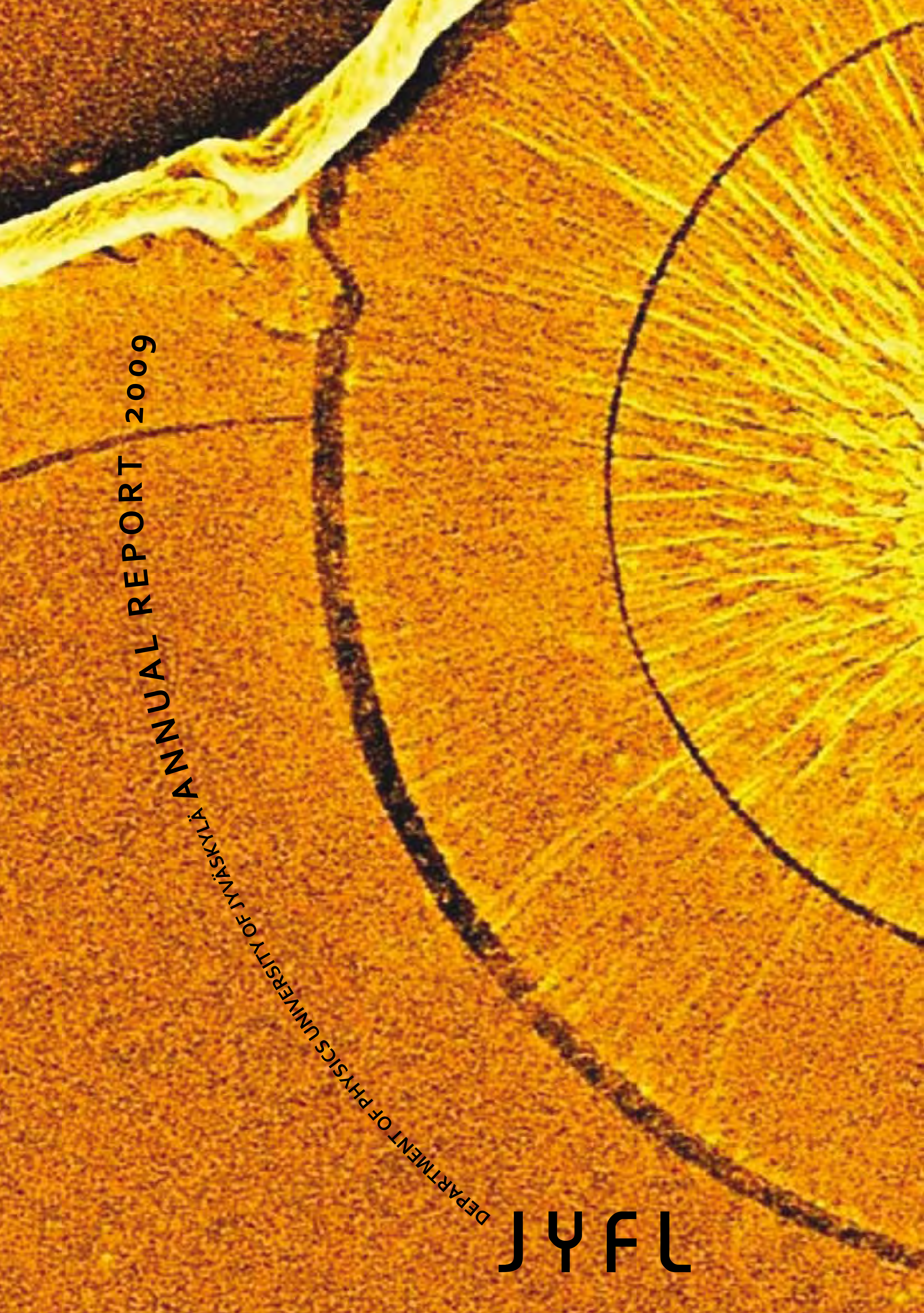

ANNUAL REPORT 2009

DEPARTMENT OF PHYSICS UNIVERSITY OF JYVÄSKYLÄ

JYFL

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UNIVERSITY OF JYVÄSKYLÄ
ANNUAL REPORT

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DEPARTMENT OF PHYSICS
UNIVERSITY OF JYVÄSKYLÄ

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Contents

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Preface

2009 will be remembered in the Department of Physics as a year of significant events and many positive developments. The extension to the Accelerator Laboratory building was completed, providing plenty of space for new research facilities. The grand entrance at midnight of the new MCC30/15 cyclotron through the open roof of the building was a spectacular event witnessed by a good audience. The arrival of the new technically advanced micro- and nano-tomography equipment, only the fourth of its type in the world, was another important addition to the infrastructure of the Department. The personnel of the laboratories showed their professionalism and high level of commitment in making the required arrangements and carrying out the extra work in a smooth and effective way.

Research

The research activity and productivity in 2009 was high in all three of our main research areas, Nanophysics, Nuclear and Accelerator-based Physics and Particle Physics. PhD Robert van Leeuwen was nominated to Professor's chair in nanophysics.

The total number of peer-reviewed research articles published in 2009 was 195, a substantial increase over our earlier numbers. We are approaching the magical limit of one publication per workday. In addition, there were approximately 80 other publications and some 250 presentations in conferences. The research activity was very international; about 70 % of the peer-reviewed articles were based around international collaborations, and there were more than 300 visits by foreign scientists to the Department, and even more visits by the personnel of the Department to overseas locations.

Photo: Jussi Jäppinen.

The active collaboration with large international infrastructures has continued. The CERN ALICE experiment started to collect its first data. The local research group carries the responsibility for ALICE in Finland and also has an important role to play at CERN. The Department also carries the main responsibility for Finnish participation in the FAIR project, the construction of a new international accelerator facility for ion and antiproton research in Darmstadt, Germany. In addition, the Department has participated in the pan-European LAGUNA project, which plans construction of a large detector for low-energy neutrinos and proton decay. The site of the facility is currently under consideration; with the nearby Pyhäsalmi mine being a candidate to act as host.

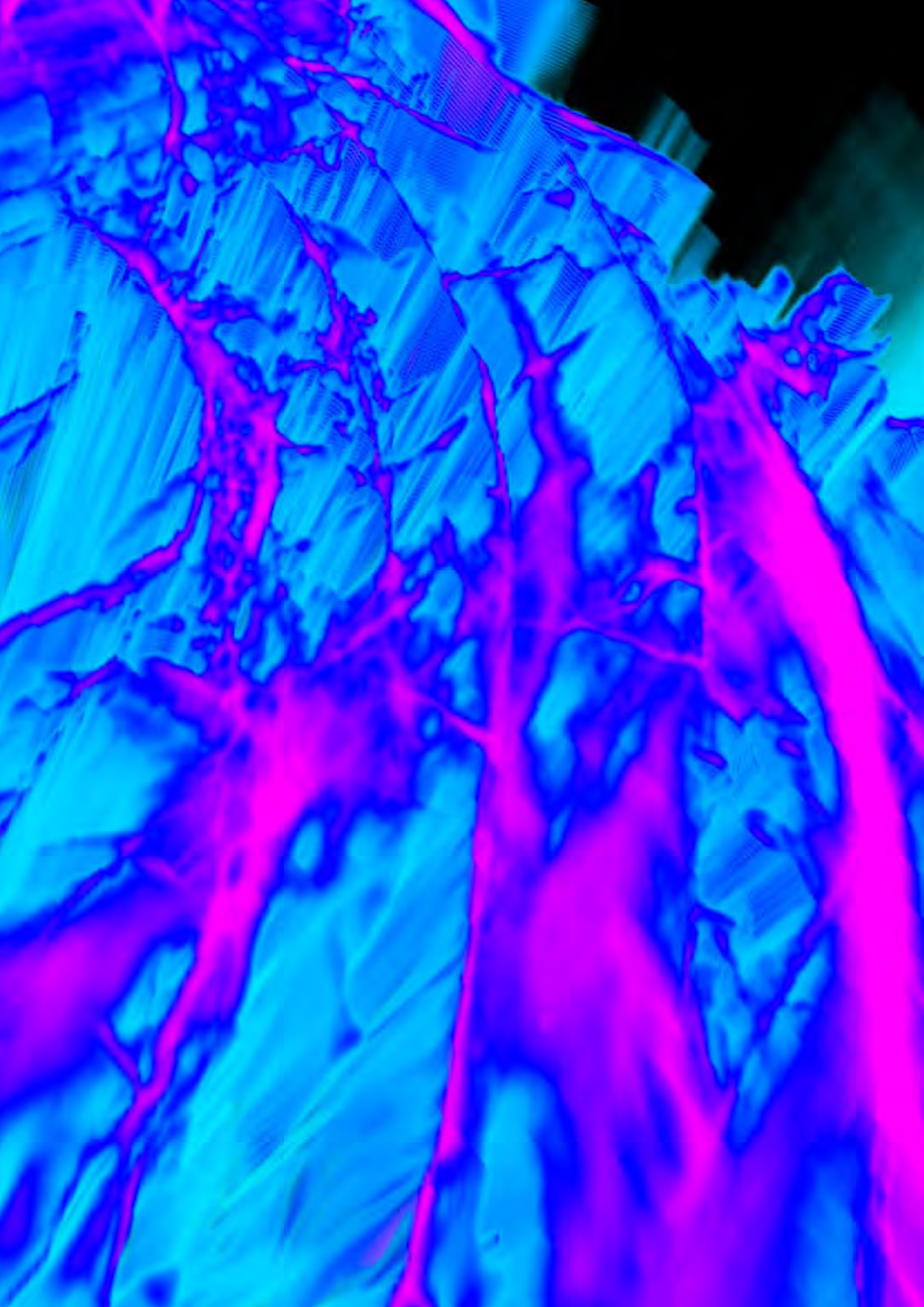
Education

From the point of view of teaching, many positive trends can be recognized from 2009. An all-time record of 17 doctoral degrees were awarded. With respect to the number of MSc degrees our standard level (35 graduations) was maintained. The high productivity of the Department in education, shown by these numbers, does not mean that we have sacrificed the quality of our education in any respect, on the contrary. The persistent efforts of the Department to improve and develop teaching and the instruction of students got 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. The quality and relevance to the labour market of the instruction given is also borne out by the record of almost 100 % employment of the students graduating from the Department.

After a worrisome drop in the enrolment of new students evidenced in the previous year, the great number of new students (99) in 2009 was a pleasant surprise and clearly had a morale-raising effect in the Department. There may be many reasons for this positive development, such as the dramatic change in the general economic situation, but the strengthened efforts of student recruiting carried out by the Department in 2008-2009 were certainly not without effect. These efforts included a new summer training program for higher secondary school students, which attracted a lot of interest and received good publicity in the media.

Administration

The total funding of the Department in 2007 was 13,9 M€, about 16 % more than in the previous year. There was an 5,4 % increase in the budget to 7.8 M€. Taking into account the increase of rent, general costs and the



Some statistical data from 2009

Personnel	183,5
- professors incl. research professors	14,5
- lecturers	5
- senior assistants	7
- researchers	130
- technicians	23
- administration	4
+ several research assistants (MSc students)	
Undergraduate students	530
of which new students	99
Graduate students	85
BSc	39
MSc degrees	35
PhLic degrees	3
PhD degrees	17
Credits (national)	11070
Median time to complete M.Sc (years)	6,0
Number of foreign visitors	~270
- in visits	~340
Visits abroad	~360
Peer reviewed publications	195
Conference proceedings	62
Others (articles in books etc.)	17
Conference and workshop contributions	
- Invited talks	~85
- Other talks	~90
- Posters	~80
Seminars outside JYFL	~115
Funding (million €)	13,9
* University budget (incl. premises)	7,8
* External funding	6,1
- Academy of Finland	2,4
- EAKR	1,2
- Technology Development Centre, T&E Centres	0,3
- International programmes	0,5
- HIP	0,6
- Contract research	0,6
- Others	0,5

salaries, the resources allocated to running costs were about 14 % lower than in 2008. The external funding of 6,1 M€ represented 44 % of the total funding.

The change of the administrative status of the Finnish Universities in the beginning of 2010, accompanied with many changes in administrative practices and tools, meant a heavy extra workload on the administrative personnel. The change also brought new duties to all of us, including the filling of timesheets in the SOLE system. It will certainly take some time before everything works smoothly and the inconveniences that disturb our main activities are over.

Events

Our weekly event, the Friday colloquium, has been very popular among the personnel and has attracted visitors from outside as well. The organization of the series has been in good hands, as is shown by the determined program planning and the active and successful recruiting of interesting speakers. The packed lecture hall has clearly impressed the speakers.

The Department had the honour to organize, in the 75th anniversary year of the University of Jyväskylä, the annual University Day. The two-day event consisted of an open door day for the general public with a lecture on cosmology, a “demo show”, demonstrations on the corridors, and excursions to the laboratories. The second day was devoted to the alumni of the Department, and witnessed many happy reunions. As a part of the event, an art exhibition presenting artistic views of our microscopic research objects was opened at the foyer of the Department.

Research technician Erkki Pesu retired in 2009 after almost twenty years’ service in the Department.

Centre of Excellence in Nuclear and Accelerator Based Physics

Rauno Julin

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 2009 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).

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.

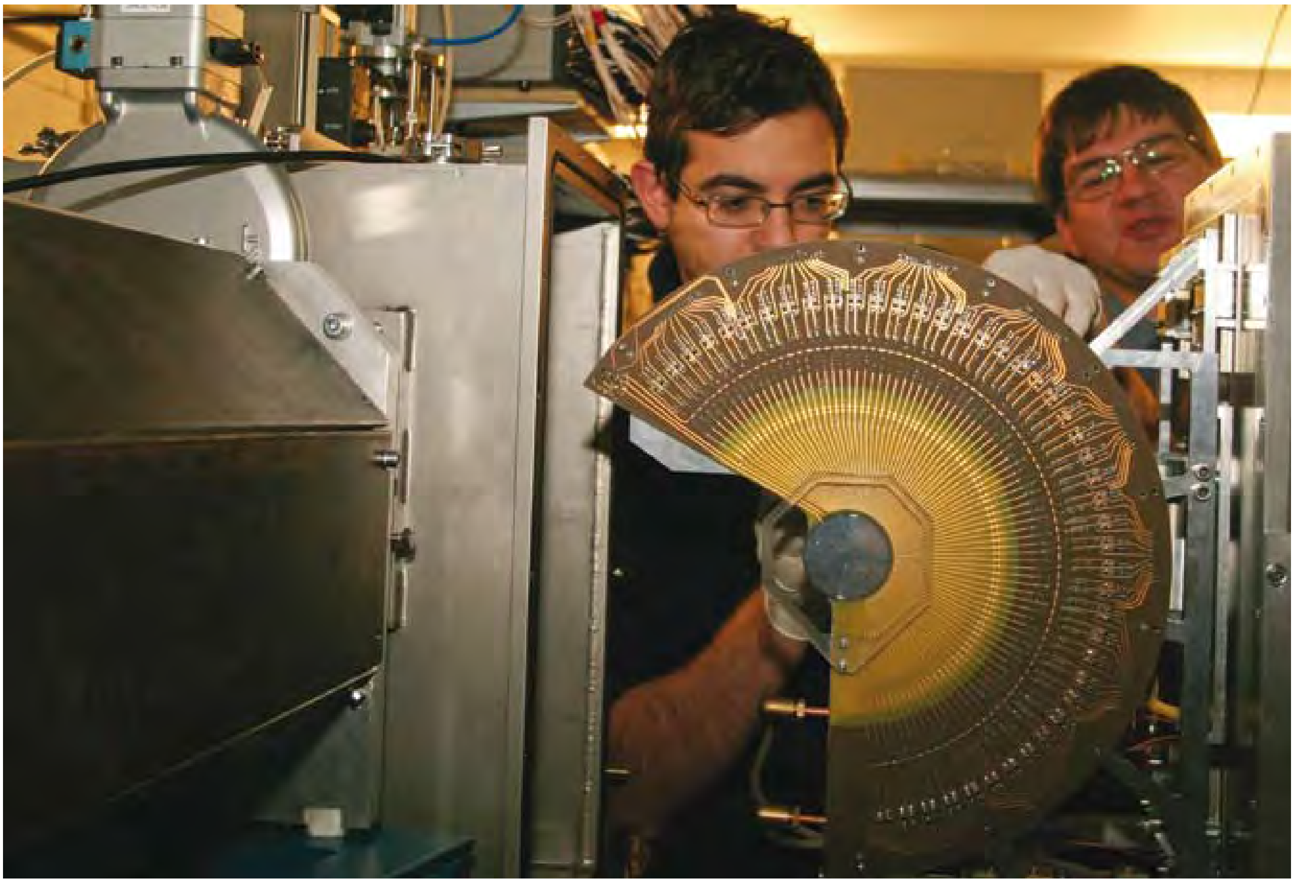
A day for the Scientific Advisory Board (SAB) meeting and for an open seminar of the JYFL-CoE was organized on 7 December 2009. In addition to the presentations of many highlights of 2008-2009 in this meeting, also strategies for a possible continuation of the CoE beyond 2011 where discussed. The year 2009 was scientifically very successful. The number of the peer reviewed publications of the eight teams was more than 100 including 10 high-impact letter-type of reports.

In 2009, the 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. On 7 February 2009 the total number of beam time hours of the K130 cyclotron exceeded the line of 100.000 hours. Important developments for the facilities at the Pelletron accelerator have also been carried out.

The highlight of the year was the advent of the new light-ion MCC30/15 cyclotron on 10 August 2009 from NIIEFA, St. Petersburg and the commissioning of the new extension of the Accelerator Laboratory constructed in 2008-2009. First beams from the cyclotron were delivered on 11th November 2009. Funding of 1.4 M€ has been allocated for equipping the new site. The new light-ion beams from the new cyclotron will be used for applications and for research carried out at the IGISOL facility, which will move to the new site. Consequently, this will release beam time for basic research, tests and service at the K130 cyclotron.

Following an international survey the Ministry of Education published a list of important research infrastructures. The JYFL Accelerator Laboratory is one of the two physics infrastructures on the list of existing national-level infrastructures. This list is expected to play an important role whenever infrastructure funding will be allocated in Finland.

On April 20-24, 2009 an Arctic JYFL Users + FiDiPro-EFES Workshop was organised in Saariselkä. Topics of the workshop covered nuclear structure theory and experiments with special focus on future developments.



On the theoretical side, new developments in describing nuclei within the energy-density-functional and shell-model methods were discussed.

In total, 36 proposals for experiments were evaluated by the Programme Advisory Committee (PAC) of the JYFL Accelerator Laboratory in the meetings on 23 April and 17 October, 2009.

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
Samuli Hemming, secretary general, Academy of Finland

Members of the Programme Advisory Committee of the JYFL Accelerator Laboratory

Mike Bentley (University of York, UK)
Klaus Blaum (University of Heidelberg, Germany)
Lorenzo Corradi (INFN-LNL, Legnaro, Italy)
Jacek Dobaczewski (University of Warsaw, Poland, chairman)
Günther Dollinger (Universität der Bundeswehr München, Germany)
Mark Huyse (Katholieke Universiteit Leuven, Belgium)

Finland Distinguished Professor – FIDIPRO – Programme

Jacek Dobaczewski

In 2009, the project has reached its midterm. The FIDIPRO team comprised 9 and 8 researchers in the first and second half of the year, respectively, working together on common project goals. All detailed information on the FIDIPRO project, and on its achievements and publications, is available on the project web page at http://www.jyu.fi/accelerator/fidipro/

In 2009, the main focus of the project was on preparing necessary infrastructure for the main three subject areas that are currently developed, namely, (i) extensions of the energy density functionals to higher order derivative terms, (ii) efficient linear-response algorithms to treat multipole excitations and β-decay probabilities in deformed nuclei, and (iii) symmetry-

Jacek Dobaczewski, research professor
Nicolas Michel, senior researcher
Jussi Toivanen, senior researcher
Rayner Rodríguez-Guzmán, senior researcher, June 2008 - May 2009
Gillis Carlsson, postdoctoral researcher
Kazuhito Mizuyama, postdoctoral researcher, August 2007 - July 2009
Alessandro Pastore, postdoctoral researcher
Petr Veselý, postdoctoral researcher
Francesco Raimondi, graduate student
Pekka Toivanen, graduate student
Marcin Borucki, ERASMUS student, September 2008 - May 2009

The FIDIPRO team on November 11, 2009. Standing, from left: Jacek Dobaczewski, Petr Veselý, Pekka Toivanen, Gillis Carlsson. Seated, from left: Francesco Raimondi, Alessandro Pastore, Nicolas Michel. Absent from the photo: Jussi Toivanen restoration methods applicable simultaneously to several broken symmetries.

N³LO functionals. We developed methods that allow for solving the self-consistent equations for the N^3LO nuclear energy density functional, which we proposed in 2008. We derived general expressions for the mean fields expressed as differential operators depending on densities and for the densities expressed in terms of derivatives of wave functions. These expressions were then specified to the case of spherical symmetry. Based on these results, we constructed the computer program HOSPHE, which solves the self-consistent equations by using the expansion of single-particle wave functions on the spherical harmonic oscillator basis.

In Fig. 1, we present results of calculations performed for ^{208}Pb and the harmonic-oscillator bases of N_0 = 10 – 70. The figure shows the convergence of the total energy in function of N_0. It turns out that the energy converges exponentially to the limiting value of E_0, namely, $E(N_0) = E_0 + E_1 \exp(-a N_0)$. However, as shown in the two panels of Fig. 1, two different values of E_0 are obtained for the regions of N_0 below and above N_0 = 38.

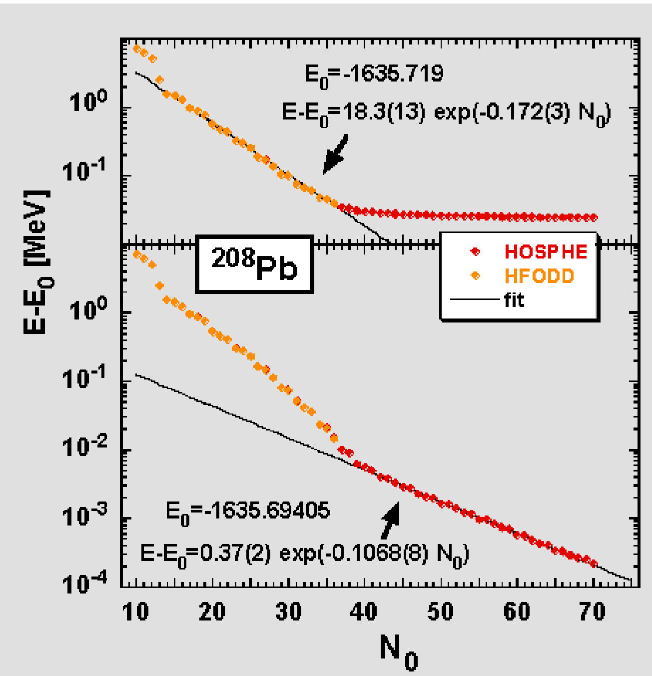


Fig. 1. The total energy of ^{208}Pb as a function of the maximum harmonic-oscillator shell included in the basis, N_0. Upper and lower panels show, in the logarithmic scale, the differences $E(N_0)$ - E_0 for two different values of E_0. Red and orange dots give results calculated by using the codes HOSPHE and HFODD, respectively. Up to N_0 = 36, where the HFODD calculations could have been performed, one sees a perfect agreement between the results given by the two codes. Solid lines give results of the exponential-decay fits.

By considering convergence patterns in a few more cases for different options and nuclei, we found that the trend with two different slopes is not a general feature. In the few cases we looked at, we found that it is only above 40 – 50 shells that the rate seems to stabilize to an exponential convergence. These results show that, in general, it is not possible to find the extrapolated limit of energy just by calculating only a few points of the curve for some small numbers of shells.

Linear-response algorithms. We implemented a new method to calculate RPA strength functions with iterative non-hermitian Arnoldi diagonalisation method, which does not explicitly calculate and store the RPA matrix. We studied treatment of spurious modes, numerical stability, and how the method scales as the used model space is enlarged. We performed the particle-hole RPA benchmark calculations for doubly magic nucleus ^{132}Sn and compared the resulting electromagnetic strength functions against those obtained within the standard RPA.

Fig. 2 compares the isoscalar 1^- strength functions of our iterative Arnoldi method with the strength functions obtained by using the standard RPA. The red line shows the strength calculated when the generated Arnoldi basis is orthogonalised against spurious mode during iteration and the orange line corresponds to similar calculation without orthogonalisation. The low-lying state at 0.72 MeV, which has a large overlap with the spurious isoscalar 1^- mode, disappears when the orthogonalisation method is used.

When no orthogonalisation is made against the spurious mode, the obtained excitations contain small components of the spurious mode. This affects the physical part of the strength distribution, especially around 20 – 30 MeV. The standard RPA strength function is not corrected for the spuriosity, but only the strength of the lowest-lying state that has a large overlap with the spurious isoscalar mode is omitted. At 20 – 30 MeV, this strength agrees well with our uncorrected strength, which shows that at these high energies, the standard RPA results are still affected by the spurious mode.

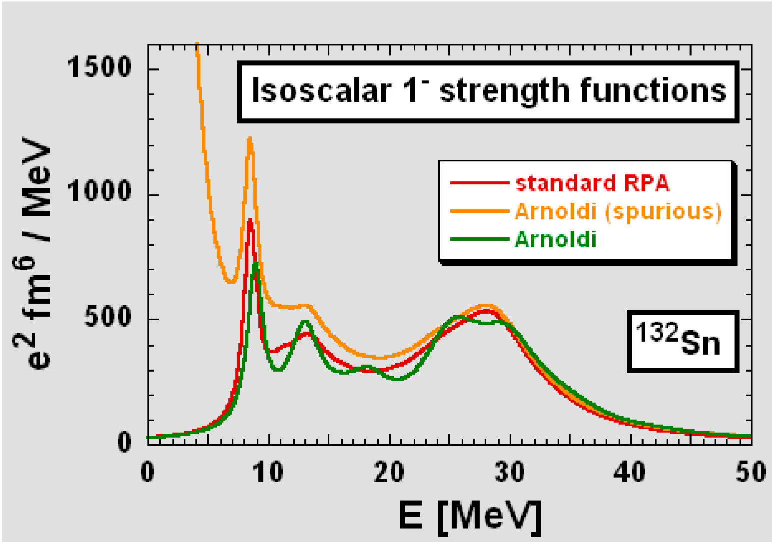


Fig. 2. The isoscalar 1^- strength functions in ^{132}Sn, calculated using 100 Arnoldi iterations and with spurious IS mode removed (green line) compared with the results of the standard RPA (red line). The orange line shows results of 140 Arnoldi iterations without orthogonalisation against the spurious isoscalar 1^- mode.

Symmetry-restoration methods. Based on the 1960 idea of Lipkin, we studied minimization of energy of a symmetry-restored mean-field state as being equivalent to the minimization of a corrected energy of a symmetry-broken state with the Peierls-Yoccoz mass. It is interesting to note that the "unphysical" Peierls-Yoccoz mass, and not the true mass, appears in the Lipkin projected energy. The Peierls-Yoccoz mass can be easily calculated from the energy and overlap kernels, which allows for a systematic, albeit approximate, restoration of translational symmetry within the energy-density formalism. Analogous methods can also be implemented for all other broken symmetries.

On April 20-24, 2009 we co-organized in Saariselkä the Arctic FIDIPRO-EFES Workshop: Future Prospects of Nuclear Structure Physics. Topics of the workshop covered nuclear structure theory and experiments with special focus on future developments. On the theoretical side, we discussed new developments in describing nuclei within the energy-density-functional and shell-model methods, with a particular emphasis on structure of exotic nuclei. On the experimental side, the physics opportunities of the upgraded facilities at JYFL and emerging opportunities at RIKEN and FAIR were discussed. Further detailed information, including the scientific program, list of participants, and electronic versions of talks, is available on the workshop home page: https://www.jyu.fi/fysiikka/en/research/accelerator/igisol/workshop/.

Accelerator Facilities

Pauli Heikkinen and Hannu Koivisto

The use of the cyclotron has exceeded 6000 hours/ year since 1996. The total operation time in 2009 was 6224 h with 4548 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. The use of protons decreased from previous years down to 17.4 % since proton runs were stopped in October 2008 due to limitations in radiation shielding during the construction of the laboratory extension. This stopped both isotope production (^{123}I) and proton induced fission studies (IGISOL). Proton runs started again in the middle of March, 2009. However, isotope

Pauli Heikkinen, chief engineer
Hannu Koivisto, senior assistant
Olli Tarvainen, postdoctoral researcher
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, graduate student
Ville Toivanen, graduate student
Markus Savonen, MSc student

Fig. 1. The joint team of the Efremov Institute, the crane company (Tikkanostot), safety officer (Ramboll) and the Department of Physics happy after the successful lifting of the cyclotron magnet from the trucks into the cyclotron bunker at 1 pm, August 11, 2009.

production has not continued yet. Beam cocktails for the space electronics tests were the most commonly used beams (26.1 %). Altogether 20 different isotopes were accelerated in 2009.

The construction of the Accelerator Laboratory extension for the new MCC30/15 cyclotron started in September 2008, and it was finished in the summer 2009. The new cyclotron arrived on August 10, 2009, about two months later than scheduled. The installation of the cyclotron started immediately by the manufacturer's (NIIEFA) specialists. Before the end of November 2009 the maximum extracted proton intensity (in pulses) was 200 μA, twice the guaranteed value, and 62 μA for deuterons, which is also more than guaranteed (50 μA). The final acceptance is assumed to be in the middle of March, 2010.

The breakdown process of ECR-heated plasma has been studied in the pulsed mode using time resolved bremsstrahlung and ion current signals. It was noticed, for example, that the ignition process is strongly affected by the electron and neutral densities at the moment of ignition. A simple qualitative model, which is in good agreement with the experiments, has been developed to interpret the results. This behavior can be important in facilities operated in pulsed mode.

Frequency tuning experiments have been carried out in collaboration with LNS-INFN (Catania/Italy) ion source group. During the experiments the frequency of microwaves used for the plasma heating was changed in a very narrow frequency gap in order to affect the electromagnetic mode structure. A clear frequency dependence was seen in highly charged ion production. In addition, a rough Q-value estimation for the plasma loaded cavity was done with the aid of reflection coefficient. The Q-value obtained, around 2000, is much higher than generally accepted but is in good agreement with the recent results obtained by the LNS ion source group.

The effect of space charge compensation on the beam quality was studied by feeding neutral gas in to the beam line close to the focal point before the mass separation. According to measurement the emittance of the ion beam decreases dramatically with the aid of neutral gas. This indicates that the degree of the beam neutralization is not adequate for efficient beam transport. The beam intensity decreases due to charge exchange processes caused by the neutral gas feed but because of strong emittance behavior the beam brightness of highly charged ion beams was approximately two fold with optimum pressure. However, regardless of improved beam emittance and

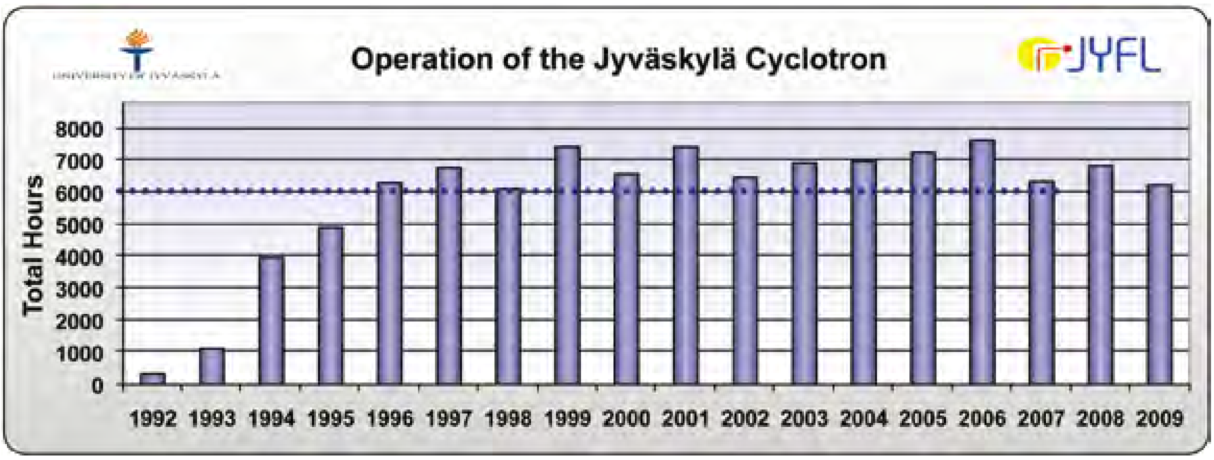


Fig 2. Operation of the Jyväskylä K130 cyclotron in 1992 – 2009.

Photo: A. Lehtiö.

brightness only a small improvement in the accelerated ion beam current was obtained. This behavior was noticed also with an emittance threshold analysis: the method mainly affects the ion beam which still remains outside the acceptance of the cyclotron. As a next step other means to improve the beam compensation will be studied.

The new plasma chamber for the JYFL 14 GHz ECRIS was completed and tested. In the case of highly charged ion beams like Xe^{30+} its performance is at least two-fold compared to the old plasma chamber.

Fig. 3. The group from the Efremov Institute (NIIEFA) is installing the cyclotron components.

Exotic Nuclei and Beams

Ari Jokinen, Iain Moore, Heikki Penttilä and Juha Äystö

Juha Äystö, professor
Ari Jokinen, lecturer
Iain Moore, senior researcher
Heikki Penttilä, senior researcher
Valery Rubchenya, senior researcher (Khlopin Radium Institute, St. Petersburg)
Anu Kankainen, teaching assistant
Christine Weber, postdoctoral researcher, – 31.3.
Tommi Eronen, postdoctoral researcher
Veli Kolhinen, postdoctoral researcher, 1.5. –
Viki-Veikko Elomaa, graduate student – 31.10, postdoctoral researcher, 1.11. –
Ville Föhr, graduate student
Jani Hakala, graduate student
Pasi Karvonen, graduate student
Juho Rissanen, graduate student
Antti Saastamoinen, graduate student
Volker Sonnenschein, graduate student
Mikael Reponen, graduate student
Jani Turunen, graduate student (STUK)
Ilkka Pohjolainen, MSc student
Heli Hoilijoki, summer student
Niina Könönen, summer student

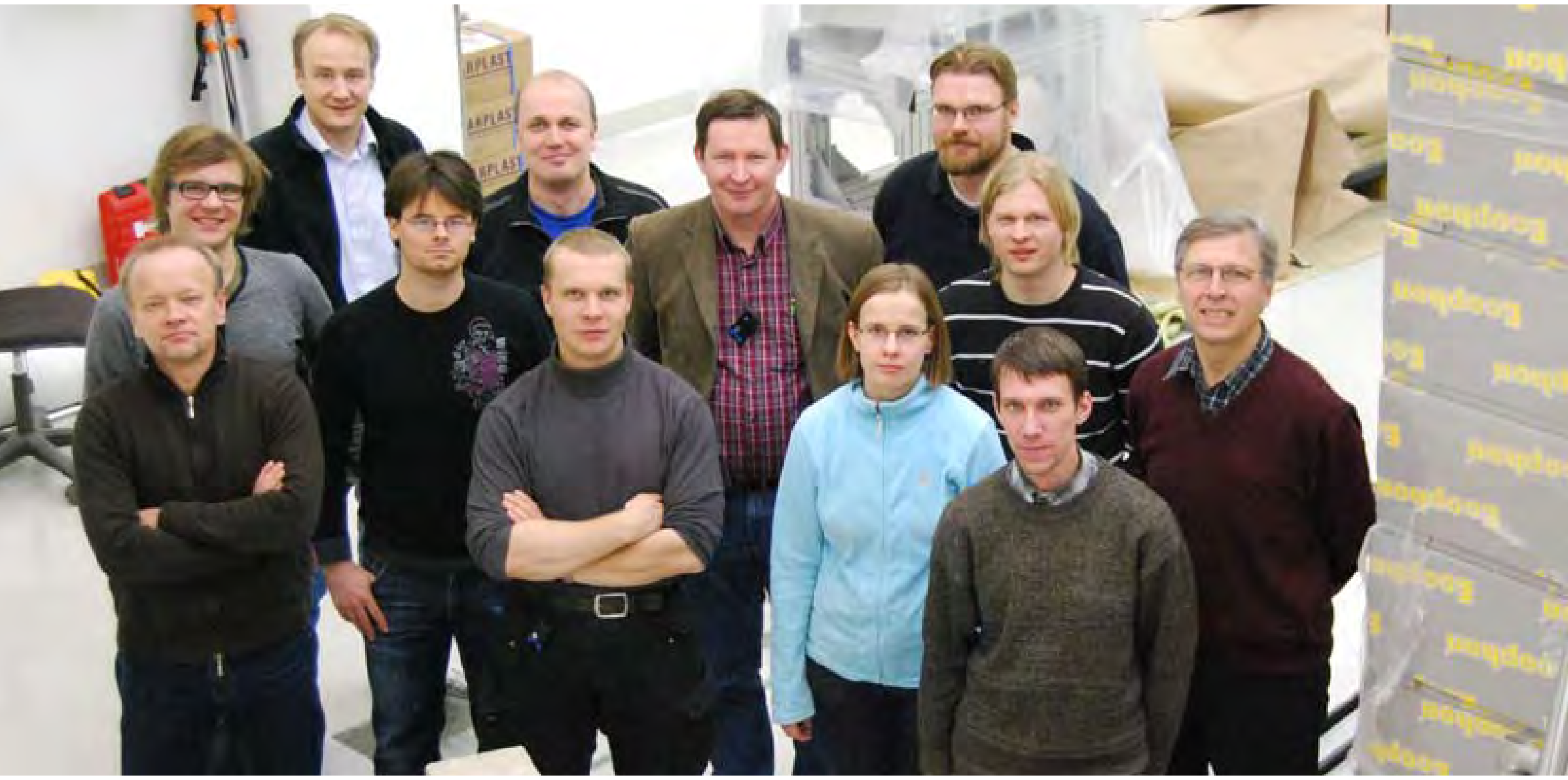
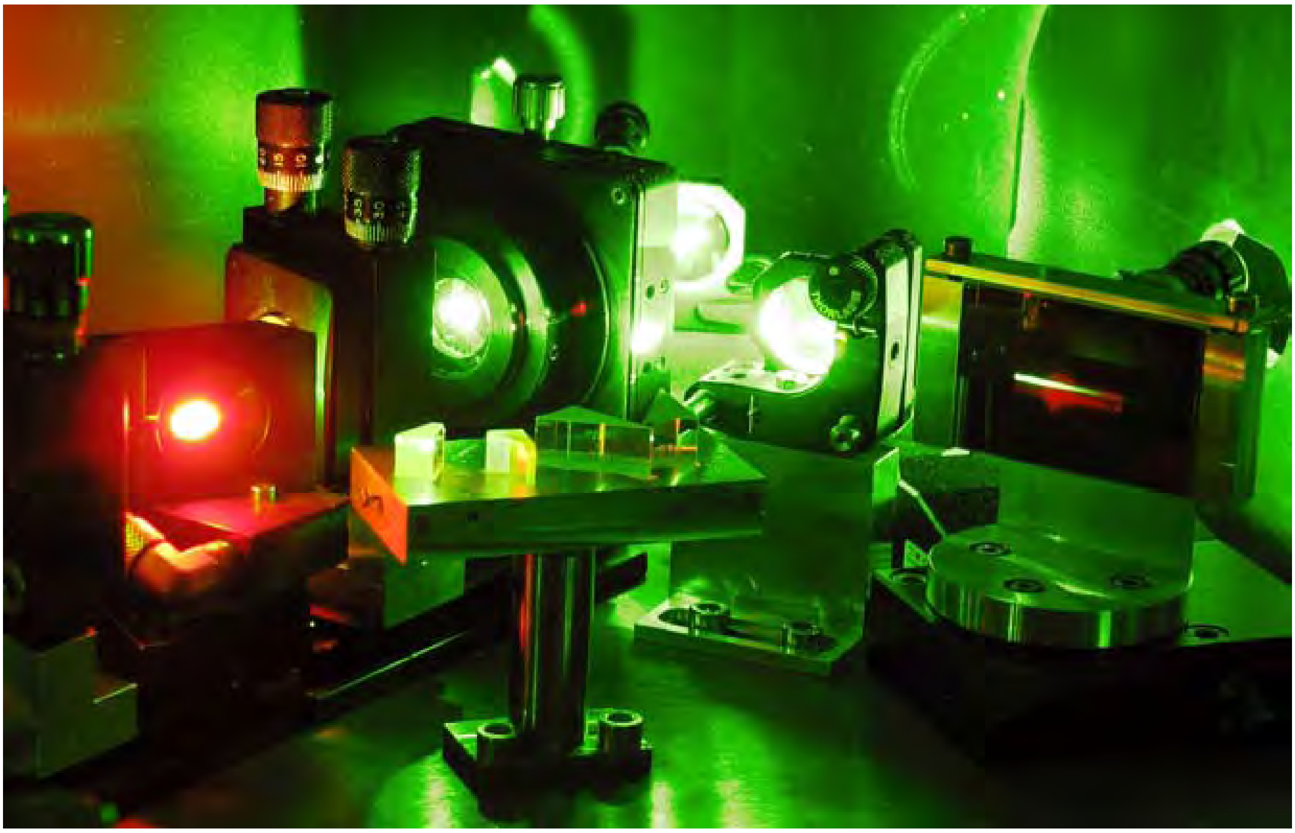


Fig. 1. The IGISOL group standing in the accelerator laboratory extension on the spot to which the IGISOL target area will be moved in 2010. This photo is the third in a series taken annually at the same location. From the left: Ari Jokinen, Mikael Reponen, Veli Kolhinen, Volker Sonnenschein, Tommi Eronen, Antti Saastamoinen, Heikki Penttilä, Anu Kankainen, Pasi Karvonen, Juho Rissanen, Dmitry Gorelov (in the front), and Juha Äystö. Iain Moore was recovering from Marcialonga 70 km skiing competition (http://www.marcialonga.it).



Activity in 2009

Fig. 2. New grating-based Ti:Sapphire laser. The grating contains 1500 lines per mm. Also shown are a variety of anamorphic prism pairs needed to expand the laser beam to cover more of the grating surface.

Our activity in 2009 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 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). Our team has significantly benefited from collaborations with several groups from Europe and North America.

The technical developments in Jyväskylä divide into strictly local activities and planning of the future FAIR experiments. The common proposal for an Advanced Trapping System (MATS) and Laser Spectroscopy (LaSpec) experiments at FAIR was finalized and submitted for review. The FAIR activities were also reflected by the experimental program, in which the delayed neutron and decay heat measurements [I136] in collaboration with Valencia, Madrid and Barcelona groups, in addition to the physics goals, benchmarked the performance of experimental equipment intended to be used at FAIR. Locally, the MCC30/15 intense beam proton cyclotron, expected to become the workhorse for the IGISOL facility in the future, was delivered in 2009. Preparations for the IGISOL move to the new experimental area escalated towards the end of the year. This did not hinder the research activities: several atomic masses of neutron-rich fission products were measured [I139] as well as the EC branching in the decay of ^{116}In, important for weak interaction theory development [I140]. Three Physics Letters B and

5 Physical Review Letters based on the research at IGISOL were accepted in 2009.

2009 also heralded a year of on-going laser ion source developments. A new grating-based Ti:Sapphire laser was built, providing superior tunability needed in the development of new laser ionization schemes. The "dual chamber" gas cell, developed by the Leuven LISOL group, was adapted for use at IGISOL. The separation of the laser ionization zone from the beam-target volume results in an increased survival of photo-ions. First on-line tests were successfully performed on a stopped beam of nickel [I134]. A full investigation of the gas jet geometry has been undertaken in order to improve the efficiency of the LIST method. Resonance ionization spectroscopy in the supersonic jet has been performed. A novel RF inductively heated ion source has been built in collaboration with the ECR group for the ^{94}Ag programme. With its simplicity, stability and reliability, the oven supersedes the previously tested FEBIAD source.

Experimental Highlights

Laser spectroscopy [I149]. The LASER-IGISOL group (Birmingham, JYFL and Manchester) has successfully started the exploration of a low Z region, entirely new to the collaboration. Using in-cooler optical pumping we have performed the first spectroscopic study of Mn over the N = 28 shell closure.

Mass measurements, shown in the left panel of Fig. 3, have previously indicated that Mn progresses smoothly through the N = 28 closure (unlike all other magic shells). Our measurements of the charge radii show a well-defined, sharp shell closure, closely following that observed in Ca. The complete contrast in mass

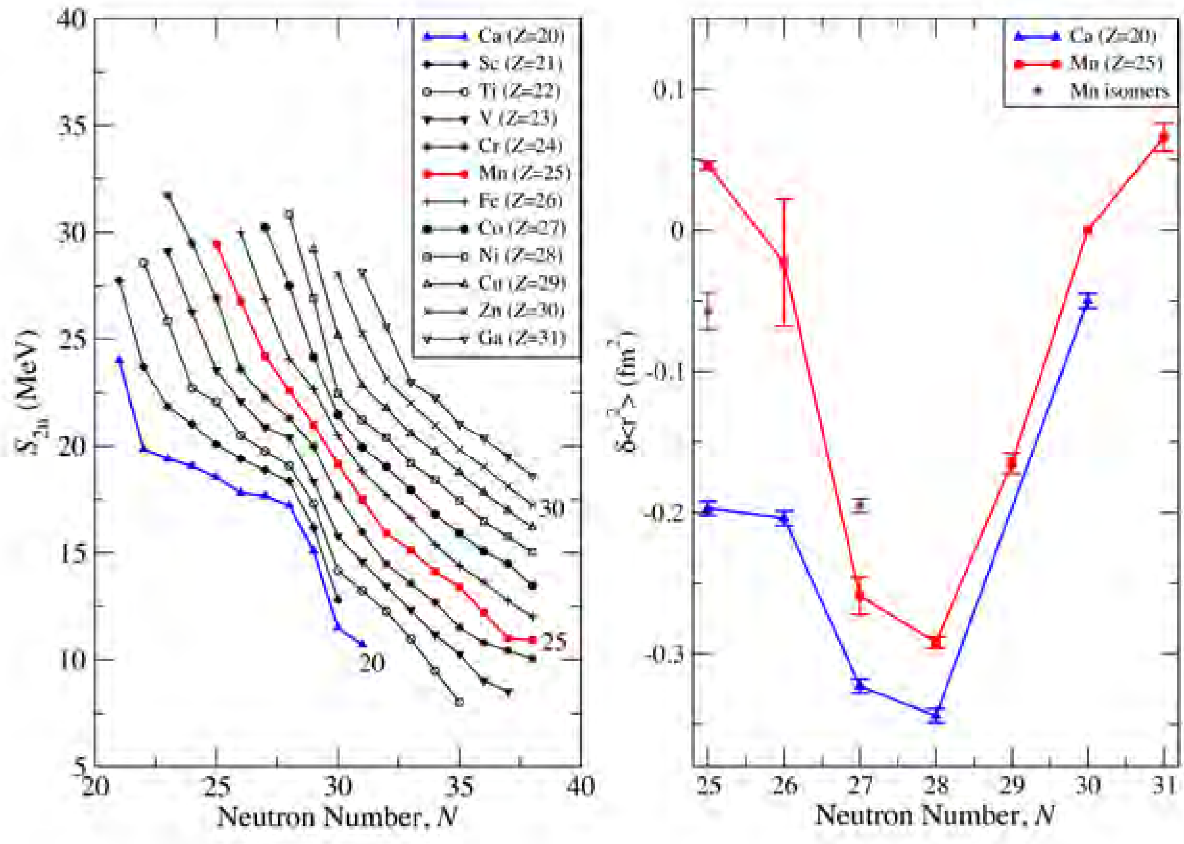


Fig. 3. Two neutron separation energies from AME2003 (left) and mean-square charge radii (right) for isotopic chains across the N = 28 shell closure.

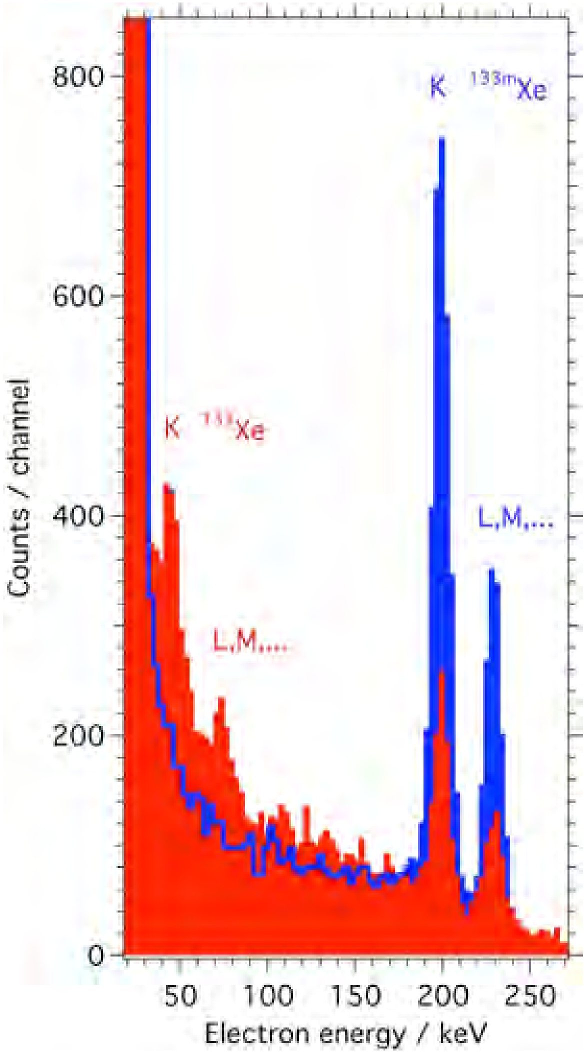


Fig. 4. The conversion electron spectrum of an ultra-pure ^{133m}Xe source. The spectrum shown in blue is recorded from a fresh source, showing no trace of the decay of ^{133}Xe ground state. The spectrum in red is recorded after 16 hours: ^{133}Xe ground state grow-in is observed.

and charge radii measurements here are strikingly different to the near identical trends seen for Z~40. Such differences critically affect our understanding of the impact of structure on binding energy.

Isomeric cleaning of spectroscopic sources [I133]. JYFLTRAP has been for years routinely used for isobaric cleaning, selecting a single isotope from an isobaric chain (isotopes having the same mass number A). With the help of so-called Ramsey cleaning, developed at JYFLTRAP for the high precision Q-value measurement program, it has become possible to produce ultra-pure sources consisting of only one of the isomeric states of the same isotope. In 2009, better than 2 ppm resolution with sufficient throughput was reached in producing a sample of ^{133m}Xe, the most complicated and crucially important nuclear weapons test signature, separated from the ground state of ^{133}Xe only by 233 keV. These isomerically pure samples, desired by the Comprehensive Nuclear-Test-Ban Treaty Organization (CTBTO), were produced in an experimental collaboration with the Finnish Radiation Safety Authority STUK.

Superallowed beta decays. A new record in precision of atomic mass difference was set in measurements of Q_{EC} values of ^{34}Cl and ^{38m}K at JYFLTRAP [I131]. The achieved precision was better than 50 eV, which is the most precise Q_{EC} measurement for any superallowed beta emitter. Our Q_{EC} values for ^{34}Cl and ^{38m}K agree with the previous reaction-based measurements establishing that there are no significant systematic differences between the different methods.

In addition, the Q_{EC} value and other experimental quantities – the branching ratio and the half-life – of ^{30}S were measured in collaboration with B. Blank et al. [I145].

Rare decays. The high precision of Q-value measurements reached at JYFLTRAP allows unique research of not only the shortest-lived isotopes but also of the smallest Q-values. These experiments do not require any accelerator to produce the studied isotopes, since they are extremely long-lived and occur naturally. The ions are produced off-line with an electric-discharge ion source.

The rare beta decay of ^{115}In ($T_{1/2} = 4.4*10^{14}$ a) was studied in collaboration with the JYFL nuclear theory group and the European Commission Joint Research Centre IRMM. The decay in question populates an excited

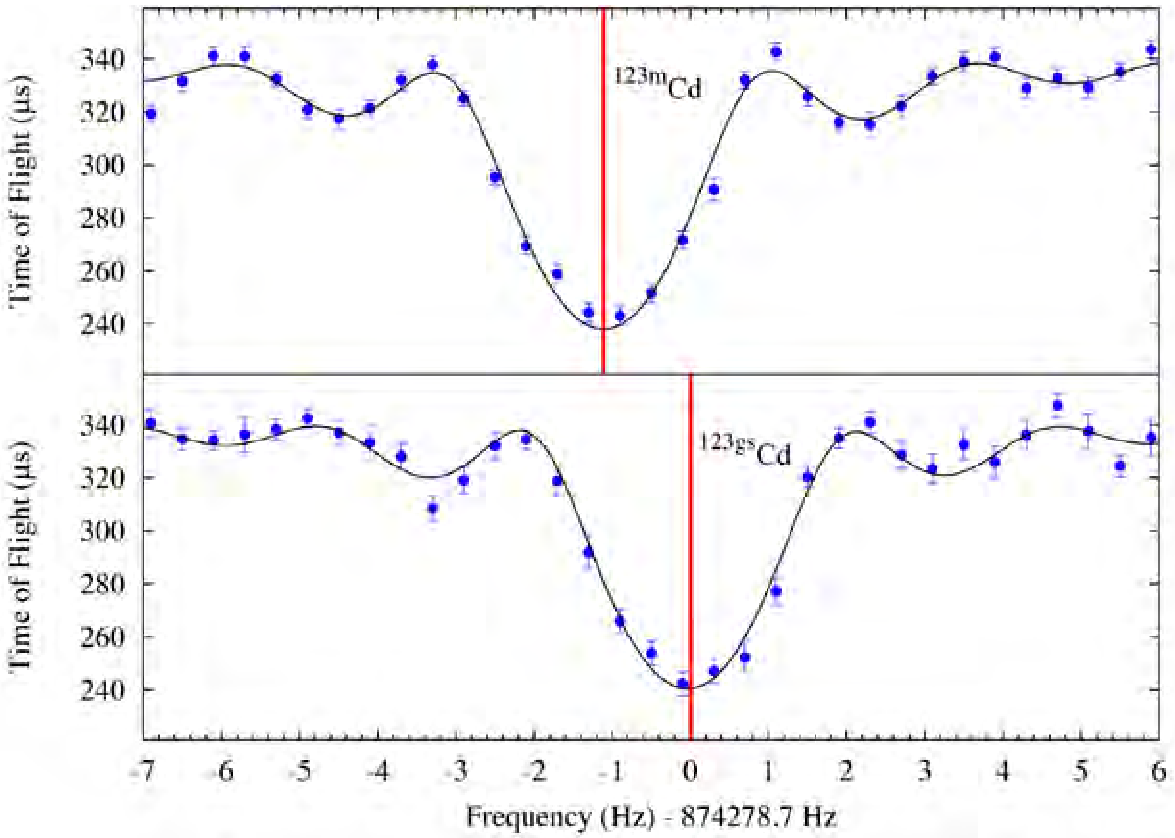


Fig. 5. The power of Ramsey cleaning in separating isomers of fission products [I139]. The shape of the time-of-flight resonance of the ^{123m}Cd isomer ($T_{1/2}$ = 2.1 s) is not disturbed by transmission of ^{123}Cd ground state ($T_{1/2}$ = 1.8 s) ions, and vice versa, indicating the isomeric states with a mass difference of 316 keV are completely separated in the Penning trap.

state in ^{115}Sn. The measured Q-value is 0.35(17) keV, being the lowest of any known nuclear beta decay. This weak transition was theoretically modeled by the JYFL theory group, and the branching ratio was measured in collaboration with IRMM in Belgium.

Furthermore, the Q-value of ^{74}Se > ^{74}Ge double beta decay was measured with similar accuracy as the Q_{EC} values of ^{34}Cl and ^{38m}K. The achieved accuracy is more than sufficient for the needs of experiments searching for the neutrinoless double electron capture decay. The third case studied was the double-beta decay of ^{112}Sn. The extracted new mass difference between ^{112}Sn and ^{112}Cd is 25 times more precise than previously measured – precise enough to reliably exclude the possibility of enhanced resonance capture in the 0n double-EC decay.

Highlights at ISOLDE. In August 2009, a compact high granularity setup was built to study beta-delayed 1p, 2p and 3p emission of ^{31}Ar at ISOLDE by the Århus-Bordeaux-CERN-Göteborg-JYFL-Madrid-collaboration. This experiment was a continuation of the project started already in the early 90's. This time, a cube of six thin DSSSD - thick Si-pad telescopes in addition to two Miniball clover Ge-detectors were used to probe possible 3p decay channels. The experiment yielded far higher statistics for the 2p channels, but the preliminary on-line analysis showed no 3p channel.

A campaign of high resolution optical spectroscopic measurements of gallium isotopes at ISOLDE using cooled and bunched beams from the newly installed ISCOOL device was extended to $^{80-82}$Ga, across the N = 50 shell closure. Extracted data on nuclear spins, magnetic and quadrupole moments and isotope shifts were largely unknown prior to the new measurements. A phenomenon of monopole migration was validated via the ground state nuclear spin determination which showed a spin inversion taking place between ^{79}Ga and ^{81}Ga. A similar inversion was observed in the copper isotopes between N = 44 and N = 46.

Experiments spokespersons and collaborating institutes in 2009

[I130] Precision measurement of the half-life of the β decay of ^{42}Ti
Spokespersons: B. Blank, I. Matea, T. Eronen
CEN Bordeaux-Gradignan, Gradignan, France; GANIL, Caen, France

[I131] Precision Q_{EC}-value measurements of the superallowed $0^+ \rightarrow 0^+$ β emitters of ^{10}C, ^{14}O, ^{34}Cl and ^{38}K^m
Spokesperson: T. Eronen
Texas A&M University, College Station, Texas, USA

[I133] Production and characterization of enriched ^{133m}Xe samples
Spokesperson: K. Peräjärvi
Liaison: J. Äystö
STUK-Radiation and Nuclear Safety Authority, Helsinki, Finland

[I 134] Continuation to the program of development of the resonance laser ion source at IGISOL: laser ionization of stopped beams
Spokesperson: I.D. Moore
University of Mainz, Germany; University of Manchester, UK

[I136] Decay properties of beta delayed neutron emitters
Spokepersons: M. B. Gómez Hornillos, D. Cano-Ott, A. Algora, A. Jokinen.
Liaison: J. Rissanen
UPC-Barcelona, Spain; University of Valencia, Spain; CIEMAT-Madrid, Spain; INR of the Hungarian Academy of Sciences, Debrecen, Hungary; PNPI, Gatchina, Russia; University of Surrey, UK; LPC-Caen, Caen, France.

[I139] Precision atomic mass measurements of neutron-rich nuclei with JYFLTRAP
Spokeperson: A. Jokinen

[I140] Electron Capture Decay of ^{116}In, charge-exchange reactions and double-beta decays
Spokesperson: A. Garcia
Liaison: I.D.Moore
University of Washington, Seattle, Washington, USA; Texas A&M University, College Station, Texas, USA; University of Valencia, Spain; Argonne National Laboratory, Argonne, Illinois, USA

[I145] Precision measurement of the half-life of the β decay of ^{30}S
Spokespersons: B. Blank, J. Souin, T. Eronen
CEN Bordeaux-Gradignan, Gradignan, France; GANIL, Caen, France

[I149] Laser spectroscopy using optical pumping in an ion cooler buncher
Spokesperson: B. Cheal
Liaison: I.D.Moore
University of Manchester, UK; University of Birmingham, UK

Nuclear Spectroscopy

Paul Greenlees, Pete Jones, Rauno Julin and Juha Uusitalo

In-beam Spectroscopy Group Members

Rauno Julin, professor
Sakari Juutinen, senior assistant
Pete Jones, senior researcher
Paul Greenlees, academy researcher
Päivi Nieminen, postdoctoral researcher
Mikael Sandzelius, postdoctoral researcher 10.8.-
Andrej Herzáň, graduate student 28.9.-
Steffen Ketelhut, graduate student
Markus Nyman, graduate student
Pauli Peura, graduate student
Panu Rahkila, graduate student
Juha Sorri, graduate student
Karl Hauschild, visiting scientist 10.8.-
Araceli Lopez-Martens, visiting scientist 10.8.-

Separator Group members

Matti Leino, professor
Cath Scholey, senior researcher
Juha Uusitalo, senior researcher
Sami Rinta-Antila, postdoctoral researcher 1.10.-
Ulrika Jakobsson, graduate student
Panu Ruotsalainen, graduate student
Jan Sarén, graduate student
David Cullen, visiting scientist -28.8.

Fig.1. The Nuclear Spectroscopy Group. From left to right,first row: Päivi Nieminen, Panu Ruotsalainen, Pauli Peura, Jan Sarén, Araceli Lopez-Martens, Juha Sorri, second row: Rauno Julin, Juha Uusitalo, Steffen Ketelhut, Ulrika Jakobsson, Cath Scholey, Panu Rahkila, and back row: Pete Jones, Sakari Juutinen, Matti Leino, Paul Greenlees, Mikael Sandzelius, Andrej Herzáň, Karl Hauschild, and Sami Rinta-Antila.

Year 2009 was again a busy and a successful period for the Nuclear Spectroscopy Group. The main activity of the group concentrated on making use of the powerful JUROGAM II+RITU+GREAT facility. In total thirteen experiments were completed, nine of them led by visiting groups. Spectroscopic studies were successfully performed covering a broad area of the nuclear landscape starting from the N=Z line below A=100, continuing through the neutron-deficient rare-earth nuclei (A = 117-160), to proton drip-line nuclei in the vicinity of Z = 82 and finally ending up in the actinide region.

Jurogam II

The full JUROGAM II array is comprised of 24 Eurogam Clover (4-fold) detectors around 90 degrees and 15 Eurogam Phase 1 or Gasp detectors at backward angles. The array was instrumented by an extended pool of digital electronics (TNT2 cards) in collaboration with the CNRS/IN2P3 GABRIELA project. The response of the array was measured (absolute efficiency of ~ 6.2% at 1.3 MeV and peak-to-total of ~45%) and is the most powerful γ-ray spectrometer to be sited at the laboratory to date.

Digital Electronics

The continued development of digital electronics instrumentation was concluded with the commissioning of the Lyrtech system in collaboration with STFC, Daresbury, UK and the University of Liverpool. The system allows for the instrumentation of up to 238 channels, and is designed for high counting rates. The data is time stamped, and read out in conjunction with the TDR system. The first commissioning of the new digital electronics was performed in October with JUROGAM II, proving that data remain synchronized and are as expected. Due to the large number of available channels the SAGE and LISA spectrometers can be instrumented for use in conjunction with JUROGAM II.

LISA Spectrometer

The commissioning of the LISA-spectrometer was performed in November 2009 [JR93]. LISA consist of a sophisticated target holder system and a silicon-detector array (a barrel and CD detectors) surrounding the target to be used for particle identification (Fig.2). In front of the silicon detectors molybdenum foils of various thicknesses are used to stop the scattered beam, whilst allowing penetration of protons and α particles to the detector. The commissioning test proved that the LISA-spectrometer combined with the JUROGAM II + RITU + GREAT facility is ready for a full campaign whenever the complete setup is available.

Fig. 2. LISA array at the target position of the RITU separator

RITU Tests

A campaign to measure the true transmission of the RITU separator continued [JRtr]. In these measurements the selectivity of the JUROGAM II array is utilized to identify fusion-evaporation products formed at the target position. When this is combined with particle identification at the focal plane using the GREAT spectrometer, true transmission of the RITU separator can be obtained. For example, the transmission and experimental ion-optical properties were measured for the recoils using the $^{150}Sm(^{40}Ar, 4n)^{186}Hg$ (Fig.3) and $^{92}Mo(^{84}Kr, 2n)^{174}Os$ fusion-evaporation reactions.

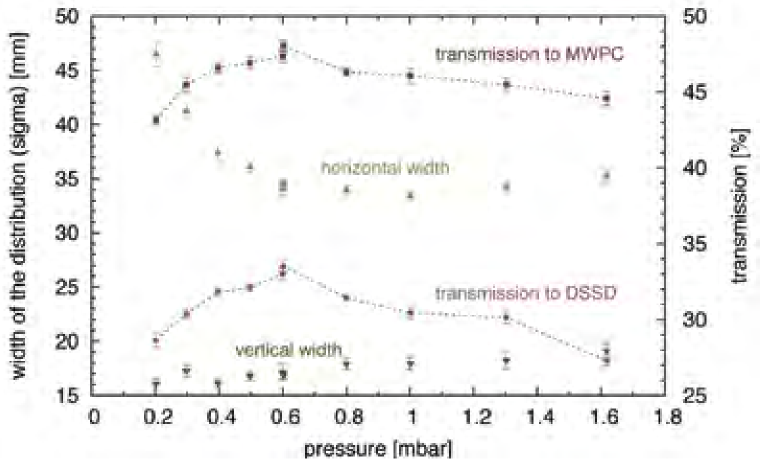


Fig. 3. Measured image size and transmission at the focal plane of RITU separator as a function of He-gas pressure using the reaction $^{150}Sm(^{40}Ar, 4n)^{186}Hg$.

Spectroscopy of Heavy Elements

The combination of digital electronics with JUROGAMII enables low cross-section in-beam experiments at high total γ-ray counting rates for heavy nuclei. Therefore, a preliminary experiment for an in-beam spectroscopic study of ^{256}Rf via the $^{208}Pb(^{50}Ti,2n)$ reaction became topical. For a real production run more intense ^{50}Ti beams need still to be developed. As a back-up experiment, a successful in-beam spectroscopy run was carried out, for the first time, for ^{246}Fm produced in the $^{208}Pb(^{40}Ar,2n)$ reaction with a cross-section of approximately 10 nb, which is the lowest cross-section so far to be studied in-beam in the heavy-element region (Fig. 4).

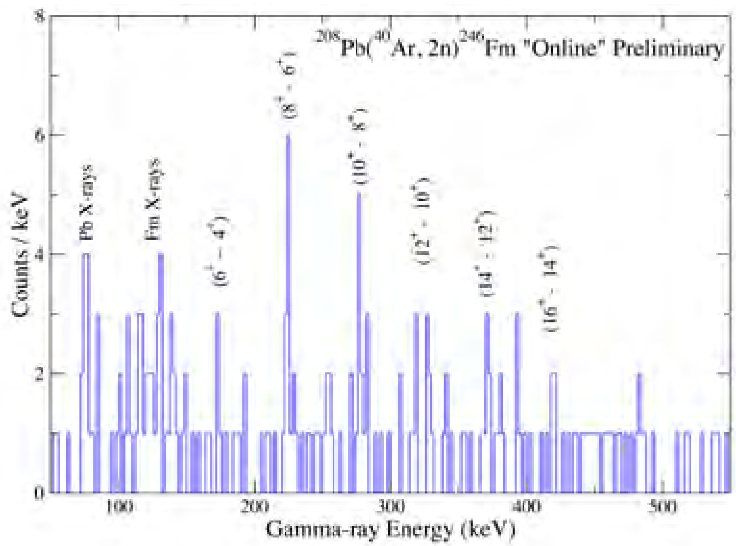


Fig. 4. Gamma-ray spectrum obtained for ^{246}Fm

First Observation of Excited States in ^{180}Pb

The program to explore nuclear structure at the proton-drip line in the lead region was continued. One intriguing question is the survival of shape coexistence when approaching the proton drip line. Following the successful development of ^{90}Zr beams by the ECR group, the JUROGAM II array at RITU was employed in an RDT experiment to observe prompt γ rays from ^{180}Pb. Excited states were populated via the cold $^{92}Mo(^{90}Zr,2n)^{180}Pb$ reaction [JR64]. The measured production cross-section was only 10 nb, representing a world record in in-beam γ-ray spectroscopy. The resulting spectrum of Fig. 5 reveals a 1168 keV line, assigned to the 2^+ to 0^+ γ-ray transition and three low-energy lines associated with a prolate intruder band on top of the 2^+ state. As expected this band lies at around

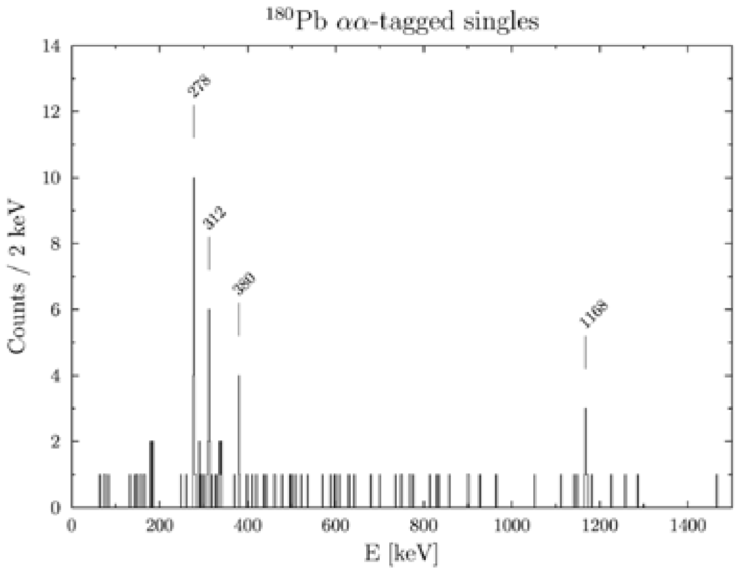


Fig. 5. Gamma-ray spectrum obtained for ^{180}Pb

300 keV higher than the one in ^{182}Pb, but the observed deviation from the smooth behavior observed within the bands in the heavier isotopes is not understood. All the excited states of ^{180}Pb are proton-unbound.

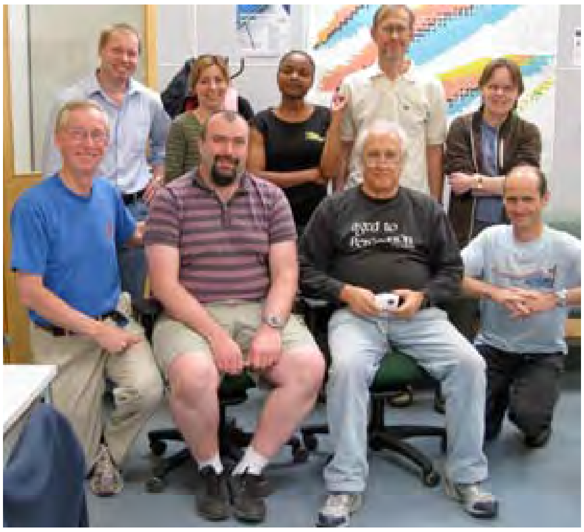


Fig. 6. People from Double Vacuum

Several in-beam studies of rare-earth nuclei were performed. These studies covered the spectroscopy of proton emitter ^{117}La [JR79]. "Double Vacuum" transitional nuclei ^{150}Sm, ^{156}Dy and ^{157}Dy [J09], high seniority states in the heaviest N=82 isotones and isomeric states in ^{139,140,141}Nd [JR87]. For the "Double Vacuum" experiment distinguished visitors from far afield came to Jyväskylä (Fig.6).

Spectroscopy at the N=Z line

In a continuation of the collaboration with the University of York, ^{66}As has been studied [JR64]. The gas-filled separator RITU was successfully employed to separate ^{66}As from beam-like projectiles. This is the lightest nucleus studied using RITU to date. A combination of recoil-beta and recoil-isomer tagging was used to identify excited states in this N=Z nucleus. The planar Ge detector was used to detect both beta particles and low energy γ rays with great success. Technical advances are still being made in order to improve this technique. The ^{66}As experiment was only possible due to new 0.5 μm mylar windows for the MWPC, which allowed higher gas pressures to be used in RITU. In the near future a test will be carried out with a phoswich type scintillator device to improve the light collection sensitivity when detecting β particles.

Experiment spokespersons and collaborating institutes in 2009

[JR64] Recoil-decay tagging of ^{180}Pb
D. Jenkins, University of York, U.K; J. Pakarinen, University of Liverpool, UK.

[JR71] Recoil-β+ tagging study of N=Z nucleus ^{66}As
R. Wadsworth, University of York, U.K; University of Manchester, U.K; JYFL

[JR76b] Decay measurement of ^{199}At
U. Jakobsson, JYFL

[JR79] Identification of excited states in the deformed proton emitter ^{117}La using recoil proton-decay tagging with JUROGAM, RITU and GREAT
J. Smith, University of the West of Scotland, U.K.; University of Liverpool U.K; JYFL; University of Manchester, U.K; KTH Stockholm, Sweden; STFC Daresbury, U.K.

[JR87] Search for the feeding transitions of the isomers in ^{140}Nd and ^{139,141}Nd
C. Petrache, IPN, Orsay, France; JYFL; CSNSM, Orsay, France; INFN Sezione di Padova, Italy; iThemba LABS, South Africa; VECC, Kolkata, India; IPHC, Strasbourg, France; Bonn University, Germany

[JR88] High Seniority states built upon proton h11/2 isomers in the heaviest N=82 isotones
D. O'Donnell, STFC Daresbury, U.K; University of Liverpool, U.K; University of Manchester, U.K; JYFL

[JR92] Investigation of X(5) critical-point symmetry in ^{138}Gd using recoil-distance plunger measurements
D. Cullen, University of Manchester, U.K; IKP Köln, Germany; JYFL

[JR93] Commissioning of the LISA Spectrometer
R. D. Page, University of Liverpool, U.K; STFC Daresbury, U.K; JYFL

[JRTr] Experimental ion-optical properties of RITU separator
J. Sarén, JYFL

[J08] Detailed spectroscopy of ^{44}Ti: Relevance for alpha-cluster structure, continuum state density and astrophysics
T. Lönnroth, Åbo Akademi, Finland; Catania, Italy; JYFL

[J09] Yrare Spectroscopy of Rare Earth "Double Vacuum" Transitional Nuclei; ^{150}Sm, ^{156}Dy and ^{157}Dy
J.F.Sharpey-Shafer, University of Western Cape, Bellville, South Africa; University of Zululand, KwaZulu Natal, South Africa; iThemba Laboratory for Accelerator Based Sciences, Somerset-West, South Africa; INRNE, Bulgarian Academy of Sciences, Sofia, Bulgaria; CSNSM, Orsay, France; TU Lund, Sweden; IreS, Strasbourg, France; ATOMKI, Debrecen, Hungary; University of Guelph, Canada; ORNL and UT, Tennessee, USA, JYFL

[R40] Alpha-decay study of the proton unbound ^{205}Ac
J. Uusitalo, JYFL; University of Oulu, Finland; University of Helsinki, Finland

Nuclear Reactions and ALICE

Jan Rak and Wladyslaw Trzaska

Alice

The first proton collisions at LHC took place at 16:47 on Monday, 23 November 2009 (Fig. 1). Over the next 40 minutes nearly 300 more collision events were registered by ALICE before the beam was switched off completing a successful LHC test. Just five days later the first ALICE paper was submitted and, after a small revision, published online on 11 December 2009 with the reconstructed longitudinal vertex, pseudorapidity dependence of $dN_{CH}/d\eta$ for inelastic and non-single diffractive collisions and with the charged-particle density in the central rapidity region. The paper was chosen by EPJ as a Highlight Paper and the first ALICE collision

Jan Rak, senior assistant
Wladyslaw Trzaska, senior scientist
Marco Bregant, postdoctoral researcher (CERN/JYFL)
DongJo Kim, postdoctoral researcher
Tuomo Kalliokoski, graduate student
Jiri Kral, graduate student
Tomasz Malkiewicz, graduate student -30.11
Norbert Novitzky, graduate student
Elena Heikkilä, MSc student - 1.7.
Karolina Kolos, MSc student - 1.7.
Michal Oledzki, MSc student - 1.4.2009
Oleg Korniyenko, research associate (CUPP)
Kai Loo, graduate student (CUPP)
Tomi Räihä, graduate student (CUPP)
Juho Sarkamo, graduate student (CUPP)
Maciej Slupecki, MSc student (Warsaw University of Technology)
Antto Virkajärvi, MSc student

Fig. 1. Celebration of the first LHC collision in the ALICE control room. Jan Rak (seating in a white shirt in the first raw) served as the Run Coordinator during this historic event.

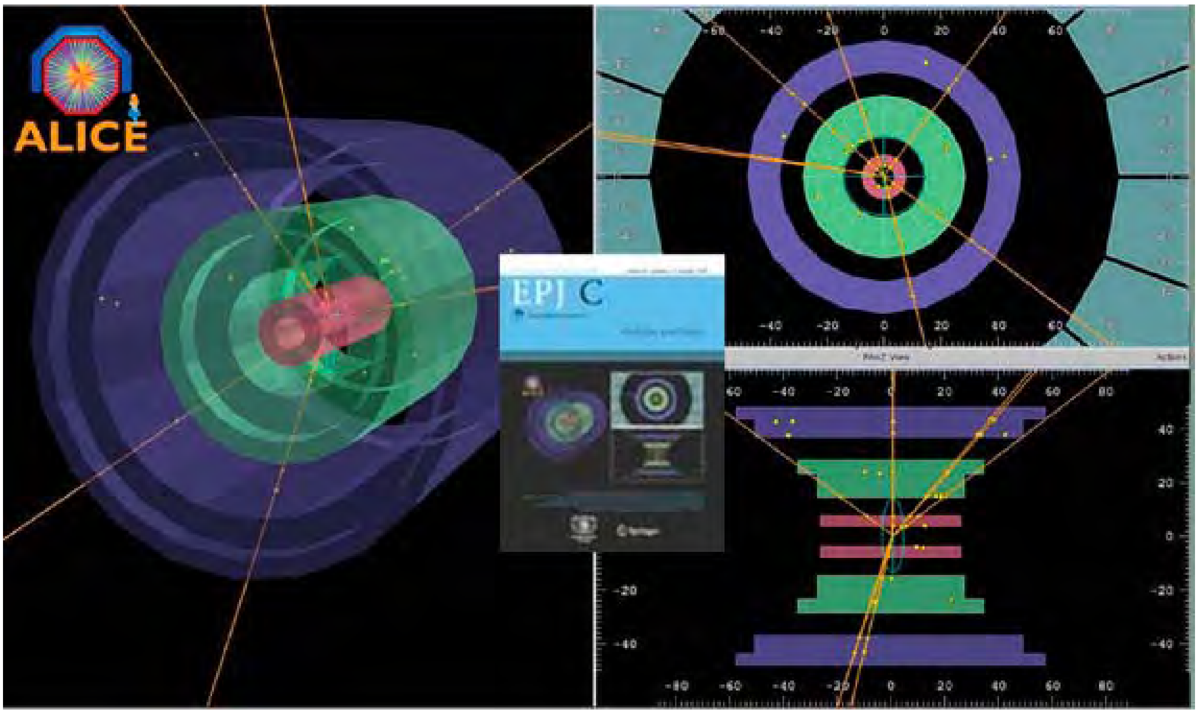


Fig. 2. The first published LHC event on the front cover of January 2010 EPJ C.

results for the charged particle pseudorapidity density at √s = 2.36 TeV.

event was selected for the cover of the January 2010 issue of EPJ C (Fig.2). As the luminosity increased, ALICE collected 0.5 million proton-proton events at √s = 900 GeV accumulating sufficient statistics for comprehensive analysis. Just one week after the first collision LHC has reached the new world record in beam energy and ALICE gave the first preliminary

Astroparticle Physics

A major international meeting being part of the LAGUNA (Large Apparatus for Grand Unification and Neutrino Astrophysics) design study took place in September 2009 in Pyhäsalmi – one of the 7 proposed sites competing for the location of the multi-purpose facility on the 0.1 - 1 Mton scale for improved studies of proton decay and of low-energy neutrinos from astrophysical origin. Pyhäsalmi is among the strongest contenders due to the excellent rock quality, the lowest neutrino background from the nuclear power plants, existing mine infrastructure, and already signed Memorandum of Understanding between the mine and the involved universities. The project has a strong political and

Fig. 3. Members of the Scientific Advisory Board just before driving to the EMMA cavern. Standing from the left: Andreas Haungs, Leonid Bezrukov, Tiina Suomijärvi and Anatoly Erlykin.

Fig. 4. Yuri Penionzhkevich welcomes participants of the EXON09 conference to the cruse on the Black Sea. During the traditional Christmas / New Year experiment at JYFL Yuri's team has measured spectroscopy of ^{6}He, ^{6}Li states using the (^{4}He, ^{7}Be) and (^{4}He, ^{7}Li) reactions on ^{9}Be.

local support. An important factor is also experience and success of the cosmic ray experiment EMMA. In its 2009 report the Scientific Advisory Board (Fig. 3) was impressed by the progress achieved in the construction of the experiment and pointed out the pioneering role of EMMA as a nucleating centre for astroparticle physics in Finland.

Nuclear Reactions

The latest results obtained by our collaboration were summarized at the EXON09 conference (Fig. 4) organized jointly by JINR Dubna, GANIL, RIEKEN, and GSI in Sochi on the Black Sea. We were allocated several talks, also invited, giving us a chance to present the status of the Accelerator Lab, Tri and Rot effects in ternary fission, large angle elastic scattering studies, and applications of the Pulse-Shape Discrimination Method for wide aperture Si-detectors.

Accelerator-based Materials Physics

Timo Sajavaara and Harry J. Whitlow

2009 was a year of major technical innovation in the group. In the early part of the year a SF_6 recycle system of the Pelletron was implemented. This not only improves environmental stewardship but also reduces costs as well as maintenance downtime. A reconditioned Scanning Electron Microscope (SEM) was taken into operation by the group at the same time. In the summer the injector was reconfigured and a SNICS heavy ion source installed (Fig 1.). Then in December the new Time of Flight Elastic Recoil Detection Analysis (ToF-ERDA) measurement system (Fig. 2) was commissioned. At the same time a number of small improvements have been implemented that decrease the cost of ownership of the Pelletron and improve it is performance. Careful planning meant that the loss of

Harry J. Whitlow, professor
Timo Sajavaara, senior assistant
Somjai Sangyuenyongpipat, postdoctoral researcher
Liping Wang, postdoctoral researcher -30.9
Mikko Laitinen, graduate student
Laura Mättö, graduate student
Rattanaporn Norarat, graduate student
Ananda Sagari A.R., graduate student
Nittipon Puttaraska, visiting PhD student, Chiang Mai, Thailand
Elisabeth Wieslander, external graduate student, EU-JRC IRMM, Belgium -31.3.
Hannele Eronen, MSc student
Jouni Heiskanen, MSc student
Jaakko Julin, MSc student
Mari Napari, MSc student
Kimmo Tolvanen, MSc student -31.3.

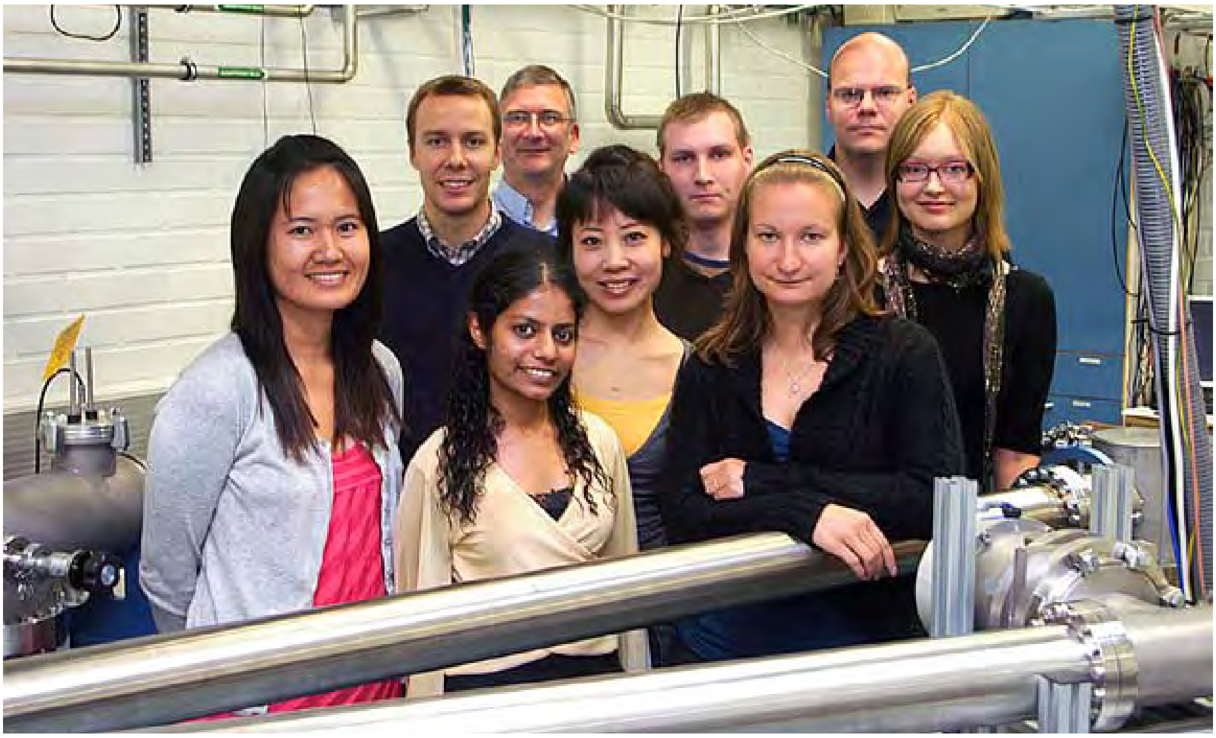


Fig. 1. Injector of the Pelletron accelerator in June 2009 (left) and in September 2009 (right) after installation of new sputtering ion source and injector magnet.

beamtime due to the modifications and maintenance was a record low of a few weeks.

Almost from the very start the new ToF-E ERDA system achieved a depth resolution of 2 nm FWHM at the surface (Fig. 3). This is attracting interest as a new tool for industry and is creating new research collaborations with researchers from academia and industry in Finland as well as internationally. Both the PIXE and MeV ion Beam Lithography system have been heavily used for projects on combustion deposits for biomass burning and study of the perturbation of Ca pathways in cells resulting from infection with mutant viruses. This has developed into a more extensive project with a senior researcher from Kasetsart University on life-element perturbations and the Department of Enviromental and Biological Sciences that is funded under the ASEAN-DUO programme. Another highpoint was the observation of potentially useful mutations in rice brought about by cyclotron ion irradiation.

It is also worthy of note that in November a extensive book on Ion beams in Nanoscience and Technology was published. One of the Editors and five chapter contributors were associated with the Science Faculty in Jyväskylä. One external PhD student, Elisabeth Weislander completed her PhD on Low background gamma ray spectrometry. This work was partly carried out at the EU Joint Research Centre in Geel Belgium.

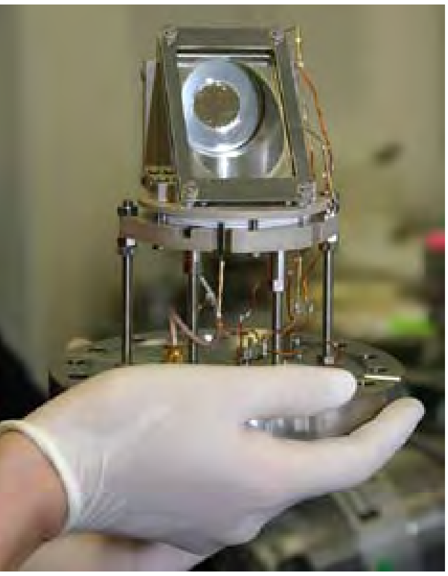


Fig. 2. Second timing gate of the new TOF-ERDA telescope being installed.

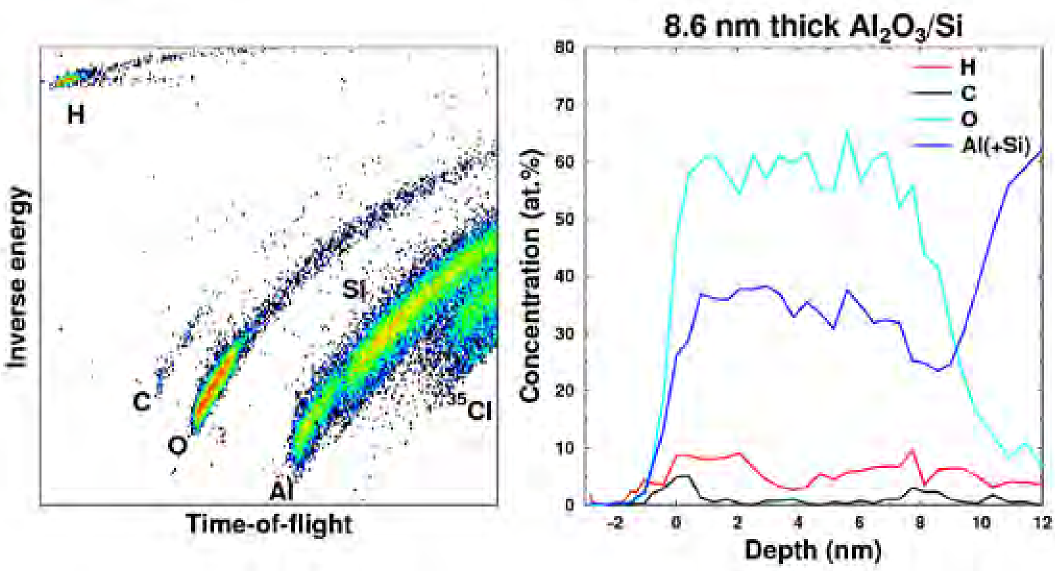


Fig. 3. One of the first measurements with the new TOF-ERDA system. On the left energy vs. time of flight histogram and on the right corresponding elemental depth profiles from 8.6 nm thick Al_2O_3 thin film on silicon. Incident beam was 5 MeV $^{35}Cl^{3+}$.

Industrial Applications

Ari Virtanen

The usage of the beam time in different industrial areas is shown in figure 1. The total beam time in 2009 was 1031 hours.

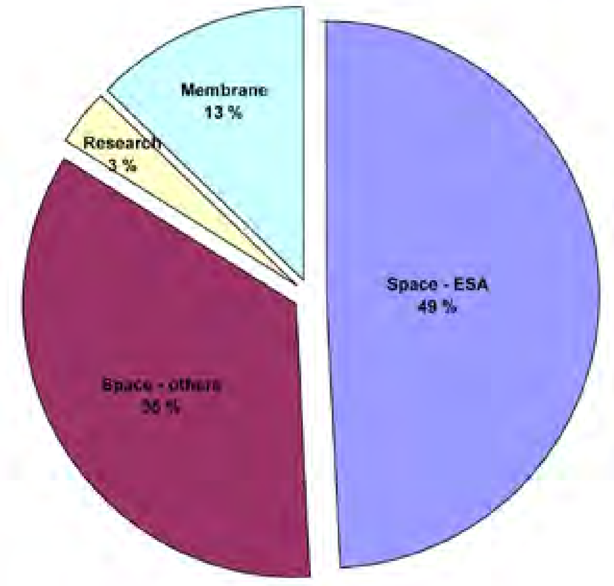


Fig. 1. Beam time distributed between different areas.

Space related study

RADEF continued the operation as one of ESA's external European Component Irradiation Facility (ECIF). In total 20 campaigns for 14 international companies or institutes were performed during 2009. The companies are in Table 1. Also NASA tested the first time their satellite components at RADEF. The amount of ESA hours was 507 and the hours for other companies were 359.

Ari Virtanen, director of industrial applications
Heikki Kettunen, senior researcher
Jukka Jaatinen, graduate student (– 31.6.)
Arto Javanainen, graduate student
Taneli Kalvas, graduate student
Suvi Päiviö, graduate student
Iiro Riihimäki, graduate student
Mikko Rossi, graduate student

Table 1. Companies, which performed radiation hardness assurance tests at RADEF

ASTRIUM SAS, Paris, France
ESA, European Space Agency, Noordwijk, The Netherland
NASA/JPL, Pasadena, CA, USA
IDA, Institut für Datentechnik und Kommunikationsnetze, Braunschweig, Germany
TRAD, Labège, France
Thales Alenia Space, Toulouse, France
CEA, Comité Européen des Assurances, Bruyere-le-Chatel, France
HIREX Engineering, Toulouse, France
RUAG Sweden, Gothenburg, Sweden
EASII IC SAS, Grenoble, France
ST Microelectronics, Crolles, France
Sandia National Laboratories, Albuquerque, USA
Democritus University of Thrace, Xanthi, Greece
Kayser Threde, Munich, Germany

We also performed research at RADEF. This was a continuation to our earlier published works for ESA to develop semi-empirical LET descriptions of heavy ions. The aim is that the values would be used in the ECIF facilities. This compiled work was introduced to the community in RADECS 2009 conference in Brugge, Belgium, and will be published in IEEE's Transactions of Nuclear Science [1]. The ECIF cocktail calculator is available for the users at http://www.jyu.fi/accelerator/radef/ECIFCalc.

Other activities

The collaboration with Oxyphen GmbH also continued steadily. The aim is to irradiate their polymer films. This is the first step in the process for creating micro porous membranes made by the company. Oxyphen performed two campaigns at RADEF in 2009. The total beam time for this activity was 133 hours.

Also the microwave ion source development was continued. The first beams were extracted and analyzed. The development towards the applications in energy and wood industry continues.

In addition to space companies, collaboration with other companies and institutes continued on a regular basis. These non-space companies are listed in Table 2.

Table 2. Collaborating companies

Bintec Oy, Hollola
Central Finland Health Care District, Jyväskylä
Centre of Expertise for Nanotechnology, Jyväskylä Innovation Oy
Centre of Expertise for Paper Making Technology, Jyväskylä Innovation Oy
Doseco Oy, Jyväskylä
Gammapro Oy, Jyväskylä
Metsäteho Oy, Helsinki
Millog Oy, Lievestuore
Oxyphen GmbH, Lachen, Switzerland
VTT Jyväskylä

References:
[1] Semi-empirical LET descriptions of heavy ions used in the European Component Irradiation Facilities
A. Javanainen, W. H. Trzaska, R. Harboe-Sørensen, A. Virtanen, G. Berger and W. Hajdas
Accepted for publication in IEEE Transactions on Nuclear Science

Nuclear Structure, Nuclear Decays, Rare and Exotic Processes

Jouni Suhonen

Jouni Suhonen, professor
Mika Mustonen, graduate student
Sami Peltonen, graduate student
Emanuel Ydrefors, graduate student

Nuclear Matrix Elements for Double Beta Decay

Extraction of the effective neutrino mass from the data of underground experiments calls for calculations of the associated nuclear matrix elements (NME) of neutrinoless double beta decay. These NME play a key role in physics related to the properties of the neutrino, in particular the mass and basic character of the neutrino. During 2009 our group has made evaluations of the NME by using cutting-edge nuclear-structure tools to limit their uncertainties. Related to this the proton-neutron version of the Microscopic Anharmonic Vibrator Approach (MAVA) [1] has been used to study the importance of four-quasiparticle structures in description of the two-neutrino double beta decay of ^{76}Ge [2] and ^{100}Mo [3].

LSP-nucleus Scattering And 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. We have 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 cesium nuclei [4]. Both the elastic and inelastic channels have been included.

Neutrino-Nucleus Interactions and Supernova Neutrinos

Neutrino-nucleus scattering experiments provide a sensitive tool for detection of neutrinos. One example is the MOON (Majorana/Mo Observatory Of Neutrinos) [5] experiment. Theoretical estimates of neutrino-nucleus scattering cross sections for relevant target nuclei are of paramount importance for future experiments. In collaboration with the Section of Theoretical Physics at the University of Ioannina we have performed calculations for neutral-current neutrino-nucleus scattering on the stable even-even isotopes of molybdenum. In figure 1 the associated cross sections as functions of the neutrino energy are visible. We have used the formalism of [6] and combined it with the QRPA (quasiparticle random-phase approximation) model to obtain the scattering cross sections. In the near future we are planning to fold the cross sections with an appropriate neutrino-energy distribution to obtain realistic results for supernova neutrinos. Extension of the analysis to odd nuclei is in progress.

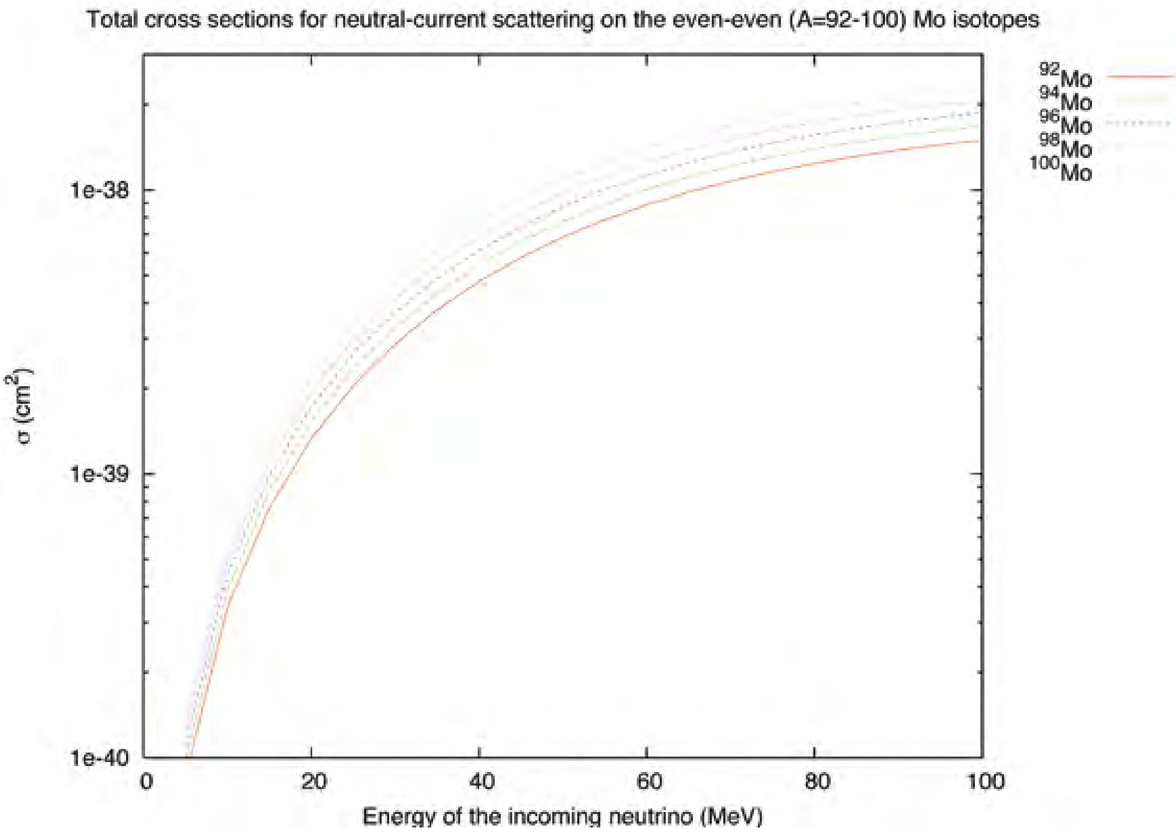


Fig. 1. Cross sections for neutral-current neutrino-nucleus scattering on molybdenum isotopes as functions of the neutrino energy.

Highlights

World-record setting Q value of the rare beta-decay branch of ^{115}In

The recently discovered [7] extremely rare decay branch of ^{115}In pushed the record of the lowest observed Q value [8,9] down by an order of magnitude. In cooperation with the local JYFLTRAP group and the HADES underground laboratory in Belgium, we have investigated this decay [8,10] theoretically applying the proton-neutron microscopic quasiparticle-phonon model (pnMQPM, [11]). The mismatch between the computed partial half-life and the measured half-life and Q value (see figure 2) suggests that the neglected atomic effects could be important in this new regime of ultra-low Q values. The relevant atomic contributions are poorly known [10] and pose new challenges for both the theoretical and experimental communities.

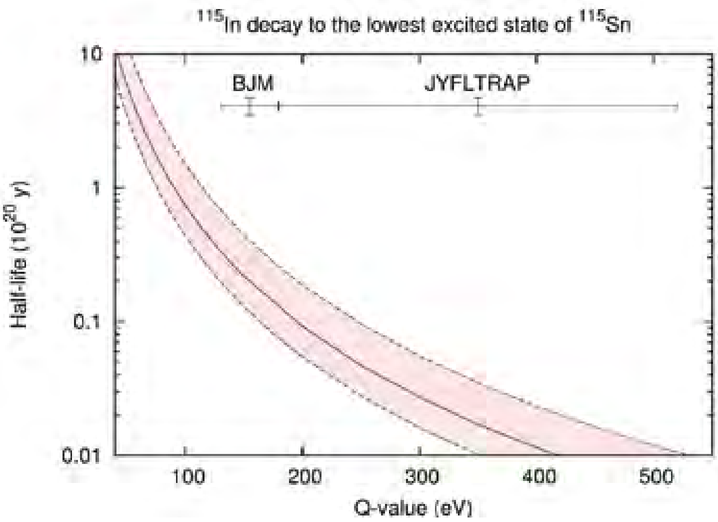


Fig. 2. Theoretical partial half-life of the ultra-low-Q-value decay channel of ^{115}In as a function of the Q value. The recent Penning trap measurements in Florida State University (BJM), [9]) and JYFL (JYFLTRAP, [8]) are combined with the HADES half-life measurement to represent the experimental data.

Rate estimates for resonant neutrinoless double electron capture of nuclei

During last few years experimental attention has been directed to a new interesting possibility to access neutrino properties, namely the neutrinoless double electron capture (0vECEC). In particular, it has been speculated that the resonant 0vECEC could be detected due to its potential million-fold resonant enhancement relative to the double-positron emitting processes. In the resonant 0vECEC the energy of the ground state of the mother nucleus matches the energy of an excited state of the daughter nucleus (see figure 3). The resonant 0vECEC is not yet well understood from the nuclear-, particle- or atomic-physics points of view. Recent advances in determination of the decay Q values by the Penning atom-trap techniques help in determination of the magnitudes of the potential resonant enhancements. These measurements together with nuclear-structure calculations and atomic data have recently been used [12,13] to analyze a few potential cases for the resonant enhancement.

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[3] J. Kotila, J. Suhonen and D.S. Delion, J. Phys. G 37 (2010) 015101

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[8] J.S.E. Wieslander et al., Phys. Rev. Lett. 103 (2009) 122501

[9] B.J. Mount, M. Redshaw and E.G. Myers, Phys. Rev. Lett. 103 (2009) 122502

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[12] S. Rahaman et al., Phys. Rev. Lett. 103 (2009) 042501

[13] V.S. Kolhinen et al., Phys. Lett. B 684 (2010) 17

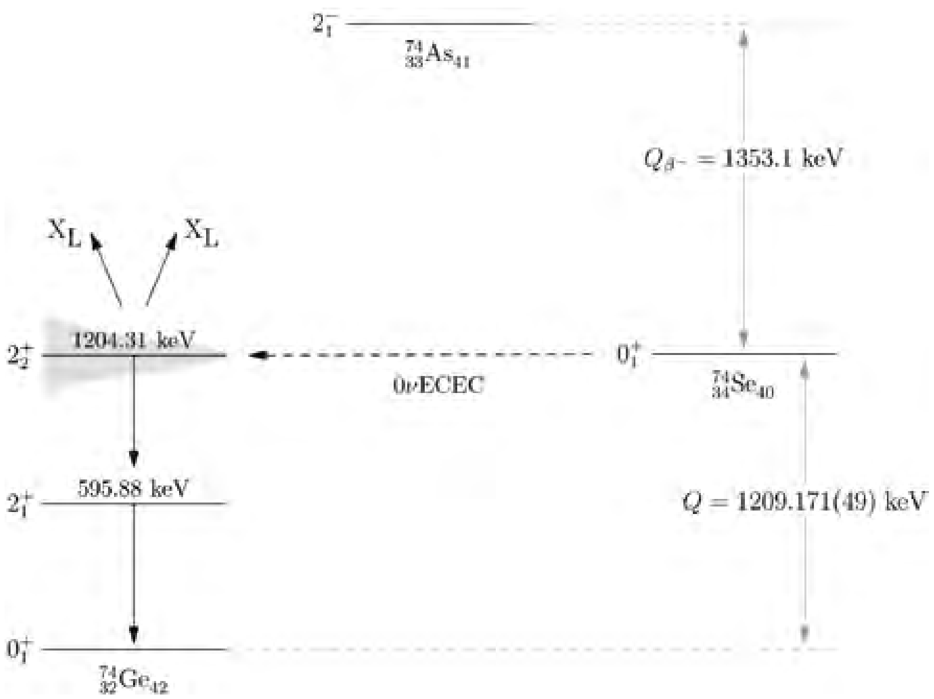

Fig. 3. Resonant neutrinoless double electron capture of ^{74}Se.

Experimental Nanophysics and Nanotechnology

Markus Ahlskog, Konstantin Arutyunov, Ilari Maasilta and Jussi Toppari

Thermal Properties of Nanostructures and Radiation Detector Development

Ilari Maasilta

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). A few highlights of the activity in 2009:

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. 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 [1]. Moreover, we have developed techniques to engineer the boundaries of nanoscale devices for controlling the heat transport [2]. This result may have applications in cooling nanoelectromechanical (NEMS) resonators and ultrasensitive bolometric radiation detectors.

Another focus field has been development of superconducting transition-edge X-ray detectors. In 2009 we continued our collaborative project with

Markus Ahlskog, professor
Ilari Maasilta, professor
Konstantin Arutyunov, senior assistant
Jussi Toppari, senior assistant 31.7., SA academy research fellow 1.8.-
Andreas Johansson, senior scientist
Saumyadip Chaudhuri, postdoctoral researcher
Pasi Jalkanen, postdoctoral researcher
Nobuyuki Zen, postdoctoral researcher 1.7.-
Tommi Hakala, graduate student
Olli Herranen, graduate student
Terhi Hongisto, graduate student
Tero Isotalo, Graduate student
Jenni Karvonen, graduate student -30.9.
Kimmo Kinnunen, graduate student
Panu Koppinen, graduate student -31.8.
Jarkko Lievonen, graduate student
Veikko Linko, graduate student
Davie Mtsuko, graduate student
Minna Nevala, graduate student
Mikko Palosaari, graduate student
Marcus Rinkiö, graduate student
Peerapong Yotprayoonsak, graduate student
Hannu-Pekka Auraneva, MSc student
Tuuli Gröhn, MSc student -30.6.
Jaakko Halkosaari, MSc student
Matti Hokkanen, MSc student
Juhani Julin, MSc student
Armen Julukian, MSc student
Sampo Kulju, MSc student
Janne Lehtinen, Msc student
Antti Juutilainen, MSc student
Anna-Leena Latvala, MSc student
Marko Manninen, MSc student
Mika Oksanen, MSc student
Seppo Paasonen, MSc student
Niko Säkkinen, MSc student
Andrii Torgovkin Msc student

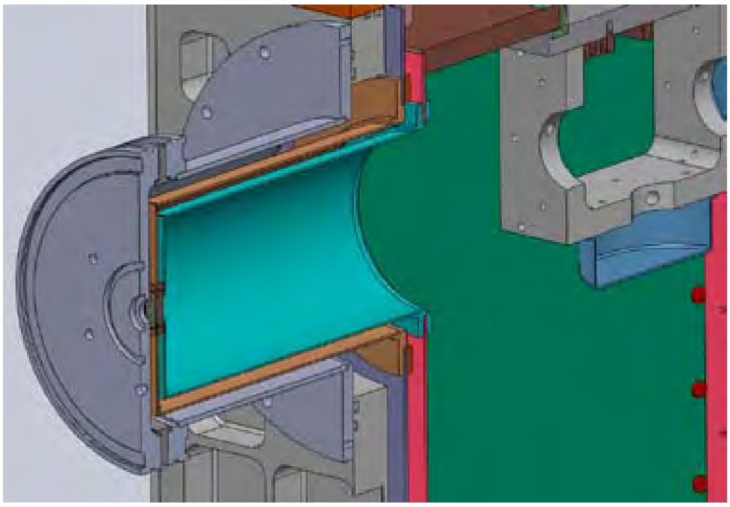

Fig. 1. Schematic of the detector "snout" designed for superconducting ultrasensitive X-ray detectors. Image courtesy of Dr. J. Ullom, NIST.

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. Main focus of work has been in the design and construction of the cryogenic detector housing in an adiabatic demagnetization refrigerator (Fig. 1), where most of the components have been machined in the physics department machine shop. In addition, novel techniques of data analysis have been developed.

In collaboration with the group of Prof. Ahlskog, we developed a technique to measure strain locally in nanoscale devices, using tunnel junctions [3]. This method is complementary to existing capacitive and piezoresistive sensors, used extensively in NEMS resonators and other nanomechanical experiments. Fig 2. shows the schematic of the experiment, where we fabricated sub-micron tunnel junctions on thin (< 100 nm) SiN membranes, pressed them with an AFM tip, and measured the electrical response of the tunnel junction.

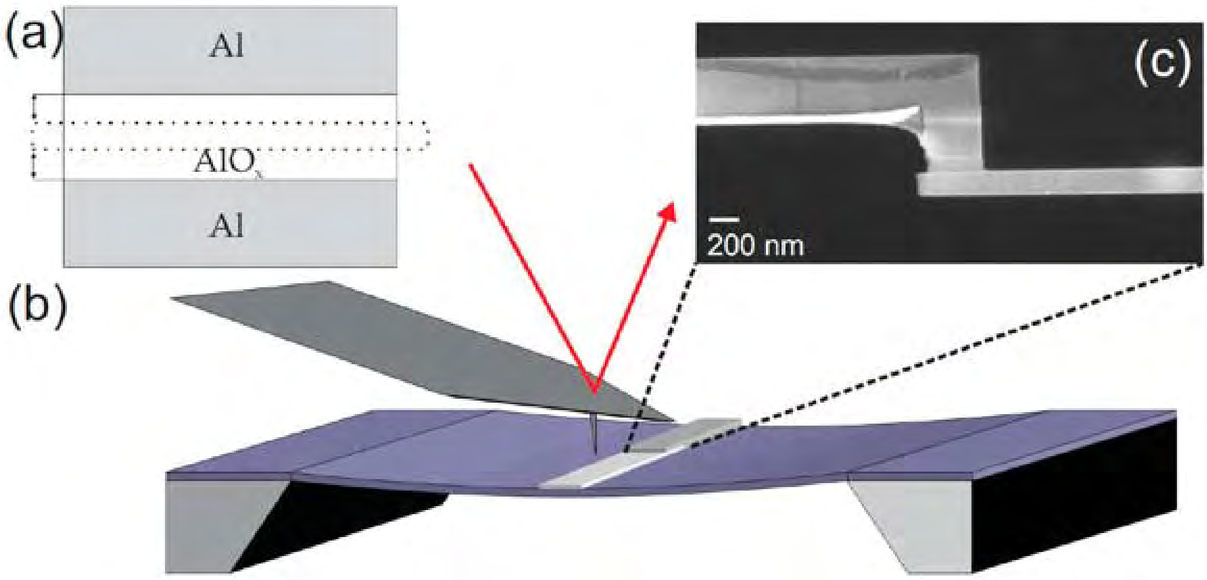

Fig. 2. Schematic of the tunnel junction strain sensor experiment [3]. Inset shows an SEM micrograph of a junction.

[1] P. J. Koppinen and I. J. Maasilta, "Phonon cooling of nanomechanical beams with tunnel junctions", Phys. Rev. Lett. 102, 165502 (2009)

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[3] P. J. Koppinen, J. T. Lievonen, M. E. Ahlskog and I. J. Maasilta, "Strain sensing with submicron Al-AlOx-Al tunnel junctions", Rev. Sci. Instrum. 81, 023901 (2010)

Molecular Technology

Markus Ahlskog

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, electron transport, and optical properties of individual carbon nanotubes are very important for current progress in studying the physics of these materials. We have correlated atomic force microscopy, Raman spectroscopy and low temperature transport measurements of individual single walled nanotubes that are electrically contacted with lithographically fabricated microelectrodes on Si/SiO_2 substrates. It enables us to give a more detailed description of the properties of each nanotube (see ref. 4).

We have also developed a method to suspend nanotubes over narrow slits, as shown in Fig. 3. In this sample geometry we combine Raman spectroscopy and electron diffraction patterning in a transmission electron microscope to get two mutually independent determinations of the individual chiral structure. The suspended geometry also gives a heavily reduced background signal in the optical measurements, which allows us to perform femto-second four-wave-mixing spectroscopy on a single carbon nanotube.

A three year long TEKES project, in collaboration with Beneq, Nokia and Vaisala, named "Molecular Scale Memory Elements" had a good ending in 2009, resulting in a record fast carbon nanotube field-effect transistor memory (see Fig. 4 and ref. 5). The carbon nanotube memory was demonstrated to operate with write and erase cycles as short as 100 nano seconds, which is 100 000 times faster than previously reported. The key element is the designed gate dielectric made out of selected layers of atomic layer deposited materials, which provide controlled charge trapping in the vicinity of the carbon nanotube. The operation speed together with a durability of more than 10 000 write and erase cycles are in parity with current state of the art flash memories. The achievement was noted in scientific press, e.g. the web editions of New Scientist, nanotechweb and physorg. In this study Professor Päivi Törmä at Aalto University has been the principal investigator.

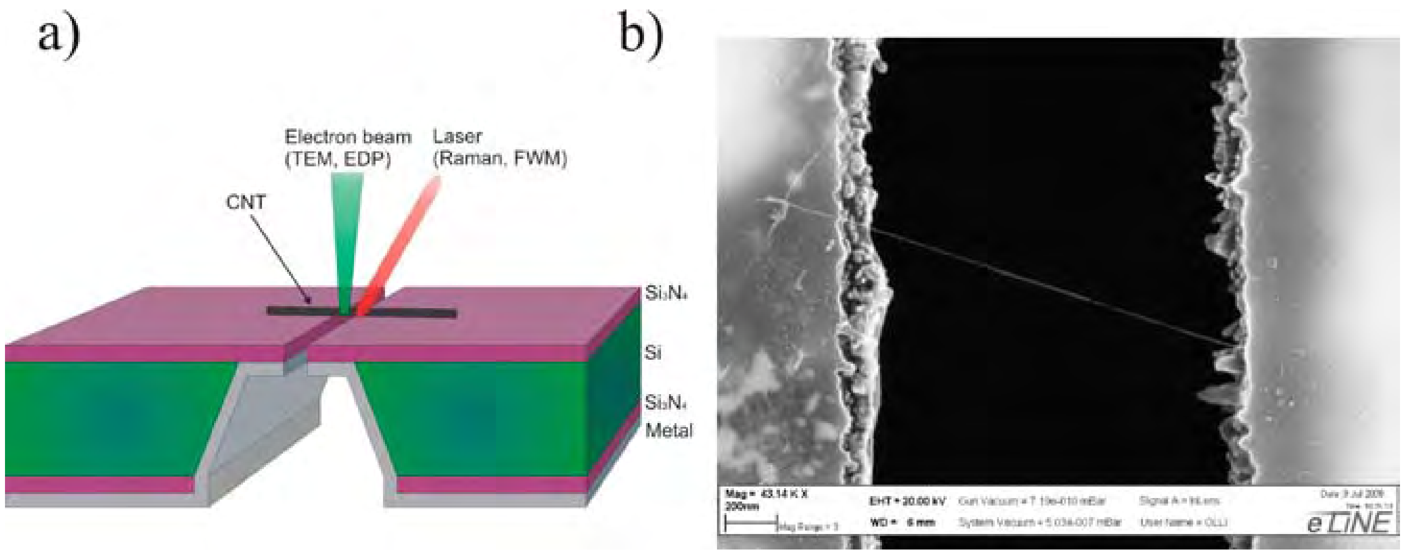

Fig 3. a) Schematic of our suspended carbon nanotube samples. b) Scanning electron micrograph of a carbon nanotube suspended across a slit.

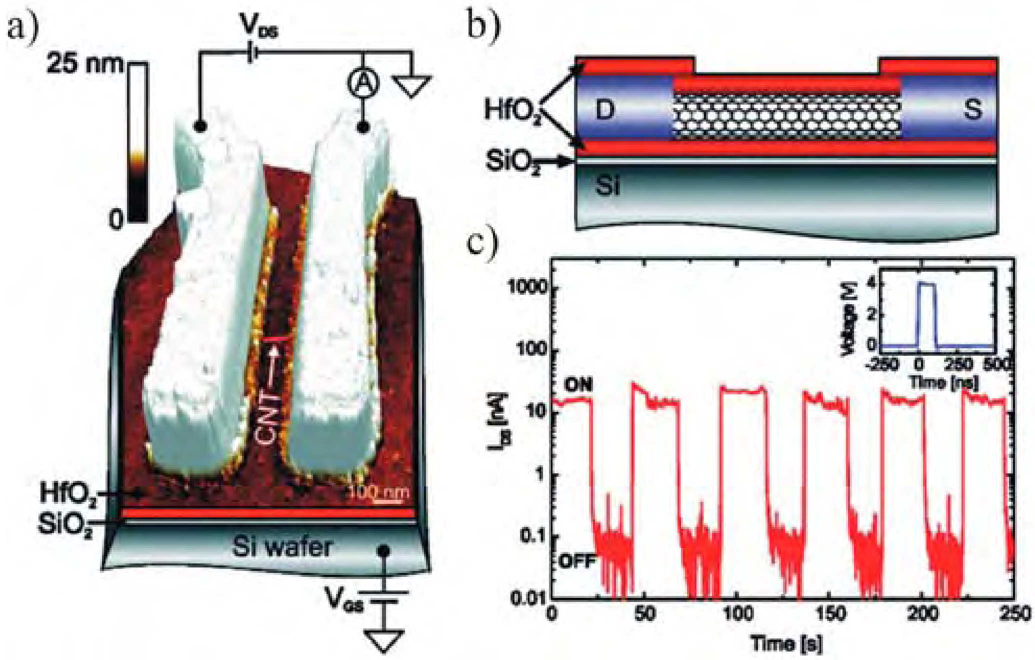

Fig. 4. a) Atomic force micrograph of a carbon nanotube memory device with a schematic of the measurement setup. b) Schematic of the carbon nanotube memory device. c) Switching between on and off state, using 100 ns short positive or negative gate voltage pulses of the shape shown in the inset.

Imaging of carbon nanotubes (CNT), and other nanoscale particles, with the atomic force microscope (AFM) is overwhelmingly done in various versions of the non-contact mode, where the AFM tip mechanically touches the object only intermittently, or not at all. Nevertheless, frictional forces are of interest in AFM and tribology, which are measured in frictional force microscopy or Lateral force microscopy (LFM), using contact mode. Contact mode operation is also important in various cases where, for example, nanotubes are mechanically measured or manipulated. As the tip sweeps along the surface in contact mode, friction between the two causes lateral forces, which are measurable as a torsion of the cantilever. Moreover, any topographical feature on the surface, either those due to the curvature of the surface itself or by nanoscale particles lying on the surface, cause lateral torsional forces via the tip to the cantilever.

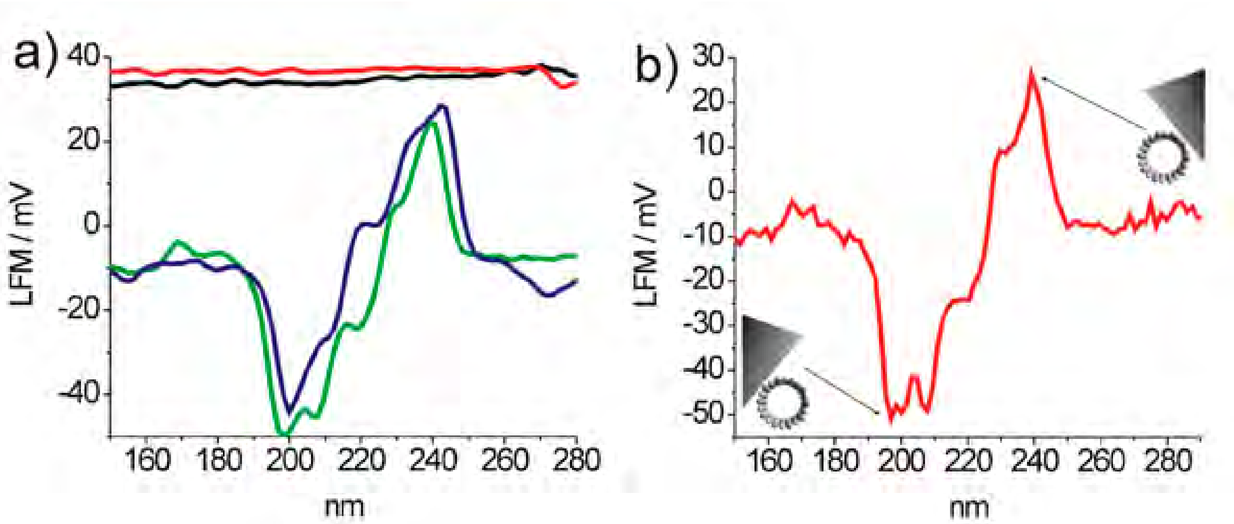

Fig 5. a) Lateral force during contact mode imaging across CNT in two different scan configurations. In the lower pair of curves the cantilever major axis is parallel and in the upper pair perpendicular to the CNT. One pair consists of left-to-right (red and blue curve) and the opposite scan directions (black and green curve). b) Illustration of suggested cause for the LFM signal peaks in one single sweep of the tip over the CNT. The good reproducibility of the LFM signal is demonstrated by data taken from three different locations of the nanotube.

We have measured lateral forces during contact mode imaging with an AFM across a carbon nanotube. We found that, qualitatively, both magnitude and sign of the lateral forces to the AFM tip were independent of scan direction and can be concluded to arise from the tip slipping on the round edges of the nanotube (see Fig. 5 and ref. 6).

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Quantum Nanolectronics

Konstantin Arutyunov

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.

Quantum Size Phenomena at Nanoscales

The group continued its study of quantum fluctuation phenomena in nano-scale superconductors. Additionally to the already observed suppression of zero resistivity in ultra-narrow superconducting nanowires, the group extended the studies on the equilibrium state of a superconductor – persistent currents in nanorings (Fig. 6) – where the quantum fluctuations quench the diamagnetic response. The discovery is of fundamental importance indicating breakdown of the text-book diamagnetism in superconductors due to the new quantum phenomenon.

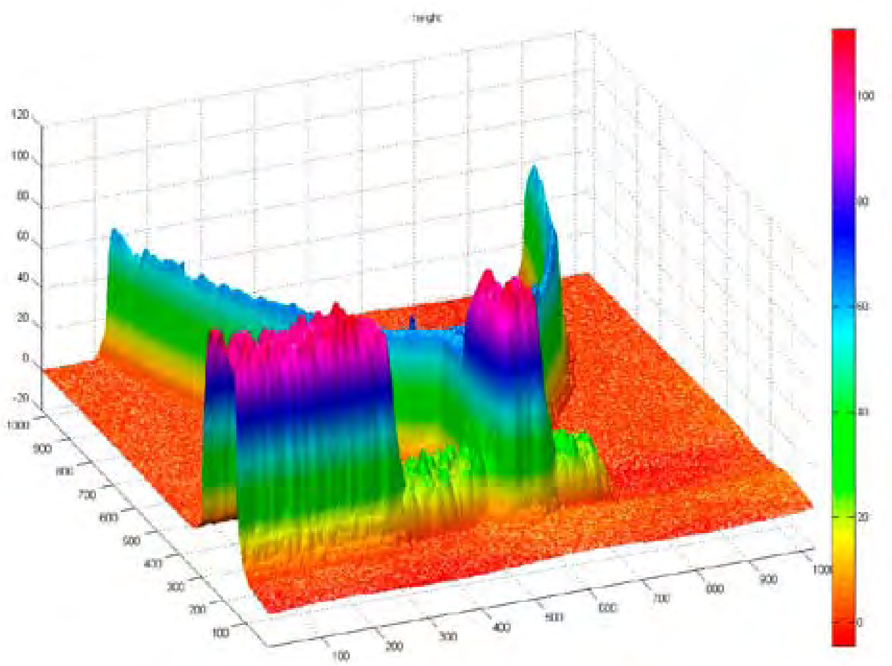


Fig. 6. AFM image of a SISIS tunnel structure with the loop-shaped central electrode [unpublished].

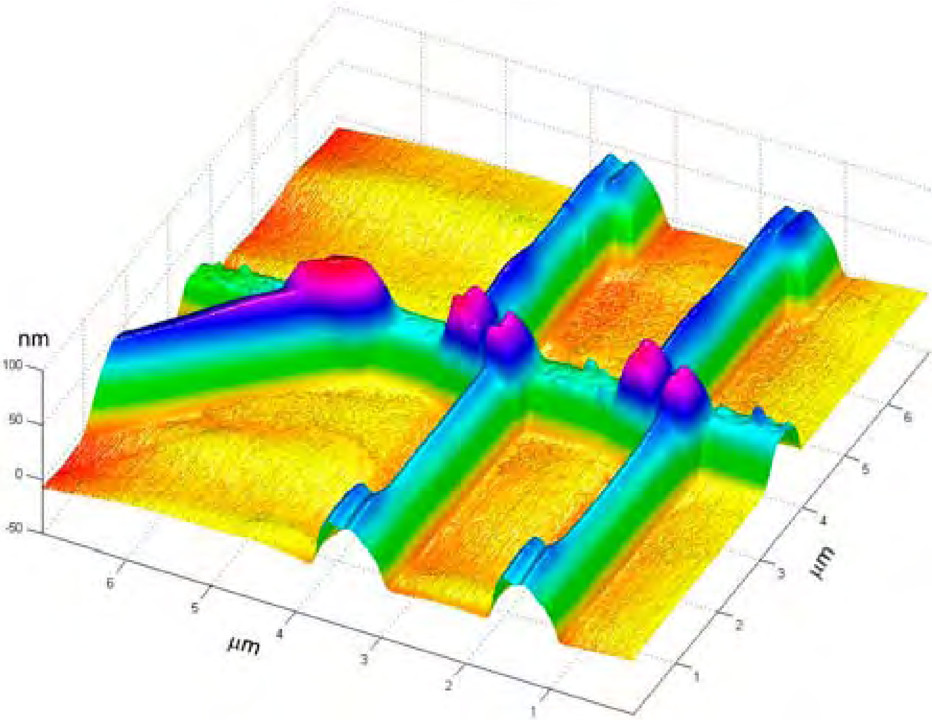


Fig. 7. AFM image of a multi-terminal NIS structure where the electrons are injected from the normal-metal electrode through the tunnel barrier (left-most), and the spatially-inhomogeneous density of states and the distribution function are measured with multiple NIS junctions along the superconductor [unpublished].

Interface Phenomena at Nanoscales

It is a common knowledge that electric current in normal metals is transported by single electrons, while in superconductors – by pairs of electrons (Cooper pairs). One may ask a reasonable question: what is the characteristic scale on which the normal electron current is converted into the supercurrent? Surprisingly, there is no commonly accepted opinion answering this simple question, if the temperature is sufficiently small and the energy of the injected electrons is above the superconducting energy gap. The topic has been studied in multi-terminal structures (Fig. 7) where the non-equilibrium excitations were injected into the superconductor (Al) from the normal metal (Cu) through a tunnel barrier (AlO_x). The study is of fundamental importance for the basic science and for numerous applications of hybrid (tunnel) nanosystems.

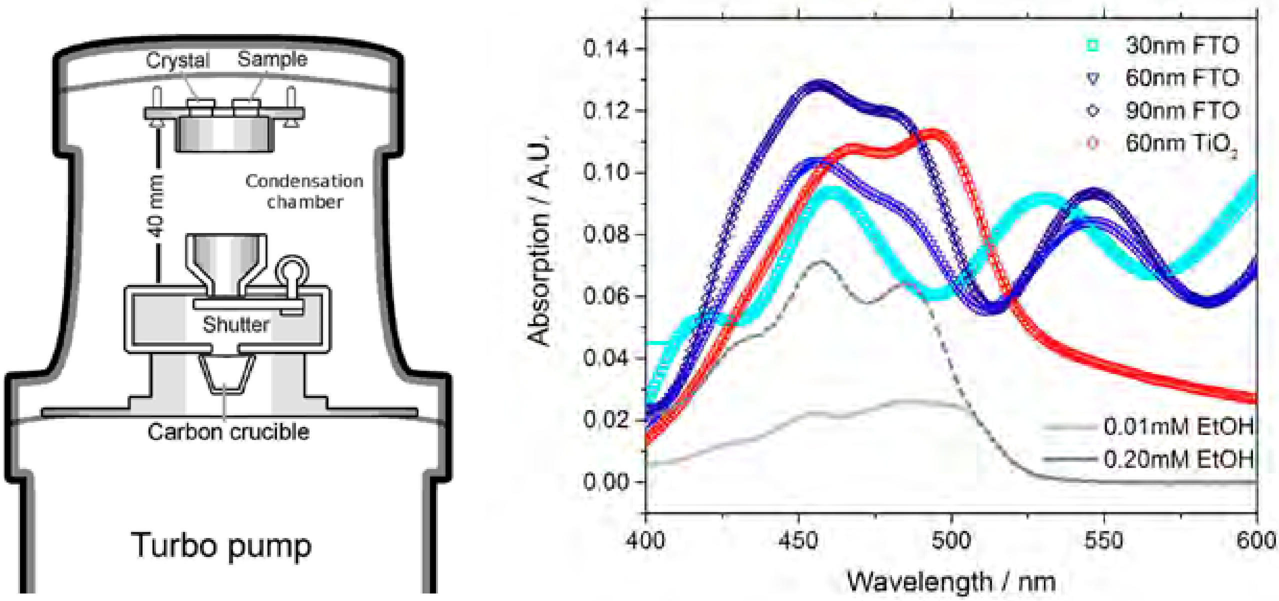


Fig. 8. (a) Schematics of the vacuum deposition chamber; (b) spectra of the thin dye-based films of various thicknesses [unpublished].

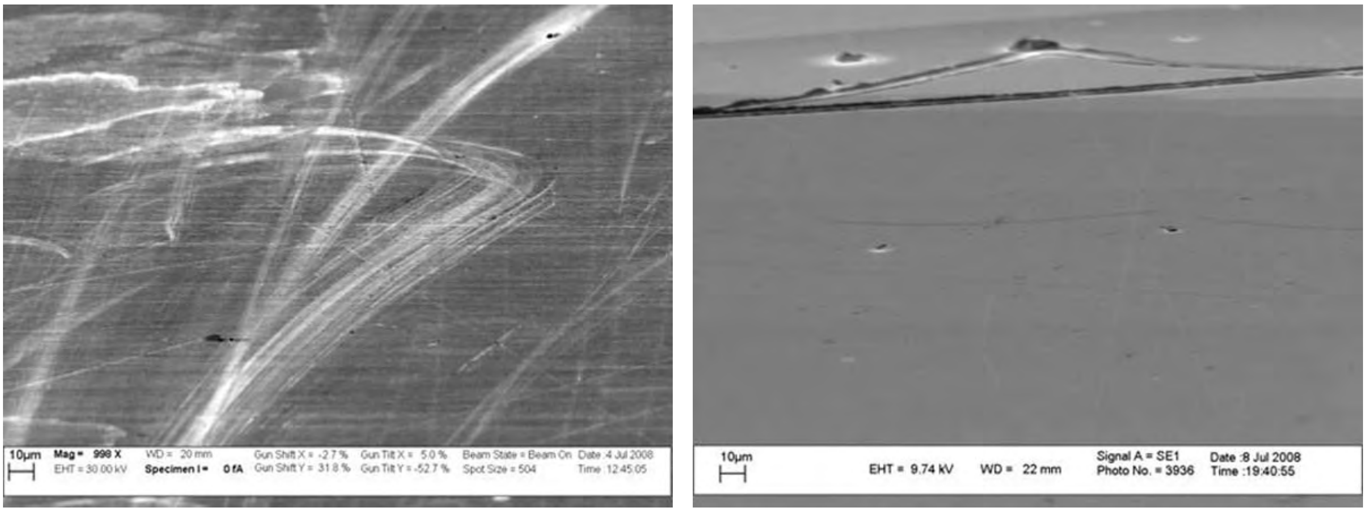


Fig. 9. SEM images of electrochemically polished machinery steel surface (left) and the same sample after the ion beam polishing (right).

Molecular Nanoelectronics

In collaboration with the team of Prof. J. Korppi-Tommola (NSC, Dept. of Chemistry) the group continued the experimental study of the dye-based molecular nanostructures. The group has developed high vacuum compatible and nanofabrication "friendly" method of deposition of organic dye molecular layers (Fig. 8a). The absorption spectra showed clear resemblance with the conventionally fabricated (by soaking in a solution) dye samples (Fig. 8b), indicating the good quality of the organic films.

Applied Nanotechnology

The group extended the patented (application FI-20060719) technology of the ion beam downscaling of nanostructures. The method can be used for multiple applications. An example of the effect of the ion beam polishing is presented in Fig. 9. The activity has been supported by the JOSKE project of the Jyväskylä scientific part and was made in collaboration with several industrial partners.

Molecular Electronics and Plasmonics

Jussi Toppari

Superior self-assembly properties of DNA can be efficiently utilized in the bottom-up fabrication of complex nanoelectronic systems. Various DNA-based structures, like DNA origamis, can serve as selective templates for other molecular components. To fully exploit the idea of DNA templates as "nanobreadboards" it is crucial to know the electrical properties of such structures themselves. In order to study these properties we have immobilized individual DNA origamis between lithographically fabricated nanoelectrodes and thereafter characterized the electrical conductivity of the structure. We have fully analyzed both DC and

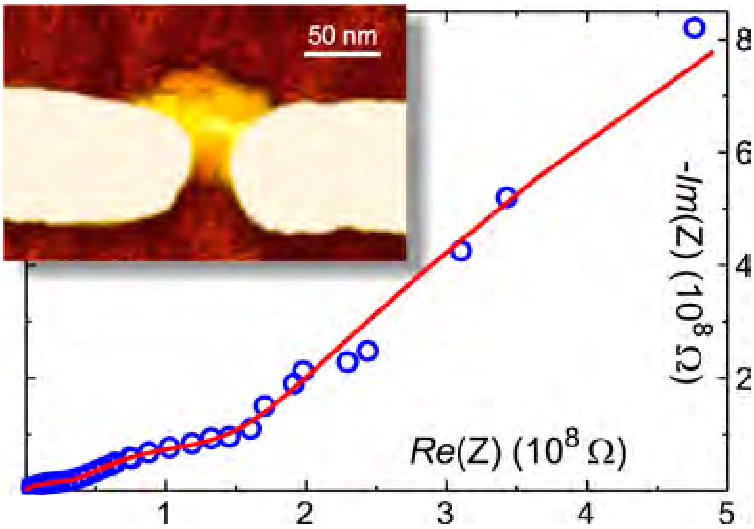


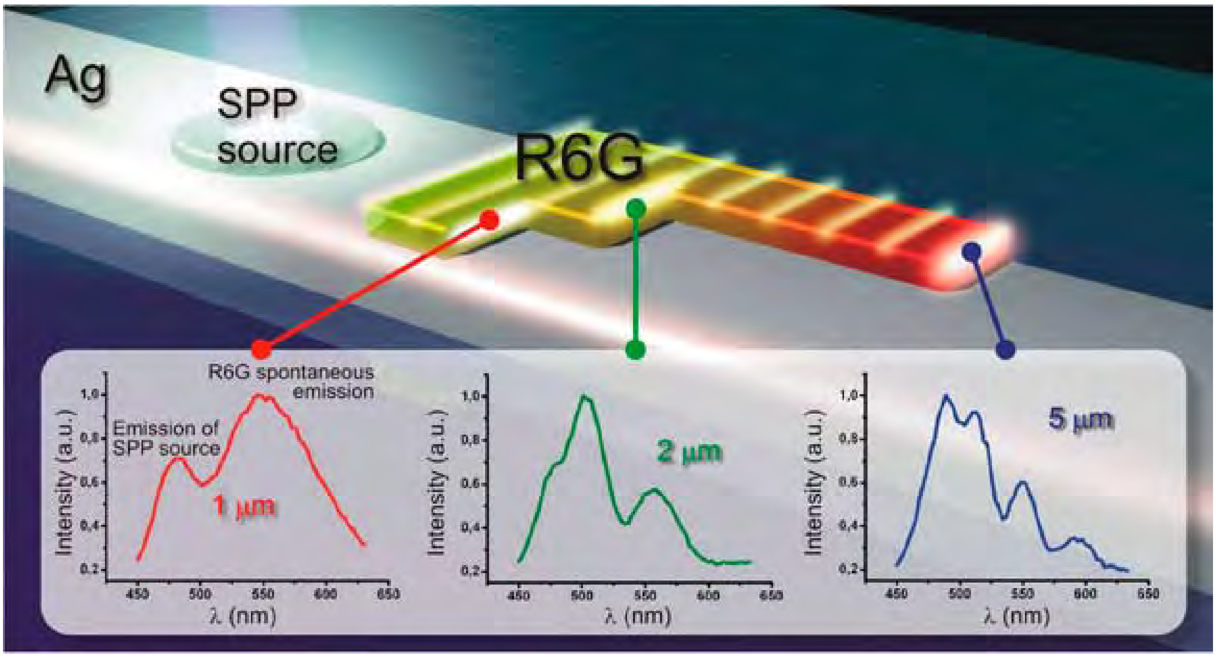
Fig.10. AFM Image of a rectangular DNA origami trapped and immobilized between nanoelectrodes, and AC impedance spectroscopy data measured from it. Circles are the measured data points and red line is a response of a fitted equivalent circuit.

Fig. 11. Schematic illustration of FINAL in the inner cover of Small.

AC characteristics (AC impedance spectroscopy) of single trapped DNA origamis with different humidity levels, and also defined the detailed equivalent circuit model describing the conductivity mechanism of the structure [7]. The results showed that the nature of the conductivity is a combination of an ionic diffusion and electronic conductivity.

We have developed a high-throughput method for pattern transfer of nano-objects, called field-induced nanolithography (FINAL) [8]. The method enables large-area printing and possibly even mass production. Thus, it can be well utilized in a fabrication of highly ordered multicomponent patterns and nanodevices. FINAL is based on the dielectrophoretic trapping of polarizable nanoparticles on the master stamp and the transfer of the trapped pattern to the target plate. The dynamic control over the trapping pattern can be used to realize a master stamp capable of transferring any desired multicomponent pattern to the target surface. We have demonstrated the feasibility of FINAL by creating arrays of quantum dots, but the method can be readily extended to trapping and thereafter arranging carbon nanotubes, biomolecules, and other objects into desired configurations. This work has been carried out as collaboration with a group of Prof. Päivi Törmä in Helsinki University of Technology.

Surface plasmon polaritons (SPPs) are coupled, wavelike, excitations of electromagnetic field and free electrons in metal. They can be confined below the diffraction limit of free space light, and thus may provide the way to integrated optical circuits in nanoscale. The interaction of SPPs with molecules is also under an intensive investigation at the moment. We have studied interactions between organic dye molecules and waveguided SPPs and demonstrated a strong coupling between SPPs and Rhodamine 6G (R6G) molecules, with double vacuum Rabi splitting energies up to 230 and 110 meV [9]. In addition, we demonstrate the emission of all three energy branches of the strongly



coupled SPP-exciton hybrid system, revealing features of system dynamics that are not visible in conventional reflectometry. Finally, we show that the Rabi splitting can be controlled by adjusting the interaction time between the waveguided SPPs and R6G deposited on top of the waveguide, as illustrated in figure 12. This work has been carried out as collaboration with a group of Prof. Päivi Törmä in Helsinki University of Technology and professors Mika Pettersson and Henrik Kunttu from Department of Chemistry, JYU.

Fig. 12. Measured spectra of scattered SPPs after propagating through 1, 2 and 5 mm long R6G interaction areas. As observed in the spectra, the strong coupling characteristics can be controlled by controlling the interaction time via R6G area length.

[7] V. Linko, S.-T. Paasonen, A. Kuzyk, P. Törmä, and J. J. Toppari "Characterization of the Conductance Mechanisms of DNA Origami by AC Impedance Spectroscopy", Small 5, 2382, (2009).
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[9] T. K. Hakala, J. J. Toppari, A. Kuzyk, M. Pettersson, H. Tikkanen, H. Kunttu, and P. Törmä " Vacuum Rabi Splitting and Strong-Coupling Dynamics for Surface-Plasmon Polaritons and Rhodamine 6G Molecules", Phys. Rev. Lett. 103, 053602, (2009).

Computational Nanosciences

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

Graphene Edges Got a Third Family Member

Pekka Koskinen

Though the peculiar properties of graphene originate from the honeycomb lattice, any real sample has edges. Since the edges of nanoscopic objects determine most of their properties, graphene edges are important, but always considered either zigzag- or armchair -type—until now.

In previous theoretical work we predicted [Koskinen et al. Phys. Rev. Lett. 101, 115502 (2008)] the existence of third member, the reczag edge, which is a local reconstruction of the zigzag edge, but has distinct mechanical and chemical properties.

Now we provide [Koskinen et al. Phys. Rev. B 80, 073401 (2009)] experimental evidence that confirms this unexpected prediction: zigzag really is a metastable edge and planar reconstruction does lower energy to forms the most stable graphene edge. Since the reconstructed edge, along with other unconventional edges we discover, has distinct chemical properties, this discovery urges for care in experiments and theory—carbon research must enter the realm beyond zigzag and armchair.

Matti Manninen, professor
Hannu Häkkinen, professor (physics and chemistry)
Robert van Leeuwen, professor
Karoliina Honkala, academy researcher (chemistry)
Esa Räsänen, academy researcher
Jaakko Akola, senior researcher
Vesa Apaja, senior researcher
Olga Lopez-Acevedo, postdoctoral researcher
Adrian Stan, postdoctoral researcher
Mikkel Strange, postdoctoral researcher
Pekka Koskinen, postdoctoral researcher
Sami Malola, postdoctoral researcher
Jenni Andersin, graduate student (chemistry)
Pentti Frondelius, graduate student (-31.8.)
Katarzyna Kacprzak, graduate student
Elena Heikkilä, graduate student (1.11.-)
Janne Kalikka, graduate student
Ville Kotimäki, graduate student
Petri Myöhänen, graduate student
Ville Mäkinen, graduate student
Lauri Nykänen, graduate student (chemistry)
Oleg O. Kit, graduate student
Antti Putaja, graduate student
Perttu Luukko, graduate student (1.9.-)
Anna-Maija Uimonen, graduate student
Niko Säkkinen, graduate student
Manana Koberidze, MSc student

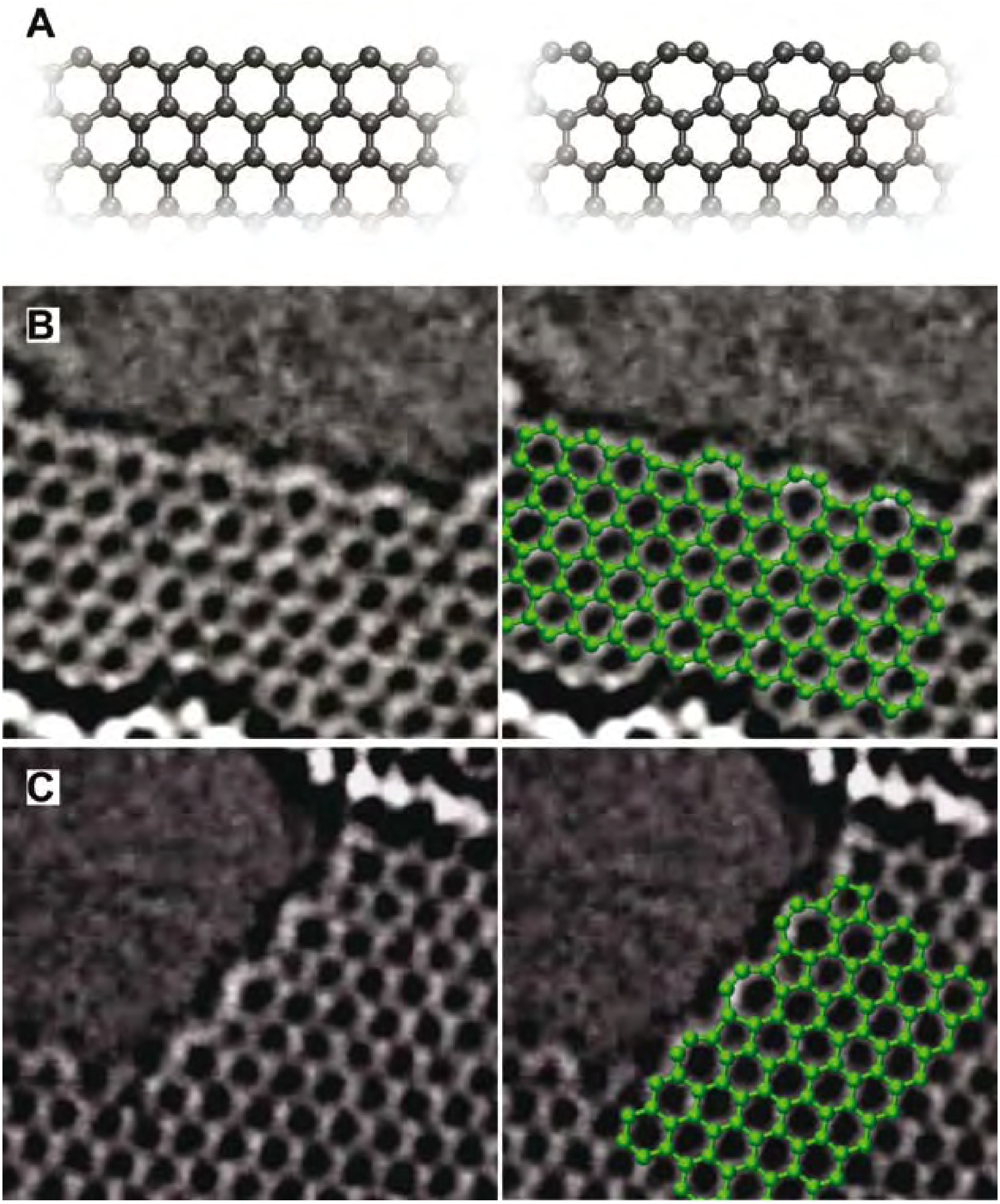

Illustration 1. Experimental evidence for zigzag reconstruction. a) Normal zigzag edge (left) and the reczag edge (right), as we predicted earlier. b, c) Transmission electron micrographs from Girit et al. Science 323, 1705 (2009), showing the zigzag edge reconstruction on left, with a highlighted structure assignment on right. Note, in b, the smooth transition from zigzag to reczag.

Quantum Control and Dynamics

Esa Räsänen

We study quantum phenomena in nanoscale systems with a particular focus on low-dimensional electronic structures. Our primary research directions are (i) many-particle effects and related methodological developments, (ii) quantum optimal control to find tailored external fields for, e.g., electronic excitations and qubit design, (iii) quantum transport in quantum-dot devices, and (iv) chaotic properties of many-particle quantum wells. Below we give examples of our activities in 2009 related with topics (i) and (ii), respectively.

The indirect (quantum mechanical) part of the Coulomb interaction is known to have a rigorous lower bound in energy. The existence of such a bound, usually referred as the Lieb-Oxford bound, is of immediate relevance to such fundamental questions as the stability of matter. We have obtained the tightest estimate to date for the bound and determined also the corresponding lower bound for two- and one-dimensional systems [E. Räsänen, S. Pittalis, K. Capelle, and C. R. Proetto, Phys. Rev. Lett. 102, 206406 (2009)]. The new forms for the bound are expected to serve as useful physical constraints in practical many-body approaches in different dimensions.

We have developed quantum optimal control theory to tailor femtosecond laser pulses for enhanced ionization of atoms or molecules [A. Castro, E. Räsänen, A. Rubio, and E. K. U. Gross, Europhys. Lett. 87, 53001 (2009)]. The procedure searches for pulses that maintain the same total length and fluence as the given initial pulse. It allows, however, for changes in frequencies (within a predefined range) and in the overall shape. We have demonstrated the high efficiency of the scheme for the H2+ molecule irradiated with short (~ 5 fs), high intensity laser pulses (see adjacent figure).

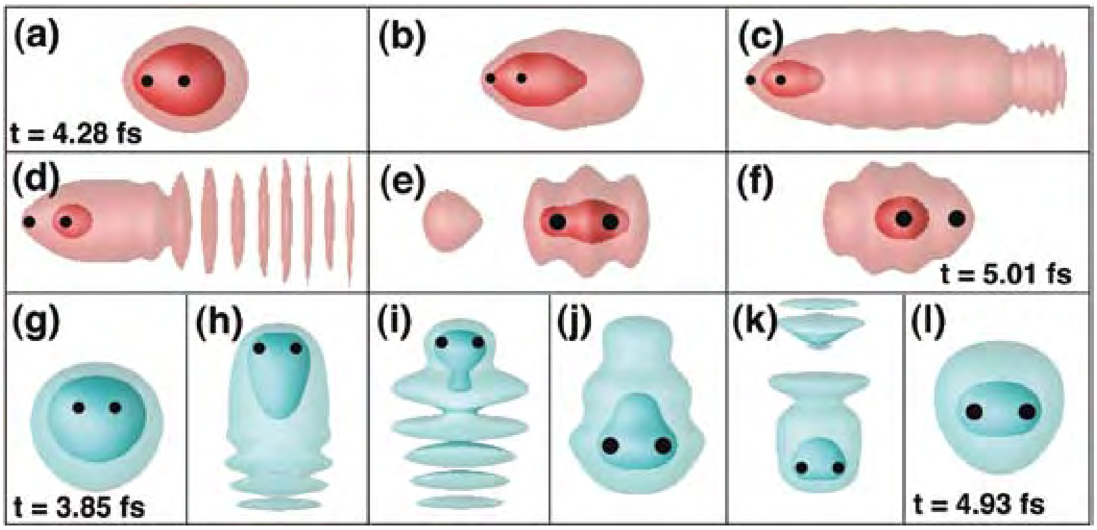

Illustration 2. Electron density of a H2+ molecule during the optimized ionization process when the pulse polarization is parallel (a-f) and perpendicular (g-l) to the molecular axis.

Characterization of Iron-carbonyl-protected Gold Clusters

Olga Lopez-Acevedo

Ligand-stabilized nanometer-sized gold particles are interesting building blocks for molecular electronics, precursors for catalysts, optical labels for biomolecules and diagnosis, and potential nontoxic carriers for therapeutics. We have characterized for the first time, by means of near-infrared and Raman spectroscopy and time-dependent density functional calculations (absorption spectra and frontier orbitals), gold clusters protected with iron-carbonyl ligands, such as $Au_{22}[Fe(CO)_4]_{12}^{-6}$ shown in the adjacent figure [O. Lopez-Acevedo, J. Rintala, S. Virtanen, C. Femoni, C. Tiozzo, H. Grönbeck, M. Pettersson and H. Häkkinen,, J. Am. Chem. Soc, 131 (35), 12573 (2009)]. Surprisingly, our results show that these novel compounds bear many analogues to another, well-studied, class of gold clusters, namely those of thiolate-monolayer-protected gold clusters. We identified $Fe(CO)_3$ and $Fe(CO)_4$ units as the protecting ligands. The NIR transitions detected can be explained in the framework of the gold superatom model which quantifies the metallicity of the gold core in terms of the effective number of itinerant electrons and accounts for the shapes and symmetries of the frontier orbitals contributing to transitions. These newly found compounds differ clearly from the earlier known carbonyl-protected bimetal Au/(Ni,Pd,Pt) or pure transition metal clusters and give a new dimension to the rich chemistry of gold-based molecular metals.

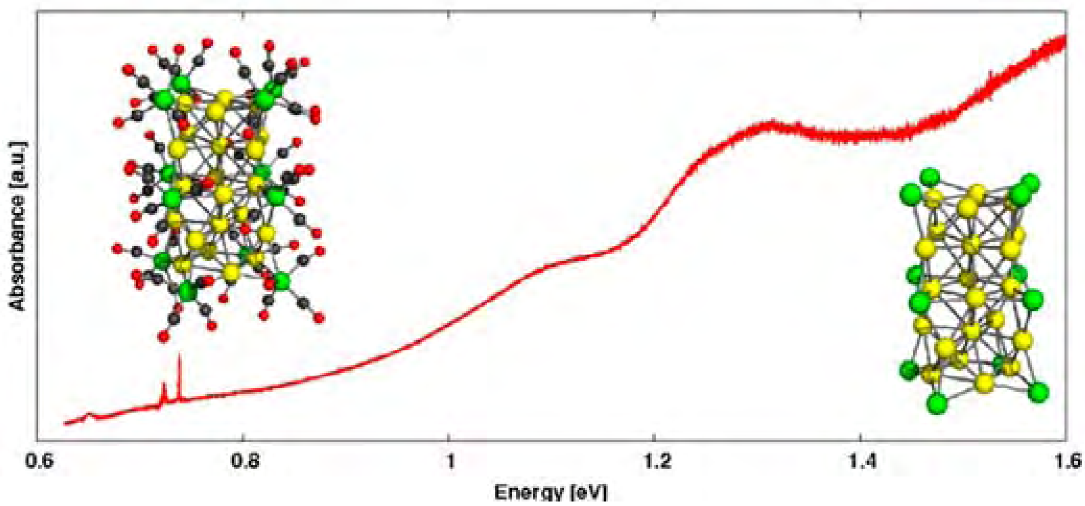

Illustration 3. NIR absorption spectrum of Au22[Fe(CO)4]12 taken in acetonitrile.

Soft Condensed Matter and Statistical Physics

Markku Kataja, Juha Merikoski and Jussi Timonen

Elastic Properties of Membranes

Our discrete element model for elastic materials with either elastic/elasto-plastic beam elements or triangular plate elements was used to analyze the elastic properties of thin sheets (membranes). In elasto-plastic membranes the pattern of ridges formed by confining the membrane into a small volume was not self-similar but dependent on membrane thickness. Therefore the fractal dimension of the crumpled structure was smaller in elasto-plastic membranes than in fully elastic membranes (Fig. 1.). A consequence of this behaviour is that elasto-plastic membranes appear stiffer under crumpling than elastic membranes, against the intuitive conception. Self-adhesion of the membrane was then added to the model via a Van der Waal type of interaction, and adhesive membranes were also considered at non-zero temperatures by Langevin dynamics. We demonstrated that rigid adhesive membranes can reach low-energy conformations by folding or scrolling (Fig. 1.), but confining them into a small spherical volume was as hard as for their non-adhesive counterparts. It seems that truly compact conformations are unattainable for large membranes under simple confinement. The existence of free-standing collapsed conformations was limited by the unbinding temperature in analogy with flexible membranes, and, in addition, by the length scale related to the nonzero bending rigidity. In general, it seems that rigid microscopic membranes such as e.g. graphene are mechanically and thermally stable under widely varying conditions in agreement with recent experimental findings.

Jussi Timonen, professor
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Andrei Rybin, docent
Markko Myllys, senior assistant
Jari Hyväluoma, postdoctoral researcher (-28.02.2009)
Ari Jäsberg, postdoctoral researcher (part time)
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Thomas Kühn, postdoctoral researcher
Petro Moilanen, postdoctoral researcher
Jouni Takalo, postdoctoral researcher (01.06.2009-)
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Keijo Mattila, graduate student (mathematical information tech.)
Lasse Miettinen, graduate student
Tuomas Tallinen, graduate student
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Arttu Miettinen, MSc student
Mikko Trygg, MSc student
Markku Väisänen, MSc student

Fig. 1. A hexagonal membrane with Van der Waals like self-attraction in a flat, scrolled, folded and multiply-folded conformation (on the left). An inside view into a crumpled structure of an elasto-plastic membrane (on the right).

Stochastic Systems

We continued our studies on stochastic models of transport of particles with internal degrees of freedom under time-dependent external fields and other constraints. For this, we used and developed methods for a numerical analysis of stochastic evolution operators, the density matrix renormalization group and the continuous-time Monte Carlo method. The model cases studied include the motion of polymers in Brownian ratchets and diffusion of particles between interacting interfaces. A strong dependence on the microscopic details of the dynamic rules of macroscopic transport was observed, and their effect on the efficiency and coherence of transport and the optimal charge distribution within the diffusing molecule was systematically explored.

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 so that the method was also applicable to materials of fairly low heat diffusion coefficient. The loss resulting from convective heat transfer was then completely eliminated by doing the experiment in a vacuum chamber, whereby still lower heat diffusivities could be determined.

An important problem in the analysis and modelling of complex processes is often related to finding of realistic material laws for the related transport properties, to which end one needs to determine the intrinsic structure in microscopic scale of the materials involved. X-ray

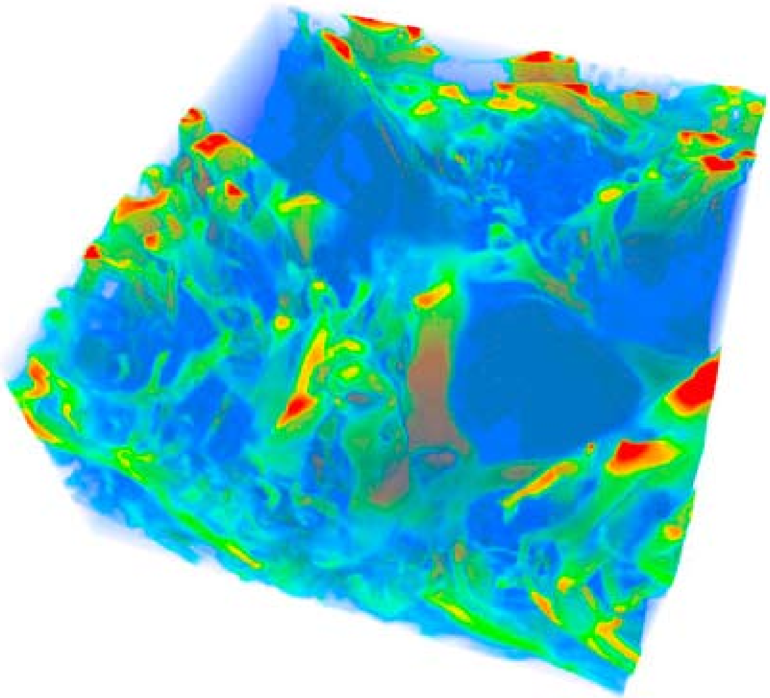


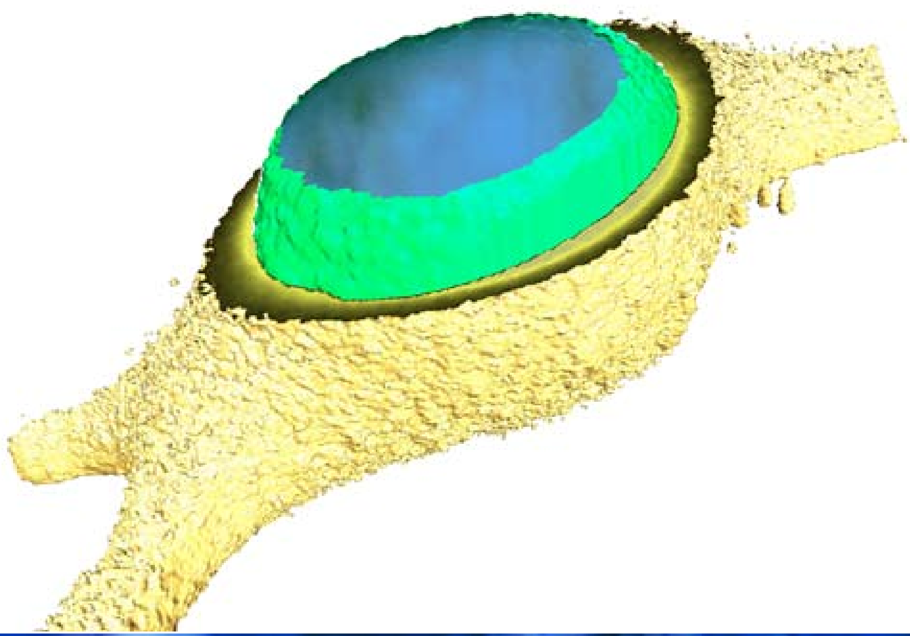
Fig. 2. A simulated flow field in a tomographic image of press felt. Bright colour indicates large velocity.

microtomography has proved to be an effective tool for revealing that structure in 3D. Given a tomographic reconstruction of a material, numerical methods can then be used to find its effective transport properties.

High-resolution tomographic reconstructions of e.g. paper, cardboard and paper-making fabrics were thus used to numerically analyze by the lattice-Boltzmann (LB) and a finite-difference method for their fluid transport properties (Fig. 2). Numerical methods were validated by analytical results and experiments. Tomographic imaging was also performed under various compression levels of materials so as to analyze the relation of their fluid transport properties to porosity. Furthermore, a layerwise analysis of these properties could be made from tomographic images, which revealed new information of the transport mechanisms compared to the real experiments. Similar methods were applied to finding the relevant material parameters for macroscopic models which describe the calandering, drying and wet pressing processes in the paper machine.

New modelling techniques for simulating diffusion of viral proteins in living cells were developed. To this end we generated a 3D digital model cell which takes the intra-cellular structure into account (Fig. 3). The cellular compartments like the cytoplasm and nucleus as well as the plasma membrane and nuclear envelope were described explicitly. Other cellular organelles were not well resolved by the measuring techniques used, but they however reduce particle mobility and the effective

Fig. 3. A 3D digital cell used in diffusion simulations as determined by the measured distribution of fluorescence within the cell. The cytoplasm, nucleus and nuclear envelope are the separately identified structural elements.



available volume. To account for their effect a model of effective porosity was introduced. Within these modelling techniques we were able to reproduce by simulation actual fluorescence recovery after photobleaching experiments, and to thereby achieve significant new insight into protein diffusion in the cell.

High-resolution x-ray Tomography

A new multi-scale tomography system was installed which can be used to image samples in 3D by a 50 nm to 30 µm resolution in the absorption as well as phase contrast mode. There are very few such systems available worldwide. Nanometre-scale resolution will open a completely new view into the structure of inhomogeneous materials. There are imminent needs to use tomographic imaging for disclosing the properties of many such materials, in basic science as well as in a number of practical applications. The new and old devices were used to analyze the 3D structure of paper, wood-fibre reinforced composites, single fibres, paper-making fabrics, mineral pigments, crystalline rock, and live cells.

Besides the in-house devices, the tomography equipment at the European Synchrotron Radiation Facility (ESRF) in Grenoble and at Lawrence Berkeley National Laboratory (LBNL) were used. The XM-2 microscope at LBNL was used to image cryo-fixed cells with soft x-rays (in the 'water window'). A resolution of 50 nm, which is enough to disclose the internal cell structure (Fig. 4.), was mostly used for imaging. The best possible resolution obtainable at LBNL is 20 nm, with the high-quality synchrotron radiation available there and using zone plates in the focusing of x-rays. In cryo-fixing the cells need not be treated with contrast enhancing chemicals, which may cause damage in their structure.

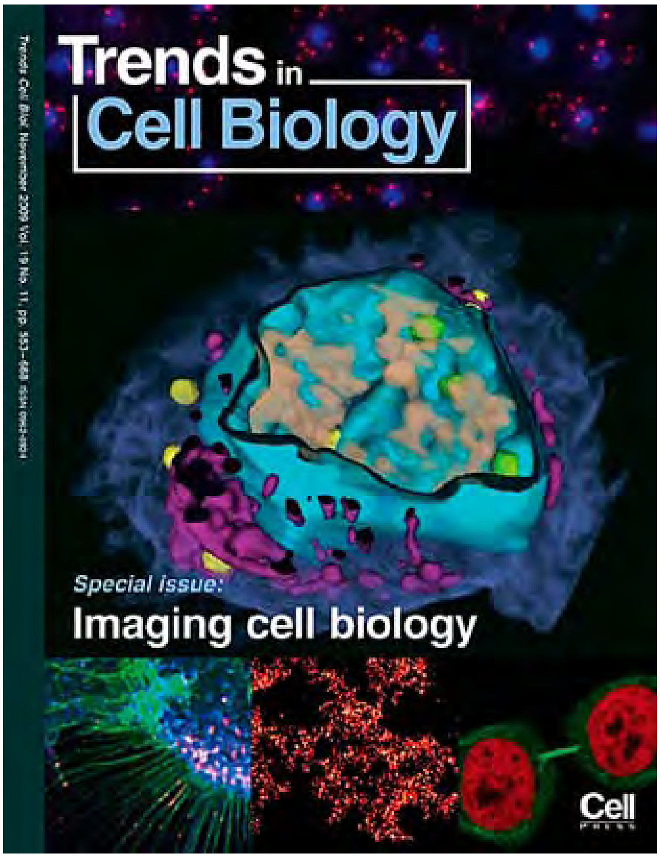


Fig. 4. Segmented X-ray tomography image (by Markko Myllys) of a cryo-fixed lymphocyte (Trends in Cell Biology 19 (2009) 553, the November issue).

Image Analysis

A number of novel 3D image processing and image analysis methods were developed with a view to analyze structural and transport properties of heterogeneous materials using their x-ray tomographic reconstructions. These methods include interface recognition, pore segmentation and individual fibre segmentation algorithms together with various filtering methods.

The dynamic interface recognition algorithm is useful especially for the analysis of the topology of surfaces and the structure of layered materials. The algorithm locates the interface by simulating a flexible surface which obeys quenched Edwards-Wilkinson dynamics with parameters related to the gray-scale values of the tomographic image. The interface is stopped at the location of the interface. The pore segmentation algorithm divides the pore space into individual pores and pore throats. Based on this information, a network ('skeleton') which represents the 3D topology of the pore space can be created. This information provides the local and statistical properties of the material for the analysis of its transport properties.

The fibre segmentation algorithm allows an automatic recognition of individual fibres from a tomographic image (see Fig. 5.). This enables analysis of many important characteristics of the network including the number and distribution of inter-fibre contacts and their area. The results can be applied e.g. in assessing the tensile properties of fibrous and fibre reinforced composite materials.

Assessment of Bone by Ultrasonic guided waves

Methods were developed for an 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) could be measured in bone at low ultrasonic frequencies (f=50-500kHz). At such frequencies, ultrasonic wavelength in bone is long enough for probing osteoporotic changes deep in the endosteal (inner) cortical bone. In an in vivo study on 550 voluntary subjects (age 10-88 y) it was shown that an array ultrasonic transducer, developed and optimized for the FAS mode, indeed probed well bone treats such as subcortical bone mineral density and cortical thickness ($r=0.7$-0.8; $p<0.001$). Furthermore, it was shown that the FAS mode discriminated low bone mineral density and osteoporotic fractures, suggesting that the ultrasonic approach has true 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 the mode has weak intensity on top of the soft tissue, but could be detected on the underlying bone surface. Techniques suitable for a non-invasive assessment of such bone surface vibrations of the SGW mode will be developed in a research project recently started. Research efforts were also directed to micro-CT analysis of bone structure, which will improve our understanding of ultrasonically determined bone properties.

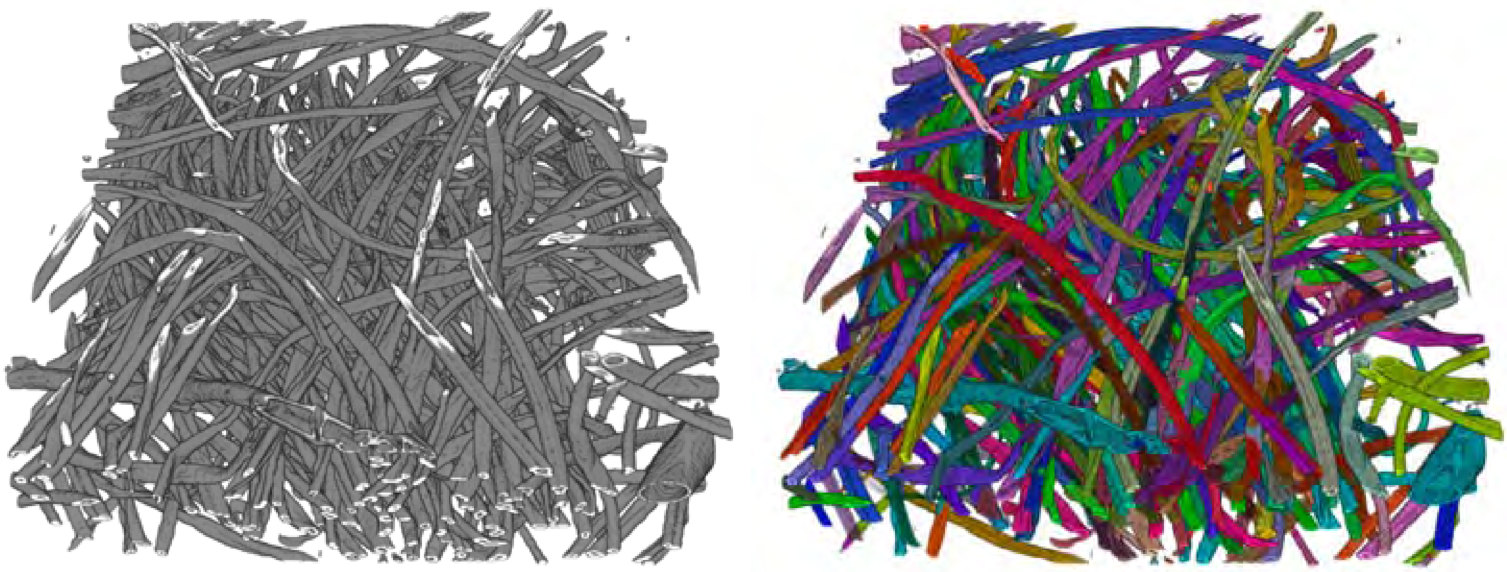


Fig. 5. Tomographic image of a felt material (on the left) and the individual segmented fibres (randomly coloured, on the right).

Ultrarelativistic Heavy Ion Collisions – Theory

Kari J. Eskola and Kimmo Tuominen

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 relevant for the LHC particle phenomenology is considered. We are financially supported by the Academy of Finland (SA), GRASPANP, private foundations and EU. Tuominen's LNCPMP HIP-project continues the successful tradition of collaboration with U. Helsinki. Locally, we work also with the Cosmology and ALICE groups. Internationally, we collaborate with various foreign colleagues, organize and participate in conferences and workshops, two European graduate-school networks and EU networks. Hannu Paukkunen reached the PhD degree and moved on to a postdoc position in Santiago Compostela, Spain.

Kari J. Eskola, professor
Kimmo Tuominen, senior assistant, HIP project leader
Vesa Ruuskanen, professor emeritus
Thorsten Renk, postdoctoral researcher –30.9., SA research fellow 1.10-
Tuomas Lappi, postdoctoral researcher
Oleg Antipin, postdoctoral researcher (HIP)
Hannu Paukkunen, graduate student -31.8.
Topi Kähärä, graduate student
Matti Heikinheimo, graduate student
Jussi Auvinen, graduate student
Tuomas Karavirta, graduate student
Hannu Holopainen, graduate student
Tuomas Hapola, MSc student
Risto Paatelainen, MSc student
Ilkka Helenius, MSc student

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 significantly further and including also RHIC data for the first time in such study (Fig.1), we released a new next-to-leading order nPDF set EPS09. Thanks to the error analysis there, the nPDF-originated uncertainties in e.g. those observables which are promising as QCD matter probes, can now be quantified.

Heavy-ion Phenomenology

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, we have predicted e.g. the hadronic p_T-spectra and elliptic flow for Pb+Pb collisions at the LHC. Currently, we are developing a hydrodynamic

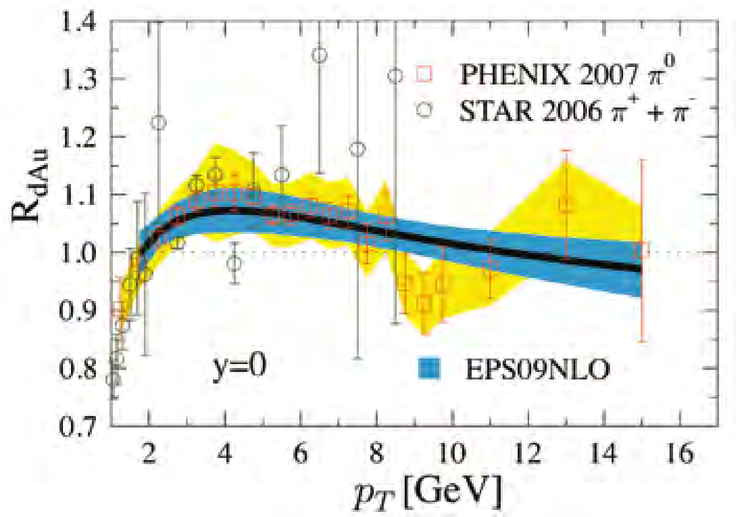


Fig. 1: The EPS09 results against RHIC data for pion production in d+Au/p+p collisions.

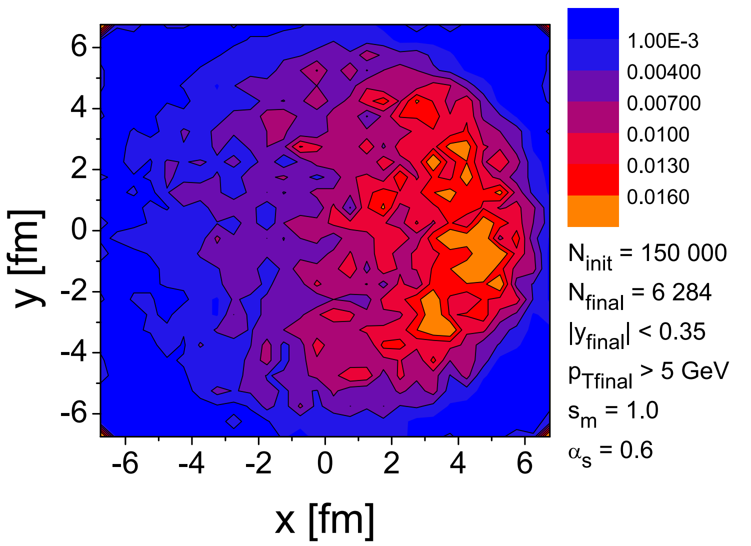


Fig. 2: A "tomography" image of the initial production points of the punch-through partons in the transverse plane of a central Au+Au collision at RHIC.

event-by-event Monte Carlo (MC) simulation for elliptic flow, and studying photon emission as a QCD matter signal.

QCD can also – in the high-energy limit – be studied in a classical field approximation (CGC). We have extended our research area to modeling the nuclear wavefunction and the initial conditions of URHIC in the CGC framework. Especially, multigluon correlations at large rapidity separations, which are a rare example of a directly experimentally observable initial stage effect, have been studied.

High-p_T particle production measurements in URHIC, ranging now from single-hadron spectra and few-particle correlations to reconstruction of full hadronic jets, form an important class of QCD matter probes at RHIC and LHC. We are currently developing MC simulations for QCD parton showering and collisional energy losses of high-p_T partons, embedding both phenomena in a hydrodynamically evolving QCD medium. First results with single-hadron spectra and jet structure look promising (Fig. 2) but 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. Explicit chiral symmetry breaking in these models was investigated and compared with the lattice data.

To address BSM phenomenology for the LHC we have focused mainly on Minimal Walking Technicolor models. We have considered collider signatures and computed the relic density of the dark matter candidates (WIMPs) in these models. We have also constructed an effective theory where both composite (Technicolor) Higgs and fundamental Higgs doublet are present. Existing data was used to constrain this model and to demonstrate its viability. Extensive lattice simulations of the gauge theory underlying Minimal Walking Technicolor were carried out with unimproved Wilson fermions; refined analyses with improved Wilson fermion action are in progress.

Theoretical Particle Physics and Cosmology

Kimmo Kainulainen and Jukka Maalampi

Neutrino Physics

We have studied the thermal leptogenesis in the Early Universe in the framework of a hybrid model, which combines the so called split fermion model and the bulk neutrino model defined in five dimensional spacetime. This model predicts the existence of a heavy neutrino pair nearly degenerate in mass, whose decays might generate a CP violation large enough for creating the baryon asymmetry of the universe through leptogenesis.

We have also studied the possibility that the three mass states of the ordinary active neutrinos actually split, as a result of mixing of active neutrinos with sterile neutrinos, into pairs of quasi-degenerate states with a tiny mass difference. Although these quasi-degenerate pairs will look in laboratory experiment identical to single active states, the CP phase factors associated with active-sterile mixing might cause cancellations in the effective electron neutrino mass m_{ee} measured in the neutrinoless double beta decay experiments thereby revealing the split nature of states.

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 (the Megaton) 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 and it

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Kimmo Kainulainen, lecturer
Markku Lehto, senior assistant
Valerio Marra, postdoctoral researcher (HIP/JYL)
Risto Hautala, graduate student
Matti Herranen, graduate student -30.9.
Pyry Rahkila, graduate student
Vappu Reijonen, graduate student (HY)
Janne Riittinen, graduate student
Jussi Virkajärvi, graduate student
Perttu Hietanen, MSc student
Mikko Pääkkönen, MSc student
Hannu Nyrhinen, MSc student

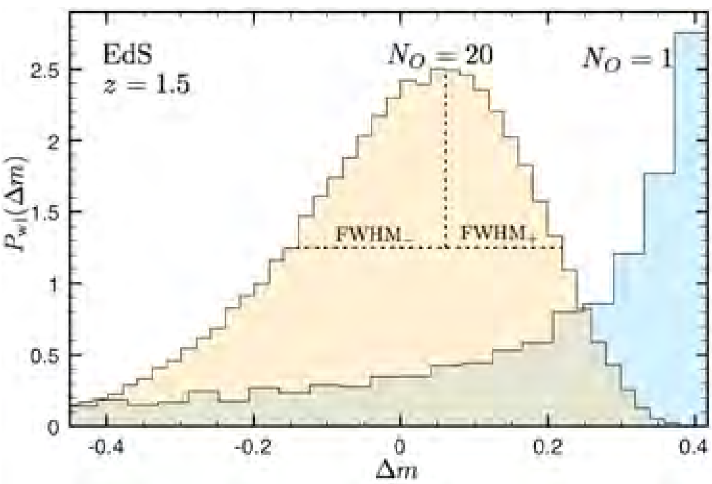
The cosmology group is closely connected to and partly supported by the Cosmophysics project belonging to the theory program in the Helsinki Institute of Physics.

involves altogether 21 research institutions and industrial partners in nine European countries. Apart from the scientific importance of the planned experiment, our interest in and activity related to the project is further boosted by the fact that the Pyhäsalmi mine, not far from the Department, is among of the possible sites of the new detector.

Cosmology

We have studied the dark matter in a class of new technicolor theories which can implement a dynamical electroweak symmetry breaking consistently with the precision electroweak data and alsoprovide an excellent gauge coupling constant unification. These models naturally contain a neutral sector reminiscent to neutralinos in the MSSM, and the lightest of the neutral eigenstates may be a stable dark matter particle similar to the LSP in the MSSM. We have computed the relic density of the new techni-DM, and found it to be easily consistent with both the cosmological observations and the experimental limits from earth-based searches. We have thus established a non-supersymmetric framework where hierarchy and naturality problems are solved, coupling constant unification is achieved and a plausible dark matter candidate exists.

Apart from the usual postulate for the existence of dark energy, the apparent accelerated expansion of the universe may, at least partly, be due to the effects of inhomogeneities on light propagation. Our group has developed a new method for computing the weak gravitational lensing effects for a stochastic distribution of dark matter halos, and we have released a public numerical code package "turboGL", which calculates the fundamental magnification probability distribution function for an arbitrary background universe model. We have used these methods to test the validity of the usual homogenous cosmolgical models, and in particular to quantify the effects of inhomogeneities on the cosmological parameter extraction from the supernova data.



Shown are the fundamental (N_0=1) and the effective magnification PDF for a set of N_0=20 observations for an inhomogenous EdS model specified in [1] for a source at redshift z=1.5.

We are also interested in the problem of the origin of baryon asymmetry in the universe. These studies necessarily involve coherent CP-violating out-of-equilibrium processes, and to this end we have developed a new quantum transport formalism which can treat non-local quantum coherence effects in noisy backgrounds. Our formalism is based on the observation that coherence information is carried by hitherto unobserved singular shells in the phase space, separate from the usual mass-shell solutions. We have used this coherent quasiparticle approximation, or cQPA, to derive consistent quantum transport equations for both bosonic and fermionic fields and we are currently applying these results to compute the baryon asymmetry created in the electroweak phase transition and in resonant leptogenesis.

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.

[1] A new stochastic approach to cumulative weak lensing, Kimmo Kainulainen and Valerio Marra, Phys.Rev.D80: 123020, 2009.

Industrial Collaboration

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

The Industrial Applications group of the accelerator laboratory had numerous contacts with domestic and foreign industry and research laboratories. Twenty irradiation campaigns with the 14 international partners were performed in RADEF facility. For the first time also NASA tested their satellite components at RADEF. Researchers from NASA's Jet Propulsion Laboratory from Pasadena, USA, were performing the tests. The irradiations of the polymer films for OxypheN GmbH also continued with the two campaigns in the year 2009. The total beam time used for these activities during the year 2009 was 1031 hours.

Due to increased radiation safety measures during the building of the laboratory's extension the activity with MAP Medical Technologies Ltd. stayed on stand-by situation. The negotiations about the continuation of the collaboration with the new cyclotron will continue in spring 2010.

Our project to use neutrons to study humidity in the wood logs was also completed. The results were reported in the report series of Metsäteho Oy and can be found from their web pages. Also, one licentiate thesis was finalized from the project. The negotiations with some most interested companies to continue the project from the feasibility level to the real applications are in progress.

The industrial collaboration continued with about ten national companies in 2009. From those Bintec Oy from Hollola and Millog Oy from Lievestuore were the most active collaborators.

The Accelerator Based Materials Physics group had active collaboration with companies in thin film processing development. The group offered Rutherford Backscattering Spectrometry (RBS) and Particle Induced X-ray Emission (PIXE) analysis services for industrial customers. In December 2009 the construction of a new analysis tool, Time-of-Flight Elastic Recoil Detection Analysis (TOF-ERDA), was finished and this technique with nanometer depth resolution for all elements is now warmly welcomed addition to the services the group can provide.

The Experimental Nanophysics groups have well established collaboration with a few companies in Finland. For example: the former Nanoelectronics 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 2009 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 have been developed in collaboration with Oxford Instruments Analytical Oy, motivated by the need of on-chip integrable ultrasensitive sensors in space research. In 2009 a TEKES/EAKR and Jyväskylä Innovation funded project continued, 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. In addition, there has been collaboration with companies Beneq Oy and Iamit.fi funded by Jyväskylä Innovations within integrable solar energy collection.

The Soft Condensed Matter and Statistical Physics group continued its long-term collaboration with a number of Finnish, European and American companies in several applied research projects and in the development of research facilities. It also started new projects funded by the Finnish Program for Strategic Centres for Science, Technology and Innovation (SHOK), as part of its EffTech research program, and by Jyväskylä Innovation, as part of the Centre of Expertise of The Paper Making Technology, which belongs to the Forest Industry Future Cluster Program in Finland.

A major upgrade of the x-ray tomographic facility was realized by the acquisition of an advanced multi-scale tomographic system, one of the very few worldwide, which makes x-ray tomography possible in a micrometre as well as nanometre scale, with a best resolution of 50 nm. While the primary funding of the system was received from the Regional Development Funds of the European Union, Governed by the Regional Government of Western Finland, a considerable contribution to its funding was received from industry and the local municipalities.

X-ray tomogoraphy was used in several industrial research projects for the analysis of the structural and transport properties of e.g. fibre-based materials, mineral compounds and thin films. Related to tomographic techniques, many advanced methods for image processing and analysis were developed.

In addition to the development of research infrastructure, the research group participated in 15 national and international research projects/ consortia funded by industry, the Technology Development Centre of Finland, the Academy of Finland and the Ministry of Employment and the Economy. These projects involved developing new experimental and numerical techniques for transport in porous media, basic and applied research on the rheological properties and dynamics of multiphase flows, application of tomographic techniques and image analysis to heterogeneous materials and coating layers, developing experimental and modelling methods for the safety assessment of repositories of spent nuclear fuel, and on ultrasound methods for the assessment and monitoring of bone quality.

Direct collaboration with industry included in addition structural analysis of fibre-based products, numerical simulation and modelling of industrial processes, analysis of transport processes in paper and rock, and rheological properties of pigment suspensions. Furthermore, the traditional close collaboration with VTT Technical Research Centre of Finland was continued, involving e.g. analysis of flow and filtration of fibre suspensions.

Industrial collaborators included Stora Enso, UPM-Kymmene, Metsä-Botnia, Posiva, M-real, Metso, Numerola, Jyväskylä Innovation, Tamfelt, Wärtsilä, Kemira, Critical Medical, ThermImage, and SIFI.

Education

Jukka Maalampi and Juha Merikoski

Education given at the Department of Physics is closely connected with frontline basic research and its applications. In addition to good teaching, informal interaction among students and between students and the personnel is strongly promoted. The whole Department including the laboratories is seen as a learning environment and, from the beginning of their studies, the students are immersed in its activities. Recognizing this, the international board of the Finnish Higher Education Evaluation Council selected the Department to be one of the ten national High-quality Education Units in 2010-12.

Jukka Maalampi, professor
Juha Merikoski, lecturer
Jussi Helaakoski, PhD student
Juho Korhonen, MSc student
Sami Loikkanen, MSc student
Ismo Jousmäki, MSc student
Vesa Maanselkä, MSc student
Toni Purontaka, MSc student
Mikko Rahkonen, MSc student

Teaching Development

In March the teachers of the Department spent one full working day at Konnevesi research station to discuss teaching and how to improve learning. A need was recognized to give the students more time to learn well basic physics, which in part is related to the increasing heterogeneity of the backgrounds and the goals of the incoming students. To facilitate this, teaching of the BSc courses was rescheduled such that, for majority of physics students, three years is now given to complete the basic and subject studies in physics. For a group of students with good highschool record, an option is provided to complete them in two years, by offering in the beginning a fast course covering the contents of the basic studies and after that a faster track to work on interesting research problems. To support these developments, a new textbook for basic courses was adopted and modern pedagogical approaches supported by it are applied. Also, the number of conventional lecture hours was decreased and a few weeks each year through the BSc studies are now dedicated to experimental work included in the courses.

Contacts with schools

To provide a hands-on experience on research work, in summer 2009 the Department offered a summer jobs for highschool students interested in science. The newspaper advertisement produced as many as hundred applicants, of whom nine from different highschools in the Central Finland district were chosen to work in the research groups. The experience was very positive for both the highschoolers and the personnel. It also gave a lot of positive publicity for the Department. In spring 2009 the highschool course *Physics Now* concentrating on modern physics was arranged again in collaboration with the Open University, with leaders of the research goups of the Department acting as teachers.

This year the Department was responsible for the local University Days, with one day devoted to school students with intriguing lectures, experimental demonstrations and laboratory tours. In addition, the annual open-doors day for student recruitment was arranged. Together, these attracted over 400 visitors. Moreover, physics students frequently visit schools to increase interest in studies in natural sciences and many high school groups visit the Accelerator laboratory and the Nanoscience center. The national training camp for Physics Olympics and training lectures for CERN visits of highschool students were arranged at the Department this year.

Teacher Education

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

Other Education Activities

In addition to its regular teaching program, the Department has continued the co-operation with the Open University supplementary-education program. The Department arranged seven courses in the 18th Jyväskylä International Summer School.

Statistics

In 2009 there were 389 applicants for physics studies, with 251 of them indicating physics as their first choice. As a whole, nearly 100 undergraduate students enrolled in 2009. Over 90% of the new BSc students are admitted based on their highschool 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 90 post-graduate students aiming at the PhD degree. In 2009 the number of MSc degrees taken at the Department was 35. The number of PhD degrees was 17, which is an all-time high.

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Peltonen Sami, Alpha decay fine structure in even-even nuclei
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Malkiewicz Tomasz, Tools for physics with LHC and RIB
JYFL Research Report 10/2009

Elomaa Viki-Veikko, Mass measurements for explosive nucleosynthesis in stars
JYFL Research Report 11/2009

Nyman Markus, Shape coexistence in light bismuth and astatine isotopes – an in-beam and decay spectroscopic study
JYFL Research Report 12/2009

Rinkiö Marcus, Carbon nanotube memory devices with designed high-k gate dielectrics
JYFL Research Report 13/2009

Hakala Tommi, Applications of light-matter interactions in nanoscience
JYFL Research Report 14/2009

Frondelius Pentti, Electronic, structural and chemical properties of gold clusters on ultra-thin oxide films
JYFL Research Report 15/2009

Tallinen Tuomas, Numerical studies on membrane crumbling
JYFL Research Report 16/2009

Miettinen Pasi, Simulations of the structure and rheology of wet webs
JYLF Research Report 17/2009

DEGREES

(alphabetical order)

BSc DEGREES

(main subject)

Eronen, Hannele (physics)
Gröhn, Tuuli (physics)
Halonen, Kimmo (physics)
Hapola, Tuomas (physics)
Heikkilä, Elena (physics)
Heinonen, Tuomas (physics)
Heiskanen, Jouni (physics)
Helenius, Ilkka (physics)
Herranen, Olli (physics)
Hietala, Perttu (physics)
Hoilijoki, Heli (physics)
Hokkanen, Matti (physics)
Huuskonen, Anna (physics)
Jousimäki, Ismo (physics)
Kallioinen, Mari (physics)
Kauko, Hanne (physics)
Kiiski, Senja (physics)
Kolos, Karolina (physics)
Kulju, Sampo (physics)
Latvala, Anna-Leena (physics)
Lehtinen, Janne (physics)
Lipponen, Heli (physics)
Loikkanen, Sami (physics)
Maanselkä, Vesa (physics)
Miettinen, Tuukka (physics)
Niemelä, Janne-Petteri (physics)
Oledzki, Michal (physics)
Palanne, Saku (physics)
Pihlainen, Sampo (physics)
Purontaka, Toni (physics)
Puurunen, Aki (physics)
Rahkonen, Mikko (physics)
Riikonen, Kari-Pekka (physics)
Ritvanen, Esa (physics)
Sidoroff, Petja (physics)
Teiniranta, Lea (physics)
Tolvanen, Kimmo (physics)
Uimonen, Anna-Maija (physics)
Väisänen, Markku (physics)

MSc DEGREES

(main subject)
* = MSc includes teachers pedagogical studies

Eskelinen, Antti-Pekka (appl. physics)
Gröhn, Tuuli (electronics)
Hapola, Tuomas (theor. physics)
Heikkilä, Elena (physics)
Heinonen, Henri T (physics)
Herranen, Olli (appl. physics)
Hietala, Perttu (theor. physics)
Jousmäki, Ismo (physics)*
Julin, Juhani (physics)
Julukian, Armen (physics)
Kauko, Hanne (appl. physics)
Kiiski, Senja (physics)
Kit, Oleg O. (theor. physics)
Kolos, Karolina (physics)
Korhonen, Juho (physics)*
Kulju, Sampo (electronics)
Laitinen, Kimmo (appl. physics)
Latvala, Anna-Leena (physics)*
Lehtinen, Janne (physics)
Loikkanen, Sami (physics)*
Maanselkä, Vesa (physics)*
Miettinen, Arttu (physics)
Miettinen, Tuukka (electronics)
Niemelä, Janne-Petteri (appl. physics)
Oledzki, Michal (physics)

Palanne, Saku (physics)
Palosaari, Mikko (physics
Pihlainen, Sampo (appl. physics)
Purontaka, Toni (physics)*
Rahkonen, Mikko (physics) *
Riikonen, Kari-Pekka (physics)
Teiniranta, Lea (appl. physics)
Tolvanen, Kimmo (appl. physics)
Uimonen, Anna-Maija (theor. physics)
Väisänen, Markku (appl. physics)

Phil.Lic DEGREES

Heiskanen Heikki, physics
Jaatinen Jukka, physics
Päiviö Suvi, physics

PhD DEGREES

Elomaa, Viki-Veikko (physics)
Frondelius, Pentti (physics)
Hakala, Tommi (physics)
Herranen, Matti (theor. physics)
Karvonen, Jenni (physics)
Koppinen, Panu (physics)
Kuzyk, Anton (appl. physics)
Malkiewicz, Tomasz (physics)
Malola, Sami (physics)
Miettinen, Pasi (physics)
Nyman, Markus (physics)
Paukkunen, Hannu (theor. physics)
Peltonen, Sami (theor. physics)
Rinkiö, Marcus (physics)
Sandzelius, Mikael (physics)
Tallinen, Tuomas (physics)
Wieslander, Elisabeth (physics)