding of CERN. The main celebration event was organised on September 29th at CERN where the Finnish delegation was led by the Secretary of State Mr. Peter Stenlund. Several events were also organised in Helsinki, Jyväskylä and Oulu. The CERN60 Symposium was organised on October 3rd at Kumpula Campus of the University of Helsinki with keynote speaker being CERN's Director General, Rolf Heuer. The presentations by Keijo Kajantie, Jorma Tuominiemi and Mikko Voutilainen introduced the historical views back to the old days, as well as the current Finnish research activities at CERN, respectively.

The board of HIP was chaired by Professor Jouko Väänänen, Dean of the Faculty of Science of the University of Helsinki. The scientific activities of the Institute were overseen by an international scientific advisory board, which was chaired by Professor Philippe Bloch, Director of the Physics Department at CERN.

CERN 60 Years, Science for Peace - Events in Finland

CERN celebrated its 60th anniversary in 2014 with the theme ”Science for peace”. Celebration events were organised over the year at CERN and in the member states.

In Finland the Helsinki Institute of Physics and the Section of Particle Physics of the Finnish Physical Society organised a symposium on research at CERN at the Kumpula Campus on 3 October with the CERN Director General, Professor Rolf Heuer as the keynote speaker.

Furthermore a thematic week ”From the Elementary Particles to the Universe” was organised at the Science Cafe (Tiedekulma, Think Corner) of the University of Helsinki from 29 September to 2 October. The events attracted daily an audience of 20–30 people. The programme was held as described below.

Monday 29 September: CERN 60 years - Inspiration to learning. Views and experiences on the topic were discussed by the CERN Education group member Riitta Rinta-Filppula, theoretical physicist Aleksi Vuorinen (HIP), who has given courses to the high school students at CERN, experimentalist Tapio Lampén (HIP), Lauri Järvilehto (Rovio Learning), physics teacher Risto Matveinen from Kauriala High School, and physics teacher Mikko Korhonen from Mikkeli High School.

Tuesday 30 September: CERN 60 years - Particle Physics and Cosmology. Professor of Cosmology Kari Enqvist and Dr. Mikko Voutilainen, an experimentalist from the Helsinki Institute of Physics working in the CMS experiment at CERN, were interviewed by science journalist Matti Mielonen from the Finnish newspaper Helsingin Sanomat.

Wednesday 1 October: CERN 60 years - CERN and Higgs. Three experimentalists working in the CMS experiment at CERN, Dr. Kati Lassila-Perini, Professor Paula Eerola and Dr. Lauri Wendland were interviewed by science journalist Sisko Loikkanen from the Finnish Broadcasting Company (YLE).

Thursday 2 October: CERN 60 years - From basic research to technology transfer. The topic was discussed by Antti Heikkilä (Bgator), Peter Vestbacka (Mighty Eagle Special Projects, Rovio), and Olli Vuola (Aalto University Ventures programme).

CERN Director General Prof. Rolf Heuer giving a talk on CERN and Particle Physics in the Kumpula symposium. *(J. Aaltonen)*

Chairman Jorma Tuominiemi introducing science journalist Matti Mielonen, Prof. Kari Enqvist and Dr. Mikko Voutilainen in the Science Cafe session. *(S. Laurila)*

The main attraction of the Higgs weekend in Finnish Science Centre Heureka was the Interactive LHC tunnel, visualising particle physics by, among other things, a proton football game. In the picture Juska Pekkanen and Mikko Voutilainen are kicking protons. *(S. Laurila)*

The CERN 60 years celebration continued during the following weekends in the science centres Heureka (Vantaa) and Tietomaa (Oulu). ”Higgs weekends” were arranged in collaboration with the science centres for the public to learn about particle physics, CERN and the Higgs boson. The weekends included public lectures, demonstration equipment like a cloud chamber, and the movie ”Particle Fever”. The public was given an opportunity to discuss with scientists. The grand jewel of the Higgs weekends was an interactive LHC tunnel borrowed from the CERN Media Laboratory. The tunnel was constructed of a video wall and sensors to allow interactive games demonstrating the LHC accelerator, the Higgs field, and what happens when particles collide. The most fun for the kids was an Angry Birds version of proton football, where one could kick Angry Birds and Bad Piggies and get them to collide.

The LHC tunnel also visited Jyväskylä, where it was located during the first three days in Tawast, a local shopping centre in downtown Jyväskylä (Monday to Wednesday, 22 to 24 September) and then on Friday 26 September at the Department of Physics, where it was one of the main attractions of the ”Hiukkasen valoa” -event. Both events were also part of the Jyväskylän Valo (City of Lights) -event that helped to gain substantial local media coverage including two stories and a video interview in the newspaper Keskisuomalainen and an interview in YLE Radio Keski-Suomi. Hiukkasen valoa brought about 1150 guests to the Physics Department and gave the general public lots of opportunities to speak about physics and CERN.

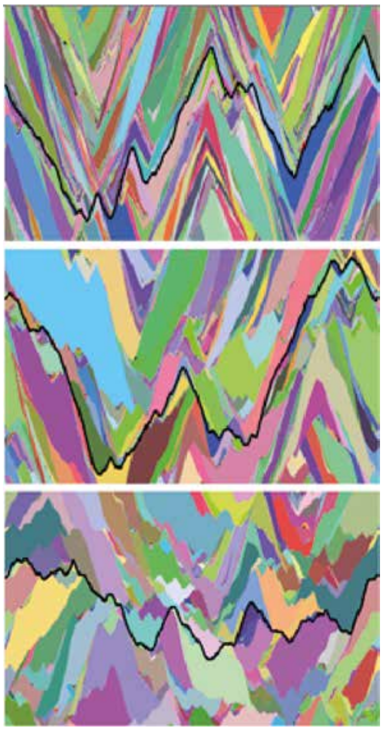
The Interactive LHC tunnel in Jyväskylä at the Hiukkasen valoa -event. *((c) Kamera-Petteri)*

Highlights of Research Results

Theory Programme

In the *Cosmology of the Early and Late Universe* project one of the highlights of the research was the analysis of the stability of the effective potential of the Higgs field during inflation. It is well known that the Higgs potential may be unstable at large Higgs field values in the Standard Model of particle physics. Because large values of the Higgs field are expected during inflation, this may render some inflationary scenarios unphysical. However, the analysis done in the Cosmology of the Early and Late Universe project showed that the curvature of space-time during inflation stabilises the Higgs potential. The paper published about this work was chosen as ”Editors' Suggestion” in Physical Review Letters.

The highlights in the *High Energy Phenomenology in the LHC Era* project include milestone results about the electroweak phase transition: the generation of gravitational waves from a first order transition as well as a precise measurement of the sphaleron rate in the Standard Model (SM) using the now known value of the Higgs mass, both published in Physical Review Letters. Finally, an extensive new research programme was initiated in 2014 to study the generation of the observed matter/antimatter asymmetry in the universe within various BSM scenarios.



The members of the *QCD and Strongly Interacting Gauge Theory* project study different aspects of strong interaction phenomenology at high energies and temperatures. Among the highlights was the first numerical solution of the next-to-leading order Balitsky-Kovchegov equation. Our proposal for a new way to measure collision centrality in diffractive electron-nucleus collisions has gained immediate interest from the experimental community. Our EPS09 nuclear parton distribution paper [JHEP 0904 (2009) 065] was cited over 100 times in the year 2014 alone.

During the year 2014, in the *Nuclear Structure for Weak and Astrophysical Processes* project we developed symmetry restoration schemes for the nuclear density functional theory. The other research topics included the role of diproton correlations in ^{6}Be and development of a computational method to calculate linear response in weakly bound superfluid nuclei close to the neutron drip line.

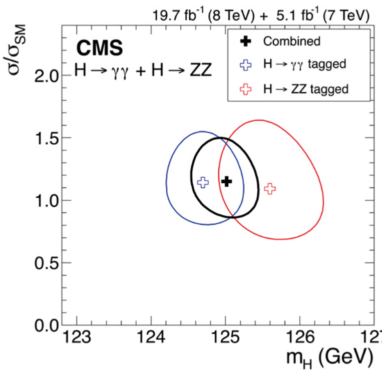
During the first year of the *Domain Wall Dynamics* project we have focused on understanding the effects of disorder on domain walls. We have developed methods to incorporate disorder (e.g., point defects and grain boundaries) into numerical simulations. We have also presented a theoretical explanation and a numerical model explaining experimental observations of a crossover between two universality classes of Barkhausen noise in disordered ferromagnetic thin films.

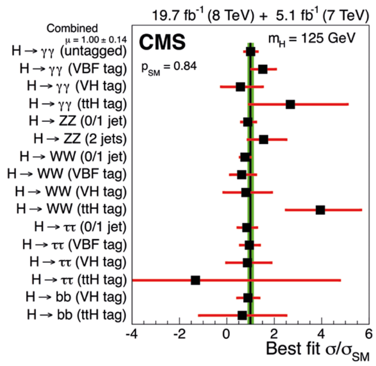
CMS Programme

The Compact Muon Solenoid (CMS) experiment is a particle physics experiment at the Large Hadron Collider (LHC) at CERN, Geneva. The main scientific goals of CMS are detailed investigations of particles and interactions at a new energy regime, understanding the origin of electroweak symmetry breaking (Higgs bosons), and a search for direct or indirect signatures of new physics beyond the Standard Model of particle physics. The first phase of the LHC operation, the so-called Run 1 (2010–2012), with proton-proton collisions at 7 and 8 TeV centre-of-mass energies, provided a total integrated luminosity of about 25 fb^{-1}, and culminated in the discovery of a Higgs boson with a mass of about 125 GeV.

The LHC accelerator and the LHC experiments are having a service break in 2013–2014, during which the equipment is being maintained and repaired or replaced. The LHC Run 2 will start in spring 2015. The collision centre-of-mass energy will be raised to 13 TeV, and the luminosity will be further increased.

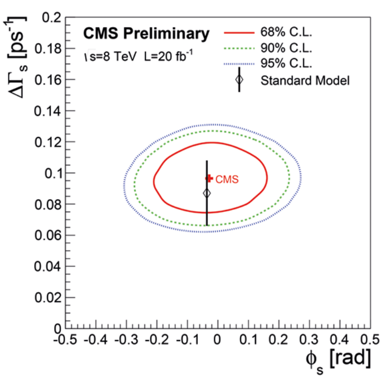
Physicists in CMS were nevertheless very busy during 2014 completing the analyses of the Run 1 data. The total number of papers submitted for publication by CMS on collision data reached 360 by the end of the year. The public CMS physics results are available at the CMS physics results twiki-page. Researchers at the University of Helsinki and the Helsinki Institute of Physics (HIP) contributed in particular to *Higgs analyses, to jet physics, and to B-physics analyses*.





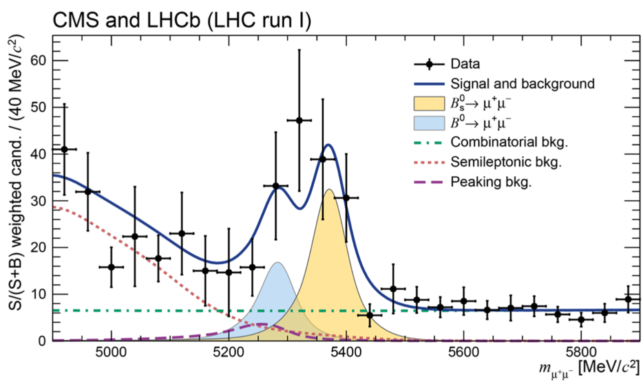
The Higgs boson properties were measured precisely [HIG-14-009; arXiv:1412.8662], and all measured properties were found to be consistent with the Standard Model predictions. New model-independent upper limits were established for the charged Higgs production cross sections times branching fraction in the charged Higgs mass range 80 to 160 GeV and 180 to 600 GeV [CMS Physics Analysis Summary HIG-14-020; http://cds.cern.ch/record/1950346?ln=en]. HIP researchers were responsible for the charged Higgs results.

M. Voutilainen was co-convener of the CMS Jets and Missing Transverse Energy Physics Object group in 2014, and made significant contributions to jet energy calibrations, which are crucial, for example, to world-leading measurements of the top quark mass. Voutilainen and his students were responsible for a new inclusive jet cross section measurement at 7 TeV proton-proton collisions [Phys. Rev. D 90 (2014) 072006]. In addition they were involved in the preliminary jet cross section measurements at 8 TeV [CMS Physics Analysis Summary SMP-12-012; https://cdsweb.cern.ch/record/1547589] and 2.76 TeV.



In B physics, researchers in Helsinki produced the first CMS results on the weak CP violation phase ϕ_s. The preliminary results [CMS Physics Analysis Summary BPH-13-012; http://cds.cern.ch/record/1744869?ln=en], comparable in accuracy with the previous world average, were presented at the ICHEP 2014 Conference in July 2014. CMS and LHCb combined their results on the rare decays $B_s \rightarrow \mu\mu$ and $B_d \rightarrow \mu\mu$ [BPH-13-007; arXiv:1411.4413], yielding a 6.2 standard deviation observation of the B_s decay and a 3.2 standard deviation excess in the search for the B_d decay. P. Eerola was a member of the B-physics Publication Committee in 2014. She also continued as a member of the CMS Management Board, representing the small CERN member states.

In 2014 the HIP TOTEM activities were moved to the CMS Programme as a project. TOTEM is a separate experiment located near the beampipe in immediate connection to CMS. TOTEM and CMS have collected some joint data, leading to published results. The future CMS Precision Proton Spectrometer project will be undertaken jointly by CMS and TOTEM, with the TOTEM Roman Pots equipped with new detectors.



The *CMS Upgrade project* received a significant second two-year (2014–2015) upgrade grant from the Academy of Finland, which will ensure the completion of the Finnish contribution to the CMS pixel detector upgrade. The project was busy with launching the pixel detector module production, which was started at the Aalto-VTT Micronova facility. A pre-series of bare pixel modules was produced with excellent results.

The *CMS Tier-2 Operations project* continued to provide reliable computing and data storage resources. In the cloud computing project "Data Indirection Infrastructure for Secure HEP Data Analysis" virtualised resources on the Ukko cluster at the Department of Computer Science, University of Helsinki, could be tested with real CMS user physics analyses.

Nuclear Matter Programme

Due to the long LHC shutdown at CERN and limited beam time available at GSI, the Nuclear Matter projects have mainly concentrated on instrument development and commissioning in 2014.

In the ALICE project a significant innovation was made in quality assurance methodology. A new method of gain mapping, based on optical scanning, was developed in the Detector Laboratory. This method replaces the expensive and time consuming electrical measurement, and thus speeds up the massive GEM production required for the ALICE upgrade.

Construction of the SPEDE conversion electron spectrometer has entered into the commissioning phase and the first in-beam tests were carried out in the Accelerator Laboratory at the University of Jyväskylä. The SPEDE concept has been validated successfully and further tests will be carried out in the Accelerator Laboratory before its final installation in the ISOLDE laboratory at CERN, where it will serve experiments at HIE-ISOLDE in late 2015.

Finnish scientists in the FAIR project have been given major responsibility in the Super-FRS diagnostics over the last years. With a positive evaluation of the last FIRI call at the end of 2014 and related funding, HIP will take responsibility of producing the so-called MUSIC detectors for Super-FRS, in addition to earlier commitments for 32 GEM TPC tracking detector and beam profile monitors. Thus Finland will have an important role in the diagnostics of Super-FRS and consequently in all of the very first experiments relying on Super-FRS.

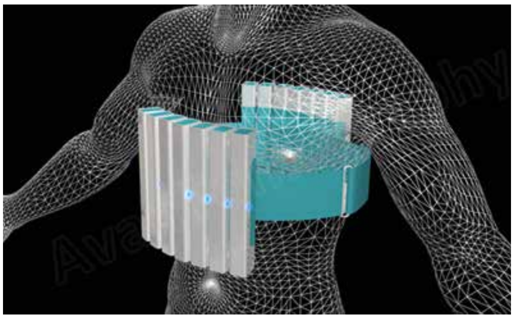
One of the very first instruments to be installed in the focal plane of the Super-FRS is an ion catcher, which serves low-energy experiments. A major step forward was taken in October 2014, when a collaboration of scientists from Justus-Liebig-Universität Gießen, the University of Jyväskylä and GSI had an extremely successful beam time with a prototype of the ion catcher. The FRS Ion Catcher, a prototype for the Super-FRS Ion Catcher, exceeded expectations and worked extremely reliably paving the way for the TDR of the Ion Catcher for Super-FRS.

Technology Programme

During the year 2014 major milestones of the Technology Programme included among others the following.

The Accelerator Technology project comprises of theoretical and experimental material research related to high-gradient normal conducting accelerating technology. The focus of the HIP contribution is on two aspects: on understanding the properties of the materials used during accelerator operation and on manufacturing and testing of accelerator components and assemblies. A significant step forward was made in the project as it obtained a ”K-contract” with CERN for the years 2015–17.

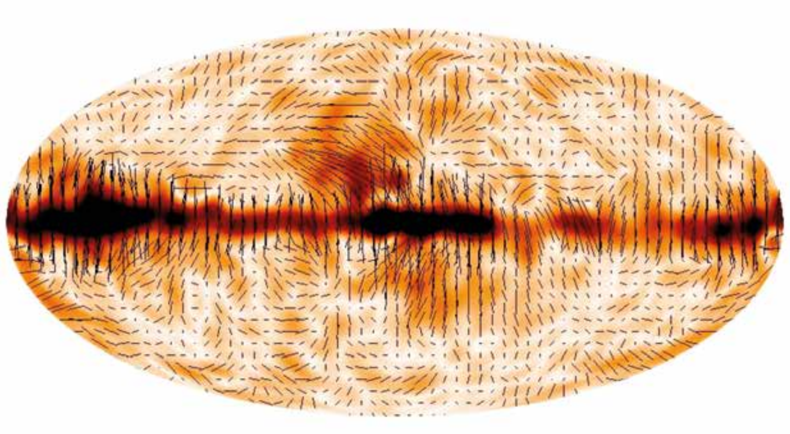
The Green Big Data project primary aims at developing methods making HEP computing more cost and energy efficient. In 2014 the project secured its participation in an EU funded research project ”Scalable and Secure Infrastructures for Cloud Operations” starting in February 2015.



The Biomedical Imaging AvanTomography project aims to construct a PET demonstrator, based on the principle of the Axial PET (AX-PET) project developed by the AX-PET research consortium in CERN. Therefore, the project aims at building an imaging device that provides improved resolution as well as high sensitivity missing in traditional PET-devices. A patent application for the new detector structure was filed in June 2014.

A new radiation-detection instrumentation development (FiDiPro) -project secured its funding during 2014 and will commence in 2015.

The new Finnish CERN BIC project aims at establishing a national, *Finnish CERN Business Incubation Center* that is involved in supporting commercialisation of CERN-related technologies commencing in 2015. The negotiations on the frame agreement between CERN and HIP were started in 2014.



Planck-Euclid

The results of the Planck satellite on the polarised foreground microwave radiation [arXiv:1409.5783] showed that the earlier purported detection of a primordial polarisation B-mode by the BICEP2 telescope must have been contaminated by polarised radiation from galactic dust. A detection of this primordial B-mode would have a dramatic effect on cosmology because it would be direct evidence of cosmological inflation in the early universe - the favourite explanation for the origin of structure in the universe - and would pin down the energy scale of inflation.

Towards the end of the year the Planck Collaboration was preparing for their second major data release including four years of Planck data and results on the polarisation of the microwave sky, and preliminary all-sky polarisation maps were presented in December 2014. The new results remain in agreement with the 5-parameter standard cosmological model, but include the detection of a number of hard-to-observe features of the standard cosmological model.

Theory Programme

Kari Rummukainen,
Theory Programme Director

The HIP Theory Programme consists of fixed term projects, chosen for their scientific excellence and how they complement the research at HIP and at the host universities. Because all previous projects ended in 2013, the year 2014 marked a complete renewal of the Theory Programme, with five new theory projects: Cosmology of the Early and Late Universe (Syksy Räsänen, Helsinki), High Energy Phenomenology in the LHC Era (Aleksi Vuorinen, Helsinki), QCD and Strongly Interacting Gauge Theory (Tuomas Lappi, Jyväskylä), Nuclear Structure for Weak and Astrophysical Processes (Markus Kortelainen, Jyväskylä) and Domain Wall Dynamics (Lasse Laurson, Aalto University). Additionally, Professor Mark Hindmarsh (Sussex University) started his five-year part-time Visiting Professor position in Helsinki, shared by HIP and the Department of Physics. This continues his successful one-year Visiting Scientist programme at HIP. He is one of the leading authorities in the physics at the intersection of particle physics and cosmology, and his presence significantly enhances research in the Cosmology and High Energy Phenomenology projects.

Cosmology of the Early and Late Universe

Syksy Räsänen,
Cosmology of the Early and Late Universe project leader

Inflation: The claimed detection of inflationary gravitational waves by the BICEP2 experiment in March (the discovery claim has since been withdrawn) brought attention to the fact that inflation is the only area of physics where it has been possible to observationally probe the combination of general relativity and quantum theory. The gravitational waves were hailed as the first evidence for quantum gravity, because they arise from quantised linear perturbations of the space-time metric. However, the scalar perturbations that act as the seeds of structure also involve a quantised metric perturbation. T. Markkanen, S. Räsänen and P. Wahlman studied inflation in the case when the space-time is classical and only the field is quantised, and showed that it is possible to recover the usual inflationary predictions. Therefore, the discovery of gravitational waves is indeed needed to confirm the quantisation of gravity even at the linear level.

Studying the Higgs field during inflation has recently become a topic of interest. This is both because the measurement of the Higgs mass has fixed the last free parameter of the Standard Model, and because the failure to find any hint of physics beyond the Standard Model at the LHC suggests that the Standard Model may be valid well beyond the electroweak scale, perhaps even at inflationary scales. Even if the Higgs is not the inflaton, it has been suggested that its quantum fluctuations during inflation may destabilise the universe. T. Markkanen and S. Nurmi, in collaboration with M. Herranen at Niels Bohr Institute and A. Rajantie at Imperial College, showed that even a small non-minimal coupling of the Higgs field to gravity is sufficient to stabilise the Higgs potential during inflation. Our article published about this work was highlighted as "Editors' Suggestion" in the November issue of Physical Review Letters.

Deviations from the FRW metric and anomalies: A key feature underpinning most cosmological analysis is the assumption that the universe over large scales is, on average, described by the Friedmann-Robertson-Walker (FRW) metric. S. Räsänen and A. Finoguenov, together with K. Bolejko at the University of Sydney, formulated a new way to test this assumption using the distance sum rule, i.e., the relation of the angular diameter distance from redshift 0 to redshift z_2 to the distances from 0 to z_1 and z_1 to z_2 - in general the former is not the sum of the two latter quantities.

Aleksi Vuorinen, High Energy Phenomenology in the LHC Era project leader

The test is kinematic and relies on geometrical optics, it is independent of the matter content of the universe and the theory of gravity on large scales. They applied this test using distance observations from type Ia supernovae and strong lensing by elliptical and lenticular galaxies. The precision of the constraints is rather poor, but the method will provide an important test of the FRW assumption with upcoming observations by Euclid and LSST.

The group of K. Kainulainen studied the evolution of spherically symmetric multifluid systems in general relativity, relevant for models with large voids. They noted that early reionization may induce large velocity flows between dark matter and baryons, which could strongly influence structure formation in systems with large structures.

A large void has been proposed as the explanation of one of the large-scale anomalies of the cosmic microwave background, the so-called Cold Spot. In particular, the discovery of a void aligned with the Cold Spot was announced in May, and it was claimed that this would explain the Cold Spot. S. Nadathur, M. Lavinto, S. Hotchkiss and S. Räsänen showed that the void is too small and shallow to explain the Cold Spot, and further that the existence of a late-time void that is sufficiently extreme to cause the Cold Spot is, in the ΛCDM model, less likely than the Cold Spot being a random fluctuation on the last scattering surface.

Dark matter, baryogenesis and quantum transport: The group of K. Kainulainen studied the opening angle distributions in quasar lensing statistics as a way to probe the dark matter distribution in galaxy clusters.

They also investigated phenomenological models for thermal dark matter in the context of minimal walking Technicolour models as well as models with extended scalar sectors. In both cases, they identified models with experimentally and observationally accessible parameters. They also continued developing cQPA, a form of quantum transport theory applicable in particular to leptogenesis and the electroweak baryogenesis problems.

Cluster astrophysics: The team of A. Finoguenov analysed the results of the BOSS spectroscopic targeting of CODEX clusters, and planned the eBOSS programme. It was shown that they will be able to achieve an 80% fraction of the sample with over 10 spectroscopic members, which is important for understanding the cluster dynamics. Completion of the programme in 2020 will lead to the largest well-understood sample of X-ray selected galaxy clusters.

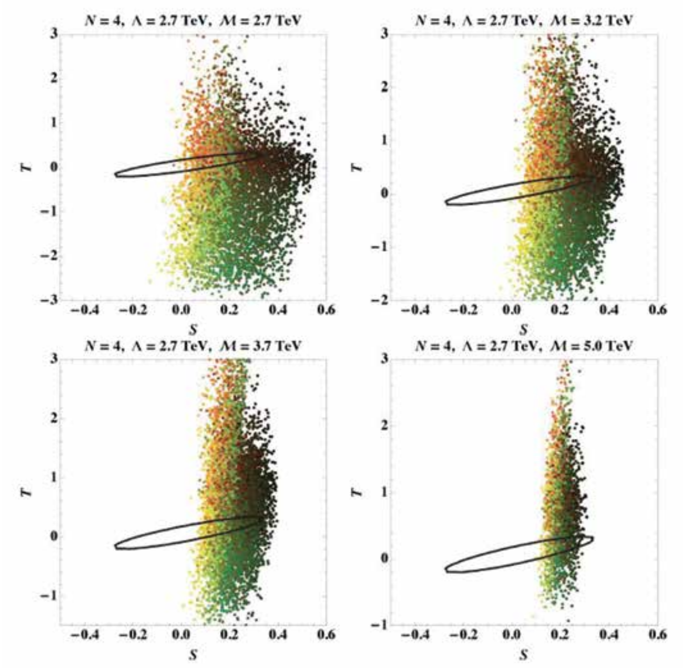
K. Kettula and A. Finoguenov worked on the cluster calibration and introduced the correction for the Eddington bias into the scaling relation. The aim is to establish a secure link between the total mass measured by weak lensing and low-scatter mass proxies, such as X-ray luminosity, temperature and the integral Sunyaev-Zeldovich effect.

Substantial progress was made by A. Finoguenov towards establishing a new data set at a redshift of 0.5, suitable for characterization of scaling relations, with large amount of data received in 2014 and the completion of the programme granted for 2015.

High Energy Phenomenology in the LHC Era

In the High Energy Phenomenology project, we have worked on a wide spectrum of topics, reflecting the many fronts of present day particle physics. The theories we study range from Quantum Chromodynamics (QCD) to various Beyond the Standard Model (BSM) scenarios, while the physics applications cover particle collider experiments, astrophysics and cosmology. On the methodological side, our work utilises both traditional perturbation theory and effective field theory tools as well as non-perturbative methods suited for the study of strongly coupled systems, such as lattice simulations and the gauge/gravity duality. Some of the highlights of the research conducted by the project members during 2014 are described below.

High energy phenomenology within and beyond the Standard Model: In BSM physics, the discovery of the Higgs boson in 2012 is still strongly reflected in the theoretical work conducted by the members of our project. Among other things, during 2014 we have studied the Higgs sector of the Minimal Supersymmetric Standard Model (MSSM) and its various extensions as well as the stabilisation of the



The points in the figure display the result of a simple Monte Carlo scan over the parameter space of the model presented in [S. Di Chiara et al., arXiv:1412.7835]. All points correspond to models in which the Higgs mass is 125 GeV, and its couplings with the electroweak gauge bosons and the Standard Model matter fermions are compatible with the experimental data. The ellipsis corresponds to a 3σ contour from the electroweak precision measurements at LEP and Tevatron.

Higgs potential with a Z' particle. In addition, we have extensively analysed scenarios where the observed Higgs boson is considered a composite particle resulting from new strong dynamics. In this context, we in particular considered a model where the gauge dynamics are effectively represented by four-fermion interactions at low energies and showed that one can thereby obtain a large mass hierarchy between the observed 125 GeV scalar resonance and the heavier states.

A different line of research deals with the details of the electroweak phase transition in the early universe and their cosmological implications. Here, two milestone results, both published in Physical Review Letters, concerned the generation of gravitational waves from a first order transition as well as a precise measurement of the sphaleron rate in the Standard Model (SM) using the now known value of the Higgs mass. Finally, an extensive new research programme was initiated in 2014 to study the generation of the observed matter/antimatter asymmetry in the universe within various BSM scenarios. Knowing that the electroweak phase transition of the Standard Model is too weak to produce the needed departure from thermal equilibrium, our goal is to build a framework for efficiently studying the transition dynamics in various BSM models. This includes building effective three-dimensional theories for the models in question - starting from the SM plus singlet scalar and the Two Higgs Doublet models - and then performing non-perturbative simulations on a lattice to determine the order of the transition.

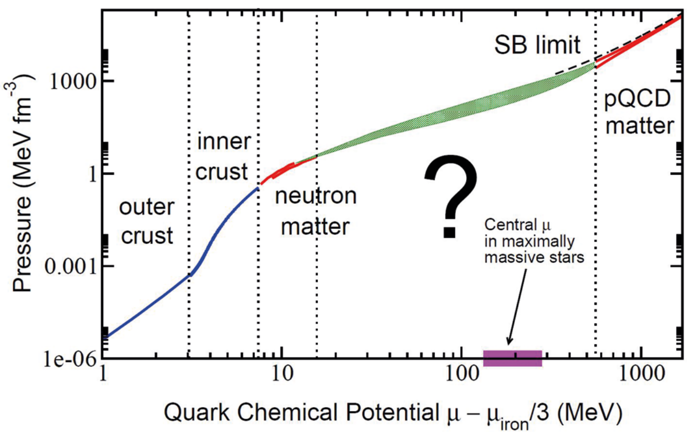
Properties of deconfined QCD matter in and out of equilibrium: Within the physics of strong interactions, the focus of our research has been on the description of the equilibrium and dynamical properties of deconfined QCD matter, both within heavy ion and compact star physics. In the former context, one of our central goals is to improve the holographic description of the equilibration process taking place in the fireball created in a heavy ion collision. To this end, we have extensively studied a simple model of thermalization dual to the gravitational collapse of a thin shell in the radial direction of 5-dimensional anti-de Sitter space-time. This dynamical process, which can be described using Einstein's theory of general relativity, is dual to the equilibration of the dual field theory, maximally supersymmetric N=4 Super Yang-Mills theory. Due to the simplicity of the set-up, it is possible to determine the time evolution of rather complicated quantities, such as various non-local entropies, that have previously been computed only in various simplified limits. In the course of this work, we discovered new universal features of strongly coupled entropy production and were able to quantitatively study the validity of the approximation schemes applied by earlier computations of the same quantities.

In addition to the thermalization process, the physics of hot quark gluon plasma (QGP) in or near thermal equilibrium contains several interesting puzzles related to the strongly coupled nature of the theory at temperatures slightly above the (crossover) transition region. During 2014, we worked on several aspects of the bulk thermodynamics, transport properties and hard

Tuomas Lappi, QCD and Strongly Interacting Gauge Theory project leader

probes of the QGP. From these, we highlight here a first principles lattice QCD computation of the jet quenching parameter as well as a resummed perturbation theory computation of the shear spectral function, to be used in an eventual non-perturbative determination of the shear viscosity of the system. In addition, our members served as editors of an extensive review article on modern QCD research, working on the section on deconfinement.

Finally, in compact star physics our main goal is to significantly reduce the uncertainties of the equation of state (EoS) of the matter that neutron (and/or quark) stars are made out of - a formidable problem due to the complicated nature of strongly interacting matter around the nuclear matter saturation density. To achieve this, we demonstrated that one can quantify the current ignorance of the quantity by introducing a parameterized EoS that interpolates between the known limits of low-density nuclear matter and high-density quark matter. In particular, we discovered that the latter constraint, utilising old results of the project members, can significantly constrain the behaviour of the EoS even at rather low densities. As a result of the exercise, we obtained the most accurate prediction for the EoS and the mass-radius relationship of compact stars to date, which can (and will) be straightforwardly further improved when new results emerge from first principle calculations either on the low or high density sides.



The pressure of cold and dense nuclear/quark matter as a function of the quark chemical potential, obtained in [A. Kurkela et al., Astrophys. J. 789 (2014) 127]. The figure demonstrates how demanding that the pressure matches the known limits at both low and high density effectively constrains the behaviour of the quantity at all relevant densities.

QCD and Strongly Interacting Gauge Theory

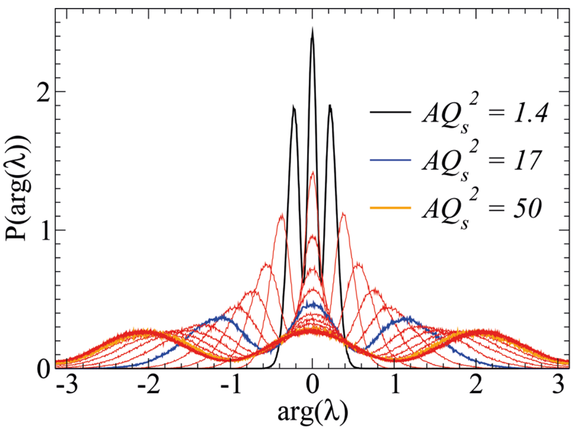
Our work revolves around different aspects of QCD at high energy and density. In addition to the phenomenology of high energy nuclear collisions at the LHC and RHIC, we are strongly involved with physics studies for planned next generation DIS experiments. We use QCD renormalization group equations (BK, DGLAP, ...) derived in the weak coupling limit to understand the energy and virtuality dependence of the partonic structure of hadrons and nuclei. An important specialty of our group is using this information to understand and model the initial stages of an ultrarelativistic heavy ion collision and the formation of a thermalized quark gluon plasma. The subsequent evolution of this plasma can then be modelled using relativistic hydrodynamics. It also serves as a background for perturbative "hard probes" that propagate through the QCD matter and can be used to study its properties.

The Balitsky-Kovchegov (BK) evolution equation describes the energy dependence of operators needed for calculating QCD scattering cross sections at high energy. We continued our work to include heavy quarks in our BK-equation fits to HERA DIS data. At the end of the year we showed publicly our first results from a numerical solution of the next-to-leading order BK equation, which we were the first group in the world to produce. For the EIC (Electron-Ion Collider), we proposed using forward detectors to measure ballistic protons in incoherent nuclear diffraction. This would be a completely novel way to experimentally measure the collision impact parameters in these events.

Applications of collinear factorisation to processes involving heavy ions continue to be one of our strongest areas. Our EPS09 nuclear parton distribution functions (nPDF) are currently the world standard. We are constantly in touch with all the major LHC experiments, providing them with our predictions (e.g., heavy gauge bosons, jets, charged particles), which contributes to our visibility. Preliminary work towards a nPDF update using data from the first LHC proton + lead run has been carried out. In such preparatory work the so-called Hessian PDF reweighting technique, which we recently devised, has turned out to be an extremely useful new tool. We have also explored the systematics of different photon and pion observables motivating the usefulness of carrying out such possible new measurements at the LHC.

Our group uses two complementary QCD approaches to describe the formation of quark gluon plasma in the initial stages of a heavy ion collision. In the classical colour field picture this is done by solving the classical equations of motion for the strong colour fields. In the perturbative QCD + saturation picture the same phenomenon is approached from the point of view of perturbative quark and gluon scattering, supplemented with a saturation conjecture to control multiparticle production.

In the classical field picture we completed a study of magnetic flux loops. Here we showed that the transverse Wilson loop (related to the flux of a longitudinal chromomagnetic field) has a remarkable universal area dependence in the infrared, which can be characterized by a non-trivial anomalous scaling exponent. We also continued developing numerical methods to study the Debye mass in classical colour field simulations.



Probability distributions for the phase angle of transverse Wilson loop eigenvalues for different loop areas, calculated from the classical colour fields in the initial stage of a heavy ion collision.

The transverse structure of the fluctuating initial state has become a crucial feature of all descriptions of the initial state for hydrodynamical evolution. We performed a systematical study of the event-by-event probability distribution of azimuthal Fourier harmonic coefficients of the initial densities. Comparing these calculations with experimental data places very tight constraints on the description of the initial state. We also studied the applicability of hydrodynamics to modelling small collision systems, such as peripheral nucleus-nucleus or proton-nucleus collisions. This can be done by calculating the Knudsen number, which characterizes the required scale separation between microscopic and macroscopic length scales. Using our new 3-1-dimensional hydrodynamical code we studied the rapidity dependence of the azimuthal flow harmonics.

In developing our NLO-improved perturbative QCD + saturation picture of the initial conditions, we are now considering event-by-event initial density fluctuations. Combined with viscous relativistic hydrodynamics to simultaneously calculate various LHC and RHIC bulk observables (multiplicities, p_T spectra, flow coefficients, correlations) this work eventually aims at a controlled estimate of the shear viscosity of the QCD matter in its different phases.

Using event-by-event relativistic hydrodynamics together with thermal production rates, we have also continued our studies of direct photon production in heavy ion collisions. In particular, we analysed the effect of the density fluctuations and formation times of the thermal system on the triangular flow coefficient of the produced thermal photons.

We also continued the development of Monte Carlo simulations, such as our YaJEM code, for in-medium QCD parton shower evolution. Such a description is necessary for a meaningful comparison of theory and experimentally reconstructed jet observables. We have studied the dependence of jet quenching (i.e., the modification of high transverse momentum particles due to interactions with the medium) on rapidity and on a potential enhancement of the medium opacity near the deconfinement transition. We have also studied the effects of the QCD medium on jet fragmentation functions and jet shapes.

Markus Kortelainen, Nuclear Structure for Weak and Astrophysical Processes project leader

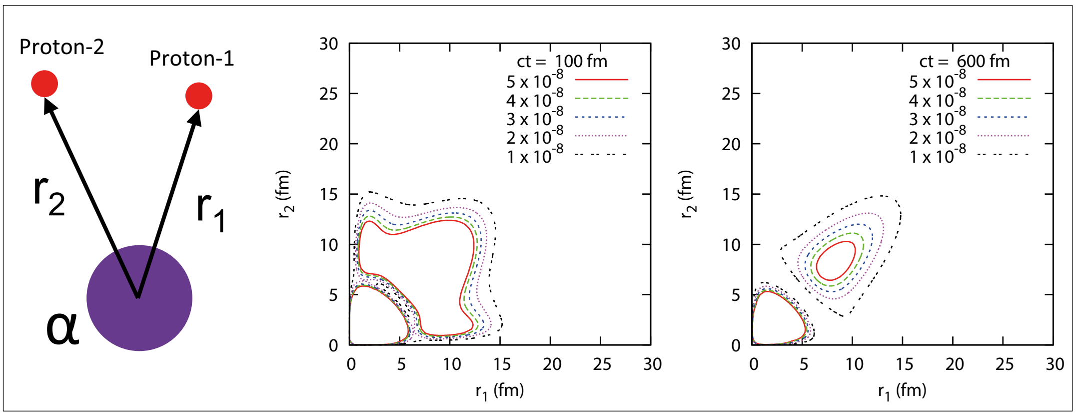
Nuclear Structure for Weak and Astrophysical Processes

Our research focuses on the low-energy nuclear structure and its applications to weak and astrophysical processes. Our tool of choice for nuclear-structure calculations is the nuclear density functional theory (DFT). The key ingredient in DFT is the energy-density-functional (EDF), which incorporates complex many-body correlations. A part of our research is directed to improving the current nuclear DFT models.

Development of symmetry restoration schemes: Usually, in the nuclear DFT, many of the correlations are introduced by breaking the associated symmetry. In principle, in the self-consistent iterative approach, these broken symmetries should be restored during every step towards solution. This is the so-called variation-after-projection (VAP) method. Unfortunately, VAP is computationally very expensive. The Lipkin VAP for particle number restoration (VAPNP), which has been developed, allows us to evaluate the approximate ground state VAP energy in a computationally inexpensive way. This is important, for example, when optimising model parameters for novel next-generation EDFs, suitable for beyond mean-field studies. The accuracy of the Lipkin-VAPNP method was found to be excellent. The chosen Lipkin operator describes well the small gauge-angle rotation of the intrinsic wave function. A similar kind of Lipkin method can also be applied for approximate restoration of other broken symmetries.

In addition to particle number restoration, we have developed a regularisation scheme for angular momentum projection. Extensions of single-reference (SR) EDFs to multireference (MR) applications involve using the generalised Wick theorem (GWT), which leads to singular energy kernels that cannot be properly integrated to restore symmetries, unless the EDFs are generated by true interactions. We proposed a new method to regularise the MR EDFs, which is based on using auxiliary quantities obtained by multiplying the kernels with appropriate powers of overlaps. By integrating the auxiliary quantities and then solving simple linear equations, one then obtains the regularised matrix elements of two-body interactions. We implemented the new regularisation method within the self-consistent Skyrme-Hartree-Fock approach and we performed a proof-of-principle angular-momentum projection (AMP) of states in the odd-odd nucleus ^{26}Al. We showed that for EDFs generated by true interactions, our regularisation method gives results identical to those obtained within the standard AMP procedure. We also showed that for EDFs that do not correspond to true interactions, it gives stable and converging results that are different from unstable and non-converging standard AMP values. The new regularisation method proposed in this work may provide us with a relatively inexpensive and efficient tool to generalise SR EDFs to MR applications, thus allowing for symmetry restoration and configuration mixing performed for typical nuclear EDFs, which most often do not correspond to true interactions.

Role of diproton correlations: As one of the successful results in the Nuclear Structure project, T. Oishi and his co-authors published



Time-dependent density-distribution of the decay-state for two protons emitted from the ^{6}Be nucleus, computed with the time-dependent three-body model. Those are plotted as functions of r_1 and r_2, where r_i is the distance between the alpha-core and the *i*-th proton. The peak at $r_1 = r_2$ corresponds to the diproton correlation.

a paper which discusses the role of the diproton correlation in two-proton emissions. By applying a time-dependent method to the ^{6}Be nucleus, it was shown that the diproton correlation plays an essential role to determine the life-time and dynamic properties of two-proton radioactive decays. It is also suggested that the treatment of pairing interaction becomes crucial in nuclear theoretical methods, including EDF, when those are applied to the unstable nuclei and/or nuclear meta-stable processes.

Monopole transition strength in weakly bound nuclei: Nuclei close to the neutron drip line can exhibit exotic threshold phenomena, sharing interdisciplinary interests with other weakly bound systems. To account for these phenomena, a coordinate space approach is more suitable for the task instead of the often employed harmonic-oscillator basis approach. In this work, we developed a finite amplitude method (FAM) for the quasiparticle random phase approximation (QRPA) for the axially symmetric coordinate space approach. The QRPA allows us to assess the linear response of a superfluid system. The developed FAM-QRPA method allows us to compute monopole excitation modes in nuclei close to the drip line with a fraction of computational cost compared to the traditional matrix formulation of the QRPA. The application of the method to neutron-rich magnesium isotopes demonstrated the emergence of collective low-energy monopole modes. The first lower energy mode was associated with the pairing halo and a near-threshold $1/2^-$ non-resonant continuum states. The second mode is most likely linked to the expected pygmy monopole mode. The low-lying electromagnetic transition strength in neutron-rich nuclei may affect the dynamics of the r-process.

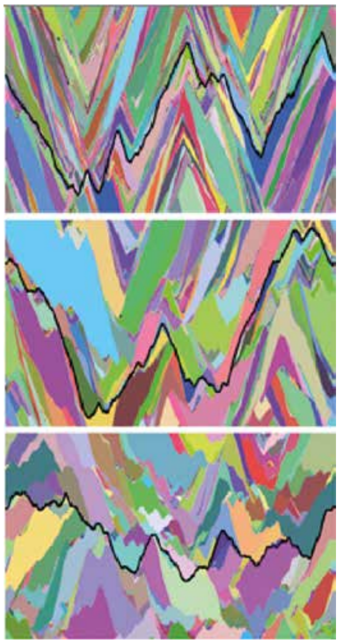
Mesons in nuclei: In a more general scheme of hadronic interactions the possibility of eta mesons bound in light nuclei has been discussed. With a connection calculated in an optical model one can draw some conclusions between bound state properties (energy and width) and the low-energy scattering parameters. In a coupled-channels generalisation of the optical potential model it can be seen that the inelasticity in scattering is essentially diminished from the conventional optical potential (in agreement with some experimental indications) making the prospects of discovering bound states more realistic. The eta meson is also one of the ingredients of isospin symmetry breaking forces associated with other parts of the project programme.

Domain Wall Dynamics

Lasse Laurson, Domain Wall Dynamics project leader

Domain wall dynamics in low-dimensional ferromagnetic structures is an active field of research driven by both numerous related potential technological applications as well as fundamental physics interests. In 2014, this was highlighted also by the Millennium Prize awarded to Stuart Parkin, a pioneer in studying devices based on domain walls and their dynamics such as the "racetrack memory".

During the first year of the project, we have focused on understanding the effect of disorder (i.e., various impurities and structural imperfections present in most materials) on domain wall dynamics induced by applied magnetic fields or spin-polarised electric currents via the spin-transfer torque (STT) mechanism. We have studied various systems and/or geometries ranging from Permalloy nanostrips to thin films with uniaxial in-plane anisotropy where the domain walls exhibit zigzag morphology, using micromagnetic simulations running on graphics processing units as well as coarse-grained models treating the domain wall as an elastic interface in random media. First, we have developed methods to incorporate disorder of various kinds (e.g., point defects and grain boundaries) into micromagnetic simulations. These methods have been and will be used to study various problems of domain wall dynamics. For instance, our study of the current-driven vortex domain wall dynamics in disordered Permalloy nanostrips reveals that the magnitude of the non-adiabatic STT contribution assumes a certain effective value due to the presence of disorder, irrespective of its bare magnitude, explaining some related experimental observations. Also, we have presented a theoretical explanation and a numerical model explaining experimental observations of a crossover between two universality classes of Barkhausen noise - the jerky, avalanche-like dynamics of domain walls - in disordered ferromagnetic thin films with uniaxial in-plane anisotropy.



Domain wall dynamics in a model of in-plane magnetised thin ferromagnetic films with different relative strengths of dipolar interactions (increasing from left to right). The domain wall morphology (example domain wall configurations shown in black) evolves from rough to zigzag, and the Barkhausen avalanches (regions with different colours) exhibit a crossover between two universality classes [Phys. Rev. B 89 (2014) 104402].

CMS Programme

Paula Eerola,
CMS Programme
director

The Compact Muon Solenoid (CMS) experiment is one of the two large multi-purpose experiments at the LHC. The first phase of the LHC operation, the so-called Run 1 (2010-2012), with proton-proton collisions at 7 and 8 TeV centre-of-mass energies, provided a total integrated luminosity of about 25 fb^{-1}, and culminated in the discovery of a Higgs boson with a mass of about 125 GeV. The year 2014 was the second year of the accelerator and the experiments service break for equipment maintenance. The LHC Run 2 will start in spring 2015. The collision centre-of-mass energy will be raised to 13 TeV, and the luminosity will be further increased. Physicists in CMS were nevertheless very busy during 2014 completing the analyses of the Run 1 data. The total number of papers submitted for publication by CMS on collision data reached 360 by the end of the year. Researchers at the University of Helsinki and the Helsinki Institute of Physics (HIP) contributed in particular to Higgs analyses, to jet physics, and to B-physics analyses. In 2014 the CMS group in Helsinki also launched the module construction of the CMS pixel detector upgrade. The activity of the Finnish group in the TOTEM experiment focused in 2014 on the analysis of the Run 1 data and on the preparations for the upcoming runs both in terms of maintenance, enlargement of physics scope and upgrade planning.

Introduction

The Compact Muon Solenoid (CMS) experiment is a particle physics experiment at the Large Hadron Collider (LHC) at CERN, Geneva. The main scientific goals of CMS are detailed investigations of particles and interactions at a new energy regime, understanding the origin of electroweak symmetry breaking (Higgs bosons), and the search for direct or indirect signatures of new physics beyond the Standard Model (SM) of particle physics. The CMS experiment has also a heavy ion research programme, studying the properties of quark-gluon plasma. The TOTEM experiment is located near the beampipe in immediate connection to CMS. TOTEM is investigating LHC collisions at small scattering angles.

Katri Lassila-Perini,
CMS Experiment
project leader

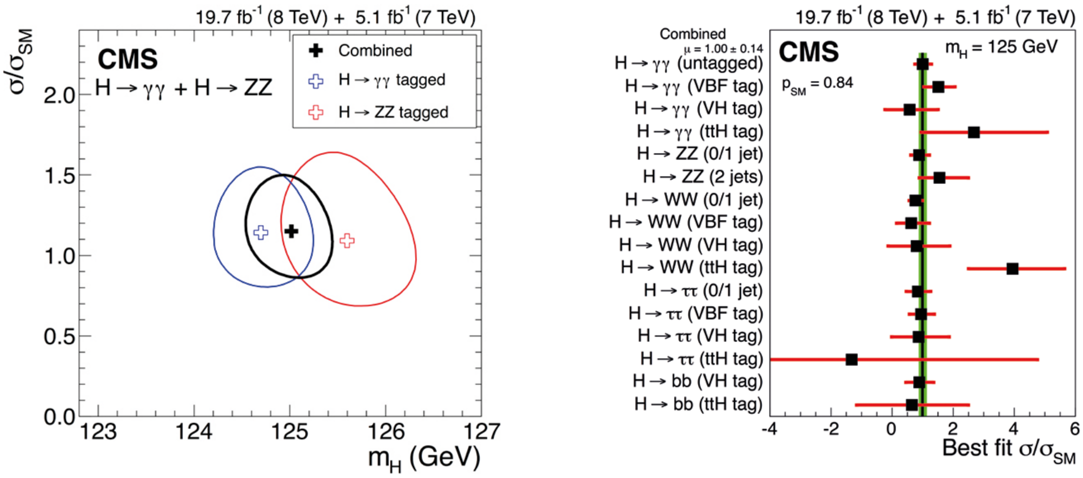
The HIP CMS Programme is responsible for co-ordinating the Finnish participation in the CMS and TOTEM experiments. The CMS Programme at HIP is divided into four projects: the *CMS Experiment project*, responsible for the physics analysis and operations, the *CMS Upgrade project*, responsible for the Finnish involvement in the CMS upgrades, the *CMS Tier-2 Operations project*, and the *TOTEM project*. The Finnish groups in CMS are: HIP (currently 15 authors), the University of Helsinki (3 authors), and Lappeenranta Technical University (1 author). In TOTEM there are 11 authors affiliated with HIP, out of which seven are also affiliated with the University of Helsinki.

The CMS Experiment Project

Introduction

The HIP *CMS Experiment project* is involved in the CMS physics analyses, concentrating in particular on B physics, Higgs searches and jet physics. The project also contributes to the tracker alignment and leads the CMS efforts in data preservation.

In 2014 the project team consisted of five senior physicists (P. Eerola (also at UH), R. Kinnunen, K. Lassila-Perini, S. Lehti, T. Lampén), three post-doc physicists (M. Kortelainen, L. Wendland, M. Voutilainen (also at UH)) and two PhD students (T. Järvinen, J. Pekkanen). Five MSc students (J. Heikkilä, Univ. of Helsinki;



Left: The 68% CL confidence regions for the signal strength σ/σ_{SM} versus the mass of the boson for the H → gg and H → ZZ final states, and their combination. The symbol σ/σ_{SM} denotes the production cross section times the relevant branching fractions, relative to the Standard Model expectation. Right: Values of the best-fit σ/σ_{SM} for the overall combined analysis (solid vertical line) and separate combinations grouped by production mode tag, predominant decay mode, or both.

S. Laurila, E. Pekkarinen and H. Siikonen, Aalto University; A. Abhishek, Univ. of Helsinki and Indian Institute of Technology Roorkee, India) were involved in the project. J. Tuominiemi and V. Karimäki contributed to the project as emeriti.

Helsinki researchers held several visible positions within the CMS Collaboration in 2014. M. Voutilainen was the JETMET (Jets and missing transverse energy) Physics Object group co-convener, and K. Lassila-Perini was co-ordinator of the CMS Data Preservation and Open Access project. Other collaboration duties included memberships in the Authorship committee (J. Tuominiemi), B-physics Editorial Board (P. Eerola), CMS Management and Finance Boards (P. Eerola), and several Tracker co-ordination bodies (P. Eerola).

Physics Analysis

Higgs Physics: Charged Higgs bosons occur in models that have at least two Higgs doublets. Therefore the observation of charged Higgs bosons would constitute undisputable evidence for a non-minimal Higgs sector. The most well-known of these models is the Minimal Supersymmetric Standard Model (MSSM). The neutral Higgs boson discovered at m_H = 125 GeV in 2012 by the CMS and ATLAS experiments is compatible with the SM prediction. A discovery of a charged Higgs boson would be a crucial turning point.

The HIP Higgs group continued to be in charge of the searches for charged Higgs bosons with the $H^+ \to \tau\nu$ decay mode in the fully hadronic final state, which is the most sensitive discovery channel for the charged Higgs boson. The researchers involved were R. Kinnunen, M. Kortelainen, S. Lehti, and L. Wendland, and S. Laurila and E. Pekkarinen (students).

The preliminary results for the mass range m_H = 80–600 GeV with all available data with the centre-of-mass energy of 8 TeV were made public [https://twiki.cern.ch/twiki/bin/view/CMSPublic/Hig14020TWiki, http://cds.cern.ch/record/1950346?ln=en]. No charged Higgs bosons were found, but the most stringent limits so far were set on their production. The

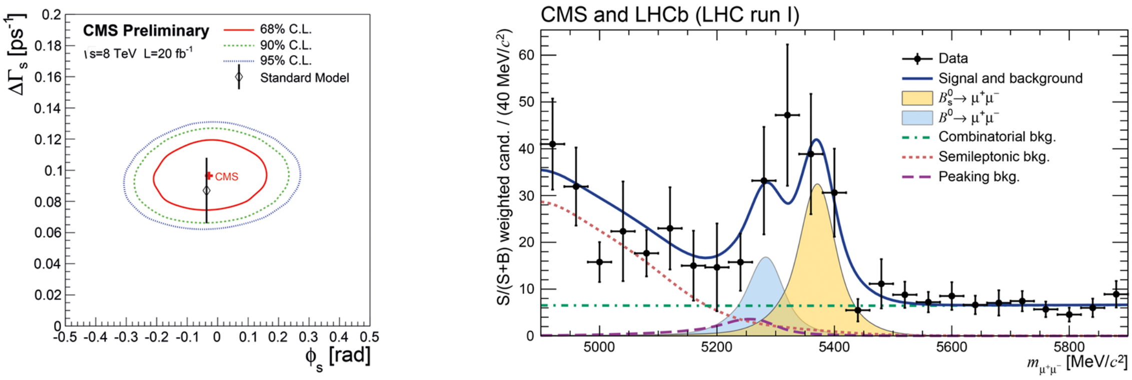
95% CL model-independent upper limits were observed to be 1.2–0.16% for the decay branching fraction of the charged Higgs boson for m_{H^+} = 80–160 GeV and 0.38–0.026 pb for the production rate of charged Higgs bosons for m_{H^+} = 180–600 GeV. The results were interpreted in various MSSM scenarios and used to set exclusion limits in the m_{H^+} - tanβ and m_A - tanβ parameter spaces. The measurements indicate that the parameter space for $m_{H^+} < 150$ GeV is ruled out at the 95% CL.

The main backgrounds, the electroweak and top-pair production with genuine taus and the potentially large QCD multi-jet background with fake taus and fake missing transverse energy, were measured from the data. An important improvement of the background measurements was initiated to combine the fraction of the electroweak and top-pair production with fake taus with the measurement of the QCD multi-jet background from the data.

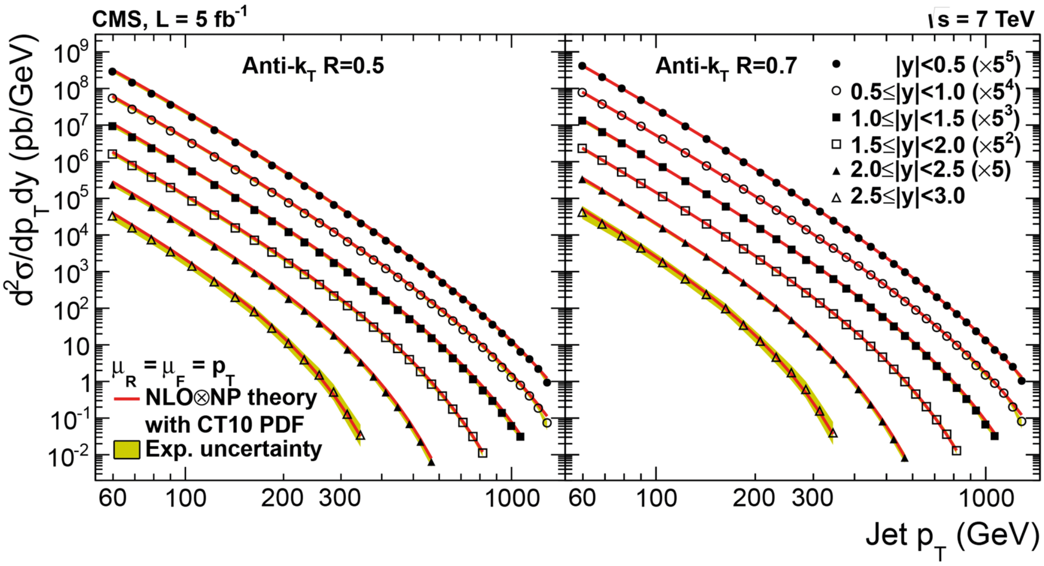
An important task was the development of the trigger for the charged Higgs boson searches in the next data taking period, where the triggering conditions will be difficult due the increased instantaneous luminosity. The work for charged Higgs boson production within the LHC Higgs Cross Section Working Group was also continued. During 2014, S. Laurila completed his Master's thesis on top quark reconstruction in the analysis of charged Higgs bosons.

J. Heikkilä developed, in co-operation with the CMS Higgs Combination and Properties Group, a profile likelihood ratio method to discriminate between the hypothesis of a single Higgs boson and that of multiple mass-degenerate Higgs bosons using the matrix of measured signal strengths in different production and decay modes [arxiv.org/abs/1409.6132]. Her contribution was recognised by the CMS Collaboration by including her in the author list of the CMS Run 1 legacy paper on the Higgs boson mass and couplings [arxiv.org/abs/1412.8662].

B Physics: In 2014, the HIP group was involved in the analysis of the decay channel $B_S \to J/\psi\,\phi$ with the J/ψ decaying into two muons and the ϕ decaying into two kaons. The B_S decay is interesting since it can indicate contributions from new physics beyond the Standard Model. Therefore the channel is one of the CMS flagship analyses in heavy flavour physics. The weak phase measurement requires tagging of the B_S meson flavour (the flavour of the bottom quark inside the B_S meson) when the meson was produced in the primary collision. T. Järvinen developed flavour tagging with opposite-side muons and electrons, and G. Fedi performed the weak phase measurement with the $B_S \to J/\psi\,\phi$ channel. The preliminary results of the weak mixing phase ϕ_S and the decay width difference



Left: The CMS $\Delta\Gamma_s$ and ϕ_s measurement with 68%, 90% and 95% CL contours, together with the Standard Model expectation, and overlaid with the Heavy Flavor Averaging Group Spring 2014 combination. Errors are statistical only. Right: Weighted distribution of the dimuon invariant mass. Superimposed on the data points in black are the combined fit (solid blue) and its components: the B_s (yellow shaded) and B_d (light-blue shaded) signal components; the combinatorial background (dash-dotted green); the sum of the semileptonic backgrounds (dotted salmon); and the peaking backgrounds (dashed violet).



Unfolded inclusive jet cross sections at 7 TeV centre-of-mass energy with jets formed with the anti-kT clustering algorithm, using radius parameters R = 0.5 (left) and R = 0.7 (right). Results are compared to next to leading order (NLO) theory predictions, corrected for non-perturbative (NP) effects.

$\Delta\Gamma_s$ with flavour tagging were made public in July 2014 [https://twiki.cern.ch/twiki/bin/view/CMSPublic/PhysicsResultsBPH13012, http://cds.cern.ch/record/1744869?ln=en], and presented at the ICHEP 2014 Conference by G. Fedi. The results, shown in the figure on the previous page, are competitive with other experiments and in agreement with the SM predictions. The aim is to publish a paper on the weak phase measurement in spring 2015.

Jet Physics: The QCD jet physics project (M. Voutilainen, J. Pekkanen) published a paper on the ratio of inclusive jet cross sections with jet radii 0.5 and 0.7 at 7 TeV [Phys. Rev. D 90 (2014) 072006] (see the figure above) and M. Voutilainen participates in the on-going measurements of inclusive jet cross sections at 8 TeV (SMP-12-012) and 2.76 TeV (SMP-14-017). These measurements allow for a better understanding of the theory predictions using perturbative QCD, and constrain the global fits of proton parton distributions functions and the running of the strong coupling constant α_s. The project is also making preparations for a search for massive new particles in the dijet mass spectrum at 13 TeV in the LHC Run 2, together with an international team of scientists from multiple institutes and universities.

The project hired two new students as research assistants, H. Siikonen BSc (Aalto University) to work on jet composition with the Pythia 8 and Herwig++ event generators, and A. Abhishek BSc (IIT Roorkee, India) to study jet flavour definitions for his MSc thesis. Both analyses are aimed at improving jet energy corrections (JEC) and preparing a proof-of-principle for a measurement of quark and gluon jet cross sections.

Jet Energy Corrections

The QCD jet physics project has a leading role in producing the final jet energy corrections (JEC) to be used for all the Run 1 data. M. Voutilainen co-convenes the CMS Jets and Missing ET group and is a lead author of the performance paper concerning JEC in the 8 TeV data, submitted to JINST [arxiv.org/abs/1411.0511]. J. Pekkanen and H. Siikonen contributed with plots and results to the JEC performance paper. The latest corrections reach world-record precision, which is particularly important for measurements of the top quark mass and the inclusive jet cross section.

Data Preservation and Open Access

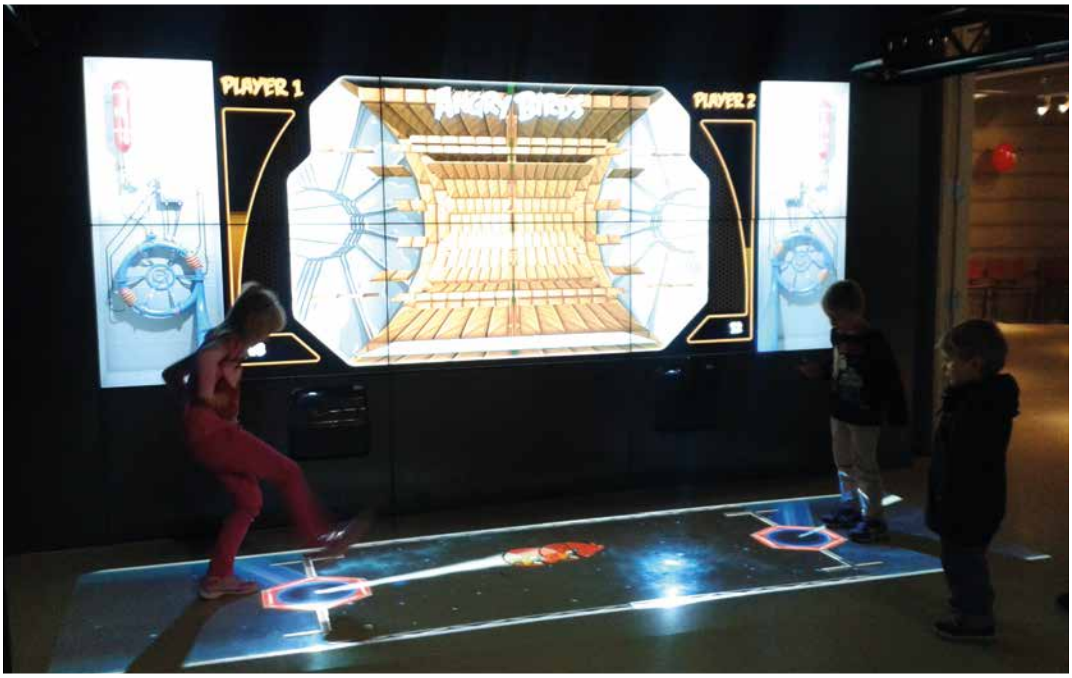
The Data preservation and open access project in CMS is led by K. Lassila-Perini from HIP. CMS will provide open access to its reconstructed data after final calibration and reconstruction. The public data releases will be accompanied by stable, open source, software and suitable documentation. The highlight of the year was the first public release of the CMS data in a format which is appropriate for analysis, together with corresponding tools and examples, through the Open Data Portal at CERN. We tested the portal and tools in a collaborative effort with Lapland University of Applied Sciences. HIP is a proactive partner in the Data preservation project and leads a pilot project to bring the scientific data to public use in schools. The pedagogical framework has been studied by S. Suoniemi (physics teacher MSc thesis, Univ. of Helsinki, March 2014).

Tracker Alignment

One of the most demanding calibration activities for the CMS Tracker is the geometrical alignment of its 15 148 modules with respect to each other. Detector alignment has been a highly important issue for the physics discoveries, and it will be one of the essential ingredients again in 2015 when the LHC restarts operation, since alignment needs to be carried out from scratch. In 2014 the HIP team continued its long-term participation in the alignment work of the CMS Tracker focusing on questions of monitoring and validation. T. Lampén was in charge of maintenance and development of the off-line track-based alignment validation tools, and was nominated as co-convener of the CMS Tracker Alignment group at the end of 2014.

Outreach

The CMS outreach activities at HIP consist of participation in regular PR-events in Kumpula, such as Open Days for alumni, high school students and new physics students, as well as organising our own events. Events, which we arrange regularly, are for example hosting the International Physics Master Class events in Kumpula for high school students, visits of high school classes who are going to CERN, and special media events with accompanying press releases. We are also participating in guiding the visiting groups of Finnish high school students and teachers at CERN. Blog writing, interviews and public lectures are other outreach activities



Angry bird accelerator in Science Centre Heureka.

we are involved in. Physicists and students from all the CMS projects within the CMS Programme participate in the outreach activities. In 2014 special events were organised to celebrate the CERN 60th Anniversary (see elsewhere in this Annual Report).

The CMS Upgrade Project

The first upgrade of the CMS detector, the so-called Phase I upgrade, is foreseen at the end of 2016. The Phase I upgrade, i.e., replacement of the CMS Pixel detector, is necessary partly due to the inefficiency of existing detectors to handle the increasing amounts of data and partly because of the extensive radiation damage in the silicon sensors after the first few years of running of the experiment. The CMS Upgrade project received a significant second two-year (2014–2015) upgrade grant from the Academy of Finland, which will ensure the completion of the Finnish contribution to the CMS pixel detector upgrade.

The larger and more comprehensive upgrade, Phase II, is foreseen after about a decade of operating the currently installed hardware, around 2022. The amount of radiation hard silicon detectors needed for the second upgrade is currently estimated to be approximately 500 m^2 in total.

There are also other research activities with various collaborators. In a HIP CMS-TOTEM joint project the goal is to develop fast and radiation hard timing detectors for the TOTEM upgrade. The CMS Upgrade project continued its active participation in the CERN RD39 and RD50 research collaborations. J. Härkönen continued as co-spokesperson of the RD39 Collaboration in 2015.

In 2014 the CMS Upgrade project group consisted of three senior scientists (J. Härkönen, I. Kassamakov and P. Luukka), two post-docs (T. Mäenpää, E. Tuovinen), four PhD students (T. Arsenovich, A. Karazhinova, T. Peltola, A. Winkler), and a MSc student (O. Pöyry). The project scientists and students work at Helsinki Physicum and at Micronova. External PhD students are A. Gädda and X. Wu (VTT).

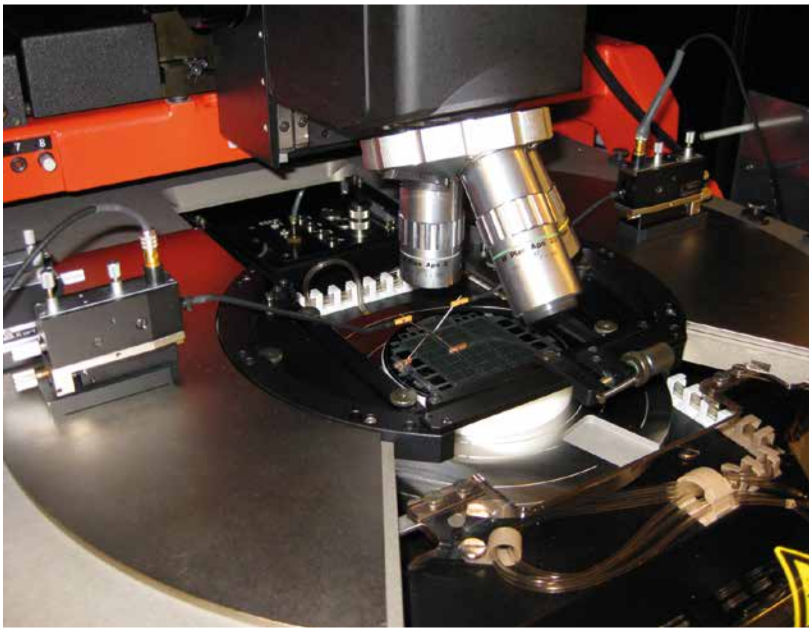
The Lappeenranta University of Technology group (T. Tuuva, J. Talvitie (PhD student)) was involved in the CMS endcap region muon trigger with Resistive Plate Chambers (RPC). In the future Lappeenranta will shift its focus towards readout electronics for the forward muon detector upgrade.

CMS Tracker Upgrades

The main activity of the HIP CMS Upgrade project in 2014 was to launch the pixel detector bare module production at the Aalto-VTT Micronova facility. This activity is part of the Phase I upgrade programme of CMS and it aims to produce 250 pixel detector modules (about 15% of all the modules needed in the CMS Phase I upgrade). New digital readout electronics is mandatory in order to handle the significantly larger amount of physics data expected during the LHC second run starting in spring 2015.

In 2014, several pre-series flip-chip bonded detector modules with new digital CMOS readout circuits (ROC) were delivered to CERN. In addition, the processing of the first production modules was started. One CMS pixel detector module consists of 16 ROCs and, thus, being

Jaakko Härkönen, CMS Upgrade project leader



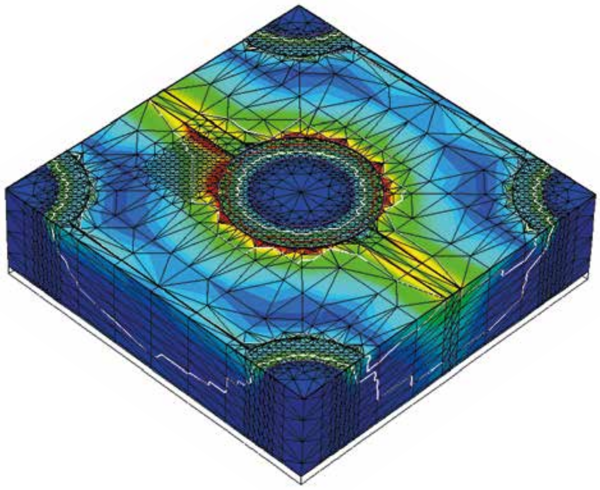
A CMS pixel detector being measured with a probe station.

Esa Tuovinen testing a CMS pixel detector module in the Micronova clean room.

a large-area and valuable assembly, the quality assurance (QA) of the modules is an intimate part of the production cycle. After the flip-chip bonding, each ROC will separately be electrically tested in order to screen out possibly malfunctioning units. The HIP CMS group installed and commissioned a pixel module testing set-up in the Micronova clean room, i.e., on the same premises where the flip-chip bonding is carried out. During our pre-series experiences, we discovered only one non-operational ROC out of the 256 bonded ROCs, indicating the excellent quality of the flip-chip bonding process.

In 2014, we continued our efforts to meet the radiation hardness challenge to be faced during the upcoming Phase II upgrade of the CMS experiment. Our silicon detector R&D activities include, e.g., participation in the CERN RD50 Collaboration and its device simulation working group, as well as the implementation of Atomic Layer Deposition (ALD) method grown thin films on pixel detectors in fruitful collaboration with the University of Helsinki Inorganic Chemistry ALD Centre-of-Excellence. One of the main breaking mechanisms of the CMS pixel modules is the electrical discharge through the thin air gap between the flip-chip bonded ROC and the detector biased at a high voltage. The ALD method is known to produce very conformal insulator thin films already at low temperatures. In 2014, we demonstrated that an entire flip-chip bonded detector module can be passivated against electrical sparking by a thin ALD grown aluminium oxide layer.

Significant increase of luminosity of the LHC is foreseen in coming years and, consequently, radiation induced defects will seriously degrade the operation of silicon detectors, especially in the pixel region. As a consequence, the charge collection distance in detectors will degrade to less than the physical segmentation of existing pixel devices, thus resulting in poor particle tracking performance. An obvious approach to maintaining sufficiently good spatial resolution is to increase the granularity of tracking detectors, i.e., scaling down the pixel size. Therefore, a R&D programme has been launched within the CMS Phase II pixel community (in particular the DESY and University of Hamburg CMS groups), HIP, and the VTT micropackaging group. In 2014, we studied the potential of the ALD technology to produce the very high capacitance and high resistance density structures needed in future ultra-fine pitch pixel detectors.



The calculated electric field distribution in an ultra-fine pitch pixel unit cell.

Lappeenranta Activities

Lappeenranta (T. Tuuva) built and tested optical links and related equipment for the CMS Resistive Plate Chambers (RPC) Trigger. During the 2013–2014 service break the RPC coverage has been increased in the forward regions by adding new detectors, and the Lappeenranta group contributed by constructing 26 ACTEL mezzanine boards and front panels, and testing the pre-production of the Link and Control boards. In the future Lappeenranta will shift its focus towards readout electronics for the forward muon detector upgrade (either glass RPCs or GEMs). The related readout electronics will be changed to cope with higher readout speed. Lappeenranta will participate in the development of the readout electronics in collaboration with CERN and other groups. The main focus will be on the VFAT3 readout chip, hybrid and interface bus.

The CMS Tier-2 Operations Project

HIP supports the computing needs of the LHC experiments ALICE, CMS and TOTEM. ALICE computing resources in Finland are part of the distributed Nordic Data Grid Facility (NDGF) Tier-1 resource within the Nordic e-Infrastructure Collaboration (NeIC), while the CMS resources are of the Tier-2 level using some services from NDGF. These Tier-1 and Tier-2 resources are part of the distributed Worldwide LHC Computing Grid, WLCG. TOTEM computing is not done with WLCG resources, it only uses local resources.

In 2014 the CMS computing needs consisted of finishing the legacy physics analyses of the LHC Run 1 data, and gearing up for the upcoming Run 2 at 13 TeV centre-of-mass energy. The grid analysis and Monte Carlo simulation production jobs were run on the Finnish CMS Tier-2 resources. The project team in 2014 consisted of T. Lindén (project leader) and S. Toor (post-doc in the DII-HEP project, in Uppsala) and O. Kraemer (student). HIP was represented in the NeIC Nordic WLCG (NLCG) steering committee with T. Lindén as chairman from February 2014. He was also a deputy member of the WLCG Grid Deployment Board. Close collaboration between HIP, CSC (IT Center for Science Ltd) and the NDGF resulted in good progress on many aspects of the CMS computing activities that are summarised in the following.

Grid Computing Activities

Hardware: The main CPU resource for CMS and ALICE was the 768 core Jade (in operation since 2009) Linux cluster situated on the CSC premises. In addition to that, the 400 core Linux cluster Korundi (in operation since 2008) and the 840 core Linux cluster Alcyone (in operation since 2011) in Kumpula were also used for CMS grid jobs as well as the up to 200 core nodeslab-0002 cloud service running on the Ukko cluster in the Department of Computer Science at the University of Helsinki. Some 40 cores on the CSC cPouta cloud system in Kajaani were connected with the HIP-protocol to the nodeslab-0002 cloud system. The Hitachi AMS 2500 dCache disk pools were decommissioned.

Software: The Advanced Resource Connector (ARC) middleware was upgraded to version 4.x on Jade, Alcyone, Korundi and nodeslab-0002. The dCache and Lustre systems at CSC were very stable in 2014.

The Academy of Finland -funded project concerning cloud computing, "Data Indirection Infrastructure for Secure HEP Data Analysis (DIIHEP)" together with the Department of Computer Science at the University of Helsinki continued in 2014 (J. White from the HIP Technology Programme and S. Tarkoma and L. Osmani from the Department of Computer Science). In addition there was close co-operation with M. Komu from the Department of Computer Science, Aalto University, related to Host Identity Protocol. Experiences and results from the OpenStack virtualised ARC nodeslab-0002 cloud service were presented at the International Symposium on Grids and Clouds 2014, the NorduGrid 2014 Conference, the 16th International Workshop on Advanced Computing and Analysis Techniques in Physics Research (ACAT), the NeIC Glenna kick-off meeting and the CMS Offline and Computing Week in November.

Operations: The Finnish CMS Tier-2 resources are operated, maintained and monitored jointly by HIP, CSC and NDGF. According to the statistics collected with the CMS monitoring tools, the Finnish Tier-2 resources were in "ready" state 74.18% of the time (81.87% in 2013). There were 6 Savannah tickets (23 in 2013) and 12 GGUS tickets (13 in 2013) issued concerning HIP in 2014. The joint monitoring by CSC, HIP and NDGF as well as the CMS and WLCG Site Availability Monitoring jobs helps to spot problems early.

PhEDEx transferred 161 TB of production data (184 TB in 2013) to HIP and 297 TB of test data (280 TB in 2013) to HIP. From HIP to elsewhere 75 TB of production data (88 TB in 2013) and 176 TB of test data (195 TB in 2013) was shipped. In total 709 TB of data was transferred with PhEDEx to or from HIP (747 TB in 2013).

A total of 1 million 409 thousand CMS grid jobs (1 million 872 thousand in 2013) using 32.7 million HEPSPEC06 CPU hours (23.2 million

Tomas Lindén, Tier-2 Operations project leader

HEPSPEC06 CPU hours in 2013) were run with an average CPU efficiency of 72.6% (76.2% in 2013). In addition to this a significant amount of local batch jobs were also run.

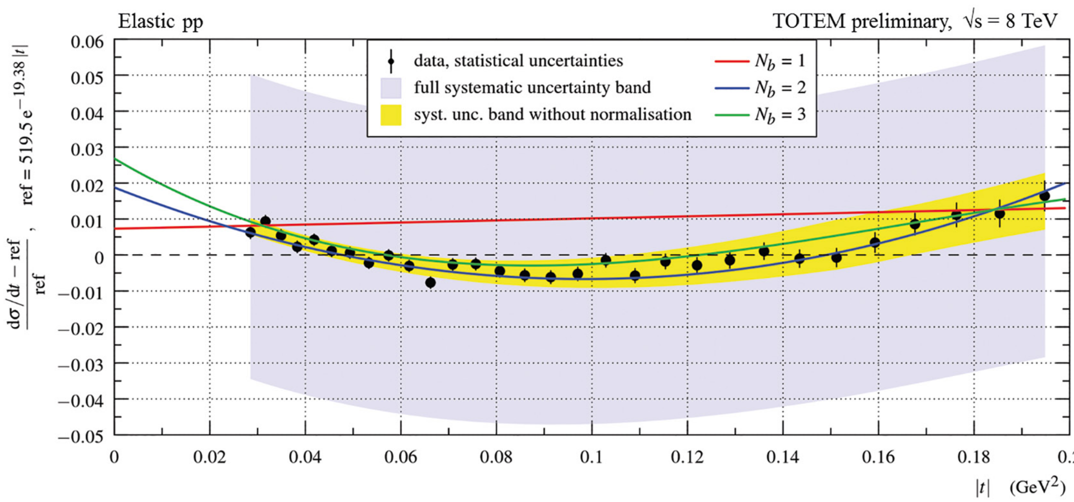
Heimo Saarikko, TOTEM project leader

The TOTEM Project

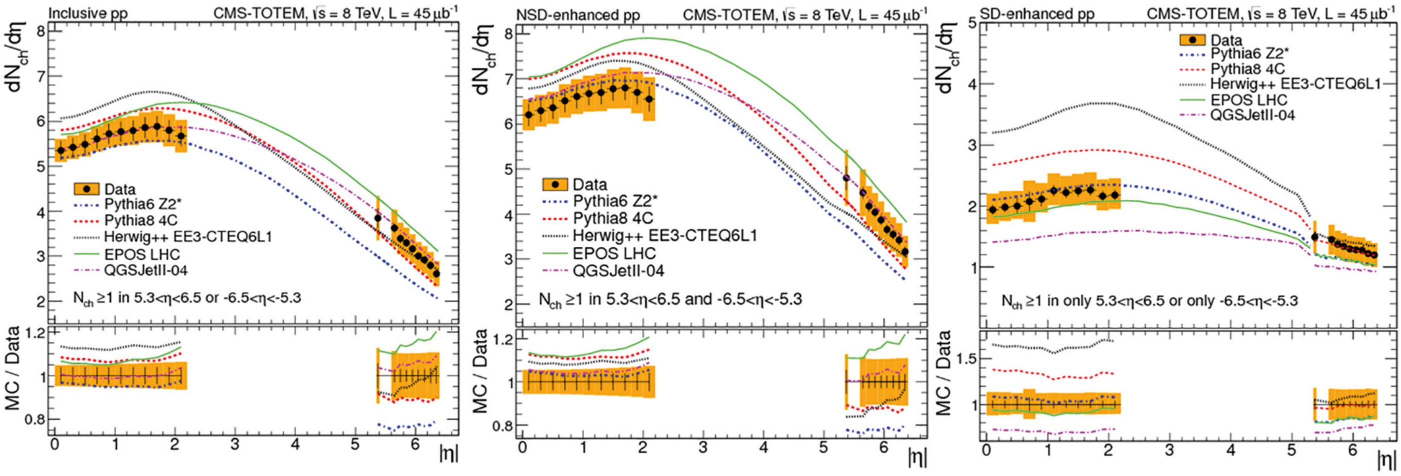
In 2014 the TOTEM Helsinki group consisted of two senior scientists, H. Saarikko and K. Österberg, one scientist H. Niewiadomski (at CERN), three PhD students T. Naaranoja, F. Oljemark and J. Welti, and one MSc student J. Mäntylä. From the HIP Detector Laboratory F. García, J. Heino, T. Hildén and R. Lauhakangas contributed to the TOTEM hardware. K. Österberg continued to co-ordinate the physics analysis of TOTEM as well as being also responsible from the TOTEM side for the common CMS-TOTEM physics analysis work.

Since 2011, the TOTEM experiment has published several important physics results, notably the first total proton-proton cross section measurement at the LHC and the differential cross section for elastic proton-proton (pp) scattering over a wide t-range. HIP has had a key role in constructing and operating the GEM detector based T2 telescope, which has contributed significantly to the TOTEM measurements of the inelastic rate, the forward charged multiplicity and the cross section of several diffractive processes. The activity in 2014 focused on the analysis of pp collision data taken in 2011–13 and on the preparations for the upcoming runs both in terms of maintenance, enlargement of physics scope and upgrade planning. During 2014, the HIP group retested the spare GEM detectors for possible replacement of faulty detectors and participated in the maintenance of the T2 telescope in view of the LHC runs in 2015.

In 2014, TOTEM showed for the first time for proton-proton collisions (previously only shown for neutron-proton collisions by the NA6 experiment) that the t-differential cross section (dσ/dt) of elastic scattering deviates significantly from a purely exponential (e^{-Bt}) in the so-called diffractive cone region where nuclear interactions are expected to dominate. The pure exponential distribution of the elastic dσ/dt is excluded by more than 7σ, as shown by the figure below, with a fit on the precise $\beta^* = 90$ m data at $\sqrt{s} = 8$ TeV taken in 2012. In addition, CMS and TOTEM published in 2014 their first joint publication: the measurement of the charged particle pseudorapidity distributions in proton-proton collisions at 8 TeV in the largest pseudorapidity range ever at a collider experiment [Eur. Phys. J. C 74 (2014) 3053]. The figure on the next page shows the measured distributions



A measurement of the relative differential cross section of elastic proton-proton scattering compared to a purely exponential reference distribution (e^{-Bt}) for data taken in a $\beta^* = 90$ m run at LHC in July 2012. The purely exponential distribution ($N_b = 1$, red curve) that would correspond to a straight line in the figure is excluded by the data at more than 7σ.



Charged-particle pseudorapidity distributions in 8 TeV proton-proton collisions for an inclusive inelastic event sample (left), a non-single diffraction (NSD) -enhanced event sample (centre), and a single diffraction (SD) -enhanced event sample (right). The error bars represent the uncorrelated systematics between neighbouring bins and the bands show the combined systematic and statistical uncertainties. The data is compared to the predictions of several event generators of which none is able to provide a consistent description of all the distributions.

for three different event samples selected based on their topology in the T2 telescope: a fully inclusive inelastic event sample and event samples either depleted or enhanced in single diffraction. The data was compared to several event generators and none of the considered ones provided a consistent description of the measured distributions.

The UH group focused in the analysis on the measurements of inelastic and diffractive processes. The measurements of the single diffractive cross sections at $\sqrt{s}$ = 7 TeV and of the inelastic rate and cross section at $\sqrt{s}$ = 2.76 TeV are well advanced. Also an inelastic event classification analysis based on multivariate approaches on 8 TeV common CMS-TOTEM data is in progress.

During 2014 TOTEM completed two Technical Design Reports (TDR) on upgrades: one standalone upgrade with timing measurements in the Vertical Roman Pots [CERN-LHCC-2014-020; TOTEM-TDR-002] and a second one on the common CMS-TOTEM proton precision spectrometer [CERN-LHCC-2014-021; TOTEM-TDR-003; CMS-TDR-13]. Both upgrades will significantly improve the experiments capability to study central diffractive processes, pp → p + X + p, in runs with common CMS-TOTEM data taking. The first one focuses on special β^* = 90 m runs and will enable unique measurements of exclusive production of glueball candidates, charmonium states and jets as well as facilitate searches for new physics via missing mass or momentum signature [Int. J. Mod. Phys. A 29 (2014) 1446019]. The second one focuses on standard low β^* runs and will enable exclusive jet and boson pair production measurements plus new physics searches. The HIP group was actively involved in the preparation of both TDRs. In relation to the second one, the group also launched an activity together with the CMS Upgrade group of HIP to develop silicon strip based timing sensors with a timing resolution better than 50 ps. The group has obtained infrastructure funding from the Academy of Finland for its contribution to the TOTEM upgrades for 2015–17.

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 hand. Exotic nuclei are studied at the ISOLDE facility while the study of quark gluon plasma and related phenomena takes place at ALICE. The project leaders are Professor Paul Greenlees (ISOLDE) and Professor Jan Rak (ALICE). The Nuclear Matter Programme has also continued co-ordinating the Finnish participation in the planning and construction of the FAIR project in Darmstadt. Here, the project leader has been Professor Ari Jokinen. FAIR stands for Facility for Antiproton and Ion Research. The Finnish involvement in FAIR includes participation in the construction of the Super-FRS facility and in the NUSTAR Collaboration for nuclear structure, reaction and astrophysics studies. Industrial participation for constructing FAIR is being explored in collaboration with TEKES.

Jan Rak, ALICE project leader

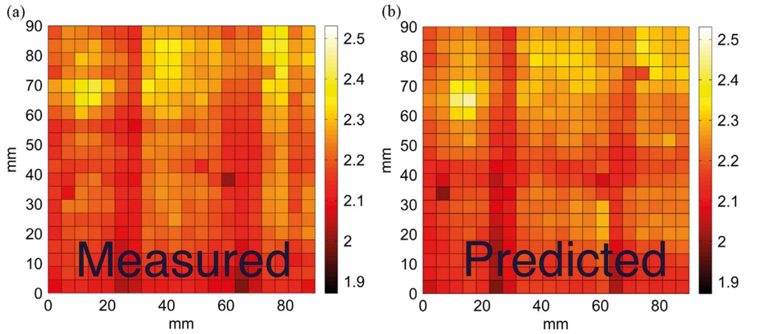
ALICE

The year 2014 was the last year of the long LHC shutdown and thus the main focus of the ALICE Collaboration was on the preparation for the upcoming Run 2. It includes the consolidation of existing detector subsystems and the installation of the new detector components. ALICE has extended its capability to measure electromagnetic probes and high-p_T jets by installation of 8 new ElectroMagnetic CALorimeter (EMCAL) supermodules which complement an existing EMCAL in the back-to-back configuration. This improves significantly the physics scope of ALICE allowing the studying of fully reconstructed dijets produced in the hard scattering events. Our group made a significant contribution to this upgrade. Our PhD student J. Král was a project leader of the fast trigger system which is designed to perform an on-line evaluation of the EMCAL data searching for energetic single photon hits. In 2014 we have produced and commissioned 32 new Trigger Region Units, the FPGA-based electronic modules, where the L0-trigger algorithm is implemented. They are now prepared, together with the newly installed EMCAL supermodules to be part of the ALICE data taking in Run 2.

J. Král successfully defended his PhD thesis ”Intrinsic transverse momentum distribution of jet constituents in p-Pb collisions at ALICE” in August 2014. He got several job offers, among those a tenure track position at Oak Ridge Nat. Lab., USA. He has finally accepted the prestige CERN Fellowship at the Accelerator Department. His responsibilities in the ALICE EMCAL trigger project were transferred to our PhD student J. Viinikainen who is currently at CERN for one year.

Besides the EMCAL upgrade, ALICE has installed several other detector extensions and upgraded the data acquisition system to be able to cope with the new high-luminosity performance of LHC expected in Run 2.

Another important activity carried out in our group is the preparation for the second long shutdown in 2018. The main tracking detector of ALICE, the Time Projection Chamber (TPC), with the existing multi-wire proportional readout chambers is limited to about 500 Hz of maximum readout speed. This will certainly be very insufficient for the future LHC runs and thus the ALICE Collaboration decided to replace all readout chambers with Gas Electron Multiplier (GEM) based technology. Our post-doc E. Brücken and PhD student T. Hildén are involved in the production of about 150 m^2 of

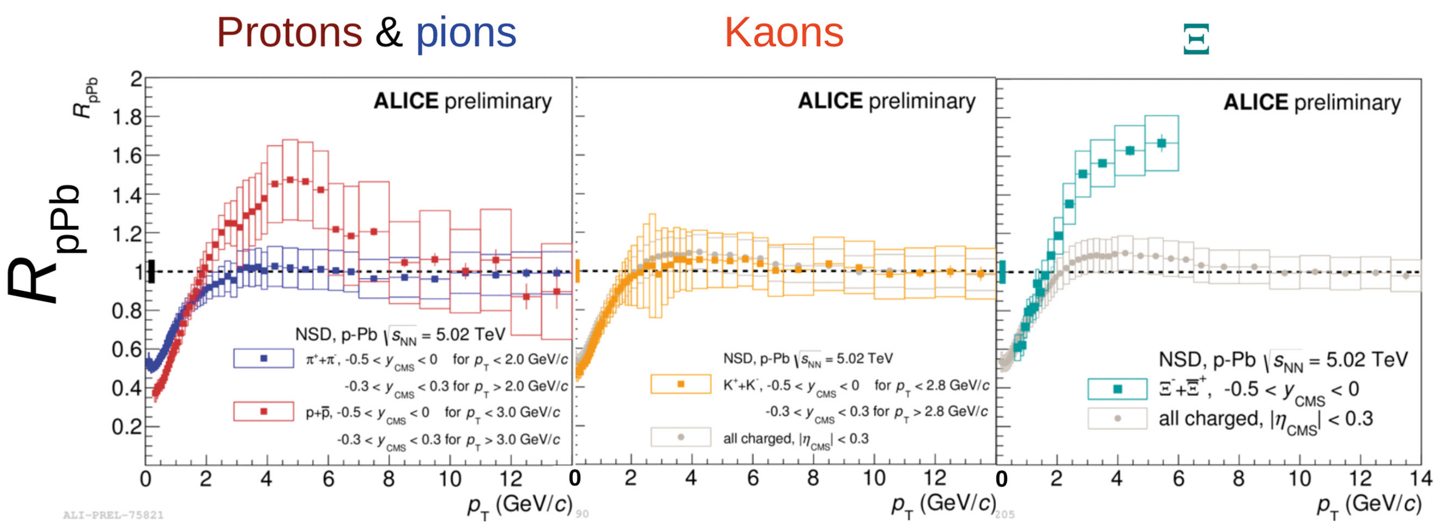


Comparison of measured GEM foil individual hole gain (a) with the gain predicted from the optical scan (b).

GEM foils. The main commitment of our group is to carry out the optical and electrical quality assurance studies of GEM foils in the HIP Detector Laboratory. E. Brücken and T. Hildén made significant progress in the preparation for this massive GEM production and found a new method of gain mapping, based on optical scanning which can replace the expensive and time consuming electrical measurement. The promising correlation between the results of the optical scanning and the electrical measurement using a radioactive source is shown in the figure above. This development is part of the PhD thesis of T. Hildén and is published in the NIMA paper "Optical quality assurance of GEM foils" [NIMA 770 (2015) 113-122].

ALICE also continues with the analysis of the Run 1 data taken in the 2010–2013 period. The main focus was to continue to explore the somewhat unexpected observations in proton-lead ($\sqrt{s_{NN}}$ = 5.02 TeV) collisions that resemble collective effects earlier seen in heavy ion collisions. For example, the figure below shows an enhancement of heavy particle yields (protons, cascades and their antiparticles) in p-Pb collisions as compared to p-p. In heavy ion collisions this "baryon anomaly" is studied within thermal production and recombination models, both indicating a dense system with a collective behaviour. However, the question whether the observed behaviour in the proton-lead collisions is due to the QCD phase transition as seen in the heavy ion collisions or some other mechanism related to, e.g., initial state saturation effects remains unanswered. This underscores the importance of new data from Run 2.

Our group develops several physics analysis projects studying the soft QCD radiation. The transverse structure of jets, sensitive to final state radiation and fragmentation of partons, was studied using jet reconstruction and two-particle correlations in all collision systems (p-p, p-Pb and Pb-Pb). We also continued dijet acoplanarity studies which can gain sensitivity to the initial state and may give constraints to models that include significant nuclear broadening at the initial state.



Relative inclusive yield of identified particles as a function of transverse momentum compared to scaled yield in proton-proton collisions.

Group photo from Prof. Thomas Hemmick's lectures at the 24th Jyväskylä summer school.

Apart from the hardware involvement and the physics analysis our group was involved in organising the 24th Jyväskylä summer school. We invited excellent speakers from the USA (Prof. Thomas Hemmick of Stony Brook University) and CERN (Dr. Andreas Morsch) to speak in the session ”Introduction to Relativistic Heavy Ion Collisions: The Beauty of the Partonic Many-Body Problem and Exploring the Medium with Hard Probes”, see the figure at the top of the page.

In September 2014 we also co-organised the ”10th International Workshop on High-p_T Physics in the RHIC/LHC era” in SUBATECH Nantes where the latest results from the high-p_T sector from the Relativistic Heavy Ion Collider (RHIC) in the USA and from the LHC were discussed.

ISOLDE

Paul Greenlees, ISOLDE project leader

In the early part of 2014 there were no experiments at ISOLDE due to the LHC shutdown LS1, but the experimental programme started up again in July, and a number of visits to ISOLDE by Finnish scientists have already been made. As mentioned in the 2013 Annual Report, the Finnish ISOLDE team joined the ISOLDE decay station collaboration (IDS). The experimental set-up uses a dedicated detector system for decay studies (beta-decay, gamma-emission, fast timing, etc) of radioactive isotopes produced at low energy in ISOLDE. The IDS data acquisition system is based on Nutaq digital electronics, which are used to great effect as part of the Total Data Readout (TDR) system in JYFL. Members of the Finnish ISOLDE team actively participated in the first experiments and played an important role in debugging the system and analysing the first on-line data. Experiments at the IDS will continue in 2015. Other members of the Finnish ISOLDE team have also taken part in laser spectroscopic and mass measurements in 2014. During the summer period, two students from JYFL (I. Murray and M. Vilen) were hosted at ISOLDE and worked on development projects related to mass and laser spectroscopy.

Development of the SPEDE conversion electron spectrometer in a project led by Academy Researcher J. Pakarinen has now entered the commissioning phase. Following the HIE-ISOLDE upgrade foreseen in 2015, multistep Coulomb excitation experiments will become routine. For complete analysis of data, all possible decay paths, including internal conversion, need to be measured. The SPEDE spectrometer, to be operated in conjunction with the MINIBALL gamma-ray spectrometer will detect the conversion electrons following the decay of Coulomb excited states. The construction of SPEDE and the associated reaction chamber housing the spectrometer were completed in 2014. Completion of the construction phase meant that the first in-beam tests could be carried out. Prior to the spectrometer being shipped to ISOLDE, tests are being made in JYFL, using

The SPEDE conversion electron spectrometer mounted for the first in-beam test at JYFL.

the stable beams available at the Accelerator Laboratory. The first tests validated the SPEDE concept, allowing direct measurement of conversion electrons emitted from nuclei in flight without the use of an electron transport unit. Further tests of SPEDE will be made in JYFL prior to the first experiments at HIE-ISOLDE in late 2015.

Nuclear Astrophysics

As reported in earlier years, experiment IS543 has been focused on trying to determine the cross section for the ^{44}Ti(α,p) reaction in order to better understand core-collapse supernovae. The amount of ^{44}Ti in stellar ejecta depends critically on the explosion mechanism of core-collapse supernovae. So far, satellite-based g-ray observations of ^{44}Ti have shown a much larger amount of ^{44}Ti than predicted with existing core-collapse supernova models. A 50 MBq source of ^{44}Ti extracted from radioactive waste at the Paul Scherrer Institute was used to produce a beam at REX-ISOLDE. For the first time, the experiment could be performed at an astrophysically relevant energy. It yielded an upper limit for the reaction cross section and suggested that the reaction proceeds more slowly than expected. The results were published in Phys. Lett. B and discussed in the New Scientist (http://www.newscientist.com/article/mg22229632.800-radioactive-waste-used-to-peek-inside-a-star-explosion.html#.VMDAlS4vyDl). A proposal to continue the studies with ^{44}Ti was submitted to INTC in June 2014.

Continuing Involvement

The Finnish community is now involved in over thirty active experiments at ISOLDE, ranging from solid state physics, through ground state nuclear properties, nuclear astrophysics and nuclear structure studies. As mentioned above, in 2015 the HIE-ISOLDE accelerator should come online, further extending the wide and varied physics programme at ISOLDE. In 2015, J. Pakarinen will replace P. Greenlees as project leader.

FAIR (Facility for Antiproton and Ion Research)

Ari Jokinen, FAIR project leader

Since 2006 Finland has contributed towards completion of the Facility for Antiproton and Ion Research (FAIR). The year 2014 saw many important stages being completed. After the shutdown of GSI the on-line experiments resumed in 2014 and the experimental campaign with the AGATA Demonstrator, which is the next-generation European gamma-ray spectrometer, was successfully concluded. Furthermore, prototypes for the Finnish in-kind contributions for the Superconducting Fragment Separator (Super-FRS) were tested at the existing GSI Fragment Separator.

Currently Finnish resources for FAIR are directed to the NUSTAR experiment, which is one of the four scientific pillars of FAIR. The agreed Finnish in-kind contributions for FAIR are devoted to the construction of Super-FRS. Following this strategy Finnish scientists will be among the first to conduct experiments at FAIR. Finland has played an active role in the Super-FRS Collaboration, which is a part of NUSTAR. Prof. J. Äystö is the chair of the Collaboration Board of the Super-FRS Collaboration.

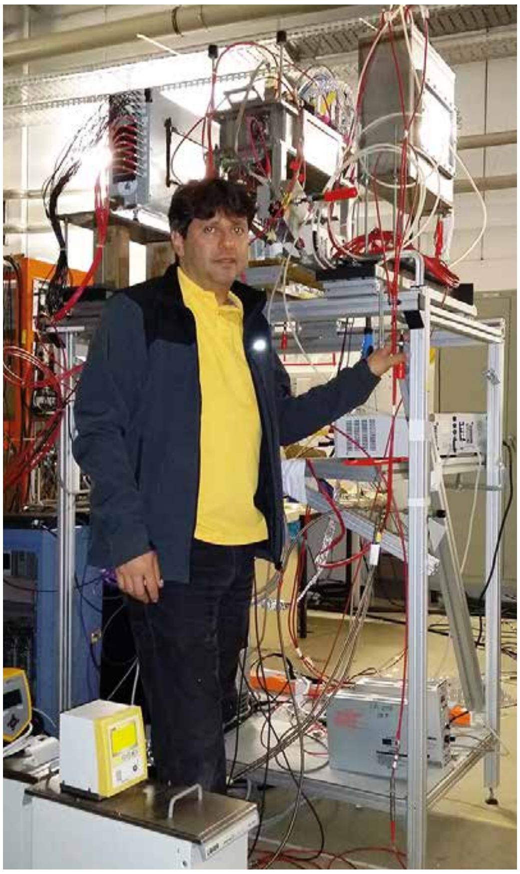
Most of the HIP scientists participating in the experiments are located in the University of Jyväskylä. FAIR construction and funding is organised through HIP. Prof. A. Jokinen is the co-spokesperson for the MATS experiment and Dr. I. Moore for the LaSpec experiment. Dr. T. Grahn and Dr. S. Rinta-Antila are connected to the present FRS experiments and future campaigns aiming for Super-FRS.

Status of In-Kind Projects

The entire Finnish in-kind contributions to FAIR will be dedicated to Super-FRS, which has been predicted to be completed by 2019. A set of mobile cranes and lifting solutions for various service purposes will be provided. Final specifications are under discussion after which the tendering phase will start. The Finnish in-kind package also includes the so-called flask-project, which contains design and construction of a moveable radiation shielded manipulation unit for the highly active beam-line components of the Super-FRS. Collaboration with Aalto University and the Holming company was initiated within this project.

Finland is also involved in the cryogenic gas catcher project with GSI and KVI-Groeningen to provide low-energy cooled ion beams for the MATS/LaSpec experiments. The new prototype was tested in 2014.

The Super-FRS beam diagnostics project consists of 32 GEM-TPC detectors that will be designed and constructed in HIP by F. García. The SEM-Grid detectors needed for intense beams will be developed by K. Rytkönen. In 2014 the Academy of Finland awarded FiRI funding for the Super-FRS diamond and MUSIC detectors that will be used for the time-of-flight and ΔE measurements, respectively.



GEM-TPC prototype set-up at the middle of the focal plane of Super-FRS.

Development of GEM-TPC Detectors for FAIR NUSTAR Super-FRS Diagnostics

In 2014 a major effort has been dedicated to the assembling and commissioning of the GEM-TPC prototype in twin configuration, called HGB4. The first quarter was devoted to the procurement of components and subsequent characterization. This period was of primarily importance for identifying the right materials and tolerances.

The second quarter was dedicated to the assembling and commissioning. The resulting prototype HGB4 was commissioned in the Kumpula Detector Laboratory.

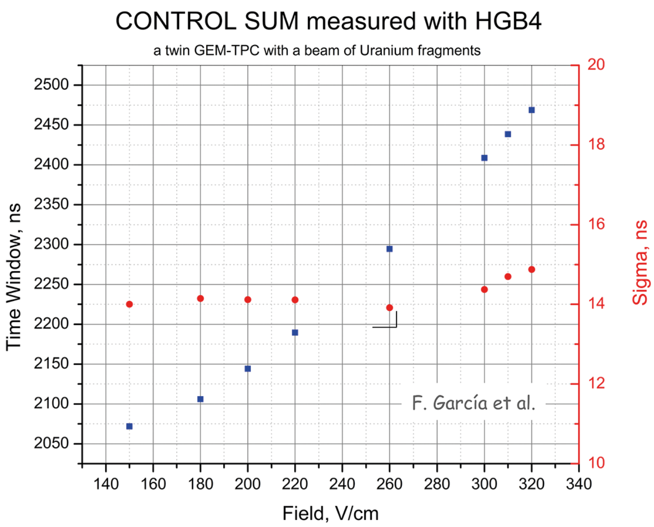
In-beam commissioning was carried out at GSI. Heavy-ion beams of Ca and U and U fission fragments were used to irradiate the detector at the middle focal plane of FRS and in Cave C (shown in the figure to the left).

As a result high quality data was recorded to study the position resolution and tracking efficiency at moderate rate and in addition to that the control sum (shown in the figure at the top of the next page) for U fragments was measured. In the near future the data analysis will be carried out.

The next year will be dedicated to further in-beam commissioning of HGB4 in the University of Jyväskylä Accelerator Laboratory and in the RIKEN RIBF facility.

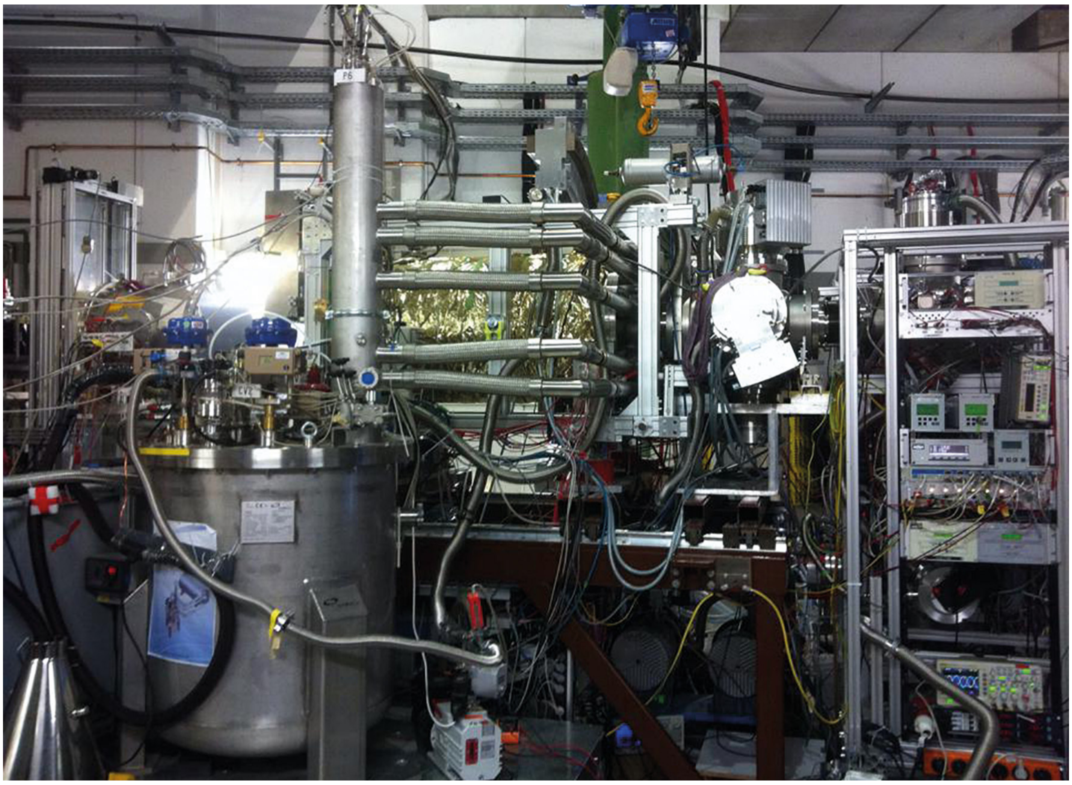
The FRS Ion Catcher Facility at GSI

The Super-FRS will provide low-energy beams for high-precision experiments utilising the many variants of laser spectroscopy and ion trapping techniques housed at the MATS and LaSpec facilities. The FRS Ion Catcher serves as a test facility for the future Low-Energy Branch (LEB),



Position and width of the control sum for a HGB4 twin GEM-TPC.

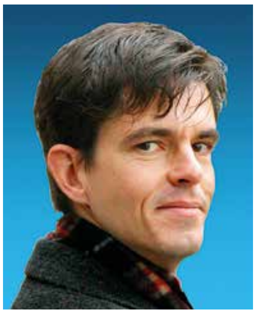
consisting of the FRS, a cryogenic stopping cell (CSC) and a multiple-reflection time-of-flight mass spectrometer (MR-TOF-MS). Projectile and fission fragments are produced at relativistic energies, separated in-flight, range-bunched, thermalized, extracted from the CSC and measured. In October 2014, a collaboration of scientists from Justus-Liebig-Universität Gießen, the University of Jyväskylä and GSI had an extremely successful beam time, two years after the initial commissioning of the facility. In the recent experiment, systematic investigations of the intensity limitations of the CSC were performed and the cleanliness was studied. A new record was set for the areal density of stopping cells with RF structures operated with a beam (6 mg/cm^2). Importantly, the MR-TOF-MS device was successfully used throughout the October beam time, acting as a "mass tagger", separating isomeric states which will be used for mass-separated decay spectroscopy in the future, as well as direct mass measurements of several nuclides. All parts of the FRS Ion Catcher exceeded expectations and worked extremely reliably. The next step is therefore to write and submit the Technical Design Report for the final stopping cell for the LEB of the Super-FRS.



A prototype of the Super-FRS gas catcher.

Technology Programme

Saku Mäkinen,
Technology Programme
director



The restructuring of the Technology Programme further integrating the projects that have significant technology development, transfer and pre-commercialisation activities in the same HIP programme was still under-way in 2014. As a result the Technology Programme at the end of 2014 included five research areas supporting the HIP strategy and on-going activities. The continuing research areas were computing performance and efficiency, accelerator technology, and medical imaging and pattern recognition. In addition to the three existing areas two new initiatives were launched, namely radiation-detection instrumentation (a new initiative starting in 2015 led by Prof. Paula Eerola), and business incubation activities (a new initiative starting in 2015 led by Prof. Saku Mäkinen). The projects included in the Technology Programme in 2014 will be described below.

Kenneth Österberg,
Accelerator
Technology
project leader

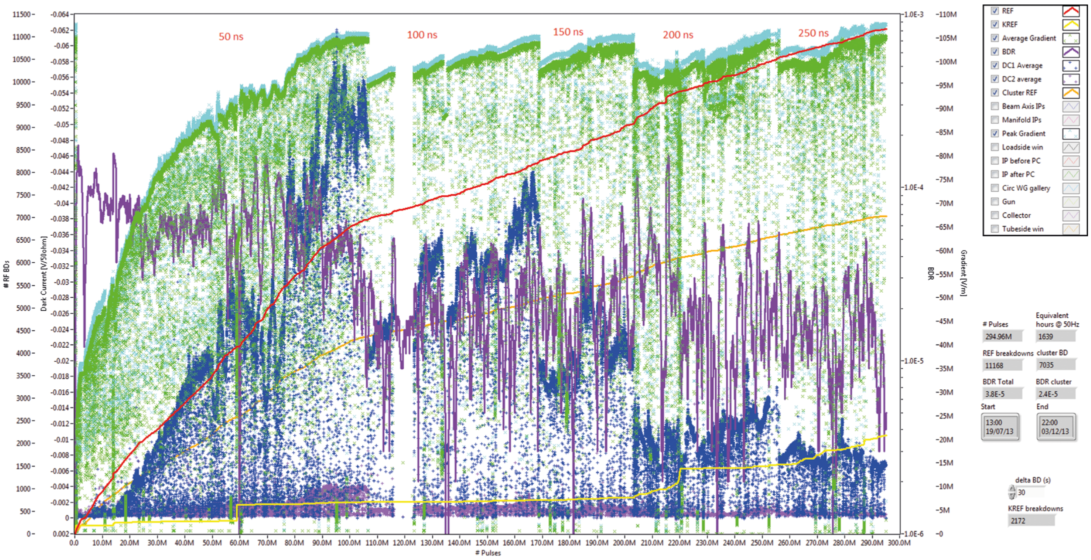
Accelerator Technology

The Accelerator Technology project mainly participates in the Compact LInear Collider (CLIC) study that develops the CLIC two-beam technology for a multi-TeV electron positron collider in view of a decision on the future direction of the high energy frontier in the coming years. After the completion of its Conceptual Design Report (CDR) during 2012, the CLIC study has now entered a new phase of technical development and optimisation that will lead to a Technical Implementation Plan by 2018. The focus of the HIP contribution is on two aspects: on the understanding of the properties of the materials used during accelerator operation, Materials for accelerator technologies (MAT), an activity led by Doc. F. Djurabekova and on manufacturing and testing of accelerator components and assemblies, Module, Structures and Manufacturing (MSM), an activity led by Doc. K. Österberg. The project obtained a "K-contract" with CERN essentially doubling the funding for the years 2015–17, and thus ensuring the current activities and even starting new ones.

Materials for accelerator technologies

The objective of the study pursued by the theoretical group within the Accelerator Technology project at HIP in close collaboration with the CLIC RF structure developing group led by Dr. W. Wuensch is increasing the achievable surface electric field of metal surfaces by developing a quantitative understanding of the physical effects which limit it. The problem of vacuum arcing is not a specific one to CLIC components only. Examples of scientific instruments and commercial devices which operate under vacuum and have metal surfaces which are exposed to high surface electric fields include X-ray sources, radio-frequency generating klystrons, particle accelerators, scanning electron microscopes, field emission tip arrays and high-current interrupters. The performance, or compactness, of many of these devices is strongly influenced by the level of electric field which can be applied before the onset of two main physical phenomena - electron field emission and vacuum breakdown. Understanding the basic science will provide a foundation for advances in real-world devices in the future.

The activity of the group is focusing on determination of fundamental mechanisms triggered in metal surfaces in the presence of high electric fields. This means that we aim



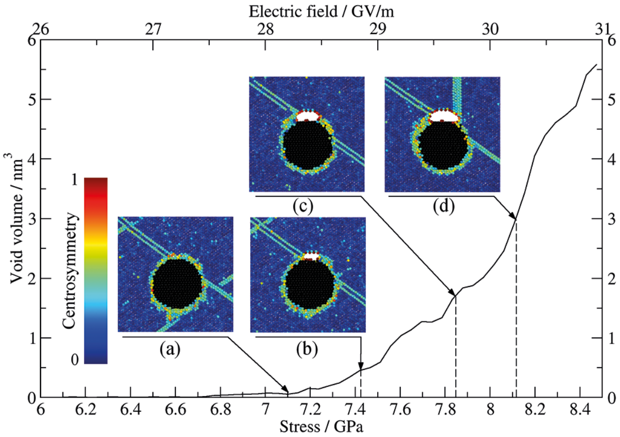
The conditioning behaviour of a CLIC prototype accelerating structure. The time corresponds to over four months of operation at 50 Hz. The vertical scale is the accelerating gradient normalised for pulse length and breakdown rate. *(W. Wuensch, CLIC workshop, 2014)*

to understand in detail the effect high surface electric fields have on the surface morphology and crystalline microstructure of metal surfaces and in particular identify the instability which leads to vacuum breakdown. This work is done within the development programme of high-gradient radio frequency accelerating structures, led by Dr. W. Wuensch for the CLIC study. This programme has recently achieved its objective of developing accelerating structures which operate above 100 MV/m. This is roughly a factor three above the gradient of state-of-the-art linacs such as those found in new XFEL facilities - 35 MV/m in SACLA and 28 MV/m in SwissFEL, for example. However, currently the study focuses on identifying the evolution of surfaces and material microstructure during the high-gradient conditioning of prototype structures to be able to understand the behaviour of Cu surfaces with time. Recent advances in the experiment allowed approaching the condition of the surface where none of the airborne contaminants are relevant to the breakdown rates. It was clearly observed that the CLIC prototype accelerating structures condition, i.e., the gradient holding capability increases, over hundreds of millions of pulses as shown in the figure above. It is at these scales that the crucial material dynamics are likely occurring when metal surfaces are exposed to high surface electric fields.

The figure above summarises results obtained with different pulse length of RF signals. Reducing the conditioning time of several months will be a significant cost savings for a project using such accelerating structures. As can be clearly seen the structure behaved consistently over all periods of the testing time in spite of the change of the pulse length with respect to the gradient normalised by the pulse length and the breakdown rate. This justifies the hypothesis of structural modifications (for instance, material hardening) during the conditioning time. This experiment confirms the necessity for studying material properties under high electric fields.

In 2014 we continued the development of a multiscale model of electrical breakdowns by including the processes which have not yet been included in the model. The highlights of the results that were accomplished during the past year can be summarised as follows.

We continued studying the mechanical properties of Cu surfaces under the tensile stress due to a high electric field by analysing the mechanisms of how the Cu surface may yield near a precipitate with harder mechanical properties than the surrounding matrix. We performed MD simulations of single crystal Cu which contained a Fe precipitate under high external tensile stresses caused by an electric field. The simulations show that precipitates, which are stronger than Cu, could provide an indirect mechanism for surface geometry change and electric field enhancement. Under external stress caused by the electric field, dislocations nucleate at the Cu-Fe interface. Multiple precipitates in close proximity may generate dislocations resulting in plateaus on the



Formation of voids in the interface between precipitate and the matrix.

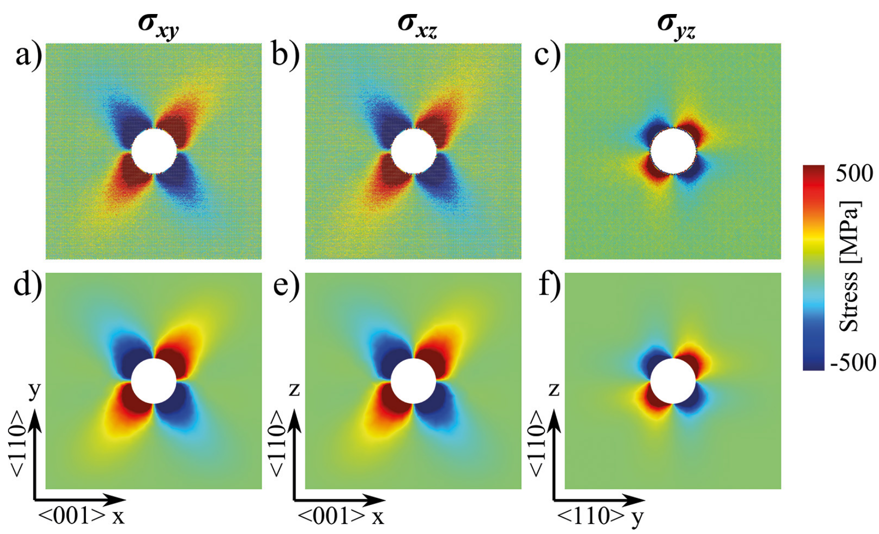
surface. A further slip can occur and create a series of steps. This mechanism increases the extent of surface geometry change. When combined with the formation of a plateau it could lead to the creation of a protrusion.

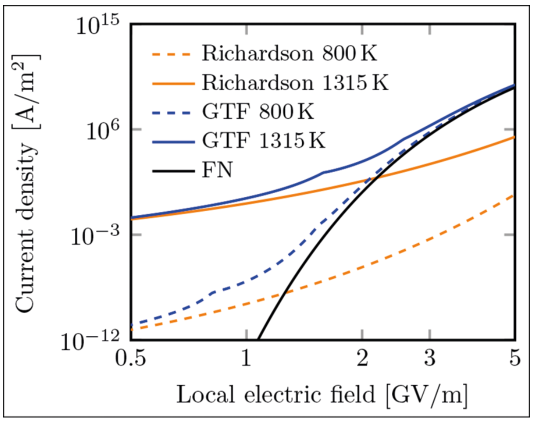
When the stress is increased, voids can form above or below the precipitate as shown in the figure above. Void formation is a random but not uncommon event. The voids offer additional sites for dislocation nucleation. A paper concerning this effect has been accepted for publication in Modelling and Simulations in Materials Science and Engineering.

We have successfully developed a methodology to incorporate surface stress effects into the solid mechanics framework (COMSOL). The developed methodology was tested by applying tensile stress on a single Cu crystal containing a test stress concentrator, in the shape of a spherical void. The proposed approach utilises pre-calculated elastic properties of crystal surfaces from MD simulations as input parameters and allows the calculation of the resulting stress distributions in a computationally efficient way. The comparison of stress distribution obtained using MD and FEM (see the figure to the left at the bottom of the page) shows good qualitative and quantitative agreement between the two methods. We have also demonstrated that the size effect, characteristic for nanoscale systems, is consistent with previous MD works. Two publications based on these results have been submitted for publication in scientific journals.

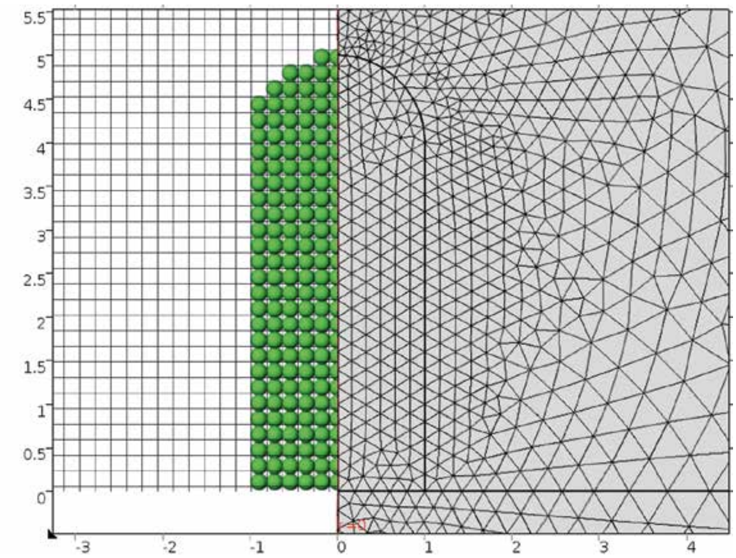
Last year we also improved the model which calculates the field emission current. Up to now the commonly applied model has been based on the Fowler-Nordheim formalism, which is well established for the conditions of field emission currents at low temperatures and high electric fields. However, this condition does not apply when a vacuum arc is developing. The temperature rise in the field emitting tips will be significant. In the figure to the right at the bottom of the page we show the current density at the apex of a protrusion as a function of the local electric field, when the temperature is 800 K. While the Richardson equation describes the current well for low fields, and the Fowler-Nordheim (FN) equation describes it well for high fields, a general thermal field equation (GTF) is needed to describe the full range.

Comparison of stress near the void surface calculated by MD and FEM (proposed in this project model).





Comparison of electron currents calculated from the tip by Fowler-Nordheim (FN), pure thermionic current (Richardson) and the generalised thermal field (GTF) formalisms.



Schematic illustration of a tip seen by MD and FEM software. Note the different shape of the elements used for calculations.

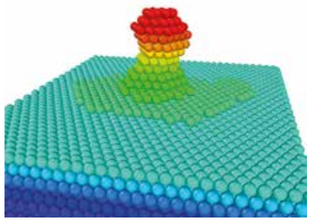
To be able to understand the experimentally measured field emission currents, which have been linked to the onset of vacuum breakdowns, it is important to estimate the current with good accuracy in simulations. This enables more realistic simulations which can be compared with experimental results, making it possible to verify the proposed mechanisms behind vacuum breakdowns.

We have compared two methods for simulating protrusions: one based on hybrid classical molecular dynamics - electrodynamics (HELMOD) and one implemented into the FEM code COMSOL (see the figure at the top of the page). While the FEM implementation enables more accurate calculation of the electric field, the MD implementation can describe dynamics more realistically. A publication has been completed and will be submitted for publication shortly.

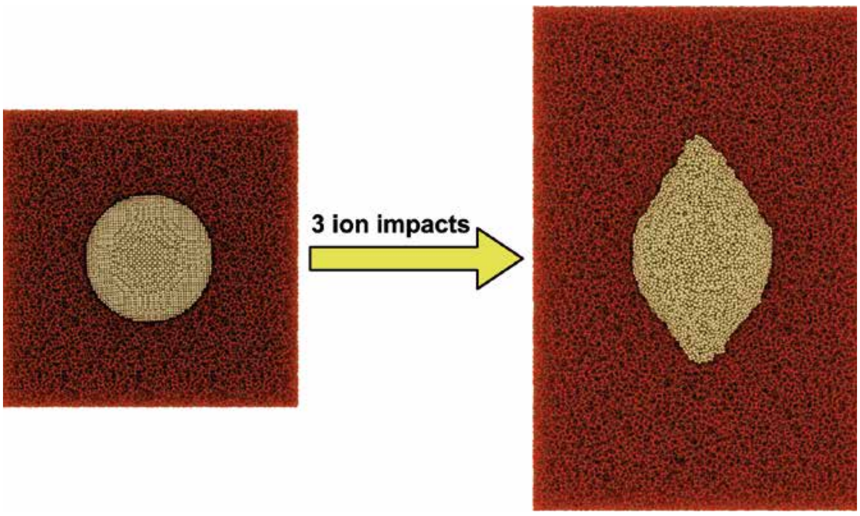
Last year we also initiated the development of new Kinetic Monte Carlo (KMC) code, Kimocs, for the surface evolution of copper. The Kimocs model uses pre-tabulated activation energy barriers for the atom jumps. The calculation of all barriers for the copper system was a major part of the effort to develop the model, as several thousands of calculations, using the Nudged Elastic Band (NEB) method, had to be performed. The activation energies give the probability for every atom jump process, which in the model is characterized by the number of nearest neighbour and next-nearest neighbours of the initial and final position of the jumping atom. This approach makes the model more precise and adaptable to different kinds of surfaces with different kinds of defects, compared to previous attempts at making KMC models for surfaces where simple bond counting formulae have been used to estimate the activation energies.

With the new KMC model, it is possible to study the long time scale evolution of the surface of the CLIC accelerating copper structure and possible surface features, such as small tips (see the figure to the right), that are believed to play a major role in vacuum arcing. A publication with a description of the code and the first results of surface evolution is in preparation.

In 2014 the computational materials research activities were marked by exciting results obtained together with the experimental group at Australian National University. We examined the experimentally observed surprising effect of controllable shape modification of nanoparticles



Initial results obtained with the code Kimocs developed within the project.



Elongation of an Au nanoparticle embedded in an amorphous SiO_2 structure after swift heavy ion impacts.

embedded in solids by very energetic (MeV and GeV) heavy ion irradiation. By combining transmission electron microscopy experiments and atomistic computer simulations (see the figure at the bottom of the previous page), we showed that flow of hot molten metal and its recrystallization between ion impacts together explain the experimentally observed elongation.

We are also continuing the experimental research activities at CERN with the high-voltage DC spark system with the high repetition rate of application of the constant voltage to match the experiments performed in RF-conditions. This activity in 2014 was focused on the following:

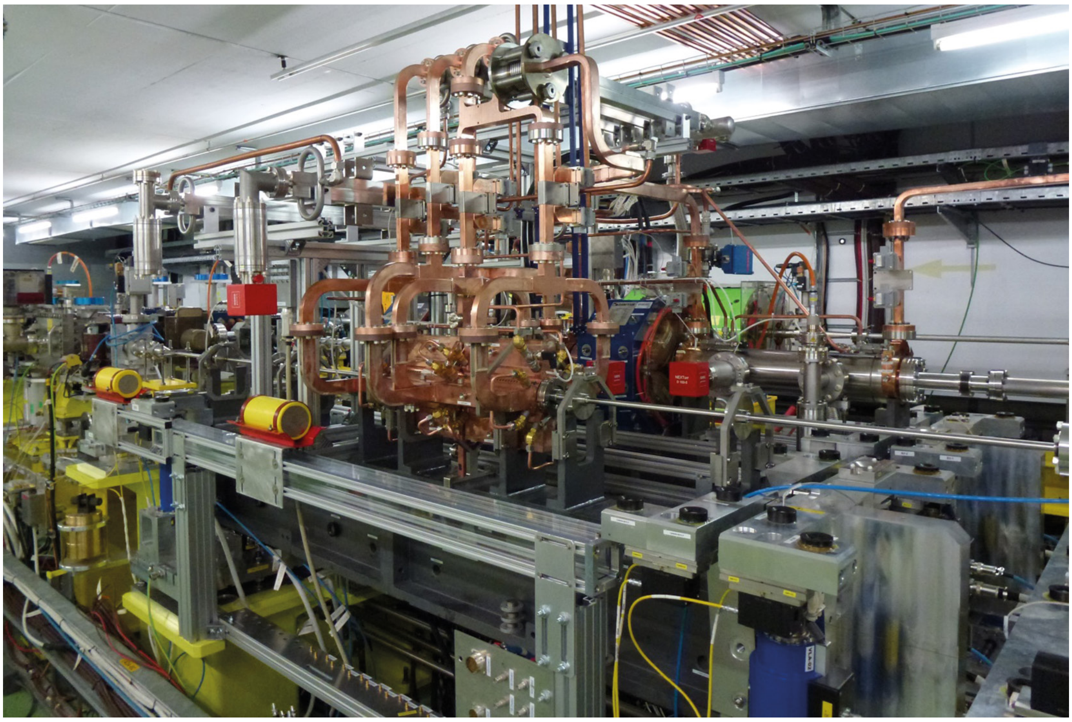
- Construction of a high repetition rate measurement system, in addition to the existing one, to enable future high repetition rate measurement runs on two systems simultaneously.
- Development of a high repetition rate system to be fully integrated with the fixed-gap system, allowing for them to be used together without the hardware attrition issues that previous experiments suffered from.
- Development of a fixed-gap system to enable condition studies comparable to RF, with initial proof-of-concept studies done, to be followed by a full conditioning experiment once fresh electrodes have been manufactured.
- Study of breakdown statistics and electrode long-term breakdown behaviour in a fixed-gap system during long measurement runs of constant-voltage and constant-pulse-length pulsing.

Module, Structures and Manufacturing

The topics covered by the Module, Structures and Manufacturing (MSM) group within the Accelerator Technology project during 2014 included industrialisation of RF structure manufacturing, the development of dynamic vacuum and internal shape measurement techniques for RF structures as well as various items related to the CLIC module programme: studies of the thermo-mechanical behaviour of CLIC prototype modules, assembly of a fully functional and high power ready CLIC module prototype for installation in CLEX and preparations for assembly of additional lab test modules for more detailed functional studies. The R&D was done in close collaboration with the CERN CLIC RF structure development and production and CLIC module groups, notably Drs W. Wuensch and S. Döbert, and several Finnish industrial and academic partners.

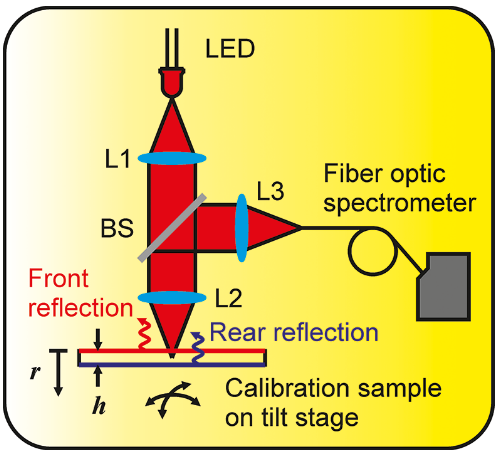
The R&D on RF structure manufacturing and precise assembly aims at involving Finnish companies in the manufacturing of components for the CLIC RF structures, five companies are notably involved through the HIP co-ordinated and EU funded ”MeChanICs” (Marie Curie Linking Industry to CERN) -project between 2010 and 2014. In 2014 within MeChanICs, after a 6-month extension of the secondment, one researcher from Loval Oy (F. Smeds) worked at CERN for another 6 months on brazing and bonding aspects of the RF structure assembly. Similarly, after an extension also for 6 months of the secondment, one researcher from Mectalent Oy (M. Rissanen) was working in 2014 for 8 months at CERN on optimisation of RF structure assembly processes in view of industrial manufacturing. The final MeChanICs project meeting took place in August at the University of Helsinki and brought the project to its conclusion with some very good feedback from the participants.

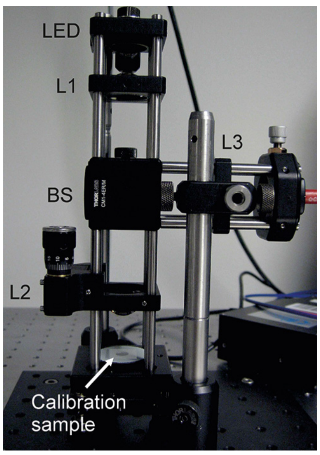
The CLIC module with all the accelerator components and necessary subsystems integrated has to maintain high precision also during CLIC operation. This is verified on one hand by measurements on a prototype module and on the other hand by modelling the thermo-mechanical behaviour of the module for various loading conditions. The MSM group has supported the exploitation of the first full-scale prototype module (without a beam) in the laboratory. Results were reported in multiple contributions to IPAC'14. In parallel, the CLIC module group at CERN, co-led by Dr. Aicheler from HIP, prepared the assembly of the fully functional CLIC module for installation and beam operation in CLEX (see the figure at the top of the next page). This task was successfully accomplished and the module saw its first beam in late 2014. Results will be presented at the CLIC workshop in January 2015.

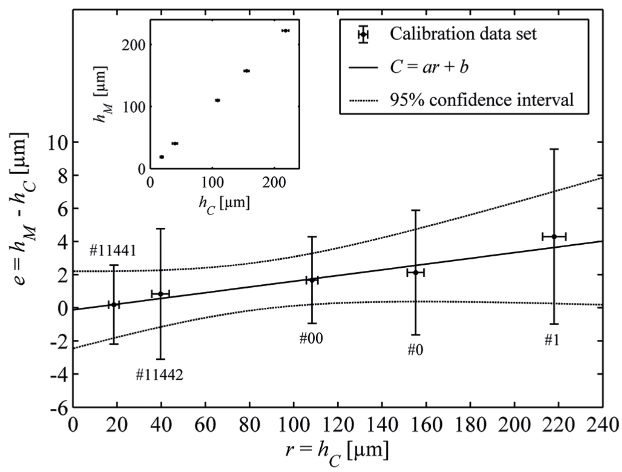


The first fully functional CLIC prototype module installed in CLEX which saw a beam already in late 2014.

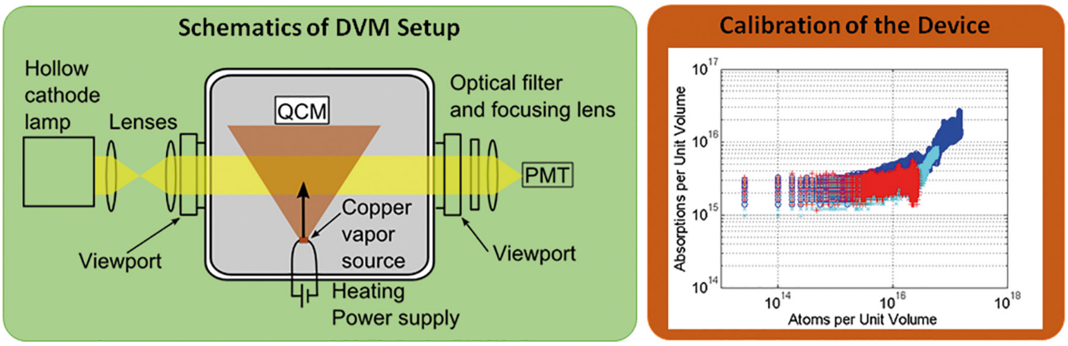
During assembly as well as during high power testing, some CLIC RF structures experience permanent µm sized shape deformations. To quantify these deformations, and as a measure of an additional tool for quality assurance during fabrication of the prototypes, an effort was launched in autumn 2012 in collaboration with Prof. E. Hæggström and his group at the University of Helsinki's Department of Physics to develop a non-destructive method with micron precision to measure the internal shape of the RF structure disk stack using Fourier Domain Short Coherence Interferometry (FDSCI). The verification of the proposed method proceeds in steps. A first set-up (the figure below) was constructed in 2013 that demonstrated the micron precision of FDSCI for thickness measurements of standardized samples. Since then, significant progress has been made throughout 2014 for the calibration of the thickness measurement as well as for the mechanical design of the probe head (performed in the framework of MeChanICs in summer 2014). A journal article on the calibration and







Schematic (left) and photograph (centre) of set-up for the verification of the micron precision of Fourier Domain Short Coherence Interferometry (FDSCI). Right: the measured FDSCI measurement bias (e) and the 2σ uncertainty for samples with different thicknesses. Inset: measured optical thickness (h_M) versus calibrated optical thickness (h_C).



Test set-up (left) and an example of a calibration curve (right) of the rapid ultralow pressure manometer. A photo multiplier tube (PMT) detects a light intensity decrease proportional to the evaporated density of copper atoms. A quartz crystal microbalance (QCM) is used for absolute calibration.

the verification is in progress and first shape measurements of copper discs are planned for spring 2015. The construction of a set-up to show that the depth range of 10 mm required for the measurement of the RF structure disk stack can be achieved with FDSCI using Fabry-Perot filtering has started.

Also the collaboration with Prof. Hæggström and his group continued on the development of a rapid ultralow pressure manometer to dynamically measure the outgassing from an RF loaded structure during one pulse train. Simulations predict outgassing levels at CLIC that are below the critical levels of feasibility, but direct measurements of 10^{-7}–10^{-8} mbar local pressure at 10–100 ns time scales in the RF structures are necessary to test the validity of the predictions. Sensitivity to 10^{-5}–10^{-6} mbar copper partial pressures in single pass measurements was obtained with a dedicated test set-up in Kumpula's Accelerator Laboratory (the figure at the top of the page) in 2013. The absolute manometer calibration is well on its way and a journal article on the calibration is in preparation. The manometer will initially be used in one of the DC-spark test stands at CERN to measure copper outgassing rates. First designs are being developed in order to integrate it.

Tapio Niemi,
Green Big Data
project leader

Green Big Data

There are several new trends in scientific computing these days: a large part of computing tasks are processed in cloud computing centres using virtualisation technologies; the sizes of the data sets have become extremely large and complex causing challenges for data analysis; and the energy consumption has become one of the main costs of computing, usually exceeding hardware and personnel costs. Therefore, there is an obvious need for new research to find more efficient hardware and software solutions for this big data analysis. Especially in computing intensive sciences, such as high energy physics (HEP), powerful but still energy-efficient solutions are essential. For example, it has been estimated that the computing needs of CERN LHC experiments will be ten times higher in 2020 than now.

The Green Big Data project has focused on optimising the energy consumption of scientific computing clusters used for HEP computing related to CERN experiments. In 2014, we contributed to this neglected area of research:

- Studying and testing how heterogeneous computer architectures can be applied to HEP computing.
- Testing modern CPU architectures such as ARM in HEP computing.
- Studying and prototyping computers as heating units.
- Developing energy efficient management methods for cloud computing.
- Developing new key performance indicators for computing resources.

The first three topics have been studied in close collaboration with Aalto University and the CMS computing team at CERN and the Department of Operations at the University of Lausanne is a key partner in the last one. This research is also funded by The Swiss National Science Foundation (SNFS) until the end of 2015.

The personnel of the project included two PhD students and three summer trainees during

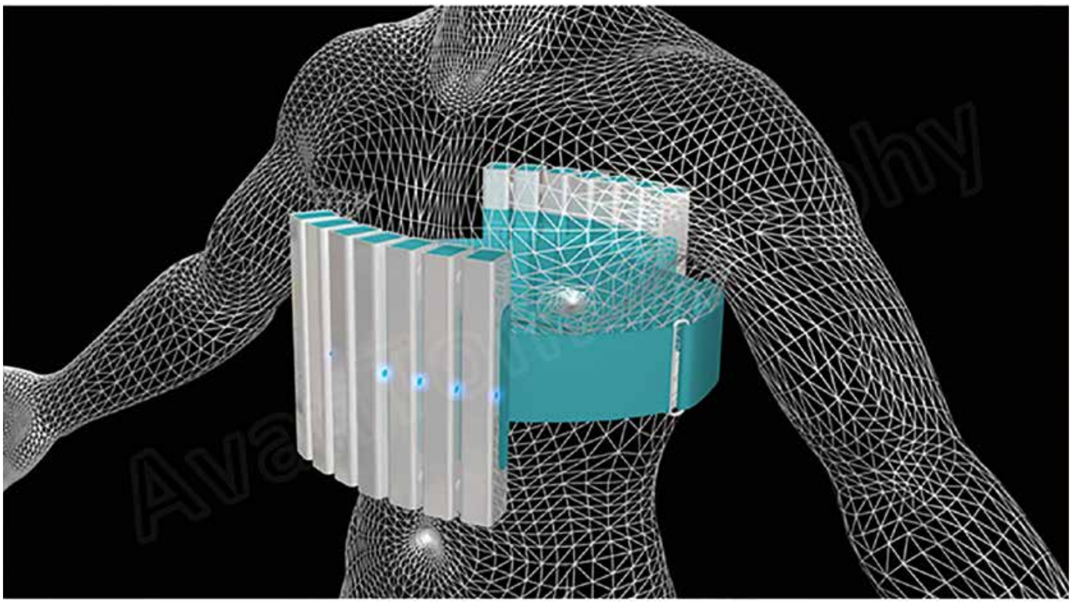
ARM EnergyCards for energy-efficiency study of scientific computing.

the summer. One MSc thesis on performance and energy profiling of ARM based servers was completed. This work was done in collaboration with the CERN CMS Computing Team and funded by the Google Summer of Code project. Two other MSc projects (using ARM in CSM computing and computer heaters) will be completed in early 2015 as well as a PhD project on energy-efficient cloud computing.

The project has modern and comprehensive test facilities for measuring energy efficiency of different computing hardware. The test hardware contains over 100 CPU cores, 200 gigabytes of memory, and several terabytes of disk space. The newest parts of the hardware are an ARM based test cluster at Aalto University and a computer heater prototype in the Energy Garage at Aalto University.

The goal for 2015 is to continue research on heterogeneous and energy-efficient hardware, further develop cloud computing for HEP applications, and apply these methods in practice to collaboration with CERN and industry partners with possible external project funding. The team is a part of an EU funded research project "Scalable and Secure Infrastructures for Cloud Operations" starting in February 2015. Also a research project proposal on heterogeneous hardware in HEP computing has been submitted to the Academy of Finland in September 2014 by Aalto University.

Heater prototype 2. Wooden frame built from recycled materials housing the temperature control system, computers and required network to connect the two. Operation requires a network connection and AC power. The unit is capable of independent operation (measurement, control and heating) and additionally it can operate as the master to other heating units.



Placement of AvanTomography modules for thorax scanning.

Ulla Ruotsalainen, Biomedical Imaging project leader

AvanTomography

The Biomedical Imaging AvanTomography project aims to construct a PET demonstrator, based on the principle of the Axial PET (AX-PET) project developed by the AX-PET research consortium at CERN. The AX-PET design consists of axially oriented scintillating crystals in a staggered grid structure, interleaved by wavelength shifter (WLS) strips. Each crystal and wavelength shifter strip is individually read and processed by multi-pixel photon counters (MPPC). In the AvanTomography project, in addition to this structure, all data is collected and stored in list-mode in the computer. The trans-axial coordinate of the gamma interaction point is acquired from the scintillating crystals, whereas the z-axis is determined by the WLS strips, which collect the light emitted from the crystals.

In conventional PET devices, there is a trade-off between sensitivity and resolution. With the concept of axially oriented crystals and orthogonally placed WLS strips, it is possible to have a good resolution as well as high sensitivity thanks to the determination of exact hit location. Also it is possible to solve the so called parallax error caused by the unknown depth of interaction in the detector crystal. This error can be avoided with the multilayer structure of the axial type PET, and the detectors can be brought near the object which increases the sensitivity of the photon detection.

The AvanTomography project is planned to bring a modular and easily transformable PET scanner structure on the market, allowing it to be used in various applications ranging from the scanning of wrists/arms to small animals. Also the sensitivity of the PET demonstrator can be improved simply by adding more layers of modules to the demonstrator. TEKES TUTLI funding for this project continued until the end of December 2014, after which the demonstrator will be ready for measurements with radioactive sources. A patent application for the new detector structure was filed in June 2014. A white paper about the AvanTomography prototype was prepared in order to work in collaboration with companies and to show the benefits of the new design to possible customers. Monte Carlo simulations of the detector module and simple scanner have been started in a MSc project. The simulations can be compared to the measurements of the existing prototype to fine-tune the simulation parameters.

Detector Laboratory

Eija Tuominen,
Detector Laboratory
coordinator

The Helsinki Detector Laboratory is an infrastructure specialised in the **instrumentation** of particle and nuclear physics. It is a joint laboratory between the Helsinki Institute of Physics (HIP) and the Department of Physics of the University of Helsinki (UH/Physics). The Laboratory provides premises, equipment and extensive know-how for research projects developing detector technologies. The personnel of the Laboratory have extensive expertise in the modelling, design, construction and testing of semiconductor and gas-filled radiation detectors. In addition, the personnel and scientists working in the Laboratory take proudly the responsibility and privilege of educating a new generation of physicists and of hosting high school students interested in physics.

Instrumentation is great fun.

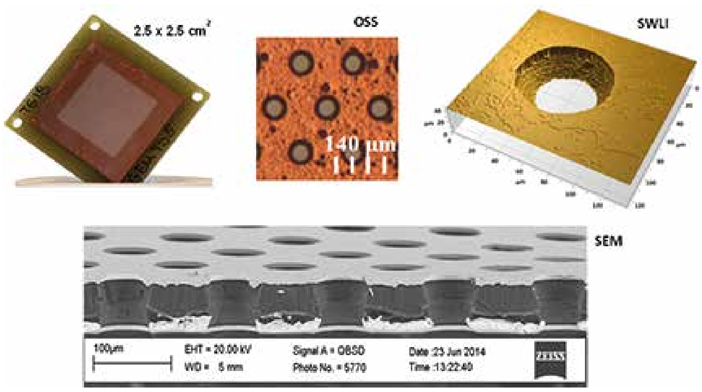
All the projects present in the Detector Laboratory have the objective to provide reliable instruments for large international physics experiments. The Laboratory is specialised in **Quality Assurance** (QA) of detectors and their components and in **detector prototyping**. In 2014, the Laboratory hosted several projects participating in the CMS, TOTEM and ALICE experiments at CERN, and the NUSTAR experiment at FAIR. To maintain the outstanding expertise of the Laboratory, new detector technologies are actively developed in the framework of the CERN CMS, RD39, RD50 and RD51 Collaborations.

The Laboratory collaborates actively with several HIP projects. Together with the **HIP CMS Upgrade project**, the Laboratory is in charge of the quality assurance of about 250 pixel detector modules for the CMS Tracker Phase I upgrade, to take place in 2016–2017. The first production modules were manufactured and tested in 2014 in co-operation with Advacam Ltd. Simultaneously, R&D work was ongoing for the needs of the CMS Tracker Phase II upgrade. In 2014, the Laboratory infrastructure was upgraded with a probe station, which strongly supports this activity.

Together with the **HIP FAIR project**, the final aim of the Laboratory is to provide 32 + spare GEM-TPC (Gaseous Electron Multiplier - Time Projection Chamber) detectors for the diagnostics of the FAIR NUSTAR Super-FRS, planned to be launched in 2018. In 2014 the R&D phase was still ongoing, and the work involved detector design and prototype construction, prototype testing and in-beam tests at GSI.

During 2014, with the **HIP TOTEM project**, the Laboratory maintained the 40 GEM detectors previously manufactured and tested in the Laboratory and installed and commissioned in the TOTEM T2 spectrometer. In addition, five spare GEM detectors were tested in the Laboratory and delivered to CERN T2.

In the framework of the **HIP ALICE project** the Laboratory prepared for the quality assurance activity of



Quality Assurance of GEM foils; imaging with three different optical devices - Optical Scanning System (OSS), Scanning White Light Interferometry (SWLI) and Scanning Electron Microscopy (SEM).

Groups of high school students frequently visit the Detector Laboratory.

the hundreds of square meters of GEM foils needed for the upgrade of the ALICE TPC detectors. An essential part of the work will be done with the Optical Scanning System (OSS) of the Laboratory that was further improved. In addition, construction of a second optoscanner (OSS2) was launched.

The Detector Laboratory supports several of the **research activities of UH/Physics**, especially in the form of sharing expertise, equipment and infrastructure with various research groups. Its connections with the Division of Particle and AstroPhysics (PAP) are naturally very tight. In addition, the Laboratory collaborates with the Electronics Research Laboratory, especially in the fields of optical imaging techniques and ultrasonic interconnection technologies. Furthermore, the co-operation with the Division of Material Physics Accelerator Laboratory is strong in the field of radiation hard semiconductor detectors. Additionally, there are strong connections with the University of Jyväskylä Accelerator Laboratory and with the Aalto University Micronova facility.

In the Detector Laboratory, special effort is devoted to developing methods of **social interaction** to ignite interest in physics among young people. In 2014, the Laboratory participated willingly in the outreach efforts organised by UH/Physics, e.g., ”Tiedebasaari”, ”Koekampus”, and the Higgs weekend at the Finnish Science Centre Heureka where the special contribution of the Laboratory was a radiation detector made from a lemonade can. In 2014, a total of **250 high school students** with their teachers from different parts of Finland visited the Laboratory for demonstrations about physics and instrumentation. In addition, 20 high school physics teachers visited the Laboratory during their refresher courses in physics, and 40 UH/Physics rookie students also visited the Laboratory. Furthermore, two secondary school TET-trainees worked in the Laboratory.

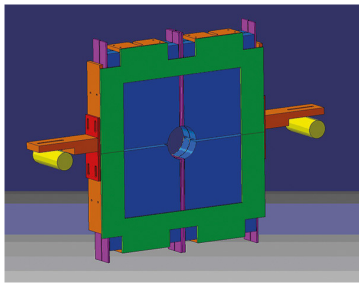
In 2014, the **physics education** given by the Detector Laboratory was further developed. Funding provided by UH/PAP made possible the acquirement of new infrastructure not only to further improve the research activities but also to establish new research-based exercises and special assignments for physics students. Scientists working in the Laboratory also took responsibility for lecturing courses of UH/Physics about semiconductor physics and detector technologies. In addition, project scientists and Laboratory personnel acted as mentors to several students working in the Laboratory for their doctoral and Master’s theses.

Forward Physics

Risto Orava,
Forward Physics
project leader

Forward Physics at the ALICE-LHC Experiment

During spring 2014, the Helsinki HIP-HY Forward Physics group initiated analysis of diffractive proton-proton collision data collected by the ALICE experiment in Run 1 of the CERN LHC. Supported by the ALICE diffractive physics team, the group concentrates on the analysis of space-time structure of hadronic collisions in extreme kinematic configurations. To accomplish this, an upgrade programme of the base line ALICE experiment was launched during the first long maintenance period of the LHC collider (LSS1). As the first step, the small angle coverage of the experiment was improved by adding 8+8 ADA/ADC detectors at ±20 meters on both sides of the proton-proton collision point IP2.



A CAD drawing of an AD module with two planes of 4+4 detector quadrants assembled together with the wavelength shifter bars. The readout is facilitated by optical fibres connected to the ends of the wavelength shifters indicated by purple colouring.

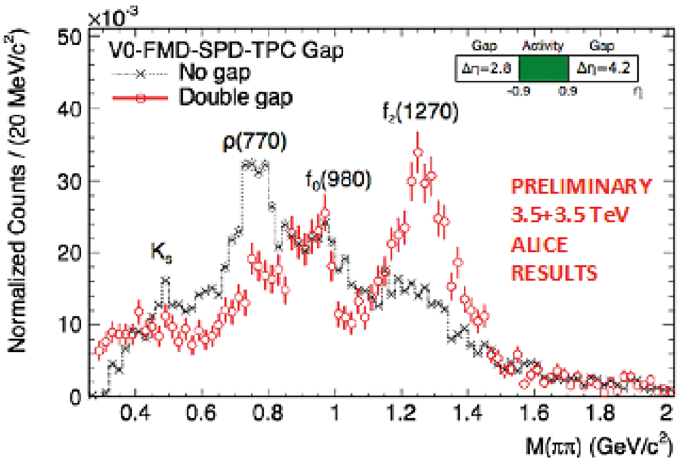
After systematic beam tests at the CERN PS in October 2014, the new detectors, with their advanced optical readout were installed in their final locations just before Christmas 2014. As the next step, the group is now preparing for a further forward detector upgrade based on a novel approach to leading proton detection at ±110 meters around IP2 [*Forward physics proposals*, presentations for the Scientific Advisory Board of the Helsinki Institute of Physics (HIP) by the Helsinki Group, 28 August 2013 and 2014].

Equipped with the present upgrade ADA/ADC forward spectrometers, ALICE will have unprecedented physics opportunities by efficiently triggering and analysing hadronic interactions in kinematical configurations that are presently poorly understood. The newly installed forward ADA/ADC detectors enable the smallest diffractive masses to be detected, and allow detailed studies of matter in the region of extremely small relative quark/gluon momenta, x_{Bj}, $x_{Bj} \geq 10^{-8}$.

The low mass central exclusive process allows meson states with the selected 'vacuum' quantum numbers to be investigated. At higher central masses, the experiment turns the LHC into a gluon collider with a high yield of clean gluon jets for the benefit of detailed QCD studies.

Due to the special machine optics conditions at the ALICE interaction point, the experiment is able to continuously collect data during the nominal LHC pp/pA running periods.

For improved analysis of the forward physics processes, the Helsinki group continued to develop advanced multivariate techniques for soft classification of diffractive events to be used for the analysis of ALICE Run 1 and forthcoming Run 2 data [M. Mieskolainen & R. Orava, *The existence and uniqueness of diffraction at the LHC*, Diffraction 2014, Primosten, Croatia]. The developed Bayesian analysis framework is driven by a convex optimisation based algorithm. Together with the chosen physics model, posterior probabilities can be estimated event-by-event in a fully Bayesian way or by iterative estimation of priors, also known as the maximum marginal likelihood or empirical Bayes. As part of the physics analysis preparations, the group customised, installed and tested the DIME Monte Carlo (MC) central exclusive processes package into the official ALICE AliROOT analysis framework. Customisations included, e.g., resonant excitation of the leading protons.



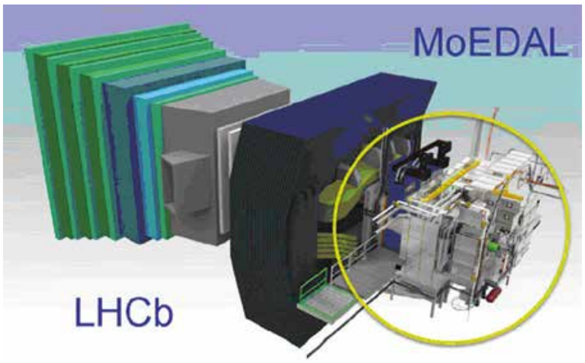
The Central Exclusive Process (CEP) acts as a 'gluon filter' to enhance production of vacuum-like spin-parity states $J^{PC} = 0^{++}, 2^{++}$ and gluon jets. A preliminary ALICE measurement of the low-mass $\pi^+\pi^-$ system exhibiting enhanced production of $f_0(980)$ and $f_2(1270)$ resonances (red circles) as compared to the background (black).

The ALICE based Forward Physics project of the Helsinki group is best characterized as a high physics impact - low cost research project with three phases: (1) analysis of the existing Run 1 data, (2) analysis of the Run 2 data to be collected by the enhanced forward ADA/ADC detectors, and (3) a further upgrade plan for leading proton detection by using the 'pocket' detectors.

MoEDAL - Monopole and Exotics Particle Searches at the LHC

The LHC is opening up a new energy regime for novel physics searches beyond the Standard Model. The search strategy for exotics - planned for the main LHC experiments - can be extended by dedicated experiments designed to complement and enhance the physics reach of the present base line detector designs. The CERN MoEDAL (Monopole and Exotics Detector at the LHC) project is such an experiment. The prime motivation of MoEDAL is to directly search for the magnetic monopole or dyon and other highly ionizing Stable (or pseudo-stable) Massive Particles (SMPs) at the LHC [Int. J. Mod. Phys. A 29 (2014) 1430050].

The experimental set-up is an example of a low cost - high physics potential project in which the existing LHC infrastructure within the LHC b experimental cavern is used for an assembly of the passive set of emulsion based detector elements.



A three-dimensional schematic depiction of the deployment of the MoEDAL detector around the LHCb VELO region at Point 8 of the LHC.

The Helsinki group plans to contribute to the MoEDAL experiment by using the special optical scanning techniques developed at the Helsinki Detector Laboratory [T. Hildén, *Quality Assurance of the Gas Electron Multiplier Detectors*, PhD thesis to be presented for public examination in spring 2015] for the search of highly ionizing particles in the emulsion sheets.

Antiproton-Proton Collider Physics at the Tevatron - Results from the CDF Experiment

For more than a decade, the Helsinki group has participated in a frontier high energy collider experiment, the CDF experiment at the Fermilab 2 TeV antiproton-proton collider. The Tevatron collider paved the way for the LHC Physics programmes, and still provides important complementary physics input to discovery physics such as the Higgs studies. As an example, the CDF analysis on Higgs decays into b-bbar pairs still provides superior sensitivity compared to the LHC experiments.

In addition to the highly popular Higgs studies, there are a number of physics analysis achievements with lesser publicity - still these represent significant new observations in high energy physics [*Forward Physics - Appendix for Annual Report 2014*, http://www.hip.fi/fp-app-ar2014]. The Helsinki CDF project has produced a record number of high impact Physical Review D and Physics Letters publications from the year 2012 on. In addition, a number of PhD and MSc theses were produced within the Helsinki group on Higgs (PhD thesis by F. Devoto) and top quark studies (MSc theses by M. Kalliokoski, P. Mehtälä and T. Aaltonen, PhD thesis by T. Mäki). In 2012, the exclusive photon-photon process in high energy hadron collisions was observed for the first time and analysed by the Helsinki group (PhD thesis by E. Brücken). A set of selected year 2014 physics highlights of the CDF experiment is presented in [*Forward Physics - Appendix for Annual Report 2014*, http://www.hip.fi/fp-app-ar2014].

The Helsinki CDF project is an example of a low cost - high physics impact project: the Helsinki group's participation in the CDF has been mostly facilitated by two major research grants by the Academy of Finland. Continuous support by the Helsinki Institute of Physics and the Department of High Energy Physics; University of Helsinki is gratefully acknowledged.

CLOUD

Markku Kulmala, CLOUD project leader

Background

Atmospheric aerosol particles influence the Earth's radiative balance and therefore the whole climate system. This influence is exerted by two mechanisms. First, aerosol particles can directly reflect or absorb solar radiation. Second, they can act as seeds for cloud condensation and cloud droplet freezing and thereby affect the cloud albedo, extent, precipitation and lifetime. To understand the climate system, it is therefore important to also understand the dynamical behaviour of ambient aerosol particles and cloud droplets, including the formation and growth processes of aerosols, cloud droplet activation and ice nucleation.

The CLOUD (Cosmics Leaving OUtdoor Droplets) experiment at CERN is currently one of the most advanced laboratory set-ups for studying the formation and growth of aerosol particles over a wide range of simulated conditions. Recent upgrades also allow for studying physical processes in clouds, such as cloud droplet activation and ice nucleation. For all the experiments at CLOUD, galactic cosmic rays (GCR) can be simulated, and their influence on physical or chemical processes investigated. A potential effect of GCR on cloud formation or properties is expected by numerous indirect observations and theoretical studies suggesting that GCR may exert a significant influence on the Earth's cloud cover and climate. The main proposed mechanisms are an enhancement of nucleation rates (i.e., the rate of formation of new particles from gas-phase precursors) by ions produced by GCR, and an enhancement of the formation of ice particles due to ionization by GCR. To date, however, the presence or significance of an influence of GCR on any such mechanism has not been experimentally verified. The CLOUD experiment aims at finding pathways for the phenomenon and their significance. Due to its high technical standards, insights are also gained on other details of the investigated processes that are still not well understood, such as nucleation and the initial growth of aerosol particles. The experiment is being undertaken by 21 institutes from 9 countries with a strong Finnish contribution.

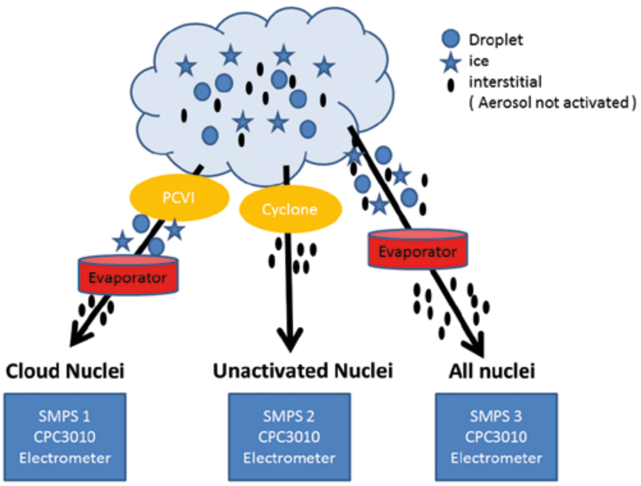
Experiments in 2014

In 2014, the first half of the year was dedicated to workshops, paper writing and development of instruments. In the second half of the year an intensive measurement campaign was organised at the CLOUD chamber at CERN. The CLOUD9 campaign from September to December 2014 had multiple research topics:

- Investigation of the chemistry happening inside a cloud using cloud condensation nuclei (CCN) of different composition and varying the gas-phase composition
- Investigation of ice nuclei (IN) capability of different seed aerosols and under various beam conditions
- Studies of different ion production mechanisms inside the CLOUD chamber
- Calibration and validation of different measurement techniques.

A wide variety of instruments was provided by the participating institutes and deployed during these experiments. The Finnish team made a major contribution to the CLOUD9 experiment, with a total of 4 persons (1 post-doc, 3 PhD students) working on site in CERN during the campaign, while the rest of the Helsinki team provided daily remote technical and data analysis support.

The CLOUD facility in the T11 area in CERN during the CLOUD9 campaign in autumn 2014. The pion/muon beam arrives from the right and hits a hodoscope that monitors the beam intensity before it passes through the chamber to the left. Instruments were employed on the 16 ports around the chamber and the new additional ports at the top and bottom of the chamber.

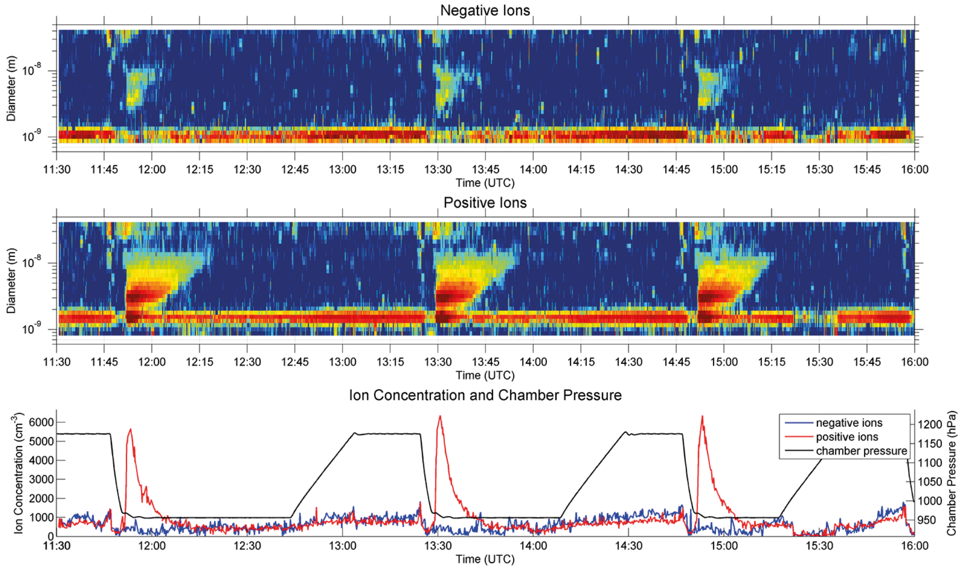


Schematic set-up of CLOUD aerosol instrumentations to study effects of charges on cloud activation. The three set-ups are running in parallel and are simultaneously monitoring the size distribution, total number and charged fraction of a) cloud nuclei (the ones which have been activated into cloud droplets or ice), b) un-activated nuclei (the ones which did not make it to droplets or ice) and c) all nuclei (activated and un-activated nuclei). By looking at these nuclei properties (size distribution, charged fraction) we gain information about cloud activation processes.

CLOUD9: The CLOUD chamber apparatus was implemented with three new external seed aerosol generators. The CLOUD chamber was also equipped with a new air pressure burst system, providing the possibility to study the effect of friction on the charging enhancement of water droplets and ice crystals. Two fast response-time temperature strings inside the CLOUD chamber monitored the chamber temperature profiles vertically and horizontally. Three CCD cameras were installed to monitor ice formation on the walls and cloud formation on the beam track of the SIMONE detectors. The chamber was equipped with an extensive suite of optical detection systems, aerosol instruments and mass spectrometers for studying comprehensively the properties of the cloud droplet and ice crystal populations formed inside the chamber upon expansions. The full list of instruments used during the CLOUD9 campaign is

- Chemical Ionization APi-TOF (CI-APi-TOF) for detecting neutral clusters below ~ 2 nm diameter
- Neutral cluster and Air Ion Spectrometer (NAIS) for ion and neutral particle size distributions up to 40 nm
- Proton-Transfer-Reaction Time-Of-Flight mass spectrometer (PTR-TOF) for gas-phase measurements
- Gas instruments for SO_2, O_3, NO_x and H_2O concentrations
- Two Particle Size Magnifiers (PSM) for detecting particles down to ~ 1.4 nm
- Three Scanning Mobility Particle Sizers (SMPS) for size distributions of 20–350 nm particles
- Three electrometers, each coupled with a butanol based CPC
- 3View-Cloud Particle Imager (3VCPI)
- Ultra High Sensitivity Aerosol Spectrometer (UHSAS)
- White Light Aerosol Spectrometer (Welas)
- Cloud Aerosol Spectrometer (CAPS)
- Scattering Intensity Measurement for the Optical detection of icE (SIMONE)
- Cloud Condensation Nuclei Counter (CCNC)
- Spectrometer for Ice Nuclei (SPIN)
- APi-TOF for Ion Composition (only in charge separation experiment).

The Finnish team was responsible for the measurement of ions and aerosol particles in the size range 0.8 to 42 nm, deploying a NAIS, PSM, SMPS, CPCs and Electrometer. The three identical sets of SMPS, CPC and Electrometer were installed to measure different properties of cloud seed particles, looking at different parts of the cloud using three specials inlets. They were measuring the 1) activated aerosol, 2) non-activated aerosol and 3) total aerosol (see the figure to the left). The two switching PSMs with two cut-off sizes were used to look at new particle formation while clouds were evaporating.



Size distributions of positive and negative ions (top and middle panel), and the concentrations of ions smaller than 20 nm and the chamber pressure (bottom panel) during expansion experiments at -30°C. A cloud forms in the chamber when the pressure drops and chamber air is cooled. This leads to a rapid increase in the 0.8–20 nm ion concentration of positive ions.

A special rebuilt pressure resistant and temperature controlled NAIS monitored ions during all the processes of the cloud formation and evaporation.

CLOUD9 extension: The CLOUD9 campaign was extended to perform more experiments focusing on ion studies. Observations of formation of 2–10 nm ions during the chamber expansions had already been made during the CLOUD8 campaign. In CLOUD9, a dedicated set of runs was performed to investigate the processes forming these ions. Conditions in the chamber were varied from -54°C to 5°C with different concentrations of cloud condensation nuclei and varying mixing fan speeds. Also the effect of ionization from the PS beam on the intensity of the ion bursts was studied. The NAIS continued operation with the sample dilution system developed for the earlier campaigns at CLOUD.

Data Analysis, Education and Reporting of Results

A comprehensive analysis of the data collected during the CLOUD7-8 campaigns is on-going within the working groups set up at the CLOUD Manchester meeting in March 2014. Several papers are currently under review, some are about to be submitted and some others have been published, such as Riccobono et al. (Science, 2014), or Kürten et al. (PNAS, 2014), for example. A complete list of publications is available on the new CLOUD website, http://cloud.web.cern.ch/content/publications.

Several CLOUD workshops were organised in Manchester, Leeds, Hyytiälä, CERN and Leipzig during 2014. Biweekly virtual meetings were organised within the different CLOUD working groups. Results were presented at different international conferences such as IAC (Busan, Korea) and IGAC (Natal, Brazil).

A summer school, "Formation and growth of atmospheric aerosols", organised by the University of Helsinki took place in August 2014 at Hyytiälä Forestry Field Station in Finland. All the PhD students in the CLOUD-TRAIN programme participated in this summer school, and obtained theoretical background relevant for the experiments conducted in the CLOUD project.

Planck-Euclid

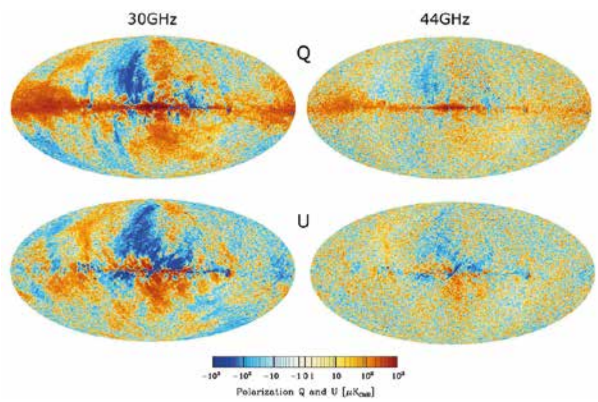
Hannu Kurki-Suonio,
Planck-Euclid
project leader

Background

Planck and Euclid are the two cosmology missions of the European Space Agency (ESA). The Planck satellite was launched on May 14th 2009, and made science observations from August 13th 2009 to October 3rd 2013. The main purpose of the Planck mission was to measure the cosmic microwave background (CMB) with unprecedented accuracy, and use this to determine the properties of the universe. Planck carried two instruments, the Low Frequency Instrument (LFI) and the High Frequency Instrument (HFI). Planck data analysis will continue until 2016.

The main purpose of Euclid is to study the so-called ”Dark Energy Question”: why is the expansion of the universe accelerating? Is it due to a mysterious ”dark energy” permeating the universe, does the law of gravity deviate from general relativity at cosmological distance scales, or is there yet another explanation, possibly related to poorly understood effects of inhomogeneities on observations? In the summer of 2013 ESA signed the contracts with industry for building the Euclid satellite and the planned launch is in March 2020. Over the course of 6 years Euclid will photograph over one third of the sky in visible and near infrared, obtaining images of over a billion galaxies and spectra of tens of millions of galaxies. Based on this data, the Euclid Consortium will determine the 3-dimensional distribution of galaxies and dark matter in the universe.

Euclid and Planck complement each other ideally in improving our understanding of the universe, its structure, composition, origin, and governing forces. In 2014 the Planck-Euclid group at HIP and the Physics Department of the University of Helsinki divided their time between analysing Planck data and preparing for the Euclid mission.

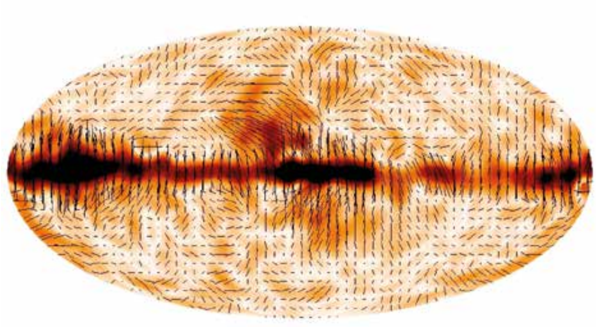


The polarisation of the microwave sky at the two lowest frequencies, 30 and 44 GHz, measured by Planck. Polarisation is represented by the two Stokes parameters Q and U, Q giving the vertical (Q positive) or horizontal (Q negative) polarisation component, U the diagonal component. These maps are in Galactic coordinates. At 30 GHz the polarisation is dominated by synchrotron radiation from our own Galaxy.
(ESA/Planck Collaboration, preliminary)

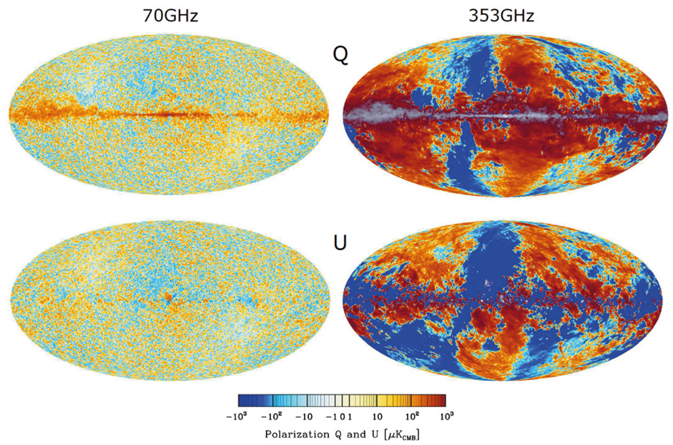
Planck Data Analysis

The Helsinki group has been responsible for producing the sky maps for the three LFI frequencies (30, 44 and 70 GHz) as well as for a number of related tasks, including null tests on the maps, estimation of their residual noise correlations, and producing large Monte Carlo simulations (at CSC - the Finnish IT Centre for Science) of the data. These simulations are needed to support the analysis of the flight data. We have also participated in the development of improved calibration and beam deconvolution methods for LFI.

We also participate in the estimation of cosmological parameters and constraints on inflation models from the CMB angular power spectra.



The large-scale polarisation observed by Planck at the 70 GHz frequency (the colour indicates the magnitude of the polarisation, the short lines both the direction and magnitude) in Galactic coordinates. The strongest polarisation at and near the plane of the Milky Way (which lies horizontally across the image in the middle) is due to Galactic synchrotron radiation, but further away we observe CMB polarisation.
(ESA/Planck Collaboration)



The polarisation of the microwave sky at the Planck 70 GHz and 353 GHz channels. At 353 GHz the polarisation is dominated by radiation from dust in our own galaxy, but at 70 GHz the cosmic microwave background dominates except near the Milky Way (the horizontal band in the middle).
(ESA/Planck Collaboration, preliminary)

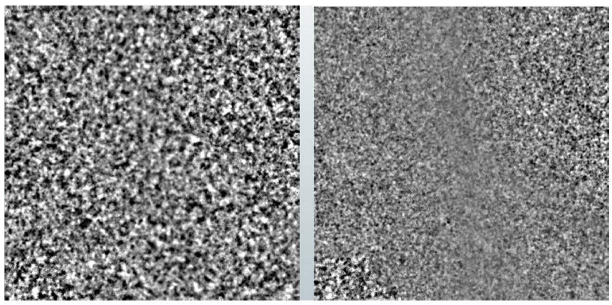
In particular, we are responsible for fitting cosmological models with primordial isocurvature (i.e., non-adiabatic) perturbations to Planck data.

The first major Planck data release was in March 2013, based on the first 15 months of Planck data on CMB temperature anisotropy. By end of 2014, we had almost completed the analysis for the second major data release, based on four years of Planck data, including also data on CMB polarisation, and preliminary cosmological results were already presented in the Planck conference in Ferrara in December 2014.

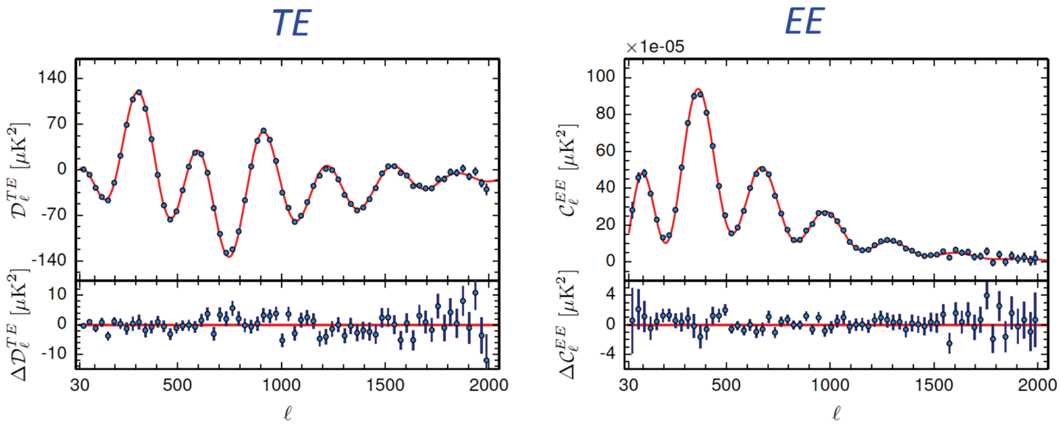
Planck Results

Planck released full-sky results of the polarised radiation from galactic dust [Planck Collaboration, "Planck intermediate results. XXX. The angular power spectrum of polarised dust emission at intermediate and high Galactic latitudes", arXiv:1409.5783] showing that the earlier purported detection of a primordial polarisation B-mode by the BICEP2 telescope at the South Pole must have been contaminated by this radiation from galactic dust.

The first cosmological results based on the full 4-year Planck satellite mission including data on the polarisation of the CMB remain in agreement with the 5-parameter standard cosmological model. In this LambdaCDM model, the main energy/matter components of the universe are dark energy, cold dark matter (CDM), and ordinary matter, with a uniform time-independent density of dark energy (the cosmological constant "Lambda"), and the primordial perturbations responsible for the origin of structure were statistically simple ("Gaussian") and almost, but not quite, scale independent, as predicted by the simplest cosmological "inflation" models. The values of these parameters are tightened by a factor of 1.5 to 2 from Planck's 2013 results - and by a factor of 3 from pre-Planck data. Planck detected a number of hard-to-observe features of the standard cosmological model including the gravitational lensing of the CMB polarisation and the free-streaming nature of the cosmic neutrino background. Planck also put the first upper limits on the non-Gaussianity of CMB



Small-scale CMB polarisation observed by Planck. The polarisation field on the sky can be divided into an E-mode (divergence) and a B-mode (curl). By combining the Planck polarisation maps at different frequencies the Galactic contribution can be removed to reveal the CMB polarisation. The left (right) panel shows the CMB E-mode (B-mode) polarisation in a 10-degree-by-10-degree region around the North Ecliptic Pole as observed by Planck. The B-mode observation is consistent with instrumental noise (which is at the same level for both modes) and thus shows no detection of a CMB B-mode, whereas the CMB E-mode shows up clearly.
(ESA/Planck Collaboration, preliminary)



Angular power spectra of the polarisation of the cosmic microwave background, showing how strong the polarisation structure is at each angular scale in the sky. The CMB polarisation is mainly in the E mode. The right panel shows the strength of CMB E-mode polarisation and the left panel its correlation with the CMB temperature anisotropy. The horizontal axis gives the angular scale in terms of the multipole number l; the corresponding angle is roughly 180 degrees / l. The blue dots are measurements by Planck; the red curve is the prediction of the standard LambdaCDM cosmological model with parameter values fit to the CMB temperature data. The bottom of each panel gives the residuals, i.e., difference of data from model, in an expanded scale. *(ESA/Planck Collaboration, preliminary)*

polarisation and tightened the limits to decaying dark matter particles in the universe, ruling out a model proposed to explain the high number of positrons observed by other space observatories, like the Alpha Magnetic Spectrometer and the Fermi Gamma-ray Space telescope.

Preparation for the Euclid Mission

The next cosmology mission after Planck will be Euclid. Euclid is a wide-angle space telescope, with imaging instruments at the visible and near infrared wavelengths and a near-infrared spectrometer. It will observe the last three quarters - about 10 billion years - of the history of the universe; complementing Planck, whose cosmological measurements are mainly from the 400 000-year-old early universe. We are participating in the development of data analysis methods for Euclid and will eventually analyse part of the Euclid data. In 2014 we participated in developing the data quality part of the Euclid data model.

We operate one of the nine Euclid Science Data Centres, SDC-Finland. To provide a uniform environment for the Euclid analysis codes, the SDCs operate on virtual machines. Currently the virtual machines of SDC-Finland run on the Pouta cloud service at the CSC Kajaani Data Center, and we have participated in and passed the four first ”SDC challenges” devised by the Euclid system team. In the latest challenge, the SDCs produced simulated Euclid data in a co-ordinated manner, so that requests for simulated data were sent from a central Euclid Archive System (EAS) to the SDCs, which then automatically produced the requested simulated data, and returned to the EAS metadata describing the produced data allowing all the SDCs to access the data produced at the other SDCs.

Administration

Mikko Sainio

The graduate education of physics students continues to be one of the main tasks of the Institute. The past year has seen a major change in the graduate education at the University of Helsinki. Four graduate schools, including the Doctoral School in Natural Sciences (http://www.helsinki.fi/doctoral-schools/natural-sciences/index.html), started their operations at the beginning of 2014. The HIP graduate students who take their degree at the University of Helsinki belong to the Doctoral programme in particle physics and universe sciences PAPU (http://blogs.helsinki.fi/papu-dp/) or the Doctoral programme in materials research and nanosciences MATRENA (http://blogs.helsinki.fi/matrena-dp/). Graduate education in other partner universities is organised in a similar manner as the Graduate Schools. In addition to the graduate students who are supported by the Doctoral programmes or by the Institute, a fair number of undergraduate students join the research groups and complete their Masters' thesis work at the Institute. Many of these students continue as graduate students in the Institute projects upon graduation. In particular, the popular summer student jobs at CERN have attracted students to graduate studies. During the period 2010–2014, 46 doctoral degrees and 60 Masters' degrees have been earned in HIP research projects.

The National Board of Education (Opetushallitus) has continued the collaboration with HIP and the Jyväskylä Educational Consortium in the CERN co-operation high school network and the collaboration with Björneborgs Svenska Samskola in the TekNatur/CERN network for Swedish speaking high school students. The aim is to develop the role of subatomic physics in school curricula in co-operation with CERN. In 2014 this programme attracted 372 Finnish students and 54 of their teachers. A related programme has been operated to bring high school physics teachers to CERN for continuing education courses. In 2014, 19 teachers participated in this programme. These visits have generated considerable coverage in local newspapers all over the country: 20 articles in total in 2014.

The technological and commercial co-operation between Finnish industry and CERN has been co-ordinated by HIP in collaboration with Top Science Services LLC, which has been the contractor with TEKES, the National Technology Agency of Finland. However, the contract with TEKES came to the end at the end of March, 2014. Therefore, new directions and solutions have to be sought. For partial solution of this situation HIP is launching with CERN a "Business Incubation Centre" pilot project which aims at supporting new business innovations in the fields of CERN technologies. Moreover, the HIP Technology Programme will use some of its resources to provide industrial liaison services both at CERN and FAIR.

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	Veli-Matti Virolainen, Vice Rector (until 20.11.2014) (Lappeenranta University of Technology)
	Kenneth Österberg (Chosen by personnel of HIP)

The Board: Jaakko Puhakka, Tuure Tuuva (substitute member), Mikko Ritala, Rauno Julin, Hannu Koskinen, Jouko Väänänen, Tuija Pulkkinen, Kari J. Eskola and Kenneth Österberg.

The Scientific Advisory Board

Chairman Philippe Bloch, Professor (CERN)

Members:

Wilfried Buchmüller, Professor (DESY)

Barbara Erazmus, Professor (CERN and CNRS)

Aarne Oja, Professor (VTT)

Günther Rosner, Professor (FAIR, U. Glasgow)

Wolfram Weise, Professor (ECT*, TU München)

Barbro Åsman, Professor (U. Stockholm)

Personnel

Theory Programme

K. Rummukainen, prof., programme director
M. Hindmarsh, prof., adj. senior scientist
K. Kajantie, prof., adj. senior scientist
A. Krasheninnikov, adj. senior scientist
M. D'Onofrio, scientist
S. Tähtinen, grad. student

Cosmology of the Early and Late Universe

S. Räsänen, docent, proj. leader
K. Enqvist, prof., adj. senior scientist
K. Kainulainen, prof., adj. senior scientist
T. Markkanen, scientist
M. Karčiauskas, adj. scientist
S. Nadathur, adj. scientist
S. Nurmi, adj. scientist
T. Sekiguchi, adj. scientist
T. Alanne, grad. student
S. Flender, grad. student
H. Jukkala, grad student
K. Kettula, grad. student
M. Lavinto, grad. student
T. Meriniemi, grad. student
H. Nyrhinen, grad. student
M. Pääkkönen, grad. student
S. Rusak, grad. student
T. Tenkanen, grad. student
V. Vaskonen, grad. student
P. Wahlman, grad. student

High Energy Phenomenology in the LHC Era

A. Vuorinen, docent, proj. leader
P. Hoyer, prof., adj. senior scientist
K. Huitu, prof., adj. senior scientist
O. Lebedev, prof., adj. senior scientist
E. Keski-Vakkuri, adj. senior scientist
K. Tuominen, docent, adj. senior scientist
T. Brauner, scientist
T. Zingg, scientist
A. Amato, adj. scientist
P. Bandyopadhyay, adj. scientist
S. Di Chiara, adj. scientist
I. Ghisoiu, adj. scientist
C. Gross, adj. scientist
N. Jokela, adj. scientist
V. Keus, adj. scientist
D. Weir, adj. scientist
T. Alho, grad. student
A. Keçeli, grad. student
L. Leinonen, grad. student
T. Tenkanen, grad. student
P. Tiitola, grad. student
H. Waltari, grad. student
A. Pönni, student

QCD and Strongly Interacting Gauge Theory

T. Lappi, docent, proj. leader
K. J. Eskola, prof., adj. senior scientist
T. Renk, adj. senior scientist
H. Niemi, scientist
H. Paukkunen, scientist
R. Perez-Ramos, adj. scientist
I. Helenius, grad. student
H. Mäntysaari, grad. student
J. Peuron, grad. student
T. Rantalaiho, grad. student
J. Suorsa, grad. student

Nuclear Structure for Weak and Astrophysical Processes

M. Kortelainen, Dr., proj. leader
J. Dobaczewski, prof., adj. senior scientist
W. Satuła, prof., adj. senior scientist
J. Niskanen, docent, adj. senior scientist
T. Oishi, scientist

Domain Wall Dynamics

L. Laurson, Dr., proj. leader
V. Estévez Nuño, scientist
T. Herranen, grad. student

CMS Programme

P. Eerola, prof., programme director

CMS Experiment

K. Lassila-Perini, Dr., proj. leader (at CERN)
R. Kinnunen, senior scientist
T. Lampén, senior scientist
S. Lehti, senior scientist
V. Karimäki, adj. senior scientist
J. Tuominiemi, adj. senior scientist
M. Kortelainen, scientist
M. Voutilainen, scientist
L. Wendland, scientist
G. Fedi, grad. student
T. Järvinen, grad. student
J. Pekkanen, grad. student
J. Heikkilä, student
E. Pekkarinen, student

CMS Upgrade

J. Härkönen, Dr., proj. leader
I. Kassamakov, senior scientist
P.-R. Luukka, senior scientist
E. Tuominen, senior scientist
T. Mäenpää, scientist
E. Tuovinen, scientist
T. Arsenovich, grad. student
A. Karadzhinova, grad. student
T. Peltola, grad. student
A. Winkler, grad. student
O. Pöyry, student

Tier-2 Operations

T. Lindén, Dr., proj. leader, grid coordinator
S. Toor, scientist (Uppsala)
O. Kraemer, student

TOTEM

H. Saarikko, prof., proj. leader
K. Österberg, senior scientist
H. Niewiadomski, scientist
T. Naaranoja, grad. student
F. Oljemark, grad. student
J. Welti, grad. student

Nuclear Matter Programme

A. Jokinen, prof., programme director

ALICE

J. Rak, prof., proj. leader
D. J. Kim, senior scientist
S. S. Räsänen, senior scientist
E. Brücken, scientist
N. Novitzky, scientist
B. Chang, grad. student
T. Hildén, grad. student
J. Král, grad. student
T. Snellman, grad. student

ISOLDE

P. Greenlees, prof., proj. leader
R. Julin, prof., adj. senior scientist
I. Moore, adj. senior scientist
T. Grahn, adj. scientist
J. Pakarinen, adj. scientist
P. Papadakis, adj. scientist
P. Rahkila, adj. grad. student

FAIR

A. Jokinen, prof., proj. leader
E. Tuominen, proj. coordinator
F. García, lab. engineer
K. Rytkönen, lab. engineer
H. Penttilä, adj. scientist
S. Rinta-Antila, adj. scientist

Technology Programme

S. Mäkinen, prof., programme director

Accelerator Technology

K. Österberg, docent, proj. leader
K. Nordlund, prof., adj. senior scientist
F. Djurabekova, senior scientist
M. Aicheler, scientist
S. Parviainen, scientist
J. Väinölä, researcher
F. Smeds, lab. engineer
K. Avchachov, grad. student
E. Baibuz, grad. student
A. Korsbäck, grad. student
A. Leino, grad. student
R. Montonen, grad. student
A. Ruzibaev, grad. student
J. Muszynski, student
R. Rajamäki, student
R. Ruuth, student

Green Big Data

T. Niemi, Dr., proj. leader (at CERN)
A.-P. Hameri, prof., senior scientist
J. K. Nurminen, prof., adj. senior scientist
J. White, senior scientist (at CERN)
K. Khan, grad. student
J. Kommeri, grad. student (at CERN)
G. Pestana, student

Biomedical Imaging

U. Ruotsalainen, prof., proj. leader
S. Ylipää, student

Detector Laboratory

E. Tuominen, lab. coordinator
J. Heino, lab. engineer
R. Lauhakangas, lab. engineer
R. Turpeinen, lab. technician

Forward Physics

R. Orava, prof., proj. leader
M. Mieskolainen, grad. student
R. Pankow, student

CLOUD

M. Kulmala, prof., proj. leader
J. Duplissy, scientist
T. Nieminen, scientist

Planck-Euclid

H. Kurki-Suonio, docent, proj. leader
M. Savelainen, scientist
J. Väliviita, adj. scientist
A.-S. Suur-Uski, grad. student
K. Kiiveri, student
V. Lindholm, student
E. Palmgren, student

Administration and Support

J. Äystö, prof., director
M. Sainio, docent, adm. manager
T. Sandelin, financial manager
T. Hardén, secretary
T. Heikkilä, secretary
T. Karppinen, secretary (at CERN)
T. Onnela, secretary (at CERN)
A. Heikkilä, tech. coordinator (at CERN)
R. Rinta-Filppula, ped. expert (at CERN)
J. Aaltonen, lab. engineer

Seminars

Seminars held in Helsinki

January 21st B. Goutéraux (NORDITA, Stockholm, Sweden)
Holographic metals and insulators

February 4th Y. Mambrini (Orsay, Frace)
Phenomenological aspects of Dark Matter in the light of recent experimental results

February 6th A. Kurkela (CERN, Switzerland)
Thermalization in weakly coupled nonabelian plasmas

February 18th J. Kersten (Hamburg, Germany)
New physics in the late early universe

February 25th A. Amato (Swansea, UK)
Transport coefficients of quark-gluon plasma

February 25th D. Rischke (Frankfurt, Germany)
Inhomogeneous phases in dense strongly interacting matter - a generic phenomenon?

March 4th L. Covi (Göttingen, Germany)
SuperWIMPs at the LHC

March 10th M. Långvik (Marseille, France)
Aspects of locally conformal spinnetworks

March 11th G. Nardini (DESY, Germany)
Higgs sector and collider signatures in the triplet extension of the MSSM

March 18th M. Mirkazemi (MPI, Garching, Germany)
Brightest X-ray clusters of galaxies in the CFHTLS wide fields: red sequence finder, optical mass estimator, and stellar mass estimation

March 25th M. Möttönen (Aalto Univ.)
Observation of Dirac monopoles in a synthetic magnetic field

April 1st V. Keus (Southampton, UK)
Multi Higgs doublet models

April 8th M. Gouzevitch (Universite Claude Bernard-Lyon I, France)
Standard Model physics at the LHC

April 15th T. Lindén (HIP)
Compact fusion reactors

April 22nd R. Paatelainen (Jyväskylä)
Modeling the space-time evolution of ultrarelativistic heavy-ion collisions

April 24th A. Schmitt (Vienna, Austria)
Sound modes and two-stream instability in a relativistic superfluid

May 6th M. Heller (Amsterdam, The Netherlands/ Warsaw, Poland)
Gauge fields out of equilibrium - a holographic approach

May 8th N. Evans (Southampton, UK)
Dynamic AdS/QCD & the conformal window

May 13th M. Panero (Madrid, Spain)
Real-time dynamics from a Euclidean lattice: the physics of jet quenching in high-temperature QCD

May 14th P. Dendooven (Groningen, The Netherlands)
Proton therapy research at KVI-Center for Advanced Radiation Technology

May 20th B. Mukhopadhyaya (Allahabad, India)
The Higgs boson as the gateway to new physics

May 27th J. Dobaczewski (Jyväskylä)
Nuclear density functional theory

May 28th M. Frank (Montreal, Canada)
Charginos and neutralinos beyond MSSM

June 3rd M. Järvinen (Heraklion, Greece)
New results from holographic V-QCD

June 5th S. K. Rai (Allahabad, India)
Some Higgs studies after the "Higgs" discovery

June 6th C. Bennett (Baltimore, USA)
Cosmology and the Cosmic Microwave Background

June 9th I. Ghisoiu (Bern, Switzerland)
Three-loop Debye mass and effective coupling in thermal QCD

June 10th A. Kurkela (CERN, Switzerland)
Bottom-up thermalization in heavy-ion collisions

August 14th T. Alho (Jyväskylä)
Thermodynamics of holographic models for QCD in the Veneziano limit

August 14th M. Ihl (Porto, Portugal)
Holographic bilayer/monolayer phase transitions

August 19th T. Markkanen (Helsinki)
Spacetime curvature and the Higgs stability during inflation

August 26th M. Laine (Bern, Switzerland)
Towards first principles in particle cosmology

September 2nd G. von Gersdorff (Sao Paulo, Brazil)
New physics effects in anomalous gauge boson vertices

September 9th B. Dev (Univ. Manchester, UK)
Naturally aligned two Higgs doublet model and its collider signatures

September 30th S. Sheikh-Jabbari (IPM, Tehran, Iran)
The quest for quantum gravity, the necessity and viewpoints

September 30th T. Hapola (Durham, UK)
Higgs plus multiple jets with HEJ

October 2nd A. Rajantie (Imperial College, UK)
Quantum field theory of elementary magnetic monopoles

October 7th S. Roy (Indian Association for the Cultivation of Science, Kolkata, India)
Phenomenology of U(1)_R -lepton number model

October 9th L. Wendland (Helsinki)
New results on charged Higgs boson searches

October 14th A. Falkowski (Orsay, France)
Higgs and electroweak precision data

October 16th M. Lippert (Amsterdam, The Netherlands)
Holographic anyonic superfluidity

October 28th T. Zingg (Helsinki)
A holographic model for strongly correlated fermions

November 4th P. Osland (Bergen, Norway)
CP violation in the Higgs sector and LHC constraints

November 11th D. Aristizabal (Univ. Liege, Belgium)
From neutrino masses to dark matter

November 13th T. Brauner (Vienna, Austria)
Applications of Galilei invariance in condensed matter physics

November 25th U. Maitra (HRI, India)
Status of additional scalar states at the LHC

December 9th C. Gross (Helsinki)
SUSY GUT models with non-Abelian flavour symmetry

December 16th N. Jokela (Helsinki)
Hall states in partially quenched Chern-Simons matter theories

Visitors

Theory Programme

Cosmology of the Early and Late Universe

M. Rinaldi (Italy) 28.–31.1.
T. Koivisto (Sweden) 3.–7.2.
S. Hotchkiss (UK) 17.–21.2
S. Yokoyama (Japan) 24.2.–7.3.
M. Bastero Gil (Spain) 3.–7.3.
K. Rosquist (Sweden) 11.–14.3.
S. Sarkar (UK) 20.–21.3.
D. Mulryne (UK) 16.4.–15.5.
V. Vennin (France) 5.–9.5.
F. Urban (Belgium) 28.–30.5.
C. Bennett (USA) 6.6.
M. Herranen (Denmark) 9.–11.6.
H. McCracken (France) 1.–3.7.
Y. Tada (Japan) 19.–24.8.
C. Haines (Chile) 11.9.
A. Golovnev (Russia) 17.9.–10.10.
F. Niedermann (Germany) 1.–3.10.
C. Rampf (UK) 3.–5.11.
A. Pourtsidou (UK) 11.–13.11.
D. Weir (Norway) 19.11.
R. Dupke (USA, Brazil) 30.11.–3.12.
J. Sakstein (UK) 2.–5.12.
D. Glavan (The Netherlands) 9.–11.12.

High Energy Phenomenology in the LHC Era

V. Keränen (UK) 16.2.2013–14.1.2014
M. Krššák (Brazil) 2.–10.1.
A. Kurkela (Switzerland) 5.–10.2.
S. Stricker (Austria) 24.2.–3.3., 5.–9.5.
D. Rischke (Germany) 25.2.
G. Nardini (Germany) 5.–13.3.
R. Paatelainen (Finland) 22.–24.4.
A. Schmitt (Austria) 23.–26.4.
Y. Zhu (Spain) 27.4.–3.5.
T. Zingg (The Netherlands) 3.–10.5.
M. Heller (The Netherlands) 4.–11.5.
N. Evans (UK) 7.–9.5.
M. Panero (Spain) 12.–18.5.
B. Mukhopadhyaya (India) 14.–29.5.
M. Frank (Canada) 18.–31.5.
S. K. Rai (India) 28.5.–19.6.
I. Ghisoiu (Switzerland) 6.–11.7.
G. von Gersdorff (Brazil) 1.–4.9.
O. Taanila (Switzerland) 19.–29.9.
S. Roy (India) 1.–31.10.
T. Brauner (Switzerland) 10.–15.11.
U. Maitra (India) 15.11.–23.12.

QCD and Strongly Interacting Gauge Theory

M. Sievert (USA) 19.–22.1.
D. Zaslavsky (USA) 23.–28.1.
B. Ducloué (France) 28.–31.1.
F. F. Van der Veken (Belgium) 5.–8.2.
D. Rischke (Germany) 13.–26.2.
G. Denicol (Canada) 16.–22.2.
P. Huovinen (Germany) 25.–28.3.
M. Stratmann (Germany) 3.–6.8.
M. Laine (Switzerland) 28.–30.8.

Planck-Euclid

M. Reinecke (Germany) 2.–7.3.
C. Bennett (USA) 6.6.

Conference participation, Talks and Visits by Personnel

Theory Programme

Cosmology of the Early and Late Universe

University of Stavanger,
10–14 March, Stavanger, Norway (T. Markkanen)

Annual Meeting of the Finnish Physical Society,
12 March, Tampere, Finland (talk by T. Alanne)

Colloquium,
11 April, Jyväskylä, Finland (talk by K. Kainulainen)

Progress on Old and New Themes in Cosmology (PONT) 2014,
14–18 April, Avignon, France (invited talk by K. Kainulainen, M. Lavinto, T. Markkanen)

Birzeit University,
16 April, Birzeit, West Bank, Palestine (S. Räsänen)

University of Barcelona,
19–23 April, Barcelona, Spain (T. Markkanen)

Arizona State University,
1–30 May, Tempe, AZ, USA (K. Kettula)

University of Stockholm,
13 May, Stockholm, Sweden (S. Räsänen)

Enqfest - 30 Years of Cosmology,
30–31 May, Helsinki, Finland (K. Kainulainen, organiser, M. Lavinto, S. Räsänen, organiser, P. Wahlman, organiser)

Clusters Paris 2014,
24–28 June, Paris, France (K. Kettula)

Rencontres du Vietnam 2014: Physics at LHC and Beyond,
10–17 August, Qui Nhon, Vietnam (invited talk by K. Kainulainen)

COSMO 2014,
25–29 August, Chicago, IL, USA (T. Markkanen)

McGill University,
1–3 September, Montreal, Canada (T. Markkanen)

University of Sussex,
15–20 September, Brighton, UK (T. Markkanen)

Particle Physics and Cosmology Workshop,
25–26 September, Tampere, Finland (talk by T. Alanne, talk by H. Jukkala, K. Kainulainen, M. Lavinto, talk by M. Pääkkönen, S. Räsänen, talk by V. Vaskonen)

Particle Cosmology after Planck,
25–29 September, DESY, Hamburg, Germany (T. Markkanen)

Dark Energy Interactions,
1–3 October, NORDITA, Stockholm, Sweden (S. Räsänen)

Particle Physics Day,
24 October, Jyväskylä, Finland (talk by T. Alanne, talk by V. Vaskonen)

Cluster Surveys Conference,
3–6 November, Madrid, Spain (K. Kettula)

York University,
24 November, Honolulu, HI, USA (talk by T. Alanne)

University of Toronto,
25 November, Toronto, Canada (talk by T. Alanne)

McGill University,
26 November, Montreal, Canada (talk by T. Alanne)

Fellow Selection Board Meeting,
3–4 December, NORDITA, Stockholm, Sweden (K. Kainulainen)

High Energy Phenomenology in the LHC Era

University of Santiago de Compostela,
13–15 January, Santiago de Compostela, Spain (talk by A. Vuorinen)

Workshop on Effective Field Theory for Quantum Many Body Systems,
15–17 January, Madrid, Spain (talk by T. Brauner, A. Vuorinen)

J. W. Goethe University,
20–24 January, Frankfurt am Main, Germany (talk by A. Vuorinen)

PRACE Prioritization Panel,
5–6 February, Brussels, Belgium (K. Rummukainen)

Uppsala University,
13–14 February, Uppsala, Sweden (talk by A. Vuorinen)

Annual Meeting of the Finnish Physical Society,
11–13 March, Tampere, Finland (session chairman A. Vuorinen)

Federal University of Rio de Janeiro and Sao Paulo State University,
18 March – 5 April, Rio de Janeiro and Sao Paulo, Brazil (talk by A. Vuorinen)

Vienna University of Technology,
14–20 April, Vienna, Austria (T. Brauner)

Technical University of Darmstadt,
22–23 April, Darmstadt, Germany (talk by A. Vuorinen)

University of Madrid,
27–29 April, Madrid, Spain (talk by K. Rummukainen)

Facing Strong Dynamics Workshop,
2–6 June, Liselund Castle, Borre, Denmark (invited talk by K. Rummukainen)

University of Regensburg,
2–6 June, Regensburg, Germany (talk by A. Vuorinen)

Vienna University of Technology,
23–25 June, Vienna, Austria (talk by A. Vuorinen)

Bielefeld University,
25–27 June, Bielefeld, Germany (A. Vuorinen)

Workshop on Strong and Electroweak Matter,
14–18 July, Lausanne, Switzerland (talk by K. Rummukainen, talk by A. Vuorinen)

Conceptual Advances in Lattice Gauge Theory (LGT14),
20 July – 1 August, CERN, Geneva, Switzerland (K. Rummukainen)

Workshop on Jets, Particle Production and Transport Properties,
3–8 August, Mainz, Germany (talk by A. Vuorinen)

LAGUNA 2014,
25–27 August, Helsinki, Finland (K. Rummukainen)

Workshop on Quark Confinement and the Hadron Spectrum,
8–12 September, St. Petersburg, Russia (talk by K. Tuominen, talk by A. Vuorinen)

NIKHEF,
15–18 September, Amsterdam, The Netherlands
(talk by A. Vuorinen)

Workshop on Holography,
21–28 September, Mainz, Germany (talk by T. Zingg)

Particle Physics and Cosmology Workshop,
25–26 September, Tampere, Finland (K. Rummukainen)

Graduate School Meeting,
25–26 September, Tampere, Finland (talk by T. Tenkanen)

University of Stavanger,
23–25 October, Stavanger, Norway
(invited talk by K. Rummukainen)

Workshop on Numerical Relativity,
8–15 December, CERN, Geneva, Switzerland
(A. Vuorinen)

QCD and Strongly Interacting Gauge Theory

Nordic Conference on Particle Physics,
2–7 January, Skeikampen, Norway (J. Peuron)

Brookhaven National Laboratory,
7–17 January, Upton, NY, USA (talk by H. Mäntysaari)

LHeC Workshop,
20–21 January, Chavanne-de-Bogis, Switzerland
(talk by H. Paukkunen)

J. W. Goethe University,
9–15 February, Frankfurt, Germany (talk by H. Niemi)

CERN,
24 February – 8 March, Geneva, Switzerland
(talk by R. Perez-Ramos)

Annual Meeting of the Finnish Physical Society,
11–13 March, Tampere, Finland
(talk by H. Mäntysaari, talk by R. Paatelainen)

The Approach to Equilibrium in Strongly Interacting Matter,
2–4 April, Brookhaven, NY, USA (talk by T. Lappi)

Lund University,
22–25 April, Lund, Sweden (talk by I. Helenius)

DIS 2014 - XXII International Workshop on Deep-Inelastic Scattering and Related Subjects,
28 April – 2 May, Warsaw, Poland
(talks by H. Mäntysaari, talks by H. Paukkunen)

Hydrodynamics for Strongly Coupled Fluids,
12–16 May, Trento, Italy (talk by H. Niemi)

J. W. Goethe University,
14–18 May, Frankfurt, Germany (talk by K. J. Eskola)

Quark Matter 2014,
19–24 May, Darmstadt, Germany (K. J. Eskola, talk by T. Lappi, H. Mäntysaari, talk by H. Niemi, R. Paatelainen, talk by H. Paukkunen, talk by T. Renk)

Workshop on Photon-Induced Collisions at the LHC,
2–4 June, CERN, Geneva, Switzerland
(talk by H. Mäntysaari)

NeD/TURIC-2014 Workshop,
9–14 June, Hersonissos, Crete, Greece
(K. J. Eskola, talk by I. Helenius, talk by R. Paatelainen)

IPhT Saclay,
11–19 June, Saclay, France (talk by T. Lappi)

3rd Heavy Ion Jet Workshop,
9–11 July, Lisbon, Portugal (talk by T. Renk)

3rd Workshop on Jet Modification in the RHIC and LHC Era,
18–20 August, Detroit, MI, USA (talk by T. Renk)

XLIV International Symposium on Multiparticle Dynamics (ISMD 2014),
8–12 September, Bologna, Italy (talk by R. Perez-Ramos)

10th International Workshop on High-pT Physics in the RHIC/LHC Era,
9–12 September, Nantes, France (talk by T. Renk)

Baruch College, CUNY,
19 September, New York, NY, USA (T. Lappi)

Workshop on the Ions at the Future Circular Collider,
22–23 September, CERN, Geneva, Switzerland
(talk by H. Paukkunen)

POETIC V: Physics Opportunities at an ElecTron-Ion Collider,
22–26 September, New Haven, CT, USA (talk by T. Lappi)

J. W. Goethe University,
23–26 October, Frankfurt, Germany (K. J. Eskola)

Particle Physics Day,
24 October, Jyväskylä, Finland (T. Lappi, H. Mäntysaari, H. Niemi, H. Paukkunen, J. Peuron)

Brookhaven National Laboratory,
27–31 October, Upton, NY, USA (talk by H. Paukkunen)

The 2nd International Conference on the Initial Stages in High-Energy Nuclear Collisions (IS2014),
3–7 December, Napa, CA, USA
(talk by T. Lappi, talk by H. Mäntysaari)

Ab Initio Approaches in Many-Body QCD Confront Heavy-Ion Experiments Workshop,
15–17 December, Heidelberg, Germany (talk by T. Lappi)

CMS Programme

Arcada University of Applied Sciences,
21 January, Helsinki, Finland (talk by T. Lindén)

Helsinki Association of Women Researchers,
27 February, Helsinki, Finland (P. Eerola in an invited panel on Internationalisation of Universities)

Annual Meeting of the Finnish Physical Society,
11–13 March, Tampere, Finland (P. Eerola, talk by J. Härkönen, T. Järvinen, talk by M. Kortelainen, J. Pekkanen, talk by M. Voutilainen)

Alumni Evening of the Faculty of Science, University of Helsinki,
20 March, Helsinki, Finland
(talks by P. Eerola, M. Kortelainen)

Annual Meeting of the Physical Society in Finland,
26 March, Helsinki, Finland (talk by T. Lindén)

Masterclass 2014,
7 and 11 April, Helsinki, Finland (J. Heikkilä, T. Järvinen, M. Kortelainen, T. Lampén, T. Lindén, T. Mäenpää, T. Peltola, talk by M. Voutilainen)

MAOL Spring Days 2014,
12 April, Espoo, Finland (talk by T. Lampén)

SciFest 2014,
24–25 April, Joensuu, Finland
(talk by S. Lehti, talk by M. Voutilainen)

EGI Community Forum,
19–23 May, Helsinki, Finland (P. Eerola, M. Kortelainen, K. Lassila-Perini, T. Lindén, talk by S. Toor)

2nd Workshop on Detectors for Forward Physics at LHC,
28–30 May, La Biodola, Isola d'Elba, Italy
(talk by J. Härkönen)

118th LHCC Meeting - Open Session,
4 June, CERN, Geneva, Switzerland (talk by J. Härkönen)

Teachers' Supplementary Course,
6 June, Helsinki, Finland (talk by T. Lampén)

24th RD50 Workshop,
11–13 June, Bucharest, Romania (talk by T. Peltola)

16th International Workshop on Radiation Imaging Detectors (iWoRID 2014),
22–26 June, Trieste, Italy (T. Peltola)

37th International Conference on High Energy Physics ICHEP 2014,
2–9 July, Valencia, Spain (talk by G. Fedi)

The 15th International Conference on B-Physics at Frontier Machines BEAUTY 2014,
14–18 July, Edinburgh, UK (talk by P. Eerola)

Plenary ECFA Meeting,
24–25 July, DESY, Hamburg, Germany
(report by P. Eerola)

16th International Workshop on Advanced Computing and Analysis Techniques in Physics Research (ACAT),
1–5 September, Prague, Czech Republic (talk by T. Lindén)

10th International Conference on Position Sensitive Detectors (PSD10),
7–12 September, Guildford, UK (talk by T. Peltola)

Prospects for Charged Higgs Discovery at Colliders,
16–18 September, Uppsala, Sweden (R. Kinnunen, talk by M. Kortelainen, talk by L. Wendland)

Tiedekulma CERN Seminar,
29 September, Helsinki, Finland (talk by T. Lampén)

Science Centre Heureka,
4–5 October, Vantaa, Finland
(talks by S. Lehti, talks by J. Tuominiemi)

10th International Conference on Radiation Effects on Semiconductor Materials, Detectors and Devices (RESMDD14),
8–10 October, Florence, Italy (talks by T. Peltola)

Science Centre Tietomaa,
10–12 October, Oulu, Finland (talks by S. Lehti)

Semiconductor Materials, Detectors and Radiation Hardness - 13th National Conference on Physics Mechanics,
17–19 October, Xiangtan, China (talk by J. Härkönen)

NeIC Glenna Kick-Off Meeting,
3 November, Stockholm, Sweden (talk by T. Lindén)

CMS Fall Offline and Computing Week,
3–7 November, CERN, Geneva, Switzerland
(talk by T. Lindén)

Etelä-Tapiola High School,
4 November, Espoo, Finland (talk by S. Lehti)

Säteilyturvallisuustutkimus Suomessa -Seminar,
5 November, Helsinki, Finland (talk by J. Härkönen)

25th RD50 Workshop,
19–21 November, CERN, Geneva, Switzerland
(talk by T. Peltola)

CMS Week,
15–19 December, Miami, FL, USA
(P. Eerola, M. Voutilainen)

TOTEM

Physics Colloquium, University of Jyväskylä,
4 April, Jyväskylä, Finland (talk by K. Österberg)

QCD and Forward Physics at the LHC,
14–18 April, Trento, Italy
(1 invited and 1 contributed talk by K. Österberg)

Long Term Strategy of INFN-CSN1 (LTS1) 2014,
22–24 May, La Biodola, Isola d'Elba, Italy
(invited talk by K. Österberg)

2nd Workshop on Detectors for Forward Physics at LHC and TOTEM Collaboration Meeting,
26–30 May, La Biodola, Isola d'Elba, Italy
(H. Saarikko, co-organised by K. Österberg)

Particle Physics Day,
24 October, Jyväskylä, Finland (F. Oljemark)

LHCC Special Session on Forward Physics,
18 November, CERN, Geneva, Switzerland
(invited talk by K. Österberg)

Workshop on Timing Detectors for CT-PPS,
19 November, CERN, Geneva, Switzerland
(talk by T. Naaranoja)

PAPU Day,
4–5 December, Tuusula, Finland (talk by J. Welti)

Oslo University,
8–10 December, Oslo, Norway (K. Österberg)

IV Workshop on QCD and Diffraction at the LHC,
15–17 December, Cracow, Poland (talk by K. Österberg)

Meetings with the LHCC Referees of TOTEM,
CERN, Geneva, Switzerland (talks by K. Österberg)

TOTEM Collaboration Meetings,
CERN, Geneva, Switzerland (T. Naaranoja, H. Saarikko, talks by F. Oljemark, J. Welti, and K. Österberg)

TOTEM Physics and Analysis Meetings,
CERN, Geneva, Switzerland (talks by F. Oljemark, J. Welti and K. Österberg, co-organised by K. Österberg)

CMS-TOTEM Combined Analysis Meetings,
CERN, Geneva, Switzerland
(talks by J. Welti, co-organised by K. Österberg)

Research Infrastructure Preparation Group Meetings, Vetenskapsrådet,
Stockholm, Sweden (K. Österberg)

Nuclear Matter Programme

ALICE

CERN,
1 January – 2 February, 25 February – 11 March, 26 May – 6 June, 23–24 August, Geneva, Switzerland (J. Rak)

ALICE Upgrade Meeting,
3–11 February, Geneva, Switzerland (J. Rak)

CERN,
10–31 March, Geneva, Switzerland (E. Brücken)

Annual Meeting of the Finnish Physical Society,
12 March, Tampere, Finland (T. Snellman)

ALICE Collaboration Meeting,
24–30 March, Geneva, Switzerland (J. Rak)

RRB Meeting,
29 April – 3 May, Geneva, Switzerland (J. Rak)

CERN,
30 April – 8 May, 24 May – 3 June, Geneva, Switzerland (J. Král)

CERN,
15 May – 3 June, Geneva, Switzerland (B. Chang)

Quark Matter 2014,
19–24 May, Darmstadt, Germany (B. Chang, D. J. Kim, J. Král, J. Rak, S. Räsänen, T. Snellman)

RD51,
16–19 June, Geneva, Switzerland (E. Brücken, T. Hildén)

ALICE Week and Summer Trainee,
30 June – 20 July, Geneva, Switzerland (J. Rak)

3rd International Conference on New Frontiers in Physics,
27 July – 7 August, Crete, Greece (invited talk by J. Rak)

CERN,
5–9 September, Geneva, Switzerland (S. Räsänen)

10th International Workshop on High-pT Physics in the RHIC/LHC Era,
8–12 September, Nantes, France (J. Rak)

ALICE Week,
13–26 September, Geneva, Switzerland (J. Rak)

Particle Physics Day,
24 October, Jyväskylä, Finland (talk by T. Snellman)

ALICE TPC Upgrade Planning Meeting,
12–13 November, Darmstadt, Germany
(talks by E. Brücken and T. Hildén)

ALICE TPC Upgrade Meetings,
CERN, Geneva, Switzerland
(talks by E. Brücken and T. Hildén)

ISOLDE

Annual Meeting of the Finnish Physical Society,
11–13 March, Tampere, Finland
(talk by T. Grahn, P. Papadakis)

Gosia Analysis Workshop,
29–30 April, Leuven, Belgium (talk by J. Pakarinen)

Advances in Radioactive Isotope Science, ARIS2014,
1–6 June, Tokyo, Japan
(T. Grahn, talk by J. Pakarinen, P. Papadakis)

EGAN Conference,
23–26 June, Darmstadt, Germany (talk by J. Pakarinen)

ISOLDE Workshop "50th Anniversary Edition",
15–17 December, CERN, Geneva, Switzerland
(talk by P. Papadakis, invited talk by J. Äystö)

FAIR

Advances in Radioactive Isotope Science, ARIS 2014,
1–6 June, Tokyo, Japan (invited talk by J. Äystö)

Super-FRS Collaboration Meeting,
12–14 November, Walldorf, Germany (talk by T. Grahn)

The 15th Program Advisory Committee for Nuclear Physics Experiments at RI Beam Factory,
12–13 December, Tokyo, Japan (talk by T. Grahn)

Technology Programme

Accelerator Technology

FAIR,
14–16 January, Darmstadt, Germany (F. Djurabekova)

CLIC Workshop 2014,
3–7 February, CERN, Geneva, Switzerland (F. Smeds, J. Väinölä and K. Österberg, talks by M. Aicheler and R. Montonen)

Towards Reality in Nanoscale Materials (TRNM) VIII Workshop,
9–12 February, Levi, Finland (F. Djurabekova, A. Leino)

Australian National University,
6–23 March, Canberra, Australia
(F. Djurabekova, A. Leino)

247th ACS National Meeting & Exposition,
16–20 March, Dallas, TX, USA
(invited talk by F. Djurabekova)

Tartu University,
24–26 March, Tartu, Estonia (F. Djurabekova)

2014 MRS Spring Meeting & Exposition,
21–25 April, San Francisco, CA, USA
(invited talk by F. Djurabekova)

Lewel Group Finland Oy,
20 May, Espoo, Finland (M. Aicheler, R. Montonen)

E-MRS 2014 Spring Meeting,
26–30 May, Lille, France
(symposium organiser F. Djurabekova)

REINM,
1–5 June, Astana, Kazakhstan
(invited talk by F. Djurabekova)

Doctoral Program in Concurrent Mechanical Engineering (DPCME) - Spring Seminar,
2–7 June, Zurich, Switzerland (talk by R. Montonen)

COSIRES 2014 Conference,
8–13 June, Alicante, Spain (S. Parviainen)

Lewel Group Finland Oy - Secondment,
9 June – 8 August, Oulu, Finland (R. Montonen)

27th International Vacuum Nanoelectronics Conference (IVNC),
6–10 July, Engelberg, Switzerland
(invited talk by F. Djurabekova)

Summer School at NRNU MEPhI,
30 July – 1 August, Moscow, Russia
(invited lecture by F. Djurabekova)

MeChanICS Final Meeting and Open Workshop,
28 August, Helsinki, Finland (organised by M. Aicheler, J. Väinölä and K. Österberg, talks by R. Montonen and F. Smeds)

HIP Scientific Advisory Board,
28–29 August, Helsinki, Finland
(F. Djurabekova and K. Österberg, talk by M. Aicheler)

Cockroft Institute for Accelerator Science and Technology,
1–3 September, Daresbury, UK
(invited seminar by F. Djurabekova)

13th European Vacuum Conference (EVC13),
8–12 September, Aveiro, Portugal (S. Parviainen)

E-MRS 2014 Fall Meeting,
15–18 September, Warsaw, Poland
(invited talk by F. Djurabekova)

IBMM 2014,
15–19 September, Leuven, Belgium (F. Djurabekova)

CERN,
29 September – 1 October, Geneva, Switzerland
(F. Djurabekova, K. Nordlund)

International Conference on Science and Technology for FAIR,
13–17 October, Worms, Germany
(F. Djurabekova, K. Nordlund)

NuMAT Conference,
27–30 October, Clearwater Beach, FL, USA
(invited talk by F. Djurabekova)

MatX-2 Workshop,
2–4 November, Darmstadt, Germany
(invited talk by F. Djurabekova)

Additive Manufacturing Workshop,
5 November, CERN, Geneva, Switzerland
(M. Aicheler, J. Väinölä)

Nanoscience Days 2014,
20–21 November, Jyväskylä, Finland (A. Leino)

K-Contract Kick-Off Meeting,
26 November, Helsinki, Finland (E. Baibuz, S. Parviainen, J. Väinölä and K. Österberg, talks by M. Aicheler and F. Djurabekova)

2014 MRS Fall Meeting & Exposition,
30 November – 5 December, Boston, MA, USA
(talk by A. Leino, symposium chair F. Djurabekova)

University of Manchester,
10–12 December, Manchester, UK (F. Djurabekova)

European Steering Group for Accelerator R&D (ESGARD) Meetings,
CERN, Geneva, Switzerland (K. Österberg)

CLIC/CTF3 Collaboration Board Meetings,
CERN, Geneva, Switzerland (K. Österberg)

CLIC Module Working Group and Review Meetings,
CERN, Geneva, Switzerland
(F. Smeds, J. Väinölä, co-organised by M. Aicheler)

Green Big Data

The Fourth International Conference on Smart Grids, Green Communications and IT Energy-aware Technologies ENERGY 2014,
20–24 April, Chamonix, France (talk by J. Kommeri)

16th International Workshop on Advanced Computing and Analysis Techniques in Physics Research (ACAT),
1–5 September, Prague, Czech Republic
(talk by G. Pestana)

Biomedical Imaging

European Association of Nuclear Medicine (EANM),
18–22 October, Gothenburg, Sweden (S. Ylipää)

IEEE NSS/MIC Conference 2014,
8–15 November, Seattle, WA, USA (D. Us)

Forward Physics

Duhok University,
12–15 May, Erbil, Iraq (invited lecture by R. Orava)

Scientific Advisory Committee of HIP,
28 August, Helsinki, Finland (talk by R. Orava)

Diffraction 2014 Conference,
10–16 September, Primosten, Croatia
(invited plenary talk by R. Orava)

International Institute of Physics School on ”New Trends in High Energy Physics and QCD”,
21 October – 2 November, Natal, Brazil (invited lectures by R. Orava)

ALICE ADA/ADC Project Meetings,
CERN, Geneva, Switzerland (R. Orava)

Diffractive Physics Meetings,
CERN, Geneva, Switzerland (R. Orava)

CLOUD

Summer School ”Formation and growth of atmospheric aerosols”,
13–22 August, Hyytiälä Forestry Field Station, Finland
(lectures by M. Kulmala, lecture by T. Nieminen)

IGAC,
22–26 September, Natal, Brazil (J. Duplissy)

Planck-Euclid

Planck Joint Core Team Meeting,
4–6 February, Paris, France
(H. Kurki-Suonio, M. Savelainen, A.-S. Suur-Uski)

Euclid SGS System Team Meeting,
7 February, Munich, Germany (H. Kurki-Suonio)

M4 ESA Microwave Polarization Satellite Meeting,
10 February, Paris, France (H. Kurki-Suonio)

Euclid Consortium Board Meeting,
13 February, Leiden, The Netherlands (H. Kurki-Suonio)

Planck Working Group 3 (CTP) Meeting,
3–5 March, Paris, France
(H. Kurki-Suonio, V. Lindholm, A.-S. Suur-Uski)

Planck LFI Core Team Meeting 37,
24–25 March, Bologna, Italy
(invited talk by A.-S. Suur-Uski)

Euclid SGS System Team Meeting,
26–28 March, Brugg, Switzerland
(H. Kurki-Suonio, V. Lindholm)

Euclid Consortium Meeting,
4–9 May, Marseille, France
(H. Kurki-Suonio, V. Lindholm)

Planck Joint Core Team Meeting,
12–16 May, Trieste, Italy (K. Kiiveri, H. Kurki-Suonio, V. Lindholm, A.-S. Suur-Uski)

Astronomer's Days 2014,
26–28 May, Savonlinna, Finland
(invited talk by H. Kurki-Suonio)

Euclid SGS Organization Group and System Team Meeting,
1–3 July, Milan, Italy (invited talk by H. Kurki-Suonio)

Planck Joint Core Team Meeting,
6–10 July, Paris, France (V. Lindholm, M. Savelainen)

Planck Papers Workshop,
31 August – 4 September, Cambridge, UK
(A.-S. Suur-Uski)

Euclid Simulation Challenge 1 Workshop,
15–17 September, Marseille, France (H. Kurki-Suonio)

Euclid SGS Organization Group Meeting,
23–24 September, Orsay, France (H. Kurki-Suonio)

Hitukosmopäivät,
25–26 September, Tampere, Finland
(talk by V. Lindholm, talk by J. Väliviita)

Euclid SGS System Team Meeting and Garage Days,
14–17 October, Paris (H. Kurki-Suonio)

Planck 2014 - The Microwave Sky in Temperature and Polarization,
1–5 December, Ferrara, Italy (K. Kiiveri, V. Lindholm, M. Savelainen, A.-S. Suur-Uski, talk by J. Väliviita)

Publications

Theory Programme

Cosmology of the Early and Late Universe

T. Alanne, K. Tuominen, and V. Vaskonen,
Strong phase transition, dark matter and vacuum stability from simple hidden sectors,
Nucl. Phys. B 889 (2014) 692

S. Aoyama, T. Sekiguchi, K. Ichiki, and N. Sugiyama,
Evolution of perturbations and cosmological constraints in decaying dark matter models with arbitrary decay mass products,
J. Cosmol. Astropart. Phys. 07 (2014) 021

P. Baratella, M. Cirelli, A. Hektor, J. Pata, M. Piibeleht, and A. Strumia,
PPPC 4 DMν: a poor particle physicist cookbook for neutrinos from Dark Matter annihilations in the Sun,
J. Cosmol. Astropart. Phys. 03 (2014) 053

K. Enqvist and M. Karčiauskas,
Does Planck really rule out monomial inflation?,
J. Cosmol. Astropart. Phys. 02 (2014) 034

K. Enqvist, R. N. Lerner, and T. Takahashi,
The minimal curvaton-higgs model,
J. Cosmol. Astropart. Phys. 01 (2014) 006

K. Enqvist, T. Meriniemi, and S. Nurmi,
Higgs dynamics during inflation,
J. Cosmol. Astropart. Phys. 07 (2014) 025

K. Enqvist, S. Nurmi, and S. Rusak,
Non-Abelian dynamics in the resonant decay of the Higgs after inflation,
J. Cosmol. Astropart. Phys. 10 (2014) 064

K. Enqvist, S. Nurmi, T. Tenkanen, and K. Tuominen,
Standard Model with a real singlet scalar and inflation,
J. Cosmol. Astropart. Phys. 08 (2014) 035

A. Hektor, M. Raidal, A. Strumia, and E. Tempel,
The cosmic-ray positron excess from a local Dark Matter over-density,
Phys. Lett. B 728 (2014) 58

M. Herranen, T. Markkanen, S. Nurmi, and A. Rajantie,
Spacetime curvature and the Higgs stability during inflation,
Phys. Rev. Lett. 113 (2014) 211102

M. Herranen, T. Markkanen, and A. Tranberg,
Quantum corrections to scalar field dynamics in a slow-roll space-time,
J. High Energy Phys. 05 (2014) 26

M. Hindmarsh, R. Kirk, and S. M. West,
Dark matter from decaying topological defects,
J. Cosmol. Astropart. Phys. 03 (2014) 037

M. Kawasaki, T. Sekiguchi, T. Takahashi, and S. Yokoyama,
Isocurvature perturbations and tensor mode in light of Planck and BICEP2,
J. Cosmol. Astropart. Phys. 08 (2014) 043

K. Kohri, Y. Oyama, T. Sekiguchi, and T. Takahashi,
Probing lepton asymmetry with 21 cm fluctuations,
J. Cosmol. Astropart. Phys. 09 (2014) 014

T. Koivisto, D. Wills, and I. Zavala,
Dark D-brane cosmology,
J. Cosmol. Astropart. Phys. 06 (2014) 036

R. N. Lerner and S. Melville,
Quantifying the 'naturalness' of the curvaton model,
J. Cosmol. Astropart. Phys. 07 (2014) 026

J. Lizarraga, J. Urrestilla, D. Daverio, M. Hindmarsh, M. Kunz, and A. R. Liddle,
Constraining topological defects with temperature and polarization anisotropies,
Phys. Rev. D 90 (2014) 103504

J. Lizarraga, J. Urrestilla, D. Daverio, M. Hindmarsh, M. Kunz, and A. R. Liddle,
Can topological defects mimic the BICEP2 *B*-mode signal?,
Phys. Rev. Lett. 112 (2014) 171301

K. Miyamoto, T. Sekiguchi, H. Tashiro, and S. Yokoyama,
CMB distortion anisotropies due to the decay of primordial magnetic fields,
Phys. Rev. D 89 (2014) 063508

S. Nadathur and S. Hotchkiss,
A robust public catalogue of voids and superclusters in the SDSS Data Release 7 galaxy surveys,
Mon. Not. R. Astron. Soc. 440 (2014) 1248

S. Nadathur, M. Lavinto, S. Hotchkiss, and S. Räsänen,
Can a supervoid explain the cold spot?,
Phys. Rev. D 90 (2014) 103510

S. Nurmi and M. S. Sloth,
Constraints on gauge field production during inflation,
J. Cosmol. Astropart. Phys. 07 (2014) 012

S. Räsänen,
A covariant treatment of cosmic parallax,
J. Cosmol. Astropart. Phys. 03 (2014) 035

T. Sekiguchi and H. Tashiro,
Constraining warm dark matter with 21 cm line fluctuations due to minihalos,
J. Cosmol. Astropart. Phys. 08 (2014) 007

T. Sekiguchi, H. Tashiro, J. Silk, and N. Sugiyama,
Cosmological signatures of tilted isocurvature perturbations: reionization and 21cm fluctuations,
J. Cosmol. Astropart. Phys. 03 (2014) 001

H. Tashiro, T. Sekiguchi, and J. Silk,
High redshift signatures in the 21 cm forest due to cosmic string wakes,
J. Cosmol. Astropart. Phys. 01 (2014) 013

W. A. Watson, J. M. Diego, S. Gottlöber, I. T. Iliev, A. Knebe, E. Martínez-González, G. Yepes, R. B. Barreiro, J. González-Nuevo, S. Hotchkiss, A. Marcos-Caballero, S. Nadathur, and P. Vielva,
The Jubilee ISW project - I. Simulated ISW and weak lensing maps and initial power spectra results,
Mon. Not. R. Astron. Soc. 438 (2014) 412

High Energy Phenomenology in the LHC Era

T. Alanne, S. Di Chiara, and K. Tuominen,
LHC data and aspects of new physics,
J. High Energy Phys. 01 (2014) 41

T. Alho, M. Järvinen, K. Kajantie, E. Kiritsis, C. Rosen, and K. Tuominen,
A holographic model for QCD in the Veneziano limit at finite temperature and density,
J. High Energy Phys. 04 (2014) 124

J. O. Andersen, T. Brauner, C. P. Hofmann, and A. Vuorinen,
Effective Lagrangians for quantum many-body systems,
J. High Energy Phys. 08 (2014) 88

P. Bandyopadhyay, S. Di Chiara, K. Huitu, and A. S. Keçeli,
Naturality vs perturbativity, B_s physics, and LHC data in triplet extension of MSSM,
J. High Energy Phys. 11 (2014) 62

A. Vuorinen in N. Brambilla et al.,
QCD and strongly coupled gauge theories: challenges and perspectives,
Eur. Phys. J. C 74 (2014) 2981

M. D'Onofrio, A. Kurkela, and G. D. Moore,
Renormalization of null Wilson lines in EQCD,
J. High Energy Phys. 03 (2014) 125

M. D'Onofrio, N. Partamies, and E. Tanskanen,
Eastward electrojet enhancements during substorm activity,
J. Atmos. Sol. - Terr. Phys. 119 (2014) 129

M. D'Onofrio, K. Rummukainen, and A. Tranberg,
Sphaleron rate in the minimal standard model,
Phys. Rev. Lett. 113 (2014) 141602

S. Di Chiara, R. Foadi, and K. Tuominen,
125 GeV Higgs from a chiral techniquark model,
Phys. Rev. D 90 (2014) 115016

R. Foadi,
The unobservable axial-pion mixing in QCD and near-conformal dynamics,
Eur. Phys. J. Plus 129 (2014) 148

P. Fonda, L. Franti, V. Keränen, E. Keski-Vakkuri, L. Thorlacius, and E. Tonni,
Holographic thermalization with Lifshitz scaling and hyperscaling violation,
J. High Energy Phys. 08 (2014) 51

E. S. Fraga, A. Kurkela, and A. Vuorinen,
Interacting quark matter equation of state for compact stars,
Astrophys. J. Lett. 781 (2014) L25

M. Frank, D. K. Ghosh, K. Huitu, S. K. Rai, I. Saha, and H. Waltari,
Left-right supersymmetry after the Higgs boson discovery,
Phys. Rev. D 90 (2014) 115021

I. Ghisoiu and M. Laine,
Right-handed neutrino production rate at T > 160 GeV,
J. Cosmol. Astropart. Phys. 12 (2014) 032

M. Heikinheimo, A. Racioppi, C. Spethmann, M. Raidal, and K. Tuominen,
Physical naturalness and dynamical breaking of classical scale invariance,
Mod. Phys. Lett. A 29 (2014) 1450077

M. Hindmarsh, S. J. Huber, K. Rummukainen, and D. J. Weir,
Gravitational waves from the sound of a first order phase transition,
Phys. Rev. Lett. 112 (2014) 041301

M. Hindmarsh, K. Rummukainen, T. V. I. Tenkanen, and D. J. Weir,
Improving cosmic string network simulations,
Phys. Rev. D 90 (2014) 043539

K. Huitu and H. Waltari,
Higgs sector in NMSSM with right-handed neutrinos and spontaneous R-parity violation,
J. High Energy Phys. 11 (2014) 53

N. Jokela, M. Järvinen, and M. Lippert,
Gravity dual of spin and charge density waves,
J. High Energy Phys. 12 (2014) 83

N. Jokela, G. Lifschytz, and M. Lippert,
Flowing holographic anyonic superfluid,
J. High Energy Phys. 10 (2014) 21

K. Kajantie,
Hot and dense quark matter at large number of colors and flavors,
Nucl. Phys. A 931 (2014) 836

V. Keränen, H. Nishimura, S. Stricker, O. Taanila, and A. Vuorinen,
Dynamics of gravitational collapse and holographic entropy production,
Phys. Rev. D 90 (2014) 064033

V. Keus, S. F. King, and S. Moretti,
Phenomenology of the inert (2+1) and (4+2) Higgs doublet models,
Phys. Rev. D 90 (2014) 075015

V. Keus, S. F. King, S. Moretti, and D. Sokolowska,
Dark matter with two inert doublets plus one Higgs doublet,
J. High Energy Phys. 11 (2014) 16

A. Kurkela, E. S. Fraga, J. Schaffner-Bielich, and A. Vuorinen,
Constraining neutron star matter with quantum chromodynamics,
Astrophys. J. 789 (2014) 127

O. Lebedev and Y. Mambrini,
Axial dark matter: The case for an invisible Z',
Phys. Lett. B 734 (2014) 350

B. Lucini and M. Panero,
Introductory lectures to large-N QCD phenomenology and lattice results,
Progr. Part. Nucl. Phys. 75 (2014) 1

M. Panero, K. Rummukainen, and A. Schäfer,
Jet quenching from the lattice,
Nucl. Phys. A 931 (2014) 393

M. Panero, K. Rummukainen, and A. Schäfer,
Investigating jet quenching on the lattice,
Nucl. Phys. A 932 (2014) 122

M. Panero, K. Rummukainen, and A. Schäfer,
Lattice study of the jet quenching parameter,
Phys. Rev. Lett. 112 (2014) 162001

A. Tranberg and D. J. Weir,
On the quantum stability of Q-balls,
J. High Energy Phys. 04 (2014) 184

QCD and Strongly Interacting Gauge Theory

R. Chatterjee, D. K. Srivastava, and T. Renk,
Thermal photon v_3 at LHC from fluctuating initial conditions,
Nucl. Phys. A 931 (2014) 670

D. d'Enterria, K. J. Eskola, I. Helenius, and H. Paukkunen,
Confronting current NLO parton fragmentation functions with inclusive charged-particle spectra at hadron colliders,
Nucl. Phys. B 883 (2014) 615

G. S. Denicol, H. Niemi, I. Bouras, E. Molnár, Z. Xu, D. H. Rischke, and C. Greiner,
Solving the heat-flow problem with transient relativistic fluid dynamics,
Phys. Rev. D 89 (2014) 074005

A. Dumitru, T. Lappi, and L. McLerran,
Are the angular correlations in *pA* collisions due to a Glasmion or Bose condensation?,
Nucl. Phys. A 922 (2014) 140

A. Dumitru, T. Lappi, and Y. Nara,
Structure of longitudinal chromomagnetic fields in high energy collisions,
Phys. Lett. B 734 (2014) 7

I. Helenius, K. J. Eskola, and H. Paukkunen,
Probing the small-*x* nuclear gluon distributions with isolated photons at forward rapidities in p+Pb collisions at the LHC,
J. High Energy Phys. 09 (2014) 138

I. Helenius, K. J. Eskola, and H. Paukkunen,
Constraining nPDFs with inclusive pions and direct photons at forward rapidities in p + Pb collisions at the LHC,
Nucl. Phys. A 932 (2014) 415

T. Lappi, A. Dumitru, and Y. Narad,
Structure of chromomagnetic fields in the glasma,
Nucl. Phys. A 931 (2014) 354

T. Lappi and H. Mäntysaari,
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Edited by Christina Helminen

Layout Mari Lindgren
Printed by Unigrafia

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