HELSINKI INSTITUTE OF PHYSICS

Annual Report 2012

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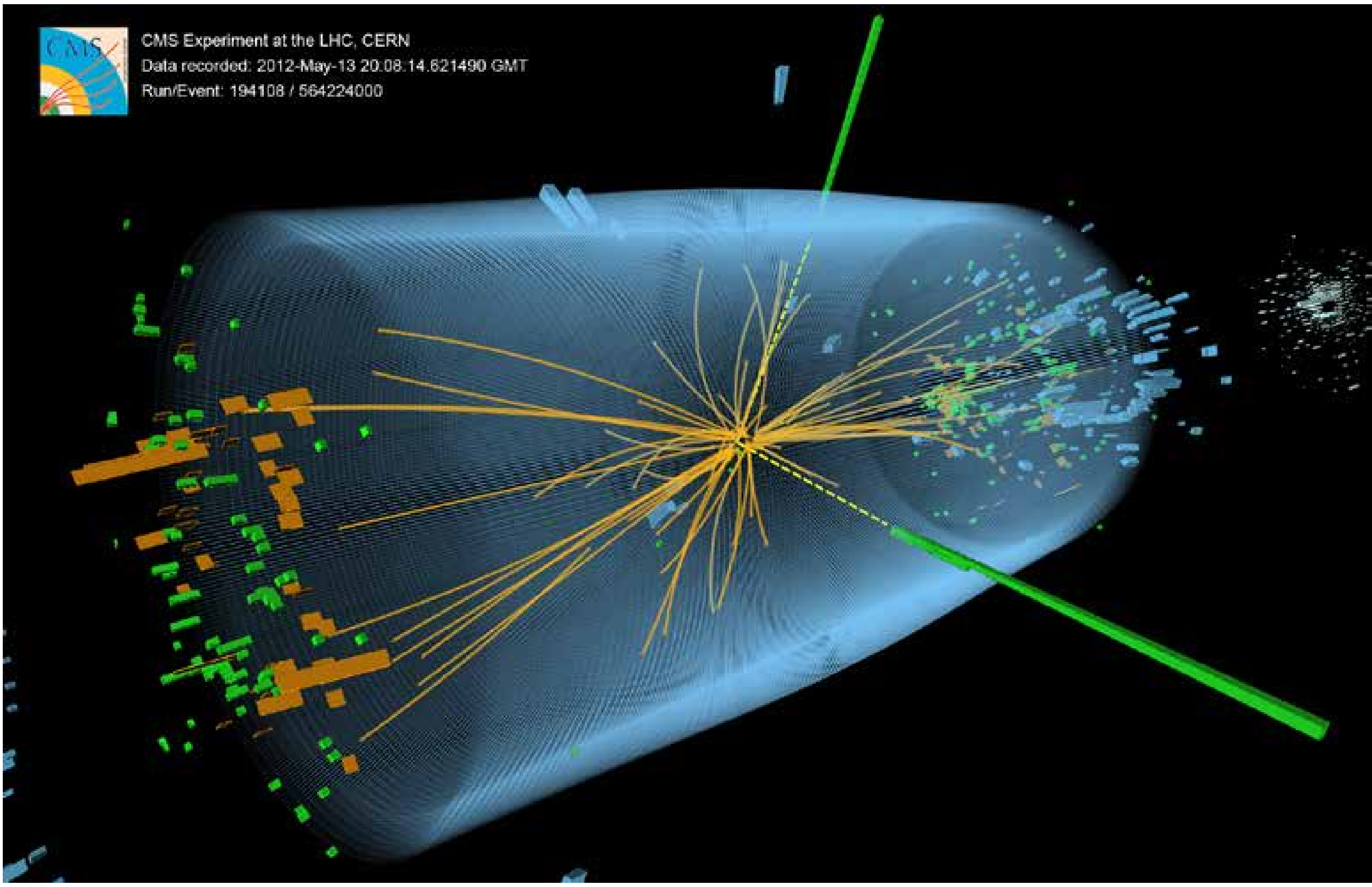

Candidate event for H → γ γ decay.

Contents

Introduction

JuhaÄ ystö

So far the year 2012 can be marked as the most remarkable milestone in the history of the Helsinki Institute of Physics after the announcement of the spectacular discovery of a Higgs-like particle in July by the CMS and ATLAS Collaborations. The Large Hadron Collider's (LHC) performance has exceeded all expectations over the last three years. Its energy was increased from 7 TeV in 2011 to 8 TeV in 2012 and its luminosity, which measures the rate of proton-proton collisions was doubled in 2012. The year also witnessed the successful operation of the TOTEM experiment at the LHC and its remarkably precise values for the cross sections for proton-proton collisions at 8 TeV. The results from ALICE on ultra-relativistic Pb-Pb collisions were among the highlights of LHC physics with emphasis on topics linked to jet properties and their modifications in Quark Gluon Plasma.

The Helsinki Institute of Physics (HIP) 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 also carries the responsibility for co-ordination of the Finnish activities at the new international Facility for Antiproton and Ion Research (FAIR) under construction in Darmstadt, Germany.

HIP is operated by the University of Helsinki, the Aalto University, the University of Jyväskylä and Lappeenranta and Tampere Universities of Technology. Administratively HIP is associated with the University of Helsinki. The HIP operations are based on the Finnish CERN strategy, which emphasises, in addition to research and research training, the development of technology know-how of 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 demonstrated by the sustained large Finnish coefficient of return for industrial supplies at CERN and by the great interest in CERN shown by Finnish high schools. In 2012 the Institute was able to host a record of 19 study visits to CERN by Finnish high school students and 1 course for teachers at CERN. By 2012, within the CERN-network of Finnish high schools of about 300 schools and 50 co-operation partners, more than 3 100 students and 300 teachers had been trained at CERN. During 2012, 9 PhD and DSc (Tech) degrees and 13 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 the summer of 2012, 18 Finnish students worked at CERN in HIP research projects.

The research activities of the Helsinki Institute of Physics in 2012 fell into 5 research programmes and 2 special research projects. The research programmes were (1) the Theory Programme, (2) the High Energy Physics Programme, (3) the CMS Programme, (4) the Nuclear Matter Programme and (5) the Technology Programme. The special projects were (a) the CLOUD experiment project at CERN, which aims at the determination of the role of cosmic radiation in climate warming and (b) the Planck project for the analysis of the data from the Planck satellite.

In the Theory Programme the projects "Cosmophysics", "Laws of nature and condensed particle matter phenomenology at the LHC", "Low dimensional quantum systems" and "Radiation damage in particle accelerator materials" continued for the second year of their second 3-year periods. A search for new 3-year projects starting in the beginning of 2014 was initiated at the end of 2012. The leader of the Cosmophysics project, Dr. Kimmo Kainulainen, was appointed to the post of Professor in the Physics Department at the University of Jyväskylä from the beginning of January 2012.

The High Energy Physics Programme continued to participate in the analysis of the data from the TOTEM experiment at the LHC and continued the physics analysis of the data from the final run of the CDF-II experiment at the Tevatron collider at Fermi National Laboratory. The CLIC project continued by an EU Marie Curie Industry-Academia Partnerships and Pathways project (IAPP) "MeChanICs - Marie Curie linking Industry to CERN", allowing engineers from Finnish industrial enterprises to work at CERN.

The CMS Programme continued its project on physics analysis and operation of the tracker and the trigger of the CMS detector at the LHC and the project on detector upgrade for the foreseen CMS luminosity upgrade. Both projects were granted continuation for the period 2013-2015 by the HIP Board. In 2012 the CMS Programme also carried the responsibility for the operation of the Finnish Tier-2 Grid computing facility, which is part of the Worldwide LHC Computing Grid WLCG.

The Nuclear Matter Programme included 3 projects. The first is a nuclear structure research project at the ISOLDE facility at CERN. The second is a project for physics analysis at and instrumentation for the ALICE detector for relativistic heavy ion collisions at the LHC. In addition the 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 ISOLDE project, Dr. Paul Greenlees, was appointed to the post of Professor in the Physics Department at the University of Jyväskylä from the beginning of August 2012.

The Technology Programme was composed of 3 research projects. The first dealt with software development for distributed data-intensive Grid computation. The aim of the second - the GreenIT project - was to develop methods and operational practices to improve the energy use efficiency of high throughput computing clusters. The goal of the third - the PET project - is to find ways to commercialise new types of Positron Emission Tomography (PET) scanners using AXPET detectors developed at CERN.

The research results of these programmes and projects were reported in a record number of 260 refereed scientific journal articles.

At the end of March 2012 Professor Dan-Olof Riska, who has led the Helsinki Institute of Physics for more than a decade, retired. Under his leadership HIP has experienced a transformation into an internationally highly reputed research institute with important connections with and support from the member universities. HIP and the Finnish subatomic physics community are extending their deepest thanks to Prof. Riska for his excellent impact. At the end of December 2011 Professor Ari-Pekka Hameri stepped down as leader of the Technology Programme. At the end of June 2012 Docent Veikko Karimäki retired from the CMS Programme after serving the CMS experiment from its date of founding. The Institute is indebted to the outstanding services of Ari-Pekka Hameri who led the Technology Programme from its first establishment in 1997 and Veikko Karimäki for his pioneering work at the CMS experiment.

During 2012 the Board of HIP was chaired by Vice Rector Johanna Björkroth 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.

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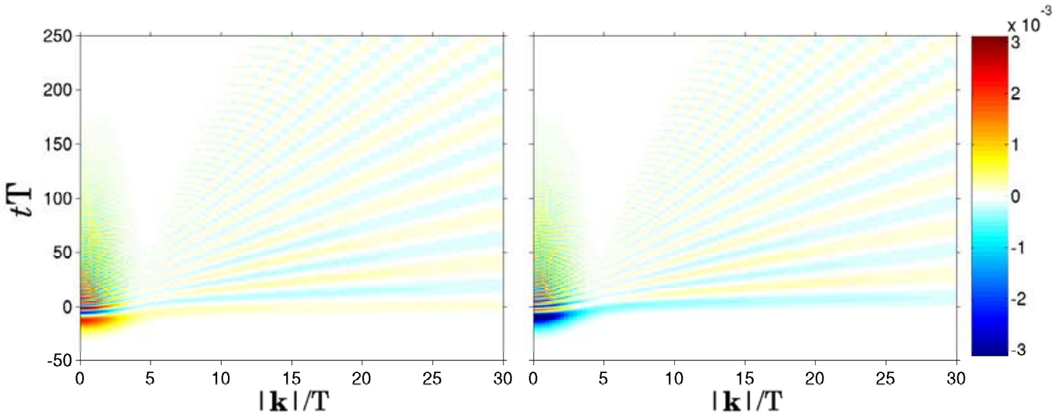
Highlights of Research Results

Theory Programme



In the *Cosmophysics* project we have derived a relativistic out-of-equilibrium transport theory including flavour- and particle-antiparticle coherences from the first principles of non-equilibrium quantum field theory, complete with explicit propagators and Feynman rules for perturbative calculations. We found that particle-antiparticle coherence can strongly influence CP-violating flavour mixing and hence the particle-antiparticle asymmetry generation for example in electroweak baryogenesis type models.

In the *Laws of Nature and Condensed Particle Matter Phenomenology* project we have considered walking Technicolour models and supersymmetric extensions of the Standard Model, and obtained constraints on the parameter spaces of these models, taking into account the reported observation of a Higgs-like boson with a mass around 125 GeV announced by the experiments at the CERN Large Hadron Collider (LHC) in July 2012. In heavy-ion phenomenology we have updated our pioneering pQCD calculation of the initial particle production to next-to-leading order as rigorously as possible. This calculable framework, which also provides an estimate of theoretical errors, defines the current state-of-the-art in the quantitative phenomenology studies of relativistic heavy ion collisions.

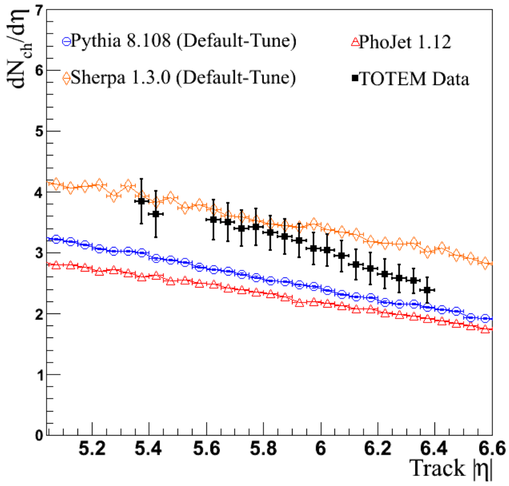
The most significant achievements in the *Low Dimensional Quantum Systems* project are related to electronic transport in graphene. Despite being only one atomic layer thick, graphene is remarkably chemically as well as thermally stable. The graphene quantum dots are theoretically very interesting, showing confinement of massless relativistic fermions. We have developed an effective cross section approach for the electronic transport, and established the fact that high-field magnetoresistance can be used to reveal the scattering mechanisms in graphene.

In the *Radiation Damage in Particle Accelerator Materials* project we developed an analytical model for the vacuum electric breakdown rate dependence on an external electric field, observed in test components for the Compact LInear Collider (CLIC) concept. The model is based on a thermodynamic consideration of the effect of an external electric field on the formation enthalpy of defects. The model reproduces very well the breakdown rate of a wide range of radio-frequency breakdown experimental data. We further show that the fitting parameter in the model can be interpreted to be the relaxation volume of dislocation loops in materials. The values obtained for the volume are consistent with dislocation loops with radii of a few tens of nanometres.

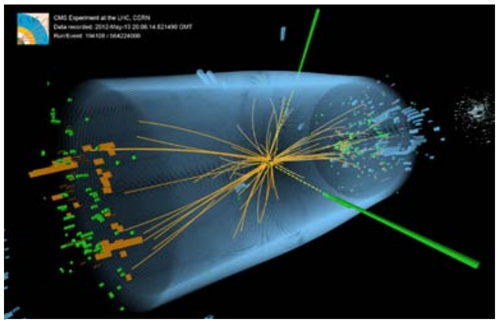
High Energy Physics Programme

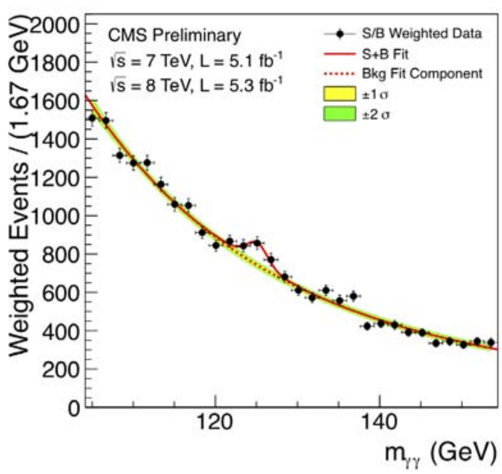
The TOTEM measurement of the forward charged particle pseudorapidity density at the LHC centre-of-mass energy of 7 TeV, published in Europhysics Letters 98 (2012) 31002, extends the existing measurements at the LHC to the previously unexplored forward region. The measurement, based entirely on the T2 telescope made up of Helsinki-built GEM-chambers, is in disagreement with the most common high energy physics and cosmic ray event generators and provides new information on the production of charged particles in the forward region for the developers of models for inelastic proton-proton collisions.

During 2012, CMS and TOTEM took common data in both special low intensity and high β* fills. Trigger information was exchanged and the data were combined off-line using the bunch number and the orbit counter. From these data, CMS and TOTEM will be able to study soft and semi-hard diffraction in detail, classify the inelastic proton-proton interactions into non-diffractive, single, double and central diffractive events as well as make unique charged multiplicity and energy flow measurements covering the pseudorapidity range $-6.5 < \eta < 6.5$.



The Compact Linear Collider (CLIC) study completed its Conceptual Design Report in 2012 of a multi-TeV linear electron-positron collider based on the CLIC two-beam concept. The first volume "A Multi-TeV linear collider based on CLIC technology" published as CERN report CERN-2012-007 contains the feasibility and description of a 3 TeV collider based on the CLIC technology. The second volume "Physics and Detectors at CLIC", CERN-2012-003, describes the physics and the detectors with their performance in such a collider. The last volume, CERN-2012-005, entitled "The CLIC Programme: towards a staged e^+e^- Linear Collider exploring the Terascale" describes the staging scenarios of a linear collider based on the CLIC two-beam concept that is closely related to the physics output of the LHC programme.





CMS Programme

In July 2012, the CMS and ATLAS experiments announced the discovery of a new particle with a mass of about 125 GeV. The new particle is a boson and its properties from the preliminary measurements were found to be compatible with those of a Higgs boson, like the one predicted in the Standard Model of particle physics. For Finnish CMS physicists this discovery was the culmination of their dedicated and committed work, which started some 20 years ago.

During 2012 the CMS Experiment project made significant contributions to the CMS Higgs analyses, providing new results on charged Higgs bosons. The project also contributed to B-physics and jet analyses. A new initiative, the CMS Data preservation and open access project, was started in 2012, and K. Lassila-Perini was nominated to co-ordinate this project.

The CMS Tier-2 Operations project continued to provide reliable computing and data storage resources. A new Academy of Finland -funded project concerning cloud computing, Data Indirection Infrastructure for

Secure HEP Data Analysis, was started together with the department of Computer Science at the University of Helsinki.

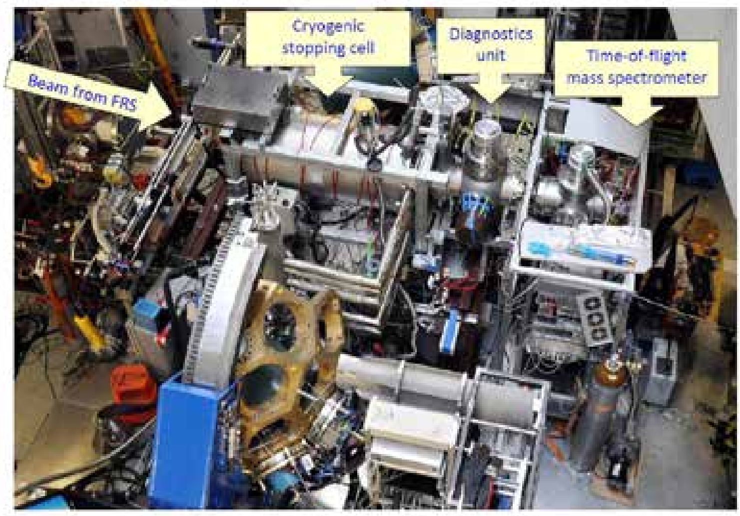
The CMS Upgrade project was engaged in the preparatory work for producing new pixel detector modules, to be installed in 2016-2017. Intensive collaboration continued with the Micronova Centre of Aalto University and VTT, and with the Accelerator Laboratory of the University of Helsinki. The Lappeenranta group started production of off-detector electronics for the muon system upgrade.

Nuclear Matter Programme

The ALICE experiment recorded a unique sample of p-Pb data at highest ever c.m. energy $\sqrt{s_{NN}}$ = 5.02 TeV. Analysis of the short pilot run already resulted in three publications [Phys. Rev. Lett. 110 (2012) 032301, arXiv:1210.4520, Phys. Lett. B 719 (2013) 29]. The measurement of the inclusive yield of charged particles over the broad range of transverse momenta provides a significant constraint on the shadowing models (e.g., arXiv:hep-ph/0308248) or models based on initial state gluon saturation (e.g., arXiv:1211.3327). A first observation of the double-peaked long-range angular correlations by the ALICE experiment [Phys. Lett. B 719 (2013) 29] initiated an intense discussion on the possible emanation of collective phenomena also in cold nuclear matter; this has so far been observed only in heavy ion collisions.

The understanding of nuclear shapes and shape co-existence was the main aim of a series of experiments using the post-accelerated radioactive beams of REX-ISOLDE. There was a large Finnish contribution to these experiments. In particular, systematic data for the 2^+ to 0^+ transition strengths of the neutron-deficient isotopes $^{188\text{-}198}$Pb are valuable for understanding the evolution of collectivity in this part of the nuclei chart. The collinear laser spectroscopy programme continued with a series of measurements on the manganese isotope chain. In particular, full hyperfine structures were measured for $^{51,53\text{-}64}$Mn.

Preparations for FAIR (Facility for Antiproton and Ion Research) continued in 2012. The Finnish contribution is centred on the Super-FRS accelerator and separator facility. The Super-FRS will provide low-energy beams for experiments. For this purpose, prototypes of the cryogenic stopping cell CSC and the time-of-flight mass spectrometer MR-TOF-MS were successfully commissioned at the FRS, GSI. This project is a collaboration between HIP (through Jyväskylä), KVI Groningen, Justus-Liebig-Universität Gießen and GSI. In addition, to satisfy the diagnostic needs of Super-FRS, the Detector Laboratory in Helsinki has made good progress in 2012 in developing and testing GEM detectors and their readout electronics. The detector showed very good position resolution and rate capability in the tests. This work is a Helsinki–Bratislava (Comenius University) collaboration. Finally, new in-kind technology projects were initiated in 2012.



Technology Programme

In 2012 the two new projects in the Technology Programme have advanced well from the previous year. The PET project secured TEKES innovation funding and filed a first patent application for CERN-led research commercialisation in

Medical Imaging and the GreenIT project, active in publishing energy efficiency best practices, has established initial collaboration ties with CERN and candidate members of academia and industry. The European Middleware Initiative (EMI) project entered its third and final project year with the DataGrid project team in the leading role for its security activities.

Theory Programme

Kari Rummukainen,
Theory Programme Director

The Theory Programme is structured around fixed term projects, chosen according to their scientific quality and the complementarity with the research at HIP and at the host universities. For the project leaders the HIP projects provide a reference frame on which to build a top class research group, and the leaders are expected to secure significant external funding for their projects. In 2012 the Theory Programme consisted of four projects: Cosmophysics (Kimmo Kainulainen, Jyväskylä), Laws of Nature and Condensed Particle Matter Phenomenology at the LHC (Kimmo Tuominen, Jyväskylä), Low Dimensional Quantum Systems (Ari Harju, Aalto), and Radiation Damage in Particle Accelerator Materials (Flyura Djurabekova, Helsinki). These will continue until the end of 2013. During 2012 the HIP Visiting Professor Programme was initiated: Professor Mark Hindmarsh (Sussex University) was present at HIP for all of 2012. He is one of the leading authorities in the physics at the intersection of particle physics and cosmology, and his presence strongly enhanced research in the Cosmophysics and the Laws of Nature projects.

Kimmo Kainulainen,
Cosmophysics
project leader

Cosmophysics

We have explored inhomogeneous cosmologies on several fronts. For example, we have carefully compared relativistic cosmological perturbation theory with Newtonian cosmology. We found, quite surprisingly, that the simulations based on the Newtonian approximation are only reliable up to the cluster scale, while at scales larger than 10Mpc there are already large differences. In general an inhomogeneous world does not necessarily evolve like a homogenous universe with similar average properties. We have compiled an authoritative review of the current status of this issue, usually referred to as "backreaction", and the mechanisms behind it. We have demonstrated that the backreaction may significantly affect cosmological distance measures even in cases where the expansion and the redshift effects are well described by the homogeneous FRW model. We also approached the backreaction problem using a gradient expansion for metric fluctuations. Our method is only constrained by a maximum time scale and not by the amplitude of perturbations and it works particularly well for large overdensities. We find that backreaction effects can be over 10% on observable quantities, suggesting that understanding backreaction may be crucial for precision cosmology.

On the other hand we have studied models with large local voids and with many fluid components to see if dark energy can be mimicked by very large-scale non-linear structures. We found that observational constraints on the dark energy equation of state depend strongly on the local matter density around the observer. For example, if we live at the centre of an inhomogeneity with a density contrast of $\delta = 0.1$–0.15, the dark energy is not a cosmological constant at the 95% confidence level. Finally, we have studied weak lensing and its impact on cosmological observables. We have extended our stochastic gravitational lensing method to include the modelling of observational biases and adapted it for computation of weak lensing distortions to the angular power spectrum in the CMB and on the angular distribution of quasar double images.

We have also studied galaxy-clustering and the cross correlation between the CMB and LSS data to constrain the LCDM model. On one hand we have verified that when new, unbiased tests are used for the analysis of high redshift clusters they, in contrast to earlier claims, show no appreciable tension with the LCDM model. On the other hand we improved our analysis of the expected integrated Sachs-Wolfe (ISW) effect in the context of the LCDM model in rare SDSS superclusters. We compared our model with the ISW maps from N-body simulations and found the differences to be small. Our conclusion is that the observed ISW signal in these systems is too large by more than three standard deviations to arise in a flat LCDM model with an initial Gaussian fluctuation spectrum. We have also used the matter and galaxy bi-spectrum to study local non-Gaussianity at small scales. Our Halo Model approach works reasonably well even at very non-linear scales and it thus seems a promising way to compute observable quantities such as the galaxy or lensing bi-spectra.

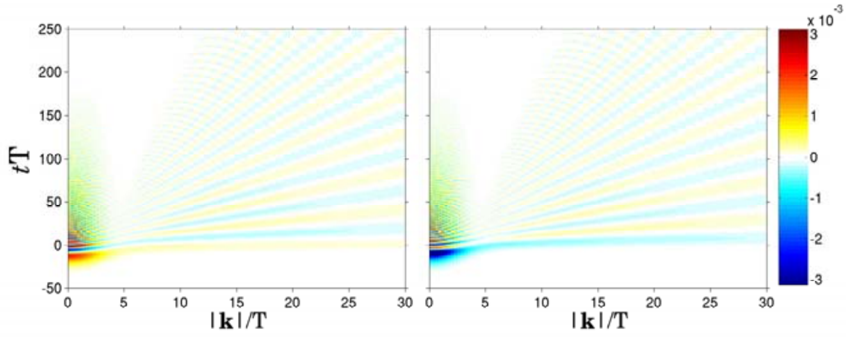
We have investigated various sources for gravitational waves. For example, they may be produced by anisotropic stresses of out-of-equilibrium fermions. We have shown that such fermions may be created in non-perturbative processes in the early universe despite Pauli blocking suppressions. While the ensuing GW's may have a large amplitude and a distinct spectral shape, they may have too high frequencies to be observed in the near future. Another way to produce GW's is through non-topological global textures arising after phase transitions. We have shown as an important result that any source which is scaling in the radiation era produces a scale invariant spectrum of GW's, independent of the topology of the cosmic defects, the order of phase transition, and the nature of the symmetry broken. Finally, we have shown that there exists an interesting loophole that may allow primordial GW production even in single field inflation models with small field excursion. The trick is to suitably customise the inflaton potential at field scales between the ones falling in the observable CMB-window and the end of inflation.

We also made a comprehensive analysis of constraints on primordial isocurvature and tensor modes. Our results show that the current data does not in any way indicate the existence of isocurvature modes of perturbation.

We continued our efforts to investigate the curvaton mechanism, with a special emphasis on relating the curvaton to the known particle physics framework. In particular, we studied a curvaton with a non-zero hypercharge. While the model can give rise to the observed perturbations, it tends to produce too much non-Gaussianity, of order $f_{NL} \approx 135$, which is ruled out at the 95% CL by WMAP data. We also studied a model where the curvaton is coupled to the Standard Model Higgs. A novel point here was to show that the curvaton decay via a parametric resonance is blocked by the Higgs boson thermal mass. Then, contrary to expectations, it is possible to obtain the observed curvature perturbation with very large curvaton-Higgs couplings, up to $g = 0.1$. We also studied a model with modulated preheating as a means of generating the curvature perturbations. Here perturbations may be efficiently generated during non-perturbative, spatially varying decay of the modulated field. However, if the modulating field is responsible for CDM, the existing bounds on CDM isocurvature perturbations preclude the model from providing dominant curvature perturbation.

An issue relevant to curvatons, and for inflation models with light fields in general, concerns the evolution of the long wavelength modes of light fields during inflation. We have shown that the thermalization time of the probability distribution of these modes can be very large. So, unless inflation lasts for up to thousands of e-folds, it may not be able to erase all initial conditions. We inverted this analysis to get a quantitative measure of how "typical" a given universe is as a function of the amplitude of the curvature perturbation. We also proved that when light fields are coupled fields with non-flat potential, fluctuations along non-flat directions generically produce effective masses for the light fields which then block their fluctuations. In such cases the naïve growth of the fields may be strongly suppressed. However, we also showed that this blocking may be temporarily avoided if the light scalars in question have large enough initial expectation values.

Regarding models for inflation we considered a simple non-metric extension of Einstein Gravity, extending the metric by a conformal scaling factor. The model was shown to give rise to the usual inflaton picture. However, in the chaotic regime, the ensuing inflaton potential may become unstable at large field values and there is a maximum number of e-folds of inflation attainable in the model. We also studied generalised non-minimally coupled Higgs infla-



Shown are the real (left) and imaginary (right) parts of the flavour-off-diagonal particle-antiparticle coherence correlator for positive helicity states obtained from cQPA analysis. The x-axis shows the absolute value of the momentum |k| and the y-axis the time t from the phase transition, both in units of the ambient temperature T.

tion models with multiple scalar fields. These models may be compatible with tree-level unitarity during inflation depending on the number of scalars and their non-minimal couplings. A particular real scalar field model with a strong hierarchy of non-minimal couplings was shown to remain both unitary and predictive even in the present vacuum.

We have studied electroweak baryogenesis in inert singlet models. These models extend the Higgs sector of MSM by an inert singlet scalar with a Z_2-symmetry. The model easily provides a strongly first order phase transition and large baryon asymmetry, it is consistent with all laboratory data and may provide a subleading component for dark matter. We are currently finishing work on inert doublet models with similar conclusions. Our quantum transport formalism, capable of describing non-local coherences, was extended in two papers published in 2012 to the case of mixing bosonic and fermionic fields. We are currently extending the formalism to include first order dispersive, dissipative and collisional corrections and applying the results for models of thermal and resonant leptogenesis.

Kimmo Tuominen, Laws of Nature and Condensed Particle Matter Phenomenology at the LHC project leader

Laws of Nature and Condensed Particle Matter Phenomenology at the LHC

Our focus is on electroweak symmetry breaking (EWSB) mechanisms and associated Beyond the Standard Model (BSM) phenomenology and on perturbative and non-perturbative strong interactions with applications to BSM physics and the properties of hot and dense QCD matter. We are in active research collaborations with various international colleagues, organise and participate in international conferences and workshops, European graduate school activities and EU networks. We are also in close contact with the local CMS (Helsinki) and ALICE (Jyväskylä) experimental groups.

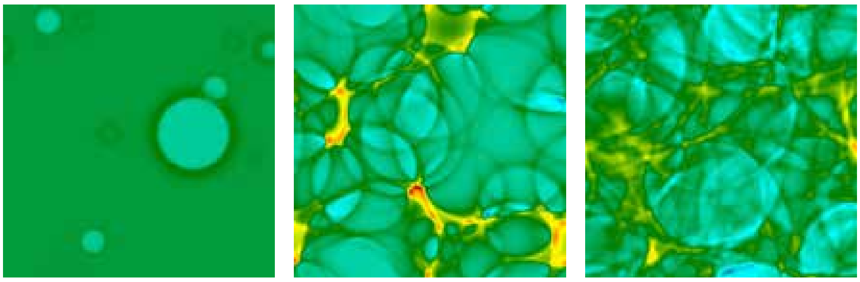
EWSB and BSM phenomenology: The remarkable discovery of a Higgs-like boson with a mass around 125 GeV was announced by the experiments at the CERN Large Hadron Collider (LHC) in July 2012. The properties of the boson are hoped to hint towards the physics responsible for the electroweak symmetry breaking, and to a possible theory beyond the Standard Model. In the studies of BSM phenomenology the new experimental constraints from the observed Higgs-like boson have been taken into account, in addition to other relevant experimental limitations on the parameter space.

Composite Higgs (i.e., Technicolour) and supersymmetric models remain well motivated candidates for BSM physics. Regarding supersymmetry, models with a rather light supersymmetric partner of the top quark, stop, are favoured by the current data. Such scenarios have been investigated earlier by our group, and studies were continued by developing a novel way to test such a scenario at the LHC. In Technicolour a light scalar is natural in quasi-conformal (i.e., walking) Technicolour. We have constructed phenomenologically viable models, and confronted them with LHC data.

Technicoloured or supersymmetric extensions to the Standard Model also provide viable dark matter candidates, and can introduce the additional charge-parity (CP) violation needed for obtaining the observed baryon asymmetry of the universe. In supersymmetry, the possibilities of scalar dark matter and neutralino dark matter with spontaneous CP violation in the next-to-minimal supersymmetric Standard Model with a right-handed neutrino were investigated and compared. The observed relic density can be produced both by a neutralino or a right-handed sneutrino as the lightest supersymmetric particle but when CP is violated new annihilation channels become available and in general they lower the relic density. Collider phenomenology was investigated for several benchmark points of the parameter space taking into account the experimental constraints and having either the neutralino or the right-handed sneutrino contribute to the dark matter abundance. The lightest supersymmetric particles were also studied in generic extensions of the minimal supersymmetric SM.

Another possibility for BSM physics, namely extra dimensional models, was considered as well. Collider phenomenology of Universal Extra Dimension models with gravity mediated decays was studied. At the collider, level-1 Kaluza-Klein (KK) particles are produced in pairs due to the conservation of KK-parity. Subsequently, KK-particles decay via cascades to the lightest KK-particle (LKP). Finally, gravity induced decay of the LKP into photons gives rise to the signal in the diphoton channel. In the search for diphoton events with large missing transverse energy no excess of events above the Standard Model expectations has been reported. The absence of any excess of the diphoton events was translated to constrain the model parameters.

Dynamics of strong interactions: One of our goals within this part of the project is to use lattice simulations and holographic methods to gain insight into non-perturbative dynamics of strongly interacting quantum field theory; the main motivation here is provided by the applications in BSM model building. Optimisation of improved Wilson fermion actions was considered in 2012 for SU(2) and SU(3) gauge theories with fermions in fundamental or higher representations, and these results can now be implemented in large scale simulations required to determine the location of the conformal window in these theories. In holography we studied the thermodynamics of QCD in the Veneziano limit within a holographic bottom-up model. As a further novel aspect of gauge-gravity duality, we have considered toy models for dynamics of strongly coupled systems far from equilibrium. An important quantity here is the time dependent spectral function. Using holographic methods, we have defined time dependent spectral functions, generalised notions of mean occupation number and developed methods for computing them in conformal theories.

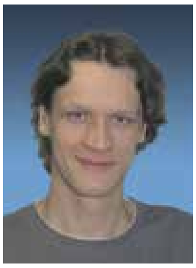


Nucleation of bubbles in a first order electroweak phase transition. David Weir 2012.

Another goal is to provide solid theory studies for applications in ultrarelativistic heavy ion collisions (URHIC). The recent LHC results from Pb+Pb collisions have strengthened the status of relativistic hydrodynamics, a long-time expertise of our group, as a cornerstone of URHIC physics. In computing the produced QGP initial densities for hydrodynamics, we improved our preservative QCD + saturation ("EKRT") framework considerably by extending the pQCD part rigorously to NLO, charting the uncertainties, and demonstrating the predictive power of the approach against the measured RHIC and LHC multiplicities and p_T spectra. In the event-by-event hydrodynamic framework developed in our group recently, we studied the centrality- and formation-time systematics of thermal photon emission in A+A collisions, addressing also the puzzlingly large elliptic flow suggested both by the RHIC and LHC measurements. We also did pioneering work in deriving relativistic dissipative fluid dynamics from the Boltzmann equation using the method of moments.

Regarding nuclear parton distribution functions (nPDFs), we determined their spatial dependence using our earlier global EKS98 and EPS09 analyses, which are now standard references in the field. The new spatially dependent nPDF sets EPS09s and EKS98s, which enable the calculation of nuclear hard processes in different centrality classes, were published, and applied to pion production in high-energy nuclear collisions: the results from the first p+Pb run at the LHC agreed nicely with our predictions.

Hard probes are another cornerstone of the RHIC and LHC experimental programme. With high statistics data from the LHC, fully reconstructed jets in Pb+Pb collisions have finally become available in addition to other high-p_T observables. We develop and maintain Monte Carlo tools for the simulation of hard probes, such as the in-medium shower code YaJEM or a code for simulating perturbative 2→2 QCD scattering processes, and have applied them successfully to a large number of novel jet observables. With a large range of available models and systematic experience in embedding computations into the fluid dynamical background, we are able to do realistic modelling of observables under experimentally relevant conditions including all relevant biases and offer guidance to the experimental community what future measurements are most likely to yield new insights. We have continued our studies of high energy QCD in the Colour-Glass-Condensate (CGC) framework. During the year 2012 we computed the azimuthal angle dependence of forward dihadron correlations at forward rapidity in deuteron-gold collisions in the RHIC kinematical region. We also proposed a new way to implement the running QCD coupling in the JIMWLK equation, performing a detailed numerical comparison of our proposal to the running coupling BK equation.



Ari Harju,
Low Dimensional
Quantum Systems
project leader

Flyura Djurabekova,
Radiation Damage in
Particle Accelerator
Materials project
leader

Low Dimensional Quantum Systems

The field of low-dimensional condensed-matter systems has been shown to be full of interesting physics that has been actively researched both theoretically and experimentally. Two recent examples are two-dimensional semiconductor structures and graphene, a two-dimensional allotrope of carbon. From the theoretical point of view, the field of two-dimensional nanoscale quantum physics forms an interface between hard-core theoretical physics and traditional condensed-matter physics. The lowered dimensionality both enhances correlation effects - in many cases necessitating the use and development of non-perturbative methods - and allows for powerful analytical techniques such as bosonization and the Bethe ansatz.

The main focus of the project has been to study two-dimensional semiconductor quantum dots in strong magnetic fields and graphene. In a semiconductor quantum dot, a controllable number of electrons are confined in space to a tuneable environment. One interesting application area of these is quantum information and computing, where the electron spin can be used as a quantum bit (qubit). Recently, we have proposed a new way to measure the spin qubit using a Y junction.

Despite being only one atomic layer thick, graphene is remarkably chemically as well as thermally stable. We have studied functionalization of graphene, and our transport studies have shown that each adsorbate on the graphene sheet has a specific transmission fingerprint.

Finally, we have continued to develop methods for using the graphics processing units to significantly speed up various simulations. In the best cases we have studied, the computation time was shown to be around one hundred times faster than on the central processing unit.

Radiation Damage in Particle Accelerator Materials

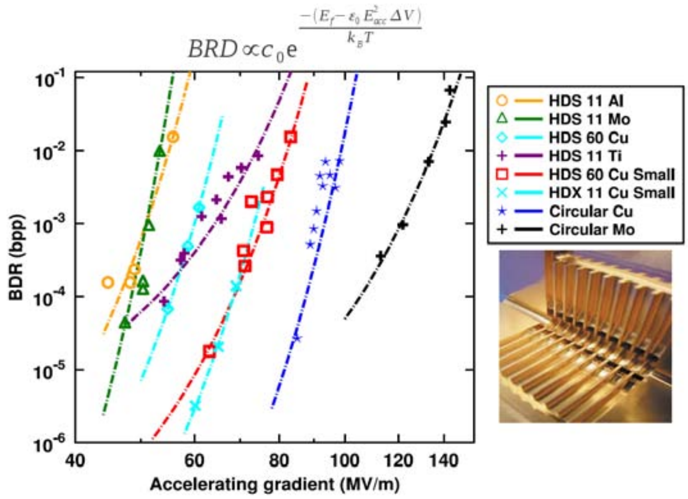
The recent discovery of a 125 GeV mass Higgs-like particle [Phys. Lett. B 716 (2012) 1, Phys. Lett. B 716 (2012) 30] at CERN's Large Hadron Collider (LHC) provides an answer, the Higgs mechanism of mass generation of the elementary particles in the Standard Model of elementary particle physics. At the same time the discovery raises more questions to be answered. For instance, it is not clear how to characterize this new Higgs-like elementary particle, and whether there are other massive Higgs-like particles. Some characteristics of this new boson, like its quantum numbers and self-coupling, are out of the range of LHC physics. The required precision measurements face a demand for a new electron-positron collider in the few hundred GeV to several TeV range. There are also compelling reasons, like dark matter in the universe, to believe that there are other new particles or phenomena to be discovered at about 0.3-3 TeV.

The most promising electron-positron collider candidate to reach multi-TeV energies is the Compact LInear Collider (CLIC) [CERN-2012-005]. The novelty of the CLIC Two-Beam Acceleration technique is to generate the high frequency, high power microwaves needed to accelerate a low-intensity beam to very high energies by decelerating a high-intensity low-energy beam, i.e., basically working as a transformer, turning high current and low voltage to lower current and higher voltage. This scheme addresses a central issue in a linear accelerator (linac) design: reaching high accelerating gradients (≥ 100 MV/m) to keep the collider length and cost within reasonable limits. Despite this, to reach a collision energy of 3 TeV, the length of the collider will have to be of the order of 50 km. One of the key reasons why the length of the collider cannot be shortened is the accelerating gradient limit. The increase of the gradient leads to the extensive power loss due to the electric breakdowns taking place at the metal surfaces of the cavities inside the multi-km pipe of the accelerating structures.

The multiscale model under development at HIP in the group lead by Doc. F. Djurabekova aims to assist the understanding of the nature of the breakdowns, their onset and possible ways of keeping the breakdown rate at the acceptable limit. The model is based on the consideration of plastic deformations initiated by the tensile stresses in the presence of high electric fields. We have shown that the extended defects present in the industrially prepared Cu samples can serve as stress concentrators for punching the dislocation loops in a repeated manner. This mechanism can lead to mass transport yielding a protrusion on the surface, a nucleus for sharper surface irregular features, which can lead to the breakdown. In 2012 we have developed an analytical model [Phys. Rev. ST Accel. Beams 15 (2012) 071002] for the vacuum electric breakdown rate dependence on an external electric field, observed in test components of CLIC. The model is based on a thermodynamic consideration of the effect of an external electric field on the formation enthalpy of defects. The model reproduced very well the breakdown rate of a wide range of radio-frequency breakdown experimental data (see the figure above). We also showed that the fitting parameter in the model can be interpreted to be the relaxation volume of dislocation loops in materials. The values obtained for the volume are consistent with dislocation loops with radii of a few tens of nanometres.

In the same project we also found an interesting healing effect of intense electronic energy deposition arising during swift heavy ion irradiation (SHI). We demonstrated this effect in the case of 3C-SiC damaged by nuclear energy deposition. The work was done within a broad international collaboration with several experimental groups in France working with the GANIL accelerator and computational groups at the University of Tennessee (UT) and HIP [Phys. Rev. B 86 (2012) 100102(R)]. Both studies provided consistent indications of disorder decrease after the irradiation, and established that SHI-induced recrystallization due to a thermal spike phenomenon takes place at amorphous-crystalline interfaces.

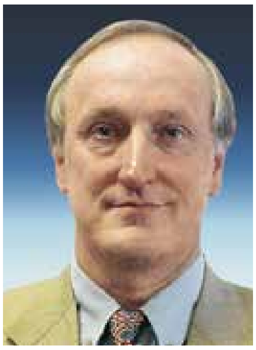
We studied the combined effect of electronic excitations and the nuclear collision cascades on the damage production in amorphous SiO_2 in the range of energies between 0.6 and 76.5 MeV of Au ions in collaboration with the experimental group from the UT. We found that in this regime, the local heating due to electronic excitations gives a significant contribution to the displacement cascade damage [J. Phys. D 45 (2012) 505305]. Together, these results show that contrary to the decades-old assumption that nuclear and electronic processes always act independently of each other, there is an ion irradiation energy and mass regime where both affect materials at the same time.



Measured dependences of BDR (in units of breakdown per pulse, bpp) versus electric field (E_{acc}) for different accelerating structures and fits of the model to the data. In the formula, E_f is the formation energy of a dislocation loop, ΔV is its activation volume.

High Energy Physics Programme

Heimo Saarikko,
High Energy Physics
Programme director



The activities of the High Energy Physics Programme in 2012 concentrated on the operation of the Helsinki-built T2 spectrometer for the TOTEM forward physics experiment, as well as preparing and leading physics analysis activities of the TOTEM data from the early LHC runs, enabling the first measurement of the total, elastic and inelastic proton-proton cross section at $\sqrt{s} = 7$ TeV. The group is one of the major contributors to the forward physics experiment at LHC TOTEM, and in the development of a competitive physics programme for it, including future upgrade plans. The Helsinki group is contributing significantly to Higgs searches in the CDF experiment at Fermilab's Tevatron antiproton-proton collider. In 2012 the Compact LInear Collider (CLIC) study completed its Conceptual Design Report of a multi-TeV linear electron-positron collider based on the CLIC two-beam concept. In 2012 the Detector Laboratory activities have supported the major experiments of HIP to a very significant extent. The extensive infrastructure of the Detector Laboratory and the wide know-how of its personnel have provided an exceptional opportunity for organising practical hands-on detector courses for the students of the Physics Department at the University of Helsinki. Intense educational programmes were carried out in connection with the research activities, both at the undergraduate and graduate levels.

Risto Orava,
TOTEM Operation
project leader

TOTEM Operation Project

Background

In 2012 the HIP/AFO Forward Physics group concentrated on: (1) completing the CDF/Tevatron physics analyses for which a series of Physical Review articles were authored by the following AFO PhD candidates: Erik Brücken, Petteri Mehtälä, Timo Aaltonen and Francesco Devoto, (2) beginning the physics analysis activities of the TOTEM/LHC experiment, based on the PhD thesis studies by Fredrik Oljemark, Jan Welti and Mikael Mieskolainen, (3) constructing the remaining reserve GEM detectors for the Helsinki-built highly successful T2-spectrometer (PhD thesis by Timo Hildén), and (4) participating in the TOTEM Upgrade phase development and detector construction work.

In close connection with its research activities, the Helsinki group continued to carry out educational programmes both at the undergraduate and graduate levels. Within the past five years, six PhDs and five MSc's have been completed in the group. Importantly, these former students of the group have rapidly been recruited to important positions in research institutions, notably at CERN, and in various industries. Domestic summer student and technical trainee programmes, tailored for university students, are continuing at CERN. Since the beginning of 1990, the Helsinki group has produced 27 PhDs, 42 MSc's and trained numerous physics and technical students in its experimental high energy physics projects at CERN and Fermilab.

The CDF and TOTEM activities of the HIP/AFO Forward Physics group are supported by the Helsinki Institute of Physics (HIP) and the Division of Elementary Particle Physics (AFO) of the Physics Department at the University of Helsinki. Important external funding contributions have been received from the Academy of Finland, the R&D funding agency TEKES, and the recently established Sensor Center Ltd, which is mainly owned by Helsinki University Funds.

TOTEM Experiment

The TOTEM experiment has rapidly gained a reputation as a frontier experiment in elastic scattering and total cross section measurements in proton-proton collisions. The first-rate LHC data collected during the low-luminosity special runs in 2011 and 2012 have yielded four major publications with a strong impact on both the experimental and theoretical community in the field. The performance of the TOTEM detectors is by now well understood, and the data collection efficiencies are at the design levels.

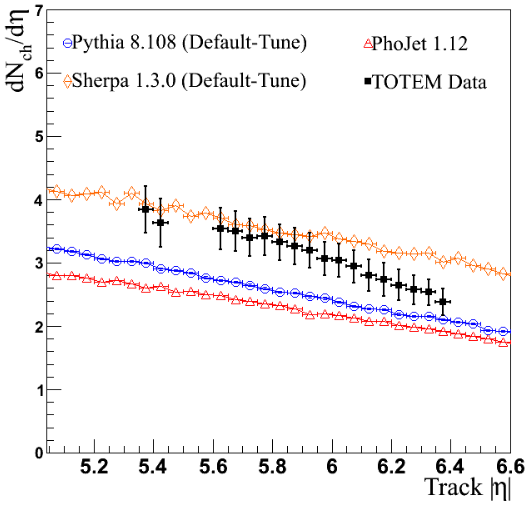
The physics results of 2012 include the first total cross section measurement at the LHC, measurement of the forward charged particle pseudorapidity density, and the differential cross section for elastic proton-proton scattering. Several other physics results are ready for publication: measurements of inelastic and single, double and central diffractive cross sections, and total cross section measurement with an 8 TeV centre-of-mass energy.

The Helsinki group has been one of the key contributors to the design and R&D of the forward detector systems at the LHC. The group has excellent potential for major contributions in the physics of inelastic diffractive scattering and central exclusive production (CED), where the ultimate goal is to measure the spin-parity properties of the Higgs boson.

The detector work of the Helsinki group focused on the maintenance of the TOTEM T2 spectrometer. During the 2012 winter shutdown, the group participated, among other things, in replacing all the position sensors on the detectors. This was accomplished by making a base support system to glue the sensors onto the detectors. This support now makes possible a much faster installation and more precise alignment of the sensors thus also enabling more reliable measurements.

The first joint TOTEM + CMS data taking was successfully completed in May 2012. The data were taken with common triggers and both experiments were in the read out. Offline data were then synchronised by orbit and bunch numbers and merged for common data samples. During the long 2013-2014 shutdown, the data acquisition system, trigger and simulation software of the two experiments will be fully integrated.

The physics analysis of the Helsinki group concentrated on inelastic and diffractive cross section measurements. The group completed the first direct inelastic cross section measure-

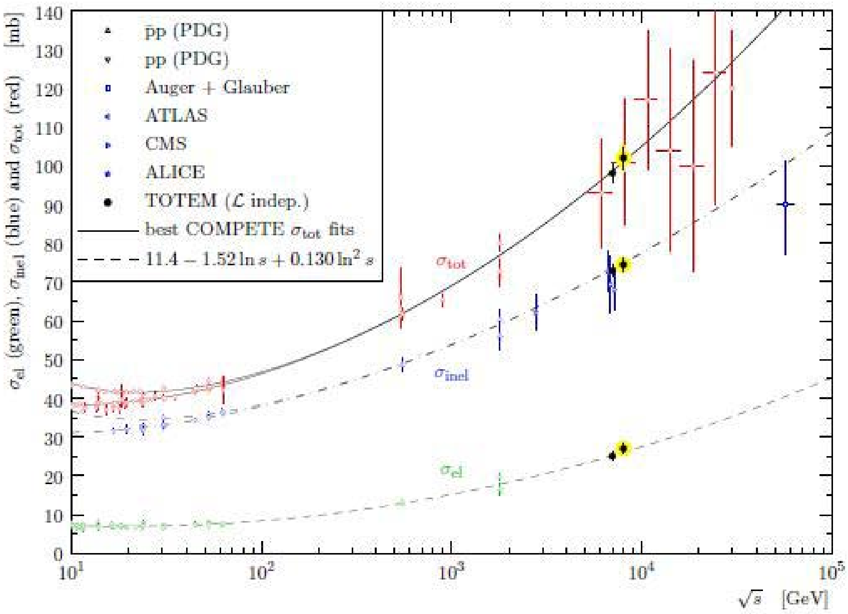


The charged-particle pseudorapidity density distribution for proton-proton collisions at 7 TeV centre-of-mass energy. Black squares, red triangles, blue circles and orange diamonds represent, respectively, the TOTEM measurement, and Phojet, Pythia8 and Sherpa event generator predictions for charged particles with transverse momentum larger than 40 MeV/c in events with at least one charged particle in the $5.3 < |\eta| < 6.5$ range.

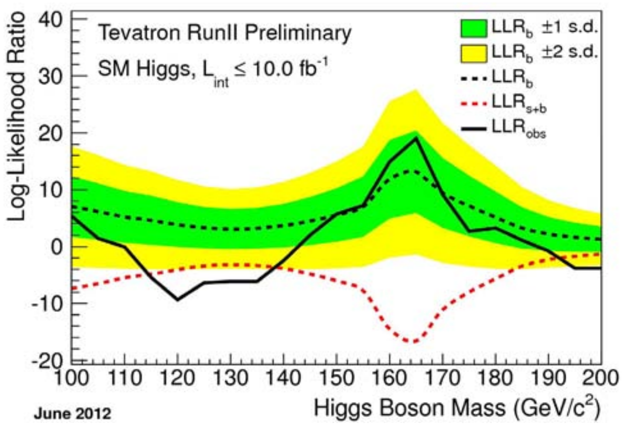
Helsinki group members participated in replacing faulty TOTEM GEM detectors.

ments with 7 TeV and 8 TeV data. The inelastic rate is measured using the T2 and T1 detectors as event counters and correcting for experimental uncertainties. The measurement was combined with the elastic rate measurement for the first luminosity independent total cross section measurement. The cross sections for inelastic, elastic and total cross sections are shown in the figure below.

The group's other physics analyses, single and double diffractive cross section measurements, are nearly completed. The single diffractive events are selected by requiring a single proton on one side of the interaction point and charged particles in the T2 and/or T1 telescopes. The double diffractive events are selected by requiring tracks in both T2s and nothing in T1 detectors. Such event selections provide extremely pure samples of single and double diffractive events.



The TOTEM measurements of the total, elastic and inelastic proton-proton cross sections at √s = 7 TeV and 8 TeV compared to other measurements of the same quantities.



The Tevatron combination of Higgs boson searches.

The TOTEM team of the Helsinki group (members & advisors) in 2012 are: Erik Brücken (PhD student), Francisco García (post-doc), Jouni Heino (lab.eng.), Timo Hildén (PhD student), Valery Khoze (advisor), Rauno Lauhakangas (detector scientist), Jerry Lämsä (advisor), Mikael Mieskolainen (MSc student), Tuula Mäki (post-doc), Fredrik Oljemark (PhD student), Risto Orava (professor, Helsinki group leader), Heimo Saarikko (professor, HIP Programme leader), Jan Welti (PhD student), Alex Winkler (PhD student) and Kenneth Österberg (University lecturer and TOTEM Physics Co-ordinator).

CDF-Experiment: Top Quark and Higgs Boson Analyses

At the end of October 2011, the Tevatron run II was finished and the Helsinki group members now concentrate on finalising their theses based on the full CDF data set of 10 fb^{-1}. In 2012, after several years of an aggressive physics programme aimed at improving Higgs-boson analysis techniques, Tevatron reached the Standard Model Higgs-boson sensitivity. The combined Tevatron Higgs search, shown in the figure to the left, resulted in a 95% C.L. exclusion for the SM Higgs mass m_H within the mass regions between 147 and 180 GeV/c^2, and 100 and 103 GeV/c^2. An excess with a significance of 2.5σ is seen, and may be interpreted as a Higgs-boson with a mass in the region of 115 to 135 GeV.

Combining the Higgs with bbar searches only, the Tevatron experiments were able to claim evidence of a Higgs-like particle, thus complementing the results published by the ATLAS and CMS experiments at CERN.

During 2012 diffractive physics studies continued with the CDF data that led to the first observation of exclusive diphoton production in hadron-hadron collisions in the previous year. The figure to the right shows the measured cross section in comparison with the theoretical expectations using different parton density distributions. The goals of the on-going studies are more precise results for the diphoton study as well as a successful search for central exclusive production of neutral hadrons.

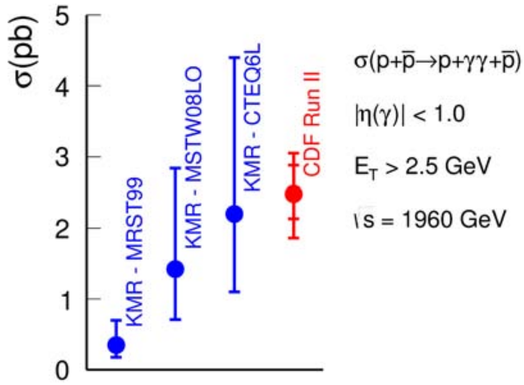
The CDF team of the Helsinki group (members & advisors) in 2012 are: Timo Aaltonen (PhD student), Erik Brücken (PhD student), Francesco Devoto (PhD student), Petteri Mehtälä (PhD student), Risto Orava (professor, Helsinki group leader), and MSc student Mikael Mieskolainen, who has developed multivariate analysis tools based on CDF data.

Linear Collider Research Project

The Linear Collider Research project 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. During 2012, the study completed its Conceptual Design Report (CDR) describing the CLIC two-beam concept and its feasibility, the physics and detectors as well as a staged approach of CLIC with centre-of-mass energies from 0.5 to 3.0 TeV with layout, performance, cost estimate and power consumption.

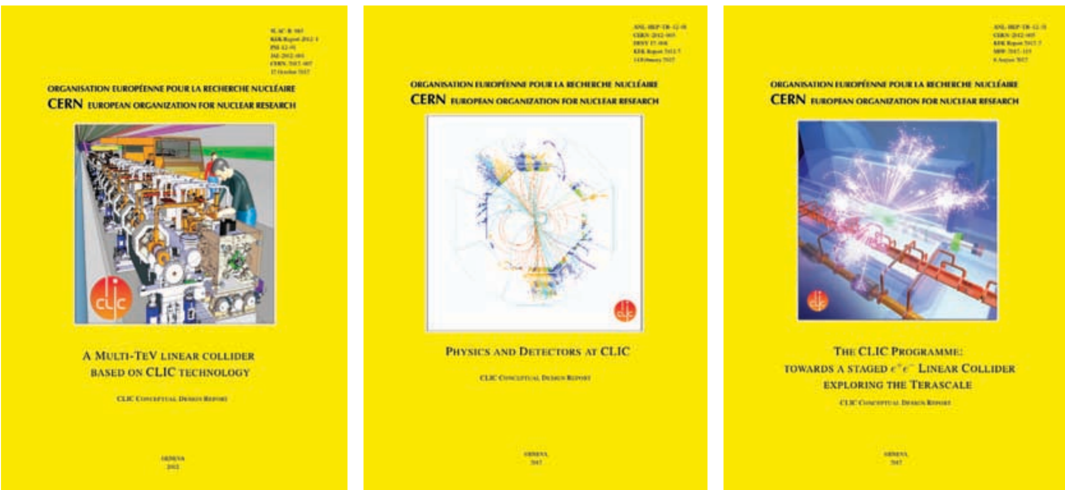
The focus of the HIP contribution was on R&D for the CLIC RF structures and the integration of the RF structures in the CLIC module. The topics covered include the study of the thermo-mechanical behaviour of the CLIC module, the development of dynamic vacuum and internal shape measurement techniques for RF structures as well as significant contributions to the cost study, manufacturing and precise assembly for the RF structures. The R&D was done in close collaboration with the CERN CLIC RF structure development group, notably Drs W. Wünsch and G. Riddone, and several Finnish industrial and academic partners, notably the Technical Research Centre of Finland (VTT). The project had three MSc students (A. Nummela, L. Kortelainen and W. Zhou) and one researcher (J. Väinölä) at CERN plus the project leader and two PhD students (A. Meriläinen and R. Montonen) in Helsinki. In addition, a new post-doc (M. Aicheler) started to work for the project at CERN in December 2012.

The RF structure manufacturing and precise assembly work involved five Finnish industrial partners through the HIP co-ordinated and EU-funded "MeChanICs"-project. Within this framework, one researcher from Metso



Comparison of the measured cross section with theoretical expected (in pb) for the exclusive photon-pair production.

Kenneth Österberg, Linear Collider Research project leader



The front cover of all three volumes of the Compact LInear Collider Conceptual Design Report published as CERN reports CERN-2012-007, CERN-2012-003 and CERN-2012-005, respectively.

Materials Technology worked at CERN for 6 months on brazing and bonding studies of materials with a view to their usage in CLIC RF structures and one researcher from CERN at Loval Oy for two months at the end of 2012 with diffusion bonding tests of disks for the RF structures. The aim of the MeChanICs-project is to enhance the industrialisation of the CLIC RF structure manufacturing as well as develop the capability in Finland to manufacture copper-based high-precision assemblies like the CLIC RF structures. A proposal ("TAVAKS") to fund the R&D to take place in the industrial partners was made to TEKES. In addition, the project headed the preparation and submission to FP7 of an Initial Training Network proposal, "CLIMB", with 13 partners from all over Europe.

A critical issue for the CLIC overall cost is the optimisation of the manufacturing costs for the RF structures, since they constitute a significant fraction of the overall cost of CLIC. HIP was involved in a study that estimated the possible cost-reduction that would be achieved if the RF structures were made in considerably longer units than currently planned. The results are documented in an MSc (eng.) thesis to be completed in 2013.

The CLIC module with all the accelerator components and services integrated has to maintain a high precision also during CLIC operation. To achieve this, different configurations of the whole CLIC module have been modelled in detail to estimate their stability with various loading conditions. Several optimisations and refinements were made during 2012 to the model to improve its performance and the results were reported at IPAC'12. This work has partially been funded by "EuCARD", a European-wide EU network on accelerator R&D, and private foundations. The results of the model will be compared to measurements with full-scale test modules (without a vacuum and beam) at CERN in 2013. HIP contributed with one MSc student to the quality assurance control work of the components for the test modules being built.

Furthermore, a study of stress and deformation of the RF structure disks during the bonding steps of the assembly was performed. During this study, the need for a method to validate the internal shape of the RF structure disk stack non-destructively after possible thermo-mechanical deformations during assembly became evident. In autumn 2012, an effort to develop such a method using the optical fibre coupled common-path Low-Coherence Interferometry (LCI) -technique was launched as a PhD thesis project in collaboration with Prof. Edward Hæggström and his group at the Electronics Laboratory (ETLA) of University of Helsinki's Department of Physics, the aim being a scanning method for the whole RF structure disk stack, emphasising the iris region, with an axial and lateral precision of a few and 100 μm, respectively.

The development of a photon absorption-based method to dynamically measure the outgassing from the RF structure surfaces during a single RF pulse train in collaboration with ETLA continued. Simulations predict outgassing levels that are below the critical levels of being a feasibility issue, but direct measurements of 10^{-8}–10^{-9} mbar local pressure at 10–100 ns time scales in RF structures are required to test the validity of these predictions. In 2012, measurements using the above method at a dedicated test set-up in the Accelerator Laboratory in Kumpula showed promising results with sensitivities to 10^{-6}–10^{-7} mbar copper partial pressures in single pass measurements. The measurement equipment and method will be developed further in 2013 to improve its sensitivity before attempting outgassing measurements at CERN's 12 GHz test stand.

A key issue for CLIC is to limit the electrical breakdown ("sparking") probability in the accelerating structures to achieve a stable beam with a sufficiently high accelerating gradient (> 100 MV/m). We collaborate closely with Prof. K. Nordlund and F. Djurabekova, PhD, who have developed a multi-scale model for the physics processes leading to breakdown and other defects on the surface of the RF structures. The multi-scale model should be able to guide us to appropriate choices for the material, for surface preparation and for the design for the accelerating structures, in view of reducing the breakdown probability. As a new line of collaboration with them, they also initiated molecular dynamics simulations of the deformation of the RF structure disks during assembly to be compared with the actual measurements of bonded RF structures.

Detector Laboratory

The Helsinki Detector Laboratory is infrastructure specialised in the **instrumentation of particle and nuclear physics**. It is a joint laboratory for 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 design, construction and testing of silicon and gas-filled detectors. The Laboratory is also active in education and outreach.

All the projects in the Detector Laboratory are aimed to provide reliable instruments for large international experiments. Therefore, special effort is being put into component testing and long-term reliability, as well as into detector assembly. In 2012, the Laboratory hosted several **HIP projects** concentrating on the CMS and TOTEM experiments at CERN, and the NUSTAR/SUPER-FRS experiment at FAIR. The Laboratory is also actively participating in the development of detector technologies in the framework of the CERN RD39, RD50 and RD51 Collaborations, mainly with the support from the Magnus Ehrnrooth foundation.

The Laboratory also supports several **UH/Physics research activities**. The connection to the Division of Elementary Particle Physics is naturally very tight. In addition, the Laboratory collaborates with the Electronics Research Laboratory, supporting especially their activities in optical imaging techniques and ultrasonic interconnection technologies. Furthermore, the co-operation with the Accelerator Laboratory of the Division of Material Physics is traditionally strong in the field of radiation hard silicon detectors. Additionally, there are strong connections with the Accelerator Laboratory of the University of Jyväskylä and with the Micronova/Nanofab facility of the School of Electronics of Aalto University.

The Laboratory participates actively in **teaching and societal interaction**. In 2012, the Laboratory offered laboratory exercises and special assignments of detector technologies for students from UH/Physics. In addition, several students continuously perform their doctoral and master studies at the Laboratory. Each month groups of high-school students and teachers visited the Laboratory for demonstrations about detector technologies. The Laboratory also actively participates in the common outreach efforts taking place at the University of Helsinki. Consultancy, based on its own expertise, is frequently given to research groups from other universities and research institutes.

The versatile **infrastructure** of the Laboratory forms a strong basis for the research activities. The infrastructure was significantly improved during 2012 thanks to funding from the Division of Elementary Particle Physics of UH/Physics. Firstly, the Laboratory obtained a new ultrasonic wire-bonding device that is crucial for manufacturing semiconductor detector modules. Secondly, the Laboratory was able to purchase several new, fast devices for detector characterization and quality control.

Eija Tuominen, Detector Laboratory coordinator

E-SAIL tether factory in the Detector Laboratory.

Students are introduced to the instrumentation of physics at the clean room of the Helsinki Detector Laboratory.

In 2012, Prof. Heimo Saarikko acted as the director of the Laboratory and Docent Eija Tuominen co-ordinated the activities. Permanent personnel consists of technician, watchmaker/micromechanic Raimo Turpeinen and laboratory engineers Dr. Francisco García, Jouni Heino, MSc (Tech) and Rauno Lauhakangas, MSc. In addition, several project scientists and students work daily at the Laboratory.

Education

The research and experimentation activities at CERN and Fermilab constitute a platform for educating and training students in physics and technology, and the Detector Laboratory also serves as the basis of education and training in experimental high energy physics. Summer student and technical training programmes at CERN and Fermilab are continuing. In connection with the research activities, educational programmes both at the undergraduate and graduate levels have been established.

Due to the versatile infrastructure of the Detector Laboratory and the wide know-how of its personnel, the Laboratory offers detector courses and advanced laboratory assignments for the students of the Physics Department. In addition, several students perform their doctoral and graduate studies at the Laboratory. The Laboratory also actively participates in interactions with society: in 2012 several groups of high school students and teachers visited the Laboratory.

The group has been involved in preparations for organising a national event for the "European Master Classes for High School Students: Hands on Particle Physics". This event is typically arranged jointly in more than 60 European university departments from about 20 countries. The programme of the Master Classes event includes high standard lectures in Modern Physics, visits and experimental work in local laboratories, as well as a common European video conference, where the results of the experiments are collected and experiences of the day exchanged between participants in other European universities.

CMS Programme

The Compact Muon Solenoid (CMS) experiment is one of the two large multi-purpose experiments at the LHC. During 2012, the LHC surpassed previous records in luminosity and collision energy, providing proton-proton collisions at 8 TeV centre-of-mass energy and reaching luminosities up to 77% of the original design value. The breakthrough of the year was the discovery of a new boson with a mass of about 125 GeV, which is most likely the long-sought Higgs boson.

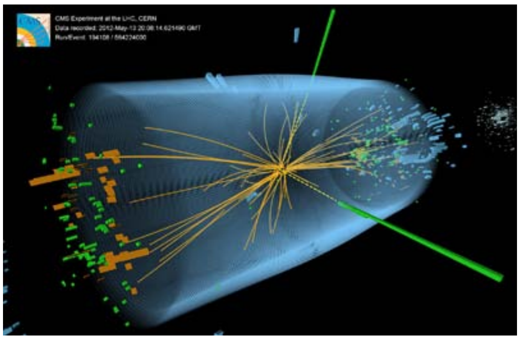
Paula Eerola,
CMS Programme director

Introduction

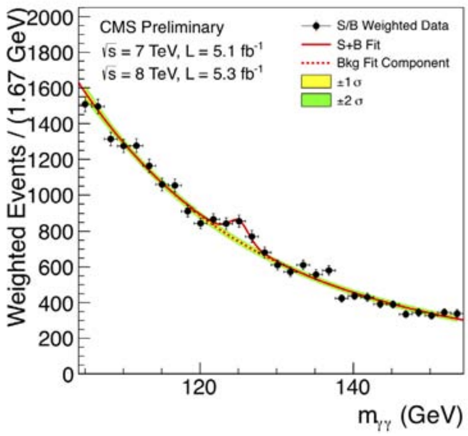
The year 2012 was an exceptional year in terms of physics outcome and machine performance. In addition to the breakthrough of the year, the observation of the Higgs-like particle announced in July, more than one hundred scientific publications in all physics areas covered by the CMS experiments were published.

The LHC delivered 23.3 fb^{-1} of integrated luminosity, exceeding the most optimistic expectations from the beginning of the year. This collected data will allow us to enter an even more challenging domain of rare signals, requiring an excellent understanding and control of background processes and systematic errors, and where the calibration and alignment efforts by the HIP group is of utmost importance.

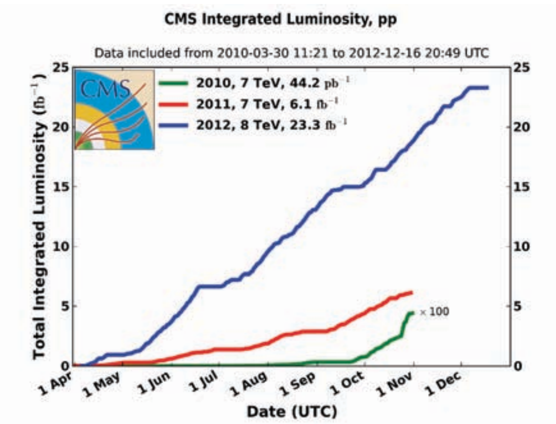
The Finnish member institutes of CMS are the Helsinki Institute of Physics (HIP), the University of Helsinki and Lappeenranta University of Technology. HIP has an overall co-ordinating role in the Finnish CMS involvement. The CMS programme at HIP is divided into three projects: the CMS Experiment project, responsible for the physics analysis and operations, the CMS Upgrade project, responsible for the Finnish involvement in the CMS upgrades, and the CMS Tier-2 Operations project. The three projects plus joint activities are described in the following.



Candidate event for $H \rightarrow \gamma\gamma$ decay.



Invariant mass spectrum for selected two-photon events.



CMS integrated proton-proton luminosities collected in 2010–2012.

Katri Lassila-Perini,
CMS Experiment
project leader

The CMS Experiment Project

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

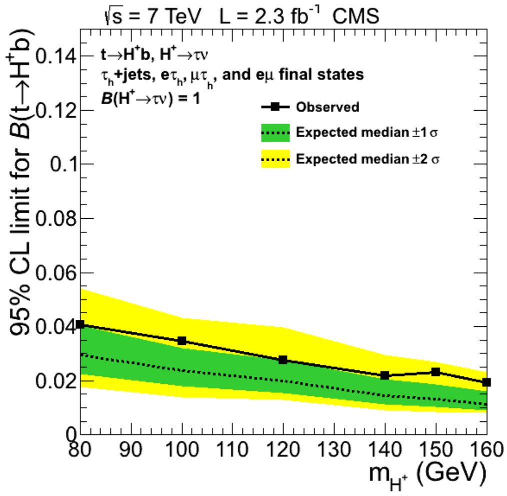
Physics Analysis

B physics. The LHC provides extremely high rates of B-hadrons due to the high b-production cross section, favourable signal-to-background ratio, and high luminosity. Due to trigger constraints, the scope of the CMS heavy flavour programme is defined by final states with di- or multimuons, and b-jets.

There were several CMS B-physics highlights in 2012: observation of a new beauty baryon Ξ_b^{*0}, observation of new unexplained states in B^+ meson decays, "melting" of Υ states in lead-lead collisions, and a new upper limit for the branching fraction of the rare decay $B_S \rightarrow \mu^+\mu^-$.

In 2012, the HIP group was particularly involved in the analysis of the decay channel $B_S \rightarrow J/\Psi\phi$, with the J/Ψ decaying into two muons and the ϕ decaying in two kaons. The B_S decay is interesting for testing possible contributions from new physics beyond the Standard Model. In 2012 we performed a measurement of the width difference of the B_S eigenstates ($\Delta\Gamma_S$) (CMS-PAS-BPH-11-006, PhD student G. Fedi). The final goal will be the measurement of the weak phase ϕ_S. The weak phase measurement requires tagging of the B flavour, i.e., extracting the flavour of the bottom quark inside the B_S meson. A.-M. Visuri completed her Master's thesis on flavour tagging by using Monte Carlo simulated samples, and the work is now being continued by MSc student Terhi Järvinen. Studies with the $B_S \rightarrow J/\Psi\phi$ channel and the reference channel $B^+ \rightarrow J/\Psi K^+$ with Monte Carlo data samples have been done, and the next step is to use the B_S and B^+ data samples collected by the CMS experiment during the year 2012.

Higgs Boson Physics. The discovery of the newly found Higgs boson candidate has raised



Model independent 95% confidence level upper limit for the branching fraction $BR(t \rightarrow bH^+)$.

an intriguing question about its type. In models with extended symmetry beyond the Standard Model there are several Higgs bosons and at least two of them have an electric charge. Observing the charged Higgs bosons would be the most stringent test of the underlying model. The Higgs analysis group of HIP is responsible for the search of the charged Higgs bosons in the most sensitive channel with $H^\pm \rightarrow \tau\nu$ decay and fully hadronic final state. In this channel the charged Higgs boson transverse mass can be reconstructed from the τ jet and the missing transverse energy to extract the signal from the selected events. Events with one τ jet, large missing transverse energy from the neutrinos, and at least three additional jets of which at least one b-tagged jet, are selected. The first paper on the searches for the light ($m_H^\pm < m_{top}$) charged Higgs bosons in the $tt \rightarrow tbH^\pm$, $H^\pm \rightarrow \tau\nu$ process was published in 2012 (JHEP 1207 (2012) 143), combined with results from the semi-leptonic final states of the same process, on data collected during the first half of 2011 at the centre-of-mass energy of 7 TeV. The number of observed events was found to be compatible with the expected Standard Model background and therefore a stringent limit was set on the branching ratio of $t \rightarrow bH^\pm$.

In addition to publishing the paper, the search was continued in 2012 on the data collected in 2011 and on the data collected in 2012 at the centre-of-mass energy of 8 TeV. The search was extended to the heavy

($m_H^\pm > m_{top}$) charged Higgs bosons produced in the process gg → tbH±. The data collected in 2012 is characterized by a significant amount of event pile-up, reaching on the average 25 additional events on the top of the triggered event, which is a challenge for a fully hadronic channel. The trigger thresholds were increased requiring recalculation of the trigger efficiencies for each period of different pile-up conditions. Work to understand the effects of the pile-up on the number of hadronic jets, on the jet and missing transverse energy scales, and on the τ jet and lepton isolations is continuing. A method to reconstruct the invariant mass of the light charged Higgs boson exploiting the top mass constraint was developed to complement the transverse mass measurement.

The backgrounds with genuine τ's from tt production and from electroweak processes were measured with data events resembling tt topology and containing an energetic muon and jets, by replacing the muon by a simulated τ decay. The QCD multijet background was measured from the data collected with the signal trigger by factorising out the τ-jet isolation and polarisation selections to ensure a sample dominated by QCD multi-jet events. An alternative method for measuring the QCD multijet background, based on reversing the τ-jet isolation in the candidate selection and on fitting the missing transverse energy shape, was developed. The results were found to agree with those from the factorisation method thus reinforcing the understanding on the measured QCD background level.

The group continued its commitment to τ trigger development and measurement. The triggers were updated for the high luminosity conditions, and new control triggers were added to improve the trigger efficiency measurements. The collaboration within the LHC Higgs Cross Section Working Group was continued by studying the SUSY parameter dependence of the experimentally excluded region of the light charged Higgs boson. The main contribution to this work was done by summer student Santeri Laurila. The group continued to participate in the maintenance and improvements of the CMS core software and in off-line data quality control of the trigger system.

Jet Physics

The inclusive jet cross section is one of the most basic Standard Model measurements at hadron colliders, and a main application of the jet energy corrections. It is used for determining proton parton distribution functions (PDFs), testing perturbative QCD and looking for new physics. Mikko Voutilainen produced an independent cross-check of the 7 TeV analysis with 5/fb, and provided feedback on the 8 TeV analysis. MSc student Mikael Kuusela studied the unfolding problems in high energy physics for his Master's thesis that was jointly supervised by the Aalto University and ETH Lausanne. Some of his work was integrated into the 7 TeV analysis that was submitted to PRD in January 2013, and he was also selected to the CMS statistics committee to act as a consultant. Mikael completed his MSc thesis on unfolding methods in summer 2012, receiving grade 5/5.

A related measurement of the ratio of jet cross sections with anti-kT clustering radii 0.5 and 0.7 was performed by Mikko Voutilainen and the complete work was presented to the SMP-J (the Jet Physics subgroup of the Standard Model group) in September. This analysis will proceed to publication in 2013, and is part of the proposed 3-year project "Precision Measurements of Quantum Chromodynamics" that won 145 000 EUR from the University of Helsinki for the 2013-2015 period.

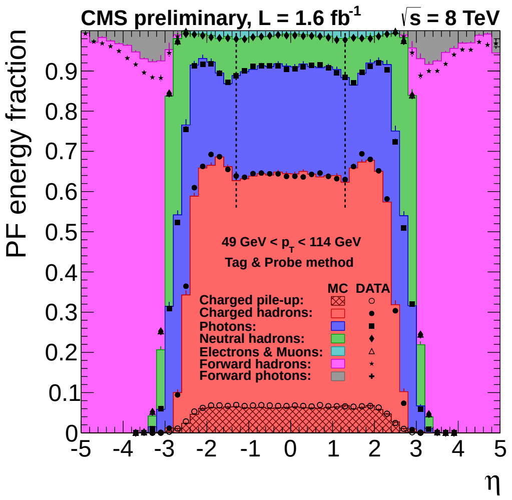
Jet Energy Corrections

The CMS Jet Energy Corrections group was co-convened by Mikko Voutilainen until mid-September 2012. During 2012, the group produced three sets of competitive calibrations. The first two of these calibrations were documented in a Detector Performance Note (2012-006 and 2012-012, respectively), while the results of the final 2012 calibration are being worked into a paper.

The biggest challenge during the year was to keep up with the increasing pile-up, which increased by a factor of two from an average

10 pile-up in interactions in 2011 to about 20 at the end of 2012. Despite the challenging conditions the group managed to maintain the highly competitive level of JEC uncertainties and even started reducing pile-up uncertainties by the end of 2012. Summer student Tommi Tenkanen contributed to the effort by analysing the high pile-up jet data for his summer project at CERN, and Mikko Voutilainen contributed to the production of pile-up corrections based on the jet area method, as well as being in charge of producing the final JEC uncertainties and their correlations.

In 2012 Juska Pekkanen continued the jet composition research, started in summer 2011, as a Master's thesis under the guidance of Mikko Voutilainen. Apart from monitoring jet structure in data and simulation and producing corresponding plots for the CMS Collaboration, we have started the development of a new method for fine tuning jet energy calibration. Our approach is to pinpoint discrepancies between the energy composition of measured and simulated jets, find what causes them and finally propose re-adjustment of the CMS detector. In practice we test different miscalibration scenarios in detector simulations using Monte Carlo generated proton-proton collisions and monitor whether miscalibration of certain detector elements could be a source of discrepancy in jet energy composition. The first results of this study are already used in the CMS software 53X in estimation of systematic uncertainties in the jet energy scale.



Jet energy composition versus jet pseudo-rapidity, measurement and simulation compared.

Physics Support

Kati Lassila-Perini has been in charge of the CMS user support for physicists for many years. This mandate came to its end as she was called to lead the new CMS Data preservation and open access project. The Physics support project oversees the tutorials and documentation for software tools needed for the physics analysis, and in 2012, the update of the basic documentation was successfully completed with the help of members of the CMS Collaboration acting as proof readers. This activity was organised during the first half of the year, and taken over by the current physics support co-ordination. The well appreciated series of physics tools -tutorials is being continued.

Data Preservation and Open Access

A major step towards open science was taken by the CMS Collaboration Board in March 2012 when the CMS policy for data preservation, re-use and open access was approved. This document describes the CMS approach for preserving scientific data in long-term and promoting its public use. K. Lassila-Perini from HIP leads the CMS project to implement this policy. A thorough review of the current CMS computing, software and data analysis practices has started and the procedures will be adapted when needed to be compatible with the long-term data preservation. HIP is a proactive partner in the data preservation project and is starting a pilot project to bring the scientific data to public use in schools.

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. As the detector alignment is a highly important issue in view of physics discoveries, continuous monitoring of the alignment is needed to detect and correct time-dependent effects and movements. In 2012 the HIP team continued its long-term participation in the alignment work of the CMS Tracker, focusing on questions of monitoring and validation. Tapio Lampén was in charge of maintenance and development of the off-line track-based alignment validation tools, and contributed to the validation process of alignment constants during the year. Summer student Jaakko Moisio carried out an important study of changes of Lorentz angle calibration of the Pixel detector. Our group also took part in the weekly alignment shift work as well as in more detailed studies, for instance the study of error estimates of Tracker modules.

The CMS Tier-2 Operations Project

Grid Computing Activities

The highlight of 2012 was the discovery of a new boson announced in a seminar on the 4th of July. The director general of CERN, Rolf Heuer said after the seminar that "Results today [were] only possible due to extraordinary performance of accelerators - experiments - Grid computing".

In 2012, CMS grid analysis and Monte Carlo production jobs were running on the Finnish CMS Tier-2 resources at an increased level to process the data from the third year long LHC high energy collision run with the increased energy of 8 TeV. For the first time more than one million grid jobs were run in a year and the CPU usage more than doubled compared to 2011.

HIP was represented in the Nordic e-Infrastructure Collaboration (NeIC) Nordic WLCG (NLCG) steering committee. The close collaboration between HIP, CSC (IT Center for Science Ltd) and the Nordic DataGrid Facility (NDGF) of NeIC resulted in good progress on many aspects of the CMS computing that are summarised in the following.

Hardware. The main CPU resource for CMS and ALICE was the 768 core Jade (2009) Linux cluster situated on the CSC premises. In addition to that, the 400 core Linux cluster Korundi (2008) and the 840 core Linux cluster Alcyone (2011) in Kumpula were also used for CMS grid jobs. The 10 Gb/s Optical Private Network (OPN) link between CSC and Kumpula was in use on both Korundi and Alcyone. The Hitachi AMS 1000 system was drained of 133 TB of data and taken out of use and replaced by the HP DL360G7 servers and HP D2600 disk shelves. The Alcyone-admin node was upgraded with new memory and disk and the PhEDEx server was given a disk upgrade. Measurement of the power used by Alcyone was implemented. Air humidity and temperature measurement was taken in use in the Korundi machine room.

Software. The Advanced Resource Connector (ARC) middleware was upgraded from version 0.8.3. to version 1.1.1.1, first on Korundi in March and then on Jade. This created problems for job submissions through the European Middleware Inititiative (EMI) Workload Management System (WMS) that were fixed in October. On Alcyone ARC version 2.0 was tested, which revealed new problems with job submissions through the EMI WMS. A problem using Terena certificates with the EMI WMS was reported and the problem was fixed in October. The dCache and Lustre systems at CSC were very stable in 2012. Monte Carlo production increased after the new WMAgent production system was taken into use at HIP.

Support for gLite version 3.2 ended and the corresponding runtime environment on all the clusters was upgraded to the EMI-2 version. The HIP site BDII server was also moved from gLite 3.2 to EMI-2. Both the PhEDEx file transfer service and the calibration service Frontier were virtualised and moved to another server. The PhEDEx service was updated, which enabled the use of the watchdog agent for the first time. A bug in the PhEDEx file deletion script was fixed. Work on the ARGUS and glexec services was started. Bugs in the Jade SGE fair share settings were fixed on Jade. The cronjob updating the CMSSW runtime environments was updated.

A new Academy of Finland -funded project concerning cloud computing, Data Indirection Infrastructure for Secure HEP Data Analysis was started together with the Department of Computer Science at the University of Helsinki. On a test OpenStack cloud setup ARC and Condor were installed and test CMSSW jobs were run successfully.

Operations. The Finnish CMS Tier-2 resources are operated, maintained and monitored jointly by HIP, CSC and NDGF. According to

Tomas Lindén, Tier-2 Operations project leader the statistics collected with the CMS monitoring tools, the Finnish Tier-2 resources performed very well and were only invited once to the bi-weekly European and Asian Tier-2 support meeting. CMS replaced the site testing tool JobRobot with the HammerCloud service. There were 140 thousand CMS HammerCloud jobs run at HIP with a mean success rate of 88.1% (97.9% in 2011). The success rate was lower than in 2011 partly because of problems with the EMI WMS service. There were 35 Savannah tickets (25 in 2011) and 7 GGUS tickets (1 in 2011) issued concerning HIP. The joint monitoring by CSC, HIP and NDGF as well as the CMS and WLCG Site Availability Monitoring jobs help to spot problems early. The stability and maintenance ease of ARC middleware allows the use of several Compute Elements for redundancy, which is important for reliability, development and testing.

PhEDEx transferred 66 TB of production data (113 TB in 2011) to HIP and 253 TB of test data (271 TB in 2011) to HIP. In 2011 the data was reconstructed more often than in 2012 which explains the larger amount of transferred data in 2011. The available storage was full partly because of the PhEDEx bug and some transfer requests had to be denied due to lack of disk space. From HIP to elsewhere 76 TB of production data (63 TB in 2011) and 178 TB of test data (175 TB in 2011) was shipped. In total 573 TB of data was transferred with PhEDEx to or from HIP (621 TB in 2011).

A total of 1 million 37 thousand CMS grid jobs (997 thousand in 2011) using 28.3 million HEPSPEC06 CPU hours (12.2 million HEPSPEC06 CPU hours in 2011) were run. In addition to this a significant amount of local batch jobs were also run.

Jaakko Härkönen, CMS Upgrade project leader

The CMS Upgrade Project

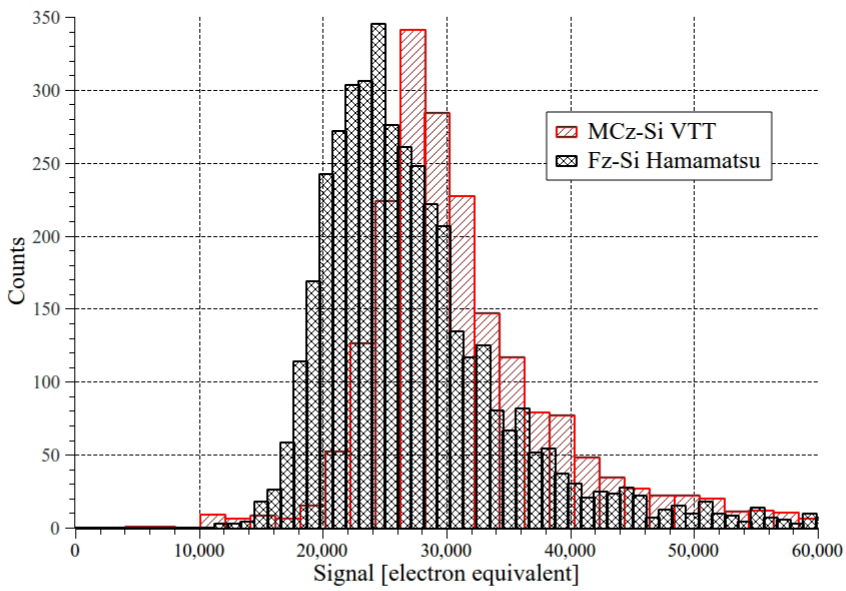
The HIP CMS Upgrade project main activity is to contribute in hardware development and operation of the CMS experiment. During 2012, the research on radiation hard silicon detectors continued in the framework of the CERN RD39 (60 members, 15 institutes) and RD50 (280 members, 55 institutes) research programmes. On a national level, intensive collaboration continued with the Micronova Centre of Aalto University and VTT, and with the Accelerator Laboratory of the University of Helsinki (UH). In 2012, Dr. Panja Luukka, nominated in 2009, continued as the CMS Tracker upgrade test beam co-ordinator. J. Härkönen, nominated in 2003, continued as RD39 spokesperson.

A technical maintenance break of the LHC for making upgrades to deliver after 2015 the maximum possible amount of beam collisions for the experiments will start in early 2013. The CMS experiment will undergo its first major hardware upgrade, named Phase I, during the shut-down period (LS1). The innermost measurement unit of the CMS, the silicon pixel detector will be completely rebuilt and equipped with new readout electronics and a cooling system capable of handling the higher amounts of data foreseen after LS1. The number of channels, i.e., pixels and related interconnections, will simultaneously be increased from the current 64 million up to 125 million channels allowing significantly better tracking performance. The HIP CMS Upgrade project is involved in the Phase I upgrade through the production and the quality assurance of a notable fraction of pixel sensor modules to be installed into the upgraded detector. The on-going activity is being carried out in co-operation with Finnish industry and VTT. The flip-chip interconnection processing is taking place at the Aalto-VTT Micronova facility. The HIP CMS group has been an active user of this facility for more than a decade.

An order of magnitude better radiation hardness will be required for silicon sensors to be implemented in the CMS experiment in the future. The CMS Collaboration has launched a R&D programme targeting at finding a technically and financially feasible solution for radiation hard silicon sensor material and design. The industrial partner of the project is Hamamatsu Photonics K.K. (HPK), which has delivered more than one hundred 150 mm diameter silicon wafers with different experimental sensor structures. A vital part of the R&D campaign is to characterize as-processed and ir-

CMS pixel read-out chip wafer in the Micronova clean room.

radiated full size sensors in real beam-like conditions with the CMS readout electronics and data acquisition (DAQ) system. The beam tests have been performed with the Silicon Beam Telescope (SiBT), the maintenance, development and operation of which has been a long-term responsibility of the HIP CMS group. The CMS test beam and related data analysis activity is co-ordinated by the HIP and FNAL CMS groups. A vital part of the novel sensor development framework is the verification of experimental results by modelling and simulations. The HIP group is participating in subgroups of RD50 and CMS sensor focused on simulation and device physics. During the past few years, more than 60 experimental sensor modules have been measured with the SiBT set-up. The initial results of the CMS-HPK project indicate that the best performing sensor material in a high luminosity environment is magnetic Czochralski silicon (MCz-Si).



Measured signal distributions of VTT magnetic Czochralski silicon sensors and Hamamatsu float-zone silicon sensors.

Activities in Lappeenranta

The Lappeenranta group has experience in building and testing optical links and related equipment for the CMS Resistive Plate Chambers (RPC) Trigger. During the LHC shutdown in 2013-2014 the RPC detectors will be upgraded by increasing the RPC coverage in the forward regions, and the Lappeenranta group will participate in this upgrade by producing some of the off-detector electronics. In 2012 Lappeenranta started the construction of ACTEL mezzanine boards and front panels for the upgrade.

Service Work and Shifts

The whole HIP-CMS programme, including people from the CMS Experiment, CMS Upgrade and CMS Tier-2 projects, participated in the CMS operations through so-called service work and shifts, as required by the CMS Collaboration.

Outreach

Outreach activities consisted of organising our own public events, such as the Higgs results announcement in July, giving information about CERN summer student programmes in several universities, as well as blog writing, giving interviews and presenting lectures to physics students, school pupils and to the general public. We also participated in joint PR-events in Kumpula, such as the alumni and new student days in 2012.

Experimental particle physics and the status of CERN and the LHC were presented in the Alumni evening at the Kumpula Campus on the 8th of March and at the Kumpula Campus Science Bazaar targeted at new students and last year upper secondary school pupils on 31st of November. Posters, a live CMS event display, videos and detector modules were exhibited with scientists answering questions and handing out brochures.

A public event was organised in Kumpula in connection with the announcement of the Higgs results on 4th of July, and consequently the results obtained very wide media coverage.

The Kumpula Detector Laboratory supervised students' laboratory projects and hosted school and other visits. At CERN, the group members contributed to the visit programme for high school student groups and high school teachers from Finland. Furthermore, several HIP members have been working as guides to the groups visiting CERN.

Nuclear Matter Programme

The Nuclear Matter Programme involves the participation of Finnish teams at CERN in studies of two aspects of nuclear and hadronic matter. These are cold exotic matter with the extreme composition of its proton and neutron numbers on the one hand and dense matter created in relativistic heavy ion collisions on the other 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 Docent 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. 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. The FAIR project leader is Professor Ari Jokinen.

Matti Leino,
Nuclear Matter
Programme director

ALICE

Table 1. ALICE recorded data summary.

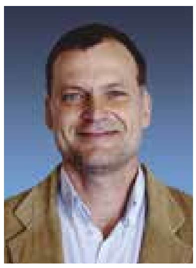
year	system	c.m. energy √s A.TeV	integrated Luminosity
2009	p – p	0.9	~ 0.1 nb^{-1}
2010	p – p	7.0	~ 5.0 nb^{-1}
	Pb – Pb	2.76	~ 10.0 μb^{-1}
2011	p – p	2.76	~ 0.4 nb^{-1}
	p – p	7.0	~ 80.0 nb^{-1}
	Pb – Pb	2.76	~ 0.1 nb^{-1}
2012	p – p	8.0	~ 9.9 pb^{-1}
	p – Pb	5.02	~ 2.0 μb^{-1}
2013	p – Pb	5.02	~ 31.1 nb^{-1}
	p – p	2.76	

Introduction

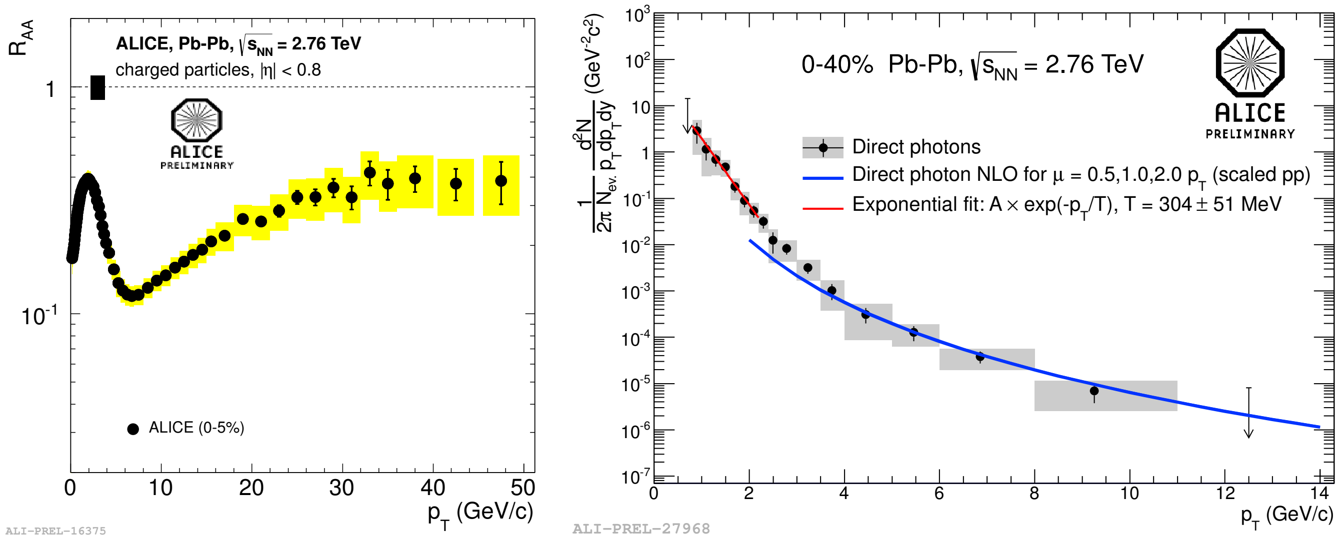
The year 2012 was very important for the ALICE Collaboration. It marked the end of the successful data taking period started by the first pp collision recorded in November 23rd 2009. Since then the ALICE experiment has recorded a rich wealth of data (see the table to the right).

The main focus of ALICE is the study of the deconfined QCD matter created in ultra-relativistic heavy ion collisions and thus the road towards the main scientific mission was opened in 2010 and 2011 when the Pb-Pb data at $\sqrt{s_{NN}}$ = 2.76 TeV were collected. An analysis of the Pb-Pb data has resulted, so far, in 14 publications in peer reviewed journals and many more are being prepared.

Although it is difficult to single out the most important ALICE results, among these there is certainly the measurement of the transverse momentum dependence of the nuclear modification factor [Phys. Lett. B 696 (2011) 30] (left panel of the figure on the following page). First of all it is the largest ever observed suppression of high-p_T charged particles in central heavy ion collisions (suppression factor around 7 at the minimum) but it also reveals new features: a rising trend and hint for saturation at p_T > 30 GeV/c. Another intriguing observation comes from the analysis of the p_T-dependency of the direct photon yields [arXiv:1210.5958] (right panel of the figure on the following page). One can clearly distinguish two components. There is the power law tail in the region p_T > 3 GeV/c (the figure on the following page, right panel, blue line) which originates mainly from pQCD Compton photoproduction. The second component, in the low transverse momentum region, is expected to originate largely from thermal radiation. The shape of this low-p_T distribution is clearly exponential and the inverse slope parameter (inv. slope T = 304±51 MeV) reflects the average temperature over the space-time evolution of



Jan Rak, ALICE
project leader

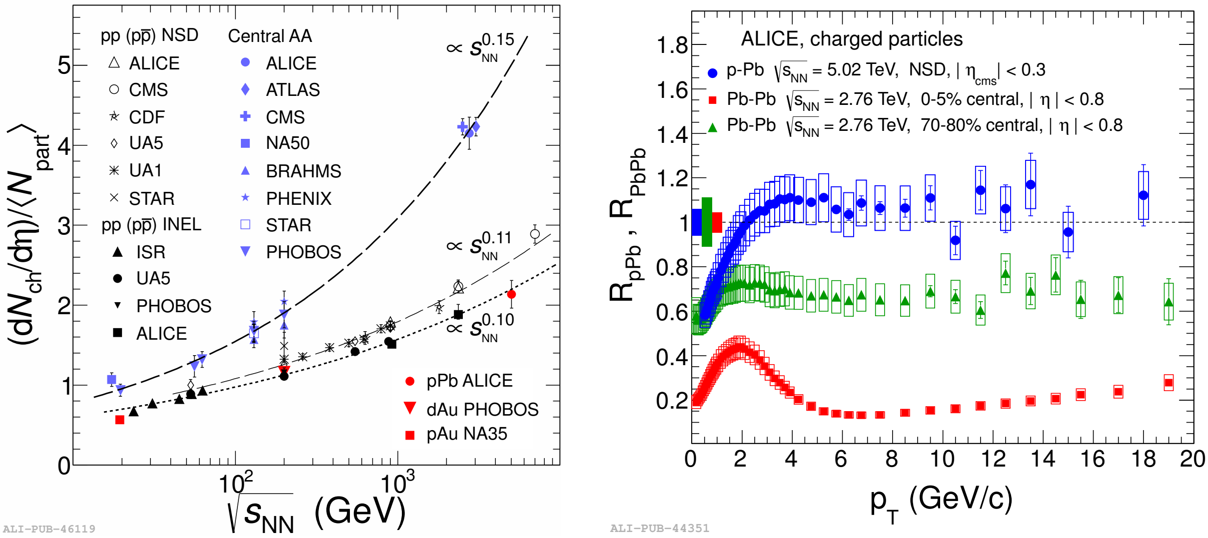


Left panel: The nuclear modification factor measured at $\sqrt{s_{NN}}$ = 2.76 TeV [Phys. Lett. B 696 (2011) 30]. Right panel: The direct photon transverse momentum distribution measure in 0-40% central Pb-Pb collisions by the ALICE experiment [arXiv:1210.5958]. Blue and red solid lines represent the NLO calculation and exponential fit, respectively.

the fireball. Due to a rapid transverse expansion, causing both blue shift of the emission and cooling of the fireball, the initial temperature of the primordial Quark Gluon Plasma (QGP) in the hydrodynamical models for Pb-Pb collisions at the LHC is typically 1.5-3 times higher than the effective temperature inferred from the slope. The real temperature of the primordial QGP plasma is, based on this measurement, in the region of 500-900 MeV. It is also worthwhile mentioning that the inverse slope measured by ALICE is about 40% larger than the one measured at c.m. energy 200 GeV by the PHENIX experiment (inv. slope T = 221±19±19 MeV) [Phys. Rev. C 81 (2010) 034911]. The observation of the ALICE experiment was interpreted as the highest ever achieved temperature in a laboratory (see http://www.guinnessworldrecords.com/world-records/10000highest-man-made-temperature).

Another important milestone was achieved in September 2012 when the pilot p-Pb run was taken and about 2x10^6 events were recorded. The analysis of p-Pb data is important to complete the systematic study of the vacuum (p-p), cold (p-Pb) and deconfined nuclear matter (Pb-Pb) phenomena. The analysis of this small p-Pb data sample led to three publications already in 2012 [Phys. Rev. Lett. 110 (2012) 032301, arXiv:1210.4520, Phys. Lett. B 719 (2013) 29]. The fact that there are now orders of magnitude of p-Pb events on tapes gives us confidence that many more papers will result from this analysis.

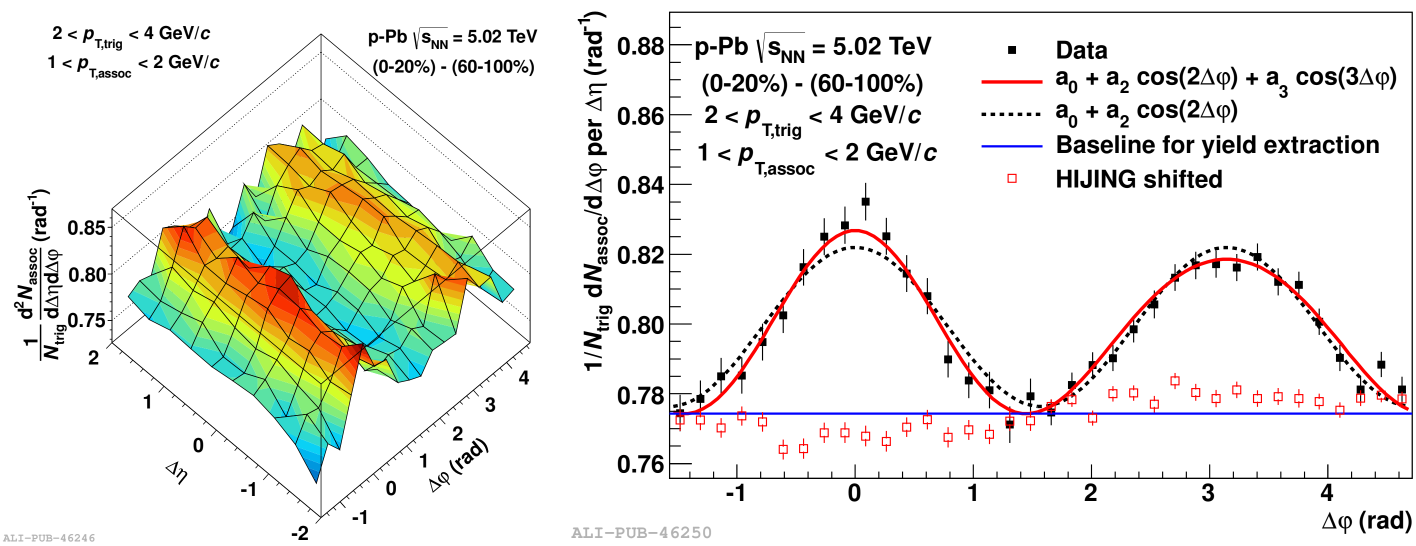
The first interesting results from the pilot p-Pb run analysis is the measurement of the charged particle pseudorapidity density in p-Pb data taken at a centre-of-mass energy of $\sqrt{s_{NN}}$ = 5.02 TeV [Phys. Rev. Lett. 110 (2012) 032301]. The charged particle density normalized to one nucleon-nucleon participant pair as a function of c.m. energy is shown in the left panel of the figure at the top of the opposite page. The red symbols show the ALICE, PHOBOS (RHIC $\sqrt{s_{NN}}$ = 200 GeV) and NA35 (SPS $\sqrt{s_{NN}}$ = 17 GeV) data. The c.m. energy evolution can be described by the power law function $s^{0.10}$. The pp (solid black symbols) and the AA data (hollow symbols) are shown as well. The power law exponent can be compared to predictions from various models like the Colour Glass Condensate (CGC) where n_{CGC} = 0.11-0.14 (see, e.g., arXiv:1211.3327). Another important result came from the measurement of the charged particle transverse momentum distribution [arXiv:1210.4520] (right panel of the figure at the top of the opposite page). The nuclear modification factor for Pb-Pb, R_{PbPb}, and for p-Pb data, R_{pPb}, is defined as a ratio of the inclusive yield measured in central Pb-Pb events over the same distribution



Left panel: The charged particle density normalized to one nucleon-nucleon participant pair as a function of c.m. energy [Phys. Rev. Lett. 110 (2012) 032301]. Right panel: The nuclear modification factor, R_{PbPb}, for central (red) and peripheral (green) Pb-Pb data and the nuclear modification factor, R_{pPb}, measured in p-Pb collisions shown in blue [arXiv:1210.4520].

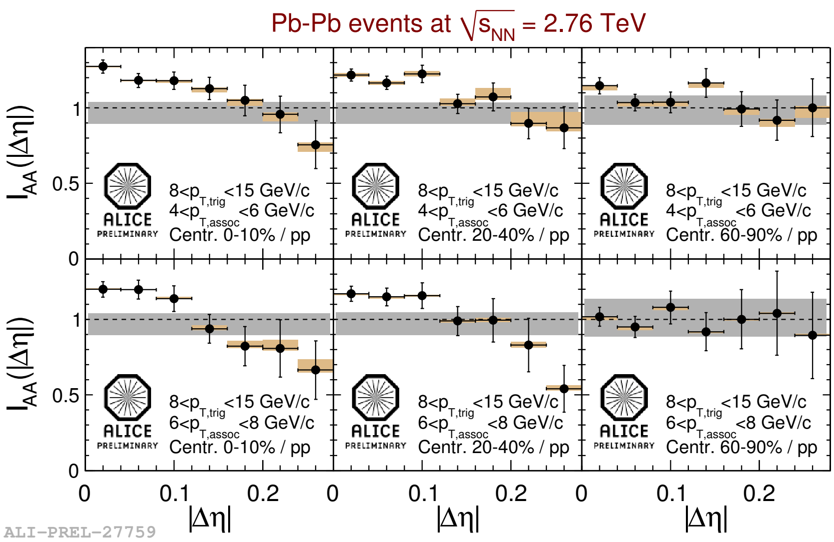
measured in p-p scaled by the average number of binary collisions (see, e.g., Phys. Rev. C 80 (2009) 054907) $R_{AA}(p_T) = (d^2N^{AA} / dp_T d\eta) / (\langle N_{binary} \rangle d^2N^{pp} / dp_T d\eta)$. The p_T dependence of the nuclear modification factor, R_{pPb}, measured in p-Pb collisions is shown in blue in the right panel of the figure above. The p_T dependencies of the nuclear modification factor, R_{PbPb}, for central (red) and peripheral (green) Pb-Pb data are shown for comparison as well. The main conclusion from this study comes from the fact that unlike in the Pb-Pb collisions there is no particle yield suppression due to the partonic energy loss. This confirms the final state origin of the observed suppression in central Pb-Pb collisions.

However the most intriguing surprise came from the two-particle correlation study in p-Pb data [Phys. Lett. B 719 (2013) 29]. Motivated by the observation of the long-range correlations by the CMS collaboration [J. High Energy Phys. 09 (2010) 091] we have con-



Left panel: The ($\Delta\varphi$,$\Delta\eta$) correlation function in p-Pb after the subtraction of the high- and low-multiplicity classes. The $\Delta\varphi$ projection of the correlation function from the right panel [Phys. Lett. B 719 (2013) 29]. The solid red line represents the Fourier fit with second and third harmonic coefficients, the dashed line shows the same fit with only the second Fourier coefficient included. The open symbols show the HIJING Monte Carlo simulation.

structed the two-dimensional correlation function, C(Δφ,Δη), where Δφ is the difference between the trigger and the associated particle in azimuth and Δη in pseudorapidity. When the events were divided into multiplicity classes (multiplicity measured by forward detectors to avoid an autocorrelation) and the C(Δφ,Δη) from the low multiplicity class was subtracted from the high multiplicity C(Δφ,Δη) a double structure, now called the near- and away-side ridge, was observed (see left panel of the figure at the bottom of the previous page). The Δφ projection of C(Δφ,Δη) (right panel of the figure at the bottom of the previous page) shows, unexpectedly, a flow-like pattern known, so far, only from heavy ion collisions. This is the first observation of this kind of long-range correlations which could be explained by a collective behaviour like that in the hot nuclear medium [Phys. Rev. C 85 (2012) 014911] or the initial state saturation effect predicted in the frame of the Colour Glass Condensate (CGC) [arXiv:1211.3701]. The CGC interpretation is attractive from the point of view of the rectification of the QCD unitarity violation [arXiv:1209.6265]. The flow explanation, on the other hand, would probably shake the basis of our understanding of the collective phenomena in heavy ion collisions.



I_{AA} as a function of |Δη| in Pb-Pb collisions at √s = 2.76 TeV. Gray bands around unity show point-to-point independent scaling uncertainty. Brown boxes around the data points represent point-to-point variable systematic uncertainty.

Data Analysis

Our group is involved in the analysis of data taken with all collision systems (see Table 1). The main focus is on the high-p_T correlations but we are also involved in direct photon analysis, x_T-scaling studies, flow analysis and other analyses.

For example, the jet shape modifications were studied by the use of the ratio of the per trigger yields in Pb-Pb to proton-proton collisions denoted as I_{AA}. The I_{AA} plotted as a function of the intra-jet pseudorapidity separation between the trigger and associated particle |Δη| is shown in the figure below. For larger trigger momenta, the trend of I_{AA}(|Δη|) seems to be falling in the central collisions indicating a narrowing of the near-side peak along the Δη direction in Pb-Pb w.r.t. pp collisions. The exact physical mechanism behind this phenomenon is not yet known, however, the possible scenarios include multiple scatterings, radiative energy loss, longitudinal flow or gluon filtering [Phys. Rev. C 84 (2011) 067902]. This analysis was presented at the Quark Matter conference in Washington, USA, by Filip Krizek on behalf of the ALICE Collaboration. Jussi Viinikainen finished his Master's thesis on this topic in November 2012.

Astrid Morreale and Jiri Kral are actively involved in the neutral pion and eta reconstruction using the data from the ALICE Electro Magnetic Calorimeter (EMCal). Astrid is working on the neutral pion and eta nuclear modification factor and Jiri is finishing the analysis of the π^0-charged particle correlations.

We are also involved in the inclusive cross section analysis using x_T-scaling [Phys. Rev. Lett. 105 (2010) 062002]. Following the conjecture in Phys. Rev. Lett. 105 (2010) 062002 that the Higher-Twist processes might be enhanced in the isolated particle sample with respect to the inclusive yield Esko Pohjoisaho performed an analysis of isolated particle yield in pp collisions in his Master's thesis (finished in December 2012). These results are now being discussed in ALICE and considered for publication.

The third MSc degree from our group in 2012 was granted to Mikko Kervinen in December 2012. In his work he studied away-side jet fragmentation using x_E-distributions at 2.76 TeV centre-of-mass energy.

Computing and Run Operations

Besides the data analysis our group is also involved in the run operations. Filip Krizek and Astrid Morreale served as subsystem run co-ordinators for the T0 and EMCal detector systems. Jiri Kral was responsible for the level-0 trigger system in EMCal. DongJo Kim and Beomsu Chang were maintaining the ALICE Collaboration Data Base and Shift Management System.

The ALICE T0 detector is a key component of the ALICE trigger system. It is used as part of the physics selection with up to five different trigger signals. It additionally contributes to the start signal for the Time-Of-Flight detector. In the year 2012, the T0 detector played an important role in the recording of 9.96 pb^{-1} of the total integrated pp luminosity by selecting the vertex position. In addition, the T0 trigger in 2012 pp running was used as an interaction trigger in the high interaction rate operation (400 kHz). Filip Krizek and Astrid Morreale served as detector experts for inspecting and improving the QA of the data as well as maintaining the official on-line monitoring tool AMORE.

Our group is also involved in the maintenance and operation of the level-0 single-photon trigger system. The trigger Region Units [Nucl. Instr. Meth. A 693 (2012) 261] developed and produced by our group have been fully operational since 2010 and significantly improved the ALICE capability to study hard scattering phenomena. Jiri Kral as a main TRU system expert together with Astrid Morreale served as on-call expert during the 2012 data taking period.

Since 2007, we have worked on the ALICE Grid project collaborating with the Helsinki Institute of Physics (HIP) and the Finnish IT Center for Science (CSC) in Helsinki. This effort has resulted in fulfilling the pledged numbers for LHC/GRID as part of the Nordic Data Grid Facility (NDGF), where we provided the maximum 370 CPUs and 100 TBytes of disk storages to ALICE this year. In the 2012 run, in addition to the continuous pp run with larger beam energy, a pilot p-Pb run was taken and successfully integrated into the grid analysis.

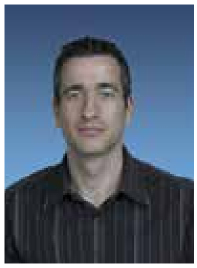
Education

Three MSc theses were approved at the end of 2012: Jussi Viinikainen, "Transverse Jet Shape Modification in Pb-Pb Collisions by ALICE", Esko Pohjoisaho, "Study of x_T Scaling in *pp* Collisions Measured by ALICE", and Mikko Kervinen, "Away-side jet fragmentation with pp at $\sqrt{s}$ = 2.76 TeV by ALICE".

A new undergraduate student in our group, Tomas Snellmann, was a successful summer trainee in Jyväskylä and earned his Bachelor degree in November 2012. Tomas continues in our group and has started his Master's thesis project on event-by-event flow analysis.

During the summer of 2012, our group also supervised two summer students at CERN; Timo Kärkkäinen from the University of Helsinki trough the HIP Summer Training programme and Shawana Hameed from the National Center of Physics in Pakistan trough the CERN Summer Training programme.

ISOLDE

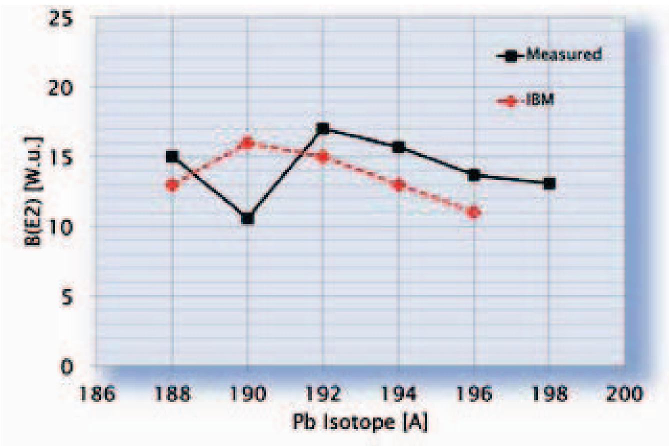


Paul Greenlees, ISOLDE project leader

Once again, scientists based in Finland have played an active role in the experimental programme carried out at the ISOLDE facility in CERN. Mainly focused on nuclear structure and spectroscopy, a significant number of experiments were attended in 2012. A total of eighteen visits to ISOLDE were made by ten scientists participating in ten different experiments. The experiments included reaction studies relevant for nuclear astrophysics, laser spectroscopy of manganese isotopes and a number of experiments exploiting the post-accelerated radioactive ion beams of REX-ISOLDE. One scientist, Joonas Konki made an extended visit to ISOLDE funded by a grant awarded by the University of Jyväskylä research mobility funds. Further support for the programme at ISOLDE came in the form of an Academy Research Fellow position awarded to Janne Pakarinen for his work on studies of shape co-existence and collectivity in heavy nuclei. Part of the project involves the development of a new device to observe internal conversion electrons known as SPEDE. SPEDE will be combined with the array of germanium detectors MINIBALL and used in Coulomb excitation experiments with the radioactive ion beams of REX-ISOLDE. Development of the next generation facility HIE-ISOLDE has also continued steadily, with most of the installation of phase one (increasing the maximum beam energy to 5 MeV/u) due to be carried out during the LHC shutdown of 2013-2014. The physics programme for HIE-ISOLDE was also enriched by the introduction of two new significant projects - the introduction of a storage ring known as the TSR (Test Storage Ring) and a spectrometer for transfer reaction studies based on an NMR magnet known as HELIOS. Finnish interest in experiments at HIE-ISOLDE was reflected in the number of proposals with Finnish participation submitted to the INTC in November. The committee evaluated a total of fifteen such proposals.

Nuclear Structure Studies with Radioactive Ion Beams

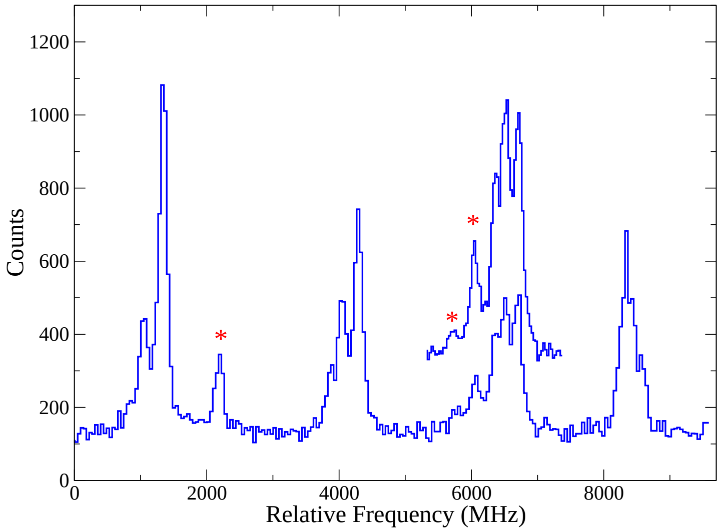
As in previous years, the theme of nuclear shapes and shape co-existence formed the basis for experiments using the post-accelerated radioactive beams of REX-ISOLDE. The technique of Coulomb excitation is employed and the gamma-ray yields are determined using the MINIBALL array of germanium detectors and associated charged particle detectors. The experiments attended by Finnish scientists involved studies of isotopes of Na (IS482), Zn (IS510), Kr (IS478), Po (IS456, IS479, IS506), Rn (IS475, IS506) and Ra (IS475). T. Grahn is the spokesperson for IS506. Analysis of the data from these experiments is underway and should result in a number of publications in the near future. In parallel to these new studies, analysis of data from experiments carried out in previous years is continuing. As reported in previous annual reports, experiment IS494 "Measurements of competing structures in neutron-deficient Pb isotopes by employing Coulomb excitation" led by T. Grahn (JYFL) and J. Pakarinen (JYFL) yielded systematic data in the sequence of isotopes from $^{188-198}$Pb. This systematic data on the transition strengths of the decay of the first excited 2^+ state to the 0^+ ground state will be invaluable in understanding the evolution of collectivity and shape co-existence in the Pb isotopes. The data obtained can be compared to theoretical predictions, especially important in the lighter isotopes close to the neutron midshell at N=104 where the interplay of prolate, oblate and spherical configurations is the most pronounced. The results of preliminary analyses are shown in the figure to the left, where the experimentally determined reduced transition probabilities (B(E2) values) are shown for the isotopes $^{188-198}$Pb. It should be noted that the results are preliminary, and may change with further analysis. However, it is expected that the observed trend will remain. Of particular interest is the behaviour of the values in the isotopes $^{188-192}$Pb, which are not well reproduced by the predictions of the Interacting Boson Model (IBM). The behaviour of these values is expected to be related to the changing structure of the 2^+ states in these isotopes and on the details of the mixing between the co-existing oblate, prolate and spherical structures. Further details of this work will be published in due course (J. Pakarinen, Private Communication).



Reduced transition probabilities for the lowest 2^+ to 0^+ transitions in the isotopes $^{188-198}$Pb deduced from Coulomb excitation data. N.B. The values are preliminary and may still change with further analysis (J. Pakarinen, Private Communication).

Collinear Laser Spectroscopy of Manganese Isotopes

The collinear laser spectroscopy programme at ISOLDE continued towards the end of the year with a series of measurements on the manganese isotope chain. This work considerably expands previous studies performed at the IGISOL facility, Jyväskylä [F. Charlwood et al., Phys. Lett. B 690 (2010) 346]. Then, laser spectroscopy was performed on the ground and isomeric states of $^{50\text{-}56}$Mn. The behaviour of the mean-square charge radii was compared to the trend in neutron-separation energies and, unlike the close correspondence found in isotope chains with higher-*Z*, no such correspondence was seen in manganese. In particular, the course of the two-neutron separation energies appears smooth through the *N*=28 shell closure, and yet, the charge radii (and quadrupole moments) show a distinct minimum and a robust shell closure. Such shell effects are also investigated through the measurement of the nuclear moments, which are a very sensitive probe of the wave functions used in shell-model calculations.



Sample hyperfine spectra of ^{60}Mn performed using proton triggering. The zoomed-in region is vertically offset for clarity. Asterisks mark only those isomer peaks which are clearly resolved from the ground-state structure.

Further from stability, the migration of single-particle levels results in a weakening or eradication of shell or sub-shell closures, while new candidates are emerging. One such candidate at *N*=40 has received much attention, probed using a variety of nuclear spectroscopic techniques. The motivation behind the recent ISOLDE experiment is to provide unambiguous measurements of nuclear spins, magnetic-dipole and electric-quadrupole moments and changes in mean-square charge radii across the *N*=40 shell closure candidate, into a region where an onset of deformation and a new "island of inversion" is predicted.

Full hyperfine structures of ^{51}Mn and $^{53\text{-}64}$Mn were measured (the *N*=40 candidate, ^{65}Mn, was not attempted in this run due to the low yield) on the 280.19-nm $^6S_{5/2} \rightarrow {}^6P_{3/2}$ atomic line. A re-measurement of the Jyväskylä data provides a useful consistency check for future atomic factor calculations. Measurements of $^{57\text{-}64}$Mn are new and include isomeric states in the ^{58,60,62}Mn nuclei. The shorter-lived of the two states in ^{60,62}Mn display characteristic spin-1 structures and could be enhanced relative to the higher spin state using proton triggering. In this method, scans across the hyperfine structure were taken using a continuous bunch-release-measurement from ISCOOL, and then repeated but counting photons from bunches created within a useful time after each proton pulse.

In the future, the laser spectroscopy programme will continue following the ISOLDE shutdown period. One of the key extensions to the current method will be the use of in-cooler optical pumping using the radio-frequency quadrupole cooler-buncher ISCOOL. By illuminating the central axis of the cooler with laser light, population transfer from the ground state to a selected ionic metastable state can occur. Such enhancements are retained as the ion beam is delivered to an experimental station, providing a method of performing collinear laser spectroscopy from a preferred metastable level of the ion. This technique was pioneered at the University of Jyväskylä, and is more efficient than the spectroscopy of a neutralised atomic beam, used in this initial study.

Nuclear Astrophysics

In order to better understand the explosion mechanism in core-collapse supernovae, an experiment (IS548) was performed to measure the cross section for the reaction ^{44}Ti(α,p)^{47}Ti at low energies. This cross section has an effect on the amount of ^{44}Ti produced in supernovae, the abundance of which can be calculated using models of supernovae. Beta decay of ^{44}Ti results in the emission of a very specific energy gamma ray which could be detected by satellites. By comparing the amount predicted by the model to what is actually observed, information on processes occurring at the core of the supernova can be gained. The material for the ^{44}Ti beam was collected from recycled radioactive waste at the Paul Scherrer Institute in Switzerland. The ^{44}Ti^{13+} beam from REX-ISOLDE impinged into a helium gas cell and the reaction products were detected with a DeltaE-E Silicon detector telescope and with a high-efficiency Ge detector. During the experiment, data at two different energies were collected and data analysis is in progress.

Ari Jokinen, FAIR project leader

FAIR (Facility for Antiproton and Ion Research)

NUSTAR Collaboration

Preparatory work for FAIR (Facility for Antiproton and Ion Research) started in 2006 and has continued through 2011. The actual construction of the FAIR facility was launched in autumn 2011. The agreed Finnish contributions will be devoted to the construction of the experimental equipment within the NUSTAR Collaboration and the Superconducting Fragment Separator (SFRS). Our main participation in FAIR experiments focuses on three experiments called MATS, LaSpec and HISPEC/DESPEC. The technical design reports of the first two have been published and approved in 2010, see Eur. Phys. J. A 183 (2010) 1. At the end of 2012, also the DESPEC Beta Decay Total Absorption Gamma-Ray Spectrometer (DTAS) Technical Design Report was reviewed and approved.

The main funding source for the FAIR construction is organised through HIP. The actual work force for the experiments is located at the University of Jyväskylä involving several persons for each experiment. A. Jokinen is a co-spokesperson for the MATS experiment and I. Moore for the LaSpec experiment. T. Grahn and S. Rinta-Antila are connected to present FRS experiments and future campaigns aiming for Super-FRS. The Super-FRS beam diagnostics project is mainly the responsibility of the HIP Detector Laboratory, where 32 GEM-TPC detectors will be built under supervision of F. García. Finland is also actively involved in the cryogenic gas catcher project with GSI and KVI-Groeningen to provide low-energy cooled ion beams for the MATS/LaSpec experiments.

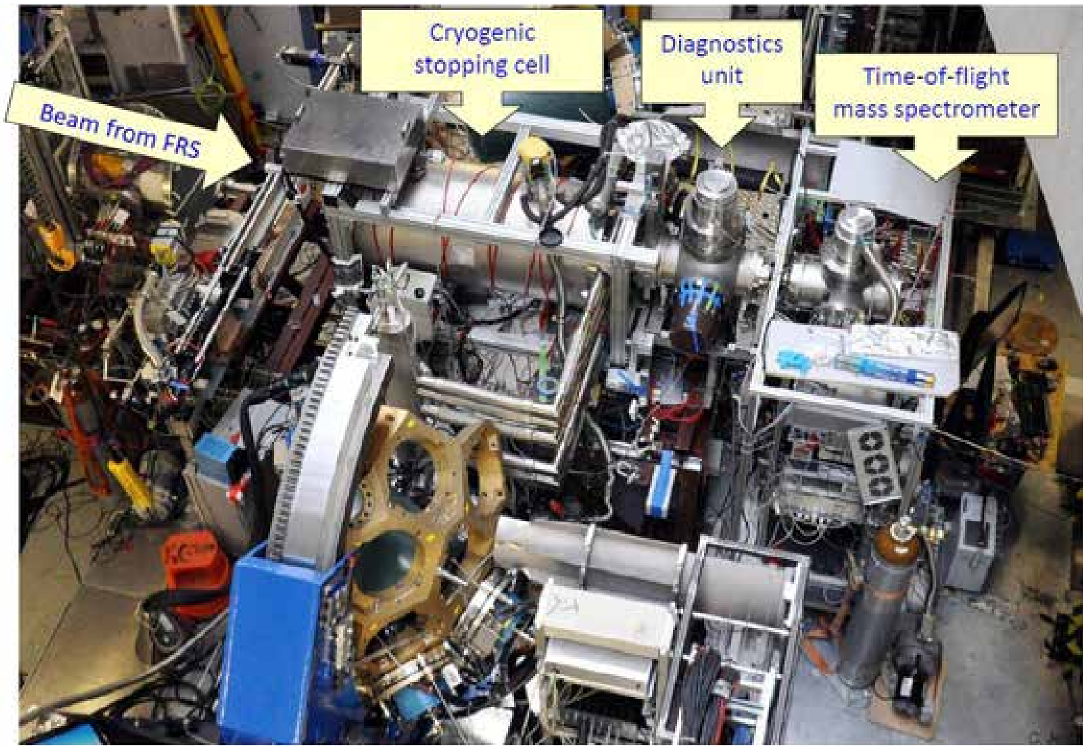
Due to the modular construction of FAIR with Super-FRS being one of the first experiments to provide new physics results, we have decided to focus on Super-FRS. As a result, new in-kind projects have been searched for and initiated in 2012. Discussions with industrial partners and the Finnish Funding Agency for Technology and Innovation (TEKES) have been launched.

Successful Commissioning of the FRS Ion Catcher

The Super-FRS will provide low-energy beams (a few tens of keV) for high-precision experiments utilising the many variants of laser spectroscopy and ion trapping techniques housed at the MATS and LaSpec facilities. For this purpose, a prototype of the cryogenic stopping cell (CSC) and a multiple-reflection time-of-flight mass spectrometer (MR-TOF-MS) for the Low-Energy Branch (LEB) have recently been commissioned at the FRS, GSI.

The so-called FRS Ion Catcher serves as a test facility for the LEB and consists of the FRS, the cryogenic stopping cell and the MR-TOF-MS. Projectile and fission fragments are produced at relativistic energies at the FRS, separated in-flight, range-focused, slowed down and thermalized in the CSC. In two beam times, October 2011 and July/August 2012, a collaboration of Justus-Liebig-Universität Gießen, KVI-University of Groningen, the University of Jyväskylä and GSI successfully commissioned the CSC and MR-TOF-MS.

For the first time, a helium-filled stopping cell for exotic nuclei was operated on-line at cryogenic temperatures to ensure gas purity. Static electric fields transport the stopped ions to the exit side where a radiofrequency (RF) carpet guides them to an exit-hole from which the gas flow sweeps the ions out. In the tests, a variety of projectile fragments produced at 1 A·GeV were thermalized using a gas density



Ion catcher at the FRS, GSI in July/August 2012. The AGATA frame can be seen in the foreground.

almost twice as high as ever reached previously for a stopping cell operating with RF ion repelling structures. Very high extraction efficiencies were achieved with extraction times of the order of a few tens of milliseconds.

The MR-TOF-MS is a unique device with a multi-purpose functionality: operation as a universal, broadband mass spectrometer (utilised in the diagnosis of the extracted ion beam); as a high resolution isobar separator (this mode will be used in the future to provide an isobarically pure beam for MATS); as a high-precision mass spectrometer, in particular for mass measurements on nuclides with ms half-lives and production rates of only a few ions per second. This latter mode has been realised in the July/August 2012 run in which direct mass measurements of short-lived nuclei were performed, among them the nuclide ^{213}Rn with a half-life of only 20 ms.

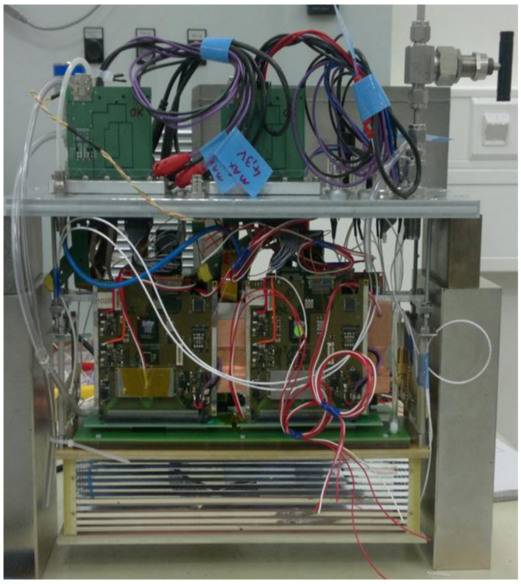
GEM-TPC Project for the Diagnostics of Super-FRS

The Superconducting Fragment Separator (Super-FRS) will be the most powerful in-flight separator for exotic nuclei up to relativistic energies. Rare isotopes of all elements up to uranium can be produced and spatially separated within some hundred nanoseconds, thus very short-lived nuclei can be studied efficiently. The Super-FRS is a large-acceptance superconducting fragment separator serving different experimental areas. The beam monitoring system consists of several diagnostic stations, where the use of position sensitive detectors is needed, in order to provide detailed information on the quality of the primary beam and its fragments.

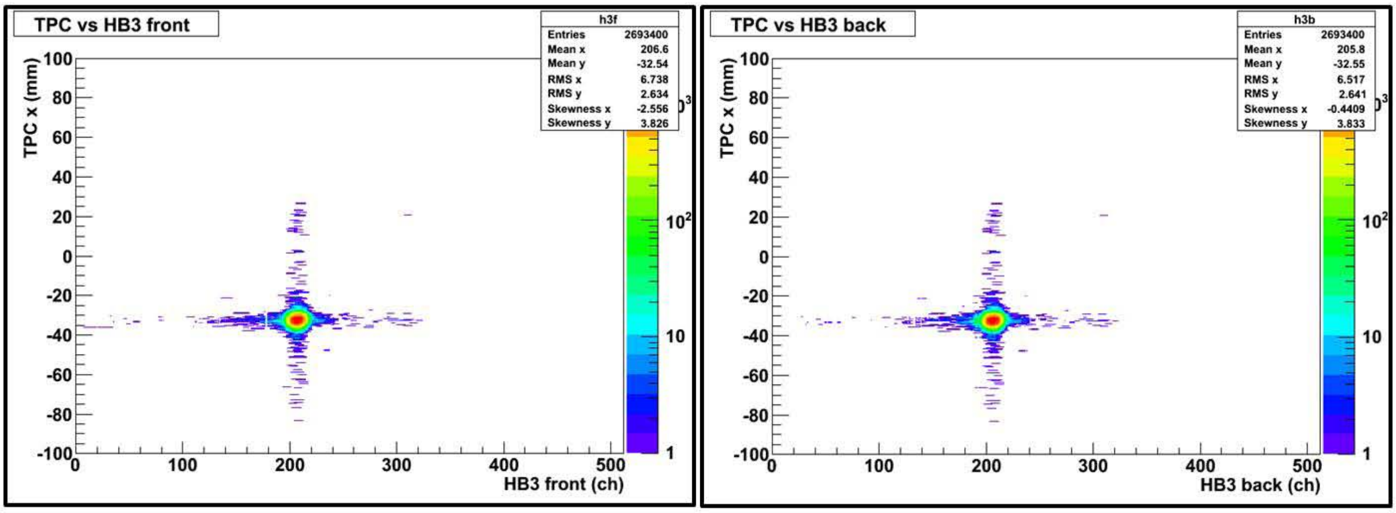
The Helsinki Institute of Physics has devoted resources for several years in collaboration with Comenius University and the Centre for Heavy Ions GSI, in order to establish a R&D project that can develop such detectors, to satisfy the requirements of the diagnostic stations along the separator. This initiative has been mainly driven by interest to take over a work package that will provide a set of *32 Gas Electron Multiplier -based Time Projection Chambers*. The Detector Laboratory at HIP has already in the past participated in the development of the GEM detectors for the TOTEM experiment, therefore the needed know-how and tools are in place, and ready to be adapted for the upcoming contribution to the FAIR facility.

During the year 2012, a prototype called Helsinki-Bratislava No. 3 (*HB3*) has been developed; one important feature tested in this new prototype was the GEMEX readout, which is based on the n-Xyter chip. The HB3 was prepared for participation in a test beam campaign at GSI after the successful integration of all its components. The detector showed very good position resolution and rate capability, which are the main requirements for the Super-FRS tracking system.

The Helsinki group co-operated tightly with JYFL-ACCLAB, in order to integrate their infrastructure into this development programme and a first step in this direction has been the granted test beam time, in order to test some of the components; as for instance the Field Cage under intensive beam conditions.



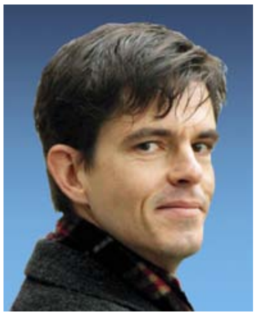
GEM-TPC HB3 equipped with GEMEX cards. One GEMEX card has two n-Xyters chips.



Position Correlation plots in the x-direction between the tracker TPC and HB3 front (left) and HB3 back (right).

Technology Programme

In 2012 three projects were hosted by the HIP Technology Programme. The GreenIT project continued to explore new ways to enhance energy efficiency in distributed computing infrastructures and the results so far are encouraging. The PET project has found promising commercialisation avenues with TEKES TUTLI-funding and is preparing for application pilots in Finland. The DataGrid project has successfully continued the EU sponsored EMI project and launched the TEKES-funded Cloud application initiative SICX. A considerable effort in the group was channelled towards obtaining external project funding. This would allow an increase in critical mass and allow the Progamme to further engage in industrial collaborations. External outreach has been maintained with various parties.



Saku Mäkinen,
Technology Programme
director

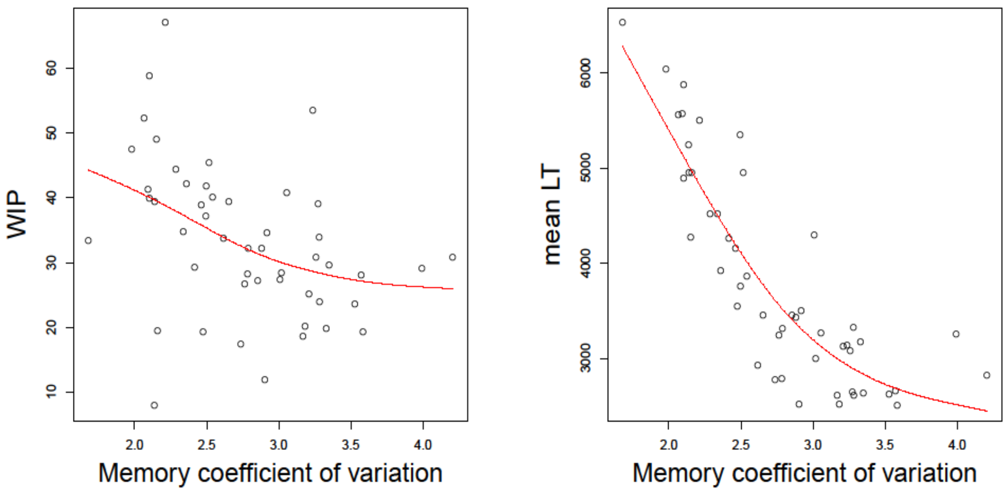
Green Information Technologies

Energy consumption has become one of the main costs of computing. It has been estimated that electricity cost can easily exceed the hardware cost during the lifetime of the system. In computing intensive sciences, such as high-energy physics (HEP), energy efficiency is an extremely important issue. Research on energy efficient computing systems, however, has mostly focused on individual components of the systems while studying the system as a whole has received less focus.

We contribute to this neglected area of research by viewing a computing facility as a production unit where we can apply well established operations management principles to run it more efficiently. The aim is to find ways to improve throughput and energy efficiency by loading all components (CPU, memory, and network) of the computing servers in an optimal way. The applied research approach follows that of operations and production optimisation research.

During its two first years, the GreenIT project has focused on optimising energy consumption of scientific computing clusters used for HEP computing related to CERN experiments. This research has included building a test environment for physics applications, statistical analysis of log data of the CERN

Tapio Niemi,
Green IT
project leader



Testing the law of resource variation with work-in-progress and mean lead time in the GreenIT project.

A new part of the GreenIT test cluster, HP Proliant DL585 G7: 4 CPUs, 64 cores and 128 GB of memory.

batch processing cluster and the Finnish Tier-2 centre, developing an operations management model for a computing centre, a prototype implementation of a fuzzy load-based scheduling algorithm, testing modern storage systems such as solid state disks (SSD), developing a simulator for testing scheduling policies and optimising virtualisation environments for physics computing. These studies have indicated significant improvement possibilities in both operational and energy efficiency. The research has been conducted in close collaboration with the Department of Operations of the University of Lausanne. The Swiss National Science Foundation (SNSF) granted a two year grant for this project in October 2012.

In 2012, the project produced three MSc degrees, hosted three summer trainees, and continued publishing in international conference and journal publications. A PhD degree on virtualisation technologies has progressed well and it will be completed as planned in 2014. The project continued to build collaborative relationships with important partners such as CERN IT and LHC experiments, universities both in Finland (the Aalto University, Tampere University of Technology) and other countries (Ecole polytechnique fédérale de Lausanne and the University of Lausanne). The industrial collaboration has mainly focused on optimising data storage solutions with a Finnish company offering a novel back-up solution.

The project has developed a modern and comprehensive test facility for measuring the energy efficiency of different computing applications. The test hardware contains over 100 CPU cores, 200 gigabytes of memory, and several terabytes of disk space. The total purchase price of the hardware is over 30 000 euros. In 2012, a modern 64-core server was added to the test facility.

The GreenIT project has also been involved in data analysis research. The year 2012 marks the end of the data integration oriented EXHADA project, funded by the the Academy of Finland. The EXHADA Collaboration between the GreenIT project and the University of Tampere exceeded its goals and extended the academic connections of the project with new organizations (the World Health Organization, Nokia Research Center, the Centre for Tropical Medicine of the University of Oxford, and the University of Applied Sciences Western Switzerland). The project has combined XMLbased data management with data retrieval, analysis and reporting. The application areas have been a mobility data project of Nokia and information retrieval for public health. A follow-up project has been submitted to the Academy of Finland and other research collaborations are being prepared.

The goal for 2013 is to continue research on applying operations management methods for computing centres and cloud computing and also to apply these methods to practice in collaboration with CERN and industry partners with possible external project funding. For research funding two project proposals have been submitted to the Academy of Finland in October 2012 and one proposal will be submitted to SNSF in January 2013 in collaboration with Swiss universities.

AX-PET Collaboration with CERN

At CERN, a new type of a positron emission tomography (PET), Axial PET (AX-PET), has been developed by the AX-PET research consortium. The AX-PET detector construction is based on long axially arranged scintillating crystals in a staggered grid and interleaving orthogonal wavelength shifter (WLS) strips. The data from the crystals and the WLS strips are individually read and processed. In PET imaging, improving sensitivity while maintaining high spatial resolution is crucial. Axially placed scintillating crystals in a staggered grid can provide high sensitivity and high resolution 3D reconstruction of the gamma interaction points. The trans-axial coordinate is given by the scintillating crystals. Interaction coordinates along the crystals are reconstructed by the weighted distribution of light escaping the crystal and entering into an array of WLS strips interleaving the crystal layers. With AX-PET it is possible to achieve many improvements for PET-imaging. The ongoing research collaboration with the AX-PET consortium and CERN will be continued in 2013.

In Finland and TUT we aim to seek ways to commercialise a new type of PET scanner using modified AX-PET -technology in totally new detector assemblies. We had a post-doctoral researcher Viivi Nuottajärvi hired for this work.

In order to distinguish our new detector design from the AX-PET -design, our technology is hereafter called AvanTomography. The AvanTomography project got TEKES-TUTLI funding for 2012. With the TEKES funding, the first patent application related to the AvanTomography technology was filed at the end of November 2012. Also market surveys, preliminary commercialisation plans and other commercialisation-related tasks were performed with the funding.

Due to the modular and transformable AvanTomography technology, several new constructions of PET scanners have already been designed in a TEKES-funded project. With the TEKES-TUTLI funding, we have already constructed our first AvanTomography demonstrator. It will be tested in a hospital environment at the beginning of the year 2013. The tests will be conducted first with certain phantoms and later with real patients.

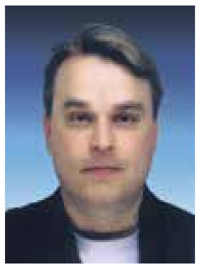
During the year 2013 the aim is, together with some companies and with TEKES-TUTLI funding, to design and start the building process of the second AvanTomography demonstrator. This demonstrator will be tested at Turku PET-Center during the year 2014.

Related to the project, MSc work by Tiziana Zedda will be finished during spring 2013. The first scientific results related to the AvanTomography research will be published at the Medical Imaging Conference at the end of the year 2013.

Ulla Ruotsalainen, PET project leader

Grid Middleware Development

In the European Middleware Initiative (EMI) project, HIP Technology Programme personnel have continued to be responsible for the co-ordination of the security area development and maintenance of security components. At the EGI conference in Prague, HIP organised the Grid security session and also the security tutorials. The third EMI security deliverable document, that outlined the progress and fu-



Miika Tuisku, DataGrid project leader

ture plans, was also produced by the group. Moreover, major contributions were made through the EMI Project Technical Board (PTB) to the overall EMI technical overview.

From the beginning of the EMI project, HIP has had the responsibility to set up and co-ordinate the various security working groups that will determine the strategic direction of the EMI project security area. HIP is currently producing the EMI Security Architecture document. The work on the implementation of the Security Token Service (STS) has finished and there are plans for the service to be piloted for the first time. HIP has also been responsible for the maintenance and certification of various components and these tasks are ongoing. The pseudo-anonymity service, essential to privacy-minded users and National Grid Initiatives, has been developed and packaged by HIP. The encrypted data storage system has been tested with commercial partners external to the EMI project, and is being reported in the *EMI Collaboration, Exploitation and Sustainability* deliverable towards the EU commission. Other EMI-related efforts during the year included contributions to the yearly EMI EU review.

Cloud Applications and Industrial Collaboration

The shift in the focus after a decade of Grid computing research and development is most obvious in the applications domain. Cloud computing is the successor of the Grid computing model, and is in general considered disruptive for current IT industry practices. The main differences with Grid computing are pay-per-use and elastic, on-demand sourcing of ICT capacities. Consequently Scientific computing users do not need capital expenditure (CAPEX) in hardware any longer to secure ICT utilities that can be accounted as Operational expenditures (OPEX) as in software and services.

As a result of intensive fund-raising efforts, the HIP Technology Programme received TEKES funding for the first of a kind project called the Secure InterCloud Exchange (SICX) at the beginning of the year. The SICX project employed all-in-all eight persons for six months and engaged two sponsoring companies. It leveraged the earlier HIP Security middleware work in EU collaborations and produced a prototype of a Secure multi-Cloud storage application. At the same time it served as one of the early pilots of a novel TEKES-funding instrument called *New knowledge and business from research ideas (TUTLI)*. While securing further TEKES funding did not succeed at the next gate, we are continuing to prepare the software in-house with the aim to engage first pilot users in 2013.

DataGrid group arranged Business model generation™ workshop at CERN as part of the TEKES-funded SICX project.

CLOUD

Markku Kulmala, CLOUD project leader

Background

Atmospheric aerosol particles influence the Earth's radiation 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 studying physical processes in clouds, such as cloud droplet activation and ice nucleation. For all 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 of 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 comprises 21 institutes from 9 countries with a strong Finnish contribution.

Experiments in 2012

In 2012, another two intensive measurement campaigns took place at the CLOUD chamber at CERN: the smaller "CLOUD 6" campaign in June and the large-scale "CLOUD 7" campaign from October to December. Again, a wide variety of instruments was provided by the participating institutes and deployed during the experiments.

CLOUD 6: The CLOUD chamber was implemented with a new control expansion system that was installed on the top of the chamber. This new system precisely controls the expansion time, from seconds to hours allowing cloud formation on seed aerosol particles generated via gas phase to particle conversion inside the chamber. The chamber was equipped with an extensive suit of optical detection systems for studying the properties of the cloud droplet population formed inside the chamber upon expansion.

The Finnish team was responsible for the measurement of ions and aerosol particles in the size range 0.8 to 42 nm, deploying an Airborne Neutral cluster and Air Ion

The CLOUD facility in the T11 area in CERN during the CLOUD 7 campaign in autumn 2012. The pion/muon beam arrives from the right and hits a hodoscope that monitors the beam intensity before it passes through the chamber. Instruments that were employed on the 16 ports around the chamber are: a Chemical Ionization Mass Spectrometer (CIMS) for H_2SO_4 measurements, two Diethylene Glycol-based Condensation Particle Counters (DEG-CPC), two Atmospheric Pressure interface Time-Of-Flight mass spectrometers (APi-TOF, one for each polarity), two Chemical ionization APi-TOFs (CI-APi-TOF), an Ion Mobility spectrometer APi-TOF (IMS-APi-TOF), a Neutral cluster and Air Ion Spectrometer (NAIS), a Proton-Transfer-Reaction Time-Of-Flight mass spectrometer (PTR-TOF), a Thermal desorption - chemical ionization TOF (TD-CI-TOF), water- and butanol-based Condensation Particle Counters (CPC), a Hygroscopicity/Organic tandem Differential Mobility Analyzer (H/O DMA), instruments for gas measurements (SO_2, O_3, H_2O), two Particle Size Magnifiers (PSM), a Scanning Mobility Particle Sizer (SMPS), a radial Differential Mobility Analyzer (rDMA) with PSM, and a LOng Path Absorption Photometer (LOPAP) and an Ion Chromatography system (IC) for measuring NH_3 and C_2H_7N.

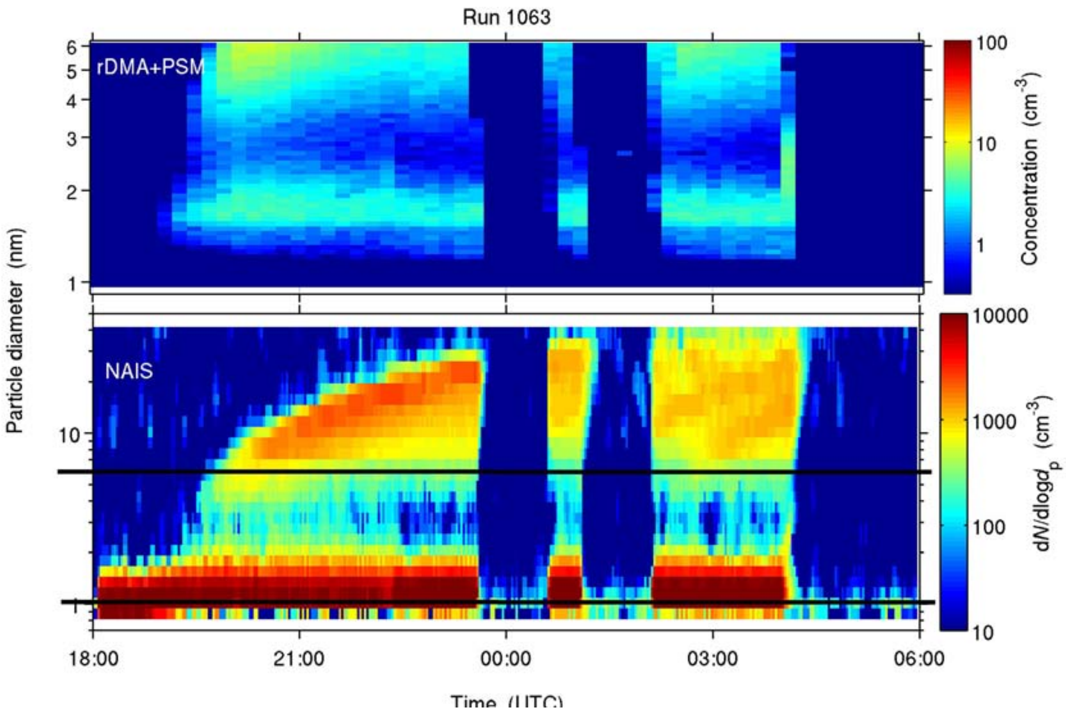
Spectrometer (ANAIS). ANAIS was operated as a prototype set-up to face the non-standard conditions present in the chamber (high pressure). Data and technical information were collected to optimise the set-up for rapid pressure changes in order to provide high quality measurements during future physics runs.

CLOUD 7: The CLOUD 7 campaign was the largest joint effort at the CLOUD chamber so far, with a large total number of instruments put to use, including for instance a total of five dual-stage condensation particle counters, capable of measuring clusters and particles < 2 nm in mobility-equivalent diameter, and a total of seven high-resolution time-of-flight mass spectrometers, attempting to determine the abundance, significance, and chemical compositions of vapours, ions, and molecular clusters that form in the initial steps of nucleation.

The Finnish team made a major contribution to CLOUD 7 with a total of 16 persons (7 post-docs, 7 PhD students, 2 MSc student) working on site in CERN during the campaign. The Finnish team was primarily responsible for the measurement of cluster precursors, clusters, small particles, and ions, and brought seven instruments to CERN: an Airborne Neutral cluster and Air Ion Spectrometer (ANAIS), two Particle Size Magnifiers (PSM), a prototype set-up comprising a radial differential mobility analyser (rDMA) and a PSM, and three Atmospheric Pressure interface Time-Of-Flight mass spectrometers, one directly connected to the chamber (APi-TOF), one of them equipped with a Chemical Ionization system (CI-APi-TOF) and one coupled with an Ion Mobility Spectrometer (IMS-TOF):

• Two PSMs were used in two different operating modes, optimising the information yielded on the size distribution and growth rates of clusters and small particles of sizes between 1 and 3 nm.

• The rDMA was implemented with a new inlet system and coupled with a PSM, used as a counter. The present improved configuration allowed measurements of size distributions of negative ions in the range 1.3-6 nm providing an interesting overlapping with the ANAIS with significantly higher size resolution.



Size distributions of negative ions during a nucleation experiment in the CLOUD 7 campaign 2012. The upper panel shows the event seen by the newly developed high resolution rDMA+PSM system prototype while the lower panel depicts the event seen by NAIS. Gaps in the plot show the times when the ions are swept out by a clearing electric field.

• The ANAIS continued operation with the sample dilution system developed for the earlier campaigns at CLOUD. It was set up inside a temperature-controlled box which was now able to maintain the same temperature as the one inside the CLOUD chamber. We could therefore minimise changes in the ion size distributions and properties due to temperature changes during sampling.

• The APi-TOF was set up to measure negatively charged ions and ion clusters, while an APi-TOF from a partner institution was responsible for measuring positively charged ions.

• The CI-APi-TOF development reached the stage that the instrument was utilised in CLOUD for the first time in the CLOUD 7 fall run. CI-APi-TOF measures the chemical composition of neutral nucleating clusters shedding, at last, light on the mystery of neutral nucleation.

• The IMS-TOF was developed during 2012 in collaboration with Tofwerk A.G. and was successfully tested during CLOUD 7. IMS-TOF is used to study the stability and structural properties of the freshly nucleated clusters and cluster precursors.

In previous experiments at CLOUD prior to 2012, nucleation processes were investigated for the systems of sulphuric acid + ammonia, sulphuric acid + dimethylamine, and sulphuric acid + oxidation products of pinanediol. The oxidation products of pinanediol were used as a surrogate for oxidation products of monoterpenes, volatile organic compounds believed to take part in atmospheric nucleation. The goals of CLOUD 7 were (a), to extend the measurements on the sulphuric acid + dimethlyamine system, making use of the extended suite of instruments deployed to reveal the molecular steps of neutral nucleation pathways; and (b), to explore nucleation and growth processes with the addition of α-pinene (together with oxidants) into the chamber, one of the naturally most abundant monoterpenes, in the presence and absence of dimethylamine and/or ammonia. This was another step towards creating chemical systems in the CLOUD chamber that are capable of nucleation, and at the same time as relevant as possible to atmospheric nucleation in the boundary layer.

The CLOUD chamber's peripheral equipment was extended and upgraded to allow us to achieve these goals, in particular to allow for a higher control and a more detailed investigation of the oxidation processes in the chamber. A HONO-generator system was developed, able to add HONO at high levels of purity into the CLOUD chamber. HONO was used to produce photolytically OH in the absence of ozone in order to separate between OH and O_3 oxidation of α-pinene. Also, H_2 could be added into the chamber at concentrations of 0.1% to act as an OH-scavenger, i.e., to remove OH quickly enough to suppress OH-induced oxidation reactions, leaving O_3 as the sole oxidizer in the chamber.

Data Analysis, Education and Reporting of Results

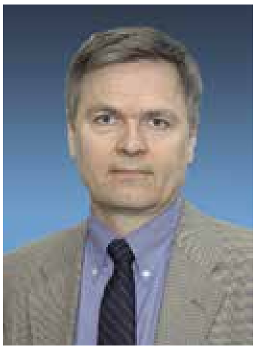
A comprehensive data analysis of the data of the two campaigns in 2012 is on-going. The analysis of data from the previous six campaigns is still not complete and continuing as well. Development of the computational tools 'TofTools' for processing and analysing the significant amount of data produced by the APi-TOF instruments continued throughout the year.

A data analysis workshop took place at the Hyytiälä Field Station in February/March 2012, involving researchers from most partner institutes. Two more workshops were organised and took place in Helsinki in May 2012 and in September 2012, focusing on the methods of determining growth rates and the interpretation of the results, combined with various theoretical approaches to model growth rates. A number of smaller meetings in Helsinki among collaborators were organised by the Helsinki team, aiming at advancing our techniques in analysing the complex data obtained from mass spectrometers, particularly to help us understand the chemical compositions of clusters in the CLOUD chamber.

A Finnish group including Finnish Marie Curie ITN students participated in the Marie Curie CLOUD-ITN final conference in Königstein, Germany (open conference 22.-24.5.2012, followed by a closed data analysis meeting).

Some results from the on-going data analysis, now also including the CLOUD 6 campaign in summer 2012 have been reported at the European Aerosol Conference 2012 in Granada, Spain, in September. Several manuscripts to be submitted to peer-reviewed journals are being prepared.

Planck



Hannu Kurki-Suonio, Planck project leader

Background

The cosmic microwave background (CMB) is radiation coming from the early universe. It was emitted when the universe was about 400 000 years old. Its intensity and polarization varies over the sky, and these variations reflect the properties and structure of the early universe as well as the later history of the universe through which this radiation has travelled.

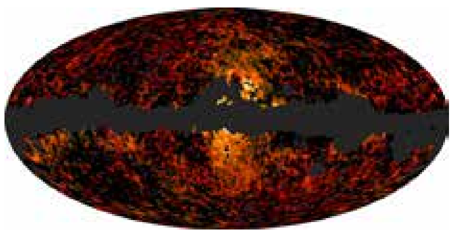
Planck is a European Space Agency (ESA) satellite whose purpose is to observe the CMB over the whole celestial sphere with high resolution and sensitivity and extensive frequency coverage. Planck is a collaboration of over 10 European countries, the USA, and Canada.

CMB measurements are contaminated by microwave radiation from our own galaxy and extragalactic objects. To be able to remove this "foreground", the observations are carried out at nine different frequencies. While being a nuisance to cosmology, this foreground is of great interest to astronomers. The detectors for the different frequencies are divided into two instruments, the Low-Frequency Instrument (LFI: 30 GHz, 44 GHz, and 70 GHz channels), and the High-Frequency Instrument (HFI: six channels from 100 GHz to 857 GHz).

Observation Programme

Planck began science observations in August 2009. In January 2012 the coolant for the last stage of the satellite's cooling system ran out, as scheduled. By that time Planck had observed the full sky five times. The operating temperature of LFI is higher than that of HFI, so LFI does not need the last stage, and observations with LFI continued during 2012. It is hoped that the first cooling stages will last until August 2013, so that LFI will be able to complete eight full sky surveys. In the two sky surveys done within a year, each location on the sky is scanned in two different directions. The scanning strategy was changed between the fourth and the fifth survey, so the 8 surveys will mean that each location on the sky is scanned twice in four different directions. This helps in solving for the polarization of the microwave radiation and in detecting systematic instrumental effects in the observations.

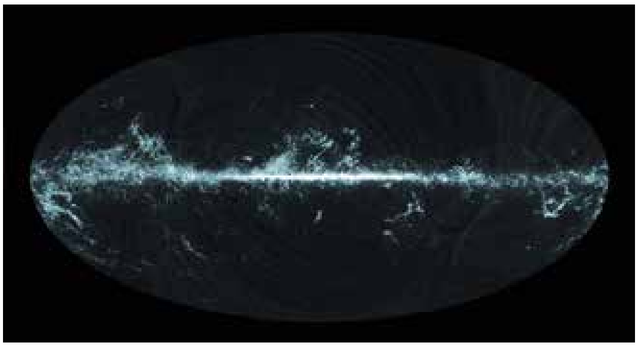
During 2012, "intermediate" results on the astrophysical foregrounds were published. The analysis of the cosmic microwave background and the derivation of cosmological results will take longer, and the first cosmological results will be published in early 2013. We discuss below some of the highlights of these intermediate results from Planck.



Galactic haze above and below the centre of the Milky Way (located at the centre of this image). Regions where other kinds of radiation are too strong for a reliable separation of the haze component are in black. Credit: ESA/Planck Collaboration.

Galactic Haze

When the different known astrophysical components are separated from Planck data by comparing the nine different frequencies, an unidentified residual component remains around the Galactic Centre. It is called the "galactic haze". The Fermi satellite has detected gamma rays from this region and it may be that they are related. Suggested explanations include supernovae and dark matter annihilation.



All-sky map of the distribution of molecular gas containing carbon monoxide. The plane of our galaxy runs horizontally across the image. Credit: ESA/Planck Collaboration.

All-Sky Map of Carbon Monoxide

Planck observations have provided the first ever all-sky map of carbon monoxide, showing the distribution of the molecular clouds where stars are born. Some Planck channels are sensitive to the emission lines of carbon monoxide, which is thus more easily detectable than the more abundant molecules, like hydrogen, in these clouds.

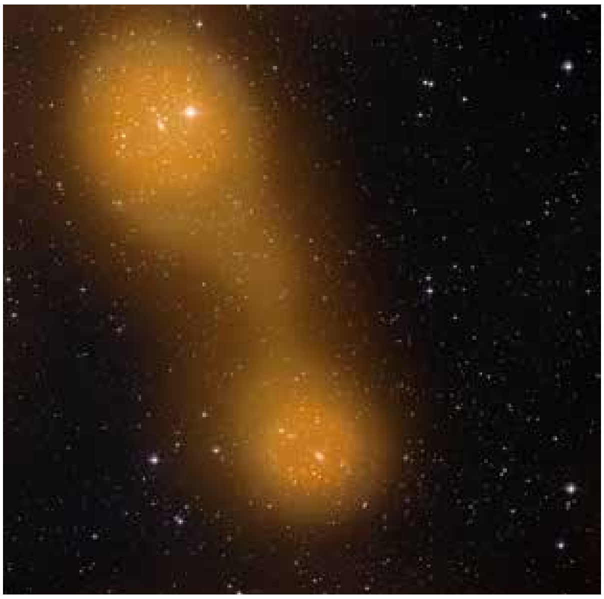
Bridge between Galaxy Clusters

A significant part of the ordinary ("baryonic") matter in the universe remains unaccounted for by the observed objects in the universe. The missing baryonic matter is believed to be in the form of a tenuous warm or hot gas forming an intergalactic medium. This intergalactic medium is best observed in galaxy clusters where it is hot and relatively dense, but it is very difficult to see outside galaxy clusters. Using the Sunyaev-Zeldovich effect, the upscattering of cosmic microwave photons to higher frequencies by the free electrons in this medium, Planck can map its distribution further out than other methods. Such Planck observations have revealed a bridge of hot gas between the two galaxy clusters Abell 399 and Abell 401.

Main Data Analysis

We have continued participating in the main data analysis of Planck and derivation of the cosmological results from them. We are responsible for producing the sky maps for the three lowest frequencies, as well as a number of related tasks, including calibration, estimation of residual noise correlations on the maps, and producing large Monte Carlo simulations (performed at CSC – the Finnish IT Centre for Science) of the data. These simulations are needed to support the analysis of flight data. For this purpose we received an award of 5 million CPUh of computing time from the European supercomputer consortium PRACE for the period November 2012 – October 2013.

We also participate in the estimation of cosmological parameters and constraints on inflation models from the CMB angular power spectra. The cosmological results from the first 15 months of Planck data should be ready in early 2013, then these 15 months of data will be published, as their proprietary period ends.



A bridge of hot gas between galaxy clusters Abell 399 and Abell 401. Credit: Sunyaev-Zel'dovich effect (orange): ESA & Planck Collaboration; optical image: STScI Digitized Sky Survey.

Administration

Mikko Sainio

The graduate education of physics students continues to be one of the main tasks of the Institute. During the past year HIP has collaborated with the Doctoral Programme in Particle and Nuclear Physics (PANU) and the Doctoral Programme in Nanoscience (NGS-NANO) as well as the Doctoral Programme in Concurrent Mechanical Engineering (CME) sponsored by the Ministry of Education. In addition to the graduate students who are supported by the graduate school and 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 have continued 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 2008-2012, 47 doctoral degrees and 59 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 the city of Tampere and Pori 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 2012 this programme attracted 366 Finnish students and 64 of their teachers. A related programme has been to bring high school physics teachers to CERN for continuing education courses. In 2012, 20 teachers participated in this programme. These visits have generated considerable coverage in local newspapers all over the country: about 23 articles in total in 2012.

The technological and commercial co-operation between Finnish industry and CERN is co-ordinated by HIP in collaboration with Top Science Services LLC, which is the contractor of TEKES, the National Technology Agency of Finland.

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J. Aaltonen, lab. engineer

Seminars

Seminars held in Helsinki

January 5th L. Bhattacharya
(Saha Institute of Nuclear Physics, Kolkata, India)
Photons from relativistic heavy ion collisions

January 12th
Particle theory 2-minute meeting

January 17th L. Wendland (Helsinki)
Latest news from the Higgs front

January 24th P. Bandyopadhyay (Helsinki)
Probing Higgs in type III seesaw at the LHC

February 14th M. Hindmarsh (Helsinki)
Cosmic strings, inflation and the cosmic microwave background

February 23rd D. Rischke (Frankfurt, Germany)
Recent results from chiral effective models

February 28th S. Huber (Sussex University, Brighton, UK)
Models for a strong electroweak phase transition

March 20th S. Ketov (Tokyo Metropolitan University, Japan)
Higgs inflation vs. Starobinsky inflation in gravity and supergravity

March 26th M. Kunz (Geneva, Switzerland)
Observing the darkness

March 27th D.-O. Riska (Helsinki)
HIP 2000-2010 and some research career highlights

April 12th K. Tuominen (Jyväskylä)
Thermodynamics of quasi-conformal gauge theories and gauge/gravity duality

April 18th V. Khoze (Durham, UK; St. Petersburg, Russia)
Central exclusive production processes at hadron colliders

April 18th E. Brücken (HIP)
Central exclusive production in proton-antiproton collisions at CDF II

May 7th K. Splittorff (Copenhagen, Denmark)
The Aoki phase versus the Sharpe-Singleton scenario

May 15th T. Meriniemi (Helsinki)
Gravitational waves produced after inflation

May 29th A. Datta (Univ. Calcutta, India)
Universal extra dimensions and its signature at the LHC

June 5th A. Mazumdar (Lancaster, UK; Copenhagen, Denmark)
Towards asymptotic freedom of gravity

June 7th A. Jipa (Bucharest, Romania)
From nuclear matter to Big Bang and back. New results on the nuclear matter dynamics in relativistic and ultrarelativistic nuclear collisions

June 11th V. Karimäki (Helsinki)
Farewell seminar: forty-five years of high energy physics

June 19th E. Gabrielli (Tallinn, Estonia)
Fermiophobic Higgs scenarios at the LHC

June 26th M. Järvinen (Heraclion, Crete, Greece)
Holographic models for QCD in the Veneziano limit

July 3rd O. W. Greenberg (Maryland, USA)
Haag expansion and covariant bound state amplitudes

August 14th A. Vuorinen (Bielefeld, Germany)
Holographic photon and dilepton production in a thermalizing plasma

August 16th K. Fujikawa (RIKEN Nishina Center, Japan)
Universally valid Heisenberg uncertainty relation

August 21st S. Stapnes (CERN, Switzerland)
The Compact Linear Collider study

August 28th G. Bhattacharyya (Saha Institute, Kolkata, India)
Electroweak symmetry breaking beyond the Standard Model

September 5th S. Stricker (Vienna, Austria)
Bootstraping gravity solutions

September 18th S. Brodsky (SLAC, USA)
AdS/QCD, light-front holography, and color confinement

September 25th L. Wendland (HIP)
Progress on Standard Model Higgs boson searches at the LHC

October 2nd D. K. Ghosh (IACS, India)
The Standard Model Higgs coupling measurement at the LHC, ILC and LHeC

October 9th A. Mykkänen (Helsinki)
Properties of QCD strings from lattice Monte Carlo

October 16th S. Di Chiara (HIP)
A perturbative realization of Miransky scaling

October 18th K. Kajantie (HIP)
Hot QCD in the limit of large number of colors and flavors

November 6th T. Markkanen (FL/HIP)
Quantum corrections to inflaton and curvaton dynamics

November 8th H. Arponen (Mathematics Dept, Helsinki)
Generalizing the Brown-Henneaux type gauge/gravity duality to higher dimensions

November 13th A. Gynther (TU Vienna, Austria)
Modelling thermodynamics of anisotropic quark-gluon plasma

November 16th Y. Schröder (Bielefeld, Germany)
The Debye screening mass of hot QCD

November 20th J. Jäykkä (Nordita, Sweden)
Dynamics and properties of Hopfions

November 27th T. Mäki (HIP)
TOTEM experiment: physics results and future

December 4th R. Lerner (HIP)
Curvaton decay by resonant production of the Standard Model Higgs

December 11th R. Rivers (Imperial College, UK)
The consequences of causality for tunable condensates undergoing rapid magnetic field quenches

December 20th N. Jokela (Santiago de Compostela, Spain)
Holographic flavors in Chern-Simons matter theories

Visitors

Theory Programme

Cosmophysics

J. Bueno Sánchez (Spain) 10.–31.1.
S. Orani (UK) 22.–27.1.
D. Alonso (Spain) 1.–12.2.
M. Zumalacarregui (Spain) 6.–15.2.
F. Urban (Canada) 8.–17.2.
A. Rajantie (UK) 27.–29.2., 4.–7.5.
S. Huber (UK) 27.2.–1.3.
D. Sapone (Spain) 12.–16.3.
O. Taanila (Germany) 12.–16.3.
S. V. Ketov (Japan) 19.–21.3.
I. Saltas (UK) 19.–23.3.
M. Kunz (Switzerland) 26.–27.3.
I. Huston (UK) 23.–27.4.
D. Daverio (Switzerland) 30.4.–25.5.
M. Karciauskas (Spain) 7.–11.5.
L. Bethke (UK) 8.–14.5.
Y. Urakawa (Spain) 15.–21.5.
G. Nardini (Germany) 21.–27.5.
A. Mazumdar (UK) 4.–6.6.
D. Bodeker (Germany) 6.–8.6.
A. Hektor (Switzerland) 6.–8.6.
A. Bueno Belloso (Spain) 3.–7.9.
G. W. Pettinari (UK) 3.–7.9.
V. Domcke (Germany) 10.–14.9.
P. Bull (UK) 1.–5.10.
O. E. Bjælde (Denmark) 16.–19.10.
M. Sloth (Denmark) 31.10.–2.11.
J.-C. Waizmann (Italy) 5.–9.11.
A. Golovnev (Russia) 3.–7.12.

Laws of Nature and Condensed Particle Matter Phenomenology at the LHC

M. Järvinen (Greece) 1.–5.1.
A. Kurkela (Canada) 1.–5.1., 16.–19.10.
A. Vuorinen (Germany) 1.–5.1., 9.–20.3., 28.–31.5., 1.8.–7.9., 26.–29.11., 18.–20.12.
P. Huovinen (Germany) 4.1., 17.–26.2.
J. Laamanen (The Netherlands) 9.–13.1.
H. Holopainen (Germany) 17.1.
G. Denicol (Germany) 1.2.–1.3.
D. Rischke (Germany) 13.–27.2.
E. Molnar (Hungary) 17.–26.2.
R. Kolevatov (Norway) 26.–28.2.
A. Rajantie (UK) 27.–29.2., 4.–7.5.
S. Huber (UK) 27.2.–1.3.
R. Perez-Ramos (Spain) 5.–7.3.
H. Ma (Spain) 8.–10.3.
O. Taanila (Germany) 1.8.–7.9.
D. Daverio (Switzerland) 25.–27.3., 29.4.–26.5.
M. Kunz (Switzerland) 25.–27.3.
M. Obradovic (Switzerland) 25.–29.3.
K. Splittorff (Denmark) 7.–8.5.
A. Datta (India) 14.5.–19.6.
G. Nardini (Germany) 21.–27.5.
M. Krššák (Germany) 28.5.–1.6., 19.–24.8.
H. Honkanen (USA) 1.–30.6.
A. Hietanen (Denmark) 6.–7.6., 17.–20.12.
D. Bödeker (Germany) 6.–8.6.
E. Gabrielli (Estonia) 19.6.
L. Del Debbio (UK) 5.–7.7.
J. Erdmenger (Germany) 13.–18.8.
S. Mogliacci (Germany) 15.–22.8.
A. Kagan (USA) 20.–21.8.
Y. Zhu (Germany) 24.–27.8.
G. Bhattacharyya (India) 25.8.–2.9.
S. Bass (USA) 30.8.–3.9.
B. Wu (Germany) 30.8.–5.9.
S. Stricker (Germany) 1.–6.9.
S. J. Brodsky (USA) 15.–21.9.
D. Ghosh (India) 15.9.–14.10.
S. West (UK) 16.–19.10.
A. Gynther (Austria) 12.–16.11.
Y. Schröder (Germany) 15.–16.11.
J. Jäykkä (Sweden) 20.11.
P. H. Damgaard (Denmark) 5.–6.12.
R. Rivers (UK) 11.12.

Hadron Physics Activity

O. W. Greenberg (USA) 11.6.–11.7.
S. Cowen (USA) 14.6.–11.7.

Technology Programme

T. Reti (Sweden) 27.–29.3., 28.–31.5.
P. Thanisch (Finland) 12.–16.11.
J. Nummenmaa (Finland) 14.–16.11.

Planck

R. Keskitalo (USA) 3.–7.9.

Conference participation, Talks and Visits by Personnel

Theory Programme

Cosmophysics

CERN,
1 January - 31 August, Geneva, Switzerland (K. Kainulainen)

Lancaster University,
6 January, Lancaster, UK (talk by R. Lerner)

University of Auckland,
10 January - 3 February, Auckland, New Zealand (S. Hotchkiss)

CERN,
16-27 January, Geneva, Switzerland (P. Rahkila)

University of Canterbury,
23-25 January, Christchurch, New Zealand (talk by S. Hotchkiss)

CERN,
6-11 February, Geneva, Switzerland (M. Pääkkönen)

University of Oxford,
23-26 February, Oxford, UK (S. Hotchkiss)

Queen Mary, University of London; Imperial College, London; University of Cambridge; University of Lancaster,
26 February - 5 March, London, Cambridge, and Lancaster, UK (talk by S. Hotchkiss)

University of Cardiff,
27 February, Cardiff, UK (talk by S. Hotchkiss)

Euclid SGS 'Kick-Off' Meeting,
5-9 March, Bologna, Italy (P. Rahkila)

University of Sussex,
9-12 March, Brighton, UK (talk by S. Hotchkiss)

7th Iberian Cosmology Meeting,
2-4 April, Lisbon, Portugal (talk by D. Figueroa, talk by T. Meriniemi)

Max Planck Institute for Astrophysics; Heidelberg University,
30 April - 21 May, Garching and Heidelberg, Germany (talk by S. Hotchkiss)

Implications of the Early LHC Results for Cosmology,
April, DESY, Hamburg, Germany (talk by D. Figueroa)

Euclid Mission Conference 2012,
15-16 May, Copenhagen, Denmark (K. Kainulainen, P. Rahkila)

Cosmology Summer School,
28-31 May, Espoo, Finland (talk by K. Enqvist, talk by D. Figueroa, talk by S. Hotchkiss, talk by R. Lerner, talk by S. Räsänen)

Nottingham University,
1 June, Nottingham, UK (talk by S. Hotchkiss)

University of Oxford,
3-5 June, Oxford, UK (S. Hotchkiss)

Imperial College,
5-8 June, London, UK (S. Hotchkiss)

University of Sussex,
11-13 June, Brighton, UK (S. Hotchkiss)

Lancaster University,
20 June, Lancaster, UK (talk by R. Lerner)

Euclid CSWG-OUSIM Joint Meeting,
8-11 July, Barcelona, Spain (P. Rahkila)

Strong and Electroweak Matter 2012,
10-13 July, Swansea, UK (K. Kainulainen)

Modern Cosmology: Early Universe, CMB and LSS,
5-25 August, Benasque, Huesca, Spain (talk by D. Figueroa, organiser, talk by T. Meriniemi)

Baryogenesis and Quantum Field Dynamics,
28-30 August, NBI, Copenhagen, Denmark (talk by D. Figueroa)

Cosmo 2012,
10-14 September, Beijing, China (talk by S. Hotchkiss, talk by T. Meriniemi)

CP3-Origins,
17-19 September, Odense, Denmark (talk by R. Lerner)

Non-Equilibrium Quantum Fields in Cosmology,
20-21 September, Imperial College, London, UK (talk by D. Figueroa, talk by R. Lerner)

DESY Theory Workshop,
25-28 September, Hamburg, Germany (talk by R. Lerner)

Aarhus University,
27-29 September, Aarhus, Denmark (K. Kainulainen)

Progress in Non-Equilibrium Green's Functions V,
27-31 September, University of Jyväskylä, Jyväskylä, Finland (talk by K. Kainulainen)

NBIA,
3-5 October, Copenhagen, Denmark (talk by R. Lerner)

University of Oxford,
19-23 November, Oxford, UK (talk by S. Hotchkiss)

Perspectives of Fundamental Cosmology,
27 November, Nordita, Stockholm, Sweden (talk by K. Enqvist)

Laws of Nature and Condensed Particle Matter Phenomenology at the LHC

Spaatind 2012 - Nordic Conference on Particle Physics,
2-7 January, Skeikampen, Norway (talk by I. Helenius, P. Hoyer)

Workshop for HEP XII,
8-12 January, Mahabaleshwar, India (talk by K. Huitu)

Imperial College,
9-13 January, London, UK (D. Weir)

European Strategy Update Preparatory Group Meeting,
13 January, 13 February, 16 March, 22 May, 12 June, 29 August, 29 November - 1 December, Geneva, Switzerland (K. Huitu)

Workshop on Exploring QCD Frontiers: from RHIC and LHC to EIC,
30 January - 3 February, Stellenbosch, South Africa (talk by T. Lappi, talk by K. Rummukainen)

Lund University,
3 February, Lund, Sweden (K. Huitu)

FIAS,
6-9 February, Frankfurt, Germany (talk by J. Auvinen)

Strong Interactions Beyond the Standard Model,
13-15 February, Physikzentrum Bad Honnef, Germany (talk by P. Hoyer)

Jagiellonian University,
23-25 February, Crakow, Poland (talk by T. Renk)

Niels Bohr Institute,
5-6 March, Copenhagen, Denmark (talk by K. Rummukainen)

University of Santiago de Compostela,
6-9 March, Santiago de Compostela, Spain (talk by T. Lappi)

The Annual Meeting of the Finnish Physical Society,
13-15 March, Joensuu, Finland (talk by I. Helenius)

Programme INT 12-1: Gauge Field Dynamics in and out of Equilibrium,
19-31 March, Seattle, WA, USA (D. Weir)

7th International Workshop on High-pT Physics at LHC,
26-27 March, Frankfurt, Germany (talk by I. Helenius, talk by T. Renk)

Syracuse University,
2-4 April, Syracuse, NY, USA (talk by D. Weir)

Programme: Mathematics and Applications of Branes in String and M-Theory; Workshop: Condensed Matter, Black Holes and Holography,
10-20 April, Isaac Newton Institute for Mathematical Sciences, Cambridge, UK (E. Keski-Vakkuri)

Workshop on Holographic Methods of Strongly Coupled Systems,
15-21 April, Swansea, UK (T. Alho, K. Kajantie, talk by K. Tuominen)

Aalto University,
26 April, Espoo, Finland (talk by M. Hindmarsh)

Stony Brook University,
7-9 May, Stony Brook, NY, USA (talk by K. Tuominen)

Brookhaven National Laboratory,
9-11 May, Upton, NY, USA (talk by K. Tuominen)

Niels Bohr Institute,
15 May - 14 June, Copenhagen, Denmark (T. Markkanen)

Niels Bohr Institute,
24-25 May, Copenhagen, Denmark (D. Weir)

Hard Probes 2012: 5th International Conference on Hard and Electromagnetic Probes of High-Energy Collisions,
27 May - 1 June, Sardinia, Italy (talk by K. J. Eskola, talk by I. Helenius, talk by T. Lappi, talk by T. Renk)

Cosmology Summer School,
28-31 May, Espoo, Finland (talk by E. Keski-Vakkuri)

Danish Technical University,
28-31 May, Copenhagen, Denmark (D. Weir)

NORDITA Program: Origin of Mass 2012,
28 May - 22 June, Stockholm, Sweden (talk by P. Hoyer, K. Huitu, K. Tuominen)

pA@LHC -Workshop,
4-8 June, CERN, Geneva, Switzerland (talk by I. Helenius)

STRONGnet Summer School 2012,
4-8 June, Firbush, UK (talk by A. Mykkänen)

Conference on the Origin of Mass 2012,
11-16 June, Stockholm, Sweden (K. Tuominen)

IPhT Saclay,
13 June - 4 July, Saclay, France (talk by T. Lappi)

Imperial College,
14-21 June, London, UK (talk by D. Weir)

Bielefeld University,
24-28 June, Bielefeld, Germany (talk by E. Keski-Vakkuri)

The XXX International Symposium on Lattice Field Theory,
24-29 June, Cairns, Australia (talk by M. D'Onofrio, talk by T. Karavirta, talk by J. Rantaharju)

Vrije Universiteit Brussel,
28-30 June, Brussels, Belgium (E. Keski-Vakkuri)

13th Marcel Grossmann Meeting,
1-6 July, Stockholm, Sweden (talk by E. Keski-Vakkuri)

36th International Conference on High Energy Physics,
4-11 July, Melbourne, Australia (M. D'Onofrio)

Light Cone 2012,
8-13 July, Crakow, Poland (talk by P. Hoyer)

Strong and Electroweak Matter 2012,
10-13 July, Swansea, UK (M. Hindmarsh, advisory committee member, talk by K. Rummukainen, D. Weir)

Heavy Ion Collisions in the LHC Era,
16-20 July, Quy Nhon, Vietnam (talk by I. Helenius)

Numerical Cosmology 2012,
17-20 July, Cambridge, UK (M. Hindmarsh, organising committee member)

University of California at Los Angeles,
21-29 July, Los Angeles, CA, USA (E. Keski-Vakkuri)

APCTP Focus Program: Holography at LHC,
1-10 August, Pohang, Republic of Korea (talk by K. Tuominen)

20th International Conference on Supersymmetry and Unification of Fundamental Interactions,
11-19 August, Beijing, China (talk by K. Huitu)

Quark Matter 2012,
13-18 August, Washington DC, USA (talk by T. Lappi, talk by T. Renk)

QFS2012: International Conference on Quantum Fluids and Solids,
15-21 August, Lancaster, UK (talk by D. Weir)

Workshop on Baryogenesis and Quantum Field Dynamics,
28-30 August, Copenhagen, Denmark (talk by M. D'Onofrio, M. Hindmarsh, talk by K. Rummukainen, talk by D. Weir)

Quantum Chromodynamics: History and Prospects,
3-8 September, Oberwölz, Austria (talk by P. Hoyer)

McGill University,
7 September - 19 December, Montreal, Canada (M. D'Onofrio)

European Strategy Update, Open Meeting,
9-13 September, Cracow, Poland (K. Huitu)

Cosmo 2012,
10-14 September, Beijing, China (talk by M. Hindmarsh)

Non-Equilibrium Field Theory in Cosmology,
20-21 September, London, UK (talk by K. Rummukainen, talk by D. Weir)

Workshop: Holographic Thermalization,
7-12 October, Lorentz Center, Leiden, The Netherlands (E. Keski-Vakkuri)

HPC in Nuclear and Particle Physics,
8 October, Espoo, Finland (talk by K. Rummukainen)

EMMA Steering Group and LAGUNA Promo,
15 October, Pyhäjärvi, Finland (K. Rummukainen)

STRONGnet 2012 Workshop on Computational Hadron Physics,
15-19 October, Madrid, Spain (J. Suorsa)

Karl-Franzens-Universität,
22-25 October, Graz, Austria (talk by A. Mykkänen)

3rd Workshop on the QCD Structure of the Nucleon (QCD-N'12),
22-26 October, Bilbao, Spain (talk by P. Hoyer)

University of Southern Denmark,
25 October, Odense, Denmark (K. Tuominen)

University of Frankfurt,
28 October - 1 November, Franfurt, Germany (talk by K. Kajantie)

Université de Montréal,
14 November, Montreal, Canada (talk by M. D'Onofrio)

Particle Physics Day 2012,
30 November, Jyväskylä, Finland (talk by I. Helenius, talk by J. Maalampi)

Quantized Flux in Tightly Knotted and Linked Systems,
3-7 December, Isaac Newton Institute, Cambridge, UK (talk by M. Hindmarsh)

Workshop on Strong Coupling Gauge Theories in the LHC Perspective (SCGT12),
4-7 December, Nagoya, Japan (talk by K. Tuominen)

QCD in Extreme Conditions,
13-15 December, Trondheim, Norway (talk by M. Hindmarsh)

Hadron Physics Activity

Symposium on Electroweak Nuclear Physics,
8-10 March, Duke University, NC, USA (talk by D.-O. Riska)

The Annual Meeting of the Finnish Physical Society,
13-15 March, Joensuu, Finland (M. Sainio)

ECT*/EJFRC Meeting,
18-20 March, Trento, Italy (M. Sainio)

5. FAIR/AFC Meeting,
14-15 May, Darmstadt, Germany (M. Sainio)

FAIR/AFC OC-WG Meeting,
12-13 September, Darmstadt, Germany (M. Sainio)

Low Dimensional Quantum Systems

Towards Reality in Nanoscale Materials V,
20-22 February, Levi, Finland (talk by A. Uppstu)

Graphene 2012,
10-13 April, Brussels, Belgium (M. Ijäs)

Graphene Week 2012,
4-8 June, Delft, The Netherlands (talk by A. Harju, A. Uppstu)

PARA 2012,
10-13 June, Helsinki, Finland (A. Harju, chairman and minisymposium organiser, talks by A. Harju and T. Siro)

Carbonhagen 2012,
25-26 June, Copenhagen, Denmark (talk by A. Harju)

The 12th International Conference on Nanoscience + Technology (ICN+T2012),
23-27 July, Paris, France (talk by A. Harju)

The 16th International Conference on Positron Annihilation (ICPA-16),
19-24 August, Bristol, UK (talk by I. Makkonen)

Progress in Non-Equilibrium Green's Functions V,
27-31 August, Jyväskylä, Finland (invited talk by A. Harju)

E-MRS 2012 Fall Meeting,
17-21 September, Warsaw, Poland (A. Harju, chairman, talks by A. Harju, M. Ijäs, and A. Uppstu)

Radiation Damage in Particle Accelerator Materials

Saint Petersburg State Polytechnic University,
19-21 January, St. Peterburg, Russia (F. Djurabekova, K. Nordlund)

CSC Spring School in Computational Chemistry,
5-9 March, Helsinki, Finland (S. Parviainen)

The Annual Meeting of the Finnish Physical Society,
13-15 March, Joensuu, Finland (F. Djurabekova, A. Leino, K. Nordlund, talk by S. Parviainen, A. Pohjonen)

Beyond Molecular Dynamics: Long Time Atomic-Scale Simulations,
26-29 March, Dresden, Germany (invited talk by F. Djurabekova, K. Nordlund)

Material Research Society Meeting,
9-13 April, San Francisco, CA, USA (talk by O. Pakarinen)

International Workshop on Breakdown Science and High Gradient Technology,
18-20 April, Tsukuba. Japan (talk by F. Djurabekova, K. Nordlund)

Okinawa Institute of Science and Technology,
22-24 April, Okinawa, Japan (lecture by F. Djurabekova, lecture by K. Nordlund)

Tampere University of Technology,
3 May, Tampere, Finland (talk by O. Pakarinen)

Saarland University,
7-8 May, Saarbrücken, Germany (lecture by F. Djurabekova, K. Nordlund)

CLIC Collaboration Working Meeting,
7-11 May, Geneva, Switzerland (F. Djurabekova, A. Korsbäck, S. Parviainen)

European Material Research Society Meeting,
13-18 May, Strasbourg, France (talk by O. Pakarinen)

International Field Emission Symposium,
19-27 May, Tuscaloosa, AL, USA (S. Parviainen)

Atomic Structure of Nanosystems from Transmission Electron Microscopy Experiments and First-Principles Simulations,
31 May - 2 June, Helsinki-Stockholm, Finland-Sweden (A. Ruzibaev)

Computer Simulations of Radiation Effects in Solids,
24-29 June, Santa Fe, NM, USA (talk by F. Djurabekova, K. Nordlund, talk by O. Pakarinen)

CSC Summer School in High-Performance Computing,
25 June - 6 July, Espoo, Finland (A. Ruzibaev)

Radiation Effects in Materials Conference,
2-5 July, Kona, HI, USA (F. Djurabekova, invited talk by K. Nordlund)

Conference on the Application of Accelerators in Research and Industry,
5-11 August, Fort Worth, TX, USA (inivited talk by O. Pakarinen)

Institute of Ion-Plasma and Laser Technology,
7 August, Tashkent, Uzbekistan (talk by K. Nordlund)

Dislocations,
27-31 August, Budapest, Hungary (talk by A. Pohjonen)

ISDEIV 2012 - XXVth International Symposium on Discharges and Electrical Insulation in Vacuum,
2-7 September, Tomsk, Russia (talk by F. Djurabekova)

18th International Conference on Ion Beam Modifications of Materials (IBMM2012),
3-7 September, Qingdao, China (talk by K. Nordlund)

European Material Research Society Meeting,
17-21 September, Warsaw, Poland (talk by K. Avchacov, invited talk by F. Djurabekova, K. Nordlund, symposium chairman, A. Ruzibaev)

The Annual Meeting of the National Doctoral Programme in Nanoscience,
18-19 September, Åbo Akademi University, Turku, Finland (talk by A. Leino)

Mechanisms of Vacuum Arcs,
30 September - 6 October, Albuquerque, NM, USA (invited talk by F. Djurabekova, organiser, talk by S. Parviainen)

International Symposium on Swift Heavy Ions in Matter & International Conference on Atomic Collisions in Solids,
22-28 October, Kyoto, Japan (talk by O. Pakarinen)

Physical and Physico-Chemical Bases of Ion Implantation,
23-26 October, Novosibirsk, Russia (invited talk by F. Djurabekova, invited talk by K. Nordlund)

Uppsala University,
27 October - 1 November, Uppsala, Sweden (S. Parviainen)

10th Anniversary of the Group of Prof. Karsten Albe at the Technical University of Darmstadt,
9 November, Darmstadt, Germany (K. Avchacov, invited talk by K. Nordlund)

GSI,
18 December, Darmstadt, Germany (K. Avchacov, F. Djurabekova, K. Nordlund)

Technical University of Darmstadt,
19 December, Darmstadt, Germany (K. Avchacov, F. Djurabekova, K. Nordlund)

High Energy Physics Programme

TOTEM Operation

Spaatind 2012,
2-7 January, Skeikampen, Norway (talk by J. Welti)

CDF Energy Scan Workshop,
16 February, Fermilab, Batavia, IL, USA (talk by E. Brücken)

Exclusive and Diffractive Processes in High Energy Proton-Proton and Nucleus-Nucleus Collisions,
27 February - 2 March, Trento, Italy (talk by M. Mieskolainen, invited plenary talk by R. Orava)

LHC Committee Meeting,
13 March, CERN, Geneva, Switzerland (J. Welti)

The Annual Meeting of the Finnish Physical Society,
13-15 March, Joensuu, Finland (T. Hildén, T. Mäki)

XX International Workshop on Deep-Inelastic Scattering and Related Subjects,
26-30 March, Bonn, Germany (talk by E. Brücken)

CDF Standard Model Group Meeting,
14 June, Fermilab, Batavia, IL, USA (talks by E. Brücken)

Low-x Meeting,
27 June - 1 July, Paphos, Cyprus (talk by T. Mäki, invited plenary talk by R. Orava)

SAB/HIP,
28 August, Helsinki, Finland (talk by R. Orava)

Diffraction 2012,
8-15 September, Lanzarote, Spain (invited plenary talk by R. Orava)

Zimaney School,
3-5 December, Budapest, Hungary (invited presentation by R. Orava)

CDF Higgs Discovery Group Meetings,
Fermilab, Batavia, IL, USA (talks by F. Devoto)

TOTEM Collaboration Meetings,
CERN, Geneva, Switzerland (talks by T. Mäki and J. Welti)

TOTEM Physics and Analysis Meetings,
CERN, Geneva, Switzerland (talks by T. Mäki and J. Welti)

Linear Collider Research

LHC Lumi Days 2012,
29 February - 1 March, CERN, Geneva, Switzerland (talk by K. Österberg)

EuCARD Annual, EuCARD Governing Board and ESGARD Board Meetings,
23-27 April, Warsaw, Poland (invited talk by K. Österberg)

Precision Engineering at CERN: Future Challenges and Opportunities,
2-3 May, Thoiry, France (J. Väinölä)

CLIC Collaboration Working Meeting,
9-11 May, CERN, Geneva, Switzerland (J. Väinölä, K. Österberg)

pA@LHC,
4-7 June, CERN, Geneva, Switzerland (talk by K. Österberg)

HIP Scientific Advisory Board,
27-28 August, Helsinki, Finland (talk by K. Österberg)

Marie Curie IAPP MeChanICs Mid-Term Review,
27 September, Helsinki, Finland (J. Väinölä, talk by K. Österberg)

CLIC Cost and Schedule Working Group Meetings,
CERN, Geneva, Switzerland (talks by A. Nummela)

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

CLIC Meetings,
CERN, Geneva, Switzerland (talks by K. Österberg)

CLIC Module Working Group Meetings,
CERN, Geneva, Switzerland (talks by L. Kortelainen, R. Raatikainen and J. Väinölä)

EuCARD WP9.2 Meetings,
CERN, Geneva, Switzerland (talks by K. Österberg)

Marie Curie IAPP MeChanICs Meetings,
CERN, Geneva, Switzerland (organised by J. Väinölä and K. Österberg)

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

TIARA PP WP3 Meetings,
CERN, Geneva, Switzerland (J. Väinölä)

TOTEM Collaboration Meetings,
CERN, Geneva, Switzerland (talks by F. Oljemark and K. Österberg)

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

CMS Programme

Spaatind 2012 - Nordic Conference on Particle Physics,
2-7 January, Skeikampen, Norway (talk by P. Eerola, talk by G. Fedi)

CMS Collaboration Meetings,
23-28 January, CERN, Geneva, Switzerland (R. Kinnunen)

CERN,
27 January - 1 February, Geneva, Switzerland (S. Lehti)

CERN,
26 February - 2 March, Geneva, Switzerland (S. Lehti)

CMS Collaboration Workshop,
27 February - 3 March, CERN, Geneva, Switzerland (V. Karimäki, R. Kinnunen)

Suomalainen tutkimus Cernissä, Eduskunta TUTKAS,
13 March, Helsinki, Finland (talk by P. Eerola)

The Annual Meeting of the Finnish Physical Society,
13-15 March, Joensuu, Finland (V. Karimäki, talk by M. Kortelainen, talk by T. Lampén, talk by M. Voutilainen)

CMS Collaboration Meetings,
20-24 March, CERN, Geneva, Switzerland (R. Kinnunen)

CMS Service Work,
16-21 April, CERN, Geneva, Switzerland (R. Kinnunen)

Worldwide LHC Computing Grid Collaboration Workshop 2012,
19-20 May, New York, NY, USA (T. Lindén)

Computing in High Energy and Nuclear Physics 2012,
21-25 May, New York, NY, USA (K. Lassila-Perini, T. Lindén)

CIPANP 2012,
29 May - 3 June, St. Petersburg, FL, USA (talk by P. Eerola)

NorduGrid Conference 2012,
30 May - 1 June, Uppsala, Sweden (talk by T. Lindén)

CMS Collaboration Meetings,
10-15 June, CERN, Geneva, Switzerland (R. Kinnunen)

CERN,
10-29 June, Geneva, Switzerland (S. Lehti)

CMS Week,
25-29 June, CERN, Geneva, Switzerland (P. Eerola, L. Wendland)

CMS Collaboration Meetings,
3-7 July, CERN, Geneva, Switzerland (R. Kinnunen)

MCnet-LPCC Summer School 2012,
23-27 July, CERN, Geneva, Switzerland (G. Fedi)

CERN,
27-31 August, Geneva, Switzerland (L. Wendland)

Helsinki Insight -Seminar,
31 August, Helsinki, Finland (talk by P. Eerola)

CMS Collaboration Meeting,
3-7 September, CERN, Geneva, Switzerland (R. Kinnunen)

CMS Week,
3-8 September, CERN, Geneva, Switzerland (P. Eerola)

European Particle Physics Strategy Open Symposium,
9-13 September, Crakow, Poland (P. Eerola)

CMS Collaboration Meetings,
10-19 September, CERN, Geneva, Switzerland (R. Kinnunen)

CERN,
11-14 September, Geneva, Switzerland (L. Wendland)

2012 LHC Days in Split,
1-6 October, Split, Croatia (talk by G. Fedi)

Stockholm University,
5 October, Stockholm, Sweden (R. Kinnunen)

Seminar on High Performance Computational Nuclear/ Particle Physics at CSC,
8 October, Espoo, Finland (talk by P. Eerola, talk by K. Lassila-Perini, talk by T. Lindén)

4th International Workshop on Prospects for Charged Higgs Discovery at Colliders,
8-11 October, Uppsala, Sweden (R. Kinnunen, talk by M. Kortelainen, talk by L. Wendland)

CERN,
15-19 October, Geneva, Switzerland (L. Wendland)

University of Copenhagen,
1 November, Copenhagen, Denmark (P. Eerola)

CMS Collaboration Meetings,
5-10 November, CERN, Geneva, Switzerland (R. Kinnunen)

2012-II Workshop on CERN RD39 Cryogenic Tracking Detectors,
13 November, CERN, Geneva, Switzerland (E. Tuominen)

21th RD50 Workshop on Radiation Hard Semiconductor Devices for Very High Luminosity Colliders,
14-16 November, CERN, Geneva, Switzerland (E. Tuominen)

Marseille Workshop on Scientific Data Preservation,
19-21 November, Marseille, France (K. Lassila-Perini)

Particle Physics Day 2012,
30 November, Jyväskylä, Finland (talk by T. Järvinen, talk by M. Kortelainen, talk by J. Pekkanen)

CMS Week and European Strategy Meeting,
9-13 December, CERN, Geneva, Switzerland (P. Eerola)

CMS Collaboration Meeting,
10-15 December, CERN, Geneva, Switzerland (R. Kinnunen)

CERN,
18 December - 2 January, Geneva, Switzerland (L. Wendland)

Nuclear Matter Programme

FUSHE2012, ENSAR-ECOS Workshop on Future Super-Heavy Element Strategy,
13-16 May, Weilrod, Germany (talk by M. Leino)

ALICE

The Annual Meeting of the Finnish Physical Society,
13-15 March, Joensuu, Finland (talk by B. Chang, talk by J. Kral, talk by N. Novitzky)

7th International Workshop on High-pT Physics at LHC,
26-29 March, Berlin, Germany (talk by J. Rak, talk by S. S. Räsänen)

28th Winter Workshop on Nuclear Dynamics,
7-14 April, Dorado del Mar, Peurto Rico (talk by N. Novitzky)

Hard Probes 2012 - 5th International Conference on Hard and Electromagnetic Probes of High-Energy Nuclear Collisions,
27 May - 1 June, Cagliari, Sardinia, Italy (talk by J. Rak)

PLHC2012,
4-9 June, Vancouver, BC, Canada (talk by D. J. Kim)

ICFP2012: International Conference on New Frontiers in Physics,
10-16 June, Kolymbari, Crete, Greece (talk by N. Novitzky)

Quark Matter 2012,
13-18 August, Washington DC, USA (talk by F. Krizek, N. Novitzky)

Measuring Multiple Partonic Interactions at the LHC,
14-18 October, Tel Aviv, Israel (talk by J. Rak)

Particle Physics Day 2012,
30 November, Jyväskylä, Finland (talk by S. S. Räsänen)

ISOLDE

ISCC Meeting,
30 January - 2 February, CERN, Geneva, Switzerland (P. Greenlees)

INTC Meeting,
1-2 February, CERN, Geneva, Switzerland (R. Julin)

Working visit to CERN,
25 February - 3 March, Geneva, Switzerland (J. Pakarinen)

ISCC Meeting,
2-4 July, CERN, Geneva, Switzerland (P. Greenlees)

Working visit to CERN,
17-18 September, Geneva, Switzerland (P. Rahkila)

Working visit to CERN,
29 September - 7 October, Geneva, Switzerland (J. Pakarinen)

INTC Meeting,
1-2 October, CERN, Geneva, Switzerland (R. Julin)

Working visit to CERN,
13-19 October, Geneva, Switzerland (J. Pakarinen)

ISCC Meeting,
29-31 October, CERN, Geneva, Switzerland (P. Greenlees)

Working visit to CERN,
22-27 November, Geneva, Switzerland (I. Moore)

FAIR

Annual NuSTAR Week,
27 February - 2 March, GSI, Darmstadt, Germany (S. Rinta-Antila, E. Tuominen)

The Annual Meeting of the Finnish Physical Society,
13-15 March, Joensuu, Finland (M. Kalliokoski)

GSI,
19-31 March, Darmstadt, Germany (F. García)

GSI,
16 April - 7 May, Darmstadt, Germany (F. García)

Beam Tests at FRS,
30 May - 6 June, GSI, Darmstadt, Germany (E. Tuominen)

GSI,
16-30 July, Darmstadt, Germany (F. García)

Nuclear Science Symposium,
29 October - 7 November, Los Angeles, CA, USA (talk by F. García)

Technology Programme

Open Source NOW,
7-8 February, Geneva, Switzerland (N. Buss, M. Tuisku)

ISGC 2012 (International Symposium on Grids and Clouds),
26 February - 2 March, Taipei, Taiwan (talks by J. White, H. Mikkonen)

The Second International Conference on Smart Grids, Green Communications and IT Energy-Aware Technologies, ENERGY 2012,
25-30 March, St. Maarten, Netherlands Antilles (talk by J. Kommeri)

3rd EMI All-Hands Meeting,
8-10 May, Hamburg, Germany (J. Hahkala, talks by H. Mikkonen, J. White)

14e Journée Solutions Bancaires, UNICORE,
31 May, Geneva, Switzerland (N. Buss)

EcoCloud's Inaugural Annual Event,
18 June, Lausanne, Switzerland (N. Buss)

Mobile Data Challenge 2012 (by Nokia) Workshop,
18-19 June, Newcastle, UK (T. Niemi, M. Niinimäki)

ICGREEN 2012, Third International Conference on Green IT Solutions,
2-3 July, Geneva, Switzerland (talks by J. Kommeri)

13e Édition des Rencontres Mondiales du Logiciel Libre (RMLL),
7-12 July, Geneva, Switzerland (N. Buss, M. Tuisku)

EGI Technical Forum 2012,
17-21 September, Prague, Czech Republic (talks by J. Hahkala, C. Lindqvist, H. Mikkonen, J. White)

Grid and Cloud Security: A Confluence (NII Shonan Meeting),
15-18 October, Kanagawa, Japan (talk by J. White)

4th EMI All-Hands Meeting,
29-31 October, Budapest, Hungary (J. Hahkala, H. Mikkonen, J. White)

Swiss Distributed Computing Day 2012: Supporting Science with Cloud Computing,
19 November, Bern, Switzerland (J. Hahkala, M. Niinimäki, J. White)

CLOUD

European Geosciences Union General Assembly 2012,
22-27 April, Vienna, Austria (talk by T. Nieminen)

CLOUD-ITN Open Conference,
22-25 May, Königstein, Germany (T. Nieminen)

16th Air Ion and Aerosol Workshop,
12-14 June, Pühajärve, Estonia (talk by T. Nieminen)

European Aerosol Conference,
2-7 September, Granada, Spain (T. Nieminen)

CRAICC Annual Meeting 2012,
26-28 September, Oslo, Norway (T. Nieminen)

Planck

LFI Core Team Meeting 26,
16-17 January, Bologna, Italy (K. Kiiveri, invited talk by H. Kurki-Suonio, M. Savelainen)

LFI Core Team Meeting 27,
15-16 March, Bologna, Italy (invited talk by H. Kurki-Suonio, V. Lindholm, M. Savelainen)

Planck Science Team Meeting,
28-29 March, Noordwijk, The Netherlands (invited talk by H. Kurki-Suonio)

Planck Inflation Meeting,
8 May, Orsay, France (H. Kurki-Suonio, M. Savelainen)

Joint Core Team Meeting,
9-11 May, Orsay, France (K. Kiiveri, H. Kurki-Suonio, M. Savelainen)

Cosmology Summer School,
28-31 May, Espoo, Finland (talk by H. Kurki-Suonio)

LFI Core Team Meeting 28,
9-10 July, Bologna, Italy (invited talk by H. Kurki-Suonio, V. Lindholm, M. Savelainen)

LFI Core Team Meeting 29,
10-14 September, Bologna, Italy (K. Kiiveri, H. Kurki-Suonio, M. Savelainen)

LFI Core Team Meeting 30,
3-4 December, Bologna, Italy (K. Kiiveri, V. Lindholm, J. Väliviita)

Administration and Support

11th International Conference on Nucleus-Nucleus Collisions,
27 May - 1 June, San Antonio, TX, USA (invited talk by J. Äystö)

CERN Co-operation High School Network Seminar,
31 August, Jyväskylä, Finland (invited talk by R. Rinta-Filppula)

Particle Physics Day 2012,
30 November, Jyväskylä, Finland (invited talk by J. Äystö)

IPPOG Meeting,
30 November - 1 December, CERN, Geneva, Switzerland (R. Rinta-Filppula)

Publications

Theory Programme

Cosmophysics

T. Brauner, O. Taanila, A. Tranberg, and A. Vuorinen,
Temperature dependence of standard model *CP* violation,
Phys. Rev. Lett. 108 (2012) 041601

T. Buchert and S. Räsänen,
Backreaction in late-time cosmology,
Ann. Rev. Nucl. Part. Sci. 62 (2012) 57

M. D'Onofrio, R. N. Lerner, and A. Rajantie,
Electrically charged curvaton,
J. Cosmol. Astropart. Phys. 10 (2012) 004

K. Enqvist, D. G. Figueroa, and T. Meriniemi,
Stochastic background of gravitational waves from fermions,
Phys. Rev. D 86 (2012) 061301(R)

K. Enqvist, D. G. Figueroa, and G. Rigopoulos,
Fluctuations along supersymmetric flat directions during inflation,
J. Cosmol. Astropart. Phys. 01 (2012) 053

K. Enqvist, S. Hotchkiss, and G. Rigopoulos,
A gradient expansion for cosmological backreaction,
J. Cosmol. Astropart. Phys. 03 (2012) 026

K. Enqvist, T. Koivisto, and G. Rigopoulos,
Non-metric chaotic inflation,
J. Cosmol. Astropart. Phys. 05 (2012) 023

K. Enqvist, R. N. Lerner, O. Taanila, and A. Tranberg,
Spectator field dynamics in de Sitter and curvaton initial conditions,
J. Cosmol. Astropart. Phys. 10 (2012) 052

C. Fidler, M. Herranen, K. Kainulainen, and P. M. Rahkila,
Flavoured quantum Boltzmann equations from cQPA,
J. High Energy Phys. 02 (2012) 065

D. G. Figueroa, E. Sefusatti, A. Riotto, and F. Vernizzi,
The effect of local non-Gaussianity on the matter bispectrum at small scales,
J. Cosmol. Astropart. Phys. 08 (2012) 036

S. F. Flender and D. J. Schwarz,
Newtonian versus relativistic cosmology,
Phys. Rev. D 86 (2012) 063527

C. D. Harrison, C. J. Miller, J. W. Richards, E. J. Lloyd-Davies, B. Hoyle, A. K. Romer, N. Mehrtens, M. Hilton, J. P. Stott, D. Capozzi, C. A. Collins, P.-J. Deadman, A. R. Liddle, M. Sahlén, S. A. Stanford, and P. T. P. Viana,
The *XMM* Cluster Survey: the stellar mass assembly of fossil galaxies,
Astrophys. J. 752 (2012) 12

M. Herranen, K. Kainulainen, and P. M. Rahkila,
Flavour-coherent propagators and Feynman rules: covariant cQPA formulation,
J. High Energy Phys. 02 (2012) 080

M. Hindmarsh and I. D. Saltas,
$f(R)$ gravity from the renormalization group,
Phys. Rev. D 86 (2012) 064029

S. Hotchkiss, A. Mazumdar, and S. Nadathur,
Observable gravitational waves from inflation with small field excursions,
J. Cosmol. Astropart. Phys. 02 (2012) 008

B. Hoyle, R. Jimenez, L. Verde, and S. Hotchkiss,
A critical analysis of high-redshift, massive, galaxy clusters. Part I,
J. Cosmol. Astropart. Phys. 02 (2012) 009

R. N. Lerner and J. McDonald,
Unitarity-violation in generalized Higgs inflation models,
J. Cosmol. Astropart. Phys. 11 (2012) 019

T. Markkanen and A. Tranberg,
Quantum corrections to inflaton and curvaton dynamics,
J. Cosmol. Astropart. Phys. 11 (2012) 027

V. Marra and M. Pääkkönen,
Exact spherically-symmetric inhomogeneous model with n perfect fluids,
J. Cosmol. Astropart. Phys. 01 (2012) 025

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The integrated Sachs-Wolfe imprint of cosmic superstructures: a problem for ΛCDM,
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Light propagation and the average expansion rate in near-FRW universes,
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Constraints on scalar and tensor perturbations in phenomenological and two-field inflation models: Bayesian evidences for primordial isocurvature and tensor modes,
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J. High Energy Phys. 11 (2012) 129

K. Huitu, P. N. Pandita, and P. Tiitola,
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