JYFL

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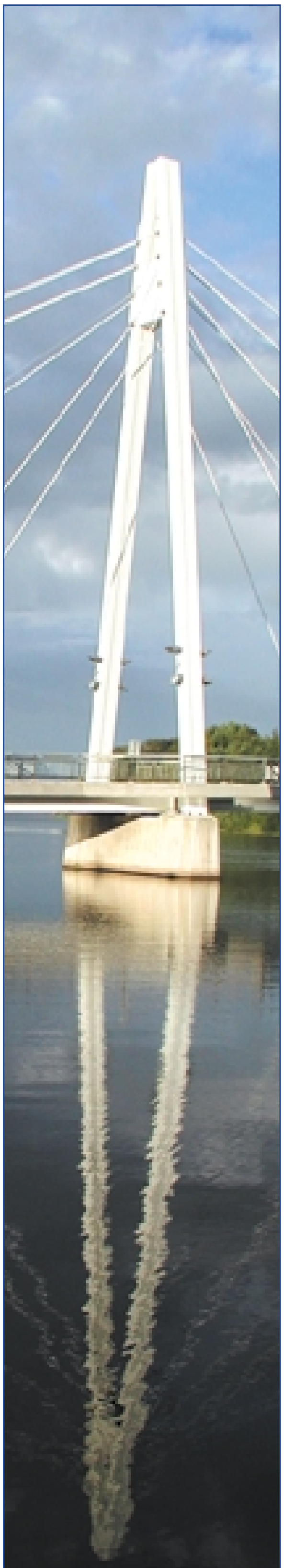
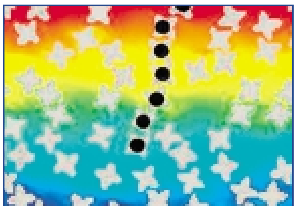
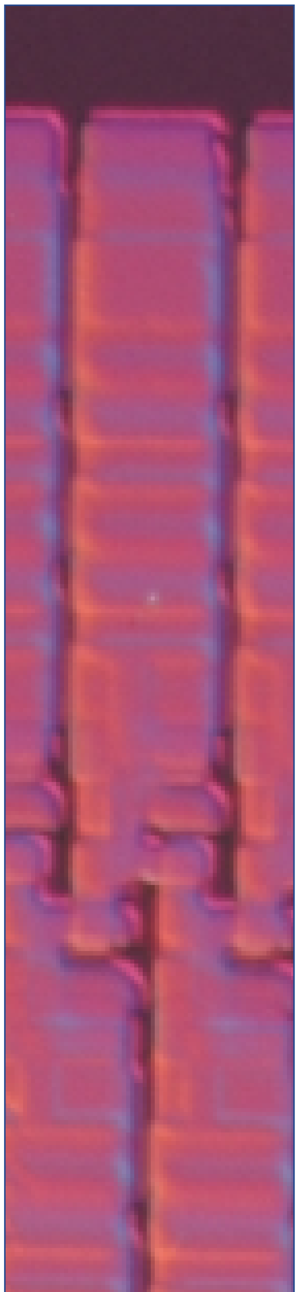
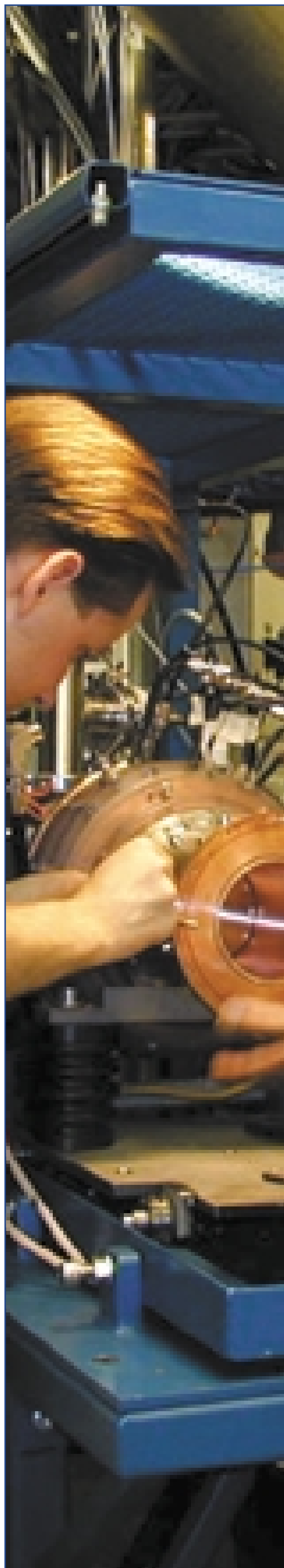
annual report 2000









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PHYSICS

Contents

Department of Physics

Rauno Julin

The University of Jyväskylä with nearly 13000 students and about 2000 employees consists of seven faculties. Department of Physics (JYFL) belongs to the Faculty of Science and hosts 570 students. At JYFL there are 13 professors, 5 lecturers, 6 senior teaching assistants, 30 senior or post doctoral scientists and 7 teaching assistants. The technical staff is composed of 29 engineers and technicians. The total number of employees, including PhD students, trainees and the administrative staff is about 150.

The total budget of JYFL was nearly 50 million marks, dominated by funds from external sources. The year 2000 was the first for JYFL as a Finnish Centre of Excellence (CoE) in Nuclear and Materials Physics. This status will guarantee stability of research funding for the next six years. JYFL was successful in obtaining research funding in the EU´s 5th framework programme: The accelerator laboratory will continue as a “Large Scale Facility”, under the new title “Major Research Infrastructure”. The JYFL groups are participating in thirteen EU and ESA research projects, in five of them as a coordinator.

In addition, the foreign users are further contributing significantly to the instrumentation of the accelerator laboratory. JYFL is the most international department of the university, the number of foreign visitors being 215 in 2000.

Education. The degree of MSc is awarded in Physics, Theoretical Physics, Electronics, Applied Physics and for Physics Teachers. All alternatives of major give access to postgraduate studies. In 2000 the number of of M.Sc. degrees granted by the Department was 36. The number of Ph.D. degrees completed in 2000 was 9. JYFL participates in the Erasmus/Sokrates network as well as in the European Mobility Scheme for Physics Students (EMSPS). More detailed statistics concerning education can be found in page 31.

Research. The results and activity of the year 2000 in research at JYFL were praised by the international scientific board of the CoE. The number of peer-reviewed articles was 119, including reports in Nature and Physical Review Letters.

Some statistical data in 2000

Personnel	150	(52)
- professors	13	(11)
- lecturers	5	(3)
- senior assistants	6	(6)
- assistants	7	(7)
- researchers and research assistants	86	(4)
- technicians,	29	(17)
- administration	4	(4)
( ) = permanent posts		
Undergraduate students	515	
of which first year students	102	
Graduate students	55	
MSc degrees	36	
PhLic degrees	2	
PhD degrees	9	
Credits (national)	5300	
Number of foreign vistors	215	
Visits abroad	280	
Peer reviewed publications	121	
Invited talks	41	
Other talks	46	
Posters	60	
Seminars given at JYFL	42	
Seminars given outside JYFL	25	
Funding (MFIM)	47,8	
* University budget (excl. premises)	21,9	
* External funding	25,9	
- Academy of Finland	8,3	
- Technology Development Centre	1,9	
- International programmes	6,9	
- Ministry of Education	2,7	
- Contract research	3,2	
- Others	2,9	

The research at JYFL concentrates on materials science, nuclear physics and related applications. Materials science includes theoretical and experimental research on the physical properties and fabrication of micro- and nanostructures, and the physics of disordered materials and nonlinear systems. The capacity of the nanotechnology laboratory was enhanced by the commissioning of a new litography facility. Head of the laboratory, Jukka Pekola, started his 5 year post as an Academy professor. Results obtained in the simulations of disordered materials are tested now in a new flow dynamics laboratory.

Novel methods developed in the accelerator laboratory are now used to probe structures of super-heavy, very neutron-deficient and neutron-rich nuclei, for the first time. The large variety of beams are applied in studies of slowing down of heavy ions in matter, MeV-implantation and testing of space-electronics. The performance of the cyclotron was significantly improved by the commissioning of a new ECR-heavy-ion source and an H^- acceleration system constructed at JYFL. Esko Liukkonen was appointed as professor in accelerator technology. Theoretical nuclear physics is focused on nuclear structure and double beta decay in particular. In co-operation with CERN and the Helsinki Institute of Physics, a group at JYFL studies ultra-relativistic heavy-ion collisions and dense nuclear matter.

Research

Nuclear and accelerator based physics

Accelerator laboratory

Matti Leino and Esko Liukkonen

In the year 2000, the established experimental programs continued together with development work aimed at extending the capabilities to probe even deeper into the physics of exotic nuclei. The installation of the H^- ion source and the 14 GHz ECR ion source induced breaks into the experimental schedule. Nevertheless, more than 6500 h of beam on target were delivered. There were about 200 foreign scientists visiting the laboratory, nearly all of which were cyclotron users. 52 scheduled experiments were performed using the cyclotron.

The Laboratory's Large Scale Facility status was renewed and the facility has been operated under the IHRP program of the 5th EU framework (Access to Major Research Infrastructures). The research performed in the laboratory has been an important contribution to the Center of Excellence in Nuclear and Materials Physics program of the Department of Physics. JYFL groups are coordinating the EU/TMR RTD project EXOTRAPS and the EU/IHP RTD project EXOTAG, and participating in the EU/IHP project EURISOL. JYFL is also coordinating the National Graduate School in Particle and Nuclear Physics and the organiser of two international meetings in nuclear physics in 2001, ENAM2001 and Euroschool on Exotic Beams.

In the following, the main acitivities of the various research groups in the year 2000 are briefly described.

H^- acceleration started. Until the year 2000, only positive ions could be accelerated in the K130 cyclotron. The intensity of proton beams (E > 20 MeV) was limited to about 20 µA due to beam losses at extraction. Recently higher proton beam intensities were required, especially 30 MeV proton beams for the radioactive isotope production. As a solution a project of negative hydrogen acceleration with stripping extraction was started in 1999 as an international collaboration with PNPI, St. Petersbug, Russia and TRIUMF, Canada. The project included construction of a new powerful multi-cusp ion source for negative ions and the stripper foil mechanics. Also some beam optical modifications in the cyclotron were needed. The cyclotron was closed down in May 2000 for a month to carry out the installations of the new components. The multi-cusp ion source was built following the guidelines by T. Kuo at TRIUMF, Canada.

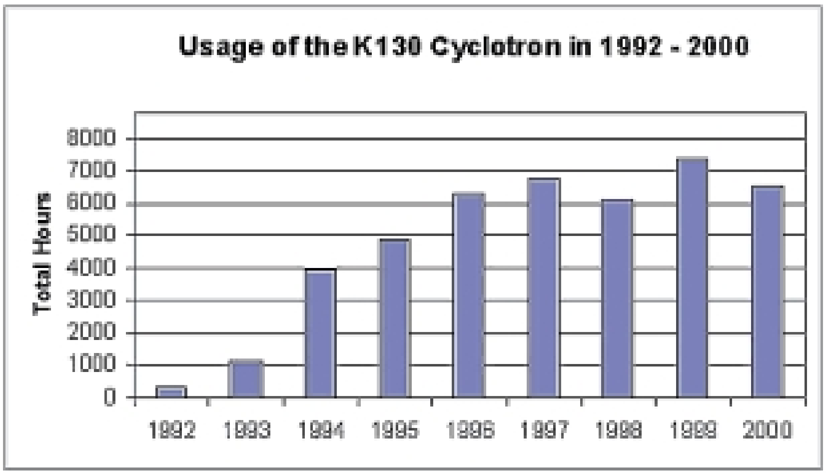

Fig.1. The K130 cyclotron was used in 2000 more than 6500 hours in different experiments.

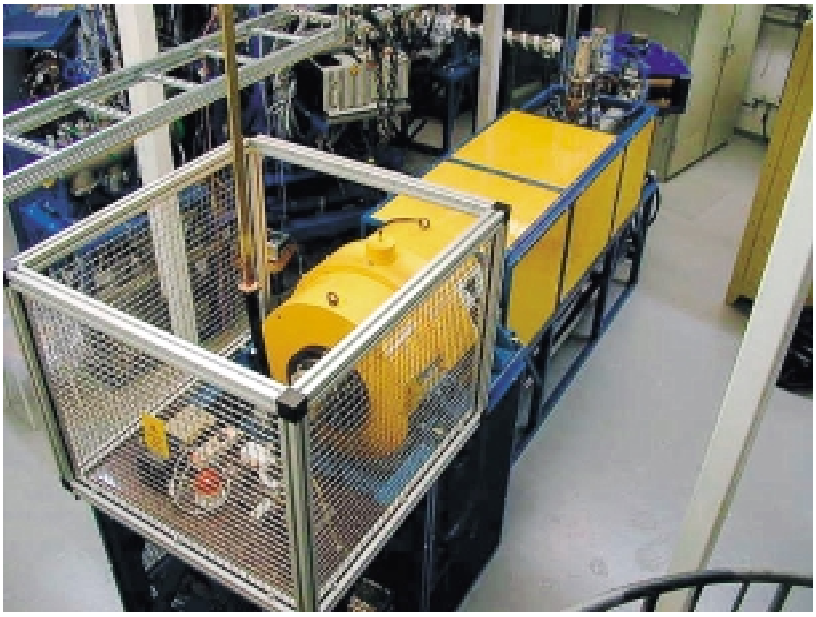

Fig. 2. The new 14 GHz ECR ion source.

In August 2000 we extracted the first 30 MeV H^- beam by stripping and the extraction efficiency was 100 % as expected. During the following weeks the intensity of the H^- beam was gradually increased to 60 mA. The new multi-cusp ion source has exceeded all expectations. It can produce up to 5.8 mA of H^- beam at low 5.9 kV extraction voltage which is needed for 30 MeV protons. The high intensity proton beams from H^- acceleration will be used once a week for ^{123}I isotope production, and also the proton beam intensities for IGISOL can be increased from the current ones.

Sami Hahto was rewarded the Pro Gradu of the Year award for his Master of Science thesis on the construction and testing of the new multi-cusp ion source.

The first results with the new JYFL 14 GHz ECR ion source. A new 14 GHz ECR ion source has been built in 1999-2000. This source belongs to the family of the LBNL AECR-U based ECR ion sources. The operation during the first few months has shown that the new ion source fulfills all expectations and it is performing well and is capable of producing intensive highly charged ion beams. For example 174 µA of O^{7+} ion beam was recorded. The MIVOC method has also been tested at this new source. In the test runs the intensity of the Fe^{11+} ion beam was 115 µA and the intensities of B^{3+} and B^{5+} ion beams were 235 µA and 52 µA, respectively. By applying the MIVOC technique the first intensive highly charged titanium beam of 45 µA of Ti^{11+} was successfully produced.

Nuclei far from stability

Ari Jokinen and Juha Äystö

http://www.phys.jyu.fi/research/igisol/

The Ion Guide Isotope Separator On-Line (IGISOL) technique was developed in Jyväskylä in the early 80's. Since then the technique has been adopted and applied by many laboratories and presently provides one of the main lines towards the next generation radioactive ion beam facilities.

Ion guide development. A new target/ion guide design for use with heavy-ion reactions was successfully tested. The system now includes two targets and the possibility to optimise the beam energy using degrader foils. Guiding ions with electric fields inside the ion guide gas cell showed promising results in off-line situations.

Gas catcher. Efficiency and delay time measurements of a gas catcher system as proposed to be used in next generation radioactive ion beam facilities were performed off-line using alpha decay recoil products. One major result from these studies is that we now have the possibility to measure the survival time of ions in helium gas.

Resonance ionisation spectroscopy. The project to develop a sensitive method of laser spectroscopy using resonance ionisation in the IGISOL gas volume has continued with off-line measurements on bismuth atoms seeded in the helium gas flow. A two-step ionisation scheme (307 nm, 355 nm) using pulsed lasers with a 50 Hz repetition rate produced spectra with a resolved hyperfine structure. Experiments are now proceeding on atom recoils from alpha-sources in the gas volume.

Ion trap. A project for improving the quality of radioactive ion beams produced at IGISOL, due to beam handling with ion traps has been progressing. Key component of this project is a system of two Penning traps, both placed in one 7 T superconducting magnet. First trap should perform isobaric purification of the beam, second one should serve the precise nuclear mass measurements. Computer simulations of ion injection, trapping and ejection were completed.

Ion cooler and collinear laser spectroscopy. A new mode of collinear laser spectroscopy using the ion beam cooler was applied for ^{175}Hf. In the new technique ion cooler is operated as an ion buncher allowing background suppression by accepting photon events only while the ion bunch created in the cooler is passing in front of the light collection system. The effect of the bunch-gating is illustrated in the figure 3. The deduced nuclear information on the static moments μ and Q_s are consistent with previous measurements and fits well with the systematics of the region. The change in the nuclear mean square charge radius can be model-independently evaluated from the IS data. The results show that ^{175}Hf is more deformed than the average of the neighbouring even-mass Hf isotopes would imply. This is consistent with the trend in all the odd-mass neutron-deficient Hf isotopes.

Spectroscopy at N=20: "Island of inversion". As a continuation of the beta-decay study of neutron-rich Al isotopes $^{34\text{-}35}$Al an experiment concentrating on the study of ^{33}Na beta decay took place at ISOLDE CERN facility. This neutron rich region is especially interesting from shell model point of view since the N=20 shell gap has been proven, both experimentally and theoretically, to vanish. The level scheme of ^{33}Mg brings additional information on this so called island of inversion and extends the systematics of N=21 nuclei following the previous study of ^{35}Si.

Superallowed beta decay of ^{74}Rb. According to the conserved vector current (CVC) hypothesis, the matrix elements of the superallowed Fermi ß transitions between (J^π,T) = (0^+,1) states should all be equal. Provided this is true, the experimental *ft* values, accounted for isospin mixing and radiative corrections (*Ft*), allow an accurate determination of the weak vector coupling constant G_v.

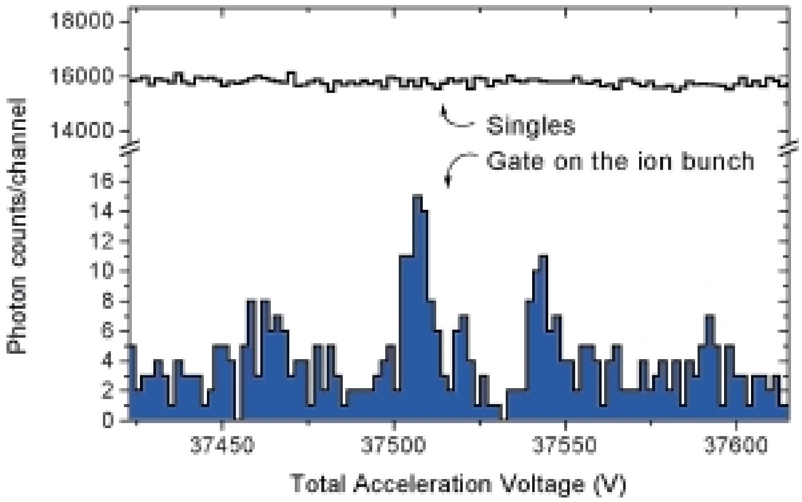

Fig. 3. Fluorescent light observed without (singles) and with the ion bunch gate for the case of ^{175}Hf.

This low energy physics result, together with the muon decay data, gives presently the most precise value for the up-down quark mixing matrix element V_{ud} in the Cabibbo-Cobayashi-Maskawa (CKM) Matrix. So far only nine super allowed ß-decays (^{10}C, ^{14}O, ^{26m}Al, ^{34}Cl, ^{38m}K, ^{42}Sc, ^{46}V, ^{50}Mn and ^{54}Co) have been measured with high precision for half-lives, decay energies and branching ratios. We have studied the beta decay of the odd-odd N=Z nucleus ^{74}Rb at ISOLDE-facility. Series of measurements included a new determination of the beta decay half-life, 64.90(9) ms, conversion electron measurement of E0 decay of the first 0^+ excited state to the ground state and precise mass measurements with ISOLTRAP and MISTRAL facilities. The new data should shed light onto the role of charge dependent effects, such as isospin mixing, in superallowed ß-decays.

Fission studies. States in neutron-rich ^{116,118}Cd isotopes have recently been studied at IGISOL via beta decay of ^{116,118}Ag. These studies provide new information on three phonon states in ^{116}Cd and two quasiparticle states in ^{116,118}Cd.

http://www.phys.jyu.fi/research/gamma/

In-beam spectroscopy

Rauno Julin

In 2000, a total of 2516 hours of beamtime were dedicated to in-beam spectroscopy. The majority of this time (1391 hours) was taken up by our third JUROSPHERE + RITU campaign, continuing our successful series of Recoil-Decay Tagging (RDT) experiments. Between 14th February and 21st August, a total of 12 experiments were carried out, involving 49 foreign collaborators from 15 overseas institutions.

An important extension to our RDT studies in 2000 was the commissioning of the SACRED + RITU device, a joint collaboration with the University of Liverpool. The device, pictured below in Fig. 4, is designed to measure cascades of prompt internal conversion electrons produced in the decay of fusion-evaporation residues.

JUROSPHERE + RITU. As in 1999, the JUROSPHERE array at the target position of RITU consisted of 15 Eurogam Phase I, 7 TESSA and 5 NORDBALL-type detectors. The total photopeak efficiency of the array was approximately 1.7% at 1.3 MeV. For three experiments, a large Super Clover Ge detector, loaned from GSI, was placed at the focal plane of RITU in order to study isomeric transitions. An additional improvement at RITU came from the construction of a time-of-flight detection system, allowing much cleaner separation of fusion-evaporation residues from scattered beam events.

Highlights from the campaign included the first observation of excited states in ^{174}Hg, ^{189}Bi and ^{190}Po [1-3]. The nucleus ^{190}Po was produced with a cross-section of approximately 200 nb, via the ^{142}Nd(^{52}Cr,4n)^{190}Po reaction. The incident beam energy was 257 MeV. Inspection of the level scheme of ^{190}Po, together with systematics of the heavier isotopes of Po, reveals a lowering of the first excited 6^{+} and 8^{+} states. This behaviour suggests the onset of prolate deformation, as observed at the same neutron number in the Pb isotopes.

The similarity in behaviour of ^{190}Po to its isotones ^{188}Pb and ^{186}Hg is further demonstrated in Fig. 5, where the kinematic moment of inertia, J$^{(1)}$, is plotted against transition energy for isotopes of Rn, Po, Pb and Hg.

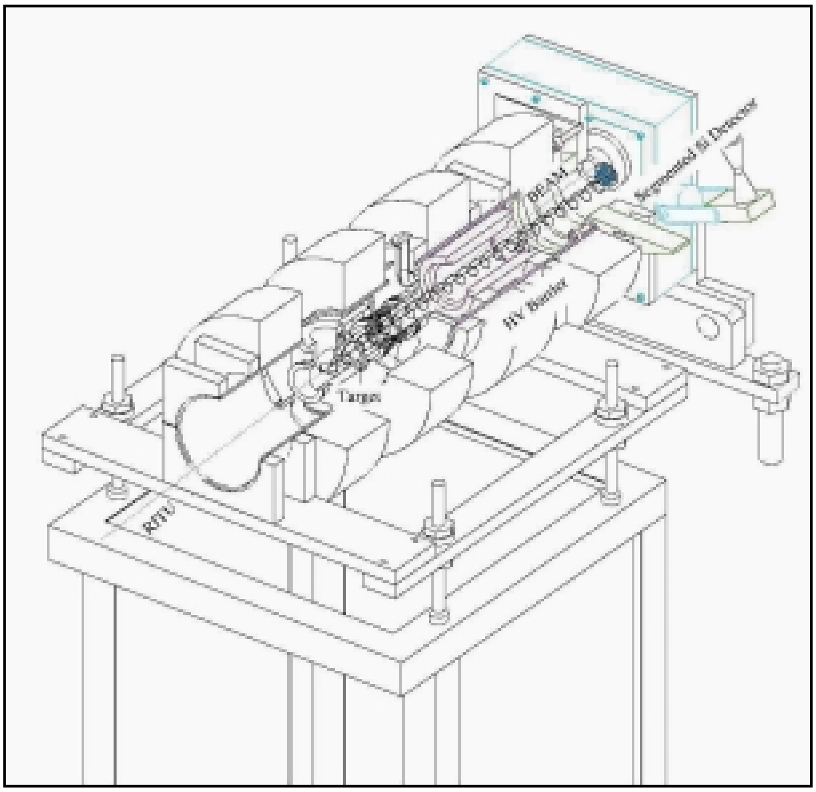

Fig. 4. The SACRED conversion-electron spectrometer installed at the target position of RITU.

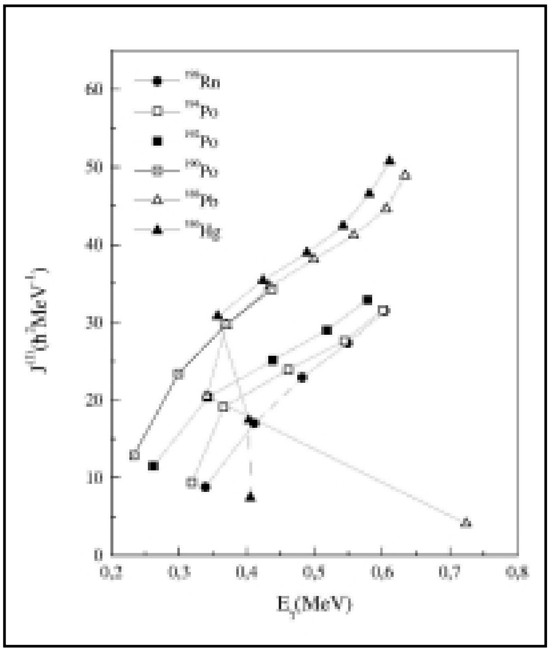

Fig. 5. Kinematic moment of inertia, J$^{(1)}$, derived from the experimental level schemes for isotopes of Rn, Po, Pb and Hg.

SACRED + RITU. In August, after the end of the JUROSPHERE campaign, the SACRED electron spectrometer was installed at the target position of RITU. The spectrometer consists of a 25-element annular Si detector, and a set of coils to provide a solenoidal magnetic field to transport electrons from the target to the detector. The device is constructed in close to collinear geometry, such that the detector sits upstream of the target, the beam and solenoidal field axes forming an angle of approximately 2.5 degrees. The high background of delta electrons, produced by interactions of the beam in the target material, is suppressed by a high voltage barrier operated at a voltage of -35 to -45 kV. Further suppression of this background comes by demanding that the observed electrons are in prompt coincidence with a recoil event at the focal plane of RITU.

November 2000 saw the first production runs using the new device. Two experiments were carried out to study the heavy isotopes ^{253,254}No. Gamma-ray spectroscopic studies of both isotopes have been carried out previously. In the case of ^{254}No, studied at Jyväskylä using the SARI array, and at the Argonne National Laboratory (ANL) using GAMMASPHERE, the ground-state rotational band is known up to the 20^+ state [4,5]. Due to high internal conversion, the 4^+ to 2^+ transition was not observed. In ^{253}No, a study at ANL showed no clear evidence of gamma-rays. A study of ^{255}Lr, carried out at JYFL in 1999, yielded a similar result. It is believed that in these odd-mass nuclei the decay proceeds mainly via highly converted M1 transitions, thus prompting the current programme of experiments to identify excited states in these nuclei using electron spectroscopic techniques.

Shown in Fig. 6 is the recoil-gated electron spectrum of ^{254}No obtained in an irradiation of approximately 70 hours using the ^{208}Pb(^{48}Ca, 2n)^{254}No reaction at a bombarding energy of 219 MeV. Peaks corresponding to transitions up to the 12^+ state can be seen. Also observed for the first time are peaks corresponding to the 4^+ to 2^+ transition. The spectrum is not background subtracted, and tests using targets of differing thickness suggest that the background is due to delta electrons produced by the No nuclei traversing the remainder of the target.

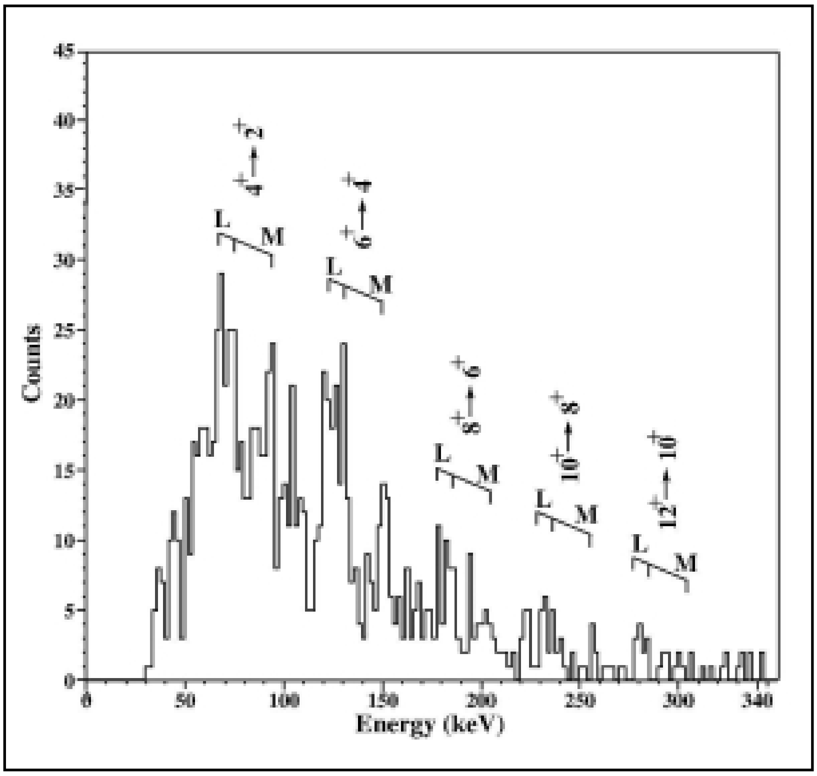

Fig. 6. Recoil-gated spectrum of internal conversion electrons obtained using the ^{208}Pb(^{48}Ca, 2n)^{254}No reaction.

Details of both the technical set-up, and further analysis of the ^{253,254}No data, will be published in due course [6,7].

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Decay experiments and detection system development at RITU

Matti Leino

RITU stand-alone experiments have led to the synthesis of new isotopes, among them ^{195}Rn [1]. This isotope has two isomeric states which decay to the two recently established isomeric states in ^{191}Po where shape staggering has been discovered in earlier RITU experiments [2]. Another significant result was the discovery of a new proton radioactivity, ^{164}Ir [3], see Fig. 7.

In addition to the development towards combining SACRED and RITU discussed above, other important projects have been started. The gas counter system at the focal plane has been extended by a time of flight detector with a resolution of a few hundred ps which allows very good separation between fusion products, transfer products and beam particles. A small rotating target wheel has been constructed and tested. This target setup allows the use of the very high beam intensities available from the new ECR (typically a few hundred pnA). The replacement of the helium gas window with a differential pumping system will serve the same purpose and also allows a significant reduction of gamma background in RDT studies. Finally, work is going on at JYFL and in several laboratories in the UK to install the GREAT focal plane detector system for highly demanding studies of exotic nuclei in the N ~ Z region and in the region of the very heavy elements.

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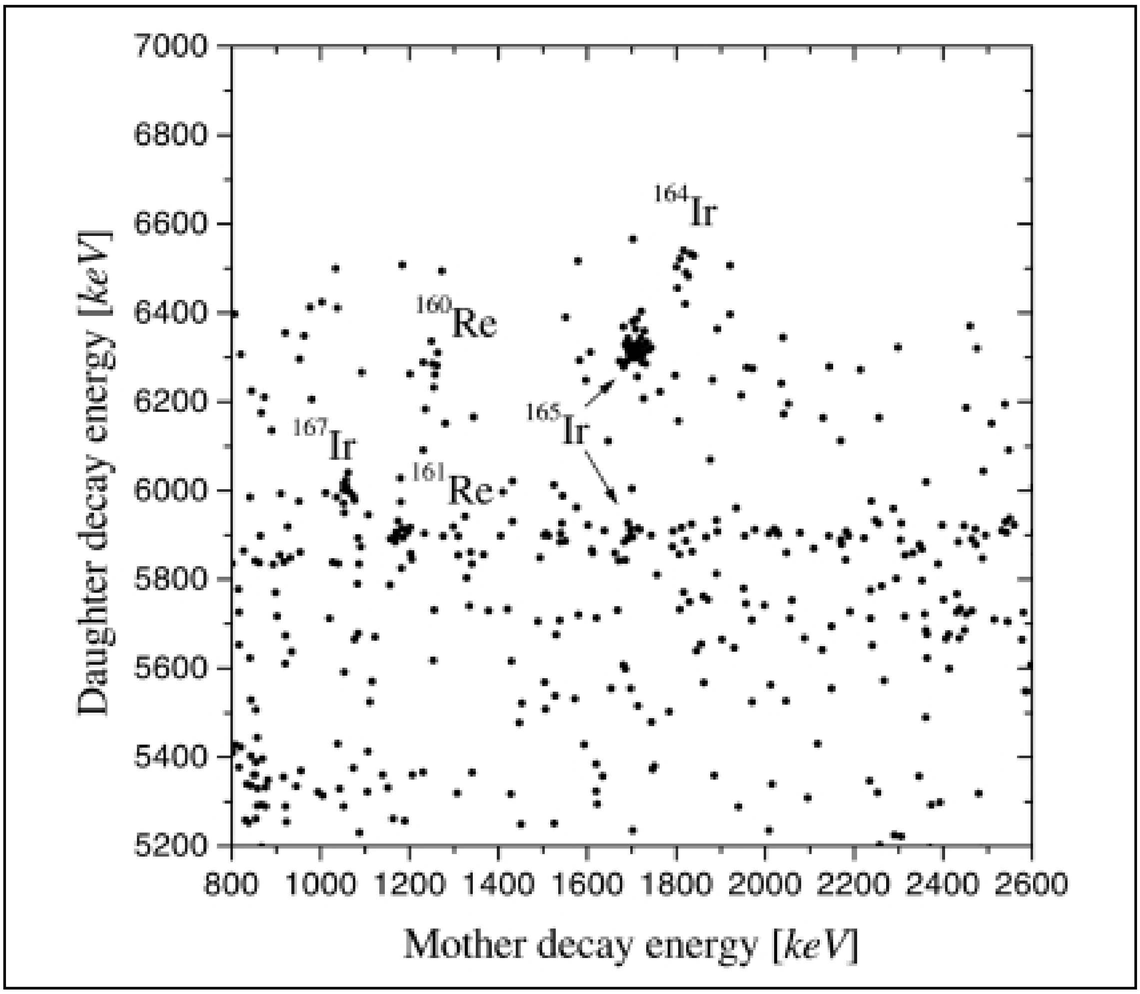


Fig. 7. RITU Correlated decay events from the reaction ^{64}Zn+^{106}Cd, showing the mother-daughter pair ^{164}Ir-^{163}Os.

Nuclear reactions

Wladyslaw Trzaska

Fusion-fission. Perhaps the most interesting results obtained in fusion-fission studies are connected with the shape of fission fragment mass distribution. As it is well known, the main structure of the mass distribution can be well described by Gaussian components. To the first approximation the double humped distribution, like the one of the spontaneous fission of Cf, can be described by just two Gaussian curves. A symmetric distribution, like the one frequently encountered in HI induced fission, can often be represented by a single Gaussian curve.

These gross structures manifest the underlying fission modes that in turn are determined by the potential energy surface of the fissioning nucleus that depends on the excitation energy and on the shell structure. Therefore precise measurements of fission fragment mass distribution are a sensitive tool in detecting anomalies and exotic fission modes. In the reaction $^{58}Ni + ^{124}Sn$ we have detected a strong asymmetric fission component superimposed on the dominant symmetric one, well described by the liquid drop model. Together with fission fragments (FF) we have also measured neutron, proton and alpha multiplicity and used them as independent clocks to indicate the time scale of fission processes.

We plan to extend the measurements to lower excitation energies and improve the mass resolution of our detection system. We intend to achieve it by replacing gas detectors with micro channel plate (MCP) based TOF spectrometers. The first results obtained during a test run with the new system are very encouraging. Excellent timing properties of MCP detectors allow shorter flight paths and more compact detection system. The reduced size of the chamber will give as the option of placing neutron detectors closer to increase detection efficiency at the expense of energy resolution.

Fine Structure. Even more exciting than the gross structure are small irregularities that persist in FF mass distributions. Our thorough study of the ^{40}Ar + U reaction confirmed our prior observation of a fine structure (FS) on top of the gross mass distribution. To reveal fully the fine structure one should remove from the mass distribution both the fast component (resulting from statistical fluctuations) and the slow component (the underlying gross structure) and arrange the results in a 2D matrix

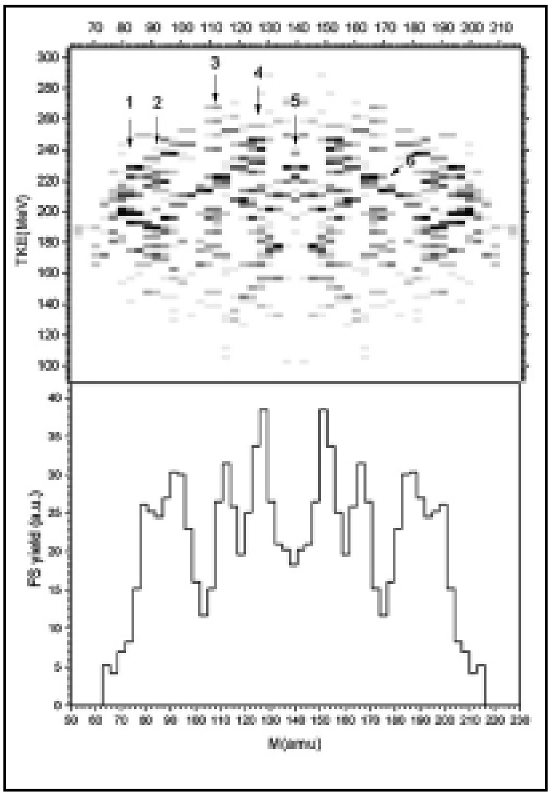


Fig. 8. 2D plot of TKE vs. mass (top) and projection to the mass axis (bottom).

linking mass of the fragment with its TKE. Preliminary results from our latest measurement are displayed in the figure above where also a total projection to the mass axis is shown. We believe that shell effects and cluster structure in nuclei are responsible for the FS.

Rainbow Scattering. Rainbow scattering group has completed the study of $^{16}O+^{12}C$ scattering by measuring at 281 and 181 MeV in addition to 132, 170, 200, 230, and 260 MeV investigated previously. This monumental task lasted several years but yielded perhaps the most pronounced manifestation of rainbow scattering effects that has ever been observed. The additional points obtained last year were crucial in reaffirming our preliminary assignment of the primary and secondary Airy minima. As the next step in the study of rainbow phenomena the $^{16}O+^{40}Ca$ reaction was chosen. At the 281 MeV bombarding energy no obvious structures were detected up to 30° c.m.

http://www.phys.jyu.fi/research/hendes/hendes/HENDES.html

http://www.phys.jyu.fi/research/hendes/lsc/LSC.html

Cluster Radioactivity. Elastic scattering on heavy targets closely mimics the exit channel for cluster radioactivity of superheavy nuclei. Unfortunately, most of the discovered clusters, for instance ^{14}C, are radioactive themselves. This poses the obvious experimental problems with availability and maximum intensity of such beams. An important exception is ^{22}Ne. The first round of measurements of the elastic $^{22}Ne+^{208}Pb$ scattering indicate three orders of magnitude drop in the cross sections ratio to the Rutherford values between 70 and 110° c.m. Further analysis is needed to evaluate whether or not this data would lead to the determination of the barrier shape and height of the ^{22}Ne cluster radioactivity.

Statistics: 842 hours of beam time; 612 hours at HENDES, 230 hours at LSC.

Ion-matter interactions and applications

Jyrki Räisänen and Ari Virtanen

The recently launched new accelerator based materials physics research activity at the Department of Physics is at the stage of expanding. The research programme consists of the following topics:

Materials research with the 6.4 GHz electron cyclotron resonance (ECR) ion source. An UHV chamber has been built for the beam line equipped with X-Y beam sweep system for performing ion implantation. An important purchase has been the UHV capable goniometer that allows implantation also at elevated temperatures. The measurement/characterisation equipment needed for sputtering experiments and studying charge state effects have been designed. The equipment includes, e.g., a time-of-flight system, deflector for charge state determination and detection systems for studying sputtering related phenomena. The test measurements will start at the beginning of next year and the upgrading of the facility will be continued.

An interesting application of the ECR ion source will be the study of various charge state effects. Charge state distributions and equilibrium charge states of ions slowing down provide relevant problems also from the theoretical point of view. Of significant interest will be the studies on sputtering effects of highly charged low energy heavy ions. The physical phenomena related to sputtering by a highly charged ion are of significant theoretical and practical interest.

Diffusion of impurity atoms and self-diffusion in compound semiconductors studied by radiotracers. The main interests in the diffusion studies are compound semiconductor materials used for micro- and optoelectronics. Radioactive beams at JYFL, University of Bonn and CERN/ISOLDE have been used for sample implantation. For depth-concentration determinations we have developed a sputtering based serial sectioning apparatus equipped with a special detector array. For lattice site determinations emission channeling experiments at JYFL have been looked into. For such purposes a two-dimensional position- sensing detector for electrons and positrons is being developed in collaboration with SiTek®. The Stuttgart-Jyväskylä-CERN-Leuven collaboration project “Diffusion Mechanisms and Lattice Locations of Thermal-Equilibrium Defects in Si-Ge Alloys” has been launched successfully and outstanding results for ^{71}Ge diffusion in SiGe alloys have been obtained. Of significant interest have been the studies on lattice location of implanted Er in SiGe alloys conducted in collaboration with Niels Bohr Institute.

Stopping powers of energetic heavy ions in solids. The programme consists of determination of poorly known heavy ion stopping powers for selected metals and polymers. Data have been obtained by the modified transmission and the novel micro channel plate based time-of-flight techniques. Information have been obtained which will improve the accuracy of the ion beam based methods in the structural characterisation of materials. The obtained data can be used for developing more accurate semi-empirical models for predicting stopping powers in important classes of materials.

http://www.phys.jyu.fi/research/applications/ http://www.phys.jyu.fi/research/ion-matter/

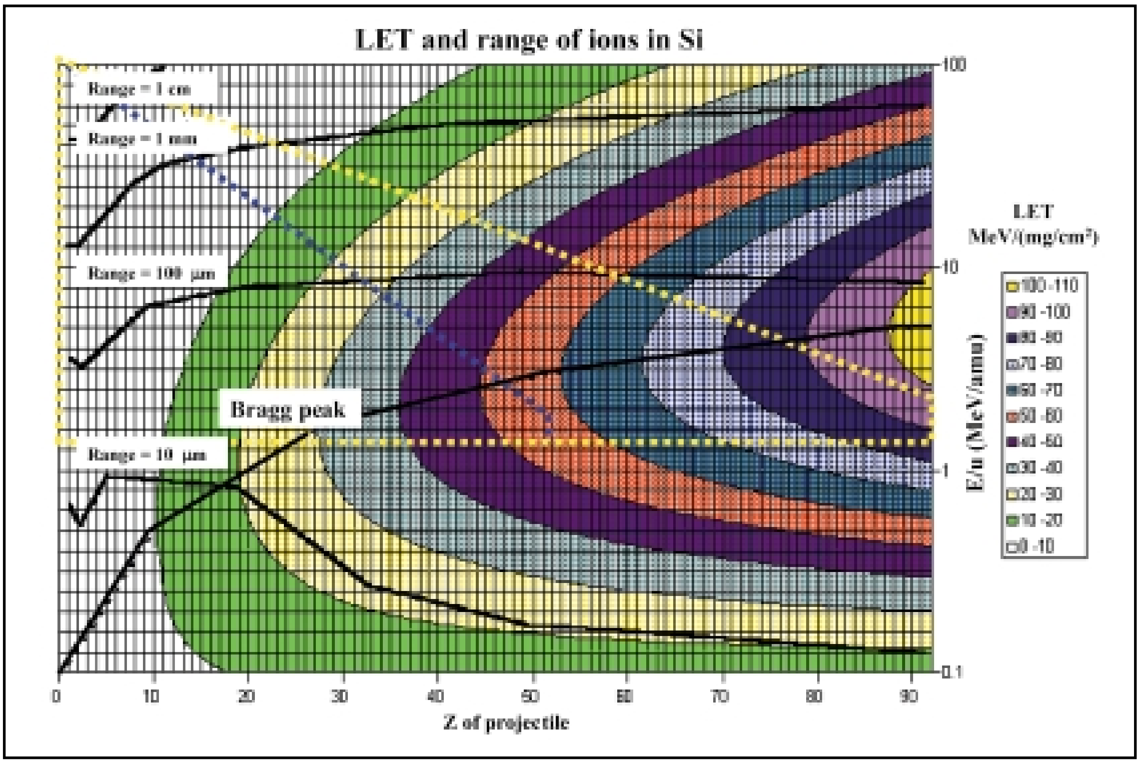


Fig. 9. A color map of LET values of ions in Silicon. The Z-values of projectiles are expressed horizontally and the energy per nucleon vertically. The dashed blue and yellow areas restrict the LET values obtained by the old and new ECR ion sources, respectively.

Status and recent developments in RADEF facility. During the last year several research groups visited Jyväskylä in performing irradiation tests. Researchers from Astrium-Space (former Daimler-Chrysler Aerospace), Helsinki Institute of Physics and CERN carried out the experiments in our RADEF facility by using heavy ions and protons. Astrium tested the radiation durability of the electronics, which will be installed into International Space Station, ISS. The motivation of CERN and HIP was to study the functionality of the most sensitive MOS components and diode detectors in the radiation environment of the LHC experiments. The use of the new ECR ion source will also increase the maximum LET values from 60 MeV/(mg/cm^2) up to almost 100 MeV/(mg/cm^2) in Silicon. This is shown in Fig. 9, where the LET values obtaineb by our ECR ion sources are indicated.

The beam homogeneity is a very critical part of irradiation tests. Therefore, we are developing a position sensitive multiwire detector, which can be used for checking beam homogeneity. It will allow us to analyse the beam homogeneity on-line and even during the irradiation very accurately. This helps the beam tuning and shortens the uniformity calibration time considerably. The development work of the detector is in progress and will be finalised during the spring 2001.

Recently we have also started collaboration with a group from Royal Institute of Technology, Stockholm. This collaboration includes a study of radiation effects in different RAM chips. We have also purchased PB-10 device programmer, which is used to program ROM chips. Our aim is to start radiation durability tests of different EPROM and EEPROM memories in Jyväskylä.

Theoretical nuclear physics

Jouni Suhonen

The theoretical nuclear physics group develops microscopic nuclear models and applies them to nuclei of current interest for both the traditional nuclear spectroscopy and for processes involving connections to modern particle-physics theories. The nuclear spectroscopy side includes studies of structure of the nuclei and their decays via alpha, beta and gamma emission. The particle-physics side involves processes connected to modern nuclear astrophysics, neutrino astrophysics, dark-matter search, weak-interaction physics and physics of massive neutrinos. In the following we highlight some important topics currently studied by the group.

On the spectroscopy side we have studied α-like resonances (a sub-group of quasimolecular resonances) using Gamow states and the multi-step shell model. We have developed the first fully microscopic description of this type of resonances. We have found that the unbound single-particle resonance states in continuum play a decisive role in quantitative description of the α-like states. Just recently we have started a fully microscopic calculation of hindrance factors of alpha decay to excited 2^+ and 0^+ states in spherical nuclei. The studied cases include decays of $^{198,200}Rn$ (2^+ states) and decays of nuclei close to Z=82 magic shell (0^+ states).

On the particle-physics side we have studied e.g. lepton-flavour violating processes (muon-to-electron conversion in ^{27}Al and ^{48}Ti nuclei) and neutrinoless double beta decay to excited 0^+ states with the aim of finding promising candidates to probe sub-eV neutrino masses in modern underground experiments using huge active-mass detectors. Furthermore, we have aimed at constrainig the structure of weak-interaction currents by muon-capture calculations using renormalized transition operators. In this work we have investigated the renormalization of the weak hadronic current in the semileptonic reactions, in particular the role of the induced pseudoscalar coupling. Finally, together with experimental groups in France and Russia we have managed to obtain new constraints for the genuine, non-induced scalar component of the fundamental weak-interaction current.

In the astrophysical studies we calculate neutrino-nucleus cross sections for solar neutrinos to yield necessary input information for the multinational SAGE and GALLEX experiments (detection of ^7Be decay by ^{71}Ga) and for the future solar-neutrino experiments using ^{127}I. These calculations are in a position to shed light to the "solar-neutrino problem" (strong discrepancy between the measured and solar-model predicted neutrino flux on the Earth). We will also study supernova explosions and the associated fluxes of the supernova neutrinos by modelling neutrino-nucleus cross sections for the p- and r-process nuclei. Finally, we study the possible constituents of the cold dark matter of the universe by calculating LSP-nucleus (LSP=Lightest Supersymmetric Particle) scattering cross sections for several potential detector nuclei.

Materials physics

Physics of nanostructures and nanotechnology

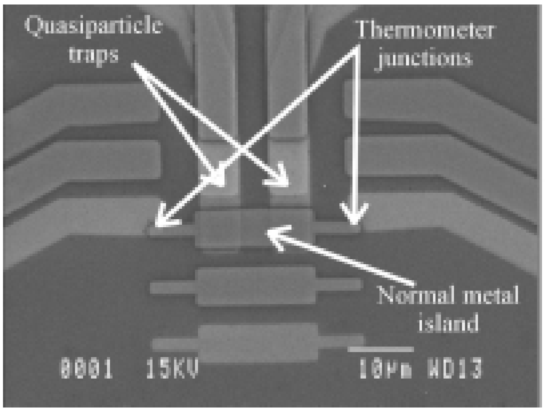
Jukka Pekola

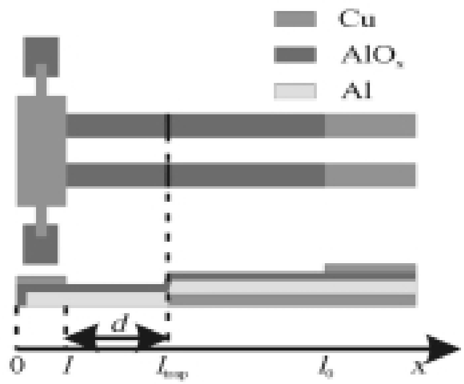
On-chip refrigeration for cryogenic radiation detectors. Development of efficient, direct cooling methods for electronic devices in sub-Kelvin range has continued in the nanotechnology group. Using a normal metal – insulator – superconductor (NIS) tunnel junctions in a symmetric SINIS structure we have managed to cool the electrons in the normal metal by a factor of three below the temperature of the bath at 300 mK with cooling power of 20 pW, which is a record in solid state refrigeration. This increase in the cooling power has been achieved by increasing the junction area, and by incorporating extra normal metal electrodes in contact with the superconductor to trap the hot quasiparticles emanating from the cooled normal metal. Optimizing the distance between the quasiparticle trap and the normal metal island is also important: If the trap is too near the junctions, the proximity effect will decrease the superconducting gap and thus the cooling power. Lately, we have successfully tested different materials between superconductor and traps, in order to place traps directly underneath the junctions without degrading the proximity effect. Once the efficient trapping is obtained, the coolers will find immediate application in cryogenic radiation detectors, such as microcalorimeters.

In addition, we have investigated the suitability of doped silicon as a material for the coolers. Measurement of the electron-phonon coupling constant is an order of magnitude smaller than for example in copper. Therefore, due to increased thermal isolation, more efficient cooling may be possible.

Transition-edge microcalorimeters for cryogenic imaging spectrometry. The *XEUS* mission (*X*-ray *E*volving *U*niverse *S*pectroscopy), currently under study by the European Space Agency, will observe the early Universe at an unprecedented sensitivity. For the purpose, novel tech-

Fig. 1. SEM image of a SINIS cooler.





nologies will need to be developed, of which one is a cryogenic imaging spectrometer capable of an energy resolution of 2 eV at 1 keV and 5 eV at 6 keV. At Jyväskylä, together with Metorex International Oy and VTT Electronics, we have developed a microcalorimeter sensor. The detector consists of a well thermally isolated superconducting Ti/Au film, an X-ray absorber, and superconducting Nb contacts. The critical temperature T_c of the Ti film is suppressed to below 100 mK by the proximity effect of the Au. Stable operation is possible by voltage biasing the detector, while having the substrate at $T_0 < T_c$. This biasing scheme also improves the speed of the device significantly. The resolution of the detector is given by $\Delta E=2.36\xi(k_B T_c^2 C\}$, where the scaling factor x represents the noise performance of the device. Typically, ξ=1, but in the absence of extra noise (such as parasitic internal thermal impedances, contact resistances etc.) ξ can be <1.

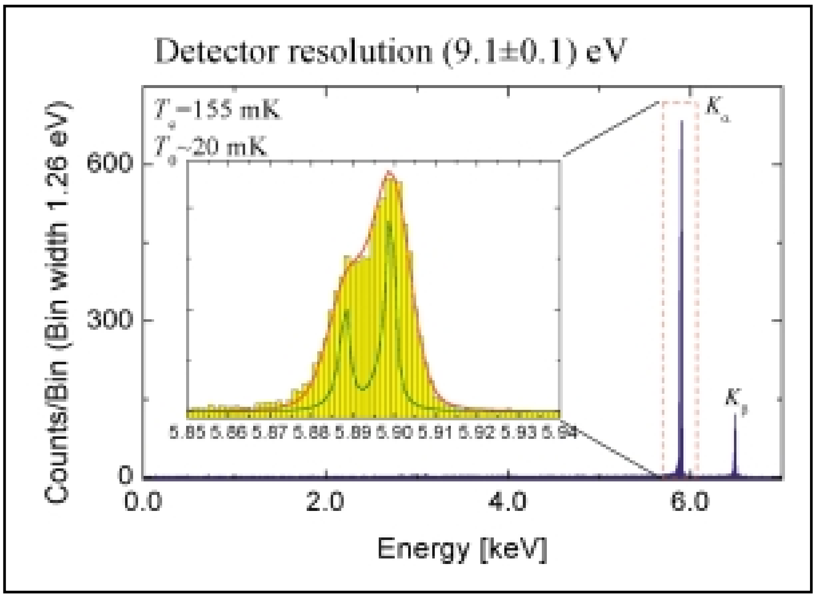


Fig. 2. ^{55}Fe X-ray spectrum measured by the Jyväskylä microcalorimeter.

Recent measurements of ^{55}Fe X-ray spectrum show an instrument resolution of (9.1±0.1) eV at 5.89 keV, corresponding to a ξ=1.5, which indicates that there is room for improvement. We expect to improve the resolution by improving the thermalization of the X-ray events and possibly by further development of the detector geometry. Besides the detector development, we are working on combining the devices with SINIS on-chip coolers, which could simplify the required cooling stages significantly.

Temperature fluctuations in mesoscopic conductors. Characterisation of intrinsic noise sources is important not only for detector applications, as noted above, but also from the fundamental point of view. Some basic theorems of temperature fluctuations are still essentially untested, for example. We have started a project, where the goal is to observe and study these fluctuations in small (~ 10 μm^2) metallic islands. Temperature measurements are done with NIS tunnel junctions fabricated by electron beam lithography. NIS junctions are optimal due to their high sensitivity in the desired temperature range of 50 mK to 1 K.

Superconducting quantum bit for quantum computation. It has been shown that computation based on quantum states can offer significant advantages over classical computation in certain applications. We are developing a superconducting, single Cooper pair box-type device, consisting of a metallic island connected to the surroundings by a Josephson junction with tunneling resistance typically a couple of times the resistance quantum, i.e. a so-called charge squbit (**S**uperconducting QUantum BIT). We have fabricated samples consisting of two capacitively coupled aluminum superconducting SETs, of which one can act as a Cooper pair box (with two junctions in parallel), and the other as a sensitive electrometer. The sensivity was sufficient to measure Cooper pair tunneling in the Cooper pair box, signalled by a 2e periodic modulation of the current through the SET, and hence to provide a first in-house demonstration of the feasibility of the concept.

One of the main challenges in the construction of a SQUBIT-based quantum computer is to achieve a sufficiently low rate of decoherence of the SQUBITs. It is therefore important to be able to measure the decoherence time and this has been the main focal point of the SQUBIT activity at JYFL during the past year. Earlier theoretical results have shown that quantum effects strongly influence the efficiency with which Cooper pairs can be coherently pumped around a closed circuit with applied periodic gate voltages. This allows a measurement of the decoherence rate as the cross-over frequency between classical and quantum pumping efficiency. For this purpose one of the two cryostats devoted to the SQUBIT experiments is being equipped with three radiofrequency (RF) coax lines (<18 GHz) for measurement of charge transport in three Josephson junction/two island arrays, in addition to the DC-lines which in both cryostats have been upgraded with filters of the powder- and/or strip type.

The main cause of decoherence is the coupling of the SQUBIT to the electromagnetic environment. Calculations of the effect suggest that the effect is reduced sufficiently provided a SQUID-based current measurement is used. This 100 mK ingredient is presently being constructed in collaboration with VTT. The three junction array has been tested at DC with 2-d scans of the current vs. the gate potentials. The design was found operational although improvements are possible. Some unwanted cross couplings will be compensated at room temperature with electronics which is under construction. The RF sources of the experiments are a 50 MHz arbitrary waveform pulse generator supplemented by a 1 GHz sine wave generator. A new electrically screened room for the SQUBIT experiments was taken into operation this year.

At higher frequencies Cooper pair pumping is modified by coherent but non-adiabatic effects. A program to investigate this effect has been started in collaboration with J. Mygind (Technical University of Denmark). Preliminary calculations indicate that the effect of the conventional Landau-Zener level crossing formula could be modified by measurable quantum mechanical interference phenomena.

Fabrication of Mesoscopic Nb Wires. A number of nanometer-scale devices such as single-electron transistors, superconducting quantum bits, and other mesoscopic superconducting devices are usually realized using the self-alignment technique, which provides submicron accuracy. Self-alignment is achieved by the shadow evaporation technique, commonly used with the resist polymethylmethacrylate **(**PMMA**)** and co-polymer **[**P**(**MMA-MAA**)]** as a double layer stencil mask patterned by electron-beam **(**e-beam**)** lithography. Until now this conventional shadow evaporation technique has been applied successfully for the soft metals such as Al, Cu and Pb. For the refractory metals such as Nb, W or Ta with high melting temperatures, however, a special kind of mask which is more robust to heating than PMMA is required. The trilayer stencil mask composed of PhenyleneEther-Sulfone (PES), Ge, and PMMA layers, developed at CNRS in Grenoble, is a good candidate for the fabrication of nanometer-scale devices with refractory materials. In particular Nb is a promising alternative to the soft metals for superconducting nanodevices such as single-electron transistors and quantum bits, because of its large superconducting gap and high stability under thermal cycling. For these reasons, we are currently implementing these novel fabrication techniques in our lab. In addition, we have improved conventional lithography techniques for fabrication of Nb wires and junctions indicating high transition temperatures.

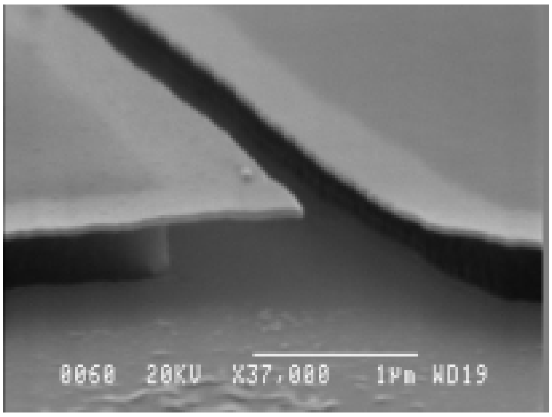


Fig. 3. Oblique view of a Ge stencil mask on top of PES resist.

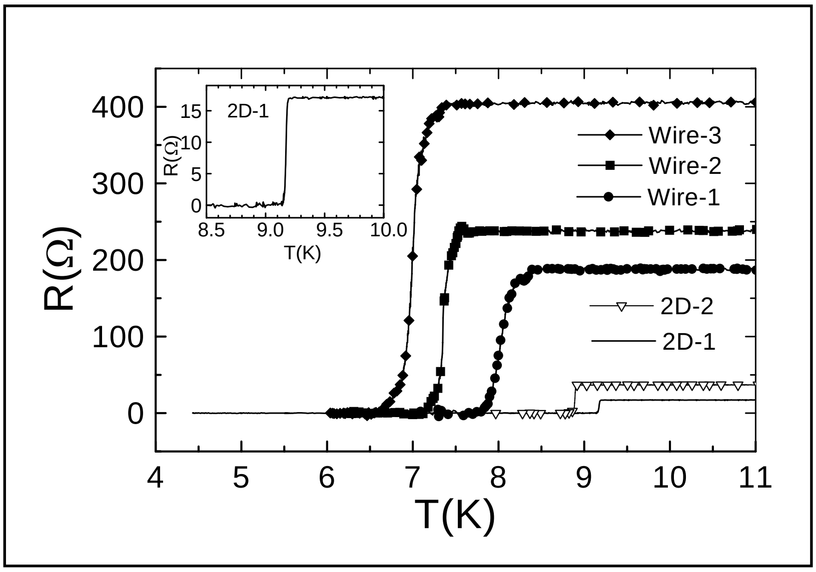


Fig. 4. Superconducting transitions for Nb wires and films fabricated with conventional techniques.

Thermometry using arrays of small tunnel junctions. Various aspects of Coulomb blockade in different types of arrays of tunnel junctions have been investigated during the past years, see the previous annual report. Nowadays, these devices are ready for thermometry in real applications.

Arrays of tunnel junctions are usually fabricated by two-angle shadow evaporation of thin aluminum films onto a silicon wafer. Typically, these devices are constructed as several (4-5) parallel chains of 20 - 50 tunnel junctions in series to enhance the signal size. A tunnel barrier is formed by oxidising the first Al layer. Those thin Al films become superconducting at around T_c = 1.3 K. But for thermometry they have to be in the normal state. Superconductivity can be suppressed by a magnetic field, yet in some cases a magnetic field can affect other experiments. Therefore we use the proximity effect to reduce T_c of the Al film: a copper layer is evaporated first. Afterwards the first Al film is evaporated onto the copper layer, so that a tunnel barrier can still be formed by the native AlOx. Since copper stays normal, it forces the Al film to the normal state, too. The final layer is then formed purely out of copper. Such arrays work down to 50 mK, the lowest temperature achieved in the present measurements.

To cover also a lower temperature range with these Coulomb blockade thermometers, the junction area as well as the total metallic volume connected to each junction has to be increased. A larger area increases the capacitance of the junctions so that they provide sufficient sensitivity at low temperatures. And a larger metallic volume improves the thermal coupling between electron and phonon systems, reducing possible temperature gradients in the thermometer. Both effects become the more important the lower the temperature is. A 10 mK lower bound seems to be feasible in the future.

This year we found out that the operating range of the Coulomb blockade thermometers could be extended up to higher temperatures all the way to 300 K, thus providing a wide range thermometer. At such high temperatures Coulomb blockade is negligible. But still the tunnelling conductance varies systematically with temperature because of the thermal broadening of the electron distribution (Fermi-Dirac statistics). This can be used as a thermometric parameter with a simple power law dependence on temperature.

Mesoscopic superconductivity. Single-crystal superconducting microstructures have been fabricated. The resistance of tin whiskers were measured in a multiprobe configuration, with contacts made of either copper, gold or niobium films using e-beam lithography followed by a lift-off process. Structures with the normal metal probes showed unusual behavior: below the critical temperature of bulk tin, the resistance decreases in distinct steps and does not reach zero even when cooled down to 1 K. The origin of these phenomena is not clear but is likely to be the related to the proximity effect of superconductivity.

We have also studied the experimental evidence of nonlocality in superconducting nanostructures: the variation of the magnitude of the order parameter induces a response at a remote point. It is shown that reasonable

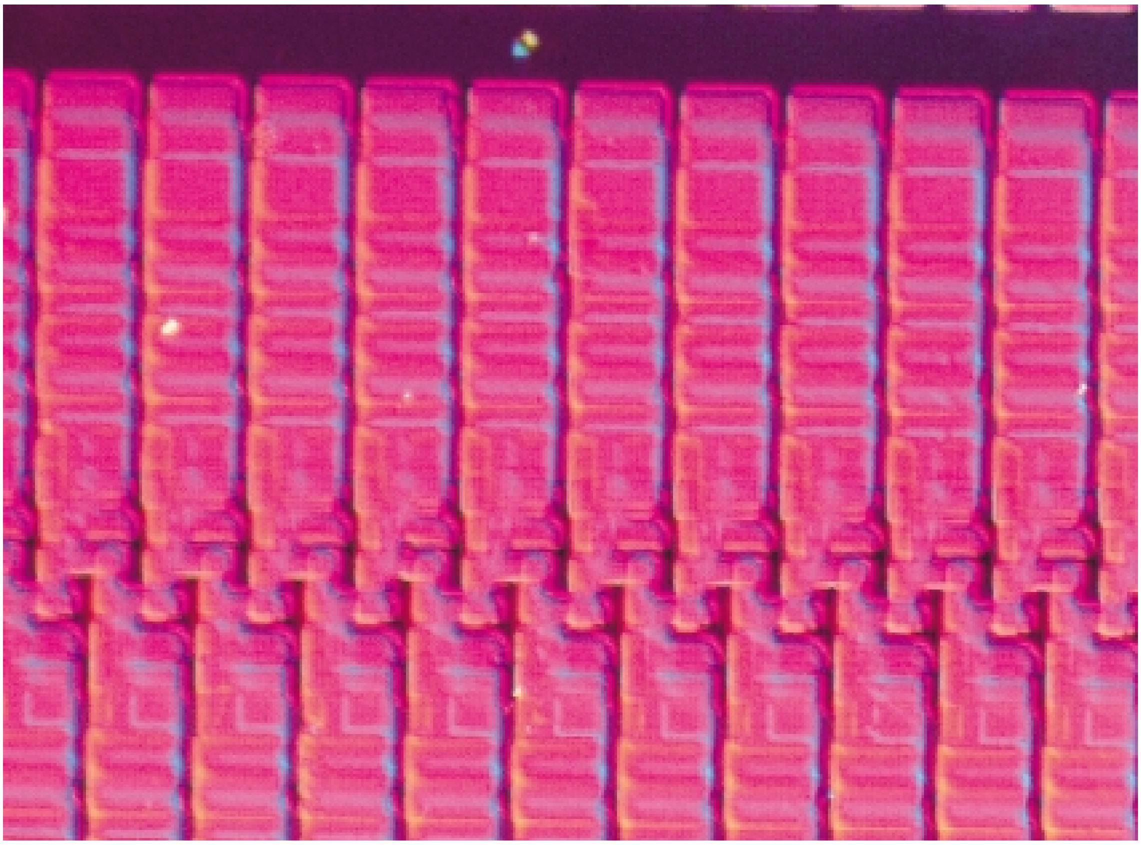


Fig. 5. Section of a Coulomb blockade thermometer for low temperatures. 21 out of a total of 204 CuAl-AlOx-Cu tunnel junctions can be seen together with their long metal pads to improve thermal coupling. Each junction has a 2*2 μm^2 wide tunneling area. The total figure size is roughly 100*75 μm^2.

agreement with experiment can be achieved by assuming non-local integral relation with the kernel function, normalized with the correlation length. Numerically this length is close to the effective Pippard coherence length, while its dependence on temperature is different from the conventional diverging behavior at the critical point T_c.

Silicon Single Electron Transistors. One of the limitations of the progress in the development of single electron tunneling devices is the requirement for the size of the structural elements for room temperature operation, which is below the resolution of modern nanolithography process. Due to the possibility to utilize standard Si technology and to use oxidation process for the reduction of the final size of the structures, silicon seems to be a very promising material for nanotechnology.

Silicon single electron transistors (SET) with a side gate have been fabricated on a heavily doped silicon-on-insulator wafer. *I-V* characteristics of all SETs under investigation demonstrate clear Coulomb blockade region at temperatures up to 100 K and pronounced nonlinear behavior even at 300 K. The well pronounced modulation of source-drain current by gate voltage was observed up to 100 K (Fig. 6). The difference between the samples

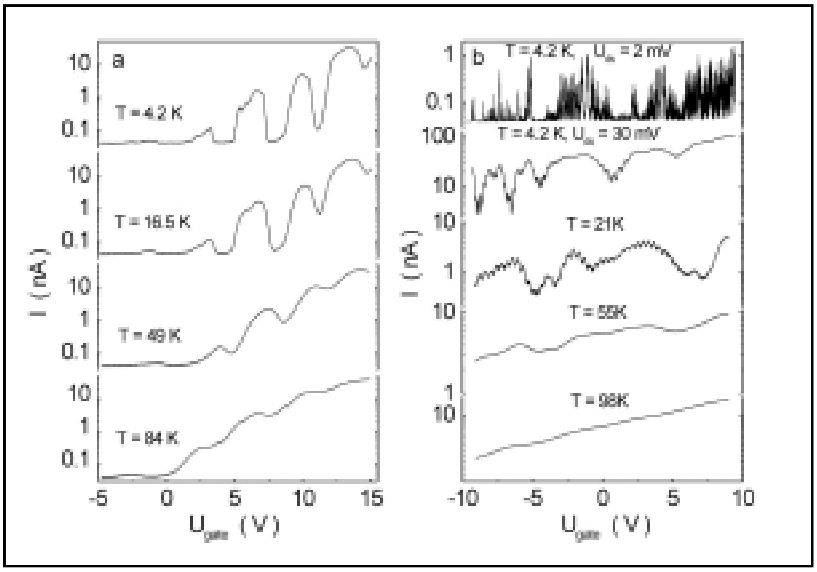


Fig 6. Drain-source current vs. gate voltage at different temperatures for (a) sample I (U_{ds}= 10 mV) and (b) sample II (U_{ds}= 3.2 mV at T > 4.2 K).

can be explained by the existence of several dots in sample II. At temperatures below 20 K, long term oscillations (relaxation) of source-drain current after switching of the gate voltage has been observed in both multiple dot and single dot SETs.

Atomic clusters and quantum dots

Matti Manninen

Electronic and ionic structure of small metal clusters. Our earlier studies have shown that the density functional theory with ab initio pseudopotentials can give reliable results for the geometrical structure and photoemission spectra of small aluminium clusters. We are now extending this study to small magnesium clusters putting special emphasis on the metallization of the clusters as the size increases. The *s-p* hybridization seems to be a complicated nonmonotonic process due to the coupling of the electronic structure to the cluster geometry. While Mg_4 and Mg_{10} with 8 and 20 electrons show magic electronic structures, the general behavior of small clusters do not fit to the simple jellium model but show more localization of the electron density.

Melting and fragmentation. First principles molecular dynamics is used to study the melting of small aluminium clusters. The comparison ofAl_{13}^- and Al_{14} shows tha the 'double magic' Al_{13}^- cluster which has an icosahedral geometry and a full electronic shell does not show any melting transition below the bulk melting temperature and only isomerization at high temperatures. Al_{14} on the contrary shows diffusion already at much lower temperatures. Surprisingly, however, the diffusion of the surface atom does not occur around the surface of the 13 atom icosahedron, but via collective movement of atoms: The surface atom goes in and another atom pops on the surface.

http://www.phys.jyu.fi/research/clusters/

Fragmentation of small sodium clusters (Na_{10} and Na_{13}) have been studied using both ab initio and classical simulations at a temperature region 1200-2400 K. Na_{10} is observed to eject equal numbers of monomers and dimers, while Na_{13} ejects slightly more monomers than dimers. Both clusters eject also larger fragments. The observed behavior is in agreement with previous observations that the electronic shell oscillations diminish strongly as a function of temperature. The fragmentation rates obtained with the ab initio method are consistent with the Kelvin equation for the equilibrium vapor pressure of small clusters. The dissociation energies for different ejected fragments are found to reflect the ordering of the fragmentation rates for each model.

Melting of large sodium clusters with several hundred atoms have been studied using both classical and ab initio calculations. These studies aim at explaining the anomalies found in the experimental results for the melting temperatures of sodium clusters.

Quantum dots. We use the density and current-density functional theories and ab initio many-body methods to study quantum dots and quantum dot molecules. In a single dot the ground state electronic structure can have a spin determined by the Hund's rule, be nonmagnetic or have a static spin-density wave. The exact calculations for small quantum dots and rings are in excellent agreement with those obtained with the local density approximation.

The effect of a magnetic field on the electronic structure has been studied using the current-density functional formalism with the local density approximation. In a high magnetic field the electrons polarize and so-called maximum density droplet is formed. Increasing the field further separates a ring of electrons from the droplet. In the local density approximation this so-dalled Chamon-Wen edge consists of localized electrons. In exact many-body calculations this localization can be seen by breaking the circular symmetry of the system. The exact calculations are in excellent agreement with those of the local density approximation.

Quantum rings. Electronic structure of quasi-one-dimensional rings is studied using exact configuration interaction technique. The results show that the electrons localize forming an antiferromagnetic ring. The rotational energy levels of the exact calculations agree quantitatively with those of the antiferromagnetic Heisenberg model. We have also studied with the CI method small quantum dots and shown that in a dot with six electrons the ground state at low densites has a pair correlation function in agreement with an antiferromagnetic ring of six electrons. A fully polarized state (spin=3), which is higher in energy, has an internal structure consistent with localized electrons in a five-fold ring with one electron in the center.

We have also studied the persistent currents in quantum rings using the current-density functional formalism. The aim is to do systematic study of the joint effects of both spin, interactions and impurities. The results show that we are able to describe effects related to Aharonov-Bohm phases.

Atomic bose condensates. The low energy rotational excitations (yrast line) of bose condensates with delta function interaction have been calculated using an exact diagonalization technique. The results are analyzed using several model approaches. In the large angular momentum region the analogy between the quantum Hall system and the weakly interacting bosons in a harmonic trap is exploited. In the region of small angular momentum the structure of single and multiple vortexes is studied using trial wave functions and analysing the exact munerical wave function.

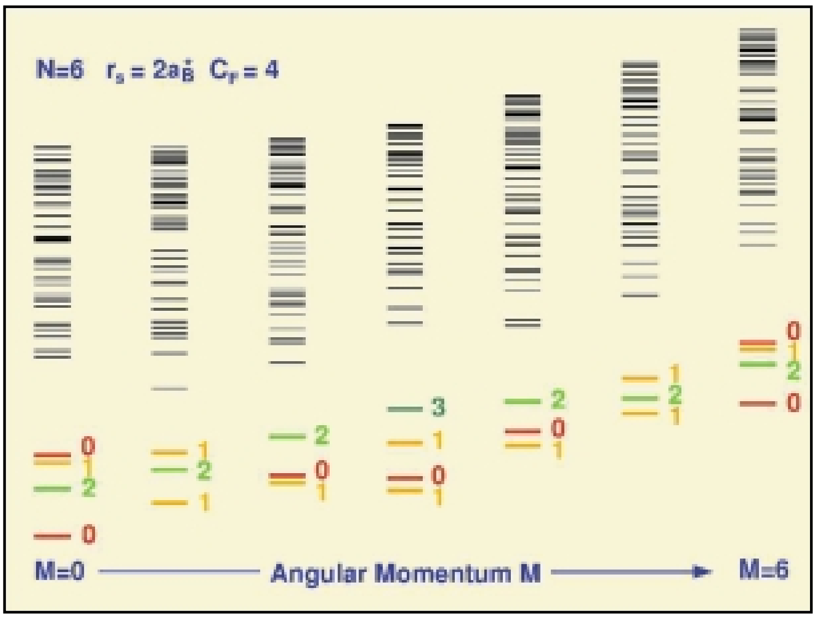


Fig. 7. Many-body specra of a quantum ring with six electrons. The structure of the low-energy band (indicated with the numbers giving the total spin) is an evidence of localization of electrons.

Disordered materials and nonlinear physics

Jussi Timonen

http://www.phys.jyu.fi/research/dismat/

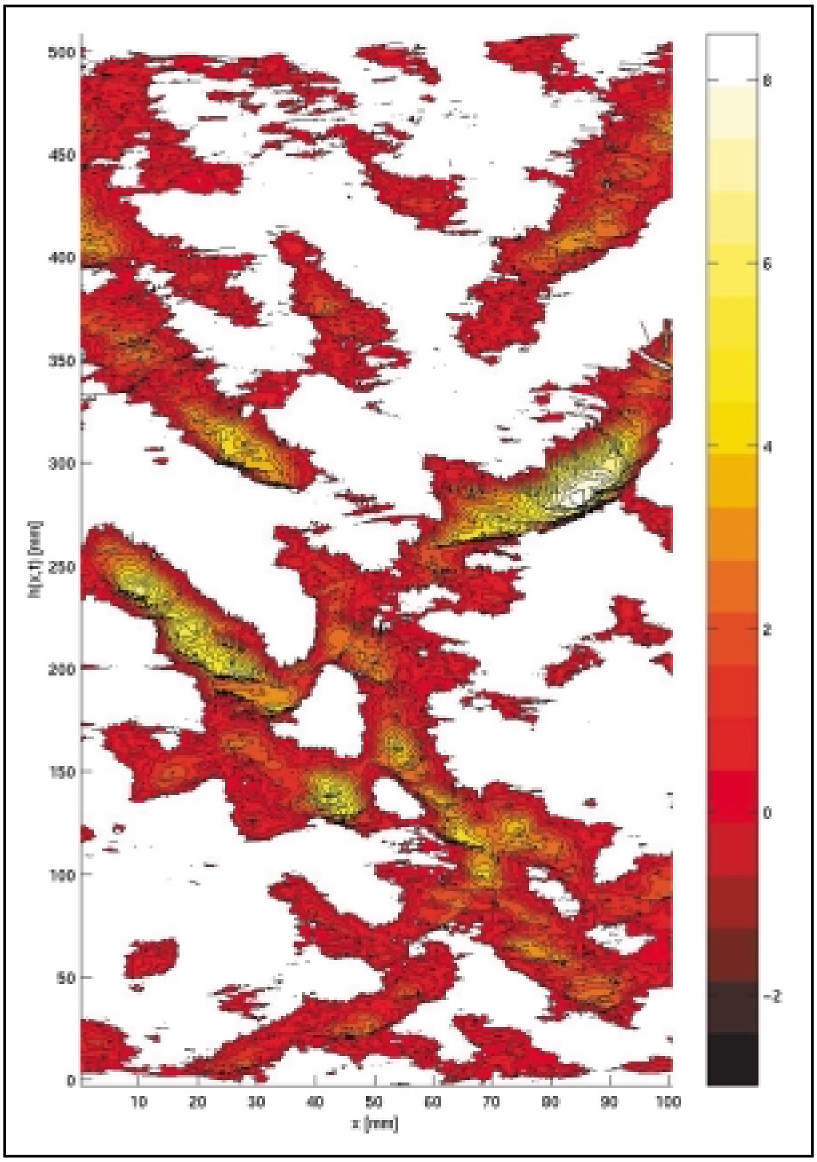
The group of disordered materials and nonlinear physics has continued its previous activities such that the main areas of research have been fragmentation of brittle systems, properties of granular packings, elasticity of fibrous structures, interface dynamics, multiphase fluid dynamics and exact solutions for strongly interacting boson systems. Applications have mostly been in paper making and bone research.

We have managed to show that both *impact fragmentation and explosive fragmentation* become critical at some value of the impact energy, or in the limit of extremely slow explosion dynamics, respectively. Criticality means here that in these particular cases the fragment size distributions are given by pure power laws, and that away from the critical points the distributions have a scaling form characterised by some critical (or scaling) exponents. Both fragmentation processes were found to have the same scaling exponents, which, unlike some previous suggestions, do not belong to the percolation universality class. Exactly the same behaviour was found in fragmentation of a model for brittle granular solids and of a Lennard-Jones liquid, and this also indicates there are universal features in fragmentation processes.

Granular packings under a compressive and shear load were shown to develope shear bands, whose static and dynamic properties were shown to be very similar to all observed characteristics of earthquakes that occur in tectonic fault zones. One of the 'anomalies' faced by the conventional friction models of earthquakes is that tectonic fault zones seem to have a much smaller internal friction than necessary for these models. Shear bands in granular packings appear to share this property of real fault zones. Similarity of shear bands and fault zones is true in particular when fragmentation of blocks is included in granular packings. The magnitude distribution of 'seismic activity' in shear bands has the same form that characterises earthquakes, and the decay of aftershock frequency obeys Omori's law in both cases. It appears natural that the bedrock is fragmented in the 'gouge' of the tectonic fault zone such that it can be described by a packing of frictional blocks. This approach also suggests there takes place a natural aging process in tectonic faults, which is reflected in the changing nature of quakes.

Another field of interest to us has been *the properties of random networks of fibres*, or of structures of a similar kind, both in two and three dimensions. We have developed a new effective medium theory for the elastic properties of systems which are composed of massive particles connected by elastic contacts, such as e.g. random networks of fibres. We showed that the porosity of such networks is given by a function, the 'process function', of a single parameter that is a combination of the basic mechanical parameters of the fibres. This process function also determines all elastic properties of such networks. The analytical results were checked against nu-

Fig. 8. Colormap of local velocities of combustion fronts in paper.



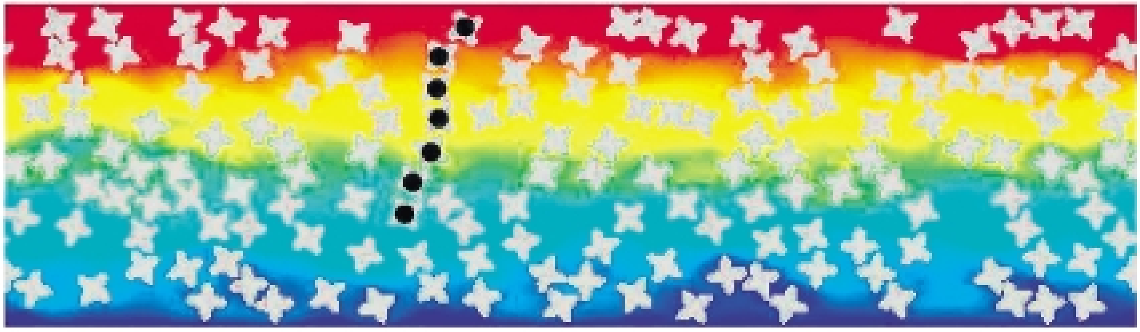


Fig. 9. A snapshot of a shear flow of star-shaped particles suspended in a fluid. Red color indicates high fluid velocity. A typical example of cluster is also shown in the figure

merical models, and applied successfully to measured elastic properties of glass-fibre felts. Application to paper is now in progress. Structural properties of woven fibrous structures were also considered, as well as the rigidity transition in random networks of fibres, which was found to be of second order. Basically all critical exponents related to this transition were determined with effective constraint counting algorithms.

Propagation of slow combustion fronts in paper were measured, and then analysed for their spatial and dynamical correlations. We have previously shown that the kinetic roughening of these fronts is asymptotically given by the Kardar-Parisi-Zhang (KPZ) model with white noise. The short scale behaviour of these fronts was now shown to exhibit apparent multiscaling properties, and the effective noise in this regime was shown to be correlated and to have power-law tails in its amplitude distribution. Asympototically these correlations and the power-law tails were shown to disappear, and the related scales were identified as the crossover scales in the front height correlations. It also appears that the apparent multiscaling at short range is due to avalanche type of local phenomena in the propagating combustion front.

The dynamics of interfaces were also analysed theoretically and by numerical simulations. Our numerical simulations of the KPZ equation with the quenched and correlated (short range) noise of the paper samples used in the measurements (inferred from beta radiographs), show behaviour very similar to the experimental observations. In particular, simulations with varying amounts of experimental input provide new insight into the interplay of noise and other factors in a KPZ-type description of interface dynamics. We have analysed theoretically the dynamics of circular fronts, interfaces with intrinsic thickness, the kinetic roughening of planar cracks propagating between two connected elastic plates, and also the implications of microscopic details on transport phenomena at surfaces.

Research on fluid dynamics problems has also included numerical simulations and experiments. As for particulate suspensions, lattice-Boltzmann methods were developed for shear flows of particulate suspensions. Shear thickening in these flows could be attributed to clustering of suspended particles, and we are now analysing different momentum transfer mechanisms in these flows to understand how viscosity is formed e.g. in typical rheological measurements on suspensions. Viscosity of various kinds of simple suspensions was measured in comparison. Formation of lubrication layer in pipe flows of fibre suspensions was analysed by numerical simulations and by experiments. This phenomenon, which has great practical value, has not however been fully understood, but now we believe to have clarified the basic mechanisms of it. Furthermore, experimental methods based on optical tomography and pulsed ultrasound were developed.

Different aspect of flow in porous media was studied in many projects. Spreading of a droplet on a (rough) porous substrate was analysed experimentally and also by numerical simulations. Depending on initial conditions, the behaviour is in agreement with or systematically deviates from the usual Tanner's law. Permeability of a computerised tomographic construction of a piece of Fontainebleau sandstone was compared with those of different theoretical constructions of the structure with the same porosity. Clear differences were found between the cases analysed, which indicates that porosity alone cannot be used to describe the transport properties of porous media. In addition diffusion in various rock samples and also in metal alloys was measured with a helium equipment. Clear structure dependent orientational effects were found in rock samples, and havar alloy was discovered to undergo a spinodal decomposition transition, which drastically affected its diffusivity properties. Finally, sap flow through a typical bordered pit that connects two tracheids in conifer xylem was simulated by the lattice-Boltzmann method in order to understand the main factors which determine the permeability of xylem. The goal of this research is to determine relevant parameters needed e.g. for models of vegetation-atmosphere interaction.

Applications in paper making included several problems in addition to the pipe flow of fibre suspension already mentioned. The filtration process in which water is drained from the suspension of water and wood fibres such that a paper web is formed, was modelled as a two-phase hydrodynamical system, and a numerical solver for the resulting set of equations is under construction. A simplified version suitable for verification against measurements with a specific filtration device has also been constructed and analysed. Measurements on paper samples and related simulations based on the lattice-Boltzmann method revealed that refining induced changes in the fibre surface and the fines content markedly affect the specific surface area of paper, such that its permeability significantly depends on these factors. Otherwise, the porosity dependence of permeability of paper was shown to follow closely the curve simulated for random networks of fibres alone. Measuring systems were developed for the coating process in a metering size press. The pressure distribution in the metering nip and in the film transfer nip were both measured, and useful correlations were found between the process parameters and the thickness of the metered coating layer. As for elasticity of paper like materials, stiffness measurements were made on glass-fibre felts, and the results were explained with the help of the effective- medium theory described above. Finally, a numerical method was constructed by which physically realistic models of woven fabrics, such as e.g. the ones used in paper machines, can be designed. The method includes a solution for 'hard-core' dynamics in which contacts between the wires can be formed and reopened during relaxation towards the minimal elastic energy of the system.

The work on interacting boson systems included calculation in one, two and three dimensions of the finite-temperature correlation function for trapped Bose-Einstein condensates. We showed in particular that the 3D 1/R decay of coherence is approximately satisfied for trapped condensates, a result which has been observed in a beautiful experiment by the Munich group. We also solved exactly the quantum dynamics of coupled condensates, especially in the strong interaction limit. Recurrent Rabi oscillations were shown to be generic for this and similar systems independent of the interaction strength, and new insight was also gained for the quantum phase problem. The attractive BE condensate was shown to undergo in two space dimensions, in which case the Gross-Pitaevskii equation allows for a true self similar solution, a delta function collapse at the centre of the trap. Other boson problems considered were the Maxwell-Bloch lattice ('q-deformed solitons') and the N-atom micromaser (the appearance of almost pure Fock states in the cavity field). The previous work on the dynamics of the magnetosphere was also continued by further analysing its coupled-map model. Conditions for when the magnetosphere appears as an input-output system and when it displays self-organised criticality were determined. Finally, the configuration and vibrational states of a specific sequence of DNA were analysed by extensive molecular dynamics simulations. It was found e.g. that there appear sudden jumps between different allowed local conformations of the double helical structure.

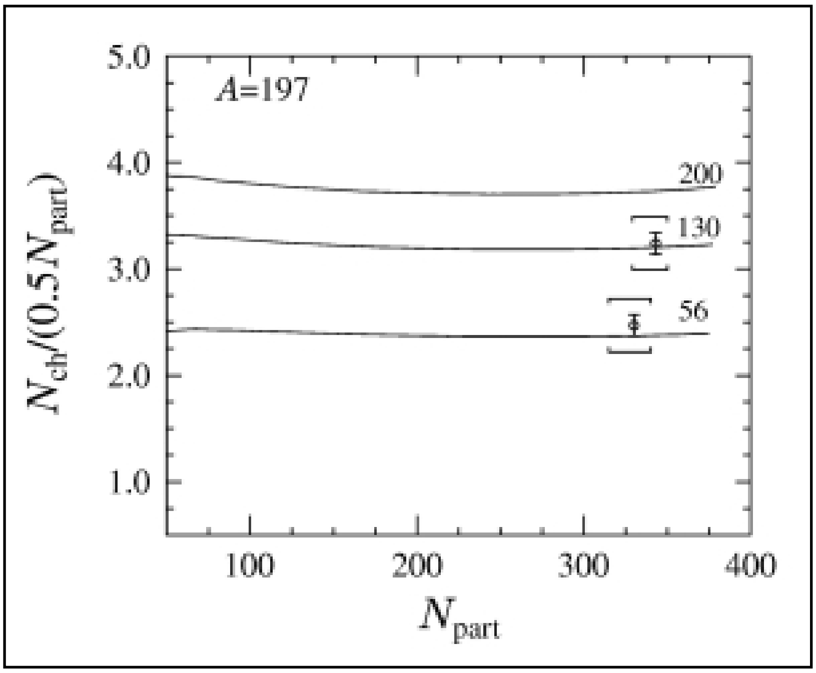
http://www.phys.jyu.fi/research/urhic/

Physics of ultrarelativistic heavy ion collisions

Vesa Ruuskanen and Kari J. Eskola

The commissioning of Relativistic Heavy Ion Collider (RHIC) at Brookhaven National Laboratory in summer 2000 was greeted with satisfaction as an event greatly advancing the research of ultrarelativistic heavy ion collisions (URHIC). Our foremost goal in the theoretical and phenomenological studies of nuclear collisions in the energy regimes of RHIC and the CERN LHC colliders has been to predict the primary production using perturbative QCD: Initial production of partons, which can be argued to be directly related to the observed multiplicity, has been calculated in NLO. Lepton pairs in pA collisions have been obtained as probes of nuclear parton distributions. Applying hydrodynamics to describe the evolution of produced matter from the calculated initial state, allows us to predict several other observable features, like the transverse energy, particle spectra and electromagnetic signals. The main interest of our experimental group is the Inner Tracking System (ITS) of ALICE station. We have concentrated on software development and in-beam testing of detector prototypes. Another important area is the development of T0 dedector based on Micro-Channel Plate (MCP) technology.

Fig. 1. Predictions for $dN_{ch}/d\eta$ vs. centrality in Au+Au RHIC. N_{part} is the number of participants. The data points are from the PHOBOS collaboration.



Multiplicities in URHIC. Gluons and quarks with transverse momenta in the range 1...2 GeV, minijets, are expected to dominate the formation of QGP at collider energies. The densities of the QGP at very early times in the collision, t_i~ 0.1...0.2 fm/c, can thus be calculated in perturbative QCD (pQCD). We have shown that in nuclear collisions at RHIC and LHC the minijet (dominantly gluon) production becomes so abundant that the parton phase space density saturates at transverse momenta $p_T \sim p_{sat} \gg \Lambda_{QCD}$. The saturation scale p_{sat} depends on $\sqrt{s}$, *A* and on the centrality the collision. Furthermore, we have shown that a rapid thermalization of the system is possible. Using hydrodynamical description of the expansion with the saturated minijet initial conditions we have predicted the measurable charged particle multiplicities of the final state for nuclear collisions at RHIC and LHC/ ALICE. The results agree remarkably well with the first measurements of $dN_{ch}/d\eta$ at RHIC in central Au+Au collisions at $\sqrt{s}$=56 *A*GeV and 130 *A*GeV, as shown in the figure below. In addition, we have made predictions of the behaviour of the multiplicities as a function of the centrality of the collision (see the figure). Whether such a saturation behaviour has already been observed at the RHIC experiments, is currently a matter of a hot debate

Minijets in NLO. A major uncertainty in minijet production, both in pp and *AA* collisions has traditionally been the unknown contribution of the next-to-leading order (NLO) terms, $\sim\alpha_s^3$, of the partonic cross sections. We have shown that the question of how much transverse energy is carried by the minijets into a certain rapidity acceptance region can indeed be defined and answered in an exact manner in terms of pQCD. The key of this problem is the measurement functions which must be constructed in such a way that the calculation of minijet

E_T is infra-red safe, free of the singularities bound to arise when the partons are massless. We have performed numerically the computation of the minijet transverse energy production in NLO by utilizing Monte Carlo integration techniques and supercomputing. The main conclusions are that pQCD is indeed applicable at the few-GeV scales, and the degree of uncertainty in the computation of the few-GeV minijet production is clearly reduced as compared with the lowest-order calculation. For ultrarelativistic heavy ion collisions, in particular, the NLO contributions directly affect the determination of the initial densities and formation times of the QGP discussed above.

Hydrodynamical evolution of nuclear collisions. Abundant secondary collisions will take place in the very dense initial parton system predicted from pQCD. These collisions are expected to change considerably the momentum distribution of the quanta building up a collective flow. Hydrodynamics provides a simple framework to study this evolution, yet implementing the conservation laws.

Combining the pQCD and hydrodynamic calculations we have predicted for central collisions the final, observable transverse momentum spectra of different hadrons. Integrating and summing the transverse momentum spectra gives the observable transverse energy. The key effect of expansion is the reduction of transverse energy by a factor of order 3. This is a consequence of the assumed thermalization and the asymmetry of the flow which initially is weak in the transverse direction and strong (scaling flow) in the longitudinal direction. Direct experimental verification of the pQCD prediction of the initial minijet state with large transverse energy scale combined with the measurement of the smaller final scale would provide a very strong case for the thermalization of final state particles.

Evidence of the formation of elliptic flow has been obtained from studies of azimuthal asymmetry of momentum distributions. Comparison with experimental data shows that the dependence on centrality of the ellipticity v_2 of the flow is well descibed by the hydrodynamical model. As a function of transverse momenta the calculated values also compare well with the measurements up to transverse momenta close to 2 GeV. At larger values of p_T and for more peripheral collisions hydrodynamics predicts too large ellipticity for the flow. It is obvious that hydrodynamics with the assumption of full thermalization will fail for peripheral collisions with small initial particle density. Details of elliptic flow, like the dependence on particle species, provides tools for closer inspection of the space-time evolution of the

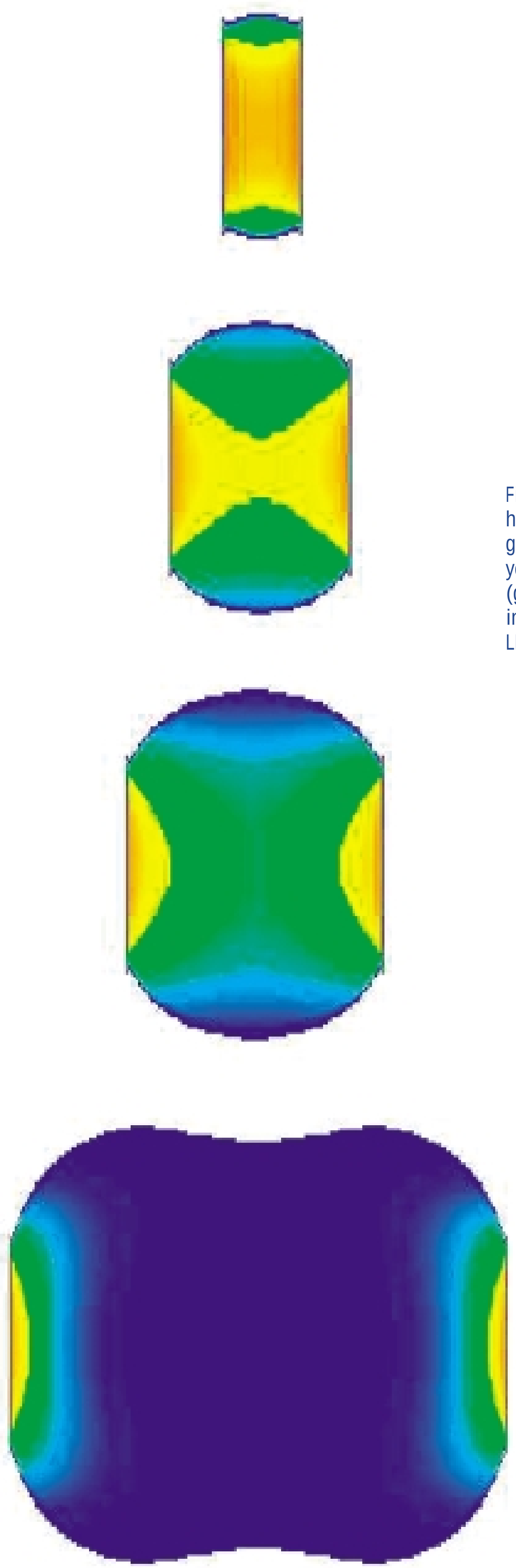


Fig. 2. Expansion and hadronization of quark-gluon plasma (orange to yellow) through mixed phase (green) to hadron gas (blue) in Pb+Pb collision at CERN LHC

collision and, promisingly, calculations show sensitivity on model details, like equation of state and freeze-out conditions.

Nuclear parton distributions. In the search of signals of the QGP in ultrarelativistic heavy ion collisions, inclusive cross sections of perturbative processes are used as a reference. These processes, such as production of large mass dileptons, direct photons, and particles at highest values of p_T, are computable in a factorizable form, provided that the nuclear parton distributions $f_{i/A}(x,Q^2)$, are known. Based on the measurements of the structure functions F_2^A in deeply inelastic lepton-nucleus scatterings, it is known that $f_{i/A}$ differ from those of the free proton. We have recently released a parametrization of the nuclear effects of the parton distributions, EKS98, for public use. It is now also implemented in the CERN routine library PDFLIB. EKS98 is based on the analysis of data of data using pQCD scale evolution equations (DGLAP) and conservation of momentum and baryon number as constraints. In order to better pin down the nuclear sea-quark distributions at large values of momenta ($x \geq 0.3$), we have studied to what extent the Drell-Yan dilepton data in p*A* collisions at the SPS energies reflects the nuclear effects. To reduce the uncertainties related to the nuclear gluon distributions, we are currently studying lepton pair production from heavy meson decays in p*A* collisions, for which constraints at different ranges of gluon momenta can be obtained from the measurements at the SPS, RHIC and LHC/ALICE. These theoretical studies provide also input for the planning of the future experiments, such as ALICE and NA60 at the SPS.

Participation in CERN ALICE experiment. Our contribution to the ALICE experiment is focused on the Inner Tracking System (ITS). Currently we have devoted most of the manpower to software development. For instance, we are responsible for the development of the ITS framework and architecture. We have also substantially contributed to the experimental verification of double track resolution of silicon drift detectors. Our software involvement has been steadily growing over the past year. Currently a member of our group has been selected to the Offline Board. The next step will be to shift the software efforts towards physics performance evaluation of the ITS and later into the analysis of the first real data. We are also developing a vastly improved user interface for various event generators and for data visualization.

ALICE requires a high quality start signal (T0 detector). It is needed as a fast trigger, as a rough but rapid determination of the longitudinal vertex position, and for all Time-of-Flight (TOF) devices. T0 must be operational from the day one of data taking. ALICE collaboration has realized this problem and urged for increased efforts to find the best solution. There are three main concepts under consideration for the T0 detector: Cherenkov Counters, Resistive Plate Chambers and Micro Channel Plate (MCP) units. The MCP concept is the most challenging but it also promises the best performance. Since our group has a lot of experience in that field, we have decided to contribute to the T0 project by additional R&D work.

Our in-beam tests at CERN of T0-MCP sector prototypes, carried jointly with St. Petersburg and Bologna groups have shown that MCP is indeed fully capable of providing sufficient efficiency and time resolution for operation with minimum ionizing particles. Although it is not obvious that the MCP solution will finally be chosen for the T0 detector, our additional efforts in that field will not be wasted. Any new experience and improved electronics will have immediate use at the Jyväskylä Accelerator Laboratory in nuclear reaction experiments and for applied physics projects. In fact, our TOF know-how and good teamwork with the applied physics group have already brought a breakthrough in the way to measure the stopping power values of elements and compound materials.

Quantum gravity

Markku Lehto

The current interest of the General Relativity Group involves quantum gravity, especially those aspects related to discrete spacetime models. Our viewpoint is that at the fundamental level Nature should be described by a theory based on discrete structures rather than on continuous manifolds as is the case in prevailing theories. This approach raises deep questions about the structure of such a theory. For example: does 'discrete' necessarily imply the existence of a fundamental length scale, and is the exact Lorentz invariance completely lost in a discrete framework? The answer to both of these questions turns out to be negative, and this has to be taken into account when constructing a discrete model. On the other hand, we argue that any sensible physical theory should be based upon a certain set of physical principles rather than on clever mathematics alone. The search for such principles in the case of quantum gravity is extremely hard, but certainly some principles should exist, since we are dealing with a physical theory, after all.

Many familiar issues of spacetime, such as dimension, topology and metric, change drastically in the context of quantum gravity, as opposed to their meaning in general relativity and standard quantum mechanics. They become dynamical variables, and it is not clear whether we should even speak of topology and metric on the Planck scale; it may as well turn out that such large-scale familiarities are consequences of some entirely different entities functioning on the fundamental level. So, we are led to abandon most of the essential concepts in general relativity. In addition to the above-mentioned, these include the concept of a spacetime point and continuous manifolds, the most essential parts of the formulation of general relativity.

Quantum mechanics presents also deep and significant problems concerning the successful marriage of these two theories, and the reason for these problems is simple: quantum theory relies completely on Newton's view of space and time. The challenge, then, is to devise a quantum theory in which space and time emerge from the relationships among objects, as is the case in general relativity. One possible approach towards this goal - and this is our main research line, including the study of quantum black holes – would be to reduce quantum mechanics essentially to information theory. If this turns out to be possible, it would give strong motivation to attempt to tie all conceptual and formal aspects of the theory to information-theoretic framework. Information theory might also be the most physical framework, since all of physics is based on interactions, which are nothing but exchange of information between systems.

http://www.phys.jyu.fi/research/gr/

Industrial collaboration

Industrial contacts related to *accelerator physics*: Daimler-Chrysler Aerospace GmbH (Astrium Space at present), CERN and Helsinki Institute of Physics performed SEE and RadHard tests of semiconductor electronics in RADEF station. A new collaboration with Royal Institute of Technology, Stockholm, and Swedish Space Corporation concerning the future test activities was also initiated. In radioisotope production the co-operation with MAP Medical Technologies Inc. continued. This included the installation of the gas target system. A sensor study and its development for measuring properties of technical fabrics with Tamfelt Oyj from Tampere was also carried out. Part of the study was done at the nuclear microprobe facility of ATOMKI, Debrecen, Hungary. A new collaboration in radiation oncology was also started. This included a preliminary study of a new sensor for monitoring radiation fields of therapy accelerators. This was done together with a private company Acatec Ltd. from Kuopio. A research funding from Technology Development Centre and Jyväskylä Science Park Ltd. has just been issued. In environmental research several dating measurements of lake sediments for the Institute for Environmental Research were done. Also, a new collaboration with two companies, Evater Ltd. and Rejlers Ltd., was started and the aim is to develop an x-ray sensor to monitor critical pollution levels of lead in soil samples.

The group on *accelerator based materials physics* is developing a resistive charge division based position sensitive detector for electrons. This work is carried out in collaboration with SiTek Electro Optics, Partille, Sweden.

The *nanotechnology group* has well established collaboration with a few companies in Finland. For about three years ultrasensitive radiation detectors based on calorimetry and bolometric sensing for x-rays and IR-radiation have been developed in collaboration with Metorex International company from Espoo. At the first stage the work has been motivated by the need of on-chip integrable ultrasensitive sensors in space research. During the past year close collaboration with Vaisala Oy was initiated to develop methods and sensors of weather conditions based on micro- and nanotechnology. This research is timely because of the foreseeable advantages due to very low power consumption, high reproducibility in production and low manufacturing costs of such sensors as compared to those of conventional bulk technology. The Nanoway company, a spin-off from the university's nanotechnology group is producing and marketing the nanothermometer invented and initially developed in our physics department. There is well defined niche market for this product and especially along with the discovery of how to extend the operation from cryogenic

temperatures up to room temperature, it may well be attractive to even a wider range of customers. Nanoway also provides micro- and nanotechnical services to interested companies and institutes.

The research *group of disordered materials* had contacts with industry in three topical areas. Research on fibrous structures and dynamics of multiphase flows was in part related to problems in paper making and paper machine technology. Several Master's and doctoral theses were being carried out in 2000 in the related research projects, which involved direct collaboration with industrial partners or were funded by Tekes. In the latter case industrial involvement was through steering committees nominated by Tekes. The second area of industrial relevance was related to diffusion in porous materials such as for example rock. Posiva Oyj was the main industrial partner in this area. The third area was related to three-dimensional visualisation by virtual-reality techniques, mainly of complicated fluid dynamics problems. Here industrial contacts were based on an EU/Esprit project, which included companies such as Astrium-Space, which is the coordinator of the project, British Aerospace, Voith, Sulzer, Metso Paper and ICEM.

The newly initiated *electronics research* in the department is establishing contacts with industry. The professorship in electronics is sponsored by local municipalities and industry, and an agreement about research and teaching collaboration was signed between Enermet company and University of Jyväskylä in 2000. This includes, among other things a three year appointment of a senior assistant to promote research and teaching in areas interesting to both parties.

Education

http://www.phys.jyu.fi/teaching/index.html http://www.phys.jyu.fi/opetus/index2.html

Physics is taught at the University of Jyväskylä at all academic levels. The degrees granted are bachelor of science (BSc), master of science (MSc), licentiate of philosophy (PhLic) and doctor of philosophy (PhD).

For the MSc, the specific major within the discipline of physics can be chosen as physics, theoretical physics, applied physics, electronics or physics teaching. Applied physics contains a master's programme in paper science and technology, designed to prepare professional physicists for careers in paper and paper machinery industry. Students may freely choose their specialisation in physics during their studies except for teacher education and the master's programme in paper science and technology. To these two programmes a restricted number of physics students are admitted by application.

The main areas of advanced and graduate courses are
- experimental nuclear and accelerator-based physics
- theoretical nuclear and particle physics
- theoretical and experimental condensed matter physics
- applied physics (nanoscience, nanotechnology, disordered and porous materials, paper science and technology, electronics, and fluid mechanics)
- quantum gravity
- teacher education.

The total number of annual lecture courses is around 55.

Basic studies. In summer 2000 the number of students applying for physics studies was 512, with 295 indicating physics as their first choice. In the autumn of 2000 the physics department enrolled 102 new students and the total number of undergraduate students was 515. Most new students are admitted on the basis of their high school record and national maturity test, while an optional entrance examination offers another opportunity.

In 2000 the number of MSc degrees awarded in physics was 36. The total number of credit points earned by the students was 5300, equivalent to 7950 ECTS credits. The median age for completing a MSc was 26-27 years. The number of MSc degrees has been clearly increasing since 1990, with a record of 41 in 1998. Employment opportunities for newly graduated MSc holders have been good.

The proportion of women among physics students and graduates from the JYFL in 2000 were 24 % and 16 %, respectively. The figures have been similar during the whole 1990's.

Teacher training in physics has been under revision since the late 1980's in response to an impending, and later materialised, shortage of qualified teachers. Good results have been obtained: two thirds of all Finnish physics teachers, who graduated in 1995-2000 came from the JYFL.

Graduate education. The number of graduate students was 55 in 2000. The number of physics PhD degrees completed was 9. The median age of a new PhD has been 29-30 years. All PhD graduates from 1990-2000 are currently employed.

The department participates in four national graduate schools: condensed matter physics (six students), particle and nuclear physics (six students), pulp and paper science and technology (one student) and teacher education (one student). In addition, the research groups have supported graduate students from research grants and the university has actively promoted graduate education with local funds.

Evaluation of teaching. Evaluation of regular lecture courses and student laboratories has become a regular procedure since 1996. The evaluation is carried out through student questionnaires. The answers are analyzed and results discussed with the students and posted on web.

Each year a "best physics teacher" award is given to a teacher chosen by the students. In 1995 Dr. Seppo Valkealahti, in 1996 Prof. Matti Leino, 1997 Dr. Markku Lehto, in 1998 Dr. Jarmo Mäkelä, 1999 Prof. Jouni Suhonen and in 2000 once again Dr. Markku Lehto won the award.

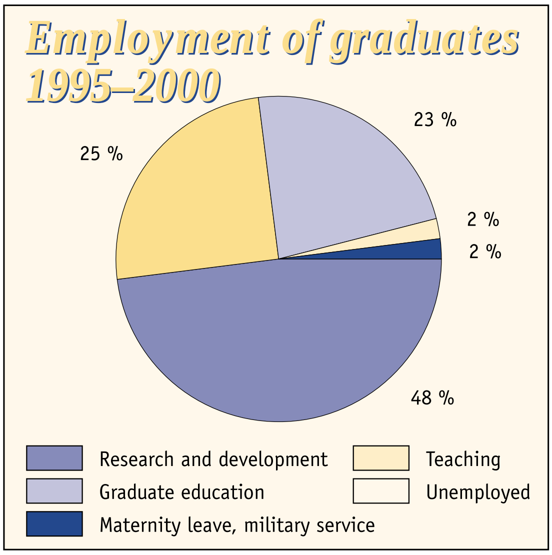
Adult education and Open University. Adult education in the University of Jyväskylä offers an opportunity to study physics in the Open University with free admission. This programme consists of basic physics courses (approbatur) only and is offered also to those university students who study physics as a minor.

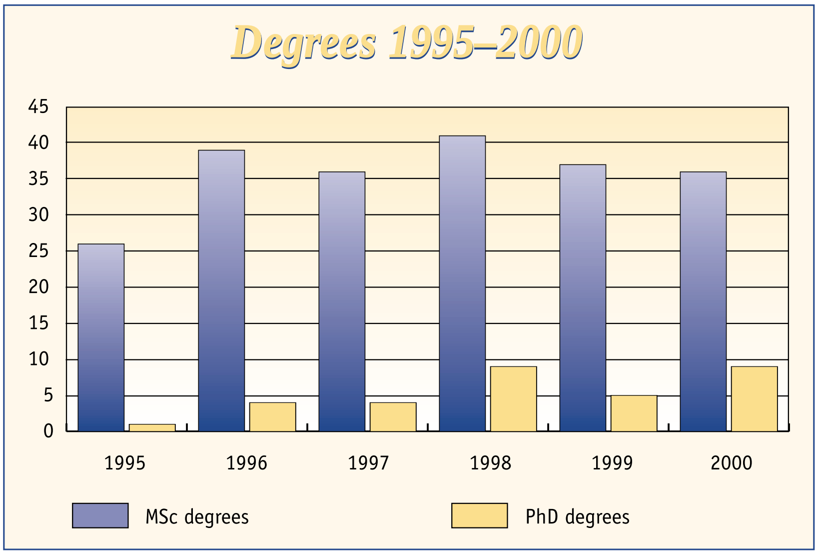
The National Board of Education started in 1996 a project called LUMA 2002 (Finnish mathematical and natural science awareness 2002) and the Department of Physics has actively supported the project to improve knowledge of physics, chemistry and mathematics in our society. We have planned together with the Open University special courses for teachers and about 20 secondary and primary school teachers will start subject studies in physics and a few teachers will also take advanced courses during 2001.

Courses for Secondary School Students. Many student groups from schools of the Central Finland visited laboratories during the year and our teachers visited many schools. About 30 students took part in the course "Physics – Now" and about 20 students started their physics studies in secondary schools at Jyväskylä in accordance with the university program for basic physics courses (approbatur). The Department of Physics organized two courses for talented students, "Laboratory Course for High School Students" and "Physics and Mathematics of Phenomena" and over 70 students participated in these courses during the year 2000.

International Summer School. The International Summer School of the University of Jyväskylä has been in session every August since 1991. Its aim is to offer advanced courses on various topics in science. All instruction is in English. Annually 250-350 students from some 25 countries have attended the school.

In 2000 the summer school celebrated its 10th anniversary. The programme of the summer school consisted of a large selection of courses in physics, biology, chemistry, mathematics, computer science and information systems, and statistics. The physics courses make up a part of the curricula of the national graduate programs. The Summer School was awarded the status of Centre of Excellence in Finnish education system.
More information: *http://www.jyu.fi/summerschool/*





Personnel

Email addresses: forename.surname@phys.jyu.fi
Note: ä=a, ö=o, å=a

http://www.phys.jyu.fi/contacts/

Research groups

Heads of the Department
Rauno Julin, prof., Head of the Department
Matti Leino, prof., Head of the Accelerator Laboratory

Nuclear and accelerator based physics

Accelerator group
Hahto S., student
Heikkinen P., senior scientist
Hyvönen J., operator
Ikonen A., operator
Koivisto H., scientist
Lassila A., engineer
Leinonen H., technician
Liukkonen E., prof., group leader
Luodes S., operator 1.5.-
Nieminen V., lab. engineer
Poikolainen T., lab. engineer
Ranttila K., engineer
Reijonen J., grad. student -30.6.
Seppälä R., technician
Ärje J., lab. engineer

Nuclei far from stability
Dendooven P., senior scientist
Huang W., scientist 11.3.-
Huikari J., grad. student
Jokinen A., senior scientist
Kolhinen V., grad. student
Lhersonneau G., senior scientist
Nieminen A., grad. student
Nummela S., grad. student
Penttilä H., senior assistant
Peräjärvi K., grad. student
Salomäki K., engineer
Szerypo J., senior scientist
Wang J., grad. student
Wang Y., grad. student
Äystö J., prof., group leader (on leave)

In-beam spectroscopy
Greenlees P., scientist
Helariutta K., assistant -31.3.
Jones P., senior scientist
Julin R., prof., group leader
Juutinen S., senior scientist
Kankaanpää H., grad. student
Keenan A., scientist
Muikku M., grad. student -30.10.
Nieminen P., grad. student
Pakarinen J., grad.student 1.9.-
Piiparinen M., senior scientist
Rahkila P., grad. student

Gas-filled recoil separator group
Enqvist T., assistant 1.11.-
Kettunen H., grad. student
Kuusiniemi P., grad. student
Leino M., prof., group leader
Leppänen A.-P., grad. student 1.8.-
Uusitalo J., scientist

Nuclear reactions
Trzaska W., senior scientist, group leader (partly shared with physics of ultrarelativistic heavy ion collisions research)
Radivojevic Z., grad. student
Rubchenya V., senior scientist

Ion-matter interactions and applications
Alanko T., grad. student
Jalkanen P. student
Kyllönen V., grad. student -31.7.
Laitinen P., grad. student 1.8.-
Matilainen A., grad. student
Oksanen M., grad. student
Riihimäki I., grad. student 1.11.-
Räisänen J., prof.,group leader
Touboltsev V., scientist
Virtanen A., senior scientist

Theoretical nuclear physics

Aunola M., assistant
Hjelt T., grad. student -31.3
Holmlund E., grad. student 1.8.2000-
Hopiavuori J., senior scientist
Kortelainen M., student
Lipas P., emeritus prof.
Suhonen J., prof., group leader

Materials physics

Physics of nanostructures and nano-technology

Arutyunov K., senior assistant
Farhangfar Sh., scientist
Gloos K., senior scientist 15.2.-
Hansen K., senior scientist
Hongisto T., student 1.6.-
Kauranen J., student 1.6.-
Kim N., scientist 15.2.-
Kinnunen K., grad. student
Kivinen P., grad. student
Kivioja J., grad. student 1.10.-
Koppinen P., student
Kulju J., trainee
Lindell A., senior scientist
Luukanen A., grad. student
Maasilta I., scientist 22.11.-
Manninen A., prof.
Nuottajärvi A., student
Pekola J., academy prof., group leader
Periainen E., technician
Poikolainen R., research asssiatnt -31.7.
Savin A., senior scientist 15.3.-
Savolainen M., grad. student
Suoknuuti J., research assistant -22.11.
Suppula T., student
Taskinen L., grad. student
Toppari J., grad. student

Atomic clusters and quantum dots

Akola J., scientist -31.8.2000
Anghel D.-V., grad. student
Kolehmainen J., grad. student -30.9.2000
Koskinen M., assistant
Manninen K., grad. student 1.9.-
Manninen M., prof., group leader
Reimann S., scientist -31.7.
Rytkönen A., assistant
Viefers S., scientist -31.1.

Disordered materials and nonlinear physics

Aaltosalmi U., grad. student
Hämäläinen J., grad. student -31.8.
Jämsen P., research assistant
Jäsberg A., grad. student
Kataja M., prof.
Koponen A., scientist (part time work)
Kähkönen S.,student
Latva-Kokko M., grad. student
Lohikoski R., grad. student
Maaranen J., student
Marjavaara P., student
Maunuksela J., grad. student
Merikoski J., senior assistant
Moilanen P., student
Myllys M., grad. student
Mäkinen J., grad. student
Pulkkinen O., grad. student
Raiskinmäki P., grad. student
Rasi M., grad. student
Rehn, E., student
Rybin A., senior scientist
Shakib-manesh A., grad. student
Timonen J., prof., group leader
Vinnurva J., grad. student
Vuoksenranta J., computer analyst
Ylinen J., student

Physics of ultrarelativistic heavy ion collisions

Ameline A., senior scientist 11.3.-
Bondila M., grad. student
Eskola K. J., senior scientist
Honkanen H., grad. student
Kolhinen V., grad. student
Komogorov M., grad. student
Lyapin W., senior scientist
Ruuskanen V. , prof., group leader
Trzaska W., senior scientist (partly shared with nuclear reactions research)
Tuominen K., grad. student

Quantum gravity

Lehto M., assistant, group leader
Luomajoki M., grad. student
Mäkelä J., assistant -31.8.
Piilonen J, student
Repo P., grad. student

Others

Teaching

Kautto E., lecturer (physics teacher education) -31.7.
Loberg K., lecturer (electronics)
Pakkanen A., prof. (physics teacher education) -30.9.
Sohlo S., lecturer
Suominen P., lecturer
Viertola R., lecturer (physics teacher education)

Computer systems

Karttunen T., PC support
Keinänen P., student
Pihkanen M., computer manager

Electronics and mechanical workshop

Hytönen M., technician
Hänninen V., lab. engineer
Kauppinen A., machinist
Kosola E., mechanician
Lahtinen M., lab. engineer
Liimatainen E., machinist
Lyhty A., machinist
Onkila P., machinist (part time work)
Pesu E., machinist
Pohjanheimo H., mechanician
Porras K., machinist
Puskala M., technician
Särkkä M., machinist

Administration

Blå A.-L., secretary
Leskinen S., departmental administrator
Taulio A., secretary
Väyrynen R., departmental secretary

Boards and Committees

Department Council 1.8.1999-31.7.2002

Rauno Julin, professor (chairman)
Matti Manninen, professor
Jukka Pekola, professor
Jyrki Räisänen, professor
Jouni Suhonen, professor
Juha Merikoski, senior assistant
Anniina Rytkönen, assistant
Teuvo Poikolainen, laboratory engineer
Sami Kähkönen, student
Kimmo Kärkkäinen, student
Jussi Saavalainen, student

Executive Board of the Accelerator Laboratory

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Rauno Julin, professor
Esko Liukkonen, professor
Matti Manninen, professor
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Ari Virtanen, Dr.
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Theses

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MSc theses

Teemu Hölttä, Embolisaatio puun vedenkuljetuksessa

Panu Rahkila, Two localizing analysis methods for gamma-ray data obtained with segmented clover detector

Arto Orava, Ultraäänen käyttöön perustuva virtausmittari

Pekka Huhtala, Luun mekaanisten ominaisuuksien määrittäminen elastisten aaltojen etenemisnopeudesta

Vesa Rantanen, Suppea suhteellisuusteoria: Einsteinin postulaattien ja aikadilaation kokeellisia varmennuksia

Jari Nissinen, In-beam test of silicon drift detectors for the Alice experiment

Ari Mononen, Simulations of water removal in impulse drying based on simplified model

Janne Pakarinen, JYFL-ECR 2-ionilähteen magneettikentän mallintaminen

Mikko Saarela, Paperitehdassysteemin aine- ja energiavirrat

Janne Suoknuuti, Kryogeenisen mikrojäähdyttimen kehittäminen erittäin herkän säteilynilmaisimen tarpeisiin

Kristiina Manninen, Armeeraussellun ja pohjapaperin yhteys päällystyskoneen katkoihin

Jukka Mattila, Mikrokalorimetri pienten suprajohtavien kiekkojen lämpökapasiteeetin mittaamiseen

Pauli Laitinen, Sputteroinnin käyttö syvyysprofiilin määrittämisessä

Ali Korhonen, Elektroniikkakomponenttien hallintajärjestelmä

Sanna Ponsimaa, Lukiolaisten kurssi "Ilmiöiden fysiikkaa ja matematiikkaa"

Aki Torvinen, Stereokuvaus putkivirtauksessa

Tomi Ryynänen, Resistive transition of low dimensional superconducting microstructures

Tuomas Jyske, Thermodilution cardiac output measurement in a patient monitor

Mika Tammenoja, Paperirainan kireysprofiili

Pieti Marjavaara, Optiseen tomografiaan perustuvan koelaitteen suunnittelu ja rakentaminen

Petro Moilanen, Ultraäänianalysaattorin toteuttaminen digitaalitekniikalla

Sami Hahto, H^--ionilähteen rakentaminen ja testaus

Raisa Manninen, Mittausautomaation tarjoamat mahdollisuudet fysiikan opetuksessa. Esimerkkinä mittausohjelma Coach 5

Matti Hämäläinen, Asenteita fysiikan opiskeluun Jämsän ja Jyväskylän ammattioppilaitoksissa

Riku Lassila, Automaattisen mittausympäristön suunnittelu testipuhelimille ja IC-piireille

Leena Jäppinen, Ääntä vaimentavat veistokset

Leena Toivakka, Geotermisen energian hyödyntämismahdollisuudet Suomessa

Jouni Porkka, Äänen historiaa ja akustiikan peruskäsitteitä

http://www.phys.jyu.fi/opetus (in Finnish)

Herkko Hakonen, Tietokoneistettu datankeruu oppilaslaboratorion töissä

Sari Kuusi, Hiilidioksidin vaikutus ilmastonmuutokseen

Kimmo Hämäläinen, Kuitususpension turbulenssin mittaaminen ultraäänellä

Miro Pihkanen, Mikrosääasemaverkosto

Juha Lohvansuu, Ohjelmoitavat digitaalipiirit tuotteen kehittämisessä. Sovelluksena ultraäänivirtausmittari

Eero Holmlund, Ydinrakennelaskut Te:n, I:n, Xe:n ja Cs:n isobaareille A=127

Sami Niskanen, Lasikuituhuovan jäykkyyden mallintaminen mikromekaanisella mallilla

Jari Kauranen, Yhdistepuolijohderakenteiden prosessointi ja Hall-mittaukset

Iiro Riihimäki, Tuhka-anturin suunnittelu ja rakentaminen

PhLic theses

Raimo Viertola, Kokeellisen työskentelyn kurssi fysiikassa lahjakkaille lukiolaisille,
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Mika Nieminen, Ilmiöiden fysiikkaa ja matematiikkaa – Kurssi fysiikassa lahjakkaille oppilaille,
JYFL Laboratory Report 3/2000

Pasi Kekko, Paperin elastiset ja plastiset ominaisuudet ja niiden merkitys LWC-paperin tuotantoprosessin hallintaan, JYFL Laboratory Report 4/2000

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Jere Kolehmainen, Density functional approach to small clusters, JYFL Research Report 1/2000

Jaakko Akola, Electronic structure calculations of aluminium and sodium clusters, JYFL Research Report 2/2000

Tuomas Hjelt, Multiconfiguration mixing approach designed for large scale nuclear structure calculations, JYFL Research Report 3/2000

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Shadyar Farhangfar, Small tunnel junctions in electromagnetic environment, JYFL Research Report 9/2000

Degrees

(alphabetical order)

BSc degrees

(main subject)

Sami Hahto (physics)
Eero Holmlund (physics)
Markus Luomajoki (physics)
Janne Pakarinen (physics)
Sami Peltonen (physics)
LeenaToivakka (physics)

MSc degrees

(main subject)
*=M.Sc. includes teacher's pedagocical studies

Sami Haapala (appl. physics)
Sami Hahto (physics)
Herkko Hakonen (physics)*
Eero Holmlund (theor. phys.)*
Kimmo Hämäläinen (appl. phys.)
Teemu Hölttä (physics)
Tuomas Jyske (electronics)
Leena Jäppinen (physics)*
Jari Kauranen (electronics)
Taito Kilponen (physics)*
Ali Korhonen (electronics)
Kalle Kuoppamäki (appl. phys.)
Sari Kuusi (physics)*
Pauli Laitinen (physics)
Riku Lassila (electronics)
Juha Lohvansuu (electronics)
Markus Luomajoki (theor. phys.)
Paula Manninen (appl. phys.)
Raisa Manninen (physics)*
Pieti Marjavaara (appl. physics)
Jukka Mattila (appl. physics)
Petro Moilanen (electronics)
Ari Mononen (physics)*
Sami Niskanen (appl. phys.)
Arto Orava (electronics)
Janne Pakarinen (physics)
Miro-Petri Pihkanen (appl. phys.)
Sanna Ponsimaa (physics)*
Jouni Porkka (physics)*
Panu Rahkila (physics)
Vesa Rantanen (physics)*
Iiro Riihimäki (physics)
Tomi Ryynänen (appl. phys.)
Janne Suoknuuti (appl. phys.)
Leena Toivakka (physics)*
Aki Torvinen (appl. phys.)

PhLic degrees

Mika Nieminen (physics)
Raimo Viertola (physics)

PhD degrees

Jaakko Akola (physics)
Dragos-Victor Anghel (theor. phys.)
Shadyar Farhangfar (appl. phys.)
Tuomas Hjelt (theor. phys.)
Jere Kolehmainen (physics)
Anssi Lindell (appl. phys.)
Maarit Muikku (physics)
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