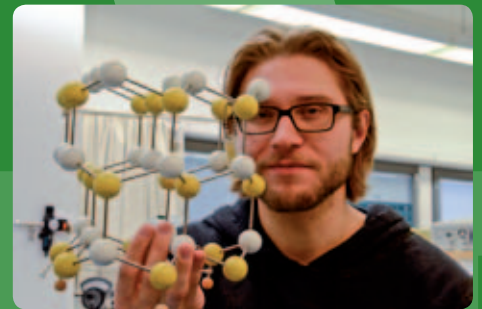


DEPARTMENT OF PHYSICS
UNIVERSITY OF JYVÄSKYLÄ
ANNUAL REPORT 2013



JYFL 2013

2013

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DEPARTMENT OF PHYSICS UNIVERSITY OF JYVÄSKYLÄ

**ANNUAL REPORT
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DEPARTMENT OF PHYSICS
UNIVERSITY OF JYVÄSKYLÄ

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REPORT

JYFL 2013

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Department of Physics

Jukka Maalampi,
Head of the Department

The Department of Physics will soon have a history spanning 50-years and 2013 was one of the most successful, both in terms of teaching and research. The number of M.Sc degrees awarded hit a new record of 50 and the number of peer-reviewed scientific articles (261) was also higher than ever. When normalized by the number of personnel, these are amongst the highest in Finland. The number of MSc degrees in physics is absolutely the largest among physics departments nationally.

Research

Research at the Department of Physics is carried out in three main fields, materials physics, particle physics, and nuclear physics. In materials physics the main research areas are experimental nanophysics, theoretical nanophysics, computational nanoscience, soft condensed matter and statistical physics. Experimental materials physics research is carried out in the laboratories of the multidisciplinary



Nanoscience Center, and in the Pelletron and tomography laboratories on the premises of the Department. The Accelerator Laboratory of the Department provides the focus for the experimental research in nuclear physics, with emphasis on the properties of nuclei far off the line of beta stability and on nuclear structure studies of exotic nuclei, along with a program of ion source studies. In addition, there is strong activity in theoretical nuclear physics. In particle physics the research activity is also divided into experimental and theoretical studies. On the theoretical side, several groups focus on strong-interaction physics of ultrarelativistic heavy ion collisions, beyond-the-standard-model physics and cosmology. Experimental studies are performed in ultrarelativistic heavy ion collisions with the ALICE experiment at CERN, and in astroparticle physics at the Pyhäsalmi mine.

In 2013, the research groups were again very productive, as evidenced by the new record in the number of peer-reviewed research articles. The major part of the research was financed by outside funding, with the main sources being the Academy of Finland and various international programs. The total number of research projects funded externally was about 100.

New professors

In 2013, three Professors chairs were filled at the Department of Physics. Ilari Maasilta was named in the field of low-temperature physics. He has led the research in this new field previously as a non permanent professor and put it on solid ground in the research profile of the Department. In the field of theoretical material physics, Tero



Heikkilä was named as Professor. Tero is holder of an ERC Junior Fellow grant, and is also part of a Centre of Excellence (CoE) led by Aalto University. These aspects of the Aalto CoE led by Tero will now become a part of the JYFL activities. The third chair was filled by Jan Rak in the field of experimental particle physics. He plays a central role in the Finnish contribution to the ALICE experiment at CERN. The foundation of this chair establishes the position of experimental particle physics as one important part in the research programme of the Department. Jan Rak is the third professor in the field in Finland.

Having been previously nominated as a Professor, in 2013 Paul Greenlees began in his position following on from his term as a Research Professor during his ERC research project. He is one of those who will carry the burden of responsibility in the important field of experimental nuclear physics in the Accelerator Laboratory, as the veteran campaigners Professors Rauno Julin, Matti Leino and Juha Äystö gradually take steps into the background.

Education

The development in the instruction of basic level courses has continued at the Department, with the emphasis shifting from teaching to learning. Thanks for this very positive development goes particularly to the younger generation of teachers, who have assimilated well the advantages of interactive teaching methods. Apart from the basic level courses, new methods are now being adopted also with more advanced level teaching, starting with the course of quantum mechanics. Also development of new ways to organize the homework problem tutorials has been continued and extended to several courses. These developments have activated the

SOME STATISTICAL DATA FROM 2013

Personnel	190
- professors incl. research professors	16
- university lecturers and researchers	31
- postdoctoral researchers	25
- graduate students	85
- technicians	29
- administration	4
+ several research assistants (MSc students)	
Undergraduate students	500
of which new students	90
Graduate students	85
BSc	34
MSc degrees	50
PhLic degrees	2
PhD degrees	13
Median time to complete MSc (years)	6,3
Number of foreign visitors	~365
- in visits	~465
Visits abroad	~340
Peer reviewed publications	~230
Conference proceedings	~30
Others (articles in books etc.)	~25
Conference and workshop contributions	
- Invited talks	~175
- Other talks	~105
- Posters	~75
Funding (million €)	16,0
* University budget (incl. premises)	8,8
* HIP cooperation	0,8
* External funding	6,3
- Academy of Finland	3,2
- EAKR	0,5
- Technology Development Centre, T&E Centres	0,2
- International programmes	1,2
- Contract research	0,9
- Others	0,3

students, resulting in considerable improvement of learning outcomes. Our future challenges in education include developing better use of various e-learning methods.

Funding

The total funding of the Department in 2013 was 16,0 M€, of which the external funding was 45 %, well above the goal of 40 % set by the University. The external funding includes the activities of the Helsinki Institute of Physics (HIP) carried out at the Department (0,8 M€). As to the competitive external funding, the Academy of Finland is the most important source providing 3,2 M€. In comparison, the support from Tekes was at worryingly low level (0,2 M€). The commercial activity, concentrated in the Accelerator Laboratory, has been very successful and the income it provided (0,9 M€) is crucial for the maintenance of the experimental facilities. The declining tendency of the budget funding through the University, which one should expect to continue in the coming years, is an issue of serious concern.

Personnel

The total number of personnel of 190 was divided into different categories as follows: professors 8%, university lecturers and researchers 16%, postdoctoral researchers 13%, graduate students 45 %, technical personnel 15 %, and administration 2%. About 55 % of the personnel are paid by external funding. Good news in 2013 included the award of Academy Researcher position to Tuomas Lappi and the Marie Curie Fellowship funding of Philippos Papadakis. On the negative side, it was a searing loss for the Department that Kimmo Tuominen left his alma mater to continue his career at the University of Helsinki.

Outlook

The Department will be facing challenges in coming years, such as the decline of budget funding and increasing competition for external funding and recruitment of good new students. I am convinced that the excellent spirit and dynamic working culture of the Department will help us to meet these challenges successfully and allow us to maintain our high standards and continue on our positive track both in research and education.

CENTRE OF EXCELLENCE IN NUCLEAR AND ACCELERATOR-BASED PHYSICS

Rauno Julin

In 2013, the JYFL Centre of Excellence (CoE) in Nuclear and Accelerator-Based Physics began the second year of its third consecutive six-year term with this status granted by the Academy of Finland (AF).

In its report delivered after the meeting held on 7th of May 2013, the Scientific Advisory Board (SAB) of the CoE assured the Academy that the CoE continues to be successful when judged by the highest international standards. On the

other hand, the SAB also pointed out issues that have to be considered to ensure the success in the future.

The highlight of the year was the decision to include the JYFL Accelerator Laboratory (JYFL-ACCLAB) in Finland's roadmap for research infrastructures. The updated roadmap will be

Fig. 1. Dr. Paul Greenlees, the new professor and his daughter Elsa



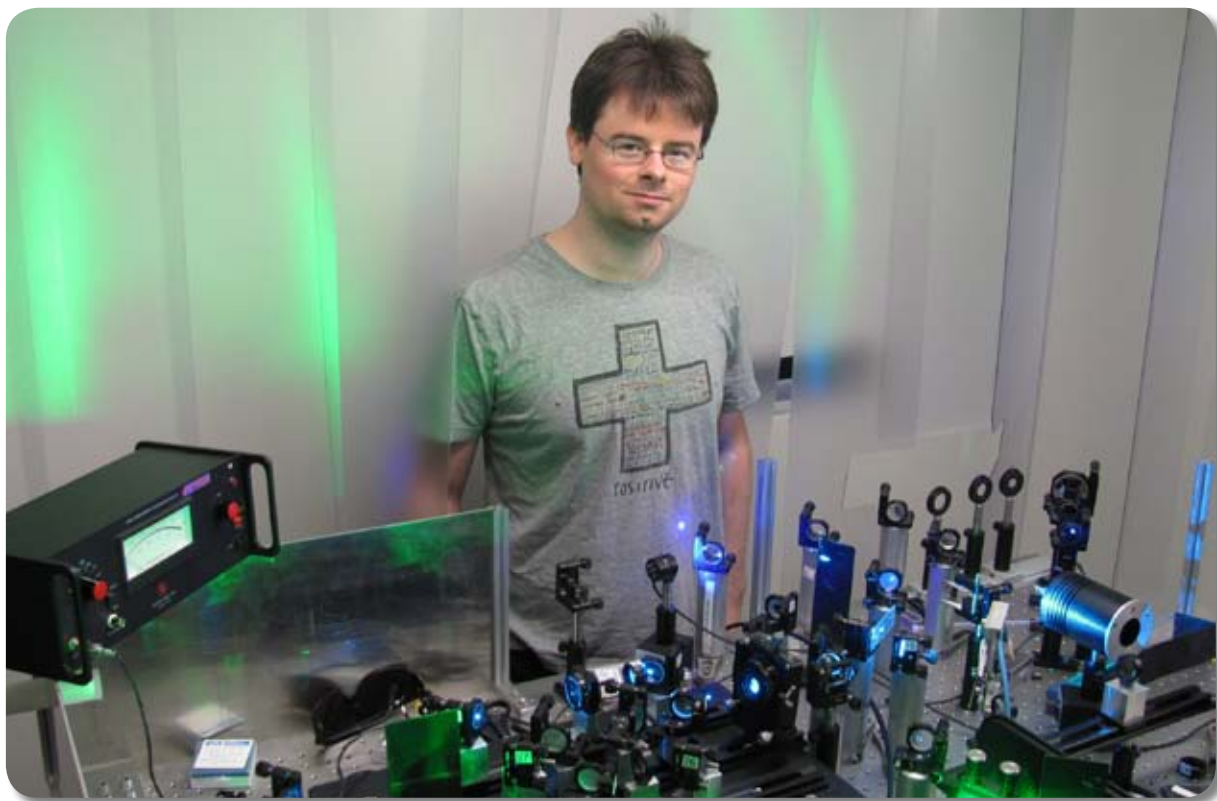


Fig. 2. M.Sc. Volker Sonnenschein, the winner of the 2013 LA3NET prize

published in March 2014. After the two-stage selection process the international evaluation panel wrote in its report: "The JYFL-ACCLAB is the most important international research infrastructure in Finland and offers infrastructure for research and applications in a large variety of fields."

As a consequence of this decision, a proposal to the Academy of Finland for design and construction of a novel ECR ion source and upgrade of ion-beam manipulation instrumentation of the IGISOL facility was awarded a FIRI infrastructure grant of 1.34M€. The ion source group has now started the design work for a new room temperature 18 GHz ECR ion source. It will be operational in 2016 and a considerable improvement in terms of ion beam intensity and energy (charge state of ions) is expected.

The JYFL-ACCLAB continued to act as an EU-FP7-IA-ENSAR-access infrastructure.

Preparations for an ENSAR2 proposal for the coming Horizon2020 call have been started with other ENSAR partners. Furthermore, the JYFL-ACCLAB continues as an accredited test laboratory of the European Space Agency (ESA).

The number of beam time hours at the K130 cyclotron used for basic research and industrial applications was 6192. The number of proposals submitted for experiments at JYFL-ACCLAB was 26, which is lower than the long-term average of 37. This is mainly due to the large number of pending proposals, especially for the IGISOL facility which was recently upgraded.

The Nuclear Spectroscopy group had another busy year running experiments using JUROGAMII and RITU with the various ancillary detector

systems. In 2013, three major campaigns were run, using the LISA spectrometer, the UoYTube CsI array for beta-tagging experiments and the SAGE combined electron-gamma spectrometer. In total 107 days of beam time were dedicated to 11 different experiments. In parallel, development and construction work for the new MARA recoil mass spectrometer continued. The electric dipole has now been constructed by DANFYSIK. Research Professor Paul Greenlees, the co-leader of the Nuclear Spectroscopy group and ERC grant holder was appointed as a full Professor starting 1st September 2013. Paul has been involved in several international activities in the field and is currently responsible for the Finnish contribution to CERN-ISOLDE via the Helsinki Institute of Physics.

In 2013 the commissioning of IGISOL-4 was still in progress. However, in addition to the significant testing and development, five proposed nuclear physics experiments were performed. The successful delivery of high intensity proton beams from the MCC30/15 cyclotron to the IGISOL target position at the end of 2013 promises an active start to the upcoming experimental program in 2014.

Volker Sonnenschein of the IGISOL group received the LA3NET prize, awarded annually to a young scientist who has made an outstanding contribution to research into the application of lasers at accelerator facilities.

The installation of two new research tools (an atomic layer deposition system in the NSC clean room and a transition edge sensor with 3eV resolution for PIXE at Pelletron) opens many new research possibilities for the accelerator-based materials physics group. The group was also strengthened by the arrival of senior researcher Dr. Kai Arstila who came from Imec, Belgium.



Fig. 3. Dr. Kai Arstila, the new senior researcher

The activities related to commercial applications continued to grow, as it has for the past four previous years. In 2013 there were 46 campaigns for 21 different companies or institutes occupying approximately 25% of the K=130 beam time. The total revenue was 771 000 €, which is an important income used to cover the running costs of the accelerators.

The CoE theory team has carried out systematic calculations of the spin-isospin Gamow-Teller 1^+ and spin-dipole 2^- excitations in nuclei by using the quasi-particle random-phase approximation. The results reveal that the weak axial-vector coupling strength is greatly suppressed in nuclei. Part of the suppression stems from the nuclear medium effects and part from the deficiencies of the many-body approximation.

The focus of the FiDiPro project was on evaluating uncertainties and propagated errors of observables determined within the energy-



Fig. 4. Prof. Gottfried Münzenberg, the new honorary doctor of JyU

density-functional methods. A fruitful collaboration with the experimental CoE teams resulted in submitting two publications: on the rotational properties of nuclei in the nobelium region and on evaluation of the neutrino-nucleus scattering.

The users meeting in June 2013 was dedicated to the JYFL-IGISOL users. It was held at JYFL with 25 foreign and 20 national participants.

The second ERINDA workshop attended by 40 participants representing 12 European countries was held in Jyväskylä in January 2013. The European Research Infrastructures for Nuclear Data Applications project aims to coordinate European efforts to exploit up-to-date neutron beam technology for novel research on advanced concepts for nuclear fission reactors and the transmutation of radioactive waste.

Professor Gottfried Münzenberg from GSI Darmstadt, who has contributed significantly to research work and education in the JYFL Accelerator Laboratory, was awarded the degree of honorary doctor by the University of Jyväskylä and the Faculty of Mathematics and Science.

SCIENTIFIC ADVISORY BOARD OF THE CENTRE OF EXCELLENCE IN NUCLEAR AND ACCELERATOR BASED PHYSICS

Witold Nazarewicz, professor, University of Tennessee, USA

Reiner Krücken, Head of the Science Division at TRIUMF, Canada

Pekka Koskela, professor, University of Jyväskylä

Jukka Pekola, professor, Academy of Finland

Jari Laamanen, science adviser, Academy of Finland

MEMBERS OF THE PROGRAMME ADVISORY COMMITTEE OF THE JYFL ACCELERATOR LABORATORY

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The FIDIPRO

Jacek Dobaczewski

Jacek Dobaczewski, research professor
Karim Bennaceur, university researcher 1.9.-
Markus Kortelainen, postdoctoral researcher
Vaia Prassa, postdoctoral researcher
Xiaobao Wang, postdoctoral researcher
Yuan Gao, graduate student
Lingfei Yu, graduate student

In 2013, the FIDIPRO project started its first year of being funded within the second FIDIPRO grant awarded by the Academy of Finland and matched by the University of Jyväskylä. The FIDIPRO team included seven researchers working together on common project goals. All detailed information on the FIDIPRO project, and on its achievements, publications, and meetings, is available on the project web page at:

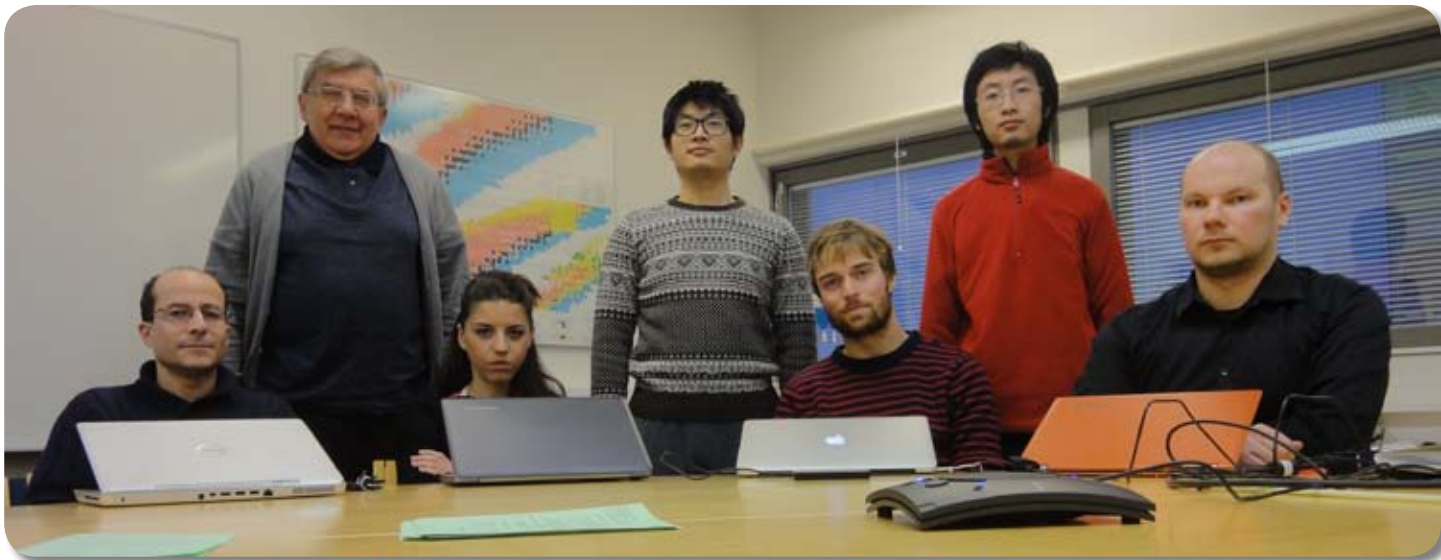
www.jyu.fi/accelerator/fidipro/.

In 2013, the main focus of the project was on evaluating statistical uncertainties of the energy-density-functional (EDF) models and on applications of these models to low-lying vibrational states and fission phenomena.

Propagation of uncertainties in the EDF model

We have determined the uncertainties of observables in all even-even semi-magic nuclei with $N = 20, 28, 50, 82,$ and 126 and $Z = 20, 28, 50,$ and 82 extending between the two-proton and two-neutron driplines. The model used was the Skyrme EDF within the Hartree-

Standing, from left: Jacek Dobaczewski, Xiaobao Wang, Yuan Gao. Seated, from left: Karim Bennaceur, Vaia Prassa, Robin Jodon (visitor), Markus Kortelainen.



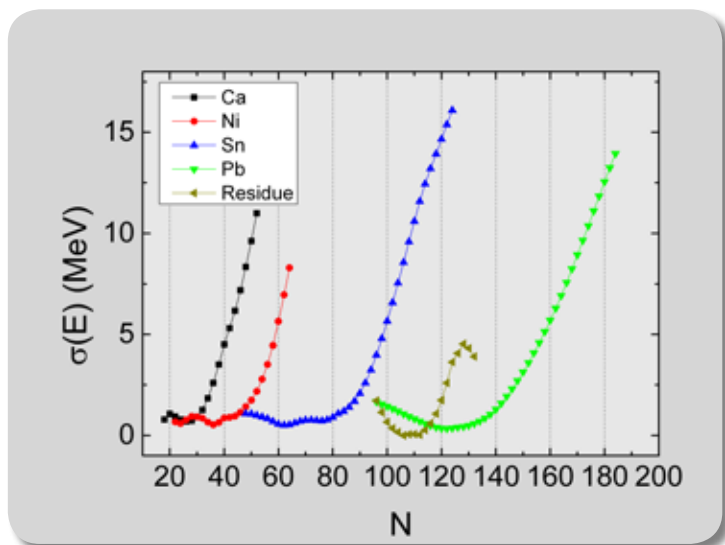


Fig. 1. Standard errors of binding energies of nuclei calculated for isotopic chains with magic proton numbers. For the Pb nuclei, modules of fit residuals with respect to experimental data are also shown.

Fock-Bogoliubov approximation. Information about the standard deviations and correlations between the model parameters was employed to determine the propagation of uncertainties from the model parameters to observables. We found that within the experimentally known regions of nuclei, standard errors of observables usually stay rather constant. Moving to the neutron rich regime, calculated standard errors increase quite rapidly. This is owing to large uncertainties of isovector parameters of the EDFs.

Neutron skin uncertainties

Neutron skin thickness, characterized as a neutron matter distribution extending beyond the proton matter distribution, is an excellent indicator of isovector properties of atomic nuclei. In this work, we assessed systematic and statistical uncertainties of neutron-skin thickness

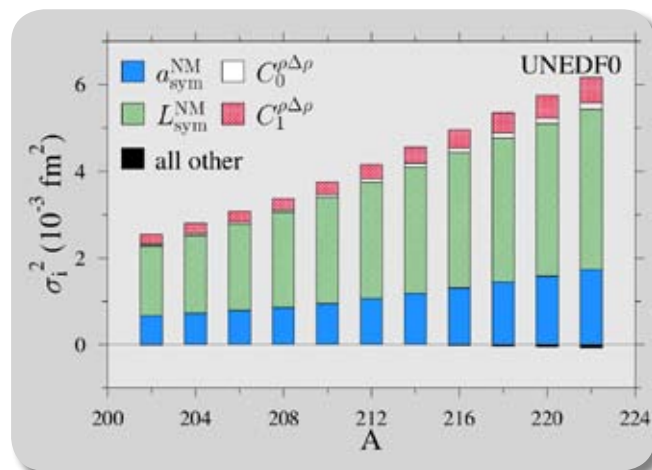


Fig. 2. Error budget of the square of statistical model error obtained for UNEDF0 functional in even-even Pb isotopes. The parameter describing the density dependence of symmetry energy, $L_{\text{sym}}^{\text{NM}}$, gives the biggest contribution.

in various EDF models and we related them to the equation of state of nuclear matter. The single major source of uncertainty was found to be poorly determined density dependence of the symmetry energy. Neutron skin thickness of ^{208}Pb was recently measured in PREX experiment. We found that the statistical theoretical error is smaller than rather large experimental error obtained in the PREX experiment.

A pathway to fission

The spontaneous fission lifetime of ^{264}Fm has been studied within nuclear density functional theory by minimizing the collective action integral for fission in a two-dimensional quadrupole collective space representing elongation (Q_{20}) and triaxiality (Q_{22}). The collective potential and inertia tensor were obtained self-consistently using the Skyrme energy density functional and density-dependent pairing interaction. The resulting spontaneous fission lifetimes

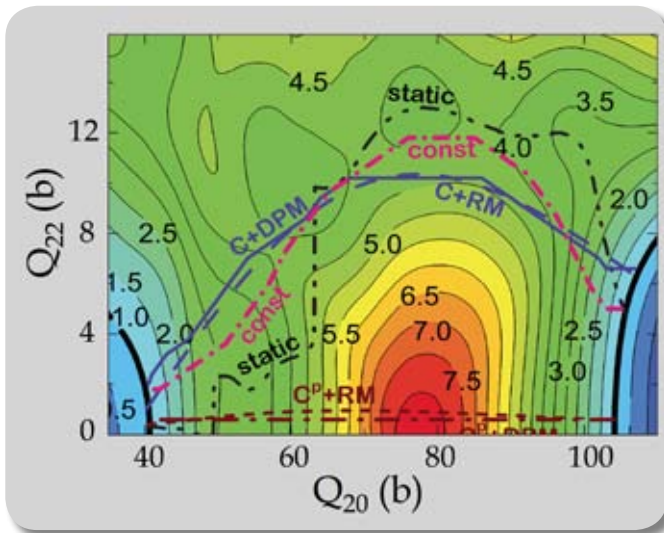


Fig. 3. Dynamic pathways for spontaneous fission of ^{264}Fm , calculated for the nonperturbative and perturbative cranking inertia using two different techniques (DMP and RM) to minimize the collective action integral. The static pathway (“static”) and that corresponding to a constant inertia (“const”) are also shown.

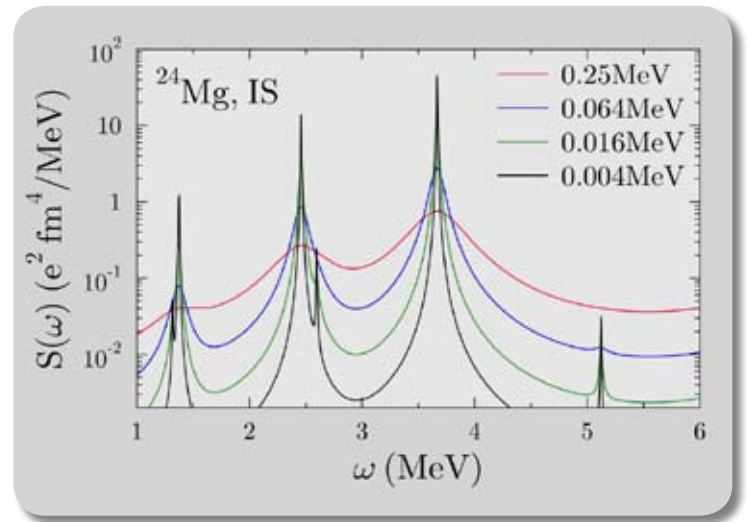


Fig. 4. The isoscalar monopole transition strength function of ^{24}Mg as a function of excitation energy ω with four different values of the smoothing parameter γ . With sufficiently small values of γ , discrete QRPA eigen-modes show up as well-separated sharp peaks.

were compared with the static results obtained with the minimum-energy pathway. We showed that fission pathways strongly depend on assumptions underlying collective inertia. With the nonperturbative mass parameters, the dynamic fission pathway becomes strongly triaxial and it approaches the static fission valley. On the other hand, when the standard perturbative cranking inertia tensor is used, axial symmetry is restored along the path to fission; an effect that is an artefact of the approximation used.

Discrete low-lying modes with finite amplitude method

Low-lying vibrational excitation modes of atomic nuclei provide valuable information about the nuclear structure. The quasiparticle random-

phase approximation (QRPA) is a well-established microscopic theory, which can be used to describe aforementioned excitations in superfluid many-nucleon systems. The drawback of the traditional matrix QRPA formulation is a large dimension of the QRPA matrix, which needs to be constructed and diagonalized. This problem is especially prominent in deformed systems, making the problem computationally challenging. We have developed an iterative method to solve discrete low-lying QRPA modes. Within this method, based on the so-called finite-amplitude method, integration around the poles of eigen-frequencies in the complex plane provides discrete QRPA eigen-modes, equivalent to those obtained from the matrix diagonalization. This method allows us to compute low-lying excited states, without any truncations, with only a fraction of cost compared to traditional matrix QRPA.

Accelerator facilities

Pauli Heikkinen
Hannu Koivisto

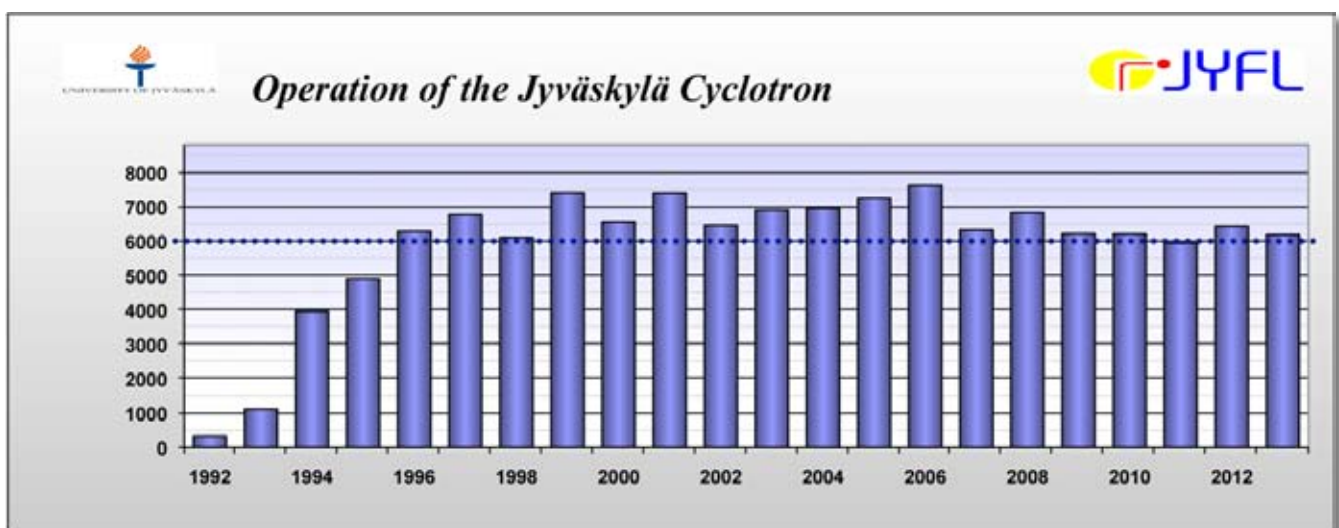
Pauli Heikkinen, chief engineer
Hannu Koivisto, senior lecturer
Olli Tarvainen, postdoctoral researcher
Taneli Kalvas, postdoctoral researcher 1.12.-
Ville Toivanen, graduate student -31.8.
Jani Komppula, graduate student
Janne Laulainen, graduate student
Risto Kronholm, MSc student
Juha Suutari, MSc student
Jaana Kumpulainen, laboratory engineer
Arto Lassila, laboratory engineer
Kimmo Ranttila, laboratory engineer
Juha Tuunanen, laboratory engineer
Juha Ärje, laboratory engineer
Markus Liimatainen, research engineer
Jani Hyvönen, operator
Anssi Ikonen, operator
Raimo Seppälä, technician

Cyclotrons

The use of the K130 cyclotron has settled to about 6000 hours per year. The total use of the cyclotron in 2013 was 6192 hours out of which 4751 hours on target. Since the first beam in 1992 the total run time for the K130 cyclotron at the end of 2013 was 130'330 hours. Most of the beam time available for experiments (84 %) was evenly distributed for IGISOL (23%), SAGE (22 %), industrial applications at RADEF (20 %) and JUROGAM (19 %). Altogether over 20 different isotopes were accelerated in 2013. The most commonly used beam was protons (27 %), beam cocktails for space electronics testing being the second one (19 %).

Fig. 1. Operation of the Jyväskylä K130 cyclotron in 1992–2013.

The MCC30/15 cyclotron was used for the first time for a few IGISOL-4 experiments in 2013



after some modification of the beam transfer line. The beams were 18 and 30 MeV protons.

In late 2013 the Academy of Finland granted the funding for the new ECR ion source called HIISI (Heavy Ion Ion Source Injector). The ion source will be designed and constructed by the JYFL ion source group with the support of international Scientific Advisory Board. The new device is expected to be operational by the end of 2016 and its performance should exceed the performance of any existing room temperature ECR ion source. The project will eventually bring a substantial advance on the nuclear physics program in terms of available beam intensity, energy and reliability. The design work for the HIISI has been started and the first simulations for the magnetic field configuration have been performed in the beginning of 2014.

A new RF-driven H⁻/D⁻ ion source called RADIS has been developed and constructed at JYFL. The source was tested at the stand of filament driven H⁻ ion source LIISA, which is with regularity used for K130 cyclotron. During the testing phase the intensity of about 0.4 mA was measured from the Faraday cup. The beam was extracted through the extraction aperture of 6 mm (ID) using the extraction voltage of 20 kV. Due to the limitations set by the nuclear physics program the RADIS ion source was decided to move on the dedicated test stand to make more efficient research and development program possible (see Fig. 2). The source will be reassembled on its new test stand by mid-March 2014.

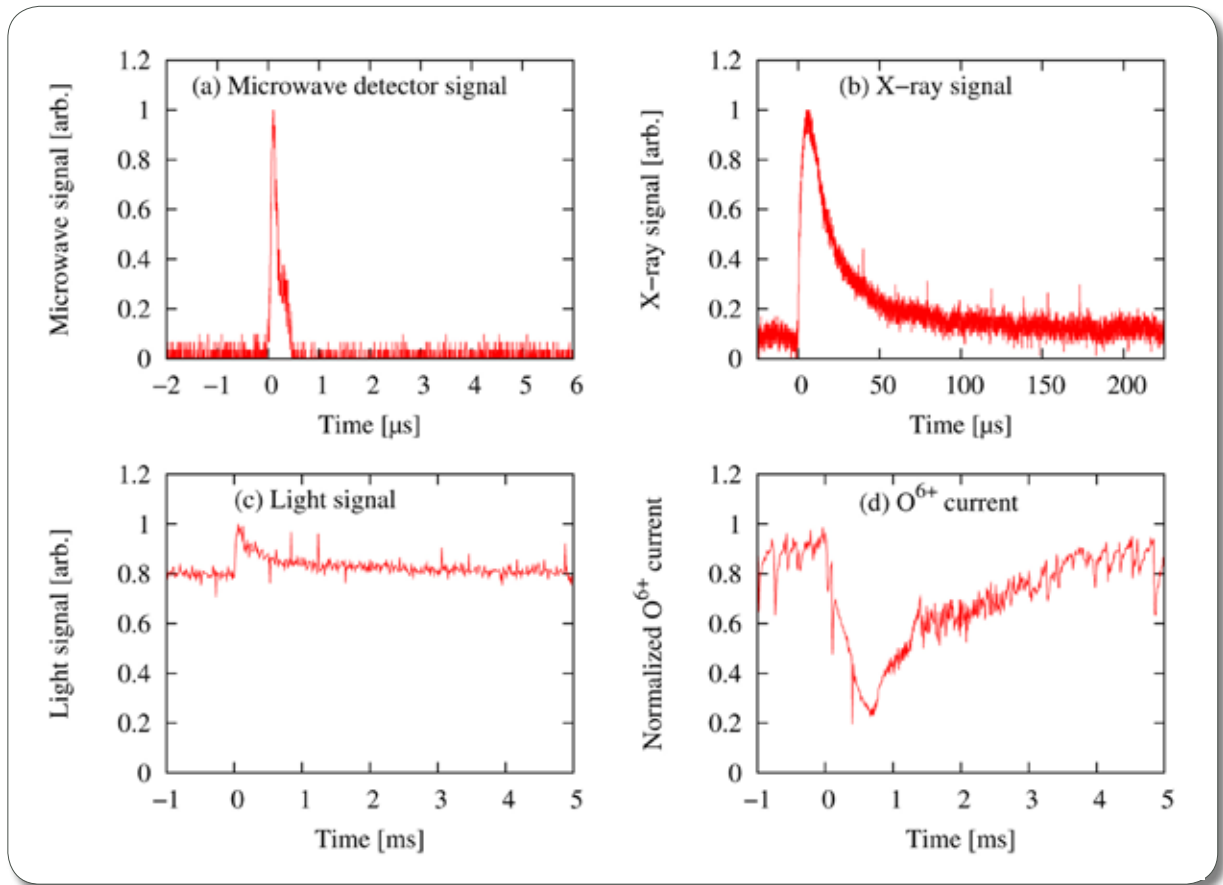
The JYFL ion source group has collaborated with the Institute of Applied Physics / Russian Academy of Sciences since 2010. In 2013 an experimental campaign focusing on experimental observation of cyclotron instabilities in minimum-B confined electron cyclotron resonance ion source plasma



Fig. 2. Dedicated test stand for RADIS is under construction.

was carried out. The instabilities are associated with strong microwave emission and a burst of energetic electrons escaping the plasma, and explain the periodic ms-scale oscillation of the extracted beam currents. As Fig. 3 shows, such non-linear effects are detrimental for the confinement of highly charged ions due to plasma perturbations at shorter periodic interval in comparison to their production time. The repetition rate of the periodic instabilities in oxygen plasmas increases with increasing magnetic field strength and microwave power and decreases with increasing neutral gas pressure, the magnetic field strength being the most critical parameter. The occurrence of the plasma turbulence restricts the parameter space available for the optimization of extracted currents of highly charged ions.

The performance of a filament-driven arc discharge negative ion source (LIISA) has been studied with hydrogen and deuterium plasmas. Differences between the isotopes can be used for improving the understanding of fundamental plasma processes and guiding the development of negative ion sources. Vacuum ultra violet



(VUV) emission was used as a probe for plasma heating and biased plasma electrode current, negative ion current and co-extracted electron current as probes for the extraction region. The transfer of the arc discharge power to the plasma was observed to be very efficient independent of the source parameters. A strong dependence of the molecule dissociation rate on the arc discharge current was observed. The results

Fig. 3. Measured beam current oscillations have been linked with plasma instabilities.

were used for benchmarking of some earlier simulations of the electron energy distribution function (EEDF) and excitation rates with good agreement.

Exotic Nuclei and Beams

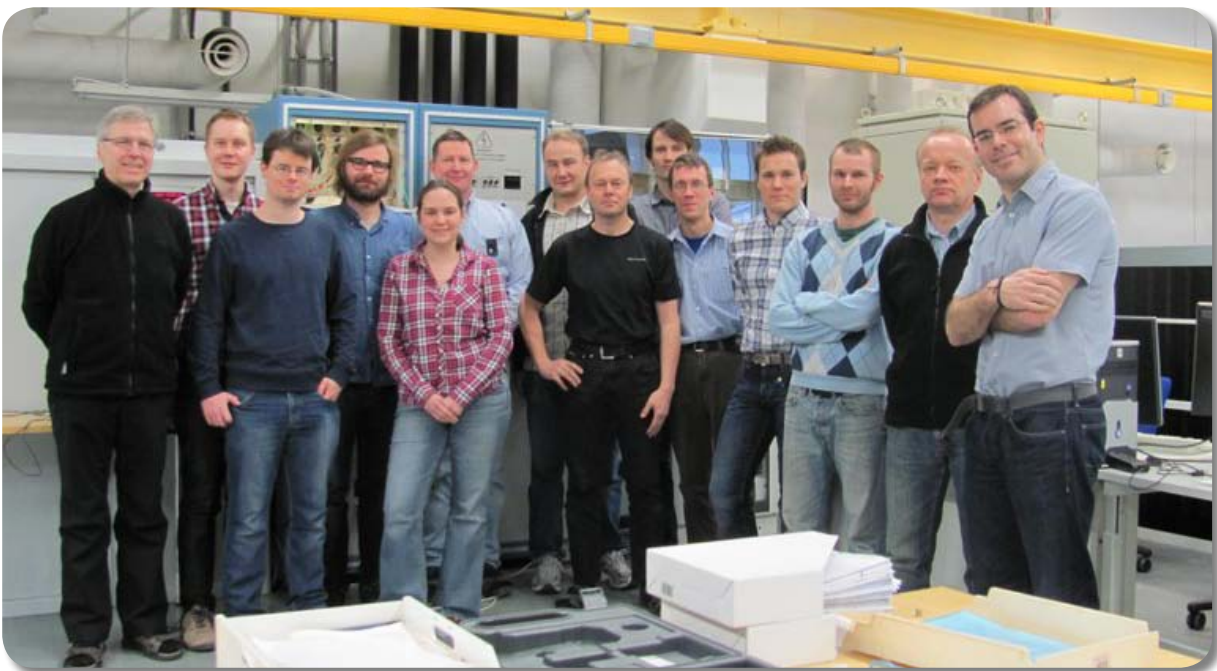
Ari Jokinen
Iain Moore
Heikki Penttilä

Ari Jokinen, professor
Heikki Penttilä, senior researcher
Iain Moore, senior lecturer
Valery Rubchenya, senior researcher (Khlopin Radium Institute, St. Petersburg)
Veli Kolhinen, senior researcher
Sami Rinta-Antila, senior researcher
Mikael Reponen, postdoctoral researcher (University of Manchester)
Annika Voss, postdoctoral researcher 1.4.-
Dmitry Gorelov, graduate student
Jani Hakala, graduate student
Jukka Koponen, graduate student
Ilkka Pohjalainen, graduate student
Volker Sonnenschein, graduate student
Juuso Reinikainen, MSc student
Kari Rytönen, laboratory engineer (HIP)
Marie l'Huterau, ENSICAEN exchange student (1.5.–31.7.)

Activity 2013

The year 2013 has been marked by impressive progress in the commissioning of the IGISOL-4 facility. The relocation that started in the summer of 2010 was mostly finalized. As the facility has also undergone a major upgrade, in particular in terms of usability and versatility, many projects are still in progress. However, in addition to test

Fig. 1. The IGISOL group in January 2014 in the control area of the MCC30 cyclotron. From the left: Juha Äystö (visitor, director of HIP), Ilkka Pohjalainen, Volker Sonnenschein, Mikael Reponen, Annika Voss, Heikki Penttilä, Veli Kolhinen, Kari Rytönen, Sami Rinta-Antila, Dmitry Gorelov, Juuso Reinikainen, Jukka Koponen, Ari Jokinen, Iain Moore.



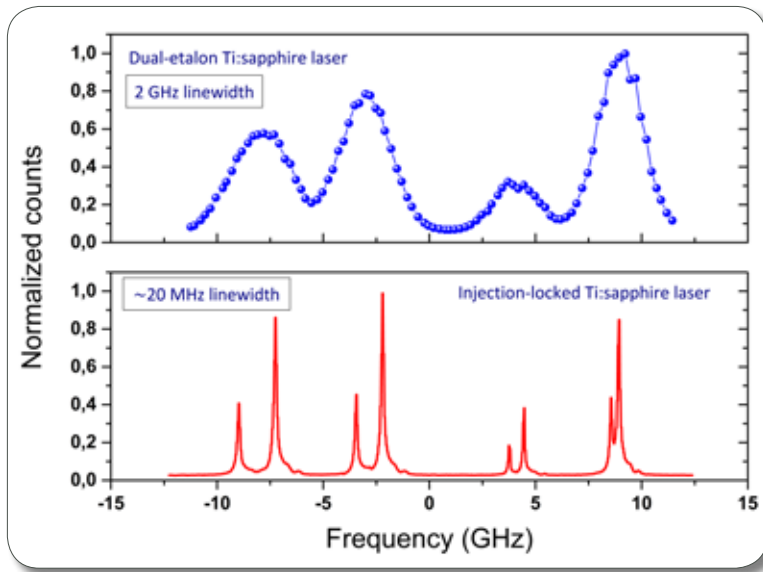


Fig. 2. Ti:sapphire frequency scans of the hyperfine structure associated with the 244-nm transition in stable copper. With a laser linewidth of ~ 20 MHz, an impressive improvement in resolution is obtained using the injection-locked laser and the peaks associated with $^{63,65}\text{Cu}$ are visible.

beam time, development and commissioning, 40 days of beam time were used for five PAC-approved experiments in 2013.

The major source of funding to rebuild the IGISOL facility has been a special grant from the Finnish Ministry of Education. The construction has also benefited from the CoE, the infrastructure funding (FIRI) calls as well as individual projects of the Academy of Finland. For example, a significant improvement to the laser suite of FURIOS, highlighted in Fig. 2, is accredited to FIRI funding. In addition, support from EU FP7 programs ENSAR, ANDES and ERINDA has played a noteworthy role in the commissioning of the facility.

In our international collaboration in FAIR and at ISOLDE in CERN, we have benefited from the Nuclear Matter Program of the Helsinki Institute of Physics (HIP). In addition to the existing involvement in NUSTAR experiments at FAIR, some of our group members have joined the Super-FRS collaboration aiming

Fig. 3. The 11th IGISOL workshop participants in June 2013.



for day-one-experiments. This decision is in line with our responsibility for the Super-FRS diagnostics, namely GEM-TPC detectors and grid profilers. Day-one experiments, comprising commissioning of the Super-FRS and the first exploratory studies, will strongly rely on the diagnostics of the machine.

The IGISOL group organized the 11th IGISOL Workshop (Conference on Stopping and Manipulation of Ions, SMI-13) in Jyväskylä in June 2013. The meeting drew 25 international participants from ten countries and 21 institutes. This workshop last took place in Finland in 1986, when the series began. The 12th IGISOL workshop will be organized by the Institute of Modern Physics, Chinese Academy of Sciences, Lanzhou, China, in 2015 or 2016.

The second part of the IGISOL Laboratory Portrait was published in *Hyperfine Interactions*, volume 223. The first articles were already published in 2012 as a special issue of *EPJA* (vol 48, issue 4). The full Portrait, describing the three decades of research at equally many versions of the IGISOL facility is accessible via our web pages.

Volker Sonnenschein received the LA³NET prize, awarded annually to a young scientist who has made an outstanding contribution to research into the application of lasers at accelerator facilities.

Technical developments

Laser ion source development. An important milestone was reached in 2013. In the first on-line test the dual-chamber gas cell was used in a $^{58}\text{Ni}(p,n)$ reaction to produce ^{58}Cu ($t_{1/2} = 3.2$ s). Resonant photo-ions were produced in a two-step ionization scheme and characteristic gamma

rays from the beta decay of ^{58}Cu were used to deduce a total efficiency of $\sim 1\%$.

Resonance ionization spectroscopy was performed on stable $^{63,65}\text{Cu}$ using a dual-etalon Ti:sapphire laser. Determination of hyperfine parameters revealed discrepancies when compared to existing higher resolution data. The construction of a scanning Fabry-Pérot interferometer enabled a systematic study of the laser mode structure in real-time during a scan of the atomic transition. The main source of the discrepancy has been traced to the commercial wavemeter.

Excellent progress has been made to implement a widely tunable injection-locked Ti:sapphire laser for high resolution in-gas-jet laser ionization. A laser linewidth reduction from a few GHz to ~ 20 MHz has been achieved with an output power of up to 5W at a repetition rate of 10 kHz. Fig. 2 illustrates the impressive improvement in resolution when scanning across the 244 nm transition on $^{63,65}\text{Cu}$ in a collimated atomic beam reference cell, compared to the dual-etalon laser system.

Re-commissioning of the collinear laser spectroscopy program. In 2013 the collinear laser spectroscopy line was fully re-commissioned and spectra were taken both off-line and on-line. Later, in a second fission experiment, spectroscopy of doubly-charged ions (naturally produced from the IGISOL in smaller quantities) was performed for the first time. Bunched beams of doubly-charged yttrium ions were optically pumped in the cooler using 232.8-nm light in order to populate a metastable electronic state from which an efficient (alkali-like) spectroscopic transition could be exploited. Three isotopes were measured ($^{96-98}\text{Y}$) which will allow all existing yttrium charge radii data to be reliably re-calibrated.

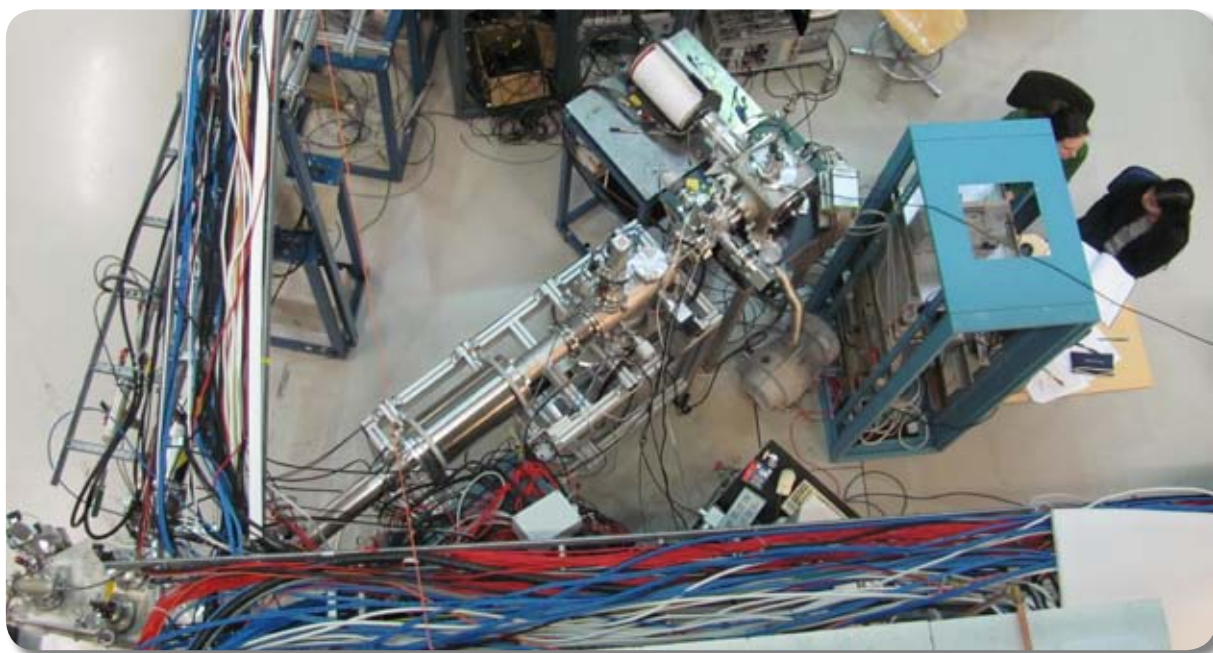


Fig. 4. The new spectroscopy beam line.

Other developments. A new spectroscopy line was constructed and commissioned off the mass separator beam switchyard (Fig. 4). It is intended for spectroscopy experiments that do not require resolving of the mass isobars with the Penning trap. Provided the isobaric background is not an issue, the experiments in the spectroscopy line can benefit from higher absolute yields and smaller decay losses. The beam line was already utilized in two experiments [I-182], [I-159] in 2013.

The cyclotron beam lines and the collimating system of the mass separator front end were revised. Reconstruction of the 65° dipole magnet chamber in the IGISOL front end area allowed delivery of a 30 MeV beam from the MCC30 to the IGISOL target position with almost 100% transmission. The efficiency of the light ion guide was determined to be ~1 % for various proton-induced reactions. The proton-induced fission yields steadily increased from 8000 ^{112}Rh

atoms/ μC in the first fission runs in February to 22 000 in yield tests in August. This was most likely due to the completion of the new buffer gas purification and gas delivery system.

Experimental highlights

Pd diffusion in nickel silicides [I-183]. Silicides are used as electrical contact materials. Monosilicides such as NiSi have better electrical properties than disilicides (e.g. Ni₂Si) but they are also more vulnerable to degradation. Their stability is increased by doping, in particular with Pt. The diffusion properties of the platinum-group element Pd in NiSi and Ni₂Si was studied by implanting ^{103}Pd radiotracer in silicide samples. Against the expectations, the Pd mobility was observed to be higher in Ni₂Si.

Laser spectroscopy of neutron rich ^{107}Mo [I-169]
An initial study of molybdenum fission fragments repeated measurements previously undertaken at IGISOL-3, easily matching previous photon-per-ion efficiencies, but with an overall counting

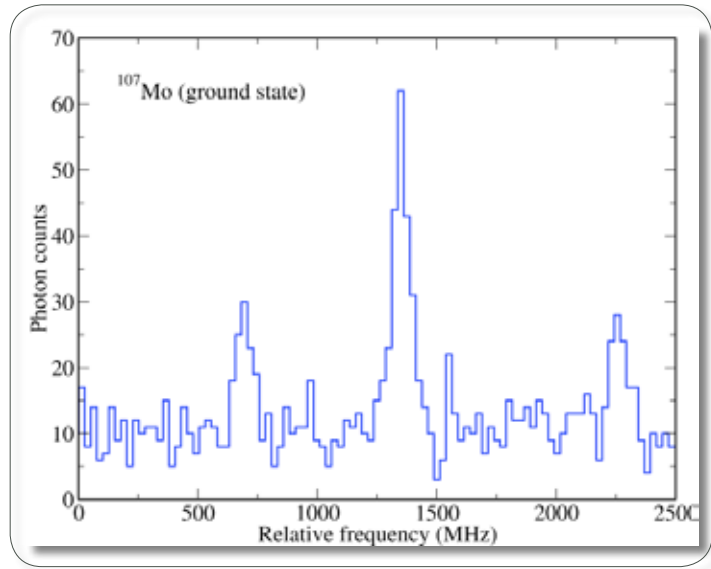


Fig. 5. Hyperfine structure of ^{107}Mo , studied on the 293.5 nm $J=1/2 \rightarrow J=1/2$ transition.

rate approximately three times higher, due to an increase in radioactive yield. These studies were then extended to the ^{107}Mo isotope (Fig. 5), which was not possible before, to determine its spin, moments and mean-square charge radius.

Isomeric ratios in fission [I-178]. The isomeric yield ratios provide direct information about the fission process and have a direct impact on astrophysical processes such as the r-process with fission recycling. In the study the isomeric yield ratios were determined for several fission products utilizing the mass separation capabilities of JYFLTRAP for 25 MeV proton-induced fission of natural U. The results seem to be consistent with earlier work performed with gamma-ray spectroscopy of mass-separated samples.

Beta-decay half-lives and branching ratios of mirror nuclei [I-159]. Nuclear mirror β decay allows, similar to super-allowed $0^+ \rightarrow 0^+$ β decay, the determination of the V_{ud} matrix element of the Cabibbo-Kobayashi-Maskawa quark mixing matrix. For this purpose, the decay Q value, the

EXPERIMENT SPOKESPERSONS AND COLLABORATING INSTITUTES IN 2013

[I-159] Precision measurements of the branching ratios of the superallowed $0^+ \rightarrow 0^+$ beta decay of ^{26}Si . Spokesperson: Bertram Blank, CENBG. JYFL liaison: Tommi Eronen. Participants: CEN Bordeaux-Gradignan; GANIL; IPN Orsay, France; CSIC Madrid, Spain.

[I-169] Laser spectroscopy of Mo and Ta using optical pumping in an ion beam cooler-buncher. Spokesperson: Bradley Cheal, The University of Manchester. JYFL liaison: Iain Moore. Participants: The University of Manchester, UK.

[I-178] Isomeric yield ratios of fission products in 25 MeV proton-induced fission of ^{238}U . Spokesperson: Mattias Lantz, Uppsala University. JYFL liaison: Heikki Penttilä. Participants: Uppsala University, Sweden.

[I-182] Experimental determination of the M4 branch of the $J^\pi = 1/2^+$ decays in $^{203,207,209}\text{Bi}$. Hexadecapole magnetic rates of the $1/2^+ \rightarrow 9/2^-$ transition in $^{197-209}\text{Bi}$. Spokesperson: Tom Lönnroth, Åbo Academi. JYFL liaison: Rauno Julin. Participants: Åbo Academi, Finland.

[I-183] Diffusion of Pt and Pb additives in silicide studied by radiotracers. Spokesperson: Annelore Schrauwen, KU Leuven. JYFL liaison: Heikki Penttilä. Participants: KU Leuven, Belgium; University of Helsinki, Finland.

half-life, the branching ratios and the Fermi-to-Gamow-Teller (F-GT) ratio have to be determined. In an experiment in November/December 2013, the half-lives and branching ratios of ^{23}Mg and ^{27}Si were measured with the required precision.

Nuclear Spectroscopy

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Paul Greenlees
Janne Pakarinen
Panu Ruotsalainen
Mikael Sandzelius

In-beam spectroscopy group members

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Juha Sorri, graduate student
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Jan Sarén, postdoctoral researcher
Kalle Auranen, graduate student
Ulrika Jakobsson, graduate student
Jari Partanen, graduate student
Panu Ruotsalainen, graduate student

In 2013 the Nuclear Spectroscopy group employed three main sets of experimental apparatus in the program to study the properties of nuclei. The first major campaign was dedicated to the LISA spectrometer, followed by experiments

Fig. 1. The Nuclear Spectroscopy Group



employing the UoYtube detector and finally a long campaign of experiments using the SAGE combined electron-gamma spectrometer. In total 107 days were dedicated to 11 different experiments. In total, the group members co-authored 21 peer-reviewed journal manuscripts and 15 contributions to conference proceedings. A clear highlight was the publication of an article in *Nature* related to studies carried out in CERN-ISOLDE and involving members of the Nuclear Spectroscopy group.

Beta tagging

The beta-tagging project was continued in 2013 in collaboration with the University of York to study nuclei around the $N=Z$ line. The first version of the charged particle veto detector UoYtube, installed at JUROGAMII target position, enabled identification of excited states up to spin $J^\pi = 6^+$ in the exotic ^{66}Se nucleus. This discovery allowed the Coulomb energy differences (CED) to be investigated across the full $A=66$ triplet for the first time. The experimental CED systematics obtained demonstrated a need for an additional isospin non-conserving interaction when compared to a shell-model calculation. Minor design faults with UoYtube were corrected and a new veto detector was built with increased geometrical detection efficiency. This new device together with the phoswich scintillator detector allowed the discovery of two lowest excited states in ^{74}Sr making the $A=74$ triplet the heaviest case where the CED systematics are currently known.

Third SAGE campaign

The third SAGE campaign was successfully executed in 2013. In total, six experiments were performed during the campaign, which ran from



Fig. 2. Cover of *Nature* highlighting research involving members of the Nuclear Spectroscopy team. Reprinted by kind permission from Macmillan Publishers Ltd: *Nature*, 497, 199 (2013), copyright 2013.

June-November. In all, 56 days were used to deliver beams to the SAGE target.

One particular highlight from the campaign, and in which the SAGE spectrometer really proved its worth, was the experiment to study ^{222}Th (S16). A vast amount of data were collected due to the relatively high cross-section, and coupled with large internal conversion coefficients good quality conversion-electron spectra were obtained. This enabled several high-energy linking transitions

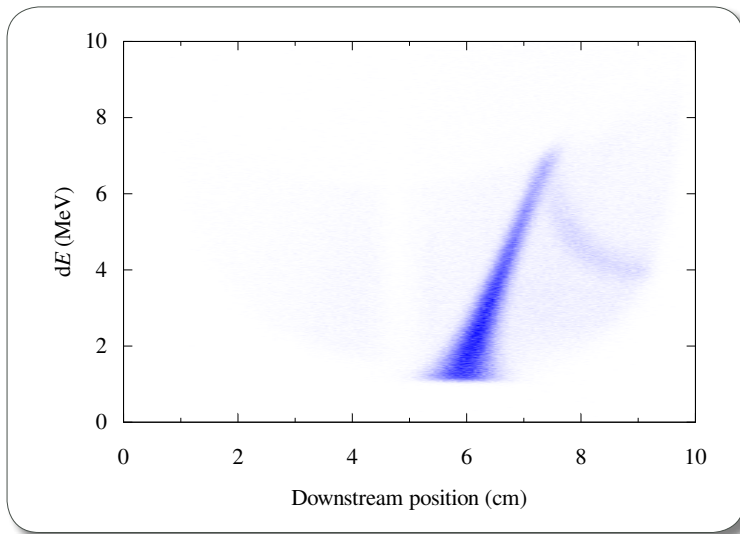


Fig. 3. Deposited energy of elastically scattered protons as a function of position in the LISA inner barrel. Protons were produced by bombarding a CH_2 target (located at 5cm) with a ^{58}Ni beam of energy 318 MeV.

emanating from an excited octupole side band to be clearly identified with the help of conversion-electron gamma-ray coincidences in conjunction with the recoil-decay tagging technique.

New records set

The ^{113}Ba (JR118) experiment in May set new benchmarks for the combined JurogamII/RITU/GREAT set-up. For the first time traces were recorded from one side of the implantation silicon detector (DSSD) and at the same time collecting data from all other channels in parallel, notably from the JUROGAMII Ge-array. The experiment saw unprecedented rates recorded. The data rate going to storage on disc was the highest recorded, at around 20 MB/s. The total amount of data collected was in the vicinity of 24 TB (also a record).

LISA Campaign

The first physics campaign with LISA (Light Ion Spectrometer Array) was carried out in the beginning of 2013. LISA was used to investigate fast charged particle emission from short-lived exotic (^{159}Re , L01) and heavy (^{218}Th , ^{216}Rn , L03) nuclei. An experiment investigating ^{154}Gd using the (p,p') reaction was also carried out. While detailed analysis is still in progress the performance of LISA can be seen from figure 3.

ISOLDE activities

While the HIE-ISOLDE upgrade prevented conducting experiments in 2013, the shutdown period was used to finalize analysis from previous campaigns and to develop new instrumentation. The Nuclear Spectroscopy group has been involved in Coulomb excitation experiments employing the MINIBALL Ge-detector array and radioactive beams from REX-ISOLDE. The data obtained for ^{220}Rn and ^{224}Ra have confirmed, for the first time, that nuclei can assume very asymmetric shapes, like a pear. While ^{224}Ra is pear-shaped, ^{220}Rn does not assume the fixed shape of a pear but rather vibrates about this shape. The experimental observation of nuclear pear shapes is not only important for understanding the theory of nuclear structure but also because it can help experimental searches for electric dipole moments in atoms. These findings were published in *Nature* 497, 199-204 (2013).

The mixing of shape coexisting structures and the low-lying 0^+ states in atomic nucleus results in noticeable E0 transition strength. The E0 transitions can only proceed via conversion electron emission, which requires a suitable spectrometer. The SPEDE spectrometer will combined with the

MINIBALL array allow simultaneous detection of both γ rays and conversion electrons. SPEDE is designed and developed in close collaboration

with University of Liverpool, UK. It will be commissioned at JYFL before experimental campaigns at HIE-ISOLDE.

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[L03] Search for fast α decays in ^{218}Th and ^{216}Ra
T.Grahn, JYFL

D.O'Donnell, University of Liverpool, U.K.
STFC Daresbury Laboratory, U.K.

[L01] Decay spectroscopy of short-lived exotic nuclei using LISA

R.D.Page, University of Liverpool, U.K.
STFC Daresbury Laboratory, U.K.
University of the West of Scotland, U.K.
JYFL

[L02] Using the (p,p' γ) reaction to investigate low-spin states in ^{154}Gd

P. Garrett, University of Guelph, Canada
University of Liverpool, U.K.
STFC Daresbury Laboratory, U.K.
JYFL

[JR124] Identification of excited states in ^{70}Kr and ^{74}Sr

R.Wadsworth, University of York, U.K.
D.G.Jenkins, University of York, U.K.
University of Oslo, Norway
JYFL

[JR118] Decay study of ^{113}Ba

T.Bäck, Royal Institute of Technology, Sweden
University of Liverpool, U.K.
University of York, U.K.
University of the West of Scotland, U.K.
University of Manchester, U.K.

[S14] Simultaneous in-beam gamma-ray – conversion electron spectroscopy of ^{194}Po employing the SAGE spectrometer

D.Judson, University of Liverpool, U.K.
J.Pakarinen, JYFL
P.Rahkila, JYFL
University of York, U.K.
KU Leuven, Belgium
Comenius University, Slovakia

[S12] Probing the E0 transitions in ^{186}Pb using the SAGE spectrometer

D.G.Jenkins, University of York, U.K.
J.Pakarinen, JYFL
P.Papadakis, JYFL
University of York, U.K.
University of Liverpool, U.K.
Australian National University, Australia
CERN-ISOLDE, Switzerland

[S16] Characterisation of a new structure in octupole-deformed ^{222}Th using gamma-ray and conversion-electron spectroscopy

J.F.Smith, University of the West of Scotland, U.K.
P.T.Greenlees, JYFL
Padova University/INFN, Italy
University of Liverpool, U.K.
University of Manchester, U.K.

[S13] Study of the structure of high-K states in ^{254}No using the SAGE spectrometer

P.Papadakis, JYFL
P.T.Greenlees, JYFL
R.-D.Herzberg, University of Liverpool, U.K.
CSNSM - IN2P3/CNRS Université Paris Sud, France

[S17] Shape Coexistence in Odd-Au Isotopes: In-beam Gamma-ray and Conversion Electron

Coincidence Spectroscopy of the ^{179}Au
M.Venhardt, Slovak Academy of Sciences, Slovakia
D.T.Joss, University of Liverpool, U.K.
University of York, U.K.
University of Manchester, U.K.
University of Surrey, U.K.
Argonne National Laboratory, U.S.A.
JYFL

[S15] Spectroscopy of the odd-proton nucleus ^{249}Md and feasibility study for ^{243}Es

Ch. Theisen, CEA Saclay, France
P. T. Greenlees, JYFL
R.-D. Herzberg, University of Liverpool, U.K.
IPHC Strasbourg, France

Instruments and Methods in Nuclear, Particle, and Astroparticle Physics

Wladyslaw Trzaska

Wladyslaw Trzaska, senior scientist
Tuomo Kalliokoski, graduate student
Kai Loo, graduate student
Maciej Slupecki, graduate student 1.9.–
Johannes Hissa, graduate student (Oulu University)
Juho Sarkamo, graduate student (Oulu University)
Katja Karppinen, MSc student
Jukka Sorjonen, MSc student
Iina Sirvio, MSc student
Grigori Tiurin, visiting researcher

In the 2012 evaluation of all physics research in Finland (Publications of Academy of Finland 8/12), an international panel of experts has asked for forging of closer links between the experimental particle physics and the accelerator-based nuclear physics at JYFL. We describe here our activity in the field of accelerator based detector technologies that corresponds to the Academy recommendation. (A part of this activity – the neutrino detector LENA – is described in the Neutrino Physics section.)

EMMA experiment

The construction of the experiment has progressed as planned. By the end of 2013 we have completed the last but one of the total of eleven stations. Seven of them are already equipped

with detectors and taking data. The data were collected during 8205 hours that is 94% of the time. The data show very good consistency in angular resolution and shower direction between the tracking stations. Currently all of the drift chambers are underground and most of them are taking data. We have also tested all of the SC16 scintillator units. The bulk of them (75%) are now fully calibrated and in use. The remaining ones need either additional calibrations or minor tuning and repairs. As the integration of SC16 units into EMMA cannot be done in one step, we have used the available detectors to launch a parallel experiment to measure muon flux and distribution at the depth of 850 meters (2450 m.w.e.). This experiment nicknamed MUM (Muon Underground Monitor) is carried out in collaboration with our Russian Colleagues and with Laboratorio Subterráneo de Canfranc (LSC). LSC is also the provider of the funding, underground facility, electronics, and covers the running costs. Our setup at LSC consists of 22 SC16 detectors arranged in three layers: 3 x 3, 2 x 2, and 3 x 3. Each SC16 consists of 16 individual pixels (12x12x3 cm³). The measurement started in September 2013 and will run for about 1 year.

Related to the EMMA and other scientific activities in Pyhäsalmi mine we have been carrying out an outreach program oriented towards high



school students and teachers, organizing visits to the mine and offering popular lectures and hands-on sessions. The highlight of the year was the November 18 – 23 Science Week at the Science Center Tietomaa in Oulu. The lectures and workshops were arranged for local schools and also for general public. After Tietomaa the exhibition was moved to Pyhäjärvi town hall to reach the local public. In total 150 students from 12 high schools have participated in the program.

ALICE T0 and FIT detectors

On 14 February 2013 LHC has entered a facelift period known as Long Shutdown One. The key driver for LS1 is the consolidation of the 10,170 high-current splices between the superconducting magnets along the 27 km circumference of LHC. At the same time ALICE is undergoing an intense maintenance and upgrade phase. This period is especially demanding for T0 detector. As part of the trigger upgrade we have to reduce the latency of the

signals from 620 ns to below 425 ns. The only way to meet this requirement was to relocate the entire T0 electronics to the racks close to the Central Trigger Processor and reroute and shorten the cables. After that the detector will have to be commissioned and calibrated anew. The work will continue throughout LS1. LS1 will be followed by Run2 at the full design energy of LHC. After about 3 years of running the second boost of LHC parameters will take place during the subsequent LS2. As a result the luminosity and collision frequency will significantly exceed the original specifications rendering most of the key ALICE detectors obsolete as they were not designed to cope with such a challenge. To remain in operation also during Run3 ALICE needs a major upgrade as outlined in the Lol from September 7, 2012. As soon as the Lol was endorsed by the LHCC the T0 team started working on the upgrade of the trigger detector. The first concept was presented to the ALICE Technical Board already in January 2013 and we have proceeded directly to writing of the Technical Design Report. Our TDR, after refereeing and gaining the approval of the collaboration was

published in November. The final approval by LHCC is expected in the spring of 2014.

Nuclear reactions

In 2013 we have continued the study of exotic cluster states in light nuclei by measuring inelastic scattering $^{13}\text{C}(\alpha, \alpha')$ and $^{11}\text{B}(\alpha, \alpha')$. We have found that the inelastic scattering differential cross-sections corresponding to the excitations of the states $1/2^-$, 8.86 MeV in ^{13}C and $3/2^-$, 8.56 MeV in ^{11}B are similar to that of the formation of the Hoyle state in $^{12}\text{C}(\alpha, \alpha')$ -reaction. The analysis showed that both states have enhanced radii approximately of the same value as the radius of the Hoyle state and may be considered the analogs of the latter. It appears that the 8.56 MeV state in ^{11}B is the head of the rotational band predicted recently. The $L = 4$ transition to the $9/2^-$, 13.1 MeV state (the probable fourth member of the band under discussion) was identified. A preliminary analysis indicates to the enhanced radius of this state.

We have also explored the influence of shell effects on the formation of binary fragments in damped collision in the composite system with $Z = 108$ produced in the reaction $^{88}\text{Sr} + ^{176}\text{Yb}$ at an energy slightly above the Bass barrier. For target-like fragments heavier than 190 u, which correspond to a mass transfer as large as twenty nucleons or more, an enhancement of the yields was observed. This striking result can be ascribed to the proton shells at $Z = 28$ and 82, and implies the persistence of the shell effects in the formation of reaction fragments even for large mass transfers.

Finally, we have investigated inelastic scattering and single-particle transfer reactions induced by 63 MeV ^4He beam on a ^9Be target measuring the angular distributions of the differential cross sections for the $^9\text{Be}(\alpha, \alpha\phi)^9\text{Be}^*$, $^9\text{Be}(\alpha, ^3\text{He})^{10}\text{Be}$ and $^9\text{Be}(\alpha, \tau)^{10}\text{B}$ reactions. The results were analysed in the framework of the optical model, coupled channels, and distorted-wave Born approximation.



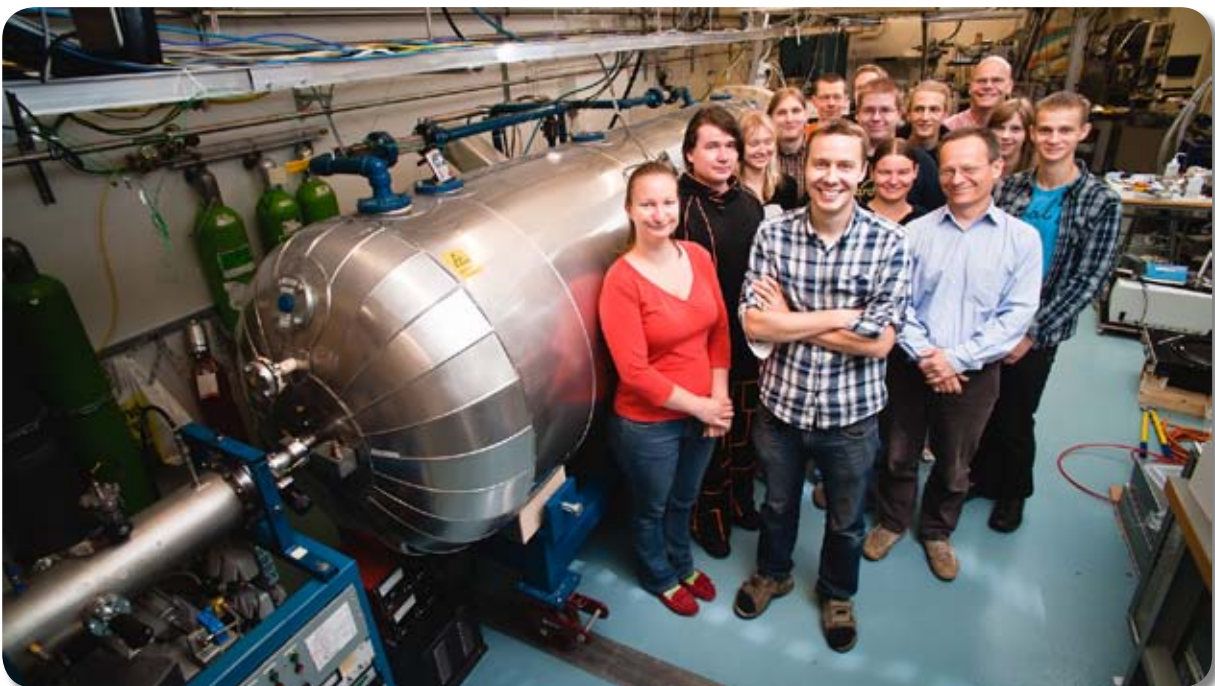
Accelerator-based Materials Physics

Timo Sajavaara

Timo Sajavaara, senior lecturer
Kai Arstila, senior researcher 1.6.-
Jari Malm, postdoctoral researcher 1.3.-
Jaakko Julin, graduate student
Mikko Laitinen, graduate student
Laura Mättö, graduate student
Mari Napari, graduate student
Rattanaorn Norarat, graduate student -30.6.
Henri Kivistö, MSc student
Mikko Konttinen, MSc student
Timo Konu, MSc student
Marko Käyhkö, MSc student
Jarno Partimaa, MSc student
Joonas Soininen, MSc student
Sonja Wegener, visiting researcher 1.4.-31.8.

The systematic upgrading work of the Pelletron accelerator continued further in 2013. The old sputtering ion source was replaced by a multicathode SNICS-II by NEC during summer 2013 as a summer trainee project. The new ion source has worked very reliably producing higher currents than its predecessor. Its multicathode revolver can hold up to 40 different cathodes, and the incident ion can be changed within seconds without breaking the vacuum.

The installation of a transition edge sensor (TES) detector for particle induced X-ray emission (PIXE) studies in collaboration with NSC researchers was the most important development in the Pelletron research instrumentation in 2013.



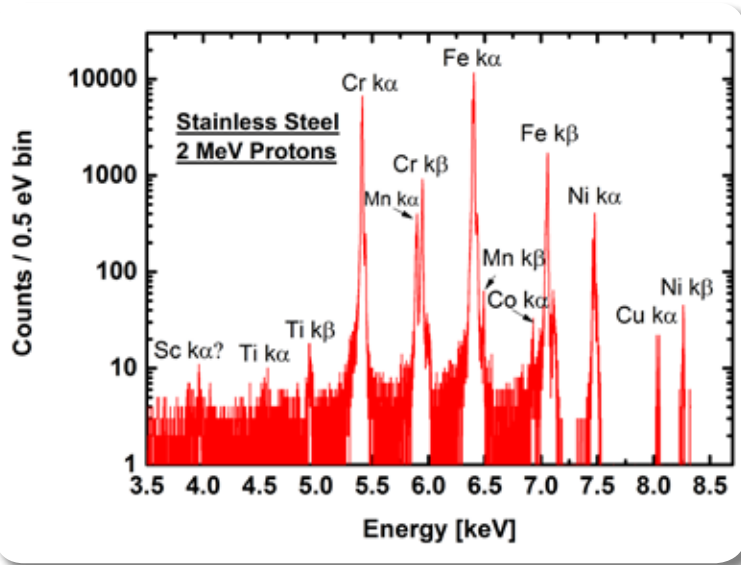


Fig. 1 A PIXE spectrum from a stainless steel sample measured using 2 MeV proton beam and TES energy detector.

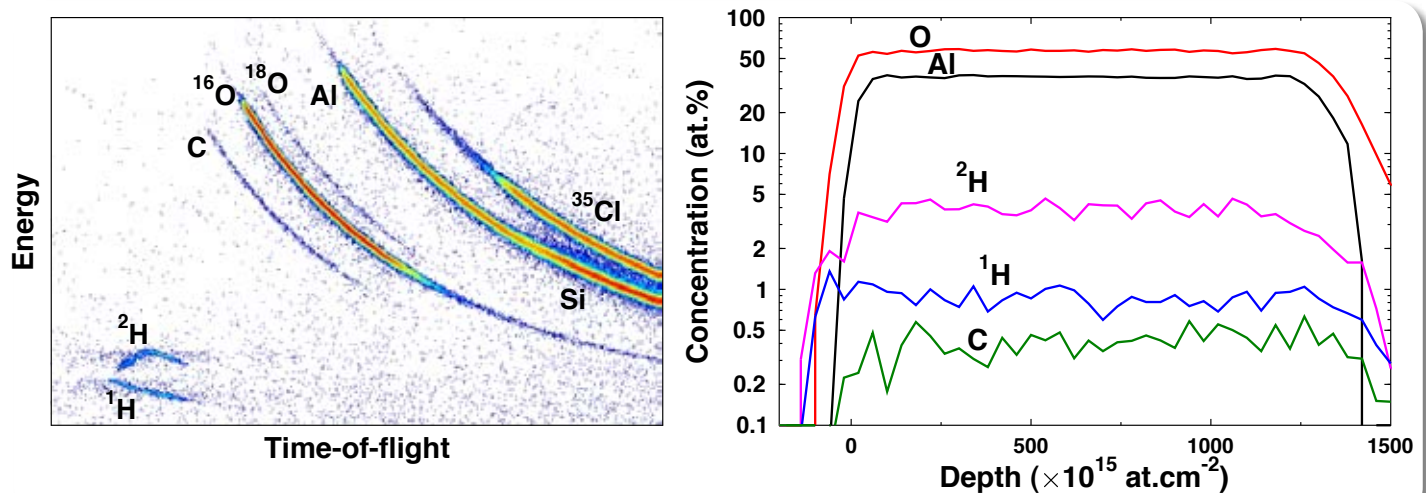
The extremely high X-ray energy resolution of 3 eV and the sensitive large area of 15.6 mm² for 160 pixels make this instrument unique in PIXE use. The usage of the TES-PIXE detector will focus both to the basic research of the light and heavy ion induced X-ray emission physics and to the application of the detector for the materials characterization. The potential of the TES-PIXE for obtaining chemical information from materials opens interesting possibilities in

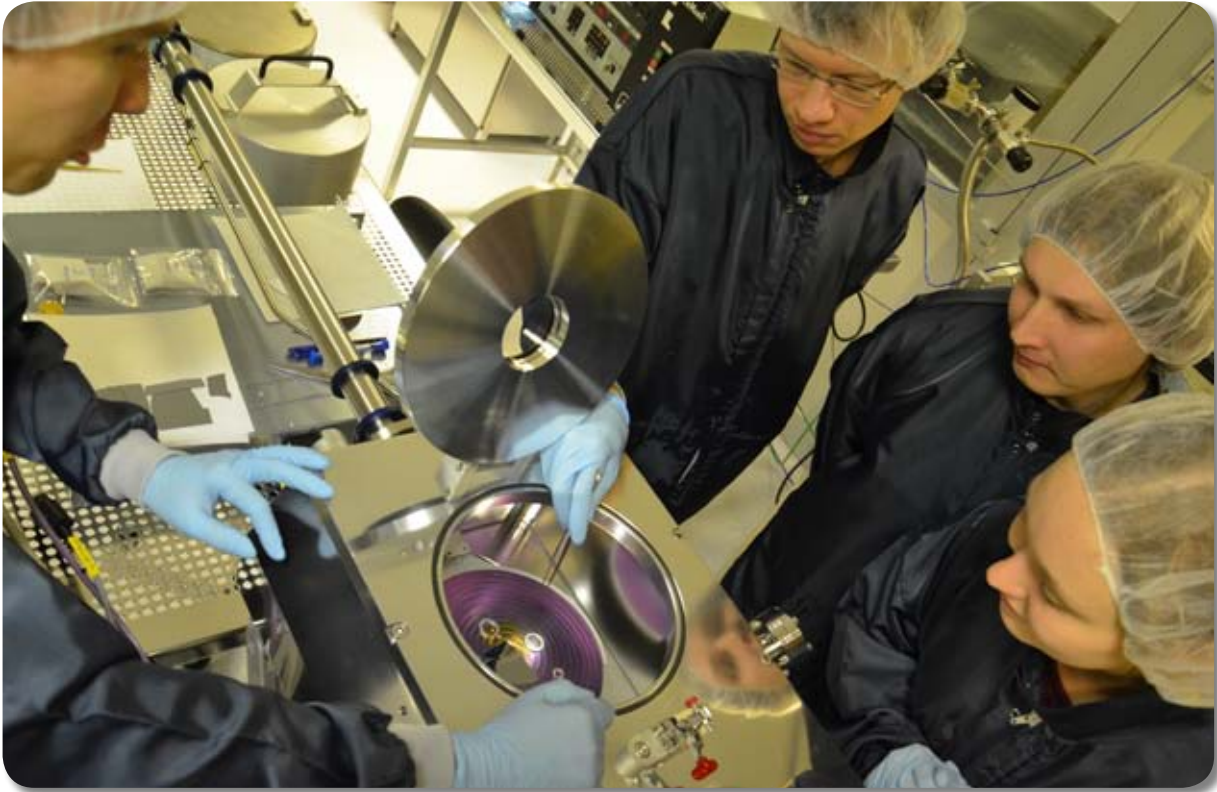
studying atomic layer deposition (ALD) grown thin films.

In connection to the strengthening of the thin film research in JYFL, the Pelletron group coordinated the purchase of a versatile ALD thin film deposition tool, Beneq TFS 200, which was funded by EU regional funds project NANOPALVA. The purchase, delivery and installation in the NSC clean room went smoothly and the first films were grown in October. After running only few months, new research projects have been initiated around the ALD tool and the first scientific publications will appear in 2014. The instrument base of the Ylistö campus is well equipped for the thin film studies and gives excellent possibilities for collaborative industrial and academic projects.

The ion beam analysis development and application work has continued actively in

Fig. 2. Time-of-flight–energy histogram (left) and corresponding depth profiles (right) from a 100 nm thick Al₂O₃ film grown on silicon with the Jyväskylä ALD tool. The deposition was made at 150 °C using Me₃Al and D₂O as precursors. The incident beam in the TOF-ERDA measurement was 8.515 MeV ³⁵Cl⁴⁺.





2013. The long term project of changing from the analogue data acquisition electronics to the digital pulse processing in all ion beam analysis measurements has progressed as planned and the final transition is expected to take place in 2014. The gas ionization energy detector was installed to the time-of-flight elastic recoil detection analysis (TOF-ERDA) setup in December 2012. After a year of operation it has proven to be a high performance and reliable tool over a wide energy and mass range, superior to the silicon detector that was used before. The understanding of the measured data has also improved. The origin of the characteristic halo visible around the lightest elements in the TOF-E histograms could be explained with delayed signals due to electrons backscattered from the microchannel plates. This knowledge is useful in planning of the next generation TOF-detectors. As part of the industrial collaboration, a full TOF-E telescope designed, constructed and tested in JYFL was installed in December 2013 at Imec, Belgium,

Fig. 3. The user training of the atomic layer deposition tool for the Pelletron group PhD students in the NSC clean room.

where it will be used for high throughput analysis involving hundreds of samples yearly.

An important part in unleashing the full capability of the heavy-ion ERDA technique is the availability of a powerful and user-friendly analysis software. To achieve this goal a collaborative project was carried out during spring 2013 between Department of Mathematical Information Technology of JyU and the Pelletron group. The resulting open source Potku software was thoroughly tested and further developed during summer 2013. Since then other ERD analysis laboratories have begun using the software. Currently the software development is continuing by several developers in GitHub.

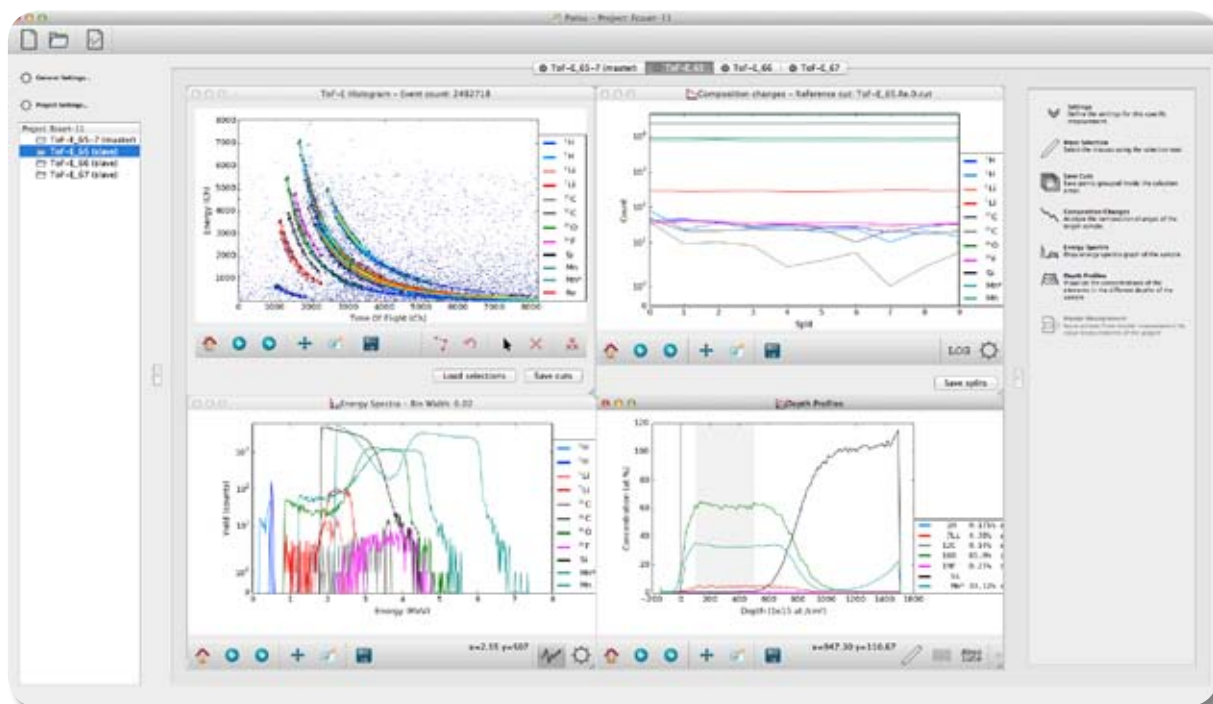


Fig. 4. The main window for Potku software for analysis of TOF-ERDA data.

The new ALD tool was also immediately integrated to the teaching given at JYFL. In the course Electron, photon and ion beam based methods in materials science the students first deposited 100 nm of TiO_2 on Si at different temperatures, and then used TOF-ERDA, Rutherford backscattering spectrometry, Raman spectroscopy and X-ray diffraction to study the different properties of the grown films. In Jyväskylä Summer School the

Pelletron group organized a course in Elemental depth profiling of nm thick films, which attracted more than 30 participants.

During the Ecaart-11 conference held in September in Namur, Belgium, the international committee of the conference decided that the next Ecaart conference will be held in Jyväskylä in July 2016. Timo Sajavaara will serve as the chairman of the conference.

Industrial Applications

Ari Virtanen

Ari Virtanen, research director
 Arto Javanainen, postdoctoral researcher
 Alexandre Bossier, graduate student 1.10.-
 Taneli Kalvas, graduate student
 Heikki Kettunen, laboratory engineer
 Jukka Jaatinen, laboratory engineer
 Mikko Rossi, laboratory engineer

Last year our graduate student Taneli Kalvas defended his thesis “Development and Use of Computational Tools for Modelling Negative Hydrogen Ion Source Extraction Systems”. Since being involved in the development of RADEF’s beam cocktails Taneli has been our group member, but last years he has worked and also did his thesis in the ion source group of the laboratory. After graduation Taneli continues as a university researcher and will be a responsible person to develop a new higher energy beam cocktail produced with the new ion source HIISI (reported elsewhere in this report).

We also got a new group member, Alexandre Bossier, who started in October as our graduate student. Alex came from the Montpellier 2 University (UM2), France, and the topic of his thesis is to study radiation effects in electronics on ground level. This is part of the collaboration we started with UM2.

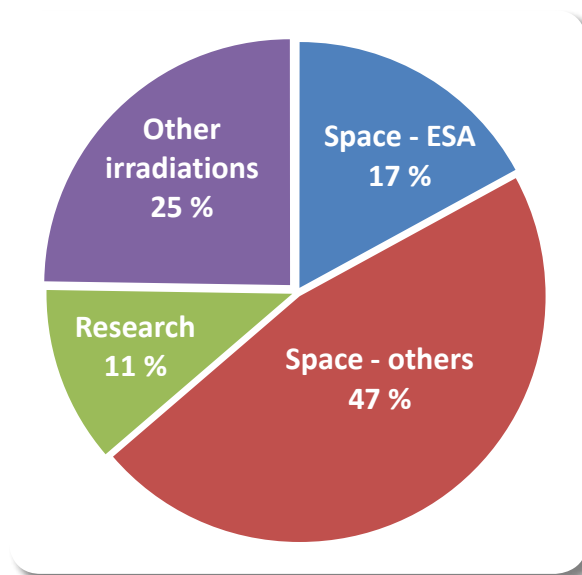


Fig. 1. Distribution of beam time usage in RADEF; Space-ESA = space component tests for ESA, Space-others = space component tests for satellite industry, Other irradiations = membrane irradiation, R&D development etc., Research = studies based on PAC proposals.

The use of the beam time

The usage of the beam time is shown in Fig. 1. The revenue continued growing already four years running being 771 000 € in the year 2013.

TABLE 1. COMPANIES, INSTITUTES AND UNIVERSITIES, WHICH PERFORMED TESTS AT RADEF IN 2013.

AEROFLEX, Gothenburg, Sweden
 ASRO, Turku, Finland
 ATMEL, Nantes, France
 CEA, Gif-sur-Yvette, France
 CNES, Toulouse, France
 Cypress Semiconductor, San Jose, CA, USA
 DLR, German Aerospace Center, Wessling, Germany
 EADS ASTRIUM, Elancourt, France
 EADS ASTRIUM, Portsmouth, UK
 ESA/ESTEC, Noordwijk, The Netherlands
 HIREX Engineering, Toulouse, France
 MapRAD, Perugia, Italy
 Naval Research Laboratory, Washington DC, USA
 Oxyphen, Wetzikon, Switzerland
 Paul Scherrer Institute, Villigen, Switzerland
 RedCat Devices, Milan, Italy
 RUAG Sweden, Gothenburg
 Saphyrion, Bioggio, Switzerland
 STUK, Radiation and Nuclear Safety Authority of Finland
 ST Microelectronics, Catania, Italy
 Synergy Health, Oxfordshire, UK
 Thales Alenia Space, Toulouse, France
 TRAD, Labege, France
 University of Bergen, Norway
 University of Cyprus, Nicosia, Cyprus
 University of Milan, Italy
 University of Montpellier, France
 University of Palermo, Italy

The studies

RADEF continued as ESA's external European Component Irradiation Facility (ECIF) for serving European satellite industry. In total 46 campaigns for 23 companies or institutes and for five universities were performed. The users are summarized in Table 1.

The technical assessment project of ESA "Effects of the ion species and energy on the oxide damage and SEGR failure" ended by December 2013 and the final results will be published in 2014. The objective of study was to determine the worst-case conditions for SEGR testing and use the results in the next ESA's SEE test guidelines.

SkyFlash (262890 EU-FP7 Project) project also continued. Its aim is to develop a RadHard by design (RHBD) methodology for non-volatile flash memories. The methodology focuses on environments affected by radiation due to electrons, protons and heavy ions. Other partners are from Cyprus, Israel, Italy, Spain and Sweden (<http://www.skyflash.eu/>). In 2013 two heavy ion tests were performed for the project.

Nuclear Structure, Nuclear Decays, Rare and Exotic Processes

Jouni Suhonen

Jouni Suhonen, professor
Emanuel Ydrefors, postdoctoral researcher 1.9.-
Wafa Almosly, graduate student
Mikko Haaranen, graduate student
Juhani Hyvärinen, MSc student
Teemu Tervo, MSc student

Double beta decays and nuclear structure

Various double-beta-decay processes are of general interest in the fields of nuclear-structure physics and neutrino physics. Such processes are the two-neutrino and neutrinoless double beta decays of the double beta-minus, double beta-plus, beta-plus/EC and EC-EC character where EC denotes electron capture. In particular the latter three processes have attracted attention lately, together with the resonance EC-EC processes, in attempts to pin down the elusive mass of the Majorana neutrino. The present status of these processes has been reviewed lately in [1,2]. Such processes have specifically been studied theoretically in ^{124}Xe [3] (article of the month, see <http://iopscience.iop.org/0954-3899/labtalk-article/53596>) and in ^{78}Kr [4]. Experimental and theoretical investigations of these processes in ^{96}Ru and ^{104}Ru have been carried out in [5].

Isovector spin monopole excitations and Gamow-Teller strength functions

Excitation of the isovector spin monopole (IVSM) $1+$ mode can pollute experimental data on Gamow-Teller strength functions in charge-exchange reactions. Since these strength functions can be used in surveys of the contributions to the double-beta nuclear matrix elements false conclusions about these contributions could be drawn due to the IVSM contamination. At present we examine theoretically the possible IVSM contamination in the Gamow-Teller strength functions generated by the (p,n) and (n,p) charge-exchange reactions in $A=76$, $A=100$ and $A=116$ systems [6].

Possible low-Q-value beta decays for neutrino mass measurements

Beta decays of very low decay energies (Q values) can potentially be used for measuring the tiny neutrino mass. Examples of such measurements are the allowed beta-minus decay in tritium (the running KATRIN experiment) and the first-forbidden unique beta-minus decay in ^{187}Re (the planned MARE experiment). Further interesting cases would be the ^{115}In decay [7], ^{135}Cs decay [8], ^{115}Cd decay [9] and decays in

^{131}I and ^{111}In . Examination of the nuclear-structure effects in such decays is under way.

Effective value of the axial-vector coupling constant from beta and double beta decays

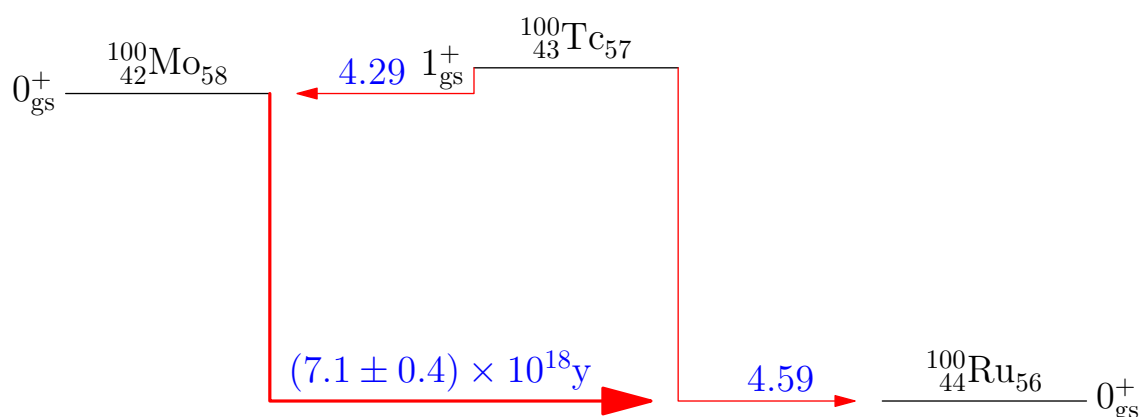
The value of the weak axial-vector coupling constant g_A plays an important role in beta and especially in double beta decays. The beta-decay rates are proportional to the second power of $1/g_A$ and the double-beta-decay rates to its fourth power. We have found a way [10] to study the effective renormalization of g_A for Gamow-Teller beta decays in triplets of isobaric nuclei where both the beta-minus and electron capture (EC) branches of the 1^+ to 0^+ transitions are known experimentally. A typical case has been presented in Fig. 1. In this particular case of $A=100$ isobars also the two-neutrino double beta transition is known and can be further used to study whether the renormalization is the same for single and double beta decays. A similar survey using a global systematics of beta-minus and EC decays has been achieved in

[11]. The contributions from the 1^+ and 2^- states are conspicuous for the nuclear matrix elements related to neutrinoless double beta decays. It is thus of paramount importance to study the quenching effects of these contributions through the renormalization of g_A . It has been shown very recently [12] that a similar quenching as for the Gamow-Teller transitions applies also to the first-forbidden unique 2^- to 0^+ transitions. Based on these studies important modifications in the computed rates of neutrinoless double beta decays are expected.

Neutrino-nucleus scattering at supernova energies

Accurate estimates of nuclear responses to supernova neutrinos are needed for studies of neutrino properties and modeling of supernovae and nucleosynthesis of heavy elements. We have extended the studies of neutral-current (NC) processes [13] to charged-current (CC) processes [14] by studying the neutrino and anti-neutrino scatterings off ^{95}Mo and ^{97}Mo at supernova energies (0-100 MeV). An interesting application of both the NC and CC formalisms was made to the supernova-neutrino scattering off ^{116}Cd in [15]. As outcome of this study we show in Fig. 2 the computed NC and CC nuclear

Fig. 1: Single beta and double beta decays in the $A=100$ triplet of isobars.



responses of ^{116}Cd to supernova electron neutrinos with and without the neutrino oscillations. With neutrino oscillations the rates depend on the assumed hierarchy of the neutrino masses (NH denotes normal hierarchy and IH denotes inverted hierarchy in the figure). The dotted vertical line marks the distance from Earth to the supernova SN1987a which exploded in 1987 in the Large Magellanic Cloud, outside our Milky Way.

We have recently finalized a nuclear-structure study of the ^{116}Cd nucleus by using 10 different Skyrme interactions in collaboration with the FIDIPRO group [16]. In this study we concentrate on the spin and spin-isospin properties of charge-changing transitions to states in ^{116}In , and on the charged-current neutrino and anti-neutrino scattering properties to states in ^{116}In and ^{116}Ag .

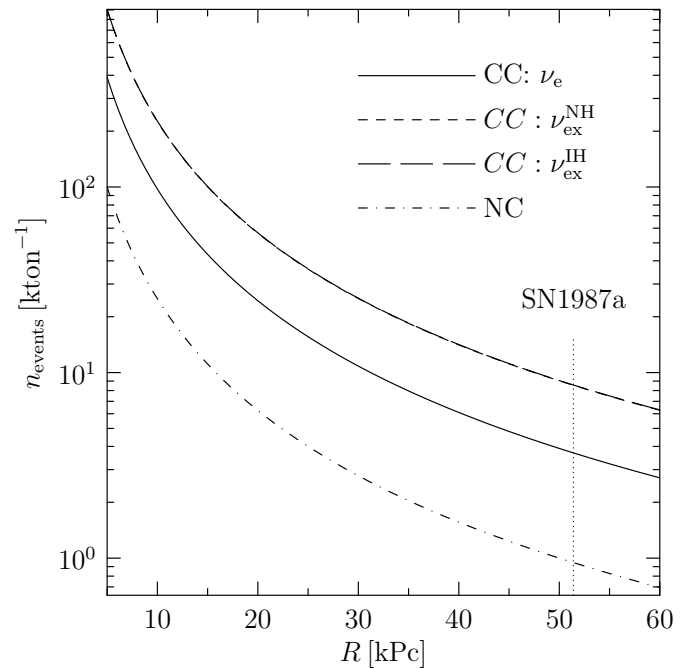


Fig. 2: Computed number of expected CC and NC events per kiloton of ^{116}Cd as functions of the distance to the supernova.

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 [9] M. Haaranen and J. Suhonen, Eur. Phys. J. A 49 (2013) 93
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 [14] E. Ydrefors and J. Suhonen, Phys. Rev. C 87 (2013) 034314
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Experimental Nanophysics and Nanotechnology

Markus Ahlskog
Konstantin Arutyunov
Ilari Maasilta
Jussi Toppari

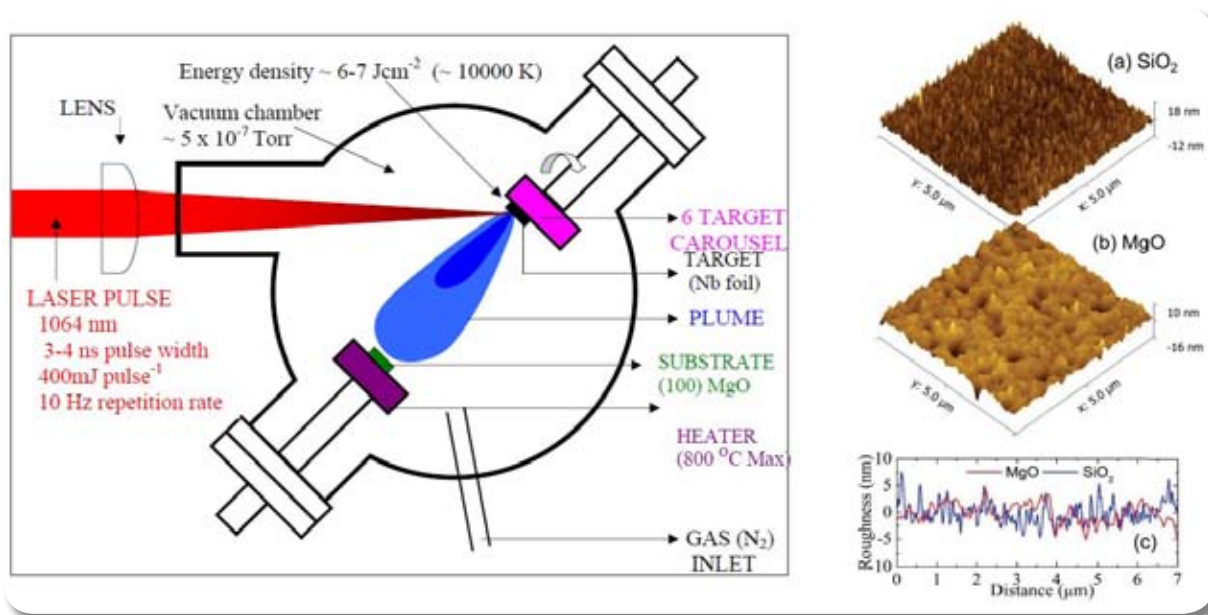
Ilari Maasilta, professor
Markus Ahlskog, professor
Jussi Toppari, Academy research fellow
Konstantin Arutyunov, senior assistant
Saumyadip Chaudhuri, postdoctoral researcher
Somjai Isotalo, postdoctoral researcher 23.9.-
Pasi Jalkanen, postdoctoral researcher 1.9.-
Tuomas Puurtinen, postdoctoral researcher
Deep Talukdar, Visiting scientist 1.4 - 31.8
Svitlana Baieva, graduate student
Zhuoran Geng, graduate student
Olli Herranen, graduate student
Matti Hokkanen, graduate student
Tommi Isoniemi, graduate student
Tero Isotalo, graduate student
Juhani Julin, graduate student
Janne Lehtinen, graduate student
Mikkko Palosaari, graduate student
Antti Pennanen, graduate student -30.6.
Peerapong Yotprayoosak, graduate student
Boxuan Shen, graduate student
Kosti Tapio, graduate student
Yolan Tian, graduate student
Andrii Torgovkin, graduate student
Tanja Andrejeff, MSc student
Hannu Pasanen, MSc student
Taneli Rantala, MSc student
Joonas Saari, MSc student
Ville Saunajoki, MSc student
Dongkai Shao, MSc student

Thermal properties of nanostructures and radiation detector development

Ilari Maasilta

The main research direction of the thermal nanostructure research team is to understand and engineer energy flow mechanisms in low-dimensional geometries, develop thermometric techniques for the study of thermal phenomena and use the obtained physical know-how in the development of ultrasensitive radiation sensors for applications (bolometry). A few highlights of the activity in 2013:

We have been quite active lately in the field of novel high-performance superconductor material and device development. Using the quite unique technique of infrared pulsed laser deposition (Fig. 1), we have recently successfully grown films of superconducting tantalum nitride (TaN) with critical temperatures up to 8 K [1]. This is the first time that superconducting TaN was grown with pulsed laser deposition (PLD). The films were also characterized with X-ray diffraction in collaboration with the chemistry department, showing that the superconducting phase was face-centered cubic, and single phase films were achieved on magnesium oxide substrates. Devices have already been fabricated successfully from the superconducting TaN films.



Another even higher critical temperature superconducting nitride material grown by PLD recently in our group is niobium nitride (NbN), with achieved critical temperature 16 K. We recently fabricated normal-metal-insulator-superconductor (NIS) tunnel junction devices from it [2]. NIS junctions have many interesting properties, for example, they act as sensitive thermometers and bolometers at low temperatures. The usual superconducting material for these devices is aluminum, due to the excellent properties of its oxide, which forms the tunnel barrier. However, the operational range for thermometry with aluminum is limited by its critical temperature up to 1.5 K. This range can now be extended up to 16 K with our NbN device technology.

Collaboration with Oslo University on the studies of magnetic field penetration in high performance superconducting NbN films (grown at NSC) has continued. In 2013, the Oslo group showed [3] that large nanosecond voltage pulses are generated if the external magnetic flux penetrates in an avalanche mode (thermomagnetic instability), due to transient electric fields.

Fig. 1. (left) Schematic of the pulsed laser deposition setup at Nanoscience Center. (right) AFM images and line scans of the TaN surface on either SiO₂ or MgO substrate.

Research in developing phononic crystals has also moved forward [4]. We have perfected the techniques how to self-assemble polystyrene (PS) nanospheres (diameter 260 nm) into ordered lattices from aqueous solutions onto lithographically pre-patterned substrates, using the so called vertical deposition method. In that technique, the substrate is withdrawn slowly (~10 μm/min) from an aqueous solution of the PS spheres, resulting into a high quality close packed self-assembly of the nanospheres due to capillary and convective forces. However, domains of various sizes separated by cracks are typically formed, with the concentration of PS solutions and speed of withdrawal affecting the average size of the domain strongly (Fig. 2.). Quite interestingly, we also found that the distribution of domain sizes is not normal, but log-normal, meaning that there is a significant tail at the high domain size end. This type of log-normality has been observed before for some

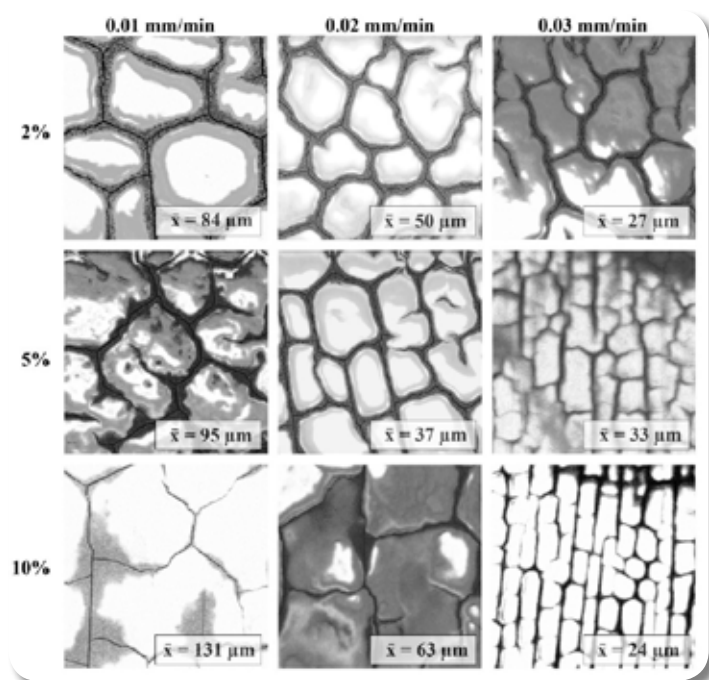


Fig. 2. SEM images of self-assembled phonic crystal domains with varying dipping speed and nanosphere concentration. All samples have been withdrawn in the vertical direction, with \bar{x} giving the average vertical domain size.

aggregation and fragmentation phenomena (such as mud-cracks in dry mud-beds), but to our knowledge our report is the first to observe it for colloidal crystal formation.

In the future, we can also fabricate complex 3D structures, such as phononic crystals, using the new 3D laser-lithography tool capable of three-dimensional patterning down to ~ 100 nm scales. The tool, so far unique in Finland, was installed in 2013 in the NSC clean room, and the investment was made possible by the EU regional funds (EAKR). Fig. 3 shows an example of a 3D microstructure fabricated at NSC clean room.

Another focus field has been development of ultrasensitive superconducting transition-edge sensor (TES) X-ray detectors. In 2013, significant

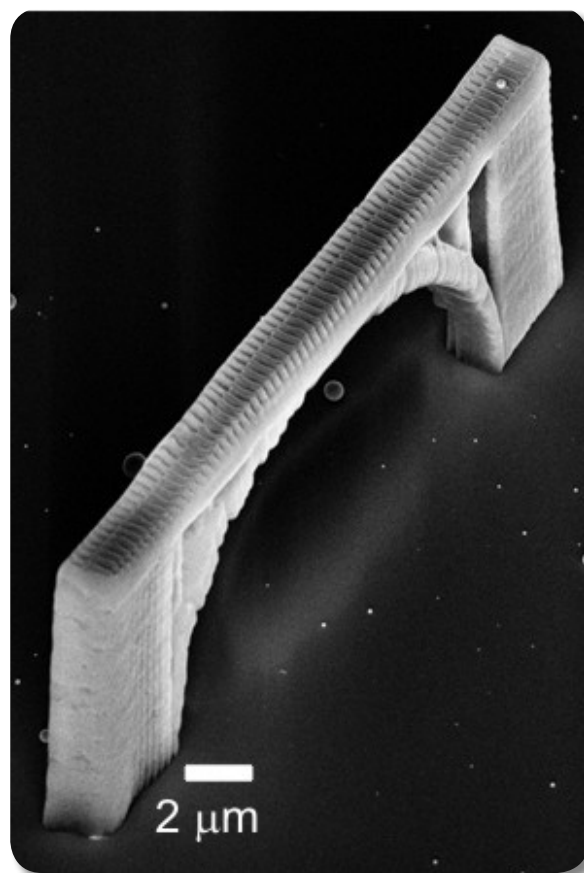


Fig.3. SEM image of a “microbridge” fabricated with the 3D lithography tool at NSC.

progress was made in introducing completely new applications for TES sensors. In collaboration with Chemical Physics Department in Lund University, Sweden, and NIST in Boulder, USA, we demonstrated a ground breaking experiment in Lund [5], where TES detector array was for the first time used in a table-top sized setup for X-ray fine structure absorption spectroscopy (EXAFS). Normally, such experiments have to be performed at large synchrotron facilities. The next goal is to do the experiments in time-resolved mode (the setup allows for that), so that dynamical chemical information is obtained. In addition, in our ongoing TEKES funded project in collaboration with NIST and the accelerator-based materials physics group at JyU, we have demonstrated [6] a *unique*

new materials analysis tool using accelerator-based excitation of characteristic X-rays from materials, and the subsequent spectral analysis of the emitted X-ray spectra using ultrahigh-resolution superconducting TES detectors (TES-PIXE). The measurements are made possible by a special cryogenic setup developed in a previous TEKES/EAKR project, where X-rays from the lab can be coupled into the 40 mK stage of a cryogen-free adiabatic demagnetization refrigerator (ADR) with a time-division multiplexed multi-stage SQUID readout electronics. Figure 4 shows the comparison between the standard silicon drift detectors (SDD) and TES detectors, demonstrating orders of magnitude improvement in the energy resolution. This will allow us to see much smaller impurity concentrations and obtain chemical information in some cases, in addition to the identification of elements and their abundance.

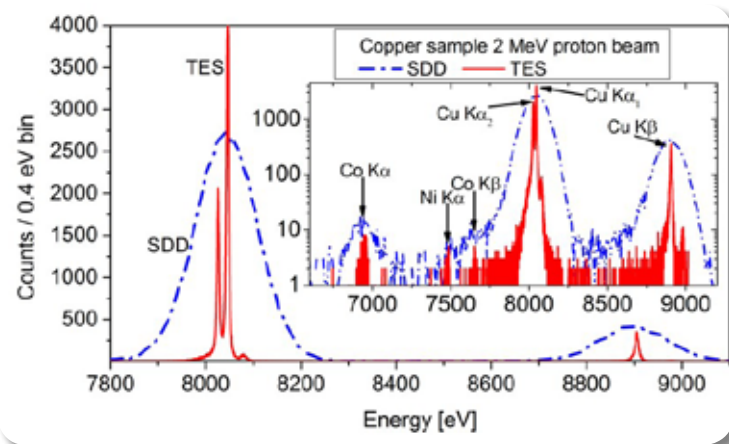


Fig. 4. Comparison of Cu-sample spectra excited with 2 MeV protons measured with TES and SDD detectors. Inset shows the same data in logarithmic scale, where the Co $K\alpha$, $K\beta$ and Ni $K\alpha$ impurity lines of the sample are more visible. The theoretical energy values for the impurity lines are represented with the vertical arrows.

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Molecular Technology

Markus Ahlskog

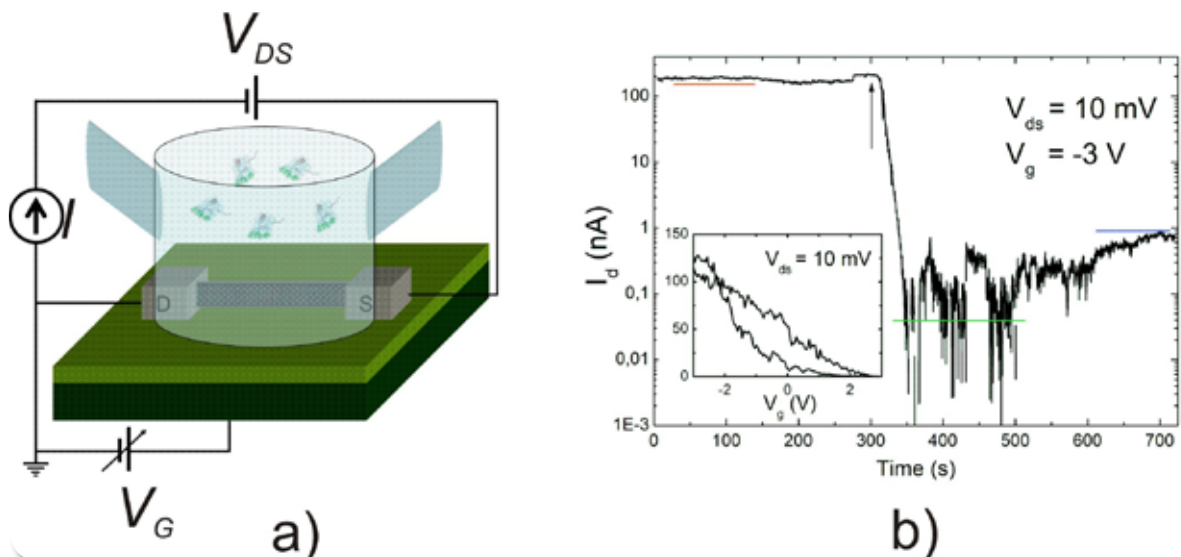
The Molecular Technology group studies electronic and mechanical properties of carbon nanotubes (CNTs) and devices that are based on them.

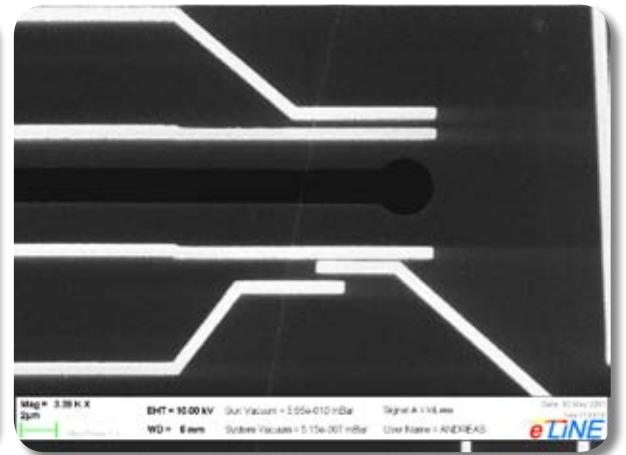
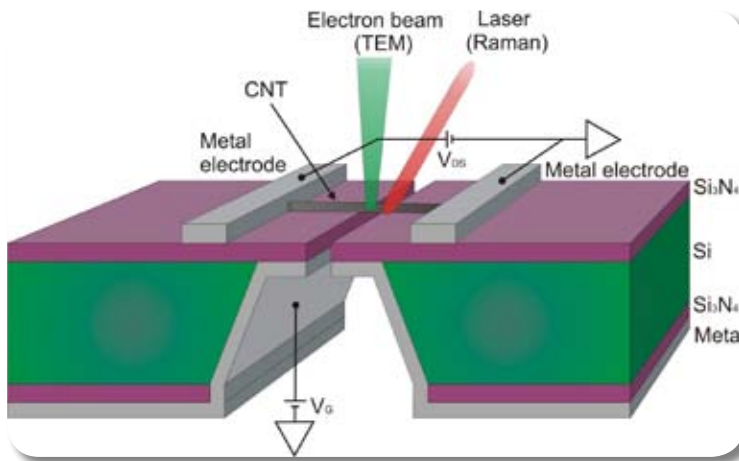
CNT's are considered as the active elements in chemical and biochemical sensor devices. For this purpose, the effects of protein adsorption on the conductance have been measured in single CNT devices [7]. In this context, nearly always the CNT is a semiconducting single wall nanotube (SWNT) forming the active channel in a field effect transistor (SWNT-FET). In this work, carbon nanotubes have been for the first time employed for electronic detection of hydrophobin (HFBI) protein molecules. HFBI is a surface active protein having both hydrophobic and hydrophilic functional groups which has

previously been used for carbon nanotube functionalization and solubilization. Our result indicates a decrease in device conductance after exposure to ~ 100 nM NCysHFBI in phosphate buffer solution. This decrease could be drastic when measured in situ in solution, see Fig. 5.

Combined techniques for measurement of structural, electron transport, and optical properties of individual carbon nanotubes are very important. We have developed methods to suspend nanotubes over narrow slits for this purpose, see Fig. 6. We have established a laminar flow CVD (chemical vapor deposition) furnace system to grow carbon nanotubes directly on top of the substrate. We pattern lithographically metal catalyst (usually Co or Fe) areas to the substrate and then place the substrate to a horizontal tube furnace. The studies are done in an interdisciplinary collaboration with the groups of Prof. Mika Pettersson at University of Jyväskylä (Raman spectroscopy, Four wave mixing spectroscopy), Prof. Martti Kauranen at Tampere University of Technology (Second harmonic generation) and Prof. Esko I. Kauppinen at Aalto University (TEM diffraction). Results were published in Ref. [8].

Fig 5. a) A schematic picture of the measurement setup in this work, with a SWNT-FET device having a flow cell on top while HFBI protein molecules are injected. b) Time dependence measurement with constant V_G , showing the change as HFBI is mixed into the buffer solution.





We have continued our transport measurement on CNT's with the aid of an expert on electronic noise measurement, Dr. D. Talukdar. Due to widespread nonlinear I-V properties, especially power-law I-V relations in nanoscale objects, the measurement and interpretation of noise in this region have become increasingly significant. For performing noise experiments in the nonlinear regime, metallic carbon nanotubes (CNTs) can be used as good test samples as they display power-law variation of conductance with bias

Fig 6. a) Schematic of our suspended carbon nanotube samples and the measurement techniques possible in this configuration. b) SEM image of fabricated nanotube device crossing slit.

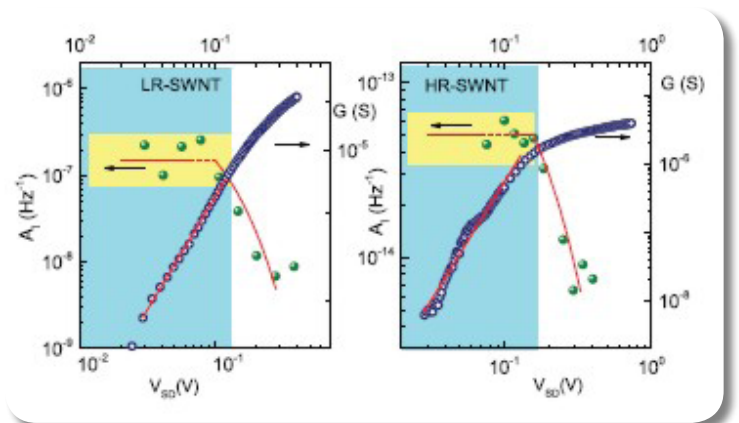


Fig. 7. Relative spectral noise power for SWNT's with low- and high-resistive contacts.

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voltage at low temperatures. We studied [9] low-frequency noise in a non-Ohmic region of metallic single walled and multiwalled carbon nanotubes, see Fig. 7. The generalized relative noise appears to be independent of applied bias in the power-law regime of the tubes and in agreement with theoretical predictions. Beyond the power-law regime the suppression of conductance due to scattering with optical phonons is accompanied

by a reduction of relative noise by an order of magnitude. The findings have important implications for metallic nanotubes being used as interconnects in nanoelectronic devices.

Molecular Electronics and Plasmonics

Jussi Toppari

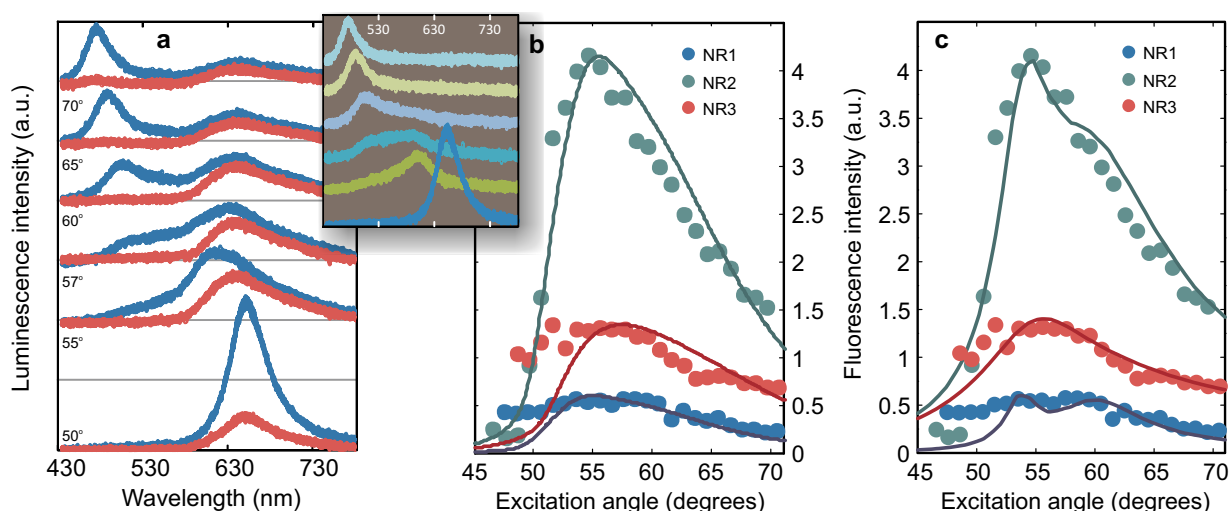
The research of the group can be roughly divided into DNA based self-assembly combined with electrical measurements, and nanoscale plasmonics with emphasis in coupling with molecules.

Due to its superior self-assembly properties DNA has been proven to be an extensive tool - usable almost in any branch of bionanotechnology. Striking examples of this are, e.g., *DNA-origami* and *TX-tile*. We have designed and fabricated various DNA-based self-assembled structures and utilized dielectrophoretic trapping to capture them between nanoscale electrodes for characterization of their electrical properties. We have also developed

devices by functionalizing these scaffolds. For example, self-assembled room temperature single electron transistor is on its final state, as well as optically active components.

Surface plasmon polaritons (SPP) have attracted vast interest because of their strongly enhanced light-matter interaction and confinement. Particularly interesting is a strong coupling between SPPs and molecular excitations (ME) which manifests itself through a formation of new SPP-ME hybrid modes exhibiting Rabi splitting. These polariton modes could, e.g., enable

Fig 8. Kretschmann configuration for SPP excitation was used to measure luminescence spectra at different excitation angles and polarizations (see Fig. 9). The sample consisted of a 50 nm layer of silver on a glass substrate with a polymer matrix on top with Nile Red embedded in. (a) Measured TE (red) and TM (blue) spectra at different excitation angles. The TE spectrum is always the plain fluorescence spectrum. (Inset) Pure polariton luminescence obtained by subtraction TM-TE. (b&c) Measured fluorescence (circles) for three Nile Red -samples together with the transfer matrix calculations (lines in b), and the quantum mechanical model (lines in c).



all optical interaction, and also the chemical properties of the molecules involved can be significantly altered.

In our demonstrations of strong coupling between SPPs and various molecules, the observed pure ME-fluorescence reveals the coexistence of the hybrid modes and non-coupled MEs (Fig. 8). As the fluorescence is directly related to the ME occupation, it provides an ideal tool for studying the polariton dynamics. We have utilized Nile Red dye to demonstrate the absence of scatterings among the polariton branches, and shown that they decay solely via dephasing and internal relaxation of the molecules to its fluorescing state (Fig. 8) [15]. This provides essential information on the dynamics of the strongly coupled modes.

In plasmonics, graphene is an emerging material, but this far restricted only to infrared wavelengths. We have carried out research on a related material, metallic-type single walled carbon nanotubes (m-SWCNT). Using optical spectroscopy in a total internal reflection we have identified surface resonances on thin films of this material (Fig. 9) [11]. The phenomenon has a resonant film thickness, is sensitive to the dielectric environment and also requires both CNT bundling and a high enrichment of metallic chiralities. In addition, the resonances

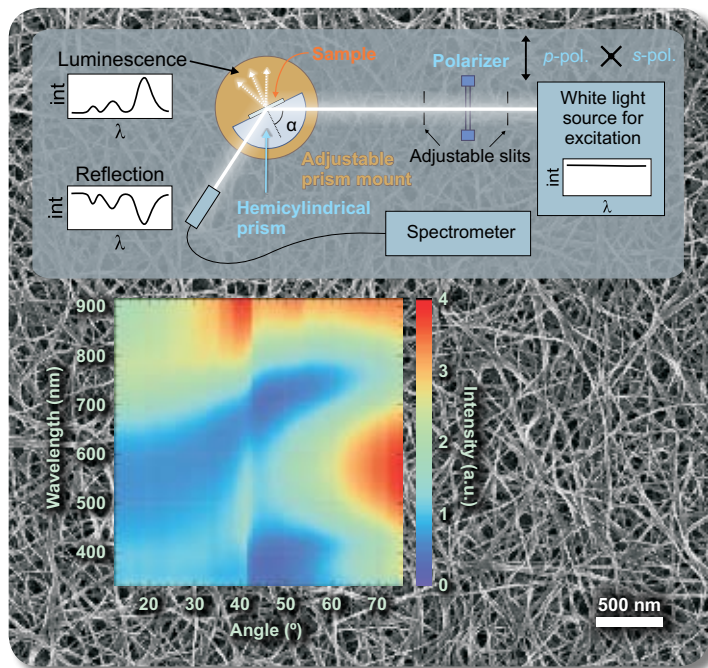


Fig. 9. Kretschmann configuration (top) for SPP excitation was used to measure reflection spectra at different excitation angles (bottom). The sample is a 100 nm thick SWCNT film with 98% metallic content (background image). The dips in reflected intensity are only prominent and angle-dependent at s-polarized excitation, implying a magnetic resonance.

are situated close to the excitonic M11 and M22 transitions of the m-SWCNTs. Magnetic plasmon polaritons supported by intertube effects within bundles are a likely interpretation, and therefore this research could also pave way for plasmonic metamaterials using m-SWCNTs.

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ACS Nano 7 (2013) 1291

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Collective optical resonances in networks of metallic carbon nanotubes
Carbon 63 (2013) 581

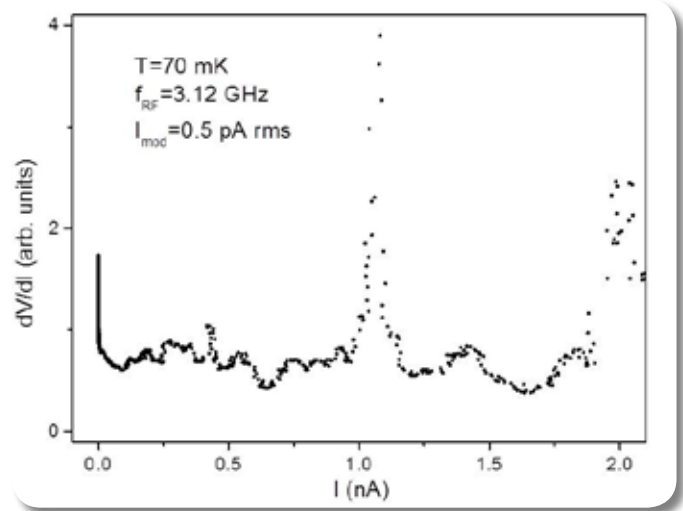
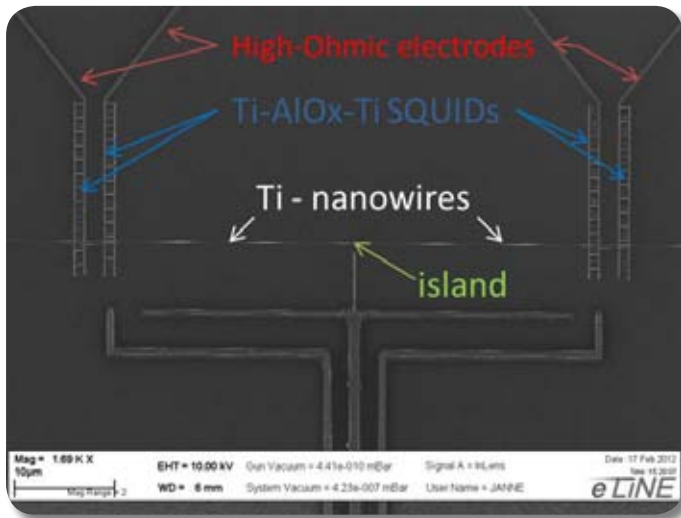
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Strong coupling between surface plasmon polaritons and β -carotene in nanolayered system
J. Chem. Phys. 138 (2013) 044707

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Self-Assembled DNA-Based Structures for Nanoelectronics
Journal of Self-Assembly and Molecular Electronics 1 (2013) 101

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Direct optical measurement of light coupling into planar waveguide by plasmonic nanoparticles
Optics Express 21 (2013) 9908

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Absence of mutual polariton scatterings for strongly coupled surface plasmon polaritons and dye molecules with large Stokes shift
Phys. Rev. B 88 (2013) 085425



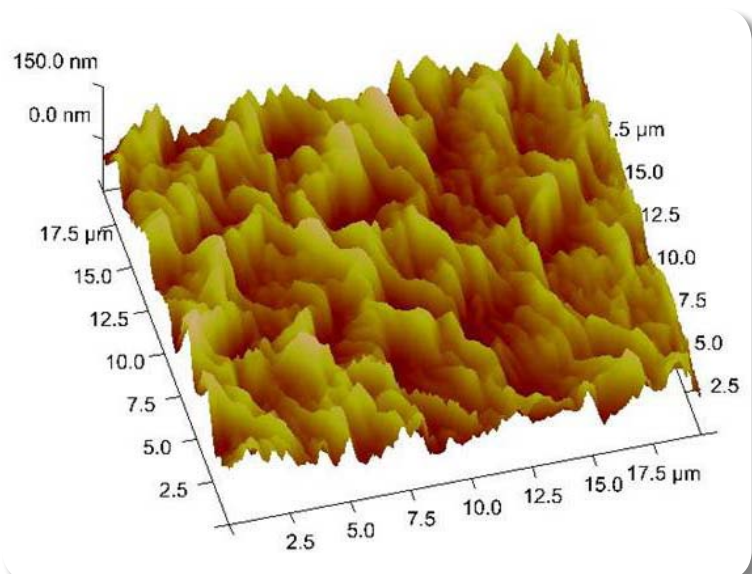
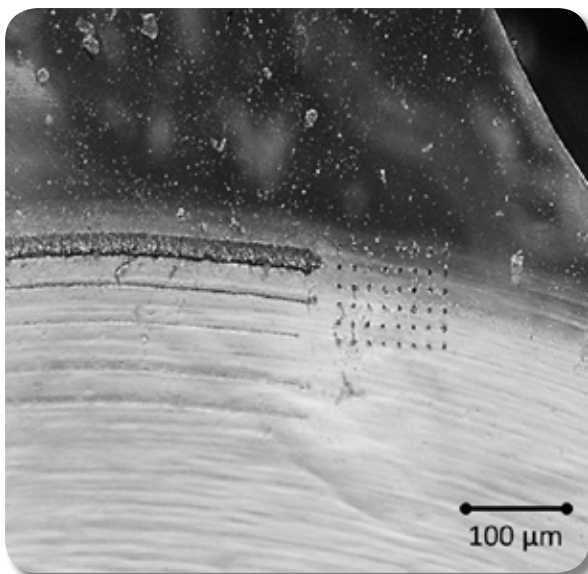
Quantum nanoelectronics

Konstantin Arutyunov

The activity of *Quantum NanoElectronics group* can be formally separated into two interlinked domains: (I) quantum size phenomena at nanoscale superconductors and (II) applied nanotechnology. In 2013 the most intriguing results were obtained related to studies of quantum fluctuation phenomena. Several breakthrough results were obtained.

Fig. 10. (a) SEM image of a hybrid QPS nanostructure with high-impedance electrodes formed by chains of SQUIDS. (b) Derivative of the I-V characteristic demonstrating sharp peak at $I(1)=1$ nA, originating from the dual Shapiro effect $I(n)=n(2e)f_{RF}$ where $f_{RF}=3.12$ GHz is the frequency of external radiation. Accuracy of the peak position is about 2%.

Fig. 11. (a) SEM image of a commercial IOL with laser processed micro grooves and holes. (b) AFM image of ion polished commercial IOL.



Recently it has been already shown in our group that the particular manifestation of quantum fluctuations in 1D superconductors – *quantum phase slip* – is the dual phenomenon to the well-known Josephson effect. QPSs provide the dynamic equivalent of conventional (static in space and time) tunnel junctions, required for operation of Josephson-based devices. Hence, all rich Josephson physics should be observed in QPS systems. One of the most intriguing applications of JJs – the quantum standard of voltage – is based on Shapiro effect, which revolutionized quantum metrology. QPS, being the dual system, offers an exciting opportunity to construct the quantum standard of electric current. The objective is very tempting and its realization requires an innovative approach. One of the mandatory requirements is the suppression of charge fluctuations. So far the, problem has not been solved. In 2013 we came with an idea to suppress quantum fluctuations of charge inserting the QPS element into an

environment with high RF impedance, but low dc resistance (Fig. 10a) [10]. The approach dramatically improved the accuracy of operation of the prototype device (Fig. 10b). The activity will be continued.

The industrial collaboration within DEMAPP and NanoVision projects successfully continued. In Fig. 11a one can see a commercial intraocular lens (IOL) with laser processed micro groves and holes (in collaboration with group of Prof. J. Timonen). Fig. 11b demonstrates the surface of a typical IOL polished with low energetic ion beam.

[10] J. S. Lehtinen, T. Rantala and K. Yu. Arutyunov, Insulating State of a Quasi-1-Dimensional Superconductor, in press, November 2013, arXiv.1311.3202.

Computational nanosciences

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PRACE computational project identifies the mechanisms for “birth of plasmons” in nanoscale gold clusters coated with organic molecules

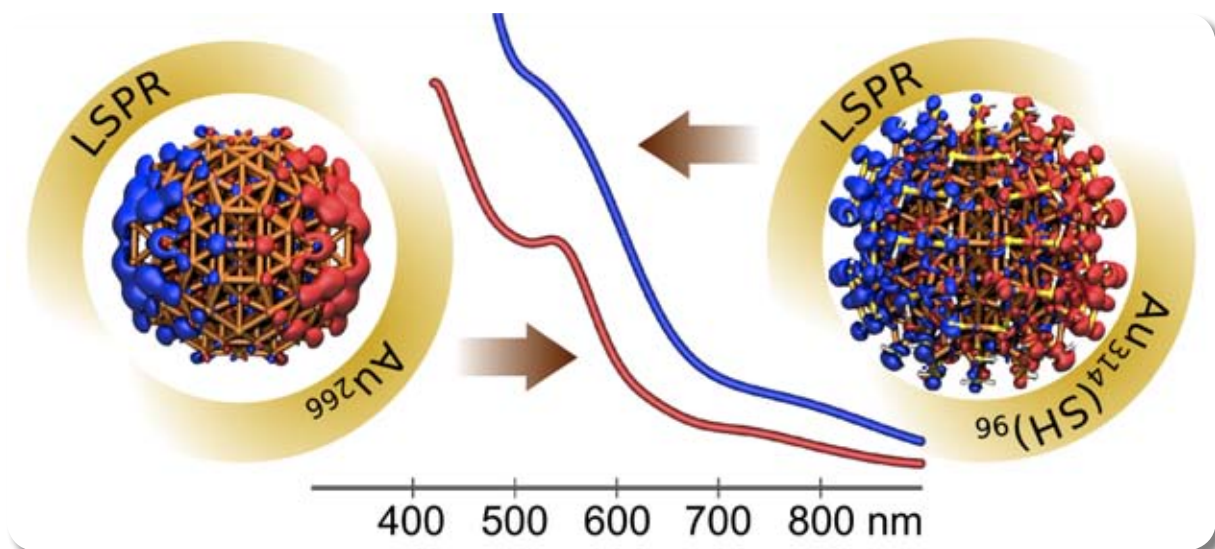
Sami Malola, Lauri Lehtovaara and Hannu Häkkinen

Gold nanoparticles coated by a stabilizing layer of organic molecules (such as thiols) are new nanomaterials that are expected to find applications in a number of fields, e.g., in molecular electronics, nanomedicine and the imaging of biological systems, and as chemical catalysts. A particle’s ability to absorb electromagnetic radiation greatly depends on its size. Smaller particles tend to absorb only specific frequencies, while larger particles effectively absorb a wide spectrum of frequencies. Larger particles also exhibit strong collective absorption in the visible light spectrum, which is called a plasmon. Plasmon resonance involves a collective oscillation of a metal’s electron density. For several years, it has been known that there is a size limit of about two nanometres, that is, particles smaller than this size do not exhibit plasmon resonance. Our recent study (1) provides new atomic-level data

on the effect that the molecular layer protecting gold particles has on the formation of plasmons. Massive calculations involving several million CPU hours showed that in particles smaller than 1.5 nanometres, the molecular layer dampens the formation of plasmon resonances, while in particles larger than 2 nanometres, the layer strengthens the resonances (Figure 1). This result shows that the layer protecting gold nanoparticles has a much more significant effect on plasmonic properties than had previously been thought. This provides new possibilities for planning the synthesis of plasmonic gold particles using molecular layers that also have specific chemical properties.

The study was made possible by a new development of a massively parallel computation method based on the linear-response time-dependent density functional theory. The method

Fig. 1. The absorption of visible light at a frequency of 540 nanometres results in collective electron cloud oscillation (blue and red areas) of the gold particles pictured. This leads to a pronounced peak in the absorption spectrum, shown in the middle (LSPR = localized surface plasmon resonance.) Credit: Sami Malola



was developed for the GPAW software suite as part of the PRACE project, using resources from both CSC and the HLRS supercomputing centre in Stuttgart. (2) The method scales up to tens of thousands of processing cores and can be applied to nanostructures having thousands of valence electrons.

(1) Sami Malola, Lauri Lehtovaara, Jussi Enkovaara and Hannu Häkkinen, "Birth of the localized surface plasmon resonance in monolayer-protected gold nanoclusters", *ACS Nano* 7, 10263 (2013), doi: 10.1021/nl4046634

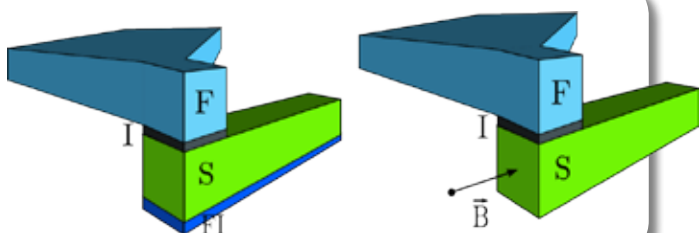
(2) <http://www.prace-ri.eu/PRACE-5thRegular-Call>

Superthermoelectrics and macroscopic vibrations in the quantum limit

Tero Heikkilä

Thermoelectric devices can convert electrical currents to cooling and temperature differences to electric power. Such effects are largest in

Fig 2. Setup containing a ferromagnet (F) coupled through an insulator (I) to a superconductor (S) containing a spin-splitting field either due to a proximity effect from a ferromagnetic insulator (FI, left) or due to a magnetic field (right).



semiconductors exhibiting an energy gap and a strong asymmetry between positive- and negative-energy excitations (electrons and holes). On the other hand, it has been long believed that superconductors exhibit at best only very weak thermoelectric effects. In our work we show that a combining ferromagnets with superconductors containing a spin-splitting exchange field can lead to a very strong thermoelectric effect, with an efficiency ideally approaching the Carnot limit (1).

When light reflects from a surface, it causes a radiation pressure force on it. Most often this is an unobservably weak force, but it forms the basis of the interaction between light and mechanical vibrations in the field of optomechanics. Recently this non-linear interaction has been used to cool mechanical vibrations to their quantum ground state. However, such systems typically reside in the correspondence limit where classical and quantum dynamics are the same, due to the intrinsically weak coupling. We have shown how such coupling can be enhanced by several orders of magnitude by placing a superconducting island inside a cavity storing the electromagnetic field, and exploiting the non-linearity of the Josephson coupling (2). This enhancement will allow reaching the quantum limit of optomechanics, ultimately allowing for storing quantum states into the macroscopic vibrations of a beam coupled to the cavity.

A. Ozaeta, P. Virtanen, F.S. Bergeret, and Tero T. Heikkilä, "Huge thermoelectric effects in ferromagnet-superconductor junctions in the presence of a spin-splitting field", *Phys. Rev. Lett.* 112, 057001 (2014)

(2.) T.T. Heikkilä, F. Massel, J. Tuorila, R. Khan, and M.A. Sillanpää, "Enhancing optomechanical coupling via the Josephson effect", under review [[arXiv:1311.3802](https://arxiv.org/abs/1311.3802)]

Graphene goes spiral

Pekka Koskinen and
Claudia Gomes da Rocha

Topology is familiar mostly from mathematics, but its concepts have crept also into natural sciences. The electronic properties of topological insulators and graphene, in particular, are governed by topological features, making their quantum information robust against impurity scattering, an important requirement for fault-tolerant quantum-computing technology.

Recently we have investigated two different graphene topologies. The first topology is graphene spiral, a novel structure akin to a finite graphite screw dislocation (Fig. 3). Electronic structure simulations on such spirals revealed an intriguing effect recognized as Rashba splitting, an interaction originated by breaking the symmetry of the system.⁽¹⁾ Because the effect emerges from the intrinsic curvature, it remains robust against distortions or impurities. The second topology is Möbius graphene nanoribbon, which has attracted interest due to its fascinating symmetry requirements for the wave functions (Fig. 4). Using revised periodic boundary conditions, method developed earlier in our group, we were able to investigate the implications of the Möbius topology systematically.⁽²⁾ It turned out that, once geometric and magnetic contributions are ignored, the effect of the global topology is unexpectedly short-ranged.

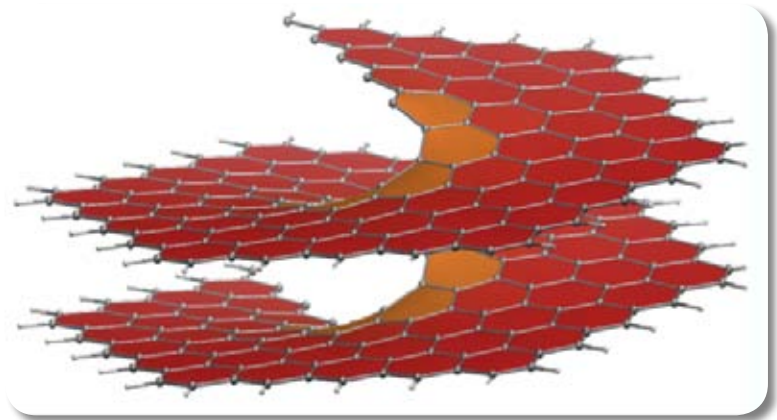


Fig. 3. Graphene spirals are finite equivalents of graphite screw dislocations.

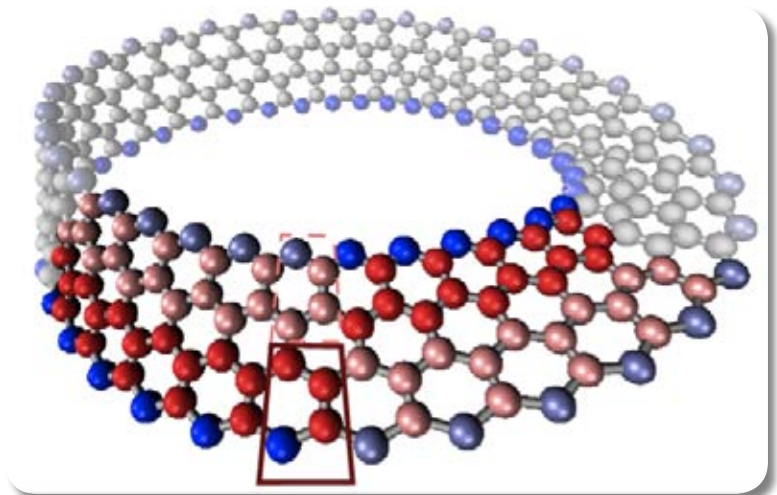


Fig. 4. Möbius graphene ribbons of arbitrary length can be calculated by minimal cell simulations via customized boundary conditions.

(1.) S. M. Avdoshenko, P. Koskinen, H. Sevincli, A. A. Popov, and C. G. Rocha, "Topological signatures in the Electronic Structure of Graphene Spirals", *Scientific Reports* 3, 1632 (2013)

(2.) T. Korhonen and P. Koskinen, "Electronic structure trends of Möbius graphene nanoribbons from minimal-cell simulations", *Comp. Mat. Sci.* 81, 264 (2014)

Soft Condensed Matter and Statistical Physics

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Pekka Kekäläinen, senior researcher
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Tero Harjupatana, graduate student
Vantte Kilappa, graduate student
Jukka Kuva, graduate student
Roope Lehto, graduate student
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Tuukka Ruhanen, MSc Student
Ilkka Sirjonen, Msc student

X-ray tomography laboratory

The primary research facility within the X-ray Tomography Laboratory includes three up-to-date tomographic scanners. Together, these devices are capable of non-intrusive three-dimensional imaging of the internal structure of heterogeneous materials with resolution ranging from 40 μm down to 50 nm. After the extensive acquisition program carried out during the years 2012-2013, the laboratory is now equipped with comprehensive set of instruments for sample preparation and manipulation, including a novel laser system for accurate cutting of small samples, a sample holder that allows mechanical straining of the sample and a device for controlling the humidity and temperature of the sample during imaging. In addition, the laboratory is equipped with specific devices for measuring various transport properties of materials. The entire facility had a high utilization rate in basic and applied research related e.g. to development of novel materials, and to analysis of structural properties of minerals and biological materials such as ceramics, bentonite clay and bone.

Heterogeneous materials

Automatic methods for estimating the length/diameter ratio of fibres in short-fibre reinforced composite materials were developed. The

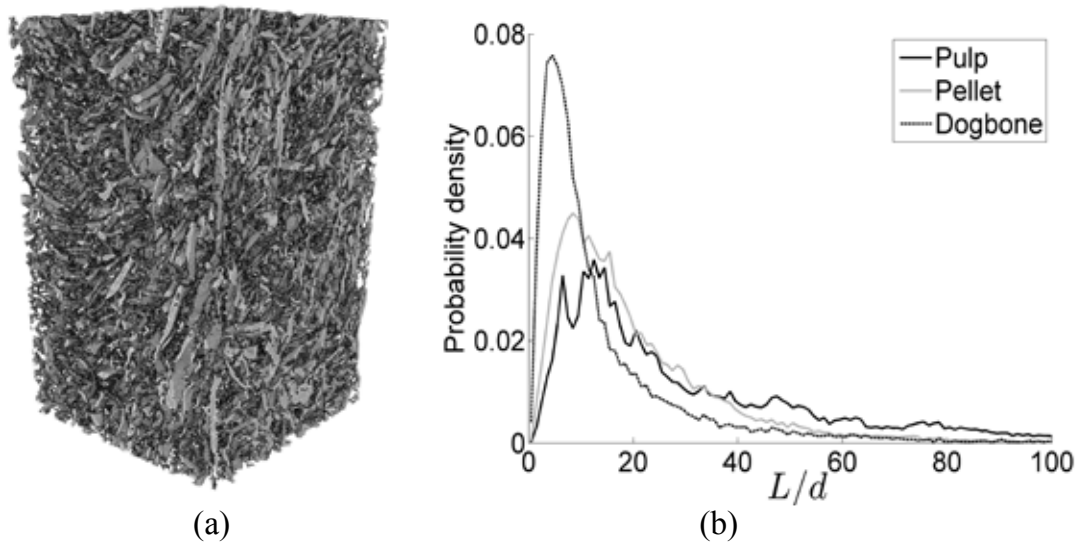


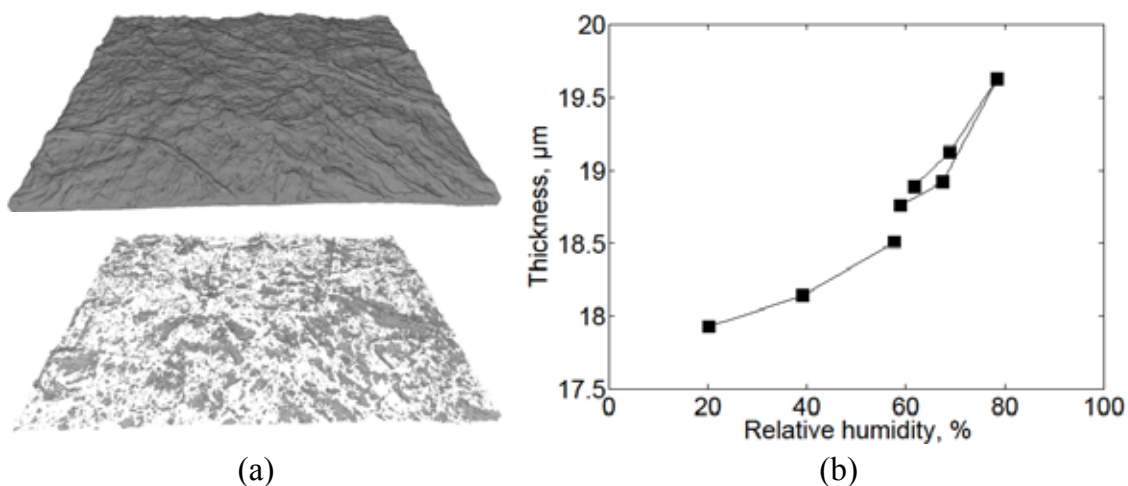
Fig 1. a) Three-dimensional visualization of fibres in biodegradable wood-based composite material. b) Length/diameter distributions of fibres in different manufacturing stages of an injection moulded thermoplastic composite material.

dogbone-shaped injection moulded tensile test specimen (Fig. 1).

length/diameter ratio, i.e. slenderness, dictates not only the reinforcing efficiency of the fibres but also the mouldability of the compound, and is thus of great importance for composite manufacturing. Applications to biodegradable injection moulded thermoplastic composite materials show remarkable decrease in the slenderness as pulp fibres are processed into

A newly developed device allows microtomographic imaging in varying relative humidity. As a proof-of-concept, the swelling and microstructure of nanocellulose films were quantified. Having potential as oxygen barrier for food packaging

Fig. 2. a) Three-dimensional visualization of nanocellulose film (top) and its micropores (bottom). b) Thickness of a nanocellulose film as a function of relative humidity.



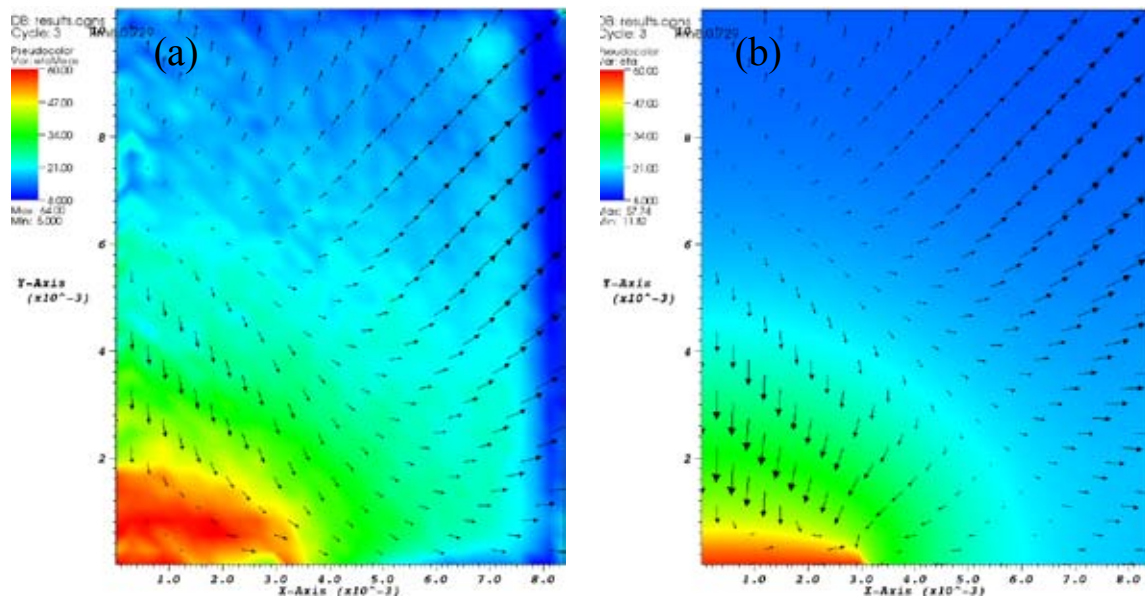


Fig. 3. (a) The measured displacement fields and moisture distributions in a bentonite sample at four phases of the wetting-swelling process (averaged over the azimuthal angle). (b) Numerical result obtained by a semiempirical swelling model (Numerola Oy).

applications, the behavior of the films in moist environments is of interest (Fig. 2).

The study of mechanical and transport properties of bentonite clay, planned to be used as a buffer material in the final repository for nuclear waste, was continued. The μ XCT method for simultaneous non-intrusive 3D measurement of water transport and the resulting intrinsic deformations in bentonite samples was further developed so as to gain better signal-to-noise ratio and to measure the swelling stress. The measurement of elasto-plastic properties of purified bentonite was extended to higher moisture content range obtained in the swelling experiments. The resulting experimental data (see Fig. 3) is used for validating numerical models for the long-term behaviour of bentonite buffer under repository conditions.

Soft X-ray Tomography

Soft X-ray tomography (SXT) has only very recently been introduced as an effective tool for gaining structural information in cell biology and to provide unique views of the nuclear structure and chromatin topology. SXT was used to analyse changes in the three dimensional native nuclear architecture of infected mouse B-cells. In this technique, the cells were frozen very fast so as to preserve their structure intact, and then they were imaged from many different angles using soft X-rays. The contrast in such 2D projections is produced directly by the differential absorption of soft X-rays (water window). Since organic material absorbs in this case about an order of magnitude more strongly than water, and X-ray absorption follows Beer's law, absorption of photons is linear and a function of the biochemical composition at each point in the cell. The 2D shadowgrams so created can be used to reconstruct the 3D distribution of the linear attenuation coefficients (LAC) of the sample with a suitable inversion algorithm. There is no need to dehydrate or

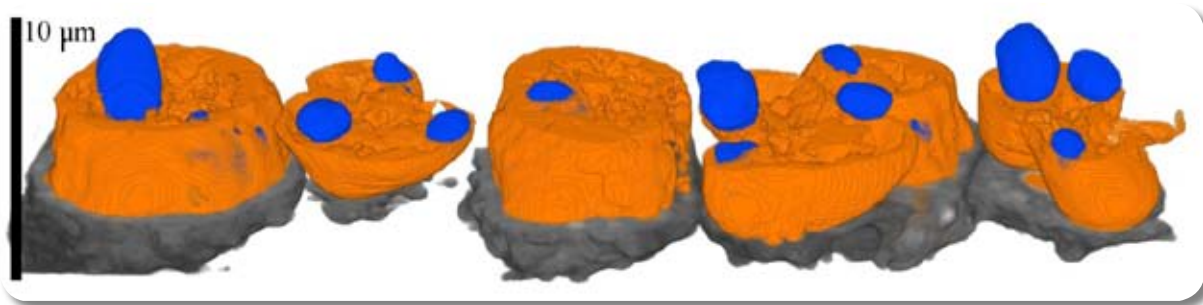


Fig. 4. Visualisation of segmented nucleoli of a mouse B-cell. Heterochromatin is shown as orange and nucleoli as blue.

stain specimens prior to being imaged. The best resolution currently available, 30 nm, is achieved by using synchrotron radiation at the Advanced Light Source. With this resolution the internal geometry of the nucleus, i.e. the spatial distribution of chromatin compartments, can be resolved (see Fig. 4). The latest upgrade of SXT was implementation of correlated confocal fluorescence tomography (CFT), which enables 3D positioning of specific nuclear organelles and their proteins (e.g. lamins and histones) by overlaying molecular information (correlated CFT) about structural data (SXT). SXT is also fast (about 5min/tomographic data set), which allows mapping of changes in the nuclear volume and shape, chromatin topology, numbers and positions of molecules, and many other parameters in large numbers of cells under many different conditions - information that cannot be obtained with any other technology. These studies are performed in close collaboration with Professor Carolyn Larabell (Lawrence Berkeley National Laboratory, USA).

Nonlinear mechanics

We studied mechanical pattern formation in layered elastic materials subject to differential growth or swelling. Depending on the stiffness and thickness ratios of the layers, such systems show diverse patterns of wrinkles or sharply cusped sulci. From theoretical perspective these systems are challenging due to extreme nonlinearities and large deformations. To this end, we have used a combination of analytical stability calculations and large strain finite element simulations. We suggest that these mechanical instabilities are responsible for patterning in various biological systems, such as villi in the gut lumen and folds in the mammalian cerebral cortex. Such mechanical pattern formation may also have potential engineering applications, for example via utilisation of swelling hydrogels to create controllable surface patterns.

Assessment of the musculo-skeletal competence
Methods were and are being developed for an enhanced assessment of the musculo-skeletal competence, so as to improve the prediction of individual's risk for osteoporotic fractures because e.g. of falling. Balance of walking was investigated by computer simulations. To this end, a semi-empirical model based on gait data, measured on a force plate, was employed so as to study responses of muscles' (angular) velocities to a tripping type of perturbation. Thus far, the results of this study indicated that the speed of

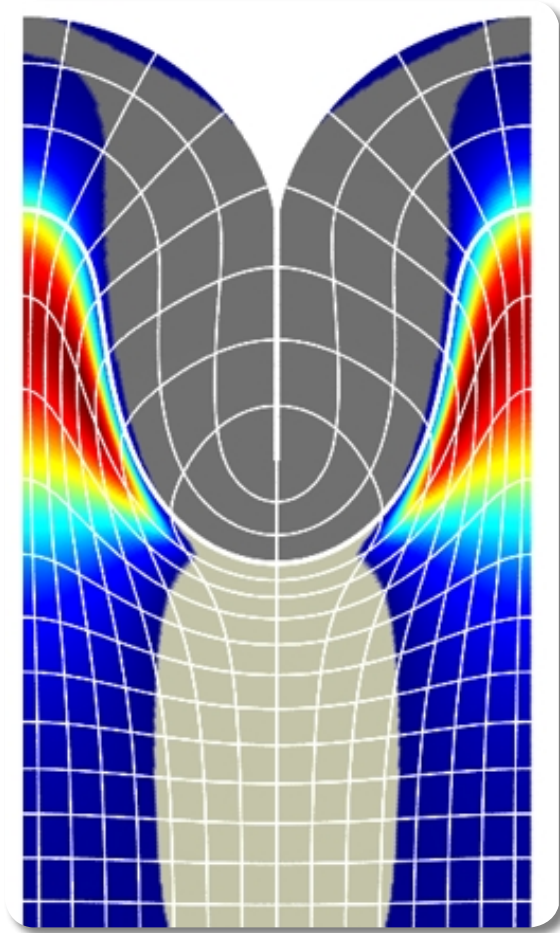


Fig. 5. Numerical simulation of a minimal sulcus in an elastic medium in which the top layer has expanded relative to the substrate layer. Colour shows the distribution of tensile stress.

walking may not be associated with stability of walking in healthy individuals. The main focus of research was on the development of ultrasound based (US) diagnostics of osteoporosis in long cortical bones, such as the radius and tibia, at low US frequencies (20-500 kHz). Such frequencies feature wavelengths in bone long enough to permit propagation of elastic guided waves which probe osteoporotic changes deep in the endosteal (inner) cortical bone. Overlying soft tissue is, however, a major obstacle for full clinical utilisation of this method. To this end, new techniques based on photo-acoustic phase-delayed excitation and improved signal

processing were developed and tested, so as to reduce the impact of the soft tissue. Preliminary experiments in bone phantoms, embraced by soft-tissue mimicking material, were positive, and development of a related in vivo measurement setup has been initiated.

Analysis of fibre networks

We introduced a new curvelet based method for estimating the orientation distribution from images of materials made of elongated particles. Estimates by this method for images of known features were demonstrated to be very accurate, and to outperform those by many traditional methods. This analysis can be made very fast so that it would allow also an on-line analysis. Furthermore it was shown to be robust and rather insensitive to noise in the image.

We demonstrated that, in order to measure the orientation distribution of a sample surface from its reflection images, three or five lights placed in the corners of a regular triangle or pentagon, respectively, should be used depending on the required accuracy. The three light system can e.g. be realised with red, green and blue LED lights, and using three colour photographs in which the RGB components are treated separately. In this case all light sources could be used simultaneously so that imaging would be fast, suitable e.g. for on-line applications. We developed an approach by which a 'fingerprint' can be defined for each paper grade in terms of suitable characteristics for each grade. One of our goals is to identify forgeries printed on paper, for instance of stamps and bank notes (see Fig. 7).

For a deposited network of elongated objects to grow height, or a 3D isotropic packing to be

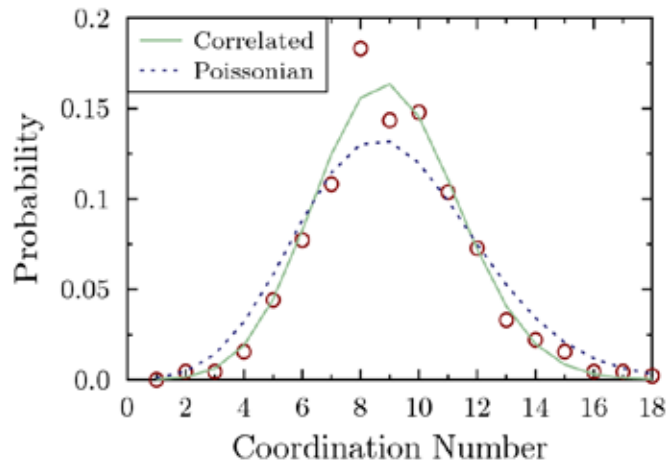


Fig. 6. A segmented image of a granular pile of short cut spaghetti. Tomographic imaging and fibre segmentation enables an accurate measurements of properties of the granular pile, e.g. the distribution of contact numbers.

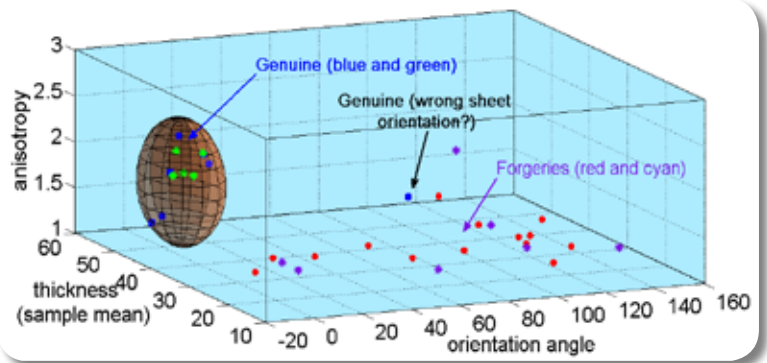
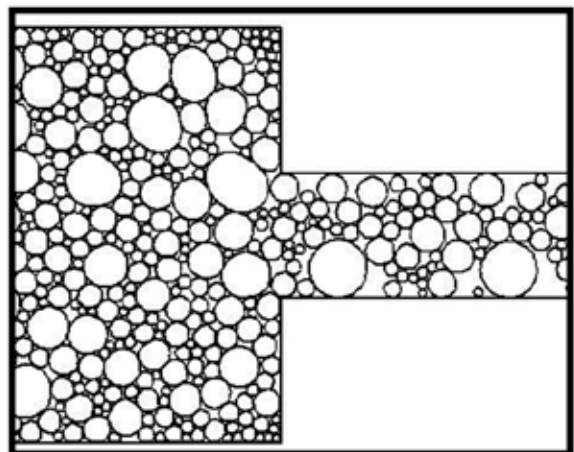
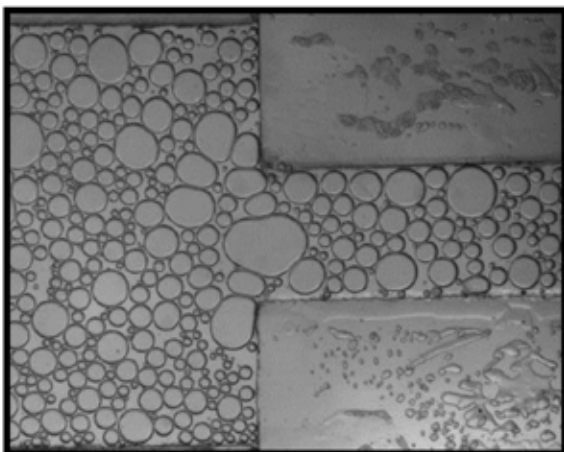


Fig. 7. Genuine and forged stamps in a parameter space suitable for this case. The three parameters here are the main angle of fibre orientation, mean thickness of the fibres and anisotropy of their orientation.

mechanically stable, one needs to consider hard-core interactions between the particles. These hard-core interactions introduce steric hindrances, and thus contacts in the packing will be correlated. To account for this, we have developed a theoretical model for contact formation in sterically hindered randomly packed elongated objects. The model predicts non-Poissonian statistics in the contact formation, which affects both the distributions of contact numbers and the segment lengths.

Fig. 8. A 2D experimental setup for foam flow (left) and its corresponding numerically simulated dynamics (right).

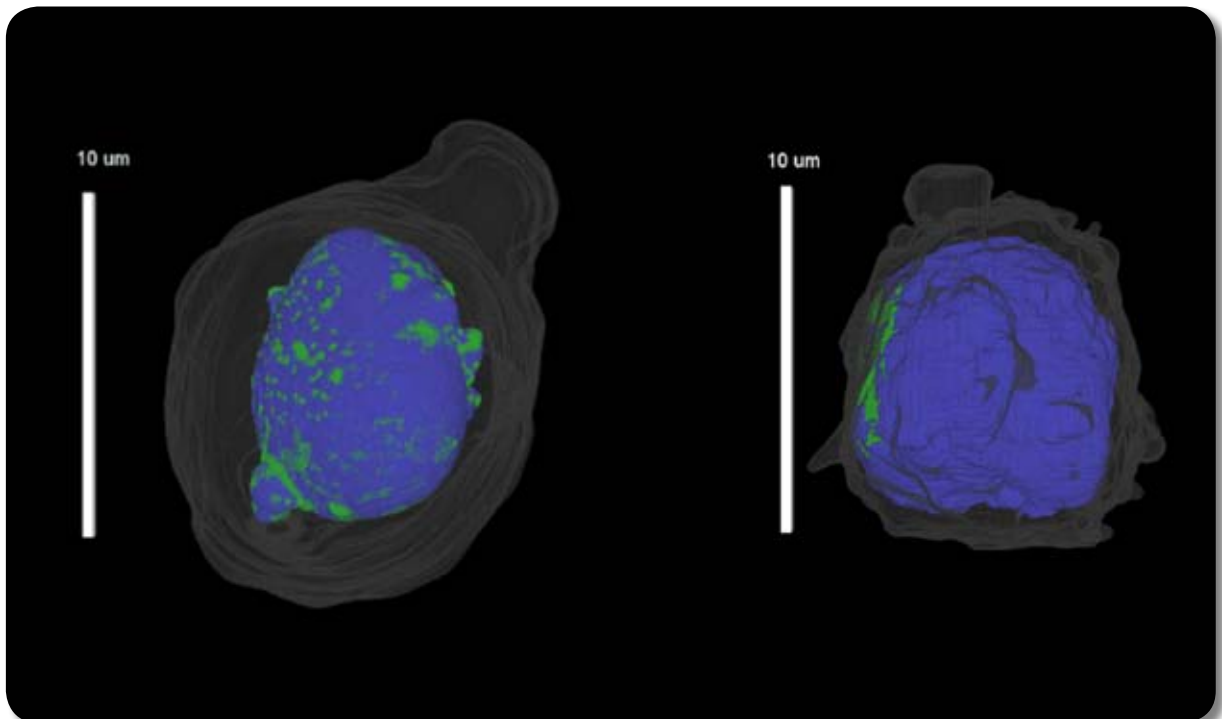


Recent interest in a new foam forming technology prompted a need for better understanding of the rheological properties of foam and foam-fiber mixtures. To this end, a numerical model for foam flow was developed. This work is done in collaboration with VTT Technical Research Centre of Finland.

Stochastic systems

We have continued our studies on dynamics of one-dimensional many-atom models from which there exist mappings onto interface

propagation models. In particular, we studied a discrete exclusion model with accelerated dynamics, in which the cluster distributions display different scaling behaviors at short and long time scales, the crossover scale being tunable by one microscopic parameter defining an effective interaction range. In the corresponding interface model the dynamics in the transient state is accelerated while e.g. the steady-state roughness is barely affected. By defining a local order parameter, even in the steady state the short-range order is found to differ considerably from e.g. that in the totally disordered state of the simple non-accelerated exclusion process.



Experimental Particle Physics

Jan Rak
Sami Räsänen

ALICE

After 3 years of successful data taking the Large Hadron Collider (LHC) at CERN entered the first long shutdown in 2013-2014 (LS1). The main focus of ALICE collaboration in 2013 was on analysis of the $\sqrt{s_{NN}}=5.02$ TeV p-Pb data taken in February 2013 and on the preparation for the upcoming LHC run II (2015-2017).

The main focus of our group is on the high- p_T correlation, direct photon analysis, x_T -scaling studies and jets analysis. In 2013, we mainly focus on paper preparation for a transverse jet shape measurement, related to the quantum coherence effects. We were studying the charged particle and jet associated yields in various collision energies and species (pp and p-Pb). For example the left panel in Fig. 1 shows the jet transverse fragmentation momentum distribution (j_T) from the di-hadron analysis with background and signal. The signal is assumed to be a sum of a Gauss (black dashed line) and a Levy functions (magenta dashed line). It is motivated by a possibility to distinguish different processes i.e the QCD parton shower (Levy component) and the hadronization (Gaussian component) in the measured j_T distribution.

The right panel in Fig. 1 shows the j_T distribution associated to the fully reconstructed jets and it is compared with a theoretical prediction obtained for partons within the framework of the

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Esko Pohjoisaho, graduate student

Jussi Viinikainen, graduate student

Marton Vargyas, graduate student (JYFL/HIP)

Tomas Snellman, MSc student

resummed perturbative QCD (Modified Leading Log Approximation).

Many of the related phenomena observed by the ALICE experiment are discussed in the book "High- p_T physics in the LHC era" (Cambridge University Press) written by Jan Rak and M. J. Tannenbaum and released in March 2013.

Our group also is involved in three hardware projects: (i) T0 timing detector. (ii) Single photon trigger system utilizing signals from the ALICE electromagnetic calorimeter. (iii) Upgrade of the Time-Projection Chamber readout system. As part of the detector upgrades in 2013 T0 team have to reduce the latency of the signals from 620 ns to below 425 ns. The only way to meet this requirement was to relocate the entire T0 electronics to the racks close to the Central Trigger Processor and reroute and shorten the

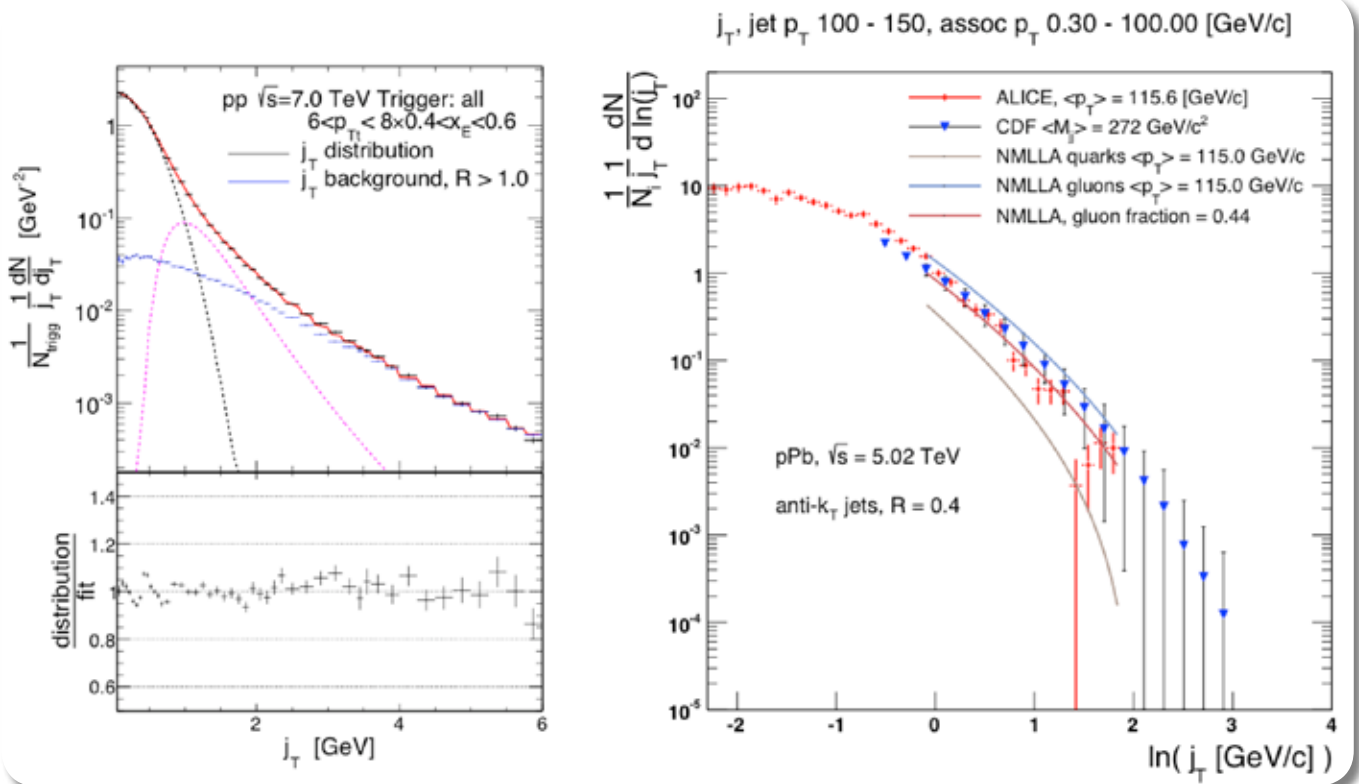
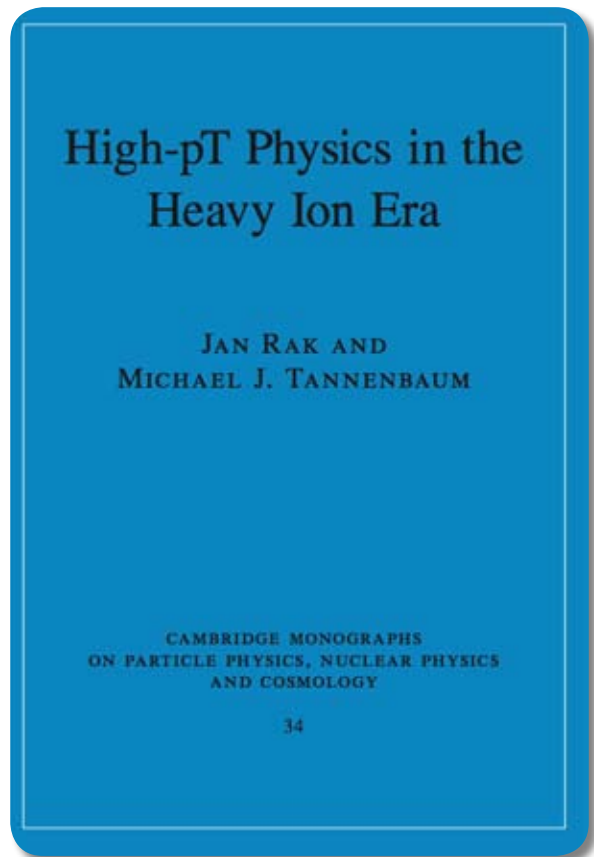


Fig. 1. Jet transverse fragmentation from di-hadron correlation (Left) and jet reconstruction (Right).

cables. After that the detector will have to be commissioned and calibrated anew.

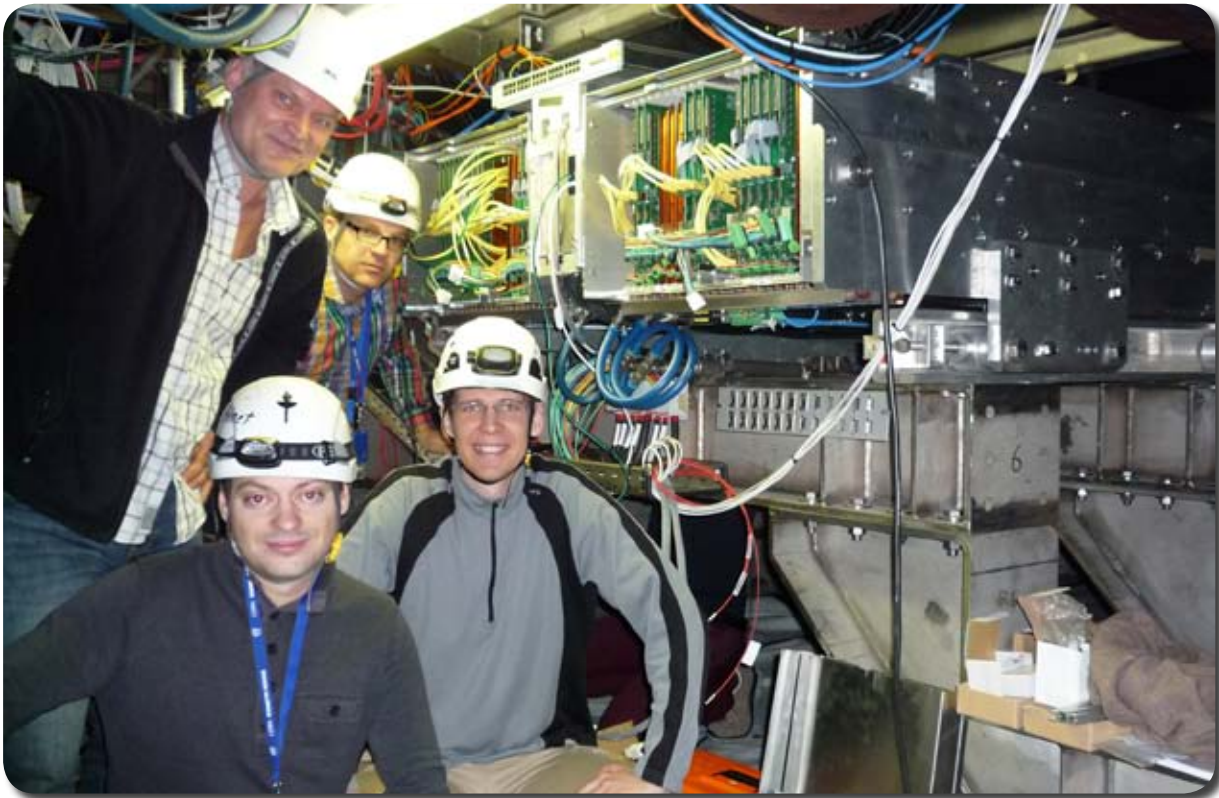
In the mean time there is also an intense preparation for the second long shutdown LS2 (2018). To be able to cope with the high luminosity operation in Run III a major upgrade as outlined in the LoI from September 7, 2012 is needed. One of the main tasks of ALICE collaboration is to upgrade the Time-Projection Chamber (TPC). It requires replacing all multi-

Fig. 2. "High-pT physics in the LHC " era book by Jan Rak and Mike Tannenbaum.



wire proportional readout chambers with the Gas Electron Multiplier (GEM) technology. Our group together with HIP committed to this upgrade by providing a suitable infrastructure (100 m² clean room of class 1000) and expertise in the GEM

technology area. New postdoc Erik Brucken and a PhD student Timo Hilden were hired to lead the quality assurance tests (optical scanning, leakage current and the gain measurements) of about 120 m² GEM foils.



Ultrarelativistic Heavy Ion Collisions – Theory

Kari J. Eskola
Tuomas Lappi
Thorsten Renk

Kari J. Eskola, professor
Thorsten Renk, academy research fellow
Tuomas Lappi, academy research fellow
Kimmo Tuominen, university lecturer –31.8.
Harri Niemi, postdoctoral researcher
Hannu Paukkunen, postdoctoral researcher
Redamy Pérez-Ramos, postdoctoral researcher
Ilkka Helenius, graduate student
Risto Paatelainen, graduate student
Heikki Mäntysaari, graduate student
Jarkko Peuron, MSc student
Joonas Korhonen, MSc student
Laura Laulumaa, MSc student
Petja Paakkinen, MSc student

Studies of strongly interacting elementary particle matter, the Quark Gluon Plasma (QGP), in ultrarelativistic heavy ion collisions (URHIC) are among the fundamental tests of the Standard Model. We aim at understanding QCD matter properties and collision dynamics through various observables measurable in the BNL-RHIC and CERN-LHC experiments. We are funded by the Academy of Finland, PANU and private foundations. We are also part of Tuominen's LNCPMP theory project at HIP. In 2013 we participated in the physics planning of the possible future electron-ion colliders in the U.S. and CERN, contributed to the JET theory collaboration and the EU network I3-HP3 TURIC activities, participated with a high profile in the largest conferences in our field,

and organized the international POETIC IV workshop in Jyväskylä. Lappi started in an academy research fellowship and Tuominen moved to Helsinki in 9/2013.

In heavy-ion phenomenology, the LHC Pb+Pb measurements have strengthened the status of relativistic hydrodynamics, a traditional expertise of our group, as a cornerstone of URHIC physics. In computing the produced QGP initial densities for hydrodynamics, we extended our NLO-improved perturbative QCD + saturation + hydro (EKRT) framework to non-central collisions and dissipative hydrodynamics: Analysing simultaneously the LHC and RHIC multiplicities, p_T spectra and elliptic flow (v_2), we charted the temperature dependence of the QCD-matter shear viscosity. With our dissipative event-by-event (EbyE) hydro framework, we studied the EbyE fluctuations of the azimuthal asymmetry coefficients of the hadron spectra, which closely reflect the QGP initial density fluctuations (fig. 1). We also assessed the importance of the 2nd-order terms in relativistic dissipative hydrodynamics, computing them from kinetic theory. Combining the thermal photon production from our EbyE hydro with the NLO pQCD baseline calculations, we studied direct photon production in A+A collisions at RHIC and LHC, addressing the big open question of understanding the photonic p_T spectra and v_2 simultaneously.

High- p_T observables, such as single hadron spectra, hard hadron correlations and jets, are another cornerstone of the experimental URHIC program at RHIC and LHC. The in-medium parton shower code YaJEM, developed and maintained by us, has been tested systematically and successfully against a large body of experimental data. Using this framework, we were able to make predictions for several observables probing the QCD dynamics of parton-medium interaction in novel ways which are of interest experimentally. For instance, we predicted the strength of hard D-D correlations and obtained the yield of conversion photons for the first time from an evolving parton shower, ultimately allowing to better pin down properties of the hot QCD medium.

Nuclear parton distribution functions (nPDFs) are needed for the computation of all collinearly factorizable hard-process cross sections in nuclear collisions. Our global analysis, the EPS09 package, defines the current state of the art for the nPDFs and their uncertainties. We have now shown how to exploit the available neutrino-DIS data in the global analysis. We also charted how the p+Pb dijet measurements of CMS at the LHC can constrain the nPDFs further. With our EPS09s set of spatially dependent nPDFs released in 2012, we addressed the centrality dependence of inclusive prompt photon production in nuclear collisions at RHIC and LHC. Our EPS09-based NLO predictions for high- p_T pion production in p+Pb collisions serve as a pQCD comparison-baseline for the LHC experiments. Related to the p+p baseline calculations, we performed a critical systematic study of the current NLO parton-to-hadron fragmentation functions, revealing the need for further analysis there.

In the Color-Glass-Condensate (CGC) framework, we are continuing our studies of high energy

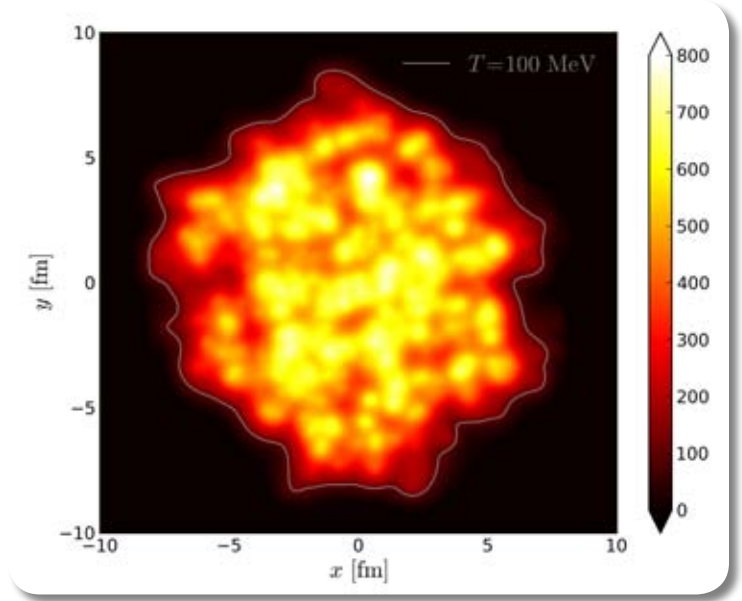


Fig. 1. Initial temperature-fluctuations of the QCD matter (mostly QGP) produced in central Pb+Pb collisions at the LHC, as computed from our pQCD+saturation model, shown in the transverse-coordinate plane. The system is hydrodynamic at temperatures above the shown $T=100$ MeV contour.

QCD, relevant e.g. for the QGP initial state in URHIC. This work has been particularly topical because of the recent p+Pb run at the LHC. We resolved a longstanding controversy in the field by showing that a proper treatment of the nuclear geometry in a CGC dipole model allows for a good simultaneous description of HERA electron-proton cross sections and the LHC nuclear modification ratio for charged particles in p+A collisions. In 2013 we also extended our previous calculations for incoherent diffractive vector meson production in nuclear collisions from deep inelastic scattering to ultraperipheral A+A collisions. Our calculation was the most successful of the theory predictions in comparison with the result released by the ALICE experiment later in the year.

Neutrino Physics and Particle Physics Beyond the Standard Model

Jukka Maalampi
Wladyslaw Trzaska
Kimmo Tuominen

Neutrino physics

Jukka Maalampi and Wladyslaw Trzaska

LAGUNA-LBNO

The EU-financed Design Study Project LAGUNA-LBNO is coming to the final stage. In this project a large-scale long-baseline neutrino oscillation and neutrino astrophysics experiment is planned to the Pyhäsalmi mine north of Jyväskylä. The main activity going on in Finland in this project is an extended site investigation, which has received a support of 1.8 M€ from regional sources. The main goal is to identify the optimal location for gigantic caverns at the depth of 1400 m. It is done through sample drilling over the wide areas followed by the analysis of the rock and in situ stress measurements.

LAGUNA is being designed to provide unique scientific data with a great potential for fundamental discoveries. Apart from the neutrinos created in astronomical sources like the Sun and supernovae, as well as in radioactive decays taking place in Earth's interior, the LAGUNA detectors will detect neutrinos artificially produced at particle accelerators hundreds of kilometers away. The main scientific goals of the experiment include the determination of the neutrino mass hierarchy and the leptonic CP violation angle, the two still unknown fundamental parameters of neutrino oscillation. The determination of the neutrino mass hierarchy is of crucial importance e.g. for the study of the neutrinoless double beta decay.

Jukka Maalampi, professor

Wladyslaw Trzaska, senior researcher

Kimmo Tuominen, senior lecturer, HIP project leader

Roshan Foadi, postdoctoral researcher 1.11.-

Hidenori Sakuma (HIP), postdoctoral researcher -31.3.

Chitta Das, visiting scientist

Tommi Alanne, graduate student

Timo Alho, graduate student

Tuomas Karavirta, graduate student

Janne Riittinen, graduate student

Kai Loo, graduate student

Tuomo Kalliokoski, graduate student

Ville Vaskonen, graduate student

Sampsa Vihonen, MSc student

In August 2013 CERN Research Board has approved WA105 experiment – a 6 x 6 x 6 m³ liquid argon demonstrator that will be exposed to charged hadrons beam in the CERN North Area. This is a major milestone for the development of the liquid argon detector for LAGUNA. In 2013 our group has contributed primarily to the design, costing, safety issues and physics performance of LENA – the liquid scintillator alternative. The most exciting result is the high competitiveness of LENA in determining the neutrino mass hierarchy with the long baseline beams and its suitability to the DAEdALUS approach to measure the phase of CP violation in the leptonic sector.

Sterile neutrinos

Sterile neutrinos lack fundamental gauge interactions, but nevertheless they should manifest themselves by modulating the known three-flavour neutrino oscillation pattern. This would affect for example the energy spectrum of solar neutrinos. We have been investigating whether the observed flatness of the SuperKamiokande neutrino electron scattering spectrum and the downturn of the charged current spectrum in solar neutrino data can be explained in the context of an extension of the standard three-neutrino scheme with light sterile neutrinos.

Particle physics beyond the Standard Model

Kimmo Tuominen

The Higgs boson, discovered at CERN Large Hadron Collider (LHC) in July 2012, is at the focus of elementary particle phenomenology. The currently established properties of the Higgs boson provide important constraints for current particle physics models. Further data and analyses are hoped to more precisely pinpoint the physics responsible for the electroweak symmetry breaking (EWSB) and to a possible theory beyond the Standard Model (BSM). For several years both EWSB and BSM have been our research focus, and several pioneering model studies have been carried out; these have now been augmented also with current LHC data. Our studies constitute an integral part of the activities of the Helsinki Institute of Physics project *Laws of Nature and Condensed Matter Phenomenology at the LHC* (project leader K. Tuominen). Additional funding sources include the Academy of Finland (SA), private foundations and EU.

Composite Higgs (i.e. Technicolor) and supersymmetric models remain as well motivated candidates for BSM physics. Within both classes (and also combining the two paradigms) we have built models, analysed their collider signatures, established possible dark matter (DM) candidates and studied the nonperturbative properties of Technicolor models on the lattice. In our studies of DM candidates we collaborate with K. Kainulainen's Cosmology group at JYFL and in lattice studies we collaborate with Prof. K. Rummukainen's group in Helsinki.

Our group has established an international leading role in using large scale lattice simulations to gain insight into nonperturbative conformal dynamics of strongly interacting SU(N) gauge theories. While our primary motivation is in the applications for BSM model building, our results are important for understanding the dynamics of strong interactions in general. The lattice calculations with Wilson fermions are subject to large discretization errors, so called lattice artifacts, but there exists a systematic way to diminish these errors by improving the fermion actions. Earlier, we have developed and optimized the improved Wilson fermion actions in SU(2) and SU(3) gauge theories with matter fields in the fundamental or higher representations. During last year these actions have been applied in large scale numerical lattice simulations to obtain reliable results on nonperturbative dynamics of these theories.

A complementary method to obtain nonperturbative information on strong interactions is the application of gauge/gravity correspondence, i.e. holography. During 2013 we studied QCD in the Veneziano limit at finite temperature and particle number density using a holographic model. The model incorporates the renormalization group running and chiral symmetry properties of the boundary

theory into the gravity dual, and also describes the nonperturbative backreaction of the fermion flavors onto the gravity solution. Analyses within this model will be continued in order to establish a dual representing real QCD as closely as possible. During 2013 we also constructed a novel holographic model for QCD-like theories.

The model was applied to compute the spectra and vacuum properties of the corresponding field theory and analysed their behaviors when approaching conformal window. The results can be used as a guide and checked in lattice simulations.



Prof. Keijo Kajantie, the new honorary doctor of JYU.

Cosmology

Kimmo Kainulainen

Kimmo Kainulainen, professor
Tommi Alanne, graduate student
Henri Jukkala, graduate student
Mikko Pääkkönen, graduate student
Pyy M. Rahkila, graduate student
Ville Vaskonen, graduate student
Antti Hämäläinen, MSc student

The current Standard Cosmological Model (SCM) is a very simple and successful theory, which explains almost all existing observational data. On the other hand, it contains several ingredients of unknown origin. We still do not know the nature or origin of the dark matter (DM) or the dark energy (DE), which control the evolution of the universe at large scales, and we do not have a particle physics model for inflation responsible for the initial density perturbations, or for the dynamical mechanism that is responsible for the origin of the matter in the Universe.

In the context of homogeneous and isotropic SCM the dark energy, in a form of a cosmological constant, is needed to explain the accelerated expansion of the universe. Yet, Universe is known to be inhomogeneous at least up to 10Mpc scale and maybe more. We have studied the influence of large nonlinear structures on cosmological observations, and in particular large local void models, which incorporate the matter and radiation fluids as well as the DE. The apparent accelerated expansion could also indicate that

Einstein's theory loses validity at large distances, and we have studied extended scalar-tensor theories and $f(R)$ -gravity models in this context. Also weak gravitational lensing by nonlinear structures can affect the interpretation of the cosmological observations. Direct modelling of WL corrections by use of N-body simulations is very time-consuming however. We have developed a stochastic method and a numerical code, turboGL, based on it, which allow a fast and accurate way to evaluate WL corrections.

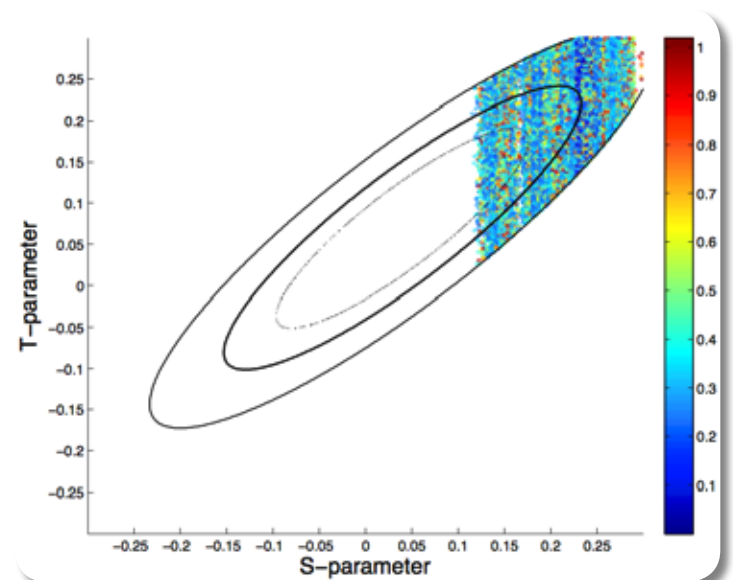


Fig 1. Distribution of Monte Carlo generated MWTC-models consistent with all constraints in the Peskin-Takeuchi (S,T)-parameter plane. Ellipses display the 1σ - 1.6σ - and 2.6σ - allowed regions from the precision electroweak data and the color coding displays the fraction of the total DM-density predicted by each model.

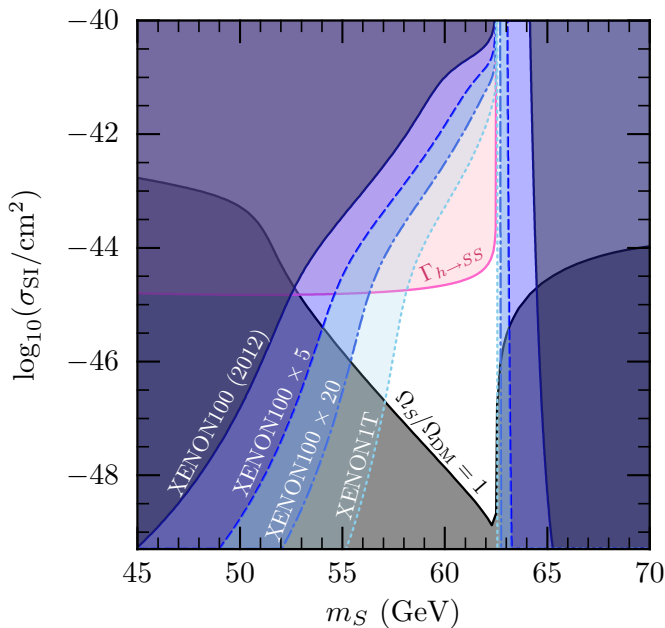


Fig. 2. Shown is the allowed region (white) in the singlet scalar DM model as a function of DM mass m_s and the predicted direct detection cross section σ_{SI} . Gray area corresponds to too much DM and dark blue areas show the current (2012) and projected constraints from the XENON experiment. Red area is ruled out by the Higgs particle decay width constraint from the LHC experiment.

We are currently adapting the method for computation of weak lensing distortions to the angular power spectrum in the CMB and on analysis of the angular distribution of quasar double images.

The second major unknown component in the SCM is the dark matter. We have studied several particle DM candidates in our group, including minimal walking technicolor models (MWTC). We have shown that our MWTC model can induce a dynamical electroweak symmetry breaking, solve the hierarchy problem, give a gauge coupling unification and provide a viable DM particle, all the while being fully consistent

with all existing cosmological and laboratory constraints. Strongest tests on the model come from the precision electroweak constraints (see Fig. 1) and from the direct DM detection experiments. We also investigated the simplest possible particle DM candidate, a singlet scalar DM. After making a thorough analysis of all existing constraints on the model we found that singlet scalar DM is a viable option in a rather wide range of model parameters. In particular, there is an interesting allowed window at $m_s \approx 55\text{GeV}-62.5\text{GeV}$, which cannot be ruled out by any foreseeable experiment (see Fig.2).

The third major problem in the SCM concerns the existence of the matter-antimatter asymmetry in the Universe. Because SCM incorporates inflation, a period of superluminal expansion, which completely erases any pre-existing distributions, it cannot be imposed as an initial condition. While we do not know the precise a dynamical mechanism that creates this asymmetry, we know that it necessarily involves C- and CP-violating out-of-equilibrium processes and both coherent and non-coherent interactions of quantum fields. Treating such systems requires advanced tools of quantum transport theory and our our group is a world leader in developing such methods. In particular the coherent Quasi Particle Approximation (cQPA), recently developed by us, can be used to model the evolution of quantum reflection- and particle-antiparticle coherences in the presence of decohering interactions. As an example, we are using cQPA to compute the particle-antiparticle asymmetry from resonant Leptogenesis. We are also applying cQPA to Electroweak Baryogenesis (EWBG), where it is the only known method that can correctly describe quantum reflections, which are crucial for steep background fields. However, for slowly varying fields the semiclassical methods, developed earlier in our group, are applicable. We used

a semiclassical analysis to study the EWBG in the singlet scalar model mentioned above, and found out that the it can explain either the

baryon asymmetry or the DM, but not both at the same time.



Doctoral defence ceremony at the Department. From the left the opponent Antonio Rago, the defender of thesis Tuomas Karavirta, and the custos Kimmo Tuominen.

Industrial Collaboration

Markus Ahlskog
Markku Kataja
Ilari Maasilta
Timo Sajavaara
Jussi Timonen
Ari Virtanen

Again in 2013, The Industrial Applications group of the accelerator laboratory had several contacts with domestic and foreign industry and research laboratories. Forty six irradiation campaigns for 23 companies or organizations and five universities were performed at RADEF facility. In addition to ESA also the institutes like German Aerospace Center (DLR), French Alternative Energies and Atomic Energy Commission (CEA) and Naval Research Laboratory (NRL) from Washington DC, USA, visited the facility. The regular company collaborators, e.g. ATMEL, EADS ASTRIUM and Thales Alenia Space were again performing tests at RADEF. Also, Cypress Semiconductor (San Jose, CA, USA) and Synergy Health (Oxfordshire, UK) performed their tests for the first time at RADEF.

In 2013 we finalized the technical assessment project for ESA on "Effects of the ion specie and energy on the oxide damage and SEGR failure". The objective of this study was to determine the worst-case conditions for SEGR testing. The results have been accepted for publication in IEEE Transactions on Nuclear Science and will be included in the next SEE test guidelines of ESA. RADEF participated also in EU's FP7-Space-2010-1 project (<http://www.skyflash.eu/>), where the aim was to develop RadHard non-volatile flash memories for space applications. This project will end in February 2014 and the methodology focused on environments affected by radiation due to electrons, protons and energetic heavy ions. Our standard high-penetration ion cocktail

was used in the three test campaigns performed during the years 2012 and 2013.

The irradiations of the polymer membranes for Oxyphen AG were also continued with several campaigns in the year 2013.

The total beam time used for these activities was 1455 hours. From those 64 % was used for space related studies, 25 % for other irradiations and R&D work and the rest of beam time was used for basic research. The revenue continued growing already four years running, being 771 000 € in the year 2013.

The Accelerator Based Materials Physics group within the Accelerator Laboratory has continued an active industrial collaboration both with international and domestic companies in 2013. The group is a research partner in a major TEKES project (MECHALD) in which the mechanical properties of atomic layer deposited films are studied within a consortium including groups from Aalto University and VTT. In a TEKES/EAKR project HIUDAKE, which ended in June 2013, new detectors and digitized data acquisition were developed for ion beam analysis, and as a result of this project a new high performance energy detector based on gas ionization was taken into use. The export of JYFL designed and constructed analysis instruments continued by installing a time-of-flight-energy telescope for ion beam analysis to Imec, Belgium. The installation of highly versatile atomic layer

deposition system to the NSC clean room has, in close connection to all the characterization tools available at the campus, opened new possibilities for industrial collaboration. This purchase was funded by the EU through the Regional Council of Central Finland, University of Jyväskylä and local companies.

The Experimental Nanophysics groups have well established collaboration with a few companies in Finland. In the past years, ultrasensitive superconducting radiation detectors for X-rays have been developed in collaboration with industry. In 2013 a TEKES funded project continued, where our new ultrasensitive X-ray spectrometer setup developed in a previous TEKES project is being used for novel terrestrial materials science applications in collaboration with the accelerator based materials physics group. In addition, in the same project commercial wafer scale superconducting detector fabrication is being developed in collaboration with VTT Micronova micro- and nanofabrication center in Espoo. The industrial partners include Oxford Instruments Nanotechnology Tools Ltd from the UK, Star Cryoelectronics Inc. from USA and Aivon Oy from Helsinki. The nanophysics groups are also actively involved in the NANOPALVA EU funded project, where novel nanoscience instrumentation tools are developed for industrial applications, such as the previously mentioned atomic layer deposition tools, as well as 3D laser lithography tool and the nanosensor test station with environmental control combined with sophisticated measurement strategies. The molecular electronics and plasmonics group continued collaboration with companies Beneq Oy and lamit.fi on integrable solar energy collection, till the summer 2013. In addition, the Molecular Technology group has collaborated with nEMCEI Ltd., a local start-up company, in investigating the conductive properties of carbon nanotubes

solubilized with hemi-cellulose. The company obtained in 2013 a patent on the solubilization method. Quantum Nanoelectronics group, on the other hand, is currently involved in the large TEKES project DEMAPP, which involves industrial collaboration with several companies such as Metso and Moventas.

The Soft Condensed Matter and Statistical Physics group continued its long-term collaboration with a number of Finnish and European companies in several long-term and short-term applied research projects.

The group runs an extensive x-ray tomographic laboratory that includes three x-ray scanners used in non-invasive three-dimensional imaging and analysis of the internal microstructure a wide range of heterogeneous materials. The laboratory is also equipped with adequate sample preparation and manipulation devices, a versatile set of instruments for measuring transport properties in porous materials, and with an ultra fast camera system for imaging absorption and spreading properties of liquid droplets of down to picolitre size. All these devices were widely used in applied research with industrial partners, e.g. for the analysis of structural and transport properties of fibre based materials, ceramics and minerals. Experimental work was complemented with material modelling, and here basic research results of the group were taken in immediate practical use. The traditional close collaboration with VTT Technical Research Centre of Finland was continued, involving e.g. 3D structural analysis of various types of materials of industrial relevance.

Individual projects were related e.g. to development of novel bio-based materials, their barrier, strength, deformation, fracture, printing and optical transmission properties, and to the safety

analysis of repositories of spent nuclear fuel. The group has a long tradition to develop ultrasound methods for the assessment and monitoring of bone quality, and for diagnosing osteoporosis, including related device development, possibly in collaboration with manufacturers. This work was successfully continued.

Industrial collaborators included Stora Enso, UPM-Kymmene, Metsä-Botnia, Posiva, Metso, Numerola, Paperra, Jyväskylä Innovation, Paroc, Borealis, Oscare Medical, CSC (IT Centre for Science Ltd), Institute for Surface Chemistry (YKI) and Innventia in Stockholm, and Glass and Ceramics in St. Petersburg. Through an EU

FP7 project collaboration was also started with Allinea Software (UK), Cray UK Ltd, German Aerospace Centre, The Center for Information Services and High Performance Computing (Germany) and The European Centre for Medium-Range Weather Forecasts.

In addition to industry, funding to applied research was received from Finnish Program for Strategic Centres for Science, Technology and Innovation (SHOK), EAKR/Regional Council of Central Finland, Technology Development Centre of Finland and the Ministry of Employment and the Economy.

Education

Jukka Maalampi
 Jussi Maunuksela
 Juha Merikoski

- Jukka Maalampi, professor
- Juha Merikoski, university lecturer
- Jussi Maunuksela, university lecturer
- Pekka Koskinen, academy research fellow
- Toni Purontaka, graduate student
- Kaisa Aho, MSc student
- Mikko Ahonen; MSc student
- Saara Alatalo; MSc student
- Mauri Jauhiainen, MSc student
- Toni Pikkarainen, MSc student
- Vesa Pitkänen; MSc student
- Paula Pöyhönen, MSc student
- Reetta Ranta-Kuivila, MSc student
- Anni Rossi, MSc student
- Joonas Soinen, MSc student



A key element behind the high-quality education of the Department is the way frontline research done at the laboratories is connected with education. Another one is the interactive approach to education by promoting contacts and collaboration among students and between students and the personnel. This is the direction in which teaching at the Department has been further developed during the year.

From teaching to learning

The development of basic level courses has continued at the Department, with the emphasis shifting from teaching to learning. This development has been extended to subject level teaching

where interactive teaching methods have been adopted on quantum mechanics courses. On the first physics courses peer instruction utilizing clickers has become an established method to promote learning. Also development of new ways to organize the homework problem recitals has been continued and extended to several other courses. These developments have further activated the students resulting in considerably better learning outcomes. The new six compulsory courses on mathematical methods have found their place in the curriculum with promising results. Ex tempore exercise sessions with immediate feedback have been used on the courses of the first year. This in part

means reduction of the amount of conventional lecture hours and increasing supervised small group work instead. Our next challenge is to continue adopting interactive teaching methods on higher-level physics courses.

Teacher Education

The trilateral co-operation between the Departments of the Faculty, the Department of teacher education and the Teacher training school has continued. Direct enrollment to teacher education, including the possibility to register during the first weeks of studies, has established itself as the main route to teacher qualifications. The Department participates in the Finnish graduate school of mathematics, physics, and chemistry education, with two students working on a degree of doctor or licentiate of philosophy in physics education.

Other Education Activities

In addition to its regular teaching program, the Department has continued the co-operation with the Open University supplementary-education program. The Department arranged four courses in the 23rd Jyväskylä International Summer School and for the first time a course was also organized for teachers. The course was called "Using Language to Teach Science: Researching Classroom Communication and Developing Dialogic Approaches".

The effort to reduce the number of undergraduates quitting their studies has continued with the introduction of teacher mentors. The teaching staff cast into this role will provide personal study counseling for each student during undergraduate studies. This effort is also aimed at enabling

completion of both undergraduate and graduate studies within their mandated times.

Contacts with schools

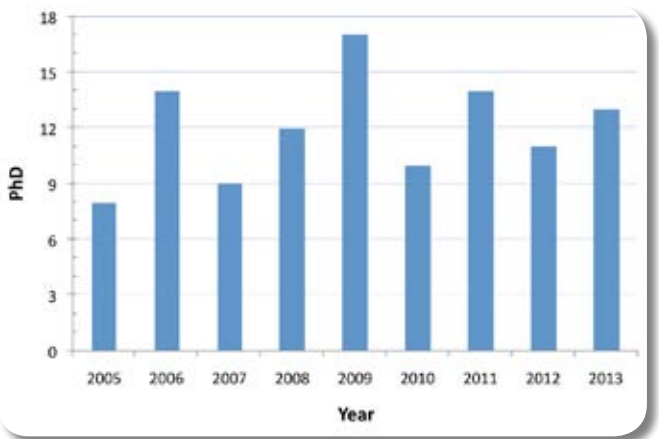
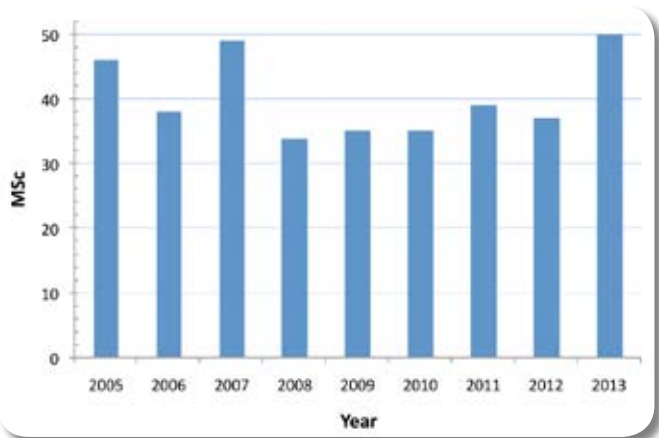
To provide high-school students a hands-on experience on research work the Department offered, in summer 2013 for a fifth time, summer jobs for students interested in science. The newspaper advertisement produced about 94 applicants from 22 schools, of whom twelve most promising students from different high schools were chosen to work in the research groups at the Department. The national training camp for Physics Olympics and training lectures for CERN visits of school students were also arranged at the Department.

The annual open-doors day for student recruitment was very successful, this time with a more attractive set of corridor demonstrations. As personal contacts have proven to be the most effective way of student recruitment, we have been reviving our visit program to schools and advertise the possibility for high-school classes to make visits in the Accelerator laboratory and the Nanoscience center. The contacts of the Departments of the Faculty with schools are being strengthened through the LuMa center of Central Finland, which was officially founded in January 2011.

Statistics

In spring 2013 there were 566 applications for physics studies, with 385 of them indicating physics as their first choice. As a whole, 90 undergraduate students enrolled in autumn 2013. Additionally 5 undergraduate students enrolled in January 2014. Over 90% of the new BSc

students are admitted based on their high school record and national matriculation exam result, the rest via a traditional entrance examination. The total number of undergraduate students is almost 500. Some students with a polytechnic engineering background study in the master programs for industrial physics and renewable energy. At the Department there are 85 post-graduate students aiming at the PhD degree. In 2013 there was a record number of MSc degrees (50 graduates) taken at the Department, 10 of them with teacher qualifications. The number of PhD degrees was 13.



Number of annual graduates with MSc degree and number of annual graduates with PhD degree.



Personnel

Head of the Department
Jukka Maalampi, prof.
Vice-Heads of the Department
Rauno Julin, prof.
Markku Kataja, prof.

PROFESSORS

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Kari J. Eskola
Paul Greenlees 1.9.-
Tero Heikkilä 1.8.-
Hannu Häkkinen
Ari Jokinen
Rauno Julin
Kimmo Kainulainen
Markku Kataja
Matti Leino
Jukka Maalampi
Ilari Maasilta
Matti Manninen, on leave
Jouni Suhonen
Jussi Timonen
Robert van Leeuwen
Juha Äystö, on leave

RESEARCH PROFESSORS

Jacek Dobaczewski (FidiPro award)
Paul Greenlees (ERC award) -31.8.

University lecturers

Konstantin Arutyunov
Sakari Juutinen
Hannu Koivisto
Markku Lehto (part time)

Kari Loberg
Jussi Maunuksela
Juha Merikoski
Iain Moore
Markko Mylly
Timo Sajavaara
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Tuomas Lappi 1.9.-
Janne Pakarinen
Thorsten Renk
Jussi Toppari

PhD scientists

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Kai Arstila
Karim Bennaceur 2.9.-
Saumyadip Chaudhuri
Claudia Gomes da Rocha
Tuomas Grahn
Pauli Heikkinen
Pasi Jalkanen (part time)
Arto Javanainen
Pekka Kekäläinen
DongJo Kim (HIP/JYFL)
Veli Kolhinen
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Topi Kähärä
Tuomas Lappi -31.8.
Jari Malm 1.3.-
Sami Malola
Keijo Mattila 2.9.-

Petro Moilanen
Astrid Morreale -15.4.
Harri Niemi
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Heikki Penttilä
Redamy Perez-Ramos
Vaia Prassa
Tuomas Puurtinen
Panu Rahkila
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Valery Rubchenya
Sami Räsänen (HIP/JYFL)
Hidenori Sakuma -31.3 (HIP)
Ari Salmi
Mikael Sandzelius
Jan Sarén
Catherine Scholey
Adrian Stan
Jouni Takalo
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Ari Virtanen
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Tommi Alanne
Timo Alho
Wafa Almosly
Kalle Auranen
Hussam Badran 15.10.-
Svitlana Baieva
Alexandre Bosser 1.3.-
Beomsu Chang (JYFL/HIP)

Axel Ekman
Yan Gao
Zhuoran Geng
Dmitry Gorelov
Mikko Haaranen 1.6.-
Jani Hakala
Tero Harjupatana
Ilkka Helenius
Olli Herranen
Andrej Herzan
Matti Hokkanen
Markku Hyrkäs
Tommi Isoniemi
Tero Isotalo
Ulrika Jakobsson
Henri Jukkala
Jaakko Julin
Juhani Julin
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Tuomo Kalliokoski
Taneli Kalvas
Tuomas Karavirta -31.1.
Vantte Kilappa
Oleg Kit
Rudolf Klemetti
Jani Komppula
Joonas Konki
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I. Helenius, K. J. Eskola and H. Paukkunen

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K. J. Eskola, H. Paukkunen and C. A. Salgado

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G. S. Denicol and H. Niemi

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T. Renk

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T. Lappi and H. Mäntysaari

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R. Chatterjee, H. Holopainen, T. Renk and K. J. Eskola

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I. Helenius, K. J. Eskola, H. Honkanen and C. A. Salgado

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T. Lappi and H. Mäntysaari

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T. Renk

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K. J. Eskola

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R. Chatterjee, H. Holopainen, T. Renk and K. J. Eskola

Centrality and initial formation time dependence of the emission of thermal photons from fluctuating initial conditions at RHIC and LHC
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T. Lappi and H. Mäntysaari

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I. Helenius, K. J. Eskola, H. Honkanen and C. A. Salgado

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T. Lappi

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T. Renk

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T. Lappi and H. Mäntysaari

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T. Renk

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R. Paatelainen, K. J. Eskola, H. Holopainen and K. Tuominen

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H. Niemi, G. S. Denicol, H. Holopainen and P. Huovinen

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T. Renk

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R. Chatterjee, H. Holopainen, I. Helenius, T. Renk and K. J. Eskola

Elliptic flow of thermal photons from event-by-event hydrodynamic model
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T. Renk

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T. Renk

The space-time structure of the energy deposition into the bulk medium due to jet quenching
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T. Renk

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T. Lappi and H. Mäntysaari

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H. Paukkunen and C. A. Salgado

Agreement of neutrino DIS data with global fits of parton distributions
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H. Paukkunen and C. A. Salgado

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PoS DIS2013 (2013) 273

H. Paukkunen, K. J. Eskola and N. Armesto for LHeC study group

Nuclear PDFs from the LHeC perspective
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NEUTRINO PHYSICS AND PARTICLE PHYSICS BEYOND THE STANDARD MODEL

See: Nuclear Structure, Nuclear Decays, Rare and Exotic Processes: Advances in High Energy Physics 2013 (2013) 505874

T. Alho, M. Järvinen, K. Kajantie, E. Kiritsis and K. Tuominen

On finite-temperature holographic QCD in the Veneziano limit
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126 GeV Higgs boson in the top-seesaw model
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M. Heikinheimo, A. Racioppi, M. Raidal, C. Spethmann and K. Tuominen

Dark supersymmetry
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See: Ultrarelativistic Heavy Ion Collisions -Theory
Phys. Rev. C 87 (2013) 4, 044904

N. Evans and K. Tuominen

Holographic modelling of a light technidilaton
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K. Tuominen

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COSMOLOGY

J. M. Cline and K. Kainulainen

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J. M. Cline and K. Kainulainen

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Phys.Rev. D 88 (2013) 055025

OTHERS

P. Koskinen

Vertaisopetus antaa oppimisen ja opetuksen elämyksiä
Yhdessä parempaa pedagogiikkaa (Jyväskylän yliopistopaino, 2013)

R. Tuovinen ja P. Koskinen

Strukturoitu pienryhmätyöskentely vapauttaa keskusteluun
Yhdessä parempaa pedagogiikkaa (Jyväskylän yliopistopaino, 2013)

THESES AND DEGREES

BSc THESES

(alphabetical order)

Aili Asikainen, Landaun teoria ja jatkuvat faasitransitiot

Eino Elo, Grafeeni elastisena materiaalina

Matti Eskelinen, Casimir-ilmiö teoriassa ja käytännössä

Hanna Hietala, iPadien käyttö fysiikan opetuksessa

Viivi Hyppönen, Tumahuokosen kuljetusmekanismi

Antti Hämäläinen, Einsteinin-Hilbertin aktio, hitaan liikkeen raja ja Schwarzschildin ratkaisu

Otto Ikäheimonen, Fluktuaatioista termodynaamisessa tasapainotilassa

Mauri Jauhiainen, Tutkimusmenetelmiä simulaatioiden käytön merkityksestä fysiikan oppimisessa

Henri Jäntti, Kosmisen taustasäteilyn löytyminen

Matias Kangas, Sähkömagneettisen säteilyn aiheuttamat ongelmat elektroniikassa

Jari Kinnunen, Bipolaaritransistorin Ebers-Moll -malli

Sami Kinnunen, Plasma-avusteinen atomikerroskasvatus

Ville Kivioja, Sähköheikon yhtenäisteorian Lagrangen tiheys

Mikko Koikkalainen, Röntgenlähteen stabiilisuus tomograamittauksessa

Joonas Korhonen, Bjorkenin hydrodynamiikka ultrarelativististen raskasionitörmäysten mallintamisessa

Olli Koskivaara, Skaalainvarianssi kvanttimekaniikassa

Jenna Kostian, Fysiikka nyt lukiokurssi

Henri Kulmala, Alkuaineiden tunnistus tuhkanäytteestä

Pekka Kurki, Oppimateriaalit fysiikan kokeellisessa opetuksessa - Nanokoulun oppilastöiden oppimateriaalien suunnittelu

Marko Käyhkö, Vismutti- ja kultavismuttinanolankojen lämmönjohtavuuden parantaminen

Topi Kääriäinen, Radioaktiiviset ionisuihkut ja niiden tuottaminen

Ilari Laajala, Geelielektroforeesioppilastyön suunnittelu ja toteutus

Valtteri Laitila, Energiatehokkuuden ennustemallien todentaminen HERS BESTEST -metodilla

Laura Laulumaa, Skalaarielektronien parinmuodostus Pöschl-Teller-potentiaalissa

Kasper Leppänen, Hiilinanoputkien ja grafeenin ominaisuuksien muokkaaminen ionisäteilytyksen avulla

Miika Leppänen, Fabrication of dc-SQUIDS for high-impedance environment

Juuso Leskinen, Katsaus pimeään aineen tutkimukseen

Taru Malminen, Ionisoivan säteilyn ja aineen välinen vuorovaikutus

Terhi Moisala, Charmoniumin energiatilojen numeerinen ratkaisu

- Tiia Nevalainen, Beetahajoaminen
yksihiukkas- ja yksiaukkoytimissä
- Johannes Nokelainen, Chaotic properties of
classical Coulomb-interacting few-particle
billiards
- Anssi Nykänen, Munuaistoiminnan
isotooppikuvauksen laadunvalvonta
dynaamisella fantomilla
- Sami Parviainen, Plasmonien
mallintamisen menetelmät metalliklustereille
- Matias Pekkarinen, Tietokonealgoritmi
elektroniikkapiirien simulointiin
- Pekka Pirinen, Kaksoismaagisten ytimien
hiukkas-aukko-viritykset
- Taneli Rantala, Fabrication and measurement
of NIS- and SIS-junctions
- Juha Suutari, Plasman karakteristinen
röntgensäteily
- Teemu Uksila, Keskittävä valosähkö
- Jukka Warttinen, KiCad-ohjelman käyttö
- Lasse Vuori, Ti/Au ohutmetallikalvojen
valmistus transiitoreunasensoreihin
- Ville Valkiala, Preparation and
Characterization of Chlorophyll A Films for
Plasmonic Applications
- Matti Väisänen, Formation of Planetary
Systems: Theories of Past and Present
- Mikko Haaranen, Microscopic Quasiparticle-
phonon Model in the Study of the Beta
Decay of Cd-115
- Hannu Hakalahti, Neutriinon
sekoitusmatriisin Majorana-vaiheet
- Jaana Hytönen, Biokaasu
liikennepolttoaineena
- Juhani Hyvärinen, Jäännösvuorovaikutuksen
mallintaminen Yukawa-potentiaalina
sovelluksena TDA-laskuja kaksoismaagisille
ytimille
- Joni Hämäläinen, Graphene Films for Gas
Sensing Applications
- Joonas Hämäläinen, Sädehoidon
annossuunnitelmien poikkeavuuksien
havaitseminen neuroverkoilla
- Tuomas Hänninen, Implementing the
3-Omega Technique for Thermal
Conductivity Measurements
- Teemu Isojärvi, Ohuiden nestefilmien
leviämisen epästabiilisuus kahden
nestefaasin tapauksessa
- Mauri Jauhainen, Argumentaatio fysiikan
simulaatio- ja oppilastyöopetuksessa
- Janne Kekäläinen, Assessment of
Environmental Impacts with Life Cycle
Methods in Nanotechnology Industry
- Jari Kinnunen, CMaS (Moventas
Condition Management System) -
kunnonvalvontajärjestelmän sisältö ja
prosessien kehitys

MSc THESES

(alphabetical order)

- Kaisa Aho, Use of Nanostructures as Oxygen
Carriers in Chemical Looping Combustion
- Mikko Ahonen, Puukuitususpension
suotautumisen kokeellinen mittaus
- Saara Alatalo, Tutkiva oppiminen ja
keskustelufoorumien käyttö yläkoulun
tähtitieteen kurssilla
- Rafael Cuellar, Analysis of 5 MW hydrogen
power system with thermal energy
- Mikko Koikkalainen, Järvisedimenttien
iänmääritys lyijyjajoituksella
- Mikko Konttinen, Mikrokokoistetut
leviämisvastus- ja nelipisteanturimittaukset
puolijohderakenteen varauksenkuljettajien
syvyysjakaumien määrittämisessä
- Joonas Koskinen, Schrödingerin
yhtälön sidottujen tilojen numeerisesta
ratkaisemisesta
- Henri Kulmala, Penningin loukun
lämpötilaregulaatio

- Annika Kurvinen, Sähköisen liikenteen kysyntäjoustopalveluiden tuottaminen ja hajautetun energiantuotannon tasapainottaminen
- Marko Käyhkö, Hiukkasherätteen röntgenemissio ohutkalvojen analysoinnissa
- Janne Laulainen, Mikroaalloilla lämmitetyn vetyplasman emittoiman valon aiheuttama fotoelektroniemissio metallipinnoilla
- Antti Lehtinen, Learner-generated Drawings in Physics Education
- Arbin Maharjan, Transparent and Conducting Thin Film Materials
- Tiia Monto, Efficiencies of the Drift Chambers in the EMMA Experiment
- Tatu Mustonen, Suora fotonituotto suurienergisissä ydintörmäyksissä sähkömagneettisen ja vahvan vuorovaikutuksen kertaluvussa $O(\alpha_{em}, \alpha_{\Sigma})$
- Dereck Mutungi, Degradation of Photovoltaics in Central Finland: A Comparative Study of Poly-Si and Heterojunction with Intrinsic Thin Layer Technologies
- Tero Nenonen, Pientalon hybridilämmitysjärjestelmän energiavirtojen ja CO₂-päästöjen analyysi
- Jarkko Nikkarikoski, Hybridilämmitysjärjestelmän tiedonkeruu ja -analysointi omakotitalokohteelle
- Mikko-Ilari Ojala, Tuulivoimalan vaihteistojen kunnonvalvonnassa käytettävän neuroverkkosovelluksen testaus, käyttöönotto ja jatkokehitys
- Tero Oravasaari, Kvasidegeneroituneiden steriilien neutriinoiden havaitseminen
- Jarno Parttimaa, Ionisuihkuanalyysien soveltuvuus Fabryn ja Perot'n interferometrin ohutkalvojen karakterisointiin
- Ossi Parvela, Polypropeenin fysikaalisten ominaisuuksien muutokset ekstruusioprosessissa
- Teemu Parviainen, Metal-nanoparticle-G4-DNA Conjugates and their DC Conductivity
- Ilkka Pekkala, Microfluidics for the Spectroscopy of Carbon Nanotubes
- Kyrylo Pervushyn, Estimating Critical Temperature of Superconductivity in A1 Nanoclusters
- Toni Pikkarainen, Initialization of the JYFLTRAP System
- Paula Pöyhönen, Hiukkanen Higgsistä
- Reetta Ranta-Kuivila, Kartoitus lukiolaisten Newtonin kolmannen lain osaamisesta voimavektorien avulla
- Taneli Rantala, Quantum fluctuations of the order parameter in superconducting nanowires
- Anni Rossi, Käsitetiestien synnyttämä keskustelu mekaniikan peruskurssilla
- Dongkai Shao, Functionalized Carbon Nanotubes for Next Generation Biosensor
- Petja Sidoroff, Uudenlaisen pystyakselitiurbiinin aerodynaaminen tarkastelu
- Tomas Snellman, Identified Charged Particle Flow and Unfolding Event-By-Event Flow in Heavy-Ion Collisions
- Joonas Soininen, Diffuusiosumukammio taustasäteilyn ja kosmisten hiukkasten havainnollistamisessa
- Janne Solanpää, Nonlinear Dynamics and Chaos in Classical Coulomb-interacting Many-body Billiards
- Ville Vaskonen, Standardimallin skaalasektorin laajennukset ja niiden kokeelliset ja kosmologiset rajoitukset
- Yliselä Eero, Paperirainan lämmityksen vaikutus vedenpoistoon paperikoneen puristinosalla

PhLic THESES

(chronological order)

Toni Purontaka, Modeling Concept Maps

Done by Physics Students

JYFL Laboratory Report 1/2013

Antti Pennanen

Light Coupling into Planar Dielectric

Waveguide by Plasmonic Nanoparticles

JYFL Laboratory Report 2/2013

PhD THESES

(chronological order)

Tuomas Karavirta, Improved lattice actions for

beyond the standard model physics

JYFL Research Report 1/2013

Rattanaorn Norarat, Development of

imaging with MeV ions

JYFL Research Report 2/2013

Ville Mäkinen

Modeling the atomic and electronic

structure of nanoparticle-ligand interfaces

JYFL Research Report 3/2013

Janne Kalikka, Density functional / molecular

dynamics simulations of phase-change

materials

JYFL Research Report 4/2013

Jani Turunen, Novel methods for analysis

of radioactive samples using position-

sensitive detectors, coincidence techniques

and event-mode data acquisition

JYFL Research Report 5/2013

Ville Toivanen, Studies of electron cyclotron

resonance ion source beam formation,

transport and quality

JYFL Research Report 6/2013

Norbert Novitzky, Study of the neutral pion

and direct photon production in Au+Au

collisions at $\sqrt{s_{NN}} = 39 - 200$ GeV

JYFL Research Report 7/2013

Panu Ruotsalainen, Development of the

recoil-beta tagging method and recoil-beta

tagging studies of As-66 and Se-66

JYFL Research Report 8/2013

Ulrika Jakobsson, A spectroscopic study of

low-lying states in neutron-deficient astatine

and francium nuclei

JYFL Research Report 9/2013

Taneli Kalvas, Development and use of

computational tools for modelling negative

hydrogen ion source extraction systems

JYFL Research Report 10/2013

Ville Kotimäki, Real-space Quantum Transport

in Two-dimensional Nanostructures in

Magnetic Fields

JYFL Research Report 11/2013

Mikko Laitinen, Improvement of time-of-flight

spectrometer for elastic recoil detection

analysis

JYFL Research Report 12/2013

Marko Rasi, Permeability Properties of Paper

Materials

JYFL Research Report 13/2013

BSc DEGREES

(main subject is physics)

Aatsinki, Olli

Andrejeff, Tanja

Eskelinen, Matti

Hakalahti, Hannu

Hyvärinen, Juhani

Hämäläinen, Antti

Jauhiainen, Mauri

Kekäläinen, Janne

Kinnunen, Jari

Kivioja, Ville

Koikkalainen, Mikko

Koskinen, Joonas

Koskivaara, Olli

Kulmala, Henri

Kurki, Pekka
 Käyhkö, Marko
 Leppänen, Kasper
 Leskinen, Juuso
 Li, Xin
 Malminen, Taru
 Parvela, Ossi
 Parviainen, Sami
 Peltonen, Teemu
 Peuron, Jarkko
 Pitkänen, Vesa
 Pohjolainen, Emmi
 Pöyhönen, Paula
 Rantala, Taneli
 Snellman, Tomas
 Suutari, Juha
 Valkiala, Ville
 Vihonen, Sampsa
 Väisänen, Matti

MSc DEGREES

(main subject)

*=MSc includes teacher's pedagogical studies

Aho, Kaisa (physics)*
 Ahonen, Mikko (appl. physics)*
 Alatalo, Saara (physics)*
 Almosly, Wafa (physics)
 Cuellar, Rafael (appl. physics)
 Haaranen, Mikko (theor. physics)
 Hakalahti, Hannu (theor. physics)
 Hytönen, Jaana (appl. physics)
 Hyvärinen, Juhani (theor. physics)
 Hämäläinen, Joni (physics)
 Hämäläinen, Joonas (appl. physics)
 Hänninen, Juho (physics)
 Isojärvi, Teemu (physics)
 Jauhiainen, Mauri (physics)*
 Kekäläinen, Janne (physics)
 Kinnunen, Jari (appl. physics)

Koikkalainen, Mikko (physics)
 Kontinen, Mikko (physics)
 Korri, Jukka (appl. physics)
 Koskinen, Joonas (theor. physics)
 Kulmala, Henri (physics)
 Kurvinen, Annika (appl. physics)
 Käyhkö, Marko (physics)
 Laulainen, Janne (appl. physics)
 Maharjan, Arbin (appl. physics)
 Monto, Tiia (physics)
 Mustonen, Tatu (theor. physics)
 Mutungi, Dereck (appl. physics)
 Nenonen, Tero (appl. physics)
 Nikkarikoski, Jarkko (appl. physics)
 Ojala, Mikko-Ilari (appl. physics)
 Oravasaari, Tero (theor. physics)
 Parttimaa, Jarno (appl. physics)
 Parvela, Ossi (appl. physics)
 Parviainen, Teemu (physics)
 Pekkala, Ilkka (physics)
 Pervushyn, Kyrylo (physics)
 Pikkarainen, Toni (physics)*
 Pitkänen, Vesa (physics)*
 Pöyhönen, Paula (physics)*
 Ranta-Kuivila, Reetta (physics)*
 Rantala, Taneli (physics)
 Rossi, Anni (physics)*
 Shao, Dongkai (physics)
 Sidoroff, Petja (physics)
 Snellman, Tomas (theor. physics)
 Soininen, Joonas (physics)*
 Solanpää, Janne (theor. physics)
 Vaskonen, Ville (theor. physics)
 Yliselä, Eero (appl. physics)

PHIL.LIC DEGREES

Toni Purontaka (physics)
 Antti Pennanen (physics)

PHD DEGREES

Tuomas Karavirta (theoretical physics)

Rattanaporn Norarat (physics)

Ville Mäkinen (physics)

Janne Kalikka (theoretical physics)

Jani Turunen (physics)

Ville Toivanen (physics)

Norbert Novitzky (physics)

Panu Ruotsalainen (physics)

Ulrika Jakobsson (physics)

Taneli Kalvas (physics)

Ville Kotimäki (theoretical physics)

Mikko Laitinen (physics)

Marko Rasi (applied physics)

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