



JYVÄSKYLÄ

DEPARTMENT OF PHYSICS UNIVERSITY OF JYVÄSKYLÄ
ANNUAL REPORT

2008



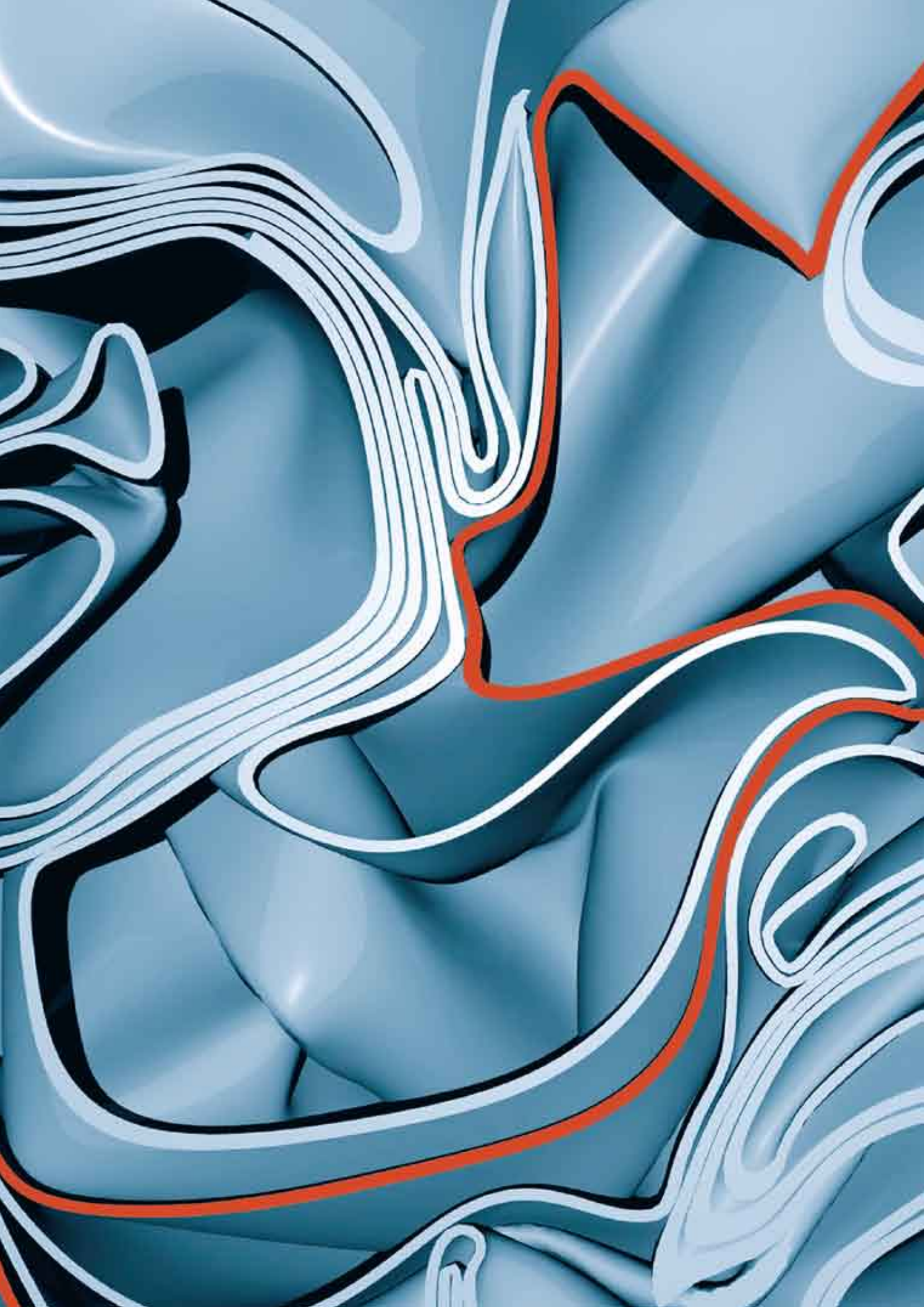
JYFL

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UNIVERSITY OF JYVÄSKYLÄ

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Contents

DEPARTMENT OF PHYSICS	4
RESEARCH	8
NUCLEAR AND ACCELERATOR BASED PHYSICS	8
Centre of Excellence in Nuclear and Accelerator Based Physics	8
Finland Distinguished Professor – FIDIPRO - Programme	10
Accelerator Facilities	12
Exotic Nuclei and Beams	14
Nuclear Spectroscopy	20
Nuclear Reactions and ALICE	25
Accelerator-Based Materials Physics	28
Industrial Applications	31
Nuclear Structure, Nuclear Decays, Rare and Exotic Processes	34
MATERIALS PHYSICS	36
Experimental Nanophysics and Nanotechnology	36
Computational Nanosciences	44
Soft Condensed Matter and Statistical Physics	47
HIGH ENERGY PHYSICS	50
Ultrarelativistic Heavy Ion Collisions – Theory	50
Theoretical Particle Physics and Cosmology	53
Industrial collaboration	55
Education	57
Personnel	60
Boards and committees	62
Peer reviewed articles	63
Theses and degrees	71
Theses	71
Degrees	72

Department of Physics

Preface

Research in the Department of Physics is focused on three main areas: high-energy physics and cosmology, materials physics, and nuclear and accelerator-based physics. The recent activities and scientific achievements of the research groups working in these fields are described in this annual report. The Accelerator Laboratory has the status of Center of Excellence (CoE) in nuclear and accelerator-based physics granted by the Academy of Finland for the period 2006-2011. The Department has also continued its relentless efforts to improve and develop the teaching and instruction of students. This activity received significant nationwide recognition when the Finnish Higher Education Evaluation Council (KKA) designated the Department

as a Centre of Excellence in University Education for the period 2010-2012.

Research

The research program in nuclear and accelerator-based physics spans basic experimental and theoretical research into nuclear structure, and extends to applications in biological and industrial physics. Our researchers in these fields have been very successful in garnering outside funding distributed on a competitive basis. Apart from the CoE, the Academy of Finland provides funds (within the Finland Distinguished Professor Programme (FiDiPro)), Professor Jacek Dobaczewski, whose group studies nuclear struc-



ture through application of the energy density functional theory. Experimental nuclear physicist Paul Greenlees was awarded by the European Research Council with a five-year ERC Starting Researcher Grant for the study of the structure and stability of heavy and superheavy elements. The Department and its accelerator laboratory carry, together with the Helsinki Institute of Physics (HIP), the main responsibility for Finnish participation in the FAIR project. Still in its infancy the project aims to construct a new international accelerator facility for ion and antiproton research in Darmstadt, Germany. The local facilities of the Department will be enhanced with the addition of a new cyclotron, the space for which is under construction with the appropriate bangs and jolting. Operation of the new accelerator is planned to begin in 2010.

In nanophysics a new professor, Ilari Maasilta, started his five year term in summer 2008. The selection process for another professorship, the position previously held by Päivi Törmä, was also started and will be completed in 2009. In addition to experimental re-

search carried out in the laboratories of the Nanoscience Center, research in theoretical and computational nanoscience has been highly recognized internationally. The nanophysics group has been active in creating collaboration with the Technical University of Tampere both in research and teaching. This activity is supported from the funds of the University Alliance Finland, the co-operative consortium of the Universities of Jyväskylä and Tampere and the Technical University of Tampere.

In high-energy physics the main activity has been concerned with the physics of ultrarelativistic heavy-ion collisions. Apart from the theoretical work in the field, which is internationally highly recognized, the Department also has an active experimental group. The experimental group participates in the ALICE experiment at the Large Hadron Collider (LHC) at CERN as well as the PHENIX experiment at Brookhaven National Laboratory. The LHC was supposed to move "from dream to reality" in autumn 2009, but unfortunately technical problems postponed the start. The Department has



continued its collaboration with the University of Oulu in the cosmic ray experiment EMMA located in the depths of the Pyhäsalmi mine. The Department also participates in LAGUNA, a pan-European project aiming to construct a large-scale underground experiment for the study of low-energy neutrinos and the stability of the proton. In cosmology, an important achievement was the development of quantum transport equations for non-equilibrium CP-violating systems. The traditionally vivid co-operation with HIP in high-energy physics and cosmology was further strengthened when two new projects of the HIP theory program started with coordination at the Department.

Industrial Collaboration

The Department has industrial collaboration in three main directions, in accelerator based physics, nanophysics and soft condensed matter physics. The industrial application group in the accelerator laboratory has numerous contacts with domestic and foreign industry and research laboratories. The RADEF facility, used for testing electronic components, made a new record in terms of the beam time used. A major event was the RADECS 2008 Workshop which was organized by the group, with Ari Virtanen as the chairman. The Jyväskylä Convention Bureau awarded the organizers of the conference in recognition of the fact that it was the year's most significantly productive international conference in Jyväskylä.

In nanophysics industrial collaboration continued under several new projects, with partners including Nokia, Planar and Vaisala. In soft condensed matter physics the main activity was related to x-ray microtomography used, for example, in the study of the structure of paper, wood-fiber composites and biological samples. Fruitful

collaboration with the paper industry has continued.

In terms of contract research income, the Department of Physics is the leading unit of the University of Jyväskylä. It can be foreseen that the importance of contract research as a source of funding will increase in the future.

Education

A strength of the education delivered at the Department is its close connection to front-line research. This connection naturally arises as teaching and research are not separated as different tasks, but all teaching and research personnel are expected to take part in both activities. Also, students are integrated into the activities of research groups at an early stage of their studies. These were some of the features highlighted by the international evaluation panel, whose report led to the status of the Centre of Excellence in University Education that the Department was awarded for 2010-2012.

In terms of the number of graduations, 2008 was quite satisfactory. The number of MSc degrees was 34, showing a considerable but understandable decrease compared with the record result of the previous year (49). It did not come as a surprise to us that there was no "boom" of Master's degrees, witnessed in other departments through out the country, due to the deadline of moving fully to the two-tier degree system. As a result of constant monitoring of the progress of the students and personal tutoring, our Department has relatively few students with delayed graduation. The number of PhD degrees was 12, just one short of the official goal.

Personnel (permanent posts in parentheses)	175,5 (61,5)
- professors incl. research professors	13,5 (13,5)
- lecturers	5 (5)
- senior assistants	10 (9)
- assistants	2 (4)
- researchers	120 (4)
- technicians	21 (21)
- administration	4 (4)
+ several research assistants (MSc students)	
Undergraduate students	490
of which new students	85
Graduate students	85
MSc degrees	34
PhLic degrees	1
PhD degrees	12
Credits (national)	9920
Median time to complete M.Sc (years)	5,9 years
Number of foreign visitors	275
- in visits	320
Visits abroad	325
Peer reviewed publications	177
Conference proceedings	43
Newspaper articles etc.	14
Conference and workshop contributions	
- Invited talks	90
- Other talks	90
- Posters	95
Seminars outside JYFL	~65
Funding (million €)	12,0
* University budget (incl. premises)	7,4
* External funding	4,6
- Academy of Finland	1,8
- Technology Development Centre and T&E Centres	0,3
- International programmes	0,6
- HIP	0,5
- Contract research	0,9
- Others	0,5

Administration

The total funding of the Department in 2007 was 12.0 M€, about 3% more than in the previous year. The budget allocation remained at the same level as in 2008, 7.4 M€, being now 62% of the total funding. The external funding was 4.6 M€, showing a slight increase from the previous year. Taking into account the increase of rents and general costs and in particular of the salary costs, the resources available for running costs effectively decreased.

Sad News

Emeritus Professor of theoretical physics Pertti Lipas passed away on 22 November 2008. It was very sad news for all of us. Pertti Lipas belonged to the first generation of Professors of the Department, and with his open and always positive personality he played a central role in creating the good atmosphere and the community spirit characteristic of the Department.

Centre of Excellence in Nuclear and Accelerator Based Physics

The Finnish Centre of Excellence in Nuclear and Accelerator Based Physics (JYFL-CoE) nominated by the Academy of Finland for the period of 2006-2011 covers research and development work as well as ion-beam applications at the Accelerator Laboratory of JYFL and theoretical nuclear physics activities carried out at JYFL. Highlights and activities of the JYFL-CoE teams in 2008 are summarized in the succeeding reports.

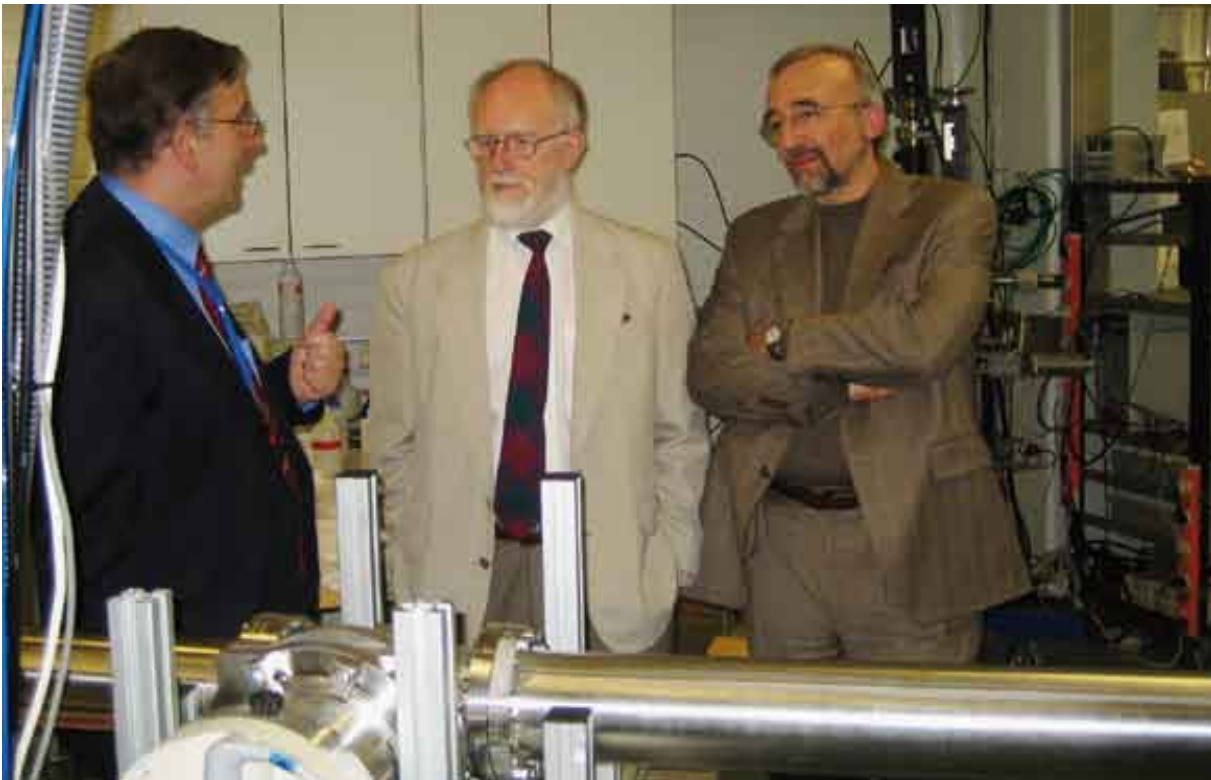
The JYFL-CoE activities at CERN including ISOLDE and ALICE form the Nuclear Matter Programme of the Helsinki Institute of Physics (HIP).

Scientific Advisory Board of the Centre of Excellence in Nuclear and Accelerator Based Physics

Witold Nazarewicz, professor, University of Tennessee, USA
William Gelletly, professor, University of Surrey, UK
Timo Tiihonen, vice-rector, University of Jyväskylä
Timo Jääskeläinen, professor, Academy of Finland
Anna Kalliomäki, secretary general, Academy of Finland

Members of the Programme Advisory Committee of the JYFL Accelerator Laboratory

Christian Beck, Dr., DRS-IPHC, Strasbourg, France
Mike Bentley, Dr., University of York, UK
Klaus Blaum, professor, MPIK and University of Heidelberg, Germany
Jacek Dobaczewski, professor, University of Warsaw, Poland and JYFL
Zenon Janas, Dr., University of Warsaw, Poland
Juhani Keinonen, professor, University of Helsinki, Finland (chairman)



Professor H. Whitlow introduces the Pelletron facility to the CoE-SAB members, Professor W. Gelletly and Professor W. Nazarewicz.

Most of the Finnish contributions in the FAIR project are covered by the activities of the JYFL-CoE teams for the FAIR-NUSTAR experiments and the Super Fragment Separator.

Following the midterm review on the 23rd April 2008, the Scientific Advisory Board (SAB) of the JYFL-CoE submitted a midterm report to the Academy of Finland. The SAB finds that the JYFL-CoE has been very successful and the proposed scenario for the future is realistic. Consequently, the Academy of Finland granted the JYFL-CoE a budget for 2009-2011 significantly higher than that for 2006-2008.

In 2008, the total number of beam time hours at the K130 cyclotron used by the JYFL- CoE teams in collaboration with foreign teams for basic research and industrial applications again summed up to more than 6000 hours. The Pelletron accelerator has also been in active use. The extension of the accelerator laboratory will be ready by the summer 2009 to house the new MCC30/15 cyclotron.



ERC-Grant Holder, Dr. Paul Greenlees.

The 8th European Workshop on Radiation Effects on Components and Systems (RADECS 2008) was organized by the Industrial Applications team on 10-12 September, 2008 in Jyväskylä. It welcomed 208 participants from 29 countries. The annual users meeting of the JYFL Accelerator Laboratory was held on 22 – 23 May 2008.

In total, 37 proposals for experiments were evaluated by the Programme Advisory Committee (PAC) of the JYFL Accelerator Laboratory in the meetings on 19 April and 4 October, 2008.

The European Research Council (ERC) has awarded a Starting Independent Researcher Grant of 1.25 million Euros to Paul Greenlees, for his research proposal "SHESTRUCT: Understanding the Structure and Stability of Heavy and Superheavy Elements". The five year project will revolve around the construction and exploitation of the new SAGE spectrometer, which is currently being constructed in a collaboration between the JYFL, the University of Liverpool and Daresbury Laboratory. A significant part of the funding for SAGE comes from a grant awarded by the U.K. EPSRC (transferred to STFC).

Jacek Dobaczewski

Finland Distinguished Professor – FIDIPRO - Programme

In 2008 the project has been going full steam. The FIDIPRO team was comprised of 9 researchers working together on common project goals. All detailed information on the FIDIPRO project and achievements is available on the project web page at <http://www.jyu.fi/accelerator/fidipro/>

In 2008, the FIDIPRO team published a study showing that single-particle energies in doubly magic nuclei depend almost linearly on the coupling constants of the nuclear energy density functional (EDF). Therefore, they can be very well characterized by the linear regression coefficients, which were calculated for the coupling constants of the standard Skyrme functional.

Jacek Dobaczewski, research professor
Jussi Toivanen, assistant (also with Nuclear Structure group)
Rayner Rodriguez Guzmán, senior researcher 1.6.-
Gillis Carlsson, postdoctoral researcher 1.1.-
Markus Kortelainen, postdoctoral researcher
Kazuhito Mizuyama, postdoctoral researcher
Francesco Raimondi, graduate student 1.9.-
Pekka Toivanen, graduate student 1.7.-
Marcin Borucki, ERASMUS student 1.9.-

This analysis has a direct connection with studies of shell structure of exotic nuclei, which are experimentally conducted at JYFL, predominantly through the mass measurements.



FIDIPRO-UNEDF collaboration meeting on nuclear energy-density-functional methods, October 9-10, 2008. Sitting from the left Andrzej Baran, Mario Stoitsov, Witek Nazarewicz, Jacek Dobaczewski*, Wojtek Satula, and Jussi Toivanen*. Standing from the left Paul-Henri Heenen, Jenni Kotila, Pekka Toivanen*, Nicolas Schunck, Markus Kortelainen*, Kazuhito Mizuyama*, Gillis Carlsson*, Francesco Raimondi*, Andrzej Staszczak, Thomas Duguet, Michael Bender, Nicolas Michel, Rayner Rodriguez-Guzman*, and Marcin Borucki*.

(*) denotes the FIDIPRO team members at JYFL (Photo: Paul Greenlees)

Regression analysis methods, relevant for the reliable determination of good nuclear energy-density-functional parameter sets for nuclear mass fits, which were in 2008 studied within the FIDIPRO project, are also closely related to the experimental program at JYFL. In particular, a simple model for nuclear binding energies and its regression analysis were used to study the validity and errors of the model's parameters and uncertainties of predicted nuclear masses. This work has won a spectacular recognition in the new on-line APS journal physics.aps.org that aims at spotlighting exceptional research: <http://physics.aps.org/synopsis-for/10.1103/PhysRevC.78.034306>

Another work completed in 2008 achieved a construction of nuclear energy density functionals in terms of derivatives of densities up to sixth, next-to-next-to-next-to-leading order (N^3LO). A phenomenological functional built in this way conforms to the ideas of the density matrix expansion and is rooted in the expansions characteristic to effective theories. It builds on the standard functionals related to the contact and Skyrme forces, which constitute the zero-order (LO) and second-order (NLO) expansions, respectively. At N^3LO , the full functional with density-independent coupling constants, and with the isospin degree of freedom taken into account, contains 376 terms, while the functionals restricted by the Galilean and gauge symmetries contain 100 and 42 terms, respectively. For functionals additionally restricted by the spherical, space-inversion, and time-reversal symmetries, the corresponding numbers of terms are equal to 100, 60, and 22, respectively. At present, we build a computer code that will solve the corresponding self-consistent equations.

On October 9-10, 2008 we organized at JYFL the FIDIPRO-UNEDF collaboration meeting on nuclear en-

ergy-density-functional methods (see the photo above). We had 10 visitors from the United States, Poland, Belgium, and France and about the same number of the JYFL participants. Instead of having formal talks, only specific discussion points were briefly introduced by selected participants and then covered in general open discussions. The main goal of the meeting was to review current and future projects, distribute tasks, set priorities, and define sequences of steps in developing the codes.

In the middle of 2008, we started a new activity aiming at the creation of an efficient Quasiparticle Random Phase Approximation (QRPA) computer program, designed for deformed nuclei. Our goal is to create a tool that would allow for a rapid determination of giant-resonance and beta-decay properties for nuclei across the mass chart. To solve the large-dimensional QRPA equations for deformed nuclei, a variant of Lanczos diagonalization method is adapted for QRPA. Two calculation strategies will be used: either a few lowest RPA phonons can be accurately calculated by using restarted Lanczos method, or strength functions can be calculated by using Lanczos moments method. Spherical code working on the harmonic-oscillator basis is being constructed first for testing and benchmarking purposes. All codes developed within this project will be rapidly published and made available to other researchers.

Related to the single-particle energies, in 2008 we also started a study of density dependent coupling constants in the nuclear EDF. In this work, density dependence has been systematically extended to all the coupling constants of the EDF. Preliminary results show that the single-particle energies cannot be too much corrected in this way, but some improvement can be obtained in the description of bulk nuclear properties.

Pauli Heikkinen and Hannu Koivisto

Accelerator Facilities

The use of the cyclotron in 2008 continued at a steady level of close to 7000 hours per year with 5341 hours on target. Rest of the time was for tuning the injection line and the cyclotron, beam developing and stand-by time caused by the experimental groups. A grand total of 100'000 hours of operation was reached on Saturday, February 7, 2009. Proton is still the most used ion, its share being 23.5 %. Protons were used mainly in IGISOL experiments and ^{123}I production for MAP Medical Technologies. Altogether 27 different isotopes from protons to ^{131}Xe were accelerated for experiments and applications in 2008.

Pauli Heikkinen, chief engineer
Hannu Koivisto, senior assistant
Olli Tarvainen, postdoctoral researcher 1.11.-
Arto Lassila, laboratory engineer
Veikko Nieminen, laboratory engineer
Jaana Kumpulainen, laboratory engineer
Kimmo Ranttila, laboratory engineer
Juha Ärje, laboratory engineer
Jani Hyvönen, operator
Anssi Ikonen, operator
Raimo Seppälä, technician
Tommi Ropponen, PhD student
Ville Toivanen, PhD student
Tarmo Koponen, MSc student
Janne Ropponen, MSc student
Markus Savonen, MSc student



Fig. 1. The construction of the Accelerator Laboratory extension, which will house the new MCC30/15 cyclotron and the IGISOL facility.

The construction of the Accelerator Laboratory extension for the new MCC30/15 cyclotron started in September 2008. Since early October, 2008, all light ion runs from the K130 cyclotron were stopped due to lack of radiation shielding towards the construction area. They can be continued in March, 2009, when the casting of concrete walls of the new laboratory area has been completed. The building will be ready by the end of June 2009 and then the installation of the new cyclotron can start. According to the contract with the manufacturer, NIIIEFA, the installation should be ready by the end of 2009.

The experiments have shown, that the main problems causing the low beam transmission of the JYFL accelerator facility are the asymmetric and hollow beam structures. The asymmetric beam is probably created by the analyzing magnet while the origin of the hollow beam structure is still partly unknown. Two quadrupoles were installed and tested upstream the analyzing magnet in order to correct the asymmetric beam shape. As a result, the accelerated beam intensity increased about 15 % in good agreement with simulations. However, in order to properly solve the asymmetric beam structure problem a new analyzing magnet is needed. A beam profiler, capable of charge state separation, will be designed and built in 2009 to study the origin of hollow beam.

Development work of the inductively heated oven was continued to improve the operation reliability. The oven was tested with the 14 GHz ECRIS for the production of titanium and chromium ion beams. In both cases the intensity of about 20 μA for the medium charge states was extracted from the ion source. The intensity of the Ti beam started to decrease after a few hours of operation.

A construction of a new plasma chamber for the JYFL 14 GHz ECRIS was started in fall 2008. Due to some modifications, enhanced beam currents of highly charged ions are expected. The commissioning of the chamber takes place by the end of 2009. Later, the new chamber will be used only for the "clean" ion beams, i.e. for materials, which do not cause contamination affecting the performance of the ion source.

The ignition of plasma was studied with the JYFL 14 GHz ECRIS in the pulsed operation mode. It was observed, for example, that it takes even several hundreds of milliseconds to reach the steady state of electron energies. The ion currents extracted from the ECR ion source reach their steady state condition faster than the bremsstrahlung emission.

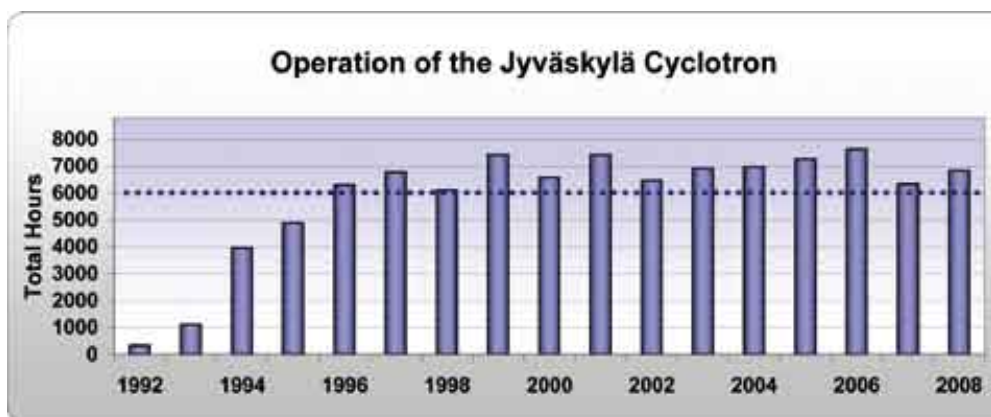


Fig 2. Operation of the Jyväskylä K130 cyclotron in 1992 – 2008.

Ari Jokinen, Iain Moore, Heikki Penttilä and Juha Äystö

Exotic Nuclei and Beams

Our activity in 2008 has followed the well-established path consisting of numerous experiments and R&D instrumentation both at JYFL and at ISOLDE, CERN. The work at ISOLDE is carried out within the Nuclear Matter Program of the Helsinki Institute of Physics (HIP). In addition, our group, with the support of HIP, has actively participated in the planning of the experiments within the NuSTAR collaboration for the Super Fragment Recoil Separator (S-FRS) at the future Facility for Antiproton and Ion Research (FAIR) at GSI.

Fig. 1. IGISOL group standing in the construction site of the accelerator laboratory extension. The plastic tube in the front in the picture goes down to the basement below the new IGISOL target area. From left to right, in the front row: Ari Jokinen, Iain Moore, Volker Sonnenschein, Juho Rissanen, Mikael Reponen, Heikki Penttilä, Jani Hakala; in the back row: Tommi Eronen, Pasi Karvonen, Antti Saastamoinen, Viki-Veikko Elomaa, Christine Weber and Juha Äystö.

Juha Äystö, professor

Ari Jokinen, lecturer

Iain Moore, senior researcher

Heikki Penttilä, head of research

Valery Rubchenya, senior researcher (Khlopin Radium Institute, St. Petersburg)

Saidur Rahaman, postdoctoral researcher – 30.9.

Christine Weber, postdoctoral researcher

Anu Kankainen, teaching assistant

Viki-Veikko Elomaa, graduate student

Tommi Eronen, graduate student

Jani Hakala, graduate student

Pasi Karvonen, graduate student

Thomas Kessler, graduate student

Juho Rissanen, graduate student

Antti Saastamoinen, graduate student

Volker Sonnenschein, graduate student

Mikael Reponen, graduate student

Jani Turunen, graduate student (STUK)

Vesa Partanen, MSc student

Heli Hoilijoki, summer student





Fig. 2. Cryogenic ion guide. Left: liquid nitrogen dewar mounted on top of the IGISOL vacuum chamber. The primary beam enters from the left. Right: view of the ion guide mounted on the end of a cold finger, surrounded by heat shielding which is also under vacuum.

Our team has significantly benefited from collaborations with several groups from Europe and the US as well as from the EURONS JRA projects and the Design Study projects EURISOL and DIRAC. Moreover, in 2008 a formal collaboration with the Finnish Radiation Safety Authority (STUK) was established on applied research.

The main developments in R&D involved studies of a cryogenic ion guide [1122] which was investigated in the framework of the DIRAC-DS in collaboration with KVI and GSI. In on-line tests a 340 MeV $^{58}\text{Ni}^{7+}$ beam from the K-130 cyclotron was degraded in energy, stopped in the cryogenic ion guide, cooled down to LN_2 temperature, and extracted successfully as a 30 keV $^{58}\text{Ni}^+$ beam. The absolute efficiency of the ^{58}Ni beam conversion was quite low, but was found to remain constant over four orders of magnitude variation of the stopped cyclotron beam, up to an ionisation rate density of 10^{14} ions $\text{s}^{-1} \text{cm}^{-3}$.

At ISOLDE, the ISCOOL project reached a successful milestone, when the new RFQ cooler/buncher started to serve on-line experiments. Clear improvements of ion-optical properties of ISOLDE-beams have been obtained, resulting in an increase of transmission efficiency and higher injection efficiency to REXTRAP. ISCOOL has also been used for the first time to improve the sensitivity of collinear laser spectroscopy at ISOLDE in a similar way as demonstrated earlier at JYFL. The obtained four orders of magnitude suppression of background has allowed the determination of spins, moments and isotope shifts for neutron-rich $^{67-80}\text{Ga}$ isotopes.

Experimental Highlights

In addition to the highlights described below, the main experimental achievements in 2008 included a demanding experiment to re-measure the EC branching of ^{100}Tc [1119] using purified sources of ^{100}Tc extracted from JYFLTRAP. The result implies that the ^{100}Mo neutrino absorption cross section to the ground state of ^{100}Tc is roughly 50% larger than previously measured. Other works included measurements of the superallowed beta decay of ^{42}Ti [1130], a double electron capture decay of ^{112}Sn , mass measurements of several proton rich isotopes in the vicinity of ^{56}Ni [1128] and of a few new neutron rich isotopes [1102] from fission (^{111}Mo , ^{114}Tc). Fission was also used to produce neutron rich medium heavy isotopes for level lifetime measurements [1132], where very good quality data were obtained for odd masses $A = 105 - 111$ using the Advanced Time-Delayed method.

IMME test at $A=23$. The isobaric multiplet mass equation (IMME) connects the masses of isobaric analogue states (IAS) of a given isospin multiplet ($T \geq 1$) in a simple polynomial form. Assuming that the charge-depend-

ent interaction is treated properly and neglecting mixing of states with different isospin, one obtains IMME in a quadratic form $M = a + bT_z + cT_z^2$.

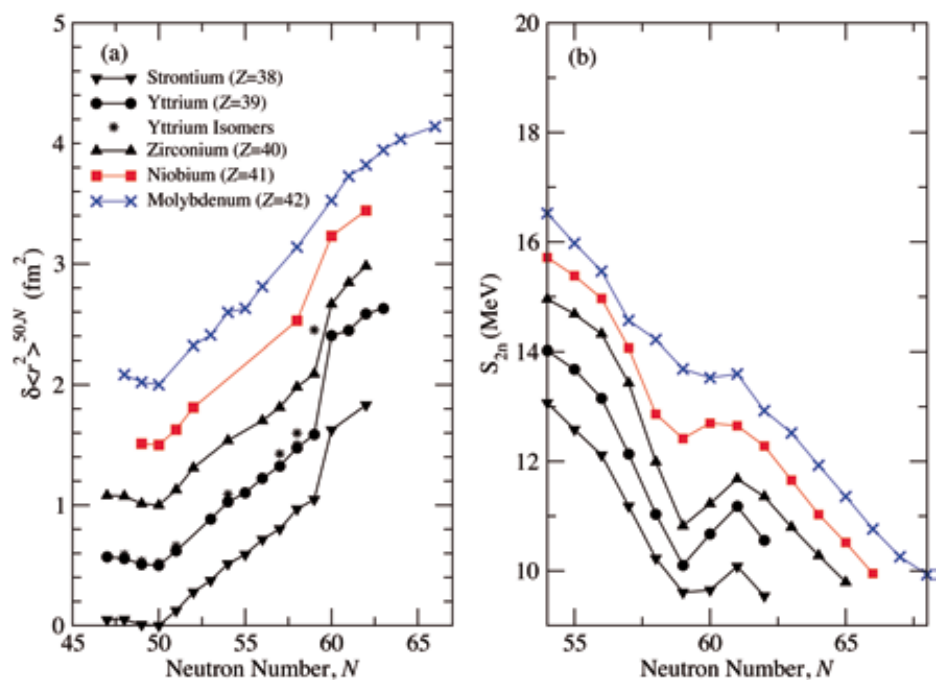
IMME can be used locally to predict masses of unknown members of an isospin multiplet. Its coefficients provide means to adjust shell model calculations. Up to now, definite deviations from a quadratic IMME have been observed only in the $A=8$ and 9 multiplets. In the $A=35$ isospin quartet some hints of a breakdown of IMME have recently been reported. We have studied another quartet with $A=23$ by measuring the mass of ^{23}Al at JYFLTRAP with sub-keV precision. By combining the new mass of ^{23}Al with an improved energy for the IAS in ^{23}Mg recently measured at Texas A&M and other well-known members of the $A=23$ isospin $T=3/2$ quartet, we get an extremely good fit for IMME in its quadratic form. The obtained value of $d = 0.25(43)$ keV for a possible cubic term coefficient suggests no need for higher than second order terms. This result now provides the most stringent test for the quadratic IMME in the sd -shell.

Laser spectroscopy [1129]. The laser-IGISOL group (Manchester and Birmingham collaboration) used 2008 to exploit their new metastable ion spectroscopy to the fullest. The exotic fission fragments of both niobium and molybdenum, two of the most challenging elements in the Periodic Table, were studied for the first time and in the latter case measurements reached as far as $N = 66$. Indications from the IGISOL mass measurements, that the sharp $N = 60$ shape change is finally lost in Mo, are borne out by the new charge radii measurements (Fig 3).

Fig. 3. Charge radii and mass measurements in the neutron-rich $A \sim 100$ region.

Superallowed beta decays [1130]. The most precise value of the V_{ud} element of the Cabibbo-Kobayashi-Maskawa (CKM) matrix is obtained from superallowed beta decays. During recent years, several experiments have been performed employing the Penning trap setup JYFLTRAP to further refine the data required for V_{ud} determination. The most recent additions are the precise Q-value measurements of ^{50}Mn and ^{54}Co with the trap and the branching ratio and half-life measurement of ^{42}Ti performed with external collaborators. The data for the thirteen most precise superallowed emitters are now in excellent agreement with each other. Additionally, the precision of ^{42}Ti was improved significantly.

Trap-assisted spectroscopy [1125, 1137]. The unique possibilities of the IGISOL facility coupled to the JYFLTRAP purification trap are used to provide monoisotopic beams of refractory elements. The studied exotic, neutron-rich nuclei around mass $A=110$ are located in a region of rapid nuclear shape changes and close to the path of the astrophysical r -process.



Radiation emitted by the exotic decaying nuclei was investigated with three Ge detectors and a 3π transmission beta counter.

The decay of ^{111}Mo , an isotope having 11 more neutrons than the nearest stable Mo isotope, was observed with sufficient statistics for the construction of the decay scheme and a measurement of the previously unknown half-life. For $^{109,111}\text{Mo}$ and $^{109,114}\text{Tc}$ a few gamma transitions previously known from spontaneous fission data were confirmed to belong in their decay. In addition, the Q_β values of ^{111}Mo and ^{114}Tc were obtained from the relative measurements of the masses of parent and daughter nuclei employing the JYFLTRAP setup. The Q_β value for both isotopes is about 1 MeV higher than the AME2003 atomic mass evaluation value. Similarly, the excitation energy of the 2.0-s isomer in ^{98}Y was measured to be significantly higher than the previous estimate. In this case, the isomeric state of ^{98}Y was prepared using the Ramsey cleaning technique.

The results prove trap-assisted spectroscopy to be a fully-fledged experimental method for finding new data on very exotic, neutron-rich nuclei. The use of extremely pure samples combined with coincidence

spectroscopy provides a firm means of ascribing gamma transitions to the decaying parent nuclei.

Beta decay of ^8B [1123]. The present solar-neutrino detectors are primarily sensitive to neutrinos from ^8B decay. As the neutrino spectrum from the Sun is now being measured with increasingly better statistics, it becomes possible to identify differences between the spectrum measured from the Sun and the laboratory measurements. We produced a very clean and intense beam of ^8B for a laboratory measurement of the spectrum of the ^8B decay. Over 10 million coincident alpha decay events following the beta-decay of ^8B were measured, improving existing statistics significantly. In particular, our alpha spectrum extends to much lower energy – corresponding to the high energy neutrinos detected in solar neutrino detectors – than any measurement before.

SnSbTe cycle at the endpoint of the rp process [1124]. One of the central features of the astrophysical rp-process in x-ray bursts is the existence of closed SnSbTe cycles, which occur when the process path crosses a predominantly alpha decay region in neutron-deficient tellurium isotopes. These cycles could cause a limited flow towards heavier nuclides and additional helium production to boost the energy generation in stars.

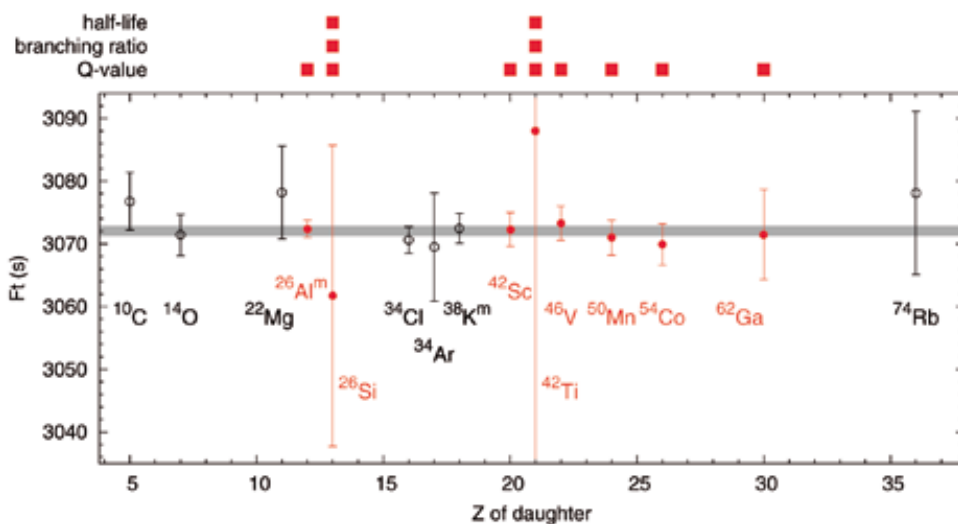
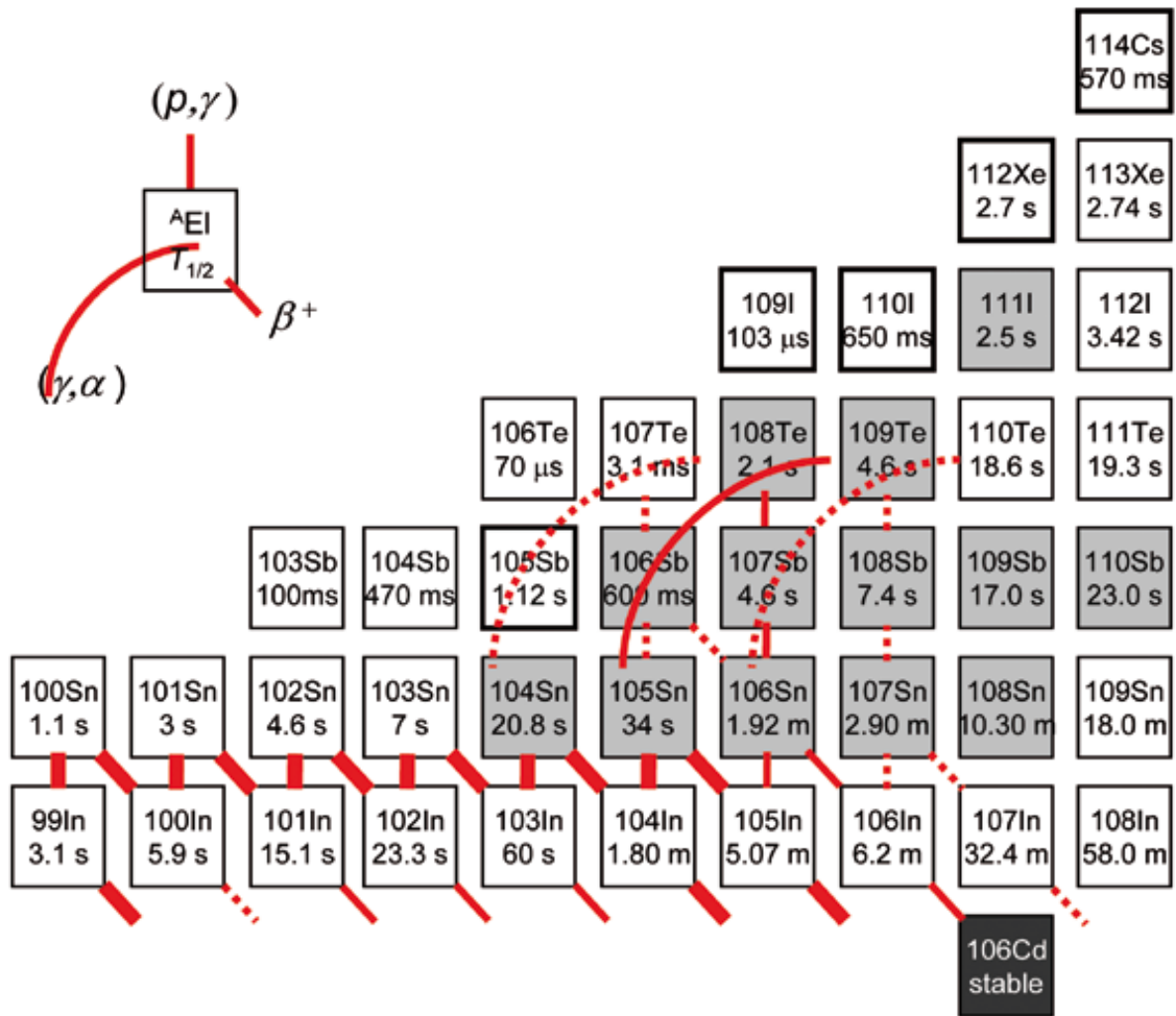


Fig. 4. Ft values for different superallowed decays. The red solid circles indicate decays that have contribution from measurements using JYFLTRAP. The solid squares depict the type of contribution. The world average Ft -value (with one standard deviation) is indicated with a grey horizontal bar.



The existence of this endpoint region depends strongly on the masses of the nuclides involved. The masses of $^{104-108}\text{Sn}$, $^{106-110}\text{Sb}$, $^{108,109}\text{Te}$ and ^{111}I have been directly measured with JYFLTRAP with δm better than 10 keV. This has allowed the determination of precise single-proton separation energies S_p for a number of exotic nuclides, see Fig 5. These include the antimony isotopes which have been considered as gates for the rp-process flow towards the region of alpha-radioactivity. Our results, for example, $S_p(^{105}\text{Sb}) = -318(23)$ keV and $S_p(^{106}\text{Sb}) = 424(8)$ keV,

Fig. 5. Endpoint region of the rp-process. The nuclides recently studied at JYFLTRAP are marked in grey. Their masses and those derived via proton or alpha decay (bold boxes) allow for a refined definition of single-proton separation energies S_p in studies of the closed SnSbTe cycles.

definitely exclude the possibility of strong SnSbTe cycles. This will diminish the secondary helium production and hence affects the composition of the ashes of type I x-ray bursts, compared with calculations based on previous experimental S_p values.

Experiment spokespersons and collaborating institutes in 2008

[I102] Precision atomic mass measurements of neutron-rich nuclei with JYFLTRAP

A. Jokinen, JYFL

[I118] Continuation to the program of development and testing of the resonance laser ion source at IGISOL

I. D. Moore, JYFL

University of Mainz, Germany; University of Manchester, UK

[I119] Electron Capture branch of ^{100}Tc with an Ion Trap

S. Sjøe, University of Washington, Seattle, USA

JYFL Liaison person: H. Penttilä

Argonne National Laboratory, Argonne, USA; Institute of Nuclear Research of the Hungarian Academy of Sciences, Debrecen, Hungary

[I120] Proton and two proton radioactivity of proton rich silver isotopes

I. Mukha, University of Seville, Spain and I. D. Moore, JYFL

PNPI, Gatchina, Russia; University of Köln, Germany; GSI, Darmstadt, Germany; JINR, Dubna, Russia; Florida State University, Tallahassee, USA; IEP, Warsaw University, Poland; Instituut voor Kern-en Stralingsfysika, K. U. Leuven, Belgium; Università "Federico II" and INFN, Napoli, Italy; Huelva University, Spain; University of Tennessee, Knoxville, USA

[I122] Cryogenic Ion Catchers

P. Dendooven, KVI, Groningen, Netherlands

JYFL Liaison person: H. Penttilä

Osaka Gakuin University, Japan; University of Turku, Finland; GSI, Darmstadt, Germany; Justus Liebig University, Giessen, Germany

[I123] ^8B study at IGISOL

B. R. Fulton, University of York and H.O.U Fynbo, University of Aarhus
JYFL Liaison person: A. Saastamoinen

CSIC Madrid, Spain; KVI, Groningen, Netherlands; CERN, Switzerland; University of York, UK; Chalmers University of Technology, Göteborg, Sweden

[I125] Trap-assisted beta-decay spectroscopy of the very neutron-rich elements around $A=110$

J. Kurpeta, University of Warsaw, Warsaw, Poland

University of Munich (LMU), Munich, Germany

[I128] Mass measurements in the vicinity of doubly-magic waiting-point nucleus ^{56}Ni

A. Kankainen, JYFL

[I129] Laser spectroscopy of Nb, Y and Ta using optical pumping in an ion cooler buncher

B. Cheal, University of Manchester, UK

University of Birmingham, UK

[I130] Precision measurement of the half-life of the super-allowed $0^+ \rightarrow 0^+$ -decay of ^{42}Ti

B. Blank, CEN Bordeaux-Gradignan, France

JYFL Liaison person: T. Eronen

GANIL, France

[I132] Systematic studies of dynamic moments of nuclear levels in neutron-rich $A \sim 120$ nuclei (continuation)

H. Mach and J. Nyberg, University of Uppsala, Sweden

JYFL Liaison person: J. Rissanen

University of Warsaw, Warsaw, Poland; Universidad Complutense, Madrid, Spain; LPSC, Grenoble, France; University of Notre Dame, Notre Dame, Indiana, USA; Soltan Institute of Nuclear Studies, Świerk-Otwock, Poland; NIPNE, Bucharest-Magurele, Romania

[I137] Trap-assisted beta-decay spectroscopy of the very neutron-rich elements

J. Kurpeta, University of Warsaw, Warsaw, Poland

JYFL Liaison person: J. Rissanen

University of Munich (LMU), Munich, Germany

[I124] Accurate mass measurements of nuclides at the closed SnSbTe cycle of the rp-process

Yu. Novikov, PNPI, St. Petersburg, Russia and F. Herfurth, GSI, Darmstadt, Germany

(Experiment in December 2007)

Päivi Nieminen, Pete Jones, Rauno Julin, Paul Greenlees, Juha Uusitalo, Cath Scholey, David Cullen

Nuclear Spectroscopy

In 2008, the Nuclear Spectroscopy Group continued studies of exotic nuclei using the power and selectivity of the JUROGAM+RITU+GREAT instrumentation, along with the Total Data Readout (TDR) acquisition system. The nine experiments attracted 77 visits by researchers from 14 foreign institutes. The main spectroscopy programs for superheavy elements in the mass 250 region and neutron-deficient nuclei were continued, as well as plunger lifetime studies. A further boost and significant recognition of the heavy element spectroscopy program came with the award of a European Research Council Starting Independent Researcher Grant of 1.25MEuro to Paul

Fig. 1. The Nuclear Spectroscopy Group combines the In-Beam Spectroscopy Group and the RITU Group. From left to right: Jan Sarén, Markus Nyman, Steffen Ketelhut, Juha Uusitalo, Panu Rahkila, Sakari Juutinen, Pauli Peura, Cath Scholey, Ulrika Jakobsson, Rauno Julin, Matti Leino, Juha Sorri, Paul Greenlees, Dave Cullen, Pete Jones, Päivi Nieminen and Panu Ruotsalainen.

In-beam Spectroscopy Group Members

Rauno Julin, professor
 Sakari Juutinen, senior assistant
 Pete Jones, senior researcher
 Paul Greenlees, academy researcher
 Päivi Nieminen, postdoctoral researcher 1.6.-
 Steffen Ketelhut, graduate student
 Markus Nyman, graduate student
 Pauli Peura, graduate student
 Panu Rahkila, graduate student
 Juha Sorri, graduate student
 Aki Puurunen, summer student
 Anna Vankka, summer student
 Mathieu Bregeon, visitor student

RITU Group Members

Matti Leino, professor
 Juha Uusitalo, senior researcher
 Cath Scholey, senior researcher
 David Cullen, visiting scientist 16.09. -
 Ulrika Jakobsson, graduate student
 Panu Ruotsalainen, graduate student
 Jan Sarén, graduate student



Greenlees for his work on the structure of heavy and superheavy elements.

Instrumentation

The JUROGAM spectrometer of 43 Ge detectors at the target position of the RITU separator finished its fifth and final campaign in May. Since 2003, 67 experiments have been performed, with over 11000 hours of beam on target. In 2008, all the detectors were instrumented with digital electronics (TNT2 cards) in collaboration with the CNRS/IN2P3 GABRIELA project, allowing for higher counting rates (50kHz/detector) than with analogue electronics. The first implementation of JUROGAM II with 15 coaxial and 12 Clover detectors (received from CLARA in Legnaro) in the



Fig. 2. Clover detectors around 90 degrees in JUROGAM II.

backward hemisphere was ready in November for the plunger lifetime measurement campaign (Fig. 2). The response of the array (absolute efficiency of $\sim 3,8\%$ at 1.3 MeV and peak-to-total of $\sim 45\%$) indicate that a full instrumentation of JUROGAM II with all 24 Clover detectors in 2009 will allow for improved sensitivity for future experiments.

The development of two new U.K.-funded instruments for the target position, complementary to JUROGAM II, is progressing steadily. The coils to produce the solenoidal magnetic field for the combined gamma- and conversion-electron spectrometer SAGE have been delivered and the mechanical construction is well under way, tests being planned for early 2009. LISA is a charged-particle spectrometer of segmented silicon detectors, which will be located in the target chamber. In a test measurement, it was demonstrated that the He gas environment of RITU does not significantly increase the detector counting rates as compared to vacuum conditions [JR73].

A campaign has been initiated to measure the true transmission of the RITU separator for fusion products from different reactions: very asymmetric (e.g. $^{20}\text{Ne} + ^{170}\text{Er}$), asymmetric (e.g. $^{40}\text{Ar} + ^{150}\text{Sm}$) and symmetric (e.g. $^{84}\text{Kr} + ^{100}\text{Mo}$). These measurements will utilise the JUROGAM II array, such that the transmission will be extracted using a gamma ray from a known fusion evaporation channel, as the ratio of its intensity in a recoil-gated spectrum relative to a singles spectrum. The measured transmission values can then be compared to theoretical ones from ion-optical calculations [1].

Spectroscopy of Heavy Elements

The program to study the nuclear structure of heavy elements continued with an experiment to determine the configuration of the $K^\pi=8^-$ isomer in ^{252}No , through the observation and characteristics of a rotational band built on this state [JR80]. In the experiment, the digital electronics allowed a total rate of >500 kHz in the JUROGAM array, resulting in a significant relative increase in focal-plane data as compared to previous successful studies on ^{254}No and ^{250}Fm . A publication highlight of the heavy element spectroscopy program is a review article by Rodi Herzberg and Paul Greenlees, which appeared in Progress in Particle and Nuclear Physics [2]. Papers relating to the structure of ^{250}Fm (spotlighted in Physics, August 2008) and ^{255}Lr (the heaviest nucleus so far studied in-beam) have been published [3] and submitted for review [4], respectively.

Spectroscopy of Neutron-Deficient Nuclei

The astrophysically important nucleus ^{70}Kr was studied in a very challenging recoil-beta-tagging experiment [JR82], with evidence of at least the first 2^+ state observed. Analysis of these data is in progress. An experiment to study ^{175}Hg revealed, for the first time, the ground state band, as well as transitions feeding and depopulating the $i_{13/2}$ isomer [JR68] (Fig.3). This work continues the systematic study of $i_{13/2}$ isomeric states across the odd-A Hg-Pt-Os-W nuclei [5].

Significant effort has been made to study astatine and radon nuclei close to proton drip line, with a recent extension to francium isotopes. The analyses of the in-beam experiments for $^{197,198,199}\text{Rn}$ [6], ^{197}At [7] and

^{199}At [8] have been completed. New excited states were found in all these nuclei, clearly indicating a transition towards more deformed shapes when the neutron number is decreased. The in-beam study for ^{197}Rn represents a world record with its cross section of 10 nanobarns. In 2008, an extensive in-beam and delayed-spectroscopy study was performed for the ^{203}Fr and ^{205}Fr nuclei [JR76,9], for which only their ground-state alpha-decay properties were previously known.

Plunger Lifetime Measurements and Coulomb Excitation

The Köln differential plunger (Fig. 5) was employed in three measurements, all using different γ -ray identification techniques. A recoil-decay tagging experiment for ^{175}Au aimed at characterising the single-particle configurations which stabilise the triple shape coexistence [JR89,10] was performed, with data obtained also for the neighbouring nuclei $^{174,175}\text{Pt}$. Excited state lifetimes were studied in the stable, E(5) candidate nucleus ^{130}Xe with projectile Coulomb excitation in inverse

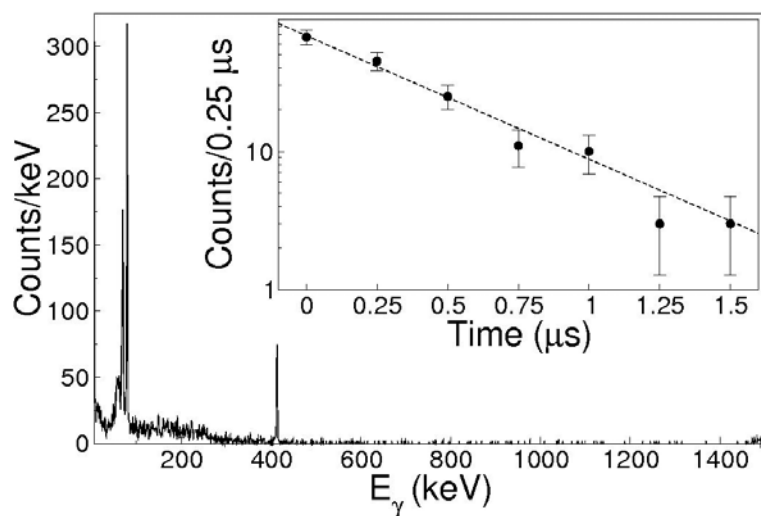


Fig.3. De-excitation of the $13/2^+$ state in ^{175}Hg via 414 keV M2 ($13/2^+$ to $9/2^-$) and 80 keV M1 ($9/2^-$ to $7/2^-$) transitions.



Fig. 4. President Abdullah Gül of the Republic of Turkey visited the gamma-RITU cave in October 2008.

kinematics [JR78]. A further experiment to study ^{109}I was the first to combine recoil- proton-decay tagging with lifetime measurement [JR81], continuing the program to establish the lifetimes of states at and beyond the proton drip line. The first experiment of this series (in 2007) studied ^{144}Ho , revealing a 6(1) pico-second lifetime for the first state above the proton $h_{11/2}$ - neutron $h_{11/2}$ isomer, in reasonable agreement with TRS calculations [11]. This was the first use of the Köln differential plunger with isomer tagging.

At the REX-ISOLDE facility at CERN, the neutron-deficient nuclei near $Z=82$ are available as radioactive beams, and therefore, for projectile Coulomb excitation. These measurements are complementary to the lifetime measurements in that they can provide a sign to the magnitude of the quadrupole moment, which one cannot obtain from the lifetimes alone. In 2008, these experiments were extended to the neutron-deficient $^{202,204}\text{Rn}$ nuclei (P. Rahkila spokesperson).

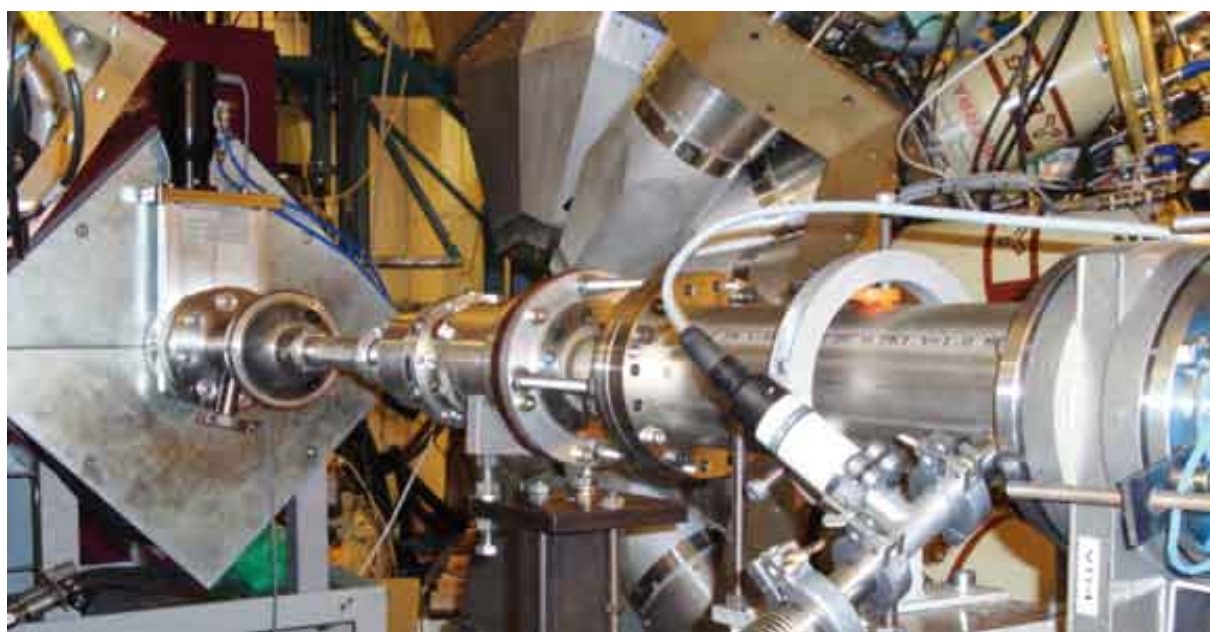


Fig. 5. Köln plunger at RITU

New Collaboration with the ECR and Pelletron Facilities

As a first step in a research program to measure alpha-capture cross-sections in inverse kinematics, the production method for ^4He implanted foils was tested [J05]. Thin aluminium foils were implanted with helium

ions from the JYFL ECR ion source and then studied using Rutherford Backscattering Spectrometry (RBS) at the JYFL 1.7MV Pelletron Accelerator. The RBS analysis showed that the number of implanted He atoms (1.5×10^{17} atoms/cm²) did not decrease in a $^{78}\text{Kr} + ^4\text{He} \rightarrow ^{82}\text{Sr}^*$ test experiment at JUROGAM.

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- [2] R.-D. Herzberg and P.T. Greenlees, Prog. Part. Nucl. Phys. 61 (2008) 674.
- [3] P.T. Greenlees et al., Phys. Rev. C 78 (2008) 021303(R).
- [4] S. Ketelhut et al., submitted.
- [5] C. Scholey et al., to be published.
- [6] K. Andgren et. al., Phys. Rev. C 77 (2008) 054303.
- [7] K. Andgren et. al., Phys. Rev. C 78 (2008) 044328.
- [8] U. Jakobsson et al., to be published.
- [9] U. Jakobsson et al., to be published.
- [10] H. Watkins et al., to be published.
- [11] P. Mason et al., To be submitted to Phys. Lett. B.

Experiment spokespersons and collaborating institutes in 2008

[JR73] Validation of the LISA design concept
R.D. Page, University of Liverpool, U.K.
STFC Daresbury Laboratory, U.K.

[J05] Production of ^4He -implanted targets and cross section measurements of alpha-capture reactions in inverse kinematics
S. Harissopulos, NCSR Demokritos, Athens, Greece.
DTL, Ruhr-Universität Bochum, Germany; FYNU/CRC, Université catholique de Louvain, Louvain-la-Neuve, Belgium; GANIL, Caen, France.

[JR76] Prompt and delayed spectroscopy of the francium isotopes ^{205}Fr and ^{203}Fr
J. Uusitalo, JYFL.

[JR80] Investigation of high-K states in ^{252}No
B. Sulignano, CEA Saclay, France; P.T. Greenlees, JYFL; R.-D. Herzberg, University of Liverpool, U.K.
Comenius University, Bratislava, Slovakia; GSI Darmstadt, Germany.

[JR68] Triple shape coexistence in ^{175}Hg
J. Simpson, CCLRC Daresbury Laboratory, U.K.; C. Scholey, JYFL, University of Liverpool, U.K.; University of Surrey, U.K.; University of York, U.K.; KTH Stockholm, Sweden; Nigde Universitesi, Turkey.

[JR82] Recoil-beta tagging study of the N<Z, T_z=-1 nucleus ^{70}Kr
B. Wadsworth, University of York, U.K.
University of Liverpool, U.K.; Argonne National Laboratory, USA; DePaul University, Chicago, USA.

[JR89] Measuring the quadrupole moments of the coexisting shape triplet in proton-unbound ^{175}Au
D.T. Joss, T. Grahm, University of Liverpool, U.K.
Universität zu Köln, Germany; IKP TU Darmstadt, Germany; STFC Daresbury Laboratory, U.K.; KTH Stockholm, Sweden; University of Tennessee, USA; TU München, Germany.

[JR81] Establishing the deformation and shape of the proton-unbound nucleus ^{109}I
D.M. Cullen, University of Manchester, U.K.
University of Liverpool, U.K.; Universität zu Köln, Germany; University of Surrey, U.K.

[JR78] Lifetime measurements in ^{130}Xe using the Coulex-plunger technique in inverse kinematics
S. Harissopulos, NCSR Demokritos, Athens, Greece; A. Dewald, IKP, Universität zu Köln, Germany.
INRNE, Sofia, Bulgaria; NIPNE Bucharest, Romania.

Nuclear Reactions and ALICE

ALICE

Past year has marked the first decade of JYFL involvement in ALICE. Unfortunately, our great expectations to see the first collisions in 2008 were quenched on September 19 together with the magnets of the sub-sector 23-25 of LHC delaying the date of the first collision by one more year.

Nevertheless, a lot of progress was made in the preparation for the first physics and completion of the ALICE hardware. The latter included development of EMCAL trigger units and commissioning of T0 detector. Our team was at CERN during all critical periods of testing and operation. The most dramatic moments were during the injection tests when ALICE was hit by dense muon showers from 450 GeV beam dumped in the vicinity of our detector. There was no damage

Jan Rak, senior assistant

Wladyslaw Trzaska, senior scientist

DongJo Kim, postdoctoral researcher

Sami Räsänen, postdoctoral researcher

Rafael Diaz Valdes, graduate student

Tuomo Kalliokoski, graduate student

Kai Loo, graduate student (University of Oulu)

Tomasz Malkiewicz, graduate student

Norbert Novitzky, graduate student

Tomi Räihä, graduate student (University of Oulu)

Juho Sarkamo, graduate student (University of Oulu)

Mikko Sillanpää, graduate student -30.4.

Sergey Yamaletdinov, graduate student -31.3.

Elena Heikkilä, MSc student

Karolina Kolos, MSc student

Lauri Olanterä, MSc student

Michal Oledzki, MSc student

Oleg Korniyenko, research associate

to the detectors and we have used these events to calibrate the timing of the trigger signals and for cross checking of the alignment. The bulk of the alignment data came from the cosmic rays tracks accumulated in several dedicated runs; all with our participation both as a team and as subdetector (T0). After the mishap at LHC, radiation shielding around ALICE and part of the detectors on the A-side were dismantled to allow for maintenance, improvements in the setup and installation of the missing modules.

Astroparticle Physics

In its 2007 roadmap Astroparticle Physics European Coordination has recommended to put forward a new large European infrastructure as a future international multi-purpose facility on the 0.1 - 1 Mt scale for



Fig.1. Jan Rak seating in the "driver's seat" of ALICE serving as run-period coordinator during the dramatic moments in the fall of 2008.

improved studies of proton decay and of low-energy neutrinos from astrophysical origin. Following that recommendation European Union has approved in 2008 a 1.7 M€ design study for LAGUNA (Large Apparatus for Grand Unification and Neutrino Astrophysics). The design study is evaluating 3 possible detection techniques and 7 European sites. Among the strongest contenders for the future location is Pyhäsalmi mine, 190 km north from Jyväskylä. It is the deepest mine in Europe and the host of EMMA experiment. The quality of the bedrock, relatively low background from nuclear power plants and the existing infrastructure with the access tunnel winding down to 1.4 km under ground are the strongest assets of the Finnish site. Needless to say JYFL is part of that design study and our EMMA experiment became an important pilot project to demonstrate cooperation between the mine and the scientific community. With the realistic plans to host a big European facility in Finland in the near future, our team has to prepare the new generation of local astrophys-

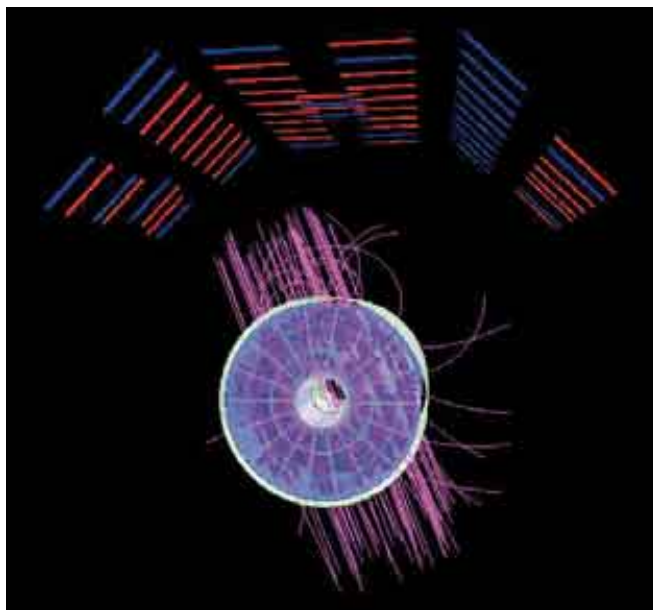


Fig. 3. Cosmic multimuon event registered by ALICE TPC and triggered by ACORDE scintillator array on top of ALICE magnet.

icists to meet that challenge. We already have 3 PhD and 3 MSc students working on EMMA and the related physics. Since the most likely detector design for



Fig. 2. Installing equipment in the underground cottages of EMMA experiment.

Pyhäsalmi is LENA – a 50 kt liquid scintillator, we have also established a close collaboration with the group at Technical University of Munich. The TUM team are coordinating LENA design studies and are members of Borexino – a smaller version of LENA-type detector that is already taking data at Grand Sasso laboratory. Our plan is to verify our simulations for LENA with the real data from Borexino. Last but certainly not least, our team is involved in the cosmic ray studies with the data taken with ALICE detector. ALICE results are important to our research on multimoon bundles with EMMA detector. ALICE Time Projection Chamber is the biggest ever build and gives excellent visualisation of particle trajectories that helps us in improving track reconstruction software for EMMA.

Nuclear Reactions

A total of 13 nuclear reaction experiments were done at JYFL clocking 897 cyclotron hours. Perhaps the most demanding and involving the largest number of collaborators from Russia, Italy, Belgium and Slovakia was the study of dynamics of the $^{64}\text{Ni}+^{238}\text{U}$ reaction as a possible tool for synthesis of superheavy element of $Z=120$. We had also had our traditional Christmas experiment benefiting from the fact that this holiday is celebrated in Russia only in January. We were searching for new cluster bands in ^{22}Ne using exotic target ^{14}C bombarded with ^{12}C beam. Logistically the most challenging was our experiment at ILL reactor in Grenoble, France where we were continuing investigation of the interplay of ROT and TRI effects in ternary fission of ^{239}Pu induced by polarized neutrons.

Fig. 4. Our Russian collaborators during the Christmas experiment at Large Scattering Chamber.



Accelerator-Based Materials Physics

The Accelerator-based materials physics group which was instigated in 2004 has continued to strengthen and now an output of completed PhDs is established and at the same time new postgraduate students and a new postdoc have joined the group. The application of ion beams of various aspects of biomedicine continues to be a strong theme in the group in addition to use of ion beams in materials modification and characterisation.

Pelletron Accelerator

The 1.7 MV Pelletron Accelerator has been heavily used over whole year. In the spring 2008 the old corona point voltage divider system was replaced with a

Harry J. Whitlow, professor

Timo Sajavaara, senior assistant

Somjai Sangyuenyongpipat, postdoctoral researcher

Liping Wang, postdoctoral researcher 2.4.-

Sergey Gorelick, graduate student -30.9.

Mikko Laitinen, graduate student

Laura Mättö, graduate student

Ananda Sagari A.R., graduate student

Elisabeth Wieslander, external graduate student

Nittipon Puttaraksa, visiting graduate student, Chiang Mai, Thailand

Hannele Eronen, MSc student

Kimmo Tolvanen, MSc student

Saku Palanne, MSc student

Terho Räisänen, MSc student

Christian Drabczyk, ERASMUS student 1.3-31.8.

Maxime Bouchetetau, ERASMUS student 1.4-31.6.



resistor chain. This gave a significant improvement in terminal voltage stability, which resulted much needed improvement in exposure control for lithography. The latter part of the year design and planning work has been carried for addition of an injector magnet and sputter ion source.

MeV Ion Beam Lithography

Much effort has been devoted to developing an understanding of how the beam defining aperture affects the lithographic pattern definition. GEANT4 has been used in an intensive study of the effects of realistic divergent beams (Fig. 1). At the same time a number of approaches to obtain high quality apertures using different polishing procedures have been examined. As a result we were able to write sub- μm features in thick resist such as walls with thickness of $\sim 300\text{ nm}$. This work is moving towards application phase where it has been used to produce functioning microfluidic circuits (Fig. 2) and PDMS stamps for patterned deposition of biological cells.

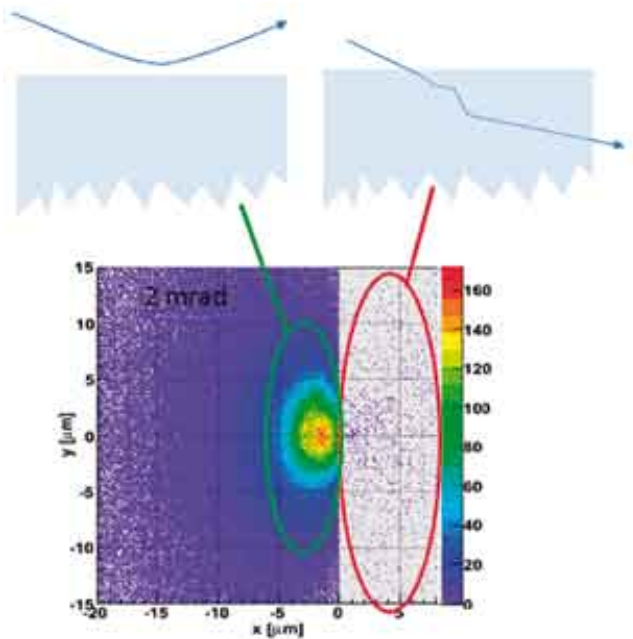


Fig. 1. GEANT4 simulations showing the specular-reflected and transmitted beam components of 3 MeV He ions impinging on the edge face of a Ta aperture.

Ion Beam Analysis

In 2008 the realisation of a new ion beam analysis facility TOF-ERDA has started. This facility will extend our analytical capabilities by making depth profiling of all elements in the nanometre region accessible. As part of this work a test-bench based on an old time of flight spectrometer has been set-up in the analysis chamber. Related to the TOF-ERDA project, a time-stamped multiparameter data acquisition system based on a Field Programmable Gate Array (FPGA) on Labview environment has been constructed which can handle up to eight channels. Another significant activity was the installation of a general purpose PIXE/RBS system at a new beam line (Fig. 3). This setup is intended for student exercises as well as analysis of samples of materials for corrosion research associat-

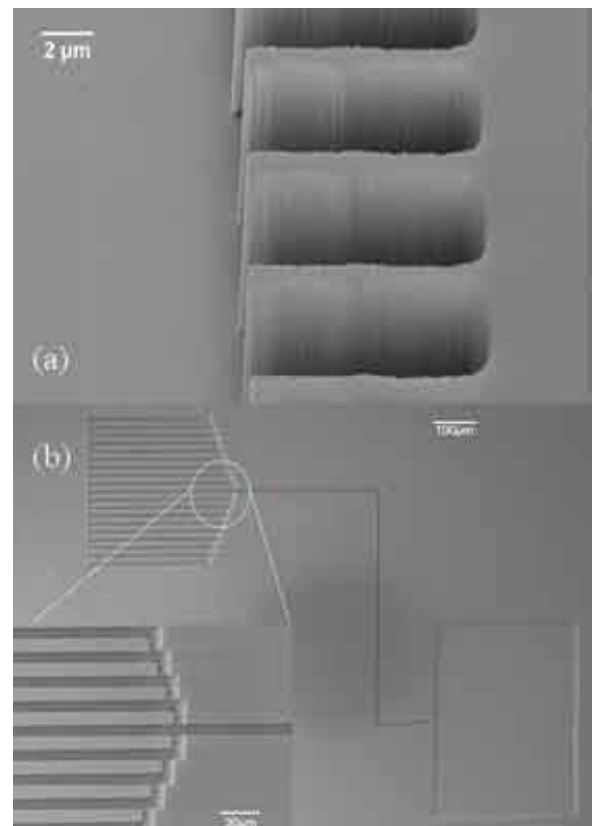


Fig. 2. (a) MeV ion beam lithography of wall structure showing sub- μm walls in thick ($8\mu\text{m}$) PMMA resist. (b) Prototype microfluidics channel test structure.



Fig. 3. Beam line and end-station for PIXE/RBS analysis.

ed with the migration of large-scale power production by biomass combustion. PIXE is also being utilised in a student project on alteration of Ca incorporation in biological cells associated with virus infections.

Setup for Low-Fluence Large Area Irradiations

A versatile setup has been developed in Jyväskylä for low-fluence, large area irradiations in the ion energy range of 0.1–5 MeV. In this setup (Fig. 4), H, He or O ions are first accelerated to a certain energy (for He for example from 200 keV to 5 MeV) with 1.7 MV Pelletron accelerator. This beam is directed to a thin

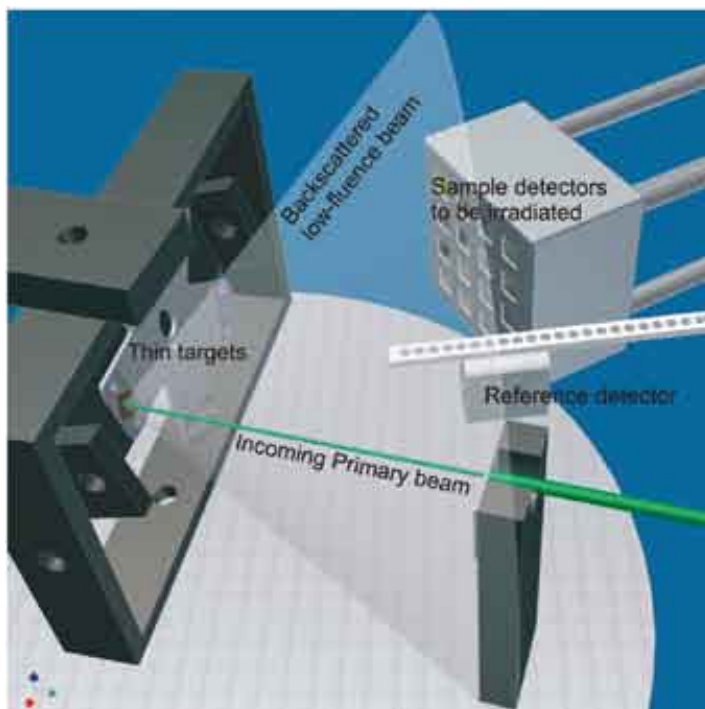


Fig. 4. Schematic image of a setup for low-fluence large area irradiations in Pelletron laboratory.

evaporated layer of heavy element on a self-supporting 50 nm thick carbon foil. The ions backscattered from this foil form the quasi-monoenergetic beam which is used in the application.

In the 18th Jyväskylä Summer School held in August 2008, the group coordinated the 2 ECTS course PH2: Nuclear Microscopy in Biomedicine and Materials. The lecturer was Dr. Minqin Ren from the National University of Singapore. The course included lab visits and extensive laboratory work using the Pelletron Accelerator.

Heikki Kettunen and Ari Virtanen

Industrial Applications

The usage of the beam time in different industrial areas is shown in figure 1. The total beam time in 2008 was 1372 hours, which is our record in annual hours and, also, in annual revenue.

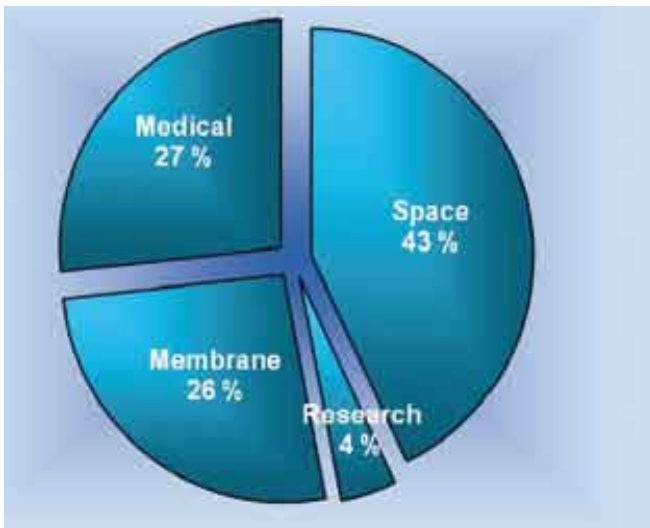


Fig.1. Beam time distributed between different industrial areas. In addition, about 4 % of beam time was used for the research.

Ari Virtanen, director of industrial applications

Heikki Kettunen, senior researcher

Jukka Jaatinen, graduate student 1.7.-

Arto Javanainen, graduate student

Taneli Kalvas, graduate student

Suvi Päiviö, graduate student

Iiro Riihimäki, graduate student

Mikko Rossi, graduate student

Hannes Vainionpää, MSc student

Space Related Study

RADEF continued the operation as one of ESA's external European Component Irradiation Facility (ECIF). Eleven space related beam times were performed during 2008. The amount of ESA hours was 307 and that of satellite companies 277. One research experiment (56 hours) was also performed [1].

The two new users in 2008 were Sandia National Laboratories from Albuquerque, New Mexico, USA, and Japan Aerospace Exploration Agency from Tsukuba Space Center, Japan.

We also started heavy ion irradiations in air. First results for the comparison were verified. Figure 2 shows the errors of the "Reference SEU monitor" [2] measured at RADEF in both conditions. The consistency is clear.

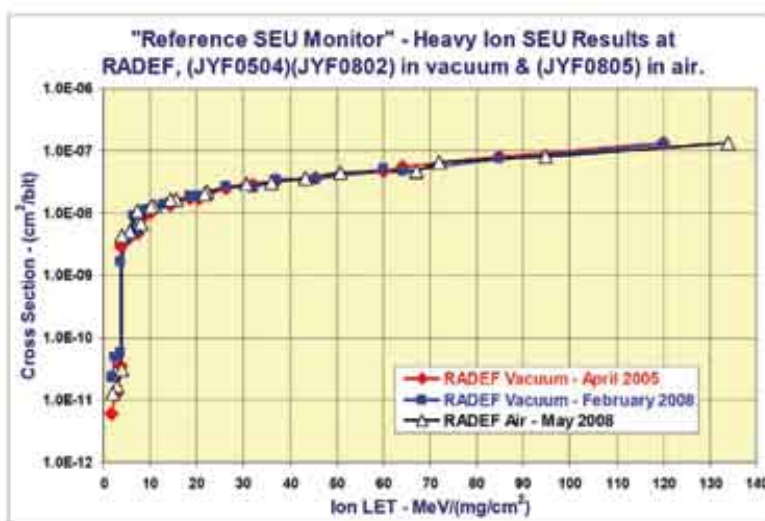


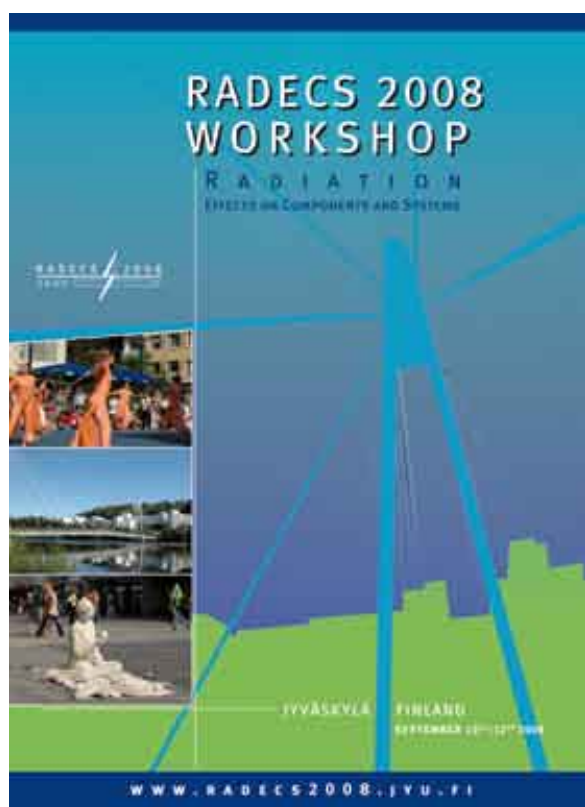
Fig. 2. Comparison of SEU obtained in vacuum and in air.

RADIATION and its Effects on Components and Systems, RADECS 2008

Group's highlight was The *RADECS 2008 Workshop*, which was held on September 10–12 in University's Agora Building. Our group served as the main organiser, but the success of the workshop depended strongly on the work of many students and secretariat of JYFL. Also, the help provided by a local congress organiser, Congresszon, was invaluable.

RADECS 2008 welcomed 208 international participants from 29 countries. During the workshop 46 invited and oral talks were given and 47 poster contributions presented. Also 10 international and three Finnish exhibiting companies were presenting their products during the workshop.

RADECS 2008 was also awarded by the city of Jyväskylä for being economically the most productive international conference in the city in 2008.



Radio-Medicine

The high-intensity proton beams from the LIISA ion source were used for the production of ^{123}I radioisotope for MAP Medical Technology Ltd. The ^{123}I based radio-medicines produced by MAP are mainly used in diagnosing brain-based diseases. During the year 2008 31 production runs were performed.

Due to increased radiation safety measures during the building of the laboratory's extension, the radioisotope production runs were stopped in September. The break will last at least until the new cyclotron is running. The negotiations with MAP Medical Technologies Ltd. about the continuation of the collaboration will be started in spring 2009.

Other Collaboration

The collaboration with Oxyphen GmbH also continued steadily. Our cooperation aims to irradiate their polymer films, which is the first step for creating micro porous membranes made by the company. Oxyphen performed four campaigns at RADEF in 2008.

Collaboration with national companies and institutes continued on a regular basis. Our project to use neutrons to study properties of wood was also completed. The main coordinator of the project was Metsäteho Ltd. Metso Paper from Pori was the other cooperating industrial company. The study was carried out together with VTT Jyväskylä.

Our collaborating companies and institutes were:

- ATMEL, Nantes, France
- CEA, Comité Européen des Assurances, Bruyere-le-Chatel, France
- Central Finland Health Care District, Jyväskylä
- Centre of Expertise for Nanotechnology, Jyväskylä Innovation Ltd.
- Centre of Expertise for Paper Making Technology, Jyväskylä Innovation Ltd.
- Doseco Ltd., Jyväskylä
- EADS Space Transportation Co., Bremen, Germany
- ESA, European Space Agency, Noordwijk, The Netherlands
- Gammapro Ltd., Jyväskylä
- HIREX Engineering Ltd., Toulouse, France
- IDA, Institut für Datentechnik und Kommunikationsnetze, Braunschweig, Germany
- INTA, Instituto Nacional de Técnica Aeroespacial, Madrid, Spain
- JAXA, Japan Aerospace Exploration Agency, Sengen, Japan
- MAP Medical Technologies Ltd., Tikkakoski
- Metsäteho Ltd., Helsinki
- Metso Paper Co., Pori and Jyväskylä
- Saab Ericsson Space Co., Gothenburg, Sweden
- Sandia National Laboratories, Albuquerque, USA
- Technical Research Centre of Finland, VTT, Jyväskylä
- TRAD, Labege, France

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Experimental linear energy transfer of heavy ions in silicon for RADEF cocktail species
RADECS Workshop Proc. (2008) 470–474
(Accepted for publication in IEEE Transactions on Nuclear Science)
- [2] *R. Harboe-Sørensen, C. Poivey, F.-X. Guerre, A. Roseng, F. Lochon, G. Berger, W. Hajdas, A. Virtanen, H. Kettunen and S. Duzellier*
From the reference SEU monitor to the technology demonstration module on-board PROBA-II
IEEE Transaction on Nuclear Science 55 No. 6 (1) (2008) 3082 - 3087

Nuclear Structure, Nuclear Decays, Rare and Exotic Processes

Nuclear Matrix Elements for Beta Decay and Double Beta Decay

At present the nuclear matrix elements (NME's) of neutrinoless double beta decay play a key role in physics related to the properties of the neutrino. In particular the mass and character of the neutrino can be studied using atomic nuclei as laboratories. During 2008 our group has made evaluations of the NME's by using cutting-edge nuclear-structure tools to limit the uncertainties associated to the NME's [1]. The proton-neutron version of the Microscopic Anharmonic Vibrator Approach (MAVA) [2] has been used to study the importance of four-quasiparticle structures in description of the two-neutrino double beta decay of ^{76}Ge . At the same time our group has addressed the complicated problem of highly forbidden beta transitions in nuclei. Special interest has been devoted to the beta-minus decay of ^{115}In to the first excited state in ^{115}Sn .

Detection Rates for Supersymmetric Dark Matter

The lightest supersymmetric particle, LSP, is a (nearly) stable favourite candidate to contribute to the bulk of cold dark matter of the Universe. Nucleus-LSP scattering can be used for direct detection of the LSP. Our group has calculated theoretical estimates for the LSP scattering cross sections and detection rates by using nuclear wave functions obtained by large-scale shell-model calculations for the stable iodine, xenon and

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Sami Peltonen, graduate student

Emanuel Ydrefors, graduate student

cesium nuclei [3]. Both the elastic and inelastic channels have been included.

Alpha-decay Fine Structure

Alpha decay to excited final states is a complex but rewarding issue. Ratios of the decay rates to excited states and the ground state constitute the alpha-decay fine structure. The fine structure is currently of great experimental and theoretical interest. We have recently studied the fine structure in both the vibrational [4] and rotational [5] nuclei.

Highlights

Orbital occupancies and the neutrinoless double beta decay of ^{76}Ge

Recently the nuclear matrix elements of the neutrinoless double beta decay (NME), computed by using the proton-neutron quasiparticle random-phase approximation (pnQRPA), have converged to a rather standard set of values [1]. However, this set of NME values deviates notably from the corresponding set of shell-model computed values [6]. We have addressed

this difference between the two sets of values by using the recently measured neutron occupancies in the ^{76}Ge and ^{76}Se nuclei as guidelines to define the neutron quasiparticle states in the $1p0f0g$ shell. The proton quasiparticles are defined by inspecting the odd-mass nuclei adjacent to ^{76}Ge and ^{76}Se . The resulting quasiparticles are inserted in a pnQRPA calculation of the NME of ^{76}Ge . A realistic model space and effective microscopic two-nucleon interactions are used. The nucleon-nucleon short-range correlations and other relevant corrections at the nucleon level are included. It is found [7] that the resulting NME is smaller than in the previous pnQRPA calculations, and closer to the recently reported shell-model result [6].

The main effect comes from the reduction of the dominating 2^- component in the angular-momentum decomposition of the leading Gamow-Teller NME. This reduction in the 2^- channel is well visible in figure 1 where the symbol 'WS' denotes a standard calcula-

tion using the Woods-Saxon mean-field orbitals and 'Adjusted' denotes the new calculation taking into account the measured neutron occupancies. This example calculation has been performed by using the Jastrow short-range correlations. In the this case the standard calculation gives $\text{NME}=4.03$, the new calculation gives $\text{NME}=2.78$ and the shell-model result [6] reads $\text{NME}=2.30$.

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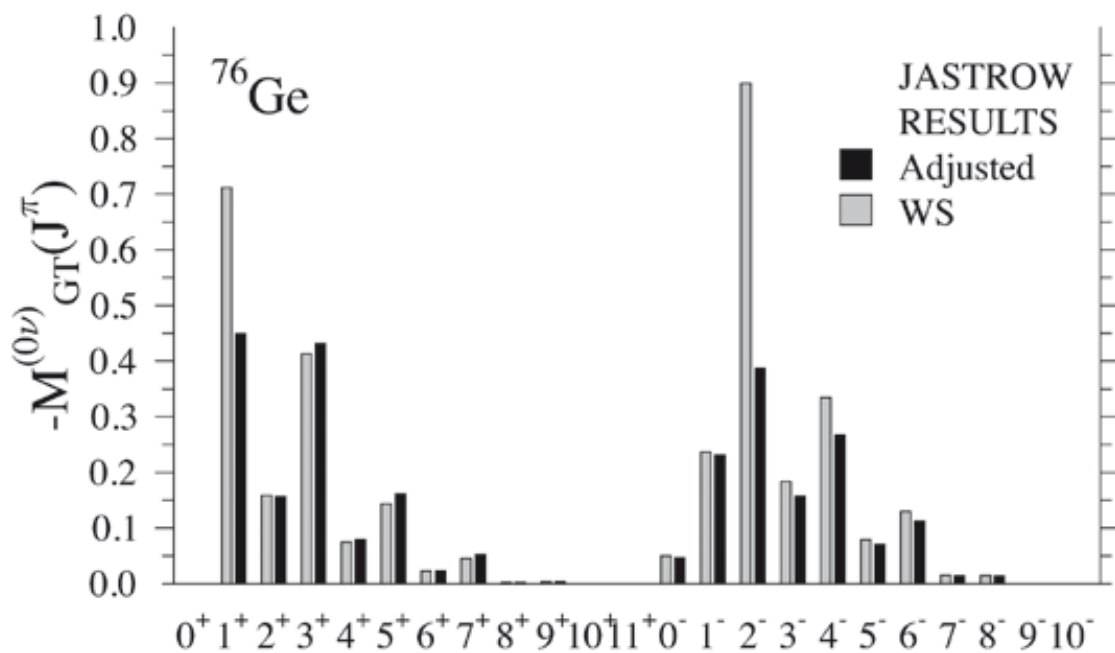


Fig. 1. Multipole decomposition of the Gamow-Teller NME for ^{76}Ge decay

Experimental Nanophysics and Nanotechnology

Ilari Maasilta

Thermal Properties of Nanostructures and Radiation Detector Development

The main research direction of the thermal nanostructure research team is to (a) understand energy flow mechanisms in low-dimensional geometries, and (b) utilize this knowledge in the development of ultrasensitive thermal and radiation sensors for applications (bolometry). In the following, just a few highlights of the activity in 2008 are presented.

Research utilizing normal-metal-superconductor tunnel junctions (NIS) for ultrasensitive thermometry in sub-Kelvin temperature range has continued, concentrating in studies of phonon thermal transport in thin 2D membranes and phonon cooling in 1D suspended nanowires (Fig. 1). We demonstrated for the first time that phonon modes together with electrons in a 1D wire can be cooled with NIS junctions down to ~40 mK starting from 100 mK. This result may have applications in cooling nanoelectromechanical (NEMS) resonators and ultrasensitive bolometric radiation detectors. In addition, we have started a collaborative project within the Finnish Academy FinNano programme, where ordered nanoparticle lattices will be used to control phononic thermal transport properties (phononic crystals). Polystyrene and PMMA nanoparticles of diameter range 100 nm-300 nm have been arranged into lattices using colloidal crystallization techniques, and further optimization of ordering and placement techniques are in progress (Fig. 2).

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 Terhi Hongisto, graduate student
 Tero Isotalo, graduate student
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 Kimmo Kinnunen, graduate student
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 Minna Nevala, graduate student
 Marcus Rinkiö, graduate student
 Peerapong Yotprayoosak, graduate student 1.9 -
 Maciek Zgirski, graduate student, - 30.9
 Hannu-Pekka Auranen, MSc student
 Tuuli Gröhn, MSc student
 Jaakko Halkosaari, MSc student
 Olli Herranen, MSc student
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 Kari-Pekka Riikonen, MSc student
 Niko Säkkinen, MSc student
 Armen Yulukian, MSc student

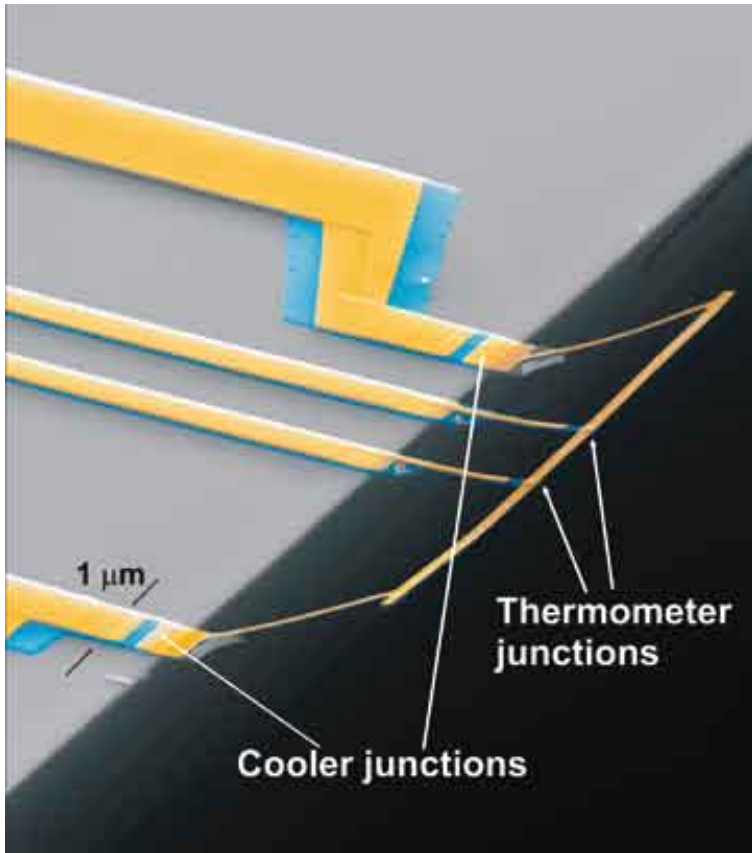


Fig.1. A SEM image of a typical suspended 1D nanowire with Cu-AlO_x-Al tunnel junction coolers integrated.

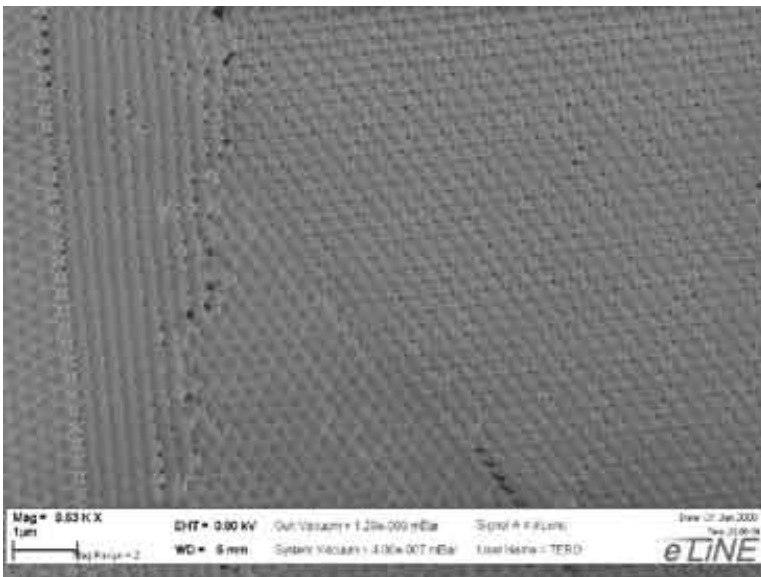


Fig.2. Ordered arrays of polystyrene nanoparticles on a Si substrate deposited by slow vertical pulling of the chip from the aqueous solution containing the particles.

Another focus field has been development of superconducting X-ray detectors. In 2008 we started a new TEKES funded project in collaboration with Lund University and NIST Boulder, where the goal is to develop a table-top experimental setup for sub-ps time-resolved X-ray absorption fine structure (XAFS) spectroscopy. Time resolution is obtained with the help of fs-laser generated sub-ps timescale X-ray pulses (optical pump-X-ray probe spectroscopy). X-ray spectra are measured using ultra-high resolution X-ray microcalorimeters based on superconducting transition-edge sensors (TES), which have been under development in Jyväskylä for several years. TES detectors provide an excellent energy resolution, and readout technologies (SQUID multiplexers) have matured sufficiently in recent years to make high efficiency detection with cryogenic arrays possible (Fig. 3).

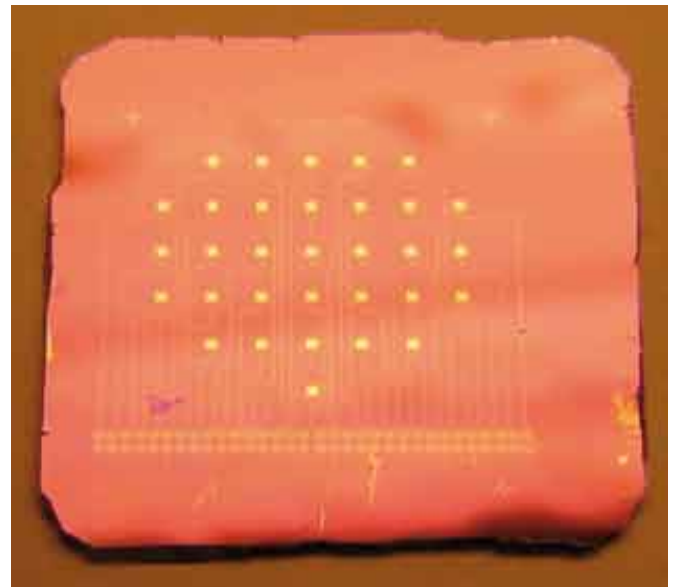


Fig. 3. A 32 pixel TES X-ray detector array fabricated for X-ray absorption spectroscopic measurements.

Konstantin Arutyunov

Quantum Nanoelectronics

The activity of Quantum nanoelectronics group can be formally separated into four topics: (I) quantum size phenomena at nanoscales; (II) interface phenomena at nanoscales; (III) molecular nanoelectronics; and (IV) applied nanotechnology.

(I) The group continued its study of 1D superconductivity [1]. The proprietary method of the group (patent application FI-20060719) has been applied to study the evolution of various size phenomena in quasi-1D normal metal and superconducting nanosystems. In addition to our previous work on the electron transport in superconducting nanowires [1-4] we extended the studies on systems with periodic boundary conditions. It has been found that the quantum fluctuations suppress persistent currents in superconducting nanorings [5-6]. The discovery is of fundamental importance indicating quenching of dimagnetism in superconductors at nanoscales (Fig. 4).

(II) Conversion of the normal electron current into the supercurrent has been studied in experiments with injection of the non-equilibrium excitations into a superconductor from the normal metal and ferromagnetic electrodes at ultra-low temperatures. The experiments are the pioneering study of the phenomena virtually non-investigated before. The preliminary results show anomalously large scales at which the non-equilibrium quasiparticles relax (Fig. 5). The study is of fundamental importance for the basic science and for numerous applications of hybrid (tunnel) nanosystems.

(III) In collaboration with Prof. J. Korppi-Tommola (NSC, Dept. of Chemistry) the group continued the experimental study of the dye-based molecular nanostructures. Clear photo-effect has been observed

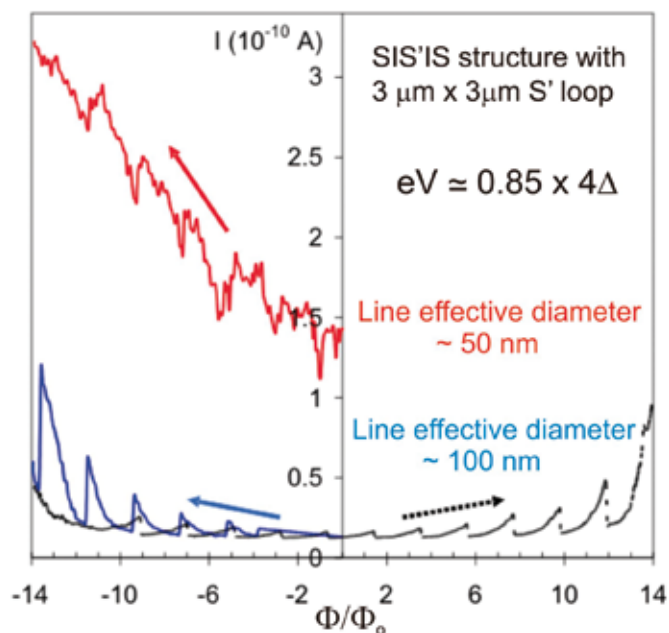


Fig. 4. Oscillations of persistent currents in a SIS structure with the loop-shaped central electrode in perpendicular magnetic field. In the sample with “large” line width the oscillations has a clear saw-tooth shape, while in the sample with the reduced cross section of the line – the oscillations degenerate due to the impact of the quantum fluctuations [5].

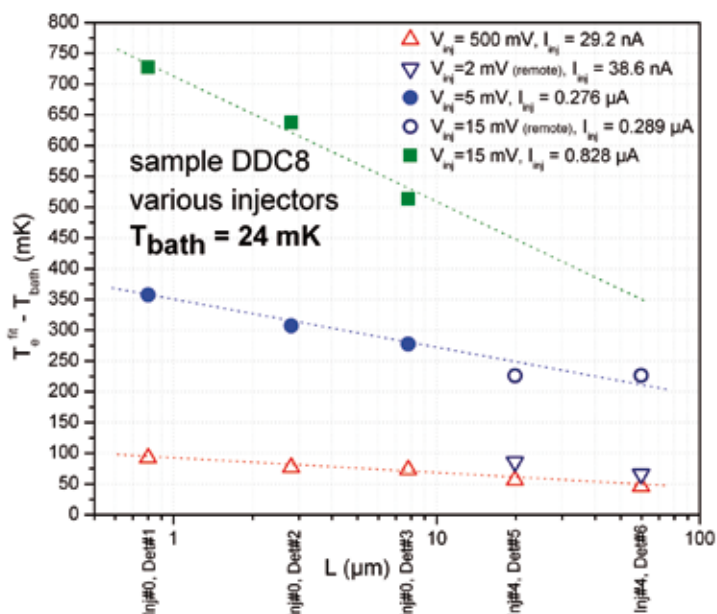


Fig. 5. Variation of the effective electron temperature inside the superconductor as function of the distance to the normal metal injector measured in a multi-terminal NIS structure [unpublished].

(Fig. 6). The activity has been supported by the Finnish Academy of Science project FUNANO.

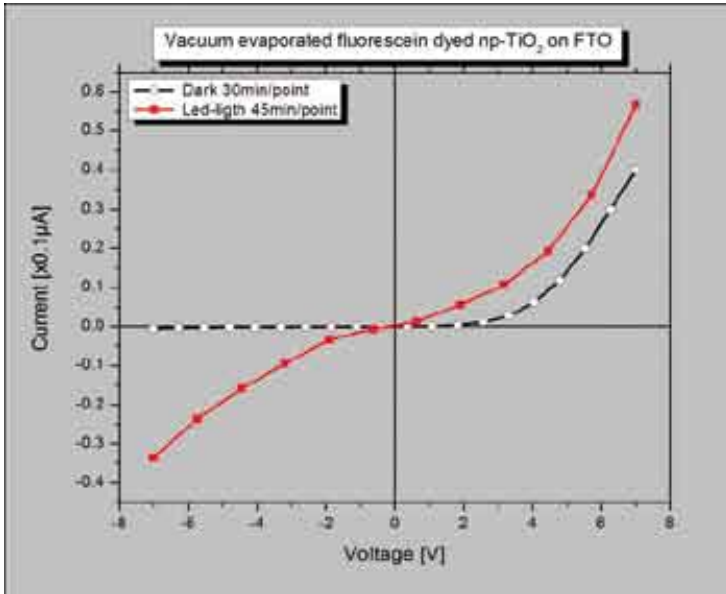
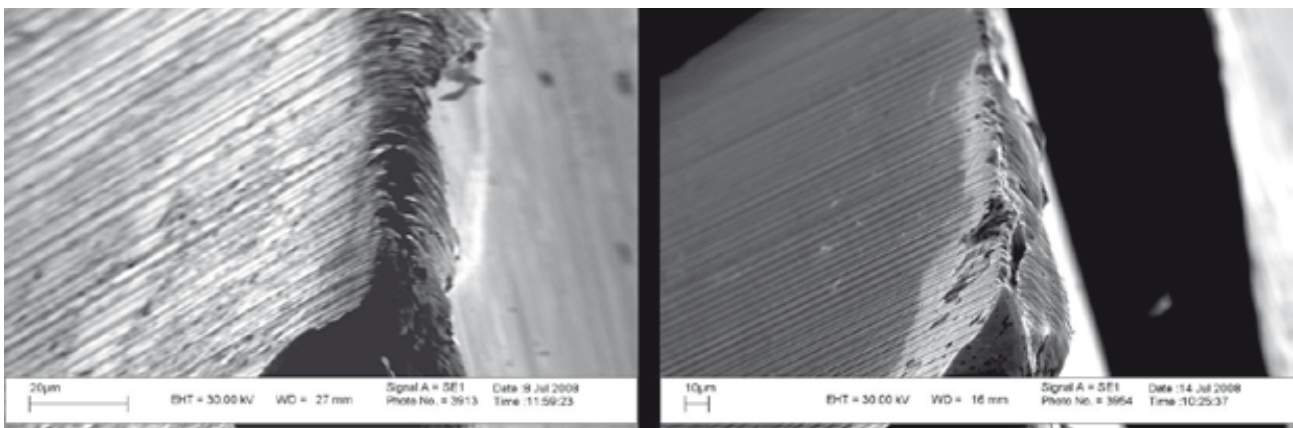


Fig. 6. I-V characteristic of the dye-based structure in dark and under illumination [unpublished].

Fig. 7. SEM images of the edge of an industrial cutting tool just after conventional fabrication (left) and after the ion beam polishing (right).



(IV) The group extended the patented (patent application FI-20060719) proprietary method of the ion beam downscaling of nanostructures [7]. It appeared that the method can be “upscaled” to micrometer dimensions resulting in super-fine polishing of industrial products (Fig. 7). The activity has been supported by the JOSKE project of the Jyväskylä scientific part and was made in collaboration with three industrial partners.

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Markus Ahlskog

Molecular Technology

The Molecular Technology group studies electronic and mechanical properties of macromolecular particles and devices that are based on them. The main focus is on carbon nanotubes (CNT), while biological particles are under consideration as well.

Combined techniques for measurement of structural, transport, and spectroscopic properties of individual carbon nanotubes are very important for current progress in the physics of these materials. We have measured the Raman spectra and low temperature transport properties of individual single walled nanotubes that are electrically contacted with lithographically fabricated microelectrodes on Si/SiO₂ substrates (as in fig. 13a). The G-band of the Raman spectra have characteristic features for metallic and, as in figure 8, semiconducting tubes, that we are able to discern. This conclusion is confirmed by transport measurements, shown in figure 9, which also clearly reveals semiconducting behavior in the gate dependent conductance, in the form of the dip in the curve. Thus we can unambiguously distinguish between metallic and semiconducting tubes by independent measurement methods.

We have fabricated a novel mesoscopic device based on a doped conducting polymer and gold dots. Ultrathin layers of polypyrrole (PPy) were electrochemically grown between microelectrodes on a Si/SiO₂ substrate. Conducting PPy was directly grown onto ultrathin discontinuous gold film between the microelectrodes, with thicknesses in the range of 10-100 nm, see Figure 10. The system therefore forms a novel (PPy/Au) nanocomposite conductor. AFM imaging and conductivity measurements indicate that at all thicknesses a relatively uniform film is formed but with significant roughness that reflects the roughness of the

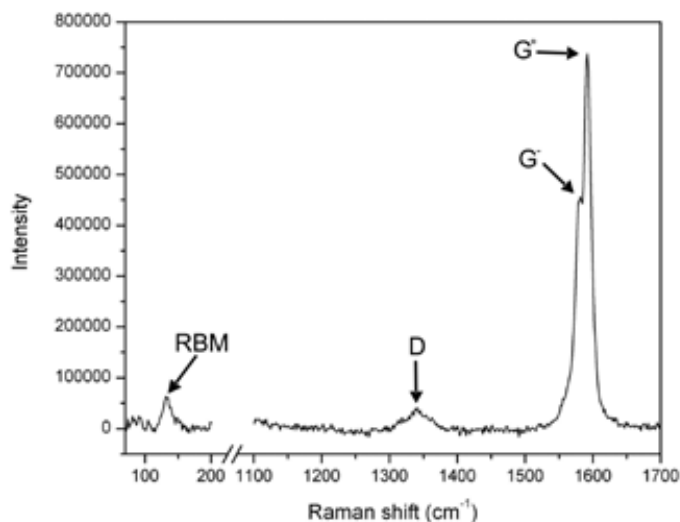


Fig. 8. A Raman spectrum of a semiconducting carbon nanotube. The different Raman signals are indicated. The RBM signal is specific to CNTs and can be used to estimate tube diameter.

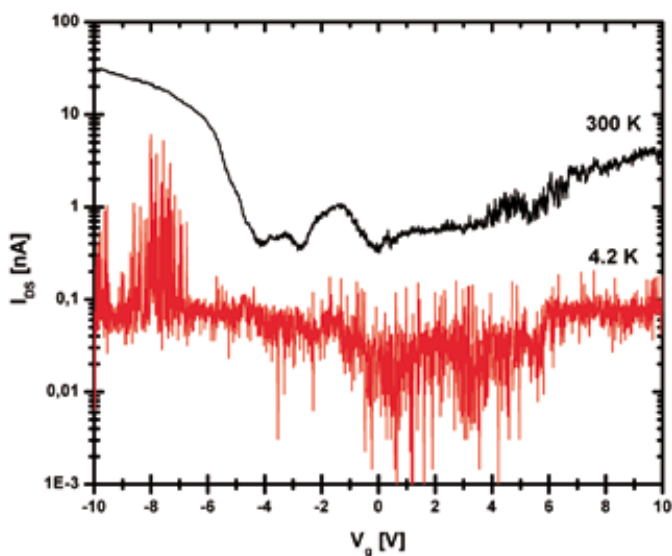


Fig. 9. Gate dependent conductance at 300 K and 4.2 K of the tube in figure 8.

metallic island layer. In PPy/Au films with thickness ~ 10 nm, the small barriers around the gold islands dominate the conduction, and as the film thickness increases to 100 nm the intrinsic conductivity of highly doped PPy dominates the charge transport. The patterns can be made very small and this also provides an opportunity of studying charge transport in conducting polymers over nanoscale distances corresponding to the inter-island gaps of the metal films.

Nanoelectronics

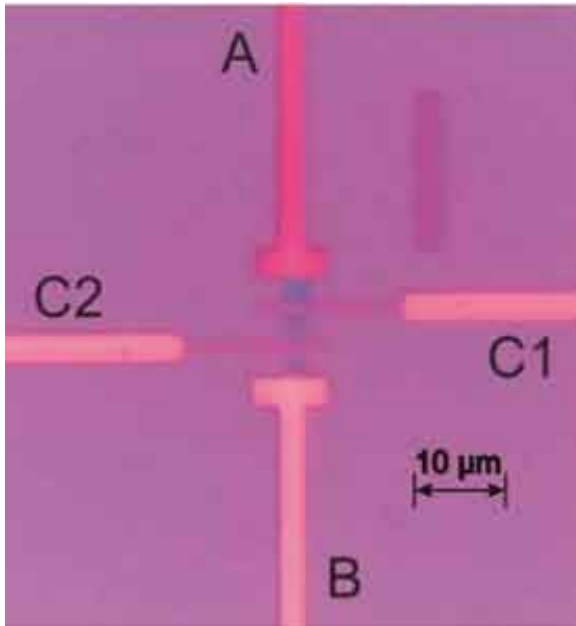


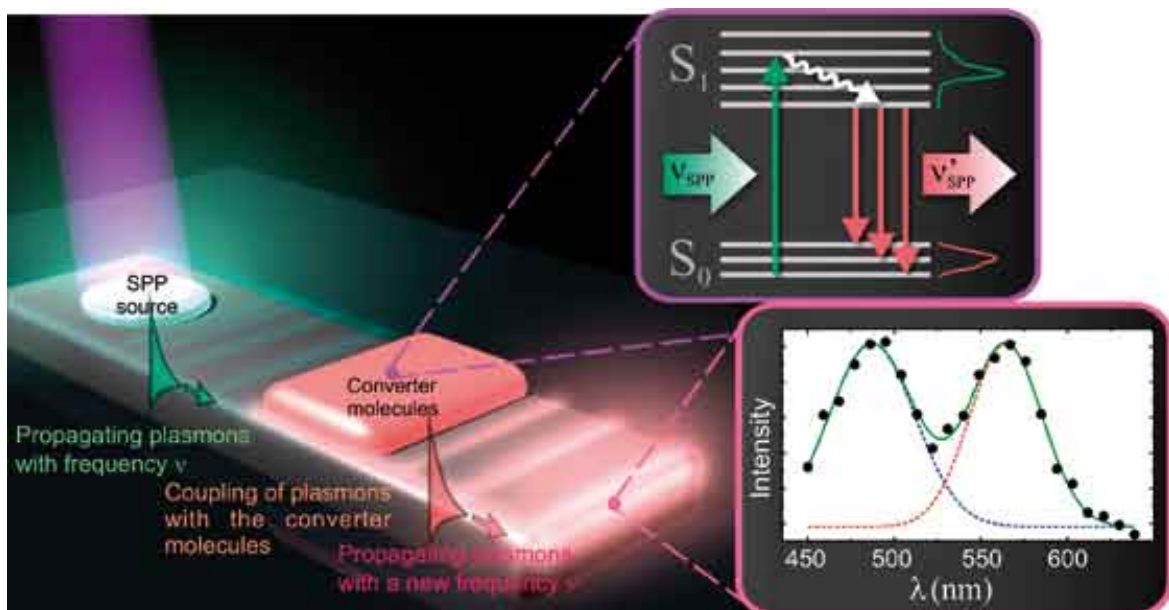
Fig. 10. Photograph of a Au island layer structure after polymerization with polypyrrole. The polymer covered island layer in the center has a width of 3 μm. A and B are anode and cathode, respectively and C1 and C2 are electrodes used to measure resistance of the composite film. A separate and identical non-connected island layer to the right of the A electrode displays the color change due to the polymerization. Polymer has also grown on the A electrode.

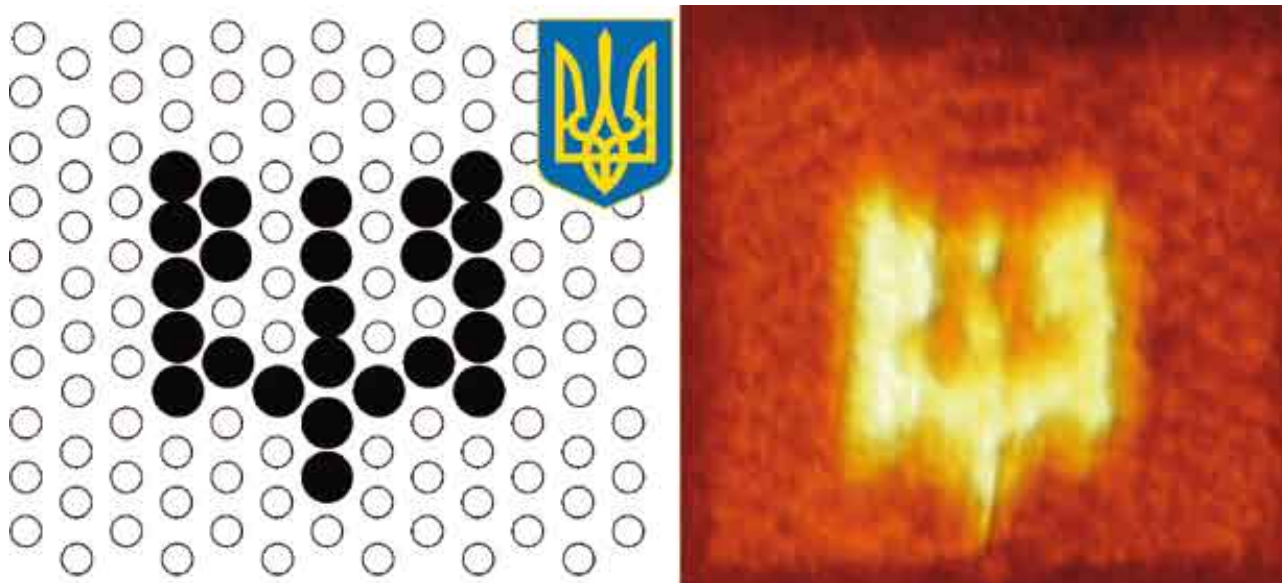
References:

D. Mtsuko, A. Avnon, J. Lievonen, R. Menon, and M. Ahlsgog, "Electrochemical deposition of polypyrrole nanolayers on discontinuous ultrathin gold films", *Nanotechnology*, 19, 125304 (2008).

Surface plasmon polaritons (SPP) are coupled excitations of electromagnetic field and free electrons in metal propagating on a surface of a conductor. The confinement to the very surface leads to many interesting features, e.g. SPPs can overcome the conventional diffraction limit. However, only with certain prerequisites light can be coupled with SPPs. We have realized a SPP frequency converter, a proof-of-principle device that converts the frequency of incoming SPP by means of organic molecules and near field coupling (see Fig. 11). The device could be used for example in SPP based communication for frequency-multiplexing. The work is done in collaboration with H. Kunttu's and M. Pettersson's groups at JYU.

Fig. 11. The schematic of a frequency converter: SPPs launched at the source (spectrum shown in inset as blue dashed line) propagate along the silvery waveguide and interact with converter molecules (upper inset), which convert them to another mean frequency (spectrum shown in inset as red dashed line). The lower inset presents data measured from the end of the waveguide (black dots). Fitting of the two spectra (green line) yields about 50 % conversion efficiency for our device.





Due to its exceptional self-assembly properties, DNA has become a key player in bottom-up fabrication, with 'DNA origami' being one of the striking examples. Various nanosize objects can be attached on any of the 6 nm sized pixels of an origami. We have successfully modified rectangular DNA origami with biotins forming the designed symbol and attached streptavidins on them. In addition, we have developed a method for trapping of DNA origamis between nanoelectrodes. Via the electrodes we have analysed both DC and AC characteristics of a single trapped DNA origamis by using impedance spectroscopy.

Carbon nanotube field-effect transistors (CNT-FETs) have been proposed as possible building blocks for future nano-electronics, but there are several challenges to solve still. One of them is to control the influence of the surrounding environment. The occurrence of mobile charges or charge traps in the vicinity of a CNT-FET is known to randomly cause hysteresis in its transfer characteristics. We are studying the possibilities to control the hysteresis and create a nano-

Fig. 12. Left: Design of the planned structure on a rectangular DNA origami. Circles correspond to pixels formed by staple strands, and closed one means biotin modified strand. Right: AFM image of a patterned DNA origami, with streptavidin connected to each biotin.

scale memory element by utilizing a single walled CNT in combination with a carefully chosen nanometer thin dielectric layer. In Fig. 13a, we show an atomic force micrograph of a typical CNT device. The highly doped Si substrate beneath the dielectric layer is used as a backgate. The ambient humidity level is found to affect the hysteresis only to a small degree, as seen in Fig 13b. A more profound influence on the hysteresis is found by varying gate insulator film. By carefully designing the insulator in layers of ALD deposited high- κ materials, the extent of hysteresis can be controlled. All measurements were made at room temperature, showing that the results may provide solutions to everyday electronics. The project is done in collaboration with M. Ahlskog's and K. Rissanen's groups at JYU and E. Kauppinen's group at HUT as well as Beneq Oy, Nokia Oy and Vaisala Oy.

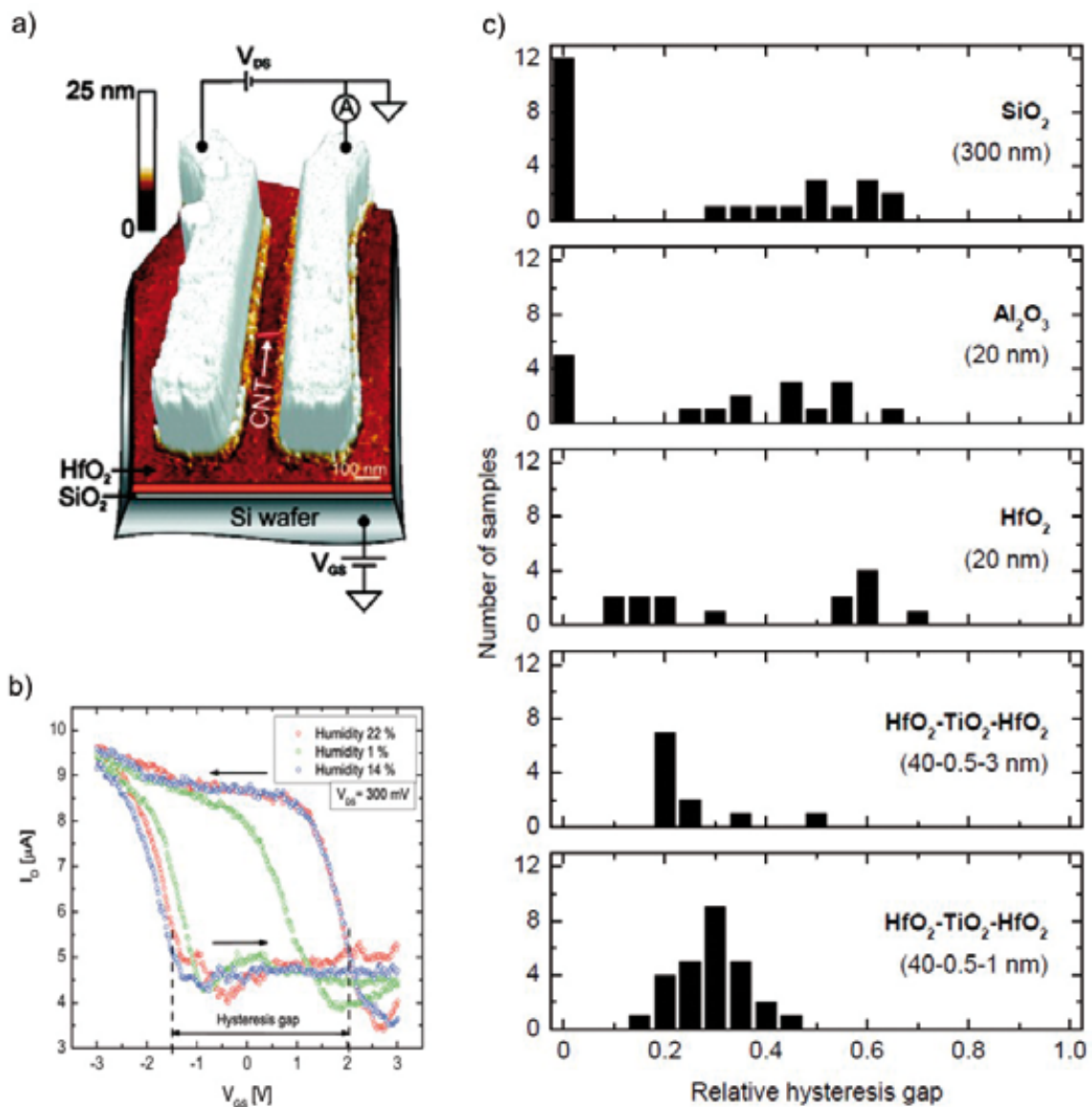


Fig. 13. a) AFM image of a carbon nanotube field-effect transistor with schematic measurement setup. b) Hysteresis in current response to change in back-gate voltage. c) Distributions of relative hysteresis gap for different gate insulators.

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Jaakko Akola, Hannu Häkkinen, Pekka Koskinen, Matti Manninen and Robert van Leeuwen

Computational Nanosciences

Reconstructed Graphene Edges

Graphite, familiar from pencils, is made from stacked graphene layers. Single graphene layers, discovered recently, have unusual properties suggesting novel applications. We investigated reconstruction patterns at the zigzag and armchair edges of graphene with density functional theory (P. Koskinen et al., Phys. Rev. Lett. 101, 115502 (2008)). It was unexpectedly found that the zigzag edge is metastable and spontaneously reconstructs at room temperature. The reconstruction self-passivates the zigzag edge, and affects profoundly its chemical properties.

Scanning Tunneling Microscopy: Effect of the Tip Electric Field

Nanoscale imaging can achieve remarkable accuracies. Interpreting the experimental images, however, is not always easy, as imaging processes themselves may affect systems under study. We demonstrated, via scanning tunneling microscopy (STM) measurements, the existence of electronic “beach states” localised at the edges of K islands on the graphite surface (F. Yin, J. Akola, P. Koskinen, M. Manninen, and R. E. Palmer, Phys. Rev. Lett. 102, 106102 (2009)). First-principles density functional calculations and simulated STM images confirm that the beach states are associated with imaging process-induced spatially dependent charge transfer from the alkali island to the surface, which is considerably enhanced at the island edge.

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 Pentti Frondelius, graduate student
 Heikki Heiskanen, graduate student
 Katarzyna Kacprzak, graduate student
 Janne Kalikka, graduate student
 Ville Kotimäki, graduate student
 Sami Malola, graduate student
 Petri Myöhänen, graduate student
 Ville Mäkinen, graduate student
 Juha-Pekka Nikkarila, graduate student -30.9.
 Antti Putaja, graduate student 1.10.-
 Lauri Nykänen, graduate student (chemistry)
 Oleg Olegovych Kit, MSc student
 Anna-Maija Uimonen, MSc student

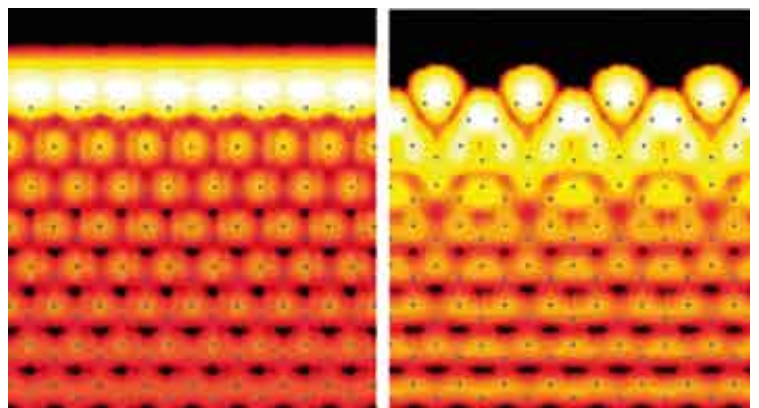


Fig. 1. Simulated STM images of zigzag (left) and reconstructed zigzag (right) edges of graphene.

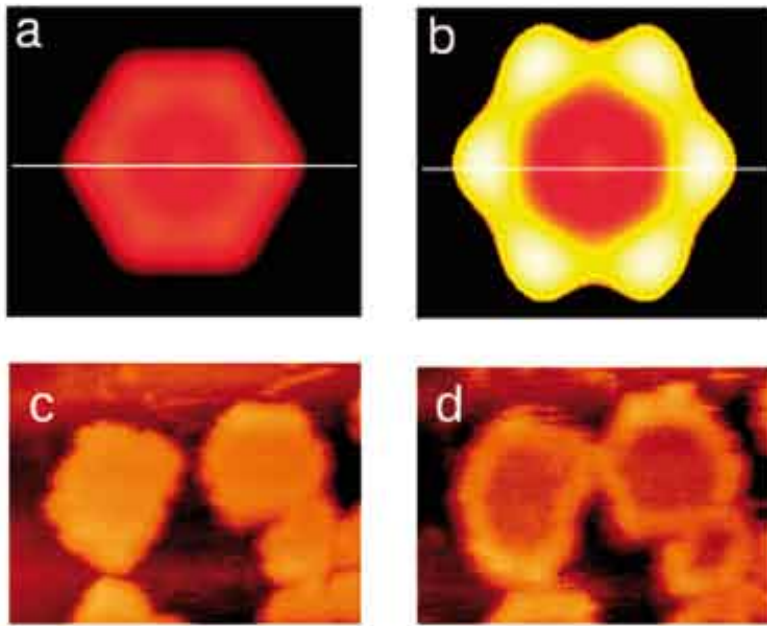
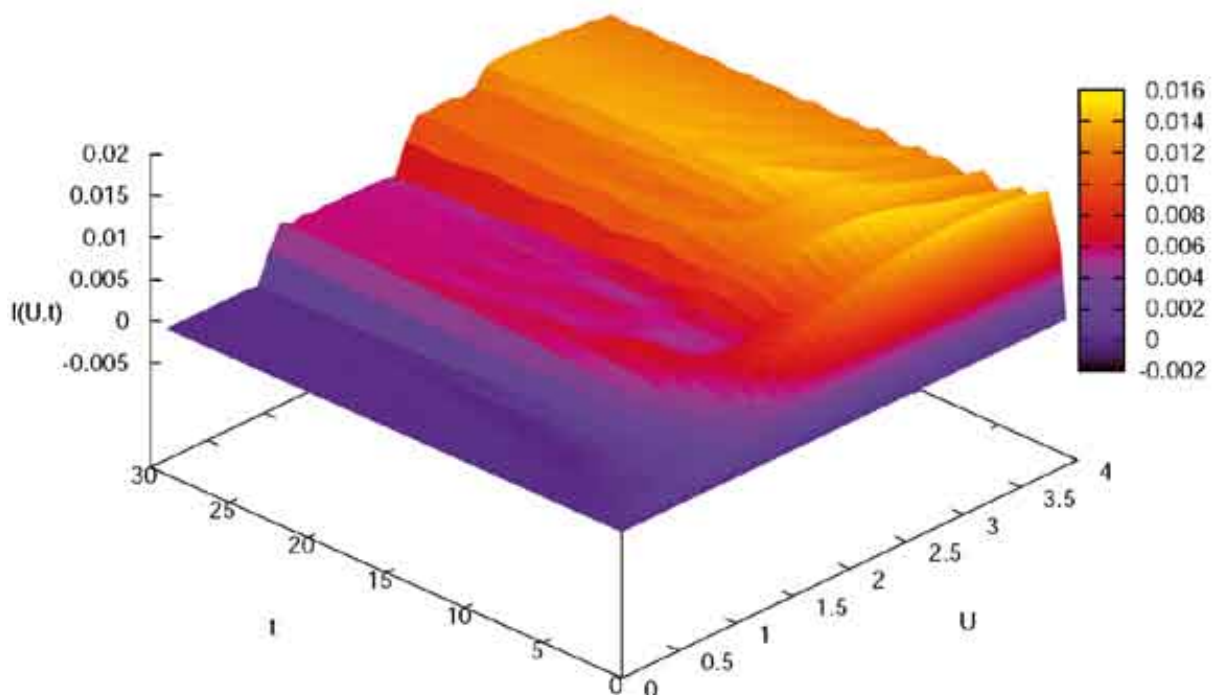


Fig. 2. K islands on graphite. Upper row: Simulated STM images (a) without and (b) with an external electric field. Lower row: STM images with (c) -2.0 V and (d) -4.0 V bias voltage. Stronger electric field from STM tip changes island's electronic structure.

Time-Dependence and Electronic Correlations in Quantum Transport

We proposed a many-body approach that can deal with both electronic interactions and time dependence in quantum transport (Myöhänen et al., Europhys.Lett. 84, 67001 (2008)). Within such a framework one can systematically study dynamical processes like relaxation and decoherence at the nanoscale. Understanding these processes is of utmost importance in molecular electronics whose ultimate goal is to miniaturize the size and maximize the speed of integrated devices. Important features of our method are the possibility to study the ultrafast transient dynamics up to the picosecond and femtosecond timescale and the inclusion of electron-electron interactions without violating the continuity equation. The method is based on time-propagation of nonequilibrium Green functions with the so-called Kadanoff-Baym equations. The method further generalizes the famous Meir-Wingreen formula to a transient regime and includes initial correlations and memory effects.



The method was tested by performing a study of time-dependent quantum transport through correlated quantum dots attached to two macroscopic leads. For this system we calculated time-dependent local currents and densities for different many-body approximations and highlighted the role of initial correlations and memory effects on the transient dynamics. It was found that the final steady state currents were strongly dependent on the level electronic correlations were incorporated. These electronic correlations were investigated at mean-field Hartree-Fock level, to second order in the electronic interactions and by certain infinite order resummations of Feynman diagrams.

We further showed that coherent charge oscillations on the quantum dots are strongly affected by the confined Coulomb interaction and can be directly related to the local equilibrium spectral density.

An example of a quantum transport calculation at Hartree-Fock level is presented in figure on previous page where we show the current through a system of five interacting dots coupled to two semi-infinite one-dimensional leads. At time zero a symmetrically applied bias voltage (value $+U$ and $-U$ in the left and right leads) is suddenly switched on and the current $I(U,t)$ flowing into the right lead is displayed as a function of time. We clearly see the development of transients with a clear oscillatory structure. When the transients saturate we obtain a clear step structure in the current as a function of the applied voltage. These steps reflect the quantized level structure of the central region leading to an increase in current when the applied bias is aligned with the levels in the central region. Also the frequencies oscillations in the transients can be understood and predicted from our theory.

Soft Condensed Matter and Statistical Physics

Membrane Crumpling

Our discrete element model for elastic materials with either elastic or elasto-plastic beam elements was used to analyze the crumpling properties of thin sheets (membranes). In fully elastic membranes a clear tendency for repeated deterministic folding was observed until the layered structure became so thick that folding was no more energetically favourable. There after further confinement of the membrane led to its random crumpling. The resulting pattern of ridges was independent of membrane thickness, i.e., it was self-similar. Introduction of plasticity destroyed this self-similarity, and the fractal dimension of crumpled structure was smaller in elasto-plastic sheets. The fractal dimension of crumpled elastic membranes was found to be given by the scaling exponents of the average ridge length and total elastic energy. No folding ap-



Fig. 1. Internal structure of a crumpled elasto-plastic membrane

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 Juha Merikoski, lecturer
 Andrei Rybin, docent
 Markko Mylly, senior assistant
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 Ari Jäsberg, postdoctoral researcher (part time)
 Pekka Kekäläinen, postdoctoral researcher
 Thomas Kühn, postdoctoral researcher
 Petro Moilanen, postdoctoral researcher
 Janne Juntunen, graduate student
 Janne Kauttonen, graduate student
 Vantte Kilappa MSc/graduate student
 Viivi Koivu, graduate student
 Keijo Mattila, graduate student (mathematical information tech.)
 Lasse Miettinen, graduate student
 Tuomas Tallinen, graduate student
 Tuomas Turpeinen, graduate student (mathematical information tech.)
 Mikko Voutilainen, graduate student
 Jarno Alaraudanjoki, research assistant
 Roope Lehto, MSc student
 Arttu Miettinen, MSc student
 Markku Väisänen, MSc student

peared in elasto-plastic membranes as they could not minimize their deformation energy under confinement by changing the deformation pattern like the elastic membranes do.

Stochastic Systems

We studied the dynamics of discrete polymers under time-dependent potentials with deterministic and stochastic switching mechanisms. The drift and diffusion coefficients of generalized Rubinstein-Duke polymers were determined. Current inversions were found as a result of coupling between the internal de-

degrees of freedom and the driven translational motion of the molecule.

In an analysis of strongly and weakly coupled driven interfaces their finite-size roughness behaviours were found to be different. Diffusion between such interfaces was analyzed numerically.

Transport Properties

The method to measure the heat diffusion coefficient of thin samples of solid material based on time development of an induced temperature distribution was developed further. Heat losses by controlled convection and radiative heat transfer were better controlled experimentally and by modelling. The accuracy of the method was so good that the temperature dependence of the convective heat-transfer coefficient could also be determined, while the heat diffusion coefficient of tantalum could be determined very precisely.

High-resolution tomographic reconstructions of paper, paper-making fabrics and granular materials were used to numerically analyze by the lattice-Boltzmann (LB) method their fluid transport properties, and the

effects on these properties of structural features. The numerical invasion percolation model was further developed so as to analyze time-dependent intrusion of nonwetting liquid in porous media as represented by their tomographic reconstructions.

Liquid droplets impacting a superhydrophobic surface decorated with micron-scale posts often bounce off the surface. However, by decreasing the impact velocity, droplets may land on the surface in a fakir state, and by increasing it, posts may impale droplets that are then stuck on the surface. We used a two-phase LB model to simulate droplet impact on such superhydrophobic surfaces, and showed that it may result in a fakir state also for reasonable high impact velocities. Simulations of flow by the LB method over surfaces with bubbles revealed that bubbles can lead to increased friction and even to negative slip due to the increased roughness they induce. This phenomenon can have applications in microfluidic devices.

We used the LB method to simulate also diffusion dynamics of fluorescent particles in cells, and to realistically model related experiments with laser scanning confocal microscope (LSCM). To this end we constructed three-dimensional digital cells using LSCM

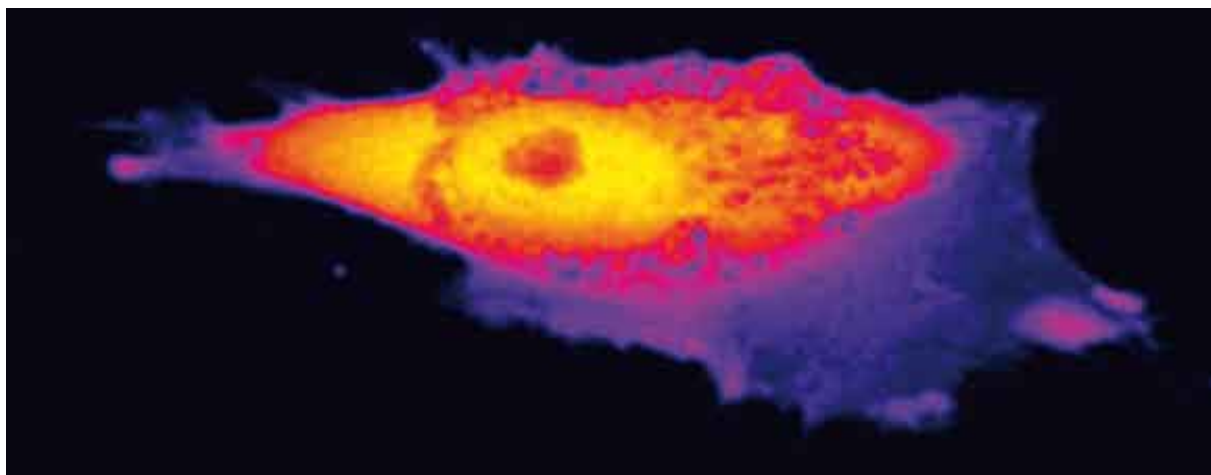


Fig. 2. A 3D digital cell used in diffusion simulations as determined by the measured distribution of fluorescence within the cell.

fluorescence data. This approach has a clear advantage over the conventional modeling tools in this case of very complicated boundary conditions. Quantitative results for diffusion could be achieved by directly correlating simulation and experimental data. A similar approach can later be constructed for determination of the binding dynamics of e.g. proteins.

Structural Studies Based on High-Resolution X-Ray Tomography

X-ray tomographic imaging was used to analyze the three-dimensional structure of paper, wood-fiber reinforced composites, paper-making fabrics, layers of mineral pigments, crystalline rock, and live cells. Both an in-house device with a resolution of about 1 μm , and the synchrotron radiation facilities at ESRF (resolutions 0.7 μm and 0.28 μm) and Lawrence Berkeley National Laboratory (resolution about 30 nm) were used. To improve image quality, new methods for noise reduction were developed, and for improved structural analysis, new segmentation methods were constructed. In the case of paper, e.g., the improved segmentation meth-

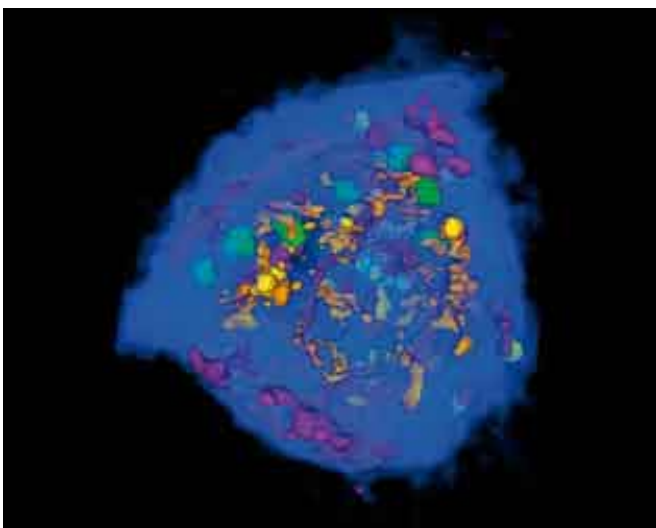


Fig. 3. Internal structure of a T-Cell as determined with 40 nm resolution in the National X-Ray Tomography Center at Berkeley National Laboratory.

ods could be used to determine more accurately than before the structure of pore space in view of its liquid transport properties. Also segmentation of individual fibers could already be done in tomographic reconstructions of wood-fiber composites. In live cells the new methods allowed automated segmentation of the internal organelles of the cells.

Assessment of Bone by Ultrasonic Guided Waves

Methods were developed for improved multi-modal ultrasonic assessment of long bones, such as the radius and tibia. Two ultrasonic guided wave modes, a fast first arriving signal (FAS) and a slow guided wave (SGW) can be measured in bone at low ultrasonic frequencies ($f=50\text{-}500\text{kHz}$). At such frequencies, ultrasonic wavelength in bone is long enough for probing osteoporotic changes deep in the endosteal (inner) cortical bone. Impact of soft tissue coating on excitation and detection of FAS mode was eliminated by designing and implementing a new ultrasonic array transducer, which allowed rapid and accurate in vivo measurement of the FAS velocity. In a small in vitro study we showed that FAS predicted well mechanical parameters such as the Young's modulus of the bone. In a large-scale in vivo study (550 voluntary subjects) we showed that the new transducer indeed probed well bone treats such as the subcortical bone mineral density and cortical thickness. We also showed that FAS assessment can discriminate low bone mineral density, suggesting that the ultrasonic approach has clinical potential. The other mode, SGW, showed excellent sensitivity to cortical thickness. Impact of soft tissue coating on this SGW mode was modelled, indicating that it has weak intensity on top of the soft tissue but could be better detected at the bone surface.

Kari J. Eskola and Kimmo Tuominen

Ultrarelativistic Heavy Ion Collisions – Theory

Studies of strongly interacting elementary particle matter, the Quark Gluon Plasma (QGP), and its transition to a gas of hadrons in ultrarelativistic heavy ion collisions (URHIC) are among the basic tests of the Standard Model (SM). We aim at understanding the QCD matter properties and collision dynamics through various observables measurable currently in the BNL-RHIC and soon in the CERN-LHC experiments. Also beyond-SM (BSM) physics is considered. We are financially supported by the Academy of Finland (SA), GRASPANP, private foundations and EU. Tuominen's LNCPMP project, which started in the HIP theory program in 2008, continues the successful traditions of the past URHIC project (2002-7 by Eskola).

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Vesa Ruuskanen, professor emeritus

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Harri Niemi, graduate student -31.8. (GRASPANP)

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Topi Kähärä, graduate student

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Hannu Holopainen, graduate student 1.10.- (HIP)

Timo Alho, MSc student

Tuomas Hapola, MSc student

Tatu Mustonen, MSc student

Tero Oravasaari, MSc student

Risto Paatelainen, MSc student



Fig. 1. The URHIC theory group. From the left; Standing: Tuomas, Matti, Hannu, Topi, Thorsten, Kimmo, Perttu; Sitting: Jussi, Kari, Vesa, Harri, Vesa.

We are in close contact with U. Helsinki and U. Oulu, and with the local ALICE group. Internationally, we collaborate with various foreign colleagues, organize and participate in conferences and workshops, European graduate school activities (e.g. HANUC-lecture week in Jyväskylä 8/08) and EU networks. Harri Niemi reached the PhD degree and moved on to a post-doc position in Frankfurt.

Global Analysis of nPDFs

Nuclear parton distribution functions (nPDFs) are needed for the computation of all collinearly factorizable hard-process cross sections in nuclear collisions. Our pioneering contribution in the global perturbative QCD (pQCD) analysis of nPDFs, the set EKS98, is now a standard reference in the field. Developing the analysis further and including also RHIC data for the first time in such study, we released a new nPDF set EPS08. We are currently preparing a next-to-leading order study with an error analysis for estimating the nPDF-originated uncertainties in e.g. those observables which are promising as QCD matter probes.

Hydrodynamic Modelling of Nuclear Collisions with Minijet Initial Conditions

One of our pioneering specialties is a comprehensive description of URHIC, where the initial QGP densities are computed from collinear pQCD factorization and gluon saturation, and the space-time evolution of the produced system is modelled by relativistic hydrodynamics. After successful tests against BNL-RHIC data, and developing the decoupling treatment further, we have predicted the bulk hadron multiplicities, p_T spectra and elliptic flow for Pb+Pb collisions at the LHC. Also electromagnetic emission has been con-

sidered as a QCD matter signal. We are now studying the effects of different fluctuations in primary particle production.

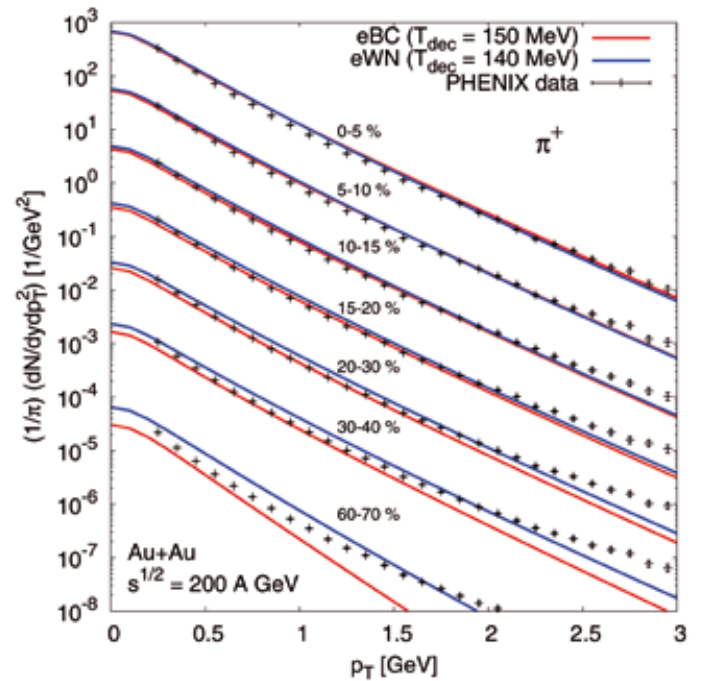


Fig. 2. Measured and computed transverse momentum spectra of pions in 200A GeV Au+Au collisions at different centralities at RHIC.

High- p_T Hadrons as QCD Matter Probes

The high- p_T particle production measurements in URHIC – an important class of QCD matter probes – are currently being extended from single-hadron spectra and few-particle correlations to reconstruction of full hadronic jets. To make contact with this experimental development, which will also be a crucial part of the LHC heavy-ion program, we are currently developing Monte Carlo simulations for QCD parton showering and collisional energy losses of high- p_T partons, embedding both phenomena in a hydrodynamical

cally evolving QCD medium. First results with single-hadron spectra and jet structure look promising but a more systematic studies are needed to identify the QCD dynamics of parton-medium interaction.

Effective Theories for QCD and Electroweak Symmetry Breaking

We have studied effective theories for QCD at finite temperature and density to obtain description of QCD thermodynamics at temperature regions relevant for URHIC. We are in progress to study explicit chiral symmetry breaking in these models in order to understand the corresponding features in the lattice data.

To address BSM phenomenology for the LHC we have focused mainly on the so-called minimal walking technicolor model (MWTC). We have considered collider signatures, computed the relic density of the dark matter candidate (WIMP) in this model and also studied how to distinguish different technicolor models from Randall-Sundrum –type extra-dimensional model in the case that a heavy (few TeV) spin-2 resonance is observed at the LHC. Extensive lattice simulations of the MWTC model are in progress.

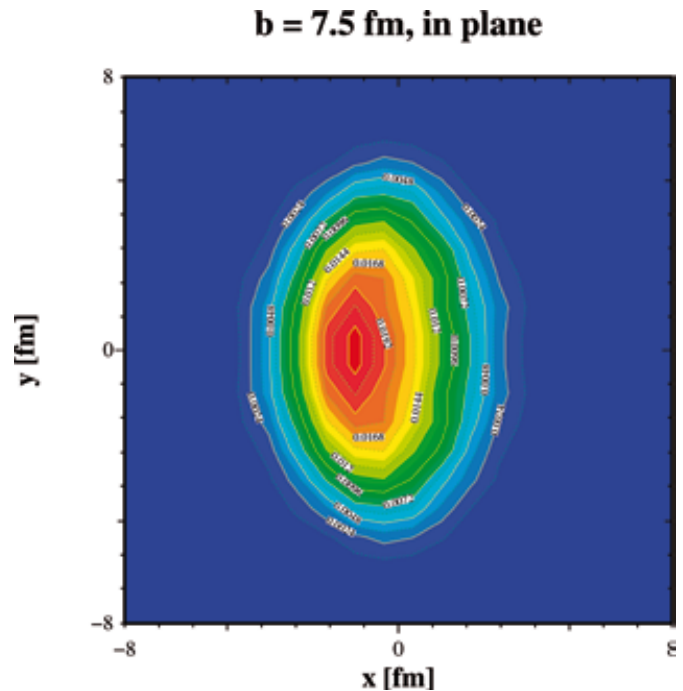


Fig. 3. Probability distribution for the location of a parton production vertex in the transverse plane, given a triggered hadron with $12 \text{ GeV} < p_T < 20 \text{ GeV}$ in a semicentral 200 AGeV Au+Au collision at RHIC.

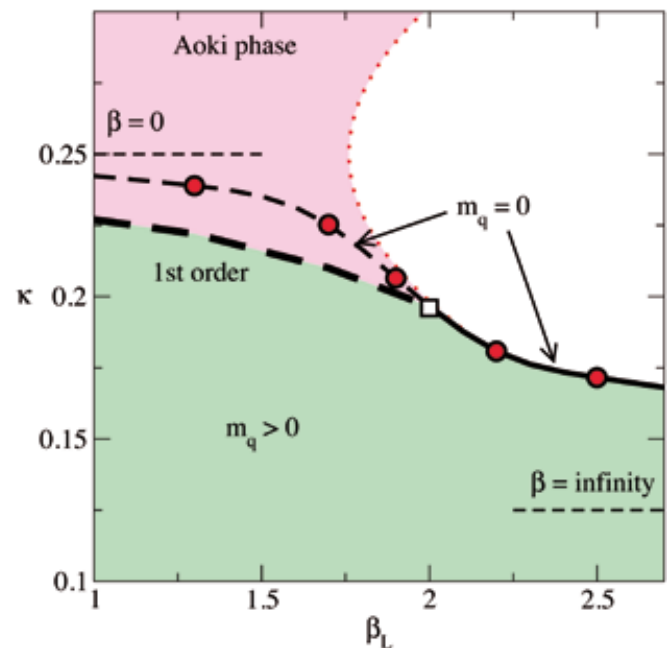


Fig. 4. The phase diagram of the MWTC model on (β_L, κ) -plane. These parameters are related to the coupling constant and quark mass as $\beta_L = 4/g^2$ and $\kappa = 1/(8+2am_q)$, where a is the lattice spacing.

Theoretical Particle Physics and Cosmology

Neutrino Physics

We have studied theoretically behaviour of neutrinos in astrophysical environments like supernovae. When neutrinos propagate in matter associated with a non vanishing magnetic field, as can be the case e.g. in supernovae, they can experience so called spin-flavour oscillations as an interplay of the effects caused by the matter and the electromagnetic field. In spin-flavour oscillations the spin of the neutrino flips its direction and the type of the neutrino changes. We have analysed this effect in the framework of relativistic quantum mechanics, that is, we have used the Dirac equation as our starting point.

We have also studied the effects of sterile neutrinos in various neutrino oscillation phenomena. Sterile neutrinos have no interactions with matter, except that they can mix quantum mechanically with the ordinary active neutrinos affecting thereby oscillations of ordinary active neutrinos. Doctoral student of the group Minja Hänninen (née Myyryläinen) defended her thesis work on these questions in February 2008.

Our group participates the LAGUNA (Large Apparatus for Grand Unification and Neutrino Astronomy), a pan-European project aiming at constructing a large scale underground experiment for studying low-energy neutrinos of astronomical and terrestrial origin and the stability of the proton. The design study of this project, scheduled for 2008-2010, is funded by EU through the FP7-Infrastructures programme. Apart from the scientific importance of the planned measurements, our interest in the project is further boosted by the fact that

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Kimmo Kainulainen, lecturer
Markku Lehto, senior assistant
Maxim Dvornikov, postdoctoral researcher -31.8.
Risto Hautala, graduate student
Matti Herranen, graduate student
Minja Hänninen, graduate student -30.4.
Diego Meschini, graduate student -28.2.
Johanna Piilonen, graduate student
Pyy Rahkila, graduate student
Janne Riittinen, graduate student
Daniel Sunhede, graduate student
Jussi Virkajärvi, graduate student
Perttu Hietanen, MSc student
Hannu Nyrhinen, MSc student

the Pyhäsalmi mine, in a two-hours driving distance from the Department, is considered as a possible location of the new detector.

Cosmology

We have studied alternative explanations for the observed (apparent) accelerated expansion of the universe. Apart from the usual postulate for the existence of dark energy, this observation could be explained either by the effect of inhomogeneities on the light propagation, or by modification of Einsteins theory of gravity at large distances. Our group has studied scalar-tensor and $f(R)$ -gravity extensions of the classical Einstein-Hilbert theory, concentrating in particular on the constraints arising from precision measurements in the Solar system. Doctoral student Daniel Sunhede defended his thesis work on these questions on May 2008. We are also computing the effect of strong in-

homogeneities on the apparent brightness of the high redshift supernovae eg. through weak gravitational lensing and redshift distortions. On the other hand we are developing particle physics motivated candidates for dark matter in the context of the walking technicolour theories.

We are also interested in the creation of baryon asymmetry in the electroweak phase transition (EWPT). To this end we have developed quantum transport equations (QTE) for non-equilibrium CP-violating systems. The QTE's for electroweak baryogenesis were first derived by us in the WKB approximation and later on in the context of the Schwinger-Keldysh closed time path formalism through a controlled expansion in gradients and in coupling constants. We have recently extended this formalism to include non-local quantum coherence effects, and we are currently using the formalism to compute the baryon asymmetry from EWPT and to study the spatial decoherence effects on neutrino propagation under flavour mixing.

Time, Space, Gravitation, and Quantum Physics

We are interested in a description of time that is connected both to quantum physics and to relativity via the concepts of premeasurement and transition. The main purpose is to find a link between the clock time and the transition-element time. So far we haven't found this link, but we have been able to introduce a candidate for a quantum-mechanical time that makes the most of metageometrical transition things and functions. Similar ideas are applied in a new approach to classical general relativity. We have been studying a bi-invariant that in a simple manner is related to clock time. This bi-invariant plays the role of transition function that in a first-order approximation reproduces the geometrical basis of general relativity. Hopefully "higher-order" analysis is going to reveal some metageometrical and quantum-mechanical features of time.

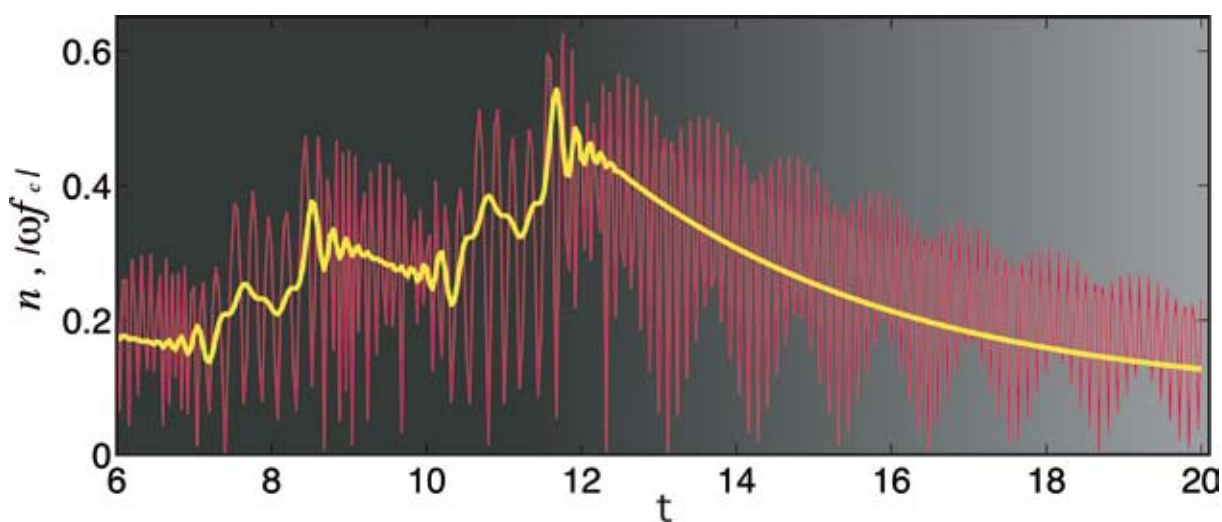


Fig. 1. Shown is the growth and the subsequent decay and thermalization of the number density (yellow curve) and of a coherence function (red oscillatory curve), under the influence of a time dependent driving force. Interactions with a thermal background are included at all times and they lead to an eventual decay of the coherence and to a thermalization of the particle number after the driving force is turned off $t = 12$.

Industrial Collaboration

The Industrial Applications group in the accelerator laboratory had numerous contacts with domestic and foreign industry and research laboratories. Fifteen irradiation campaigns with the 12 international partners were performed in RADEF facility. The total beam time of 1372 hours is a new record and so is the annual revenue. The new collaborators were SANDIA National Laboratories from Albuquerque, USA, and Japan Aerospace Exploration Agency, JAXA, who were doing the space electronics tests.

Group's highlight was The *RADECS 2008 Workshop*, which was organised on September 10–12 in University's Agora Building. More than 200 international participants from 29 countries contributed to the oral and poster sessions and 13 exhibiting companies were presenting their products during the workshop. *RADECS 2008* was awarded by the city of Jyväskylä for being economically the most productive international conference in 2008.

The irradiations of the polymer films for Oxyphen GmbH also continued with the four campaigns in the year 2008. Due to increased radiation safety measures during the building of the laboratory's extension the activity with MAP Medical Technologies Ltd. was stopped in September. The negotiations about the continuation of the collaboration with the new cyclotron will be started in spring 2009.

Our project to use neutrons to study properties of wood was also completed. The main coordinator was Metsäteho Ltd. Metso Paper from Pori was the other cooperating industrial company. The study was car-

ried out together with VTT Jyväskylä. The negotiations with several companies to continue the project from the feasibility level to the real applications are in progress.

The Experimental Nanophysics groups have well established collaboration with a few companies in Finland. For example: the Molecular Electronics and Plasmonics group in collaboration with the companies Enermet, Metso Drives, and JSP (Jyväskylä Science Park), was earlier funded by Tekes within the Miniaturization of Electronics research. The project focused on micro- and nanosensors and a patenting process has been started as a result of this former project.

During the year 2008 the industry collaboration was continued under new projects and including companies interested in nanotechnology such as Nokia, Planar and Vaisala, with funding from the FinNano Nanotechnology Programme of Tekes. In addition, short term collaboration with other companies, e.g. ABB Oy, exists also in the form of co-supervised master thesis.

In the past years, ultrasensitive superconducting radiation detectors for x-rays and IR-radiation have been developed in collaboration with Oxford Instruments Analytical Oy, motivated by the need of on-chip integrable ultrasensitive sensors in space research. In 2008 a new TEKES/EAKR funded project started, where the goal is to develop terrestrial applications of these detectors for materials analysis. The consortium includes also Aivon Oy and Star Cryoelectronics Inc. as industrial partners in addition to Oxford Instruments.

The Soft Condensed Matter and Statistical Physics group continued its established collaboration with a number of companies in several branches of industry.

X-ray microtomography was used in several applied and industrial research projects for studying e.g. the structure of paper, paper-making fabrics, wood-fiber composites, minerals, and biological samples. In this work an in-house table-top x-ray scanner was used together with the synchrotron radiation based tomography facility at ESRF. Work at ESRF involved large international collaboration with more than ten research groups in Europe and the USA. Related to these tomographic techniques, noise-reduction and segmentation algorithms were developed. Flow simulations based on the lattice-Boltzmann method were also carried out in tomographic images of industrially relevant materials so as to gain better understanding of their transport properties.

The research group continued participation in five large national research consortia funded by Tekes, industry and the Ministry of Trade and Commerce. These proj-

ects focused on developing new experimental and numerical techniques for flow in porous media, on basic and applied research on the rheological properties and dynamics of fibre suspensions, on tomographic imaging of paper-like materials and pigment layers, transport issues related to nuclear waste management and on ultrasound methods in assessment and monitoring of the quality of bone.

Several other projects involving direct collaboration with industry were carried out. These projects included experimental structure research, numerical simulation and modeling, and involved problems like transport of fluid in paper, matrix diffusion, rheological properties of pigment suspensions, and structural properties of paper and paper-making fabrics and mineral wool. A device developed by the group for testing properties of intraocular lenses was installed in the research laboratory of an international pharmaceutical company.

Industrial collaborators included Metso Paper, Stora Enso, UPM, M-real, ABB, Sulzer Pumps Finland, Omya Finland, Specialty Minerals Nordic, Tamfelt, KCL, Critical Medical, Numerola, Paroc, Posiva, and SIFI.

Jukka Maalampi and Juha Merikoski

Education

Education given at the Department of Physics is closely connected with frontline research. The whole Department including the laboratories is seen as a learning environment and the students are taken to participate in all its activities. Collaboration between students and informal contacts with personnel are strongly promoted starting from the early stages of physics studies. This long-standing tradition of the Department has become widely recognized. In 2008 teaching was evaluated by the international board of the Finnish Higher Education Evaluation Council and, as a result, for the second time, the Department was selected to be one of the ten national High-quality Education Units in 2010-12.

Summer students and PhD students are proud of the detector frame they have constructed

Jukka Maalampi, professor
Juha Merikoski, lecturer
Jussi Helaakoski, graduate student
Asko Mäkynen, graduate student
Mika Nieminen, graduate student
Pauliina Keränen, MSc student
Antti Lehtinen, MSc student
Lauri Pirkkalainen, MSc student
Minna Saloviin, MSc student
Perttu Tolvanen, MSc student

Degrees and Students

The Department offers study programs at all academic levels. In 2008 the number of MSc degrees taken at the Department was 34, of which 9 includ-



ed teacher qualifications, and the number of PhD degrees was 12. In 2008 there were 410 applicants for physics studies, with 210 of them indicating physics as their first choice. As a whole, 85 undergraduate students enrolled in 2008. Over 90% of the new BSc students were admitted based on their high school record and national maturity test result, the rest via a traditional entrance examination.

The total number of undergraduate students is about 500. Some 30 students, many of them with a polytechnic engineering background, study in the master programs for industrial physics, nanoelectronics and renewable energy. At the Department there are about 85 post-graduate students aiming at the PhD degree.

Teacher Education

Direct enrollment to teacher education, including the possibility to register during the first weeks of studies, has become the main route to teacher qualifications. Teacher students now commonly write already their BSc theses on questions related to physics teaching and often continue that project in their MSc thesis. The trilateral co-operation between the Departments of the Faculty, the Department of teacher education and the Teacher training school has continued, including collaboration in thesis supervision and further education of personnel involved in teacher education.

The Department participates in the *Finnish graduate school of mathematics, physics, and chemis-*



try education, with three students working on a degree of doctor or licentiate of philosophy in physics education.

Mika Nieminen defended his PhD thesis *Finnish Air Force Cadets in network – experience in use of on-line learning environment in basic studies of Mathematics* in 2008.

Teaching Development

At the Department students participate actively in teaching development. Initiated by student response, two new courses were launched in 2008, the third-year course *Physicist in working life* and the MSc level course *Researcher's toolbox*, to complement the first-year course *Flying start*, which was given for the eighth time. The transition period into the Bologna system ended in the summer and work was

initiated to produce the next version of the BSc degree to better take into account the needs of the research community and the increasing heterogeneity of the backgrounds of the incoming students. One major theme of the pedagogical development is to further increase the interactivity of teaching by reducing the number of traditional lectures and increasing the time used for other modes of teaching. Increasingly more effort is put in school co-operation and student recruitment to invert the common trend of declining number of applicants in the field.

Other Education Activities

In addition to its regular teaching program, the Department continues the co-operation with the Open University supplementary-education program for teacher qualification. The Department was active in the 17th Jyväskylä International Summer School. The Department has intensified co-operation with schools in the Central Finland district. The *Physics Now* course is being arranged again in high schools in collaboration with the Open University to reach wider audiences. Physics students frequently visit high schools to increase interest in studies in natural sciences and many high school groups visit the Accelerator laboratory and the Nanoscience center. The Department collaborates with schools within the CERN network by organizing training lectures prior to the CERN visits of student groups.



Head of the Department

Jukka Maalampi, prof.

Vice-Head of the Department

Rauno Julin, prof.

Professors

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 Kari J. Eskola
 Hannu Häkkinen
 Rauno Julin
 Markku Kataja
 Matti Leino
 Jukka Maalampi
 Ilari Maasilta 1.8.-
 Matti Manninen
 Jouni Suhonen
 Jussi Timonen
 Harry J. Whitlow
 Juha Äystö

Emeritus professor

Vesa Ruuskanen

Research professor

Jacek Dobaczewski (FidiPro award)

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 Kimmo Kainulainen
 Kari Loberg
 Juha Merikoski
 Matti Piiparinen

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 Sakari Juutinen
 Hannu Koivisto
 Markku Lehto
 Markko Myllys (on leave)
 Jan Rak (JYFL/HIP)
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Jaakko Akola
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Gillis Carlsson
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 Dave Cullen 16.9.-
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M. Dvornikov, T. Rashba and V. Semikoz
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MSc Theses*(Alphabetical order)*

Esko Ala-Myllymäki, Keskijänniteverkoista

Timo Alho, Gauge/gravity dualities

Tapio Envall, Permeability and its effect on the utilization of geothermal energy

Hannu Holopainen, Viskositeetti ja poikittaisvirtaus raskasioneitörmäysten hydrodynamiikassa

Jukka Jaatinen, Optoerottimien säteilytystestit protoneilla

Erna Kaleva, Astatiinitutkimus

Janne Kalikka, Vierasmolekyylien sitoutumisen mallintaminen lipokaliniiproteiineissa

Pauliina Keränen, Lukiolaisten ja peruskoulun yhdeksäsluokkalaisten asenteita fysiikkaa ja kemiaa kohtaan Keski-Suomessa

Vantte Kilappa, Analytical and numerical evaluation of errors in axial ultrasound measurements with an array transducer

Ilkka Kohvakka, Imeytyminen huokoiseen aineeseen

Tarmo Koponen, Höyrystysuunien kehittäminen metalli-ionisuihkujen tuottamista varten

Ville Kotimäki, Carbon nanotube azafullerene peapods and their electronic transport properties

Aarno Kärnä, Ionisaatiokammimatriisin käyttö intensiteettimuokatus sädehoidon laadunvarmistuksessa

Antti Lehtinen, Opettajan puhe sähköopin yksityisopetuksessa

Jaakko Leppäniemi, Multiwalled carbon nanotubes as field-effect transistors

Perttu Luukko, Vuorovaikuttavien satunnaiskävelijöiden autokorrelaatiot ja leveys

Vesa Maanselkä, Superraskaiden ydinten tutkimukseen liittyvä laitteisto ja RITU-rekyyliseparaattorin ionioptisia mittauksia

Ville Mäkinen, Dye molecules on titanium dioxide surface: cluster and periodic surface models

Tuomas Nuorento, Mallipäälysterakenteiden analysoiminen röntgentomografian avulla

Mikael Pajunen, Fabrication of a suspended nanotube nanomechanical device viae-beam lithography

Saku Palanne, Nanomanipulaatioon ja elektroni-mikroskopiaan perustuva hiilinanoputkien käsittelymenetelmä

Antti Pennanen, Enhancing silicon solar cell efficiency with metal nanoparticles

Jouko Perkkiö, Suuritehoisen puolijohdelaserin ohjelmoitava tehölähde

Lauri Pirkkalainen, Lukion fysiikan soveltava kurssi "Uusiutuva energia virtuaalikurssina"

Janne Ropponen, ECR-ionilähteen tuottaman röntgensäteilyn simulointi

Minna Saloviin, Fysiikan naisnobelistit, atomiytimen rakenne ja ydinfysiikan kouluopetus

Kari Sarvala, Measurements of high-frequency dielectric properties of nanocomposite materials

Pekka Toivanen, Dark matter detection by LSP scattering

Ville Toivanen, Ionisuihkun laadun ja siirtolinjan toiminnan kartoittaminen Jyväskylän yliopiston fysiikan laitoksen kiihdytinlaboratoriossa

Perttu Tolvanen, Fysiikan opiskelijoiden mallin muodostaminen

Laura Tuomikoski, Puolijohdediodit ulkoisen sädehoidon potilasannosmittauksissa

Kari Uusitalo, Tehokkuuden määrittäminen SAGE-järjestelmän elektronispektrometrin koelaitteistossa

Antti Vanhanen, Sädehoidon annossuunnitelmien säteilybiologinen vertailu

PhLic ThesesEero Kauppinen, Annoksen määrittäminen mammografiassa digitaalisesta kuvainformaatiosta
Laitosraportti 1/2008

PhD Theses

(Chronological order)

Diego Meschini, A metageometric enquiry concerning time, space, and quantum physics
JYFL Research Report 1/2008

Minja Hänninen, Studies of sterile neutrinos in astrophysics
JYFL Research Report 2/2008

Mika Nieminen, Ilmavoimien kadetit verkossa – kokemuksia verkkopohjaisen oppimisympäristön käytöstä matematiikan perusopetuksessa
JYFL Research Report 3/2008

Daniel Sunhede, Dark energy, extended gravity and solar system constraints
JYFL Research Report 4/2008

Jenni Kotila, Microscopic nuclear-structure calculations for the low-lying collective states in even-even nuclei
JYFL Research Report 5/2008

Juha-Pekka Nikkarila, Theoretical studies of artificial atoms and lattices
JYFL Research Report 6/2008

Harri Niemi, Hydrodynamical flow and hadron spectra in ultrarelativistic heavy ion collisions at RHIC and the LHC
JYFL Research Report 7/2008

Thomas Kessler, Development and application of laser technologies at radioactive ion beam facilities
JYFL Research Report 8/2008

Sergey Gorelick, MeV ion beam lithography of high aspect ratio structures with a focused or aperture-shaped beam for applications in biomedical studies and microfluidics
JYFL Research Report 9/2008

Maciej Zgirski, Experimental study of fluctuations in ultra-narrow superconducting nanowires
JYFL Research Report 10/2008

Timo Koponen, Fermionic superfluidity in optical lattices
JYFL Research Report 11/2008

Tommi Eronen, High precision Q_{EC} value measurements of superallowed $0^+ \rightarrow 0^+$ beta decays with JYFLTRAP
JYFL Research Report 12/2008

Degrees

(alphabetical order)

BSc degrees

Afflekt, Kristian (physics)
Alho, Timo (physics)
Envall, Tapio (physics)
Eskelinen, Antti-Pekka (physics)
Huovinen, Ville (physics)
Julin, Juhani (physics)
Järvinen, Riku (physics)
Koponen, Hanna (physics)
Korhonen, Juho (physics)
Kotimäki, Ville (physics)
Miettinen, Arttu (physics)
Palosaari, Mikko (physics)
Pellikka, Janne (physics)
Pennanen, Antti (physics)
Sario, Terhi (physics)
Tolvanen, Perttu (physics)
Toivanen, Ville (physics)
Väänänen, Ari (physics)

MSc Degrees

(main subject)

*=MSc includes teachers pedagogical studies

Ala-Myllymäki, Esko (physics)
Alho, Timo (theor. physics)
Envall, Tapio (applied physics)
Holopainen, Hannu (theor. physics)
Jaatinen, Jukka (applied physics)
Kaleva, Erna (physics)
Kalikka, Janne (physics)
Keränen, Pauliina (physics)*
Kilappa, Vantte (applied physics)
Kohvakka, Ilkka (physics)*
Koponen, Tarmo (applied physics)
Kotimäki, Ville (physics)
Kärnä, Aarno (applied physics)
Lehtinen, Antti (physics)*
Leppäniemi, Jaakko (applied physics)
Luukko, Perttu (theor. physics)
Mäkinen, Ville (theor. physics)

Nuorento, Tuomas (applied physics)
Pajunen, Mikael (physics)
Pennanen, Antti (applied physics)
Perkkiö, Jouko (electronics)
Pirkkalainen, Lauri (physics)*
Ropponen, Janne (physics)
Sario, Terhi (physics)*
Sarvala, Kari (electronics)
Saloviin, Minna (physics)*
Tikkala, Topi (electronics)
Toivanen, Ville (physics)
Toivanen, Pekka (theor. physics)
Tolvanen, Perttu (physics)*
Torkkola, Kari (physics)*
Tuomikoski, Laura (applied physics)
Uusitalo, Kari (physics)*
Vanhanen, Antti (applied physics)

PhLic Degrees

Kauppinen, Eero (applied physics)

PhD Degrees

Gorelick, Sergey (applied physics)
Eronen, Tommi (physics)
Hänninen, Minja (theor. physics)
Kessler, Thomas (physics)
Koponen, Timo (theor. physics)
Kotila, Jenni (theor. physics)
Meschini, Diego (theor. physics)
Niemi, Harri (theor. physics)
Nieminen, Mika (physics, physics teaching)
Nikkarila, Juha-Pekka (physics)
Sunhede, Daniel (theor. physics)
Zgirski, Maciej (physics)

